

REGIONAL MODELING OF ATMOSPHERIC AEROSOLS FOR EXPOSURE ANALYSIS: AN APPLICATION TO THE EASTERN U. S.

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Introduction. This work evaluates the viability of regional aerosol models for performing analysis of potential population exposure to PM, through case studies focusing on model sensitivity and through assessment of relevant model input databases. The objective of this work is to produce, test, and evaluate components for the Modeling ENvironment for TOtal Risk Studies (MENTOR) currently being developed at EOHSI, extending the framework of EDMAS¹. These components will offer various alternatives for calculating and evaluating estimates of spatiotemporal fields of ambient airborne pollutants, including fine particulate matter².

Methodology. The present study couples together various relevant models within the MENTOR framework. Aerosol dynamics are described by the University of Delaware model (UDAERO)³. This is a size- and composition-resolved sectional aerosol model that explicitly simulates the transport of volatile species between gas and aerosol particles. The model solves the following equation:

$$\frac{\partial n_{mi}(D_p^*, \mathbf{x}, t)}{\partial t} = H_i(D_p^*, \mathbf{x}, t) n_m(D_p^*, \mathbf{x}, t) - \frac{1}{3} \frac{\partial H n_{mi}(D_p^*, \mathbf{x}, t)}{\partial D_p^*},$$

where $D_p^* = \log(D_p/D_{p0})$ is the log diameter; $n_{mi}(D_p^*, \mathbf{x}, t)dD_p^*$ is the mass concentration of species i between log diameters D_p^* and $D_p^* + dD_p^*$ and $n_m = \sum_{i=1}^s n_{mi}$; $H_i = (1/m)(dm_i/dt)$ is the normalized condensation rate of species i and $H = \sum_{i=1}^s H_i$; m_i is the mass of species i in an individual particle of total mass $m = \sum_{i=1}^s m_i$.

The UDAERO model is incorporated into the North Carolina Supercomputer Center's (NCSC's) Multiscale Air Quality Simulation Platform (MAQSIP) to form a regional particulate model (MAQSIP-UDAERO). In the vertical direction, the model domain encompasses nearly the entire troposphere, and so the clouds play a significant role in mixing vertically the aerosol particles and contributing to the change in aerosol mass and composition through aqueous reactions. To account for these cloud effects the Regional Acid Deposition Model (RADM) cloud scheme and the MAQSIP resolved cloud scheme are used to treat deep and shallow cumulus clouds and non-convective clouds respectively. The cloud modules are modified so that they can interface with the sectional aerosol model.

In order to address potential population exposure issues, the MAQSIP-UDAERO predictions for ambient PM have to be incorporated with population information. This is done by using a GIS (Geographic Information System) based set of exposure assessment tools that have been developed to estimate potential outdoor population exposures⁴. These tools are components of MENTOR and can also be used in conjunction with other modules to estimate individual exposures within different microenvironments.

Case Studies. In the case studies MAQSIP-UDAERO was applied to predict the ambient PM concentration over the eastern United States during the July 9-13, 1995 episode. Figure 1 shows the predicted total PM₁₀ and PM_{2.5} spatial distributions at 8:00am, July 13, 1995. In order to

utilize the GIS based exposure assessment tool, a virtual geo-referenced grid is created through the GIS system over the same eastern U.S. domain, with a resolution compatible with the grid of MAQSIP-UDAERO. County population data taken from the U.S. Census are then resolved at grid cell level. Then the potential outdoor exposure, defined as $E_{p,o} = (\text{PM Concentration} \times \text{Population})$ per grid cell, is obtained and maps of population, PM concentrations and exposure patterns are created to graphically represent the exposure scenario.

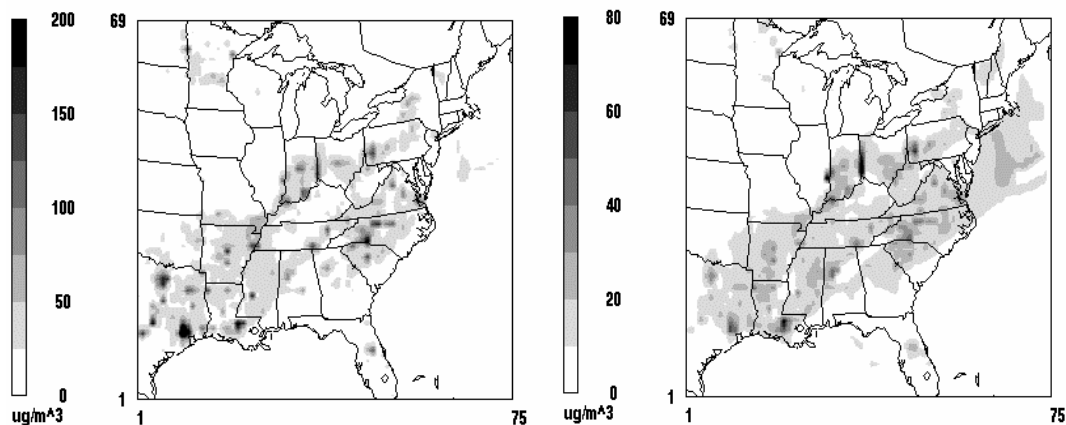


Figure 1: Predicted ambient PM₁₀ (left panel) and PM_{2.5} (right panel) concentrations at 8am EDT, July 13, 1995.

The available data for primary PM emissions contains only two species, PM_{2.5} and PM₁₀, plus primary sulfate emissions. In order for these data to be used as inputs to the model, they have to be first broken down into different species, then split into size sections according to an assumed size distribution, since MAQSIP-UDAERO requires size- and composition-resolved PM emission data. The breakdown into species is done empirically, while the split into size sections is accomplished by assuming a log-normal size distribution profile. To evaluate the effect of the assumed size profiles on the final predicted PM concentrations, different parameters for the log-normal profile are tested as part of sensitivity studies.

Another component of the sensitivity analysis aims to evaluate the impact of different control strategies on the ambient PM concentrations and the corresponding potential population exposure to PM. In the past, policy studies have considered reduction of SO₂ emissions as the main approach to reduce ambient PM_{2.5} mass. However, recent studies have shown that reductions in PM sulfate concentration may cause inorganic PM_{2.5} mass to respond nonlinearly, as a result of more nitric acid gas condensing to the aerosol phase. This study examines the effect of reduced sulfur emissions on the predicted aerosol nitrate concentration and the final impact on the total ambient PM and potential population exposure to PM. The effect of reducing the primary PM emissions is also examined.

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