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Adjusting weather radar data to rain gauge measurements with data-driven models

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Weather radar networks provide data with good spatial coverage and temporal resolution. Hence they are able to describe the variability of precipitation. Typical radar stations determine the rain rate for every square kilometre and make a full volume scan within about 5 minutes. A weakness however, is their often poor metering precision limiting the applicability of the radar for hydrological purposes. In contrast to rain gauges, which measure precipitation directly on the ground, the radar determines the reflectivity aloft and remote. Due to this principle, several sources of possible errors occur. Therefore improving the radar estimates of rainfall is still a vital topic in radar meteorology and hydrology.

This paper presents data-driven approaches to improve radar estimates of rainfall by mapping radar reflectivity measurements Z to rain gauge data R. The analysis encompasses several input configurations and data-driven models. Reflectivity measurements at a constant altitude and the vertical profiles of reflectivity above a rain gauge are used as input parameters. The applied models are Artificial Neural Network (ANN), Model Tree (MT), and IBk a k-nearest-neighbour classifier. The relationship found between the data of a rain gauge and the reflectivity measurements is subsequently applied to another site with comparable terrain. Based on this independent dataset the performance of the data-driven models in the various input configurations is evaluated.

For this study, rain gauge and radar data from the province of Styria, Austria, were available. The data sets extend over a two-year period (2001 and 2002). The available rain gauges use the tipping bucket principle with a resolution of 0.1 mm. Reflectivity measurements are obtained from the Doppler weather radar station on Mt. Zirbitzkogel (by courtesy of AustroControl GmbH). The designated radar is a high-resolution C-band weather-radar situated at an altitude of 2372 m above mean sea level.

The data-driven models exhibit different performances on the various input configurations. Also data transformations were applied. The logarithm recommends itself for this transformation because the original Z-R-relationship is a power function, and the logarithm linearises this non-linear relationship. The MT which is a piecewise linear model performs best on logarithmised data. The IBk works well when transforming the reflectivity data in rain rate first. Overall the ANN exhibits the best performance showing a 10 % improvement in correlation and RMSE compared to the standard Z-R-relationship. When applying the vertical profile of reflectivity as input parameter, the correlation exhibits a more than 30 % improvement.

The results indicate that the vertical profile of reflectivity provided by weather radars yields not only information on the type of precipitation, whether it is stratiform or convective. In data-driven models the vertical profile of reflectivity can help to get better estimates of rain rates on the ground, even in mountainous terrain without low-altitude radar measurements.