Lincoln Laboratory NEXRAD Dual Pol Radar Product Development for Aviation

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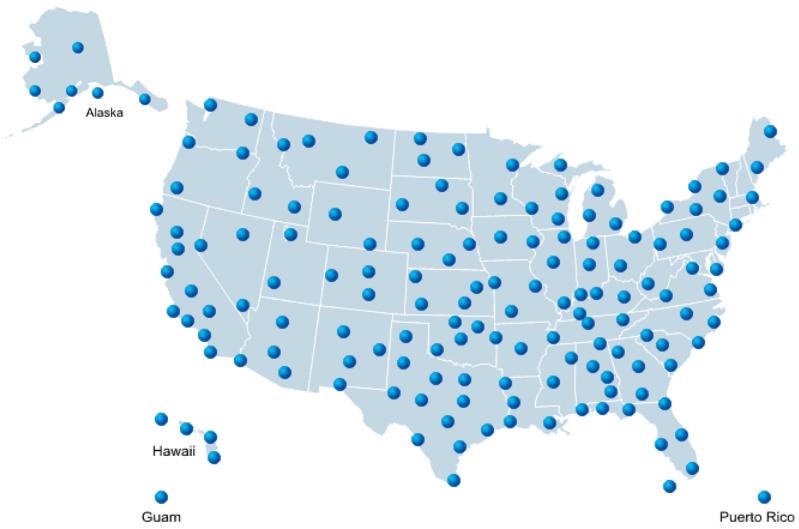
Background

- NEXRAD radar network is the primary provider of weather coverage and intensity to FAA weather systems
  - Deployed throughout 1990s
  - Open era beginning 2000 (leads to new RPG and RDA)
  - Dual pol upgrade deployment beginning 2011



courtesy of the National Weather Service

- FAA funding LL for NEXRAD product enhancements since 2001
  - Four algorithms with three operational products fielded
  - Currently in 2nd year of 5 year FAA business plan to develop dual pol products

Motivation

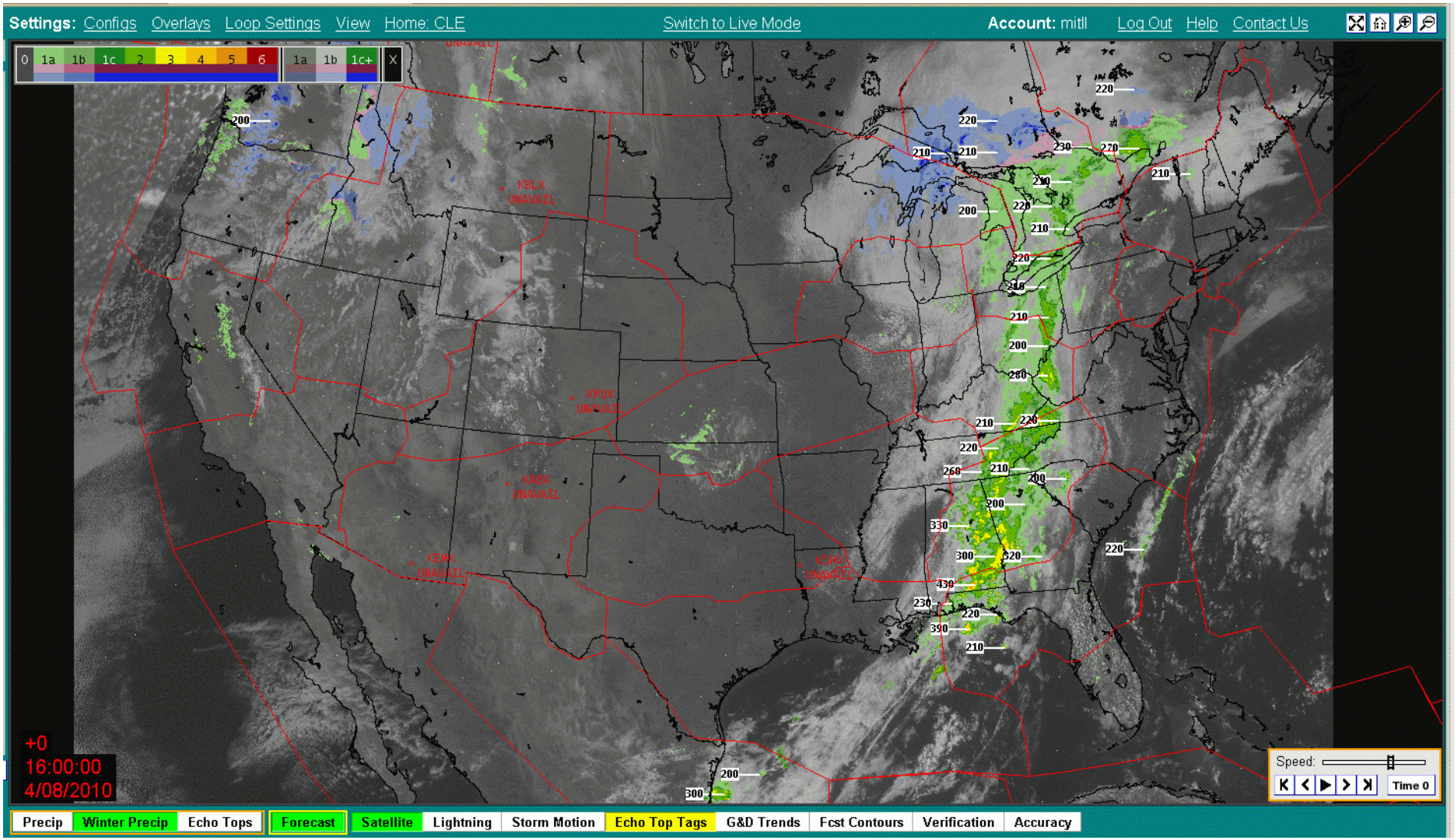
- **Provide benefit to FAA weather systems with NEXRAD products using dual pol data**
  - **Corridor Integrated Weather System (CIWS)**
  - **Integrated Terminal Weather System (ITWS)**
  - **Weather and Radar Processor (WARP)**

- **Create new products or enhance existing products from the Dual Polarization upgrade of NEXRAD**
  - **NEW: Icing Hazard Levels (IHL)** ***greatest benefit***
  - **NEW: Hail Hazard Layers (HHL)**
  - **NEW: Automated Microburst Detection Algorithm (AMDA)**
  - **Data Quality Assurance (DQA)**
  - **High Resolution Vertically Integrated Liquid (HRVIL)**

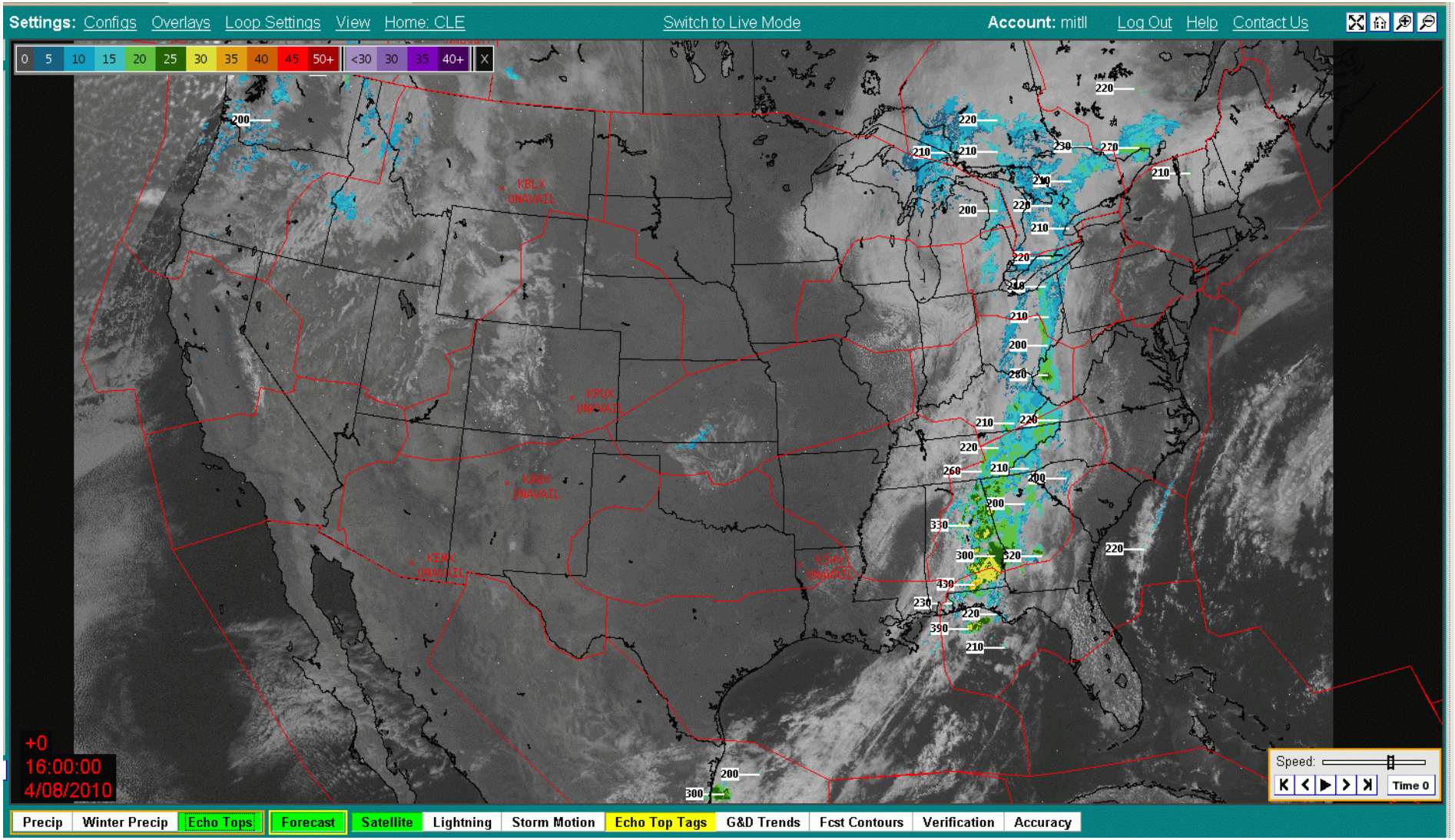
Outline

- Developed non-Dual Pol Products Now in Use
- Dual Pol Product Development Program
- Dual Pol Product Examples

High Resolution VIL in CIWS

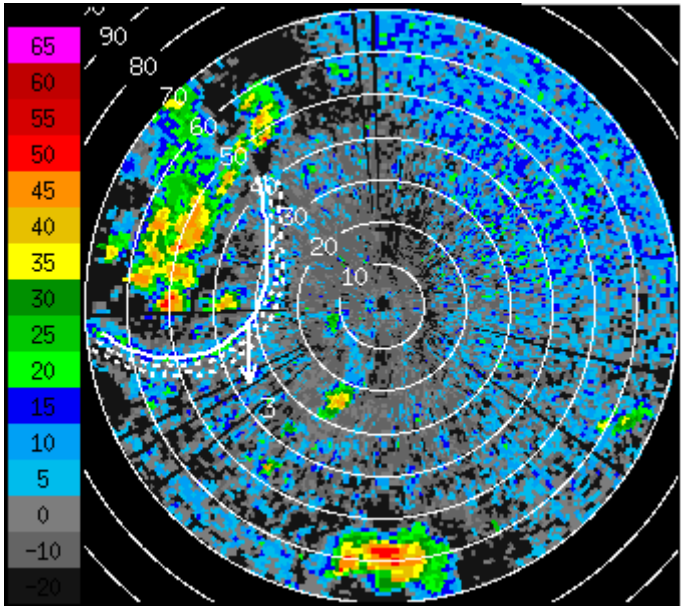


High Resolution Enhanced Echo Tops in CIWS



NEXRAD MIGFA Product Description

Range Coverage	**70 km (terrain permitting)**
Azimuthal Coverage	**360 degrees**
Merged Tilts Processed	**0.5^0 and 1.3^0 (VCP 12)** **0.5^0 and 1.5^0 (other VCPs)**
Output	**<u>Per radar volume</u>:** **Detections with 10 and 20 minute forecast positions** **u,v front propagation** **u,v wind behind front** **delta-V**



"Tuned" to provide performance akin to TDWR MIGFA

Potential use in ITWS for remote sites without TDWR MIGFA

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Contributions to Dual Pol Algorithms

- Full featured Icing Hazard Level Product concept and code
- Provide CIP model sounding recommendations for IHL

- Recommendations for HCA, Freezing Level, Freezing Drizzle
- Monitor performance of implemented version of algorithm

- Data Quality algorithm techniques
- Hail algorithm techniques
- Melting Layer Algorithm

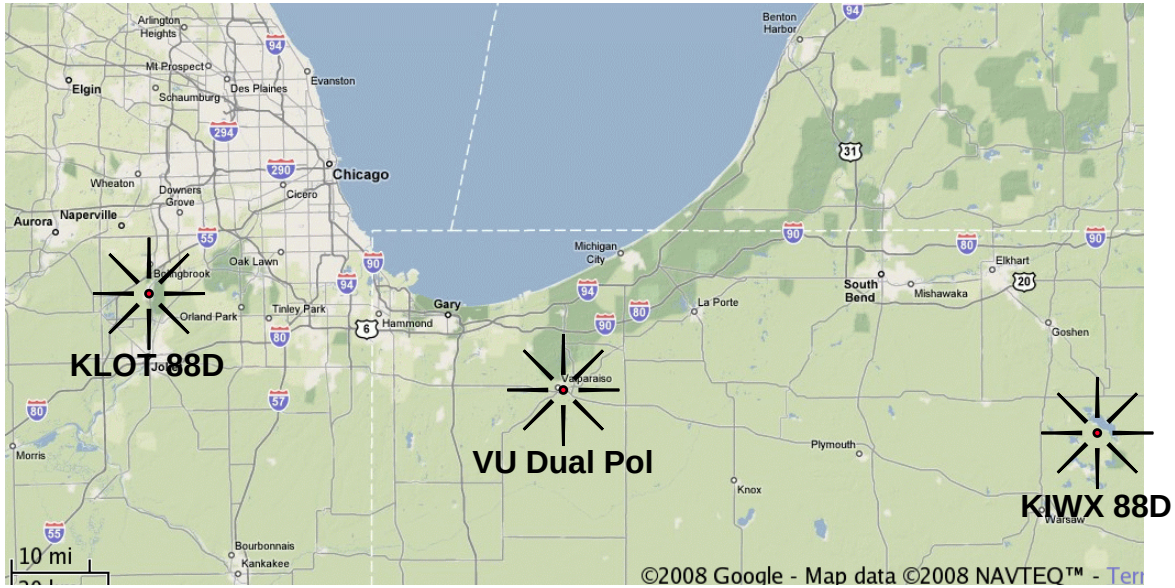
Dual Pol Algorithm

- Concepts for dual pol algorithms
- ICD product output format
- Develop interpretations of dual pol parameters

- Use of current HCA hail class
- Future large/small hail classes
- Freezing rain class (near surface)

- Recommendation for supercooled class (aloft)
- VIL recovery from partial beam blockage

Valparaiso University Dual Pol Radar



Frequency: 5.6 GHz

Transmitted Pulse: 1 MW

Transmit Mode: sim. H/V

Pulse width: 0.4 – 2.0 μs

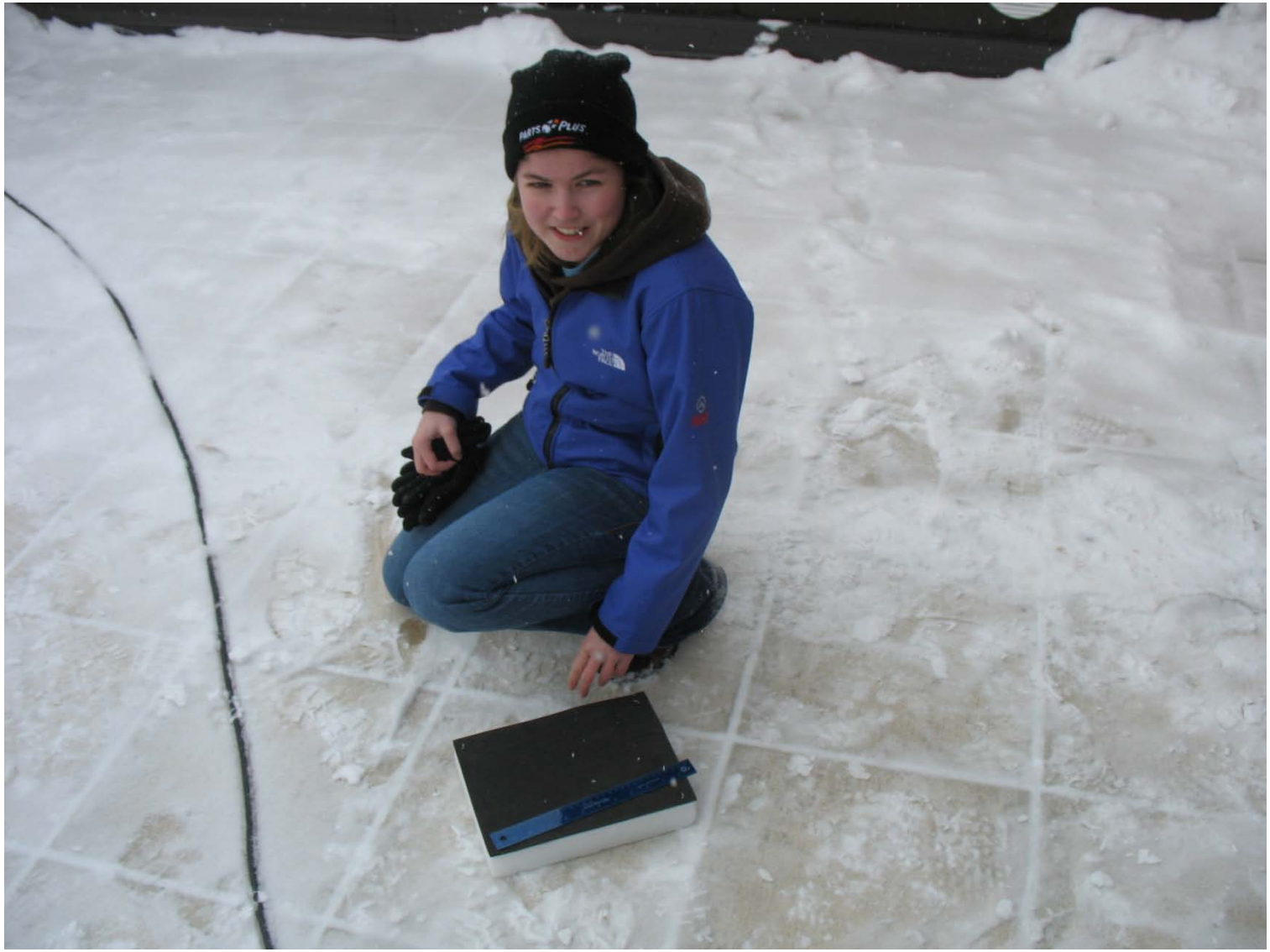
3 standard moments

Z_{DR}, Rho_{HV}, Phi_{DP}, K_{DP}

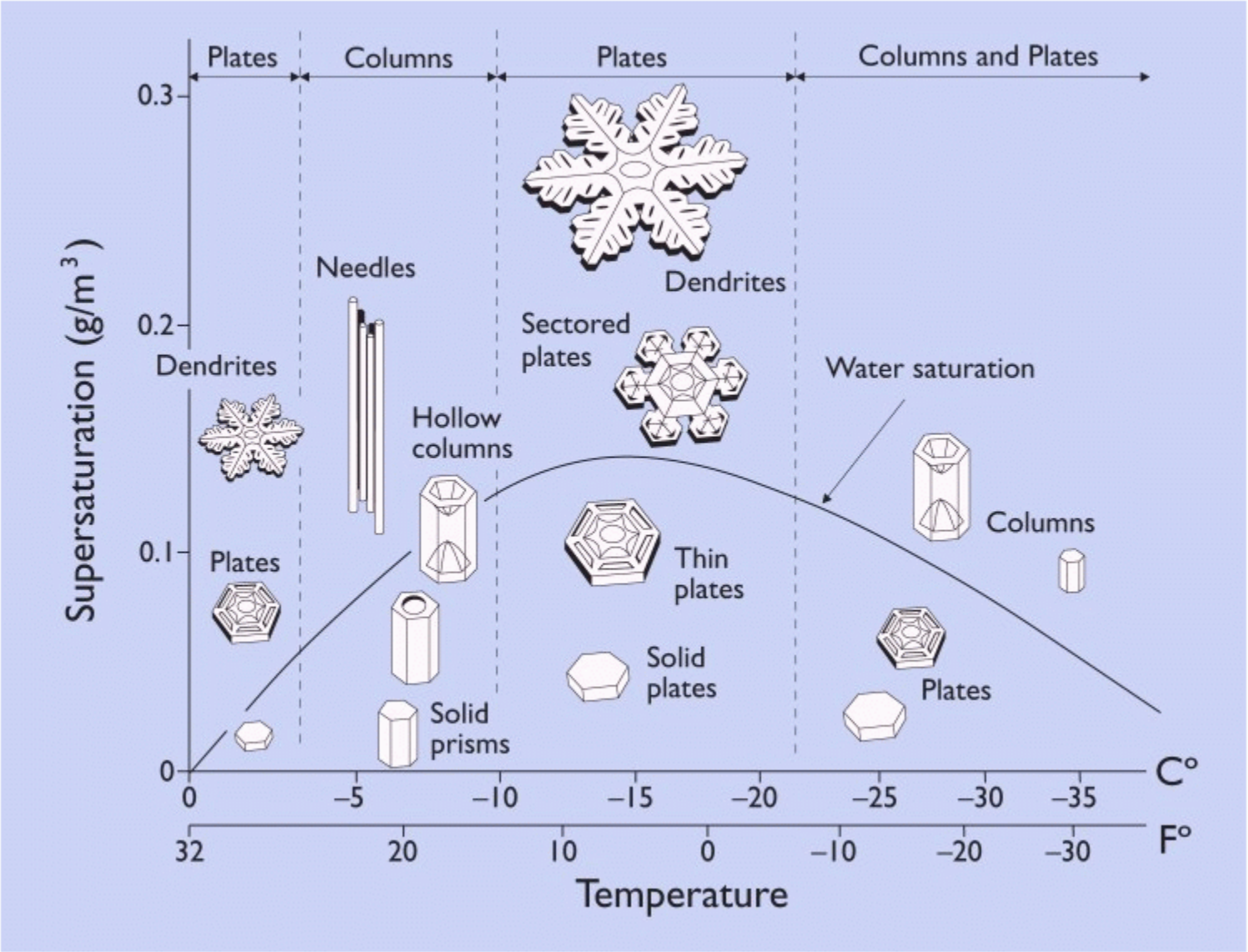
- **Three year partnership**
- **Icing and convective weather events**
- **On-site radiosonde capability (6 icing event launches in winter campaign 1 (2008-2009))**
- **Second winter campaign (2009-2010) with verification plan and more (12) soundings**
- **Third winter campaign with NEXRAD KLOT upgrade to Dual Pol (expected Jan. 2011)**

Balloon Sounding on February 9, 2010

Collection Pad for Ice Crystal/Snowflake Analysis in Winter Storms

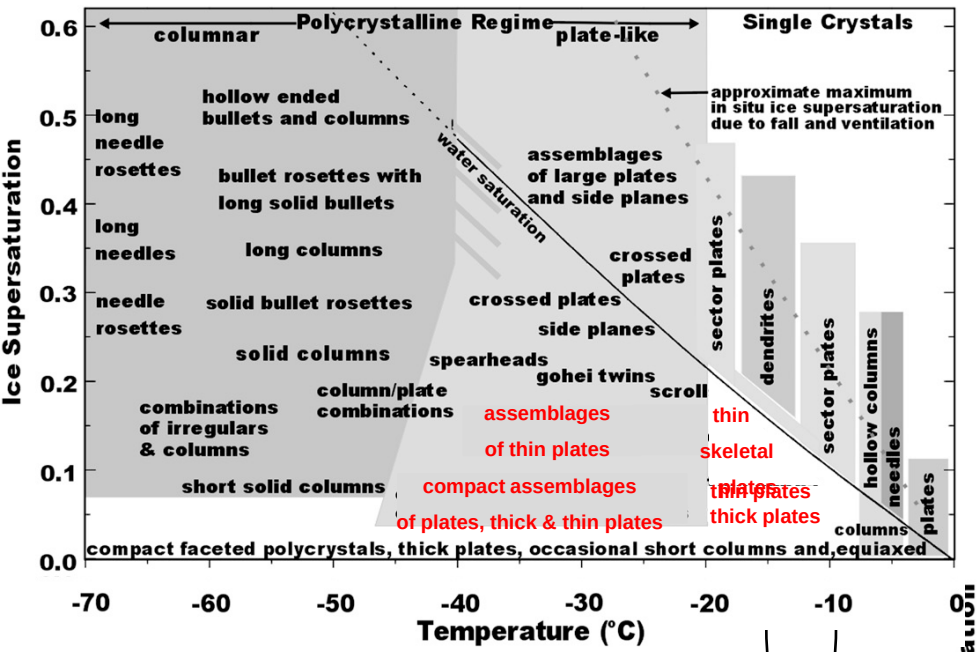


Ice Crystal Habit vs. Temperature and Water Saturation

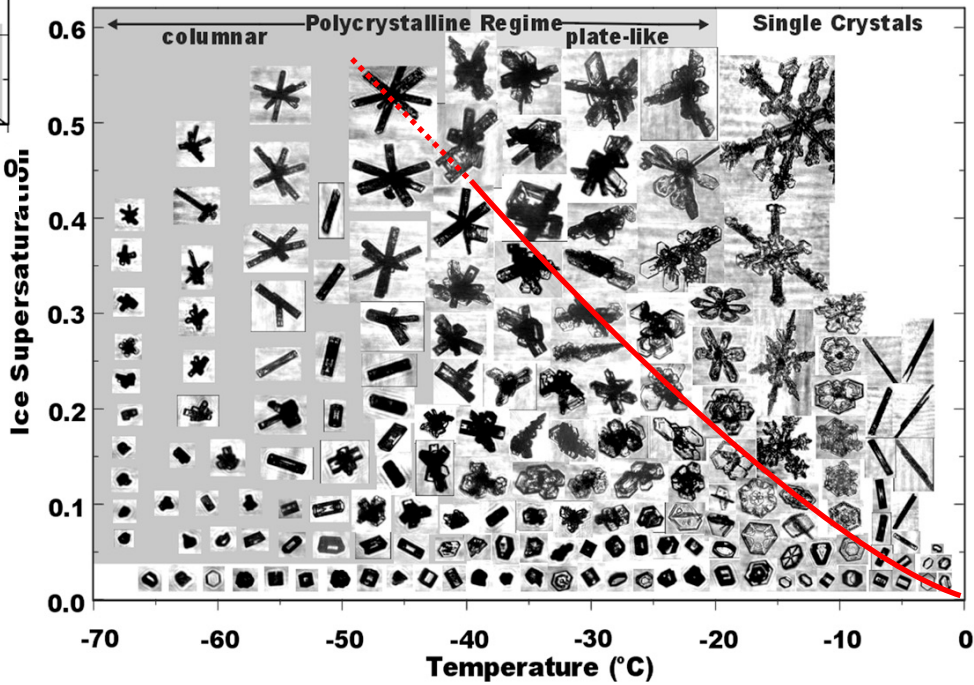


Comprehensive 'Phase Diagram' for Ice Crystal Habit

(from: Bailey and Hallett (2009)



Range of ZdR 'Bright Bands'



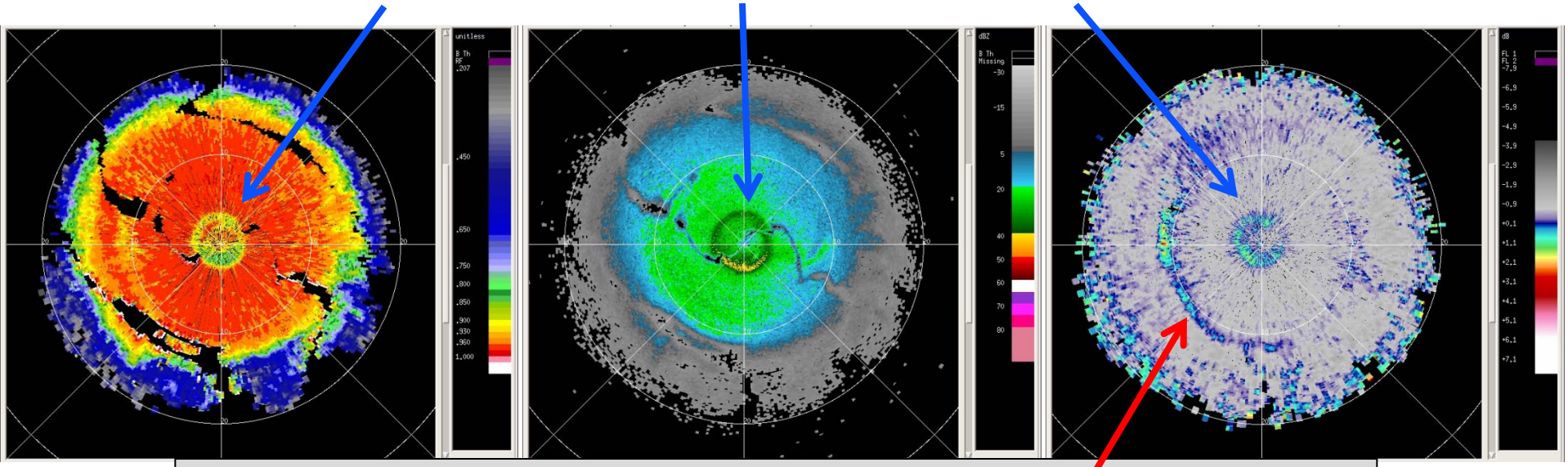
Humidity Condition is Crucial for Interpretation

Humidity condition	Supercooled water?	Riming?	Crystal growth state	Aggregation?
Water supersaturation	Yes	Yes	Dendrite growth	Strong
Ice supersaturation / water subsaturation	No	No	Hexagonal plate growth	Weak
Ice subsaturation	No	No	Hexagonal plate sublimation	None

Practical Note: Typical humidity measurements on thermodynamic soundings are not adequate to distinguish ice from water saturation

Two Bright Bands on December 8, 2009 (14 deg elevation)

Melting Layer bright band location

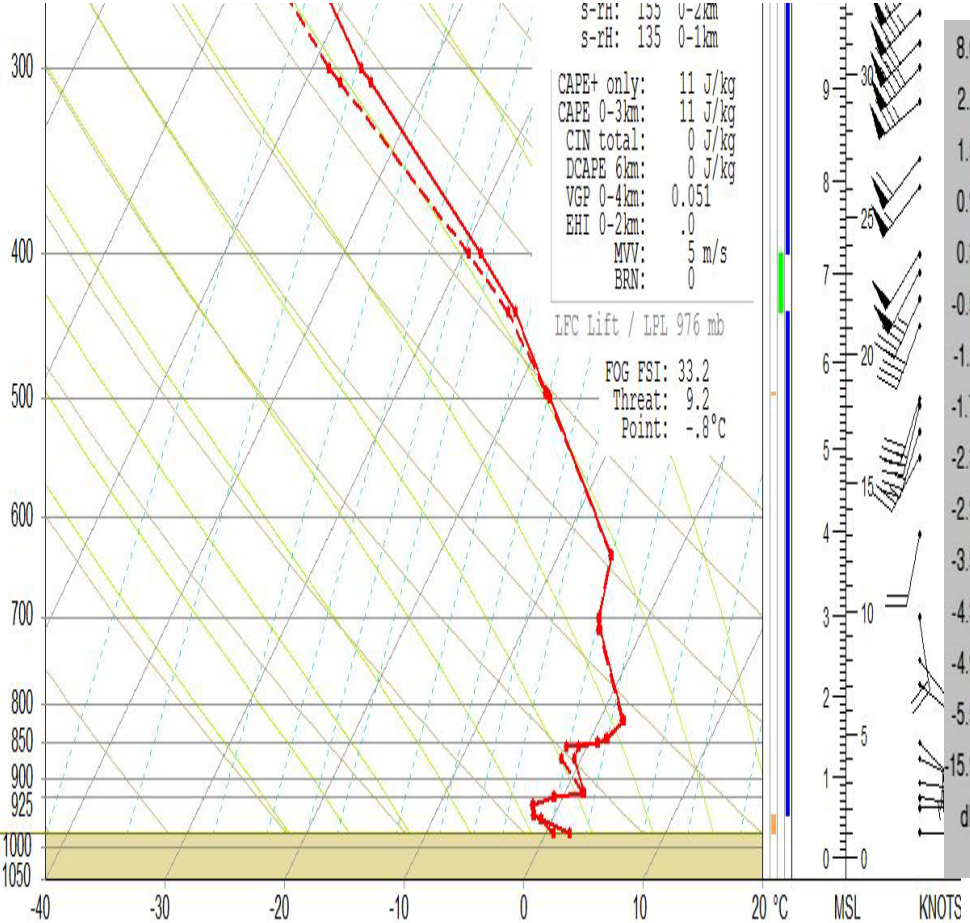


RHO_{Hv} **Z** **ZdR**

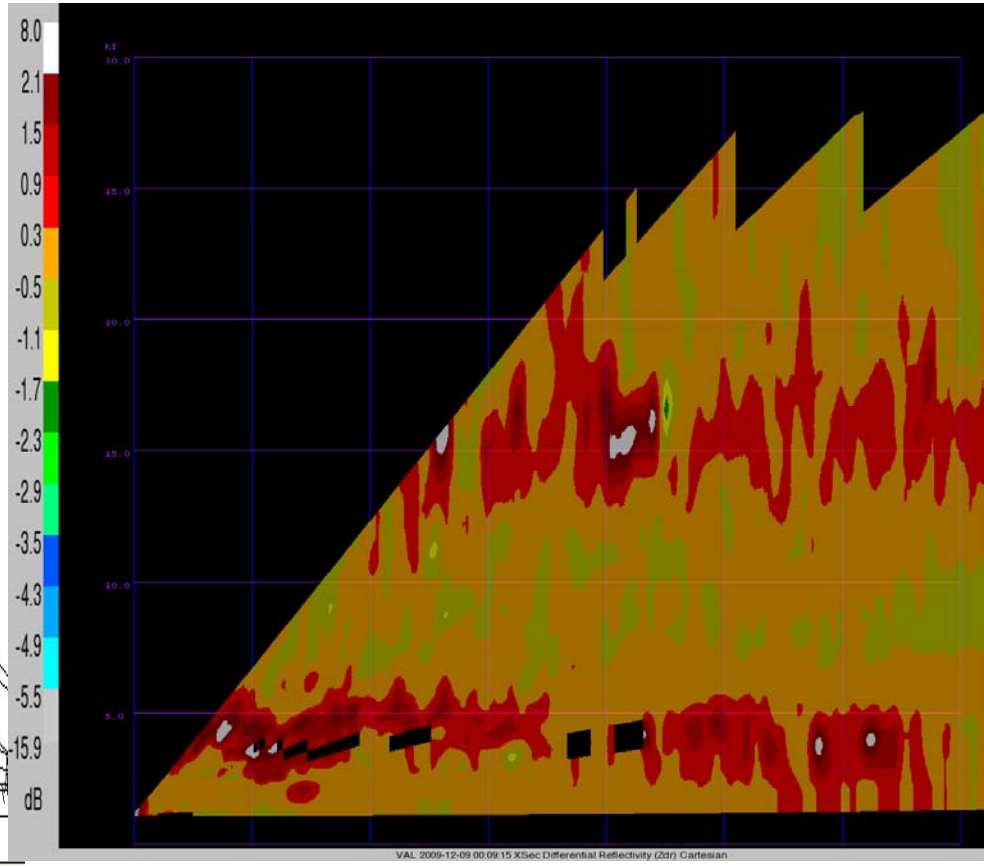
+ZDR bright band location

Use of Proximity Soundings to Identify Bright Band Temperature

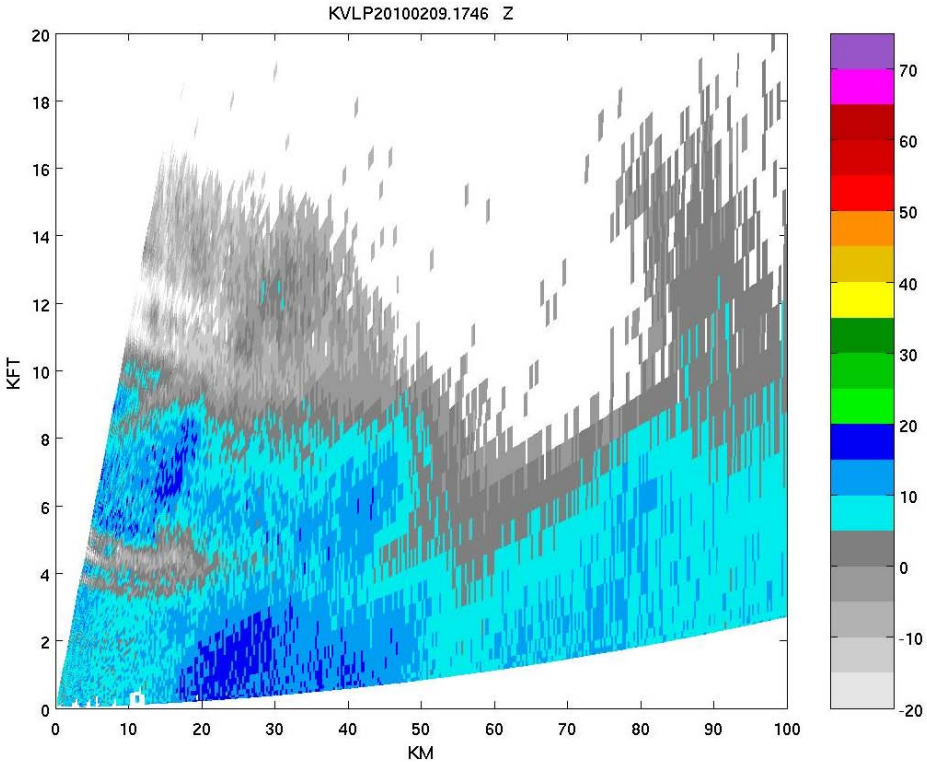
Radio Sounding

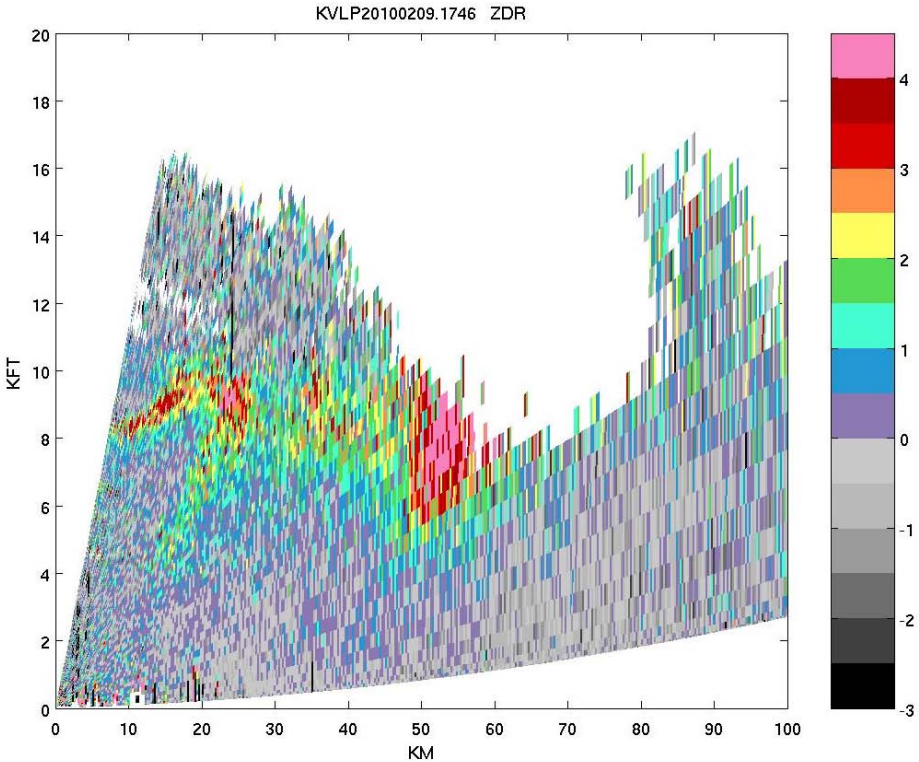


ZdR RHI

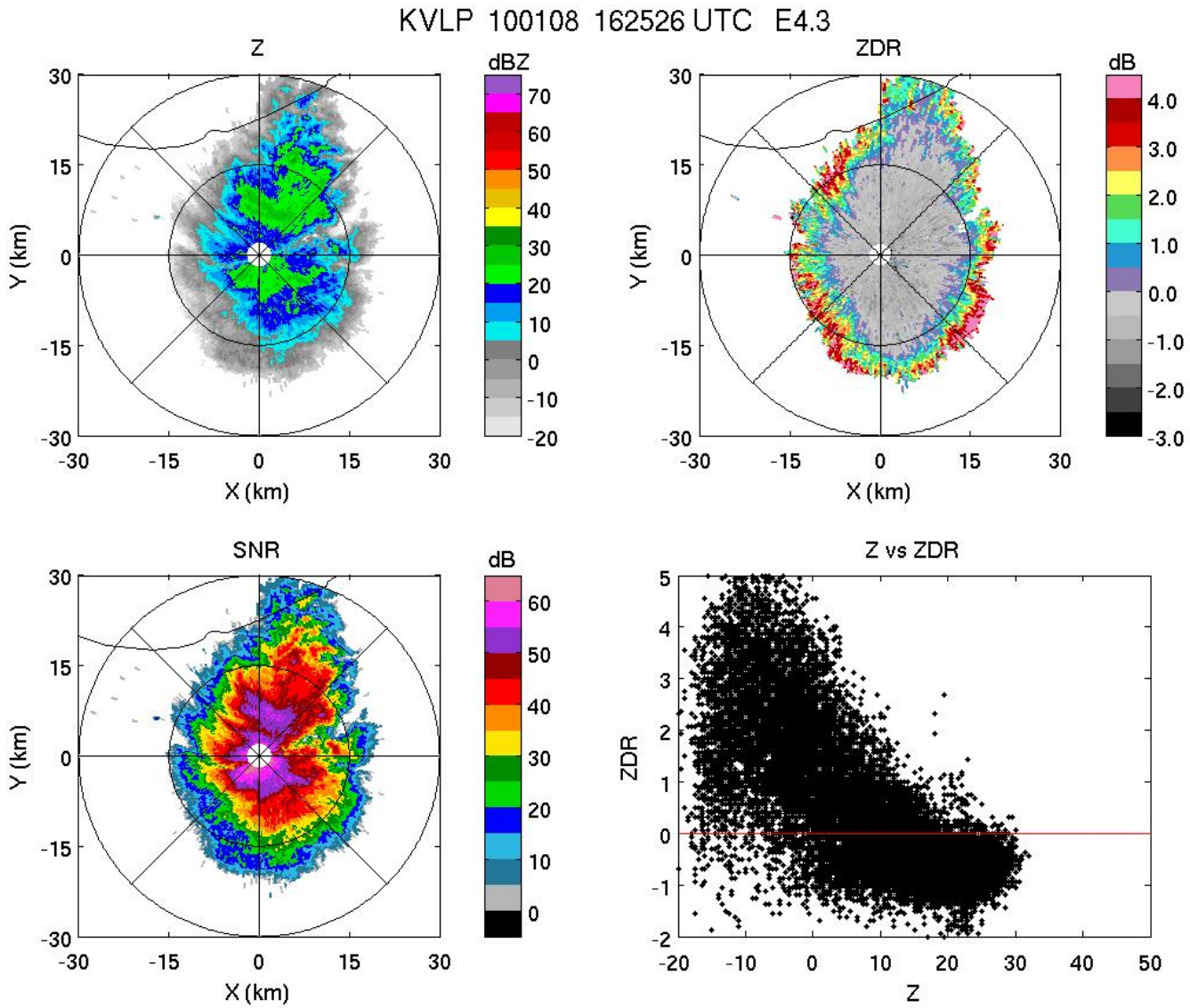


Reflectivity and ZdR on February 9, 2010





“Cocoon Storm” on January 8, 2010



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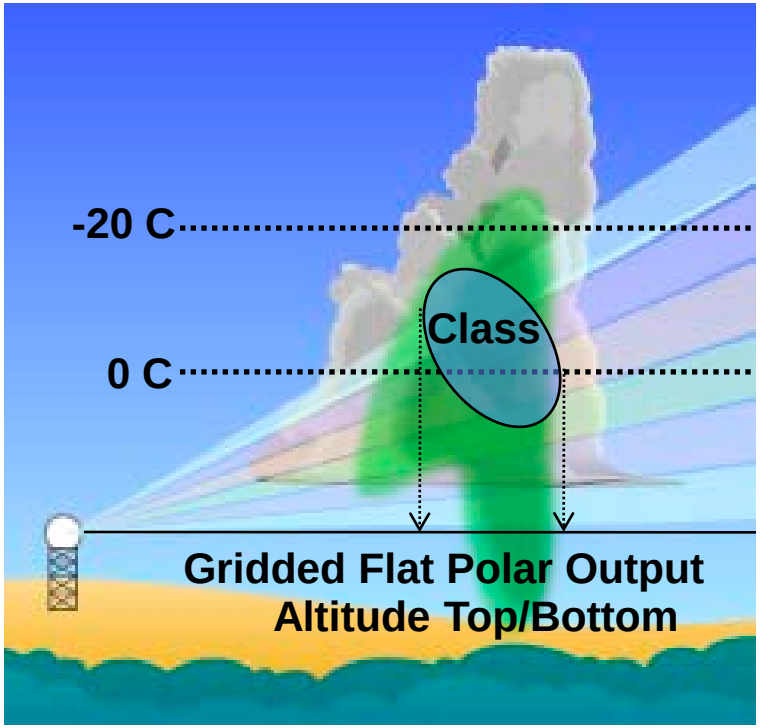
Icing Hazard and Hail Hazard Products



- Identify 3D hazard regions in radar volume
- Version 1 with NEXRAD hydrometeor classification, T/RH model soundings, and dual pol fields (target summer 2011)
- Version 2 with added techniques from Lincoln Laboratory and partner labs (target delivery in out years)
- *Likely need for surface data and/or additional sounding fields*

- 1º x 1 km grid to 300 km range
- Top/bottom altitude of hazard per grid point
- Severity and confidence indices in final version

- LL transforming alpha version dual pol algorithms functioning in the ORPG CODE to Version 1 algorithms

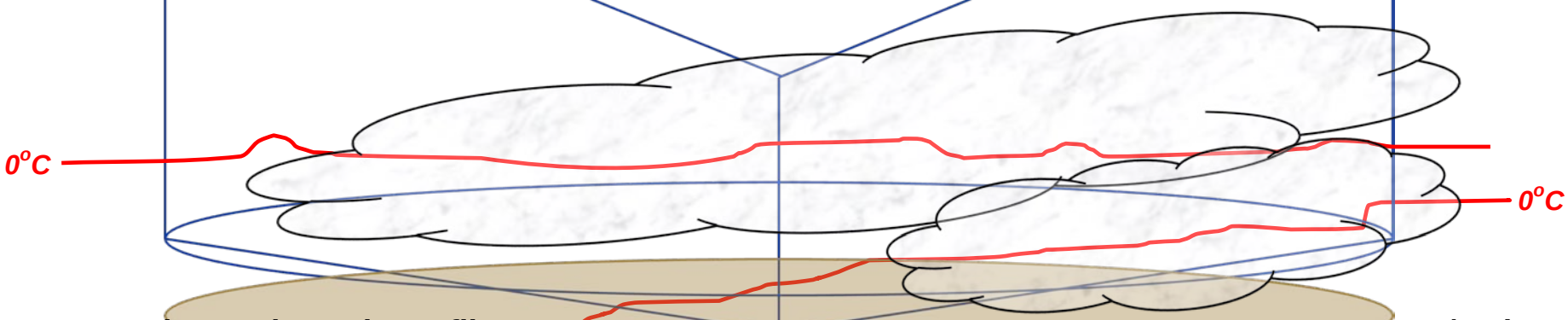
Icing Hazard Vision

WITHIN STORM AND RADAR VOLUME ICING HAZARDS

Supercooled water major threat; en route applications

Ice crystal ingest a potential secondary threat

Icing hazard products from ORPG and/or NextGen NWP



Thermodynamic profile between the lowest scan and the surface determines type beneath cloud deck

Snow, sleet, rain, freezing rain, supercooled water, virga

Temperature near/at the surface determines surface conditions

Snow, sleet, rain, freezing rain

SURFACE AND BENEATH SCAN ICING HAZARDS

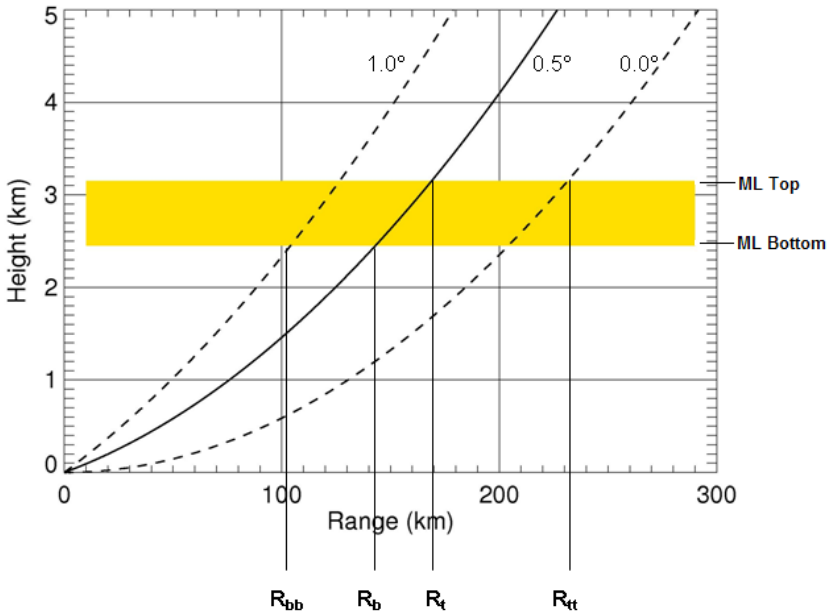
"extend" surface range of radar; terminal applications

NEXRAD Hydrometeor Classification and Melting Layer Detection Algorithms

HCA Categories

- **GC** Ground clutter / anomalous propagation
- **BI** Biological
- **DS** Dry snow
- **WS** Wet snow
- **IC** Ice crystals
- **BD** Big drops
- **RA** Rain (light and moderate)
- **HR** Heavy rain
- **GR** Graupel
- **HA** Hail (mixed with rain)
- **UK** Unknown
- **ND** No data (less than threshold)

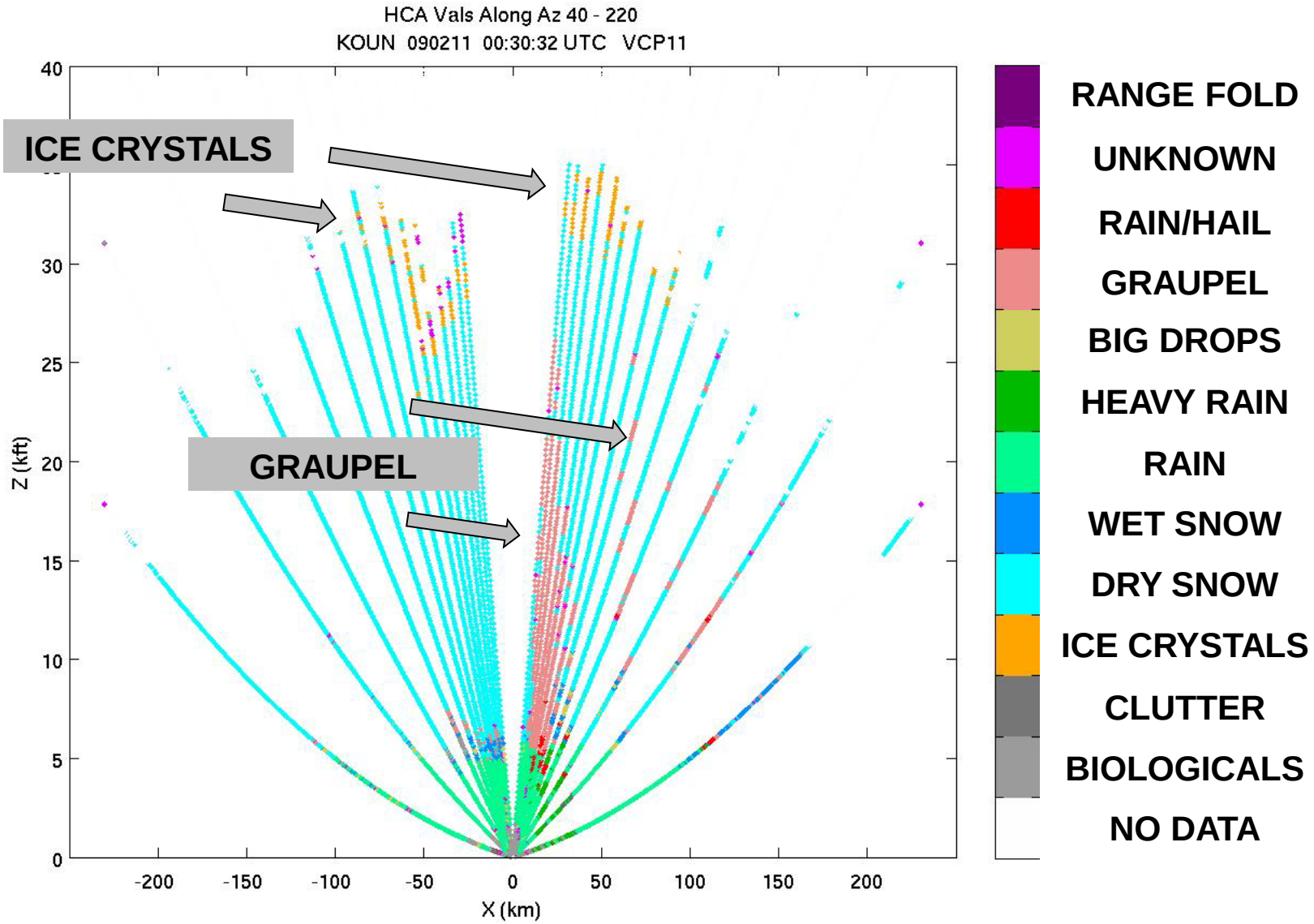
Courtesy Istok (2009) NWS OS&T



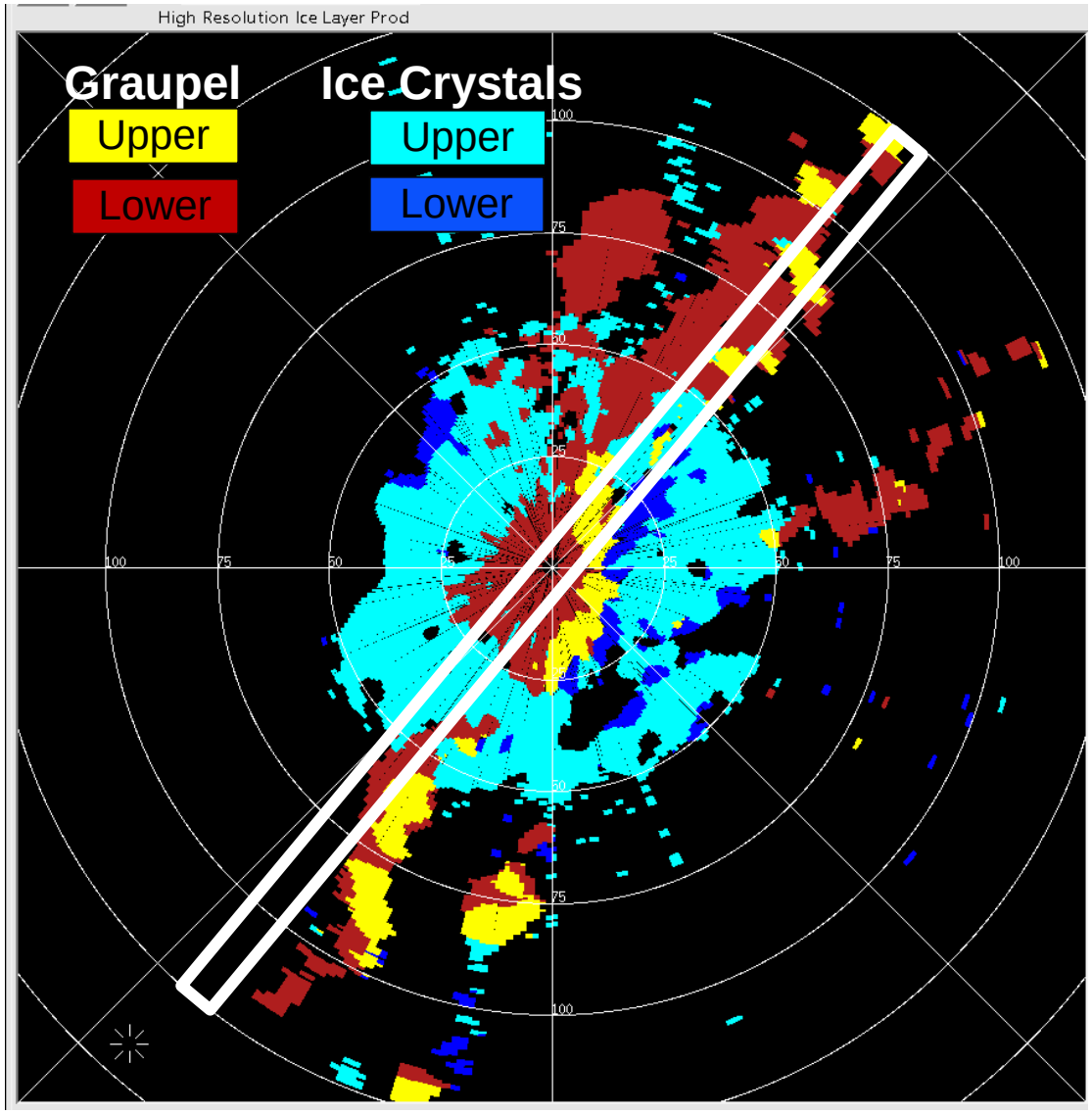
Melting Layer Constrains HCA

- **Completely below:**
  - GC, BI, BD, RA, HR, HA, UK, ND
- **Partly below:**
  - GC, BI, WS, BD, RA, GR, HR, HA, UK, ND
- **Mostly within:**
  - GC, BI, DS, WS, BD, GR, HA, UK, ND
- **Partly above:**
  - GC, BI, DS, WS, IC, BD, GR, HA, UK, ND
- **Completely above:**
  - DS, IC, GR, HA, UK, ND

Hydrometeor Classification
180º Azimuthal Vertical Cross-section

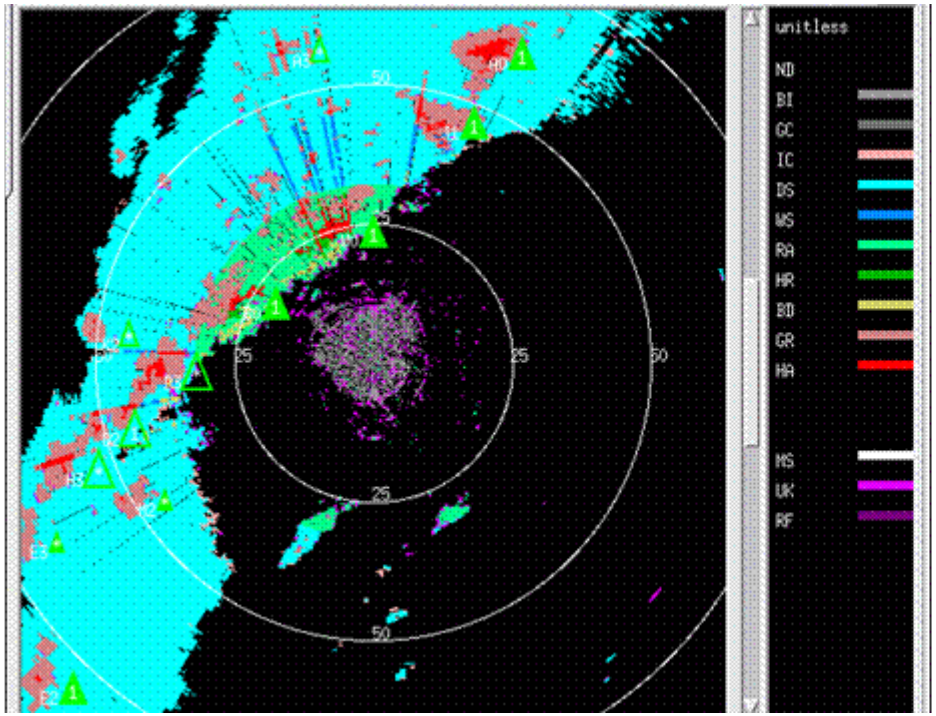


Notional Use of IHL in FAA Weather System

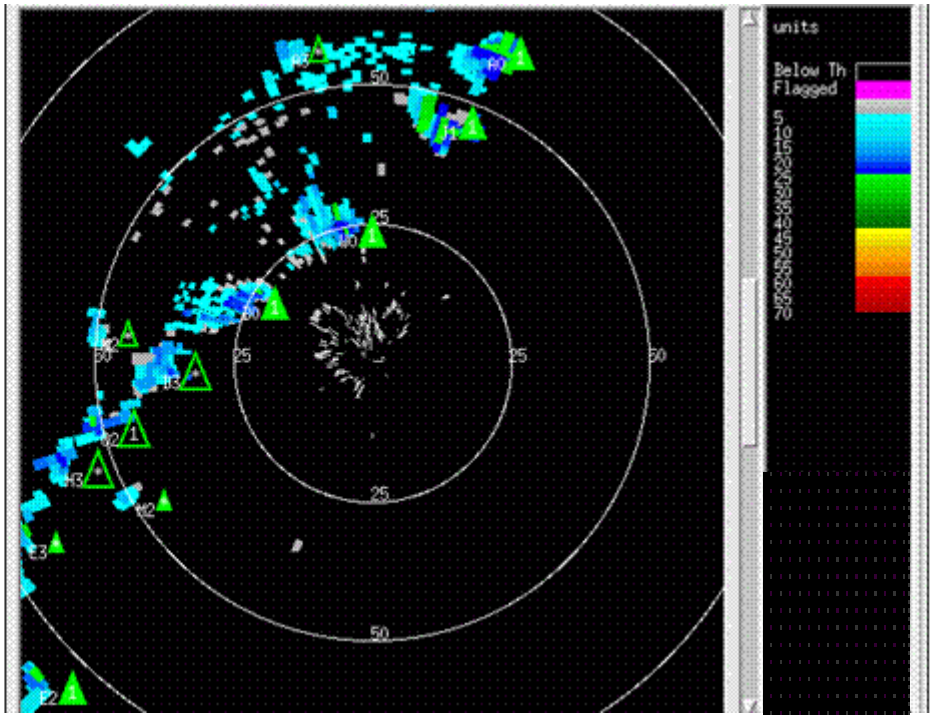


- Products tailored to FAA weather system needs
- Notional example based on altitude-defined aviation responses to hazard
- 3D hazard regions are distilled by an altitude threshold above (upper) or below (lower) 18 kft
- Further, the implied supercooled water hazard (graupel) supersedes the ice crystal hazard

Hail Hazard Layer (HHL) Product Comparison



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

Triangles depict storm cells identified with hail by the legacy Hail algorithm. Large triangles represent greater hail likelihood. Filled triangles represent greater severe hail likelihood.

Summary

- NEXRAD network Dual Pol upgrade begins in 2011
- LL developing Dual Pol aviation weather products
- First version dual pol hazard products available ~2012/3
- LL requests end-user participation to deliver hazard products appropriately