Estimating radar reflectivity - snowfall rate relationships and their uncertainties over Antarctica by combining disdrometer and radar observations

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1. Motivation

- Precipitation measurements over the Antarctic Ice Sheet are scarce
- However, precipitation is an important regulator of the surface mass balance and regulates sea level change.
- Radar offers the possibility to obtain direct ground-based measurements of precipitation intensity.
- To convert radar reflectivity (Ze) to snowfall rates (SR), information about the microphysical characteristics of snow particles is necessary.

2. Instrumentation

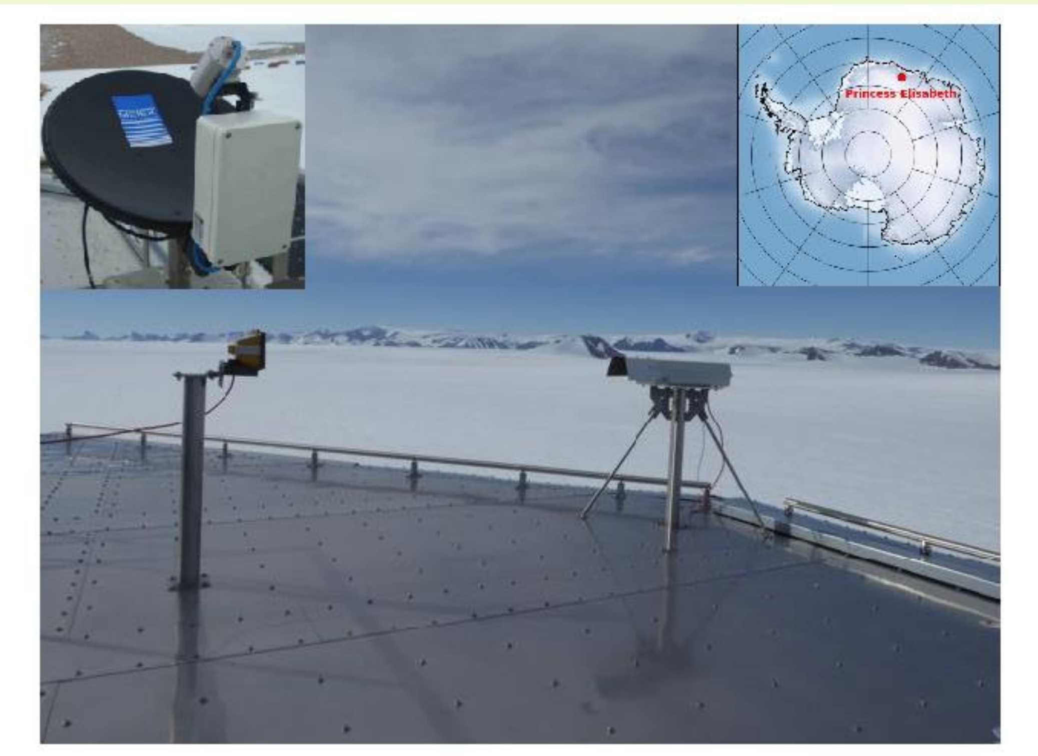
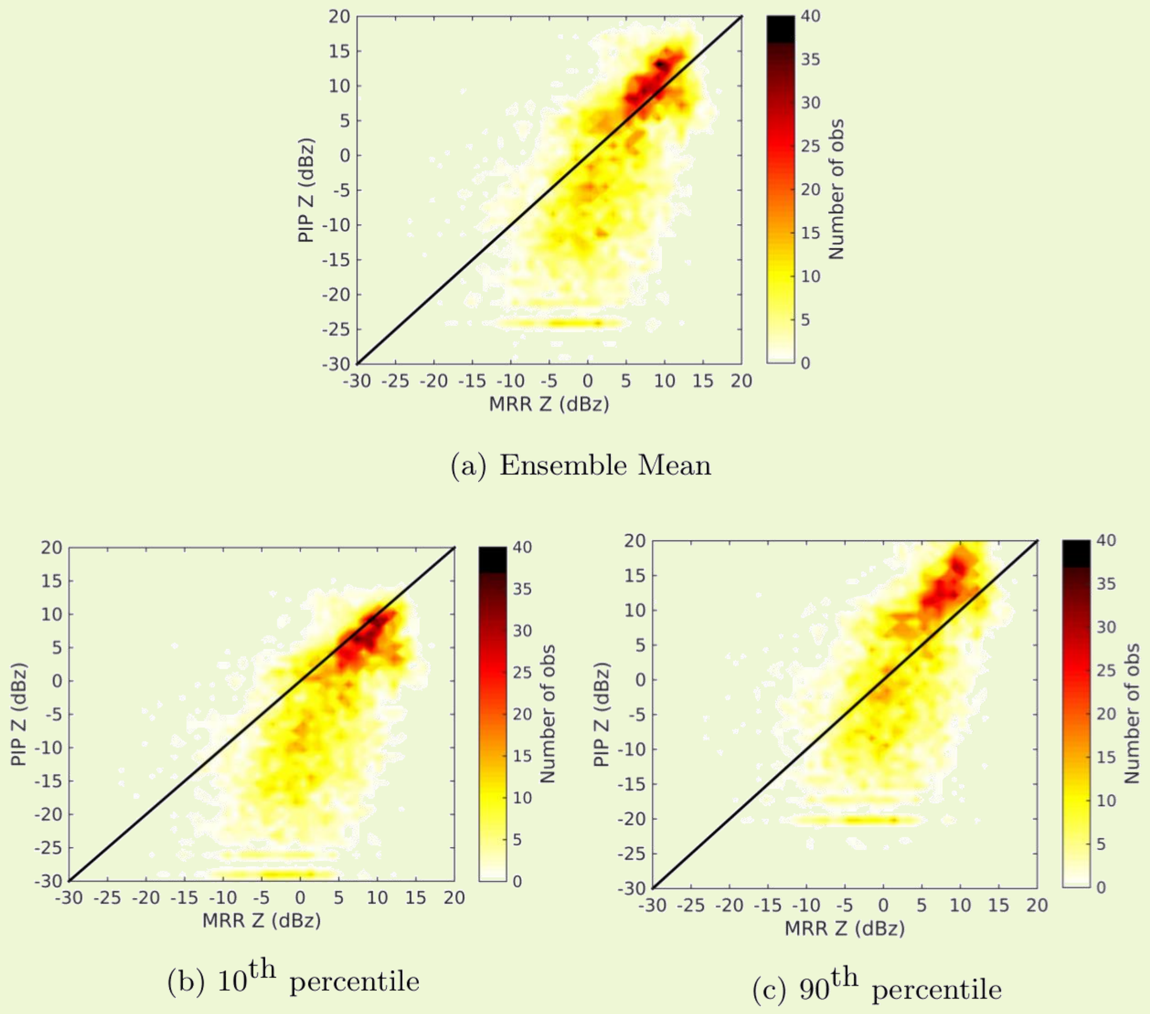


Fig. 1: The PIP deployed on the roof of the Princess Elisabeth station. The upper left inset shows the MRR, while the upper right inset shows the location of the Princess Elisabeth station.

- Precipitation Imaging Package (PIP; Newman et al., 2009):
  - High speed camera (360 frames/second)
  - Obtains snow microphysical properties as e.g.:
    - Particle size and distribution
    - Fall speeds using a tracker algorithm
- Micro Rain Radar (MRR)
  - Vertically pointing radar (24 GHz)
  - Adapted for snowfall (Maahn and Kollias, 2012)

3. PIP vs MRR



(a) Ensemble Mean

(b) 10th percentile

(c) 90th percentile

Fig. 2: Comparison of the Z values measured by the MRR and the ensemble mean, 10th and 90th percentile of the bootstrapping simulations of the PIP.

- Reflectivity values of PIP are obtained at the surface, while for the MRR at 300 m above ground level.
- For smallest snowfall events, there is a bigger discrepancy between both instruments. Low level sublimation plays a big role (Wood, 2011).

4. Ze-SR relation and uncertainty estimation

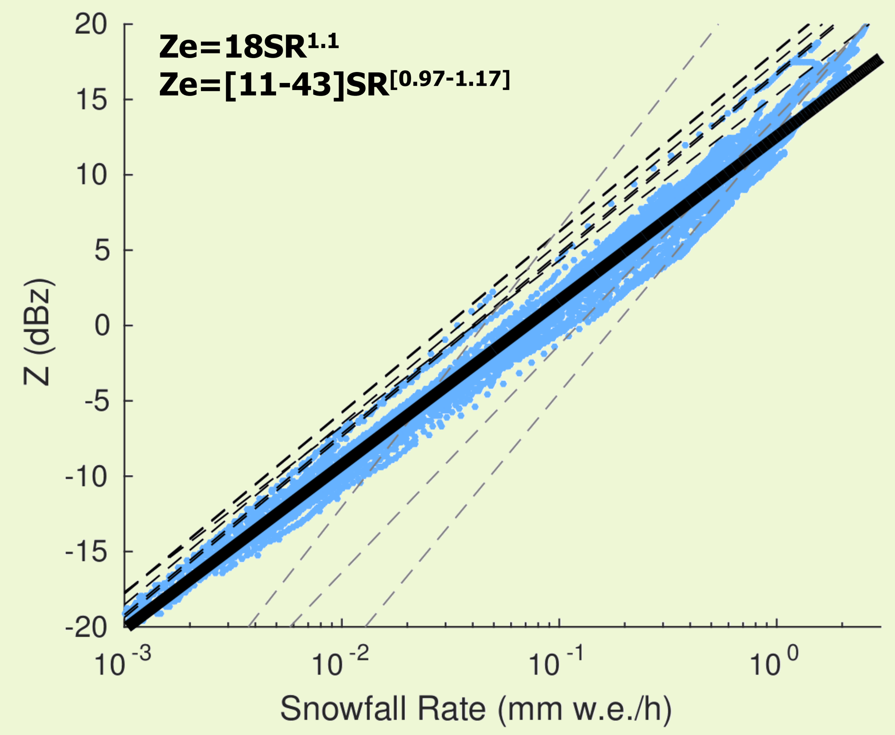


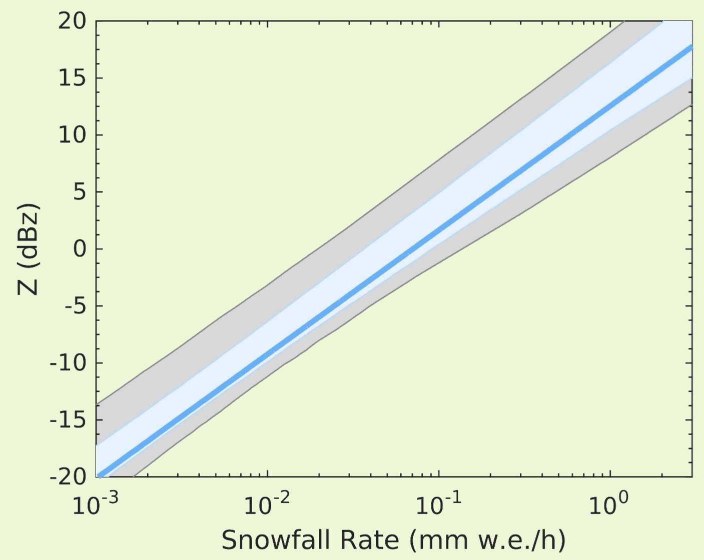
Fig. 3: Ensemble Z and SR values derived from the median of the bootstrapping simulations (blue dots). Dashed black and grey lines denote relations obtained from literature, while the thick black line indicates the resulting average Ze-SR.

1) Uncertainties on Ze-SR are smaller than the individual uncertainties on Ze and SR as errors compensate each other (Tab. 1).

2) Parameter uncertainty is the largest uncertainty term apart from the variability between snow storms (Tab. 1).
- Mainly attributed to the uncertainty in mass of snow particles.
- Not the detection of the shape of snow particles, but mass needs to be constrained in order to improve Ze-SR relations efficiently.

3) The Ze-SR relation has a lower prefactor (A=18) than relations derived over mid-latitudes.
- The size of snow particles during an event and the value of the prefactor (A) are related.
- A sensitivity study showed the prefactor equals 44 at more coastal sites (larger snowflakes), while at inland location it approximates 7 (smaller snowflakes).

Fig. 4: The 10-90 and 1-99 percentile uncertainty (blue and grey shaded area) on the Ze-SR relation. The ensemble average relation is denoted by the thick blue line.



Uncertainty	Ze	SR	Ze-SR relation
Measurement	[-24% +34%]	[-18% +21%]	[-8% +9%]
Shape	[-23% +42%]	[-13% +14%]	[-11% +12%]
Parameter	[-52% +106%]	[-59% +56%]	[-39% +38%]
N(D) variability	/	/	[-36% +66%]
Total	[-59% +132%]	[-54% +77%]	[-59% +60%]

Tab. 1: 10-90 percentile uncertainties on the estimates of Ze and SR and the derived Ze-SR relations.

Approach

- Using PIP measurements it is possible to calculate radar reflectivity (Ze) and snowfall rate (SR).

$$Ze = 10^{18}\frac{\lambda}{\pi^5|K|^2}\int_0^\infty \sigma_b(D)N(D)dD \qquad SR = \frac{3600}{\rho_w}\int_0^\infty m(D)v(D)N(D)dD$$

- 12 snow storms are sampled (> 120 hours of data).
- Uncertainties are estimated (Fig. 3)
- A bootstrapping technique was applied to obtain uncertainty.

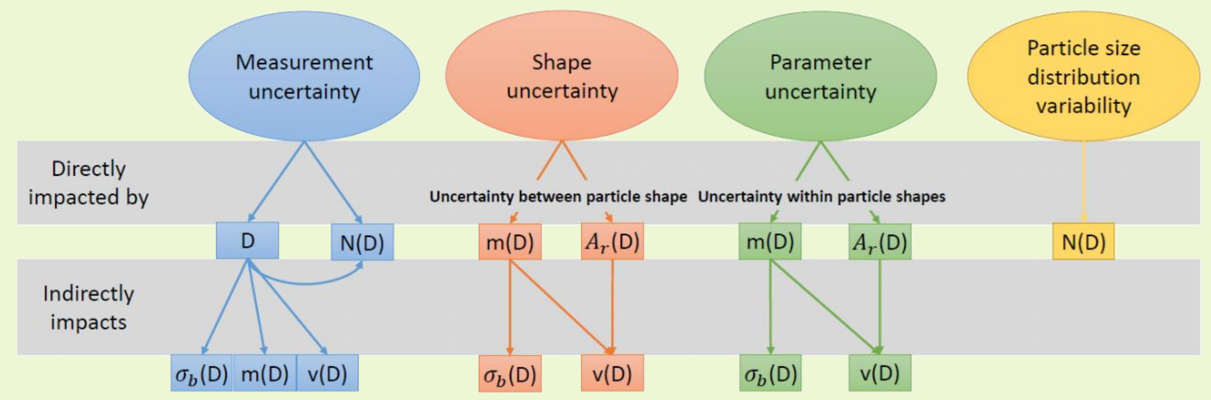


Fig. 3: Overview scheme listing the four uncertainty terms and different terms contributing to each uncertainty. The lines denote error propagation.

References

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- Wood, N.B, 2011. Estimation of snow microphysical properties with application to millimeter-wavelength radar retrievals for snowfall rate. PhD thesis, Colorado State University, pp. 218.