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Combine K-band meteorological radar profiler and disdrometer in an Antarctic site to obtain snowfall classification and improve quantitative precipitation estimation

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Snow plays a crucial role in the hydrological cycle and the energy budget of the whole Earth. Besides, snowfall can sensibly affect human activities, infrastructures, and the environment. These aspects lead to a need for continuous measurements, observations, and now/fore-casting of snowfall events in which operational and scientific communities are deeply committed. In this framework, the use of remote sensing instruments for snowfall observations is essential since it ensures, among other things, the necessary spatial coverage for monitoring purposes. Furthermore, radars have the unique scan and resolution capability of obtaining slanted measurements to describe the 3D structure of a precipitating systems as well as single vertical profiles when used in a fixed pointing profiling mode. Nevertheless, obtaining quantitative estimates of precipitation (QPE) using meteorological radar is extremely challenging, notably in solid precipitation, due to the variability of hydrometeors' microphysical features [1]. In such cases, QPE is usually based on a relationship derived from a comparison between radar and ground sensors that links the equivalent radar reflectivity factor (Ze) to the liquid-equivalent snowfall rate (SR). Due to the high uncertainty of the physical assumptions (such as particle's habits, shape, orientation, and density), the Ze-SR relationship is not univocal. Numerous relations have been developed and applied by operational and scientific communities so far, but very few of them take advantage form the estimation of snowflakes' microphysical characteristics. In this work, we use a vertically pointing Micro Rain Radar (MRR, manufactured by Metek GmbH) at K-band, operating since November 2018, to probe low-level atmospheric layers over the Italian Antarctic station "Mario Zucchelli" (Northern Victoria Land) in terms of radar reflectivity factor and vertical velocity. MRR records spectra at 32 vertical range gates and was set with the highest vertical resolution (i.e., 35 m), allowing the first trusted range gate at only 100 meter height. We exploited such measures paired up with an OTT Parsivel disdrometer to develop QPE methods tuned for the Antarctic site's precipitation, introducing new specific Ze-SR relationships and using the more suitable one as a function of snow classification. Indeed, snow particles were classified into six different categories of habit (i.e., aggregate, aggregate-dendrites, aggregate-plates, pristine, pristine-dendrites, pristine-plates) by comparing the Ze directly derived by radar with the Ze calculated starting from particle size distribution and NASA database of hydrometeor backscattering values based on the Discrete Dipole Approximation. Specifically, we calculated the root mean square errors between MRR Ze measurement and each of the six values of disdrometer derived reflectivity, one for each habit category, in a 10-minute time window. The category with the lowest RMSE value has been considered representative of the prevailing type of particles in that time window. This methodology has been applied to the snowfall events of two Antarctic summer seasons (2018-19 and 2019-20) with a total of 23565 minutes of precipitation. The 15.3% of such time period were recognized as having aggregate features by our snowflake classification, 33.3% as dendrite, 7.3% aggregate-plates, 12.5% pristine, 24% pristine-dendrites, and 7.6% as pristine-plates. Applying the appropriate Ze-SR relationship, we calculated a total amount of 87 mm w.e. (77.9–96.5, 10th and 90th percentile, respectively). This result differs considerably from the amount computed by the software of disdrometer manufacturer (more than 500 mm), but also from the total found by applying a unique Ze-SR. Our methodology demonstrates the viability and effectiveness of the synergetic use of MRR and disdrometer in retrieval microphysical properties of the snow.

References

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