10D.4

SENSITIVITY OF MODELED TROPICAL CYCLONE TRACK AND STRUCTURE OF HURRICANE IRENE (1999) TO THE CONVECTIVE PARAMETERIZATION SCHEME

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1. INTRODUCTION*

Subgrid convective processes in mesoscale models such as the PSU-NCAR MM5 model include representing clouds by convective parameterization schemes (CPSs). These CPSs, using varying closure assumptions to determine cumulus-scale convection, parameterize aspects of the relationship between microscale and cloud-scale phenomena. In order to correctly represent tropical convection, a CPS must correctly parameterize the distribution and effect of latent heating on the temperature and moisture profiles of the gridbox. Precipitating cumulus clouds cause a release of latent heat of condensation and also involve freezing and melting phase changes in a region of conditional instability (Frank 1983). This energy is critical to the generating and maintenance of tropical cyclones.

Ensemble forecast studies indicate that numerical models can be sensitively dependent on either the initial conditions or the model physics (Lorenz 1963; Leith 1974). Hurricane Irene (1999) shows strong sensitivity to the CPS used. This case was selected because it experiences extratropical transition (ET) and post-transition re-intensification, and also because forecasts of both track and intensity were problematic during its lifecycle, especially near its time of transition (Avila 1999). In the sensitivity studies of each CPS, errors in forecasting speed and direction of movement occurred near the transition period, directly impacting the nature of the simulated ET in Irene. The evolving storm structures bore little resemblance to each other once ET had commenced.

2. METHODS

Hurricane Irene (1999) underwent extratropical transition between 18Z 17 Oct and 00Z 19 Oct. Irene was simulated using the nonhydrostatic MM5 version 2 initialized with NOGAPS data at 12Z on 16 Oct; initialization 24 hr in advance of the transition period allowed the model storm vortex to stabilize prior to the commencement of ET. A 45x45 km grid size and 29 vertical terrain-following (sigma) levels are used for these simulations. In addition, grid-scale precipitation is represented by explicit prediction with simple ice physics. The sole variation between the model runs was the choice of either the Betts-Miller (BM) or the Kain-Fritsch (KF) CPS.

2.1. The Betts-Miller scheme

One of the objectives of the GARP (Global Atmospheric Research Program) Atlantic Tropical Experiment (GATE) was to develop a CPS for deep tropical convection (Betts 1986). A product of this objective is the Betts-Miller CPS, which constrains the vertical temperature and moisture structures to a realistic, quasi-equilibrium value in the presence of deep convection. In this manner, subgrid convection is represented at the grid scale by an adjustment of the atmosphere toward observed environmental profiles in the presence of convection (Betts and Miller, 1993). The representation is accomplished by constraining the temperature and moisture fields by the convective cloud field.

2.2. The Kain-Fritsch scheme

The KF scheme uses a mass-conserving, one-dimensional entraining-detraining plume model that parameterizes updrafts as well as downdrafts (Kain and Fritsch, 1990, 1993). Mixing is allowed at all vertical levels through entrainment and detrainment. Convective heating is related to the fluxes of environmental potential temperature through the top and bottom of an updraft as well as those into and out of the convective draft. Convection in the model removes convective available potential energy (CAPE) at each gridpoint. Unlike the BM model, the KF model does not consider shallow convection, instead assuming that shallow convection is resolved by grid-scale processes (Kain and Fritsch, 1993).

3. ANALYSIS AND RESULTS

The difference in track assimilation between the CPSs is significant (Fig. 1). In the BM run, Irene misses an interaction with a 300 hPa jet streak and upper-level trough; it lags steadily further behind the KF run until near the time of transition, when the two runs diverge directionally, as well. In the BM run, Irene moves out to sea and dies over cool SSTs. The KF run is much closer to truth, given by the National Hurricane Center (NHC) best track analysis, and to the control run, given by NOGAPS reanalysis); however, it moves Irene with too

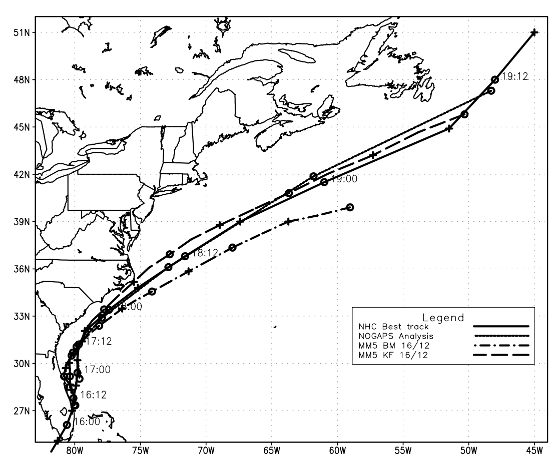

Figure 1. Track plot of the NHC best track data (solid line), NOGAPS analysis data (dotted line), MM5 BM run (dot-dashed line), and MM5 KF run (dashed line).

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much of a northerly component.

In the BM run, Irene begins to lose intensity around 12Z 17 Oct; meanwhile, cyclogenesis occurs near the favored right entrance region of the jet streak (JS), where Irene is too far away to interact. Irene veers to the east, and the midlatitude cyclonic development associated with the JS continues to deepen until 12Z 19 Oct. A slight intensification of the storm near the end of the analysis period indicates that the interaction with upper-level features arrives too late, when the storm is already nearly dissipating over the Atlantic. In addition, the feature interacting with the BM storm is not the JS that interacts with the analysis and the KF cases but rather the midlatitude cyclone that developed earlier in association with the JS, in the place where the ET of Irene should have occurred. By contrast, in the KF run, Irene moves into in the right entrance region of the JS near the beginning of ET, as observed. With the enhancement of baroclinic development by the JS over the transitioning hurricane, Irene experiences post-ET intensification, and the associated cyclone is deeper than that produced by the BM JS alone.

Heating due to convective processes is crucial to the maintenance of the tropical cyclone core. As a result of the differences between the BM and KF schemes, the convective warming over the TC core near the beginning of the lifecycle is greater at mid-levels with the KF scheme (Fig. 2a); the presence of downdrafts near the surface is indicated by cooling rates., while the warming rates are concentrated at upper levels with BM until near the end of its lifecycle (Fig. 2b). Differences in the position of convective warming affects the resulting storm structure, such as the depth of the potential voriticity field. Deeper storms are steered by deeper mean flow than shallower ones, resulting in a difference in speed and direction of motion (Velden and Leslie, 1991).

4. CONCLUSIONS AND SUMMARY

The track differences between the BM and KF model runs are indirectly attributable to the choice of CPS. The case of Irene was particularly sensitive to the height of the tropical convection produced because of the environmental steering flow and the subsequent interaction with upper-level features. Thus, the slight differences in storm structure in its early stages contributed to the major differences in storm characteristics in the last 24 hours of the analysis, when the observed TC was completing ET.

Further research is required to understand the dynamic linkages between differences in convective warming and subsequent differences in storm structure, especially with respect to the potential vorticity distribution, wind profiles and fields, and thermal structures. It is possible that no individual CPS will be able to represent an extratropically transitioning tropical cyclone accurately; instead, it may be necessary to create algorithms that can switch between CPSs as a cyclone changes its nature.

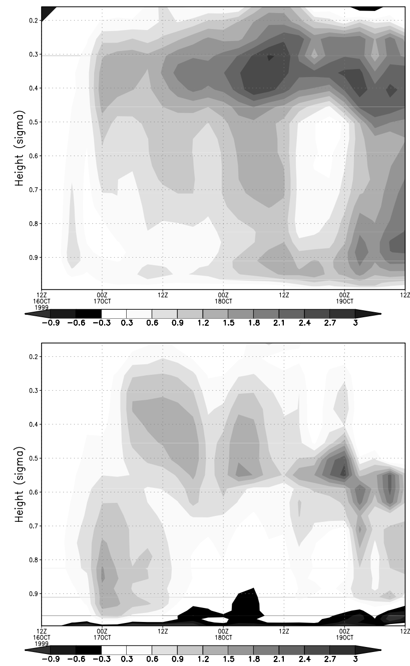

Figure 2. Vertical profile of convective warming throughout the lifecycle of Irene for the BM (a) and KF (b) runs, averaged in a 45 km radius around the center of the storm.

a.

b.

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