Cloud Microphysics Impact on Hurricane Track as Revealed in Idealized Experiments

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Introduction

Cloud microphysical parameterizations (MPs) have been shown to have a tremendous impact on forecasts of both tropical cyclone (TC) intensity and track (Wang 2002; Zhu and Zhang 2006; Fovell and Su 2007). Indeed, a physics based forecast ensemble varying the available MPs in one model produces a spread in forecast tracks equal to that of a multi-model ensemble.

To explain the differences in the tangential wind profiles, we turn to the physical mechanisms and sensitivity tests presented by Fovell and Su (2007). They showed that different MPs modulated storm width and speculated this could be one reason for the substantial difference in tracks, similar to the findings of Fiorino and Elsberry (1989).

\[ \Delta p = \frac{\rho g}{R_d} \Delta T_v \]

The goal of the present research is to uncover and understand the physical processes in MPs that control TC size, and to first order, storm motion.

Model Design

• "Real-Ideal" WRF V2.2.1: ARW core, retains Earth’s curvature, but no land (Hill and Lackmann 2008)
• Three telescoping domains 27/9/3 km, 30 vertical levels, 50 hPa model top, RRTM radiation scheme
• Initialized with the Jordan (1958) sounding but with no initial environmental flow and a constant 29°C sea surface temperature
• A coherent vortex is spun up from the addition of a warm, moist anomaly to the initial conditions (No MP scheme is used during the spin up, but the Kain-Fritsch cumulus parameterization (CP) is on)
• After 24 hrs, the CP is turned off and one of three MPs (Kessler, LFO, or WSM3) is turned on
• In addition to the standard run, sensitivity experiments with the CAM radiative scheme, no radiation, no graupel in the LFO run, and all condensate in the Kessler MP immediately turns to rain were conducted

Results

The tracks and tangential wind profiles of Fovell and Su (2007) are reproduced:

- The Kessler storm moves much more quickly and further to the west than either of the storms with ice microphysics (left), and exhibits a much broader tangential wind profile out to large radii at 850 hPa (right).
- The LFO storm produces a huge anvil and travels the furthest west. K/NOCLOUD has almost no anvil and resembles the ice MP tracks, while K/NOCLOUD2 moves like the original K. This was due to similar \( \Delta T_v \) in the runs because of cooling in the V₉ = 0 zone where rain is more likely to evaporate.

Discussion and Summary

• Clearly, there are other effects on storm motion not examined here, including tilt of the vortex (Wu and Emanuel 1983; Wang and Holland 2006) and convective asymmetries (Nolan et al. 2001), but the assumptions used in cloud MPs drastically affect the motion of TCs
• This effect is realized here by the size of the upper tropospheric anvil and its cloud-radiation feedback effects on the horizontal temperature gradients, pressure gradients and ultimately, the wind fields