A comparison between observed and simulated hydrometeor size distributions in MCS using the AMMA 2006 microphysical data set

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Objective

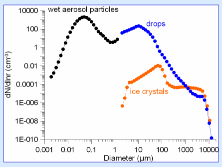
Objective : **improving our understanding of the cloud particle spectra in deep convective clouds and their effect on cloud radar reflectivity**

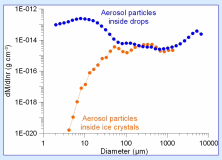
Can detailed cloud modeling in a highly resolved 3D dynamical frame reproduce the observed features of a convective tropical MCS?

In this model study special emphasis is put on :

- Observed and modeled spectra of hydrometeors and their effect on radar reflectivity
- The role of the crystal shape for the observed size distributions and for the simulated reflectivity as observed by a cloud radar

The model





Detailed (bin) microphysics in the 3D non-hydrostatic dynamics of Clark et al (2002)

= DESCAM 3D (*Leroy et al., 2009*)

Warm microphysical processes :
aerosol particle growth and activation, droplet de-activation, growth of drops by condensation and collision-coalescence, break up.

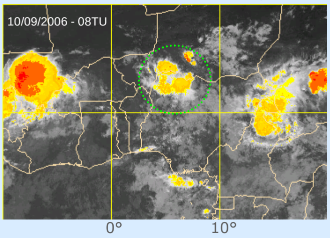
Cold microphysical processes :
homogeneous and heterogeneous nucleation, growth by vapor deposition, riming and melting.

f_d : drop number
f_i : ice crystal number
f_{AP} : wet aerosol particle number
$g_{AP,d}$: aerosol mass inside drops
$g_{AP,i}$: aerosol mass inside ice crystals

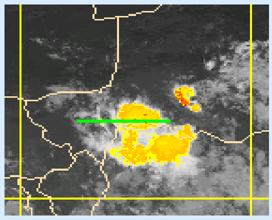
* Initialization: sounding of Niamey on 9 sept. 2006, 17 h
* aerosol spectra from aircraft observations in July '06 during AMMA SOP2B

Observations

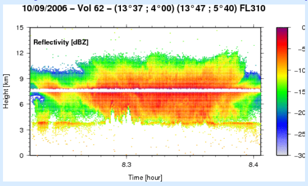
convective systems on 10 sept. 2006



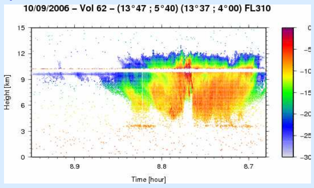
flight track from 8 to 9 h



Reflectivity of the airborne Cloud Radar (Rasta) at 2 different altitudes



flight track at 7.5 km

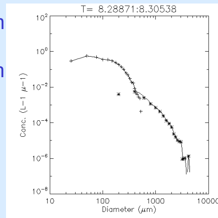


flight track at 10 km

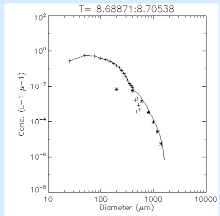
Hydrometeor spectra observed by PMS 2D-C and 2D-P

at 7.5 km

1 min. mean

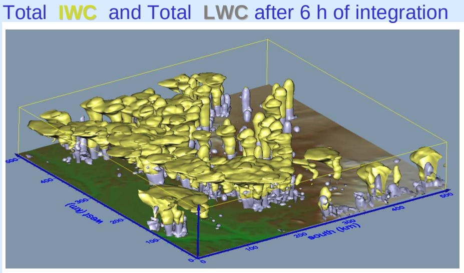


at 10 km

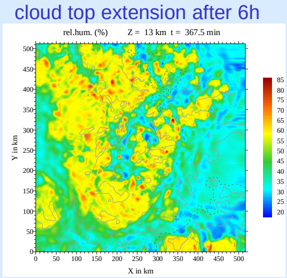


Model results

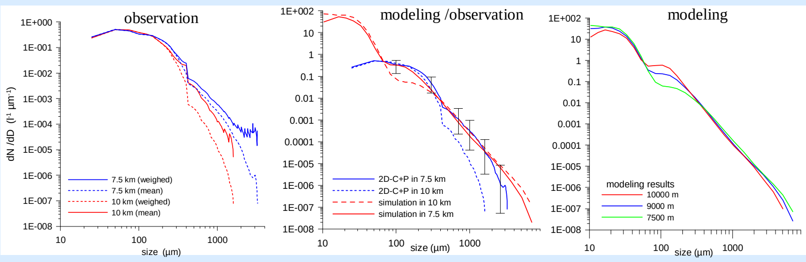
Total **IWC** and Total **LWC** after 6 h of integration



cloud top extension after 6h



Observed and simulated hydrometeor spectra



Aircraft measurements of 1 Hz for hydrometeors > 25 µm were observed on horizontal flight tracks at 7.5 and 10 km – each observation took 11 -12 min.

- the dashed lines show the mean spectra over all 700 individual samples
- in the solid (weighed) spectra the statistical underestimation for large particles was corrected

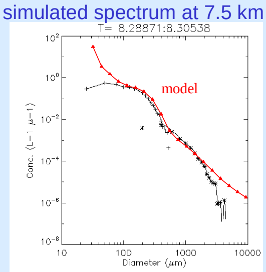
- Observed particle numbers for sizes < 300 µm do not differ between 7.5 and 10 km ! Simulations, however, show in the range from 80 – 300 µm a strong variability with height. The number increase in this range results from the increasing ice crystal concentration due to the decrease in temperature.

- Observed hydrometeor numbers > 500 µm decrease with altitude, the simulated spectra, however, show only a very weak decrease with height.
- the mean spectra presented for the simulations also represent 700 individual samples.

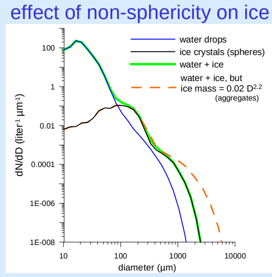
➔ More sophisticated measurements are needed in order to understand the microphysical structure, the ice/water partitioning and the morphology of the ice particles in deep convective clouds

Modeled vs. observed cloud spectra

simulated spectrum at 7.5 km



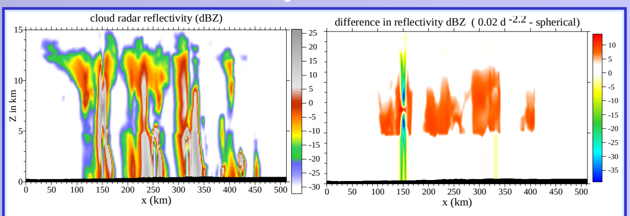
effect of non-sphericity on ice



- a significant mode occurs between 100 – 400 µm: the model results explain this effect by presence of numerous ice crystals

- ice crystals sizes increase significantly if mass-diameter relations are considered

Cloud radar reflectivity



Simulated radar reflectivity (wavelength 3.1 mm, attenuation included):

- The left figure gives the reflectivity based on calculations for spherical hydrometeors (ice crystals and drops are optically well distinguished)
- The right figure gives the difference between calculations for Z_R that considers all ice crystals > 200 µm following a mass-diameter relation $m = 0.02d^{2.2}$ and Z_R that uses a spherical shape for all ice crystals (as illustrated in the right figure)

➔ using a mass diameter relation for large ice crystals already causes an increase of more than +10 dBZ in the major parts of the deep convective clouds

Acknowledgements

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References:

Leroy D., W. Wobrock and A. I. Flossmann, 2009: The role of boundary layer aerosol particles for the development of deep convective clouds: a high resolved 3D model with detailed (bin) microphysics applied to CRYSTAL-FACE. *Atmos. Res., DOI: 10.1016/j.atmosres.2008.06.001*