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Project Summary

Development of Seasonal and Annual Biogenic Emissions Inventories for the U.S. and Canada

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Historically, ozone control programs based on reductions of known anthropogenic volatile organic compound (VOC) emissions have had limited success in obtaining the National Ambient Air Quality Standard. Researchers have therefore been actively evaluating VOC emission sources not routinely considered in ozone control strategies. One potentially large source of reactive VOCs is thought to be emissions from crop and forest foliage. A biogenic emissions inventory for the U.S. and Canada was developed to assess the role of biogenic emissions in ozone formation. Emission inventories were developed at hourly and grid (1/4 x 1/6°) levels from input data at the same scales. Emissions were calculated as a function of biomass density and meteorological parameters (solar radiation, cloud cover, temperature, wind speed, and relative humidity). These factors were applied to a forest canopy algorithm that simulated processes generating biogenic emissions from foliage. Resultant emissions were aggregated to monthly, seasonal, and annual levels and spatially to counties and states.

Approximately 50% of the biogenic hydrocarbon emissions occur in the summer, approximately equal amounts (20%) in the spring and fall, and much lower amounts in the winter. Isoprene emissions result primarily from deciduous tree species in forest canopies; therefore, the contribution is lower in the winter than in the other seasons since deciduous biomass is assumed to be zero between the first and last frost dates. Isoprene emissions from deciduous trees are dependent on the incident solar radiation intensity and therefore have a maximum emission rate with warm temperatures and maximum solar intensity which occur during the summer. The relative contribution of alpha-pinene and other monoterpenes to the total hydrocarbon emissions is higher in the winter, especially in the South where the climate is relatively moderate. The relative contribution of alpha-pinene and other monoterpenes to total hydrocarbons in Canada is higher than in the U.S., as more deciduous foliage is present in the U.S. The estimated annual biogenic hydrocarbon budget is 18.8 Tg for the U.S. and 6.7 Tg for Canada.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

A biogenic emissions inventory for the U.S. and Canada was developed to address research and assessment needs on the role of biogenic emissions in ozone formation. The seasonal and annual biogenic emissions inventories in this study were developed at the hourly and grid levels. Input data at these same temporal and spatial scales were developed for compatibility with emissions algorithms.

Since the emissions algorithms available rely on meteorological data as input, diurnal profiles for each month were developed for a 3-year period that would represent the meteorological conditions around the year 1985. The representative diurnal meteorological parameters were spatially interpolated to 1/6° latitude by 1/4° longitude grid cells and were used to calculate biogenic emissions using gridded land cover data with the same spatial resolution. The calculated emissions were then aggregated spatially to the county and state levels, and temporally to monthly, seasonal, and annual levels. The resulting database provides estimates of biogenic emissions that rely on spatially and temporally variable conditions, but are represented at larger spatial and temporal scales for use in emissions assessment evaluations comparing the magnitude of anthropogenic and natural sources.

A secondary objective of the research was to process an updated version of the county level natural particulate data which was developed after the completion of the 1985 NAPAP Emissions Inventory (Version 2). The updated natural particulate data incorporated improvements to the emissions calculation methodologies for dust resulting from unpaved road travel in the U. S. and improvements in the state-to-county allocation methodologies.

Background

The National Acid Precipitation Assessment Program (NAPAP) was established by Congress in 1980 to expand the understanding of the processes that result in acid deposition phenomena in and around the U. S. A principal objective of NAPAP was to develop a complete and accurate inventory of natural and anthropogenic emissions of acid deposition precursors. The 1985 NAPAP Emissions Inventory (Version 2) was delivered in February 1990. This inventory included anthropogenic emission data for SO_2, NO_x, NO, NO_2, VOC, THC, CO, TSP, NH_3, SO_4, HCl, HF, 32 hydrocarbon reactivity classes, and 15 classes of particulate based on reactivity and size classes. Emissions data were also developed for 12 classes of natural particulate data based on reactivity and size classes.

Another potentially large source of reactive VOCs in certain areas is thought to be emissions resulting from biogenic processes in forest and crop biomass. Although the details regarding the emission mechanisms and the controlling factors affecting biogenic sources are not well understood, significant advances have been made in attempts to quantify these emission source strengths.

Biogenic VOC emissions can affect the atmospheric chemistry of urban ozone plumes when introduced to an urban area as a background flux. In addition, these emissions can react with small amounts of NO_x left over from urban processes or with additional natural sources of NO_x. The principal known sources of VOC from natural processes are direct emissions from the leaf surface of forest biomass and agricultural crops. Emissions of NO_x from natural sources are thought to arise from chemistry and biochemistry in soils and from lightning. Natural sources of other air pollutants may also be important for other environmental concerns. For example, emissions of natural particulate can have effects on visibility, and the alkaline components of particulate may interact in the atmospheric and cloud chemistry of acid rain.

The development of the emissions algorithms and supporting data for the calculation of biogenic emissions was not sufficiently advanced to allow the inclusion of natural hydrocarbon and NO_x emissions in the NAPAP Version 2 inventory. Biogenic emissions algorithms, which depend on meteorological data inputs, were made available shortly after the completion of the NAPAP inventory. These algorithms can be used to estimate emissions of isoprene, alpha-pinene, other monoterpenes, unknown hydrocarbons, NO, and NO_2. For this inventory, only grassland NO_x emissions were considered. Other sources of biogenic NO_x are known to exist but have not been well quantified to date. A methodology to apply these algorithms was developed by the EPA's Atmospheric Research and Exposure Assessment Laboratory (AREAL) for episodic (day specific) simulations using the Regional Acid Deposition Model (RADM) for model evaluation and research purposes.

While the availability of the episodic emissions estimates were valuable for application to the specific days selected for the RADM evaluation simulations, it was desirable to develop representative seasonal and annual emissions estimates for other NAPAP and EPA analyses. Earlier efforts, performed by researchers at Washington State University, were based at the county level and relied on monthly average meteorological data (e.g., temperature and wind speed). The emissions rates calculated by the emissions algorithms are highly dependent on hourly temperature and solar radiation data. A comparison of the results of this study with earlier efforts is presented with the emissions data. In general, biogenic hydrocarbon emissions estimated using data and methodologies presented in this report are lower than those reported in earlier efforts on an annual and seasonal basis.

Biogenic Emissions Overview

The objective of the work documented in this report is to develop county- and state-level emissions inventories of biogenic hydrocarbon and NO_x emissions representative of the monthly, seasonal, and annual temporal scales. The methodology followed to achieve this objective was to calculate gridded hourly biogenic emissions for a representative day in each month and sum these emissions to larger temporal and spatial scales.

Three years of hourly surface airways meteorological data from the National Climatic Data Center, reported at over 500 measurement sites in the U.S., were obtained and quality checked. Data at over 130 measurement sites in Canada were obtained from the Canadian Climate Centre of Environment Canada. These data were used to develop diurnal profiles representative of each month of the year at each reporting site. These data were spatially interpolated to generate monthly average diurnal profiles for the entire study region in a grid based system defined by grid cells of 1/4° longitude by 1/6° latitude. Gridded land use cover data were available from the NAPAP program. Leaf biomass data were available at the county level from the Oak Ridge National Laboratory's geoecology data base. These data were disaggregated to the grid level using gridded land use/cover data.

Biogenic hydrocarbon emissions were calculated for the representative hour and day in each grid cell for each month of the year using the Canopy Emissions Model developed for NAPAP by researchers at Washington State University. The Canopy Model considers the leaf temperature and solar radiation gradient within the forest canopy. Since the emissions from trees are highly dependent on both temperature and solar radiation, this algorithm provides more representative estimates of the emissions rates than does a simpler treatment based on the assumption that all of the biomass is exposed to the same unattenuated solar radiation intensity. Algorithms were provided by the National Oceanic and Atmospheric Administration (NOAA) to calculate emissions of NO_x from undisturbed (uncultivated) grassland areas. Similar to the biogenic hydrocarbons, grassland NO_x emissions are also dependent on temperature. NO_x emissions algorithms for other land use types

were not available for application to this study. Additional emissions of NO_x from soils in forests, from agricultural lands, for deserts, and from wetlands have been observed in measurement programs; however, their dependencies on meteorological and other factors were not yet determined for use in this effort.

The resulting hourly gridded emissions calculations were aggregated to develop monthly mean emissions magnitudes at the grid level. Allocation factors, based on the grid/county overlap, were used to aggregate the gridded emissions to county and then state totals. Finally, the monthly averages were aggregated to seasonal and annual totals.

The resultant emissions data indicate that biogenic hydrocarbon emissions and NO_x are highest during the summer and lowest during the winter. For the spring and fall, the magnitudes of the biogenic emissions are similar for the U.S. In Canada, biogenic hydrocarbon emissions are higher in the fall than in the spring. Analysis of state-level seasonal totals indicates that during the winter and summer, total State land area appears to be the controlling factor in determining states and provinces with the highest biogenic hydrocarbon emissions magnitudes, although emissions are also dependent on the canopy foliage biomass. In the spring and fall, land area as well as geographic location appear to be important.

Report Organization

The primary objectives of this report are to document the development of a biogenic hydrocarbon emissions inventory using representative monthly diurnal profiles of meteorological data and the implementation of the Canopy Model software. The calculated emissions at varying levels of spatial and temporal aggregation are also summarized.

The remainder of the report consists of:

Section 2: Development of Representative Gridded Diurnal Meteorological Profiles

Section 3: Calculation of Biogenic Hydrocarbon Emissions

Section 4: Natural Particulate and Biogenic Emissions Data

Section 5: Summary and Recommendations.

The emissions calculation methodology and summary for grassland NO_x emissions are also provided in Sections 3 and 4.

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The complete report, entitled "Development of Seasonal and Annual Biogenic Emissions Inventories for the U.S. and Canada," (Order No. PB92-126 796/AS; Cost: $26.00; subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
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