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ASSIMILATION OF NEARSHORE WINDS INTO A HIGH-RESOLUTION ATMOSPHERE/WAVE MODELING SYSTEM

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1. INTRODUCTION

The evolving sea spectra depends implicitly on the physical processes associated with wind generated waves that impact the high frequency end of the wave spectrum. As a result, the near surface wind field is a critical component of any wave forecast or hindcast system (e.g., Teixeira et al., 1995; de León and Ocampo-Torres 1998). Moderately high-resolution (on the order of 10-15 km in the horizontal) surface wind fields are available in near-real time from a suite of model output generated at the National Centers for Environmental Prediction (NCEP). However, despite the advancements in mesoscale modeling, known problems such as errors in the diurnal signal of surface wind speed and temperature persist (Colle et al. 2002; Mass et al. 2002, etc.). Further, although the spatial resolution of the operational atmospheric models has continued to improve, it is not likely sufficient to support high-resolution wave forecasting in the coastal zone.

In response to these and other issues the Florida Institute of Technology (FIT) has received NOAA CSTAR funding for a three-year collaborative wind and wave modeling project with National Weather Service Forecast Offices in Melbourne and Miami Florida. The project consists of two basic components: 1) the real-time coupling of high-resolution wave and atmospheric models and 2) data assimilation. The latter work is presented here while details of the former can be found in a companion preprint (Howard et al. 2009). The project goal is to generate accurate high-resolution real-time wave forecasts in the coastal zone of East Central Florida. Improved wind and wave forecasts in coastal regions will positively impact boating and beach going interests with respect to issues such as rip currents, Gulf Stream wave heights, coastal flooding, beach erosion, and support of Hazardous Materials (HazMat) spills recovery efforts. Additional benefits include coastal engineering applications, storm response planning, and coastal zone management. Coastal zone wave forecasts are relevant to NASA launch, landing, booster retrieval, and daily ground processing forecasts for the Kennedy Space Center and Cape Canaveral Air Station.

2. METHODS

The Advanced Regional Prediction System (ARPS) Data Assimilation System (ADAS, Brewster 1996) is used to assimilate the wind observations. Scatterometer and WSR-88D winds are the only sources of high density data across an otherwise data-sparse marine region. Assimilated radar, satellite and surface winds are blended with NCEP's 12 km North American Mesoscale Model (NAM, Black 1994) 10 m winds to provide an improved set of initial conditions for short-term (24 h) high-resolution Weather Research and Forecasting Environmental Modeling System WRF-EMS forecasts (e.g., see Fig. 1). Three different WRF configurations are currently being evaluated and include single grid horizontal resolutions of 4.5 km and 10 km as well as a nested grid with a fine inner mesh resolution of 1.5 km and outer nest of 4.5 km. Each of the domains has horizontal grid dimensions of 468 km x 545 km (Fig. 2), with a stretched vertical grid consisting of 19 sigma levels. Here, results are shown for the 4.5 km domain only. Although it is not yet clear whether or not the high-resolution nested WRF is superior, early indications suggest that the 4.5 km WRF outperforms (i.e., produces

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better wave forecasts) both the nested and 10 km domains (Howard et al. 2009).

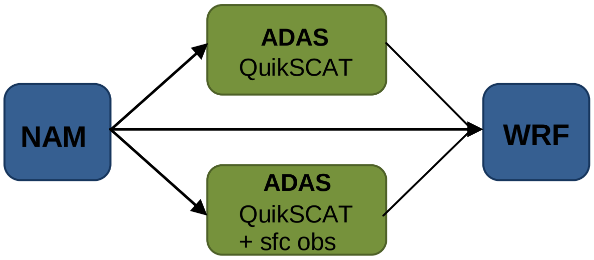

Fig. 1. WRF/ADAS data assimilation options. The center arrow depicts the case with no wind assimilation.

The initial build of the real-time system extends eastward over Atlantic coastal waters of central Florida and is coupled, one-way, with a high-resolution nearshore wave model (Fig. 2). The wave simulations are run independently over five subdomains along the Florida east coast (Howard et al. 2009). As illustrated in Fig. 1, three WRF-EMS initialization options are considered here including forecasts driven 1) solely by the NAM initial conditions, 2) by NAM initial conditions blended with QuikSCAT winds, and 3) by NAM initial conditions blended with both QuikSCAT winds and surface observations. NAM boundary conditions are used for all three scenarios and are updated at 3 h intervals. Four NAM subset tiles (http://www.emc.ncep.noaa.gov/mmb/research/tiles.218.html) are required to launch the WRF forecasts that are initialized using the NAM output from the 00 UTC cycle. The 00 UTC cycle coincides (i.e., within an hour) with a QuikSCAT overpass time for the study area. QuikSCAT grib files (http://www.opc.ncep.noaa.gov/grids/data/) are converted into ADAS friendly LAPS surface observation (lso) format and then blended with the NAM with the output comprising the initial conditions for a 24 h WRF-EMS forecast.

3. RESULTS

Preliminary results are presented for a case study of the tropical storm (TS) Fay event which impacted Florida over a 5-day period from 18-23 August 2008 (Fig. 3).

3.1 T.S. Fay Synopsis

Albeit only a tropical storm, Fay is a challenging case for both wave and atmospheric modeling. Approaching from the southwest, Fay generated an extended period of onshore fetch over the forecast region. The flow then shifted to off shore as the storm region. Sustained wind speeds at NCDC buoy 41009 (Fig. 2) exceeded 15 ms^{-1} for a 24 h period center moved north of the beginning around 16 UTC 20 August 2008 and remained over 10 ms^{-1} through 00 UTC 23 August 2008. Additionally, significant wave heights peaked at 5.1 m around 08 UTC 20 August 2008.

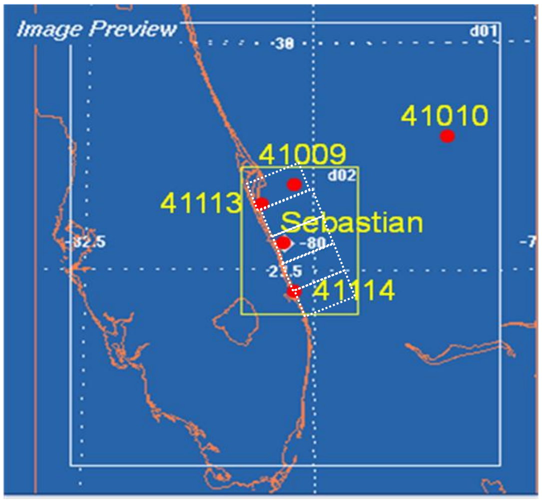

Fig. 2. WRF-EMS domain boundaries showing inner nest (yellow solid line) and outer nest (white solid line). Also shown are the 5 wave model subdomains (dotted boxes) and locations of the validation buoys.

3.2 Data Assimilation

The 00 UTC 20 August 2008 10 m winds for the QuikSCAT overpass[2], NAM first guess field, and a 4-pass ADAS analysis are shown in Fig. 4.

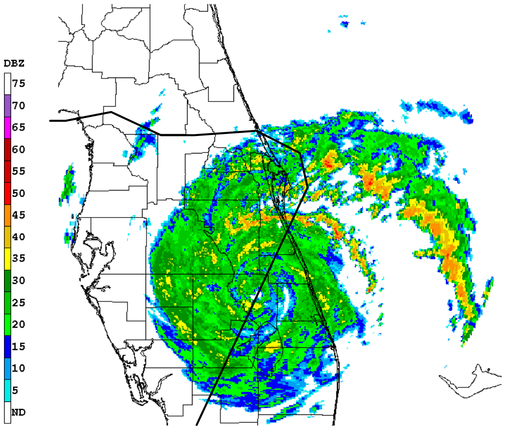

Fig. 3. Melbourne FL National Weather Service WSR-88D reflectivity (0.5 degree) for tropical storm Fay valid 00:12 LST 20 August 2008. Approximate storm path delineated by solid black line.

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[2] The QuikSCAT swath through the region is actually valid between 23 and 00 UTC.

The length scale, which is a function of the analysis iteration, ranges from 30 to 5 km. The QuikSCAT footprint for the standard product is 25 km (Tang et al. 2004). However, in order to glean as much wind information as possible within the coastal zone, the high-resolution (12.5 km) QuikSCAT wind product is used here. A special observation error table was created for the QuikSCAT winds with the error in u and v components set to 1.5 ms^{-1}. This value is consistent with buoy minus high-resolution QuikSCAT wind residuals reported in the literature (Tang et al. 2004). The largest impact on the wind direction occurs east and northeast of the center of circulation where the QuikSCAT winds have a more easterly component that the NAM. The NAM center of circulation appears to be slightly offset southwest of the official National Hurricane Center 00 UTC 20 August 2008 position.

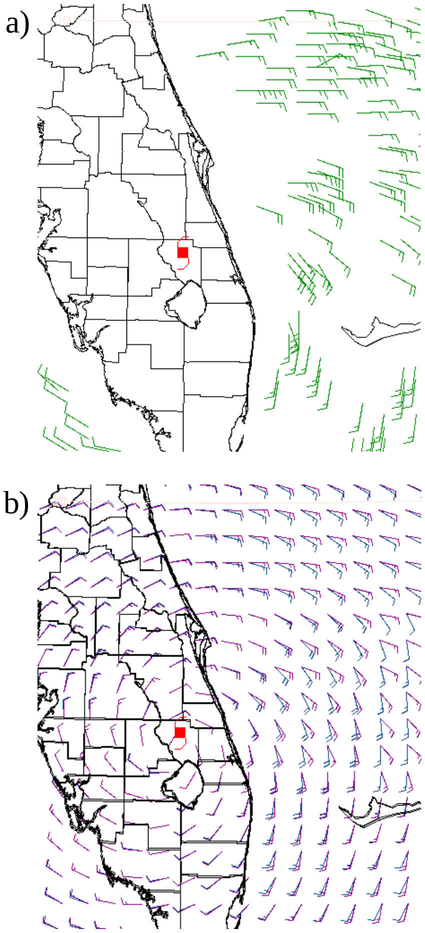

Fig. 4. 10 m winds (ms^{-1}) for a) QuikSCAT valid at 00 UTC 20 August 2008 and b) 00 UTC NAM (blue barbs) and ADAS analysis with QuikSCAT winds (magenta barbs). Full barb = 10 ms^{-1}. Red tropical storm symbol denotes the official (National Hurricane Center) position.

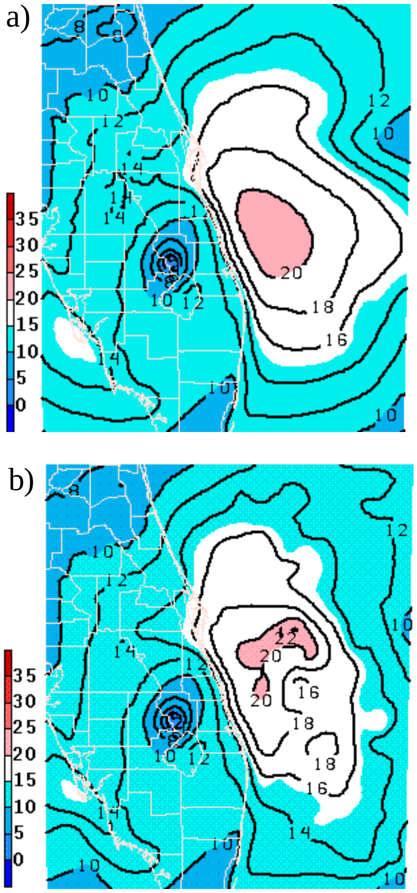

Fig. 5. 10 m wind speed (ms^{-1}) for a) NAM valid at 00 UTC 20 August 2008 and b) 00 UTC ADAS analysis with QuikSCAT winds. Contour interval is 2 ms^{-1}.

QuikSCAT winds impact the ADAS analysis over the oceans only. Wind speeds are diminished off the east-central Florida coast as a result of the cluster of QuikSCAT observations located northwest of Grand Bahama (Fig. 5). Some impact is also seen in the southwest portion of the domain where the wind speeds have decreased.

3.3 WRF Forecast

10 m wind speed differences (ADAS with QuikSCAT minus NAM) for a 24 h WRF forecast launched at 00 UTC 20 August 2008 are shown in Figures 6a-c. The initial conditions (Fig. 6a) indicate that QuikSCAT reduces (increases) the wind magnitude to the east (northeast) of the storm center as seen in the velocity difference couplet. By forecast hour 12, the largest wind differences are concentrated around and near the center of circulation. Differences are generally negative implying that the QuikSCAT assimilation has weakened the circulation some. At the end of the 24 h forecast, however, differences approach

6 ms^{-1} and are both positive and negative. This indicates possible differences in the position of the center of circulation between the two simulations and is currently under investigation.

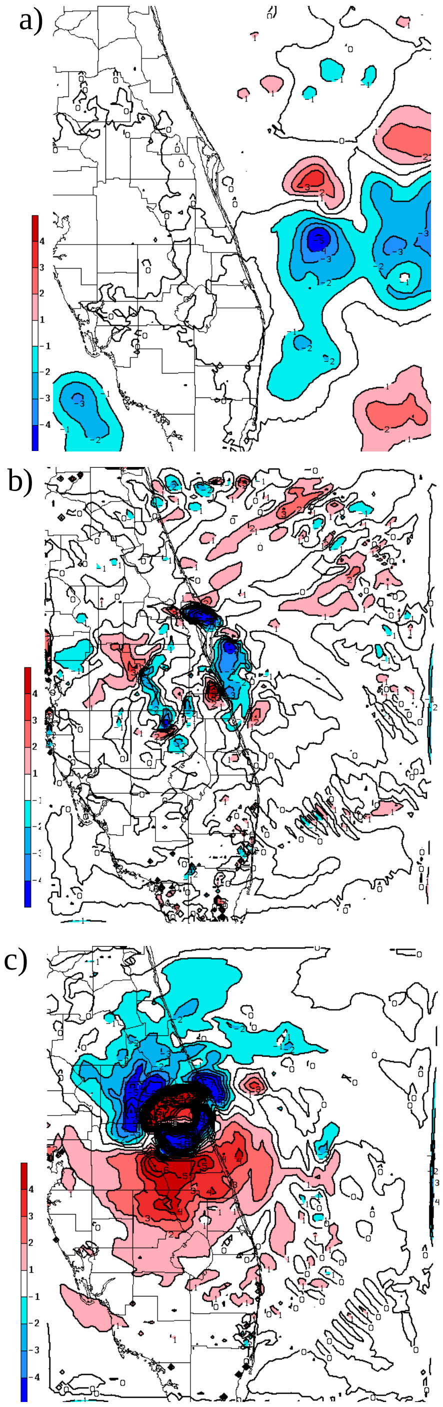

Fig. 6. 10 m wind difference (ms^{-1}) between the NAM and ADAS analysis (i.e., ADAS minus NAM) with QuikSCAT winds at a) 00 UTC 20 August 2008, b) 12 UTC 20 August 2008, and c) 0 UTC 21 August 2008.

4. FUTURE WORK

TS Fay is an ideal event to evaluate the impact of wind assimilation on a forecast. Here, only QuikSCAT data were incorporated with the anticipation of adding WSR-88D radial velocities as the next step. Further, an intermittent data assimilation approach whereby the WRF is initialized with a hot start followed by a short forecast period and subsequent data assimilation (e.g., radar) is planned. The work presented here is part of a larger project in which the ultimate metric is the impact of an improved surface wind field on wave forecasts in the nearshore environment. Hence, evaluation of the assimilation hinges on improvements gained from the incorporation of the various data streams. Wave model forecasts will be launched using the output from the assimilation experiments and compared directly to NAM forced simulations.

5. REFERENCES

Black, T. L., 1994: The new NMC Eta model: Description and forecast examples. *Wea. Forecasting*, **9**, 265–278.

Brewster, K., 1996: Implementation of a Bratseth analysis scheme including Doppler radar data. Preprints, *15th Conf. on Weather Analysis and Forecasting*, Norfolk, Virginia, Amer. Meteor. Soc., 92-95.

Colle, B.A., J.B. Olson, and J.S. Tongue, 2003: Multiseason Verification of the MM5. Part I: Comparison with the Eta Model over the Central and Eastern United States and Impact of MM5 Resolution. *Wea. Forecasting*, **18**, 431–457.

Howard, K., M. Splitt, S. Lazarus, G. Zarillo, S. Chiao, P. Santos, and D. Sharp, 2009: The impact of atmospheric model resolution on a coupled wind/wave forecast system. *Preprints, 16th Conference on Air-Sea Interaction,* Phoenix, Arizona, Amer. Meteor. Soc., CD-ROM P9.2.

Mass, C. F., D. Ovens, K. Westrick, and Brian A. Colle, 2002: Does Increasing Horizontal Resolution Produce More Skillful Forecasts? *Bull. Amer. Meteor. Soc.*, **83**, 407-430.

Ponce de León, S. and F. J. Ocampo-Torres, 1998: Sensitivity of a wave model to wind variability, *J. Geophys. Res.* 103 (C2), pp. 3179–3201.

Tang W., W. T. Liu and B. W. Stiles, 2004: Evaluation of High-Resolution Ocean Surface Vector Winds Measured by QuikSCAT Scatterometer in Coastal Regions, *IEEE Trans. on Geosci. Remote Sens*., **42**, 1762-1769.

Teixeira, J.C., M.P. Abreu and C. Guedes Soares, 1995: Uncertainty of Ocean Wave Hindcasts due to Wind Modelling, J. Offshore Mech. and Arctic Eng., **117**, 294–297.