Validation Using Multifrequency Airborne Radar Observations in Warm Season Validation

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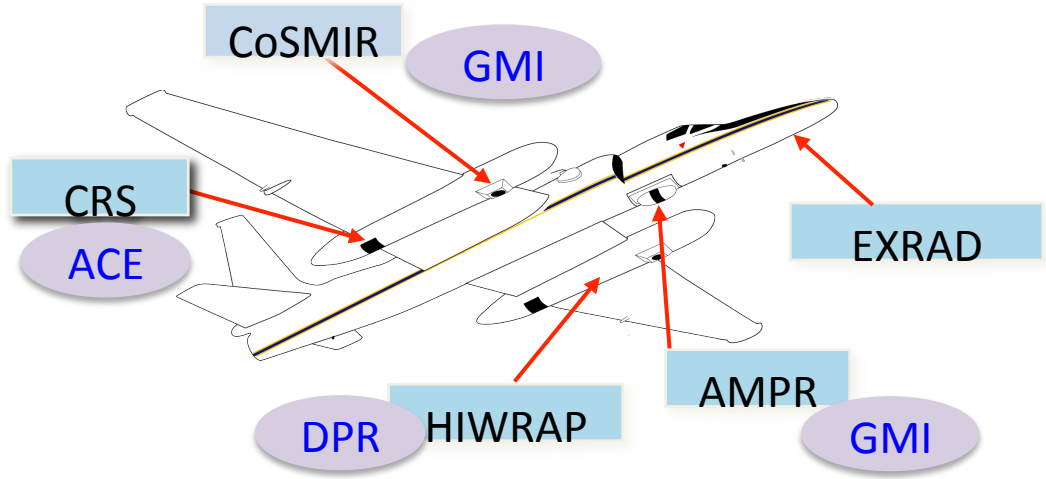
Acknowledgements:
Matthew McLinden, Lihua Li, Michael Coon: NASA GSFC
Martin Perrine: NASA GSFC
Vijay Venkatesh: SSAI, Inc.

Presentation

- GPM validation during Integrated Precipitation Hydrology Experiment (IPHEx) using ER-2, *in situ* aircraft, and ground based radars.
- Highlight a few IPHEx cases:
  - Stratiform/light rain on 5 June 2014
  - Moderate convection on 11 June 2014
  - Hail storms on 23/24 May 2014
- How this data will be used for GPM algorithms.

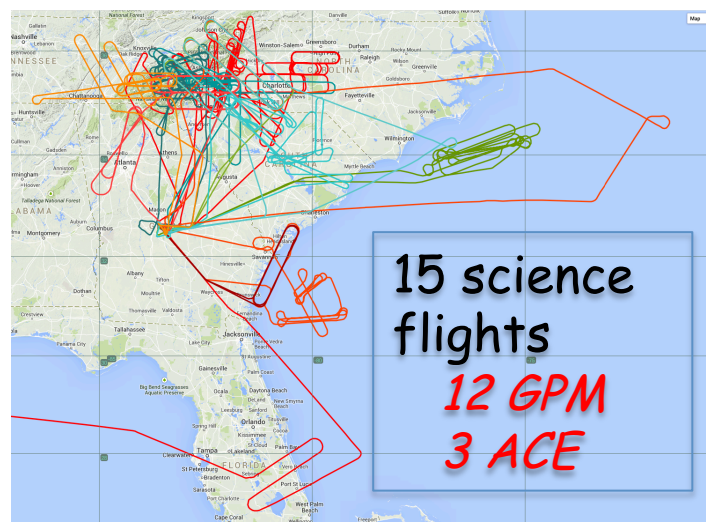
Integrated Precipitation & Hydrology Experiment (IPHEx) May-June 2014 SE U.S.

- Ground network based near Asheville, NC
- ER-2 based in Warner Robins, GA
- Coordination with Citation, NPOL, D3R and and other ground radars.



GPM airborne simulator – ER-2

GSFC-CoSMIR (85-183 GHz)
-> high freq radiometer
MSFC AMPR (10-85 GHz)
-> low freq radiometer
GSFC-HIWRAP, CRS, EXRad Radars
(9.6, 13.5, 35, 95 GHz)
MSFC-LIP *-> lightning*



ER-2 Radars During IPHEx

HIWRAP

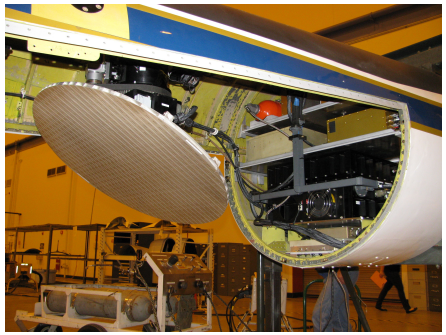
High-altitude Imaging Wind and Rain Airborne Profiler

CRS

Cloud Radar System

ExRad

ER-2 X-band Radar



HIWRAP
Ku (13.9 GHz), Ka (35.5 GHz)
Beamwidh: 3 deg (Ku)
1 deg (Ka)
Nadir, Pulse Compression
Doppler, Cross pol
MDS (dBZ): +5 (Ku), -10 (Ka)

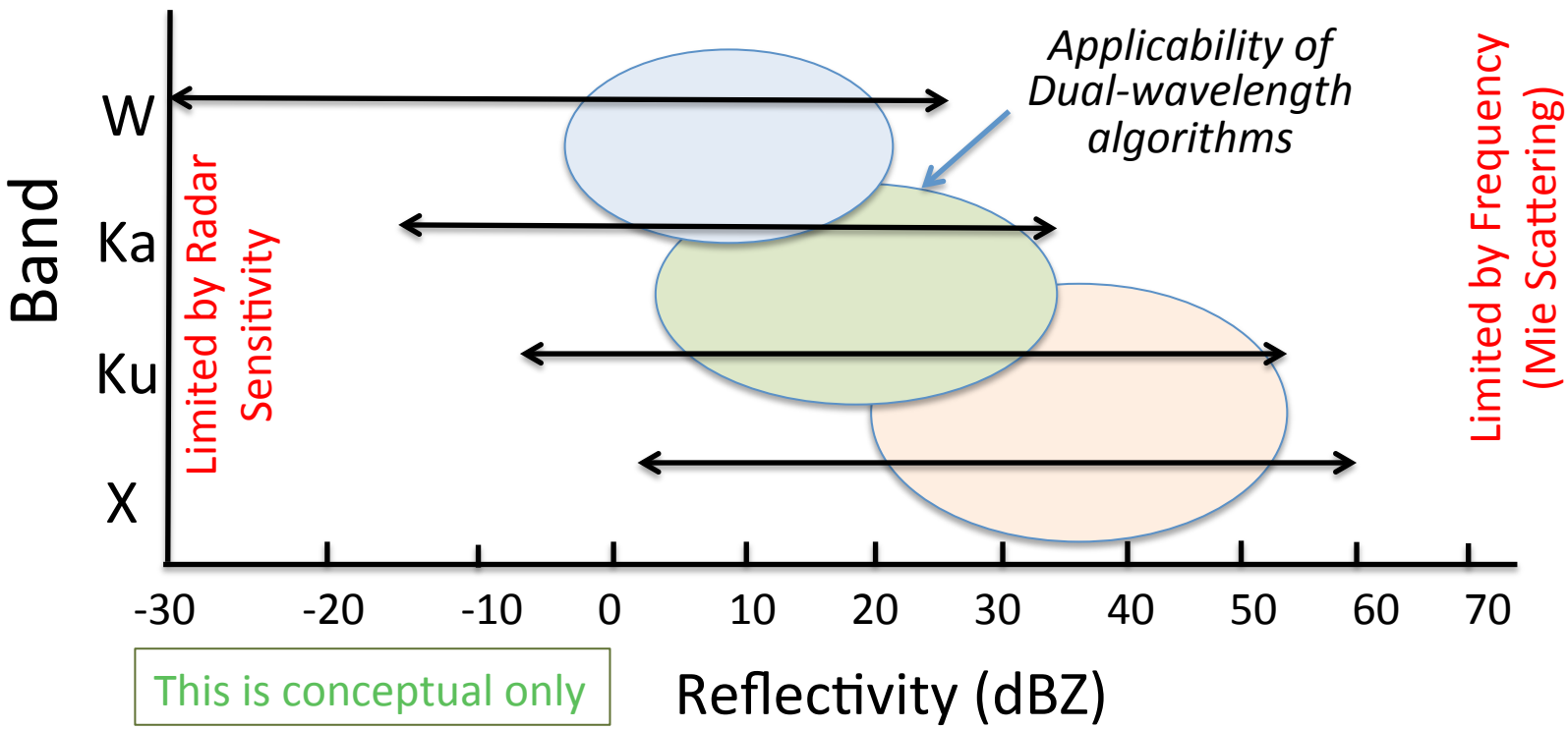
Cloud Radar System (CRS)
Freq: 94 GHz
Beamwidth: 0.4 deg
Nadir, Pulse Compression
Doppler
MDS (dBZ): -28

ER-2 X-band Radar (ExRad)
Freq: 9.6 GHz
Beamwidth: 3 deg
2 Beams: Nadir; Scanning
Doppler
MDS (dBZ): -10 scanning
-15 nadir

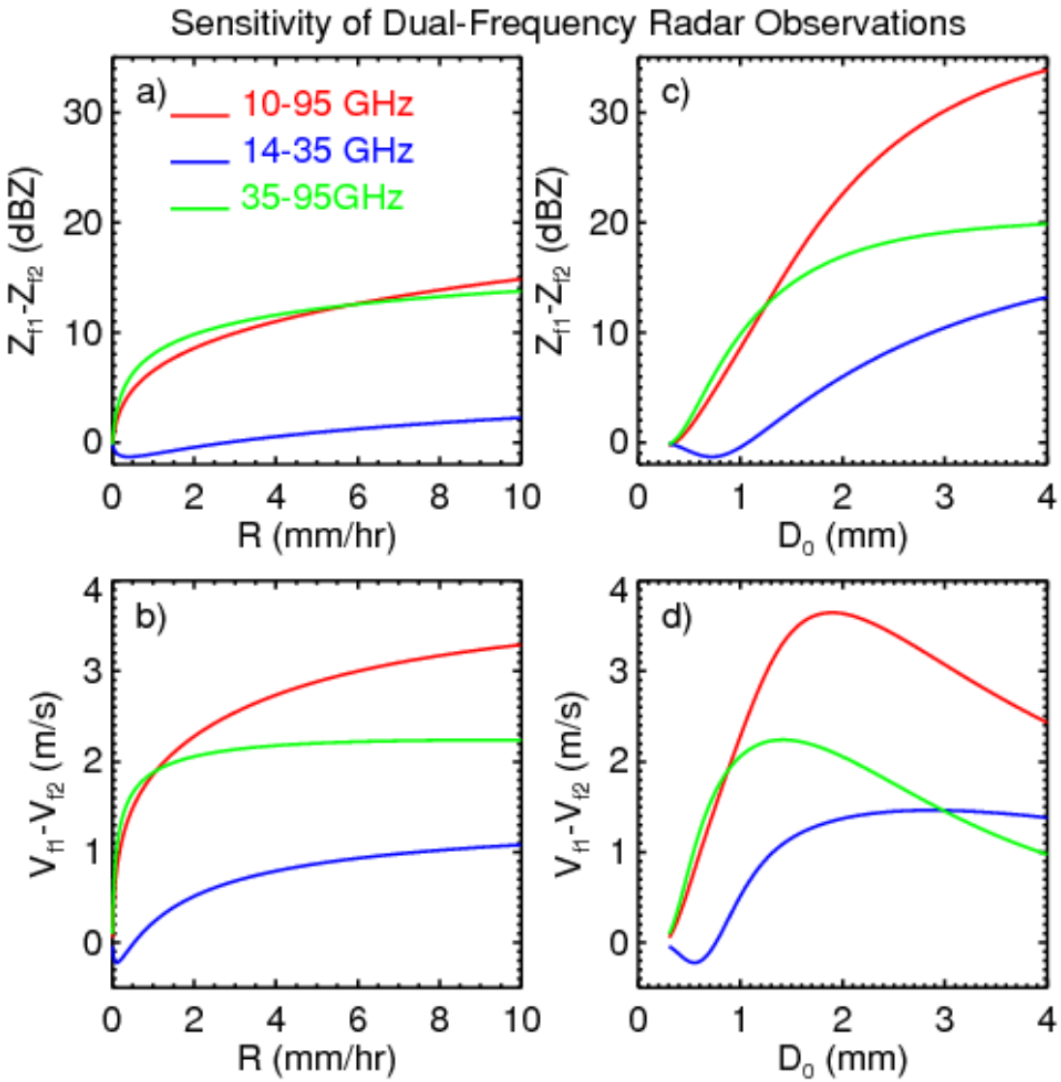
GPM DPR sensitivity ~12 dBZ (Ka-band) and ~13 dBZ (Ku-band)

Why 4 Radar Frequencies?

- Increased dynamic range for dual-frequency algorithms.
- Consistency for forward modeling.
- Separate Mie, attenuation, and multiple scattering.

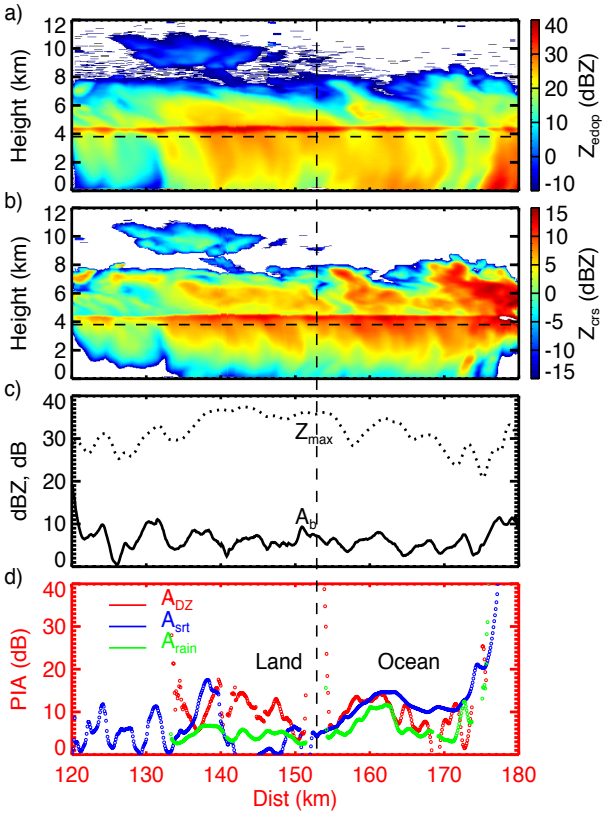


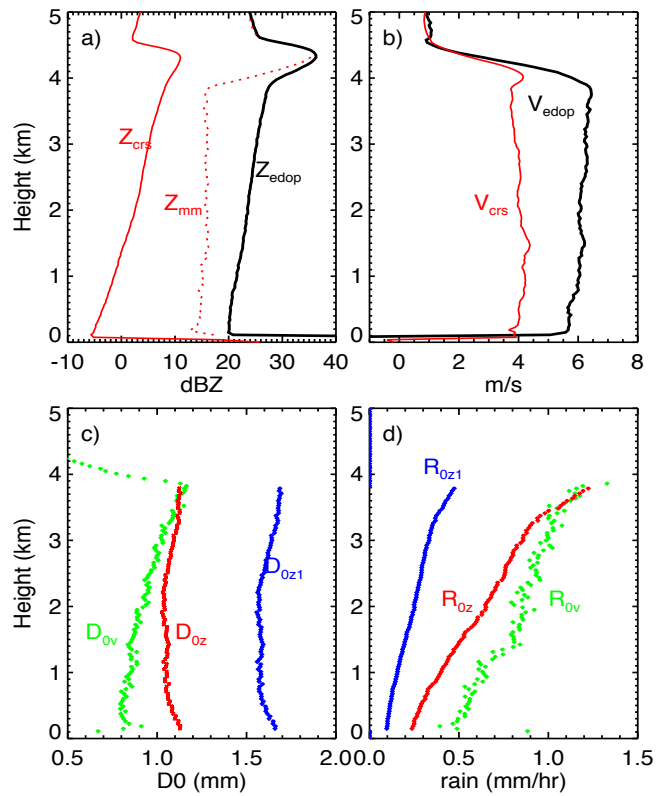
Light Rain: DFR and DDV



Combination of 10 and 95 GHz are much more sensitive than 14 and 35 GHz for light rain retrieval.

Example: Light Rain - X & W-band

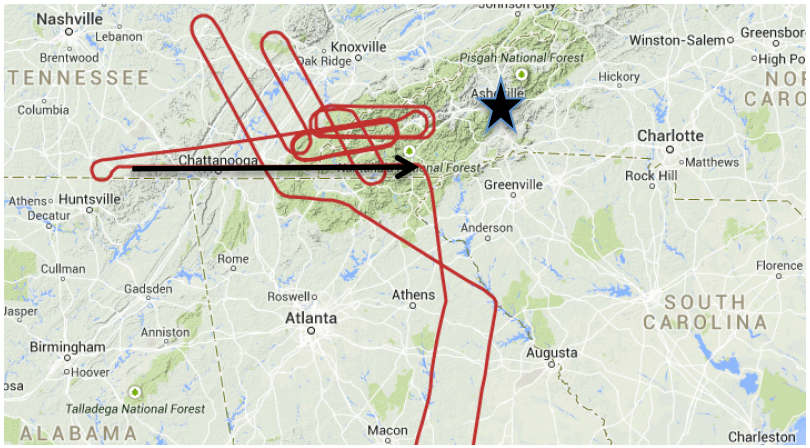




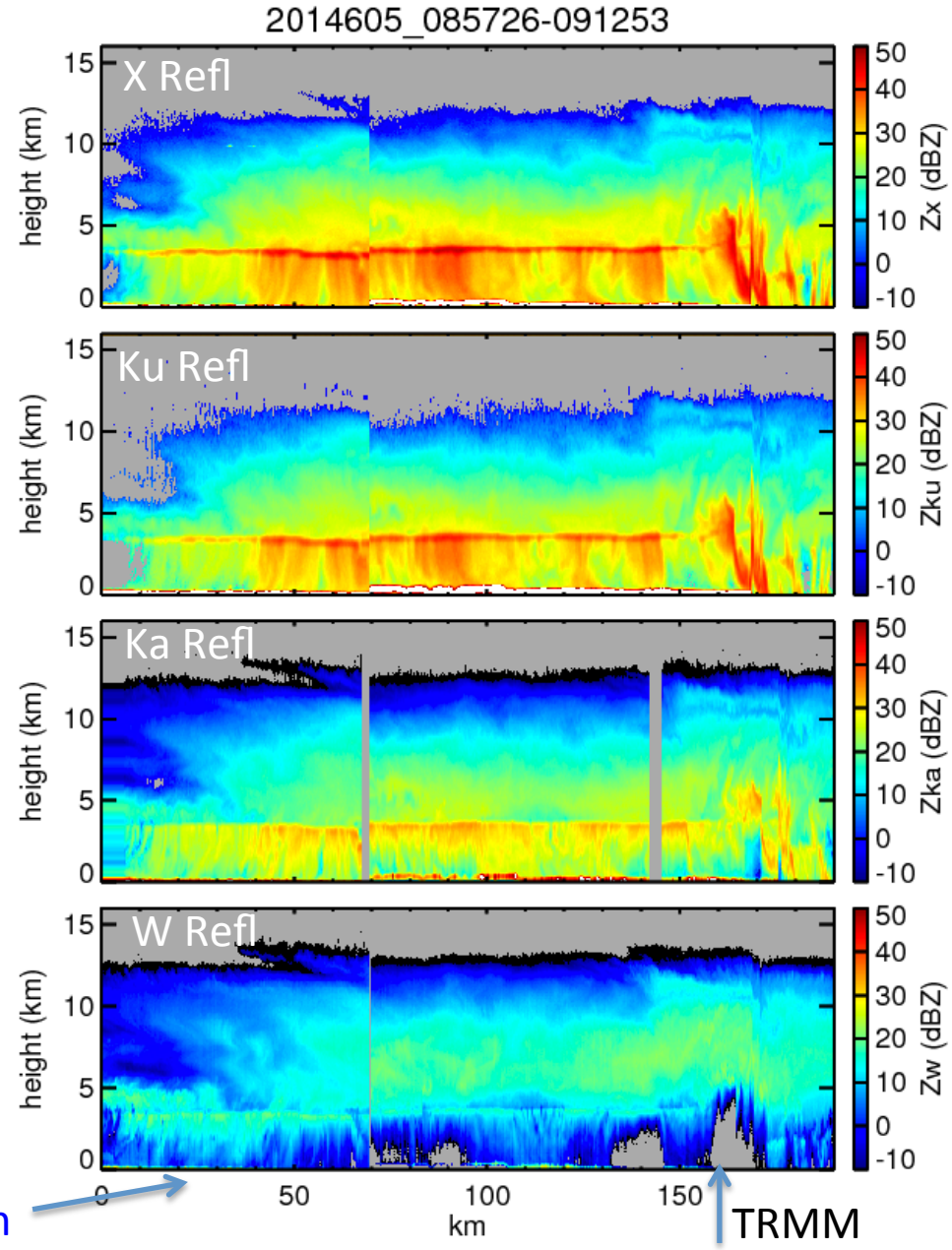
Tian et al., 2007: Properties of Light Stratiform Rain Derived from 10 and 94 GHz Airborne Doppler Radars Measurements, *JGR*.

a) **Reflectivity at X- and W-band**
b) **Doppler velocities at X- and W-band, and the retrieved vertical air velocity (w);**
c) **Retrieved D_0 and N_0**
d) **Rainfall rate R, and rain water content Wc.**

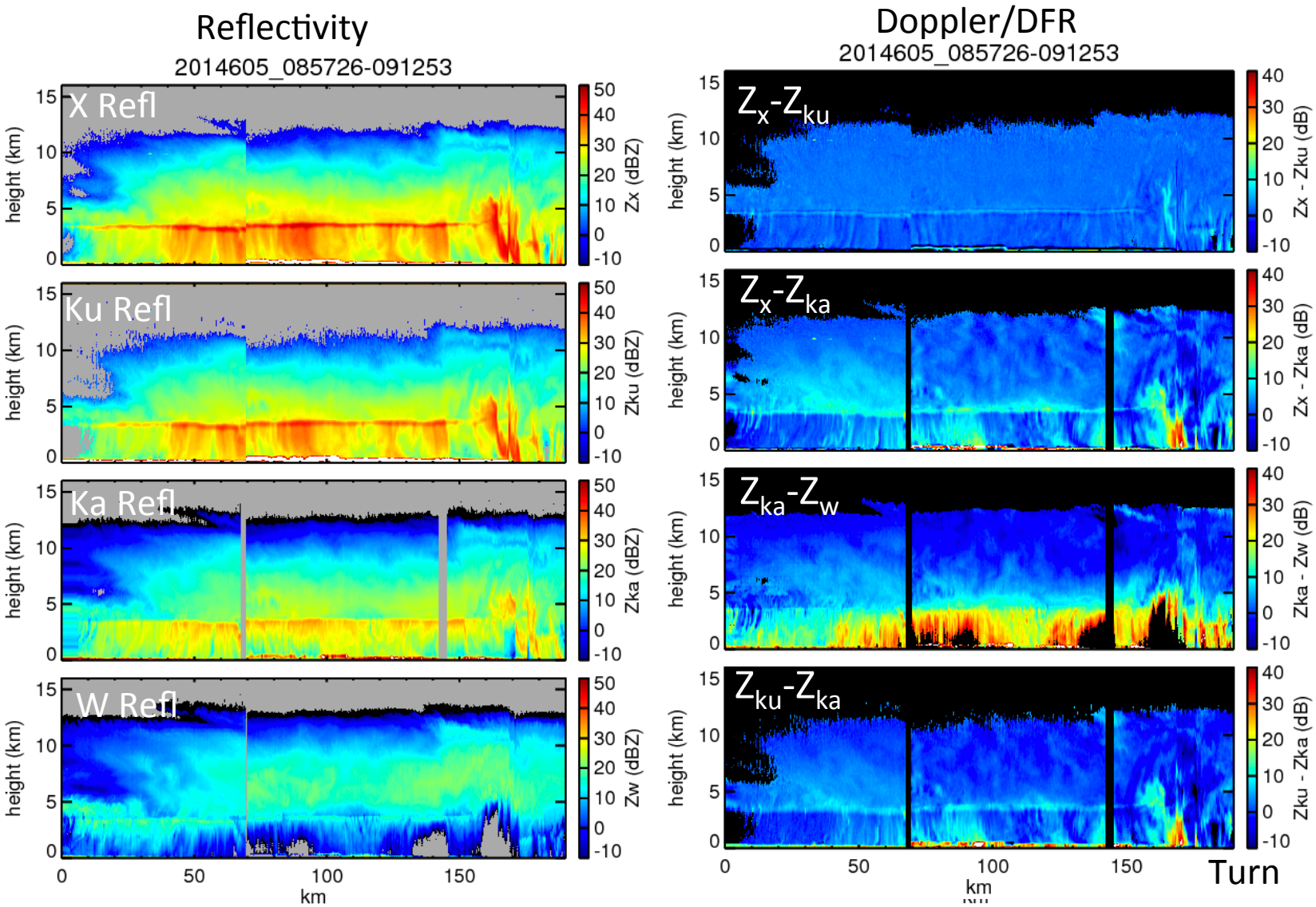
Deep Stratiform Rain over Eastern Tennessee 5 June 2014



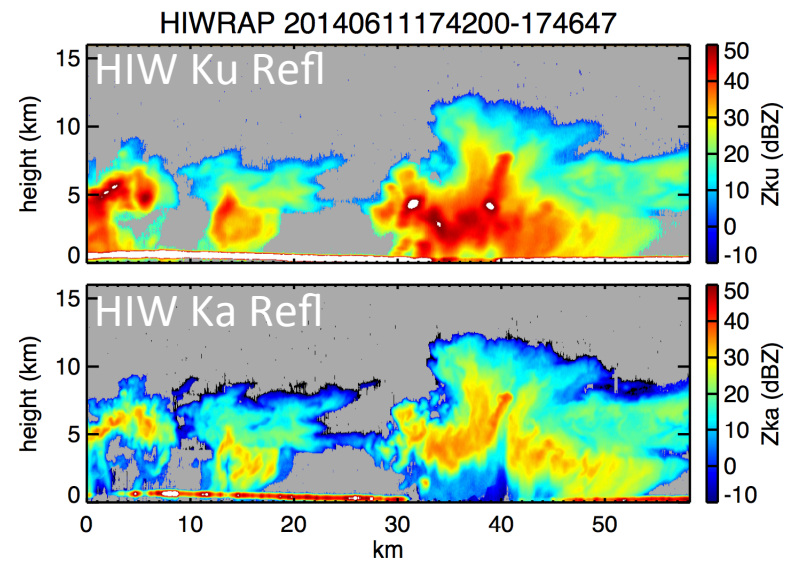
- Stratiform associated with MCS well south and west of Pigeon Basin.
- TRMM overpass 0909 UTC.
- Weak convection eastern end.
- Citation stacked legs; no CoSMIR.

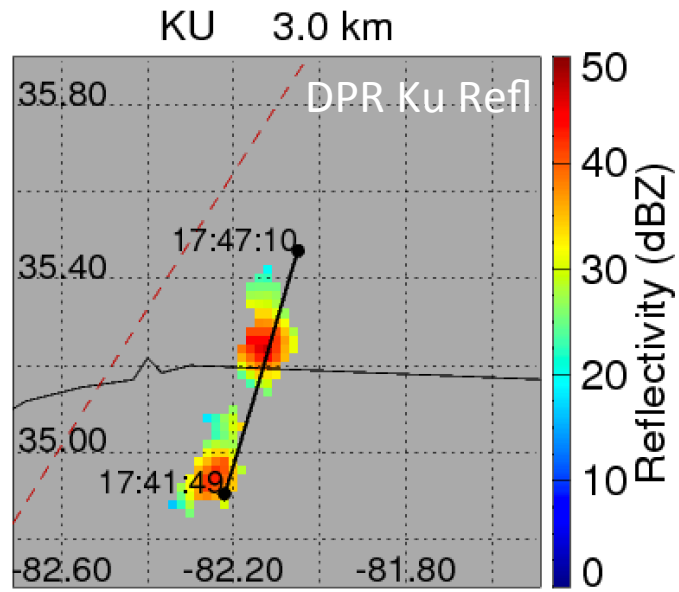


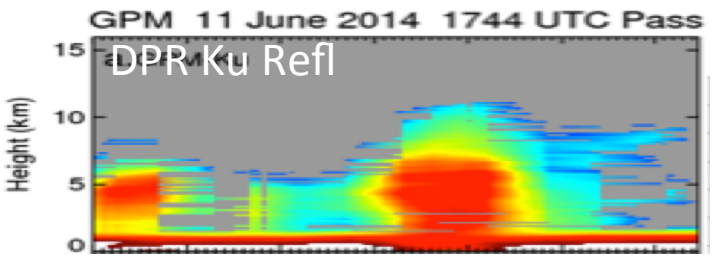
5 June 2014 Doppler and DFR



11 June 2014 – Moderate Convection



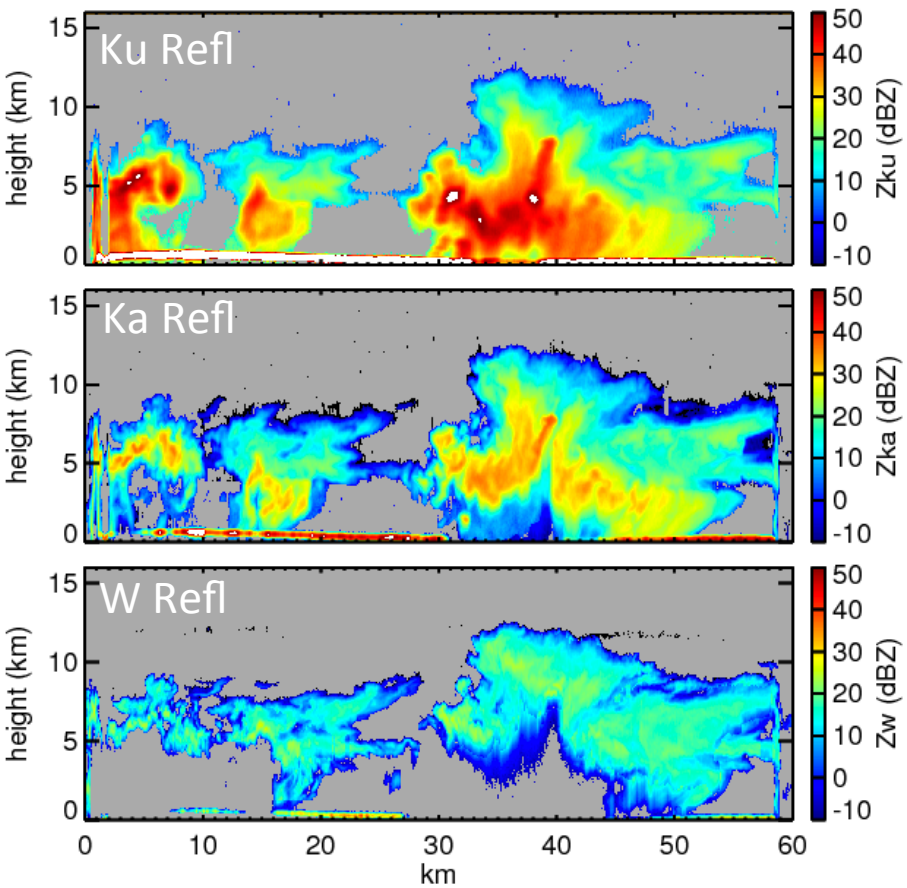




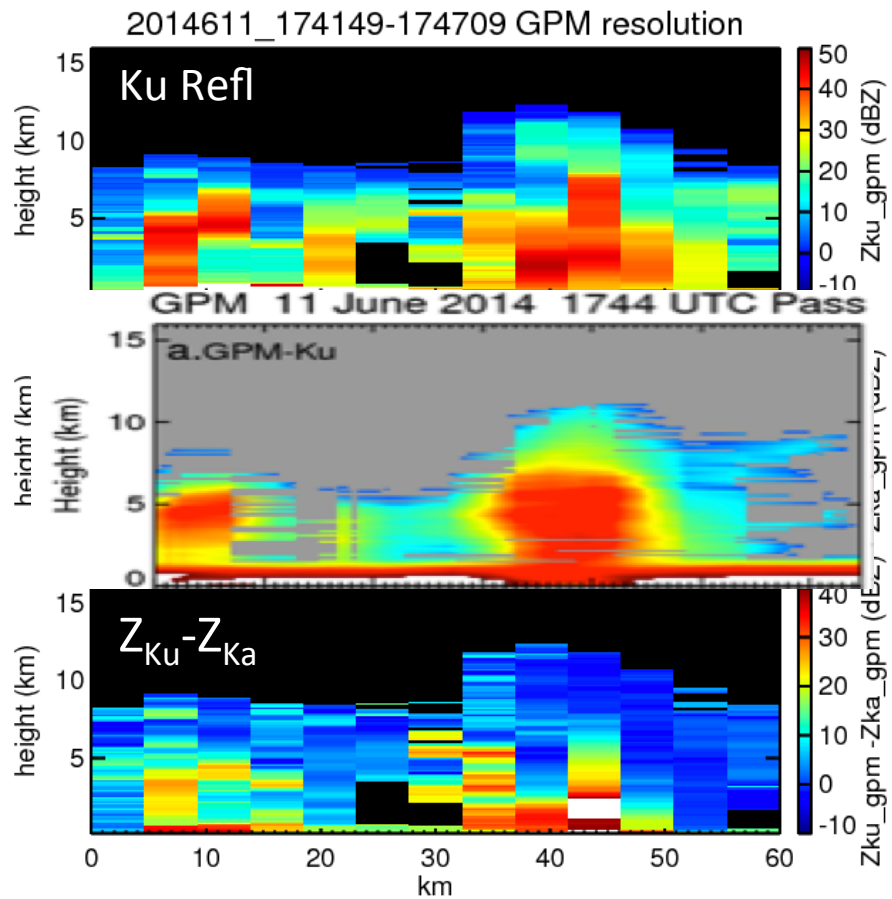
- *ER-2 line was only within DPR Ku swath.*
- *DPR mapped (interpolated) to each ER-2 profile resulting is less pixelated image.*
- *Ground clutter was present at lower altitudes to west of storms along scan edge. The black line is the ER2 flight line.*

11 June 2014
ER-2 Reflectivity Degraded to DPR Resolution

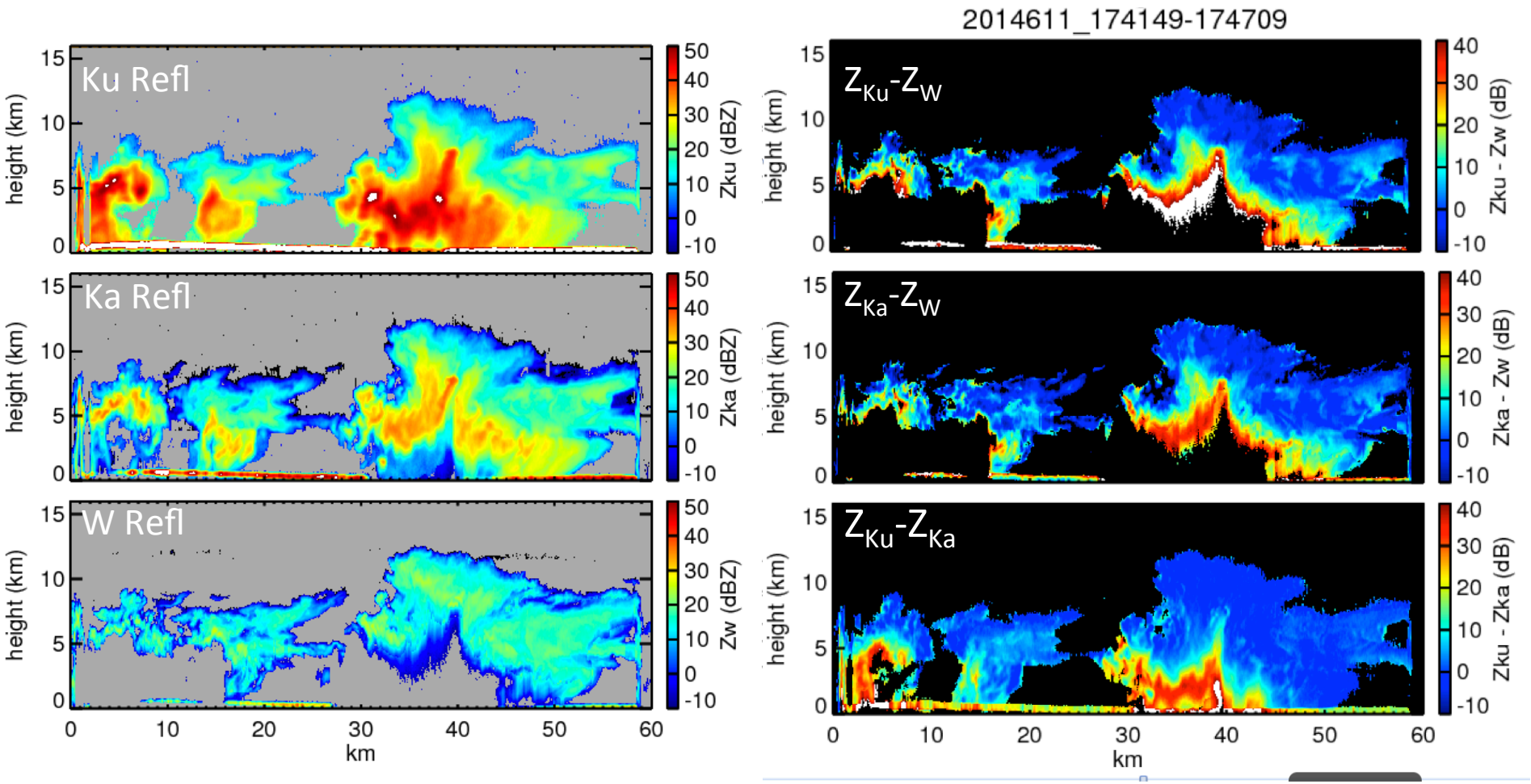
ER-2



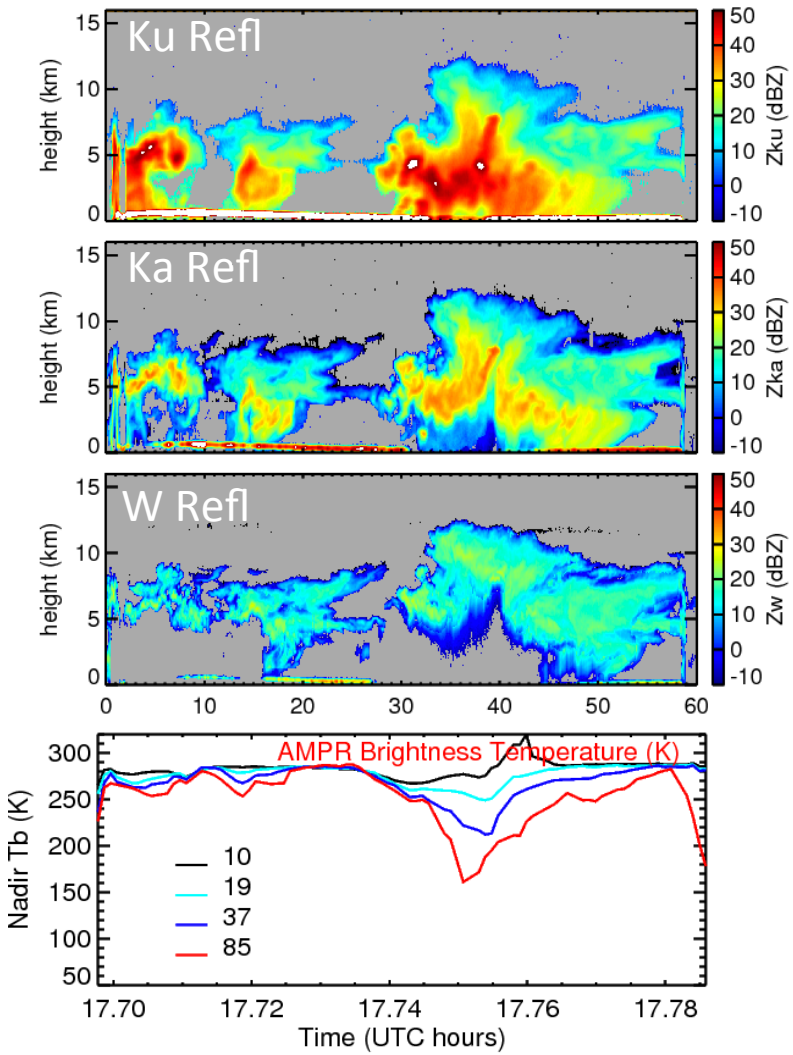
DPR resolution

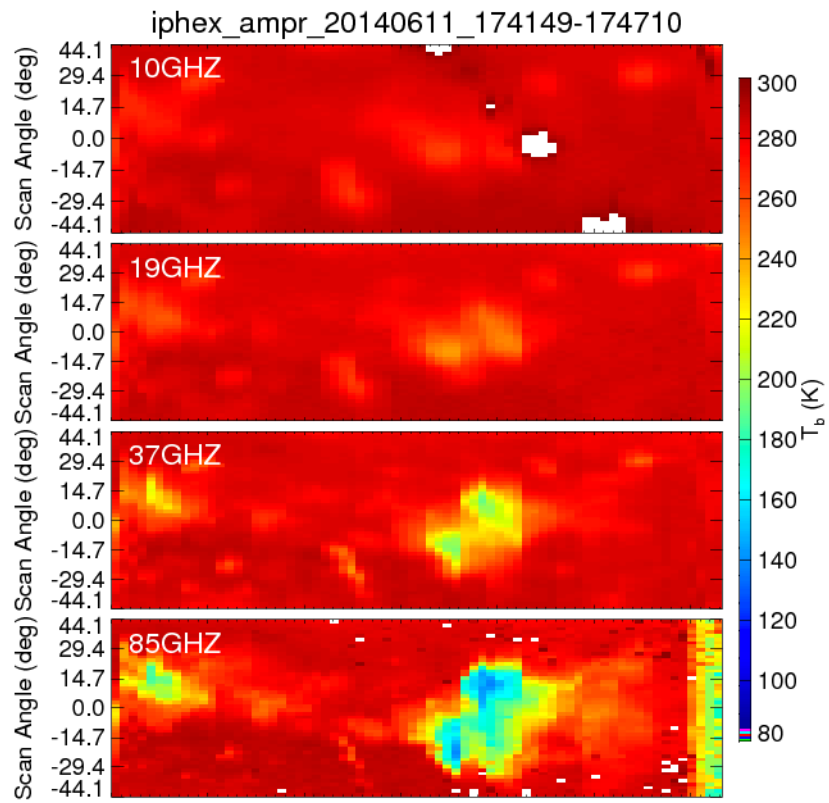


11 June 2014 – Doppler and DFR

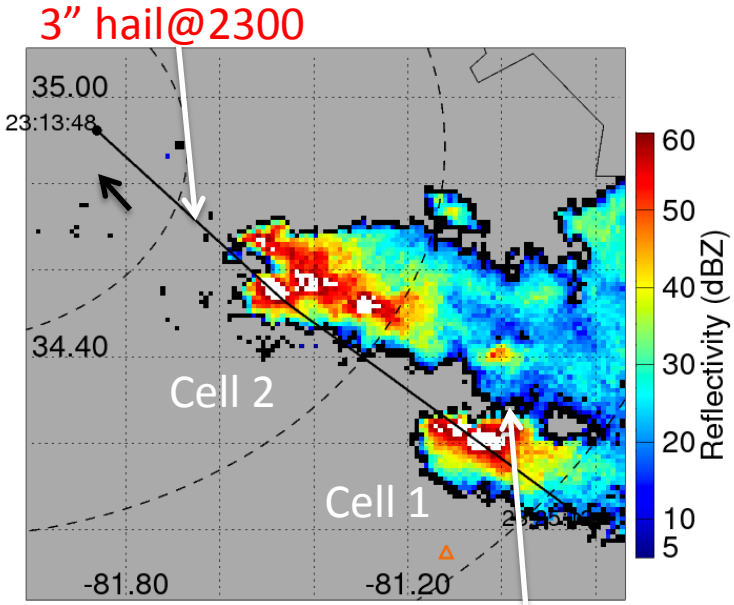


11 June 2014 – Radar/Radiometer(AMPR)



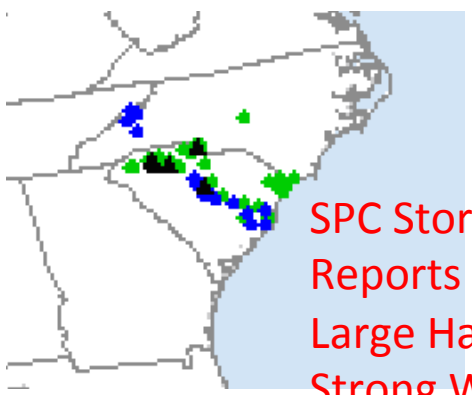


23 May 2014 Hail Storms

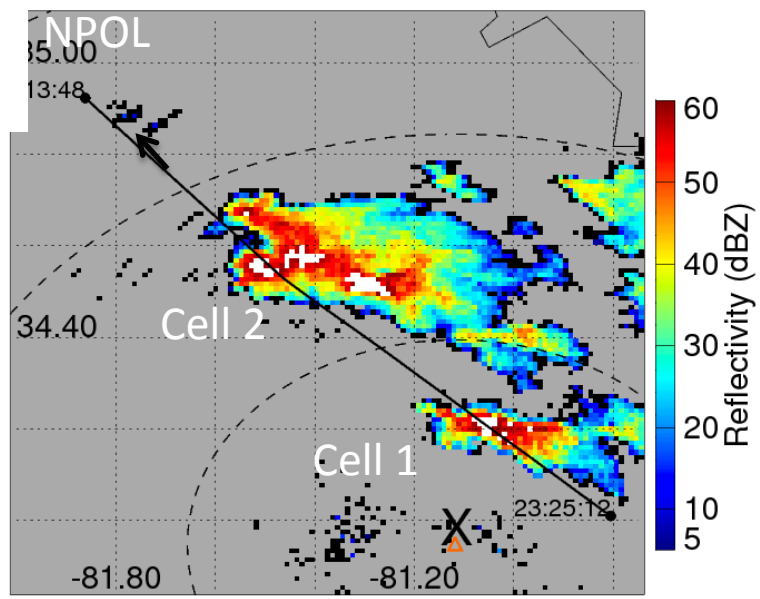


KGSP Greer, SC
23 May 14 @ 231742 UTC

- Large hail reported in SPC
- GPM overpass at 23:16 UTC
- Far from IPHEx network but within range NPOL & 88Ds
- KGSP, KCAE, NPOL all >65 dBZ.



SPC Storm Reports Hail, Large Hail, Strong WInds



KCAE
Columbia, SC
23 May 14
231742 UTC
1.6 deg elev.

Multiple Scattering From Hail Column Oklahoma Storm during MC3E 23 May 2011

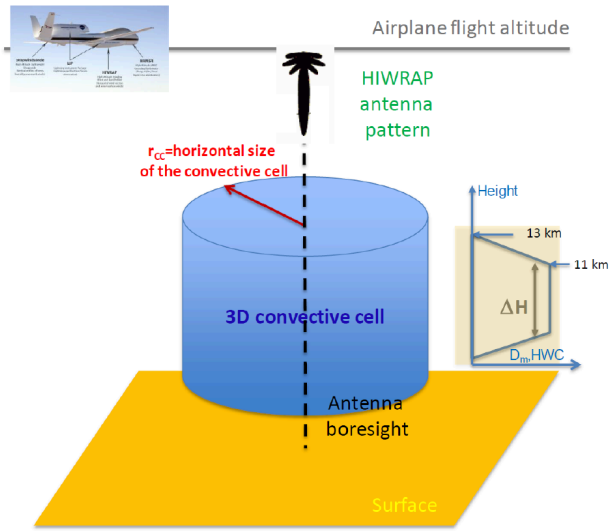
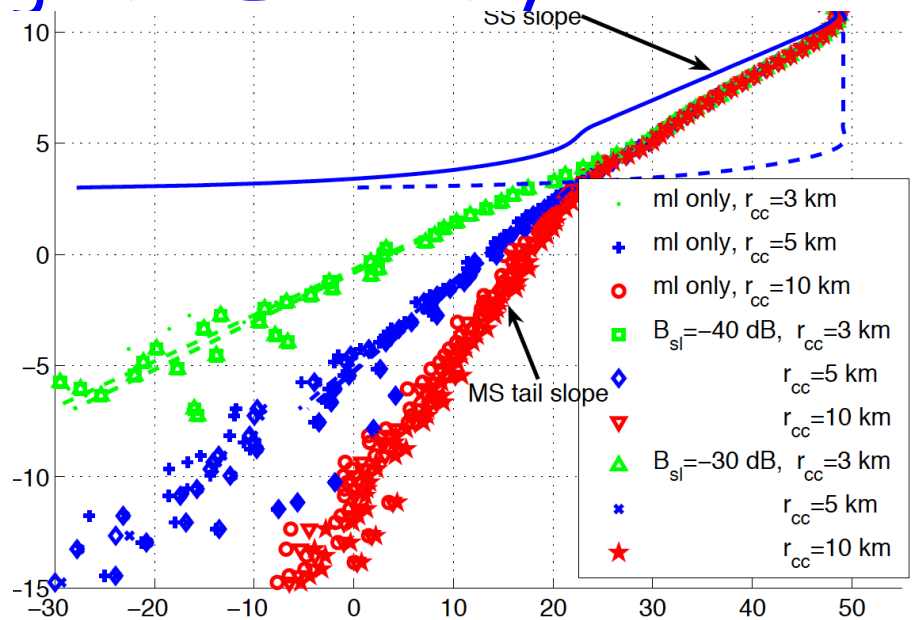


Figure 4. Geometry of the MS simulations for the airborne configuration. The trapezoidal shape represents the model assumption for the hail microphysics vertical profile.



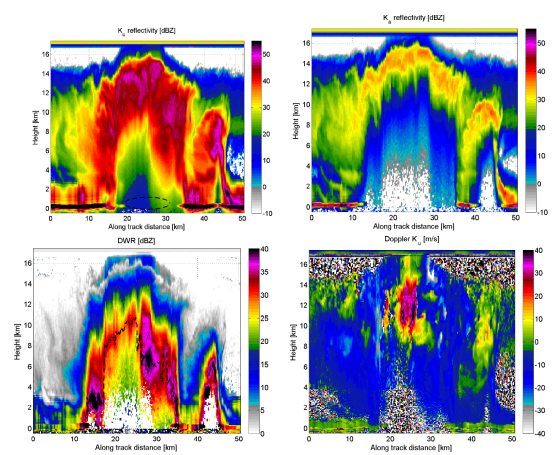
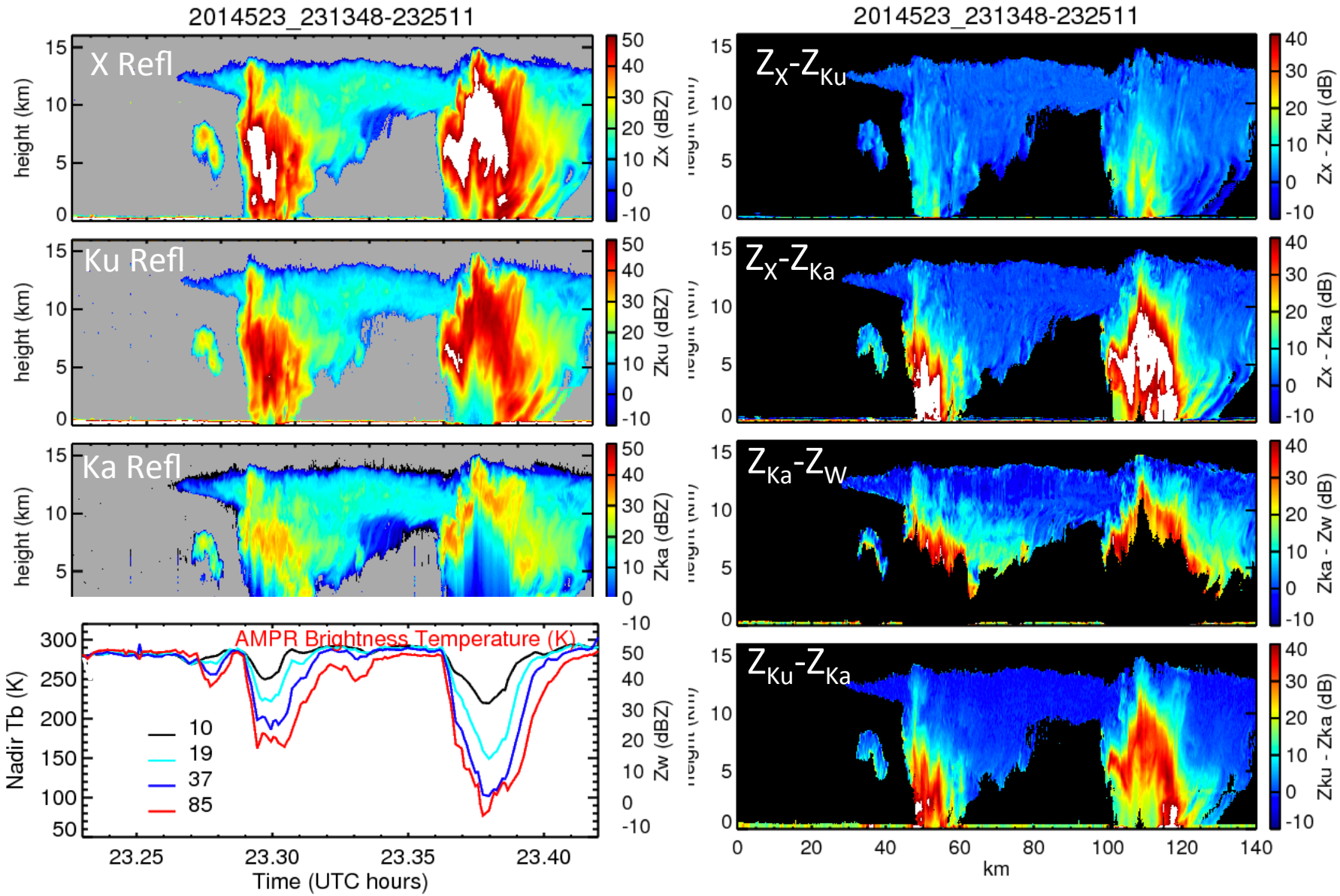


Figure 1. Top panels: HIWRAP K_u and K_a vertical profiles of reflectivities for a convective cell observed during the MC3 campaign. Bottom panels: DWR (left) and K_u Doppler velocity for the convective cell considered in this study. The dashed black line in the bottom left indicates the position of the DWR *knee*.

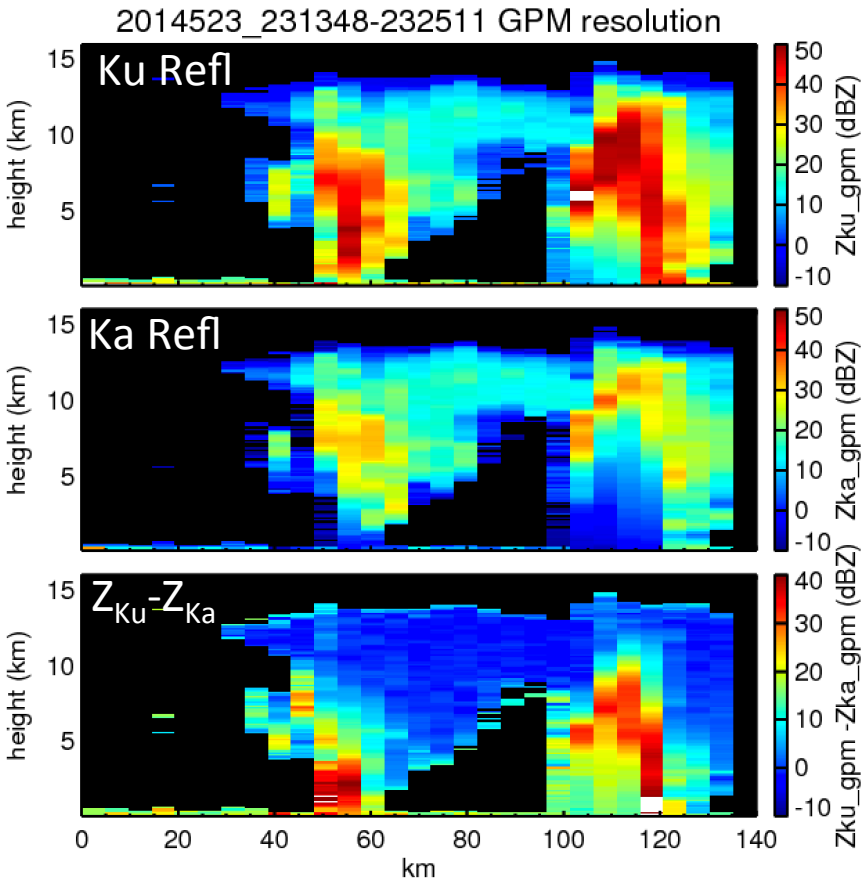
Battaglia, A., S. Tanelli, G. M. Heymsfield, and L. Tian, 2014: The dual wavelength ratio knee: a signature of multiple scattering in airborne ku–ka observations. J. Appl. Meteor. Climatol., ***53****, 1790–1808.*

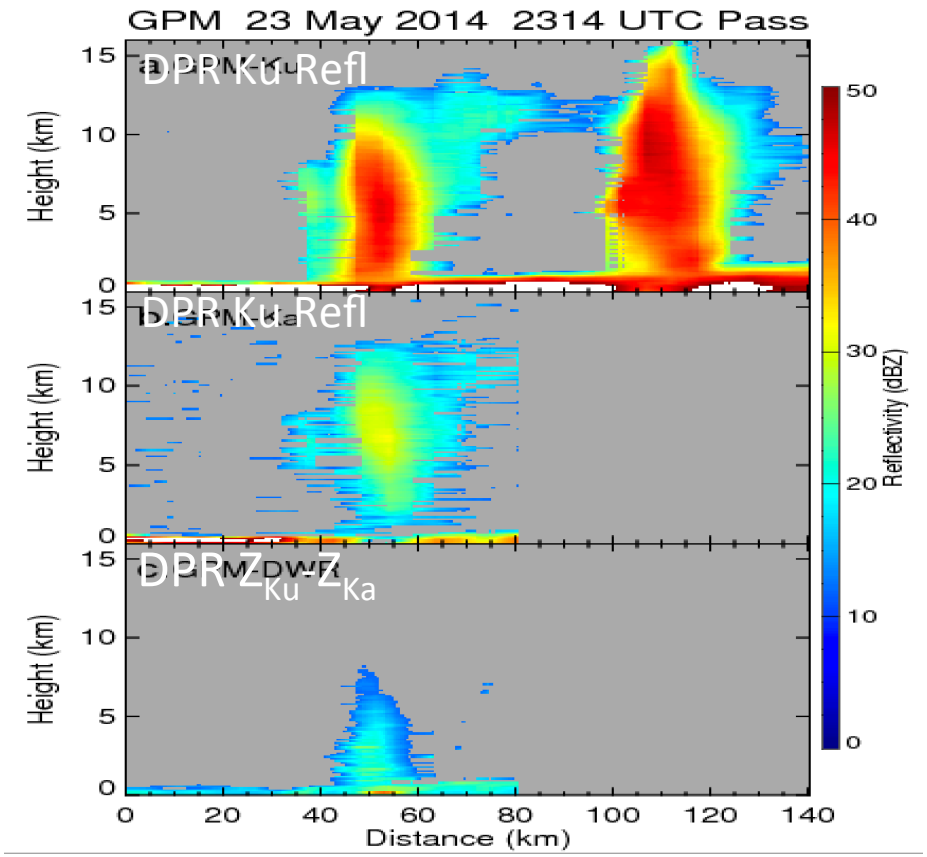
Heymsfield, G.M. and coauthors, 2013: Airborne Radar Observations of Severe Hailstorms: Implications for Future Spaceborne Radar. J. Appl. Meteor. Climatol., ***52****, 1851–1867.*

23 May 2014 Reflectivity, DFR, AMPR



23 May 2014
HIWRAP: DPR Resolution & DPR: 2321UTC

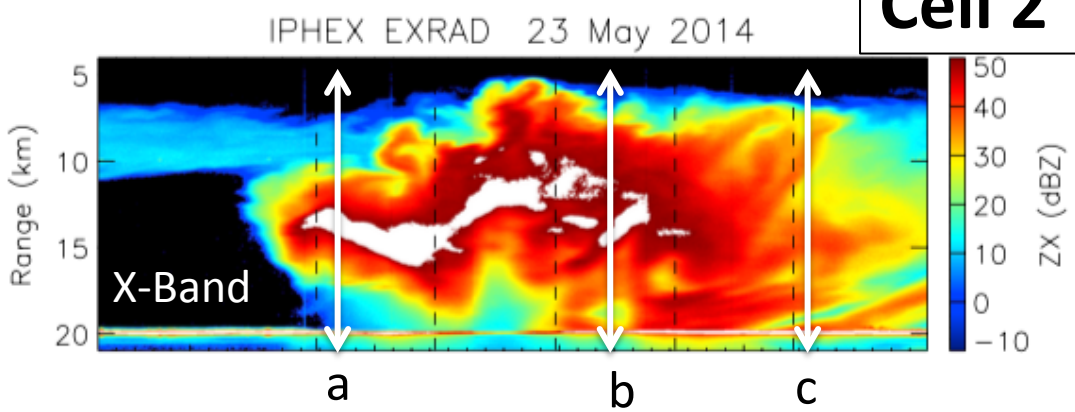


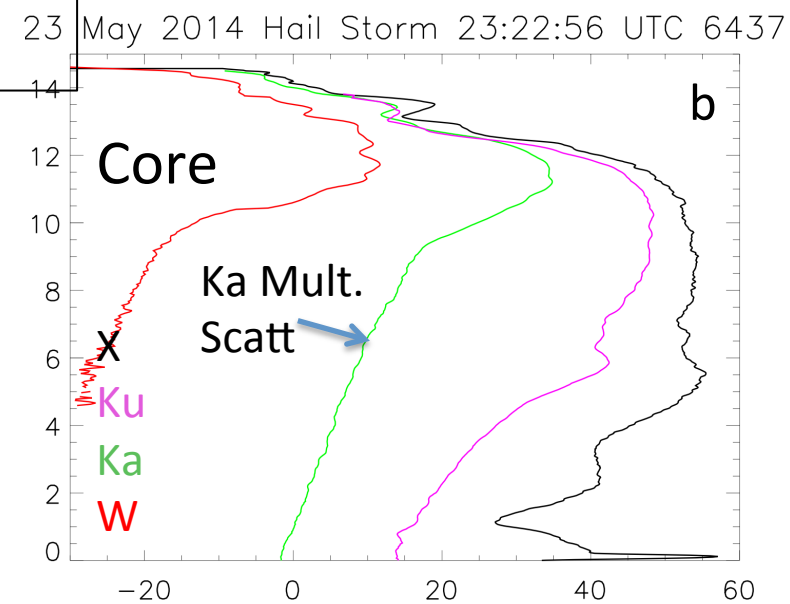


- DPR Data: Special level-2 products provided by Drs. Kubota and Iguchi due to DPR sidelobe reduction test period.

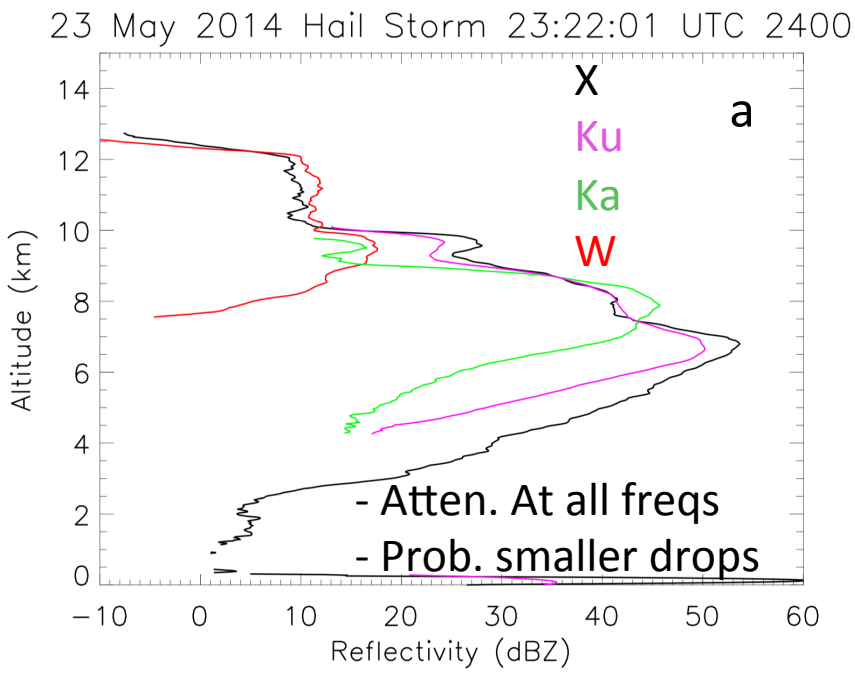
23 May 2014 Vertical Reflectivity Profiles

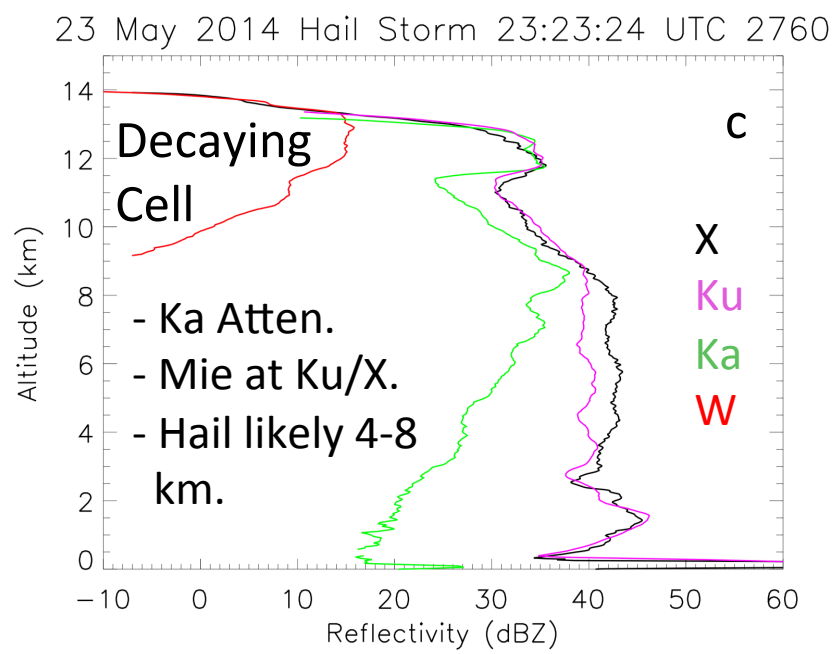
Cell 2



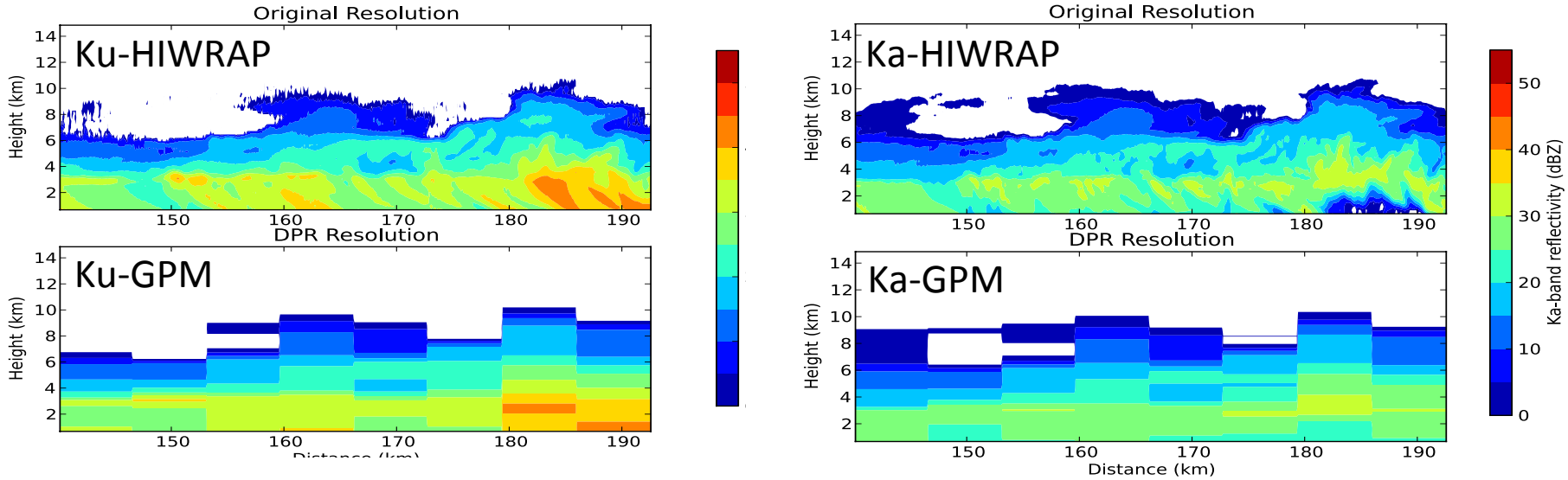


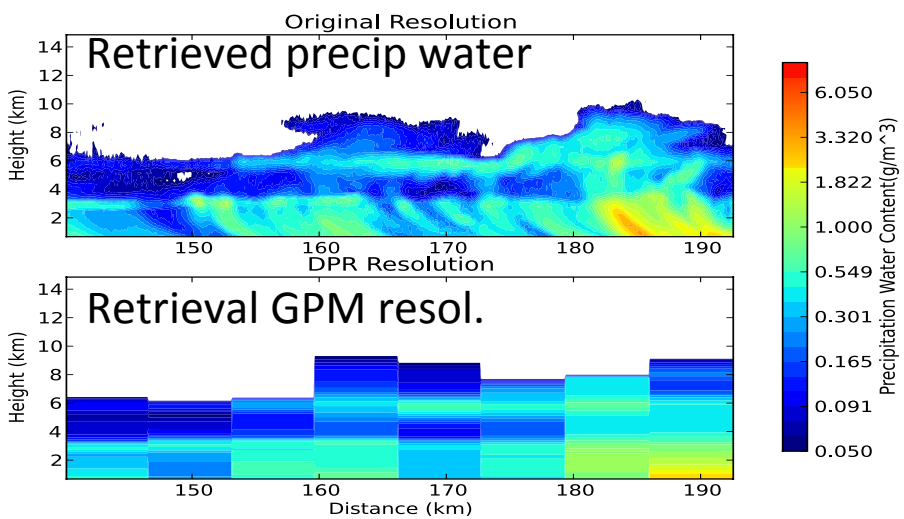
In young growing cell





Example of HIWRAP Data Used to Investigate the Impact on NUBF on DPR Dual-Frequency Retrievals.





- Grecu et al. (2011) modified with multiple scattering.
- Original resolution multiple frequency data is used to derive (high-resolution) precipitation retrievals and then used to generate synthetic DPR-resolution radar observations.
- Synthetic DPR-observations are used to derive precipitation retrievals that are evaluated against fine resolution retrievals to study the impact of NUBF on DPR dual-frequency retrievals.

Grecu et al., 2011: Dual-frequency radar profiling algorithm. *J. Appl. Meteor. Climatol*.

Summary

- IPHEx ER-2 flights provided an excellent data set for examining/improving GPM algorithm physics assumptions (PSD assumptions, multiple scattering, NUBF, etc.).
- 23 May 2011 MC3E 24/24 May 2014 IPHEx provide first conclusive measurements of multiple scattering at Ka-band.
- Future Work: Examine 3 or 4 flights in more detail using Citation *in situ* and S-band polarimetric radar data.
  - Collaboration with DPR, GMI, and combined algorithm developers.
- OLYMPEX – 3 ER-2 radars will fly under ACE/RADEX.

Questions?