Melting Layer Ice Microphysical Processes in Winter Storms as Revealed by Quasi-Vertical Profiles of Polarimetric WSR-88D Radar Data

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Quasi-vertical profiles (QVPs) obtained from a large-scale database of U.S. WSR-88D radar data are used to document the polarimetric characteristics of the melting layer (ML) in cold-season storms. A polarimetric technique to define the top and bottom of the ML is first introduced. Using the QVPs, statistical relationships are then developed to gain insight into the evolution of microphysical processes above, within, and below the ML, leading to a statistical polarimetric model of the ML that reveals characteristics that reflectivity data alone are not able to provide. Results reveal strong positive correlation between $Z_H$ in rain (i.e., 0.3 km below ML) and $Z_H$ in snow (i.e., 0.3 km above ML) and between maximum $Z_{DR}$ in the ML and $Z_{DR}$ in rain. Strong positive correlation is also observed between maximum $K_{DP}$ and maximum $Z_H$ in the ML. Strong negative correlation occurs between minimum $\rho_{hv}$ in the ML and ML depth and negative correlation occurs between minimum $\rho_{hv}$ in the ML and the corresponding enhancement of $Z_H$ (i.e., $\Delta Z_H = Z_{H_{\text{max}}} - Z_{H_{\text{rain}}}$). Quantifying the $\Delta Z(\min(\rho_{hv}))$ dependence is crucial for implementation of a polarimetric vertical profiles of rain (PVPR) technique designed to mitigate the impact of ML contamination on QPE. The evidence of large $Z_{DR}$ (up to 4 dB), $\delta$ up to 10°, and low $\rho_{hv}$ (down to 0.80) associated with lower $Z_H$ (-10 to 20 dBZ) in the ML is documented in situations when pristine, non-aggregated ice falls through it. A strong microphysically-driven connection between polarimetric signatures in the ML and aloft in the dendritic growth layer (DGL, between -10 and -20°C) and the temperature at the top of the cloud has been observed. For example, “sagging” of the ML typically occurs during periods of enhanced $K_{DP}$ in the DGL and taller cloud tops. Also, a moderate positive correlation between $K_{DP}$ in the DGL and $K_{DP}$ in the ML is observed.