Initial Operating Capabilities of the Quantitative Precipitation Estimation in the Multi-Radar Multi-Sensor (MRMS) System

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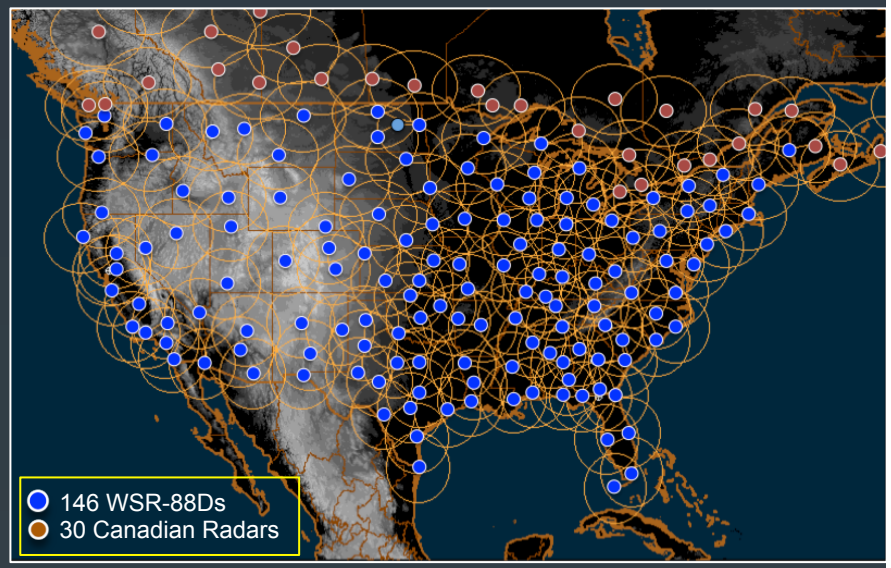
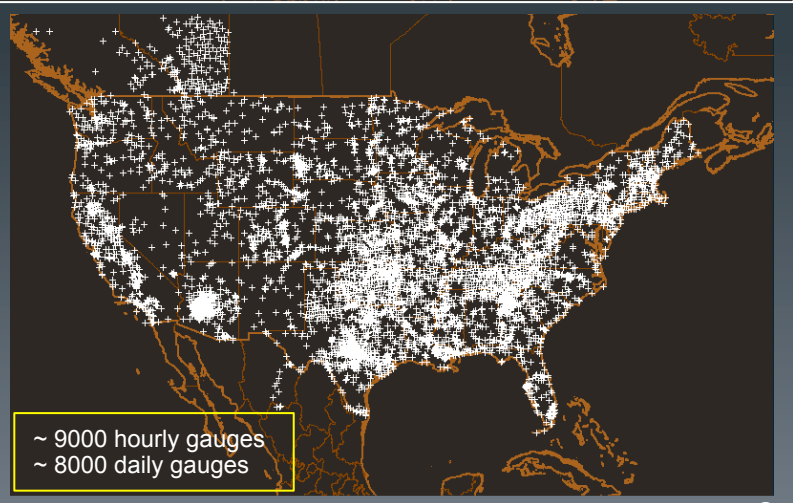
Overview of the MRMS System

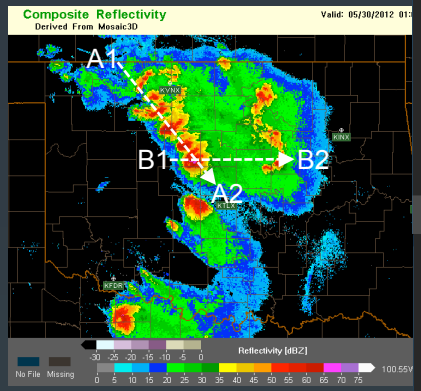
- Domain: 20-55°N, 130-60°W
- Resolution
  - 0.01°lat x 0.01°long
  - 2 min update cycle
- Data Sources
  - ~180 radars every 4-5min
  - ~9000 gauges every hour
  - RAP model hourly 3D analyses
  - Satellite and lightning: optional
- System Locations
  - National Severe Storms Lab (Norman, OK); 2006
  - William J. Hughes Technical Center (Atlantic City, NJ); 2010
  - NCEP Central Operations (NCO): Oct. 2014
    - Also FLASH (*Flooded Locations And Simulated Hydrographs Project*)

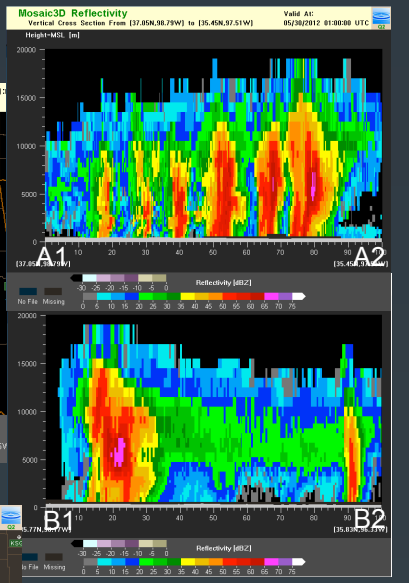


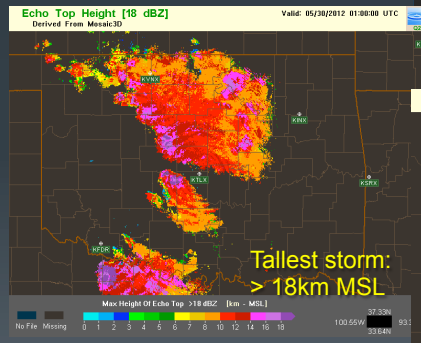


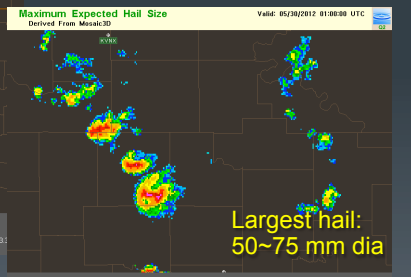
Initial Operating Capabilities – Severe Weather

- Key *Severe Weather* Products
  - Composite Reflectivity
  - 3D Reflectivity Mosaic
  - Storm Top Heights
  - Max Expected Hail Size
  - Hail Swath
  - Storm Rotation Tracks
  - …

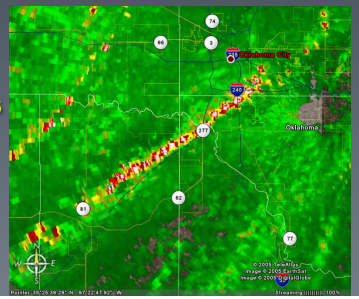




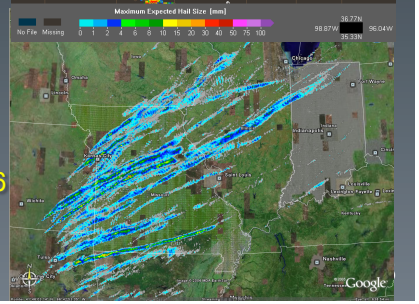




Storm Rotation Tracks
3 May 1999
(Moore, OK Tornado outbreak)

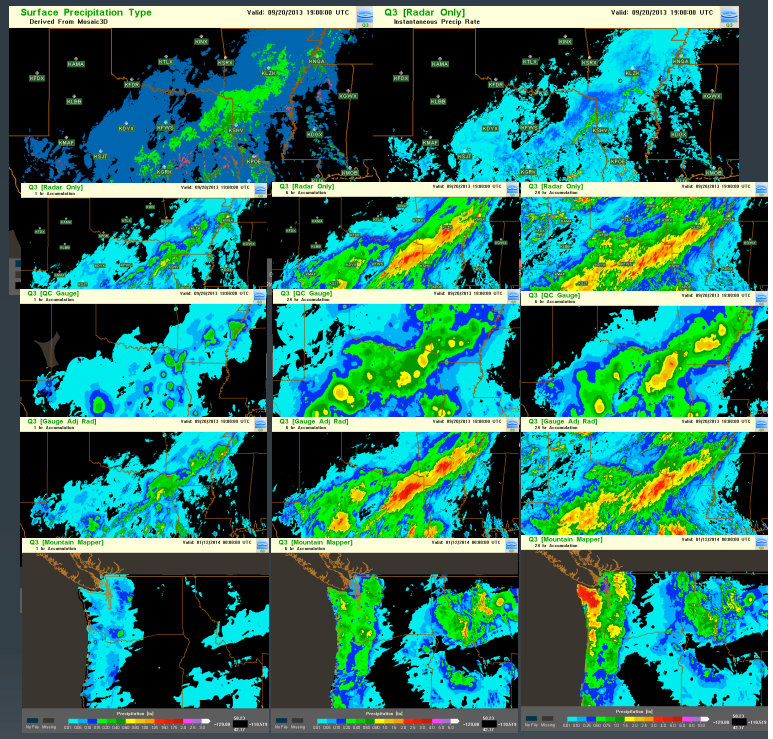


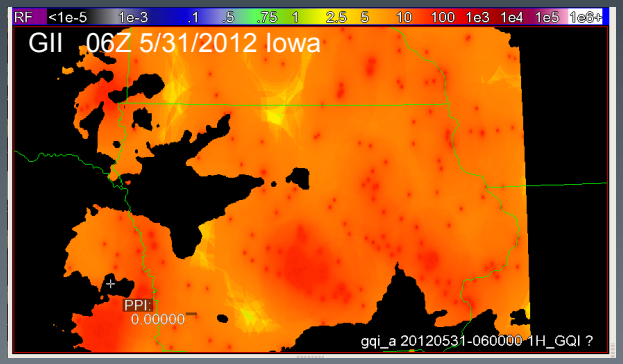
Hail Swath
12-13 Mar 2006
(MO Tornado outbreak)

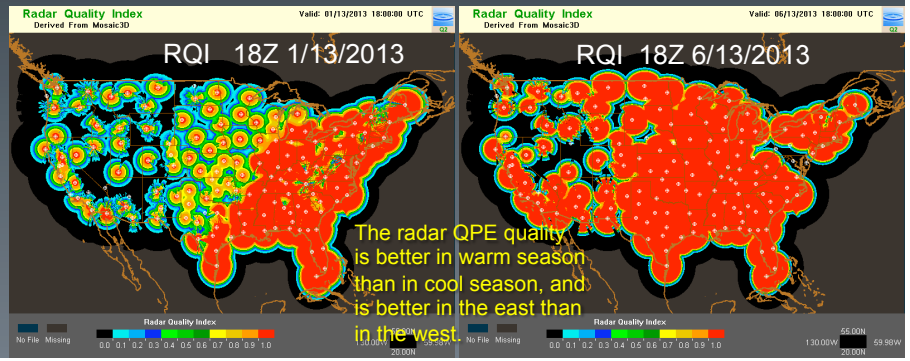


Initial Operating Capabilities – QPE

- Key *QPE* Products
  - Surface Precip Type
  - Surface Precip Rate
  - Radar QPE (1, 6, 24, 48, 72h, 10day acc)
  - Gauge QPE
  - Local gauge bias corrected radar QPE
  - Gauge + orographic pcp climatology QPE
  - Radar QPE Quality Index (RQI)
  - Gauge Influence Index (GII)





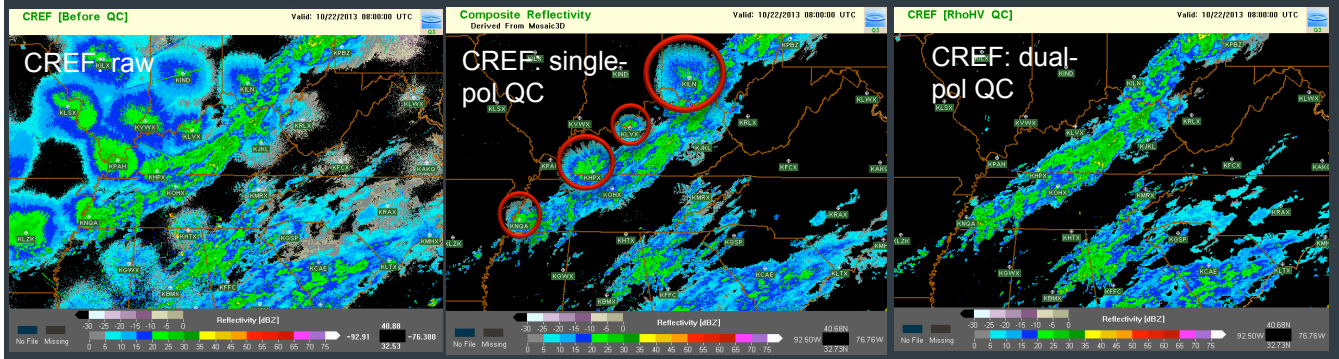


MRMS QPE Processes

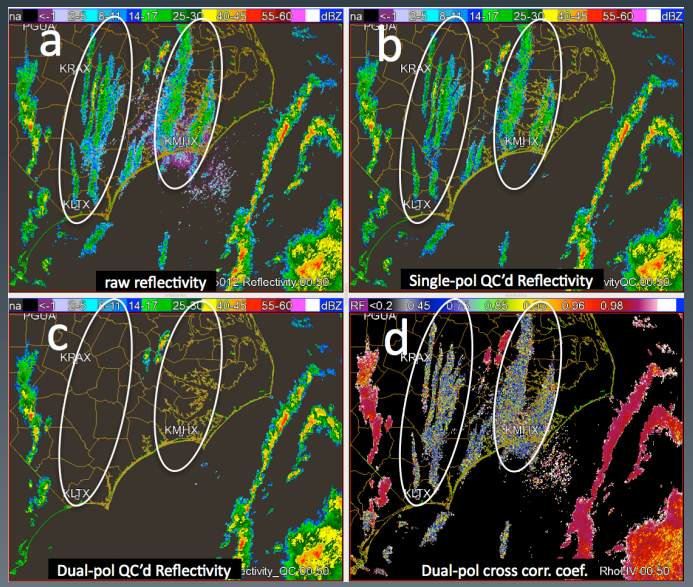
- Polarimetric radar data quality control
  - To remove non-precipitation echoes in radar data
- Multi-sensor surface precipitation classification
  - For automated selections of a R[Z] (R[Z, Z_{DR}], R[K_{DP}]) relationship that is most suited for the precipitation regime
- Non-standard blockage mitigation
  - To mitigate discontinuities in the radar QPE due to man-made towers or growing trees.
- Vertical profile of reflectivity correction
  - To correct for the range-dependent errors in the radar QPE (e.g., overestimation in the bright band)
- Multi-sensor gauge quality control
  - To identify bad gauges based on the radar QPE

Dual-pol Radar QC Advantages

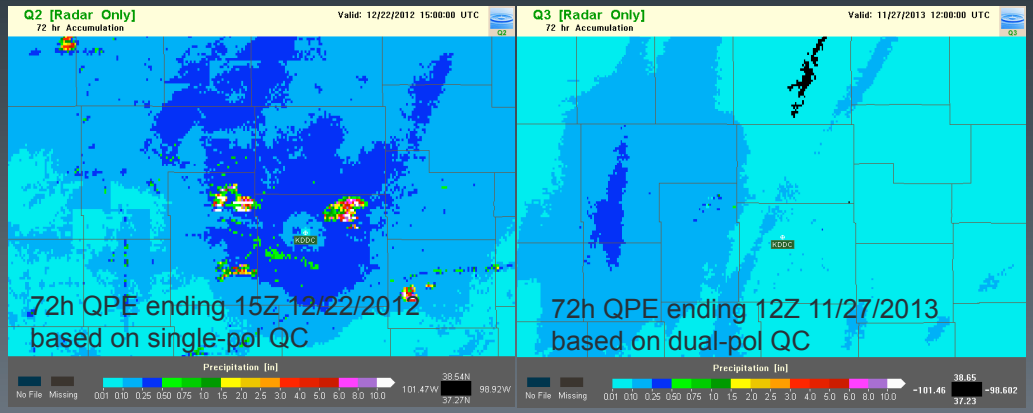
Biological echoes (“blooms”)/AP



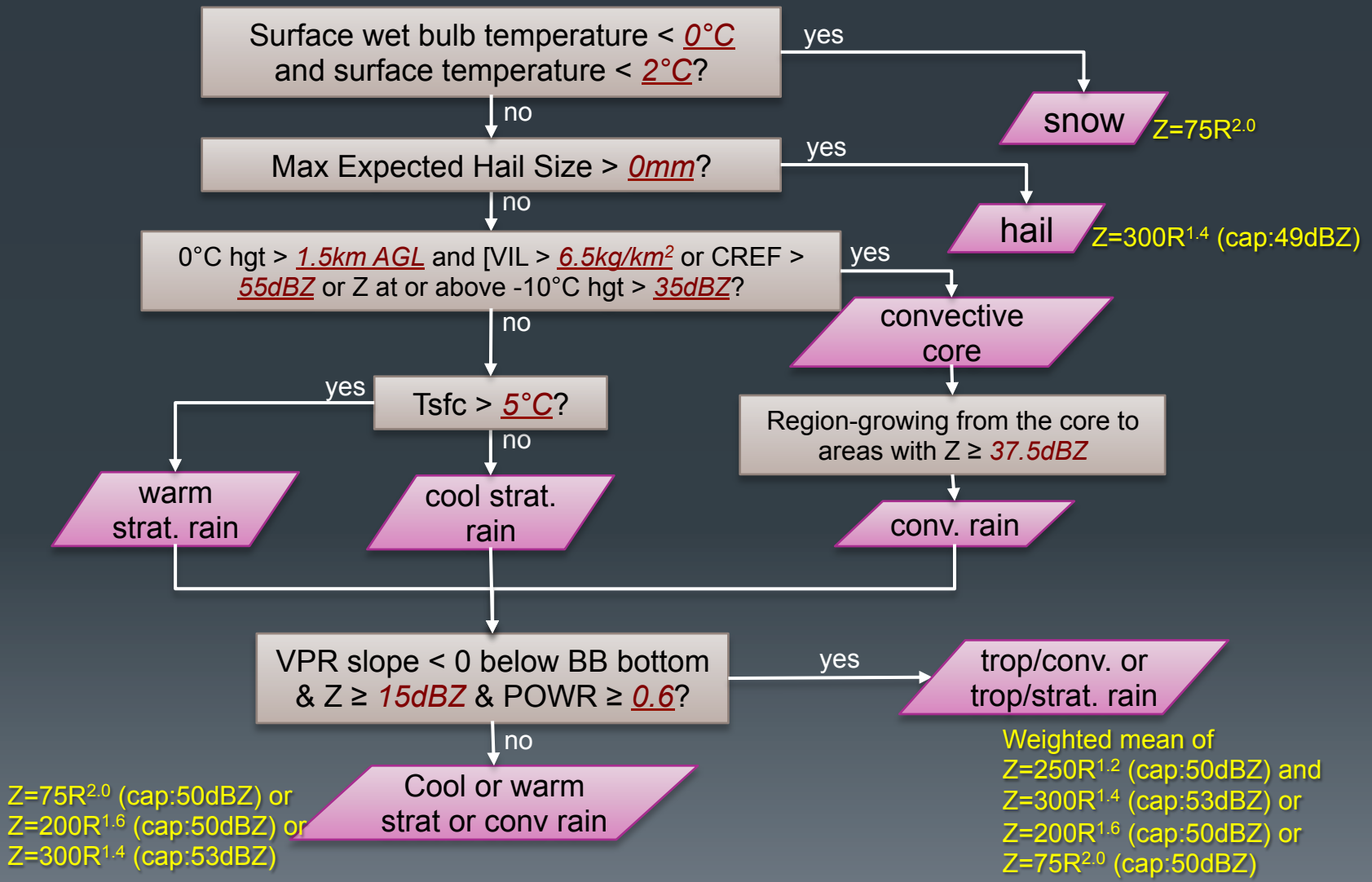
Chaff



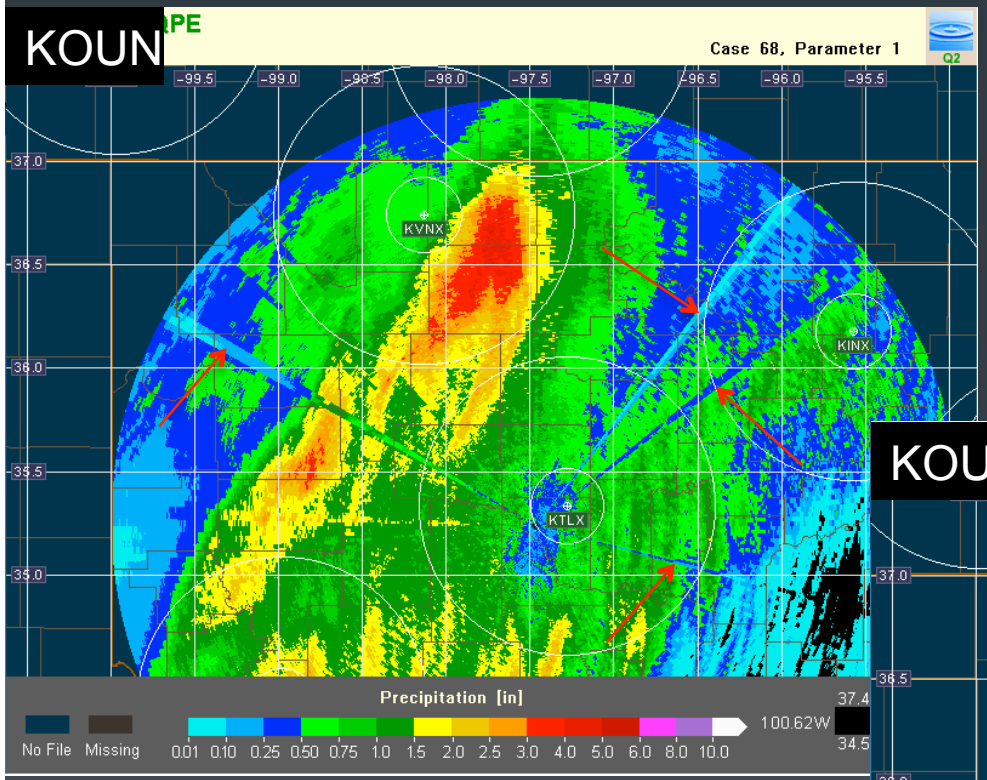
Wind farms



Surface Precipitation Classification



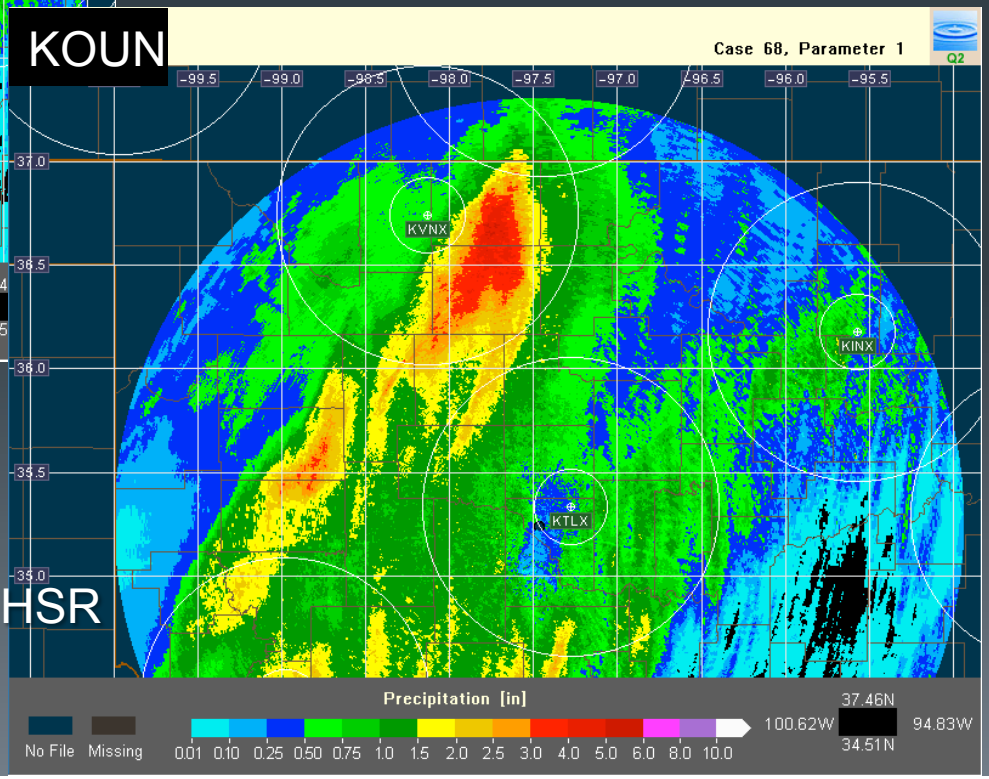
Non-standard blockage mitigation



Standard HSR

Left: Radar QPE from the standard hybrid scan reflectivity shows blockages from man-made towers.

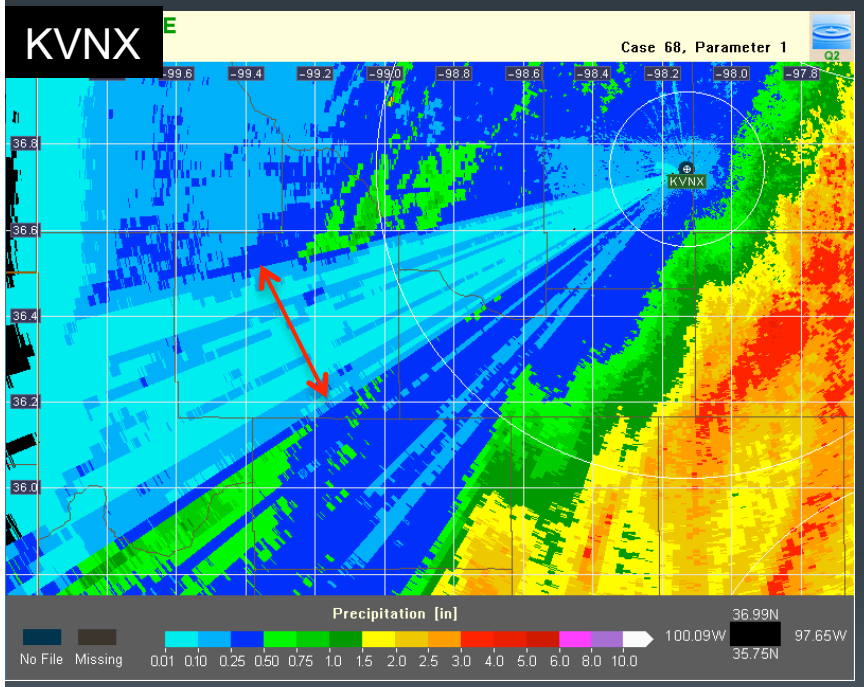
Below: Interpolation across small gaps of non-standard blockages produced a continuous rainfall field.



"Seamless" HSR

Non-standard blockage mitigation

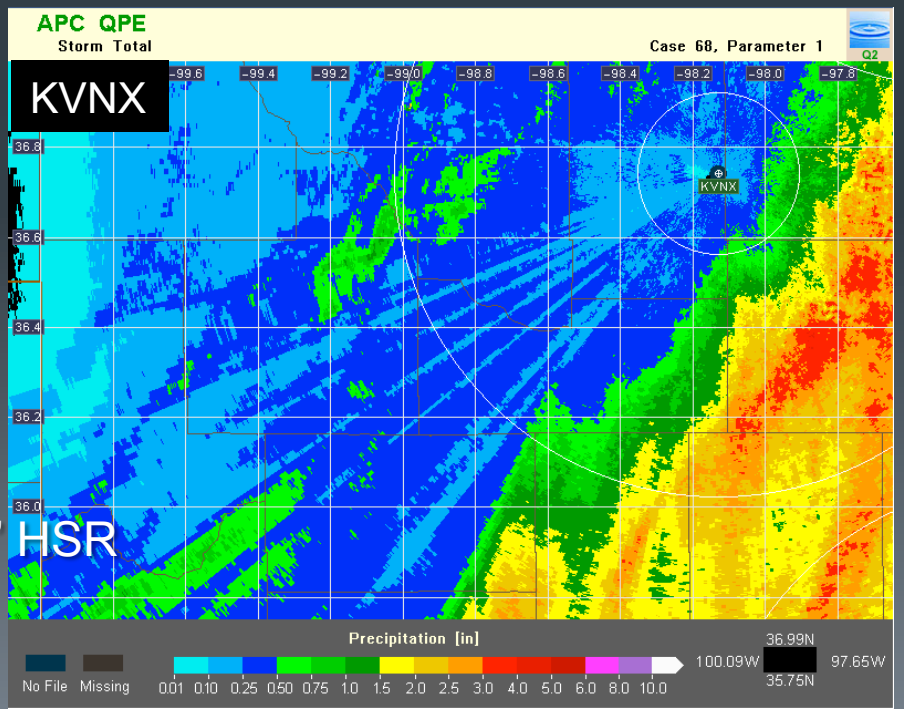
Standard HSR



KVNX:

Left: Large gaps in the radar QPE due to growing trees.

Right: Filling in the large gaps with upper tilt data improved the continuity.

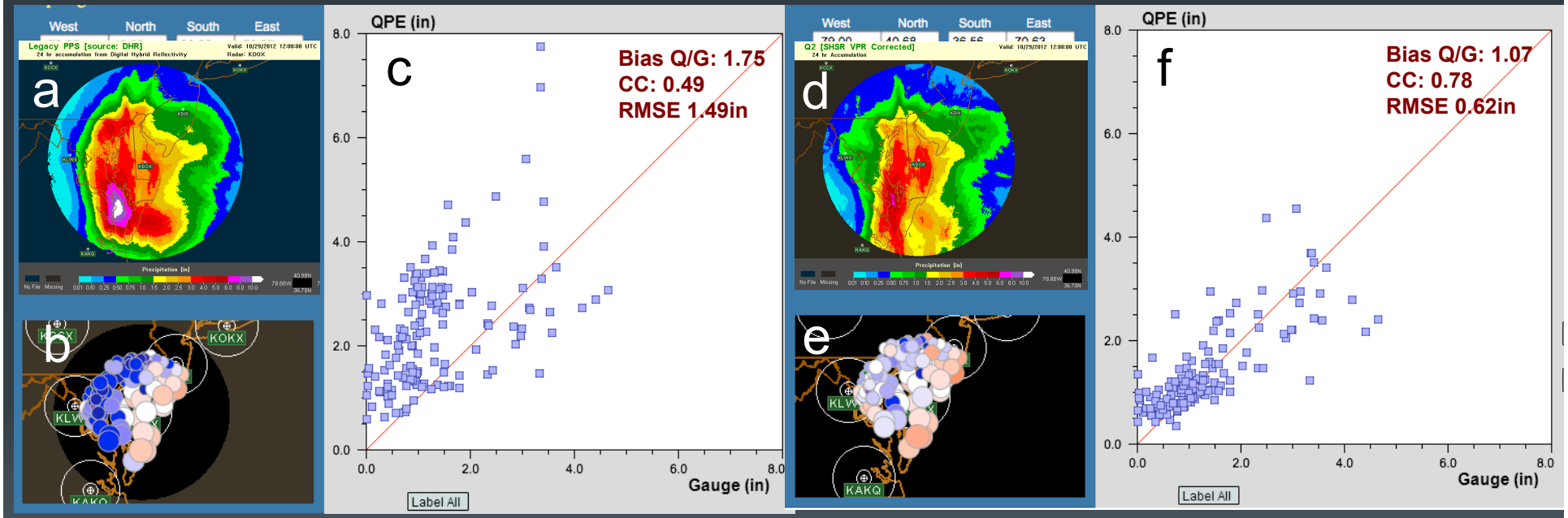


"Seamless" HSR

Radar QPEs Before & After the VPR Correction

Before

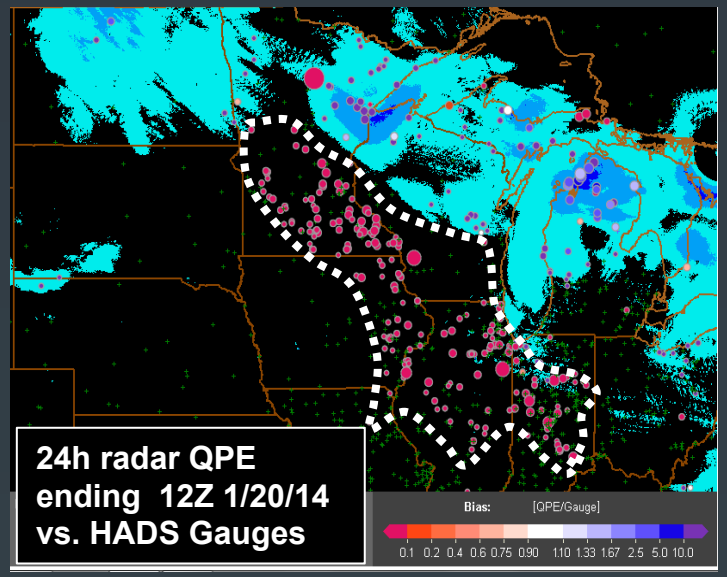
After



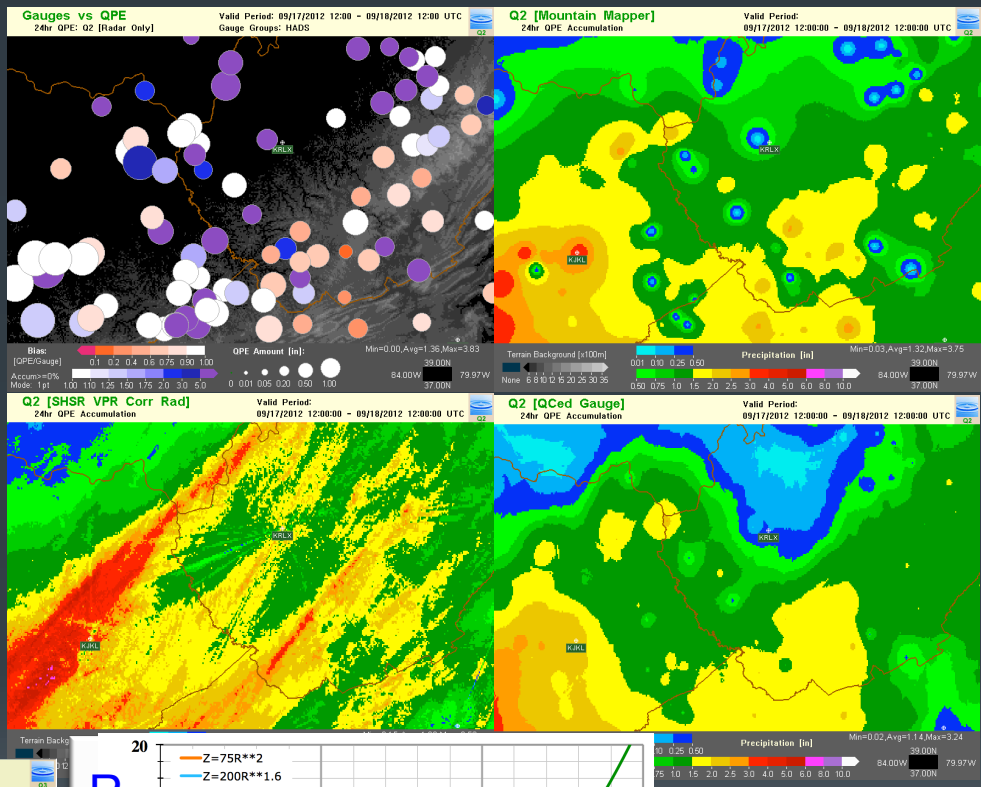
KDOX 24h QPE ending 12Z 10/29/12

Multi-Sensor Gauge QC

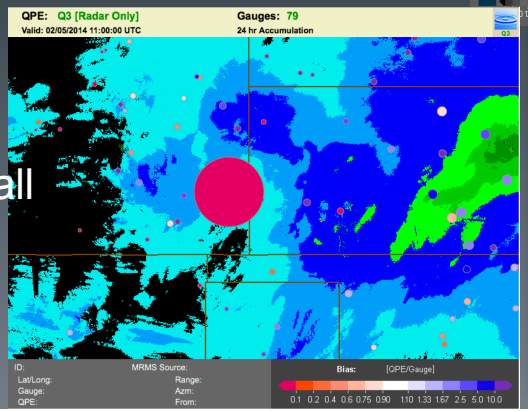
Gauges reporting false precip

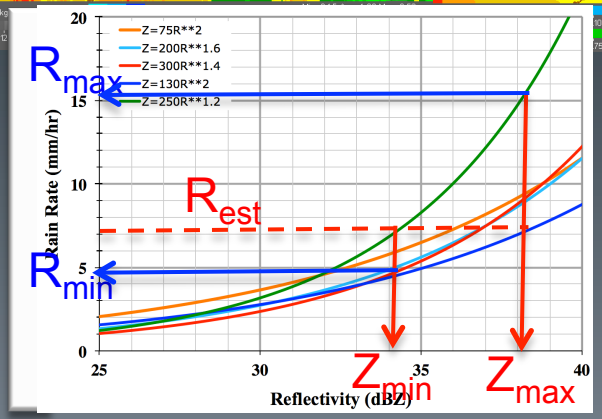


Gauges reporting false "0"



Gauges reporting unrealistic large/small values





Summary

- MRMS is a real-time system that produces a suite of advanced severe weather and QPE products on CONUS at 1 km resolution and 2 min update cycle.
- MRMS will be transitioned into the NWS operations in Oct. 2014.
- The research MRMS system at NSSL serves as a real-time testbed for new technologies and facilitates rapid science to operations transfers of the new technologies.
- *Real-time MRMS product display and verification page: mrms.ou.edu*

Thanks!

Contact: *jian.zhang@noaa.gov*

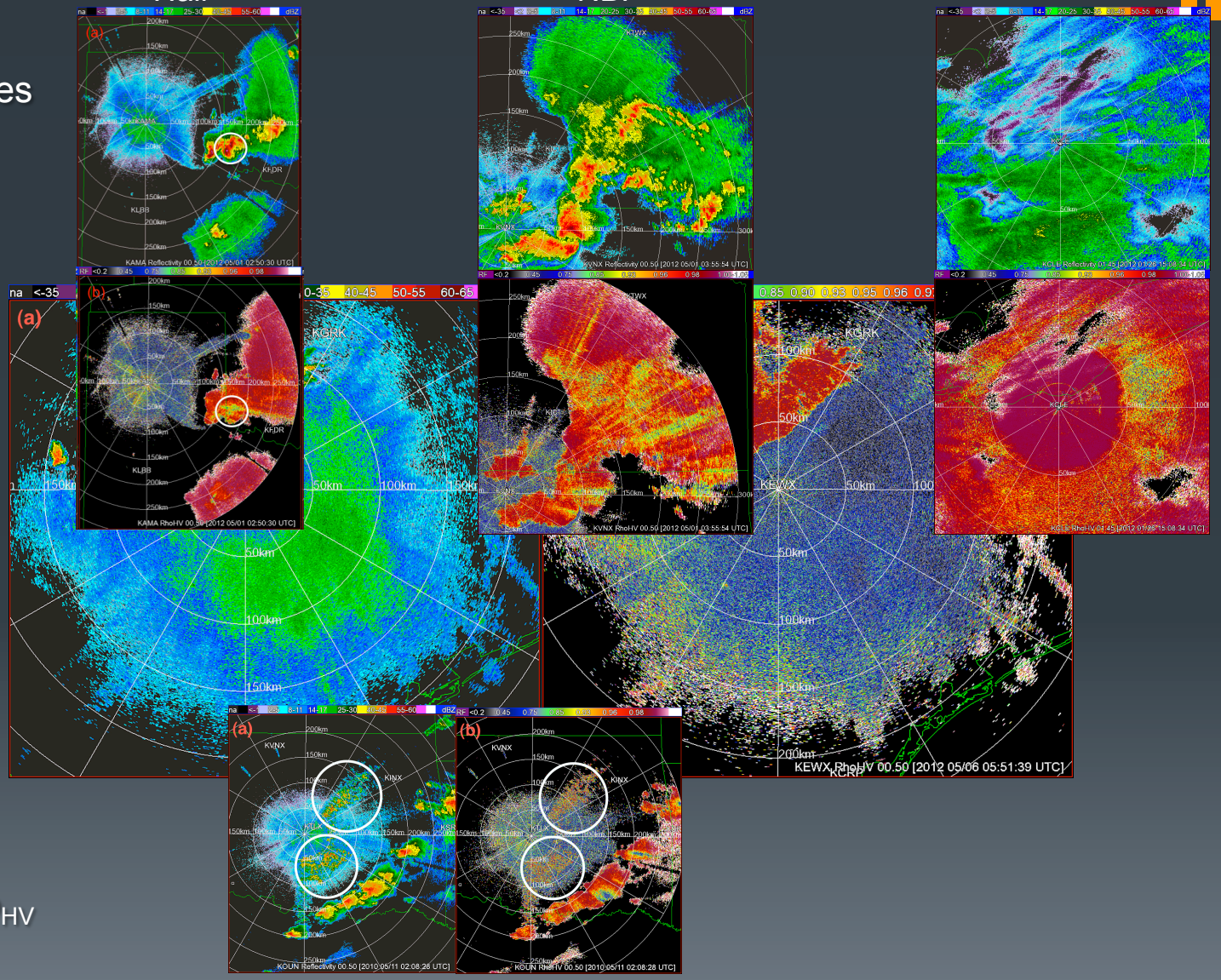
Backup Slides

dpQC: Basic Theories

Hail NBF ML

Precipitation echoes with low ρ_{HV}

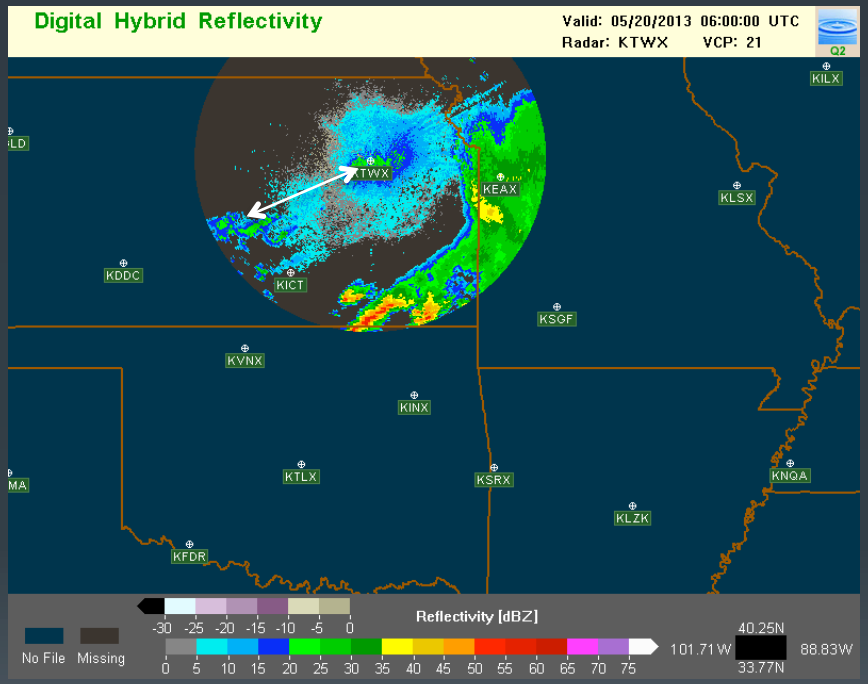
Generally,
Precipition:
High ρ_{HV}
Non-Precipition:
Low ρ_{HV}

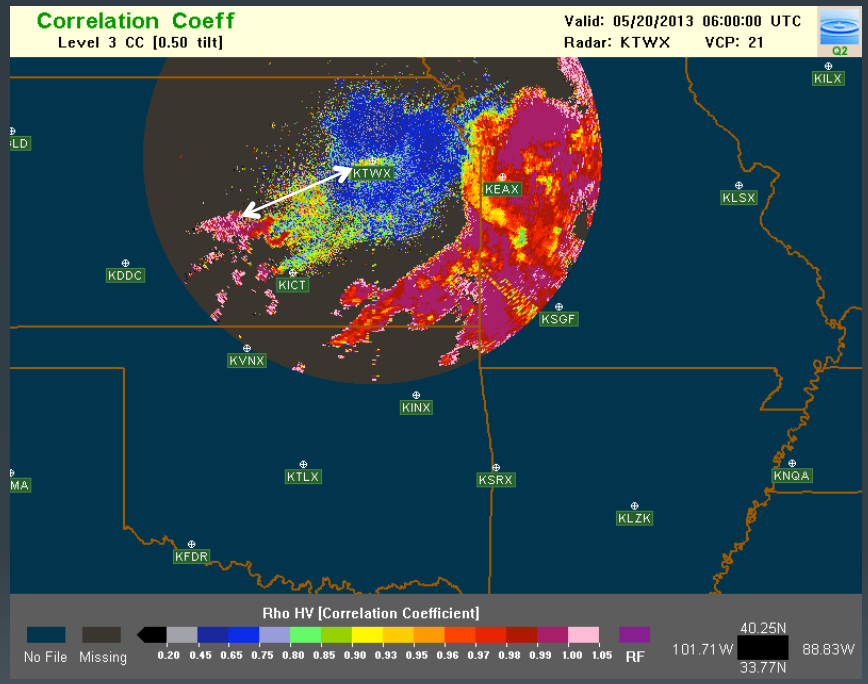


Non-Precipitation echoes with high ρ_{HV}

AP

Precipitation vs. Non-Precipitation: Radar Obs

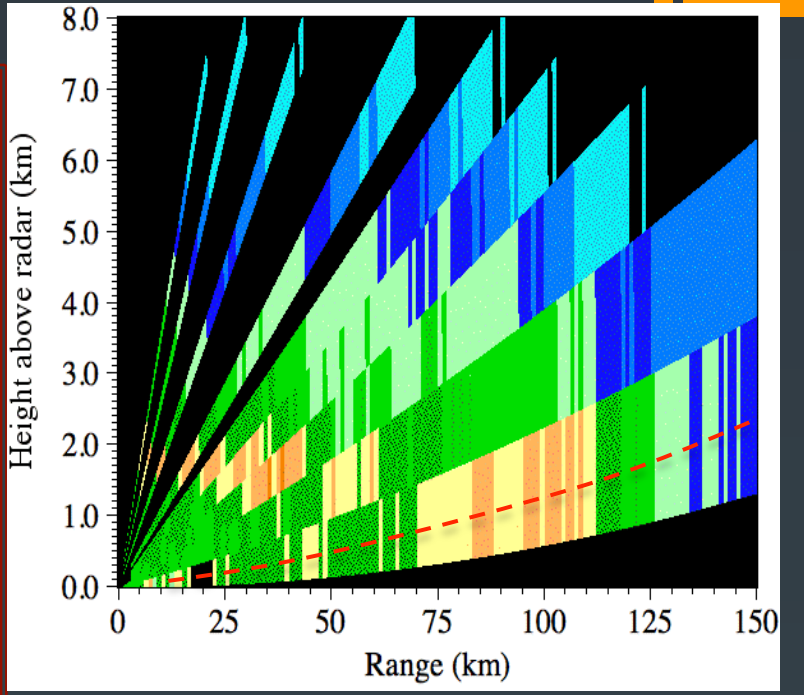


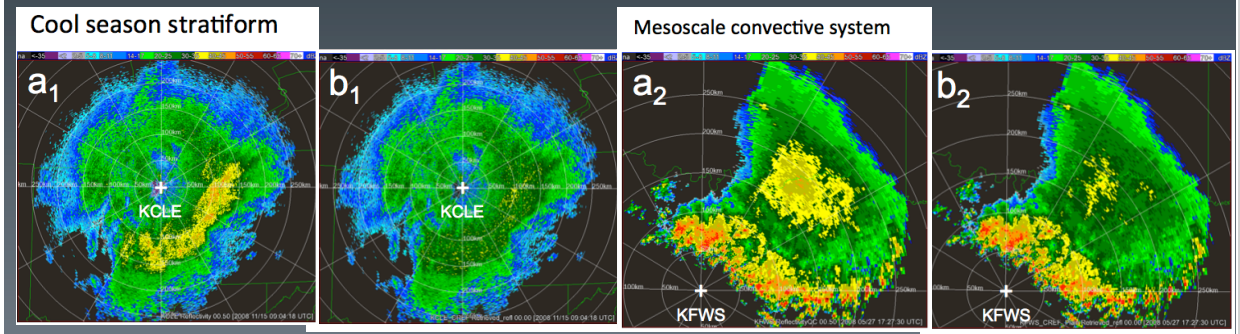


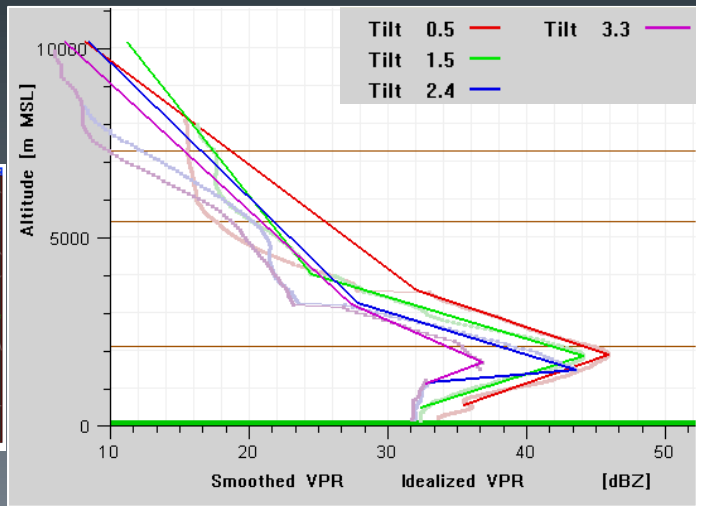
Polarimetric radar observations (ρ_{HV}) shows distinctively different characteristics of precipitation and non-precipitation echoes, while the single-pol data do not.

AVPR Correction

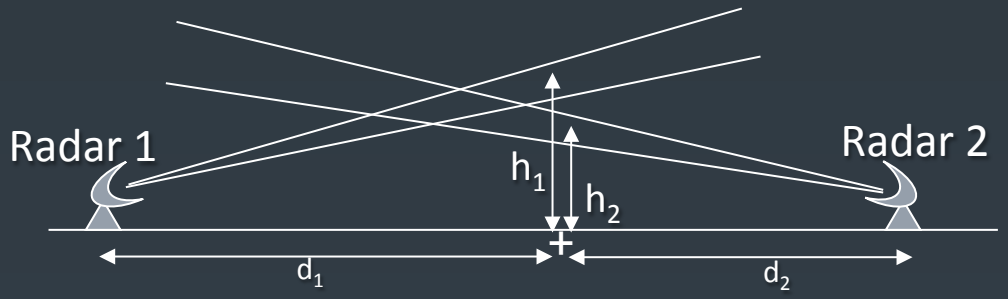
- Brightband (BB) areas are delineated based on 1) close proximity to the freezing level; 2) high reflectivity; 3) low ρ_{HV}; and 4) high Z_{DR}.
- An **Apparent Vertical Profile of Reflectivity** is computed by taking azimuthal mean of reflectivities in **non-convective** areas in a tilt, and then fit a 3-piece linear model.
- The differences between the mean reflectivity at the BB bottom and those above in the AVPR are considered "biases" that would cause range-dependent radar QPE errors.







Seamless HSR Mosaic Experiments



"Nearest Neighbor":

– Using the *lowest (height) single radar HSR* observation.

General Weighted Mean:

– Taking average of the multiple radars HSRs:

$$SHSRm = \frac{\sum_i w_L^i \bullet w_H^i \bullet SHSRs^i}{\sum_i w_L^i \bullet w_H^i}$$

$$W_L = \exp\left(-d^2 / L^2\right); \quad L = 100km$$

$$W_H = \exp\left(-h^2 / H^2\right); \quad H = 2km$$

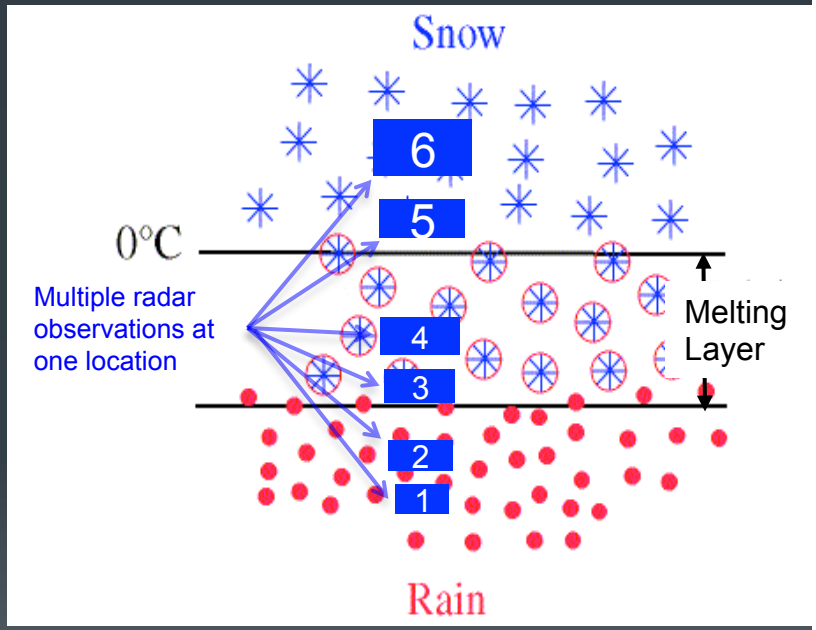
Hydrometeor Phase Based Weighted Mean:

– if the lowest SHSR shows no precip, then set the SHSR mosaic as "no precip"

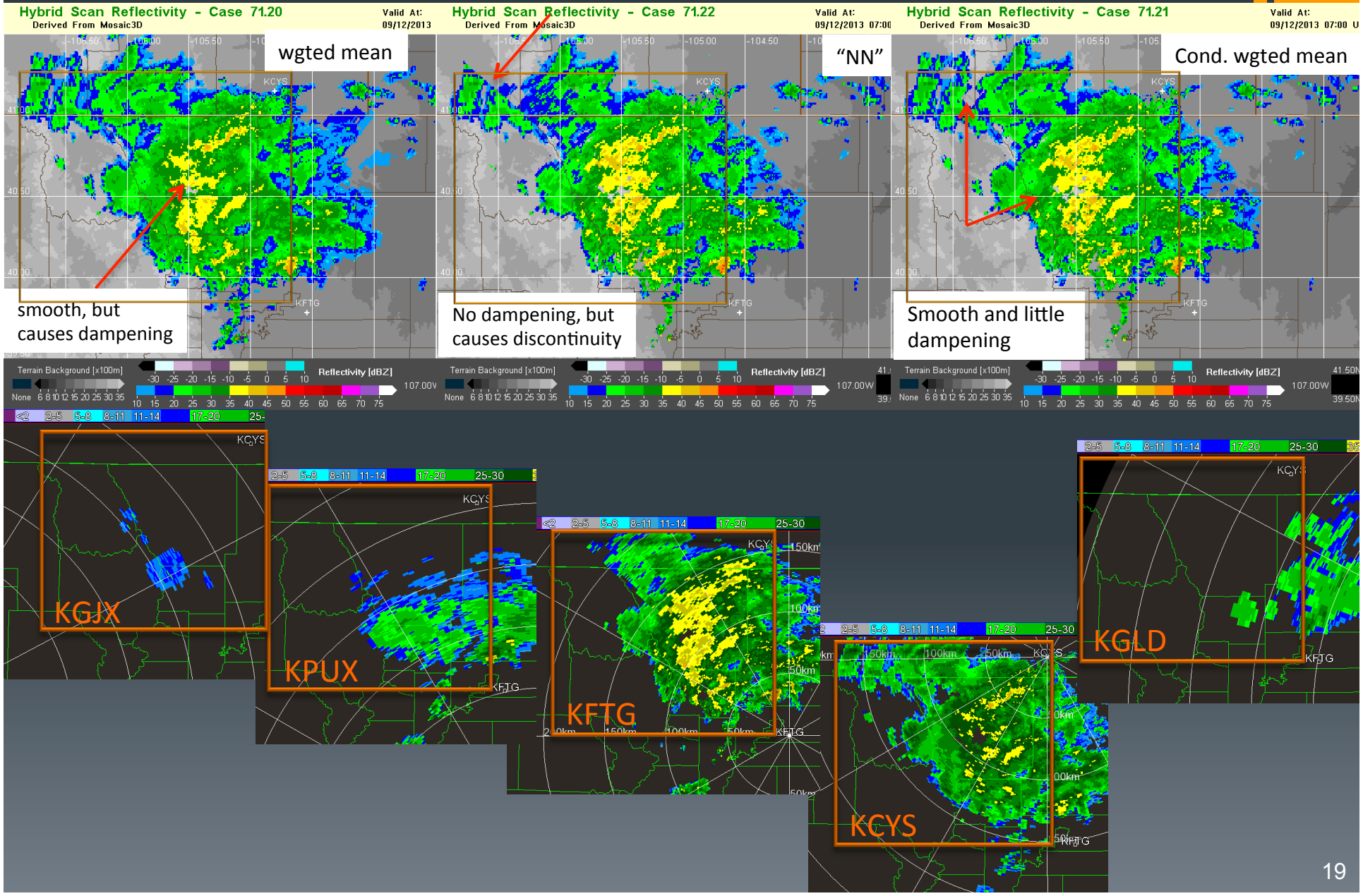
– If one or more SHSRs *below the ML*: take the weighted mean

– Else: if one or more SHSRs *within the ML*: take the weighted mean

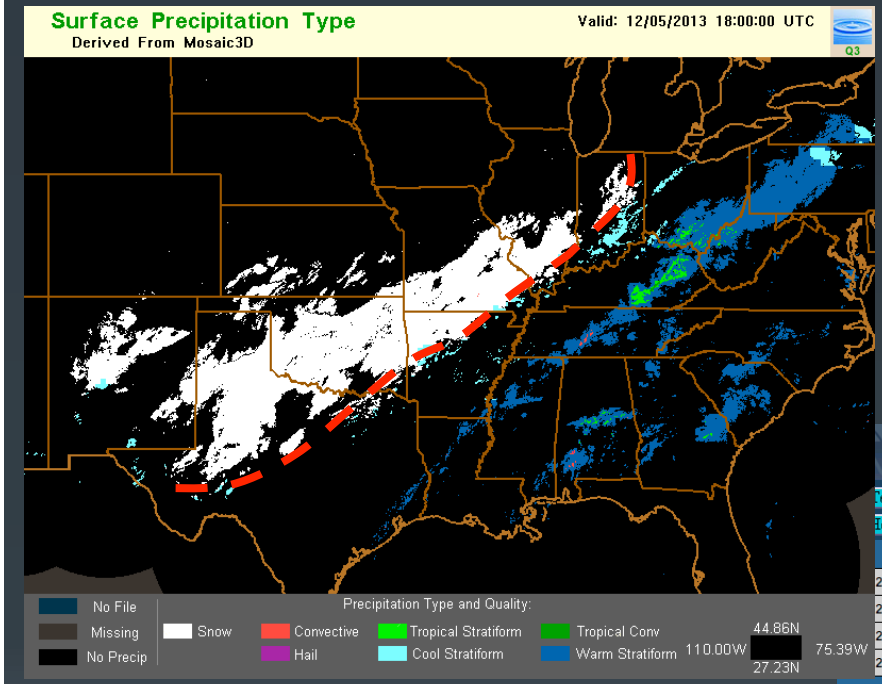
– Else: if one or more SHSRs *above the ML*: take the weighted mean



Seamless HSR Mosaic Experiments

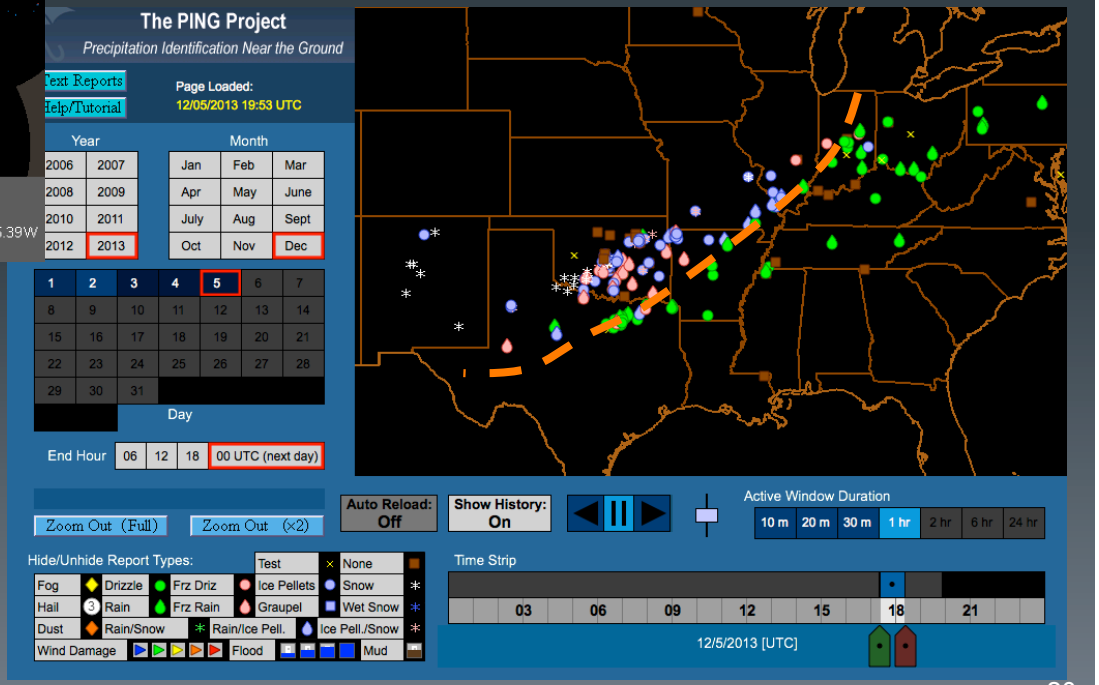


Surface Precipitation Classification: Rain/Snow Line

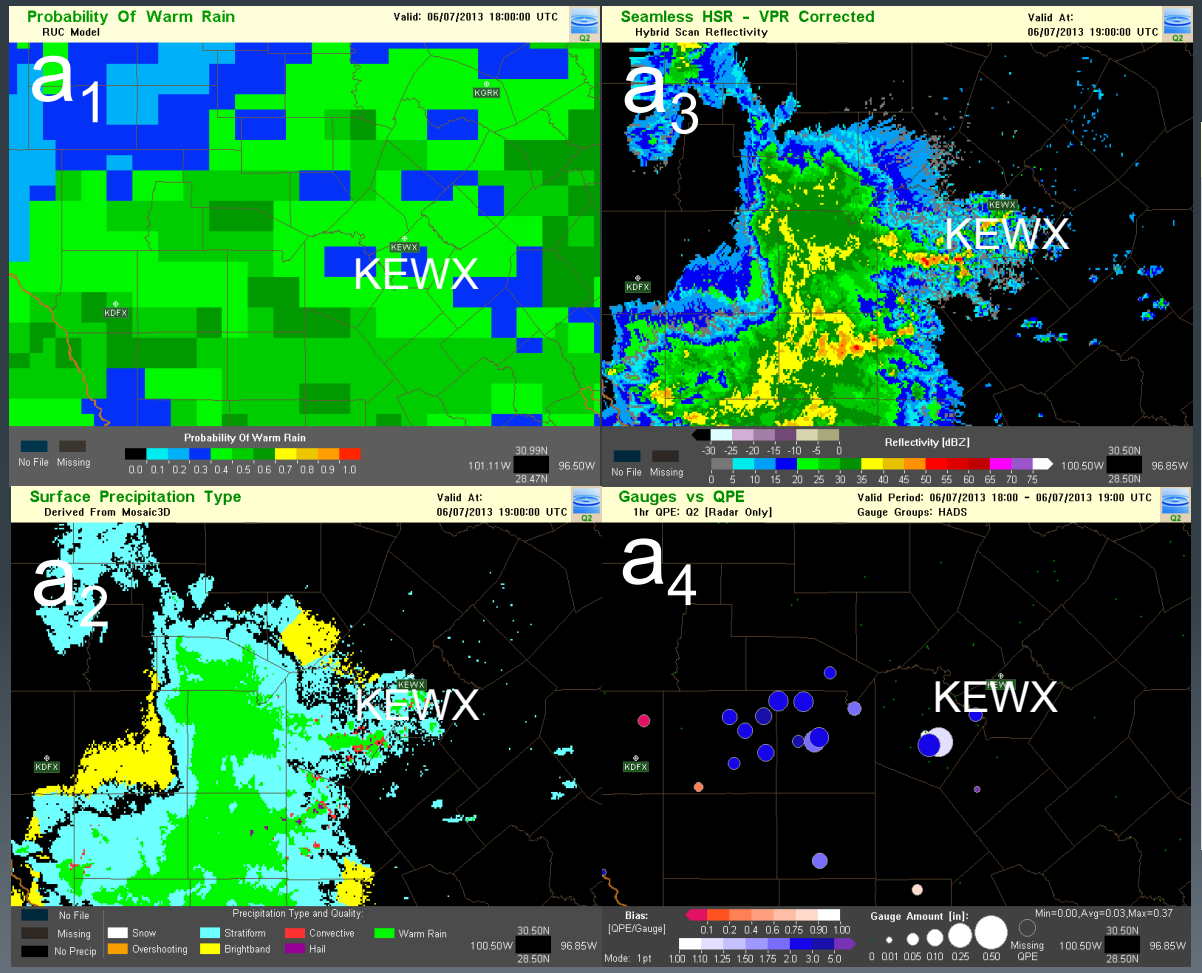


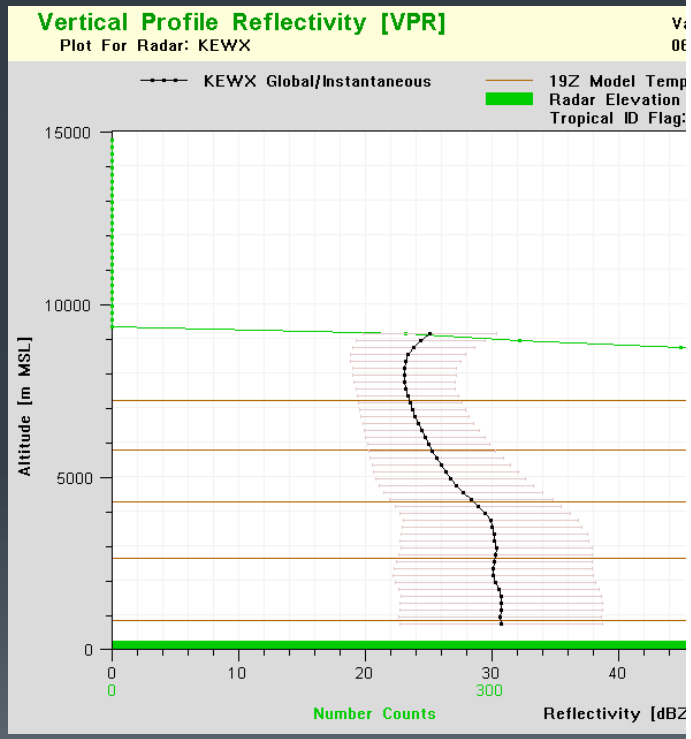
MRMS rain/snow line

mPING rain/snow line

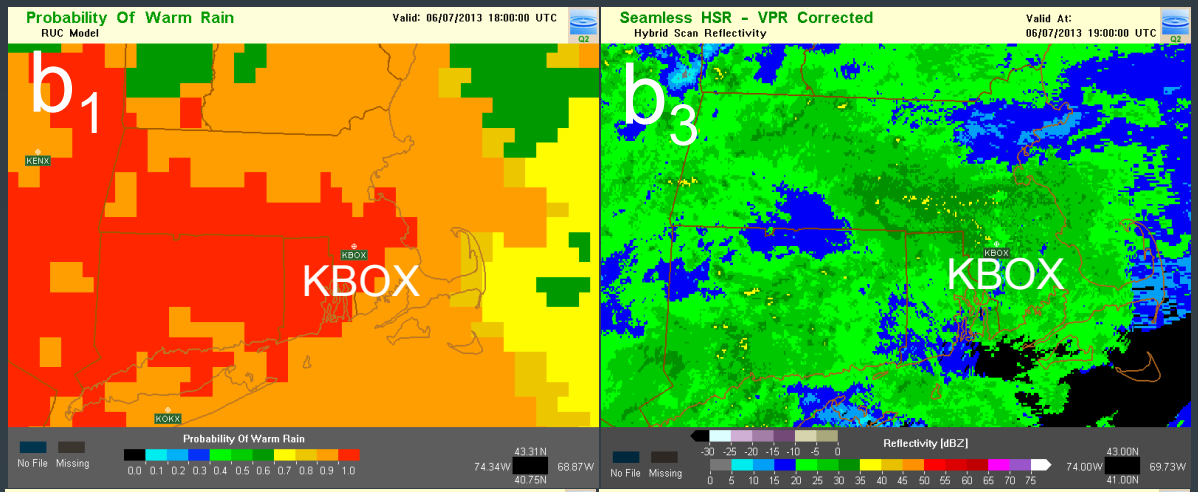


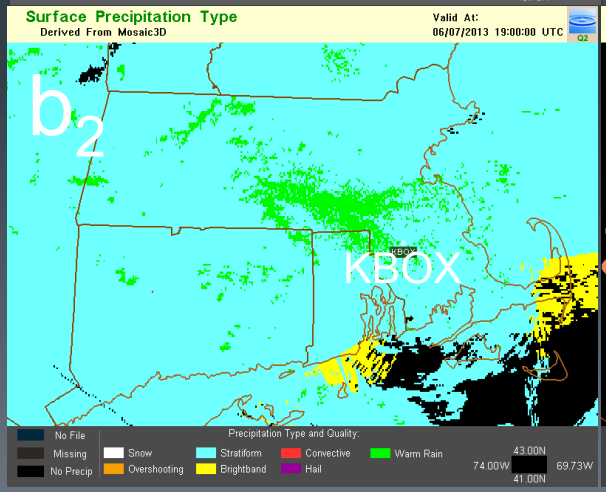
Surface Precipitation Classification: Mesoscale Convective System

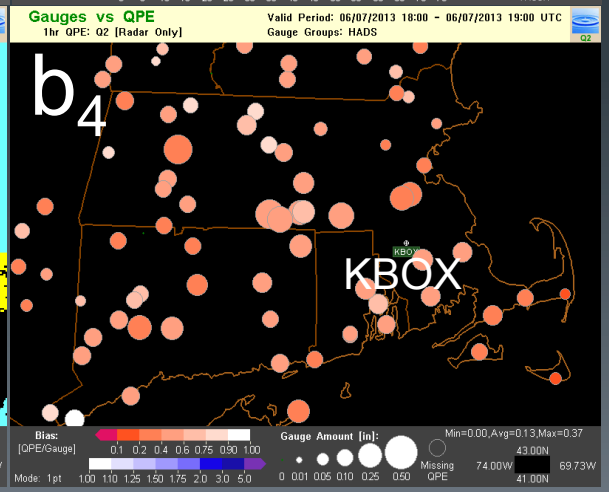


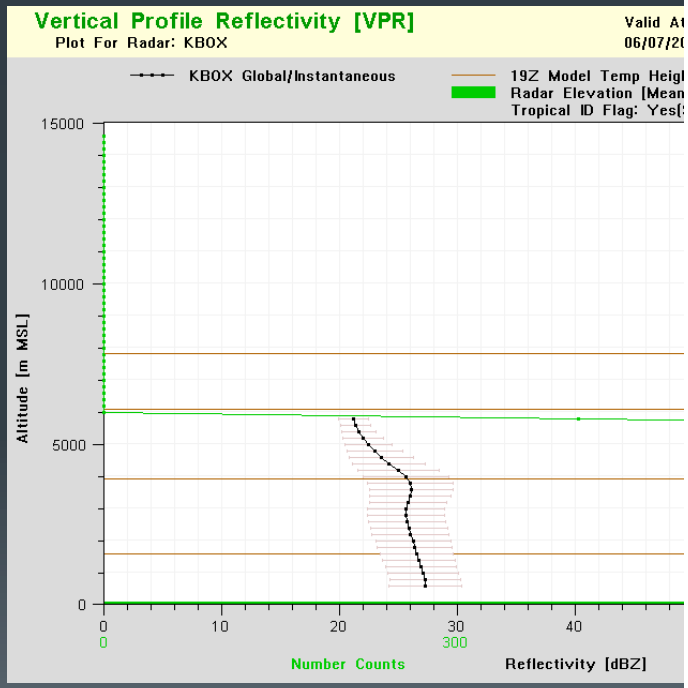


Surface Precipitation Classification: Tropical Storm









Radar Precipitation Rate

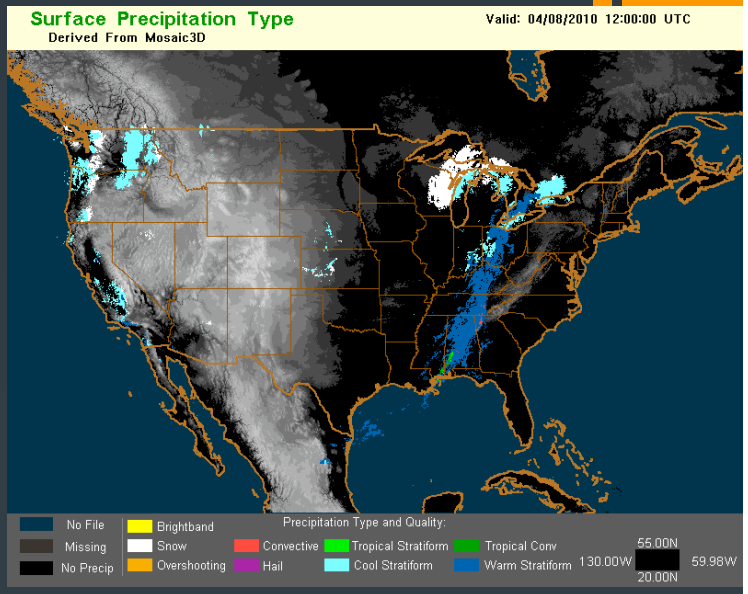
The MRMS radar precipitation rate is computed from the mosaicked *hybrid scan reflectivity* field using different Z-R relationships:

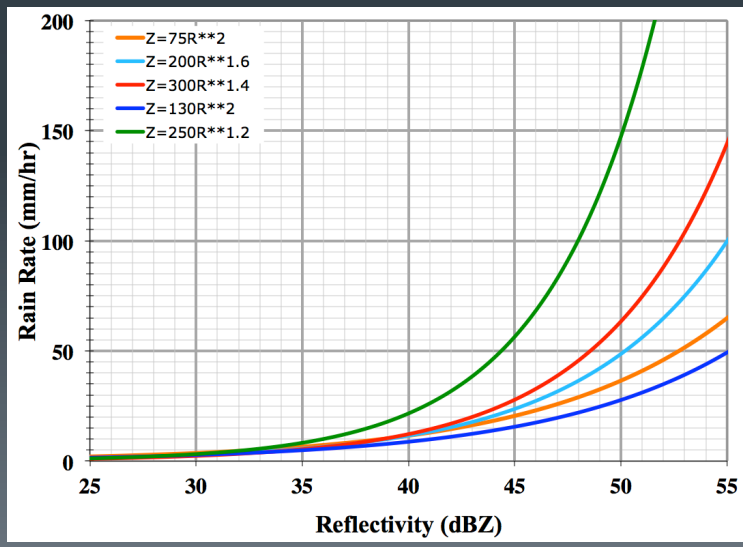
- Warm stratiform rain: $Z=200R^{1.6}$ (cap: *50dBZ*)
- Cool stratiform rain: $Z=130R^{2.0}$ (cap: *50dBZ*)
- Convective rain: $Z=300R^{1.4}$ (cap: *53dBZ*)
- Hail: $Z=300R^{1.4}$ (cap: *49dBZ*)
- Snow: rain: $Z=75R^{2.0}$ (no cap)
- Tropical: $Z=250R^{1.2}$ (cap: *50dBZ*)

$$R = \frac{w_{stra}R_{stra}(w_{conv}R_{conv}) + \alpha \cdot w_{trop}R_{trop}}{w_{stra}(w_{conv}) + w_{trop}}$$

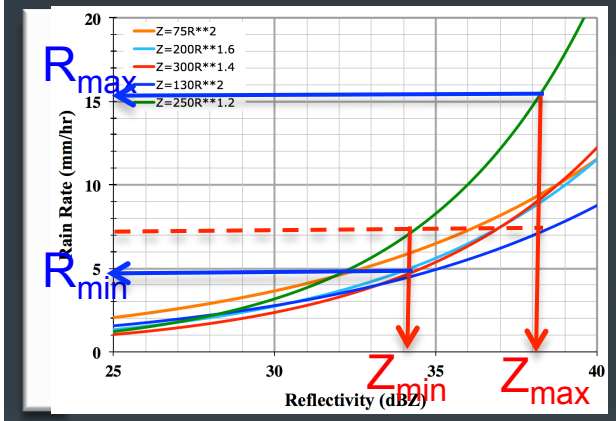
$0 \le w_{stra}\ (w_{conv},\ w_{trop}) \le 1$

$1 \le \alpha \le 1.5$





Multi-Sensor Gauge QC



RQI > *0.5*?

yes

Radar 1hr QPE ≥ *0.01in*

yes → Gauge obs = 0?

yes → stuck gauge

no

Radar 1hr QPE = 0?

yes → Gauge obs > 0?

no → False precip report

no

Convert radar 1hr QPE to Z_{min} and Z_{max}

Convert Z_{min}/Z_{max} to R_{min}/R_{max}

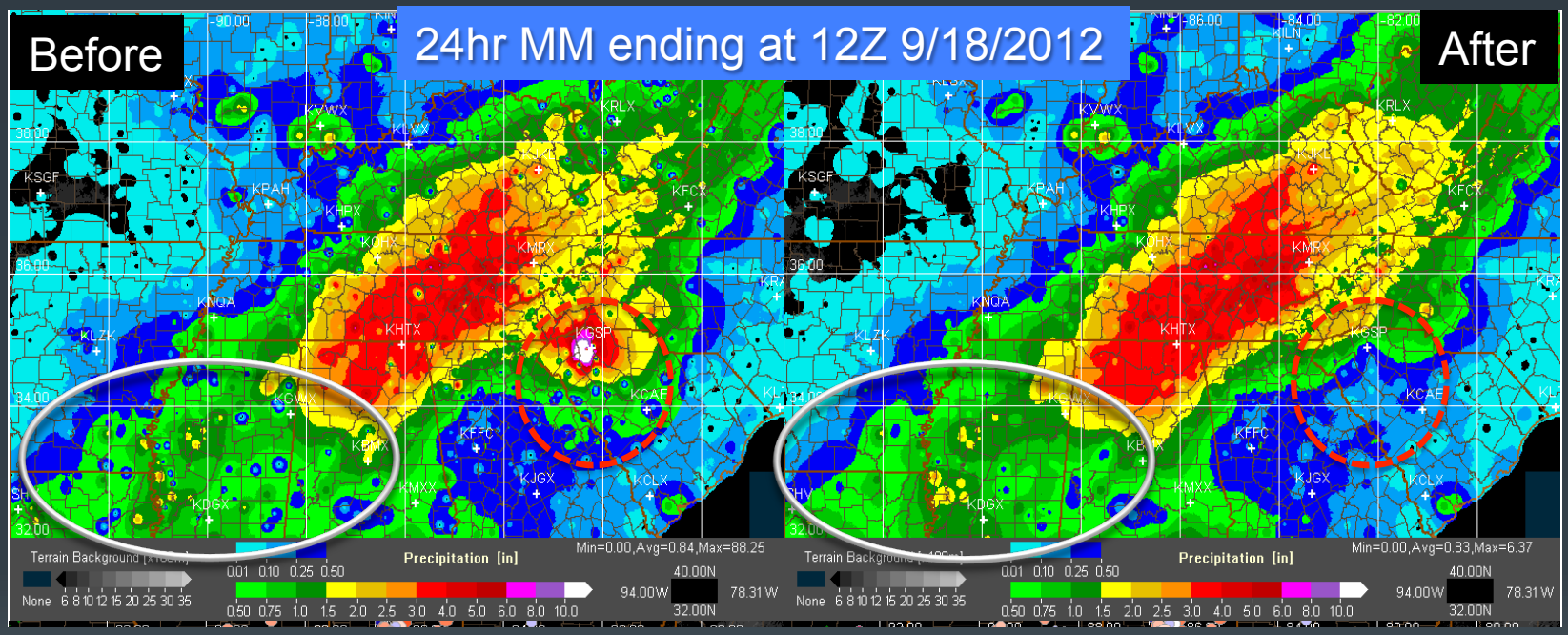
*0.8*R_{min} ≤ gauge obs ≤ *1.2*R_{max}?

no → Bad gauge report

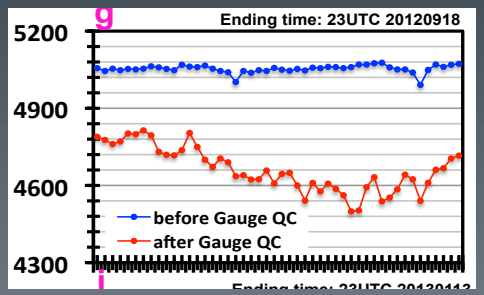
yes

Good gauge report

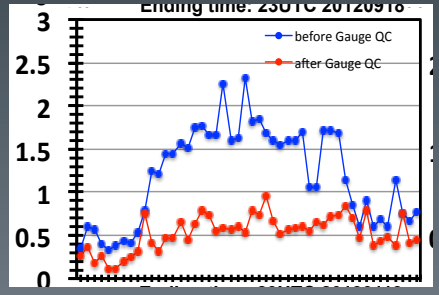
Gauge QC Before & After



# of gauges



Gauge-ST4 RMSE



Gauge-ST4 CC