THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

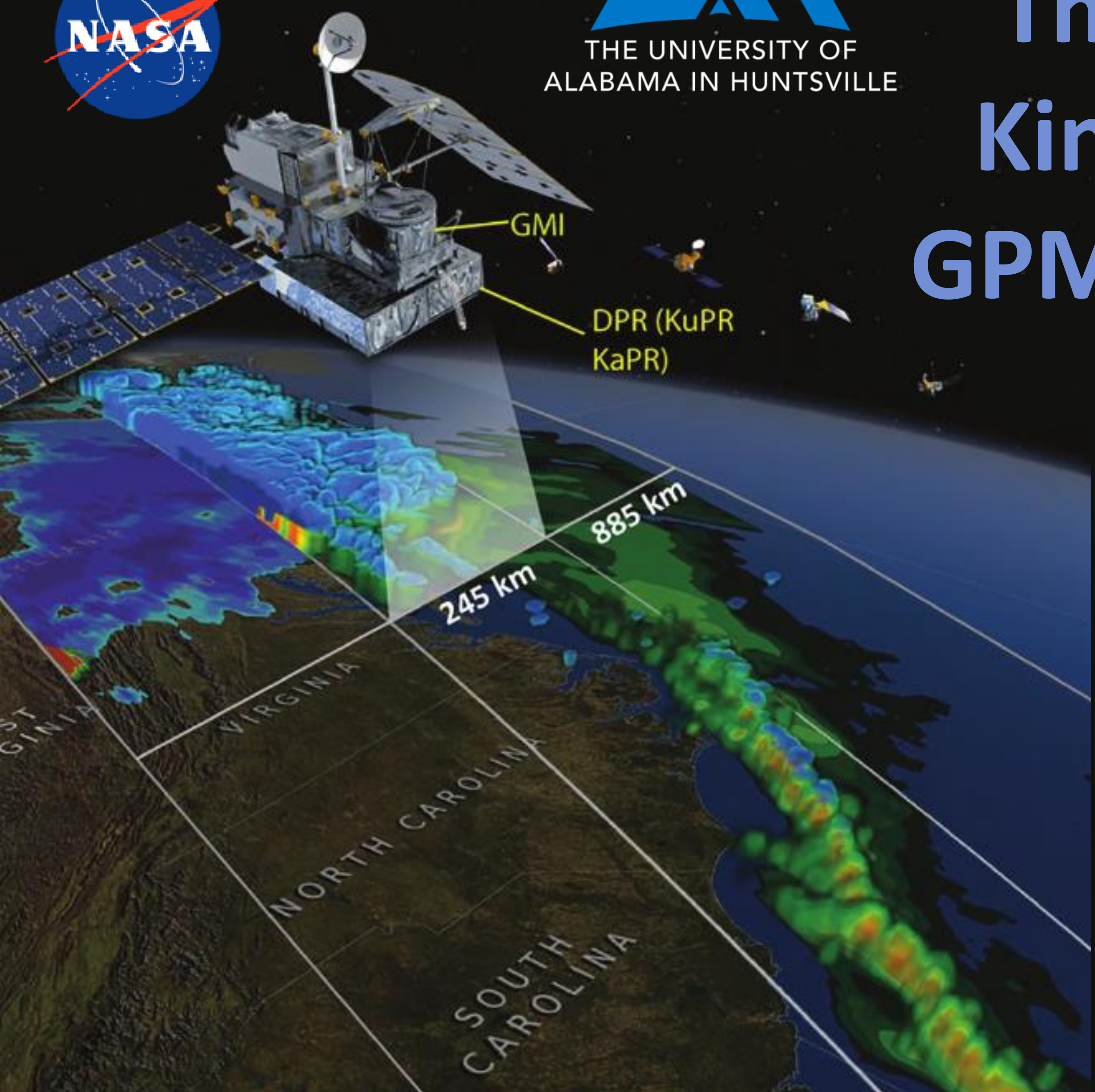

Fig. 1, Skofronick-Jackson et al. 2017, DOI: 10.1002/qj.3313

The Microphysical and Kinematic Properties of GPM Precipitation Profiles

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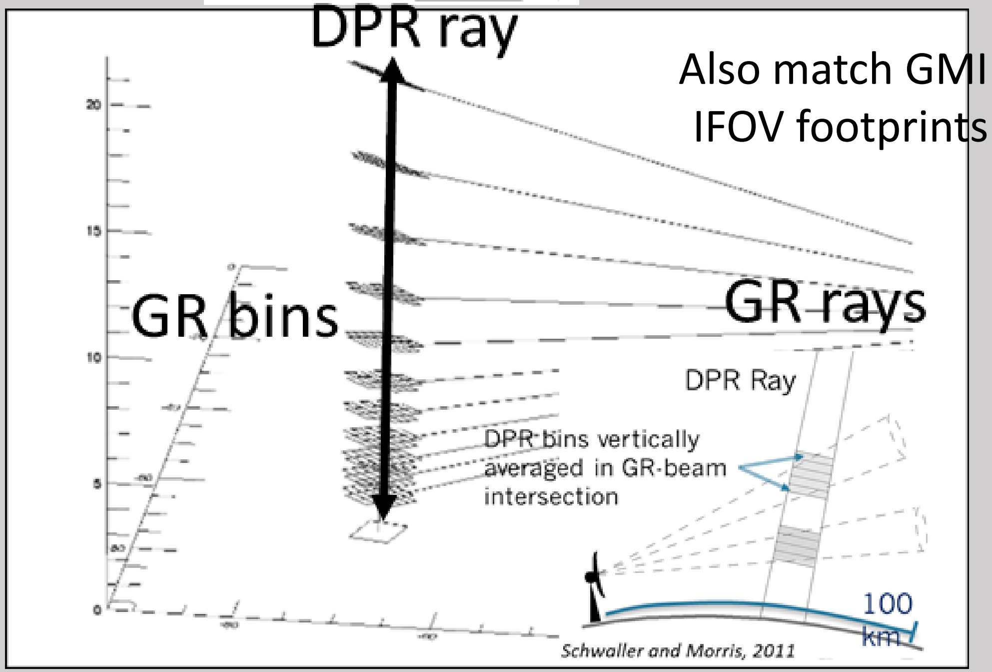
Overview of the GPM Validation Network (VN)

Primary Function: Validate GPM "Core" Level 1 Science Requirements

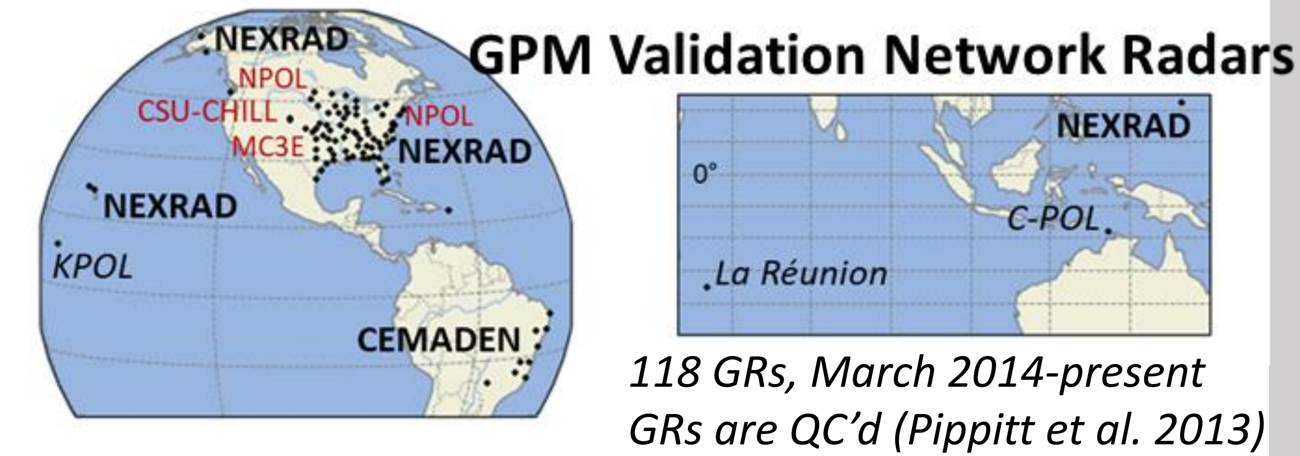
Geometric Matching

Retains 3-D characteristics



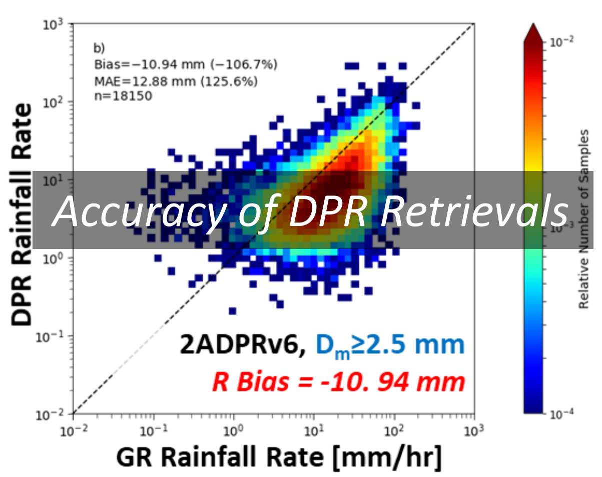
Schwaller & Morris, 2011

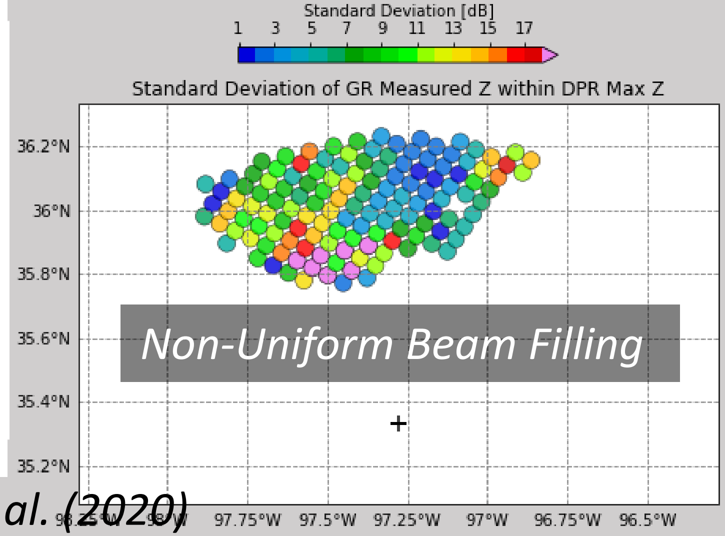
Polarimetric Ground-based Radars (GRs)



118 GRs, March 2014-present

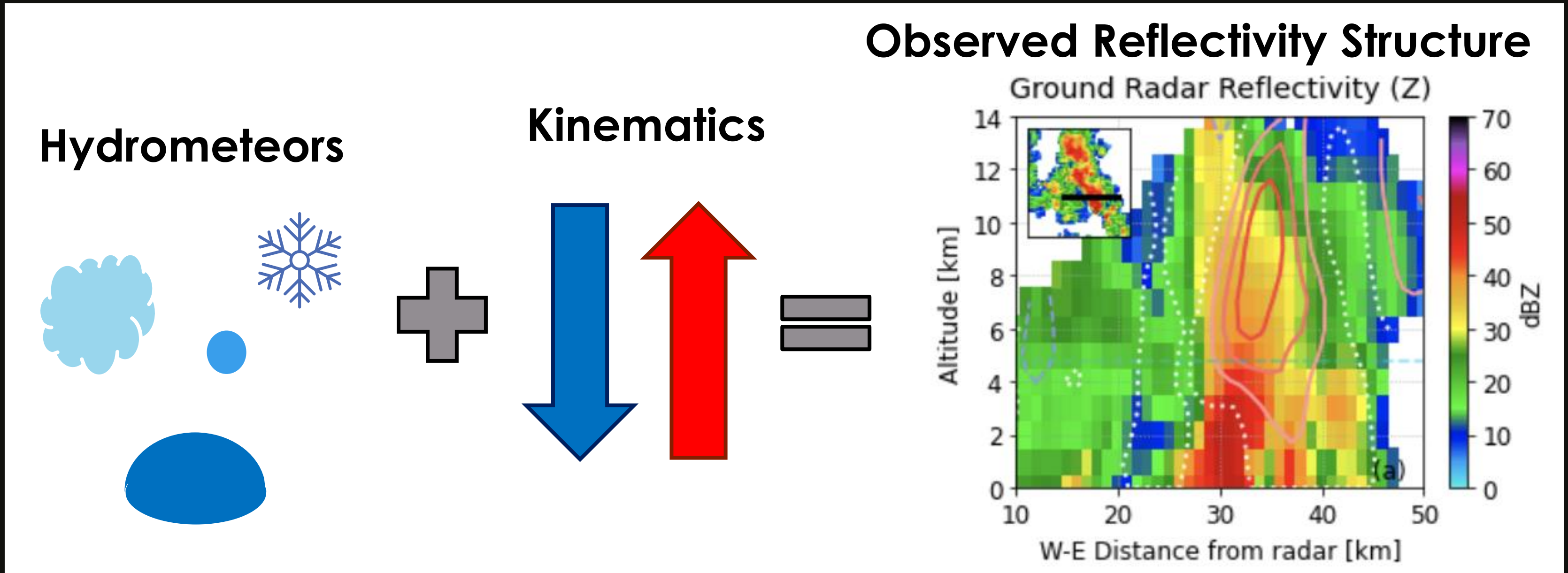
GRs are QC'd (Pippitt et al. 2013)





Petersen et al. (2019); Gatlin et al. (2020)

The GPM Validation Network (VN)



Objective:
Leverage GR dual-pol, Doppler velocity data to infer microphysical and kinematic properties reflected in DPR data

Research Questions:

1. Can GPM DPR reflectivity data be classified based on convective regime? (e.g., TRMM characterization by Boccippio et al., 2005)
2. Can VN GR capabilities enable further diagnosis of categorized DPR reflectivity regimes?
   - Employ GR Doppler velocity-derived vertical winds, dual-pol moments

Integration of 3D Winds into VN Dataset

- GR Doppler velocity data, derivatives not previously stored within VN dataset
- 3D winds retrieved from proximal radar pairs using dual-Doppler analysis
    - Closer radars = shorter baseline, better resolution and reduced error

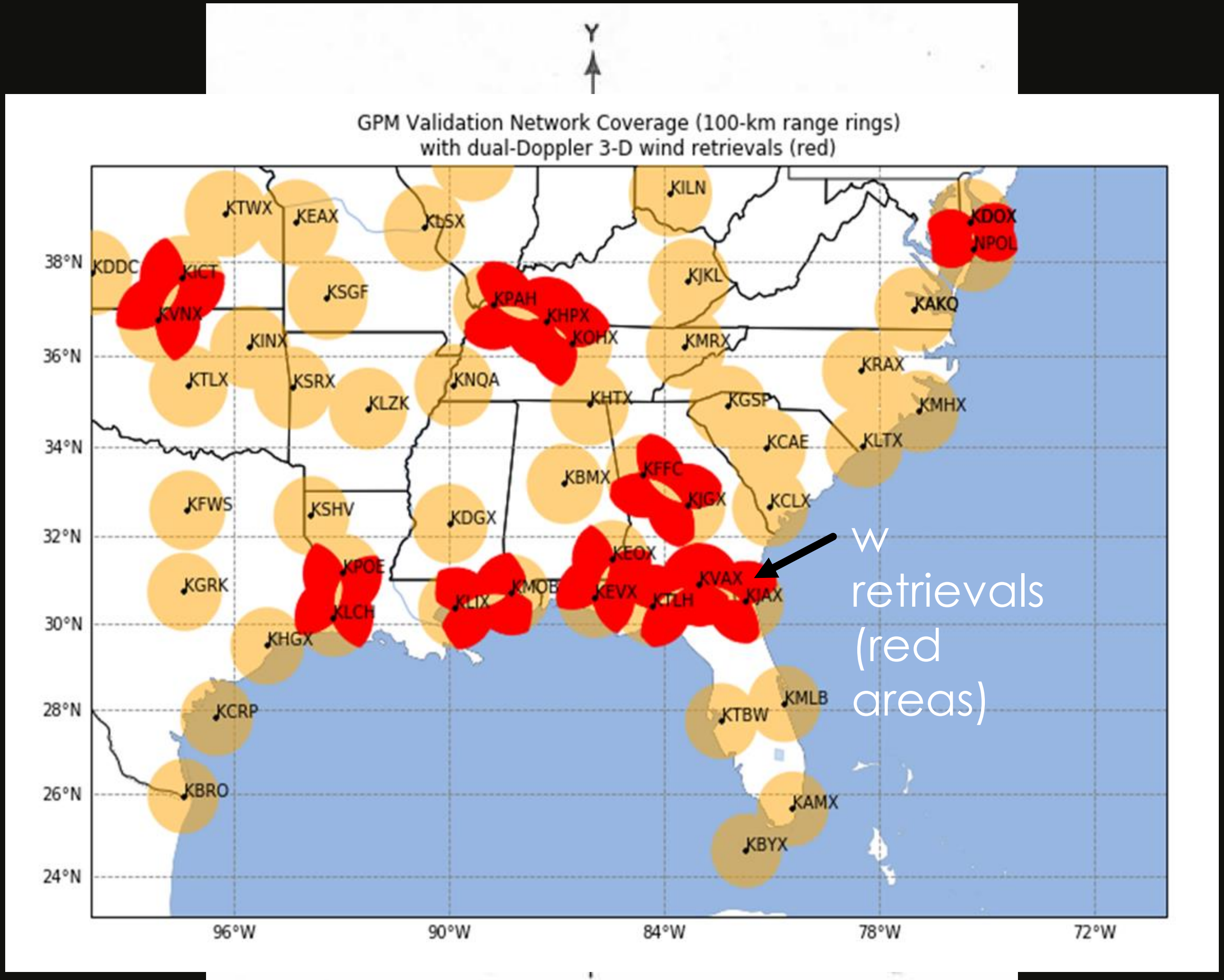


FIG. 1a. The area $A_1(\beta)$, denoted by stippling. This area is the locus of points which subtend between-beam angles in the range $[\beta, \pi-\beta]$, and is outlined by two circles with centers at $(0, \pm d \cot\beta)$ and radii, $d \csc\beta$. The radars are located at $(\pm d, 0)$.

Integration of 3D Winds into VN Dataset

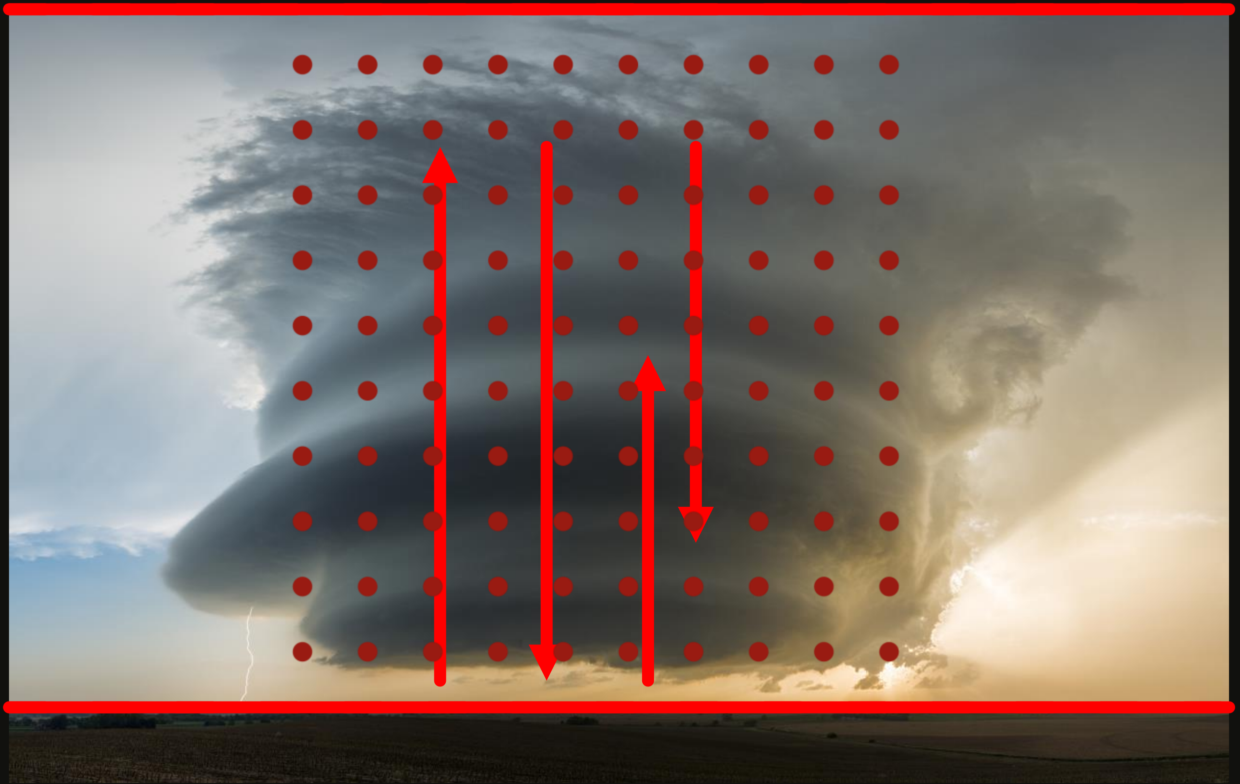
Dual-Doppler analysis of VN Doppler velocity data:

3DVAR technique (Shapiro et al., 2009; Potvin et al., 2012)

$$J = J_O + J_M + J_V + J_S, \quad (1)$$

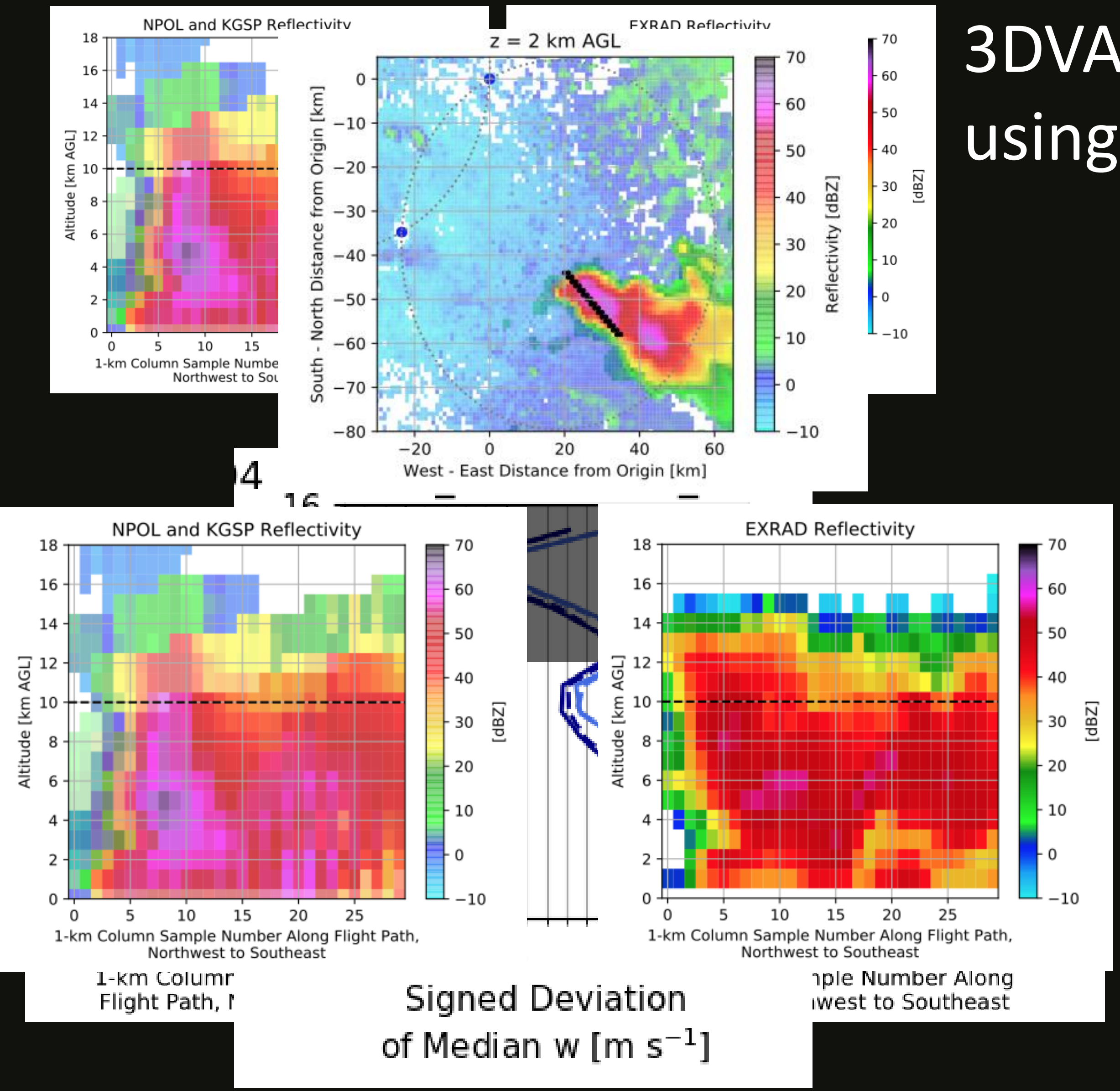
$$\frac{\partial \rho}{\partial t} + \nabla \bullet (\rho \vec{u}) = 0$$

$$J_M \equiv \sum_{\mathrm{Cart}} \lambda_M \left[\frac{\partial u^a}{\partial x} + \frac{\partial v^a}{\partial y} + \frac{\partial w^a}{\partial z} + \frac{w^a}{\rho}\frac{\partial \rho}{\partial z} \right]^2, \quad (5)$$



- 3DVAR method resistant to error propagation in traditional integration techniques
- Cost function method, requires some tuning
    - Which terms (observations, mass continuity, vorticity, smoothness), how much weight?

Integration of 3D Winds into VN Dataset

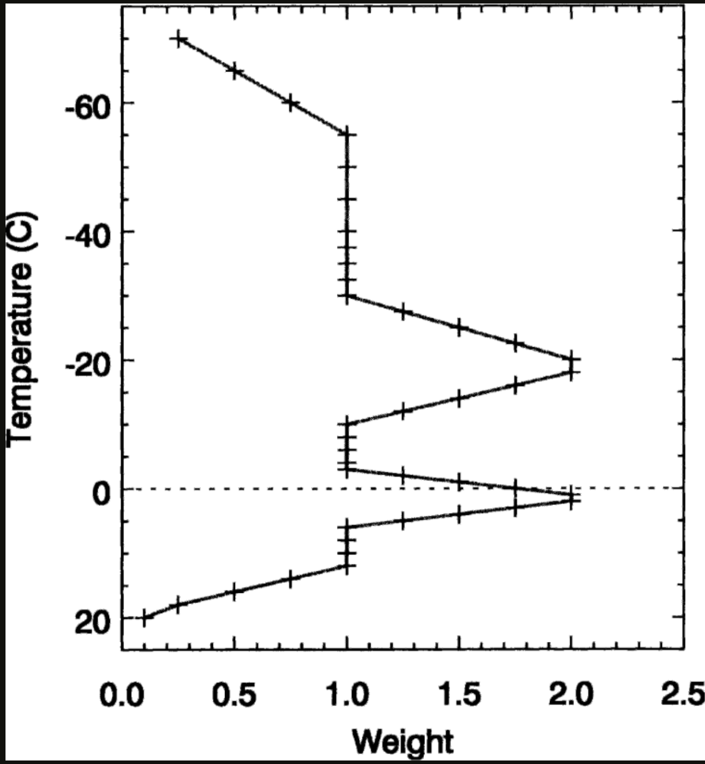


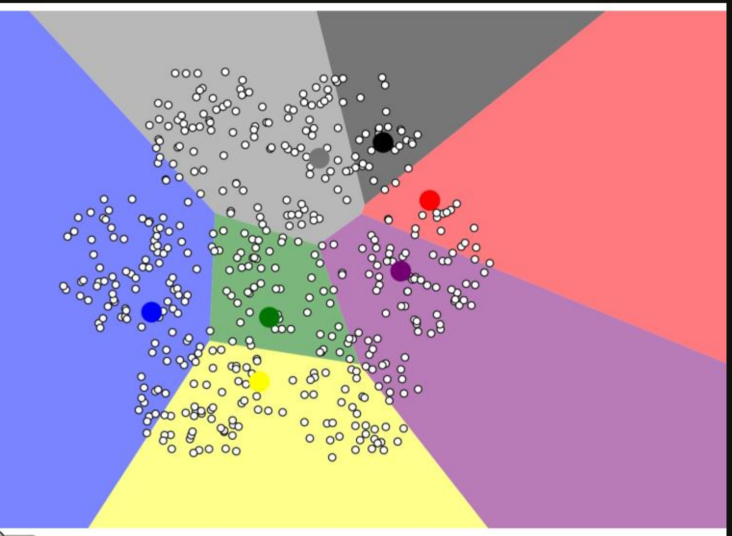
3DVAR technique tuned for GR data in the VN using field project datasets (MC3E, IPHEx)

- Ground-based 3D wind retrievals vs. Doppler velocity data from aircraft
- Attention to vertical component (updrafts, downdrafts)
  - Tested 15+ 3DVAR configurations
- Retrievals within ±3-5 m s^{-1} of aircraft data (expected instrument, method error)

Categorizing DPR Reflectivity Profiles

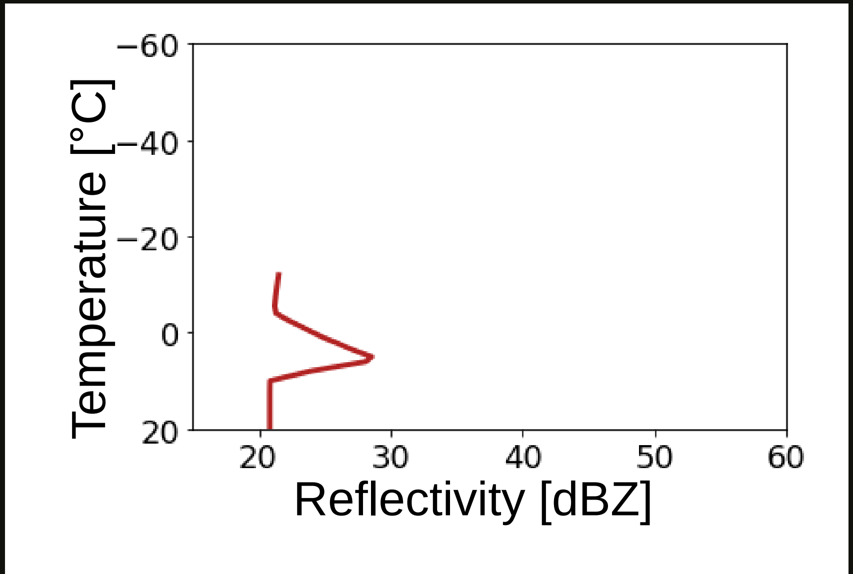
- Categorized (clustered) DPR Ku-band data based on weighted inputs:
  - Corrected DPR reflectivity at 40 temperature levels between 20°C and -70°C
  - Derived rain rate
  - Binary convective, stratiform, and “other” precipitation indicators
  - Binary bright band marker



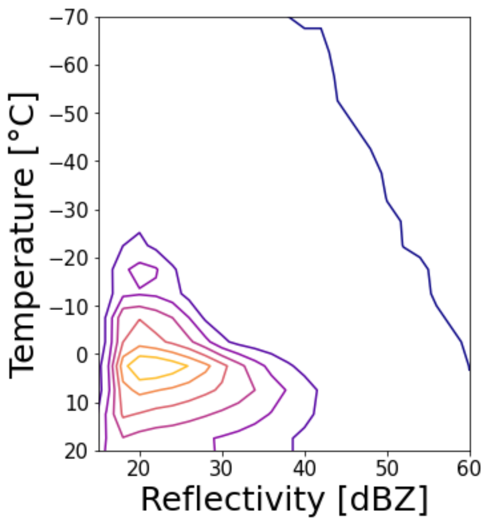


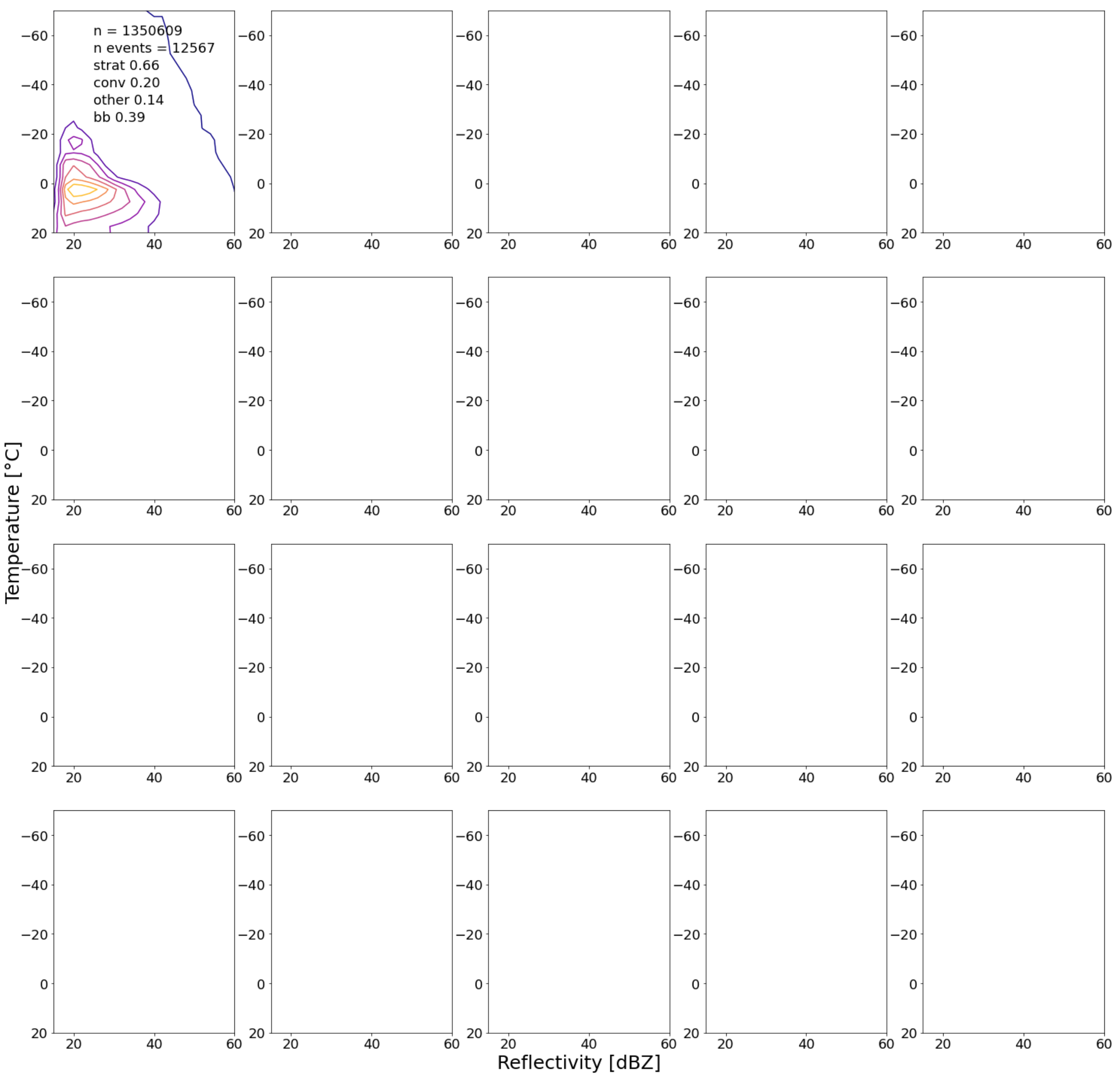
- Used K-Means clustering method to group more than 1.35 million “quality” DPR reflectivity profiles by 45 inputs
  - Caveats/considerations: High-dimension data, no pre-determined correct number of clusters

Categorizing DPR Reflectivity Profiles



Relative frequency of reflectivity profiles → DPR profile cluster

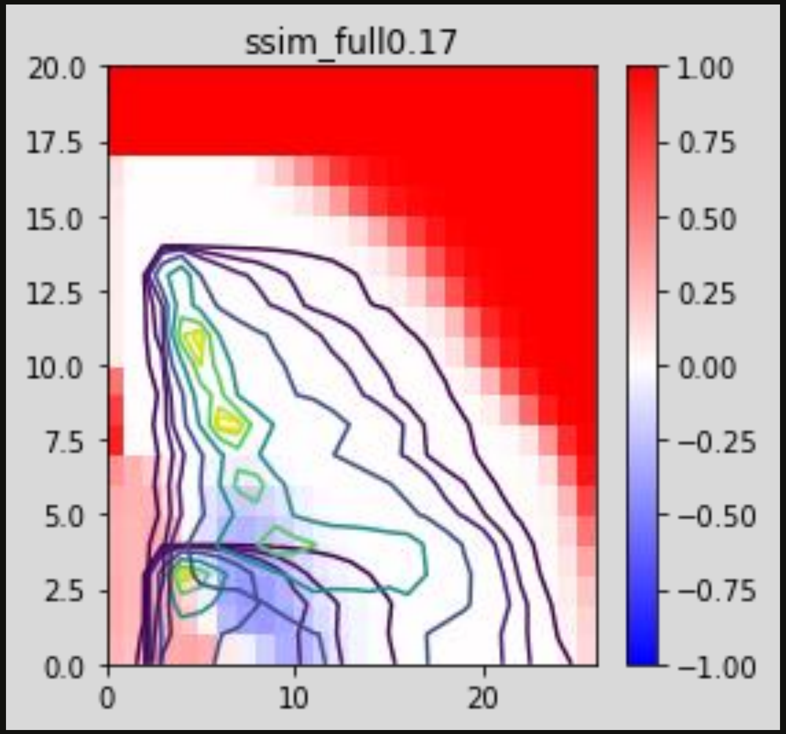


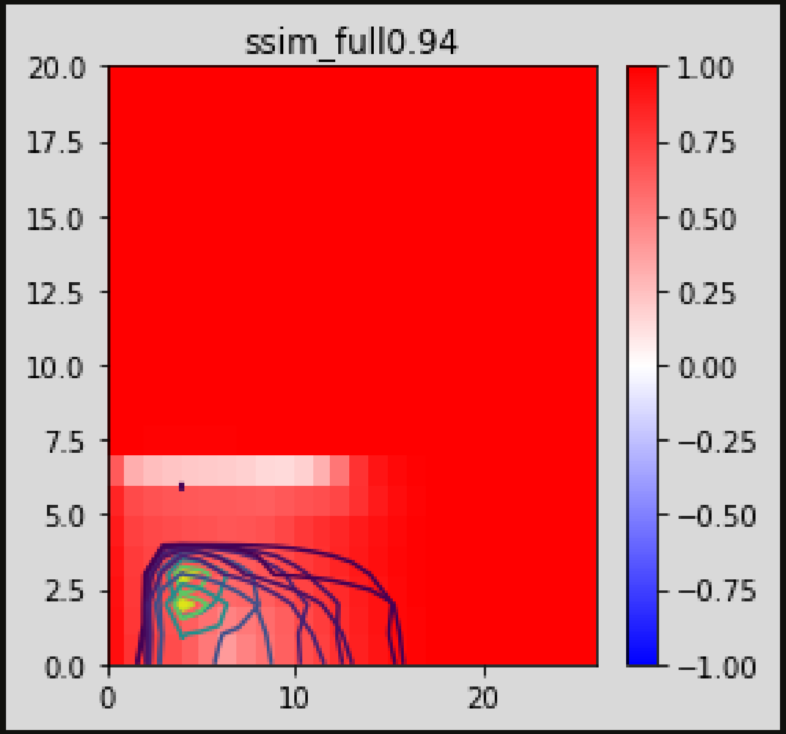


Categorizing DPR Reflectivity Profiles

How to identify "correct" number of clusters?

- Evaluated similarity scores of clustered reflectivity profiles while increasing N clusters
- $SSIM(x,y) = \frac{(2\mu_x\mu_y+c_1)(2\sigma_{xy}+c_2)}{(\mu_x^2+\mu_y^2+c_1)(\sigma_x^2+\sigma_y^2+c_2)}$



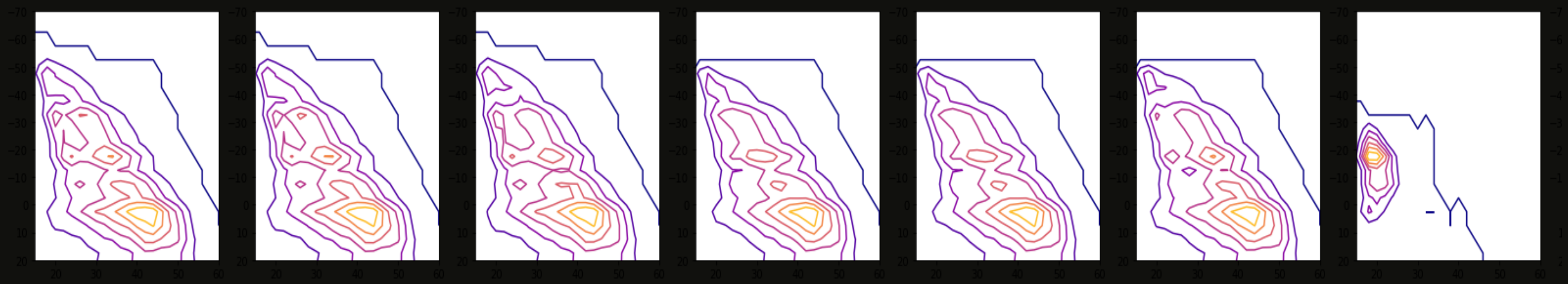


Categorizing DPR Reflectivity Profiles

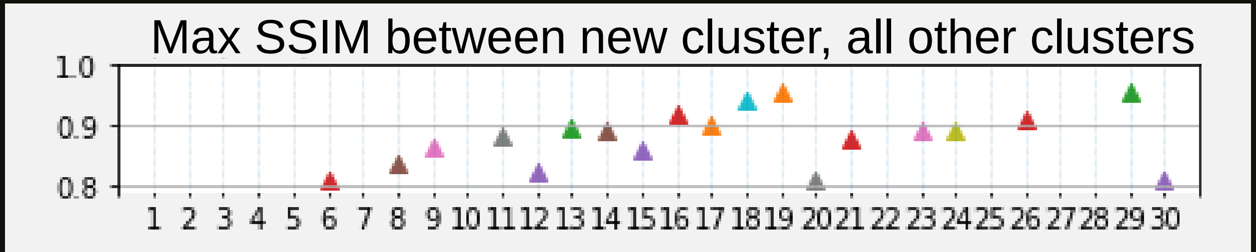
N distinct clusters considered robust until:

1. SSIM between previous cluster and most identical cluster in next N cluster increase no longer considerably high (<0.5) over series of increases:

N clusters = 10 11 12 13 14 15 **16**



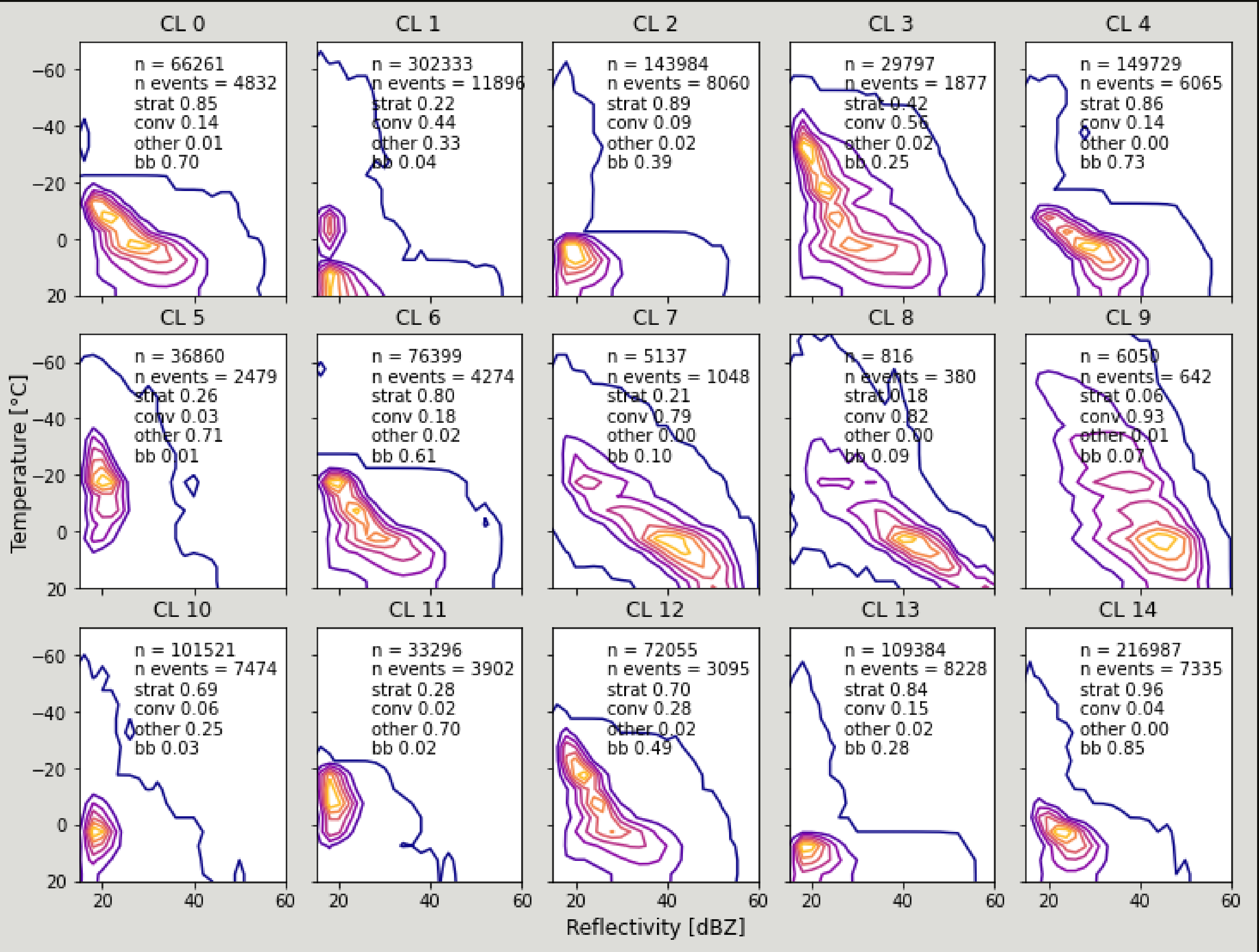
2. New clusters exhibit strong similarity (>0.9) with existing clusters



Identified 15 robust clusters in profile data

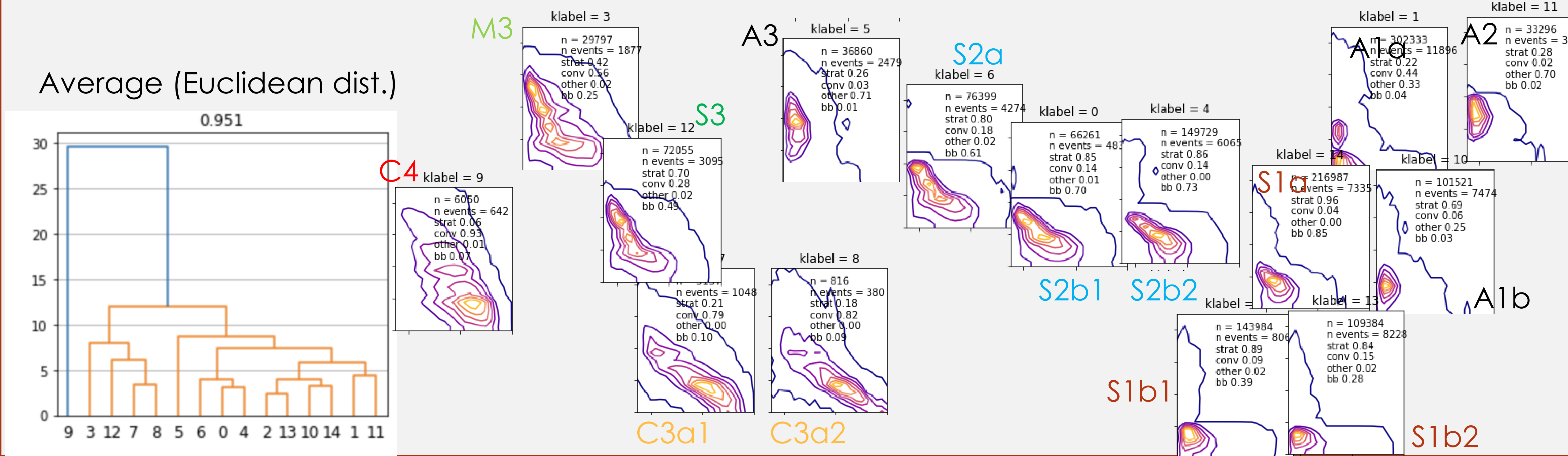
Categorizing DPR Reflectivity Profiles

- Relative frequency of reflectivity with height → representative reflectivity of each cluster
- **What do clusters convey about storm mode?**



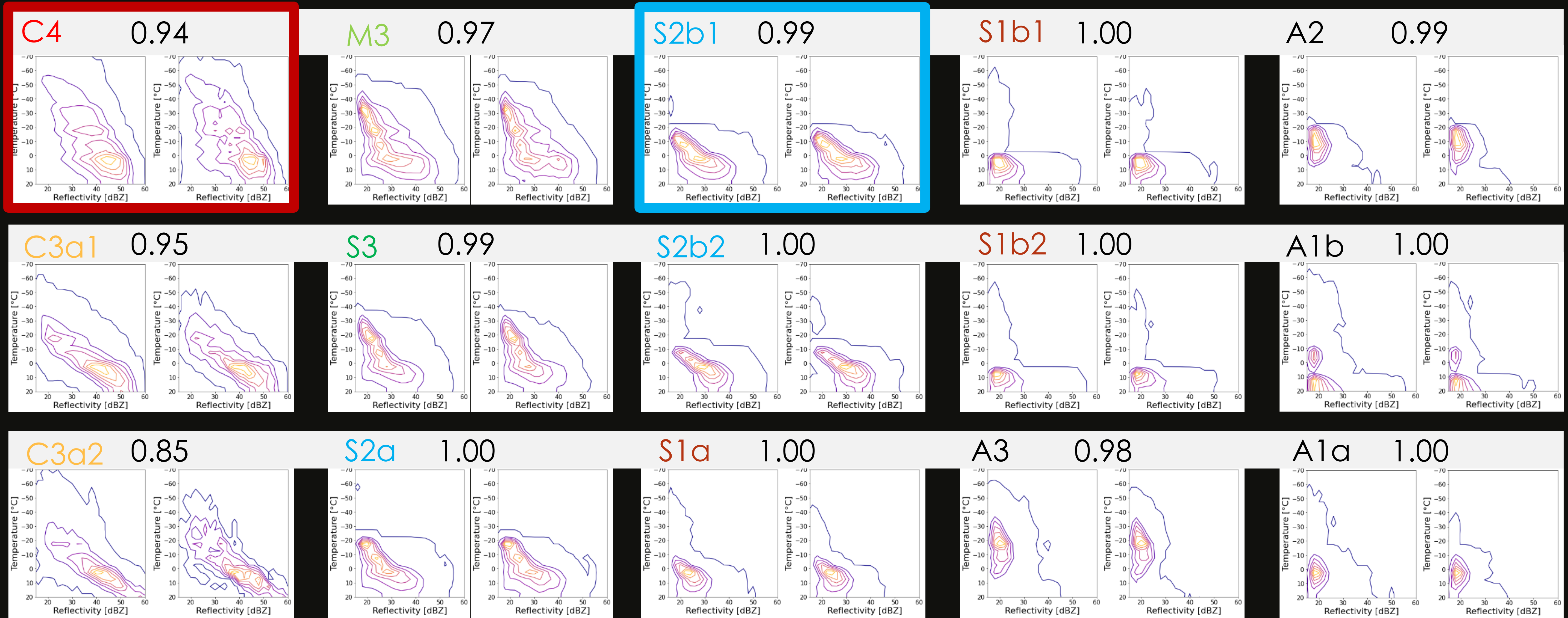
Categorizing DPR Reflectivity Profiles

- Hierarchical classification
  - Agglomerative clustering of 40-element centroids corresponding to clustered reflectivity profiles
  - Objectively segments like-clusters; subjectively assign mode/label by temperature and reflectivity characteristics

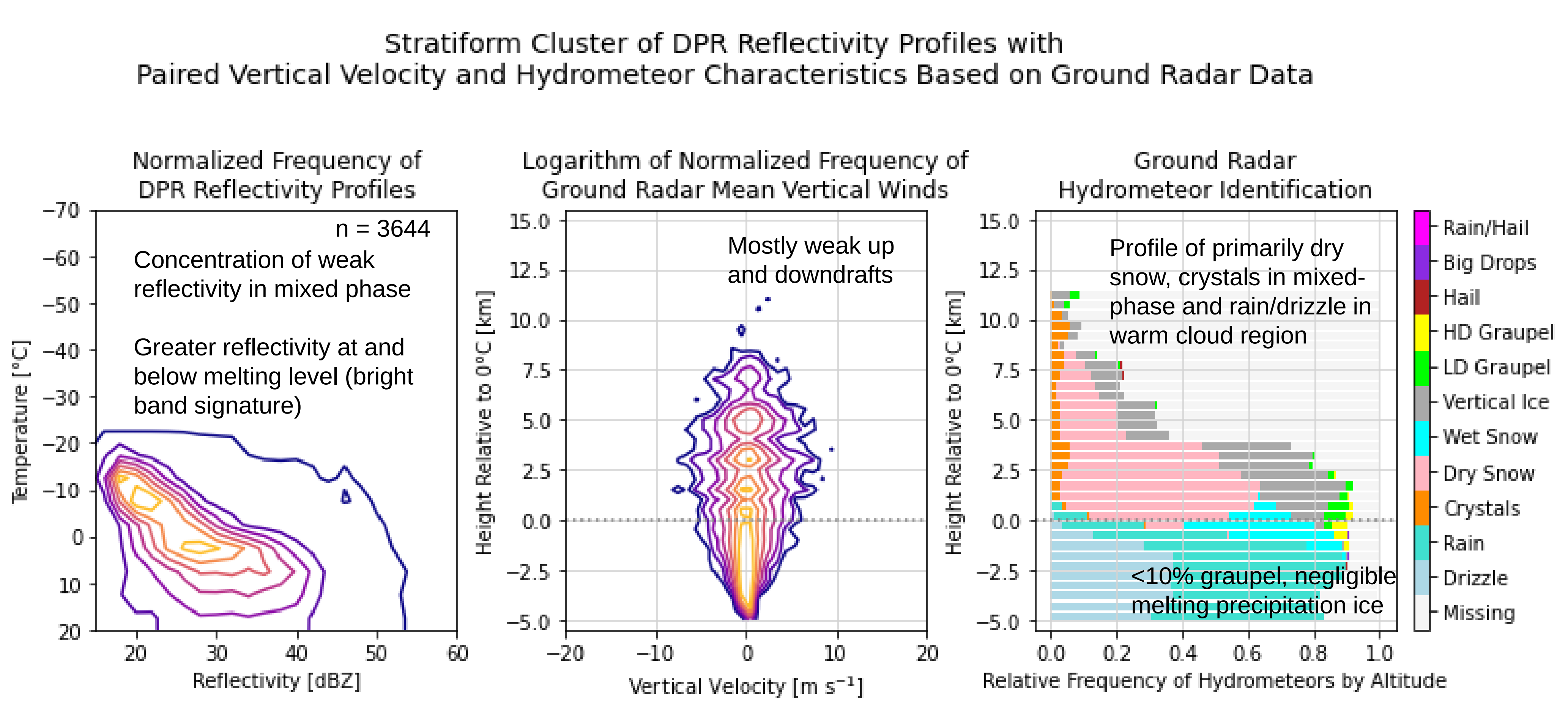


Velocity and Mass Characteristics of Profiles

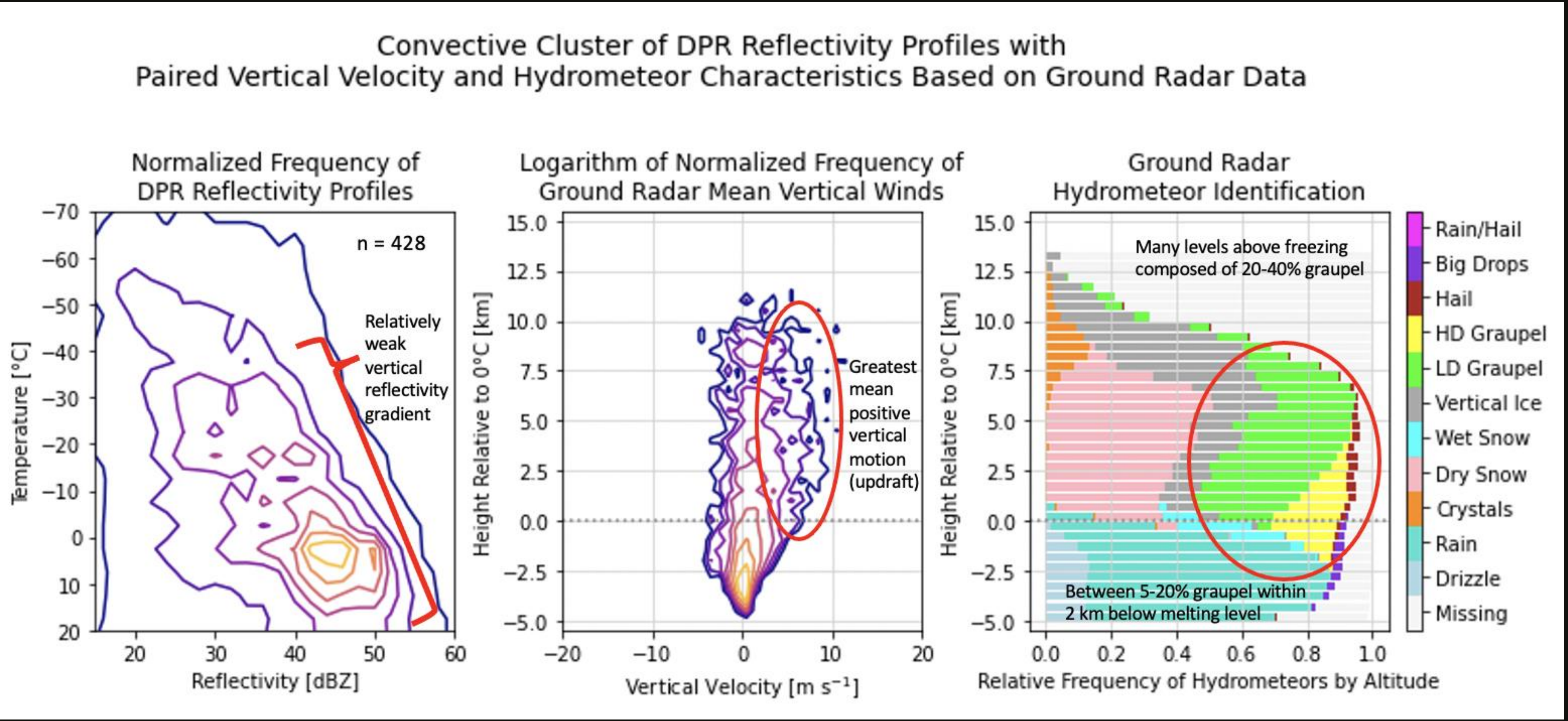
- Ground-based HID (mass) characteristics available for full VN matched dataset
- Rely on similarity with 3D wind data subset to infer relationships over full VN
- 1.35 million profiles in full VN dataset; 67,665 profiles include vertical velocity



Velocity and Mass Characteristics of Stratiform Profiles

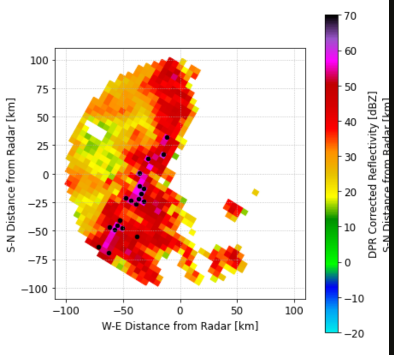


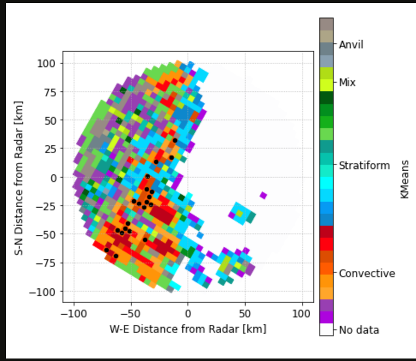
Velocity and Mass Characteristics of Convective Profiles

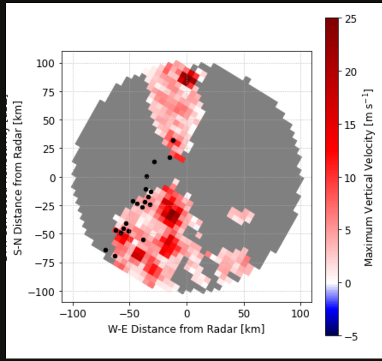


What’s Next?

1. Extend findings from small VN sample with winds data to larger VN record of DPR data
    - Infer kinematic characteristics from reflectivity structure
    - Deep learning applications



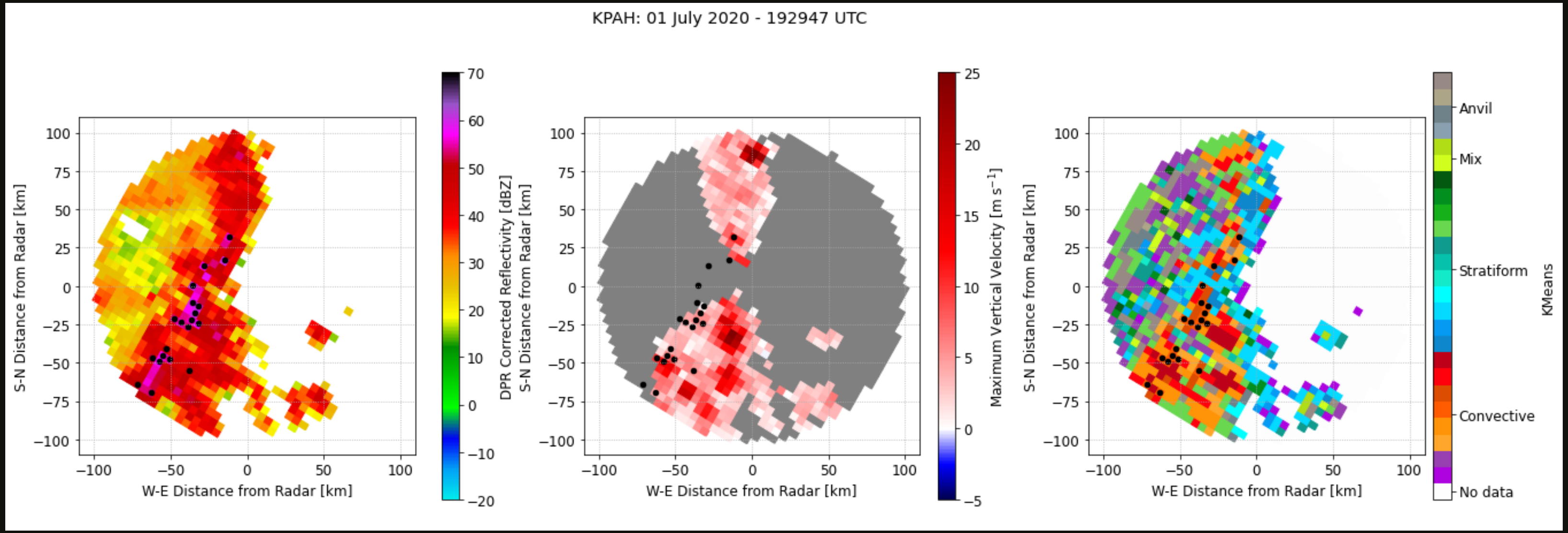




2. Implication of results for DPR algorithms:
    - Refine techniques to identify and depict multiple scattering in spaceborne radar-based precipitation retrievals in deep convection

What's Next?

3. Demonstration of deeper insights extracted from GPM Program of Record: impact design of future satellite missions with capability to observe winds and greater extent of convective precipitation processes (ATMOS/ACCP)



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