Response of developing tropical cyclones to CCN and microphysics

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Introduction

- We examine the implications of simulations of the impact of African dust on hurricane intensity (Zhang et al., 2007; Zhang, 2008; Zhang et al., 2009) to TC genesis and intensification
- Rosenfeld et al 2007 also examined the impacts of variable CCN on TC intensity

RAMS Setup

- RAMS was initialized with the pressure, temperature and wind fields of an axisymmetric MCV consistent with observations obtained from several pre-TC MCVs (Montgomery et al., 2006).
- Three nested domains with horizontal resolutions of 24, 6 and 2 km were used.
- RAMS was initialized with a horizontally uniform Jordan sounding (Jordan, 1958)

- The MCV was allowed to grow for 3 days in a zero wind environment over the ocean with a constant sea surface temperature (SST) of 29C
- The two-moment bin-emulating microphysics scheme described in Cotton et al. (2003) and Saleeby and Cotton (2004), in which bin microphysics for collection and sedimentation was used.
- The scheme includes two modes of droplets and explicit activation of CCN and GCCN(Saleeby and Cotton *(*2004)

Cloud Droplet Nucleation

Number nucleated obtained from lookup table as a function of

- CCN number concentration
- Vertical velocity
- Temperature

Lookup table generated previously (offline) from detailed parcel-bin model. Tables have been expanded to include variable kappa to represent chemistry

$N_{c1} = N_{ccn}$

$N_{c2} = N_{gccn}$; $S_w > 0.0$

Ice nucleation follows the approach described by Meyers et al. (1992):

$$N_i = N_{IN} \exp [12.96 (S_i - 1)]$$

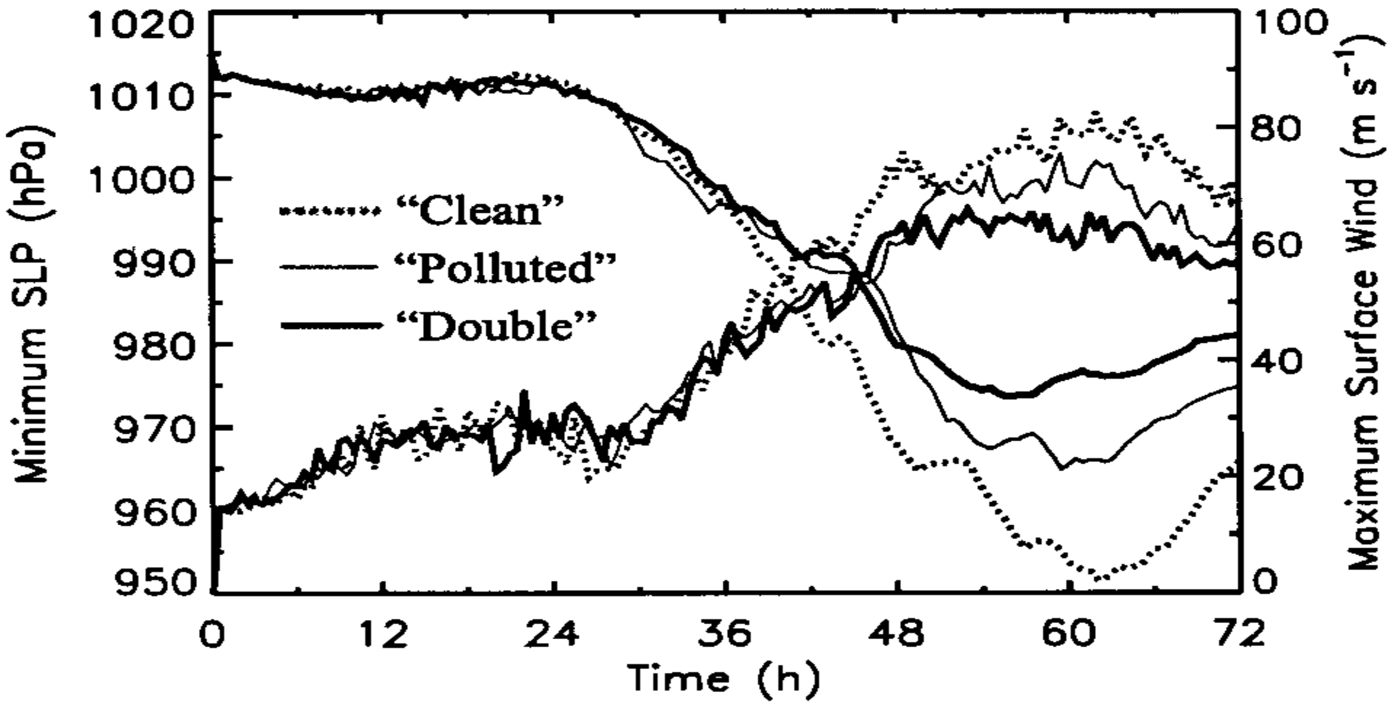
$T < -5^oC$; $r_v > r_{si}$ (supersaturation with respect to ice), and $T < -2^oC$; $r_v > r_{sl}$ (supersaturation with respect to liquid), where N_{IN} is a model forecast variable and can be initialized horizontally and vertically inhomogeneously.

- CCN is horizontally homogeneous. "Clean" has $100cm^{-3}$ from surface to 25km.
- "Polluted" enhanced the CCN in 1km-5km to $1000cm^{-3}$.
- "Double" has CCN of $2000cm^{-3}$ in 1-5km.
- Intermediate values of 500/cc and 1500/cc were also run by Zhang(2008) and even 101/cc

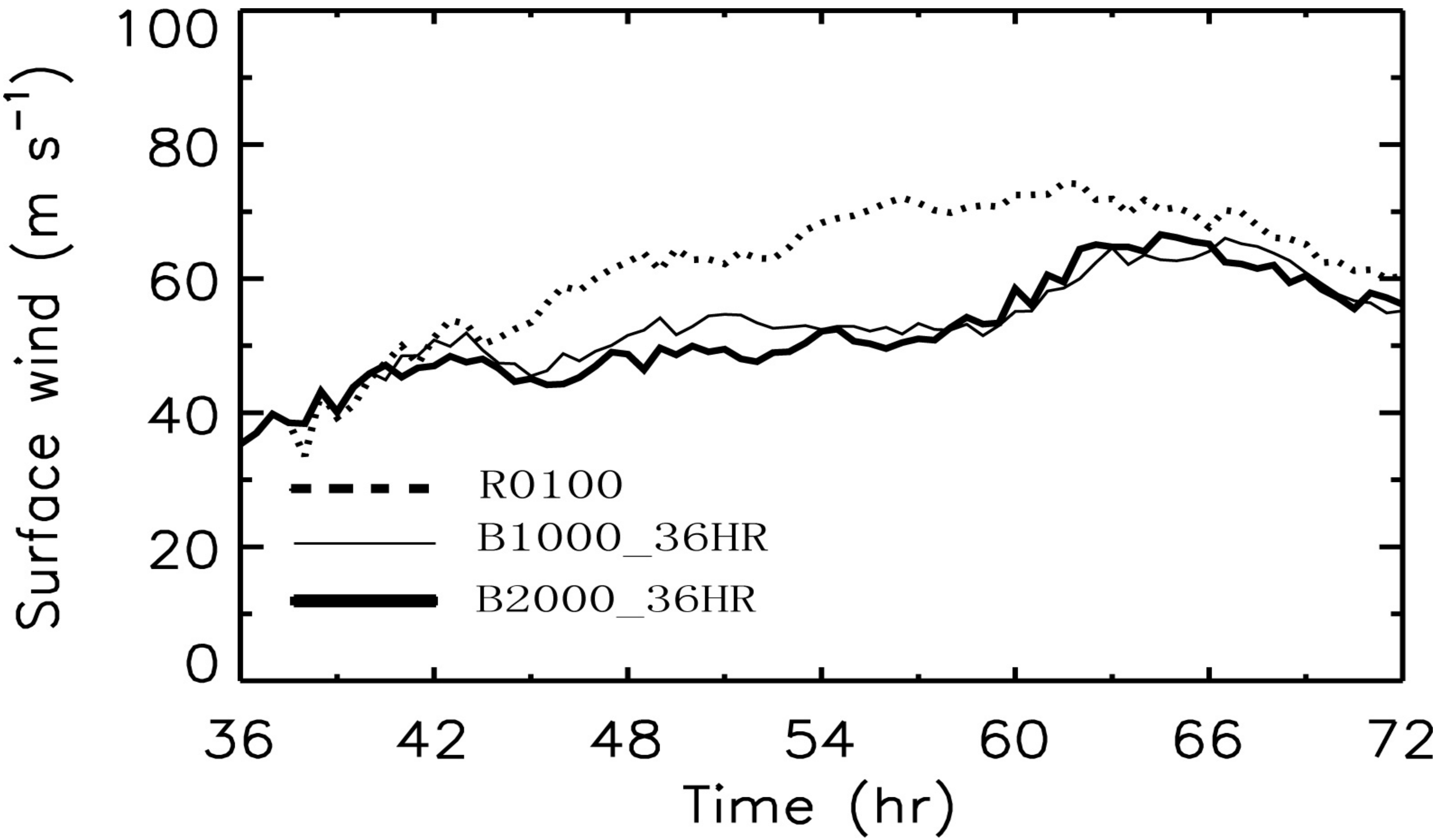
- Zhang(2008) also performed simulations with CCN introduced after 36h of simulation at the boundaries of Grid#3 or just in Grids#1 and 2.
- Similarly CCN was introduced at the boundaries at 60h.

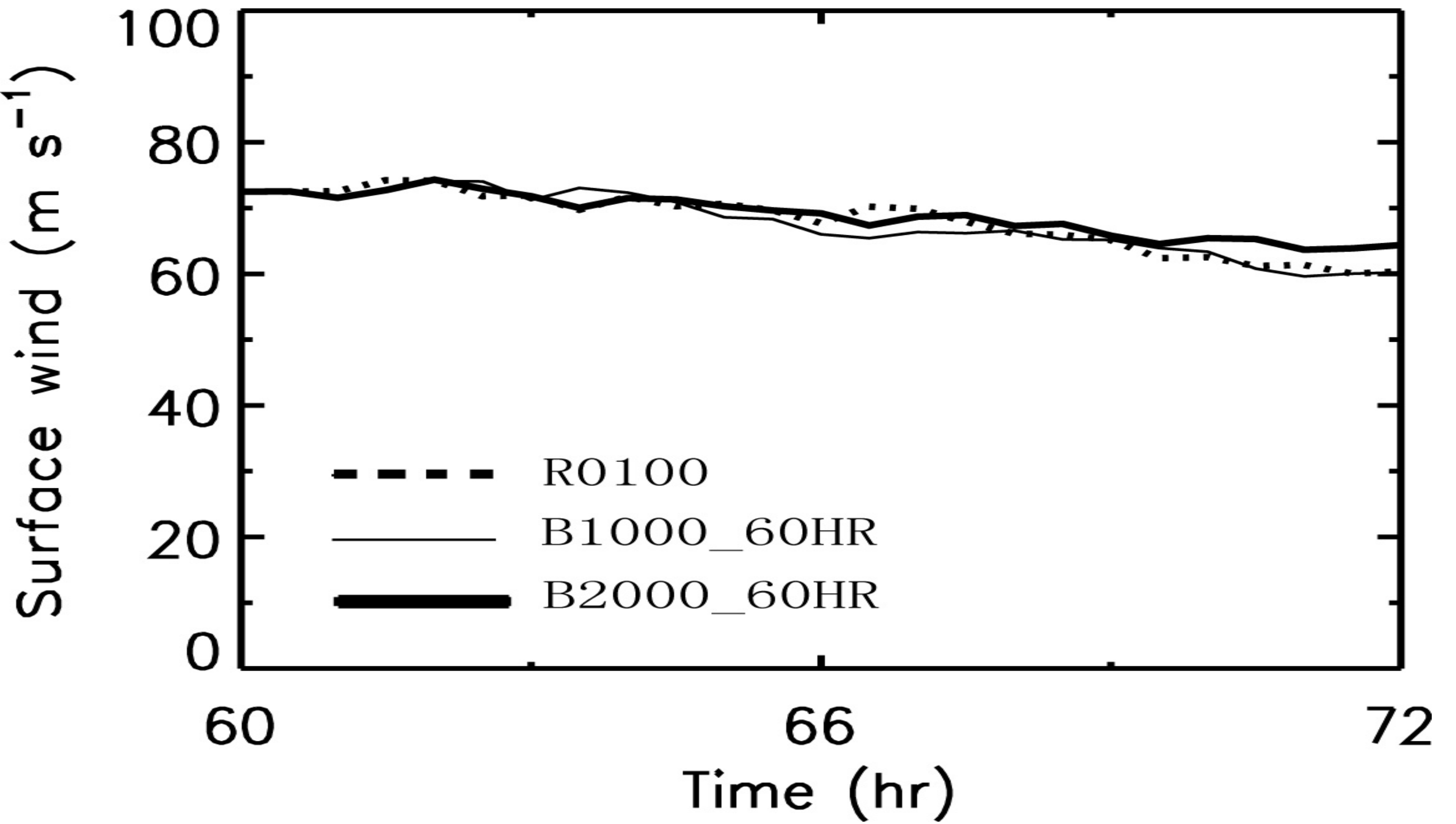
Results

‘‘Clean’’ (dotted line), ‘‘Polluted’’ (thin solid line) and ‘‘Double’’ (thick solid line).



Simulations with CCN at boundaries at 36h

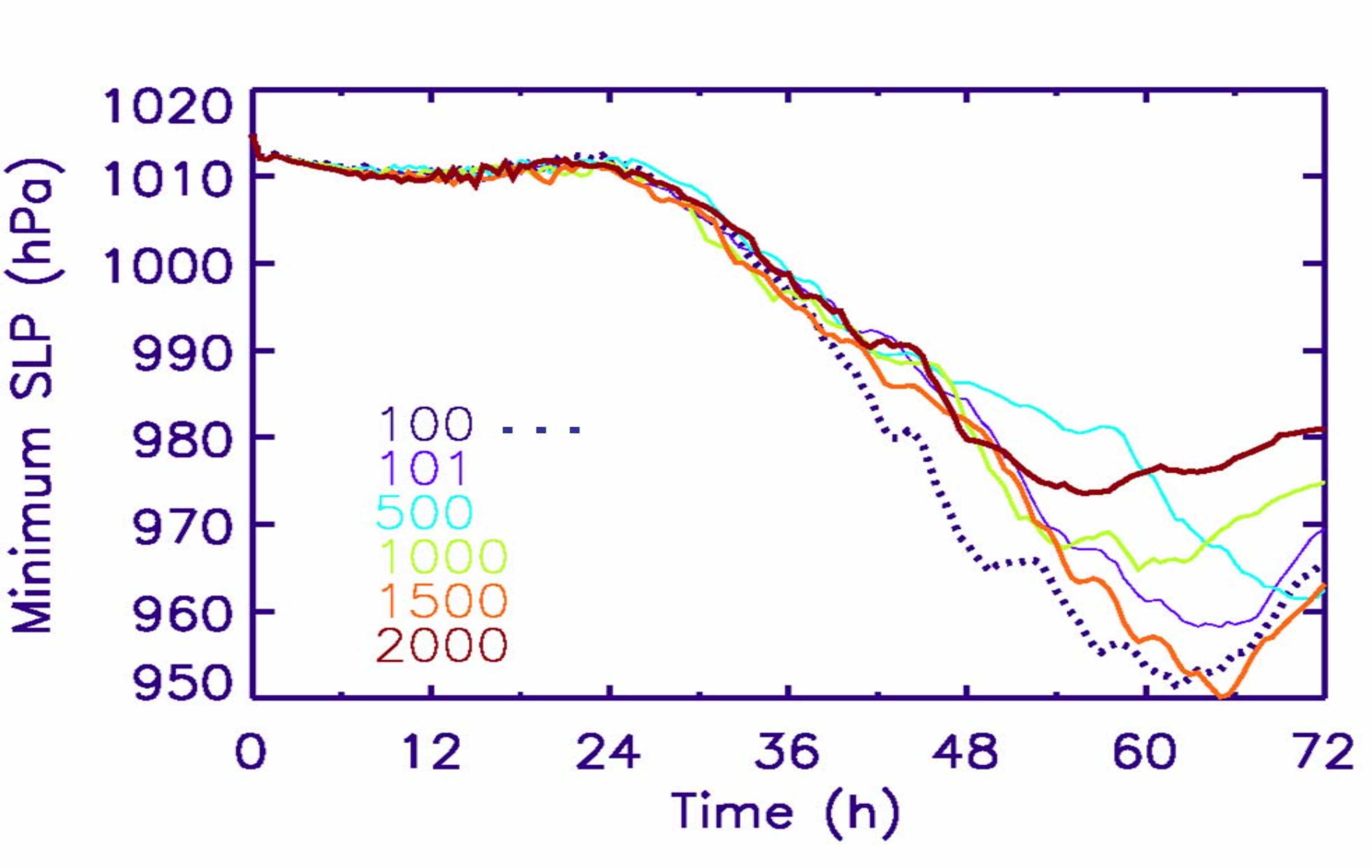




100
80
60
40
20
0
Surface wind (m s-1)
60
66
72
Time (hr)
R0100
B1000_60HR
B2000_60HR

- Impact of introducing CCN at boundaries at 36h were lessoned but still significant
- By 60h the storm was more mature and dynamically “stiff” and responded little to CCN

Zhang also introduced intermediate values of CCN initially



- Results were no longer monotonic with increasing CCN, but an overall tendency for increasing CCN to reduce storm intensity was found

- Note that the time at which the greatest response to CCN occurs, corresponds to the time in which spiral rainbands form in the simulation.
- Zhang (2008) concluded that enhanced convection and stronger cold pools in the spiral rainbands divert enthalpy from the eyewall region thus contributing to a weakening of the storm.

- Note that the simulations do not reveal any significant response to enhanced CCN in the eyewall region or within a radius of 45km.
- This is because the enhanced CCN are washed out well before they are transported close to the eyewall. Throughout the simulations CCN concentrations in the eyewall region remain low and probably unrealistically low (about 1/cc or less) owing to the fact that sea-spray generation of CCN is not simulated.

Other Research

- McFarquahar et al(2006), Rosenfeld et al.,(2007), Fovell and Su(2007), and Fovell and Corbosiero(2009) all find a pronounced sensitivity of simulated hurricanes to the details of the parameterization of cloud microphysics
- Fovell and Su find that the influence is greatest in the outer rainbands as far as the direction of storm movement is concerned

Implications

- Changes in the microphysics and dynamical structure of convection in outer rainbands during the genesis and intensification stages of a TC can have an appreciable influence on the storm.

Recommendations

- Measurements are needed of CCN beneath outer rainband clouds and low-level cloud droplet concentrations and sub-cloud raindrop spectra of outer rainband clouds
- Measurements of the variability of cold pools beneath outer rainband convection are also needed in relation to varying thermodynamics and cloud microstructure.
- Measurements of the aerosol properties outside the storm and within the storm are needed during various phases of TC development and intensification
- Measurements of the variability of amounts of SLW are needed in the outer rainband regions