Meteorological Modeling Using WRF-ARW for Grand Bay Intensive

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INTRODUCTION

NOAA's Air Resources Laboratory operates a station for the long-term monitoring of atmospheric mercury and other trace species at the Grand Bay National Estuarine Research Reserve (NERR) in Moss Point, MS. The station is one of the first such sites established by the National Atmospheric Deposition Program's Atmospheric Mercury Network (AMNet). Measurements at the site 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 conducted at the site in summer 2010 and spring 2011.

Detailed meteorological data are required to properly represent the weather conditions, in order to determine the transport and dispersion of plumes, including the wet and dry deposition of mercury. To describe the mesoscale features required for the plume calculations for mercury episodes during the Grand Bay Intensive campaigns, fine resolution meteorological simulations were conducted using the Weather Research and Forecasting (WRF) model. Mercury concentrations and deposition at the site will be modeled using the Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT) with the different meteorological inputs. We intend to investigate the influence of spring and summer synoptic weather phenomena on the fate and transport of atmospheric mercury in the region around the Grand Bay measurement site.

MODEL CONFIGURATION

Model: WRF-ARW version 3.2
Period: 2010/07/28 – 08/15 (summer 2010)
2011/04/19 – 05/09 (spring 2011)
43 vertical layers with model top at 50 hPa
15 layers below 850 hPa

❖ Initial & boundary condition

- **NARR** 3 hourly in 32-km resolution with 45 lays
- **GFS** 6 hourly in 1x1 degree resolution with 27 lays

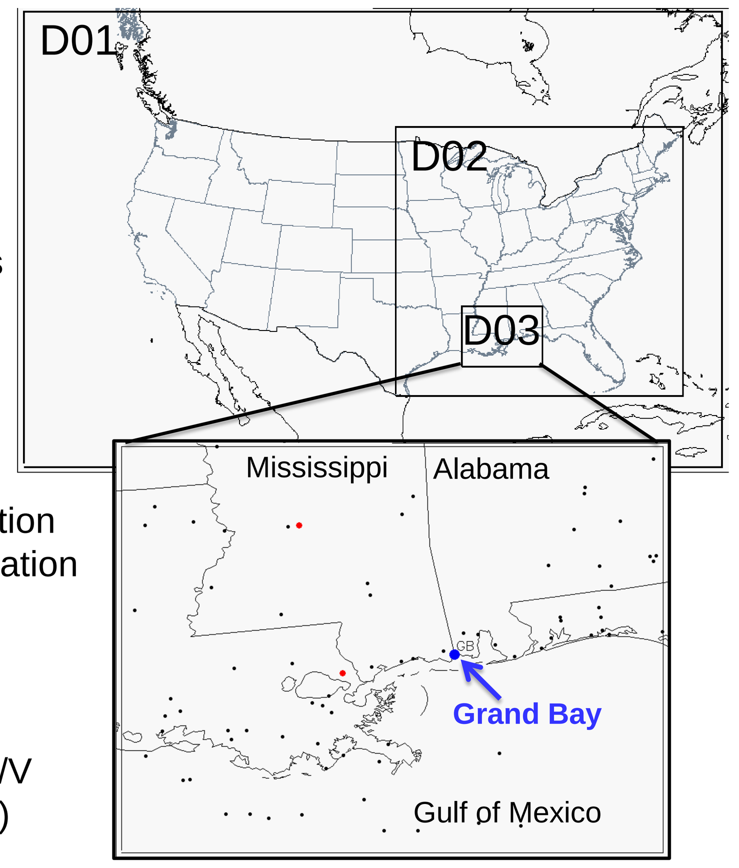
❖ Physical options

Microphysics: WSM 3-class scheme
Land surface model: PX LSM
PBL scheme: ACM2 scheme
Radiation scheme: RRTM scheme for longwave radiation
Dudhia scheme for shortwave radiation
Cumulus scheme: Grell-Devenyi Ensemble scheme

❖ Nudging options

3D grid nudging for T, Q and U/V
Surface grid nudging and observational nudging for U/V
("wdDA" in nudging tests presented on the right panel)

Fig 1 Top: simulation domains in 36-km (D01), 12-km (D02) and 4-km (D03) resolution. Bottom: observations in D03 including surface stations (black), soundings (red) and Grand Bay station (blue).



NUDGING TESTS

Nudging is commonly used in meteorological modeling to minimize error growth during the simulation to provide more accurate fields for chemistry and dispersion calculations. Three nudging simulations using NARR initialization were performed for the summer 2010 campaign: **1) allDA**, grid nudging (including surface) and observational nudging for all fields (T,Q,U,V); **2) wdDAno3D**, observational nudging for wind components; **3) wdDA**, grid nudging (including surface) and observational nudging for wind fields. Statistical summaries for surface temperature and wind speed are shown in the table (better scores are highlighted in pink & red). "wdDA" and "allDA" configurations showed similar skill in wind predication but "wdDA" was slightly better. For temperature, "allDA" was the best, perhaps not surprising since it included temperature observations in the nudging. A run using GFS initialization with "wdDA" nudging was conducted and it produced better scores in wind fields for this campaign compared to the run using NARR.

IC/BC	nudging	R	Bias	RMSE	IOA	
wrf-NARR	allDA	0.573	0.531	1.565	0.697	10-m wind speed 17458 samples
wrf-NARR	wdDAno3D	0.519	0.648	1.669	0.638	
wrf-NARR	wdDA	0.579	0.440	1.512	0.690	
wrf-GFS	wdDA	0.672	0.251	1.337	0.763	
wrf-NARR	allDA	0.934	-0.167	1.329	0.961	2-m temperature 17359 samples
wrf-NARR	wdDAno3D	0.812	-0.310	2.145	0.890	
wrf-NARR	wdDA	0.833	0.019	2.010	0.905	
wrf-GFS	wdDA	0.848	-0.377	1.966	0.912	

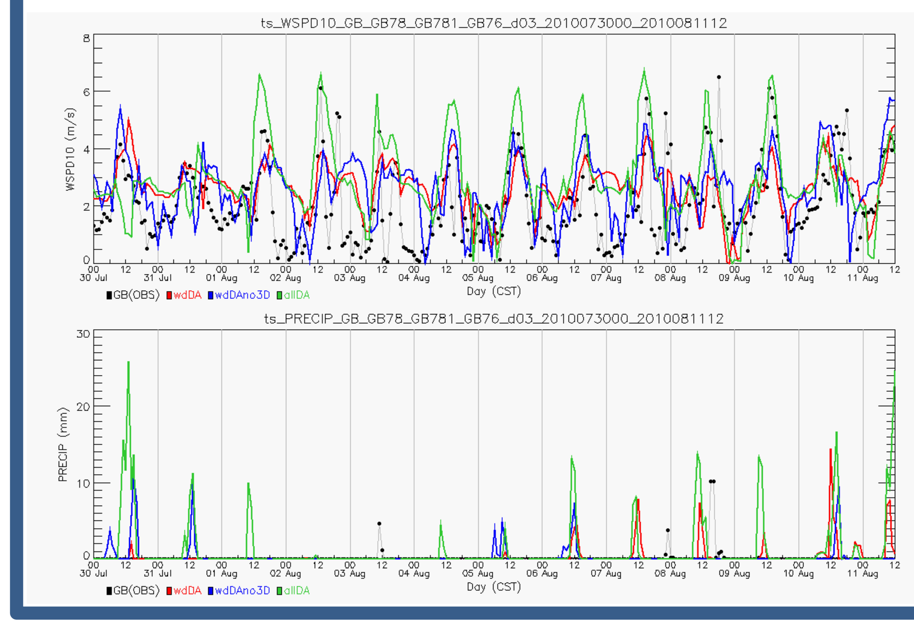


Fig 8 Time series of 10-m wind speed (top) & precipitation (bottom) at Grand Bay during the campaign in summer 2010. The "allDA" case produced higher surface wind speed than other two runs and could simulate the peak value occasionally. However, it over-predicted the frequency and intensity of precipitation, which would have an important impact on the modeling of mercury wet deposition.

RESULTS AND DISCUSSIONS

Grand Bay Intensive summer 2010

A high pressure system was dominant in the Gulf of Mexico in the beginning of the study period. It was weakening and a weak stationary front was approaching the coast of Mississippi on August 2nd (frontal passages are marked with green arrows in Fig 2). The ambient temperature was about 33 ^{0}C for daytime maximum and 25 ^{0}C for nighttime minimum while wind speed was light to moderate, with mostly southerly to southwesterly flow. High Reactive Gaseous Mercury (RGM) peaks, in range of 20 – 60 pg/m^3, were observed at Grand Bay on August 2nd, 4th – 7th (marked with green stars in Fig 2). The average Gaseous Elemental Mercury (GEM) level of the campaign period was 1.42 ng/m^3. There was another stationary front approaching the Grand Bay station on August 7th.

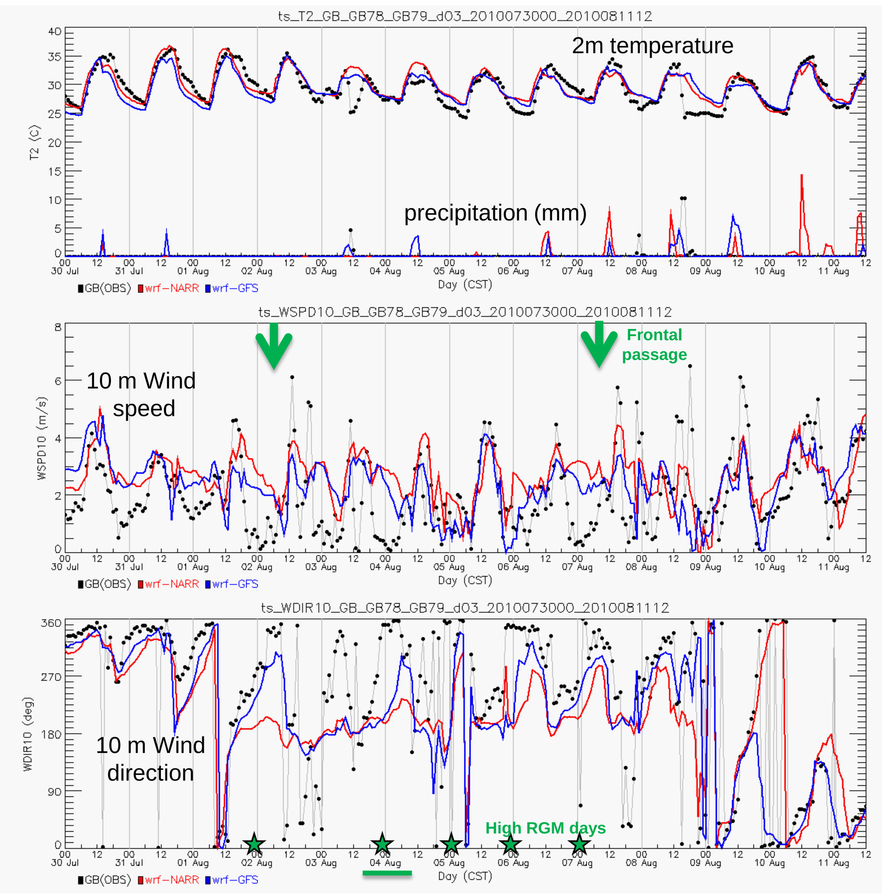


Fig 2 Time series of 2-m temperature & precipitation (top), 10-m wind speed (middle) and wind direction (bottom) at Grand Bay during the campaign in summer 2010.
Wind speed predicted by wrf-GFS simulation was slightly lower than wrf-NARR. But the wrf-GFS case was able to produce more southerly components in wind direction on Aug 2nd, 4th, 6th – 9th.

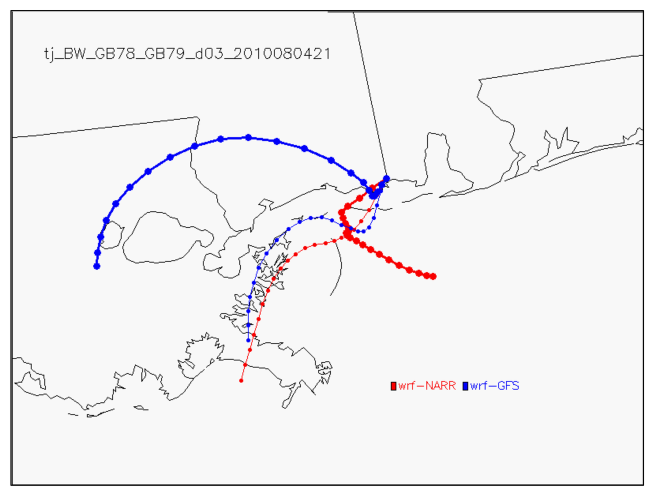


Fig 4 Backward trajectories ending at 21 UTC on Aug 4th, 2010 at Grand Bay at height of 10 m (thin lines) and 200 m (bold lines). The meteorological inputs are wrf-NARR (red) and wrf-GFS (blue)

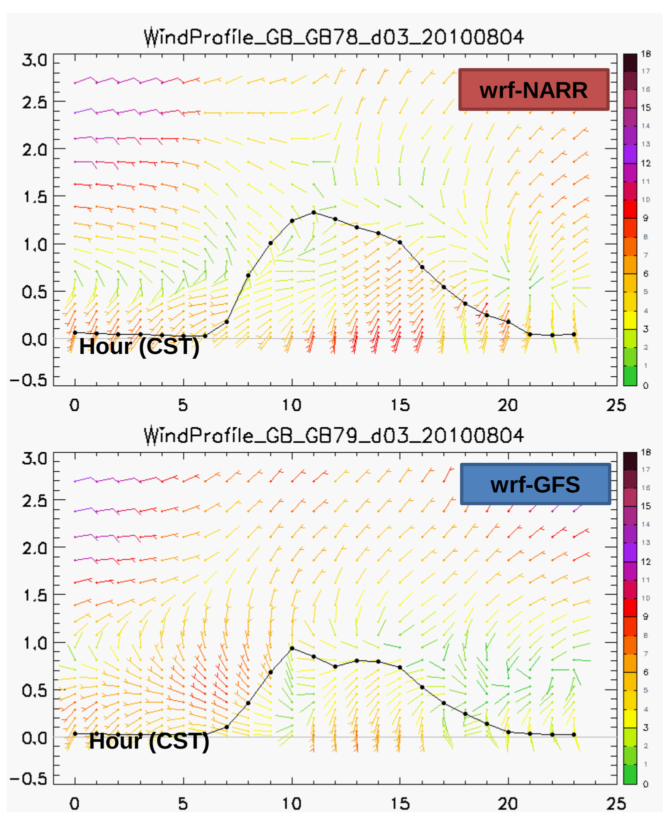


Fig 3 Wind profiler plot at the Grand Bay station Aug 4th, 2010, a day with high RGM concentrations, from wrf-NARR (top) and wrf-GFS (bottom). The colors of wind barbs represent model wind speed while the black line is model Planetary Boundary Layer (PBL) height.
Winds near the surface (in PBL) were stronger in wrf-NARR than wrf-GFS. The PBL height predicted by wrf-NARR grew faster and higher than modeled by wrf-GFS.

Grand Bay Intensive spring 2011

Frontal activity was confined largely to the North of Grand Bay region so the Grand Bay area was dominated by southerly flows. On April 28th and May 3rd, cold fronts (marked with green arrows in Fig 5) passed through bringing continental cold air masses to the station. Those days experienced post-frontal conditions – dry air, low night time temperature and light northeasterly wind in the morning with southerly sea breeze in the afternoon – and high levels of RGM were observed at Grand Bay station. The episodic days were April 29th and May 4th – 7th (marked with green stars in Fig 5) with peak values in range of 30 – 70 pg/m^3, while the average GEM value during spring campaign was 1.53 ng/m^3.

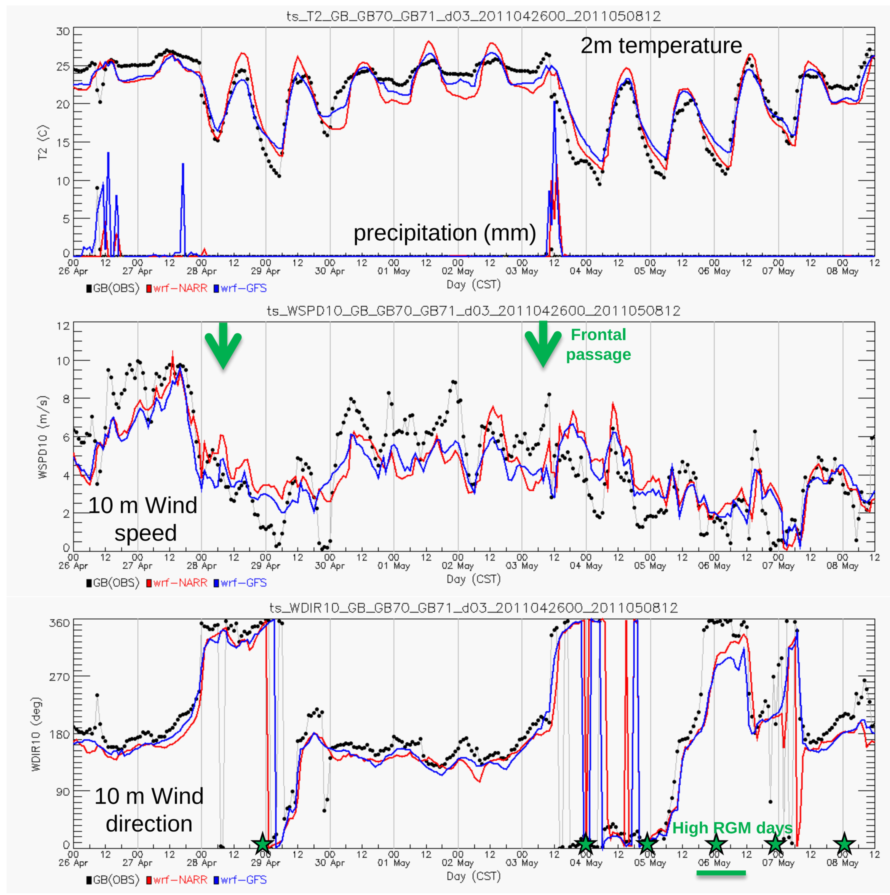


Fig 5 Time series of 2-m temperature & precipitation (top), 10-m wind speed (middle) and wind direction (bottom) at Grand Bay during the campaign in spring 2011. Both runs had similar simulation on the surface wind and in good agreement with the Grand Bay measurement.

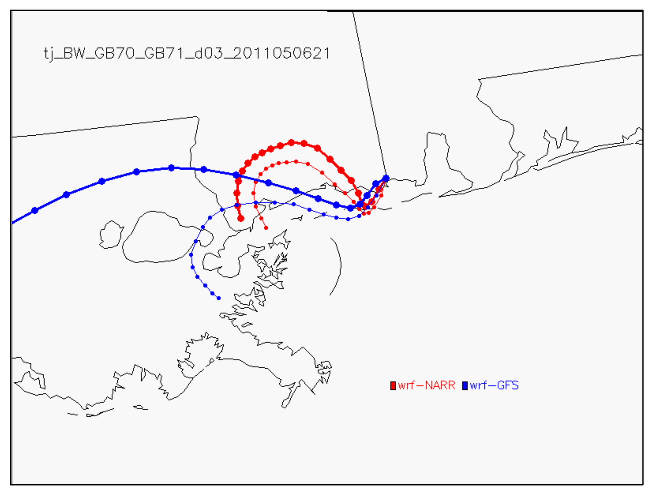


Fig 6 Backward trajectories ending at 21 UTC on May 6th, 2011 at Grand Bay driven by wrf-NARR (red) and wrf-GFS (blue) at height of 10 m (thin lines) and 200 m (bold lines).
Trajectories generated by two WRF data are more similar in the spring period than the summer campaign.

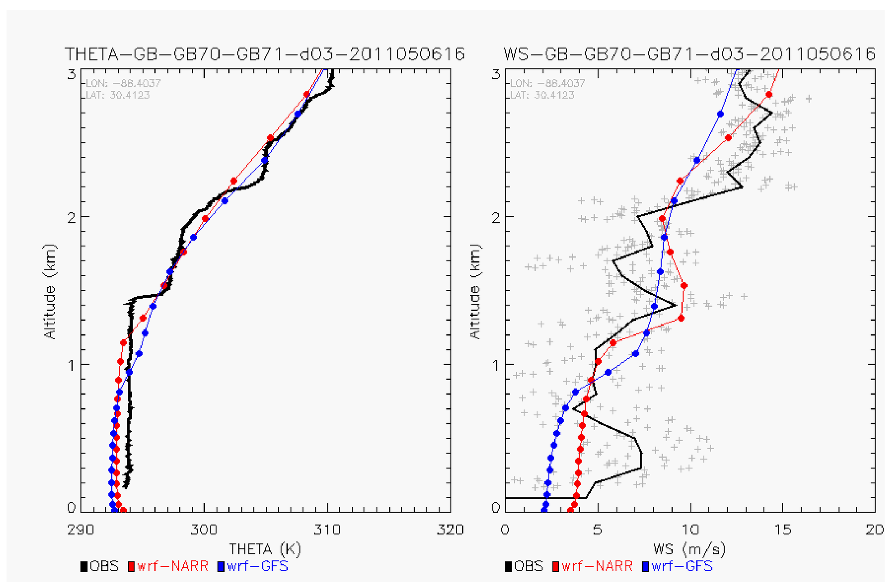


Fig 7 Sounding launched at Grand Bay at 16 UTC on May 6th, 2011 for potential temperature (left) and wind speed (right). The simulated potential temperature had a cold bias within PBL, and the model predicted a lower PBL height compared to the sounding. Wind speeds in the lowest 800 m were under-predicted while wrf-GFS had slightly more bias than wrf-NARR.

SUMMARY

❖ WRF-ARW was used to provide fine resolution meteorological fields to aid understanding of the atmospheric fate and transport of mercury during the Grand Bay Intensive in summer 2010 and spring 2011.

❖ The simulations by WRF-ARW with grid and observational nudging generated reasonable results and were in good agreement with the Grand Bay measurements.

❖ Nudging of wind components with grid and observational data reduced wind errors successfully but nudging of mass fields (temperature and moisture) tended to over-predict precipitation, which would introduce inaccuracies into wet deposition simulations.

❖ Larger differences were observed in WRF results initialized by NARR and GFS in the summer campaign than the spring campaign. In the backward trajectory analysis of a mercury episode (Aug 4, 2010), wrf-GFS simulation showed the air coming from the west, potentially bringing pollutants from sources in the west to Grand Bay, while wrf-NARR air masses coming from the Gulf.

ONGOING WORK

❖ The WRF-ARW results will be further analyzed with other observations that are not included in the nudging, such as Soil Climate Analysis Network (SCAN) or mesonet data from Meteorological Assimilation Data Ingest System (MADIS).

❖ Mercury modeling using HYSPLIT model will be performed with different meteorological inputs for both campaigns.

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