Abstract  Characteristics of the melting layer and raindrop size distribution can be exploited to further improve radar quantitative precipitation estimation (QPE). Using dual-polarimetric radar and disdrometers, we found that the characteristic size of raindrops reaching the ground in stratiform precipitation often varies linearly with the depth of the melting layer. As a result, a radar rainfall estimator was formulated using $D_m$ that can be employed by polarimetric as well as dual-frequency radars (e.g., space-based radars such as the GPM DPR), to lower the bias and uncertainty of conventional single radar parameter rainfall estimates by as much as 20%. Polarimetric radar also suffers from issues associated with sampling the vertical distribution of precipitation. Hence, we characterized the vertical profile of polarimetric parameters (VP3)—a radar manifestation of the evolving size and shape of hydrometeors as they fall to the ground—on dual-polarimetric rainfall estimation. The VP3 revealed that the profile of $Z_{DR}$ in stratiform rainfall can bias dual-polarimetric rainfall estimators by as much as 50%, even after correction for the vertical profile of reflectivity (VPR). The VP3 correction technique that we developed can improve operational dual-polarimetric rainfall estimates by 13% beyond that offered by a VPR correction alone.

Huntsville, Alabama

Radar configuration for RHI sampling over disdrometers

ARMOR  Distance from disdrometers: 15 km
- Frequency: 5625 MHz (C-band)
- Peak transmitted power: 350 kW
- Pulse duration: 0.8 µs
- Pulse repetition frequency: 1200 Hz
- Number of samples per bin: 128
- Beamwidth (3 dB): 1.0°
- Antenna: 3.7 m diameter; Center Feed Parabolic
- Range resolution: 125 m

NPOL  Distance from disdrometers: 10 km
- Frequency: 2780-2810 MHz (S-band)
- Peak transmitted power: 850 kW
- Pulse duration: 0.8 µs
- Pulse repetition frequency: 1100 Hz
- Number of samples per bin: 72
- Beamwidth (3 dB): 0.95°
- Antenna: 8.5 m diameter; Center Feed Parabolic
- Range resolution: 150 m
- Polarization: Simultaneous Transmit/Receive of h and v

Drop Size as a function of Melting Layer Thickness and Height

$D_m$ increases with a thickening ML

$D_m$ decreases with a lowering ML

Drop size increases as ML thickens and as it lowers

Vertical Variability of the DSD below the Melting Layer

- Normalized Gamma DSD:
  $$N(D) = N_0 f^b \left( \frac{D}{D_m} \right)^b \exp \left( -\frac{D}{D_m} \right)$$
- T-matrix scattering simulations
- Retrieve $D_m$ and $N_w$ from 2,530 RHIs

ARMOR/NPOL DSD Retrieval Uncertainty

<table>
<thead>
<tr>
<th>RMSE</th>
<th>Relative Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_m$</td>
<td>0.101 / 0.138 mm</td>
</tr>
<tr>
<td>$N_w$</td>
<td>1374 / 3972 mm$^{-3}$</td>
</tr>
</tbody>
</table>

Drop Size Implications for Radar QPE: A technique to further constrain $Z$.

$R(Zh, Dm) = 6.50 \times 10^{-3} D_m - 2.186 Z_h$ 0.96

$R(Zh, Dm)$ reduces error by 15%

Vertical Profile of Polarimetric Parameters (VP3)

- Larger raindrops fall from thicker ML
- $D_m$ exhibits a distinct profile
- $N_w$ profile just below ML is more variable than it is closer to ground

Depth of ML can provide insight into RSD profile

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