INCUS

Ground Validation (Cal/Val)

Vertical transport of water & air in convective clouds as manifested in dZ_e/dt

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Fundamental "Val" in the "Cal/Val": Convective Mass Flux (CMF)

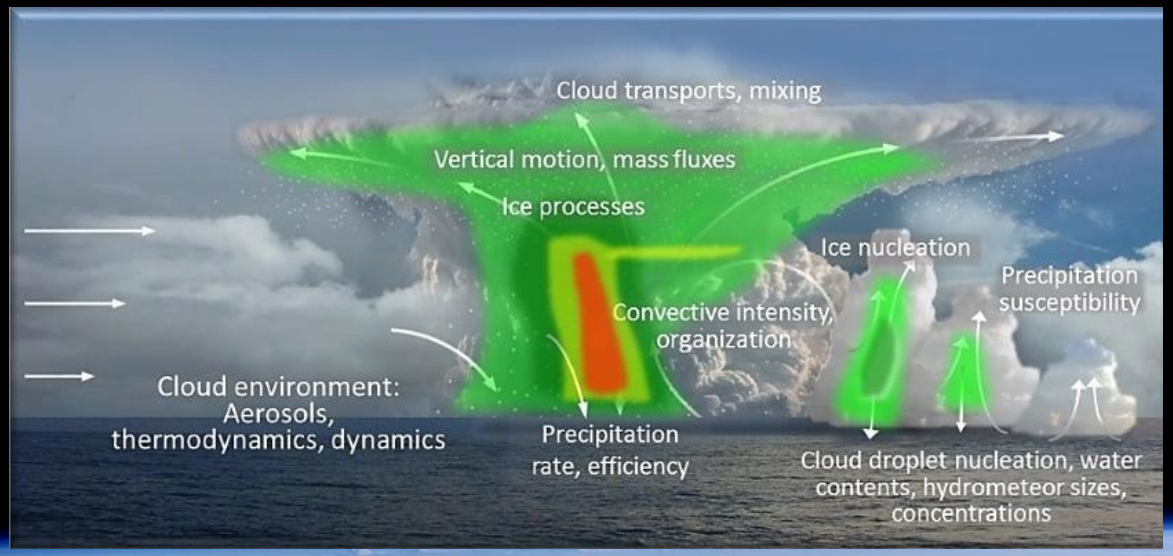
INVESTIGATION OF CONVECTIVE UPDRAFTS

Vertical transport of water & air in convective clouds as manifested in dZ_e/dt

$$\frac{\Delta Z_e}{\Delta t} = -\overrightarrow{V_{xy}} \cdot \overrightarrow{\nabla_{xy} Z_e} - W_C \frac{\Delta Z_e}{\Delta z} + \text{Mic}\,(\alpha * W_C)$$

$(\Delta$-t)	Horizontal Advection	Vertical Advection	Microphysical conversions

Profiles*: Z_e, $\Delta Z_e/\Delta t$, $W_c(w_{air}, V_t)$, *CMF*, q_i
Important ancillary: hydrometeor types (i), precip rates



Working GV Measurement Foci:

- **Updraft vertical profile* evolution, for a variety of convective cores (intensity, lifecycle, type) @ high space/time resolution**
- **Updrafts > 2 m/s @mid/upper levels (e.g., T < 0°C) with estimation uncertainty in CMF of <1.8 kg/m^2.**
- **Microphysics: hydrometeor types/contents**

Getting equation components with GV assets

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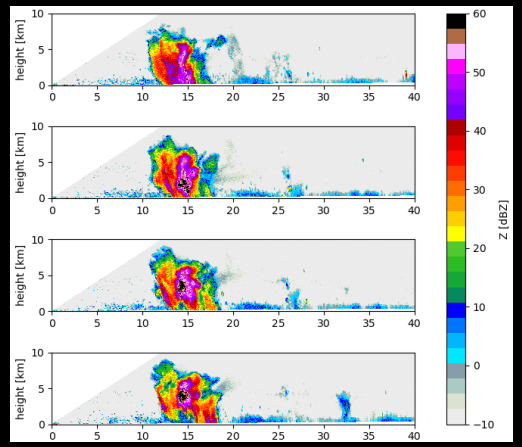
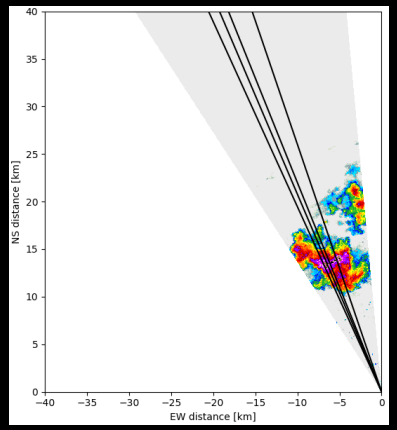
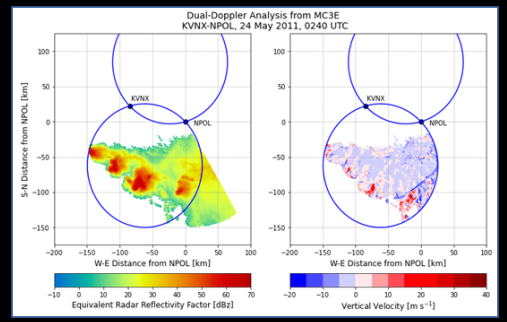
(Δ-t)
Repeated RHIs/Sectors

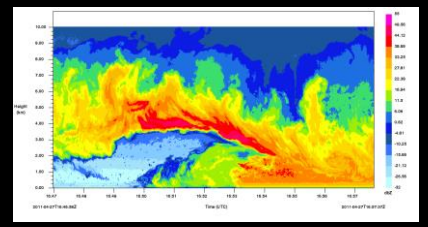


Horizontal Advection
tracking sectors, multi-Doppler

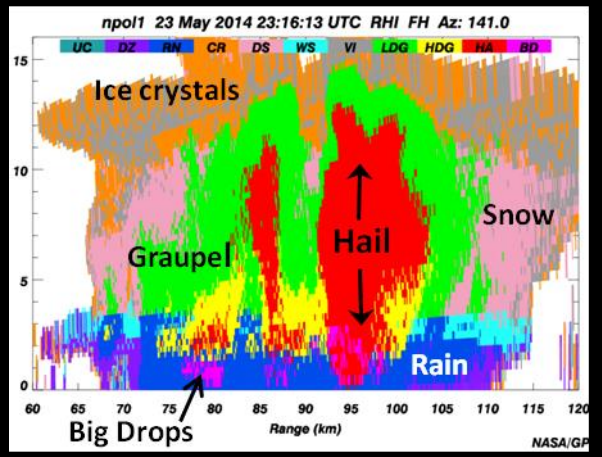


Vertical Advection
RHIs, multi-Doppler, Profiler(s)





Microphysical conversions
Polarimetric



Profiles: W_C (w_{air}, V_t), CMF , q_i….
Also important: precip rates, phase changes/process

INCUS Validation Concepts

INVESTIGATION OF CONVECTIVE UPDRAFTS

Approach:

- One-three field sites leveraging existing multi-radar + profiler facilities to collect a breadth of profile measurements
- Mine/leverage pre-existing datasets (e.g., profiler, multi-Doppler radar, airborne etc.) for case/statistical analysis
- *Secondary focus*, satellite coincidence collections f(inclination, sites, cooperation of "nature")

Baseline Cal/Val Approach	Outcomes
1. Pre-Launch: a) Pre-existing Dataset analysis (non-INCUS field campaigns) b) Site/platform evaluation & testing for field architecture/ops c) Data processing tools d) Convective Mode Scorecard (CMS)	• Targeted statistical analysis – specific datasets *under survey*) • Optimized site target recon (CMS), radar ops, and automated target selection (MAAS) • Functional multi-Doppler and hydrometeor retrievals from field obs • Ka-Band Z_e transfer functions from field radar wavelengths
2. Post-Launch: Field Measurements **a) Multi-field Sites**/"regimes"-SE U.S., S. Plains, possibly Front Range; extended observations b) Rapid scan X-S-band dual-pol/Doppler radars, wind profilers, [augment with other measurements as available]	• Optimized convective core sampling @ <120 s, < 1km between radars and over profilers; updraft (CMF, q_i), f(storm character, CMS) • Combined with AUX/PoR variables (GOES, lightning, environment].

Validation to target underlying algorithms and utility for science objectives

Multiple INCUS GV Field Sites Under Study

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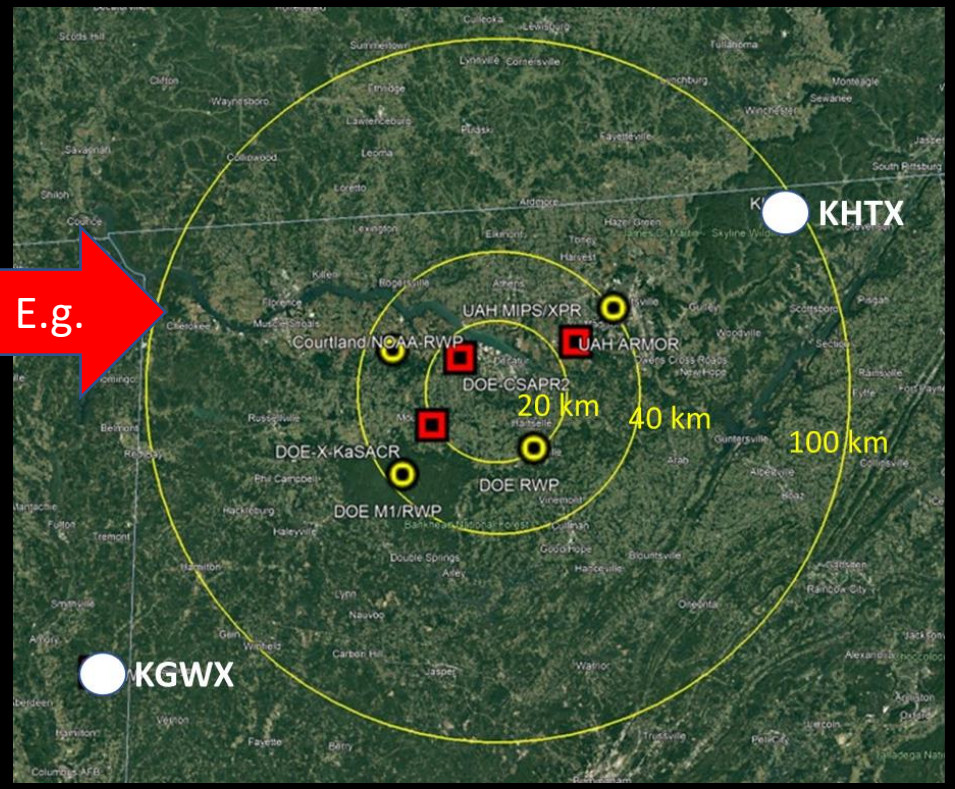
Pre-Launch Site Evaluation and Testing All TBC

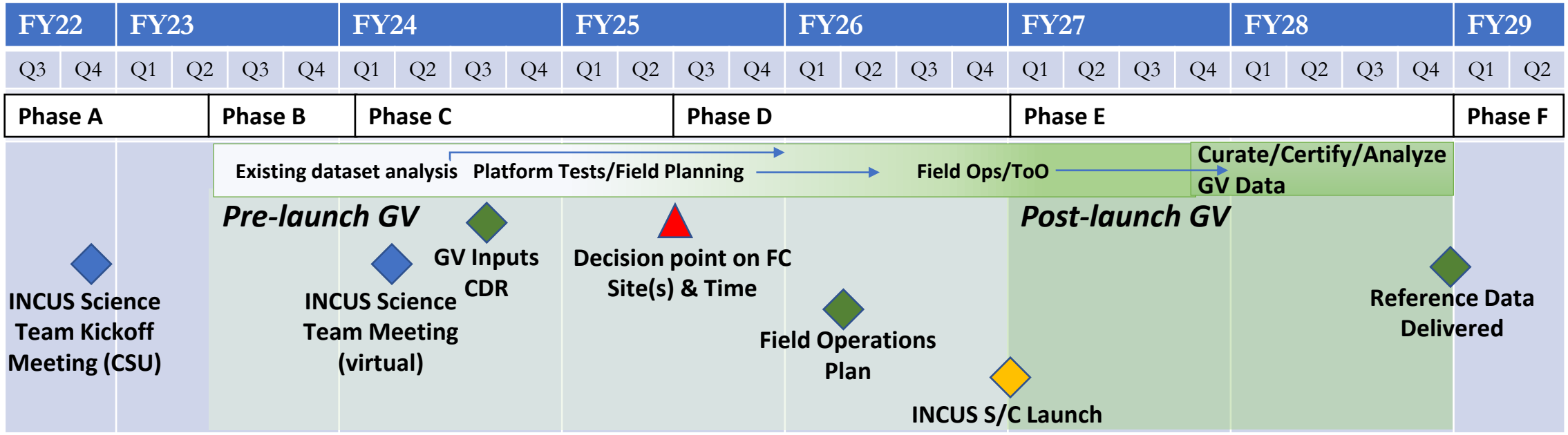
Location	Radar Assets
Huntsville, Alabama *DOE/NOAA/UAH collaboration*	DOE CSAPR2: C-band, polarimetric, Doppler, MAAS DOE XSAPR: X-band scanning radars, polarimetric, Doppler DOE AMF3 RWP (2): 915-MHz profiler, Doppler MAX: X-band polarimetric, Doppler, *MAAS*, mobile ARMOR: C-band polarimetric, Doppler, *MAAS* XPR: X-band radar profiler, Doppler, mobile RADAPS/MIPS: 915-MHz profiler, Doppler, mobile NOAA Profilers: 449-MHz profiler, Doppler
Greely, Colorado CSU	CHIVO: C-band polarimetric, Doppler, MAAS CHILL: S-band + X-band polarimetric, Doppler NOAA Snow-level Radar: S-band profiler, Doppler
Norman, Oklahoma OU	RaxPol: X-band polarimetric, Doppler, rapid scan, mobile PAIR: C-band phased array (PAR), polarimetric, mobile HORUS: S-band PAR, polarimetric, mobile

E.g.



Note: Complementary aux observations/instrumentation incl. Lightning Mapping Arrays exist at all sites

Notional Schedule for INCUS Ground Validation



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Roles and Responsibilities

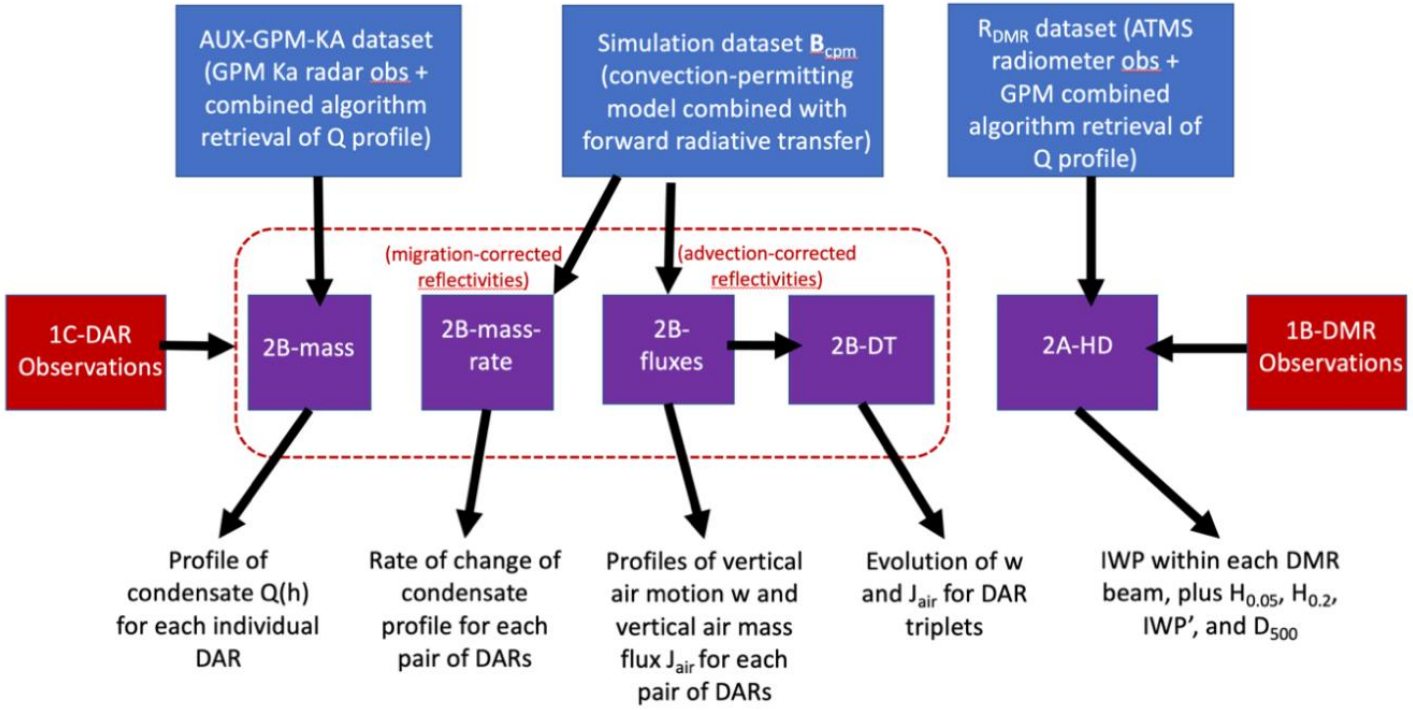
NASA MSFC and Texas A&M Univ. overall responsibility for providing reference datasets to the INCUS Science Team for ground validation activities.

- GV Team: MSFC/TAMU/CSU/SBU: Pre/Post launch planning and execution of field measurements, dataset production/delivery, exploration and analysis of existing datasets for pre-launch validation

Preliminary Cal/Val plan

Timeline: Prelim version due 30 days before CDR (Jun 2024), final version due 30 days before ORR (2026)

Goal: Describe approach for i) validating INCUS instrument data (L1, Simone Tanelli), ii) characterizing the performance of the retrieval algorithms and data-product accuracy (L2, Walt/Courtney/Patrick)



- Regular meet-ups every three weeks, next meeting is December 19th at 11 am MT
- Please feel free to join in our calls or contribute material and ideas

Preliminary Cal/Val plan

Minimum requirements for plan (draft in progress):

1. Description of planned validation activities including what is being analyzed and how it relates to instrument performance to produce specific data products
   - *Emphasis on high-quality w and dz measurements above 0°C at high delta t (splinter group to focus on equivalent Ka calculations)*
   - *Priority is CMF and validation of 2B-fluxes, but other algorithms and their components will be assessed*
2. Plan for coordination with available or ongoing ground data collection and field campaigns
   - *Existing datasets – e.g., ESCAPE, NARL profilers*
   - *Pre-launch opportunities (2024-26) – e.g., mini-campaigns in CO and OK, DOE/NOAA/UAH collaboration in AL*
   - *Creation of field operations "blueprint" with suggested instrumentation and MAAS scanning strategy*
3. Plan for conducting field studies during INCUS operations
   - *Extend pre-launch operations for longer record and enhanced statistics, and to other locations (including outside of CONUS) using "blueprint"*
   - *Ensure sufficient sampling of convective modes (current action item is to mine satellite climatologies)*
4. Schedule for release and archiving of the validating data products
5. Timeline and annual budget with milestones

Challenge: Observe and "measure" rapidly evolving physics at fine scales

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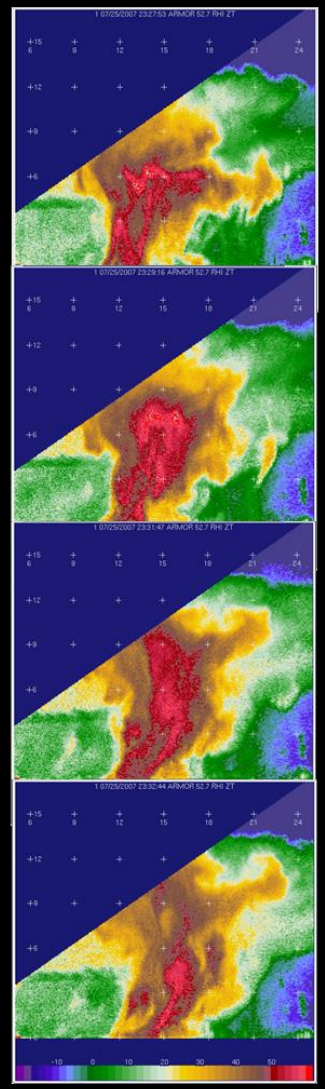
T

T + 83s

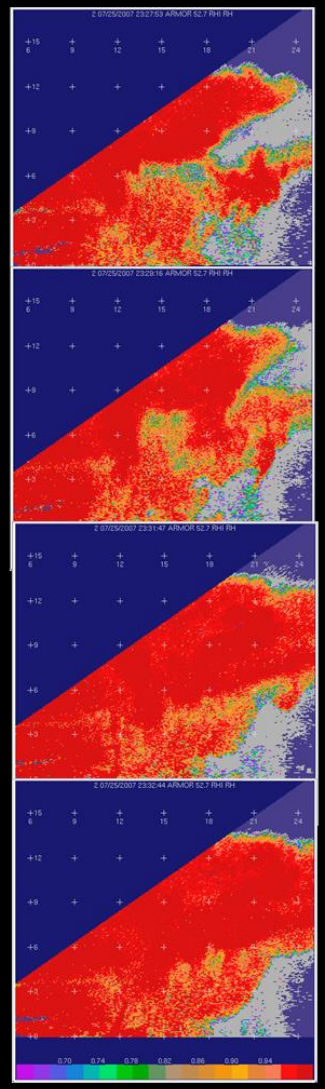
T + 234 s

T + 291 s

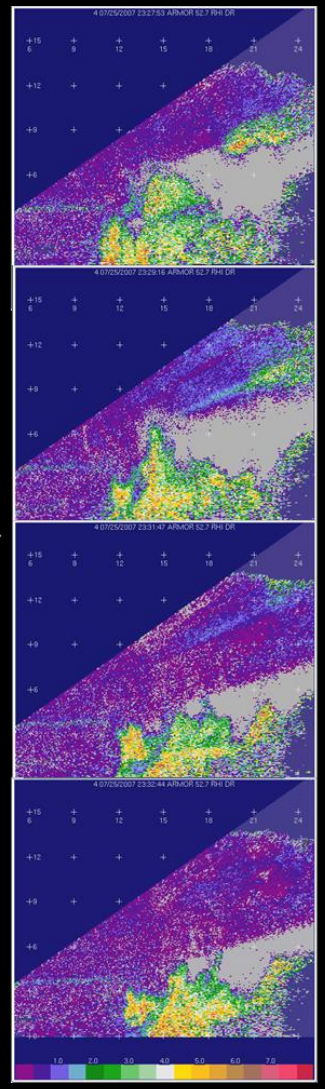
Z



ρ_{hv}



ZDR



Vertical Development Mixed Phase

Extended Mixed Phase

Glaciating (ed)

Glaciated

ARMOR RHI Scans 07/05/2007 multi-az. RHI volumes

All within a typical 88D volume scan

Isolated deep storm, rain/hail mix