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AIR QUALITY IMPACTS OF DESERT WIND-BLOWN DUST IN A SOUTHWESTERN U.S. URBAN VALLEY: PRELIMINARY RESULTS FROM HIGH-RESOLUTION 3-D MODEL SIMULATIONS

V.R. Kotamarthi,[1,*] M.A. Lazaro,[2] Y.-S. Chang,[2] D.E. James,[3] J. Kuiper,[2] and S. Pulugurtha[3]
[1]Environmental Research Division and [2]Environmental Assessment Division, Argonne National Laboratory, Argonne, Illinois; [3]Civil and Environmental Engineering, University of Nevada, Las Vegas, Nevada

1 INTRODUCTION

Estimating the effect of wind-blown dust on aerosol concentrations in semiarid areas of the southwestern United States is crucial to defining the extent of suspended particulates and to distinguishing natural versus anthropogenic contributions to health exposure concerns related to PM_{10} and $PM_{2.5}$ concentrations. The spatial and temporal variations in emissions of suspended wind-blown dust are estimated by using an empirical formulation derived from a series of field observations made with a mobile wind tunnel over a representative set of "wind-erodible" soils and soil conditions. Soils covering eight distinct wind erodibility groups were sampled in the Las Vegas Valley region of the Mojave Desert. The groups were based on a set of soil parameters collected during a comprehensive soil survey conducted in the early 1980s (Speck and McKay, 1985). In addition to the friction velocities and PM_{10} horizontal fluxes measured with the wind tunnel, our derivation of the wind-blown dust emission formulation relied on a set of representative data collected from field studies in arid regions (Gillette, 1977, 1979; Marticornea and Bergametti, 1995). The vertical flux parameterizations derived from these observations are generally presented in terms of surface friction velocity as

$$F_V = \square F_h \, , \qquad (1)$$

where F_V and F_h □ f (u_*^3, u_{*t}^3) are the vertical and horizontal PM_{10} fluxes, □ relates the horizontally measured flux to the vertical dust flux (commonly referred to as the K-factor), and u_{*t}^3 is the wind-tunnel-derived threshold friction velocity, which reflects the capacity of a soil to be eroded by wind. This capacity is dependent on the soil's physical and compositional characteristics and its condition. One form of the surface friction velocity (u_*) dependence on wind-blown dust flux has been proposed to be represented as u_* (u_*^2 - u_{*t}^2) (Gillette et al., 1996). This representation for suspension and transport of wind-generated dust from the surface is being considered by the U.S. Environmental Protection Agency for incorporation in the CMAQ model. We recently performed a number of experiments in and around Las Vegas, Nevada, to determine the functional relationship between wind-blown dust and surface friction velocity for a variety of soil types and conditions. The parameterizations developed from this study are used in a dust-modified CMAQ (Version 4.3; EPA, 1999) model (CMAQ-WBD) to calculate wind-blown dust and its transport characteristics in the Las Vegas Valley and the surrounding region. Here we discuss the methodology used for the CMAQ simulations and some preliminary results from this modeling activity.

2 MODELING PROTOCOL AND PRELIMINARY RESULTS

The three-tiered, nested modeling domain for the study is shown in Figure 1. The outer domain (D01) has a grid size of 12 km and covers an area of approximately 100,000 km^2 over parts of California, Nevada, New Mexico, and Arizona. The intermediate domain (D02), which is mainly over Clark County, Nevada, has a grid size of 4 km and covers an area of 8,464 km^2. The inner domain (D03) covers Las Vegas and surrounding communities, an area of approximately 1,300 km^2, at a grid resolution of 1.3 km.

The temperature, pressure, and wind dynamics were generated by using the latest version of the Mesoscale Model, Version 3.6.1 (MM5-V3; Dudhia, 1993). The model's initial and boundary conditions were generated by using the U.S. Department of Energy Reanalysis 2 data products for the mandatory pressure levels and surface data for the summer months of June, July, and August 2000. Additional model constraints were imposed by using upper-air and surface ADP data sets from the National Center for Atmospheric Research to perform model-grid-level four-dimensional data assimilation (FDDA). Additional observations of wind speed, wind direction, and temperature from 12 Clark County Bureau of Air Quality surface meteorological

**Corresponding author address:* V.R. Kotamarthi, Environmental Research Division, 9700 South Cass Avenue, Argonne National Laboratory, Argonne, IL 60439-4843; e-mail: vrkotamarthi@anl.gov.

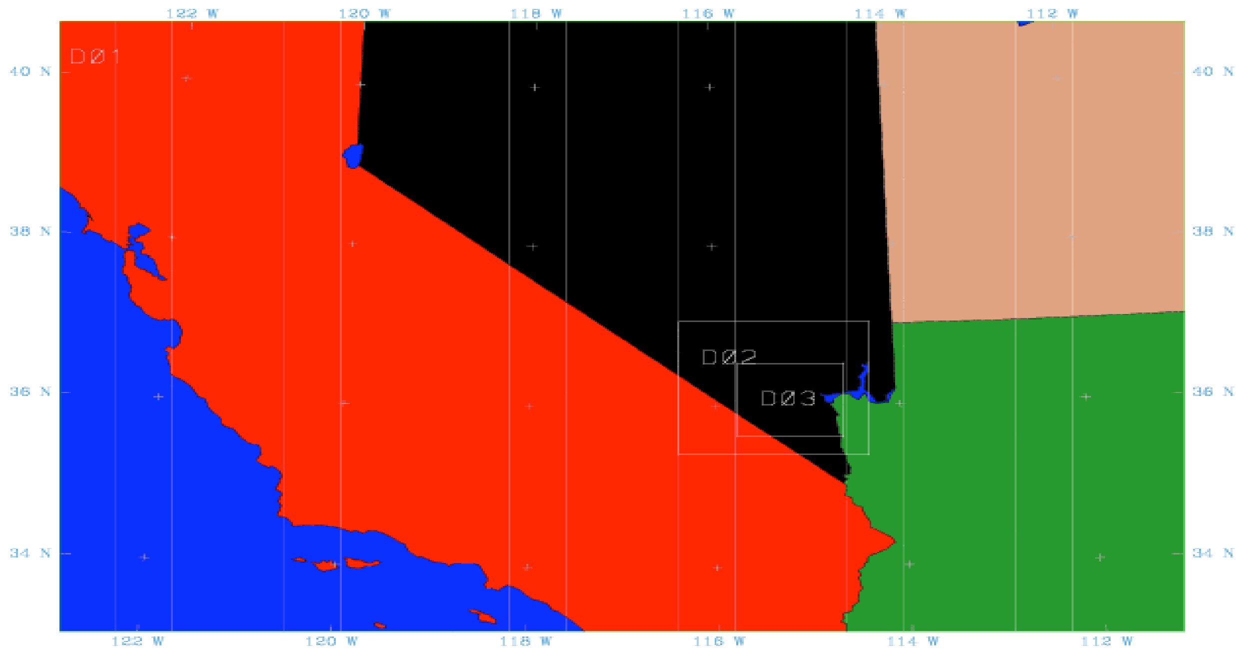

Figure 1. Nested MM5/CMAQ-WBD modeling domain used for this study. The outer domain (entire area, D01), the intermediate domain (D02), and the local domain (D03) are described in the text.

monitoring stations, instrumented with sonic anemometers, were used to nudge the intermediate- and inner-domain wind fields by using FDDA.

The surface observational FDDA gave the best results with data from the monitoring sites updated every 3 h. Use of FDDA improved the root mean square (rms) error between the observed and modeled wind speeds by about 1 m s^{-1} over the 12 monitoring stations (Figure 2). The rms error between measured and modeled wind speeds averaged 3 m s^{-1} when FDDA was not used and improved to 2 m s^{-1} when observational and grid FDDA where turned on. The wind direction calculated by the model showed a much larger improvement. An example of the model-generated and observed wind directions at one of the locations is shown in Figure 3. The observation data assimilations for the MM5 model runs shown in both Figures 2 and 3 used measured wind speed and direction from the station shown and from 11 other stations in and around Las Vegas.

Emissions for the CMAQ simulation were generated by using the SMOKE-2.0 emission generation model. This version of the SMOKE model includes MOBILE 6.2 and BEIS 3.0. The NEI (1999) emission inventory for mobile, area, and point emissions was used to model the coarse (outer) domain. Spatial surrogates required to generate gridded emissions with the SMOKE model and these inventories were generated by using shape files available from the U.S. Environmental Protection Agency and ArcInfo software available at Argonne National Laboratory.

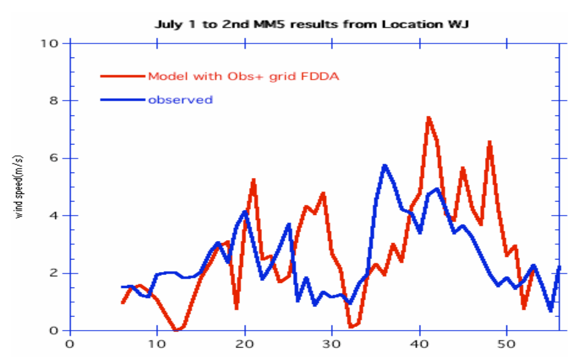

Figure 2. Calculated and measured wind speeds at an air pollution monitoring site in Las Vegas over a 48-h period in June 2000. The observational data were updated every 3 h for nudging of the model predictions.

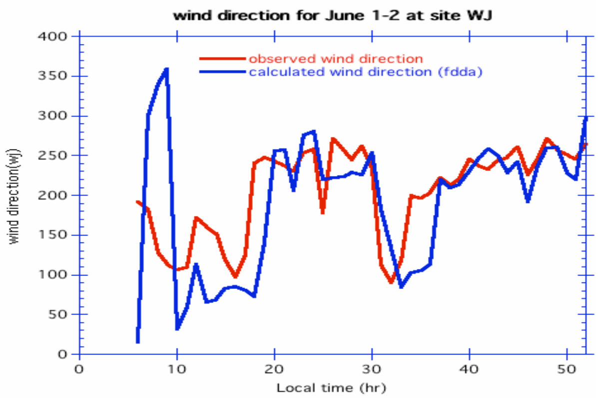

Figure 3: The calculated and measured wind directions at an air pollution monitoring site in Las Vegas over a 48-h period in June 2000. The observational data were updated every 3 h for the nudging of the model predictions.

Figure 4 shows the measured ozone values over Las Vegas at one of the monitoring stations and results of a CMAQ model run for the 12-km-grid outer domain for June 2000. The results show reasonable agreement between measured and modeled ozone for this simulation period. Results for PM_{10} and the impact of wind-blown dust on the modeled PM_{10} for the inner 1.3-km-grid domain over Las Vegas are currently being calculated and will be presented.

3 ACKNOWLEDGMENT

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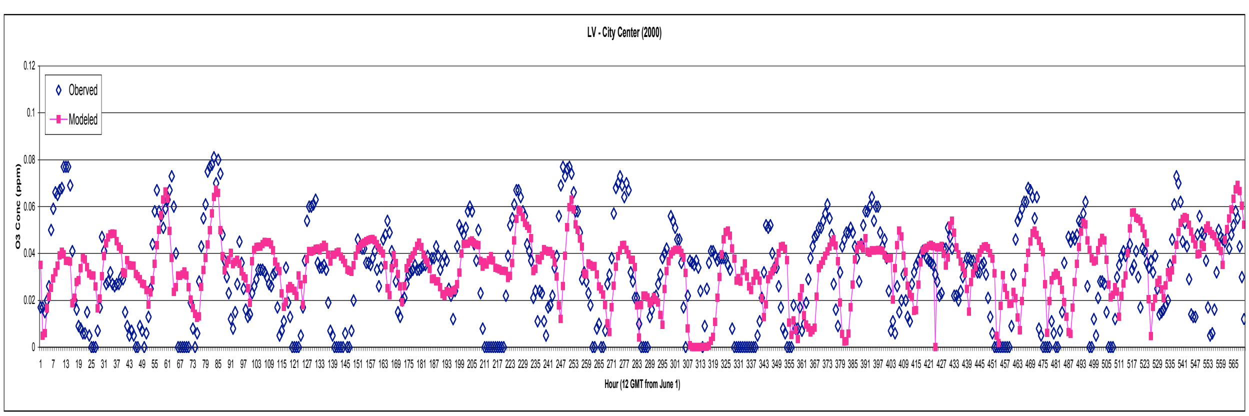

Figure 4. Comparison of regional ozone model predictions with observations over Las Vegas in June 2000.