The microphysics and kinematics of GPM's satellite radar profiles

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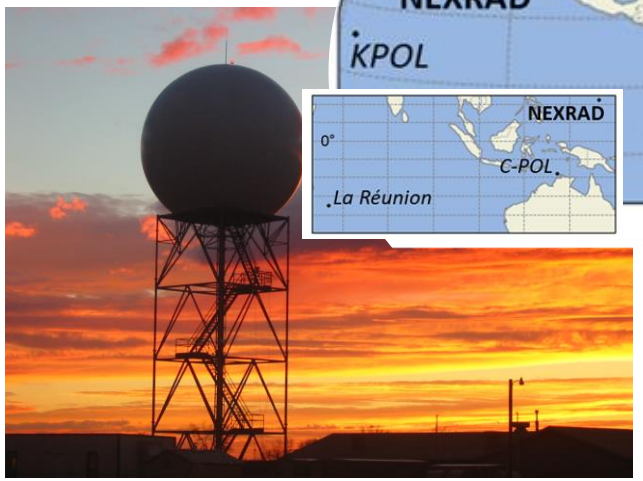
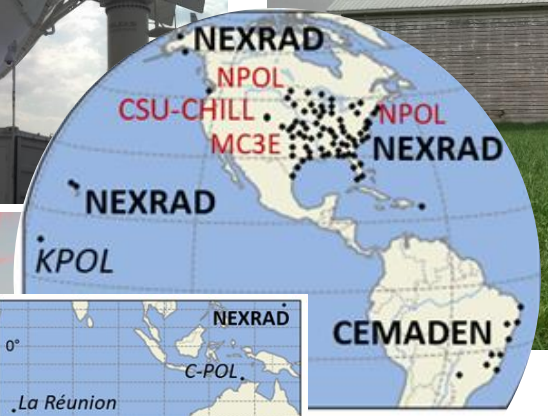
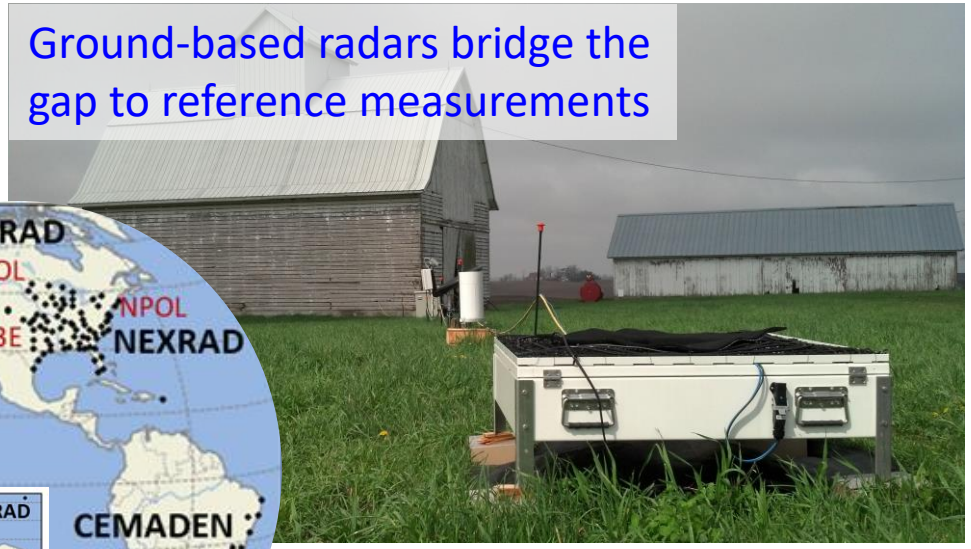
Ground-based Radar Validation Networks for GPM satellite products

Satellite Measurements → *Ground-based Measurements*



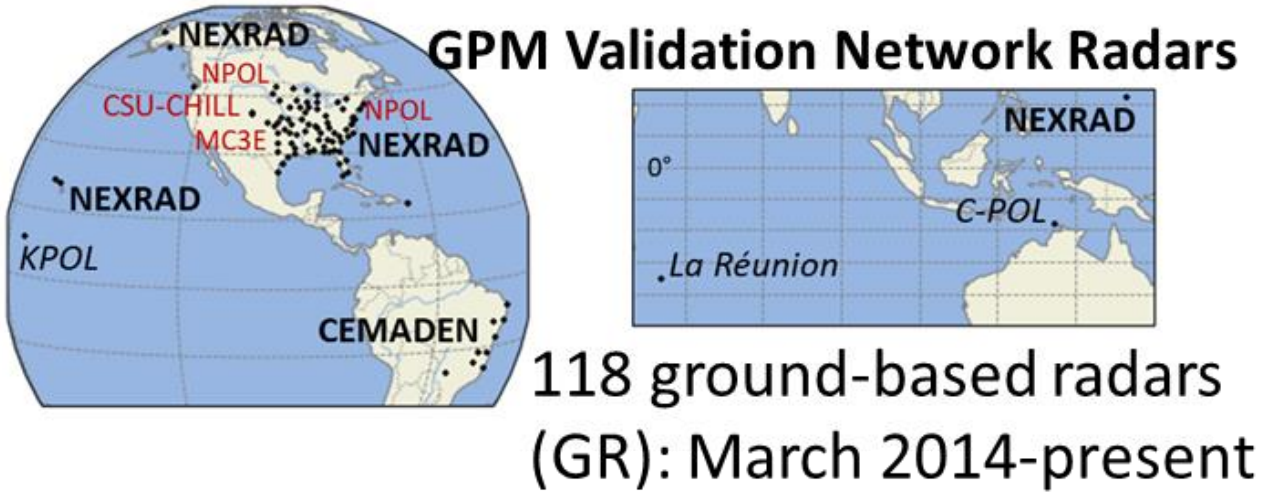




Ground-based radars bridge the gap to reference measurements

Use Ground-based Polarimetric Weather Radars for long-term statistical assessment of GPM retrieval algorithms

Building a Diverse Statistical Database for Physical Validation



6 seasons of field campaigns to develop, refine, and evaluate precipitation retrieval algorithms for GPM radar and radiometer:

- *2ADPR*: DPR profile + Model T + Attenuation correction + variability
- *GPROF*: GMI Tbs + a priori CRM simulations
- *CORRA*: 2ADPR + 1CGMI + a priori hydrometeor profiles from CRM simulations and observations

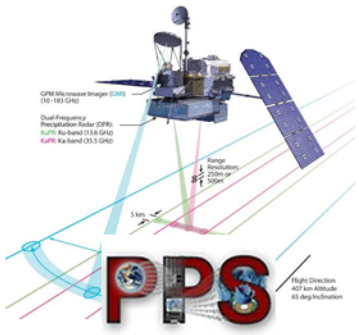
Polarimetric Radars

Operational Radars	Research Radars
WSR-88D (NEXRAD)	NPOL
CEMADEN (Brazil S-band)	CSU-CHILL
Meteo-France La Reunion (S-band pol.)	C-POL (Darwin)
KPOL (Kwajalein)	

The VN facilitates a means to investigate the 3D depiction of physical processes in the algorithms:

- Rainfall rate
- Liquid and ice water content
- Drop-size distribution
- Hydrometeor type

GPM core satellite: Dual-frequency Precipitation Radar (DPR) at Ku- and Ka-band (JAXA), Microwave Radiometer (NASA)

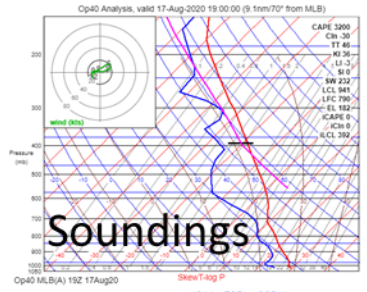


GPM Overpass within 200-km of GR?

YES

Research Radars

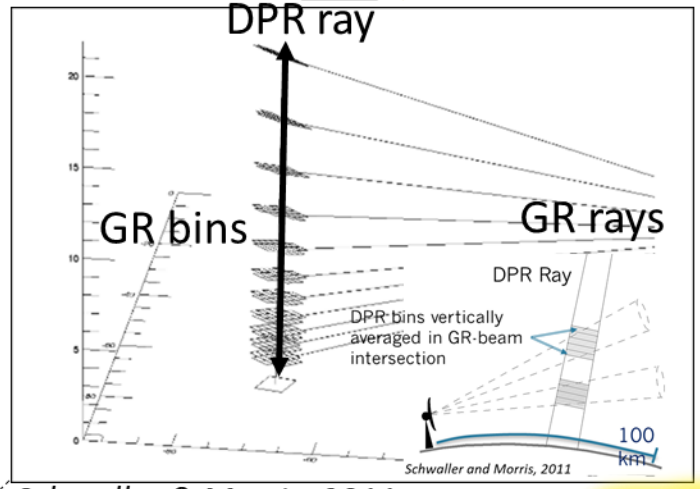
Operational Radars



GR Quality Control (Pippit et al. 2013)

GR Retrieval of Geophysical Variables (Tokay et al. 2020; Dolan et al. 2013; Ciffeli et al. 2011; Bringi et al. 2004)

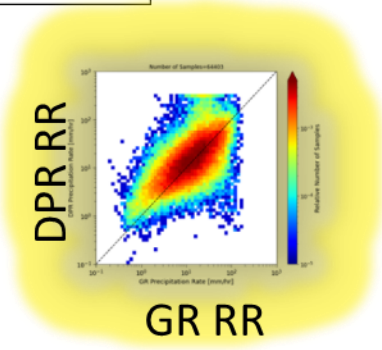
RSL_in_IDL & PyART



Schwaller & Morris, 2011

DPR/GMI-GR Geometric Matching

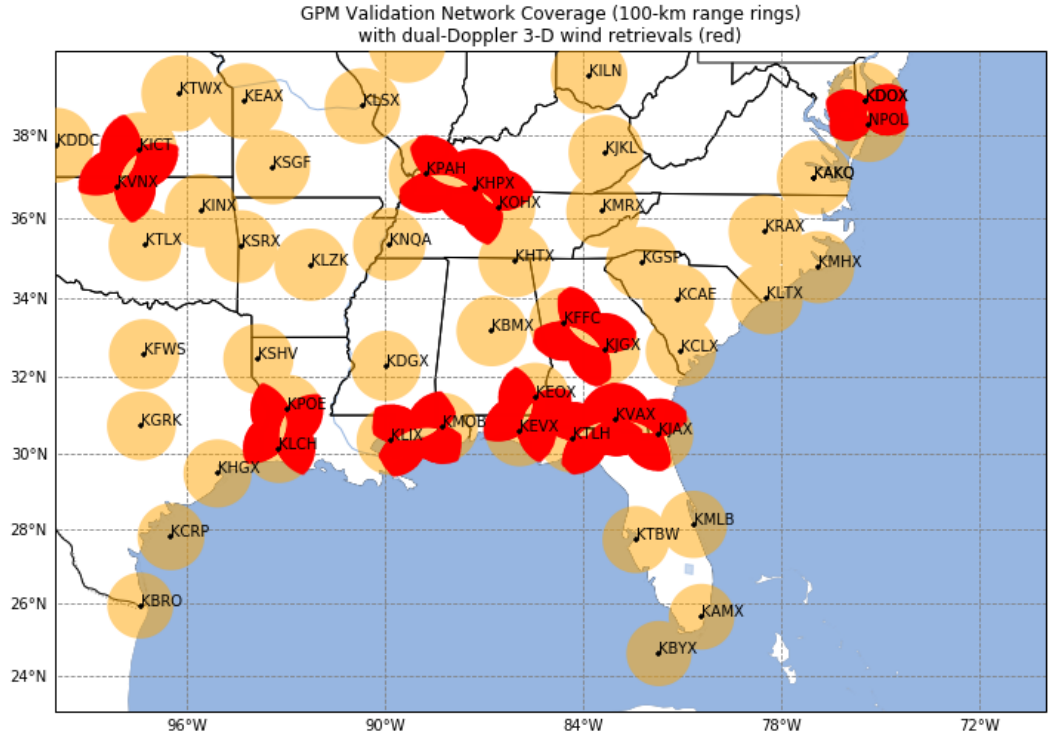
VN matchup files



"*20-in-100*" criteria: 20 footprints of DPR with *Rain_Certain* in 2AKu within 100-km of GR

Current version of VN software: v2.4

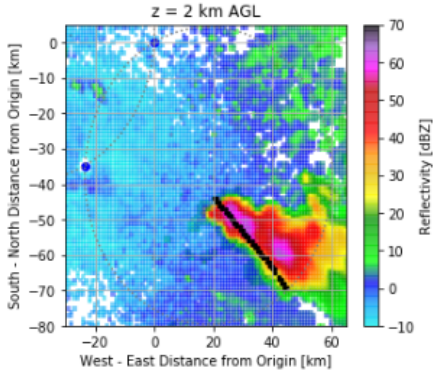
Vertical motion included in the GPM VN matchups

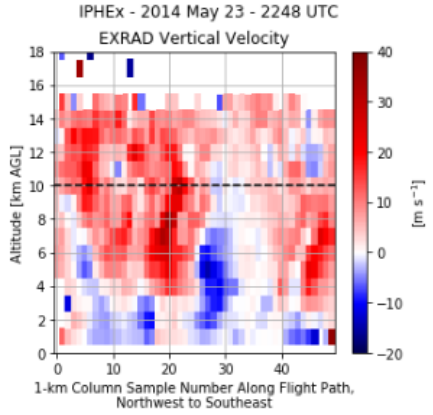


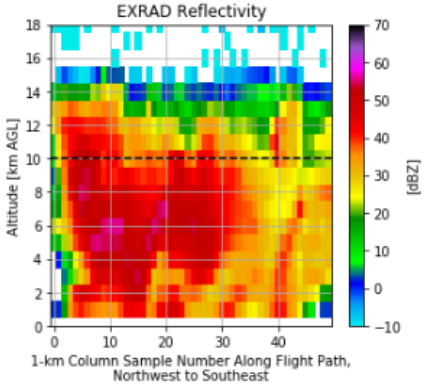
- 10 radar pairs in GPM Validation Network
- PyDDA with automated cost function weights (auglag)
- Quality Control to remove range folding artifacts in level 2 data
- Compute W_{max}, W_{min}, W_{stdev} of GR gates within intersecting DPR rays → VN matchup files

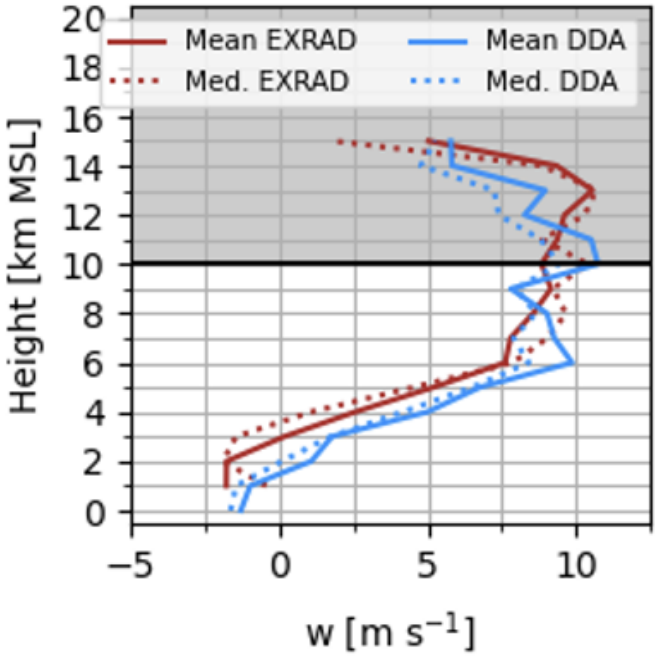
Comparison (KGSP+NPOL) with Airborne Doppler Radar

IPHEx 23 May 2014
North Carolina
Hailstorm
Battaglia et al., 2016









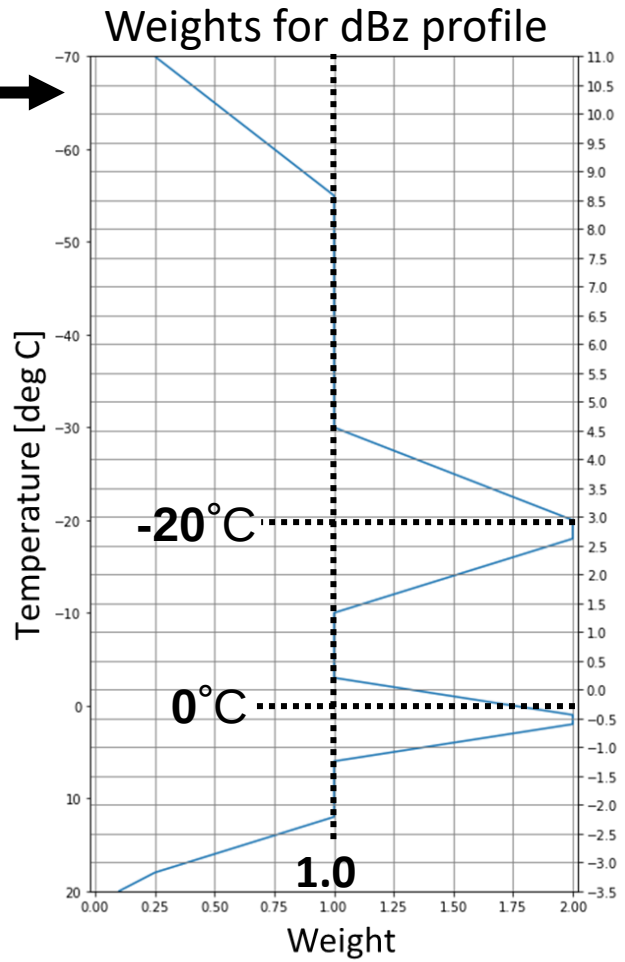
Clustering of DPR profiles using K-means

Similar to clustering method used on TRMM profiles by Boccippio et al., 2005

Inputs: 45 fields from GPM VN matchups of GR with DPR inner DPR rays for T_{sfc} ≥10˚C

- Corrected DPR reflectivity at 40 temperature levels→ various weights (see right)
- Precipitation type from 2ADPR (convective, stratiform, other) → weight=0.5
- Bright band flag from 2ADPR → weight 1.5
- GR retrieved rainfall rate (CSU_HIDRO) → weight=2.0

➢ 1.34 million DPR profiles (>57,000 overpass events)



Preparation, Initialization, Results

- Principal components to reduce dimensionality of dataset for clustering

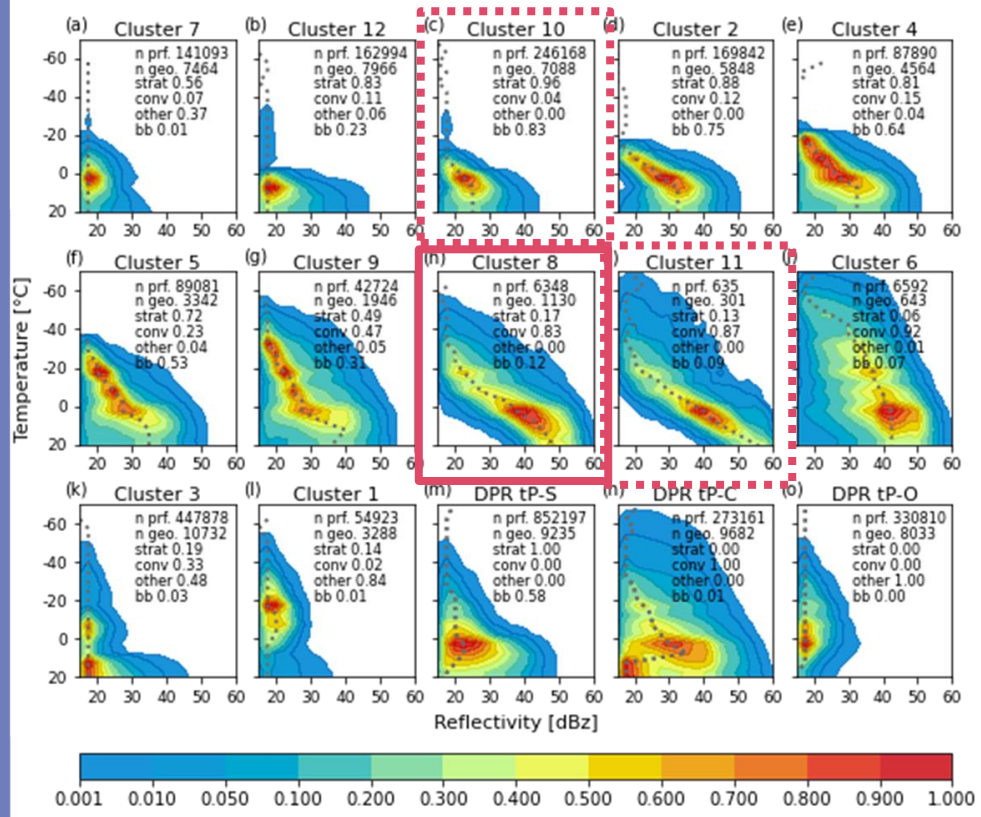
➢ 8 PCs describe > 92 % of variance in profiles

- PC scores provided to k-means initialized from 2 to 20 clusters
- Elbow plotting technique to identify optimal number of clusters

➢ 12 clusters identified

Results of clustering: Comparison of clustered DPR profiles

DPR profiles of reflectivity in each cluster

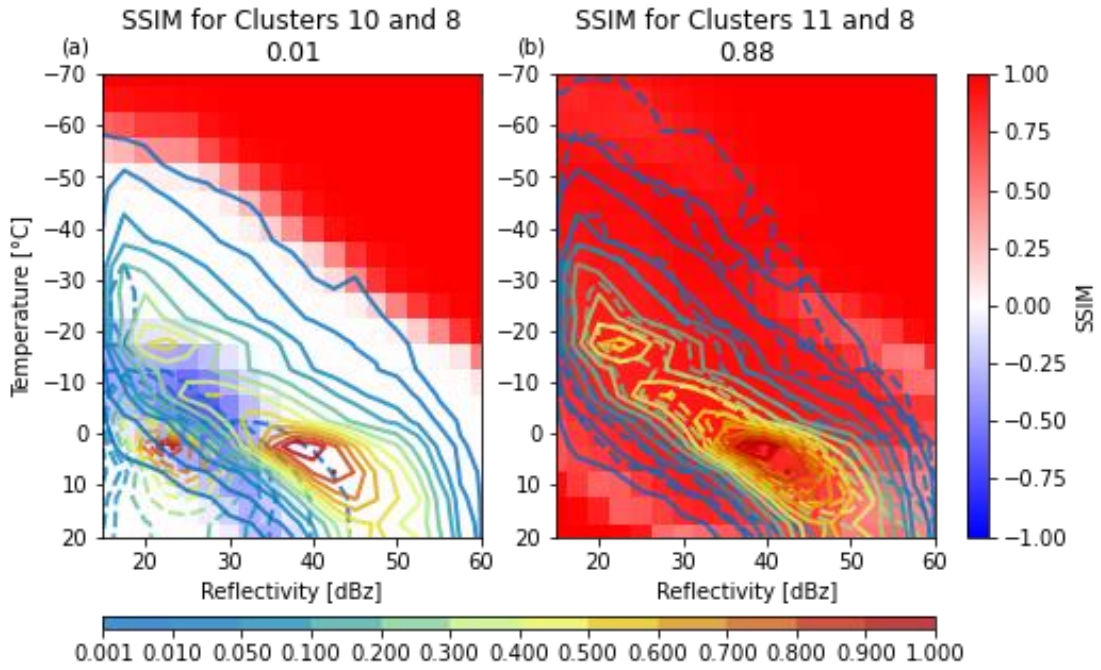


Structural Similarity (SSIM): Compares structure, luminance, contrast of two images → mean square error

SSIM computed with scikit image package in Python

SSIM=1.0→same structure

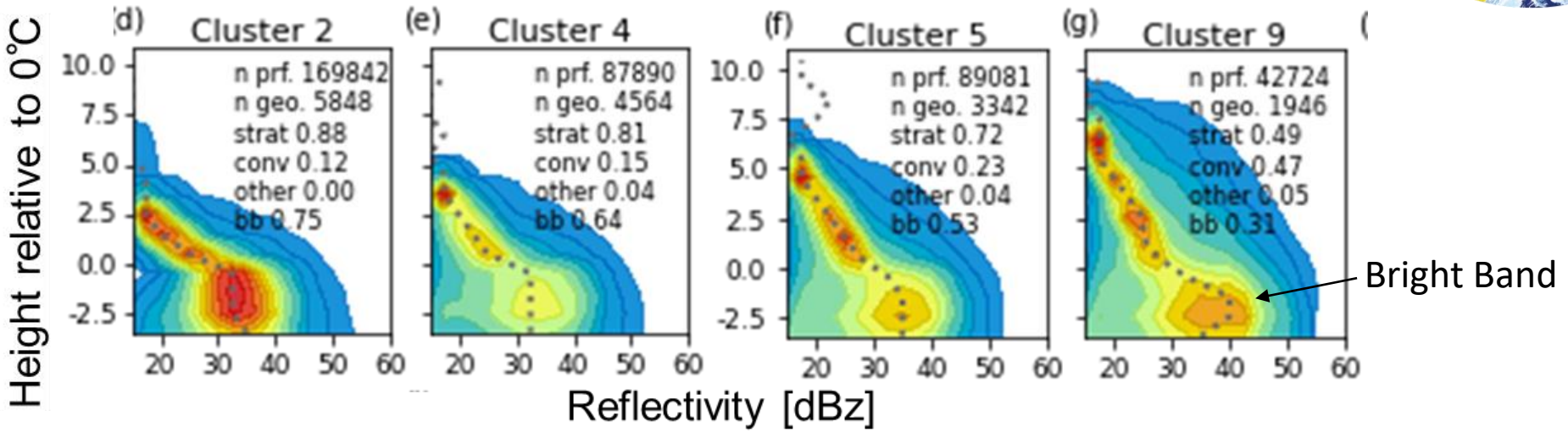
SSIM=0.0→no similarity



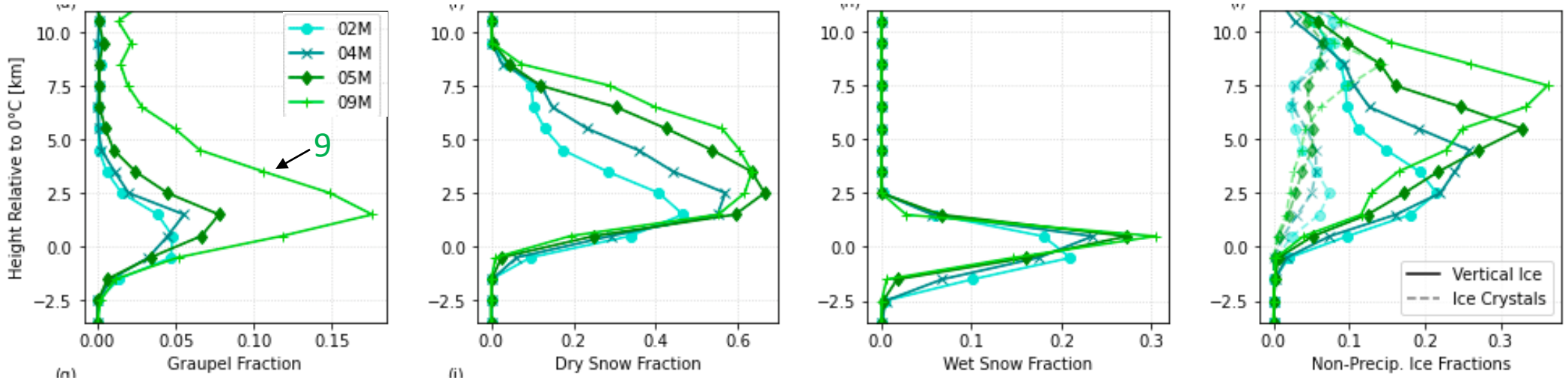
Clusters with reflectivity depicting variations of intense stratiform precipitation (e.g., trailing stratiform of mesoscale convective systems) have SSIM from 0.6-0.8

Comparison of MCS-like Trailing Stratiform Features

DPR Profiles



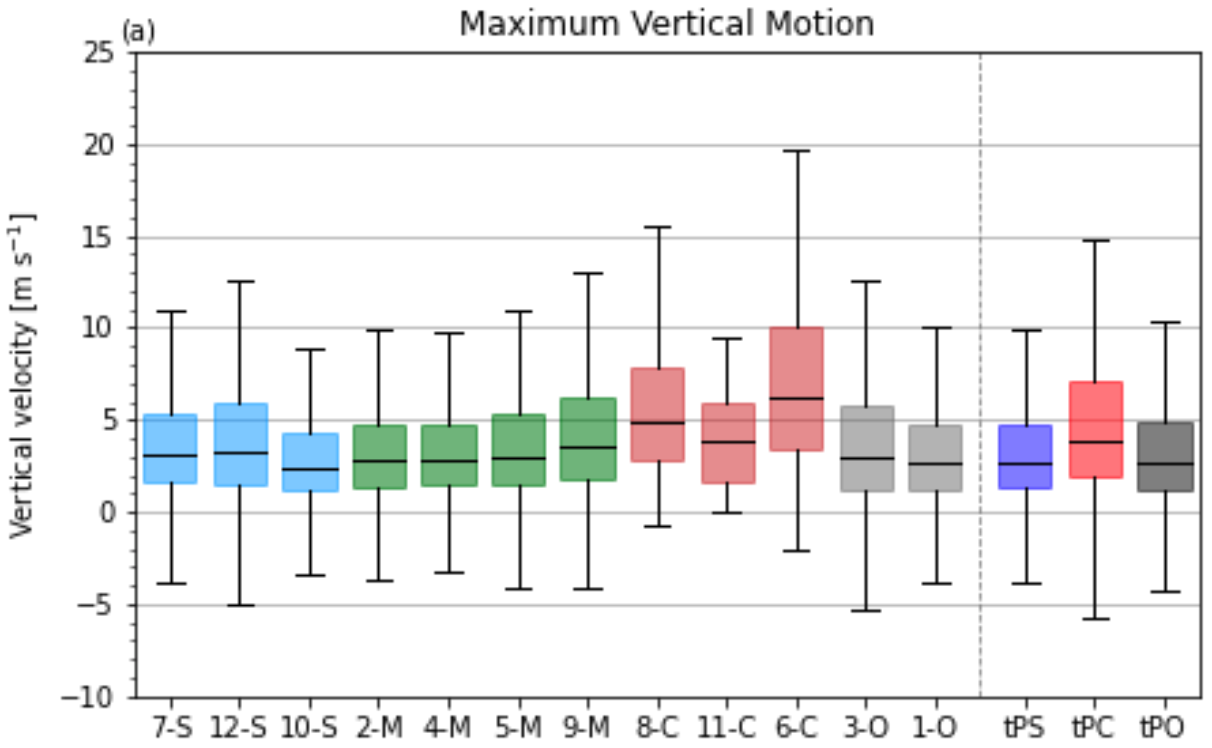
GR Profiles of Hydrometeor Type (HID)



Distinct differences in rimed ice and dry snow fractions

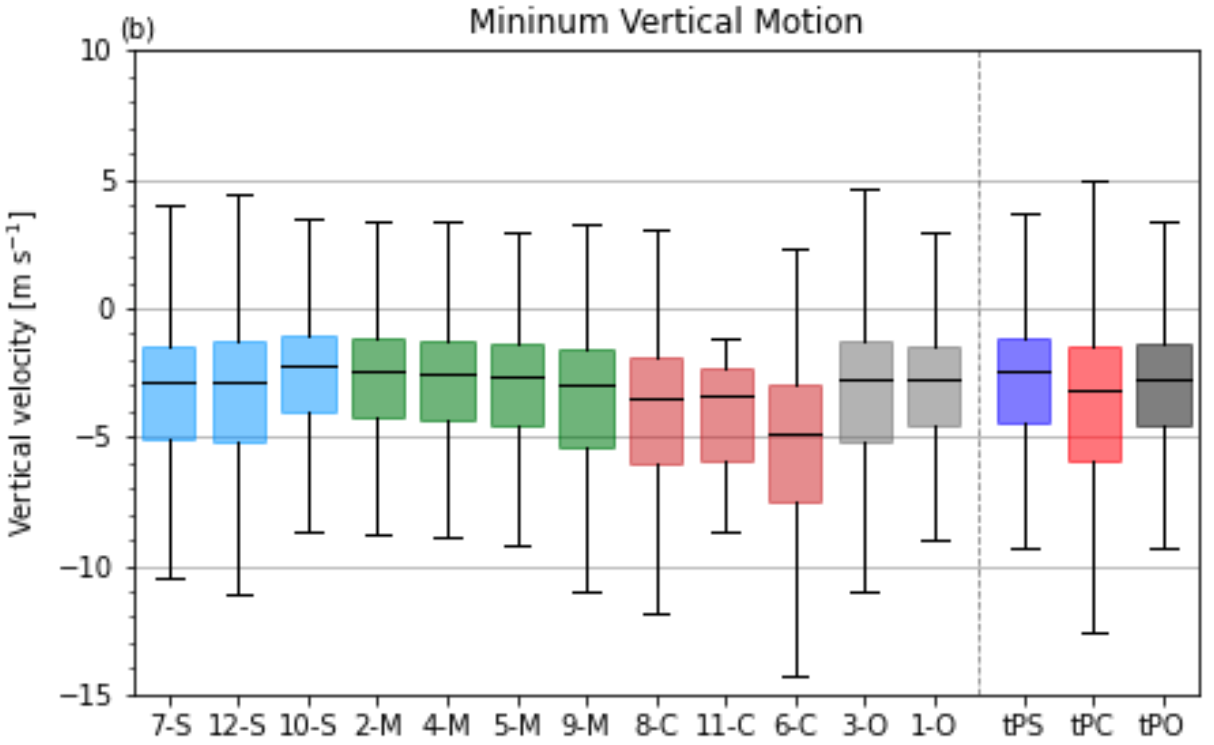
Bulk Vertical Motion Characteristics of DPR profiles

~54,000 DPR profiles (5%) have corresponding wind information



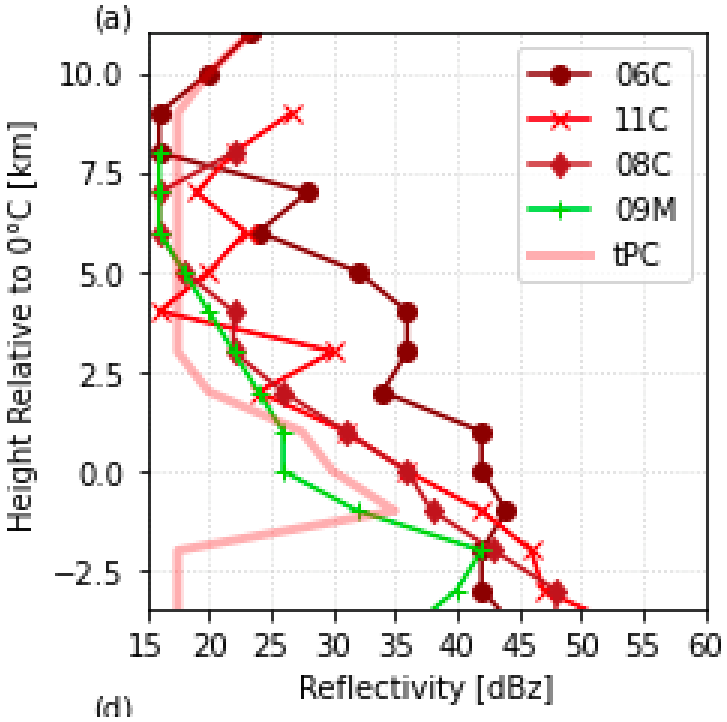
- Profiles with active riming have larger W (e.g., deep convection, deep trailing stratiform of MCS)
- Most convective profiles have W<10m/s
- Deep convective profiles have strongest vertical motions and exhibit most variability

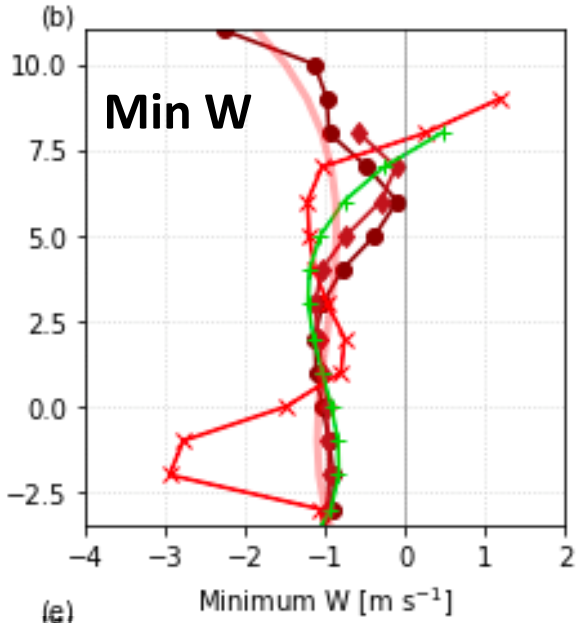
- Clustering depicts different modes/stages of convective intensity correspond to observed mass distributions in DPR profiles
- Stratiform and mixed profiles have weak upward motion (< 5 m/s)

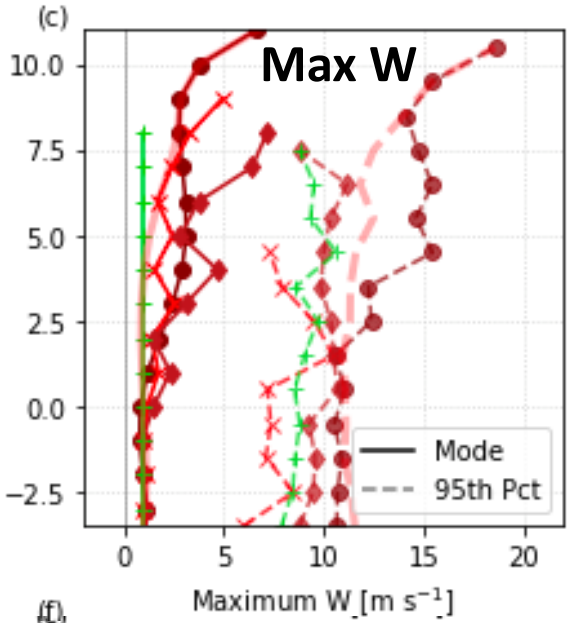


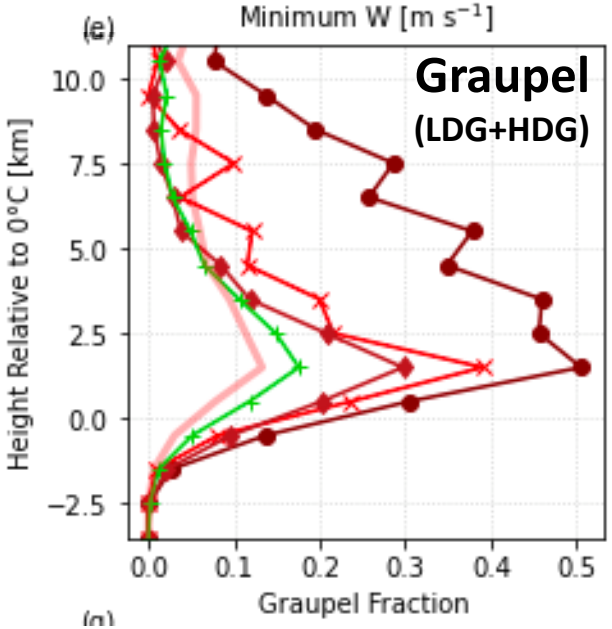
Characteristics of DPR profiles through Deep Convection

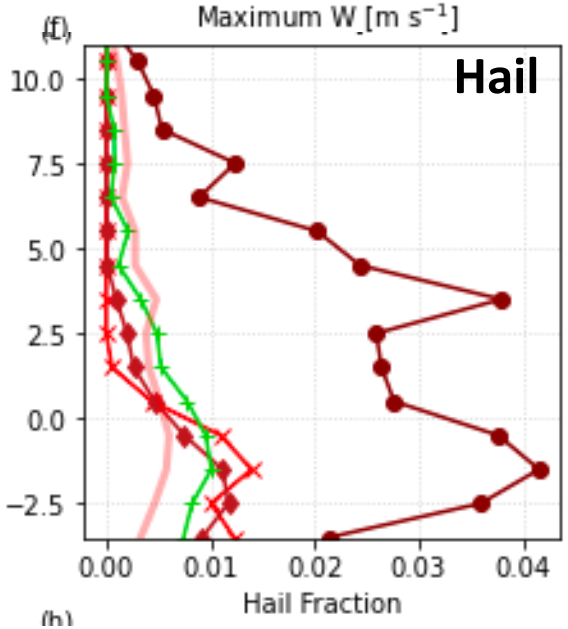
Mode of DPR Reflectivity











Upward Vertical Motions ≥ 15 m/s for cluster 6

Downward Vertical Motions near 3 m/s for cluster 11

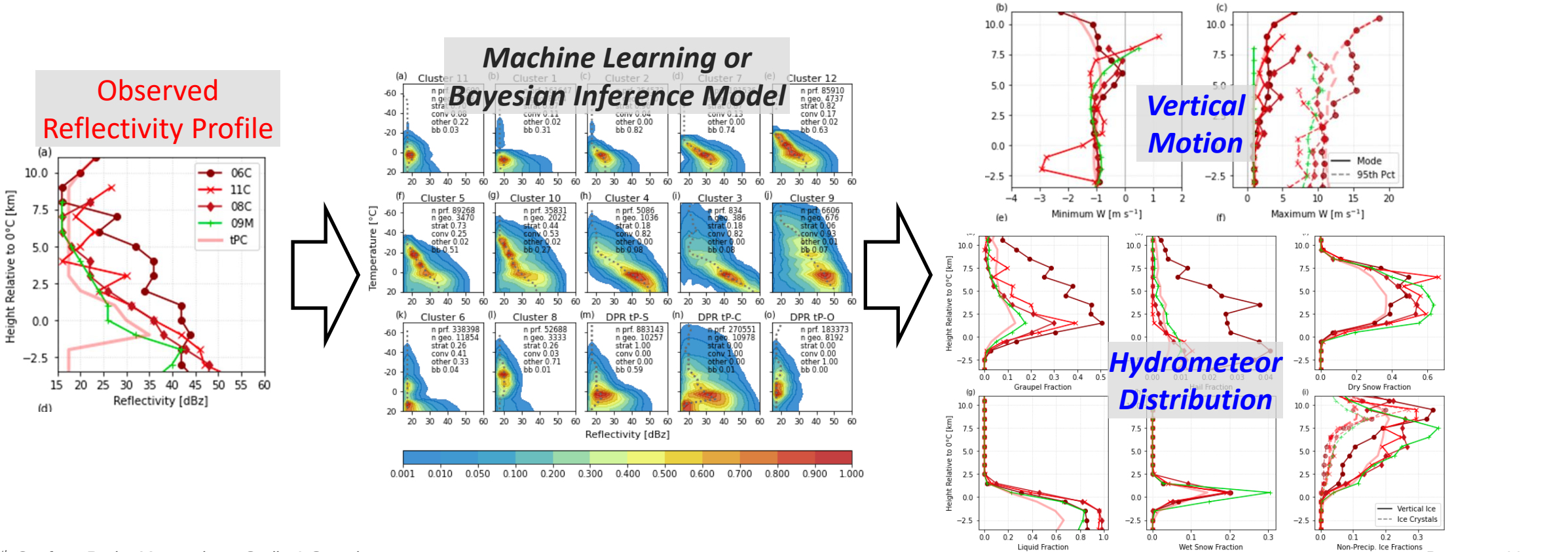
Cluster 6 has highest fraction of rimed ice

Cluster 11 has 10% greater fraction of rimed ice than cluster 8

Implications for satellite missions that study deep convection

- NASA's future Atmospheric Observing System (AOS) will use satellite-based Doppler radars to provide a global-view of vertical air motions and precipitation properties in convective storms
- Leveraging the Program-of-Record is essential to achieving AOS goals

➢ Use tools like the VN to extract kinematic & microphysical information from existing satellite-based radar observations (e.g., TRMM PR and GPM DPR) on a global scale



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External contributions to the ever-expanding GR datasets used in the VN:

- National Center for Monitoring and Alerting of Natural Disasters for access to data from the CEMADEN radar network (Brazil)
- Alain Protat and Scott Collis for CPOL radar data (Darwin, AUS)
- MeteoFrance for data from La Réunion Piton Villers radar
- CSU for CHILL radar data
- UAH for ARMOR radar data