Comparisons between CloudSat products and in situ observations Part I : cirrus cloud characterization

J-F Gayet(1), G. Mioche(1), A. Minikin(2), A. Schwarzenboeck(1), J. Pelon(3) and A. Protat(3)

[1] LaMP CNRS / Université Blaise Pascal, Aubière, France, [2] DLR, Oberpfaffenhofen, Germany, [3] LATMOS CNRS / Université Pierre et Marie Curie, Paris, France

In order to validate new space remote sensing observations (CALIOP on CALIPSO and CPR on CloudSat on board the A-Train) validation plans took place including in situ measurements co-located with satellite along-tracks. During the CIRCLE-2 campaign, carried out in Western Europe in May 2007, several mid-latitude cirrus clouds were sampled at temperatures ranged from -30°C and -60°C. The airborne microphysical instruments including the Polar Nephelometer probe, the high resolution Cloud Particle Imager (CPI) and standard PMS 2D-C and FSSP-100 instruments were mounted on board the DLR Falcon aircraft. This poster illustrates results of quasi co-located observations carried out in an outflow cirrus on 26 May over Germany. The retrieved microphysical cloud parameters (*IWC, R_{eff}* and particle concentration) from CloudSat algorithms are then discussed with in situ observations. New parameterizations of cloud parameter relationships versus reflectivity factor are proposed from the dataset obtained in cirrus clouds.

Derivation of cloud parameters from CPI and PMS 2D-C data :

(Z_{eq} : Equivalent reflectivity factor, *IWC* : ice water content, σ : extinction coef., D_{eff} : effective diameter)

$$Z_{eq}(mm^6 m^{-3}) = 10^{18} \times \frac{|K_i|^2}{|K_w|^2} \times N(D) \times f(D) \times \left(\frac{\rho_{eq}}{\rho_i}\right)^2 \times D^6$$

$$Z_{eq}(dBZ) = 10 \times \log_{10} Z(mm^6 m^{-3})$$

$|K_i|^2 |K_w|^2$: Dielectric constants of ice (0.176) and water (0.75) at 94 GHz

$\rho_{eq}(j,D)$: equivalent density of particles of diameter *D* and type *j*

ρ_i : Density of pure ice

$n_j(D)$: Size distribution of particles of type J

$f(D)$: Correction factor of Mie effects

$$IWC = \frac{0.135 \sum_i X_i^{0.793}}{V}$$ (Baker and Lawson, 2006)

with $X = \frac{A \times W \times 2 \times (L+W)}{P}$

A, W, L, P : surface, width, length and perimeter of the particle image,
V : sampling volume

$$\sigma = 2 \times \frac{\sum_i A_i}{V} \qquad D_{eff} = A \times \frac{IWC}{\sigma}$$

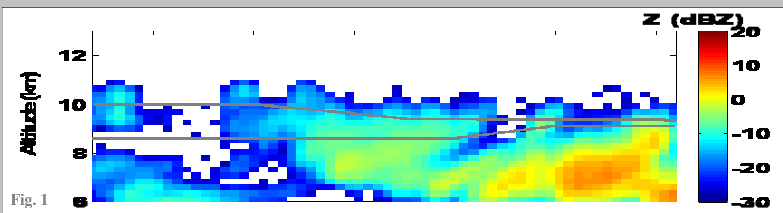

Fig. 1

Fig. 1 displays the vertical profile of CloudSat reflectivity (*Z*) and the Falcon flight altitudes (T ~ -40°C). Comparisons along the flight trajectory of the CloudSat (CPR) equivalent radar reflectivity factor (*Z*) and the reflectivity factor deduced from in situ measurements (CPI) are reported on Fig. 2. In situ measurements are averaged over the CPR horizontal resolution (~1.7 km). The time separation between CPR and CPI is within ± 8 mn. The scatter plot of CloudSat and in situ reflectivities fit well (Fig. 3) with a slope parameter of 1.06 and a correlation coefficient of 0.62.

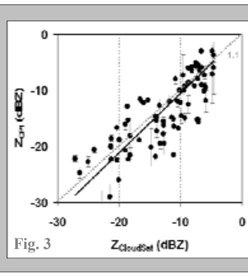

Fig. 3

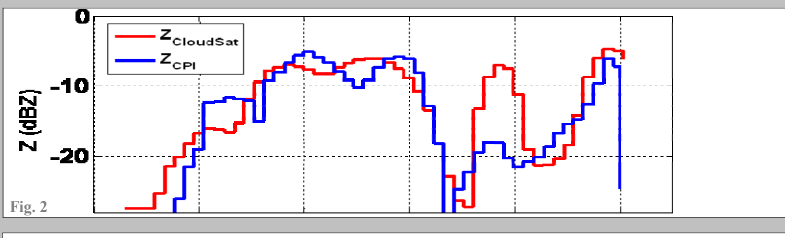

Fig. 2

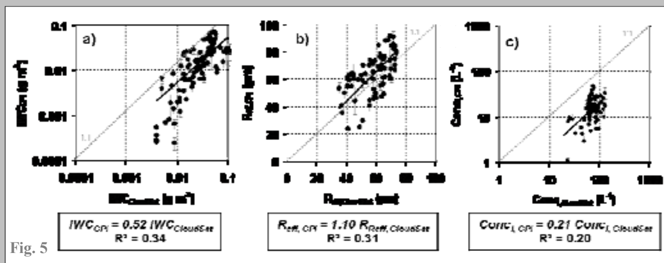

Fig. 5

Fig. 4 displays the vertical profiles of the retrieved microphysical cloud parameters from CloudSat algorithms in terms of Ice water content (*IWC*), effective radius (R_{eff}) and particle concentration (*Conc*) with the Falcon flight altitudes. The scatter plot of remote and in situ values are reported on Fig. 5 with slope parameters and correlation coefficients. Comparison results show relationships with a poor correlation ($R^2 < 0.34$), a systematic overestimation of remote IWC and Conc (Fig. 5.a & 5.c) but with a better correspondence for R_{eff} (Fig. 5.b). A similar trend is found for all cirrus situations during CIRCLE-2.

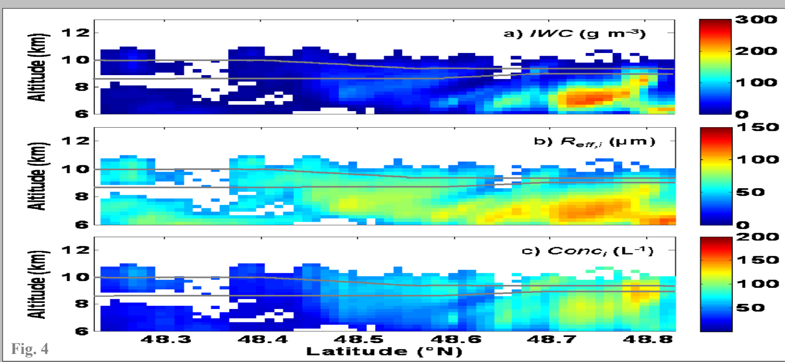

Fig. 4

The large in situ cloud data set obtained during CIRCLE-2 campaign in outflow and frontal cirrus with temperatures ranged from -30°C to -60°C allow to propose parameterized relationships of cloud parameters versus the reflectivity factor (*Z*). Fig. 6 displays the scatter plots for *IWC*, effective diameter (D_{eff}), extinction (σ) and particle concentration. The data points are coloured according to the temperature.

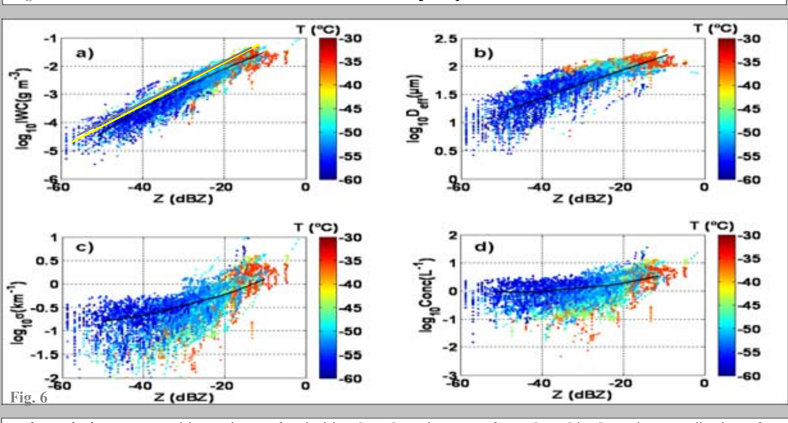

Fig. 6

Cloud parameter relationships expressed in terms of *Z* and *T* give the best correlations (see Table). *IWC-Z* and *Deff-Z* relationships are found with a rather good correlation coefficients (>0.75) whereas σ and *Conc* are much more scattered (see Figs. 6.c & d). On Fig. 6 are superimposed the corresponding parameterized relation-ships (black curves) with previous results (yellow & grey curves) in mid-latitude cirrus clouds (*IWC-Z*, Fig. 6.a) from Liu and Illingworth (JAM, 2000) and Protat et al. (JAMC, 2007) respectively.

Parameters	Relationships	R²	RMS
IWC	$\log_{10} IWC = -0.00113\ Z_e T + 0.0171\ Ze - 0.0396\ T - 2.67$	0.87	0.29
D_{eff}	$\log_{10} D_{eff} = -0.000686\ Z_e T + 0.00999\ Ze - 0.0165\ T + 1.66$	0.75	0.16
σ	$\log_{10} \sigma = 0.000824\ Z_e T + 0.0748\ Ze - 0.00000131\ T + 0.47$	0.53	0.32
Conc	$\log_{10} Conc = 0.00108\ Z_e T + 0.0849\ Ze - 0.00713\ T + 0.585$	0.43	0.37

Conclusions. Well coordinated flights with satellite tracks during CIRCLE-2 allow to obtain a significant data set in cirrus clouds for comparison issues for CloudSat (and CALIPSO, see Mioche et al., JGR, 2010) products. CPR and in situ reflectivities are in a close agreement with a slope parameter of 1.06 ± 0.10 and $R^2 > 0.60$ which confirms the validation of the CPR retrieval algorithm for mid-latitude cirrus clouds. On the contrary, the retrieved cloud parameters are not well correlated ($R^2 < 0.34$) mainly due to ambiguous relationships versus Z and large uncertainties on in situ measurements.

Acknowledgements. This work was funded by CNES and a grant from CNRS/INSU. The contribution of DLR as well as large part of Falcon flight hours was funded in the framework of the DLR PAZI-2 project. Thanks are due to the members of DLR and SAFIRE who organized the experiment management and aircraft operations. We acknowledge NASA Langley Research Atmospheric Science Data Center, as well as ICARE Center in Lille for the CALIPSO data. We acknowledge C. Gourbeyre, and J-F Fournol (LaMP), B. Weinzierl and H. Rüba (DLR) for their active participation to the experiment.

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

CNRS INSU Institut national des sciences de l'Univers — Université Blaise Pascal — OPGC