# Observing the Full Spectrum of the Rain Drop Size Distribution

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## 1. Objective: Verify and Improve GPM Drop Size Distribution Retrievals

- Drop size distributions (DSD; $D_m$, $N_w$) are critical to GPM DPR-based rainfall retrievals.
- Examine physical consistency between GV, algorithms, and within and between algorithms.
- Comparisons with GV suggest DPR $D_m$ bias in convective rain is correlated to underestimation of rain rate. What is the source?
- Light rain/small DSDs are a challenge: Should a generalized gamma (GG) approach be used to model the full DSD spectrum?
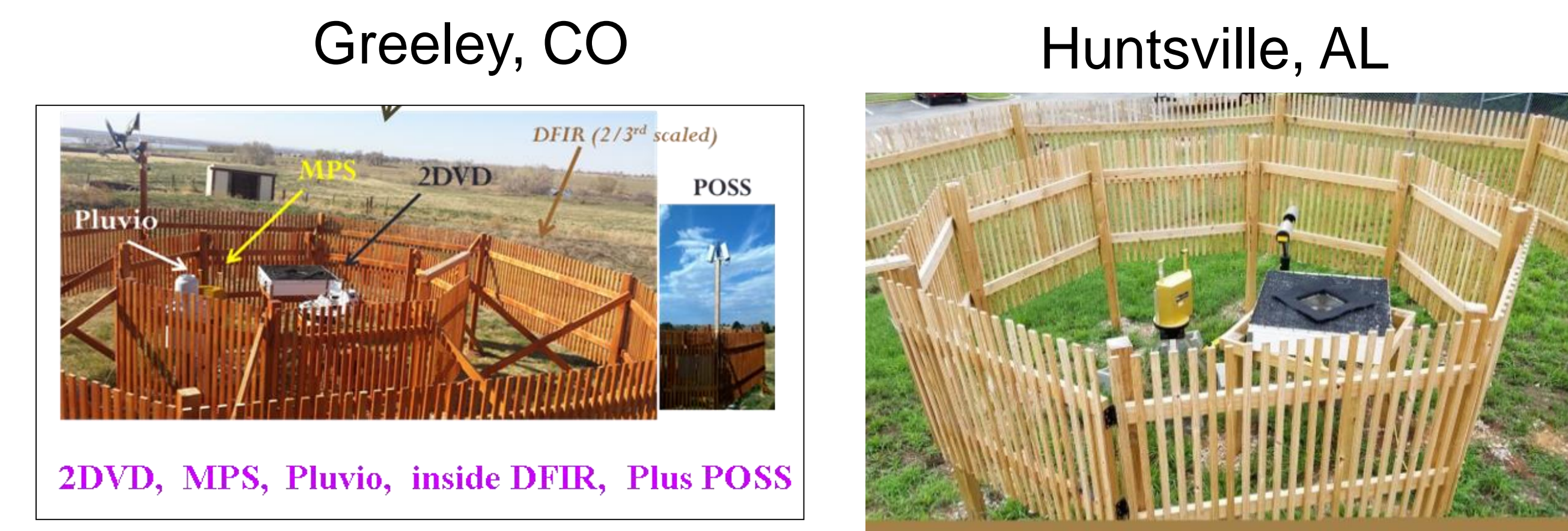
## 2. Continental to Site Specific GV and DPR studies



Greeley, CO

Huntsville, AL
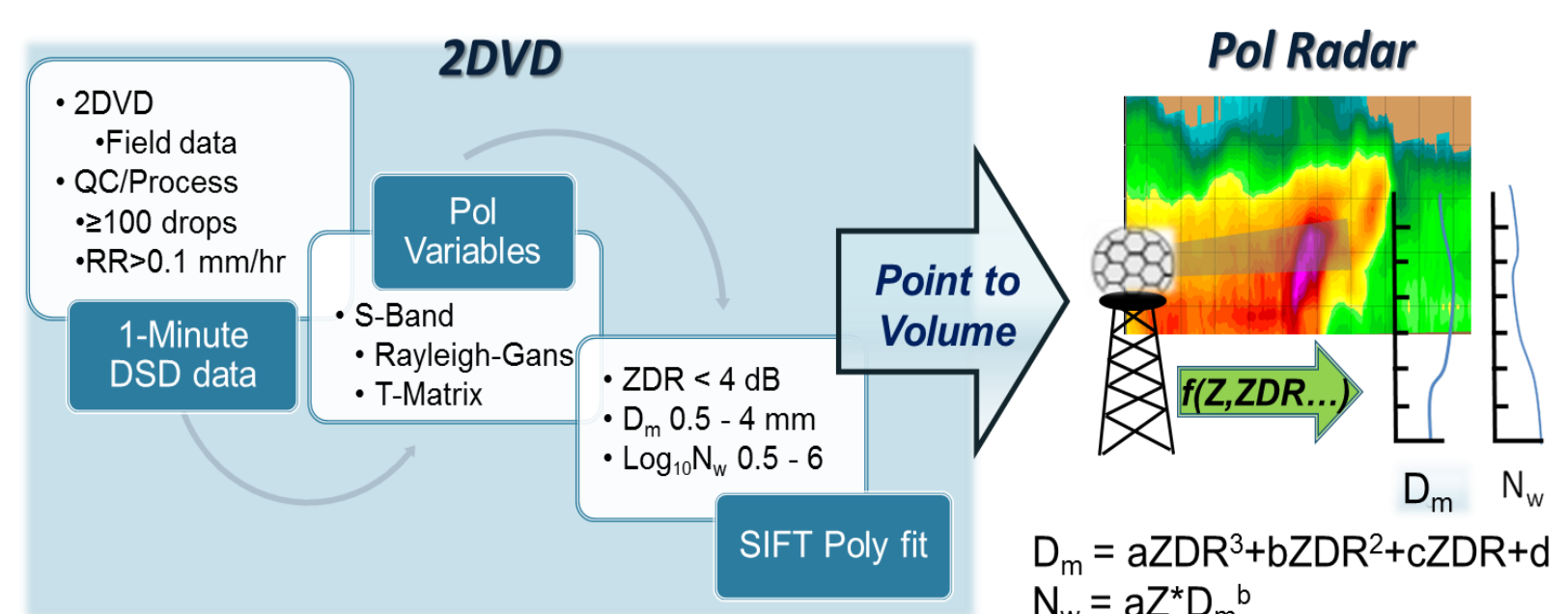
2D Video Disdrometer (2DVD) measurements in a multitude of regimes translated to dual-pol radar moments and DSD retrieval equations
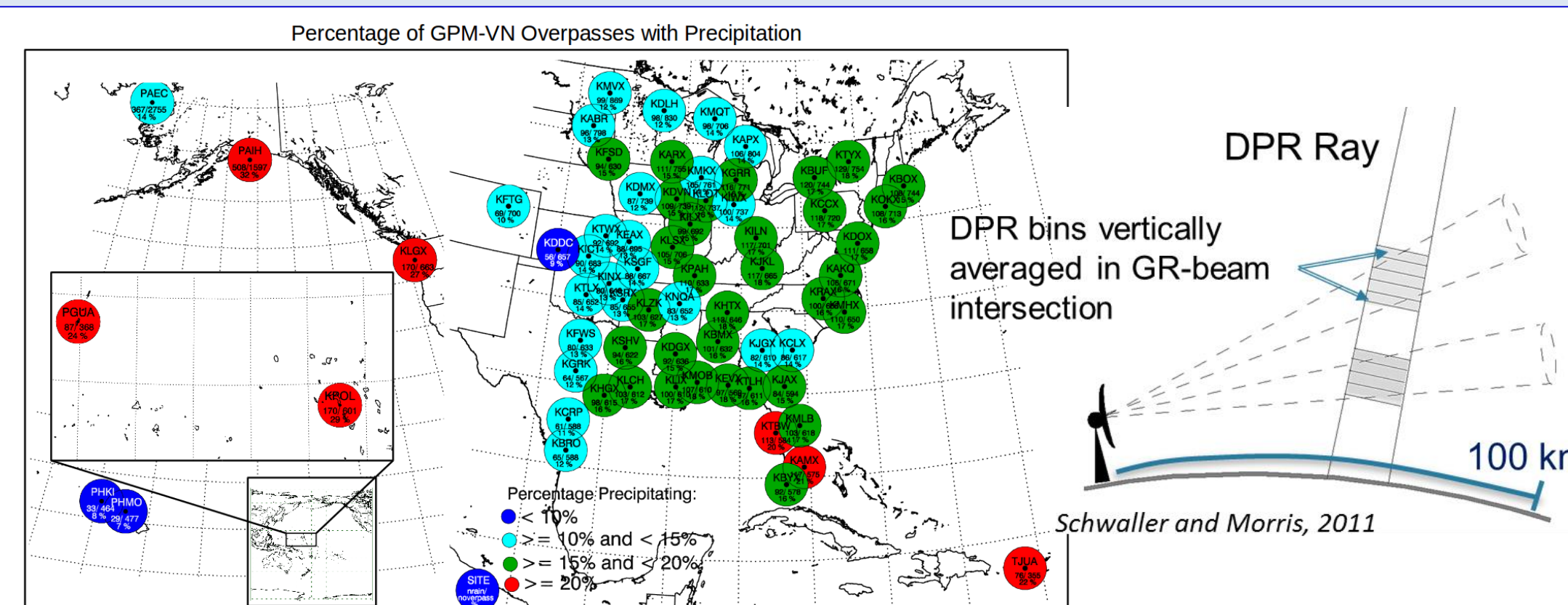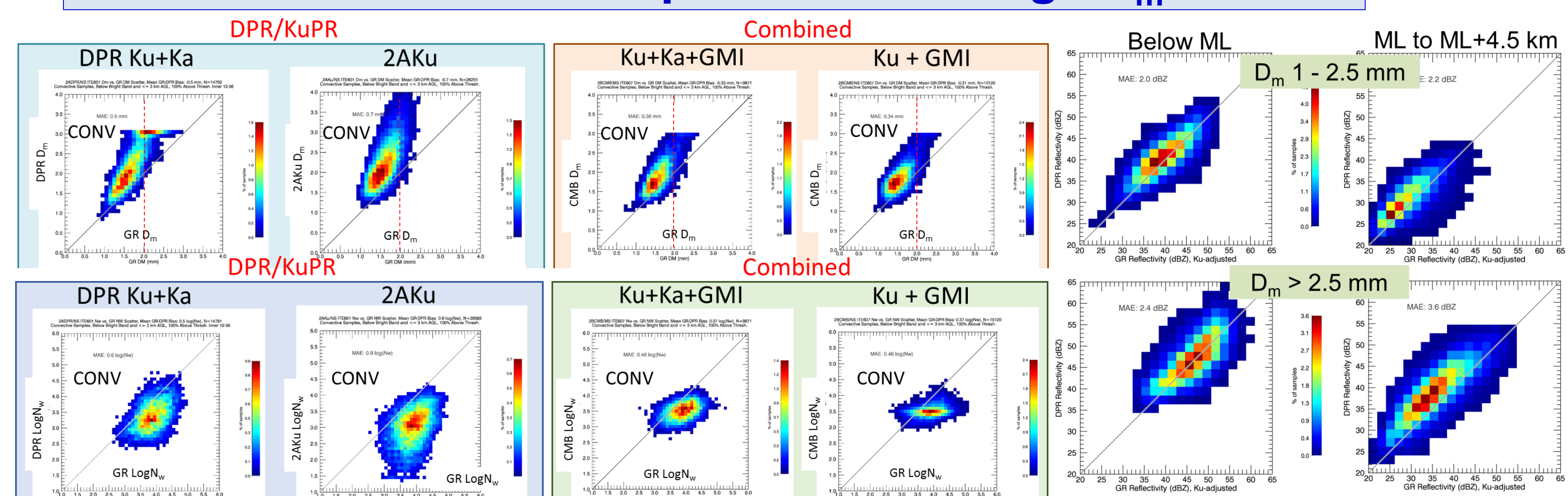
Sample and collocate coincident GV radar and DPR DSDs for O[50-300] raining overpass volumes per radar site within VN radar network

Greeley CO (left) and Huntsville AL sites (right): 2DVD and Meteorological Particle Spectrometer (MPS) enable studies of the *full* DSD spectrum.
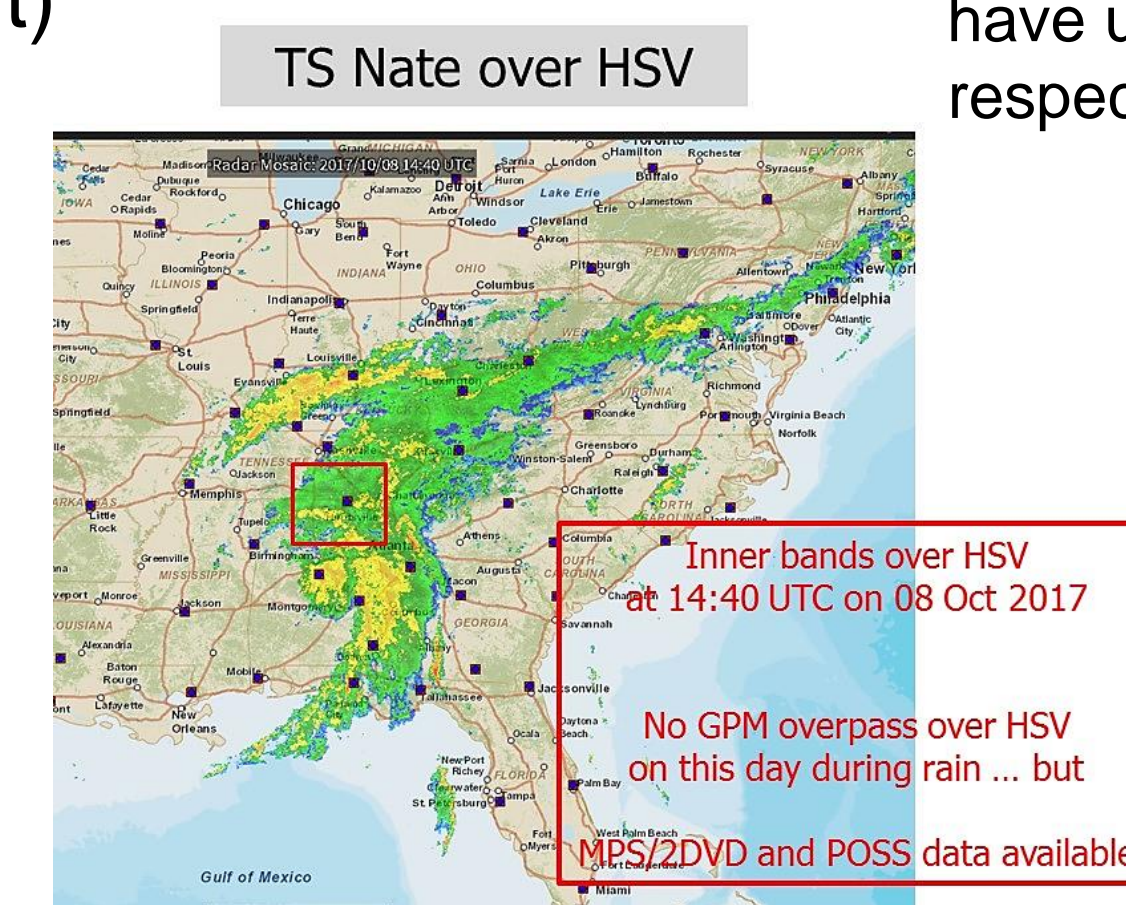
## 3. Focus on Convective spectrum and large $D_m$



KuPR Z-corrected for convection below and above melting layer (ML) common (left) and "big" $D_m$ (right) regimes

Above: Positive bias in convective $D_m$ (top) increases with $D_m$ > 2 mm (red-dash line). $N_w$ (bottom) inconsistent across algorithms, over-compensates negative bias in KuPR $D_m$.

Convective Z below ML similar to GV regardless of $D_m$; Convective Z increases aloft with large $D_m$

$\varepsilon$ vs. GV: KuPR for $D_m$ limits

Recall: $R = a \varepsilon^{4.258} D_m^{5.42}$

Impact: $\varepsilon$ is key to PIA correction and like an $N_w$; If too low, underestimation of convective rain rates when $D_m$ is too large

HID has enhanced ice-phase in convection with large $D_m$- makes sense, but also more intra pixel variability in Z (above ML- shown, and below- not shown)

**Large $D_m$ issue a possible symptom of NUBF (PIA correction)?**

## 4. Focus on Small $D_m$ and GG model for complete DSD spectrum

### The GG Model

For consistency with standard gamma, moments (M) I=3, J=4 used in this study; others have used 3, 6, respectively
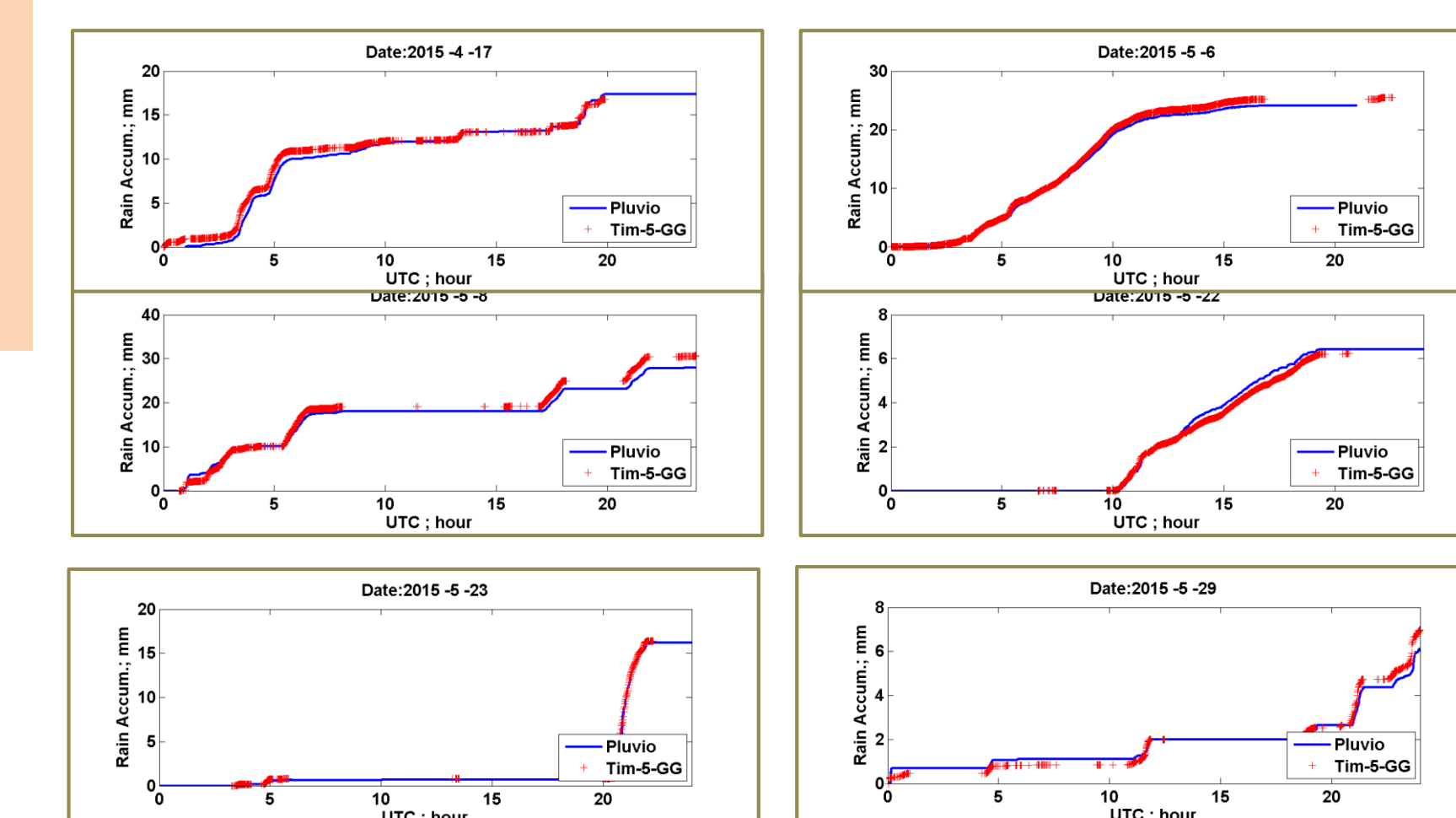
$$N(D) = N_0' \, h_{GG(i,j,\mu,c)}(x)$$

$$where \quad N_0' = M_i^{(j+1)/(j-i)} M_j^{(i+1)/(i-j)} \quad and \quad D_m' = (M_i/M_j)^{1/(i-j)}$$

$$h_{GG(i,j,\mu,c)}(x) = c \, \Gamma_i^{\frac{(j+c\mu_{GG})}{(i-j)}} \, \Gamma_j^{\frac{(-i-c\mu_{GG})}{(i-j)}} \, x^{c\mu_{GG}-1} \, exp\left[-\left(\frac{\Gamma_i}{\Gamma_j}\right)^{\frac{c}{(i-j)}} x^c\right]$$

$$\Gamma_i = \Gamma\left(\mu_{GG} + \frac{i}{c}\right) \quad and \quad \Gamma_j = \Gamma\left(\mu_{GG} + \frac{j}{c}\right) \quad and \quad x = \left(\frac{D}{D_m}\right)$$
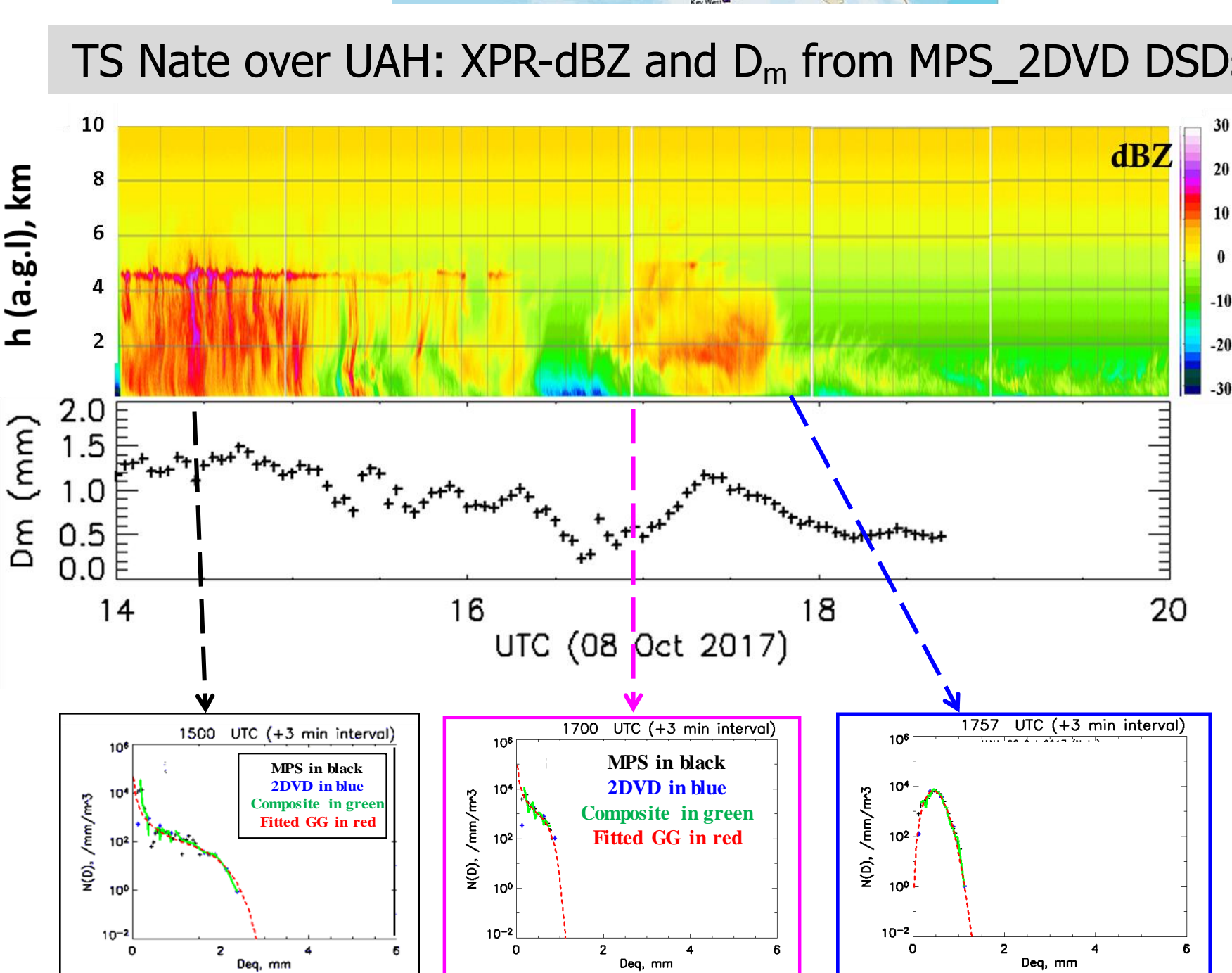
### GXY cases: R and Accum vs. Pluvio



Above: Greely (GXY) CO site. MPS-2DVD DSD fits result in robust accumulation performance for a variety of event types.
Below- Little bias in MPS-2DVD GG data-fits until large diameters (sampling impact)

TS Nate over HSV

(GPM Overpass)

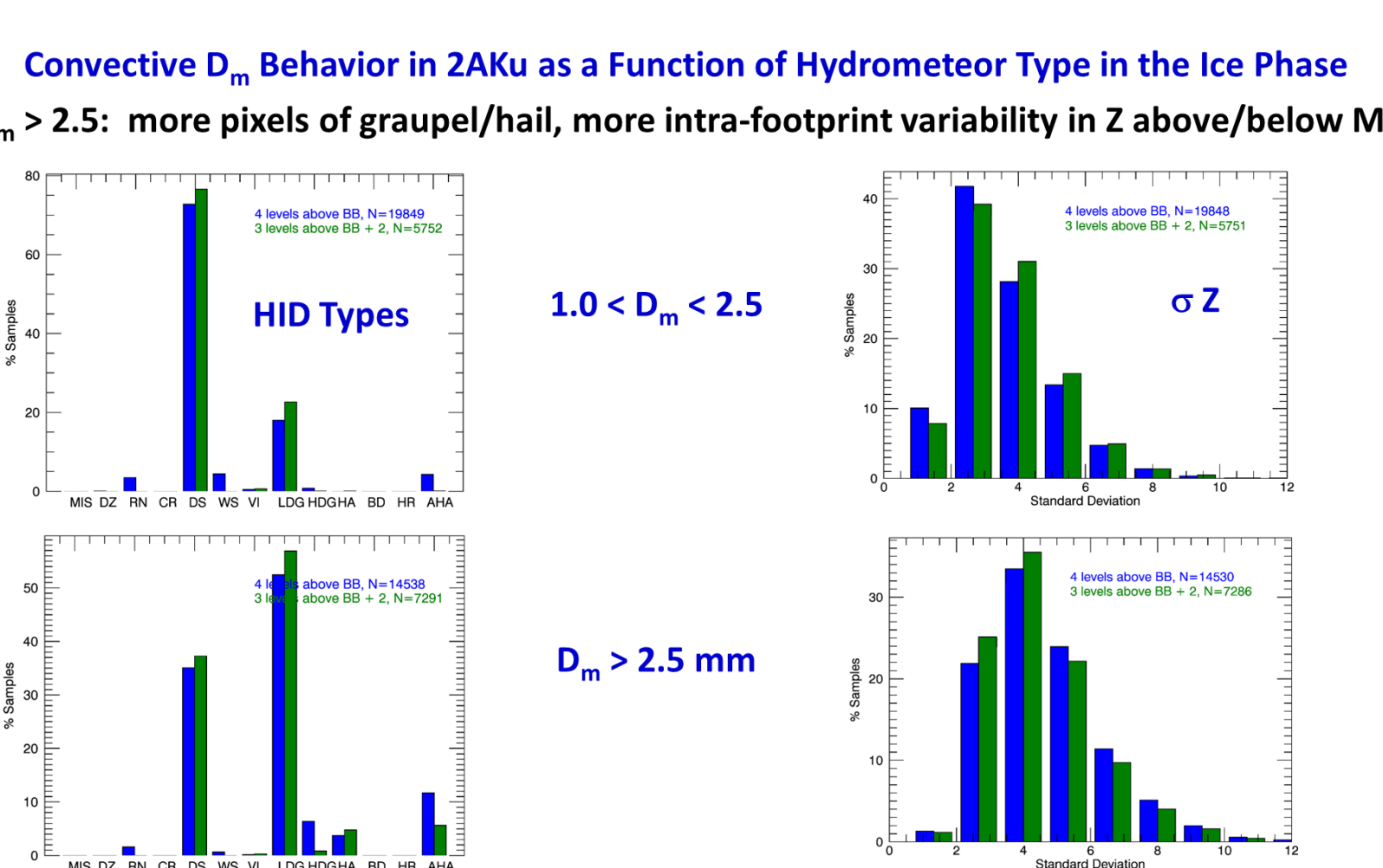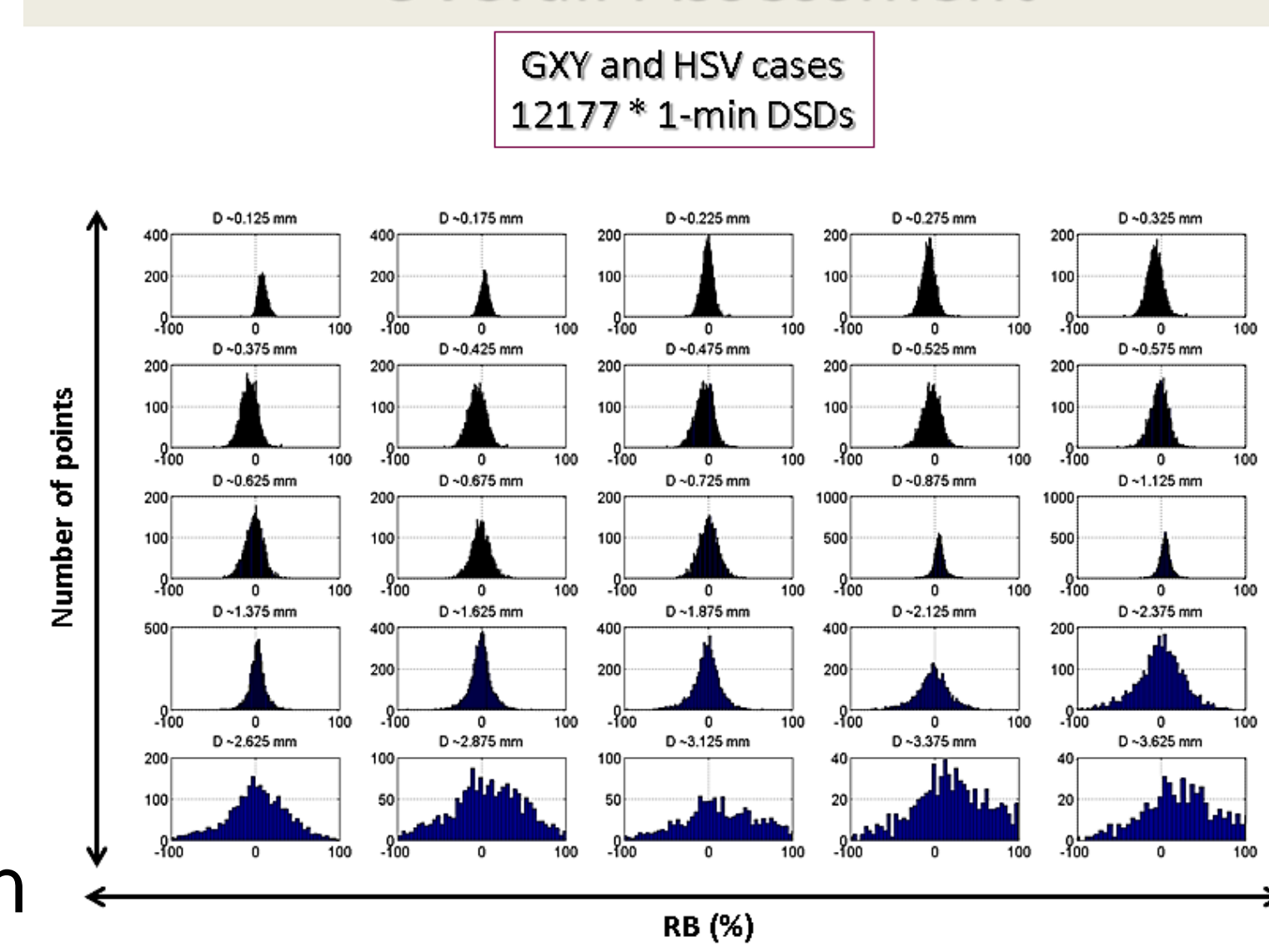TS Nate over UAH: XPR-dBZ and $D_m$ from MPS_2DVD DSDs

Top: XPR Observations of TS Nate during weak bright band period and shallow warm rain.
Bottom: DSDs as indicated. GG approach represents varying spectra in light rain very well.
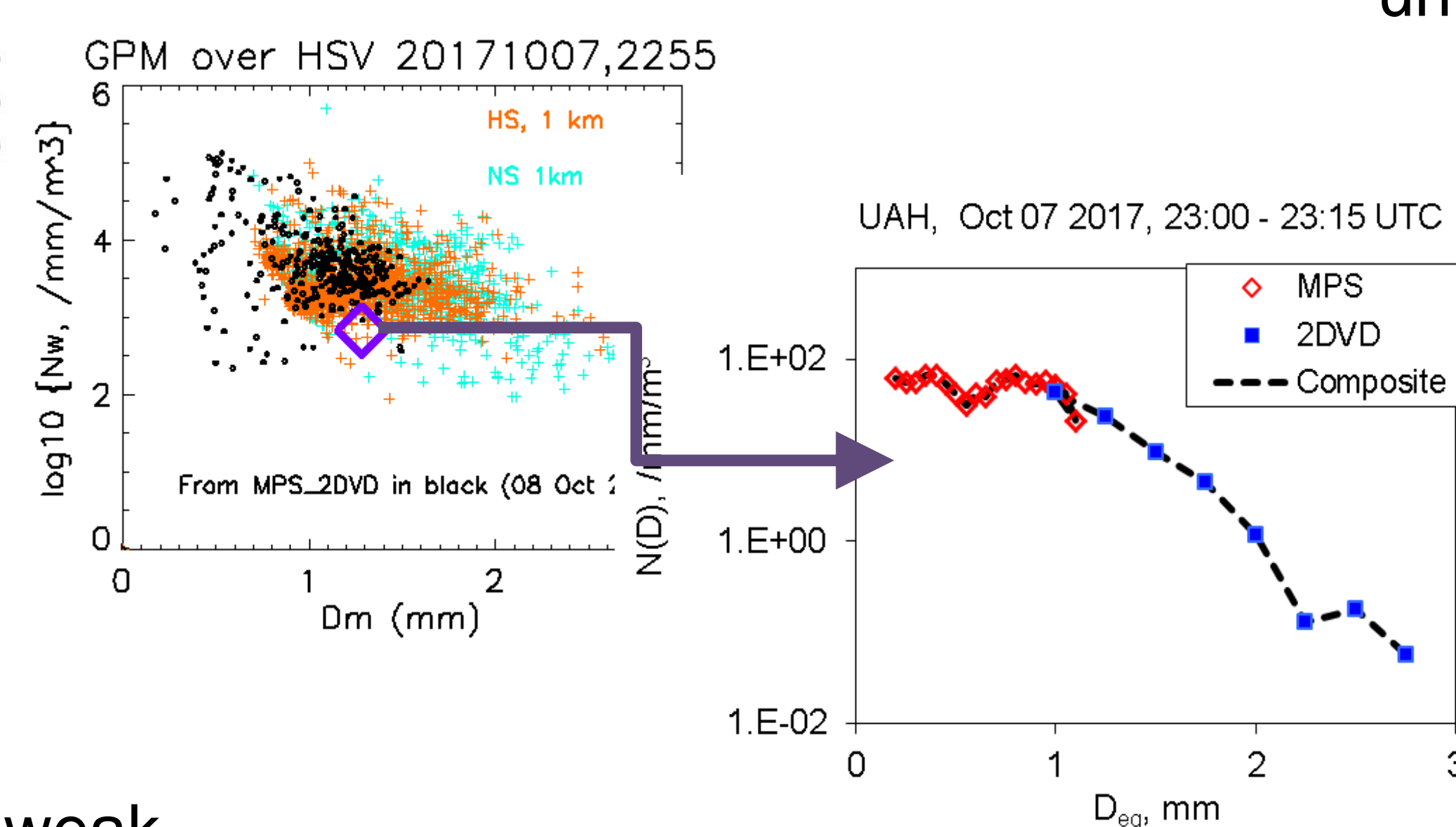
MPS and GPM Observations of TS Nate DSD in full bands on 8 Oct. (left). Diamond represents DSD sampled in HSV during overpass (right)

### Overall Assessment

GXY and HSV cases 12177 * 1-min DSDs

**Collectively, the GG approach seems robust; how might we might implement the approach in future GPM algorithms?**

## 4. Summary

GPM DSD retrievals exhibit inconsistencies between GV, DPR and Combined algorithm retrievals. Development of positive bias in convective $D_m$ rain DSD noted, and strongest in KuPR retrieval. Associated epsilons are too low and result in markedly reduced convective rain rates (a current issue in the retrievals). Source may be NUBF. Issues with the large end of the DSD not withstanding, on the small end of the DSD, combined MPS and 2DVD measurements fit with generalized gamma functions exhibit strong potential for representing the entire spectrum of the DSD and subsequently the whole rain rate spectrum.