Structure of Tropical Cyclones at the Onset of Rapid Intensification in the HWRF Model

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Objectives

Forecasting tropical cyclone (TC) rapid intensification (RI) is challenging. Operational forecasts of RI events based on numerical models sometimes capture RI even in inimical environmental conditions, whereas in some cases RI could not occur despite model storms embedded in very favourable conditions. Questions of specific interest are:

1. What is the vertical structure of the model vortex at the onset of the rapid intensification in the HWRF model?
2. How does the model storm development depend on the initial vortex structure in the HWRF model?

Experiment description

- Triple nested domains 27/9/3 km configuration;
- Use an HWRF idealized configuration in moist (Jordan (1965) tropical profile) and dry (50% RH reduction) environment;
- Modify the bogus initial structure to allow for changing the height of the maximum surface wind (VMAX)

$$V(r,\sigma) = V_m \frac{r}{r_m}\left[\sin^{2-\delta}\left(\frac{\pi}{2}\sigma\right)\cos^{\delta}\left(\frac{\pi}{2}\sigma\right)\right]^{0.5} \exp\left\{\frac{1}{\delta}\left[1-\left(\frac{r}{r_m}\right)^2\right]\right\} \quad (1)$$

- Constant SST, quiescent environment, and open boundary condition;
- Model physics include Ferrier microphysics scheme, GFDL radiation for short/long wave; GFS PBL scheme; no SAS cumulus convection for 3km domain.

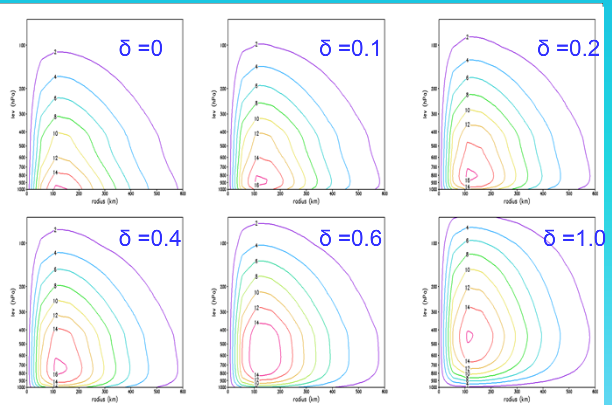

Figure 1. Radius-height cross sections of idealized vortices at the initial time for a range of values of the parameter δ given in Eq. (1). The larger the value of δ, the higher the level of the maximum surface wind (ZMAX) is. All initial vortices have the same tangential wind magnitude of 14 m s^{-1}.

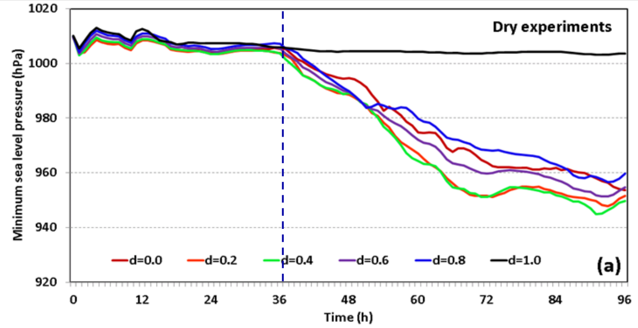

Figure 2. Time series of the minimum sea level pressure (hPa) for a range of δ in the dry experiments. Dashed line denotes the RI onset moment.

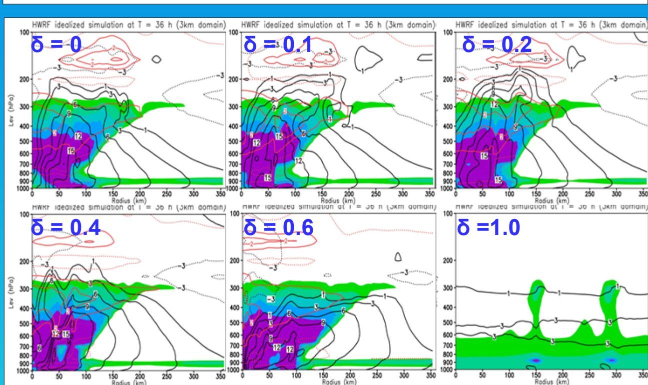

Figure 3. Radius-height cross sections of RH (shaded,%), tangential wind (black, ms^{-1}), and T anomalies (red, K) at the RI onset in the dry experiments.

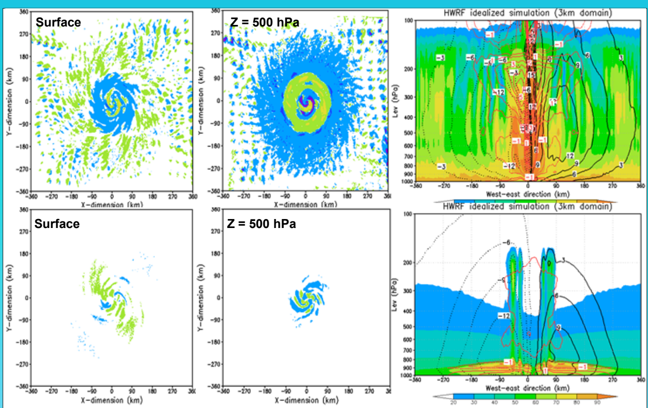

Figure 6. Upper panels: Horizontal cross sections at the surface and 500 hPa for the moist convergence (shaded) and the vertical cross section through the storm center of the relative humidity (shaded) and the tangential wind (black contours) in the moist experiment. (lower panels): similar to the upper panels but for the dry experiment.

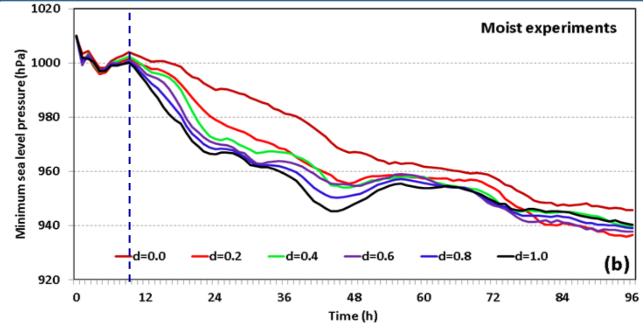

Figure 4. Time series of the minimum sea level pressure (hPa) for a range of δ in the moist experiments. Dashed line denotes the RI onset moment.

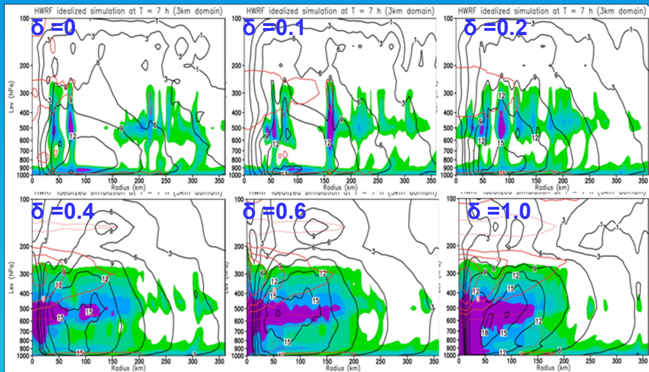

Figure 5. Radius-height cross sections of RH (shaded,%), tangential wind (black, ms^{-1}), and temperature anomalies (red, K) at the RI onset in moist experiments.

Discussions and Summary

1. The onset of RI in the HWRF model is characterized by a phase-lock condition including i) a saturated core, ii) a warm anomaly 3-5K, and iii) tangential wind > 12 m s^{-1};
2. In dry experiments, the saturated core is built from the bottom up due to lack of moisture in the model atmosphere. Time scale for this is ~ 36 h, which may be too long for midlevel vortices to build a statured core. As such, the higher the level of VMAX is, the slower the storm will grow;
3. In moist experiments, the phase-lock is built faster (~ 7-h into integration) because midlevel convergence can trigger deep pulses of convection within the storm central region, Convergence at the midlevel is more effective than that at the lower level, so vortices with higher ZMAX grow faster;
4. This study suggests that moist initialization should be included in any vortex initialization scheme to better capture the storm development.

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