In-situ statistical validation of airborne reflectivity measurements during AMMA2006 and Megha-Tropiques 2010 experiments: Hydrometeor growth processes and PSD variability.

Dupuy R.(1), Duroure C.(1), Fontaine E.(1), Gourbeyre C.(1), Wobrock W.(1), Schwarzenboeck A.(1), Bouniol D.(2) and Protat A.(3)

(1)LaMP, CNRS/UBP, France (r.dupuy@opgc.univ-bpclermont.fr), (2) CNRM, Toulouse, France, (3) LATMOS, Paris, France

Email: R.Dupuy@opgc.univ-bpclermont.fr

INTRODUCTION

During the AMMA 2006 experiment, collocated remote sensing and in-situ estimation of radar reflectivities of MCS systems have been performed by the French Falcon research aircraft using airborne radar (RASTA) and in-situ measurements of particle size distributions (PSD) obtained with hydrometeors imaging instrumentation (2DC, 2DP and 1DP Knollenberg probes). In addition, the Megha-Tropiques experiment in August 2010, located in the same region, allowed us to extend the observed MCS cases using modern imaging probes (2DS, CIP and PIP) as compared to AMMA.

In-situ estimation of reflectivity is very sensible to the assumed diameter to mass function which resumes the main mode of hydrometeor growth. This study will show new results for a better estimation of hydrometeor mass in MCS.

CASE STUDY DESCRITPION

These two figures represent an example of flight pattern (a) and MCS (b) sampled during the Megha-Tropiques validation experiment in Niger on August 18th 2010.

The sampling strategy was usually to approach the convective front of the MCS in a swiping mode for an horizontal coverage followed by a vertical sampling along the convective line.

The thick red line shows the zone most sampled vertically for this flight.

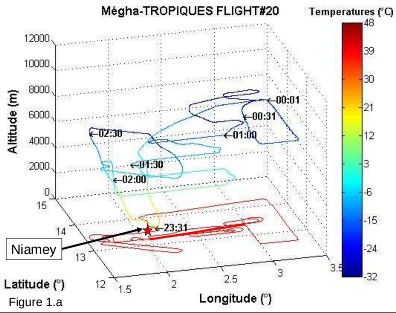
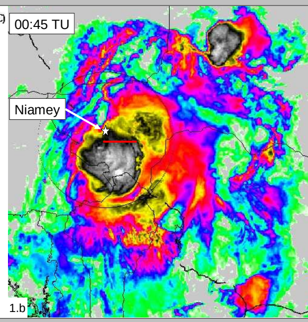


Figure 1.a



1.b

RADAR REFLECTIVITY

Radar reflectivity has been calculated following the equation below for a wavelength of 94 GHz with |Ki|² and |Kw|² set to respectively 0.176 and 0.75 (corresponding temperature of -10°C), f(D) represent the impact of Mie theory over Rayleigh theory for hydrometeors larger than 1 mm (Boudala et al., 2006).

$$Z_e = \frac{|K_i|^2}{|K_w|^2}\left(\frac{6}{\pi\rho_{ice}}\right)^2 \sum N(D)\, m(D)^2 f(D)$$

The result is shown on figure 2 for the Flight #20 with a mass-diameter relationship for agglomerates particles ($m=0.037D^{1.9}$). It clearly shows that mass (or hydrometeor density) estimation is getting weaker with altitude decreasing (01:15 to 02:00 am).

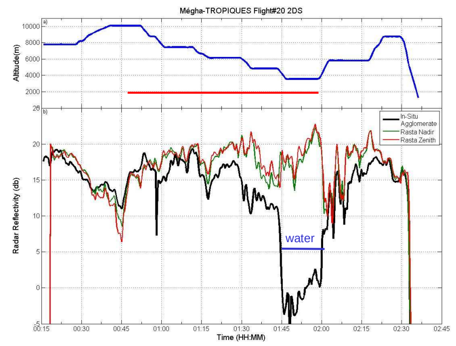


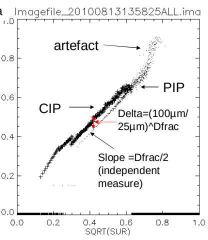
Figure 2: Variation with time of altitude of flight (a) and in situ reflectivity estimation compared with the closest Radar (RASTA) measurements (b) for MT flight #20. The red line represents the sampled zone as on figure 1.

DENSITY VERSUS RUGOSITY EXPONENT

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. As, the 2DS, CIP and PIP imaging probes allow us to estimate the rugosity exponent (i.e. the fractal dimension of hydrometeor images) with different pixel sizes (10, 25 and 100 µm), 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 two probes (Figure 3.a).

In order to estimate the particle density, we recurrently compared radar reflectivities measured with RASTA to those estimated using constant densities over the size spectrum (20s average). This first approach has been done for **4 flights**. The result shows the relationship between density and the rugosity exponent (figure 3.b) which translate the fact that the lesser rough the particle is the denser it is due to rimming.

3.a



3.b

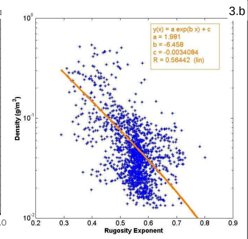


Figure 3: 2D histogram of perimeter versus square root of surface (a) which slope gives the rugosity exponent (Dfrac) and its variation with the hydrometeors density estimated by comparing in-situ and Radar reflectivities (b) with best fit found.

PARTICLE SIZE DISTRIBUTION (PSD)

Statistical studies of the PSD shape (regardless of the exact concentration measured) are made in view of studying possible renormalization of the PSD.

In order to describe the PSD shape, we define four particle size ranges assuming that quite different hydrometeor growth processes occur :

- «**pristine**» range (80 to 250 µm) for the vapor deposition.
- «**drizzle**» range (250 to 1500 µm) for mainly riming and aggregation processes from a small number of individual crystal
- «**precipitation**» range (1500 to 5000 µm) for stable riming and aggregation processes the size range in which hydrometeors are made with large number of single crystal or supercooled droplets.

For the three size ranges, we choose to fit the PSD with power law decreasing functions over the corresponding size range. Observations and simple model has shown that this kind of fitting is correct even at small scale (few hundred meters of in-situ measurements).

The **large size tail** of the PSD (D > 5000 µm) could not be fitted with any power law decrease neither for undersampling nor for physical limit of hydrometeor sizes. For this range, we use a classical exponential decrease (Marshall-Palmer like function) to quantify the PSD shape.

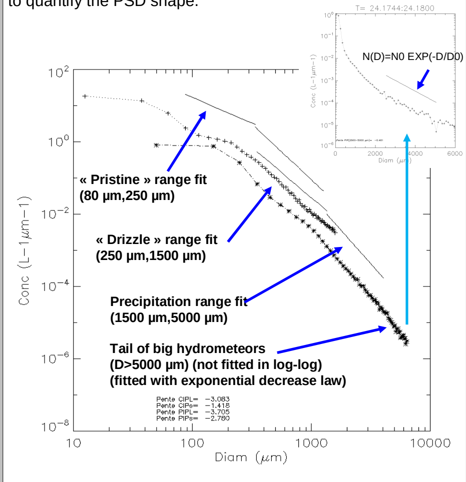


Figure 4: Example of multi-probe particle size distribution measurement fitted with three slopes and presenting the four ranges explained above. The inserted figure shows the same PSD with linearly spaced diameters and the exponential function used for fitting the last range of particles.

PSD SLOPE VARIABILITY

The figure 5 shows an example of anticorrelation observed between the power law slope of the "Drizzle" part of the PSD (250-1500µm) and the (1500-5000µm) for the flight#20 between 00:26 and 01:09 am. Each points correspond to a 20 seconds sampling.

This kind of observation indicates complex evolution of the PSD shape in some part of the MCS.

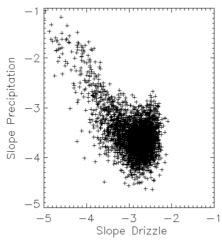


Figure 5

CONCLUSION

On the one hand, we have shown that the rugosity exponent can be a simple parameter to estimate the density of hydrometeors in the MCS sampled during Megha-Tropiques experiment. On the other hand, we have also shown that the PSD sampled clearly show different growth processes prevailing at different size ranges. Thus, using a constant density for particles sizes is not only inaccurate, but we also need to consider using different mass/diameter relationship for the four size ranges established in this study.

In consequence, our future work will be to precise the relationship between the density and the rugosity exponent using different relationship for the different size range established.

Acknowledgements : The French Falcon Operator SAFIRE, especially the pilots who allow measurements in severe MCS. We wish to thank CNES for the full financial support of the Méghe-Tropiques measurement campaign .

Laboratoire de Météorologie Physique, *http://wwwobs.univ-bpclermont.fr/atmos*

CNRS INSU Observer & comprendre
Université Blaise Pascal
OPGC Observatoire de Physique du Globe de Clermont-Ferrand