Comparison of Microphysical Properties for the IMPACTS 2020 Feb 1st Case with Aircraft and GPM Data and MERRA-2 Reanalysis

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I. INTRODUCTION

The Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS) field campaign in 2020 sampled a frontal precipitation system with coincident Global Precipitation Measurement (GPM) observations. In this study, we compare the radar and in-situ observations obtained by GPM and ER-2 and P-3 aircrafts. Radar reflectivities and the GPM retrievals of the mass-weighted mean diameter, D_m, are compared at multiple radar frequencies. The environment of the system is illustrated with MERRA-2 data.

We choose to conduct this comparison between the GPM retrieved D_m and the D_m derived from the aircraft in-situ data, despite a limited number of collocated samples from the dual-frequency precipitation radar (DPR). It is motivated by a recent study (Han and Braun 2021) where a global 3-dimensional D_m distribution was investigated, suggesting a necessity to evaluate D_m at high altitudes.

II. Synoptic Environment

The MERRA-2 reanalysis provides an overview of the synoptic environment for the Feb 1st case. A relatively weak low pressure system was located off shore of the Virginia coast. A baroclinic zone extended from the Low northeastward was associated with the precipitation system.

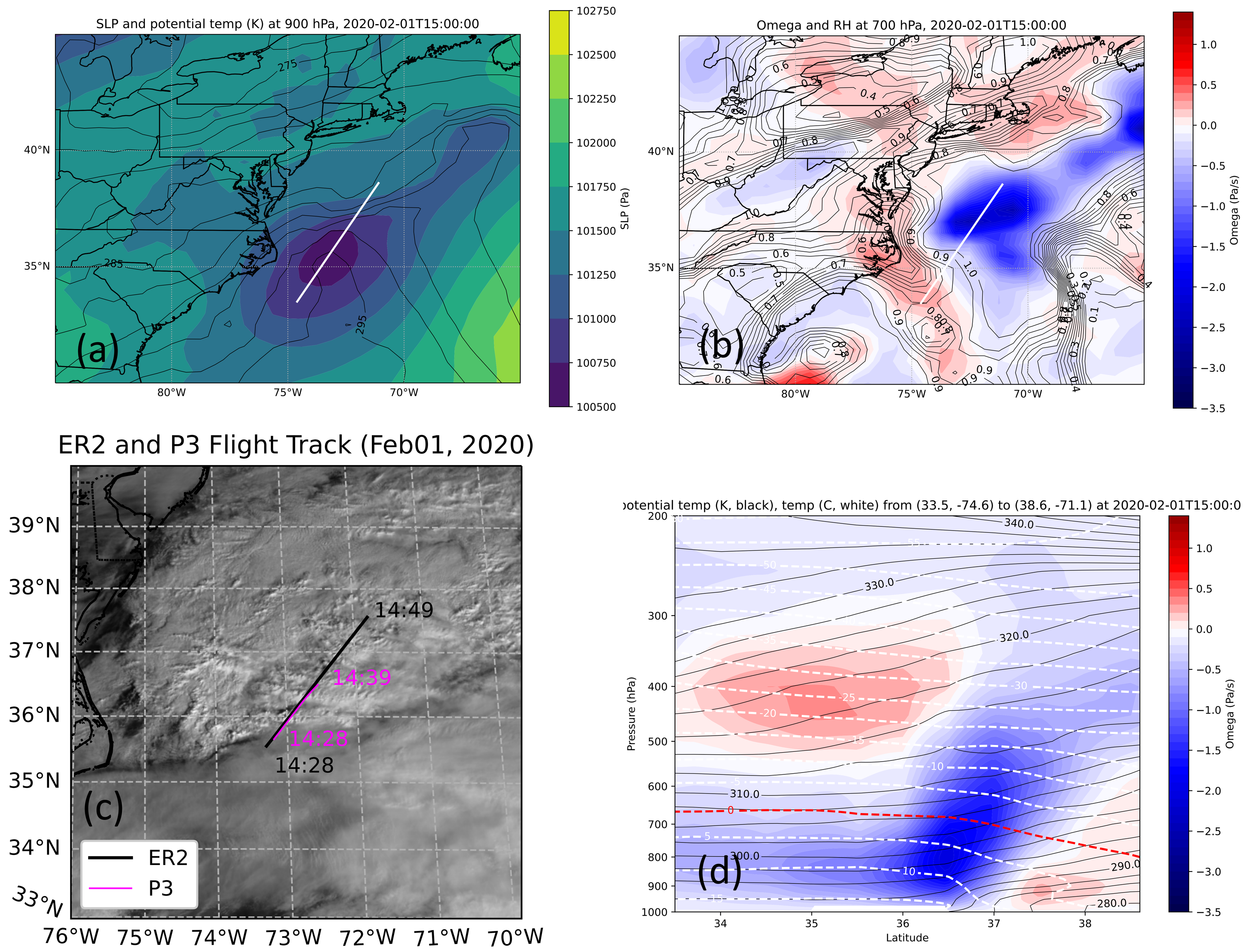


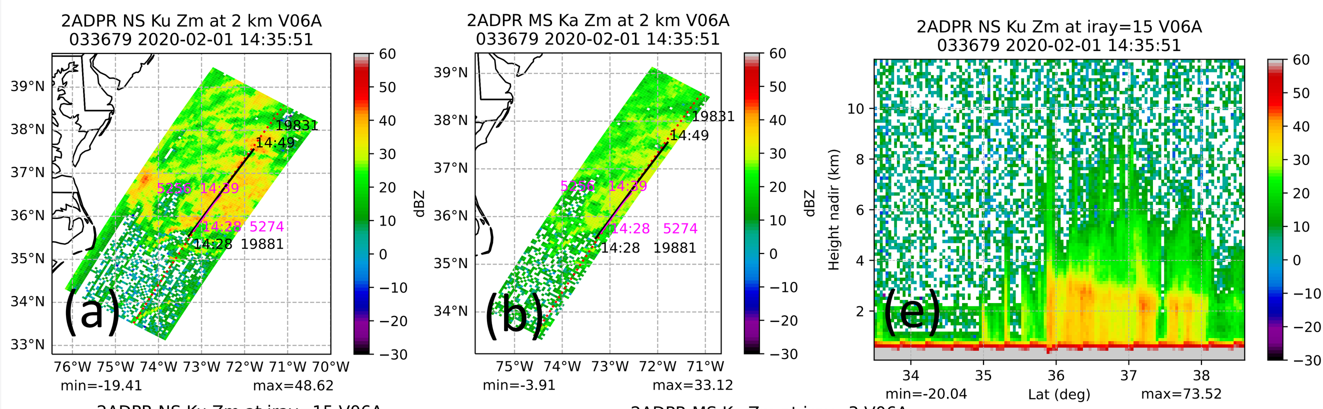
Fig. 1: MERRA-2 (15 UTC) analysis (a, b, d) and GOES (14:35:51 UTC) Chanel 1 ABI L1b radiance (c). The white line (a, b) shows the location of the cross section along the GPM overpass (also shown as red dotted line in panels a and b in Figs. 2-4), where a MERRA-2 cross section (d) is analyzed. The ER-2 (black) and P-3 (magenta) flight tracks (c) are along the GPM overpass (Figs. 2-4)

- Sea Level Pressure (SLP) and potential temperature at 900 mb depict a cyclone and fronts with relatively weak intensity.
- 700 mb Omega and Relative Humidity (RH) show the upward motion associated with the front-low system and the environment is saturated.
- GOES16 mesosector image shows fine-scale streaks of cloud feature, where ER-2 and P-3 took samples.
- Potential temperature field in the cross section (d) shows a moderate slope of the front. Updraft occurred along the sloped front zone.
  - The updraft is stronger near 36° to 37° N, near the P-3 and ER-2 sampling track.
  - At higher levels, the updraft extended further north, corresponding to the GOES cloud deck.
  - A slanted 0° C isotherm (red dash line) corresponds to a slanted bright band in radar observations.

Heymsfield, A. et al. 2004: Effective Ice Particle Density Derived from Aircraft Data, JAS, **61,** 982–1003.
*Heymsfield, A. et al. 2010: Improved representation of ice particle masses based on observations in natural clouds. JAS, **67,** 3303-3318.*
*Kuo et al. 2016: The Microwave Radiative Properties of Falling Snow Derived from Nonspherical Ice Particle Models. Part I: An Extensive Database of Simulated Pristine Crystals and Aggregate Particles, and Their Scattering Properties. JAMC, **55,** 691-708.*
Han and Braun 2021: Understanding the Global Three-dimensional Distribution of Precipitation Mean Particle Size with the Global Precipitation Measurement Mission. JCli, in press.

III. GPM DPR observations and retrievals

The GPM coincident overpass is analyzed. Below we show the Ku and Ka measured reflectivity (Z_m), the corrected reflectivity (Z_c), and the retrieval of the mass-weighted mean diameter (D_m) with the GPM Combined Radar-Radiometer Algorithm (CORRA). Normal scan (NS) and matched scan (MS) swathes are shown.



Panel e shows a longer cross section, located at the red dotted line in panels a and b – the same cross section as Fig. 1d.

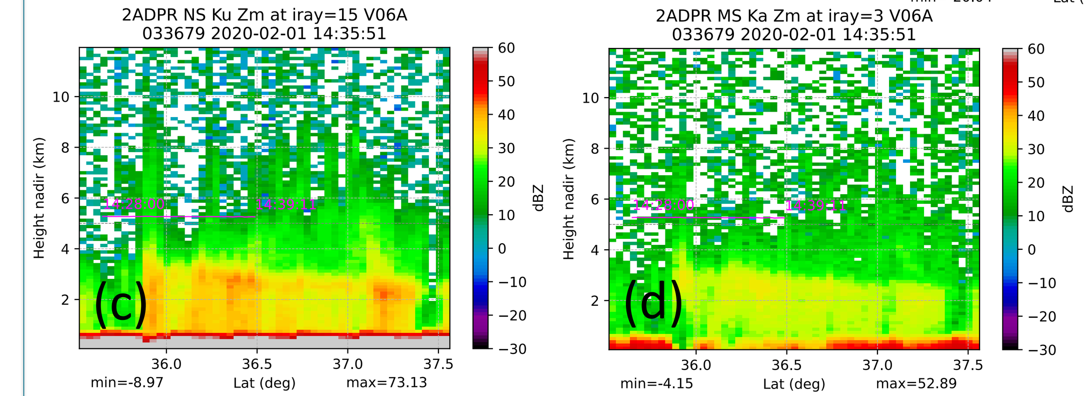


Fig. 2: GPM 2ADPR measured reflectivity (Z_m) at 2 km (a, b) and cross sectional views (c, d) along the ER-2 flight leg (black line in a and b) near 14:35 UTC. P-3 flight leg within the cross section is shown at the P-3 flight altitude.

- Z_m shows the structure of the frontal precipitation with its bright band slope downward to the north.
- Upper-level towers of precipitation appear similar to generating cells – corresponding to the streaks feature in the ABI radiance (shown in Fig. 1c).
- The bright band signature in Z_m seems more evident than that in Z_c (see Fig. 3).

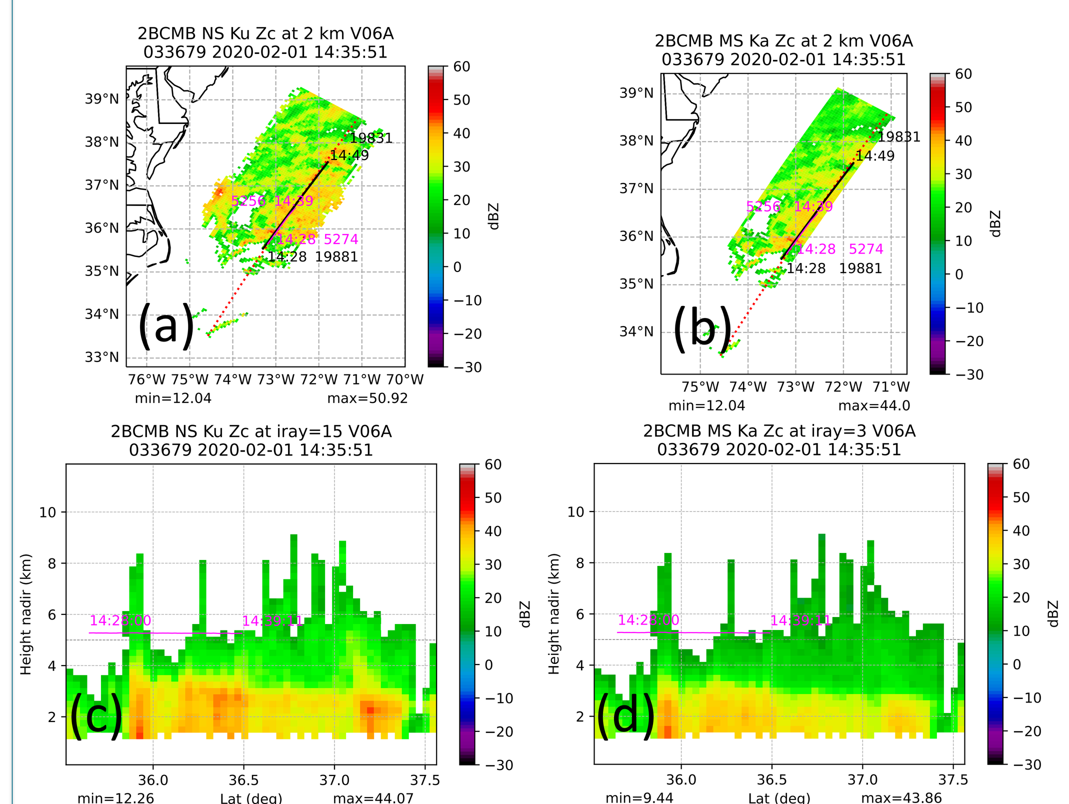


Fig. 3: same as Fig. 2 but for CORRA corrected reflectivity (Z_c).

- Z_c shows narrower generating cells – reflectivity less than 12 dBZ at Ku was not included.
- The 11-minute P-3 flight leg near 5260 m that is coincident with ER-2 only intercepts 8 pixels in the GPM Z_c cross section.

The GPM CORRA algorithm retrieves D_m with an ensemble-based optimal-estimation framework that does not directly utilizing the relationship between D_m and the Ku and Ka dual-frequency ratio. D_m is the ratio of the 4th to the 3rd moment of the particle size distribution. The size of a solid particle is the liquid-equivalent diameter.

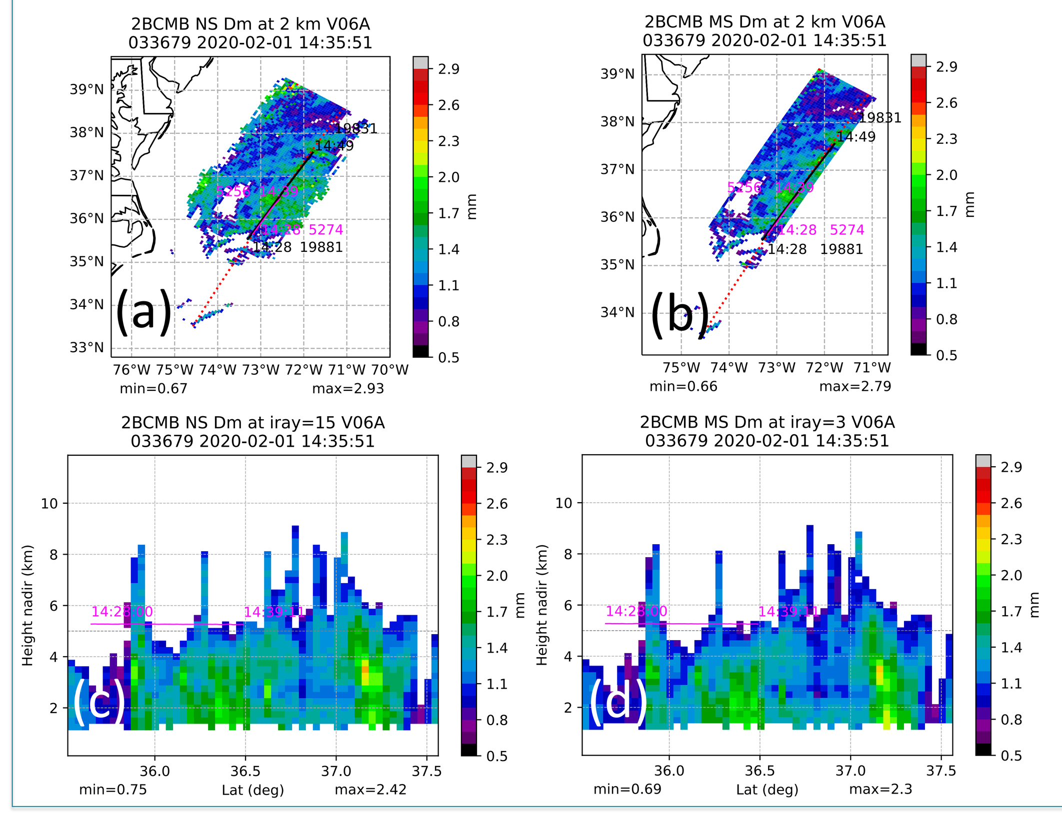


Fig. 4: same as Fig. 3 but for D_m.

- The generating cells have relatively small D_m
- MS D_m appears slightly smaller than NS D_m. The former considers both Ka and Ku constrains, while the latter only has Ku. Both MS and NS retrievals use some constrains from GMI to a certain extent.
- The D_m at bright band appears small – likely a problem with the treatment for melting.

IV. ER-2 and P-3 observations

The ER-2 has sampled 21 minutes along the GPM overpass, close to a fixed DPR incident angle. The ER-2 cross sectional views are compared to the GPM cross section shown in panels c and d in Figs. 2-4.

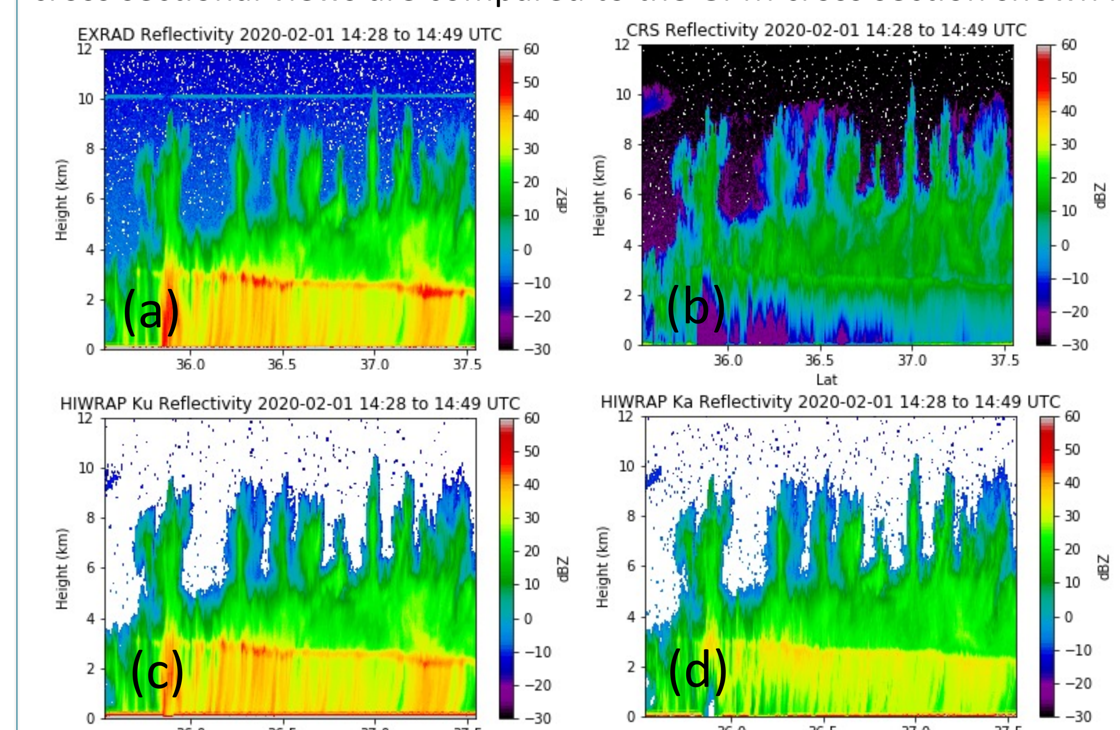


Fig. 5: ER-2 X- (EXRAD), W- (CRS), Ku-, and Ka- (HIWRAP) band reflectivity. Lidar (CPL) retrieved cloud phase (e) is for reference. The location of the cross section is shown as the black line in the horizonal views of Figs. 1-4.

- Much finer features in reflectivities sampled by radars onboard ER-2.
- Generating cells shown in the HIWRAP Ku are quite comparable to the GPM Ku Z_m. HIWRAP Ka shows much finer reflectivity of the generating cells than the DPR matched scan Ka Z_m
- Attenuation below the bright band is apparent at Ka and W band.

The P-3 has sampled the first 11 minutes along with ER-2. Data from the NCAR High Volume Precipitation Spectrometers (HVPS3) is analyzed.

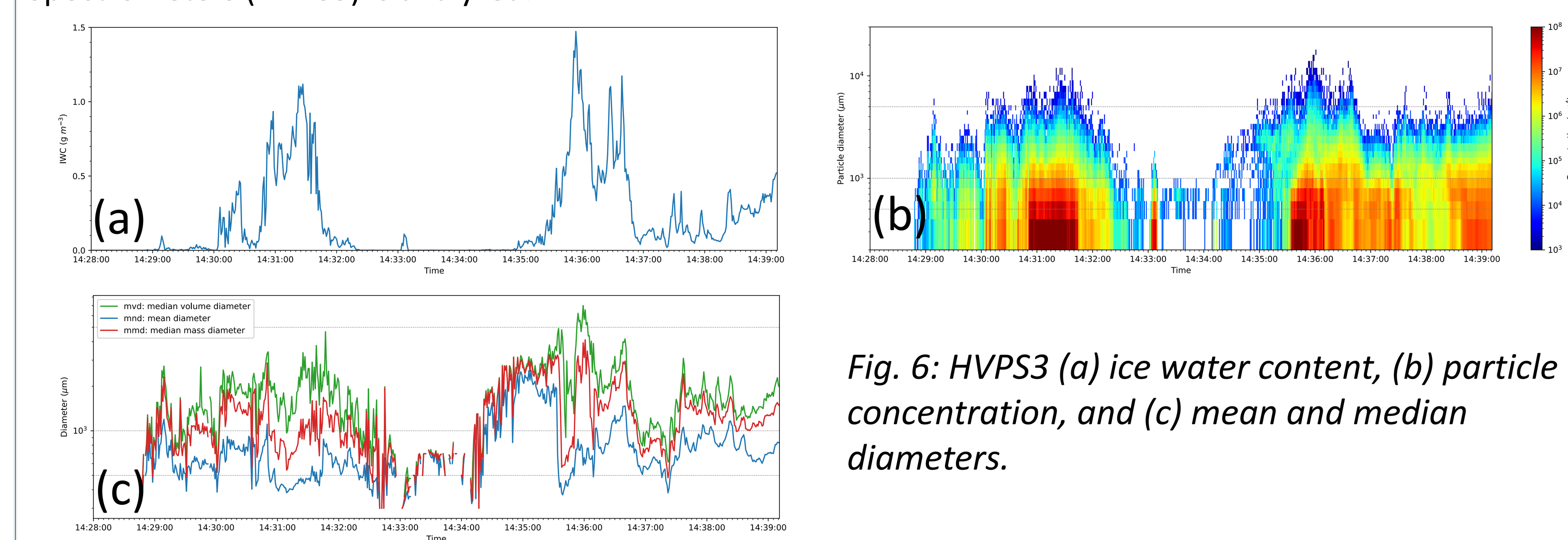


Fig. 6: HVPS3 (a) ice water content, (b) particle concentration, and (c) mean and median diameters.

- The two high IWC and concentration peaks are associated with two generating cells. And the smaller peak toward the end of the 11-min appears corresponding to a weaker / shallower cell.
- The median volume diameter, median mass diameter, and mean diameter are integrals of the solid particle dimension with *m=0.0061*D^2.05* (Heymesfield et al. 2004) , provided by the HVPS3 data.

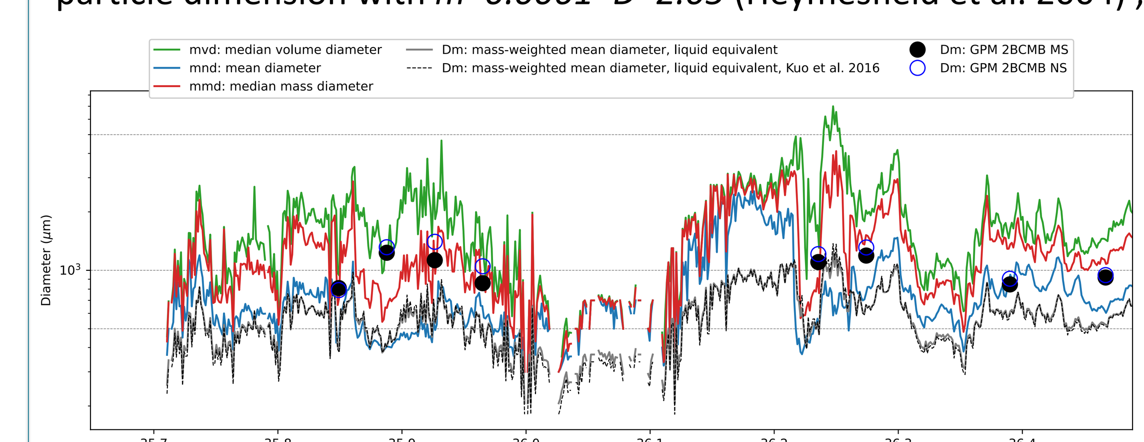


Fig. 7: GPM CORRA retrieved D_m (black dot for MS, open blue dot for NS) overlaid with the D_m calculated with the HVPS3 data (gray solid and black dash lines), along with mvd, mnd, and mmd shown in Fig. 6c.

- D_m calculated with the above *m-D* relationship applied to liquid equivalent (gray) is close to the one (black) calculated with the *m-D* relationship (*m=0.007*D^2.2*) used in Kuo et al. (2016) and Heymesfield et al. (2010).
- Both CORRA MS and NS D_m are generally larger than the D_m derived from the HVPS3 data. MS with Ka information is slightly closer to the in-situ derivation – limited samples

V. SUMMARY

The IMPACTS field campaign has provided coincident aircrafts observations with a GPM overpass on Feb 1, 2020. A relatively weak low pressure and frontal precipitation system was sampled by the space-borne and aircraft radars at multiple frequencies and by in-situ particle probes. Our investigation depicts the structure of the precipitation system that was associated with multiple generating cells atop. Microphysical properties of the generating cells are studied. The available GPM CORRA retrieval of the mass-weighted mean diameter, D_m, is compared with the derived diameters with HVPS3 data. Both CORRA MS and NS D_m appear somewhat larger than the values derived from HVPS3. Future studies and more samples are needed to better characterize D_m at high altitudes.