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Evaluating the use of outputs from comprehensive meteorological models in air quality modeling applications

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Abstract

Currently used dispersion models, such as the AMS/EPA Regulatory Model (AERMOD), process routinely available meteorological observations to construct model inputs. Thus, model estimates of concentrations depend on the availability and quality of meteorological observations, as well as the specification of surface characteristics at the observing site. We can be less reliant on these meteorological observations by using outputs from prognostic models, which are routinely run by the National Oceanic and Atmospheric Administration (NOAA). The forecast fields are available daily over a grid system that covers all of the United States. These model outputs can be readily accessed and used for dispersion applications to construct model inputs with little processing. This study examines the usefulness of these outputs through the relative performance of a dispersion model that has input requirements similar to those of AERMOD. The dispersion model was used to simulate observed tracer concentrations from a Tracer Field Study conducted in Wilmington, California in 2004 using four different sources of inputs: (1) onsite measurements; (2) National Weather Service measurements from a nearby airport; (3) readily available forecast model outputs from the Eta Model; and (4) readily available and more spatially resolved forecast model outputs from the MM5 prognostic model. The comparison of the results from these simulations indicate that comprehensive models, such as MM5 and Eta, have the potential of providing adequate meteorological inputs for currently used short-range dispersion models such as AERMOD.

Keywords: Prognostic meteorological models; Dispersion modeling; Model evaluation; Tracer experiment; Thermal internal boundary layer

1. Introduction

Meteorological data are critical inputs in dispersion models such as AERMOD (Cimorelli et al., 2005), which was introduced recently by the US Environmental Protection Agency (EPA) as a replacement for Industrial Source Complex (ISC) model for estimating the air quality impact of sources for source–receptor distances of kilometers. AERMOD is designed to use vertical profiles of wind speed and turbulence measured at the site

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where the model is applied. Currently AERMOD can accept the following turbulence measurements: standard deviation of the horizontal wind component, σ_θ, and standard deviation of the vertical wind component, σ_w. There are future plans to include other turbulence parameters. Such meteorological observations are usually not available at most sites of interest, and insisting on site-specific measurements is not practical. Thus, AERMOD uses a processor to construct inputs from routinely available National Weather Service (NWS) surface and upper air data from nearby locations. Using NWS observations can pose problems because observation sites can be located tens or even hundreds of kilometers from the location at which AERMOD is being applied. Also, upper air meteorological data needed to estimate mixing heights are usually not collocated with the surface observations. Thus, these data are often not representative of the application site. Furthermore, because the data have to be quality controlled and archived by the National Climatic Data Center (NCDC), they might not be available for months after they are collected.

One possible way for solving this problem with meteorological inputs is to use comprehensive meteorological models to provide estimates of the boundary layer variables required by AERMOD at the site of interest. Because these models have a long history of use in regional air quality models such as the Regional Acid Deposition Model (Chang et al., 1987) and the EPA's Community Multiscale Air Quality (CMAQ) modeling system (Byun and Ching, 1999; Byun and Schere, 2006) their accuracy has improved over the past decade as process parameterizations have been improved by the growing user community. There is an extensive history of coupling numerical weather prediction models and dispersion models (e.g. Yamada et al., 1992; Draxler and Hess, 1998; Draxler, 2003). Outputs from prognostic models run by the National Oceanic and Atmospheric Administration (NOAA) are available in near-real-time over a 12 km grid system that covers the United States. Thus, a model user has ready access to the most recent meteorological data, which can be used in air quality simulations with little further processing. In the future, it should be possible to convert these data to the formats needed for air quality dispersion models at nominal cost. In addition, the formats for the meteorological data from comprehensive models will become standardized as EPA moves to a "one-atmosphere" modeling approach involving national to local scales air quality assessments (Touma et al., 2006).

This paper examines whether gridded outputs from comprehensive meteorological models can be used to construct meteorological inputs for dispersion models such as AERMOD. These outputs correspond to forecast data from two comprehensive meteorological models: the National Centers for Environmental Prediction's (NCEP's) North American Mesoscale (NAM) Model, i.e., the Eta Model (Black, 1994; Rogers et al., 1996), and the fifth-generation Penn State/National Center for Atmospheric Research Mesoscale Model (MM5) (Grell et al., 1995). The Eta model output fields used here are specifically processed for air quality forecasting system (Otte et al., 2005) and are generated with 12-km horizontal grid spacing. Although these models are commonly used in NWS practice (Cheng and Steenburgh, 2005), it is important to assess the ability of operational models to be used as drivers for air pollution modeling and forecasting. Some of the studies demonstrate the limitations of the Eta model in accurately predicting winds in the boundary layer and suggest that for accurate predictions, the horizontal resolution should be about 5 km in complex terrain (e.g., Cairns and Corey, 2003). The version of MM5 used here provides forecasts for Southern California at 3 km horizontal grid spacing (DRI, 2005).

The value of these meteorological model outputs for air quality modeling is evaluated by first comparing them with measurements made onsite, and then using them as inputs to a dispersion model and comparing its performance to those based on the following inputs: (1) onsite measurements relevant to AERMOD, and (2) AERMOD inputs derived from the nearest National Weather Service (NWS) stations. The meteorological inputs correspond to a field study conducted in Wilmington, California, in 2004, which is described next.

2. Wilmington field study

The Wilmington field experiment was conducted by the University of California, Riverside (UCR) in the vicinity of the Harbor Generating Station of the City of Los Angeles's Department of Water and Power (LADWP), located in Wilmington, California (Yuan et al., 2006). The objective of the