High-resolution vertical profiles of X-band polarimetric radar observables during snowfall in the Swiss Alps

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Motivation

Snow crystal habit

- Can snow microphysical processes be observed with an X-band polarimetric radar?
- Can such a radar distinguish different snow particles?

General atmospheric behavior

- Do X-band polarimetric variables exhibit a general behavior with height?
- Can such a behavior be related to atmospheric processes?
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In order to properly quantify the instrumental errors, it is necessary that the accuracy of the local deviation estimates is significantly smaller than the considered errors. The first step in checking this concerns the quality of the sun ephemeris. (\cite{sun_ephemeris}) provides an accuracy for the sun position in azimuth and elevation with a maximum error of about 0.003 deg from 2003 to 2023, which is far enough. In order to reach this accuracy, the geographic position (referred to WGS84 ellipsoid) of the center of rotation of the antenna has to be known with an error smaller than 0.001 deg (i.e. about 110 m, reachable with a standard GPS beacon). It must be noted that the vertical deflection can be non-negligible, especially in mountainous regions, and in that case must be taken into account. This angle represents the difference at the same position between the true zenith, which is the reference for the astronomical Radar at 2133 m above sea level.

- Considered period: End of February to end of April 2010.
- Around 110 hours of snowfall collected above the melting layer.
- Contrasting snow events: cold dry snow, aggregates, graupel, dendrites.
Overview

GPS receiver

Radar

Snow height, temperature and humidity stations

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Radar constant determined with a corner reflector.
Radar orientation determined by sun tracking.
$Z_{dr}$ is calibrated by rotating the antenna at 90° elevation.
Experimental data (1)

**Radar**
- RHI scan every 5 min.
- 150 samples per ray at 1° resolution.
- 6 vertical profiles extracted between 5 and 10 km distance from the radar.

**Water vapor**
- Water vapor path (WVP) inferred from GPS signal.
- WVP separated into three temperature segments by using the humidity and temperature measurements at different height levels.

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- Snow accumulation per time inferred from several snow height sensors.

**Temperature profile**

- Determination of the $0^\circ$ level by fitting temperature measurements at different height levels.
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Distribution of polarimetric observables

Dendrification signal in $Z_{dr}$ and $K_{dp}$ \rightarrow Kennedy et al., JAMC, 2011.

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Mean Hydrometeor identification

- Increasing abundance of aggregates towards higher temperatures.
- Increasing abundance of graupel towards higher temperatures.

Aggregates, Crystals, High density graupel, Low density graupel

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Polarimetric profiles as a function of humidity

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Polarimetric profiles as a function of humidity

- Signature of dendrification in high water vapor conditions.
- Increased abundance of graupel in high water vapor conditions.
- Increased abundance of crystals in low water vapor conditions.

Aggregates, Crystals, High density graupel, Low density graupel
Hydrometeor identification vs. snowfall rate

- Increased abundance of aggregates for high snowfall rates.

Aggregates, Crystals, High density graupel, Low density graupel

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- The average behavior of around 8000 vertical polarimetric profiles measured with an X-band radar above the melting layer has been studied.
- X-band polarimetric profiles as a function of the height above 0°C are related to microphysical processes such as dendrification, aggregation and riming.
- High snowfall rates are coupled to increased riming occurrence.

Outlook

- Are we able to theoretically reproduce and confirm these observations by coupling an electrodynamical model to a snow microphysics model?
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