Comparison between CloudSat and in-situ radar snowfall rates in East Antarctica

Florentin Lemonnier[1], Jean-Baptiste Madeleine[1], Claudio Duran-Alarcon[2], Alexis Berne[3], Chantal Claud[1], Cyril Palerme[4], Norman Wood[5], Tristan L'Ecuyer[5], Niels Souverijns[6], Nicole Van Lipzig[6], and Christophe Genthon[2].

[1] Laboratoire de Météorologie Dynamique, France | [2] Université Grenoble Alpes, France | [3] École Polytechnique Fédérale de Lausanne, Switzerland
[4] Norwegian Meteorological Institute, Norway | [5] University of Wisconsin-Madison, USA | [6] University of Leuven, Belgium

Motivations.

In the context of global warming, predicting the evolution of the Antarctic ice sheet is a major challenge. Snowfall is the principal gain of the ice sheet mass balance and some field campaigns with in-situ observations were realized to estimate local snow accumulations. However ground-based measurements are sparse and difficult in Antarctica and the size of this continent does not allow to cover and study the whole distribution, frequency and rate of precipitation.

The A-Train satellite CloudSat and its cloud-profiling radar (CPR) provided the first real opportunity to estimate precipitation at polar continental scale but currently the uncertainties for snowfall rate range from about 50% up to 175% *(Wood, 2011)*.

→ With the aim of assessing CloudSat radar uncertainties over Antarctica, **CloudSat tracks passing over Dumont d'Urville and Princess Elizabeth stations were compared with MRR on a total of 4 recorded snowfall events** *(fig. 1&2)*.

Methods.

The CloudSat CPR is a nadir-looking radar, it measures cloud particles signal backscattered by hydro-meteors. Radar reflectivity profiles are divided into 150 vertical bins at a resolution of 240m. 2C-SNOW-PROFILE product *(Wood, 2011)* retrieves profiles of liquid-equivalent snowfall rates. The product is based on assumption of snow particle size distribution, micro-physical and scattering properties which induce many uncertainties in the calculation of the relationship between radar reflectivity and snowfall rate.

The Micro Rain Radar (MRR) is a vertically profiling radar with a resolution of 100 m per bin ranging from 300 to 3000m. Two MRR are based in Antarctica. At Dumont d'Urville station, the MRR confidence interval is 95% *(Grazioli et al., 2017)* and at Princess Elizabeth, it is 40% *(Souverijn et al., 2017)*.

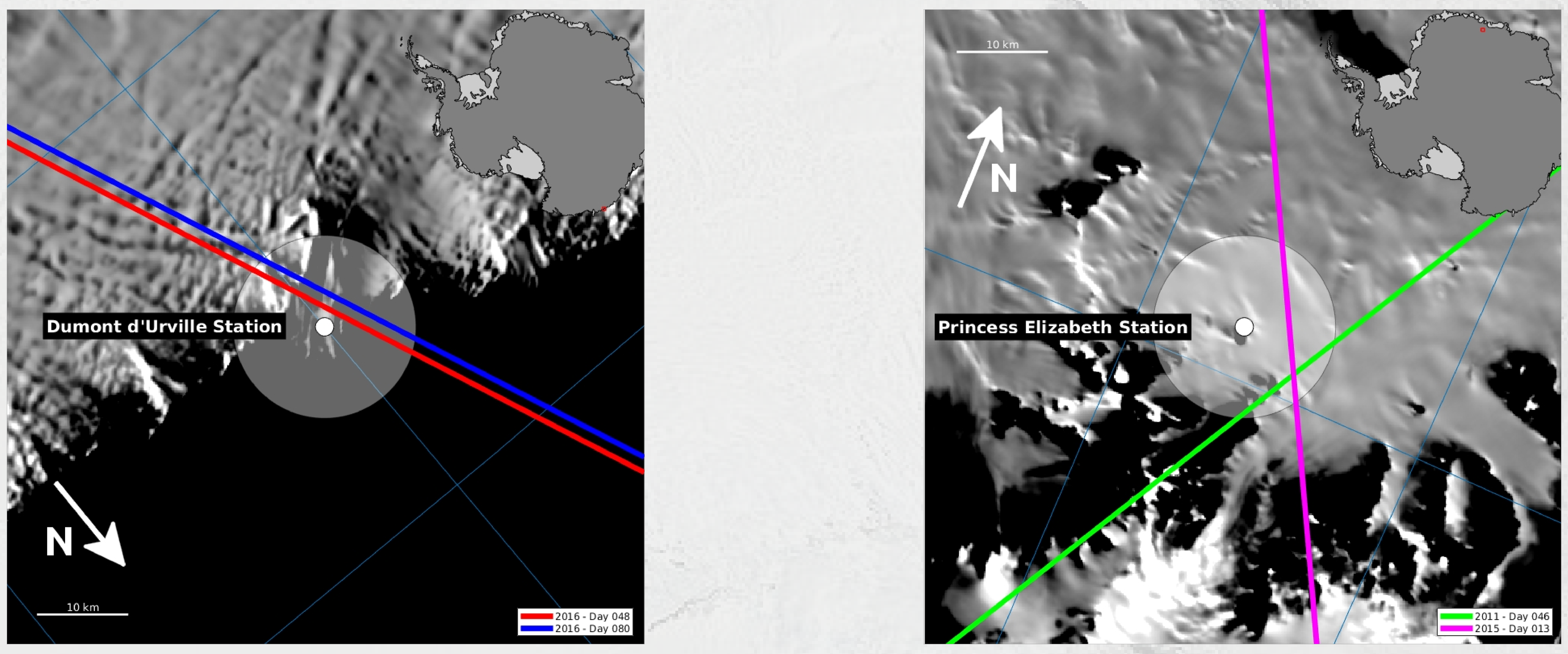

Fig. 1 – *Left :* CloudSat radar tracks passing over the French Dumont d'Urville station for the 48th and the 80th days of year 2016. *Right :* CloudSat radar tracks passing over the Belgian Princess Elizabeth station for the 46th day of year 2011 and the 13th day of year 2015.
We only considered the measured profiles crossing in a 10 km radius represented by a white disc plane around the stations.

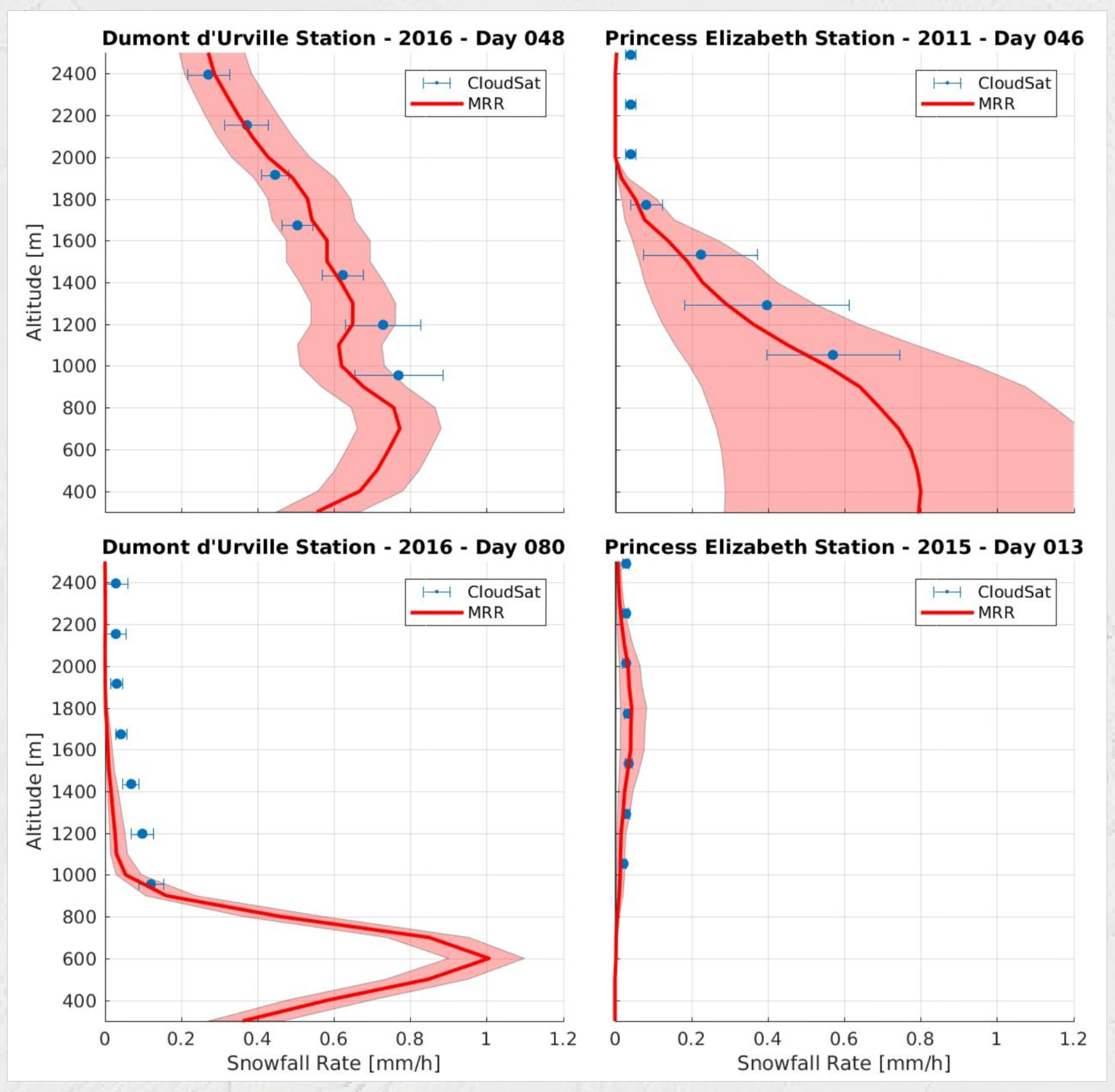

Fig. 2 – Comparison between CloudSat in **blue** dots with standard deviation bars and MRR in **red** solid line with swath representing 95% confidence interval at Dumont d'Urville (left) and 40% confidence interval at Princess Elizabeth (right).

Results.

By assuming that CloudSat and MRR datasets are following Gaussian distribution laws, a correlation coefficient is calculated in order to establish the degree of similarities of both observations *(fig. 2)*. By using the covariance of both data records, we found a **correlation coefficient of 99%** *(fig. 3)*, which confirms the good agreement between data sets.

For each CloudSat vertical bin, we calculated the distance of satellite measurement to the corresponding interpolated MRR observation. We averaged these values by weighting them with the MRR confidence intervals and we found **a range of CloudSat uncertainties of -21% / +25%**.

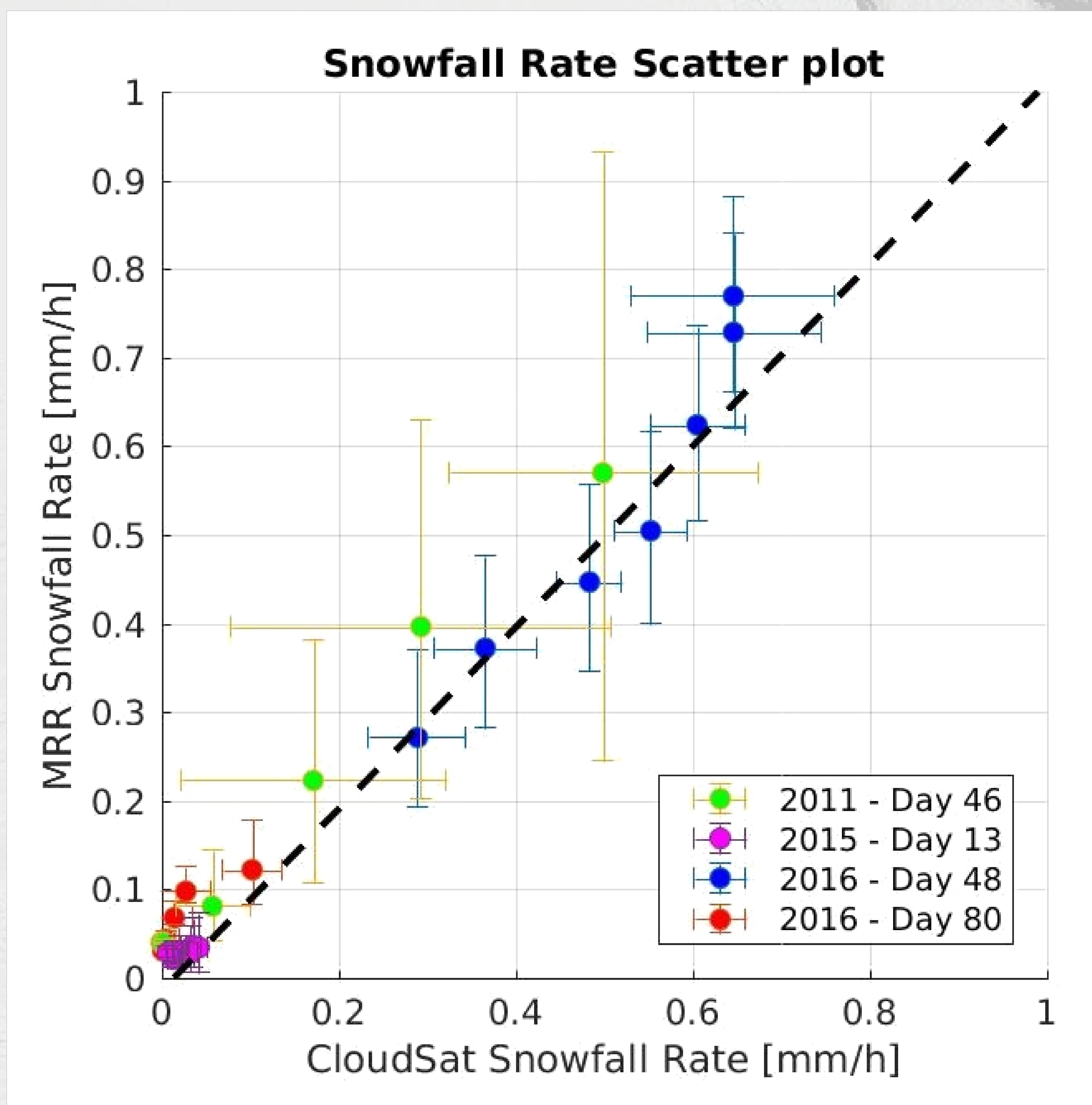

Fig. 3 – Scatter plot of the MRR and CloudSat snowfall rates in mm/h with correlation between both datasets showed the linear regression in dashed line. The errorbars are computed using the confidence intervals for the MRR and standard deviations over the duration of the averages at each vertical bin for CloudSat.

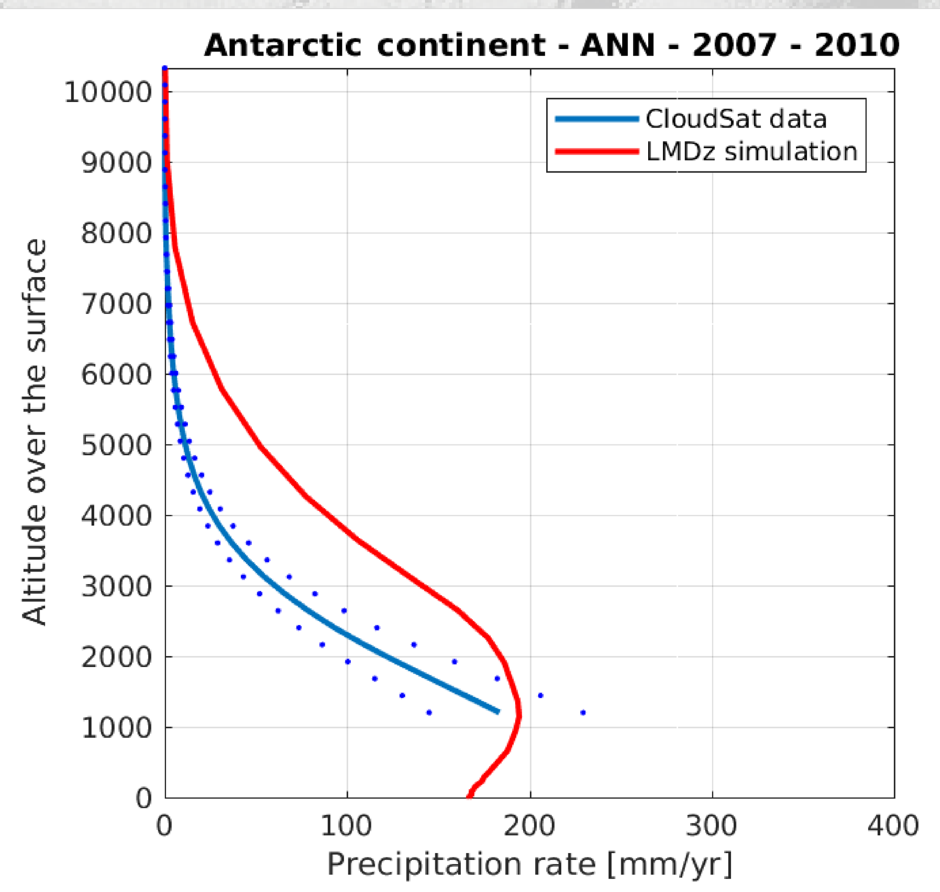

Fig. 4 – Comparison of East-Antarctica averaged precipitation profiles between CloudSat observations in **blue** solid line with dots representing the new CloudSat uncertainties and LMDz/IPSL climate model in **red** solid line.
Simulation was performed over the 2007-2010 period of CloudSat full activity with a 96x71 grid and 79 vertical levels.

Conclusion and outlooks.

The comparisons for the four cases of MRR recorded precipitation events that coincide with CloudSat observations shows a near-perfect correlation.

Based on these 4 precipitation events and from our correlation and statistic studies based on the quantification of the CloudSat deviation to the MRR values, we reassessed the CloudSat precipitation uncertainties ranging to **-21% / +25%**.

This reassessment of the CloudSat uncertainties over Antarctica gives confidence in the retrieval and justify further analysis of this dataset in this region of the globe, where snowfall is critical and poorly known :

- A 3D comparison of the CloudSat dataset with climate models based on *Palerme et al., 2014,* is underway *(fig. 4)* and will improve current knowledge of the microphysical processes controlling snow precipitation over the entire continent. It also will enhance the numerical prediction of global climate with greater representation of polar weather processes.
- This approach can also be applied to the instrumental validation of the EarthCARE onboard radar. Its measurements should be even more instructive and will improve our understanding of clouds and snowfall in the polar regions, where field observations are so hard to perform.

References & Contacts.

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E-mail : florentin.lemonnier@lmd.jussieu.fr / Website : http://flo-lemonnier.fr

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