P1.25 EVALUATION OF IMPROVEMENTS OF MOIST PROCESSES IN THE COUPLED OCEAN ATMOSPHERE MODELING SYSTEM (COAMPS™)[1]

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1. INTRODUCTION

Microphysical processes affect a forecast in many ways. In the direct sense, the amount, position and occurrence of precipitation and cloud systems are directly influenced. Just as important, however, are the indirect feedbacks related to latent heating and its influence on the structure of larger-scale systems. As model resolution increases, an increasing amount of this heating will be explicitly resolved. The effectiveness of a microphysical parameterization should thus be tested at several levels, reflecting both the direct and indirect impacts.

This study documents the validation and testing of recent modifications to the COAMPS microphysics parameterization. Initial tests conducted by Chen et al. (2002) indicated considerable improvements in both the equitable threat score (ETS) and bias scores when the modified scheme was applied. Those tests strictly evaluated precipitation, and were limited to strongly forced events. This study is an attempt to evaluate the impacts on moderately forced events with strong convective components. Three tropical cyclones were simulated, two of which rapidly deepened and a third which failed to deepen. An additional test was conducted by running a series of forecasts over a one-month period from mid February to mid March 2003 over the southeastern US. These tests displayed mixed results, and were as much a statement of the limitations of model resolution as they were a test of the microphysics.

2. MODEL PHYSICS

All simulations were run using COAMPS as described by Hodur (1997). The model is nonhydrostatic and is formulated with a terrain-following sigma coordinate. Subgrid-scale convective processes are parameterized using the method described by Kain and Fritsch (1993). Boundary conditions were supplied by the Navy Global Atmospheric Prediction System (NOGAPS).

The existing Rutledge and Hobbs (1983) parameterization is a single-moment bulk scheme where the mixing ratios of water vapor, pristine ice, cloud water and snow are predicted. The modifications, described in detail by Schmidt (2001), include the addition of secondary ice nucleation, as well as various liquid-to-ice conversion processes. The mixing ratios for drizzle, graupel, and aggregates were also added to the scheme. The adjustment to saturation for temperature and mixing ratio was modified using the implicit solution described by Soong and Ogura (1973), and pristine ice was given a nonzero fall speed. These represent the primary differences separating the benchmark and new microphysics schemes that are investigated in this work.

3. TROPICAL CYCLONE SIMULATIONS

Super typhoon Keith and Hurricane Lili represent the two developing tropical cyclones that were simulated. Keith developed in late October 1997 in the western Pacific while Lili deepened in the Gulf of Mexico in early October 2002. The Keith simulation was initialized at 0000 UTC, 31 October and integrated for 48 hours using nested grids with spacings of 81, 27, and 9 km, respectively. The Lili simulation employed 45, 15 and 5 km grids, was initialized at 0000 UTC, 2 October, and was integrated for 24 hours. Both simulations were initialized from the NOGAPS analysis during the deepening stages of the respective storms. Both storms were initialized by inserting circulations into the initial fields. Lili was initialized using improved methods detailed by Liou (2002). Unlike a typical operational simulation, convective parameterization was not used on the fine grids. Latent heating was thus supplied entirely by the explicit scheme.

The central pressure traces for both storms (Fig. 1) indicate the modified scheme was far better at sustaining pressure falls than the old scheme. Central pressures actually increased for both benchmark runs. Although the central pressure in Keith was unknown, the sustained winds were estimated to be 80 m s^{-1} by the time of the 48-hour forecast. Thus the central pressures were probably quite low, and the deepening trend predicted by the modified scheme was likely correct. Interestingly, storm track errors did not improve significantly, indicating that intensity played a relatively minor role in these two cases. Intensity may have a greater affect on the track as storms interact with land or other meteorological features.

Tropical storm Cimaron, which formed in the western Pacific in May 2001, represents the nondeveloping case. The simulation was initialized at 0000 UTC on 12 May 2001 using the same grid spacings as the Keith simulation.

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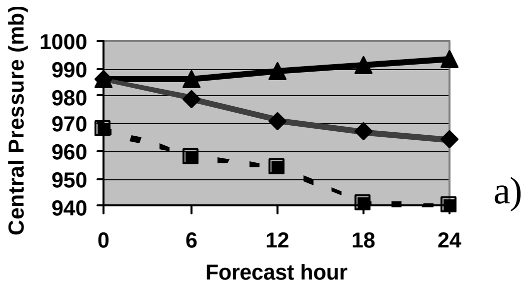

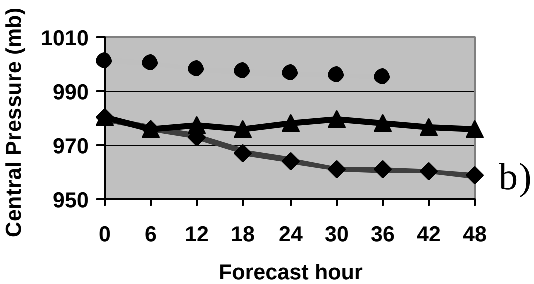

Fig. 1. In a) central pressure forecasts for Lili from the bench and modified microphysics are plotted as the solid and stippled lines. The observed central pressures are dashed. In b) central pressure forecasts for Keith from the bench and modified microphysics are plotted as the solid and dark stippled lines. The Cimaron central pressure forecast from the modified microphysics is plotted as the light stippled line.

Though observed surface pressures were again unknown, observed winds were never greater than 26 m s^{-1} through the forecast period, and the storm never attained typhoon strength. The modified microphysics scheme (Fig. 1b) was likely correct in simulating only modest pressure falls associated with this storm. The simulation may have been a bit weak as the simulated winds at 10 m AGL were between 15 and 20 m s^{-1}.

4. SOUTHEASTERN US SIMULATIONS

The final test in this study entailed one-month of 24-hour forecasts spaced at 12-hour intervals over the southeastern US during the period from 20 February to 18 March 2003. This p eriod was characterized by a number of heavy rain events over the southeastern US. The simulations were run on three nested grids with spacings of 81, 27 and 9 km with the previous 12-hour forecast acting as a first guess in the analysis update cycle. The 9 km grid covered most of Georgia Mississippi, Alabama, South Carolina and northern Florida, and convective parameterization was not used on this grid.

The lack of adequate convective parameterization turned out to be quite detrimental to these simulations. Most of the cases were typified by weak to moderate upper tropospheric forcing along a preexisting east-west stationary front. These cases were often very poorly simulated, especially when convection was nocturnal. Bias scores were quite low regardless of the microphysics

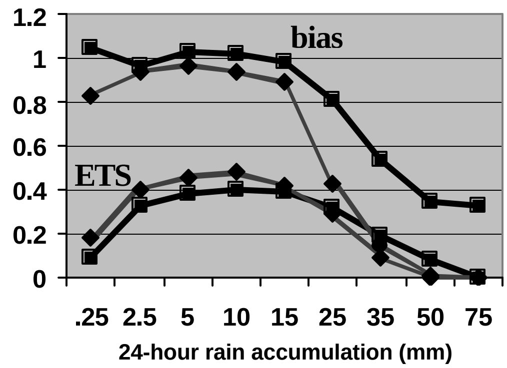

Fig. 2. Grid-total 24-hour precipitation statistics on the 9 km southeastern US grid from the forecast initialized at 1200 UTC on 21 February 2003. Bias scores from the modified and bench microphysics are plotted as solid and stippled lines. ETS scores from the modified and bench microphysics are plotted as solid and stippled, respectively.

scheme. The 9 km grid spacing falls within the range of scales where explicit microphysical parameterizations may fail to simulate convection if the forcing is insufficient. Unfortunately, most convective parameterizations are also not valid at this scale.

A few cases were characterized by forcing large enough in scale to produce precipitation on the 9 km grid. A strong cyclone and cold front produced widespread precipitation on 21-22 February. The 24-hour precipitation bias scores, compared against the River Forecast Center 4 km stage-4 precipitation analysis, (Fig. 2) indicate the modified scheme produced more precipitation at the high thresholds. Bias values were still below one though. ETS scores showed mixed results with reduced scores at low thresholds and increased scores at high thresholds. These limited results indicate the modifications to the microphysics may contribute more to the precipitation at high rain rates. For future work, a subset of cases has been chosen for simulation with a 3 km grid to better resolve the convection.

5. CONCLUSIONS

Microphysical parameterizations are difficult to verify since direct microphysical measurements are highly localized and relatively rare. Precipitation or latent-heating related variables must often suffice. This is further complicated by the reality that real-time forecasts have only recently entered the realm where bulk schemes can resolve the relevant processes. These tests indicate that tropical cyclone intensity forecasts can be improved by modifying the explicit scheme. There is also some indication that forecasts of other types of strongly forced or large-scale systems can be improved. The results are scale dependent, however. If the system is not properly resolved, no amount of upgrades will improve the forecast. As model resolution continues to increase, the microphysics will have an increasingly important role.

6. REFERENCES

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