

NUMERICAL EXPERIMENTS ON THE SENSITIVITY OF WRF-CMAQ SIMULATIONS OF AIR QUALITY IN THE MISSISSIPPI GULF COASTAL REGION TO PBL AND LAND SURFACE MODELS

Venkata Srinivas Challa, Jayakumar Indracanti, Monika K.Rabarison, John Young, Chuck Patrick, Julius M.Baham, Robert Hughes and Anjaneyulu Yerramilli *
Trent Lott Geospatial and Visualization Research Centre @Mississippi e-Centre, Jackson State University, MS USA

1. INTRODUCTION

Atmospheric Dispersion Studies are carried out in the Mississippi Gulf coastal zone to develop predictive modeling capability for air pollution dispersion and air quality assessment. The ARW Weather Research and Forecasting model (ARW-WRF) (Skamarock et al., 2005) has recently been used to provide meteorological inputs to Community Multiscale Air Quality Model (CMAQ) (Byun and Ching, 1999) for air quality research applications due to WRF's accurate numerics and high quality mass conservation characteristics (Byun and Kim, 2003). Several physical schemes are available in WRF for boundary layer turbulence and surface processes which play important role in the simulation of lower atmospheric winds, temperature and mixing layer depth which in turn effect the simulations of dispersion / air quality. It is important to ensure accurate meteorological inputs from weather model to obtain precise estimations from air quality models since errors in the meteorological fields are passed on to the air quality model (Gilliam et al., 2006). Present study attempts to explore the sensitivity of CMAQ predicted air quality estimations to two PBL and two land surface schemes in the WRF model. The goal of the work is to study the relative performance of the above schemes and model sensitivity to minimize the uncertainty in air quality simulations.

2. NUMERICAL EXPERIMENTS

Meteorological conditions of Mississippi Gulf coastal region are simulated using ARW-WRF version 2.2 for a 3-day period in June 8-11, 2006 and for a 2-day period in June 28-30, 2007 in typical summer synoptic condition. Three nested grids with 60x50 grid points (36 km grid spacing), 124x82 grid points (12 km grid spacing) and 202x136 grid points (4 km grid spacing) and with

34 vertical layers are used in the model (Fig 1). The area of interest is the inner fine grid (4km) covering the MS Gulf coast. The NCEP Eta analysis data at 40 km resolution is used for initial and boundary conditions. FDDA observation nudging is performed to temperature, mixing ratio, and wind fields using NCEP ADP surface and upper air observations up to 720 min. The model physics options are selected as WSM3 class simple ice scheme for microphysics, Kain-Fritsch scheme for convection, RRTM for long wave radiation and Dudhia scheme for shortwave radiation processes. Two PBL schemes (Yonsei University scheme (YSU); Mellor-Yamada-Janjic (MYJ)) and two surface schemes (5-layer soil diffusion model ; Noah land surface model (Noah LSM)) are considered alternatively for the study.

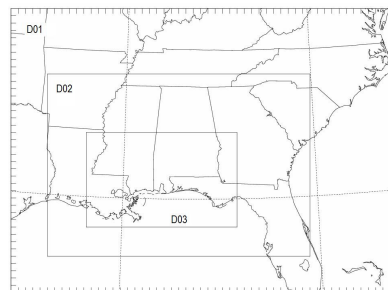


Fig. 1. Model domains in WRF model

The four numerical experiments are i)YSU PBL with Soil model ii)YSU PBL with Noah LSM iii) MYJ PBL with soil model and iv) MYJ PBL with Noah LSM. Air quality simulations are made using CMAQ v4.6 over the MS Gulf coastal region covered by WRF inner fine domain. Same emissions data, initial and boundary conditions are used in CMAQ in the four experiments except the meteorological data which is taken separately from the above runs in each case. Same grid dimensions as in WRF 3rd domain are used in CMAQ while creating meteorological inputs through Meteorology-Chemistry Interface Processor (MCIP).

*Corresponding author: Yerramilli Anjaneyulu, e-mail: yerramilli.anjaneyulu@jsums.edu, Phone: 601-979-3654

3. RESULTS

Simulation results are evaluated with observations of surface air temperature, surface wind from meso-net stations, and pollutant concentrations from continuous ambient monitoring stations. About 8 upper air stations and 12 meso-net station data is used for evaluating model performance. Diurnal trends of the surface wind and air temperature from the model experiments are compared with observations at an inland station Newton and the coastal site Pascagoula (Figs. 2,3 and 4). After the initial spin up time the model values followed the observed trends. Surface wind speed and wind direction are better simulated in the experiment with YSU PBL and Noah LSM. Strengthening surface winds, and shift in direction associated with sea breeze observed at Pascagoula coastal place is better noticed in the second experiment.

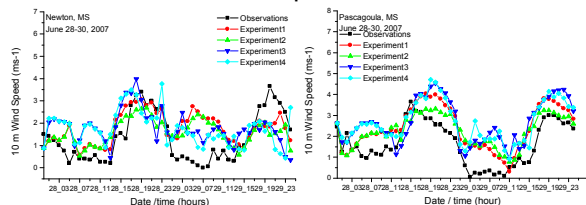


Figure 2. Time series of 10 m wind-speed at Newton (left) and Pascagoula (right).

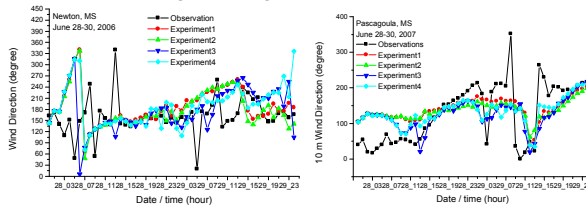


Figure 3. Time series of 10 m wind-direction at Newton (left) and Pascagoula (right)

While the diurnal trend in surface air temperature is similarly predicted in all the experiments, the values obtained in the second experiment are more closer to the observations both during day time and in the night conditions. Temperatures are generally predicted more during the night time and are close to observations during day time in all the cases.

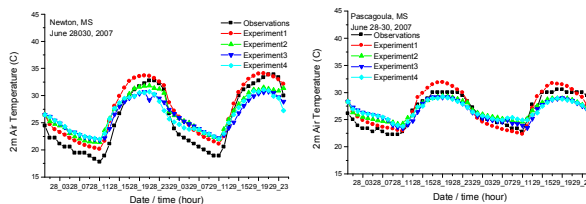


Figure 4. Time series of 2m air temperature at Newton (left) and Pascagoula (right)

Boundary layer height is an important parameter in air quality studies as it determines the effective depth of turbulent mixing of pollutants and their dilution. Model potential temperature at Harrison location near Gulfport is qualitatively compared with GP Sonde observations taken in a boundary layer experiment at the site for June 28th (Fig. 5). Among the different physics used the YSU PBL with Noah LSM produces the observed stable boundary layer in the morning and the well mixed convective boundary layer in the day time.

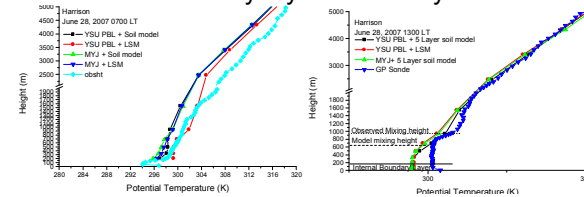


Figure 5. Model and observed potential temperature profiles at Harrison coastal site near MS Gulf coast.

PBL height is expected to be low at the coastal site Pascagoula and relatively high at the inland location Newton. Time series of PBL height in all the model experiments shows this pattern, however experiments with the MYJ scheme shows fluctuations and the daytime PBL height given by it are relatively very high (Fig 6). Experiment with YSU PBL and Noah LSM gives a smooth variation and realistic values at both the sites, however this needs comparison with observations.

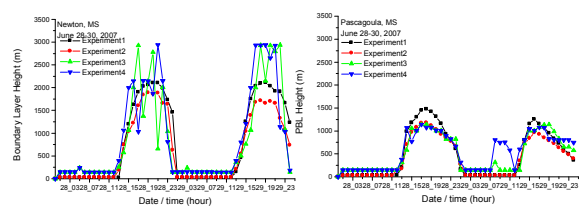


Figure 6. Time series of simulated PBL height at Newton (left) and Pascagoula (right).

Spatial plots of horizontal wind in the 3rd domain show almost similar trends in all the experiments (Fig 7). All the experiments indicate strong southeasterly winds associated with sea breeze and its considerable inland extent. Spatial plots of boundary layer height (Fig 8) indicate coastal belts in Mississippi, Louisiana and Alabama have relatively lower mixing height in the experiments with YSU PBL scheme. GP Sonde observations of potential temperature (Fig 5) confirmed this shallow mixing height forming in the day time due to internal boundary layer development after sea breeze setting at the coast.

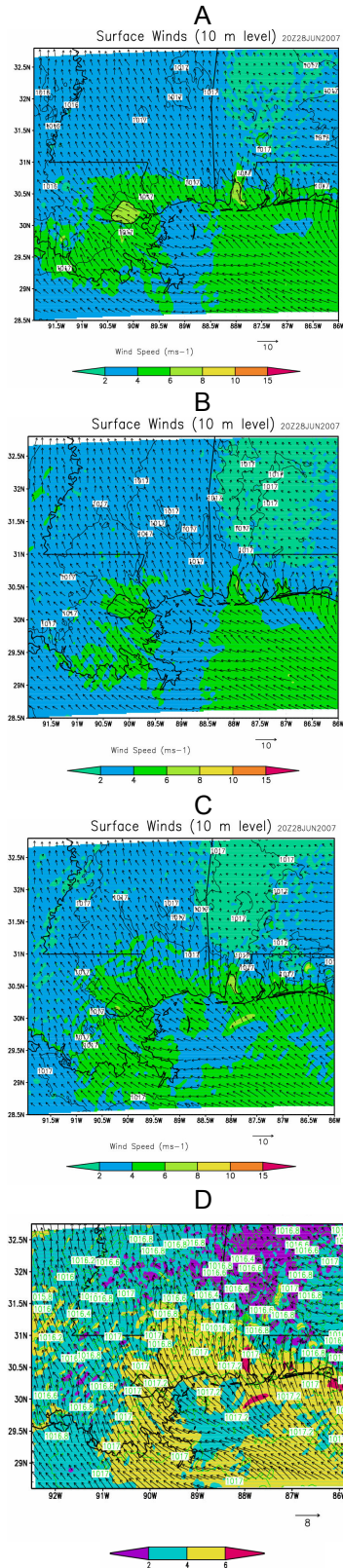


Figure 7. Spatial plots of horizontal wind and sea level pressure at 20 UTC (14 LTC), 28th June, 2007, a) YSU PBL, Soil model b) YSU PBL, Noah LSM c) MYJ PBL, Soil model and d) MYJ PBL, Noah LSM.

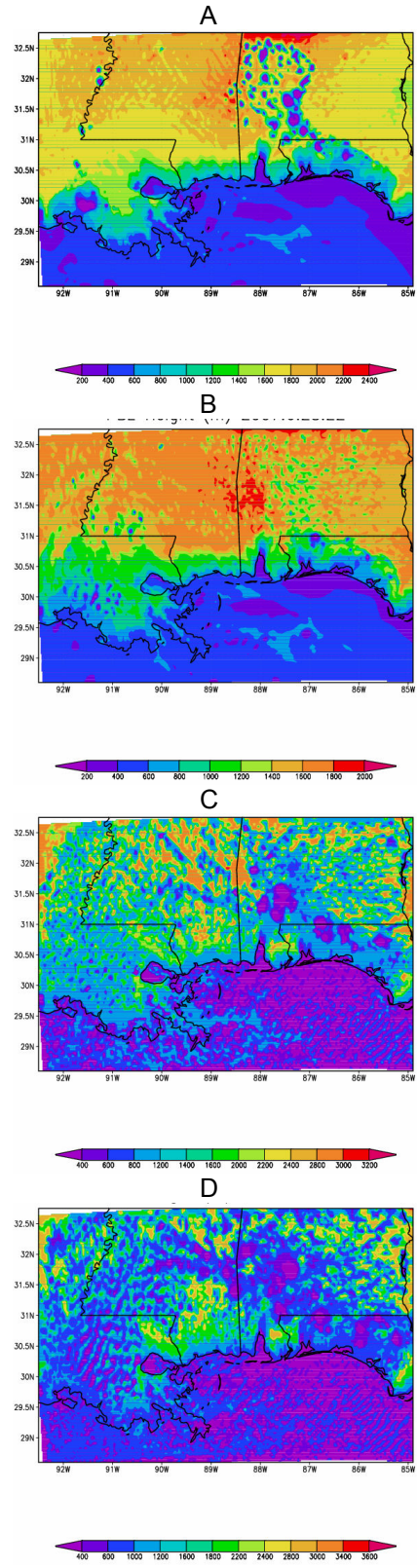


Figure 8. Spatial plots of boundary layer height at 20 UTC (14 LTC), 28th June, 2007, a) YSU PBL, Soil model b) YSU PBL, Noah LSM c) MYJ PBL, Soil model and d) MYJ PBL, Noah LSM

Additional analysis with detailed statistics (correlation, bias and root mean square error) of the predicted and observed mean meteorological parameters both at surface and 850 hpa levels are being made to study the relative performance of the experiments with different options for PBL and surface processes. Analysis of CMAQ model predicted ozone and other pollutant concentrations in each case of the meteorological inputs from the above experiments are being conducted to study the sensitivity of the predicted air concentrations.

4. CONCLUSION

WRF ARW model (version 2.2) is used to simulate the meteorological conditions in the Mississippi Gulf coastal region to simulate a high ozone episode during June 28-30, 2007 and June 8-11, 2006 using CMAQ. Numerical experiments with several physics options for PBL and surface processes indicate YSU PBL along with Noah LSM give realistic meteorological predictions in the lower atmospheric region. Winds, temperature and mixing height near the coast are better simulated with the above combination. Further work for inferring the relative performance of the model with the PBL and surface process schemes is being performed basing on detailed statistical indices of correlation, root mean square error and bias. Also the skill of each experiment and its sensitivity on the CMAQ simulated concentrations is to be studied.

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