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

Gerry Heymsfield
Goddard Space Flight Center
Gerald.Heymsfield@nasa.gov

Lin Tian/ Morgan State Univ.

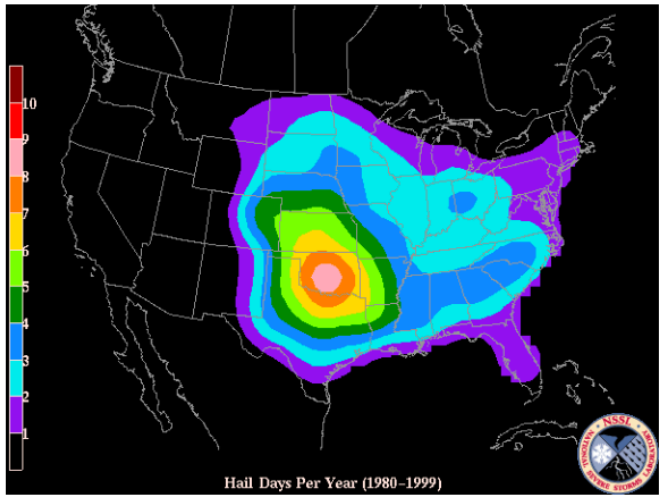
Collaborators:
Alessandro Battaglia/ University of Leicester, U.K.
Mircea Grecu/ Morgan State Univ.
Robert Meneghini, Goddard Space Flight Center
William Olson/ University of Maryland, Baltimore

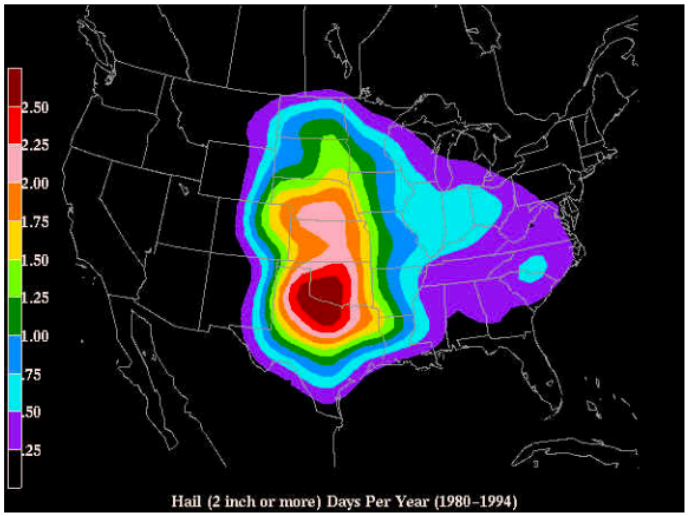
Presentation

- Motivation for focus on deep convection.
- Status of Midlatitude Continental Convectvie Clouds (MC3E) analysis of ER-2 remote sensing and ground-based radar measurements.
- Future plans - Integrated Precipitation and Hydrology Experiment (IPHEX) in 2014.

Why Are We Focusing on Convection?

- For GPM DPR profiling algorithms,
  - Hail, graupel, & mixed phase response to Ku/Ka band.
  - Estimate PIA in convection over land.
  - How to transfer knowledge from aircraft to DPR.
- For numerical modelling and forward radiative transfer models, need guidance from observations on correct structure of convective systems and their environment.





Hail Freq. and hail size in U.S.

(from NOAA/ NSSL)

Hail Distribution Globally (Model-based)

Hail occurrence based on convective diagnosis procedure used by U.K. Met Office. [P. Field et al. (2008), European Aviation Safety]

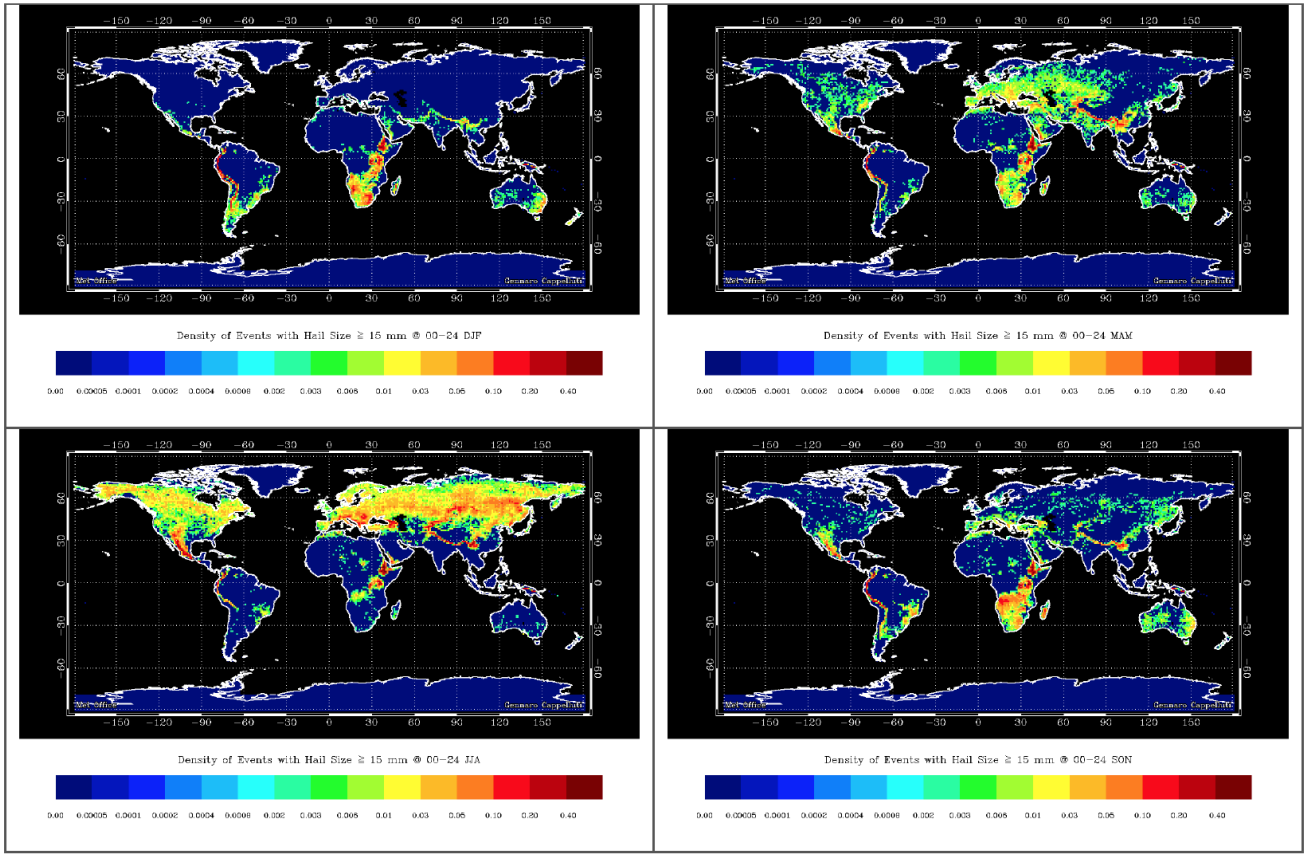


Figure 7.1: Global distribution of hail occurrence (number of events per day per 1 degree square) in each season.

→Cecil and Blankenship (2012) – Microwave based hail occurrence

MC3E
ER2 – satellite simulator

- HIWRAP (High Altitude Imaging Wind and Rain Airborne Profiler): dual-wavelength Doppler Radar
  Ku – band: 13.5GHz, 2.8 cm
  Ka – band: 35 GHz, 8 mm

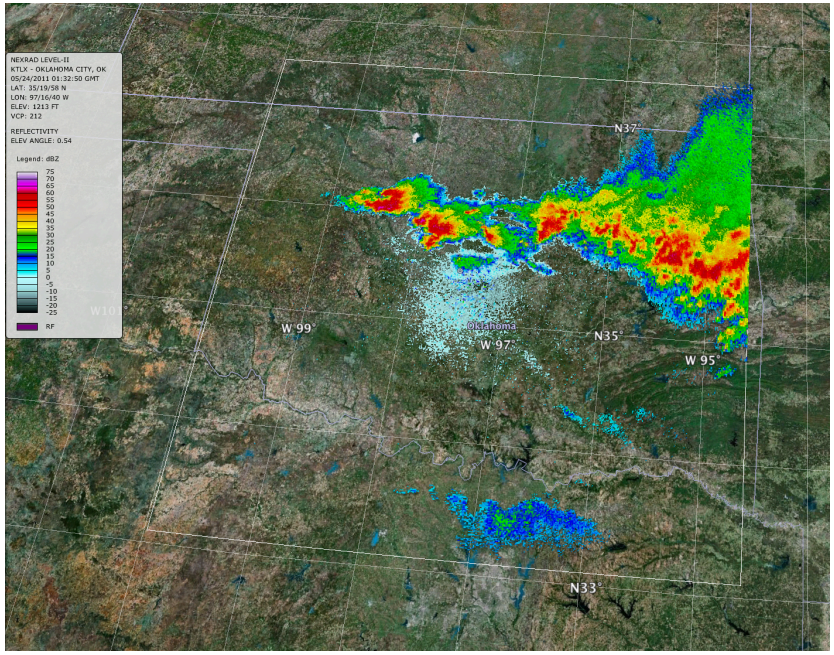
- COSMIR(Conical Scanning Mm-wave Imaging) Radiometers 50.3, 52.8, 89vh, 165vh, 183+-(1, 2, 3) GHz

- AMPR (Advanced Microwave Precipitation Radiometer) 10.7vh, 19.35vh, 37.1vh, and 85.5vh GHz

Ground Validation

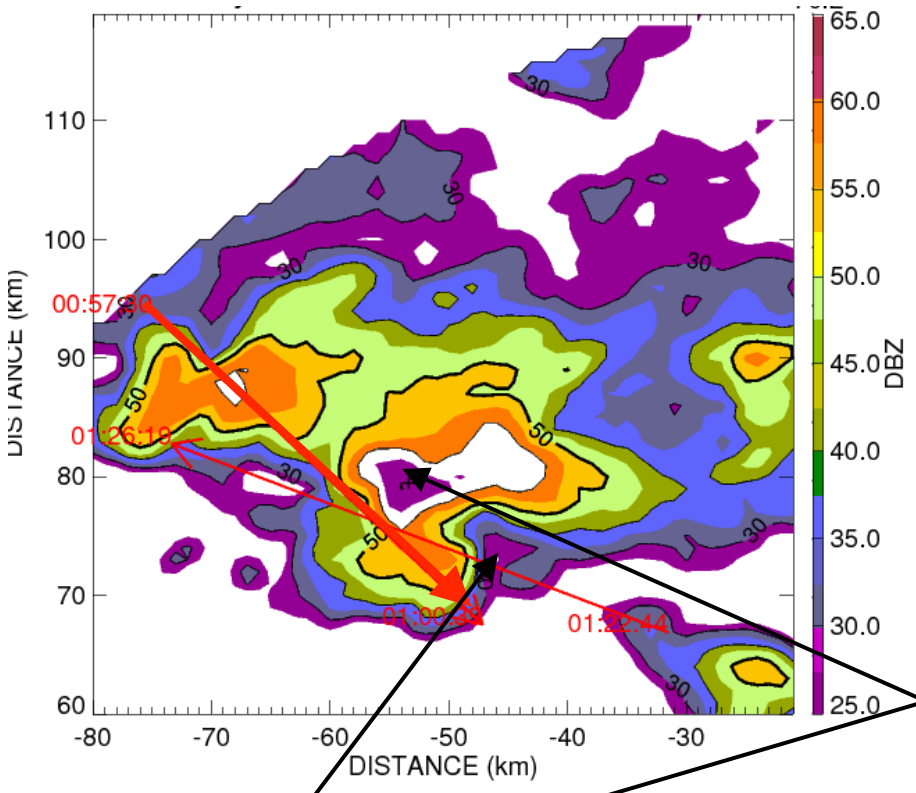
23-24 May 2011

- What can we say about more severe storms from the airborne dual-frequency radar/radiometer, and the ground-based polarimetric measurements?
- Hail, extremely high CAPE over two days.
- Two ER-2 flights.
- Excellent ground-based polarimetric data.
- Storms were too intense for in situ microphysics.

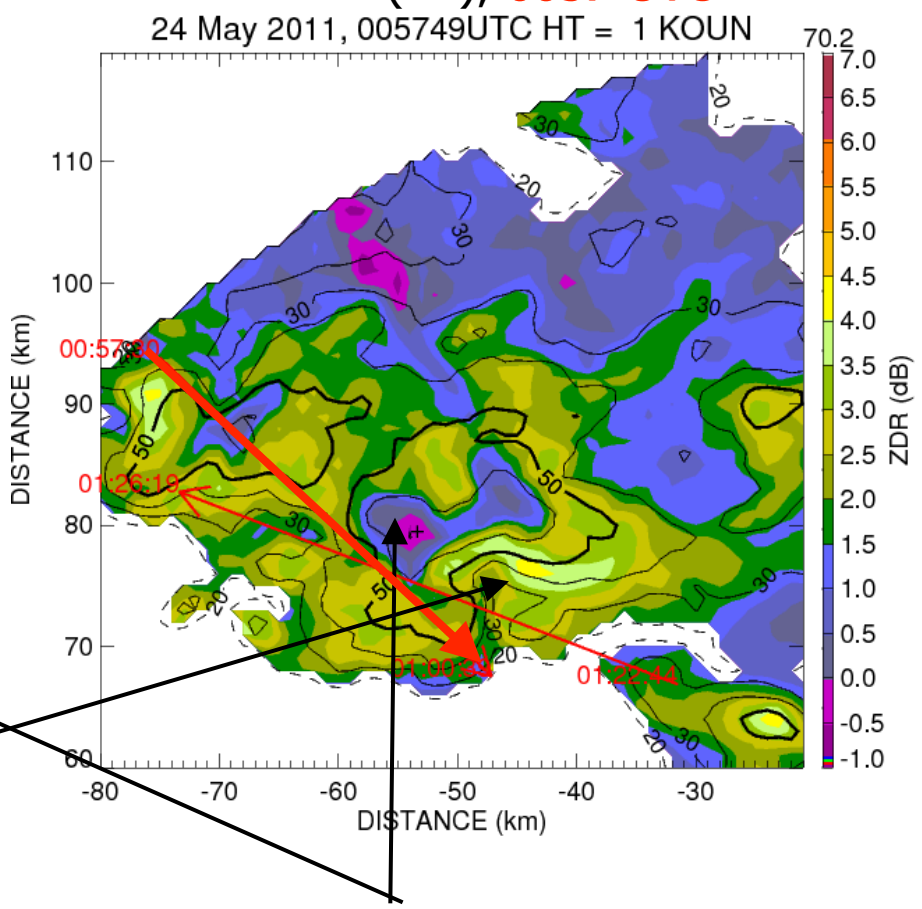


Hail Signatures from S-band Z & ZDR

KOUN Reflectivity (dBZ), **0057 UTC**



KOUN ZDR (dB), **0057 UTC**

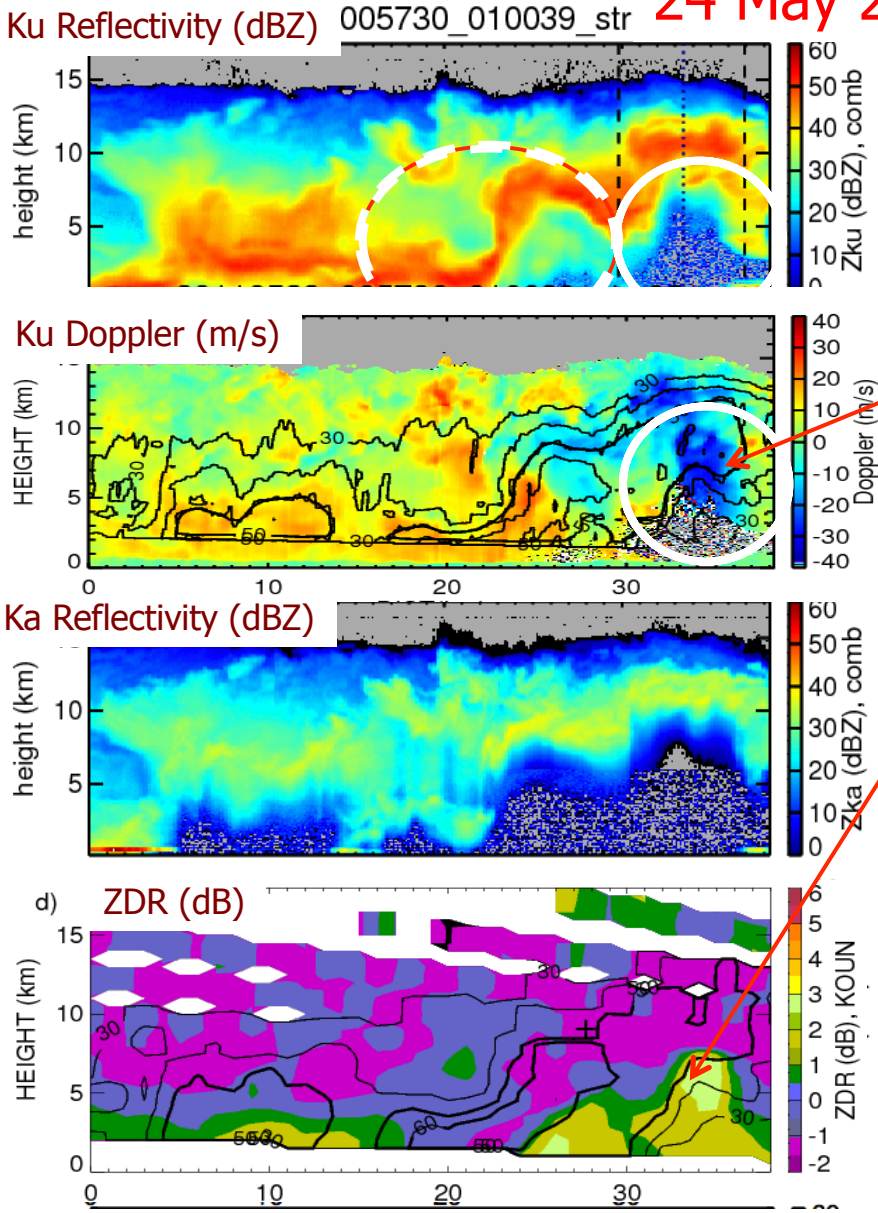


- Bounded Weak Echo Region (BWER)
  - ➢ Coexist with updraft inflow and ZDR column

- High reflectivities (> 60 dBZ, max = 70 dBZ) and minimum ZDR
  - ➢ Heavy rain and large hail

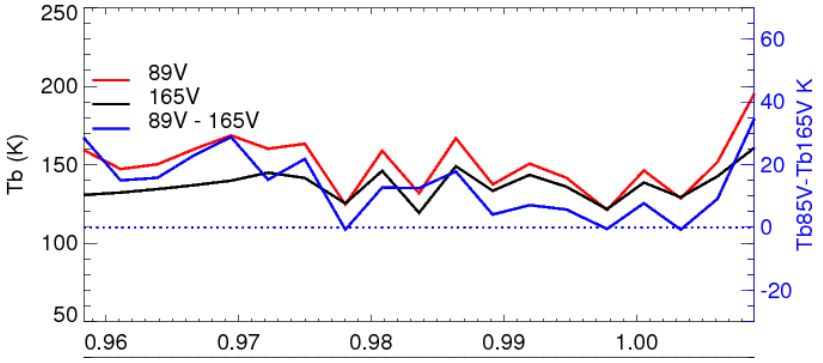
Vertical cross-section from HIWRAP

24 May 2011 @ 0057 UTC

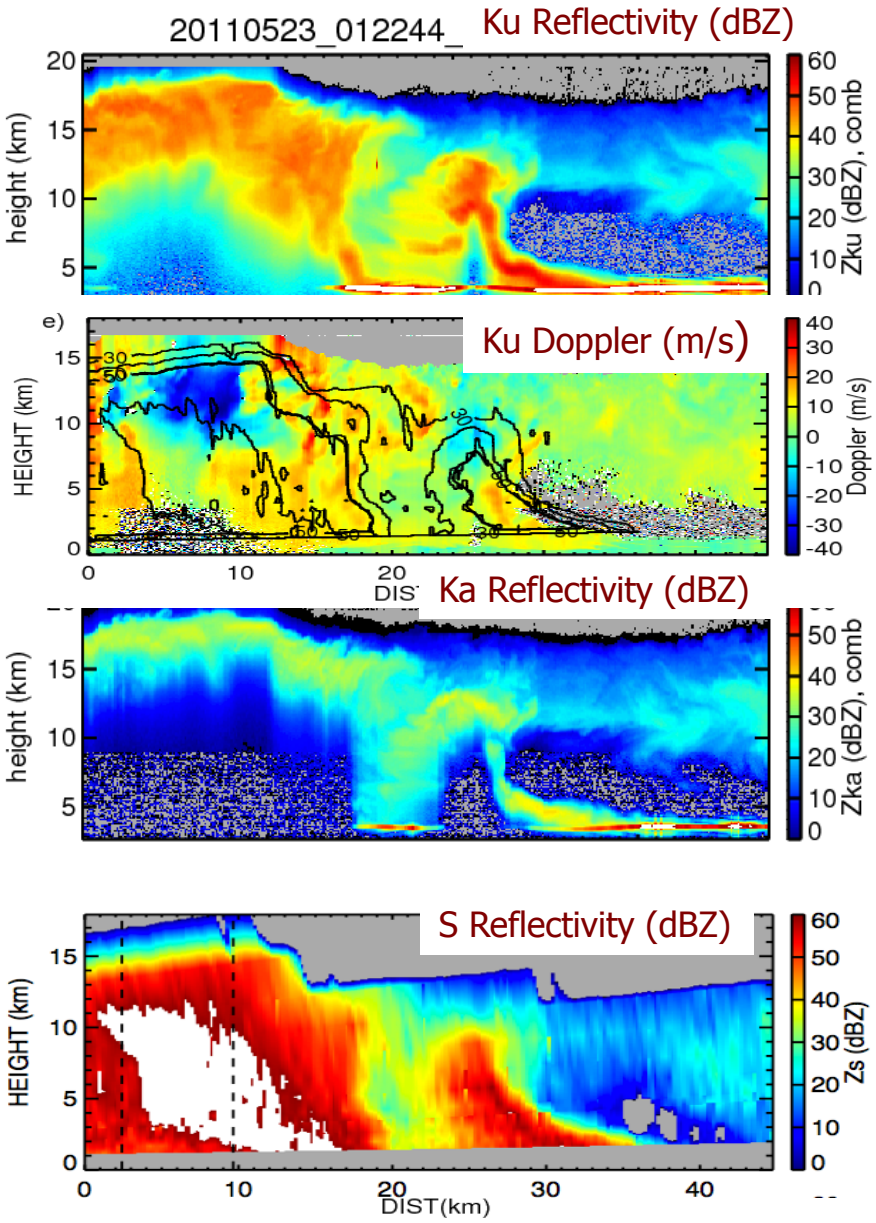


- Lower Z for both Ku and Ka bands as compared to S-band
- Substantial attenuation (hail, graupel)
- Doppler -30 m/s -> Strong updraft (> 40 m/s)
- The ZDR column is nearly centered on the location of minimum Doppler

COSMIR Tb at 89 and 165GHz did not show a significant decrease.



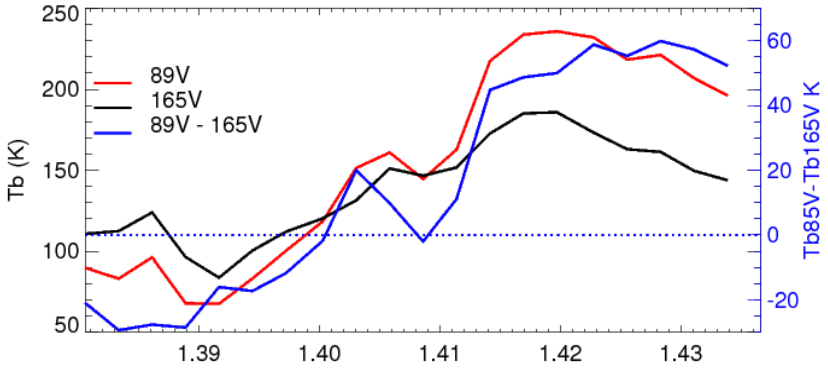
Vertical cross-section from HIWRAP



24 May 2011 @ 0121 UTC

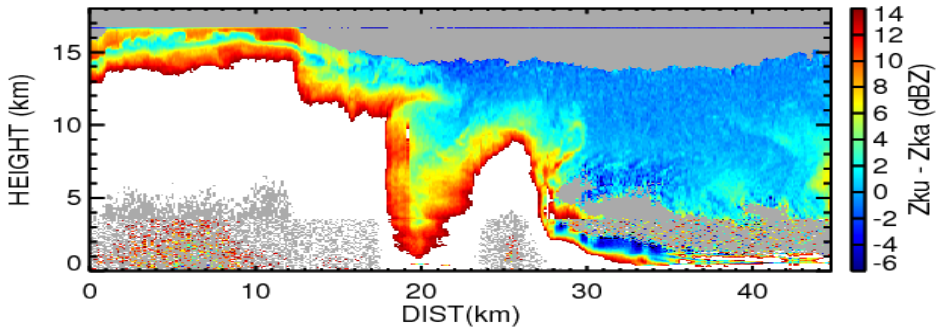
- Doppler -40 m/s -> Strong updraft (> 60 m/s) between 10 – 15 km
- Hail at high altitude

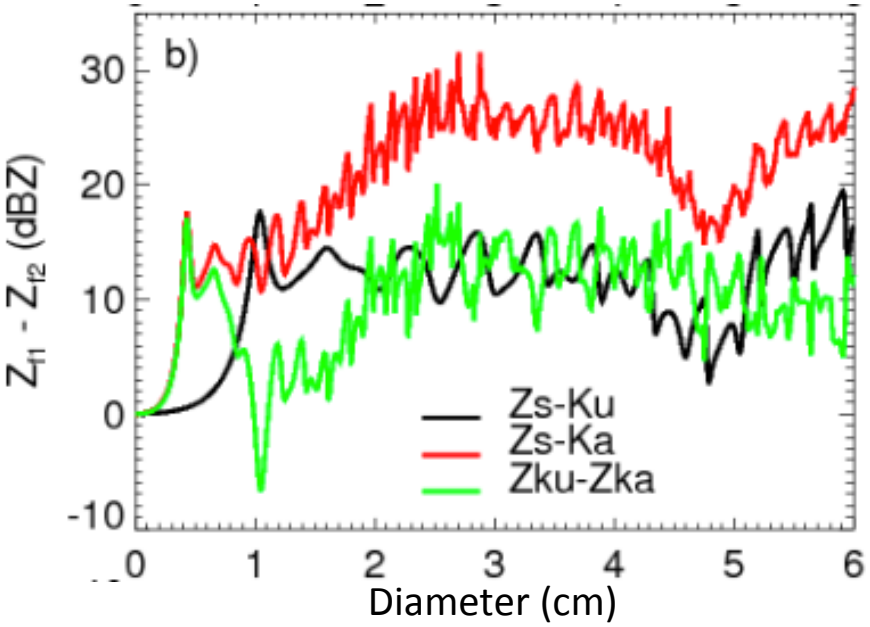
- Tb89 < 100K and Tb89 – Tb165 < 0K indicate large hydrometeors.



What Can DFR Tell Us About Hail?

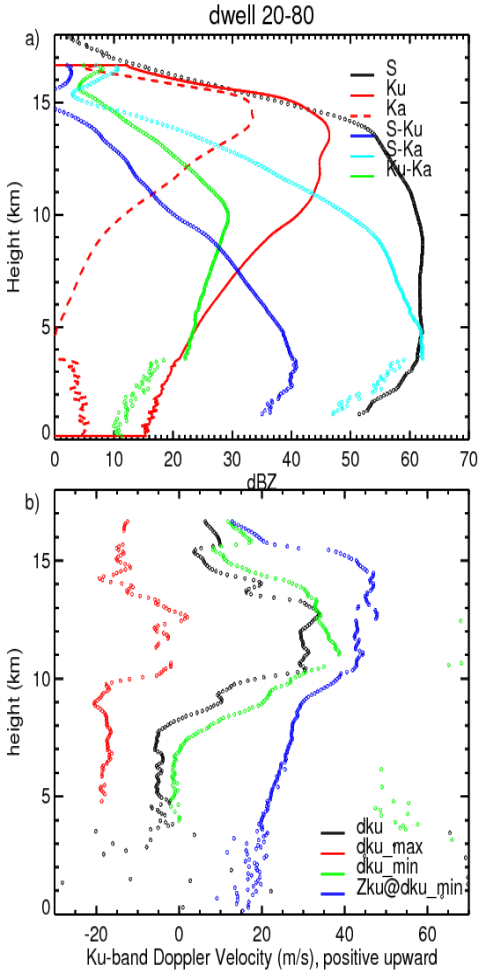
ZKu – ZKa (dB) 0121 UTC



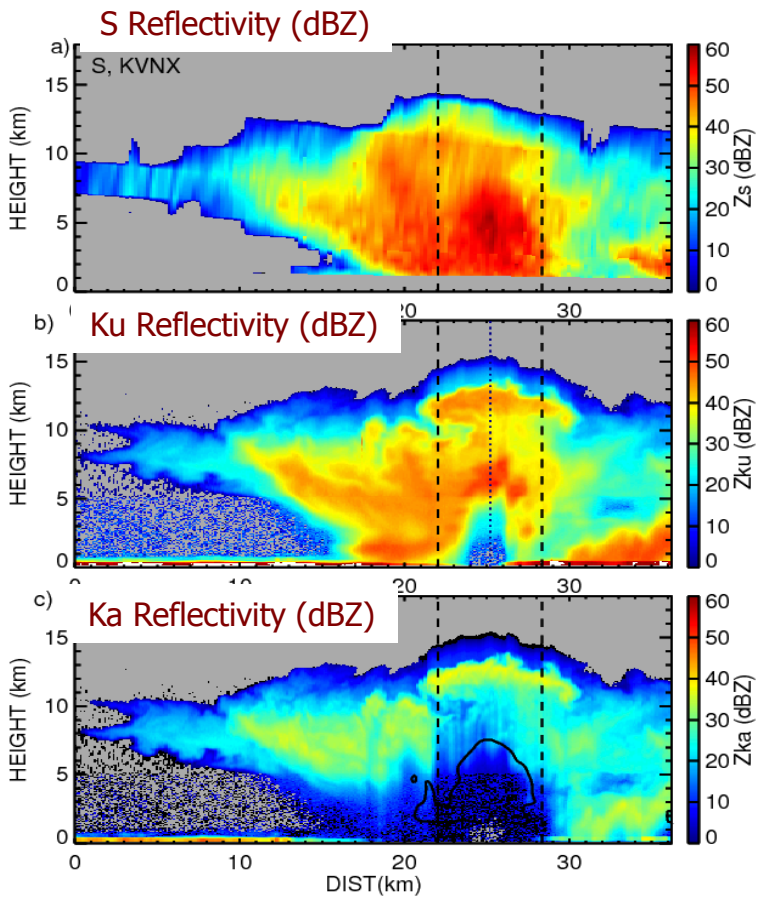


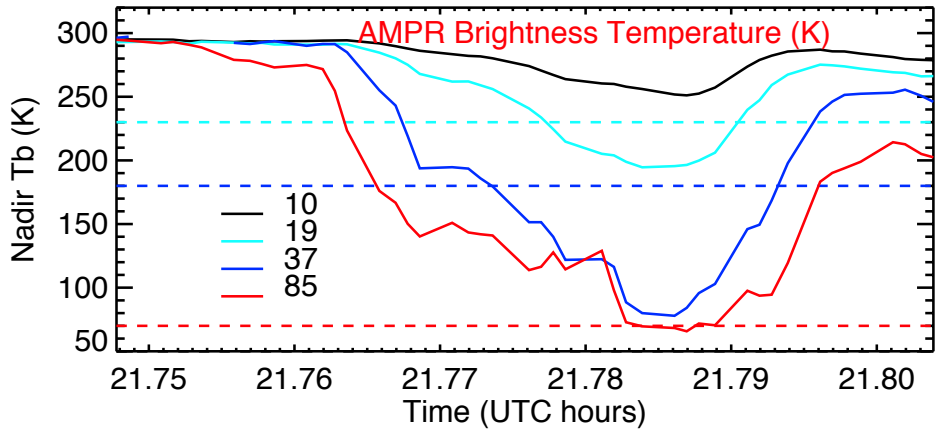
Mono-dispersed dry hail size distribution assuming ice density of 0.917 gcm^{-3}.

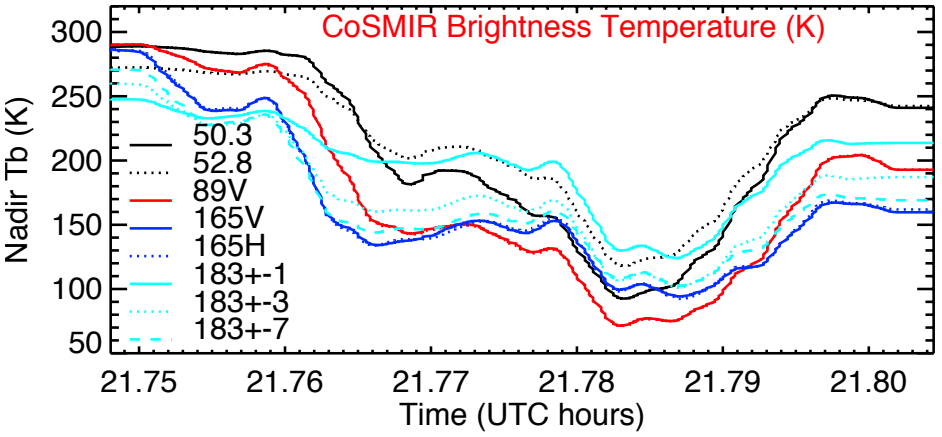
Sharp increase of DFR near cloud top



Brightness Temperatures 10-183 GHz

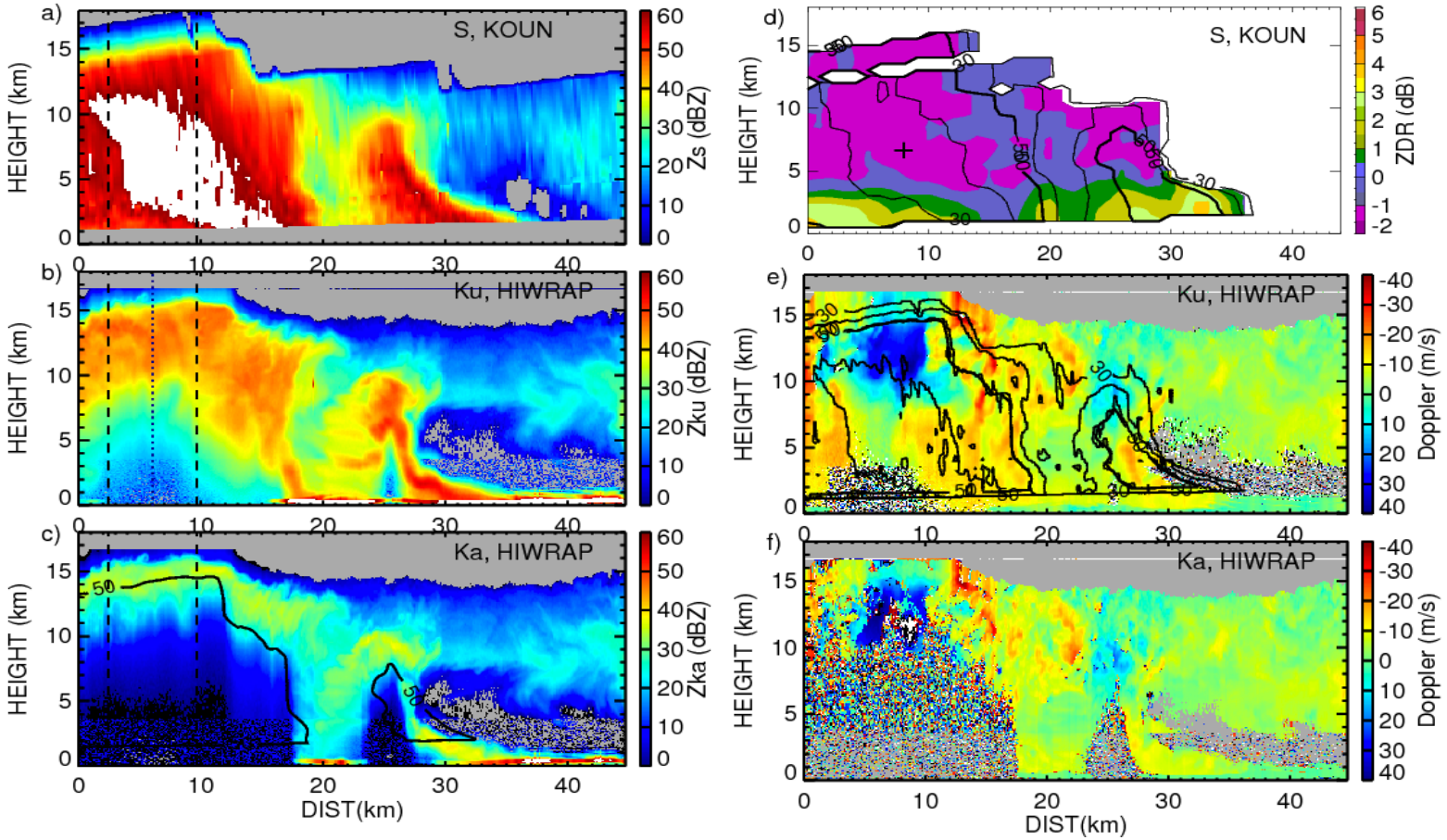






37 GHz down to 80K!

Mie, Attenuation & Multiple Scattering



- *Features appear similar to Battaglia et al. (2011) studies on MS effects on reflectivity and Doppler at W-band.*
- *Did not have LDR measurements with HIWRAP that help identify MS.*

IPHEX

May-June 2014, Southeast U.S.

Summary and Conclusions

- Combined aircraft remote sensing, ground-based polarimetric, and *in situ* measurements worked well for studying convection and stratiform during MC3E.
- First Ku & Ka observations of a hailstorm are thought provoking in terms of radar algorithms. -> these are extreme cases but they occur globally.
  - Large size hail (> 3 cm) at high altitude suggested by >40 m/s Doppler velocity and >60 dBZ reflectivity.
  - Large hail/graupel produces sharp increase in observed DFR
  - Significantly lower reflectivity at Ku & Ka compared to S-band due to Mie scattering and attenuation.

Summary and Conclusions (cont'd)

Unanswered questions and challenges:

- Can we identify hail/graupel better with dual-frequency ratio (DFR) than reflectivity given the large satellite footprints?
- Will hail be included in the radar algorithms?
- Where is multiple scattering important and how will it be incorporated into the algorithms? -> Battaglia and Tanelli

Relevant Talks:

Bill Olson – MC3E stratiform
Tanelli – multiple scattering

Posters:

Lin Tian – related to this talk

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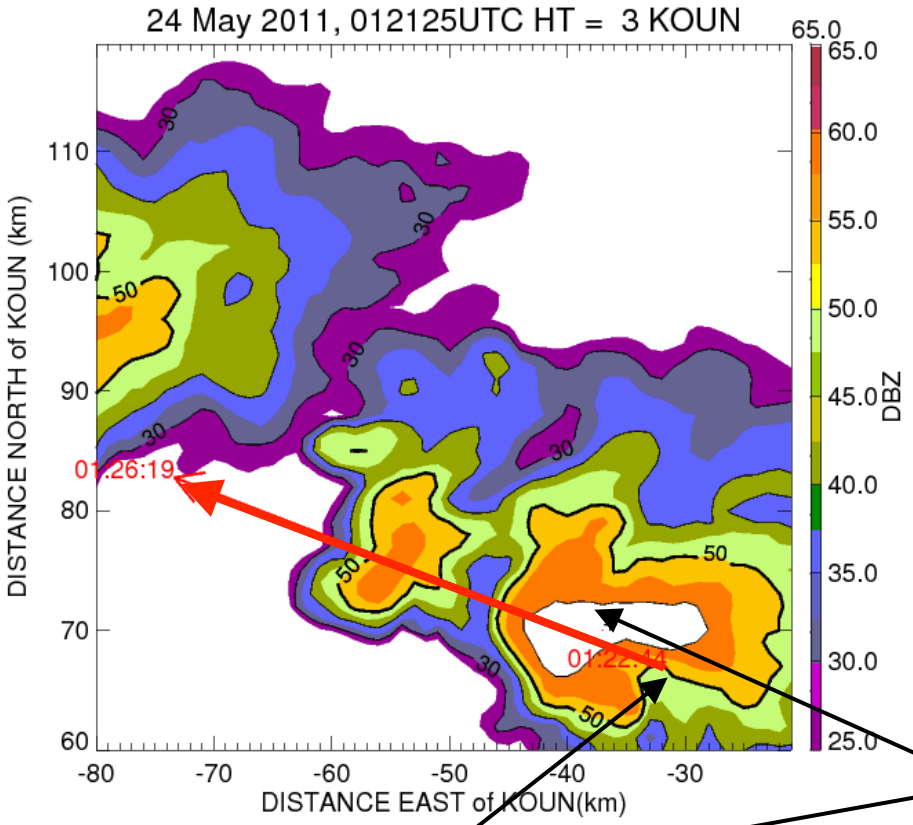
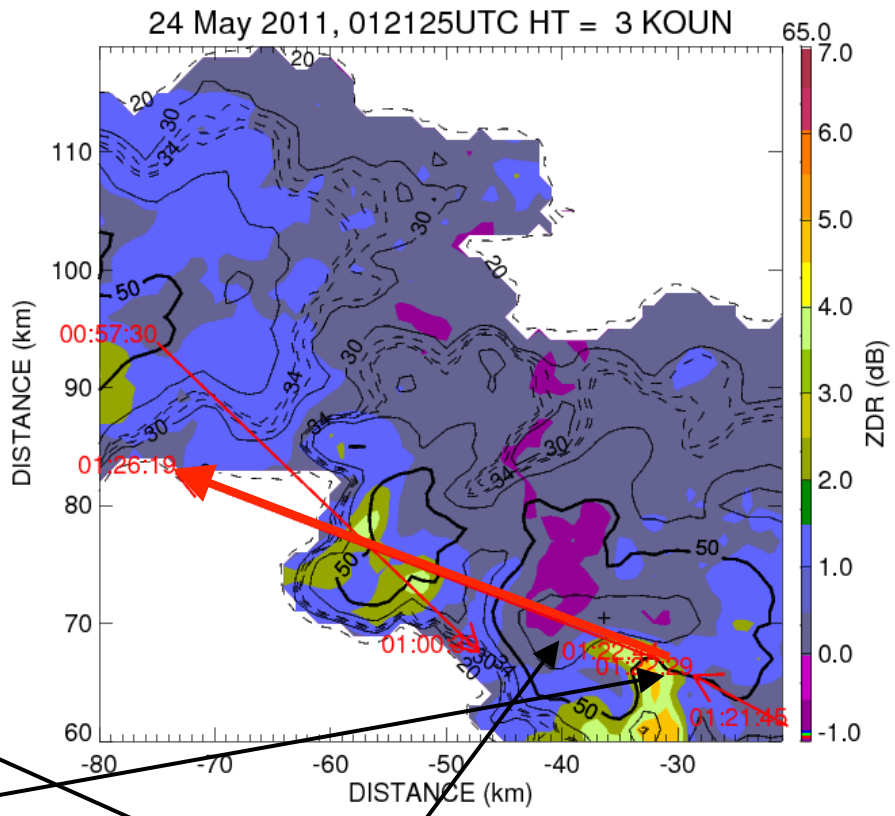


KOUN ZDR (dB), 0121 UTC



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