Using variable relationships between radar reflectivity and snowfall rate obtained from coincident MRR and disdrometer measurements to estimate snowfall at Mario Zucchelli Antarctic Station

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Motivations

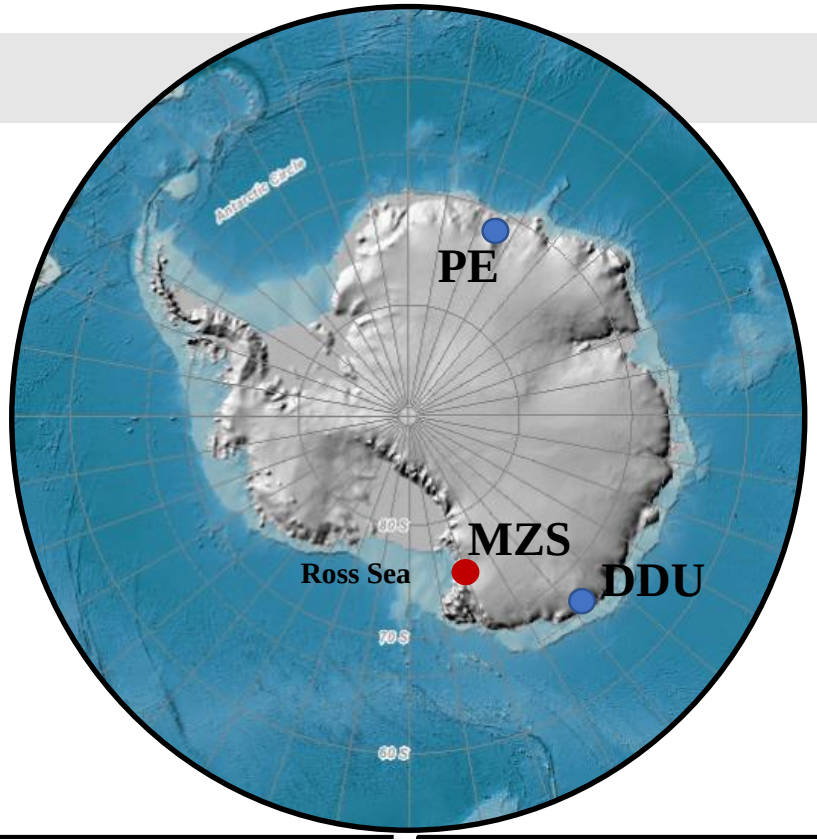
- Quantitative Precipitation Estimation (QPE) and microphysical features of **Antarctic precipitation remain largely unknown** and not well-estimated by numerical weather/climate models or satellite measurements.
- Knowledge of precipitation amounts is particularly significant in Antarctica as **precipitation is the most considerable positive term** of the surface mass balance of the Antarctic Ice Sheet.
- Estimations of snowfall rate are usually accomplished using different in-situ measuring devices (disdrometers, weighing pluviometers) and also weather radar through fixed or climatologically tuned **relationships between Radar Reflectivity (Ze)** and **liquid-equivalent Snowfall Rate (SR)**. However, **very few relationships consider snow type**.

Goals

- **To develop Ze-SR relationships as a function of snow type** from radar and disdrometer observations
- **To classify the falling hydrometeors** based on microphysical features through the **consistency between disdrometer and radar measurements.**
- **To improve Radar QPE** by applying different Ze-SR relationships **according to snow classification**.

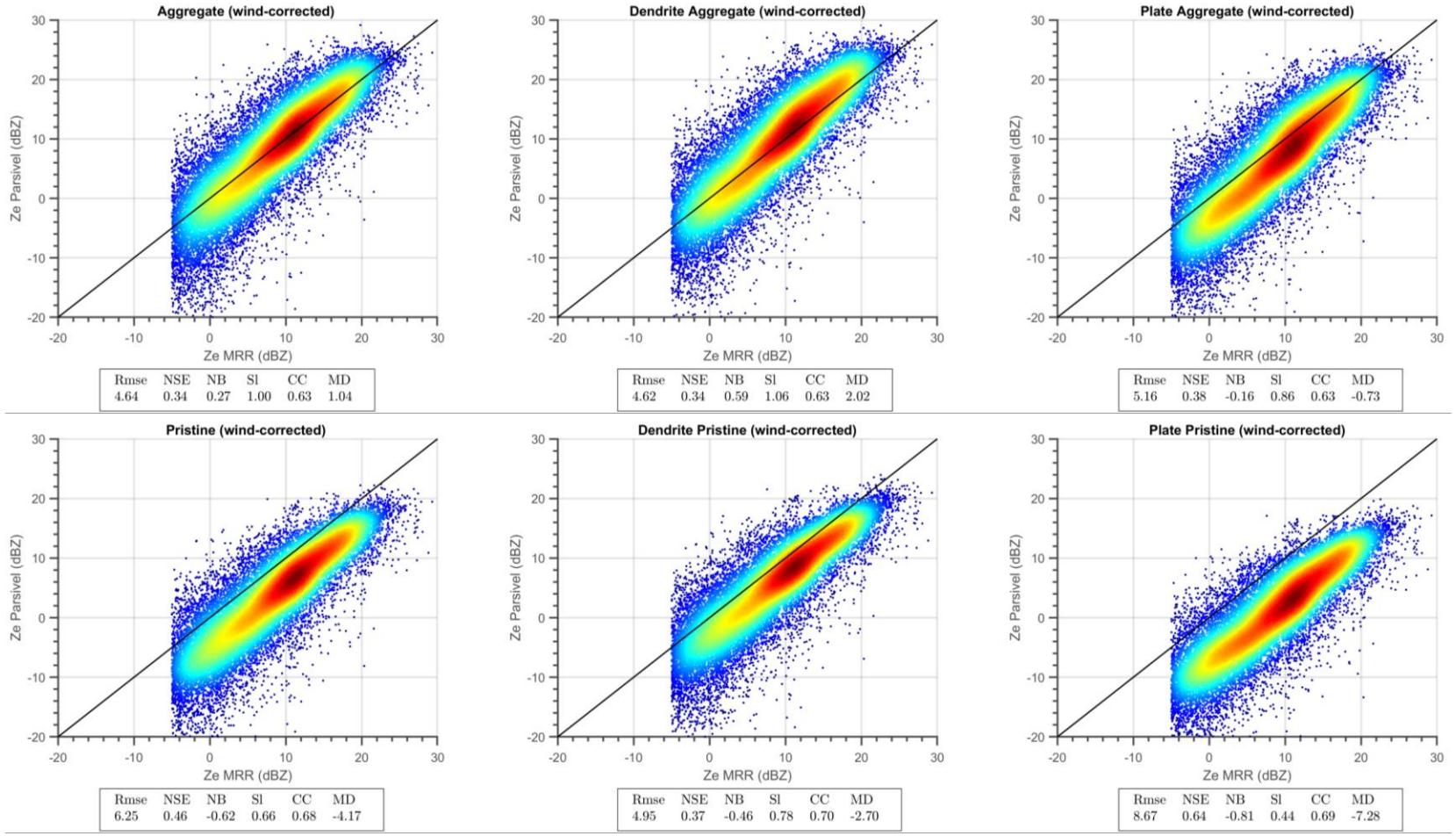
Antarctic Site, Instruments and Dataset

- The Italian research station "**Mario Zucchelli" (MZS)** has been hosting the ground-based instruments since December 2016.
- The **Particle Size and Velocity (Parsivel)** is an optical disdrometer that measures simultaneously the **sizes** and **fall velocities** of the hydrometeors.
- The **Micro Rain Radar 2 (MRR)** is a profiling Doppler radar, that operates at the K-band (24 GHz) to derive **Doppler power spectra.** MRR was set at **35m vertical resolution**, allowing us to obtain the **first reliable measurement at 105 m a.g.l.**
- Observations during two Antarctic summers, from November to March 2018–2019 and 2019–2020: **52 days with precipitation**, for more than **392 h of snowfall data**.



Methodology

1. **Disdrometer Reflectivity**: combining disdrometer data and radar backscattering cross sections for 6 different snow categories (*aggregate, dendrite aggregate, plate aggregate, pristine, dendrite pristine, plate pristine*) to calculate 6 different disdrometer-derived radar reflectivity ($Ze_{Parsivel}$) after a procedure of wind-correction for disdrometer data.



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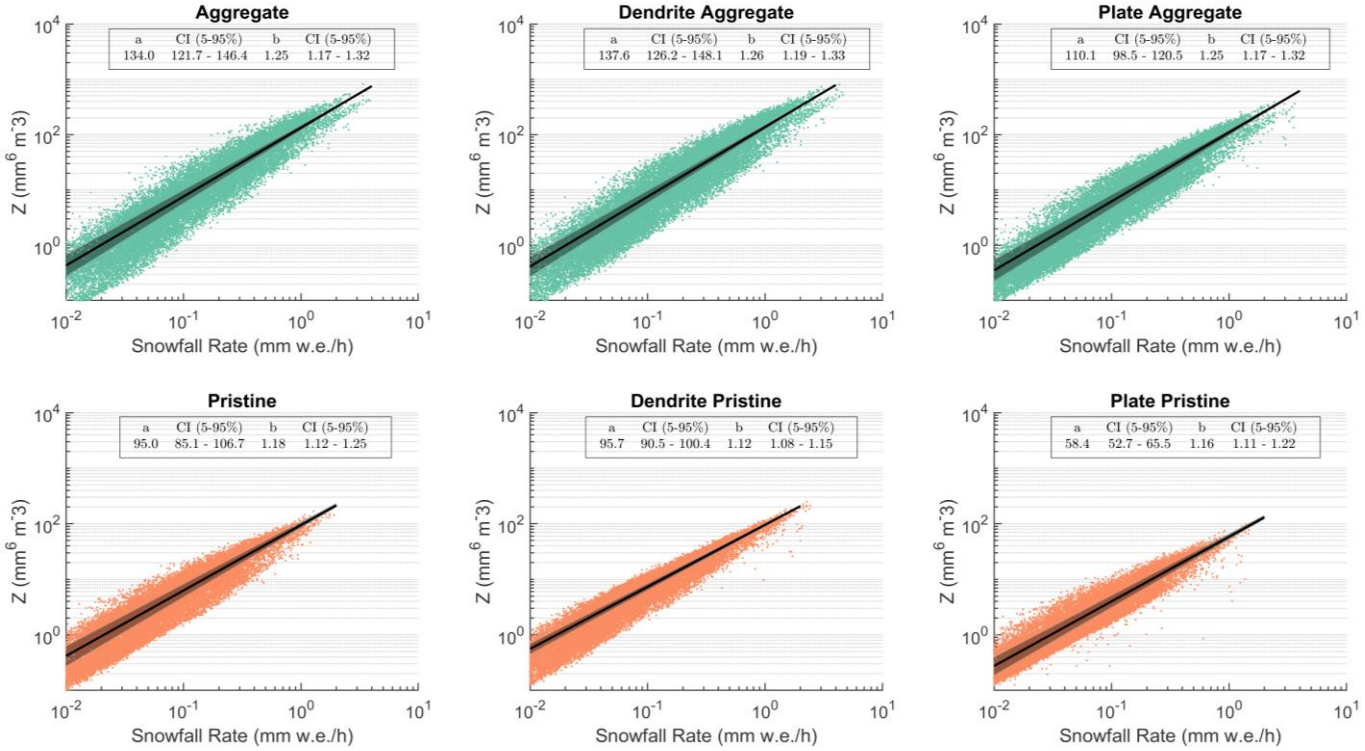
2. **Ze-SR Relationships:** deriving 6 Ze-SR relationships (one for each snow category) by using $Ze_{Parsivel}$ and snowfall rates *SR*s. *SRs* (in mm liquid water equivalent) are estimated starting from disdrometer data and applying proper velocity-diameter and mass-diameter relationships.



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3. **Snow Classification:** root mean square errors (RMSE) between the radar reflectivity at the 105 m height measured by the MRR (Ze_{MRR}) and each of the six values of $Ze_{Parsivel}$ (one for each snow category) were calculated in a 10-min time window. The category with the lowest RMSE value is considered to be representative of the prevailing type of particles in that time window.

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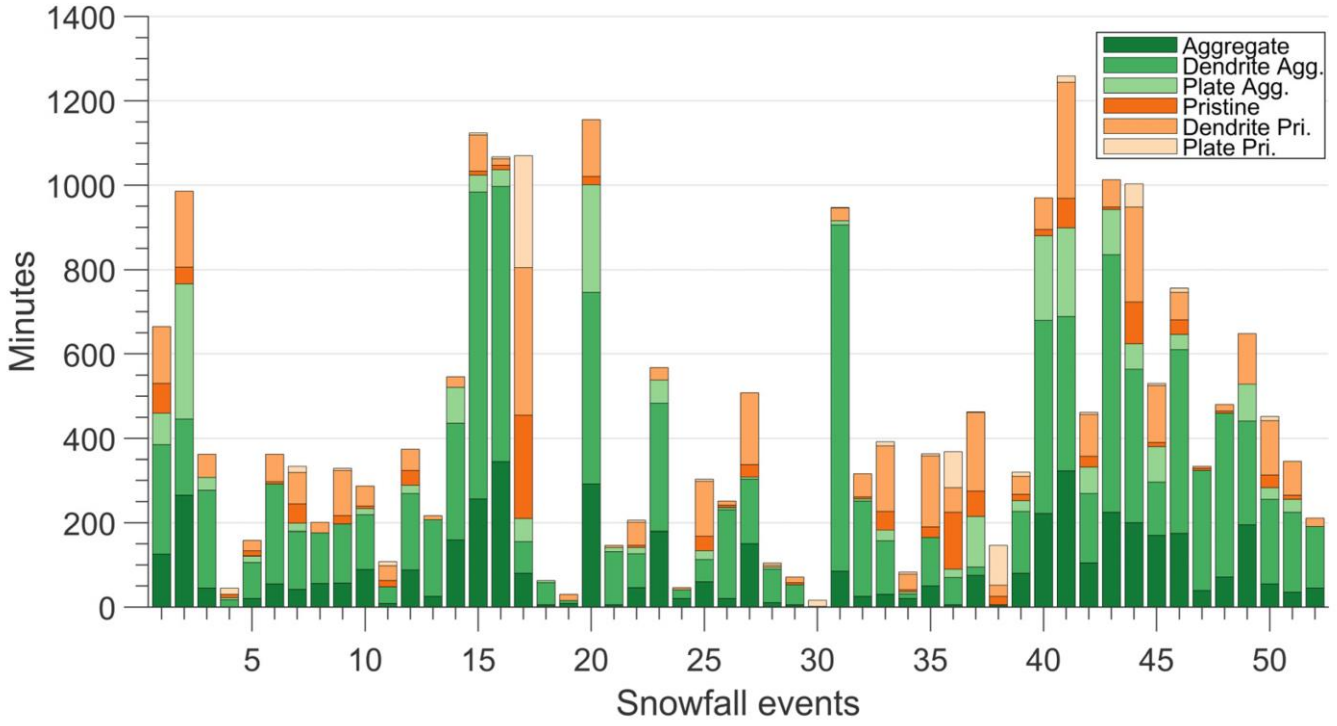
4. **QPE improvement**: according to the snow category, the proper Ze-SR relationship is applied in that time window to estimate snow precipitation on the ground.

Results 1/2

Snow Classification

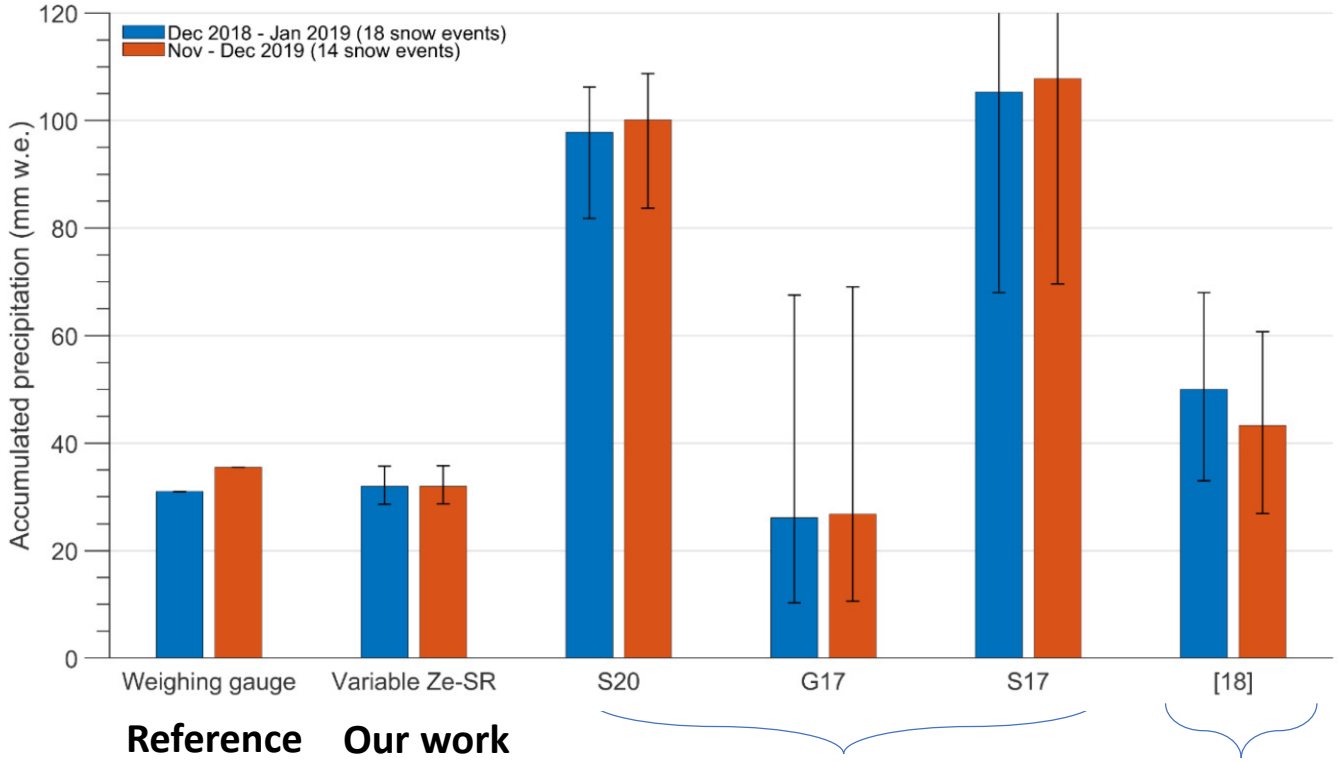
- Categories of **aggregates better approximate the hydrometeors at MZS.**
- **Aggregate** categories account for 17735 minutes out of 23566, with an incidence of **more than 75%.**
- Categories of **pristine snow represent a minority** (5830 min) and mainly exhibit dendrite pristine features.



Results 2/2

QPE Improvement

- Accumulated precipitation calculated by our **variable Ze-SR** approach is compared against a **weighing gauge (used as reference)** and fixed Ze-SR approaches for 32 of the 52 events.
- Snowfall amount using our **variable Ze-SR** relationship **performs better** than applying a **fixed Ze-SR** taken from literature.
- **Accumulated values for the same periods**, reported in Scarchilli et al. (2020), are **slightly larger** than our estimates.



Conclusions

- The **combination of MRR and a disdrometer** is undoubtedly **valuable** and workable in snowfall estimations.

- **Synergic use of MRR and disdrometer** allows obtaining precious information on **snow microphysical features** and improving knowledge on **microphysical processes.**

- Instead of a fixed one, the use of **variable Ze-SR** relationship approach makes it possible to mitigate the impact of snow microphysical variability in QPE, leading to an **improvement in snowfall quantitative estimations**.

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Further details can be found in:

Bracci, A., Baldini, L., Roberto, N., Adirosi, E., Montopoli, M., Scarchilli, C., Grigioni, P., Ciardini, V., Levizzani V., & Porcù, F. (2021).
Quantitative Precipitation Estimation over Antarctica Using Different Ze-SR Relationships Based on Snowfall Classification Combining Ground Observations. Remote Sensing, 14(1), 82. https://doi.org/10.3390/rs14010082