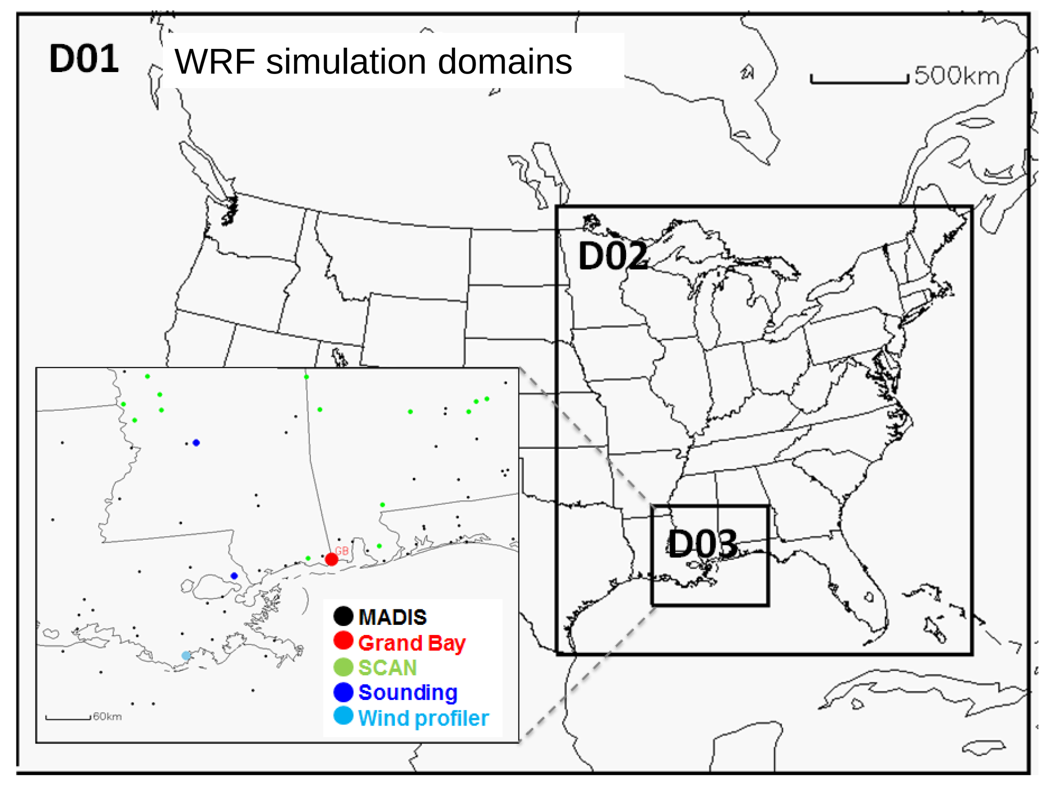
Meteorological Modeling Using WRF-ARW Model for Grand Bay Intensive Studies of Atmospheric Mercury

Fong (Fantine) Ngan[1,2] , Mark Cohen[1], Winston Luke[1], Xinrong Ren[1,2] and Roland Draxler[1]

[1] NOAA/ARL, College Park, MD, [2] UMD/CICS, College Park, MD

INTRODUCTION

Measurements at the Grand Bay National Estuarine Research Reserve (NERR) in Moss Point, MS (30.412°N, 88.404°W) support a range of research activities aimed at improving understanding of the atmospheric fate and transport of mercury. Routine monitoring was enhanced by two intensive measurement periods at the site in summer 2010 (July 28th – August 15th) and spring 2011 (April 19th – May 9th). To support mercury modeling in conjunction with the intensive, WRF-ARW was used to develop fine resolution meteorological fields for the two campaign periods. Two sets of sensitivity tests were performed, to examine influences on model performance and regional flow predictions: 1) the use of different reanalysis data for WRF initialization; and 2) the use of different nudging configurations. WRF results were evaluated with conventional observations and additional measurements including surface and sounding data obtained at the Grand Bay station during the intensive. Backward trajectories using HYSPLIT were constructed for illustrative mercury peaks with different WRF meteorology to understand the influence of meteorology inputs on model-estimated source-receptor relationships at the site.



Grand Bay site – surface and sounding
MADIS – Meteorological Assimilation Data Ingest System including surface, sounding and wind profiler
SCAN – Soil Climate Analysis Network surface data

WRF model configuration

Model version: Advanced Research WRF v3.2
Model grid: D01 (36-km), D02 (12-km), D03 (4-km), 43 vertical layers
Physics options: Rapid Radiative Transfer Model for longwave radiation, Dudhia scheme for shortwave radiation
Pleim-Xiu land surface model, the Asymmetrical Convective Model 2 PBL scheme,
WSM3 microphysics, Grell-Devenyi Ensemble cloud scheme.

EXPERIMENTAL DESIGN

Reanalysis data used for WRF model

Case	Dataset	Spatial resolution	Vertical layers	Temporal interval
NARR	NCEP North American Regional Reanalysis	32 km	29 p levels	3 hourly
GFS	NCEP Global Final Analysis	1 deg	26 layers	6 hourly
NNRP	NCEP/ NCAR Reanalysis Product	2.5 deg	17 p levels 28 sigma	6 hourly
CFSR	NCEP Climate Forecast System Reanalysis	38 km	64 p levels	6 hourly

Nudging configuration

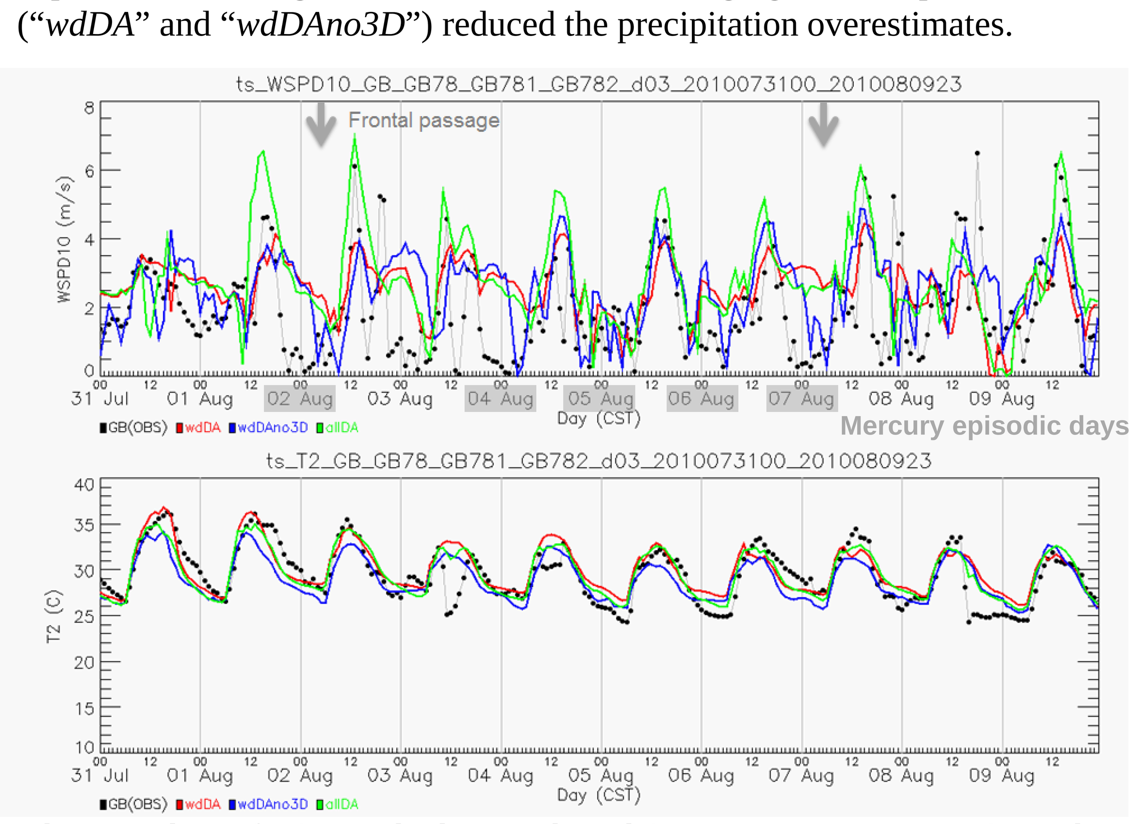
Case	Grid nudging (including surface)	Obs nudging	Nudge u- & v-wind	Nudge T & moisture
allDA	Yes	Yes	Yes	Yes
wdDAno3D	No	Yes	Yes	No
wdDA	Yes	Yes	Yes	No

NOTE: Data from MADIS including surface, sounding and wind profiler were ingested in the simulations through objective analysis and nudging. The Grand Bay data (both surface and sounding) and SCAN data were reserved as an independent dataset for model evaluation.

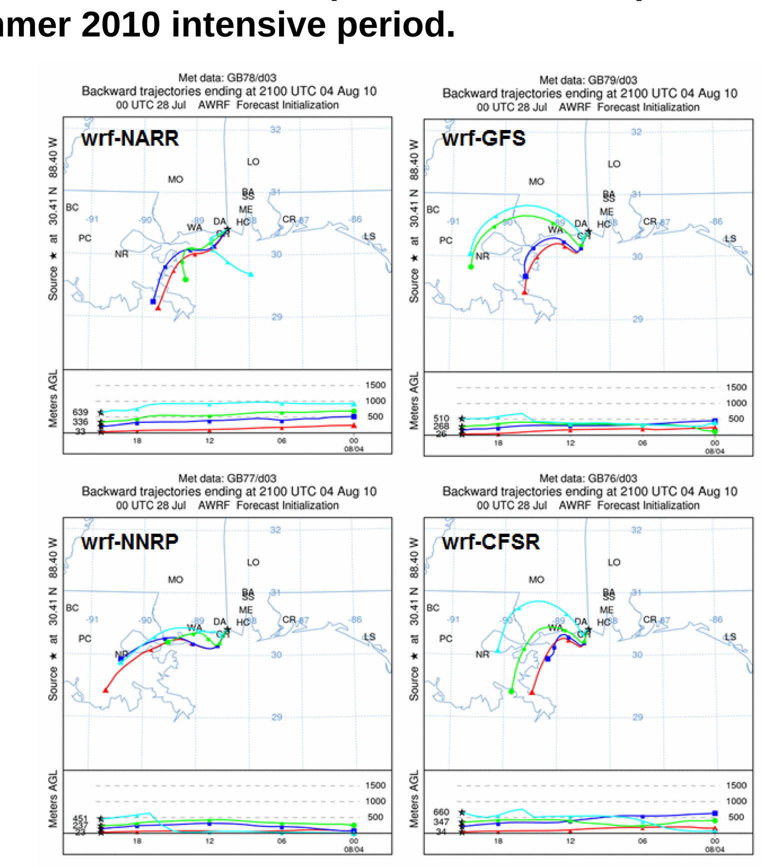
RESULTS AND DISCUSSIONS

WRF had good prediction for the 2-m temperature and 10-m wind speed at the Grand Bay site. During nighttime, the model over-predicted temperature and wind speed occasionally.

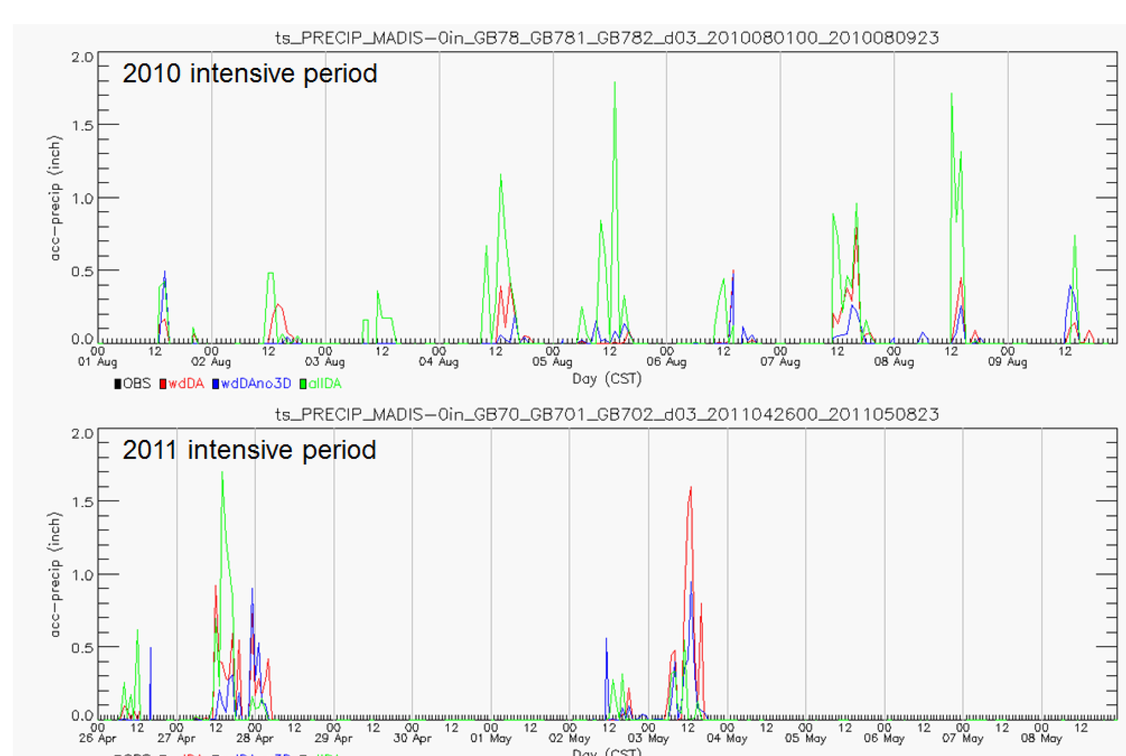
"*allDA*" generated the most significant overestimates of precipitation (and wind speed) in all nudging cases. Gaseous oxidized mercury (GOM), are highly vulnerable to wet removal processes, extraneous precipitation would lead to artificially high wet deposition. Turning off the observational nudging for temperature and moisture ("*wdDA*" and "*wdDAno3D*") reduced the precipitation overestimates.



Time series of 10-m wind speed and 2-m temperature at Grand Bay for summer 2010 intensive period.



Backward trajectories ending at 21 UTC on August 4th, 2010 at Grand Bay utilizing WRF simulations initialized with different reanalysis data.
The "*GFS*", "*NNRP*", and "*CSFR*" cases showed air parcels arriving at the site from the west, potentially bringing pollutants from sources in the west to Grand Bay site. The "*NARR*" indicated air masses coming from the Gulf where the air would be expected to be relatively clean.



Time series of hourly precipitation total accumulation over MADIS stations with zero precipitation for two intensive periods.

"*wdDA*" demonstrated the best skill in simulating wind speed and direction. Nudging of temperature and moisture ("*allDA*") or turning off grid nudging ("*wdDAno3D*") degraded the accuracy of wind prediction in this application. Similar wind speed errors in the upper atmosphere were generated by the three nudging configurations. However, when grid nudging was turned off ("*wdDAno3D*"), larger mean absolute errors for temperature and relative humidity.

Among cases using different reanalysis data, the comparison with SCAN data shows that "*NARR*" had smaller mean absolute error (MAE) in wind speed prediction but the score of "*GFS*" was better in the sounding comparison. For temperature and relative humidity, the "*GFS*" had the best performance at the surface. The influences of the reanalysis data through IC/LBC were observed even in the most inner domain (D03).

Mean absolute error computed with SCAN observations for summer 2010.

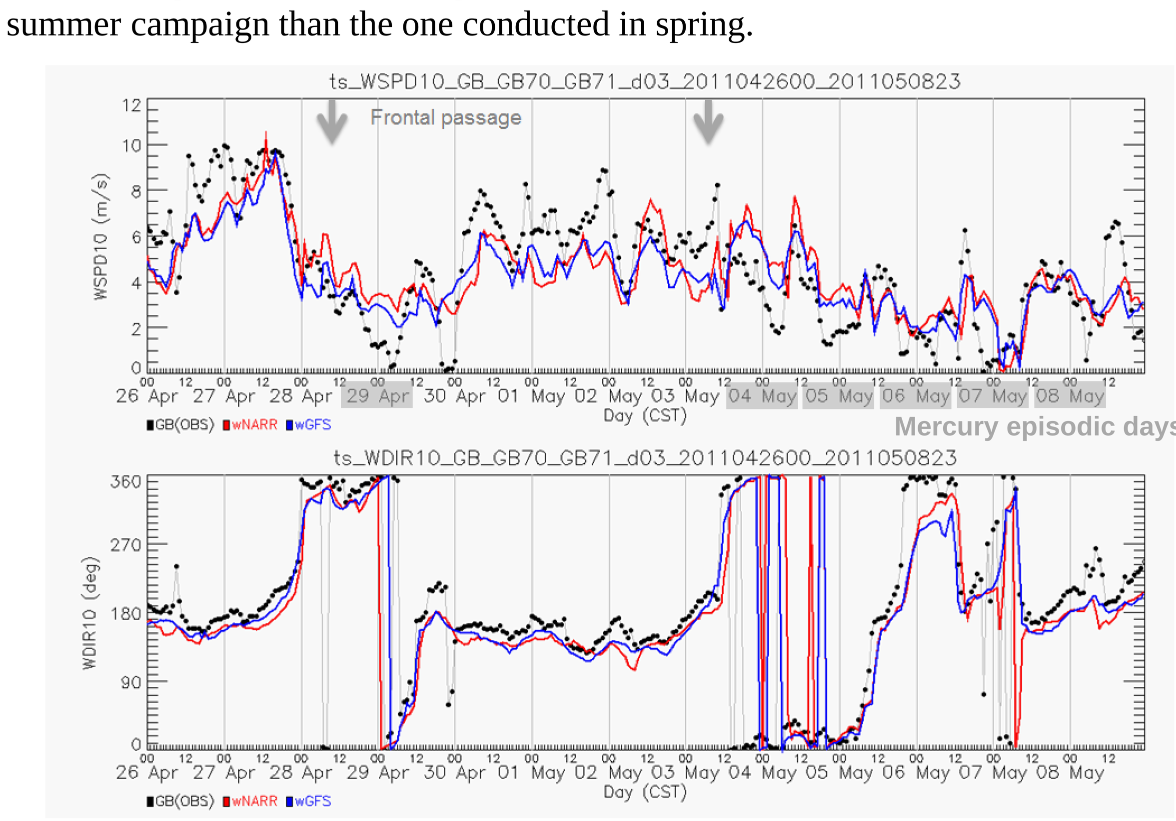
ICBC	nudging	Wind speed (ms^{-1})	Wind direction (degree)	Temperature (°C)	Raltive Humidity (%)
wrf-NARR	allDA	1.180	61.425	2.230	8.860
wrf-NARR	wdDAno3D	1.222	60.476	1.858	7.663
wrf-NARR	wdDA	1.171	59.629	2.482	8.912
wrf-GFS	wdDA	1.251	60.680	1.651	8.334
wrf-NNRP	wdDA	1.366	61.566	1.787	9.246
wrf-CFSR	wdDA	1.207	58.772	2.021	8.806

Mean absolute error of soundings at Grand Bay during the summer 2010.

ICBC	nudging	Wind speed (ms^{-1})	Wind direction (degree)	Temperature (°C)	Raltive Humidity (%)
wrf-NARR	allDA	1.641	33.274	0.636	10.854
wrf-NARR	wdDAno3D	1.656	41.510	0.780	14.003
wrf-NARR	wdDA	1.613	32.391	0.652	11.254
wrf-GFS	wdDA	1.548	31.722	0.607	15.003
wrf-NNRP	wdDA	2.054	33.469	0.731	9.671
wrf-CFSR	wdDA	1.898	30.434	0.603	13.425

For the spring 2011 intensive, sensitivity cases predicted similar wind patterns, generally capturing the turning of the wind direction after the frontal passages, as well as the dominant southerly flow in between. This period was less stormy than the summer 2010 period. No precipitation was observed at Grand Bay on days with high atmospheric GOM that was simulated well by the modeling.

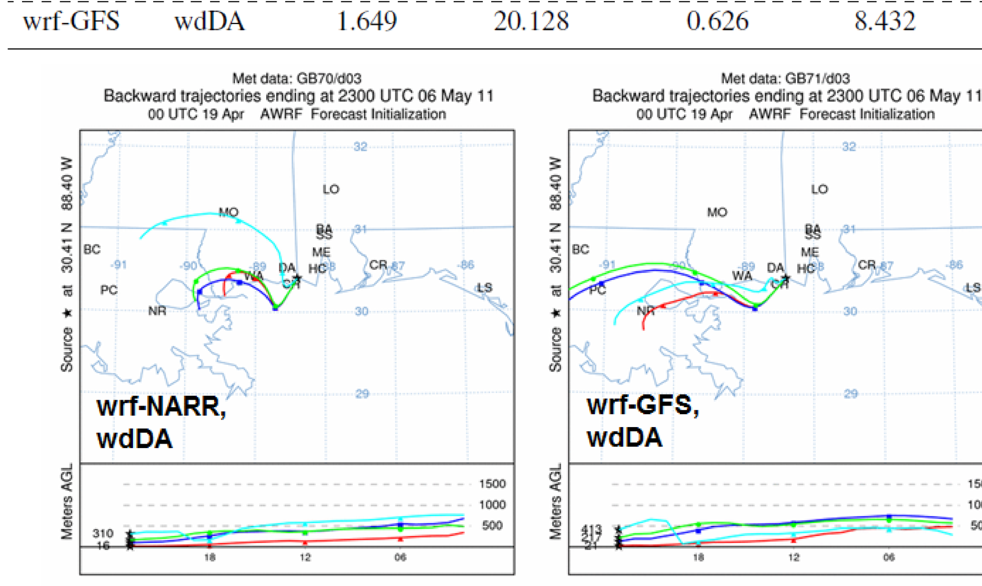
All four variables had very similar MAE among simulations with different model configurations. In comparison of two intensive periods, the reanalysis data had more obvious impact on the WRF performance, even to the most inner domain, in the summer campaign than the one conducted in spring.



Time series of 10-m wind speed and direction at Grand Bay for spring 2011 intensive period.

MAE of soundings at Grand Bay during the spring 2011 period.

ICBC	nudging	Wind speed (ms^{-1})	Wind direction (degree)	Temperature (°C)	Raltive Humidity (%)
wrf-NARR	allDA	1.698	21.938	0.915	9.797
wrf-NARR	wdDAno3D	1.869	21.822	0.895	8.825
wrf-NARR	wdDA	1.683	22.059	0.838	8.575
wrf-GFS	wdDA	1.649	20.128	0.626	8.432



Backward trajectories ending at 23 UTC on May 6th, 2011 at Grand Bay.
The trajectories using the "*GFS*" traveled longer distances than those generated by the "*NARR*" WRF results. The differences in wind speed and direction shown in the trajectory results would likely affect dispersion modeling results from relevant sources in the region.

CONCLUSIVE REMARKS

- WRF-ARW model was used to generate fine resolution meteorological fields for the Grand Bay intensive studies of atmospheric mercury. The results were evaluated with conventional observations in the region and measurements obtained at the Grand Bay site to understand the inaccuracy in meteorological data possibly impacting the simulation of pollutant transport.
- The simulations with grid and observational nudging were in good agreement with observations. Grid nudging at the fine spatial grid did not degrade but reduced errors in the wind predictions. Nudging of temperature and moisture resulted in more extraneous precipitation over the domain that would have potentially large impacts on mercury modeling through effects on wet deposition.
- The most inner domain, even with observational nudging, inherited differing features of reanalysis data that resulted in generating different regional wind patterns. Larger differences were observed in WRF-ARW results in the summer campaign than the spring period.
- Backward trajectory analyses were used to illustrate how even relatively small differences in regional wind fields can impact modeled source-receptor relationships. In a summer 2010 period , the GFS-based simulation showed the air coming from the west potentially bringing pollutants from emissions sources to Grand Bay, while the NARR-based simulation had air masses coming from the Gulf where has no large source of mercury.

Contact information *Address*: 5830 University Research Court, Rm. 4208, College Park, MD 20740 *Email*: Fantine.Ngan@noaa.gov *Tel*: 301-683-1375