THE INFLUENCE OF HIGHLY RESOLVED SEA SURFACE TEMPERATURES ON METEOROLOGICAL SIMULATIONS OFF THE SOUTHEAST US COAST

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1. Introduction

The coastal region of the southeastern United States is an important socio-economic area, particularly during the warm season of May through September. Severe thunderstorms often develop along the sea breeze front, accompanied by large hail and dangerous lightning (Blanchard and Lopez, 1985). Various tourism and recreational activities are affected by these severe weather events, which greatly influence the regional economy. Sea breeze circulations are important when considering pollutant transport and deposition near coastal areas (Lyons et al., 1973; Lyons et al., 1976; Kitada and Ueda, 1989; Rhome et al., 2002). Moreover, in emergency situations such as forest fires or accidental release of hazardous materials, the sea breeze circulation must be explicitly considered (Simpson, 1994; Gilliam et al., submitted) by emergency management personnel.

Studies on sea breeze evolution have highlighted several regional scale features as controlling factors in sea breeze development. These include coastline configuration (McPherson, 1970), topography (Darby et al., 2002), landuse (Baker et al., 2001), and sea surface temperature (SST). With these controlling factors well recognized, it is possible to operationally simulate sea breeze structure and evolution. Weather forecasters along the southeastern United States have many tools available to assist in forecasting sea breeze formation and propagation, including several numerical weather prediction models.

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The GFS, RUC and Eta are some of the weather prediction models that are used by forecasters, with grid spacings of 50, 20 and 12 km, respectively. While the topography, coastline configuration and landuse are relatively well represented in these models; the SST is often not very representative of real-time observations. All these models use a climatological mean SST field, with a grid spacing of 40 km, developed by the National Center for Environmental Prediction (NCEP). Several events were observed where actual SST's off the southeastern US coastline were greater or less than 10 C of climatology. These discrepancies may lead to large errors in simulating the development and penetration of the sea breeze front. To further study the effects of SST's on the mesoscale boundary layer structure off the southeastern US coast, two numerical simulations were performed. The first simulation, hereafter the *Control Simulation,* is an MM5 simulation using the climatological SST data provided by NCEP. The second simulation, hereafter the *Experimental Simulation*, is identical to the MM5 simulation above with the exception of incorporation of high-resolution (1.44 km) SST data assimilation provided by NOAA's Coastwatch Center.

2. Numerical Simulations

The PSU/NCAR Mesoscale Model 5 (MM5) is used to study the mesoscale structure off the southeastern US coastline. The MM5 model is a terrain following, fully compressible, primitive equation model with nonhydrostatic dynamics and multiple physics option. Two simulations of the MM5 are performed in this study. Both the Control Simulation and Experimental Simulation are single nested domains centered over the southeastern United States. The simulations are initialized at 00 UTC 29 July 2003 and integrated for 48 hours through 00 UTC 31 July 2003. This period was chosen as weak high pressure was centered over the eastern United States,

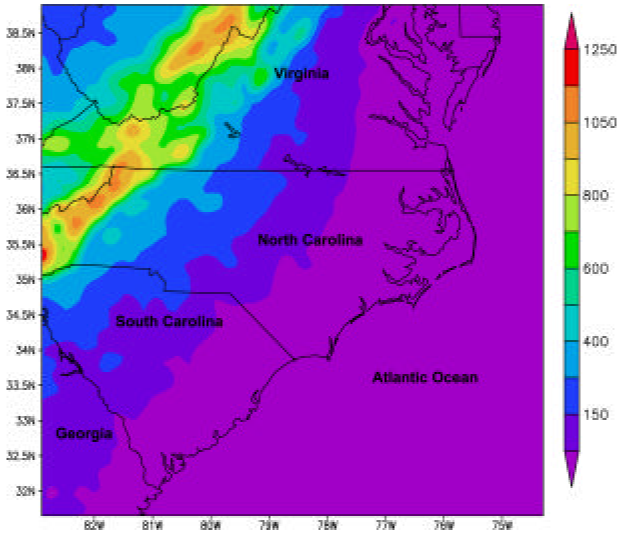

Figure 1. MM5 domain setup over the southeastern United States.

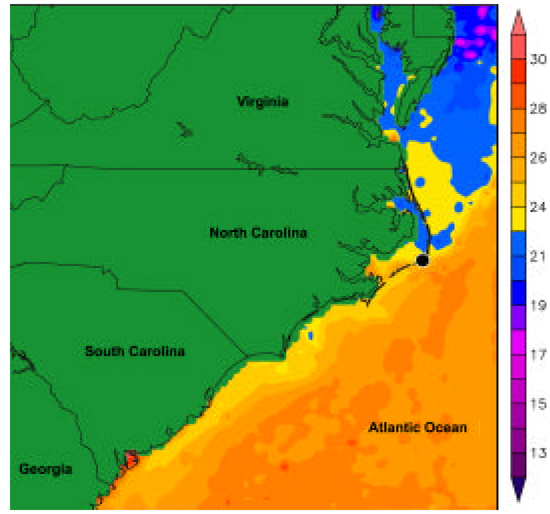

Figure 2. High resolution (1.44 km) sea surface temperature data (C) valid 29 July 2003 used in the experimental MM5 simulation. (Source: NOAA's Coastwatch database)

creating a favorable environment for the formation of sea/land breezes. Figure 1 shows the domain setup used in both simulations. The horizontal grid spacing is 12 km. Elevation data is shaded in meters. The horizontal grid spacing is 12 km with (84 x 84) grid points in the horizontal and 37 vertical sigma levels. Reisner 2 moisture physics is used to simulate explicit cloud processes, while the Kain-Fritsch cumulus parameterization is used to account for sub-grid scale cloud processes. The Eta Mellor-Yamada 1.5 order TKE closure model is used for boundary layer processes, while the Noah Land Surface Model is used for land-atmosphere interactions. Both simulations are initialized from the NCEP 40 km Eta212 model, archived by the National Center for Atmospheric Research. The only difference between the two simulations is the SST data used in the model initialization. The Control Simulation uses the NCEP 40 km climatological SST data, while the Experimental Simulation uses high-resolution (1.44 km) SST data obtained from NOAA's Coastwatch dataset. The Coastwatch SST data is updated twice a day using sensors from the Advanced Very High Resolution Radiometer (AVHRR) satellite. Figure 2 shows the high-resolution (1.44 km) SST data C used in the Experimental Simulation. SST values less than 22 C were observed off Cape Hatteras, North Carolina, while SST values in excess of 29 C were present about 100 km off the coast of southeastern NC, in proximity to the Gulf Stream.

3. Results and Discussion

The main goal of this research is to study the effects of high resolution SST on the mesoscale boundary layer structure off the southeastern US coast. Two mesoscale simulations were performed to aid in the study. The Control Simulation initialized the SST data using a climatological (40 km) dataset developed by NCEP, while the Experimental Simulation initialized the SST data using real-time high-resolution (1.44 km observations obtained from NOAA's Coastwatch dataset. Figure 3 shows the difference between the real-time high-resolution SST data and the coarse climatological SST data for 00 UTC 29 July 2003 used in the two numerical experiments. Just to the north and east of Cape Hatteras North Carolina, shown with a black oval on the figure, is a region of SST anomalies of –5 C, meaning the real-time SST data was 5 degrees C cooler than the climatological data. However, just to the south and east of Cape Hatteras, the real-time SST data is nearly 6 C warmer than the climatological SST data.

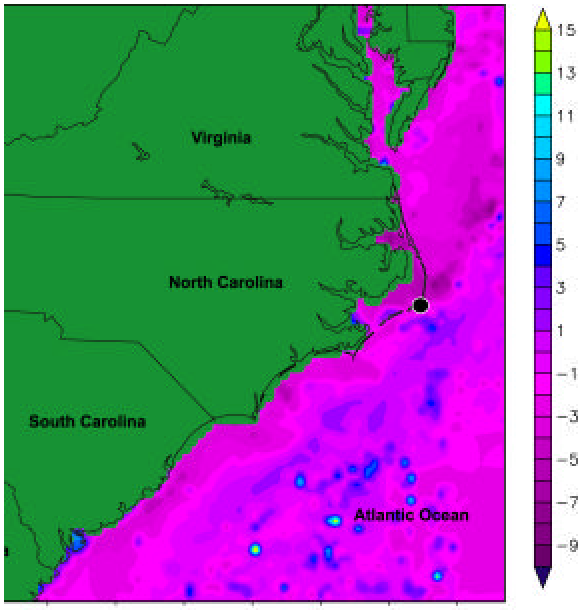

Figure 3. Temperature difference (C) between the high-resolution sea surface temperature data and the coarse climatological sea surface temperature data.

To understand the effects of the SST anomalies on the near surface wind patterns, a comparison between the two simulations and surface observations is presented. Figure 4a shows a time series plot of surface (10 m) wind speed (m/s) for Cape Hatteras, North Carolina, valid 12 UTC (08 LT) 29 July through 12 UTC (08 LT) 30 July 2003. The surface wind observations are shown in red, while the Control and Experimental simulations are presented in blue and green, respectively. Throughout the 24 hr period, the observations from Cape Hatteras are generally less than the model predicted wind speeds in both simulations. However, between 13 LT 29 July and 06 LT 30 July, the Experimental Simulation agreed better with the observations as compared to the Control Simulation. The Control Simulation near surface wind speeds were consistently greater than observations and the simulated winds from the Experimental Simulation. The SST's in the Control Simulation were 5 C warmer than in the Experimental Simulation within 2 km of Cape Hatteras. The warmer SST's in the Control Simulation may have created a more turbulent boundary layer, which allowed for higher speed momentum transfer to the surface.

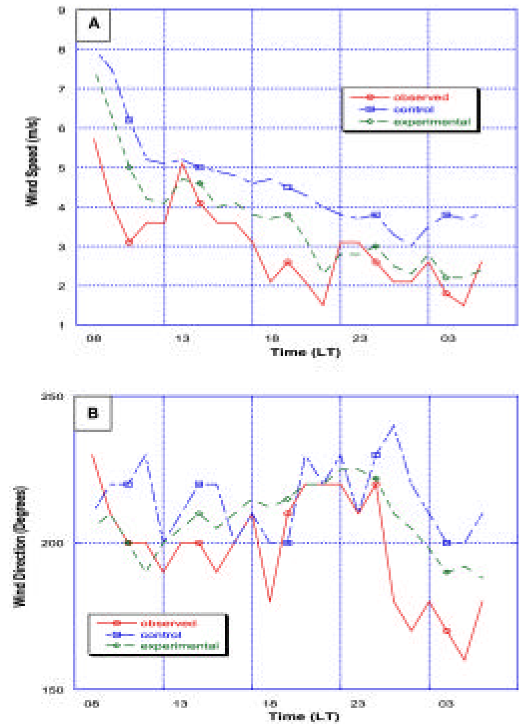

Figure 4. Surface (10 m) wind speed (m/s) valid 12 UTC (08 LT) 29 July through 12 UTC (08 LT) 30 July 2003 for Cape Hatteras, North Carolina is shown in Figure 4a. Observed, control and experimental wind speeds are shown in red, blue and green, respectively. Figure 4b shows the surface (10 m) wind direction valid 12 UTC (08 LT) 29 July through 12 UTC (08 LT) 30 July 2003 for Cape Hatteras, North Carolina. The observed, control and experimental directions are also shown in red, blue and green.

Another possible reason is increased low level convergence associated with larger than actual SST gradients.

A time series plot of surface (10 m) wind direction for Cape Hatteras, North Carolina, valid 12 UTC (08 LT) 29 July through 12 UTC (08 LT) 30 July 2003 is shown in Figure 4b. The surface wind direction observations are shown in red, while the Control and Experimental wind direction simulations are presented in blue and green, respectively. Both the Control and Experimental simulations exhibited significantly less variability as compared to the observations. However, the Experimental Simulation agreed more closely with observations and the observed trends. For example, between 20 LT and 23 LT of 29 July, the observations showed a constant wind direction of 220°, while the Experimental Simulation showed a wind direction between 220 and 225°. The Control Simulation however, predicted rapidly changing wind directions between 220 and 235°.

4. Conclusions

Rapid advance in computer processing speeds is allowing numerical weather simulations to be generated at progressively smaller scales. Assimilation systems coupled with numerous remotely sensed observations, standard surface, upper-airs and aircraft observations are providing numerical weather models more realistic initial atmospheric state. However, few mesoscale modeling systems take full advantage of the semi-daily, high-resolution scans of the sea surface temperature provided by satellites. Results from this study show that the simulation with higher resolution SST's agreed more closely with observations from Cape Hatteras, North Carolina. Large anomalies are present between the Experimental and Control SST datasets. The SST's in the Control Simulation are 5 C warmer than in the Experimental Simulation within 2 km of Cape Hatteras. A more turbulent boundary layer, driven by warmer SST's, and horizontal SST gradients may have led to the greater wind speeds predicted in the Control Simulation. The Experimental Simulation predicted low level wind speeds that agreed more closely with observations as compared to the Control Simulation.

Very heavy rainfall also occurred over Raleigh, North Carolina on 29 July 2003. Preliminary results, not presented here, show that the Experimental Simulation agreed more closely with observed rainfall than the Control Simulation. Further research is needed to fully explore the impacts of high-resolution SST data on simulations of mesoscale boundary layer structure off the southeastern US coastline.

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Robert Gilliam participated in this research when he was affiliated with the State Climate Office of North Carolina and made significant contributions into assimilating the high-resolution SST data into the MM5 model. This research was supported by the State Climate Office of North Carolina and the NC Agricultural Research Service, North Carolina State University.

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