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

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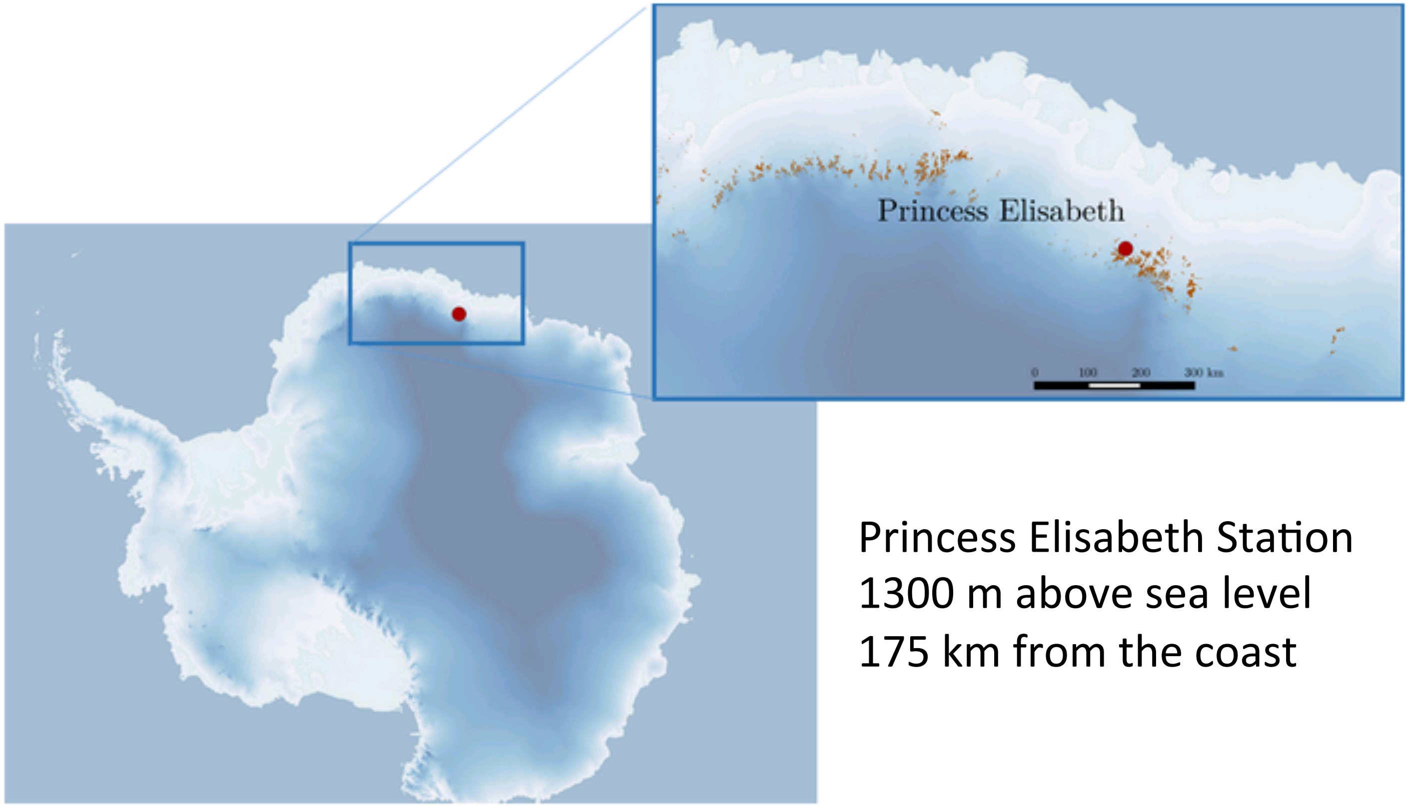
Presenting author: N.P.M. van Lipzig

The setting

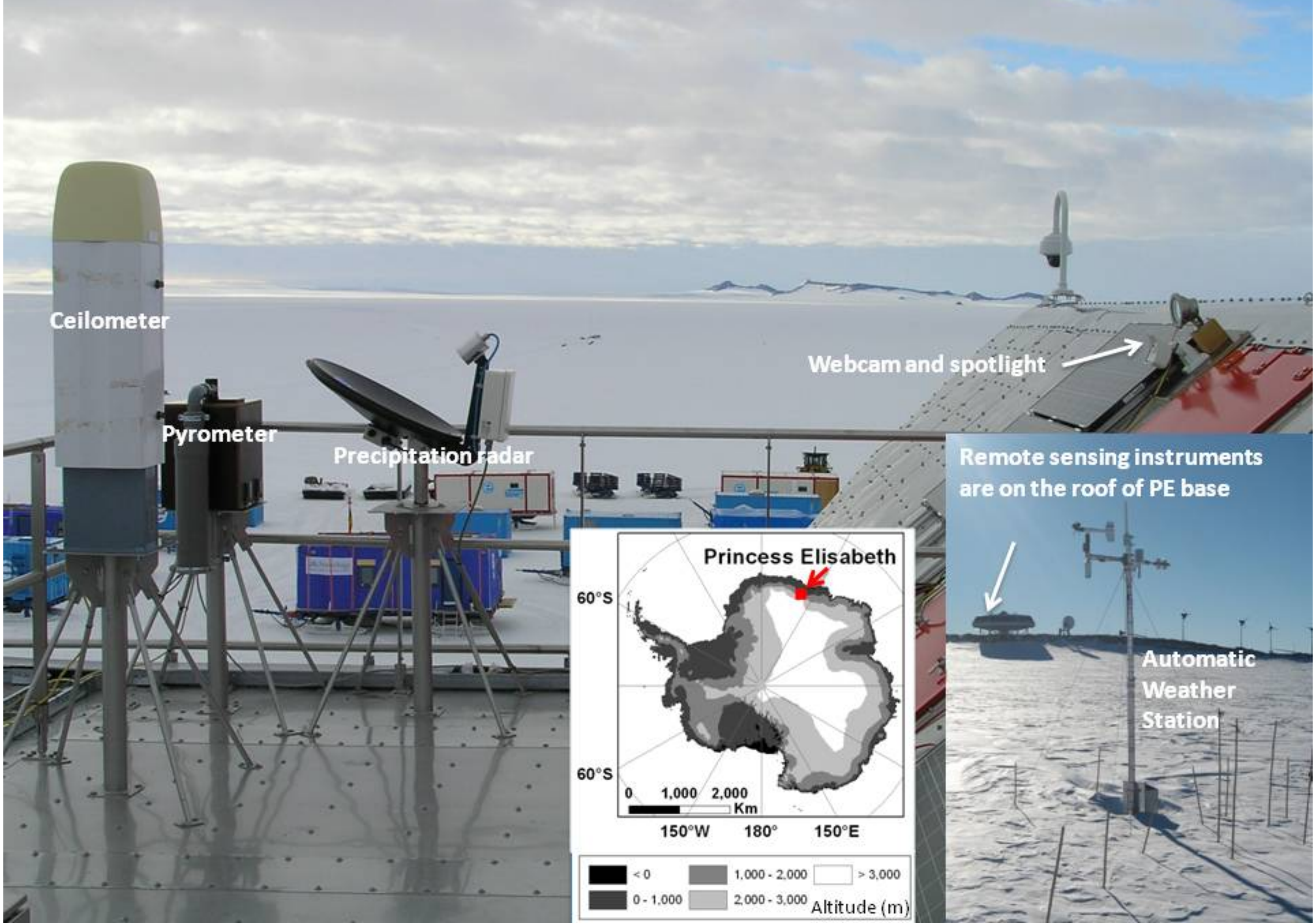


Princess Elisabeth Station
1300 m above sea level
175 km from the coast

Motivation

- Antarctic ice sheet equivalent to about 60m global sea level rise
- Precipitation is the only source of mass to the ice sheet
- Information mostly about net accumulation (stakes, height ranger)
- Precipitation measurements over the Antarctic Ice Sheet are scarce
- Information on clouds is limited, which stands in contrast with their importance for the surface energy balance

Robust, low power consumption, low cost instrumentation: www.aerocloud.be

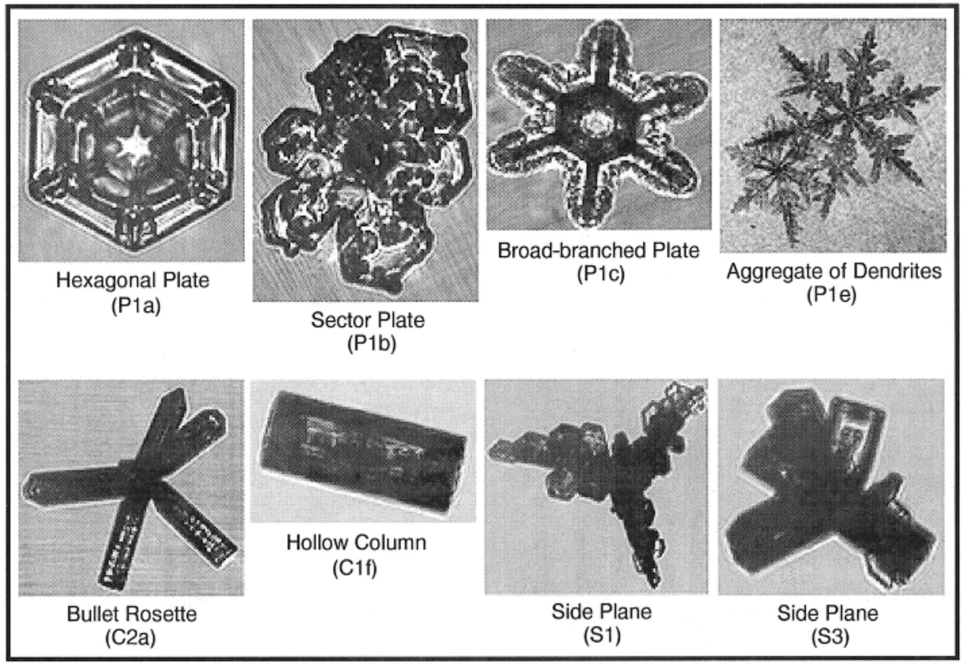


Gorodetskaya, van Lipzig, et al., the cryosphere, 2014

Motivation

- Radar: ground-based measurements of precipitation intensity.

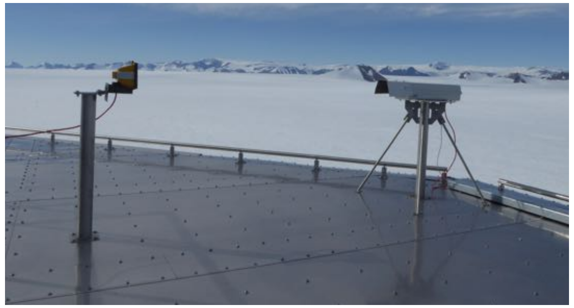
- To convert radar reflectivity factor (Ze) to snowfall rates (SR), information about the microphysical characteristics of snow particles is necessary



Heymsfield and Miloshevich, 2003

Instrumentation

- 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.
  - Jan-May 2016
  - Vertical profiling between 300-3000m



- Micro Rain Radar (MRR):
  - Vertically pointing radar (24 GHz)
  - Adapted for snowfall (Maahn and Kollias, 2012)
  - Low cost and low power consumption radar
  - Operational since 2009

Souverijns, van Lipzig, et al., AR, 2017

Methodology

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

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

- 120 hours of snowfall (12 individual events)

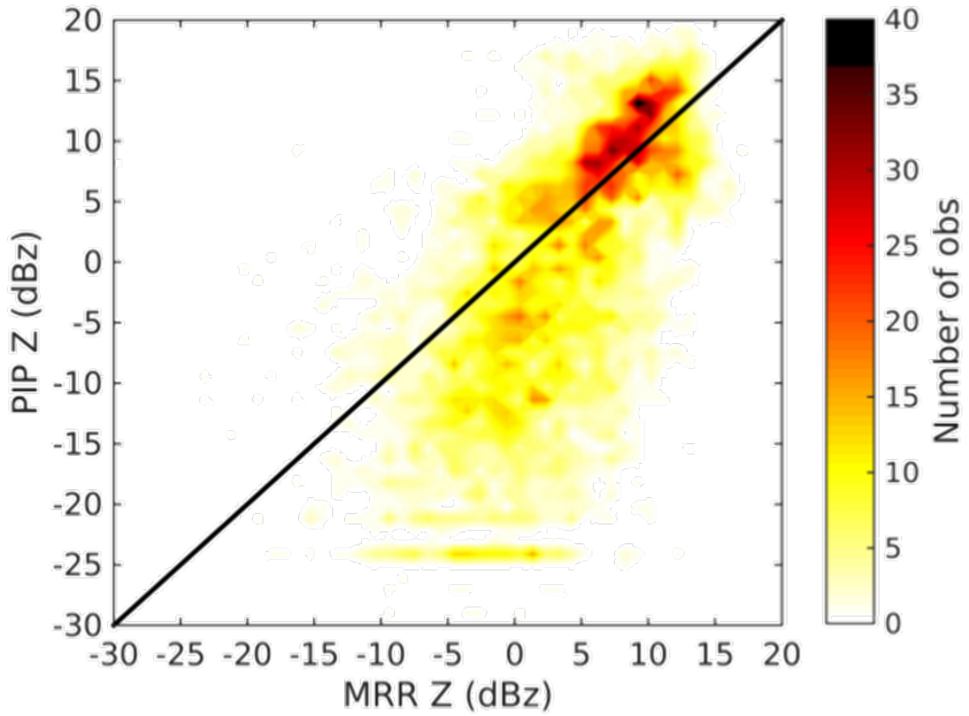
→ Calculate Ze from PIP measurements and compare that with the MRR

→ Derive Ze-SR relation from PIP

Souverijns, van Lipzig, et al., AR, 2017

Micro Rain Radar vs PIP

- Compare radar reflectivity measured by the Micro Rain Radar and calculated by 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 due to low level sublimation

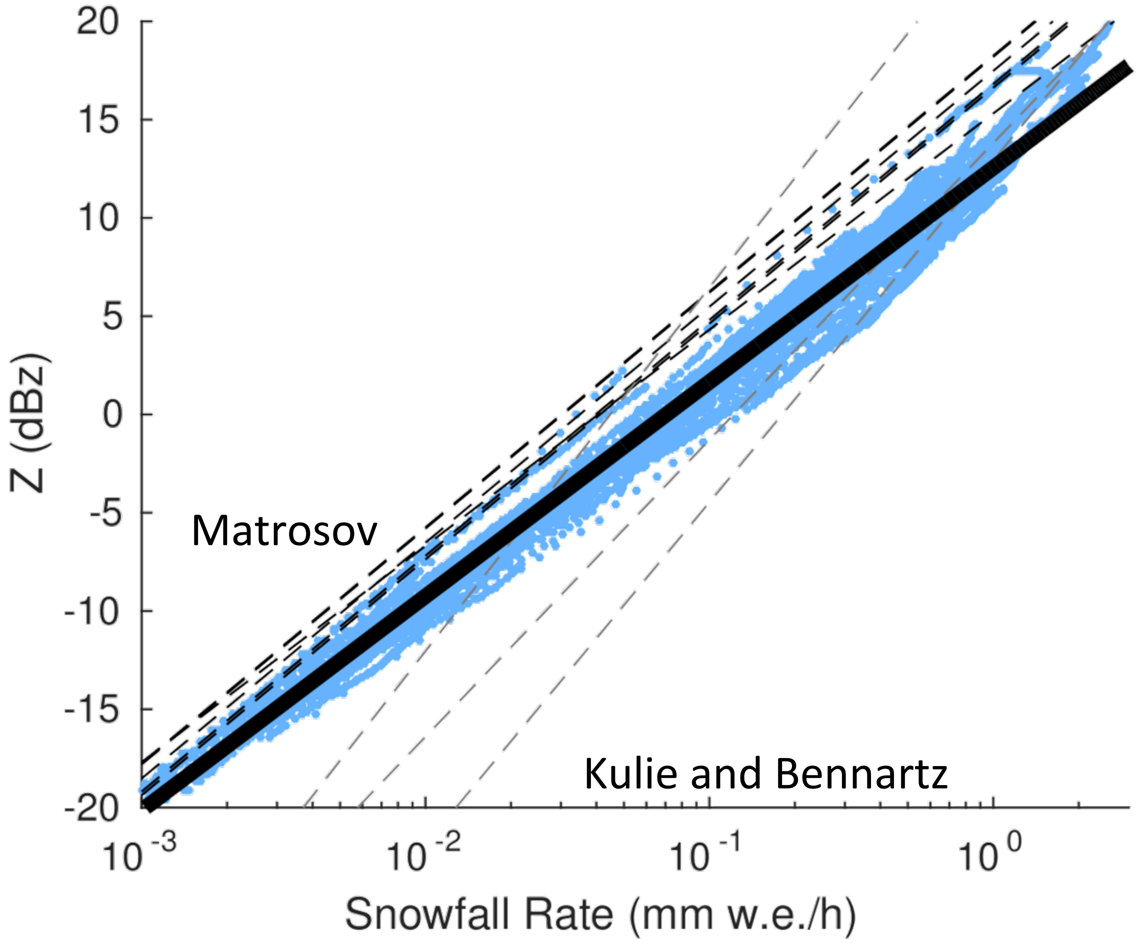


Souverijns, van Lipzig, et al., AR, 2017

Ze-SR relation from PIP

- $Ze = 18 * SR^{1.1}$

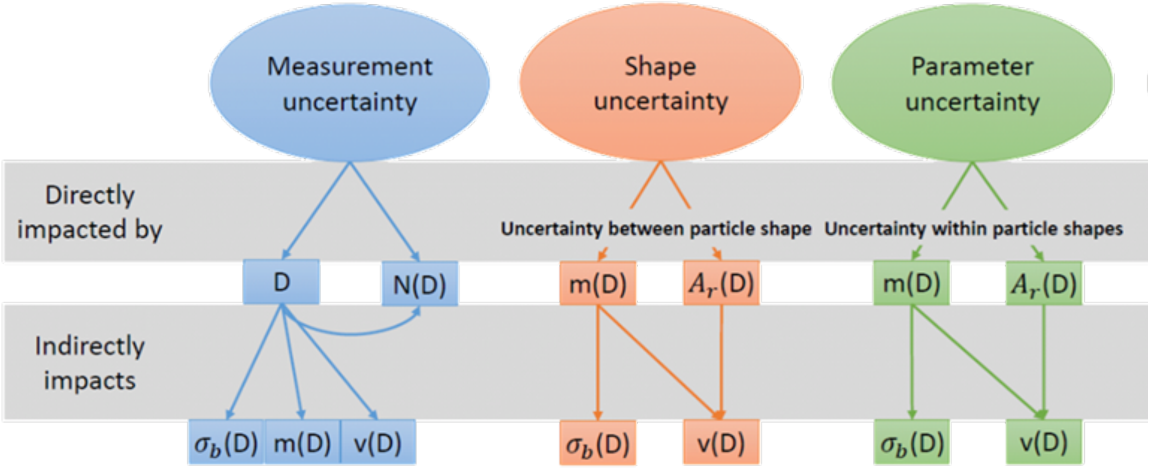
- The Ze-SR relation has a lower prefactor (A=18) than relations derived over mid-latitudes.
- Size of snow particles ~ value of the prefactor (A).
- Prefactor (A) equals 44 at coastal sites (larger snowflakes), at inland locations it approximates 7 (smaller snowflakes).



Souverijns, van Lipzig, et al., AR, 2017

Uncertainty assessment

- Uncertainty was estimated using a bootstrapping approach
- All storms were samples 10000 times



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

$$SR = \frac{3600}{\rho_w}\int_0^\infty m(D)v(D)N(D)dD$$

Souverijns, van Lipzig, et al., AR, 2017

Ze-SR relation: uncertainty

- $Ze = [11\text{-}43] * SR^{[0.97\text{-}1.17]}$

- Largest uncertainty due to mass diameter relationship
- This uncertainty must be reduced for better snowfall retrievals

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

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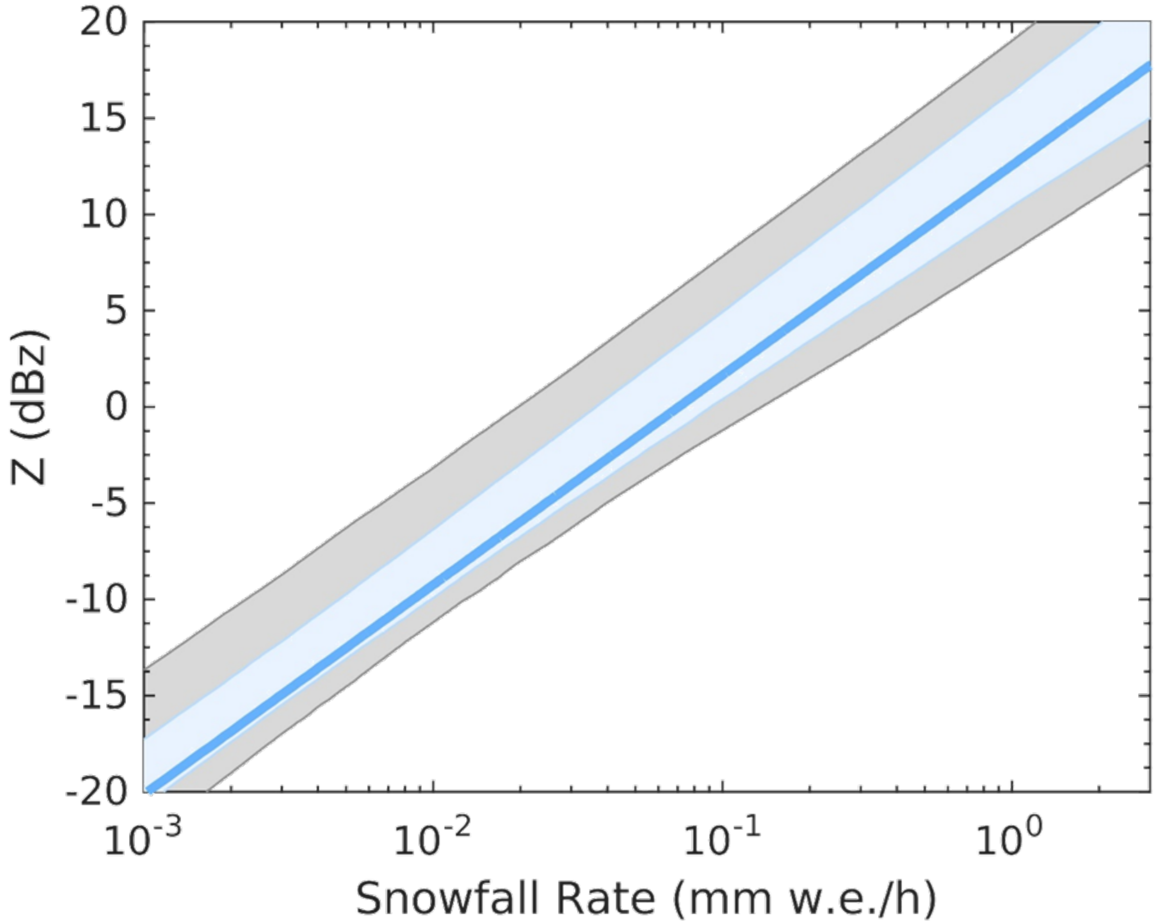
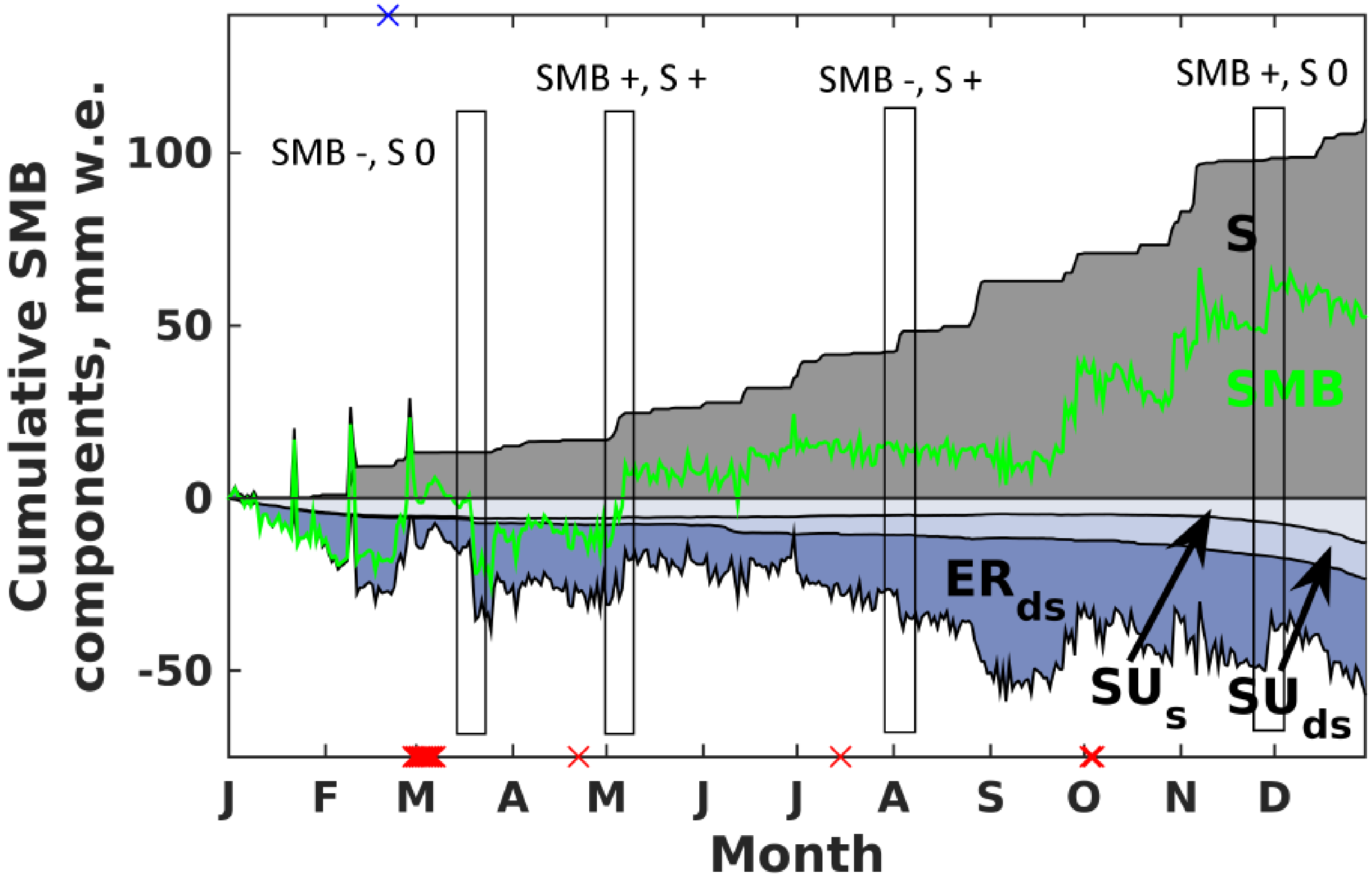


Souverijns, van Lipzig, et al., AR, 2017

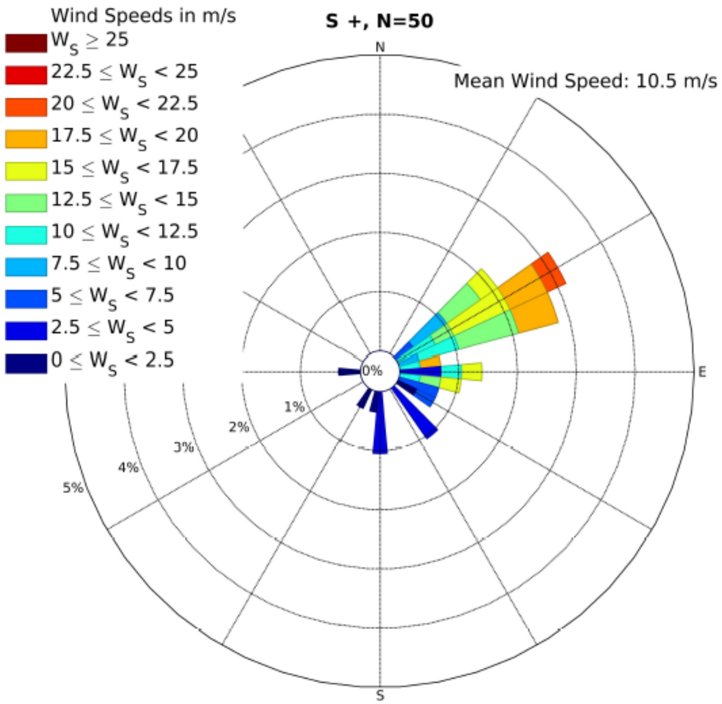
Cumulative daily surface mass balance components during 2012

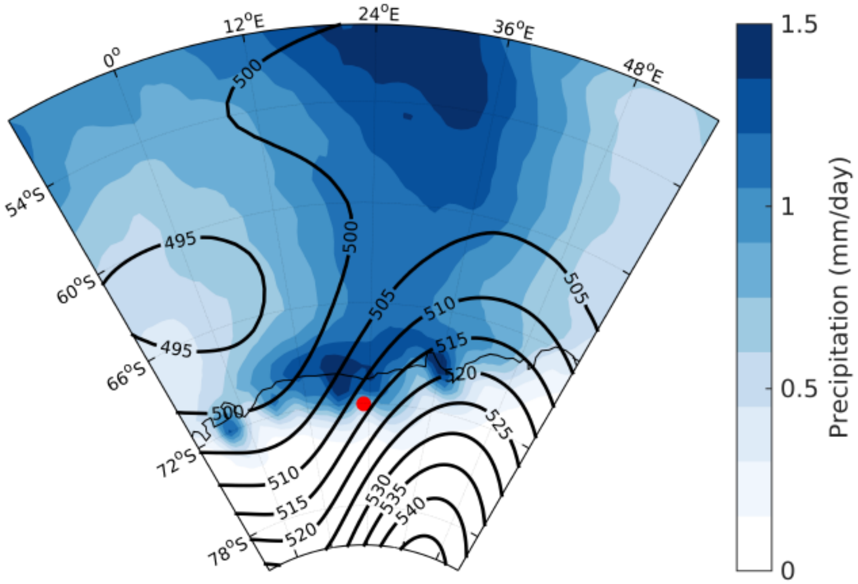
$$SMB = S + SU_s + SU_{ds} + ME + ER_{ds}$$



Souverijns, van Lipzig, et al., the cryosphere, 2017

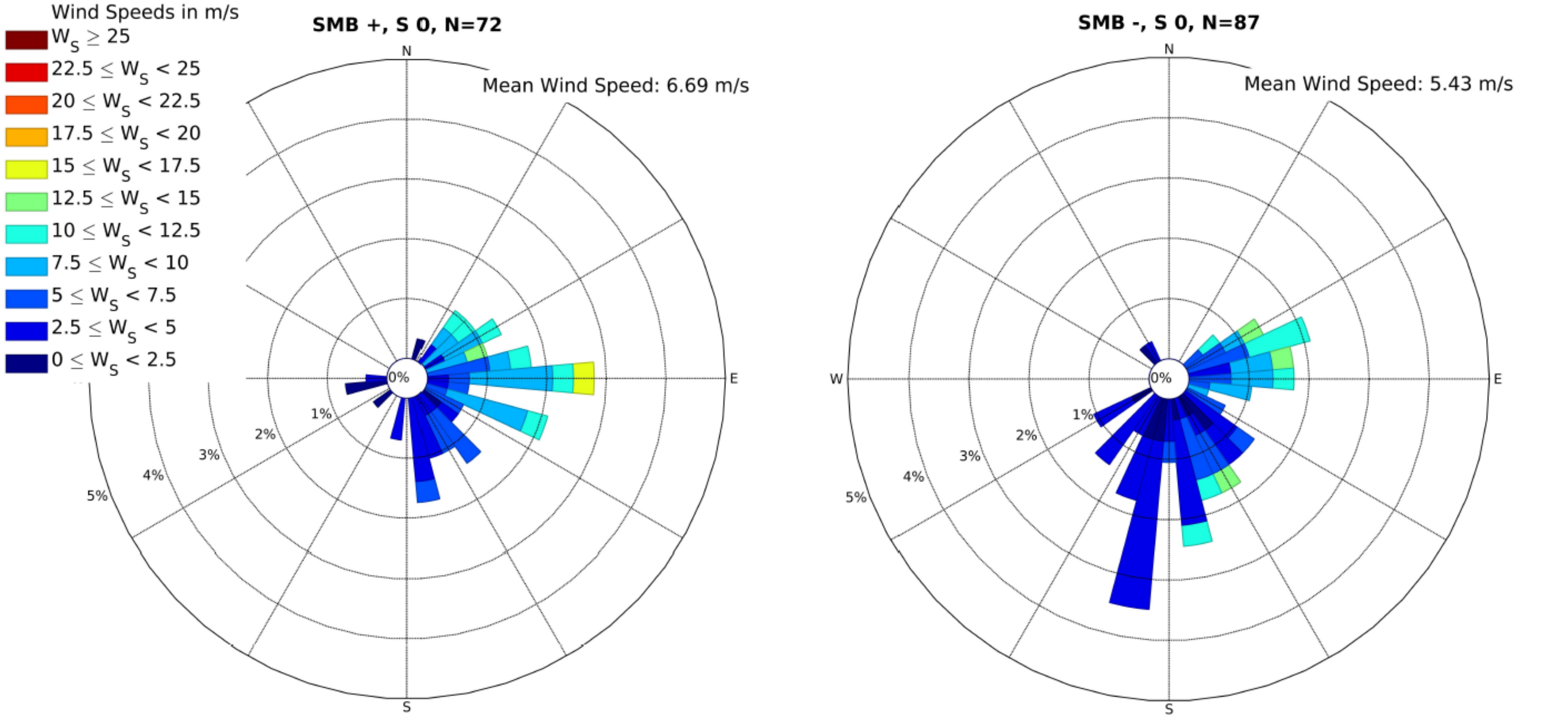
Dominant circulation during snowfall





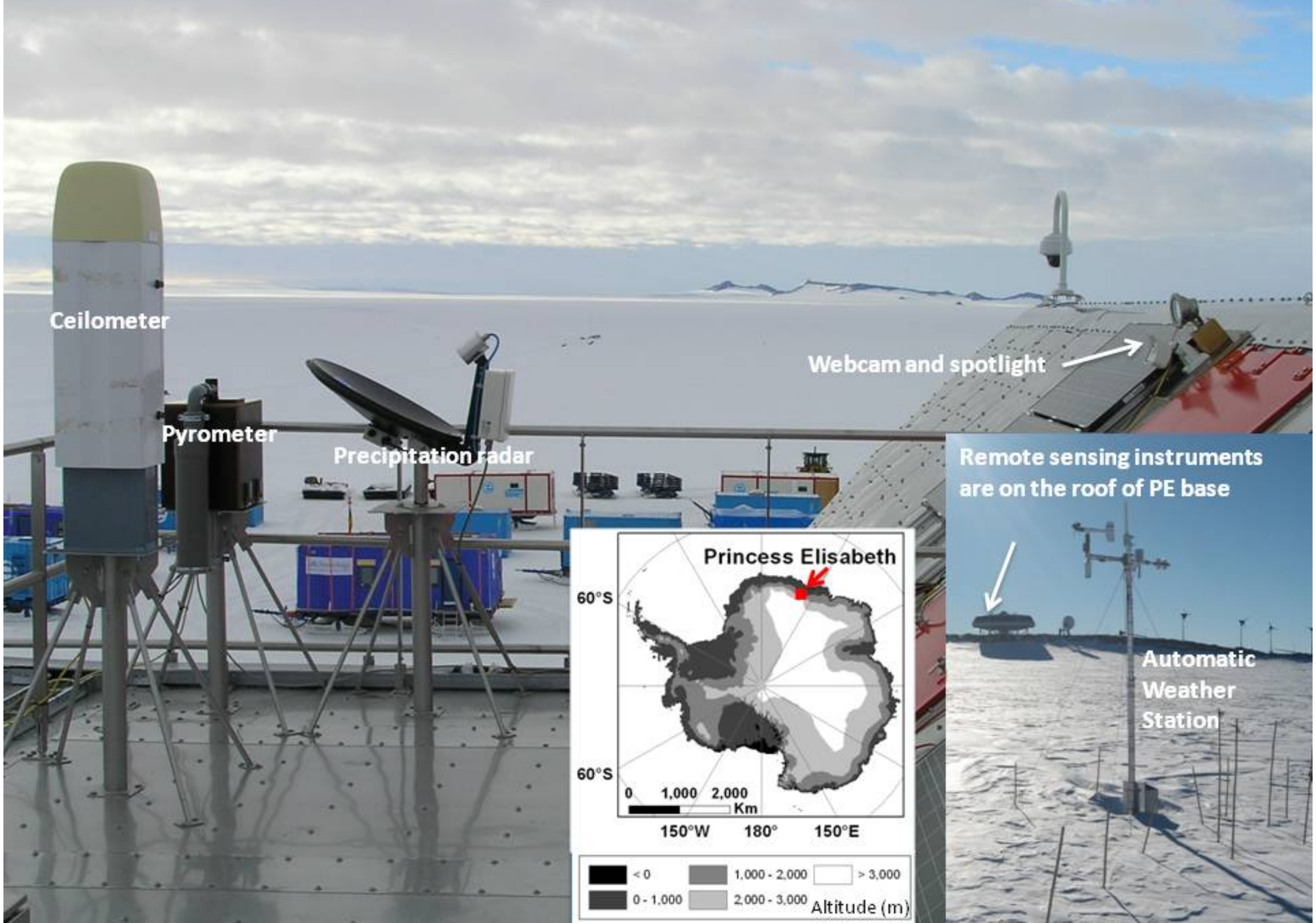
Souverijns, van Lipzig, et al., the cryosphere, 2017

Factors determining accumulation and ablation without snowfall



Souverijns, van Lipzig, et al., the cryosphere, 2017

Interesting set of instrumentation for remote glacier regions: www.aerocloud.be



Gorodetskaya, van Lipzig, et al., the cryosphere, 2014

Conclusions

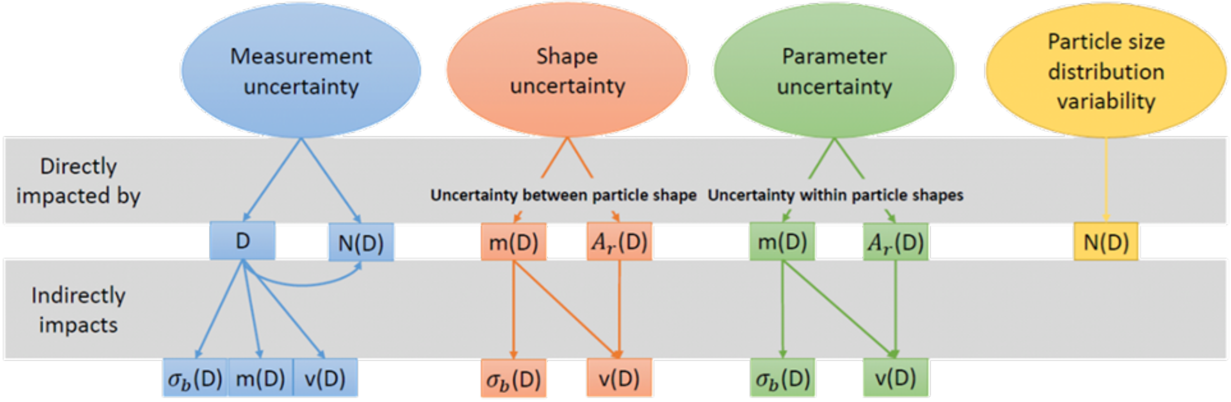
Low cost robust instrumentation can give

- Publication:
  - Souverijns, N., Gossart, A., Lhermitte, S., Gorodetskaya, I. V., Kneifel, S., Maahn, M., Bliven, F. L., van Lipzig, N. P. M., 2017. Estimating radar reflectivity - snowfall rate relationships and their uncertainties over Antarctica by combining disdrometer and radar observations. Atmospheric Research 196, 211-223.
  - https://doi.org/10.1016/j.atmosres.2017.06.001

Ze-SR relation: uncertainty

- Uncertainties on Ze-SR are smaller than the individual uncertainties on Ze and SR as errors compensate each other

- Parameter uncertainty is the largest uncertainty term apart from the variability between snow storms
  - Mainly mass uncertainty
  - Shape detection is less important to lower uncertainty.



Uncertainty	Ze	SR	Ze-SR relation
Measurement	[-30% +41%]	[-21% +27%]	[-10% +11%]
Shape	[-23% +42%]	[-13% +14%]	[-11% +12%]
Parameter	[-52% +106%]	[-59% +56%]	[-39% +38%]
Snow storm variability	/	/	[-36% +66%]
Total	[-59% +132%]	[-54% +77%]	[-59% +60%]

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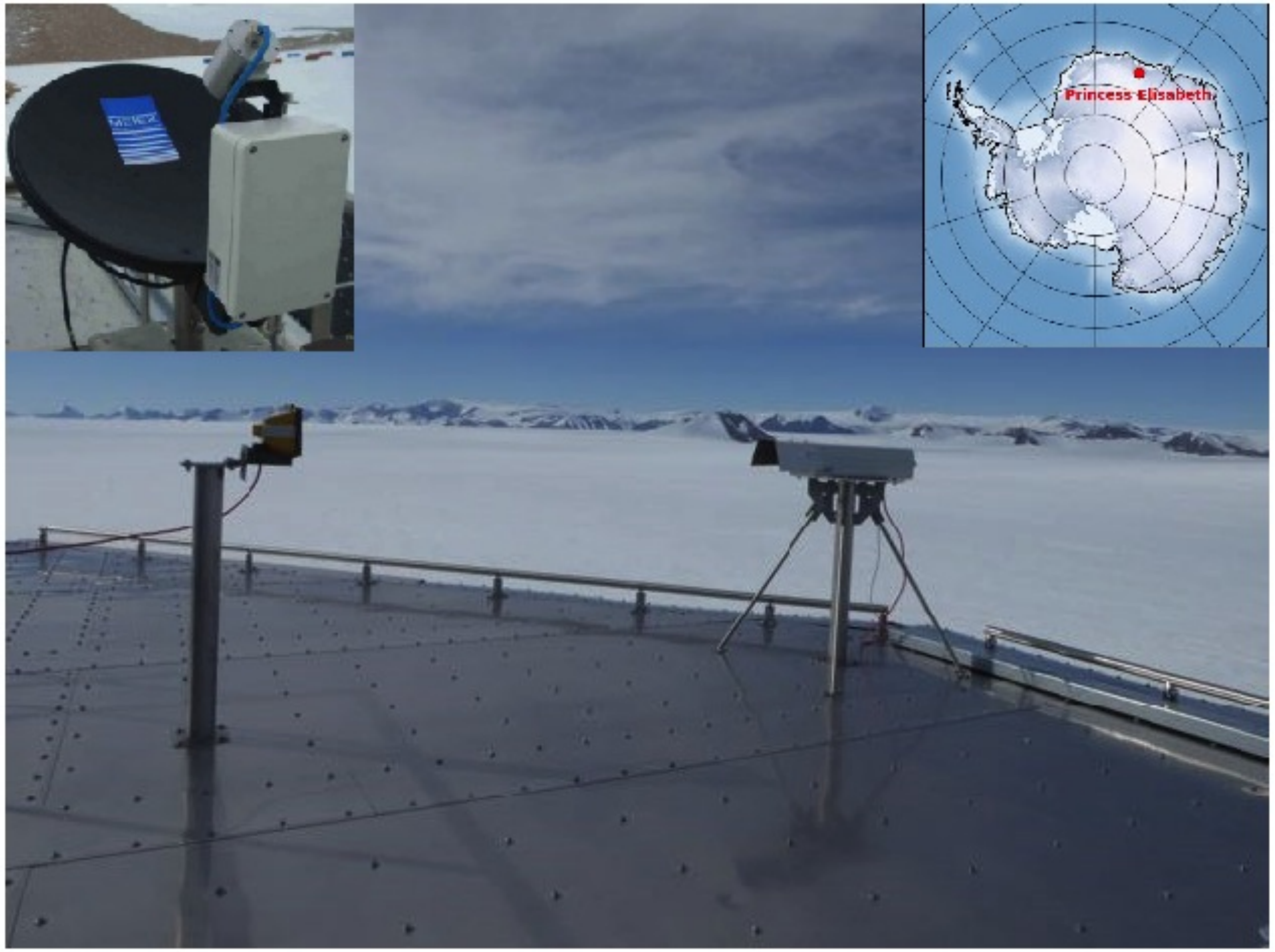
The project

- AEROCLOUD
  - Improve the understanding and modeling of precipitation, clouds and their interaction with aerosols in Dronning Maud Land (East Antarctica)
  - Achieved by using:
    - The observational framework at the Princess Elisabeth station in East Antarctica
    - Regional climate modeling (COSMO-CLM^2)

Instrumentation



Methodology

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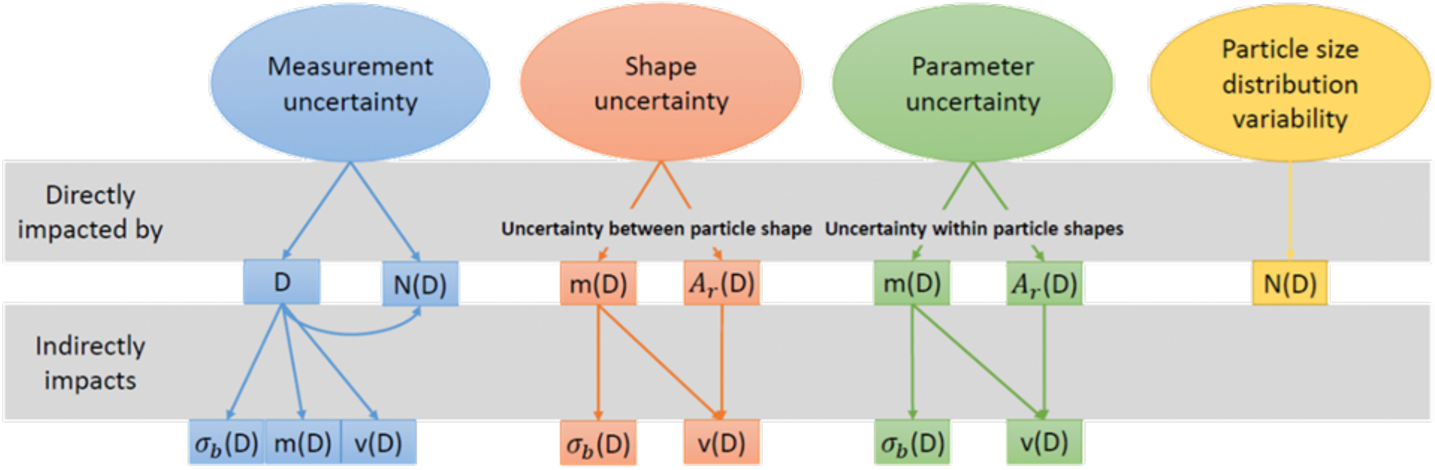

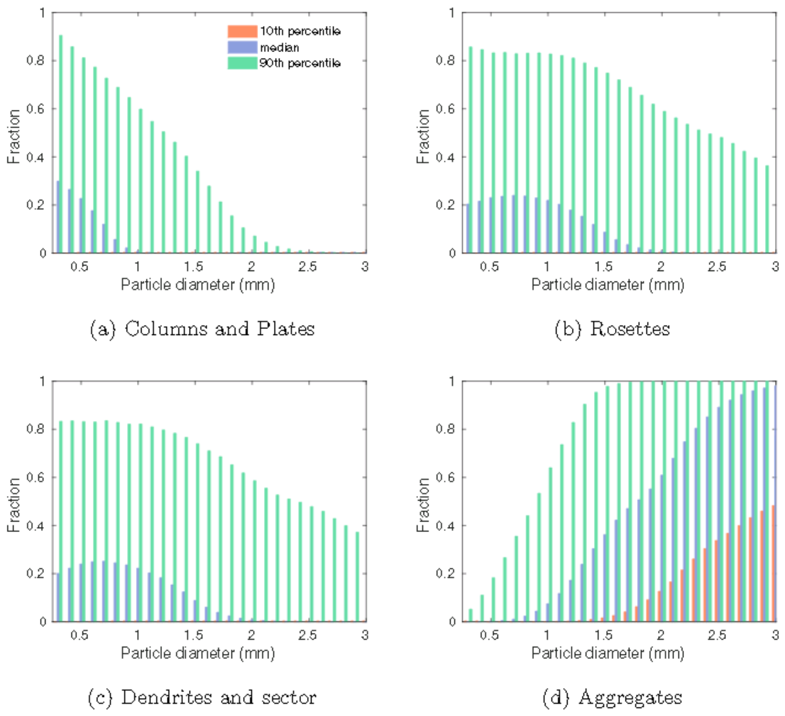

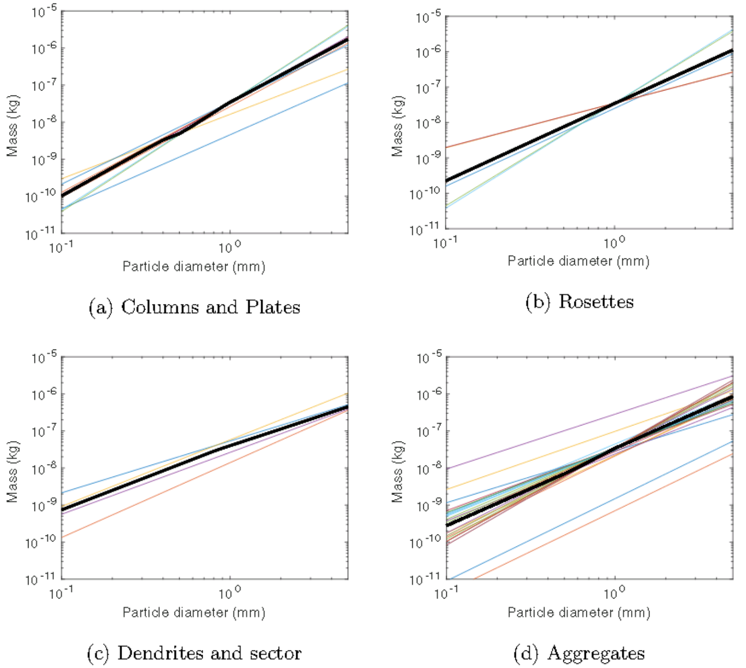

Souverijns et al., 2017