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# EVALUATION OF MM5 WITH CASTNET DATA FOR A HIGH OZONE EVENT OVER THE EASTERN UNITED STATES

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## 1. INTRODUCTION

One of the critical components in the application of air quality simulation models (AQSM) is the need for accurate representation of meteorological fields within the planetary boundary layer (PBL) to provide for the transport and dispersion of the pollutant species. Often, the application of AQSMs is based upon historical meteorological events, and recently there has been an increased trend in using the prognostic meteorological models, such as MM5 and RAMS to develop the required meteorological inputs. While it is critical to evaluate these simulations prior to their use with the AQSMs, such an assessment is some what limited by the sparsity of measurements that are independent of the FDDA process.

In this study, we evaluated the MM5 simulations using Blackadar (BL) and Gayno-Seaman (GS) planetary boundary layer (PBL) schemes at 12 km grid resolution for a 9-day period of July 1999 high ozone episode over the eastern United States (Zhang et al., 2001). To this end we utilized meteorological data from the Clean Air Status and Trends Network (CASTNet) that were not part of the data employed in the FDDA process. There are about 47 CASTNet stations in the eastern United States that are primarily situated in remote, rural regions. The CASTNet database considered in this study are hourly temperature, wind speed and direction, and ozone. The objectives of this paper are to assess the performance of MM5 under two commonly applied PBL schemes and to examine their application in simulating pollutant concentrations with a photochemical model, Models3/CMAQ.

## 2. THE METEOROLOGICAL MODEL (MM5V3)

The meteorological model used in this study is the PSU-NCAR MM5 nonhydrostatic mesoscale model. In this study, the model configuration comprises of a triply-nested domain having horizontal grid resolutions of 108/36/12 km, respectively. All three domains had 25 vertical layers with the lowest level at 10 m height. We employed two different boundary-layer schemes for the MM5 simulations: the hybrid local (stable condition) and non-local (convective condition) closure scheme proposed by Blackadar (Blackadar, 1979; Zhang and Anthes, 1982), and the 1.5-order turbulent kinetic energy (TKE) closure scheme developed by Gayno et al., (1994). The meteorological fields were developed for the high ozone event of July 10-19, 1999. Details on the set up and application of MM5 can be found in Zhang et al. (2001).

## 3. RESULTS AND DISCUSSION

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The standard statistical metrics (Willmott et al., 1985) were employed to examine the skill of MM5 by comparing the hourly CASTNet surface measurements. The variables considered for this analysis are the temperature, wind speed, and wind direction. The metrics calculated are the mean error (bias), root-mean-square error (RMS), and index of agreement and are listed in Table 1. Both BL and GS schemes slightly over-predict (positive bias) the observed temperature with similar RMS error and high index of agreement. In the case of wind speed, GS PBL shows a smaller bias and RMS error relative to BL PBL and similar results for wind direction. In general, these estimates compare quite well with similar estimates obtained by Seaman and Michelson (2000) for a 1995 high-ozone episode in the Northeast U.S., indicating that there are no systemic differences in the application of the MM5 system.

To further assess the performance of MM5, we examined the diurnal profile of temperature and wind speed. Figure 1 displays the measured diurnal variation for temperature and wind speed averaged over 47 CASTNet sites from July 11 12Z to 19 12Z, 1999 along with those based on BL and GS PBL schemes. For the temperature field, both BL and GS exhibit slight over prediction and are in-phase with the observations. It should be noted that there was no application of the FDDA within the PBL for the temperature fields in these MM5 simulations. The in-phase agreement of the diurnal variation in temperature between MM5 predictions and observations indicates that the MM5 estimates appear to properly simulate the PBL thermodynamic processes.

In the case of diurnal variation of wind speed, both PBL schemes, similar to temperature, show an overall over-prediction over the observations. The wind speed estimates based on BL are often higher than those based on GS. However, the BL scheme appears to be more in-phase with the observed than the GS scheme. The diurnal variation of the measured temperature and wind speed shows that they are both in-phase with the higher wind speed associated with maximum temperature and the lower wind speed with temperature minimum. While this appears to be generally the case for BL scheme with about 1 to 2 hour phase lag behind temperature, the GS scheme exhibits a phase lag of about 4 to 6 hours. This phase lag between wind speed and temperature suggests that both schemes are unable to properly handle the dynamic processes within the PBL. A notable example of this inconsistency is the decrease in wind speed with increasing temperature in the GS scheme as opposed from the measured data.

### 3.1 Air quality application

The MODELS3/CMAQ system is employed to assess the impact of the wind fields generated by these two PBL schemes on the pollutant concentrations. Due to non-availability of emissions data for this time period, in this study we used the emissions data that were developed for the July 1995 high-ozone episode (Sistla et al., 2001).

Figure 2 shows the average diurnal variation of the predicted and measured O3 concentrations over 47 CASTNet sites. The measured data are shown here to indicate the observed profile rather than as an assessment of the modeling system. The GS PBL scheme predicts higher averaged O3 concentration than the BL PBL scheme, which in part may be due to the low mixing heights (Ku et al., 2001) and the lower wind speeds under the GS PBL scheme. These differences are found to be more pronounced for the urban sites (not shown here).

## 4. SUMMARY

In this study we found that the surface wind fields in MM5 simulations are very sensitive to the selected PBL scheme. While the statistical measures such as mean error, RMS error and the index of agreement failed to discriminate between the Blackadar and Gayno-Seaman schemes, the average diurnal distributions of the wind speed and temperature demonstrated the differences between them. This is suggesting the need to examine the physical processes and parameterization and careful design of the statistical metrics for model evaluation. It was also shown that the uncertainty in the meteorological parameters would in turn propagate through the photochemical model simulations.

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TABLE 1: Summary of statistical measures

| Variable | PBL Scheme | Bias | RMS Error | Index of Agreement |
|---|---|---|---|---|
| Temperature | BL | 1.15 | 3.58 | 0.86 |
| | GS | 1.38 | 3.63 | 0.86 |
| Wind Speed | BL | 0.85 | 1.77 | 0.57 |
| | GS | 0.41 | 1.57 | 0.57 |
| Wind Direction | BL | -9.2 | 141 | 0.43 |
| | GS | -9.8 | 142 | 0.42 |

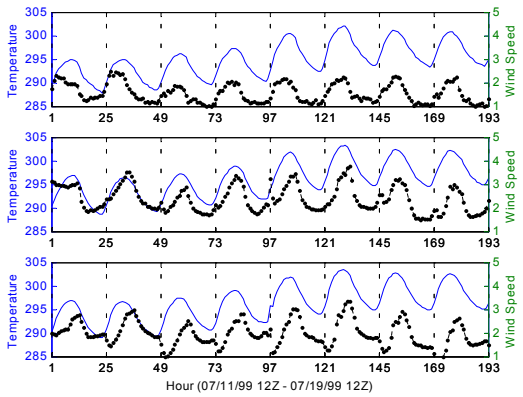


Figure 1: Diurnal variation for temperature (solid line) and wind speed (dot line) for Obs, BL and GS.

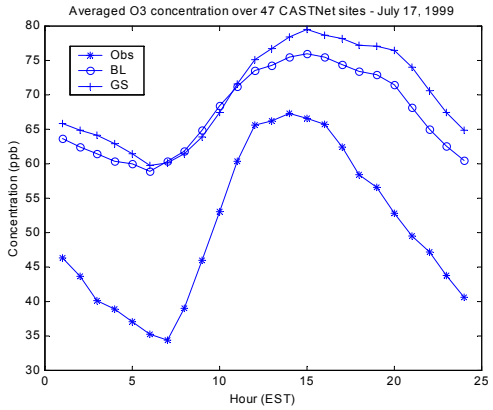


Figure 2:Averaged diurnal variation of the O3 concentration over 47 CASTNet sites on July 17, 1999.