Partitioning of LWP in its cloud and rain components by ADMIRARI at different precipitation regimes

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NASA PMM Science Team Meeting
Denver, Nov. 7-11, 2011

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OUTLINE

- ADMIRARI microwave radiometer.
- Participation during GPM/GV field campaigns
  - Pre-CHUVA, Brazil
  - LPVEx, Finland
  - MC3E, USA
- Retrieval of Cloud/Rain LWP
- Retrieval sensitivity study
- Upcoming GCPEx campaign
- Summary

ADvanced MIcrowave RAdiometer for Rain Identification

http://www2.meteo.uni-bonn.de/admirari

AIM: simultaneously retrieve CLOUD, RAIN LWP and IWV

- Three-freq. 10.7, 21.0 and 36.5 Ghz
- Dual-pol, V & H
- RMS 1sec. : 0.5 K
- Dicke-switch, sky-tip calibration
- Auxiliary Active instrumentation: Micro rain radar 24.1 Ghz and cloud Lidar 0.92 μm
- Measurement collected: Brightness temperature (TB), polarization difference (PD=TB_V-TB_H), MRR reflectivity and cloud base altitude
- Integration time: 1 sec for radiometer, 10 sec for MRR and 30 sec for cloud Lidar
- Beamwidth: 6° for radiometer, 1.5° for MRR and 2 mrad for cloud Lidar.

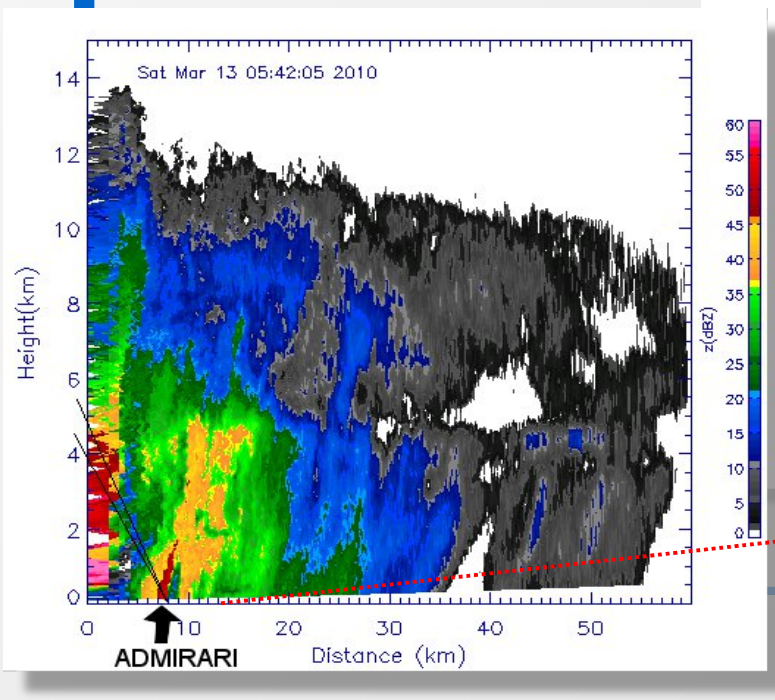
Participation during GPM/GV field campaigns

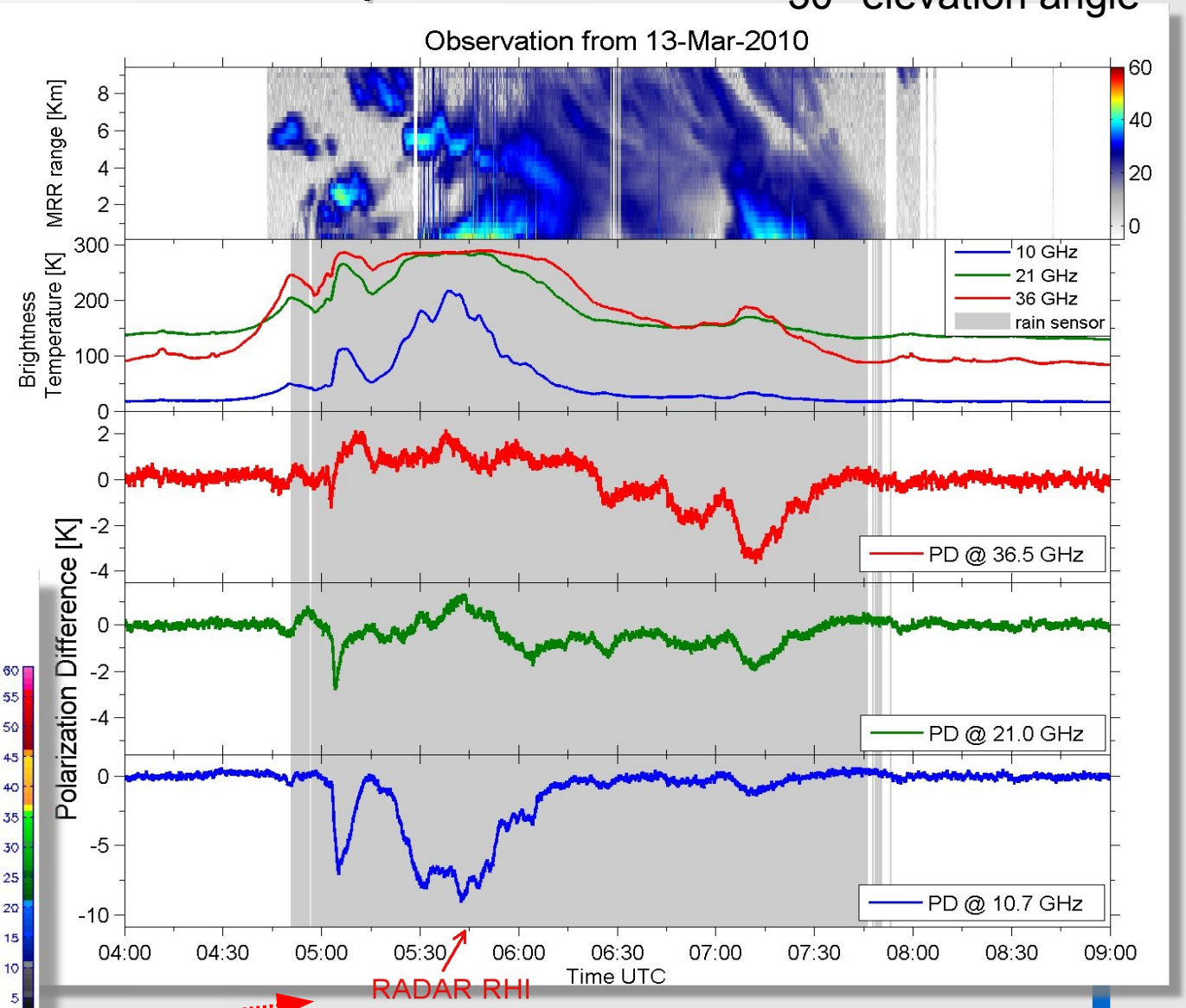
1) TROPICS:
In March 2010, ADMIRARI participated in the pre-CHUVA campaign in Alcantara, Brazil (Lat: -2° 23' , Long.: -44° 22')

Pre-CHUVA measurement example

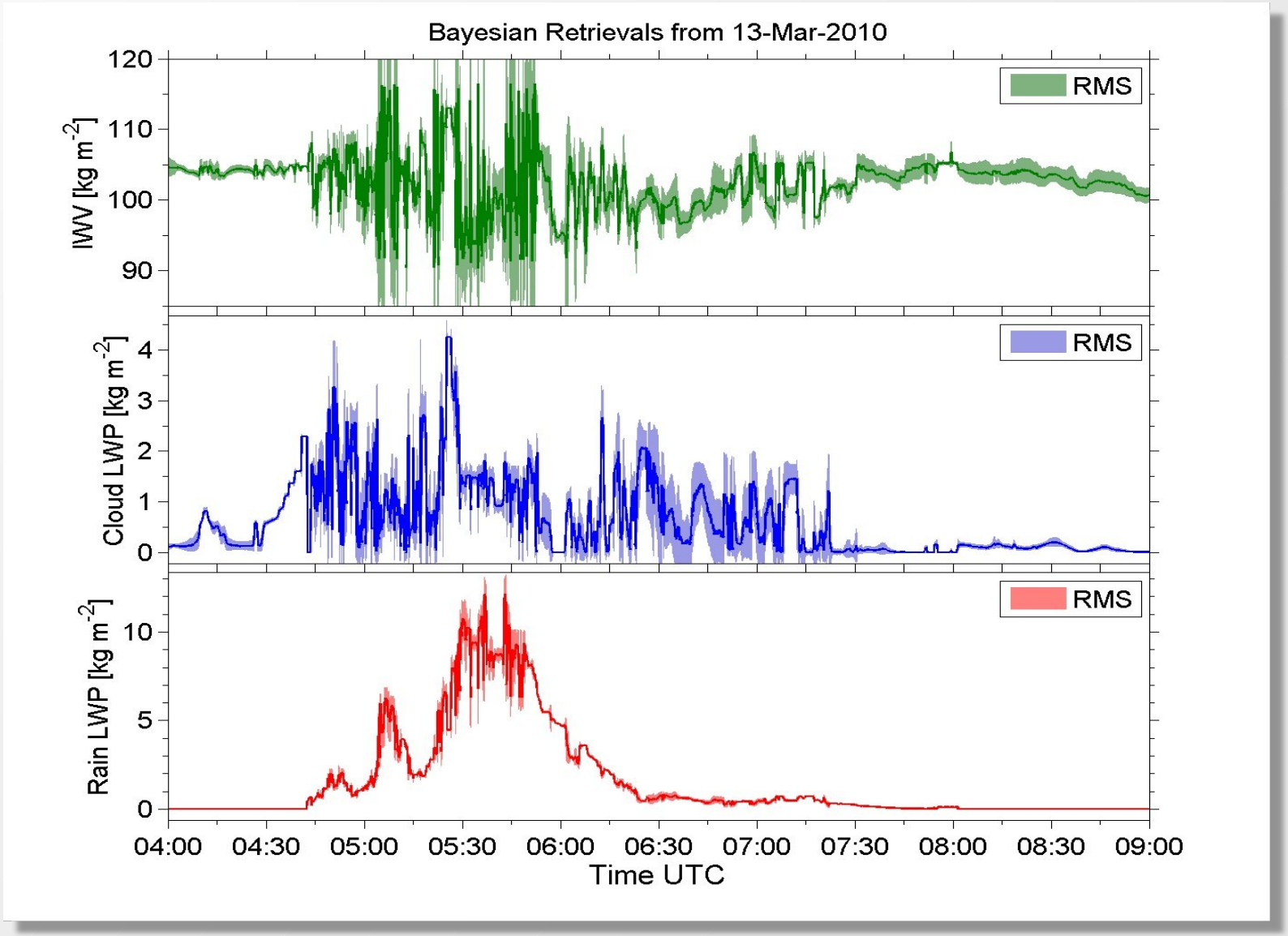
30° elevation angle

The X-Band dual-pol Radar has performed a RHI over ADMIRARI every 6 min.



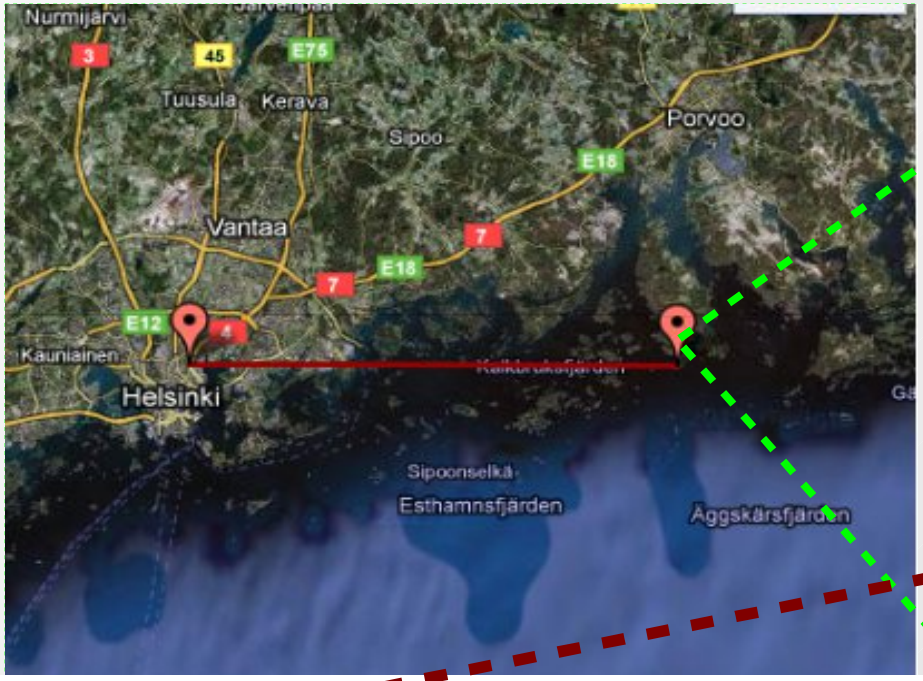


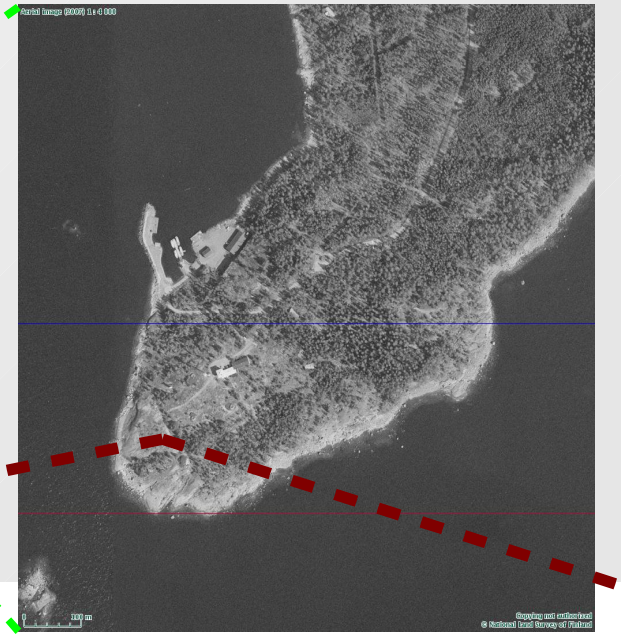
Pre-CHUVA retrieval example



Participation during GPM/GV field campaigns

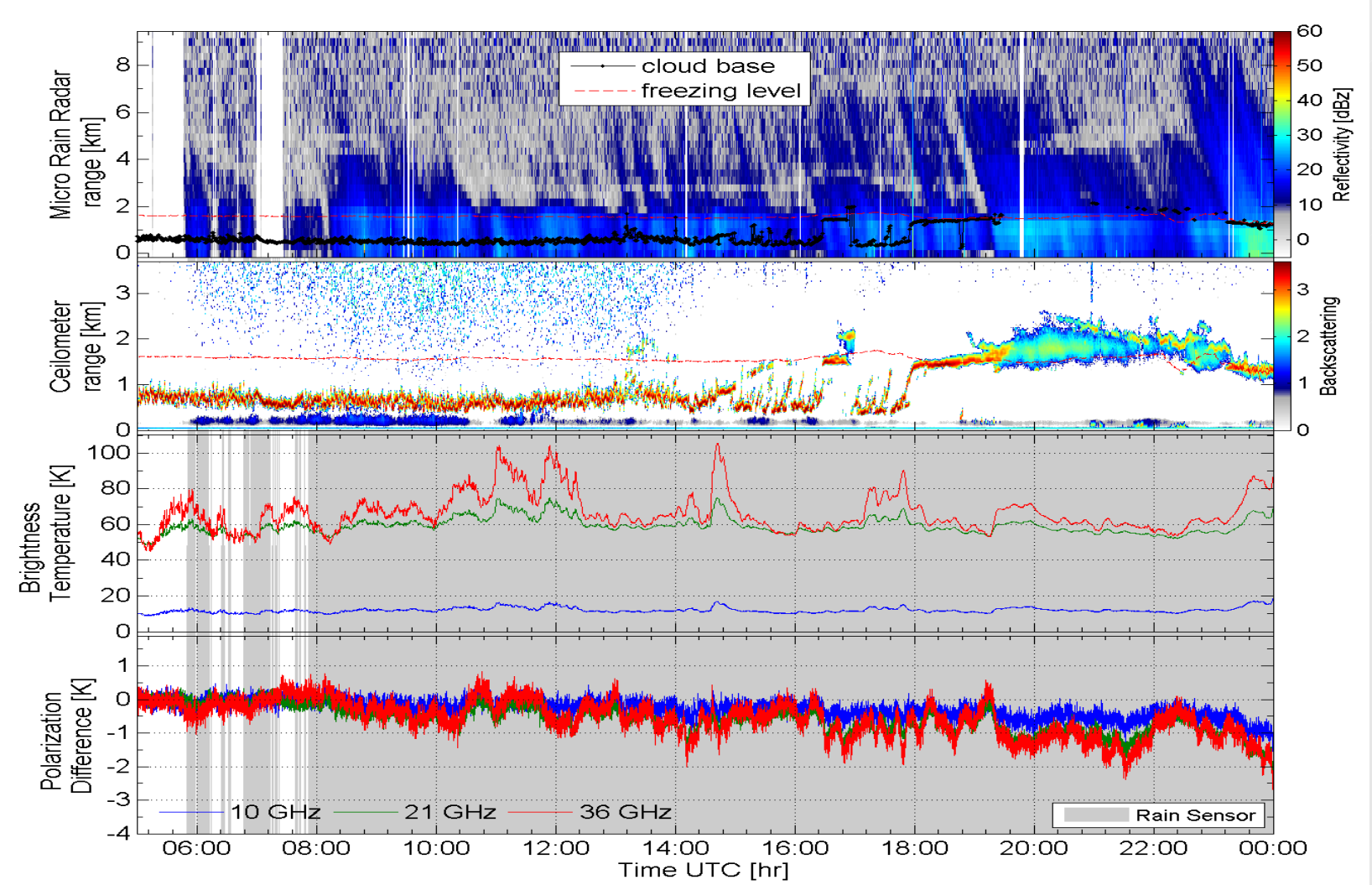
2) HIGH LATITUDE:
During Sept. - October 2010, ADMIRARI participated in the LPVEx campaign in Finland (Lat. 60° 12' 13.7" North, Lon. 25° 37' 30.5" East).



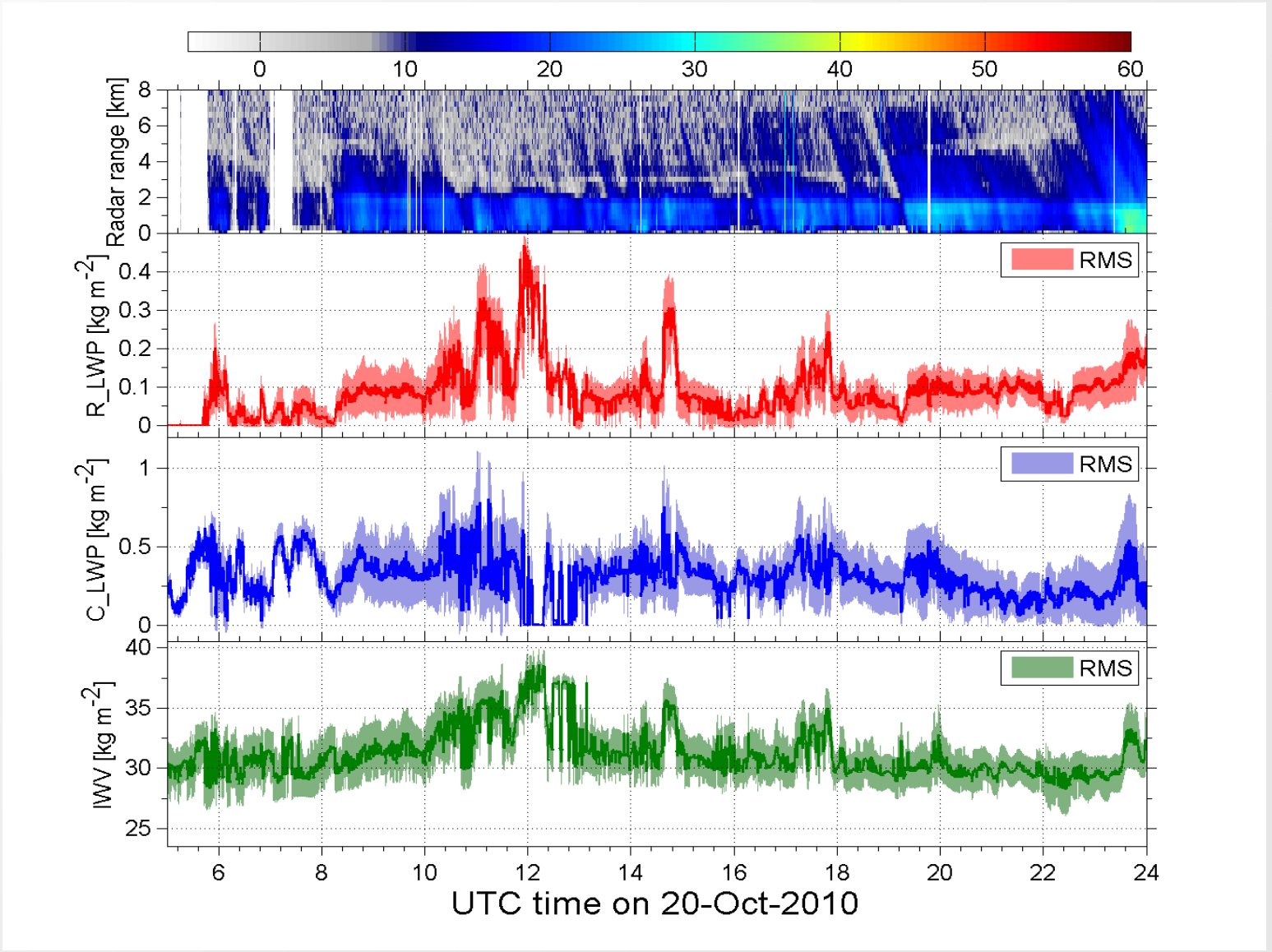


LPVEx observations on 20th October

30° elevation angle

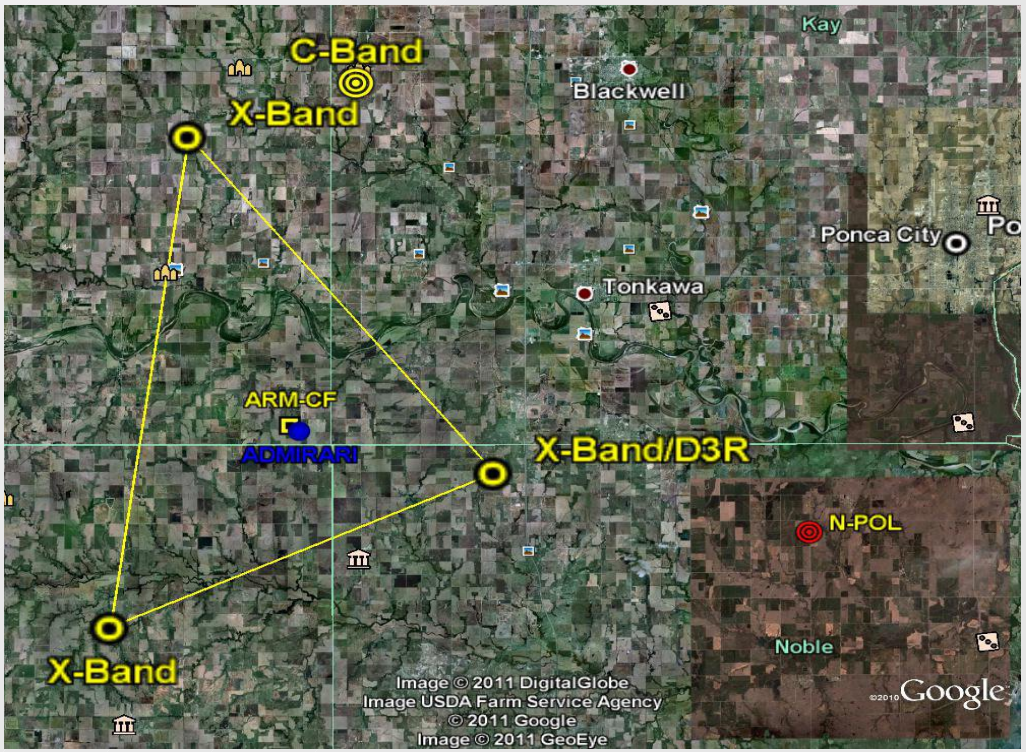


LPVEx retrieval for October 20th

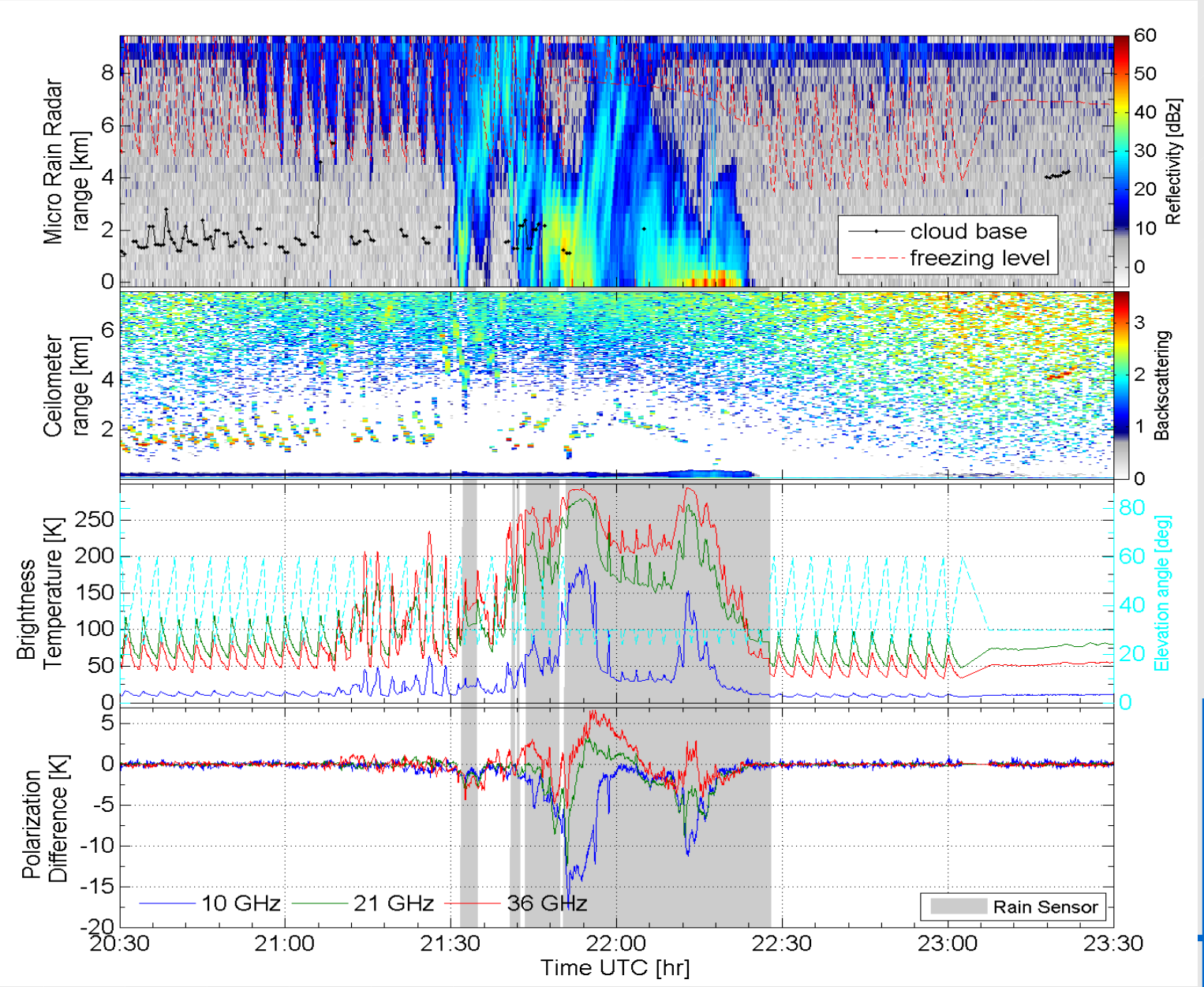


Participation during GPM/GV field campaigns

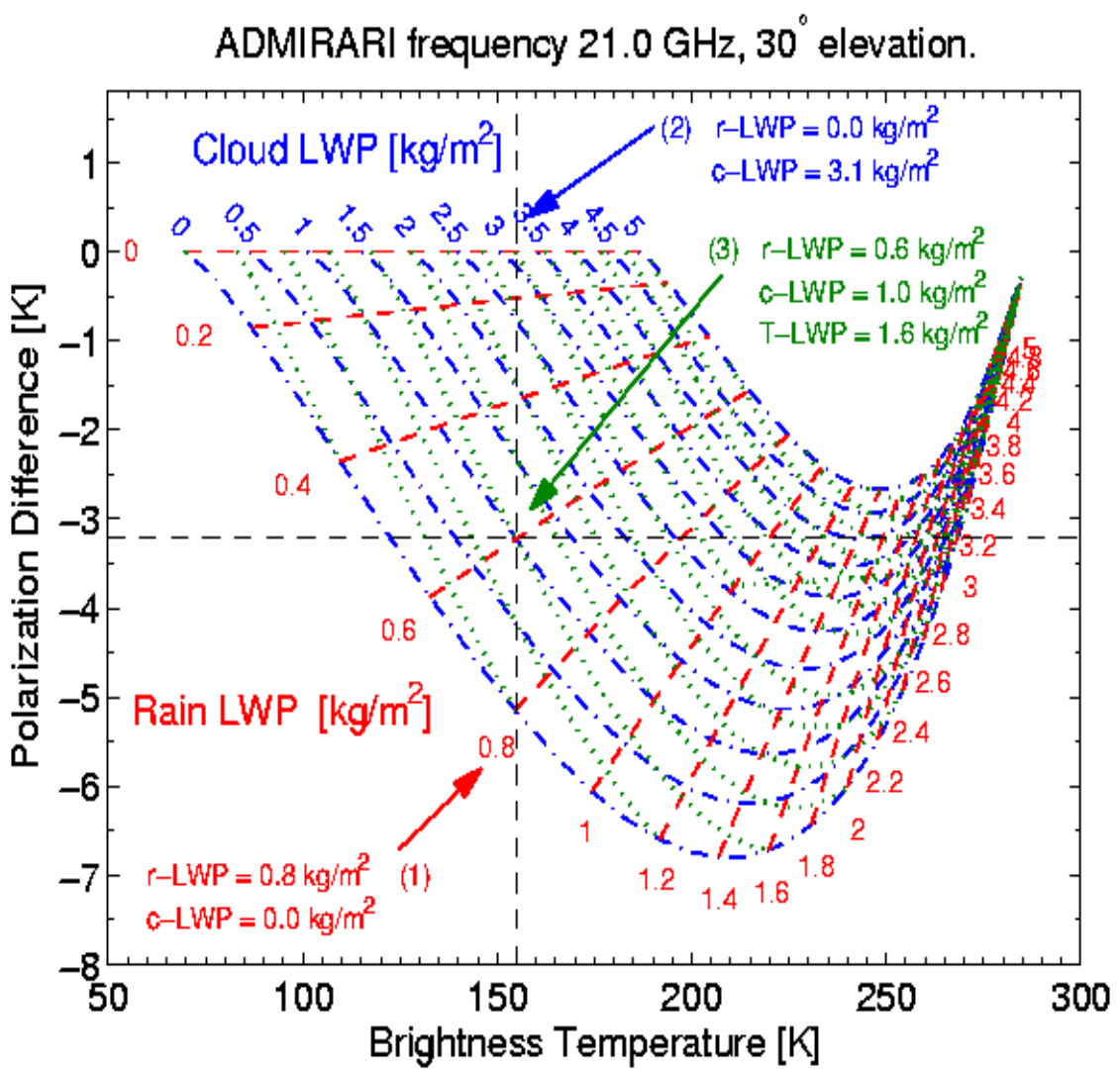
3) MID-LATITUDE:
In May to June 2011, ADMIRARI take part at the MC3E campaign at the ARM SGP site in Oklahoma, (Lat.: 36° 36' 05.076” N, Long.: 97° 28' 52.176” W)

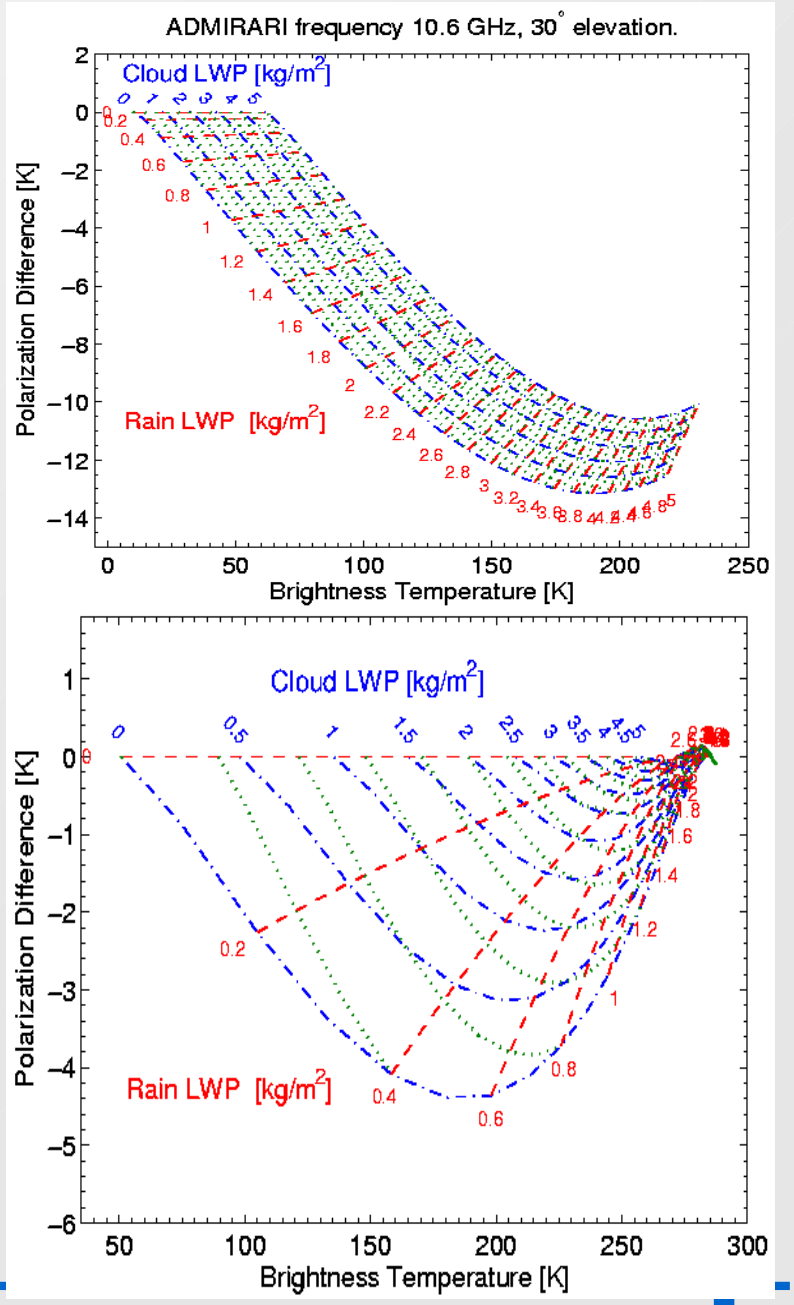


MC3E observation on 24th May, RHI toward North



Retrieval of Rain and Cloud LWP

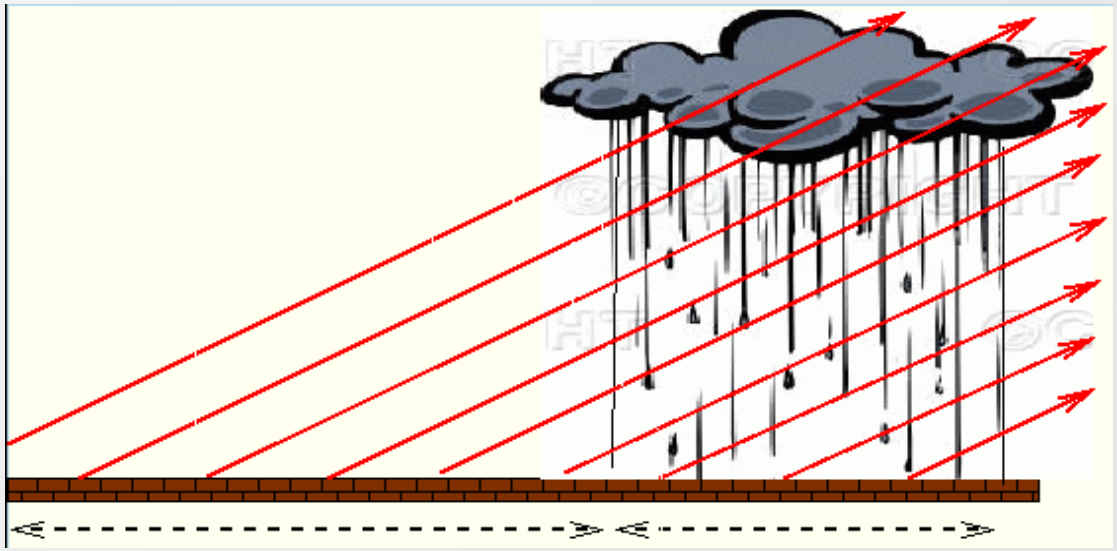




Retrieval of Rain and Cloud LWP

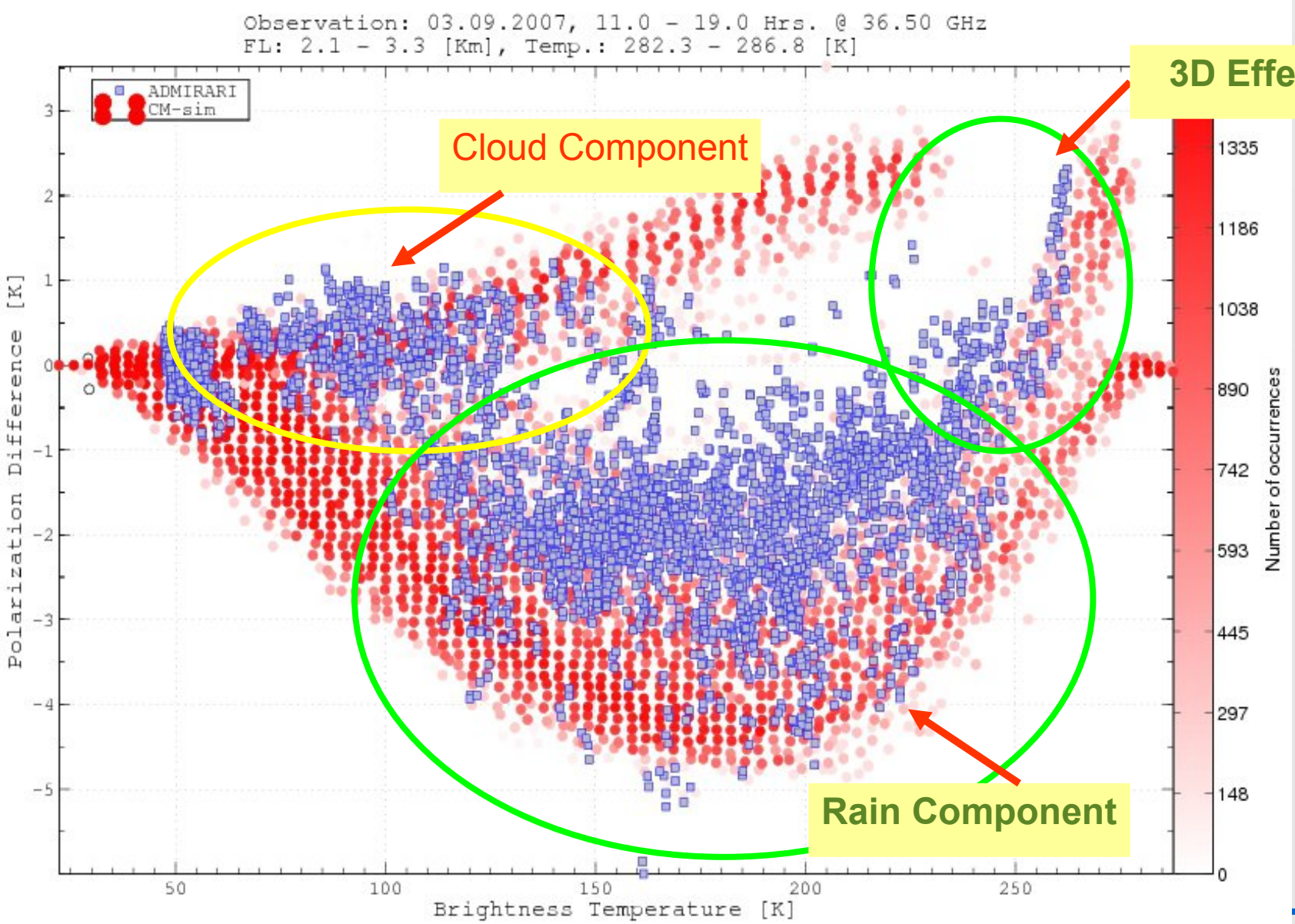
- Retrieval algorithm based on the Bayesian technique.
- Hydro-meteor vertical profiles are obtained from CRM outputs.
- *a-priori* (TB,PD) dataset was generated from the RT calculations based on 3D, and 1D slant path for finite and infinite plane-parallel precipitating cloud, respectively.
- Attenuated reflectivity profiles are computing using MIE for the MRR freq.
- Rain drops are assumed to be non-spherical with horizontal alignment (mandatory to produce polarization)
- Two main retrieval approaches:
  - based on radiometer measurements only and uses the radar and ceilometer data to constrain the rain structure from the *a-priori* dataset (RAD, aslo RAD1021, RAD1036 and RAD2136)
  - The reflectivity profile is fully incorporated to the retrieval technique (RADMRR)

Retrieval of Rain and Cloud LWP



- Simulation at different radiometer positions
- Database include a range of radiometer elevation angles
- Exponential DSD with 4 Intercept parameters:
  - N0= 1400 m^{-3} mm^{-1} (Thunderstorm)
  - N0= 4000 m^{-3} mm^{-1} (Heavy-rain)
  - N0= 8000 m^{-3} mm^{-1} (Marshall-Palmer)
  - N0=32000 m^{-3} mm^{-1} (Light-rain)

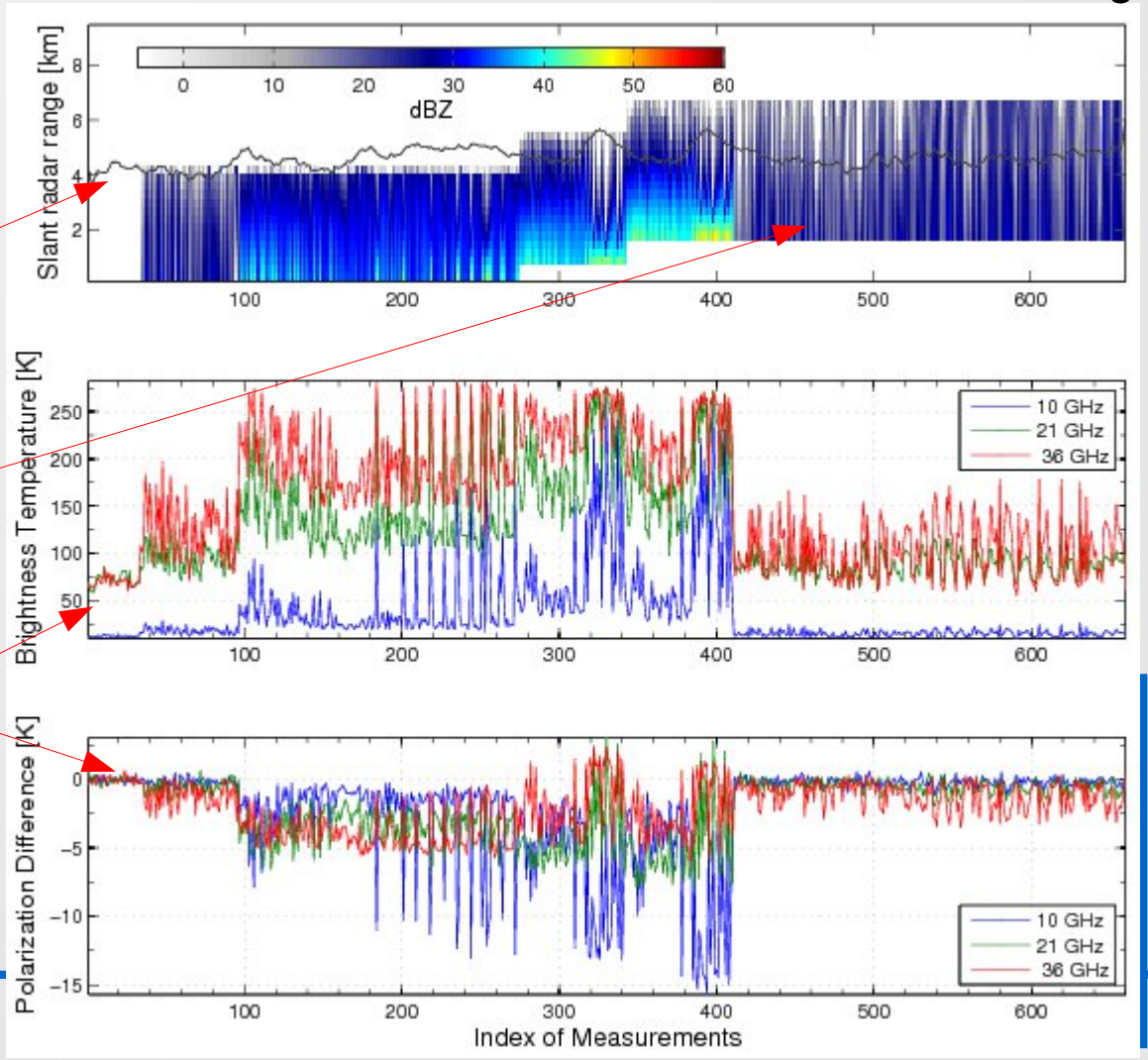
The real picture when observations and simulations are overlaped



Sensitivity Study

- A sub set of 660 samples were extracted from the whole data set and trated as synthetic measurement
- Composed by range of cloud and rain LWP and the four N_0 DSD parameter

30° elevation angle



Pure cloud cases

Different rain positon rel. to the radiometer:

Instrument noise of 0.5 K was added to the TB and PD

Bayesian technique

$$P_{post}(\mathbf{x}|\mathbf{y}_O) = \frac{p_f(\mathbf{y}_O|\mathbf{x})\, p_{pr}(\mathbf{x})}{\int p_f(\mathbf{y}_O|\mathbf{x})\, p_{pr}(\mathbf{x})\, d\mathbf{x}},$$

Where $\boldsymbol{y}_o$ are the measurements for two approaches:

- $\boldsymbol{Y}_o$ = [TB,PD], called approche RAD and degrading to dual freq. RAD1021, etc.
- $\boldsymbol{Y}_o$ = [TB,PD, Ze], called approche RADMRR

and **x** are composed by the atmospheric parameters

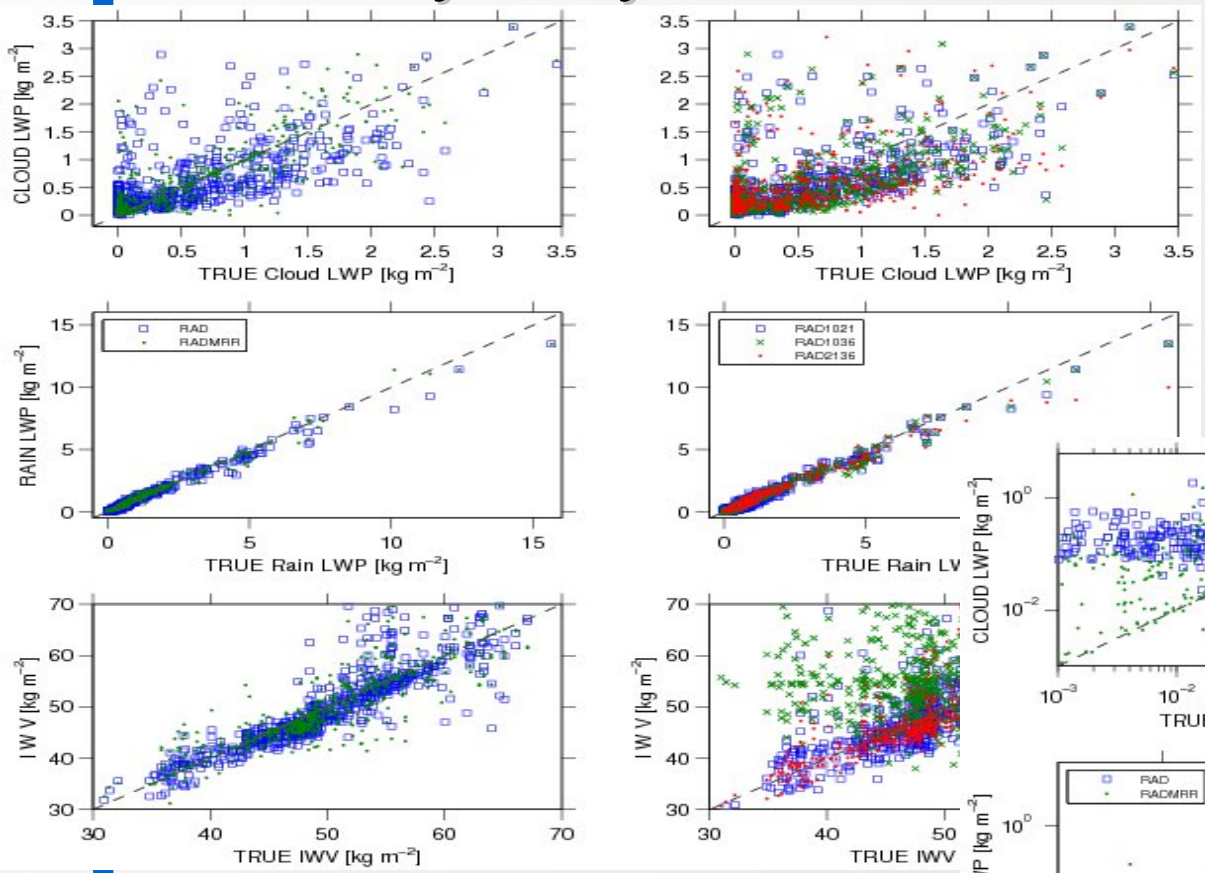
$$P([\mathbf{y}_O - \mathbf{y}_S(\mathbf{x})]) \propto \exp\{-\frac{1}{2}\,([\mathbf{y}_O - \mathbf{y}_S(\mathbf{x})]^T(\mathcal{O}+\mathcal{S})^{-1}[\mathbf{y}_O - \mathbf{y}_S(\mathbf{x})])\}$$

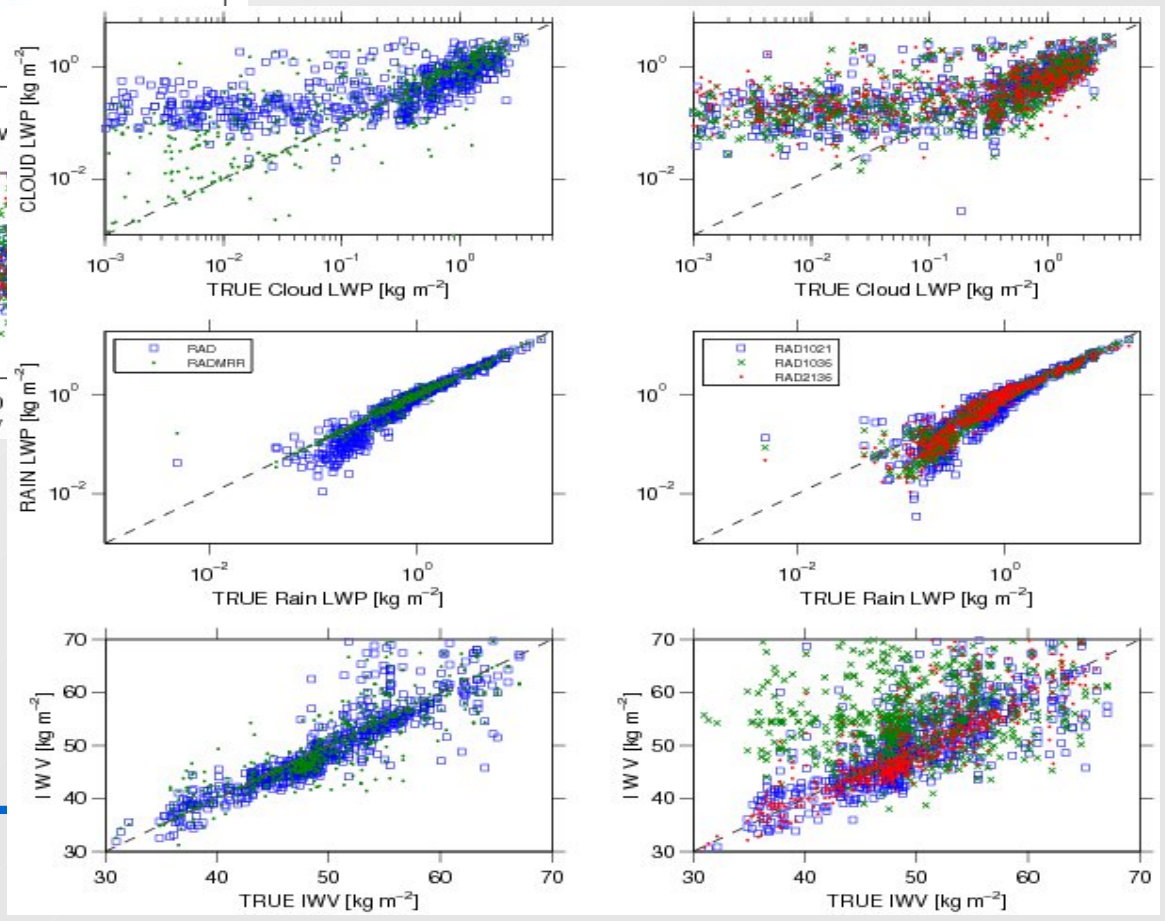
$$P_{post}(\mathbf{x}|\mathbf{y}_O) = \frac{\exp(-\frac{1}{2}\,\delta^2)\, p_{pr}(\mathbf{x})}{\int \exp(-\frac{1}{2}\,\delta^2)\, p_{pr}(\mathbf{x})\, d\mathbf{x}}.$$

$$< \mathbf{x} > = \int \mathbf{x}\, P_{post}(\mathbf{x}|\mathbf{y}_O)\, d\mathbf{x}.$$

$$\sigma^2_{\mathbf{x}} = \int (\mathbf{x} - < \mathbf{x} >)^2\, P_{post}(\mathbf{x}|\mathbf{y}_O)\, d\mathbf{x}$$

Sensitivity study: Retrievals results vs true

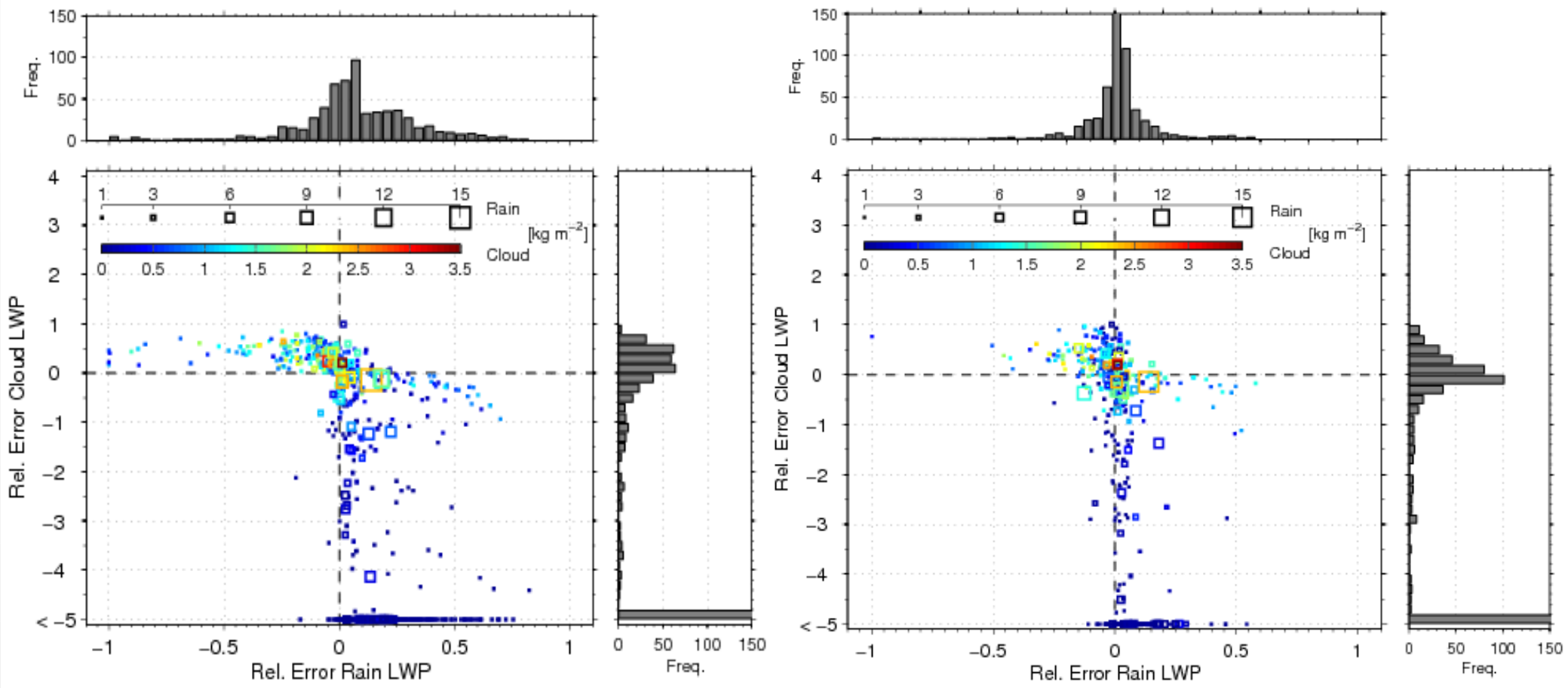




Sensitivty study: relative errors

RAD: Only radiometer

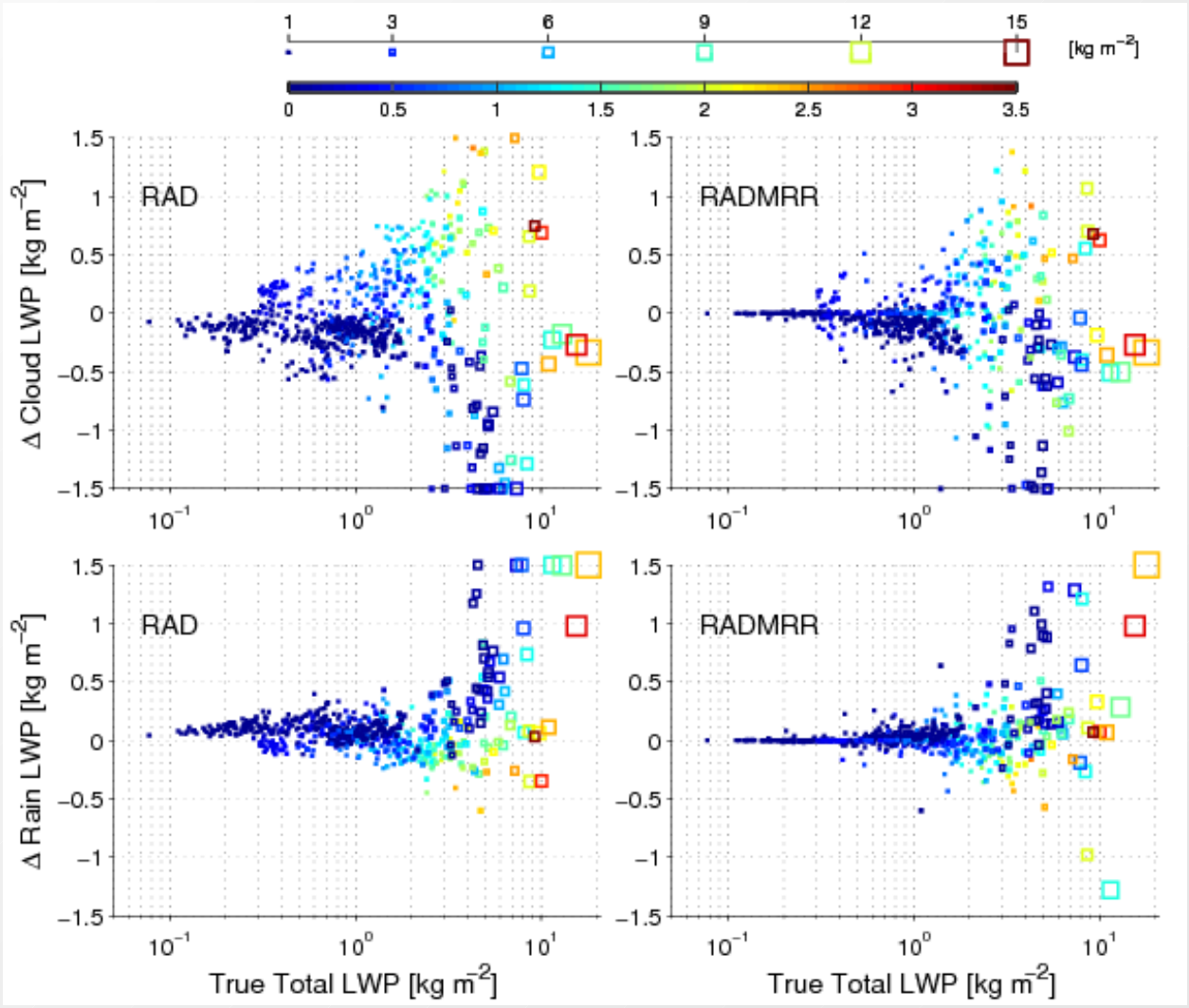
RADMRR: radiometer+MRR



Overestimate Cloud LWP and Underestimate Rain LWP

Sensitivity study: what about Total LWP

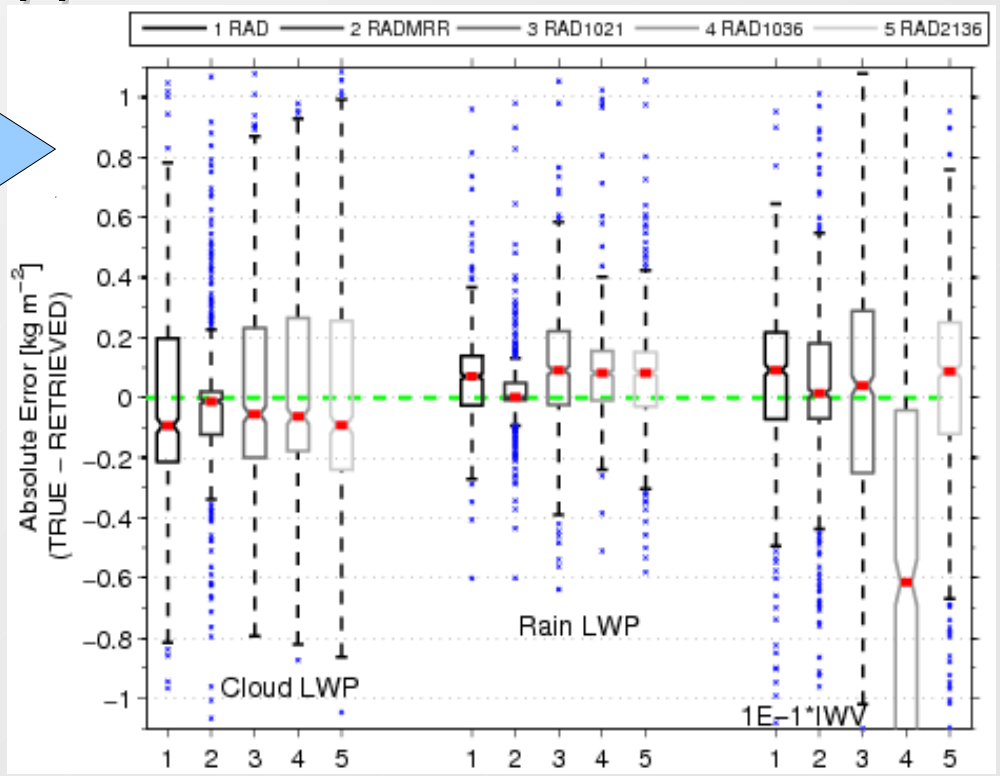
Δ = TRUE - RETRIEVED

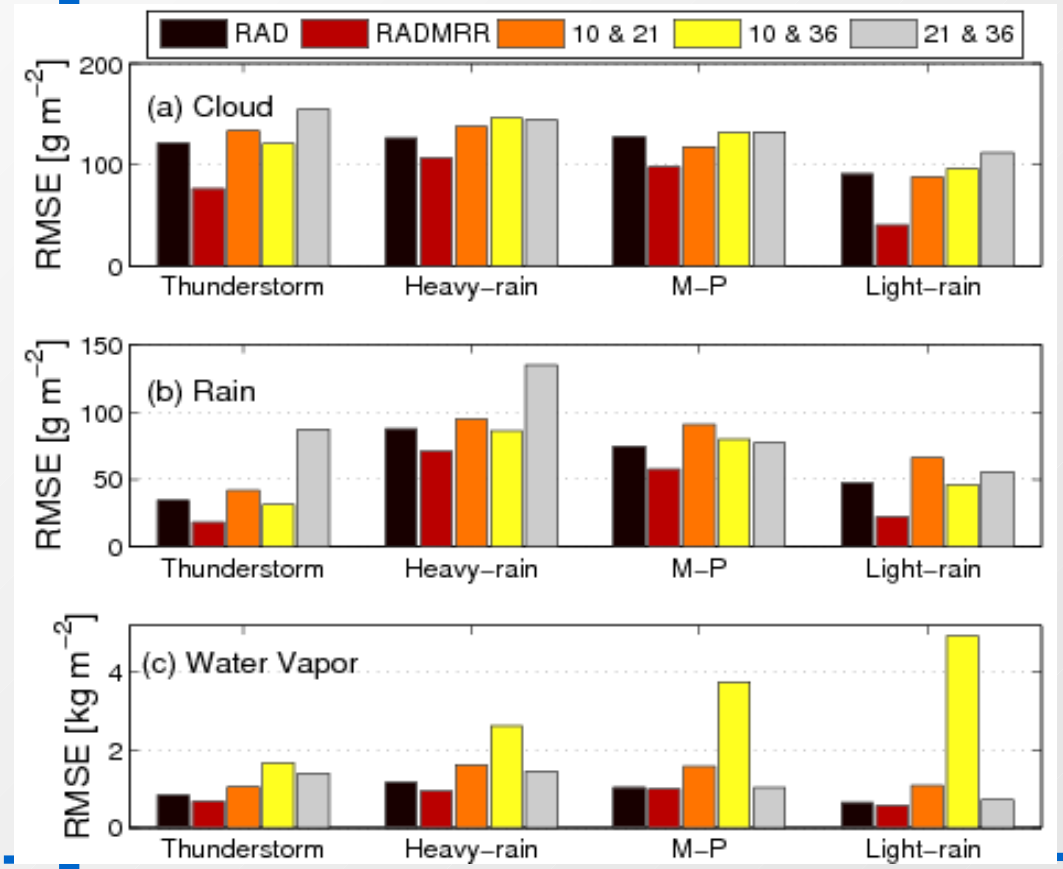


For cases with low water content, the PD signal is close to the instrument noise, then is better to avoid the PD in order to reduce uncertainty on the retrievals

Overview at the five Retrieval approaches

Absolute errors for retrievals with only the radiometer RAD, with radar RADMRR and by degrading the radiometer to dual-freq.



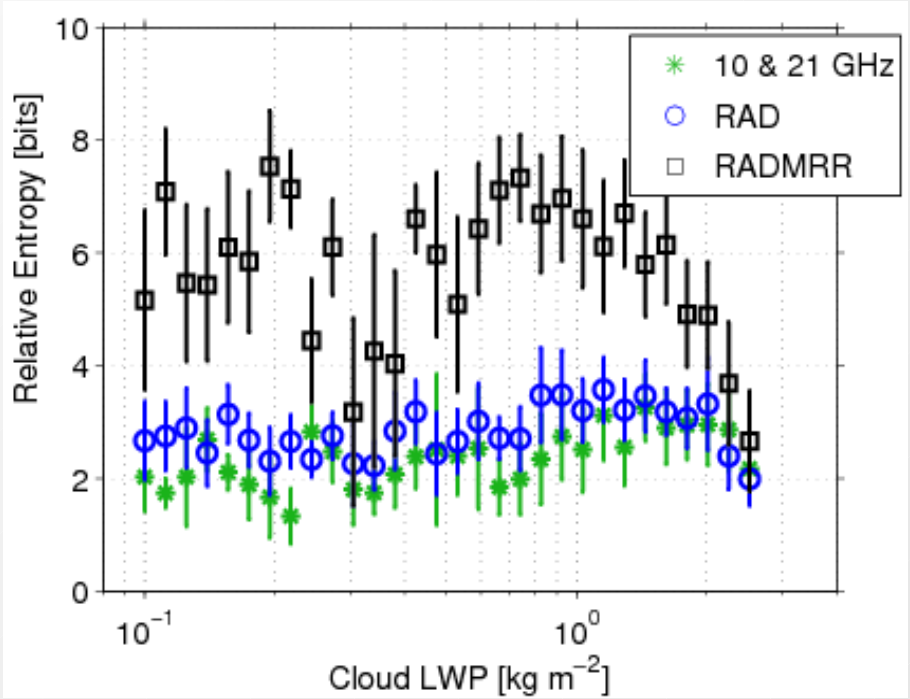


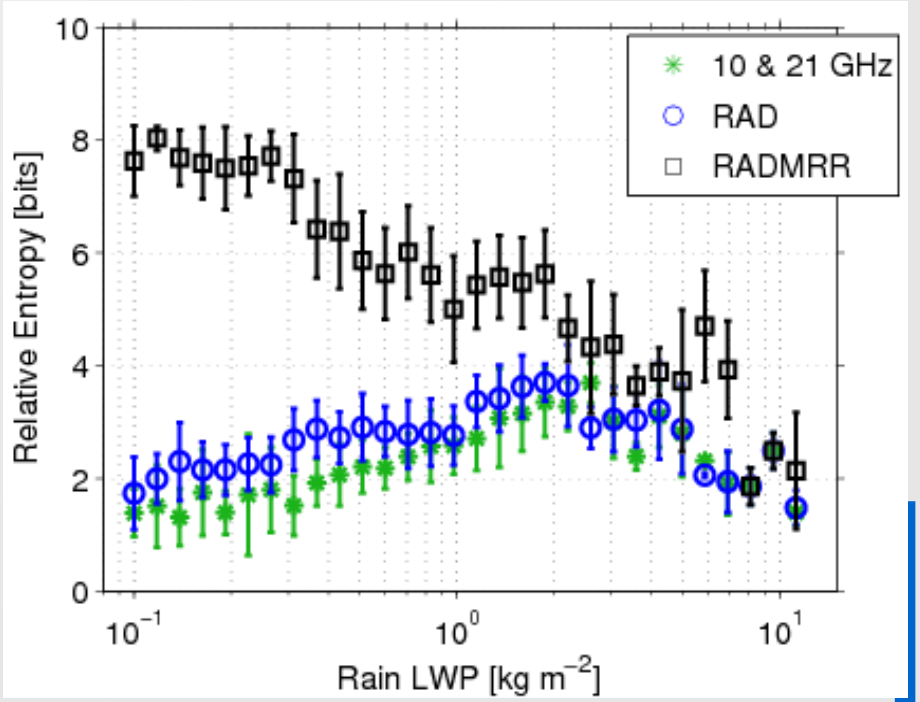
RMSE as a function of the 4 DSD parameters, the five retrieval approches and the three Retrieved parameters: R_LWP, C_LWP and IWV

Information content on the retrievals

In a Bayesian framework, the information content can be estimated by the **relative entropy** which defines the amount of information added to the retrieval by the observation

$$H = \int P_{post}(\mathbf{x}|\mathbf{y}_O)\, ln \left[\frac{P_{post}(\mathbf{x}|\mathbf{y}_O)}{p_{pr}(\mathbf{x})}\right] d\mathbf{x}$$

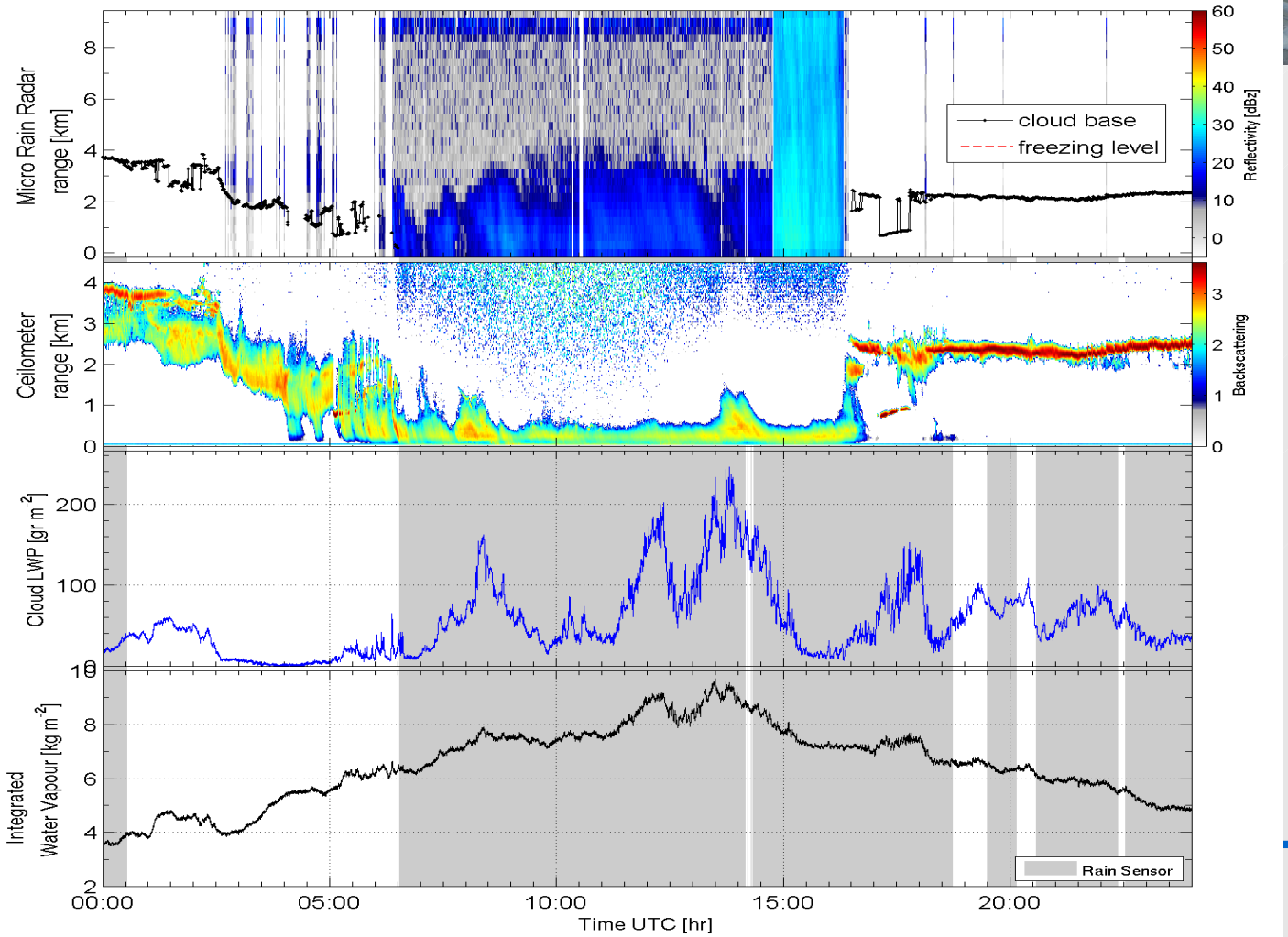




Upcoming GCPEx campaign

We are preparing the instruments to deploy to the CARE site in Canada:

· Dual-pol radiometer 90 GHz & 150 Ghz (V & H) in colaboration with the University of Cologne in Germany:



ADMIRARI has provided good performance durig snow condition in the last winter in Helsinki

Summary

- Operational retrieval algorithm is based on the RAD approach, the radar reflectivity profile is being incorporated to the retrieval

- After the Canadian campaign, the work will concentrate on the generation of the retrieved database from ADMIRARI for the four GPM/GV campaign

- Issues with the generation of the *a-priori* database:
  - Melting layer modeling is not incorporated to the RT yet
  - The pre-CHUVA campaign has undercover that NUBF and 3D radiative affecs must be taken into account in the retrieval. For that high resolution CRM are needed in order to mimic the observations by ADMIRARI (*Battaglia et al., Understanding 3D effects in polarized observations with the ground-based ADMIRARI radiometer during the CHUVA campaign. 2011*)
  - Alternatives to CRM to built-up hydrometeor profiles, feasibility to otain that information from other instrumets must be pursued.

- Validation for the cloud/rain partitioning is difficult task, since no other instrument provides that kind retrevals. Simultaneous observations with dual-freq. Radar (e.g. D3R) can give an oportunity to tacke this issue.