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


Lawrence D. Carey[1], Patrick N. Gatlin[1,2], Walter A. Petersen[3], Matthew T. Wingo[1], Timothy J. Lang[2], and David B. Wolff[3]

[1] University of Alabama in Huntsville
[2] NASA MSFC
[3] NASA GSFC/Wallops Flight Facility

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

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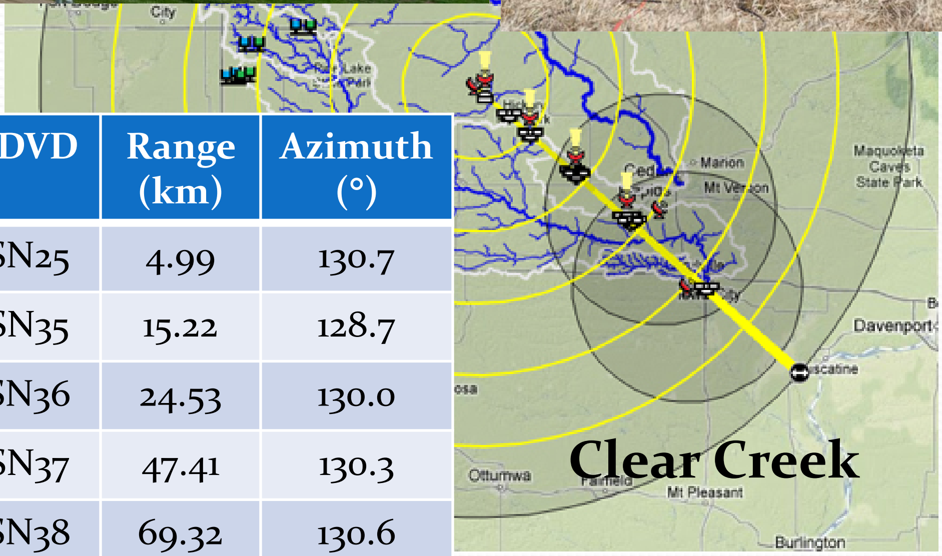
# NASA GPM Iowa Flood Studies (IFloodS) Goals

- 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

**NPOL domain (25 km range rings)**



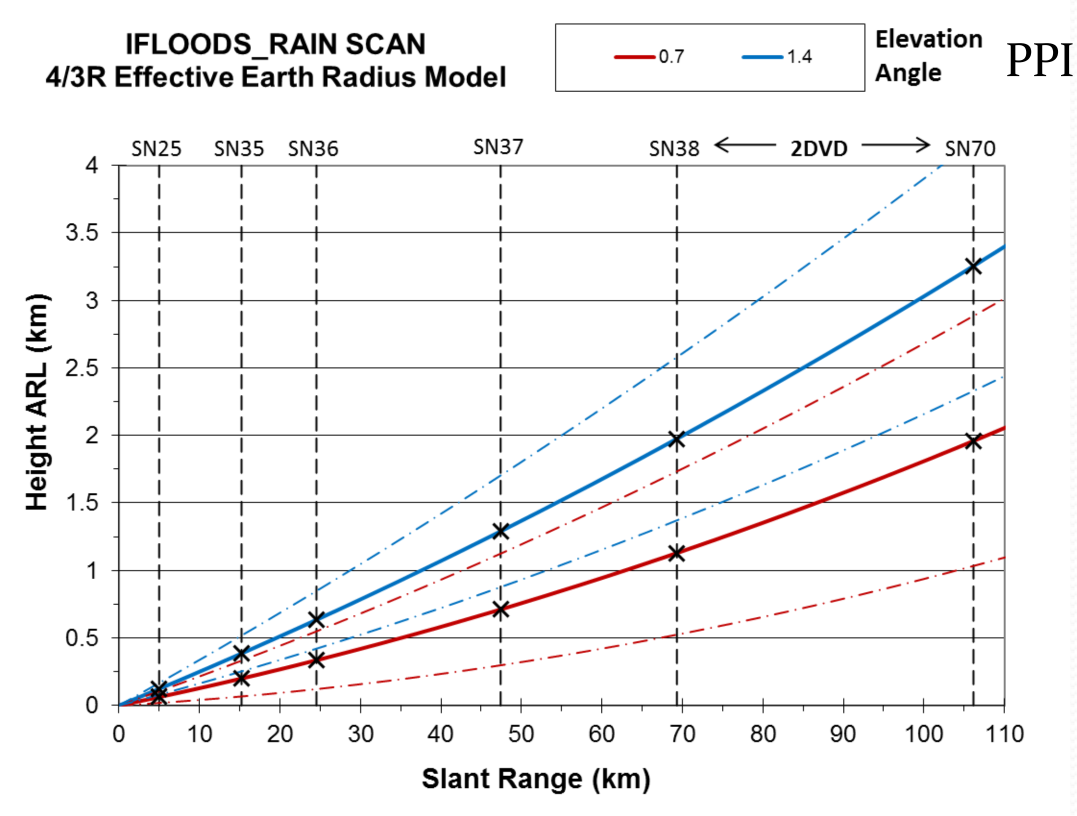

| 2DVD | Range (km) | Azimuth (°) |
|---|---|---|
| SN25 | 4.99 | 130.7 |
| SN35 | 15.22 | 128.7 |
| SN36 | 24.53 | 130.0 |
| SN37 | 47.41 | 130.3 |
| SN38 | 69.32 | 130.6 |
| SN70 | 106.16 | 130.8 |

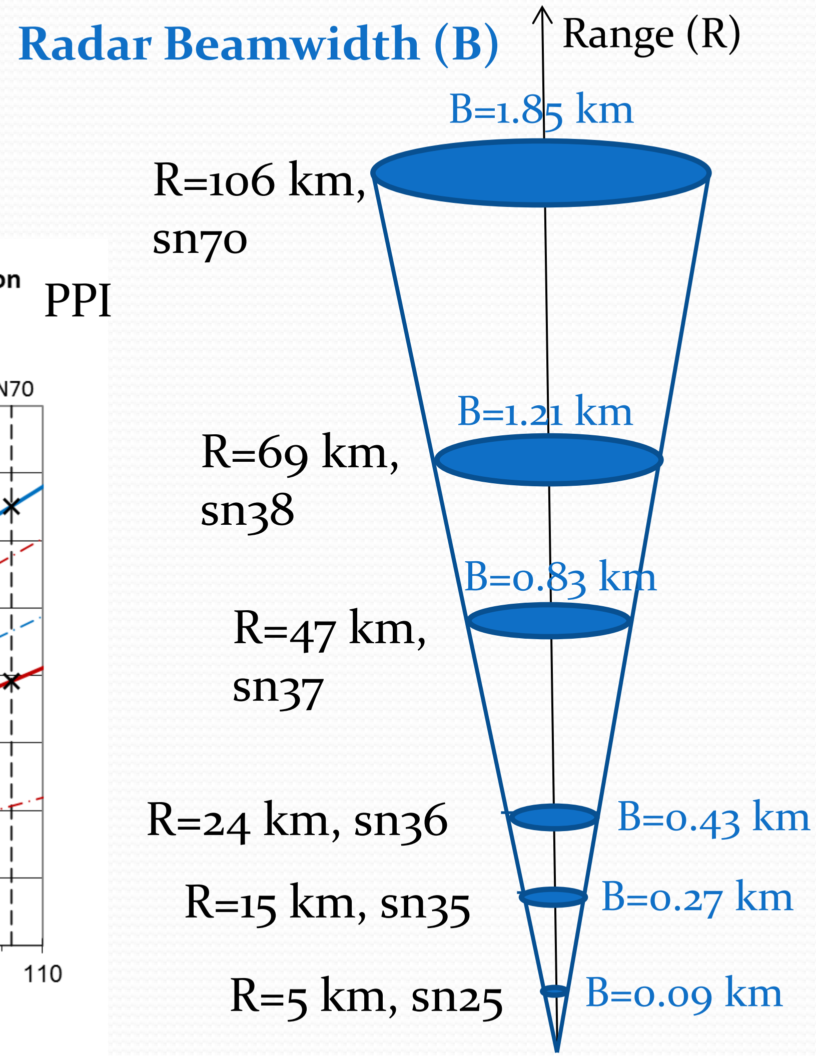
2DVD network along NPOL's 130° azimuth

# 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 and Resolution with Range




Beam height (h) increases with range (R) due to Earth curvature and beam refraction.

Beamwidth (B) increases with range (R), B ∝ R, or radar resolution ∝ 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 ($N_T$): $N_T$ > 100 drops
- 2DVD DSD moments ($P_n$) calculated from binned and gamma fit data, N(D)
  - Mass Weighted Mean Diameter ($D_m$)

$$D_m = \frac{\int_{D_{\min}}^{D_{\max}} D \cdot D^3 \cdot N(D)\,dD}{\int_{D_{\min}}^{D_{\max}} D^3 \cdot N(D)\,dD} = \frac{\int_{D_{\min}}^{D_{\max}} D^4 \cdot N(D)\,dD}{\int_{D_{\min}}^{D_{\max}} D^3 \cdot N(D)\,dD} = \frac{P_4}{P_3}$$

# Methodology

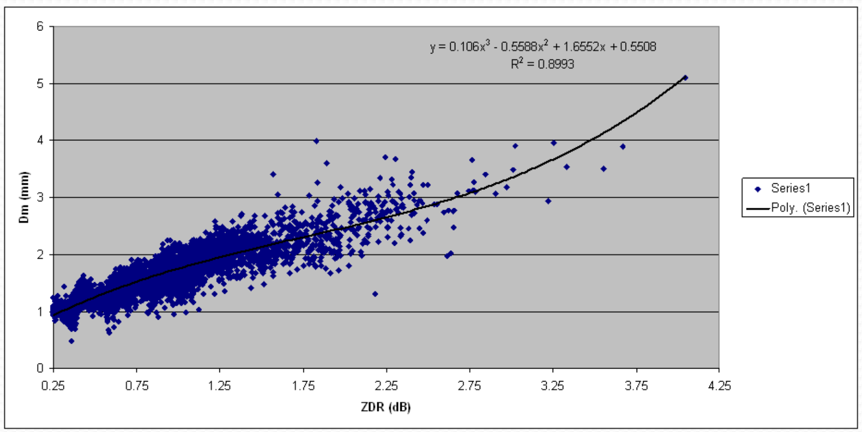
- Quality control NPOL radar data
  - Relative calibration of differential reflectivity ($Z_{dr}$) using bird bath (vertically pointing scans)
- NPOL PPI (and RHI) scans available every 2 to 3 minutes
- Insure rain (or mitigate presence of ice).
  - Beam height < 2.2 km (below bright band)
  - Elevation angle < 1.5°
  - $\rho_{hv} > 0.97$, $\sigma(\phi_{dp}) < 18°$, 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 r*eflectivity-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)

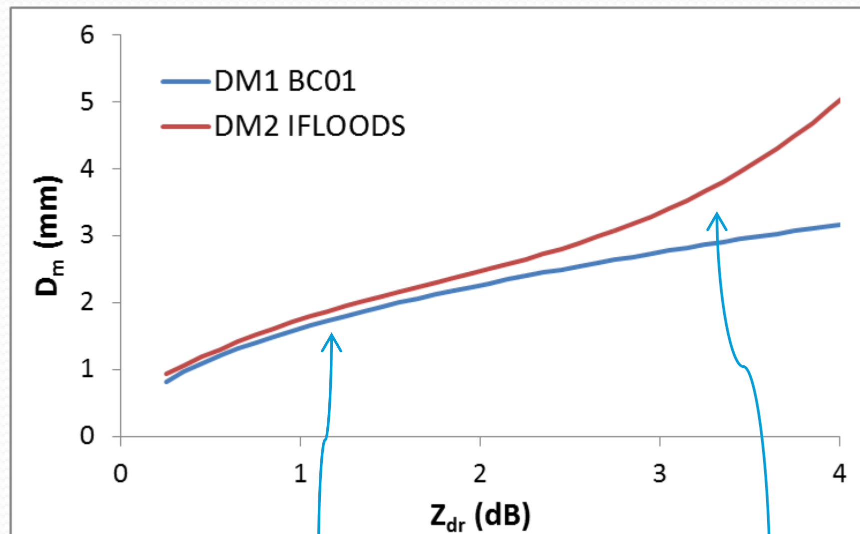
# Methodology

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

([1]: *Bringi and Chandrasekar 2001*)

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



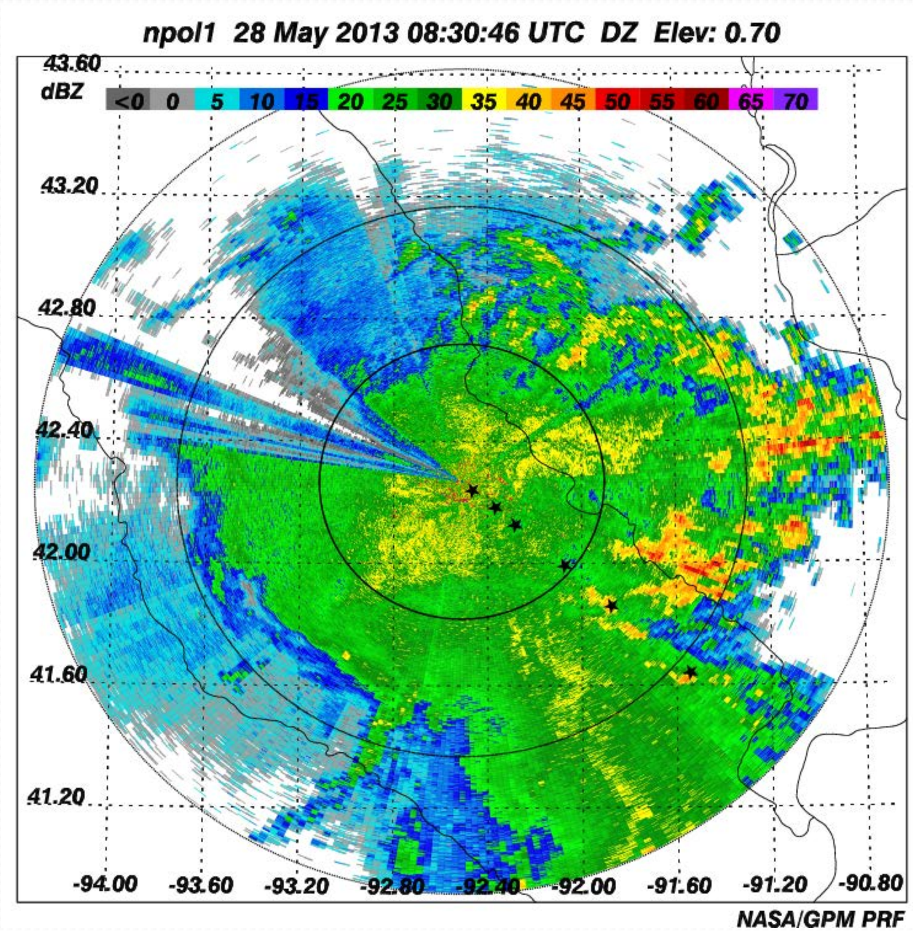




[2]: *IFloodS 2DVD DSD data*
T-matrix: rain (oblate spheroid)
Frequency = S-band, T=20°C
Shape model = 80m bridge experiment (Thurai and Bringi 2005)
Canting angle σ = 6°

Slight bias at low-moderate $Z_{dr}/D_m$

Large bias at large $Z_{dr}/D_m$

# NPOL PPI, radar reflectivity, $Z_h$ (dBZ)
# 28 May 2013, 07 – 10 UTC




IFloodS NASA 2DVD Network.
Location relative to NASA NPOL

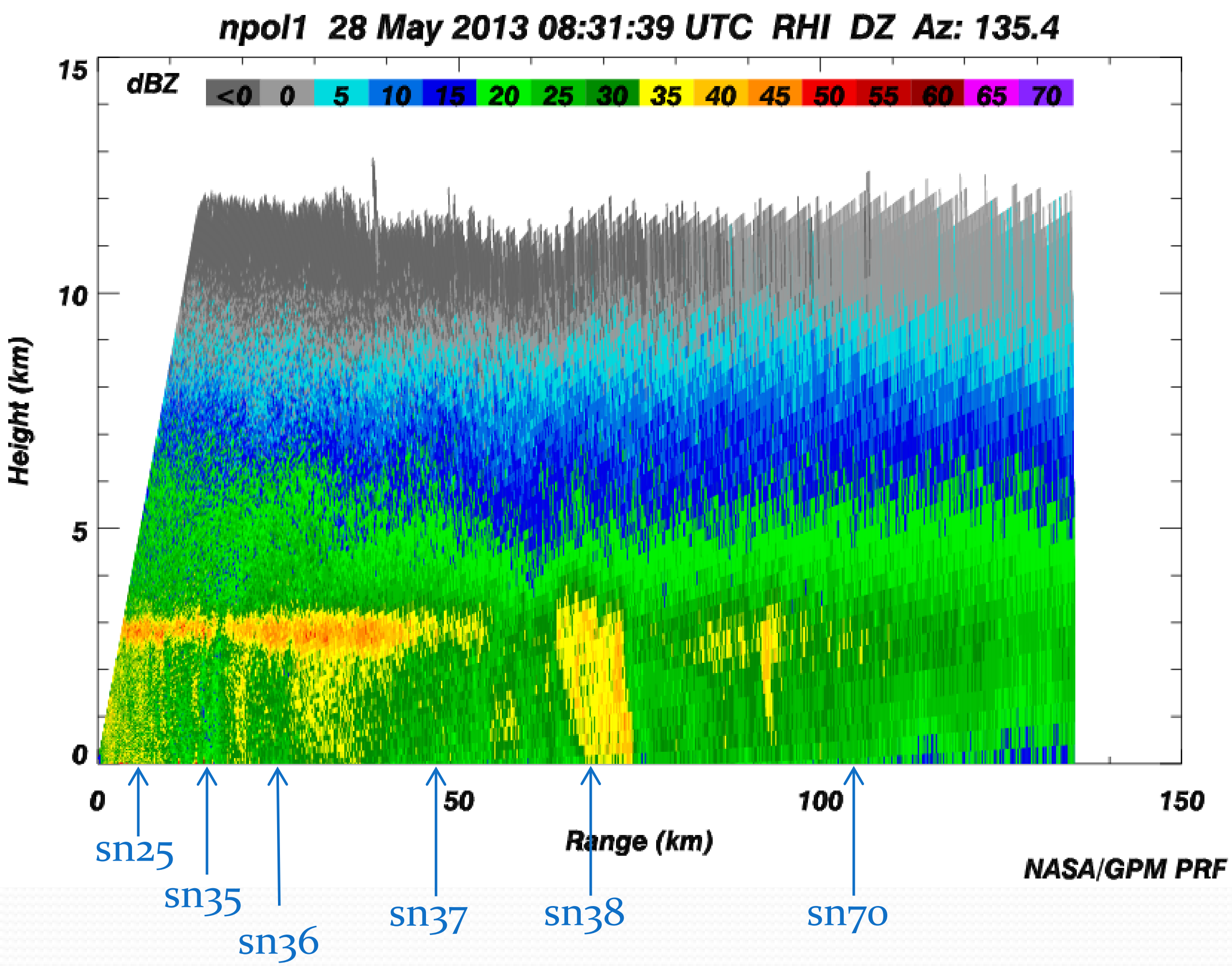
| # | 2DVD | Range (km) | Azimuth (°) |
|---|---|---|---|
| 1. | SN25 | 4.99 | 130.7 |
| 2. | SN35 | 15.22 | 128.7 |
| 3. | SN36 | 24.53 | 130.0 |
| 4. | SN37 | 47.41 | 130.3 |
| 5. | SN38 | 69.32 | 130.6 |
| 6. | SN70 | 106.16 | 130.8 |

★ 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

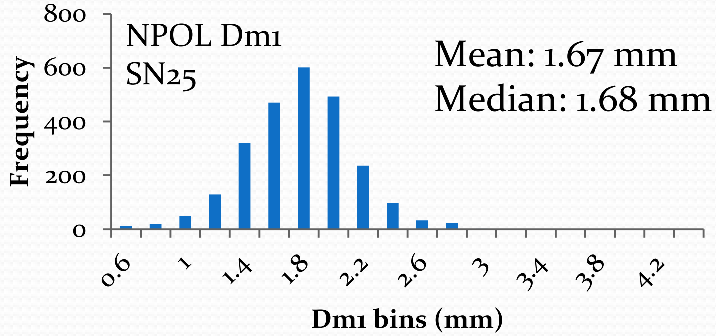


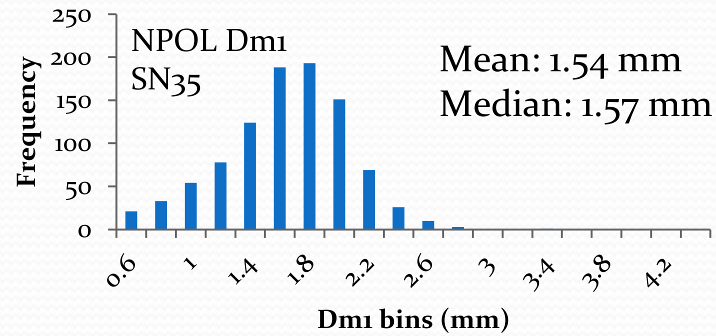
# Statistical Results:  NPOL PPI vs. 2DVD

## 28 May 2013

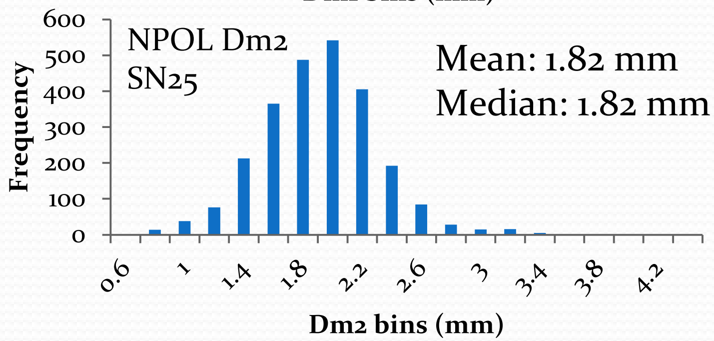
**SN25 (R=5.0 km, 0702-0909 UTC)** | **SN35 (R=15.2 km, 0707-0910 UTC)**

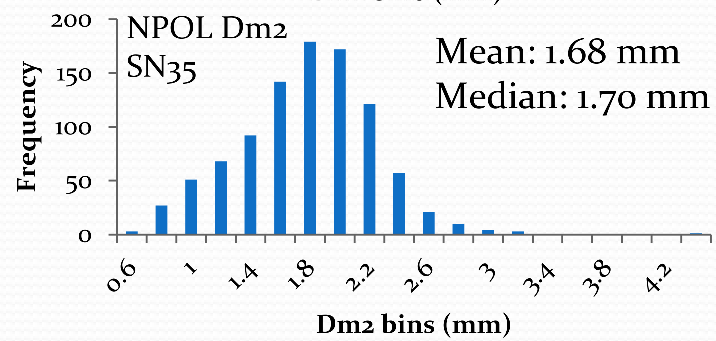
**NPOL $D_{m1}$**



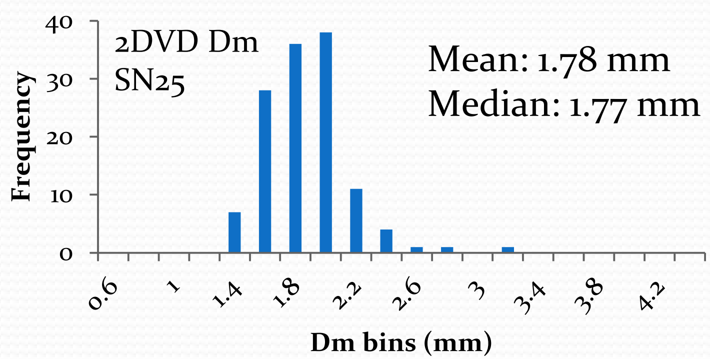



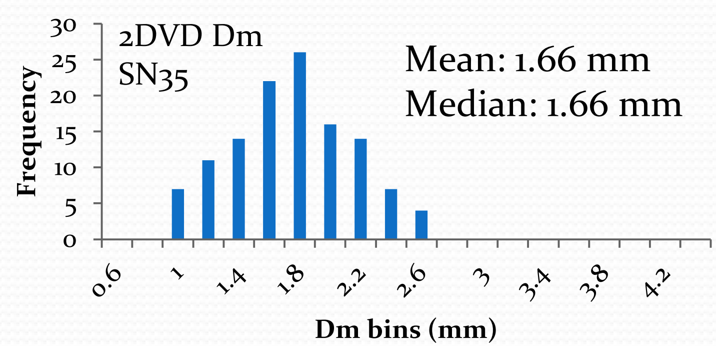

**NPOL $D_{m2}$**




**2DVD $D_m$**




Excellent agreement between NPOL $D_{m2}$ (IFloodS relation) and 2DVD $D_m$ at close range

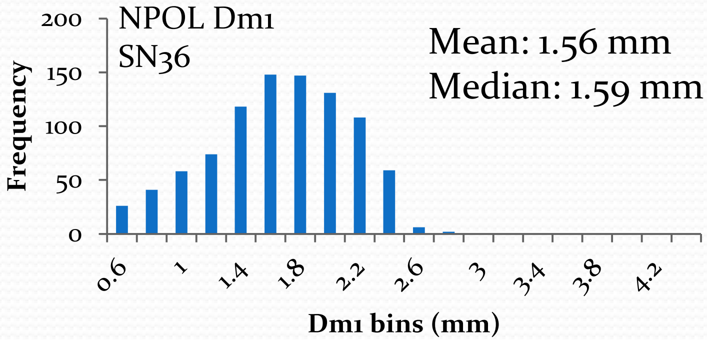
# Statistical Results: NPOL PPI vs. 2DVD

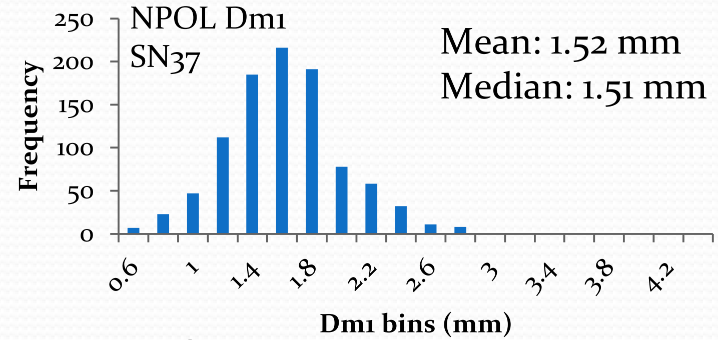
## 28 May 2013

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

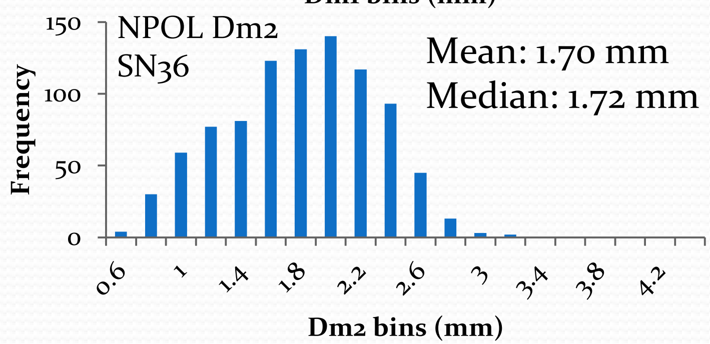
### SN37 (R=47.4 km, 0702-0957 UTC)

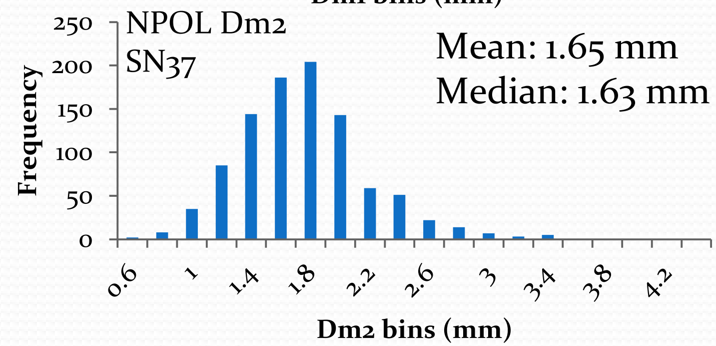
**NPOL $D_{m1}$**



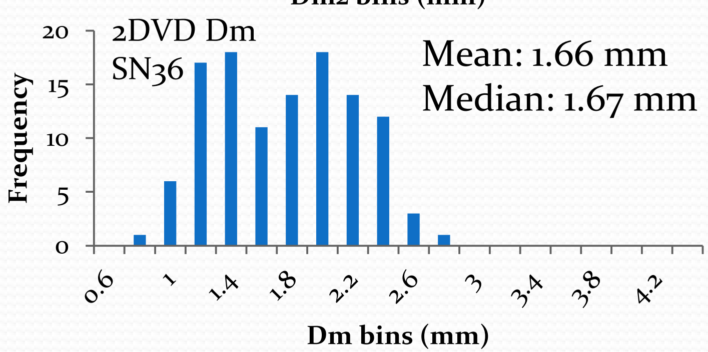



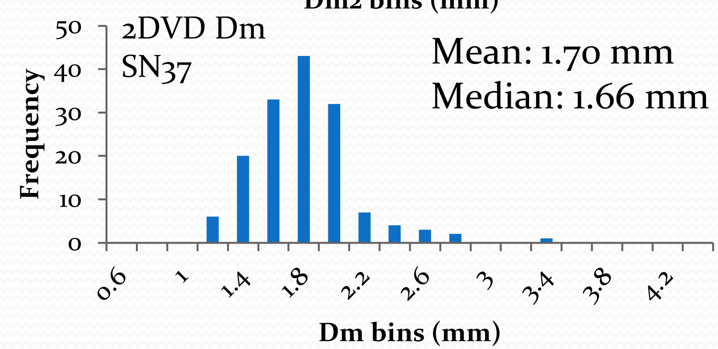

**NPOL $D_{m2}$**




**2DVD $D_m$**




Good agreement but NPOL slight underestimate by 47 km range (SN37)

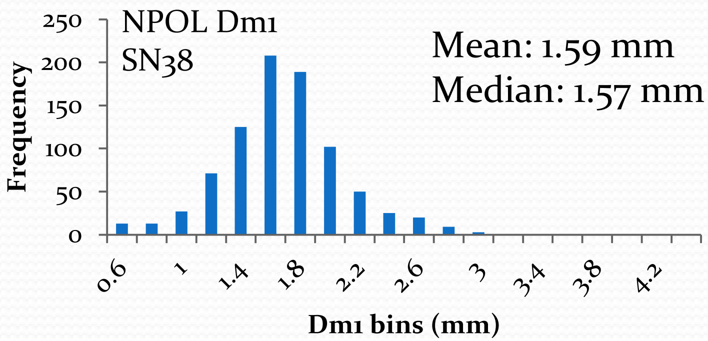
# Statistical Results: NPOL PPI vs. 2DVD

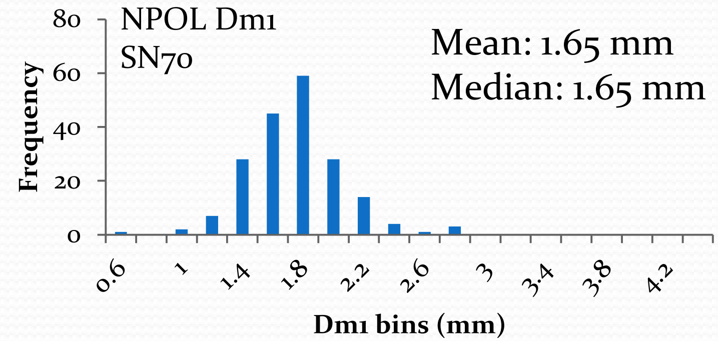
## 28 May 2013

### SN38 (R=69.3 km, 0702-0913 UTC)

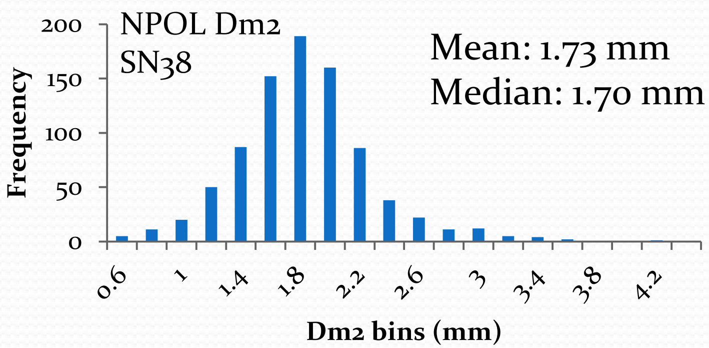
### SN70 (R=106.2 km, 0823-0930 UTC)

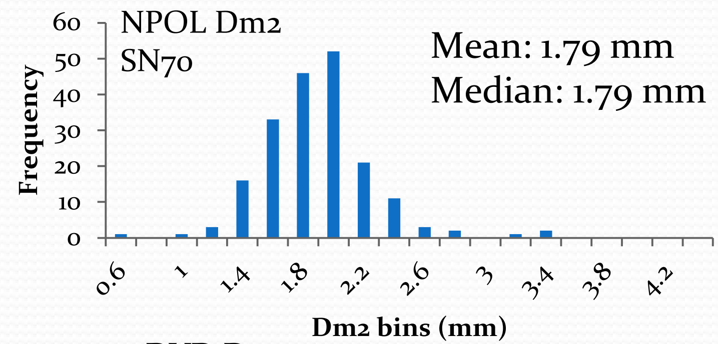
**NPOL $D_{m1}$**



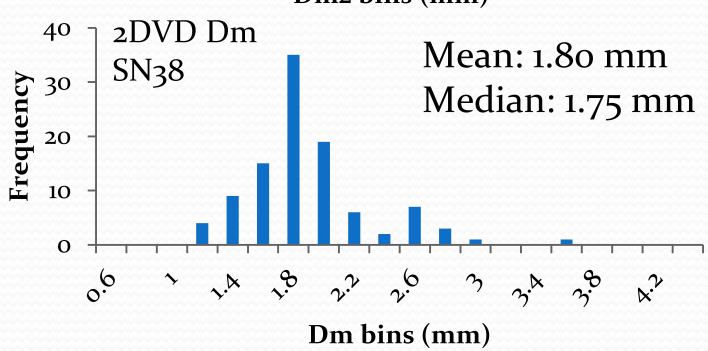



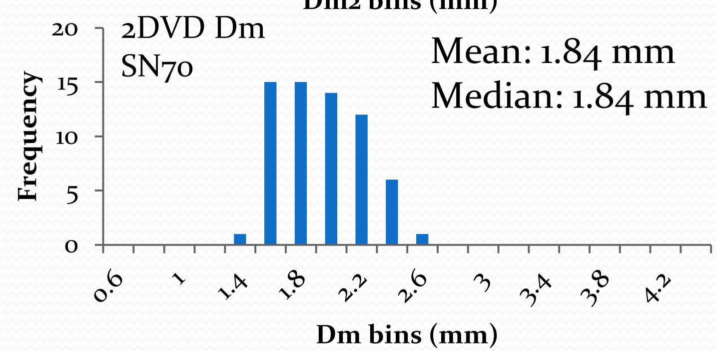

**NPOL $D_{m2}$**



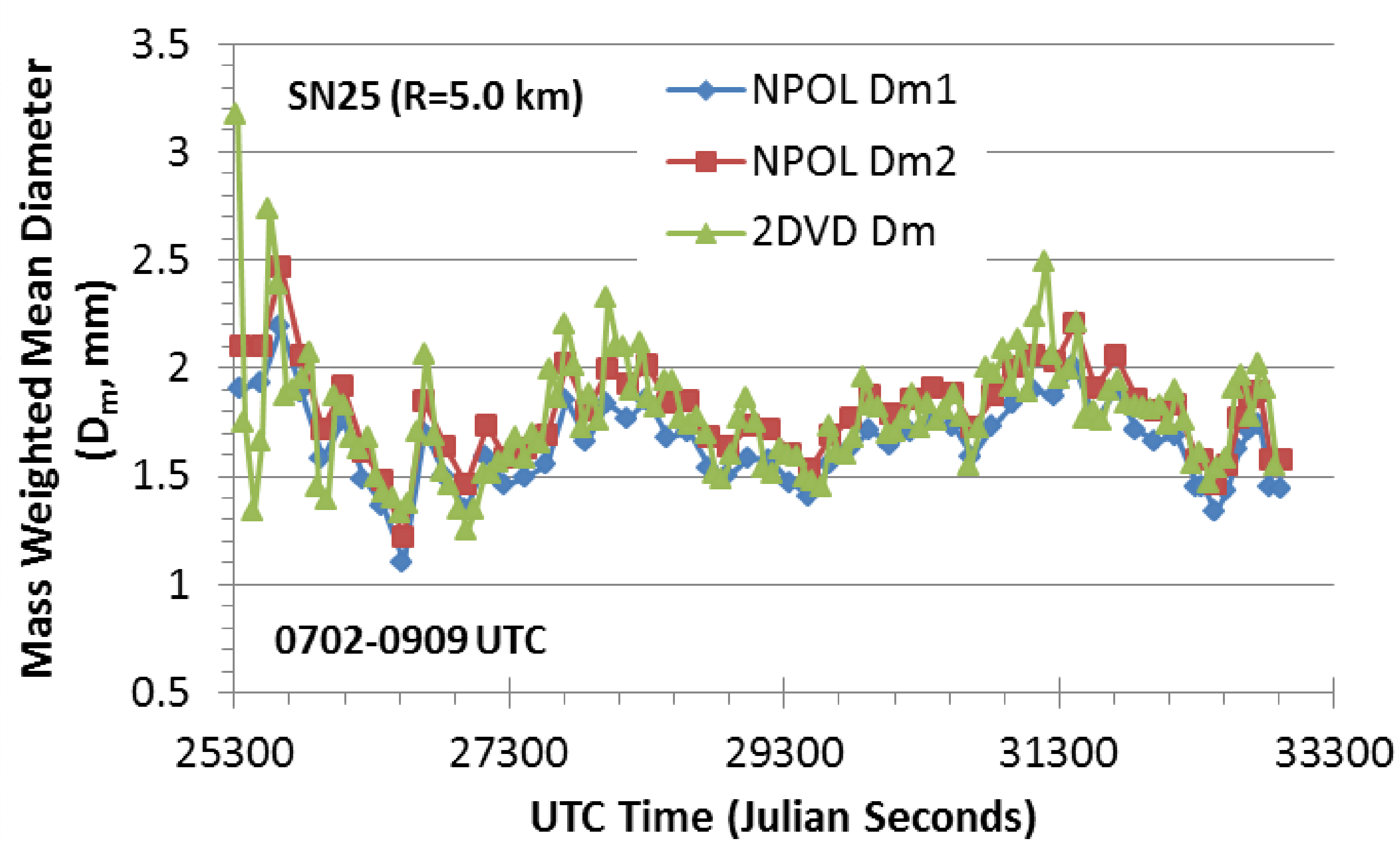

**2DVD $D_m$**



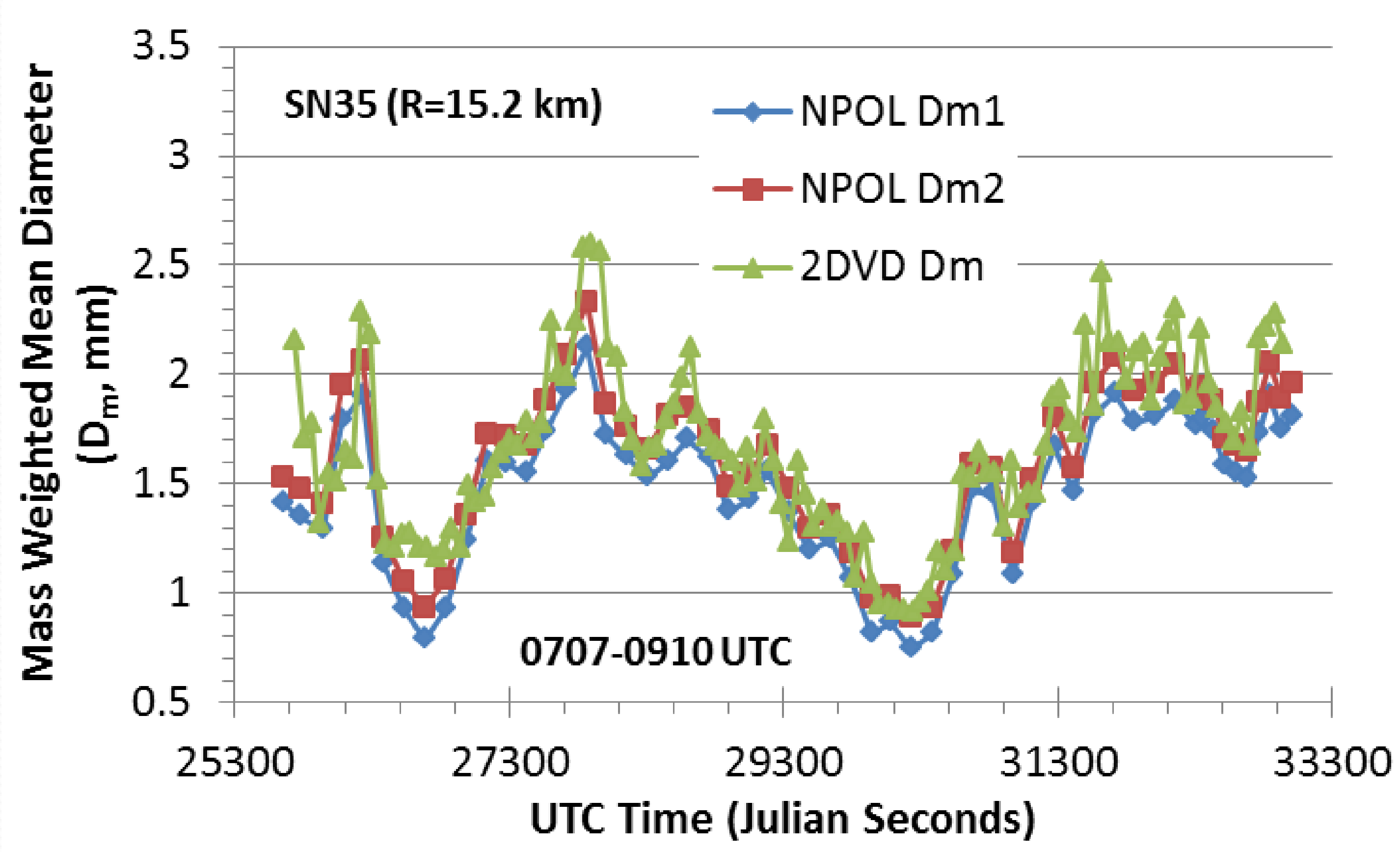

Reasonable agreement but evidence of NPOL slight underestimate at larger ranges

# Time Series Results: NPOL PPI vs. 2DVD




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).

# Time Series Results: NPOL PPI vs. 2DVD

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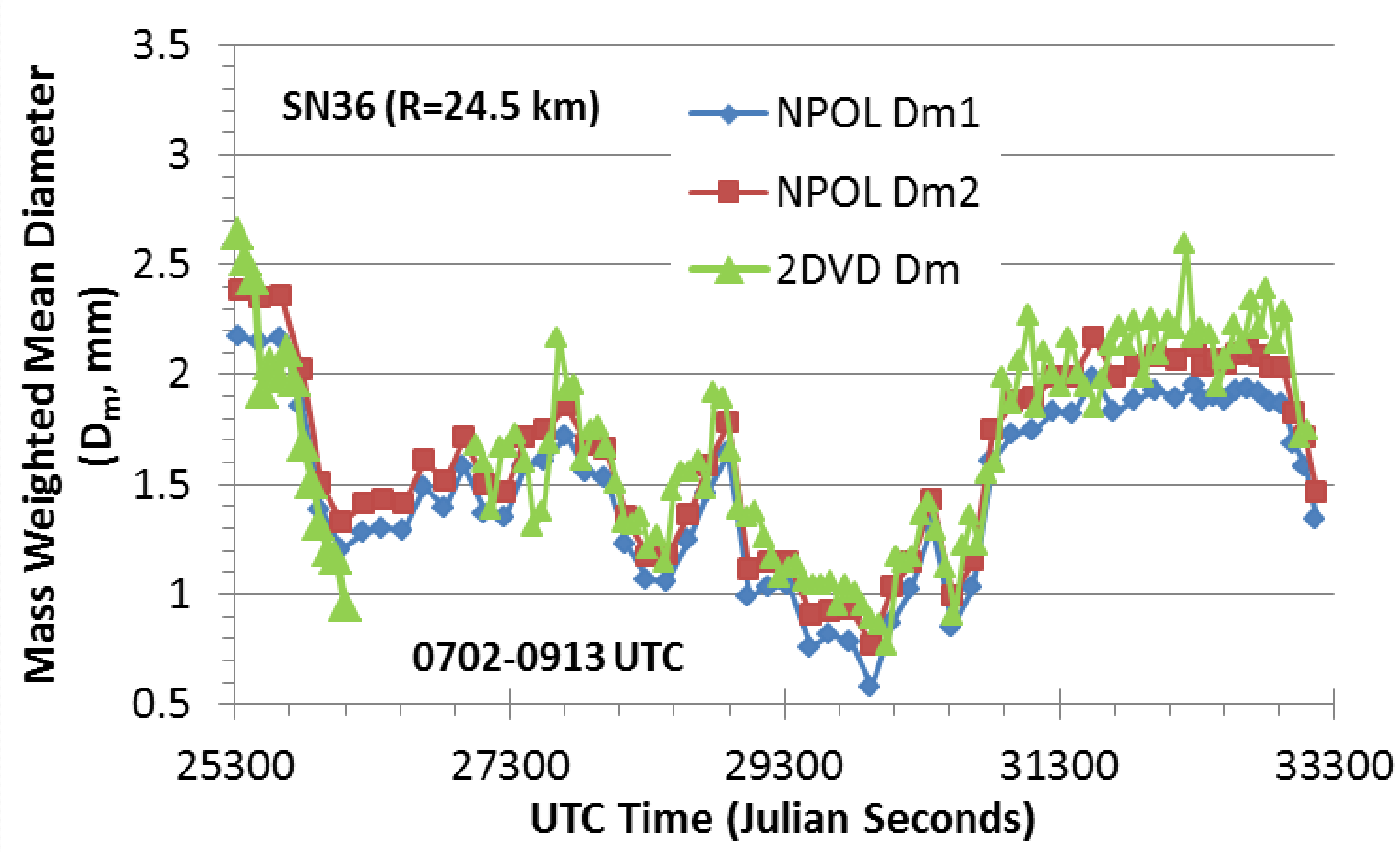


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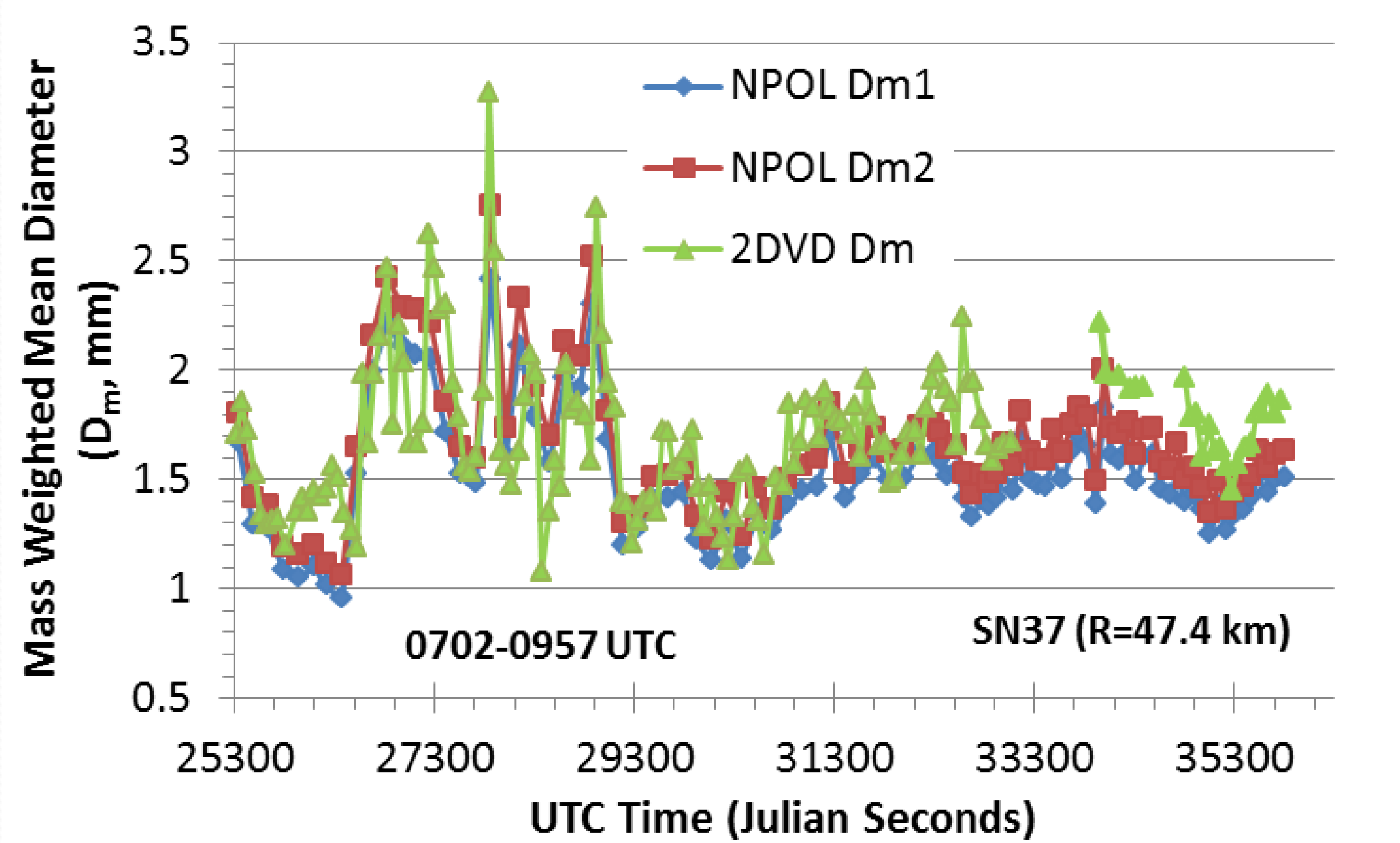


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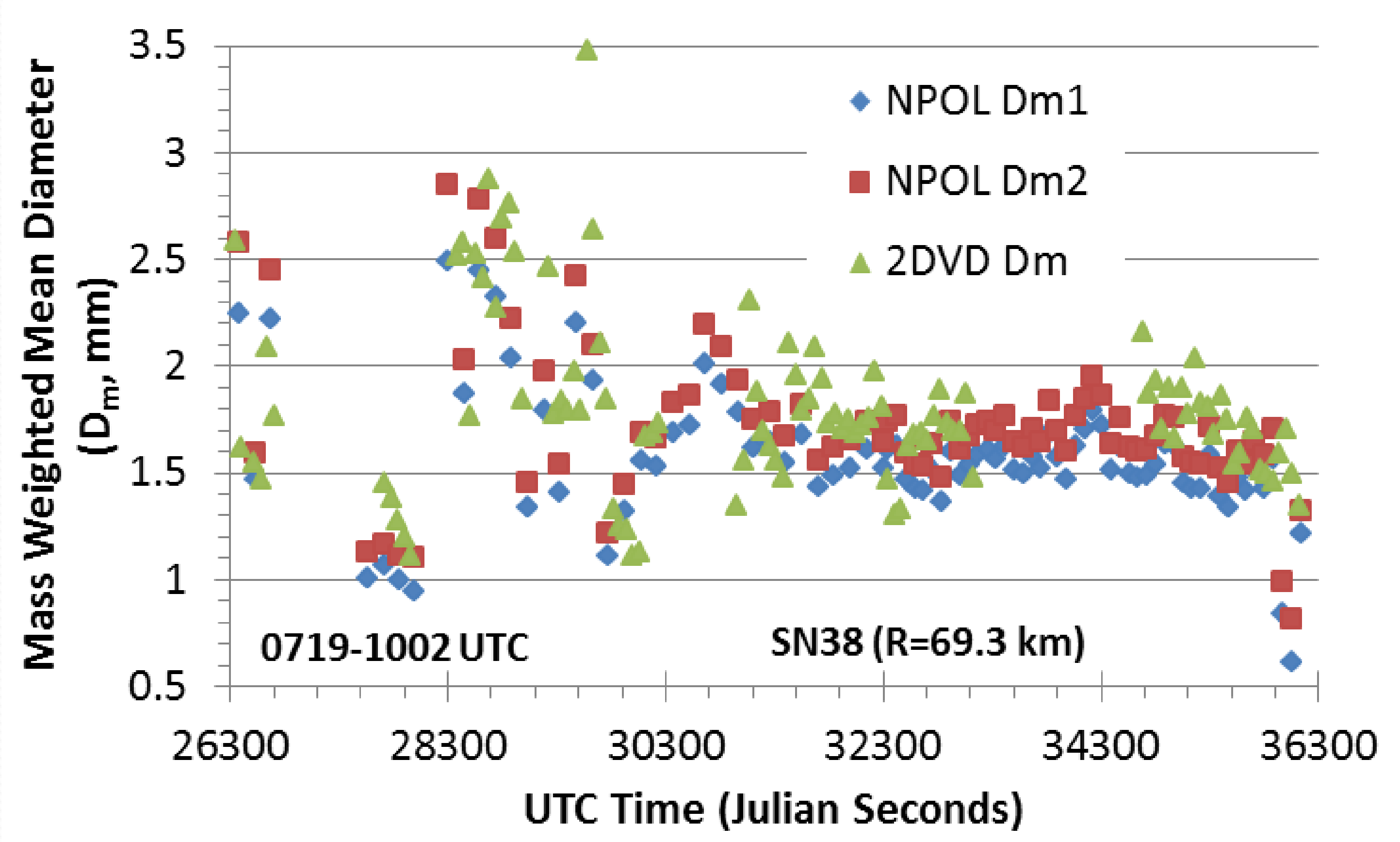


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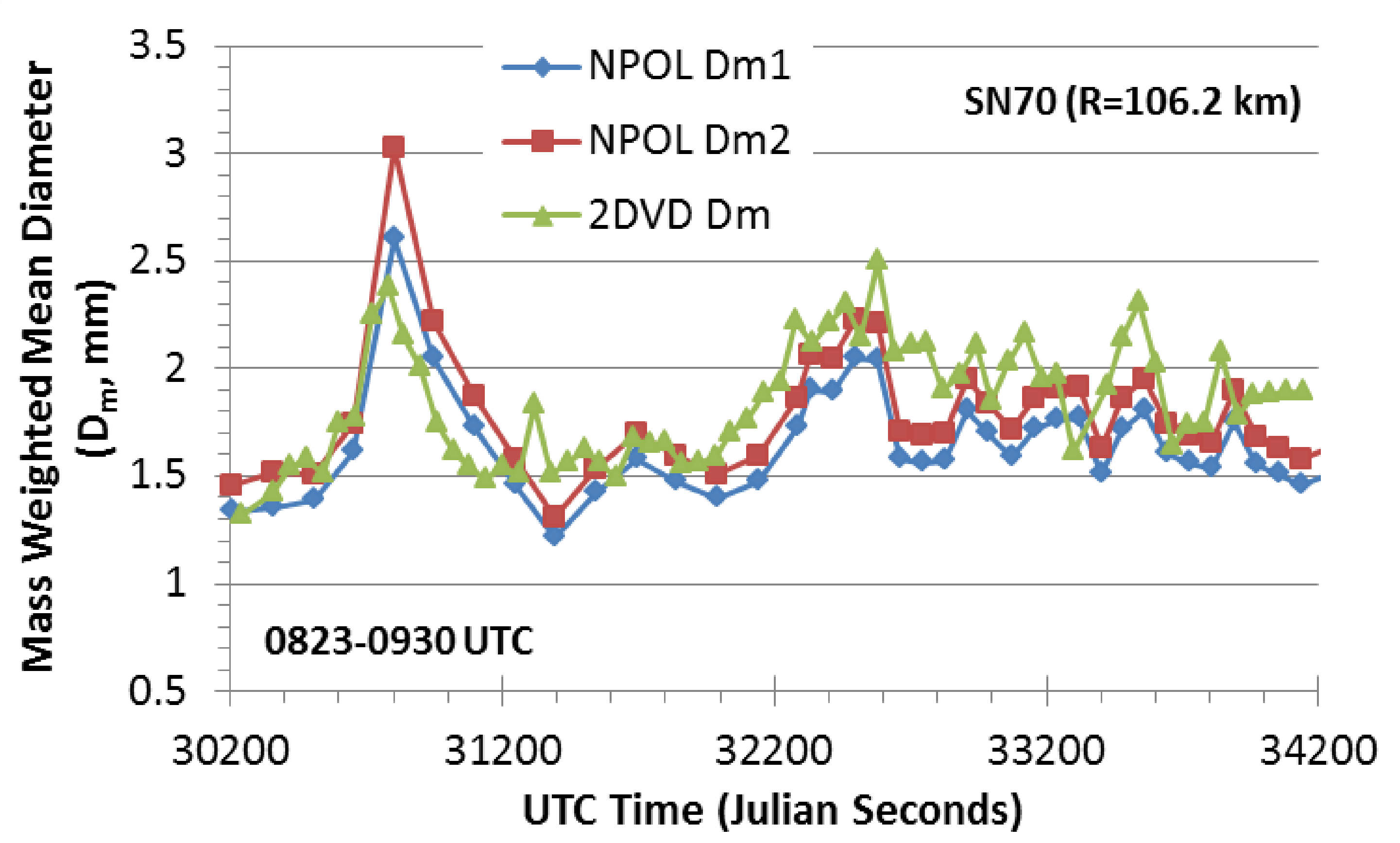


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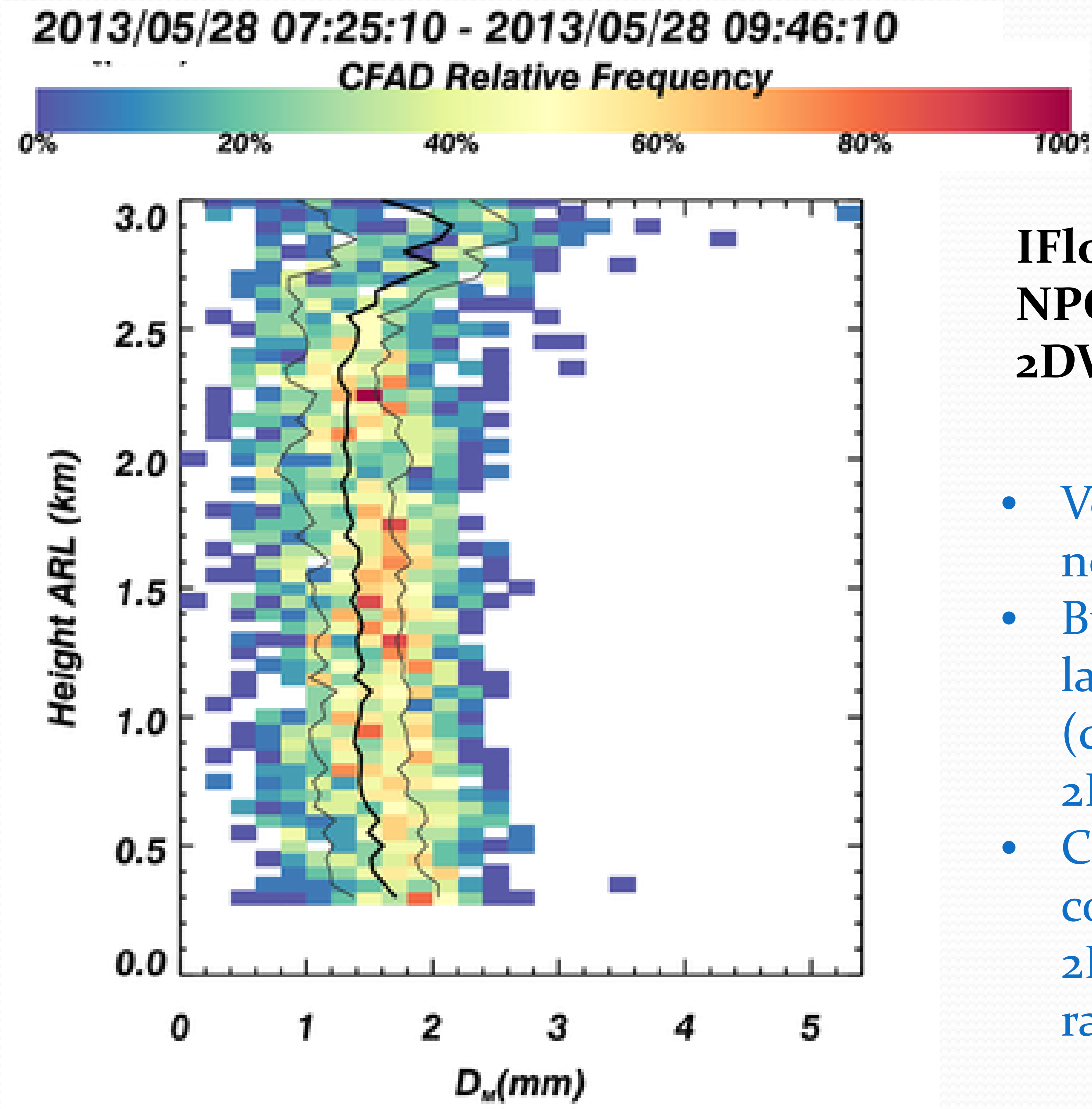
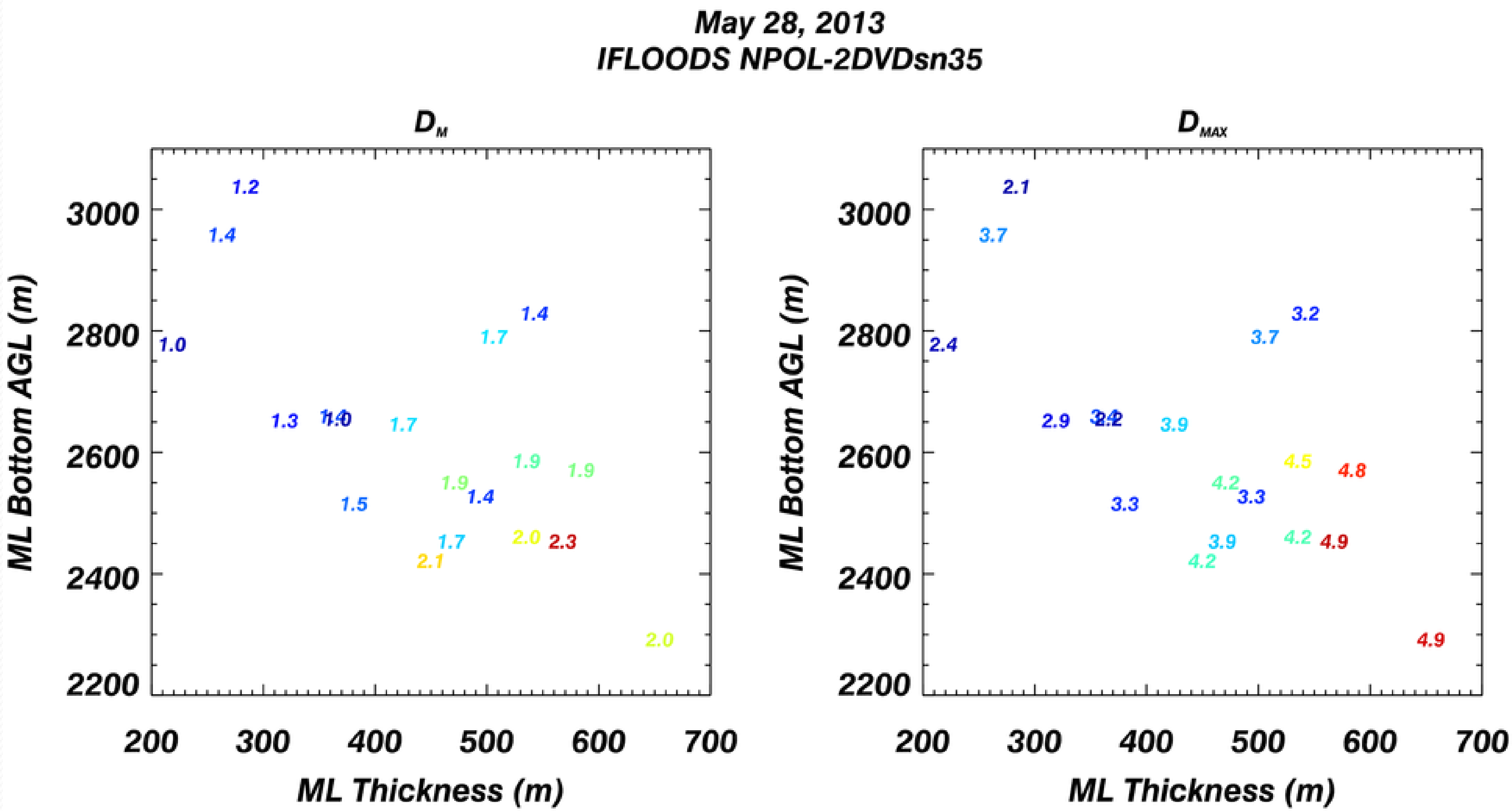
# Vertical variability of DSD




**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) → 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