Radiometer Physics GmbH

Discrimination of cloud and rain liquid water path by groundbased polarized microwave radiometry

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Overview

1. Introduction
2. Motivation:
   - Rain contamination of microwave liquid water path (LWP) measurements
   - Sensitivity problem
3. Radiative transfer modeling
4. Sensitivity of TB and PD to a raining atmosphere
5. Proposed retrieval technique
6. Validation results
7. Instrument design

Rain contamination of LWP measurements

- Thick clouds: „in-cloud“ rain, drizzle, no surface rain
- Definition: r < 0.5 mm „cloud“
  r > 0.5 mm „rain“
- Mixture of rain/cloud a-priori unknown

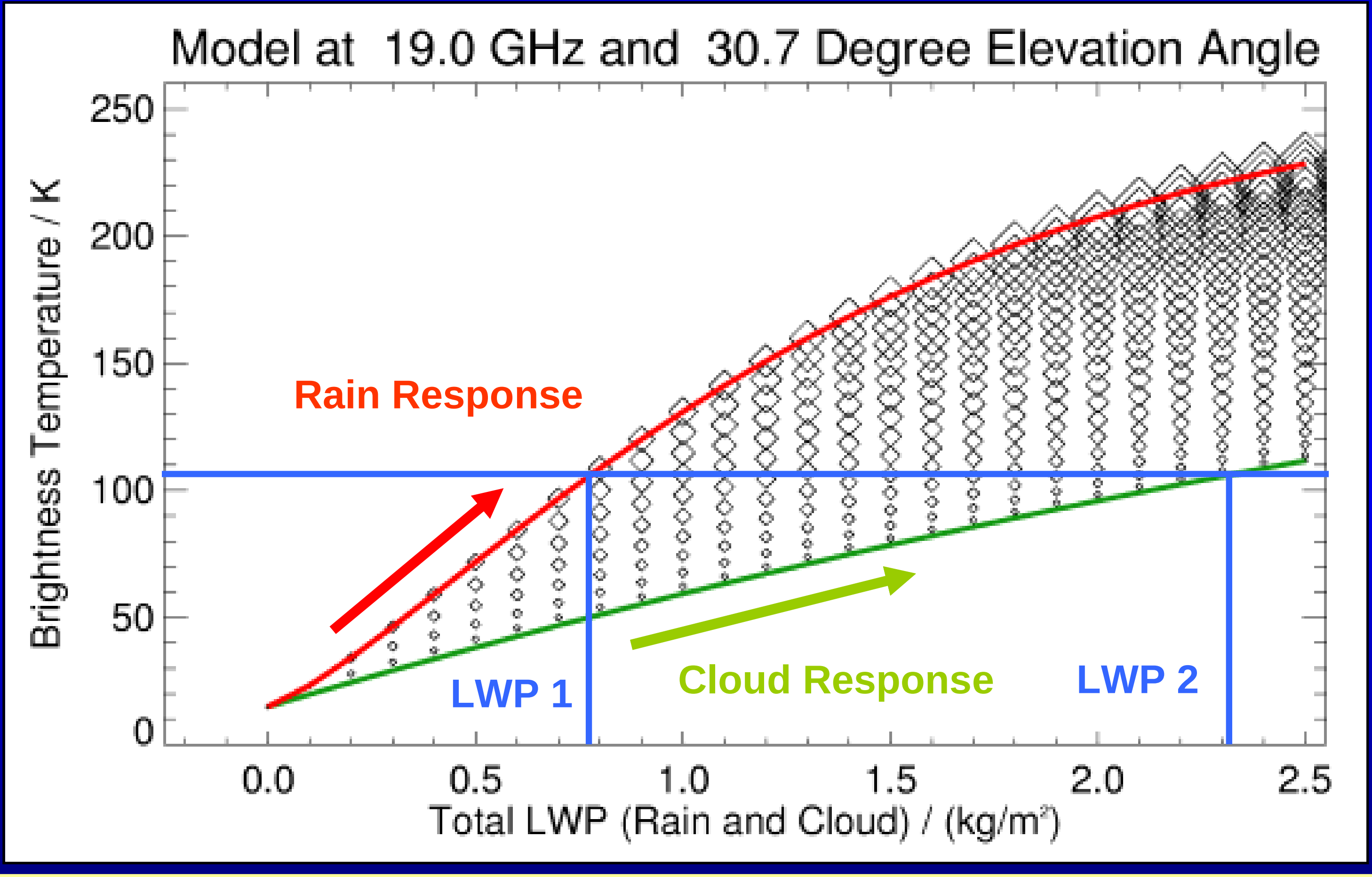
- Passive Microwave observations:
  – ambiguous sensitivity in (TB)
  \+ polarization difference (PD) caused by rain only

- Dual-polarized microwave radiometers required for decomposition of rain and cloud fraction

- Radiative transfer model: TB/PD response of cloud/rain mixtures

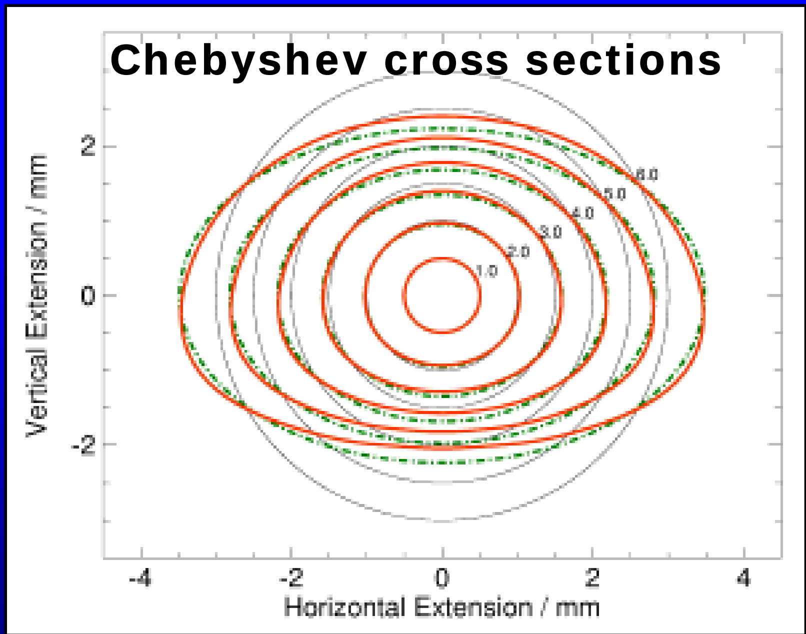
Sensitivity to Drop Size Distribution

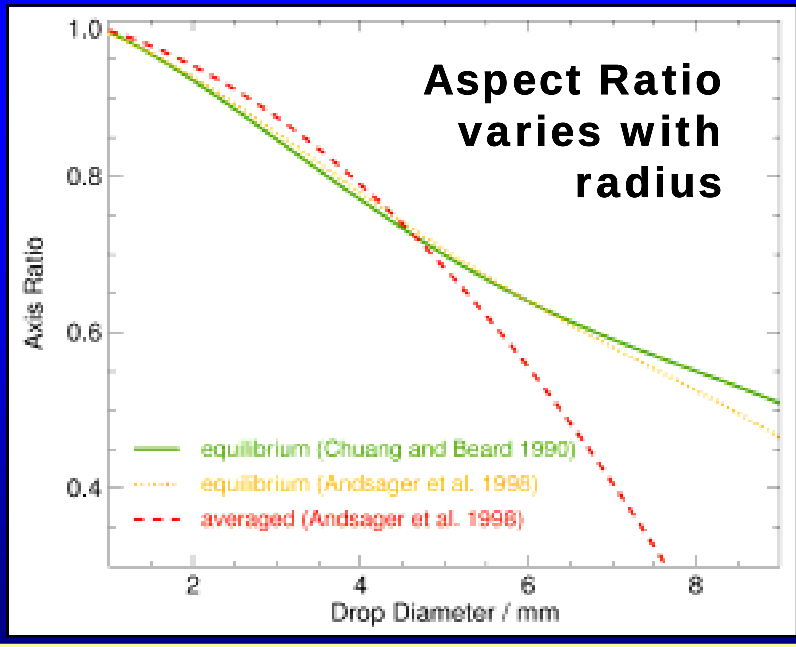
- Sensitivity of TB/LWP dependance different for rain and cloud
- Mixture of rain and cloud unknown
- Ambiguous LWP estimation in the presence of rain



Radiative Transfer Model

- Solves the vector radiative transfer equation (VRTE)
- One-dimensional, plane parallel (coordinates z and Theta)
- Multiple scattering: Successive order of scattering (SOS)
- Single scattering properties: T-Matrix code by Mishchenko
- Rain drops: Chebyshev shapes, Marshall-Palmer DSD
- Mixing of rain and cloud simultaneously in one layer





Vector radiative transfer equation VRTE

$$\frac{d^3\,\overline{\mathbf{I}}(x,y,z,\theta,\phi)}{\frac{1}{\gamma}dx\;\frac{1}{\delta}dy\;\frac{1}{\mu}dz} = -\;\overline{\overline{\sigma}}_e(x,y,z,\theta,\phi)\,\overline{\mathbf{I}}(x,y,z,\theta,\phi)$$

extinction matrix

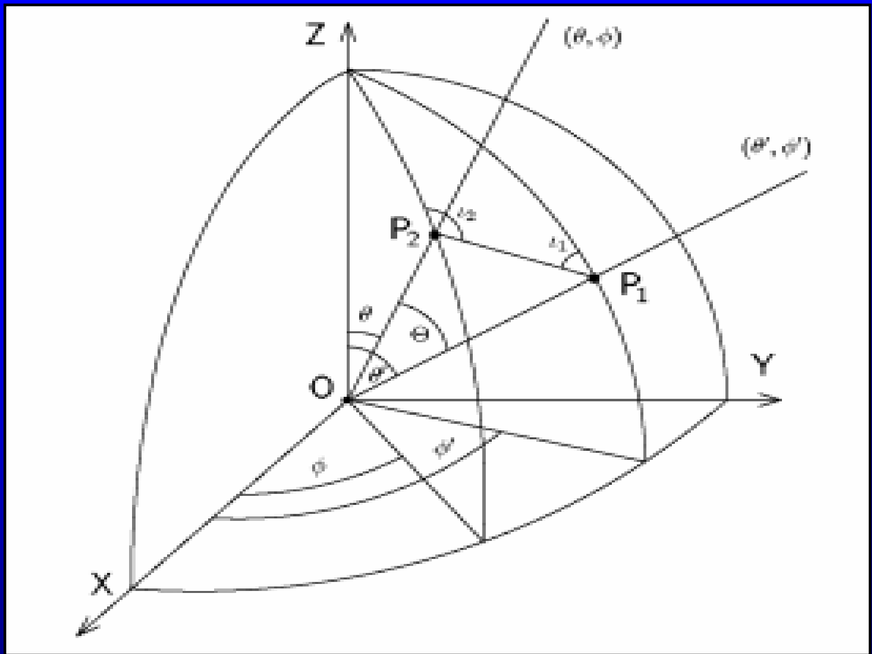
differential change of Stokes vector

$$+\;\overline{\sigma}_a(x,y,z,\theta,\phi)\,B(T(x,y,z))$$

absorption vector

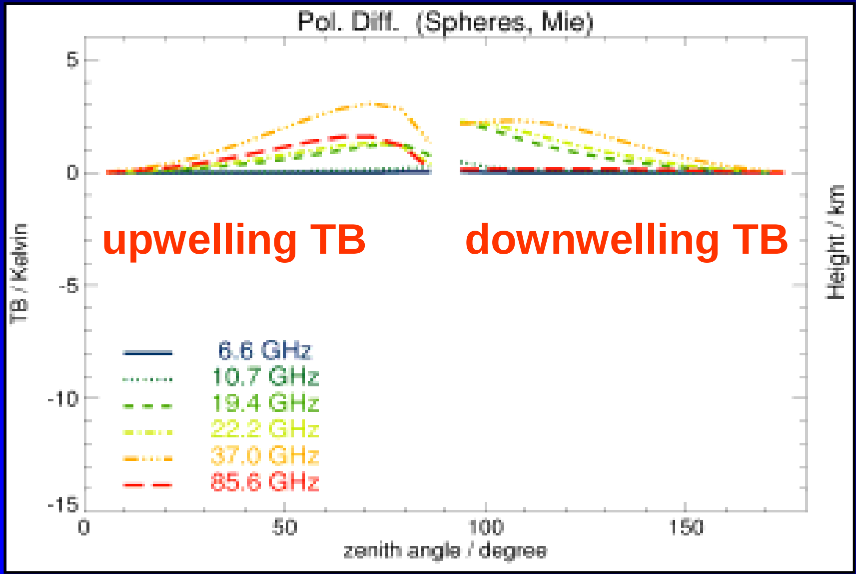
$$+\int_0^{2\pi}\int_0^{\pi}\overline{\overline{\mathbf{P}}}(x,y,z,\theta,\phi,\theta',\phi')\,\overline{\mathbf{I}}(x,y,z,\theta',\phi')\,\sin\theta' d\theta'\,d\phi'$$

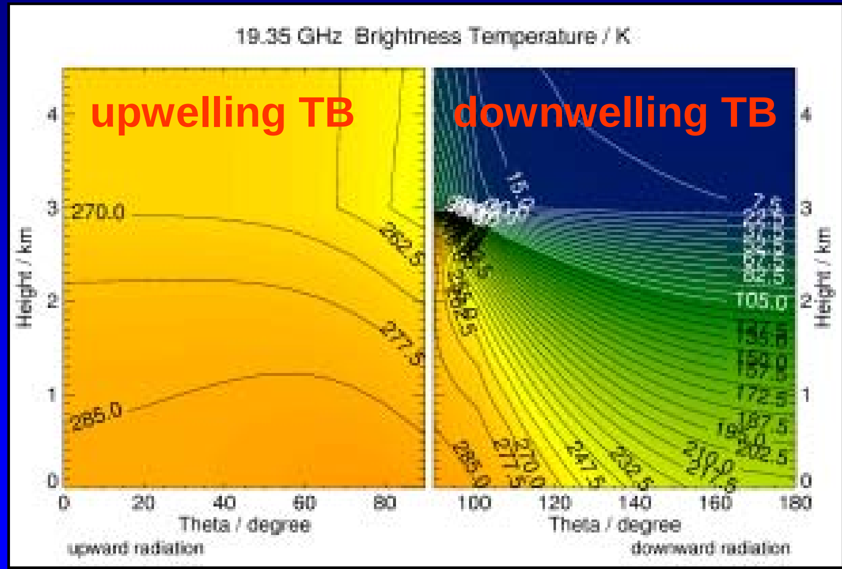
scattering phase matrix

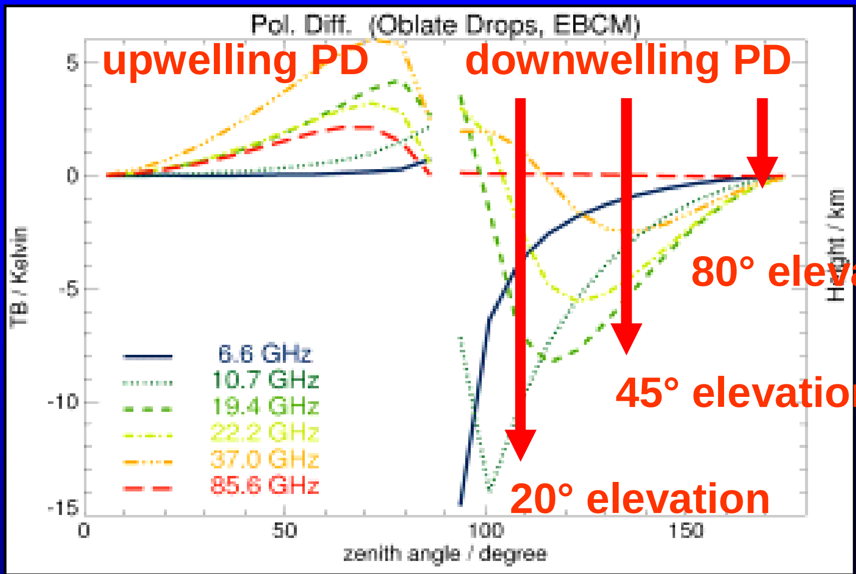


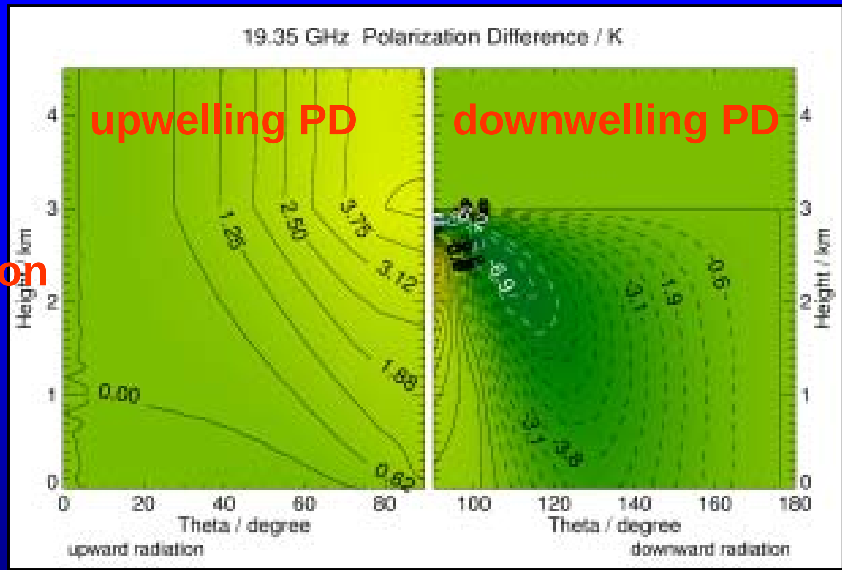
Angles and planes of polarization

Radiative transfer results



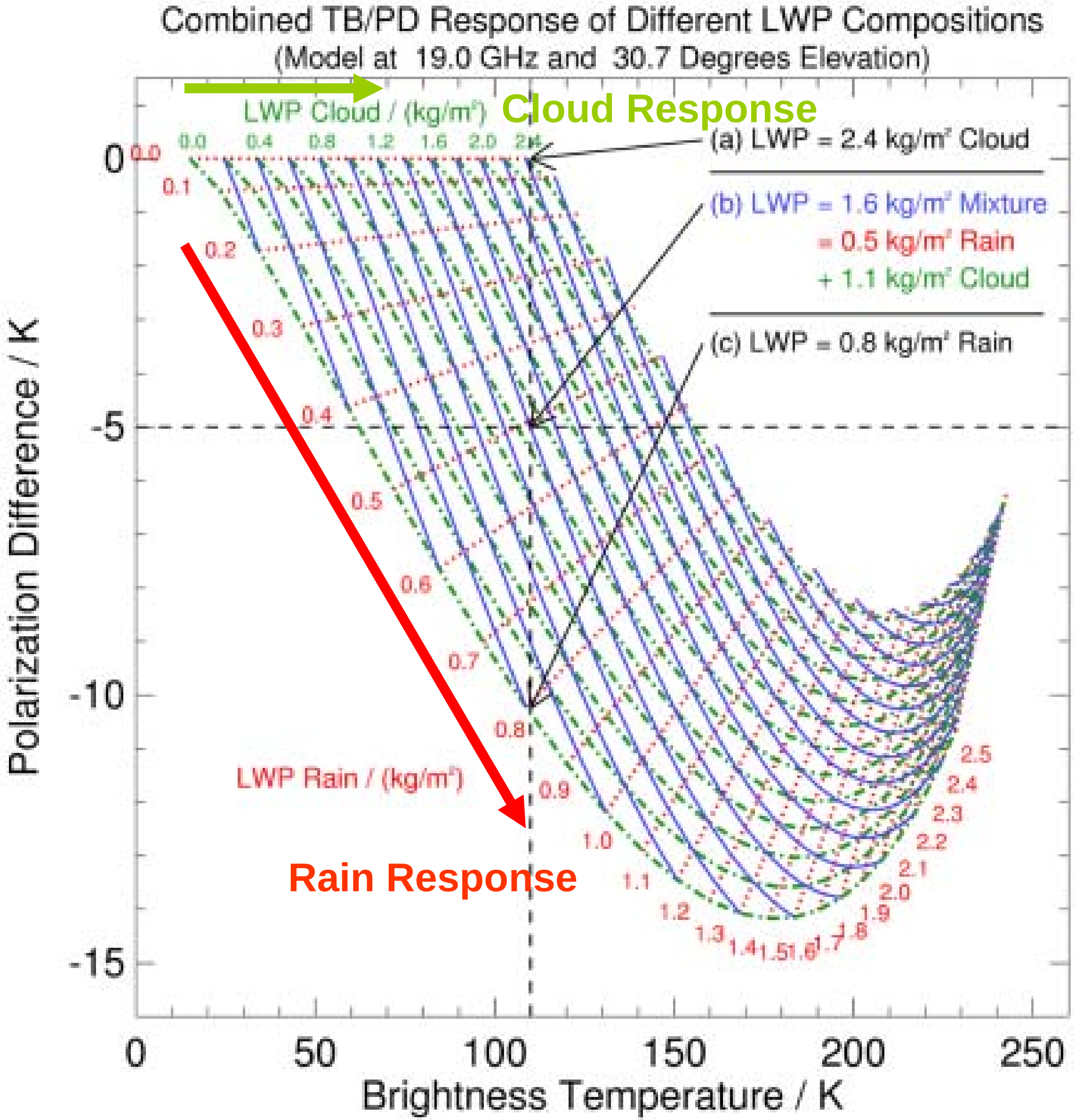






Proposed Retrieval Method

Czekala et al, Geophys. Res. Lett. 28 (2), 267–270, 2001.



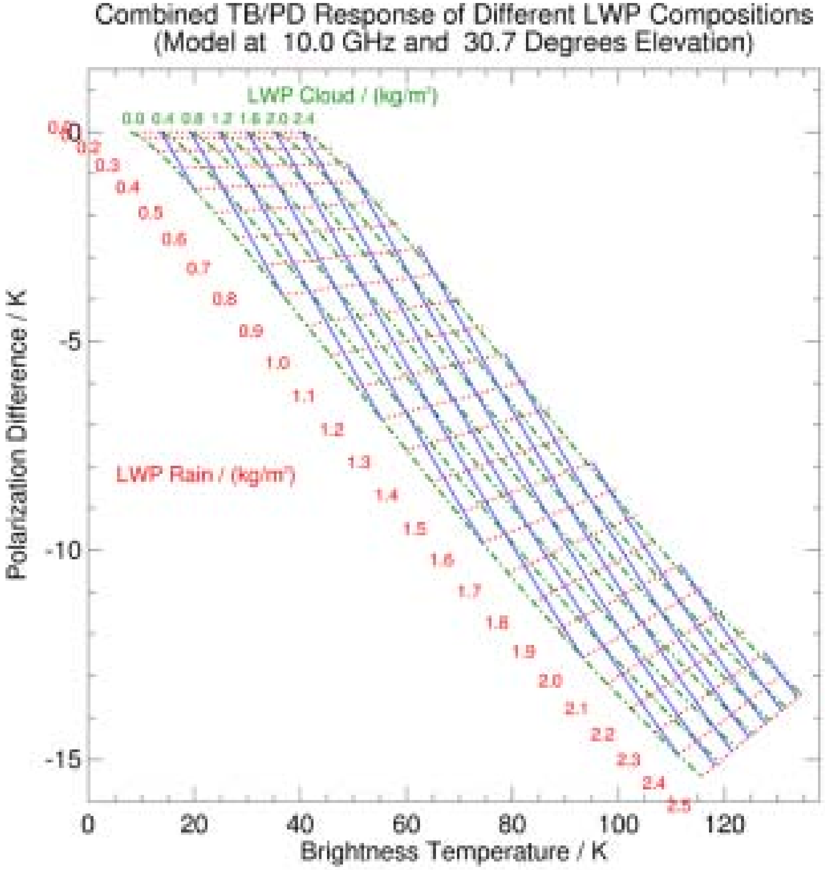
- Along red lines: rain LWP constant, increasing cloud LWP (left to right)
- Along green lines: cloud LWP constant, increasing rain LWP (top to bottom)
- Along blue lines: total LWP constant

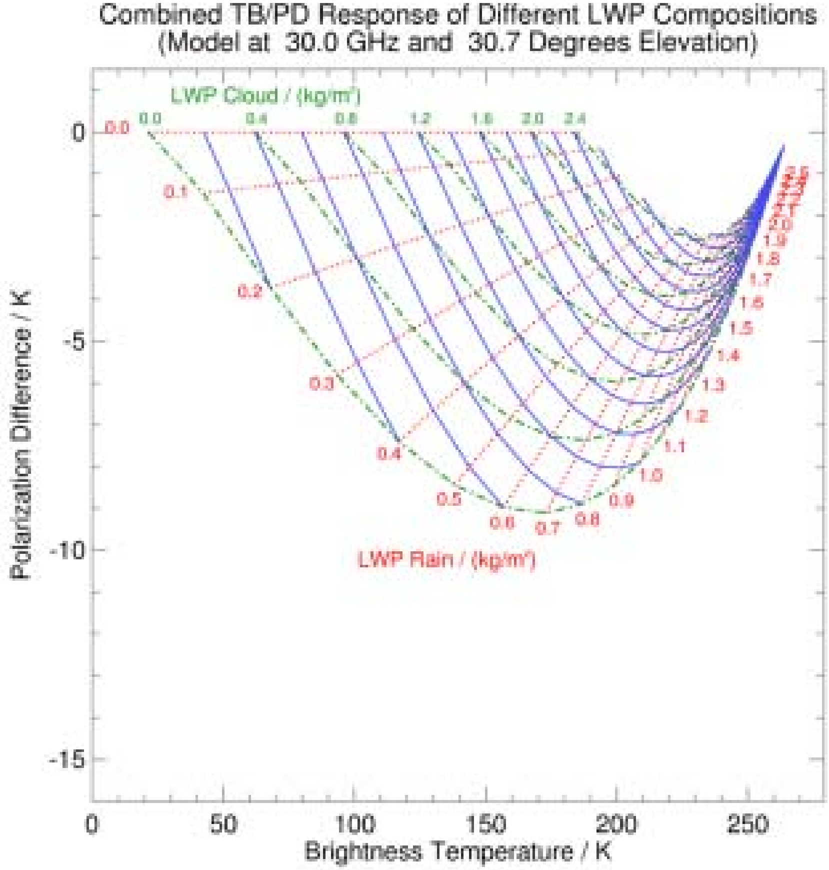
- Simultaneous measurement of brightness temperature and polarization difference
- Independent retrieval of cloud and rain fractions possible
- Accuracy of polarization measurement crucial
- Re-calibration with clear sky conditions

Sensitivity to Frequency

(10 and 30 GHz 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



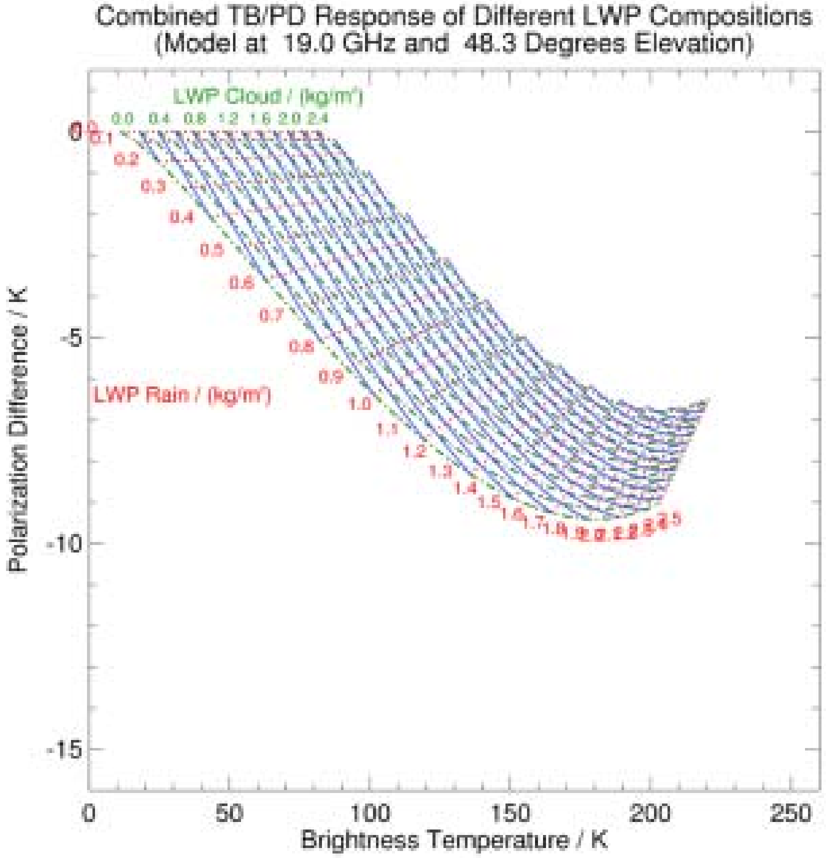


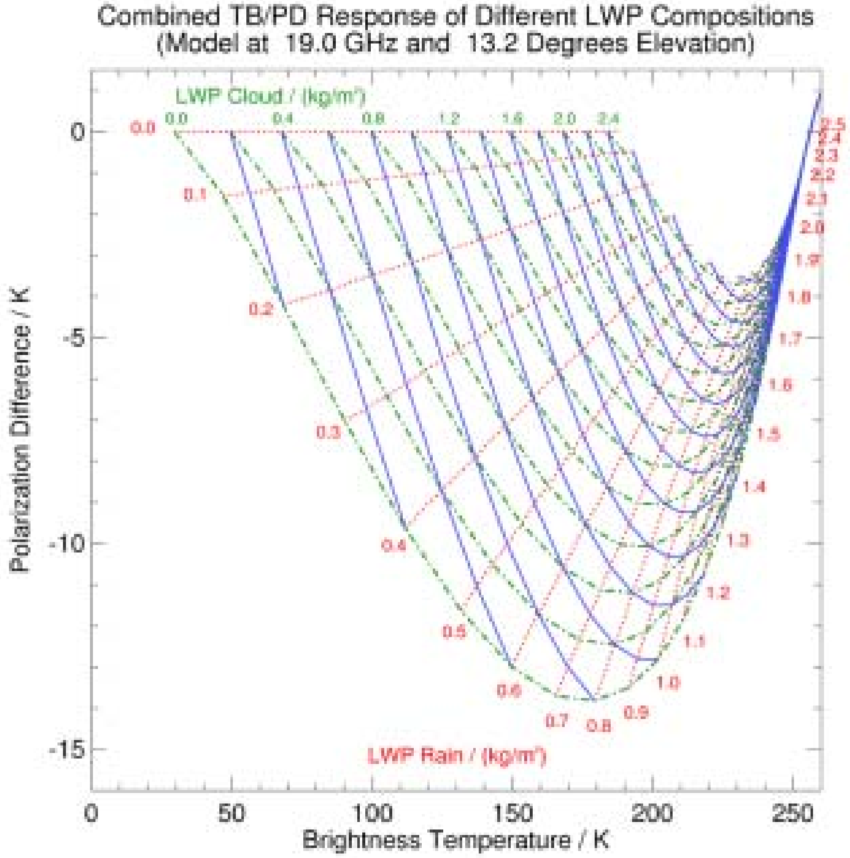
10 GHz: no saturation, good for heavy precip

30 GHz, better for light rain

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

- 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

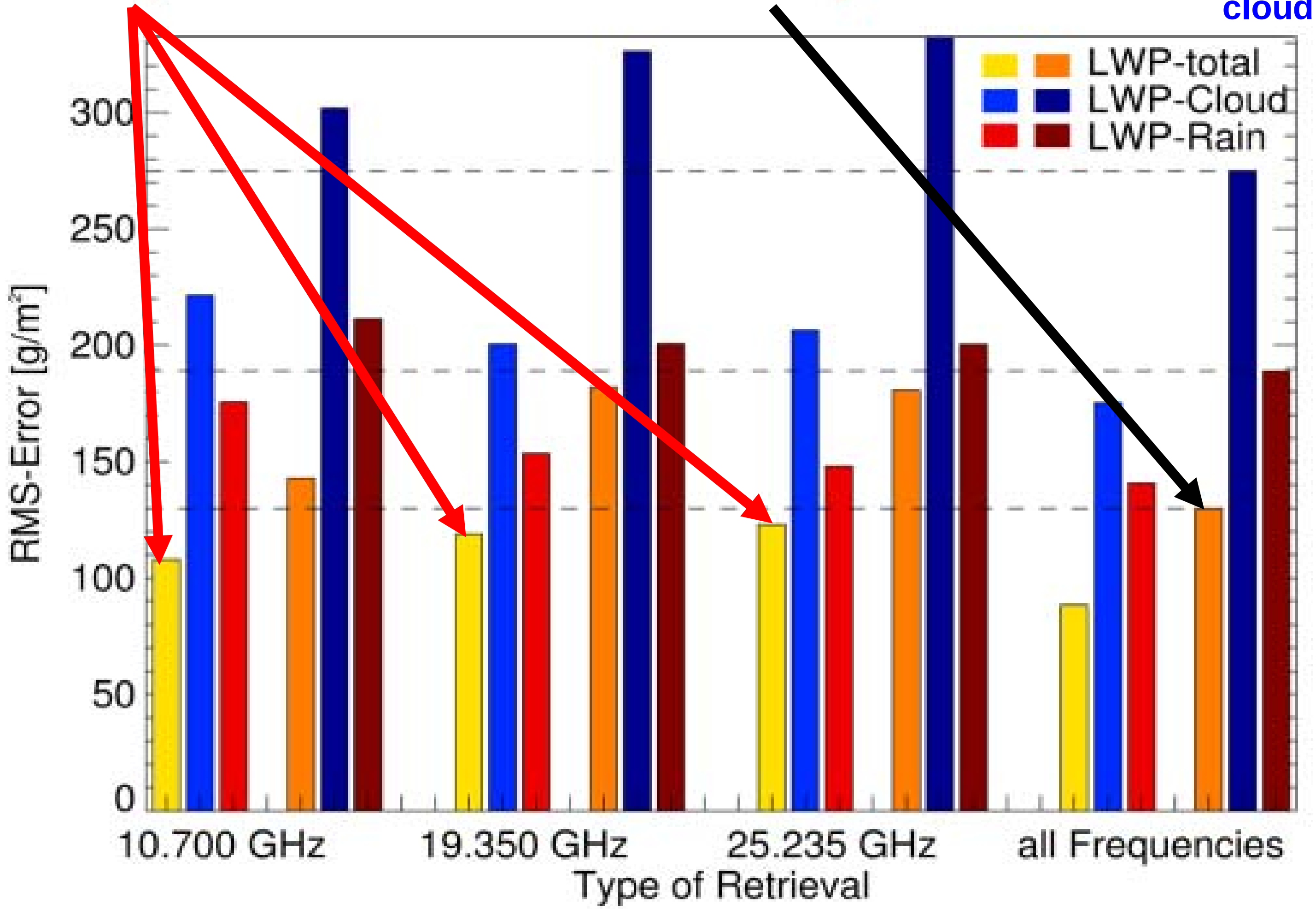
Simulated Effects on LWP Retrieval

(from: Thiele et al. 2001)

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

⟹ One polarized channel is better than 3 unpolarized channels!

Realistic drop size distributions from detailed Microphysical cloud model



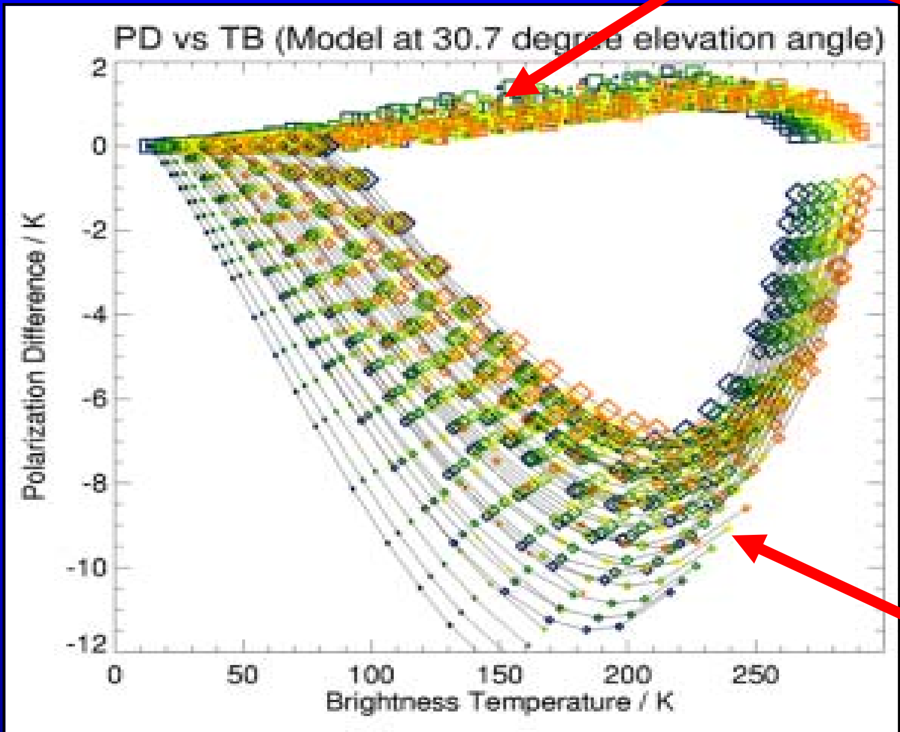
Validation: Model versus Measurements

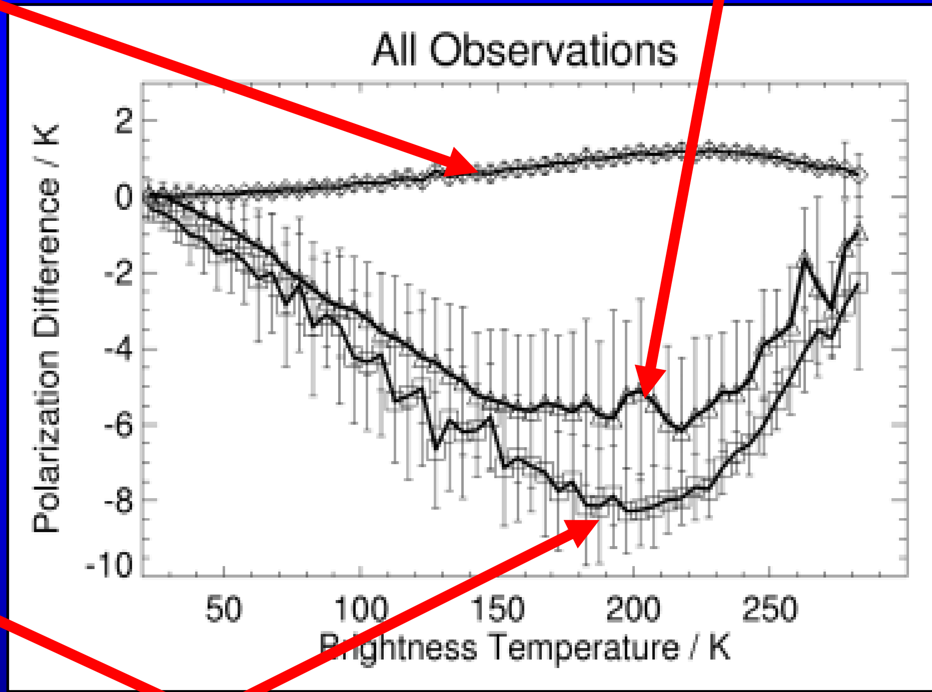
Model calculation with varying
- rain rate
- rain layer height
- air temperature

Measurement data:
- Dual polarized 19 GHz radiometer
- 18 months of data, 10s resolution
- groundbased
- 30° elevation

model with spheres

measurement data

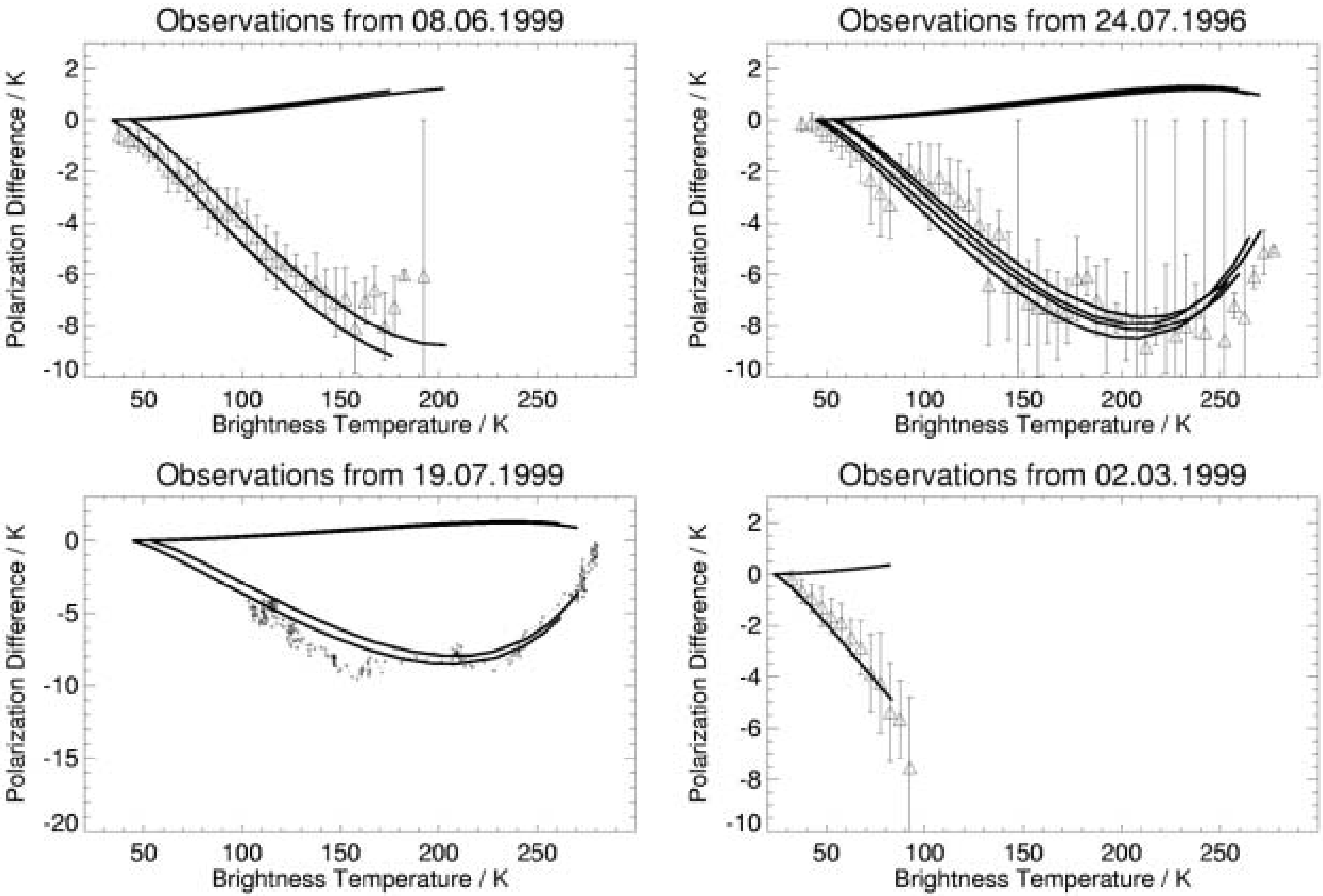




model with non-spherical rain drops

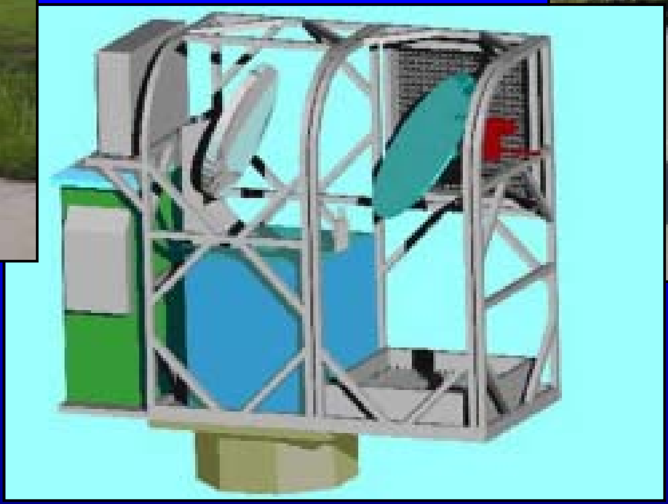
More Measurements

Czekala et al, J. Appl. Meteorology 40 (11), 1918–1932, 2001.



Dual polarized radiometers

- Best frequency: 19 GHz
  additional channels at 10 GHz, and between 30 to 40 GHz
- Vertical and horizontal polarization with better than 0.5 K accuracy
- Non-nadir observation, typically 45° elevation
- Highly stable low-noise receivers



Conclusions

- Polarization signal from oriented nonspherical rain drops gives additional information for the remote sensing of LWP
- Cloud and rain LWP can be derived independently
- Use of polarization leads to higher accuracy of LWP in thick clouds
- Independent and remotely sensed rain detection possible

For further information on polarized instruments and algorithms:

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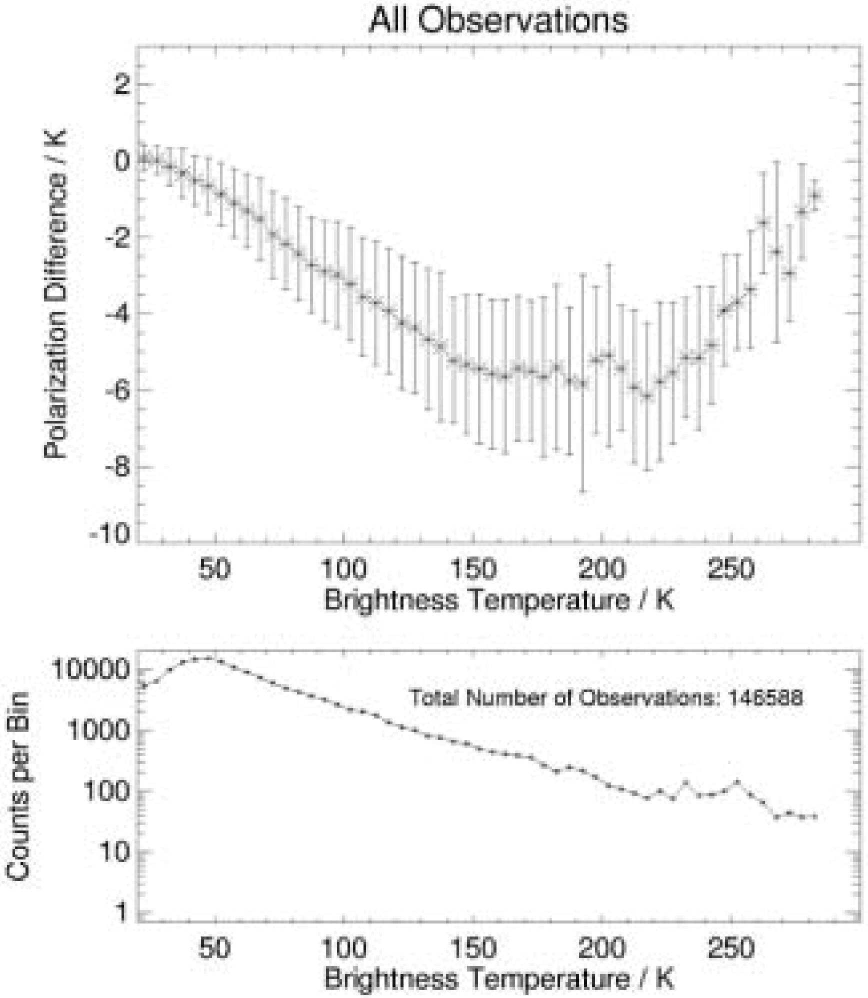
http://www.radiometer-physics.de

More Measurements

Czekala et al, Journal of Applied Meteorology 40 (11), 1918–1932, 2001.

Observation from 18 months



Observations of single rain event