AMS 104TH ANNUAL MEETING
38th Conference on Hydrology
28 JANUARY- 1 FEBRUARY 2024
Baltimore, MD

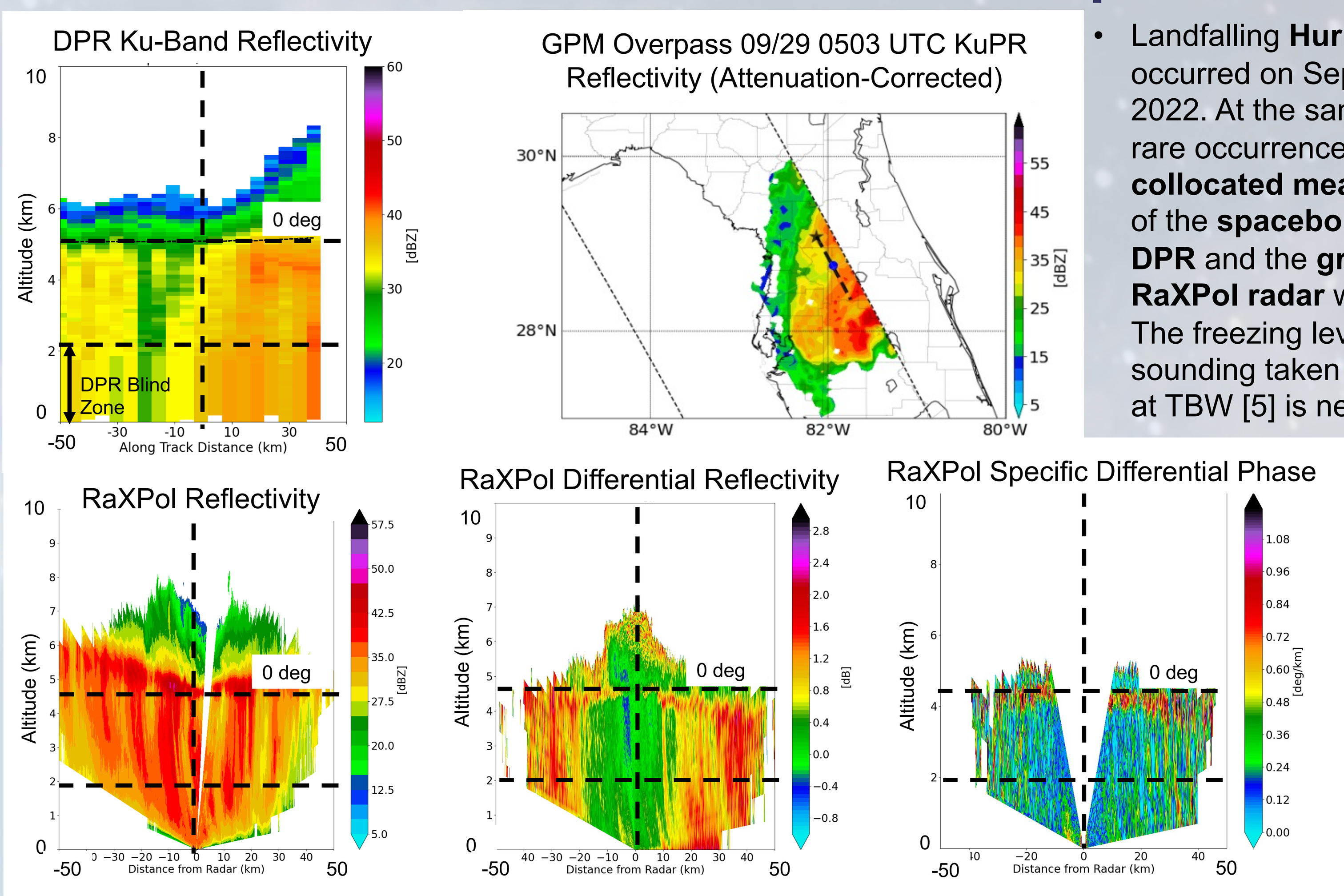
A multi-radar perspective on the stratiform precipitation region of landfalling hurricane Ian (2022)

Aimee Matland-Dixon[1,2], Noah Brauer[1,2], Pierre Kirstetter[1,2,3,5], Addison Alford[4,5], Jacquelyn Ringhausen[4,5]
[1]Advanced Radar Research Center, University of Oklahoma, Norman, OK, USA
[2]School of Meteorology, University of Oklahoma, Norman, OK, USA
[3]School of Civil Engineering and Environmental Science, Norman, OK, USA
[4]The Cooperative Institute for Severe and High-Impact Weather Research and Operations (CIWRO), Norman, OK, USA
[5]NOAA National Severe Storms Laboratory, Norman, OK, US

1. Objectives/Motivation

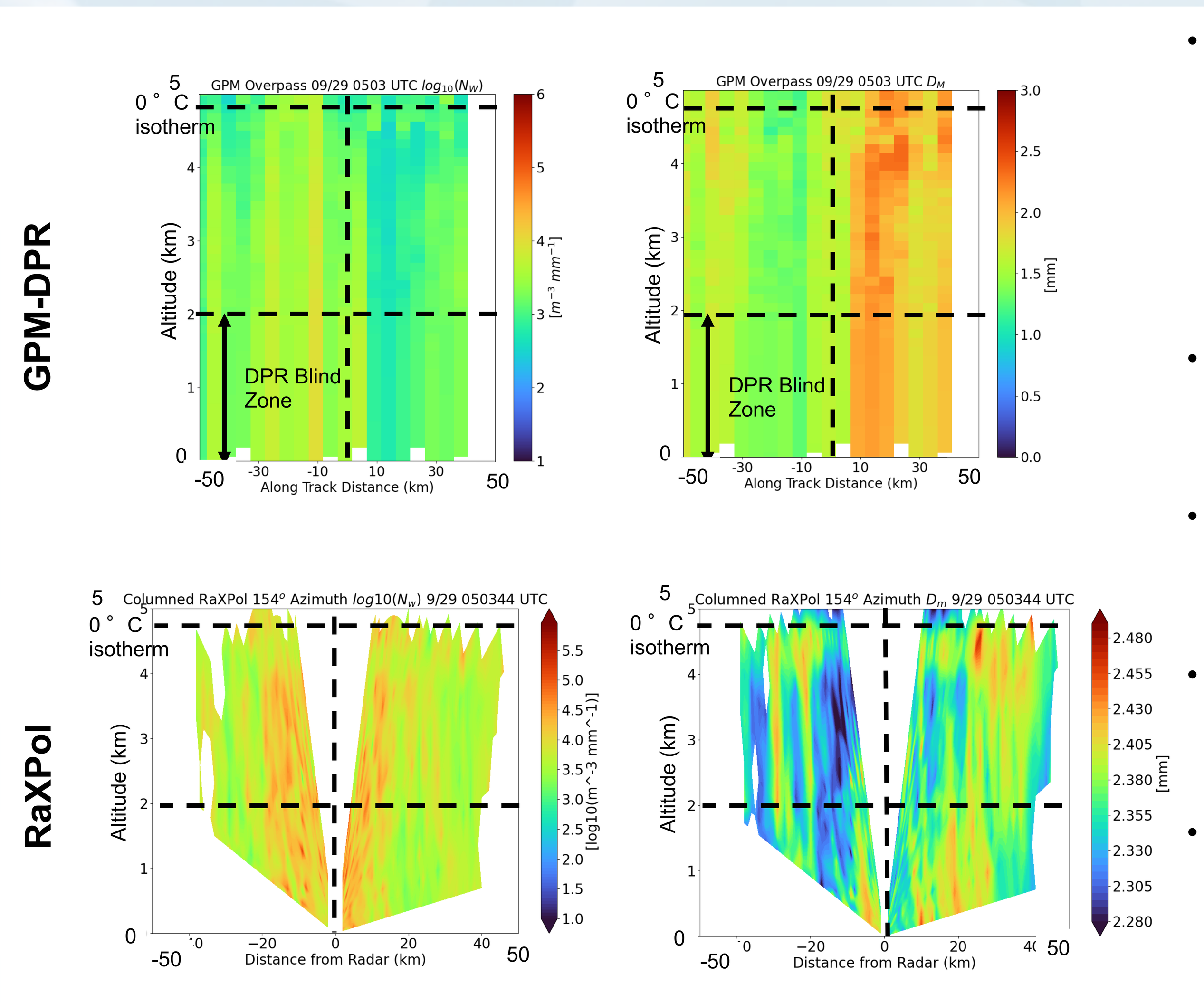
- This work examines a **rare occurrence of an overpass of the NASA Global Precipitation Measurement (GPM) Mission Dual-Frequency Precipitation Radar (DPR) [1] matched with a ground-based mobile polarimetric radar (RaXPol)** [2] sampling in the outer stratiform region of landfalling Hurricane Ian (2022).
- **The GPM-DPR** is a dual-frequency precipitation radar onboard NASA's low earth orbiting GPM Core Observatory satellite that is composed of a Ku-Band and a Ka-Band radar with matched 5 km horizontal footprints at nadir and a vertical sampling resolution of 250 m. The dual-frequency allows for an improved estimate of satellite-radar precipitation rate and **columnar particle size distributions**, but it suffers from a satellite **blind-zone** and attenuation effects near the surface. A ground-based mobile radar, like OU's RaXPol, can fill these gaps when deployed in a storm offering insight on precipitation (1) close to the surface, (2) at a high spatial resolution, (3) over temporal context.
- **RaXPol** is a mobile X-band polarimetric radar that can complete a 10-elevation-step volume scan in about 20 s and for the current measurement has a radar resolution volume spacing of 30 m with a 1° angular resolution which allows for high resolution insight within the DPR blind zone (approximately from the surface to 2 km in altitude)
- Drop size parameters of **normalized intercept parameter** (Nw) and **mean drop diameter** (Dm) can be estimated with accuracy for the DPR using a dual-frequency estimation technique [3] and methods utilizing a combination of polarimetric variables reflectivity (Z), differential reflectivity (Zdr), and specific differential phase (Kdp) have been evaluated as a more accurate way of estimating Nw and Dm for a ground-based X-band radar for tropical convective systems [4] (biases may exist since this study looks at the outer stratiform region of hurricain Ian).
- Changes in estimated number concentration and drop diameter lead to **insights about processes occurring within the blind zone.**

2. Measurement Setup



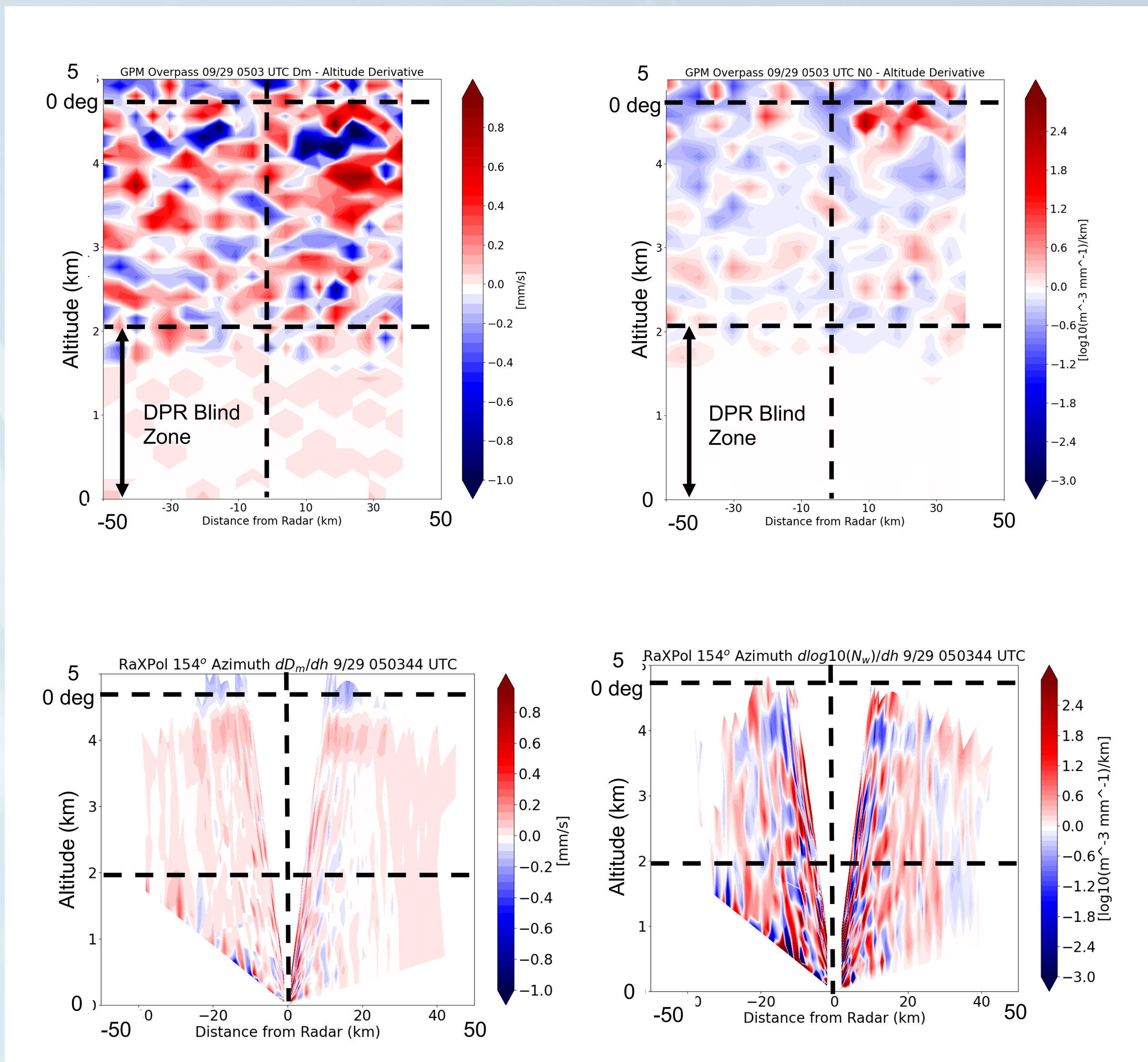
- Landfalling **Hurricane Ian** occurred on September 29th, 2022. At the same time a rare occurrence of a **collocated measurement** of the **spaceborne GPM-DPR** and the **ground-based RaXPol radar** was captured. The freezing level for a sounding taken at 1200 UTC at TBW [5] is near 4.8 km.

3. Matched Spaceborne Ku and Ground-based X-band Profiles

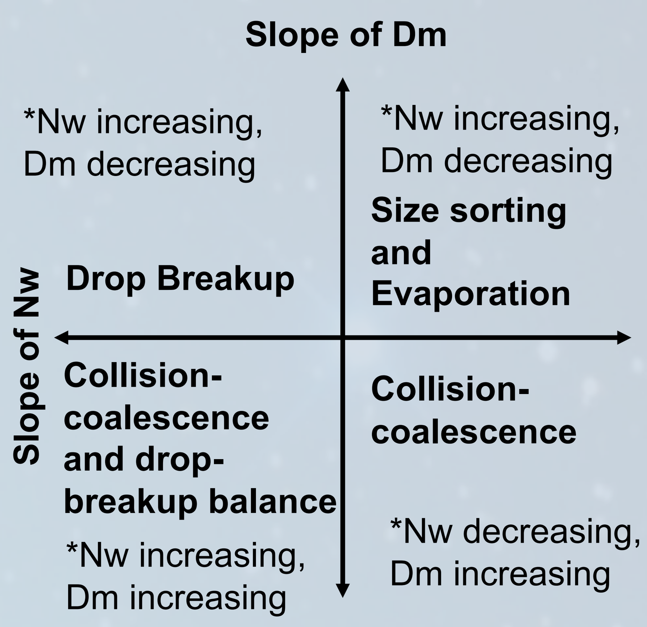


- Estimation algorithms were used to calculate the number concentration (Nw) and the mean drop diameter (Dm) for the space-based DPR and the ground-based RaXPol
- The DPR algorithm relies on a dual-frequency estimation technique [3]
- The RaXPol algorithm relies on polarimetric variables Z, Zdr, and Kdp [4]
- The range of Nw derived values is larger for RaXPol than for the DPR
- The range of Dm derived values is larger for the DPR than for RaXPol

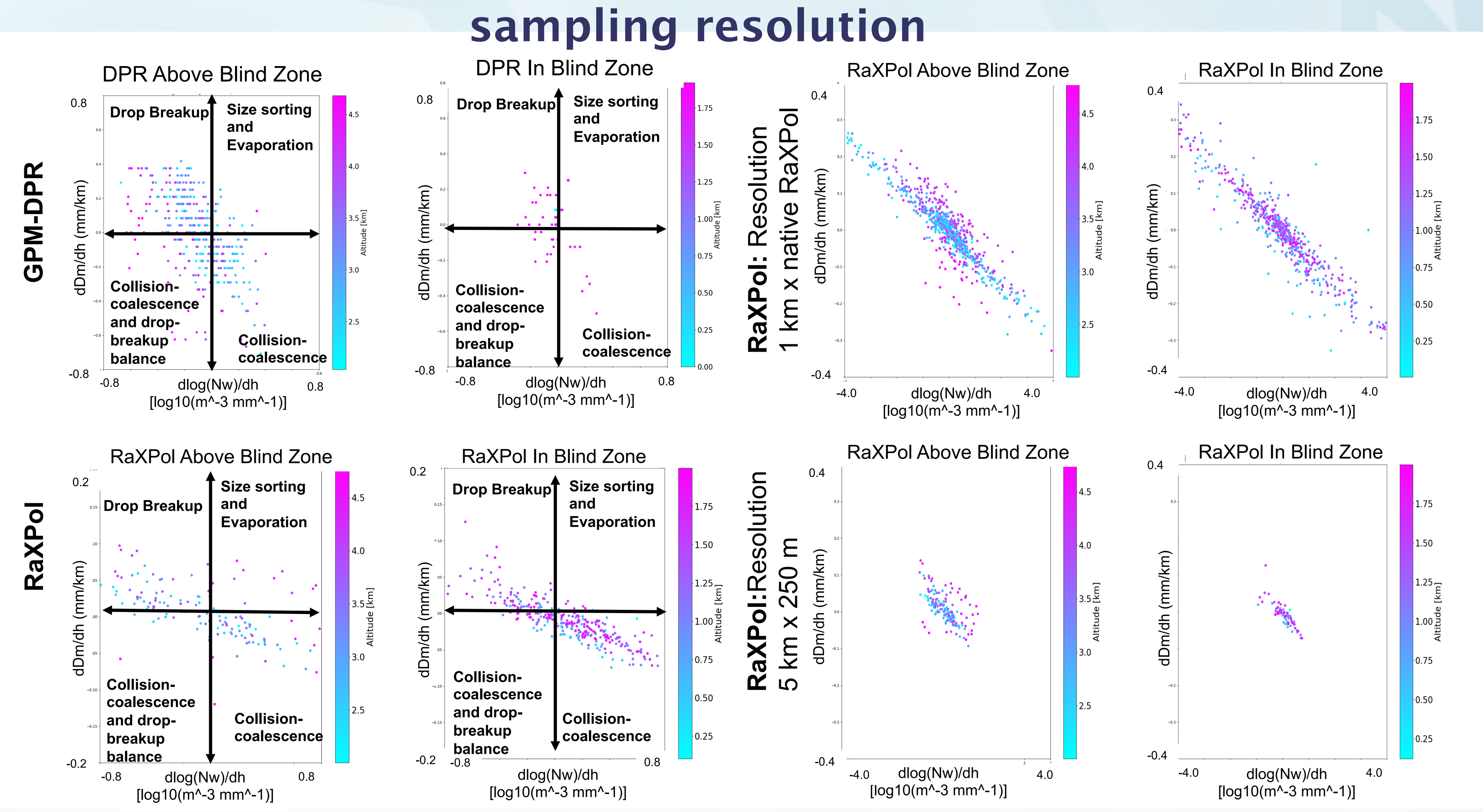
4. Liquid phase processes



- **Altitude derivatives of Nw and Dm provide insight into processes occurring in the liquid phase** because they indicate how drop sizes and concentrations increase or decrease towards the surface:



5. Process Rates and the impact of instrument sampling resolution



6. Conclusions

- **Radar measurements in the liquid phase were considered above and within the DPR blind zone** of a the outer-stratiform region of a tropical cyclone with weak embedded convection, Hurricane Ian (2022). The DPR blind zone extends from the surface to 2 km in altitude. Changes with altitude of estimated Nw and Dm were performed on matched DPR and RaXPol profiles to **identify process signatures**, indicating:
  - RaXPol and DPR **consistently show signatures of drop breakup and collision-coalescence processes**.
  - **RaXPol detects more signatures of size sorting above the blind zone than DPR** especially at higher altitudes (> 4 km).
  - From RaXPol observations, process signatures are similar above and within the blind zone. It indicates that **missing DPR data within the blind zone could be estimated via translation of process information from the DPR above the blind zone**.
  - RaXPol Dm changes with altitude display lower magnitudes than DPR, while RaXPol log(Nw) changes with altitude display higher magnitudes than DPR. It suggests that **different instrument retrievals may imply different process rates** for the same collocated observation. Such differences could be caused by the radar differences in operating frequencies, viewing angles, and PSD parameter retrievals algorithms.
- **The implications of this work are applicable for**:
  - **Ground validation** of satellite precipitation estimates
    - This case study indicates a potential technique for **blind-zone gap-filling**
  - **Numerical weather prediction modeling** with process rates at various scales
    - **The rates of processes vary with sampling resolution**. Decreasing the RaXPol resolution to match the DPR resolution reduces the range of visible process rates.

References

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