VERTICAL STRUCTURE OF RAIN PARAMETERS AS OBSERVED WITH MICRO RAIN RADARS

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The validation of weather radar rain fall estimates is nearly solely based on surface data obtained with in-situ rain gauges or distrometers. Separating and quantifying the various sources of uncertainty of these estimates is difficult, as long as no simultaneous reference data are available in the radar scattering volume.

Here we return to the suggestion of Atlas *et al.* [1973] to use Doppler radar at vertical incidence for deriving the drop size distribution via the relation between terminal fall velocity and drop size. Special low power micro rain radars (MRR) operating at 24.1 GHz are used for this purpose. The characteristics and performance of these radars are described in more detail in Peters *et al.* [2002]. While no areal coverage is possible in this mode of radar operation, it allows the observation of the vertical structure of precipitation and of its microphysical parameters. If the MRR profiles intersect with the beam of a weather radar, simultaneous measurements in common volumes may eventually allow the use of continuously updated Z-R-relations.

Here we show on the basis of several years of measurements that significant transformations of drop size distributions occur on the fall path with the consequence that the application of surface based Z-R-relations yields erroneous rain fall estimates.

The data were obtained with 3 MRRs, located at various sites at the Baltic Sea. Height resolutions of 100 and 35 m and time resolutions of 10 s and 60 s were used at the different sites. Only heights below 1500 m during summer seasons were considered in order to avoid the ice phase. The Doppler spectra, obtained at vertical incidence, reflect the fall velocity distribution of hydro-meteors and can be converted into drop size distributions (DSDs) using the known relation between drop size and terminal fall velocity. We used the analytic fit of Atlas *et al.* [1973] to the data of Gunn and Kinzer [1949]. Height dependent air density effects on the droplet fall speed and micro-wave attenuation due to rain were included in the DSD-retrieval. The assumption of zero vertical wind is probably the most severe source of error of retrieved DSDs and corresponding rain parameters. Nevertheless, the analysis of these errors using measured vertical wind data from a tower close to a MRR gave us confidence that the results discussed in this paper are realistic. The data were stratified into classes according to the rain rate during the corresponding rain event. Various rain parameters were calculated from the Doppler spectra of each rain event, and the corresponding parameter-profiles were averaged separately for each class.

- The DSDs show systematic height dependences with shift to larger drops at lower heights. This is particularly pronounced at high rain rates.
- Due to this transformation of DSDs on the fall path, Z-R-relations show systematic differences between ground level and aloft. The observed annual Z-gradient reaches -6 dB/km for given (height independent) rain rates > 10 mm/h. Consequently, weather radars significantly underestimate high rain rates, if surface based Z-R-relations are employed.

We assume that the process of transforming the ”initial” DSD towards some ”equilibrium” DSD starts right below the melting layer. Therefore, the height distance to the melting layer rather than the height above ground will be will be chosen as independent variable in a future re-analysis of the data. We expect to reduce in this way some of the variability of the observed Z-gradients and to obtain a height dependent Z-R-relation applicable for improved radar rainfall estimates.

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