A Preliminary Analysis of Precipitation Properties and Processes during NASA GPM IFloodS

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NASA GPM Iowa Flood Studies (IFloodS) Goals

- NASA's GPM ground validation (GV) team partnered with the Iowa Flood Center at the University of Iowa
- collect detailed measurements of surface precipitation
  - ground instruments (e.g., rain gauges, disdrometers, MRR)
  - advanced weather radars (e.g., NPOL, D3R, XPOL)
  - satellites passing overhead
- characterize precipitation properties and processes in the vertical column, including type, amount and size
- improve rainfall estimates from satellite algorithms, especially upcoming NASA GPM mission's Core Observatory satellite (Launch date: Feb 27, 2014)
- input to flood forecasting models, improve capabilities and test utility and limitations of satellite precipitation data for flood forecasting
IFloods Data

- Eastern Iowa
- 1 May – 15 June 2013
- NASA NPOL radar
  - S-band, dual-polarization
  - Hydrometeor type, size, amounts
- NASA 2D Video Disdrometer (2DVD) network over Clear Creek river basin
  - Drop size, shape, fall speed

<table>
<thead>
<tr>
<th>2DVD</th>
<th>Range (km)</th>
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<tbody>
<tr>
<td>SN25</td>
<td>4.99</td>
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2DVD network along NPOL’s 130° azimuth
Preliminary Objectives of this Study

- focus on analysis of NASA NPOL (S-band, polarimetric) radar and NASA 2D Video Disdrometer (2DVD) measurements
  1. assessing **impact of range** on polarimetric radar estimates of rain drop size distribution (DSD) properties
  2. documenting **evolution of rain DSD** as a function of **melting layer** processes
- Case Study
  - 28 May 2013: Mesoscale Convective System (MCS) with widespread precipitation, including stratiform and convection
Beam height (h) increases with range (R) due to Earth curvature and beam refraction.

Beamwidth (B) increases with range (R), $B \propto R$, or radar resolution $\propto \frac{1}{R}$.
Methodology

- 2DVD drop size distribution (DSD) data binned (at 1 minute) and quality controlled
  - Rain Rate (R): R > 0.5 mm h⁻¹
  - Total Number Drops (Nₜ): Nₜ > 100 drops
- 2DVD DSD moments (Pₙ) calculated from binned and gamma fit data, N(D)
  - Mass Weighted Mean Diameter (Dₘ)

\[
D_m = \frac{\int_{D_{\text{min}}}^{D_{\text{max}}} D \cdot D^3 \cdot N(D) dD}{\int_{D_{\text{min}}}^{D_{\text{max}}} D^3 \cdot N(D) dD} = \frac{\int_{D_{\text{min}}}^{D_{\text{max}}} D^4 \cdot N(D) dD}{\int_{D_{\text{min}}}^{D_{\text{max}}} D^3 \cdot N(D) dD} = \frac{P_4}{P_3}
\]
Methodology

- Quality control NPOL radar data
  - Relative calibration of differential reflectivity ($Z_{dr}$) using bird bath (vertically pointing scans)
- NPOL PPI (and RHI) scans available every 2 to 3 minutes
- Insure rain (or mitigate presence of ice).
  - Beam height < 2.2 km (below bright band)
  - Elevation angle < 1.5°
  - $\rho_{hv} > 0.97$, $\sigma(\phi_{dp}) < 18^\circ$, HDR < 0 dB, $Z_{dr} > 0$ dB
- Keep NPOL gate samples within 0.5 km of 2DVD
- Estimate mass weighted mean diameter ($D_m$) from $Z_{dr}$
  - $Z_{dr}$ is reflectivity-weighted measure of drop shape and size
  - Must use empirical relationship, $D_m = F(Z_{dr})$
  - Use equation 1) from Bringi and Chandrasekar (2001) and 2) derived from IFloodS 2DVD DSD and radar scattering model (T-matrix)
Methodology

\[ D_{m1} = 1.619 \cdot (Z_{dr})^{0.485} \]  \[ [1] \]

\[ D_{m2} = 0.106 \cdot (Z_{dr})^3 - 0.5588 \cdot (Z_{dr})^2 + 1.6552 \cdot (Z_{dr}) + 0.5508 \]  \[ [2] \]

[2]: I FloodS 2 DVD DSD data
T-matrix: rain (oblate spheroid)
Frequency = S-band, T=20°C
Shape model = 80m bridge experiment (Thurai and Bringi 2005)
Canting angle \( \sigma = 6^\circ \)
NPOL PPI, radar reflectivity, $Z_h$ (dBZ)  
28 May 2013, 07 – 10 UTC

IFloodS NASA 2DVD Network. Location relative to NASA NPOL

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★ 2DVD

Range rings every 50 km
NPOL RHI, radar reflectivity, $Z_h$ (dBZ) 28 May 2013, 07 – 10 UTC

- RHI along the 2DVD network
- NPOL’s 130.4° azimuth
Excellent agreement between NPOL $D_{m2}$ (IFloodS relation) and 2DVD $D_m$ at close range
Statistical Results: NPOL PPI vs. 2DVD 28 May 2013

SN36 (R=24.5 km, 0719-1002 UTC)

NPOL Dm1 SN36
Mean: 1.56 mm
Median: 1.59 mm

NPOL Dm2 SN36
Mean: 1.70 mm
Median: 1.72 mm

2DVD Dm SN36
Mean: 1.66 mm
Median: 1.67 mm

SN37 (R=47.4 km, 0702-0957 UTC)

NPOL Dm1 SN37
Mean: 1.52 mm
Median: 1.51 mm

NPOL Dm2 SN37
Mean: 1.65 mm
Median: 1.63 mm

2DVD Dm SN37
Mean: 1.70 mm
Median: 1.66 mm

Good agreement but NPOL slight underestimate by 47 km range (SN37)
Reasonable agreement but evidence of NPOL slight underestimate at larger ranges
Excellent agreement between NPOL $D_{m2}$ and 2DVD $D_m$ at small to moderate range. Good agreement elsewhere but evidence of NPOL slight underestimate at large range, except in large drop core where mixed (NPOL sometimes too low or high).
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Vertical variability of DSD

IFloodS: May 28th, 2013
NPOL-retrieved Dm over
2DVD-SN35 (15 km range)

• Vertical variability of $D_m$ not large
• But tendency for slightly larger $D_m$ at lower heights (closer to surface and 2DVD’s)
• Can partially explain comparison of NPOL to 2DVD $D_m$ as function of range (i.e., SN unit)
DSD evolution below varying Melting Layer (ML)

Lower and Thicker Melting Layer (ML) $\rightarrow$ Larger raindrops
Summary

- Demonstrated robust NPOL retrievals of $D_m$ relative to 2DVD using both statistics and time series
  - Important for ability to increase $D_m$ sample using NPOL
- Empirical $D_{m2} = F(Z_{dr})$ polynomial derived from IFloodS data provided more accurate NPOL estimates compared to literature relation
- Slightly increased error in NPOL $D_m$ with range
  - Slight NPOL underestimate relative to 2DVD at $R \geq 50$ km (except in intense convection where results mixed)
  - Likely associated with 1) beam height with range and vertical variability of DSD and 2) beam size/resolution
- Lower and Thicker Melting Layer (ML) $\rightarrow$ Larger raindrops
  - Can help improve parameterizations for radar DSD and rain rate retrievals