Nowcasting of stratiform rain exploiting signatures in the dendritic growth layer, microphysical retrievals and spectral bin modelling

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Previous studies have suggested that nowcasting of imminent precipitation enhancements is possible based on bands of enhanced specific differential phase (KDP) in the dendritic growth layer (DGL) signaling increased ice crystal number concentration and pronounced downward increase in reflectivity (ZH) indicating intense aggregation. Surface precipitation enhancements can be expected after the time needed for the snowflakes (or raindrops, after passing through the melting layer) to reach the ground. However, the identification and quantification of snow generated in the DGL requires the azimuthal averaging inherent to the methodology of Quasi-Vertical-Profiles (QVPs); it cannot be based, e.g., on 3D radar composites because the signal is often much too noisy.

Time series of QVPs from 52 stratiform precipitation events observed with the polarimetric X-band radar BoXPol in Bonn/Germany between 2013 and 2016 have been statistically analyzed in order to infer microphysical processes occurring in the DGL and/ or modifying the precipitation flux down to the surface. Since the bulk of snow precipitation forms within the DGL, it is reasonable to expect that ice water content (IWC) or snow precipitation flux (S) in the DGL correlate with precipitation intensity at the surface –be it snow or rain –when the falling trajectories are taken into account.

As a first step, we assume the precipitation flux does not change much on the way down to the surface. Trajectories of snow generated aloft down to the surface are constructed from wind profiles derived from radar-based velocity azimuth displays (VAD) to narrow down the location where the DGL-generated snow reaches the surface as rain. The lagged correlation analysis between KDP in the DGL and ZH at that corresponding surface location reveals correlations up to 0.80 with lead times up to 120 minutes and provides a proof of concept for future nowcasting applications based on DGL monitoring. The comparison of DGL-derived snow precipitation flux S(IWC) with both surface reflectivity-derived and gauge-observed rain rates at the expected locations and times shows good agreement. However, due to the unknown details of development of S(IWC) with for example accretion, riming, and evaporation along the precipitation trajectories from the DGL down to the surface, no conclusions regarding the source of specific biases in surface rainfall estimates based on the polarimetric S(IWC) retrievals can be drawn at this stage.

In addition to uncertainties in the S(IWC)-retrievals, sublimation of ice below the DGL and evaporation of rain below the melting layer (ML) are likely contributors to the discrepancy between DGL-based S(IWC) and rain rate at the surface. For example, for the cases considered, radar reflectivity decreases below the ML by about 2 dB on average while differential reflectivity (ZDR) is hardly affected, which suggests rain evaporation is the dominant effect. Thus, as a second step, processes modifying the precipitation flux from the DGL down to the surface are estimated using spectral bin modeling initialized with radar-derived particle size distributions and environmental conditions from the nearest radiosounding and COSMO-model analyses. Microphysical retrievals both in ice aloft and rain below the ML are used to explore the transformation of the ice size distribution above the ML into the rain size distribution below the ML. The consistency between simulated and observed IWC aloft and LWC in rain is investigated. A first attempt is presented to include sublimation and evaporation in the DGL-based nowcasting routine of

stratiform rain.

Keywords: dendritic growth layer, stratiform rain, nowcasting, sublimation, evaporation

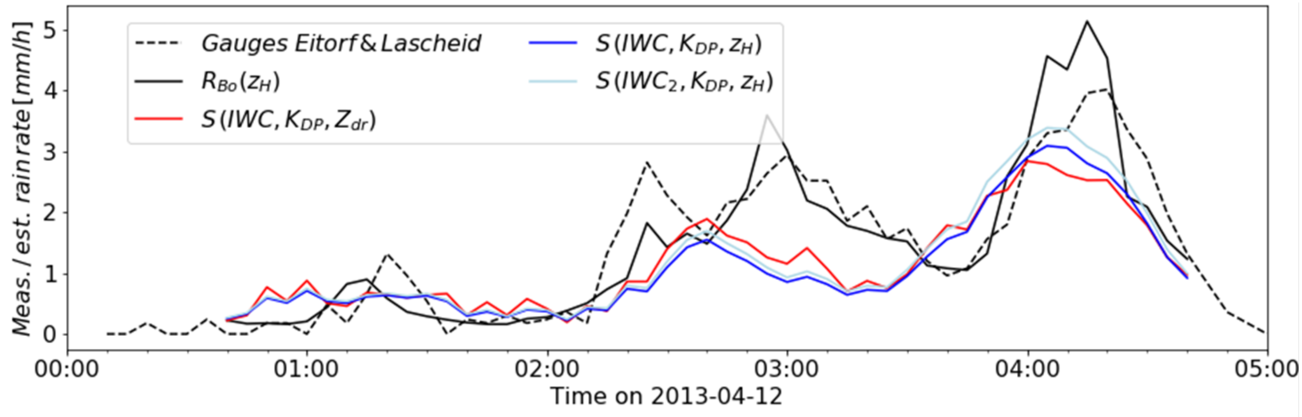

Figure: High correlations between DGL-derived snow precipitation flux S(IWC) and both surface reflectivity-derived and gauge-observed rain rates at predicted surface location 30 minutes later for an example event on 12 April 2013.