TITLE: The Role of the Sea-Surface Temperature Distribution on Numerically Simulated Cyclogenesis During ERICA

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SIGNIFICANT ACCOMPLISHMENTS IN THE PAST YEAR:

Many investigators have suggested that the warm waters of the Gulf Stream provide necessary energy for the explosive deepening which is a frequently observed characteristic of winter maritime cyclogenesis off the east coast of the United States and Canada. Data collected during ERICA (Experiment on Rapidly Deepening Cyclones over the Atlantic) held during the winter of 1988-89 affords the opportunity to investigate the effect of the Gulf Stream on well documented rapidly developing systems.

We know that the sea-surface temperature (SST) change across the north wall of the Gulf Stream is 10-15 °C in 5 to 20 km and that cyclone initiation was repeatedly encountered at the north wall on ERICA research flights. It is likely that the SST difference produces differential fluxes of heat and vapor into the atmosphere that form an atmospheric front in the boundary layer. The question is whether this atmospheric front significantly alters cyclone formation and movement.

The goal of this study is to quantify the extent to which a SST front can influence cyclogenesis. The approach is to use the Drexel Limited-Area Mesoscale Prediction System (LAMPS) dynamical model to simulate cyclogenesis over various SST fields. It is easy to specify various SST fields and show the differences they induce in the simulated cyclogenesis. However, the challenge is to specify the initial conditions of the large-scale flow and to insure reasonable initial adjustment to the specified SST field. If the initial boundary layer structure and the underlying SST field are significantly out of balance, unrealistically large initial heat and moisture fluxes may be produced as the boundary layer tries to reach "balance". This boundary layer "spin up" may obfuscate the results of sensitivity experiments designed to determine and understand the impact of the SST and boundary layer on rapid cyclogenesis.

Research during the past year has focused on the development and testing of a four dimensional data assimilation (FDDA) technique within LAMPS. The technique is a continuous dynamical assimilation where forcing terms are added to the governing model equations to gradually "nudge" the model solution toward a gridded analysis. In this study, nudging is used as a dynamic initialization tool during a 12 hour preforecast to generate model-balanced initial conditions for a subsequent 24 hour numerical prediction. Tests were performed to determine which variables to nudge and how to specify the four-dimensional weighting function used to scale the nudging terms. To this date, optimal results were obtained by nudging the u and v-components of the wind along with the potential temperature. The weighting function ranges form 0 to 1 and varies in time as a quadratic polynomial. It is initialized at 0, reaches its maximum at 9 hours into the preforecast and falls back to 0 at 12 hours. The nudging terms are included in the model equations for all grid points except those within the model predicted oceanic boundary layer. This design attempts to confine changes imposed by the specified SST field to the oceanic boundary layer during the preforecast period.

The scheme has been tested on a real data case of extreme cyclogenesis during ERICA on 4-5 January 1989. A model configuration with horizontal spacing of approximately 70 km and 20 vertical levels was used. The SST fields were identical in all experiments while testing the assimilation scheme. Results from three experiments are shown here. Two simulations were initialized at 12 UTC 3 January and integrated for 36 hours. One run included nudging during the first 12 hours while the other does not. The third simulation was initialized 12 hours later at 00 UTC 4 January and was integrated for 24 hours. Figure 1 shows that the simulation initialized 00 UTC 4 January produced a more intense system (curve B) than that produced when starting the model 12 hours earlier (curve A). The figure shows the success of the nudging technique which significantly improved the central pressure of the simulated cyclone in comparison with the 36 hour forecast without nudging (compare curves A and C). It is also worth noting that nudging also significantly improved the storm track (not shown).

Other tests were performed to determine the effect of various combinations of horizontal and vertical resolutions on the cyclogenesis. To this point, horizontal grid spacing of 140, 70, and 35 km have been used in combination with vertical resolutions of 1 and 0.5 km (20 and 34 vertical levels). It was found that the most significant improvement in deepening occurred when increasing the vertical resolution in the 70 km simulations. This was a surprising result considering that increased vertical resolution with horizontal spacing of 140 km had virtually no impact. Testing has just begun at 35 km with high vertical resolution and preliminary results show highly detailed precipitation patterns associated with the intense cyclone. Figure 2 shows the time evolution of the simulated total precipitation rate at 6 and 18 hours into the forecast from the 35 km run. Comparison between subjective analyses (not shown) and the precipitation patterns indicates the model successfully reproduced many of the mesoscale features associated with the event.

FOCUS OF CURRENT RESEARCH AND PLANS FOR NEXT YEAR:

The next phase of the work will be to complete testing of the nudging technique. Once testing is completed, a series of experiments will be performed using variations of the SST fields, such as elimination of the Gulf Stream, a weakened Gulf Stream SST front or idealized Gulf Stream fronts. These types of experiments will be performed on a number of ERICA cases. Other work includes comparison of the model simulations and SSM/I (Special Sensor Microwave Imager) observations to aircraft radar returns and in situ measurements of atmospheric temperature, moisture, wind and microphysics data. This will enable some verification of simulated vertical structure to the LAMPS condensate fields, and also help interpret more accurately the SSM/I data.

PUBLICATIONS:

Perkey, D.J., F.R. Robertson, W.M. Lapenta, and C. Cohen, 1990: Comparison of SSM/I measurements to numerically-simulated cloud and precipitation during ERICA. Preprints, 5th Conference on Satellite Meteorology and Oceanography, American Meteorological Society, September 3-7, 1990, London, England.

Perkey, D.J., W.M. Lapenta, F.R. Robertson, and C.W. Kreitzberg, 1991: The Role of the Sea-Surface Temperature Distribution on Numerically Simulated Cyclogenesis During ERICA IOP-4. Preprints, 1st International Winter Storm Symposium, January 13-18, 1991, New Orleans, LA.

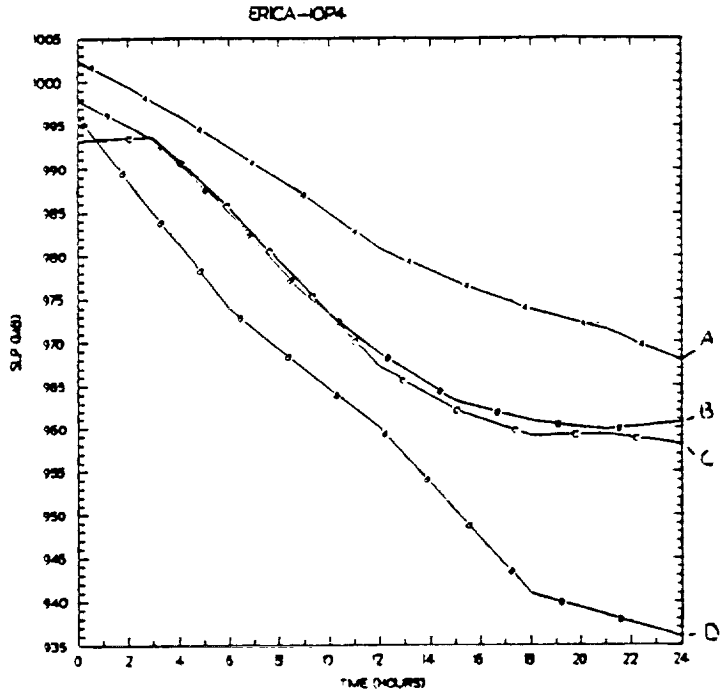

Figure 1. Comparison of model-simulated central pressure for the 36h no-nudging (curve A), 36h nudging (curve C) and the 24h no-nudging (curve B) versus time with observed central pressure (curve D) for the time period valid 00 UTC 4 January to 00 UTC 5 January 1989.0

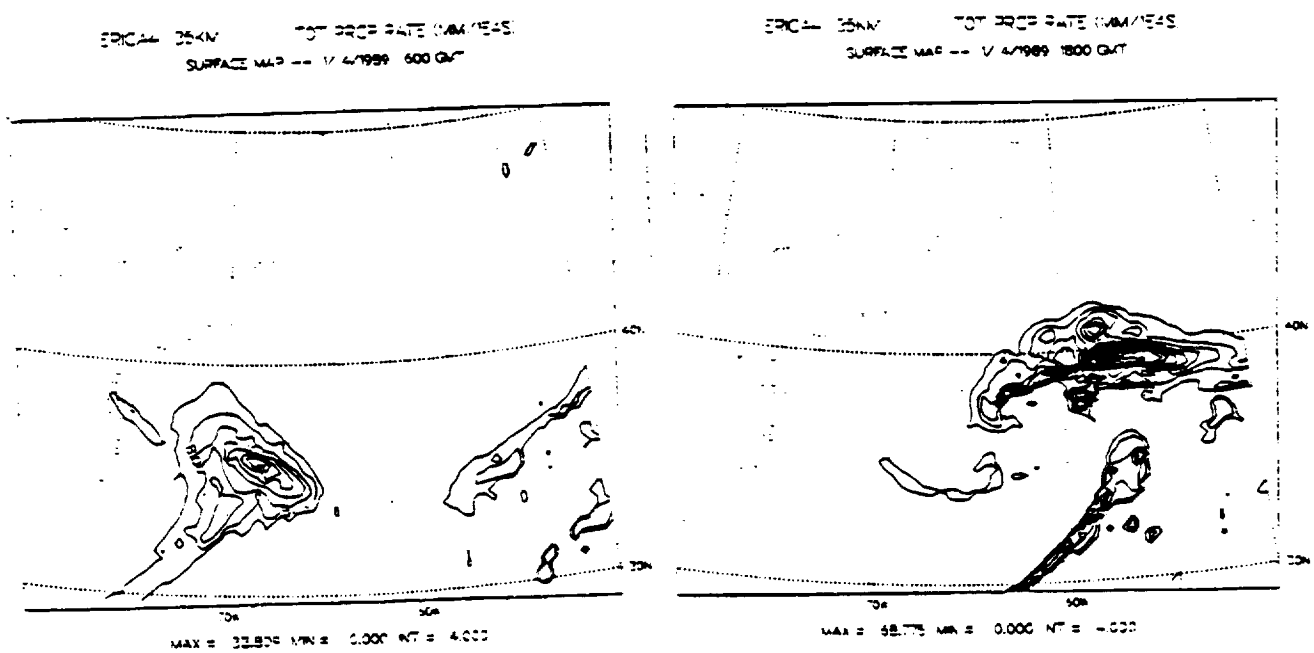

Figure 2. LAMPS total precipitation rate valid at 06 and 18 UTC 4 January 1989 (06 and 18 hours into model integration) for the 35 km run. Contour interval is 4 mm $(10^3\ s)^{-1}$.4