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Observations of ice particle growth regimes and size distributions in West-African mesoscale convective systems

Observations des modes de croissance des hydrométéores dans les systèmes convectifs méso-échelles africains

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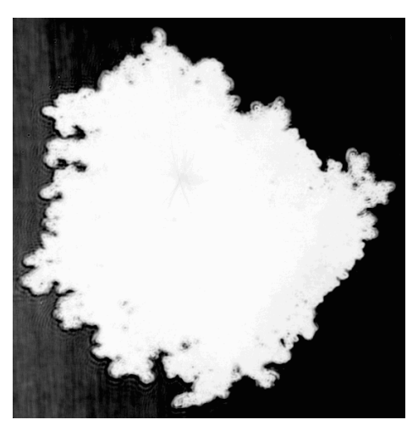
Ice particle growth regimes in MCS clouds

- Precipitation efficiency and microphysical processes are two major subjects in order to better understand & quantify the transformation of water vapor into precipitation, which is the major objective of the AMMA and Megha-Tropique experiments (Niger, August 2006,2010).

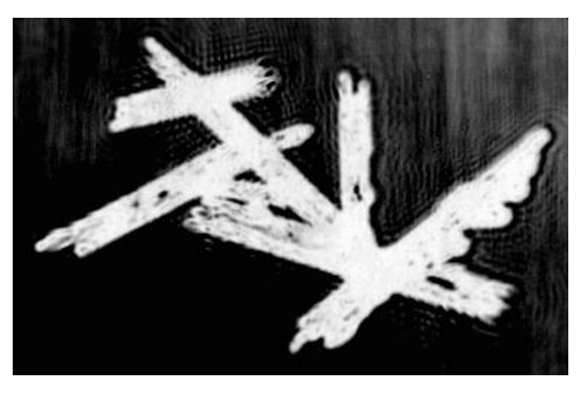
- Aircraft measurements of hydrometeor images allow to quantitatively measure their concentration and size distribution, and also to qualitatively observe the growth regime of hydrometeors.

- After the first step of cloud particle nucleation and subsequent vapor deposition, the hydrometeors have two possibilities to become precipitation particles:

a) **Riming** (graupel, hail)



b) **Aggregation** (snowflake)

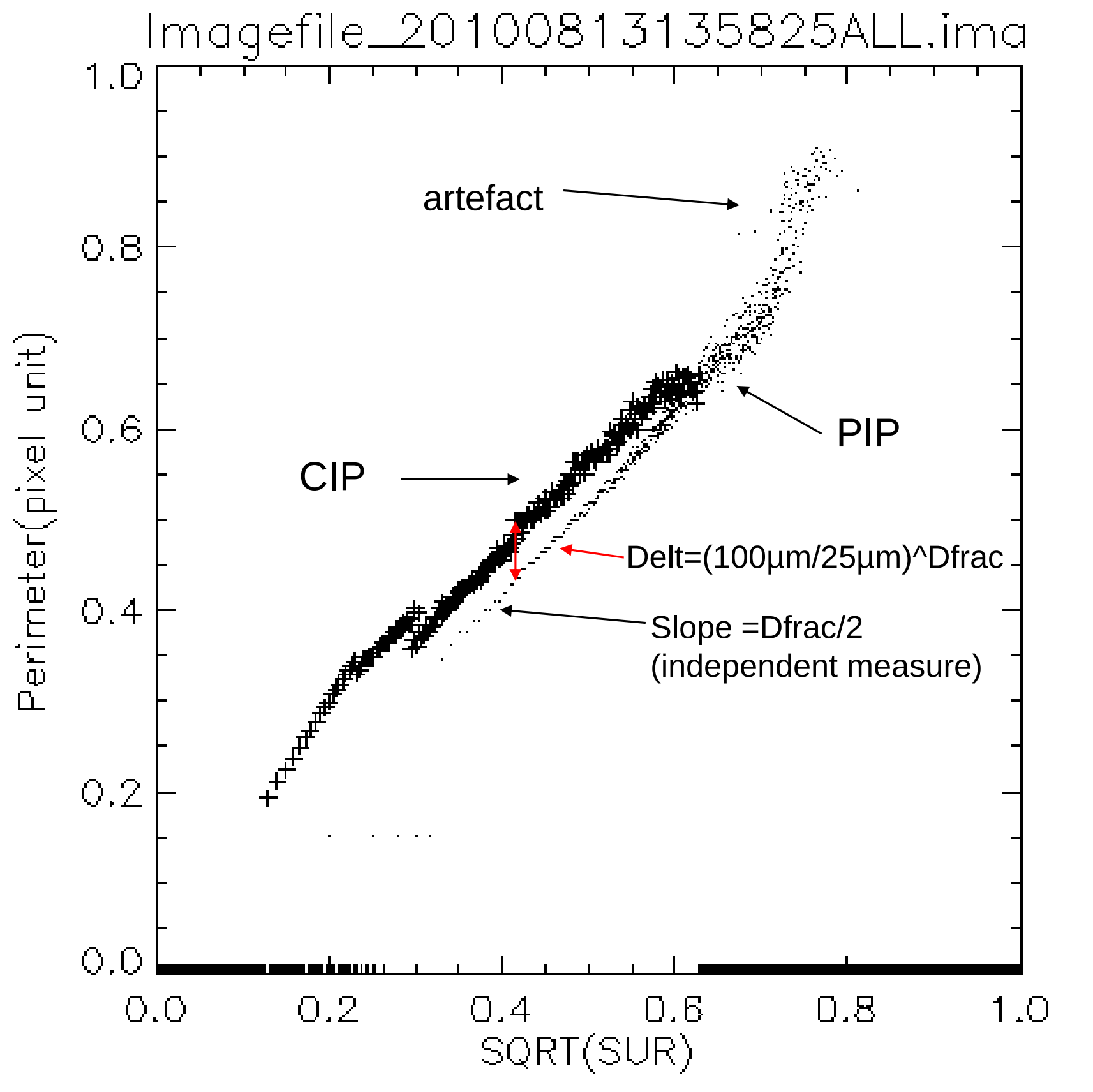


- Observations in African Monsoon MCS (AMMA & Megha-Tropiques):

Even if it exist a pure riming regime (graupel and hail) in the core of « convective » regions (not sampled), a pure aggregation regime (snowflakes) even in « stratiform » parts of MCS systems is hardly observed. Precipitating hydrometeors seem to be the result of a complex mixture of riming and aggregation processes, even far away (few hundred of kilometers) from convective regions.

Compared to mid latitude convective systems, tropical MCS evidence somewhat « mixed » growth scenarios.

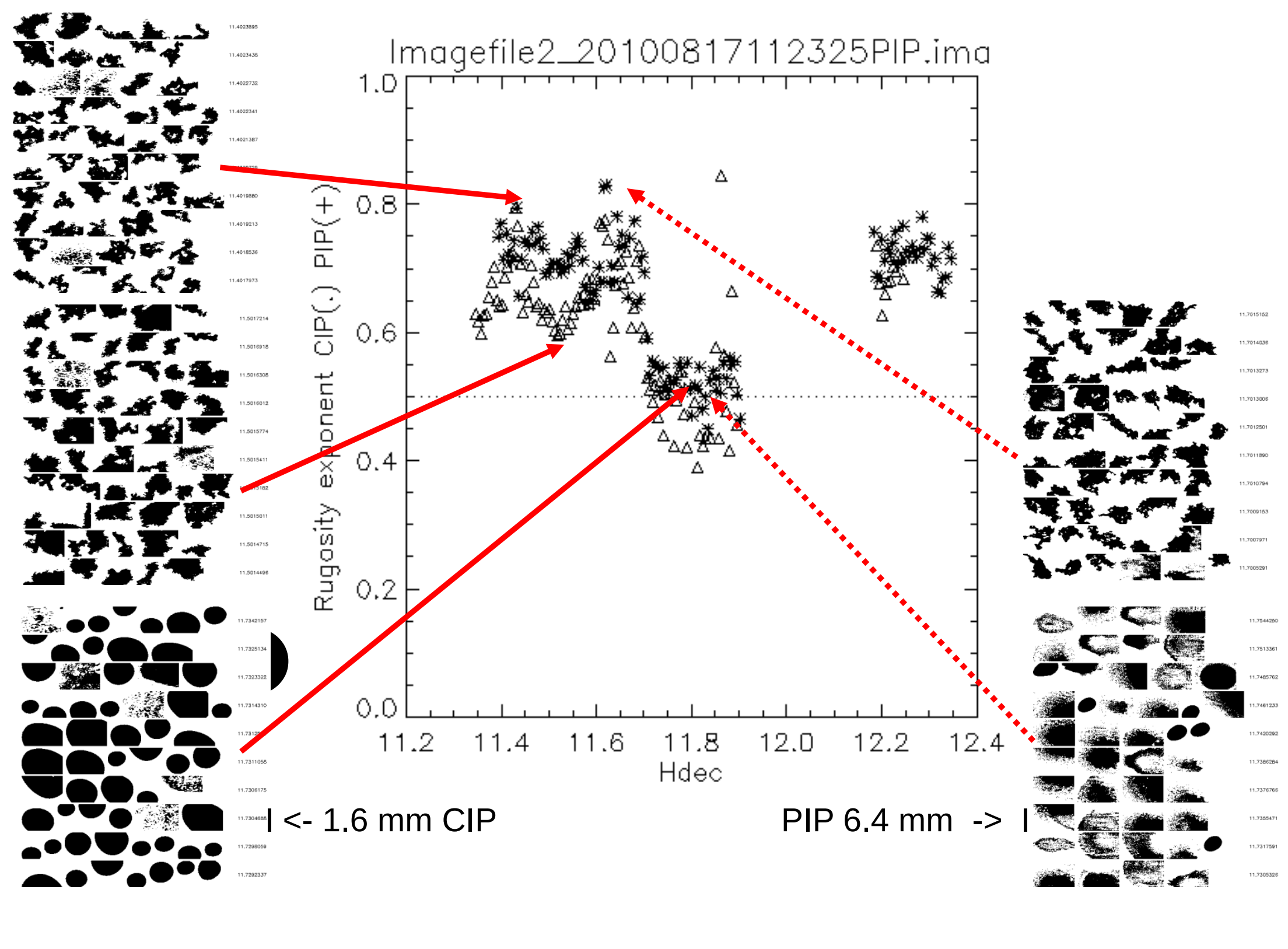
- The figures below try to quantify the growth regime through analysis of the roughness exponent of a large population of hydrometeors present at the same location within the MCS but composed of different particle sizes (Duroure et al., 1992):



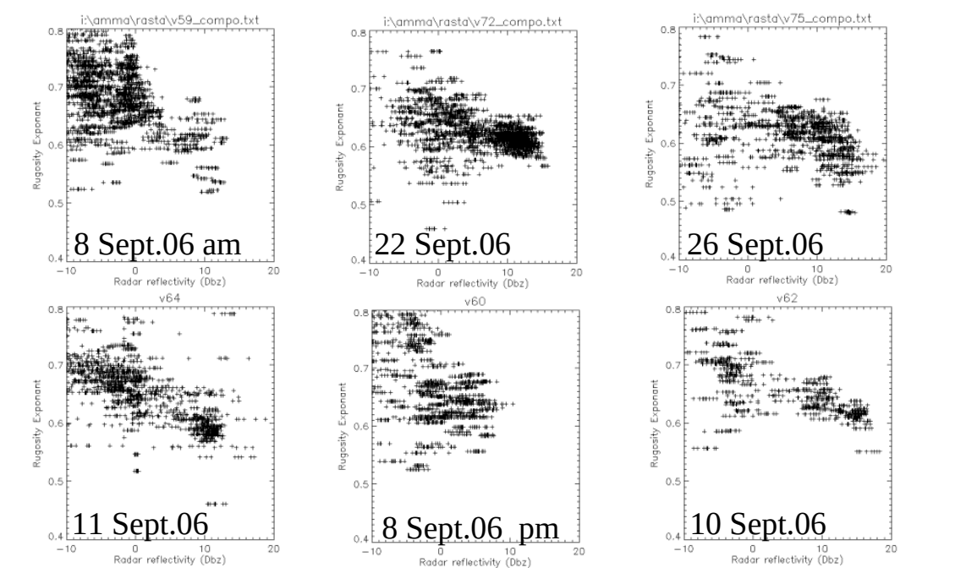
The rugosity exponent is estimated from a power law fitting of the bi-dimensional histogram of the surface and the perimeter from a local population of hydrometeors composed of different particle sizes.

Thus, the 2DS, CIP and PIP imaging probes allow us to estimate the rugosity exponent (= the fractal dimension of hydrometeor images) with different pixel sizes (10, 25 and 100 µm) for the three probes. Thus, the estimation of the rugosity exponent is made with at least two independent techniques.

First results during Megha-Tropiques show a good agreement for the rugosity exponent estimated from the three probes.



Six case studies for rugosity versus radar reflectivity distribution



For the large AMMA microphysic data base the riming attractor scheme seem to be observed.

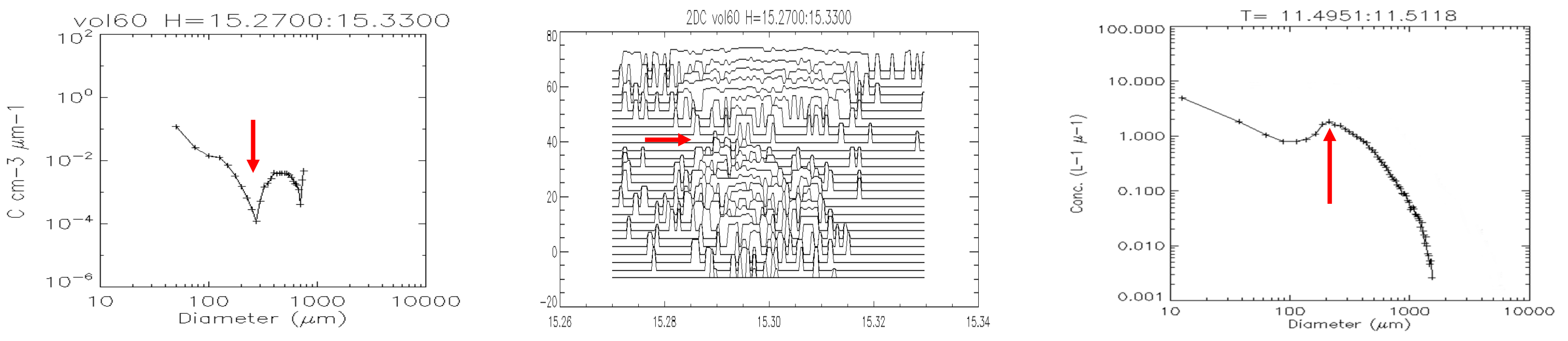
Variations in ice particle size distributions

- Quantification of particle size, surface and volume distributions from hydrometeor images allow to calculate radar reflectivities and precipitation rates (assuming reasonable functions for the diameter-mass relationship).

- For these studies the size distribution of particularly large particles is most important. In general, PIP (or 2DP) precipitation probes show exponentially decreasing particle size distributions (PSD), like the classical Marshal and Palmer PSD.

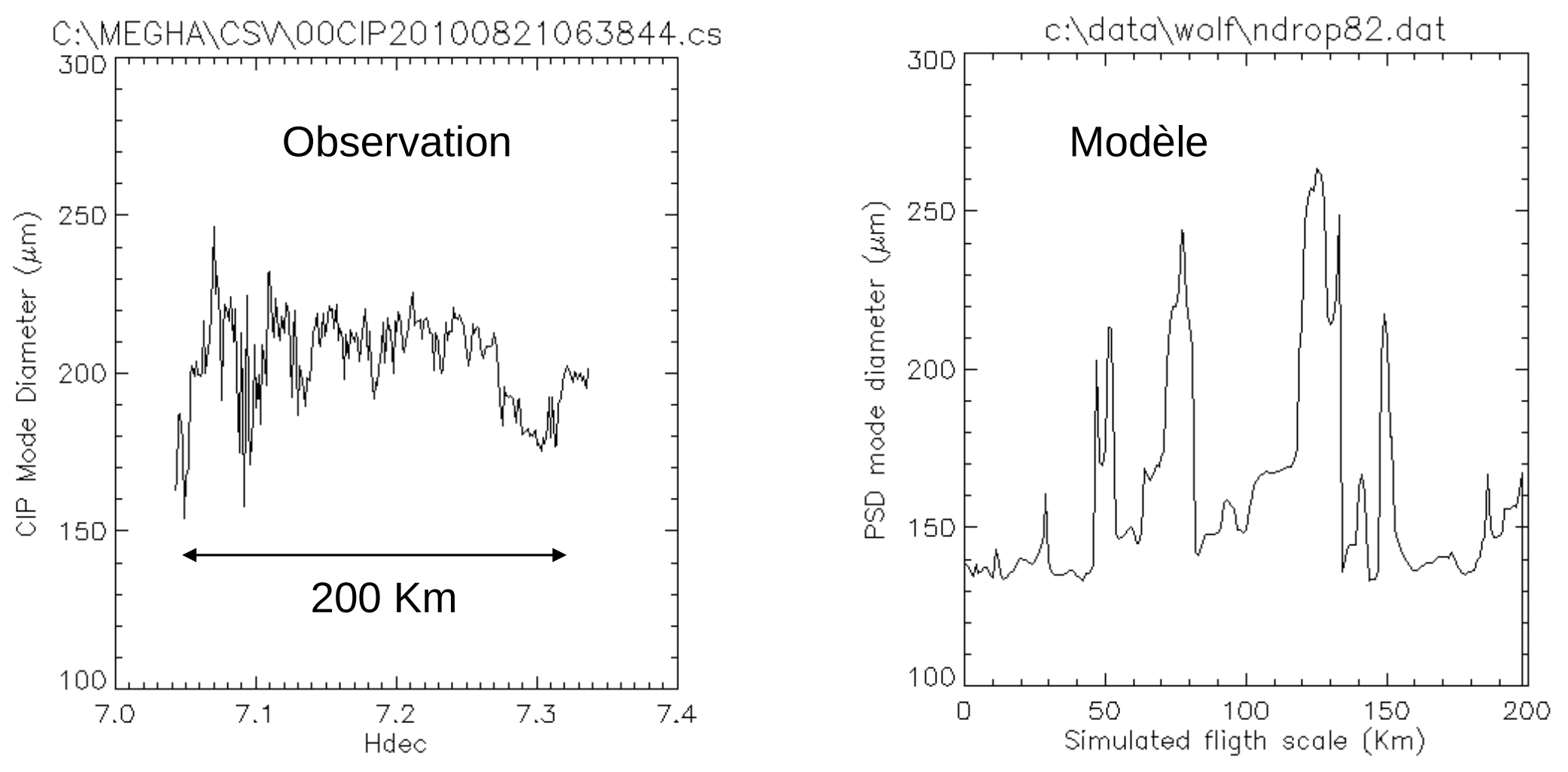
- When the agglomeration process, however, is dominant some fraction of the MCS yield sub-exponential PSD. In these cases the growth regime of the hydrometeors must be taken into account (including the correct mass to diameter function).

- The medium size particle diameters of the PSD (from 100µm to 500 µm), well sampled with CIP, 2D-S, and 2D-C probe, often show (more than 20%) a modal behaviour.



- In some cases this mode of the spectrum could be interpreted as a lagrangian mixing (cloud particles in the same place having had different histories) of different populations of hydrometeors (for example small pristine crystals and precipitating graupels).

- The figure below compare the statistics of observed bimodal PSD with the results of a microphysical detailled mesoscale model (DESCAM, LaMP):

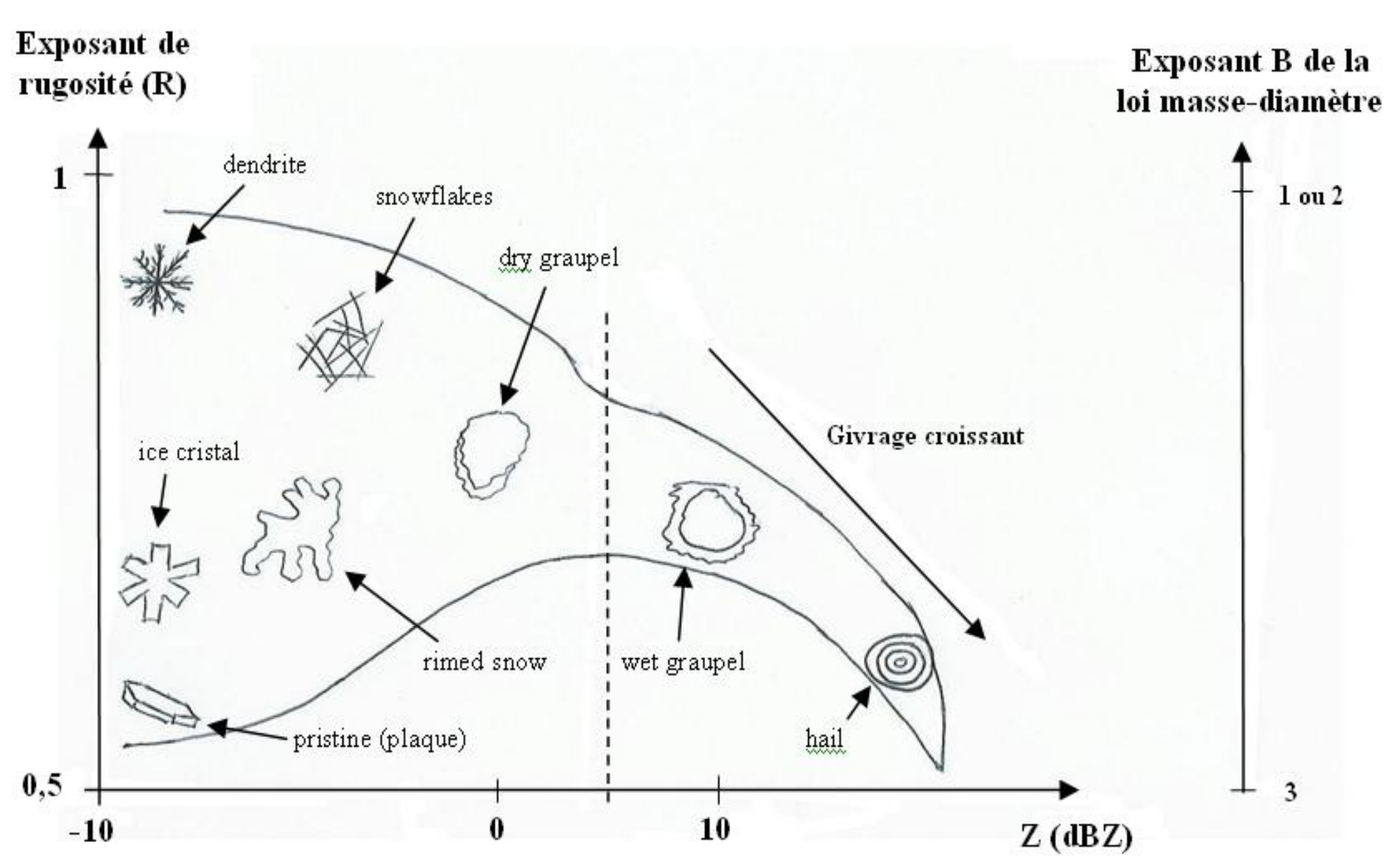


Observations and modelisation show small mesoscale (10 Km) coherent evolution of the transition diameter mode (pristine crystals -> precipitable hydrometeors)

More statistical studies are needed to compare observations and model for a more comprehensive study of the transition of growth regimes.

- The figure below shows a schematic combining growth regime, surface roughness, mass-diameter relationship, and reflectivity:

Evolution of the exponent of the mass-diameter relationship B(R) as a function of the radar (RASTA) reflectivity. B is estimated from the roughness exponent R of hydrometeor 2D images taking into account an empirical function based on geometrical arguments, since the 2D probes only record 2-dimensional projection of the particles.



This schematic representation of the rugosity exponent and the related growth regime should be useful to better estimate remote sensing data of precipitation (radar, micro-wave radiometers).

- For a large « precipitation signal » exists a « riming attractor » with a simple mass to diameter law
- For moderate « precipitation signal », we need some other remote measure to detect the main growth regime.

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