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MESOSCALE FORCING OF OCEAN WAVES DURING GULF STREAM NORTH WALL EVENTS

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1. BACKGROUND

During the months from late Fall to early Spring strong polar and arctic air masses move southeast out of north central Canada to the mid-Atlantic coast of the United States. These air masses bring near freezing temperatures to the mid-Atlantic coast and adjacent coastal waters. The cold air outbreaks (CAO) produce rapidly increasing strong winds and high near-shore seas (Fig. 1) posing hazards to coastal regions, mariners and naval operations. These events, known to mariners and coastal meteorologists as “North Wall” events, are typically poorly modeled, both in the atmosphere and ocean models, as a result of multiple scale interactions, strong ocean forcing on the atmosphere, and their duration. These events can produce localized regions of relatively high waves near-shore inspite of obvious fetch limitations.

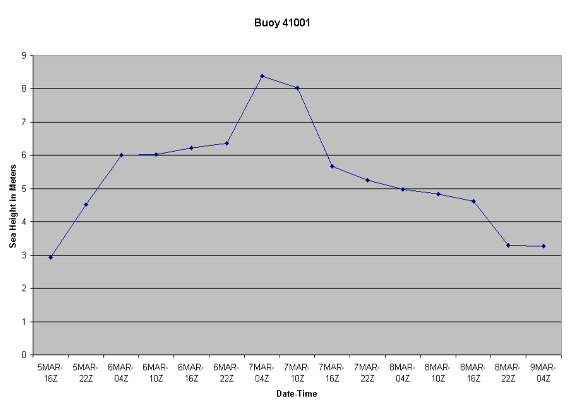

Fig. 1 – Time series of significant wave height at buoy 41001.

As strong polar and artic air masses move southeast from north central Canada they bring cold offshore directed northwest winds to the mid-Atlantic coast (Fig. 2). North Wall events occur as a result of the strong air-sea temperature difference between the cold air mass and warm waters of the Atlantic western boundary current, the Gulf Stream. The large air-sea temperature difference results in intense upward heat fluxes and downward momentum fluxes which work in tandem to destabilize the boundary layer and induce mesoscale circulations embedded in the synoptic pattern. The introduction of mesoscale circulations enhances the offshore synoptic flow to produce localized regions of strong surface winds (described in section 3). Air mass characteristics (temperature and moisture), the off-shore wind trajectory as well as the location and temperature of the Gulf

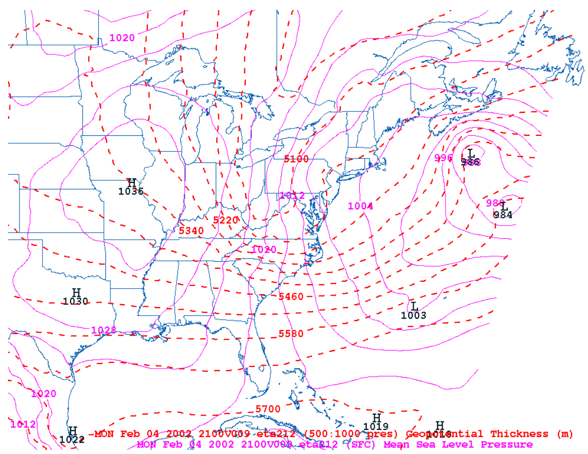

Fig. 2 – Sea-level pressure and 1000-500 mb thickness for 2100 UTC 4 Feb. 2002 from the ETA model 9 hour forecast.

Stream are crucial elements that determine the duration and strength of North Wall events. Localized strong winds and rapidly building seas occur in the vicinity of the north wall of the Gulf Stream as a result of the strong air-sea temperature discontinuity and associated strong winds. The possible role of mesoscale atmospheric forcing in generating high waves is the focus of this study. This study examines three events using a mesoscale numerical

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model and the preliminary results from one of these cases is discussed in section 3.

2. METHOD

Three North Wall event case studies have been examined. Each case chosen was characterized by a strong polar air mass located over the eastern United States, strong northwesterly offshore flow over coastal North Carolina and the Gulf Stream that lasted for a minimum of 18 hours. Two of the cases occurred in early February of 1998 and 2002, while the third case study was from early March 2001. In each of the cases a strong cold, high pressure system moves East-southeast from south central Canada across the Ohio river valley and the Appalachian Mountains. The High pressure, while rarely stationary, produces a strong northwesterly flow over the Gulf Stream.

Numerical simulations of the atmosphere have been generated using the U.S. Navy Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS, version 2.0.15) non-hydrostatic model in order to capture the induced mesoscale circulation as well as the background synoptic-scale flow. The model domain shown in Fig. 3, depicts three nested grids of 81, 27 and 9 km. A static 10 km sea surface temperature (Fig. 4) for each case was meshed under the grid domain to provide mesoscale ocean forcing.

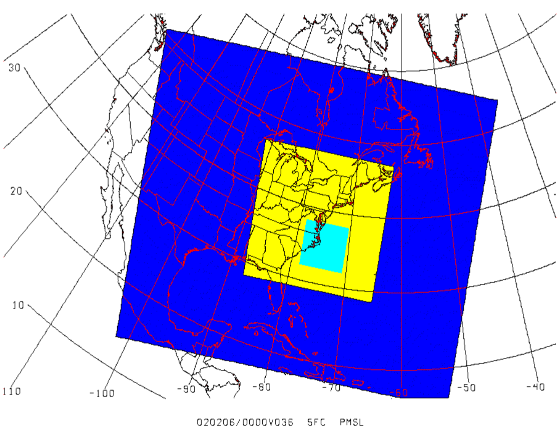

Fig. 3 – Nested model domains used to simulate these “North Wall” events. Outer domain (blue) is 81km resolution, middle domain (yellow) is 27 km resolution and inner domain (cyan) is 9km resolution.

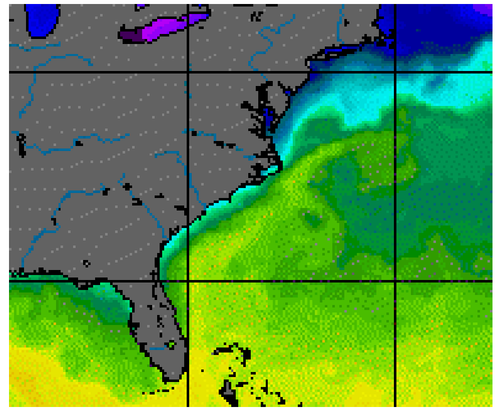

Fig 4 – 10 km sea surface temperature analysis from 4 Feb. 2002 used for model simulation.

COAMPS model runs were conducted to simulate the observed atmospheric structure and compared to various observations for each case. After a adequate atmospheric simulation was complete, the COAMPS model run was placed over Wave Watch 3 (WW3) to produce the coastal wave field. In addition, empirical wave forecast techniques were utilized and compared to WW3 output from each model run. Ship/buoy observations and remote sensing observations of the wave field are used to verify the WW3 output.

3. PRELIMINARY RESULTS

The February 4-5, 2002 synoptic pattern indicates a 500mb trough located over the Mississippi river valley that moves east over the western Atlantic ocean over a 36 hour period. During this time a 110 knot jet maximum also exits the east coast of South Carolina. The associated low pressure system, which begins southeast of Long Island, tracks northeast and deepens over the period (Fig. 2). Strong northwesterly winds dominate the coastal mid-Atlantic region over the period. Buoy and coastal station observations indicate that gale force winds develop 6 hours after the CAO then increase to near storm force and last for 16 hours. Coastal seas (fetch limited to 30 km) build from 1 to 3 meters 2 hours after the onset of gale force winds with observed seas building to 5-6 meters in the north wall of the Gulf Stream, as observed at various buoy locations. The COAMPS model simulation (not shown) shows the development of localized near storm force winds and a strong mesoscale flow embedded in the synoptic pattern 6 hours after the CAO. This produces northwest flow over the Gulf Stream. These regions of storm-force winds precede the rapid development of the near-shore high waves at various buoys. Northwesterly surface flow dominated the Gulf Stream region for approximately 18 hours then veered northerly resulting in air mass modification from the coastal waters and the gradual decay of the coastal wave field.

While the mesoscale forcing of WW3 by COAMPS for this case study is not yet available, simulations using NOGAPS (Navy Operational Global Atmospheric Predictions System) and WW3 indicate an under forecasting of the coastal wave field, specifically in the vicinity of the gulf stream. Additionally, empirical wave calculations for coastal, fetch limited, wave growth for this Feb. 2002 case are 7-8 feet, based on the general characteristics of the COAMPS wind fields. A more thorough analysis of the localized, mesoscale wave forcing is underway and will be presented.

4. SUMMARY

Preliminary results indicate that high resolution modeling, can produce an adequate representation of the mesoscale wind forcing that generates near-shore regions of high waves. Empirical wave height estimates using these mesoscale wind fields tend to underestimate the wave heights. Wave forecasts from WW3, while not yet complete for this study, are typically adequate farther off-shore, but tend to fall short of observed near-shore wave heights. These results suggest that more direct coupling between the ocean model and the atmosphere may be needed to replicate the rapid wave growth.