# INTEGRATED GOES-R GLM/ABI APPROACHES FOR THE DETECTION AND FORECASTING OF CONVECTIVELY INDUCED TURBULENCE (CIT)

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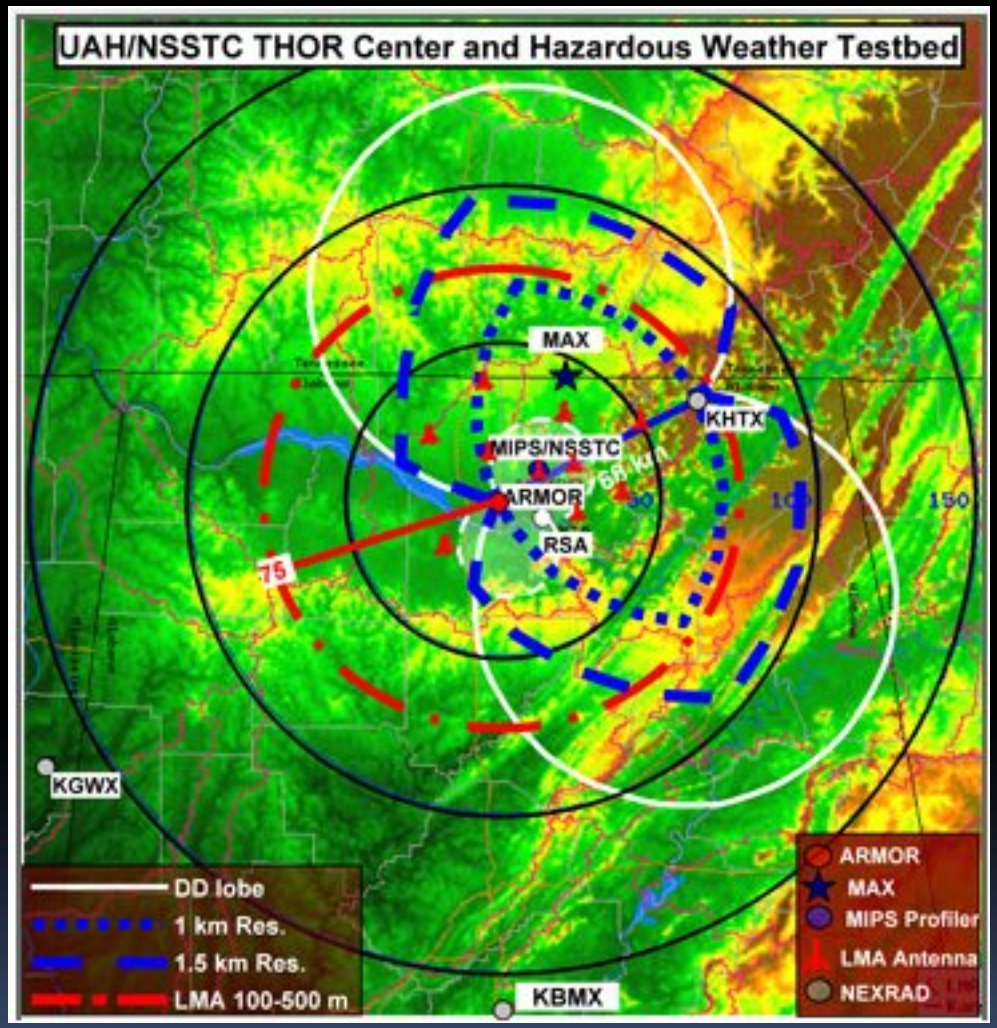
# Goals and Approach

- Objective: investigate the potential for GOES-R multi-sensor detection and short-term forecasting of turbulence and other aviation hazards associated with rapidly growing and mature convective cells.
- Approach: Advanced Baseline Imager (ABI) proxy cloud top cooling and overshooting-top (OT) and Geostationary Lightning Mapper (GLM) proxy total lightning flash rates for diagnosis of storm intensity and growth rate

# Data

- Total lightning data are obtained from the VHF-based Northern Alabama Lightning Mapping Array (NALMA) or the Earth Networks Total Lightning Network (ENLTN)
- Cloud top cooling and OT detection are obtained from Geostationary Operational Environmental Satellite (GOES) observations over the NALMA domain (≤ 100-150 km)
- Turbulence occurrence is determined objectively using eddy dissipation rate (EDR) from the NCAR turbulence algorithm applied to commercial aircraft navigation data over NALMA.




- Also KHTX and ARMOR radar data.

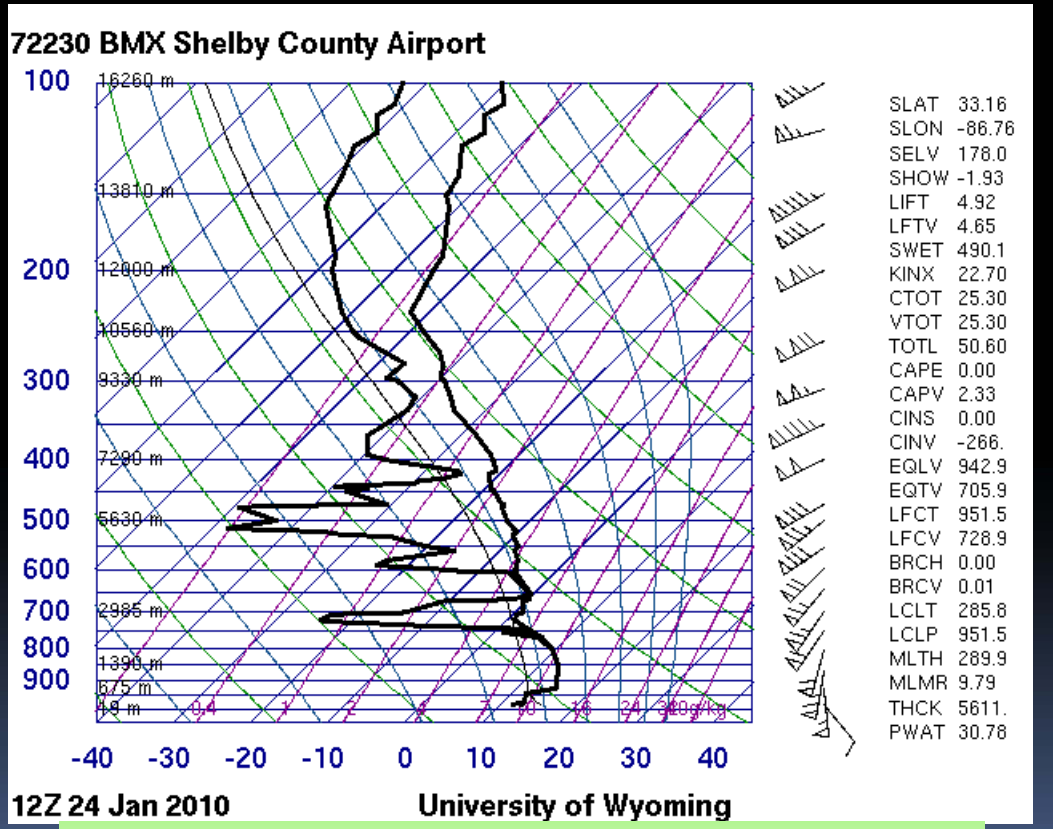
# Research Priorities

1. Developing database of concurrent NALMA (or ENTLN), GOES, EDR and radar data during a variety of convectively induced turbulence (CIT) conditions (light, moderate, severe) over NA-LMA,
2. Processing NA-LMA (or ENTLN) for total lightning flash occurrence and rates and GOES for convective cooling rate, OT occurrence and other properties, and
3. Investigating the temporal and spatial relationships between these total lightning properties, overshooting-tops (OTs), infrared (IR) cooling rates and CIT/EDR events.

# Case Study of Moderate Turbulence: January 24, 2010

**Synoptic:**

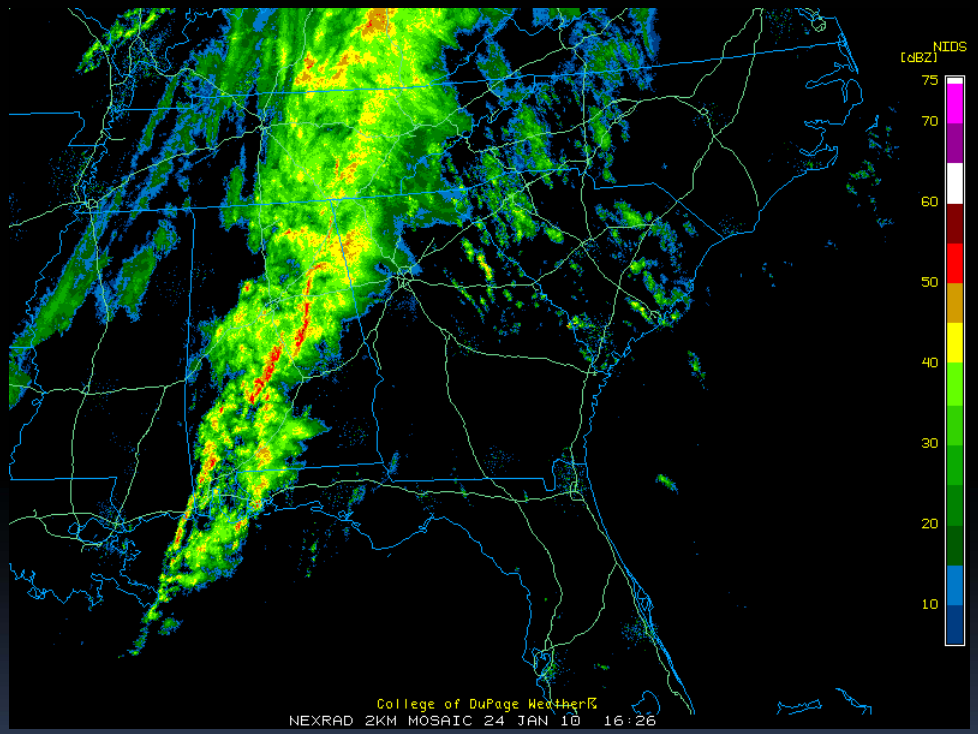
- 500mb trough axis over the Plains
- 95 kt flow at 500mb
- 65 kt LLJ bringing moisture into central AL
- **overall a strongly sheared low buoyancy setup**




BMX 12 UTC Sounding (Skew-T Log-P)

# Case Study of Moderate Turbulence: January 24, 2010

- Convection:
  - Most severe reports were near the gulf coast and southeast
  - Intensity: mostly low dBZ (<50) at times of turbulence reports near NALMA
  - Morphology: widespread weak echo with linear segments
  - Weakly electrified
- Duration:
  - 8-19 UTC roughly
  - several rounds of convection
- Moderate turbulence report of interest near NALMA:
  - **1702 UTC: MDT (ATL to MEM)**




NEXRAD 2 KM composite 1626 UTC

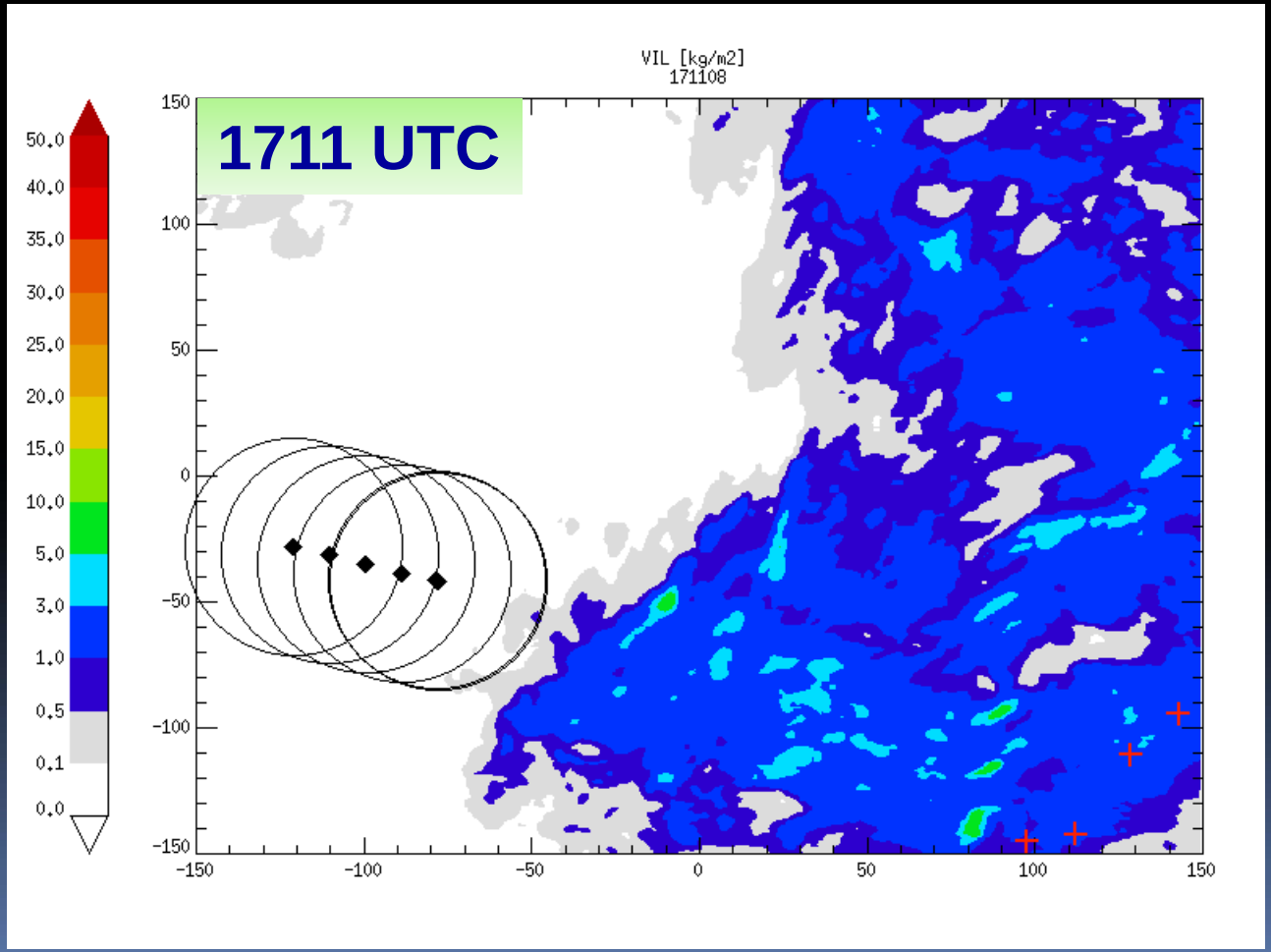
- Flight arrives in area at 1653 UTC and is moving from southeast to northwest
- Little-to-no lightning across domain consistent with low VIL but some cells are notable for very low flash rate (< 1 $min^{-1}$)
- Although VIL is weak, cell in path of flight (red arrow) is one of three cells producing lightning prior to its passage
- Moderate EDR reported as aircraft flies over (or very nearby) lightning producing cell (1702-1707 UTC)

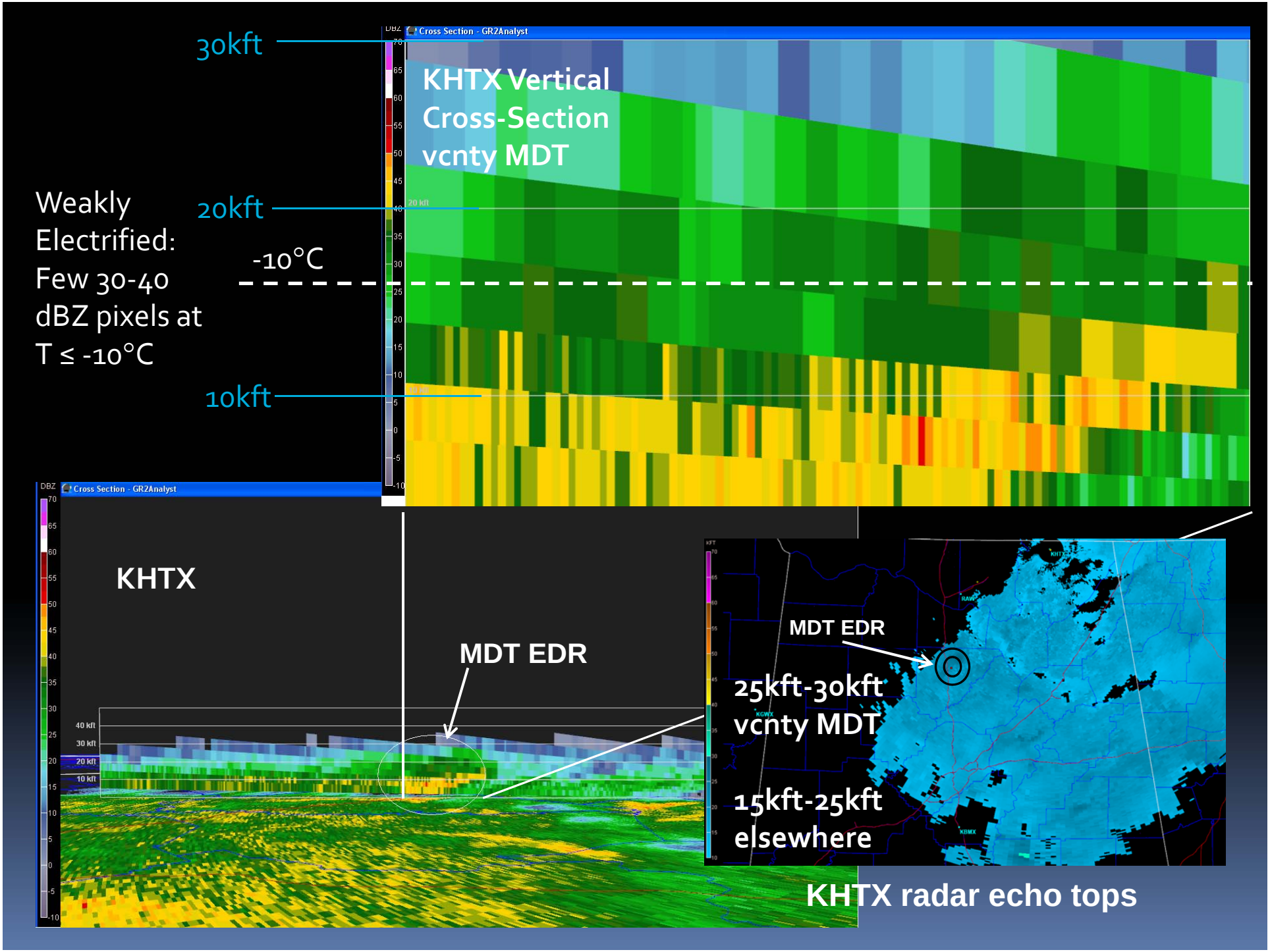
**KHTX Vertically Integrated Liquid (VIL) (shaded, kg $m^{-2}$)**

+ NALMA flash

20 mile

- MDT Turbulence
- LGT Turbulence
- NO Turbulence



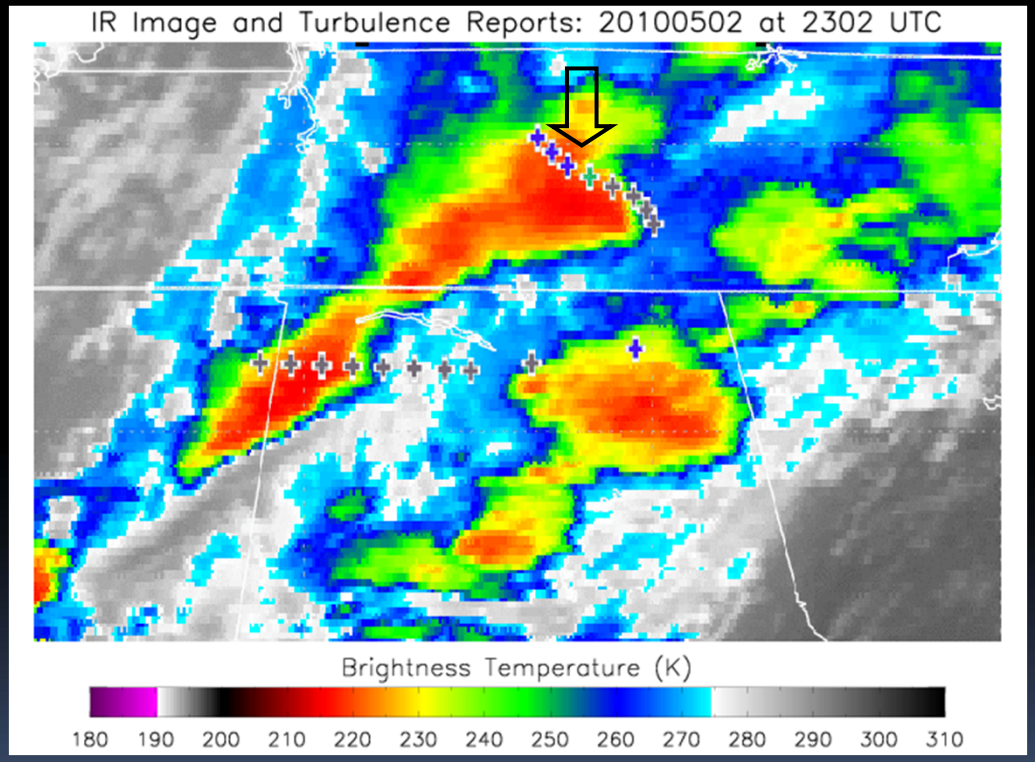

30kft
20kft
10kft
-10°C
Weakly Electrified: Few 30-40 dBZ pixels at T ≤ -10°C
Cross Section - GR2Analyst
KHTX Vertical Cross-Section vcnty MDT
KHTX
MDT EDR
40 kft
30 kft
20 kft
10 kft
MDT EDR
25kft-30kft vcnty MDT
15kft-25kft elsewhere
KHTX radar echo tops

# Case Study of Moderate Turbulence: January 24, 2010

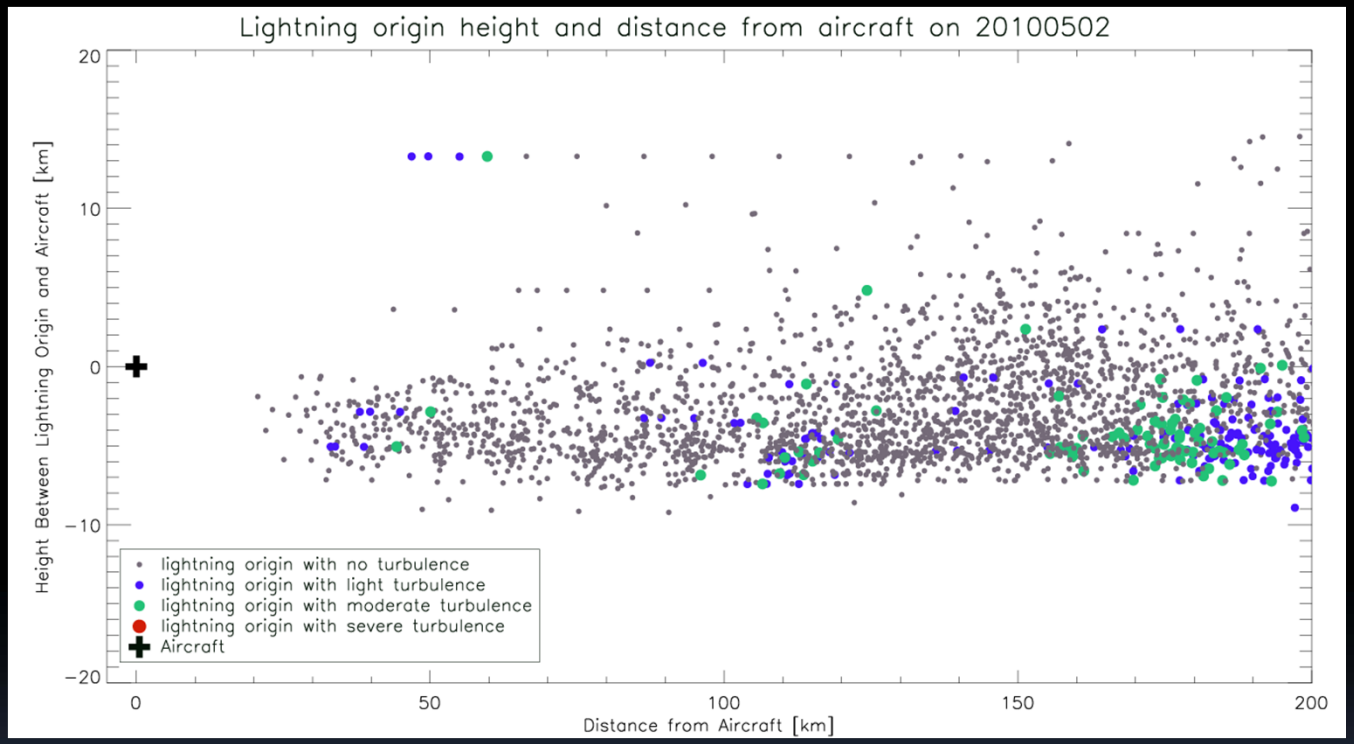
- As seen in KHTX VIL, storm tops and vertical reflectivity structure, relatively weak convection over the Tennessee Valley
- NALMA flash data indicate the cell is charged and may be stronger than what is obvious from radar alone (e.g., VIL, vertical reflectivity structure, ET)
- Cell in question is 1 of 3 in NALMA domain producing any lightning just prior and during moderate EDR reports
  - Thunderstorms and associated MDT turbulence easily avoidable with NALMA/GLM proxy

# Case Study of Moderate Turbulence: May 2, 2010

Seeking to answer the question: Why the flight in Tennessee experienced moderate turbulence while the flight in northwest Alabama did not experience any?



# Case Study of Moderate Turbulence: May 2, 2010



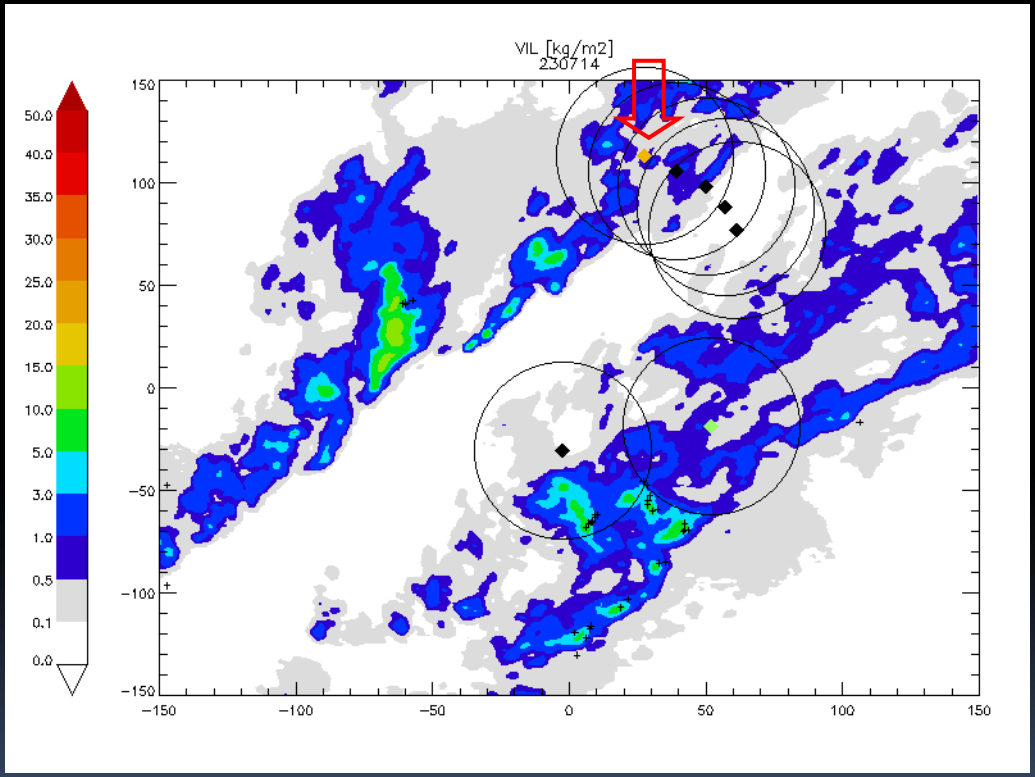

Lightning does not appear to be correlated to the turbulence events, as the nearest lightning strikes to the aircraft were not associated with turbulence.

Note: Lack of lightning associated with turbulence in this case is likely due to pilots doing a good job avoiding direct interaction within and nearby thunderstorm cells.

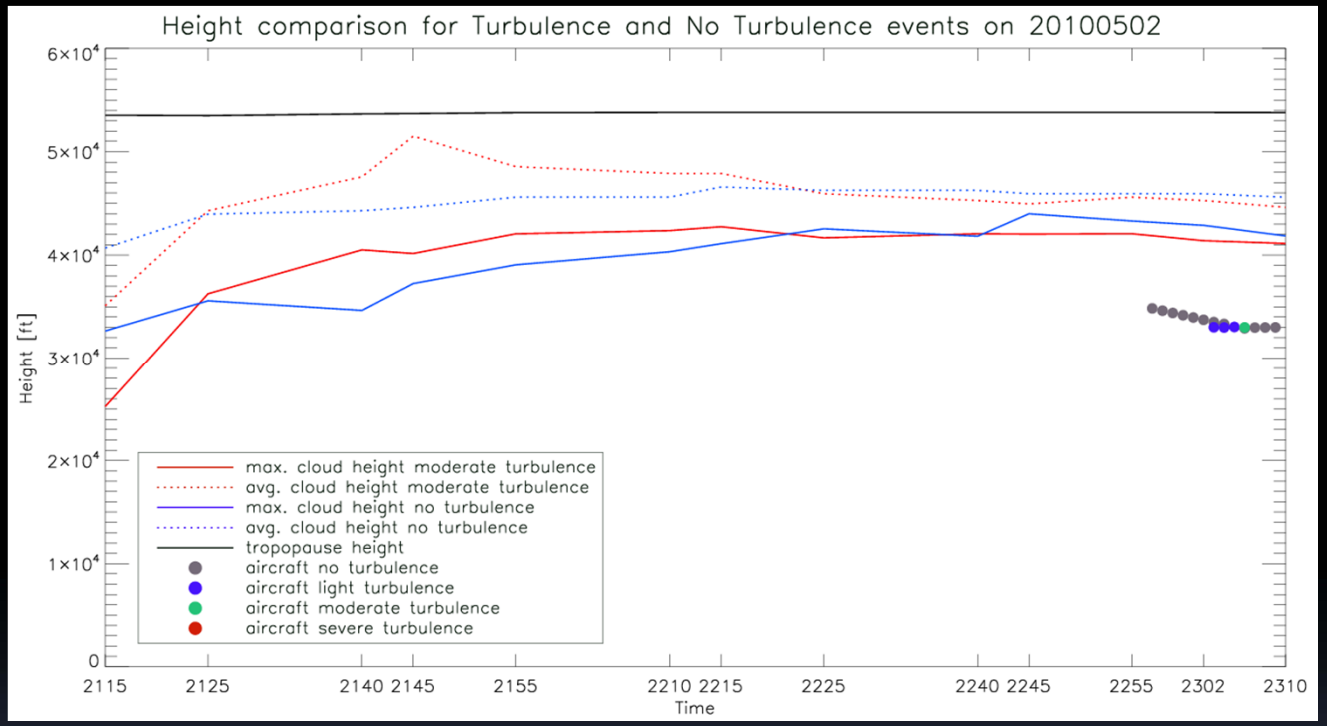
Lesson: Not all turbulence in the vicinity of mesoscale convection is easily associated with a nearby (< 32 km or 20 mile) thunderstorm cell. Possibly due to effects of gravity waves emanating from thunderstorms extending beyond 32 km. Need meteorology/NWP model.

# Case Study of Moderate Turbulence: May 2, 2010

KHTX radar VIL is very low(< 3 kg $m^{-2}$) and there is no NALMA lightning in the vicinity of the precipitation associated with this moderate turbulence event in Tennessee.

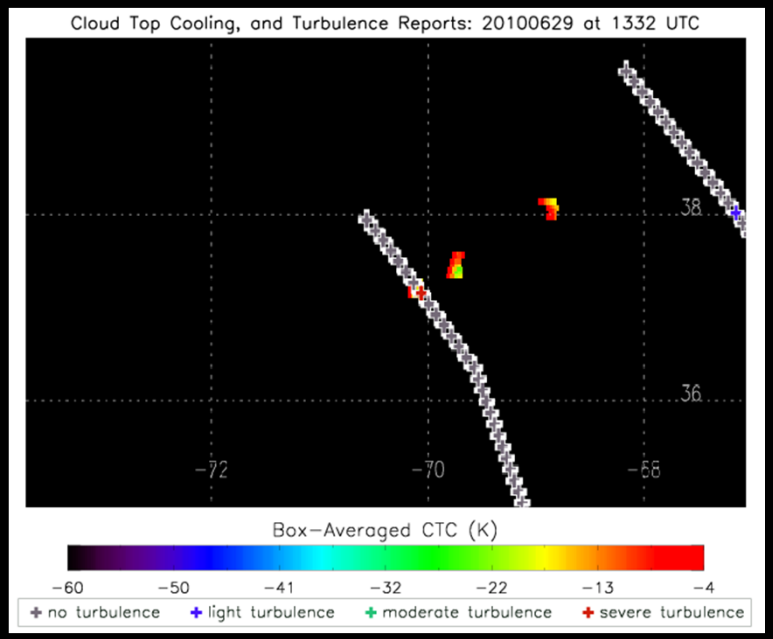


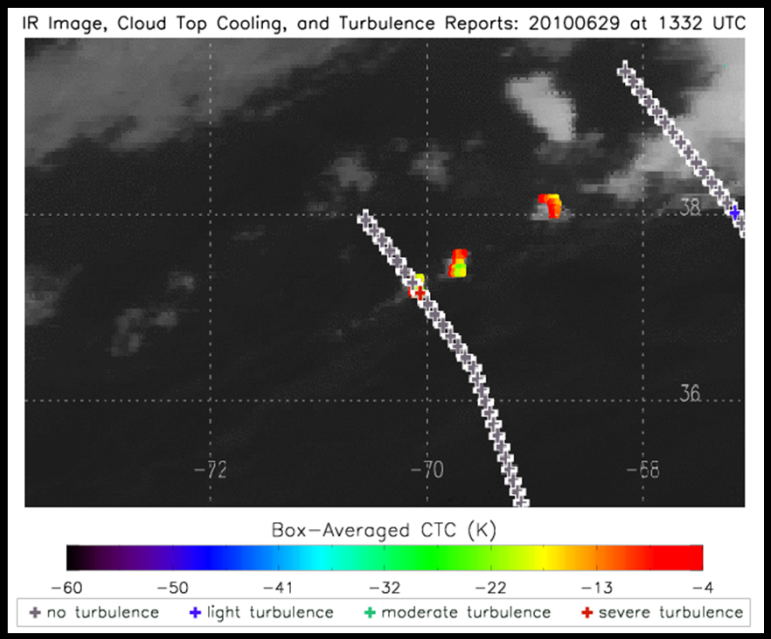
# Case Study of Moderate Turbulence: May 2, 2010

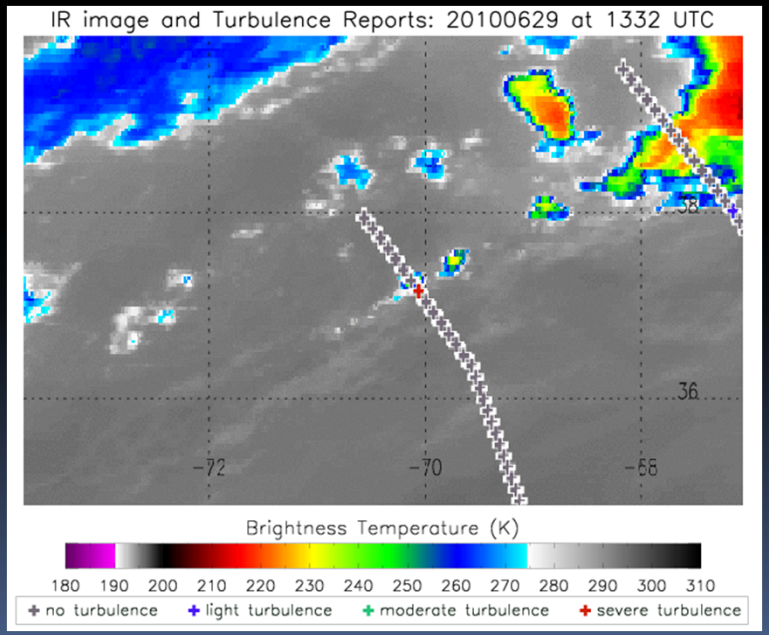



- Both aircraft flew into the storm system, as evident by the cloud heights being higher than the flight height. Neither cloud cluster appears to be growing from IR.
- Cloud clusters manually tracked using Warning Decision Support System -- Integrated Information (WDSS-II).

# Cloud Top Cooling: Relationship to CIT




- **Flying over a cloud which is rapidly cooling can cause severe turbulence, as seen in this case over the Atlantic Ocean**
- **Next step is to calculate how often this occurs**

# Comparisons Between OT Detections and Total Lightning Observations From The Northern Alabama LMA

K. Bedka and C. Fleeger (SSAI @ NASA LaRC)

An objective overshooting convective cloud top detection algorithm has been developed within the GOES-R Aviation Algorithm Working Group.

The method uses IR spatial gradients and thresholding in combination with a NWP tropopause temperature field. It performs optimally with high spatial resolution IR imagery from MODIS or GOES-R ABI, but operates effectively using current GOES. See Bedka et al. (JAMC, 2010) for details.

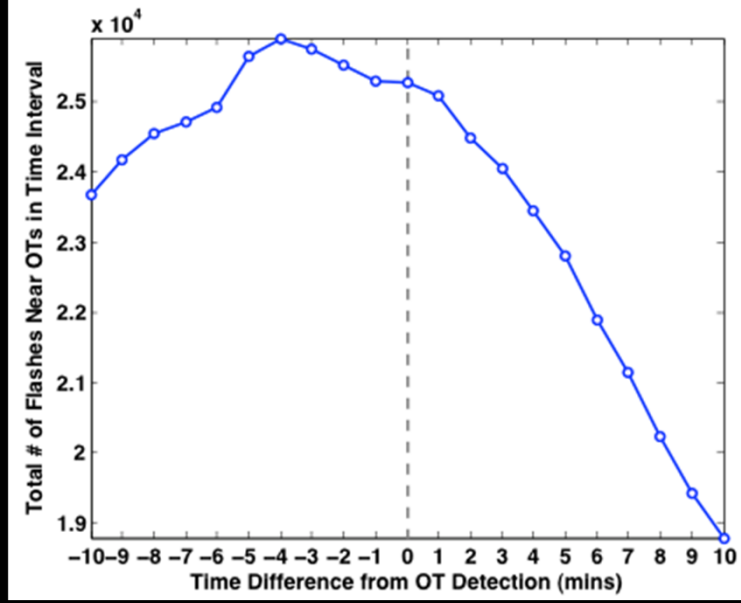
**GOAL:** Analyze bulk relationships between GOES overshooting top (OT) detections and total lightning observations

**METHOD:** Compared ~2500 OT detections with NALMA data across 37 days each featuring 40+ OT detections

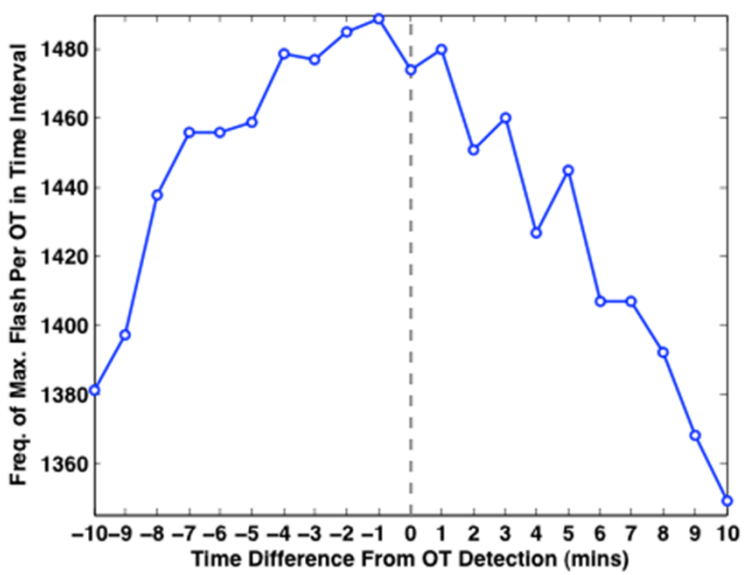
Compared lightning flash rates within 10 km of OT detection at 1 min intervals

**RESULTS:** Lightning flashes peak 0-4 mins before OT detection due to accelerating convective updrafts that later produces a detectable OT signature in GOES IR imagery

Total NALMA Flashes Within 10 km of an OT Detection




Time of Max Flash Rate Within 10 km of an OT Detection



# Comparisons Between OT Detections and Total Lightning For An Individual Storm

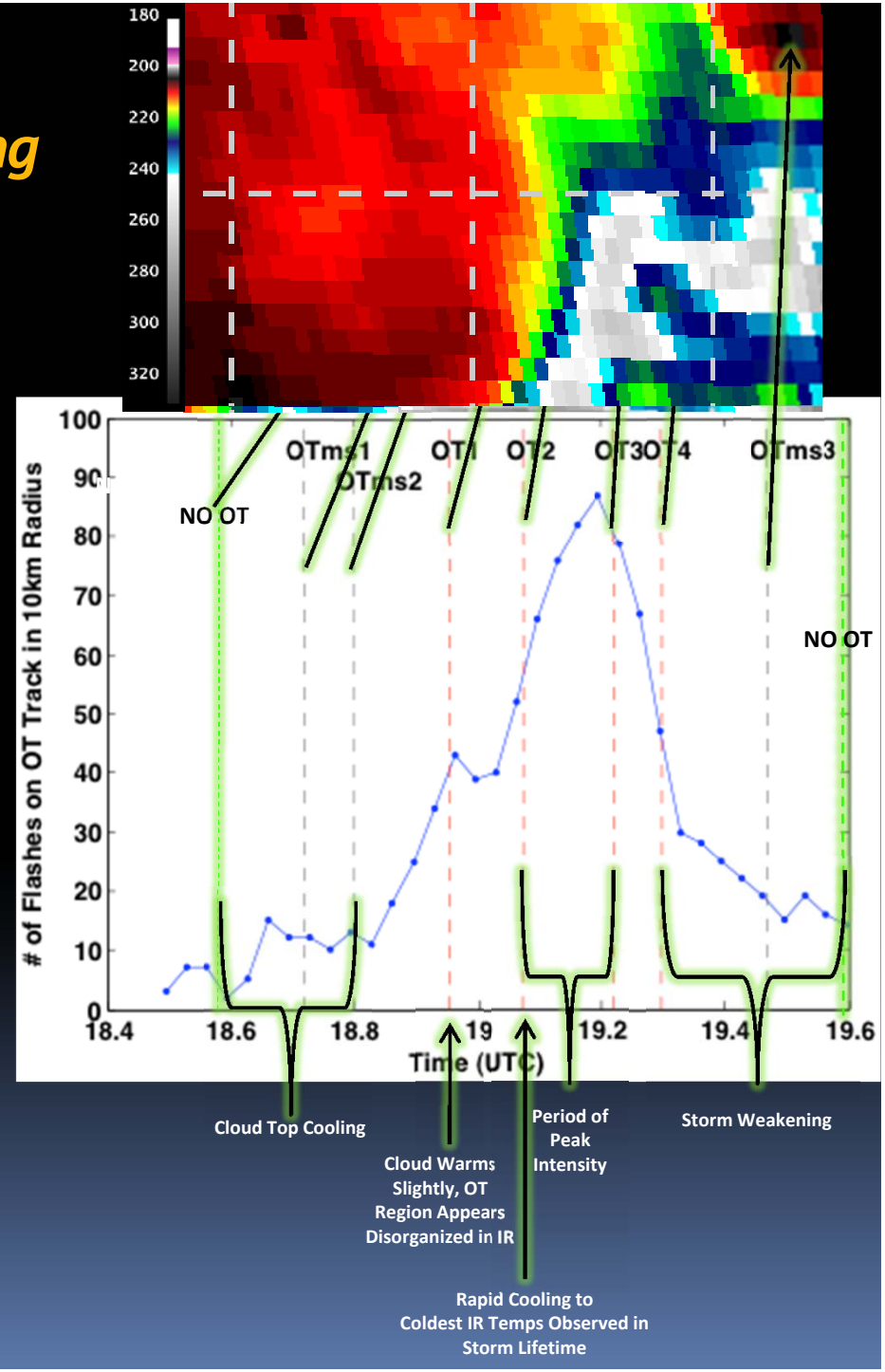
**GOAL:** Understand the co-evolution between satellite observed overshooting top (OT) signatures in rapid scan GOES imagery and total lightning observations

**METHOD:** Identify cases where OT signatures were repeatedly observed and detected within 100 km of Huntsville, AL

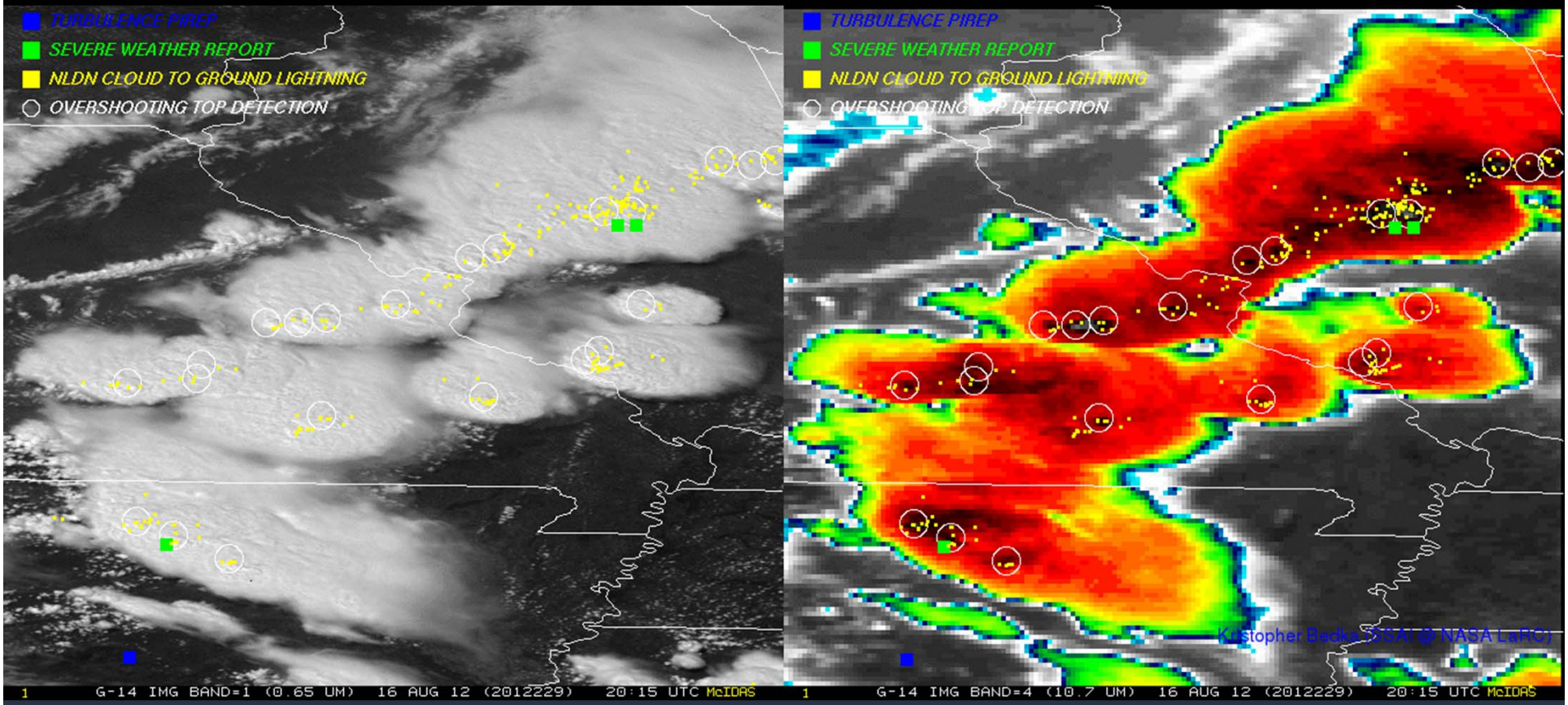
Fit line to OT track and compare with lightning flash rate at 1 min intervals and at a 10 km radius from each of the 1-min updraft positions

**RESULTS:** ENTLN[1] lightning flash rate peaked during the period when OTs were consistently detected using GOES-13 5 km IR imagery on 27 April 2011

[1]This storm was too far from the NALMA network to provide reliable comparisons coupled with the fact that the NALMA network may have been partially compromised on 27 April due to severe weather damage to sensors/communications.



# OT Detections Using GOES-14 1-Minute Super Rapid Scan Observations (SRSO)




**FUTURE WORK:** Analyze OT-lightning co-evolution for individual storm cells within 1-min GOES Super Rapid Scan imagery collected during summer 2012

# Ongoing Work

1. Continuing to expand the GLM-ABI-proxy, EDR, and ground-based radar datasets for CIT events of varying intensities
2. Using WDSS-II object-tracking tools optimized for radar, total lightning and/or IR objects to calculate ABI-proxy IR-cooling rates, GLM-proxy flash rate and OT trends in convective cells leading up to EDR-CIT events
3. Investigating the temporal and spatial relationships between total lightning properties, overshooting-tops (OTs), infrared (IR) cooling rates and CIT events
   1. Incorporate GOES SRSO's whenever possible
   2. Incorporate ENTLN (Earth Networks Total Lightning Network) with NALMA as baseline when possible
   3. Once validated, ENTLN allows expansion of total lightning studies to larger domain, including traditionally data denied areas (nearby oceans).