Sensitivity of cloud microphysical processes on hurricane intensity

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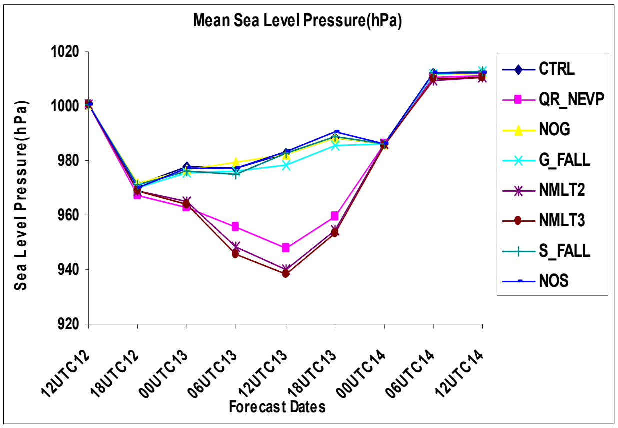
In this study we have conducted seven cloud microphysics sensitivity experiments and a control run (CTRL) to elucidate the impact of different microphysical processes (e.g. melting, evaporation) and parameters (e.g. fall speed, intercept parameter) of hydrometeors (e.g. cloud ice, snow, graupel) on the intensity of the hurricane Charley, 2004. We have used a high resolution (3km) triply nested (27/9/3) state of art mesoscale model (MM5) with NASA Goddard Space Flight Center (GSFC) microphysical parameterization Scheme (Tao and Simpson 1993) for carrying out these experiments. The seven different microphysical sensitivity experiments are as follows: NMLT3: where melting of ice, graupel and snow were suppressed, NMLT2: melting of ice and graupel were not allowed, QR_NEVP: evaporation of falling rain were eliminated, G_FALL: fall speed of graupel hydrometeor doubled, NOG: intercept parameter for graupel hydrometeors doubled, S_FALL: fall speed of snow hydrometeors were doubled and NOS: where intercept parameter of snow were doubled.

We noticed profound impact of the different cloud microphysical processes (i.e. melting, evaporation, fall speed and intercept parameter) on the intensity of hurricane Charley. The sensitivity experiments where physical processes such as melting of graupel and snow (i.e. NMLT2), melting of graupel, snow and cloud ice (i.e. NMLT3) and evaporation of rainwater (i.e. QR_NEVP) were eliminated from the model explicit parameterization scheme produced the most intense storms (Fig 1a). The reason of this intensification in NMLT2 and NMLT3 experiments can be attributed mainly due to the absence of melting processes in sub cloud layer which results in enhanced production and rapid fallout of graupel hydrometeors and a positive feedback to the latent heat release. The intensification of the storm generated from the sensitivity experiment where we have eliminated the rainwater evaporation from the model (i.e. QR_NEVP) can be explained as, lack of evaporation results in the reduction of the cooling tendencies within the storm eye wall which inhibit the generation of penetrative downdraft in the inner core and hence preventing the flow of cooler and drier equivalent temperature (θe) from mid troposphere to boundary layer thus maintaining the warming within the inner core of the hurricane (Fig 1b). We also noted that the variations made in the formulations which determines the fall speed and intercept parameter of graupel and snow hydrometeors did affect the intensity of the hurricane but not as much as in comparison to the suppression of inter conversion processes such as melting and evaporation of (i.e. graupel, snow and rain water). All intense storms (i.e. NMLT2, NMLT3 and QR_NEVP) exhibited stronger upward motion (Fig 1c) in the vicinity of eye wall and these called for the large scale influx of sensible and latent heat from marine boundary layer to the storm inner core, which facilitated the intensification rate. In (Fig 1d) we showed that the magnitudes of inner core warming (vertical structure of zonal temperature deviation) for the most intense storms (i.e. NMLT2, NMLT3 and QR_NEVP) are larger than those generated from the other sensitivity experiments, which reconfirms the profound influence of different microphysical processes in modulating the inner core of the hurricane and so also its intensity.

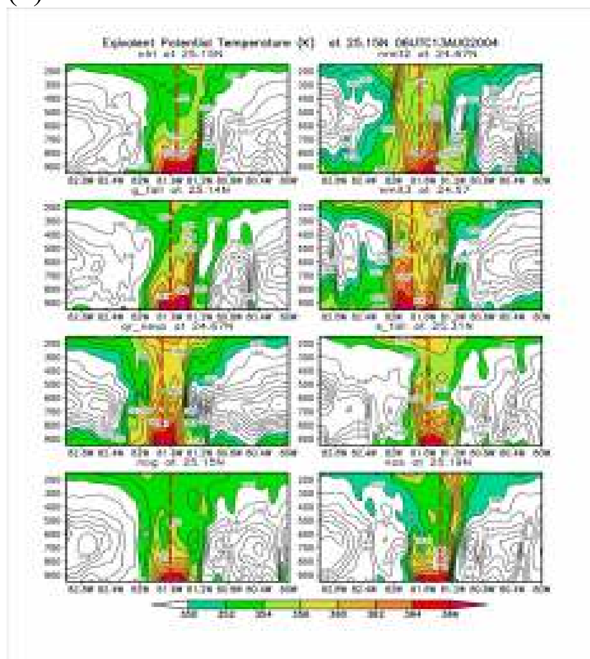
References:

Tao, W.-K., and J. Simpson, 1993: Goddard Cumulus Ensemble Model. Part I: Model description. Terrestrial, Atmospheric, and Oceanic Sciences, 4, 35-72.

(a)



(b)



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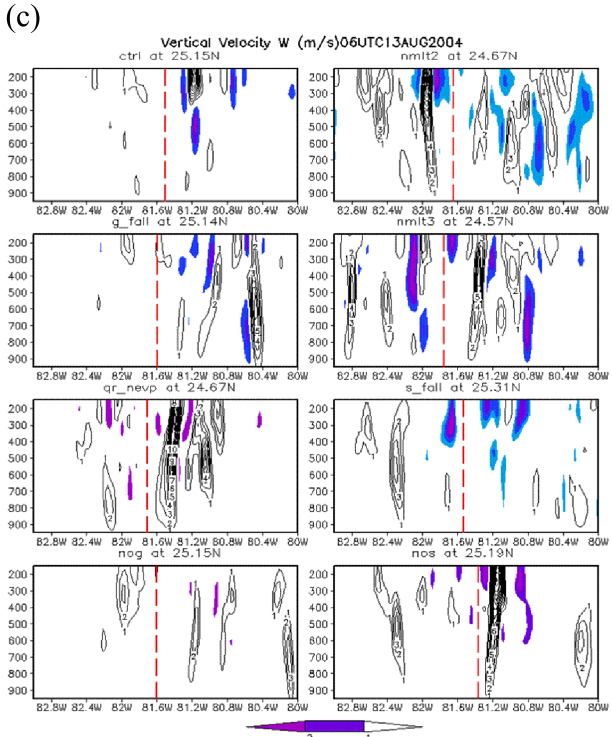

(d)

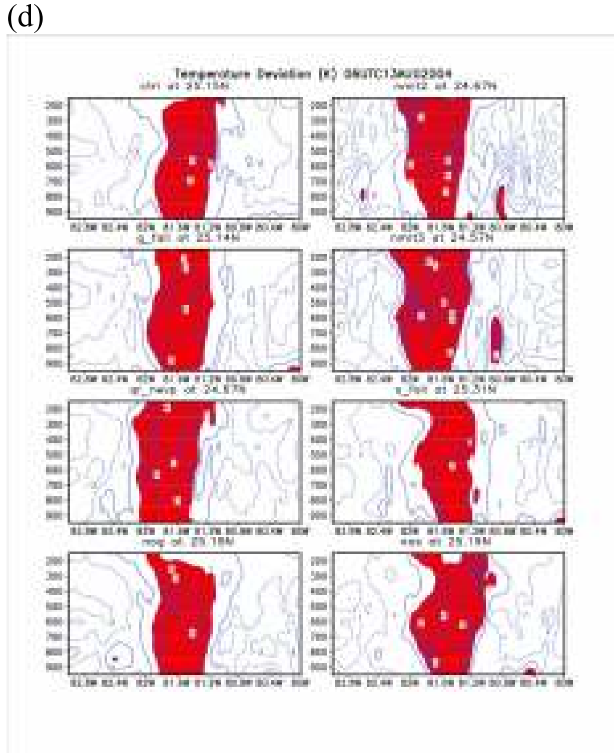

Figure 1 (a through d): (a) 48hour forecast of minimum sea level pressure (hPa) for microphysics sensitivity experiments; (b through d) Vertical structure snap shots for different microphysics sensitivity experiments at 0600 UTC 13 August 2004 (b) Equivalent potential temperature (K), (c)Vertical velocity (m/s) and (d) Deviation of temperature (K) with respect to zonal mean between 83.0W and 80W.