DATA ASSIMILATION AND PERFORMANCE EVALUATION OF WRF FOR AIR QULAITY MODELING IN MISSISSIPPI GULF COASTAL REGION

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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) along with Community Multiscale Air Quality Model (CMAQ) (Byun and Ching, 1999) is widely used for air quality research applications. 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). Interaction of the synoptic flow and the local meso-scale circulations such as sea-breeze at the Mississippi coastal region attain importance in meso-scale simulations and consequently on the predicted air quality. Data assimilation has been shown to improve the initial conditions to the meteorological models and their performance (Seaman, 1992; Stauffer and Seaman, 1994). In this work an attempt is made to examine the impact of data assimilation on the WRF produced meteorological fields using the conventional observations and analysis fields and their sensitivity to air quality estimations in the Mississippi Gulf coastal region for the summer 2006.

2. NUMERICAL EXPERIMENTS

Meteorological conditions of Mississippi Gulf coastal region are simulated using ARW-WRF version 2.2 for the period June 8-11,2006 associated with a high ozone occurrence event in the region. 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. Model physics options selected are WSM3 class simple ice scheme for microphysics, MRF scheme for PBL turbulence parameterization, Noah LSM for ground temperature and moisture prediction, Kain-Fritisch scheme for convection, RRTM for long wave radiation and Dudhia scheme for shorwave radiation processes.

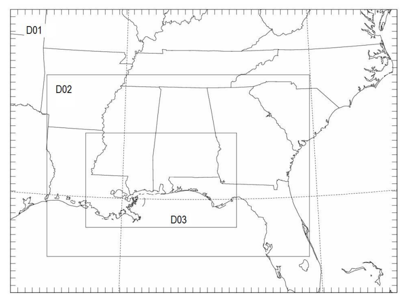

Fig. 1. Model domains in WRF model

Three numerical experiments are conducted: the first is a control run with no data assimilation, the second one with FDDA observation nudging using NCEP ADP surface and upper air observations upto 720 min and the third with grid nudging up to 12 hours.
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 three 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).

3. RESULTS

Model simulation results are evaluated with observations of air temperature, surface wind, from meso-net stations , and pollutant concentrations from continuous ambient monitoring stations. Diurnal trends of the surface

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wind speed and wind direction from the three individual runs are compared with observations at an inland station Newton and the coastal site Pascagoula (Figs.2 and 3). Both the experiments with data assimilation show improvement in day time wind over the control run which is significantly noticed at Pascagoula coastal place. Wind shift at the coastal site due to sea breeze, timing of its onset and associated strong winds are better predicted in the experiment with data assimilation. Also results from grid nudging appear to be better predicted than those from observation nudging.

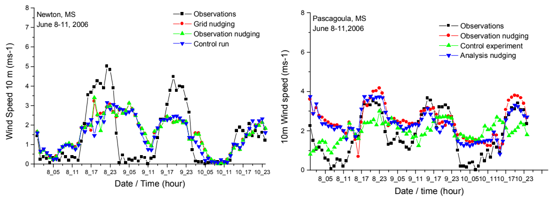

Figure 2. Time series of 10 wind-speed at Newton (left) and Pascagoula (right).

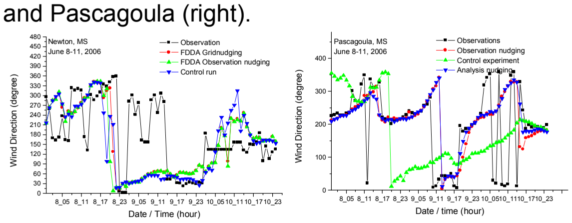

Figure 3. Time series of 10 wind-direction at Newton (left) and Pascagoula (right)

Surface air temperature at 2 m height is predicted similarly in all the three experiments (Fig.3). Temperatures are over predicted during the night time and are close to observations during day time.

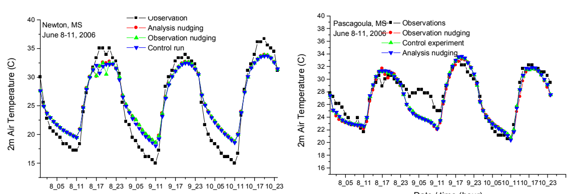

Figure 3. Time series of 2m air temperature at Newton (left) and Pascagoula (right)

Boundary layer height is an important parameter in air quality studies as it determines the effective depth of turbulent mixing. PBL height from the three experiments (Fig 4) indicates smooth diurnal variation in the case with analysis nudging and seems to be more realistic, however this needs comparison with observations.

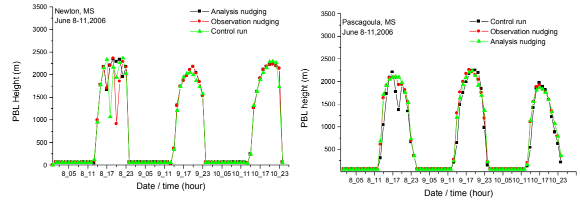

Figure 4. Time series of simulated PBL height at Newton (left) and Pascagoula (right).

Plots of horizontal wind in the 3rd domain show almost similar spatial trends in the experiments with data assimilation (Fig 5). Winds associated with sea breeze, its spatial extent are better simulated in both the experiments with data assimilation.

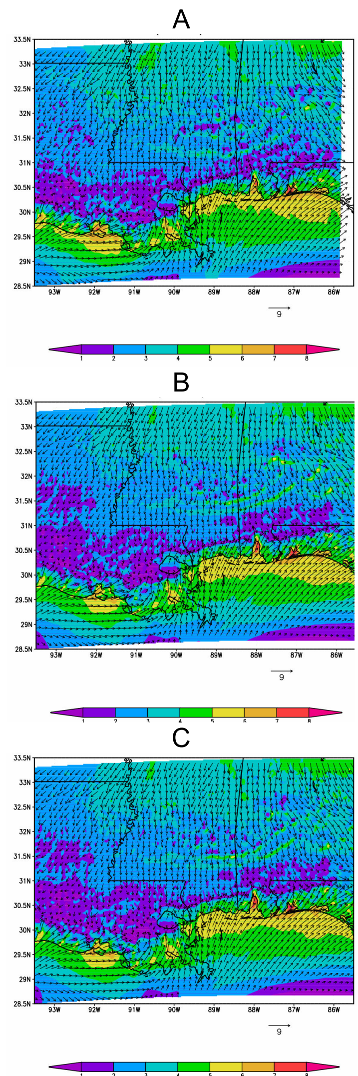

Figure 5. Spatial plots of horizontal wind at 22 UTC (16 LTC), 8th June,2006, a) control run b) observation nudging c) analysis nudging.

Spatial plots of boundary layer height (Fig 6) indicate coastal belts in Mississippi and Alabama have relatively lower mixing height in the experiment with observation nudging than the control run and the analysis nudging. This needs verification with profiler observations in the region. However lower mixing heights are anticipated adjacent to the coast especially in the day time when sea breeze penetrates inland and forms an internal boundary layer.

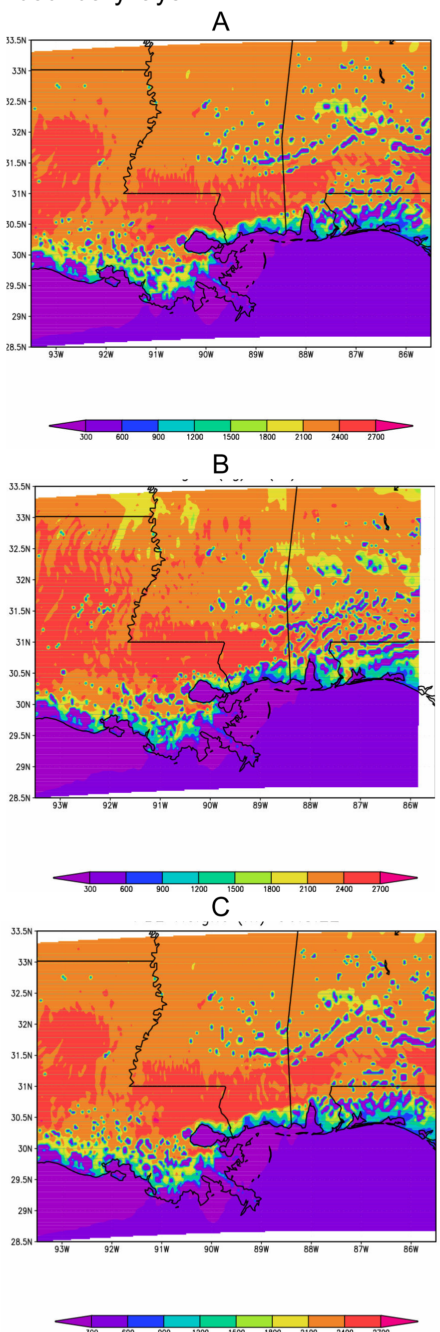

Figure 6. Spatial plots of boundary layer height at 22 UTC (16 LTC), 8th June,2006, a) control run b) observation nudging c) analysis nudging

Additional analysis with detailed statistics (correlation, bias and root mean square error) of the predicted and observed meteorological parameters both at surface and 850 hpa levels are being carried out to study the relative performance of the experiments with nudging. 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 impact of data assimilation and their relative skills on the predicted 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 8-11, 2006 using CMAQ. WRF simulations with data assimilation have shown improvement over the control run in the prediction of near surface winds, temperature and the spatial trends of mixing height. Model parameters near the coast are better simulated with data assimilation, such as wind direction and mixing height. Further work for determining the relative performance of data assimilation techniques has to be done basing on the detailed statistical indices of correlation, root mean square error and bias. Also the skill of each experiment on the CMAQ simulated concentrations is to be studied.

ACKNOWLEDGEMENT

Authors thank for the support of the Atmospheric Dispersion Project (ADP) funded by the National Oceanic and Atmospheric Administration through the U.S. Department of Commerce (Silver Springs, MD); Contract #NA06OAR4600192.

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