Using Airborne Radar Measurements to Improve Physical Assumptions in DPR and GMI Algorithms

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Objectives

- Improvements of the GPM radar, radiometer, and combined algorithms for convection, light rain, and snow using the existing (X/W-band) measurements as well as new HIWRAP (Ku/Ka- band) dual-wavelength airborne radar measurements.
- Application of new ER-2 data sets from MC3E to assist in validation of the GPM pre-launch operational algorithms..
- Development of merged aircraft radar and radiometer data sets for science team distribution that will be used for exploiting information on the algorithm physical assumptions.
- Work with GPM algorithm developers on evaluation of radar and combined algorithms using the airborne radar and radiometer data sets.

Previous measurements from EDOP (X-band) and CRS (W-band) were used to study various aspects of the radar algorithms.

X/W vs. Ku/Ka For Rain and DSD Retrieval

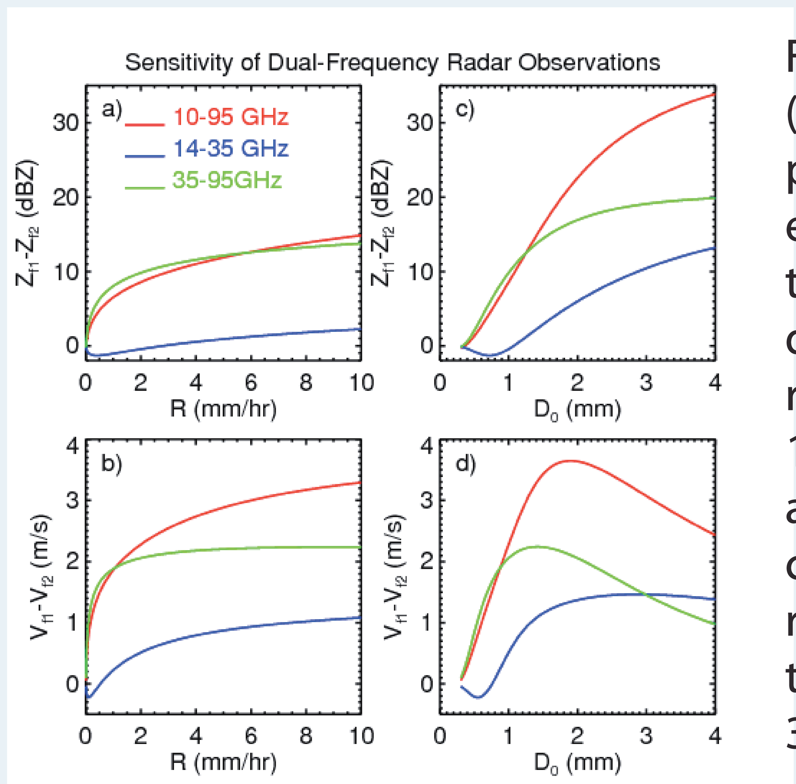


Fig. 1 Difference of reflectivity (DFR) and difference of the Doppler velocity (DDV) at two different radar frequencies as a function of rain rate, R, and medium drop diameter, D_0. Three pairs of radar frequencies are examined: 10 and 95 GHz, 14 and 35 GHz, 35 and 95 GHz. It shows that the combinations of 10 and 95 GHz radars are much more sensitive to the light rain than that of 14 and 35 GHz for light rain retrieval.

Dual-Wavelength (X-/W-band) for Light Rain

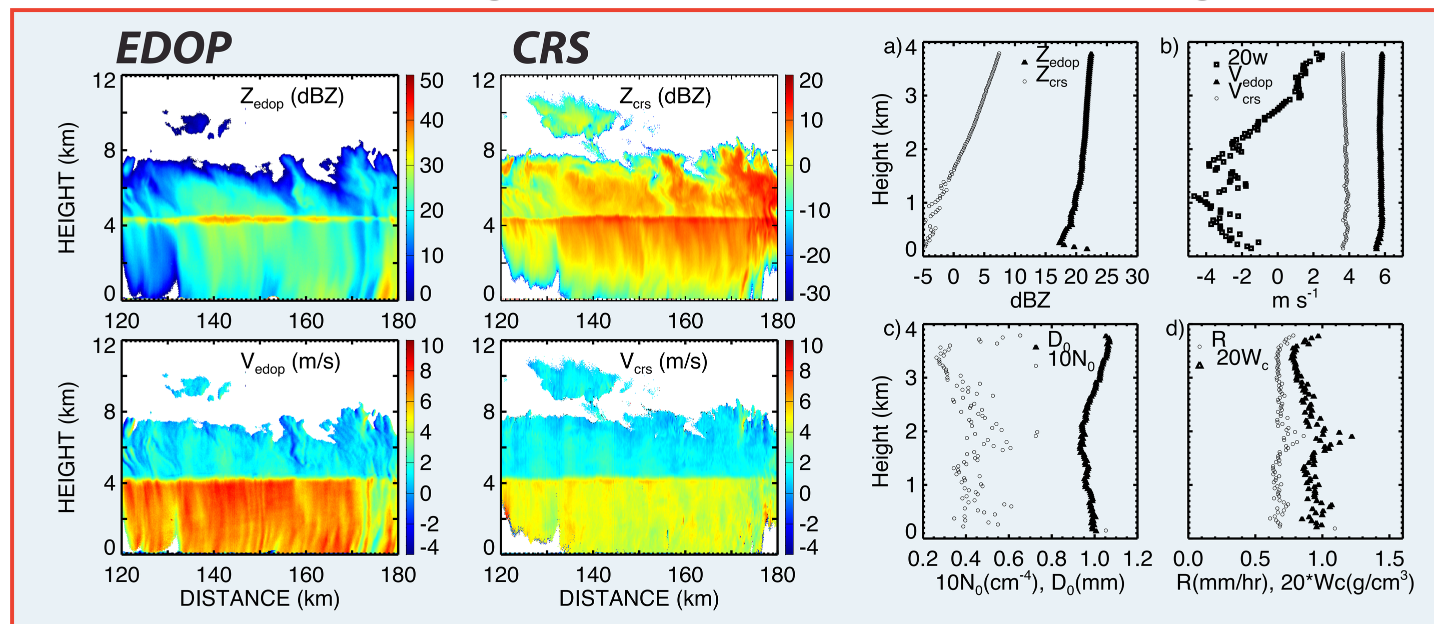
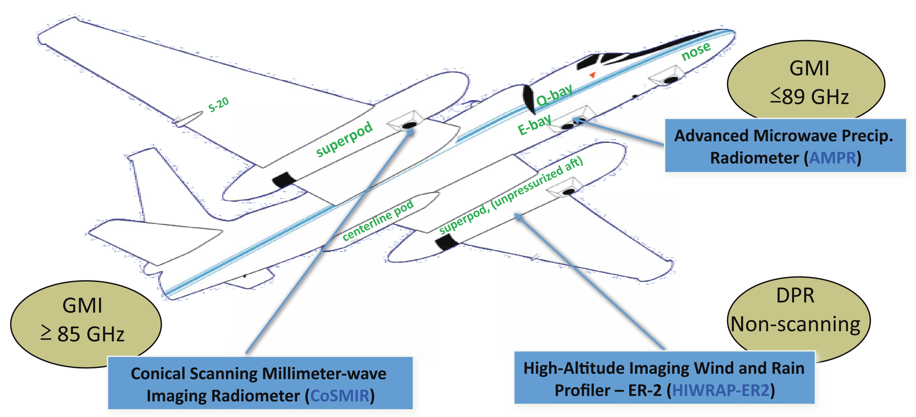


Fig. 2. Stratiform rain observed with EDOP and CRS in July 2002 over Florida. In the rain region below the melting band (4.3 km), scattering at 10 GHz is in the Rayleigh regime except for very large raindrops, the while at 94 GHz it is in the Mie regime except for the very small raindrops. The signal at 10 GHz is subject to little or no attenuation in light rain while the signal at 94 GHz is subject to significant attenuation by rain and water vapor. Consequently, the mean Doppler velocity and reflectivity measured at the two frequencies are quite different. These differences have been exploited to retrieve the parameters of an exponential raindrop size distribution, vertical air velocity, and attenuation by rain, melting band and water vapor for the entire rain fields. Graphs (right panels) show the averages for the entire rain fields: median volume diameter, D_0, and the intercept parameter, N_0, rainfall rate R, and rain water content W.

ER-2 Flights During MC3E



High-Altitude Imaging Wind and Rain Profiler-ER-2 (HIWRAP-ER2)

HIWRAP that normally flies in a scanning mode on the Global Hawk was adapted to a nadir-pointing mode for the ER-2. The main change from the Global Hawk was a new dual-frequency antenna. HIWRAP's frequencies are Ku (13.92 GHz) and Ka (33.7 GHz). The Ku and Ka beamwidths are 3[0] and 1[0], respectively.

Dual-Wavelength (X-/W-band) and In situ Comparisons

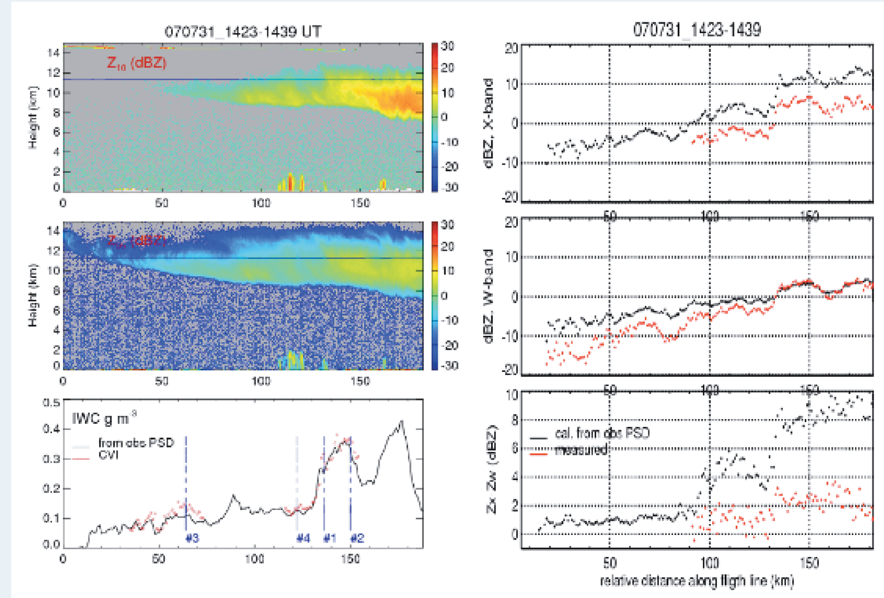


Fig. 3 Left: reflectivity measured by EDOP (top) and CRS (middle), IWC (bottom) calculated from in-situ ice particle size distribution and independent IWC measurement. The horizontal line shows the DC8 flight level where the in-situ data is collected. Right: the reflectivity calculated from the in-situ IPSD (black) and measured (red) at X-band (top), W-band (middle) and the difference between X- and W-band.

One of the challenges of applying the dual-wavelength method to snow is the large uncertainty of snow density and shapes. During NASA TC4 mission, the EDOP and CRS radars provided excellent coordinated observations with the in-situ observation on DC8. Figure 3 shows that although calculated IWC from in-situ PSD's agrees with independently measured IWC, the reflectivities calculated from the in-situ ice PSD's are larger compared to the observed reflectivity. Such differences are due to the uncertainties in particle shape and assumption for ice densities. Combining airborne radar and in-situ data will help GPM algorithm developers to improve the physical assumptions used in forward model.

Understanding Dual-Wavelength Observations in Deep Convection

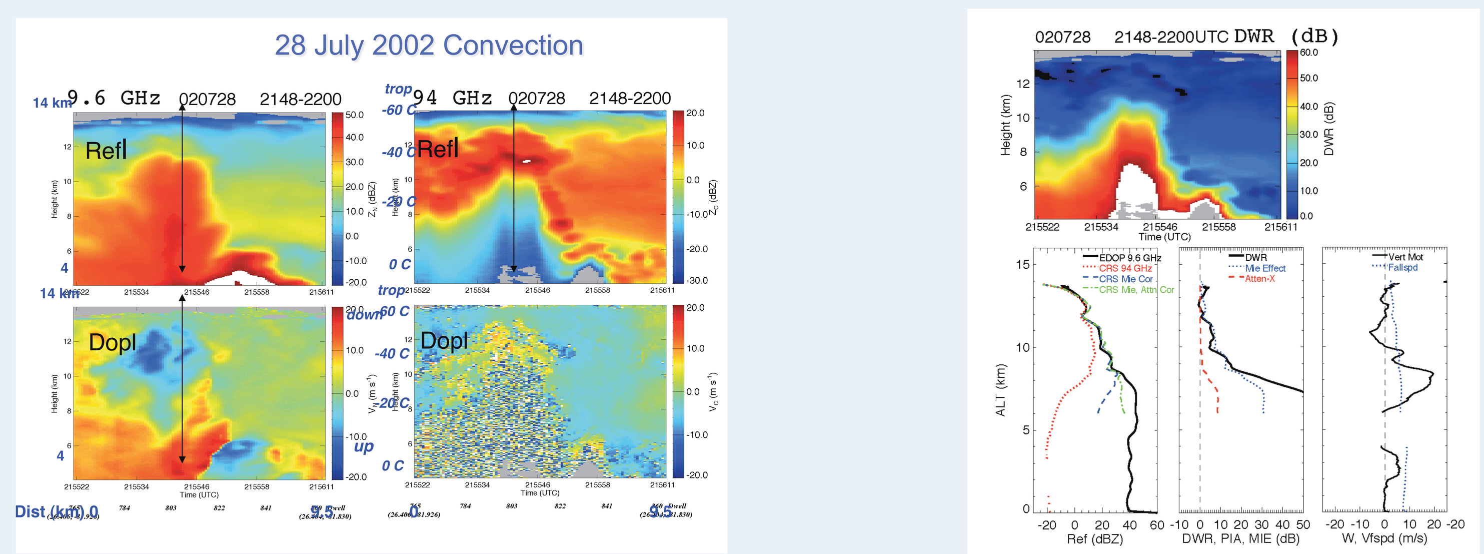
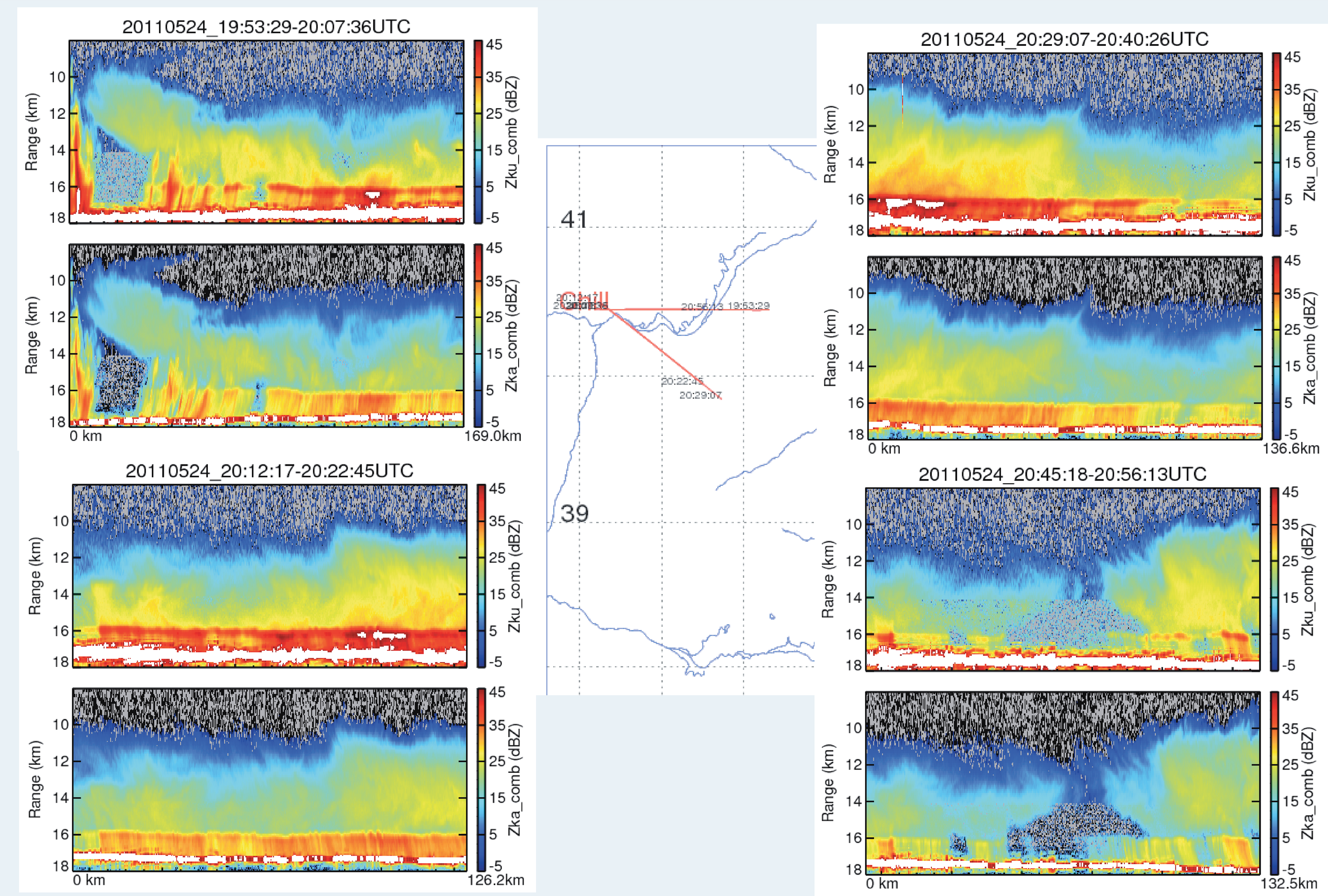


Fig. 4. Previous EDOP and CRS measurements provide important microphysical and kinematic information on intense convection. CRS becomes strongly attenuated in intense updraft cores at -35C altitude as shown by the "hole" in the W-band reflectivity observations. We have attributed most of the strong W-band attenuation aloft to graupel, but many questions remain in the mixed phase portion of the updrafts (e.g., graupel and supercooled cloud drops). The dual-wavelength measurements still are not sufficient to provide unambiguously particle size and phase information. Microwave measurements from high frequencies such as CoSMIR, can provide additional information on the hydrometeor profile. These relationships will be explored more with dual-frequency observations from HIWRAP.

HIWRAP Flights Near CHILL 24 May 2011



Coordination with CHILL on 2 inbound and 2 outbound radials. Mostly stratiform with freezing level near 2 km.

Merged Radar-Radiometer Measurements for GPM Algorithm Testing

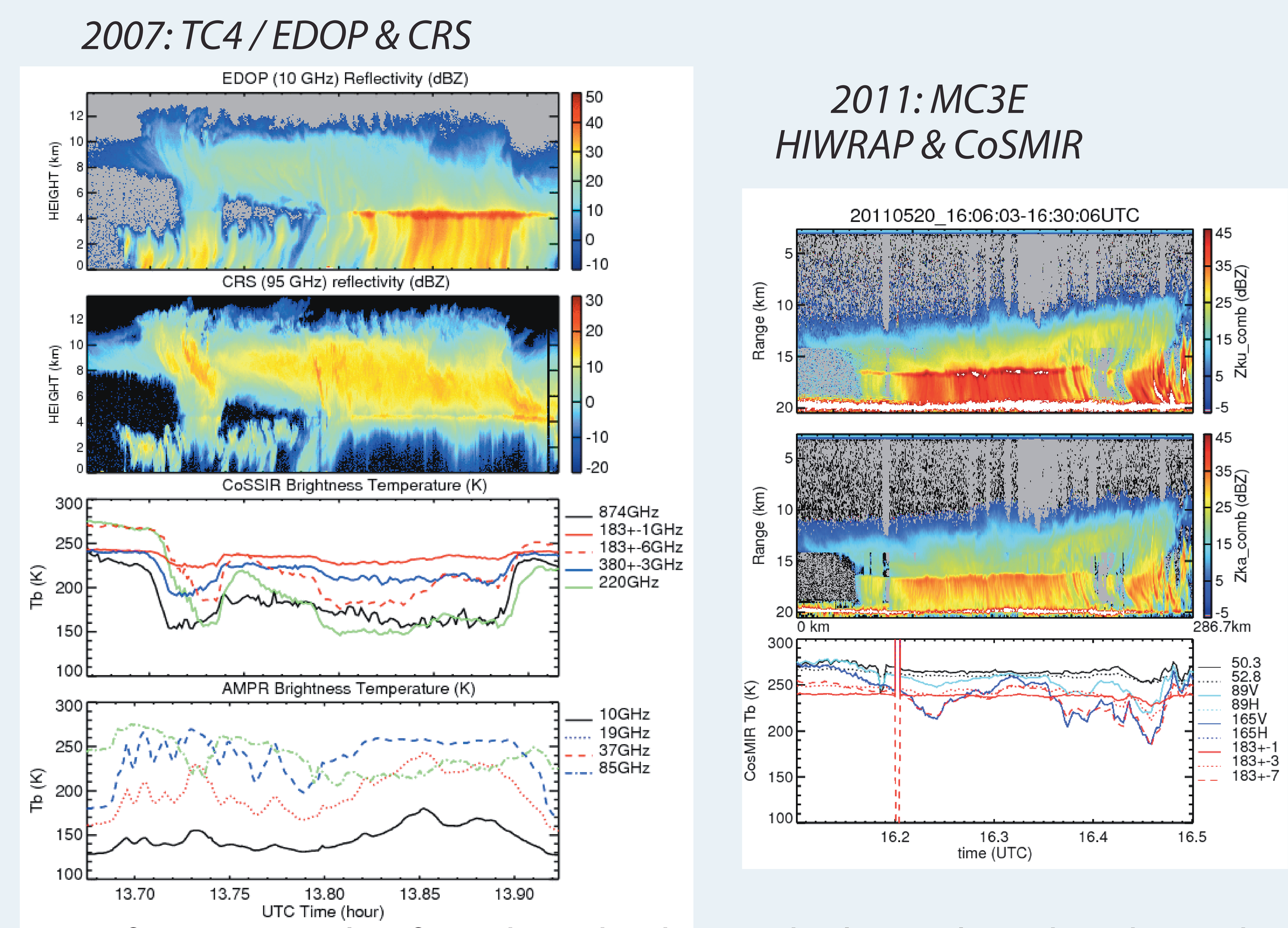


Fig. 5. Left: An example of combined airborne dual-wavelength radar and radiometer observations using EDOP, CoSSIR, and AMPR from TC4 in 2006. From top to bottom, reflectivity measure by EDOP, CRS, and brightness temperature by CoSSIR and AMPR. Right: Example of merged HIWRAP radar reflectivity and CoSMIR radiometer brightness temperature from MC3E.

Future Plans

- DSD retrievals from MC3E HIWRAP measurement for light rain cases using dual-wavelength reflectivity and Doppler measurements.
- Characterization of dual-wavelength HIWRAP Ku/Ka-band convection measurements, particularly microphysics and mixed phase information.
- In deep convection, ground-based polarimetric radar data will be used to understand the dual-wavelength measurements.
- Produce ER-2 merged radar/radiometer data sets for DPR, GMI, and combined algorithm development.
- HIWRAP data archival and calibration refinement.