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URBAN AIRSHED MODEL STUDY OF FIVE CITIES

(Summary Report)

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(Summary Report)

By

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U. S. ENVIRONMENTAL PROTECTION AGENCY

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Abstract

The 5-City study embodied two major elements. These are (1) a demonstration of the "low-cost" application of the Urban Airshed Model (UAM) and, (2) the use of the model to assess peak ozone impacts in several cities (New York, St. Louis, Atlanta, Dallas-Fort Worth and Philadelphia) due to various emissions strategies.

The Urban Airshed Model (UAM) is EPA's preferred model for conducting ozone air quality simulation analyses. Faced with nearly 100 ozone nonattainment areas, concerns were raised about feasibility of widespread applications of a complicated model like the UAM. The "low-cost" element of the project addressed applications related concerns by outlining procedures which reduce both the technical complexities and resources typically associated with UAM modeling.

The project was conducted over a 15 month timeframe (July, 1988 - November, 1989) covering a period during which various emissions related issues drew significant public interest and scrutiny. At the onset of the study, the project served as a timely tool to address the ozone impact implications related to alcohol blended fuels, mobile source evaporative running losses, and Reid Vapor Pressure (RVP) reductions. Similarly, during the early project stages the role of natural hydrocarbon emissions (biogenics) on ozone precursor control calculations began to emerge as a major ozone air quality issue. The later stages of the project coincided with the Clean Air Act (CAA) amendment efforts which included lengthy debates on alternative fuels, particularly methanol, and numerous discussions on the relative merits of hydrocarbon and oxides of nitrogen (NOx) control measures. Throughout this period, UAM analyses were performed to provide information for planning purposes and policy decisions on the aforementioned topics.

The project is documented in this Summary Report and the following 5 topic reports:

Report 1. Demonstration of Low-Cost Application of the Model to the City of Atlanta and the Dallas-Fort Worth Metroplex Region

Report 2. Evaluation of Base Case Model Performance for the Cities of St. Louis and Philadelphia Using Rich and Sparse Data Bases

Report 3. Low-Cost Application of the Model to Atlanta and Evaluation of the Effects of Biogenic Emissions on Emission Control Strategies

Report 4. A Low-Cost Application of the Urban Airshed Model to the New York Metropolitan Area and the City of St. Louis (note, this report reflects Phase I efforts from FY-88)

Report 5. Low-Cost Application of the Model to Future Year SIP Control and Alternative Fuel Strategies for Dallas-Fort Worth, Atlanta, Philadelphia, and St. Louis

The Summary Report condenses key material from each report and synthesizes key results and conclusions for the entire study. Reports 1 and 2 address the "low-cost" testing of the UAM. Reports 3-5 document the results of the emissions strategy analyses. This preliminary overview provides a synopsis of the project structure and principal findings.

Low-Cost Applications (Reports 1 and 2)

As part of this study a set of procedures referred to as the Practice for Low-cost Application in Nonattainment Regions (PLANR) approach was developed to demonstrate UAM applications using routinely available data. The approach relies upon routinely available meteorological and air quality data to formulate UAM input files. Existing meteorological, air quality and emissions data are transformed to more highly resolved (in space, time and chemical composition) data fields through the use of default paramatization and surrogate substitution schemes to drive the UAM. Historical UAM applications typically have relied on special field studies to collect air quality and meteorological data to supplement routinely available data. Thus, major cost savings result from PLANR by eliminating special field monitoring programs.

Although ozone concentrations were simulated for 5 cities, only two cities - Atlanta and Dallas-Fort Worth - truly reflect "PLANR" applications. Special field studies had been performed previously on the remaining cities. More importantly, the PLANR approach may be sufficient only for certain cities which are considered relatively uncomplicated. For example, the combination of simple terrain and prevailing climatological features as well as a separation from major pollutant transport corridors may permit simplified modeling approaches in cities

such as Atlanta and Dallas-Fort Worth. Report 1 presents PLANR base case[1] applications to Atlanta and Dallas-Fort Worth. These base case applications exhibited good performance for Dallas-Fort Worth and reasonable performance for Atlanta. Both applications identified critical deficiencies in routinely available data bases which must be addressed for future "low-cost" applications.

A PLANR approach was emulated for St. Louis and Philadelphia by degrading the rich observational bases supplied by the original field studies. The degradation was not systematic. Elements of the rich data base considered to be "routinely available" were retained, but the remaining elements which reflected measurements based on intensive field studies were rejected. This design permitted parallel comparison of model performance using disparate data bases. Report 2 presents the comparison study which suggested that the PLANR approach is not adequate for cities like Philadelphia which are complicated by regional pollutant transport.

Emission Strategy Results (Reports 3-5)

Emissions strategy results reflecting simulations considering the importance of biogenic emissions and ozone impacts associated with alternative fuels and various hydrocarbon and NOx control measures are presented in Reports 3-5. Complete consistency in emissions strategies among all cities was not adhered to as budget and time restrictions forced certain city specific emission strategy designs. For example, the design of simulations for Atlanta was influenced by the fact that it was a test city for biogenics sensitivity. Based on the sets of emissions strategies among the 5 cities, several major findings are reported:

1) biogenic emissions can affect ozone precursor control calculations and must be included in modeling analyses,

2) hydrocarbon control measures in the absence of NOx controls by themselves will not exacerbate peak ozone,

[1]base case applications refer to simulations using best emissions estimates and comparing model results with observed pollutant concentrations

3) effectiveness of combined hydrocarbon and NOx control measures should be assessed on a case by case basis as the direction of benefit on peak ozone appears to be city dependent,

4) implementation of pure component alternative fuel strategies (M100, CNG) or proposed tightening of tailpipe emissions limits will cause small but beneficial impacts on peak ozone, and

5) conversion to alcohol blended fuels will have negligible impact on peak ozone beyond the benefits gained from reducing gasoline volatility.

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1 INTRODUCTION

BACKGROUND

EPA's 5-City UAM study applied the Urban Airshed Model (UAM) to the cities of New York, St. Louis, Atlanta. Dallas-Ft. Worth, and Philadelphia. The 5-City UAM study was motivated by the perceived need that gridded photochemical air quality simulation models would encounter widespread use in addressing ozone precursor control requirements for post-87 State Implementation Plans (SIPs). Previous applications of models like the UAM generally were conducted with the benefit of an intensive site specific field study designed to collect air quality and meteorological data to drive and evaluate performance of the model. Faced with over 50 ozone nonattainment areas, the requirement to conduct separate field studies for each model application could be prohibitively expensive. Consequently, EPA initiated the 5-City project to determine the feasibility of applying the UAM with routinely available data (i.e., without a field study). For perspective, combined costs for a modeling application with a field study would range from one to several million dollars; costs for a model application with routine data would range from $100,000 to $400,000.

Commencing in the summer of 1988, the study was sponsored principally by EPA's Offices of Air Quality Planning and Standards (OAQPS), Policy Planning and Evaluation (OPPE), Research and Development (ORD), and Regional Offices III, IV and VI. EPA's Office of Mobile Sources (OMS) provided guidance on mobile source emissions. Systems Applications, Incorporated (SAI) performed the modeling analyses discussed in this report. Besides conducting a "paper" study, the project resulted in a transfer of the UAM system to participating States -Georgia, Maryland, and Texas. Previous UAM capability was largely limited to California and New York. In addition to investigating the feasibility of lower cost UAM applications, the project provided data bases for assessing the impact on ozone concentrations due to alternative fuels, biogenic volatile organic compound (VOC) emissions, hydrocarbon and NOx control strategies. Overall project objectives included:

1. Demonstration of UAM base case application with routine data (referred to as the Practice for Low-cost Application in Nonattainment Regions -PLANR).

2. Comparison of model behavior based on rich (i.e., with field study) and sparse (PLANR procedure) data bases.

3. Demonstrating use of the UAM for SIP control strategy evaluations.

4. Determining impact of various alternative fuels on ambient ozone levels.

5. Determining the effect of biogenic emissions on ozone precursor control requirements.

6. Distributing UAM technology to participating States.

7. Developing an Emissions Preprocessing System (EPS) which translates SIP/county level emissions inventories into gridded, speciated and time variant UAM input files.

Results of the project are compiled in 5 reports (listed below) organized to reflect the major objectives.

Report 1. Demonstration of Low-Cost Application of the Model to the City of Atlanta and the Dallas-Fort Worth Metroplex Region

Report 2. Evaluation of Base Case Model Performance for the Cities of St. Louis and Philadelphia Using Rich and Sparse Data Bases

Report 3. Low-Cost Application of the Model to Atlanta and Evaluation of the Effects of Biogenic Emissions on Emission Control Strategies

Report 4. A Low-Cost Application of the Urban Airshed Model to the New York Metropolitan Area and the City of St. Louis (note, this report reflects Phase I efforts from FY-88)

Report 5. Low-Cost Application of the Model to Future Year SIP Control and Alternative Fuel Strategies for Dallas-Fort Worth, Atlanta, Philadelphia, and St. Louis

The remainder of this summary discusses key results from each report.

OVERVIEW OF THE MODELING PROCESS

A brief overview of the modeling process will facilitate comprehension of project results. The UAM is a gridded photochemical air quality simulation model which produces hourly concentrations of ozone, hydrocarbons, nitrogen oxides and other species for several vertical layers (usually 4 or 5) in grid cells (having a horizontal dimension from 2 to 8 km) which overlay the city and surrounding area of interest. Ozone analyses conducted with photochemical grid models typically are comprised of 5 steps:

1. Compiling air quality, meteorological and emissions data to develop current year base case UAM input files and provide air quality observations to evaluate base year model performance.

2. Conducting diagnostic analyses. The principal purpose of diagnostic analyses is to properly characterize the system. Nevertheless, the visible product is enhanced model performance (i.e., better spatial and temporal agreement with observed data). Diagnostic runs refer to simulations based on adjustments of input data within the limits of known data uncertainty to better understand physical/chemical conditions.

3. Projecting base case emissions to future year base case emissions files.

4. Developing future year emissions control strategy files which reflect chosen control measures such as basin wide reductions in VOC or alternative fuel scenarios.

5. Performing future year simulations and assessing effectiveness of various strategies.

The PLANR approach refers to specific procedures for using available data minimizing uncertainty associated with sparse data sets. For example, the PLANR approach used in this project (and described below) for Atlanta and Dallas relied on available meteorological and air quality data from existing monitoring programs. In contrast, specific field programs designed to collect extensive data for model inputs have been set up in St. Louis, Los Angeles and other cities. The modeling protocol followed for either approach resembles the steps listed above.

Existing modeling data bases from previous studies were available

for New York, St. Louis, and Philadelphia; current base modeling years associated with those cities are 1980, 1976, and 1979, respectively. Current base year modeling data bases were developed for Atlanta (1984) and Dallas-Fort Worth (1985). All 5 cities used 1995 as the future year for assessing impact on ozone of various emissions control strategies. It should be noted that simulations performed for this project are intended as demonstrations and do not reflect the modeling effort necessary to comply with post-1987 SIP or proposed Clean Air Act modeling requirements. For example, future modeling applications are likely to use emissions inventories superior to the 1985 NAPAP inventory used in this project. In addition, only one ozone episode was modeled for each city; typically two or more episodes may be required for modeling demonstrations.

2 DESCRIPTION OF PLANR PROCEDURES

The PLANR approach consists of applying the UAM without conducting an intensive field monitoring program. Available data are used as described below for each of three major data categories.

Emissions The PLANR application utilizes the best available emissions inventory, which ordinarily is county based and lacks the required spatial, temporal and chemical resolution needed to drive the UAM. Spatial, temporal and chemical speciation surrogates are used to transform the available inventory into the more highly resolved UAM input files. This "top-down" approach is facilitated with an emissions preprocessing system (EPS), developed as part of the project. The EPS is a group of fortran programs which cross reference source category codes with user supplied surrogates (e.g., population distribution, land use data, species profiles) to develop the gridded, hourly and speciated UAM emissions inputs.

Air Quality The UAM must be provided initial concentrations of all non-steady state chemical species (currently 23) for every grid cell and boundary concentrations over the duration of the simulation. Generally insufficient routinely available data exist to adequately characterize these concentration fields. Thus, to minimize the influence of initial concentrations, the UAM simulation time is extended from 1/2 to 1 day before the actual period of high ozone. Similarly, the upwind modeling domain is expanded to lessen the influence of boundary conditions. Available data are utilized when possible for initial and boundary concentrations; however, default concentrations are substituted in the absence of adequate data.

It should be recognized that these approaches for minimizing uncertainty related to sparse air quality data place greater reliance on emissions data. In effect the emissions are developing the boundary and initial concentration fields of interest. Accordingly, compilation of accurate emissions inventories is a crucial step in applying the UAM.

Meteorology Generally, data are available which can be used to develop the wind fields and mixing heights for the UAM. The PLANR approach relies on the best use of available data from local monitoring networks, National Weather Service (NWS), Federal Aviation Administration (FAA) and other sources such as existing special field studies. For clarification throughout

this report, routinely available data refer to data sources separate from specially designed field programs.

Diagnostic techniques A more complete explanation of the PLANR approach as it is imbedded in the modeling protocol described above is provided in Report 4. However, diagnostic analyses can play an integral role in modeling and should be discussed briefly. Diagnostic analyses are an evaluation of the adequacy of model inputs in characterizing the system (i.e., prevailing meteorological, emissions and chemical characteristics). The need for diagnostic analyses often arises from attempting to explain poor model performance; although, diagnostic analyses should be conducted on model inputs independent of simulation results to check for obvious errors of omission (e.g., major emissions sources) and mischaracterization. The most controversial diagnostic analyses are model simulations in which input variables are adjusted to determine possible reasons for poor model performance. Any adjustments are based on a reasonable understanding of the system and within constraints related to inherent uncertainty in data and best technical judgement as to why certain available data are not representative. At the time of this project, clear guidelines on model performance criteria or acceptable use of diagnostic analysis procedures were not available. In the context of the 5-City project, the PLANR diagnostic analysis procedures consisted of:

1. checking the meteorological, emission and air quality fields for obvious omissions and mischaracterized events,

2. performing a minimal number of simulations (1 to 3 beyond the unadjusted base case simulation).

Specifics regarding diagnostic analyses for the individual cities are provided in the relevant reports, and discussed briefly in appropriate sections in this summary report.

RATIONALE BEHIND THE PLANR APPROACH

The PLANR approach is best suited to urban areas relatively isolated from long distance transport of ozone and its precursors, and in regions without complex meteorology (e.g., sea breeze effects) or terrain. Therefore, Atlanta, Dallas-Fort Worth (DFW) and St. Louis are considered good candidates for the PLANR techniques.

Uncertainty due to data base design and resolution exists in all three types of data. Historically, emission inventories have not included major sources such as automotive evaporative running losses and biogenic emissions, and they lack adequate spatial, temporal, and chemical resolution. Typically, air quality monitoring data reflect a small number of receptor/impact sites located in and downwind of central urban cores. While these sites are useful for evaluating model performance, upwind locations are required to specify boundary concentrations. Air quality data generally are inadequate in their temporal and chemical resolution, and there is often a total lack of measurements to characterize pollutant concentrations in grid cells aloft. Also disturbing is the lack of meteorological data to characterize surface and upper air flows and mixing heights. For example, FAA surface wind monitors located in urban areas report wind speed and direction only averaged over a few minutes each hour; the UAM requires true hourly averages of speed and direction. Upper air soundings which are used to define hourly elevated wind flows and mixing heights often are located outside the domain of interest and are reported only two times a day. Obviously, assumptions must be invoked with available data to attain satisfactory model performance.

The task becomes tractable when one assumes that the available emissions inventory is fixed and not subject to alteration (other than episodic adjustments such as temperature sensitivity of evaporative emissions not accounted for in "typical" summer day inventory). This assumption allows us to focus on procedures for overcoming uncertainties in the available air quality and meteorological data base, and may be appropriate in that emissions are the ultimate target of control and analysis. The starting point for emission inputs is the available emission inventory (e.g., the 1985 NAPAP inventory was used in this project). Emission inventories which are being compiled as part of the post-87 SIP requirements are essentially similar to the NAPAP inventory with respect to spatial (county level), temporal (summer day average), and chemical resolution (not speciated). The UAM Emission Processing System translates the NAPAP level inventory into resolved UAM files by cross referencing spatial, temporal and speciation surrogates with different source category codes. Example surrogates include population distribution, historical diurnal traffic profiles. An analogous, intensive approach might require developing an inventory for each grid cell by every hour. When guidance and further documentation on the use of the EPS are completed, the system will be a useful tool for model users in bridging the gap between SIP inventories

and UAM emission files.

The influence of initial conditions on hourly concentrations of interest is reduced as the simulation period is lengthened. Simulations often start at noon the day before a high ozone event. In effect, the concentration field is then influenced to a greater extent by local emissions relative to initial concentrations. To reduce dependence on boundary conditions, the upwind modeling domain is specified sufficiently large so that the flux of species entering the inner area of greatest interest has been developed primarily by upwind emission fields. Sensitivity tests on the necessary simulation period and extent of upwind domain needed to minimize the effects of initial and boundary conditions can be performed to optimize computer storage and speed requirements. Recommended "clean" default initial and boundary air quality concentrations, representative of background conditions, are presented in the reports.

Meteorological data present very difficult problems when constrained to routinely available data, particularly when limited to NWS and FAA data. Mixing heights and wind speeds set dilution rates for ozone, primary precursors and intermediate species involved in ozone formation. Misalignment of urban plumes due to errors in wind direction could have significant impact on assessing the relative contributions of different source groups. The PLANR approach uses available morning and afternoon National Weather Service (NWS) soundings (or other available sources) to develop diurnal profiles of mixing heights and upper wind velocities. Soundings can be located in rural areas outside the modeling domain. Preferably, the most representative sounding is used. Available surface wind data combined with upper wind data are used to drive the diagnostic wind model (DWM) which generates hourly, gridded wind velocities for all vertical levels in the UAM domain. The DWM interpolates wind velocities between stations and accounts for terrain induced effects.

Once the input files are developed and the first simulation completed, results are analyzed to determine how adequately resultant meteorological and concentration fields represent actual conditions. At this point advantage of diagnostic simulations is taken, if necessary, to establish a better representation of episode meteorology.

3 DEMONSTRATION OF LOW-COST APPLICATION OF THE MODEL TO THE CITY OF ATLANTA AND THE DALLAS-FORT WORTH METROPLEX REGION (REPORT 1)

The Atlanta and Dallas-Fort Worth base case applications have been separated from the other cities because historical modeling data bases are not available. Hence, they best reflect PLANR approaches using routinely available data and perhaps offer a glimpse into similar future applications for other cities. Current year model inputs were based on 1985 NAPAP emissions inventory and air quality and meteorological data from 1984 (Atlanta) and 1985 (Dallas-Fort Worth).

ATLANTA RESULTS

The Atlanta simulation for June 4, 1984 (starting at 1200 June, 3) produced reasonable temporal and spatial tracking of observed ozone, but tended to underpredict peak values. The model produced a region wide daily peak ozone value of 132 ppb, relative to observed value of 147 ppb. A diagnostic run which accounted for additional upwind biogenic VOC and eliminated a poorly sited surface wind station was considered the final base case simulation. Note, that the Atlanta study included biogenic VOC emissions which constituted a significant fraction (59% - mass basis) of total VOC emissions. Figure 1 presents the station plots of predicted versus observed hourly ozone for three monitors in the Atlanta domain.

Given the level of peak ozone underprediction, a sensitivity analysis was performed which assumed a 50% reduction in the reported FAA wind speeds to determine the importance of surface level wind measurements. FAA wind stations report wind speed and direction averaged over a 1-3 minute time span; the UAM requires hourly average representations. Consequently, the FAA reported measurements would tend to overstate hourly average speeds. Further justification for this adjustment was based on quantified differences between collocated hourly average and instantaneous monitors in California. The model simulation with reduced wind speeds resulted in improved peak ozone performance (predicted = observed=147 ppb) and better diurnal tracking (Figure 2).

DALLAS-FORT WORTH RESULTS

The DFW simulation spanned two and a half days (August 29-31, 1985). The last day was a Saturday which required weekend emissions adjustments (provided as part of the NAPAP inventory).

Biogenic emissions were also included. Model performance was considered very good as predicted hourly ozone closely tracked observed values for most surface stations (Figure 3). The predicted regional peak ozone value (164 ppb) over the 2-1/2 day simulation compared favorably with an observed value of 170 ppb. Also, model predictions accurately tracked (spatially and temporally) observed NOx concentrations.

A preliminary diagnostic analysis revealed that the available temperature soundings did not produce realistic mixing heights. Consequently, default values representing typical summer day mixing heights were taken from Holzworth.

4 EVALUATION OF BASE CASE MODEL PERFORMANCE FOR THE CITIES OF ST. LOUIS AND PHILADELPHIA USING RICH AND SPARSE DATA BASES (REPORT 2)

Previous UAM studies using intensive data bases obtained in special field studies had been conducted for St. Louis and Philadelphia as part of the Regional Air Pollution Study (RAPS) and Philadelphia Oxidant Study (POS), respectively. The intention of this part of the project was to compare both base case model performance and ozone response to VOC control by conducting side by side UAM simulations based on detailed (i.e., the RAPS and POS data bases) and sparse (i.e., data routinely available) observations. Such a comparison might provide insight on the limitations of the PLANR approach as well as isolate key input parameters which could optimize data gathering in future field studies.

BASE CASE RESULTS

St.Louis

The Regional Air Pollution Study provided intensive field data for an ozone episode on July 13, 1976. This day was modeled previously with an earlier version of the UAM with carbon bond-II (CB-II) chemistry (the current UAM utilizes CB-IV, a more recently developed mechanism). Model runs based on the RAPS data are referred to as RAPS simulations. A third approach referred to as SIMPLE used no diagnostic simulations and very limited meteorological data. Base case model performance statistics for four approaches (RAPS-CBII, RAPS-CBIV, PLANR, and SIMPLE) are presented in Table 1. This discussion is restricted to comparisons between RAPS-CBIV and PLANR; that is , the same model with different inputs. The PLANR approach was based on routine air quality and meteorological data. The 1976 emission files from the RAPS modeling were used in all approaches (with translation of CB-II to CB-IV categories), and biogenic emissions were not included. The PLANR results presented in Table 1 reflect an assumed 50% wind speed reduction in NWS/FAA surface monitors (refer to the related discussion above on Atlanta). The PLANR peak predicted ozone of 195 ppb is compared with observed (222 ppb), RAPS-CB-IV (242), RAPS-CBII (174) and SIMPLE (118). Good overall performance resulted from the PLANR application, although not as impressive (or expected) as the RAPS-CBIV.

The analysis is complicated by constraining the domain size and simulation period for the PLANR approach to that used by the

RAPS-CBIV. Recall that the PLANR approach recommended expanding upwind domain and simulation time in the absence of adequate air quality data. However, to be consistent with the existing RAPS simulations, a short one day simulation period and limited domain was retained for the PLANR application. Moreover, the PLANR initial and boundary values were based on relatively clean defaults, the impact of which would have been mitigated by imposing a larger domain and simulation period. A recommended improvement for these analyses would utilize the original RAPS initial and boundary conditions with the PLANR meteorological inputs. This would isolate differences between the PLANR and RAPS approaches to a set of meteorological variables, rather than sets of both meteorological and air quality variables - as we have seen, these simulations are very sensitive to meteorology.

Philadelphia

The Philadelphia Oxidant Study (POS) provided detailed data for an ozone episode on July 13, 1979. Base case model performance statistics (Table 2) exhibit poor peak ozone performance for the PLANR application. Although the predicted PLANR peak of 187 ppb compares favorably with the observed peak (205 ppb) and the POS peak (236 ppb), the PLANR peak is located about 45 km east of the observed peak, and at the location of the observed peak the PLANR simulation underpredicts by 46%.

Two factors complicate the Philadelphia analysis: 1) the area is not isolated from intercity transport of ozone and its precursors and 2) July 13 was an extreme stagnation day which limits thorough description of the wind fields and impairs the models ability to spatially track concentration gradients. These results suggest that the PLANR approach is not recommended for complicated ozone episodes.

Differences in the simulation results may result from different diagnostic approaches as well as the quality of observed data. The original POS modeling with CB-II chemistry has been criticized for seemingly excessive iterations of diagnostic simulations. In contrast, only two diagnostic simulations were performed for the Philadelphia PLANR application.

CONTROL STRATEGY ANALYSIS

Perhaps of greater interest are concentration prediction comparisons from across-the-board VOC control strategies between the PLANR and RAPS approaches. Ultimately, the UAM will have to demonstrate attainment of the ozone NAAQS. An important interpretive problem exists when peak model predictions under or overpredict observed peak values. Three approaches (for a single episode) can be used to define attainment for a particular episode[1]:

1. unbiased acceptance of model predictions, i.e., disregard difference between peak and observed values and accept the control required to attain predicted value of 120 ppb,

2. decrement approach (in terms of ppb) which requires a predicted peak ozone reduction equivalent to the observed peak minus 120 ppb, and

3. the percentage approach which requires a percentage decrease in predicted peak ozone equivalent to percentage decrease required to lower observed peak ozone to 120 ppb.

These approaches have separate advantages/disadvantages. For example, the unbiased approach might be desirable in cases of overprediction to provide a conservative buffer. On the other hand, biased techniques might be needed to prevent understated control targets when model predictions underpredict observed values.

Results of the three methods for St. Louis are presented in Figure 4. In terms of estimating the level of VOC control to demonstrate attainment, excellent agreement exists between PLANR (73% control) and RAPS (78%) with the decrement procedure. The Philadelphia results (Figure 5) exhibit large differences (at various VOC control levels) with all three approaches, and suggest that the PLANR approach must be considered carefully before being applied in complex areas.

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[1]the issue of how many episodes are required to demonstrate attainment based on the statistical representativeness of the ozone NAAQS is beyond the scope of this project

CONCLUDING REMARKS ON PLANR APPLICATIONS

Some additional comments based on the PLANR applications presented in Reports 1 and 2 are provided before proceeding to Reports 3-5 which address control strategy issues. The base case performance results for Atlanta, Dallas-Fort Worth and St. Louis generally track observed hourly ozone data in space and time, but typically underpredicted peak ozone. In these analyses diagnostic simulations emphasized meteorological parameters; however, the emission data bases in these studies - the 1976 RAPS, 1979 POS, and 1985 NAPAP - are suspected of containing significant gaps. For example, the RAPS and POS data do not include biogenic or running loss emissions and the NAPAP data were designed to be accurate on a national scale. Since the PLANR approach underpredicted and the detailed approach overpredicted in both cities, it is likely that inclusion of these missing sources would upgrade the PLANR performance relative to the RAPS and POS applications.

Model users must be aware of the dangers of using limited data bases. When diagnostic analysis work is phrased with seemingly logical expressions like "adjustments within the limits of data uncertainty", the likelihood that good results are achieved for the wrong reasons is increased. Accordingly, very explicit and careful guidance on diagnostic analysis procedures must eventually be provided to model users. Equally important is the recommendation that routine meteorological monitoring networks which rely heavily on NWS/FAA stations be enhanced and redesigned to reduce uncertainty in key model inputs.

One finding of significance is that estimated control requirements depend on the model's ability to predict base case ozone accurately. This raises important questions which supercede the rich/sparse data base question. In concept, the model provides a tool for the decision maker to judge which of several different technically feasible strategies will produce the greatest benefit. Several metrics (e.g., grid cells above certain values, different averaging times, total risk, population exposure) can be produced which take advantage of the spatial and temporal resolution provided by the model. When applied in a relative context for evaluating the merits of different control approaches, the requirement for superior model performance probably is less important, and lower cost applications become more viable.

5 LOW-COST APPLICATION OF THE MODEL TO ATLANTA AND EVALUATION OF THE EFFECTS OF BIOGENIC EMISSIONS ON EMISSION CONTROL STRATEGIES (REPORT 3)

Interest in the role of VOC emissions from vegetation (biogenic emissions) in ozone formation and precursor control escalated when Chameides et al. of Georgia Institute of Technology published a paper in the journal Science in the fall of 1988. The Chameides study modeled an Atlanta ozone episode (June 4, 1984; peak observed ozone = 147 ppb) with EPA's OZIPM4 model, a Lagrangian approach lacking the spatial resolution of the UAM. The analysis looked at the amount of anthropogenic VOC control required with and without biogenic emissions in the total VOC inventory. The OZIPM4 model indicated that significantly greater VOC control would be required to reduce peak ozone to 120 ppb when biogenic emissions are included relative to anthropogenic emissions only.

A major concern with the OZIPM4 application was the model's inability to properly account for relative spatial distributions of anthropogenic and biogenic emissions. The 5-City project provided a timely vehicle to reproduce the Georgia Tech work with more detailed grid modeling. Base case performance results for Atlanta have been discussed above. Results of across-the-board anthropogenic VOC controls and constant NOx emissions for both cases (with and without biogenics) in Figure 6 are based on the original wind fields which produced a predicted peak of 132 ppb with biogenic emissions. The results clearly show the same general effect observed in the Georgia Tech. study - inclusion of biogenic emissions will increase the predicted level of anthropogenic VOC control required to reduce peak ozone for Atlanta on June 4, 1984. To reach predicted attainment based on normalized percentage reductions of peak ozone, the biogenics and nonbiogenics cases require 100% and 62% anthropogenic VOC control, respectively.

Estimated biogenic emissions constitute roughly 59% of all VOC emissions (mass basis) for the modeling day. Isoprene which is a very reactive VOC category comprises about 19% of the biogenic estimates. An uncertainty factor of +/- 200% typically is associated with biogenic emission estimates. It must be emphasized that these results are not generalized for other urban areas and, perhaps, for different episodes in Atlanta. Atlanta may be distinctive for three reasons. First, Atlanta is predominantly a residential/commercial city with a limited urban core relative to other major urban areas. Hence, the ratio of

biogenic to anthropogenic emissions might also be greater throughout the domain, relative to other cities. Second, biogenic emission models exhibit extreme temperature sensitivity, and southern cities are characterized by high summer temperatures. Lastly, the distribution of vegetation types in the Atlanta area might be classified as high emitters.

The original base case performance results were improved when reported FAA wind speeds were reduced 50% (Figure 2). Results from identical VOC control strategy simulations with the new windfield (Figure 7) suggest a reduced impact, relative to the original windfield, on control calculations due to biogenic emissions. Simulations based on the new windfield produced VOC control levels of 63% and 52% to reach attainment for biogenic and nonbiogenic cases, respectively (compared to 100% and 62% with the original windfield). Rather than deciding which windfield is more representative, the new windfield might be viewed as an additional modeling day with a slower mean trajectory. In this scenario anthropogenic emissions now comprise a greater fraction of total VOC emissions because the slower wind speed increases the residence time ratios of anthropogenic to biogenic emissions, relative to the original windfield with higher wind speeds.

...ded photochemical models enable air quality pl
estimate future air quality as a function of vario
emission scenarios. Once a current year base case
accepted, emissions are projected to the future des
account for expected changes in growth, development,
distribution and technology. The two remaining repo
are similar in that they present results on future ye
strategies. Various emissions strategies are present
cities in the two reports. Since the emphasis on this
the project was strategy analysis, the best available
bases were used (e.g., RAPS and POS for St. Louis and
Philadelphia). The New York analyses utilized inputs f
Oxidant Modeling for the New York Metropolitan Area Pro
(OMNYMAP) with modifications as described in Report 4.

Report 4 reflects FY-88 efforts which developed oxygenate
fuel/gasoline blend scenarios as well a limited number of
control strategies (strategies other than fuel based are r
to as SIP strategies). Several 1995 scenarios were design
illustrate the effect on ozone due to changes in gasoline p
vapor pressure (RVP), consideration of evaporative running
losses, substitution of oxygenated blends, and selective
reduction of highly reactive VOCs. This discussion is limit
the following RVP and oxygenated fuel scenarios (scenario
numbering is consistent with that used in Report 4 - base cas
refers to projection of 1985 emissions to 1995 assuming exist
controls):

New York

1. base case with mobile emissions at current RVP (11.5 psi).
2. base case with low RVP (9.0 psi).
3. base case with 100% market penetration of 10% ethanol blend at low RVP and 1 psi exemption (10.0 psi).
4. base case at current RVP (11.5 psi) without running losses.

St. Louis

1. base case with mobile emissions at current RVP (9.0 psi).

2. base case with low RVP (7.8 psi).

5. base case with 50% market penetration of 10% ethanol blend at low RVP and 1 psi exemption (8.8 psi).

6. base case with low RVP (7.8 psi) and 100% penetration of ethyl tertiary butyl ether (ETBE) blended fuel with a 2% oxygen content.

7. base case with mobile emissions at current RVP (9 psi) and a near doubling of evaporative running losses.

[1]SIP RUN X. base case with low RVP and enhanced I/M and other stationary source measures to achieve an overall VOC reduction of 40%.

SIP RUN Y. base case with a 40% VOC reduction targeting most reactive VOC classes.

Emission totals and predicted peak ozone for all scenarios are tabulated in Tables 3 and 4, respectively.

REID VAPOR PRESSURE

Lowering RVP produces VOC emission reductions of 24% and 15% for New York and St. Louis (Table 3). Model results for peak ozone indicate negligible impact on ozone for New York and approximately a 3% decrease for St. Louis (Table 4). The New York results are confounded by regional transport of ozone and ozone precursors (i.e., high boundary concentrations) which severely limit sensitivity of local emission changes. In these simulations, boundary conditions were held constant. A commensurate reduction in boundary conditions might have produced greater ozone sensitivity. The apparent small effect on St. Louis peak ozone (i.e., 3% ozone decrease for 15% VOC emissions

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[1]SIP RUN X and SIP RUN Y refer to SIP A and SIP B in Report 4. They are renamed here to avoid confusion with naming convention in Report 5.

decrease) is attributed to the nonlinear ozone response to changes in VOC emissions, which is especially flat during initial incremental emission changes. RVP reductions were brought about by removing the necessary C-4 fraction (mostly butane). No reformulation assumptions to boost octane content following the removal of high octane butane were assumed (ethanol is an octane enhancer).

FUEL BLENDS

Two important factors which potentially impact ozone should be recognized when analyzing modeling studies on oxygenated fuel blends:

1. Splash blending ethanol with gasoline produces RVP increases which result in increased evaporative emission losses. However, evaporative VOCs typically are less reactive relative to total composition of all VOC emissions.

2. The increased oxygen content enhances combustion which should reduce CO emissions. However, CO emission benefits from alcohol blends are a strong function of mobile source distribution. Since modern automobiles with advanced combustion control systems emit less CO, reductions in CO due to use of ethanol blends would be expected to diminish in future years.

[Reformulation assumptions can also enter into these analyses as reformulation can affect the exhaust VOC composition and thus change emissions reactivity.]

The results for New York and St. Louis show that use of ethanol blends have negligible impact (either increase or decrease) on peak ozone beyond that already achieved with RVP reduction. Note that the proper comparisons in Table 4 are between scenarios 2 and 3 (New York) and 2 and 5 (St. Louis). Thus, the effects of increased VOC and decreased CO emissions attendant with use of ethanol blends approximately counterbalance one another.

The ETBE scenario for St. Louis shows a negligible benefits (only a 1 ppb decrease in ozone). ETBE is attractive in that splash blending does not result in RVP increase, yet the combustion benefits due to oxygen increase are retained.

RUNNING LOSS AND SIP SCENARIOS

Running losses are evaporative emissions of VOC occurring while a motor vehicle is in use. The New York scenario 4 and St. Louis scenario 7 were sensitivity analyses motivated by the large uncertainty in these evaporative mobile source emissions. All other scenarios used best estimates of running losses. Reasons for the apparent small changes in peak ozone are identical to those presented above in the RVP discussion. However, at the start of this study EPA used very rough running loss estimates based on limited data. These estimates were added to the evaporative and exhaust emission factors provided by Mobile 3.9 (Mobile 3.9 did not account for running losses). More recent data incorporated in EPA's more recent mobile source model (Mobile 4) suggest that running losses were overstated in the 1995 scenarios in Report 4. [The Atlanta and Dallas-Fort Worth scenarios as well as all 1995 strategies in Report 5 were developed with Mobile 4 - running losses were not considered in the RAPS, POS and OMNYMAP data bases.]

The St. Louis SIP scenarios illustrate the potential differences due to consideration of VOC emissions composition. Scenario X (10% peak ozone reduction) reflects a 40% reduction of all VOC categories. Scenario Y (19% peak ozone reduction) reduced the most reactive carbon bond classes by 80% to obtain a total VOC emissions decrease of 40%.

7 LOW-COST APPLICATION OF THE MODEL TO FUTURE YEAR SIP CONTROL AND ALTERNATIVE FUEL STRATEGIES FOR DALLAS-FORT WORTH, ATLANTA, PHILADELPHIA, AND ST. LOUIS (REPORT 5)

The last part of the 5-City study attempted to illustrate development of future year SIP strategies representing both across-the-board (referred to as Type A) and source category specific (Type B) emission reductions. As the project also coincided with preparation of numerous Clean Air Act proposals, simulations reflecting proposed new gasoline regulations and alternative fuels were conducted for St. Louis, Philadelphia and Dallas-Fort Worth. The alternative fuel strategies are based on vehicles fueled by M100 and CNG and offer more radical approaches than alcohol blends (Report 4) which are technologically compatible with the existing automobile fleet. Simulations based on proposed gasoline regulations go beyond the simple RVP analyses of Report 4 by incorporating specific tailpipe emission constraints.

Due to time and budget restraints similar strategies were not performed in every city. In the strategy descriptions listed below, note that two "1995 base cases" exist for the alternative fuel cities (St. Louis, Dallas and Philadelphia). The first is referred to as "base case" and reflects growth projections of the 1985 NAPAP emissions to 1995 with existing controls. A second base case referred to as "GAS" reflects new proposed gasoline regulations was developed after the original future year base case. Finally, all the 1995 strategies included biogenic VOC emissions; a comprehensive tabulation of all emission totals is provided in Report 5 (as Table 2). The 1995 strategies are listed below:

1. Base case: reflecting source growth projections to 1995 and existing controls with enhanced mobile source I/M and reduced RVP (Atlanta, St. Louis, Dallas and Philadelphia).

2. GAS: base case reflecting most recent CAA proposals including enhanced I/M, reduced RVP, and tighter tailpipe emission limits (St. Louis, Dallas and Philadelphia).

3. M100: base case with assumed 100% penetration (total mobile source fleet) of pure methanol fueled vehicles (St. Louis, Dallas and Philadelphia).

4. CNG: base case with 100% penetration of vehicles fueled with compressed natural gas (St. Louis, Dallas and Philadelphia).

5. SIP Type A: base case with multiple percentage across-the-board VOC emission reductions (Atlanta-30%,60%,90%; Dallas 30%,60%).

6. SIP Type B Scenario 1: base case with VOC reductions from stationary solvent sources and NOx reductions from tighter tailpipe limits and control of major boilers (Atlanta, Dallas and St. Louis).

7. SIP Type B Scenario 2: Identical to SIP Type B Scenario 1 with further control of major boilers to achieve additional NOx reductions.

Please note that the three fuel strategies (GAS, M100, CNG) were based on a 20 mph average speed assumption, which is somewhat lower than speeds in the 1985 NAPAP inventory used for developing the 1995 base case emissions estimates. Care should be exercised when comparing results among the 1995 base case and fuel strategies, since exhaust emissions factors increase with decreasing vehicle speed. Potentially larger differences in peak ozone between the 1995 base case and fuel strategies than reported in Tables 5a,b might result if all 1995 scenarios utilized identical speed assumptions.

RESULTS OF FUEL RELATED STRATEGIES

A listing of daily peak ozone values for fuel strategies are provided in Tables 5a,b - the results suggest:

1. proposed gasoline regulations, M100, and CNG all impart small beneficial impacts on peak ozone,

2. M100 and CNG produce very small peak ozone benefits relative to implementation of new gasoline regulations; CNG produces the greatest benefit.

In addiiton to the above caveat concerning dissimilar speeds, the apparent small impacts from the fuel scenarios might be due to the projected future decrease of the mobile source fraction of total VOC emissions. For example, the 1995 base case emissions for Atlanta and Dallas (Table 2, Report 5) indicate considerable reductions in mobile source VOC relative to 1984 and 1985 base years, despite expected increases in vehicle miles. The

reductions between 1984/1985 and 1995 base cases are substantially larger than the differences between the 1995 base cases (i.e., with and without new gas regulations). The major factor causing these projected differences is automobile fleet turnover. Evidently, the 1995 fleet is very efficient relative to 1985. Interpretations of these analyses should recognize the substantial emission reductions from this "built in" control associated with fleet turnover. Additional substantial VOC reductions (relative to the 1995 base case) are projected with implementation of new gasoline regulations which require tighter tailpipe emission limits.

Emission factors for the M100, CNG and GAS strategies (Table 6 - light duty vehicles) were provided by the Office of Mobile Sources and, to the extent possible, were based on available test data. Relative differences in VOC emission totals between GAS and M100 strategies are due primarily to reduced evaporative loss in M100 vehicles. CNG strategies assume no evaporative losses and lower exhaust emission factors relative to the GAS and M100 strategies. Identical CO and NOx emissions were assumed for the three strategies (M100, CNG and GAS).

Speciation of exhaust gas VOCs for the M100 and CNG scenarios were based on work performed by the California Air Resources Board (CARB). The order of scenarios by exhaust gas reactivity determined by weighted k-OH values (min^{-1}) at 298 K is: GAS - 3107, M100 - 1683, CNG - 130.

In summary, predicted region-wide peak ozone values indicate very small decreases attributed to either M100 or CNG, relative to proposed new gasoline regulations. Given the significant differences among scenarios in both quantity and reactivity within the mobile source fraction, the most plausible explanation for the minimal impact on peak ozone is due to substantial emission reductions predicted to be achieved by both fleet turnover and the new gasoline regulations. The mobile source fraction of total VOC decreases as one proceeds to future years. Imbedded in those emission projections are assumptions on deterioration rates and effectiveness of control devices and efficiencies of I/M programs. Although best estimates of these factors are used in the emissions models, it is possible that they will overstate achievable control.

RESULTS OF SIP STRATEGIES

A listing of the hydrocarbon and combined hydrocarbon and NOx

strategies and associated region wide daily peak ozone values is given in Table 7. From a city specific perspective, the simulations suggest:

Dallas-Fort Worth;

- VOC control appears effective
- NOx control appears to offset benefits from VOC controls

St. Louis;

- combined VOC/NOx controls show benefits; but additional NOx control to maximum levels might exacerbate ozone

Atlanta;

- combined VOC/NOx controls are more effective than VOC only
- combined VOC/NOx with maximum NOx control yields additional benefits
- NOx control by itself is effective.

All SIP strategy results are expressed relative to the 1995 base case. It should be noted that the Type A across-the-board VOC strategies are hypothetical reductions which can not be translated directly to applied control measures. Nevertheless, Type A strategies are simple to construct and useful for developing a general picture of ozone response to VOC controls - they can indicate broad control levels that a package of technology based, source specific control measures should meet. On the other hand, Type B strategies reflect reductions derived from source specific control measures and explicitly account for source distribution and composition (i.e., reactivity). The Type B strategies in this project included control measures resulting in combined reductions in VOC and NOx emissions. Reductions were based on a set of prospective control measures prepared for the South Coast Air Quality Management District (SQAMD). The principal source for VOC reductions came from solvent control; NOx reductions were based on tailpipe restrictions and control from major boilers.

The blend of VOC only and combined VOC and NOx strategies in three cities provides a small opportunity to speculate on the widespread effects of VOC and NOx control measures. For example,

the peak ozone results in Table 7 suggest a strong relation between city and effectiveness of NOx control. Aggressive NOx control appears to reduce peak ozone in Atlanta (scenarios 1 and 2), while additional NOx control (Scenario 2) exacerbates peak ozone in Dallas and St.Louis. Optimum control approaches appear to be case specific and influenced by the emissions (anthropogenic and biogenic) profiles of individual cities. One is tempted to generalize that areas with strong biogenic emission rates are good candidates for NOx control. For example, consider Atlanta and Dallas with 66% and 41% biogenic contributions to the projected 1995 total VOC emissions (Table 2, Report 5), respectively. Such a simple approach should acknowledge the uncertainty factors introduced with the inclusion of natural emissions. What if biogenics actually contribute only 30% in Atlanta, or 60% in Dallas? While natural emissions represent a necessary component in determining control strategy effectiveness, they have added complexity to the control decision process. Clearly, increasing the precision and accuracy of natural and anthropogenic emission rates would increase the confidence in modeling results and provide regulators with clear information for basing decisions on control approaches.

8 CONCLUDING REMARKS

The 5-City study addressed many issues broad in scope ranging from model application procedures to impacts on ozone resulting from specific control strategies. As a result, key findings were spread throughout the five reports and the various sections in this summary report. The following remarks provide a synopsis of important findings and major issues related to project objectives presented in the Introduction.

PLANR APPROACH AND COMPARISON WITH RICH/SPARSE DATA BASES

The PLANR application has been demonstrated in Atlanta and Dallas-Ft. Worth, and to a lesser extent in St. Louis and Philadelphia (i.e., recognizing previous modeling data bases in St. Louis and Philadelphia). The base case performance results ranged from very good (Dallas-Fort Worth) to poor (Philadelphia). Overall, the approach is a useful and relatively inexpensive means of designing and evaluating relative benefits of ozone precursor control strategies with certain provisions:

- the application is limited to areas not complicated by long range transport or difficult meteorology,
- adequate emissions inventories are supplied, and
- uncertainty due to gaps in air quality data is mitigated by expanding the upwind modeling domain and simulation period.

In addition, important fundamental modeling issues including minimum data requirements and appropriate diagnostic analysis procedures were identified (e.g., the adequacy of NWS/FAA wind data in Atlanta). Resolution of those issues must be addressed in the development of guidance on use of PLANR, as well as more detailed applications of this model.

Results from Report 2 on comparing simulation results with rich and sparse data inputs were generally inconclusive. Comparisons were complicated by constraining the domain size and simulation time for the PLANR approach to that used in the original modeling analyses, and suspected omissions in the "so-called" intensive emissions data bases. Three methods for demonstrating attainment when model results do not match observed ozone were presented: 1) unbiased, 2) decrement and 3) percentage. Each method provided a different VOC control target depending on the approach used

(i.e., PLANR or intensive). A consensus approach for demonstrating attainment when model predictions are not closely matched with observed data should be developed.

OVERVIEW OF STRATEGY RESULTS

Although related to one another through photochemical considerations, three areas of interest have been addressed: 1) alternative fuels (including gasoline measures - e.g., RVP reductions), 2) biogenic VOC emissions, and 3) VOC and NOx control measures. Most of the fuel-related strategies showed very little impact on peak ozone concentrations. Substitution of 10% ethanol/gasoline blends produced no significant ozone impact - the increase in evaporative VOCs from a 1 psi exemption apparently is balanced by reduction in CO emissions. The proposed gasoline regulations, conversion to M100 or CNG, all impart small, beneficial effects on peak ozone. The level of impact may be viewed as small, but can be explained by the projected decreasing mobile source fraction of total VOCs, in combination with the nonlinear response of ozone to reductions in VOCs.

Based on our current ability to quantify natural VOC emissions, the Atlanta biogenic sensitivity simulations indicate that the level of anthropogenic VOC control may be understated for some urban areas when these emissions are not considered. This finding generally agrees with earlier EKMA modeling performed by the Georgia Institute of Technology. Results of these analyses have implications concerning the usefulness of NOx controls in certain areas. In regions strongly influenced by biogenic emissions the ambient daytime VOC/NOx ratios might be elevated to levels where the system is saturated with respect to hydrocarbons. This emission pattern partly explains the minimal effect on peak ozone due to substantial VOC emission changes (Figure 6). In a crude sense areas like Atlanta may be in a NOx limited condition where ozone is more sensitive to changes in NOx.

An illustration of the role of biogenic emissions on the relative effectiveness of VOC or combined VOC and NOx control is provided by the SIP strategies for Atlanta, Dallas-Fort Worth and St. Louis. Implementation of aggressive NOx controls (combined with VOC control) showed peak ozone benefits only in Atlanta (considered a "high" biogenics area). In contrast, peak ozone was exacerbated by vigorous NOx control in both St. Louis and Dallas-Fort Worth - areas not as strongly influenced by biogenic

emissions. All three cities benefitted from anthropogenic VOC control (in the absence of NOx control), although Atlanta exhibited a relatively insensitive peak ozone response. In fact, the vast response differences among cities indicate that case specific control measure approaches probably yield optimum benefits. Also, implementation of nationwide NOx control measures might exacerbate peak ozone in certain areas.

TECHNOLOGY DEVELOPMENT AND TRANSFER TO PARTICIPATING STATES

Emissions preprocessing software

Significant resources are applied in processing basic emissions inventory data into UAM emissions input files. The task includes translating county level, daily VOC, NOx and CO emissions into gridded, transient (i.e., hourly) and speciated (VOCs and NOx) UAM inputs. As part of the 5-City project, SAI developed (to near completion for public use) a package of FORTRAN utility programs referred to as the Emissions Preprocessing System (EPS) which automates the translation process and provides a means for invoking various levels of control strategy measures (e.g., from across-the-board to source specific) and other tasks such as merging anthropogenic area source emissions with biogenic emissions. The EPS was applied throughout the 5-City study and is expected to be widely used by State and local air pollution agencies. SAI is finalizing the EPS and will include the software in a public domain UAM system package including UAM main source code with CB4 chemistry, all preprocessors and complete documentation in the Spring of 1990.

Transfer of UAM to participating States

As part of the project the air pollution control agencies of New York, Georgia, Texas and Maryland have or will receive the UAM with CB4 chemistry plus one or two days of installation and set-up assistance. New York and Georgia have the UAM installed; Texas and Maryland requested that installation be delayed until appropriate hardware was inplace. Maryland was selected because of their location and interest in working with EPA to develop a regional modeling center and conduct several Region III analyses including Philadelphia, Washington D.C and Baltimore.

TABLE 1. Comparison of performance statistics for four modes of application of the UAM to St. Louis for July 13, 1976.

Performance Measure	UAM (CB-II)	RAPS UAM	PLANR UAM	SIMPLE UAM
Hourly Ozone Concentrations (matched by time and location)				
Numbers of pairs	184*	265	265	265
Average observed (pphm)	8.3	6.8	6.8	6.8
Average predicted (pphm)	7.4	7.5	5.4	4.3
Bias (pphm)	0.9	-0.7	1.4	2.5
Average percent difference	11%	10%	21%	37%
Average absolute (gross) error	N/A	1.7	2.02	2.9
Gross error percent difference	N/A	25%	30%	43%
Correlation coefficient	0.95	0.91	0.90	0.79
Daily Maximum Ozone Concentration (matched by location but not time)				
Number of pairs	N/A	14	14	14
Average observed (pphm)	N/A	15.0	15.0	15.0
Average predicted (pphm)	N/A	16.0	12.3	8.2
Bias (pphm)	N/A	-1.0	2.7	6.8
Average percent difference	N/A	7%	18%	45%
Average absolute (gross) error	N/A	2.4	3.9	6.8
Gross error percent difference	N/A	16%	26%	45%
Correlation coefficient	N/A	0.68	0.55	0.20
Peak Ozone Concentration				
Peak observed (pphm)	22.2	22.2	22.2	22.2
Unmatched by time or location:				
Predicted region-wide maximum (pphm)	17.4	24.2	19.5	11.8
Ratio of prediction to observation	0.78	1.09	0.88	0.53
Matched by location but not time:				
Predicted maximum (pphm)	16.8	21.9	11.7	10.0
Ratio of prediction to observation	0.76	0.99	0.75	0.45
Hours difference in prediction	N/A	+2	0	-2

* Due to differences in sample sizes between the historical UAM (CB-II) and the current UAM performance statistics, statistics for non-peak ozone results cannot be directly compared.

TABLE 2. Comparison of performance statistics for the UAM (CB-II), POS UAM, and PLANR UAM applications to Philadelphia for July 13, 1979.

Performance Measure	UAM (CB-II)	POS UAM	PLANR UAM
Hourly Ozone Concentrations (matched by time and location)			
Number of pairs	N/A	330	330
Average observed (pphm)	N/A	6.23	6.23
Average predicted (pphm)	N/A	7.64	7.03
Bias (pphm)	N/A	-1.41	-0.80
Average percent difference	N/A	23	13
Average absolute (gross) error (pphm)	N/A	2.54	2.82
Gross error percent difference	N/A	41	45
Correlation coefficient	N/A	0.80	0.68
Daily Maximum Ozone Concentration (matched by location but not time)			
Number of pairs	19	19	19
Average observed (pphm)	13.90	13.90	13.90
Average predicted (pphm)	14.90	13.21	11.75
Bias (pphm)	-1.00	0.69	2.15
Average percent difference	7	5	16
Average absolute (gross) error (pphm)	2.02	2.21	3.60
Gross error percent difference	15	16	26
Correlation coefficient	0.73	0.72	-0.10
Peak Ozone Concentration			
Peak observed (pphm)	20.5	20.5	20.5
Unmatched by time or location:			
Predicted region-wide maximum (pphm)	26.6	23.6	18.7
Ratio of prediction to observation	1.30	1.15	0.91
Matched by location but not time:			
Predicted maximum (pphm)	18.5	17.7	11.1
Ratio of prediction to observation	0.90	0.86	0.54
Hours difference in prediction to observation	+2	0	0

TABLE 3

SUMMARY OF REGION-WIDE TOTAL EMISSION RATES, VOC-TO NOX RATIOS, AND PERCENT DIFFERENCES WITH THE 1995 SCENARIOS 1 AND 2 FOR THE 1995 EMISSION SCENARIOS

Scenario*	VOC			CO			NOx			VOC-to-NOx Ratio
	Total (tons/day)	Percent Change from Scenario 1	Percent Change from Scenario 2	Total (tons/day)	Percent Change from Scenario 1	Percent Change from Scenario 2	Total (tons/day)	Percent Change from Scenario 1	Percent Change from Scenario 2	
New York										
Scenario 1	4429	-	+32	3547	-	+8	1181	-	0	10.8
Scenario 2	3344	-24	-	3298	-7	-	1183	0	-	8.1
Scenario 3	3496	-21	+5	2763	-22	-16	1209	+2	+2	8.3
Scenario 4	2960	-33	-11	3547	0	+8	1182	0	0	7.2
St. Louis										
Scenario 1	676	-	+18	592	-	+7	350	-	0	5.6
Scenario 2	575	-15	-	555	-6	-	350	0	-	4.7
Scenario 5	586	-13	+2	523	-12	-6	352	+1	+1	4.8
Scenario 6	568	-16	-1	511	-14	-8	352	+1	+1	4.6
Scenario 7	849	+26	+48	592	0	+7	350	0	0	7.0
SIP Scenario X	404	-40	-30	592	0	+7	350	0	0	3.3
SIP Scenario Y	405	-40	-30	592	0	+7	350	0	0	3.3

*See text for elaboration of scenarios (pages 49-50).

TABLE 4

COMPARISON OF PREDICTED PEAK OZONE, PERCENT CHANGE IN PEAK OZONE, AND VOC EMISSIONS BETWEEN SCENARIOS 1 AND 2 AND ALL OTHER 1995 EMISSION SCENARIOS.

Scenario*	Highest Ozone Concentration (pphm)	Percent Change of Highest Ozone with Scenario 1	Percent Change of VOC Emissions with Scenario 1	Percent Change of Highest Ozone with Scenario 2	Percent Change of VOC Emissions with Scenario 2
New York+					
Scenario 1 (current RVP)	17.4	0	0	0	+32
Scenario 2 (low RVP)	17.4	0	-24	0	0
Scenario 3 (low RVP with ethanol)	17.5	+ 0.5	-21	+ 0.5	+ 5
Scenario 4 (current RVP with no running losses)	17.4	0	-33	0	-11
St. Louis					
Scenario 1 (current RVP)	15.0	0	0	+ 7.0	+18
Scenario 2 (low RVP)	14.5	- 3.1	-15	0	0
Scenario 5 (low RVP with ethanol)	14.5	- 3.1	-13	0	+ 2
Scenario 6 (low RVP with ETBE)	14.4	- 3.8	-16	- 0.2	- 1
Scenario 7 (current RVP with high running losses)	15.4	+ 2.7	+26	+ 6.2	+48
SIP Scenario X (40% VOC reduction)	13.5	-10.0	-40	- 6.9	-30
SIP Scenario Y (40% VOC reduction based on reactivity)	12.3	-18.7	-40	-15.7	-30

*See text for elaboration of scenarios (pages 49-50).

+The analysis did not consider the effects of changes in emissions of the different emission scenarios on the long-range transport of pollutants (i.e., boundary conditions). This contributes heavily to the apparent insensitivity of the ozone peak to large changes in the VOC inventory for the New York applications. The reader is referred to the text for further explanation (pages 132-133).

Table 5a. Region-wide maximum ozone concentrations (pphm) for observed, current and 1995 base cases.

Strategy	Dallas-Fort Worth	Philadelphia	St. Louis
[1]Observed	17.0	20.5	22.3
[1]Current base	16.4	23.6	24.4
[2]1995 base	13.7	18.6	14.5

1 - 1985, 1979, and 1976 are current base years for Dallas-Fort Worth, Philadelphia, and St. Louis, respectively.

2 - The 1995 base emissions projections utilized vehicle speeds based on the NAPAP inventory; these speeds are generally higher than the 20 mph used in the fuel strategies in Table 3-3b, below. Care should be taken when comparing results from this strategy with those below since a 20 mph assumption would increase the 1995 base emissions.

Table 5b. Region-wide maximum ozone concentrations (pphm) for 1995 fuel strategies.

Strategy	Dallas-Fort Worth	Philadelphia	St. Louis
New Gas Regs	13.0	18.2	14.3
M100	12.4	18.2	14.1
CNG	12.2	18.0	13.9

Table 6a

Projected In-Use Emissions For
Light-Duty Gasoline Vehicles (grams per mile)
Dallas (T min. 77°, T max. 102°)

Type of Emission	7.8 psi RVP			9.0 psi RVP		
	NMHC	CO	NOx	NMHC	CO	NOx
Exhaust	0.45	5.56	0.71	0.50	7.36	0.73
Evap	0.184			0.26		
Running Losses	0.154			0.39		
Uncontrolled Refueling	0.17			0.20		

Gasoline NMHC speciation guidance provided in the August 23, August 30, and September 2, 1988 memos from Phil Lorang to Ralph Morris, and a September 7, 1988 memo from Phil Lorang to Gene Durman.

Exhaust emission factors calculated at an average speed of 20 mph.

66% control of these refueling emissions should be assumed.

TABLE 6b

PROJECTED IN-USE EMISSIONS FOR
LIGHT-DUTY ALTERNATIVE-FUELED VEHICLES

(grams per mile)

Type of Emission	Vehicles Optimized for 100% Methanol					Dedicated CNG Vehicles				
	NMHC	MeOH	HCHO	CO	NOx	NMHC	MeOH	HCHO	CO	NOx
Exhaust	0.049	0.490	0.015	Same as LDGV	Same as LDGV	0.186	0	0.00	Same as LDGV	Same as LDGV
Hot Soak/ Diurnal	0	0.020	0	0	0	0	0	0	0	0
Running Loss	0	0.007	0	0	0	0	0	0	0	0
Refueling	0	See Note #3	0	0	0	0	0	0	0	0

1. Speciation for M100 and CNG exhaust NMHC should be taken from the May 19, 1989 CARB technical report titled, "Definition of a Low-Emission Motor Vehicle in Compliance with the Mandates of Health and Safety Code Section 39037.05 (Assembly Bill 234, Leonard, 1987)."

2. Exhaust emission factors calculated at an average speed of 20 mph.

3. For the M100 case, assume 24% as much methanol as there is NMHC in the gasoline case. This is 91% control of the mass.

Table 7. Peak Ozone (ppb) Results from 1995 SIP Control Strategies.

	St. Louis	Observed Peak
1976 Base	244	223
[1]1995 Base	145	
[2]24% VOC/25% NOx	133	
[3]24% VOC/38% NOx	134	
Atlanta		
1984 Base	132	147
[4]1995 Base	125	
[5]30% VOC	119	
60% VOC	111	
90% VOC	106	
18% VOC/32% NOx	113	
[3]18% VOC/50% NOx	108	
Dallas-Fort Worth		
1985 Base	164	170
[6]1995 Base	137	
30% VOC	116	
60% VOC	108	
24% VOC/40% NOx	133	
[4]24% VOC/60% NOx	134	

1 - all 1995 reductions relative to 1995 base

2 - combined VOC/NOx controls are source specific from LA Tier 1 control measures plus NOx control on major boilers; these are referred to as SIP type B strategies in text

3 - additional NOx control beyond previous strategy from major boilers

4 - Atlanta 1995 base represents 9% increase and 35% decrease in NOx and VOC, respectively, over 1984 levels

5 - all VOC only controls are across-the-board and are referred to as SIP type A strategies in text

6 - Dallas 1995 base represents 32% increase and 17% decrease in NOx and VOC, respectively, over 1985 levels (weekday emissions)

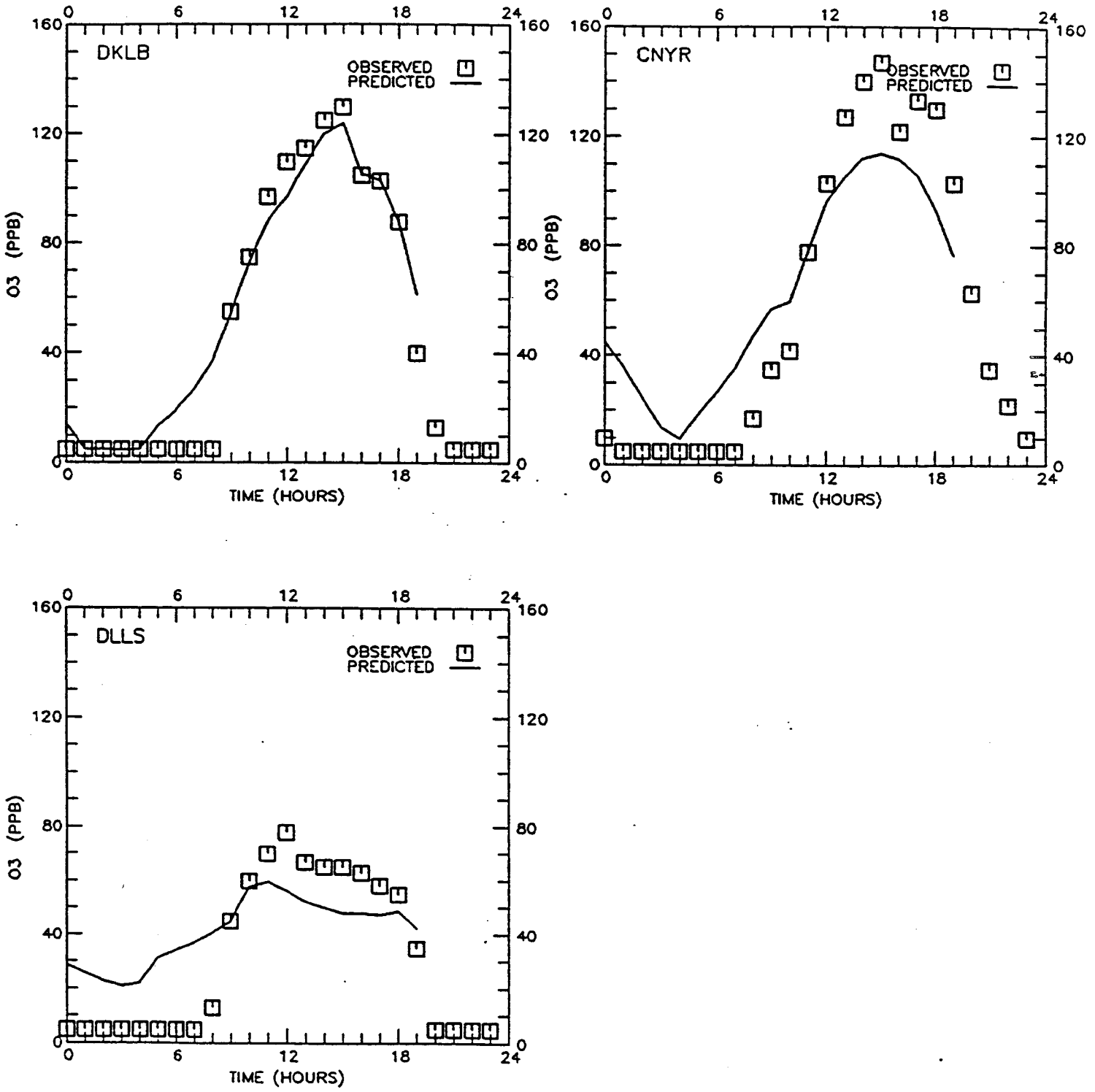


Figure 1. Observed and nearest-neighbor predicted (two-cell search) ozone concentrations (ppb) for the Atlanta evaluation run 2.

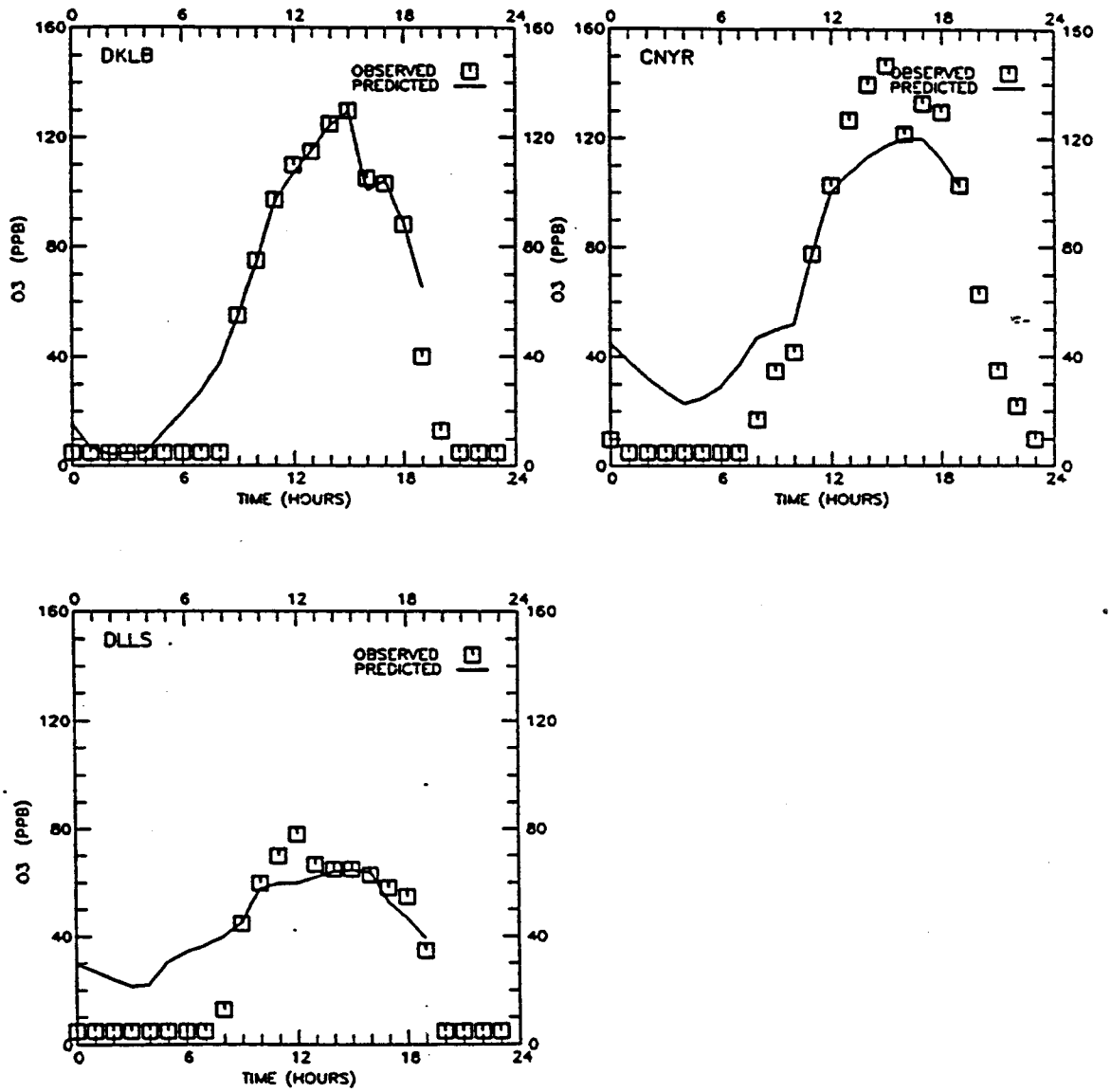


Figure 2. Observed and nearest-neighbor predicted (two-cell search) ozone concentrations (ppb) for the Atlanta reduced wind speed sensitivity test.

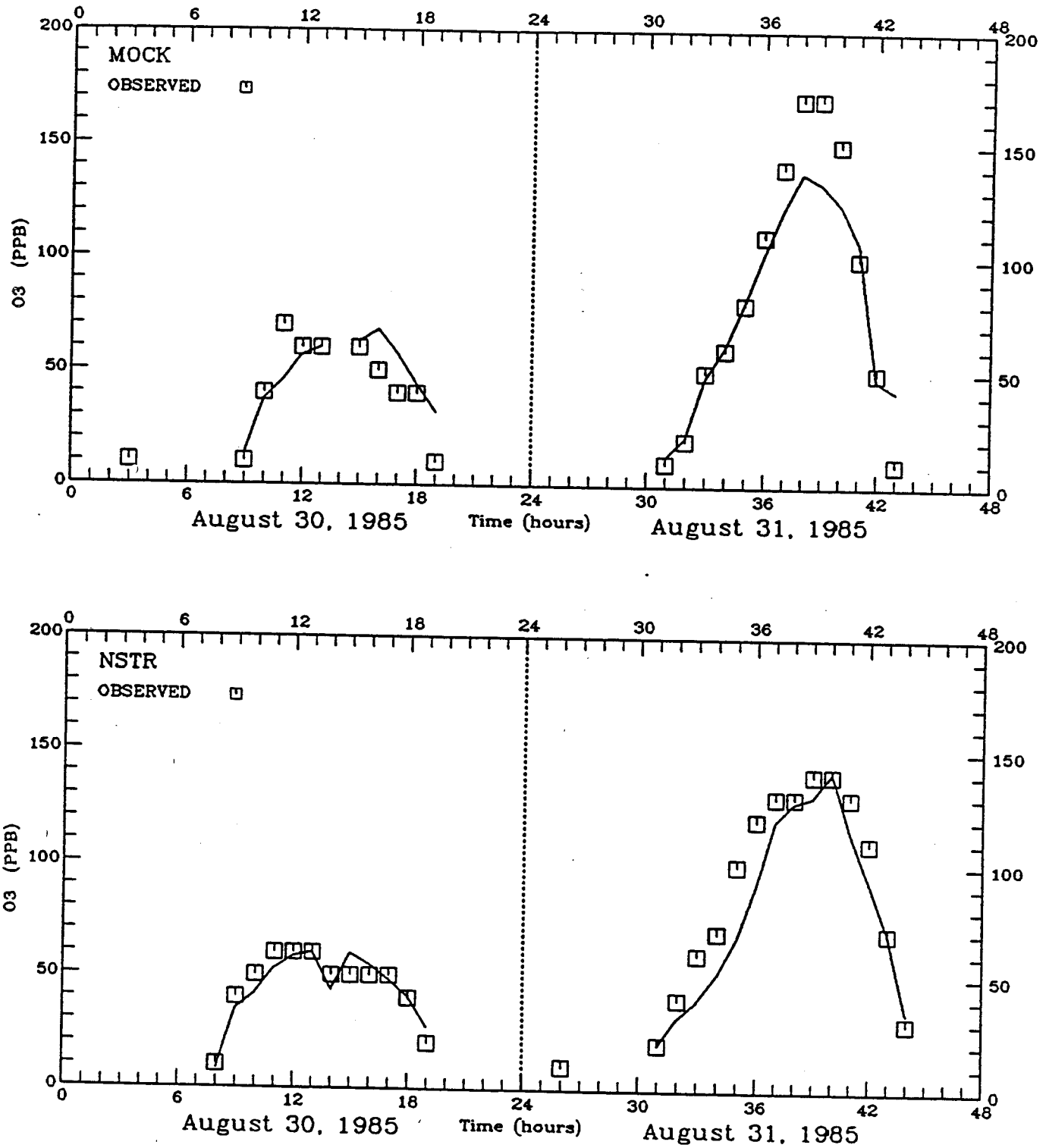
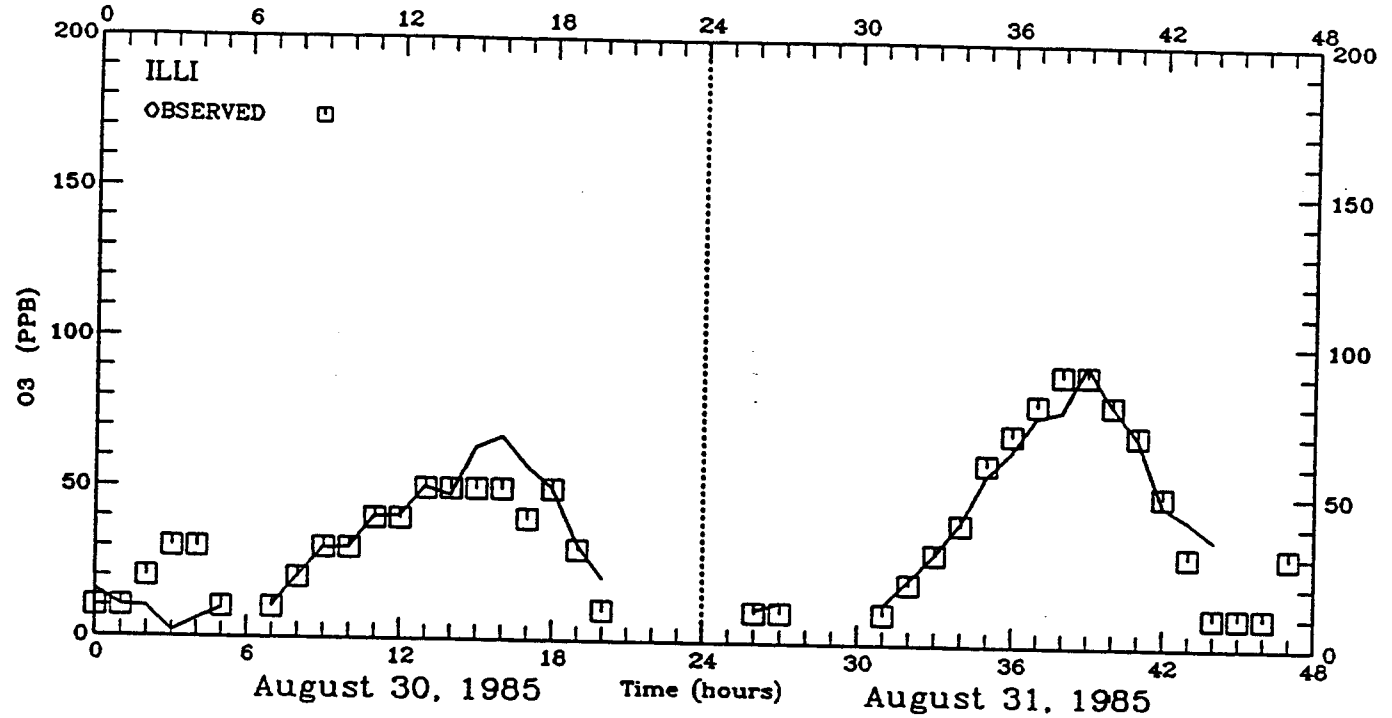


Figure 3. Observed and nearest-neighbor predicted (two-cell search) ozone concentrations (ppb) for the Dallas-Ft. Worth 30-31, August 1985 base case simulation.



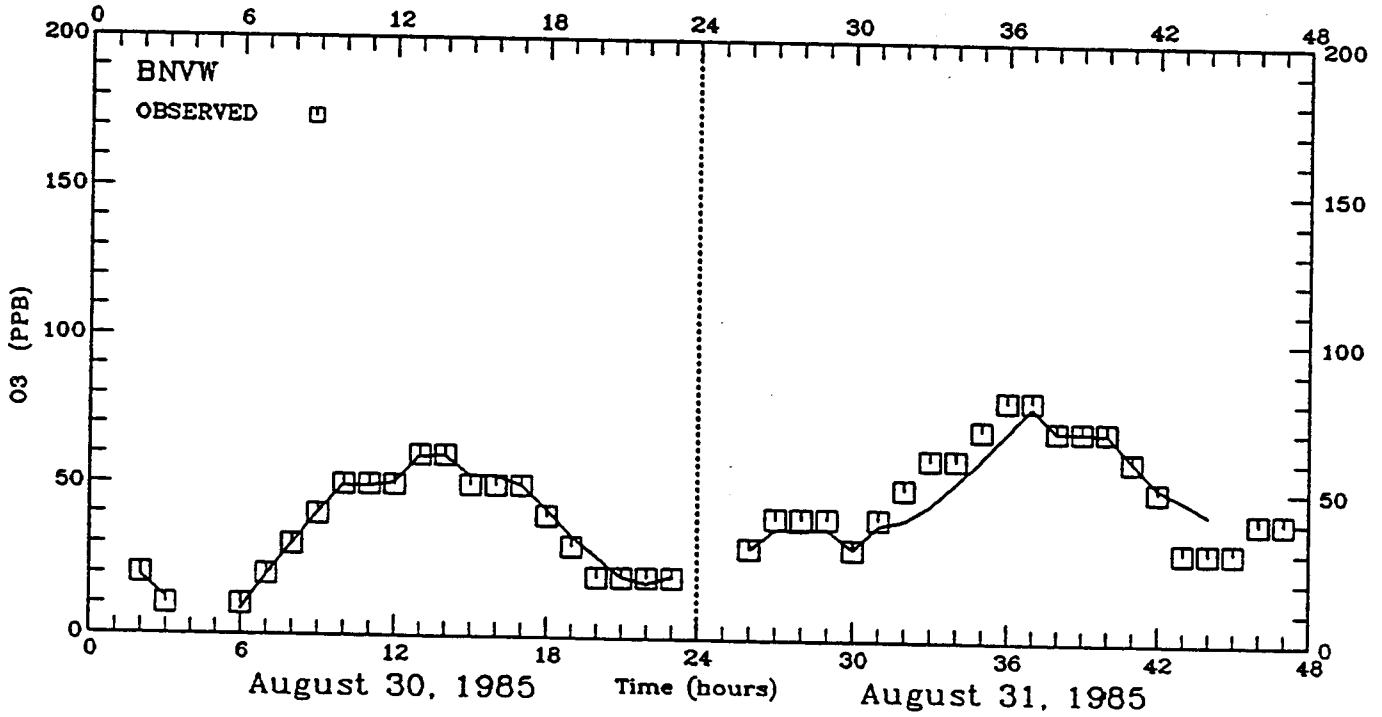
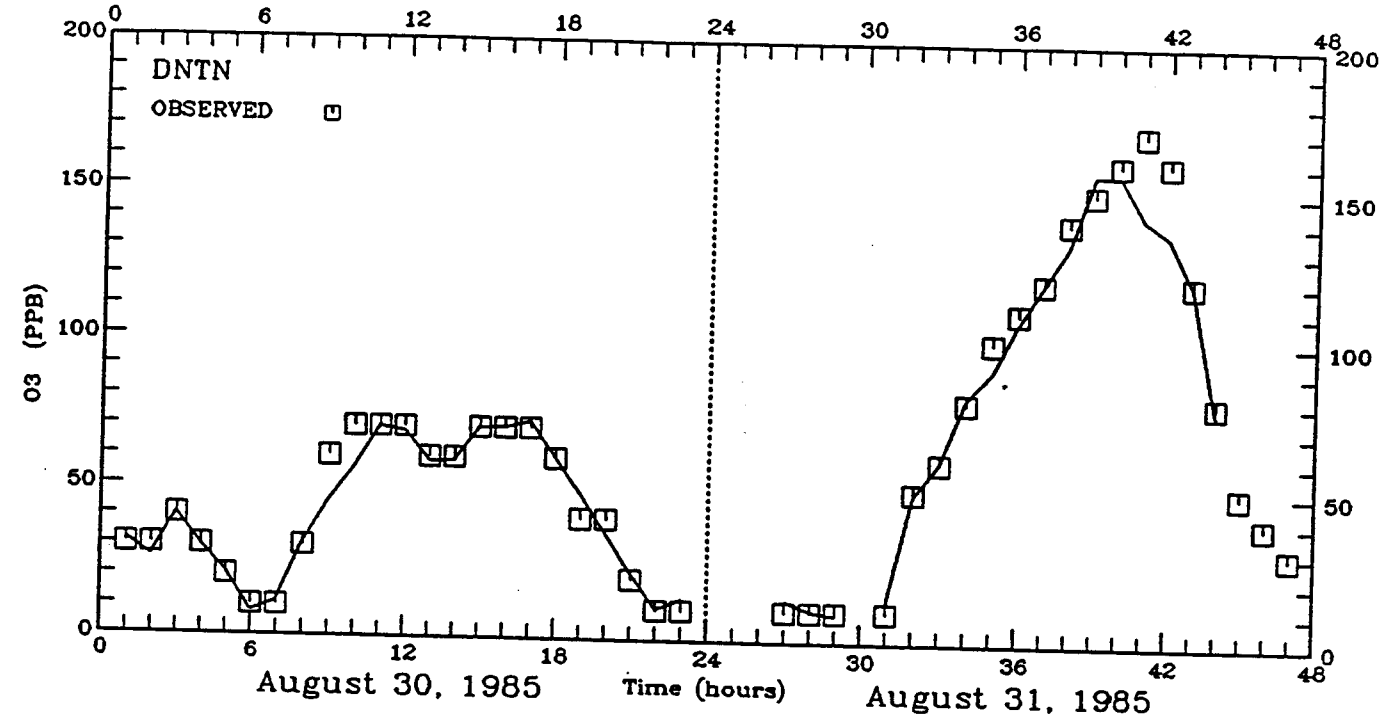


Figure 3. continued



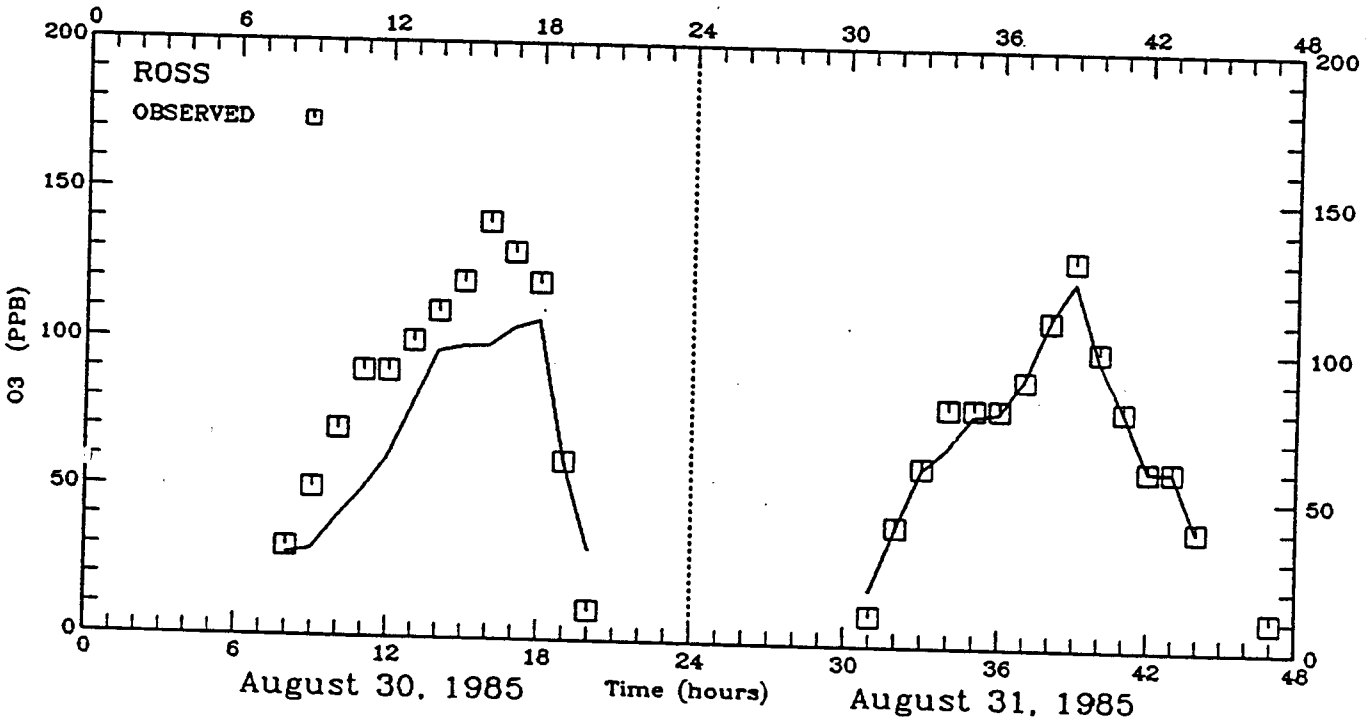
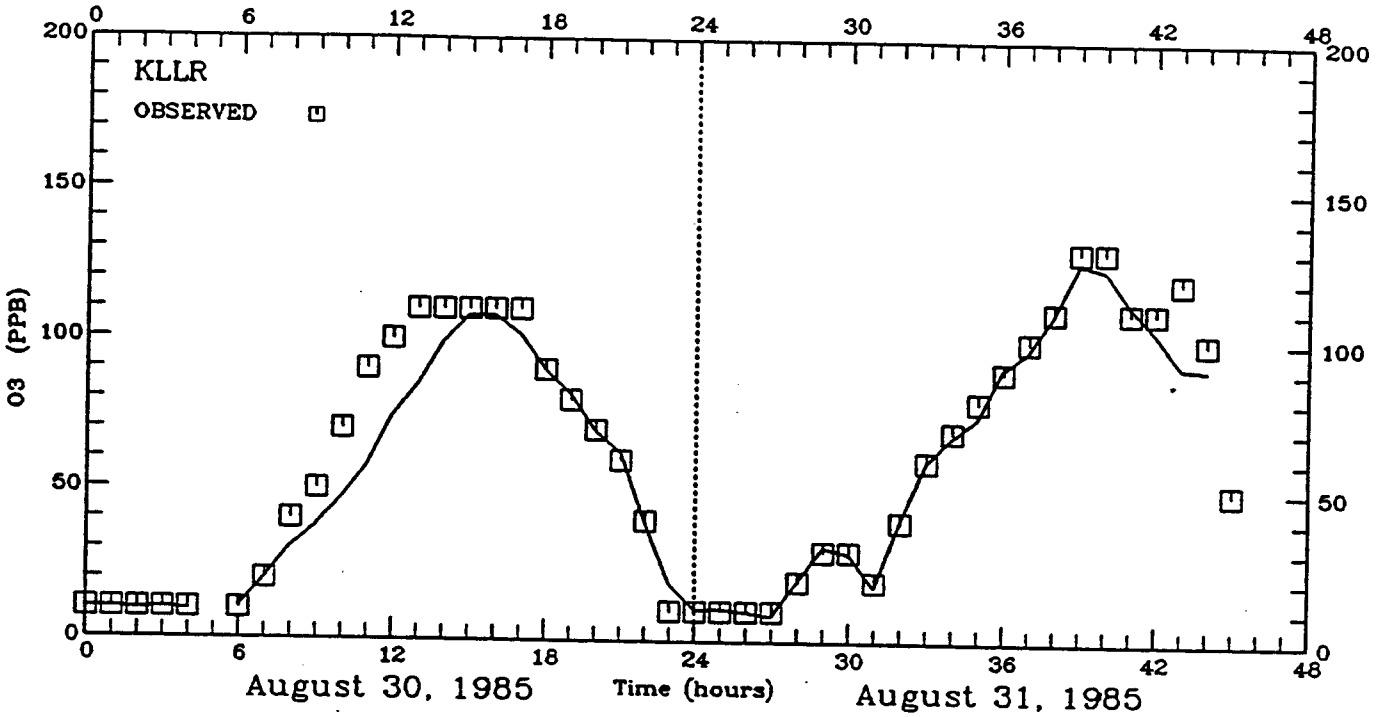


Figure 3. continued



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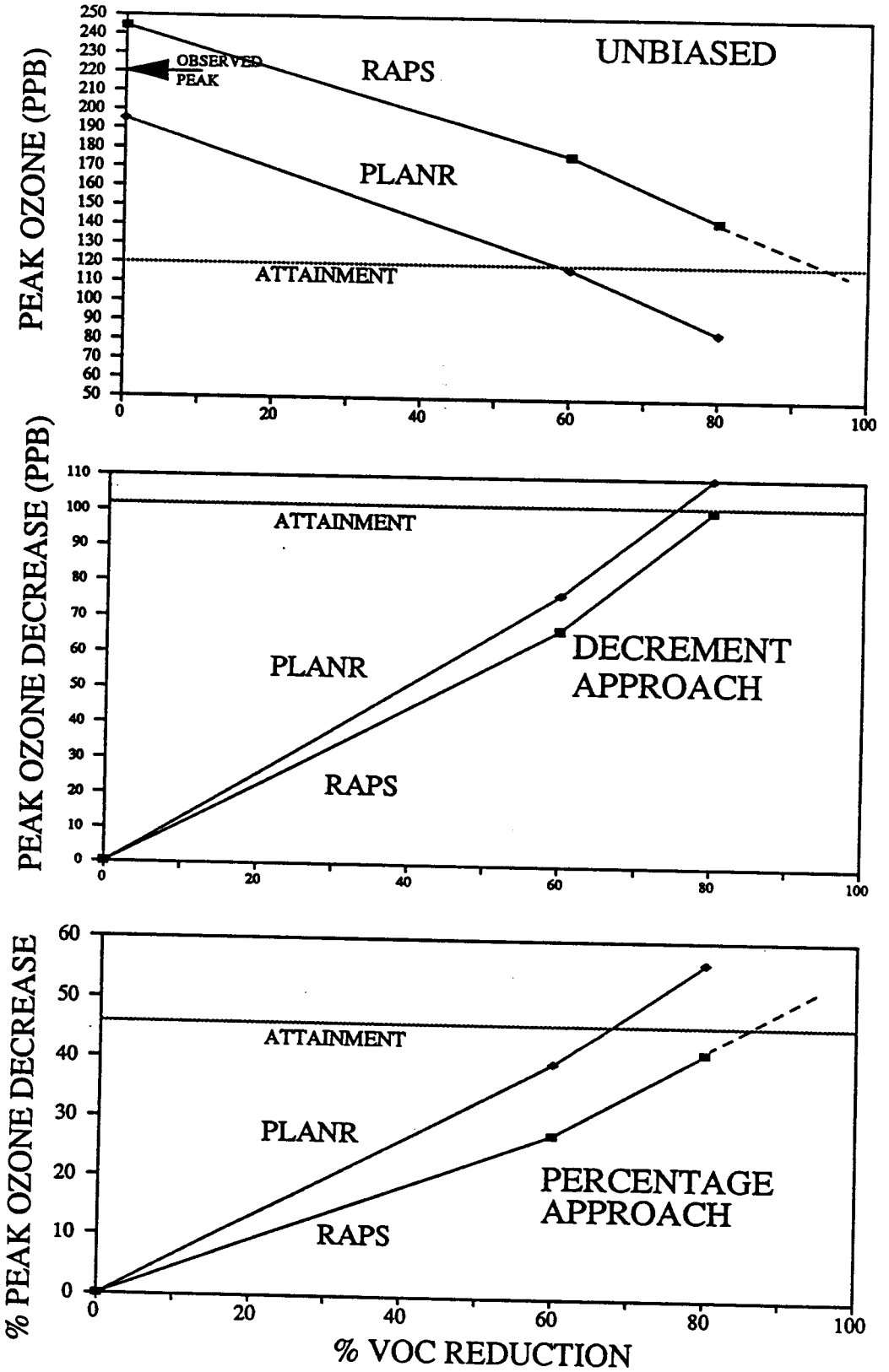

Figure 4. Peak ozone response for St. Louis to across-the-board VOC controls using three different approaches when predicted peak ozone does not match observed value.

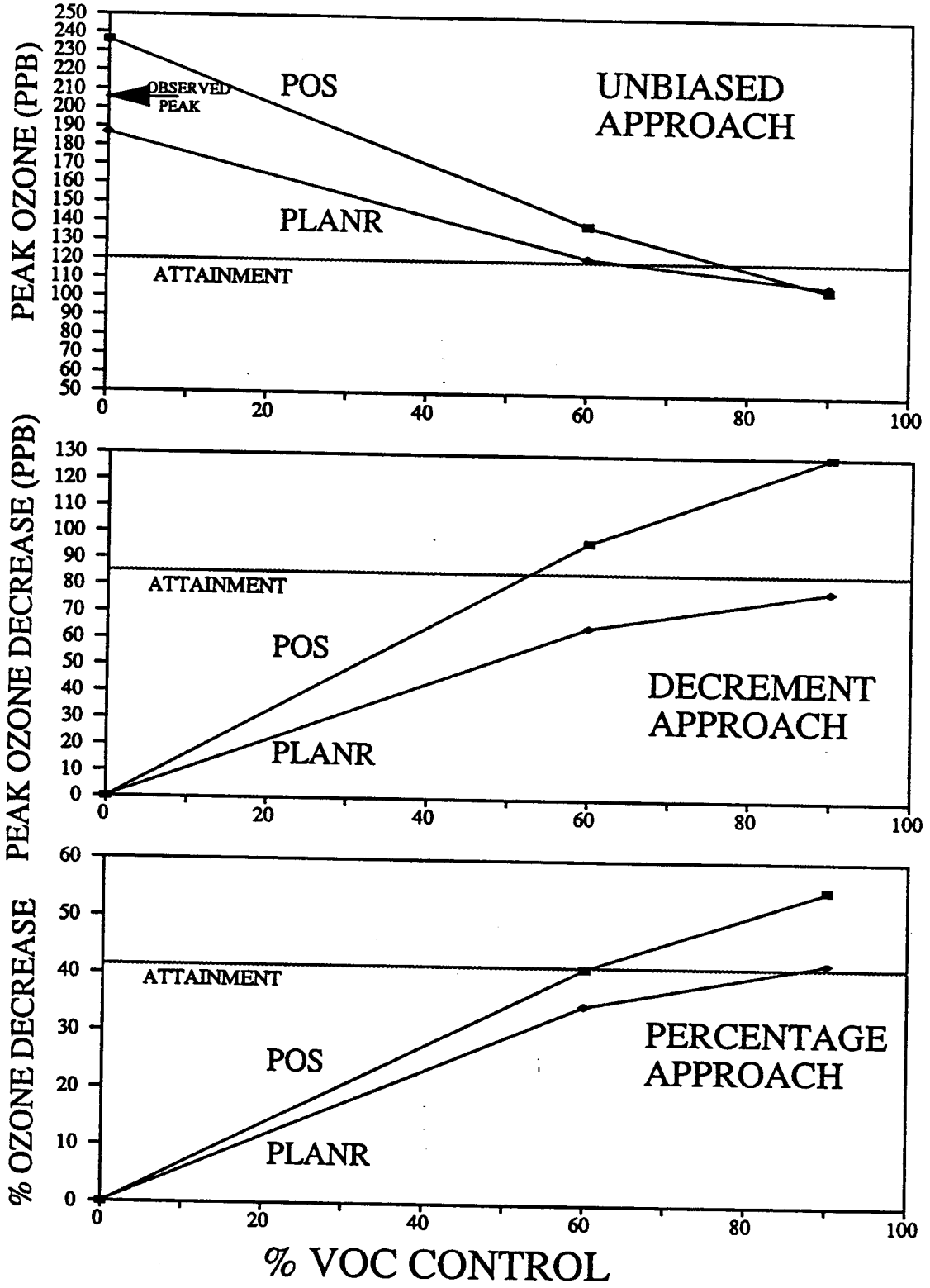

Figure 5. Peak ozone response for Philadelphia to across-the-board VOC controls using three different approaches when predicted peak ozone does not match observed value.

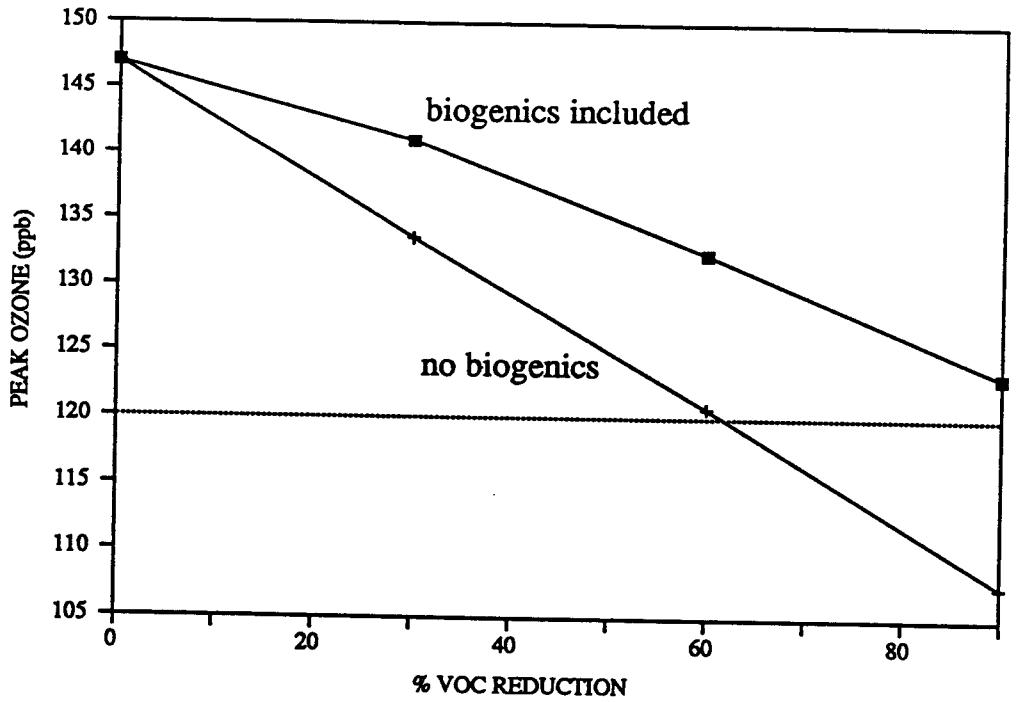

Figure 6. Peak ozone response in Atlanta to across-the-board VOC controls with original (higher speed) wind speeds.

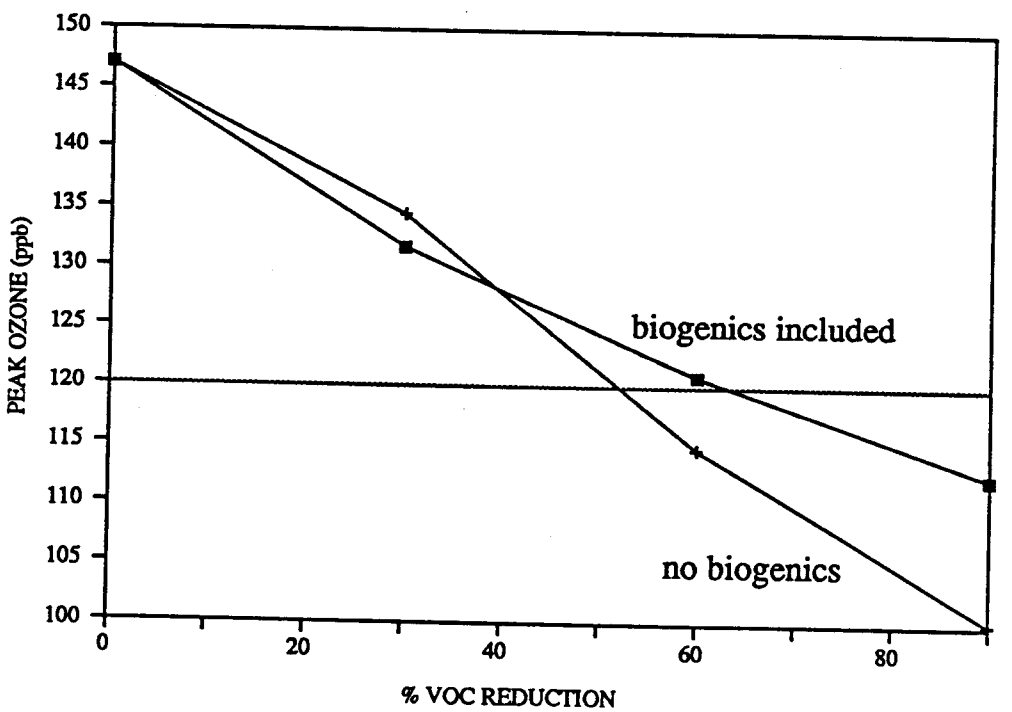

Figure 7. Peak ozone response in Atlanta to across-the-board VOC controls with new (lower speed) wind speeds.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

This document provides an overview and summary of the 5-City UAM Study.

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a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Urban Airshed Model Ozone Control strategies		

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