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An object-based approach for areal rainfall estimation and validation of atmospheric models

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An object-based approach for areal rainfall estimation is applied to pseudo-radar data simulated of a weather-forecast model as well as to real radar volume data. The method aims at an as fully as possible exploitation of three-dimensional radar signals produced by precipitation generating systems during their lifetime to enhance areal rainfall estimation. Therefore tracking of radar-detected precipitation-centroids is performed and rain events are investigated using so-called Integral Radar Volume Descriptors (IRVD) containing relevant information of the underlying precipitation process. Some investigated descriptors are statistical quantities from the radar reflectivities within the boundary of a tracked rain cell like the area mean reflectivity or the compactness of a cell; others evaluate the mean vertical structure during the tracking period at the near surface reflectivity-weighted center of the cell like the mean effective efficiency or the mean echo top height. The stage of evolution of a system is given by the trend in the brightband fraction or related quantities. Furthermore, two descriptors not directly derived from radar data are considered: the mean wind shear and an orographic rainfall amplifier.

While in case of pseudo-radar data a model based on a small set of IRVDs alone provides rainfall estimates of high accuracy, the application of such a model to the real world remains within the accuracies achievable with a constant Z-R-relationship. However, a combined model based on single IRVDs and the Marshall-Palmer Z-R-estimator already provides considerable enhancements even though the resolution of the data base used has room for improvement.

The mean echo top height, the mean effective efficiency, the empirical standard deviation and the Marshall-Palmer estimator are detected for the final rainfall estimator. High correlations between storm height and rain rates, a shift of the probability distribution to higher values with increasing effective efficiency, and the possibility to classify continental and maritime systems using the effective efficiency confirm the informative value of the qualified descriptors.

The IRVDs especially correct for the underestimation in case of intense rain events, and the information content of descriptors is most likely higher than demonstrated so far. We used quite sparse information about meteorological variables needed for the calculation of some IRVDs from single radiosoundings, and several descriptors suffered from the range-dependent vertical resolution of the reflectivity profile. Inclusion of neighbouring radars and assimilation runs of weather forecasting models will further enhance the accuracy of rainfall estimates.

Finally, the clear difference between the IRVD selection from the pseudo-radar data and from the real world data hint to a new object-based avenue for the validation of higher resolution atmospheric models and for evaluating their potential to digest radar observations in data assimilation schemes.