Meteorologisches Institut

Universität Bonn

Multiple Scattering Effects by Nonspherical Hydrometeors

Jörg Schulz
Meteorological Institute, University of Bonn
E-mail: joerg.schulz@uni-bonn.de

Harald Czekala
RPG Radiometer Physics GmbH, Meckenheim
E-mail: czekala@radiometer-physics.de

Sponsored by:

Meteorologisches Institut

Universität Bonn

Contents

1. Brief overview about main activities of our group at the Meteorological Institute at the Bonn University;

2. A report on the discrimination of cloud and rain liquid water path by ground-based polarized passive microwave radiometry;

3. Some thoughts about the construction of a single scattering data base for the coming joint ESA project on the development of a radiative transfer model for ν = 1 – 1000 GHz.

Meteorologisches Institut Universität Bonn

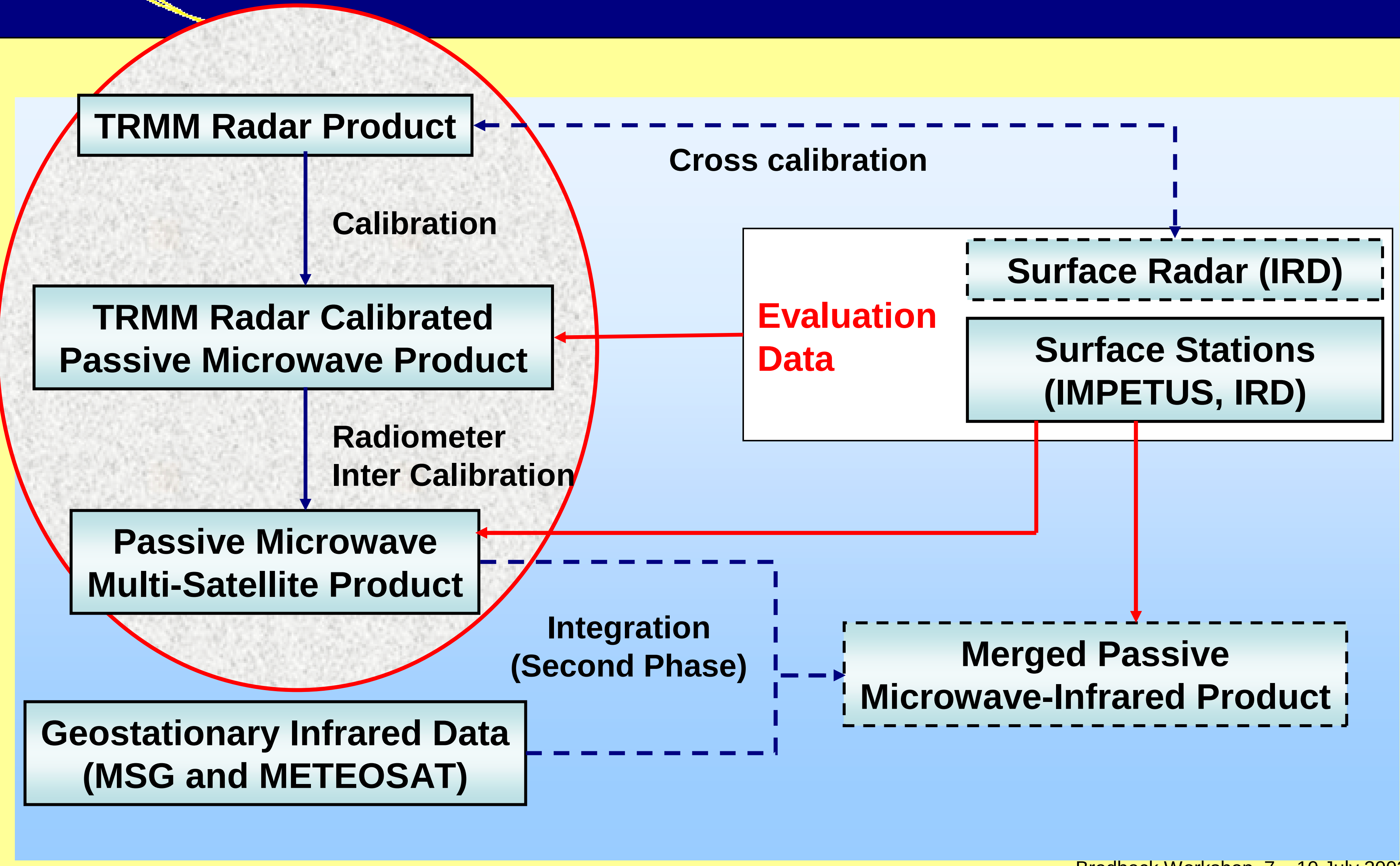
Instruments for Ground Validation

Instruments at Bonn University:

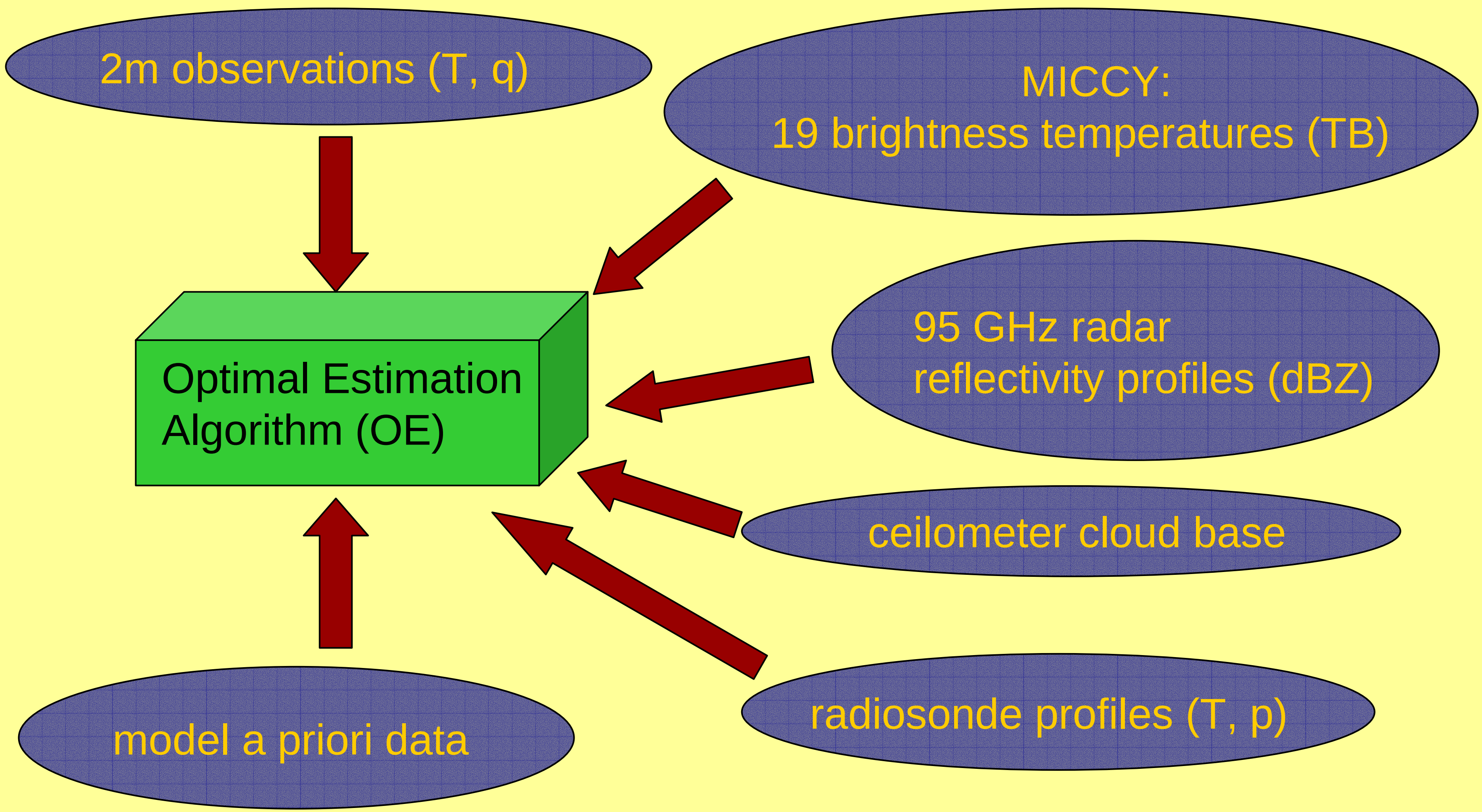
- X-band Doppler radar at Bonn University (continuous measurements since 1998)
- Two FM-CW Doppler radars (brand-new)
- Rain gauges (Network of Erftverband, 7 own stations)
- Ceilometer at Bonn (measurements since 2000)
- MICCY (**MI**crowave radiometer for **C**loud **C**arthograph**Y**)
- Low cost microwave radiometer

Meteorologisches Institut Universität Bonn

A Satellite Based Rainfall Monitoring System for Northwest Africa

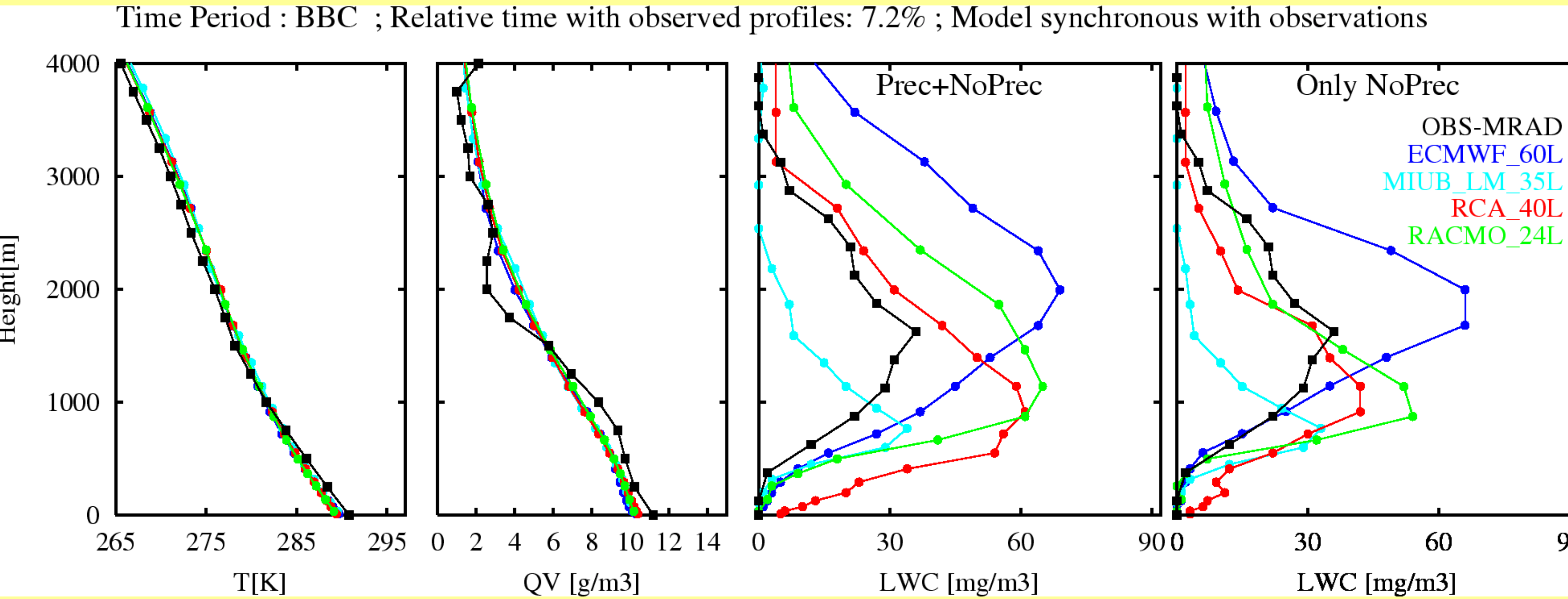


Multi Instrument Cloud Property Retrieval



Meteorologisches Institut
Universität Bonn

Observation vs Modelled Profiles



Refers to an older study by …..

DISCRIMINATION OF CLOUD AND RAIN LIQUID WATER PATH BY GROUNDBASED POLARIZED MICROWAVE RADIOMETRY

Harald Czekala

Columbia University / NASA Goddard Institute for Space Studies, New York

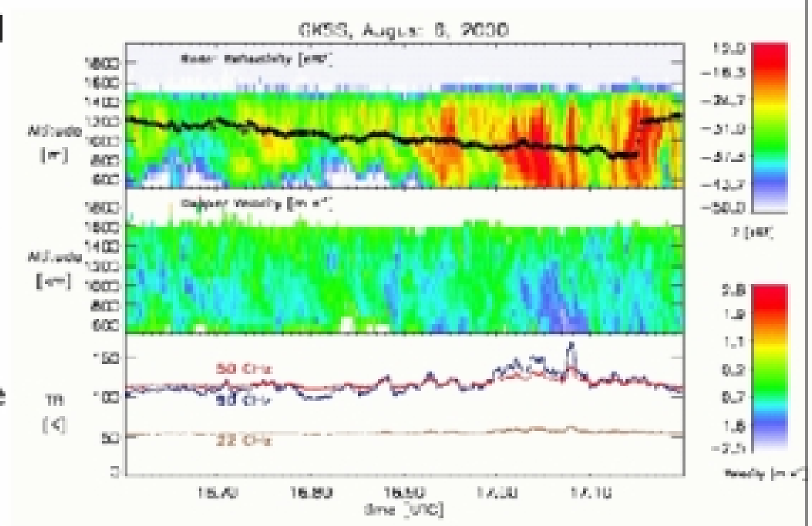
(now at: Meteorological Institute, University of Bonn, Germany) (now at PC)

Susanne Crewell, Clemens Simmer, and Ariane Thiele

Meteorological Institute, University of Bonn, Germany

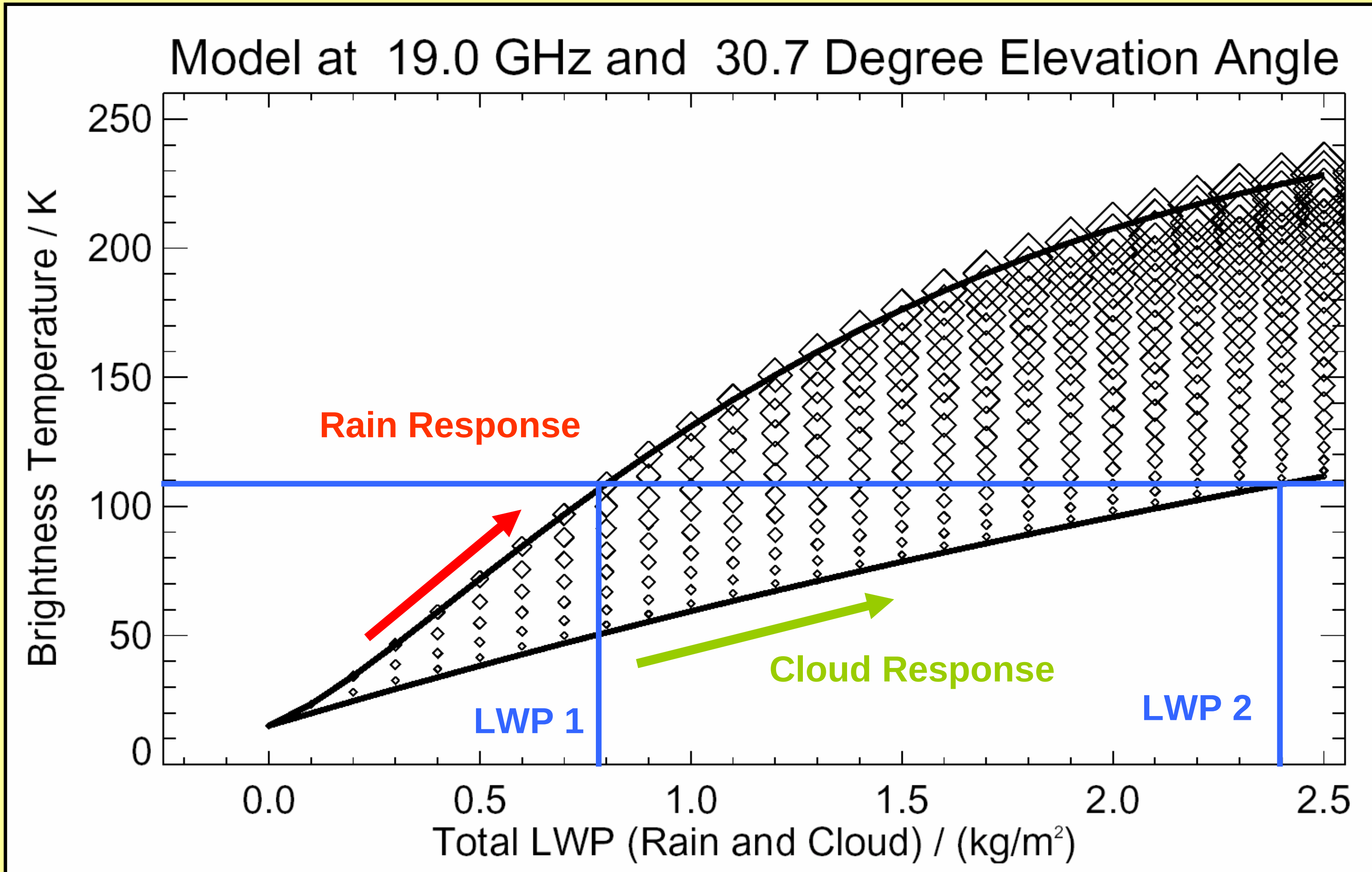
Motivation

- Most clouds: drizzle or rain inside cloud
- In-cloud rain even without surface rain
- Radar too sensitive to particle spectrum: small rain fractions dominate cloud signal
- Definitions
  - Clouds: small droplets ($r < 500\mu m$)
  - Rain: larger particles ($0.5 < r < 5mm$)
- Oblate raindrops: growing non-sphericity with size
- Use model studies to assess possible sources of information to
  - overcome problems
  - improve LWP retrieval in raining clouds
- Quantitative LWP retrieval: polarized passive microwave



Meteorologisches Institut Universität Bonn

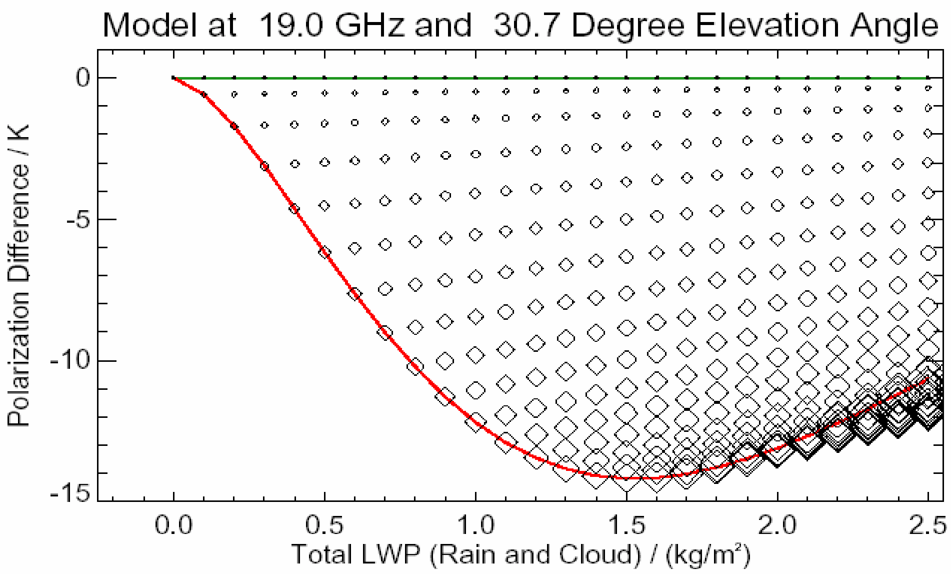
Limitations of TB Based LWP Retrieval



Meteorologisches Institut
Universität Bonn

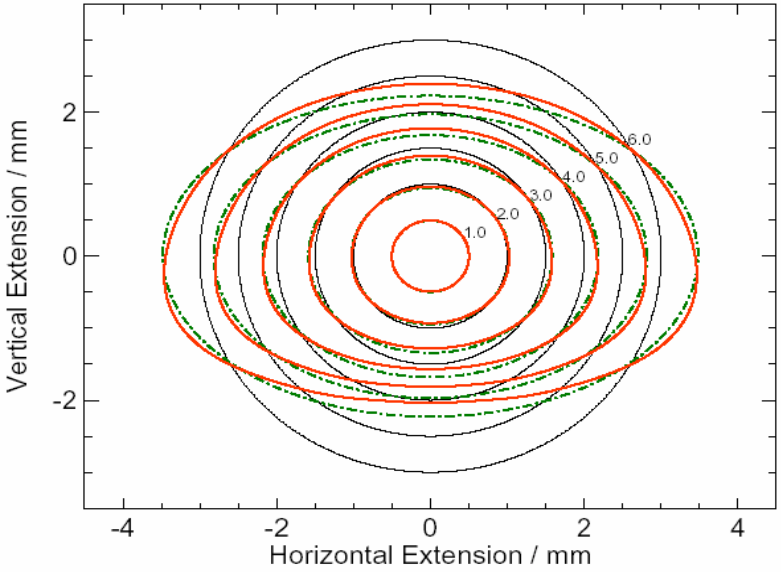
Polarization Signal vs LWP

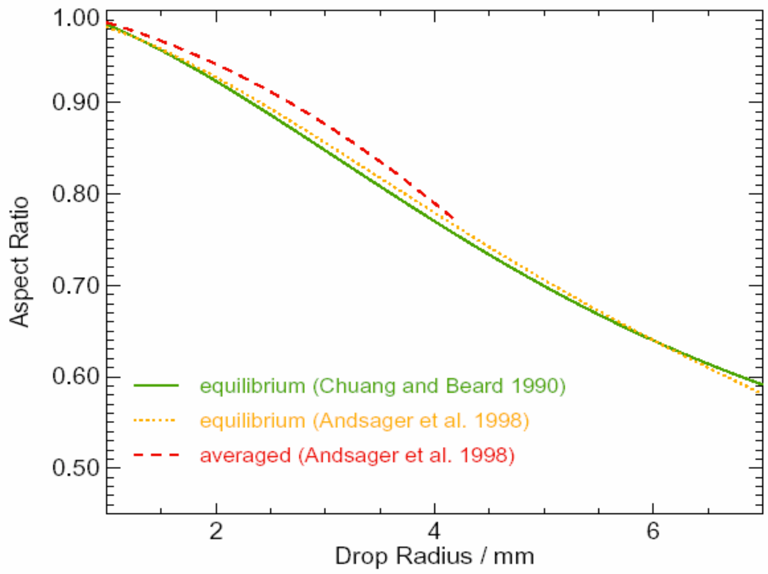
- Polarization signal also depends on rain/cloud mixture
- Convective clouds often contain fractions of rain
- In-cloud rain evaporates in the dry air below cloud base (no surface rain rate observed)



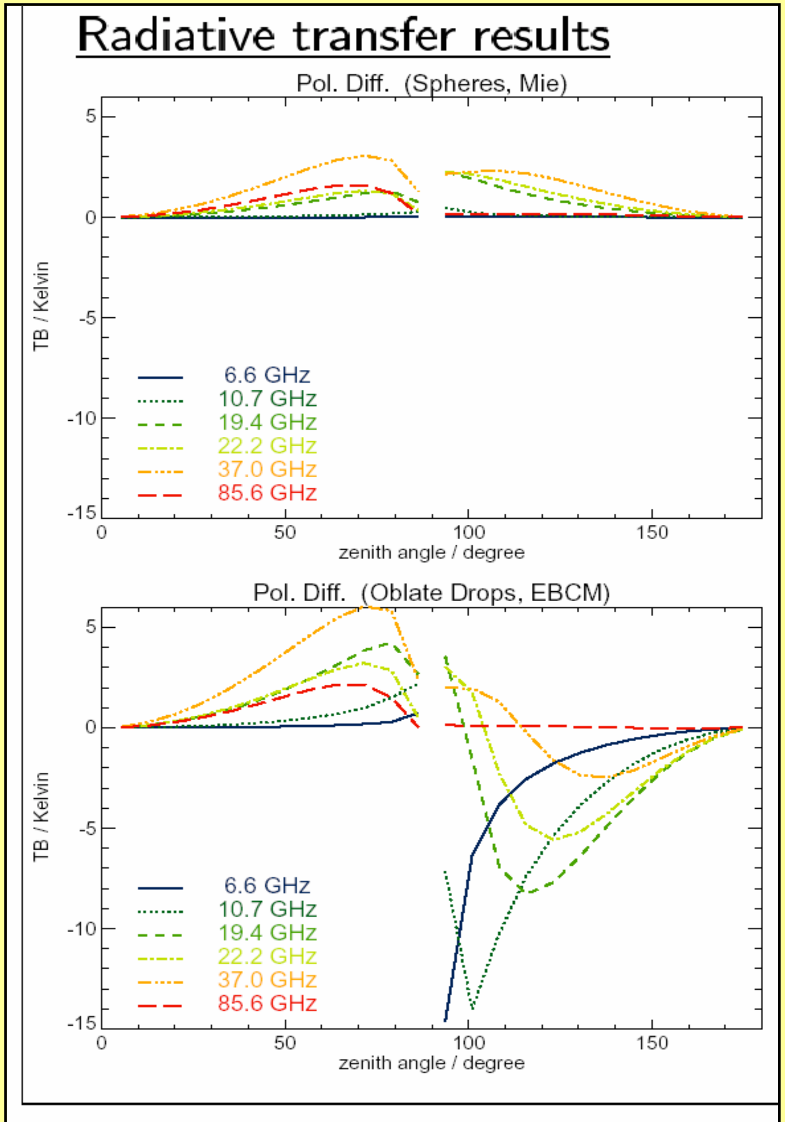
Radiative Transfer Model

- Solves the vector radiative transfer equation (VRTE)
- Atmosphere: One-dimensional, plane parallel
- Single scattering calculations: T-matrix (Mishchenko)
- Solving method: Successive order of scattering (SOS)
- Rain drop size distribution: Marshall-Palmer
- Mixing of rain and cloud layer with cloud particle size distribution





Radiative Transfer Results



Meteorologisches Institut

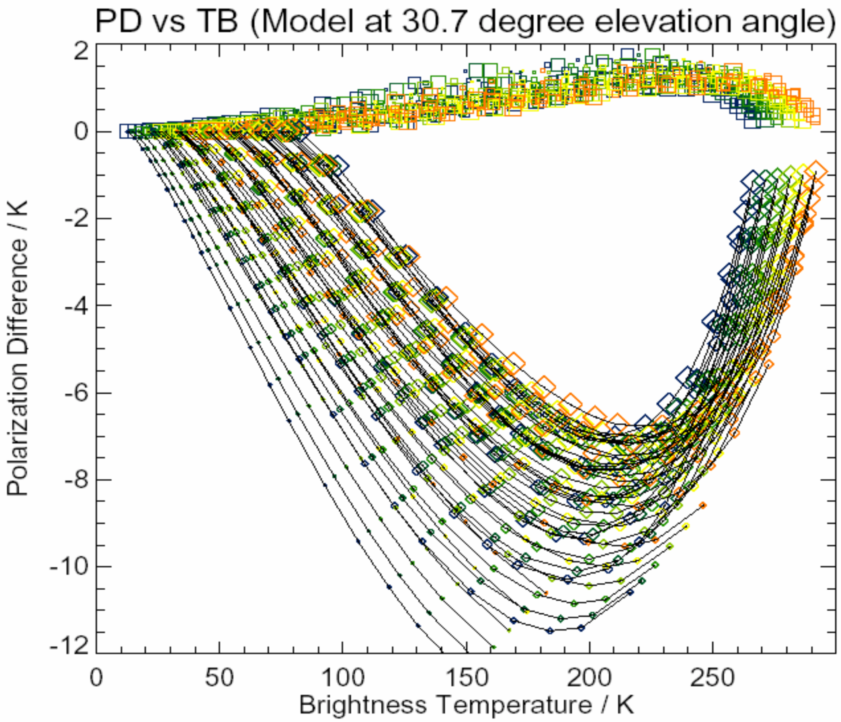
Universität Bonn

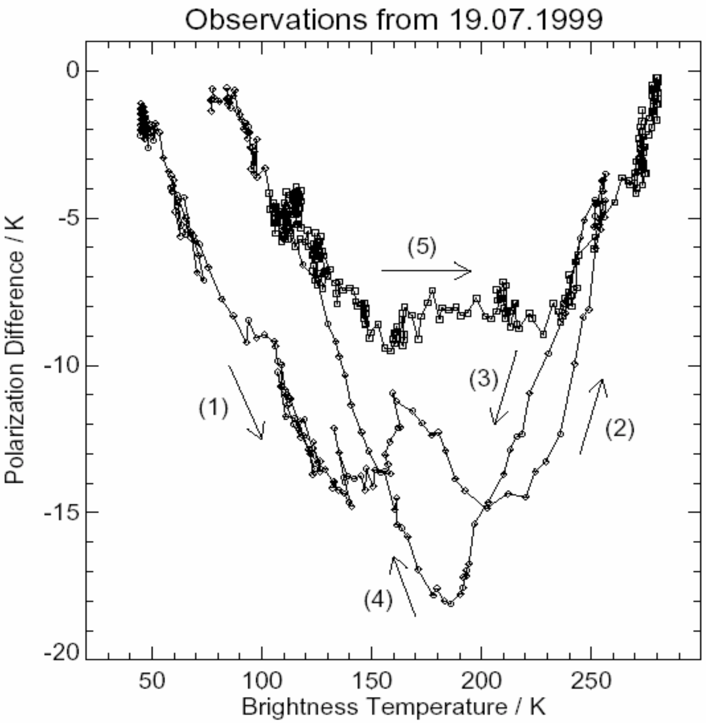
Model vs Measurements: Validation at 19 Ghz

Model calculation with varying
- rain rate
- atmospheric temperature
- rain layer height

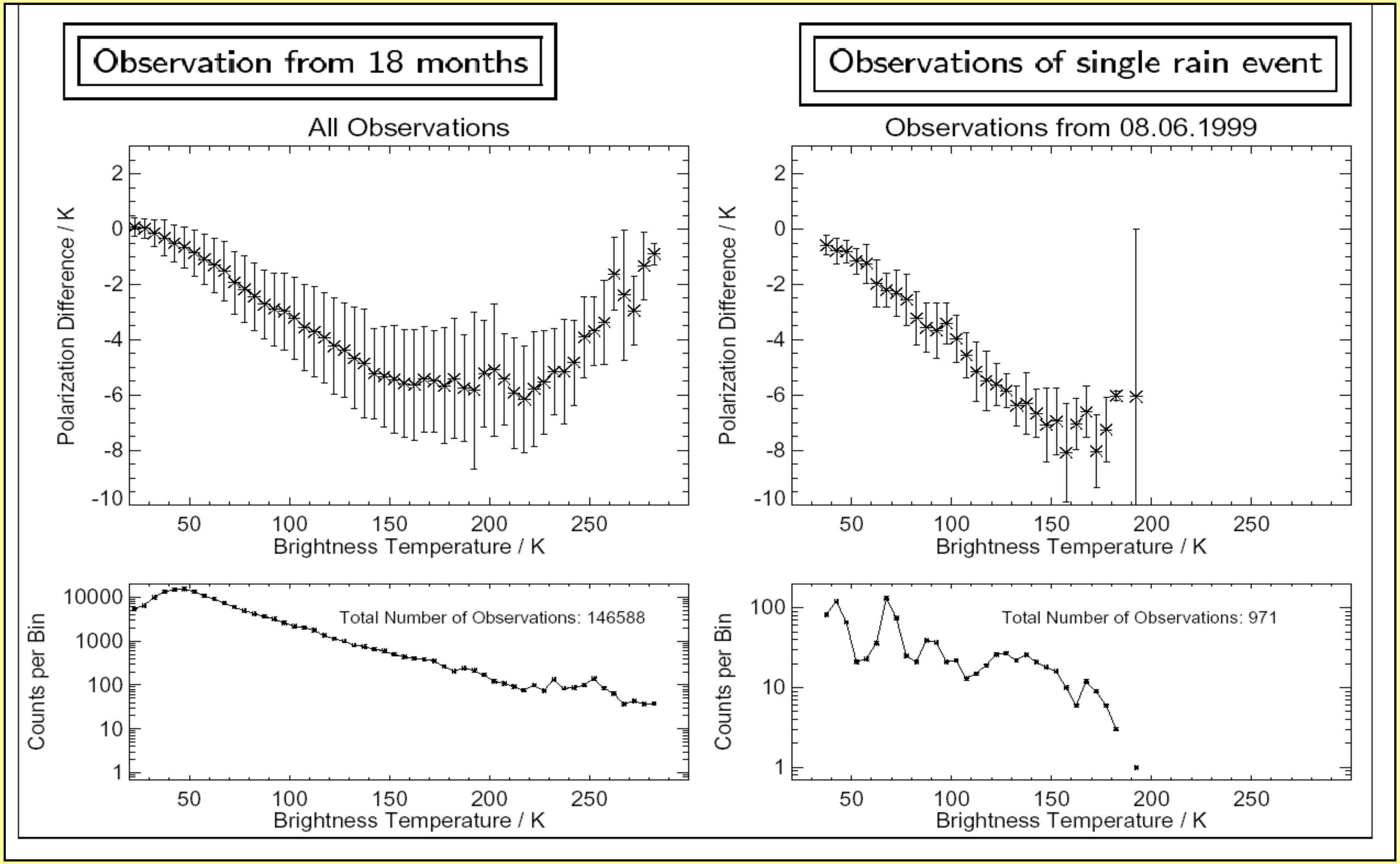
for spheres and nonspherical raindrops

Measurements with a groundbased dual polarized 19 GHz radiometer at 30 degree elevation

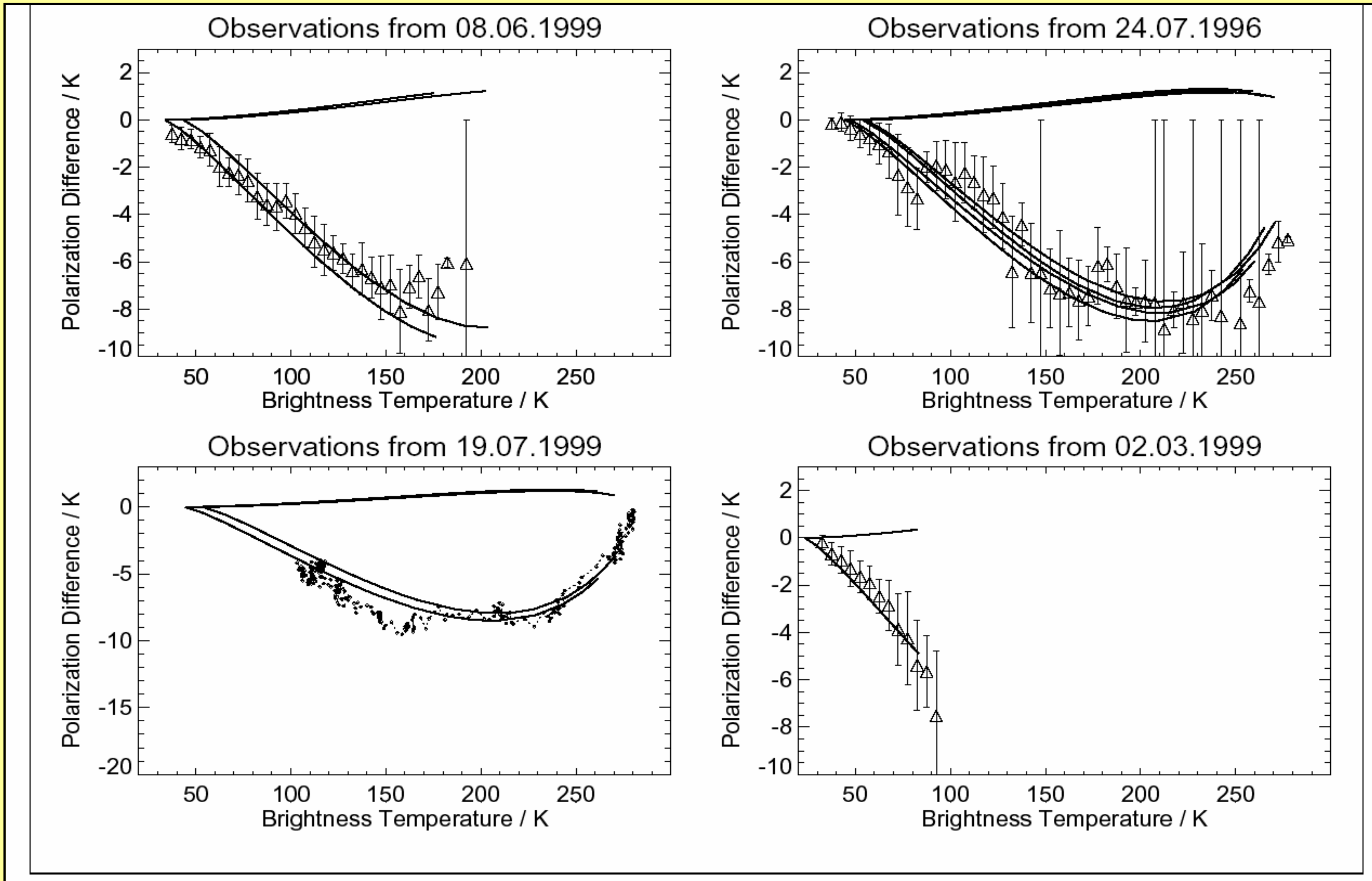




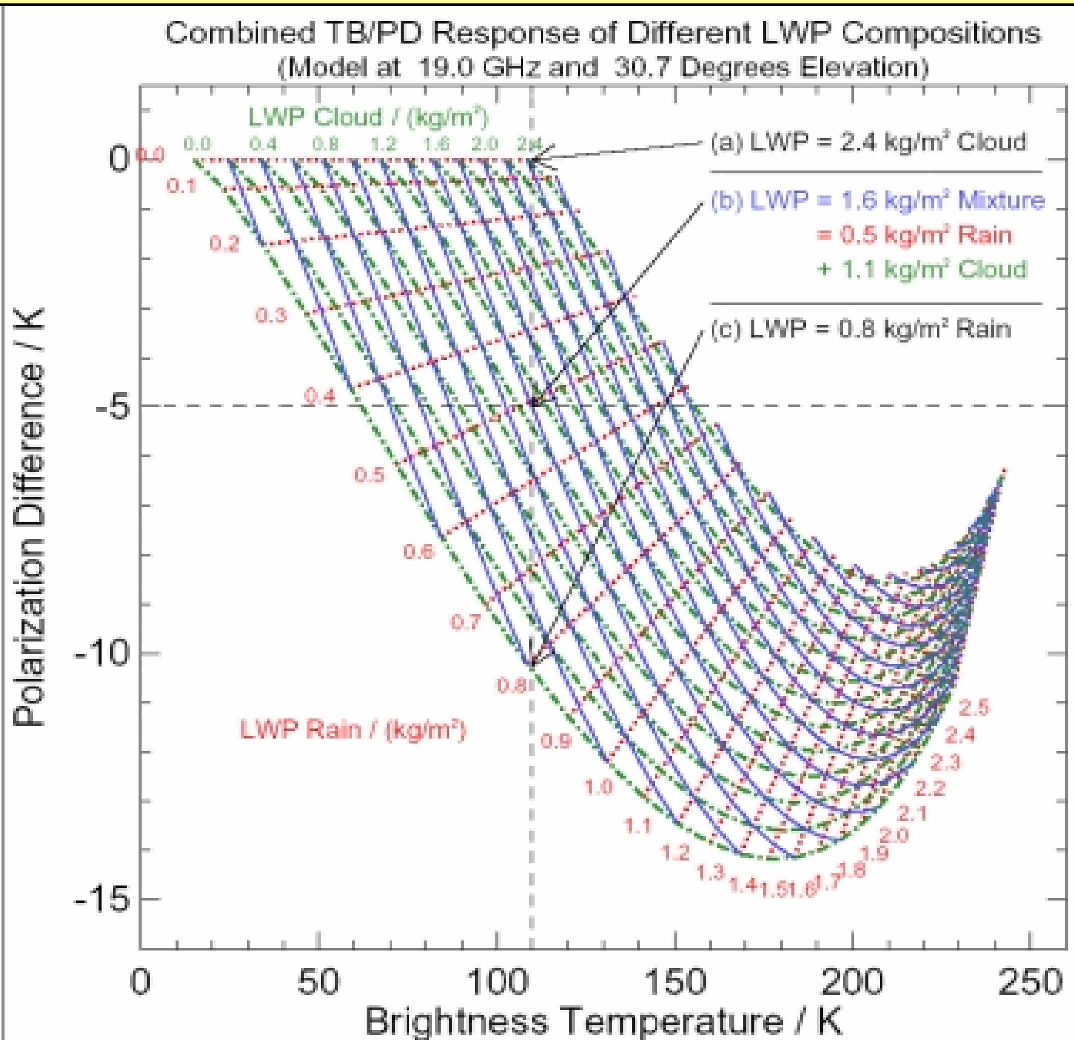
More Measurements



More Measurements



Proposed Retrieval Method



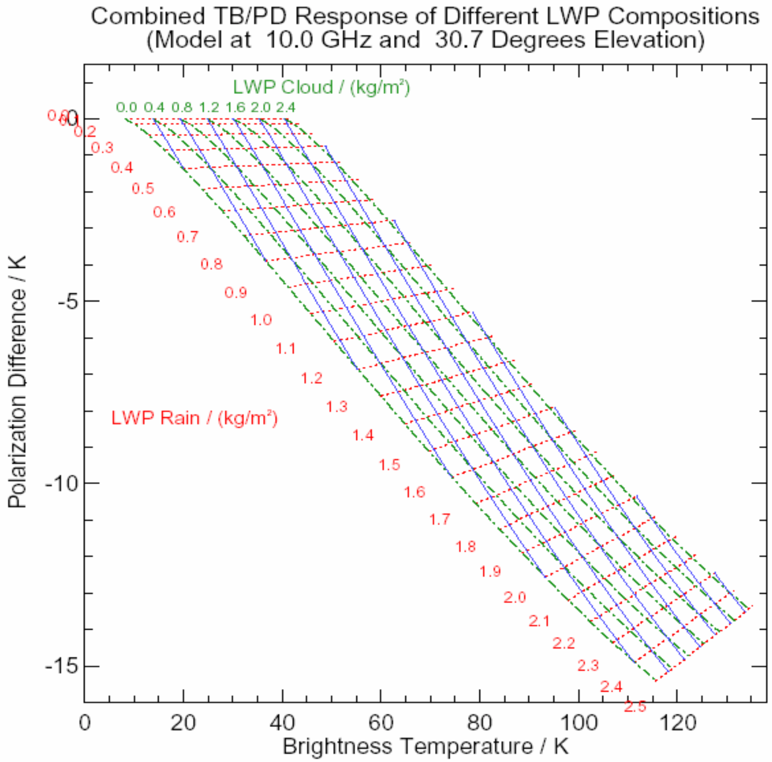
- Along red lines:
  rain LWP constant, increasing cloud LWP (left to right)
- Along green lines:
  cloud LWP constant, increasing rain LWP (top to bottom)
- Along blue lines:
  total LWP constant

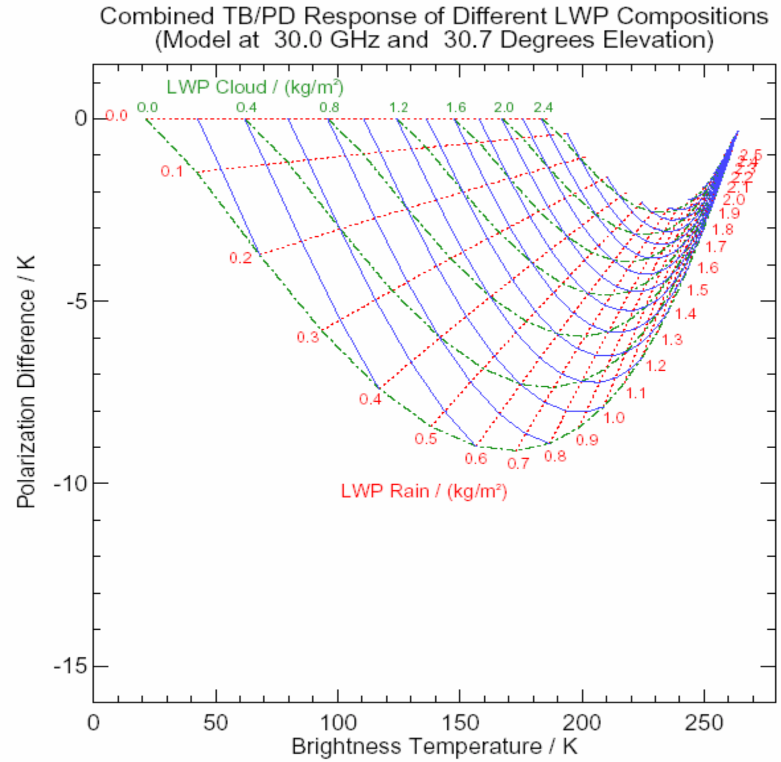
- Simultaneous measurement of brightness temperature and polarization difference
- Independent retrieval of cloud and rain fractions possible
- Accuracy of polarization measurement crucial
- Re-calibration with clear sky conditions

Meteorologisches Institut
Universität Bonn

Sensitivity to Frequency (10 and 30 instead of 19 GHz)

- Less saturation at smaller frequencies, but smaller sensitivity to rain
- Higher sensitivity to rain with increasing frequency
- Multi frequency measurements allow for complete coverage of LWP range



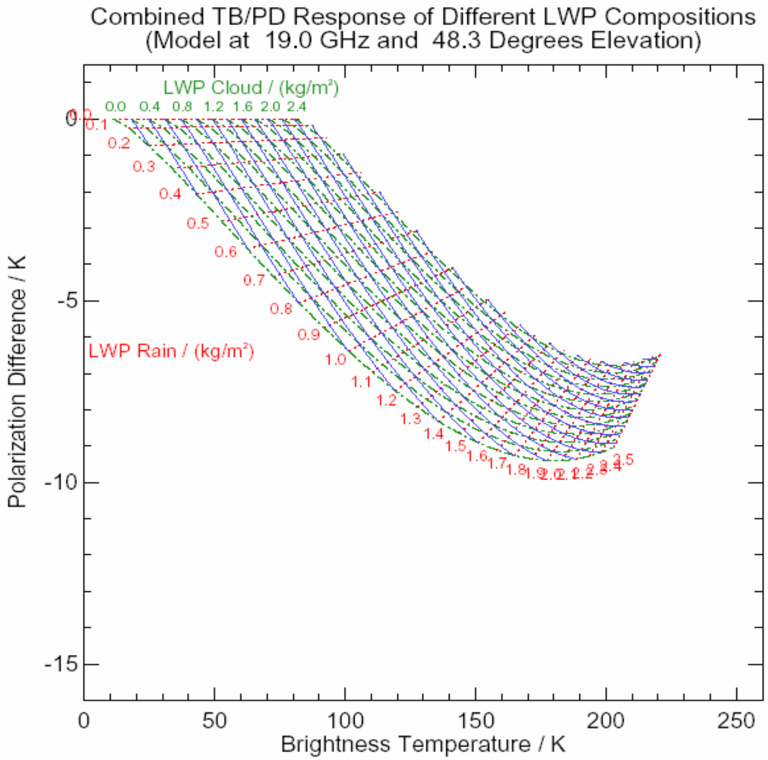


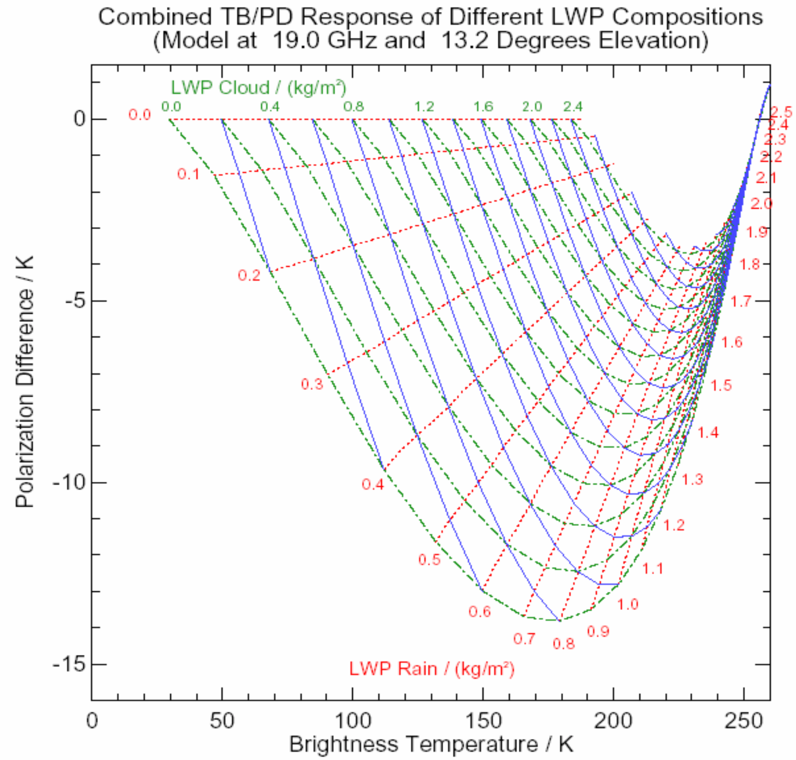
10 GHz: no saturation, good for heavy precip

30 GHz, better for light rain

Sensitivity to Elevation Angle (48° and 13° instead of 30°)

- Change in total optical thickness with path length
- Sensitivity changes with elevation angle
- Field-of-view problem towards low elevation angles





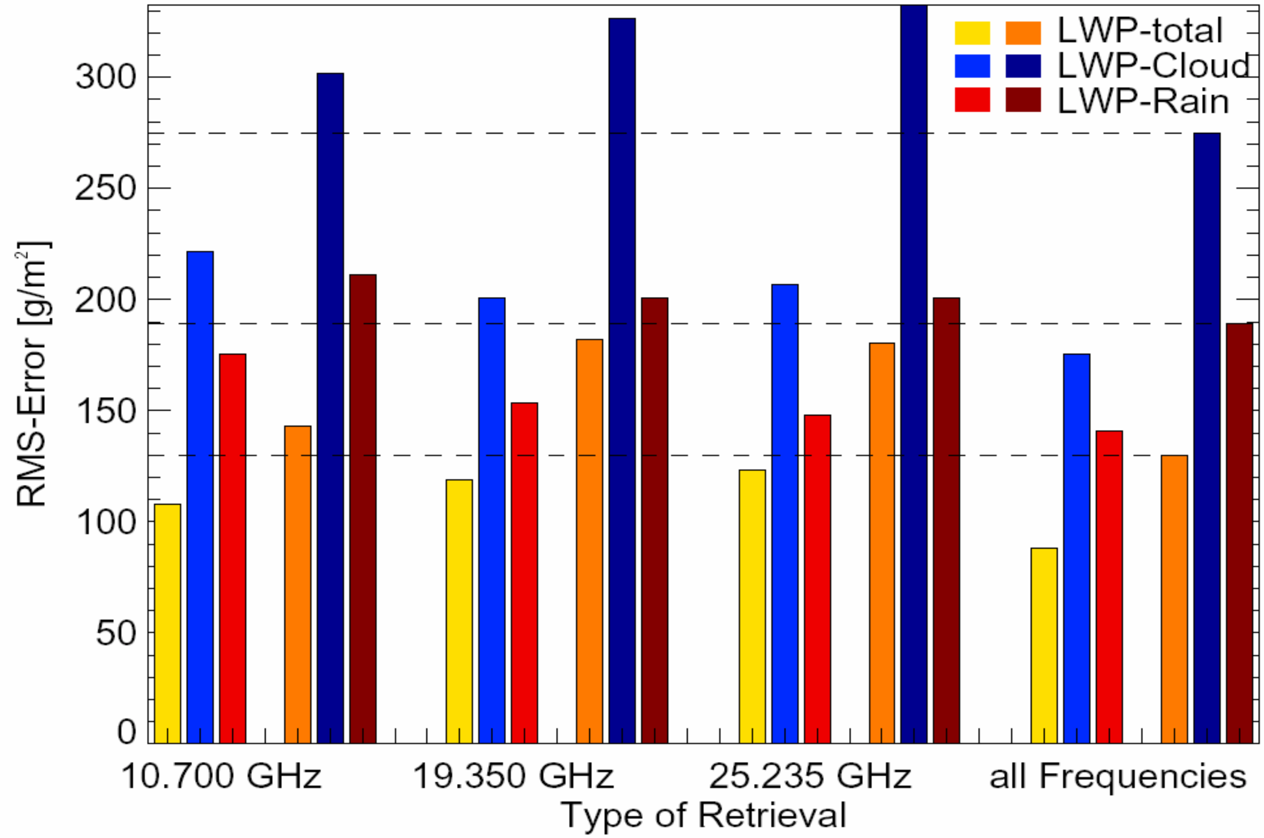
48 degrees, closer to nadir

13 degrees, closer to horizontal

Simulated Effects on LWP Retrieval (from Thiele et al., 2001)

- Regression with and without the polarization difference as input
- Three different single frequencies, one combined retrieval

$\Longrightarrow$ One polarized channel is better than 3 unpolarized channels!



Meteorologisches Institut Universität Bonn

Conclusions

- Polarization signal from oriented nonspherical rain drops gives additional information w.r.t. remote sensing of LWP

- Cloud and rain liqiud water path can be determined independently
  → leads to improved LWP retrieval in raining clouds;

- Rain/drizzle can be detected in clouds with no surface rain rate
  → useful for cloud process studies;

- Requirements for future radiometers:
  - Good pointing quality (beamwidth below 1°)
  - High accuracy (absolute calibration and relative stability)

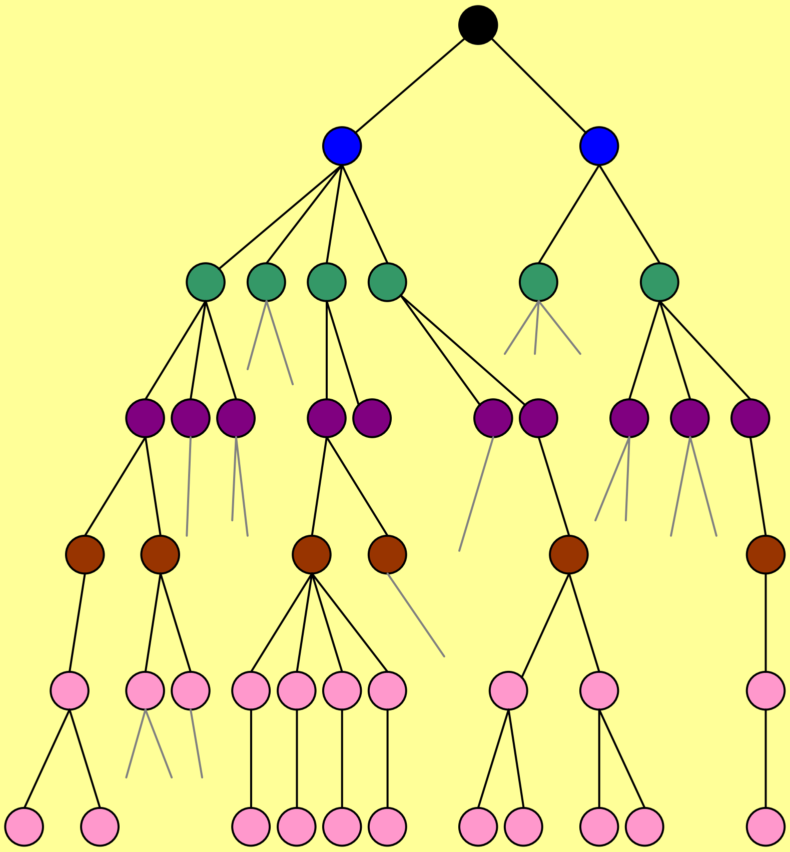
Meteorologisches Institut Universität Bonn

Single scattering data base (general motivation)

- Scattering from nonspherical particles (especially ice particles) has been neglected in almost all satellite retrieval studies;
- There is an interest in the rain community to establish a single scattering data base for the use with any radiation transfer code;

Meteorologisches Institut Universität Bonn

Single Scattering Data Base (old implementation)



- Root node
- Phase
- Shape (encoded)
- Frequency
- Radius
- Real Part of RI
- Imaginary Part of RI

Scattering Data Base (problems to be solved)

- Use improved data base server (MySQL or others, may need help);
- Resolve redundancies (reduce the number of layers if possible);
- Azimuth and zenith angle resolution (determines the size of the stored targets);
- What should be the resolution in RI or temperature? (may depend on ratio of real and imaginary parts of RI);
- How far can we drive the interpolation of results? (e.g. interpolation between different frequencies, angles, etc.);
- Make the data base applicable for as many people (models) as possible;
- Others…