1.3 ENSEMBLE AIR QUALITY FORECASTS OVER THE LOWER FRASER VALLEY, BRITISH COLUMBIA: A SUMMER 2004 CASE STUDY

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1. INTRODUCTION

The ensemble-averaging approach is potentially a technique for improving the performance of real-time photochemical air-quality modeling. Ensemble photochemical air-quality forecasts are tested extensively using the Community Multiscale Air Quality (CMAQ) model-system with mesonet observations from the Emergency Weather Net (EmWxNet) and the Quality-Controlled AQ Data Set over the Lower Fraser Valley (LFV).

The CMAQ model is run daily over a 12 km resolution domain (Figure 1 top) covering southern British Columbia, Washington State, and the northern portion of Oregon State. A 4 km resolution grid (Figure 1 bottom) is nested within the 12km grid, and it covers the southern tip of British Columbia (including the LFV) and the northern part of Washington State (including the Seattle area).

CMAQ is driven by two different meteorological models: the Mesoscale Compressible Community Model (MC2), and the Fifth-Generation NCAR / Penn State Mesoscale Model (MM5).

2. DISCUSSION

Ensemble weather forecasts have been extensively evaluated over the past decade, and have been found to provide better accuracy than any single numerical model run (Wobus and Kalnay 1995; Molteni et al. 1996; Du et al. 1997; Hamill and Colucci 1997; Toth and Kalnay 1997; Stensrud et al. 1998; Krishnamurti et al. 1999; Evans et al. 2000; Kalnay 2003). Different Numerical Weather Prediction (NWP) models usually perform better for different synoptic situations, and often their behavior cannot be anticipated.

Hence, their combination into a multi-model ensemble is usually fruitful. Very clear evidence has been presented by Wandishin et al (2001), Richardson (1999) and the US National Centers for Environmental Prediction (NCEP, 2004: http://www.hpc.ncep.noaa.gov/ensembletraining) that the best short-range forecasts are achieved with multi-model ensembles.

NWP ensembles have been created with different inputs (Toth and Kalnay 1993; Molteni et al. 1996) (initial conditions ICs and/or boundary conditions BCs), different parameterizations within a single model (Stensrud et al. 1998) (physics packages, parameter values), different numerics within a single model (Thomas et al. 2002) (finite difference approximations and solvers, grid resolutions, compiler optimizations), and different models (Hou et al. 2001), trying to take into account different sources of uncertainties.

The ensemble technique can potentially yield similar benefits to air-quality (AQ) modeling, because there are similar code complexities and constraints (Delle Monache and Stull 2003). Different AQ models can be better for different air-pollution episodes, also in ways that cannot always be anticipated. For AQ, the ensemble-mean can be created similarly with different inputs (background concentrations, emissions inventories, meteorology), different parameterizations within a single model (chemistry mechanisms, rate constants, advection and dispersion packages), different numerics within a single model (finite difference approximations and solvers, grid resolutions, compiler optimizations), and different models (Delle Monache and Stull 2003). Given the nonlinear nature of photochemical reactions, the ensemble spread might be useful to account for the uncertainties associated with each component of the modeling process.

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Results of an AQ ensemble forecast system are presented. The system includes the CMAQ AQ model, driven by the mesoscale models MM5 and MC2. CMAQ is run with a resolution of 12 and 4 km. The spatial domain considered in the simulation (Figure 1) includes the LFV in Southern British Columbia. In this region, the Emergency Weather Net (EmWxNet) meteorological data and the Quality-Controlled AQ Data Set (from Environment Canada and the Greater Vancouver Regional District) are provided each day for several locations, and include hourly time series of meteorology, ozone, and particulate matter (PM). This data set allows extensive testing, in a wide range of meteorological scenarios and air-pollution episodes.

The ensemble tested in this study has some desirable features. For example, there are differences in the emission data of each ensemble member, partly because the hourly emission values (i.e., biogenic and mobile sources) depend on the meteorology that differs from one mesoscale model to another. These differences can take into account the uncertainty in the emissions estimate, which is often a factor of three or more, and which is the dominant limitation in the photochemical model performance (Russell and Dennis 2000). For the same reason, the different meteorological input fields from MM5 and MC2 allow the ensemble to filter out some of the unpredictable components of the weather. Furthermore, different ensemble members run at different resolutions, which lead to different parcel trajectories, and this allows the ensemble to take into account the uncertainties related to the different but plausible choices of the grid location and resolution.

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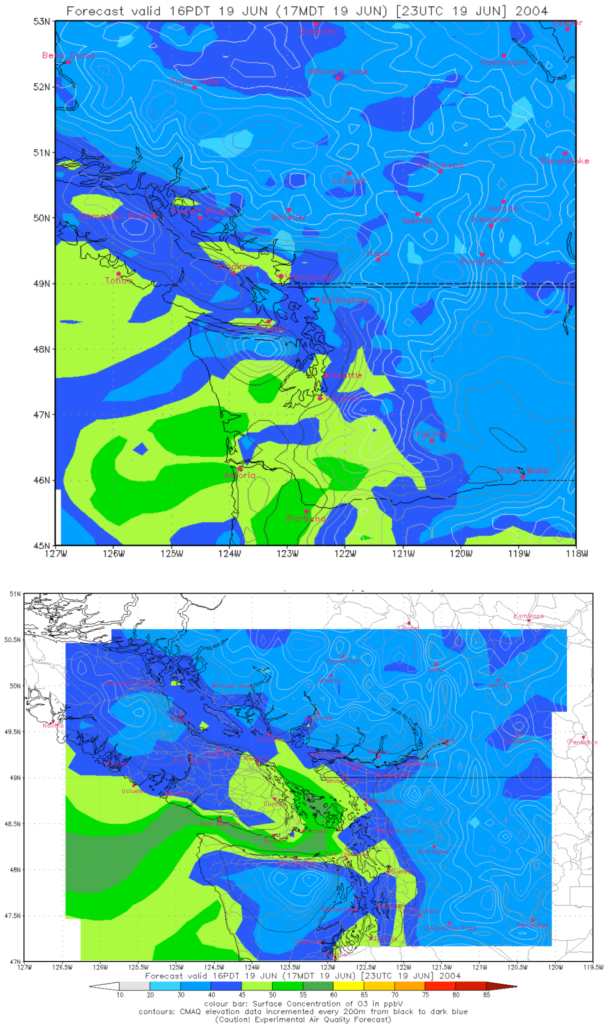

Figure 1: Ozone surface concentration for 16 PDT, June 19 2004. Top: 12 km domain. Bottom: 4 km domain.