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Quantitative precipitation estimation in complex orography using quasi-vertical profiles of dual polarization radar variables

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Weather radars are nowadays a unique tool to estimate quantitatively the rain precipitation near the surface. This is an important task for a plenty of applications. For example, to feed hydrological models, mitigate the impact of severe storms at the ground using radar information in modern warning tools as well as aid the validation studies of satellite-based rain products. With respect to the latter application, several ground validation studies of the Global Precipitation Mission (GPM) products have recently highlighted the importance of accurate QPE from ground-based weather radars.

To date, a plenty of works analyzed the performance of various QPE algorithms making use of actual and synthetic experiments, possibly trained by measurement of particle size distributions and electromagnetic models. Most of these studies support the use of dual polarization variables not only to ensure a good level of radar data quality but also as a direct input in the rain estimation equations. Among others, one of the most important limiting factors in radar QPE accuracy is the vertical variability of particle size distribution that affects at different levels, all the radar variables acquired as well as rain rates. This is particularly impactful in mountainous areas where the altitudes of the radar sampling is likely several hundred of meters above the surface.

In this work, we analyze the impact of the vertical profile variations of rain precipitation on several dual polarization radar QPE algorithms when they are tested a in complex orography scenario. So far, in weather radar studies, more emphasis has been given to the extrapolation strategies that make use of the signature of the vertical profiles in terms of radar co-polar reflectivity. This may limit the use of the radar vertical profiles when dual polarization QPE algorithms are considered because in that case all the radar variables used in the rain estimation process should be consistently extrapolated at the surface. To avoid facing such a complexity, especially with a view to operational implementation, we propose to look at the features of the vertical profile of rain (VPR), i.e. after performing the rain estimation. This procedure allows characterizing a single variable (i.e. rain) when dealing with vertical extrapolations.

Some case studies of severe thunderstorms that hit the mountainous area surrounding Rome in Italy causing floodings and damages and observed by the research C-band polarization agility Doppler radar named Polar 55C, managed by the Institute of Atmospheric Sciences and Climate (ISAC) at the National Research Council of Italy (CNR), are used to support the concept of VPR.

Our results indicate that the combined algorithm, which merges together the differential phase shift (Kdp), the reflectivity factor at horizontal polarization (Zhh), and differential reflectivity (Zdr), once accurately processed, performs best among those tested that make use of Zhh alone, Kdp alone, and Zhh and Zdr pair. Improvements from 25% to 80% are found for the total rain accumulations in terms of normalized bias when the VPR extrapolation is applied.