# Interpretation of airplane measurements by a 3D model with bin microphysics

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## Case study : CRYSTAL-FACE 18 July 2002

Microphysical measurements in the anvil of a deep convective cloud (Heymsfield et al., 2005)

The updraft core can be divided into two regions (Figs. 1, 2 and 3):
Region B: w > 20m/s, entirely glaciated, T ≈ -32.5°C
Region C: w ≈ 10 m/s, liquid water is present, T ≈ -35.5°C

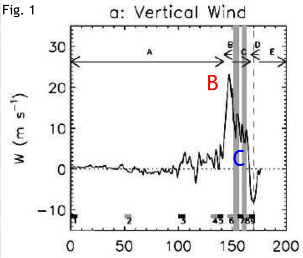
Fig. 1


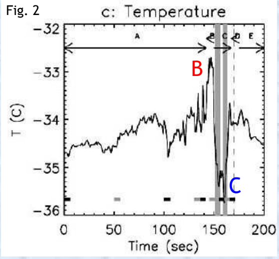
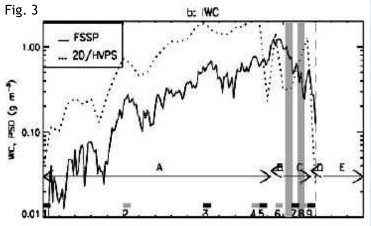

Fig. 2



Fig. 3



## Model : DESCAM 3D

Dynamics : Clark and Hall (1991)
Microphysics : ***DE***tailed ***SCA***venging ***M***odel (Flossmann et al. 1985; Leroy et al., 2006)

**3 number density distribution functions** (aerosol particles, drops, ice crystals)
**2 mass density distribution functions** of aerosol in drops and crystals
} 5 x 39 bins = 195 microphysical variables

*Microphysical processes* : AP activation, heterogeneous and homogeneous nucleation, growth of droplets and ice crystals, coalescence, riming.
*Set up* : Model domain : 128x128x64 points; $\Delta x=\Delta y=\Delta z=250$m.
Miami airport sounding, 15h, 18 July 2002.
Initial aerosol particle spectra : Fridlind et al. (2004) ~1800 particles/cm$^3$
Initialization of the convection by a large thermal bubble

## Results :

- Model results and observations are compared after roughly 41min of integration when the top of the cloud reaches 14 km and the anvil is around 20 km wide as observed (Fig. 4).

-Temperature field (Fig. 5) shows variations similar to observed (more than 3°C along line BB'). At 11km (Fig. 7), the model reproduce a strong updraft with a warm temperature (similar to region B) and near, an area with moderate winds and colder temperature (like region C).

-Along AA' cross-section (Fig. 5), both winds and microphysical measurements are close to observations (Fig. 6). Liquid water is negligible when vertical winds are greater than 20m/s, but becomes 0.3gm$^{-3}$ in the moderate updraft region C. The IWC for crystals larger than 40µm shows two maxima as observed.

-The region C is well reproduced with both W, LWC and IWC in agreement with the observations. The particles distributions are also coherent with the measurements (Figs. 8 and 9).

-Back-trajectories (Fig. 10) from points 1 to 3 (Fig. 7) show clearly that the air masses in regions B and C originate at different altitudes. The analysis of the temperature evolution reveals that the impact of microphysical phase changes are of minor importance compared to the dynamical processes.

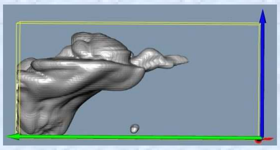


Fig. 4 : Simulated cloud after 41min of integration (LWC+IWC=0.01g/m³)

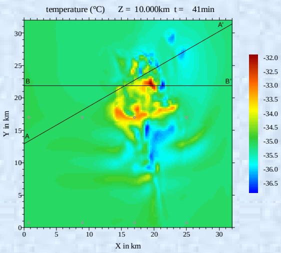



Fig. 5 : Simulated temperature field at 10 km

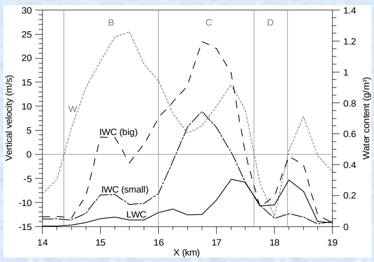



Fig. 6 : Simulated vertical velocity, IWC and LWC at 10km height along the AA' flight track (Fig. 5). IWC (big) = crystals > 80µm.

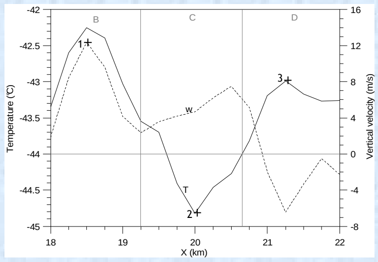



Fig. 7 : Simulated vertical velocity and temperature at 11km along the BB' flight track (Fig. 5)

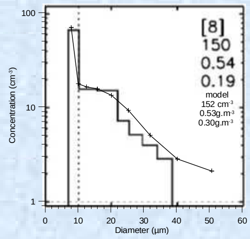



Fig. 8 : Simulated and observed particle spectra in region C for diameter <60µm

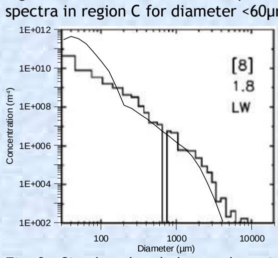



Fig. 9 : Simulated and observed particle spectra in region C for diameter >30µm

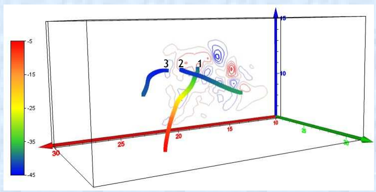


Fig. 10 : Calculated back trajectories for points 1, 2 and 3 (Fig. 7). The colors indicates temperature (°C).

## Conclusions :

✓ DESCAM 3D simulates a realistic cloud with features similar to observed at 10km for vertical winds, temperature and microphysical measurements for both the liquid and ice phase.

✓The study of back-trajectories shows clearly that region B and C of the core originates at different vertical levels. Region B is part of the main updraft core whereas region C corresponds to an air at high altitude that is transported by the horizontal winds over the updraft and is thus forced to rise. For both B and C air masses, the temperature evolution is determined by dynamical processes.

**References :**
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Flossmann, A. I., W. D. Hall, and H. R. Pruppacher, 1985 : A theoretical study of the wet removal of atmospheric pollutants. Part I : The redistribution of aerosol particles captured through nucleations and impaction scavenging by growing cloud drops. *J. Atmos. Sci.*, **42**, 582-606.
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