Radar Derived Precipitation Physics: Implications for GPM

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Background

- Reflectivity-based rain estimation central to TRMM and GPM
- We will investigate the polarimetric radar derived "structure" of rainfall in several locations and discuss these structures in regards to Z-R relationships
- Give a little background on polarimetric variables
- Show mid-latitude and tropical data examples
- Conclusions/Suggestions

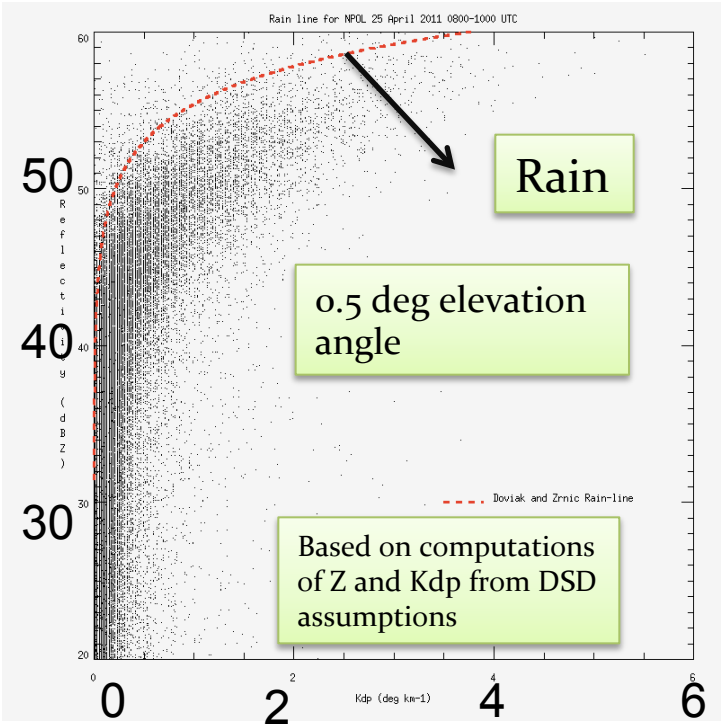
A little background…

K_{dp} proportional to mass content and mass-weighted oblateness ratio

K_{dp} is a measure of the difference in wave propagation between H and V polarizations; sensitive to non-spherical particles

$$K_{dp} = C\lambda^{-1}\int D^3(1-r)N(D)dD$$

$$K_{dp} \propto LWC \bullet (1-\bar{r}_m)$$

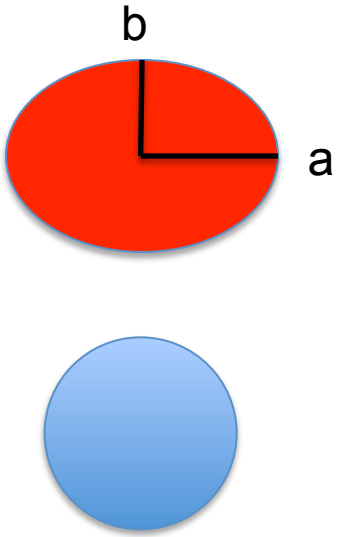


$$Z \propto \int D^6 N(D)dD$$

$Z \approx D^6$ Reflectivity

$$Z_{dr} = 10\log_{10}(Z_{HH}/Z_{VV})$$

Differential Reflectivity

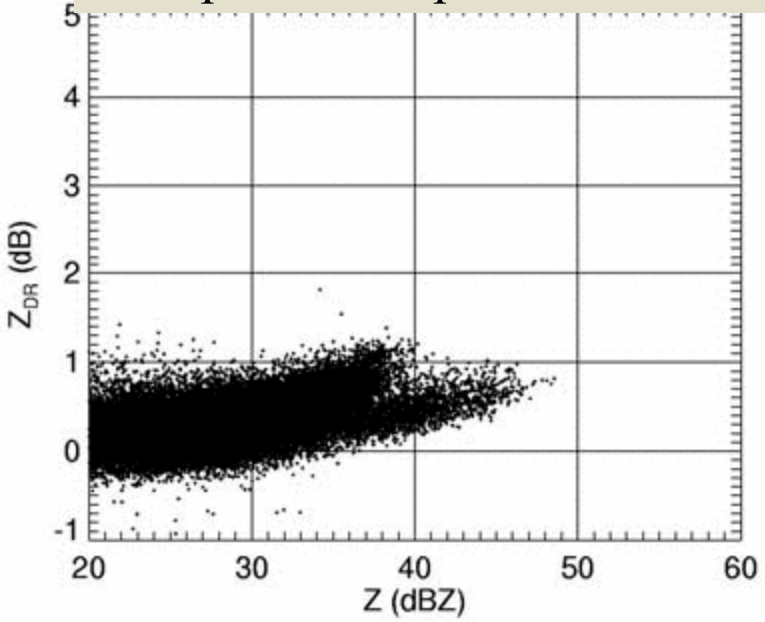


$r = b/a$

K_{dp} deg/km Difference in H,V phase in degrees

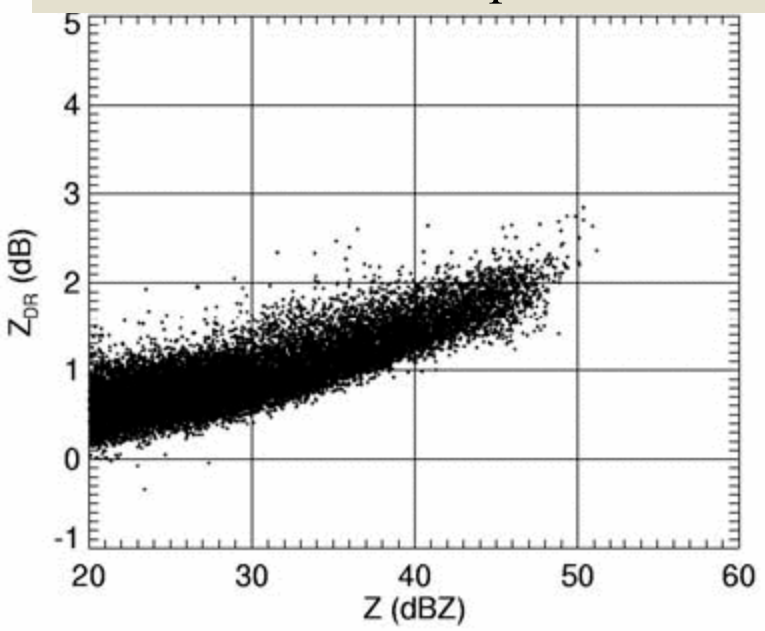
Z, Z_{dr} observations reflect differences in drop size distributions

A tropical example



(Ryzhkov et al.)

A mid-latitude example



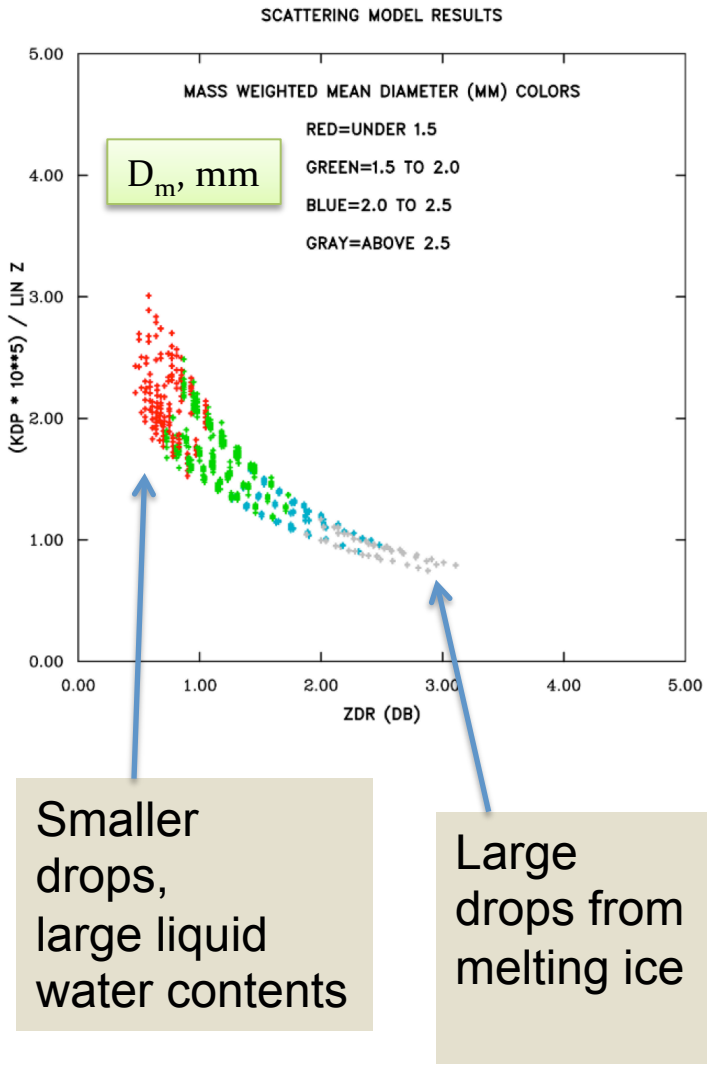
Application of polarimetric data……

Gorgucci et al. (2006, JTECH) showed that a parameter space formed by K_{dp} / Z vs. Z_{dr} was useful for characterizing precipitation physics.

Figure on the right shows results of scattering simulations for various **Gamma DSD's** with mean diameters (D_m) ranging from 1.2 to 3.5 mm. **Variations in D_m are evident as well-defined curving paths in K_{dp}/Z vs. Z_{dr} space.**

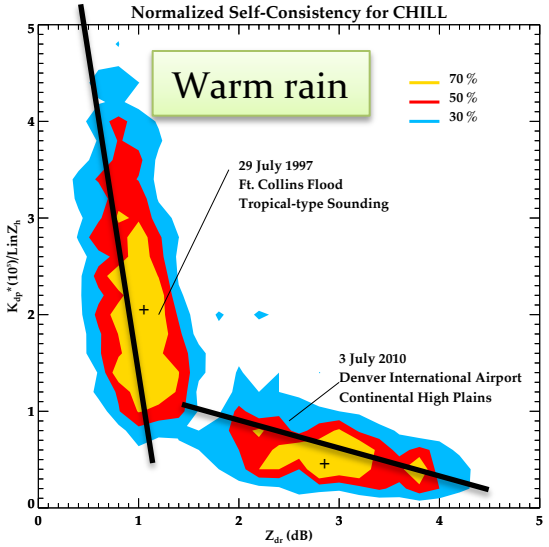
This technique can also be used to distinguish convective rain produced by warm rain environments (high freezing level and active drop coalescence processes, smaller drop sizes) from rain derived from the melting of graupel and hail (larger drop sizes), as distinguished by K_{dp}/ Z; Z_{dr} pairs.

For a given rainfall regime, behavior of K_{dp}/Z vs. Z_{dr} represents precipitation physics.



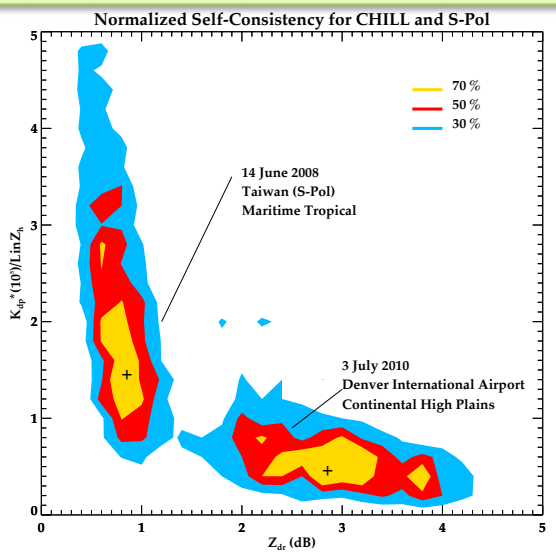
Let's examine some data, two distinct examples first…..

Normalized density of points expressed as a percentage



Colorado and "tropical" events

Ice based



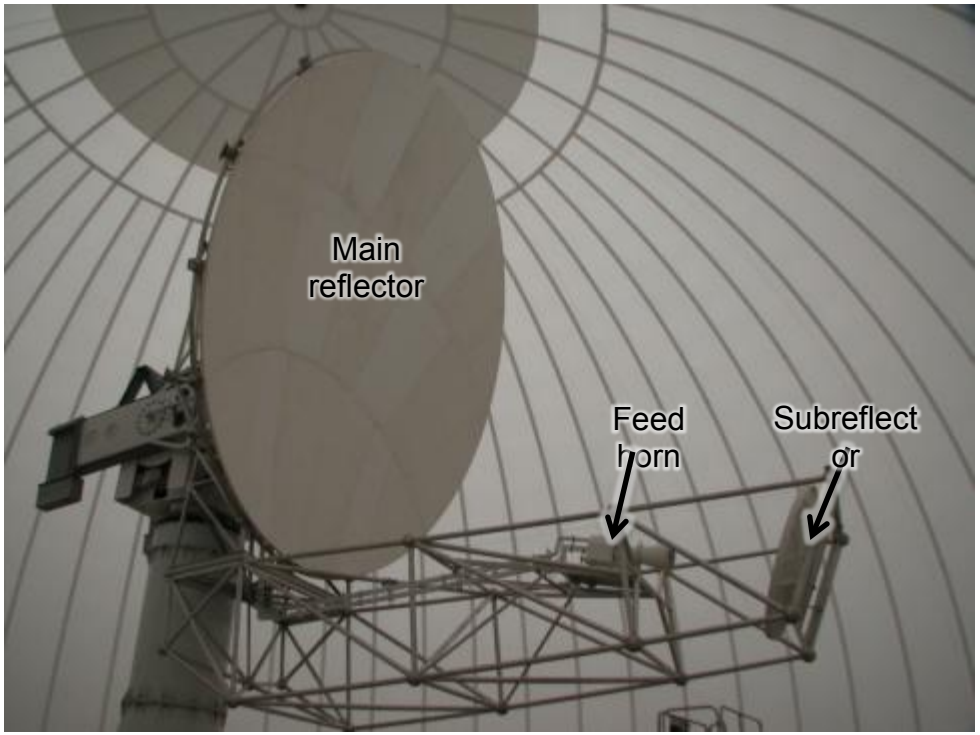
Large LWC
Small drops
(K_{dp}/Z large)

Large drops via melting ice, high Z_{dr} and large Z

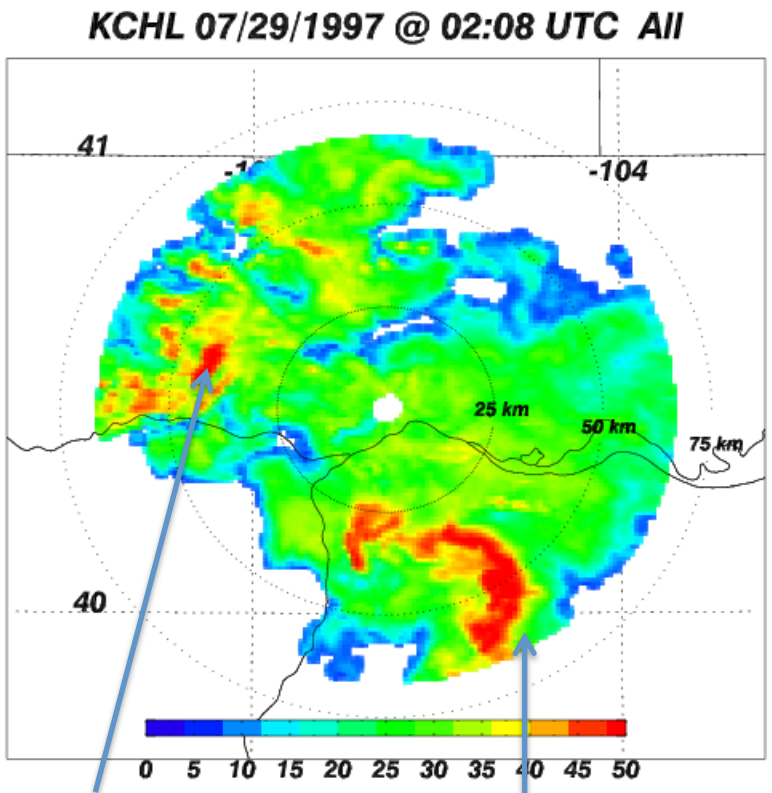
FNL flood nearly overlays tropical event from Taiwan…..

Colorado observations, using CSU-CHILL

- Dual-offset Gregorian antenna
- Choice of three symmetric OMT feed horns
  - S-band only
  - X-band only
  - Dual wavelength
- S-band beamwidth 1 degree
- X-band beamwidth 0.3 degree
- Sidelobe levels better than 50 dB at S-band
- Single-wavelength feeds achieve exceptional cross-polar isolation better than 50 dB



Colorado, contrasting the FNL flood case with a nearby bow echo storm…

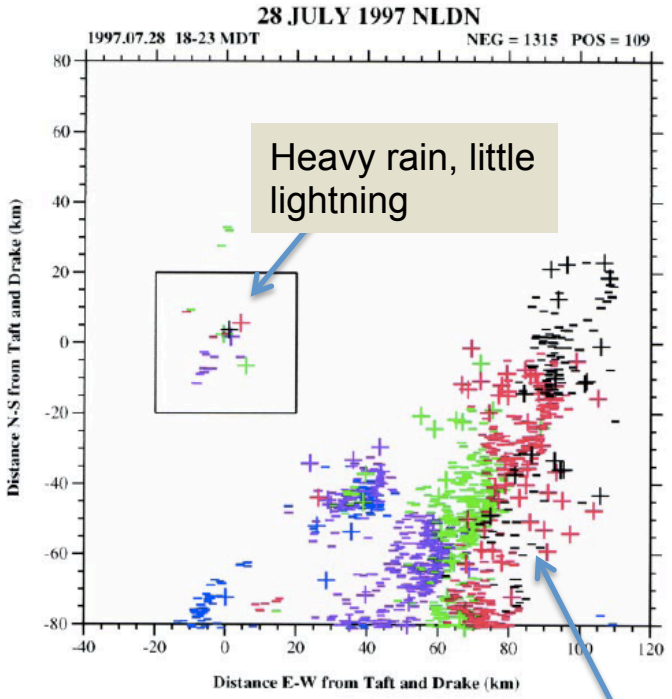


FNL storm

BEC storm

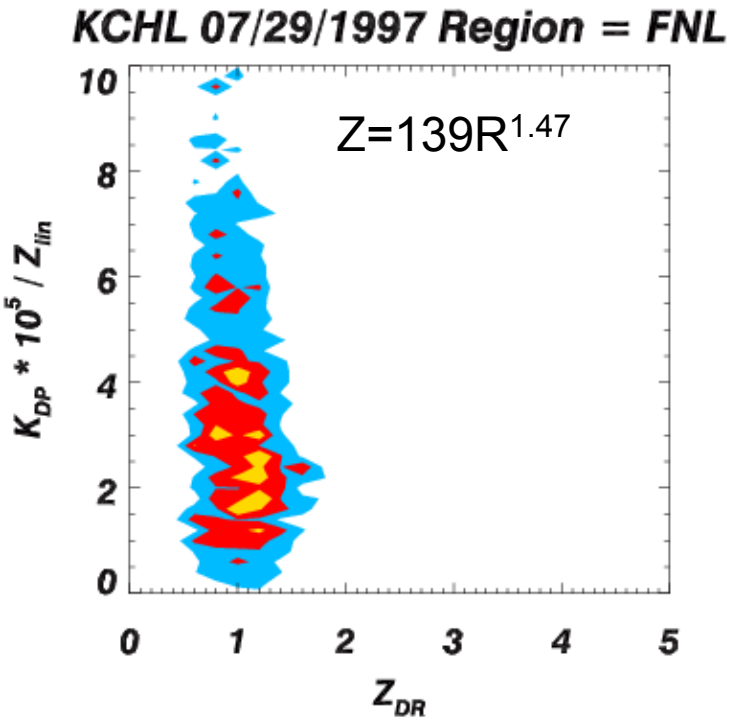
10 inches of rain in a 5 hour period, major flooding, property damage and loss of life

NLDN lightning for 5 hour period



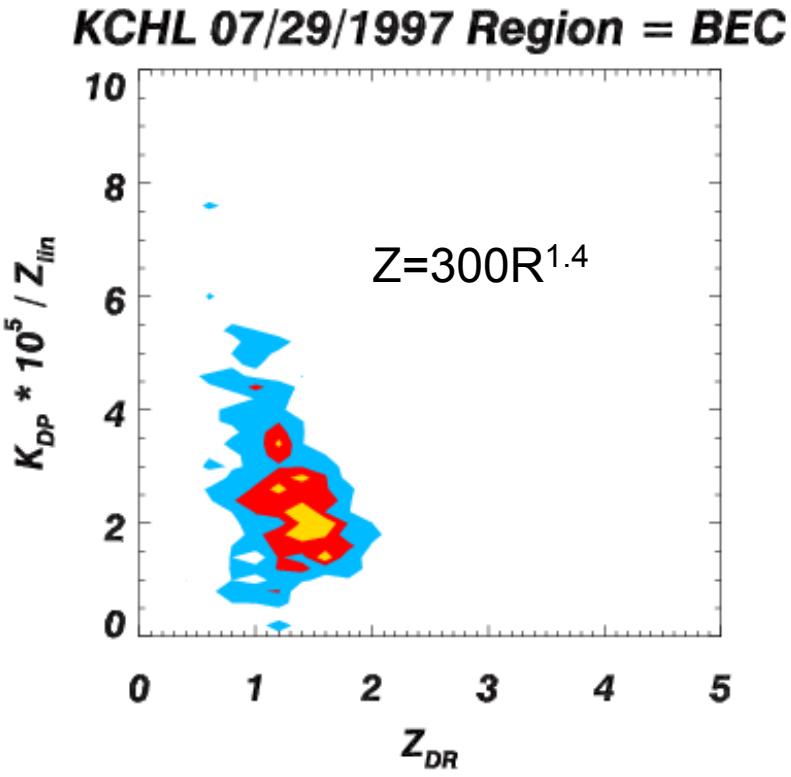
Heavy rain, little lightning

Lightning with bow echo storm

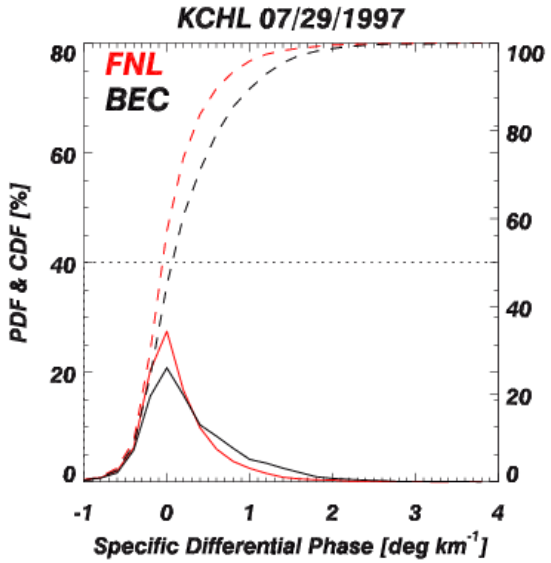


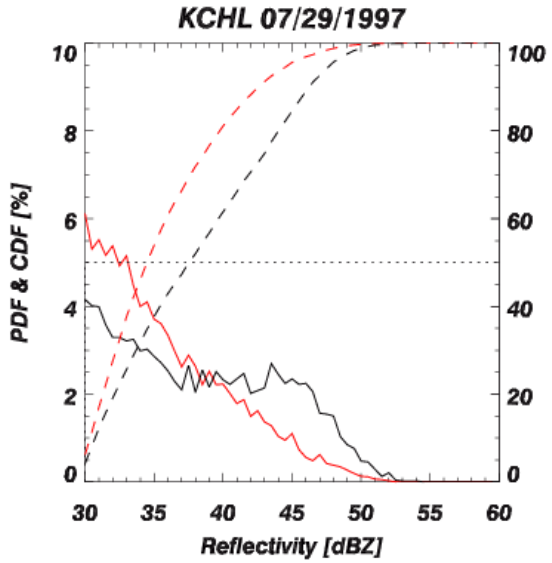
FNL FLOOD CASE; tropical like heavy rain event. $Z=300R^{1.4}$ SERIOUSLY UNDERESTIMATED RAINFALL. $Z=139R^{1.47}$ was best Z-R. Developed from polarimetric data.

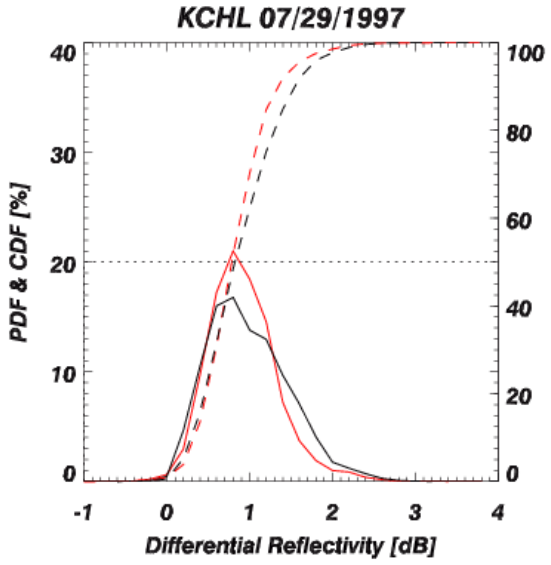
NEARBY BOW ECHO STORM

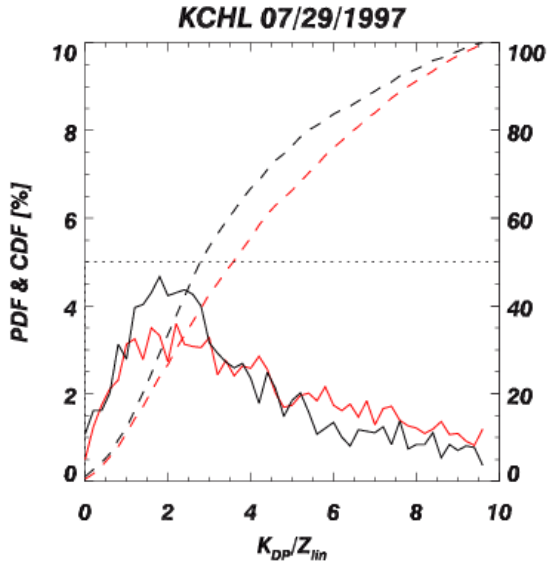


All points > 30 dBZ used









Flood (tropical like) event distinguished from bow echo by reduced Z and Z_{dr}.

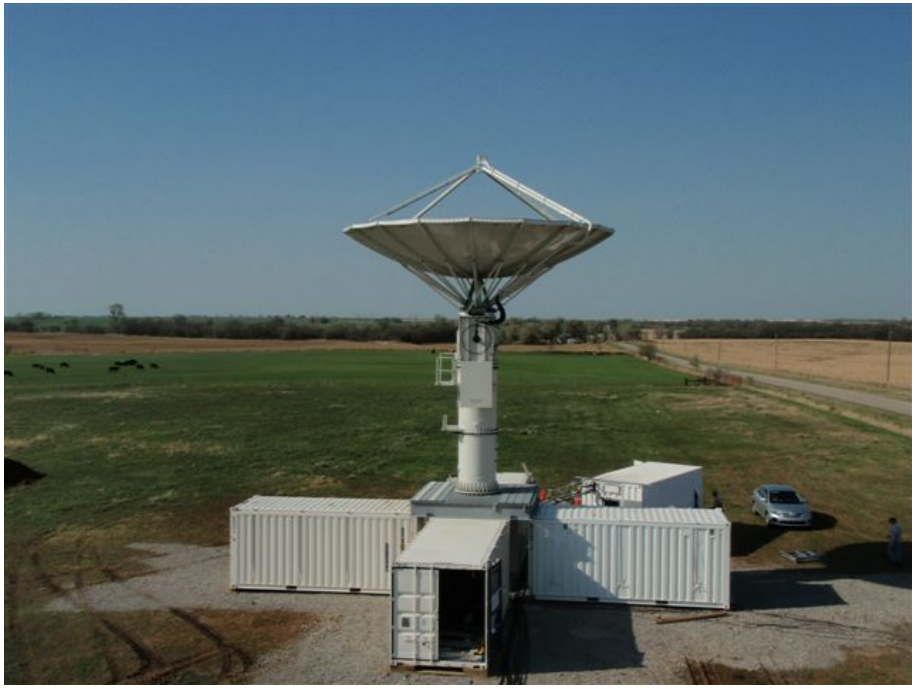
K_{dp}/Z shifted to higher values for FNL (flood) case. Implies large LWC consisting of relatively small drops.

Polarimetric variables consistent with Z-R forms for these events

Small drops, high LWC, small A

Large drops, large A

N-Pol in **MC3E** sporting its new center-fed parabolic antenna and other upgrades

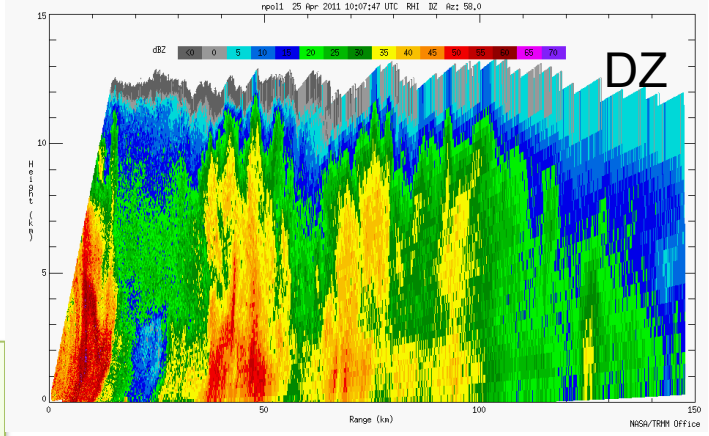


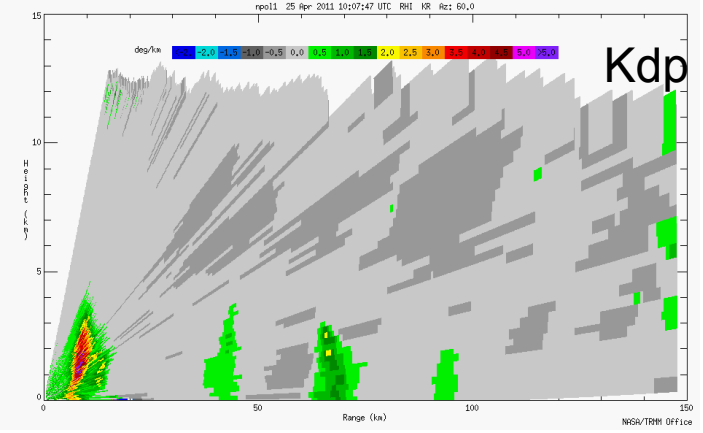
Midlatitude Continental Convective Clouds Experiment

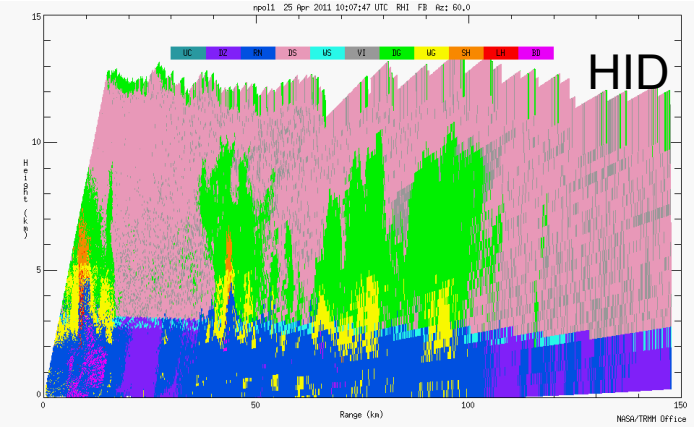
May-June 2011

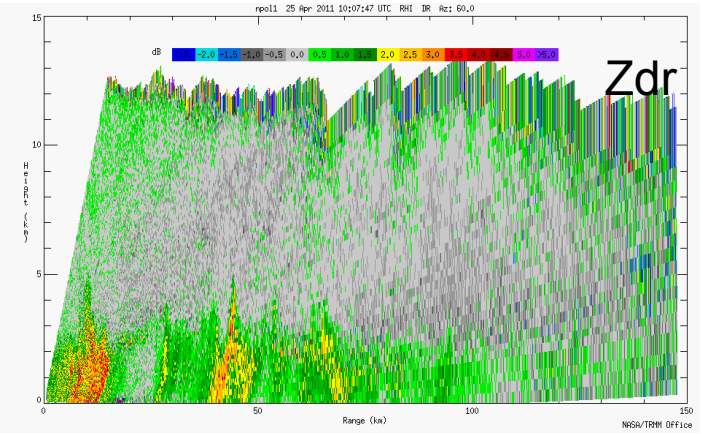
Observations from MC3E…..

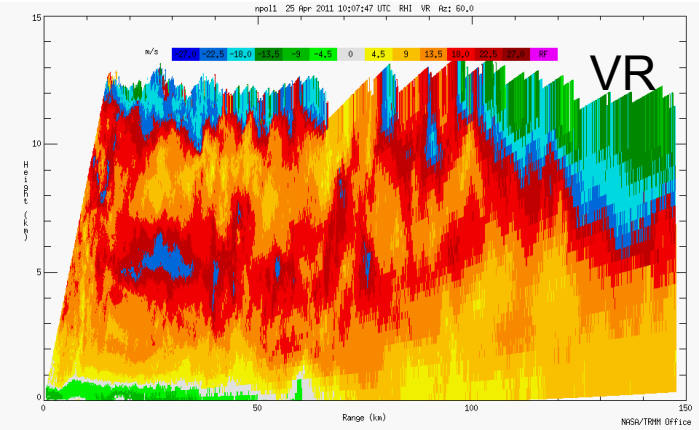
25 April 2011: Multiple Convective Cores

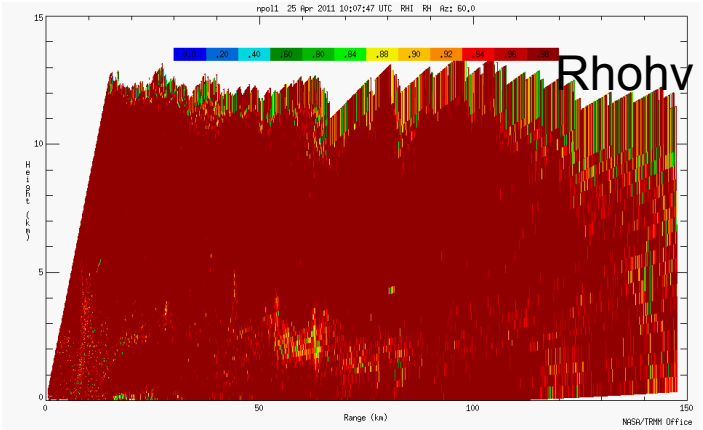




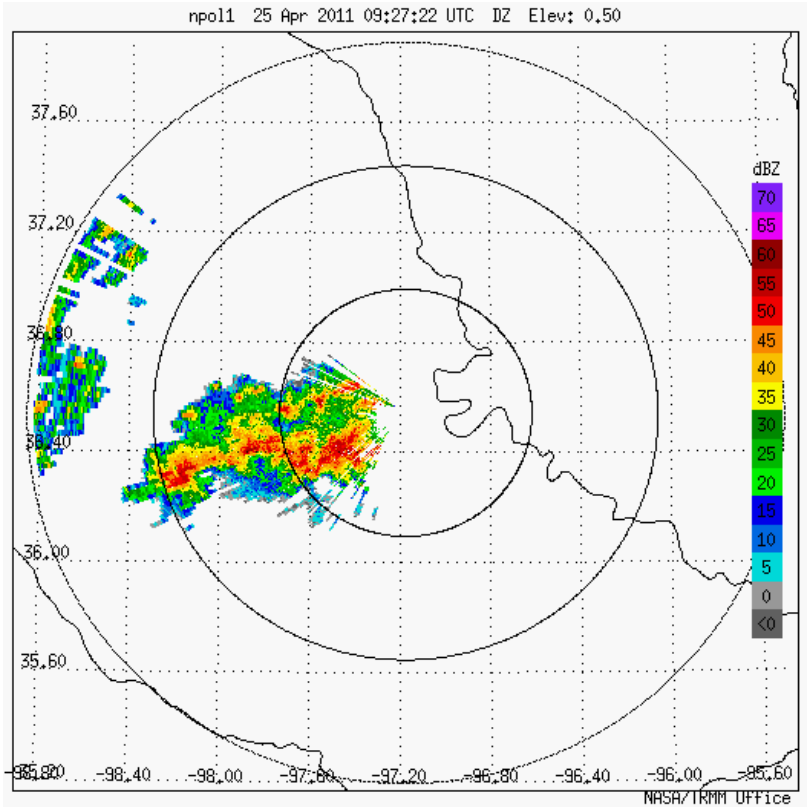




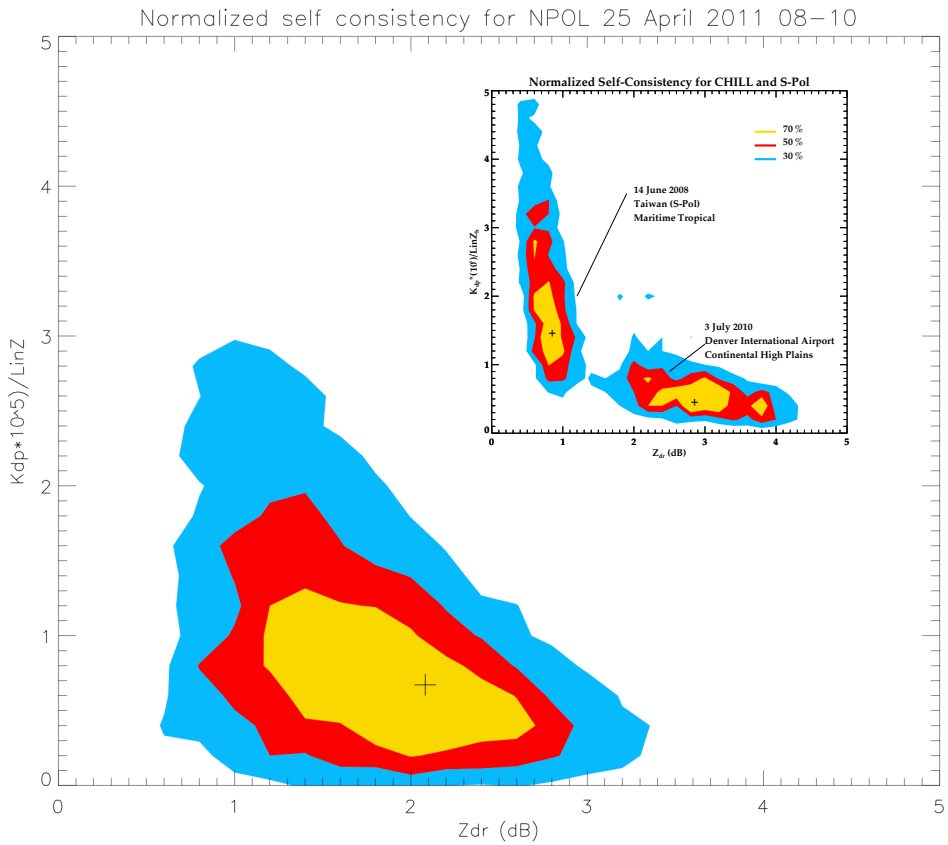




25 April 2011
08-10 UTC

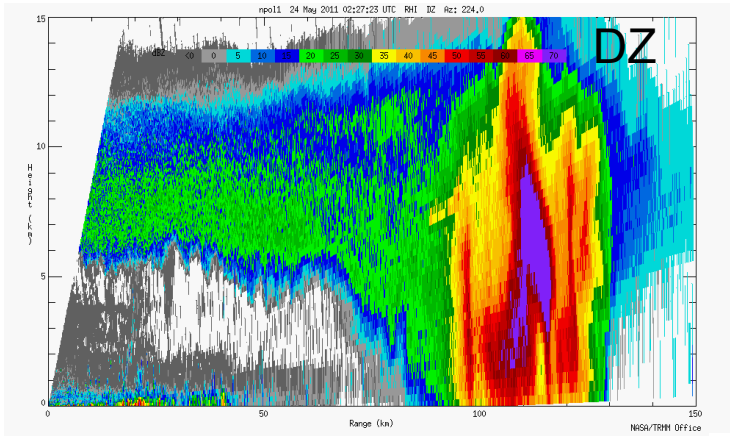


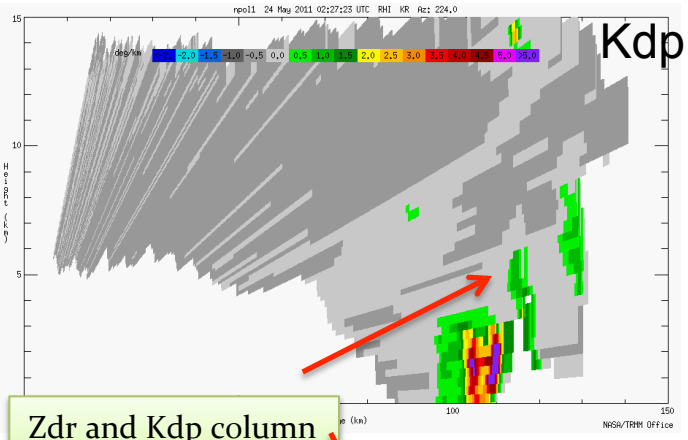
Oklahoma case appears as a blend of warm rain coalescence and melting ice regimes



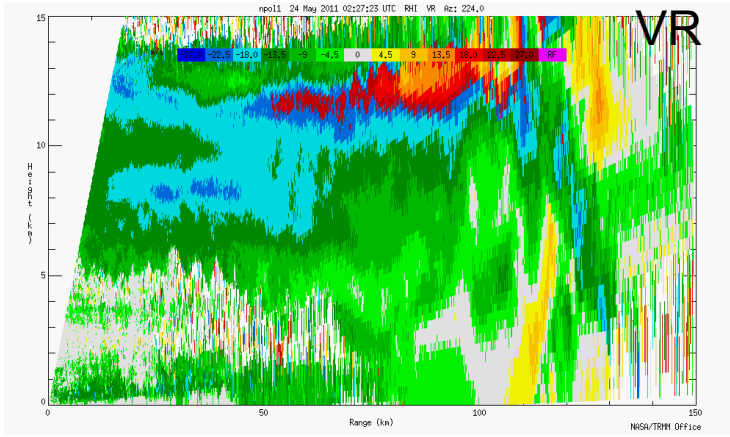
24 May 2011 Severe storm

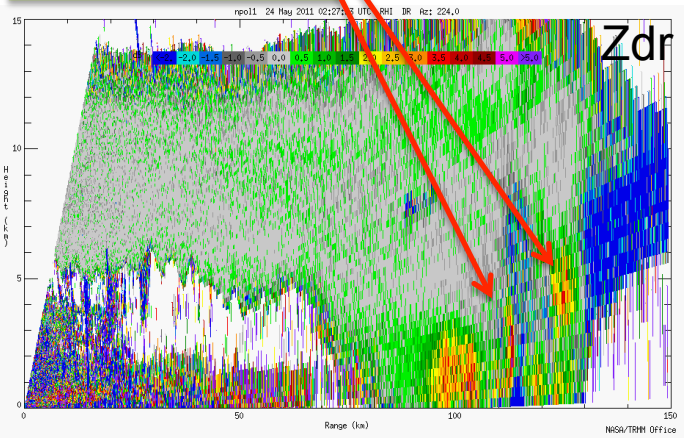
- 70+ dBZ up to 10 km
- Large (+5 º/km) K_{dp} at the surface
- Signature of large hail (in RH and ZDR)
- Strong tilted updraft and divergence aloft
- Data of high quality at significant ranges

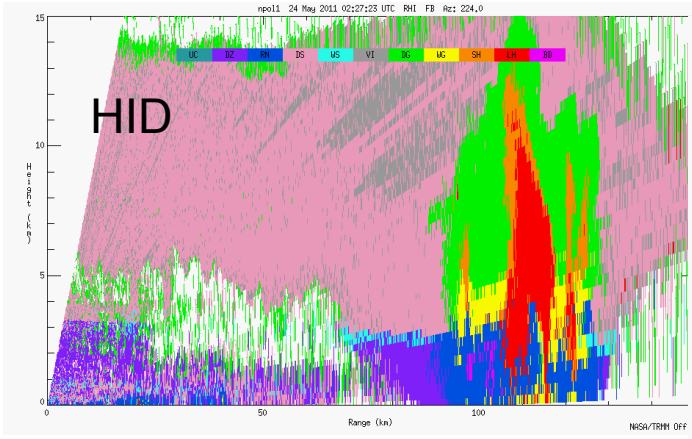


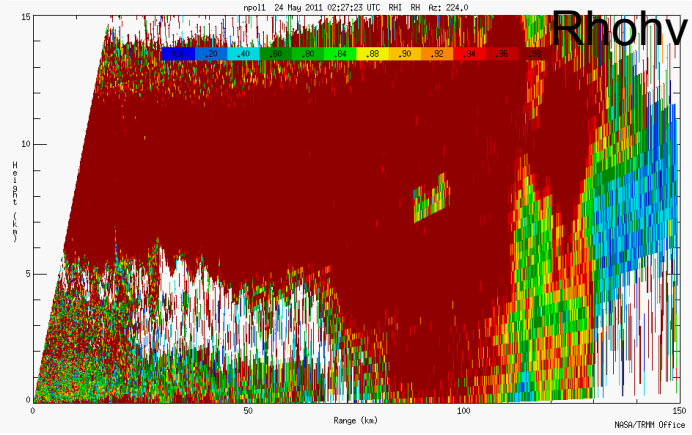


Zdr and Kdp column



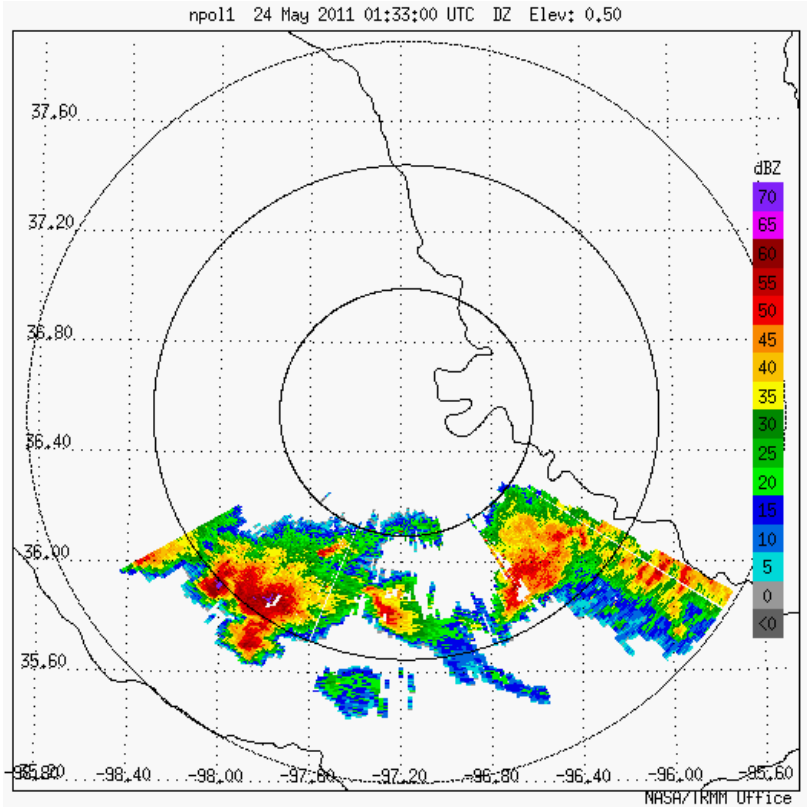


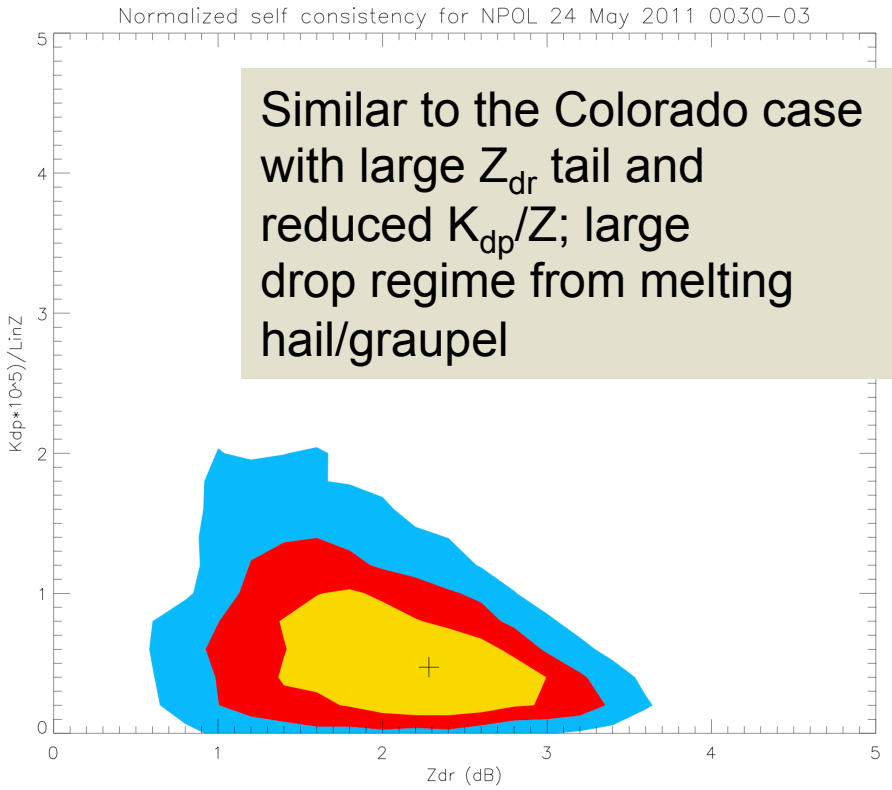




24 May 2011
0030-0300 UTC

Oklahoma intense, severe storm





Similar to the Colorado case with large Z_{dr} tail and reduced K_{dp}/Z; large drop regime from melting hail/graupel

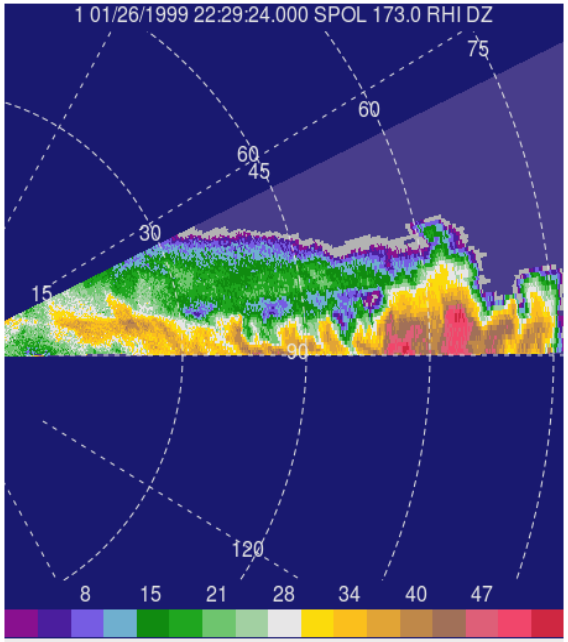
Shift to the tropics…..

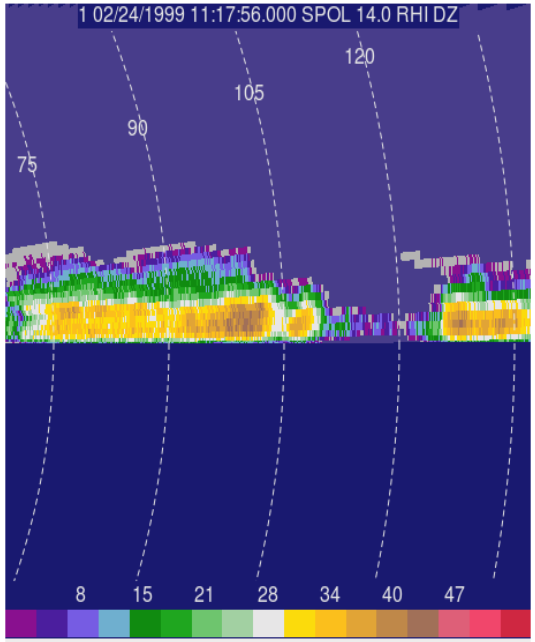
TRMM LBA, Jan-Feb 1999

NCAR S-pol radar deployed for TRMM-LBA

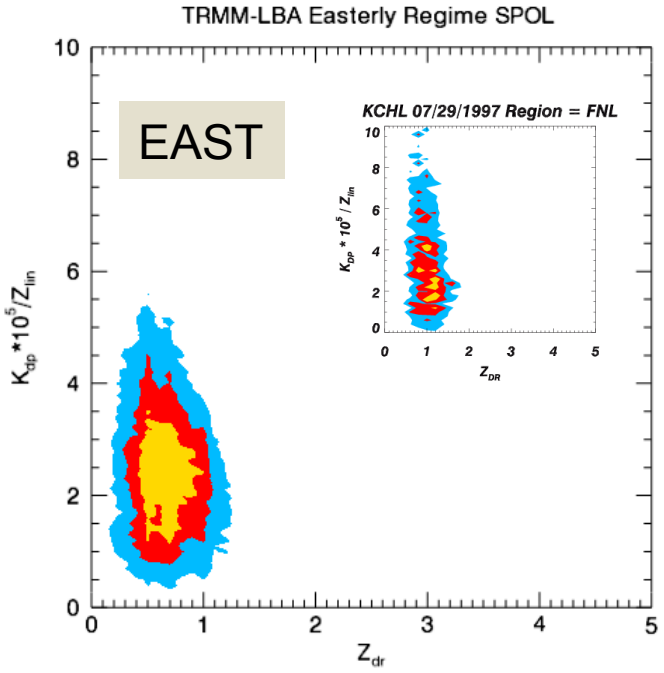
Documented east-west regime with 7-10 day variability (Petersen and Rutledge, 2002)

26 Jan 1999 EAST case. Stronger convection, higher CAPE.

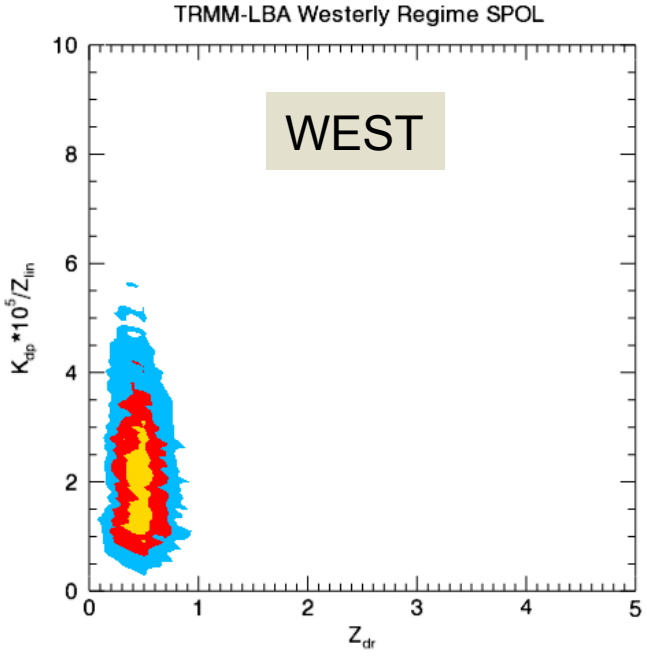


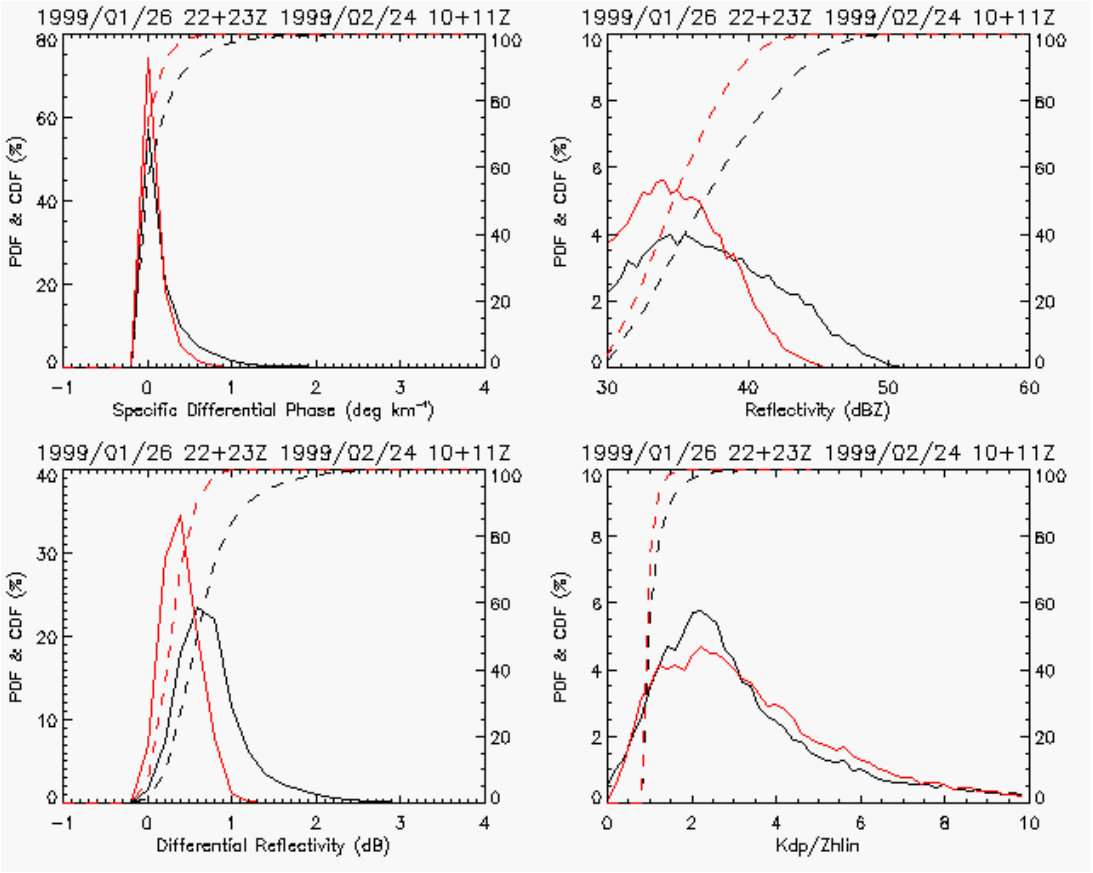


24 Feb 1999 WEST case. Lower CAPE, monsoon-like regime.



Subtle differences between East and West





WEST

EAST

LARGER Z_{DR} VALUES IN EAST CASE COMPARED TO WEST. INDICATIVE OF LARGER DROPS. CONSISTENT WITH INCREASED REFLECTIVITY IN EAST PHASE.

IN WEST PHASE, LARGER K_{dp}/Z INDICATING SUBSTANTIAL LWC CONTAINED BY SMALL DROPS.

IT IS ALSO EVIDENT THAT THESE TROPICAL CASES DO NOT PRODUCE THE LARGE DROPS EVIDENT IN CO AND OK

LARGE ICE PARTICLES REQUIRED

NASA KPOL radar on Kwajalein atoll

Frequency Range:
2800 MHz

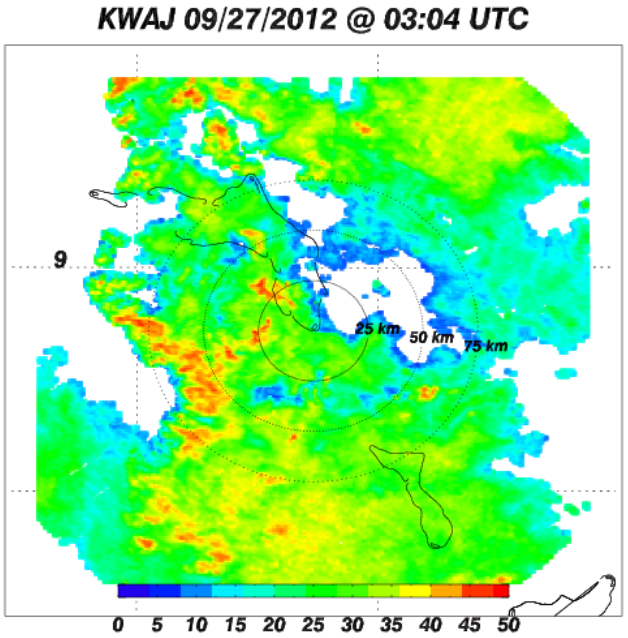
Peak Power:
700 kW

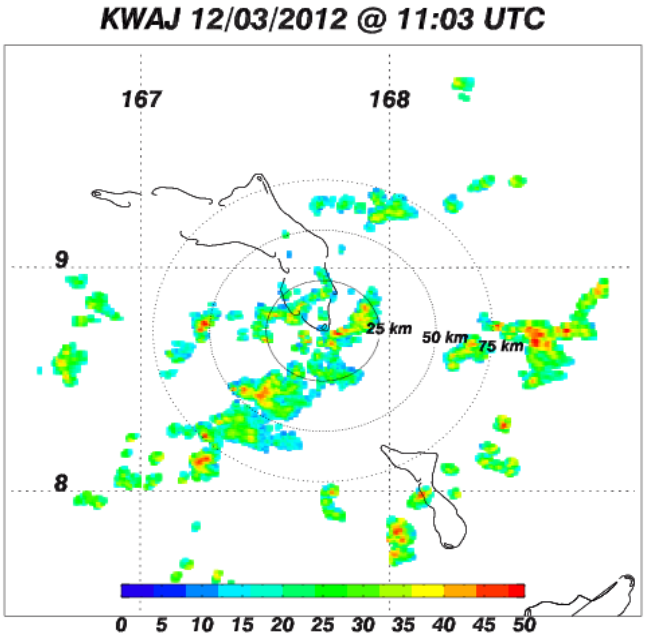
PRF Range:
264-1536 Hz

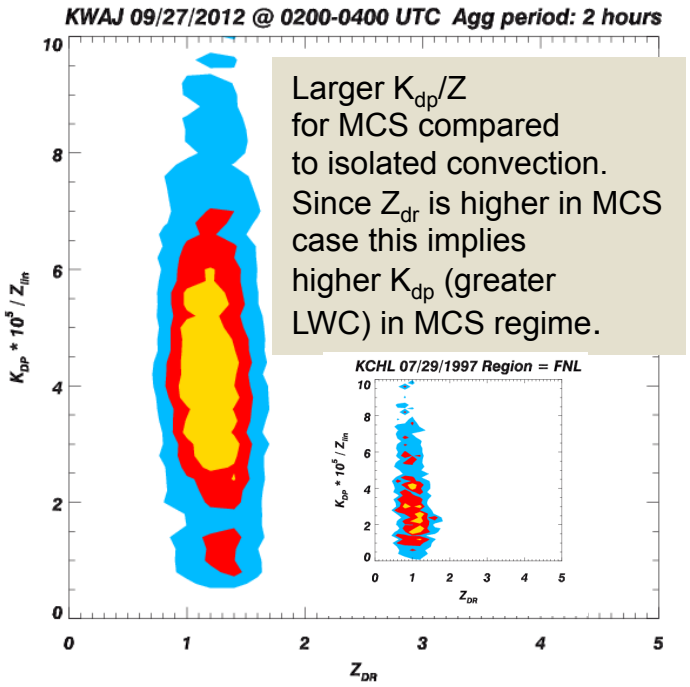
Antenna Gain:
43.8 dB

Antenna Diameter:
8.2m (27 ft)

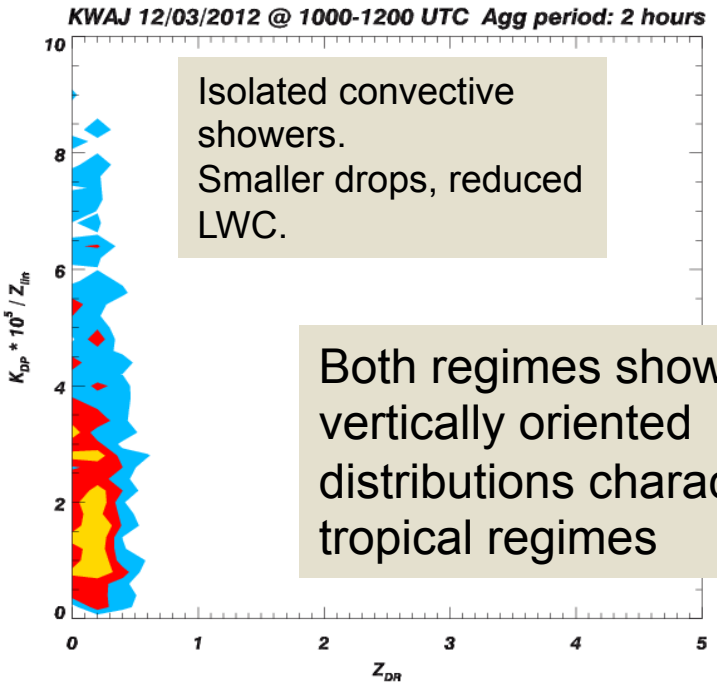
Antenna Beamwidth:
0.95°







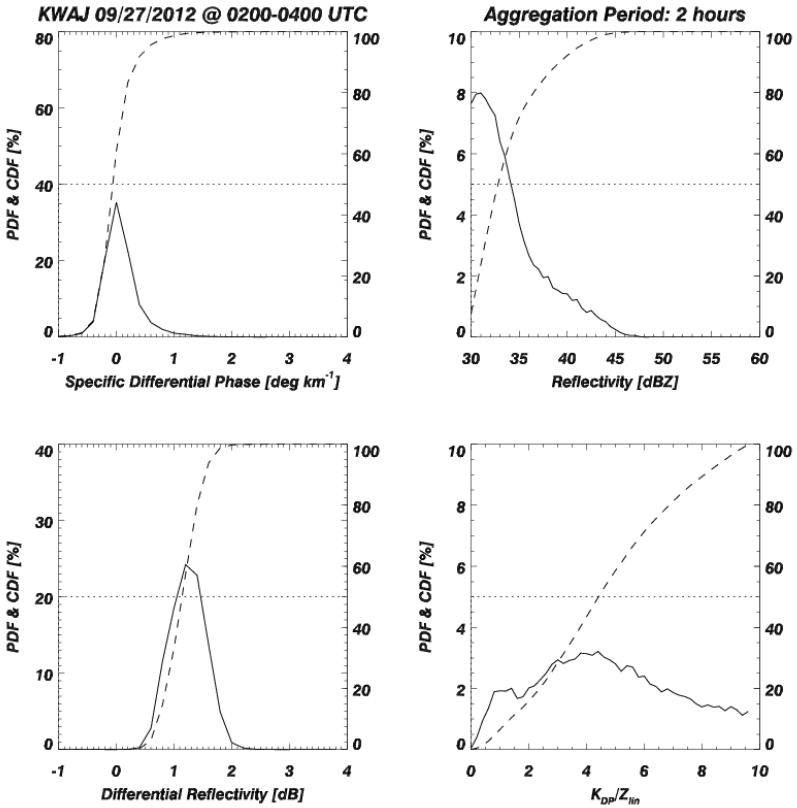
Larger K_{dp}/Z for MCS compared to isolated convection. Since Z_{dr} is higher in MCS case this implies higher K_{dp} (greater LWC) in MCS regime.



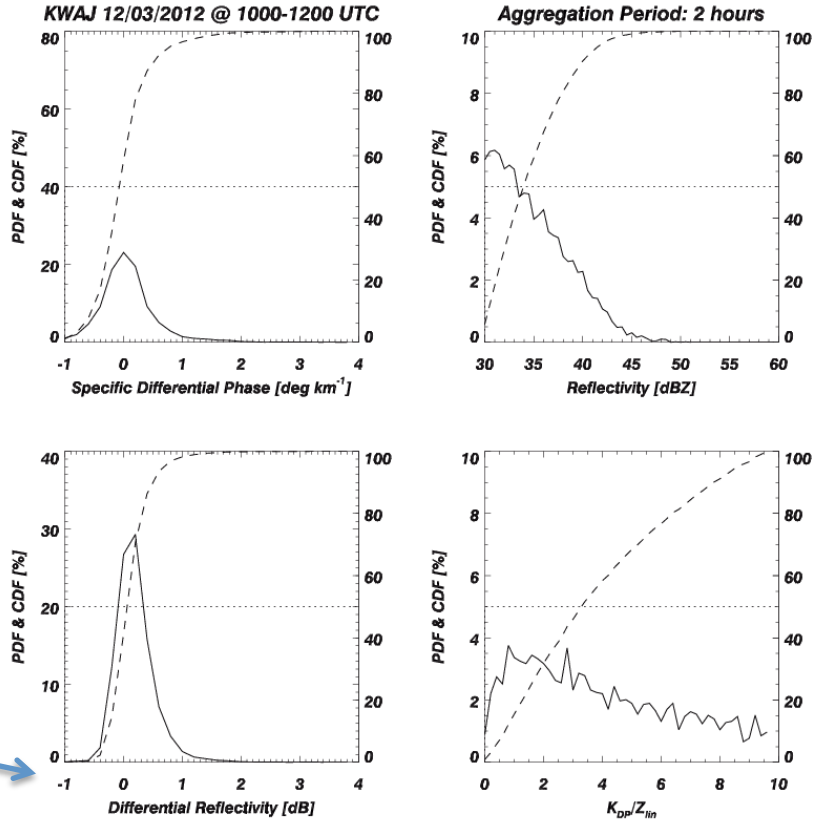
Isolated convective showers. Smaller drops, reduced LWC.

Both regimes show vertically oriented distributions characteristic of tropical regimes

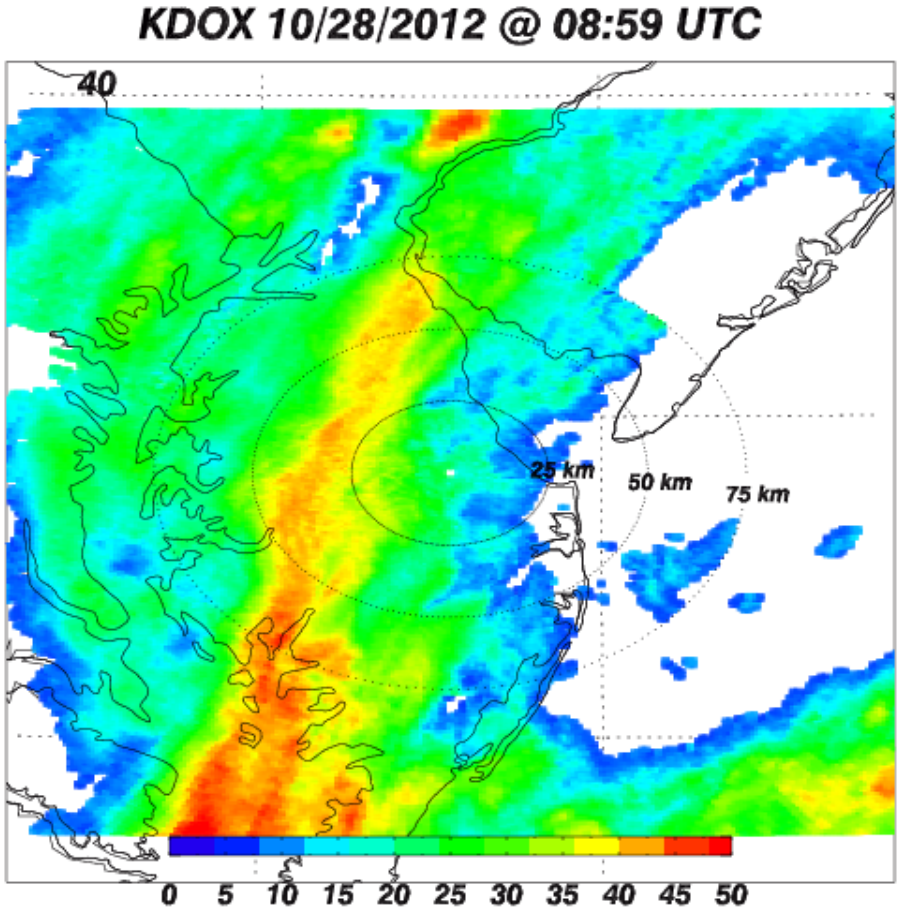
MCS regime

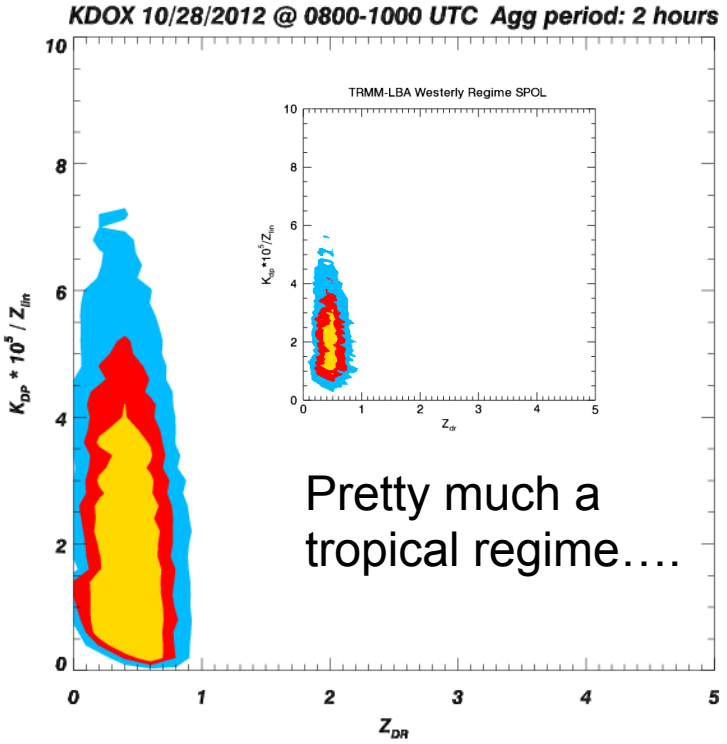


Trade Q regime

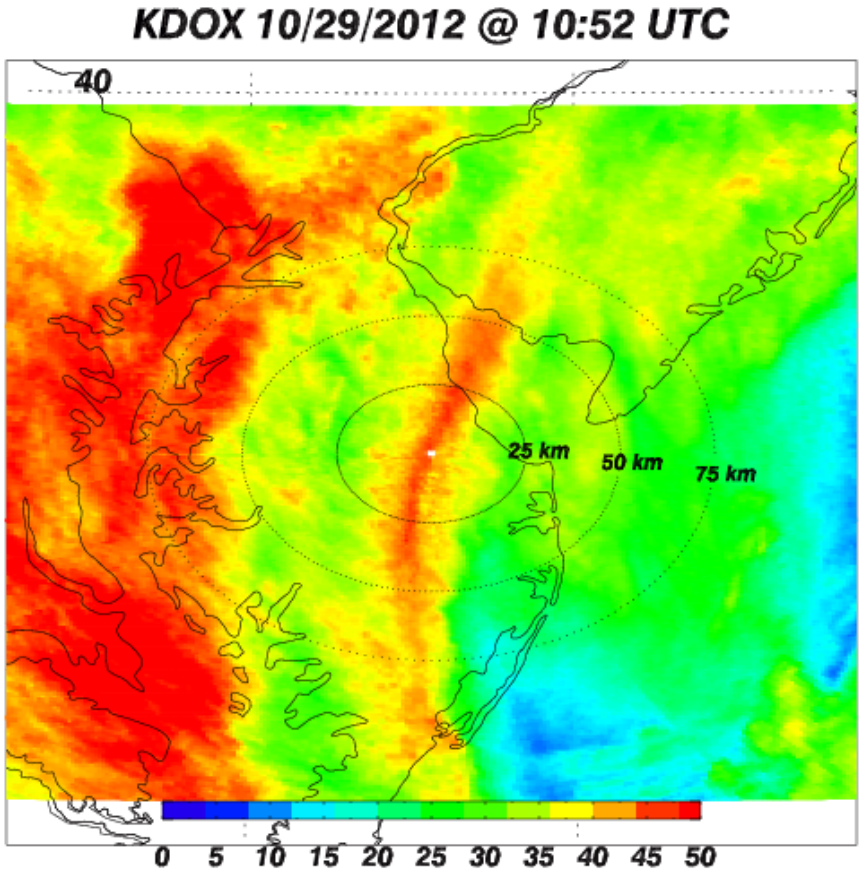


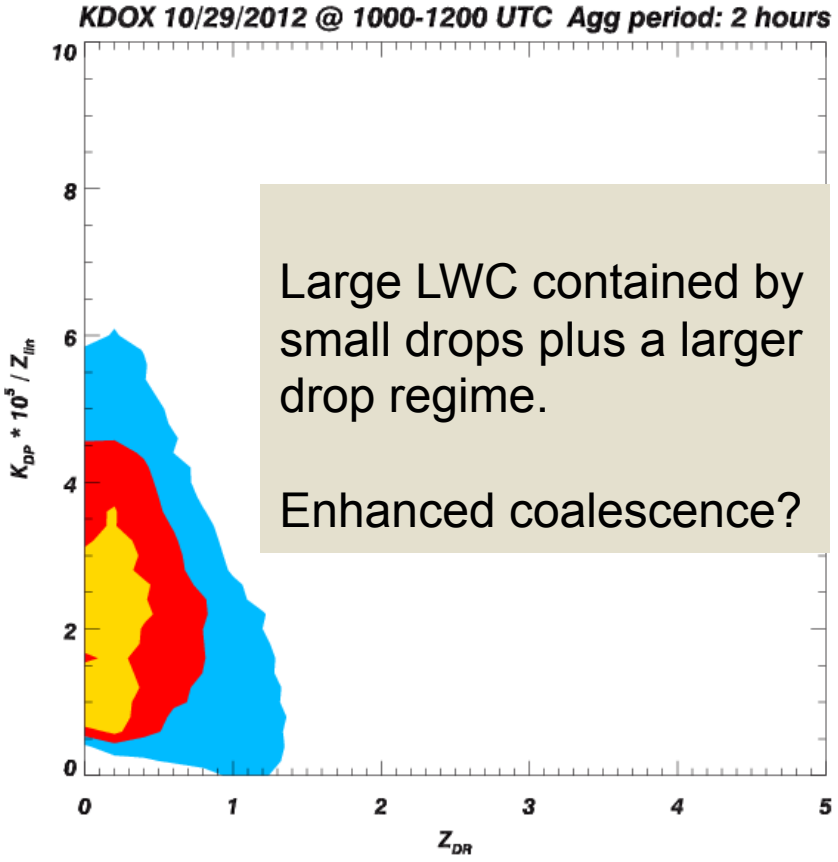
Snapshots of Hurricane Sandy in late October 2012…….





KDOX 10/28/2012: Merger of Sandy's outer bands with N/S oriented front. This confluence caused significant precipitation along the western shore of the Chesapeake Bay.



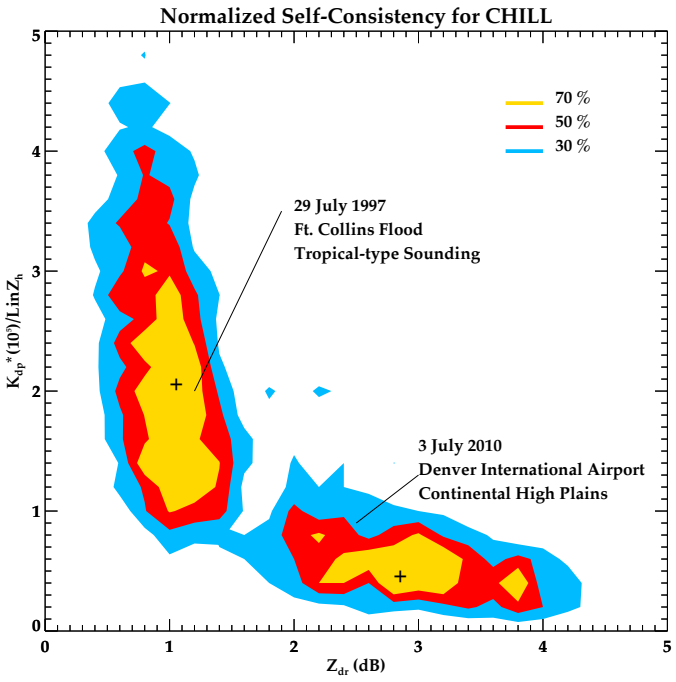


Large LWC contained by small drops plus a larger drop regime.

Enhanced coalescence?

KDOX 10/29/2012: Inner bands with eye approaching from the south and east. This period is where Wallops got the bulk of its nearly 10" of rain.

IMPLICATIONS FOR TRMM rain mapping

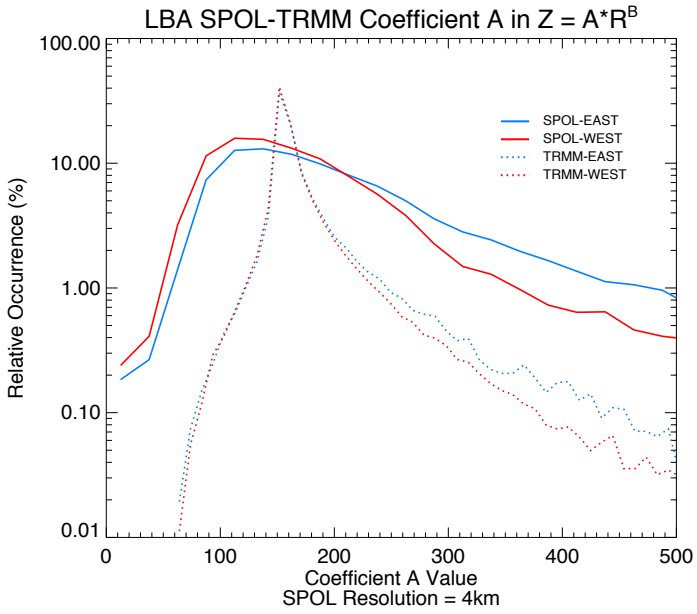


The precipitation physics revealed by these polarimetric data have a direct bearing on Z-R based rain estimation and Z based attenuation correction

Shift to upper left implies smaller “A” coefficient in $Z=AR^{b}$ and more rain for a given Z.

Shift to lower right implies larger “A” coefficient in $Z=AR^{b}$ and less rain for a given Z.

Have seen clear examples of these distinctive shifts…….



Kind of the crux of the matter…..

Comparison of A coefficient in $Z=AR^b$ between TRMM and those derived from S-pol polarimetric radar

Rain physics variability not well captured

With N_w and D_m calculations from GPM DPR rain estimates will be improved.

Ground based polarimetric radars can be used to provide high quality rain estimates to compare with GPM to identify when precipitation physics are well captured by GPM compared to times when they are not.