Snow particle orientation observed by ground-based microwave radiometry

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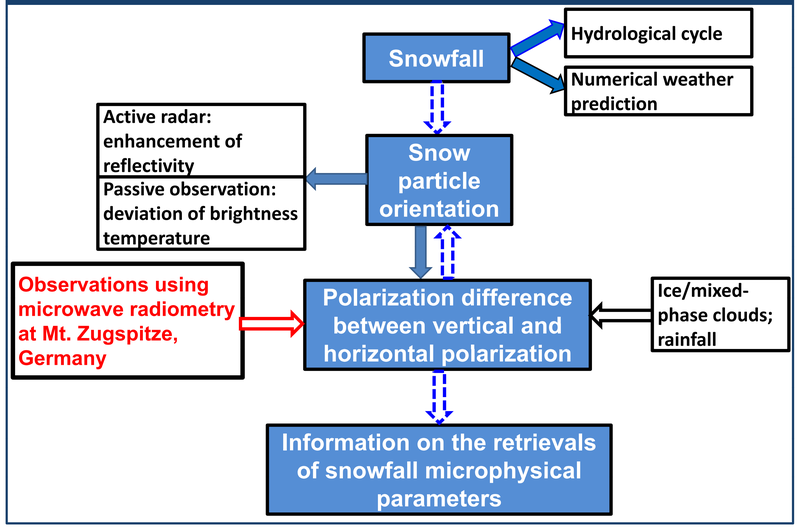
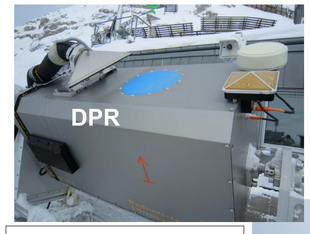
1. Introduction



2. Instrumentation



Dual-Polarization Radiometer (DPR)
- 3 channels: 150 GHz (V & H pol.) & 90 GHz
- Elevation scan period: ~ 14 min (9 elevation angle between 15° ~ 90°)
- Integration time: 2 s

Brightness temperature: $TB_{150} = \frac{1}{2}(TB_{v,150} + TB_{h,150})$
Polarization difference: $PD_{150} = \frac{1}{2}(TB_{v,150} - TB_{h,150})$

Humidity And Temperature PROfiler (HATPRO)
- 7 channels between 22.2 GHz~31.4 GHz;
- 7 channels between 50 GHz~60 GHz

HATPRO:
- Retrievals of Liquid water path and integrated water vapor
- Accuracy: LWP ~30 g/m² IWV ~0.5 kg/m²

Micro-Rain Radar (MRR)
- Frequency: 24.1 GHz
- 1 min temporal resolution
- 100 m vertical resolution

MRR Integrated reflectivity factor (Ze_{int}):
$Ze_{int} = 10*\log_{10}\int Ze(h')dh$
(Ze in $m^{-3}mm^6$)

DPR PD bias correction

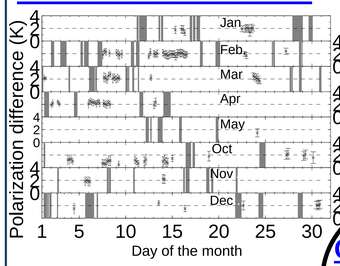


Fig. 1 Time series of 4-hourly mean values and standard deviations of PD during clear sky at 34.8◦ elevation angle in 2010; gray intervals indicate snow periods.

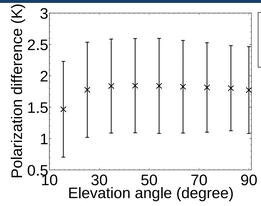


Fig. 2 PD mean value and standard deviation at 150 GHz during clear sky periods in 2010.

Clear-sky period in 2010: **398.5 h**

- PD mean error independent of elevation angles
- mean error ~2 K, std ~0.5 K

- Clear-sky identified by ceilometer and webcams
- DPR has a systematic, but stable offset

Statistical analysis

485 h of snowfall in 2010

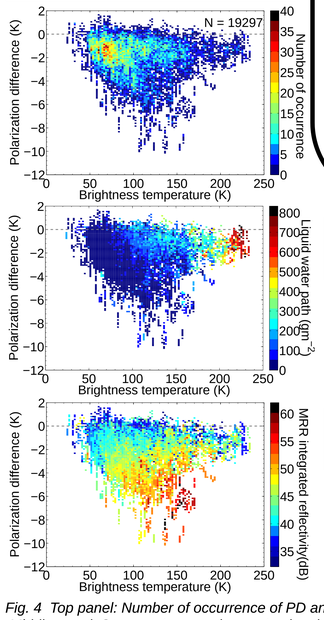


Fig. 4 Top panel: Number of occurrence of PD and TB at 34.8◦ elevation angle for snowfall cases in 2010. Middle panel: Same as top panel except color shows the simultaneously measured zenith LWP derived by HATPRO. Bottom panel: Same as top panel except color shows the vertically integrated reflectivity factor from MRR.

Case study: April 4th,2010

Snow duration: 11 - 19 UTC

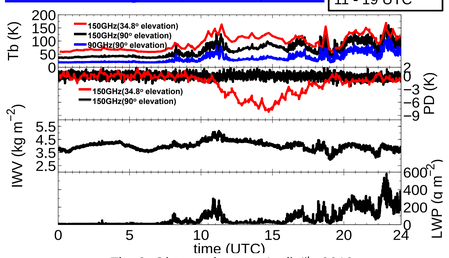


Fig. 3 Observations on April 4th, 2010.

2m-temperature during the day ranged from -6◦C to -12◦C

- **LWP and IWV derived from HATPRO**
- **PD reaches as much as -8 K**
- **TBs are enhanced during snowfall**
- **PD and TB are sensitive to super-cooled liquid water**

Dependence of TB/PD on LWP derived by HATPRO

- Supercooled water **enhances TB** due to strong emission
- Supercooled water **damps PD**
- PD > -4 K only when LWP < 200 g/m²

Dependence of TB/PD on Ze_{int} from MRR

- Ze_{int} closely related to snow water path
- **TB and PD values increase with Ze_{int}**
- PD up to -8 K with Ze_{int} > 55 dB and LWP < 200 g/m²

4. Analysis based on radiative transfer calculations

Case study: April 4th,2010

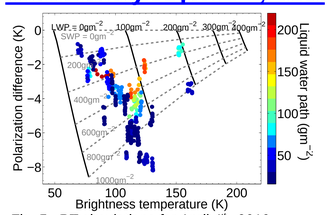


Fig. 5 RT simulations for April 4th, 2010

With the increase of LWP(SWP),
PDs decrease(increase);
TBs increase(increase)
→Consistent with measurements in *Fig.4*

To interpret observation results, RT calculations are performed:

- T-matrix & RT4 model
- **Horizontally-oriented snow oblates** with an aspect ratio (AR) of 0.5
- Mass-size relationship: Matrosov 2007
- Exponential size distribution
- mono-size liquid water drops

SWP contours (0~1000g/m²): gray dashed lines
LWP contours (0~400g/m²): black solid lines

Dots in *Fig. 5* → DPR measurements between 11 UTC and 19 UTC (*Fig. 3*)
Dots' color → corresponding zenith LWP derived by HATPRO

Mismatch between measurements and simulation due to
- **Different observation geometry (slant vs zenith)**
  e.g. rapid change of LWP at the beginning and at the end of snowfall (*Fig. 3*)
  →**instrument scan synchronization**
- **Uncertainties of snow microphysics**
  e.g. snow particle aspect ratio, shape, density, liquid water, and surface emissivity…effects on TB /PD
  →**further studies…**

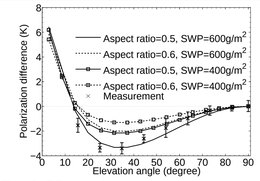
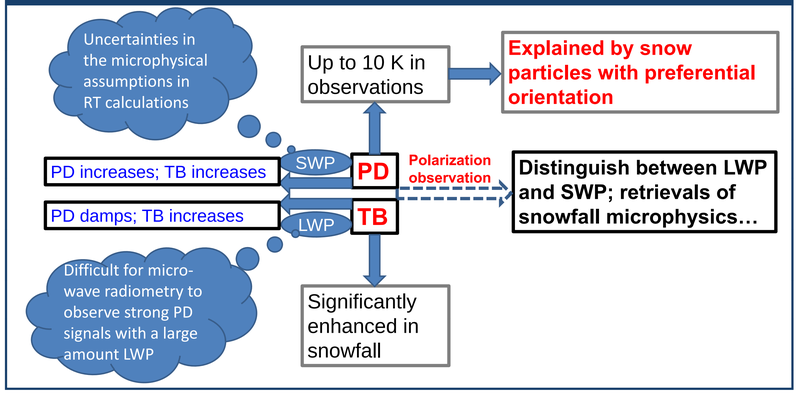


Fig. 6 PD as a function of elevation angle (measurement results between 16 UTC-16:30 UTC)

Information with elevation scan & AR/SWP effects

5. Conclusions and discussion



Reference: *Xie, X., U. Löhnert, S. Kneifel, and S. Crewell, 2011: Snow particle orientation observed by ground-based microwave radiometry, submitted to Journal of Geophysical research.*