HAIL HAZARD LAYERS

Decision Briefing

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NEXRAD TAC

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LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Outline

- Hail Hazard Layers Algorithm – Motivation
- Hail Hazard Layers Algorithm – Details
- Sample Performance
- Challenges
- Summary

Motivation for Hail Hazard Layers

"My husband and I were on the Frontier flight. We were told it was hit by lightning twice, along with the wind and hail. The pilot told us the wind screen was cracked and that we wouldn't be able to reach the normal altitude of over 30,000 ft. We were flying at 22,000 ft. We didn't have enough fuel to reach Denver so we landed in Kansas City. It was quite scary. We were also told by the flight attendants that there were 2 flights in front of us that didn't hit any bad weather. Other people on flight said there was a hole in one of the wings."

- Mary

Frontier Airlines encounters hail hazard on ascent out of Little Rock (Feb. 2012)

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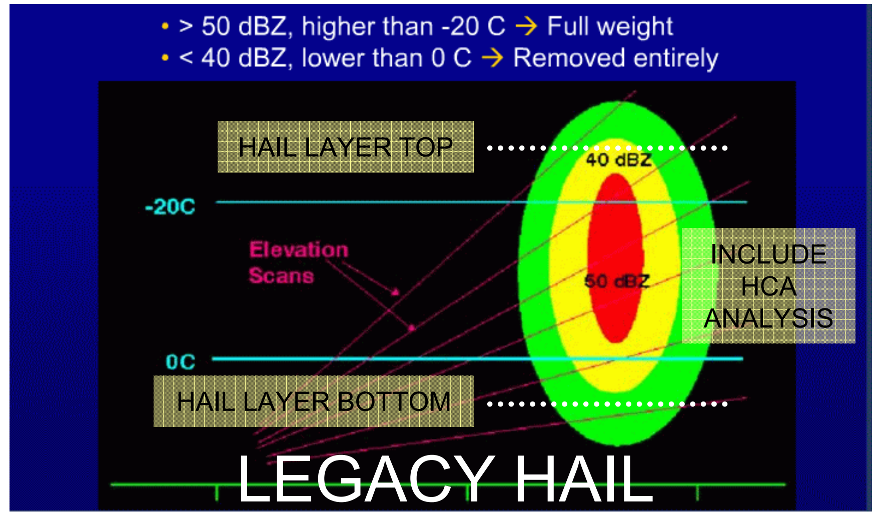
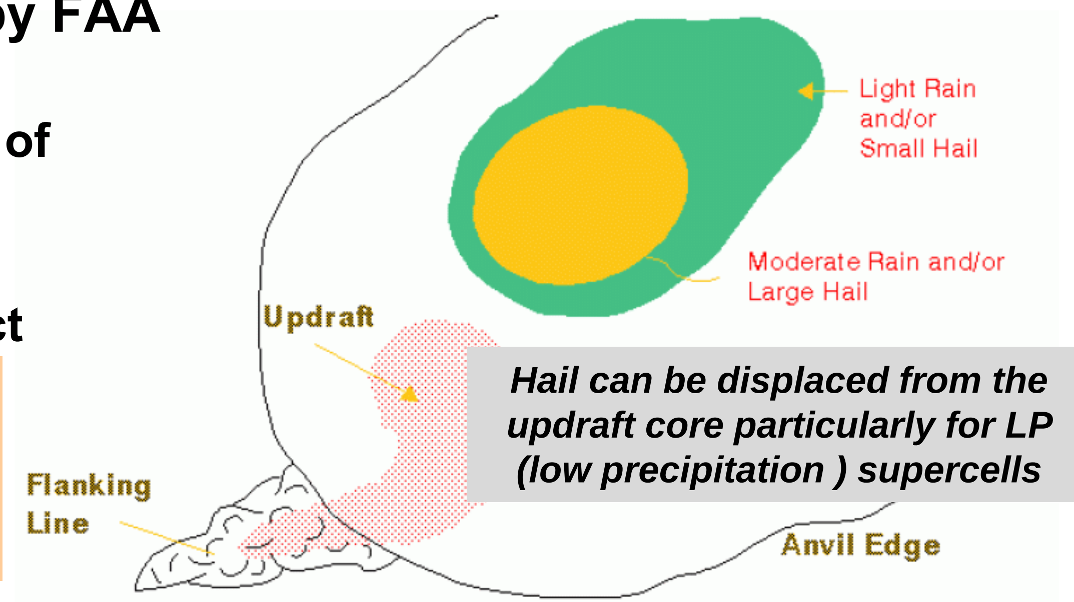
Motivation for Hail Hazard Layers (cont.)

- **HHL Addresses**
  - **Dual pol hail detection benefit**
  - **Unexpected hail aloft**
  - **Identify early hail potential (indicator of future cell intensity)**
  - **Microburst precursor**
- **Supplement use of current NEXRAD hail algorithm by FAA weather systems**
  - **Provide vertical extent of hazard**
  - **ITWS operational use**
  - **WARP receives product**

Heinselman and Ryzhkov (2006) show hail class algorithm with CSI of 89% vs. 56% for traditional algorithm





Hail can be displaced from the updraft core particularly for LP (low precipitation) supercells

WARP = Weather and Radar Processor; CSI = Critical Success Index
ITWS = Integrated Terminal Weather System

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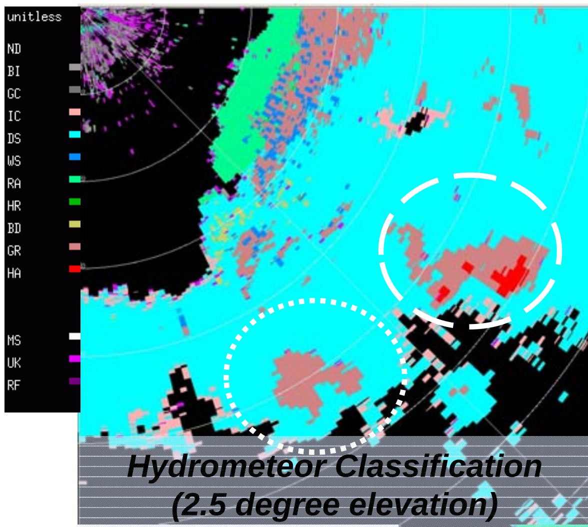
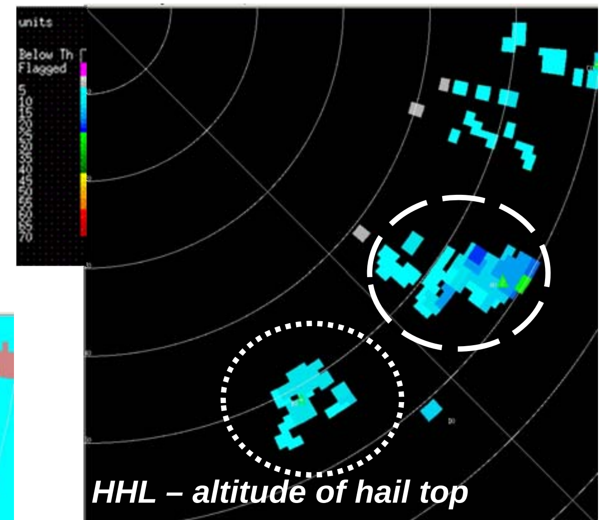
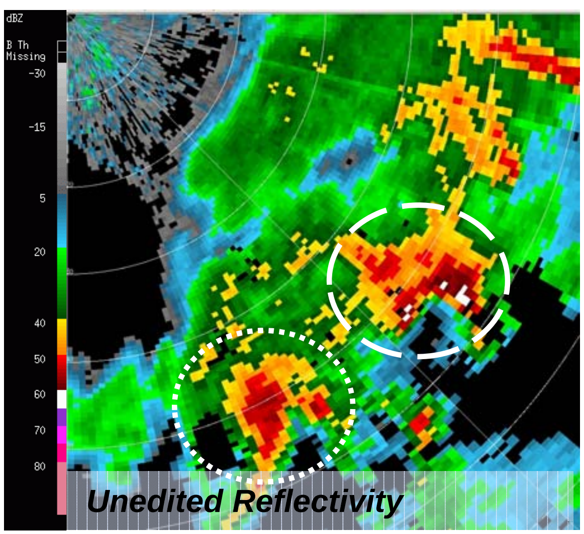
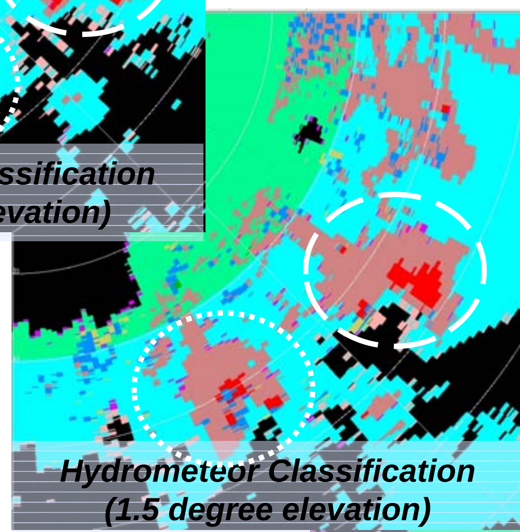
Use HCA Rain/Hail Classification to Derive HHL Altitude Top and Bottom from Tilts

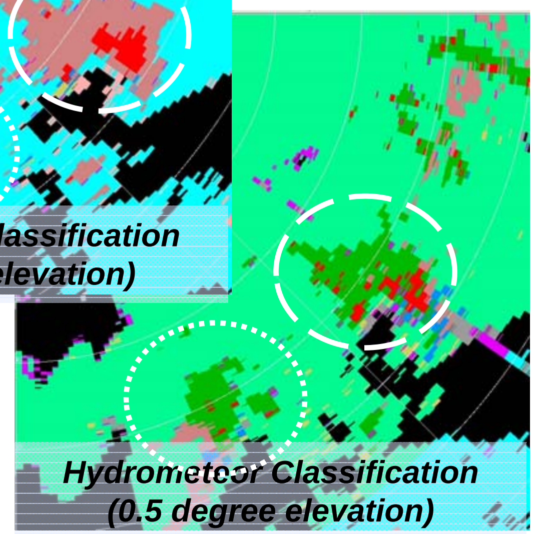
Note graupel class (pink) surrounds and caps rain/hail class (red) above freezing level







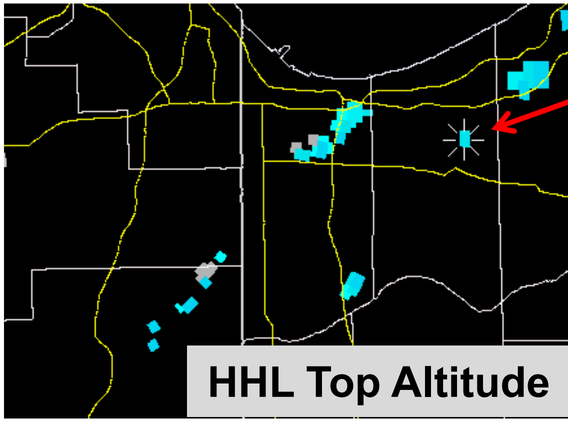




KOUN
02/24/2011
1653 UTC

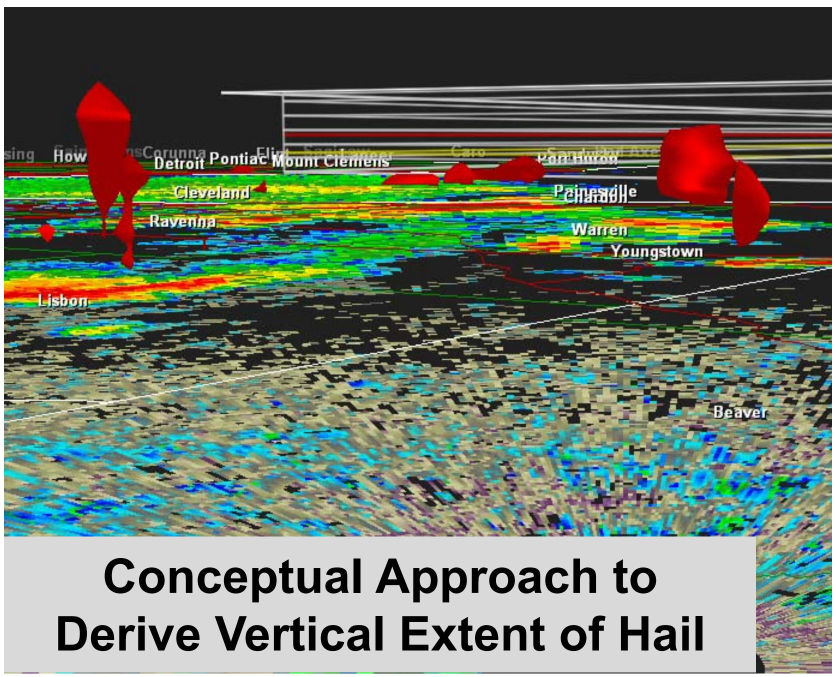
HCA = NEXRAD Hydrometeor Classification Algorithm

NEXRAD Hail Hazard Layers
Product Description



HHL Top Altitude

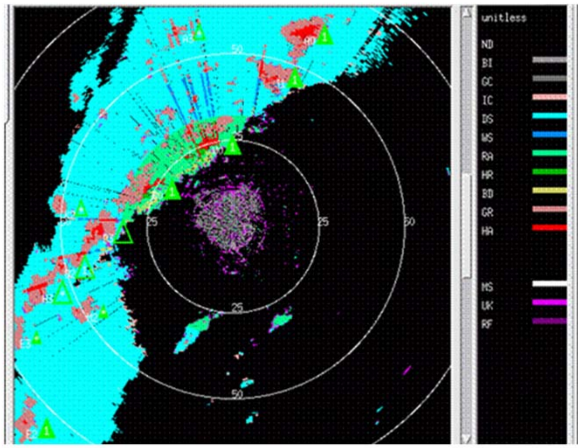
Spotter Verification



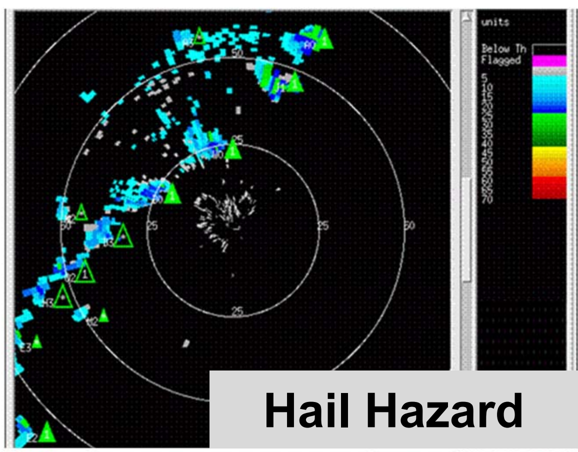
Conceptual Approach to Derive Vertical Extent of Hail

Range Coverage	**300 km (dual pol range)**
Azimuthal Coverage	**360 degrees**
Range Gate Resolution	**1 km**
Azimuth Resolution	**1 degree**
Volume Product Output **(one group for top, one for bottom)**	**Altitude (in kft)** **Severity* (up to 5 levels)** **Confidence* (up to 10 levels)** *** - future version**

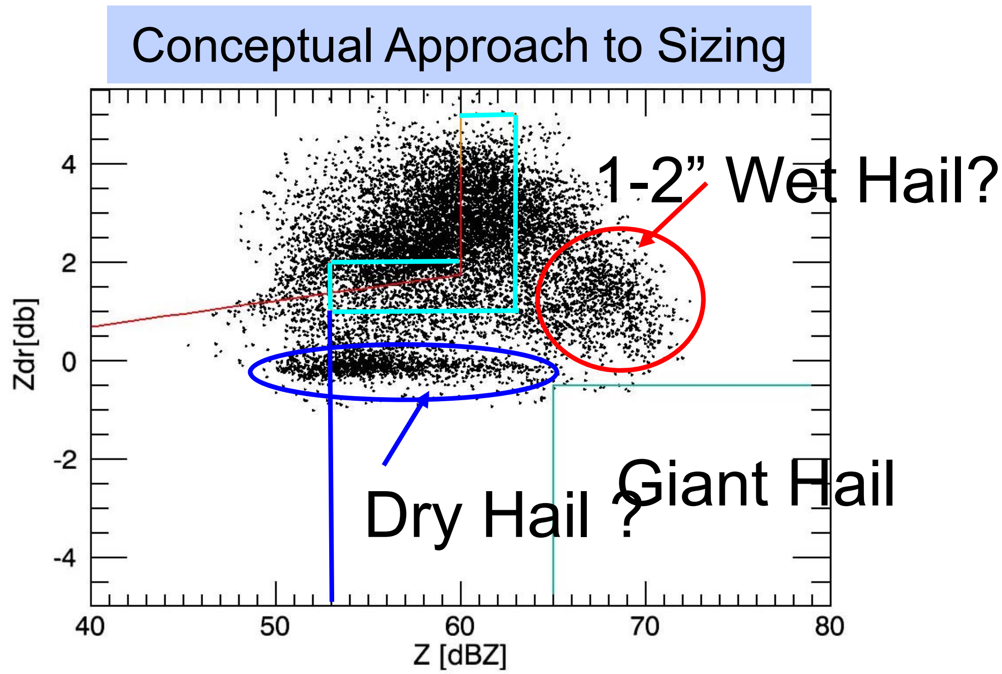
Future Severity based on Hail Sizing



Hydrometeor Classification for mid-level scan of radar volume (red indicates rain/hail class)



HHL volume product depicting top altitude of hail found in radar volume by azimuth and range



- **NEXRAD HCA rain/hail class is the basis for sizing of large hail**
- **NSSL method for large hail (> 2.5 cm dia.) uses Z, ZDR, ρ_{hv}, and height from melting layer**
- **Sizing logic will be a sidebar to NEXRAD HCA**
- **Small and giant hail sizing targeted for future**

Z = Reflectivity; ZDR = Differential Reflectivity
ρ_{hv} = cross-polar correlation coefficient

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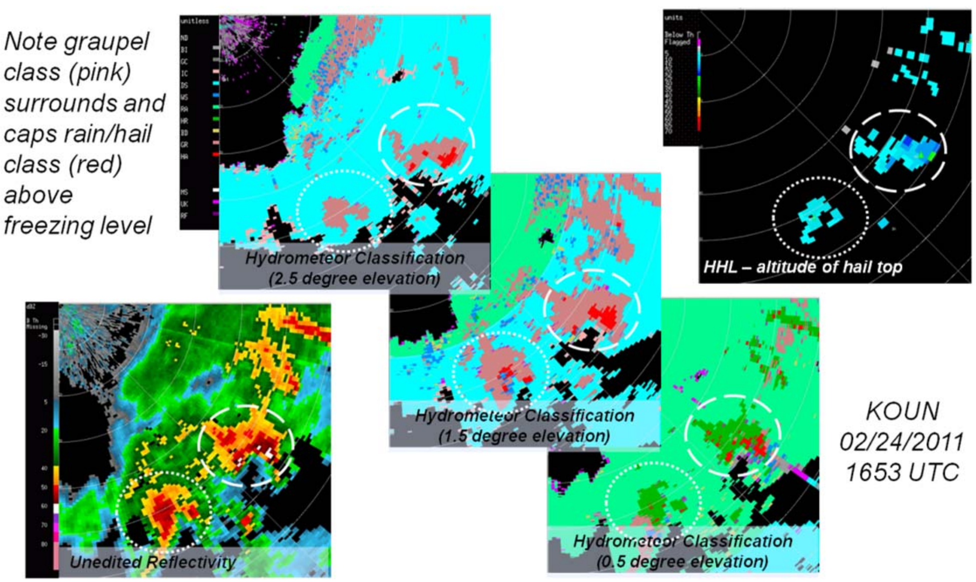
Hail Hazard Layers (HHL) Algorithm

- **NEXRAD HHL performance evaluation and tuning**
  - **Product based on rain/hail class from HCA**
  - **Currently running 24/7 at 34 sites**
  - **Cross checked against hail reports**
    - **National Weather Service Storm Data**
    - **Community Collaborative Rain, Hail, and Snow network (CoCoRaHS)**

Note graupel class (pink) surrounds and caps rain/hail class (red) above freezing level



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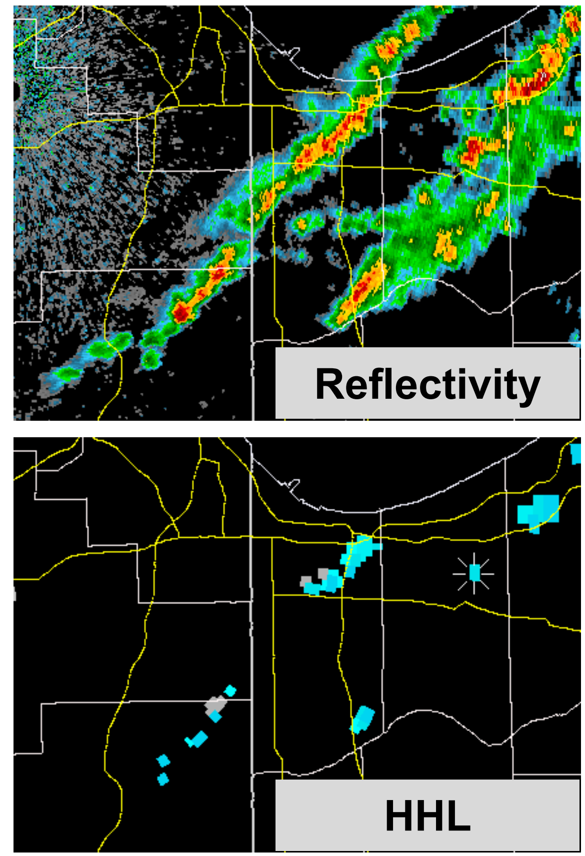
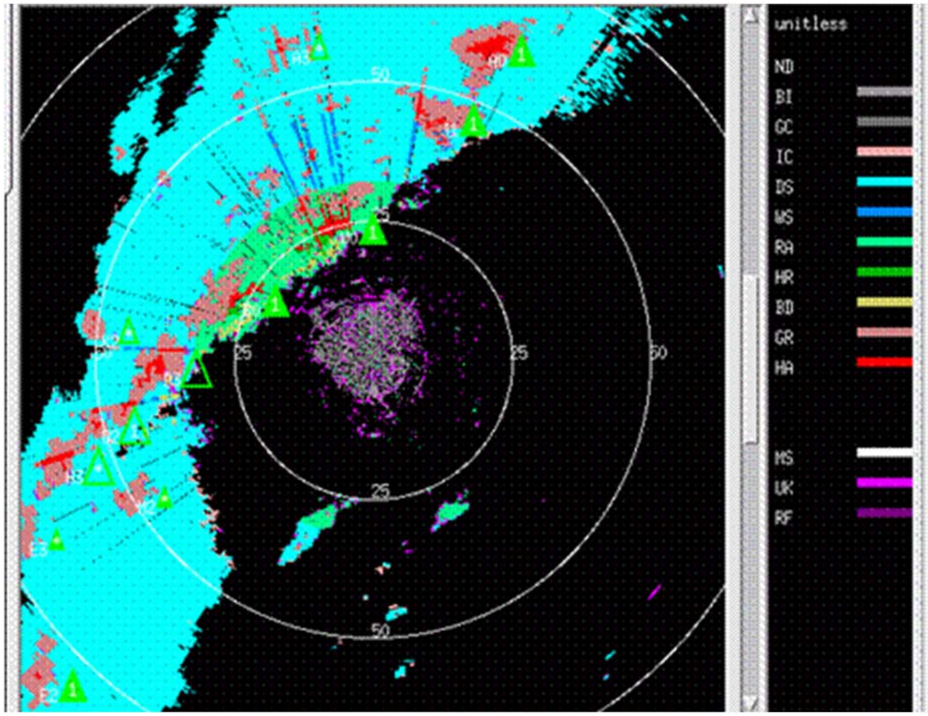


Validation of hail KLOT March 30, 2012 1358 UTC

HCA = NEXRAD Hydrometeor Classification Algorithm

HHL Comparison to Legacy Hail



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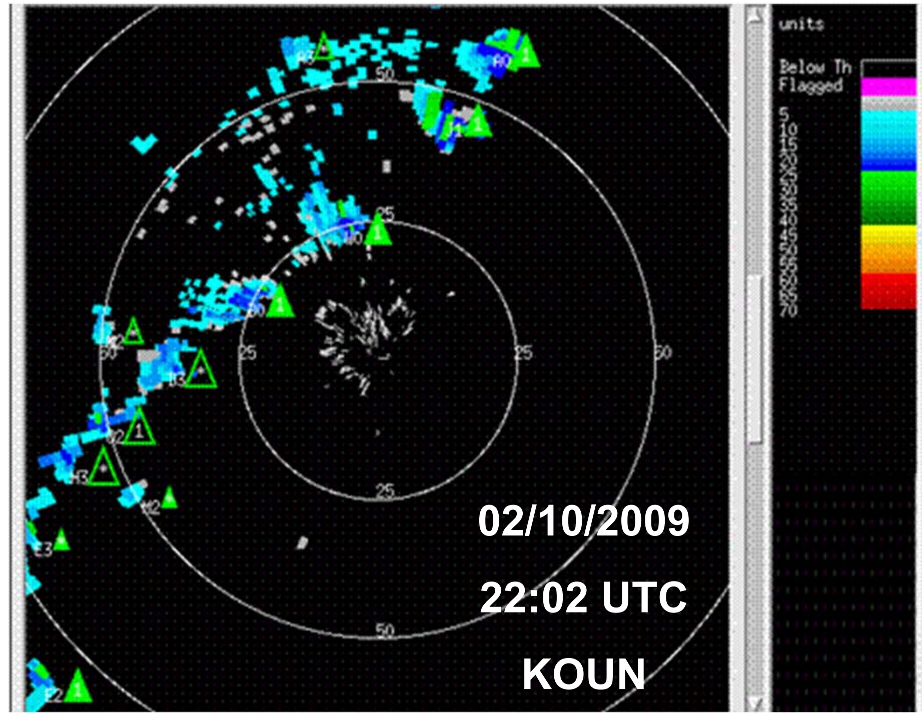
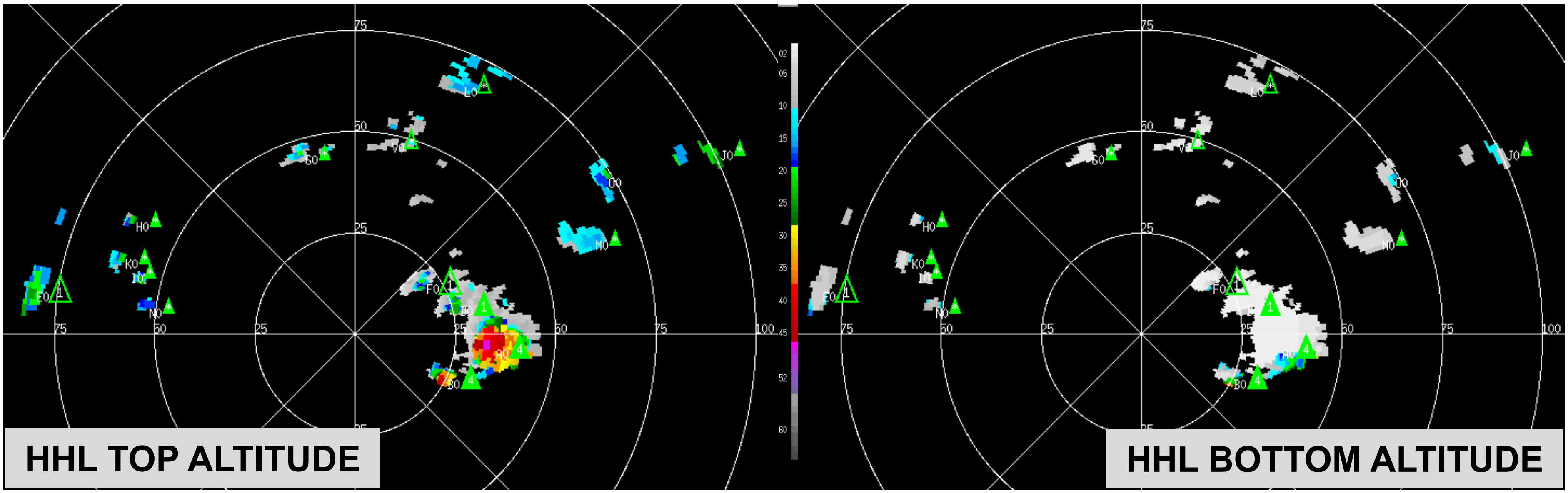


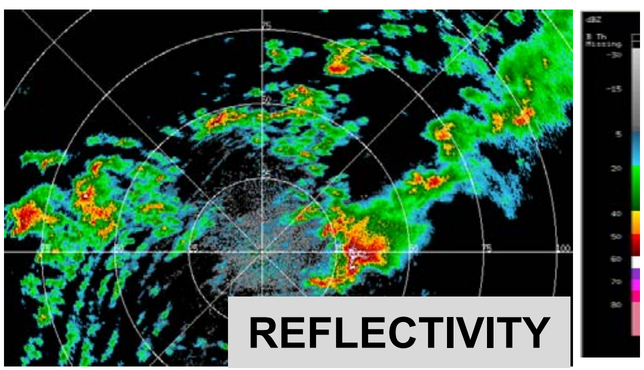
HHL volume product depicting top altitude of hail found in radar volume by azimuth and range

Triangles are storm cells with hail likely from the legacy Hail algorithm. Large triangles represent greater hail likelihood. Filled triangles represent greater severe hail likelihood.

KLSX 04/28/2012 2101Z Compare

The Great St. Louis Metropolitan Hail Storms
April 28th 2012





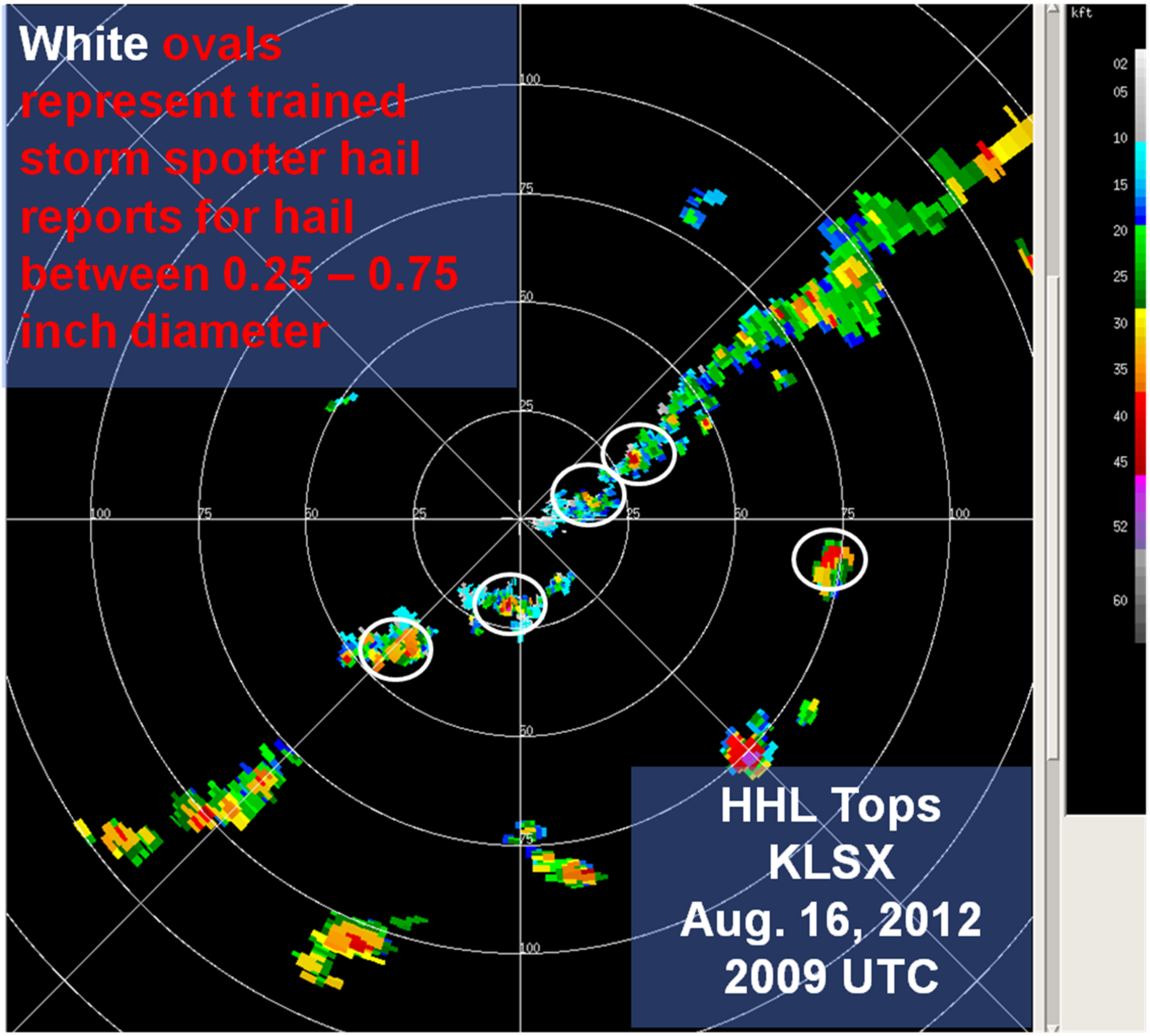
Typical results observed between HHL and Legacy Hail for widespread events

From the Storm – NWS Survey, Reports, Samples

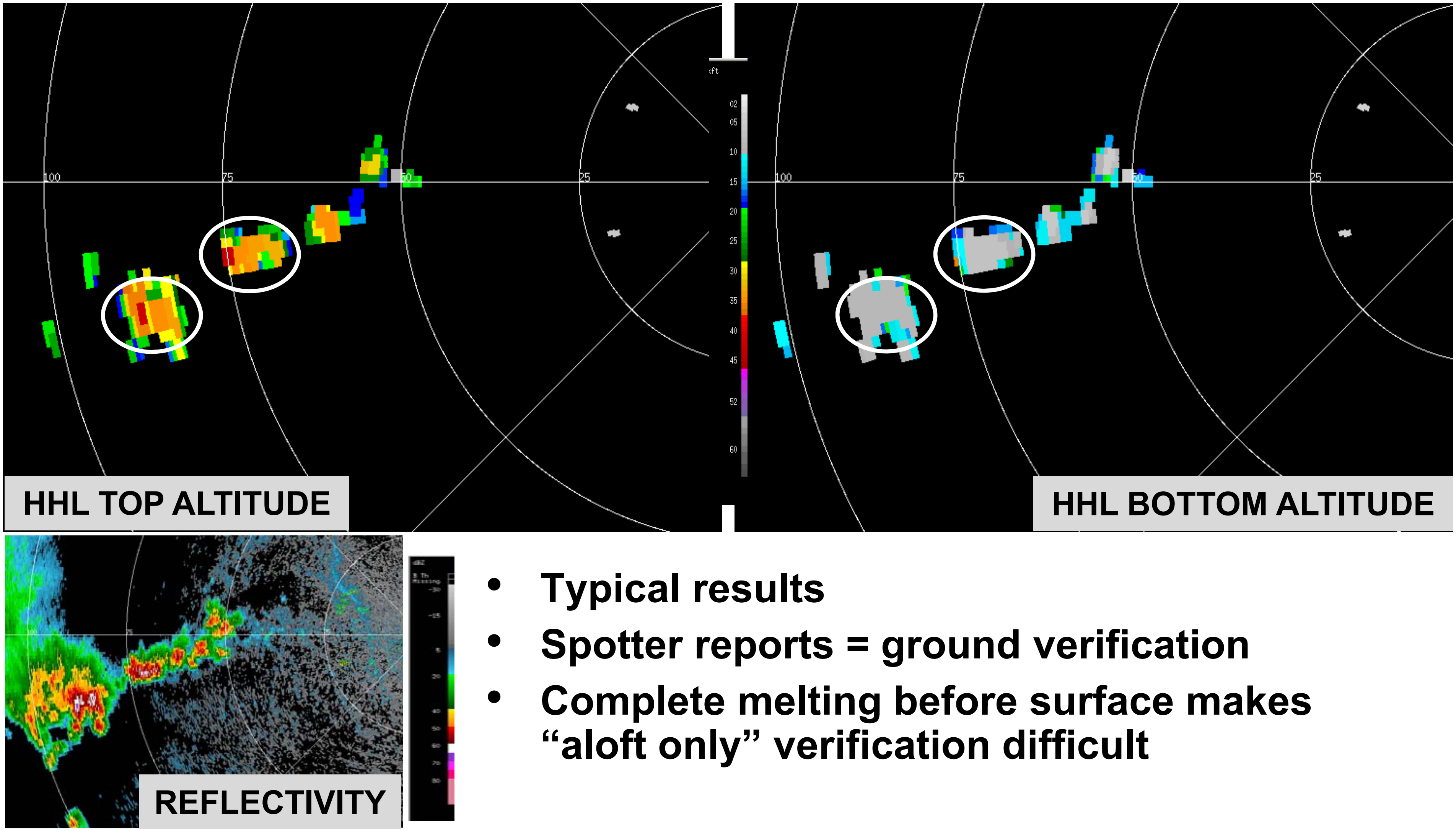
KLSX HHL Tops 08/16/2012 2009 UTC

Spotter and CoCoRaHS typical results . . .

Have not observed spotter reports absent of HHL indication (50+ events)



KDDC HHL 08/24/2012 2054 UTC with Spotter Reports



- Typical results
- Spotter reports = ground verification
- Complete melting before surface makes “aloft only” verification difficult

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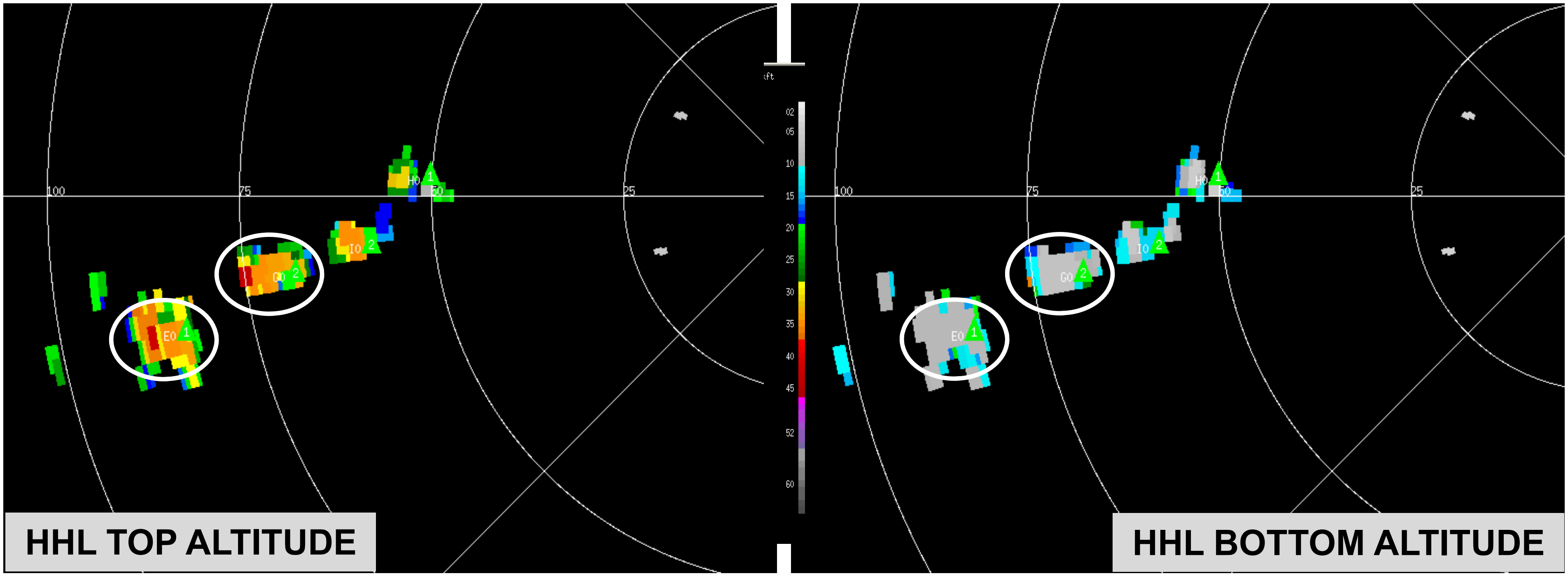
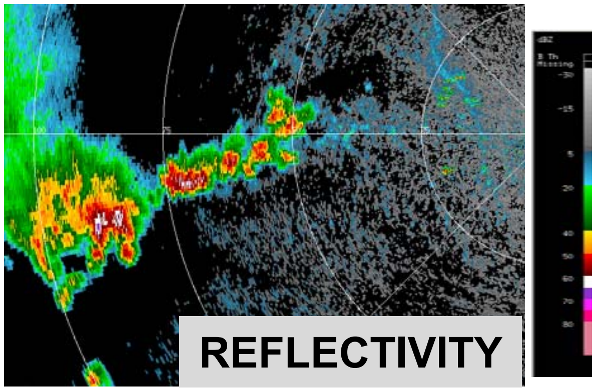
KDDC HHL 08/24/2012 2054 UTC with Spotter Reports, Legacy Hail





- **Typical results**
- **Spotter, HHL, and Legacy Hail agree for two cells**

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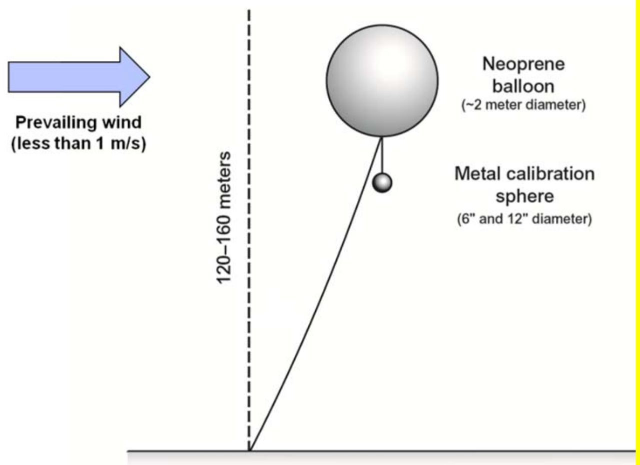
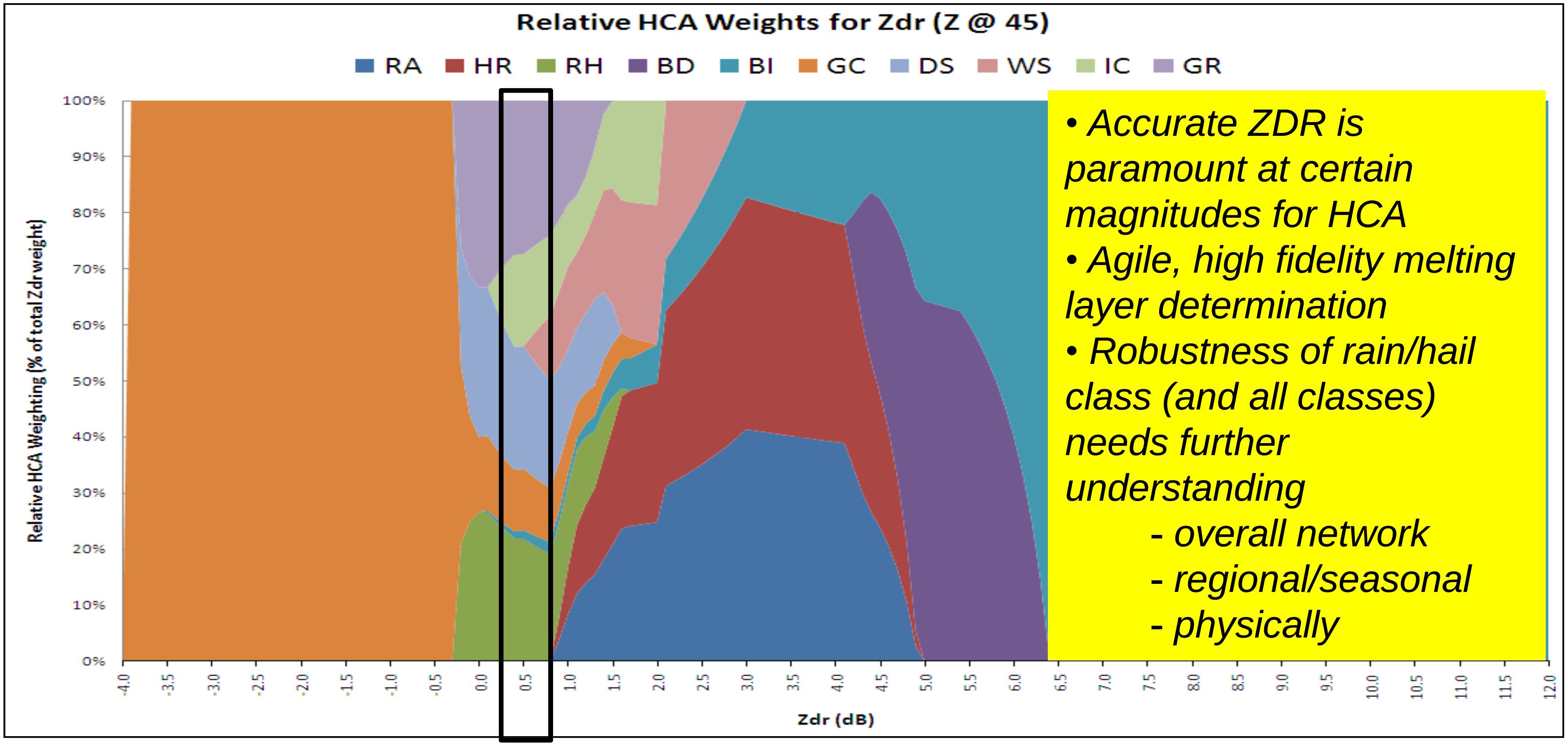
Overarching Dual Pol Data Quality Issues



- **The overall quality of the dual pol parameters impacts all downstream algorithms**
- **ZDR calibration critical**
  - **Initial calibration**
  - **Recalibration**
  - **Magnitude**
  - **Stability**
  - **Monitoring**
- **Relative calibration between radars for ZDR**
- **NEXRAD dual pol algorithms might need to account for the “state of the radar”**

ZDR = Differential Reflectivity

HCA Sensitive to "State of the Radar"



- *Accurate ZDR is paramount at certain magnitudes for HCA*
- *Agile, high fidelity melting layer determination*
- *Robustness of rain/hail class (and all classes) needs further understanding*
  - *overall network*
  - *regional/seasonal*
  - *physically*

ZDR = 0.5	RA	HR	RH	BD	BI	GC	DS	WS	IC	GR	Sum
HCA Weight	0	0	0.8	0	0.06	0.4	0.8	0	0.6	1.0	3.66
%	0	0	22%	0	2%	11%	22%	0	16%	27%	100%

Small variations in ZDR result in large impacts to HCA
Liquid classes restricted above melting layer

ZDR = Differential Reflectivity; HCA = NEXRAD Hydrometeor Classification Algorithm

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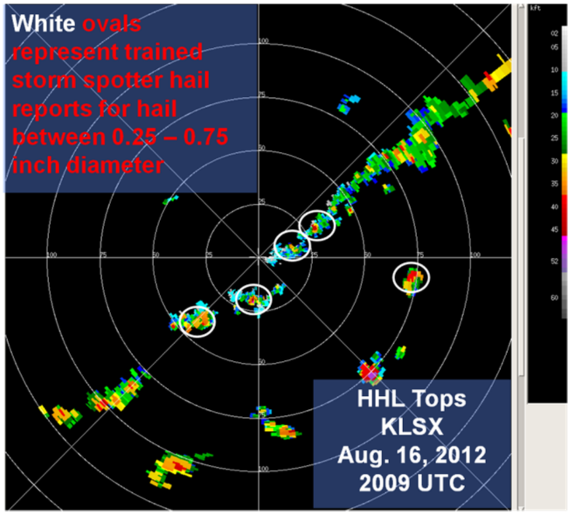
Development Path of HHL Algorithm

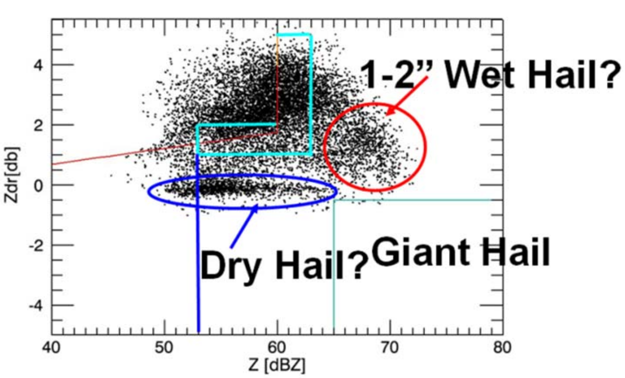
- **Continue to monitor HHL**
  - **Robustness of HCA's rain/hail class**
    When is it not hail?
  - **Evolution of dual pol NEXRAD**

- **Next: Test/Implement hail sizing (severity)**
  - **Initial NSSL version: large (> 1" dia.)**
  - **Future NSSL version: up to 4 sizes**

- **Further development**
  - **Hail transition/melting concepts**
  - **Relationship with microburst evolution**
  - **Evolution of rain/hail class**



HCA Rain/Hail detections for 20040602 4.5 degree elevation



HCA = NEXRAD Hydrometeor Classification Algorithm
NSSL = National Severe Storms Laboratory

Summary

- Legacy hail algorithm does not take advantage of dual pol capability
- HHL is based on the dual pol rain/hail classification and introduces the concept of vertical location/extent
- Logical results consistently observed between HHL and ground reports of hail
- Request a decision from the NEXRAD TAC