WAM PERFORMANCE IN THE GULF OF MEXICO WITH COAMPS WIND

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1. INTRODUCTION

In support of the Northern Gulf of Mexico Littoral Initiative (NGLI) project, directional wave measurement systems were deployed in September 2000 to collect data for wave model evaluation and validation. NGLI project is a multi-agency effort to develop an oceanographic simulation and monitoring capability for the Mississippi Sound and its adjoining waters encompassing the rivers, bays, and coastal regions of eastern Louisiana, Mississippi, and Alabama. One of the main objectives is to develop a modeling system consisting of a three-dimensional circulation model, a sand-silt sediment transport model, and a wave model.

The Gulf of Mexico (GOM) offers a unique environment for testing and evaluating wave models. The GOM is an essentially enclosed basin, and is not so large as to often have complicated wave conditions resulting from more than one major weather event. An operational SWAN (Simulation of Waves in Nearshore; Booij, et al, 1999) model driven by WAM (Wave Model) and COAMPS (Coupled Ocean/Atmosphere Mesoscale Prediction System) atmospheric model has been developed. The performance of SWAN depends heavily on the accuracy of the WAM and COAMPS. This report focuses on the evaluation of WAM driven by COAMPS wind.

2. OVERVIEW OF MODEL SETUP AND WAVE MEASUREMENT SYSTEMS

COAMPS represents an analysis-nowcast and short-term forecast tool applicable for any given region of the earth. COAMPS includes an atmospheric data assimilation system comprised of data quality control, analysis, initialization, and non-hydrostatic atmospheric model components and a choice of two hydrostatic ocean models (Hodur and Doyle 1998). On the mesoscale, it has frequently provided better surface wind prediction than the other Navy wind models. In this study, the whole Gulf of Mexico, and therefore the entire NGLI region, is covered within the larger Central American grid, which has a resolution of 0.2 degree or about 27 km. It is run twice daily, providing hourly forecasts of up to 48 hours.

The WAM wave model is a spectral wave prediction model developed by the WAMDI Group (1988). It is a third-generation wind wave model, so it introduces no ad hoc assumptions on the spectral shape. It is the primary wave forecast model at the Naval Oceanographic Office. For this study, a 5’ resolution WAM is nested with the 0.25 degree resolution Gulf of Mexico run, which is nested with global WAM. Both regional WAM models use COAMPS wind.

Funded by NGLI, two NDBC operational buoys (42040, depth 238 m and 42007, depth 13.4 m) were upgraded to directional wave measurement system, and a third experimental directional buoy (42042, depth 35 m) was deployed in September 2000. All buoys use 3-m discus hull and Datawell Hippy 40, which measures heave acceleration, pitch angle, and roll angle. The buoy locations are plotted in Figure 1.

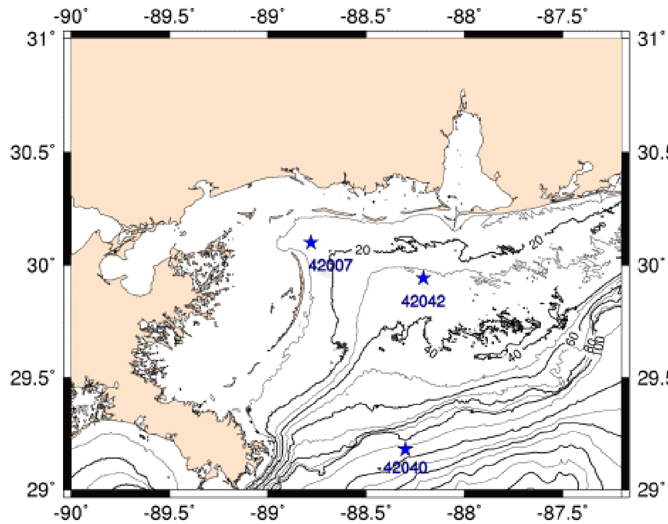

Fig. 1 ¾ NGLI depths in meters, locations of NDBC buoys

3. WIND AND WAVE CONDITIONS

Figure 2 illustrates the wind and wave conditions at buoys 42042. During the September 2000 study period, wind ranged from near calm to a strong breeze within a general regime of moderate easterly flow. From the wave height plot, there are two major wave events (all wave heights referred to in this report are significant wave height). One event starts on September 5 with easterly wind; waves are locally generated. The other starts on September 17 and is a combination of the arrival of 11-second swell from tropical storm Gordon off south Florida and locally generated waves.

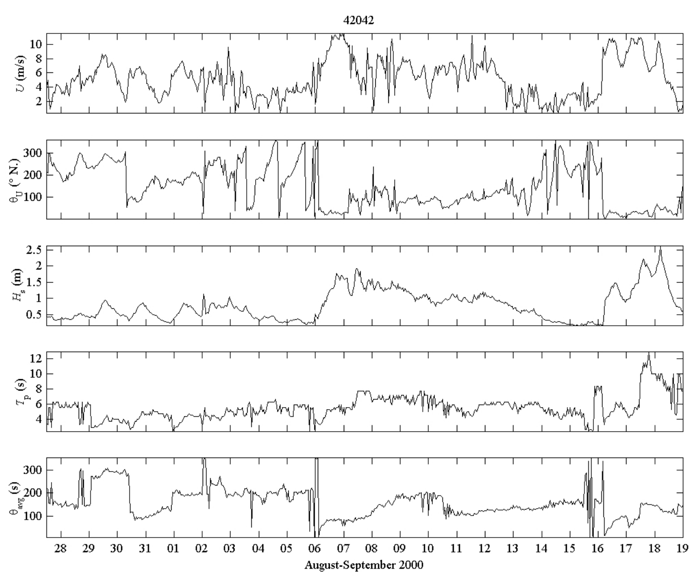

Fig. 2 ¾ Time series of wind and wave conditions at station 42042

4. PERFORMANCE EVALUATION OF COAMPS AND WAM

This section gives the results of the comparison between NDBC buoy measurements and model output. The time series plots, and error statistics are presented here.

4.1 COAMPS Evaluation

Figure 3 compares COAMPS and three NDBC buoy wind measurements. In general, their agreement is quite good. The scatter plots of wind speed and average direction are presented in Fig. 4. As shown by the error statistics in Table 1, COAMPS wind speeds are of relatively high quality, with estimated wind speeds showing an average RMS error of 2 m/s. The average RMS error of wind direction is 49.4 degree. A much smaller value can be achieved if the data include only wind speeds exceeding 0.5 m/s. Buoy winds at such low wind speeds show many angular fluctuations.

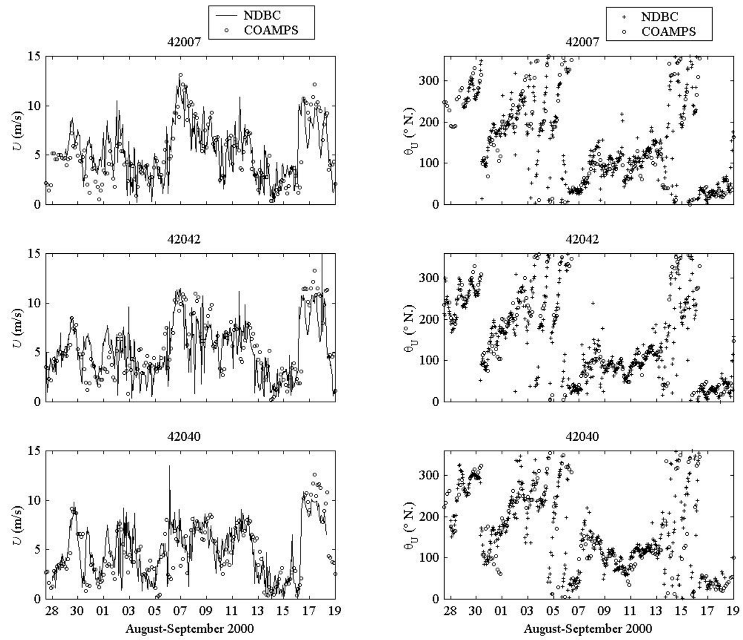

Fig. 3 — Time series of COAMPS wind estimates and NDBC wind measurements.

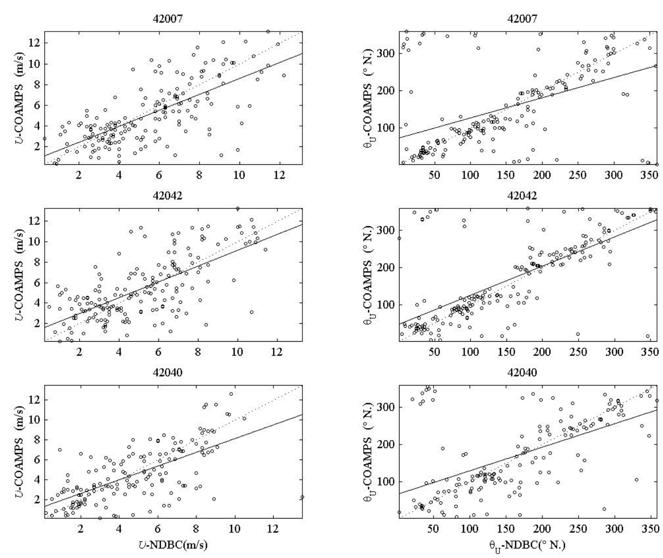

Fig. 4 ¾ Scatter diagrams of COAMPS wind estimates vs. NDBC measurements

Table 1 — Error Statistics of COAMPS Model vs. NDBC Buoy Station Wind Measurements
(Wind Speed in Meters/Second, Wind Directions in Degrees Clockwise from North)

42007					
N	***R***	***RMS***	***m***	***b***	***Model***
167	0.77	1.95	0.852	0.45	COAMPS *U*
167	0.89	51.8	1.07	-7.1	COAMPS θ_U
42042					
N	***R***	***RMS***	***m***	***b***	***Model***
166	0.76	2.0	0.86	0.97	COAMPS *U*
166	0.92	46.3	1.09	-1.9	COAMPS θ_U
42040					
N	***R***	***RMS***	***m***	***b***	***Model***
153	0.73	2.1	0.75	1.42	COAMPS *U*
153	0.88	50.0	1.01	-6.6	COAMPS θ_U

N is the number of comparisons; *R* is the linear correlation coefficient between the model estimates and measurements; *RMS* is the root-mean-squares error; *m* is the slope of the linear regression curve through the set of model-measurement pairs; and *b* is the *y*-intercept of the linear regression curve through the set of model-measurement pairs.

4.2 WAM Evaluation

Figure 5 shows the comparison between WAM and the buoy 42040. Table 2 presents the error statistics and the corresponding scatter plots can be found in Hsu et al (2002). WAM produces excellent wave height agreement with a root-mean-squares (RMS) error of 0.21 m. The average period agreement is good with a RMS error of 0.48 second. The WAM arrival of the swell event in September 17 is lagging behind the buoy for about half a day. Further discussion of the swell event is presented in the next section. The comparison of time series model estimates and buoy 42042 and 42007 data are shown in Figures 6 and 7. Their error statistics is presented in Tables 3 and 4. WAM performance at 42040 is similar to its values at 42040, with a RMS error of 0.26 m in height and 0.75 second in wave period. Among three buoys, WAM performance at 42007 (13.4 m depth) is the least accurate, with a RMS error of 0.34 m in height and 1.02 second in wave period. This is expected because WAM is running at 8 km resolution, therefore it cannot account for effects of the rapid depth changes at shallower water. Swell height at 42007 is reduced due to refraction. It is presented and discussed in details in another paper (Dykes et al. 2002) in the proceedings of this workshop.

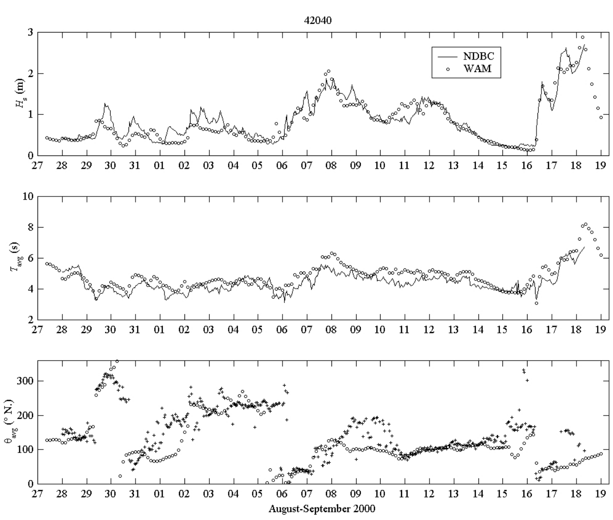

Fig. 5— Time series of wave parameters comparison between WAM and buoy 42040

Table 2 — Error Statistics of WAM Model at NDBC 42040

N	***R***	***RMS***	***M***	***b***	*Model*
153	0.91	0.21	0.96	-0.013	WAM H_s
153	0.81	0.48	0.88	0.85	WAM T_{avg}
153	0.63	24.1	0.63	24.0	WAM θ_{avg}

For explanation of symbols, see Table 1.

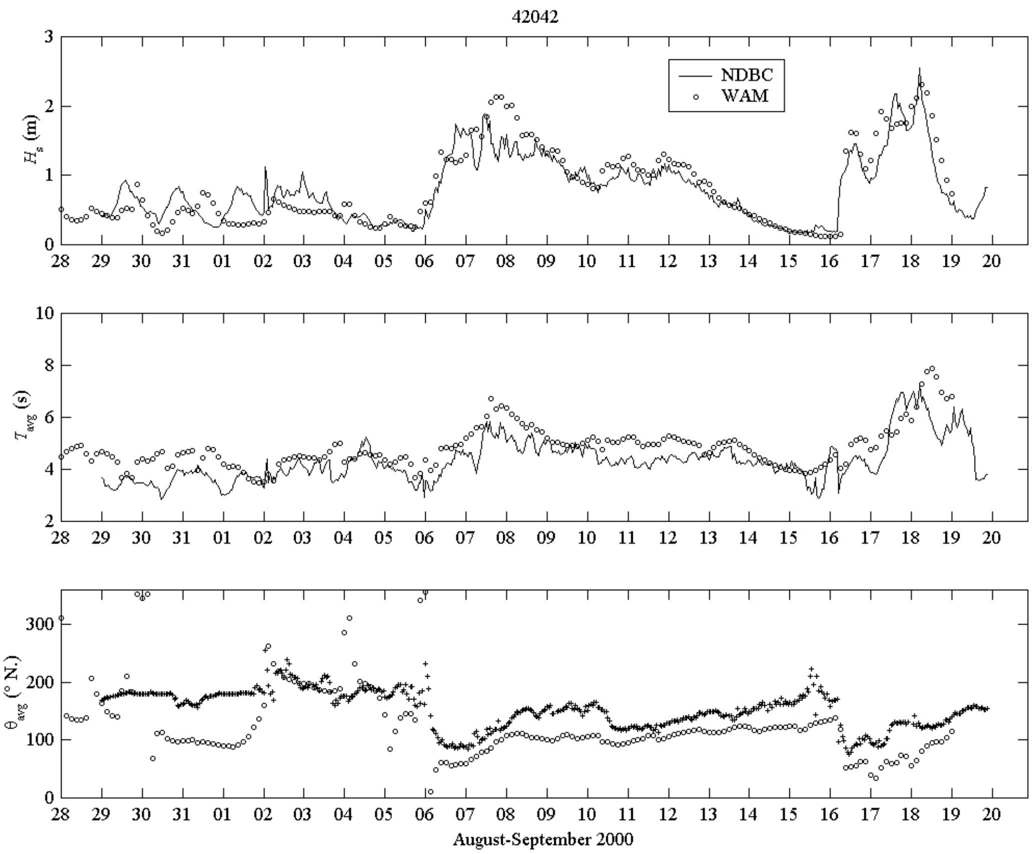

Fig. 6 — Time series of wave parameters comparison between WAM and buoy 42042

Table 3 — Error Statistics of WAM Model at NDBC 42042

N	***R***	***RMS***	***M***	***b***	*Model*
173	0.90	0.26	1.10	-0.04	WAM H_s
173	0.79	0.75	0.85	1.18	WAM T_{avg}
173	0.60	34.4	1.20	-60.4	WAM θ_{avg}

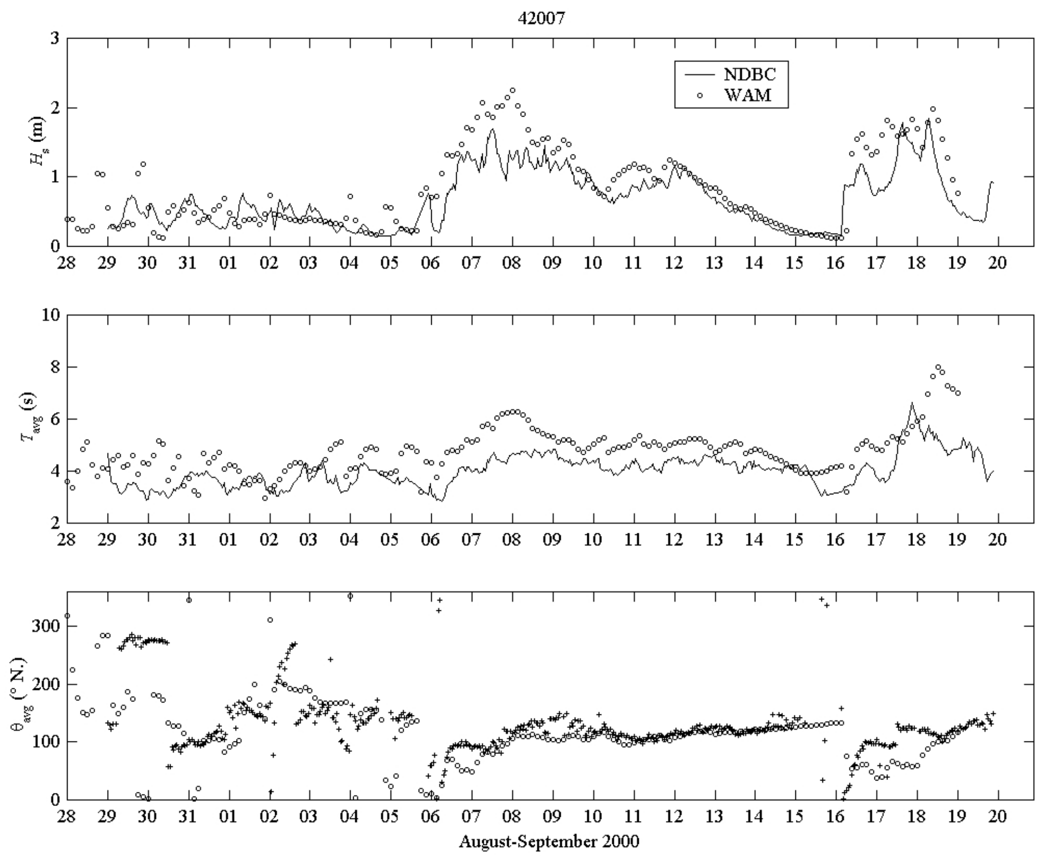

Fig. 7 — Time series of wave parameters comparison between WAM and buoy 42007

Table 4 — Error Statistics of WAM Model at NDBC 42007

N	***R***	***RMS***	***M***	***b***	*Model*
162	0.87	0.34	1.22	0.02	WAM H_s
162	0.70	1.02	0.98	0.71	WAM T_{avg}
162	0.69	24.5	0.67	29.6	WAM θ_{avg}

4.3 The Swell Event from the Tropical Storm Gordon

As mention earlier, the arrival of September 17 swell event is late in WAM. The arrival of swells can be examined by the peak wave period. The peak periods of all three buoys and WAM are presented in Fig. 8. During this period, buoy 42040 experienced a satellite transmitter problem, thus much data are missing as represented by zero value and fall on the x axis. Since the swell is coming from southeast, it reaches buoy 42040 first. Figure 9 compares spectral shapes from buoy 42040 and WAM at the early stage of a swell event. WAM completely misses the arrival of the 11-second swell.

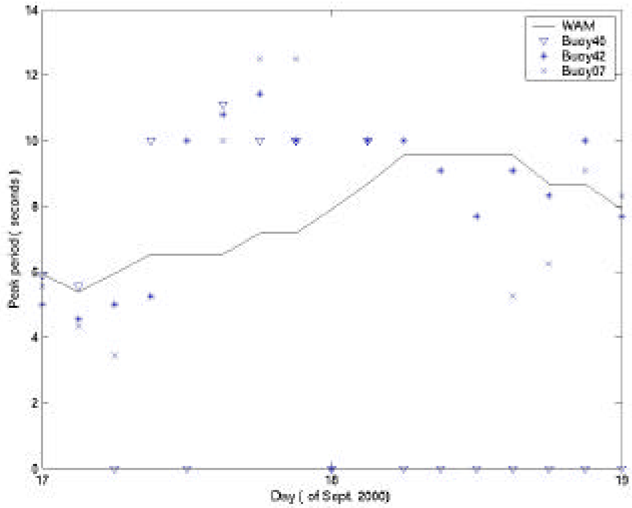

Fig. 8 — Comparison of peak period between WAM and buoys

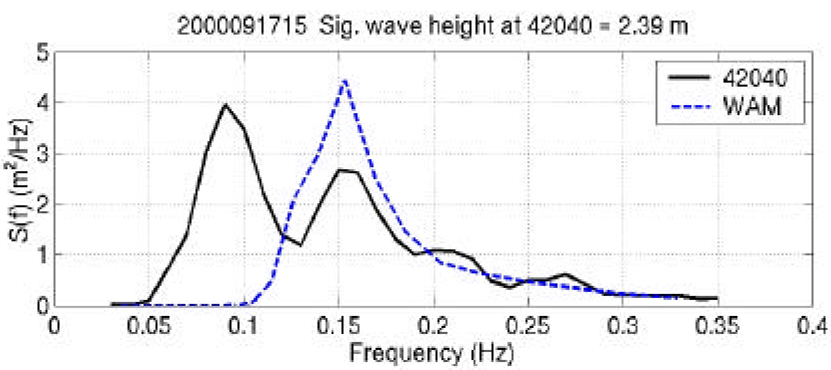

Fig. 9 — Comparison of spectra between WAM, SWAN, and buoys for hour 15, Sept. 17, 2000

As shown in Fig. 10, Tropical storm Gordon started in September 15 and eventually landed on the west coast of Florida in September 18. The storm generated long period swells rarely seen in Gulf of Mexico. Based on distance and wave group velocity, swells arriving at 42040 at midday, September 17 were generated around a day earlier. Wind comparisons between two NDBC buoys and COAMPS are presented in Fig. 11. It can be seen that COAMPS performance at buoy 42003 in the early stage of storm development on the mid day of September 16 is not very good whereas its performance a day later at buoy 42036 is excellent. Examination of the COAMPS wind velocity plot of the whole region during this period reveals that the wind pattern was not well formed around September 16, but it becomes a tight spiral afterwards. Therefore, the late arrival of WAM swell can be associated to the COAMPS wind performance in the early stage of the storm development.

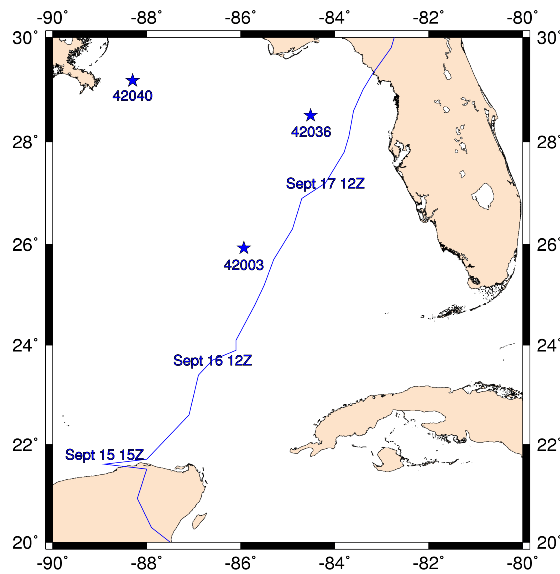

Fig. 10 ¾ Track of the tropical storm Gordon and NDBC buoy locations.

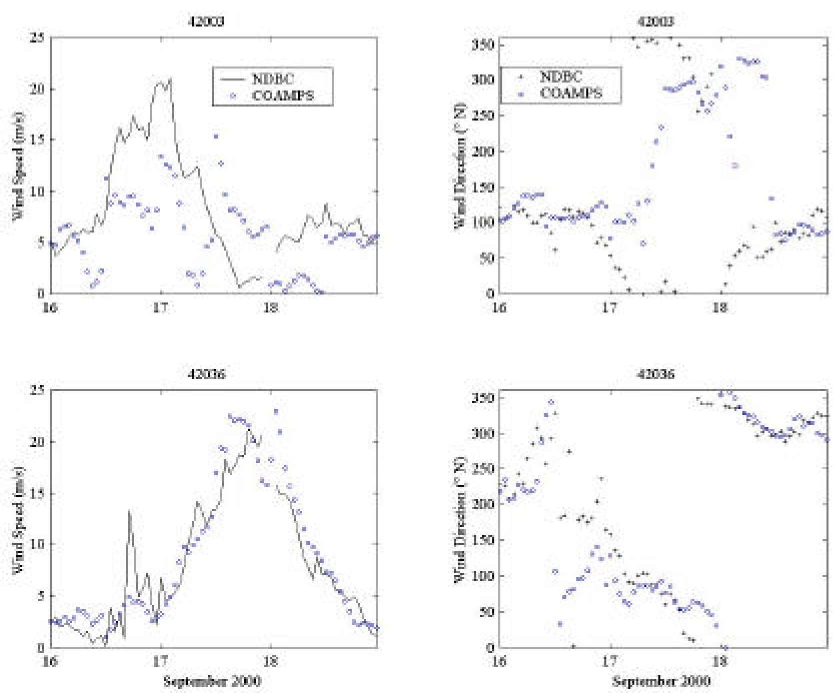

Fig. 11 ¾ Wind comparison between COAMPS and NDBC buoys 42003 and 42036

5. SUMMARY

COAMPS and WAM are evaluated and validated using three NDBC buoys in the Mississippi Bight. COAMPS wind agrees well with buoys at 42040, 42042 and 42007. It has an average RMS error of 2 m/s. The COAMPS performance is good even under the tropical storm Gordon except at the early stage of the storm development. The WAM performance at buoy 42040 and 42040 is excellent with an average RMS error of 0.24 m. Its performance at 42007 at 13.4 m depth is slightly worse, but it is due to the WAM grid resolution of 8 km, which is not sufficient to represent the bathymetry variability in shallow water.

ACKNOWLEDGMENTS

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