Risk and Exposure Assessment to Support the Review of the SO_2 Primary National Ambient Air Quality Standards: First Draft

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Table of Contents

List of Tables

List of Figures

1.0 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is presently conducting a review of the primary, health based national ambient air quality standards (NAAQS) for sulfur dioxide (SO_2). Sections 108 and 109 of the Clean Air Act (The Act) govern the establishment and periodic review of the NAAQS. These standards are established for pollutants that may reasonably be anticipated to endanger public health and welfare, and whose presence in the ambient air results from numerous or diverse mobile or stationary sources. The NAAQS are to be based on air quality criteria, which are to accurately reflect the latest scientific knowledge useful in indicating the kind and extent of identifiable effects on public health or welfare that may be expected from the presence of the pollutant in ambient air. The EPA Administrator is to promulgate and periodically review, at five-year intervals, primary (health-based) and secondary (welfare-based) NAAQS for such pollutants. Based on periodic reviews of the air quality criteria and standards, the Administrator is to make revisions in the criteria and standards and promulgate any new standards as may be appropriate. The Act also requires that an independent scientific review committee advise the Administrator as part of this NAAQS review process, a function now performed by the Clean Air Scientific Advisory Committee (CASAC).

The Agency has recently decided to make a number of changes to the process for reviewing the NAAQS (described at http://www.epa.gov/ttn/naaqs/). In making these changes, the Agency consulted with CASAC. This new process, which is being applied to the current review of the SO_2 NAAQS, contains four major components. Each of these components, as they relate to the review of the SO_2 primary[1] NAAQS, is described below.

The first component of the review process is the development of an integrated review plan. This plan presents the schedule for the review, the process for conducting the review, and the key policy-relevant science issues that will guide the review. The final integrated review plan is informed by input from CASAC, outside scientists, and the public. The integrated review plan for this review of the SO_2 primary NAAQS is presented in the Integrated Review Plan for the Primary National Ambient Air Quality Standard for Sulfur Dioxide (EPA, 2007a).

[1]Note that evidence related to environmental effects of SO_x will be considered separately as part of the review of the secondary NAAQS for NO_2 and SO_2.

The second component of the review process is a science assessment. A concise synthesis of the most policy-relevant science has been compiled into a draft Integrated Science Assessment (draft ISA). The draft ISA is supported by a series of annexes that contain more detailed information about the scientific literature. The current draft of the ISA to support this review of the SO_2 primary NAAQS is presented in the Integrated Science Assessment for Oxides of Sulfur - Health Criteria (Second External Review Draft), henceforth referred to as the draft ISA (EPA, 2008a).

The third component of the review process is a risk and exposure assessment (REA), the first draft of which is described in this document. The first draft REA will be informed by the 1st and 2nd drafts of the ISA for SO_x and will detail the assessment of exposures and risks associated with recent ambient levels of SO_2 and with levels that just meet the current standards. The second draft REA will be informed by comments from CASAC, and the public, as well as findings and conclusions contained in the final ISA, and will also include an assessment of the risks and exposures associated with just meeting potential alternative standards. The results of the risk and exposure assessment will be considered alongside the health evidence, as evaluated in the final ISA, to inform the policy assessment and rulemaking process (see below). The plan for conducting the risk and exposure assessment to support the SO_2 primary NAAQS was presented in the Sulfur Dioxide Health Assessment Plan: Scope and Methods for Exposure and Risk Assessment, henceforth referred to as the Health Assessment Plan (EPA, 2007b).

The fourth component of the process is the policy assessment and rulemaking. The Agency's views on policy options will be published in the Federal Register as an advance notice of proposed rulemaking (ANPR). This policy assessment will address the adequacy of the current standard and of any potential alternative standards, which will be defined in terms of indicator, averaging time, form, and level. To accomplish this, the policy assessment will consider the results of the final risk and exposure assessment as well as the scientific evidence (including evidence from the epidemiological, controlled human exposure, and animal toxicological literatures) evaluated in the final ISA. Taking into consideration CASAC advice and recommendations as well as public comment on the ANPR, the Agency will publish a proposed rule, to be followed by a public comment period. Taking into account comments received on the proposed rule, the Agency will issue a final rule to complete the rulemaking process.

As mentioned above, an initial step in the review process was the development of an integrated review plan. This plan identified policy relevant questions that would guide the review of the SO_2 NAAQS. These questions are particularly important for the REA because they provide a context for both evaluating health effects evidence presented in the draft ISA, as well as for selecting the appropriate analyses for assessing exposure and risks associated with current ambient SO_2 levels, and levels that just meet the current standards. These policy relevant questions are:

- Has new information altered/substantiated the scientific support for the occurrence of health effects following short- and/or long-term exposure to levels of SO_x found in the ambient air?
- Does new information impact conclusions from the previous review regarding the effects of SO_x on susceptible populations?
- At what levels of SO_x exposure do health effects of concern occur?
- Has new information altered conclusions from previous reviews regarding the plausibility of adverse health effects caused by SO_x exposure?
- To what extent have important uncertainties identified in the last review been reduced and/or have new uncertainties emerged?
- What are the air quality relationships between short-term and longer-term exposures to SO_x?

Additional questions will become relevant if the evidence suggests that revision of the current standard might be appropriate. These questions are:

- Is there evidence for the occurrence of adverse health effects at levels of SO_x different than those observed previously? If so, at what levels and what are the important uncertainties associated with that evidence?
- Do exposure estimates suggest that levels of concern for SO_x-induced health effects will occur with current ambient levels of SO_2, or with levels that just meet the current, or potential alternative standards? If so, are these exposures of sufficient magnitude such

that the health effects might reasonably be judged to be important from a public health perspective? What are the important uncertainties associated with these exposure estimates?

- Do the evidence, the air quality assessment, and risk/exposure assessment, provide support for considering different standard indicators, averaging times, or forms?
- What range of levels is supported by the evidence, the air quality assessment, and risk/exposure assessment? What are the uncertainties and limitations in the evidence and assessments?

1.1 HISTORY

1.1.1 History of the SO_2 NAAQS

The first SO_2 NAAQS was established in 1971. At that time, a 24-hour standard of 0.14 ppm, not to be exceeded more than one time per year, and an annual standard of 0.03 ppm were judged to be both adequate and necessary to protect public health. The most recent review of the SO_2 NAAQS was completed in 1996 and focused on the question of whether an additional short-term standard (e.g., 5-minute) was necessary to protect against short-term, peak exposures. Based on the scientific evidence, the administrator judged that repeated exposures to 5-minute peak SO_2 levels ($\geq$0.60 ppm) could pose a risk of significant health effects for asthmatic individuals at elevated ventilation rates. The Administrator also concluded that the likely frequency of such effects should be a consideration in assessing the overall public health risks. Based upon an exposure analysis conducted by EPA, the Administrator concluded that exposure of asthmatics to SO_2 levels that could reliably elicit adverse health effects was likely to be a rare event when viewed in the context of the entire population of asthmatics, and therefore did not pose a broad public health problem for which a NAAQS would be appropriate. On May 22, 1996, EPA's final decision not to promulgate a 5-minute standard and to retain the existing 24-hour and annual standards was announced in the Federal Register (61 FR 25566).

The American Lung Association and the Environmental Defense Fund challenged EPA's decision not to establish a 5-minute standard. On January 30, 1998, the Court of Appeals for the District of Columbia found that EPA had failed to adequately explain its determination that no revision to the SO_2 NAAQS was appropriate and remanded the decision back to EPA for further explanation. Specifically, the court required EPA to provide additional rationale to support the

Agency judgment that 5-minute peaks of SO_2 do not pose a public health problem from a national perspective even though those peaks would likely cause adverse health impacts in a subset of asthmatics. In response, EPA has collected and analyzed additional air quality data focused on 5-minute concentrations of SO_2. These air quality analyses conducted since the last review will help inform the current review, which will address issues raised in the Court's remand of the Agency's last decision. No further Agency action has been taken with respect to responding to the remand.

1.1.2 Health Evidence from the Previous Review

The 1982 Air Quality Criteria Document (AQCD) for Particulate Matter and Sulfur Oxides (EPA, 1982), and its subsequent addenda and supplement (EPA, 1986a, 1994) presented an evaluation of SO_2 associated health effects primarily drawn from epidemiological and human clinical studies. In general, these documents identified adverse health effects that were likely associated with both short-(generally hours to days), and long-term (months to years) exposures to SO_2 at concentrations present in the ambient mixture of air pollutants. Moreover, these documents presented evidence for bronchoconstriction and respiratory symptoms in exercising asthmatics following controlled exposures to short-term (5-10 minutes) peak concentrations of SO_2.

Evidence drawn from epidemiological studies supported a likely association between 24-hour average SO_2 exposure and daily mortality, aggravation of bronchitis, and small, reversible declines in children's lung function (EPA 1982, 1994). In addition, a few epidemiological studies found an association between respiratory symptoms and illnesses and annual average SO_2 concentrations (EPA 1982, 1994). However, it was noted that most of these epidemiological studies were conducted in years and cities where particulate matter (PM) counts were also quite high, thus making it difficult to quantitatively determine whether the observed health effects were the result of SO_2, PM, or a combination of exposure to both pollutants.

Evidence drawn from clinical studies exposing exercising asthmatics to <1.0 ppm SO_2 for 5-10 minutes found that these types of SO_2 exposures evoked health effects that were similar to those asthmatics would experience from other commonly encountered stimuli (e.g. exercise, cold/dry air, psychological stress, etc., EPA, 1994). That is, there was an acute-phase response characterized by bronchoconstriction and/or respiratory symptoms that occurred within 5-10 minutes of exposure but then subsided on its own within 1 to 2 hours. This acute-phase response was followed by a short refractory period where the individual was relatively insensitive to additional SO_2 challenges. Notably, the SO_2-induced acute-phase response was found to be ameliorated by the inhalation of beta-agonist aerosol medications, and to occur without an additional, often more severe, late-phase inflammatory response.

The 1994 supplement to the CD noted that of particular concern was the subset of asthmatics in these clinical studies that appeared to be hyperresponsive- those experiencing greater-than-average bronchoconstriction or respiratory symptoms at a given SO_2 concentration. Thus, for a given concentration of SO_2, the number of asthmatics likely to experience bronchoconstriction (and/or symptoms) of a sufficient magnitude to be considered a health concern was estimated. At 0.6 to 1.0 ppm SO_2, EPA estimated that more than 25% of mild to moderate exercising asthmatics would likely experience decrements in lung function or respiratory symptoms distinctly exceeding typical daily variations in lung function, or the response to commonly encountered stimuli (EPA, 1994). Furthermore, the CD concluded that the severity of effects experienced at 0.6-1.0 ppm was likely to be of sufficient concern to cause a cessation of activity, medication use, and/or the possible seeking of medical attention. In contrast, at 0.2 – 0.5 ppm SO_2, it was estimated that at most 10 – 20% of mild to moderate exercising asthmatics were likely to experience lung function decrements larger than those associated with typical daily activity, or the response to commonly encountered stimuli (EPA, 1994).

1.1.3 Assessment from Previous Review

The risk and exposure assessment from the previous review of the SO_2 NAAQS qualitatively evaluated both the existing 24-hour (0.14 ppm) and annual standards (0.03 ppm), but primarily focused on whether an additional standard was necessary to protect against very short-term (e.g., 5-minute) peak exposures. Based on the human clinical data mentioned above, it was judged that exposures to 5-minute SO_2 levels at or above 0.60 ppm could pose an immediate significant health risk for a substantial proportion of asthmatics at elevated ventilation rates (e.g., while exercising). Thus, EPA analyzed existing ambient monitoring data to estimate the frequency of 5-minute peak concentrations above 0.50, 0.60, and 0.70 ppm, the number of repeated exceedances of these concentrations, and the sequential occurrences of peak concentrations within given a day (SAI, 1996). The results of this analysis indicated that in the vicinity of local sources, several locations in the U.S. had a substantial number of 5-minute peak concentrations at or above 0.60 ppm.

In addition to the ambient air quality analysis, the previous review also included several annual exposure analyses that in general, combined SO_2 emission estimates from utility and non-utility sources with exposure modeling to estimate the probability of exposure to short-term peak SO_2 concentrations. The first such analysis conducted by the Agency estimated the number of 5-minute exposures ≥0.5 ppm associated with four selected coal-fired power utilities (EPA, 1986b). An expanded analysis sponsored by the Utility Air Regulatory Group (UARG) considered the frequency of short-term exposure events that might result from the nationwide operation of all power utility boilers (Burton et al., 1987). Additionally, the probability of peak concentrations surrounding non-utility sources was the focus of another study conducted by the Agency (Stoeckenius et al., 1990). The resultant combined exposure estimates considering these early analyses indicated that between 0.7 and 1.8 percent of the total asthmatic population potentially could be exposed one or more times annually, while outdoors at exercise, to 5-minute SO_2 concentrations ≥0.50 ppm. It also was noted that the frequency of 5-minute exposures above the health effect benchmark of 0.60 ppm, while not part of the analysis, would be anticipated to be lower.

In addition to the early analyses mentioned above, two other analyses were considered in the prior review. The first was an exposure assessment sponsored by the UARG (Rosenbaum et al., 1992) that focused on emissions from fossil-fueled power plants. That study accounted for the anticipated reductions in SO_2 emissions after implementation of the acid deposition provisions (Title IV) of the 1990 Clean Air Act Amendments. This UARG-sponsored analysis predicted that these emission reductions would result in a 42% reduction in the number of 5-minute exposures to 0.50 ppm for asthmatic individuals (reducing the number of asthmatics exposed from 68,000 down to 40,000) in comparison with the earlier Burton et al. (1987) analysis. The second was a new exposure analysis submitted by the National Mining Association (Sciences International, Inc. 1995) that reevaluated non-utility sources. In this analysis, revised exposure estimates were provided for four of the seven non-utility source categories by incorporating new emissions data and using less conservative modeling assumptions in comparison with those used for the earlier Stoeckenius et al. (1990) non-utility analysis. Significantly fewer exposure events (i.e., occurrence of 5-minute 0.50 ppm or greater exposures) were estimated in this industry-sponsored revised analysis, decreasing the range of estimated exposures for these four sources by an order of magnitude (i.e., from 73,000-259,000 short-term exposure events in the original analysis to 7,900-23,100 in the revised analysis).

1.2 SCOPE OF THE RISK AND EXPOSURE ASSESSMENT FOR THE CURRENT REVIEW

1.2.1 Overview of Assessment

The overall goal of this document is to describe exposure and risks associated with recent ambient levels of SO_2 and with levels that just meet the current standards. Chapters 2-4 evaluate background information presented in the draft ISA that is relevant for conducting an exposure and risk assessment. This includes information on 1) human exposure to SO_2 2) at-risk populations, and 3) health effects associated with short- and long-term exposures to SO_2. Considering the information discussed in these chapters, staff found it appropriate to focus its exposure and risks analyses on respiratory morbidity associated with 5-minute peak and short-term (≥ 1-hour, generally 24-hours) exposures to SO_2.

With regard to 5-minute peak exposures, staff found sufficient evidence of bronchoconstriction and respiratory symptoms from human exposure studies presented in the draft ISA to conduct a series of analyses to estimate the risks associated with exposure to 0.4-0.6 ppm SO_2 in asthmatics at elevated ventilation rates. Chapter 6 presents an air quality characterization for the occurrence of 5-minute peak concentrations above the potential health benchmark values of 0.4, 0.5, and 0.6 ppm under current air quality, and air quality simulated to just meet the current standards. Chapter 7 presents initial results from an exposure analysis case study conducted in the state of Missouri. This analysis provides estimates of the number and percent of asthmatics residing within 20 kilometers (km) of major SO_2 sources experiencing 5-minute exposures to 0.4, 0.5, 0.6 ppm SO_2 while at elevated ventilation rates under the air quality scenarios mentioned above. Chapter 8 of this document describes ongoing work to develop health risk estimates for the number and percent of these exposed asthmatics that would experience moderate or greater lung function decrements under these same air quality scenarios.

Evidence presented in the draft ISA for respiratory morbidity associated with short-term SO_2 exposure was primarily drawn from epidemiological studies. Staff found that the epidemiological evidence presented in the draft ISA was largely mixed, but suggestive of an association between short-term SO_2 exposure and both respiratory symptoms in children, as well as emergency department (ED) visits and hospitalizations for all respiratory causes and asthma, particularly in children and older adults. Thus, Chapter 9 of this document describes ongoing work that will qualitatively assess the relationship between SO_2 air quality levels at the time key U.S. and Canadian epidemiological studies were conducted and these health endpoints.

With respect to long-term exposure, staff concluded that there was insufficient information to conduct a risk assessment based on epidemiological studies examining long-term SO_2 exposure. This was primarily because the draft ISA found the evidence linking long-term SO_2 exposure to morbidity and mortality to be inadequate to infer the presence or absence of a causal relationship (ISA, Table 5-3). The draft ISA noted that a major consideration for this determination was the inability to attribute health effects observed in long-term epidemiological studies to SO_2 alone; the draft ISA found a high correlation among pollutant levels, particularly between long-term average SO_2 and PM concentrations.

1.2.2 Species of Sulfur Oxides Included in Analyses

The sulfur oxides include multiple gaseous (e.g., SO_2, SO_3) and particulate (e.g., sulfate) species. In considering what species of sulfur oxides are relevant to the current review of the SO_2 NAAQS, we note that the health effects associated with particulate species of sulfur oxides have been considered within the context of the Agency's review of the primary NAAQS for particulate matter (PM). In the most recent review of the NAAQS for PM, it was determined that size-fractionated particle mass, rather than particle composition, remains the most appropriate approach for addressing ambient PM. This conclusion will be re-assessed in the parallel review of the PM NAAQS; however, at present it would be redundant to also consider effects of particulate sulfate in this review. Therefore, the current review of the SO_2 NAAQS will focus on gaseous species of sulfur oxides and will not consider health effects directly associated with particulate sulfur oxide species. Additionally, of the gaseous species, EPA has historically determined it appropriate to specify the indicator of the standard in terms of SO_2 because other gaseous sulfur oxides (e.g. SO_3) are likely to be found at concentrations many orders of magnitude lower than SO_2 in the atmosphere, and because the majority of health effects and exposure information is for SO_2. The draft ISA has again found this to be the case, and therefore this REA will use SO_2 as a surrogate for all gaseous sulfur oxides.

1.2.3 Scenarios for the Current Assessment

The first draft REA, described in this document, will be informed by the 1st and 2nd drafts of the ISA for SO_x and will detail the assessment of exposures and characterization of health risks associated with recent ambient levels of SO_2 and with levels that just meet the current standards. Moreover, this document will assess exposure and characterize risks associated with SO_2 emissions from anthropogenic sources. In the vast majority of the U.S., most SO_2 emissions originate from industrial point sources, with fossil fuel combustion at electric utilities and other facilities accounting for the majority of total emissions (see section 2.2). The second draft of this document is scheduled to be released in November 2008 and will be informed by comments from CASAC, and the public, as well as findings and conclusions contained in the final ISA. The second draft REA will include an assessment of the risks and exposures associated with just meeting potential alternative standards. The final REA is scheduled is to be completed in January 2009, and will also be informed by comments from CASAC, and the public, as well as findings and conclusions contained in the final ISA.

2.0 HUMAN EXPOSURE

2.1 OVERVIEW

The integrated exposure of a person to a given pollutant is the sum of the exposures over all time intervals for all environments in which the individual spends time. People spend different amounts of time in different microenvironments and each microenvironment is characterized by different pollutant concentrations. There is a large amount of variability in the time that different individuals spend in different microenvironments, but on average people spend the majority of their time (about 87%) indoors. Most of this time spent indoors is spent at home with less time spent in an office/workplace or other indoor locations (draft ISA, figure 2-21). In addition, people spend about 8% of their time outdoors and 6% of their time in vehicles. A potential consequence of multiple sources of exposure or microenvironments is the exposure misclassification that may result when total human exposure is not disaggregated between these various microenvironments. Such misclassification may obscure the true relationship between ambient air pollutant exposures and health outcomes

In addition to accounting for the times spent in different microenvironments, it is also important to describe the type of exposure experienced. Types of exposure can be characterized as instantaneous, peak, average, or integrated over all the environments a person encounters. These distinctions are important because health effects caused by long-term, low-level exposures may differ from those caused by single or repeated short-term, peak exposures.

2.2 SOURCES OF SO_2

In order to estimate risks associated with SO_2 exposure, principle sources of the pollutant must first be characterized because the majority of human exposures are likely to be in the vicinity of these sources. Anthropogenic SO_2 emissions originate chiefly from point sources, with fossil fuel combustion at electric utilities (~66%) and other industrial facilities (~29%) accounting for the majority of total emissions (draft ISA section 2.1). Other anthropogenic sources of SO_2 include both the extraction of metal from ore as well as the burning of high sulfur containing fuels by locomotives, large ships, and non-road diesel equipment. Notably, almost the entire sulfur content of fuel is released as SO_2 or SO_3 during combustion. Thus, based on the sulfur content in fuel stocks, sulfur emissions can be calculated to a higher degree of accuracy than can emissions for other pollutants such as PM and NO_2 (draft ISA, section 2.1).

The largest natural sources of SO_2 are volcanoes and wildfires. Although SO_2 constitutes a relatively minor fraction (0.005% by volume) of total volcanic emissions, concentrations in volcanic plumes can be in the range of several to tens of ppm. Volcanic sources of SO_2 in the U.S. are limited to the Pacific Northwest, Alaska, and Hawaii. Emissions of SO_2 can also result from burning vegetation. The amount of SO_2 released from burning vegetation is generally in the range of 1 to 2% of the biomass burned and is the result of sulfur from amino acids being released as SO_2 during combustion.

2.3 AMBIENT LEVELS OF SO_2

Since the integrated exposure to a pollutant is the sum of the exposures over all time intervals for all environments in which the individual spends time, understanding the temporal and spatial patterns of SO_2 levels across the U.S is an important component of conducting an exposure and risk analysis. SO_2 emissions and ambient concentrations follow a strong west to east gradient due to the large numbers of electric generating units in the Ohio River Valley and upper South regions. In the 12 CMSAs that had at least 4 SO_2 regulatory monitors from 2003-2005, 24-hour average concentrations in the continental U.S. ranged from a reported low of ~0.001 ppm in Riverside, CA and San Francisco, CA to a high of ~0.012 ppm in Pittsburgh, PA and Steubenville, OH (draft ISA section 2.4.4). In addition, inside CMSAs from 2003-2005, the annual average SO_2 concentration was 0.004 ppm (draft ISA, Table 2.4). However, spikes in hourly concentrations occurred; the mean 1-hour maximum concentration was 0.013 ppm, with a maximum value of greater than 0.70 ppm (draft ISA, Table 2.4).

It should be noted that there is concern about the degree of instrument error associated with the measurement of ambient SO_2. The SO_2 monitoring network was designed and put into place when SO_2 concentrations were considerably higher, and thus, well within the standard monitor's limits of detection. However, SO_2 concentrations have fallen considerably over the years (draft ISA, Figure 2-8) and are currently at, or very near these monitors' lower limit of detection (~0.003 ppm). This introduces a degree of uncertainty because as monitors approach their detection limits there can be greater error in their measurements.

EPA has generally conducted NAAQS risk assessments on levels of a pollutant that are in excess of policy relevant background (PRB). Policy relevant background levels are defined as concentrations of a pollutant that would occur in the U.S. in the absence of anthropogenic emissions in continental North America (defined here as the United States, Canada, and Mexico). However, throughout much of the United States, SO_2 PRB levels are estimated to be at most 30 parts per trillion and contribute less than 1% to present day SO_2 concentrations (draft ISA, section 2.4.6). We note that in the Pacific Northwest and Hawaii, PRB concentrations can be considerably higher due to geothermal activity (e.g. volcanoes); in these areas, PRB can account for 70-80% of total SO_2 concentrations (draft ISA, section 2.4.6). Since we do not plan on conducting SO_2 risk assessment in areas with high background SO_2 levels due to natural sources, and the contribution of PRB is negligible in all other areas, EPA is addressing the risks associated with monitored and/or modeled ambient levels without regard to PRB levels.

2.4 RELATIONSHIP OF PERSONAL EXPOSURE TO AMBIENT CONCENTRATIONS

Of major concern is the ability of SO_2, measured by ambient monitors, to serve as a reliable indicator of personal exposure to SO_2 of ambient origin. The key question is what errors are associated with using SO_2 measured by ambient monitors as a surrogate for personal exposure to ambient SO_2. There are three aspects to this issue: (1) ambient and personal sampling issues; (2) the spatial variability of ambient SO_2 concentrations; (3) the associations between ambient concentrations and personal exposures as influenced by exposure factors, e.g., indoor sources and time spent indoors and outdoors.

Determining the relationship between personal exposure and ambient concentrations is often difficult. This is in part because SO_2 levels in general are often below the limits of detection of currently available personal samplers[2]. In these situations, associations between ambient concentrations and personal exposures are inadequately characterized (ISA, section 2.5.3.2). However, the ISA noted that when personal exposure concentrations are above detection limits of personal samplers, a reasonably strong association is observed between personal exposures and ambient concentrations (ISA, section 2.5.3.2).

[2] The lower limit of detection of personal samplers is ~60 ppb for 1-hour and ~5 ppb for 24-hour. A discussion of personal sampler detection limits can be found in section 2.5.2 of the draft ISA.

There is also uncertainty associated with the spatial and temporal variation of SO_2 across communities. In some U.S. cities, there are low site-to-site correlations of SO_2 concentrations among monitors (draft ISA, Table 2-3). This suggests that at any given time, SO_2 concentrations at individual monitoring sites may not highly correlate with the average SO_2 concentration in the community. This could be the result of local sources (e.g. power plants) causing an uneven spatial distribution of SO_2, monitors being sited to represent concentrations near local sources, or effects related to terrain or weather (draft ISA, section 2.5.4.1.2).

Since people spend most of their time indoors there is also uncertainty in the relationship between ambient concentrations measured by local monitors and actual personal exposure related to ambient sources. Indoor, or nonambient, sources of SO_2 could complicate the interpretation of associations between personal exposure to ambient SO_2 in exposure studies. Possible sources of indoor SO_2 are associated with the use of sulfur-containing fuels, with higher levels expected when emissions are poorly vented (draft ISA, section 2.5). In the U.S., the contribution of indoor sources is not thought to be a major contributor to overall SO_2 exposure because the only known indoor source in the U.S. is kerosene heaters and there use is not thought to be widespread (draft ISA, section 2.5).

3.0 AT RISK POPULATIONS

3.1 OVERVIEW

The risk of an adverse health effect following exposure to a pollutant is dependent on a number of factors, such as the individual's personal attributes (age, gender, preexisting health conditions) and the toxic properties of the pollutant (e.g., as indicated by dose- or concentration-response relationships). The previous review of the SO_2 NAAQS identified certain groups within the population that may be more susceptible to the effects of SO_2 exposure, including those with pre-existing respiratory disease and cardiovascular disease (CVD). Individuals in potentially sensitive groups are of concern, as they may experience adverse effects from lower levels of SO_2 compared to the general population or experience a greater impact with the same level of exposure. The draft ISA defined which groups within the population may be more susceptible to adverse health effects associated with SO_2 exposure. The draft ISA also identified groups considered to be vulnerable to SO_2 exposure because they are potentially exposed to higher than average SO_2 concentrations. Groups considered to be particularly susceptible and/or vulnerable are discussed in more detail below.

3.2 DISEASE AND ILLNESS

Both recent epidemiological and human clinical studies have strengthened the 1982 AQCD conclusion that individuals with pre-existing respiratory disease are likely more susceptible to the effects of SO_2 than the general public (draft ISA, section 4.2.1.1). Epidemiological studies have reported associations between short- and long-term SO_2 ambient concentrations and a range of respiratory symptoms in individuals with respiratory disease. Additionally, numerous controlled human exposure studies have found that asthmatics are more responsive to the respiratory effects of SO_2 than healthy, non-asthmatic individuals. Specifically, clinical studies have demonstrated that in non-asthmatics, SO_2-attributible decrements in lung function have generally not been shown at concentrations <1.0 ppm. In contrast, both increases in respiratory symptoms and decrements in lung function have been shown in a significant proportion of exercising mild and moderate asthmatics following 5-10 minute exposures to SO_2 concentrations as low as 0.4-0.6 ppm (draft ISA, section 4.2.1.1).

The draft ISA also examined the possible effects of pre-existing CVD on SO_2 susceptibility. The draft ISA found that results from a limited number of epidemiological studies provided inconsistent evidence that individuals with pre-existing CVD were more susceptible than the general public to adverse health effects associated with ambient SO_2 exposure (draft ISA, section 4.2.1.2). Moreover, results from a single human clinical study found no evidence to suggest that patients with stable angina were more susceptible to SO_2- related health effects than healthy individuals. Overall, the draft ISA found the limited evidence for an association between pre-existing CVD and increased susceptibility to SO_2 related health effects to be inconclusive (draft ISA, section 4.2.1.2).

3.3 GENETIC SUSCEPTIBILITY

The draft ISA noted that a consensus now exists among scientists that the potential association between genetic factors and increased susceptibility to ambient air pollution merits serious consideration. Thus, the draft ISA examined the differential effects of air pollution among genetically diverse subpopulations for a number of genes. There was only one study that specifically looked at SO_2 as the pollutant of interest and it found a significant association between adverse health effects and the homozygous wild-type allele for TNF-α (draft ISA, section 4.2.2). However, the draft ISA concluded that the data were too limited to reach a conclusion regarding the effects of SO_2 exposure on genetically distinct subpopulations at this time.

3.4 AGE

Although the evidence is limited, the draft ISA identified children (i.e., <18 years of age) and older adults (i.e. >65 years of age) as groups that are potentially more susceptible than the general population to the health effects associated with SO_2 exposure. In children, the developing lung is highly susceptible to damage from environmental toxicants as it continues to develop through adolescence. The basis for increased susceptibility in the elderly is unknown, but one hypothesis is that it may be related to changes in antioxidant defenses in the fluid lining the respiratory tract. However, regardless of the mechanisms involved, the ISA found a number of epidemiological studies that observed increased respiratory symptoms in children associated with increasing SO_2 exposures. In addition, several studies have reported that the excess risk estimates for ED visits and hospitalizations for all respiratory causes, and to a lesser extent asthma, associated with a 10-ppb increase in 24-hour average SO_2 concentrations were higher for children and older adults than for all ages together (draft ISA, section 4.2.3).

3.5 VULNERABILITY

Indoor and personal SO_2 concentrations are generally much lower than outdoor ambient concentrations. Therefore, people who spend most of their time indoors are generally less vulnerable to SO_2 related health effects than those who spend a significant amount of time outdoors at increased exertion levels. In addition, the health effects evidence from controlled human exposure studies indicated that some SO_2-related health responses (e.g., lung function and respiratory symptoms in asthmatic subjects) occurred at the lowest concentration levels when subjects were engaged in moderate or greater exertion. Thus, children who spend a significant amount of time outdoors at elevated ventilation rates (e.g. while playing) and adult asthmatics who work, exercise, or play outdoors are expected to have increased vulnerability and be at greater risk of experiencing SO_2-related health effects.

4.0 HEALTH EFFECTS

4.1 INTRODUCTION

The draft ISA along with its annexes integrates newly available epidemiological, human clinical, and animal toxicological evidence with consideration of key findings and conclusions from prior reviews to draw conclusions about the relationship between short- and long-term exposure to SO_2 and numerous human health endpoints. For these health effects, the draft ISA characterizes judgments about causality with a hierarchy (for discussion see draft ISA, section 1.x) that contains the following five levels:

- Sufficient to infer a causal relationship
- Sufficient to infer a likely causal relationship (i.e., more likely than not)
- Suggestive but not sufficient to infer a causal relationship
- Inadequate to infer the presence or absence of a causal relationship
- Suggestive of no causal relationship

The ISA noted that these judgments about causality were informed by a series of aspects of causality that were based on those set forth by Sir Austin Bradford Hill in 1965 (draft ISA, Table 1-2). These aspects include strength of the observed association, availability of experimental evidence, consistency of the observed association, biological plausibility, coherence of the evidence, temporal relationship of the observed association, and the presence of an exposure-response relationship.

For the purpose of characterization of SO_2-related health risks, we have focused on health endpoints for which the draft ISA concludes that the available evidence is sufficient to infer a causal relationship. The draft ISA concludes that there is sufficient evidence to infer a causal relationship between respiratory morbidity and short-term exposure to SO_2 (draft ISA, section 5.2). This conclusion is based on the consistency, coherence, and plausibility of findings observed in controlled human exposure studies examining SO_2 exposures of 5-10 minutes, epidemiological studies mostly using 24-hour average exposures, and animal toxicological studies using exposures of minutes to hours (draft ISA, section 5.2). The evidence for causal associations between SO_2 exposure and other health endpoints is judged to be less convincing, at most suggestive but not sufficient to infer a causal relationship, and therefore will not be discussed in this document. Key conclusions reached in the draft ISA are listed below:

- **Sufficient to infer a causal relationship:**
  - Short-Term Respiratory Morbidity
- **Suggestive but not sufficient to infer a causal relationship:**
  - Short-Term Mortality
- **Inadequate to infer the presence or absence of a causal relationship**
  - Short-Term Respiratory Morbidity;
  - Short-Term Cardiovascular Morbidity;
  - Long-Term Respiratory Morbidity;
  - Long-Term Mortality;
  - Long-Term Other Morbidity;

A more detailed summary of these conclusions can be found in Table 5-3 of the draft ISA.

4.2 SHORT-TERM PEAK (<1-HOUR, GENERALLY 5-10 MINUTES) SO_2 EXPOSURES AND RESPIRATORY HEALTH EFFECTS

4.2.1 Overview

The draft ISA concludes that there is sufficient evidence to infer a causal relationship between respiratory morbidity and short-term exposure to SO_2 (draft ISA, section 5.2). In large part, this determination is based on controlled human exposure studies demonstrating a relationship between short-term peak SO_2 exposures and adverse effects on the respiratory system in exercising asthmatics. More specifically, the draft ISA finds consistent evidence from numerous human clinical studies demonstrating increased respiratory symptoms (e.g. cough, chest tightness, wheeze) and decrements in lung function in a substantial proportion of exercising asthmatics (generally classified as mild to moderate asthmatics) following short-term peak exposures to SO_2 at concentrations $\geq$ 0.4 ppm. As in previous reviews, the draft ISA also concludes that at concentrations below 1.0 ppm, healthy individuals are relatively insensitive to the respiratory effects of short-term peak SO_2 exposures (draft ISA, sections 3.1.3.1 and 3.1.3.2).

4.2.2 Respiratory Symptoms

The 1994 Supplement to the Second Addendum described multiple studies that evaluated respiratory symptoms (e.g. cough, wheeze, or chest tightness) following controlled exposures of asthmatic subjects to SO_2. Linn et al. (1983) reported that relative to exposure to clean air, exposure to SO_2 levels as low 0.4 ppm for 5 minutes in exercising asthmatics resulted in a statistically significant increase in an overall respiratory symptoms score that included wheeze, chest tightness, cough, and substernal irritation. In an additional study, Linn et al. (1987) observed that 43% of exercising asthmatics exhibited respiratory symptoms following a 10-minute exposure to 0.6 ppm SO_2; this study also found that exposure to SO_2 concentrations as low as 0.4 ppm resulted in 15% of study subjects experiencing respiratory symptoms (draft ISA, 3.3.3.1). In addition, Balmes et al. (1987) reported that 7 out of 8 asthmatic adults at elevated ventilation rates developed respiratory symptoms following a 3-minute exposure to 0.5 ppm SO_2 (draft ISA section 3.3.3.1).

Controlled human exposure studies published since the 1994 Supplement to the Second Addendum have provided additional evidence of short-term peak SO_2 exposures resulting in respiratory symptoms in asthmatics at elevated ventilation rates (draft ISA, section 3.1.3.1). In a study conducted by Gong et al. (1995), unmedicated SO_2-sensitive asthmatics were exposed to 0-, 0.5-, and 1-ppm SO_2 for 10 minutes while performing different levels of exercise (light, medium, or heavy). The authors found that respiratory symptoms increased with increasing SO_2 concentrations. Moreover, they found that exposure to 0.5-ppm SO_2 during light exercise evoked a more severe symptomatic response than heavy exercise in clean air. In a separate study, Trenga et al. (1999) observed a significant correlation between decreases in FEV_1 and increases in respiratory symptoms following 10-minute exposures to 0.5 ppm SO_2. However, it should be noted that the study conducted by Trenga et al. used a mouthpiece and that these types of studies often produce more exaggerated effects because they deliver SO_2 directly into the mouth, thereby bypassing the natural SO_2 scrubbing effects of the nasal passages and resulting in greater doses reaching the lung.

4.2.3 Lung function

In the previous review, it was established that subjects with asthma are more sensitive to the respiratory effects of SO_2 exposure than healthy individuals (draft ISA, section 3.1.3.2).

Asthmatics exposed to SO_2 concentrations as low as 0.4-0.6 ppm for 5-10 minutes during exercise have been shown to experience significant bronchoconstriction, measured as an increase in specific airway resistance (sRaw) of ≥100%, or decrease in forced expiratory volume in the first second (FEV_1) of ≥15% after correction for exercise-induced responses in clean air (Bethel et al., 1983; Linn et al., 1983, 1984, 1987; 1988; 1990; Magnussen et al., 1990; Roger et al., 1985). It was also found that those asthmatics that are the most sensitive to the respiratory effects of SO_2 have been shown to experience significant decrements in lung function following SO_2 exposure ≤0.3 ppm while at exercise (draft ISA, section 3.1.3.2; Horstman et al., 1986; Sheppard et al., 1981). Moreover, the draft ISA finds that among asthmatics, both the magnitude of SO_2-induced lung function decrements and the percent of individuals affected have been shown to increase with increasing 5- to 10-minute SO_2 exposures in the range of 0.2 to 1.0 ppm.

The draft ISA also finds supporting evidence in studies published since the previous review. Gong et al. (1995) found that increasing SO_2 concentrations resulted in both a decrease in FEV_1 as well as an increase in sRaw. This same study found that increasing the concentration of SO_2 had a greater effect on sRaw and FEV_1 than increasing the level of exercise. In a separate study, following a 10-minute exposure to 0.5 ppm SO_2 by mouthpiece (see caveat in section 4.2.2), Trenga et al. (1999) observed that 25 out of 47 exercising adult asthmatics experienced a drop in FEV_1 versus baseline (mean = 17.2%).

4.2.4 Decrements in Lung Function in the Presence of Respiratory Symptoms

When evaluating health effects associated with short-term peak SO_2 exposures, the draft ISA recognized recent guidance by the American Thoracic Society (ATS) regarding what constitutes an adverse effect of air pollution (draft ISA, section 3.1.3.2). In its official statement, the ATS recommended that transient loss in lung function associated with clinical respiratory symptoms attributable to air pollution should be considered adverse to individuals (ATS 2000; draft ISA section 3.1.3). Accordingly, in light of this definition the draft ISA re-evaluated experimental data from controlled human exposure studies previously considered in the last SO_2 NAAQS review (draft ISA, section 3.1.3.2; Balmes et al., 1987; Linn et al., 1987; 1988; 1990; 1983; Roger et al., 1985), along with supporting data from a recent controlled human exposure study (draft ISA section 3.1.3.2; Gong et al., 1995) for evidence of lung function decrements with concurrent respiratory symptoms. This re-evaluation found evidence demonstrating frequent decrements in lung function in the presence of respiratory symptoms in exercising asthmatics exposed to short-term peaks of SO_2. More specifically, the draft ISA concludes the evidence collectively indicates that at elevated ventilation rates, asthmatic individuals experience moderate or greater decrements in lung function combined with respiratory symptoms following peak exposures to SO_2 as low as 0.4-0.6 ppm (draft ISA, section 3.1.3.5; Table 3-1).

4.3 SHORT-TERM (≥ 1-HOUR, GENERALLY 24-HOUR) SO_2 EXPOSURE AND RESPIRATORY HEALTH EFFECTS

In addition to the human clinical evidence described above (section 4.2), the draft ISA also bases its causal determination for an association between exposure to short-term (5-minutes to 24-hour) SO_2 and respiratory morbidity on results from epidemiological studies examining 1) respiratory symptoms, 2) emergency department (ED) visits and hospitalizations for all respiratory causes, asthma, chronic obstruction pulmonary disease (COPD), and other respiratory diseases 3) lung function, 4) respiratory related absences, 5) airway inflammation, and 6) airway hyperresponsiveness and allergy. However, this section will focus on the results presented in the draft ISA concerning respiratory symptoms and hospitalization and ED visit for all respiratory causes and asthma. This is because staff found the results and breadth of the epidemiological evidence for these health endpoints within the broader category of respiratory morbidity to be most robust. Therefore, other respiratory morbidity endpoints (see draft ISA section 3.1.4) will not be discussed in this document, but will be considered qualitatively in the policy assessment that is prepared after completion of the final ISA.

4.3.1 Respiratory Symptoms

The draft ISA finds that the strongest epidemiological evidence for an association between short-term SO_2 concentrations and respiratory symptoms was in children, and comes from two large U.S. multi-city studies: the National Cooperative Inner-City Asthma Study (NCICAS; Mortimer et al., 2002; ISA section 3.1.4.1.1 and 3.1.4.1.2), and the Childhood Asthma Management Program (CAMP; Schildcrout et al., 2006; ISA section 3.1.4.1.1). Both of these studies found significant associations between level of SO_2 concentration and the risk of respiratory symptoms in asthmatic children (Mortimer et al., 2002; Schildcrout et al., 2006;). However, it should be noted that the Harvard Six Cities Study (Schwartz et al., 1994) suggested that the association between SO_2 and respiratory symptoms in children could be confounded by

PM_{10}; the authors found that the effect of SO_2 was substantially diminished after adjustment for PM_{10} in copollutant models (draft ISA, section 3.1.4.1). These key studies are discussed in more detail below.

The National Cooperative Inner-City Asthma Study (NCICAS, Mortimer et al. 2002) included asthmatic children (n = 846) from eight U.S. urban areas and examined the relationship between respiratory symptoms and summertime air pollution levels. The strongest associations were found between morning symptoms and the median 3-hour average SO_2 concentrations during morning hours (8 a.m. to 11 a.m.)- following a 1- to 2-day lag (draft ISA, Figure 3-2). 3 – hour average concentrations ranged from 17 ppb in Detroit to 37 ppb in East Harlem, NY. This relationship remained robust and statistically significant in multi-pollutant models with ozone (O_3), and nitrogen dioxide (NO_2). When PM_{10} was also added to the model, the effect estimate was similar although no longer statistically significant (draft ISA, Figure 3-2), but the ISA notes that this loss of statistical significance could have been the result of reduced statistical power (only three of eight cities were included in this analysis) or collinearity resulting from adjustment of multiple pollutants (draft ISA, section 3.1.4.1).

The Childhood Asthma Management Program (CAMP, Schildcrout et al. 2006) examined the association between ambient air pollution and asthma exacerbations in children (n = 990) from eight North American cities. The median 24-hour average SO_2 concentrations (collected in seven of the eight study locations) ranged from 2.2 ppb in San Diego to 7.4 ppb in St. Louis. All lag structures were positively associated with an increased risk of asthma symptoms, but only the 3-day moving average was statistically significant (draft ISA, Figure 3-3). In joint-pollutant models with carbon monoxide (CO) and NO_2, the 3-day moving average effect estimates remained robust and statistically significant. In a joint-pollutant model with PM_{10}, the 3-day moving average effect estimate remained robust, but was no longer statistically significant (draft ISA figure 3-3).

A longitudinal study of 1,844 schoolchildren during the summer months from the Harvard Six Cities Study suggested that the association between SO_2 and respiratory symptoms could be confounded by PM_{10} (Schwartz et al., 1994). It should be noted that unlike the NCICAS and CAMP studies, this study was not limited to asthmatic children. The median 24-hour average SO_2 concentration during this period was 4.1 ppb (10th–90th percentile: 0.8, 17.9;

maximum 81.9). SO_2 concentrations were found to be associated with cough incidence and lower respiratory tract symptoms. However, the effect of SO_2 was substantially reduced after adjustment for PM_{10}. PM_{10} had the strongest association with respiratory symptoms, and the effect of PM_{10} remained robust in copollutant models. Because PM_{10} concentrations were correlated strongly to SO_2-derived sulfate particles (r = 0.80), the reduced SO_2 effect estimate may indicate that for PM_{10} dominated by fine sulfate particles, PM_{10} has a slightly stronger association than SO_2 to cough incidence and lower respiratory symptoms (draft ISA, section 3.1.4.1.1).

In addition to epidemiological studies examining the relationship between ambient SO_2 concentrations and respiratory symptoms in children, the draft ISA also describes studies that looked for associations between SO_2 levels and respiratory symptoms in adults (draft ISA, section 3.1.4.2.1). The draft ISA notes that compared to the number of epidemiological studies examining the association between SO_2 exposure and respiratory symptoms in children, fewer studies examined this association in adults. Moreover, results in adults were mixed; some studies demonstrated positive associations while others showed no relationship at current ambient SO_2 levels (draft ISA, section 3.1.4.1.2).

4.3.2 Emergency Department Visits and Hospitalizations for All Respiratory Causes

Respiratory causes for ED and hospitalization visits typically include asthma, pneumonia, bronchitis, emphysema, upper and lower respiratory infections, as well as other minor categories. Overall, the draft ISA concludes that there is suggestive evidence of an association between ambient SO_2 concentrations and combined ED visits and hospitalizations for all respiratory causes (draft ISA, section 3.1.4.6.1). The ISA also finds that when analyses are restricted by age, the results among children (0-14 years) and older adults (65+ years) are mainly positive, but not always statistically significant (draft ISA, section 3.1.4.6.1). When all age groups are combined, the ISA finds that the results of studies are mainly positive; however, the excess risk estimates are generally smaller compared to children and older adults (see draft ISA, figure 3-6). Results from key epidemiological studies conducted in the U.S. and Canada are described below, and a more detailed discussion of both the U.S. and international epidemiological literature can be found in the draft ISA (draft ISA, section 3.1.4.6.1).

Wilson et al. (2005) examined the association between SO_2 levels and ED visits for all respiratory causes in Portland, ME and Manchester, NH. The authors found a negative association in Portland when analyses were limited to children. In Portland, they found a positive and statistically significant 9% (95% CI: 5, 14) excess risk per 10 ppb increase in 24-hour average SO_2 in adults. Largest effects were observed among the elderly, with a 16% (95% CI: 7, 26) excess risk per 10 ppb increase in 24-hour average SO_2. When all ages were combined, a positive and statistically significant 7% (95% CI: 3, 12) excess risk per 10 ppb increase in 24-hour average SO_2 was observed in Portland. No relationship was observed between SO_2 concentrations and ED visits for all respiratory causes in Manchester in the analyses of all ages or any age-stratified group.

Schwartz (1995) conducted a study in New Haven, CT and Tacoma, WA evaluating the relationship between hospital admissions for all respiratory causes (n ≈ 8,800 in New Haven and n ≈ 4,600 in Tacoma) and ambient SO_2 concentrations in older adults (65+ years). The average 24-hour SO_2 concentration was 29.8 ppb in New Haven and 16.8 ppb in Tacoma. Schwartz et al. found positive associations between hospitalizations and SO_2, with a 2% (95% CI: 1, 3) excess risk in New Haven and 3% (95% CI: 1, 6) excess risk in Tacoma per 10 ppb increase in 24-hour average SO_2. Notably, the effect estimate for New Haven remained robust and statistically significant in two-pollutant models with PM_{10}, but in Tacoma was substantially reduced and no longer statistically significant (draft ISA, Figure 3-8). Additional evidence for an association between SO_2 exposure and hospital admissions for all respiratory causes in older adults was found in two studies conducted in Vancouver, BC. Fung et al. (2006) and Yang et al. (2003) both found positive associations between hospitalizations and 24-hour average SO_2 concentrations in older adults.

Peel et al. (2005) investigated the relationship between 1-hour maximum SO_2 concentrations and respiratory ED visits (n ≈ 480,000) for all ages in Atlanta, GA. The mean 1-hour maximum SO_2 concentration was 16.5 ppb. A weak and statistically non-significant relationship was observed for respiratory ED visits. Specifically, Peel et al. found an excess risk of 1.6% (95% CI: −0.6, 3.8) per 40 ppb increase in 1-hour maximum SO_2. Tolbert et al (2007) recently reanalyzed the data from this study along with four additional years of data and found similar results.

4.3.3 Emergency Department Visits and Hospitalizations for Asthma

The draft ISA also finds suggestive evidence of an association between SO_2 levels and ED visits and hospitalizations for asthma. The document notes that most of the effect estimates associated with asthma ED visits are positive (suggesting an association with ambient SO_2), although few are statistically significant (draft ISA, section 3.1.4.6.1). In an analysis encompassing all ages, Wilson et al. (2005) found a statistically significant positive association between asthma ED visits and SO_2, with an 11% (95% CI: 2, 20) excess risk per 10 ppb increase in 24-hour average SO_2 in Portland, ME. In Manchester NH, the authors found a positive, although not statistically significant association with a 6% (95% CI: -4, 17) excess risk per 10 ppb increase in 24-hour average SO_2. Ito et al. (2007) also examined the association between SO_2 and asthma ED visits in all ages. This study was conducted in New York City and found a 6% (95% CI: 3, 10) excess risk per 10 ppb increase in 24-hour average SO_2 in all year analyses. Multipollutant analyses were conducted in data limited to the warm season only. While the SO_2 effect estimate was robust and remained statistically significant after adjustment for $PM_{2.5}$, O_3, and CO in two-pollutant models, it was found to diminish to null when adjusting for NO_2. Peel et al. (2005) also examined the association between asthma ED visits and ambient SO_2. This study was conducted in Atlanta and found a null association between ED visits for asthma and 1-hour maximum SO_2 levels. In addition to these ED studies, a hospital admissions study conducted by the New York Department of Health (NY DOH, 2006) found a statistically significant 10% (95% CI: 5, 15) excess risk for asthma hospital admissions per 10 ppb increase in 24-hour average SO_2 for residents of the Bronx, but a null association for those living in Manhattan.

In three Ohio cities, Jaffe et al. (2003) examined the association between SO_2 concentrations and asthma ED visits among asthmatics, aged 5-34 years. The mean 24-hour average SO_2 concentrations were 14 ppb in Cincinnati, 15 ppb in Cleveland, and 4 ppb in Columbus. A statistically significant association was observed in the multicity analysis. The authors found an excess risk of 6% (95% CI: 1, 11) per 10 ppb increase in 24-hour average SO_2. In the city-stratified analyses, statistically significant associations were observed for Cincinnati (17% [95% CI: 5, 31]), but not in Cleveland (3% [95% [CI -4, 11]) or Columbus (13% [95% CI: -14, 49]).

Lin et al. (2004b) conducted a case-control study of children aged 0-14 years in Bronx County, NY. The authors examined the potential association between daily ambient SO_2 concentrations (categorized into quartiles of both average and maximum levels) and cases admitted into the hospital for asthma, or controls who were admitted for reasons other than asthma. The results of this study demonstrated that cases were exposed to higher daily average concentrations of SO_2 than controls. When the highest exposure quartile (>20 ppb, 24-h average SO_2) was compared with the lowest (2.9-9.4 ppb, 24-h average SO_2), the odds ratios (ORs) were strongest when a 3-day lag was employed (OR 2.16 [95% CI: 1.77, 2.65]). However, the results were positive and statistically significant for all lag days examined. Lin et al. (2005) observed a weak positive association between hospitalizations for asthma and SO_2 among girls, and a null association for boys (Toronto, ON; mean 24-h average SO_2 of 5.36 ppb [SD 5.90]). In addition to these hospitalizations studies, Wilson et al. (2005) found a positive, but not statistically significant 5% (95% CI -12, 25) excess risk per 10 ppb increase in 24-hour average SO_2 for asthma ED visits in Portland, ME, and a positive, but not statistically significant 20% (95% CI -3, 49) excess risk in Manchester, NH among children aged 0-14 years.

5.0 OVERVIEW OF RISK AND EXPOSURE ASSESSMENT

5.1 INTRODUCTION

As previously discussed in Chapter 4, the draft ISA concludes that there is a causal relationship between short-term (ranging from 5-minute to 24-hours) SO_2 exposure and respiratory morbidity, while finding associations between SO_2 exposure (both short- and long-term) and other health endpoints to be less convincing (draft ISA, Table 5-3). The draft ISA bases these conclusions on the cohesiveness and overall strength of evidence from human clinical, epidemiological, and animal toxicological studies. Thus, based on the scientific evidence presented in the draft ISA, staff concludes that the most appropriate use of time and resources is to conduct an exposure and risk assessment based on select respiratory morbidity endpoints. Moreover, based on the nature of the scientific evidence (predominantly human clinical for peak exposures and epidemiological for short-term exposures), staff judges it most appropriate to perform separate and distinct analyses to evaluate exposure and risks associated with different averaging times of SO_2 exposure. A general description of each analysis is described in the following sections.

5.2 APPROACH FOR ASSESSING EXPOSURE AND RISK ASSOCIATED WITH 5-MINUTE PEAK SO_2 EXPOSURES

Three analyses will be performed to assess the risks associated with short-term peak SO_2 exposures. The first analysis compares 5-minute potential health effect benchmark values, based on the draft ISA's evaluation of relevant controlled human exposure studies with an air quality analysis to determine the frequency with which these benchmark values are exceeded considering current air quality, and air quality adjusted to simulate just meeting the current standards (Chapter 6). The second analysis combines these same benchmark values derived from controlled human exposure studies with results from exposure modeling to estimate the number of individuals that are likely to experience exposures exceeding these benchmark levels (Chapter 7). Finally, the third analysis is a quantitative risk assessment combining outputs from the exposure analysis with estimated exposure-response functions based on data from controlled human exposure studies to estimate the percentage, and number of asthmatics likely to experience a given decrement in lung function associated with recent air quality and SO_2 levels adjusted to simulate just meeting the current standards (Chapter 8). This third analysis is not yet complete and, thus, this draft of the REA provides a brief description of the overall approach.

To identify potential health benchmarks to be used in combination with the air quality and exposure analyses, staff reviewed the controlled human exposure evidence presented in the draft ISA for evidence of SO_2 concentrations that resulted in decrements in lung function in the presence of respiratory symptoms because this combination of lung function decrements and respiratory symptoms is considered to be adverse in ATS guidance, which the staff and CASAC have generally endorsed as appropriate. As discussed above, the draft ISA identified 0.4-0.6 ppm SO_2 for 5-10 minutes as an exposure range resulting in a substantial percentage of exercising asthmatics experiencing moderate or greater increases in sRAW, or decreases in FEV_1 in the presence of respiratory symptoms. Therefore, we judge that 0.4-0.6 ppm SO_2 is an appropriate range to use in the benchmark analyses associated with 5-minute peak SO_2 concentrations.

5.3 APPROACH FOR ASSESSING EXPOSURE AND RISK ASSOCIATED WITH SHORT-TERM (≥1 HOUR) SO_2 EXPOSURES

As discussed in more detail in Chapter 9, staff has concluded that a number of factors make it particularly difficult to quantify with confidence the unique contribution of SO_2 to respiratory health effects and therefore, we judge that the results of a quantitative risk assessment based on concentration-response functions from epidemiological studies for these health outcomes would be highly uncertain and of limited utility in the decision-making process. However, even though we do not believe that the body of U.S. and Candian epidemiological literature is robust enough to support a quantitative assessment of risk, we do agree that the results of these studies, as well as supportive evidence from international studies suggest an association between SO_2 exposure and respiratory symptoms in children, and hospital admissions and ED visits for all respiratory causes and asthma, and as a result, warrant a characterization of risk.

Staff plans to use epidemiological data from recent U.S. and Canadian studies examining ED visits and hospitalizations for all respiratory causes and asthma, as well as epidemiological studies examining respiratory symptoms, to qualitatively assess the range of SO_2 air quality levels that are associated with these health endpoints (see Chapter 9). We requested the authors of key U.S. and Canadian studies identified in the draft ISA to provide more detailed SO_2 air quality distribution data. This data will be used to generate tables and graphs relating specific air quality statistics at the time the studies were conducted to health effect estimates. This data will then be used to compare SO_2 levels in studies where health effects were observed to those levels that would be estimated to occur in areas just meeting the current 24-hour standard. In addition, the second draft of this document will also compare air quality levels seen in studies that observed respiratory health effects to air quality levels that could occur under any alternative standards that may be under consideration.

6.0 AMBIENT AIR QUALITY AND BENCHMARK HEALTH RISK CHARACTERIZATION FOR 5-MINUTE PEAK SO_2 EXPOSURES

6.1 INTRODUCTION

The first step in evaluating SO_2 exposure to 5-minute peaks was to characterize air quality relying largely on ambient SO_2 monitoring data and the information provided in the draft ISA and relevant Annexes. In this analysis, ambient SO_2 concentrations served as a surrogate for total human exposure and were used in developing statistical relationships among various averaging times. This analysis considered information on SO_2 air quality patterns, historic trends, local sources, and 5-minute potential health effect benchmarks in the range of 0.4-0.6 ppm; staff identified this range, based on the health effects information presented in the draft ISA (see section 4.2).

Staff developed statistical relationships between 5-minute peak concentrations and hourly concentrations using ambient monitoring data. This was done because the averaging times for the current SO_2 NAAQS (daily and annual), much of the ambient monitoring data (1-hour), and outputs from dispersion models (1-hour) were not comparable to the selected health effects averaging time of 5-minutes. Both measured and modeled 5-minute data were then evaluated considering air quality conditions as they existed at the time of measurement (henceforth referred to as "air quality *as is*"), as well as under simulated conditions that would just meet the current form and level of the primary 24-hour SO_2 standard of 0.14 ppm (one allowable exceedance) and the annual average SO_2 standard of 0.03 pm (henceforth referred to as "just meeting the current standards").

Overall, the objectives of this analysis are to: (1) evaluate trends in short- and long-term SO_2 concentrations using available 5-minute and 1-hour average ambient SO_2 monitoring data, (2) develop a statistical approach to estimate the 5-minute concentrations associated with 1-hour average ambient monitoring concentrations, (3) estimate the frequency of short-term peak concentrations at ambient monitoring locations above potential health effect benchmark levels using both measured data and statistical model predictions, and (4) identify key uncertainties in the analysis.

6.2 APPROACH

6.2.1 Monitoring data

SO_2 air quality data available since the previous review (1997-2007) was assembled from EPA's Air Quality System (EPA, 2007c). Monitoring data were collected over 5-minute or 1-hour averaging times. The 5-minute SO_2 monitoring data exist in either one of two forms; the single highest 5-minute concentration occurring in a 1-hour period (referred to here as max-5), or all twelve 5-minute concentrations within a 1-hour period (referred to here as continuous-5). A summary of all available 5-minute and 1-hour SO_2 monitoring data is presented in Table 6-1 and a more detailed description of these data can be found in Appendix A.

Table 6-1. Summary of available 5-minute and 1-hour SO_2 ambient monitoring data.

Sample Type	Number of Monitors	Number of States[1]	Years in Operation	Number of Measurements
Max-5	104	13 + DC	1997-2007	3,457,057
Continuous-5	16	6 + DC	1999-2007	3,328,725
1-hour	935	49 + DC, PR, VI	1997-2007	47,206,918

[1] DC=District of Columbia, PR=Puerto Rico, VI=Virgin Islands.

The data sets listed in Table 6-1 were screened for locations where monitor IDs contained multiple parameter occurrence codes (POCs) and identical monitoring times (see Appendix A), an indication that SO_2 concentrations were measured simultaneously at a given location (i.e., co-located monitors). As a result, three additional data sets were identified for further analyses (summarized in Table 6-2.):

1. A data set containing all simultaneous measures collected at the same location and time for:

A. max-5 duplicates (i.e. simultaneous measurements from co-located max-5 monitors)

B. max-5 and continuous-5 duplicates (i.e. simultaneous measurements from a co-located max-5 monitor and continuous-5 monitor)

These data were used for quality assurance purposes. Duplicate measures were not used in the statistical model development.

2. A complete set of 5-minute maximum SO_2 concentrations without duplicate 5-minute measures (combined from max-5 and maximums reported in continuous-5 monitoring data), combined with their corresponding measured 1-hour SO_2 concentrations. These data were used for developing the statistical model and for characterizing air quality.

3. All 1-hour SO_2 data that do not have any corresponding 5-minute concentrations. These data were used for application of the statistical model and characterizing air quality.

Table 6-2. Number of duplicate samples within and between max-5 and continuous-5 data sets.

Sample Type	Within Set Duplicates (n)	Available Data (n)	Combined Set Duplicates (n)	Final Combined Max-5 Data (n)	Final Combined Max-5 & 1-hour (n)
Max-5	300,438	3,156,619	29,058	3,410,763	2,408,420
Continuous-5	0	283,202[1]			
1-hour	0	47,195,533	-	-	

[1] The number of 5-minute maximum samples.

6.2.2 Monitoring Siting

The siting of the monitors is of particular importance, recognizing that proximity to local sources likely influences measured SO_2 concentration data. Stationary sources (in particular, power generating utilities using fossil fuels) are the largest contributor to SO_2 emissions in the U.S. (EPA, 2007b). Analyses were performed here to determine the distances and the types of stationary source emissions to the ambient monitors. Two points are worthy of mention for this analysis; the first being the difference between the number of 5-minute and 1-hour monitors located across the U.S., and the second being the potential for differences in types of sources influencing each of the monitors. While there is overlap in the measurement of 5-minute maximum and its associated 1-hour concentration in some locations (n=98), over 800 1-hour monitors are sited in other locations where 5-minute measurements have not been collected. There is a possibility that sources in close proximity to the 1-hour monitors have a different impact on SO_2 concentrations measured at these monitors compared with those sources influencing concentrations measured at the 5-minute monitors.

However, the comparison of the sources located within 20 km of the 5-minute and 1-hour monitors indicates strong similarity in the types of sources potentially influencing the measured concentrations at each type of monitor. Figure 6-1A shows the percent of total SO_2 emissions for sources located within 20 km of the 5-minute maximum monitors. Approximately 70% of the stationary source emissions originate from power generation, divided among fossil fuel and hydroelectric utilities. Primary smelters (9%) and petroleum refineries (7%) comprise the next highest sources of emissions, and much of the remaining total emissions (17%) are divided among numerous other sources. Figure 6-1B shows that the emissions sources within 20 km of the available 1-hour SO_2 ambient monitors are similar to the 5-minute maximum monitors in type and percent of total emissions. Seventy-eight percent of total emissions result from power generation, followed next by petroleum refineries (5%) and other lower emitting sources. The largest distinction between the sources surrounding the two groups of monitoring data is the contribution from primary smelters with greater emissions within 20 km of the 5-minute monitors (8.8%) than within 20 km of the 1-hour monitors (1.1%).

6.2.3 Statistical Model for Estimating 5-minute Maximum Concentrations

6.2.3.1 Background

The overwhelming majority of the SO_2 ambient monitoring data is for 1-hour average, while important health effects are associated with 5-minute peak concentrations of SO_2. Therefore, a model needed to be designed to allow for estimation of 5-minute maximum SO_2 based on the available 1-hour average monitoring data. Staff reviewed the air quality characterization conducted in the prior SO_2 NAAQS review and supplementary analyses, much of which focused on evaluating the relationship between the maximum 5-minute SO_2 concentration and the 1-hour average SO_2 concentration, or peak-to-mean ratios (PMRs) (SAI, 1995; Thompson, 2000). On average, the PMR was determined to be approximately two; however, the ratio varies. It was shown that there is increased variability in the ratio with decreasing 1-hour average SO_2 concentrations, that is, there is a greater likelihood of values greater than 2 at low hourly average concentrations than expected at high hourly average concentrations. In addition, the occurrence of short-term peak concentrations at ambient monitors is likely to be influenced by their distance from local sources and source characteristics including the magnitude of emissions, temporal operating patterns (e.g., seasonal, time-of-day),

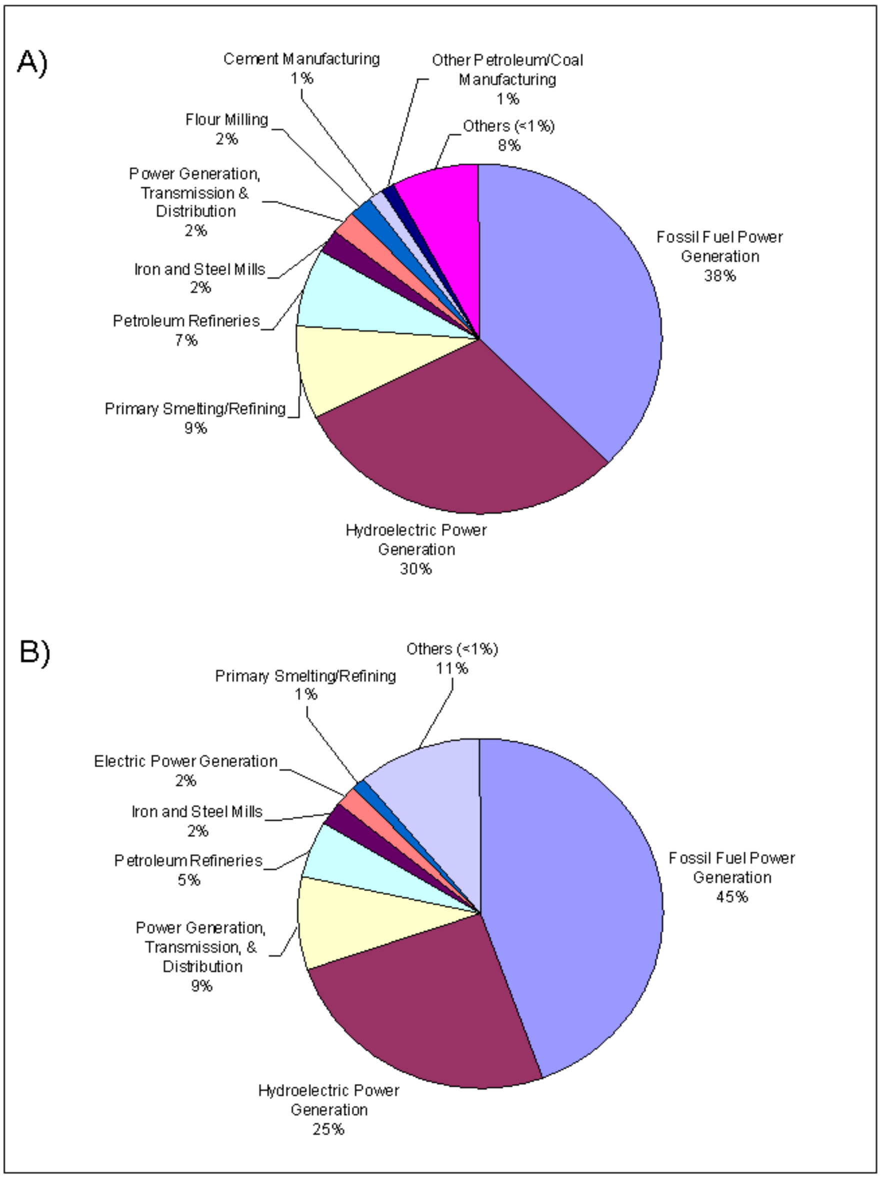

Figure 6-1. The percent of total SO_2 emissions by source types located within 20 km of ambient monitors. A) 5-minute maximum SO_2 monitors, B) 1-hour SO_2 monitors.

facility maintenance, and other physical parameters (e.g., stack height, area terrain), as well as by local meteorological conditions. As part of a sensitivity analysis conducted for copper-smelters, the dependence of PMRs on the distance from the source was evaluated for three ranges of normalized 1-hour mean concentrations (Sciences International, 1995).[3] Distance was found to be inversely proportional to the PMR in all three of the 1-hour mean stratifications (i.e., ≤ 0.04 ppm, 0.04 to ≤ 0.15 ppm, and >0.15 ppm), with the highest 1-hour category containing the lowest range of PMR.

6.2.3.2 Current Approach

The model used here to generate the relationship between short-term peak and 1-hour concentrations is given in equation 6-1.

$$C_{\max-5} = PMR \times C_{1-hour} \qquad \text{equation (6-1)}$$

where,

C_{max-5}	=	estimated maximum 5-minute SO_2 concentration (ppb)
PMR	=	peak to mean ratio (PMR)
C_{1-hour}	=	measured 1-hour average SO_2 concentration

The application of this model considers the limited geographic span of the monitoring data and the overall uncertainty regarding the amount of influence of a specific source on any given monitor. This approach is based on hourly concentration levels and relative standard deviations (or coefficient of variation (COV)) observed at the monitors measuring the continuous or maximum 5-minute SO_2 concentrations and simultaneous SO_2 1-hour concentrations. The assumption is that the temporal and spatial pattern in SO_2 source emissions is influenced by the type of source(s) and its operating conditions and that this emission pattern(s) will be reflected in the ambient SO_2 concentration distribution measured at the monitor. This approach is discussed in more detail below.

6.2.3.3 Relationship Between 1-hour and 5-minute SO_2 Concentrations

There were multiple analyses performed here using the available 5-minute monitoring data, the first of which involved evaluating the relationship between the variability in 1-hour and

[3] In that analysis, normalized 1-hour SO_2 concentrations were obtained by dividing by the maximum hourly concentration.

5-minute SO_2 concentrations. As noted above, the variability in these concentrations could serve as a surrogate for source emissions, source types, or distance to sources. The purpose was to develop a categorical variable to use for connecting the statistical model to both the 1-hour monitoring data and 1-hour dispersion model estimates (where no 5-minute SO_2 data concentration exist).

First, all available 5-minute SO_2 concentrations from the 16 continuous monitors for all years were averaged for each monitor, that is, all of the continuous-5 data available for each monitor were averaged to generate a single 5-minute mean concentration and its respective standard deviation (a total of 16 monitor- specific 5-minute values). Then, the 5-minute SO_2 concentrations were averaged to generate 1-hour average SO_2 concentrations for each monitor, which were then averaged to generate a single 1-hour mean and its corresponding standard deviation (a total of 16 monitor-specific 1-hour values). The COV for the 1-hour and 5-minute data at each monitor are illustrated in Figure 6-2. As expected, a strong direct linear relationship exists between the variability in 5-minute and 1-hour SO_2 concentrations at each monitor, although the 1-hour monitoring COV is approximately 75% that of the 5-minute monitoring COV. Even with the limited geographic representation (the monitors come from only 6 states plus Washington DC), there is a wide range in the observed concentration variability for both the 5-minute and associated hourly measurements (COVs around 75 – 300%). In general, this analysis indicates that variability in 5-minute SO_2 concentrations is directly related to the variability in 1-hour SO_2 concentrations, and may be used as a categorical parameter to describe the potential variability in emissions and possible source types influencing any ambient SO_2 monitor.

A second comparison was made using the 1-hour concentrations measured at each of the 5-minute monitors and the 1-hour monitors. Figure 6-3 illustrates the Cumulative Density Functions (CDFs) for the hourly COV at each of the 98 monitors that measured both 5-minute maximum and 1-hour SO_2 concentrations (the final combined max-5 and 1-hour data set) and the 927 hourly monitors containing no 5-minute maximum measurements. While the 5-minute monitors exhibit greater variability in hourly concentration at most percentiles of the distribution, the overall shape and span of the distributions are very similar. This could indicate that on the whole, the proximity to sources, their magnitude of emissions, and the types of sources affecting either set of ambient monitors (i.e., the 1-hour monitors versus the 5-minute monitors) are similar. This, combined with the distance and emissions analysis that indicated similar source type emission proportions in Appendix A, provides further support for using COV as a categorical parameter to extrapolate PMRs developed from the 5-minute SO_2 monitors to the 1-hour monitors.

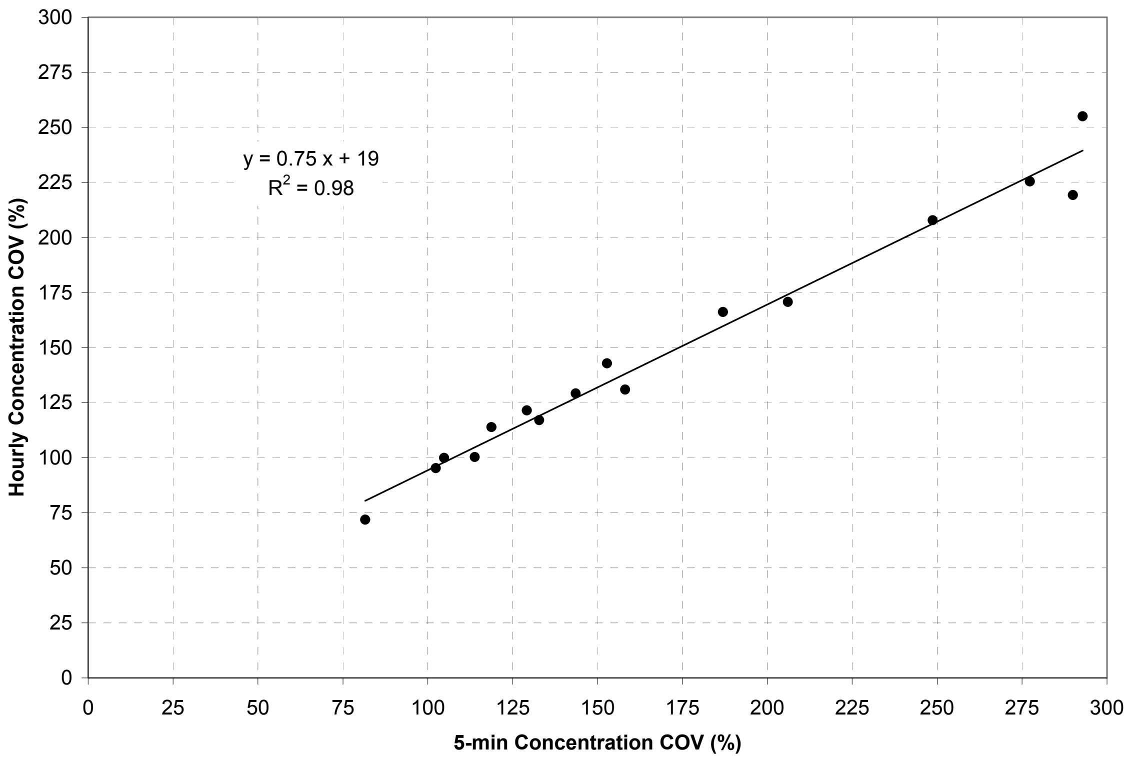

Figure 6-2. Comparison of hourly COV and 5-minute COV at 16 continous-5 monitors, over multiple years of monitoring.

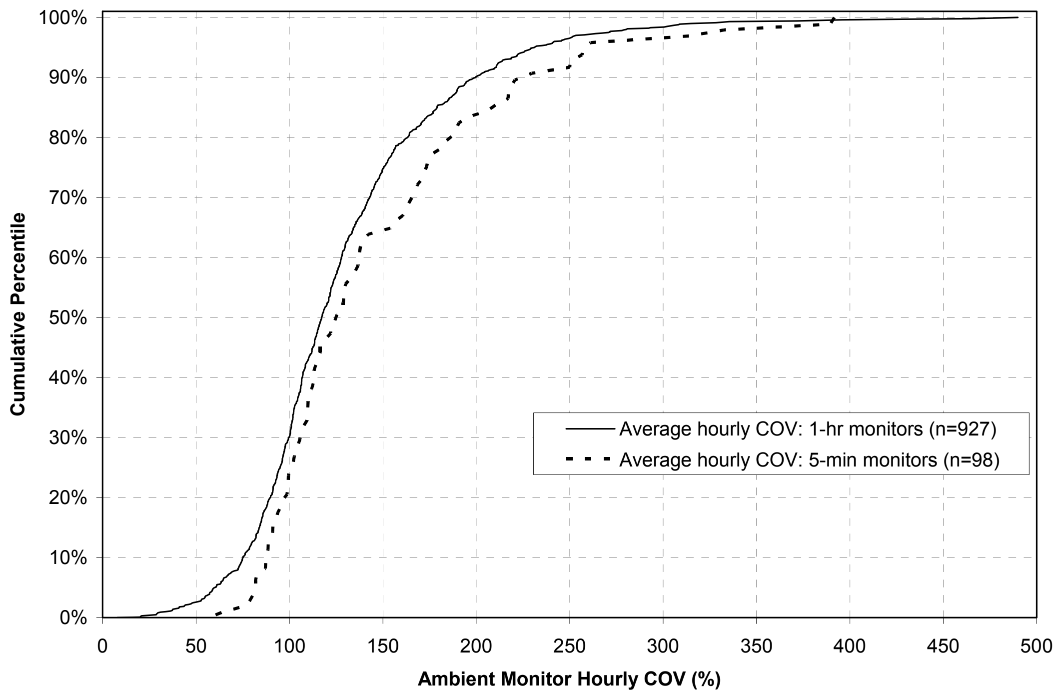

Figure 6-3. Cumulative density functions (CDFs) for hourly COV at 1-hour and 5-minute SO_2 monitors.

6.2.3.4 Development of Peak to Mean Ratio (PMR) Distributions

A key parameter in the statistical model to estimate the frequency of maximum 5-minute SO_2 concentrations at locations where only 1-hour average values were measured is the PMR. The method used here builds upon prior analyses conducted by Thompson (2000)[4], however the updated approach includes the development of several PMR cumulative density functions (CDFs) based on more recent 5-minute SO_2 monitoring data, and considers a COV categorical parameter describing each monitor and the measured (or modeled) 1-hour SO_2 concentration level.

First, the PMR data were screened for validity, recognizing that the combined max-5 and 1-hour SO_2 data set may still contain certain anomalies (e.g., 5-max concentration < 1-hour mean concentration). A value of 1 was selected as the lower bound PMR, accepting that it may be possible that the 5-minute maximum concentrations (and all other 5-minute concentrations within the same hour) may be identical to the 1-hour average concentration. A PMR of 12 was

[4] A single semi-empirical distribution of PMRs based on 6 ratio bins was used that assumed independence between the ratio and the 1-hour concentration.

selected as the upper bound since it would be a mathematical impossibility to generate a value above that given there are 12 5-minute measurements within any 1-hour period.[5] This screening resulted in a total of nearly 2.4 million valid PMRs.

COV has been identified above as an important attribute in characterizing potential sources affecting the ambient monitors. Based on the hourly COV distributions in Figure 6-3, we assigned one of three COV bins to each of the 98 monitors containing both the 5-minute maximum and 1-hour average SO_2 concentrations: COV ≤ 100%, 100% < COV ≤ 200%, and COV > 200%. The three COV bins were selected to capture the upper and lower tails of the distribution and a mid-range area. In addition, the level of the 1-hour mean concentration has been identified as an important consideration in defining the appropriate PMR distribution. The PMR CDFs were further stratified by five 1-hour mean concentration ranges: 1-hour mean < 33.3 ppb, 33.3 ≤ 1-hour mean ≤ 100 ppb, 100 < 1-hour mean ≤ 200 ppb, 200 < 1-hour mean ≤ 300 ppb, and 1-hour mean > 300 ppb. While PMR CDFs were generated for 1-hour concentrations < 33.3 ppb, it should be noted that the corresponding 5-minute concentration would be below that of the lowest potential health effect benchmark level of 400 ppb. The stratification was done by equivalent 100 ppb increments to represent the variability in PMR anticipated across the 1-hour SO_2 concentration and COV categories, to allow for a reasonable assignment of PMR to an appropriate 1-hour concentration, while also limiting the total possible number of PMR distributions. Based on the COV and 1-hour mean categories, this resulted in a total of thirteen separate PMR CDFs,[6] summarized in Appendix B. Due to the large number of samples available for several of the PMR distributions, the data were summarized into semi-empirical distributions, with the cumulative percentiles ranging from 0 to 100, by increments of 1.

Figure 6-4 illustrates two trends in the PMRs when comparing the distributions across the stratification categories. First, the monitors with the highest COVs contain the highest PMRs at each of the percentiles of the distribution (Figure 6-4C) when compared with monitors from the

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[5] As the 5-minute maximum concentration goes to infinity, the other 11 concentrations measured in the hour comparatively tend to zero, giving PMR = Peak/Mean = $C_{max}/[(C_{max}+ 0*11)/12] = 12$.

[6] Although there were a total 15 PMR CDFs possible, the COV < 100% category did not contain any 1-hour concentrations above 200 ppb. Also note that each of the three lowest concentration category PMRs (<33.3 ppb) are not illustrated in Figure 4 for improved clarity.

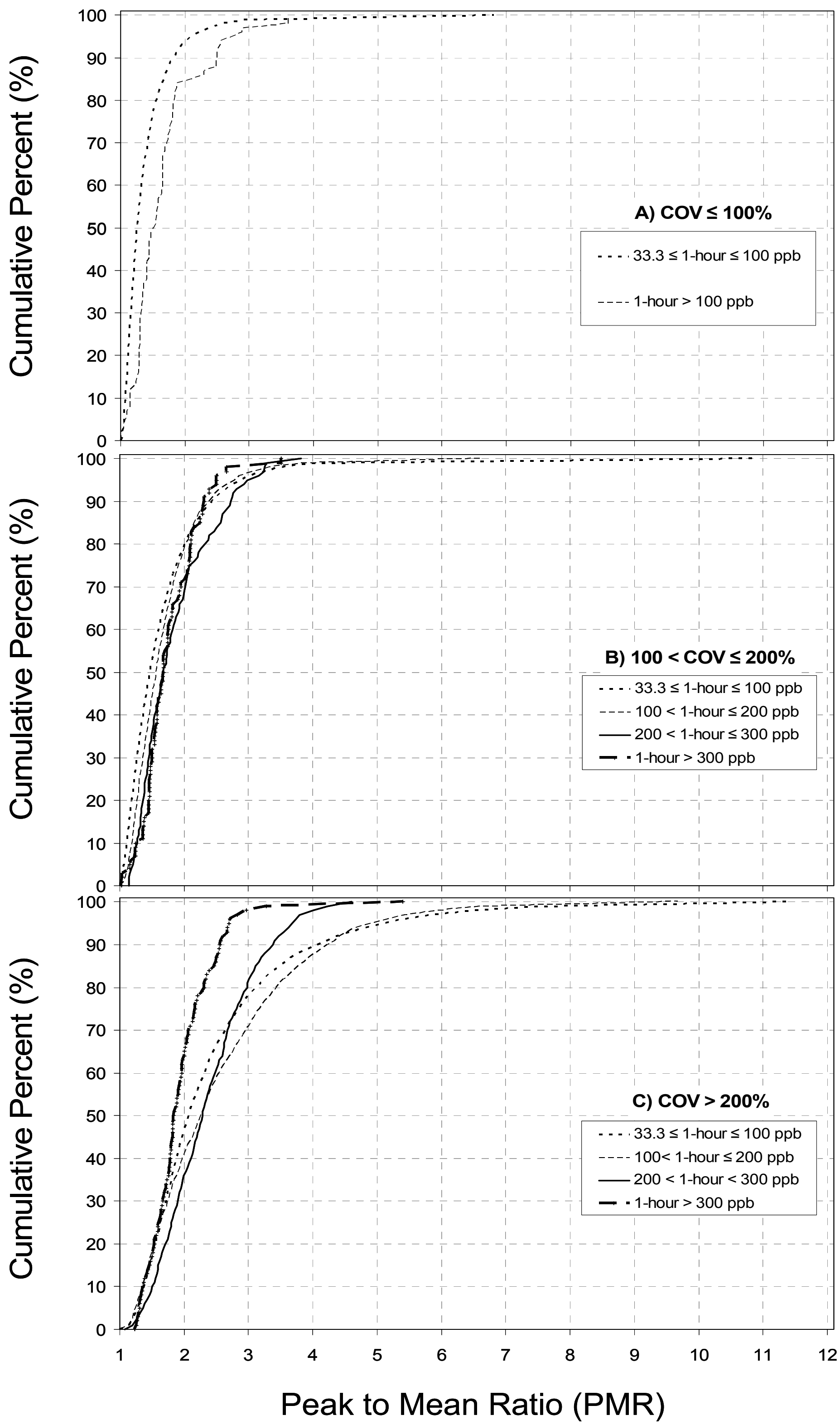

Figure 6-4. Peak to mean ratio (PMR) distributions for three variability categories and 1-hour concentration groups. A) COV ≤ 100%, B) 100 < COV ≤ 200%, and C) COV > 200%.

other two COV categories (Figures 6-4A and 6-4B), while the mid-range COV category monitors (Figure 6-4B) contained higher PMRs than the lowest COV category (Figure 6-4A). These distinctions in PMR are consistent with the results illustrated in Figure 6-2, that is, variability in the hourly average concentrations is directly related to the variability in the short-term concentrations. Second, differences were observed in the PMR distributions within each PMR category when categorized by 1-hour average concentrations. This is most evident in the highest COV category (Figure 6-4c); the highest 1-hour concentration category (> 300 ppb) contained the lowest PMRs at each of the distribution percentiles compared with the distributions for the lower concentration categories (e.g., 33.3 – 100 ppb). In fact, the maximum PMR for the > 300 ppb category was only 5.4, compared with a maximum PMR of 11.45 for the 33.3 – 100 ppb category. The hourly average concentration was used for categorization to prevent use of high PMRs developed from lower hourly concentrations being applied to higher hourly concentrations. This stratification by 1-hour average concentration and COV is designed to control for aberrant assignment of PMRs to 1-hour concentrations.

6.2.3.5 Application of Peak to Mean Ratios (PMRs)

As described above with respect to the 5-minute monitoring data, each of the 929 1-hour monitors that did not contain 1-hour measurements was characterized by its respective hourly COV value, and placed in one of the three COV bin (COV ≤ 100%, 100% < COV ≤ 200%, and COV > 200%). Based on the monitor COV bin and every 1-hour SO_2 concentration, PMRs were randomly sampled[7] from the appropriate PMR CDFs for each hour and used to estimate a 5-minute maximum concentration using equation 6-1. After this calculation, each 1-hour ambient monitor contained a simulated 5-minute maximum concentration for each period when the 1-hour SO_2 concentration was > 0 (otherwise the 5-minute maximum concentration was estimated as zero). These data were then summarized by calculating the number of times an estimated 5-minute peak concentration above a potential health effect benchmark level occurred.

6.2.3.6 Evaluation of Estimation Procedure

The procedure for estimating the 5-minute maximum SO_2 concentrations was evaluated using the data from the 98 monitors where both 5-minute and 1-hour concentrations were

[7] The random sampling was based selection of a value from a uniform distribution {0,100}, whereas that value was used to select the PMR from the corresponding CDF percentile value.

measured. The statistical model described in sections 6.2.3.2 through 6.2.3.4 was used to generate predicted values at the 5-minute monitors. The precision of the statistical model was then assessed by comparing measured 5-minute maximum SO_2 concentrations to the predicted values. The objective of this first evaluation was to determine the approximate number of simulations needed to produce stable 5-minute maximum concentrations predictions. Twenty simulations were run for all max-5 monitors (n=98) across all years of data to generate the number of 5-minute maximum SO_2 concentrations above 400 ppb (*peak* concentrations) for each monitor in each simulation. Predicted versus measured differences in the number of peaks estimated at each monitor were normalized to provide equal weighting for this comparison (equation 6-2). The mean number of predicted peaks (P) at each individual monitor (j) for all simulations was first calculated and compared with the measured number of peaks (M) at each individual monitor to estimate an absolute difference between the total simulation average and the measured data. Then predicted differences were calculated for each of the progressive simulations ($i = 1,2,3,\ldots 20$) at each monitor and compared to the total simulation difference at each monitor. The calculated value indicates the proportion of the difference, including negative (underestimations) and positive (overestimations) values, and values of zero (where the particular simulation estimate was the same as the measured). There was only one difference in predicted versus measured peaks that resulted in a value of zero ($P_j = M_j$ at Monitor ID 301110080), therefore results from this monitor were removed from further analysis. The remaining relative differences for each of the 97 monitors were then averaged to generate an average absolute relative difference (*Diff*) for each progressive simulation as follows:

$$\overline{Diff_i} = \frac{\sum_{j=1}^{n} \frac{\overline{P}_{ij} - M_j}{\overline{P}_j - M_j}}{n} \qquad \text{equation (6-2)}$$

Note that at the 20th simulation, $P_{ij} = P_j$ and results in an absolute relative difference of 1.0 at each of the 98 monitors. Figure 6-5 illustrates the results of this calculation. As expected the estimated number of peaks is most variable over the fewest number of simulations, although though the range of relative difference in these estimates resultant from the fewer simulations is still small (+/- 10%). By approximately 13 simulations, the relative absolute difference appears to straddle 1.0 closely, suggesting that within the range of 13-20 model simulations, much of the variability in the estimation procedure has been represented well by the total number of simulations.

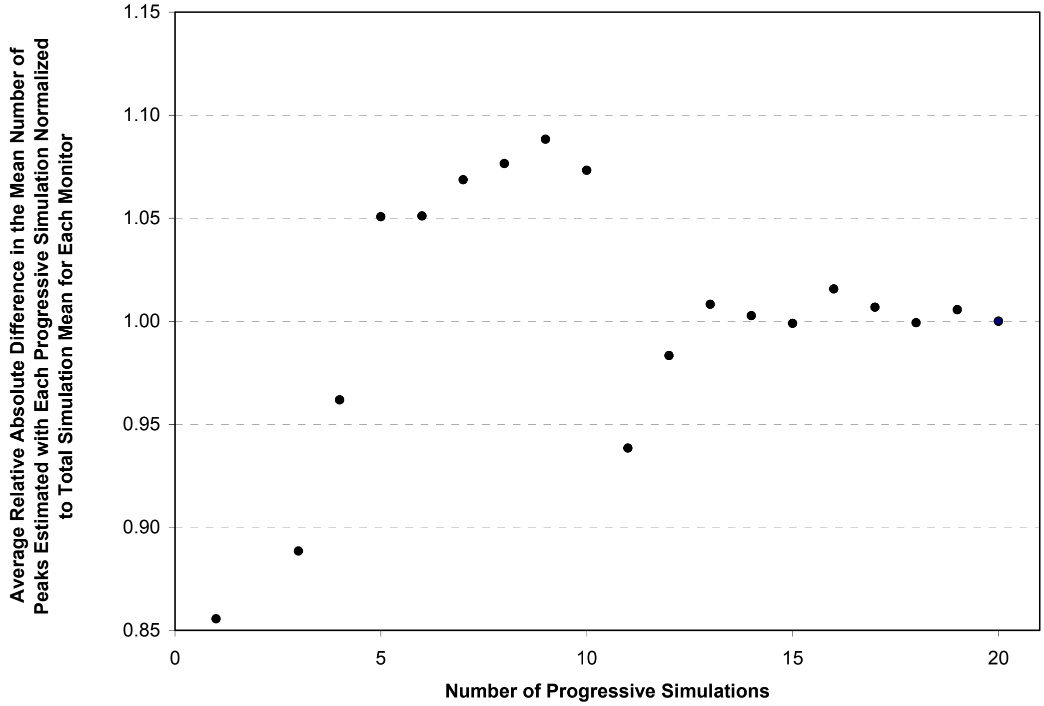

Figure 6-5. Comparison of the mean relative absolute difference in number of predicted and measured peaks above 400 ppb, across progressive model simulations using the monitors that contained measurements for 5-minute maximum SO_2 concentrations.

Variability in the model estimation was also evaluated as a function of the predicted number of peaks (Figure 6-6) at each monitor. A similar degree of variability, as represented by a COV of about 25%, was observed for the number of peak estimates ranging from 15 upwards to 450. Variability increases dramatically when fewer than 15 peak concentrations above 400 ppb are estimated. This is largely the result of estimating a few exceedances in one or a few simulations, along with zero exceedances in other simulations. This evaluation suggests that where a monitor has about 15 or more estimated maximum 5-minute SO_2 concentrations at or above the 400 ppb in a year, it is likely that the number of exceedances would be consistently estimated at that level in each model simulation.

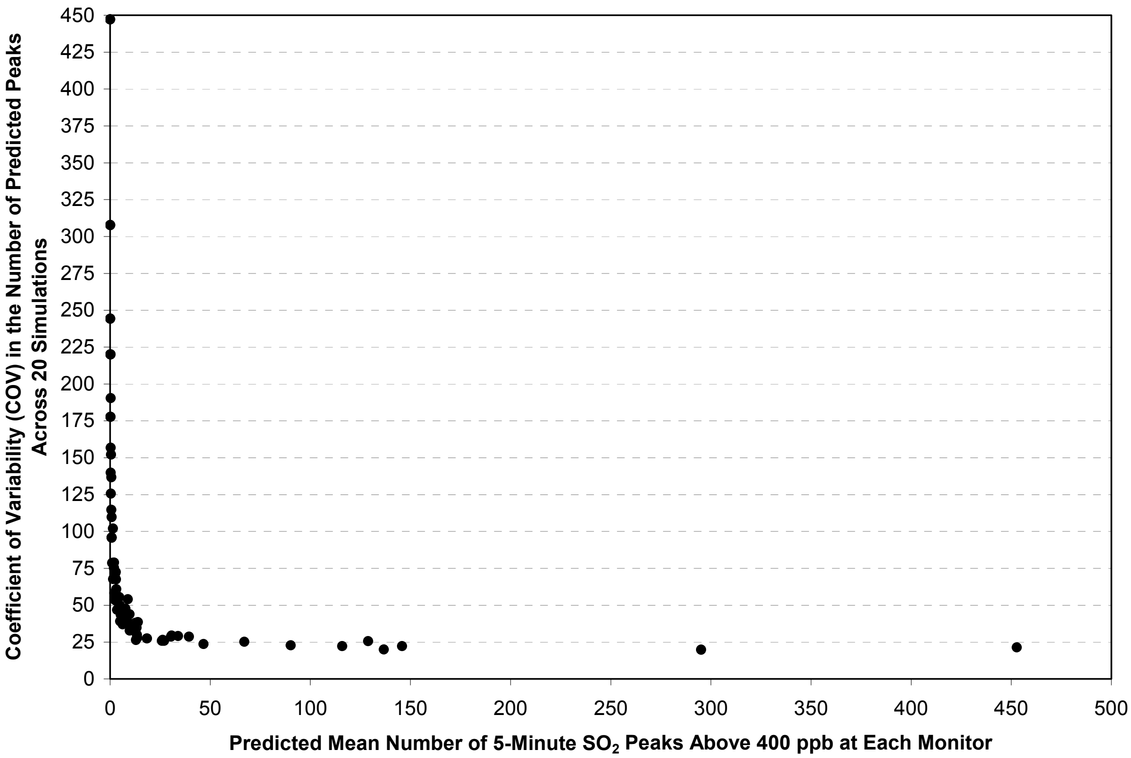

Figure 6-6. Variability in the predicted number of 5-minute maximum concentrations above 400 ppb at monitors that measured 5-minute maximum concentrations.

Accuracy of the procedure was evaluated by comparing the mean monitor estimates from the 20 simulations with the measured values at the ninety-eight 5-minute maximum SO_2 monitors (Figure 6-7). Good agreement between predicted and measured was observed when the entire data set was evaluated. A total of 1,808 5-minute maximum SO_2 concentrations at or above 400 ppb were measured, while an average of 1,956 5-minute maximum were predicted by the simulations, an overestimation of only 8%. Larger differences in the estimation were apparent when comparing results for individual monitors, particularly at the monitor that recorded the highest number of concentrations above 400 ppb (monitor ID 290930030). The total estimated mean number of exceedances of 400 ppb was about 450; this was about 375 less than the actual measured number of exceedances (an underestimation of about 45%). This ambient monitor is a source-oriented monitor, located within 1.7 km of a primary smelter containing estimated SO_2 emissions of 43,340 tpy. This is the only stationary source located within 20 km of this monitor (Appendix A). Another source-oriented monitor in the area (monitor ID 290930031), potentially influenced by the same smelter, but located at a greater distance away (i.e., 4.6 km), exhibited better agreement between the estimated and measured number of peaks (approximately 13% over-prediction) suggesting the underestimation at the closer monitor may not simply be a function of the source-type but possibly the proximity of the monitor to the source emission.

Another notable difference occurred at a different monitoring location (monitor ID 380590002), whereas a total mean of 129 exceedances was predicted by the simulations although there were no measured values above 400 ppb at this site. This site may be affected by a nearby petroleum refinery located within 2.6 km with estimated emissions of 4,600 tpy. A comparison of several monitors located within varying distances (1.5 – 6.6 km) of a petroleum refinery emitting approximately 720 tpy SO_2 in a different location exhibits good agreement between measured and modeled estimates (Table 6-3), suggesting there may be a unique characteristic about the particular source located at monitor ID 380590002 rather than suggesting there is a unique pattern of emissions characteristic of the source-type as a whole that is not being captured by the statistical model. When excluding the two sites with the greatest model over-/under-estimations, there is improved agreement between the modeled and measured data for the other ninety-six monitors used (predicted = 1.02 * measured, $R^2 = 0.91$).[8]

Table 6-3. Comparison of measured and modeled number of 5-minute maximum concentrations above 400 ppb located near a petroleum refinery.

Monitor ID	Number of 5-minute Maximum SO_2 > 400 ppb	
	Measured	Mean Modeled
291831002	0	3
301110066	5	13
301110079	0	0
301110080	3	3
301110082	0	0
301110083	1	1
301110084	0	0
301112008	0	0

[8] Using all 98 monitors the regression analysis yields the predicted = 0.61 * measured, $R^2 = 0.85$.

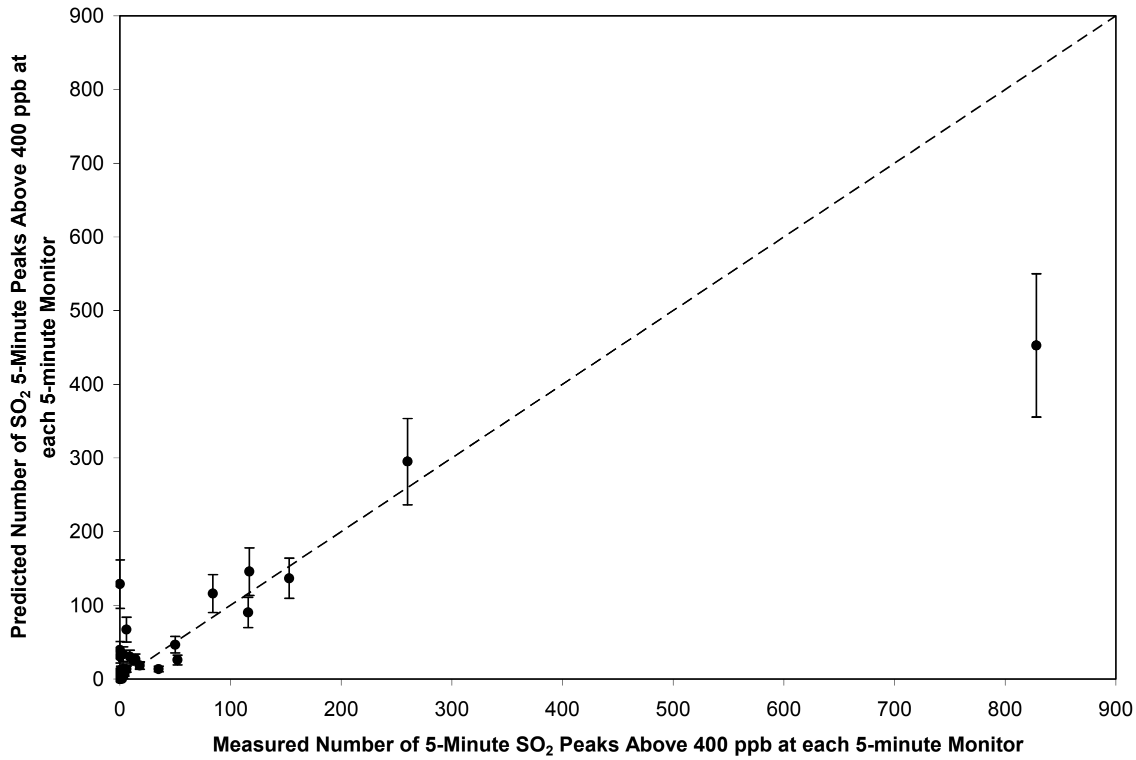

Figure 6-7. Comparison of the mean predicted (from 20 simulations) and the measured number of 5-minute SO_2 concentrations at 98 monitors that measured 5-minute maximum SO_2 concentrations. Bars indicate the standard deviation of the mean.

6.3 APPROACH FOR SIMULATING JUST MEETING THE CURRENT SO_2 STANDARD

6.3.1 Introduction

A primary goal of this draft of the risk and exposure assessments is to aid in judging whether or not the current SO_2 primary standards of 0.14 ppm, 24-hour average and 0.03 ppm, annual average adequately protect public health. All areas of the U.S. currently have annual average levels below the current NAAQS (EPA, 2007c). One site in Northampton County, Pa., measured concentrations above the level of the 24-hour standard in 2006. Therefore, in order to evaluate whether the current standards adequately protect public health, nearly all SO_2 concentrations need to be adjusted upwards for all areas included in our assessment in order to simulate levels of SO_2 that would just meet the current standard levels.

In developing a simulation approach to adjust air quality to meet a particular standard level, policy-relevant background (PRB) levels in the U.S. were first considered. Policy-relevant background is defined as the distribution of SO_2 concentrations that would be observed in the U.S. in the absence of anthropogenic emissions of SO_2 in the U.S., Canada, and Mexico. Estimates of PRB have been reported in the draft ISA and for most of the continental U.S. the PRB is estimated to be less than 10 parts per trillion (ppt) annual average (draft ISA, section 2.4.6). In the Ohio River Valley, where present-day SO_2 concentrations are highest (>5 ppb), this amounts to a contribution of less than 1% percent of the total observed ambient SO_2 concentration. In the Northwestern U.S. and Hawaii, where there are geothermal sources of SO_2 (e.g., volcanic activity) the contribution of PRB to total SO_2 can be as high as 70 to 80% in the vicinity of volcanic activity. However, since PRB is well below concentrations that might cause potential health effects at most locations, PRB will not be considered separately in any characterization of health risk associated with *as is* air quality or air quality just meeting the current standards. In monitoring locations where PRB is expected to be of particular importance however (e.g., Hawaii county, HI) data will be noted as under possible influence of natural rather than anthropogenic sources and will not be used in analyses simulating air quality that would just meet the current standards.

This procedure for adjusting ambient concentrations was necessary to provide insight into the degree of exposure and risk which would be associated with an increase in ambient SO_2 levels such that the levels were just at or near the current standards in the areas analyzed. We recognize that it is extremely unlikely that SO_2 concentrations in any of the selected areas where concentrations have been adjusted would rise to meet the current NAAQS and that there is considerable uncertainty associated with the simulation of conditions that would just meet the current standards. Nevertheless, this procedure was necessary to assess the ability of the current standards, not current ambient levels, to protect public health.

6.3.2 Approach

Criteria were identified to select ambient monitoring data that would provide the most support to any conclusions drawn from an analysis of ambient concentrations that are adjusted to simulate just meeting the current standards. The first criteria used was to select locations where monitors had concentrations at or near the current NAAQS and/or where monitors contained a number of 5-minute maximum concentrations at or above the potential health effect benchmark levels. Northampton County, Pa. was selected first based on the exceedance of the 24-hour NAAQS in year 2006. Two counties in Missouri (Iron and Jefferson) contained the most frequently measured 5-minute maximum concentrations above the potential health effect benchmarks (see Appendix C). To expand the number of locations to a total of 20, an additional 17 counties were selected using the following criteria. First, the analysis used only the more recent data, specifically years 2002 through years 2006.[9] Next, locations of interest were screened for those having at least three 1-hour monitors with valid ambient monitoring concentrations within a county for a given year (based on criteria discussed in Appendix A). Using a county to define the location is consistent with current policies on the designation of appropriate boundaries of non-attainment areas (Meyers, 1983).

While annual average concentrations have declined over the time period of analysis, the variability in both the annual average and 1-hour concentrations has remained relatively stable (see results of air quality trends in Appendix C). Therefore, a multiplicative proportional adjustment approach was selected to allow for the simulation of air quality just meeting the current 24-hour and annual SO_2 NAAQS, considering the current deterministic form of each standard. The 24-hour standard of 0.14 ppm is not to be exceeded more than once per year, therefore, the second highest daily mean observed at each monitor was used as the target for adjustment. The rounding convention, which is part of the form of the standard, defines values up to 0.144 ppm as just meeting the 24-hour standard. The form of the current annual standard requires that the standard level of 0.030 ppm is not to be exceeded, therefore, the highest annual average concentration at each monitor served as the target for adjustment. With a rounding convention to the fourth decimal, values of up to 0.0304 ppm would just meet the current standard. For each county (i) and year (j), 24-hour and annual SO_2 concentration adjustment factors (F) were derived by the following equation:

$$F_{ij} = S / C_{\max,ij} \qquad \text{equation (6-3)}$$

where,

[9] 1-hour concentrations were typically only available through April 2007, therefore most years were incomplete. All data from 2007 were excluded from this simulation.

F_{ij}	=	Adjustment factor derived from either the 24-hour or annual average concentrations at monitors in location $_i$ for year $_j$ (unitless)
S	=	concentration values allowed that would just meet the current NAAQS (144 ppb for 24-hourr, 30.4 ppb for annual average)
$C_{max,ij}$	=	2nd highest daily mean SO_2 concentration at a monitor in location *i* and year *j* or the maximum annual average SO_2 concentration at a monitor in location *i* and year *j* (ppb)

Further, to conduct a both meaningful and efficient analysis, the potential adjustment factors for the annual and 24-hour average were compared to one another to determine which standard would likely be more protective (i.e., containing the lower adjustment factor). A comparison of the generated adjustment factors using the data screened by year (i.e., 2002 through 2006) and number of monitors in a county (≥ 3) is presented in Figure 6-8. Most locations (64%) contained target concentrations closer to the 24-hour standard than the annual standard. When considering locations containing 2nd highest maximum concentrations within an order of magnitude of the 24-hour standard, an even greater percentage (72 %) of locations contain concentrations closer to the 24-hour standard than the annual standard. For monitors within a factor of five, 85% contained concentrations closer to the 24-hour than the annual standard. Therefore, proximity of the 2nd highest 24-hour concentration to the 24-hour standard was the criterion for selecting locations of particular focus.

The mean adjustment factor for each county was calculated using each yearly value and then ranked in ascending order. The remaining 17 counties were selected from the top 17 values, that is, those counties containing the lowest mean daily adjustment factor. The locations selected, the years of monitoring data available for that county, and the adjustment factors used to simulate just meeting the current standards are provided in Table 6-4. Both the annual and daily adjustment factors are given for all counties, however the lower value was selected to adjust concentrations. The variability measure (i.e., COV) indicates the variability associated with each of the calculated factors when considering all of the monitors in a county. Lower COVs indicate similarity in that concentration metric in the county, while higher values indicate less homogeneity in concentrations (whether spatially or temporally).

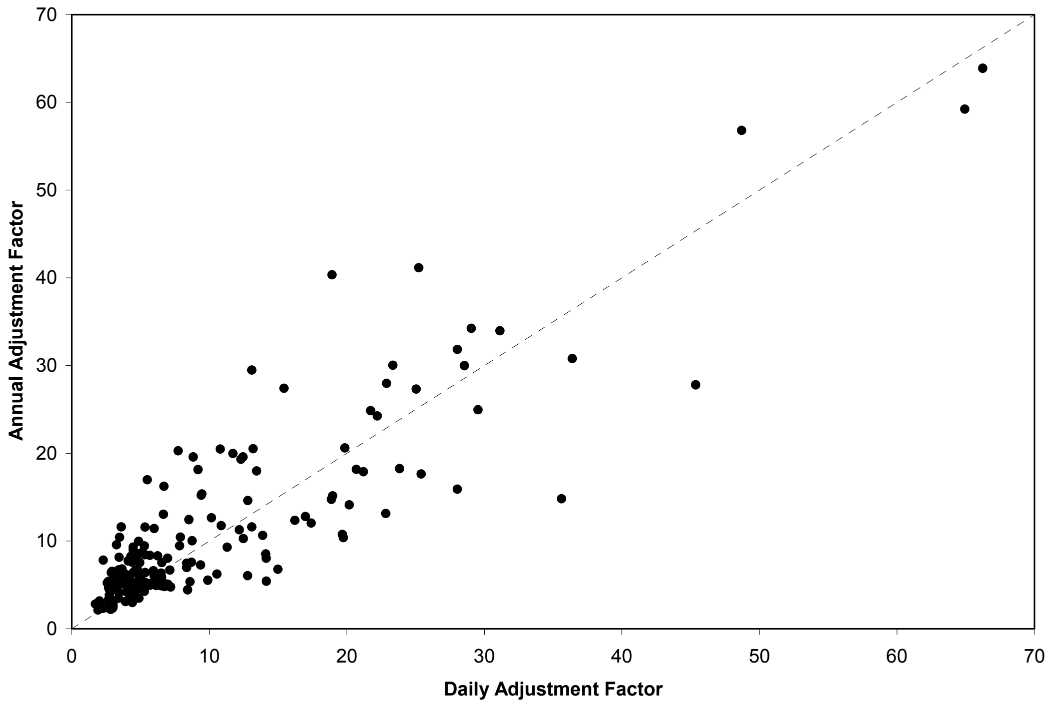

Figure 6-8. Comparison of annual and daily adjustment factors derived from counties containing at least three 1-hour ambient SO_2 monitors with valid data, years 2002 through 2006.

Table 6-4. Estimated population, number of ambient SO_2 monitors, and concentration adjustment factors for simulating just meeting the current SO_2 NAAQS in selected counties by year.

State	County[1] (Population)[2]	Year	Daily Adjustment			Annual Adjustment		
			n	Factor	COV	n	Factor	COV
DE	New Castle (500,265 - 525,587)	2002	4	2.67	9	4	5.39	8
		2003	5	2.75	9	3	3.83	11
		2004	4	2.58	13	3	5.23	2
		2005	4	2.73	11	4	4.52	7
		2006	4	2.68	14	4	4.67	8
FL	Hillsborough (998,948 – 1,157,738)	2002	7	3.09	16	6	4.66	8
		2003	6	3.09	19	6	5.54	14
		2004	6	4.95	32	6	7.55	26
		2005	6	4.40	25	6	8.19	20
		2006	6	4.19	29			
IA	Linn (191,701 - 201,853)	2002	3	4.70	5	3	7.97	5
		2003	3	3.45	5	3	8.16	7
		2004	3	2.29	10	3	7.83	14
		2005	3	3.41	9	3	6.70	12

State	County[1] (Population)[2]	Year	Daily Adjustment			Annual Adjustment		
			n	Factor	COV	n	Factor	COV
		2006	3	4.10	35	3	7.73	44
	Muscatine (41,722 - 72,883)	2002	3	3.87	11	3	6.05	7
		2003	3	4.09	12	3	6.09	5
		2004	3	2.78	16	3	4.51	9
		2005	3	2.90	17			
		2006	3	2.94	10	3	6.54	5
IL	Madison (258,941 - 265,303)	2002	4	2.88	12	4	6.41	4
		2003	3	3.60	6	3	5.22	6
		2004	3	3.61	18	3	5.84	5
		2005	3	4.19	11	3	5.73	4
		2006	3	4.90	16	3	6.12	7
IN	Floyd (70,823 - 72,570)	2002	3	4.85	6	3	5.52	1
		2003	3	4.14	5	3	5.32	5
		2004	3	5.05	16	3	5.04	16
		2005	3	4.59	2	3	3.98	7
		2006	3	3.64	5	1	5.65	
MI	Wayne (2,061,162 - 1,971,853)	2002	3	2.97	15	2	6.18	6
		2003	3	3.30	5	3	5.85	3
		2004	3	2.99	12	3	4.70	8
		2005	3	3.35	7	3	4.88	7
		2006	3	2.95	13	3	5.41	11
MO	Greene (240,391 - 254,779)	2002	5	3.47	32	3	10.42	30
		2003	5	5.12	26	5	8.69	16
		2004	5	5.29	29	5	9.45	23
		2005	5	4.87	34	5	9.96	14
		2006	5	4.46	19	5	9.32	18
MO	Iron[3] (10,697 - 10,279)	2002	2	2.11	2	2	4.38	1
		2003	2	2.44	2	1	4.61	
		2004	2	15.85	6			
MO	Jefferson[3] (198,099 – 216,469)	2002	1	3.89				
		2003	1	5.65				
		2004	1	1.87		1	2.95	
		2005	1	2.13				
		2006	1	1.93				
OH	Cuyahoga (1,393,978 - 1,314,241)	2002	5	6.83	4	5	5.10	7
		2003	5	3.98	5	4	4.21	8
		2004	4	4.54	11	4	4.93	8
		2005	4	3.43	6	4	4.11	8
		2006	4	4.25	8	4	4.64	6
OK	Tulsa (563,299 - 577,795)	2002	3	4.51	2	3	5.00	6
		2003	3	3.65	6	3	5.11	3
		2004	3	4.07	3	3	4.21	2
		2005	3	4.92	4	3	4.57	2
		2006	4	5.69	59	3	4.95	6
PA	Allegheny	2002	7	2.99	5	6	2.40	3

State	County[1] (Population)[2]	Year	Daily Adjustment			Annual Adjustment		
			n	Factor	COV	n	Factor	COV
	(1,281,666 - 1,223,411)	2003	7	2.23	5	7	2.54	3
		2004	7	2.81	6	7	2.87	3
		2005	7	2.17	7	7	2.35	4
		2006	6	2.97	8	6	3.05	4
	Beaver (181,412 - 175,736)	2002	3	1.91	6	3	2.14	5
		2003	3	1.73	6	3	2.82	5
		2004	3	3.02	6	3	2.62	3
		2005	3	2.98	4	3	2.42	4
		2006	3	2.67	8	3	3.28	2
	Northampton (267,066 - 291,306)	2002	2	5.95	3	2	5.01	0
		2003	2	4.49	9	2	3.73	11
		2004	2	3.28	9	2	2.28	12
		2005	2	4.24	8	2	3.55	2
		2006	2	0.98	19	2	2.85	10
	Washington[4] (202,897 - 206,432)	2002	3	3.91	5	3	3.11	4
		2003	3	4.41	2	3	2.99	5
		2004	3	4.20	5	3	3.42	1
		2005	3	3.07	5	3	3.18	0
		2006	3	4.89	4	3	3.48	3
TN	Shelby (897,472 - 911,438)	2002	3	4.79	20	3	6.72	3
		2003	3	3.75	21	3	5.24	6
		2004	3	4.46	20	3	5.13	6
		2005	4	3.90	46	3	6.20	3
		2006	3	4.12	44	2	4.78	10
TX	Jefferson (252,051 - 243,914)	2002	3	4.82	4	3	8.53	18
		2003	3	4.30	4	3	8.03	7
		2004	3	4.47	13	3	8.99	14
		2005	3	5.67	7	3	8.38	14
		2006	3	4.31	4	3	8.25	16
WV	Hancock (32,667 - 30,911)	2002	9	2.38	3	9	2.45	2
		2003	9	2.30	3	9	2.34	2
		2004	8	2.62	5	7	2.38	2
		2005	7	2.84	3	7	2.22	3
		2006	7	2.97	2	7	2.34	3
	Wayne (42,903 - 41,647)	2002	4	4.19	3	4	3.30	1
		2003	4	3.41	7	3	3.47	0
		2004	3	2.87	9	3	3.30	2
		2005	3	2.02	11	3	3.17	3

Notes:
[1] Listed counties were selected based on lowest mean concentration adjustment factor, derived from at least 3 monitors per year for years 2002-2006.
[2] Value is from 2000 Census for Year 2000 to that estimated for 2006.
[3] Selected based on frequent 5-minute maximum concentrations above potential health effect benchmark levels.
[4] Selected based on exceedance of 24-hour SO_2 NAAQS in 2006. Note value for 2006 is a downward concentration adjustment.

When simulating a proportional roll-up in ambient SO_2 concentrations using adjustment factors generated by equation (6-3), it was assumed that the current temporal and spatial distribution of air concentrations (as characterized by the current air quality data) was maintained and that increased SO_2 emissions would contribute to increased SO_2 concentrations. For the daily averages, the 2nd highest monitor concentration would be adjusted so that it meets the current 0.14 ppm, 24-hour average standard. For the annual average concentration, the maximum monitor concentration would be adjusted so that it meets the current 0.03 ppm, annual average standard. For each county and calendar year, all the hourly concentrations in a location were multiplied by the same constant value F (whichever adjustment value was lower) for that location and year. For example, of the seven monitors measuring SO_2 in Allegheny County, PA for year 2003, the 2nd highest 24-hour mean concentration was 64.6 ppb, giving an adjustment factor of F_{daily} = 144/64.6 = 2.23 for that year. This is lower than the adjustment factor considering the maximum annual average concentration for that year (F_{annual} = 30.4/11.9 = 2.54). All hourly concentrations measured at all monitoring sites in that location would then be multiplied by 2.23, resulting in an upward scaling of all hourly SO_2 concentrations for that year. Therefore, one monitoring site in Allegheny County, Pa. for year 2003 would have the 2nd highest 24-hour average concentration at 0.14 ppm, while all other monitoring sites would have their 2nd highest daily average concentrations below that value, although still proportionally scaled up by 2.23. Then, using the adjusted hourly concentrations to simulate just meeting the current standard (either the daily or annual average standard), 5-minute maximum concentrations were estimated using equation (6-1). Air quality characterization metrics of interest (e.g., annual mean SO_2 concentration, daily mean concentrations, the number of potential health effect benchmark exceedances) were estimated for each site and year.

6.4 RESULTS

6.4.1 Measured 5-minute Maximum and 1-Hour Ambient Monitoring SO_2 Concentrations

Ambient monitoring data were evaluated at the 98 locations where both the 1-hour and 5-minute maximum concentrations were measured. Due to the large size of the data sets, mean, maximum, and measures of variability are summarized first in a series of figures, with comprehensive Tables in Appendix C providing more complete descriptive statistics for the 5-minute maximum and 1-hour SO_2 concentrations.

Figure 6-9 illustrates the distribution in the mean 5-minute maximum and 1-hour SO_2 concentrations at each monitor by year. In general, annual mean concentrations at these monitors have consistently declined from maximum observed levels in 1998 and currently range from around 2-20 ppb and <1-10 ppb for the 5-minute maximum and 1-hour concentrations, respectively. Results from a one-way analysis of variance (ANOVA) of each of the mean concentrations indicated a statistically significant effect for monitoring year, although the simply constructed models did not account for a large proportion of the variance (Table 6-5).

Maximum observed concentrations followed a similar pattern to the mean concentrations. In general, maximum 5-minute maximums and maximum 1-hour SO_2 concentrations have decreased from those measured in 1998. Results from the ANOVA also indicate a statistically significant effect for monitoring year, although a smaller amount of variance is explained for the maximum concentrations compared to the respective mean concentrations (Table 6-6). This is likely due to limited stability in the range of the maximum observed concentrations, most notably in the 5-minute maximum data. Even though fewer monitors contain concentrations at the higher end of the range with increasing monitoring year (thus there is an overall decline in maximum 5-minute max concentrations with increasing monitoring year), the maximum 5-minute maximum SO_2 ranges consistently from around 10 to 1000 ppb across the entire monitoring period.

While concentrations have declined with time, the relative variability in those concentrations has remained stable (Figure 6-9). There is no discernable trend over the monitoring period, with a COV range of 50-400% for the 5-minute maximum data and a range of around 50-300% for the 1-hour concentrations. There does appear to be a reduction in the upper level of the COV for years 2005-2007 (i.e, upwards to 250% rather than 300%), however the effect of year on COV from both concentration measures was not significant (Table 6-5).

Table 6-5. Model results from one-way analysis of variance (ANOVA) testing for effect of monitoring year (years 1997-2007).

SO_2 Data	Dependent Variable	R^2	F	p
5-minute maximum	Mean	0.15	8.08	< 0.0001
	Maximum	0.06	2.85	0.002
	COV	0.01	0.69	0.732
1-hour	Mean	0.19	10.68	<0.0001
	Maximum	0.07	3.39	0.0003
	COV	0.01	0.66	0.758

Of particular interest is the occurrence of 5-minute SO_2 concentrations above particular concentrations. As discussed previously, potential health effect benchmark levels of 400, 500, and 600 ppb were selected for comparison with the measured ambient monitoring concentrations. Figure 6-10 shows the distribution of the number of exceedances of each of the benchmarks from those monitors measuring 5-minute maximum concentrations. During the earlier half of the monitoring period (1997-2001), the number of 5-minute maximum SO_2 concentrations above 400, 500, 600 ppb was as high as 130, 90, and 60 per year respectively. This frequency was limited to only a few monitors. Only about 15 to 35% of monitors recorded a single peak above the lowest potential health effect benchmark level. Therefore, about 75% of the monitors recording 5-minute maximum SO_2 concentrations did not contain a single 5-minute concentration above 400 ppb in a year from 1997-2001.

The frequency of concentrations above the benchmark levels declines with increasing monitoring year. When considering more recent air quality (e.g., 2004-2007), the maximum number of concentrations measured above 400 ppb at a monitor was between 25 to 50 times in a year, with most monitors measuring only a few exceedances, if at all. To put additional perspective on the frequency, there are 8,760 possible 5-minute maximum concentration events in a year. Fifty exceedances would account for less than 1% of the total possible events considering the recent as is air quality. Note however that the number of monitors measuring 5-minute maximum SO_2 concentrations sharply drops from a peak of 60 in year 2002 to just over 20 in year 2007 (Figure 6-11). This could be a contributing factor to the observed downward trend in the number of maximum concentrations above the potential health effect benchmark levels. Although the percent of monitors recording at least one exceedance of 400 ppb over this

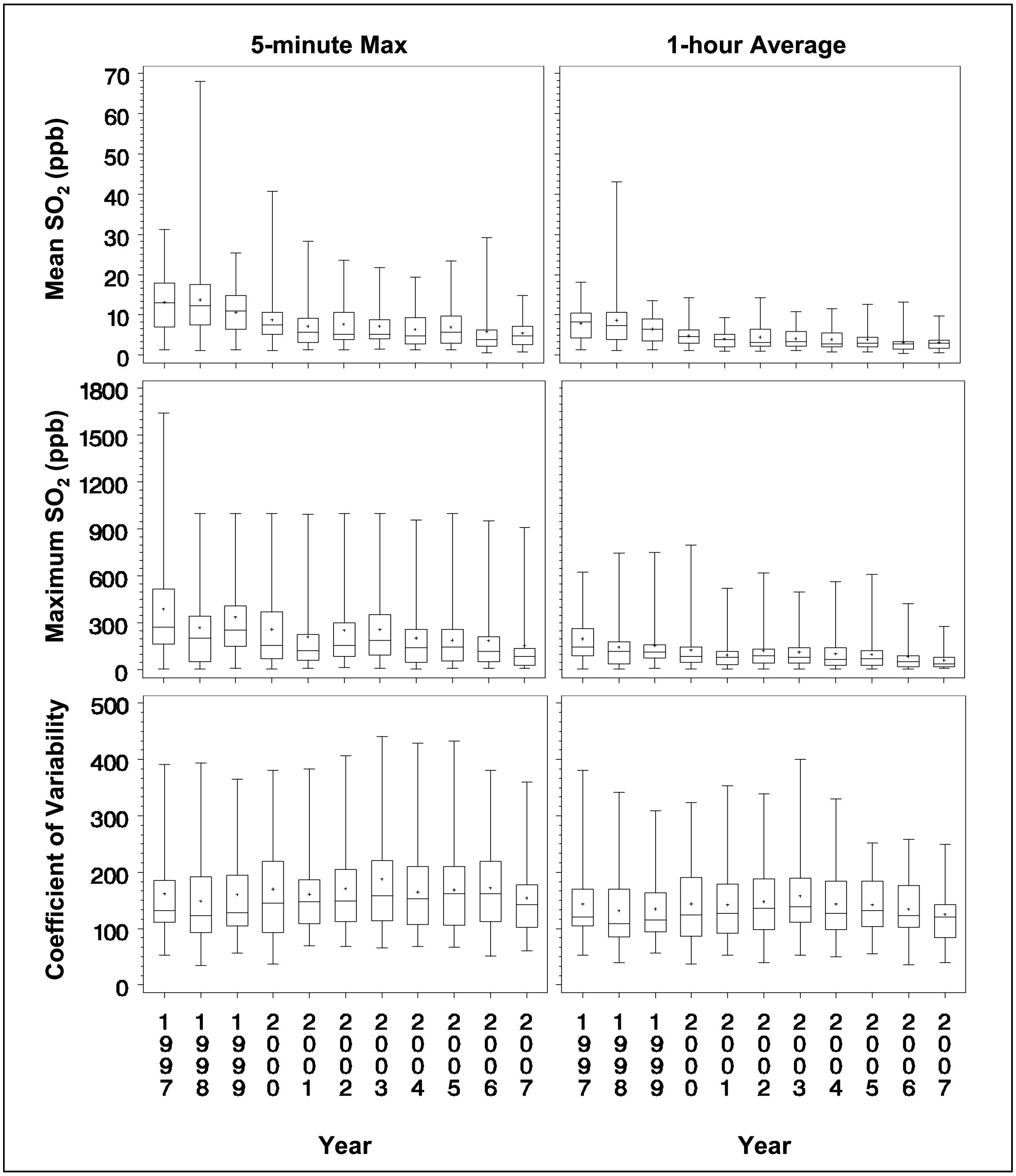

Figure 6-9. Distribution of the mean SO_2 concentrations, the maximum SO_2 concentrations and the coefficient of variability for each monitor that measured both the 5-minute maximum and 1-hour concentrations, Years 1997 through 2007.

time period ranges from about 8 to 17%, there may not be a reduction in concentrations above a given level but a reduction in number of total measurements.

To evaluate the impact of a reduction in the number of monitors, the frequency of concentrations above the potential health effect benchmark levels was normalized by the total number of measurements. The results of this analysis for each year of monitoring is summarized in Figure 6-12. There is a downward trend in the frequency of concentrations above each of the three potential health effect benchmark concentrations when normalized to the number of samples collected. While the lowest frequency occurs in year 2007, it should be noted that only only four of the 21 monitors contained enough samples to be considered a complete year. In addition, the single monitor in Iron County, Missouri was not in operation beyond year 2003. Previously, that monitor in Iron County frequently measured concentrations above 400 ppb for each year. Thus, while it appears that the normalized frequency of concentrations above selected levels is in decline, possibly due to reduction in episodic peak concentrations, additional reasoning would include the reduced number of monitors in operation and their particular siting.

Finally, the occurrence of the short-term peak concentrations was evaluated with regard to the current level of the SO_2 NAAQS. Completeness criteria described in Appendix A for calculating each metric (i.e, 75% complete) were applied to the 1-hour SO_2 monitoring data. Figure 6-13 compares the number of 5-minute maximum SO_2 concentrations above the potential health effect benchmark levels with the annual average SO_2 concentration from each monitor. None of the monitors in this data set contained annual average SO_2 concentrations above the current NAAQS, however as described above, several of the monitors in several years frequently contained concentrations above the potential health effect benchmark levels. Many of those monitors where frequent exceedances occurred contained annual average SO_2 concentrations between 5 and 15 ppb, with no apparent correlation between the annual average SO_2 concentration and number of peaks above any of the selected short-term benchmark levels.

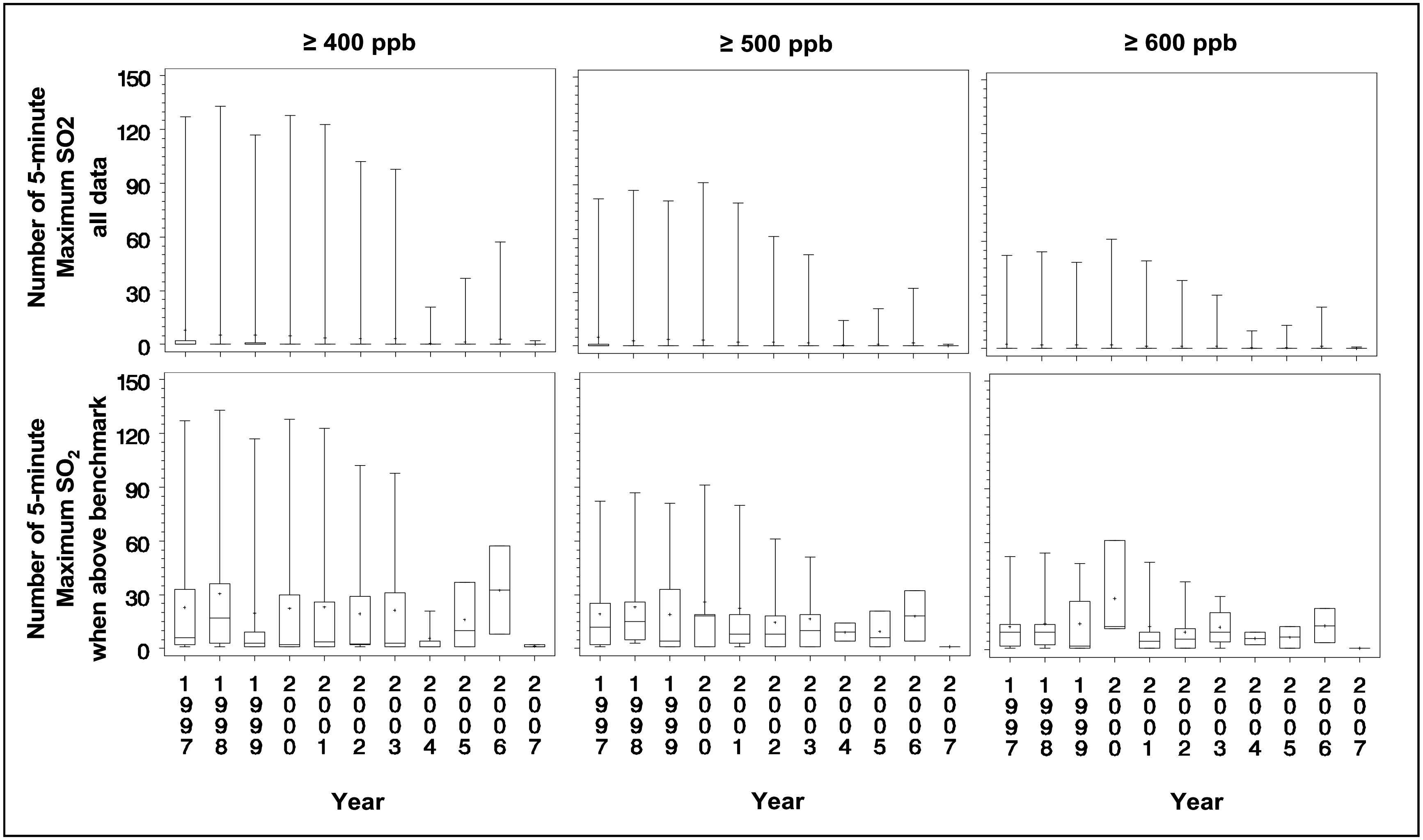

Figure 6-10. Distribution of the number of measured 5-minute maximum SO_2 concentrations above potential health effect benchmark levels at each monitor, Years 1997 through 2007. The top row represents the distribution for all monitors (including those with no exceedances), the bottom row represents the distribution for those monitors with at least one measured exceedance.

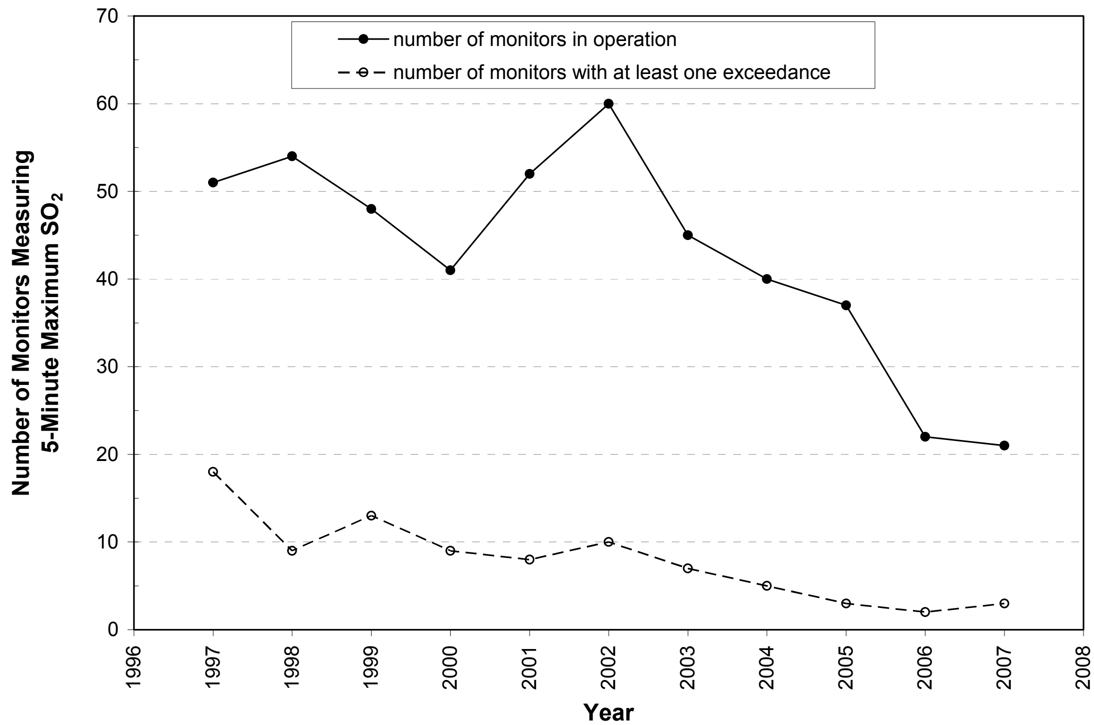

Figure 6-11. Number of ambient monitors measuring 5-minute maximum SO_2 concentrations and number of monitors with at least one benchmark exceedance by year, Years 1997 through 2007.

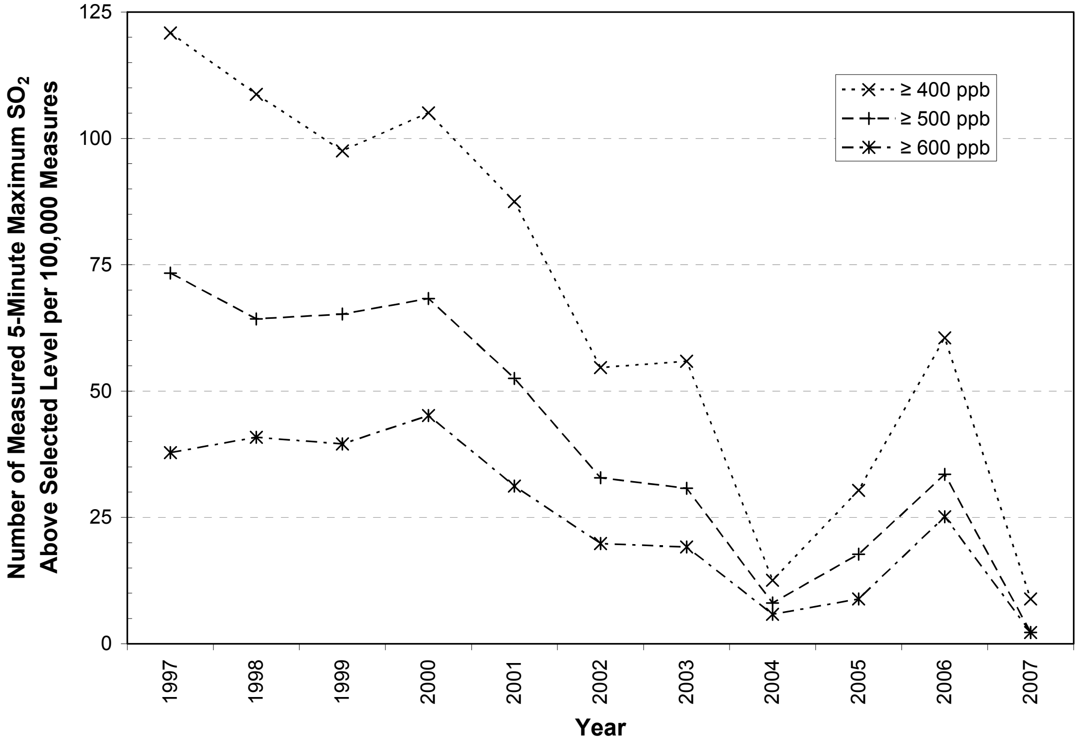

Figure 6-12. Frequency of measured 5-minute maximum SO_2 concentrations above potential health effect benchmark levels in each year, normalized to 100,000 measurements, Years 1997 through 2007.

Figure 6-14 compares the 24-hour average concentrations with the number of 5-minute SO_2 concentrations above potential health effect benchmark levels. Five monitor site-years contained 24-hour average concentrations above 140 ppb, including 3 in Buchanan County, Missouri (years 1997, 1998) and one each in Morton County, North Dakota (1998) and Allegheny County, Pennsylvania (1999). These highest daily average SO_2 concentrations corresponded to frequent concentrations above the potential health effect benchmark levels at each of the locations save one, Morton County, which did not have any measured 5-minute maximum concentrations above 400 ppb. A trend is observed when considering all of the data above and below a daily mean concentration of 140 ppb; with increasing 24-hour average SO_2 concentration, there is an increase in the number of 5-minute SO_2 concentrations above the potential health effect benchmark levels. For example, when there were at least 7 5-minute maximum concentrations above 400 ppb, all 24-hour average concentrations were above 70 ppb. However there is also a great amount of spread in the relationship, with a wide range in 24-hour average concentrations associated with at least 1 exceedance of 400 ppb (5-minute max) in a day

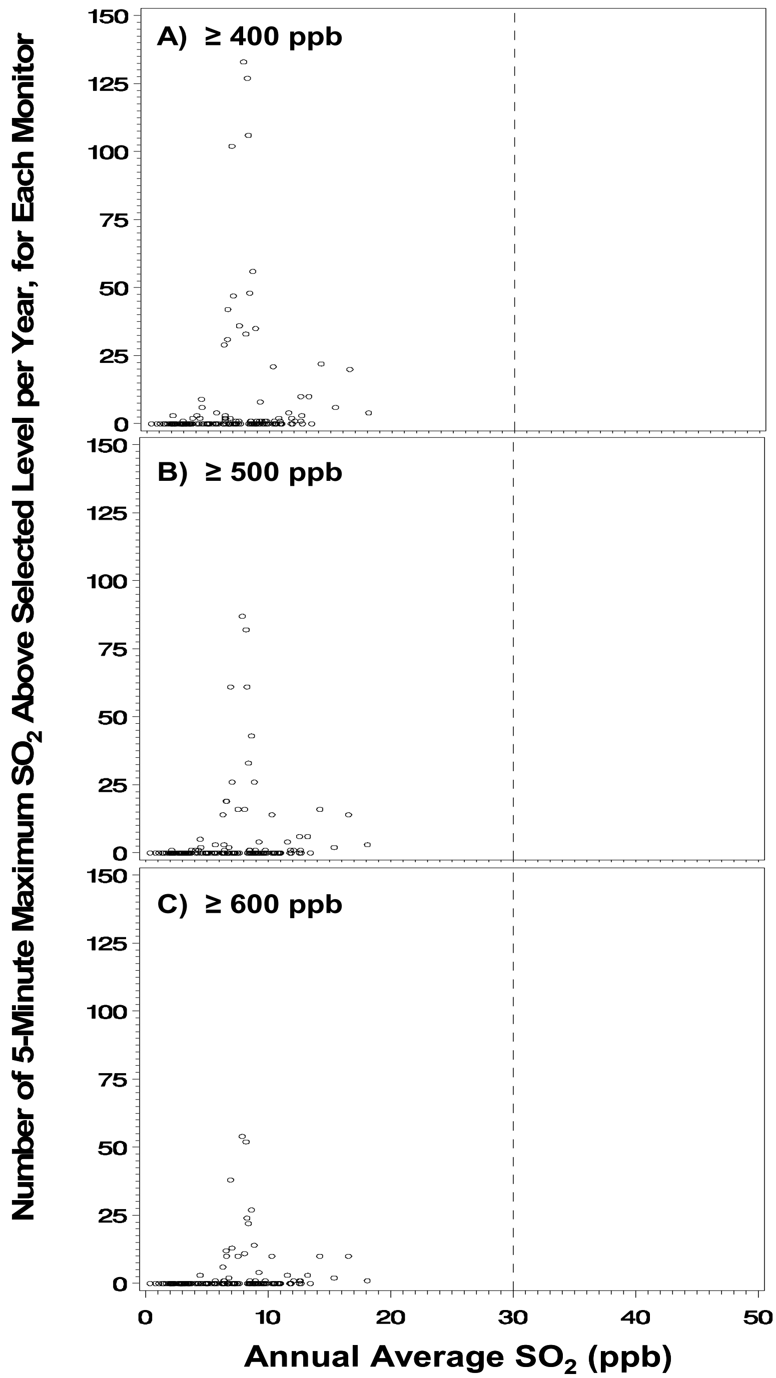

Figure 6-13. Comparison of the number of measured 5-minute maximum SO_2 concentrations above potential health effect benchmark levels at each monitor per year and the associated annual average SO_2 concentration, Years 1997 through 2007. A) number of 5-minute maximums ≥400 ppb/year, B) number of 5-minute maximums ≥500 ppb/year, C) number of 5-minute maximums ≥600 ppb/year. The annual average SO_2 NAAQS of 0.03 ppm is indicated by the dashed line.

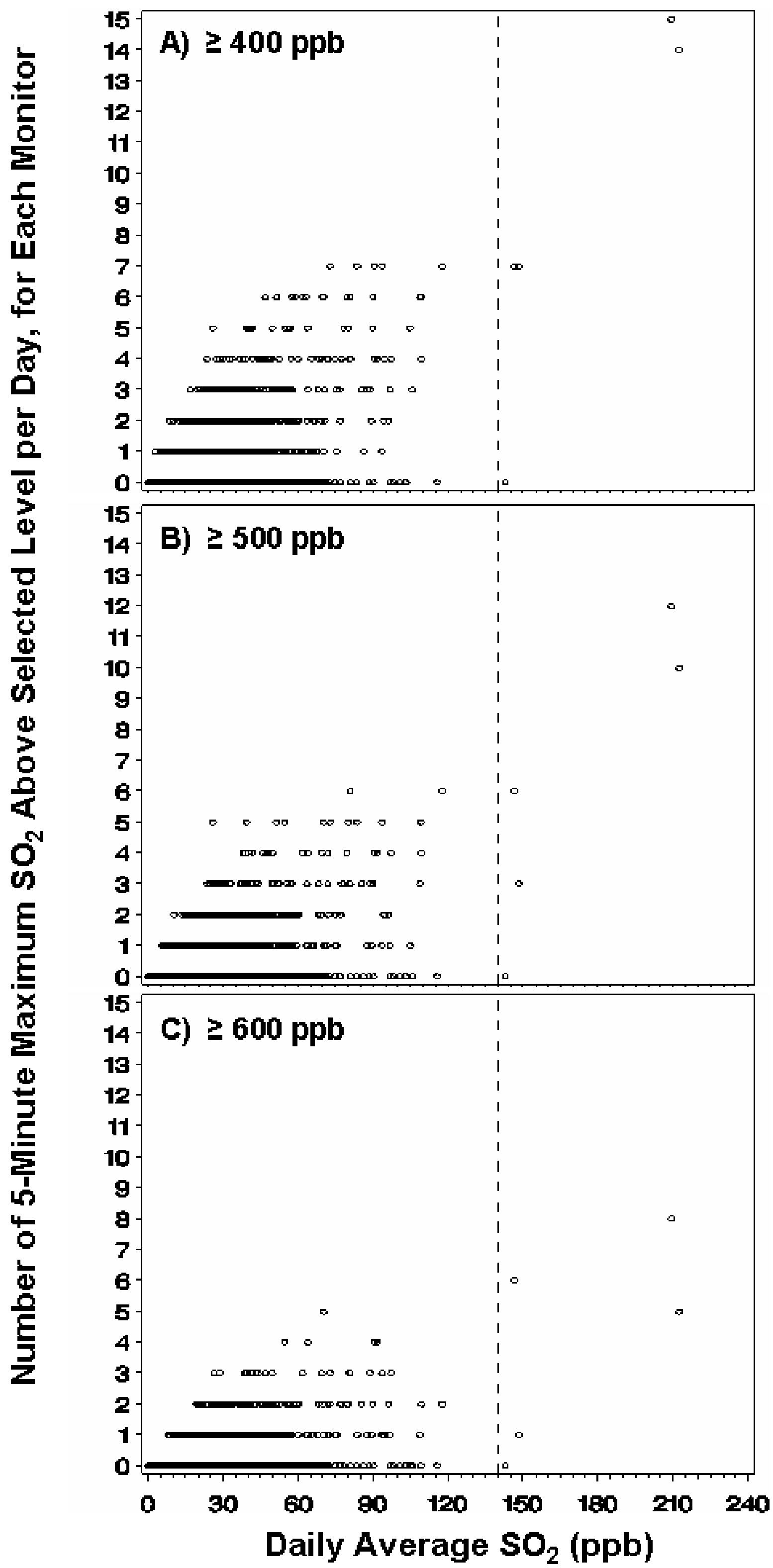

Figure 6-14. Comparison of the number of measured 5-minute maximum SO_2 concentrations above potential health effect benchmark levels at each monitor per day and the associated daily average SO_2 concentration. The 24-hour SO_2 NAAQS of 0.14 ppm is indicated by the dashed line.

(ranging from 1 to about 90 ppb), along with a similar range in 24-hour average concentrations having no measured exceedances of 400 ppb per day.

6.4.2 Measured 1-Hour and Modeled 5-Minute Maximum Ambient Monitoring SO_2 Concentrations

As described in section 6.2.3, a statistical model was developed to estimate 5-minute maximum SO_2 concentrations using all available 1-hour SO_2 ambient monitoring concentrations. This was primarily because there were a much greater number of 1-hour ambient monitors sited in the U.S. compared to 5-minute monitors. This expanded monitoring network, and the utilization of modeled 5-minute values derived from 1-hour values (section 6.2.3) allowed for a comprehensive description of the hourly SO_2 ambient monitoring concentrations across the U.S., and an analysis of potential 5-minute maximum concentration levels where 1-hour, but not 5-minute SO_2 measurements were collected.

Twenty separate simulations were performed to estimate the 5-minute maximum SO_2 concentration associated with each 1-hour measurement (see section 6.2.3). The individual simulation results were summarized using descriptive statistics and then combined to generate a mean estimate for each of the metrics of interest (e.g., the number of 5-minute concentrations ≥ 400 ppb). For example, each 1-hour monitor for every year simulated contains a concentration distribution, defined by parameters such as a mean, a standard deviation and various percentiles. Each of the parameters were averaged from the 20 simulations to give the most representative estimate of the simulations for each of the parameters (i.e., the mean of the mean, the mean of the maximums, etc.). The means were estimated in this manner rather than combining all of the data to generate a single set of parameters from the twenty simulations, since that type of aggregation could allow an individual year to adversely influence particular areas of the distribution. The modeled (5-minute maximum) and measurement (1-hour) data were analyzed in a similar manner as performed on the measured 5-minute maximum and 1-hour SO_2 concentrations described in section 6.4.1. Due to the extremely large size of the data sets, the mean, maximum, and measures of variability are summarized primarily in a series figures.

Figure 6-15 illustrates temporal trends in the modeled mean 5-minute maximum and measured 1-hour SO_2 concentrations from each monitor. In general, annual mean concentrations have declined from maximum observed levels in 1997 and currently range from around 2-20 ppb

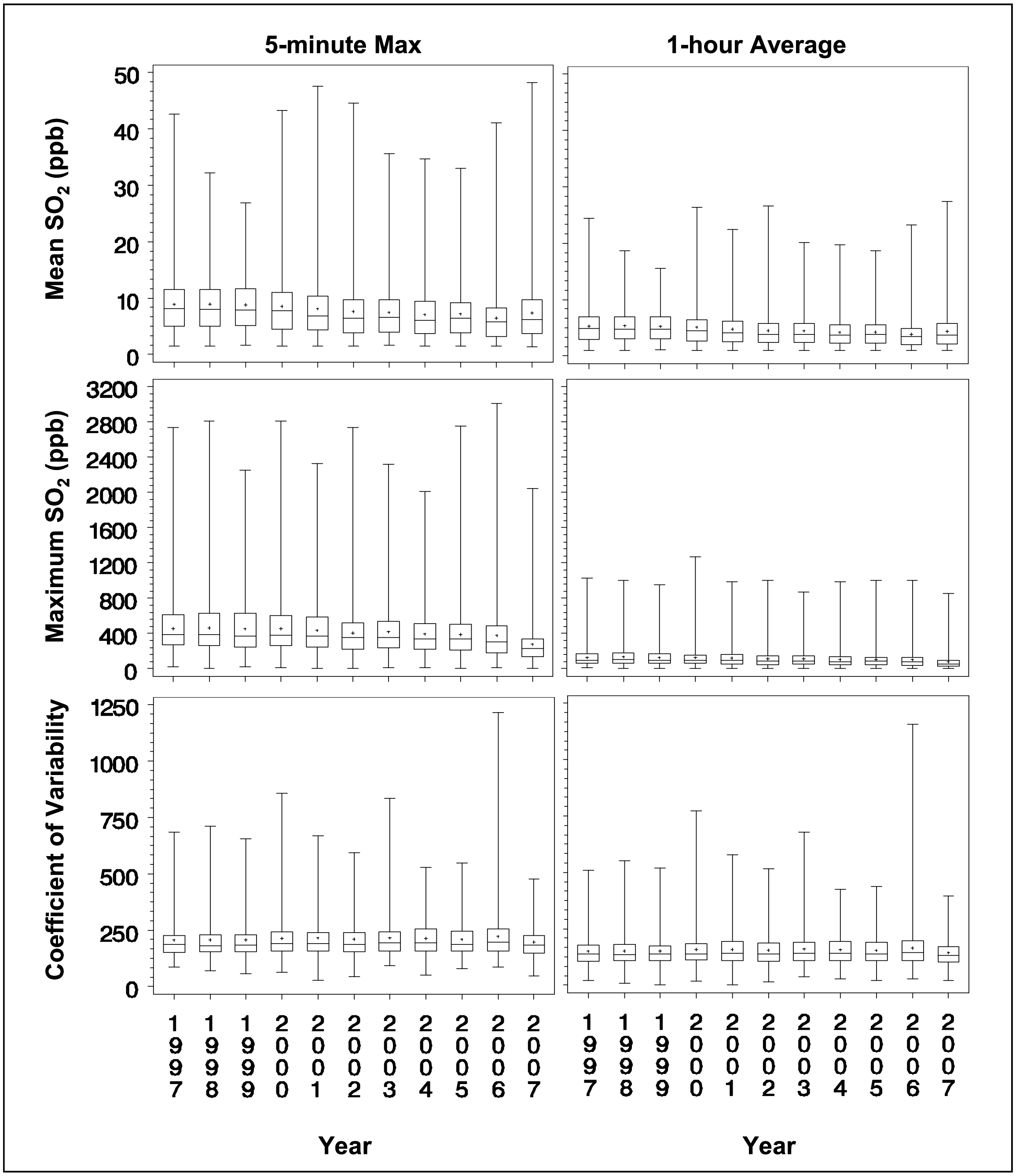

Figure 6-15. Distribution of the mean SO2 concentrations, the maximum SO2 concentrations, and the coefficient of variability for each monitor that measured 1-hour concentrations, Years 1997 through 2007. 5-minute maximum SO_2 concentrations were estimated using a statistical model.

Table 6-6. Model results from one-way analysis of variance (ANOVA) testing for effect of monitoring year (years 1997-2007).

SO_2 Data	Dependent Variable	R^2	F	p
5-minute maximum	Mean	0.025	13.8	< 0.0001
	Maximum	0.026	14.6	<0.0001
	COV	0.004	2.4	0.007
1-hour	Mean	0.027	15.0	<0.0001
	Maximum	0.019	10.2	<0.0001
	COV	0.004	2.27	0.012

and <1-10 ppb for the 5-minute maximum and 1-hour concentrations, respectively. This is similar to what was observed in the data set containing the measured 5-minute maximum and associated 1-hour monitoring data. Results from a one-way ANOVA of each of the mean concentrations indicated a statistically significant effect for monitoring year, although the simply constructed models did not account for a large proportion of the variance (Table 6-6).

There are a few 1-hour monitors that contained annual average SO_2 concentrations within 10-20 ppb, along with associated modeled annual average 5-minute maximum SO_2 concentrations between 20-50 ppb. Many of the highest concentration data were measured at monitors sited in Pennsylvania (PA) and West Virginia (WV), although some of the more recent 1-hour average SO_2 concentrations above 15 ppb were measured in Hawaii (Table 6-7). While the PA and WV monitors are likely influenced by local and regional anthropogenic source emissions, two ambient monitors in Hawaii (ID 150010005 and 150010007) containing these high annual average SO_2 concentrations were sited to capture the impact of volcanic activity on ambient SO_2 concentrations in the area.

There were similar temporal trends in the distribution of maximum observed concentrations (Figure 6-15) compared to the trends observed using mean concentrations. In general, maximum 5-minute maximum and maximum 1-hour SO_2 concentrations have steadily decreased from those measured in 1997. Results from the ANOVA also indicate a significant effect from monitoring year, although this explains a smaller amount of variance for the maximum concentrations (Table 6-6) than for the mean concentrations (Table 6-5). Again, most of the locations with the highest modeled 5-minute maximum SO_2 concentrations, as well as the

Table 6-7. Descriptive statistics for modeled 5-minute maximum and measured 1-hour SO_2 concentrations for monitors with 1-hour annual average SO_2 concentration above 15 ppb.

					Modeled 5-minute Maximum SO_2									Measured 1-hour SO_2								
State	County	Monitor ID	Year	n	Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
WV	Marshall	540511002	1997	8615	26	54	207	1	8	156	188	246	1161	15	27	176	1	5	88	105	131	495
NM	San Juan	350451005	1997	8398	27	64	235	0	4	185	225	306	1076	16	32	205	0	3	105	123	159	500
WV	Hancock	540290009	1997	8681	29	40	138	1	17	118	140	186	952	17	17	102	1	11	60	70	87	292
IN	Vanderburgh	181631002	1997	8639	29	35	119	0	19	104	120	154	702	17	14	81	0	12	48	52	61	259
PA	Allegheny	420030021	1997	58	31	44	135	0	12	150	150	209	209	18	19	110	0	8	56	56	72	72
HI	Hawaii	150010005	1997	7188	33	131	392	0	4	286	414	634	2738	15	58	381	0	3	118	157	255	1024
IA	Cerro Gordo	190330018	1997	1250	37	115	312	0	4	377	483	627	1240	16	43	273	0	3	144	188	245	345
NC	Forsyth	370670022	1997	17	43	45	103	4	32	168	168	168	168	24	19	80	3	26	70	70	70	70
PA	Washington	421250200	1998	14	24	22	87	6	17	87	87	87	87	17	12	72	4	13	53	53	53	53
WV	Marshall	540511002	1998	8712	26	53	204	1	9	153	187	251	1022	15	26	172	1	6	86	105	132	351
WV	Brooke	540090007	1998	8436	27	45	167	1	14	122	147	200	982	16	20	131	1	9	65	76	97	335
NM	San Juan	350451005	1998	8481	28	67	242	0	4	188	232	326	1115	16	34	210	0	3	106	128	166	345
PA	Beaver	420070005	1998	2087	28	49	174	0	11	142	172	231	725	16	23	142	0	8	72	85	117	235
PA	Warren	421230004	1998	6388	30	59	195	1	10	169	206	275	1007	17	29	166	1	6	94	109	145	408
OK	Tulsa	401430235	1998	8661	32	42	131	0	18	123	142	179	856	19	18	95	0	12	61	66	77	230
WV	Hancock	540290016	1999	8542	26	41	156	1	15	116	140	188	927	15	18	117	1	10	60	69	87	237
PA	Warren	421230004	1999	8575	26	53	202	1	9	147	185	257	1032	15	25	168	1	6	80	101	138	299
IN	Warrick	181731001	1999	7630	27	58	217	0	11	160	203	282	1092	15	29	187	0	8	88	116	154	476
WV	Hancock	540290011	1999	8584	27	44	162	1	14	121	146	197	930	15	19	125	1	9	63	72	93	286
NY	Bronx	360050080	2000	2881	24	26	109	2	16	75	87	114	383	17	12	73	2	13	46	52	59	109
NY	Kings	360470076	2000	24	31	23	69	12	25	115	115	115	115	21	7	34	12	19	36	36	36	36
AR	Union	051390006	2000	20	43	61	140	3	10	199	199	199	199	26	36	138	2	5	103	103	103	103
AR	Pulaski	051191002	2001	5	25	30	118	4	13	77	77	77	77	15	18	121	3	9	47	47	47	47
PA	Allegheny	420033003	2001	6992	26	39	152	0	14	116	137	175	842	15	17	115	0	10	62	70	82	192
PA	Warren	421230004	2001	8686	28	58	207	1	8	175	213	281	1030	16	29	178	1	5	97	117	150	297
ID	Caribou	160290031	2001	7501	48	164	345	0	2	592	723	882	2330	22	75	335	0	1	271	366	450	512
HI	Hawaii	150010007	2002	7662	28	113	406	0	0	272	366	584	2284	16	60	380	0	0	160	203	298	967
WV	Wayne	540990005	2002	14	38	24	59	15	33	96	96	96	96	23	8	37	13	19	37	37	37	37
WV	Wayne	540990003	2002	9	43	26	58	17	37	101	101	101	101	27	8	29	14	29	37	37	37	37
MO	Iron	290930030	2002	15	45	111	238	1	5	420	420	420	420	19	40	210	1	3	153	153	153	153
HI	Hawaii	150010007	2003	8346	36	124	348	0	0	335	435	640	2047	20	65	325	0	0	188	234	315	867
WV	Brooke	540090007	2004	8672	26	34	131	1	16	103	121	164	787	15	14	92	1	10	50	59	73	238
HI	Hawaii	150010007	2004	6447	35	112	323	0	0	297	389	585	1985	20	59	300	0	0	172	217	288	987
HI	Hawaii	150010007	2005	8177	33	135	408	0	0	341	485	724	2362	19	72	385	0	0	195	262	375	928
HI	Hawaii	150010005	2006	8358	36	155	436	0	0	418	576	798	3015	16	70	436	0	0	162	232	369	999
HI	Hawaii	150010007	2006	7892	41	142	347	0	2	399	532	735	2394	23	76	326	0	2	227	283	382	963
TN	Blount	470090002	2007	2062	30	56	188	2	9	162	198	264	796	17	27	157	2	6	91	102	139	265
HI	Hawaii	150010005	2007	2746	42	147	350	0	0	449	568	733	2042	19	63	341	0	0	182	226	308	812
HI	Hawaii	150010007	2007	2578	48	152	315	0	0	446	586	799	1927	27	81	298	0	0	237	314	433	857

highest measured 1-hour maximum SO_2 concentrations also contained high annual average concentrations (Table 6-7).

The coefficient of variability (COV) for the modeled 5-minute maximum concentrations range from 80 to 600%, while the 1-hour measurement COV ranges from about 0 to 400% (re 6-15). These COV ranges are broader than those reported for the 98-monitor measurement data set, however it should be noted that this current data set includes monitors with as few as two 1-hour SO_2 measurements and also used reported concentrations that included values of zero[10]. There appears to be a consistent reduction in the range of COV for recent monitoring years 2004-2007 compared with the earlier years of data, with a significant effect of year on COV from both concentration measures (Table 6-6).

As done earlier, the potential health effect benchmark levels of 400, 500, and 600 ppb were selected for comparison with the modeled 5-minute maximum concentrations at monitors that measured 1-hour ambient SO_2 concentrations. The number of estimated exceedances for each monitor by year appears in Figure 6-16. For most years, the number of 5-minute maximum concentrations above 400, 500, 600 ppb was estimated to be as high as 150, 100, and 70 per year respectively. Estimated exceedances of the selected concentration levels were observed at a fraction of the total monitors operating during any one year, with between 14-44% (mean of 35%) of monitors recording a single peak above the lowest potential health effect benchmark level (Figure 6-17). Therefore, about 65% of the monitors did not contain a single modeled 5-minute concentration above 400 ppb in a year. Even when excluding the monitors where there were no exceedances of the lowest potential benchmark level of 400 ppb, only 262 out of 6,103 site years of data (<5%) contained an estimated mean number of exceedances above 10 per year, with less than half of those site years (127) containing greater than 20 exceedances of 400 ppb in a year.

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[10] Completeness criteria were only used when comparing the ambient monitoring data to the current SO_2 NAAQS. There were also no below detection limit substitutions.

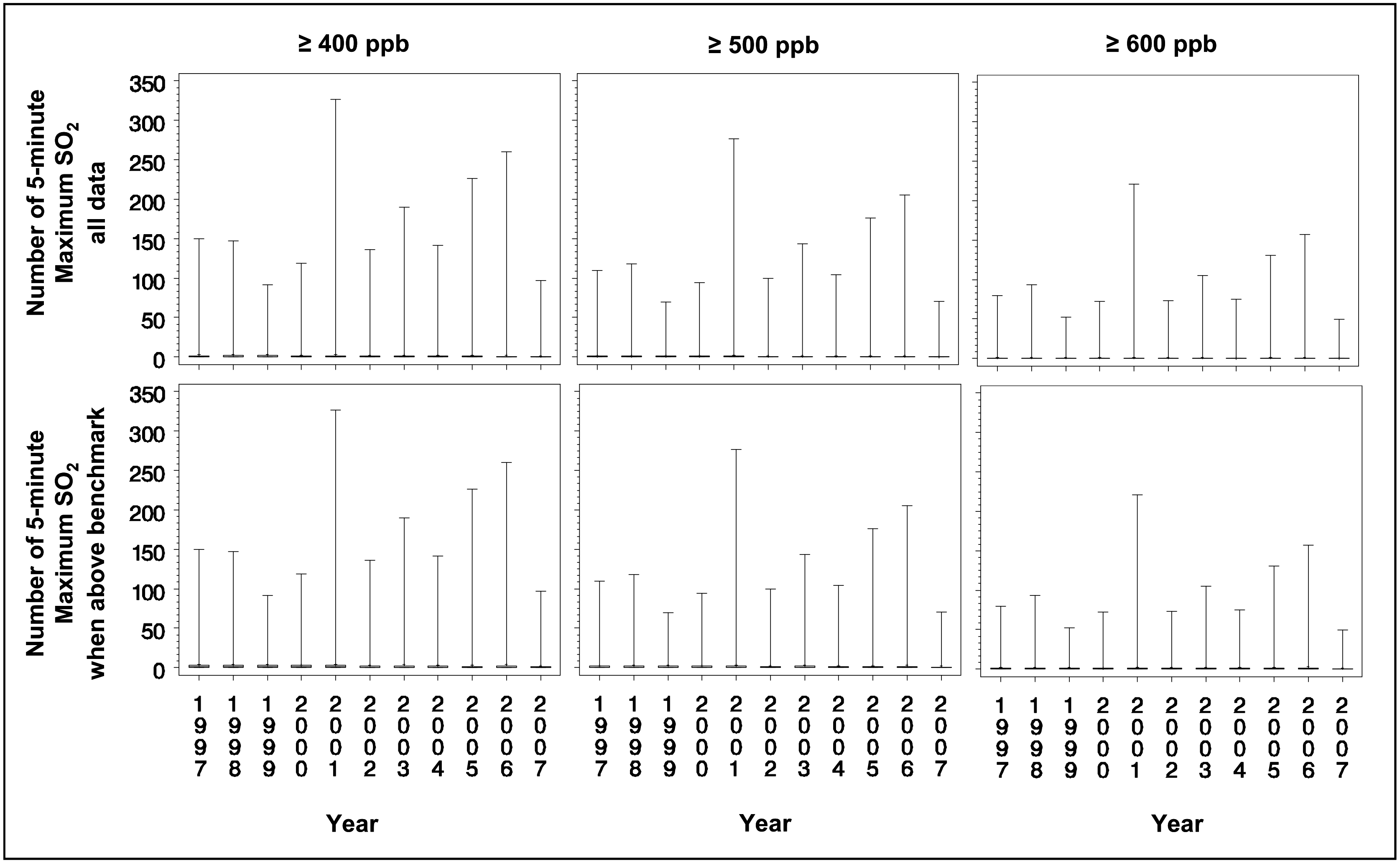

Figure 6-16. Distribution of the modeled 5-minute maximum SO_2 concentrations above potential health effect benchmark levels at each monitor by year, Years 1997 through 2007. The top row represents the distribution for all monitors (including those with no exceedances), the bottom row represents the distribution for those monitors with at least one estimated exceedance.

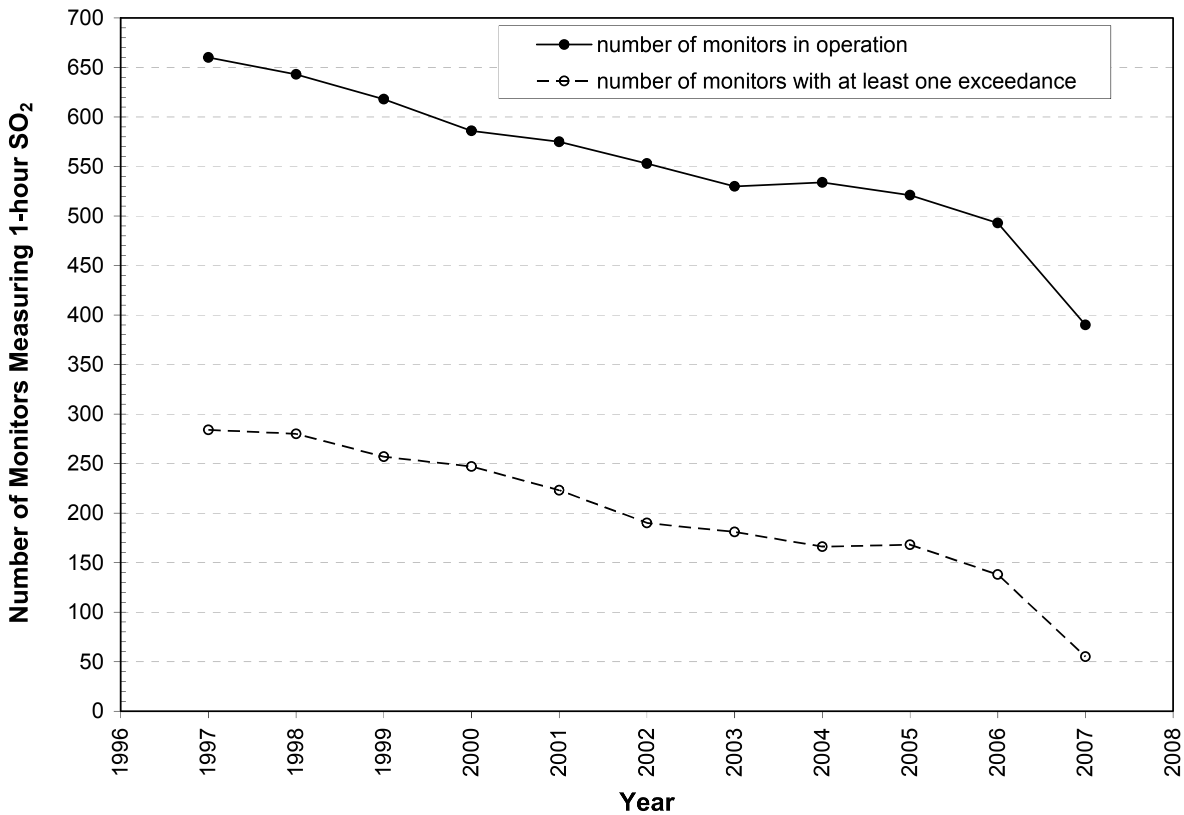

Figure 6-17. Number of ambient monitors measuring 1-hour average SO_2 concentration concentrations and number of monitors with at least one benchmark exceedance by year, Years 1997 through 2007.

As mentioned earlier, there were a few years where the 1-hour SO_2 concentrations in Hawaii County, HI were among some of the highest measured (Table 6-7). The impact of these measurements on the estimated number of peak concentrations above the selected levels is indicated in the tails of the distribution Figure 6-16, particularly for years 2005 and 2006. In addition, an unusual number of concentrations above the benchmark levels were observed in 2001, driven exclusively by results for Caribou, Idaho (monitor ID 160290031). This monitor is a stationary source-oriented monitor sited within close proximity of a chemical manufacturing facility (0.76 km) with estimated emissions of over 10,000 tpy. In excluding these two locations from the analysis for clarity regarding all other monitoring sites, additional trends in the estimated 5-minute maximum concentrations are present (Figure 6-18). There is a decrease in the number of exceedances with each monitoring year, both for the range and the average number of exceedances. When considering more recent air quality (e.g., 2004-2007), the maximum number of concentrations measured above 400 ppb at a monitor was about 20 to 60 times in a year (of 8,760 total possible events or less thank 1%, with most monitors measuring a few exceedances, if at all. It should also be noted that this frequency would only apply at locations where exceedances may occur, on average at about one-third of all 1-hour SO_2 monitors in operation for a given year. As observed with the 5-minute maximum monitoring network, the number of 1-hour monitors steadily drops from a peak of 660 in year 1997 to just under 400 in year 2007 (Figure 6-17). This could be a contributing factor to the observed reduction in the number of estimated concentrations above the potential health effect benchmark levels. While the percent of monitors with at least one estimated exceedance of 400 ppb considering the more recent air quality (i.e., 2004-2007) ranges from about 15 to 32% and appears to be reduced, the effect may be due to a reduction in number of total measurements.

To evaluate the impact of a reduction in the number of monitors, the frequency of concentrations above the potential health effect benchmark levels was normalized by the total number of 1-hour measurements. The results of this analysis for each year of monitoring are summarized in Figure 6-19. There is a downward trend in the frequency of concentrations above each of the three potential health effect benchmark concentrations when normalized to the number of samples collected, most dramatic from years 1999 though 2002. A similar frequency in normalized exceedances can be observed for the period from 2002 through 2007[11], estimated to be around 20, 10 and 5 per 100,000 hourly measurements for the 400, 500, and 600 ppb levels, respectively. Thus, while it appears that the normalized frequency of concentrations above selected levels is in decline possibly due to reduction in episodic peak concentrations when considering the entire monitoring period, the estimated frequency of occurrence may have stabilized since 2002.

Finally, the occurrence of the short-term peak concentrations was evaluated with regard to the current SO_2 NAAQS. Completeness criteria described in Appendix A for calculating each metric (i.e, 75% complete) were applied to the 1-hour measurements in the data set. Figures 6-20 (all monitors) and 6-21 (without Hawaii and Caribou County) compare the number of 5-minute maximum SO_2 concentrations above the potential health effect benchmark levels with the

[11] It should be noted that the 1-hour monitoring data for year 2007 were incomplete for all locations, it is unclear whether this would increase or decrease the estimated frequency.

annual average concentration from each monitor. None of the monitors in this data set contained annual average concentrations near the current NAAQS (0.03 ppm), however as described above, several of the monitors in several years frequently contained concentrations above the potential health effect benchmark levels. Many of those monitors where frequent exceedances occurred contained annual average concentrations between 10 and 20 ppb, with a limited trend indicated between the annual average concentration and the estimated number of peaks above any of the selected short-term concentrations (Figure 6-20). In removing the results for Hawaii and Caribou Counties, the relationship observed between the annual average concentrations and the number of exceedances of the selected benchmark levels is generally weaker, along with containing fewer exceedances at each of the levels (Figure 6-21).

Figure 6-22 compares the 24-hour average concentrations with the number of 5-minute SO_2 concentrations above potential health effect benchmark levels. Ninety-two monitor site-days contained 24-hour average SO_2 concentrations above 140 ppb, of which 76% were measured in either Hawaii or Caribou County (Table 6-8). Other locations with measured concentrations above 140 ppb were scattered across several years and states, including Illinois, Indiana, Iowa, Louisiana, Oklahoma, Pennsylvania, and Tennessee. These highest daily average SO_2 concentrations also corresponded to the most frequent number of concentrations above the potential health effect benchmark levels. There is a clear trend when considering all of the data above and below a daily mean concentration of 140 ppb, that is, with increasing 24-hour average concentration, there is an increase in the number of estimated 5-minute SO_2 concentrations above the potential health effect benchmark levels. For example, where there were at least 7 estimated occurrences above 500 ppb in a day, all 24-hour average concentrations were greater than 140 ppb. There is also a greater variability in the relationship, with a wide range in 24-hour average concentrations associated with at least 3 estimated exceedances of 500 ppb in a day (ranging from 50 to about 140 ppb), along with a similar range in 24-hour average concentrations (ranging from 0 to about 110 ppb) with no estimated exceedances of 500 ppb per day. Figure 6-23 presents the comparison of the 24-hour average concentrations with the number of 5-minute SO_2 concentrations above potential health effect benchmark levels excluding the results from Hawaii and Caribou Counties.

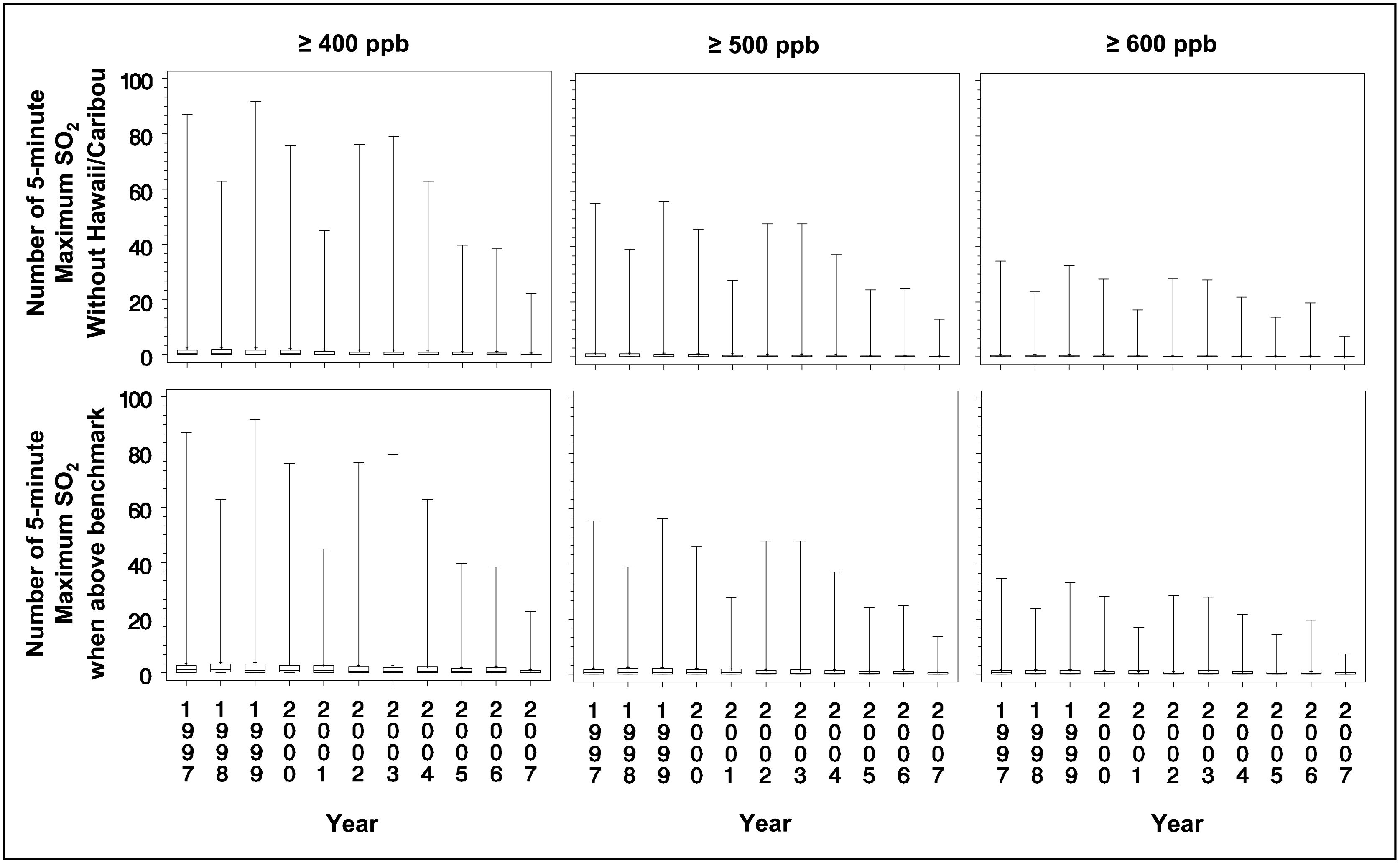

Figure 6-18. Number of modeled 5-minute maximum SO_2 concentrations above potential health effect benchmark levels at each monitor, Years 1997 through 2007. The top row represents the distribution for all monitors excluding Hawaii County and Caribou, Idaho for year 2001, the bottom row represents the distribution for those monitors with at least one estimated exceedance.

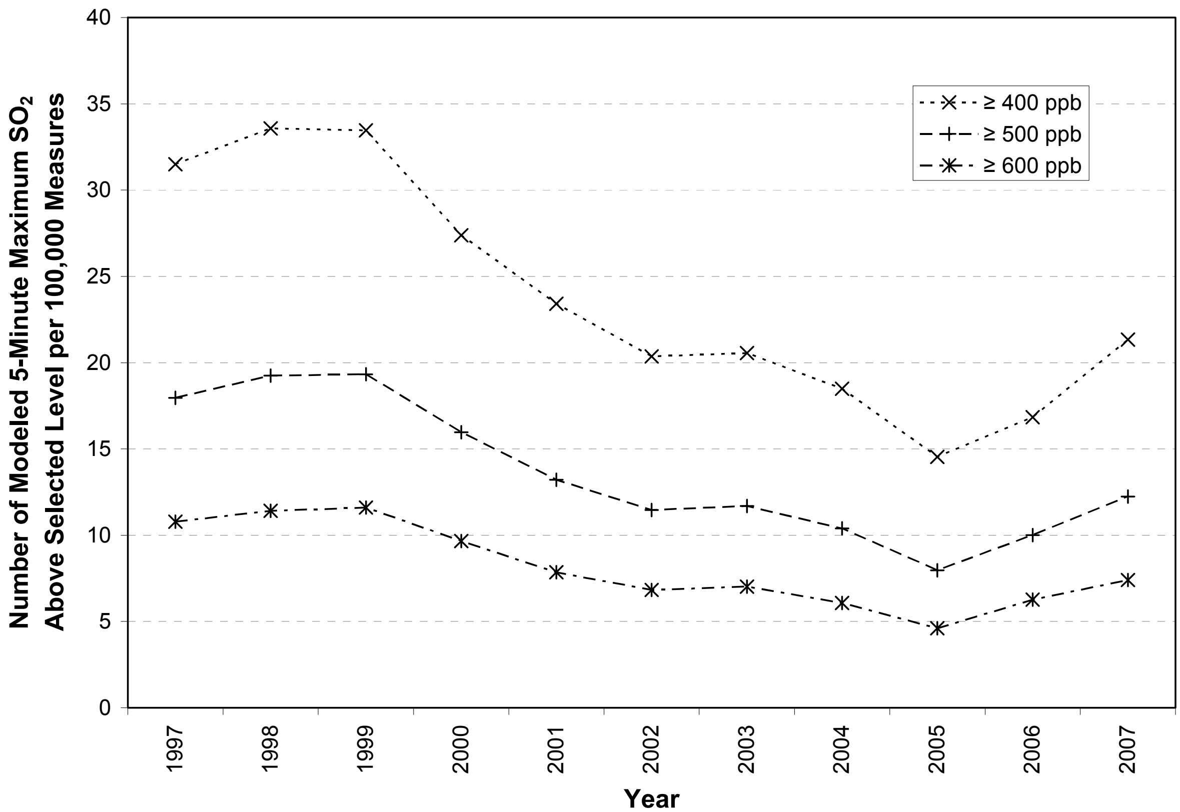

Figure 6-19. Frequency of modeled 5-minute maximum SO_2 concentrations above potential health effect benchmark levels in each year, normalized to 100,000 measurements, Years 1997 through 2007, without Hawaii County and Caribou, Id. (2001).

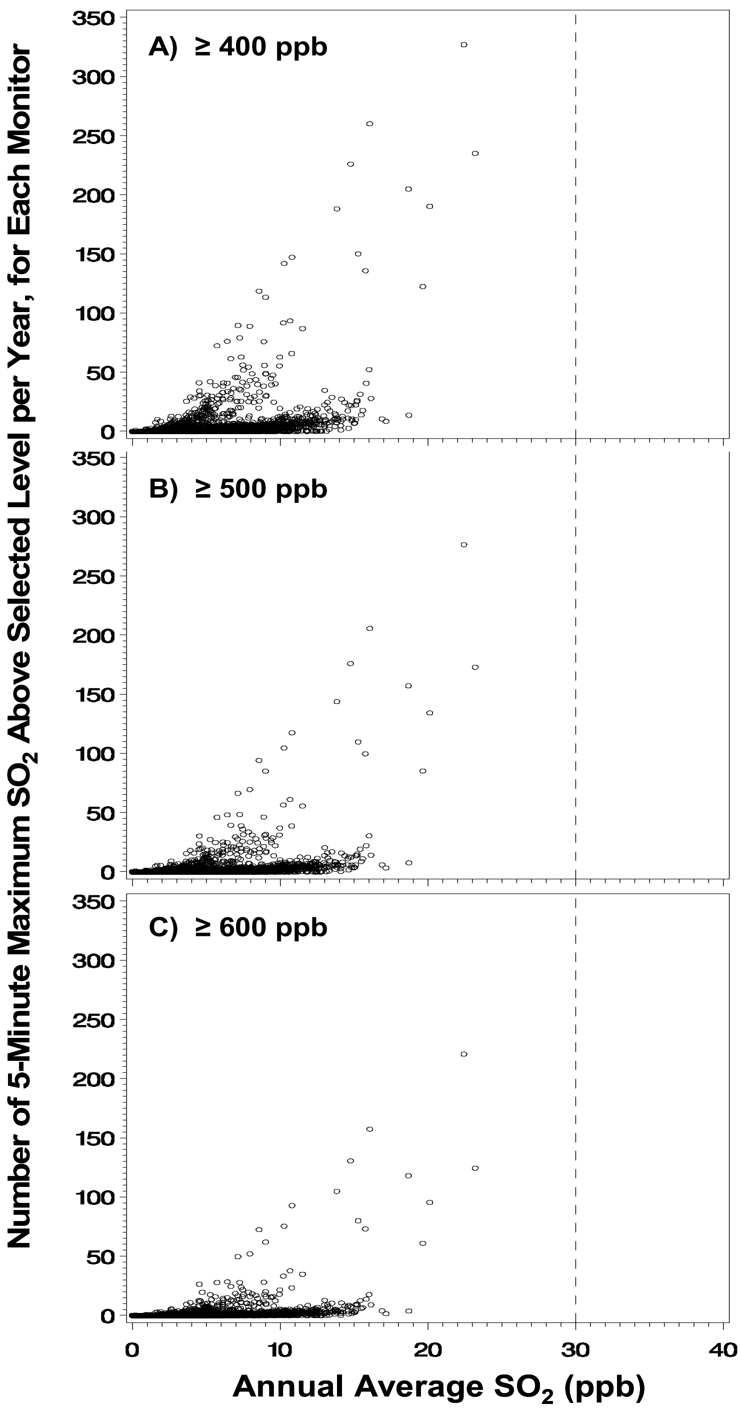

Figure 6-20. Comparison of the number of modeled 5-minute maximum SO_2 concentrations above potential health effect benchmark levels at each monitor per year and the associated annual average SO_2 concentration, Years 1997 through 2006, all 1-hour monitors. A) number of 5-minute maximums ≥400 ppb/year, B) number of 5-minute maximums ≥500 ppb/year, C) number of 5-minute maximums ≥600 ppb/year. The level of the annual average SO_2 NAAQS of 0.03 ppm is indicated by the dashed line.

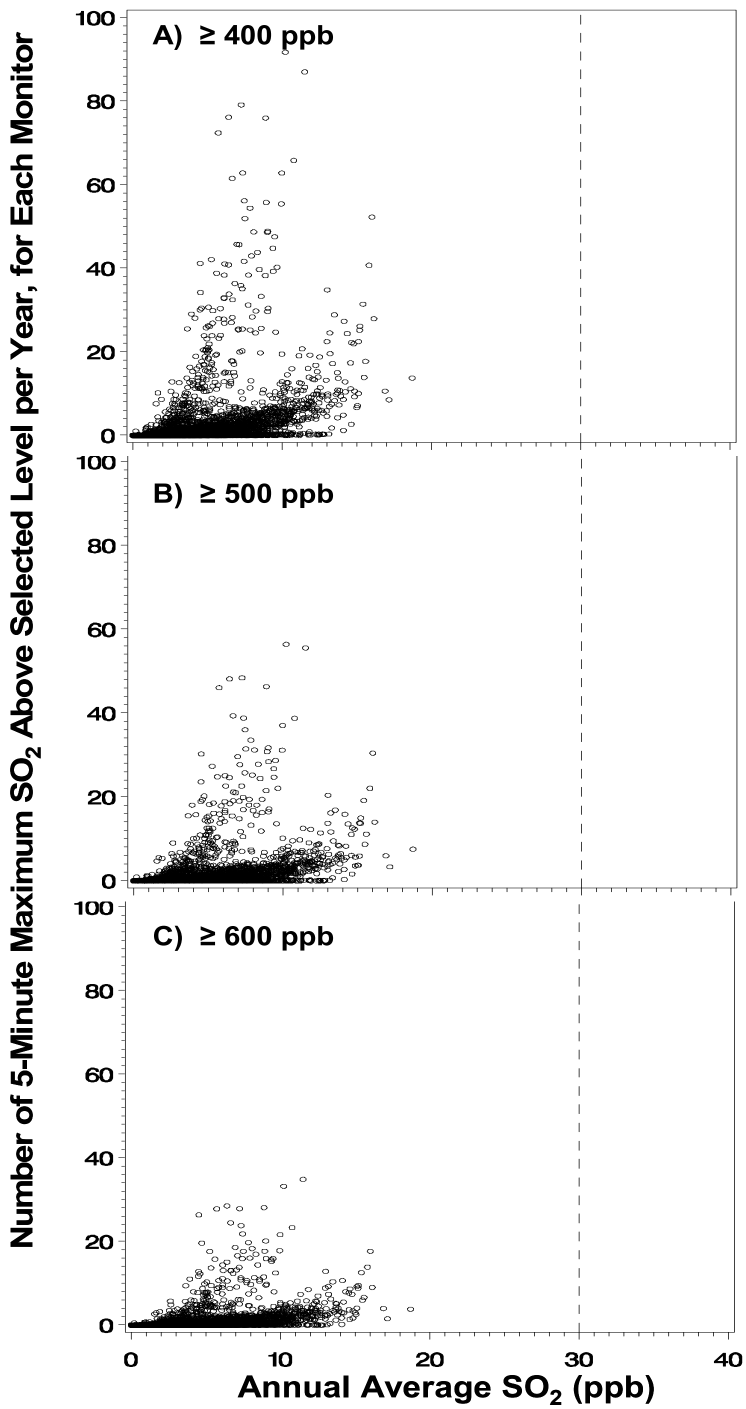

Figure 6-21. Comparison of the number of modeled 5-minute maximum SO_2 concentrations above potential health effect benchmark levels at each monitor per year and the associated annual average SO_2 concentration, Years 1997 through 2006, without Hawaii and Caribou Counties (2001 only). A) number of 5-minute maximums ≥400 ppb/year, B) number of 5-minute maximums ≥500 ppb/year, C) number of 5-minute maximums ≥600 ppb/year. The level of the annual average SO_2 NAAQS of 0.03 ppm is indicated by the dashed line.

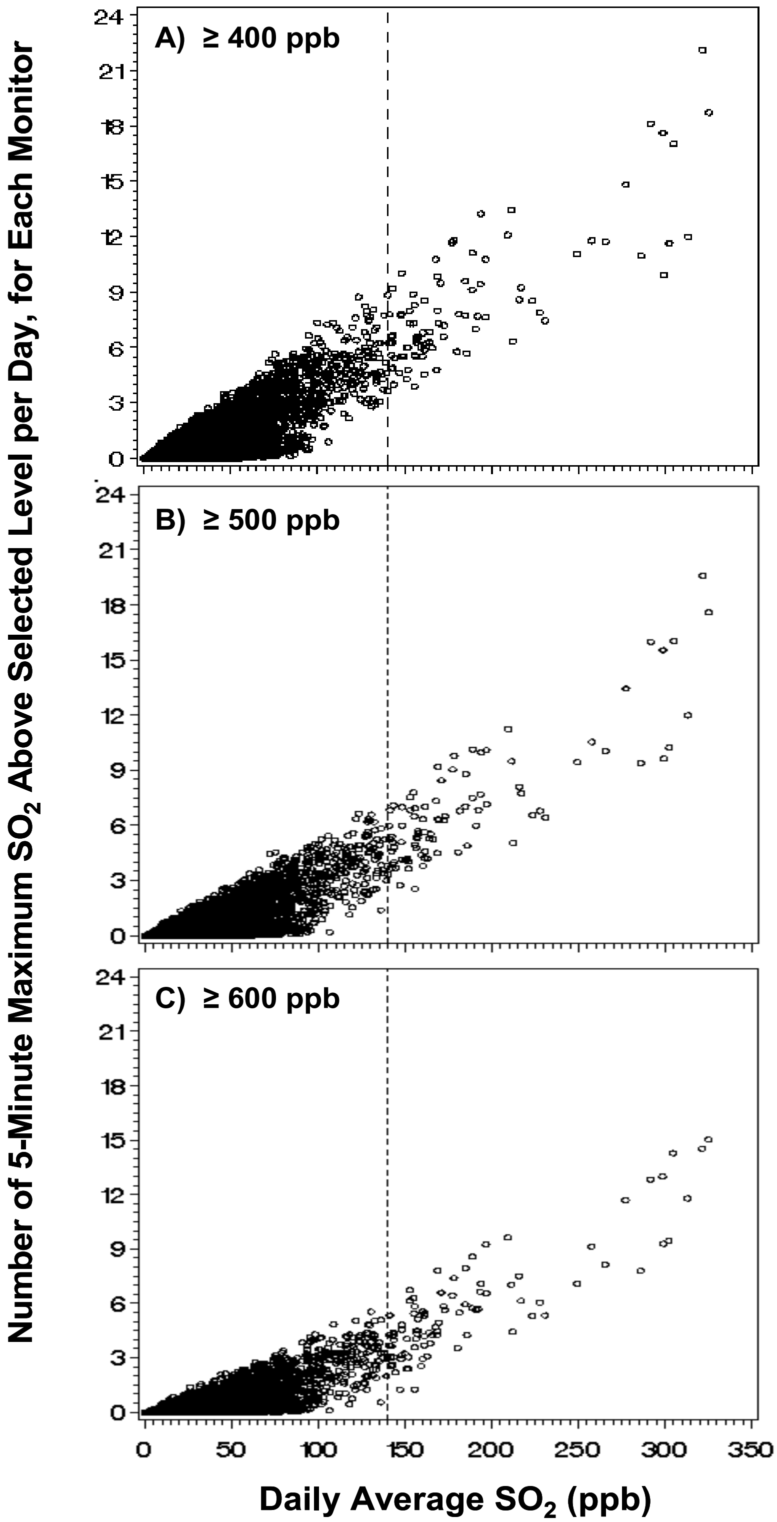

Figure 6-22. Comparison of the number of modeled 5-minute maximum SO_2 concentrations above potential health effect benchmark levels at each monitor per day and the associated daily average SO_2 concentration, Years 1997 through 2007, all 1-hour SO_2 monitors. The level of the 24-hour SO_2 NAAQS of 0.14 ppm is indicated by the dashed line.

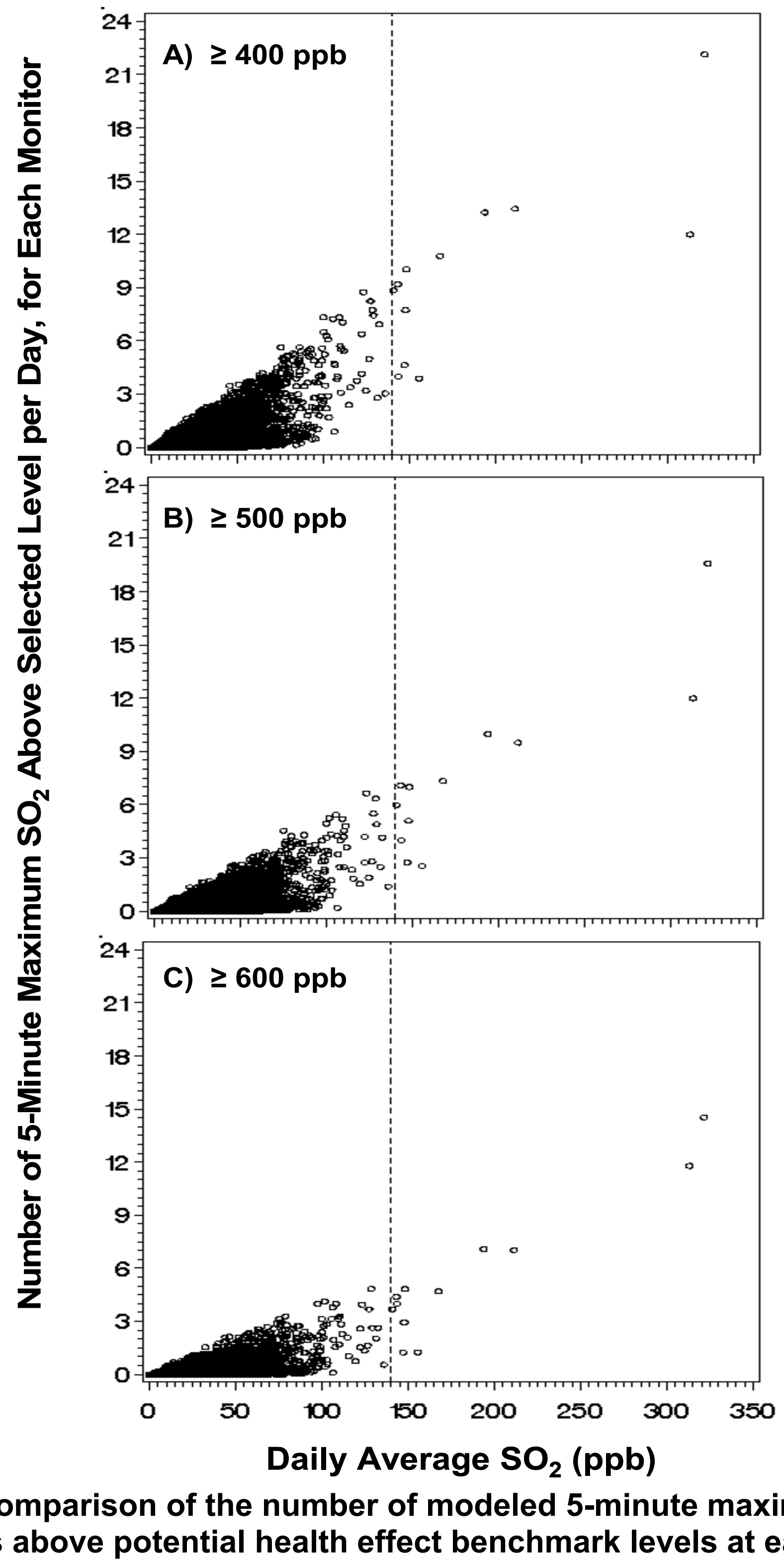

Figure 6-23. Comparison of the number of modeled 5-minute maximum SO_2 concentrations above potential health effect benchmark levels at each monitor per day and the associated daily average SO_2 concentration, Years 1997 through 2007, all 1-hour SO_2 monitors not including Hawaii and Caribou Counties. The level of the 24-hour SO_2 NAAQS of 0.14 ppm is indicated by the dashed line.

Table 6-8. Ambient monitors containing a daily average SO_2 concentration greater than 140 ppb and their modeled 5-minute maximum concentrations above selected potential health effect benchmark levels, Years 1997 through 2007.

						Daily SO_2 (ppb)		Modeled Number of 5-minute Maximum SO_2		
Monitor ID	State	County	Year	Month	Day	Mean	Std	≥400ppb	≥500ppb	≥600ppb
150010005	HI	Hawaii	1997	8	13	157	244	7	5	4
150010005	HI	Hawaii	1997	10	10	164	270	7	4	4
150010005	HI	Hawaii	1997	10	12	158	234	7	6	4
150010005	HI	Hawaii	1997	11	8	148	243	7	5	3
150010005	HI	Hawaii	1997	11	16	181	255	8	7	4
150010005	HI	Hawaii	1998	1	14	258	232	11	11	9
150010005	HI	Hawaii	1998	1	15	191	285	9	7	7
150010005	HI	Hawaii	1998	8	11	157	243	7	6	6
150010005	HI	Hawaii	1998	11	8	157	294	6	4	3
150010005	HI	Hawaii	1998	11	11	302	319	12	9	9
150010005	HI	Hawaii	1998	12	8	153	222	8	6	5
191390020	IA	Muscatine	1998	4	12	143	121	10	10	6
471390007	TN	Polk	1998	1	24	194	114	13	9	5
150010005	HI	Hawaii	1999	1	16	197	257	7	7	7
150010005	HI	Hawaii	1999	5	29	161	256	6	5	5
190330018	IA	Cerro Gordo	1999	10	22	141	81	8	7	5
191390020	IA	Muscatine	1999	12	1	148	68	7	6	2
150010005	HI	Hawaii	2000	2	9	189	206	11	7	5
150010005	HI	Hawaii	2000	3	14	217	311	10	6	5
180630001	IN	Hendricks	2000	3	24	144	317	4	4	4
150010007	HI	Hawaii	2001	2	12	145	119	5	3	2
150010007	HI	Hawaii	2001	3	23	143	135	5	4	2
150010007	HI	Hawaii	2001	11	22	150	172	6	4	4
160290031	ID	Caribou	2001	1	8	278	186	15	15	14
160290031	ID	Caribou	2001	1	11	325	176	19	16	14
160290031	ID	Caribou	2001	2	10	185	208	9	9	7
160290031	ID	Caribou	2001	2	12	305	180	17	17	15
160290031	ID	Caribou	2001	3	4	210	196	12	12	8
160290031	ID	Caribou	2001	3	5	292	148	18	17	14
160290031	ID	Caribou	2001	3	16	155	186	10	8	8
160290031	ID	Caribou	2001	7	13	178	169	13	12	9
160290031	ID	Caribou	2001	7	16	169	205	9	9	7
160290031	ID	Caribou	2001	7	28	197	216	12	11	11
160290031	ID	Caribou	2001	8	9	189	202	12	9	8
160290031	ID	Caribou	2001	8	21	299	157	17	15	13
150010005	HI	Hawaii	2002	9	25	266	274	11	9	6
150010005	HI	Hawaii	2002	10	13	155	224	8	8	6
150010007	HI	Hawaii	2002	5	12	194	213	9	8	8
150010007	HI	Hawaii	2002	8	13	144	273	5	5	5
150010007	HI	Hawaii	2002	9	23	142	161	6	6	4
150010007	HI	Hawaii	2002	9	25	224	274	8	7	5

Monitor ID	State	County	Year	Month	Day	Daily SO_2 (ppb)		Modeled Number of 5-minute Maximum SO_2		
						Mean	Std	≥400ppb	≥500ppb	≥600ppb
150010007	HI	Hawaii	2002	10	13	148	186	8	5	3
150010007	HI	Hawaii	2002	10	17	152	118	3	2	2
150010007	HI	Hawaii	2002	11	24	152	146	4	3	3
150010005	HI	Hawaii	2003	3	5	141	177	8	5	5
150010005	HI	Hawaii	2003	3	29	173	220	7	7	7
150010005	HI	Hawaii	2003	6	2	162	166	8	7	4
150010007	HI	Hawaii	2003	6	2	250	194	10	9	5
150010007	HI	Hawaii	2003	10	19	212	263	6	5	4
150010007	HI	Hawaii	2003	10	27	160	121	8	3	2
171790004	IL	Tazewell	2003	5	11	148	100	12	8	5
180510002	IN	Gibson	2003	4	1	212	106	16	10	7
150010005	HI	Hawaii	2004	5	20	143	203	5	4	3
150010007	HI	Hawaii	2004	11	6	181	219	4	3	3
150010007	HI	Hawaii	2004	11	7	144	127	7	6	3
150010007	HI	Hawaii	2004	11	9	140	239	5	4	3
150010005	HI	Hawaii	2005	1	25	161	261	7	7	7
150010005	HI	Hawaii	2005	1	26	216	292	9	9	7
150010005	HI	Hawaii	2005	1	27	151	319	4	4	4
150010005	HI	Hawaii	2005	3	17	142	176	7	6	4
150010005	HI	Hawaii	2005	3	26	170	274	6	6	5
150010005	HI	Hawaii	2005	5	2	185	234	8	5	4
150010005	HI	Hawaii	2005	12	17	178	120	15	12	7
150010007	HI	Hawaii	2005	3	17	192	223	8	8	7
150010007	HI	Hawaii	2005	3	26	299	316	10	10	9
150010007	HI	Hawaii	2005	5	2	228	272	6	5	5
150010007	HI	Hawaii	2005	9	24	169	152	8	8	5
150010007	HI	Hawaii	2005	12	4	156	203	5	5	3
150010005	HI	Hawaii	2006	2	11	156	220	9	8	6
150010005	HI	Hawaii	2006	6	25	171	216	10	9	8
150010005	HI	Hawaii	2006	9	15	153	216	7	7	6
150010005	HI	Hawaii	2006	9	25	172	286	6	6	6
150010005	HI	Hawaii	2006	10	7	353	308	15	15	15
150010005	HI	Hawaii	2006	11	26	161	339	5	5	5
150010007	HI	Hawaii	2006	2	17	231	231	7	6	6
150010007	HI	Hawaii	2006	2	28	165	228	5	4	3
150010007	HI	Hawaii	2006	3	2	163	129	5	3	2
150010007	HI	Hawaii	2006	6	25	162	222	9	6	4
150010007	HI	Hawaii	2006	8	1	160	173	6	4	3
150010007	HI	Hawaii	2006	9	25	166	211	5	5	4
150010007	HI	Hawaii	2006	10	7	286	230	12	10	9
150010007	HI	Hawaii	2006	11	1	152	117	6	4	4
150010007	HI	Hawaii	2006	11	25	143	142	4	3	1
150010007	HI	Hawaii	2006	11	26	169	320	5	5	5
150010007	HI	Hawaii	2006	11	28	142	148	6	5	3
220330009	LA	East Baton Rouge	2006	7	30	313	242	12	12	12

Monitor ID	State	County	Year	Month	Day	Daily SO_2 (ppb) Mean	Std	Modeled Number of 5-minute Maximum SO_2 ≥400ppb	≥500ppb	≥600ppb
400219002	OK	Cherokee	2006	5	4	322	84	22	17	13
420958000	PA	Northampton	2006	11	12	156	65	2	2	1
420958000	PA	Northampton	2006	11	13	147	92	3	2	1
150010007	HI	Hawaii	2007	3	7	157	161	6	6	4
150010007	HI	Hawaii	2007	3	15	186	253	7	6	5
171790004	IL	Tazewell	2007	3	2	168	87	12	10	5

6.4.3 Air Quality Just Meeting the Current Daily Standard

Twenty counties were selected for detailed analyses, including an evaluation of ambient concentration distributions and the estimated numbers of exceedances of the potential health effect benchmark levels using as is air quality and air quality adjusted to just meeting the current standard. The locations were selected based on the number of monitors within the county, containing daily average concentrations closest to the current daily standard, and for a few locations, containing a high frequency of measured concentrations above the potential health effect benchmark levels. The most recent air quality data were used for this analysis, including years 2002 through 2006. Table 6-9 identifies the 20 counties selected for detailed analyses, originating from 13 states and covering various geographic regions. Due to the large size of the data sets, mean, maximum, and measures of variability are summarized mainly in figures, with a few tables containing descriptive statistics for each of the twenty counties at the end of the chapter. Supplemental information for these analyses is provided in section 6.3 (selection criteria and factors used for adjusting air quality), Appendix A (ambient monitor siting and proximity to SO_2 stationary source emissions), and Appendix C (descriptive statistics for concentrations and estimated exceedances in tables by monitor and monitor year).

Twenty simulations were performed to estimate the 5-minute maximum SO_2 concentration associated with each 1-hour measurement. These simulation results were combined to generate a mean estimate for each of the metrics of interest (e.g., the number of 5-minute concentrations $\geq$ 400 ppb) selected here as the most representative estimate from the twenty simulations. The data analysis and aggregation approach for the modeled (5-minute maximum) and measurement (1-hour) data for the 20 selected counties was the same as that performed for all 1-hour monitors (section 6.4.2).

Table 6-9. Identification of twenty locations for detailed analyses.

State	Abbreviation	County
Delaware	DE	New Castle
Florida	FL	Hillsborough
Iowa	IA	Linn
		Muscatine
Illinois	IL	Madison
Indiana	IN	Floyd
Michigan	MI	Wayne
Missouri	MO	Greene
		Iron
		Jefferson
Ohio	OH	Cuyahoga
Oklahoma	OK	Tulsa
Pennsylvania	PA	Allegheny
		Beaver
		Northampton
		Washington
Tennessee	TN	Shelby
Texas	TX	Jefferson
West Virginia	WV	Hancock
		Wayne

Figure 6-24 illustrates temporal trends in the mean 5-minute maximum and 1-hour SO_2 concentrations from each monitor in the twenty counties. The illustration includes the air quality data as is (1-hour measured with 5-minute maximum modeled SO_2) and air quality adjusted to meet the current daily standard (either the 0.14 ppm daily or 0.03 ppm annual average). In general, annual mean concentrations range from around 2-25 ppb and <1-15 ppb for the 5-minute maximum and 1-hour SO_2 concentrations, respectively, and do not appear to be correlated with year of monitoring considering the as is air quality. A similar pattern is noted for the air quality adjusted to just meeting the current standard, although concentrations for both averaging times are about a factor of three greater than as is air quality. Results from a one-way analysis ANOVA of each of the mean concentrations indicate the lack of a statistically significant effect for monitoring year for either air quality scenario (Table 6-10).

There were also no temporal trends in the maximum SO_2 concentrations for both the as is air quality and concentrations adjusted to just meeting the current standard (Figure 6-25). Results from a one-way ANOVA of each of the maximum concentrations also indicate the lack of a statistically significant effect for monitoring year for either air quality scenario (Table 6-10). The coefficient of variability (COV) for both concentration measures is presented in Figure 6-26 and, by design the values are identical for each air quality scenario. In general, COVs for the modeled 5-minute maximum concentrations range from 100 to 500%, while the 1-hour measurement COV ranges from about 50 to 400%. There was not a significant effect of year on COV for either concentration measure (Table 6-10).

Table 6-10. Model results from one-way analysis of variance (ANOVA) testing for effect of monitoring year. Results are from detailed analysis of twenty selected counties, Years 2002 through 2006.

Air Quality Scenario	SO_2 Data	Dependent Variable	R^2	F	p
As Is	5-minute maximum	Mean	0.010	0.93	0.448
		Maximum	0.018	1.61	0.171
		COV	0.007	0.60	0.662
	1-hour	Mean	0.011	0.99	0.411
		Maximum	0.013	1.23	0.297
		COV	0.008	0.69	0.602
Just Meeting the Current Daily Standard	5-minute maximum	Mean	0.016	1.44	0.219
		Maximum	0.011	0.99	0.414
		COV	0.006	0.59	0.671
	1-hour	Mean	0.016	1.44	0.223
		Maximum	0.011	0.99	0.412
		COV	0.008	0.69	0.603

The potential health effect benchmark levels of 400, 500, and 600 ppb were selected for comparison with the modeled 5-minute maximum concentrations at monitors with measured 1-hour ambient SO_2 concentrations. The number of estimated exceedances for each monitor by year appears in Figure 6-27. The number of 5-minute maximum concentrations above 400, 500, 600 ppb was estimated to be as high as 35, 15 and 8 per year respectively for as is air quality, although the majority of monitors were estimated to have much less. The estimated number of exceedances of the selected concentration levels were observed at a fraction of the total monitors operating during

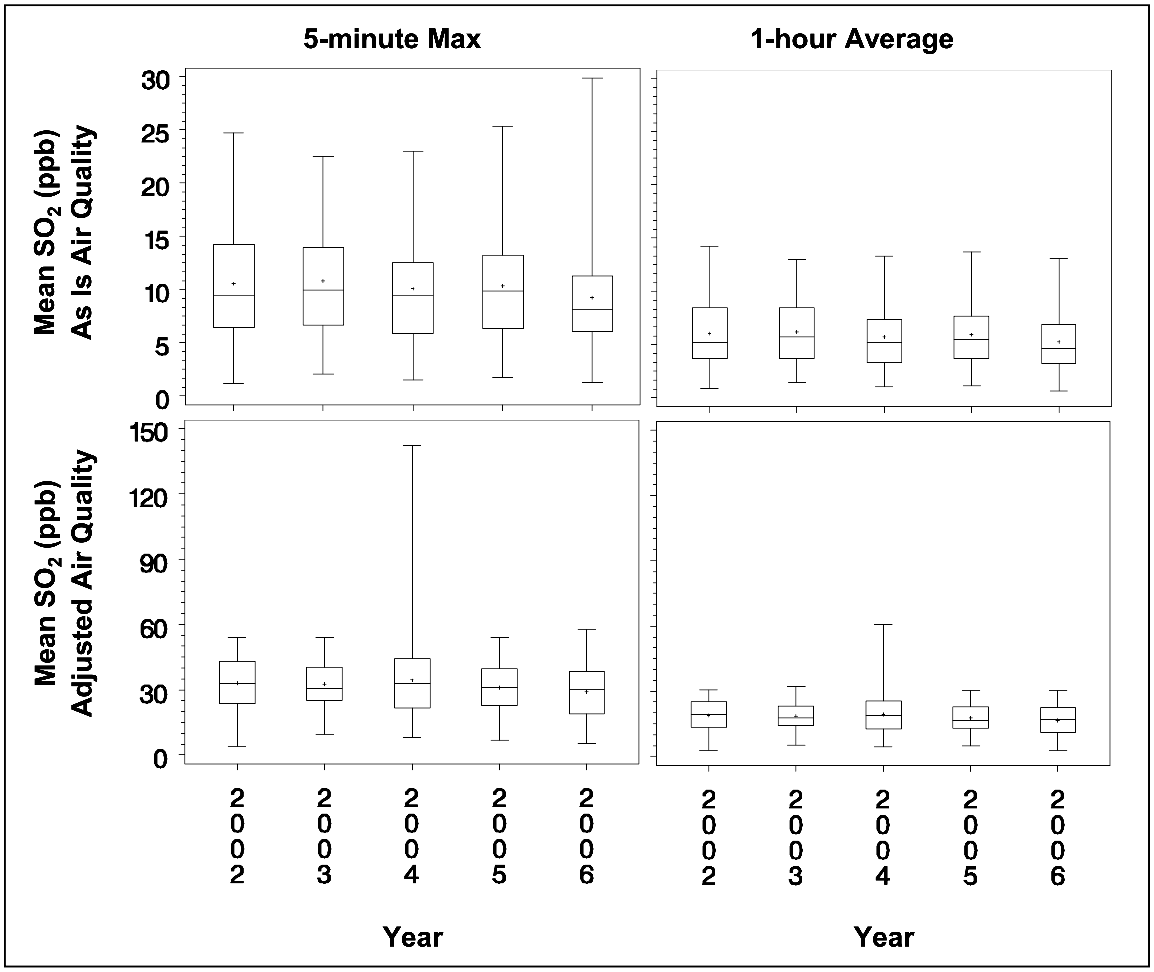

Figure 6-24. Mean SO_2 concentrations for modeled 5-minute maximum and measured 1-hour SO_2 concentrations, Years 2002 through 2006 at 20 selected counties, with air quality as is and air quality adjusted to just meeting the current standards (either one exceedance of 0.14 ppm daily average or no exceedance of 0.03 ppm annual average).

any one year, with between 26-39% (mean of 33%) of monitors recording a single peak above the lowest potential health effect benchmark level for the as is air quality. The number of estimated exceedances however is greater by at least factor of five when considering concentrations adjusted to just meeting the current standards (Figure 6-27). Nearly all of the monitors contained at least one exceedance of the lowest potential health effect level when air quality was adjusted to just meeting the current standard. The mean percentage of monitors across all years was 98%.

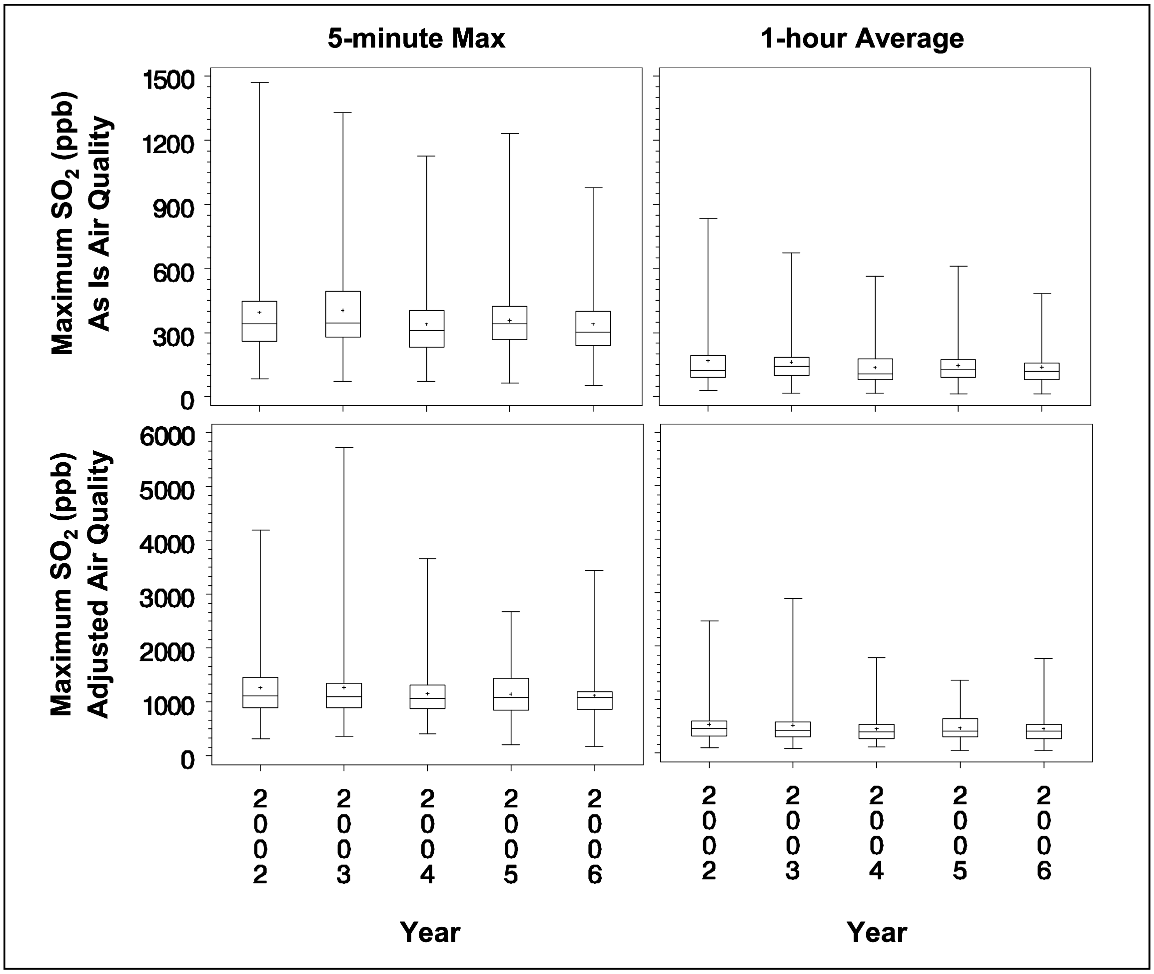

Figure 6-25. Maximum Mean SO_2 concentrations for modeled 5-minute maximum and measured 1-hour SO_2 concentrations, Years 2002 through 2006 at 20 selected counties, with air quality as is and air quality adjusted to just meeting the current standard (either one exceedance of 0.14 ppm daily average or no exceedance of 0.03 ppm annual average).

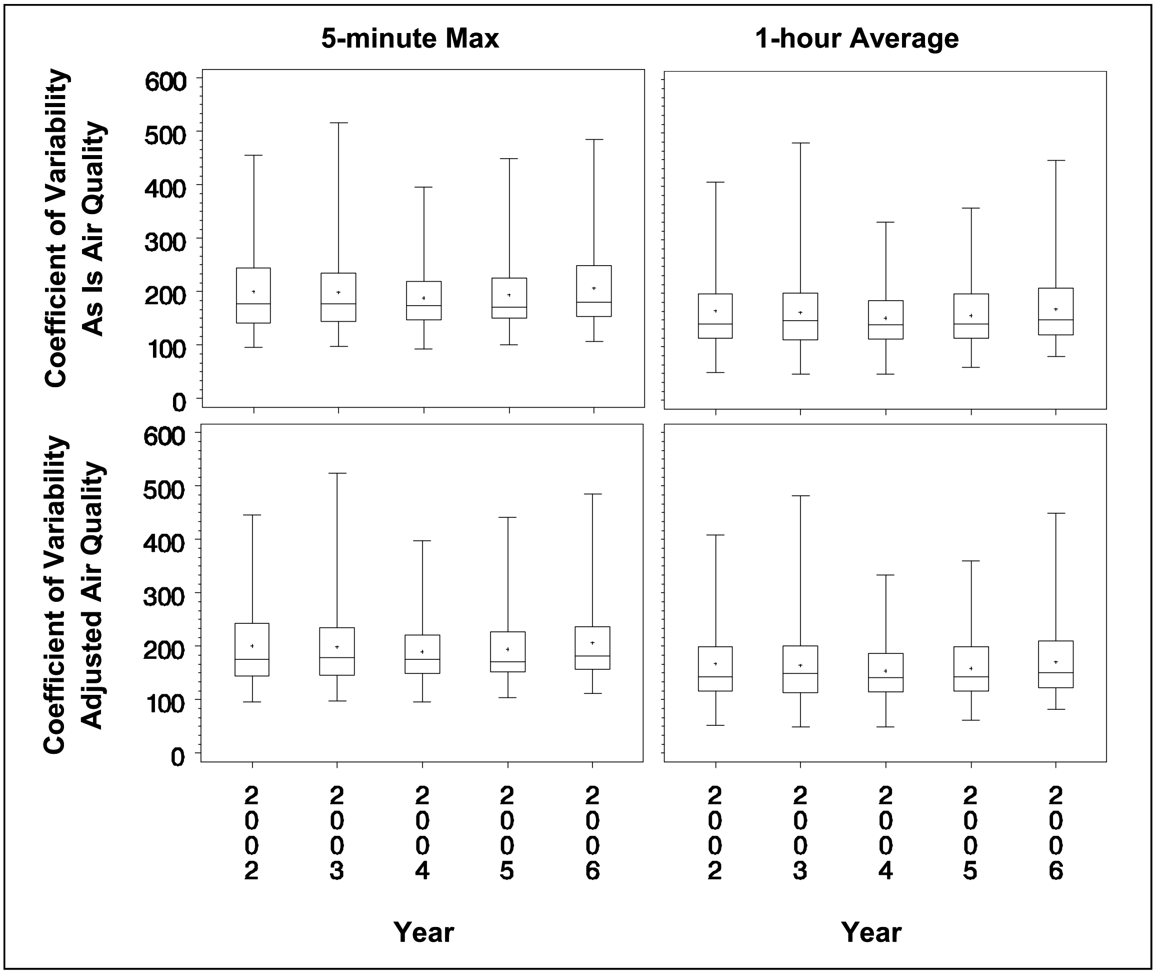

Figure 26. Coefficient of variability (COV, %) for modeled 5-minute maximum and measured 1-hour SO_2 concentrations, Years 2002 through 2006 at 20 selected counties, with air quality as is and air quality adjusted to just meeting the current standards (either one exceedance of 0.14 ppm daily average or no exceedance of 0.03 ppm annual average).

The number of concentrations above the potential health effect benchmark levels was normalized by the total number of 1-hour SO_2 measurements to determine temporal trends in the frequency of exceedances. The results of this analysis for each air quality scenario are summarized in Figure 6-28. There is a small downward trend in the frequency of concentrations above each of the three potential health effect benchmark concentrations when normalized to the number of samples collected, although there is a slight rise in the frequencies for 2006. The normalized frequency of exceedances was estimated to be around 20, 8, and 4 per 100,000 hourly measurements for the 400, 500, and 600 ppb levels, respectively and appears to have stabilized in these selected locations since 2002. The frequency of estimated concentrations above the potential health effect benchmark levels was greater when concentrations were adjusted to just meeting the current standard, with about 575, 350, and 225 exceedances per 100,000 measurements per year of the 400, 500, and 600 ppb levels, respectively.

Finally, the occurrence of the short-term peak concentrations was evaluated with regard to the current SO_2 NAAQS in the selected counties. Completeness criteria described in Appendix A for calculating each metric (i.e, 75% complete) were applied to the 1-hour SO_2 measurements in the data set. Figure 6-29 compares the number of 5-minute maximum SO_2 concentrations above the potential health effect benchmark levels with the annual average concentration from each monitor using the as is air quality data. None of the monitors in the selected counties contained annual average concentrations near the current NAAQS (0.03 ppm), however as described above, a few of the monitors in some of the years contained modeled concentrations above the potential health effect benchmark levels, with decreasing numbers of exceedances with increasing potential health effect benchmark concentration.

Figure 6-30 compares the estimated number of exceeedances of the potential health effect benchmark levels with the annual average SO_2 concentration when the air quality data were adjusted to just meet the standards. Both the number of exceedances and the annual average concentrations have increased dramatically, although there is no clear trend between the two parameters.

Figure 6-31 compares the 24-hour average concentrations with the number of 5-minute SO_2 concentrations above potential health effect benchmark levels considering as is air quality. The two daily average concentrations above the 140 ppb level were observed in Northampton County, Pa. In general the highest daily average SO_2 concentrations corresponded to the most frequent number of concentrations above the potential health effect benchmark levels, although most locations were estimated to have fewer than 5 exceedances of the lowest potential health effect benchmark level of 400 ppb.

Figure 6-32 illustrates a clear trend in 24-hour average concentrations and the estimated number of exceedances when considering air quality adjusted to just meeting the current standard. Increases in 24-hour average concentration correspond to an increase in the number of estimated 5-minute SO_2 concentrations above the potential health effect benchmark levels. Similar to what was noted when using all of the monitors at current air quality conditions, where there were at least seven estimated concentrations above 500 ppb in a day, all 24-hour average concentrations were greater than 140 ppb. There is also a broad range in 24-hour average concentrations associated and any number of exceedances. For example, where there were 3 estimated exceedances of 500 ppb in a day, the daily average concentrations could range from 60 to about 200 ppb. In addition, a similar range in 24-hour average concentrations (ranging from 0 to about 150 ppb) could have no estimated exceedances of the 500 ppb benchmark level per day.

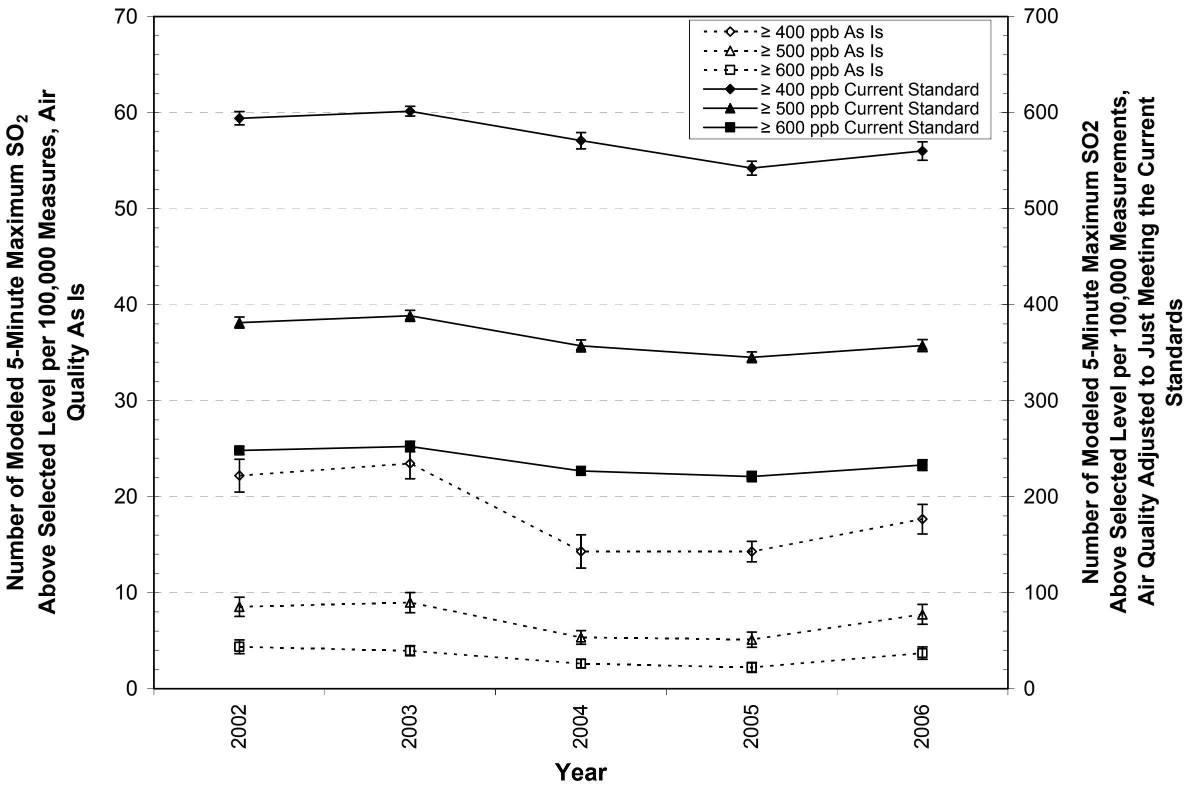

Figure 6-27. Frequency of modeled 5-minute maximum SO_2 concentrations above potential health effect benchmark levels in each year, normalized to 100,000 measurements, Years 2002 through 2006 at twenty selected counties, with air quality as is and air quality adjusted to just meeting the current standards (either one exceedance of 0.14 ppm daily average or no exceedance of 0.03 ppm annual average). Bars indicate standard deviation of the mean from the twenty model simulations.

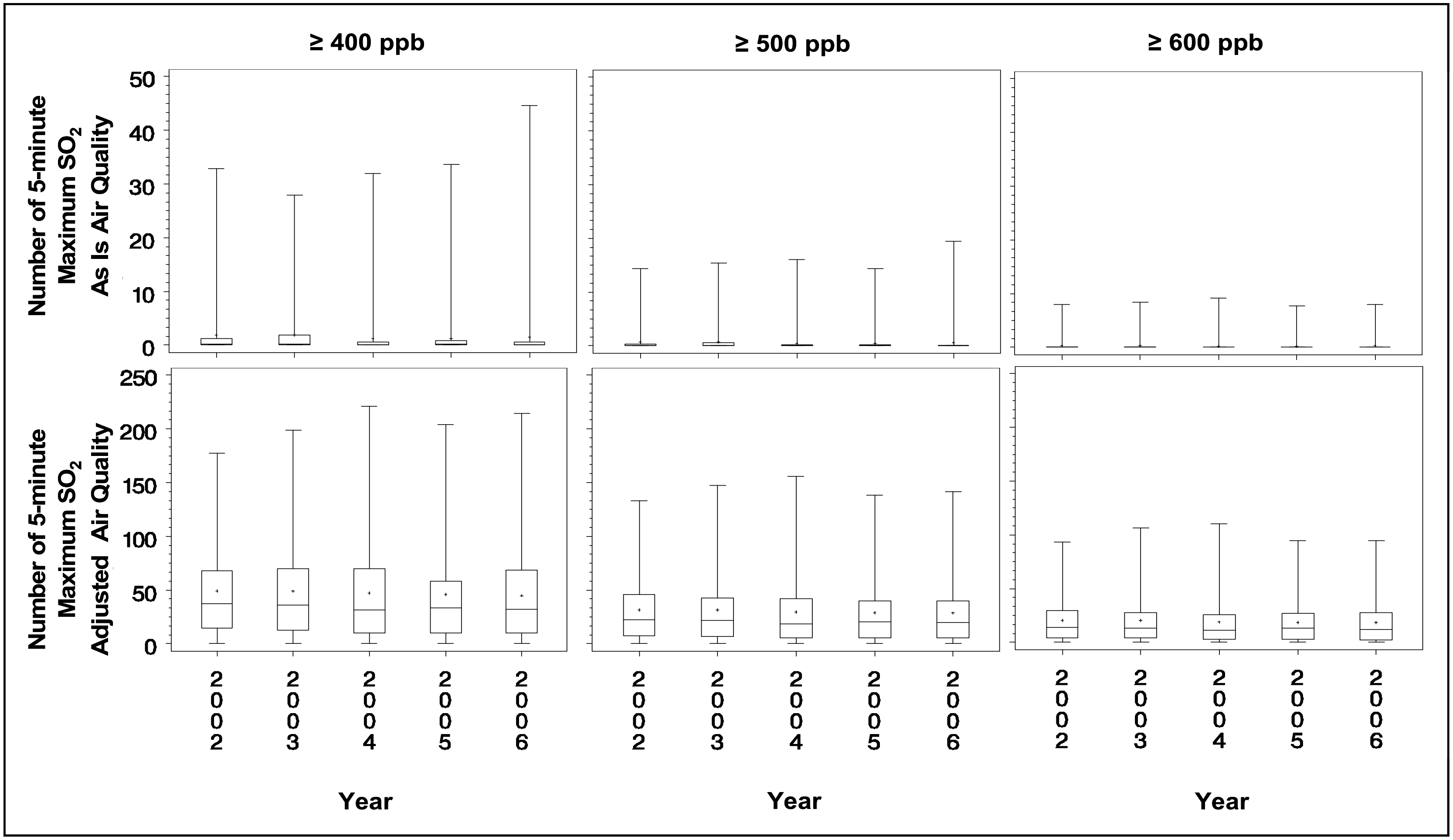

Figure 6-28. Number of modeled 5-minute maximum SO_2 concentrations above potential health effect benchmark levels at each monitor by year, Years 2002 through 2006 at 20 selected counties, with air quality as is and air quality adjusted to just meeting the current standards (either one exceedance of 0.14 ppm daily average or no exceedance of 0.03 ppm annual average).

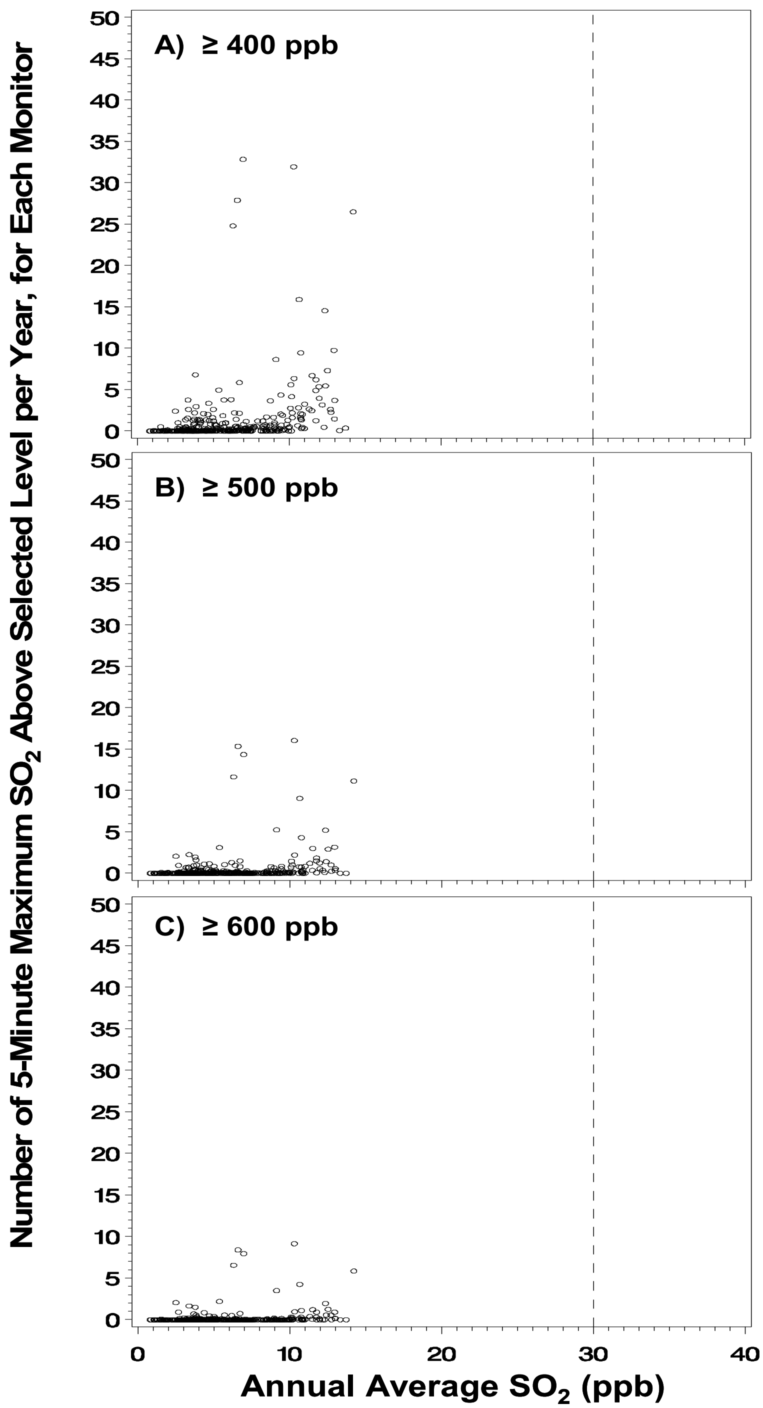

Figure 6-29. Comparison of the number of modeled 5-minute maximum SO_2 concentrations above potential health effect benchmark levels at each monitor per year and the associated annual average SO_2 concentration, Years 2002 through 2006 for 20 selected counties, air quality data as is. A) number of 5-minute maximums ≥400 ppb/year, B) number of 5-minute maximums ≥500 ppb/year, C) number of 5-minute maximums ≥600 ppb/year. The level of the annual average SO_2 NAAQS of 0.03 ppm is indicated by the dashed line.

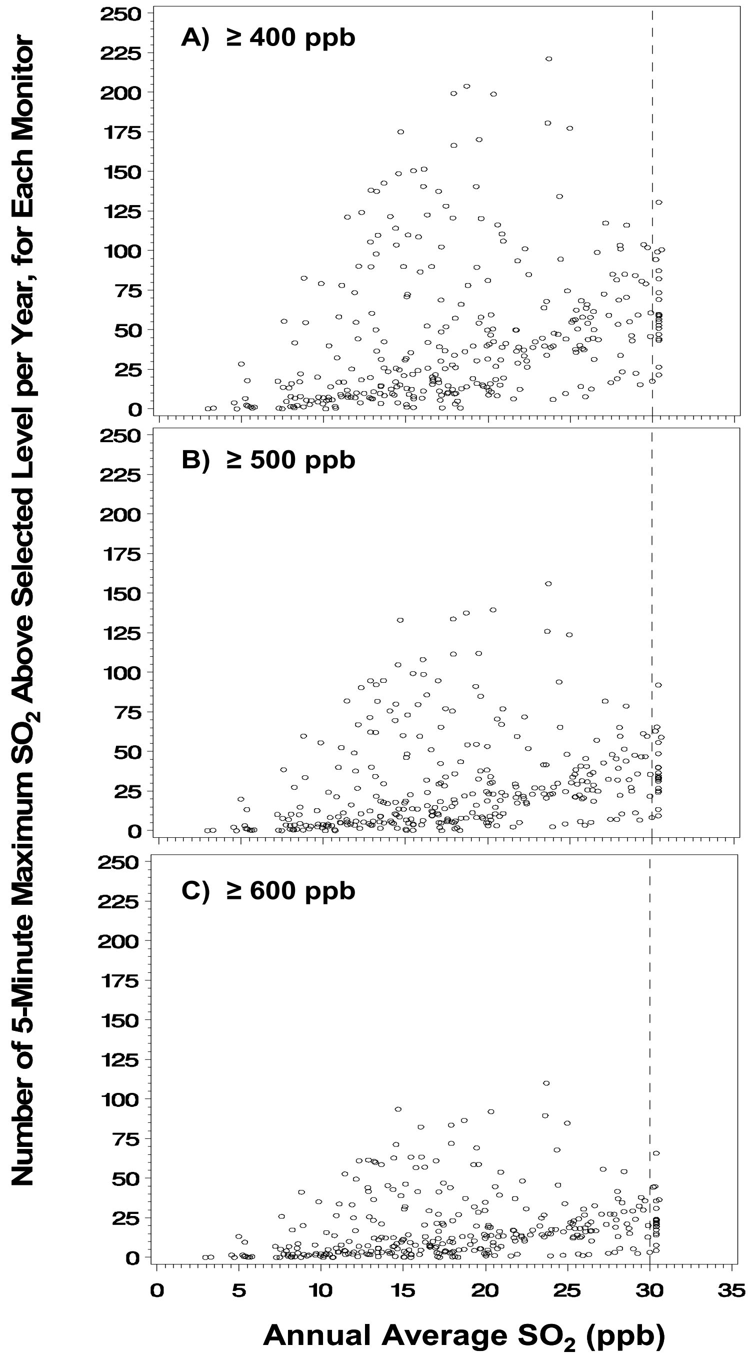

Figure 6-30. Comparison of the number of modeled 5-minute maximum SO_2 concentrations above potential health effect benchmark levels at each monitor per year and the associated annual average SO_2 concentration, Years 2002 through 2006 for 20 selected counties, air quality data adjusted to just meet the current standards (either one exceedance of 0.14 ppm daily average or no exceedance of 0.03 ppm annual average). A) number of 5-minute maximums ≥400 ppb/year, B) number of 5-minute maximums ≥500 ppb/year, C) number of 5-minute maximums ≥600 ppb/year. The level of the annual average SO_2 NAAQS of 0.03 ppm is indicated by the dashed line.

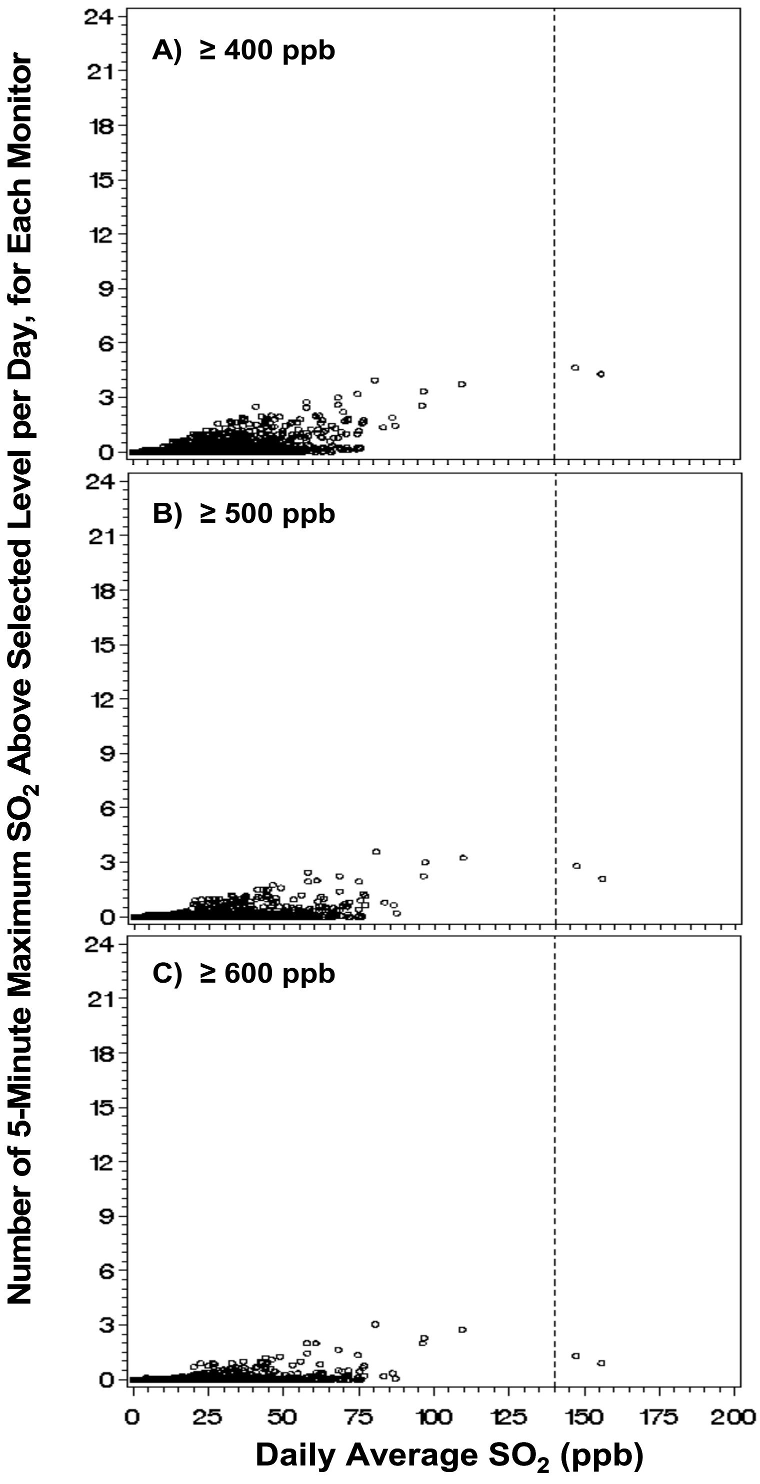

Figure 6-31. Comparison of the number of modeled 5-minute maximum SO_2 concentrations above potential health effect benchmark levels at each monitor per day and the associated daily average SO_2 concentration, Years 2002 through 2006 for 20 selected counties, air quality data as is. The level of the 24-hour SO_2 NAAQS of 0.14 ppm is indicated by the dashed line.

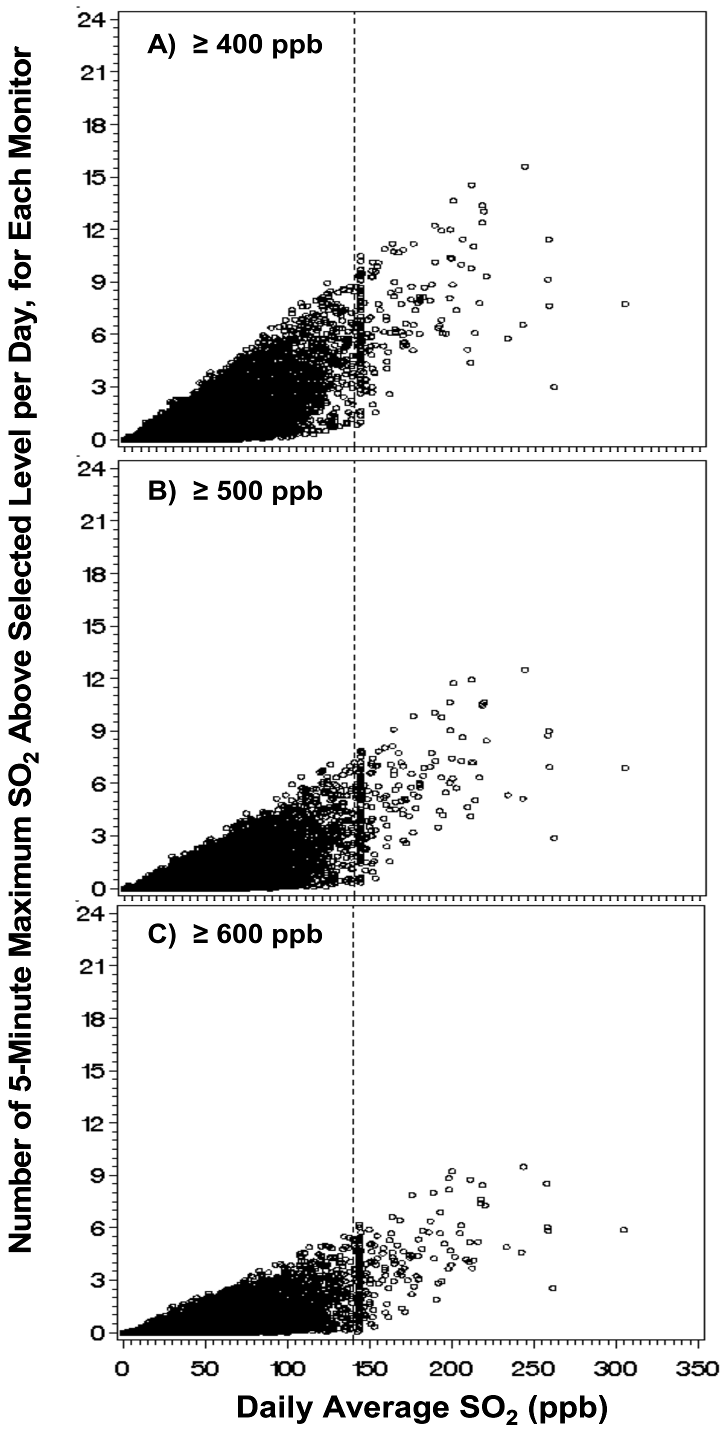

Figure 6-32. Comparison of the number of modeled 5-minute maximum SO_2 concentrations above potential health effect benchmark levels at each monitor per day and the associated daily average SO_2 concentration, Years 2002 through 2006 for 20 selected counties, air quality data adjusted to just meet the current standards (either one exceedance of 0.14 ppm daily average or no exceedance of 0.03 ppm annual average). The level of the 24-hour SO_2 NAAQS of 0.14 ppm is indicated by the dashed line.

Tables 6-11 through 6-14 summarizes the estimated number of 5-minute maximum SO_2 concentrations above the potential health effect benchmark levels in each of the twenty counties across the time period modeled (years 2002 through 2006). Descriptive statistics were estimated from the twenty model simulations for each of the two air quality scenarios and considering two SO_2 concentration averaging times (annual and daily means). Each county distribution presents the descriptive statistics for the twenty simulations using from all monitors in operation across the five year period of analysis. There was no additional weighting of the county-level data using monitor-years since nearly all monitors were in operation during 2002 through 2006. The concentration distributions present estimates of the central tendency (means and medians) and associated variability in the daily and annual average SO_2 concentrations within each county across years 2002-2006, as well as the extremes possible in any one year at a particular monitoring site (98^{th} and 99^{th} percentiles). The distributions for the estimated number of exceedances also represents the county similarly, with measures of central tendency applicable to the county on average and the upper percentiles representing the extreme number of exceedances possible in a year at a particular site within the county.

In considering the as is air quality in the selected counties using 1-hour SO_2 measurements, all individual monitoring sites contained annual average concentrations under 10 ppb, with few exceptions (Table 6-11). The upper percentiles of the distribution in the counties, based on a few to several monitors in operation and the years of monitoring available, indicate little deviation from the mean level at no more than a factor of two for most locations. The mean and median number of estimated exceedances of 400 ppb were similar to one another, each numbering less than five per year in 18 of the 20 counties, with half of the counties estimated to have no exceedances at most monitoring sites and years. As expected, both Jefferson and Iron counties in Missouri contained the highest estimated number of exceedances, averaging around thirty 5-minute maximum SO_2 per year above 400 ppb for each location. Estimated numbers of exceedances at the upper percentiles were less than 10 per year for 75% of the counties, with five counties estimated to contain between 10 and 40 estimated exceedances of 400 ppb per year. Also as expected, the number of exceedances of the higher potential health effect benchmark levels were less than that of the 400 ppb level, with most locations on average containing no exceedances of either the 500 ppb or 600 ppb benchmark level.

In considering SO_2 air quality adjusted to just meeting the current daily standard in the selected counties using 1-hour SO_2 measurements, annual average concentrations are increased by a factor of about 2 to 4 when compared with the as is air quality concentrations, with most locations containing estimated annual average concentrations between 15 and 30 ppb (Table 6-12). The upper percentiles of the distribution in the counties indicate little deviation from the mean level at no more than a factor of two for most locations. The mean number of estimated exceedances of 400 ppb tended to be greater than the median values, although 75% of the counties contained between 10 and 65 exceedances per year considering either metric. As expected, both Jefferson and Iron counties in Missouri contained the highest estimated mean number of exceedances, averaging around 140 5-minute maximum SO_2 per year above 400 ppb at either location. All counties contained more than 60 exceedances of 400 ppb in a year when considering the upper percentiles, with over one-half estimated to contain more than 100 exceedances, though 90% were below 200 exceedances per year. The number of estimated exceedances per year of the higher potential health effect benchmark levels of 500 ppb and 600 ppb were about 30% and 50% less, respectively when compared with the mean or median number of exceedances of the 400 ppb level. Similar percentages were observed when comparing the upper percentile estimates of the number of exceedances of 500 ppb and 600 ppb benchmark levels to the 400 ppb level (25% to 45% less, respectively).

The means for the daily average concentrations (Table 6-13) were similar to that reported for the annual averages (Table 6-11) when considering the as is air quality. Most counties had measured daily average concentrations of less than 10 ppb during 2002 through 2006. The upper percentiles for the daily average concentrations were about 3 to 5 times greater than the average concentrations, with 75% of sites within the range of 20 – 40 ppb. There were no estimated exceedances per day at each of the counties, regardless of the benchmark level or percentile, except for Iron and Jefferson counties in Missouri, and Beaver County, Pa. At most there were one to two estimated exceedances per day of 400 ppb concentration at these three counties. Consider however that this is an upper percentile daily estimate that likely occurred at one monitoring site on one day. While it is estimating the upper percentile for a given day, there may be additional days throughout the year at the same monitoring site or other monitoring sites in

Table 6-11. Summary of annual average SO_2 concentrations and estimated number of 5-minute maximum SO_2 concentrations above potential health effect benchmark levels per year in 20 counties using 20 model simulations, Years 2002 through 2006, air quality data as is.

		Annual Average SO_2 (ppb)					Estimated Number of 5-minute Maximum SO_2														
							≥ 400 ppb per Year					≥ 500 ppb per Year					≥ 600 ppb per Year				
State	County	mean	std	p50	p98	p99	mean	std	p50	p98	p99	mean	std	p50	p98	p99	mean	std	p50	p98	p99
DE	New Castle	5	1	5	8	8	0	1	0	3	4	0	0	0	1	2	0	0	0	0	1
FL	Hillsborough	3	1	3	7	7	0	1	0	3	3	0	0	0	1	1	0	0	0	1	1
IA	Linn	3	1	3	5	5	1	2	0	8	9	0	1	0	2	3	0	0	0	2	2
IA	Muscatine	4	1	4	7	7	1	2	0	6	9	0	1	0	3	3	0	0	0	2	2
IL	Madison	4	1	4	6	6	0	1	0	3	3	0	0	0	1	1	0	0	0	0	1
IN	Floyd	5	1	5	8	8	1	2	1	6	7	1	1	0	4	4	0	1	0	2	3
MI	Wayne	4	1	4	6	6	0	1	0	2	2	0	0	0	1	1	0	0	0	0	1
MO	Greene	2	1	2	3	3	0	0	0	1	1	0	0	0	0	1	0	0	0	0	1
MO	Iron	7	0	7	7	7	29	5	28	39	43	14	3	14	19	19	8	2	8	12	12
MO	Jefferson	10	0	10	10	10	32	6	32	44	44	16	4	17	22	22	9	2	9	13	13
OH	Cuyahoga	5	1	5	7	7	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0
OK	Tulsa	6	1	6	7	7	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0
PA	Allegheny	8	2	8	13	13	1	2	0	9	11	0	1	0	3	4	0	0	0	1	1
PA	Beaver	9	2	9	14	14	5	7	3	30	33	2	3	1	13	14	1	2	0	7	8
PA	Northampton	7	3	7	13	13	2	5	0	19	20	1	3	0	11	12	0	1	0	6	6
PA	Washington	8	1	9	10	10	0	0	0	1	2	0	0	0	1	1	0	0	0	0	0
TN	Shelby	4	1	4	6	6	0	1	0	2	3	0	0	0	1	2	0	0	0	1	2
TX	Jefferson	3	1	3	4	4	1	1	0	5	6	1	1	0	3	3	0	1	0	2	3
WV	Hancock	11	2	11	14	14	2	3	2	12	16	1	1	0	4	6	0	0	0	2	3
WV	Wayne	8	1	8	10	10	0	1	0	3	4	0	0	0	1	1	0	0	0	0	0

Table 6-12. Summary of annual average SO_2 concentrations and estimated number of 5-minute maximum SO_2 concentrations above potential health effect benchmark levels per year in 20 counties using 20 model simulations, Years 2002 through 2006, air quality data adjusted to just meeting the current standards (either one exceedance of 0.14 ppm daily average or no exceedance of 0.03 ppm annual average).

		Annual Average SO_2 (ppb)					Estimated Number of 5-minute Maximum SO_2														
							≥ 400 ppb per Year					≥ 500 ppb per Year					≥ 600 ppb per Year				
State	County	mean	std	p50	p98	p99	mean	std	p50	p98	p99	mean	std	p50	p98	p99	mean	std	p50	p98	p99
DE	New Castle	13	4	13	22	22	23	28	9	96	101	14	18	5	62	67	9	12	3	40	42
FL	Hillsborough	11	4	10	20	20	33	37	16	125	130	22	27	10	91	95	15	19	6	63	65
IA	Linn	11	4	13	18	18	85	58	97	170	173	56	39	64	116	119	36	26	40	77	79
IA	Muscatine	14	4	14	20	20	75	80	26	212	215	50	55	18	150	152	32	35	12	99	104
IL	Madison	16	4	16	24	24	47	38	39	137	139	32	28	23	95	98	21	20	14	70	73
IN	Floyd	22	5	24	30	30	101	63	86	229	230	70	45	59	161	163	48	32	41	114	116
MI	Wayne	14	4	14	21	21	40	35	26	116	121	24	21	15	72	75	14	13	9	42	44
MO	Greene	11	4	11	18	18	48	56	19	149	155	31	37	13	107	111	20	23	8	71	75
MO	Iron	15	1	15	16	16	142	28	142	184	189	108	22	109	144	147	79	15	80	102	107
MO	Jefferson	19	0	19	19	19	141	7	142	153	153	91	6	91	101	101	59	6	58	69	69
OH	Cuyahoga	21	6	21	30	30	38	21	38	82	84	23	13	22	50	53	15	9	14	33	36
OK	Tulsa	24	4	24	30	30	52	22	48	94	98	30	13	28	56	60	20	9	18	41	42
PA	Allegheny	20	5	19	31	31	26	31	11	108	112	15	19	6	63	66	9	12	3	41	43
PA	Beaver	21	5	20	30	30	47	36	34	122	126	30	26	20	84	88	20	18	12	59	61
PA	Northampton	22	10	28	30	30	23	21	15	61	66	13	13	8	38	39	8	9	4	27	29
PA	Washington	27	4	28	30	30	30	20	21	72	76	16	13	9	44	45	9	9	4	28	30
TN	Shelby	19	4	18	26	26	28	21	31	67	69	18	13	19	41	43	11	9	12	27	30
TX	Jefferson	13	4	12	21	21	63	30	59	118	123	42	21	41	83	84	28	15	27	64	66
WV	Hancock	25	4	25	30	30	53	24	49	113	121	31	16	28	74	81	19	10	17	51	55
WV	Wayne	24	5	26	30	30	31	22	29	73	78	18	14	17	47	50	11	9	9	32	33

Table 6-13. Summary of daily average SO_2 concentrations and estimated number of 5-minute maximum SO_2 concentrations above potential health effect benchmark levels per day in 20 counties using 20 model simulations, Years 2002 through 2006, air quality data as is.

		Daily Average SO_2 (ppb)					Estimated Number of 5-minute Maximum SO_2														
							≥ 400 ppb per Day					≥ 500 ppb per Day					≥ 600 ppb per Day				
State	County	mean	std	p50	p98	p99	mean	std	p50	p98	p99	mean	std	p50	p98	p99	mean	std	p50	p98	p99
DE	New Castle	5	5	4	19	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FL	Hillsborough	3	3	2	12	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IA	Linn	3	5	1	19	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IA	Muscatine	4	5	3	22	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IL	Madison	4	5	3	18	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IN	Floyd	5	5	4	21	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MI	Wayne	5	6	3	22	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MO	Greene	2	3	2	12	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MO	Iron	6	9	3	36	45	0	0	0	1	2	0	0	0	1	1	0	0	0	0	1
MO	Jefferson	9	11	5	43	56	0	0	0	1	2	0	0	0	1	1	0	0	0	0	1
OH	Cuyahoga	5	4	4	17	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OK	Tulsa	6	6	4	21	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PA	Allegheny	8	6	7	26	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PA	Beaver	9	8	7	33	40	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
PA	Northampton	7	7	6	22	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PA	Washington	8	5	7	23	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TN	Shelby	4	3	3	13	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TX	Jefferson	3	5	1	17	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WV	Hancock	11	8	9	32	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WV	Wayne	8	6	7	22	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6-14. Summary of daily average SO_2 concentrations and estimated number of 5-minute maximum SO_2 concentrations above potential health effect benchmark levels per day in 20 counties using 20 model simulations, Years 2002 through 2006, air quality data adjusted to just meeting the current standards (either one exceedance of 0.14 ppm daily average or no exceedance of 0.03 ppm annual average).

		Daily Average SO_2 (ppb)					Estimated Number of 5-minute Maximum SO_2														
							≥ 400 ppb per Day					≥ 500 ppb per Day					≥ 600 ppb per Day				
State	County	mean	std	p50	p98	p99	mean	std	p50	p98	p99	mean	std	p50	p98	p99	mean	std	p50	p98	p99
DE	New Castle	13	14	10	52	66	0	0	0	1	2	0	0	0	1	1	0	0	0	0	1
FL	Hillsborough	11	12	7	42	53	0	1	0	1	2	0	0	0	1	2	0	0	0	1	1
IA	Linn	11	18	5	70	94	0	1	0	4	5	0	1	0	2	4	0	1	0	2	3
IA	Muscatine	14	18	9	71	96	0	1	0	3	5	0	1	0	2	4	0	0	0	2	3
IL	Madison	16	17	11	70	94	0	1	0	2	3	0	0	0	1	2	0	0	0	1	2
IN	Floyd	22	22	16	88	106	0	1	0	3	4	0	1	0	3	3	0	1	0	2	3
MI	Wayne	14	18	8	69	86	0	1	0	2	3	0	0	0	1	2	0	0	0	1	1
MO	Greene	11	14	8	54	78	0	1	0	2	4	0	1	0	2	3	0	0	0	1	2
MO	Iron	20	26	8	104	122	1	1	0	5	7	0	1	0	4	5	0	1	0	3	4
MO	Jefferson	23	25	15	102	125	1	1	0	5	6	0	1	0	4	5	0	1	0	3	4
OH	Cuyahoga	21	19	16	73	88	0	0	0	1	2	0	0	0	1	1	0	0	0	1	1
OK	Tulsa	24	24	15	91	103	0	1	0	2	2	0	0	0	1	2	0	0	0	1	1
PA	Allegheny	20	16	17	65	80	0	0	0	1	2	0	0	0	1	1	0	0	0	1	1
PA	Beaver	21	19	16	74	91	0	1	0	2	2	0	0	0	1	2	0	0	0	1	1
PA	Northampton	22	20	16	78	95	0	0	0	1	1	0	0	0	1	1	0	0	0	0	1
PA	Washington	27	17	24	74	87	0	0	0	1	2	0	0	0	1	1	0	0	0	1	1
TN	Shelby	18	15	14	58	77	0	0	0	1	2	0	0	0	1	1	0	0	0	0	1
TX	Jefferson	13	21	5	80	106	0	1	0	2	3	0	1	0	2	3	0	0	0	1	2
WV	Hancock	25	18	21	74	85	0	1	0	2	2	0	0	0	1	2	0	0	0	1	1
WV	Wayne	24	18	20	71	94	0	0	0	1	2	0	0	0	1	1	0	0	0	1	1

the particular county with similar values (i.e., one or two). For example, in comparing this Table 6-13 with Table 6-11, there were about 40 estimated exceedances of 400 ppb per year in Jefferson County, Mo., indicating that there were approximately 20 to 30 days where the number of daily exceedances was between 1 and 2.

When SO_2 concentrations were adjusted to just meeting the current standards, there were few estimated exceedances of any of the 5-minute benchmark levels per day. Only Iron and Jefferson counties in Missouri contained a mean estimate greater than zero (1/day for the 400 ppb and 500 ppb), though all location were estimated to have no exceedances per day when considering the median value. Just under half of the locations contained 1 – 2 exceedances of 400 ppb per day when considering the upper percentiles of the daily estimates, though Iron and Jefferson counties were estimated to have as many as 6 or 7 exceedances per day. The estimated number of 5-minute maximum above 500 ppb or 600 ppb were less frequent, with an increasing number of counties with at most 1 – 2 estimated exceedances per day with increasing benchmark level.

6.5 UNCERTAINTY ANALYSIS

This uncertainty analysis identifies the sources of the assessment that do or do not reduce the certainty in the risk and exposure results, and provide a rationale for why this is the case. The analysis is primarily qualitative, however incorporates several of the quantitative elements introduced through the statistical model evaluation performed earlier.

6.5.1 Air Quality Data

One basic assumption is that the AQS SO_2 air quality data used are quality assured already. Reported concentrations contain only valid measures, since values with quality limitations are either removed or flagged. There is likely no selective bias in retention of data that is not of reasonable quality, it is assumed that selection of high concentration poor quality data would be just as likely as low concentration data of poor quality. Given the numbers of measurements used for this analysis, it is likely that even if a few low quality data are present in the data set, they would not have a substantial effect on the results presented here. In addition, a quantitative analysis of available simultaneous measures in Appendix A indicated little to no bias in measured concentrations. Therefore, the air quality data measurements database used likely do not have a negative impact on the generated results.

Temporally, some of the ambient monitoring data used in this analysis contained both 5-minute maximum and 1-hour measurements and appropriately accounted for variability in concentrations that are commonly observed for SO_2, and by the selection criteria used herein, were representative of either a valid day or year. In addition, having more than one monitor accounted for some of the spatial variability in selected counties. However, the degree of representation of the monitoring data used in this analysis can be evaluated from several perspectives, one of which is how well the temporal and spatial variability are represented. In particular, missing 5-minute maximum or hourly measurements at a monitor may introduce bias (if different periods within a day, month or a year have different numbers of measured values) and reduce certainty in the estimations. Furthermore, the spatial representativeness will be poor if the monitoring network is not dense enough to resolve the spatial variability (reducing certainty) or if the monitors are not evenly distributed (causing a bias). The uncertainty regarding temporal and spatial representation by the monitors is expanded below.

6.5.2 Measurement Technique for Ambient SO_2

The draft ISA notes various positive and negative sources of interference that could reduce certainty in the measurement of SO_2 (draft ISA, sections 2.3.1 and 2.3.2). Many of the identified sources (e.g., polycyclic aromatic hydrocarbons, stray light, collisional quenching) have limited impact to SO_2 measurement due to the presence of instrument controls that prevent the interference. The actual impact on any individual monitor is unknown, i.e., the presence of negative and positive interferences has not been quantitated. Therefore, reported ambient monitoring concentrations could be either over- or under-estimated, but is likely minimally due to instrument controls.

6.5.3 Temporal Representation

Data are valid 5-minute and 1-hour average measures and are of the same temporal scale as identified health effect benchmarks. There are frequent missing values within a given valid year that may reduce the degree of certainty in concentration distributions and model estimations, however given the level of the benchmark concentrations and the low frequency of exceedances, it is likely of negligible consequence. Bias may be introduced if some seasons, day-types (e.g., weekday/weekend), or times of the day (e.g., nighttime or daytime) are not equally represented. Since 75 percent days/year and hours/day completeness rules were applied for some of the analyses, these potential biases are likely to have been removed. Data were not interpolated in the analysis; missing data were not substituted with estimated values, concentrations reported as zero were used as is. Since the concentrations of interest here are those orders of magnitude above the detection limits, there is a negligible effect on certainty in the analyses from not estimating these extremely low concentrations.

There may be bias and added uncertainty if the years monitored vary significantly between locations and the two monitor averaging times. Monitoring sites across the U.S. have changed over time, with a trend of decreasing number of monitors most evident for those measuring the 5-minute maximum SO_2. The 5-minute monitoring has been performed less frequently than the hourly monitoring, generally only a few years of data exist per 5-minute monitor. Due to the limited number of measurements, all the available 5-minute maximum data were used in developing the statistical relationships and for model evaluation without meeting the completeness criteria. In addition, the use of the older ambient monitoring data in some of the analyses here carries the assumption that the sources present at that time are the same as current sources, potentially reducing certainty if this is not the case. However, the variability in monitoring concentrations (both the 1-hour and 5-minute maximum SO_2) did not have a significant relationship with monitoring year (i.e., years 1997 though 2007) and contained a comparable range between the two monitor averaging times. Therefore, any negative impact to certainty is expected to be minimal regarding both bias direction and magnitude for analyses performed using each of these data sets across multiple years.

6.5.4 Spatial Representation

Relative to the physical area, there are only a limited number of monitors in each location, particularly when considering the number of monitors that measured 5-minute maximum SO2. When considering ambient monitoring at the county level, data were assumed to be spatially representative of those particular locations analyzed here. This includes areas between the ambient monitors that may or may not be influenced by similar local sources of SO_2. For these reasons, the potential bias at spatial networks with limited numbers of monitors may be large, although the monitoring network design should have addressed these issues within the available resources and other monitoring constraints. Portions of the air quality characterization used all monitors meeting the 75 percent completeness criteria, without taking into account the monitoring objectives or land use for the monitors. Thus, there may be lack of spatial representation and contribution to uncertainty due to either the inclusion or exclusion of monitors that are near local source emissions of SO_2.

In comparing the emission sources in close proximity to the 5-minute maximum or 1-hour monitors, similar distributions in the types of sources impacting both were observed. This indicates that the relationships derived from the 5-minute measurement data and how they were applied to the 1-hour monitoring likely do not reduce certainty when considering the monitoring data wholly. At any individual monitor there may be very different source types, each at variable proportions influencing the SO_2 concentrations measured at the monitor. This may reduce certainty in estimates at individual monitors, however the method of applying both concentration level and variability measures to each hourly concentration at each monitor should have controlled for some of the variability anticipated by differing source types.

6.5.5 Air Quality Adjustment Procedure

The empirical method used to estimate exceedances under the current-standard scenario may or may not represent the true relationship between the daily or annual mean concentrations over a calendar year and the number of exceedances. The empirical method assumes that if the daily means change then all the hourly concentrations will change proportionately. Universal application of the proportional simulation approach at each of the selected counties was done for consistency and was designed to preserve the inherent variability in the concentration profile. However, different sources may have different temporal emission profiles, so that applied changes to the daily mean concentrations at monitors may not correspond well to all parts of the concentration distribution equally. Similarly, emissions changes that affect the concentrations at the monitoring site with the 2nd highest daily mean concentration will not necessarily impact lower concentration sites proportionately. This could result in overestimations in the number of exceedances at monitors recording lower 1-hour SO_2 concentrations within a selected county.

6.5.6 Ambient Monitor to Exposure Representation

Human exposure is characterized by contact of a pollutant with a person, and as such, the air quality characterization contains the broad assumption that the monitoring concentrations can serve as a surrogate for exposure. The ISA reports that personal exposure measurements are of limited use since ambient concentrations are typically below the detection limit of the personal samplers. There is no method to quantitatively assess the relationship between 5-minute ambient monitoring data and 5-minute personal exposures, particularly since personal exposures are time-averaged over hours or days, and never by 5-minute averages. Therefore the relationship of 5-minute maximum personal exposure concentrations (i.e., attributed to ambient) to 5-minute maximum ambient is unknown and thus may add to uncertainty. An evaluation in the ISA indicates the relationship between longer-term averaged ambient monitoring concentrations and personal exposures is reasonably strong, particularly when ambient concentrations are above detection limits. The strength of the relationship between personal and ambient concentrations is supported further by the limited presence of indoor sources, much of an individuals' personal exposure is of ambient origin. However, personal exposure concentrations are reportedly a small fraction of ambient concentrations. This is because local outdoor SO_2 concentrations are typically ½ of the ambient monitoring concentrations, and indoor concentrations about ½ of the local outdoor concentrations. Therefore, while the relationship between personal exposures and ambient is strong, the use of monitoring data as a surrogate for exposure would likely lead to an overestimate in the number of peak concentrations those individuals might encounter.

6.5.7 Statistical Model

A criterion was developed to select data from the data sets containing the measured 5-minute maximum and 1-hour SO_2 concentrations. The generation of peak to mean ratios of <1 imply the 5-minute peak is less than the 1-hour average, a physical impossibility, and values >12 are a mathematical impossibility. Data were screened for values outside of these bounds, increasing confidence in the PMRs used for development of the statistical model. The use of all screened 5-minute maximum SO_2 data (1997 to 2007) in developing PMR CDFs still carries an assumption that the source emissions present at that time of measurement are similar to recent source emissions, possibly reducing the degree of certainty in results generated in areas where source emissions have changed. However, as noted with the concentration variability, PMRs do not have any apparent trend with monitoring year and have averaged around 1.6 (Figure 6-33). This indicates that the use of older monitoring data may have a negligible impact on model estimates.

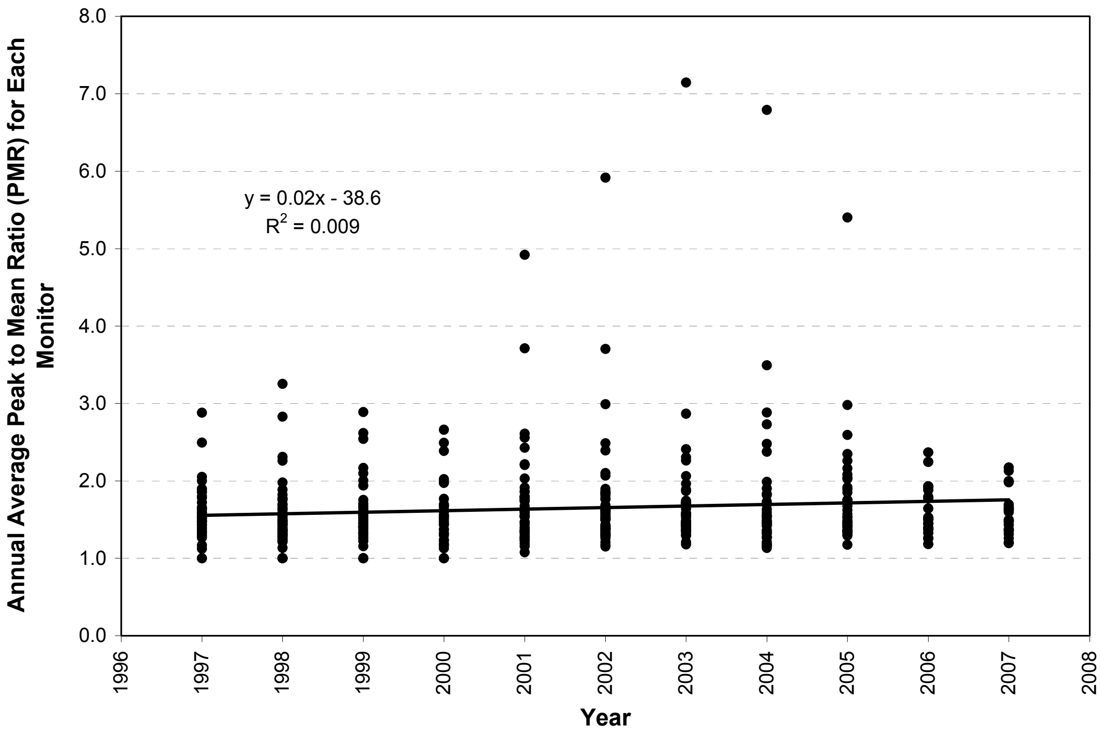

Figure 6-33. Annual average peak to mean ratio (PMR) for each monitor measuring 5-minute maximum and 1-hour SO_2 concentrations, Years 1997 through 2006.

The accuracy in the number of estimated 5-minute maximum concentrations above 400 ppb was evaluated using the measured 5-minute maximum SO_2. The results indicate that on average, the statistical model performed well in generating reasonable estimates of short-term peak concentrations (section 6.2.3.6). However, a few results from this comparison indicate numbers of 5-minute maximum concentrations above 400 ppb could be either over- or under-estimated, under certain conditions. The greatest number of maximum concentrations observed above 400 ppb at one monitor was consistently underestimated by a factor of about two. This could imply that the number of modeled 5-minute maximum concentrations that are beyond an apparent linear upper bound (i.e., approximately 300 per monitor) may be underestimated by approximately a factor of two. In addition, there were a few sites without any measured 5-minute maximum concentrations above 400 ppb, although the statistical model estimated several to just over a hundred per monitor. This could imply that some monitors have overestimations in the number of 5-minute maximum concentrations. Neither situation appeared directly related to source type, with additional monitors sited in the same area impacted by similar source types containing reasonable model estimates. Again, when considering individual monitors, there may be limits to the certainty in the number of estimated exceedances, however in evaluating results for all of the monitors, the uncertainty in the estimation is likely less.

Reproducibility in the estimates was determined by performing multiple model simulations. Across the first 10 model runs, the relative absolute difference between the single simulation estimates and those from the total simulation remained within +/- 15 percent, leading to very stable estimates (+/- 1%) at around 15 model simulations (section 6.2.3.6). For the sake of modeling efficiency, a limit of twenty simulations was determined sufficient to generate stable model estimations. Ninety-five percent prediction intervals (PI95) were generated for each monitor in the twenty counties selected for detailed analysis, using the 20 model simulations for each air quality scenario and for each potential health effect benchmark level. The percentile distributions of the twenty simulations were calculated for the number of estimated exceedances at each monitor that were summed by year, with the 2.5th, 50th, and 97.5th percentile values retained. These median peak values were ranked and used to generate a CDF for illustration. The 2.5th and 97.5th percentile provide a 95% interval (i.e., 97.5-2.5=95) about the median estimate. Figure 6-34 presents the results of this analysis for the number of exceedances per year at monitors in the selected counties when using as is air quality data. As noted earlier, nearly 70% of the monitor site-years did not have any estimated exceedances of the lowest potential health effect benchmark level of 400 ppb. When a small number of exceedances of 400 ppb were estimated (e.g., 5 or less in a year), the 95% prediction interval tended to include an estimate of zero, suggesting that when a monitor contains this few estimated mean or median number of exceedances, the certainty in the prediction may be limited. At numbers of exceedances of 400 ppb in a year greater than 10, the 95% prediction interval tended to exclude a value of zero, indicating greater certainty about the estimated mean or median number of exceedances. This is best illustrated in Figure 6-35 where the same procedure was applied to the results using the air quality adjusted to just meeting the current standards. The PI95 spans about 15 and is consistent across a wide range of estimated number of potential health effect benchmark exceedances and for each level, indicating little bias in the estimation procedure at any individual monitor. The procedure was also applied to each monitor, where numbers of exceedances were summed by day. It was a rare event where the daily number of estimated exceedances were greater than zero, particularly for the as is air quality. Only 212 site-days out of a total of 124,207 contained a median estimated number of exceedances of 400 ppb greater than one, with all of these estimated exceedances at four or less per day. These data were not used to develop PI95 due to the sample size limitations. About 5.5% of the air quality adjusted to just meeting the current standard contained median number of exceedances of 400 ppb greater than one, all of which were 15 exceedances or less per day (Figure 6-36). With prediction intervals spanning around 10, the estimated number of exceedances of 400 ppb on a given day may be less certain for most site-days, in particular where the number of exceedances is less than five.

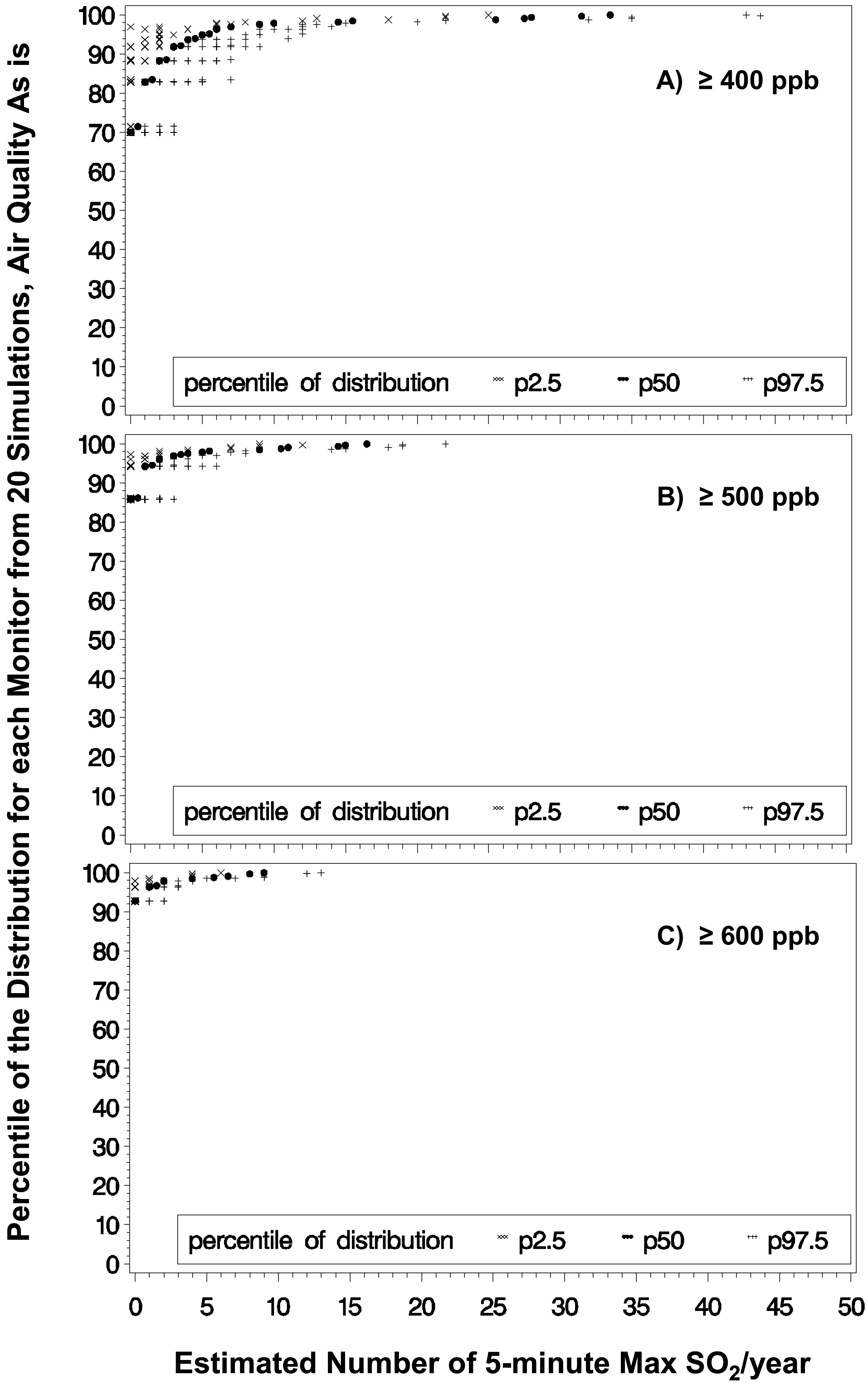

Figure 6-34. 95% prediction intervals for estimated number of 5-minute maximum SO_2 concentrations in a year above potential health effect benchmark levels at each monitor, Years 2002 through 2006 for 20 selected counties, air quality data as is.

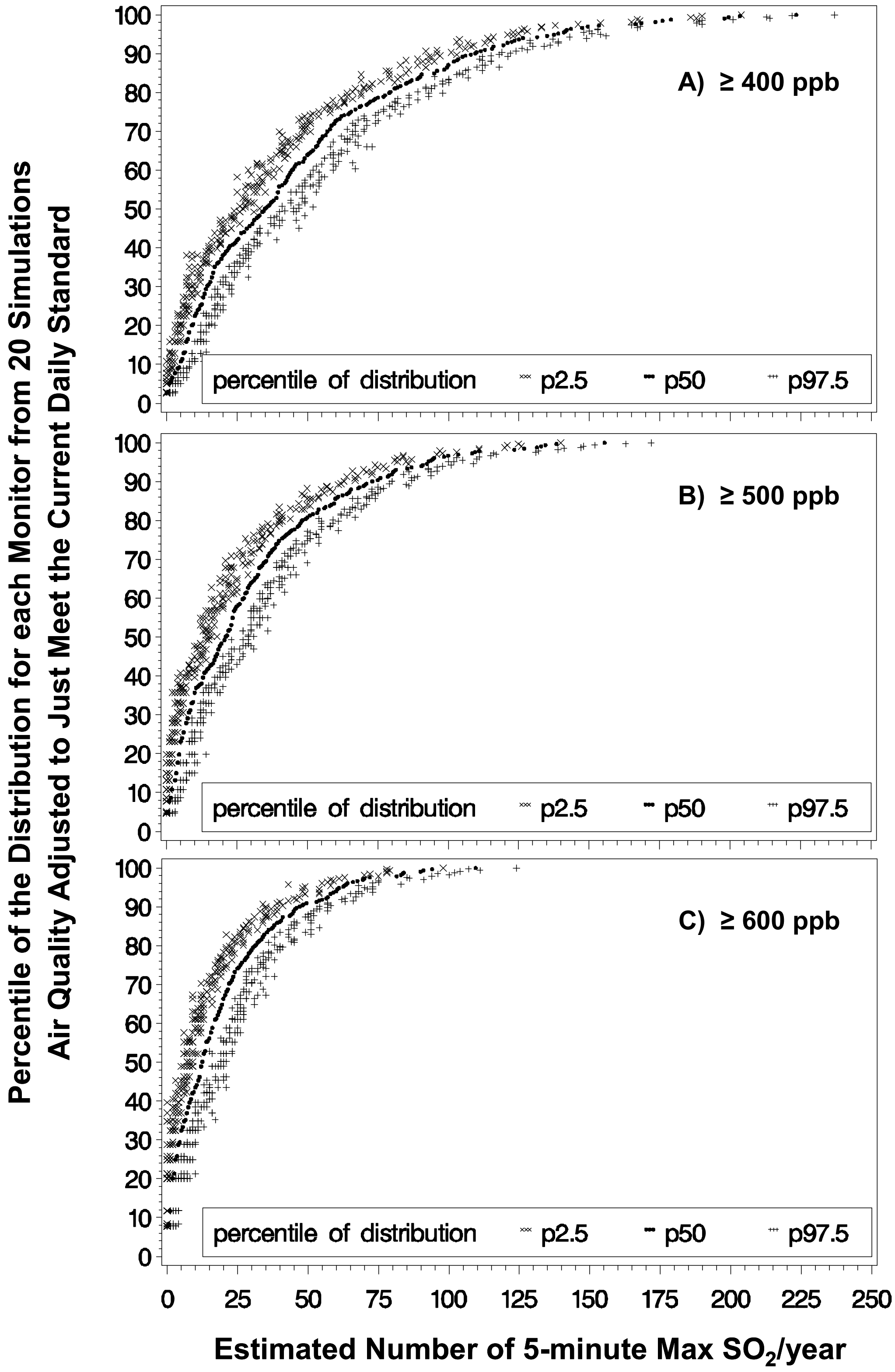

Figure 6-35. 95% prediction intervals for estimated number of 5-minute maximum SO_2 concentrations in a year above potential health effect benchmark levels at each monitor, Years 2002 through 2006 for 20 selected counties, air quality data adjusted to just meeting the current standards (either one exceedance of 0.14 ppm daily average or no exceedance of 0.03 ppm annual average).

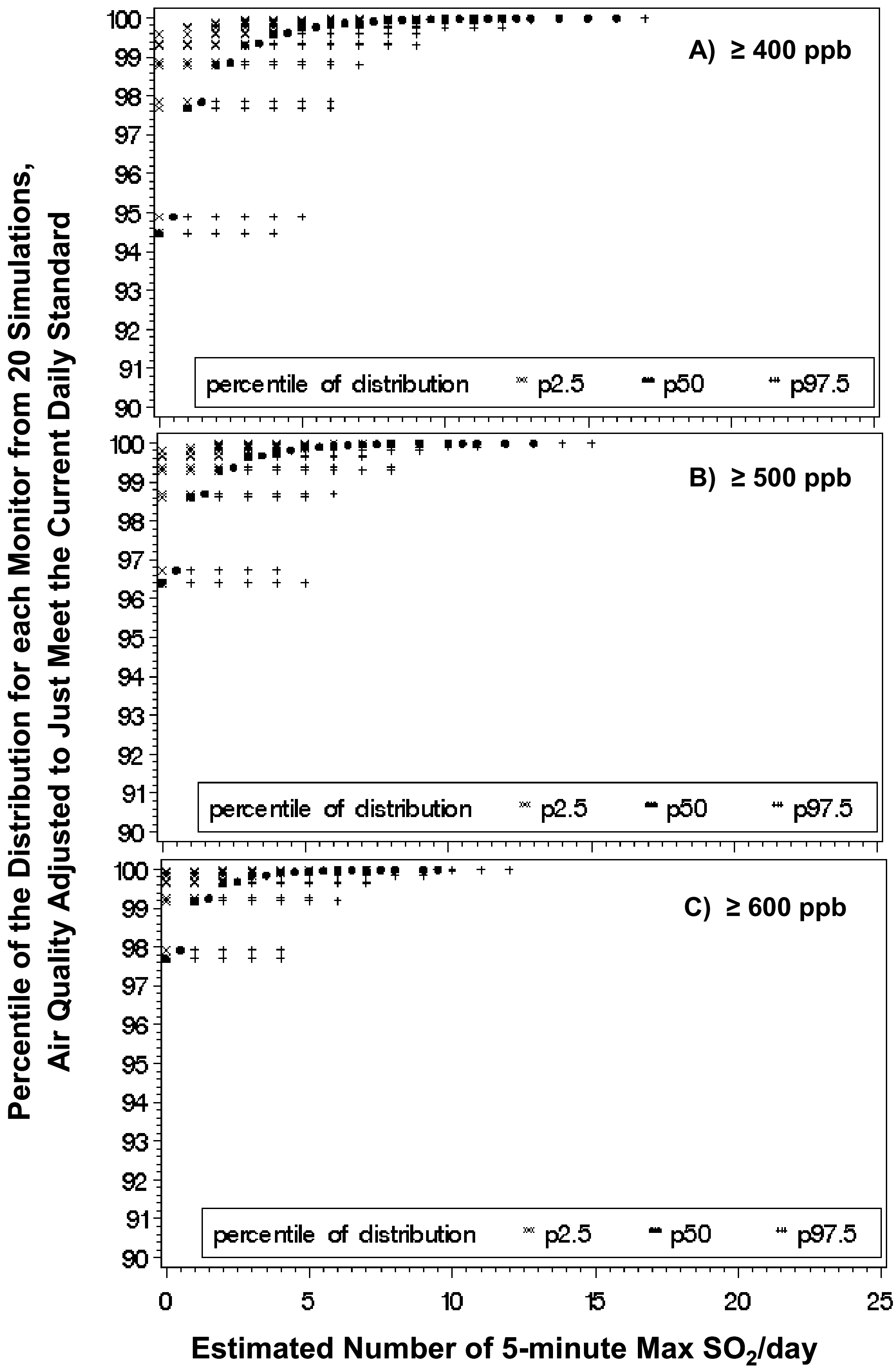

Figure 6-36. 95% prediction intervals for estimated number of 5-minute maximum SO_2 concentrations per day above potential health effect benchmark levels at each monitor, Years 2002 through 2006 for 20 selected counties, air quality data adjusted to just meeting the current standards (either one exceedance of 0.14 ppm daily average or no exceedance of 0.03 ppm annual average).

6.5.8 Single vs. Multiple Short-Term Peak Concentrations

The model estimates the frequency of a single exceedance of a potential health effect benchmark in one hour. However, multiple short-term peak concentrations above selected levels are possible in any hour. Analysis of the 5-minute continuous monitoring data indicates that multiple occurrences of concentrations above the 400, 500, and 600 ppb within the same hour are common. Using continuous monitoring data obtained from years 1997-2006, multiple peak concentrations (i.e., 2 or more) at or above 600 ppb within the same hour occurred with a 35% frequency (Table 6-15). The frequency in multiple exceedances was greater for the lower 5-minute SO_2 concentration levels, where 44% of the time a single exceedance of 500 ppb was observed, there were two or more exceedances within the same hour. Forty-one of the 66 hourly periods with a 5-minute concentration at or above 400 ppb had more than one exceedance within that same hour (or 62% of the time).

These results suggest that a single peak approach for estimating the 5-minute maximum SO_2 concentrations alone as a surrogate for exposure may lead to an underestimate in the number of potential exposure events. However, there would be added uncertainty in the extrapolation of these results since the continuous monitoring data were only from 16 source-oriented monitors, each with a limited number of monitoring years.

Table 6-15. Number of multiple exceedances of potential health effect benchmark levels within an hour.

Number of Exceedances of 5-minute SO_2 in 1-hour	Number of Hours with Multiple 5-minute SO_2		
	≥ 600 ppb	≥ 500 ppb	≥ 400 ppb
12	0	0	0
11	0	0	0
10	0	0	1
9	0	1	1
8	1	1	1
7	0	0	1
6	0	0	1
5	1	0	4
4	0	2	5
3	2	6	7
2	4	7	20
1	15	22	25
Total	**23**	**39**	**66**

6.5.9 Health Benchmark

The choice of potential health effect benchmarks, and the use of those benchmarks to assess risks, can reduce the level of certainty in the risk assessment results. For example, the potential health effect benchmarks used were from studies where volunteers were exposed to SO_2 for varying lengths of time. Typically, the SO_2 exposure durations were between 5 and 10 minutes. This may limit some certainty into the characterization of risk, which compared the potential health effect benchmarks to estimates of exposure over a 5-minute time period. Use of a 5-minute averaging time could over- or under-estimate risks. In addition, the human exposure studies evaluated airways responsiveness in asthmatics. For ethical reasons, more severely affected asthmatics and asthmatic children were not included in these studies. Severe asthmatics and/or asthmatic children may be more susceptible than mildly asthmatic adults to the effects of SO_2 exposure. Therefore, the potential health effect benchmarks based on these studies could underestimate risks in populations with greater susceptibility.

7.0 EXPOSURE ANALYSIS

7.1 OVERVIEW

This section documents the methodology and data used in the inhalation exposure assessment and associated health risk characterization for SO_2 conducted in support of the current review of the SO_2 primary NAAQS. Two important components of the analysis include the approach for estimating temporally and spatially variable SO_2 concentrations and simulating human contact with these pollutant concentrations. Both air quality and exposure modeling approaches have been used to generate estimates of 5-minute maximum, 24-hour and annual average SO_2 exposures within selected areas of the U.S. for year 2002. Exposures were characterized considering recent air quality conditions (*as is*) and for air quality adjusted to just meet the current SO_2 standards in selected locations. Briefly, the discussion in this chapter includes the following:

- description of the inhalation exposure model and associated input data,
- evaluation of estimated SO_2 exposures,
- assessment of the quality and limitations of the input data for supporting the goals of the SO_2 NAAQS exposure and risk characterization.

A combined dispersion modeling and exposure modeling approach was used to simulate personal exposures of individuals residing in close proximity to important SO_2 emission sources. Person-based exposure profiles were generated for a given population under direct impact from these local sources of SO_2, focused on the number of 5-minutes daily peak exposure events in an entire year. This combined dispersion and exposure modeling approach was both time and labor intensive. To date, only the exposure results and the risk characterization comparing exposures against several potential health effect benchmarks for areas within the state of Missouri are complete and are presented in this draft document. As discussed in Chapter 8, the exposure results also will be an input to the health risk assessment for lung function responses related to 5-minute exposures to SO_2 for the asthmatic population that is currently underway.

7.2 OVERVIEW OF HUMAN EXPOSURE MODELING USING APEX

The purpose of this exposure analysis is to allow comparisons of population exposures to ambient SO_2 among and within selected locations, and to characterize risks associated with current air quality levels and with just meeting the current standards. This section provides a brief overview of the model used by EPA to estimate SO_2 population exposure.

The EPA has developed the Air Pollutants Exposure Model (APEX) model for estimating human population exposure to criteria and air toxic pollutants. APEX serves as the human inhalation exposure model within the Total Risk Integrated Methodology (TRIM) framework (EPA 2006a; 2006b). APEX was recently used to estimate population exposures in 12 urban areas for the O_3 NAAQS review (EPA, 2007d; 2007e) and in estimating population NO_2 exposures in Philadelphia County as part of the NO_2 NAAQS review (EPA, 2008).

APEX is a probabilistic model designed to account for sources of variability that affect people's exposures. APEX simulates the movement of individuals through time and space and estimates their exposure to a given pollutant in indoor, outdoor, and in-vehicle microenvironments. The model stochastically generates a sample of simulated individuals using census-derived probability distributions for demographic characteristics. The population demographics are drawn from the year 2000 Census at the tract, block-group, or block level, and a national commuting database based on 2000 census data provides home-to-work commuting flows. Any number of simulated individuals can be modeled, and collectively they approximate a random sampling of people residing in a particular study area.

Daily activity patterns for individuals in a study area, an input to APEX, are obtained from detailed diaries that are compiled in the Consolidated Human Activity Database (CHAD) (McCurdy et al., 2000; EPA, 2002). The diaries are used to construct a sequence of activity events for simulated individuals consistent with their demographic characteristics, day type, and season of the year, as defined by ambient temperature regimes (Graham and McCurdy, 2004). The time-location-activity diaries input to APEX contain information regarding an individuals' age, gender, race, employment status, occupation, day-of-week, daily maximum hourly average temperature, the location, start time, duration, and type of each activity performed. Much of this information is used to best match the activity diary with the generated personal profile, using age, gender, employment status, day of week, and temperature as first-order characteristics. The approach is designed to capture the important attributes contributing to an individuals' behavior, and of likely importance in this assessment (i.e., time spent outdoors) (Graham and McCurdy, 2004). Furthermore, these diary selection criteria give credence to the use of the variable data that comprise CHAD (e.g., data collected were from different seasons, different states of origin, etc.).

APEX has a flexible approach for modeling microenvironmental concentrations, where the user can define the microenvironments to be modeled and their characteristics. Typical indoor microenvironments include residences, schools, and offices. Outdoor microenvironments include for example near roadways, at bus stops, and playgrounds. Inside cars, trucks, and mass transit vehicles are microenvironments which are classified separately from indoors and outdoors. APEX probabilistically calculates the concentration in the microenvironment associated with each event in an individual's activity pattern and sums the event-specific exposures within each hour to obtain a continuous series of hourly exposures spanning the time period of interest. The estimated pollutant concentrations account for the effects of ambient (outdoor) pollutant concentration, penetration factors, air exchange rates, decay/deposition rates, proximity to important outdoor sources, and indoor source emissions, each depending on the microenvironment, available data, and estimation method selected by the user. And, since the modeled individuals represent a random sample of the population of interest, the distribution of modeled individual exposures can be extrapolated to the larger population.

The model simulation can be summarized in the following five steps:

1. **Characterize the study area**. APEX selects census blocks within a study area – and thus identifies the potentially exposed population – based on user-defined criteria and availability of air quality and meteorological data for the area.
2. **Generate simulated individuals**. APEX stochastically generates a sample of hypothetical individuals based on the census data for the study area and human profile distribution data
3. **Construct a sequence of activity events**. APEX constructs an exposure event sequence spanning the period of the simulation for each of the simulated individuals and based on the activity pattern data.
4. **Calculate 5-minute and hourly concentrations in microenvironments**. APEX users define microenvironments that people in the study area would visit by assigning location codes in the activity pattern to the user-specified microenvironments. The model calculates 5-minute and hourly concentrations of a pollutant in each of these microenvironments for the period of simulation, based on the user-provided microenvironment descriptions, the hourly air quality data, and the PMRs. Microenvironmental concentrations are calculated for each of the simulated individuals.
5. **Estimate exposures**. APEX estimates a concentration for each exposure event based on the microenvironment occupied during the event. These values can be

averaged by clock hour to produce a sequence of hourly average exposures spanning the specified exposure period. The values may be further aggregated to produce daily, monthly, and annual average exposure values.

7.3 CHARACTERIZATION OF STUDY AREAS

7.3.1 Study Area Selection

The selection of areas to include in the exposure analysis takes into consideration the availability of ambient monitoring, the desire to represent a range of geographic areas considering SO_2 emission sources, population demographics, general climatology, and results of the ambient air quality characterization.

The first area of interest was initially identified based on the results of a preliminary screening of the 5-minute ambient SO_2 monitoring data that were available. The state of Missouri was one of only a few states having both 5-minute maximum and continuous 5-minute SO_2 ambient monitoring (approximately 14, including a few collocated monitors), as well as having over 30 1-hour SO_2 monitors in operation at some time during the period from 1997 to 2007. In addition, the air quality characterization described in Chapter 6 estimated frequent exceedances above the potential health effect benchmark levels at several of the 1-hour ambient monitors. In a ranking of estimated SO_2 emissions reported in the National Emissions Inventory (NEI), Missouri ranked 7^{th} for the number of stacks with > 1000 tpy emissions out of all US states. These stack emissions were associated with a variety source types such as electrical power generating units, chemical manufacturing, cement processing, and smelters. Two additional states of interest that contained similar ranking for emissions and SO_2 measurement data from several ambient monitors include Pennsylvania (5^{th}) and West Virginia (10^{th}). If it is possible within the time and resource constraints to model additional locations, the primary selection criterion would be based on total number of emission facilities regardless of available ambient SO_2 monitoring data, which would include in ranked order the following states: Texas, Ohio, Illinois, and Indiana.

7.3.2 Study Area Description

Although it would be useful to characterize SO_2 exposures nationwide, because the modeling approach is both time and labor intensive, a regional and source-oriented approach was selected to make the study tractable. Based on the criteria in section 7.3.1, several modeling domains were characterized within the selected state of Missouri to test the feasibility of the modeling methods. These modeling domains were defined as areas within 20 km of a major point source of SO_2 emission, more completely defined in the next section. Although we report on several of the Missouri modeling domains in this draft risk and exposure assessment, additional analyses are planned for more domains in the state and may expand the study to other U.S. locations.

7.4 CHARACTERIZATION OF AMBIENT HOURLY AIR QUALITY DATA USING AERMOD

7.4.1 Overview

Air quality data used for input to APEX were generated using AERMOD, a steady-state, Gaussian plume model (EPA, 2004). For each identified model domain location, the following steps were performed.

1. **Collect and analyze general input parameters.** Meteorological data, processing methodologies used to derive input meteorological fields (e.g., temperature, wind speed, precipitation), and information on surface characteristics and land use are needed to help determine pollutant dispersion characteristics, atmospheric stability and mixing heights.

2. **Estimate emissions**. The emission sources modeled included, major stationary emission sources and non-point source emissions.

3. **Define receptor locations**. Two sets of receptors were identified for the dispersion modeling, including ambient monitoring locations (where available) and census block centroids.

4. **Estimate concentrations at receptors**. Hourly concentrations were estimated for year 2002 by combining concentration contributions from each of the emission sources.

Estimated hourly concentrations output from AERMOD were then used as input to the APEX model to estimate population exposure concentrations. Details regarding both modeling approaches and input data used are provided below.

7.4.2 Introduction

Several regions in the state of Missouri were selected for analysis. AERMOD, a steady-state, Gaussian plume model (EPA, 2004) was used to perform dispersion modeling of SO_2 emitted from stationary point sources and estimate hourly concentrations at census block receptors for the 2002 time period. Major facility point sources within the state were included in the analysis, in a set of modeling subdomains to characterize impacted areas in the state.

Statewide, the majority of SO_2 emissions originate from point sources: about 85 percent in Missouri in 2002 according to the most recent NEI. To capture the impact of these emissions on populations within the state, point sources at major facilities were identified and paired to a representative surface meteorological station. For this study major facilities were defined as those with an SO_2 emission total exceeding 1000 tpy in 2002. Within such facilities, every stack emitting more than 1 tpy was included in the modeling inventory. Fourteen representative collections of emission sources were thus created, capturing all major facility point sources in the state. All block centroids within 20 km of any of these sources were designated as modeling receptors. The coupled sources, meteorological stations, and block centroid receptors define the modeling domain for each of the fourteen regions. Table 7-1 lists the fourteen domains and the corresponding number of sources and receptors and each domain is illustrated in Figure 8-1.

Table 7-1. SO_2 dispersion modeling domains for Missouri.

Modeling Domain[1]	Meteorological Database	Number of Receptors[2]	Number of Stacks
03935	ISH	5,323	2
03945	ISH	3,720	9
03947	ISH	29,387	19
03960	LCD	8,131	19
03966	ISH	2,832	4
03975	LCD	3,653	3
03994	LCD	2,945	8
13987	ISH	2,814	1
13994	ISH	29,245	15
13995	ISH	7,469	11
13997	LCD	3,653	2
14938	LCD	1,407	3
53869	LCD	1,262	11
93989	LCD	5,330	8
Total		107,171	115

[1] As derived from the corresponding surface meteorological station's WBAN ID.
[2] Some receptors are duplicated between some scenarios.

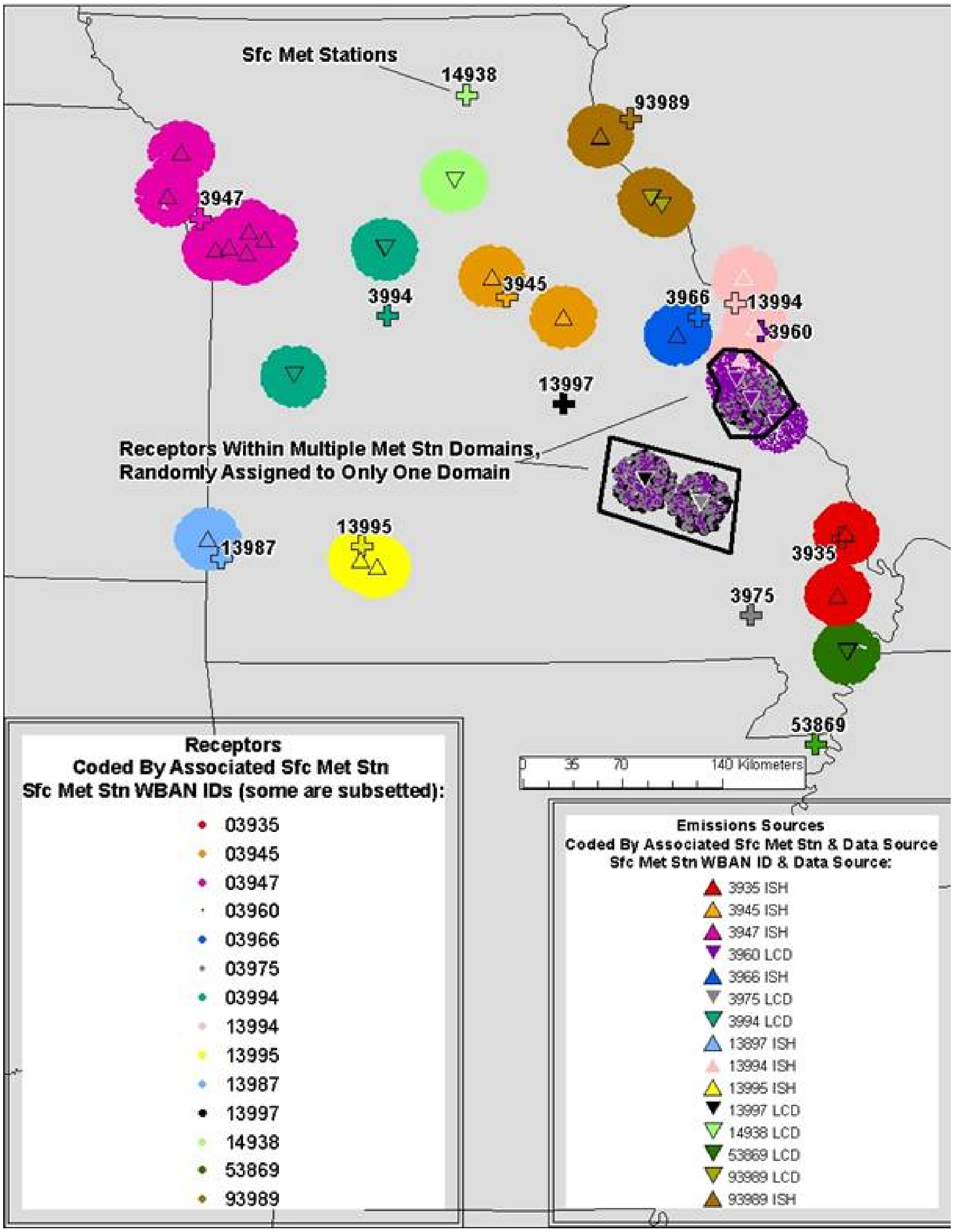

Figure 7-1. Modeling domains for the state of Missouri.

7.4.3 Meteorological Inputs

All meteorological data used for the AERMOD dispersion model simulations were processed with the AERMET meteorological preprocessor, version 06341. This section describes the input data and processing methodologies used to derive input meteorological fields for each of the fourteen domains modeled within Missouri.

7.4.3.1 Data Selection

Raw surface meteorological data for the 2002 period were obtained from both the Integrated Surface Hourly (ISH) Database,[12] and the Quality Controlled Local Climatological Database (LCD)[13]. Both of these databases are maintained by the National Climatic Data Center (NCDC). Two sets of data were required to assure that the most representative meteorological observations were paired to each of the fourteen modeling domains. Both datasets consist of typical hourly surface parameters (including air and dew point temperature, atmospheric pressure, wind speed and direction, precipitation amount, and cloud cover) from hourly Automated Surface Observing System (ASOS) stations. However, the formats of the data differ. ISH data is generally preferable, since the AERMET meteorological preprocessor for the AERMOD model is pre-configured to accept this format. However, there are significantly fewer stations included in this database. The LCD dataset includes more stations, such as minor airports and non-ASOS stations, but must be reformatted before use in the AERMET preprocessor. No on-site observations were used.

Grouping of individual stacks to surface meteorological stations was made as follows. To address concerns with use of reprocessed LCD-formatted meteorological data, preference was given to the ISH dataset. That is, when an ISH station was within 50 km of a given stack it was used, even if there was a closer LCD station. The algorithm for pairing meteorological stations and stacks is shown in Figure 7-2. The surface meteorological stations used to define modeling domains for this analysis are detailed in Table 7-2.

[12] http://www1.ncdc.noaa.gov/pub/data/techrpts/tr200101/tr2001-01.pdf
[13] http://cdo.ncdc.noaa.gov/qclcd/QCLCD

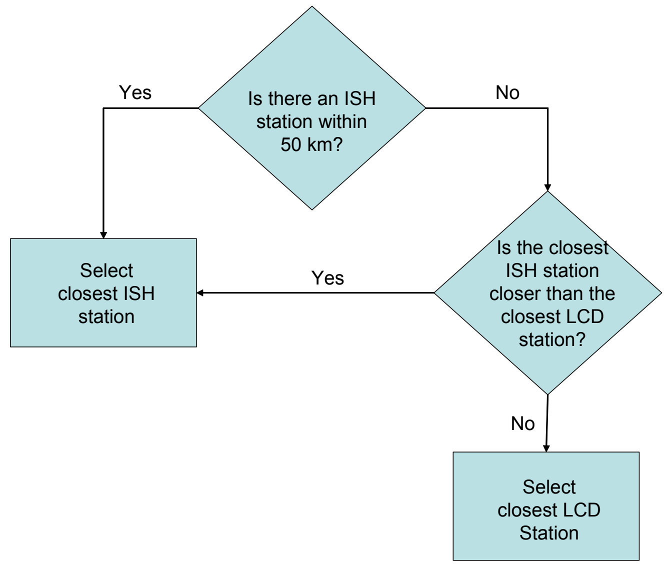

Figure 7-2. Decision tree for selection of meteorological stations.

Table 7-2. Surface meteorological stations dictating modeling domains.

Modeling Domain	Call Sign	Name	Location	Latitude (decimal degrees)	Longitude (decimal degrees)	Station Height (m)	Time Zone[1] (hours)
03935	CGI	Cape Girardeau, MO	Cape Girardeau Regional Airport	37.23	-89.57	107	6
03945	COU	Columbia, MO	Columbia Regional Airport	38.82	-92.22	274	6
03947	MCI	Kansas City, MO	Kansas City International Airport	39.30	-94.72	313	6
03960	CPS	Cahokia/St.Louis, IL	St Louis Downtown Airport	38.57	-90.17	126	6
03966	SUS	St Louis, MO	Spirit Of St Louis Airport	38.67	-90.67	141	6
03975	POF	Poplar Bluff, MO	Poplar Buff Municial Airport	36.77	-90.32	100	6
03994	DMO	Sedalia, MO	Sedalia Memorial Airport	38.70	-93.18	276	6
13987	JLN	Joplin, MO	Joplin Regional Airport	37.15	-94.50	300	6
13994	STL	St Louis, MO	Lambert-St Louis International Airport	38.75	-90.37	216	6
13995	SGF	Springfield, MO	Spngfld-Branson Regl Airport	37.23	-93.38	387	6
13997	VIH	Rolla/Vichy, MO	Rolla National Airport	38.13	-91.77	347	6
14938	IRK	Kirksville, MO	Kirksville Regional Airport	40.10	-92.53	294	6
53869	HKA	Blytheville, AR	Blytheville Municipal Airport	35.93	-89.83	78	6
93989	UIN	Quincy, IL	Quincy Regional-Baldwin Field Airport	39.93	-91.18	234	6

[1] Time zone is the offset from UTC/GMT to LST in hours.

The percentages of surface observations per station accepted by AERMET (i.e., those observations that were both not missing and within the expected ranges of values) were typically ≥99%.

Mandatory and significant levels of upper-air data were obtained from the NOAA Radiosonde Database.[14] Upper air observations show less spatial variation than do surface observations; thus they are both representative of larger areas and measured with less spatial frequency than are surface observations. Upper-air stations were selected to minimize both the distance to the emission sources and the number of missing data records. Four upper air stations were available to characterize the fourteen modeling domains. The selected stations for each modeling domain are shown in Table 7-3.

Table 7-3. Upper air stations paired to each modeling domain.

Upper Air Station	Modeling Domain	Call Sign	Name	Location	Latitude	Longitude	Station Height (m)	Time Zone[1]
4833	03960	ILX	Lincoln, IL	Lincoln-Logan County Ap	40.15	89.33	178	6
	03966							
	13994							
	93989							
13897	03935	BNA	Nashville, TN	Nashville International Airport	36.25	86.57	180	6
	53869							
13995	03945	SGF	SpringfielD, MO	Springfield-Branson Regional Airport	37.23	93.40	394	6
	03975							
	03994							
	13987							
	13995							
	13997							
13996	03947	TOP	Topeka, KS	Philip Billard Municipal Airport	39.07	95.62	268	6
	14938							

* Time zone is the offset from UTC/GMT to LST in hours.

The percentage of upper-air observations per station per height interval accepted by AERMET were typically ≥99% for the pressure, height, and temperature parameters. However, dewpoint temperature, wind direction, and wind speed parameters had lower acceptance rates (sometimes ≤75%), particularly for the greater atmospheric heights.

[14] http://raob.fsl.noaa.gov/

7.4.4 Surface Characteristics and Land Use Analysis

In addition to the standard meteorological observations of wind, temperature, and cloud cover, AERMET analyzes three principal variables to help determine atmospheric stability and mixing heights: the Bowen ratio[15], surface albedo[16] as a function of the solar angle, and surface roughness[17].

AERSURFACE version 08009 was used to estimate land-use around the meteorological observation site and calculate the Bowen ratio, surface albedo, and surface roughness as part of the AERMET processing. AERSURFACE uses the US Geological Survey (USGS) National Land Cover Data 1992 archives (NLCD92)[18]. However, to optimize objectivity and efficiency in the analysis of such a large number of stations, AERSURFACE was run in an automated fashion, with the appropriate state land cover data file from USGS and the maximum number of sectors allowed: twelve. These twelve land-use sectors are used to identify the Bowen ratio and surface albedo, which are assumed to represent an area around the station of radius 10 km, and to calculate surface roughness by wind direction.

A monthly temporal resolution was used for the Bowen ratio, albedo, and surface roughness for all fourteen meteorological sites defining the modeling domains. Because the fourteen sites were located at airports, a lower surface roughness was calculated for the 'Commercial/Industrial/Transportation' land-use type to reflect the dominance of transportation land cover rather than commercial buildings. None of the fourteen regions are arid regions, but the Colombia, Kansas City, Kirksville, and Quincy, IL, stations are each considered to have at least one winter month of continuous snow cover, as they fall within the CLIMAPS[19] contours of stations experiencing at least 28.5 days of at least 1 inch (25.4 mm) of ground snow depth. This time period of snow cover was the closest contour interval to 1 month for which data is

[15] For any moist surface, the Bowen Ratio is the ratio of heat energy used for sensible heating (conduction and convection) to the heat energy used for latent heating (evaporation of water or sublimation of snow). The Bowen ratio ranges from about 0.1 for the ocean surface to more than 2.0 for deserts. Bowen ratio values tend to decrease with increasing surface moisture for most land-use types.

[16] Surface albedo is the ratio of the amount of electromagnetic radiation reflected by the earth's surface to the amount incident upon it. Values vary with surface composition. For example, snow and ice ranger from 80% to 85% and bare ground from 10% to 20%.

[17] Surface roughness refers to the presence of buildings, trees, and other irregular land topography that is associated with its efficiency as a momentum sink for turbulent air flow, due to the generation of drag forces and increased vertical wind shear.

[18] http://seamless.usgs.gov/

[19] NCDC Climate Maps of the United States database (CLIMAPS). See http://cdo.ncdc.noaa.gov/cgi-bin/climaps/climaps.pl.

available; here we assume these to be contiguous days. This designation increases wintertime albedo and decreases wintertime Bowen ratio and surface roughness for most land-use types compared to snow-free areas.

Seasons were assigned for each site on a monthly basis, determined by standard seasonal definitions and modified to local regions based on CLIMAPS data for median date of first freeze, average daily maximum temperature, and median last freeze date. Table 7-4 provides the seasonal and snow cover definitions for each domain.

Table 7-4. Seasonal and snow cover specifications by meteorological domain.

Model Domain	Snowy Region	Winter Months	Spring Months	Summer Months	Fall Months
03935		Dec.,Jan.,Feb.	Mar.,Apr.,May	Jun.,Jul.,Aug.	Sep.,Oct.,Nov.
03945	Yes	Dec.,Jan.,Feb.	Mar.,Apr.,May	Jun.,Jul.,Aug.	Sep.,Oct.,Nov.
03947	Yes	Dec.,Jan.,Feb.	Mar.,Apr.,May	Jun.,Jul.,Aug.	Sep.,Oct.,Nov.
03960		Dec.,Jan.,Feb.	Mar.,Apr.,May	Jun.,Jul.,Aug.	Sep.,Oct.,Nov.
03966		Dec.,Jan.,Feb.,Mar.	Apr.,May	Jun.,Jul.,Aug.	Sep.,Oct.,Nov.
03975		Dec.,Jan.,Feb.,Mar.	Apr.,May	Jun.,Jul.,Aug.	Sep.,Oct.,Nov.
03994		Dec.,Jan.,Feb.	Mar.,Apr.,May	Jun.,Jul.,Aug.	Sep.,Oct.,Nov.
13987		Dec.,Jan.,Feb.	Mar.,Apr.,May	Jun.,Jul.,Aug.	Sep.,Oct.,Nov.
13994		Dec.,Jan.,Feb.	Mar.,Apr.,May	Jun.,Jul.,Aug.	Sep.,Oct.,Nov.
13995		Dec.,Jan.,Feb.,Mar.	Apr.,May	Jun.,Jul.,Aug.	Sep.,Oct.,Nov.
13997		Dec.,Jan.,Feb.	Mar.,Apr.,May	Jun.,Jul.,Aug.	Sep.,Oct.,Nov.
14938	Yes	Dec.,Jan.,Feb.,Mar.	Apr.,May	Jun.,Jul.,Aug.	Sep.,Oct.,Nov.
53869		Dec.,Jan.,Feb.,Mar.	Apr.,May	Jun.,Jul.,Aug.	Sep.,Oct.,Nov.
93989	Yes	Dec.,Jan.,Feb.	Mar.,Apr.,May	Jun.,Jul.,Aug.	Sep.,Oct.,Nov.

Season definitions provided by the AERSURFACE manual:	
Winter (continuous snow):	Winter with continuous snow on ground
Winter (no snow):	Late autumn after frost and harvest, or winter with no snow
Spring:	Transitional spring with partial green coverage or short annuals
Summer:	Midsummer with lush vegetation
Fall:	Autumn with unharvested cropland

7.4.5 Meteorological Analysis

The AERMET (version 06341) meteorological preprocessor was run with the surface characteristics and meteorological data discussed above. The application location and elevation were specified as the meteorological monitoring site, which serves as the anchor for each modeling domain. Each site was processed for the 2002 year, creating fourteen complete surface and upper air paired datasets, or one for each modeling domain.

7.4.6 Stationary Sources Emissions Preparation

7.4.6.1 Emitting Sources and Locations

As discussed above, as a first approximation point sources at major facilities were assumed to represent the SO_2 emissions throughout Missouri[20], where major facilities were defined as those with SO_2 emissions totals exceeding 1,000 tpy. Nationwide, there are 918 major facilities and 10,651 associated stacks, according to the 2002 NEI. Within Missouri, 281 major facility stacks were identified, but only 115 of these stacks have greater than or equal to 1.0 tpy SO_2 emissions in the 2002 NEI. Each of these stacks was paired to a surface meteorological station, defining its modeling domain. These are the final list of stacks identified in Table 7-1, above.

Additionally, the locations of the stacks were corrected based on GIS analysis. This was necessary because many stacks in the NEI are assigned the same location, which often corresponds to a location in the facility – such as the front office – rather than the actual stack locations. To correct for this, stack locations were reassigned manually with the Microsoft® Live Maps® Virtual Earth® tool to visually match stacks from the NEI database to their locations within the facilities using stack heights as a guide to stack identification.

7.4.6.2 Source Terrain Characterization

All corrected locations for the final list of major facility stacks in Missouri were processed with the AERMAP terrain preprocessing tool. Terrain height information was taken from the series of 36 USGS 1 x 1 degree GeoData Digital Elevation Model (DEM)[21] data files covering the entire state.

7.4.6.3 Emissions Data Sources

Data for the parameterization of major facility point sources in Missouri comes primarily from three sources: the 2002 NEI (EPA, 2007f), Clean Air Markets Division (CAMD) Unit Level Emissions Database (EPA, 2007g), and temporal emission profile information contained in the EMS-HAP (version 3.0) emissions model[22]. The NEI database contains stack locations, emissions release parameters (i.e., height, diameter, exit temperature, exit velocity), and annual

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[20] After a first round of air dispersion modeling, model-to-monitor comparisons suggested that area sources of SO_2 and/or cross-border point sources should be added to some of the modeling domains. The modeling for those domains was not completed as of the date of this report.

[21] http://erg.usgs.gov/isb/pubs/factsheets/fs04000.html

[22] http://www.epa.gov/ttn/chief/emch/projection/emshap30.html

SO_2 emissions. The CAMD database has information on hourly SO_2 emission rates for all the electric generating units in the US, where the units are the boilers or equivalent, each of which can have multiple stacks[23]. These two databases generally contain complimentary information, and were first evaluated for matching facility data. However, CAMD lacks SO_2 emissions data for facilities other than electric-generating units. To convert annual total emissions data from the NEI into hourly temporal profiles required for AERMOD, a three tiered approach was used, as follows.

1. CAMD hourly concentrations to create relative temporal profiles.
2. EMS-HAP seasonal and diurnal temporal profiles for source categorization codes (SCCs).
3. Flat profiles.

Details of these processes are as follows.

Tier 1: CAMD to NEI Emissions Alignment and Scaling

Of the 115 major facility stacks within MO identified above, 50 were able to be matched directly to sources within the CAMD database. Stack matching was based on the facility name, Office of Regulatory Information Systems (ORIS) identification code (when provided) and facility total SO_2 emissions. For these stacks the relative hourly profiles were derived from the hourly values in the CAMD database, and the annual emissions totals were taken from the NEI. That is, hourly emissions in the CAMD database were scaled to match the NEI annual total emissions.

Tier 2: EMS-HAP to NEI Emissions Profiling

Of the 115 major facility stacks within MO, 46 stacks could not be matched to a stack in the in the CAMD database, but had SCC values that corresponded to SCCs that have temporal profiles included in the EMS-HAP emissions model.

In these cases, the SCC-specific seasonal and hourly variation (SEASHR) values from the EMS-HAP model were used to characterize the temporal profiles of emissions for each hour

[23] The CAMD database also contains hourly NO_2 emission data for both electric generating units and other types of industrial facilities. In the case of facilities for which CAMD has hourly NO_2 data but not SO_2 data, SO_2 relative temporal profiles could be approximated by NO_2 temporal profiles. However, there were no such cases for MO facilities.

of a typical day by season and day type. However, to maintain consistency with the other stacks, these profiles were expanded into a full series of values for each stack for each hour of the year, with each value scaled so that the annual total matched the NEI value.

Tier 3: Other Emissions Profiling

Of the 115 major facility stacks within Misosuri, 18 could not be matched to a stack in CAMD database, or to profiles in the EMS-HAP model by SCC code. In these cases, a flat profile of emissions was assumed. That is, emissions were assumed to be constant for all hours of every day, but with an annual total that equals the values from the NEI.

A summary of the point source emissions used for modeling domains analyzed in the draft of the assessment is given in Table 7-5. Appendix D, Table D-1 contains all 115 stacks in Missouri and the data source used to determine their emissions profiles. As far as the point source emissions that were modeled, most counties were at or near 100%, that is, nearly all of the point sources were accounted for by the dispersion modeling. When considering the total county emissions, several of the locations were also near 100%, with a few containing accounted emissions at around 80%, and one at about 50% of total emissions. The total emissions accounted for most of the modeling domains was at about 80% or greater, indicating reasonable coverage by the approach used here. In counties where a lowered percent of total emissions are accounted for, additional area source modeling may be required. However, in a county such as Cape Girardeau where only 49% total emissions were accounted for, the result of additional area source modeling is likely to be inconsequential due to the overall low total emissions in the county.

Table 7-5. Summary of NEI emission estimates and total emissions used for dispersion modeling in Missouri.

Modeling Domain	County	NEI Emissions: Point Source (tpy)	NEI Emissions: Total (tpy)	Emissions Used for Dispersion Modeling: Stacks (n)	Point Source (tpy)	Point Source (%)	Total Emissions (%)	Total Domain Emissions
3935	Cape Girardeau	1,680	2,809	1	1,362	81%	49%	79%
	Scott	6,237	6,870	1	6,236	100%	91%	
3945	Boone	10,621	11,795	7	9,729	92%	82%	86%
	Osage	4,142	4,355	2	4,142	100%	95%	
3994	Henry	15,826	16,092	6	15,826	100%	98%	96%
	Saline	1,450	1,830	2	1,449	100%	79%	
53869	New Madrid	19,889	19,891	11	20,570	100%	97%	97%
13987	Jasper	4,463	5,914	1	4,349	97%	74%	74%
13995	Greene	9,218	11,819	11	9,047	98%	77%	77%
14938	Randolph	15,231	15,497	3	15,221	100%	98%	98%
93989	Marion	1,834	2,270	4	1,834	100%	81%	95%
	Pike	13,496	13,799	4	13,494	100%	98%	

7.4.7 Urban and Rural Source Characterization

Additional analysis was made to determine whether the stacks in each domain should be modeled with urban or rural dispersion characteristics. The AERMOD dispersion model defaults to rural dispersion characteristics for all sources unless both the modeling scenario and each individual source is declared urban, in which case additional dispersion effects from increased surface heating within an urban area under stable atmospheric conditions are included. The magnitude of this effect is weakly proportional to the urban area population.

According to the Environmental Protection Agency (40 CFR Part 51, Appendix W[24]), the land use classification procedure to determine appropriate dispersion coefficients involves the following:

> (1) Classify the land use within the total area, A_o, circumscribed by a 3 km radius circle about the source using the meteorological land use typing scheme proposed by *Auer*;
>
> (2) If land use types I1, I2, C1, R2, and R3 account for 50 percent or more of A_o, use urban dispersion coefficients; otherwise, use appropriate rural dispersion coefficients.

where I1, I2, C1, R2, and R3 are heavy industrial, light/moderate industrial, commercial, and compact residential (single- and multi-family). Classification of land use in this schema were not readily available, but land use designation from the NLCD92 database are, from the AERSURFACE processing for meteorological analysis. Table 7-6 lists these categories.

Table 7-6. NLCD92 land use characterization.

Category	Land Use Type
0	Outside Boundary
11	Open Water
12	Perennial Ice/Snow
21	Low Intensity Residential
22	High Intensity Residential
23	Commercial/Industrial/Transp
31	Bare Rock/Sand/Clay
32	Quarries/Strip Mines/Gravel
33	Transitional
41	Deciduous Forest
42	Evergreen Forest
43	Mixed Forest
51	Shrubland
61	Orchards/Vineyard/Other
71	Grasslands/Herbaceous
81	Pasture/Hay
82	Row Crops
83	Small Grains
84	Fallow
85	Urban/Recreational Grasses
91	Woody Wetlands
92	Emergent Herbaceous Wetlands
99	Missing Data

[24] Part III, Environmental Protection Agency, 40 CFR Part 51, *Revision to the Guideline on Air Quality Models: Adoption of a Preferred General Purpose (Flat and Complex Terrain) Dispersion Model and Other Revisions; Final Rule*, 68218 Federal Register, Vol. 70, No. 216, Wednesday, November 9, 2005, Rules and Regulations.

To resolve each scenario as urban or rural, we applied the same 50% threshold criteria within 40 CFR Part 51, Appendix W, but determined the spatial coverage as the sum of the coverage of land use categories 21 – 23 from the NLCD92. These are the categories considered developed by AERSURFACE.[25] However, there was no simple, consistent way to determine the coverage of these land-use types over each of the modeling domains. Thus, the urban or rural designation was made as follows. Within each modeling domain stacks within 10 km of each other were grouped together, resulting in groups of one to thirteen stacks. The AERSURFACE model was then applied to each group to extract the land use within 10 km of any stack. The urban fraction was estimated over the entire modeling domain by averaging the urban fractions around each component stack group. This method is similar to analyzing the land use around each stack in the modeling domain and averaging, but it avoids double counting of the land around multiple stacks in close proximity. It also foregoes a 3 km radius of definition around each stack for a consideration of "whole urban [or rural] complexes", as identified in the modeling guidance.[26] Ultimately, no modeling domain in the state was considered urban. Table 7-7 shows the overall urban fraction of each modeling domain thus determined, and its resulting urban/rural designation.

Table 7-7. Urban/Rural characterization of each modeling domain

Modeling Domain	Average Urban Fraction	Scenario Designation
03994	4%	Rural
03975	0%	Rural
03945	5%	Rural
03947	19%	Rural
03935	3%	Rural
03966	1%	Rural
13995	6%	Rural
13997	0%	Rural
93989	2%	Rural
13994	17%	Rural
13987	0%	Rural
03960	1%	Rural
53869	4%	Rural
14938	2%	Rural

[25] *AERSURFACE User's Guide*, U.S. EPA, OAQPS, Research Triangle Park, NC, EPA-454/B-08-001, January 2008.
[26] AERMOD Implementation Guide, U.S. EPA, OAQPS, Research Triangle Park, NC, Revised: January 9, 2008.

7.4.8 Receptor Locations

Receptor locations were selected to represent the locations of census block centroids near major SO_2 sources. GIS analysis was used to determine all block centroids in Missouri that lie within 20 km (12 miles) of any of the 115 major facility stacks. Note that although all sources modeled lie within the State of MO, not all receptors do. In total, 107,171 block centroids were selected across all modeling domains, as given by Table 7-1, with some duplication of receptors between domains.[27] All receptors were modeled at a breathing height of 5.9 feet (1.8 m).

7.4.8.1 Receptor Terrain Characterization

All locations for the final list of major facility stacks in Missouri were processed with the AERMAP terrain preprocessing tool. All terrain height information was taken from the series of 36 USGS 1 x 1 degree GeoData Digital Elevation Model (DEM)[28] data files covering all modeling domains (and extending beyond the state boundaries).

7.4.9 Other Modeling Specifications

AERMOD was applied to the each of the fourteen modeling domains in Missouri with the emissions and meteorological data and dispersion parameterizations as described above. The AERMOD regulatory default settings were employed in all cases. Because all sources in Missouri are considered rural, SO_2 chemistry was not applied by the model.

7.4.10 Estimate Air Quality Concentrations

The hourly SO_2 concentrations estimated from each of the sources within a modeling domain were combined at each receptor. Dispersion modeling runs were completed for several of the modeling domains where there were no ambient monitors available for comparison, therefore based on the total emissions accounted for (Table 7-5) there were no adjustments for sources that may have not been modeled or accounted for. For Greene County, there were five monitors used for comparison with the AERMOD concentration estimates. Rather than compare concentrations estimated at a single modeled receptor point to the ambient monitor concentrations, a distribution of concentrations was developed for the predicted concentrations for all receptors within a 4 km distance of the monitors. Further, instead of a comparison of

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[27] For receptors located in multiple modeling domains, the concentration contributions from source in each domain were summed in post-processing and the receptor randomly assigned to one of the domains for input to APEX.

[28] http://erg.usgs.gov/isb/pubs/factsheets/fs04000.html

central tendency values (mean or median), the modeled and measurement concentration distributions were used for comparison. At each AERMOD receptor point within 4 km of the monitors, the minimum and maximum modeled concentrations were used to generate two separate concentration distributions (i.e., one distribution for all of the modeled maximum concentrations, and one for the minimum concentrations). Four of the monitors overlapped with the same 4 km AERMOD distributions. Each of the AERMOD concentration distributions are illustrated in Figure 7-3, along with the measured concentration distributions in Greene County, Mo. All of the monitor concentration distributions are completely bounded by the modeled distributions, except for part of one monitor (ID 290770026) exhibiting slightly higher concentrations at the lower percentiles of the distribution. The upper percentiles of the distribution are well represented by the AERMOD predicted concentrations, an important result given that the 1-hour concentrations of most interest here are at or above 33.3 ppb. The concentration distribution from the final monitor in Greene County was also compared with the concentration distribution bounds estimated from AERMOD (Figure 7-4). Over 90% of the measured concentrations are less than 5 ppb, although each is above the upper bound predicted by AERMOD. This indicates that AERMOD is possibly under-predicting at very low concentrations at this location. However, measured concentrations at the upper percentiles of the distribution (i.e, above the 95^{th} %ile ranging from about 6 – 30 ppb) are completely bounded by the AERMOD distributions, suggesting the modeled are representing these concentration levels well. Based on these comparisons and the high percentage of point source and total emissions modeled in Greene County Table 7-5), none of the AERMOD concentrations were adjusted to any particular monitor concentration.

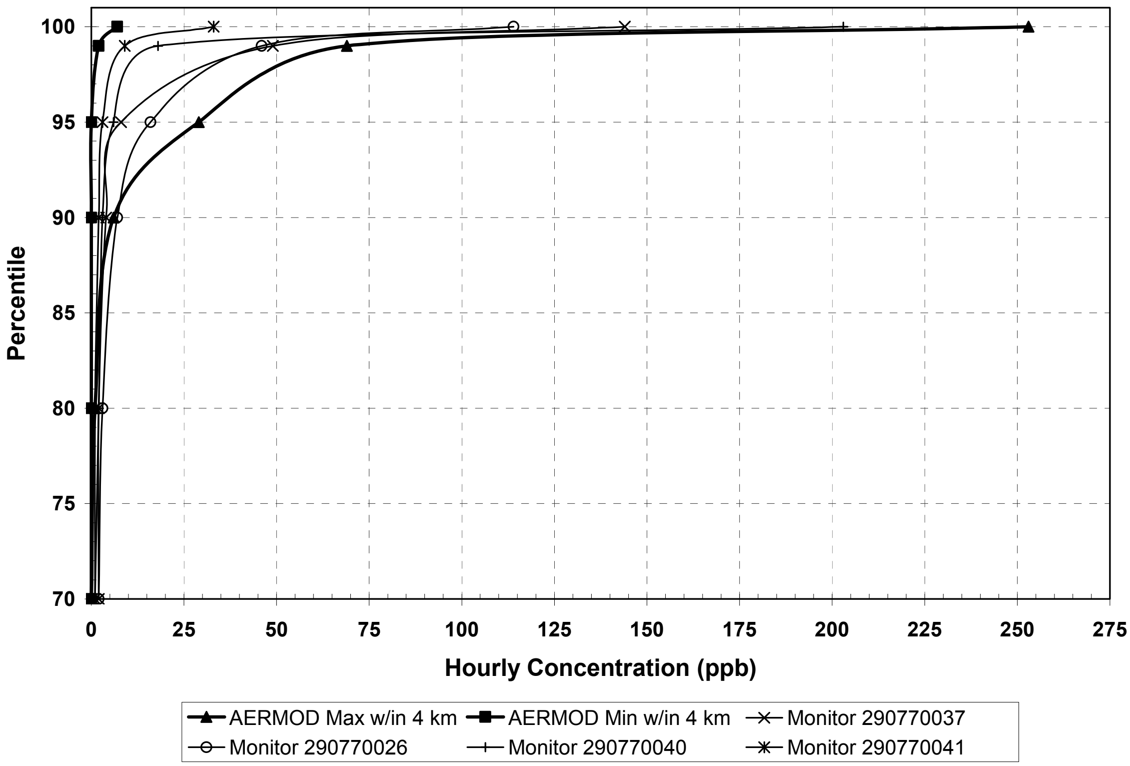

Figure 7-3. Distributions of 1-hour SO_2 concentrations in Greene County, Mo., estimated by AERMOD and measured at four ambient monitors.

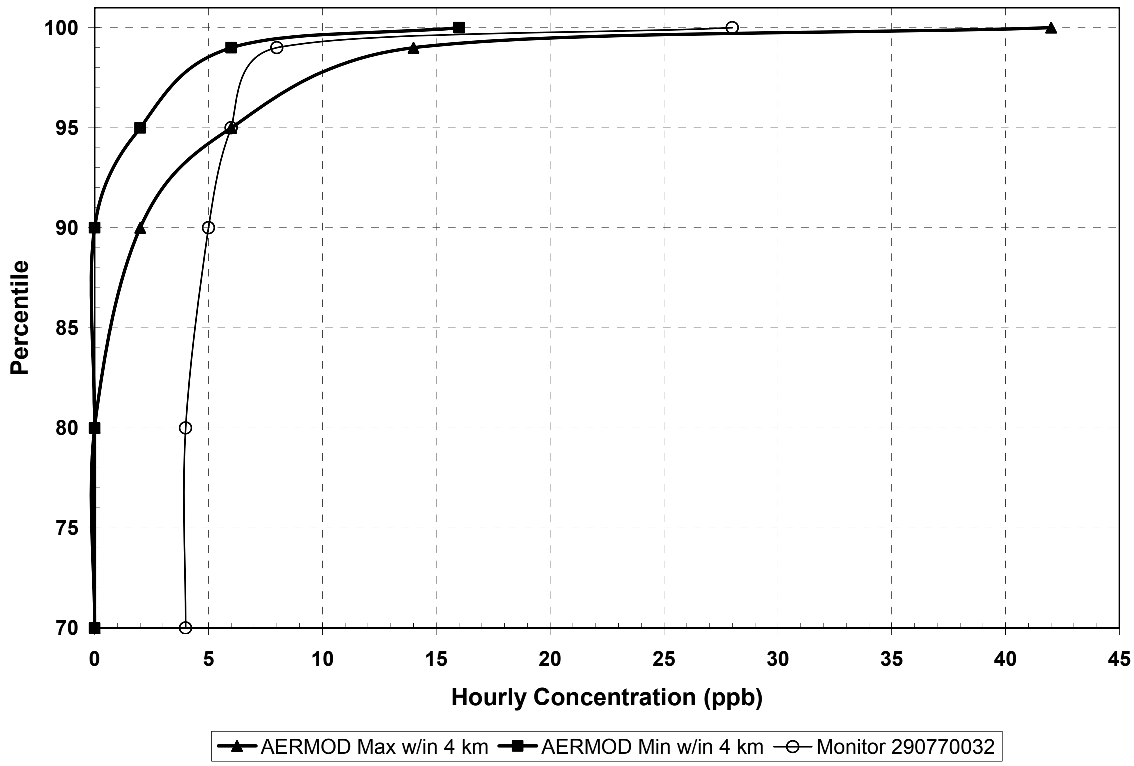

Figure 7-4. Distributions of 1-hour SO_2 concentrations in Greene County, Mo., estimated by AERMOD and measured at one ambient monitor.

7.5 POPULATION MODELED

A detailed consideration of the population residing in each modeled area was included where the exposure modeling was performed. The assessment included the general population residing in each modeled area and susceptible subpopulations identified in the ISA. These include population subgroups defined from a health perspective. The population subgroups identified by the ISA and that were modeled in the exposure assessment include asthmatics of all ages and asthmatic children (ages 5-18). While the model can estimate total population exposure, the focus of the analysis was on these identified susceptible individuals.

7.5.1 Simulated Individuals

APEX takes population characteristics into account to develop accurate representations of study area demographics. Population counts and employment probabilities by age and gender are used to develop representative profiles of hypothetical individuals for the simulation. Block-level population counts by age in one-year increments, from birth to 99 years, come from the 2000 Census of Population and Housing Summary File 1 (SF-1). This file contains the 100-

percent data, which is the information compiled from the questions asked of all people and about every housing unit.

Asthma Prevalence Rates

One of the important population subgroups for the exposure assessment is asthmatic children. Evaluation of the exposure of this group with APEX requires the estimation of children's asthma prevalence rates. The proportion of the population of children characterized as being asthmatic was estimated by statistics on asthma prevalence rates recently used in the NAAQS review for O_3 (US EPA, 2007g). Specifically, the analysis generated age and gender specific asthma prevalence rates for children ages 0-17 using data provided in the National Health Interview Survey (NHIS) for 2003 (CDC, 2007). These asthma rates were characterized by geographic regions, namely Midwest, Northeast, South, and West. The rates characterized for Midwest children were used for all Missouri modeling domains Table 7-7. Adult asthma prevalence rates were estimated by gender and for each particular modeling domain based on Missouri regional data (Table 7-8, from MO Department of Health, 2002).

Table 7-7. Asthma prevalence rates by age for children the Midwestern U.S.

Region (Study Area)	Age	Females				Males			
		Prevalence	se	L95	U95	Prevalence	se	L95	U95
Midwest	0	0.070	0.036	0.021	0.203	0.031	0.015	0.010	0.090
	1	0.071	0.020	0.037	0.130	0.063	0.018	0.033	0.115
	2	0.073	0.018	0.042	0.124	0.108	0.021	0.070	0.163
	3	0.075	0.019	0.042	0.132	0.158	0.027	0.107	0.228
	4	0.081	0.022	0.044	0.144	0.216	0.037	0.145	0.308
	5	0.095	0.026	0.051	0.171	0.178	0.035	0.113	0.270
	6	0.092	0.029	0.045	0.178	0.128	0.028	0.078	0.204
	7	0.090	0.026	0.047	0.166	0.121	0.026	0.074	0.193
	8	0.086	0.022	0.048	0.149	0.128	0.027	0.079	0.200
	9	0.110	0.027	0.063	0.186	0.147	0.030	0.093	0.226
	10	0.162	0.035	0.098	0.255	0.177	0.030	0.120	0.254
	11	0.196	0.039	0.123	0.298	0.190	0.030	0.131	0.266
	12	0.212	0.040	0.137	0.313	0.195	0.031	0.135	0.272
	13	0.170	0.034	0.107	0.258	0.169	0.028	0.115	0.242
	14	0.140	0.026	0.092	0.209	0.168	0.026	0.117	0.235
	15	0.133	0.023	0.091	0.192	0.180	0.026	0.130	0.243
	16	0.140	0.022	0.098	0.198	0.201	0.030	0.142	0.277
	17	0.165	0.040	0.093	0.275	0.237	0.058	0.132	0.388

se – Standard error of the mean
L95 - Lower 95% interval
U95 – Upper 95% interval

Table 7-8. Asthma prevalence rates by gender for adults the Missouri.

MET Station	Region Encompassed	Adult Females	Adult Males	Data Used
3935	SE	0.130	0.074	SE
3945	Central	0.098	0.056	Central
3947	Kansas City/NW	0.149	0.085	Kansas City
3960	SE/Central/St. Louis	0.093	0.053	St. Louis
3966	St. Louis	0.093	0.053	
3975	SE/Central	0.130	0.074	SE
3994	SW/Kansas City /NW/NE	0.110	0.063	State mean
13987	SW	0.107	0.061	
13994	St. Louis	0.093	0.053	
13995	SW	0.107	0.061	
13997	SE/Central	0.098	0.056	Central
14938	NE	0.108	0.061	
53869	SE	0.130	0.074	
93989	NE/St. Louis	0.108	0.061	NE

The total population considered in the analysis completed in the draft of the assessment was approximately ¾ million persons, of which approximately 10% were asthmatics. The model simulated approximately nearly 200,000 children, of which there were nearly 25,000 asthmatics. Individual domain populations are provided in Table 7-9.

Table 7-9. Population modeled in Missouri modeling domains.

Modeling Domain	Population		Asthmatic Population	
	All Ages	Children (0 – 18)	All Ages	Children (0 – 18)
3935	105372	27504	11867	3673
3945	135710	33393	12279	4400
3994	36044	9177	3568	1215
13987	56490	15775	5609	2155
13995	275825	68675	26712	9005
14938	9108	2538	910	350
53869	17085	4339	1869	595
93989	100889	26046	9944	3594
Total	**736523**	**187447**	**72758**	**24987**

7.5.2 Employment Probabilities

Employment data from the 2000 Census provide employment probabilities for each gender and specific age groups for every Census tract. The employment age groupings were: 16-19, 20-21, 22-24, 25-29, 30-34, 35-44, 45-54, 55-59, 60-61, 62-64, 65-69, 70-74, and >75 years of age. Children under the age of 16 are assigned employment probabilities of zero.

7.5.3 Commuting Patterns

To ensure that individuals' daily activities are accurately represented within APEX, it is important to integrate working patterns into the assessment. Commuting data were originally derived from the 2000 Census and were collected as part of the Census Transportation Planning Package (CTPP) (US DOT, 2007). CTPP contains tabulations by place of residence, place of work, and the flows between the residence and work.

It is assumed that all persons with home-to-work distances up to 120 km are daily commuters, and that persons who travel further than 120 km do not commute daily. Therefore the list of commuting destinations for each home tract is restricted to only those work tracts that are within 120 km of the home tract.

APEX allows the user to specify how to handle individuals who commute to destinations outside the study area. One option is to drop them from the simulation. If they are included, the user specifies values for two additional parameters, called L_M and L_A (Multiplicative and Additive factors for commuters who Leave the area). While a commuter is at work, if the workplace is outside the study area, then the ambient concentration cannot be determined from any air district (since districts are inside the study area). Instead, it is assumed to be related to the average concentration $C_{AVE\,(t)}$ over all air districts at the time in question. The ambient concentration outside the study area at time t, $C_{OUT\,(t)}$, is estimated as:

$$C_{OUT\,(t)} = L_M * C_{AVE\,(t)} + L_A$$

The microenvironmental concentration (for example, in an office outside the study area) is determined from this ambient concentration by the same model (mass balance or factor) as applied inside the study area. The parameters L_M and L_A were both set to zero for this modeling analysis; thus, exposures to individuals are set to zero when they are outside of the study area. Although this tends to underestimate exposures, it is a small effect and this was done since we have not estimated ambient concentrations of SO_2 in counties outside of the modeled areas.

While school age children were simulated as commuting to and from school, they did so to-and-from their home tract. This results in the implicit assumption that children attend a school with ambient SO_2 concentrations similar to concentrations near their residence.

7.5.4 Characterizing Ventilation Rates

Human activities are variable over time, a wide range of activities are possible even within a single hour of the day. The type of activity an individual performs, such as sleeping or jogging, will influence their breathing rate. The ISA indicates that adverse health effects associated with short-term peak exposures occurs with moderate to heavy exertion levels. Therefore, ventilation rates needed to be defined to further characterize exposures of interest. The target ventilation for adults (both a mix of males and females) experiencing effects from 5-10 minute SO_2 exposures from most of the clinical trials was between 40-50 L/min. Since there were limited clinical data available for asthmatic children, the ventilation targets needed to be adjusted. As done in the O_3 NAAQS review (EPA, 2007g), target ventilation rates were normalized to body surface area (BSA) to allow for such an extrapolation from adults to children. The resulting normalization yields an equivalent ventilation rate or EVR. Since BSA was not measured in the clinical trials and the data were reported as grouped, median estimates for males (1.94 m^2) and females (1.69 m^2) were obtained from EPA (1997) and averaged to normalize the target ventilation rates. Therefore, an EVR = 40/1.81 = 22 L/min-m^2 was used to characterize the minimum target ventilation rate of interest. Individuals at or above an EVR of 22 L/min-m^2 (children or adult) would be characterized as performing activities at a moderate ventilation rate.

7.6 CONSTRUCTION OF LONGITUDINAL ACTIVITY SEQUENCES

Exposure models use human activity pattern data to predict and estimate exposure to pollutants. Different human activities, such as spending time outdoors, indoors, or driving, will result in varying pollutant exposure concentrations. To accurately model individuals and their exposure to pollutants, it is critical to understand their daily activities.

The Consolidated Human Activity Database (CHAD) provides data for where people spend time and the activities performed. CHAD was designed to provide a basis for conducting multi-route, multi-media exposure assessments (McCurdy et al., 2000; EPA, 2002). Table 7-10 summarizes the studies in CHAD used in this modeling analysis, providing nearly 16,000 diary-days of activity data (3,075 diary-days for ages 5-18) collected between 1982 and 1998.

Table 7-10. Studies in CHAD used for the exposure analysis.

Study name	Geographic coverage	Study time period	Subject ages	Diary-days	Diary-days (ages 5-18)	Diary type and study design	Reference
Baltimore	One building in Baltimore	01/1997-02/1997, 07/1998-08/1998	72 - 93	292	0	Diary	Williams et al. (2000)
California Adolescents (CARB)	California	10/1987-09/1988	12 - 17	181	181	Recall; Random	Robinson et al. (1989), Wiley et al. (1991a)
California Adults (CARB)	California	10/1987-09/1988	18 - 94	1,552	36	Recall; Random	Robinson et al. (1989), Wiley et al. (1991a)
California Children (CARB)	California	04/1989- 02/1990	<1 - 11	1,200	683	Recall; Random	Wiley et al. (1991b)
Cincinnati (EPRI)	Cincinnati metro. area	03/1985-04/1985, 08/1985	<1 - 86	2,587	740	Diary; Random	Johnson (1989)
Denver (EPA)	Denver metro. area	11/1982- 02/1983	18 - 70	791	7	Diary; Random	Johnson (1984) Akland et al. (1985)
Los Angeles: Elementary School	Los Angeles	10/1989	10 - 12	51	51	Diary	Spier et al. (1992)
Los Angeles: High School	Los Angeles	09/1990-10/1990	13 - 17	42	42	Diary	Spier et al. (1992)
National: NHAPS-Air	National	09/1992-10/1994	<1 - 93	4,326	634	Recall; Random	Klepeis et al. (1996), Tsang and Klepeis (1996)
National: NHAPS-Water	National	09/1992-10/1994	<1 - 93	4,332	691	Recall; Random	Klepeis et al. (1996), Tsang and Klepeis (1996)
Washington, D.C. (EPA)	Wash., D.C. metro. area	11/1982-02/1983	18 - 98	639	10	Diary; Random	Hartwell et al. (1984), Akland et al. (1985)
Total diary days				**15,993**	**3,075**		

Typical time-activity pattern data available for inhalation exposure modeling consist of a sequence of location/activity combinations spanning 24-hours, with 1 to 3 diary-days for any single individual. Exposure modeling typically requires information on activity patterns over longer periods of time, e.g., a full year. For example, even for pollutant health effects with short averaging times (e.g., SO_2 5-minute maximum concentration) it may be desirable to know the frequency of exceedances of a concentration over a long period of time (e.g., the annual number of exceedances of a 5-minute SO_2 concentration of 500 ppb for each simulated individual).

Long-term multi-day activity patterns can be estimated from single days by combining the daily records in various ways, and the method used for combining them will influence the variability of the long-term activity patterns across the simulated population. This in turn will influence the ability of the model to accurately represent either long-term average high-end exposures, or the number of individuals exposed multiple times to short-term high-end concentrations.

An algorithm has been developed and incorporated into APEX to represent the day-to-day correlation of activities for individuals, used most recently in the NO_2 NAAQS Review (EPA, 2008). The algorithms first use cluster analysis to divide the daily activity pattern records into groups that are similar, and then select a single daily record from each group. This limited number of daily patterns is then used to construct a long-term sequence for a simulated individual, based on empirically-derived transition probabilities. This approach is intermediate between the assumption of no day-to-day correlation (i.e., re-selection of diaries for each time period) and perfect correlation (i.e., selection of a single daily record to represent all days). Further details regarding the Cluster-Markov algorithm and supporting evaluations are provided in Appendix F of the draft NO_2 TSD (EPA, 2008).

7.7 CALCULATING MICROENVIRONMENTAL CONCENTRATIONS

7.7.1 Overview

Probabilistic algorithms are used to estimate the pollutant concentration associated with each exposure event. The estimated pollutant concentrations account for temporal and spatial variability in ambient (outdoor) pollutant concentration and factors affecting indoor microenvironment, such as a penetration, air exchange rate, and pollutant decay or deposition rate. APEX calculates air concentrations in the various microenvironments visited by the simulated person by using the ambient air data estimated for the relevant blocks/receptors, the user-specified algorithm, and input parameters specific to each microenvironment. The method used by APEX to estimate the microenvironment depends on the microenvironment, the data available for input to the algorithm, and the estimation method selected by the user. At this time, APEX calculates hourly concentrations in all the microenvironments at each hour of the simulation for each of the simulated individuals using one of two methods: by mass balance or a transfer factors method.

The mass balance method simulates an enclosed microenvironment as a well-mixed volume in which the air concentration is spatially uniform at any specific time. The concentration of an air pollutant in such a microenvironment is estimated using the following processes:

- Inflow of air into the microenvironment
- Outflow of air from the microenvironment
- Removal of a pollutant from the microenvironment due to deposition, filtration, and chemical degradation
- Emissions from sources of a pollutant inside the microenvironment.

A transfer factors approach is simpler than the mass balance model, however, most parameters are derived from distributions rather than single values to account for observed variability. It does not calculate concentration in a microenvironment from the concentration in the previous hour as is done by the mass balance method, and it has only two parameters. A proximity factor is used to account for proximity of the microenvironment to sources or sinks of pollution, or other systematic differences between concentrations just outside the microenvironment and the ambient concentrations (at the measurements site or modeled receptor). The second, a penetration factor, quantifies the amount of outdoor pollutant penetrates into the microenvironment.

7.7.2 Approach for Estimating 5-Minute Peak Concentrations

The 5-minute peak concentrations were estimated probabilistically considering the empirically-derived PMR CDFs developed from recent 5-minute ambient monitoring data (section 6.2). Thus for every 1-hr concentration estimated at each receptor, an associated 5-minute peak SO_2 concentration was generated.

The approach is designed to generate the maximum 5-minute SO_2 concentrations to use in evaluating exceedances of the potential health effects benchmarks. In general, it is not an objective to estimate each of the other eleven 5-minute concentrations within the hour with a high degree of certainty. While the occurrence of multiple peak concentrations is possible (section 6.5), the potential health effect benchmark levels are related to single peak exposures. The APEX model originally used 1-hr ambient SO_2 concentrations as input prior to the calculation of microenvironmental concentrations. The current APEX model now can use ambient concentrations of most any time step, downward to 5-minutes. The file size was an issue with this approach however, since each of the thousands of receptor files generated by AERMOD would be increase by a factor of twelve, creating both disk space and processing difficulties. An algorithm was incorporated into the flexible time-step APEX model to estimate the 5-minute maximum SO_2 concentrations real-time using the 1-hour SO2 concentration, an appropriate PMR (section 6.2), and equation 6-1. The additional eleven 5-minute concentrations within an hour at each receptor approximated using the following:

$$X = \frac{n\overline{C} - P}{n-1} \qquad \text{eq (7-1)}$$

where,

X = 5-minute concentration in each of non-peak concentration periods in the hour at a receptor (ppb)

$\overline{C}$ = 1-hr mean concentration estimated at a receptor (ppb)

P = estimated peak concentration at a receptor (ppb) estimated probabilistically using equation 6-1.

n = number of time steps within the hour (12)

In addition to the level of the maximum concentration, the actual time of when the contact occurs with a person is also of importance. There is no reason to expect a temporal relationship of the peak concentrations within the hour, thus clock times for peak values were estimated randomly (i.e., any one of the 12 possible time periods within the hour). The PMR assignment also assumes a standard frequency during any hour of the day.

7.7.3 Microenvironments Modeled

In APEX, microenvironments represent the exposure locations for simulated individuals. For exposures to be estimated accurately, it is important to have realistic microenvironments that match closely to the locations where actual people spend time on a daily basis. As discussed above, the two methods available in APEX for calculating pollutant levels within microenvironments are: 1) factors and 2) mass balance. A list of microenvironments used in this study, the calculation method used, and the type of parameters used to calculate the microenvironment concentrations can be found in Table 7-11.

Table 7-11. List of microenvironments modeled and calculation methods used.

Microenvironment	Calculation Method	Parameter Types used [1]
Indoors – Residence	Mass balance	AER and DE
Indoors – Bars and restaurants	Mass balance	AER and DE
Indoors – Schools	Mass balance	AER and DE
Indoors – Day-care centers	Mass balance	AER and DE
Indoors – Office	Mass balance	AER and DE
Indoors – Shopping	Mass balance	AER and DE
Indoors – Other	Mass balance	AER and DE
Outdoors – Near road	Factors	PR
Outdoors – Public garage - parking lot	Factors	PR
Outdoors – Other	Factors	None
In-vehicle – Cars and Trucks	Factors	PE and PR
In-vehicle - Mass Transit (bus, subway, train)	Factors	PE and PR

[1] AER=air exchange rate, DE=decay-deposition rate, PR=proximity factor, PE=penetration factor

7.7.4 Microenvironment Descriptions

7.7.4.1 Microenvironment 1: Indoor-Residence

The Indoor-Residence microenvironment uses several variables that affect NO_2 exposure: whether or not air conditioning is present, the average outdoor temperature, the NO_2 removal rate, and an indoor concentration source.

Air conditioning prevalence rates

Since the selection of an air exchange rate distribution is conditioned on the presence or absence of an air-conditioner, for each modeled area the air conditioning status of the residential microenvironments is simulated randomly using the probability that a residence has an air conditioner. A value of 95.5% was calculated to represent location-specific air conditioning prevalence using the data and survey weights for St. Louis, Missouri obtained from the American Housing Survey of 2003 (AHS, 2003a; 2003b).

Air exchange rates

Air exchange rate data for the indoor residential microenvironment were obtained from EPA (2007g). Briefly, data were reviewed, compiled and evaluated from the extant literature to generate location-specific AER distributions categorized by influential factors, namely temperature and presence of air conditioning. In general, lognormal distributions provided the best fit, and are defined by a geometric mean (GM) and standard deviation (GSD). To avoid unusually extreme simulated AER values, bounds of 0.1 and 10 were selected for minimum and maximum AER, respectively.

There are no AER data available that are specific for Missouri, therefore a distribution was selected from the study locations thought to have similar characteristics to the city to be modeled, qualitatively considering factors that might influence AERs. These factors include the age composition of housing stock, construction methods, and other meteorological variables not explicitly treated in the analysis, such as humidity and wind speed patterns. The AER distributions used for each of the modeling domains are provided in Table 7-12.

Table 7-12. Geometric means (GM) and standard deviations (GSD) for air exchange rates by A/C type and temperature range.

Area Modeled	Derived Location	A/C Type	Temp (ºC)	N	GM	GSD
Missouri (No A/C)	Areas Outside California	Central or Room A/C	<=10	179	0.9185	1.8589
			10-20	338	0.5636	1.9396
			20-25	253	0.4676	2.2011
			25-30	219	0.4235	2.0373
			>30	24	0.5667	1.9447
		No A/C	<=10	61	0.9258	2.0836
			10-20	87	0.7333	2.3299
			>20	44	1.3782	2.2757

SO_2 Removal Rate

According to (Grontoft and Raychaudhuri, 2004), the indoor decay rates depend on surface materials and relative humidity. Due to differences in morning and afternoon relative humidity in Missouri we stratified the distributions diurnally. For each time of day we estimated a lower and upper bound of a uniform distribution based on reasonable variations in the relative composition of surface materials inside homes and offices (e.g., painted wall board, wall paper, wool carpet, synthetic carpet, synthetic floor covering, cloth). Resulting estimates were as follows; morning: 4.9 – 19.8 h^{-1} and afternoon: 3.4 – 9.8 h^{-1}.

7.4.1.2 Microenvironments 2-7: All Other Indoor Microenvironments

The remaining five indoor microenvironments, which represent Bars and Restaurants, Schools, Day Care Centers, Office, Shopping, and Other environments, were all modeled using the same data and functions. As with the Indoor-Residence microenvironment, these microenvironments use both AER and removal rates to calculate exposures within the microenvironment. The air exchange rate distribution (GM = 1.109, GSD = 3.015, Min = 0.07, Max = 13.8) was developed based on an indoor air quality study (Persily et al, 2005; see EPA, 2007g for details in derivation). The decay rate is the same as used in the Indoor-Residence microenvironment discussed previously.

7.4.1.3 Microenvironments 8-10: Outdoor Microenvironments

All outdoor microenvironmental concentrations are well represented by the modeled concentrations. Therefore, both the penetration factor and proximity factor for this microenvironment were set to 1.

7.4.1.4 Microenvironments 11 and 12: In Vehicle- Cars and Trucks, and Mass Transit

There were no available measurement data for SO_2 penetration factors, therefore the penetration factors used were developed from NO_2 data provided in Chan and Chung (2003) and used in the recent NO_x NAAQS review (EPA, 2008). Inside-vehicle and outdoor NO_2 concentrations were measured with for three ventilation conditions, air-recirculation, fresh air intake, and with windows. Mean values range from about 0.6 to just over 1.0, with higher values associated with increased ventilation (i.e., window open). A uniform distribution was selected for the penetration factor for Inside-Cars/Trucks (ranging from 0.6 to 1.0) due to the limited data available to describe a more formal distribution and the lack of data available to reasonably assign potentially influential characteristics such as use of vehicle ventilation systems for each location. Mass transit systems, due to the frequent opening and closing of doors, was assigned a point estimate of 1.0 based on the reported mean values for open windows ranging from 0.96 and 1.0.

7.8 Exposure and Health Risk Calculations

APEX calculates exposure as a time-series of exposure concentrations that a simulated individual experiences during the simulation period. APEX calculates exposure by identifying concentrations in the microenvironments visited by the person according to the composite diary. In this manner, a time-series of event exposures are found. Then, the time-step exposure concentration at any clock hour during the simulation period is calculated using the following equation:

$$C_i = \frac{\sum_{j=1}^{N} C_{time-step(j)} t_{(j)}}{T}$$

where,

C_i	=	Time-step exposure concentration at clock hour *i* of the simulation period (ppm)
N	=	Number of events (i.e., microenvironments visited) in time-step *i* of the simulation period.
$C_{time-step(j)}$	=	Time-step concentration in microenvironment *j* (ppm)
$t_{(j)}$	=	Time spent in microenvironment *j* (minutes)
T	=	Length of time-step (or 5 minutes in this analysis)

From the time-step exposures, APEX calculates time-series of 1-hour, 24-hour, and annual average exposure concentrations that a simulated individual would experience during the simulation period. APEX then statistically summarizes and tabulates the 5-minute time-step (or daily, or annual average) exposures. From this, APEX can calculate two general types of exposure estimates: counts of the estimated number of people exposed to a specified SO_2 concentration level and the number of times per year that they are so exposed; the latter metric is in terms of person-occurrences or person-days. The former highlights the number of individuals exposed at least *one or more* times per modeling period to the health effect benchmark level of interest. APEX can also report counts of individuals with multiple exposures. This person-occurrences measure estimates the number of times per season that individuals are exposed to the exposure indicator of interest and then accumulates these estimates for the entire population residing in an area.

APEX tabulates and displays the two measures for exposures above levels ranging from 0 to 800 ppb by 50 ppb increments for all exposures. These results are tabulated for the population and subpopulations of interest.

To simulate just meeting the current standard, dispersion modeled concentration were not rolled-up as done in the air quality characterization. A proportional approach was used as performed in the Air Quality Characterization, but to reduce processing time, the potential health effect benchmark levels were proportionally reduced by the similar factors described for each specific location and simulated year. Since it is a proportional adjustment, the end effect of adjusting concentrations upwards versus adjusting benchmark levels downward within the model is the same. The difference in the exposure and risk modeling was that the modeled air quality concentrations were used to generate the adjustment factors. There was only one modeling domain that contained an ambient monitor for model runs completed in this draft of the exposure assessment, Greene County, Mo. (modeling domain ID 13995). Table 7-13 provides the adjustment factors used and the adjusted potential health effect benchmark concentrations to simulate just meeting the current daily standard (as derived from Table 6-4).

Table 7-13. Adjustment factors and potential health effect benchmark levels used by APEX to simulate just meeting the current daily standard in Greene County, Mo.

Simulated Year (factor)	Potential Health Effect Benchmark Level (ppb)	
	Actual	Adjusted
Greene County, Mo. 2002 (3.47)	400	115
	500	144
	600	173

7.9 EXPOSURE MODELING AND HEALTH RISK CHARACTERIZATION RESULTS

7.9.1 Introduction

Exposure results are presented for simulated asthmatic populations residing in several of the modeling domains in Missouri. Five-minute maximum SO_2 exposures were estimated within each hour of the day for year 2002. The short-term exposures evaluated for all asthmatics and asthmatic children corresponded with heightened activity levels. The number of daily maximum 5-minute exposures that were at or above any level from 0 through 800 ppb in 50 ppb increments was counted. Therefore, depending on the concentration level, an individual would have at most one exceedance of a particular level per day, or 365 per year, provided that the person was at a moderate (or higher) exertion level.

The number of exposures at or above a particular concentration level is presented in a series tables below.

7.9.2 Number of Exceedances Considering As Is Air Quality

Exposure results are presented for the as is air quality scenario using the modeled concentrations in several modeling domains in Missouri. The number of each of the concentration levels varies as expected, with decreasing numbers of persons estimated to have exposures with increasing concentration level and summarized for all modeling domains completed in this draft (Table 7-14). Considering the ¾ million persons simulated, approximately 10% of which were asthmatic, two were estimated to contain at least one exposure above the lowest potential health effect benchmark concentration of 400 ppb while at a moderate or greater exertion level, while none were estimated to be exposed above 500 ppb. Experiencing more than one 5-minute exposure per year was much less frequent. At most, only 3 persons contained at least two exposures above 200 ppb in a year. In general, the exposure results for asthmatic children were similar on a relative scale for each of the concentration levels, with only two persons experiencing exposures above 400 ppb in a year and no others with estimated exposures above 450 ppb (Table 7-15).

Table 7-14. Number of all asthmatics at moderate or greater exertion with 5-minute maximum exposures above selected exposure concentrations, all Missouri modeled domains combined, as is air quality.

Exposure Level (ppb)	Number of persons with indicated number of exposures above selected level					
	1	2	3	4	5	6
0	70579	69972	69479	68958	68526	68153
50	2311	613	269	155	111	74
100	839	145	61	19	8	3
150	278	15	5	0	0	0
200	87	3	0	0	0	0
250	32	0	0	0	0	0
300	15	0	0	0	0	0
350	2	0	0	0	0	0
400	2	0	0	0	0	0
450	0	0	0	0	0	0
500	0	0	0	0	0	0
550	0	0	0	0	0	0
600	0	0	0	0	0	0
650	0	0	0	0	0	0
700	0	0	0	0	0	0
750	0	0	0	0	0	0
800	0	0	0	0	0	0

Table 7-15. Number of asthmatic children at moderate or greater exertion with 5-minute maximum exposures above selected exposure concentrations, all Missouri modeled domains combined, as is air quality.

Exposure Level (ppb)	Number of persons with indicated number of exposures above selected level					
	1	2	3	4	5	6
0	24984	24984	24982	24979	24977	24974
50	1627	468	218	127	99	70
100	585	112	51	17	8	3
150	209	15	5	0	0	0
200	66	3	0	0	0	0
250	25	0	0	0	0	0
300	13	0	0	0	0	0
350	2	0	0	0	0	0
400	2	0	0	0	0	0
450	0	0	0	0	0	0
500	0	0	0	0	0	0
550	0	0	0	0	0	0
600	0	0	0	0	0	0
650	0	0	0	0	0	0
700	0	0	0	0	0	0
750	0	0	0	0	0	0
800	0	0	0	0	0	0

7.9.3 Number of Exceedances Considering Air Quality Adjusted to Just Meeting the Current Standard

Greene County, Missouri was selected for evaluating exposures associated with air quality the just meets the current daily standard. The number of estimated exceedances of each of the potential health effect benchmark levels was greater when compared with the as is air quality. Considering the total asthmatic population (adults and children), nearly 120 were estimated to contain exposures above the lowest potential health effect benchmark concentration of 400 ppb while at a moderate or greater exertion level (Table 7-16). This amounts to just under 0.5% of all asthmatics modeled, or about 43 per 100,000 of the total simulated population. In general, the exposure results for asthmatic children (Table 7-17) were slightly higher on a relative basis, with 75 individuals experiencing a single 5-minute exposure above 400 ppb in a year (approximately 0.8%).

Table 7-16. Number of all asthmatics at moderate or greater exertion with 5-minute maximum exposures above selected exposure concentrations, Greene County, Mo., air quality adjusted to just meeting the current daily standard.

Exposure Level (ppb)	Number of persons with indicated number of exposures above selected level					
	1	2	3	4	5	6
50	3683	1294	635	358	225	159
100	1274	268	135	81	69	49
150	664	124	63	38	19	16
200	458	72	36	19	11	11
250	306	52	22	16	11	8
300	209	30	13	11	5	3
350	157	21	8	5	3	0
400	119	11	3	0	0	0
450	77	8	0	0	0	0
500	49	8	0	0	0	0
550	36	5	0	0	0	0
600	22	3	0	0	0	0
650	17	3	0	0	0	0
700	11	3	0	0	0	0
800	5	0	0	0	0	0

Table 7-17. Number of asthmatic children at moderate or greater exertion with 5-minute maximum exposures above selected exposure concentrations, Greene County, Mo., air quality adjusted to just meeting the current daily standard.

Exposure Level (ppb)	Number of persons with indicated number of exposures above selected level					
	1	2	3	4	5	6
50	2437	956	510	288	190	132
100	880	201	107	66	60	41
150	453	88	55	36	16	16
200	320	50	30	16	11	11
250	209	38	19	13	11	8
300	144	24	13	11	5	3
350	100	21	8	5	3	0
400	75	11	3	0	0	0
450	47	8	0	0	0	0
500	31	8	0	0	0	0
550	19	5	0	0	0	0
600	11	3	0	0	0	0
650	11	3	0	0	0	0
700	8	3	0	0	0	0
800	3	0	0	0	0	0

7.10 UNCERTAINTY ANALYSIS

7.10.1 Introduction

The methods and the model used in this assessment conform to the most contemporary modeling methodologies available. APEX is a powerful and flexible model that allows for the realistic estimation of air pollutant exposure to individuals. Since it is based on human activity diaries and accounts for the most important variables known to affect exposure, it has the ability to effectively approximate actual conditions. In addition, the input data selected were the best available data to generate the exposure results. However, there are constraints and uncertainties with the modeling approach and the input data that limit the realism and accuracy of the model results.

All models have limitations that require the use of assumptions. Limitations of APEX lie primarily in the uncertainties associated with data distributions input to the model. Broad uncertainties and assumptions associated with these model inputs, utilization, and application include the following, with more detailed analysis summarized below and presented previously (see EPA, 2007g; Langstaff, 2007). General uncertainties include:

- The CHAD activity data used in APEX are compiled from a number of studies in different areas, and for different seasons and years. Therefore, the combined data set may not constitute a representative sample for a particular study scenario.
- Commuting pattern data were derived from the 2000 U.S. Census. The commuting data address only home-to-work travel. The population not employed outside the home is assumed to always remain in the residential census tract. Furthermore, although several of the APEX microenvironments account for time spent in travel, the travel is assumed to always occur in basically a composite of the home and work block. No other provision is made for the possibility of passing through other blocks during travel.
- APEX creates seasonal or annual sequences of daily activities for a simulated individual by sampling human activity data from more than one subject. Each simulated person essentially becomes a composite of several actual people in the underlying activity data.

- The APEX model currently does not capture certain correlations among human activities that can impact microenvironmental concentrations (for example, cigarette smoking leading to an individual opening a window, which in turn affects the amount of outdoor air penetrating the microenvironment).
- Certain aspects of the personal profiles are held constant, though in reality they change as individuals age. This is only important for simulations with long timeframes, particularly when simulating young children (e.g., over a year or more).
- The estimation of 5-minute SO_2 concentrations from 1-hour SO_2 concentrations considers ambient monitor concentration variability and hourly concentration levels. The air quality characterization indicated that the approach is reasonably accurate and precise when applied to where 5-minute measurements were available. However, the level of uncertainty in the use of the statistical model to estimate 5-minute SO_2 concentrations at each modeled receptor is dependent on the particular sources affecting each, information that is largely unknown.

7.10.2 Input Data Evaluation

Modeling results are heavily dependent on the quality of the data that are input to the system. The input data used in this assessment were selected to best simulate actual conditions that affect human exposure. Using well characterized data as inputs to the model lessens the degree of uncertainty in exposure estimates. Still, the limitations and uncertainties of each of the data streams affect the overall quality of the model output. These issues and how they specifically affect each data stream are discussed this section.

7.10.2.1 Meteorological Data

Meteorological data are taken directly from monitoring stations within the modeling domains. One strength of these data is that it is relatively easy to see significant errors if they appear in the data. Because general climactic conditions are known for each area simulation, it would have been apparent upon review if there were outliers in the dataset. Although APEX only uses one temperature value per day and does not represent minute-to-minute variations in meteorological conditions throughout the day, this likely would not affect SO_2 exposure estimates within microenvironments.

7.10.2.2 Air Quality Data

Air quality data used in the exposure modeling was determined through use of EPA's recommended regulatory air dispersion model, AERMOD (version 07026), with meteorological data discussed above and emissions data based on the EPA's National Emissions Inventory for 2002 and the CAMD Emissions Database for stationary sources and mobile sources determined from local travel demand modeling and EPA's MOBILE6.2 emission factor model. All of these are high quality data sources. Parameterization of meteorology and emissions in the model were made in as accurate a manner as possible to ensure best representation of air quality for exposure modeling. For some of the domains, minor source emissions were not included in the dispersion modeling. This occurred at several of the modeling domains, some of which contained ambient monitoring data. Where ambient monitoring was available, there was good agreement between the distribution of 1-hour modeled SO_2 concentrations and 1-hour measurement data. This suggests the approach for using only the major point source emissions provides a reasonable approximation of the 1-hour SO_2 concentrations at each receptor.

Additional uncertainties associated with the air quality data used for the development of the PMRs used in estimating 5-minute maximum SO_2 concentrations in the exposure modeling are discussed in section 6.5. These include potential effects from changes in source-types over time and for different geographic locations, in addition to the potential for multiple occurrences of peak concentrations within an hour rather than the single occurrence that was modeled here. One additional uncertainty in the 5-minute maximum SO_2 concentration estimation that remains largely unknown is in the application of the PMRs to the 1-hour SO_2 concentrations at each receptor. While SO_2 concentrations were estimated at each receptor considering the contribution from multiple sources (if multiple sources were present), the calculation does not account for a 5-minute SO_2 concentration profile from each source. Therefore, a calculation using the total 1-hour receptor concentrations would likely overestimate 5-minute maximum SO_2 concentrations where multiple source emissions are present.

7.10.2.3 Population and Commuting Data

The population and commuting data are drawn from U.S. Census data from the year 2000. This is a high quality data source for nationwide population data in the U.S. However, the data do have limitations. The Census used random sampling techniques instead of attempting to reach all households in the U.S., as it has in the past. While the sampling techniques are well established and trusted, they introduce some uncertainty to the system. The Census has a quality section (http://www.census.gov/quality/) that discusses these and other issues with Census data.

In addition to these data quality issues, certain simplifying assumptions were made in order to better match reality or to make the data match APEX input specifications. For example, the APEX dataset does not differentiate people that work at home from those that commute within their home tract, and individuals that commute over 120 km a day were assumed to not commute daily. In addition to emphasizing some of the limitations of the input data, these assumptions introduce uncertainty to the results.

Furthermore, the estimation of block-to-block commuter flows relied on the assumption that the frequency of commuting to a workplace block within a tract is proportional to the amount of commercial and industrial land in the block. This assumption introduces additional uncertainty.

7.10.2.4 Activity Pattern Data

It is probable that the CHAD data used in the system is the most subject to limitations and uncertainty of all the data used in the system. Much of the data used to generate the daily diaries are over 20 years old. Table 7-10 indicates the ages of the CHAD diaries used in this modeling analysis. While the specifics of people's daily activities may not have changed much over the years, it is certainly possible that some differences do exist. In addition, the CHAD data are taken from numerous surveys that were performed for different purposes. Some of these surveys collected only a single diary-day while others went on for several days. Some of the studies were designed to not be representative of the U.S. population, although a most of the data are from National surveys. Furthermore, study collection periods occur at different times of the year, possibly resulting in seasonal differences. A few of these limitations are corrected by the approaches used in the exposure modeling (e.g., weighting by US population demographics for a particular location, adjusting for effects of temperature on human activities).

A sensitivity analysis was performed to evaluate the impact of the activity pattern database on APEX model results for O_3 (see Langstaff (2007) and EPA (2007d)). Briefly, exposure results were generated using APEX with all of the CHAD diaries and compared with results generated from running APEX using only the CHAD diaries from the National Human Activity Pattern Study (NHAPS), a nationally representative study in CHAD. There was very good agreement between the APEX results for the 12 cities evaluated, whether all of CHAD or only the NHAPS component of CHAD is used. The absolute difference in percent of persons above a particular concentration level ranged from -1% to about 4%, indicating that the exposure model results are not being overly influenced by any single study in CHAD. It is likely that similar results would be obtained here for SO_2 exposures, although remains uncertain due to different averaging times (5-minute vs. 8-hour average).

7.10.2.5 Air Exchange Rates

There are several components of uncertainty in the residential air exchange rate distributions used for this analysis. EPA (2007g) details an analysis of uncertainty due to extrapolation of air exchange rate distributions between-CMSAs and within-CMSA uncertainty due to sampling variation. In addition, the uncertainty associated with estimating daily air exchange rate distributions from air exchange rate measurements with varying averaging times were discussed. The results of those earlier investigations indicate the exposure model results are sensitive to variability in air exchange rates, particularly noting the significant influence of city location (or variability between different cities), while the within-location variability was determined not to be overly influential.

7.10.2.6 Air Conditioning Prevalence

Because the selection of an air exchange rate distribution is conditioned on the presence or absence of an air-conditioner, for each modeled area, the air conditioning status of the residential microenvironments was simulated randomly using the probability that a residence has an air conditioner, i.e., the residential air conditioner prevalence rate. For this study we used location-specific data from the American Housing Survey of 2003. EPA (2007d) details the specification of uncertainty estimates in the form of confidence intervals for the air conditioner prevalence rate, and compares these with prevalence rates and confidence intervals developed from the Energy Information Administration's Residential Energy Consumption Survey (RECS) of 2001 for more aggregate geographic subdivision (e.g., states, multi-state Census divisions and regions). Reported standard error on the mean estimate of 95.5% for St. Louis is relatively small, at just under 1.7%. The corresponding upper and lower 95% confidence interval is also small and ranges from approximately 92.3% to 98.8%. The RECS prevalence estimate for Census Divisions was 92% (ranging between 86.4% and 98.4%), while the Census Region prevalence estimate was 83.6% (ranging between 80.0% and 87.2%). This suggests that the air conditioning prevalence used, while likely being representative of a city in Missouri, may be overestimated for non-urban locations. The overall impact on the results generated here is minimal, since the exposure events are most likely to occur outdoors.

8.0 HEALTH RISK ASSESSMENT FOR LUNG FUNCTION RESPONSES IN ASTHMATICS ASSOCIATED WITH 5-MINUTE PEAK EXPOSURES

8.1 INTRODUTION

In the previous review, it was clearly established that subjects with asthma are more sensitive to the respiratory effects of SO_2 exposure than healthy individuals (draft ISA, section 3.1.3.2). As discussed above in section 4.2, asthmatics exposed to SO_2 concentrations as low as 0.4-0.6 ppm for 5-10 minutes during exercise have been shown to experience significant bronchoconstriction, measured as an increase in sRaw (≥100%) or decrease in FEV_1 (≥15%) after correction for exercise-induced responses in clean air. These studies exposed asthmatic volunteers to SO_2 in the absence of other pollutants that often confound associations in the epidemiological literature. Therefore, these controlled human exposure studies provide direct evidence of a causal relationship between exposure to SO_2 and respiratory health effects. Staff judges the controlled human exposure evidence presented in the ISA with respect to lung function effects in exercising asthmatic subjects as providing an appropriate basis for conducting a quantitative risk assessment for this health endpoint and exposure scenario.

A brief description of the approach that EPA plans to use to conduct this health risk assessment is presented below. We plan to include a more detailed description of the approach used and results of this risk assessment in the second draft REA document and in a technical support document. The goals of this SO_2 risk assessment are: (1) to develop health risk estimates of the number and percent of the asthmatic population that would experience moderate or greater lung function decrements in response to 5-minute daily maximum peak exposures while engaged in moderate or greater exertion for several air quality scenarios (described below); (2) to develop a better understanding of the influence of various inputs and assumptions on the risk estimates; and (3) to gain insights into the risk levels and patterns of risk reductions associated with meeting alternative SO_2 standards. EPA will estimate health risks for the following three scenarios: (1) recent ambient levels of SO_2, (2) air quality adjusted to simulate just meeting the current 24-hour standard, and (3) air quality adjusted to simulate just meeting several alternative 1-hour standards. As discussed in Chapter 7, the initial geographic scope of the assessment includes selected locations encompassing a variety of SO_2 emission source types in the state of

Missouri. The second draft REA document also will evaluate exposures in the remainder of Missouri and we also are currently planning to include areas of Pennsylvania, West Virginia, and other locations with large SO_2 emission sources.

8.2 DEVELOPMENT OF APPROACH FOR 5-MINUTE LUNG FUNCTION RISK ASSESSMENT

The proposed risk assessment is based on the health effects information evaluated in the draft ISA and discussed above in Chapter 4. The basic structure of the risk assessment reflects the fact that we have available controlled human exposure study data from several studies involving volunteer asthmatic subjects who were exposed to SO_2 concentrations at specified exposure levels while engaged in moderate or greater exertion for 5- or 10-minute exposures. As discussed in the draft ISA (section 3.1.3.5), among asthmatics, both the magnitude of SO_2-induced lung function decrements and the percent of individuals affected have been shown to increase with increasing 5- to 10-minute SO_2 exposures in the range of 0.2 to 1.0 ppm. Therefore, for the SO_2 lung function risk assessment we will be developing probabilistic *exposure-response* relationships based on these data. The analysis will be of the combined data set consisting of all available individual data that describe the relationship between a measure of personal exposure to SO_2 and measures of lung function recorded in these studies. For the purposes of this risk assessment, all of the individual data, including both 5- and 10-minute exposure duration, will be combined and treated as representing 5-minute responses. These probabilistic exposure-response relationships will be combined with 5-minute daily maximum peak exposure estimates for mild and moderate asthmatics engaged in moderate or greater exertion associated with the various air quality scenarios mentioned above. A more detailed description of the exposure assessment that will be the source of the estimated daily maximum 5-minute peak exposures under moderate or greater exertion is provided above in Chapter 7.

8.2.1 General Approach

The major components of the lung function health risk assessment are illustrated in Figure 8-1. As shown in Figure 8-1, under the lung function risk assessment, exposure estimates for mild and moderate asthmatics for a number of different air quality scenarios (i.e., recent year of air quality, just meeting the current 24-hour standard, just meeting

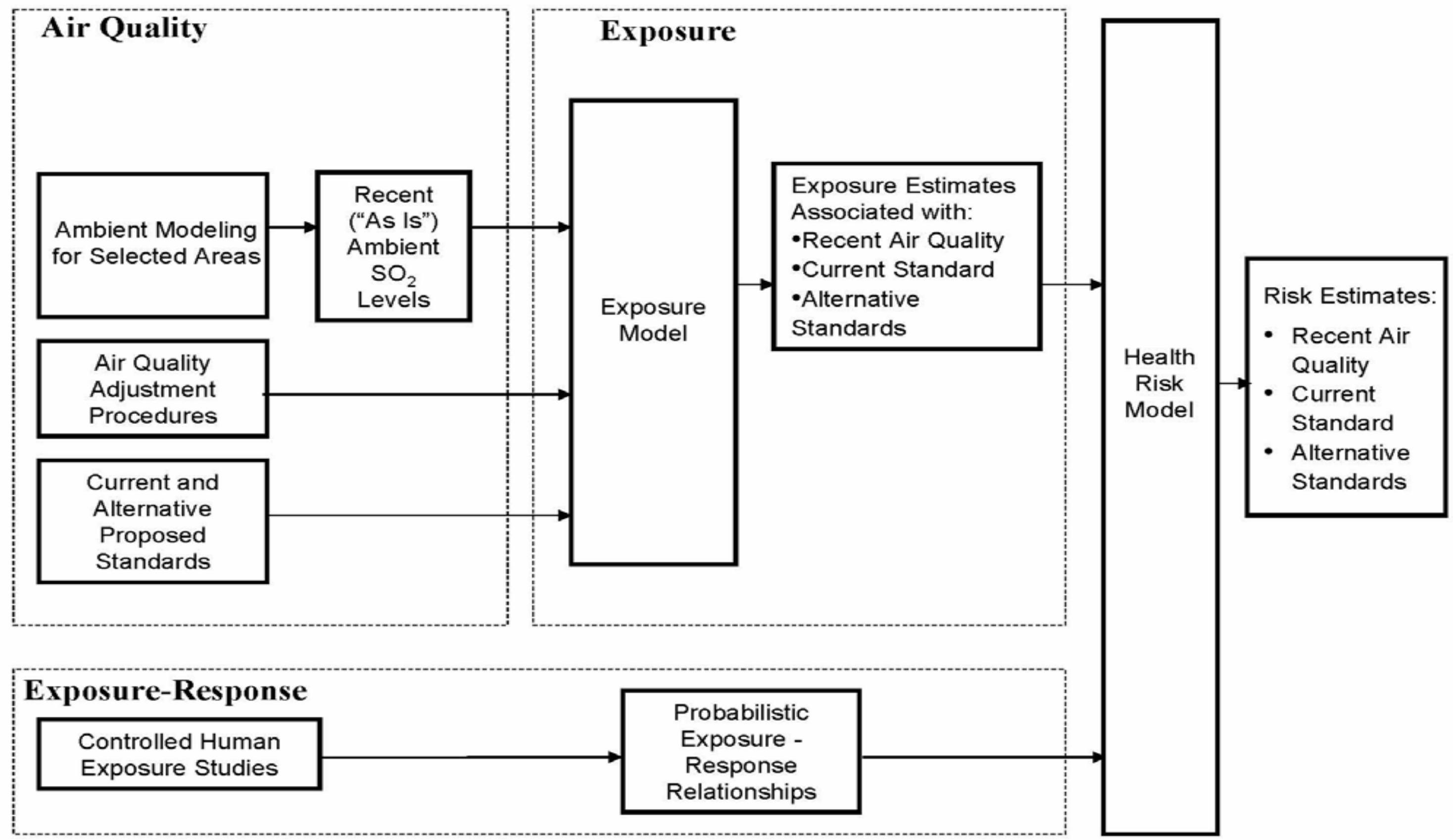

Figure 8-1. Major Components of 5-Minute Peak Lung Function Health Risk Assessment Based on Controlled Human Exposure Studies

alternative standards) will be combined with probabilistic exposure-response relationships derived from a combined data base consisting of data from several controlled human exposure studies to develop risk estimates. The air quality and exposure analysis components that are integral to this risk assessment are discussed in greater detail in Chapter 7, and only the aspects affecting the scope of the assessment are briefly discussed in section 8.2.2. A brief description of the overall approach to estimating the exposure-response relationship is addressed in section 8.2.3 below.

8.2.2 Exposure Estimates

As noted above, exposure estimates used in the lung function risk assessment will be obtained from running the APEX exposure model asthmatic individuals for selected locations encompassing a variety of SO_2 emission source types in the state of Missouri. The second draft REA document also will evaluate exposures in the remainder of Missouri and we also are currently planning to include areas of Pennsylvania, West Virginia, and other locations with large SO_2 emission sources. Chapter 7 provides additional details about the inputs and methodology used to estimate 5-minute daily maximum peak exposures for the asthmatic population. Exposure estimates for asthmatic children and adult asthmatics will be combined separately with probabilistic exposure-response relationships for lung function response associated with 5-minute daily maximum peak exposures while engaged in moderate or greater exertion. Only the highest 5-minute peak exposure (with moderate or greater exertion) on each day will be considered in the lung function risk assessment, since the controlled human exposure studies have shown an acute-phase response that was followed by a short refractory period where the individual was relatively insensitive to additional SO_2 challenges.

8.2.3 Exposure-Response Functions

Similar to the approach used in the ozone lung function risk assessment (Abt Associates, 2007), we plan to use a Bayesian Markov Chain Monte Carlo approach to estimate probabilistic exposure-response relationships for lung function decrements associated with 5-minute daily maximum peak exposures while engaged in moderate or greater exertion using the WinBUGS software (Spiegelhalter et al., 1996).[29] The combined data set includes all available individual data from controlled human exposure studies of mild-to-moderate asthmatic individuals exposed

[29] See Gleman et al. (1995) or Gilks et al. (1996) for an explanation of these methods.

Table 8-1. Percentage of Asthmatic Individuals in Controlled Human Exposure Studies Experiencing SO_2-Induced Decrements in Lung Function.

SO_2 Level (PPM)	Exposure Duration	No. of Subjects	Ventilation (L/min)	Lung Funct.	Cumulative Percentage of Responders (Number of Subjects)[1]			Reference	Respiratory Symptoms: Supporting Studies
					sRaw ≥ 100% ↑ / FEV1 ≥ 15% ↓	sRaw ≥ 200% ↑ / FEV1 ≥ 20% ↓	sRaw ≥ 300% ↑ / FEV1 ≥ 30% ↓		
0.2	10 min	40	~40	sRaw	5% (2)	0	0	Linn et al. (1987)[2]	Some evidence of SO_2-induced increases in respiratory symptoms in the most sensitive individuals: Linn et al. (1983; 1984; 1987; 1988; 1990), Schacter et al. (1984)
	10 min	40	~40	FEV_1	13% (5)	5% (2)	3% (1)	Linn et al. (1987)	
0.25	5 min	19	~50-60	sRaw	32% (6)	16% (3)	0	Bethel et al. (1985)	
	5 min	9	~80-90	sRaw	22% (2)	0	0		
	10 min	28	~40	sRaw	4% (1)	0	0	Roger et al. (1985)	
0.3	10 min	20	~50	sRaw	10% (2)	5% (1)	5% (1)	Linn et al. (1988)[3]	
	10 min	21	~50	sRaw	33% (7)	10% (2)	0	Linn et al. (1990)[3]	
	10 min	20	~50	FEV_1	15% (3)	0	0	Linn et al. (1988)	
	10 min	21	~50	FEV_1	24% (5)	14% (3)	10% (2)	Linn et al. (1990)	
0.4	10 min	40	~40	sRaw	23% (9)	8% (3)	3% (1)	Linn et al. (1987)	Stronger evidence with some statistically significant increases in respiratory symptoms: Balmes et al. (1987)[4], Gong et al. (1995), Linn et al. (1983; 1987), Roger et al. (1985)
	10 min	40	~40	FEV_1	30% (12)	23% (9)	13% (5)	Linn et al. (1987)	
0.5	5 min	10	~50-60	sRaw	60% (6)	40% (4)	20% (2)	Bethel et al. (1983)	
	10 min	28	~40	sRaw	21% (6)	4% (1)	4% (1)	Roger et al. (1985)	
	10 min	45	~30	sRaw	36% (16)	16% (7)	13% (6)	Magnussen et al. (1990)[4]	

SO_2 Level (PPM)	Exposure Duration	No. of Subjects	Ventilation (L/min)	Lung Funct.	Cumulative Percentage of Responders (Number of Subjects)[1]			Reference	Respiratory Symptoms: Supporting Studies
					sRaw				
					≥ 100% ↑	≥ 200% ↑	≥ 300% ↑		
					FEV_1				
					≥ 15% ↓	≥ 20% ↓	≥ 30% ↓		
0.6	10 min	40	~40	sRaw	35% (14)	28% (11)	18% (7)	Linn et al. (1987)	Clear and consistent increases in SO_2-induced respiratory symptoms: Linn et al.(1984; 1987; 1988; 1990), Gong et al. (1995), Horstman et al. (1988)
	10 min	20	~50	sRaw	60% (12)	35% (7)	10% (2)	Linn et al. (1988)	
	10 min	21	~50	sRaw	57% (12)	33% (7)	14% (3)	Linn et al. (1990)	
	10 min	40	~40	FEV_1	53% (21)	45% (18)	20% (8)	Linn et al. (1987)	
	10 min	20	~50	FEV_1	55% (11)	55% (11)	5% (1)	Linn et al. (1988)	
	10 min	21	~50	FEV_1	45% (9)	35% (7)	19% (4)	Linn et al. (1990)	
1.0	10 min	28	~40	sRaw	54% (15)	25% (7)	14% (4)	Roger et al. (1985)	
	10 min	10	~40	sRaw	60% (6)	20% (2)	0	Kehrl et al. (1987)	

[1]Data presented from all references from which individual data were available. Percentage of individuals who experienced greater than or equal to a 100, 200, or 300% increase in specific airway resistance (sRaw), or a 15, 20, or 30% decrease in FEV_1. Lung function decrements are adjusted for effects of exercise in clean air.
[2]Responses of mild and moderate asthmatics reported in Linn et al. (1987) have been combined.
[3]Analysis includes data from only mild (1988) and moderate (1990) asthmatics who were not receiving supplemental medication.
[4]Indicates studies in which exposures were conducted using a mouthpiece rather than a chamber.

Source: Draft ISA, Table 3-1 (EPA, 2008).

for 5- or 10-minutes while engaged in moderate or greater exertion. As noted above, for the purposes of this risk assessment, all of the individual data, including both 5- and 10-minute exposure duration, will be combined and treated as representing 5-minute responses. Table 8-1 summarizes the available controlled human exposure data that will be used to develop the probabilistic exposure-response relationships for the lung function risk assessment. Consistent with the way the responses are reported in this table, the risk assessment will be based on responses that have been corrected for the effect of exercise in clean air to remove any bias that might be present in the data attributable to an exercise effect.

8.2.4 Characterizing Uncertainty and Variability

An important issue associated with any population health risk assessment is the characterization of uncertainty and variability. *Uncertainty* refers to the lack of knowledge regarding both the actual values of model input variables (parameter uncertainty) and the physical systems or relationships (model uncertainty – e.g., the shapes of exposure-response functions). In any risk assessment, uncertainty is, ideally, reduced to the maximum extent possible, but significant uncertainty often remains. It can be reduced by improved measurement and improved model formulation. In addition, the degree of uncertainty can be characterized, sometimes quantitatively. *Variability* refers to the heterogeneity in a population or variable of interest that is inherent and cannot be reduced through further research.

Our approach to characterizing uncertainty includes both qualitative and quantitative elements. From a quantitative perspective, the statistical uncertainty surrounding the estimated SO_2 exposure-response relationships due to sampling error will be reflected in the credible intervals that will be provided for the risk estimates in the second draft REA document. We also will consider whether sensitivity analyses are appropriate to address possible alternative functional forms to represent the shape of the exposure-response relationships.

In addition to uncertainties arising from sampling variability considerations and alternative model forms, there are other uncertainties associated with the use of the exposure-response relationships for lung function responses which will be addressed qualitatively. These additional uncertainties include:

- Length of exposure. The 5-minute lung function risk estimates are based on a combined data set from several controlled human exposure studies, most of which evaluated responses associated with 10-minute exposures. However, since some studies which evaluated responses after 5-minute exposures found responses occurring as early as 5-minutes after exposure, we are using all of the 5- and 10-minute exposure data to represent responses associated with 5-minute exposures. We do not believe that this approach would appreciably impact the risk estimates.

- Exposure-response for mild/moderate asthmatics. The data set that is being used to estimate exposure-response relationships included mild and/or moderate asthmatics. There is uncertainty with regard to how well the population of mild and moderate asthmatics included in the series of controlled human exposure studies represent the distribution of mild and moderate asthmatics in the U.S. population.

- Extrapolation of exposure-response relationships. It will be necessary to estimate responses at SO_2 levels below the lowest exposure levels used in the controlled human exposure studies (i.e., below 0.2 ppm).

- Reproducibility of SO_2-induced response. The risk assessment will assume that the SO_2-induced responses for individuals are reproducible.

- Age and lung function response. Because the vast majority of controlled human exposure studies investigating lung function responses were conducted with adult subjects, the risk assessment will rely on data from adult asthmatic subjects to estimate exposure-response relationships that will be applied to all asthmatic individuals, including children. The draft ISA (section 3.1.3.5) indicates that there is a strong body of evidence that suggests adolescents may experience many of the same respiratory effects at similar SO_2 levels, but recognizes that these studies administered SO_2 via inhalation through a mouthpiece rather than an exposure chamber. This technique bypasses nasal aborption of SO_2 and can result in an increase in lung SO_2 uptake. Therefore, the uncertainty will be greater in the risk estimates for asthmatic children.

- Exposure history. The risk assessment will assume that the SO_2-induced response on any given day is independent of previous SO_2 exposures.

- Interaction between SO_2 and other pollutants. Because the controlled human exposure studies that will be used in the risk assessment involved only SO_2 exposures, it will be assumed that estimates of SO_2-induced health responses would not be affected by the presence of other pollutants (e.g., $PM_{2.5}$, O_3, NO_2).

With respect to variability, the lung function risk assessment will incorporate some of the variability in key inputs to the analysis by its use of location-specific inputs for the exposure analysis (e.g., location specific population data, air exchange rates, air quality, and temperature data). The extent to which there may be variability in exposure-response relationships for the populations included in the risk assessment residing in different geographic areas is currently unknown. Temporal variability also is more difficult to address, because the risk assessment focuses on some unspecified time in the future. To minimize the degree to which values of inputs to the analysis may be different from the values of those inputs at that unspecified time, we plan to use the most current inputs available.

9.0 RISK CHACTERIZATION FOR SHORT-TERM (≥1 HOUR, GENERALLY 24-HOUR) SO_2 EXPOSURES

9.1 OVERVIEW

As previously mentioned, the draft ISA concludes that the overall weight of the evidence supports a causal relationship between short-term SO_2 exposure and respiratory morbidity. The ISA bases this conclusion on the consistency, coherence, and plausibility of findings observed in controlled human exposure studies examining SO_2 exposures of 5-10 minutes for mild to moderate asthmatics, epidemiological studies mostly using 24-hour average exposures, and animal toxicological studies using exposures of minutes to hours (draft ISA, section 5.2). Moreover, within the broader category of respiratory morbidity, the draft ISA finds an association between short-term SO_2 exposure and respiratory symptoms in children, as well as a suggestive association between SO_2 exposure and hospital admissions and ED visits for all respiratory causes and asthma (draft ISA, section 3.1.4). Supporting evidence for an association between short-term SO_2 exposure and overall respiratory morbidity is found in epidemiological studies examining other respiratory morbidity endpoints (e.g. respiratory illness-related absences), but the overall breadth of the evidence for these endpoints is judged by staff to be too limited to use as a basis for a quantitative risk assessment. However, we do plan to use results from these studies as supporting evidence in the decision making process.

It is important to note that the conclusions stated above are based primarily on the strength of both U.S and international epidemiological literature, but for purposes of potentially conducting a quantitative risk assessment for locations in the U.S., staff recommends primarily relying on U.S. studies. Taking this into account, we reviewed the available epidemiological literature and found relatively few studies that focused on the association between short-term SO_2 exposures and respiratory symptoms or ED visits and hospital admissions for all respiratory causes or asthma, were conducted in U.S. cities. In those cities where epidemiological studies had been conducted, many of the SO_2 effect estimates were positive, but not statistically significant in single pollutant models. Moreover, in the relatively few studies that employed multi-pollutant models, inclusion of PM_{10} in the model often resulted in a loss of statistical significance for the SO_2 effect estimate. Results from the Harvard Six Cities Study (Schwartz et al. 1994) also suggested that the respiratory effects of SO_2 could be confounded by PM_{10}; in this study, there was a significant attenuation of the SO_2 effect estimate after including PM_{10} in a two-pollutant model examining respiratory symptoms (draft ISA; section 3.1.4.1.1). Similarly, after inclusion of PM_{10} in a two-pollutant model with SO_2, a significant attenuation of the SO_2 effect estimate was found in a hospital admissions study in Tacoma, WA; although, it should be noted that in the same study, results in New Haven, CT remained positive and statistically significant in a two-pollutant model with PM_{10} (Schwartz et al. 1995; draft ISA, Figure 3-8). Staff also found that very few U.S. studies examined SO_2 in a multi-pollutant model with $PM_{2.5}$, and we believe that this is an important uncertainty given the relationship between SO_2 and particulate sulfates. Overall, we conclude that these factors would make it particularly difficult to quantify with confidence the unique contribution of SO_2 to respiratory health effects and therefore, we judge that the results of a quantitative risk assessment based on concentration-response functions from epidemiological studies for these health outcomes would be highly uncertain and of limited utility in the decision-making process.

However, even though we do not believe that the body of U.S. epidemiological literature is robust enough to support a quantitative assessment of risk, we do agree that the results of these studies suggest an association between SO_2 exposure and respiratory symptoms in children, and hospital admissions and ED visits for all respiratory causes and asthma, and as a result, warrant a characterization of risk. Therefore, the overall goal of this chapter will ultimately be to qualitatively assess whether specific SO_2 air quality statistics correlate with the observed health effects reported in these epidemiological studies. The results of these analyses will not be available until the 2nd draft of this document; therefore this chapter will focus on the methods that will be employed.

9.2 APPROACH

Staff sent a request to those authors of U.S. and Canadian epidemiological studies that were identified in Table 5-4 of the draft ISA as providing important information about the association between SO_2 exposure and respiratory symptoms in children, and SO_2 exposure and ED visits and hospital admissions for all respiratory causes and asthma in all age groups. We specifically requested the 98th and 99th percentile air quality statistics from the monitor recording the highest value for the averaging times (3-hour average, 12-hour average, 24-hour average, or 1-hour max) examined in their particular studies. Alternatively, if the authors found it more convenient, we gave them the option of either providing their entire study data set, or the specific study periods and monitor IDs used in their analyses. In these instances, EPA staff would calculate the 98th and 99th percentile statistics from the author's data set directly, or retrieved the relevant data from AQS and performed the necessary calculations.

Staff specifically requested information on the 98th and 99th percentile statistics to assess whether the health effects observed in epidemiological studies are being driven by exposure to short-term peaks of SO_2. As described previously in this document (section 4.2), there is strong controlled human exposure evidence demonstrating that exposure to peak SO_2 concentrations can result in adverse effects on the respiratory system (section 4.2). In characterizing this potential risk, we will first assess whether there is a correlation between 98th or 99th percentile SO_2 concentrations and the magnitude of the effect estimates observed in epidemiological studies. Next, we will qualitatively assess whether there is a correlation between these percentile values of SO_2 and the statistical significance of U.S. and Canadian epidemiological results. Staff will also compare these air quality statistics to current air quality, and air quality adjusted to simulate just meeting the current 24-hour standard to estimate the number of times these values are exceeded under these air quality scenarios. Once completed, we will then use the results of these analyses to inform decisions on which potential alternative SO_2 standards should be analyzed. Finally, these air quality statistics will be compared to air quality levels adjusted to simulate just meeting any potential alternative standards to estimate whether these 98th or 99th percentile values would be exceeded under these alternative standard air quality scenarios.

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APPENDIX A: AMBIENT MONITORING SITE CHARACTERIZATION

This appendix contains supplementary information on the SO_2 ambient monitoring data used in the air quality characterization described in Chapter 6 of this document. Included in this appendix are spatial and temporal attributes important for understanding the relationship between the ambient monitor and those sources affecting air quality measurements. In section A-1, important spatial characteristics described include the physical locations of the ambient monitors (e.g., U.S. states, counties, territories, and cities). Temporal attributes of interest include, for example, the number of samples collected, sample averaging times, and years of monitoring data available. Attributes of the monitors that measured both the 5-minute maximum and the 1-hour SO_2 concentrations are provided in Table A-1, while the supplemental characteristics of the 1-hour SO_2 monitors used is given in Table A-2. The method for calculating the proximity of the ambient monitors follows, along with the results summarized in Tables A-3 and A-4. In addition, Table A-5 summarizes the validity criteria used to selecting valid ambient monitoring data for comparison to the NAAQS standards. Section A-2 details the analyses performed on simultaneous measurements at co-located monitors.

A.1 SPATIAL AND TEMPORAL ATTRIBUTES OF AMBIENT SO_2 MONITORS

Table A-1. General site attributes of ambient monitors measuring 5-minute maximum and corresponding 1-hour SO_2 concentrations.

State	County	Monitor ID	Latitude	Longitude	Years		
					First	Last	n
AR	Pulaski	051190007	34.756111	-92.275833	2002	2007	6
AR	Pulaski	051191002	34.830556	-92.259444	1997	2001	5
AR	Union	051390006	33.215	-92.668889	1997	2007	11
CO	Denver	080310002	39.75119	-104.98762	1997	2006	10
DE	New Castle	100031008	39.577778	-75.611111	1997	1998	2
DC	District of Columbia	110010041	38.897222	-76.952778	2000	2007	6
FL	Nassau	120890005	30.658333	-81.463333	2002	2005	4
IA	Cerro Gordo	190330018	43.16944	-93.202426	2001	2005	5
IA	Clinton	190450019	41.823283	-90.211982	2001	2005	5
IA	Muscatine	191390016	41.419429	-91.070975	2001	2005	5
IA	Muscatine	191390017	41.387969	-91.054504	2001	2005	5
IA	Muscatine	191390020	41.407796	-91.062646	2001	2005	5
IA	Scott	191630015	41.530011	-90.587611	2001	2005	5
IA	Van Buren	191770005	40.689167	-91.994444	2001	2004	4
IA	Van Buren	191770006	40.695078	-92.006318	2004	2005	2
IA	Woodbury	191930018	42.399444	-96.355833	2001	2002	2
LA	West Baton Rouge	221210001	30.501944	-91.209722	1997	2000	4
MO	Buchanan	290210009	39.731389	-94.8775	1997	2000	4
MO	Buchanan	290210011	39.731389	-94.868333	2000	2003	4
MO	Greene	290770026	37.128333	-93.261667	1997	2007	11
MO	Greene	290770037	37.11	-93.251944	1997	2007	11
MO	Iron	290930030	37.466389	-90.69	1997	2004	8
MO	Iron	290930031	37.519444	-90.7125	1997	2004	8
MO	Jefferson	290990004	38.2633	-90.3785	2004	2007	4
MO	Jefferson	290990014	38.267222	-90.379444	1997	2001	5
MO	Jefferson	290990017	38.252778	-90.393333	1998	2001	4
MO	Jefferson	290990018	38.297694	-90.384333	2001	2003	3
MO	Monroe	291370001	39.473056	-91.789167	1997	2007	11
MO	Pike	291630002	39.3726	-90.9144	2005	2007	3
MO	Saint Charles	291830010	38.579167	-90.841111	1997	1998	2
MO	Saint Charles	291831002	38.8725	-90.226389	1997	2000	4
MT	Yellowstone	301110066	45.788318	-108.459536	1997	2003	7
MT	Yellowstone	301110079	45.769439	-108.574292	1997	2003	4
MT	Yellowstone	301110080	45.777149	-108.47436	1997	2001	5
MT	Yellowstone	301110082	45.783889	-108.515	2001	2003	3
MT	Yellowstone	301110083	45.795278	-108.455833	1999	2003	5
MT	Yellowstone	301110084	45.831453	-108.449964	2003	2006	4
MT	Yellowstone	301112008	45.786389	-108.523056	1997	1997	1

State	County	Monitor ID	Latitude	Longitude	Years		
					First	Last	n
NC	Forsyth	370670022	36.110556	-80.226667	1997	2004	8
NC	New Hanover	371290006	34.268403	-77.956529	1999	2002	4
ND	Billings	380070002	46.8943	-103.37853	1998	2007	10
ND	Billings	380070003	46.9619	-103.356699	1997	1997	1
ND	Burke	380130002	48.9904	-102.7815	1999	2005	7
ND	Burke	380130004	48.64193	-102.4018	2003	2007	5
ND	Burleigh	380150003	46.825425	-100.76821	2005	2007	3
ND	Cass	380171003	46.910278	-96.795	1997	1998	2
ND	Cass	380171004	46.933754	-96.85535	1998	2007	10
ND	Dunn	380250003	47.3132	-102.5273	1997	2007	11
ND	McKenzie	380530002	47.5812	-103.2995	1997	2007	9
ND	McKenzie	380530104	47.575278	-103.968889	1998	2007	10
ND	McKenzie	380530111	47.605556	-104.017222	1998	2007	10
ND	Mercer	380570001	47.258853	-101.783035	1997	1999	3
ND	Mercer	380570004	47.298611	-101.766944	1999	2007	9
ND	Morton	380590002	46.84175	-100.870059	1997	2005	9
ND	Morton	380590003	46.873075	-100.905039	1998	2005	8
ND	Oliver	380650002	47.185833	-101.428056	1997	2007	11
ND	Steele	380910001	47.599703	-97.899009	1997	2000	4
ND	Williams	381050103	48.408834	-102.90765	2002	2007	6
ND	Williams	381050105	48.392644	-102.910233	2002	2007	6
PA	Allegheny	420030002	40.500556	-80.071944	1997	1999	3
PA	Allegheny	420030021	40.413611	-79.941389	1997	2002	4
PA	Allegheny	420030031	40.443333	-79.990556	1997	1999	3
PA	Allegheny	420030032	40.414444	-79.942222	1997	1999	3
PA	Allegheny	420030064	40.323611	-79.868333	1997	2002	4
PA	Allegheny	420030067	40.381944	-80.185556	1997	1999	3
PA	Allegheny	420030116	40.473611	-80.077222	1997	2002	4
PA	Allegheny	420031301	40.4025	-79.860278	1997	1999	3
PA	Allegheny	420033003	40.318056	-79.881111	1997	2002	4
PA	Allegheny	420033004	40.305	-79.888889	1997	1999	3
PA	Beaver	420070002	40.56252	-80.503948	1997	1998	2
PA	Beaver	420070005	40.684722	-80.359722	1997	2007	8
PA	Berks	420110009	40.320278	-75.926667	1997	1999	3
PA	Cambria	420210011	40.309722	-78.915	1997	1999	3
PA	Erie	420490003	42.14175	-80.038611	1997	1999	3
PA	Philadelphia	421010022	39.916667	-75.188889	1997	2001	5
PA	Philadelphia	421010048	39.991389	-75.080833	1997	1999	3
PA	Philadelphia	421010136	39.9275	-75.222778	1997	2003	7
PA	Warren	421230003	41.857222	-79.1375	1997	1998	2
PA	Warren	421230004	41.844722	-79.169722	1997	1998	2
PA	Washington	421250005	40.146667	-79.902222	1997	1999	3
PA	Washington	421250200	40.170556	-80.261389	1997	1999	3
PA	Washington	421255001	40.445278	-80.420833	1997	1998	2
SC	Barnwell	450110001	33.320344	-81.465537	2000	2002	3
SC	Charleston	450190003	32.882289	-79.977538	2000	2002	3
SC	Charleston	450190046	32.941023	-79.657187	2000	2002	3

State	County	Monitor ID	Latitude	Longitude	Years		
					First	Last	n
SC	Georgetown	450430006	33.362014	-79.294251	2000	2002	3
SC	Greenville	450450008	34.838814	-82.402918	2000	2002	3
SC	Lexington	450630008	34.051017	-81.15495	2001	2002	2
SC	Oconee	450730001	34.805261	-83.2377	2000	2002	3
SC	Richland	450790007	34.093959	-80.962304	2000	2002	3
SC	Richland	450790021	33.81468	-80.781135	2000	2002	3
SC	Richland	450791003	34.024497	-81.036248	2001	2002	2
UT	Salt Lake	490352004	40.736389	-112.210278	1997	1998	2
WV	Wayne	540990002	38.39186	-82.583923	2002	2002	1
WV	Wayne	540990003	38.390278	-82.585833	2002	2005	4
WV	Wayne	540990004	38.380278	-82.583889	2002	2005	4
WV	Wayne	540990005	38.372222	-82.588889	2002	2005	4
WV	Wood	541071002	39.323533	-81.552367	2001	2005	5

Table A-2. General site attributes of ambient monitors measuring 1-hour SO_2 concentrations.

State	County	Monitor ID	Latitude	Longitude	Years First	Years Last	Years n
AL	Colbert	010330044	34.690556	-87.821389	1997	2006	10
AL	Colbert	010331002	34.760556	-87.650556	2002	2003	2
AL	Jackson	010710020	34.876944	-85.720833	1997	2006	10
AL	Jefferson	010731003	33.485556	-86.915000	1997	2007	11
AL	Lawrence	010790003	34.589571	-87.109445	1997	2000	4
AL	Limestone	010830004	34.685702	-86.880810	2003	2004	2
AL	Mobile	010970028	30.958333	-88.028333	1997	1999	3
AL	Mobile	010972005	30.474674	-88.141140	2000	2006	7
AL	Montgomery	011011002	32.407120	-86.256367	1997	1998	2
AZ	Gila	040070009	33.399135	-110.858896	1999	2007	9
AZ	Gila	040071001	33.006179	-110.785797	1999	2007	9
AZ	Maricopa	040130019	33.483850	-112.142570	1997	1998	2
AZ	Maricopa	040133002	33.457930	-112.046010	1997	2007	11
AZ	Maricopa	040133003	33.479680	-111.917210	1997	2007	11
AZ	Maricopa	040133010	33.460930	-112.117480	1997	1999	3
AZ	Maricopa	040139997	33.503643	-112.095001	2005	2007	3
AZ	Pima	040191011	32.208333	-110.872222	1997	2007	11
AZ	Pinal	040212001	32.600479	-110.633598	1997	2007	9
AR	Miller	050910096	33.187500	-94.023889	1998	1999	2
AR	Miller	050910097	33.323055	-93.997500	1998	1999	2
AR	Miller	050910098	33.330277	-93.998055	1998	1999	2
AR	Miller	050910099	33.205833	-94.003889	1998	1999	2
AR	Pulaski	051190007	34.756111	-92.275833	2004	2004	1
AR	Pulaski	051191002	34.830556	-92.259444	1997	2001	5
AR	Pulaski	051191005	34.676268	-92.337164	2002	2002	1
AR	Union	051390006	33.215000	-92.668889	1997	2005	8
CA	Alameda	060010010	37.760300	-122.192500	2001	2003	3
CA	Contra Costa	060130002	37.936000	-122.026200	1997	2007	11
CA	Contra Costa	060130003	37.950000	-122.356111	1997	1997	1
CA	Contra Costa	060130006	37.947800	-122.365100	1997	2007	11
CA	Contra Costa	060130010	38.031300	-122.131800	2001	2003	3
CA	Contra Costa	060131001	38.055556	-122.219722	1997	2007	11
CA	Contra Costa	060131002	38.010556	-121.641389	1997	2007	11
CA	Contra Costa	060131003	37.964167	-122.339167	1997	2002	6
CA	Contra Costa	060131004	37.960280	-122.356670	2002	2007	6
CA	Contra Costa	060132001	38.013056	-122.133611	1997	2007	11
CA	Contra Costa	060133001	38.029167	-121.902222	1997	2007	11
CA	Fresno	060190008	36.781389	-119.772222	1997	1997	1
CA	Fresno	060190243	36.767220	-119.827500	2003	2003	1
CA	Fresno	060190244	36.803060	-119.769170	2003	2003	1
CA	Humboldt	060231004	40.776944	-124.177500	2007	2007	1
CA	Imperial	060250005	32.676111	-115.483333	1997	2007	11
CA	Imperial	060250006	32.677778	-115.389722	1997	1998	2
CA	Kern	060290014	35.356111	-119.040278	1997	2001	3
CA	Kern	060290232	35.438889	-119.015833	1997	1997	1
CA	Los Angeles	060370030	34.035278	-118.216667	2001	2002	2
CA	Los Angeles	060370031	33.786111	-118.246389	2001	2002	2
CA	Los Angeles	060371002	34.176050	-118.317120	1997	2007	11

State	County	Monitor ID	Latitude	Longitude	Years First	Last	n
CA	Los Angeles	060371103	34.066590	-118.226880	1997	2007	11
CA	Los Angeles	060374002	33.823760	-118.189210	1997	2007	11
CA	Los Angeles	060375001	33.922880	-118.370260	1997	2004	8
CA	Los Angeles	060375005	33.950800	-118.430430	2004	2007	4
CA	Orange	060591003	33.674640	-117.925680	1997	2007	11
CA	Riverside	060658001	33.999580	-117.416010	1997	2007	11
CA	Sacramento	060670002	38.712778	-121.380000	1997	2007	11
CA	Sacramento	060670006	38.614167	-121.366944	1997	2007	11
CA	San Bernardino	060710012	34.426111	-117.563056	1997	1998	2
CA	San Bernardino	060710014	34.512500	-117.330000	1997	1999	3
CA	San Bernardino	060710015	35.775000	-117.366667	1997	1997	1
CA	San Bernardino	060710017	34.141944	-116.055000	1997	1997	1
CA	San Bernardino	060710306	34.510000	-117.330556	2000	2007	8
CA	San Bernardino	060711234	35.763889	-117.396111	1997	2007	11
CA	San Bernardino	060712002	34.100020	-117.492010	1997	2007	11
CA	San Bernardino	060714001	34.418056	-117.284722	1997	1998	2
CA	San Diego	060730001	32.631231	-117.059075	1997	2007	11
CA	San Diego	060731007	32.709172	-117.153975	1997	2005	9
CA	San Diego	060731010	32.701492	-117.149653	2005	2007	3
CA	San Diego	060732007	32.552164	-116.937772	1997	2007	11
CA	San Francisco	060750005	37.766000	-122.399100	1997	2007	11
CA	San Francisco	060750006	37.733610	-122.383330	2004	2005	2
CA	San Luis Obispo	060791005	35.043889	-120.580278	1997	2002	6
CA	San Luis Obispo	060792001	35.125000	-120.633333	1997	2004	8
CA	San Luis Obispo	060792004	35.022222	-120.569444	1997	2007	11
CA	San Luis Obispo	060794002	35.028333	-120.387222	1998	2006	9
CA	Santa Barbara	060830008	34.462222	-120.024444	1997	2007	11
CA	Santa Barbara	060831007	34.948056	-120.434444	1997	1998	2
CA	Santa Barbara	060831012	34.451944	-120.457778	1997	1998	2
CA	Santa Barbara	060831013	34.725556	-120.427778	1997	2007	11
CA	Santa Barbara	060831015	34.478056	-120.210833	1997	1998	2
CA	Santa Barbara	060831016	34.477778	-120.205556	1997	1998	2
CA	Santa Barbara	060831019	34.475278	-120.188889	1997	1998	2
CA	Santa Barbara	060831020	34.415278	-119.878611	1997	2007	11
CA	Santa Barbara	060831025	34.489722	-120.045833	1997	2007	11
CA	Santa Barbara	060831026	34.479444	-120.032500	1997	1999	3
CA	Santa Barbara	060831027	34.469167	-120.039444	1997	1999	3
CA	Santa Barbara	060832004	34.637500	-120.456389	1997	2007	11
CA	Santa Barbara	060832011	34.445278	-119.827778	1997	2007	11
CA	Santa Barbara	060834003	34.596111	-120.630278	1997	2007	11
CA	Santa Barbara	060835001	34.780833	-120.606389	1997	1997	1
CA	Santa Cruz	060870003	37.011944	-122.193333	1997	2007	11
CA	Solano	060950001	38.052222	-122.144722	1997	1997	1
CA	Solano	060950004	38.102700	-122.238200	1997	2007	11
CA	Ventura	061113001	34.255000	-119.142500	1997	2004	8
CO	Adams	080010007	39.800000	-104.910833	2001	2004	4
CO	Adams	080013001	39.838180	-104.949840	1997	2007	11
CO	Denver	080310002	39.751190	-104.987620	1998	2007	10
CO	El Paso	080416001	38.633611	-104.715556	1997	2001	5
CO	El Paso	080416004	38.921389	-104.812500	1997	2001	5

State	County	Monitor ID	Latitude	Longitude	Years First	Years Last	Years n
CO	El Paso	080416011	38.846667	-104.827222	1997	2001	5
CO	El Paso	080416018	38.811389	-104.751389	1997	2001	5
CT	Fairfield	090010012	41.195000	-73.163333	1997	2006	10
CT	Fairfield	090010017	41.003611	-73.585000	1997	2006	4
CT	Fairfield	090011123	41.399167	-73.443056	1997	2006	10
CT	Fairfield	090012124	41.063056	-73.528889	1997	2005	9
CT	Fairfield	090019003	41.118333	-73.336667	1997	2006	10
CT	Hartford	090031005	42.015833	-72.518056	1997	1999	3
CT	Hartford	090031018	41.760833	-72.670833	1997	1998	2
CT	Hartford	090032006	41.742500	-72.634444	1997	2006	10
CT	New Haven	090090027	41.301111	-72.902778	2004	2006	3
CT	New Haven	090091003	41.310556	-72.915556	1997	1998	2
CT	New Haven	090091123	41.310833	-72.916944	1997	2004	8
CT	New Haven	090092123	41.550556	-73.043611	1997	2006	10
CT	New London	090110007	41.361111	-72.080000	1997	1999	3
CT	Tolland	090130003	41.730000	-72.213611	1997	1999	3
DE	New Castle	100031003	39.761111	-75.491944	1997	2003	7
DE	New Castle	100031007	39.551111	-75.730833	2000	2007	8
DE	New Castle	100031008	39.577778	-75.611111	1997	2007	11
DE	New Castle	100031013	39.773889	-75.496389	2003	2007	5
DE	New Castle	100032002	39.757778	-75.546389	1997	1998	2
DE	New Castle	100032004	39.739444	-75.558056	1999	2007	9
DE	Sussex	100051002	38.644444	-75.613056	1997	1997	1
DC	District of Columbia	110010041	38.897222	-76.952778	1997	2007	11
FL	Brevard	120090011	28.469380	-80.666830	2007	2007	1
FL	Broward	120110010	26.128611	-80.167222	1997	2007	11
FL	Duval	120310032	30.356111	-81.635556	1997	2007	11
FL	Duval	120310080	30.308889	-81.652500	1997	2007	11
FL	Duval	120310081	30.422222	-81.621111	1997	2007	11
FL	Duval	120310097	30.367222	-81.594167	1997	2007	11
FL	Escambia	120330004	30.525000	-87.204167	1997	2007	11
FL	Escambia	120330022	30.544722	-87.216111	1997	2006	10
FL	Hamilton	120470015	30.411111	-82.783611	1997	2007	11
FL	Hillsborough	120570021	27.947222	-82.453333	1997	1999	3
FL	Hillsborough	120570053	27.886389	-82.481389	1997	2006	10
FL	Hillsborough	120570081	27.739722	-82.465278	1997	2007	11
FL	Hillsborough	120570095	27.922500	-82.401389	1997	2007	11
FL	Hillsborough	120570109	27.856389	-82.383667	1997	2007	11
FL	Hillsborough	120571035	27.928056	-82.454722	1997	2007	11
FL	Hillsborough	120571065	27.892222	-82.538611	2001	2002	2
FL	Hillsborough	120574004	27.992500	-82.125833	1998	2006	9
FL	Manatee	120813002	27.632778	-82.546111	1998	2007	10
FL	Miami-Dade	120860019	25.897500	-80.380000	1997	2007	11
FL	Nassau	120890005	30.658333	-81.463333	1997	2007	10
FL	Nassau	120890009	30.686389	-81.447500	1997	1998	2
FL	Orange	120952002	28.599444	-81.363056	1997	2007	11
FL	Palm Beach	120993004	26.369722	-80.074444	1997	2007	11
FL	Pinellas	121030023	27.863333	-82.623333	1997	2007	11
FL	Pinellas	121033002	27.871389	-82.691667	1997	2007	11

State	County	Monitor ID	Latitude	Longitude	Years First	Years Last	Years n
FL	Pinellas	121035002	28.090000	-82.700833	1997	2007	11
FL	Pinellas	121035003	28.141667	-82.739722	1998	2007	10
FL	Polk	121050010	27.856111	-82.017778	1997	2005	9
FL	Polk	121052006	27.896944	-81.960278	1997	2003	7
FL	Putnam	121071008	29.687500	-81.656667	1997	2007	11
FL	Sarasota	121151002	27.299722	-82.524444	1997	1999	3
FL	Sarasota	121151005	27.306944	-82.570556	1997	2001	5
FL	Sarasota	121151006	27.350278	-82.480000	1999	2007	9
GA	Baldwin	130090001	33.153258	-83.235807	1998	2006	4
GA	Bartow	130150002	34.103333	-84.915278	1997	2005	9
GA	Bibb	130210012	32.805244	-83.543628	1997	2007	6
GA	Chatham	130510019	32.093889	-81.151111	1997	2002	6
GA	Chatham	130510021	32.069050	-81.048949	1997	2007	11
GA	Chatham	130511002	32.090278	-81.130556	1998	2007	7
GA	Dougherty	130950006	31.567778	-84.102778	1998	2001	2
GA	Fannin	131110091	34.985556	-84.375278	1997	2007	11
GA	Floyd	131150003	34.261113	-85.323018	1997	2007	11
GA	Fulton	131210048	33.779189	-84.395843	1997	2007	11
GA	Fulton	131210055	33.720428	-84.357449	1997	2007	11
GA	Glynn	131270006	31.169530	-81.496046	1999	2007	4
GA	Muscogee	132150008	32.521099	-84.944695	1999	2005	3
GA	Richmond	132450003	33.393611	-82.006389	1997	2004	4
HI	Hawaii	150010005	19.433611	-155.261111	1997	2007	11
HI	Hawaii	150010007	19.418889	-155.288056	2001	2007	7
HI	Honolulu	150030010	21.329167	-158.093333	1997	2007	11
HI	Honolulu	150030011	21.337222	-158.119167	1997	2007	11
HI	Honolulu	150031001	21.310278	-157.858056	1997	2007	11
HI	Honolulu	150031006	21.347500	-158.113333	1997	2007	11
ID	Bannock	160050004	42.916389	-112.515833	1997	2006	10
ID	Bannock	160050015	42.876725	-112.460347	1997	1999	3
ID	Caribou	160290003	42.661298	-111.591443	1997	2002	6
ID	Caribou	160290031	42.695278	-111.593889	2001	2006	6
ID	Power	160770011	42.912500	-112.535556	2004	2005	2
IL	Adams	170010006	39.933010	-91.404237	1997	2007	11
IL	Champaign	170190004	40.123796	-88.229531	1997	2000	4
IL	Cook	170310050	41.707570	-87.568574	1997	2007	11
IL	Cook	170310059	41.687500	-87.536111	1997	2000	4
IL	Cook	170310063	41.876969	-87.634330	1997	2007	11
IL	Cook	170310064	41.790787	-87.601646	1997	1997	1
IL	Cook	170310076	41.751400	-87.713488	2004	2007	4
IL	Cook	170311018	41.773889	-87.815278	1997	2004	8
IL	Cook	170311601	41.668120	-87.990570	1997	2007	11
IL	Cook	170312001	41.662109	-87.696467	1997	2003	7
IL	Cook	170314002	41.855243	-87.752470	1997	2007	11
IL	Cook	170314201	42.139996	-87.799227	2004	2007	4
IL	Cook	170318003	41.631389	-87.568056	1997	2002	6
IL	DuPage	170436001	41.813049	-88.072827	1997	2000	4
IL	La Salle	170990007	41.293015	-89.049425	2006	2007	2
IL	Macon	171150013	39.866834	-88.925594	1997	2007	11
IL	Macoupin	171170002	39.396075	-89.809739	1997	2007	11

State	County	Monitor ID	Latitude	Longitude	Years First	Years Last	Years n
IL	Madison	171190008	38.890186	-90.148031	1997	2002	6
IL	Madison	171190017	38.701944	-90.149167	1997	2000	4
IL	Madison	171191010	38.828303	-90.058433	1997	2007	11
IL	Madison	171193007	38.860669	-90.105851	1997	2007	11
IL	Madison	171193009	38.865984	-90.070571	1997	2007	11
IL	Peoria	171430024	40.687420	-89.606943	1997	2007	11
IL	Randolph	171570001	38.176278	-89.788459	1997	2007	11
IL	Rock Island	171610003	41.511944	-90.514167	1997	2000	4
IL	Saint Clair	171630010	38.612034	-90.160477	1997	2007	11
IL	Saint Clair	171631010	38.592192	-90.165081	1997	2002	6
IL	Saint Clair	171631011	38.235000	-89.841944	1997	2001	5
IL	Sangamon	171670006	39.800614	-89.591225	1997	2007	11
IL	Tazewell	171790004	40.556460	-89.654028	1997	2007	11
IL	Wabash	171850001	38.397222	-87.773611	1997	2006	10
IL	Wabash	171851001	38.369444	-87.834444	1997	2006	10
IL	Will	171970013	41.459963	-88.182019	1997	2007	11
IN	Daviess	180270002	38.572778	-87.214722	1997	2006	10
IN	Dearborn	180290004	39.092778	-84.855000	1997	2007	11
IN	DeKalb	180330002	41.364167	-84.926389	1997	1997	1
IN	Floyd	180430004	38.367778	-85.833056	1997	2006	10
IN	Floyd	180430007	38.273333	-85.836389	1997	2006	10
IN	Floyd	180431004	38.308056	-85.834167	1997	2007	11
IN	Fountain	180450001	39.964167	-87.421389	1997	2006	10
IN	Gibson	180510001	38.361389	-87.748611	1997	2006	10
IN	Gibson	180510002	38.392778	-87.748333	1997	2006	10
IN	Hendricks	180630001	39.876944	-86.473889	1998	2006	6
IN	Hendricks	180630002	39.863361	-86.470750	1998	2006	6
IN	Hendricks	180630003	39.880833	-86.542194	1998	2006	6
IN	Jasper	180730002	41.187778	-87.053333	1997	2007	11
IN	Jasper	180730003	41.135833	-86.987778	1997	2002	6
IN	Jefferson	180770004	38.776667	-85.407222	1997	2005	9
IN	Lake	180890022	41.606667	-87.304722	1997	2005	9
IN	Lake	180891016	41.600278	-87.334722	1997	1997	1
IN	Lake	180892008	41.639444	-87.493611	1997	2007	11
IN	LaPorte	180910005	41.716944	-86.907500	1997	2007	11
IN	LaPorte	180910007	41.679722	-86.852778	1997	2002	6
IN	Marion	180970042	39.646254	-86.248784	1997	2007	11
IN	Marion	180970054	39.730278	-86.196111	1997	1997	1
IN	Marion	180970057	39.749019	-86.186314	1997	2007	11
IN	Marion	180970072	39.768056	-86.160000	1997	2000	4
IN	Marion	180970073	39.789167	-86.060833	1997	2005	9
IN	Morgan	181091001	39.515000	-86.391667	1997	2006	4
IN	Perry	181230006	37.994330	-86.763457	1997	2004	8
IN	Perry	181230007	37.983773	-86.772202	1997	2004	8
IN	Pike	181250005	38.519167	-87.249722	1997	2006	10
IN	Porter	181270011	41.633889	-87.101389	1997	2007	11
IN	Porter	181270017	41.621944	-87.116389	1997	2002	6
IN	Porter	181270023	41.616667	-87.145833	1997	2002	6
IN	Spencer	181470002	37.982500	-86.966380	1997	2001	5
IN	Spencer	181470010	37.955360	-87.031800	2002	2007	6

State	County	Monitor ID	Latitude	Longitude	Years		
					First	Last	n
IN	Sullivan	181530004	39.099444	-87.470556	1997	2006	10
IN	Vanderburgh	181630012	38.021667	-87.569444	1997	2007	11
IN	Vanderburgh	181631002	37.902500	-87.671389	1997	2006	10
IN	Vigo	181670018	39.486111	-87.401389	1997	2007	11
IN	Vigo	181671014	39.514722	-87.407778	1997	2006	10
IN	Warrick	181730002	37.937500	-87.314167	1997	2006	10
IN	Warrick	181731001	37.938056	-87.345833	1997	2003	7
IN	Wayne	181770006	39.812222	-84.890000	1997	2007	11
IN	Wayne	181770007	39.795833	-84.880833	1997	2007	11
IA	Cerro Gordo	190330018	43.169440	-93.202426	1997	2007	11
IA	Clinton	190450018	41.824722	-90.212778	1997	1997	1
IA	Clinton	190450019	41.823283	-90.211982	1997	2007	10
IA	Clinton	190450020	41.845833	-90.216389	1997	1998	2
IA	Dubuque	190610012	42.525556	-90.641944	1997	1997	1
IA	Lee	191110006	40.392222	-91.400000	1997	1998	2
IA	Lee	191111007	40.582500	-91.427500	1997	2000	4
IA	Linn	191130026	42.008333	-91.678611	1997	1997	1
IA	Linn	191130028	41.910556	-91.651944	1997	2001	5
IA	Linn	191130029	41.974722	-91.666667	1997	2007	11
IA	Linn	191130031	41.983333	-91.662778	1997	2007	11
IA	Linn	191130032	41.964722	-91.664722	1997	2000	4
IA	Linn	191130034	41.971111	-91.645278	1997	2000	4
IA	Linn	191130035	41.943056	-91.622500	1998	1998	1
IA	Linn	191130038	41.941111	-91.633889	1998	2007	10
IA	Linn	191130039	41.934167	-91.682500	2000	2001	2
IA	Muscatine	191390016	41.419429	-91.070975	1997	2007	9
IA	Muscatine	191390017	41.387969	-91.054504	1997	2007	10
IA	Muscatine	191390020	41.407796	-91.062646	1997	2007	11
IA	Polk	191530030	41.603183	-93.643300	2007	2007	1
IA	Scott	191630014	41.699174	-90.521944	2005	2005	1
IA	Scott	191630015	41.530011	-90.587611	1997	2007	11
IA	Scott	191630017	41.467236	-90.688451	1997	1997	1
IA	Van Buren	191770004	40.711111	-91.975278	1997	1999	3
IA	Van Buren	191770005	40.689167	-91.994444	1999	2004	5
IA	Van Buren	191770006	40.695078	-92.006318	2005	2007	3
IA	Woodbury	191930018	42.399444	-96.355833	2001	2002	2
KS	Linn	201070002	38.135833	-94.731944	1998	2007	10
KS	Montgomery	201250006	37.046944	-95.613333	1997	2007	11
KS	Montgomery	201250007	37.062930	-95.638820	2005	2006	2
KS	Pawnee	201450001	38.176250	-99.108028	1997	1997	1
KS	Sedgwick	201730010	37.701111	-97.313889	1997	1997	1
KS	Sumner	201910002	37.476944	-97.366389	2000	2007	8
KS	Trego	201950001	38.770278	-99.763611	2001	2007	7
KS	Wyandotte	202090001	39.113056	-94.624444	1997	1999	3
KS	Wyandotte	202090020	39.151389	-94.617500	1997	1999	3
KS	Wyandotte	202090021	39.117500	-94.635556	1999	2007	9
KY	Boyd	210190015	38.465833	-82.621111	1997	2001	5
KY	Boyd	210190017	38.459167	-82.640556	2001	2007	7
KY	Boyd	210191003	38.388611	-82.602500	1997	1999	3
KY	Campbell	210370003	39.065556	-84.451944	2000	2006	7

State	County	Monitor ID	Latitude	Longitude	Years		
					First	Last	n
KY	Campbell	210371001	39.108611	-84.476111	1997	1999	3
KY	Daviess	210590005	37.780833	-87.075556	1997	2007	11
KY	Fayette	210670012	38.065000	-84.500000	1997	2007	11
KY	Greenup	210890007	38.548333	-82.731667	1997	2007	11
KY	Hancock	210910012	37.938889	-86.896944	1997	2004	8
KY	Henderson	211010013	37.858889	-87.575278	1997	2002	6
KY	Henderson	211010014	37.871389	-87.463333	2003	2007	5
KY	Jefferson	211110032	38.182500	-85.861667	1997	2002	6
KY	Jefferson	211110051	38.060833	-85.896111	1997	2007	11
KY	Jefferson	211111041	38.231630	-85.826720	1997	2007	11
KY	Jessamine	211130001	37.893333	-84.589167	2007	2007	1
KY	Kenton	211170007	39.072500	-84.525000	2006	2007	2
KY	Livingston	211390004	37.070833	-88.334167	1997	2007	11
KY	McCracken	211450001	37.131667	-88.813333	1997	1999	3
KY	McCracken	211451024	37.058056	-88.572500	2000	2007	8
KY	McCracken	211451026	37.040833	-88.541111	1997	1999	3
KY	Muhlenberg	211771004	37.227222	-87.158333	2001	2002	2
KY	Ohio	211830032	37.319725	-86.956097	2005	2007	3
KY	Pike	211950002	37.482778	-82.535278	2001	2003	3
KY	Warren	212270008	37.036667	-86.250556	2002	2006	5
LA	Bossier	220150008	32.536260	-93.748910	1997	2007	11
LA	Calcasieu	220190008	30.261667	-93.284167	1997	2007	11
LA	East Baton Rouge	220330009	30.461980	-91.179220	1997	2007	11
LA	Jefferson	220511001	30.043333	-90.275000	2005	2006	2
LA	Ouachita	220730004	32.509713	-92.046093	1997	2007	11
LA	St. Bernard	220870002	29.981944	-89.998611	1997	2005	9
LA	St. Bernard	220870007	29.944750	-89.976263	2007	2007	1
LA	St. Bernard	220870009	29.936909	-89.955703	2007	2007	1
LA	West Baton Rouge	221210001	30.501944	-91.209722	1997	2007	11
ME	Androscoggin	230010011	44.089406	-70.214219	1997	2002	6
ME	Androscoggin	230013003	44.097778	-70.193611	1997	1997	1
ME	Aroostook	230030009	47.351667	-68.303611	1997	1998	2
ME	Aroostook	230030012	47.354444	-68.314167	1997	1998	2
ME	Aroostook	230031003	47.351667	-68.311389	1997	1998	2
ME	Aroostook	230031013	46.123889	-67.829722	1997	1998	2
ME	Aroostook	230031018	46.660899	-67.902066	2002	2005	4
ME	Aroostook	230031100	46.696431	-68.033006	2006	2006	1
ME	Cumberland	230050014	43.659722	-70.261389	1997	1998	2
ME	Cumberland	230050027	43.661944	-70.265833	1999	2006	8
ME	Hancock	230090103	44.377050	-68.260900	2004	2007	4
ME	Oxford	230170011	44.550278	-70.534167	1997	1997	1
ME	Oxford	230172007	44.543056	-70.545833	1997	2004	8
MD	Allegany	240010006	39.649722	-78.762778	1997	1998	2
MD	Anne Arundel	240032002	39.159722	-76.511667	1997	2003	7
MD	Baltimore	240053001	39.310833	-76.474444	2003	2006	4
MD	Baltimore (City)	245100018	39.314167	-76.613333	1997	1998	2
MD	Baltimore (City)	245100036	39.265000	-76.536667	1997	1998	2
MA	Bristol	250050010	41.688056	-71.175278	1997	1997	1
MA	Bristol	250051004	41.683279	-71.169171	1997	2007	11

State	County	Monitor ID	Latitude	Longitude	Years		
					First	Last	n
MA	Bristol	250056001	41.753889	-71.197500	1997	1997	1
MA	Essex	250090005	42.709444	-71.146389	1997	2002	6
MA	Essex	250091004	42.515556	-70.931389	1997	1997	1
MA	Essex	250091005	42.525000	-70.934167	1997	1997	1
MA	Essex	250095004	42.772222	-71.061111	1997	2001	5
MA	Hampden	250130016	42.108581	-72.590614	1997	2007	11
MA	Hampden	250131009	42.085556	-72.579722	1997	1999	3
MA	Hampshire	250154002	42.298279	-72.333904	1997	2007	11
MA	Middlesex	250171701	42.474444	-71.111111	1997	2000	4
MA	Middlesex	250174003	42.383611	-71.213889	1997	1999	3
MA	Suffolk	250250002	42.348873	-71.097163	1997	2007	11
MA	Suffolk	250250019	42.316394	-70.967773	1997	2007	11
MA	Suffolk	250250020	42.309417	-71.055573	1997	2007	11
MA	Suffolk	250250021	42.377833	-71.027138	1997	2007	11
MA	Suffolk	250250040	42.340251	-71.038350	1997	2007	11
MA	Suffolk	250250042	42.329400	-71.082500	2000	2007	8
MA	Suffolk	250251003	42.401667	-71.031111	1997	1999	3
MA	Worcester	250270020	42.267222	-71.798889	1997	2003	7
MA	Worcester	250270023	42.263877	-71.794186	2004	2007	4
MI	Delta	260410902	45.796667	-87.089444	1997	2004	8
MI	Genesee	260490021	43.047224	-83.670159	1997	2007	11
MI	Genesee	260492001	43.168336	-83.461541	2003	2004	2
MI	Kent	260810020	42.984173	-85.671339	1997	2007	11
MI	Macomb	260991003	42.513340	-83.005971	1997	2007	11
MI	Missaukee	261130001	44.310555	-84.891865	2002	2003	2
MI	St. Clair	261470005	42.953336	-82.456229	1997	2007	11
MI	Schoolcraft	261530001	46.288877	-85.950227	2005	2005	1
MI	Wayne	261630001	42.228620	-83.208200	1997	1998	2
MI	Wayne	261630005	42.267231	-83.132086	1997	2001	5
MI	Wayne	261630015	42.302786	-83.106530	1997	2007	11
MI	Wayne	261630016	42.357808	-83.096033	1997	2007	11
MI	Wayne	261630019	42.430840	-83.000138	1997	2007	11
MI	Wayne	261630025	42.423063	-83.426263	1997	1998	2
MI	Wayne	261630027	42.292231	-83.106807	1997	2001	5
MI	Wayne	261630033	42.306674	-83.148754	1997	2001	5
MI	Wayne	261630062	42.340833	-83.062500	1997	1997	1
MI	Wayne	261630092	42.296111	-83.116944	1997	1998	2
MN	Anoka	270031002	45.137680	-93.207720	2003	2007	5
MN	Carlton	270176316	46.733611	-92.418889	2000	2003	4
MN	Dakota	270370020	44.763230	-93.032550	1997	2007	11
MN	Dakota	270370423	44.775530	-93.062990	1997	2007	11
MN	Dakota	270370439	44.748039	-93.043266	1998	2000	3
MN	Dakota	270370441	44.746800	-93.026110	1999	2007	9
MN	Dakota	270370442	44.738570	-93.004960	2000	2007	8
MN	Hennepin	270530954	44.980995	-93.273719	1997	2007	11
MN	Hennepin	270530957	45.021111	-93.281944	1997	2002	6
MN	Koochiching	270711240	48.605278	-93.402222	1997	2000	4
MN	Ramsey	271230864	44.991944	-93.183056	1997	2002	6
MN	Sherburne	271410003	45.420278	-93.871667	1997	1997	1
MN	Sherburne	271410011	45.394444	-93.897500	1997	1998	2

State	County	Monitor ID	Latitude	Longitude	Years		
					First	Last	n
MN	Sherburne	271410012	45.394444	-93.885000	1997	1998	2
MN	Sherburne	271410013	45.369444	-93.898056	1997	1998	2
MN	Washington	271630436	44.847370	-92.995400	1997	2007	11
MN	Wright	271710007	45.329167	-93.835833	1997	1997	1
MS	Alcorn	280030004	34.909167	-88.601667	2001	2002	2
MS	Choctaw	280190001	33.378889	-89.203889	1997	1997	1
MS	Harrison	280470007	30.446806	-89.029139	1997	2004	8
MS	Hinds	280490018	32.296806	-90.188306	1997	2005	9
MS	Jackson	280590006	30.378425	-88.533985	1997	2007	11
MS	Lee	280810004	34.263333	-88.759722	1997	1997	1
MS	Marshall	280930001	34.955000	-89.423000	2004	2005	2
MS	Panola	281070001	34.359944	-89.890889	1998	1999	2
MO	Buchanan	290210009	39.731389	-94.877500	2000	2000	1
MO	Buchanan	290210011	39.731389	-94.868333	2002	2003	2
MO	Clay	290470025	39.183889	-94.497500	1997	2002	6
MO	Greene	290770026	37.128333	-93.261667	1997	2004	5
MO	Greene	290770032	37.205278	-93.283333	1997	2006	10
MO	Greene	290770037	37.110000	-93.251944	1999	2004	2
MO	Greene	290770040	37.108889	-93.252778	2002	2007	6
MO	Greene	290770041	37.108611	-93.272222	2002	2007	6
MO	Iron	290930030	37.466389	-90.690000	2002	2002	1
MO	Iron	290930031	37.519444	-90.712500	2002	2002	1
MO	Jackson	290950034	39.104722	-94.570556	1997	2007	11
MO	Jefferson	290990004	38.263300	-90.378500	2004	2007	4
MO	Jefferson	290990014	38.267222	-90.379444	1997	2001	5
MO	Jefferson	290990017	38.252778	-90.393333	1998	2001	4
MO	Jefferson	290990018	38.297694	-90.384333	2002	2002	1
MO	Monroe	291370001	39.473056	-91.789167	1998	2006	3
MO	Pike	291630002	39.372600	-90.914400	2005	2007	3
MO	Platte	291650023	39.300000	-94.700000	1997	2005	9
MO	Saint Charles	291830010	38.579167	-90.841111	1997	1998	2
MO	Saint Charles	291831002	38.872500	-90.226389	2000	2000	1
MO	Saint Louis	291890001	38.521667	-90.343611	1997	1998	2
MO	Saint Louis	291890004	38.532500	-90.382778	1998	2005	8
MO	Saint Louis	291890006	38.613611	-90.495833	1997	2005	9
MO	Saint Louis	291890014	38.710900	-90.475900	2005	2007	3
MO	Saint Louis	291893001	38.641389	-90.345833	1997	2007	11
MO	Saint Louis	291895001	38.766111	-90.285833	1997	2005	9
MO	Saint Louis	291897002	38.727222	-90.379444	1997	2001	5
MO	Saint Louis	291897003	38.720917	-90.367028	2001	2004	4
MO	St. Louis City	295100007	38.542500	-90.263611	1997	2006	10
MO	St. Louis City	295100072	38.624167	-90.198611	1997	2001	5
MO	St. Louis City	295100080	38.682778	-90.246667	1997	1999	3
MO	St. Louis City	295100086	38.672222	-90.238889	2000	2006	7
MT	Big Horn	300030038	45.754462	-107.596336	2002	2003	2
MT	Cascade	300132000	47.532222	-111.271111	1997	2000	4
MT	Cascade	300132001	47.530000	-111.283611	2000	2006	7
MT	Jefferson	300430903	46.557679	-111.918098	1997	2001	5
MT	Jefferson	300430908	46.538889	-111.932500	1997	1997	1
MT	Jefferson	300430909	46.554167	-111.916944	1997	1997	1

State	County	Monitor ID	Latitude	Longitude	Years		
					First	Last	n
MT	Jefferson	300430910	46.554444	-111.876111	1997	1997	1
MT	Jefferson	300430911	46.548056	-111.873333	1997	2001	5
MT	Jefferson	300430912	46.542778	-111.868611	1997	1997	1
MT	Jefferson	300430913	46.534722	-111.861389	1997	2001	5
MT	Jefferson	300430914	46.553611	-111.862222	1997	1997	1
MT	Jefferson	300430915	46.550556	-111.860278	1997	1997	1
MT	Jefferson	300430916	46.528889	-111.858056	1997	1997	1
MT	Lewis and Clark	300490701	46.573056	-111.910278	1997	1997	1
MT	Lewis and Clark	300490702	46.583333	-111.934444	1997	2001	5
MT	Lewis and Clark	300490703	46.593889	-111.920000	1997	2001	5
MT	Musselshell	300650004	46.267050	-108.454808	2002	2003	2
MT	Rosebud	300870700	45.886944	-106.628056	1997	2001	5
MT	Rosebud	300870701	45.901944	-106.637778	1997	2001	5
MT	Rosebud	300870702	45.863889	-106.557778	1997	2001	5
MT	Rosebud	300870760	45.668056	-106.518889	1997	2004	8
MT	Rosebud	300870761	45.603056	-106.464167	1997	2004	8
MT	Rosebud	300870762	45.648333	-106.556667	1997	2004	8
MT	Rosebud	300870763	45.976667	-106.660556	1997	1998	2
MT	Yellowstone	301110016	45.656389	-108.765833	1997	2005	9
MT	Yellowstone	301110066	45.788318	-108.459536	2001	2007	5
MT	Yellowstone	301110079	45.769439	-108.574292	2001	2004	4
MT	Yellowstone	301110080	45.777149	-108.474360	1997	2001	5
MT	Yellowstone	301110082	45.783889	-108.515000	2001	2004	2
MT	Yellowstone	301110083	45.795278	-108.455833	2000	2003	4
MT	Yellowstone	301110084	45.831453	-108.449964	2003	2006	4
MT	Yellowstone	301111065	45.801944	-108.426111	1997	2005	9
MT	Yellowstone	301112005	45.803889	-108.445556	1997	2005	9
MT	Yellowstone	301112006	45.810000	-108.413056	1997	2006	10
MT	Yellowstone	301112007	45.832778	-108.377778	1997	2006	10
MT	Yellowstone	301112008	45.786389	-108.523056	1997	1997	1
NE	Douglas	310550048	41.323889	-95.942778	1997	1999	3
NE	Douglas	310550050	41.332778	-95.956389	1999	2004	6
NE	Douglas	310550053	41.297778	-95.937500	1999	2007	9
NE	Douglas	310550055	41.362433	-95.976112	2004	2007	4
NV	Clark	320030022	36.390775	-114.906810	1998	2003	6
NV	Clark	320030078	35.465050	-114.919615	2000	2003	4
NV	Clark	320030539	36.144444	-115.085556	1998	2006	9
NV	Clark	320030601	35.978889	-114.844167	2001	2003	3
NH	Cheshire	330050007	42.930556	-72.277778	1997	2004	8
NH	Coos	330070019	44.488611	-71.180278	1997	2002	6
NH	Coos	330070022	44.458333	-71.154167	1997	1998	2
NH	Coos	330071007	44.596667	-71.516667	1997	2002	6
NH	Hillsborough	330110016	42.992778	-71.459444	1997	1999	3
NH	Hillsborough	330110019	43.000556	-71.468056	1999	2001	3
NH	Hillsborough	330110020	43.000556	-71.468056	2001	2007	7
NH	Hillsborough	330111009	42.764444	-71.467500	1997	2001	5
NH	Hillsborough	330111010	42.701944	-71.445000	1997	2003	7
NH	Merrimack	330130007	43.206944	-71.534167	1997	2003	7
NH	Merrimack	330131003	43.177222	-71.462500	1997	2003	7
NH	Merrimack	330131006	43.132444	-71.458270	2002	2007	6

State	County	Monitor ID	Latitude	Longitude	Years		
					First	Last	n
NH	Merrimack	330131007	43.218491	-71.458270	2004	2006	3
NH	Rockingham	330150009	43.078056	-70.762778	1997	2001	5
NH	Rockingham	330150014	43.075278	-70.748056	2003	2007	5
NH	Rockingham	330150015	43.082500	-70.761944	2001	2003	3
NH	Sullivan	330190003	43.364444	-72.338333	1997	2002	6
NJ	Atlantic	340010005	39.530240	-74.460690	1997	2006	10
NJ	Bergen	340030001	40.808333	-73.992778	1997	1998	2
NJ	Bergen	340035001	40.882370	-74.042170	1997	2006	10
NJ	Burlington	340051001	40.078060	-74.857720	1997	2006	10
NJ	Camden	340070003	39.923040	-75.097620	1997	2006	10
NJ	Camden	340071001	39.684250	-74.861490	1997	2006	10
NJ	Cumberland	340110007	39.422270	-75.025200	1997	2006	10
NJ	Essex	340130011	40.726667	-74.144167	1997	1999	3
NJ	Essex	340130016	40.722222	-74.146944	2001	2003	3
NJ	Gloucester	340150002	39.800340	-75.212120	1997	2006	10
NJ	Hudson	340170006	40.670250	-74.126080	1997	2006	10
NJ	Hudson	340171002	40.731690	-74.066570	1997	2006	10
NJ	Middlesex	340232003	40.508880	-74.268200	1997	2006	10
NJ	Morris	340273001	40.787630	-74.676300	1997	2006	10
NJ	Union	340390003	40.662450	-74.214740	1997	2006	10
NJ	Union	340390004	40.641440	-74.208360	1997	2006	10
NM	Dona Ana	350130008	31.930556	-106.630556	1997	2003	7
NM	Dona Ana	350130017	31.795833	-106.557500	1997	2006	10
NM	Eddy	350151004	32.855556	-104.411389	1997	2007	11
NM	Grant	350170001	32.759444	-108.131389	1997	2002	6
NM	Grant	350171003	32.691944	-108.124444	1997	2007	11
NM	Hidalgo	350230005	31.783333	-108.497222	1997	2002	6
NM	San Juan	350450008	36.735833	-108.238333	1997	2003	7
NM	San Juan	350450009	36.742222	-107.976944	1997	2006	10
NM	San Juan	350450017	36.752778	-108.716667	1997	1998	2
NM	San Juan	350451005	36.796667	-108.472500	1997	2006	10
NY	Albany	360010012	42.680690	-73.756890	1997	2007	11
NY	Bronx	360050073	40.811389	-73.910000	1997	1999	3
NY	Bronx	360050080	40.836080	-73.920210	1997	2000	4
NY	Bronx	360050083	40.865860	-73.880750	2000	2007	8
NY	Bronx	360050110	40.816160	-73.902070	1999	2007	9
NY	Bronx	360050133	40.867989	-73.878203	2007	2007	1
NY	Chautauqua	360130005	42.290730	-79.589580	1997	2001	5
NY	Chautauqua	360130006	42.499450	-79.318880	1999	2007	9
NY	Chautauqua	360130011	42.290730	-79.586580	1997	2007	11
NY	Chemung	360150003	42.111050	-76.802490	1997	2007	11
NY	Erie	360290005	42.876840	-78.809880	1997	2007	11
NY	Erie	360294002	42.995490	-78.901570	1997	2007	11
NY	Erie	360298001	42.818889	-78.840833	1997	1999	3
NY	Essex	360310003	44.393090	-73.858920	1997	2007	11
NY	Franklin	360330004	44.434309	-74.246010	2003	2007	5
NY	Franklin	360337003	44.980577	-74.695005	2004	2007	4
NY	Hamilton	360410005	43.449570	-74.516250	1997	2007	11
NY	Herkimer	360430005	43.685780	-74.985380	1997	2007	11
NY	Kings	360470011	40.732770	-73.947220	1997	1999	3

State	County	Monitor ID	Latitude	Longitude	Years		
					First	Last	n
NY	Kings	360470076	40.671850	-73.978240	1997	2000	4
NY	Madison	360530006	42.730460	-75.784430	1997	2007	11
NY	Monroe	360551004	43.165450	-77.554790	1997	2004	8
NY	Monroe	360551007	43.146198	-77.548130	2004	2007	4
NY	Monroe	360556001	43.161000	-77.603570	1997	2004	8
NY	Nassau	360590005	40.743160	-73.585490	1997	2007	11
NY	New York	360610010	40.739444	-73.986111	1997	2001	5
NY	New York	360610056	40.759170	-73.966510	1997	2007	11
NY	Niagara	360632006	43.085833	-78.996389	1997	1997	1
NY	Niagara	360632008	43.082160	-79.000990	1998	2007	10
NY	Onondaga	360670017	43.042630	-76.143310	2001	2001	1
NY	Onondaga	360671015	43.052380	-76.059200	1997	2007	11
NY	Putnam	360790005	41.441510	-73.707620	1997	2007	11
NY	Queens	360810004	40.735833	-73.816944	1997	1997	1
NY	Queens	360810097	40.755270	-73.758610	1998	2001	4
NY	Queens	360810124	40.736200	-73.823170	2001	2007	7
NY	Rensselaer	360830004	42.781870	-73.463610	2001	2007	7
NY	Rensselaer	360831005	42.724440	-73.431660	1997	2001	5
NY	Richmond	360850067	40.597330	-74.126190	1997	2000	4
NY	Schenectady	360930003	42.799630	-73.940190	1997	2007	11
NY	Steuben	361010003	42.090710	-77.210250	2007	2007	1
NY	Suffolk	361030002	40.745290	-73.419190	1997	2000	4
NY	Suffolk	361030009	40.827500	-73.056940	2000	2007	8
NY	Ulster	361111005	42.143800	-74.494140	1997	2007	11
NC	Alexander	370030003	35.903611	-81.184167	1999	2003	2
NC	Beaufort	370130003	35.357500	-76.779722	1997	2000	4
NC	Beaufort	370130004	35.377241	-76.748997	1997	1999	3
NC	Beaufort	370130006	35.377778	-76.766944	2001	2007	7
NC	Chatham	370370004	35.757222	-79.159722	1998	2001	2
NC	Cumberland	370511003	34.968889	-78.962500	1999	2006	3
NC	Davie	370590002	35.809289	-80.559115	1997	2000	2
NC	Duplin	370610002	34.954823	-77.960781	1999	1999	1
NC	Edgecombe	370650099	35.988333	-77.582778	1999	2004	2
NC	Forsyth	370670022	36.110556	-80.226667	1997	2006	8
NC	Johnston	371010002	35.590833	-78.461944	1999	1999	1
NC	Lincoln	371090004	35.438556	-81.276750	1997	2000	2
NC	Martin	371170001	35.810690	-76.897820	1998	2007	4
NC	Martin	371170002	35.830670	-76.806310	2006	2007	2
NC	Mecklenburg	371190034	35.248611	-80.766389	1997	1999	3
NC	Mecklenburg	371190041	35.240100	-80.785683	1999	2007	9
NC	New Hanover	371290002	34.364167	-77.838611	2005	2005	1
NC	New Hanover	371290006	34.268403	-77.956529	1997	2007	11
NC	Northampton	371310002	36.484380	-77.619980	1997	2000	2
NC	Person	371450003	36.306965	-79.091970	1998	2004	3
NC	Pitt	371470099	35.583333	-77.598889	1997	2000	2
NC	Rowan	371590021	35.551868	-80.395039	1997	1998	2
NC	Rowan	371590022	35.534482	-80.667560	1997	1998	2
NC	Swain	371730002	35.435509	-83.443697	1998	2007	4
NC	Wake	371830014	35.856111	-78.574167	2002	2007	6
ND	Billings	380070002	46.894300	-103.378530	2001	2005	2

State	County	Monitor ID	Latitude	Longitude	Years First	Years Last	Years n
ND	Billings	380070003	46.961900	-103.356699	1997	1997	1
ND	Billings	380070111	47.296667	-103.095556	1997	1997	1
ND	Burke	380130002	48.990400	-102.781500	2001	2005	4
ND	Burke	380130004	48.641930	-102.401800	2005	2006	2
ND	Burleigh	380150003	46.825425	-100.768210	2005	2007	3
ND	Cass	380171003	46.910278	-96.795000	1997	1997	1
ND	Cass	380171004	46.933754	-96.855350	2004	2007	4
ND	Dunn	380250003	47.313200	-102.527300	1997	2005	4
ND	McKenzie	380530002	47.581200	-103.299500	1997	2005	2
ND	McKenzie	380530104	47.575278	-103.968889	1997	2004	3
ND	McKenzie	380530111	47.605556	-104.017222	1998	2007	10
ND	McLean	380550113	47.606667	-102.036389	1997	2006	10
ND	Mercer	380570001	47.258853	-101.783035	1997	1997	1
ND	Mercer	380570004	47.298611	-101.766944	2005	2007	2
ND	Mercer	380570102	47.325000	-101.765833	1997	2007	11
ND	Mercer	380570118	47.371667	-101.780833	1997	2007	11
ND	Mercer	380570123	47.385725	-101.862917	1997	2007	11
ND	Mercer	380570124	47.400619	-101.928650	1997	2007	11
ND	Morton	380590002	46.841750	-100.870059	1997	2005	2
ND	Morton	380590003	46.873075	-100.905039	2003	2005	2
ND	Oliver	380650002	47.185833	-101.428056	1997	2005	2
ND	Steele	380910001	47.599703	-97.899009	1997	1997	1
ND	Williams	381050103	48.408834	-102.907650	1997	2001	5
ND	Williams	381050105	48.392644	-102.910233	1997	2006	6
OH	Adams	390010001	38.795000	-83.535278	1997	2007	11
OH	Allen	390030002	40.772222	-84.051944	1997	2007	11
OH	Ashtabula	390071001	41.959444	-80.572500	1997	2007	11
OH	Belmont	390133002	39.968056	-80.747500	1997	2007	10
OH	Butler	390170004	39.383333	-84.544167	1997	2007	11
OH	Butler	390171004	39.530000	-84.392500	1997	2007	11
OH	Clark	390230003	39.855556	-83.997500	1997	2007	11
OH	Clermont	390250021	38.961273	-84.094450	1997	2005	9
OH	Columbiana	390290016	40.634722	-80.546389	1997	2000	4
OH	Columbiana	390290022	40.635000	-80.546667	2001	2007	7
OH	Columbiana	390292001	40.620278	-80.580833	1997	1999	3
OH	Cuyahoga	390350026	41.445278	-81.660833	1997	1997	1
OH	Cuyahoga	390350038	41.476944	-81.681944	1997	2007	11
OH	Cuyahoga	390350045	41.471667	-81.657222	1997	2007	11
OH	Cuyahoga	390350060	41.493955	-81.678542	1997	2007	11
OH	Cuyahoga	390350065	41.446389	-81.661944	1997	2007	11
OH	Cuyahoga	390356001	41.504722	-81.623889	1997	2003	7
OH	Franklin	390490004	39.992222	-83.041667	1997	2000	4
OH	Franklin	390490034	40.002500	-82.994444	1997	2007	11
OH	Gallia	390530002	38.944167	-82.112222	2001	2006	6
OH	Hamilton	390610010	39.214931	-84.690723	1997	2007	11
OH	Hamilton	390610039	39.198056	-84.468611	1998	1999	2
OH	Hamilton	390612002	39.158611	-84.748889	1997	1997	1
OH	Hamilton	390612003	39.228889	-84.448889	1997	1998	2
OH	Jefferson	390810016	40.362778	-80.615556	1998	2003	6
OH	Jefferson	390810017	40.366104	-80.615002	2003	2007	5

State	County	Monitor ID	Latitude	Longitude	Years		
					First	Last	n
OH	Jefferson	390811001	40.321944	-80.606389	1997	2004	8
OH	Jefferson	390811012	40.359444	-80.623056	1997	1997	1
OH	Lake	390850003	41.673056	-81.422500	1997	2007	11
OH	Lake	390853002	41.722500	-81.241944	1997	2007	11
OH	Lawrence	390870006	38.520278	-82.666667	1997	2007	11
OH	Lawrence	390871009	38.421111	-82.572222	1997	1997	1
OH	Lorain	390930017	41.368056	-82.110556	2000	2004	5
OH	Lorain	390930026	41.471667	-82.143611	1997	2003	7
OH	Lorain	390931003	41.365833	-82.108333	1997	2000	4
OH	Lucas	390950006	41.648056	-83.529167	1997	1997	1
OH	Lucas	390950008	41.663333	-83.476667	1997	2007	11
OH	Lucas	390950024	41.644167	-83.546667	1998	2007	10
OH	Mahoning	390990009	41.098333	-80.651944	1997	1999	3
OH	Mahoning	390990013	41.096111	-80.658611	2000	2007	8
OH	Meigs	391051001	39.037778	-82.045556	1997	2007	11
OH	Montgomery	391130025	39.758333	-84.200000	1997	2004	8
OH	Morgan	391150003	39.631667	-81.673056	1997	2006	10
OH	Morgan	391150004	39.634221	-81.670038	2006	2007	2
OH	Scioto	391450013	38.754167	-82.917500	1997	2007	11
OH	Scioto	391450020	38.609048	-82.822911	2004	2007	4
OH	Scioto	391450022	38.588034	-82.834973	2004	2007	4
OH	Stark	391510016	40.827778	-81.378611	1997	2004	8
OH	Summit	391530017	41.063333	-81.468611	1997	2007	11
OH	Summit	391530022	41.080278	-81.516389	1997	2007	11
OH	Tuscarawas	391570003	40.516389	-81.476389	1997	2003	7
OH	Tuscarawas	391570006	40.511416	-81.639149	2003	2007	5
OK	Cherokee	400219002	35.854080	-94.985964	1999	2006	8
OK	Kay	400710602	36.705328	-97.087656	1997	2007	11
OK	Kay	400719003	36.662778	-97.074444	1999	2004	6
OK	Kay	400719010	36.956222	-97.031350	2004	2006	3
OK	Mayes	400979014	36.228408	-95.249943	2004	2006	3
OK	Muskogee	401010167	35.793134	-95.302235	1997	2007	11
OK	Oklahoma	401090025	35.553056	-97.623611	1998	2003	6
OK	Oklahoma	401091037	35.614131	-97.475083	2004	2007	4
OK	Ottawa	401159004	36.922222	-94.838889	2001	2005	5
OK	Tulsa	401430175	36.149877	-96.011664	1997	2007	11
OK	Tulsa	401430235	36.126945	-95.998941	1997	2007	11
OK	Tulsa	401430501	36.161270	-96.015784	1997	2007	10
OK	Tulsa	401431127	36.204902	-95.976537	2006	2007	2
OR	Lincoln	410410002	44.612522	-123.928405	2003	2004	2
OR	Multnomah	410510080	45.496667	-122.602222	2005	2006	2
PA	Allegheny	420030002	40.500556	-80.071944	1997	2007	11
PA	Allegheny	420030010	40.445577	-80.016155	1997	2007	11
PA	Allegheny	420030021	40.413611	-79.941389	1997	2007	11
PA	Allegheny	420030031	40.443333	-79.990556	1997	2000	4
PA	Allegheny	420030032	40.414444	-79.942222	1997	1999	3
PA	Allegheny	420030064	40.323611	-79.868333	1997	2007	11
PA	Allegheny	420030067	40.381944	-80.185556	1997	2007	11
PA	Allegheny	420030116	40.473611	-80.077222	1997	2007	11
PA	Allegheny	420031301	40.402500	-79.860278	1997	2000	4

State	County	Monitor ID	Latitude	Longitude	Years First	Years Last	Years n
PA	Allegheny	420033003	40.318056	-79.881111	1997	2005	9
PA	Allegheny	420033004	40.305000	-79.888889	1997	2000	4
PA	Beaver	420070002	40.562520	-80.503948	1997	2007	11
PA	Beaver	420070004	40.635575	-80.230605	1997	1998	2
PA	Beaver	420070005	40.684722	-80.359722	1998	2007	10
PA	Beaver	420070014	40.747796	-80.316442	1997	2007	11
PA	Berks	420110009	40.320278	-75.926667	1999	2006	8
PA	Berks	420110100	40.335278	-75.922778	1997	1998	2
PA	Blair	420130801	40.535278	-78.370833	1997	2007	11
PA	Bucks	420170012	40.107222	-74.882222	1997	2007	11
PA	Cambria	420210011	40.309722	-78.915000	1999	2007	9
PA	Centre	420270100	40.811389	-77.877028	2002	2007	6
PA	Dauphin	420430401	40.245000	-76.844722	1997	2007	11
PA	Delaware	420450002	39.835556	-75.372500	1997	2007	11
PA	Delaware	420450109	39.818715	-75.413973	1997	2000	4
PA	Erie	420490003	42.141750	-80.038611	1998	2007	10
PA	Greene	420590002	39.816222	-80.284917	1997	2007	11
PA	Indiana	420630004	40.563330	-78.919972	2004	2007	4
PA	Lackawanna	420692006	41.442778	-75.623056	1997	2007	11
PA	Lancaster	420710007	40.046667	-76.283333	1997	2007	11
PA	Lawrence	420730015	40.995848	-80.346442	1997	2007	11
PA	Lehigh	420770004	40.611944	-75.432500	1997	2007	11
PA	Luzerne	420791101	41.265556	-75.846389	1997	2007	11
PA	Lycoming	420810100	41.250800	-76.923800	2001	2007	7
PA	Lycoming	420810403	41.246111	-76.989722	1997	2001	5
PA	Mercer	420850100	41.215014	-80.484779	1997	2007	11
PA	Monroe	420890001	40.860004	-75.429614	1997	1999	3
PA	Montgomery	420910013	40.112222	-75.309167	1997	2007	11
PA	Northampton	420950025	40.628056	-75.341111	1997	2007	11
PA	Northampton	420950100	40.676667	-75.216667	1997	1999	3
PA	Northampton	420958000	40.692224	-75.237156	1999	2007	9
PA	Perry	420990301	40.456944	-77.165556	1997	2007	11
PA	Philadelphia	421010004	40.008889	-75.097778	1997	2007	11
PA	Philadelphia	421010022	39.916667	-75.188889	1997	2001	5
PA	Philadelphia	421010024	40.076389	-75.011944	1997	1999	3
PA	Philadelphia	421010027	40.010556	-75.151944	1997	1999	3
PA	Philadelphia	421010029	39.957222	-75.173056	1997	2005	9
PA	Philadelphia	421010047	39.944722	-75.166111	1997	1999	3
PA	Philadelphia	421010048	39.991389	-75.080833	1997	1999	3
PA	Philadelphia	421010055	39.922517	-75.186783	2004	2007	4
PA	Philadelphia	421010136	39.927500	-75.222778	1997	2007	11
PA	Schuylkill	421070002	40.783889	-76.343611	1997	1997	1
PA	Schuylkill	421070003	40.820556	-76.212222	1997	2007	11
PA	Warren	421230003	41.857222	-79.137500	1997	2007	11
PA	Warren	421230004	41.844722	-79.169722	1998	2007	10
PA	Washington	421250005	40.146667	-79.902222	1998	2007	10
PA	Washington	421250200	40.170556	-80.261389	1998	2007	10
PA	Washington	421255001	40.445278	-80.420833	1998	2007	10
PA	Westmoreland	421290008	40.304694	-79.505667	1997	2007	11
PA	York	421330008	39.965278	-76.699444	1997	2007	11

State	County	Monitor ID	Latitude	Longitude	Years		
					First	Last	n
RI	Providence	440070012	41.825556	-71.405278	1997	2007	11
RI	Providence	440071005	41.878333	-71.378889	1997	1997	1
RI	Providence	440071009	41.823611	-71.411667	1997	2007	11
SC	Aiken	450030003	33.342226	-81.788731	1997	1999	3
SC	Anderson	450070003	34.776927	-82.490386	2005	2006	2
SC	Barnwell	450110001	33.320344	-81.465537	1997	2007	11
SC	Charleston	450190003	32.882289	-79.977538	1997	2007	10
SC	Charleston	450190046	32.941023	-79.657187	1997	2007	11
SC	Georgetown	450430006	33.362014	-79.294251	1997	2007	11
SC	Greenville	450450008	34.838814	-82.402918	1997	2007	10
SC	Greenville	450450009	34.899141	-82.313070	2004	2007	4
SC	Lexington	450630008	34.051017	-81.154950	1997	2007	11
SC	Oconee	450730001	34.805261	-83.237700	1997	2007	11
SC	Orangeburg	450750003	33.299590	-80.442218	2002	2004	3
SC	Richland	450790007	34.093959	-80.962304	1997	2007	10
SC	Richland	450790021	33.814680	-80.781135	2000	2007	8
SC	Richland	450791003	34.024497	-81.036248	1997	2007	11
SC	Richland	450791006	33.817902	-80.826596	1997	2001	5
SD	Custer	460330132	43.557800	-103.483900	2005	2006	2
SD	Jackson	460710001	43.745610	-101.941218	2005	2006	2
SD	Minnehaha	460990007	43.537626	-96.682001	2002	2006	5
SD	Roberts	461094003	45.354381	-96.555279	2001	2002	2
TN	Anderson	470010028	36.027778	-84.151389	1997	2006	8
TN	Blount	470090002	35.775000	-83.965833	1997	2007	11
TN	Blount	470090006	35.768056	-83.976667	1997	2007	11
TN	Blount	470090101	35.631490	-83.943512	1999	2000	2
TN	Bradley	470110004	35.296111	-84.893611	1997	1998	2
TN	Bradley	470110102	35.283164	-84.759371	1997	2007	11
TN	Coffee	470310004	35.582222	-86.015556	1998	2005	4
TN	Davidson	470370011	36.205000	-86.744722	1997	2007	11
TN	Dickson	470430009	36.246667	-87.364444	1999	2000	2
TN	Hamblen	470630003	36.307778	-83.134472	1997	2006	5
TN	Hawkins	470730002	36.366944	-82.977778	1997	2007	8
TN	Haywood	470750002	35.765833	-89.433889	1998	1998	1
TN	Haywood	470750003	35.468056	-89.167778	2002	2006	3
TN	Humphreys	470850020	36.051944	-87.965000	1997	2006	8
TN	Knox	470931030	35.898333	-83.957222	2000	2001	2
TN	Loudon	471050003	35.790000	-84.301944	1997	1997	1
TN	McMinn	471070101	35.297330	-84.750760	1997	2007	11
TN	Meigs	471210104	35.288997	-84.946044	2002	2006	4
TN	Montgomery	471250006	36.520056	-87.394167	1997	2007	11
TN	Montgomery	471250106	36.504529	-87.396675	1997	2007	11
TN	Montgomery	471251010	36.625000	-87.169167	2000	2006	4
TN	Obion	471310004	36.345181	-89.319208	2003	2004	2
TN	Polk	471390003	35.026111	-84.384722	1997	2006	10
TN	Polk	471390007	34.988333	-84.371667	1997	2006	10
TN	Polk	471390008	34.995833	-84.368333	1997	2000	4
TN	Polk	471390009	34.989722	-84.383889	1997	2000	4
TN	Roane	471450009	35.947222	-84.522222	1997	2005	7
TN	Roane	471451020	35.885000	-84.375278	1999	2000	2

State	County	Monitor ID	Latitude	Longitude	Years		
					First	Last	n
TN	Sevier	471550101	35.696667	-83.609722	2006	2007	2
TN	Shelby	471570034	35.043400	-90.013600	2000	2005	6
TN	Shelby	471570043	35.087778	-90.025278	1997	2000	4
TN	Shelby	471570046	35.272778	-89.961389	1997	2007	11
TN	Shelby	471571034	35.087222	-90.133611	1997	2007	11
TN	Shelby	471572005	35.188000	-89.642000	2005	2006	2
TN	Stewart	471610007	36.389722	-87.633333	1997	2005	7
TN	Sullivan	471630007	36.534804	-82.517078	1997	2007	11
TN	Sullivan	471630009	36.513971	-82.560968	1997	2007	11
TN	Sumner	471651002	36.341667	-86.398333	1997	2007	8
TN	Sumner	471651005	36.375000	-86.422222	1998	1999	2
TX	Bowie	480370099	33.192778	-94.038611	1998	1999	2
TX	Brewster	480430101	29.302500	-103.167820	1999	2000	2
TX	Cameron	480610006	25.892509	-97.493824	1997	2000	4
TX	Cass	480670099	33.121667	-94.029167	1998	1999	2
TX	Dallas	481130069	32.819952	-96.860082	1997	2007	11
TX	Ellis	481390015	32.436944	-97.025000	1997	2007	11
TX	Ellis	481390016	32.482222	-97.026944	1997	2007	11
TX	Ellis	481390017	32.473611	-97.042500	2004	2006	3
TX	El Paso	481410033	31.776944	-106.501667	1997	1999	3
TX	El Paso	481410037	31.768281	-106.501253	1997	2007	11
TX	El Paso	481410053	31.758504	-106.501023	1997	2007	11
TX	El Paso	481410057	31.662189	-106.303079	1999	2000	2
TX	El Paso	481410058	31.893928	-106.425813	2000	2007	8
TX	Galveston	481670005	29.385236	-94.931526	2004	2007	4
TX	Galveston	481671002	29.398611	-94.933333	1997	2004	8
TX	Gregg	481830001	32.378710	-94.711834	1999	2007	9
TX	Harris	482010046	29.827500	-95.283611	1997	2007	11
TX	Harris	482010051	29.623611	-95.473611	1997	2007	11
TX	Harris	482010059	29.705833	-95.281111	1997	1998	2
TX	Harris	482010062	29.625833	-95.267500	1997	2007	11
TX	Harris	482010070	29.735129	-95.315583	2000	2007	8
TX	Harris	482010416	29.686389	-95.294722	2006	2007	2
TX	Harris	482011035	29.733713	-95.257591	1997	2007	11
TX	Harris	482011050	29.583032	-95.015535	2001	2007	7
TX	Jefferson	482450009	30.036446	-94.071073	1997	2007	11
TX	Jefferson	482450011	29.894030	-93.987898	1997	2007	11
TX	Jefferson	482450020	30.066070	-94.077383	1997	2007	11
TX	Kaufman	482570005	32.564969	-96.317660	2000	2007	8
TX	Nueces	483550025	27.765340	-97.434272	1997	2007	11
TX	Nueces	483550026	27.832409	-97.555381	1997	2007	11
TX	Nueces	483550032	27.804482	-97.431553	1997	2007	11
TX	Travis	484530613	30.418600	-97.601400	2003	2006	4
UT	Cache	490050004	41.731111	-111.837500	2002	2006	5
UT	Davis	490110001	40.886389	-111.882222	1997	2003	7
UT	Davis	490110004	40.902967	-111.884467	2003	2006	4
UT	Salt Lake	490350012	40.807500	-111.921111	1997	2006	10
UT	Salt Lake	490351001	40.708611	-112.094722	1997	2006	10
UT	Salt Lake	490352004	40.736389	-112.210278	1997	2006	10
UT	Tooele	490450002	40.597778	-112.466667	1997	1997	1

State	County	Monitor ID	Latitude	Longitude	Years		
					First	Last	n
VT	Chittenden	500070003	44.478889	-73.211944	1997	2000	4
VT	Chittenden	500070014	44.476200	-73.210600	2004	2004	1
VT	Rutland	500210002	43.608056	-72.982778	1997	2006	10
VA	Charles	510360002	37.343294	-77.260034	1997	2007	11
VA	Fairfax	510590005	38.893889	-77.465278	1997	2007	11
VA	Fairfax	510590018	38.742500	-77.077500	1997	1998	2
VA	Fairfax	510591004	38.868056	-77.143056	1997	2001	5
VA	Fairfax	510591005	38.837517	-77.163231	2002	2007	6
VA	Fairfax	510595001	38.931944	-77.198889	1997	2007	11
VA	Madison	511130003	38.521944	-78.436111	1999	2007	9
VA	Roanoke	511611004	37.285556	-79.884167	1997	2007	11
VA	Rockingham	511650002	38.389444	-78.914167	1997	2004	8
VA	Rockingham	511650003	38.477320	-78.819040	2004	2007	4
VA	Alexandria City	515100009	38.810833	-77.044722	1997	2007	11
VA	Hampton City	516500004	37.003333	-76.399167	1997	2007	11
VA	Norfolk City	517100023	36.850278	-76.257778	1997	2005	9
VA	Norfolk City	517100024	36.857778	-76.301667	2006	2007	2
VA	Richmond City	517600021	37.563056	-77.467500	1997	1997	1
VA	Richmond City	517600024	37.562778	-77.465278	1998	2007	10
WA	Clallam	530090010	48.113333	-123.399167	1997	1998	2
WA	Clallam	530090012	48.097500	-123.425556	1997	2004	8
WA	King	530330057	47.563333	-122.340600	1997	1999	3
WA	King	530330080	47.568333	-122.308056	2000	2006	7
WA	Pierce	530530021	47.281111	-122.374167	1997	1999	3
WA	Pierce	530530031	47.265600	-122.385800	1997	1999	3
WA	Skagit	530570012	48.493611	-122.551944	1997	1999	3
WA	Skagit	530570018	48.460101	-122.519110	2003	2006	4
WA	Skagit	530571003	48.486111	-122.549444	1997	1999	3
WA	Snohomish	530610016	47.983333	-122.209722	1997	1999	3
WA	Whatcom	530730011	48.750278	-122.482778	1997	1999	3
WV	Brooke	540090005	40.341023	-80.596635	1997	2007	11
WV	Brooke	540090007	40.389655	-80.586235	1997	2007	11
WV	Cabell	540110006	38.424133	-82.425900	1997	2007	11
WV	Greenbrier	540250001	37.819444	-80.512500	1997	1998	2
WV	Hancock	540290005	40.529021	-80.576067	1997	2007	11
WV	Hancock	540290007	40.460138	-80.576567	1997	2007	11
WV	Hancock	540290008	40.615720	-80.560000	1997	2007	11
WV	Hancock	540290009	40.427372	-80.592318	1997	2007	11
WV	Hancock	540290011	40.394583	-80.612017	1997	2007	11
WV	Hancock	540290014	40.435520	-80.600579	1997	2003	7
WV	Hancock	540290015	40.618353	-80.540616	1997	2007	11
WV	Hancock	540290016	40.411944	-80.601667	1997	2004	8
WV	Hancock	540291004	40.421539	-80.580717	1997	2007	11
WV	Kanawha	540390004	38.343889	-81.619444	1997	2000	4
WV	Kanawha	540390010	38.345600	-81.628317	2000	2007	8
WV	Kanawha	540392002	38.416944	-81.846389	1997	1999	3
WV	Marshall	540511002	39.915961	-80.733858	1997	2007	11
WV	Monongalia	540610003	39.649367	-79.920867	1997	2007	11
WV	Monongalia	540610004	39.633056	-79.957222	1997	2001	5
WV	Monongalia	540610005	39.648333	-79.957778	1997	2006	10

State	County	Monitor ID	Latitude	Longitude	Years		
					First	Last	n
WV	Ohio	540690007	40.120430	-80.699265	1997	2003	7
WV	Wayne	540990002	38.391860	-82.583923	1997	2003	7
WV	Wayne	540990003	38.390278	-82.585833	1997	2002	6
WV	Wayne	540990004	38.380278	-82.583889	1997	2005	7
WV	Wayne	540990005	38.372222	-82.588889	1997	2002	6
WV	Wood	541071002	39.323533	-81.552367	1997	2007	8
WI	Brown	550090005	44.516667	-87.993889	1997	2006	10
WI	Dane	550250041	43.100833	-89.357222	1997	1999	3
WI	Forest	550410007	45.564980	-88.808590	2004	2006	3
WI	Marathon	550730005	45.028333	-89.652222	1997	1999	3
WI	Milwaukee	550790007	43.047222	-87.920278	1997	2001	5
WI	Milwaukee	550790026	43.061111	-87.912500	2002	2006	5
WI	Milwaukee	550790041	43.075278	-87.884444	1997	2002	6
WI	Oneida	550850996	45.645278	-89.412500	1997	2006	10
WI	Sauk	551110007	43.435556	-89.680278	2002	2004	3
WI	Vilas	551250001	46.048056	-89.653611	2002	2004	3
WI	Wood	551410016	44.382500	-89.819167	1997	2000	4
WI	Wood	551410017	44.359444	-89.861944	2000	2001	2
WY	Campbell	560050857	44.277222	-105.375000	2002	2005	4
WY	Fremont	560136001	42.994444	-108.370278	2004	2005	2
WY	Sweetwater	560370200	41.406555	-108.144987	2006	2007	2
WY	Weston	560450800	43.845390	-104.205120	2005	2007	3
PR	Barceloneta	720170003	18.436111	-66.580556	1997	2005	9
PR	Bayamon	720210004	18.412778	-66.132778	1997	2005	9
PR	Bayamon	720210006	18.416667	-66.150833	1997	2006	10
PR	Catano	720330004	18.430556	-66.142222	1997	2006	10
PR	Catano	720330007	18.444722	-66.116111	2000	2003	4
PR	Catano	720330008	18.440028	-66.127076	2004	2007	4
PR	Catano	720330009	18.449964	-66.149043	2004	2007	4
PR	Guayama	720570009	17.966844	-66.188014	2001	2006	6
PR	Guayanilla	720590017	18.025175	-66.770175	2006	2007	2
PR	Salinas	721230001	17.963002	-66.254749	2004	2006	3
PR	San Juan	721270009	18.418889	-66.087500	2004	2005	2
PR	Yabucoa	721510005	18.052778	-65.875000	1997	1998	2
VI	St Croix	780100006	17.706944	-64.780556	1997	2006	10
VI	St Croix	780100011	17.719167	-64.775000	1997	2006	10
VI	St Croix	780100013	17.722500	-64.776667	1998	2006	9
VI	St Croix	780100014	17.734444	-64.783333	1998	2006	9
VI	St Croix	780100015	17.741667	-64.751944	1998	2006	9

A.1.1 Analysis of SO_2 Emission Sources Surrounding Ambient Monitors

Distances of the 5-minute and 1-hour ambient monitoring sites to stationary sources emitting SO_2 were estimated using data from the 2002 National Emissions Inventory[1] (NEI). The NEI database reports emissions of SO_2 in tons per year (tpy) for 98,667 unique emission sources at various points of release. The release locations were all taken from the latitude longitude values within the NEI. First, all SO_2 emissions were summed for identical latitude and longitude entries while retaining source codes for the emissions (e.g., Standard Industrial Code (SIC), or North American Industrial Classification System (NAICS)). Therefore, any facility containing similar emission processes were summed at the stack location, resulting in 32,521 observations. These data were then screened for sources with emissions greater than 5 tpy, yielding 6,104 unique SO_2 emission sources. Locations of these stationary source emissions were compared with ambient monitoring locations using the following formula:

$$d = \arccos(\sin(lat_1) \times \sin(lat_2) + \cos(lat_1) \times \cos(lat_2) \times \cos(lon_2 - lon_1)) \times r$$

where

d	=	distance (kilometers)
lat_1	=	latitude of a monitor (radians)
lat_2	=	latitude of source emission (radians)
lon_1	=	longitude of monitor (radians)
lon_2	=	longitude of source emission (radians)
r	=	approximate radius of the earth (or 6,371 km)

Location data for monitors and sources provided in the AQS and NEI data bases were given in units of degrees therefore, these were first converted to radians by dividing by 180/π. For each monitor, source emissions within 20 km of the monitor were retained.

Table A-3 contains the summary of the distance of stationary source emissions to each of the monitors measuring 5-minute SO_2 concentrations. There were varying numbers of sources emitting >5 tpy of SO_2 and located within a 20 km radius for many of the monitors. Some of the monitors are point-source oriented, that is, sited to measure ambient concentrations potentially

[1] 2002 National Emissions Inventory Data & Documentation. Office of Air Quality Planning and Standards, Research Triangle Park, NC. Available at: http://www.epa.gov/ttn/chief/net/2002inventory.html.

influenced by a specific single sources (e.g., Missouri monitor IDs 290210009, 290210011, 290930030), or by several sources (e.g., Pennsylvania monitor IDs 420030021, 420030031) of varying emission strength. A few of the monitors contained no source emissions >5 tpy (e.g., Iowa monitor IDs 191770005, 191770006). Similar distributions for the distances to stationary sources and associated emissions were generated for the 1-hour SO_2 monitors (Table A-4), with some of the monitors in close proximity to a single source or few sources of varying emission strength, while others with no significant SO_2 source emissions.

Table A-3. Distance of 5-minute maximum ambient monitors to stationary sources emitting > 5 tons of SO_2 per year, within a 20 kilometer distance of monitoring site, and SO_2 emissions associated with those stationary sources.

		Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
Monitor ID	n	mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	p100
051190007	1	6.3		6.3	6.3	6.3	6.3	6.3	20		20	20	20	20	20
051191002	1	13.7		13.7	13.7	13.7	13.7	13.7	20		20	20	20	20	20
051390006	6	7.7	4.2	1.9	1.9	8.8	11.7	11.7	421	689	8	8	22	1689	1689
080310002	24	9.2	4.5	3.9	3.9	7.0	19.5	19.5	1098	3356	6	6	28	15958	15958
100031008	24	10.9	6.9	2.2	2.2	13.9	19.7	19.7	1657	4554	5	5	60	19923	19923
110010041	13	11.7	6.5	0.6	0.6	11.5	19.8	19.8	1410	4437	7	7	24	16141	16141
120890005	4	4.5	5.0	1.1	1.1	2.5	12.0	12.0	1262	1594	11	11	765	3509	3509
190330018	4	3.9	3.7	0.4	0.4	3.2	8.8	8.8	2684	3305	20	20	1934	6850	6850
190450019	2	1.3	1.0	0.6	0.6	1.3	2.0	2.0	4694	839	4101	4101	4694	5287	5287
191390016	5	8.7	6.9	2.4	2.4	7.4	19.2	19.2	6227	6934	83	83	3790	15901	15901
191390017	4	3.8	3.6	0.6	0.6	3.1	8.5	8.5	7763	6956	463	463	7345	15901	15901
191390020	4	4.9	4.4	0.9	0.9	4.0	10.4	10.4	7763	6956	463	463	7345	15901	15901
191630015	7	9.5	5.0	1.1	1.1	11.7	15.1	15.1	1345	1810	17	17	336	4963	4963
191770005	0														
191770006	0														
191930018	4	6.4	4.3	0.7	0.7	7.1	10.7	10.7	9208	10818	15	15	7845	21127	21127
221210001	28	5.4	4.7	2.4	2.4	3.4	18.1	18.1	1116	3650	6	6	33	18680	18680
290210009	1	0.7		0.7	0.7	0.7	0.7	0.7	3563		3563	3563	3563	3563	3563
290210011	1	0.9		0.9	0.9	0.9	0.9	0.9	3563		3563	3563	3563	3563	3563
290770026	4	8.2	4.5	2.3	2.3	9.3	11.8	11.8	2302	2728	5	5	1772	5657	5657
290770037	4	9.2	6.1	0.6	0.6	11.0	14.0	14.0	2302	2728	5	5	1772	5657	5657
290930030	1	1.7		1.7	1.7	1.7	1.7	1.7	43340		43340	43340	43340	43340	43340
290930031	1	4.6		4.6	4.6	4.6	4.6	4.6	43340		43340	43340	43340	43340	43340
290990004	5	9.7	7.4	0.2	0.2	11.4	17.1	17.1	11145	10277	243	243	15223	23258	23258
290990014	5	9.8	7.4	0.7	0.7	11.9	17.5	17.5	11145	10277	243	243	15223	23258	23258
290990017	5	10.2	7.1	1.6	1.6	10.6	17.3	17.3	11145	10277	243	243	15223	23258	23258
290990018	4	8.3	6.6	1.4	1.4	8.2	15.3	15.3	8117	8927	243	243	7889	16447	16447
291370001	0														
291630002	2	7.3	6.6	2.7	2.7	7.3	12.0	12.0	6747	934	6087	6087	6747	7408	7408
291830010	0														
291831002	15	12.6	3.4	4.3	4.3	13.5	17.3	17.3	4516	11970	6	6	136	45960	45960
301110066	4	3.1	0.5	2.6	2.6	3.1	3.7	3.7	1370	1322	75	75	1135	3135	3135

Monitor ID	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	p100
301110079	4	7.8	3.0	5.8	5.8	6.7	12.2	12.2	1370	1322	75	75	1135	3135	3135
301110080	4	2.4	1.8	0.9	0.9	1.9	5.0	5.0	1370	1322	75	75	1135	3135	3135
301110082	4	3.4	2.7	1.7	1.7	2.3	7.3	7.3	1370	1322	75	75	1135	3135	3135
301110083	4	3.4	0.7	2.7	2.7	3.4	4.4	4.4	1370	1322	75	75	1135	3135	3135
301110084	6	10.3	6.6	3.1	3.1	7.4	18.6	18.6	2550	2627	75	75	1976	7415	7415
301112008	4	4.0	2.6	2.3	2.3	3.0	7.8	7.8	1370	1322	75	75	1135	3135	3135
370670022	9	6.3	5.7	1.2	1.2	3.9	17.8	17.8	438	848	5	5	46	2591	2591
371290006	12	6.9	4.8	0.6	0.6	7.1	14.5	14.5	2502	5987	6	6	50	20865	20865
380070002	1	11.4		11.4	11.4	11.4	11.4	11.4	283		283	283	283	283	283
380070003	1	4.0		4.0	4.0	4.0	4.0	4.0	283		283	283	283	283	283
380130002	0														
380130004	1	18.6		18.6	18.6	18.6	18.6	18.6	426		426	426	426	426	426
380150003	1	9.8		9.8	9.8	9.8	9.8	9.8	4592		4592	4592	4592	4592	4592
380171003	3	7.7	6.9	3.0	3.0	4.6	15.7	15.7	257	226	15	15	294	462	462
380171004	2	9.0	1.1	8.2	8.2	9.0	9.7	9.7	378	119	294	294	378	462	462
380250003	1	13.9		13.9	13.9	13.9	13.9	13.9	5		5	5	5	5	5
380530002	1	17.3		17.3	17.3	17.3	17.3	17.3	210		210	210	210	210	210
380530104	0														
380530111	2	16.1	0.1	16.1	16.1	16.1	16.2	16.2	411	522	42	42	411	781	781
380570001	2	2.5	2.6	0.7	0.7	2.5	4.3	4.3	45808	55924	6264	6264	45808	85352	85352
380570004	2	2.7	2.0	1.3	1.3	2.7	4.1	4.1	45808	55924	6264	6264	45808	85352	85352
380590002	1	2.6		2.6	2.6	2.6	2.6	2.6	4592		4592	4592	4592	4592	4592
380590003	1	5.1		5.1	5.1	5.1	5.1	5.1	4592		4592	4592	4592	4592	4592
380650002	1	8.5		8.5	8.5	8.5	8.5	8.5	28565		28565	28565	28565	28565	28565
380910001	0														
381050103	1	2.8		2.8	2.8	2.8	2.8	2.8	1605		1605	1605	1605	1605	1605
381050105	1	1.8		1.8	1.8	1.8	1.8	1.8	1605		1605	1605	1605	1605	1605
420030002	19	7.4	5.9	0.6	0.6	8.6	18.1	18.1	103	137	7	7	30	468	468
420030021	64	11.7	3.3	3.2	4.8	13.1	18.0	18.7	819	5274	5	7	47	5395	42018
420030031	62	13.9	5.1	1.3	1.4	14.4	18.7	19.8	757	5327	5	7	46	468	42018
420030032	64	11.7	3.3	3.1	4.7	13.2	18.1	18.7	819	5274	5	7	47	5395	42018
420030064	54	6.0	5.2	2.0	2.0	3.1	17.9	18.2	213	741	5	6	52	1164	5395
420030067	16	15.1	3.5	6.1	6.1	15.7	19.7	19.7	73	105	7	7	29	407	407
420030116	19	7.4	5.1	2.1	2.1	7.7	17.0	17.0	103	137	7	7	30	468	468

Monitor ID	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	p100
420031301	57	9.9	4.6	1.1	1.1	11.0	17.5	17.8	914	5587	5	7	47	5395	42018
420033003	54	5.6	5.4	1.0	1.0	2.3	17.8	17.8	213	741	5	6	52	1164	5395
420033004	55	5.9	6.0	0.6	0.7	3.3	18.8	18.8	209	735	5	6	49	1164	5395
420070002	10	13.0	3.2	9.2	9.2	11.4	18.6	18.6	18726	19819	18	18	15912	59928	59928
420070005	8	9.6	5.6	2.5	2.5	8.8	17.1	17.1	5173	10474	9	9	157	30312	30312
420110009	13	9.8	7.1	1.3	1.3	10.3	19.8	19.8	1140	3818	14	14	37	13841	13841
420210011	4	8.5	7.4	1.5	1.5	8.9	14.9	14.9	4195	5171	34	34	3004	10738	10738
420490003	5	3.1	1.9	1.2	1.2	2.6	5.4	5.4	824	1068	10	10	228	2398	2398
421010022	66	8.0	5.6	0.9	1.0	7.0	19.4	20.0	285	1022	5	5	26	4450	6720
421010048	60	10.4	4.9	0.9	1.7	10.7	18.6	19.2	104	318	5	6	22	560	2378
421010136	68	8.8	5.4	1.1	1.4	9.3	18.7	19.8	319	1042	5	5	27	4450	6720
421230003	2	4.0	1.2	3.2	3.2	4.0	4.9	4.9	2445	659	1979	1979	2445	2911	2911
421230004	2	3.0	1.6	1.9	1.9	3.0	4.1	4.1	2445	659	1979	1979	2445	2911	2911
421250005	33	15.7	4.7	1.1	1.1	17.5	18.7	18.7	257	945	5	5	47	5395	5395
421250200	1	1.1		1.1	1.1	1.1	1.1	1.1	7		7	7	7	7	7
421255001	8	15.9	4.1	9.3	9.3	17.2	19.7	19.7	321	439	7	7	82	1017	1017
450110001	1	13.2		13.2	13.2	13.2	13.2	13.2	65		65	65	65	65	65
450190003	16	7.2	5.0	1.1	1.1	6.2	16.3	16.3	2183	6339	6	6	28	25544	25544
450190046	0														
450430006	7	4.6	4.3	0.2	0.2	3.4	13.2	13.2	5834	14038	6	6	24	37622	37622
450450008	12	11.7	4.5	2.1	2.1	10.7	17.4	17.4	89	136	6	6	20	411	411
450630008	11	11.5	5.4	0.5	0.5	13.0	19.2	19.2	948	2944	5	5	9	9820	9820
450730001	1	14.9		14.9	14.9	14.9	14.9	14.9	5		5	5	5	5	5
450790007	10	14.0	4.1	6.4	6.4	15.9	18.7	18.7	61	103	5	5	18	343	343
450790021	8	14.7	1.2	12.3	12.3	15.3	15.6	15.6	5061	12720	7	7	89	36378	36378
450791003	13	10.9	5.9	1.4	1.4	10.9	18.5	18.5	995	2730	5	5	52	9820	9820
490352004	3	9.8	8.0	2.4	2.4	8.9	18.3	18.3	1245	1415	8	8	939	2788	2788
540990002	8	9.7	5.5	1.7	1.7	10.6	16.0	16.0	1271	2194	25	25	343	6285	6285
540990003	8	9.6	5.5	1.5	1.5	10.7	15.8	15.8	1271	2194	25	25	343	6285	6285
540990004	8	9.6	6.0	1.0	1.0	11.3	15.8	15.8	1271	2194	25	25	343	6285	6285
540990005	8	9.5	6.4	0.9	0.9	11.4	16.2	16.2	1271	2194	25	25	343	6285	6285
541071002	11	8.5	5.4	2.7	2.7	8.8	17.0	17.0	4375	9095	7	7	1517	31006	31006

[1] Mean, std , min, p2.5, p50, p97.5, max are the arithmetic average, standard deviation, minimum, 2.5^{th}, 50^{th}, 97.5^{th} percentiles, and maximum distances and emissions.

Table A-4. Distance of 1-hour ambient monitors to stationary sources emitting > 5 tons of SO_2 per year, within a 20 kilometer distance of monitoring site, and SO_2 emissions associated with those stationary sources.

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
010330044	3	6.0	0.7	5.5	5.5	5.9	6.8	6.8	16680	28821	30	30	51	49960	49960
010331002	4	15.6	5.3	7.7	7.7	18.0	18.6	18.6	12512	24965	8	8	41	49960	49960
010710020	3	5.7	2.4	3.1	3.1	6.2	7.8	7.8	15119	25004	98	98	1276	43983	43983
010731003	43	11.4	5.5	1.1	1.2	13.1	16.8	19.8	151	227	5	5	38	786	982
010790003	5	8.4	1.7	5.5	5.5	8.6	9.8	9.8	1787	3416	6	6	58	7852	7852
010830004	4	14.6	0.8	13.8	13.8	14.6	15.4	15.4	2229	3776	6	6	529	7852	7852
010970028	10	7.5	5.8	1.4	1.4	6.1	19.1	19.1	6613	13057	14	14	214	38917	38917
010972005	9	7.7	2.1	4.3	4.3	7.2	10.1	10.1	132	154	5	5	72	440	440
011011002	4	12.7	7.2	4.5	4.5	13.2	19.9	19.9	913	1183	180	180	403	2663	2663
040070009	0														
040071001	2	1.3	0.5	0.9	0.9	1.3	1.6	1.6	9219	10723	1637	1637	9219	16801	16801
040130019	8	11.0	3.6	5.6	5.6	10.2	16.9	16.9	23	19	10	10	19	69	69
040133002	9	10.8	6.6	1.9	1.9	11.2	19.2	19.2	21	19	10	10	14	69	69
040133003	9	12.5	4.7	5.5	5.5	12.4	18.5	18.5	20	19	6	6	14	69	69
040133010	8	10.0	5.3	5.0	5.0	8.5	18.9	18.9	23	19	10	10	18	69	69
040139997	7	11.3	3.6	8.1	8.1	9.9	18.9	18.9	24	21	10	10	19	69	69
040191011	1	6.1		6.1	6.1	6.1	6.1	6.1	3119		3119	3119	3119	3119	3119
040212001	0														
050910096	5	8.4	0.0	8.4	8.4	8.4	8.5	8.5	74	55	29	29	53	164	164
050910097	5	10.2	0.0	10.2	10.2	10.2	10.2	10.2	74	55	29	29	53	164	164
050910098	5	10.8	0.0	10.8	10.8	10.8	10.8	10.8	74	55	29	29	53	164	164
050910099	5	8.0	0.0	8.0	8.0	8.0	8.1	8.1	74	55	29	29	53	164	164
051190007	1	6.3		6.3	6.3	6.3	6.3	6.3	20		20	20	20	20	20
051191002	1	13.7		13.7	13.7	13.7	13.7	13.7	20		20	20	20	20	20
051191005	1	9.7		9.7	9.7	9.7	9.7	9.7	20		20	20	20	20	20
051390006	6	7.7	4.2	1.9	1.9	8.8	11.7	11.7	421	689	8	8	22	1689	1689
060010010	7	8.9	5.4	1.2	1.2	9.0	16.8	16.8	53	66	5	5	14	187	187
060130002	15	13.5	2.8	9.6	9.6	13.3	17.8	17.8	1004	2007	6	6	58	7009	7009
060130003	9	12.8	5.8	3.3	3.3	14.3	18.5	18.5	559	789	5	5	38	1829	1829
060130006	9	13.0	6.4	2.5	2.5	15.0	19.3	19.3	559	789	5	5	38	1829	1829
060130010	15	8.3	5.6	1.6	1.6	6.4	19.7	19.7	1189	1977	6	6	419	7009	7009
060131001	13	10.1	5.9	0.2	0.2	9.9	19.8	19.8	1507	2036	6	6	793	7009	7009
060131002	3	11.7	1.4	10.1	10.1	12.4	12.7	12.7	26	21	6	6	25	48	48

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
060131003	9	12.6	4.8	5.4	5.4	12.2	19.0	19.0	559	789	5	5	38	1829	1829
060131004	9	12.8	5.7	4.1	4.1	13.5	19.1	19.1	559	789	5	5	38	1829	1829
060132001	15	8.8	5.4	2.3	2.3	6.7	19.9	19.9	1189	1977	6	6	419	7009	7009
060133001	16	9.8	6.1	0.7	0.7	11.4	18.6	18.6	507	1104	6	6	48	4337	4337
060190008	6	14.1	4.8	8.5	8.5	12.4	19.9	19.9	28	22	9	9	24	70	70
060190243	4	10.1	3.5	5.7	5.7	10.7	13.3	13.3	30	28	9	9	20	70	70
060190244	4	13.2	1.9	10.7	10.7	13.5	15.2	15.2	30	28	9	9	20	70	70
060231004	2	4.7	0.1	4.6	4.6	4.7	4.8	4.8	23	25	5	5	23	41	41
060250005	1	18.0		18.0	18.0	18.0	18.0	18.0	7		7	7	7	7	7
060250006	0														
060290014	6	10.8	2.2	7.0	7.0	11.5	13.1	13.1	39	52	5	5	17	138	138
060290232	7	7.3	6.8	2.1	2.1	3.4	18.4	18.4	35	48	5	5	11	138	138
060370030	14	10.4	5.4	2.8	2.8	8.7	17.3	17.3	39	36	7	7	30	119	119
060370031	27	7.2	5.8	1.1	1.1	4.3	19.0	19.0	208	336	5	5	37	1503	1503
060371002	3	6.8	2.1	4.7	4.7	6.9	8.8	8.8	17	7	10	10	17	24	24
060371103	15	13.8	5.1	6.3	6.3	12.5	19.8	19.8	37	36	7	7	29	119	119
060374002	32	10.4	5.2	4.1	4.1	9.3	19.5	19.5	183	313	5	5	46	1503	1503
060375001	31	13.4	5.9	3.7	3.7	16.4	19.6	19.6	203	342	5	5	61	1503	1503
060375005	12	9.1	5.9	2.3	2.3	6.0	19.8	19.8	192	332	6	6	33	1119	1119
060591003	7	13.9	5.7	5.3	5.3	15.6	19.7	19.7	10	5	5	5	7	18	18
060658001	4	16.8	4.7	9.8	9.8	18.8	19.6	19.6	75	76	17	17	50	181	181
060670002	1	14.8		14.8	14.8	14.8	14.8	14.8	5		5	5	5	5	5
060670006	1	9.7		9.7	9.7	9.7	9.7	9.7	58		58	58	58	58	58
060710012	1	11.9		11.9	11.9	11.9	11.9	11.9	8		8	8	8	8	8
060710014	2	8.0	3.0	5.9	5.9	8.0	10.1	10.1	126	132	32	32	126	219	219
060710015	3	5.7	6.9	1.7	1.7	1.8	13.7	13.7	97	85	6	6	110	175	175
060710017	0														
060710306	2	8.1	3.3	5.7	5.7	8.1	10.4	10.4	126	132	32	32	126	219	219
060711234	3	4.9	5.8	1.3	1.3	1.9	11.7	11.7	97	85	6	6	110	175	175
060712002	2	13.2	2.9	11.2	11.2	13.2	15.3	15.3	102	112	22	22	102	181	181
060714001	1	6.5		6.5	6.5	6.5	6.5	6.5	32		32	32	32	32	32
060730001	1	4.0		4.0	4.0	4.0	4.0	4.0	21		21	21	21	21	21
060731007	3	12.9	1.3	11.8	11.8	12.5	14.4	14.4	11	9	5	5	7	21	21
060731010	3	13.1	2.2	10.8	10.8	13.3	15.2	15.2	11	9	5	5	7	21	21
060732007	1	16.4		16.4	16.4	16.4	16.4	16.4	21		21	21	21	21	21
060750005	6	13.3	6.2	1.8	1.8	15.2	18.3	18.3	66	83	5	5	39	224	224

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
060750006	5	12.2	5.8	2.5	2.5	14.4	16.8	16.8	35	35	5	5	14	80	80
060791005	7	1.0	0.2	0.8	0.8	1.0	1.5	1.5	536	1369	6	6	24	3642	3642
060792001	7	10.5	0.2	10.2	10.2	10.4	10.9	10.9	536	1369	6	6	24	3642	3642
060792004	7	2.5	0.1	2.3	2.3	2.6	2.7	2.7	536	1369	6	6	24	3642	3642
060794002	7	18.4	0.1	18.3	18.3	18.5	18.5	18.5	536	1369	6	6	24	3642	3642
060830008	3	9.7	6.2	2.8	2.8	11.3	14.9	14.9	39	43	10	10	18	89	89
060831007	7	17.3	0.1	17.1	17.1	17.3	17.5	17.5	536	1369	6	6	24	3642	3642
060831012	2	16.5	0.1	16.4	16.4	16.5	16.5	16.5	554	357	302	302	554	807	807
060831013	2	14.1	0.1	14.1	14.1	14.1	14.2	14.2	554	357	302	302	554	807	807
060831015	1	15.6		15.6	15.6	15.6	15.6	15.6	18		18	18	18	18	18
060831016	1	15.2		15.2	15.2	15.2	15.2	15.2	18		18	18	18	18	18
060831019	1	13.7		13.7	13.7	13.7	13.7	13.7	18		18	18	18	18	18
060831020	3	7.3	8.2	2.0	2.0	3.2	16.7	16.7	39	43	10	10	18	89	89
060831025	3	10.9	8.9	0.8	0.8	14.2	17.7	17.7	39	43	10	10	18	89	89
060831026	3	9.9	8.0	0.9	0.9	12.6	16.2	16.2	39	43	10	10	18	89	89
060831027	3	10.3	7.7	1.7	1.7	12.8	16.4	16.4	39	43	10	10	18	89	89
060832004	2	4.2	0.1	4.2	4.2	4.2	4.2	4.2	554	357	302	302	554	807	807
060832011	3	10.4	8.4	3.9	3.9	7.5	20.0	20.0	39	43	10	10	18	89	89
060834003	2	16.4	0.1	16.4	16.4	16.4	16.5	16.5	554	357	302	302	554	807	807
060835001	0														
060870003	1	0.8		0.8	0.8	0.8	0.8	0.8	722		722	722	722	722	722
060950001	13	7.1	3.3	2.1	2.1	7.5	13.8	13.8	1371	2071	6	6	790	7009	7009
060950004	12	13.0	4.9	5.5	5.5	13.6	19.6	19.6	1480	2124	6	6	791	7009	7009
061113001	2	10.4	5.1	6.8	6.8	10.4	14.0	14.0	9	3	7	7	9	11	11
080010007	24	9.8	6.1	2.4	2.4	8.2	19.7	19.7	1001	3352	8	8	25	15958	15958
080013001	20	8.3	5.8	1.6	1.6	5.9	19.8	19.8	1191	3657	8	8	28	15958	15958
080310002	24	9.2	4.5	3.9	3.9	7.0	19.5	19.5	1098	3356	6	6	28	15958	15958
080416001	3	6.2	8.6	0.8	0.8	1.8	16.1	16.1	1670	2857	7	7	34	4969	4969
080416004	3	13.0	3.9	10.7	10.7	10.9	17.6	17.6	2849	4920	7	7	10	8530	8530
080416011	3	9.9	7.6	2.5	2.5	9.6	17.7	17.7	2849	4920	7	7	10	8530	8530
080416018	2	6.8	0.5	6.5	6.5	6.8	7.2	7.2	4268	6026	7	7	4268	8530	8530
090010012	11	6.1	4.9	2.1	2.1	4.8	19.7	19.7	425	1198	5	5	21	4024	4024
090010017	3	9.6	6.4	5.7	5.7	6.2	17.0	17.0	252	423	5	5	11	741	741
090011123	0														
090012124	4	7.4	6.0	2.3	2.3	6.5	14.4	14.4	192	366	5	5	10	741	741
090019003	10	13.2	5.1	4.0	4.0	14.0	19.5	19.5	504	1257	5	5	10	4024	4024

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
090031005	28	14.2	3.6	3.0	3.0	14.2	19.9	19.9	45	106	5	5	12	522	522
090031018	7	7.7	6.3	1.9	1.9	3.7	18.4	18.4	16	9	5	5	15	30	30
090032006	6	4.5	5.1	0.5	0.5	1.8	11.4	11.4	14	7	5	5	15	25	25
090090027	8	6.3	7.3	1.0	1.0	3.1	18.6	18.6	595	1388	5	5	32	4012	4012
090091003	9	7.4	8.2	0.7	0.7	2.6	19.7	19.7	565	1302	5	5	43	4012	4012
090091123	9	7.3	8.2	0.8	0.8	2.7	19.7	19.7	565	1302	5	5	43	4012	4012
090092123	5	9.0	5.7	0.8	0.8	8.9	15.2	15.2	86	96	9	9	28	198	198
090110007	6	8.4	3.0	3.3	3.3	8.7	12.7	12.7	650	1088	7	7	110	2755	2755
090130003	0														
100031003	34	9.0	5.2	1.5	1.5	8.1	19.8	19.8	975	1619	5	5	112	6720	6720
100031007	11	10.5	2.2	9.1	9.1	9.8	16.2	16.2	3126	6528	15	15	103	19923	19923
100031008	24	10.9	6.9	2.2	2.2	13.9	19.7	19.7	1657	4554	5	5	60	19923	19923
100031013	34	9.1	4.8	2.8	2.8	8.3	18.9	18.9	975	1619	5	5	112	6720	6720
100032002	36	10.2	6.2	1.1	1.1	9.4	19.7	19.7	802	1272	5	5	97	5051	5051
100032004	39	10.9	6.2	1.3	1.3	11.1	19.8	19.8	1526	3681	5	5	116	19923	19923
100051002	5	8.0	7.6	0.3	0.3	6.8	18.5	18.5	674	1447	5	5	47	3262	3262
110010041	13	11.7	6.5	0.6	0.6	11.5	19.8	19.8	1410	4437	7	7	24	16141	16141
120090011	5	12.3	2.7	9.7	9.7	11.6	17.0	17.0	3101	4254	10	10	2102	10334	10334
120110010	8	11.0	6.1	5.1	5.1	7.5	19.2	19.2	2397	6653	17	17	41	18861	18861
120310032	14	9.0	4.2	1.3	1.3	9.1	18.5	18.5	2715	5784	5	5	287	20908	20908
120310080	15	12.0	4.7	1.1	1.1	13.3	19.7	19.7	2534	5617	5	5	257	20908	20908
120310081	13	7.9	4.6	1.3	1.3	6.5	15.5	15.5	2923	5965	5	5	317	20908	20908
120310097	14	9.2	4.7	3.1	3.1	7.7	19.5	19.5	2715	5784	5	5	287	20908	20908
120330004	6	9.3	4.2	4.9	4.9	8.9	14.6	14.6	7262	14101	6	6	330	35417	35417
120330022	6	7.6	4.4	2.4	2.4	8.4	12.3	12.3	7262	14101	6	6	330	35417	35417
120470015	3	3.0	0.5	2.6	2.6	2.7	3.6	3.6	755	1268	18	18	27	2218	2218
120570021	18	11.6	6.5	1.4	1.4	14.3	18.2	18.2	4986	11445	6	6	341	47103	47103
120570053	19	10.8	3.5	5.9	5.9	12.1	17.3	17.3	4728	11180	6	6	104	47103	47103
120570081	18	14.4	4.5	8.1	8.1	15.1	19.6	19.6	6781	13097	6	6	1116	47103	47103
120570095	17	10.1	6.2	2.5	2.5	14.2	19.3	19.3	3845	11285	6	6	61	47103	47103
120570109	16	9.9	4.0	6.7	6.7	7.4	19.9	19.9	4084	11610	6	6	83	47103	47103
120571035	18	10.6	5.8	1.6	1.6	12.9	16.3	16.3	4986	11445	6	6	341	47103	47103
120571065	20	13.1	4.8	3.3	3.3	12.5	19.6	19.6	4502	10928	6	6	156	47103	47103
120574004	3	14.2	8.5	4.4	4.4	18.9	19.3	19.3	2872	4949	11	11	19	8587	8587
120813002	5	7.2	8.3	0.7	0.7	2.2	16.5	16.5	73	93	6	6	9	208	208
120860019	7	9.6	5.8	2.6	2.6	6.9	19.1	19.1	34	45	5	5	12	130	130

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
120890005	4	4.5	5.0	1.1	1.1	2.5	12.0	12.0	1262	1594	11	11	765	3509	3509
120890009	4	4.2	4.6	1.1	1.1	2.4	11.0	11.0	1262	1594	11	11	765	3509	3509
120952002	5	13.8	2.8	10.1	10.1	13.6	17.6	17.6	9	4	5	5	10	14	14
120993004	6	12.0	3.1	7.0	7.0	12.0	16.7	16.7	39	38	5	5	32	103	103
121030023	7	7.4	6.4	2.3	2.3	3.7	19.6	19.6	3546	7041	6	6	104	18822	18822
121033002	6	10.3	4.2	3.5	3.5	10.0	15.4	15.4	4136	7521	23	23	156	18822	18822
121035002	2	13.6	0.1	13.5	13.5	13.6	13.7	13.7	15398	21767	7	7	15398	30790	30790
121035003	2	9.8	4.0	7.0	7.0	9.8	12.6	12.6	15398	21767	7	7	15398	30790	30790
121050010	9	10.4	3.1	3.7	3.7	10.8	14.4	14.4	2386	2929	6	6	1210	8587	8587
121052006	13	11.9	6.2	2.7	2.7	13.7	19.9	19.9	1691	2627	6	6	230	8587	8587
121071008	3	5.8	3.4	2.6	2.6	5.6	9.3	9.3	9965	12565	12	12	5799	24083	24083
121151002	0														
121151005	0														
121151006	2	15.8	0.8	15.2	15.2	15.8	16.4	16.4	71	90	7	7	71	135	135
130090001	2	11.3	5.4	7.5	7.5	11.3	15.1	15.1	36975	52282	6	6	36975	73943	73943
130150002	4	10.4	5.2	2.5	2.5	13.0	13.0	13.0	40604	80047	21	21	862	160673	160673
130210012	11	10.1	5.2	1.5	1.5	8.8	19.9	19.9	245	468	6	6	17	1576	1576
130510019	14	7.1	4.1	0.4	0.4	6.6	12.0	12.0	1362	2664	8	8	235	7969	7969
130510021	14	6.8	4.4	1.4	1.4	7.2	14.0	14.0	1362	2664	8	8	235	7969	7969
130511002	14	6.2	3.4	1.6	1.6	6.6	10.0	10.0	1362	2664	8	8	235	7969	7969
130950006	4	6.3	5.3	2.2	2.2	4.4	14.1	14.1	1693	2220	5	5	932	4905	4905
131110091	1	1.6		1.6	1.6	1.6	1.6	1.6	1900		1900	1900	1900	1900	1900
131150003	8	1.4	0.4	1.1	1.1	1.2	2.3	2.3	4057	9625	5	5	101	27594	27594
131210048	7	10.3	2.1	8.4	8.4	9.2	14.0	14.0	4339	10445	68	68	169	27993	27993
131210055	7	15.1	3.3	8.0	8.0	15.6	18.1	18.1	4339	10445	68	68	169	27993	27993
131270006	3	3.6	2.8	1.8	1.8	2.2	6.8	6.8	821	948	14	14	586	1865	1865
132150008	4	12.5	2.6	10.1	10.1	12.4	15.1	15.1	1740	3214	8	8	197	6559	6559
132450003	15	8.0	1.4	4.7	4.7	8.2	10.0	10.0	1335	2379	8	8	545	8275	8275
150010005	0														
150010007	0														
150030010	7	5.0	4.6	2.5	2.5	3.3	15.3	15.3	2231	2339	79	79	1566	6978	6978
150030011	7	5.7	5.3	2.2	2.2	4.1	17.5	17.5	2231	2339	79	79	1566	6978	6978
150031001	3	10.1	8.2	0.7	0.7	13.8	15.7	15.7	1043	1509	6	6	350	2774	2774
150031006	7	6.1	4.8	1.8	1.8	5.0	16.5	16.5	2231	2339	79	79	1566	6978	6978
160050004	2	1.3	0.1	1.2	1.2	1.3	1.4	1.4	804	606	376	376	804	1233	1233
160050015	4	13.1	7.6	6.5	6.5	13.1	19.7	19.7	412	572	13	13	201	1233	1233

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
160290003	13	2.9	0.4	2.7	2.7	2.8	4.3	4.3	967	2904	7	7	33	10544	10544
160290031	13	1.4	1.1	0.8	0.8	1.2	4.9	4.9	967	2904	7	7	33	10544	10544
160770011	2	0.8	0.1	0.7	0.7	0.8	0.8	0.8	804	606	376	376	804	1233	1233
170010006	4	4.8	4.5	1.9	1.9	2.9	11.5	11.5	965	614	392	392	817	1834	1834
170190004	3	1.8	0.9	0.8	0.8	2.3	2.4	2.4	121	182	10	10	21	331	331
170310050	47	11.0	5.0	2.1	3.4	10.2	19.7	19.8	900	1775	5	5	65	5951	8443
170310059	40	7.5	5.2	1.5	1.5	5.8	19.3	19.5	910	1928	5	5	65	7381	8443
170310063	23	11.0	6.8	0.9	0.9	9.3	19.7	19.7	1041	1800	5	5	17	6229	6229
170310064	50	14.6	4.1	3.9	6.4	16.4	19.9	19.9	1015	1902	5	5	51	6229	8443
170310076	36	13.2	4.0	4.9	4.9	13.3	19.7	19.7	930	1976	5	5	26	8443	8443
170311018	26	10.7	6.8	0.5	0.5	11.6	19.8	19.8	924	1721	5	5	16	6229	6229
170311601	12	14.1	6.4	4.0	4.0	18.5	19.3	19.3	3807	5540	7	7	1090	15934	15934
170312001	43	16.5	3.2	3.4	8.4	17.7	19.3	19.9	920	1807	5	5	64	6229	8443
170314002	25	9.0	3.1	3.9	3.9	9.5	18.5	18.5	982	1738	5	5	17	6229	6229
170314201	4	18.0	3.0	13.4	13.4	19.4	19.7	19.7	165	230	7	7	77	498	498
170318003	36	8.8	2.4	2.9	2.9	8.4	14.7	14.7	835	1797	5	5	70	8443	8443
170436001	12	16.5	5.1	1.5	1.5	18.1	19.8	19.8	2986	5690	6	6	17	15934	15934
170990007	4	7.2	6.1	0.5	0.5	6.7	14.8	14.8	890	1527	6	6	189	3178	3178
171150013	11	3.3	2.3	1.8	1.8	3.2	9.9	9.9	1251	2596	22	22	164	8032	8032
171170002	0														
171190008	15	10.1	3.7	3.2	3.2	9.5	19.7	19.7	4510	11972	6	6	111	45960	45960
171190017	40	9.5	6.6	0.5	0.7	11.2	19.0	19.6	877	2339	6	6	117	9663	12063
171191010	28	10.5	6.8	0.7	0.7	15.6	18.4	18.4	954	2564	6	6	183	12063	12063
171193007	28	12.2	6.9	2.4	2.4	16.1	18.9	18.9	2595	8875	6	6	214	45960	45960
171193009	26	12.4	7.5	2.9	2.9	14.7	19.8	19.8	2789	9193	6	6	247	45960	45960
171430024	10	13.2	5.8	1.3	1.3	15.5	18.8	18.8	7333	11752	5	5	67	35748	35748
171570001	2	6.4	0.4	6.0	6.0	6.4	6.7	6.7	13148	18554	28	28	13148	26268	26268
171610003	10	11.4	5.6	2.3	2.3	12.3	17.2	17.2	945	1612	7	7	169	4963	4963
171630010	30	9.3	4.1	1.3	1.3	9.6	18.5	18.5	445	1152	6	6	68	6250	6250
171631010	30	10.4	4.3	1.1	1.1	11.7	19.4	19.4	445	1152	6	6	68	6250	6250
171631011	2	4.0	0.6	3.6	3.6	4.0	4.4	4.4	13148	18554	28	28	13148	26268	26268
171670006	5	7.3	3.6	4.9	4.9	5.6	13.5	13.5	2170	3169	9	9	202	7210	7210
171790004	6	5.4	5.2	0.8	0.8	3.6	13.8	13.8	12212	13311	22	22	10290	35748	35748
171850001	3	2.9	0.1	2.8	2.8	2.9	3.1	3.1	42452	25439	27097	27097	28443	71817	71817
171851001	3	5.9	0.1	5.8	5.8	5.8	6.0	6.0	42452	25439	27097	27097	28443	71817	71817
171970013	19	6.6	4.8	1.1	1.1	5.2	18.6	18.6	2439	6269	6	6	37	25224	25224

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
180270002	6	6.3	0.6	5.8	5.8	6.0	7.3	7.3	10869	16456	9	9	2241	41536	41536
180290004	7	4.2	4.1	1.2	1.2	3.4	12.8	12.8	21579	32930	174	174	1574	85699	85699
180330002	2	0.8	0.0	0.8	0.8	0.8	0.8	0.8	80	42	50	50	80	109	109
180430004	8	13.4	3.1	8.8	8.8	12.3	17.7	17.7	6500	10778	12	12	484	23995	23995
180430007	10	9.2	6.4	1.1	1.1	7.3	19.9	19.9	6721	10131	12	12	516	23995	23995
180431004	9	10.0	3.5	5.0	5.0	9.8	14.7	14.7	7442	10470	12	12	798	23995	23995
180450001	3	9.8	8.7	4.5	4.5	5.1	19.8	19.8	18552	32099	10	10	28	55617	55617
180510001	3	2.0	0.1	1.8	1.8	2.0	2.1	2.1	42452	25439	27097	27097	28443	71817	71817
180510002	3	2.9	0.0	2.9	2.9	2.9	3.0	3.0	42452	25439	27097	27097	28443	71817	71817
180630001	0														
180630002	1	19.2		19.2	19.2	19.2	19.2	19.2	147		147	147	147	147	147
180630003	0														
180730002	4	4.3	1.0	3.5	3.5	4.0	5.8	5.8	6874	1422	6085	6085	6204	9002	9002
180730003	4	10.2	1.2	9.5	9.5	9.7	12.1	12.1	6874	1422	6085	6085	6204	9002	9002
180770004	2	4.3	0.1	4.3	4.3	4.3	4.4	4.4	19099	1297	18182	18182	19099	20016	20016
180890022	50	14.1	4.0	0.8	1.8	14.6	19.8	19.9	1014	1502	5	6	188	5951	6318
180891016	52	14.2	4.2	2.1	2.1	14.8	19.5	19.7	1138	1804	5	6	188	6318	8443
180892008	39	6.4	4.1	1.6	1.6	5.6	17.6	17.6	938	1945	5	5	72	8443	8443
180910005	3	9.1	9.7	0.4	0.4	7.3	19.6	19.6	4166	4640	20	20	3301	9178	9178
180910007	2	6.0	0.8	5.4	5.4	6.0	6.5	6.5	4599	6476	20	20	4599	9178	9178
180970042	22	11.2	2.9	7.8	7.8	11.0	17.0	17.0	2358	6820	5	5	36	30896	30896
180970054	20	3.3	2.3	0.9	0.9	2.4	9.2	9.2	2554	7138	5	5	23	30896	30896
180970057	20	4.2	2.0	0.9	0.9	4.3	9.8	9.8	2554	7138	5	5	23	30896	30896
180970072	21	6.9	3.5	0.8	0.8	6.6	18.7	18.7	2433	6980	5	5	19	30896	30896
180970073	20	13.7	2.3	6.2	6.2	14.5	15.3	15.3	2547	7141	5	5	18	30896	30896
181091001	3	4.3	2.4	2.1	2.1	4.0	6.9	6.9	6006	9709	242	242	561	17216	17216
181230006	8	7.7	4.3	2.8	2.8	7.0	14.3	14.3	7033	17145	7	7	38	49028	49028
181230007	8	6.8	4.2	2.1	2.1	5.7	13.1	13.1	7033	17145	7	7	38	49028	49028
181250005	6	3.0	4.7	0.9	0.9	1.1	12.7	12.7	10869	16456	9	9	2241	41536	41536
181270011	23	6.7	6.2	2.2	2.2	3.6	18.7	18.7	1703	2266	20	20	1062	9178	9178
181270017	22	5.4	5.7	2.0	2.0	2.6	17.8	17.8	1363	1612	20	20	1029	6318	6318
181270023	21	4.1	4.4	1.1	1.1	2.4	14.6	14.6	1427	1623	23	23	1062	6318	6318
181470002	7	13.0	3.6	8.0	8.0	15.0	16.6	16.6	15627	24405	7	7	66	53196	53196
181470010	4	12.3	6.6	3.3	3.3	14.0	17.9	17.9	15099	25616	20	20	3589	53196	53196
181530004	3	12.1	6.4	4.8	4.8	14.7	16.8	16.8	9270	8089	10	10	12846	14955	14955
181630012	5	13.1	7.7	3.1	3.1	18.0	19.6	19.6	1806	2589	5	5	382	6004	6004

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
181631002	5	8.5	5.3	3.4	3.4	9.5	16.5	16.5	1806	2589	5	5	382	6004	6004
181670018	6	6.8	3.6	5.0	5.0	5.5	14.1	14.1	10842	25028	12	12	417	61901	61901
181671014	6	6.8	5.9	1.9	1.9	5.5	17.3	17.3	10842	25028	12	12	417	61901	61901
181730002	8	2.9	0.4	2.5	2.5	3.0	3.3	3.3	13636	16457	50	50	3559	41049	41049
181731001	8	3.0	0.5	2.5	2.5	2.9	3.7	3.7	13636	16457	50	50	3559	41049	41049
181770006	2	2.1	1.4	1.1	1.1	2.1	3.1	3.1	6446	9089	19	19	6446	12873	12873
181770007	2	3.2	2.5	1.4	1.4	3.2	5.0	5.0	6446	9089	19	19	6446	12873	12873
190330018	4	3.9	3.7	0.4	0.4	3.2	8.8	8.8	2684	3305	20	20	1934	6850	6850
190450018	2	1.4	0.9	0.7	0.7	1.4	2.0	2.0	4694	839	4101	4101	4694	5287	5287
190450019	2	1.3	1.0	0.6	0.6	1.3	2.0	2.0	4694	839	4101	4101	4694	5287	5287
190450020	2	3.4	0.6	3.0	3.0	3.4	3.8	3.8	4694	839	4101	4101	4694	5287	5287
190610012	2	4.0	2.9	1.9	1.9	4.0	6.1	6.1	1886	52	1848	1848	1886	1923	1923
191110006	1	3.7		3.7	3.7	3.7	3.7	3.7	29		29	29	29	29	29
191111007	2	13.3	6.3	8.8	8.8	13.3	17.7	17.7	104	105	29	29	104	179	179
191130026	7	7.0	3.1	2.8	2.8	7.7	11.8	11.8	2200	2428	12	12	1954	5480	5480
191130028	7	5.8	2.4	2.8	2.8	6.7	8.8	8.8	2200	2428	12	12	1954	5480	5480
191130029	7	3.8	3.1	0.5	0.5	4.0	9.2	9.2	2200	2428	12	12	1954	5480	5480
191130031	7	4.3	3.2	0.5	0.5	4.7	9.3	9.3	2200	2428	12	12	1954	5480	5480
191130032	7	3.5	2.7	0.6	0.6	3.1	8.8	8.8	2200	2428	12	12	1954	5480	5480
191130034	7	3.6	2.5	0.2	0.2	2.9	7.4	7.4	2200	2428	12	12	1954	5480	5480
191130035	7	4.3	1.7	1.3	1.3	4.8	5.9	5.9	2200	2428	12	12	1954	5480	5480
191130038	7	3.9	1.9	0.6	0.6	4.2	6.2	6.2	2200	2428	12	12	1954	5480	5480
191130039	7	4.6	3.0	1.1	1.1	4.2	10.3	10.3	2200	2428	12	12	1954	5480	5480
191390016	5	8.7	6.9	2.4	2.4	7.4	19.2	19.2	6227	6934	83	83	3790	15901	15901
191390017	4	3.8	3.6	0.6	0.6	3.1	8.5	8.5	7763	6956	463	463	7345	15901	15901
191390020	4	4.9	4.4	0.9	0.9	4.0	10.4	10.4	7763	6956	463	463	7345	15901	15901
191530030	1	4.9		4.9	4.9	4.9	4.9	4.9	20		20	20	20	20	20
191630014	1	18.7		18.7	18.7	18.7	18.7	18.7	2329		2329	2329	2329	2329	2329
191630015	7	9.5	5.0	1.1	1.1	11.7	15.1	15.1	1345	1810	17	17	336	4963	4963
191630017	7	9.6	4.2	1.1	1.1	11.2	13.6	13.6	2120	3515	17	17	303	8983	8983
191770004	0														
191770005	0														
191770006	0														
191930018	4	6.4	4.3	0.7	0.7	7.1	10.7	10.7	9208	10818	15	15	7845	21127	21127
201070002	0														
201250006	4	5.8	9.3	0.5	0.5	1.6	19.7	19.7	468	464	11	11	428	1006	1006

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
201250007	4	7.2	6.9	3.3	3.3	3.9	17.5	17.5	468	464	11	11	428	1006	1006
201450001	0														
201730010	3	11.4	3.1	9.0	9.0	10.2	14.9	14.9	269	448	6	6	15	785	785
201910002	3	16.3	2.4	13.6	13.6	17.3	18.0	18.0	269	448	6	6	15	785	785
201950001	0														
202090001	14	9.2	5.9	3.5	3.5	7.1	19.8	19.8	1388	2341	6	6	34	7625	7625
202090020	14	9.0	6.1	0.6	0.6	7.7	18.9	18.9	1388	2341	6	6	34	7625	7625
202090021	13	8.6	5.5	3.4	3.4	6.6	19.1	19.1	1494	2402	6	6	40	7625	7625
210190015	9	12.3	5.5	1.6	1.6	14.6	17.7	17.7	1323	2058	25	25	401	6285	6285
210190017	10	12.8	5.4	2.9	2.9	13.8	19.5	19.5	1193	1983	25	25	343	6285	6285
210191003	8	9.3	5.4	1.3	1.3	9.9	15.4	15.4	1271	2194	25	25	343	6285	6285
210370003	11	12.0	3.0	8.1	8.1	10.8	17.8	17.8	6817	20950	12	12	268	69953	69953
210371001	11	8.5	3.4	4.2	4.2	7.5	15.5	15.5	465	664	12	12	213	1848	1848
210590005	4	7.4	6.8	2.2	2.2	5.5	16.5	16.5	15241	25506	26	26	3871	53196	53196
210670012	3	3.2	2.2	1.2	1.2	2.7	5.6	5.6	209	316	12	12	42	573	573
210890007	5	10.9	6.2	5.1	5.1	7.6	19.8	19.8	961	1147	25	25	401	2589	2589
210910012	9	10.4	5.1	1.2	1.2	10.6	18.9	18.9	12162	22226	7	7	38	53196	53196
211010013	4	10.2	5.5	2.0	2.0	12.7	13.3	13.3	2256	2755	5	5	1508	6004	6004
211010014	10	12.9	1.4	11.5	11.5	12.8	16.6	16.6	10948	15581	5	5	2980	41049	41049
211110032	14	11.4	5.6	2.4	2.4	13.7	18.3	18.3	6208	8948	38	38	516	23995	23995
211110051	12	10.6	7.5	1.6	1.6	14.6	18.7	18.7	3259	5326	38	38	168	14977	14977
211111041	11	9.1	7.3	1.3	1.3	7.7	19.3	19.3	6268	9779	12	12	234	23995	23995
211130001	2	17.0	1.4	16.0	16.0	17.0	18.0	18.0	23589	32550	573	573	23589	46605	46605
211170007	12	11.9	4.8	4.7	4.7	12.5	18.6	18.6	455	637	12	12	240	1848	1848
211390004	4	8.0	6.9	3.1	3.1	5.4	17.9	17.9	444	869	6	6	11	1747	1747
211450001	7	7.5	3.4	2.0	2.0	9.4	11.2	11.2	8769	13010	174	174	7435	37077	37077
211451024	3	18.2	2.1	15.8	15.8	19.3	19.5	19.5	587	1005	6	6	7	1747	1747
211451026	3	15.3	2.2	12.7	12.7	16.5	16.7	16.7	587	1005	6	6	7	1747	1747
211771004	3	15.9	0.3	15.5	15.5	15.9	16.2	16.2	32380	45236	38	38	13028	84073	84073
211830032	3	13.5	5.7	7.1	7.1	15.4	18.0	18.0	35331	42262	8893	8893	13028	84073	84073
211950002	0														
212270008	1	19.1		19.1	19.1	19.1	19.1	19.1	52		52	52	52	52	52
220150008	2	8.7	0.1	8.6	8.6	8.7	8.8	8.8	77	21	62	62	77	91	91
220190008	16	7.6	6.1	1.2	1.2	5.8	16.7	16.7	3352	5531	6	6	184	18851	18851
220330009	28	5.8	5.6	1.5	1.5	3.2	20.0	20.0	1406	3913	6	6	45	18680	18680
220511001	20	14.1	2.9	8.8	8.8	13.1	18.3	18.3	425	869	6	6	38	3359	3359

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
220730004	1	10.1		10.1	10.1	10.1	10.1	10.1	2166		2166	2166	2166	2166	2166
220870002	18	8.8	4.2	0.5	0.5	7.8	19.0	19.0	419	846	8	8	52	3009	3009
220870007	18	6.4	4.9	0.9	0.9	3.8	15.9	15.9	419	846	8	8	52	3009	3009
220870009	18	5.7	5.8	1.3	1.3	2.0	17.9	17.9	419	846	8	8	52	3009	3009
221210001	28	5.4	4.7	2.4	2.4	3.4	18.1	18.1	1116	3650	6	6	33	18680	18680
230010011	9	6.6	4.3	1.3	1.3	6.5	13.3	13.3	31	41	5	5	23	140	140
230013003	9	7.5	4.8	0.8	0.8	8.3	15.2	15.2	31	41	5	5	23	140	140
230030009	1	1.9		1.9	1.9	1.9	1.9	1.9	90		90	90	90	90	90
230030012	1	1.0		1.0	1.0	1.0	1.0	1.0	90		90	90	90	90	90
230031003	1	1.3		1.3	1.3	1.3	1.3	1.3	90		90	90	90	90	90
230031013	3	4.7	4.5	1.4	1.4	2.8	9.9	9.9	16	17	5	5	7	36	36
230031018	4	8.5	5.6	0.3	0.3	10.3	13.0	13.0	193	233	7	7	133	499	499
230031100	5	10.4	7.2	0.7	0.7	10.5	18.4	18.4	155	219	6	6	15	499	499
230050014	12	6.1	4.8	1.2	1.2	5.0	16.8	16.8	267	628	5	5	16	2091	2091
230050027	12	6.0	4.7	0.8	0.8	4.8	16.6	16.6	267	628	5	5	16	2091	2091
230090103	1	5.3		5.3	5.3	5.3	5.3	5.3	26		26	26	26	26	26
230170011	2	0.7	0.1	0.7	0.7	0.7	0.8	0.8	249	344	6	6	249	492	492
230172007	2	1.0	0.1	1.0	1.0	1.0	1.1	1.1	249	344	6	6	249	492	492
240010006	2	8.9	4.0	6.0	6.0	8.9	11.7	11.7	681	685	197	197	681	1166	1166
240032002	20	11.9	4.5	2.7	2.7	13.3	19.9	19.9	3247	9622	5	5	21	39974	39974
240053001	22	11.9	3.3	4.6	4.6	12.1	19.2	19.2	4429	11101	5	5	27	39974	39974
245100018	21	9.1	4.6	1.4	1.4	7.6	16.7	16.7	3101	9402	5	5	22	39974	39974
245100036	21	6.6	3.3	1.6	1.6	6.8	16.0	16.0	4635	11331	5	5	22	39974	39974
250050010	25	8.1	7.2	0.2	0.2	4.2	20.0	20.0	1794	7923	6	6	27	39593	39593
250051004	24	7.5	6.7	0.1	0.1	3.8	18.9	18.9	1867	8085	6	6	31	39593	39593
250056001	40	13.6	5.7	4.6	4.7	15.5	19.9	19.9	1146	6273	5	5	24	21997	39593
250090005	25	9.6	6.6	0.3	0.3	9.2	19.9	19.9	65	148	6	6	26	762	762
250091004	23	11.3	6.3	0.8	0.8	12.8	20.0	20.0	878	3071	5	5	16	14132	14132
250091005	22	11.2	6.3	0.7	0.7	11.9	18.6	18.6	917	3137	5	5	16	14132	14132
250095004	14	8.6	4.2	0.7	0.7	10.1	14.7	14.7	88	197	8	8	25	762	762
250130016	34	7.6	5.2	0.5	0.5	7.4	19.2	19.2	216	907	5	5	14	5282	5282
250131009	32	8.4	4.7	1.7	1.7	7.4	18.9	18.9	65	148	5	5	13	671	671
250154002	12	15.8	3.4	9.1	9.1	16.8	19.7	19.7	72	113	6	6	29	363	363
250171701	55	13.3	4.6	0.4	2.9	15.0	19.4	20.0	139	678	5	5	15	640	5007
250174003	57	12.2	4.0	0.6	5.6	12.4	19.5	19.7	127	663	5	5	13	460	5007
250250002	62	9.6	6.1	0.7	1.1	8.6	19.5	19.7	129	639	5	5	14	640	5007

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
250250019	50	12.0	3.8	0.7	4.2	12.0	18.1	18.4	156	710	5	5	14	640	5007
250250020	58	10.0	5.0	1.1	3.0	9.1	19.2	19.2	138	660	5	5	15	640	5007
250250021	58	10.6	4.7	1.8	3.4	9.3	19.5	20.0	137	660	5	5	14	640	5007
250250040	59	10.2	5.3	1.0	1.4	9.5	19.5	19.8	135	654	5	5	14	640	5007
250250042	60	9.4	5.8	0.5	0.7	9.1	19.1	19.3	133	649	5	5	14	640	5007
250251003	58	11.0	4.6	1.0	2.1	10.4	19.3	19.4	380	1952	5	5	15	5007	14132
250270020	28	5.0	5.9	0.1	0.1	2.8	19.5	19.5	25	35	6	6	12	178	178
250270023	28	5.1	5.8	0.6	0.6	2.9	19.1	19.1	25	35	6	6	12	178	178
260410902	3	2.5	1.5	0.8	0.8	3.3	3.4	3.4	1407	1264	671	671	685	2867	2867
260490021	4	10.9	4.5	4.2	4.2	13.1	13.1	13.1	42	24	7	7	48	63	63
260492001	2	19.0	0.4	18.8	18.8	19.0	19.3	19.3	64	79	7	7	64	120	120
260810020	9	10.5	5.6	4.3	4.3	10.6	19.4	19.4	60	96	9	9	12	280	280
260991003	3	14.0	3.4	10.2	10.2	15.2	16.7	16.7	239	287	10	10	148	560	560
261130001	1	10.3		10.3	10.3	10.3	10.3	10.3	58		58	58	58	58	58
261470005	3	8.7	5.9	3.8	3.8	6.9	15.2	15.2	524	431	31	31	715	826	826
261530001	0														
261630001	36	10.9	4.0	5.4	5.4	9.6	20.0	20.0	1780	5390	5	5	109	30171	30171
261630005	34	6.1	5.4	1.2	1.2	4.4	19.0	19.0	1894	5529	5	5	117	30171	30171
261630015	32	5.5	4.2	1.5	1.5	3.8	17.9	17.9	1070	2436	5	5	117	8913	8913
261630016	31	9.0	2.7	3.6	3.6	8.6	17.0	17.0	1104	2469	5	5	121	8913	8913
261630019	23	17.3	4.5	3.7	3.7	18.9	19.8	19.8	1358	2828	10	10	121	8913	8913
261630025	6	14.8	2.4	11.2	11.2	15.2	17.8	17.8	13	14	5	5	9	42	42
261630027	33	5.5	5.2	0.4	0.4	3.9	19.7	19.7	1952	5605	5	5	121	30171	30171
261630033	32	5.0	4.5	0.4	0.4	4.2	15.8	15.8	1070	2436	5	5	117	8913	8913
261630062	31	9.0	2.9	3.1	3.1	8.5	17.2	17.2	1104	2469	5	5	121	8913	8913
261630092	33	5.4	5.1	0.9	0.9	3.0	19.9	19.9	1952	5605	5	5	121	30171	30171
270031002	10	14.3	4.4	4.7	4.7	15.5	18.9	18.9	1332	4067	5	5	11	12904	12904
270176316	5	13.7	6.8	2.2	2.2	16.4	19.7	19.7	72	84	5	5	26	190	190
270370020	15	11.9	6.1	0.9	0.9	12.4	19.6	19.6	610	1015	9	9	104	3071	3071
270370423	17	11.6	5.5	0.4	0.4	12.4	18.8	18.8	805	1227	9	9	205	3821	3821
270370439	14	12.5	5.8	2.6	2.6	13.1	20.0	20.0	639	1047	9	9	79	3071	3071
270370441	12	11.6	5.7	1.6	1.6	12.6	19.0	19.0	720	1114	9	9	79	3071	3071
270370442	11	12.2	5.5	2.3	2.3	13.8	18.8	18.8	506	873	9	9	54	2869	2869
270530954	24	10.9	5.8	0.6	0.6	12.2	19.0	19.0	913	2729	5	5	48	12904	12904
270530957	21	10.7	5.3	0.9	0.9	10.9	18.3	18.3	878	2877	5	5	12	12904	12904
270711240	1	0.3		0.3	0.3	0.3	0.3	0.3	67		67	67	67	67	67

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
271230864	27	12.0	4.8	3.9	3.9	12.6	19.7	19.7	769	2540	5	5	46	12904	12904
271410003	1	4.9		4.9	4.9	4.9	4.9	4.9	26742		26742	26742	26742	26742	26742
271410011	1	1.7		1.7	1.7	1.7	1.7	1.7	26742		26742	26742	26742	26742	26742
271410012	1	1.8		1.8	1.8	1.8	1.8	1.8	26742		26742	26742	26742	26742	26742
271410013	1	1.1		1.1	1.1	1.1	1.1	1.1	26742		26742	26742	26742	26742	26742
271630436	21	11.1	5.6	0.9	0.9	11.4	18.4	18.4	545	997	7	7	104	3821	3821
271710007	2	11.8	6.5	7.2	7.2	11.8	16.3	16.3	13397	18873	52	52	13397	26742	26742
280030004	2	7.1	0.7	6.6	6.6	7.1	7.6	7.6	19	19	5	5	19	32	32
280190001	2	5.8	6.2	1.5	1.5	5.8	10.2	10.2	2376	3351	6	6	2376	4745	4745
280470007	2	6.5	7.9	0.9	0.9	6.5	12.1	12.1	12535	17718	6	6	12535	25064	25064
280490018	5	7.3	5.4	3.2	3.2	6.0	16.6	16.6	51	45	15	15	30	128	128
280590006	7	7.0	4.9	3.3	3.3	5.4	17.3	17.3	4903	10049	12	12	96	27207	27207
280810004	0														
280930001	1	19.0		19.0	19.0	19.0	19.0	19.0	75		75	75	75	75	75
281070001	1	2.3		2.3	2.3	2.3	2.3	2.3	5		5	5	5	5	5
290210009	1	0.7		0.7	0.7	0.7	0.7	0.7	3563		3563	3563	3563	3563	3563
290210011	1	0.9		0.9	0.9	0.9	0.9	0.9	3563		3563	3563	3563	3563	3563
290470025	15	11.9	4.8	2.8	2.8	10.8	18.2	18.2	1682	2364	6	6	105	7625	7625
290770026	4	8.2	4.5	2.3	2.3	9.3	11.8	11.8	2302	2728	5	5	1772	5657	5657
290770032	4	7.8	3.9	3.0	3.0	8.5	11.0	11.0	2302	2728	5	5	1772	5657	5657
290770037	4	9.2	6.1	0.6	0.6	11.0	14.0	14.0	2302	2728	5	5	1772	5657	5657
290770040	4	9.2	6.2	0.5	0.5	11.0	14.1	14.1	2302	2728	5	5	1772	5657	5657
290770041	4	8.6	5.5	1.2	1.2	9.7	13.8	13.8	2302	2728	5	5	1772	5657	5657
290930030	1	1.7		1.7	1.7	1.7	1.7	1.7	43340		43340	43340	43340	43340	43340
290930031	1	4.6		4.6	4.6	4.6	4.6	4.6	43340		43340	43340	43340	43340	43340
290950034	14	8.7	4.9	1.4	1.4	8.1	15.4	15.4	1388	2341	6	6	34	7625	7625
290990004	5	9.7	7.4	0.2	0.2	11.4	17.1	17.1	11145	10277	243	243	15223	23258	23258
290990014	5	9.8	7.4	0.7	0.7	11.9	17.5	17.5	11145	10277	243	243	15223	23258	23258
290990017	5	10.2	7.1	1.6	1.6	10.6	17.3	17.3	11145	10277	243	243	15223	23258	23258
290990018	4	8.3	6.6	1.4	1.4	8.2	15.3	15.3	8117	8927	243	243	7889	16447	16447
291370001	0														
291630002	2	7.3	6.6	2.7	2.7	7.3	12.0	12.0	6747	934	6087	6087	6747	7408	7408
291650023	4	17.8	1.3	16.0	16.0	18.1	19.1	19.1	2757	3602	19	19	1693	7625	7625
291830010	1	1.7		1.7	1.7	1.7	1.7	1.7	47610		47610	47610	47610	47610	47610
291831002	15	12.6	3.4	4.3	4.3	13.5	17.3	17.3	4516	11970	6	6	136	45960	45960
291890001	14	14.8	4.4	6.4	6.4	15.9	19.7	19.7	1748	4547	8	8	35	16447	16447

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
291890004	9	14.0	3.1	9.8	9.8	15.2	18.2	18.2	2535	5610	8	8	13	16447	16447
291890006	7	14.7	4.6	8.4	8.4	15.7	19.9	19.9	27	48	6	6	8	136	136
291890014	8	11.9	6.2	3.2	3.2	11.3	19.7	19.7	33	47	6	6	10	136	136
291893001	29	15.2	4.2	5.1	5.1	16.0	20.0	20.0	370	1164	6	6	60	6250	6250
291895001	35	15.1	3.1	6.7	6.7	15.9	20.0	20.0	1911	7823	6	6	111	45960	45960
291897002	14	13.2	5.7	3.9	3.9	14.6	20.0	20.0	50	75	6	6	16	277	277
291897003	18	14.1	5.4	3.5	3.5	16.2	19.4	19.4	403	1461	6	6	37	6250	6250
295100007	19	12.5	6.0	0.5	0.5	14.0	19.6	19.6	1312	3936	8	8	50	16447	16447
295100072	30	8.8	3.8	2.0	2.0	9.7	19.2	19.2	445	1152	6	6	68	6250	6250
295100080	34	10.7	4.3	0.4	0.4	10.5	19.7	19.7	397	1088	6	6	61	6250	6250
295100086	32	9.8	3.9	1.7	1.7	10.0	18.6	18.6	421	1118	6	6	68	6250	6250
300030038	0														
300132000	2	4.1	3.6	1.5	1.5	4.1	6.7	6.7	351	481	11	11	351	691	691
300132001	2	4.1	4.9	0.7	0.7	4.1	7.5	7.5	351	481	11	11	351	691	691
300430903	1	3.3		3.3	3.3	3.3	3.3	3.3	234		234	234	234	234	234
300430908	1	1.3		1.3	1.3	1.3	1.3	1.3	234		234	234	234	234	234
300430909	1	3.0		3.0	3.0	3.0	3.0	3.0	234		234	234	234	234	234
300430910	1	4.7		4.7	4.7	4.7	4.7	4.7	234		234	234	234	234	234
300430911	1	4.5		4.5	4.5	4.5	4.5	4.5	234		234	234	234	234	234
300430912	1	4.6		4.6	4.6	4.6	4.6	4.6	234		234	234	234	234	234
300430913	1	4.9		4.9	4.9	4.9	4.9	4.9	234		234	234	234	234	234
300430914	1	5.6		5.6	5.6	5.6	5.6	5.6	234		234	234	234	234	234
300430915	1	5.5		5.5	5.5	5.5	5.5	5.5	234		234	234	234	234	234
300430916	1	5.1		5.1	5.1	5.1	5.1	5.1	234		234	234	234	234	234
300490701	1	5.1		5.1	5.1	5.1	5.1	5.1	234		234	234	234	234	234
300490702	1	6.2		6.2	6.2	6.2	6.2	6.2	234		234	234	234	234	234
300490703	1	7.3		7.3	7.3	7.3	7.3	7.3	234		234	234	234	234	234
300650004	0														
300870700	1	19.8		19.8	19.8	19.8	19.8	19.8	16735		16735	16735	16735	16735	16735
300870701	1	19.0		19.0	19.0	19.0	19.0	19.0	16735		16735	16735	16735	16735	16735
300870702	1	19.8		19.8	19.8	19.8	19.8	19.8	16735		16735	16735	16735	16735	16735
300870760	0														
300870761	0														
300870762	0														
300870763	1	15.2		15.2	15.2	15.2	15.2	15.2	16735		16735	16735	16735	16735	16735
301110016	0														

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
301110066	4	3.1	0.5	2.6	2.6	3.1	3.7	3.7	1370	1322	75	75	1135	3135	3135
301110079	4	7.8	3.0	5.8	5.8	6.7	12.2	12.2	1370	1322	75	75	1135	3135	3135
301110080	4	2.4	1.8	0.9	0.9	1.9	5.0	5.0	1370	1322	75	75	1135	3135	3135
301110082	4	3.4	2.7	1.7	1.7	2.3	7.3	7.3	1370	1322	75	75	1135	3135	3135
301110083	4	3.4	0.7	2.7	2.7	3.4	4.4	4.4	1370	1322	75	75	1135	3135	3135
301110084	6	10.3	6.6	3.1	3.1	7.4	18.6	18.6	2550	2627	75	75	1976	7415	7415
301111065	4	4.7	2.7	0.7	0.7	5.7	6.7	6.7	1370	1322	75	75	1135	3135	3135
301112005	4	4.1	1.8	1.5	1.5	4.6	5.7	5.7	1370	1322	75	75	1135	3135	3135
301112006	6	10.1	7.2	1.1	1.1	7.6	18.8	18.8	2550	2627	75	75	1976	7415	7415
301112007	6	11.4	3.9	4.7	4.7	11.2	15.3	15.3	2550	2627	75	75	1976	7415	7415
301112008	4	4.0	2.6	2.3	2.3	3.0	7.8	7.8	1370	1322	75	75	1135	3135	3135
310550048	5	12.7	7.5	0.5	0.5	13.6	19.3	19.3	6370	9218	6	6	58	20257	20257
310550050	5	13.4	7.5	1.0	1.0	14.7	19.6	19.6	6370	9218	6	6	58	20257	20257
310550053	5	11.3	5.7	3.3	3.3	10.6	18.0	18.0	6370	9218	6	6	58	20257	20257
310550055	3	13.0	7.3	4.7	4.7	16.1	18.2	18.2	3845	6637	6	6	20	11509	11509
320030022	4	3.9	0.0	3.8	3.8	3.9	3.9	3.9	45	27	16	16	44	75	75
320030078	0														
320030539	0														
320030601	0														
330050007	1	0.3		0.3	0.3	0.3	0.3	0.3	81		81	81	81	81	81
330070019	1	1.7		1.7	1.7	1.7	1.7	1.7	638		638	638	638	638	638
330070022	1	2.3		2.3	2.3	2.3	2.3	2.3	638		638	638	638	638	638
330071007	2	0.6	0.1	0.6	0.6	0.6	0.7	0.7	9	4	6	6	9	12	12
330110016	3	17.3	1.3	16.5	16.5	16.6	18.8	18.8	10269	10386	149	149	9754	20902	20902
330110019	3	17.0	2.3	15.7	15.7	15.7	19.6	19.6	10269	10386	149	149	9754	20902	20902
330110020	3	17.0	2.3	15.7	15.7	15.7	19.6	19.6	10269	10386	149	149	9754	20902	20902
330111009	11	12.7	6.0	4.4	4.4	14.7	19.0	19.0	41	42	6	6	20	149	149
330111010	16	13.0	3.0	7.2	7.2	12.0	19.0	19.0	48	42	6	6	38	149	149
330130007	4	7.3	3.9	1.4	1.4	9.0	9.6	9.6	7708	9906	41	41	4945	20902	20902
330131003	4	7.7	5.4	4.0	4.0	5.6	15.4	15.4	7708	9906	41	41	4945	20902	20902
330131006	4	8.2	8.8	1.3	1.3	5.8	19.8	19.8	7708	9906	41	41	4945	20902	20902
330131007	4	9.3	2.1	7.5	7.5	8.6	12.3	12.3	7708	9906	41	41	4945	20902	20902
330150009	9	9.0	6.9	2.0	2.0	4.4	19.2	19.2	1523	2990	6	6	52	8057	8057
330150014	9	9.6	7.0	1.0	1.0	5.5	19.9	19.9	1523	2990	6	6	52	8057	8057
330150015	9	8.9	7.1	1.9	1.9	4.1	19.5	19.5	1523	2990	6	6	52	8057	8057
330190003	2	2.5	1.7	1.3	1.3	2.5	3.7	3.7	110	81	53	53	110	168	168

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
340010005	0														
340030001	74	11.1	4.4	2.9	2.9	11.1	19.0	19.1	391	2221	5	5	18	2302	18958
340035001	61	14.8	3.7	2.2	5.2	15.7	19.7	19.9	457	2442	6	6	22	2302	18958
340051001	21	10.7	6.7	1.5	1.5	12.3	19.9	19.9	719	3104	5	5	35	14266	14266
340070003	60	9.7	3.4	2.0	2.8	9.6	17.2	19.9	179	644	5	5	25	2378	4450
340071001	2	10.2	0.5	9.9	9.9	10.2	10.5	10.5	8	1	8	8	8	9	9
340110007	4	7.5	6.6	1.8	1.8	5.7	16.8	16.8	161	198	28	28	81	456	456
340130011	59	13.1	4.9	1.6	2.2	14.2	19.2	19.4	465	2471	5	6	25	1845	18958
340130016	61	13.4	5.0	1.8	2.7	14.3	19.8	19.9	453	2431	5	6	25	1845	18958
340150002	50	13.2	3.7	2.1	4.6	12.9	19.2	19.7	529	1281	5	6	44	4450	6720
340170006	59	13.0	4.6	2.0	3.2	13.5	19.9	19.9	467	2471	5	5	25	1845	18958
340171002	71	11.9	5.0	0.8	0.8	11.6	19.7	19.8	421	2267	5	5	18	2302	18958
340232003	21	8.6	4.6	1.8	1.8	9.2	15.8	15.8	80	206	6	6	16	958	958
340273001	2	17.7	3.1	15.5	15.5	17.7	19.8	19.8	19	8	13	13	19	25	25
340390003	38	11.5	5.3	2.3	2.3	12.4	20.0	20.0	610	3074	5	5	19	18958	18958
340390004	38	11.2	5.6	0.7	0.7	12.1	19.9	19.9	609	3075	5	5	19	18958	18958
350130008	1	17.9		17.9	17.9	17.9	17.9	17.9	37		37	37	37	37	37
350130017	13	14.8	4.0	1.7	1.7	15.7	17.7	17.7	44	92	5	5	11	345	345
350151004	4	8.6	8.4	0.9	0.9	8.7	16.1	16.1	1058	973	168	168	983	2099	2099
350170001	1	6.1		6.1	6.1	6.1	6.1	6.1	263		263	263	263	263	263
350171003	1	1.5		1.5	1.5	1.5	1.5	1.5	263		263	263	263	263	263
350230005	0														
350450008	7	17.2	3.5	11.9	11.9	19.2	19.3	19.3	2478	2496	11	11	2554	5919	5919
350450009	2	3.3	2.0	2.0	2.0	3.3	4.7	4.7	293	378	25	25	293	560	560
350450017	0														
350451005	8	6.1	3.8	3.2	3.2	3.5	11.9	11.9	6274	10983	11	11	2630	32847	32847
360010012	9	10.8	5.2	3.5	3.5	9.0	18.0	18.0	40	46	7	7	20	153	153
360050073	68	10.0	4.9	3.4	3.4	9.1	19.2	19.7	399	2309	5	6	22	2302	18958
360050080	66	10.6	5.0	1.8	3.0	9.6	19.5	19.9	406	2344	5	6	18	2302	18958
360050083	56	11.2	5.6	1.6	1.8	11.3	19.6	19.6	119	355	6	6	19	1129	2302
360050110	67	10.1	4.9	2.7	2.8	9.0	19.2	19.7	402	2326	5	6	21	2302	18958
360050133	56	11.4	5.7	1.5	1.7	11.6	19.9	19.9	119	355	6	6	19	1129	2302
360130005	0														
360130006	1	2.0		2.0	2.0	2.0	2.0	2.0	52177		52177	52177	52177	52177	52177
360130011	0														
360150003	2	10.2	13.6	0.6	0.6	10.2	19.9	19.9	202	270	11	11	202	393	393

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
360290005	10	10.2	4.7	2.5	2.5	11.1	15.4	15.4	4073	12273	8	8	182	38999	38999
360294002	16	10.4	6.2	1.6	1.6	12.3	18.3	18.3	2608	9706	8	8	166	38999	38999
360298001	9	13.5	5.6	4.6	4.6	14.7	19.0	19.0	4518	12932	8	8	247	38999	38999
360310003	0														
360330004	0														
360337003	2	9.8	7.7	4.3	4.3	9.8	15.2	15.2	1244	1404	250	250	1244	2237	2237
360410005	0														
360430005	0														
360470011	77	10.3	5.5	0.7	1.9	10.8	19.2	19.7	377	2178	5	5	18	2302	18958
360470076	67	11.6	4.8	2.3	3.1	11.5	19.4	19.9	428	2333	5	5	17	2302	18958
360530006	0														
360551004	4	11.0	4.2	7.6	7.6	10.0	16.5	16.5	12595	14519	8	8	11988	26395	26395
360551007	4	11.3	4.1	6.4	6.4	11.9	15.0	15.0	12595	14519	8	8	11988	26395	26395
360556001	4	10.5	6.8	5.2	5.2	8.5	19.8	19.8	12595	14519	8	8	11988	26395	26395
360590005	12	11.8	4.8	1.9	1.9	11.8	19.1	19.1	151	301	6	6	26	1057	1057
360610010	77	10.4	5.4	0.3	1.4	11.1	19.4	19.6	375	2178	5	5	17	2302	18958
360610056	76	9.9	5.4	0.3	1.4	10.6	19.9	19.9	382	2192	5	5	18	2302	18958
360632006	12	8.5	7.0	0.5	0.5	9.0	19.7	19.7	3395	11213	14	14	166	38999	38999
360632008	13	9.3	7.3	0.3	0.3	12.2	19.8	19.8	3134	10777	8	8	118	38999	38999
360670017	5	7.9	5.8	5.0	5.0	5.5	18.2	18.2	669	1428	8	8	30	3223	3223
360671015	4	5.9	4.3	1.9	1.9	5.2	11.5	11.5	820	1602	8	8	24	3223	3223
360790005	0														
360810004	65	12.7	3.9	1.9	2.6	12.8	19.6	20.0	124	345	5	6	21	1129	2302
360810097	60	14.8	4.0	2.9	5.0	15.5	19.9	20.0	136	358	5	6	22	1129	2302
360810124	66	12.5	4.0	2.1	2.3	12.4	19.5	20.0	122	342	5	6	21	1129	2302
360830004	3	18.4	1.8	16.3	16.3	19.3	19.6	19.6	126	106	10	10	153	217	217
360831005	2	17.6	1.6	16.5	16.5	17.6	18.8	18.8	94	124	6	6	94	182	182
360850067	48	14.0	4.0	5.5	6.2	14.2	19.6	19.9	515	2737	5	6	17	1845	18958
360930003	4	9.5	6.6	2.0	2.0	9.7	16.5	16.5	24	26	6	6	14	62	62
361010003	2	15.8	1.0	15.1	15.1	15.8	16.6	16.6	8	3	6	6	8	11	11
361030002	9	9.3	5.8	1.9	1.9	7.3	18.2	18.2	156	344	6	6	19	1057	1057
361030009	10	11.3	5.7	2.0	2.0	11.9	19.3	19.3	734	2013	11	11	42	6453	6453
361111005	0														
370030003	0														
370130003	1	2.2		2.2	2.2	2.2	2.2	2.2	4730		4730	4730	4730	4730	4730
370130004	1	2.7		2.7	2.7	2.7	2.7	2.7	4730		4730	4730	4730	4730	4730

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
370130006	1	1.1		1.1	1.1	1.1	1.1	1.1	4730		4730	4730	4730	4730	4730
370370004	4	17.2	3.7	11.8	11.8	18.6	19.9	19.9	119	71	12	12	148	165	165
370511003	5	15.8	2.5	11.5	11.5	16.5	17.9	17.9	295	264	17	17	173	675	675
370590002	4	15.3	4.3	10.4	10.4	15.6	19.6	19.6	1949	3658	13	13	175	7432	7432
370610002	5	12.3	4.9	4.1	4.1	13.1	17.0	17.0	83	132	6	6	36	317	317
370650099	1	16.1		16.1	16.1	16.1	16.1	16.1	325		325	325	325	325	325
370670022	9	6.3	5.7	1.2	1.2	3.9	17.8	17.8	438	848	5	5	46	2591	2591
371010002	2	10.3	7.5	5.0	5.0	10.3	15.6	15.6	15	4	12	12	15	17	17
371090004	1	10.7		10.7	10.7	10.7	10.7	10.7	10		10	10	10	10	10
371170001	2	6.6	7.8	1.1	1.1	6.6	12.2	12.2	1713	2329	66	66	1713	3360	3360
371170002	2	5.9	2.3	4.3	4.3	5.9	7.6	7.6	1713	2329	66	66	1713	3360	3360
371190034	12	13.3	4.7	6.3	6.3	12.8	19.8	19.8	86	121	5	5	11	320	320
371190041	12	12.7	5.0	6.3	6.3	12.2	19.8	19.8	68	103	5	5	11	320	320
371290002	9	14.5	4.9	2.3	2.3	15.4	19.0	19.0	3325	6800	6	6	313	20865	20865
371290006	12	6.9	4.8	0.6	0.6	7.1	14.5	14.5	2502	5987	6	6	50	20865	20865
371310002	3	4.2	1.8	2.1	2.1	5.1	5.3	5.3	805	759	16	16	871	1529	1529
371450003	3	18.8	0.5	18.4	18.4	18.7	19.3	19.3	32251	54874	5	5	1136	95610	95610
371470099	2	1.3	0.0	1.3	1.3	1.3	1.3	1.3	14	3	12	12	14	16	16
371590021	6	15.2	4.2	8.0	8.0	15.8	19.9	19.9	1443	2950	12	12	190	7432	7432
371590022	6	13.0	4.9	5.8	5.8	15.4	17.3	17.3	599	1184	12	12	139	3004	3004
371730002	0														
371830014	4	11.5	4.9	5.2	5.2	11.8	17.1	17.1	17	16	6	6	11	41	41
380070002	1	11.4		11.4	11.4	11.4	11.4	11.4	283		283	283	283	283	283
380070003	1	4.0		4.0	4.0	4.0	4.0	4.0	283		283	283	283	283	283
380070111	0														
380130002	0														
380130004	1	18.6		18.6	18.6	18.6	18.6	18.6	426		426	426	426	426	426
380150003	1	9.8		9.8	9.8	9.8	9.8	9.8	4592		4592	4592	4592	4592	4592
380171003	3	7.7	6.9	3.0	3.0	4.6	15.7	15.7	257	226	15	15	294	462	462
380171004	2	9.0	1.1	8.2	8.2	9.0	9.7	9.7	378	119	294	294	378	462	462
380250003	1	13.9		13.9	13.9	13.9	13.9	13.9	5		5	5	5	5	5
380530002	1	17.3		17.3	17.3	17.3	17.3	17.3	210		210	210	210	210	210
380530104	0														
380530111	2	16.1	0.1	16.1	16.1	16.1	16.2	16.2	411	522	42	42	411	781	781
380550113	0														
380570001	2	2.5	2.6	0.7	0.7	2.5	4.3	4.3	45808	55924	6264	6264	45808	85352	85352

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
380570004	2	2.7	2.0	1.3	1.3	2.7	4.1	4.1	45808	55924	6264	6264	45808	85352	85352
380570102	2	5.4	2.3	3.8	3.8	5.4	7.0	7.0	45808	55924	6264	6264	45808	85352	85352
380570118	2	10.7	2.2	9.1	9.1	10.7	12.2	12.2	45808	55924	6264	6264	45808	85352	85352
380570123	2	14.3	1.4	13.3	13.3	14.3	15.3	15.3	45808	55924	6264	6264	45808	85352	85352
380570124	2	18.6	1.0	17.9	17.9	18.6	19.3	19.3	45808	55924	6264	6264	45808	85352	85352
380590002	1	2.6		2.6	2.6	2.6	2.6	2.6	4592		4592	4592	4592	4592	4592
380590003	1	5.1		5.1	5.1	5.1	5.1	5.1	4592		4592	4592	4592	4592	4592
380650002	1	8.5		8.5	8.5	8.5	8.5	8.5	28565		28565	28565	28565	28565	28565
380910001	0														
381050103	1	2.8		2.8	2.8	2.8	2.8	2.8	1605		1605	1605	1605	1605	1605
381050105	1	1.8		1.8	1.8	1.8	1.8	1.8	1605		1605	1605	1605	1605	1605
390010001	1	11.4		11.4	11.4	11.4	11.4	11.4	19670		19670	19670	19670	19670	19670
390030002	9	8.5	0.4	7.9	7.9	8.3	9.3	9.3	442	535	16	16	45	1469	1469
390071001	5	17.3	0.6	16.6	16.6	17.2	18.2	18.2	1731	3761	12	12	34	8458	8458
390133002	5	14.5	5.1	6.0	6.0	15.8	19.8	19.8	27781	23029	795	795	35454	56009	56009
390170004	11	14.7	6.9	0.9	0.9	18.5	19.3	19.3	907	1265	56	56	233	3998	3998
390171004	9	6.5	6.5	1.7	1.7	3.3	19.8	19.8	1546	2186	56	56	309	6275	6275
390230003	4	12.2	6.1	5.8	5.8	12.0	19.2	19.2	509	349	105	105	492	946	946
390250021	6	15.0	2.7	12.7	12.7	14.1	18.7	18.7	15304	28111	26	26	145	69953	69953
390290016	9	12.7	3.6	7.2	7.2	13.5	18.1	18.1	20696	19955	18	18	24766	59928	59928
390290022	9	12.7	3.6	7.2	7.2	13.6	18.2	18.2	20696	19955	18	18	24766	59928	59928
390292001	8	11.4	4.1	4.6	4.6	10.8	19.3	19.3	22401	20621	18	18	25596	59928	59928
390350026	10	9.9	4.3	2.1	2.1	9.8	14.5	14.5	740	916	15	15	382	2453	2453
390350038	10	9.8	4.9	1.9	1.9	11.7	14.3	14.3	740	916	15	15	382	2453	2453
390350045	10	10.1	5.5	1.2	1.2	10.4	15.8	15.8	740	916	15	15	382	2453	2453
390350060	10	10.4	5.7	1.0	1.0	13.3	15.5	15.5	740	916	15	15	382	2453	2453
390350065	10	9.8	4.3	2.0	2.0	9.8	14.5	14.5	740	916	15	15	382	2453	2453
390356001	13	13.8	7.1	1.7	1.7	16.8	20.0	20.0	5759	16867	8	8	382	61629	61629
390490004	6	8.7	3.4	2.9	2.9	9.2	12.9	12.9	75	74	5	5	64	192	192
390490034	6	9.5	3.0	3.4	3.4	10.4	11.5	11.5	75	74	5	5	64	192	192
390530002	6	7.0	7.4	1.0	1.0	3.6	16.5	16.5	31718	26583	9	9	29551	74452	74452
390610010	10	16.1	3.0	8.6	8.6	16.8	19.7	19.7	9265	26865	12	12	537	85699	85699
390610039	11	7.0	4.9	2.5	2.5	5.6	19.5	19.5	465	664	12	12	213	1848	1848
390612002	8	10.3	4.6	3.0	3.0	10.6	18.1	18.1	18883	31426	12	12	1122	85699	85699
390612003	11	8.7	5.5	0.4	0.4	8.0	19.4	19.4	660	817	12	12	268	2164	2164
390810016	17	9.5	7.1	1.7	1.7	5.6	19.0	19.0	13129	20063	10	10	361	59928	59928

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
390810017	17	9.6	6.9	2.0	2.0	5.9	18.6	18.6	13129	20063	10	10	361	59928	59928
390811001	13	4.9	5.6	0.3	0.3	2.9	18.0	18.0	6005	15392	10	10	234	53414	53414
390811012	17	9.5	7.3	1.5	1.5	5.3	19.3	19.3	13129	20063	10	10	361	59928	59928
390850003	6	9.1	4.2	5.6	5.6	7.4	15.2	15.2	12044	24426	8	8	2390	61629	61629
390853002	3	5.3	6.0	1.1	1.1	2.6	12.3	12.3	1600	2615	18	18	163	4618	4618
390870006	8	13.7	6.0	2.2	2.2	15.5	19.3	19.3	1425	2178	25	25	343	6285	6285
390871009	8	10.7	4.8	5.0	5.0	10.9	17.8	17.8	1271	2194	25	25	343	6285	6285
390930017	3	11.4	2.2	8.9	8.9	12.5	12.8	12.8	165	241	6	6	47	442	442
390930026	2	3.3	0.5	3.0	3.0	3.3	3.6	3.6	27	29	6	6	27	47	47
390931003	3	11.6	2.1	9.2	9.2	12.5	13.1	13.1	165	241	6	6	47	442	442
390950006	10	10.8	6.6	2.8	2.8	8.1	19.9	19.9	3745	4443	113	113	2406	13581	13581
390950008	9	8.1	5.5	2.5	2.5	4.5	14.6	14.6	4149	4513	204	204	3712	13581	13581
390950024	10	11.4	6.4	3.9	3.9	9.5	18.6	18.6	3745	4443	113	113	2406	13581	13581
390990009	10	12.4	7.3	2.0	2.0	15.6	19.6	19.6	2107	5350	6	6	353	17244	17244
390990013	10	12.4	7.5	1.7	1.7	15.8	19.6	19.6	2107	5350	6	6	353	17244	17244
391051001	6	13.6	2.2	11.6	11.6	13.0	17.8	17.8	31718	26583	9	9	29551	74452	74452
391130025	6	13.4	5.4	7.3	7.3	13.4	19.4	19.4	1609	2326	105	105	753	6275	6275
391150003	2	4.8	0.2	4.6	4.6	4.8	4.9	4.9	57763	38696	30401	30401	57763	85125	85125
391150004	2	5.1	0.3	4.9	4.9	5.1	5.3	5.3	57763	38696	30401	30401	57763	85125	85125
391450013	0														
391450020	3	9.6	6.9	4.6	4.6	6.7	17.5	17.5	1450	1306	25	25	1737	2589	2589
391450022	3	8.4	7.5	2.8	2.8	5.4	16.9	16.9	1450	1306	25	25	1737	2589	2589
391510016	7	6.6	1.5	4.5	4.5	5.9	8.7	8.7	181	213	10	10	43	510	510
391530017	4	5.0	2.4	1.4	1.4	6.0	6.6	6.6	2763	2244	863	863	2091	6009	6009
391530022	4	3.9	0.7	3.0	3.0	4.1	4.6	4.6	2763	2244	863	863	2091	6009	6009
391570003	7	12.0	6.4	0.6	0.6	13.3	18.6	18.6	368	741	15	15	38	2017	2017
391570006	6	6.4	6.1	0.4	0.4	5.3	14.2	14.2	426	795	15	15	38	2017	2017
400219002	0														
400710602	2	3.4	2.3	1.8	1.8	3.4	5.0	5.0	3502	457	3178	3178	3502	3825	3825
400719003	2	1.8	2.0	0.4	0.4	1.8	3.2	3.2	3502	457	3178	3178	3502	3825	3825
400719010	0														
400979014	6	4.7	1.3	2.7	2.7	5.5	5.7	5.7	3180	5200	173	173	713	13428	13428
401010167	8	5.9	4.2	3.7	3.7	3.7	15.8	15.8	3751	4529	23	23	1130	9866	9866
401090025	2	8.7	4.5	5.6	5.6	8.7	11.9	11.9	91	110	13	13	91	169	169
401091037	2	8.8	7.9	3.2	3.2	8.8	14.4	14.4	91	110	13	13	91	169	169
401159004	1	5.2		5.2	5.2	5.2	5.2	5.2	62		62	62	62	62	62

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
401430175	10	11.8	6.9	1.4	1.4	13.9	18.3	18.3	938	1088	9	9	263	2729	2729
401430235	10	10.7	6.9	1.5	1.5	13.4	18.1	18.1	938	1088	9	9	263	2729	2729
401430501	10	12.6	6.8	2.7	2.7	14.2	19.2	19.2	938	1088	9	9	263	2729	2729
401431127	8	12.6	5.0	5.0	5.0	12.4	18.7	18.7	1126	1148	9	9	802	2729	2729
410410002	1	0.3		0.3	0.3	0.3	0.3	0.3	307		307	307	307	307	307
410510080	7	13.5	4.1	7.8	7.8	12.8	18.9	18.9	46	34	9	9	47	109	109
420030002	19	7.4	5.9	0.6	0.6	8.6	18.1	18.1	103	137	7	7	30	468	468
420030010	55	14.2	5.6	2.5	2.5	15.5	20.0	20.0	85	101	5	7	49	407	468
420030021	64	11.7	3.3	3.2	4.8	13.1	18.0	18.7	819	5274	5	7	47	5395	42018
420030031	62	13.9	5.1	1.3	1.4	14.4	18.7	19.8	757	5327	5	7	46	468	42018
420030032	64	11.7	3.3	3.1	4.7	13.2	18.1	18.7	819	5274	5	7	47	5395	42018
420030064	54	6.0	5.2	2.0	2.0	3.1	17.9	18.2	213	741	5	6	52	1164	5395
420030067	16	15.1	3.5	6.1	6.1	15.7	19.7	19.7	73	105	7	7	29	407	407
420030116	19	7.4	5.1	2.1	2.1	7.7	17.0	17.0	103	137	7	7	30	468	468
420031301	57	9.9	4.6	1.1	1.1	11.0	17.5	17.8	914	5587	5	7	47	5395	42018
420033003	54	5.6	5.4	1.0	1.0	2.3	17.8	17.8	213	741	5	6	52	1164	5395
420033004	55	5.9	6.0	0.6	0.7	3.3	18.8	18.8	209	735	5	6	49	1164	5395
420070002	10	13.0	3.2	9.2	9.2	11.4	18.6	18.6	18726	19819	18	18	15912	59928	59928
420070004	7	14.5	5.1	7.4	7.4	16.0	19.8	19.8	5881	11104	9	9	118	30312	30312
420070005	8	9.6	5.6	2.5	2.5	8.8	17.1	17.1	5173	10474	9	9	157	30312	30312
420070014	10	12.0	3.1	7.1	7.1	12.0	17.2	17.2	4400	9400	8	8	157	30312	30312
420110009	13	9.8	7.1	1.3	1.3	10.3	19.8	19.8	1140	3818	14	14	37	13841	13841
420110100	12	8.7	6.3	1.5	1.5	7.5	17.2	17.2	1231	3973	14	14	34	13841	13841
420130801	1	1.3		1.3	1.3	1.3	1.3	1.3	441		441	441	441	441	441
420170012	22	11.1	6.5	1.2	1.2	12.4	19.6	19.6	687	3033	5	5	27	14266	14266
420210011	4	8.5	7.4	1.5	1.5	8.9	14.9	14.9	4195	5171	34	34	3004	10738	10738
420270100	4	10.4	6.2	2.3	2.3	11.4	16.6	16.6	1090	1267	53	53	834	2638	2638
420430401	8	5.4	4.0	0.8	0.8	3.7	12.1	12.1	107	99	10	10	78	313	313
420450002	57	13.6	5.5	1.3	1.9	15.8	19.8	19.8	681	1415	5	5	47	5051	6720
420450109	45	12.4	6.4	0.5	1.6	13.3	19.9	20.0	855	1553	5	5	91	5051	6720
420490003	5	3.1	1.9	1.2	1.2	2.6	5.4	5.4	824	1068	10	10	228	2398	2398
420590002	1	11.5		11.5	11.5	11.5	11.5	11.5	156		156	156	156	156	156
420630004	3	18.4	1.4	17.0	17.0	18.4	19.8	19.8	4796	5156	1497	1497	2154	10738	10738
420692006	5	10.9	7.4	2.1	2.1	8.2	19.6	19.6	13	5	6	6	15	18	18
420710007	5	3.7	3.7	0.6	0.6	2.7	10.1	10.1	75	109	6	6	23	264	264
420730015	9	12.5	5.6	0.6	0.6	13.2	18.0	18.0	3206	8423	6	6	28	25551	25551

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
420770004	13	12.5	5.8	0.3	0.3	12.0	19.3	19.3	703	1041	7	7	120	2888	2888
420791101	4	12.3	3.4	7.8	7.8	12.9	15.8	15.8	117	160	9	9	53	351	351
420810100	3	11.3	0.7	10.6	10.6	11.2	12.0	12.0	28	28	6	6	18	59	59
420810403	3	15.8	1.1	14.9	14.9	15.4	16.9	16.9	28	28	6	6	18	59	59
420850100	2	10.8	11.8	2.4	2.4	10.8	19.1	19.1	14	4	11	11	14	17	17
420890001	8	16.4	1.7	14.1	14.1	16.4	18.4	18.4	1287	1237	21	21	1126	2888	2888
420910013	28	15.3	4.5	1.4	1.4	16.2	20.0	20.0	171	704	5	5	15	3753	3753
420950025	18	13.1	4.3	4.0	4.0	14.1	19.7	19.7	676	1020	7	7	86	2888	2888
420950100	15	10.4	5.5	2.5	2.5	10.7	19.3	19.3	2179	5602	7	7	120	22057	22057
420958000	16	10.1	5.9	0.6	0.6	9.1	18.8	18.8	2045	5439	7	7	86	22057	22057
420990301	0														
421010004	61	10.5	5.2	1.0	1.3	10.9	19.2	19.7	102	316	5	6	20	560	2378
421010022	66	8.0	5.6	0.9	1.0	7.0	19.4	20.0	285	1022	5	5	26	4450	6720
421010024	36	13.0	3.8	6.3	6.3	12.6	19.9	19.9	46	77	5	5	13	407	407
421010027	63	9.8	4.6	0.8	1.7	11.0	19.7	19.7	99	311	5	6	20	560	2378
421010029	67	8.3	4.7	1.1	1.8	6.8	18.9	19.6	262	1007	5	5	24	4450	6720
421010047	65	7.9	4.5	0.6	0.8	6.4	17.6	17.9	270	1022	5	5	26	4450	6720
421010048	60	10.4	4.9	0.9	1.7	10.7	18.6	19.2	104	318	5	6	22	560	2378
421010055	66	7.9	5.4	1.3	1.4	6.8	18.8	20.0	286	1022	5	5	26	4450	6720
421010136	68	8.8	5.4	1.1	1.4	9.3	18.7	19.8	319	1042	5	5	27	4450	6720
421070002	4	12.4	2.8	8.7	8.7	13.0	15.0	15.0	1020	715	362	362	988	1743	1743
421070003	6	10.4	7.4	3.3	3.3	8.8	19.2	19.2	831	687	8	8	674	1743	1743
421230003	2	4.0	1.2	3.2	3.2	4.0	4.9	4.9	2445	659	1979	1979	2445	2911	2911
421230004	2	3.0	1.6	1.9	1.9	3.0	4.1	4.1	2445	659	1979	1979	2445	2911	2911
421250005	33	15.7	4.7	1.1	1.1	17.5	18.7	18.7	257	945	5	5	47	5395	5395
421250200	1	1.1		1.1	1.1	1.1	1.1	1.1	7		7	7	7	7	7
421255001	8	15.9	4.1	9.3	9.3	17.2	19.7	19.7	321	439	7	7	82	1017	1017
421290008	3	9.8	1.4	8.7	8.7	9.3	11.5	11.5	24	9	16	16	22	34	34
421330008	9	9.3	5.8	0.8	0.8	10.1	17.7	17.7	8943	22698	14	14	171	68932	68932
440070012	54	8.4	5.8	0.3	0.4	5.9	18.9	19.0	41	90	5	5	13	392	521
440071005	55	9.1	5.5	0.9	1.0	8.4	18.5	19.0	41	89	5	5	13	392	521
440071009	55	8.6	6.0	0.1	0.4	6.3	19.5	19.9	41	89	5	5	13	392	521
450030003	13	15.3	1.5	11.4	11.4	15.3	17.5	17.5	1654	2599	8	8	549	8275	8275
450070003	8	15.4	4.1	8.5	8.5	16.0	19.8	19.8	986	1952	6	6	40	5543	5543
450110001	1	13.2		13.2	13.2	13.2	13.2	13.2	65		65	65	65	65	65
450190003	16	7.2	5.0	1.1	1.1	6.2	16.3	16.3	2183	6339	6	6	28	25544	25544

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
450190046	0														
450430006	7	4.6	4.3	0.2	0.2	3.4	13.2	13.2	5834	14038	6	6	24	37622	37622
450450008	12	11.7	4.5	2.1	2.1	10.7	17.4	17.4	89	136	6	6	20	411	411
450450009	13	10.1	5.7	4.0	4.0	5.4	17.3	17.3	83	132	6	6	19	411	411
450630008	11	11.5	5.4	0.5	0.5	13.0	19.2	19.2	948	2944	5	5	9	9820	9820
450730001	1	14.9		14.9	14.9	14.9	14.9	14.9	5		5	5	5	5	5
450750003	5	8.5	5.1	3.4	3.4	9.6	15.8	15.8	1433	1913	5	5	211	4088	4088
450790007	10	14.0	4.1	6.4	6.4	15.9	18.7	18.7	61	103	5	5	18	343	343
450790021	8	14.7	1.2	12.3	12.3	15.3	15.6	15.6	5061	12720	7	7	89	36378	36378
450791003	13	10.9	5.9	1.4	1.4	10.9	18.5	18.5	995	2730	5	5	52	9820	9820
450791006	10	17.5	3.3	8.2	8.2	18.9	19.1	19.1	4289	11350	7	7	89	36378	36378
460330132	0														
460710001	0														
460990007	1	17.5		17.5	17.5	17.5	17.5	17.5	496		496	496	496	496	496
461094003	1	6.3		6.3	6.3	6.3	6.3	6.3	11756		11756	11756	11756	11756	11756
470010028	8	12.2	6.5	0.9	0.9	12.8	18.8	18.8	5595	14808	7	7	34	42188	42188
470090002	3	5.7	5.7	0.7	0.7	4.5	11.9	11.9	1421	2325	6	6	153	4104	4104
470090006	3	5.4	5.3	1.4	1.4	3.3	11.3	11.3	1421	2325	6	6	153	4104	4104
470090101	3	12.1	6.9	4.2	4.2	15.4	16.7	16.7	1421	2325	6	6	153	4104	4104
470110004	2	11.4	1.6	10.2	10.2	11.4	12.5	12.5	2719	3687	112	112	2719	5326	5326
470110102	2	2.5	1.2	1.6	1.6	2.5	3.4	3.4	2719	3687	112	112	2719	5326	5326
470310004	0														
470370011	9	10.4	3.6	5.6	5.6	10.7	17.6	17.6	891	2248	9	9	60	6842	6842
470430009	0														
470630003	5	15.3	3.5	9.4	9.4	17.1	18.2	18.2	8178	9105	6	6	5377	19666	19666
470730002	3	2.9	2.1	1.7	1.7	1.7	5.2	5.2	11831	10420	6	6	15822	19666	19666
470750002	1	19.7		19.7	19.7	19.7	19.7	19.7	7		7	7	7	7	7
470750003	0														
470850020	6	3.2	1.8	1.6	1.6	2.6	6.3	6.3	18599	44191	12	12	281	108788	108788
470931030	7	11.9	4.7	6.7	6.7	9.5	19.6	19.6	762	1491	6	6	191	4104	4104
471050003	6	6.9	4.5	3.3	3.3	6.0	15.5	15.5	705	1346	7	7	194	3437	3437
471070101	3	7.6	10.2	0.5	0.5	3.0	19.3	19.3	1834	3024	64	64	112	5326	5326
471210104	2	16.2	1.6	15.1	15.1	16.2	17.3	17.3	2719	3687	112	112	2719	5326	5326
471250006	6	6.2	6.9	1.0	1.0	2.5	15.0	15.0	222	401	8	8	35	1025	1025
471250106	6	7.1	7.3	1.5	1.5	3.5	16.3	16.3	222	401	8	8	35	1025	1025
471251010	3	12.2	6.4	8.5	8.5	8.6	19.6	19.6	95	103	35	35	35	214	214

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
471310004	0														
471390003	1	3.1		3.1	3.1	3.1	3.1	3.1	1900		1900	1900	1900	1900	1900
471390007	1	1.6		1.6	1.6	1.6	1.6	1.6	1900		1900	1900	1900	1900	1900
471390008	1	1.4		1.4	1.4	1.4	1.4	1.4	1900		1900	1900	1900	1900	1900
471390009	1	1.0		1.0	1.0	1.0	1.0	1.0	1900		1900	1900	1900	1900	1900
471450009	4	10.9	6.7	5.3	5.3	9.5	19.1	19.1	19470	22311	9	9	19188	39495	39495
471451020	9	14.0	2.9	7.6	7.6	13.2	17.4	17.4	9351	16734	7	7	390	39495	39495
471550101	1	18.9		18.9	18.9	18.9	18.9	18.9	66		66	66	66	66	66
471570034	18	11.4	2.2	4.8	4.8	11.8	15.3	15.3	1204	2391	5	5	32	6540	6540
471570043	18	9.6	1.7	5.3	5.3	10.0	11.4	11.4	1204	2391	5	5	32	6540	6540
471570046	2	6.0	6.7	1.3	1.3	6.0	10.8	10.8	1973	2640	106	106	1973	3839	3839
471571034	19	3.5	5.6	0.5	0.5	0.7	18.0	18.0	1150	2336	5	5	35	6540	6540
471572005	0														
471610007	3	1.8	0.2	1.7	1.7	1.7	1.9	1.9	5561	5107	21	21	6580	10081	10081
471630007	10	3.7	2.6	1.7	1.7	2.6	10.7	10.7	3010	5303	22	22	495	16855	16855
471630009	12	5.7	6.0	2.0	2.0	2.7	18.7	18.7	2513	4935	13	13	286	16855	16855
471651002	4	4.2	1.8	2.9	2.9	3.5	6.9	6.9	8593	10129	88	88	7029	20226	20226
471651005	4	4.3	3.2	0.2	0.2	5.0	6.9	6.9	8593	10129	88	88	7029	20226	20226
480370099	5	7.3	0.0	7.2	7.2	7.3	7.3	7.3	74	55	29	29	53	164	164
480430101	0														
480610006	0														
480670099	5	15.1	0.0	15.0	15.0	15.1	15.1	15.1	74	55	29	29	53	164	164
481130069	9	12.1	5.7	2.0	2.0	12.9	20.0	20.0	34	25	9	9	18	69	69
481390015	12	9.5	5.8	2.3	2.3	9.4	16.6	16.6	664	993	13	13	57	3003	3003
481390016	12	9.0	6.3	2.9	2.9	6.1	17.4	17.4	664	993	13	13	57	3003	3003
481390017	12	9.6	6.9	1.9	1.9	7.6	18.6	18.6	664	993	13	13	57	3003	3003
481410033	13	9.8	2.0	4.0	4.0	10.1	12.1	12.1	44	92	5	5	11	345	345
481410037	13	9.7	1.8	4.5	4.5	10.0	12.0	12.0	44	92	5	5	11	345	345
481410053	13	9.7	1.6	5.1	5.1	9.9	11.9	11.9	44	92	5	5	11	345	345
481410057	12	14.2	0.7	12.7	12.7	14.4	15.1	15.1	45	96	5	5	11	345	345
481410058	16	13.9	2.3	9.5	9.5	14.7	16.0	16.0	38	83	5	5	12	345	345
481670005	43	2.3	1.3	1.2	1.3	2.0	3.3	9.5	185	611	5	6	22	1937	3599
481671002	43	3.6	1.1	2.5	2.5	3.3	4.6	9.5	185	611	5	6	22	1937	3599
481830001	5	18.9	0.5	18.6	18.6	18.7	19.9	19.9	13289	12287	6	6	19024	24837	24837
482010046	29	12.8	3.1	6.2	6.2	13.1	19.6	19.6	606	1182	6	6	161	5097	5097
482010051	2	19.1	0.6	18.7	18.7	19.1	19.5	19.5	13	8	7	7	13	18	18

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
482010059	38	10.3	5.9	1.8	1.8	8.5	19.5	19.5	674	1486	6	6	48	6968	6968
482010062	37	14.8	3.8	7.8	7.8	15.7	20.0	20.0	694	1503	6	6	49	6968	6968
482010070	31	10.7	5.3	2.2	2.2	8.7	19.5	19.5	790	1622	6	6	161	6968	6968
482010416	37	11.9	5.6	3.3	3.3	10.0	19.8	19.8	691	1503	6	6	49	6968	6968
482011035	39	8.6	5.4	1.6	1.6	7.7	17.6	17.6	657	1470	6	6	46	6968	6968
482011050	46	16.5	3.9	5.0	5.3	17.9	19.1	19.9	243	1028	6	7	36	829	6968
482450009	16	14.8	6.8	0.4	0.4	18.7	19.7	19.7	863	2732	6	6	80	11064	11064
482450011	27	9.0	5.3	2.8	2.8	7.0	18.1	18.1	999	2362	6	6	45	11064	11064
482450020	8	10.8	8.1	1.8	1.8	11.3	19.9	19.9	170	306	6	6	64	908	908
482570005	0														
483550025	17	6.7	3.0	4.2	4.2	5.2	16.4	16.4	468	1086	6	6	43	3955	3955
483550026	19	10.0	3.3	4.6	4.6	11.0	13.6	13.6	424	1032	6	6	43	3955	3955
483550032	17	3.9	4.1	0.4	0.4	1.7	16.0	16.0	468	1086	6	6	43	3955	3955
484530613	3	12.2	0.7	11.8	11.8	11.9	13.0	13.0	86	90	5	5	70	183	183
490050004	1	1.8		1.8	1.8	1.8	1.8	1.8	5		5	5	5	5	5
490110001	6	8.2	5.8	1.5	1.5	8.1	17.7	17.7	468	500	8	8	366	1332	1332
490110004	6	9.7	6.0	2.3	2.3	9.8	19.2	19.2	468	500	8	8	366	1332	1332
490350012	6	4.9	3.7	0.6	0.6	4.5	8.9	8.9	468	500	8	8	366	1332	1332
490351001	7	13.0	6.5	2.1	2.1	13.0	19.6	19.6	833	1006	8	8	712	2788	2788
490352004	3	9.8	8.0	2.4	2.4	8.9	18.3	18.3	1245	1415	8	8	939	2788	2788
490450002	1	11.6		11.6	11.6	11.6	11.6	11.6	8		8	8	8	8	8
500070003	1	1.6		1.6	1.6	1.6	1.6	1.6	6		6	6	6	6	6
500070014	1	1.9		1.9	1.9	1.9	1.9	1.9	6		6	6	6	6	6
500210002	0														
510360002	18	12.1	7.2	2.0	2.0	13.6	19.9	19.9	4818	17274	7	7	35	73839	73839
510590005	5	17.2	1.6	15.0	15.0	17.3	19.4	19.4	31	46	8	8	11	114	114
510590018	10	13.5	3.9	8.4	8.4	15.7	17.5	17.5	1820	5043	8	8	74	16141	16141
510591004	11	10.9	3.5	3.7	3.7	11.2	16.3	16.3	1664	4813	7	7	59	16141	16141
510591005	13	13.6	4.3	4.6	4.6	13.8	19.0	19.0	1416	4435	7	7	59	16141	16141
510595001	11	14.8	4.4	5.1	5.1	16.0	19.8	19.8	1566	4837	6	6	24	16141	16141
511130003	1	10.8		10.8	10.8	10.8	10.8	10.8	7		7	7	7	7	7
511611004	8	9.3	5.5	2.9	2.9	9.7	19.1	19.1	85	117	5	5	34	341	341
511650002	7	12.3	5.1	5.1	5.1	13.9	17.8	17.8	40	36	8	8	32	108	108
511650003	6	11.4	5.4	6.3	6.3	10.3	17.9	17.9	39	40	5	5	25	108	108
515100009	11	9.6	5.1	1.1	1.1	8.6	17.9	17.9	1663	4813	7	7	59	16141	16141
516500004	15	11.1	4.9	4.0	4.0	11.3	17.9	17.9	285	505	6	6	92	1983	1983

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
517100023	21	8.3	3.4	3.6	3.6	8.3	18.8	18.8	1738	7026	5	5	85	32344	32344
517100024	24	9.0	5.6	0.5	0.5	9.0	18.9	18.9	1553	6571	5	5	79	32344	32344
517600021	14	9.4	5.8	1.1	1.1	10.4	19.8	19.8	191	363	6	6	16	1148	1148
517600024	14	9.4	5.8	1.2	1.2	10.3	20.0	20.0	191	363	6	6	16	1148	1148
530090010	1	5.6		5.6	5.6	5.6	5.6	5.6	756		756	756	756	756	756
530090012	1	5.3		5.3	5.3	5.3	5.3	5.3	756		756	756	756	756	756
530330057	5	4.0	6.0	0.6	0.6	1.3	14.7	14.7	241	301	63	63	117	771	771
530330080	5	5.0	4.2	2.5	2.5	3.1	12.5	12.5	241	301	63	63	117	771	771
530530021	3	3.2	1.1	2.1	2.1	3.2	4.3	4.3	179	213	11	11	109	419	419
530530031	3	1.8	0.9	1.2	1.2	1.3	2.8	2.8	179	213	11	11	109	419	419
530570012	4	2.2	0.8	1.3	1.3	2.3	3.1	3.1	2238	2630	21	21	1793	5345	5345
530570018	4	3.6	1.0	2.8	2.8	3.3	5.1	5.1	2238	2630	21	21	1793	5345	5345
530571003	4	1.7	0.6	1.1	1.1	1.7	2.4	2.4	2238	2630	21	21	1793	5345	5345
530610016	2	0.5	0.1	0.4	0.4	0.5	0.6	0.6	191	194	53	53	191	328	328
530730011	9	16.9	6.2	0.5	0.5	19.3	19.7	19.7	488	695	8	8	349	2286	2286
540090005	13	5.3	5.3	0.9	0.9	2.7	16.8	16.8	6005	15392	10	10	234	53414	53414
540090007	17	10.7	5.3	3.9	3.9	8.3	18.8	18.8	13129	20063	10	10	361	59928	59928
540110006	5	13.2	7.1	0.5	0.5	16.2	17.2	17.2	1501	2677	124	124	401	6285	6285
540250001	0														
540290005	8	9.3	5.3	4.7	4.7	7.5	17.6	17.6	22069	20983	18	18	25596	59928	59928
540290007	16	13.1	3.8	4.8	4.8	13.1	18.3	18.3	9282	17668	10	10	238	59928	59928
540290008	9	12.1	4.2	6.3	6.3	11.2	19.8	19.8	20696	19955	18	18	24766	59928	59928
540290009	15	11.0	3.5	1.0	1.0	12.0	17.7	17.7	9894	18112	10	10	243	59928	59928
540290011	17	10.7	5.2	3.2	3.2	8.8	18.8	18.8	13129	20063	10	10	361	59928	59928
540290014	16	11.8	4.0	1.5	1.5	11.1	19.4	19.4	9282	17668	10	10	238	59928	59928
540290015	9	12.1	3.5	7.1	7.1	12.4	18.2	18.2	20696	19955	18	18	24766	59928	59928
540290016	16	10.8	4.3	1.1	1.1	10.6	18.3	18.3	10611	17732	10	10	302	59928	59928
540291004	16	11.5	3.9	1.8	1.8	11.8	19.8	19.8	10611	17732	10	10	302	59928	59928
540390004	4	10.2	4.3	6.0	6.0	10.0	14.8	14.8	1529	1146	854	854	1008	3245	3245
540390010	4	9.7	4.6	5.2	5.2	9.8	14.0	14.0	1529	1146	854	854	1008	3245	3245
540392002	5	9.1	5.6	2.3	2.3	6.7	15.5	15.5	22698	47491	750	750	1009	107633	107633
540511002	5	10.1	4.7	2.2	2.2	11.4	15.0	15.0	27781	23029	795	795	35454	56009	56009
540610003	2	4.6	1.4	3.6	3.6	4.6	5.6	5.6	45992	63840	850	850	45992	91134	91134
540610004	4	11.8	8.9	0.8	0.8	13.5	19.4	19.4	24472	44468	850	850	2952	91134	91134
540610005	3	9.2	9.7	1.0	1.0	6.7	19.9	19.9	32132	51128	850	850	4412	91134	91134
540690007	2	13.9	1.8	12.7	12.7	13.9	15.2	15.2	37391	22660	21367	21367	37391	53414	53414

Monitor ID[2]	n	Distance of monitor to SO_2 emission source (km)[1]							SO_2 emissions (tpy) from sources within 20 km of monitor[1]						
		mean	std	min	p2.5	p50	p97.5	max	mean	std	min	p2.5	p50	p97.5	max
540990002	8	9.7	5.5	1.7	1.7	10.6	16.0	16.0	1271	2194	25	25	343	6285	6285
540990003	8	9.6	5.5	1.5	1.5	10.7	15.8	15.8	1271	2194	25	25	343	6285	6285
540990004	8	9.6	6.0	1.0	1.0	11.3	15.8	15.8	1271	2194	25	25	343	6285	6285
540990005	8	9.5	6.4	0.9	0.9	11.4	16.2	16.2	1271	2194	25	25	343	6285	6285
541071002	11	8.5	5.4	2.7	2.7	8.8	17.0	17.0	4375	9095	7	7	1517	31006	31006
550090005	7	4.2	3.4	1.1	1.1	3.1	9.7	9.7	3413	5045	9	9	850	13470	13470
550250041	7	7.4	4.7	2.8	2.8	5.2	14.7	14.7	1293	2743	7	7	71	7417	7417
550410007	1	8.3		8.3	8.3	8.3	8.3	8.3	5		5	5	5	5	5
550730005	3	10.7	9.2	0.1	0.1	15.8	16.2	16.2	4040	6715	24	24	303	11792	11792
550790007	9	6.5	3.4	1.8	1.8	5.9	12.9	12.9	1750	4858	5	5	28	14686	14686
550790026	9	7.6	3.0	3.5	3.5	7.5	12.8	12.8	1750	4858	5	5	28	14686	14686
550790041	9	10.1	3.0	5.9	5.9	10.2	14.5	14.5	1750	4858	5	5	28	14686	14686
550850996	2	0.9	0.1	0.9	0.9	0.9	1.0	1.0	1152	1617	9	9	1152	2295	2295
551110007	2	14.7	7.4	9.5	9.5	14.7	19.9	19.9	31	35	7	7	31	56	56
551250001	0														
551410016	6	5.3	2.6	2.3	2.3	4.9	9.8	9.8	2374	2368	6	6	2032	5782	5782
551410017	6	5.8	2.6	2.3	2.3	5.6	10.3	10.3	2374	2368	6	6	2032	5782	5782
560050857	4	4.6	6.5	1.1	1.1	1.6	14.4	14.4	2527	3868	23	23	896	8291	8291
560136001	1	17.0		17.0	17.0	17.0	17.0	17.0	40		40	40	40	40	40
560370200	0														
560450800	2	0.5	0.0	0.5	0.5	0.5	0.5	0.5	389	14	379	379	389	399	399

[1] Mean, std , min, p2.5, p50, p97.5, max are the arithmetic average, standard deviation, minimum, 2.5^{th}, 50^{th}, 97.5^{th} percentiles, and maximum distances and emissions.
[2] There were no emissions above 5 tpy for located within 20 km of the monitors sited in Puerto Rico and the Virgin Islands.

Table A-5. Requirements for valid data when comparing ambient SO_2 monitoring concentrations to the current NAAQS.

Standard	Averaging Time	Level (ppm)	Validity Requirements
Primary	24-hour	0.14	The day must contain 18 one-hour measurements.
	Annual	0.03	75% of days in a year (n=274) must contain valid daily measurements.

A.2 ANALYSIS OF CO-LOCATED MONITOR SO_2 MEASUREMENTS

An analysis was performed on the 5-minute maximum SO_2 concentrations where simultaneous measurements were made. The relative percent difference (RPD) was calculated for each simultaneous 5-minute maximum concentration, considering measurements within the 5-max data set (n=300,438) and the measurements between the continuous-5 and the max-5 data sets (n=29,058) separately. We anticipated that small fluctuations in concentration between the two simultaneous measurements would have a greater influence on the RPD at lower concentrations than at higher concentrations. Therefore, the two simultaneous measurements were separated into two concentration groups for analysis; one where the maximum concentrations were ≤ 10 ppb and the other where concentrations were > 10 ppb. The following was used to calculate the RPD for each duplicate measurement:

$$RPD = \frac{(C_1 - C_2)}{(C_1 + C_2)} \times 200$$

where,

RPD	=	Relative percent difference (%)
C_1	=	5-minute maximum SO_2 concentration at the first collocated monitor
C_2	=	5-minute maximum SO_2 concentration at the second collocated monitor

Depending on the difference in concentration, the value for the calculated RPD could be as low as -200 or as high +200, indicating the maximum difference between any two values, while an RPD of zero indicates no difference. The sign of the value can also indicate the direction of bias when comparing the first concentration to the second. In the first comparison (i.e., the within max-5 duplicates), C_1 was selected as the ambient monitor containing the overall greater sample size/duration.

Table A-6 summarizes the distribution of RPDs for where duplicate measurements of SO_2 concentrations were less than 10 ppb within the max-5 monitoring data set. On average, there were relatively small differences in the duplicate measures at each of the monitors. Most duplicate concentrations were within +/-67% of one another, although some are noted at or above 100% (absolute difference). In considering that these maximum 5-minute SO_2 concentrations are well below that of potential interest in the exposure and risk analysis, this degree of agreement between the two monitors at these concentration levels is acceptable.

Table A-6. Distribution of the relative percent difference (RPD) between simultaneous measurements by collocated max-5 monitors where SO_2 concentrations were ≤ 10 ppb.

Monitor ID	n	Relative Percent Difference (%)[1]						
		mean	std	min	p5	p50	p95	max
290210009	25868	0	34	-196	-50	0	67	100
290210011	22247	-7	22	-143	-40	0	18	67
290930030	54904	8	34	-181	-40	0	67	100
290930031	48417	-14	29	-122	-67	0	67	67
290990004	22788	-8	27	-120	-50	0	67	100
290990014	33245	-12	29	-133	-67	0	29	67
290990017	21460	2	30	-120	-50	0	67	120
290990018	17025	2	25	-156	-40	0	67	100
291630002	11528	-3	34	-164	-40	0	67	67

[1] the mean, std, min, p5, p50, p95, max are the arithmetic average, standard deviation, minimum, 5th, median, 95th, and maximum, respectively.

When considering duplicate concentrations > 10 ppb, the RPD was much lower at each of the monitors (Table A-7). Most of the RPDs are within +/-10%, indicating excellent agreement among the simultaneous measurements. A small negative bias may exist with selection of the monitor with the greatest number of samples as the base monitor, but on average the difference was typically less than 3%.

Table A-7. Distribution of the relative percent difference (RPD) between duplicate measurements by collocated max-5 monitors where SO_2 concentrations were > 10 ppb.

Monitor ID	n	Relative Percent Difference (%)[1]						
		mean	std	min	p5	p50	p95	max
290210009	2333	-2	6	-133	-10	0	6	18
290210011	2344	0	3	-66	-6	0	5	18
290930030	8068	-1	6	-120	-9	0	4	24
290930031	7652	-3	6	-134	-13	-2	0	10
290990004	8627	-1	4	-100	-7	0	5	20
290990014	4973	2	16	-17	-8	0	9	184
290990017	5138	-1	7	-137	-11	0	10	32
290990018	2626	0	6	-81	-7	0	10	32
291630002	1195	-6	32	-137	-133	0	11	29

[1] the mean, std, min, p5, p50, p95, max are the arithmetic average, standard deviation, minimum, 5th, median, 95th, and maximum, respectively.

Analyses were also performed for where the max-5 sampling times corresponded with the continuous-5 monitoring at the same location. Of the 29,058 duplicate measurement values, only 312 contained different values among the two sample types (i.e, a non-zero RPD). Since there were very few numbers of samples with RPDs deviating from zero, the following analysis included only the samples that were different and at all concentration levels. The distribution for the RPD given these monitors and duplicate monitoring events is provided in Table A-8. On average there may be a small positive bias in selecting the continuous-5 monitoring concentrations where differences existed, however given that there were only 1% of samples that differed among the two data sets, the overall impact to the below estimation procedure is negligible. In addition, selection of the continuous-5 measurement preserves the relationship between the actual 5-minute maximum and the calculated 1-hour concentration derived from the multiple 5-minute measurements that occurred within the hour.

Table A-8. Distribution of the relative percent difference (RPD) between duplicate measurements by collocated max-5 and continuous-5 monitors.

Monitor ID	n [1]	Relative Percent Difference (%) [2]						
		mean	std	min	p5	p50	p95	max
301110066	76	26	57	-143	-117	16	133	160
301110079	149	27	48	-178	-67	29	67	164
301110082	47	25	52	-67	-67	29	67	186
301110083	40	78	64	-120	-53	67	160	160

[1] This distribution is for the number of samples where the RPD was non-zero. The majority of the duplicate measures (n=28,746) were identical.
[2] the mean, std, min, p5, p50, p95, max are the arithmetic average, standard deviation, minimum, 5th, median, 95th, and maximum, respectively.

APPENDIX B: PEAK-TO-MEAN SUMMARY TABLE

Peak-to-mean ratios (PMR) were calculated using the measured values for each the 5-minute maximum and 1-hour SO_2 concentrations. PMRs were aggregated into 15 groups[1] based on the observed variability (3 bins) and concentrations ranges (5 bins) in measured 1-hour ambient monitor concentrations. Table B-1 summarizes the PMR distributions used for estimating 5-minute maximum concentrations from 1-hour measurements.

Table B-1. Distribution of 5-minute peak to 1-hour mean ratios (PMRs) by monitors categorized by 1-hour coefficient of variation (COV) and 1-hour mean concentration.

Monitor	COV ≤ 100%			100 < COV ≤ 200%					COV > 200%				
[1-hour] group[1]	0	1	2	0	1	2	3	4	0	1	2	3	4
percentile													
p0	1.00	1.00	1.02	1.00	1.00	1.00	1.14	1.02	1.00	1.00	1.00	1.08	1.23
p1	1.00	1.03	1.02	1.00	1.00	1.07	1.14	1.02	1.00	1.14	1.15	1.19	1.25
p2	1.00	1.03	1.02	1.00	1.03	1.09	1.15	1.04	1.00	1.19	1.19	1.25	1.26
p3	1.00	1.04	1.05	1.00	1.04	1.11	1.15	1.04	1.00	1.22	1.21	1.29	1.29
p4	1.00	1.05	1.05	1.00	1.05	1.12	1.18	1.16	1.00	1.25	1.22	1.32	1.30
p5	1.00	1.05	1.08	1.00	1.06	1.14	1.21	1.16	1.00	1.27	1.25	1.36	1.30
p6	1.00	1.06	1.11	1.00	1.07	1.15	1.21	1.18	1.00	1.30	1.27	1.38	1.31
p7	1.00	1.06	1.11	1.00	1.08	1.16	1.22	1.24	1.00	1.32	1.29	1.42	1.32
p8	1.00	1.06	1.15	1.00	1.09	1.17	1.23	1.24	1.00	1.34	1.30	1.46	1.33
p9	1.00	1.07	1.15	1.00	1.10	1.18	1.24	1.24	1.00	1.36	1.33	1.49	1.34
p10	1.00	1.08	1.15	1.00	1.11	1.19	1.27	1.24	1.00	1.38	1.35	1.50	1.36
p11	1.00	1.08	1.16	1.00	1.11	1.20	1.27	1.36	1.00	1.40	1.37	1.54	1.37
p12	1.00	1.08	1.16	1.00	1.12	1.21	1.30	1.36	1.00	1.42	1.39	1.56	1.38
p13	1.00	1.09	1.24	1.00	1.13	1.22	1.30	1.36	1.00	1.43	1.41	1.58	1.43
p14	1.00	1.09	1.24	1.00	1.14	1.22	1.32	1.37	1.00	1.45	1.42	1.59	1.44
p15	1.00	1.09	1.26	1.00	1.15	1.23	1.32	1.37	1.00	1.47	1.45	1.60	1.46
p16	1.00	1.10	1.28	1.00	1.15	1.24	1.32	1.38	1.00	1.48	1.46	1.62	1.47
p17	1.00	1.10	1.28	1.00	1.16	1.25	1.33	1.45	1.00	1.50	1.48	1.64	1.50
p18	1.00	1.11	1.30	1.00	1.17	1.26	1.34	1.45	1.00	1.52	1.50	1.65	1.51
p19	1.00	1.11	1.30	1.00	1.18	1.27	1.35	1.46	1.00	1.53	1.52	1.68	1.53
p20	1.00	1.11	1.30	1.00	1.18	1.28	1.36	1.46	1.00	1.55	1.54	1.71	1.54
p21	1.00	1.12	1.30	1.00	1.19	1.29	1.38	1.46	1.00	1.57	1.56	1.75	1.54
p22	1.00	1.12	1.30	1.00	1.20	1.29	1.38	1.46	1.00	1.58	1.57	1.76	1.57
p23	1.00	1.13	1.30	1.00	1.21	1.30	1.39	1.46	1.00	1.60	1.60	1.77	1.59
p24	1.00	1.13	1.30	1.00	1.22	1.31	1.39	1.47	1.00	1.61	1.61	1.79	1.59
p25	1.00	1.13	1.31	1.00	1.22	1.31	1.39	1.47	1.00	1.63	1.63	1.80	1.61
p26	1.00	1.14	1.31	1.00	1.23	1.32	1.43	1.47	1.00	1.64	1.65	1.82	1.63
p27	1.00	1.14	1.31	1.05	1.24	1.34	1.43	1.47	1.00	1.66	1.67	1.84	1.64

[1] The results are for only 13 groups, since there were no values observed for the lowest COV bin (<100%) and the two highest concentration bins (where the 1-hour mean was between 200-300 ppb and 1-hour mean > 300 ppb).

Monitor [1-hour] group[1]	COV ≤ 100%			100 < COV ≤ 200%					COV > 200%				
percentile	0	1	2	0	1	2	3	4	0	1	2	3	4
p28	1.00	1.15	1.31	1.07	1.25	1.34	1.44	1.48	1.00	1.68	1.70	1.86	1.64
p29	1.00	1.15	1.31	1.09	1.26	1.35	1.44	1.51	1.00	1.70	1.73	1.89	1.66
p30	1.00	1.16	1.32	1.11	1.27	1.36	1.45	1.51	1.00	1.71	1.75	1.90	1.67
p31	1.00	1.16	1.34	1.11	1.28	1.37	1.46	1.51	1.00	1.73	1.77	1.91	1.69
p32	1.00	1.17	1.34	1.13	1.28	1.38	1.46	1.51	1.00	1.75	1.79	1.92	1.69
p33	1.00	1.17	1.35	1.13	1.29	1.39	1.46	1.54	1.00	1.76	1.81	1.95	1.72
p34	1.00	1.17	1.35	1.14	1.30	1.40	1.49	1.55	1.00	1.78	1.83	1.97	1.73
p35	1.00	1.18	1.35	1.16	1.31	1.41	1.49	1.55	1.00	1.79	1.85	1.97	1.73
p36	1.00	1.18	1.36	1.17	1.32	1.42	1.51	1.55	1.00	1.81	1.88	1.99	1.76
p37	1.00	1.19	1.36	1.18	1.33	1.43	1.51	1.55	1.00	1.83	1.91	2.02	1.77
p38	1.00	1.19	1.41	1.20	1.34	1.44	1.53	1.57	1.00	1.85	1.93	2.06	1.77
p39	1.00	1.20	1.41	1.20	1.35	1.45	1.53	1.57	1.00	1.86	1.95	2.08	1.78
p40	1.00	1.20	1.41	1.20	1.36	1.46	1.54	1.57	1.00	1.88	1.98	2.11	1.78
p41	1.00	1.21	1.42	1.22	1.37	1.48	1.56	1.58	1.00	1.89	2.01	2.13	1.79
p42	1.00	1.21	1.42	1.25	1.38	1.48	1.56	1.58	1.00	1.91	2.03	2.15	1.80
p43	1.00	1.22	1.45	1.25	1.39	1.49	1.59	1.60	1.00	1.93	2.06	2.16	1.80
p44	1.00	1.22	1.45	1.25	1.40	1.50	1.61	1.60	1.00	1.95	2.10	2.18	1.81
p45	1.00	1.23	1.45	1.25	1.41	1.51	1.62	1.64	1.00	1.97	2.13	2.20	1.82
p46	1.00	1.24	1.45	1.26	1.42	1.52	1.63	1.64	1.00	1.98	2.16	2.21	1.82
p47	1.07	1.24	1.45	1.29	1.43	1.54	1.64	1.64	1.00	2.00	2.19	2.24	1.82
p48	1.09	1.24	1.47	1.30	1.44	1.55	1.64	1.67	1.00	2.03	2.21	2.25	1.83
p49	1.11	1.25	1.47	1.33	1.45	1.56	1.67	1.67	1.00	2.05	2.23	2.27	1.84
p50	1.11	1.26	1.51	1.33	1.46	1.57	1.67	1.68	1.08	2.06	2.26	2.28	1.84
p51	1.13	1.26	1.55	1.33	1.47	1.58	1.68	1.68	1.11	2.09	2.29	2.29	1.85
p52	1.14	1.27	1.55	1.33	1.49	1.59	1.72	1.68	1.14	2.11	2.31	2.31	1.87
p53	1.15	1.28	1.56	1.33	1.50	1.60	1.72	1.68	1.18	2.14	2.34	2.33	1.89
p54	1.17	1.28	1.56	1.36	1.51	1.61	1.73	1.68	1.20	2.16	2.36	2.35	1.89
p55	1.17	1.29	1.57	1.39	1.53	1.62	1.74	1.70	1.24	2.18	2.39	2.36	1.91
p56	1.20	1.29	1.59	1.40	1.54	1.63	1.74	1.74	1.25	2.21	2.42	2.39	1.91
p57	1.20	1.30	1.59	1.43	1.56	1.65	1.79	1.74	1.25	2.23	2.44	2.40	1.93
p58	1.20	1.31	1.65	1.44	1.57	1.66	1.79	1.74	1.30	2.26	2.48	2.43	1.94
p59	1.22	1.32	1.65	1.50	1.58	1.67	1.80	1.74	1.33	2.28	2.51	2.45	1.95
p60	1.25	1.32	1.65	1.50	1.60	1.68	1.83	1.76	1.33	2.31	2.55	2.47	1.96
p61	1.25	1.33	1.65	1.50	1.61	1.69	1.83	1.76	1.33	2.34	2.59	2.50	1.97
p62	1.25	1.34	1.65	1.50	1.63	1.71	1.86	1.78	1.38	2.36	2.62	2.53	1.97
p63	1.25	1.34	1.65	1.50	1.65	1.72	1.87	1.81	1.43	2.39	2.67	2.55	1.98
p64	1.29	1.35	1.65	1.50	1.66	1.73	1.91	1.81	1.48	2.42	2.71	2.59	2.00
p65	1.31	1.36	1.66	1.50	1.68	1.75	1.93	1.82	1.50	2.46	2.76	2.61	2.01
p66	1.33	1.37	1.66	1.54	1.70	1.77	1.93	1.82	1.50	2.49	2.79	2.62	2.02
p67	1.33	1.38	1.66	1.58	1.71	1.78	1.97	1.90	1.50	2.52	2.83	2.63	2.04
p68	1.33	1.40	1.70	1.60	1.73	1.80	1.99	1.93	1.50	2.56	2.88	2.64	2.04
p69	1.33	1.41	1.70	1.67	1.75	1.82	2.01	1.93	1.50	2.59	2.91	2.67	2.06
p70	1.33	1.42	1.72	1.67	1.77	1.83	2.01	1.96	1.53	2.63	2.95	2.67	2.07
p71	1.38	1.43	1.74	1.69	1.79	1.84	2.03	1.96	1.60	2.67	3.01	2.70	2.09
p72	1.40	1.44	1.74	1.75	1.81	1.86	2.04	2.02	1.67	2.71	3.04	2.71	2.13
p73	1.43	1.46	1.77	1.79	1.83	1.87	2.05	2.06	1.71	2.76	3.08	2.75	2.14

Monitor	COV ≤ 100%			100 < COV ≤ 200%					COV > 200%				
[1-hour] group[1]	0	1	2	0	1	2	3	4	0	1	2	3	4
percentile													
p74	1.50	1.47	1.77	1.84	1.85	1.89	2.06	2.06	1.78	2.80	3.13	2.77	2.15
p75	1.50	1.48	1.80	1.90	1.87	1.91	2.07	2.08	1.85	2.85	3.17	2.81	2.17
p76	1.50	1.49	1.82	2.00	1.90	1.94	2.16	2.08	2.00	2.89	3.22	2.84	2.17
p77	1.50	1.50	1.82	2.00	1.92	1.96	2.20	2.09	2.00	2.94	3.26	2.88	2.19
p78	1.50	1.51	1.83	2.00	1.95	1.98	2.23	2.09	2.00	3.00	3.35	2.90	2.21
p79	1.50	1.53	1.83	2.00	1.98	2.01	2.26	2.09	2.00	3.06	3.38	2.92	2.27
p80	1.50	1.55	1.84	2.00	2.00	2.03	2.32	2.11	2.00	3.13	3.43	2.98	2.31
p81	1.50	1.57	1.85	2.00	2.04	2.06	2.37	2.11	2.00	3.19	3.48	2.99	2.31
p82	1.58	1.60	1.85	2.00	2.07	2.08	2.39	2.13	2.00	3.25	3.55	3.01	2.33
p83	1.67	1.62	1.88	2.00	2.11	2.11	2.47	2.13	2.00	3.32	3.63	3.04	2.36
p84	1.67	1.64	1.88	2.00	2.14	2.14	2.50	2.16	2.00	3.40	3.71	3.09	2.38
p85	1.75	1.67	2.09	2.05	2.18	2.16	2.57	2.25	2.00	3.48	3.78	3.11	2.47
p86	1.93	1.69	2.30	2.18	2.22	2.19	2.58	2.25	2.18	3.57	3.87	3.16	2.49
p87	2.00	1.72	2.30	2.29	2.26	2.22	2.59	2.29	2.33	3.67	3.94	3.20	2.50
p88	2.00	1.74	2.50	2.40	2.31	2.26	2.65	2.29	2.50	3.78	4.04	3.25	2.53
p89	2.00	1.78	2.50	2.50	2.37	2.33	2.71	2.29	2.61	3.91	4.14	3.32	2.54
p90	2.00	1.82	2.50	2.60	2.43	2.39	2.73	2.31	2.83	4.06	4.23	3.38	2.56
p91	2.00	1.86	2.50	2.79	2.50	2.46	2.75	2.31	3.00	4.20	4.35	3.41	2.57
p92	2.00	1.90	2.50	3.00	2.57	2.49	2.76	2.39	3.08	4.37	4.42	3.47	2.61
p93	2.00	1.96	2.56	3.00	2.66	2.55	2.81	2.39	3.33	4.56	4.53	3.54	2.67
p94	2.00	2.02	2.56	3.17	2.76	2.67	2.93	2.50	3.75	4.82	4.68	3.62	2.67
p95	2.00	2.10	2.73	3.49	2.88	2.79	2.98	2.51	4.11	5.08	4.89	3.67	2.70
p96	2.25	2.22	2.89	4.00	3.01	2.87	3.16	2.51	5.00	5.41	5.18	3.74	2.72
p97	2.50	2.36	2.89	4.32	3.21	3.07	3.23	2.66	5.67	5.82	5.43	3.80	2.82
p98	3.00	2.57	3.61	5.00	3.49	3.33	3.25	2.66	10.00	6.49	5.96	4.01	2.97
p99	3.50	2.95	3.61	7.06	3.97	3.84	3.27	3.51	10.00	7.49	6.63	4.23	3.28
p100	12.00	6.81	3.61	12.00	10.91	6.63	3.82	3.51	12.00	11.45	9.67	4.60	5.39

[1] 1-hour SO_2 concentration groups were as follows:
0 = 1-hour mean <33.3 ppb
1 = 33.3 ≤ 1-hour mean ≤ 100 ppb
2 = 100 < 1-hour mean ≤ 200 ppb
3 = 200 < 1-hour mean ≤ 300 ppb
4 = 1-hour mean > 300 ppb.

APPENDIX C: DETAILED AIR QUALITY CHARACTERIZATION TABLES

Table C-1. Descriptive statistics for measured 5-minute maximum SO_2 concentrations by year and number of concentrations above potential health effect benchmark levels. Data used were from 98 monitors that measured both the 5-minute maximum and 1-hour concentrations for years 1997 through 2007.

					Measured 5-minute Maximum SO_2 (ppb)[1]										Number of 5-minute Maximum		
State	County	Monitor ID	Year	n	Mean	Std	COV	p0	p50	p97	p98	p99	p100	≥ 400 ppb	≥ 500 ppb	≥ 600 ppb
AR	Pulaski	051190007	2002	7183	4	3	77	1	3	11	12	14	131	0	0	0
AR	Pulaski	051190007	2003	7800	4	3	76	1	3	10	11	14	94	0	0	0
AR	Pulaski	051190007	2004	7690	3	3	90	1	2	11	12	15	47	0	0	0
AR	Pulaski	051190007	2005	6702	3	2	78	1	2	8	9	11	38	0	0	0
AR	Pulaski	051190007	2006	8356	4	2	51	1	4	9	10	12	52	0	0	0
AR	Pulaski	051190007	2007	2062	4	2	60	2	3	10	12	13	28	0	0	0
AR	Pulaski	051191002	1997	8322	2	2	79	1	2	6	7	9	30	0	0	0
AR	Pulaski	051191002	1998	6857	2	2	93	1	1	6	7	8	35	0	0	0
AR	Pulaski	051191002	1999	6277	2	2	101	1	1	6	7	8	80	0	0	0
AR	Pulaski	051191002	2000	7943	3	3	109	1	2	8	9	12	90	0	0	0
AR	Pulaski	051191002	2001	8334	2	2	78	1	2	6	7	9	62	0	0	0
AR	Union	051390006	1997	8347	8	22	259	1	3	54	69	105	361	0	0	0
AR	Union	051390006	1998	7084	10	19	198	1	5	47	58	77	659	3	3	1
AR	Union	051390006	1999	6153	8	14	173	1	4	44	54	72	238	0	0	0
AR	Union	051390006	2000	8176	9	20	228	1	3	59	77	111	313	0	0	0
AR	Union	051390006	2001	8265	5	8	176	1	3	19	24	33	422	1	0	0
AR	Union	051390006	2002	6297	4	5	114	1	2	14	17	22	103	0	0	0
AR	Union	051390006	2003	7240	4	12	342	1	2	15	17	23	511	3	1	0
AR	Union	051390006	2004	4431	4	8	235	1	2	14	19	27	273	0	0	0
AR	Union	051390006	2005	4923	3	6	173	1	2	10	13	21	240	0	0	0
AR	Union	051390006	2006	8364	4	5	141	1	3	9	13	20	306	0	0	0
AR	Union	051390006	2007	2061	4	2	63	2	3	8	10	14	31	0	0	0
CO	Denver	080310002	1997	7045	13	17	131	1	7	58	67	84	192	0	0	0
CO	Denver	080310002	1998	4363	17	17	99	1	11	58	65	79	216	0	0	0
CO	Denver	080310002	1999	1637	14	15	105	1	9	54	61	76	122	0	0	0
CO	Denver	080310002	2000	2459	10	13	127	1	6	46	56	68	134	0	0	0
CO	Denver	080310002	2001	5625	14	15	112	1	8	52	61	73	199	0	0	0
CO	Denver	080310002	2002	6863	10	13	127	1	5	46	52	63	174	0	0	0
CO	Denver	080310002	2003	6262	7	8	114	1	5	27	32	42	110	0	0	0
CO	Denver	080310002	2004	4480	8	8	97	1	5	28	31	36	86	0	0	0

State	County	Monitor ID	Year	n	Measured 5-minute Maximum SO_2 (ppb)[1]									Number of 5-minute Maximum		
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	≥ 400 ppb	≥ 500 ppb	≥ 600 ppb
CO	Denver	080310002	2005	4172	7	7	106	1	5	26	30	36	59	0	0	0
CO	Denver	080310002	2006	6519	6	7	105	0.2	4	24	27	33	104	0	0	0
DE	New Castle	100031008	1997	7501	20	38	194	1	6	145	171	195	328	0	0	0
DE	New Castle	100031008	1998	4901	18	34	190	1	6	118	143	169	381	0	0	0
DC	District of Columbia	110010041	2000	3751	10	8	80	3	8	29	33	42	108	0	0	0
DC	District of Columbia	110010041	2001	8302	8	10	115	1	6	29	33	42	395	0	0	0
DC	District of Columbia	110010041	2002	8575	9	9	100	1	6	31	37	47	106	0	0	0
DC	District of Columbia	110010041	2003	4282	11	12	111	2	8	31	34	45	482	1	0	0
DC	District of Columbia	110010041	2004	2770	9	8	83	1	8	27	33	39	138	0	0	0
DC	District of Columbia	110010041	2007	6394	6	7	115	2	5	18	21	30	400	1	0	0
FL	Nassau	120890005	2002	8415	11	29	263	1	2	88	110	152	467	2	0	0
FL	Nassau	120890005	2003	8662	6	17	279	1	1	47	57	81	302	0	0	0
FL	Nassau	120890005	2004	6507	6	15	275	1	1	40	50	67	473	1	0	0
FL	Nassau	120890005	2005	4120	8	21	261	1	1	67	84	103	297	0	0	0
IA	Cerro Gordo	190330018	2001	518	2	5	231	1	1	10	16	28	59	0	0	0
IA	Cerro Gordo	190330018	2002	3718	2	5	242	1	1	6	9	18	100	0	0	0
IA	Cerro Gordo	190330018	2003	5179	3	11	326	1	1	21	29	52	166	0	0	0
IA	Cerro Gordo	190330018	2004	8676	2	4	234	1	1	7	10	19	81	0	0	0
IA	Cerro Gordo	190330018	2005	3713	1	3	191	1	1	5	7	11	92	0	0	0
IA	Clinton	190450019	2001	1346	3	3	89	1	2	9	11	13	25	0	0	0
IA	Clinton	190450019	2002	6773	5	6	133	1	3	18	21	27	109	0	0	0
IA	Clinton	190450019	2003	6193	4	7	160	1	2	16	19	25	213	0	0	0
IA	Clinton	190450019	2004	7472	4	6	151	1	2	17	20	26	129	0	0	0
IA	Clinton	190450019	2005	4153	5	9	162	1	3	25	31	44	174	0	0	0
IA	Muscatine	191390016	2001	1962	4	6	162	1	2	17	20	37	88	0	0	0
IA	Muscatine	191390016	2002	8597	5	7	157	1	3	18	23	37	151	0	0	0
IA	Muscatine	191390016	2003	7698	5	10	200	1	3	24	30	45	187	0	0	0
IA	Muscatine	191390016	2004	8167	5	8	178	1	3	22	27	39	148	0	0	0
IA	Muscatine	191390016	2005	4255	5	12	216	1	3	30	40	65	166	0	0	0
IA	Muscatine	191390017	2001	1603	3	3	106	1	1	8	9	11	38	0	0	0

State	County	Monitor ID	Year	n	Measured 5-minute Maximum SO_2 (ppb)[1]									Number of 5-minute Maximum		
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	≥ 400 ppb	≥ 500 ppb	≥ 600 ppb
IA	Muscatine	191390017	2002	8139	4	7	173	1	3	13	20	31	204	0	0	0
IA	Muscatine	191390017	2003	8533	5	8	156	1	4	20	28	43	157	0	0	0
IA	Muscatine	191390017	2004	8415	5	7	151	1	3	20	25	40	125	0	0	0
IA	Muscatine	191390017	2005	4214	4	9	210	1	2	17	27	38	185	0	0	0
IA	Muscatine	191390020	2001	2018	7	13	188	1	2	48	52	68	105	0	0	0
IA	Muscatine	191390020	2002	8201	8	18	219	1	3	58	73	96	204	0	0	0
IA	Muscatine	191390020	2003	8412	8	21	249	1	2	66	84	114	256	0	0	0
IA	Muscatine	191390020	2004	8717	11	27	236	1	3	89	110	142	255	0	0	0
IA	Muscatine	191390020	2005	4304	10	27	272	1	2	85	110	150	307	0	0	0
IA	Scott	191630015	2001	1438	2	3	158	1	1	9	12	16	46	0	0	0
IA	Scott	191630015	2002	8073	3	4	134	1	1	14	18	23	59	0	0	0
IA	Scott	191630015	2003	7916	3	4	128	1	1	12	14	19	53	0	0	0
IA	Scott	191630015	2004	7638	3	4	126	1	1	12	14	18	41	0	0	0
IA	Scott	191630015	2005	3919	4	5	126	1	2	16	18	24	41	0	0	0
IA	Van Buren	191770005	2001	701	1	1	75	1	1	4	5	6	9	0	0	0
IA	Van Buren	191770005	2002	6692	1	1	74	1	1	4	4	6	31	0	0	0
IA	Van Buren	191770005	2003	7486	1	1	66	1	1	4	4	5	16	0	0	0
IA	Van Buren	191770005	2004	5341	1	1	109	1	1	4	5	7	22	0	0	0
IA	Van Buren	191770006	2004	1032	1	1	68	1	1	4	4	5	7	0	0	0
IA	Van Buren	191770006	2005	3957	1	1	67	1	1	3	4	5	11	0	0	0
IA	Woodbury	191930018	2001	1686	2	4	174	1	1	14	18	22	36	0	0	0
IA	Woodbury	191930018	2002	4048	3	5	186	1	1	17	21	28	59	0	0	0
LA	West Baton Rouge	221210001	1997	4971	13	26	206	1	5	74	100	139	446	1	0	0
LA	West Baton Rouge	221210001	1998	7566	12	23	188	1	6	61	86	130	428	1	0	0
LA	West Baton Rouge	221210001	1999	7279	11	21	185	1	5	58	77	109	401	1	0	0
LA	West Baton Rouge	221210001	2000	7370	14	27	197	1	6	78	104	143	430	1	0	0
MO	Buchanan	290210009	1997	8484	21	77	362	1	3	244	315	433	928	106	61	24
MO	Buchanan	290210009	1998	8161	18	61	347	1	3	184	242	337	728	47	26	13
MO	Buchanan	290210009	1999	7419	5	8	178	1	3	22	32	44	165	0	0	0
MO	Buchanan	290210009	2000	5299	4	9	211	1	2	22	31	47	157	0	0	0
MO	Buchanan	290210011	2000	1672	10	19	195	1	4	67	83	106	156	0	0	0

State	County	Monitor ID	Year	n	Measured 5-minute Maximum SO_2 (ppb)[1]									Number of 5-minute Maximum		
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	≥ 400 ppb	≥ 500 ppb	≥ 600 ppb
MO	Buchanan	290210011	2001	6415	7	13	185	1	3	49	57	70	133	0	0	0
MO	Buchanan	290210011	2002	6467	8	17	218	1	3	53	70	95	176	0	0	0
MO	Buchanan	290210011	2003	5142	7	15	208	1	3	52	67	88	170	0	0	0
MO	Greene	290770026	1997	4765	9	19	221	1	2	63	77	99	230	0	0	0
MO	Greene	290770026	1998	5813	12	23	190	1	2	82	91	107	214	0	0	0
MO	Greene	290770026	1999	7242	8	16	203	1	2	56	65	78	213	0	0	0
MO	Greene	290770026	2000	8721	10	21	219	1	2	74	87	108	211	0	0	0
MO	Greene	290770026	2001	8304	9	20	221	1	2	69	82	101	183	0	0	0
MO	Greene	290770026	2002	7055	9	19	213	1	2	68	78	95	159	0	0	0
MO	Greene	290770026	2003	7935	6	13	202	1	2	44	52	62	173	0	0	0
MO	Greene	290770026	2004	6574	6	14	215	1	1	48	56	66	144	0	0	0
MO	Greene	290770026	2005	8756	6	13	227	1	1	47	55	68	149	0	0	0
MO	Greene	290770026	2006	8753	6	15	228	1	1	53	63	74	123	0	0	0
MO	Greene	290770026	2007	6520	6	15	225	1	1	52	59	73	129	0	0	0
MO	Greene	290770037	1997	6563	12	36	307	1	2	107	145	185	480	6	0	0
MO	Greene	290770037	1998	8135	7	18	242	1	3	57	76	99	265	0	0	0
MO	Greene	290770037	1999	8554	6	19	307	1	2	54	75	115	273	0	0	0
MO	Greene	290770037	2000	5339	14	40	277	1	2	139	178	223	327	0	0	0
MO	Greene	290770037	2001	6710	9	27	293	1	2	84	104	142	329	0	0	0
MO	Greene	290770037	2002	6374	9	26	298	1	2	79	110	143	317	0	0	0
MO	Greene	290770037	2003	8181	6	16	253	1	2	56	69	87	285	0	0	0
MO	Greene	290770037	2004	6575	5	13	269	1	2	36	48	71	192	0	0	0
MO	Greene	290770037	2005	8760	6	15	273	1	2	40	53	82	259	0	0	0
MO	Greene	290770037	2006	8745	7	21	295	1	1	62	82	115	259	0	0	0
MO	Greene	290770037	2007	6496	5	15	317	1	1	46	62	86	185	0	0	0
MO	Iron	290930030	1997	8707	22	85	391	1	3	201	311	492	1001	127	82	52
MO	Iron	290930030	1998	8475	22	86	394	1	2	235	334	508	998	133	87	54
MO	Iron	290930030	1999	6547	25	91	357	1	3	267	372	541	997	117	81	48
MO	Iron	290930030	2000	4088	41	124	304	1	3	411	530	675	1001	128	91	61
MO	Iron	290930030	2001	5393	28	101	356	1	2	330	437	594	945	123	80	49
MO	Iron	290930030	2002	7961	20	79	388	1	2	225	314	444	998	102	61	38
MO	Iron	290930030	2003	6964	22	80	369	1	3	244	328	453	907	98	51	30
MO	Iron	290930030	2004	1846	3	3	107	1	2	11	12	15	22	0	0	0
MO	Iron	290930031	1997	6178	17	59	350	1	3	120	203	325	844	41	25	10

State	County	Monitor ID	Year	n	Measured 5-minute Maximum SO_2 (ppb)[1]									Number of 5-minute Maximum		
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	≥ 400 ppb	≥ 500 ppb	≥ 600 ppb
MO	Iron	290930031	1998	7991	15	53	351	1	3	113	179	286	1002	36	16	10
MO	Iron	290930031	1999	7919	16	59	365	1	4	109	158	286	1001	48	33	22
MO	Iron	290930031	2000	5172	18	63	342	1	3	153	214	318	1002	33	18	13
MO	Iron	290930031	2001	8426	14	53	383	1	2	123	175	280	994	42	19	10
MO	Iron	290930031	2002	8665	13	46	364	1	3	93	135	242	950	29	14	6
MO	Iron	290930031	2003	8230	13	52	388	1	3	105	153	256	999	31	19	12
MO	Iron	290930031	2004	2172	4	3	76	2	3	13	15	17	36	0	0	0
MO	Jefferson	290990004	2004	8034	19	49	251	1	5	118	140	209	957	21	14	10
MO	Jefferson	290990004	2005	7144	23	60	255	1	5	149	190	306	999	37	21	13
MO	Jefferson	290990004	2006	6525	29	71	244	1	5	164	215	367	954	57	32	23
MO	Jefferson	290990004	2007	2125	12	31	245	1	3	72	96	156	467	2	0	0
MO	Jefferson	290990014	1997	7543	16	54	336	1	5	102	156	247	1645	33	16	11
MO	Jefferson	290990014	1998	8130	8	27	349	1	3	35	45	84	877	9	5	3
MO	Jefferson	290990014	1999	7828	8	24	303	1	3	41	54	87	595	6	2	0
MO	Jefferson	290990014	2000	8259	5	17	310	1	2	25	34	57	575	2	1	0
MO	Jefferson	290990014	2001	2730	5	13	271	1	2	29	38	65	225	0	0	0
MO	Jefferson	290990017	1998	5721	15	54	351	1	4	86	138	246	998	27	15	14
MO	Jefferson	290990017	1999	7289	20	66	338	1	5	128	207	332	960	56	43	27
MO	Jefferson	290990017	2000	7162	13	50	376	1	3	72	127	229	997	30	19	12
MO	Jefferson	290990017	2001	1045	16	43	265	1	5	111	163	238	480	3	0	0
MO	Jefferson	290990018	2001	3495	13	43	338	1	3	71	97	183	968	10	8	5
MO	Jefferson	290990018	2002	6306	12	51	407	1	3	61	104	217	999	29	20	12
MO	Jefferson	290990018	2003	6009	9	39	440	1	2	38	50	95	977	13	10	8
MO	Monroe	291370001	1997	8280	3	4	104	1	2	11	13	17	98	0	0	0
MO	Monroe	291370001	1998	8426	3	3	104	1	2	9	10	14	75	0	0	0
MO	Monroe	291370001	1999	8714	4	3	71	1	3	11	13	16	66	0	0	0
MO	Monroe	291370001	2000	8617	3	2	69	1	3	9	12	14	26	0	0	0
MO	Monroe	291370001	2001	4347	2	2	83	1	2	7	8	9	21	0	0	0
MO	Monroe	291370001	2002	5358	2	2	89	1	2	7	8	10	53	0	0	0
MO	Monroe	291370001	2003	5951	2	2	80	1	2	7	8	10	26	0	0	0
MO	Monroe	291370001	2004	5125	3	3	95	1	2	9	11	14	33	0	0	0
MO	Monroe	291370001	2005	6519	3	2	85	1	2	8	10	12	30	0	0	0
MO	Monroe	291370001	2006	6170	2	2	78	1	2	6	7	9	38	0	0	0
MO	Monroe	291370001	2007	526	2	3	115	1	2	7	8	11	38	0	0	0

State	County	Monitor ID	Year	n	Measured 5-minute Maximum SO_2 (ppb)[1]									Number of 5-minute Maximum		
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	≥ 400 ppb	≥ 500 ppb	≥ 600 ppb
MO	Pike	291630002	2005	4883	7	11	156	1	4	38	46	60	124	0	0	0
MO	Pike	291630002	2006	6473	6	9	160	1	4	27	36	48	209	0	0	0
MO	Pike	291630002	2007	1020	6	9	155	1	3	25	36	48	86	0	0	0
MO	Saint Charles	291830010	1997	8153	6	13	218	1	3	28	36	47	516	2	1	0
MO	Saint Charles	291830010	1998	4811	6	9	153	1	3	28	34	44	190	0	0	0
MO	Saint Charles	291831002	1997	8515	9	15	161	1	5	42	52	76	358	0	0	0
MO	Saint Charles	291831002	1998	8122	10	14	146	1	5	43	53	74	200	0	0	0
MO	Saint Charles	291831002	1999	7970	8	13	156	1	5	38	45	61	275	0	0	0
MO	Saint Charles	291831002	2000	6422	7	10	139	1	4	31	38	53	176	0	0	0
MT	Yellowstone	301110066	1997	6890	18	23	129	1	10	72	81	104	538	2	1	0
MT	Yellowstone	301110066	1998	7205	15	20	131	1	8	64	76	96	344	0	0	0
MT	Yellowstone	301110066	1999	5776	18	22	123	1	11	72	84	103	296	0	0	0
MT	Yellowstone	301110066	2000	6123	18	25	137	1	10	80	97	116	481	1	0	0
MT	Yellowstone	301110066	2001	6880	17	23	137	1	9	79	94	114	215	0	0	0
MT	Yellowstone	301110066	2002	8347	14	24	168	1	6	68	81	102	843	2	2	2
MT	Yellowstone	301110066	2003	5700	16	22	133	1	9	74	85	111.5	222	0	0	0
MT	Yellowstone	301110079	1997	3167	7	7	109	1	5	24	27	34	106	0	0	0
MT	Yellowstone	301110079	2001	837	7	5	70	1	6	19	22	23	37	0	0	0
MT	Yellowstone	301110079	2002	8034	3	3	113	1	1	11	13	16	38	0	0	0
MT	Yellowstone	301110079	2003	5107	5	4	79	1	4	14	16	19	40	0	0	0
MT	Yellowstone	301110080	1997	5462	20	27	138	1	11	82	98	136	374	0	0	0
MT	Yellowstone	301110080	1998	5412	17	24	137	1	10	68	79	102	398	0	0	0
MT	Yellowstone	301110080	1999	5617	17	23	135	1	10	71	83	106	478	2	0	0
MT	Yellowstone	301110080	2000	6032	16	24	144	1	8	75	88	115	374	0	0	0
MT	Yellowstone	301110080	2001	2029	14	24	169	1	8	65	75	93	693	1	1	1
MT	Yellowstone	301110082	2001	2607	7	7	110	1	5	24	28	38	110	0	0	0
MT	Yellowstone	301110082	2002	8212	4	5	140	1	2	15	19	24	93	0	0	0
MT	Yellowstone	301110082	2003	5180	5	6	125	1	3	17	22	28	213	0	0	0
MT	Yellowstone	301110083	1999	2087	15	16	104	1	10	54	62	82	172	0	0	0
MT	Yellowstone	301110083	2000	3857	11	16	148	1	6	46	51	64	531	1	1	0

State	County	Monitor ID	Year	n	Measured 5-minute Maximum SO_2 (ppb)[1]									Number of 5-minute Maximum		
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	≥ 400 ppb	≥ 500 ppb	≥ 600 ppb
MT	Yellowstone	301110083	2001	5606	9	13	150	1	4	41	50	62	253	0	0	0
MT	Yellowstone	301110083	2002	6847	4	8	181	1	2	22	28	38	146	0	0	0
MT	Yellowstone	301110083	2003	1641	4	6	154	1	2	23	25	33	60	0	0	0
MT	Yellowstone	301110084	2003	759	5	8	156	1	3	26	33	46	92	0	0	0
MT	Yellowstone	301110084	2004	2468	7	11	171	1	3	35	44	60	194	0	0	0
MT	Yellowstone	301110084	2005	2578	6	11	190	1	2	33	40	55	151	0	0	0
MT	Yellowstone	301110084	2006	1984	5	9	167	1	2	29	35	45	119	0	0	0
MT	Yellowstone	301112008	1997	2580	7	9	123	1	4	26	30	37	144	0	0	0
NC	Forsyth	370670022	1997	8383	10	11	115	0.2	6	34	40	53	188	0	0	0
NC	Forsyth	370670022	1998	7124	10	13	131	1	7	36	42	59	494	1	0	0
NC	Forsyth	370670022	1999	6434	9	10	117	1	6	31	38	52	178	0	0	0
NC	Forsyth	370670022	2000	5205	8	9	109	0.2	5	30	34	44	123	0	0	0
NC	Forsyth	370670022	2001	7634	7	9	123	1	5	28	34	44	163	0	0	0
NC	Forsyth	370670022	2002	7023	9	14	150	1	5	40	50	68	238	0	0	0
NC	Forsyth	370670022	2003	8077	8	10	119	0.2	5	31	37	52	117	0	0	0
NC	Forsyth	370670022	2004	4711	8	13	155	1	4	36	45	65	219	0	0	0
NC	New Hanover	371290006	1999	8208	9	22	263	1	1	66	79	101	579	3	1	0
NC	New Hanover	371290006	2000	7980	11	25	237	1	1	87	101	124	374	0	0	0
NC	New Hanover	371290006	2001	8168	15	41	269	1	1	136	161	205	652	4	3	1
NC	New Hanover	371290006	2002	8028	16	37	239	1	2	124	142	178	805	2	1	1
ND	Billings	380070002	1998	1940	1	1	80	1	1	4	5	7	12	0	0	0
ND	Billings	380070002	1999	3216	1	1	75	1	1	4	5	6	12	0	0	0
ND	Billings	380070002	2000	2724	1	1	77	1	1	4	5	7	11	0	0	0
ND	Billings	380070002	2001	2860	2	2	104	1	1	5	7	10	23	0	0	0
ND	Billings	380070002	2002	3114	2	2	107	1	1	6	7	10	53	0	0	0
ND	Billings	380070002	2003	342	2	1	66	1	2	6	6	7	10	0	0	0
ND	Billings	380070002	2004	1256	2	2	117	1	1	6	7	10	47	0	0	0
ND	Billings	380070002	2005	837	2	2	86	1	1	7	8	9	17	0	0	0
ND	Billings	380070002	2006	418	3	3	91	1	2	8	9	10	25	0	0	0
ND	Billings	380070002	2007	221	2	2	94	1	2	7	8	12	17	0	0	0
ND	Billings	380070003	1997	2657	3	4	169	1	2	9	12	19	97	0	0	0

State	County	Monitor ID	Year	n	Measured 5-minute Maximum SO_2 (ppb)[1]									Number of 5-minute Maximum		
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	≥ 400 ppb	≥ 500 ppb	≥ 600 ppb
ND	Burke	380130002	1999	3852	6	11	188	1	1	33	37	50	172	0	0	0
ND	Burke	380130002	2000	5268	6	13	227	1	2	34	41	54	381	0	0	0
ND	Burke	380130002	2001	5653	5	10	205	1	1	33	39	51	201	0	0	0
ND	Burke	380130002	2002	5368	5	11	204	1	1	31	39	50	182	0	0	0
ND	Burke	380130002	2003	6328	5	11	216	1	2	31	39	53	231	0	0	0
ND	Burke	380130002	2004	5230	5	11	206	1	2	33	41	53	165	0	0	0
ND	Burke	380130002	2005	3099	6	11	189	1	2	35	42	53	151	0	0	0
ND	Burke	380130004	2003	882	4	7	158	1	2	22	28	38	61	0	0	0
ND	Burke	380130004	2004	3198	4	6	147	1	2	21	25	35	94	0	0	0
ND	Burke	380130004	2005	2238	4	5	131	1	2	17	20	25	77	0	0	0
ND	Burke	380130004	2006	3152	4	6	164	1	2	17	20	29	120	0	0	0
ND	Burke	380130004	2007	1228	6	8	142	1	3	25	28	32	108	0	0	0
ND	Burleigh	380150003	2005	684	6	5	83	1	4	18	19	22	29	0	0	0
ND	Burleigh	380150003	2006	3708	4	5	122	1	2	15	17	20	61	0	0	0
ND	Burleigh	380150003	2007	948	7	8	106	1	5	26	28	38	80	0	0	0
ND	Cass	380171003	1997	2254	2	2	133	1	1	7	10	13	26	0	0	0
ND	Cass	380171003	1998	2943	2	2	97	1	1	6	8	11	23	0	0	0
ND	Cass	380171004	1998	2501	1	0	39	1	1	2	3	3	8	0	0	0
ND	Cass	380171004	1999	3325	1	1	57	1	1	3	3	4	9	0	0	0
ND	Cass	380171004	2000	1868	1	1	61	1	1	4	4	5	9	0	0	0
ND	Cass	380171004	2001	1686	1	1	87	1	1	4	5	7	29	0	0	0
ND	Cass	380171004	2002	2476	1	1	68	1	1	3	4	5	17	0	0	0
ND	Cass	380171004	2003	1297	2	2	92	1	1	6	7	9	17	0	0	0
ND	Cass	380171004	2004	3140	2	1	81	1	1	4	5	7	20	0	0	0
ND	Cass	380171004	2005	928	2	1	81	1	1	6	7	8	11	0	0	0
ND	Cass	380171004	2006	7863	1	1	130	0.1	0.3	2.3	2.7	3.8	10.7	0	0	0
ND	Cass	380171004	2007	2258	1	1	136	0.1	0.5	3.3	3.8	5.6	20.2	0	0	0
ND	Dunn	380250003	1997	3313	2	2	111	1	1	6	8	10	48	0	0	0
ND	Dunn	380250003	1998	2688	2	3	142	1	1	10	12	19	52	0	0	0
ND	Dunn	380250003	1999	5099	2	3	135	1	1	7	8	11	59	0	0	0
ND	Dunn	380250003	2000	7455	2	2	137	1	1	6	8	10	70	0	0	0
ND	Dunn	380250003	2001	3576	2	2	110	1	1	8	9	12	30	0	0	0
ND	Dunn	380250003	2002	4485	2	2	110	1	1	6	7	9	41	0	0	0
ND	Dunn	380250003	2003	7289	2	2	96	1	2	6	7	10	37	0	0	0

State	County	Monitor ID	Year	n	Measured 5-minute Maximum SO_2 (ppb)[1]									Number of 5-minute Maximum		
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	≥ 400 ppb	≥ 500 ppb	≥ 600 ppb
ND	Dunn	380250003	2004	6019	2	2	111	1	1	6	8	10	26	0	0	0
ND	Dunn	380250003	2005	1314	2	3	125	1	1	7	9	11	34	0	0	0
ND	Dunn	380250003	2006	2214	2	2	113	1	1	8	10	14	26	0	0	0
ND	Dunn	380250003	2007	667	3	3	102	1	2	8	10	13	48	0	0	0
ND	McKenzie	380530002	1997	2557	2	2	111	1	1	8	9	12	26	0	0	0
ND	McKenzie	380530002	1998	1989	2	2	102	1	1	7	9	12	25	0	0	0
ND	McKenzie	380530002	2001	754	2	1	84	1	1	5	6	7	12	0	0	0
ND	McKenzie	380530002	2002	3361	1	1	83	1	1	4	5	6	18	0	0	0
ND	McKenzie	380530002	2003	5345	2	2	98	1	1	6	7	10	40	0	0	0
ND	McKenzie	380530002	2004	4614	2	2	113	1	1	6	6	8	45	0	0	0
ND	McKenzie	380530002	2005	2525	2	1	81	1	1	5	6	7	14	0	0	0
ND	McKenzie	380530002	2006	2897	2	1	86	1	1	5	6	7	18	0	0	0
ND	McKenzie	380530002	2007	511	3	2	76	1	2	7	8	8	18	0	0	0
ND	McKenzie	380530104	1998	1525	5	12	232	1	2	21	27	43	199	0	0	0
ND	McKenzie	380530104	1999	1501	6	16	300	1	3	19	23	29	387	0	0	0
ND	McKenzie	380530104	2000	2757	4	14	356	1	2	13	17	28	482	1	0	0
ND	McKenzie	380530104	2001	2281	3	5	145	1	2	12	14	16	143	0	0	0
ND	McKenzie	380530104	2002	1528	5	17	352	1	2	19	31	82	284	0	0	0
ND	McKenzie	380530104	2003	2333	5	19	415	1	1	19	42	103	385	0	0	0
ND	McKenzie	380530104	2004	2241	2	4	204	1	1	6	7	10	141	0	0	0
ND	McKenzie	380530104	2005	1905	2	6	312	1	1	5	6	10	138	0	0	0
ND	McKenzie	380530104	2006	1828	2	9	381	1	1	5	7	11	214	0	0	0
ND	McKenzie	380530104	2007	764	2	2	84	1	1	6	6	10	13	0	0	0
ND	McKenzie	380530111	1998	2071	8	20	254	1	3	33	46	91	288	0	0	0
ND	McKenzie	380530111	1999	2382	5	14	262	1	2	22	28	46	422	1	0	0
ND	McKenzie	380530111	2000	2808	6	23	380	1	2	21	27	45	499	3	0	0
ND	McKenzie	380530111	2001	3183	4	5	143	1	2	16	19	24	91	0	0	0
ND	McKenzie	380530111	2002	2256	5	16	346	1	2	18	23	48	360	0	0	0
ND	McKenzie	380530111	2003	2243	5	14	315	1	2	16	24	66	355	0	0	0
ND	McKenzie	380530111	2004	2857	3	14	429	1	1	8	10	36	319	0	0	0
ND	McKenzie	380530111	2005	2794	2	10	433	1	1	6	8	18	285	0	0	0
ND	McKenzie	380530111	2006	2942	2	8	328	1	1	6	8	12	212	0	0	0
ND	McKenzie	380530111	2007	724	3	10	359	1	2	8	10	12	245	0	0	0
ND	Mercer	380570001	1997	2826	6	9	151	1	3	29	33	44	99	0	0	0

State	County	Monitor ID	Year	n	Measured 5-minute Maximum SO_2 (ppb)[1]									Number of 5-minute Maximum		
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	≥ 400 ppb	≥ 500 ppb	≥ 600 ppb
ND	Mercer	380570001	1998	4735	6	12	203	1	3	27	36	51	241	0	0	0
ND	Mercer	380570001	1999	320	8	6	72	2	7	24	26	27	36	0	0	0
ND	Mercer	380570004	1999	5584	5	10	201	1	2	26	31	40	260	0	0	0
ND	Mercer	380570004	2000	7348	4	7	189	1	1	20	24	32	209	0	0	0
ND	Mercer	380570004	2001	4648	6	11	203	1	2	26	35	57	169	0	0	0
ND	Mercer	380570004	2002	3701	5	10	197	1	2	22	25	35	274	0	0	0
ND	Mercer	380570004	2003	5555	4	7	173	1	2	18	22	34	103	0	0	0
ND	Mercer	380570004	2004	4678	5	8	157	1	2	24	29	36	107	0	0	0
ND	Mercer	380570004	2005	3046	5	7	149	1	2	21	25	33	95	0	0	0
ND	Mercer	380570004	2006	2756	5	7	127	1	3	23	26	33	70	0	0	0
ND	Mercer	380570004	2007	1133	4	6	146	1	2	17	21	32	73	0	0	0
ND	Morton	380590002	1997	6552	19	40	206	1	3	146	161	179	348	0	0	0
ND	Morton	380590002	1998	4699	19	40	207	1	3	144	164	189	295	0	0	0
ND	Morton	380590002	1999	6838	16	33	203	1	2	119	132	156	248	0	0	0
ND	Morton	380590002	2000	7964	13	28	217	1	2	101	116	133	297	0	0	0
ND	Morton	380590002	2001	5952	16	28	178	1	3	98	108	125	229	0	0	0
ND	Morton	380590002	2002	6261	14	26	189	1	2	89	104	123	207	0	0	0
ND	Morton	380590002	2003	8034	13	29	220	1	2	106	119	137	366	0	0	0
ND	Morton	380590002	2004	7534	14	28	198	1	2	102	116	132	261	0	0	0
ND	Morton	380590002	2005	1452	10	12	123	1	4	41	44	52	104	0	0	0
ND	Morton	380590003	1998	1924	8	17	225	1	2	50	74	91	197	0	0	0
ND	Morton	380590003	1999	6529	11	21	186	1	3	71	87	106	378	0	0	0
ND	Morton	380590003	2000	5988	11	18	172	1	3	64	75	92	167	0	0	0
ND	Morton	380590003	2001	6351	11	18	167	1	3	63	74	91	222	0	0	0
ND	Morton	380590003	2002	5248	10	18	177	1	3	59	72	93	208	0	0	0
ND	Morton	380590003	2003	7991	8	15	206	1	2	48	61	84	194	0	0	0
ND	Morton	380590003	2004	6341	10	17	178	1	3	59	71	89	183	0	0	0
ND	Morton	380590003	2005	1014	9	12	124	1	5	42	46	57	101	0	0	0
ND	Oliver	380650002	1997	2360	9	14	167	1	3	49	57	74	164	0	0	0
ND	Oliver	380650002	1998	4178	8	15	192	1	3	46	55	74	203	0	0	0
ND	Oliver	380650002	1999	4860	6	14	215	1	2	39	49	67	207	0	0	0
ND	Oliver	380650002	2000	4766	6	11	199	1	2	33	41	58	164	0	0	0
ND	Oliver	380650002	2001	2404	6	12	185	1	2	39	47	60	173	0	0	0
ND	Oliver	380650002	2002	4483	5	9	187	1	2	29	36	47	137	0	0	0

State	County	Monitor ID	Year	n	Measured 5-minute Maximum SO_2 (ppb)[1]									Number of 5-minute Maximum		
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	≥ 400 ppb	≥ 500 ppb	≥ 600 ppb
ND	Oliver	380650002	2003	6973	4	11	266	1	1	24	29	47	244	0	0	0
ND	Oliver	380650002	2004	6140	5	11	227	1	2	28	37	52	323	0	0	0
ND	Oliver	380650002	2005	2444	8	15	186	1	3	48	56	69	257	0	0	0
ND	Oliver	380650002	2006	3370	6	10	172	1	2	32	37	49	121	0	0	0
ND	Oliver	380650002	2007	781	8	14	172	1	4	48	56	78	136	0	0	0
ND	Steele	380910001	1997	3134	1	1	53	1	1	3	4	4	7	0	0	0
ND	Steele	380910001	1998	2804	2	2	94	1	1	9	9	11	36	0	0	0
ND	Steele	380910001	1999	1845	1	1	63	1	1	3	4	5	10	0	0	0
ND	Steele	380910001	2000	805	1	0	36	1	1	2	2	3	5	0	0	0
ND	Williams	381050103	2002	2726	8	23	290	1	2	51	71	120	301	0	0	0
ND	Williams	381050103	2003	3327	5	10	198	1	2	31	37	53	149	0	0	0
ND	Williams	381050103	2004	3438	5	14	252	1	2	31	38	52	398	0	0	0
ND	Williams	381050103	2005	2331	10	24	240	1	2	71	96	120	350	0	0	0
ND	Williams	381050103	2006	2976	4	8	200	1	1	23	31	41	99	0	0	0
ND	Williams	381050103	2007	834	7	13	171	1	3	45	52	70	98	0	0	0
ND	Williams	381050105	2002	2844	17	28	163	1	4	86	97	124	302	0	0	0
ND	Williams	381050105	2003	3523	14	23	157	1	3	78	86	96	221	0	0	0
ND	Williams	381050105	2004	4129	14	24	175	1	3	69	77	95	485	1	0	0
ND	Williams	381050105	2005	4492	18	32	184	1	3	99	115	165	358	0	0	0
ND	Williams	381050105	2006	2938	11	19	184	1	2	64	72	87	243	0	0	0
ND	Williams	381050105	2007	263	10	18	184	1	3	58	64	91	124	0	0	0
PA	Allegheny	420030002	1997	7825	19	25	132	1	10	88	102	125	400	1	0	0
PA	Allegheny	420030002	1998	72	68	55	80	5	54.5	187	245	299	299	0	0	0
PA	Allegheny	420030002	1999	6986	16	18	112	1	10	61	71	86	290	0	0	0
PA	Allegheny	420030021	1997	7830	29	33	112	1	18	96	110	138	620	4	3	1
PA	Allegheny	420030021	1998	72	13	10	77	2	11	36	41	41	41	0	0	0
PA	Allegheny	420030021	1999	8280	12	10	90	1	8	37	42	53	158	0	0	0
PA	Allegheny	420030021	2002	7291	9	10	101	1	7	30	35	44	136	0	0	0
PA	Allegheny	420030031	1997	8000	15	13	89	1	11	45	50	63	232	0	0	0
PA	Allegheny	420030031	1998	68	14	11	77	3	11	40	41	45	45	0	0	0
PA	Allegheny	420030031	1999	7445	12	15	123	1	9	38	42	49	928	1	1	1
PA	Allegheny	420030032	1997	7951	23	32	135	1	13	95	110	138	883	6	2	2
PA	Allegheny	420030032	1998	60	55	30	54	4	55.5	113	113	121	121	0	0	0
PA	Allegheny	420030032	1999	4328	11	11	96	1	8	37	43	53	114	0	0	0

State	County	Monitor ID	Year	n	Measured 5-minute Maximum SO_2 (ppb)[1]									Number of 5-minute Maximum		
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	≥ 400 ppb	≥ 500 ppb	≥ 600 ppb
PA	Allegheny	420030064	1997	7527	16	17	107	1	11	57	66	80	262	0	0	0
PA	Allegheny	420030064	1998	71	26	9	34	8	26	41	43	45	45	0	0	0
PA	Allegheny	420030064	1999	7234	17	22	131	1	10	63	73	90	822	1	1	1
PA	Allegheny	420030064	2002	8239	15	19	126	1	9	61	72	85	373	0	0	0
PA	Allegheny	420030067	1997	8235	14	16	111	1	9	51	59	71	463	1	0	0
PA	Allegheny	420030067	1998	72	20	14	70	3	16	51	52	54	54	0	0	0
PA	Allegheny	420030067	1999	5892	13	12	91	1	9	43	50	60	132	0	0	0
PA	Allegheny	420030116	1997	7810	20	34	167	1	12	78	101	149	806	10	6	3
PA	Allegheny	420030116	1998	70	21	13	63	2	18.5	45	51	55	55	0	0	0
PA	Allegheny	420030116	1999	5687	19	35	183	1	11	73	96	167	885	8	4	2
PA	Allegheny	420030116	2002	5403	9	10	116	1	5	33	39	53	157	0	0	0
PA	Allegheny	420031301	1997	7665	13	16	119	1	9	46	54	70	457	1	0	0
PA	Allegheny	420031301	1998	70	17	9	54	6	14	41	46	54	54	0	0	0
PA	Allegheny	420031301	1999	8162	13	16	122	1	9	47	55	69	439	1	0	0
PA	Allegheny	420033003	1997	7424	16	19	115	1	10	65	78	96	220	0	0	0
PA	Allegheny	420033003	1998	45	16	9	52	2	17	32	33	33	33	0	0	0
PA	Allegheny	420033003	1999	6998	19	31	161	1	11	78	91	115	938	9	4	2
PA	Allegheny	420033003	2002	7363	18	27	154	1	9	87	100	123	733	3	1	1
PA	Allegheny	420033004	1997	7519	13	14	109	1	9	42	49	61	265	0	0	0
PA	Allegheny	420033004	1998	66	18	9	49	4	16	41	41	42	42	0	0	0
PA	Allegheny	420033004	1999	7411	12	13	108	1	9	39	44	55	336	0	0	0
PA	Beaver	420070002	1997	7889	19	27	145	1	9	88	101	126	545	2	1	0
PA	Beaver	420070002	1998	6207	19	27	142	1	10	93	110	134	356	0	0	0
PA	Beaver	420070005	1997	7450	27	49	185	1	12	116	144	210	1099	20	14	10
PA	Beaver	420070005	1998	6388	26	50	195	1	10	129	160	230	922	17	10	8
PA	Beaver	420070005	2002	8491	24	49	206	1	7	124	158	225	902	22	16	10
PA	Beaver	420070005	2003	8706	17	29	169	1	6	85	99	131	494	2	0	0
PA	Beaver	420070005	2004	8656	18	31	174	1	7	84	98	126	921	4	4	3
PA	Beaver	420070005	2005	8578	19	34	178	1	8	83	104	147	682	10	6	1
PA	Beaver	420070005	2006	8457	15	34	219	1	4	82	99	151	771	8	4	4
PA	Beaver	420070005	2007	7556	15	26	177	1	7	68	82	114	912	1	1	1
PA	Berks	420110009	1997	7805	13	17	130	1	8	53	64	87	273	0	0	0
PA	Berks	420110009	1998	8643	13	15	116	1	9	45	54	77	279	0	0	0
PA	Berks	420110009	1999	2790	13	16	117	1	10	41	54	68	288	0	0	0

State	County	Monitor ID	Year	n	Measured 5-minute Maximum SO_2 (ppb)[1]									Number of 5-minute Maximum		
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	≥ 400 ppb	≥ 500 ppb	≥ 600 ppb
PA	Cambria	420210011	1997	8129	13	12	94	1	10	41	47	59	168	0	0	0
PA	Cambria	420210011	1998	7908	12	13	112	1	8	42	52	69	211	0	0	0
PA	Cambria	420210011	1999	2835	12	11	87	2	10	40	47	56	134	0	0	0
PA	Erie	420490003	1997	8173	16	23	146	1	9	79	96	128	318	0	0	0
PA	Erie	420490003	1998	8418	17	27	158	1	9	90	110	152	304	0	0	0
PA	Erie	420490003	1999	2779	18	30	164	1	10	97	125	171	340	0	0	0
PA	Philadelphia	421010022	1997	8297	13	14	110	1	8	44	51	65	260	0	0	0
PA	Philadelphia	421010022	1998	8065	11	11	104	1	7	40	45	54	181	0	0	0
PA	Philadelphia	421010022	1999	2670	12	15	124	1	7	45	50	62	262	0	0	0
PA	Philadelphia	421010022	2000	3631	11	10	93	1	8	37	41	49	154	0	0	0
PA	Philadelphia	421010022	2001	2094	11	10	94	1	8	38	42	50	98	0	0	0
PA	Philadelphia	421010048	1997	8456	16	47	300	1	7	66	99	208	954	35	26	14
PA	Philadelphia	421010048	1998	7286	8	8	97	1	6	29	32	39	89	0	0	0
PA	Philadelphia	421010048	1999	3941	8	9	114	1	5	31	35	42	215	0	0	0
PA	Philadelphia	421010136	1997	7532	6	7	112	1	4	25	29	36	102	0	0	0
PA	Philadelphia	421010136	1998	6492	7	8	110	1	5	25	29	35	158	0	0	0
PA	Philadelphia	421010136	1999	7147	7	9	117	1	5	27	32	41	224	0	0	0
PA	Philadelphia	421010136	2000	7045	8	8	104	1	5	27	32	38	90	0	0	0
PA	Philadelphia	421010136	2001	5149	9	10	109	1	6	33	39	48	106	0	0	0
PA	Philadelphia	421010136	2002	7275	7	8	112	1	5	25	28	35	180	0	0	0
PA	Philadelphia	421010136	2003	2585	9	9	109	1	6	29	34	44	164	0	0	0
PA	Warren	421230003	1997	7158	15	18	116	1	9	57	67	87	255	0	0	0
PA	Warren	421230003	1998	2126	10	10	103	1	6	37	42	52	96	0	0	0
PA	Warren	421230004	1997	7022	31	51	161	1	11	156	179	217	772	14	12	2
PA	Warren	421230004	1998	1966	23	38	163	1	8	126	142	172	345	0	0	0
PA	Washington	421250005	1997	8374	12	11	97	1	8	39	46	57	150	0	0	0
PA	Washington	421250005	1998	8540	11	11	93	1	8	37	42	53	177	0	0	0
PA	Washington	421250005	1999	2822	11	11	98	1	8	37	43	56	141	0	0	0
PA	Washington	421250200	1997	8369	14	16	113	1	8	54	62	75	181	0	0	0
PA	Washington	421250200	1998	8658	13	15	109	1	8	50	57	70	228	0	0	0
PA	Washington	421250200	1999	2830	13	14	105	1	8	48	54	62	230	0	0	0
PA	Washington	421255001	1997	8425	17	22	127	1	9	78	92	113	357	0	0	0
PA	Washington	421255001	1998	6559	18	20	113	1	11	72	82	104	282	0	0	0
SC	Barnwell	450110001	2000	790	5	4	76	2	4	14	16	18	46	0	0	0

State	County	Monitor ID	Year	n	Measured 5-minute Maximum SO_2 (ppb)[1]									Number of 5-minute Maximum		
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	≥ 400 ppb	≥ 500 ppb	≥ 600 ppb
SC	Barnwell	450110001	2001	2626	4	5	125	1	3	11	13	17	116	0	0	0
SC	Barnwell	450110001	2002	2545	3	3	94	1	2	9	10	11	62	0	0	0
SC	Charleston	450190003	2000	1703	9	9	97	2	6	30	34	43	104	0	0	0
SC	Charleston	450190003	2001	4807	6	7	115	1	4	23	27	35	105	0	0	0
SC	Charleston	450190003	2002	3509	4	6	136	1	2	18	21	29	68	0	0	0
SC	Charleston	450190046	2000	1267	6	6	91	1	4	19	25	33	50	0	0	0
SC	Charleston	450190046	2001	3497	3	4	115	1	2	13	15	22	68	0	0	0
SC	Charleston	450190046	2002	2927	3	5	143	1	2	13	16	22	84	0	0	0
SC	Georgetown	450430006	2000	604	8	9	113	2	5	35	37	45	71	0	0	0
SC	Georgetown	450430006	2001	2218	8	13	154	1	4	45	50	68	144	0	0	0
SC	Georgetown	450430006	2002	1169	4	9	196	1	2	21	32	45	122	0	0	0
SC	Greenville	450450008	2000	1988	6	6	91	1	4	20	23	32	60	0	0	0
SC	Greenville	450450008	2001	6418	5	6	108	1	4	17	20	27	167	0	0	0
SC	Greenville	450450008	2002	4679	4	4	109	1	3	12	14	17	117	0	0	0
SC	Lexington	450630008	2001	3941	8	18	223	1	3	54	72	99	273	0	0	0
SC	Lexington	450630008	2002	4242	9	20	232	1	3	60	71	101	277	0	0	0
SC	Oconee	450730001	2000	1218	4	3	76	2	3	13	14	17	31	0	0	0
SC	Oconee	450730001	2001	4304	3	2	75	1	3	10	10	13	23	0	0	0
SC	Oconee	450730001	2002	3063	2	2	83	1	2	7	8	9	24	0	0	0
SC	Richland	450790007	2000	1808	6	4	70	2	5	15	17	19	54	0	0	0
SC	Richland	450790007	2001	6420	5	6	104	1	4	18	22	28	99	0	0	0
SC	Richland	450790007	2002	4349	4	4	99	1	3	14	16	20	51	0	0	0
SC	Richland	450790021	2000	912	6	9	151	1	4	24	36	54	95	0	0	0
SC	Richland	450790021	2001	2706	5	8	156	1	3	27	33	49	93	0	0	0
SC	Richland	450790021	2002	2507	4	8	178	1	2	22	28	42	88	0	0	0
SC	Richland	450791003	2001	3347	4	5	111	1	3	14	18	24	92	0	0	0
SC	Richland	450791003	2002	4324	4	5	116	1	3	14	18	24	79	0	0	0
UT	Salt Lake	490352004	1997	4529	5	9	185	1	3	19	25	35	209	0	0	0
UT	Salt Lake	490352004	1998	5797	3	5	132	1	2	13	15	20	139	0	0	0
WV	Wayne	540990002	2002	8711	10	10	97	1	7	36	40	46	112	0	0	0
WV	Wayne	540990003	2002	7417	13	15	115	1	8	45	51	59	503	1	1	0
WV	Wayne	540990003	2003	8060	12	13	109	1	7	44	49	58	182	0	0	0
WV	Wayne	540990003	2004	8659	12	12	106	1	7	46	49	56	226	0	0	0
WV	Wayne	540990003	2005	8142	13	15	115	1	8	61	66	75	143	0	0	0

State	County	Monitor ID	Year	n	Measured 5-minute Maximum SO_2 (ppb)[1]									Number of 5-minute Maximum		
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	≥ 400 ppb	≥ 500 ppb	≥ 600 ppb
WV	Wayne	540990004	2002	8560	14	17	117	1	9	56	65	79	416	1	0	0
WV	Wayne	540990004	2003	8571	13	19	141	1	8	58	69	88	750	1	1	1
WV	Wayne	540990004	2004	8673	10	10	107	1	6	35	41	53	151	0	0	0
WV	Wayne	540990004	2005	8587	11	12	103	1	7	41	49	59	146	0	0	0
WV	Wayne	540990005	2002	8283	15	22	148	1	8	78	97	122	215	0	0	0
WV	Wayne	540990005	2003	7930	15	27	177	1	8	76	111	150	361	0	0	0
WV	Wayne	540990005	2004	8681	9	9	95	1	7	32	37	45	113	0	0	0
WV	Wayne	540990005	2005	8454	10	9	97	1	7	32	36	43	213	0	0	0
WV	Wood	541071002	2001	2152	11	20	183	1	5	44	52	82	409	1	0	0
WV	Wood	541071002	2002	8648	15	20	132	1	8	61	73	97	366	0	0	0
WV	Wood	541071002	2003	8641	14	21	151	1	7	58	75	105	374	0	0	0
WV	Wood	541071002	2004	8581	16	23	147	1	9	63	82	116	484	1	0	0
WV	Wood	541071002	2005	6219	13	24	177	1	5	66	80	117	508	1	1	0

[1] Mean, std, COV represent the arithmetic mean, the standard deviation of the mean, and the coefficient of variation (std/mean*100), respectively. Percentiles of the distribution include p0, p50, p97, p98, p100 representing the minimum, the median, the 97th, 98th, 99th percentiles, and maximum, respectively.

Table C-2. Descriptive statistics for measured 1-hour SO_2 concentrations by year. Data used were from 98 monitors that measured both the 5-minute maximum and 1-hour concentrations for years 1997 through 2007.

					Measured 1-hour SO_2 (ppb)[1]								
State	County	Monitor ID	Year	n	Mean	Std	COV	p0	p50	p97	p98	p99	p100
AR	Pulaski	051190007	2002	7183	3	1	53	1	2	6	7	8	14
AR	Pulaski	051190007	2003	7800	2	1	53	1	2	6	6	7	16
AR	Pulaski	051190007	2004	7690	2	2	77	1	1	6	6	8	17
AR	Pulaski	051190007	2005	6702	2	1	61	1	2	5	5	6	11
AR	Pulaski	051190007	2006	8356	3	1	35	1	3	6	6	7	13
AR	Pulaski	051190007	2007	2062	3	1	39	1	3	5	6	7	11
AR	Pulaski	051191002	1997	8322	2	1	61	1	2	5	6	7	26
AR	Pulaski	051191002	1998	6857	2	1	79	0	1	5	6	8	22
AR	Pulaski	051191002	1999	6277	2	1	65	0	2	5	6	7	13
AR	Pulaski	051191002	2000	7943	2	1	68	0	2	6	6	8	19
AR	Pulaski	051191002	2001	8334	2	1	53	0	2	5	5	6	17
AR	Union	051390006	1997	8347	5	11	212	1	3	22	30	50	244
AR	Union	051390006	1998	7084	6	7	115	1	5	22	28	41	152
AR	Union	051390006	1999	6153	5	7	134	0	3	19	24	33	108
AR	Union	051390006	2000	8176	5	9	194	1	2	25	33	49	173
AR	Union	051390006	2001	8265	3	4	124	0	2	10	12	16	138
AR	Union	051390006	2002	6297	3	2	78	1	2	8	10	12	42
AR	Union	051390006	2003	7240	2	5	239	1	1	7	9	11	258
AR	Union	051390006	2004	4431	2	3	124	1	1	9	10	12	59
AR	Union	051390006	2005	4923	2	3	110	1	2	6	7	10	110
AR	Union	051390006	2006	8364	3	2	76	1	3	6	7	11	66
AR	Union	051390006	2007	2061	3	1	43	2	3	6	6	8	22
CO	Denver	080310002	1997	7045	7	9	138	1	3	31	37	46	135
CO	Denver	080310002	1998	4363	7	9	129	1	4	31	36	45	148
CO	Denver	080310002	1999	1637	7	8	122	1	4	28	31	41	96
CO	Denver	080310002	2000	2459	7	9	132	1	4	28	35	46	87
CO	Denver	080310002	2001	5625	7	9	134	1	4	29	33	41	162
CO	Denver	080310002	2002	6863	5	7	136	1	3	25	30	35	102
CO	Denver	080310002	2003	6262	4	5	121	1	2	15	18	23	60
CO	Denver	080310002	2004	4480	4	4	113	1	2	15	18	21	50
CO	Denver	080310002	2005	4172	4	4	104	1	2	14	16	20	38
CO	Denver	080310002	2006	6519	3	4	107	1	2	13	15	18	53
DE	New Castle	100031008	1997	7501	10	18	175	1	5	60	77	103	215
DE	New Castle	100031008	1998	4901	9	15	169	1	4	48	58	82	155
DC	District of Columbia	110010041	2000	3751	9	6	72	3	7	24	27	31	82
DC	District of Columbia	110010041	2001	8302	7	6	95	1	5	22	25	30	123
DC	District of Columbia	110010041	2002	8575	7	6	83	1	6	20	24	31	72
DC	District of Columbia	110010041	2003	4282	9	6	69	1	7	23	25	31	79
DC	District of Columbia	110010041	2004	2770	8	6	70	1	7	20	23	28	90
DC	District of Columbia	110010041	2007	6394	5	4	74	1	4	13	15	18	111
FL	Nassau	120890005	2002	8415	6	15	240	1	2	43	59	82	322
FL	Nassau	120890005	2003	8662	3	9	261	1	1	23	30	38	204

State	County	Monitor ID	Year	n	Measured 1-hour SO_2 (ppb)[1]								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100
FL	Nassau	120890005	2004	6507	3	7	224	1	1	21	25	36	150
FL	Nassau	120890005	2005	4120	4	10	250	1	1	31	39	51	174
IA	Cerro Gordo	190330018	2001	518	1	3	275	0	0	9	11	19	36
IA	Cerro Gordo	190330018	2002	3718	1	4	305	0	0	5	6	13	78
IA	Cerro Gordo	190330018	2003	5179	2	7	400	0	0	14	19	33	136
IA	Cerro Gordo	190330018	2004	8676	1	3	330	0	0	5	7	12	65
IA	Cerro Gordo	190330018	2005	3713	1	1	204	0	0	3	4	7	29
IA	Clinton	190450019	2001	1346	2	2	79	0	2	6	7	8	14
IA	Clinton	190450019	2002	6773	3	3	104	0	2	12	13	15	40
IA	Clinton	190450019	2003	6193	3	3	112	0	2	10	11	14	45
IA	Clinton	190450019	2004	7472	3	3	109	0	2	10	12	15	47
IA	Clinton	190450019	2005	4153	4	4	112	0	2	14	16	20	53
IA	Muscatine	191390016	2001	1962	3	4	142	0	2	12	15	24	65
IA	Muscatine	191390016	2002	8597	4	5	136	0	3	12	16	23	134
IA	Muscatine	191390016	2003	7698	4	7	185	0	2	14	18	27	166
IA	Muscatine	191390016	2004	8167	3	5	149	0	2	14	17	23	131
IA	Muscatine	191390016	2005	4255	4	7	184	0	2	16	23	35	121
IA	Muscatine	191390017	2001	1603	2	2	84	0	2	6	7	8	17
IA	Muscatine	191390017	2002	8139	3	4	136	0	2	9	11	14	158
IA	Muscatine	191390017	2003	8533	4	4	114	0	3	11	13	20	89
IA	Muscatine	191390017	2004	8415	3	4	113	0	2	12	14	18	80
IA	Muscatine	191390017	2005	4214	3	4	132	0	2	10	12	16	92
IA	Muscatine	191390020	2001	2018	5	10	185	0	2	36	41	51	76
IA	Muscatine	191390020	2002	8201	5	10	199	0	2	31	40	53	123
IA	Muscatine	191390020	2003	8412	5	11	216	0	2	32	41	62	143
IA	Muscatine	191390020	2004	8717	7	15	218	0	2	47	58	81	183
IA	Muscatine	191390020	2005	4304	5	13	252	0	2	37	49	70	200
IA	Scott	191630015	2001	1438	1	2	177	0	1	6	7	10	30
IA	Scott	191630015	2002	8073	2	3	137	0	1	10	12	15	46
IA	Scott	191630015	2003	7916	2	3	127	0	1	8	9	13	35
IA	Scott	191630015	2004	7638	2	3	123	0	1	8	10	12	32
IA	Scott	191630015	2005	3919	2	3	117	0	1	10	11	14	24
IA	Van Buren	191770005	2001	701	1	1	89	0	1	3	4	5	8
IA	Van Buren	191770005	2002	6692	1	1	87	0	1	3	4	4	15
IA	Van Buren	191770005	2003	7486	1	1	80	0	1	3	4	4	8
IA	Van Buren	191770005	2004	5341	1	1	155	0	1	3	4	6	21
IA	Van Buren	191770006	2004	1032	1	1	95	0	1	3	4	4	7
IA	Van Buren	191770006	2005	3957	1	1	77	0	1	3	3	4	9
IA	Woodbury	191930018	2001	1686	1	2	168	0	1	8	9	13	23
IA	Woodbury	191930018	2002	4048	1	3	194	0	1	9	11	15	42
LA	West Baton Rouge	221210001	1997	4971	7	13	178	1	4	35	43	58	203
LA	West Baton Rouge	221210001	1998	7566	8	11	142	1	5	27	35	54	185
LA	West Baton Rouge	221210001	1999	7279	6	10	150	1	4	27	33	48	152
LA	West Baton Rouge	221210001	2000	7370	7	11	153	1	4	33	39	58	189
MO	Buchanan	290210009	1997	8484	8	32	381	1	2	58	96	158	626
MO	Buchanan	290210009	1998	8161	7	24	342	1	2	49	76	114	469
MO	Buchanan	290210009	1999	7419	3	3	111	1	2	9	11	16	47
MO	Buchanan	290210009	2000	5299	2	3	128	1	2	7	9	14	73

State	County	Monitor ID	Year	n	Measured 1-hour SO_2 (ppb)[1]								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100
MO	Buchanan	290210011	2000	1672	5	9	162	1	3	26	36	49	89
MO	Buchanan	290210011	2001	6415	4	5	143	1	2	17	22	31	83
MO	Buchanan	290210011	2002	6467	4	7	183	1	2	19	26	41	92
MO	Buchanan	290210011	2003	5142	4	7	173	1	3	17	25	41	115
MO	Greene	290770026	1997	4765	4	10	223	1	1	27	34	44	145
MO	Greene	290770026	1998	5813	6	12	204	1	2	40	48	60	154
MO	Greene	290770026	1999	7242	4	8	184	1	2	25	30	40	123
MO	Greene	290770026	2000	8721	5	10	206	1	2	33	40	51	136
MO	Greene	290770026	2001	8304	5	10	213	1	2	30	38	53	122
MO	Greene	290770026	2002	7055	4	9	212	1	1	31	38	49	114
MO	Greene	290770026	2003	7935	3	6	176	1	2	20	25	35	68
MO	Greene	290770026	2004	6574	3	6	200	1	1	22	27	36	68
MO	Greene	290770026	2005	8756	3	6	201	1	1	20	25	33	77
MO	Greene	290770026	2006	8753	3	7	215	1	1	22	27	38	88
MO	Greene	290770026	2007	6520	3	7	221	1	1	22	27	38	107
MO	Greene	290770037	1997	6563	5	15	296	1	1	38	52	77	264
MO	Greene	290770037	1998	8135	4	7	173	1	3	21	28	40	128
MO	Greene	290770037	1999	8554	3	8	246	1	1	17	26	45	125
MO	Greene	290770037	2000	5339	6	18	282	1	1	53	72	101	187
MO	Greene	290770037	2001	6710	4	11	264	1	1	26	35	54	171
MO	Greene	290770037	2002	6374	4	10	242	1	2	27	36	54	144
MO	Greene	290770037	2003	8181	3	7	210	1	2	19	27	39	106
MO	Greene	290770037	2004	6575	3	5	177	1	2	13	18	26	70
MO	Greene	290770037	2005	8760	3	6	199	1	2	15	20	31	122
MO	Greene	290770037	2006	8745	3	8	259	1	1	23	31	47	120
MO	Greene	290770037	2007	6496	2	6	249	1	1	15	22	33	102
MO	Iron	290930030	1997	8707	8	26	319	1	2	49	82	139	548
MO	Iron	290930030	1998	8475	8	25	317	1	2	61	88	144	377
MO	Iron	290930030	1999	6547	9	28	301	1	3	73	101	157	753
MO	Iron	290930030	2000	4088	14	46	323	1	2	126	166	234	798
MO	Iron	290930030	2001	5393	9	32	345	1	2	82	115	178	521
MO	Iron	290930030	2002	7961	7	24	339	1	2	55	81	130	409
MO	Iron	290930030	2003	6964	8	23	306	1	2	64	87	123	497
MO	Iron	290930030	2004	1846	2	3	104	1	1	10	11	12	18
MO	Iron	290930031	1997	6178	8	25	304	1	2	47	70	125	440
MO	Iron	290930031	1998	7991	8	23	303	1	2	45	62	112	746
MO	Iron	290930031	1999	7919	8	26	309	1	3	40	58	100	592
MO	Iron	290930031	2000	5172	8	25	301	1	2	59	82	125	390
MO	Iron	290930031	2001	8426	7	23	354	1	2	42	65	106	466
MO	Iron	290930031	2002	8665	6	19	293	1	3	33	50	89	392
MO	Iron	290930031	2003	8230	7	21	319	1	2	39	56	88	418
MO	Iron	290930031	2004	2172	4	3	72	1	3	11	13	14	22
MO	Jefferson	290990004	2004	8034	10	23	219	1	4	60	70	94	563
MO	Jefferson	290990004	2005	7144	11	25	218	1	4	69	85	120	609
MO	Jefferson	290990004	2006	6525	13	27	207	1	3	78	93	127	415
MO	Jefferson	290990004	2007	2125	6	12	189	1	2	35	43	59	189
MO	Jefferson	290990014	1997	7543	8	19	230	1	4	45	58	90	362
MO	Jefferson	290990014	1998	8130	4	9	212	1	2	19	24	34	255
MO	Jefferson	290990014	1999	7828	5	9	207	1	2	21	27	41	192
MO	Jefferson	290990014	2000	8259	4	6	169	1	2	14	18	27	131

State	County	Monitor ID	Year	n	Measured 1-hour SO_2 (ppb)[1]								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100
MO	Jefferson	290990014	2001	2730	3	5	175	1	2	13	17	24	97
MO	Jefferson	290990017	1998	5721	7	19	256	1	3	35	48	76	473
MO	Jefferson	290990017	1999	7289	9	22	256	1	3	44	61	112	569
MO	Jefferson	290990017	2000	7162	6	17	273	1	2	27	38	74	507
MO	Jefferson	290990017	2001	1045	8	17	214	1	3	35	43	68	234
MO	Jefferson	290990018	2001	3495	5	12	220	1	2	28	34	48	224
MO	Jefferson	290990018	2002	6306	6	15	269	1	2	26	35	64	328
MO	Jefferson	290990018	2003	6009	4	10	236	1	2	19	24	36	324
MO	Monroe	291370001	1997	8280	3	3	98	1	2	9	11	14	92
MO	Monroe	291370001	1998	8426	2	2	95	1	2	7	8	10	39
MO	Monroe	291370001	1999	8714	4	2	66	1	3	9	10	13	39
MO	Monroe	291370001	2000	8617	3	2	70	1	2	8	10	13	23
MO	Monroe	291370001	2001	4347	2	1	81	1	1	6	6	8	18
MO	Monroe	291370001	2002	5358	2	1	82	1	1	6	7	8	15
MO	Monroe	291370001	2003	5951	2	1	82	1	1	5	6	8	18
MO	Monroe	291370001	2004	5125	2	2	100	1	2	7	9	12	28
MO	Monroe	291370001	2005	6519	2	2	89	1	1	7	8	10	24
MO	Monroe	291370001	2006	6170	2	1	73	1	1	5	6	7	14
MO	Monroe	291370001	2007	526	2	2	108	1	1	5	7	8	27
MO	Pike	291630002	2005	4883	4	5	124	1	3	18	21	28	74
MO	Pike	291630002	2006	6473	4	5	119	1	3	13	16	23	113
MO	Pike	291630002	2007	1020	3	4	120	1	2	12	14	18	43
MO	Saint Charles	291830010	1997	8153	4	8	183	1	2	19	24	33	284
MO	Saint Charles	291830010	1998	4811	4	6	132	1	3	18	22	32	76
MO	Saint Charles	291831002	1997	8515	6	7	122	1	3	22	26	35	122
MO	Saint Charles	291831002	1998	8122	6	8	125	1	4	25	32	41	112
MO	Saint Charles	291831002	1999	7970	6	7	129	1	4	21	25	34	149
MO	Saint Charles	291831002	2000	6422	5	5	118	1	3	17	20	28	89
MT	Yellowstone	301110066	1997	6890	8	11	134	1	4	34	40	52	209
MT	Yellowstone	301110066	1998	7205	7	9	133	1	4	30	35	43	206
MT	Yellowstone	301110066	1999	5776	8	10	125	1	4	32	36	45	148
MT	Yellowstone	301110066	2000	6123	8	10	133	1	4	32	39	51	192
MT	Yellowstone	301110066	2001	6880	8	10	135	1	4	34	41	51	114
MT	Yellowstone	301110066	2002	8347	7	12	170	1	3	32	38	49	502
MT	Yellowstone	301110066	2003	5700	7	10	135	1	4	33	39	50	111
MT	Yellowstone	301110079	1997	3167	4	4	106	1	3	15	16	19	59
MT	Yellowstone	301110079	2001	837	5	4	80	1	4	13	14	17	26
MT	Yellowstone	301110079	2002	8034	2	2	101	1	1	7	8	10	26
MT	Yellowstone	301110079	2003	5107	3	3	85	1	2	9	10	12	33
MT	Yellowstone	301110080	1997	5462	8	10	134	1	4	31	37	49	194
MT	Yellowstone	301110080	1998	5412	7	9	134	1	4	29	33	42	224
MT	Yellowstone	301110080	1999	5617	6	8	123	1	4	25	30	38	139
MT	Yellowstone	301110080	2000	6032	6	8	123	1	4	25	29	38	104
MT	Yellowstone	301110080	2001	2029	6	6	114	1	4	21	25	30	86
MT	Yellowstone	301110082	2001	2607	4	5	110	1	3	15	17	22	57
MT	Yellowstone	301110082	2002	8212	2	3	119	1	1	9	11	14	56

State	County	Monitor ID	Year	n	Measured 1-hour SO_2 (ppb)[1]								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100
MT	Yellowstone	301110082	2003	5180	3	3	111	1	2	10	12	16	71
MT	Yellowstone	301110083	1999	2087	8	8	99	1	6	27	30	36	86
MT	Yellowstone	301110083	2000	3857	5	5	115	1	3	18	21	27	61
MT	Yellowstone	301110083	2001	5606	4	6	128	1	2	18	22	28	97
MT	Yellowstone	301110083	2002	6847	2	3	139	1	1	9	12	16	48
MT	Yellowstone	301110083	2003	1641	2	3	135	1	1	10	13	18	31
MT	Yellowstone	301110084	2003	759	3	5	151	1	2	12	15	20	68
MT	Yellowstone	301110084	2004	2468	3	5	156	1	2	16	21	28	81
MT	Yellowstone	301110084	2005	2578	3	5	168	1	1	16	20	26	58
MT	Yellowstone	301110084	2006	1984	3	5	165	1	1	14	16	24	90
MT	Yellowstone	301112008	1997	2580	4	5	115	1	2	15	17	20	86
NC	Forsyth	370670022	1997	8383	7	7	99	0	5	23	27	33	93
NC	Forsyth	370670022	1998	7124	7	8	108	1	5	22	26	36	181
NC	Forsyth	370670022	1999	6434	6	6	101	1	4	19	23	29	88
NC	Forsyth	370670022	2000	5205	6	6	101	1	4	19	21	26	86
NC	Forsyth	370670022	2001	7634	5	6	110	1	3	18	21	27	101
NC	Forsyth	370670022	2002	7023	6	8	134	1	4	23	27	39	169
NC	Forsyth	370670022	2003	8077	6	6	105	1	4	20	24	32	78
NC	Forsyth	370670022	2004	4711	6	8	148	1	3	23	28	41	149
NC	New Hanover	371290006	1999	8208	4	8	203	1	1	27	32	42	211
NC	New Hanover	371290006	2000	7980	5	9	191	1	1	31	37	48	90
NC	New Hanover	371290006	2001	8168	6	14	240	1	1	43	54	76	162
NC	New Hanover	371290006	2002	8028	6	14	215	1	2	45	54	71	436
ND	Billings	380070002	1998	1940	1	1	80	1	1	4	5	7	12
ND	Billings	380070002	1999	3216	1	1	75	1	1	4	5	6	12
ND	Billings	380070002	2000	2724	1	1	77	1	1	4	5	7	11
ND	Billings	380070002	2001	2860	1	1	82	1	1	4	5	6	20
ND	Billings	380070002	2002	3114	1	1	78	1	1	4	4	6	26
ND	Billings	380070002	2003	342	1	1	59	1	1	4	4	5	7
ND	Billings	380070002	2004	1256	1	1	69	1	1	3	4	5	16
ND	Billings	380070002	2005	837	1	1	64	1	1	4	4	5	8
ND	Billings	380070002	2006	418	2	1	82	1	1	5	6	7	10
ND	Billings	380070002	2007	221	1	1	84	1	1	4	6	7	13
ND	Billings	380070003	1997	2657	2	2	88	1	1	5	5	8	27
ND	Burke	380130002	1999	3852	3	5	165	1	1	15	18	24	52
ND	Burke	380130002	2000	5268	3	6	195	1	1	15	18	26	149
ND	Burke	380130002	2001	5653	3	5	182	1	1	16	20	26	88
ND	Burke	380130002	2002	5368	3	5	178	1	1	14	17	24	80
ND	Burke	380130002	2003	6328	3	5	183	1	1	13	17	24	111
ND	Burke	380130002	2004	5230	3	5	182	1	1	14	17	26	83
ND	Burke	380130002	2005	3099	3	5	173	1	1	16	19	25	75
ND	Burke	380130004	2003	882	3	4	138	1	1	14	17	22	35
ND	Burke	380130004	2004	3198	3	4	130	1	1	12	14	19	40
ND	Burke	380130004	2005	2238	2	3	129	1	1	11	13	16	55
ND	Burke	380130004	2006	3152	2	3	140	1	1	9	11	14	63
ND	Burke	380130004	2007	1228	4	5	136	1	2	17	18	22	81
ND	Burleigh	380150003	2005	684	3	3	87	1	2	11	12	14	18
ND	Burleigh	380150003	2006	3708	2	3	111	1	1	9	11	13	30

State	County	Monitor ID	Year	n	Measured 1-hour SO_2 (ppb)[1]								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100
ND	Burleigh	380150003	2007	948	4	4	115	1	2	16	17	22	40
ND	Cass	380171003	1997	2254	2	2	133	1	1	7	10	13	26
ND	Cass	380171003	1998	2943	2	2	97	1	1	6	8	11	23
ND	Cass	380171004	1998	2501	1	0	39	1	1	2	3	3	8
ND	Cass	380171004	1999	3325	1	1	57	1	1	3	3	4	9
ND	Cass	380171004	2000	1868	1	1	61	1	1	4	4	5	9
ND	Cass	380171004	2001	1686	1	1	69	1	1	3	5	6	12
ND	Cass	380171004	2002	2476	1	0	39	1	1	2	2	3	6
ND	Cass	380171004	2003	1297	1	1	65	1	1	3	4	4	15
ND	Cass	380171004	2004	3140	1	1	50	1	1	3	3	4	7
ND	Cass	380171004	2005	928	1	1	55	1	1	3	3	4	8
ND	Cass	380171004	2006	7863	0	0	107	0	0	1	2	2	6
ND	Cass	380171004	2007	2258	1	1	134	0	0	2	3	4	10
ND	Dunn	380250003	1997	3313	1	1	83	1	1	4	5	6	17
ND	Dunn	380250003	1998	2688	2	2	116	1	1	7	8	11	31
ND	Dunn	380250003	1999	5099	2	2	104	1	1	5	5	7	34
ND	Dunn	380250003	2000	7455	1	1	103	1	1	4	5	7	50
ND	Dunn	380250003	2001	3576	2	1	93	1	1	5	6	8	25
ND	Dunn	380250003	2002	4485	1	1	83	1	1	4	4	6	23
ND	Dunn	380250003	2003	7289	1	1	85	1	1	4	5	7	23
ND	Dunn	380250003	2004	6019	1	1	84	1	1	4	5	7	17
ND	Dunn	380250003	2005	1314	1	2	103	1	1	5	6	7	19
ND	Dunn	380250003	2006	2214	2	2	102	1	1	5	6	8	18
ND	Dunn	380250003	2007	667	2	1	91	1	1	5	6	9	22
ND	McKenzie	380530002	1997	2557	1	1	82	1	1	5	6	7	18
ND	McKenzie	380530002	1998	1989	2	2	95	1	1	5	6	9	23
ND	McKenzie	380530002	2001	754	1	1	64	1	1	3	4	5	9
ND	McKenzie	380530002	2002	3361	1	1	62	1	1	3	4	4	13
ND	McKenzie	380530002	2003	5345	1	1	86	1	1	4	5	7	27
ND	McKenzie	380530002	2004	4614	1	1	85	1	1	4	5	6	29
ND	McKenzie	380530002	2005	2525	1	1	67	1	1	3	4	5	14
ND	McKenzie	380530002	2006	2897	1	1	72	1	1	3	4	5	21
ND	McKenzie	380530002	2007	511	2	1	82	1	1	5	6	7	12
ND	McKenzie	380530104	1998	1525	2	5	207	1	1	9	10	14	123
ND	McKenzie	380530104	1999	1501	2	4	161	1	1	7	9	13	66
ND	McKenzie	380530104	2000	2757	2	4	207	1	1	6	8	12	138
ND	McKenzie	380530104	2001	2281	2	2	104	1	1	5	6	8	48
ND	McKenzie	380530104	2002	1528	2	4	213	1	1	7	9	14	100
ND	McKenzie	380530104	2003	2333	2	5	267	1	1	6	10	20	107
ND	McKenzie	380530104	2004	2241	1	1	101	1	1	4	4	5	43
ND	McKenzie	380530104	2005	1905	1	2	175	1	1	3	3	5	80
ND	McKenzie	380530104	2006	1828	1	2	135	1	1	3	4	5	33
ND	McKenzie	380530104	2007	764	1	1	78	1	1	4	5	6	12
ND	McKenzie	380530111	1998	2071	3	7	236	1	1	12	17	29	141
ND	McKenzie	380530111	1999	2382	2	5	229	1	1	9	11	15	134
ND	McKenzie	380530111	2000	2808	3	8	309	1	1	10	12	18	267
ND	McKenzie	380530111	2001	3183	2	2	116	1	1	7	8	11	47
ND	McKenzie	380530111	2002	2256	2	4	188	1	1	6	8	13	77
ND	McKenzie	380530111	2003	2243	2	4	189	1	1	7	9	17	65
ND	McKenzie	380530111	2004	2857	2	6	326	1	1	5	5	10	166

State	County	Monitor ID	Year	n	Measured 1-hour SO_2 (ppb)[1]								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100
ND	McKenzie	380530111	2005	2794	1	3	235	1	1	3	4	5	102
ND	McKenzie	380530111	2006	2942	1	2	177	1	1	3	4	6	87
ND	McKenzie	380530111	2007	724	2	2	117	1	1	5	6	9	25
ND	Mercer	380570001	1997	2826	3	4	146	1	1	13	16	22	53
ND	Mercer	380570001	1998	4735	3	6	194	1	2	13	16	23	178
ND	Mercer	380570001	1999	320	5	3	60	2	4	13	14	15	18
ND	Mercer	380570004	1999	5584	3	4	152	1	1	13	15	19	66
ND	Mercer	380570004	2000	7348	2	4	166	1	1	10	12	16	159
ND	Mercer	380570004	2001	4648	3	5	184	1	1	13	17	26	89
ND	Mercer	380570004	2002	3701	3	5	173	1	1	10	13	17	131
ND	Mercer	380570004	2003	5555	2	3	141	1	1	9	11	16	58
ND	Mercer	380570004	2004	4678	3	4	136	1	1	11	14	19	60
ND	Mercer	380570004	2005	3046	2	3	134	1	1	10	13	16	43
ND	Mercer	380570004	2006	2756	3	3	122	1	1	11	14	17	35
ND	Mercer	380570004	2007	1133	2	3	139	1	1	10	11	15	51
ND	Morton	380590002	1997	6552	9	20	218	1	2	72	88	108	159
ND	Morton	380590002	1998	4699	9	22	242	1	2	68	85	123	241
ND	Morton	380590002	1999	6838	8	17	221	1	1	54	64	87	171
ND	Morton	380590002	2000	7964	6	15	225	1	1	51	61	77	161
ND	Morton	380590002	2001	5952	7	14	181	1	2	49	56	65	140
ND	Morton	380590002	2002	6261	6	12	192	1	2	39	47	60	133
ND	Morton	380590002	2003	8034	6	14	219	1	1	48	56	70	157
ND	Morton	380590002	2004	7534	7	13	196	1	2	46	54	69	158
ND	Morton	380590002	2005	1452	5	6	125	1	2	21	23	29	46
ND	Morton	380590003	1998	1924	4	7	201	1	1	18	26	39	113
ND	Morton	380590003	1999	6529	5	9	175	1	2	28	36	47	123
ND	Morton	380590003	2000	5988	5	8	171	1	2	25	30	44	106
ND	Morton	380590003	2001	6351	5	8	165	1	2	26	31	41	115
ND	Morton	380590003	2002	5248	4	8	171	1	2	23	29	40	100
ND	Morton	380590003	2003	7991	4	6	179	1	1	19	24	32	91
ND	Morton	380590003	2004	6341	4	7	158	1	2	22	26	34	88
ND	Morton	380590003	2005	1014	4	5	133	1	2	17	21	27	48
ND	Oliver	380650002	1997	2360	4	7	169	1	2	24	29	36	101
ND	Oliver	380650002	1998	4178	4	7	184	1	2	21	26	35	121
ND	Oliver	380650002	1999	4860	3	7	200	1	1	18	24	36	139
ND	Oliver	380650002	2000	4766	3	6	177	1	1	15	20	26	110
ND	Oliver	380650002	2001	2404	3	6	171	1	1	20	25	30	85
ND	Oliver	380650002	2002	4483	3	5	175	1	1	13	16	23	77
ND	Oliver	380650002	2003	6973	2	6	235	1	1	10	14	22	129
ND	Oliver	380650002	2004	6140	3	5	187	1	1	14	18	26	87
ND	Oliver	380650002	2005	2444	4	7	174	1	1	21	26	35	99
ND	Oliver	380650002	2006	3370	3	4	152	1	1	15	18	23	52
ND	Oliver	380650002	2007	781	4	7	170	1	2	18	26	35	81
ND	Steele	380910001	1997	3134	1	1	53	1	1	3	4	4	7
ND	Steele	380910001	1998	2804	2	2	94	1	1	9	9	11	36
ND	Steele	380910001	1999	1845	1	1	63	1	1	3	4	5	10
ND	Steele	380910001	2000	805	1	0	36	1	1	2	2	3	5
ND	Williams	381050103	2002	2726	3	8	238	1	1	16	25	40	140
ND	Williams	381050103	2003	3327	2	4	150	1	1	12	14	19	55
ND	Williams	381050103	2004	3438	3	5	207	1	1	11	15	20	191

State	County	Monitor ID	Year	n	Measured 1-hour SO_2 (ppb)[1]								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100
ND	Williams	381050103	2005	2331	4	8	228	1	1	20	26	38	190
ND	Williams	381050103	2006	2976	2	2	123	1	1	8	10	13	39
ND	Williams	381050103	2007	834	3	5	138	1	2	16	18	24	46
ND	Williams	381050105	2002	2844	7	11	161	1	2	35	39	47	118
ND	Williams	381050105	2003	3523	6	9	166	1	2	33	38	48	77
ND	Williams	381050105	2004	4129	6	11	188	1	2	30	35	43	322
ND	Williams	381050105	2005	4492	7	13	191	1	1	42	47	59	193
ND	Williams	381050105	2006	2938	4	7	178	1	1	23	27	32	117
ND	Williams	381050105	2007	263	4	6	157	1	1	22	24	30	32
PA	Allegheny	420030002	1997	7825	13	15	120	1	7	52	60	75	193
PA	Allegheny	420030002	1998	72	43	32	75	3	38	97	168	173	173
PA	Allegheny	420030002	1999	6986	11	11	101	1	8	39	45	53	166
PA	Allegheny	420030021	1997	7830	18	19	104	1	12	57	65	82	421
PA	Allegheny	420030021	1998	72	10	8	81	1	8	30	34	36	36
PA	Allegheny	420030021	1999	8280	9	8	88	1	7	28	32	40	126
PA	Allegheny	420030021	2002	7291	7	7	100	1	5	25	27	35	89
PA	Allegheny	420030031	1997	8000	11	10	88	1	8	34	39	47	118
PA	Allegheny	420030031	1998	68	11	9	82	2	9	34	38	39	39
PA	Allegheny	420030031	1999	7445	9	8	87	1	7	30	33	38	73
PA	Allegheny	420030032	1997	7951	15	19	126	1	9	60	69	90	496
PA	Allegheny	420030032	1998	60	35	21	59	3	35	75	75	92	92
PA	Allegheny	420030032	1999	4328	8	8	95	1	6	28	32	38	84
PA	Allegheny	420030064	1997	7527	12	13	110	1	8	44	51	63	159
PA	Allegheny	420030064	1998	71	20	8	40	6	20	35	35	38	38
PA	Allegheny	420030064	1999	7234	12	14	118	1	7	47	55	69	420
PA	Allegheny	420030064	2002	8239	11	13	122	1	6	46	52	65	159
PA	Allegheny	420030067	1997	8235	10	11	107	1	7	39	43	52	160
PA	Allegheny	420030067	1998	72	17	13	74	2	12	42	44	50	50
PA	Allegheny	420030067	1999	5892	10	9	88	1	7	33	38	44	78
PA	Allegheny	420030116	1997	7810	13	18	134	1	8	48	56	79	311
PA	Allegheny	420030116	1998	70	17	11	65	1	15	37	38	42	42
PA	Allegheny	420030116	1999	5687	12	16	132	1	8	41	48	75	333
PA	Allegheny	420030116	2002	5403	7	8	114	1	4	25	29	40	135
PA	Allegheny	420031301	1997	7665	9	10	105	1	6	33	38	46	160
PA	Allegheny	420031301	1998	70	13	7	54	5	10	29	34	39	39
PA	Allegheny	420031301	1999	8162	10	10	100	1	7	34	38	46	135
PA	Allegheny	420033003	1997	7424	12	14	117	1	7	48	58	72	135
PA	Allegheny	420033003	1998	45	11	6	55	1	11	24	26	26	26
PA	Allegheny	420033003	1999	6998	14	20	147	1	8	57	68	85	449
PA	Allegheny	420033003	2002	7363	13	18	144	1	7	63	75	92	350
PA	Allegheny	420033004	1997	7519	9	10	105	1	6	31	36	47	129
PA	Allegheny	420033004	1998	66	13	6	46	3	12	27	27	28	28
PA	Allegheny	420033004	1999	7411	9	9	106	1	6	29	33	39	256
PA	Beaver	420070002	1997	7889	12	15	130	1	7	51	57	70	320
PA	Beaver	420070002	1998	6207	13	16	127	1	8	55	63	82	216
PA	Beaver	420070005	1997	7450	17	25	152	1	8	70	82	111	474
PA	Beaver	420070005	1998	6388	16	27	166	1	8	75	94	126	569
PA	Beaver	420070005	2002	8491	14	27	186	1	5	69	88	127	620
PA	Beaver	420070005	2003	8706	11	17	158	1	4	54	63	78	302
PA	Beaver	420070005	2004	8656	12	18	153	1	5	50	59	75	368

State	County	Monitor ID	Year	n	Measured 1-hour SO_2 (ppb)[1]								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100
PA	Beaver	420070005	2005	8578	13	18	145	1	7	52	62	87	345
PA	Beaver	420070005	2006	8457	9	19	200	1	2	46	56	79	423
PA	Beaver	420070005	2007	7556	10	14	143	1	5	43	50	67	279
PA	Berks	420110009	1997	7805	9	9	103	1	6	30	35	45	111
PA	Berks	420110009	1998	8643	9	8	85	1	7	26	29	35	155
PA	Berks	420110009	1999	2790	9	8	91	1	7	27	31	38	144
PA	Cambria	420210011	1997	8129	10	9	94	1	7	32	36	43	119
PA	Cambria	420210011	1998	7908	9	10	110	1	6	31	36	51	165
PA	Cambria	420210011	1999	2835	10	8	82	2	8	30	34	41	99
PA	Erie	420490003	1997	8173	10	11	115	1	7	36	45	60	139
PA	Erie	420490003	1998	8418	11	14	128	1	7	40	50	74	182
PA	Erie	420490003	1999	2779	11	15	132	1	8	43	56	90	207
PA	Philadelphia	421010022	1997	8297	9	9	102	1	6	29	32	40	109
PA	Philadelphia	421010022	1998	8065	7	7	96	1	5	25	28	34	71
PA	Philadelphia	421010022	1999	2670	8	8	106	1	5	29	33	38	84
PA	Philadelphia	421010022	2000	3631	8	7	90	1	6	25	27	31	57
PA	Philadelphia	421010022	2001	2094	8	7	95	1	5	26	30	36	58
PA	Philadelphia	421010048	1997	8456	9	18	207	1	5	33	41	66	620
PA	Philadelphia	421010048	1998	7286	6	6	96	1	4	22	25	28	61
PA	Philadelphia	421010048	1999	3941	6	7	108	1	4	22	26	32	106
PA	Philadelphia	421010136	1997	7532	5	6	111	1	3	19	22	28	60
PA	Philadelphia	421010136	1998	6492	5	6	105	1	3	19	22	27	78
PA	Philadelphia	421010136	1999	7147	6	6	107	1	4	20	24	30	93
PA	Philadelphia	421010136	2000	7045	6	6	104	1	4	21	24	29	69
PA	Philadelphia	421010136	2001	5149	7	7	110	1	5	25	29	37	87
PA	Philadelphia	421010136	2002	7275	5	6	106	1	4	19	23	27	108
PA	Philadelphia	421010136	2003	2585	7	7	99	1	5	23	26	36	63
PA	Warren	421230003	1997	7158	11	12	110	1	7	38	45	58	168
PA	Warren	421230003	1998	2126	8	7	97	1	5	26	29	36	68
PA	Warren	421230004	1997	7022	17	28	164	1	7	84	100	129	538
PA	Warren	421230004	1998	1966	14	22	156	1	6	74	88	110	211
PA	Washington	421250005	1997	8374	9	8	94	1	7	29	34	41	115
PA	Washington	421250005	1998	8540	9	8	88	1	7	29	32	39	96
PA	Washington	421250005	1999	2822	8	8	92	1	6	26	32	41	99
PA	Washington	421250200	1997	8369	11	11	107	1	7	40	45	55	130
PA	Washington	421250200	1998	8658	10	10	100	1	7	39	44	51	115
PA	Washington	421250200	1999	2830	10	10	97	1	7	37	42	49	90
PA	Washington	421255001	1997	8425	13	15	120	1	7	54	64	79	244
PA	Washington	421255001	1998	6559	13	13	97	1	9	48	56	73	164
SC	Barnwell	450110001	2000	790	4	3	72	2	3	10	12	15	39
SC	Barnwell	450110001	2001	2626	3	3	96	1	2	8	9	12	57
SC	Barnwell	450110001	2002	2545	2	2	81	1	1	7	7	8	16
SC	Charleston	450190003	2000	1703	6	5	86	2	4	19	21	26	59
SC	Charleston	450190003	2001	4807	4	4	99	1	3	15	17	20	59
SC	Charleston	450190003	2002	3509	3	3	122	1	2	12	13	17	51
SC	Charleston	450190046	2000	1267	5	4	91	2	3	13	15	23	64
SC	Charleston	450190046	2001	3497	3	3	99	1	2	10	11	14	38
SC	Charleston	450190046	2002	2927	2	3	124	1	1	8	10	14	48
SC	Georgetown	450430006	2000	604	5	4	89	2	4	15	20	23	49
SC	Georgetown	450430006	2001	2218	5	6	128	1	3	22	26	31	89

State	County	Monitor ID	Year	n	Measured 1-hour SO_2 (ppb)[1]								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100
SC	Georgetown	450430006	2002	1169	3	4	173	1	1	9	13	24	83
SC	Greenville	450450008	2000	1988	5	4	77	1	4	14	16	20	41
SC	Greenville	450450008	2001	6418	4	4	91	1	3	13	15	18	101
SC	Greenville	450450008	2002	4679	3	3	91	1	2	10	11	13	59
SC	Lexington	450630008	2001	3941	4	8	186	1	2	23	30	39	139
SC	Lexington	450630008	2002	4242	4	9	194	1	2	26	33	46	120
SC	Oconee	450730001	2000	1218	4	3	75	2	3	11	12	15	30
SC	Oconee	450730001	2001	4304	3	2	72	1	2	8	9	11	19
SC	Oconee	450730001	2002	3063	2	2	84	0	1	6	6	8	19
SC	Richland	450790007	2000	1808	4	3	63	2	4	11	12	14	31
SC	Richland	450790007	2001	6420	4	3	89	1	3	12	14	17	50
SC	Richland	450790007	2002	4349	3	3	92	1	2	10	11	15	31
SC	Richland	450790021	2000	912	4	5	124	2	3	14	19	32	74
SC	Richland	450790021	2001	2706	4	5	131	1	2	13	18	27	65
SC	Richland	450790021	2002	2507	3	5	165	1	2	12	16	24	70
SC	Richland	450791003	2001	3347	3	3	89	1	2	9	11	14	38
SC	Richland	450791003	2002	4324	3	3	97	1	2	9	11	14	38
UT	Salt Lake	490352004	1997	4529	2	3	108	1	2	8	9	12	50
UT	Salt Lake	490352004	1998	5797	2	2	86	1	1	6	7	9	32
WV	Wayne	540990002	2002	8711	7	7	95	1	5	26	30	34	91
WV	Wayne	540990003	2002	7417	8	9	107	1	5	31	35	41	110
WV	Wayne	540990003	2003	8060	9	10	111	1	5	39	41	44	100
WV	Wayne	540990003	2004	8659	9	9	103	1	6	40	44	48	108
WV	Wayne	540990003	2005	8142	10	12	123	1	6	43	60	66	124
WV	Wayne	540990004	2002	8560	9	9	100	1	6	32	37	46	96
WV	Wayne	540990004	2003	8571	9	10	115	1	6	31	37	48	232
WV	Wayne	540990004	2004	8673	7	7	92	1	5	24	27	33	79
WV	Wayne	540990004	2005	8587	8	6	83	1	6	23	26	32	92
WV	Wayne	540990005	2002	8283	8	10	116	1	5	33	38	50	114
WV	Wayne	540990005	2003	7930	8	11	133	1	5	33	40	55	167
WV	Wayne	540990005	2004	8681	7	6	84	1	5	22	24	29	62
WV	Wayne	540990005	2005	8454	7	6	83	1	5	21	23	26	51
WV	Wood	541071002	2001	2152	8	13	161	1	4	30	36	48	262
WV	Wood	541071002	2002	8648	10	11	114	1	6	36	43	56	136
WV	Wood	541071002	2003	8641	9	12	129	1	5	38	44	60	216
WV	Wood	541071002	2004	8581	11	13	122	1	7	40	47	64	240
WV	Wood	541071002	2005	6219	8	13	152	1	4	38	45	60	197

[1] Mean, std, COV represent the arithmetic mean, the standard deviation of the mean, and the coefficient of variation (std/mean*100), respectively. Percentiles of the distribution include p0, p50, p97, p98, p100 representing the minimum, the median, the 97th, 98th, 99th percentiles, and maximum, respectively.

Table C-3. Descriptive statistics for modeled 5-minute maximum and measured 1-hour SO_2 concentrations for monitors in 20 selected counties, Years 2002 through 2006, air quality as is.

					Modeled 5-minute Maximum SO_2									Measured 1-hour SO_2								
State	County	Monid	Year	n	Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
DE	New Castle	100031003	2002	8573	5	13	239	0	0	34	41	56	287	3	6	199	0	0	19	22	28	105
DE	New Castle	100031007	2002	8614	5	12	239	0	2	29	37	57	304	3	6	200	0	1	15	19	28	115
DE	New Castle	100031008	2002	8631	10	27	277	0	1	68	88	135	480	6	14	248	0	1	38	50	71	200
DE	New Castle	100032004	2002	8546	7	14	188	0	4	36	45	63	333	4	6	148	0	2	18	21	30	103
FL	Hillsborough	120570053	2002	8663	6	12	194	0	2	32	39	53	285	4	6	155	0	2	17	20	27	77
FL	Hillsborough	120570081	2002	8708	5	15	276	0	1	35	46	66	352	3	7	237	0	1	20	26	35	172
FL	Hillsborough	120570095	2002	8477	7	24	350	0	1	51	72	123	500	3	9	290	0	1	20	28	47	169
FL	Hillsborough	120570109	2002	8623	8	29	337	0	2	61	93	165	457	4	12	292	0	1	24	37	68	164
FL	Hillsborough	120571035	2002	8634	11	21	188	0	5	56	70	97	432	7	10	159	0	3	31	37	49	192
FL	Hillsborough	120571065	2002	4323	7	15	211	0	2	39	49	66	264	4	7	174	0	1	22	26	34	90
FL	Hillsborough	120574004	2002	8696	5	8	164	0	3	21	26	36	191	3	3	125	0	2	10	12	17	59
IL	Madison	171190008	2002	8656	6	12	196	0	2	32	39	54	297	4	6	156	0	2	16	20	26	84
IL	Madison	171191010	2002	8676	8	18	220	0	3	45	57	83	365	5	9	189	0	2	25	31	43	129
IL	Madison	171193007	2002	8673	7	13	180	0	3	35	42	57	299	4	6	141	0	2	18	22	27	92
IL	Madison	171193009	2002	8700	8	20	245	0	3	40	52	83	466	5	10	214	0	2	22	28	42	229
IN	Floyd	180430004	2002	7497	9	18	203	1	3	47	59	85	485	5	9	178	1	2	26	31	42	274
IN	Floyd	180430007	2002	8142	10	14	149	1	5	38	46	63	351	6	7	119	1	4	19	22	29	175
IN	Floyd	180431004	2002	8559	11	23	211	0	4	64	84	123	443	5	9	179	0	3	23	31	45	189
IA	Linn	191130029	2002	8607	5	12	247	0	1	31	40	58	226	3	6	212	0	1	17	22	31	88
IA	Linn	191130031	2002	8663	8	22	261	0	2	62	83	119	349	4	8	215	0	1	24	31	44	110
IA	Linn	191130038	2002	8659	6	20	329	0	1	52	71	109	396	3	8	283	0	1	22	28	40	173
IA	Muscatine	191390016	2002	8597	6	11	169	0	4	26	33	48	279	4	5	136	0	3	12	16	23	134
IA	Muscatine	191390017	2002	8141	5	9	173	0	3	20	25	34	313	3	4	136	0	2	9	11	14	158
IA	Muscatine	191390020	2002	8202	11	27	245	0	3	81	105	145	436	5	10	199	0	2	31	40	53	123
MI	Wayne	261630015	2002	6452	12	32	266	0	4	80	101	139	1469	7	17	243	0	3	46	56	72	832
MI	Wayne	261630016	2002	8707	9	18	210	0	3	50	63	86	341	5	9	178	0	2	28	34	46	108
MI	Wayne	261630019	2002	8024	6	11	184	0	2	32	38	49	282	4	5	143	0	2	17	19	24	63
MO	Greene	290770026	2002	7055	9	26	269	1	2	73	96	138	393	4	9	212	1	1	31	38	49	114
MO	Greene	290770032	2002	8656	4	5	112	0	3	11	13	21	95	3	2	62	0	3	6	7	8	28
MO	Greene	290770037	2002	6374	8	25	299	1	2	59	87	146	431	4	10	242	1	2	27	36	54	144

					Modeled 5-minute Maximum SO_2									Measured 1-hour SO_2								
State	County	Monid	Year	n	Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
MO	Greene	290770040	2002	7465	3	12	455	0	0	14	20	35	394	2	6	408	0	0	8	11	18	203
MO	Greene	290770041	2002	7476	1	3	264	0	0	6	9	14	87	1	2	218	0	0	4	5	9	33
MO	Iron	290930030	2002	7976	15	55	367	1	2	132	206	304	1065	7	24	338	1	2	55	83	131	409
MO	Iron	290930031	2002	8687	13	44	335	1	4	82	126	227	997	6	19	293	1	3	33	50	89	392
MO	Jefferson	290990018	2002	6318	12	34	292	0	3	71	100	162	843	6	15	269	0	2	26	35	64	328
OH	Cuyahoga	390350038	2002	8524	9	14	158	0	4	43	51	67	177	5	7	135	0	3	23	27	33	80
OH	Cuyahoga	390350045	2002	8610	8	10	138	0	4	31	36	49	177	4	5	111	0	3	16	19	23	87
OH	Cuyahoga	390350060	2002	8557	10	14	134	0	6	43	51	67	179	6	7	110	0	4	23	25	30	72
OH	Cuyahoga	390350065	2002	8591	5	10	196	0	1	29	35	46	180	3	5	167	0	1	16	18	23	84
OH	Cuyahoga	390356001	2002	8638	9	14	162	0	4	39	47	67	259	5	7	141	0	3	20	24	31	117
OK	Tulsa	401430175	2002	8609	11	18	170	0	3	53	62	79	254	6	9	143	0	2	29	33	38	74
OK	Tulsa	401430235	2002	8304	7	13	197	0	3	36	44	60	259	4	6	166	0	2	19	24	32	112
OK	Tulsa	401430501	2002	8356	9	16	167	0	4	48	56	71	242	5	8	140	0	3	26	29	35	82
PA	Allegheny	420030002	2002	7932	15	22	143	0	8	63	76	101	354	9	10	114	0	6	31	37	48	110
PA	Allegheny	420030010	2002	8736	14	15	105	0	10	45	57	83	236	10	8	75	0	8	28	31	37	124
PA	Allegheny	420030021	2002	7757	13	17	135	0	8	50	59	78	318	7	7	100	0	6	25	29	36	89
PA	Allegheny	420030064	2002	8431	19	28	147	0	9	85	100	130	392	11	13	121	0	6	46	52	65	159
PA	Allegheny	420030067	2002	8145	13	17	132	0	8	50	61	86	318	9	10	104	0	7	31	35	42	142
PA	Allegheny	420030116	2002	8477	13	18	139	0	7	51	61	80	337	7	8	108	0	5	25	29	39	135
PA	Allegheny	420033003	2002	7864	22	36	163	0	10	114	139	188	619	13	18	142	0	7	61	73	91	350
PA	Beaver	420070002	2002	8402	18	31	178	0	8	91	110	146	519	10	15	146	0	5	49	59	73	185
PA	Beaver	420070005	2002	8538	25	52	209	0	7	131	170	256	1226	14	26	186	0	5	69	88	127	620
PA	Beaver	420070014	2002	8586	12	21	170	0	6	61	72	93	445	7	9	132	0	4	32	37	44	119
PA	Northampton	420950025	2002	8465	9	9	109	0	7	29	35	47	201	6	5	84	0	5	17	18	22	92
PA	Northampton	420958000	2002	8617	11	15	141	0	6	43	51	67	213	6	7	116	0	4	22	25	30	107
PA	Washington	421250005	2002	8604	9	13	138	0	6	35	46	66	256	6	7	108	0	5	21	25	33	124
PA	Washington	421250200	2002	8527	13	17	131	0	8	56	67	86	388	9	9	104	0	6	31	36	45	204
PA	Washington	421255001	2002	8580	17	23	134	0	9	69	83	111	326	10	11	109	0	6	36	41	52	152
TN	Shelby	471570034	2002	8264	5	5	95	0	4	14	17	32	83	4	2	52	0	3	8	9	11	40
TN	Shelby	471570046	2002	8304	6	12	191	0	4	21	35	40	334	4	6	167	0	3	7	11	23	155
TN	Shelby	471571034	2002	8300	8	13	168	0	4	37	47	67	232	5	6	141	0	3	21	26	37	85
TX	Jefferson	482450009	2002	8638	6	18	291	0	0	48	62	91	366	4	9	264	0	0	27	35	48	169
TX	Jefferson	482450011	2002	8591	3	10	371	0	0	23	31	46	229	1	5	328	0	0	14	18	26	113

					Modeled 5-minute Maximum SO_2									Measured 1-hour SO_2								
State	**County**	**Monid**	**Year**	**n**	**Mean**	**Std**	**COV**	**p0**	**p50**	**p97**	**p98**	**p99**	**p100**	**Mean**	**Std**	**COV**	**p0**	**p50**	**p97**	**p98**	**p99**	**p100**
TX	Jefferson	482450020	2002	8524	5	17	372	0	0	39	50	70	858	3	9	338	0	0	22	27	39	457
WV	Hancock	540290005	2002	8703	21	35	163	0	11	103	132	182	619	12	17	139	0	8	56	69	95	331
WV	Hancock	540290007	2002	8706	18	26	147	1	10	72	89	127	446	10	12	119	1	6	36	44	62	193
WV	Hancock	540290008	2002	8696	16	33	198	1	6	92	118	167	525	9	16	173	1	4	50	67	88	255
WV	Hancock	540290009	2002	8695	17	25	147	1	8	73	87	116	434	10	12	116	1	6	38	42	53	163
WV	Hancock	540290011	2002	8684	17	28	158	1	9	81	97	129	598	10	13	128	1	6	43	48	63	316
WV	Hancock	540290014	2002	8669	19	26	141	1	10	79	95	128	464	11	12	112	1	7	41	47	62	193
WV	Hancock	540290015	2002	8700	21	33	158	2	10	106	128	167	485	12	16	133	2	6	58	69	84	205
WV	Hancock	540290016	2002	8483	14	20	140	1	9	59	71	95	432	8	8	102	1	6	30	35	42	94
WV	Hancock	540291004	2002	8463	19	26	137	1	12	76	91	124	466	11	12	106	1	8	38	43	59	225
WV	Wayne	540990002	2002	8712	11	13	122	1	7	44	53	69	185	7	7	95	1	5	26	30	34	91
WV	Wayne	540990003	2002	7426	15	20	133	1	8	60	70	90	282	9	9	107	1	5	31	35	41	110
WV	Wayne	540990004	2002	8561	16	20	124	1	10	62	74	98	264	9	9	100	1	6	32	37	46	96
WV	Wayne	540990005	2002	8297	15	21	141	1	8	62	76	107	284	8	10	115	1	5	33	38	50	114
DE	New Castle	100031003	2003	731	11	15	132	0	7	45	54	71	180	7	6	95	0	5	22	23	28	54
DE	New Castle	100031007	2003	8549	6	12	206	0	2	31	38	52	293	3	5	165	0	1	16	19	25	90
DE	New Castle	100031008	2003	8609	14	29	208	0	6	78	103	152	427	8	14	183	0	4	44	56	81	186
DE	New Castle	100031013	2003	5947	13	17	136	0	8	51	61	81	310	7	8	103	0	5	25	30	39	99
DE	New Castle	100032004	2003	7703	10	15	151	0	6	42	49	66	310	6	6	112	0	4	21	23	29	68
FL	Hillsborough	120570053	2003	8693	6	10	175	0	3	28	34	46	253	3	5	137	0	2	14	17	22	88
FL	Hillsborough	120570081	2003	8604	4	13	285	0	1	29	37	54	312	3	6	244	0	1	16	20	29	135
FL	Hillsborough	120570095	2003	8697	6	18	324	0	1	37	51	83	378	3	7	248	0	1	15	20	31	131
FL	Hillsborough	120570109	2003	8688	9	25	287	0	3	53	74	132	500	4	10	229	0	2	21	29	47	167
FL	Hillsborough	120571035	2003	8718	9	15	162	0	5	44	53	70	318	5	7	128	0	3	23	27	34	108
FL	Hillsborough	120574004	2003	8672	3	7	218	0	1	16	21	30	187	2	3	173	0	1	8	10	14	60
IL	Madison	171191010	2003	8699	7	15	209	0	3	40	50	71	304	4	8	179	0	2	22	27	36	127
IL	Madison	171193007	2003	8700	6	13	210	0	3	30	37	54	403	4	6	177	0	2	16	18	26	214
IL	Madison	171193009	2003	8653	10	24	239	0	4	55	76	132	439	6	12	213	0	3	29	41	69	171
IN	Floyd	180430004	2003	8124	8	20	241	1	2	51	65	97	436	5	10	214	1	1	28	36	50	182
IN	Floyd	180430007	2003	6602	7	11	157	1	4	28	35	48	218	4	5	121	1	2	14	16	21	102
IN	Floyd	180431004	2003	8703	12	29	236	0	4	75	99	146	654	6	12	205	0	3	27	36	56	266
IA	Linn	191130029	2003	8627	4	12	288	0	1	28	38	59	276	2	6	252	0	1	16	21	34	104
IA	Linn	191130031	2003	8646	8	25	299	0	1	62	85	131	454	4	9	237	0	1	24	33	46	122

					Modeled 5-minute Maximum SO_2									Measured 1-hour SO_2								
State	**County**	**Monid**	**Year**	**n**	**Mean**	**Std**	**COV**	**p0**	**p50**	**p97**	**p98**	**p99**	**p100**	**Mean**	**Std**	**COV**	**p0**	**p50**	**p97**	**p98**	**p99**	**p100**
IA	Linn	191130038	2003	8640	7	26	354	0	1	64	89	143	500	3	10	303	0	1	27	35	52	177
IA	Muscatine	191390016	2003	7716	6	13	213	0	3	28	35	51	341	4	7	185	0	2	14	18	26	166
IA	Muscatine	191390017	2003	8553	6	10	150	0	4	25	31	46	222	4	4	114	0	3	11	13	20	89
IA	Muscatine	191390020	2003	8439	11	27	256	0	3	80	109	152	444	5	11	216	0	2	32	41	62	143
MI	Wayne	261630015	2003	7772	9	23	250	0	2	62	79	114	349	5	12	222	0	1	35	45	60	140
MI	Wayne	261630016	2003	8574	9	20	220	0	3	55	69	96	352	5	10	189	0	2	30	38	50	149
MI	Wayne	261630019	2003	8139	7	17	240	0	2	41	51	70	488	4	8	205	0	1	23	27	34	223
MO	Greene	290770026	2003	7957	7	17	234	0	2	50	65	96	274	3	6	177	0	2	20	25	35	68
MO	Greene	290770032	2003	8723	2	3	143	0	1	8	10	12	72	1	1	98	0	1	5	6	7	17
MO	Greene	290770037	2003	8181	7	18	262	1	2	48	69	104	321	3	7	210	1	2	19	27	39	106
MO	Greene	290770040	2003	8674	4	9	228	0	2	19	25	40	216	2	4	196	0	1	9	14	22	86
MO	Greene	290770041	2003	8676	2	3	147	0	2	8	10	14	88	2	2	104	0	1	4	5	7	42
MO	Iron	290930030	2003	6964	16	54	333	1	3	152	212	296	1031	8	23	306	1	2	64	87	123	497
MO	Iron	290930031	2003	8230	14	48	351	1	3	95	141	243	1128	7	21	319	1	2	39	56	88	418
MO	Jefferson	290990018	2003	6009	10	25	259	1	3	53	69	101	753	4	10	236	1	2	19	24	36	324
OH	Cuyahoga	390350038	2003	8487	11	18	165	0	5	53	63	85	347	6	9	138	0	4	28	33	42	165
OH	Cuyahoga	390350045	2003	8596	7	13	174	0	4	35	41	56	257	4	6	140	0	3	18	21	27	101
OH	Cuyahoga	390350060	2003	8583	12	18	142	0	7	53	61	80	308	7	8	113	0	5	28	33	38	145
OH	Cuyahoga	390350065	2003	8613	6	11	196	0	2	33	39	53	237	3	5	162	0	2	18	22	26	71
OH	Cuyahoga	390356001	2003	4313	10	16	163	0	5	45	54	72	299	6	8	136	0	3	23	28	37	147
OK	Tulsa	401430175	2003	8663	10	18	183	0	2	54	63	78	286	6	9	154	0	1	29	33	39	75
OK	Tulsa	401430235	2003	8358	10	19	189	0	4	58	69	92	322	6	10	160	0	2	32	39	47	153
OK	Tulsa	401430501	2003	8716	8	15	193	0	2	45	52	65	273	5	7	160	0	1	24	28	33	84
PA	Allegheny	420030002	2003	8356	14	19	137	0	8	55	64	84	380	8	8	102	0	6	28	31	38	90
PA	Allegheny	420030010	2003	8630	14	16	118	0	10	45	52	75	326	10	9	88	0	8	29	32	38	163
PA	Allegheny	420030021	2003	7728	12	17	136	0	8	49	58	74	354	7	7	98	0	5	24	27	33	122
PA	Allegheny	420030064	2003	8502	18	29	162	0	9	83	100	135	464	10	14	133	0	6	43	52	69	187
PA	Allegheny	420030067	2003	8212	12	16	134	0	7	44	51	71	270	8	8	104	0	6	29	32	39	135
PA	Allegheny	420030116	2003	8506	13	17	131	0	8	52	61	79	378	8	7	95	0	5	26	30	35	80
PA	Allegheny	420033003	2003	8528	21	37	177	0	9	112	140	187	555	12	18	151	0	6	62	76	98	238
PA	Beaver	420070002	2003	8627	18	32	178	0	8	92	113	151	619	10	15	147	0	6	50	60	78	209
PA	Beaver	420070005	2003	8729	19	35	190	0	6	98	118	160	644	11	17	158	0	4	54	63	78	302
PA	Beaver	420070014	2003	8510	11	22	200	0	4	62	73	96	510	6	10	158	0	3	34	39	47	118

					Modeled 5-minute Maximum SO_2									Measured 1-hour SO_2								
State	County	Monid	Year	n	Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
PA	Northampton	420950025	2003	8720	6	9	157	0	3	24	28	39	176	4	5	127	0	2	16	18	21	109
PA	Northampton	420958000	2003	8725	14	18	127	0	9	54	64	84	254	8	8	100	0	6	27	32	38	83
PA	Washington	421250005	2003	8718	9	13	153	0	5	38	47	65	304	6	7	122	0	4	22	26	33	131
PA	Washington	421250200	2003	8742	14	16	117	1	9	54	63	82	265	9	8	91	1	7	30	34	40	99
PA	Washington	421255001	2003	8602	18	24	134	0	10	75	90	122	318	10	11	111	0	6	40	45	57	141
TN	Shelby	471570034	2003	8084	6	6	98	1	4	14	17	34	128	4	2	49	1	3	9	10	11	71
TN	Shelby	471570046	2003	8285	6	12	182	3	4	21	34	38	318	4	6	155	3	3	7	10	21	152
TN	Shelby	471571034	2003	8306	10	16	156	3	5	47	58	78	282	6	7	128	3	3	26	32	41	95
TX	Jefferson	482450009	2003	8567	7	20	308	0	1	46	56	76	857	4	10	273	0	1	26	32	41	409
TX	Jefferson	482450011	2003	8488	4	23	516	0	0	31	42	59	1330	3	12	482	0	0	19	25	32	674
TX	Jefferson	482450020	2003	8650	5	18	365	0	0	42	56	85	345	3	9	332	0	0	25	32	45	157
WV	Hancock	540290005	2003	8695	21	40	186	1	10	108	139	203	738	12	20	163	1	6	60	74	103	290
WV	Hancock	540290007	2003	8616	18	30	173	1	9	81	101	151	543	10	15	145	1	6	42	52	72	243
WV	Hancock	540290008	2003	8683	15	30	195	1	6	84	107	151	508	9	15	166	1	4	46	58	82	189
WV	Hancock	540290009	2003	8344	19	31	162	1	9	86	107	150	519	11	15	135	1	6	45	54	78	252
WV	Hancock	540290011	2003	8694	20	33	162	1	10	96	118	161	567	12	16	135	1	7	53	63	81	255
WV	Hancock	540290014	2003	8686	20	28	138	1	12	81	98	141	472	11	12	108	1	8	41	49	68	174
WV	Hancock	540290015	2003	8694	21	34	164	1	9	106	129	171	501	12	17	138	1	6	58	71	88	173
WV	Hancock	540290016	2003	8657	15	20	130	1	10	59	72	98	403	9	8	95	1	8	27	33	44	153
WV	Hancock	540291004	2003	8533	23	30	134	1	14	91	112	155	506	13	14	105	1	10	45	54	76	199
WV	Wayne	540990002	2003	2056	14	14	107	2	9	51	61	80	157	9	7	78	2	7	29	35	40	58
WV	Wayne	540990003	2003	8060	15	21	137	1	8	68	78	97	296	9	10	111	1	5	39	41	44	100
WV	Wayne	540990004	2003	8571	15	21	141	1	8	60	72	99	446	9	10	115	1	6	31	37	48	232
WV	Wayne	540990005	2003	7930	14	23	159	1	8	63	78	112	394	8	11	133	1	5	33	40	55	167
DE	New Castle	100031007	2004	6137	5	10	182	0	3	26	32	43	243	3	4	137	0	2	13	15	19	89
DE	New Castle	100031008	2004	8364	10	22	216	0	4	59	75	107	414	6	11	185	0	3	32	42	57	169
DE	New Castle	100031013	2004	8119	9	16	175	0	4	43	52	70	360	5	7	138	0	3	22	26	35	96
DE	New Castle	100032004	2004	8617	9	13	155	0	5	37	45	60	303	5	6	116	0	3	19	22	26	77
FL	Hillsborough	120570053	2004	8543	4	7	168	0	2	19	24	32	172	2	3	129	0	2	10	12	15	52
FL	Hillsborough	120570081	2004	8492	4	8	177	0	2	21	25	34	180	3	4	140	0	2	10	12	16	76
FL	Hillsborough	120570095	2004	8643	2	6	293	0	0	14	20	29	160	1	2	196	0	0	6	8	10	31
FL	Hillsborough	120570109	2004	8515	7	18	279	0	2	40	55	96	400	3	8	237	0	2	14	20	35	187
FL	Hillsborough	120571035	2004	8643	7	12	172	0	3	32	39	55	207	4	6	143	0	2	17	20	27	79

					Modeled 5-minute Maximum SO_2									Measured 1-hour SO_2								
State	**County**	**Monid**	**Year**	**n**	**Mean**	**Std**	**COV**	**p0**	**p50**	**p97**	**p98**	**p99**	**p100**	**Mean**	**Std**	**COV**	**p0**	**p50**	**p97**	**p98**	**p99**	**p100**
FL	Hillsborough	120574004	2004	8572	2	5	243	0	0	11	13	19	126	1	2	197	0	0	6	7	9	43
IL	Madison	171191010	2004	8729	8	16	206	0	3	42	55	80	300	5	8	175	0	2	23	29	43	109
IL	Madison	171193007	2004	8692	6	10	166	0	3	29	35	46	240	4	4	127	0	2	15	17	21	55
IL	Madison	171193009	2004	8594	9	22	240	0	3	49	67	106	435	5	11	215	0	2	25	35	58	204
IN	Floyd	180430004	2004	8358	10	20	192	1	4	52	67	105	382	6	10	173	1	3	28	35	52	163
IN	Floyd	180430007	2004	7538	4	9	223	1	2	19	25	38	213	2	4	193	1	1	10	14	21	95
IN	Floyd	180431004	2004	8251	11	28	266	0	2	73	96	134	611	5	12	253	0	1	25	33	55	225
IA	Linn	191130029	2004	8381	3	11	309	0	1	23	31	48	304	2	5	264	0	1	12	17	26	102
IA	Linn	191130031	2004	8664	8	27	325	0	2	60	82	133	557	4	10	245	0	1	23	32	51	140
IA	Linn	191130038	2004	8208	8	33	396	0	1	64	96	176	613	4	13	334	0	1	27	37	72	201
IA	Muscatine	191390016	2004	8167	6	11	187	0	3	27	34	48	306	3	5	149	0	2	14	17	23	131
IA	Muscatine	191390017	2004	8415	6	9	152	0	3	24	30	41	194	3	4	113	0	2	12	14	18	80
IA	Muscatine	191390020	2004	8725	15	40	264	0	3	118	158	216	606	7	15	218	0	2	47	58	81	183
MI	Wayne	261630015	2004	8502	11	27	237	0	3	75	96	138	400	6	14	209	0	2	43	53	73	156
MI	Wayne	261630016	2004	8656	7	16	226	0	2	44	55	77	339	4	8	191	0	1	25	30	42	98
MI	Wayne	261630019	2004	8662	6	12	215	0	2	34	41	55	291	3	6	171	0	1	18	22	28	67
MO	Greene	290770026	2004	8776	7	17	244	1	2	49	63	91	296	3	6	187	1	1	22	26	35	68
MO	Greene	290770032	2004	8754	2	3	183	0	1	6	9	12	73	1	1	139	0	1	4	5	7	22
MO	Greene	290770037	2004	8777	6	16	262	0	2	38	53	86	294	3	6	202	0	2	16	22	33	84
MO	Greene	290770040	2004	8694	6	8	144	0	4	21	28	40	203	3	4	115	0	3	9	13	19	92
MO	Greene	290770041	2004	8687	3	4	139	0	2	10	12	18	93	2	2	97	0	2	6	7	9	56
MO	Iron	290930030	2004	1846	6	8	149	1	2	28	33	41	84	2	3	104	1	1	10	11	12	18
MO	Iron	290930031	2004	2172	9	9	104	1	6	34	38	45	92	4	3	72	1	3	11	13	14	22
MO	Jefferson	290990004	2004	8044	23	57	253	1	6	153	199	282	1128	10	23	219	1	4	60	70	94	563
OH	Cuyahoga	390350038	2004	8603	11	17	158	0	5	51	61	82	256	6	8	131	0	3	28	32	41	88
OH	Cuyahoga	390350045	2004	8679	5	10	178	0	3	27	33	43	194	3	4	144	0	2	14	16	20	61
OH	Cuyahoga	390350060	2004	8617	8	14	177	0	3	38	48	67	233	4	7	147	0	2	20	25	35	67
OH	Cuyahoga	390350065	2004	8405	6	11	179	0	3	32	37	50	211	4	5	143	0	3	18	20	25	64
OK	Tulsa	401430175	2004	8292	13	22	176	0	3	65	75	98	299	7	11	152	0	2	35	39	45	130
OK	Tulsa	401430235	2004	8460	12	21	176	0	4	62	75	100	331	7	11	151	0	3	33	39	48	148
OK	Tulsa	401430501	2004	8700	10	18	180	0	3	52	60	77	270	6	9	151	0	2	28	31	36	105
PA	Allegheny	420030002	2004	8646	13	18	141	0	7	51	61	81	342	7	8	110	0	5	26	30	39	173
PA	Allegheny	420030010	2004	8616	10	14	138	0	6	40	49	71	220	7	8	108	0	5	26	30	36	83

					Modeled 5-minute Maximum SO_2									Measured 1-hour SO_2								
State	County	Monid	Year	n	Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
PA	Allegheny	420030021	2004	8663	10	15	139	0	6	42	50	67	283	6	6	105	0	4	21	24	30	84
PA	Allegheny	420030064	2004	8680	16	24	149	0	8	72	85	113	384	9	11	119	0	6	37	42	55	135
PA	Allegheny	420030067	2004	8373	10	15	151	0	6	41	51	75	371	7	8	119	0	5	27	31	38	218
PA	Allegheny	420030116	2004	8676	11	15	138	0	6	44	51	68	323	6	6	101	0	4	22	25	30	107
PA	Allegheny	420033003	2004	8611	18	30	166	0	8	91	113	156	396	11	15	141	0	6	49	60	80	163
PA	Beaver	420070002	2004	8522	16	29	183	0	6	82	102	139	511	9	14	157	0	4	44	55	72	251
PA	Beaver	420070005	2004	8755	20	35	174	0	8	95	115	162	738	12	18	153	0	5	50	59	75	368
PA	Beaver	420070014	2004	8733	13	20	159	0	6	60	71	92	368	7	9	129	0	4	32	37	45	195
PA	Northampton	420950025	2004	8702	7	9	136	0	4	25	29	39	164	5	5	101	0	3	16	18	22	74
PA	Northampton	420958000	2004	8648	23	21	93	0	18	68	82	120	340	13	8	62	0	11	32	36	46	151
PA	Washington	421250005	2004	8662	11	12	115	0	7	39	48	67	234	7	7	87	0	6	23	26	31	103
PA	Washington	421250200	2004	8680	12	15	123	1	7	48	58	76	342	8	8	96	1	6	28	31	38	200
PA	Washington	421255001	2004	8656	15	23	146	0	8	69	82	112	313	9	11	123	0	6	36	42	51	172
TN	Shelby	471570034	2004	8240	5	5	96	0	4	15	18	35	91	4	2	49	0	3	9	10	12	30
TN	Shelby	471570046	2004	8119	7	12	166	3	4	30	36	49	420	4	5	135	3	3	12	17	27	222
TN	Shelby	471571034	2004	8005	10	16	151	2	6	46	57	82	258	6	7	124	2	3	24	30	43	104
TX	Jefferson	482450009	2004	8679	6	20	343	0	1	42	55	82	762	3	11	317	0	1	24	30	43	399
TX	Jefferson	482450011	2004	8507	3	10	333	0	0	24	31	45	246	2	5	289	0	0	14	18	25	124
TX	Jefferson	482450020	2004	8244	5	16	337	0	0	38	50	75	281	3	8	304	0	0	22	29	41	132
WV	Hancock	540290005	2004	8723	20	35	172	1	10	99	129	184	710	12	17	149	1	6	53	67	96	354
WV	Hancock	540290007	2004	8646	18	28	153	1	10	79	97	137	514	11	14	128	1	7	40	49	70	262
WV	Hancock	540290008	2004	8726	15	28	187	1	6	81	100	137	461	9	14	161	1	4	45	55	72	216
WV	Hancock	540290009	2004	8700	15	25	175	1	6	73	89	122	403	8	12	146	1	4	39	47	62	152
WV	Hancock	540290011	2004	8676	19	29	156	1	9	89	109	147	440	11	14	129	1	6	48	59	76	191
WV	Hancock	540290015	2004	8717	19	31	166	1	8	95	114	154	435	11	15	141	1	5	51	60	77	162
WV	Hancock	540290016	2004	4514	14	18	129	1	9	57	68	87	366	8	8	96	1	6	28	36	43	98
WV	Hancock	540291004	2004	8385	22	29	131	1	14	87	108	146	457	13	13	105	1	10	45	53	68	243
WV	Wayne	540990003	2004	8659	16	21	132	1	9	69	79	100	341	9	9	103	1	6	40	44	48	108
WV	Wayne	540990004	2004	8673	12	16	126	1	8	48	56	73	321	7	7	92	1	5	24	27	33	79
WV	Wayne	540990005	2004	8681	12	15	121	1	8	45	52	68	307	7	6	84	1	5	22	24	29	62
DE	New Castle	100031007	2005	7283	6	12	183	0	3	32	38	52	295	4	5	142	0	2	16	19	25	121
DE	New Castle	100031008	2005	8634	12	26	226	0	5	64	84	130	540	7	13	197	0	3	35	46	67	238
DE	New Castle	100031013	2005	7604	12	16	139	0	7	47	56	73	345	7	7	105	0	5	24	27	34	140

					Modeled 5-minute Maximum SO_2									Measured 1-hour SO_2								
State	County	Monid	Year	n	Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
DE	New Castle	100032004	2005	8539	8	12	152	0	5	36	43	56	284	5	5	111	0	3	18	21	25	53
FL	Hillsborough	120570053	2005	8698	4	6	165	0	2	18	22	29	145	2	3	127	0	1	9	11	13	40
FL	Hillsborough	120570081	2005	8679	3	7	222	0	1	18	23	31	197	2	4	182	0	1	10	12	15	92
FL	Hillsborough	120570095	2005	8650	2	10	449	0	0	13	20	35	275	1	4	360	0	0	6	8	11	98
FL	Hillsborough	120570109	2005	8618	6	19	337	0	1	36	52	95	403	3	8	296	0	1	14	18	36	151
FL	Hillsborough	120571035	2005	8657	6	12	183	0	3	31	38	53	220	4	6	151	0	2	17	20	26	91
FL	Hillsborough	120574004	2005	8716	2	5	206	0	1	12	15	21	123	1	2	158	0	1	6	8	10	27
IL	Madison	171191010	2005	8669	8	16	197	0	3	43	54	77	288	5	8	169	0	2	23	29	41	121
IL	Madison	171193007	2005	8703	7	11	166	0	3	30	37	50	245	4	5	130	0	2	16	18	24	78
IL	Madison	171193009	2005	8519	9	21	225	0	3	50	67	107	364	5	11	201	0	2	27	36	54	162
IN	Floyd	180430004	2005	8345	13	20	150	1	7	55	70	100	377	8	10	127	1	5	28	35	49	168
IN	Floyd	180430007	2005	8063	9	20	233	1	3	44	54	78	564	5	10	207	1	2	23	28	39	277
IN	Floyd	180431004	2005	8264	9	24	270	0	2	61	83	126	476	4	10	237	0	1	23	31	46	176
IA	Linn	191130029	2005	8600	4	11	274	0	1	24	33	50	271	2	5	232	0	1	13	18	27	100
IA	Linn	191130031	2005	8632	10	29	281	0	2	81	107	157	463	5	10	230	0	1	31	41	55	122
IA	Linn	191130038	2005	8615	8	27	324	0	1	69	99	154	426	4	10	274	0	1	28	39	60	125
IA	Muscatine	191390016	2005	8644	8	21	255	0	3	51	68	103	448	4	8	187	0	2	22	30	41	121
IA	Muscatine	191390017	2005	8603	6	10	176	0	3	24	30	44	256	3	4	140	0	2	11	14	20	92
IA	Muscatine	191390020	2005	8693	14	38	272	0	3	114	150	206	574	6	14	229	0	2	45	56	74	200
MI	Wayne	261630015	2005	8193	11	26	238	0	3	77	97	136	377	6	13	213	0	2	43	55	71	145
MI	Wayne	261630016	2005	8044	8	17	220	0	3	46	58	80	356	4	8	189	0	2	25	32	43	176
MI	Wayne	261630019	2005	7917	6	13	217	0	2	35	43	57	282	3	6	179	0	1	20	24	29	91
MO	Greene	290770026	2005	8756	6	17	267	1	2	47	62	92	314	3	6	201	1	1	20	25	33	77
MO	Greene	290770032	2005	8661	2	3	157	0	1	9	12	15	82	1	2	119	0	1	6	7	9	30
MO	Greene	290770037	2005	8760	6	16	260	1	2	38	52	84	389	3	6	199	1	2	15	20	31	122
MO	Greene	290770040	2005	8669	5	13	269	0	2	24	33	56	304	3	7	242	0	2	12	18	32	138
MO	Greene	290770041	2005	8660	3	4	164	0	2	10	12	17	106	2	2	121	0	1	6	7	9	57
MO	Jefferson	290990004	2005	7166	25	62	244	0	5	183	231	311	1232	11	25	218	0	4	69	85	120	609
OH	Cuyahoga	390350038	2005	8570	12	20	171	0	5	59	69	92	342	7	10	143	0	3	33	35	45	150
OH	Cuyahoga	390350045	2005	8631	7	13	189	0	3	33	40	55	292	4	6	151	0	2	17	20	25	125
OH	Cuyahoga	390350060	2005	8602	13	18	145	0	7	55	63	85	304	7	9	116	0	5	29	33	40	125
OH	Cuyahoga	390350065	2005	8355	7	13	201	0	2	36	43	58	316	4	6	165	0	1	19	23	29	174
OK	Tulsa	401430175	2005	8551	12	19	169	0	3	59	68	89	326	7	10	145	0	2	32	36	42	176

					Modeled 5-minute Maximum SO_2									Measured 1-hour SO_2								
State	County	Monid	Year	n	Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
OK	Tulsa	401430235	2005	8442	10	18	178	0	4	49	60	79	411	6	9	154	0	3	27	31	39	224
OK	Tulsa	401430501	2005	8515	9	16	175	0	3	48	56	71	234	5	8	148	0	2	26	29	36	93
PA	Allegheny	420030002	2005	8639	11	17	151	0	6	49	58	76	372	7	7	113	0	4	25	29	35	115
PA	Allegheny	420030010	2005	8731	12	15	124	0	8	42	50	71	257	8	7	90	0	6	27	31	37	98
PA	Allegheny	420030021	2005	8650	11	17	150	0	6	48	57	75	379	7	7	112	0	4	23	27	34	126
PA	Allegheny	420030064	2005	8658	16	26	161	0	8	79	94	122	486	9	12	130	0	5	42	50	62	138
PA	Allegheny	420030067	2005	8689	10	14	144	0	6	40	47	61	260	7	8	112	0	5	26	30	36	85
PA	Allegheny	420030116	2005	8699	12	17	144	0	7	49	59	79	392	7	7	104	0	5	25	29	36	122
PA	Allegheny	420033003	2005	8490	23	41	181	0	9	122	148	200	651	13	20	157	0	6	69	80	99	295
PA	Beaver	420070002	2005	8682	16	26	165	0	7	76	92	124	449	9	13	140	0	5	40	48	61	222
PA	Beaver	420070005	2005	8626	22	36	167	0	10	99	124	183	719	13	18	145	0	7	52	62	85	345
PA	Beaver	420070014	2005	8660	12	20	167	0	5	59	71	91	342	7	9	135	0	4	32	37	45	98
PA	Northampton	420950025	2005	8512	10	10	100	0	8	33	40	59	165	7	5	72	0	6	20	22	26	93
PA	Northampton	420958000	2005	8652	15	20	134	0	8	60	70	91	275	9	9	108	0	6	31	35	41	132
PA	Washington	421250005	2005	8603	14	15	109	0	9	46	58	81	272	10	8	80	0	7	27	32	37	116
PA	Washington	421250200	2005	8720	13	16	122	0	8	48	59	81	260	9	8	93	0	6	29	33	41	106
PA	Washington	421255001	2005	8606	16	25	157	0	7	77	89	114	362	9	12	131	0	5	41	46	54	145
TN	Shelby	471570034	2005	8121	6	6	106	0	4	16	20	36	120	4	2	61	0	3	9	10	13	53
TN	Shelby	471570046	2005	8282	8	17	219	3	4	33	36	57	628	4	9	200	3	3	14	19	31	349
TN	Shelby	471571034	2005	8160	8	14	167	3	5	36	48	71	266	5	7	140	3	3	18	26	40	98
TN	Shelby	471572005	2005	5864	2	2	120	1	1	6	7	12	63	1	1	69	1	1	3	4	5	13
TX	Jefferson	482450009	2005	8360	6	16	253	0	1	47	59	82	251	4	8	228	0	1	28	33	43	121
TX	Jefferson	482450011	2005	8071	3	11	341	0	0	25	34	50	234	2	6	307	0	0	14	19	27	114
TX	Jefferson	482450020	2005	7797	3	13	378	0	0	28	37	59	291	2	7	343	0	0	16	20	31	151
WV	Hancock	540290005	2005	8684	20	29	144	1	11	88	109	151	424	12	14	119	1	7	47	56	71	202
WV	Hancock	540290007	2005	8702	17	25	144	1	9	72	87	122	405	10	11	116	1	6	37	44	61	165
WV	Hancock	540290008	2005	8701	12	23	187	1	5	66	83	113	371	7	11	160	1	3	36	45	60	155
WV	Hancock	540290009	2005	8687	19	28	151	1	9	83	100	134	584	11	14	126	1	6	45	52	65	329
WV	Hancock	540290011	2005	8541	20	31	157	1	10	90	111	150	559	11	15	134	1	7	48	58	74	292
WV	Hancock	540290015	2005	8705	16	26	165	1	7	76	91	125	424	9	13	139	1	5	41	49	65	183
WV	Hancock	540291004	2005	8651	24	27	115	1	16	85	102	138	394	14	12	88	1	11	42	49	63	180
WV	Wayne	540990003	2005	8142	17	25	152	1	9	82	98	124	449	10	12	123	1	6	43	60	66	124
WV	Wayne	540990004	2005	8622	13	17	125	1	8	50	59	77	406	8	6	83	1	6	23	26	32	92

					Modeled 5-minute Maximum SO_2									Measured 1-hour SO_2								
State	County	Monid	Year	n	Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
WV	Wayne	540990005	2005	8454	12	14	125	1	7	43	50	67	308	7	6	83	1	5	21	23	26	51
DE	New Castle	100031007	2006	8424	5	9	172	0	3	24	29	40	233	3	4	128	0	2	11	14	18	72
DE	New Castle	100031008	2006	8573	11	24	212	0	5	62	79	113	460	7	12	184	0	3	35	44	60	206
DE	New Castle	100031013	2006	8631	8	14	185	0	4	37	46	64	351	4	7	147	0	3	19	24	32	163
DE	New Castle	100032004	2006	8600	8	11	144	0	5	33	39	51	244	5	5	102	0	3	15	18	22	62
FL	Hillsborough	120570053	2006	6506	3	6	200	0	1	16	20	26	141	2	3	160	0	1	8	10	13	48
FL	Hillsborough	120570081	2006	6509	3	7	277	0	0	16	20	27	265	1	3	232	0	0	8	10	14	143
FL	Hillsborough	120570095	2006	6517	1	5	419	0	0	9	12	23	141	1	2	302	0	0	5	6	9	40
FL	Hillsborough	120570109	2006	6462	6	19	301	0	2	41	59	101	343	3	7	247	0	1	16	22	36	130
FL	Hillsborough	120571035	2006	6486	7	14	194	0	3	36	46	64	257	4	7	163	0	2	19	23	33	137
FL	Hillsborough	120574004	2006	6367	3	5	178	0	1	12	14	21	116	1	2	134	0	1	5	7	9	38
IL	Madison	171191010	2006	8651	6	14	220	0	2	37	46	66	255	4	7	192	0	1	21	25	35	108
IL	Madison	171193007	2006	8682	5	9	178	0	2	25	32	42	194	3	4	146	0	2	14	16	21	75
IL	Madison	171193009	2006	8627	9	21	238	0	3	51	70	110	376	5	11	215	0	2	28	38	56	158
IN	Floyd	180430004	2006	5928	12	20	161	1	6	58	68	94	315	7	10	135	1	4	32	35	43	139
IN	Floyd	180430007	2006	6240	9	16	179	1	5	37	48	70	358	5	8	152	1	4	19	24	32	169
IN	Floyd	180431004	2006	8339	11	30	264	0	4	64	86	140	945	5	12	232	0	3	23	30	52	483
IA	Linn	191130029	2006	8648	1	3	197	0	1	6	8	12	83	1	1	155	0	1	3	3	5	28
IA	Linn	191130031	2006	8549	7	20	284	0	1	54	72	105	350	3	7	225	0	1	21	27	37	105
IA	Linn	191130038	2006	8250	9	24	281	0	2	69	93	133	407	4	9	234	0	1	27	35	50	131
IA	Muscatine	191390016	2006	8708	8	25	311	0	2	56	77	126	495	4	9	248	0	1	23	29	45	175
IA	Muscatine	191390017	2006	8715	6	10	173	0	3	26	33	45	263	3	4	133	0	2	12	15	22	83
IA	Muscatine	191390020	2006	8714	10	32	308	0	2	88	121	176	496	5	12	257	0	1	36	46	67	143
MI	Wayne	261630015	2006	8429	10	27	273	0	1	77	98	138	405	6	14	245	0	1	44	56	75	154
MI	Wayne	261630016	2006	8722	6	16	248	0	2	44	55	75	347	4	8	210	0	1	25	31	41	86
MI	Wayne	261630019	2006	8325	5	11	233	0	1	30	36	48	257	3	5	190	0	1	17	20	25	55
MO	Greene	290770026	2006	8753	7	19	277	1	2	53	71	104	347	3	7	215	1	1	22	27	38	88
MO	Greene	290770032	2006	8727	3	4	169	0	2	12	13	20	121	2	2	128	0	1	7	9	11	44
MO	Greene	290770037	2006	8745	7	21	303	1	2	54	78	123	345	3	8	259	1	1	23	31	47	120
MO	Greene	290770040	2006	8637	3	9	278	0	2	16	24	39	241	2	5	246	0	1	8	12	21	113
MO	Greene	290770041	2006	8581	2	3	197	0	1	6	8	13	112	1	2	155	0	1	4	4	6	62
MO	Jefferson	290990004	2006	6541	30	69	232	0	4	218	269	354	977	13	27	207	0	3	78	93	127	415
OH	Cuyahoga	390350038	2006	8391	8	16	183	0	3	46	55	72	247	5	8	155	0	2	25	29	37	95

					Modeled 5-minute Maximum SO_2									Measured 1-hour SO_2								
State	**County**	**Monid**	**Year**	**n**	**Mean**	**Std**	**COV**	**p0**	**p50**	**p97**	**p98**	**p99**	**p100**	**Mean**	**Std**	**COV**	**p0**	**p50**	**p97**	**p98**	**p99**	**p100**
OH	Cuyahoga	390350045	2006	8594	6	12	191	0	3	31	36	50	239	4	5	156	0	3	15	20	25	103
OH	Cuyahoga	390350060	2006	8637	11	19	165	0	5	57	69	91	278	7	9	139	0	3	30	38	48	110
OH	Cuyahoga	390350065	2006	8521	8	18	225	0	3	42	53	77	372	5	9	197	0	2	23	28	40	170
OK	Tulsa	401430175	2006	7204	11	18	166	0	3	55	65	82	209	6	9	144	0	2	30	34	40	75
OK	Tulsa	401430235	2006	7223	6	12	197	0	2	36	44	60	202	4	6	168	0	1	20	24	31	79
OK	Tulsa	401430501	2006	7193	8	13	167	0	3	39	46	59	193	5	6	140	0	2	21	24	28	69
OK	Tulsa	401431127	2006	431	1	4	259	0	1	9	12	17	50	1	2	209	0	0	6	7	8	20
PA	Allegheny	420030002	2006	8690	9	14	154	0	5	39	47	61	269	5	6	118	0	3	20	23	27	124
PA	Allegheny	420030010	2006	8612	10	12	123	0	7	33	39	58	223	7	6	92	0	5	21	23	28	101
PA	Allegheny	420030021	2006	8711	11	15	136	0	6	44	51	68	308	6	6	103	0	4	22	25	31	83
PA	Allegheny	420030064	2006	8665	17	28	159	0	8	83	100	134	398	10	13	132	0	6	45	53	65	181
PA	Allegheny	420030067	2006	8568	8	12	148	0	5	34	40	58	197	6	7	118	0	4	23	25	31	88
PA	Allegheny	420030116	2006	7567	10	14	130	0	6	41	48	61	285	6	6	95	0	4	20	23	27	114
PA	Beaver	420070002	2006	8682	14	24	165	0	7	68	81	109	399	8	11	134	0	5	36	41	52	157
PA	Beaver	420070005	2006	8673	16	36	228	0	4	86	108	158	966	9	18	201	0	2	46	56	79	423
PA	Beaver	420070014	2006	8627	13	18	140	0	8	54	63	81	364	7	8	103	0	5	28	32	39	80
PA	Northampton	420950025	2006	8712	7	10	154	0	5	25	29	41	266	5	5	106	0	4	16	18	21	61
PA	Northampton	420958000	2006	8512	18	36	195	0	11	74	96	146	921	11	17	164	0	8	33	43	67	406
PA	Washington	421250005	2006	8693	11	12	110	0	8	39	49	66	215	8	6	81	0	6	21	25	33	108
PA	Washington	421250200	2006	8609	13	14	107	0	9	47	56	72	245	9	7	81	0	7	26	29	35	110
PA	Washington	421255001	2006	8695	11	18	170	0	4	52	65	90	267	6	9	146	0	3	29	34	45	124
TN	Shelby	471570046	2006	8189	6	9	152	3	4	21	26	36	294	4	4	122	3	3	6	8	15	141
TN	Shelby	471571034	2006	8156	11	16	148	2	6	48	59	83	269	6	8	121	2	4	25	31	42	96
TN	Shelby	471572005	2006	2867	2	2	127	1	1	7	9	12	57	1	1	81	1	1	5	5	7	13
TX	Jefferson	482450009	2006	8553	6	24	412	0	0	43	62	108	517	3	13	386	0	0	25	35	57	230
TX	Jefferson	482450011	2006	8417	3	15	485	0	0	26	41	71	326	2	8	449	0	0	16	23	40	150
TX	Jefferson	482450020	2006	8647	6	21	324	0	0	44	59	92	790	4	11	293	0	0	24	33	50	410
WV	Hancock	540290005	2006	8340	19	25	136	1	11	79	96	127	381	11	12	109	1	7	42	49	61	148
WV	Hancock	540290007	2006	8550	17	26	148	1	9	75	91	126	402	10	12	122	1	6	40	47	60	201
WV	Hancock	540290008	2006	8636	13	23	177	1	6	68	84	115	396	7	11	148	1	4	36	47	60	144
WV	Hancock	540290009	2006	8690	22	30	134	2	12	95	112	148	484	13	14	110	2	8	50	58	73	242
WV	Hancock	540290011	2006	8605	21	27	125	1	14	82	99	133	404	12	12	99	1	10	43	50	60	195
WV	Hancock	540290015	2006	8678	16	26	155	1	8	78	93	123	410	9	12	128	1	5	43	50	60	219

					Modeled 5-minute Maximum SO_2									Measured 1-hour SO_2								
State	**County**	**Monid**	**Year**	**n**	**Mean**	**Std**	**COV**	**p0**	**p50**	**p97**	**p98**	**p99**	**p100**	**Mean**	**Std**	**COV**	**p0**	**p50**	**p97**	**p98**	**p99**	**p100**
WV	Hancock	540291004	2006	8678	19	25	133	1	11	75	91	126	380	11	12	105	1	8	38	45	60	145

Table C-4. Descriptive statistics for modeled 5-minute maximum and measured 1-hour SO_2 concentrations for monitors in 20 selected counties, Years 2002 through 2006, air quality adjusted to just meet the current daily standard.

					Modeled 5-minute Max SO_2									1-hour SO_2								
State	County	Monitor ID	Year	n	Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
DE	New Castle	100031003	2002	8573	14	34	240	0	0	91	110	150	824	8	16	199	0	0	51	59	75	280
DE	New Castle	100031007	2002	8614	14	33	237	0	5	78	99	152	800	8	16	200	0	3	40	51	75	307
DE	New Castle	100031008	2002	8631	26	73	278	0	3	181	233	359	1374	15	37	248	0	3	101	133	189	534
DE	New Castle	100032004	2002	8546	20	36	184	0	9	96	121	168	782	11	17	148	0	5	48	56	80	275
FL	Hillsborough	120570053	2002	8663	19	37	196	0	8	101	122	170	895	11	17	155	0	6	53	62	83	238
FL	Hillsborough	120570081	2002	8708	17	46	274	0	4	110	141	202	1020	10	23	237	0	3	62	80	108	531
FL	Hillsborough	120570095	2002	8477	21	74	349	0	3	157	224	382	1468	10	29	290	0	3	62	86	145	522
FL	Hillsborough	120570109	2002	8623	26	88	337	0	6	191	292	513	1497	12	36	292	0	3	74	114	210	507
FL	Hillsborough	120571035	2002	8634	35	65	187	0	15	176	215	297	1237	20	32	159	0	9	96	114	151	593
FL	Hillsborough	120571065	2002	4323	21	45	210	0	6	122	149	202	844	12	21	174	0	3	68	80	105	278
FL	Hillsborough	120574004	2002	8696	14	24	163	0	8	66	79	111	581	8	11	125	0	6	31	37	53	182
IA	Linn	191130029	2002	8607	23	56	245	0	7	145	188	271	1029	13	28	212	0	5	80	103	146	414
IA	Linn	191130031	2002	8663	39	103	262	0	9	288	388	561	1735	18	39	215	0	5	113	146	207	517
IA	Linn	191130038	2002	8659	29	96	329	0	5	246	339	519	1818	13	37	283	0	5	103	132	188	813
IA	Muscatine	191390016	2002	8597	25	42	170	0	15	102	129	186	1096	14	20	136	0	10	47	60	88	519
IA	Muscatine	191390017	2002	8141	20	34	171	0	12	77	95	132	1168	11	16	136	0	9	34	41	54	612
IA	Muscatine	191390020	2002	8202	43	104	244	0	11	311	408	562	1637	19	39	199	0	8	120	154	207	478
IL	Madison	171190008	2002	8656	18	35	195	0	7	93	113	156	848	10	16	156	0	6	46	58	75	242
IL	Madison	171191010	2002	8676	23	52	221	0	9	131	165	240	997	14	25	189	0	6	72	89	124	372
IL	Madison	171193007	2002	8673	20	36	179	0	9	101	120	161	861	12	16	141	0	6	52	63	78	265
IL	Madison	171193009	2002	8700	24	58	243	0	9	117	151	239	1324	14	29	214	0	6	63	79	121	661
IN	Floyd	180430004	2002	7497	43	86	200	5	15	227	286	401	2282	25	44	178	5	10	126	150	204	1330
IN	Floyd	180430007	2002	8142	46	68	147	5	25	185	222	302	1585	27	32	119	5	19	92	107	141	849
IN	Floyd	180431004	2002	8559	54	113	210	0	19	308	409	596	1968	25	45	179	0	15	112	150	218	917
MI	Wayne	261630015	2002	6452	36	95	264	0	12	236	295	408	4194	21	51	243	0	9	137	166	214	2470
MI	Wayne	261630016	2002	8707	25	53	211	0	9	148	185	257	1052	15	26	178	0	6	83	101	137	321
MI	Wayne	261630019	2002	8024	18	34	185	0	7	94	111	145	831	11	15	143	0	6	50	56	71	187
MO	Greene	290770026	2002	7055	33	89	270	3	7	255	337	482	1460	15	32	212	3	3	108	132	170	396
MO	Greene	290770032	2002	8656	14	16	113	0	11	39	47	75	354	10	6	62	0	10	21	24	28	97
MO	Greene	290770037	2002	6374	29	88	300	3	9	206	304	504	1503	14	34	242	3	7	94	125	188	500
MO	Greene	290770040	2002	7465	9	42	446	0	0	49	69	119	1276	5	22	408	0	0	28	38	63	705

State	County	Monitor ID	Year	n	Modeled 5-minute Max SO_2									1-hour SO_2								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
MO	Greene	290770041	2002	7476	4	11	268	0	0	21	30	48	310	3	6	218	0	0	14	17	31	115
MO	Iron	290930030	2002	7976	31	115	367	2	4	281	438	641	2247	15	50	338	2	4	116	175	276	862
MO	Iron	290930031	2002	8687	28	92	336	2	8	173	262	481	2101	13	39	293	2	6	70	105	188	827
MO	Jefferson	290990018	2002	6318	45	132	292	0	12	275	390	627	3280	21	58	269	0	8	101	136	249	1277
OH	Cuyahoga	390350038	2002	8524	44	72	163	0	20	217	256	336	1071	25	34	135	0	15	117	138	168	408
OH	Cuyahoga	390350045	2002	8610	39	55	143	0	21	161	188	250	1064	22	25	111	0	15	82	97	117	444
OH	Cuyahoga	390350060	2002	8557	53	73	138	0	29	221	258	336	1095	30	33	110	0	20	117	128	153	367
OH	Cuyahoga	390350065	2002	8591	27	54	201	0	8	149	180	237	1029	15	26	167	0	5	82	92	117	429
OH	Cuyahoga	390356001	2002	8638	45	75	167	0	22	200	243	343	1335	26	37	141	0	15	102	122	158	597
OK	Tulsa	401430175	2002	8609	47	80	169	0	14	239	278	352	1135	27	39	143	0	9	131	149	171	333
OK	Tulsa	401430235	2002	8304	30	58	195	0	12	162	198	268	1109	17	28	166	0	9	86	108	144	505
OK	Tulsa	401430501	2002	8356	43	73	170	0	18	220	256	326	1165	25	35	140	0	14	117	131	158	369
PA	Allegheny	420030002	2002	7932	36	52	145	0	20	153	184	240	928	21	24	114	0	14	74	89	115	264
PA	Allegheny	420030010	2002	8736	34	36	107	0	24	105	125	189	683	24	18	75	0	19	67	74	89	298
PA	Allegheny	420030021	2002	7757	31	42	136	0	19	124	145	191	803	18	18	100	0	13	61	69	86	213
PA	Allegheny	420030064	2002	8431	45	68	151	0	22	203	241	312	1124	26	32	121	0	15	110	124	155	382
PA	Allegheny	420030067	2002	8145	31	42	133	0	20	114	138	198	826	22	23	104	0	17	74	84	101	341
PA	Allegheny	420030116	2002	8477	30	43	142	0	17	124	149	198	854	18	19	108	0	12	60	70	94	325
PA	Allegheny	420033003	2002	7864	53	89	168	0	23	272	329	443	1471	31	43	142	0	16	147	176	218	840
PA	Beaver	420070002	2002	8402	33	59	176	0	15	172	206	274	1045	19	28	146	0	10	94	113	139	353
PA	Beaver	420070005	2002	8538	47	100	211	0	14	250	320	488	2598	27	51	186	0	9	131	169	242	1183
PA	Beaver	420070014	2002	8586	24	39	168	0	11	114	135	176	862	14	18	132	0	8	61	71	84	227
PA	Northampton	420950025	2002	8465	43	47	111	0	30	136	168	240	888	30	25	84	0	25	85	90	110	461
PA	Northampton	420958000	2002	8617	52	75	144	0	28	215	251	335	1223	30	35	116	0	20	110	125	150	536
PA	Washington	421250005	2002	8604	29	40	139	0	19	106	133	204	759	20	22	108	0	16	65	78	103	386
PA	Washington	421250200	2002	8527	41	54	133	0	25	164	200	271	1193	28	29	104	0	19	97	112	140	635
PA	Washington	421255001	2002	8580	53	72	136	0	28	216	256	342	1138	30	33	109	0	19	112	128	162	473
TN	Shelby	471570034	2002	8264	26	25	96	0	19	68	82	151	425	18	9	52	0	14	38	43	53	192
TN	Shelby	471570046	2002	8304	30	59	195	0	19	101	168	196	1557	17	29	167	0	14	34	53	110	743
TN	Shelby	471571034	2002	8300	38	64	169	0	20	178	231	329	1125	22	31	141	0	14	101	125	177	407
TX	Jefferson	482450009	2002	8638	30	87	292	0	0	230	300	435	1715	17	45	264	0	0	130	169	231	815
TX	Jefferson	482450011	2002	8591	13	47	373	0	0	113	150	220	1117	7	24	328	0	0	67	87	125	545
TX	Jefferson	482450020	2002	8524	22	82	363	0	0	187	238	341	3643	13	44	338	0	0	106	130	188	2203

State	County	Monitor ID	Year	n	Modeled 5-minute Max SO_2									1-hour SO_2								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
WV	Hancock	540290005	2002	8703	51	84	164	0	26	247	312	434	1513	29	41	139	0	19	133	164	226	787
WV	Hancock	540290007	2002	8706	42	62	148	2	23	172	213	305	1079	24	29	119	2	14	86	105	147	459
WV	Hancock	540290008	2002	8696	39	78	199	2	14	220	282	398	1343	22	39	173	2	10	119	159	209	606
WV	Hancock	540290009	2002	8695	41	61	148	2	20	174	206	275	1043	24	27	116	2	14	90	100	126	387
WV	Hancock	540290011	2002	8684	41	65	156	2	21	191	227	305	1339	24	31	128	2	14	102	114	150	751
WV	Hancock	540290014	2002	8669	44	62	141	2	25	186	225	303	1097	26	29	112	2	17	97	112	147	459
WV	Hancock	540290015	2002	8700	50	80	160	5	23	250	303	399	1163	29	39	133	5	14	138	164	200	487
WV	Hancock	540290016	2002	8483	34	47	139	2	21	141	168	221	1011	20	20	102	2	14	71	83	100	223
WV	Hancock	540291004	2002	8463	45	61	138	2	28	178	215	293	1147	26	27	106	2	19	90	102	140	535
WV	Wayne	540990002	2002	8712	35	44	123	3	21	136	165	219	662	25	24	95	3	17	86	98	113	299
WV	Wayne	540990003	2002	7426	48	66	137	3	26	198	231	299	1039	28	30	107	3	17	102	116	135	363
WV	Wayne	540990004	2002	8561	52	67	128	3	30	209	245	325	1069	30	30	100	3	20	106	122	152	317
WV	Wayne	540990005	2002	8297	48	69	143	3	26	206	247	341	1033	28	32	115	3	17	109	125	165	376
DE	New Castle	100031003	2003	731	31	41	130	0	21	120	143	194	477	18	17	95	0	14	60	63	77	148
DE	New Castle	100031007	2003	8549	15	32	205	0	5	84	102	143	754	9	15	165	0	3	44	52	69	247
DE	New Castle	100031008	2003	8609	38	79	208	0	16	215	285	418	1225	22	40	183	0	11	121	154	223	511
DE	New Castle	100031013	2003	5947	35	48	138	0	22	141	169	225	913	20	21	103	0	14	69	82	107	272
DE	New Castle	100032004	2003	7703	27	39	148	0	15	114	135	179	804	15	17	112	0	11	58	63	80	187
FL	Hillsborough	120570053	2003	8693	18	31	176	0	9	86	106	140	770	10	14	137	0	6	43	53	68	272
FL	Hillsborough	120570081	2003	8604	14	39	284	0	4	89	114	165	921	8	20	244	0	3	49	62	90	417
FL	Hillsborough	120570095	2003	8697	17	56	328	0	5	116	158	258	1305	8	20	248	0	3	46	62	96	405
FL	Hillsborough	120570109	2003	8688	27	77	288	0	9	163	229	408	1424	13	30	229	0	6	65	90	145	516
FL	Hillsborough	120571035	2003	8718	29	48	162	0	15	136	164	217	944	17	22	128	0	9	71	83	105	334
FL	Hillsborough	120574004	2003	8672	9	21	221	0	4	49	64	91	617	5	9	173	0	3	25	31	43	185
IA	Linn	191130029	2003	8627	15	43	289	0	4	96	129	204	948	9	22	252	0	3	55	72	117	359
IA	Linn	191130031	2003	8646	28	84	299	0	5	213	290	453	1482	13	30	237	0	3	83	114	159	421
IA	Linn	191130038	2003	8640	25	89	351	0	3	217	307	486	1569	11	35	303	0	3	93	121	179	610
IA	Muscatine	191390016	2003	7716	25	52	209	0	13	112	143	207	1318	14	27	185	0	9	58	73	107	678
IA	Muscatine	191390017	2003	8553	26	39	150	0	16	103	129	188	891	15	17	114	0	11	43	54	83	363
IA	Muscatine	191390020	2003	8439	44	113	256	0	11	327	448	619	1801	20	44	216	0	8	129	166	254	585
IL	Madison	171191010	2003	8699	26	56	211	0	11	142	177	254	1102	15	27	179	0	7	79	97	129	457
IL	Madison	171193007	2003	8700	22	46	209	0	9	110	135	192	1324	13	23	177	0	7	58	65	94	770
IL	Madison	171193009	2003	8653	36	87	238	0	14	197	275	465	1564	21	45	213	0	11	104	147	248	615

State	County	Monitor ID	Year	n	Modeled 5-minute Max SO_2									1-hour SO_2								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
IN	Floyd	180430004	2003	8124	35	83	239	4	8	209	269	400	1731	20	43	214	4	4	116	149	207	753
IN	Floyd	180430007	2003	6602	28	43	156	4	15	117	144	196	935	16	19	121	4	8	58	66	87	422
IN	Floyd	180431004	2003	8703	51	119	235	0	17	313	410	605	2583	24	49	205	0	12	112	149	232	1101
MI	Wayne	261630015	2003	7772	30	76	252	0	7	206	265	383	1249	17	38	222	0	3	116	149	198	463
MI	Wayne	261630016	2003	8574	30	65	218	0	10	180	226	315	1108	17	32	189	0	7	99	126	165	492
MI	Wayne	261630019	2003	8139	24	56	239	0	7	135	165	228	1479	14	28	205	0	3	76	89	112	737
MO	Greene	290770026	2003	7957	38	90	235	0	10	258	338	490	1559	18	32	177	0	10	103	129	178	348
MO	Greene	290770032	2003	8723	11	15	143	0	7	41	52	62	358	7	7	98	0	5	26	31	36	87
MO	Greene	290770037	2003	8181	36	94	262	5	10	247	351	538	1580	17	36	210	5	10	97	136	200	543
MO	Greene	290770040	2003	8674	20	46	226	0	10	100	129	201	1092	12	23	196	0	5	46	72	113	441
MO	Greene	290770041	2003	8676	12	17	149	0	8	39	52	71	471	8	9	104	0	5	20	26	36	215
MO	Iron	290930030	2003	6964	39	131	332	2	7	368	518	713	2511	18	57	306	2	5	156	212	300	1210
MO	Iron	290930031	2003	8230	34	118	350	2	8	229	344	596	2747	16	51	319	2	5	95	136	214	1018
MO	Jefferson	290990018	2003	6009	54	140	259	6	17	299	389	570	4252	25	59	236	6	11	107	136	203	1830
OH	Cuyahoga	390350038	2003	8487	44	73	167	0	20	211	253	342	1353	25	35	138	0	16	111	131	167	657
OH	Cuyahoga	390350045	2003	8596	29	49	172	0	14	139	165	222	1008	17	23	140	0	12	72	84	108	402
OH	Cuyahoga	390350060	2003	8583	50	71	142	0	27	214	246	326	1157	29	33	113	0	20	111	131	151	577
OH	Cuyahoga	390350065	2003	8613	23	47	200	0	9	130	156	215	1002	13	22	162	0	8	72	88	104	283
OH	Cuyahoga	390356001	2003	4313	39	63	163	0	20	179	218	291	1081	22	30	136	0	12	92	111	147	585
OK	Tulsa	401430175	2003	8663	36	66	184	0	8	196	227	287	1072	21	32	154	0	4	106	121	142	274
OK	Tulsa	401430235	2003	8358	38	71	188	0	14	213	253	331	1218	22	35	160	0	7	117	142	172	559
OK	Tulsa	401430501	2003	8716	29	57	195	0	7	164	191	239	1037	17	27	160	0	4	88	102	121	307
PA	Allegheny	420030002	2003	8356	30	42	138	0	18	124	144	188	873	18	18	102	0	13	62	69	85	200
PA	Allegheny	420030010	2003	8630	31	36	118	0	22	101	117	172	691	22	19	88	0	18	65	71	85	363
PA	Allegheny	420030021	2003	7728	28	37	134	0	17	109	128	163	786	16	16	98	0	11	53	60	74	272
PA	Allegheny	420030064	2003	8502	39	63	162	0	19	184	222	296	1027	23	30	133	0	13	96	116	154	417
PA	Allegheny	420030067	2003	8212	26	35	135	0	16	98	114	159	627	18	19	104	0	13	65	71	87	301
PA	Allegheny	420030116	2003	8506	30	39	132	0	18	117	136	176	813	17	16	95	0	11	58	67	78	178
PA	Allegheny	420033003	2003	8528	46	82	177	0	20	248	310	426	1203	27	40	151	0	13	138	169	218	530
PA	Beaver	420070002	2003	8627	31	56	180	0	14	161	197	262	1042	18	26	147	0	10	86	104	135	361
PA	Beaver	420070005	2003	8729	32	61	190	0	10	171	205	275	1181	19	29	158	0	6	92	109	134	520
PA	Beaver	420070014	2003	8510	19	38	200	0	6	105	126	166	836	11	18	158	0	5	59	67	81	204
PA	Northampton	420950025	2003	8720	21	32	157	0	11	89	103	138	659	15	18	127	0	7	60	67	78	407

State	County	Monitor ID	Year	n	Modeled 5-minute Max SO_2									1-hour SO_2								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
PA	Northampton	420958000	2003	8725	53	68	130	0	31	205	238	317	1057	30	30	100	0	22	101	119	142	310
PA	Washington	421250005	2003	8718	26	40	157	0	15	104	126	191	866	18	22	122	0	12	66	78	99	392
PA	Washington	421250200	2003	8742	40	48	120	3	24	146	180	253	820	28	25	91	3	21	90	102	120	296
PA	Washington	421255001	2003	8602	53	74	140	0	28	223	265	349	1150	30	34	111	0	18	120	135	170	422
TN	Shelby	471570034	2003	8084	21	21	98	4	15	54	65	129	479	15	7	49	4	11	34	38	41	266
TN	Shelby	471570046	2003	8285	24	45	186	11	15	79	127	140	1293	14	22	155	11	11	26	38	79	570
TN	Shelby	471571034	2003	8306	38	59	157	11	19	179	217	291	1032	22	28	128	11	11	98	120	154	356
TX	Jefferson	482450009	2003	8567	28	85	300	0	5	196	240	329	3428	16	44	273	0	4	112	138	176	1760
TX	Jefferson	482450011	2003	8488	19	99	524	0	0	137	181	259	5728	11	52	482	0	0	82	108	138	2901
TX	Jefferson	482450020	2003	8650	21	76	365	0	0	182	240	366	1456	12	40	332	0	0	108	138	194	676
WV	Hancock	540290005	2003	8695	50	93	187	3	22	250	321	475	1677	28	46	163	2	14	138	170	237	667
WV	Hancock	540290007	2003	8616	40	69	170	2	20	186	233	343	1191	23	34	145	2	14	97	120	166	559
WV	Hancock	540290008	2003	8683	35	68	193	2	14	191	244	343	1142	20	34	166	2	9	106	133	189	435
WV	Hancock	540290009	2003	8344	44	71	162	2	21	199	250	352	1133	25	34	135	2	14	104	124	179	580
WV	Hancock	540290011	2003	8694	47	75	161	2	23	222	270	371	1227	27	37	135	2	16	122	145	186	587
WV	Hancock	540290014	2003	8686	46	63	137	2	28	185	225	320	1088	26	29	108	2	18	94	113	156	400
WV	Hancock	540290015	2003	8694	48	79	165	3	21	244	295	398	1126	28	38	138	2	14	133	163	202	398
WV	Hancock	540290016	2003	8657	35	45	130	2	23	135	163	223	911	20	19	95	2	18	62	76	101	352
WV	Hancock	540291004	2003	8533	52	69	133	2	32	207	258	352	1150	30	31	105	2	23	104	124	175	458
WV	Wayne	540990002	2003	2056	46	50	107	8	30	175	213	274	557	32	25	78	7	24	99	120	137	198
WV	Wayne	540990003	2003	8060	52	71	137	3	27	231	265	333	976	30	33	111	3	17	133	140	150	341
WV	Wayne	540990004	2003	8571	51	72	142	3	29	206	250	341	1515	29	33	115	3	20	106	126	164	792
WV	Wayne	540990005	2003	7930	49	77	158	3	26	217	268	377	1338	28	38	133	3	17	113	137	188	570
DE	New Castle	100031007	2004	6137	14	26	181	0	7	67	83	112	595	8	11	137	0	5	34	39	49	230
DE	New Castle	100031008	2004	8364	26	56	216	0	10	152	193	274	1052	15	28	185	0	8	83	108	147	437
DE	New Castle	100031013	2004	8119	23	41	175	0	10	112	134	181	868	13	19	138	0	8	57	67	90	248
DE	New Castle	100032004	2004	8617	22	34	155	0	12	96	115	154	794	13	15	116	0	8	49	57	67	199
FL	Hillsborough	120570053	2004	8543	21	34	168	0	10	97	117	157	836	12	15	129	0	10	50	59	74	257
FL	Hillsborough	120570081	2004	8492	21	38	176	0	12	102	121	171	894	12	17	140	0	10	50	59	79	376
FL	Hillsborough	120570095	2004	8643	10	31	296	0	0	71	99	145	787	5	10	196	0	0	30	40	50	153
FL	Hillsborough	120570109	2004	8515	33	92	280	0	10	198	272	475	2022	16	37	237	0	10	69	99	173	926
FL	Hillsborough	120571035	2004	8643	35	60	174	0	16	161	197	277	1078	20	28	143	0	10	84	99	134	391
FL	Hillsborough	120574004	2004	8572	9	23	247	0	0	56	66	98	624	5	10	197	0	0	30	35	45	213

State	County	Monitor ID	Year	n	Modeled 5-minute Max SO_2									1-hour SO_2								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
IA	Linn	191130029	2004	8381	8	25	317	0	2	53	71	110	770	5	12	264	0	2	28	39	60	234
IA	Linn	191130031	2004	8664	19	62	326	0	4	139	190	306	1311	9	22	245	0	2	53	73	117	321
IA	Linn	191130038	2004	8208	19	76	398	0	2	146	219	402	1508	9	29	334	0	2	62	85	165	461
IA	Muscatine	191390016	2004	8167	17	31	187	0	9	76	94	133	885	10	14	149	0	6	39	47	65	364
IA	Muscatine	191390017	2004	8415	16	25	158	0	9	67	82	114	747	9	10	113	0	6	32	38	49	223
IA	Muscatine	191390020	2004	8725	42	110	264	0	9	333	442	600	1683	19	41	218	0	6	131	161	226	507
IL	Madison	171191010	2004	8729	28	58	205	0	11	150	193	288	1068	16	29	175	0	7	83	105	155	393
IL	Madison	171193007	2004	8692	22	36	165	0	11	102	125	168	806	13	16	127	0	7	54	61	76	198
IL	Madison	171193009	2004	8594	33	79	242	0	11	175	241	383	1638	19	40	215	0	7	90	126	209	736
IN	Floyd	180430004	2004	8358	53	103	195	5	22	267	346	533	1988	30	52	173	5	15	141	176	262	821
IN	Floyd	180430007	2004	7538	19	44	225	5	8	97	126	191	1067	11	22	193	5	5	50	71	106	479
IN	Floyd	180431004	2004	8251	53	141	265	0	8	368	482	679	2693	24	60	253	0	5	126	166	277	1133
MI	Wayne	261630015	2004	8502	34	79	236	0	9	225	288	411	1187	19	40	209	0	6	129	158	218	466
MI	Wayne	261630016	2004	8656	21	49	228	0	6	132	167	228	975	12	24	191	0	3	75	90	126	293
MI	Wayne	261630019	2004	8662	17	36	211	0	5	102	123	166	785	10	17	171	0	3	54	66	84	200
MO	Greene	290770026	2004	8776	36	88	243	5	11	257	334	477	1464	17	33	187	5	5	114	139	184	357
MO	Greene	290770032	2004	8754	8	15	184	0	5	33	47	64	409	6	8	139	0	5	21	26	37	116
MO	Greene	290770037	2004	8777	31	82	262	0	11	200	285	455	1548	15	31	202	0	8	84	117	175	444
MO	Greene	290770040	2004	8694	29	44	149	0	20	114	148	212	1102	17	20	115	0	16	48	69	101	487
MO	Greene	290770041	2004	8687	15	21	140	0	11	53	63	92	493	11	10	97	0	11	32	37	48	296
MO	Iron	290930030	2004	1846	88	132	149	16	32	446	524	648	1329	39	41	104	16	16	159	174	190	285
MO	Iron	290930031	2004	2172	142	149	104	16	94	540	611	729	1435	61	43	72	16	48	174	206	222	349
MO	Jefferson	290990004	2004	8044	42	107	252	2	11	286	372	528	2111	19	42	219	2	7	112	131	176	1053
OH	Cuyahoga	390350038	2004	8603	48	76	157	0	23	228	274	374	1146	28	37	131	0	14	127	145	186	400
OH	Cuyahoga	390350045	2004	8679	24	43	178	0	14	120	152	200	879	14	20	144	0	9	64	73	91	277
OH	Cuyahoga	390350060	2004	8617	35	62	177	0	15	173	218	307	1023	20	30	147	0	9	91	114	159	304
OH	Cuyahoga	390350065	2004	8405	29	51	177	0	14	146	170	229	953	17	24	143	0	14	82	91	114	291
OK	Tulsa	401430175	2004	8292	51	89	176	0	12	263	306	399	1216	29	45	152	0	8	142	159	183	529
OK	Tulsa	401430235	2004	8460	49	87	177	0	17	252	302	405	1402	28	43	151	0	12	134	159	195	602
OK	Tulsa	401430501	2004	8700	40	73	181	0	11	213	246	311	1102	23	35	151	0	8	114	126	146	427
PA	Allegheny	420030002	2004	8646	35	50	142	0	20	144	172	227	1077	20	22	110	0	14	73	84	110	486
PA	Allegheny	420030010	2004	8616	29	40	138	0	17	111	136	197	655	20	22	108	0	14	73	84	101	233
PA	Allegheny	420030021	2004	8663	29	41	140	0	17	119	139	187	873	17	18	105	0	11	59	67	84	236

State	County	Monitor ID	Year	n	Modeled 5-minute Max SO_2									1-hour SO_2								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
PA	Allegheny	420030064	2004	8680	46	68	148	0	24	201	238	316	1080	26	32	119	0	17	104	118	155	379
PA	Allegheny	420030067	2004	8373	29	43	151	0	17	114	142	210	1050	20	24	119	0	14	76	87	107	613
PA	Allegheny	420030116	2004	8676	30	42	138	0	17	123	145	193	927	18	18	101	0	11	62	70	84	301
PA	Allegheny	420033003	2004	8611	52	85	165	0	22	257	319	430	1166	30	42	141	0	17	138	169	225	458
PA	Beaver	420070002	2004	8522	41	76	185	0	17	215	265	365	1338	24	37	157	0	10	115	144	189	658
PA	Beaver	420070005	2004	8755	52	93	177	0	21	250	302	417	1881	30	46	153	0	14	131	155	196	966
PA	Beaver	420070014	2004	8733	33	52	160	0	16	156	184	233	1067	19	25	129	0	10	84	97	118	511
PA	Northampton	420950025	2004	8702	15	22	142	0	9	58	68	91	414	11	11	101	0	7	36	41	50	169
PA	Northampton	420958000	2004	8648	52	52	99	0	39	162	196	275	974	30	19	62	0	25	73	82	105	344
PA	Washington	421250005	2004	8662	37	43	118	0	24	124	158	225	837	26	22	87	0	21	79	89	106	353
PA	Washington	421250200	2004	8680	42	52	124	3	24	157	191	264	1125	29	28	96	3	21	96	106	130	685
PA	Washington	421255001	2004	8656	52	78	148	0	27	232	277	368	1252	30	37	123	0	21	123	144	175	589
TN	Shelby	471570034	2004	8240	24	23	96	0	18	65	80	151	432	17	8	49	0	13	40	45	53	134
TN	Shelby	471570046	2004	8119	31	50	161	13	19	133	160	219	1733	18	24	135	13	13	53	76	120	990
TN	Shelby	471571034	2004	8005	46	69	151	9	25	203	256	363	1092	26	33	124	9	13	107	134	192	464
TX	Jefferson	482450009	2004	8679	26	91	347	0	4	190	245	365	3665	15	48	317	0	4	107	134	192	1782
TX	Jefferson	482450011	2004	8507	13	43	331	0	0	107	139	200	1033	8	22	289	0	0	63	80	112	554
TX	Jefferson	482450020	2004	8244	21	70	337	0	0	173	225	331	1311	12	36	304	0	0	98	129	183	589
WV	Hancock	540290005	2004	8723	49	84	173	2	23	234	301	436	1544	28	42	149	2	14	126	160	229	843
WV	Hancock	540290007	2004	8646	44	68	154	2	24	190	233	329	1233	25	32	128	2	17	95	117	167	624
WV	Hancock	540290008	2004	8726	35	66	189	2	14	193	236	321	1108	20	33	161	2	10	107	131	171	514
WV	Hancock	540290009	2004	8700	35	62	176	2	14	176	214	295	1018	20	29	146	2	10	93	112	148	362
WV	Hancock	540290011	2004	8676	45	69	156	2	22	214	259	348	1112	26	33	129	2	14	114	141	181	455
WV	Hancock	540290015	2004	8717	45	75	168	2	19	223	269	363	1130	26	36	141	2	12	121	143	183	386
WV	Hancock	540290016	2004	4514	34	44	130	2	21	135	164	212	827	19	19	96	2	14	67	86	102	233
WV	Hancock	540291004	2004	8385	53	70	132	2	33	208	255	351	1213	30	32	105	2	24	107	126	162	579
WV	Wayne	540990003	2004	8659	46	61	133	3	26	196	228	289	1012	26	27	103	3	17	115	126	138	310
WV	Wayne	540990004	2004	8673	36	46	128	3	22	138	163	212	934	21	19	92	3	14	69	78	95	227
WV	Wayne	540990005	2004	8681	35	42	120	3	22	127	147	191	905	20	17	84	3	14	63	69	83	178
DE	New Castle	100031007	2005	7283	18	32	182	0	8	86	104	143	799	10	14	142	0	5	44	52	68	331
DE	New Castle	100031008	2005	8634	32	71	223	0	12	177	229	346	1354	18	36	197	0	8	96	126	183	650
DE	New Castle	100031013	2005	7604	32	45	142	0	19	130	154	201	968	18	19	105	0	14	66	74	93	382
DE	New Castle	100032004	2005	8539	22	34	152	0	13	98	117	154	758	13	14	111	0	8	49	57	68	145

State	County	Monitor ID	Year	n	Modeled 5-minute Max SO_2									1-hour SO_2								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
FL	Hillsborough	120570053	2005	8698	17	28	166	0	9	81	98	128	695	10	13	127	0	4	40	48	57	176
FL	Hillsborough	120570081	2005	8679	15	33	222	0	6	81	101	139	905	9	16	182	0	4	44	53	66	405
FL	Hillsborough	120570095	2005	8650	10	44	442	0	0	59	89	150	1113	5	18	360	0	0	26	35	48	431
FL	Hillsborough	120570109	2005	8618	25	84	336	0	6	162	230	413	1802	12	36	296	0	4	62	79	158	665
FL	Hillsborough	120571035	2005	8657	28	52	184	0	13	138	169	233	1010	16	25	151	0	9	75	88	114	401
FL	Hillsborough	120574004	2005	8716	10	20	204	0	5	53	66	94	502	6	9	158	0	4	26	35	44	119
IA	Linn	191130029	2005	8600	14	37	272	0	5	82	109	170	928	8	18	232	0	3	44	61	92	341
IA	Linn	191130031	2005	8632	35	98	281	0	7	274	370	535	1597	15	36	230	0	3	106	140	188	416
IA	Linn	191130038	2005	8615	28	92	323	0	4	236	338	524	1450	13	35	274	0	3	96	133	205	426
IA	Muscatine	191390016	2005	8644	24	60	254	0	8	147	196	290	1332	12	23	187	0	6	65	86	120	352
IA	Muscatine	191390017	2005	8603	16	28	177	0	9	68	86	125	790	9	13	140	0	6	32	41	58	266
IA	Muscatine	191390020	2005	8693	40	109	273	0	8	334	439	593	1628	18	41	229	0	6	131	163	213	580
IL	Madison	171191010	2005	8669	34	67	197	0	13	183	228	327	1117	19	33	169	0	8	96	122	172	507
IL	Madison	171193007	2005	8703	29	47	164	0	14	127	154	212	951	17	22	130	0	8	67	75	101	327
IL	Madison	171193009	2005	8519	39	88	227	0	13	211	281	448	1642	22	45	201	0	8	113	151	226	679
IN	Floyd	180430004	2005	8345	53	81	153	4	29	220	278	401	1555	30	39	127	4	20	112	139	195	669
IN	Floyd	180430007	2005	8063	34	80	233	4	12	174	214	304	2071	20	41	207	4	8	92	112	155	1103
IN	Floyd	180431004	2005	8264	35	97	276	0	8	242	327	509	1796	16	39	237	0	4	92	123	183	701
MI	Wayne	261630015	2005	8193	36	87	238	0	9	259	330	459	1212	21	44	213	0	7	144	184	238	486
MI	Wayne	261630016	2005	8044	26	57	220	0	9	152	194	272	1162	15	28	189	0	7	84	107	144	589
MI	Wayne	261630019	2005	7917	20	43	218	0	7	118	143	191	903	11	20	179	0	3	67	80	97	305
MO	Greene	290770026	2005	8756	32	84	267	5	8	230	308	454	1438	14	29	201	5	5	96	122	163	376
MO	Greene	290770032	2005	8661	10	16	158	0	6	43	56	71	427	7	9	119	0	5	29	34	44	146
MO	Greene	290770037	2005	8760	31	80	260	5	11	185	254	407	1888	15	30	199	5	9	75	99	151	593
MO	Greene	290770040	2005	8669	23	62	269	0	10	116	164	276	1509	13	32	242	0	10	58	88	156	672
MO	Greene	290770041	2005	8660	12	20	162	0	7	48	58	82	495	9	11	121	0	5	29	34	44	278
MO	Jefferson	290990004	2005	7166	54	132	244	0	11	387	491	665	2626	24	53	218	0	9	147	181	256	1298
OH	Cuyahoga	390350038	2005	8570	40	69	173	0	17	201	238	317	1170	23	33	143	0	10	113	120	154	514
OH	Cuyahoga	390350045	2005	8631	23	43	186	0	10	114	135	186	995	13	20	151	0	7	58	69	86	429
OH	Cuyahoga	390350060	2005	8602	44	63	145	0	23	190	219	292	1046	25	29	116	0	17	99	113	137	429
OH	Cuyahoga	390350065	2005	8355	22	44	198	0	7	122	148	201	1129	13	21	165	0	3	65	79	99	597
OK	Tulsa	401430175	2005	8551	53	90	170	0	16	268	312	403	1474	30	44	145	0	9	146	164	192	804
OK	Tulsa	401430235	2005	8442	45	81	180	0	18	227	271	364	1923	26	40	154	0	14	123	142	178	1023

State	County	Monitor ID	Year	n	Modeled 5-minute Max SO_2									1-hour SO_2								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
OK	Tulsa	401430501	2005	8515	42	73	176	0	12	219	254	327	1101	24	36	148	0	9	119	132	164	425
PA	Allegheny	420030002	2005	8639	25	38	153	0	13	107	128	168	853	14	16	113	0	9	54	63	76	249
PA	Allegheny	420030010	2005	8731	26	32	124	0	17	91	107	154	555	18	16	90	0	13	59	67	80	212
PA	Allegheny	420030021	2005	8650	24	37	152	0	13	103	122	164	848	14	16	112	0	9	50	59	74	273
PA	Allegheny	420030064	2005	8658	36	57	162	0	17	172	204	265	1006	20	27	130	0	11	91	108	134	299
PA	Allegheny	420030067	2005	8689	21	31	144	0	13	87	102	134	533	15	17	112	0	11	56	65	78	184
PA	Allegheny	420030116	2005	8699	26	37	142	0	15	108	130	171	844	15	16	104	0	11	54	63	78	264
PA	Allegheny	420033003	2005	8490	49	88	180	0	20	264	323	437	1293	28	44	157	0	13	150	173	215	639
PA	Beaver	420070002	2005	8682	38	64	169	0	17	184	223	301	1186	22	31	140	0	12	97	116	148	537
PA	Beaver	420070005	2005	8626	53	89	169	0	24	239	296	431	1712	30	44	145	0	16	125	150	205	834
PA	Beaver	420070014	2005	8660	29	49	169	0	13	141	168	219	951	17	22	135	0	10	77	89	109	237
PA	Northampton	420950025	2005	8512	37	38	104	0	27	111	131	202	711	26	19	72	0	21	71	78	92	331
PA	Northampton	420958000	2005	8652	52	73	138	0	28	212	247	331	1134	30	33	108	0	21	110	124	146	469
PA	Washington	421250005	2005	8603	42	46	109	0	28	142	179	248	799	29	23	80	0	21	83	98	113	356
PA	Washington	421250200	2005	8720	40	48	121	0	25	147	183	249	763	27	26	93	0	18	89	101	126	325
PA	Washington	421255001	2005	8606	49	78	157	0	21	235	272	346	1118	29	38	131	0	15	126	141	166	445
TN	Shelby	471570034	2005	8121	22	23	103	0	16	61	77	140	443	15	9	61	0	12	35	39	51	207
TN	Shelby	471570046	2005	8282	29	66	225	12	17	125	140	223	2680	17	34	200	12	12	55	74	121	1360
TN	Shelby	471571034	2005	8160	33	55	167	12	18	140	185	276	1025	19	27	140	12	12	70	101	156	382
TN	Shelby	471572005	2005	5864	7	8	114	4	5	22	28	47	214	5	3	69	4	4	12	16	19	51
TX	Jefferson	482450009	2005	8360	36	91	253	0	7	268	336	465	1371	21	47	228	0	6	159	187	244	687
TX	Jefferson	482450011	2005	8071	18	61	342	0	0	139	189	281	1466	10	32	307	0	0	79	108	153	647
TX	Jefferson	482450020	2005	7797	19	72	377	0	0	160	210	334	1654	11	37	343	0	0	91	113	176	857
WV	Hancock	540290005	2005	8684	45	67	148	2	24	198	239	331	1094	26	31	119	2	16	104	124	157	447
WV	Hancock	540290007	2005	8702	38	56	148	2	20	160	195	265	1079	22	25	116	2	13	82	97	135	365
WV	Hancock	540290008	2005	8701	27	52	191	2	11	148	184	250	981	16	25	160	2	7	80	100	133	343
WV	Hancock	540290009	2005	8687	41	64	154	2	20	186	222	297	1257	24	30	126	2	13	100	115	144	729
WV	Hancock	540290011	2005	8541	43	70	161	2	22	202	243	335	1260	25	34	134	2	16	106	128	164	647
WV	Hancock	540290015	2005	8705	35	58	169	2	15	169	205	277	1049	20	28	139	2	11	91	109	144	405
WV	Hancock	540291004	2005	8651	53	62	118	2	34	190	228	305	1020	30	27	88	2	24	93	109	140	399
WV	Wayne	540990003	2005	8142	33	51	153	2	18	167	199	250	934	19	24	123	2	12	87	121	133	250
WV	Wayne	540990004	2005	8622	27	33	125	2	17	98	118	153	765	15	13	83	2	12	46	52	65	186
WV	Wayne	540990005	2005	8454	23	29	125	2	15	88	103	135	616	13	11	83	2	10	42	46	52	103

State	County	Monitor ID	Year	n	Modeled 5-minute Max SO_2									1-hour SO_2								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
DE	New Castle	100031007	2006	8424	14	23	170	0	7	64	78	109	590	8	10	128	0	5	29	38	48	193
DE	New Castle	100031008	2006	8573	30	65	214	0	13	169	214	309	1175	17	32	184	0	8	94	118	161	552
DE	New Castle	100031013	2006	8631	21	38	184	0	11	99	123	169	943	12	18	147	0	8	51	64	86	437
DE	New Castle	100032004	2006	8600	21	30	142	0	13	89	104	137	620	12	13	102	0	8	40	48	59	166
FL	Hillsborough	120570053	2006	6506	12	25	202	0	5	65	82	107	628	7	11	160	0	4	34	42	55	201
FL	Hillsborough	120570081	2006	6509	11	29	273	0	0	66	84	114	1006	6	14	232	0	0	34	42	59	600
FL	Hillsborough	120570095	2006	6517	5	23	427	0	0	38	52	97	624	3	8	302	0	0	21	25	38	168
FL	Hillsborough	120570109	2006	6462	26	79	303	0	8	173	242	421	1522	12	31	247	0	4	67	92	151	545
FL	Hillsborough	120571035	2006	6486	29	57	194	0	13	150	191	266	1114	17	28	163	0	8	80	96	138	575
FL	Hillsborough	120574004	2006	6367	11	19	173	0	6	50	58	87	451	6	8	134	0	4	21	29	38	159
IA	Linn	191130029	2006	8648	6	12	205	0	4	26	33	49	385	3	5	155	0	4	12	12	20	115
IA	Linn	191130031	2006	8549	29	82	283	0	5	222	292	431	1429	13	30	225	0	4	86	111	152	430
IA	Linn	191130038	2006	8250	35	99	281	0	7	285	382	543	1655	16	38	234	0	4	111	143	205	537
IA	Muscatine	191390016	2006	8708	24	73	309	0	6	166	230	371	1470	11	28	248	0	4	67	86	132	515
IA	Muscatine	191390017	2006	8715	17	29	172	0	9	76	96	133	731	10	13	133	0	6	36	45	66	244
IA	Muscatine	191390020	2006	8714	30	93	307	0	5	257	349	517	1471	14	35	257	0	3	106	134	196	421
IL	Madison	171191010	2006	8651	31	69	220	0	10	183	229	329	1141	18	35	192	0	5	103	123	172	530
IL	Madison	171193007	2006	8682	25	45	180	0	11	125	155	210	951	15	21	146	0	10	69	78	103	368
IL	Madison	171193009	2006	8627	42	100	237	0	13	251	340	530	1717	24	52	215	0	10	137	186	275	775
IN	Floyd	180430004	2006	5928	44	71	161	4	22	208	247	337	1121	26	35	135	4	15	117	128	157	506
IN	Floyd	180430007	2006	6240	33	59	181	4	18	136	174	255	1395	19	29	152	4	15	69	87	117	616
IN	Floyd	180431004	2006	8339	41	107	264	0	15	231	315	506	3444	20	46	232	0	11	84	109	189	1760
MI	Wayne	261630015	2006	8429	29	79	272	0	4	228	294	413	1154	17	41	245	0	3	130	165	221	455
MI	Wayne	261630016	2006	8722	19	47	247	0	4	128	163	223	980	11	23	210	0	3	74	92	121	254
MI	Wayne	261630019	2006	8325	13	32	237	0	3	87	106	140	782	8	15	190	0	3	50	59	74	162
MO	Greene	290770026	2006	8753	31	85	275	4	7	235	317	470	1300	14	30	215	4	4	96	119	167	394
MO	Greene	290770032	2006	8727	12	20	171	0	7	53	60	93	530	8	10	128	0	4	31	40	49	196
MO	Greene	290770037	2006	8745	31	95	305	4	7	238	352	548	1571	15	38	259	4	4	102	139	209	536
MO	Greene	290770040	2006	8637	15	42	281	0	7	74	106	165	1041	9	21	246	0	4	36	54	94	504
MO	Greene	290770041	2006	8581	8	16	200	0	5	27	35	56	505	6	9	155	0	4	18	18	27	277
MO	Jefferson	290990004	2006	6541	58	134	233	0	9	421	520	686	1874	25	52	207	0	6	150	179	245	799
OH	Cuyahoga	390350038	2006	8391	36	66	184	0	13	192	229	303	1078	21	32	155	0	8	106	123	157	403
OH	Cuyahoga	390350045	2006	8594	26	49	190	0	13	132	154	215	981	15	23	156	0	13	64	85	106	437

State	County	Monitor ID	Year	n	Modeled 5-minute Max SO_2									1-hour SO_2								
					Mean	Std	COV	p0	p50	p97	p98	p99	p100	Mean	Std	COV	p0	p50	p97	p98	p99	p100
OH	Cuyahoga	390350060	2006	8637	48	80	165	0	21	244	296	391	1178	28	39	139	0	13	127	161	204	467
OH	Cuyahoga	390350065	2006	8521	34	76	225	0	13	178	224	320	1675	20	39	197	0	8	98	119	170	722
OK	Tulsa	401430175	2006	7204	53	89	169	0	15	274	317	402	1181	30	44	144	0	10	149	168	198	372
OK	Tulsa	401430235	2006	7223	31	62	199	0	11	178	219	297	1086	18	30	168	0	5	99	119	154	391
OK	Tulsa	401430501	2006	7193	39	66	171	0	15	193	226	291	1100	22	31	140	0	10	104	119	139	342
OK	Tulsa	401431127	2006	431	7	16	227	0	2	44	54	75	181	4	9	209	0	1	28	33	39	99
PA	Allegheny	420030002	2006	8690	27	42	157	0	14	117	139	181	862	15	18	118	0	9	59	68	80	368
PA	Allegheny	420030010	2006	8612	29	36	125	0	20	99	116	177	688	21	19	92	0	15	62	68	83	300
PA	Allegheny	420030021	2006	8711	32	45	139	0	18	130	153	205	916	19	19	103	0	12	65	74	92	246
PA	Allegheny	420030064	2006	8665	51	81	158	0	24	246	294	388	1176	30	39	132	0	18	133	157	193	537
PA	Allegheny	420030067	2006	8568	24	36	149	0	14	101	119	172	574	17	20	118	0	12	68	74	92	261
PA	Allegheny	420030116	2006	7567	31	41	132	0	18	122	142	185	860	18	17	95	0	12	59	68	80	338
PA	Beaver	420070002	2006	8682	38	63	165	0	19	180	214	286	1043	22	30	134	0	13	96	110	139	420
PA	Beaver	420070005	2006	8673	42	95	224	0	10	228	287	422	2318	24	49	201	0	6	123	150	211	1130
PA	Beaver	420070014	2006	8627	34	47	137	0	20	142	167	216	932	20	20	103	0	13	75	86	104	214
PA	Northampton	420950025	2006	8712	7	10	158	0	4	24	29	41	287	5	5	106	0	4	16	18	21	60
PA	Northampton	420958000	2006	8512	18	35	195	0	11	71	93	141	924	10	17	164	0	8	32	42	65	397
PA	Washington	421250005	2006	8693	38	43	113	0	26	125	164	244	737	26	21	81	0	21	73	87	115	376
PA	Washington	421250200	2006	8609	44	49	112	0	29	151	189	260	903	30	25	81	0	24	91	101	122	383
PA	Washington	421255001	2006	8695	36	63	174	0	15	185	225	301	1102	21	31	146	0	10	101	118	157	432
TN	Shelby	471570046	2006	8189	25	37	150	12	17	87	108	148	1131	14	18	122	12	12	25	33	62	582
TN	Shelby	471571034	2006	8156	46	68	148	10	25	197	242	344	1125	26	32	121	8	16	103	128	173	396
TN	Shelby	471572005	2006	2867	8	11	131	4	5	29	39	49	246	6	5	81	4	4	21	21	29	54
TX	Jefferson	482450009	2006	8553	25	105	415	0	0	183	268	469	2359	14	56	386	0	0	108	151	246	992
TX	Jefferson	482450011	2006	8417	13	64	486	0	0	111	174	297	1336	8	34	449	0	0	69	99	172	647
TX	Jefferson	482450020	2006	8647	28	89	320	0	0	188	257	401	3062	16	47	293	0	0	103	142	216	1768
WV	Hancock	540290005	2006	8340	44	62	140	2	25	186	224	296	1093	25	28	109	2	16	98	115	143	346
WV	Hancock	540290007	2006	8550	40	61	152	2	21	179	217	292	1103	23	29	122	2	14	94	110	140	470
WV	Hancock	540290008	2006	8636	30	54	178	2	13	157	195	265	1026	17	26	148	2	9	84	110	140	337
WV	Hancock	540290009	2006	8690	53	73	139	5	28	223	264	348	1185	30	34	110	5	19	117	136	171	566
WV	Hancock	540290011	2006	8605	50	64	129	2	31	195	231	307	1120	29	29	99	2	23	101	117	140	456
WV	Hancock	540290015	2006	8678	38	61	158	3	18	183	216	282	1170	22	28	128	2	12	101	117	140	512
WV	Hancock	540291004	2006	8678	44	60	134	2	26	176	212	287	1062	26	27	105	2	19	89	105	140	339

APPENDIX D: SUPPLEMENTARY FILES FOR AERMOD MODELING

Table D-1. Emission parameters by stack for all major facility stacks in Missouri.

Stack ID	City	Facility Name	NEI Site ID	UTM X (m)[1]	UTM Y (m)[1]	SO_2 Emissions (tpy)	Stack Height (m)	Exit Temp. (K)	Stack Diam. (m)	Exit Velocity (m/s)	Profile Method[2]
4990	CLINTON	KANSAS CITY POWER & LIGHT CO-MONTROSE GENERATING STATION	NEI 7485	418,276	4,240,693	5,648	137	416	3.1	37	Tier 1
4991	ANNAPOLIS	DOE RUN COMPANY-GLOVER SMELTER	NEI 34282	703,986	4,151,076	3	129	376	4.4	13	Tier 2
4994	ANNAPOLIS	DOE RUN COMPANY-GLOVER SMELTER	NEI 34282	704,098	4,151,018	1,288	114	344	2.3	16	Tier 2
4995	ANNAPOLIS	DOE RUN COMPANY-GLOVER SMELTER	NEI 34282	704,182	4,151,029	42,049	186	366	3.7	11	Tier 2
5014	COLUMBIA	UNIVERSITY OF MISSOURI - COLUMBIA-POWER PLANT	NEI MO0190004	557,837	4,311,095	4,842	99	450	2.7	11	Tier 2
5016	COLUMBIA	UNIVERSITY OF MISSOURI - COLUMBIA-POWER PLANT	NEI MO0190004	557,748	4,311,019	49	96	450	3.0	17	Tier 2
5017	COLUMBIA	UNIVERSITY OF MISSOURI - COLUMBIA-POWER PLANT	NEI MO0190004	557,750	4,311,008	1,242	96	450	3.0	17	Tier 2
5018	COLUMBIA	UNIVERSITY OF MISSOURI - COLUMBIA-POWER PLANT	NEI MO0190004	557,740	4,311,005	40	96	450	3.0	17	Tier 2
5019	COLUMBIA	UNIVERSITY OF MISSOURI - COLUMBIA-POWER PLANT	NEI MO0190004	557,740	4,311,015	1,056	96	450	3.0	17	Tier 1
5020	COLUMBIA	UNIVERSITY OF MISSOURI - COLUMBIA-POWER PLANT	NEI MO0190004	557,732	4,311,009	2,465	96	450	3.0	17	Tier 2
5021	COLUMBIA	UNIVERSITY OF MISSOURI - COLUMBIA-POWER PLANT	NEI MO0190004	557,744	4,311,009	36	96	450	3.0	17	Tier 3
5039	ST. JOSEPH	AQUILA INC-LAKE ROAD PLANT	NEI 7487	339,144	4,398,873	2,838	69	443	3.0	21	Tier 1
5041	ST. JOSEPH	AQUILA INC-LAKE	NEI 7487			724	46	430	2.1	17	Tier 2

Stack ID	City	Facility Name	NEI Site ID	UTM X (m)[1]	UTM Y (m)[1]	SO_2 Emissions (tpy)	Stack Height (m)	Exit Temp. (K)	Stack Diam. (m)	Exit Velocity (m/s)	Profile Method[2]
		ROAD PLANT		339,251	4,398,905						
5043	CAPE GIRARDEAU	LONE STAR INDUSTRIES INC-CAPE GIRARDEAU	NEI 16367	806,949	4,130,237	1,362	64	405	3.4	22	Tier 2
5045	MISSOURI CITY	INDEPENDENCE POWER AND LIGHT-MISSOURI CITY STATION	NEI MO0470096	387,119	4,343,259	25	91	401	2.4	17	Tier 2
5046	MISSOURI CITY	INDEPENDENCE POWER AND LIGHT-MISSOURI CITY STATION	NEI MO0470096	387,100	4,343,257	1,209	91	401	2.4	17	Tier 2
5049	LABADIE	AMERENUE-LABADIE PLANT	NEI 7514	688,392	4,270,394	10,970	213	444	6.2	28	Tier 1
5050	LABADIE	AMERENUE-LABADIE PLANT	NEI 7514	688,357	4,270,439	14,753	213	444	6.2	28	Tier 1
5051	LABADIE	AMERENUE-LABADIE PLANT	NEI 7514	688,461	4,270,338	14,285	213	444	8.8	28	Tier 1
5054	LABADIE	AMERENUE-LABADIE PLANT	NEI 7514	688,442	4,270,322	7,602	213	444	8.8	28	Tier 1
5063	SPRING-FIELD	CITY UTILITIES OF SPRINGFIELD MISSOURI-JAMES RIVER POWER PLANT	NEI 7525	476,842	4,106,944	1,137	107	422	2.5	15	Tier 2
5064	SPRING-FIELD	CITY UTILITIES OF SPRINGFIELD MISSOURI-JAMES RIVER POWER PLANT	NEI 7525	476,853	4,106,922	1,433	107	422	2.5	15	Tier 1
5066	SPRING-FIELD	CITY UTILITIES OF SPRINGFIELD MISSOURI-JAMES RIVER POWER PLANT	NEI 7525	476,913	4,106,929	757	61	422	3.7	6	Tier 1
5068	SPRING-FIELD	CITY UTILITIES OF SPRINGFIELD MISSOURI-JAMES RIVER POWER PLANT	NEI 7525	476,884	4,106,932	159	61	422	3.7	6	Tier 1
5069	SPRING-FIELD	CITY UTILITIES OF SPRINGFIELD MISSOURI-JAMES RIVER POWER PLANT	NEI 7525	476,890	4,106,922	660	61	422	3.7	5	Tier 1
5070	SPRING-FIELD	CITY UTILITIES OF SPRINGFIELD MISSOURI-JAMES	NEI 7525	476,918	4,106,919	567	61	422	3.7	5	Tier 1

Stack ID	City	Facility Name	NEI Site ID	UTM X (m)[1]	UTM Y (m)[1]	SO_2 Emissions (tpy)	Stack Height (m)	Exit Temp. (K)	Stack Diam. (m)	Exit Velocity (m/s)	Profile Method[2]
		RIVER POWER PLANT									
5073	SPRING-FIELD	CITY UTILITIES OF SPRINGFIELD MISSOURI-JAMES RIVER POWER PLANT	NEI 7525	476,919	4,106,930	218	60	422	3.7	6	Tier 1
5074	SPRING-FIELD	CITY UTILITIES OF SPRINGFIELD MISSOURI-JAMES RIVER POWER PLANT	NEI 7525	476,952	4,106,940	255	60	422	3.7	6	Tier 1
5076	SPRING-FIELD	CITY UTILITIES OF SPRINGFIELD MISSOURI-JAMES RIVER POWER PLANT	NEI 7525	477,050	4,106,880	219	60	422	3.7	6	Tier 1
5077	SPRING-FIELD	CITY UTILITIES OF SPRINGFIELD MISSOURI-JAMES RIVER POWER PLANT	NEI 7525	476,992	4,106,881	252	60	422	3.7	6	Tier 1
5084	SPRING-FIELD	CITY UTILITIES OF SPRINGFIELD MISSOURI-SOUTHWEST POWER PLANT	NEI 12640	465,416	4,111,816	3,390	117	397	3.4	21	Tier 2
5087	CLINTON	KANSAS CITY POWER & LIGHT CO-MONTROSE GENERATING STATION	NEI 7485	418,274	4,240,761	7	137	416	4.6	37	Tier 1
5088	CLINTON	KANSAS CITY POWER & LIGHT CO-MONTROSE GENERATING STATION	NEI 7485	418,316	4,240,766	4,048	137	416	4.6	37	Tier 1
5089	CLINTON	KANSAS CITY POWER & LIGHT CO-MONTROSE GENERATING STATION	NEI 7485	418,295	4,240,722	10	137	416	4.6	37	Tier 1
5090	CLINTON	KANSAS CITY POWER & LIGHT CO-MONTROSE GENERATING STATION	NEI 7485	418,352	4,240,716	6,105	137	416	4.6	37	Tier 1
5091	CLINTON	KANSAS CITY POWER & LIGHT CO-MONTROSE GENERATING	NEI 7485	418,247	4,240,717	7	137	416	3.1	37	Tier 1

Stack ID	City	Facility Name	NEI Site ID	UTM X (m)[1]	UTM Y (m)[1]	SO_2 Emissions (tpy)	Stack Height (m)	Exit Temp. (K)	Stack Diam. (m)	Exit Velocity (m/s)	Profile Method[2]
		STATION									
5092	BOSS	DOE RUN COMPANY-BUICK SMELTER	NEI MO0930009	664,790	4,167,123	4,144	61	347	5.2	9	Tier 2
5093	BOSS	DOE RUN COMPANY-BUICK SMELTER	NEI MO0930009	664,946	4,167,101	41	3	295	0.0	0	Tier 2
5096	KANSAS CITY	TRIGEN ENERGY CORPORATION-GRAND AVENUE STATION	NEI MO0950021	363,375	4,330,430	2,714	86	430	5.1	19	Tier 3
5097	KANSAS CITY	TRIGEN ENERGY CORPORATION-GRAND AVENUE STATION	NEI MO0950021	363,367	4,330,423	1,074	86	430	5.1	19	Tier 3
5106	KANSAS CITY	KANSAS CITY POWER & LIGHT CO-HAWTHORN STATION	NEI 7484	372,272	4,332,280	3,751	92	412	6.2	38	Tier 1
5108	SIBLEY	AQUILA INC-SIBLEY GENERATING STATION	NEI 7486	397,709	4,337,274	9,160	213	423	4.1	32	Tier 1
5109	SIBLEY	AQUILA INC-SIBLEY GENERATING STATION	NEI 7486	397,739	4,337,279	415	213	423	4.1	32	Tier 1
5111	LOUISIANA	AQUALON DIV OF HERCULES INC-MISSOURI CHEMICAL WORKS	NEI 34503	669,398	4,365,781	1,765	39	445	1.5	17	Tier 2
5113	WEST ALTON	AMERENUE-SIOUX PLANT	NEI 7516	735,034	4,310,876	24,932	183	427	5.8	29	Tier 1
5114	WEST ALTON	AMERENUE-SIOUX PLANT	NEI 7516	735,027	4,310,819	21,025	183	427	5.8	29	Tier 1
5115	WEST ALTON	AMERENUE-SIOUX PLANT	NEI 7516	734,948	4,310,864	2	65	436	1.4	15	Tier 1
5116	SIBLEY	AQUILA INC-SIBLEY GENERATING STATION	NEI 7486	397,722	4,337,273	415	213	423	4.1	32	Tier 1
5117	SIBLEY	AQUILA INC-SIBLEY GENERATING STATION	NEI 7486	397,628	4,337,247	415	213	423	4.1	32	Tier 1
5118	SIBLEY	AQUILA INC-SIBLEY GENERATING STATION	NEI 7486	397,734	4,337,235	467	213	423	4.1	32	Tier 1
5119	SIBLEY	AQUILA INC-SIBLEY GENERATING	NEI 7486			467	213	423	4.1	32	Tier 1

Stack ID	City	Facility Name	NEI Site ID	UTM X (m)[1]	UTM Y (m)[1]	SO_2 Emissions (tpy)	Stack Height (m)	Exit Temp. (K)	Stack Diam. (m)	Exit Velocity (m/s)	Profile Method[2]
		STATION		397,665	4,337,228						
5120	SIBLEY	AQUILA INC-SIBLEY GENERATING STATION	NEI 7486	397,704	4,337,218	467	213	423	4.1	32	Tier 1
5125	INDEPEN-DENCE	INDEPENDENCE POWER AND LIGHT-BLUE VALLEY STATION	NEI 7523	385,328	4,327,827	1,360	76	436	2.0	29	Tier 1
5127	INDEPEN-DENCE	INDEPENDENCE POWER AND LIGHT-BLUE VALLEY STATION	NEI 7523	385,376	4,327,816	1,354	47	433	1.7	19	Tier 2
5129	INDEPEN-DENCE	INDEPENDENCE POWER AND LIGHT-BLUE VALLEY STATION	NEI 7523	385,361	4,327,857	1,862	47	431	1.7	19	Tier 2
5130	ASBURY	EMPIRE DISTRICT ELECTRIC CO-ASBURY PLANT	NEI 7483	357,877	4,126,497	4,349	123	417	4.0	23	Tier 1
5131	HERCU-LANEUM	DOE RUN COMPANY-HERCULANEUM SMELTER	NEI 34412	729,589	4,238,084	2	3	295	0.0	0	Tier 2
5141	HERCU-LANEUM	DOE RUN COMPANY-HERCULANEUM SMELTER	NEI 34412	729,543	4,237,936	2	9	287	0.3	6	Tier 3
5145	HERCU-LANEUM	DOE RUN COMPANY-HERCULANEUM SMELTER	NEI 34412	729,537	4,237,973	15,219	168	350	6.1	18	Tier 2
5147	FESTUS	AMERENUE-RUSH ISLAND PLANT	NEI 12618	739,910	4,223,934	2	76	577	1.5	9	Tier 1
5148	FESTUS	AMERENUE-RUSH ISLAND PLANT	NEI 12618	739,893	4,223,827	10,511	213	405	8.8	25	Tier 1
5149	FESTUS	AMERENUE-RUSH ISLAND PLANT	NEI 12618	739,931	4,223,869	12,744	213	405	8.8	25	Tier 1
5150	PALMYRA	BASF AGRI CHEMICALS-HANNIBAL PLANT	NEI 34442	634,112	4,410,128	832	33	422	2.7	0	Tier 2
5151	PALMYRA	BASF AGRI CHEMICALS-HANNIBAL PLANT	NEI 34442	634,201	4,410,431	918	33	422	2.7	0	Tier 2
5153	PALMYRA	BASF AGRI CHEMICALS-HANNIBAL PLANT	NEI 34442	634,153	4,410,140	34	38	344	1.0	12	Tier 2

Stack ID	City	Facility Name	NEI Site ID	UTM X (m)[1]	UTM Y (m)[1]	SO_2 Emissions (tpy)	Stack Height (m)	Exit Temp. (K)	Stack Diam. (m)	Exit Velocity (m/s)	Profile Method[2]
5156	PALMYRA	BASF AGRI CHEMICALS-HANNIBAL PLANT	NEI 34442	634,213	4,410,449	50	23	352	1.1	5	Tier 2
5159	MARSTON	ASSOCIATED ELECTRIC COOPERATIVE INC-NEW MADRID POWER PLANT	NEI 7526	807,900	4,046,536	8,109	244	430	6.1	24	Tier 1
5160	MARSTON	ASSOCIATED ELECTRIC COOPERATIVE INC-NEW MADRID POWER PLANT	NEI 7526	807,913	4,046,552	7,689	244	426	6.1	21	Tier 1
5181	NEW MADRID	NORANDA ALUMINUM INC-NORANDA ALUMINUM INC	NEI 34464	807,392	4,046,098	117	23	360	2.3	8	Tier 2
5182	NEW MADRID	NORANDA ALUMINUM INC-NORANDA ALUMINUM INC	NEI 34464	807,843	4,045,978	117	15	344	1.7	13	Tier 3
5183	NEW MADRID	NORANDA ALUMINUM INC-NORANDA ALUMINUM INC	NEI 34464	807,696	4,046,215	117	17	344	1.7	13	Tier 3
5189	NEW MADRID	NORANDA ALUMINUM INC-NORANDA ALUMINUM INC	NEI 34464	807,358	4,045,789	68	22	352	1.3	12	Tier 2
5190	NEW MADRID	NORANDA ALUMINUM INC-NORANDA ALUMINUM INC	NEI 34464	807,674	4,045,798	642	38	359	4.4	12	Tier 2
5191	NEW MADRID	NORANDA ALUMINUM INC-NORANDA ALUMINUM INC	NEI 34464	807,579	4,045,878	642	38	357	4.4	12	Tier 3
5192	NEW MADRID	NORANDA ALUMINUM INC-NORANDA ALUMINUM INC	NEI 34464	807,979	4,045,995	2,029	90	360	7.9	14	Tier 2
5193	NEW MADRID	NORANDA ALUMINUM INC-NORANDA ALUMINUM INC	NEI 34464	807,382	4,045,903	180	22	352	1.3	12	Tier 2
5194	NEW MADRID	NORANDA ALUMINUM INC-NORANDA ALUMINUM INC	NEI 34464	807,518	4,045,798	179	22	352	1.3	12	Tier 2
5196	CHAMOIS	CENTRAL ELECTRIC POWER COOPERATIVE-CHAMOIS PLANT	NEI 7527	608,177	4,282,519	1,226	50	445	2.4	19	Tier 1
5197	CHAMOIS	CENTRAL ELECTRIC POWER	NEI 7527			2,916	45	431	2.1	11	Tier 2

Stack ID	City	Facility Name	NEI Site ID	UTM X (m)[1]	UTM Y (m)[1]	SO_2 Emissions (tpy)	Stack Height (m)	Exit Temp. (K)	Stack Diam. (m)	Exit Velocity (m/s)	Profile Method[2]
		COOPERATIVE-CHAMOIS PLANT		608,204	4,282,496						
5199	CLARKS-VILLE	HOLCIM (US) INC-CLARKSVILLE	NEI 16369	676,989	4,360,616	7,408	76	447	6.4	10	Tier 2
5203	LOUISIANA	AQUALON DIV OF HERCULES INC-MISSOURI CHEMICAL WORKS	NEI 34503	670,124	4,365,823	2,019	39	445	1.5	17	Tier 2
5206	LOUISIANA	AQUALON DIV OF HERCULES INC-MISSOURI CHEMICAL WORKS	NEI 34503	669,445	4,365,767	2,301	39	445	1.5	17	Tier 2
5211	WESTON	KANSAS CITY POWER & LIGHT CO-IATAN GENERATING STATION	NEI 12573	329,597	4,368,256	20	215	416	7.3	25	Tier 1
5212	WESTON	KANSAS CITY POWER & LIGHT CO-IATAN GENERATING STATION	NEI 12573	329,574	4,368,270	14,836	215	416	7.3	25	Tier 1
5213	THOMAS HILL	ASSOCIATED ELECTRIC COOPERATIVE INC-THOMAS HILL ENERGY CENTER-POWER DIVISION	NEI 34521	531,200	4,378,118	3,287	125	451	5.3	10	Tier 1
5214	THOMAS HILL	ASSOCIATED ELECTRIC COOPERATIVE INC-THOMAS HILL ENERGY CENTER-POWER DIVISION	NEI 34521	531,165	4,378,157	3,753	122	456	5.3	14	Tier 1
5241	THOMAS HILL	ASSOCIATED ELECTRIC COOPERATIVE INC-THOMAS HILL ENERGY CENTER-POWER DIVISION	NEI 34521	530,982	4,378,218	8,181	190	441	9.3	14	Tier 1
5244	STE. GENE-VIEVE	MISSISSIPPI LIME COMPANY-MISSISSIPPI LIME CO	NEI MO1860001	757,358	4,207,065	62	23	519	3.2	4	Tier 3
5245	STE. GENE-VIEVE	MISSISSIPPI LIME COMPANY-MISSISSIPPI LIME CO	NEI MO1860001	757,384	4,207,015	89	23	469	3.4	6	Tier 3
5246	STE. GENE-	MISSISSIPPI LIME	NEI			103	23	469	3.4	6	Tier 3

Stack ID	City	Facility Name	NEI Site ID	UTM X (m)[1]	UTM Y (m)[1]	SO_2 Emissions (tpy)	Stack Height (m)	Exit Temp. (K)	Stack Diam. (m)	Exit Velocity (m/s)	Profile Method[2]
	VIEVE	COMPANY-MISSISSIPPI LIME CO	MO1860001	757,697	4,206,939						
5247	STE. GENE-VIEVE	MISSISSIPPI LIME COMPANY-MISSISSIPPI LIME CO	NEI MO1860001	757,666	4,206,950	106	23	469	3.4	6	Tier 3
5248	STE. GENE-VIEVE	MISSISSIPPI LIME COMPANY-MISSISSIPPI LIME CO	NEI MO1860001	757,697	4,206,981	105	23	469	3.4	6	Tier 3
5261	STE. GENE-VIEVE	MISSISSIPPI LIME COMPANY-MISSISSIPPI LIME CO	NEI MO1860001	757,561	4,206,988	1,290	35	343	1.7	11	Tier 3
5262	STE. GENE-VIEVE	MISSISSIPPI LIME COMPANY-MISSISSIPPI LIME CO	NEI MO1860001	757,735	4,206,971	1,394	35	343	1.7	11	Tier 3
5263	STE. GENE-VIEVE	MISSISSIPPI LIME COMPANY-MISSISSIPPI LIME CO	NEI MO1860001	757,727	4,206,997	1,505	35	344	1.7	13	Tier 3
5264	STE. GENE-VIEVE	MISSISSIPPI LIME COMPANY-MISSISSIPPI LIME CO	NEI MO1860001	757,550	4,206,964	67	35	346	2.1	9	Tier 3
5265	STE. GENE-VIEVE	MISSISSIPPI LIME COMPANY-MISSISSIPPI LIME CO	NEI MO1860001	757,524	4,206,924	77	35	346	2.1	9	Tier 3
5267	STE. GENE-VIEVE	MISSISSIPPI LIME COMPANY-MISSISSIPPI LIME CO	NEI MO1860001	757,633	4,206,999	2	20	367	1.1	15	Tier 2
5270	STE. GENE-VIEVE	MISSISSIPPI LIME COMPANY-MISSISSIPPI LIME CO	NEI MO1860001	757,627	4,206,989	1	20	362	1.2	11	Tier 3
5271	STE. GENE-VIEVE	MISSISSIPPI LIME COMPANY-MISSISSIPPI LIME CO	NEI MO1860001	757,540	4,206,931	1,199	35	343	1.7	11	Tier 3
5276	ST. LOUIS	AMERENUE-MERAMEC PLANT	NEI 7515	732,584	4,253,799	5,195	107	463	4.9	33	Tier 1
5277	ST. LOUIS	AMERENUE-MERAMEC PLANT	NEI 7515	732,631	4,253,790	6,463	107	447	4.3	31	Tier 1
5278	ST. LOUIS	AMERENUE-MERAMEC PLANT	NEI 7515	732,677	4,253,784	2,359	76	436	3.4	27	Tier 1
5279	ST. LOUIS	AMERENUE-MERAMEC PLANT	NEI 7515	732,714	4,253,779	2,430	76	436	3.2	27	Tier 1
5287	MARSHALL	MARSHALL MUNICIPAL UTILITIES-MARSHALL MUNICIPAL UTILITIES	NEI 7524	482,098	4,330,328	1,184	50	450	1.5	18	Tier 2

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5290	MARSHALL	MARSHALL MUNICIPAL UTILITIES-MARSHALL MUNICIPAL UTILITIES	NEI 7524	482,113	4,330,323	265	34	433	1.4	6	Tier 2
5292	SIKESTON	SIKESTON POWER STATION-SIKESTON POWER STATION	NEI 12763	801,228	4,086,762	6,236	137	411	4.6	2	Tier 1
5293	ST. LOUIS	ANHEUSER-BUSCH INC-ST LOUIS	NEI 34732	742,736	4,275,786	2	30	371	1.2	3	Tier 2
5295	ST. LOUIS	ANHEUSER-BUSCH INC-ST LOUIS	NEI 34732	742,775	4,275,743	176	69	450	3.0	6	Tier 2
5296	ST. LOUIS	ANHEUSER-BUSCH INC-ST LOUIS	NEI 34732	742,750	4,275,704	256	69	450	3.0	6	Tier 2
5297	ST. LOUIS	ANHEUSER-BUSCH INC-ST LOUIS	NEI 34732	742,781	4,275,753	249	69	450	3.0	6	Tier 2
5298	ST. LOUIS	ANHEUSER-BUSCH INC-ST LOUIS	NEI 34732	742,800	4,275,764	158	69	450	3.0	6	Tier 2
5299	ST. LOUIS	ANHEUSER-BUSCH INC-ST LOUIS	NEI 34732	742,759	4,275,714	3,066	69	461	3.0	6	Tier 2
5302	ST. LOUIS	ANHEUSER-BUSCH INC-ST LOUIS	NEI 34732	742,739	4,275,677	2,339	69	439	3.0	6	Tier 2
5304	ST. LOUIS	ANHEUSER-BUSCH INC-ST LOUIS	NEI 34732	742,711	4,275,740	4	22	486	1.2	9	Tier 2

[1]UTM Zone 15 values in all cases.

[2]Three methods were possible to convert annual total emissions data from the NEI into hourly temporal profiles required for AERMOD, based on availability of data:

Tier 1: CAMD hourly concentrations to create relative temporal profiles.
Tier 2: EMS-HAP seasonal and diurnal temporal profiles for source categorization codes (SCCs).
Tier 3: Flat profiles

United States
Environmental Protection
Agency

Office of Air Quality Planning and Standards
Air Quality Strategies and Standards Division
Research Triangle Park, NC

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