GOES-R Aviation and Lightning Risk Reduction Initiatives

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GOES-R Aviation Team

AWG Aviation Team Chairs : Ken Pryor, Wayne Feltz

- Convective Initiation
  - John Mecikalski (Lead)
  - Wayne MacKenzie
  - Kris Bedka/Wayne Feltz
- Enhanced-V/Overshooting top detection
  - Kristopher Bedka (Lead)
  - Jason Brunner
  - Wayne Feltz
- Turbulence
  - Anthony Wimmers (Lead)
  - Wayne Feltz
- Volcanic ash
  - Mike Pavolonis (Lead)
  - Justin Sieglaff (Support)
- SO_2
  - Mike Pavolonis (Lead)
  - Andrew Parker (Support)
- Fog/Low Cloud
  - Mike Pavolonis (Lead)
  - Corey Calvert (Support)
- Aircraft Icing
  - Bill Smith, Jr. (Lead)
  - Stephanie Houser (Support)
- Visibility
  - Brad Pierce (Lead)
  - Wayne Feltz

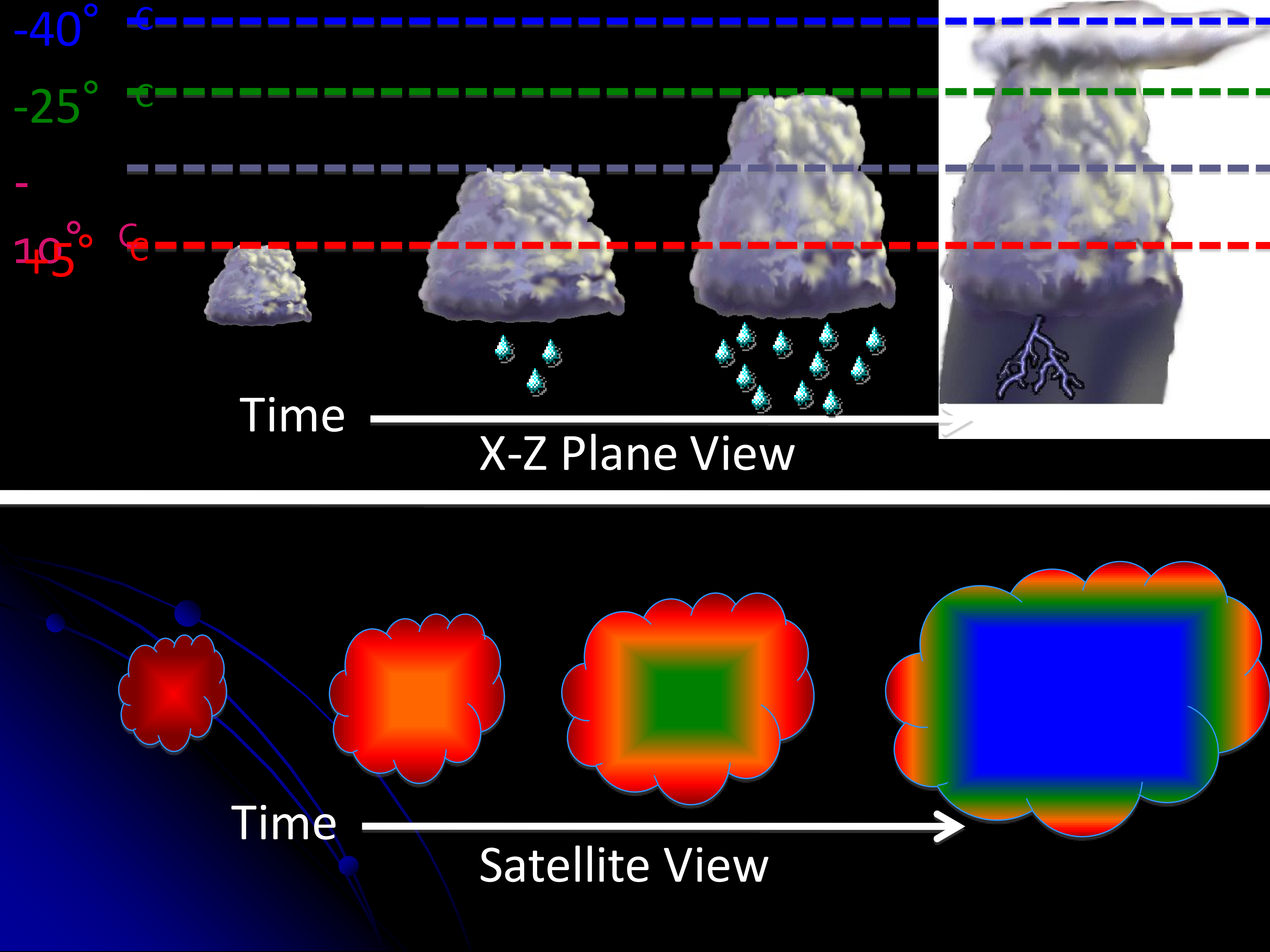
Goals

- GOES-R Aviation Requirements
  - Lightning relationships
  - Areas of synergy
- Convective Initiation
- Overshooting-top
- Turbulence
- Collaboration opportunities between AWG/R3 teams and applications

Convective Initiation

CI Definition

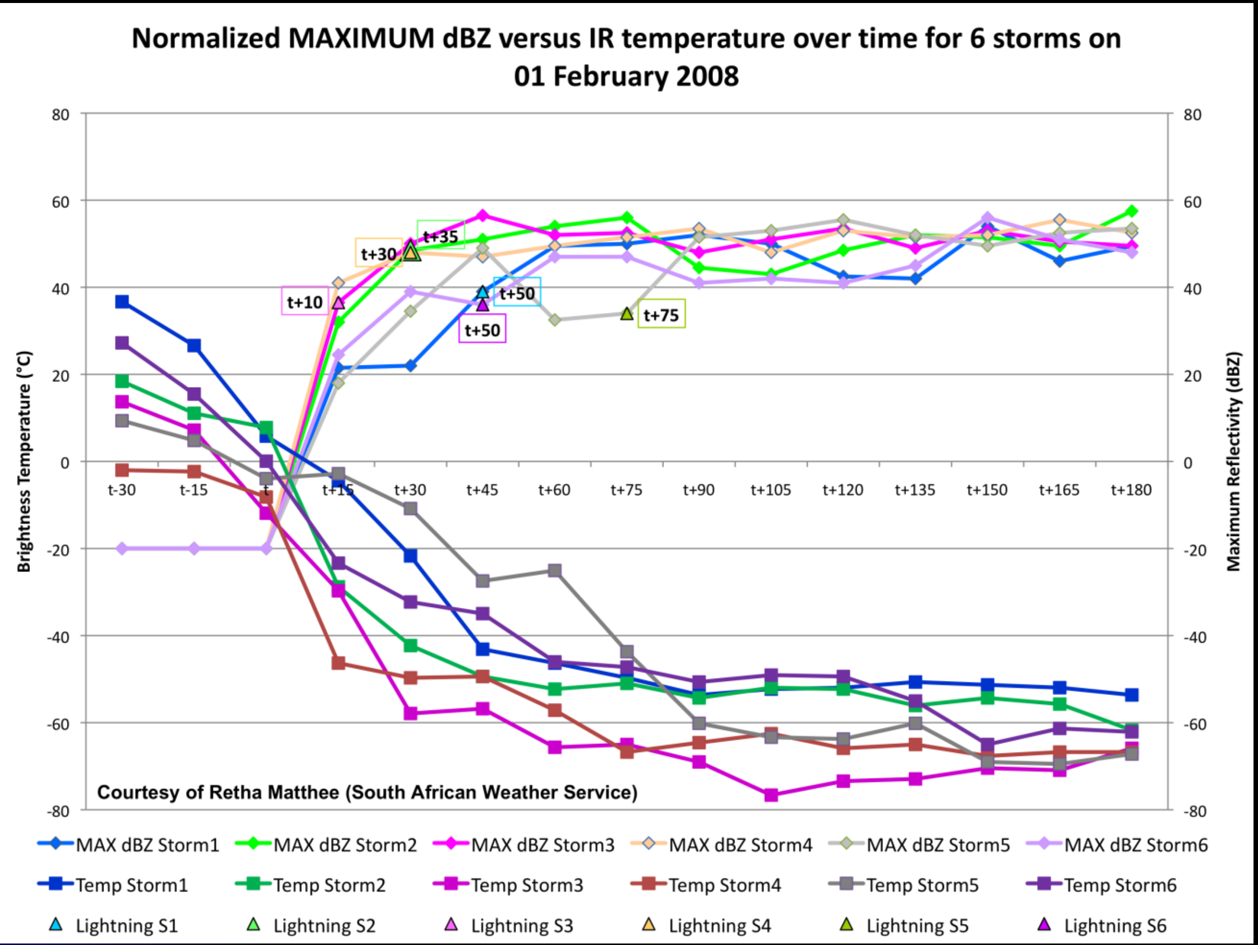
Roberts and Rutledge (2003) and Mecikalski and Bedka (2006) define Convective Initiation as the "first occurrence of a 35 dBZ radar reflectivity ."



-40° C
-25° C
-
10° C
+5° C
Time
X-Z Plane View
Time
Satellite View

Satellite Observations of Convective Initiation

- Rapid IR window cloud-top cooling can precede significant rainfall (> 35 dBZ) by ~30-60 mins, imager-based (not sounder)
- Roberts and Rutledge 2003 (WAF)
- The first cloud-top ground strikes were most often observed at IR window BTs of ~-40° C in a study over S. Africa



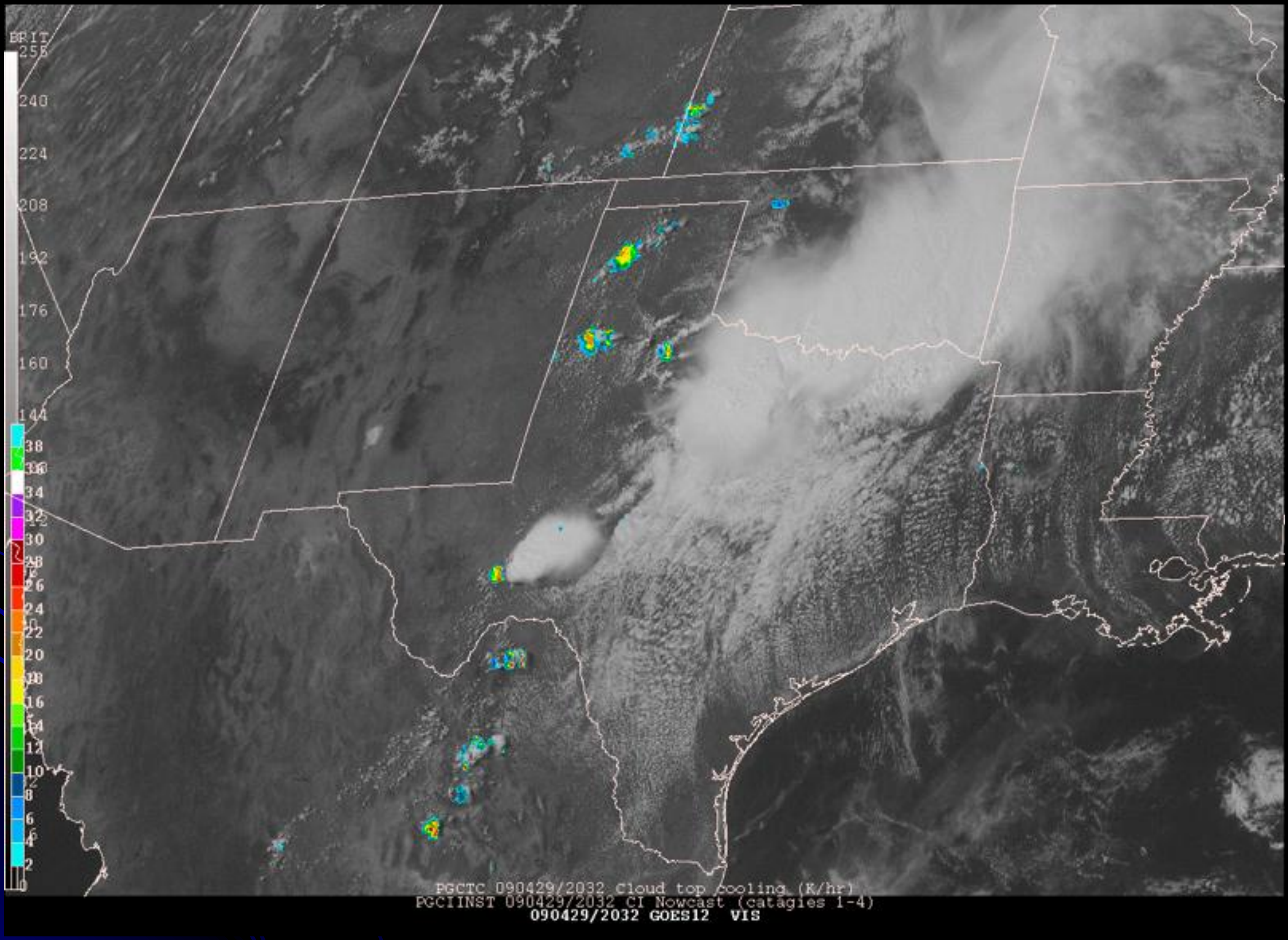
CDR Algorithm

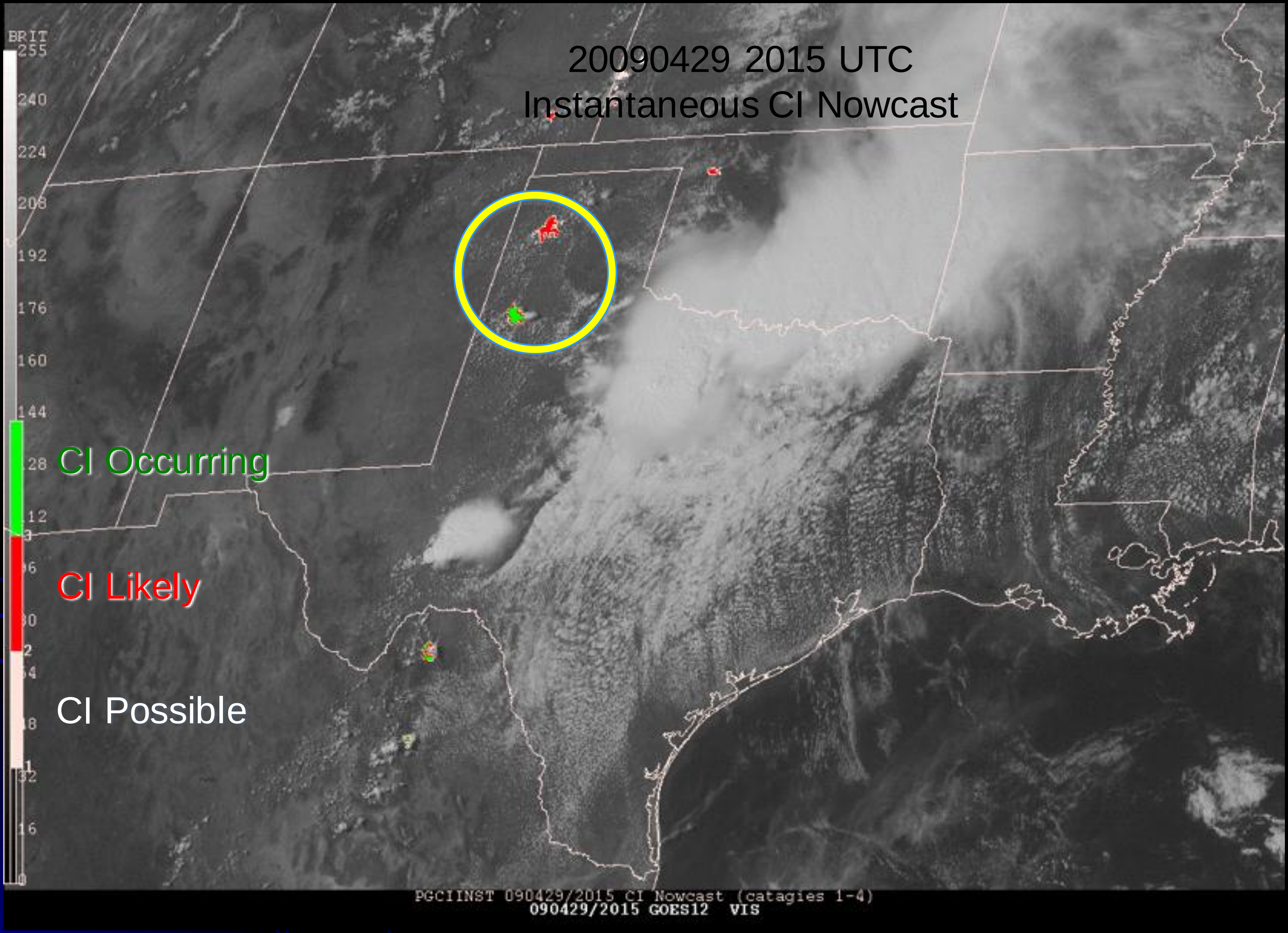
- At CDR, there were two basic solutions under consideration
  - Object based Multi-spectral thresholding technique (Mecikalski and Bedka 2006)
  - Box-average/cloud top cooling

UWCI Algorithm Description

- Day/Night UW Cloud typing product (Pavolonis et al, uses 3.9, 6.7, 10.7, and 12.0/13.3 um channels)
- Monitor microphysical properties
- Infrared window (10.7 um) box-averaging conducted (monitoring mean 10.7 um cooling rate over area)
- This algorithm for convective initiation phase only
- Two primary algorithm products are cloud top cooling (CTC) rate and CI nowcast
- http://cimss.ssec.wisc.edu/goes_r/proving-ground/GOES_CINowcast.html

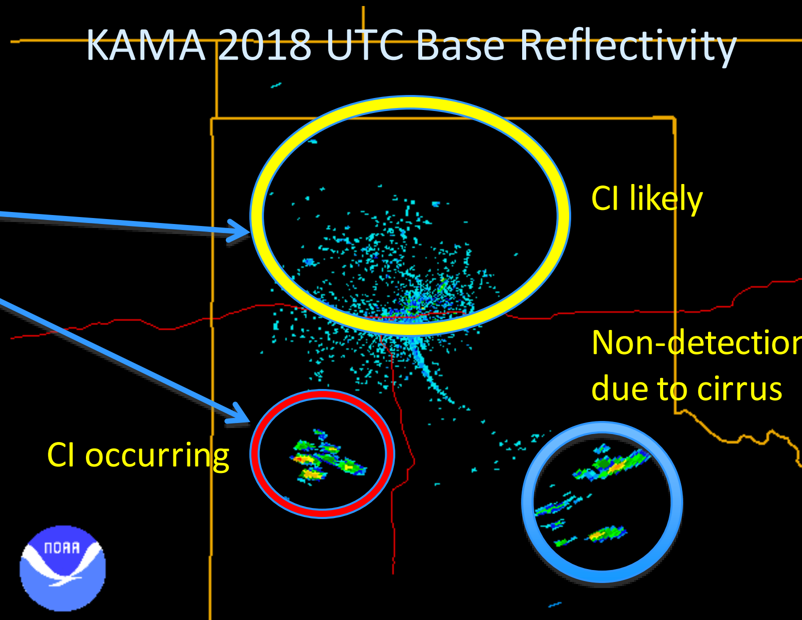
20090429 Dryline CI Case
SPC HWT Proving Ground

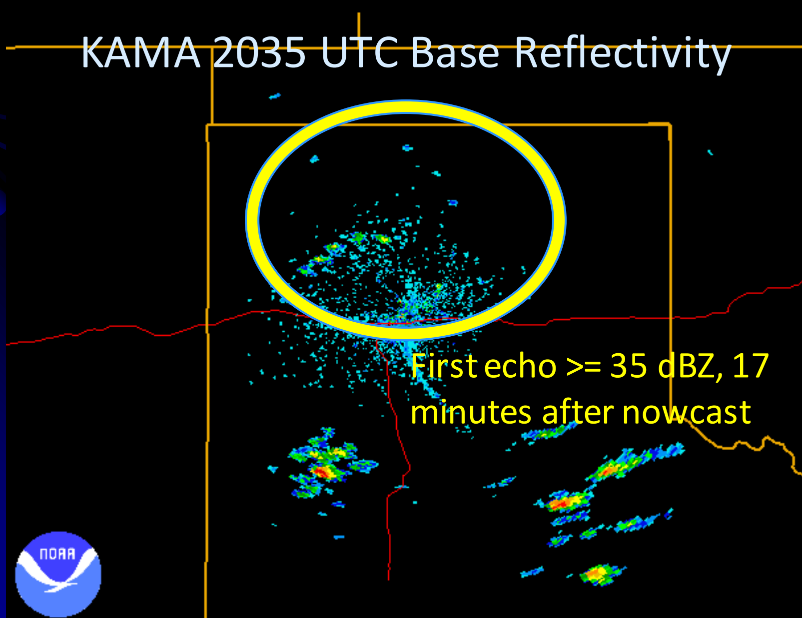


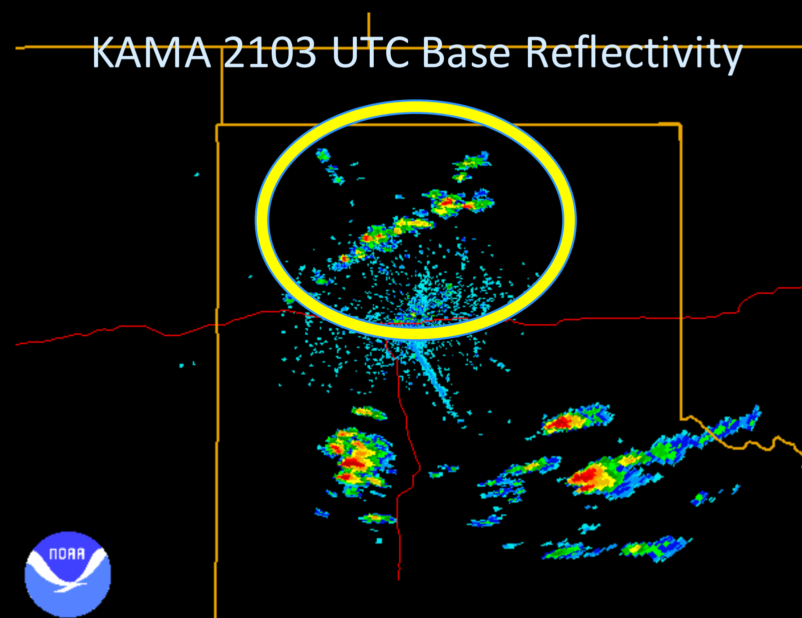

20090429 2015 UTC
Instantaneous CI Nowcast
BRIT
255
240
224
208
192
176
160
144
CI Occurring
CI Likely
CI Possible
PGCIINST 090429/2015 CI Nowcast (catagies 1-4)
090429/2015 GOES12 VIS

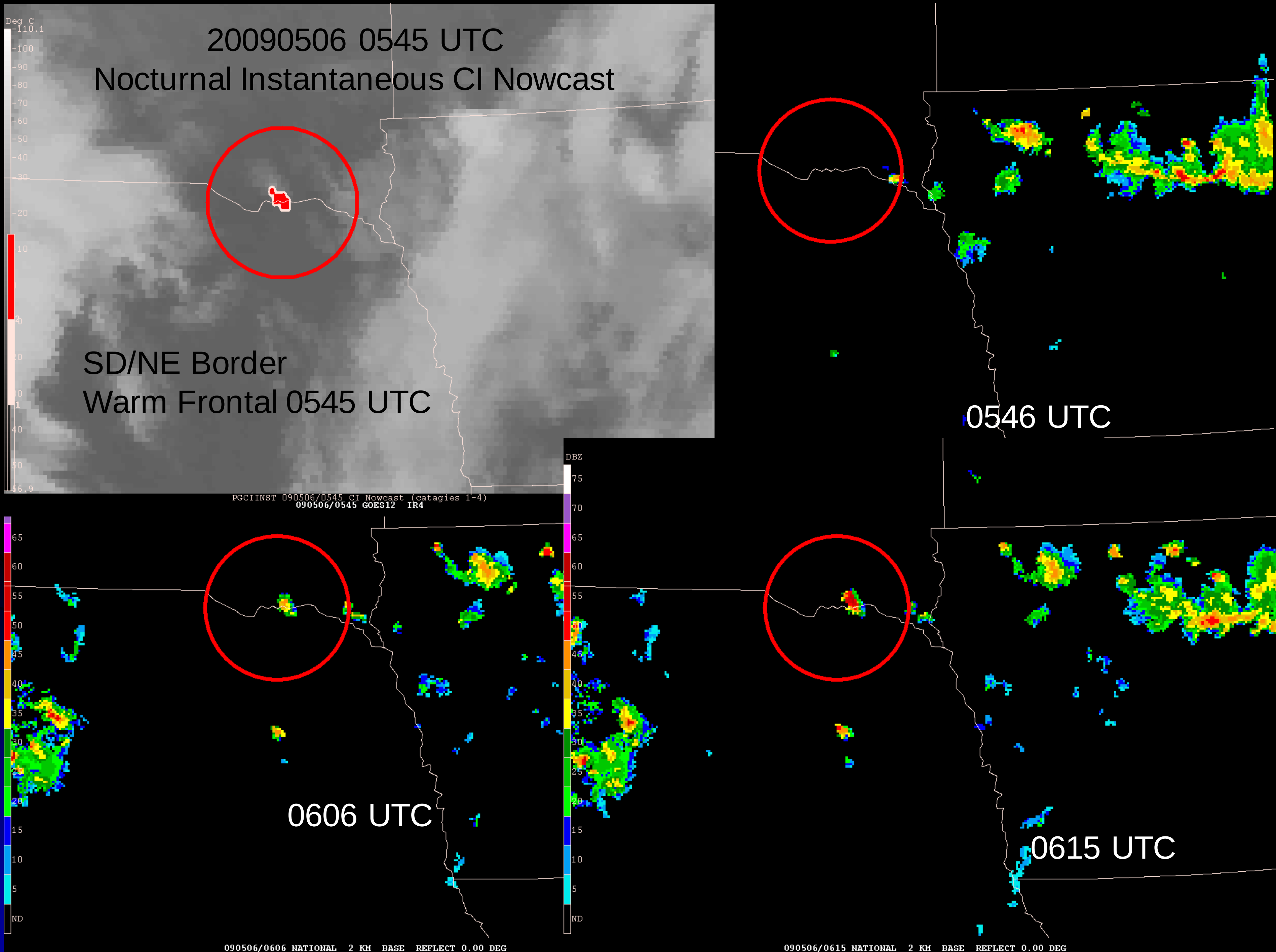
CI nowcast at 2015 UTC

29 April 2009



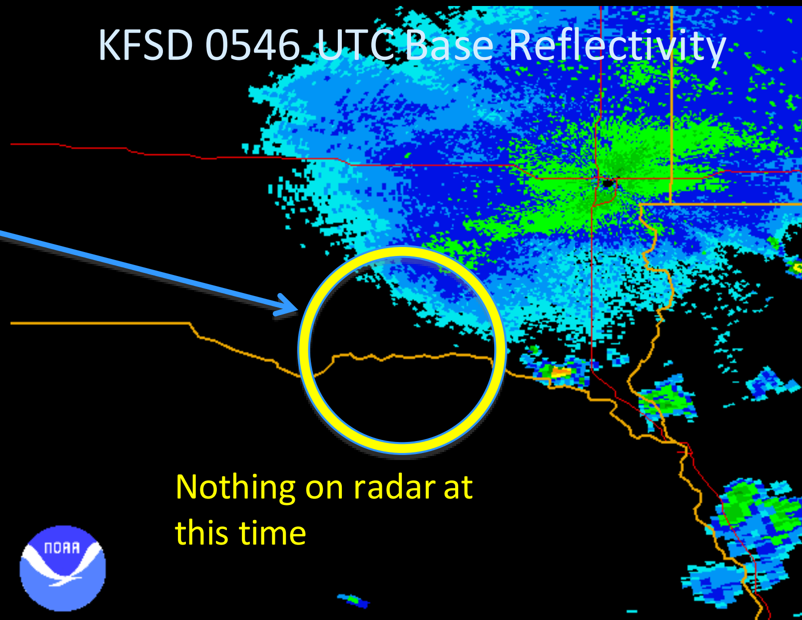


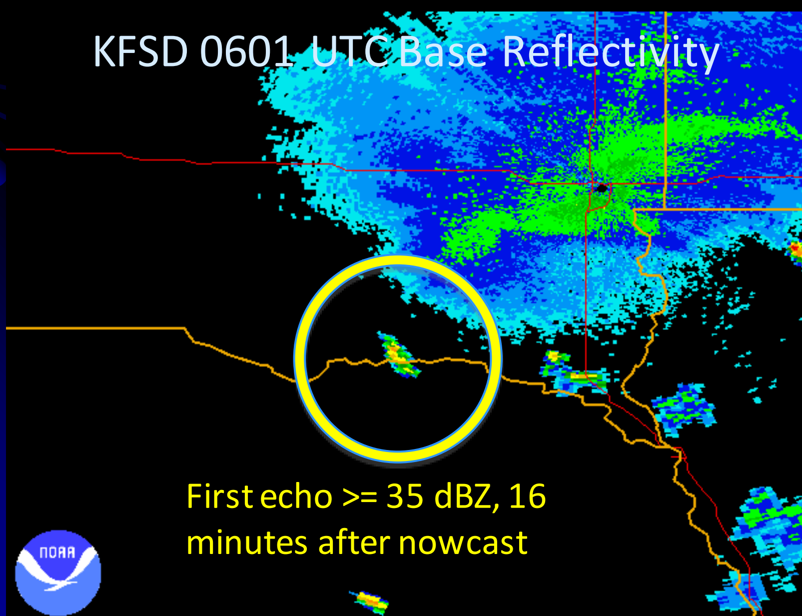


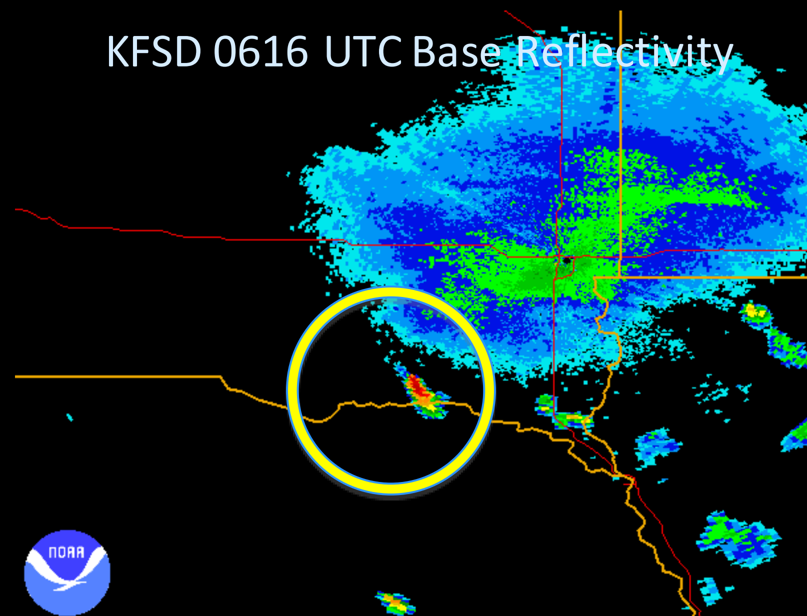

20090506 0545 UTC
Nocturnal Instantaneous CI Nowcast
SD/NE Border
Warm Frontal 0545 UTC
Deg C
PGCIINST 090506/0545 CI Nowcast (catagies 1-4)
090506/0545 GOES12 IR4
0546 UTC
DBZ
0606 UTC
090506/0606 NATIONAL 2 KM BASE REFLECT 0.00 DEG
0615 UTC
090506/0615 NATIONAL 2 KM BASE REFLECT 0.00 DEG

CI nowcast at 0545 UTC

6 May 2009







University of Wisconsin Convective Initiation (UWCI)

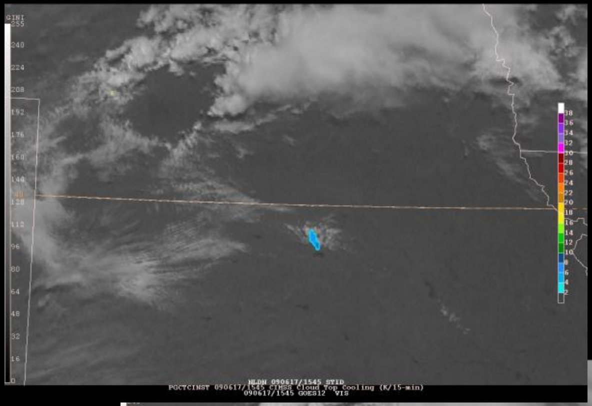
High-level algorithm overview

• Compute IR-window brightness temperature cloud top cooling rates for growing convective clouds using a box-average approach

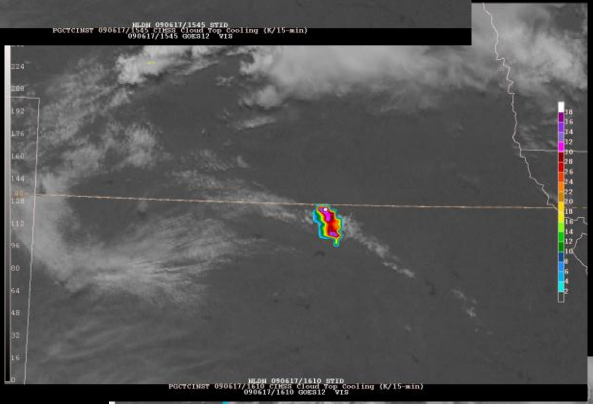
• Combine cloud-top cooling information with cloud-top microphysical (phase/cloud type) transitions for convective initiation nowcasts

Example from June 17, 2009 over northern KS

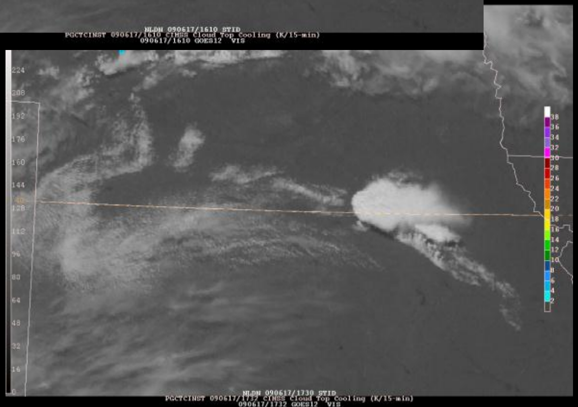
First UWCI cooling rate signal precedes NEXRAD 35 dBz signal by 33 minutes



1545 UTC – first cloud top cooling signal

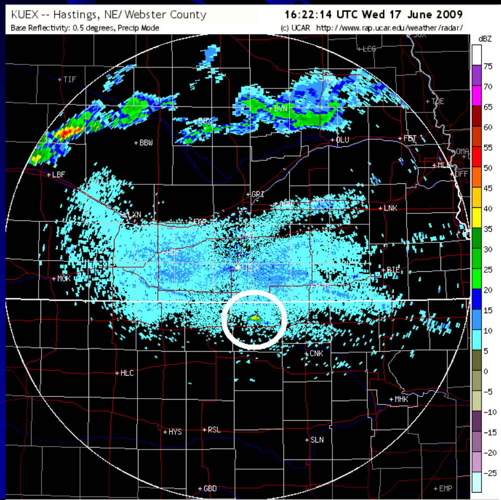


1610 UTC - Continued cooling signal

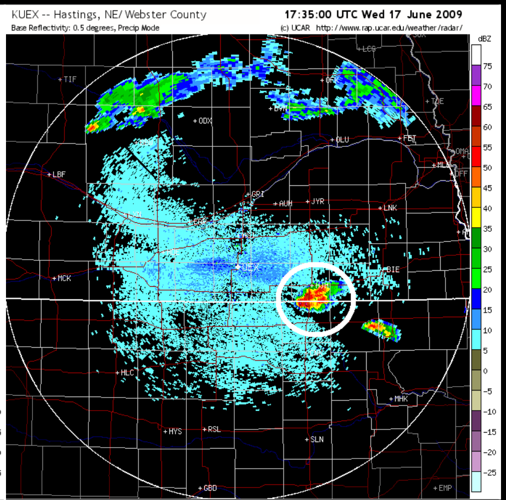


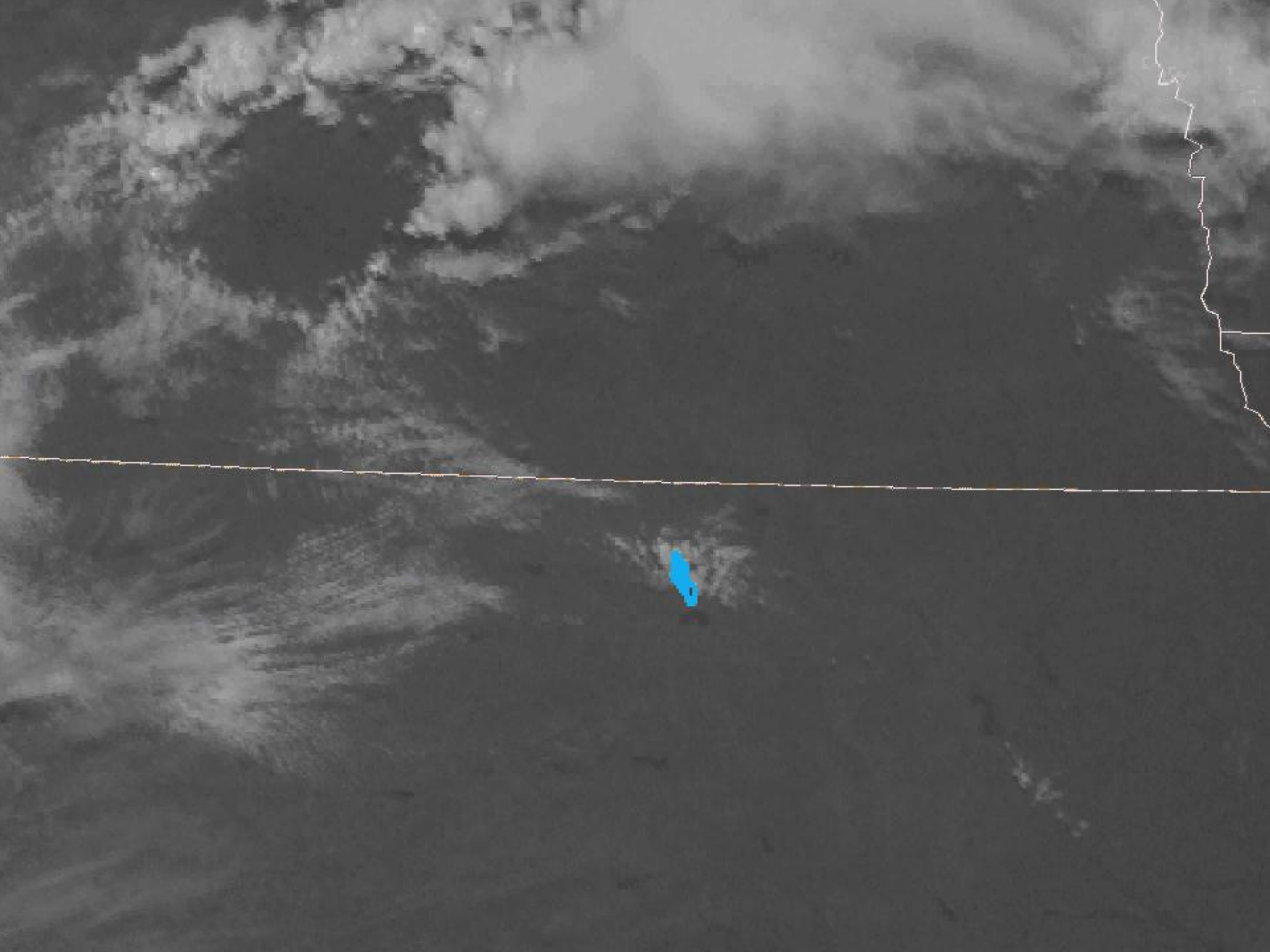
1732UTC - Severe t-storm

First NEXRAD 35+ dBz echo at 1617 UTC

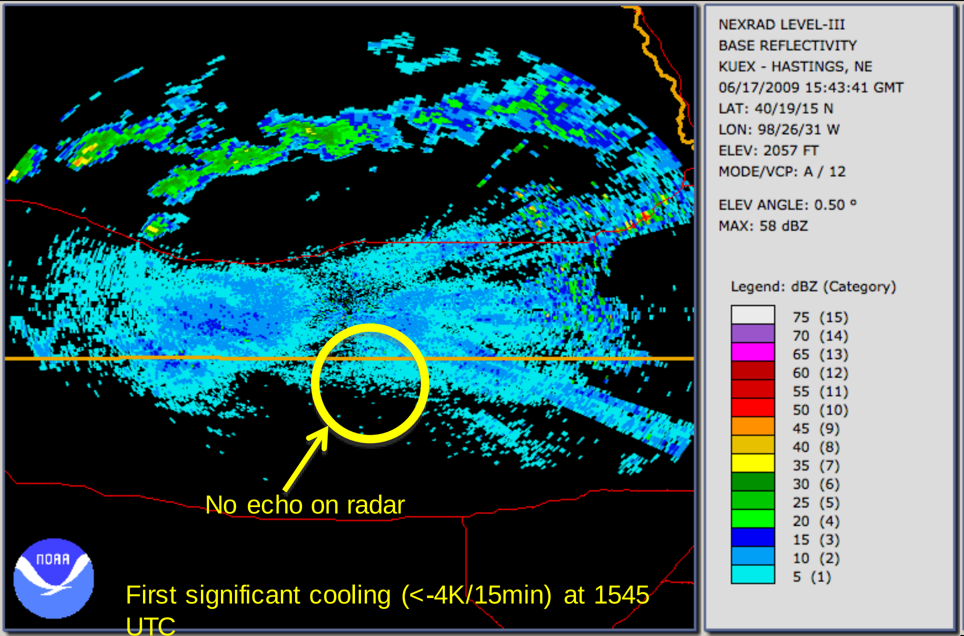


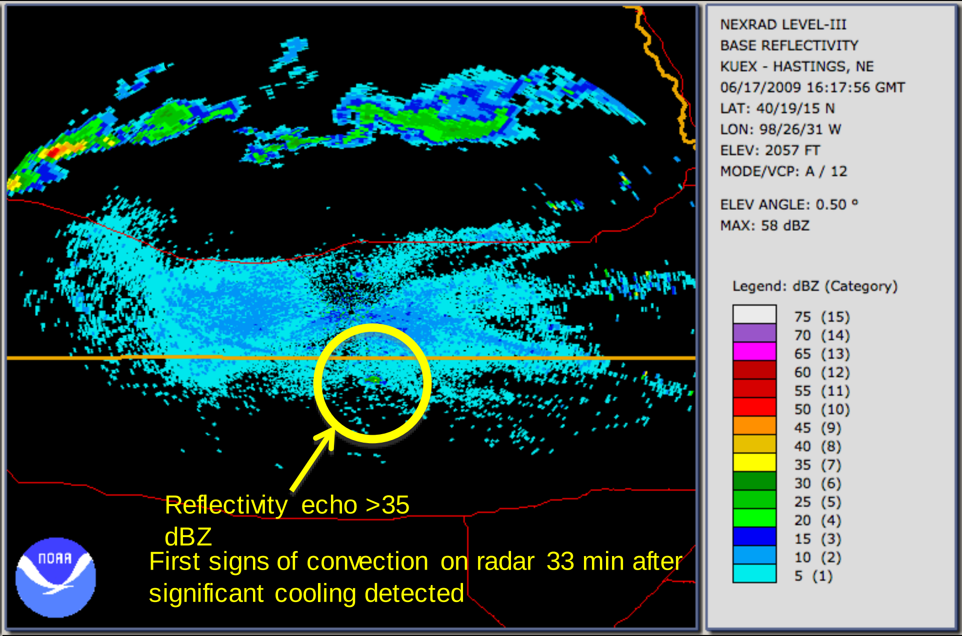
NEXRAD at 1735 UTC

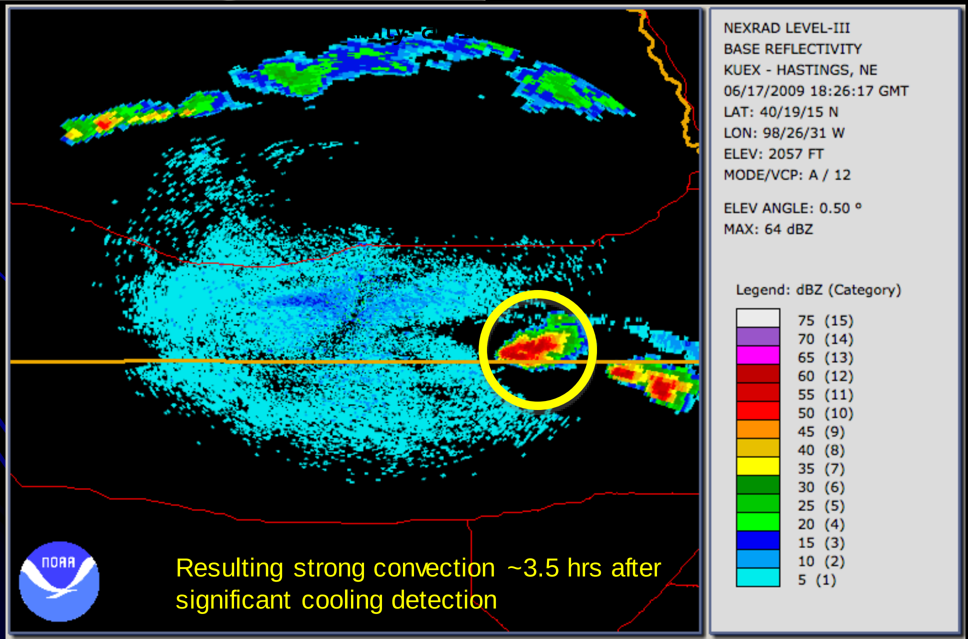




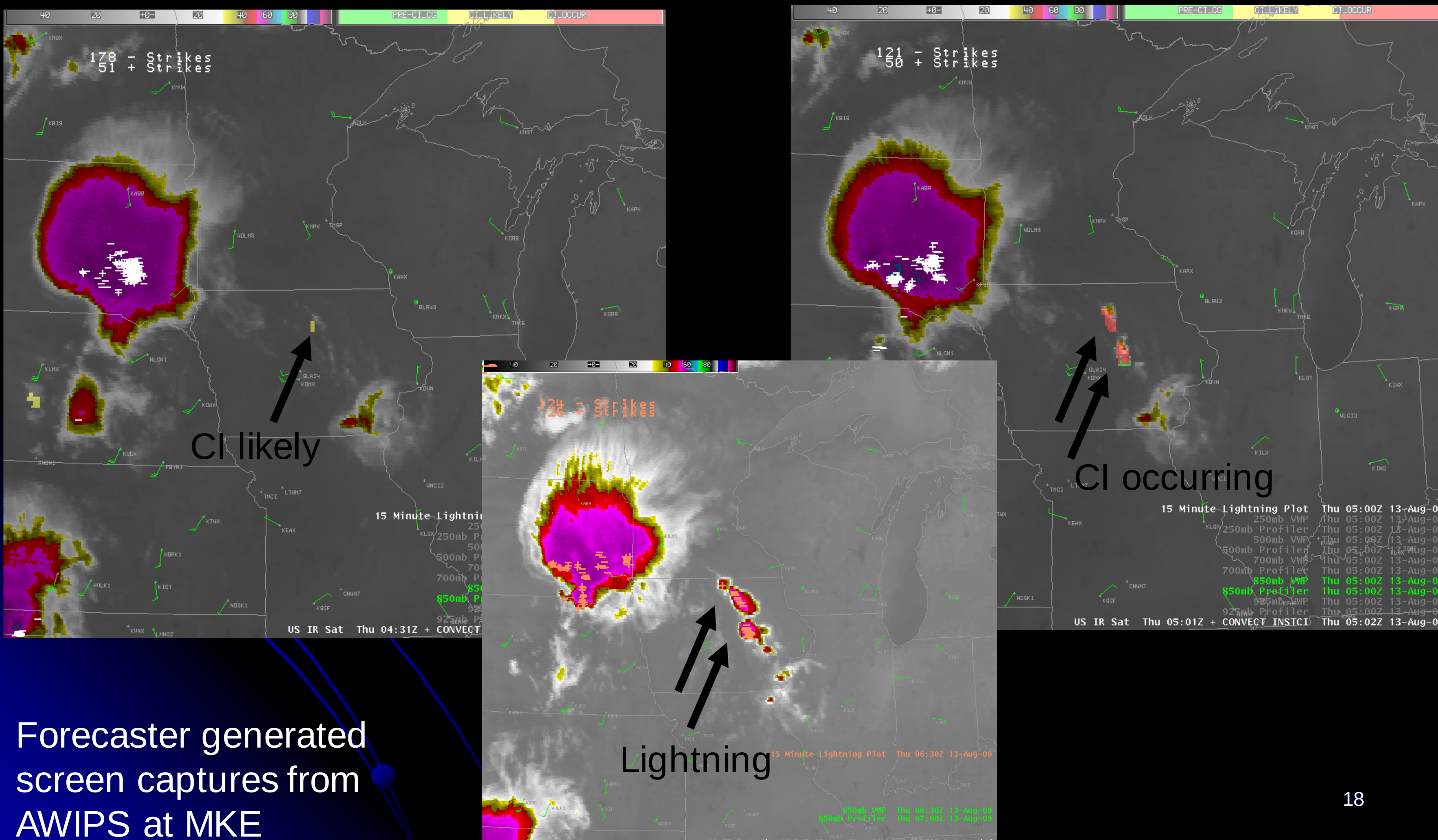
Hastings, NE NEXRAD Radar Reflectivity from 06/17/2009







AWIPS CI/CTC Interaction with Sullivan (MKE) NWS Office



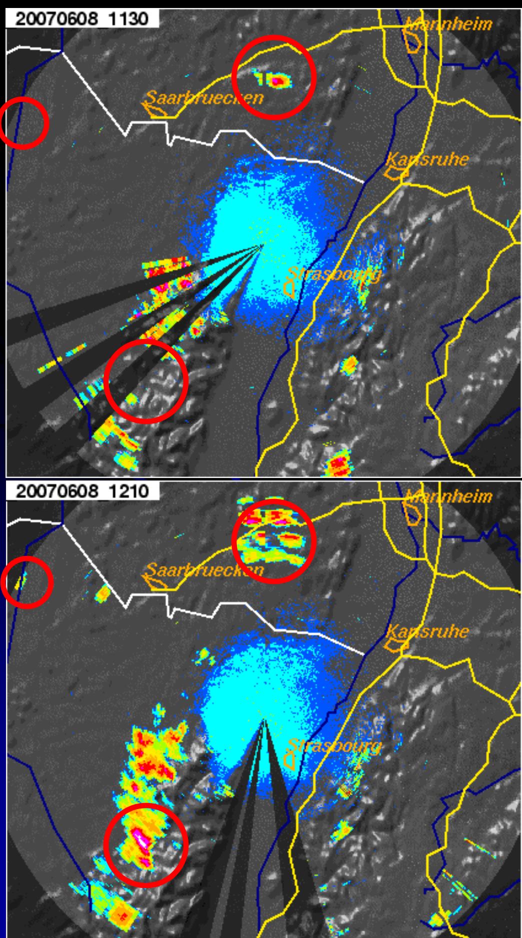
Forecaster generated screen captures from AWIPS at MKE

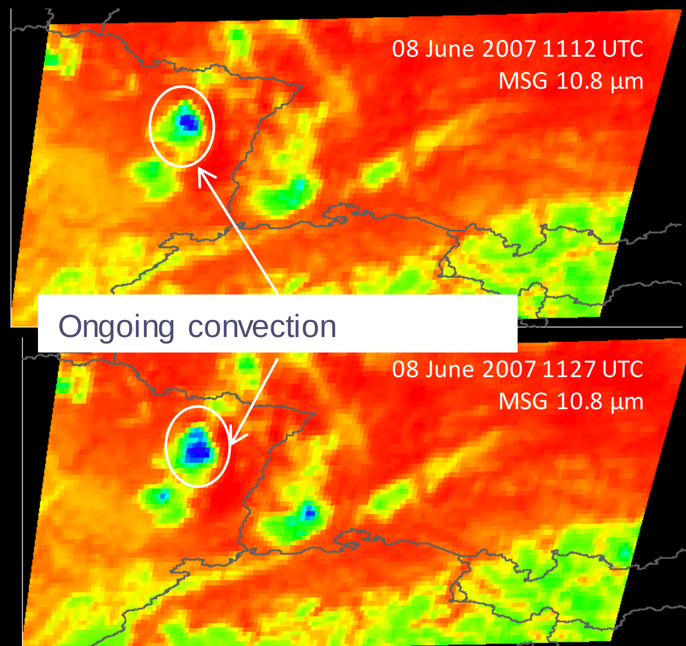
AWIPS CI/CTC Interaction with Sullivan (MKE) NWS Office

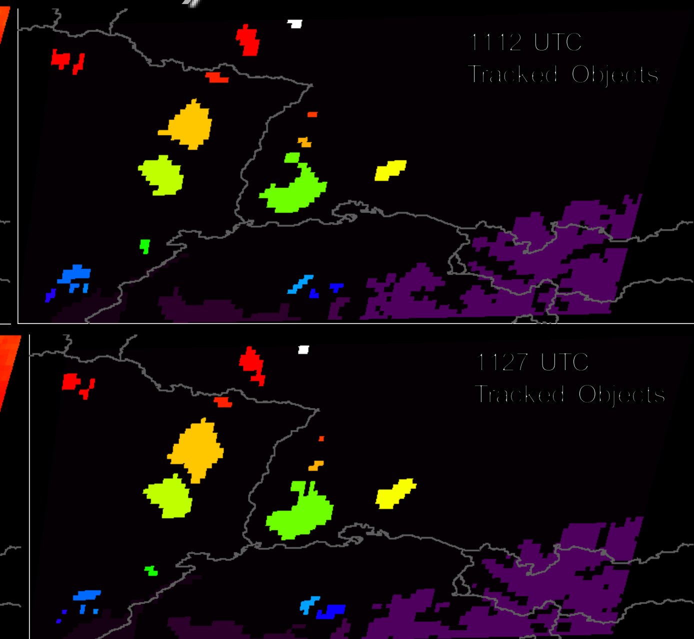
"The UWCI performed very well in Iowa last night! These thunderstorms fired up along an existing boundary and are coincident with the leading edge of 700mb moisture transport and weak 850mb warm air advection."

- Marcia Cronce NWS Forecaster

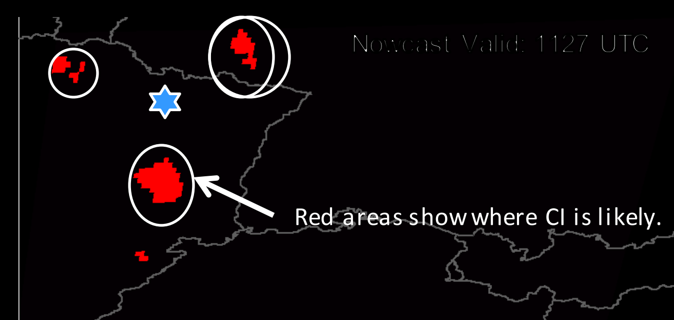
Algorithm Example
UAH Overlap Object Tracking
(SPC HWT Candidate 2010)







Circled areas show the nowcasted regions, and their locations on the radar. There was ongoing convection, and the CI algorithm picked up on regions where CI was going to occur with ~40 minute lead time.

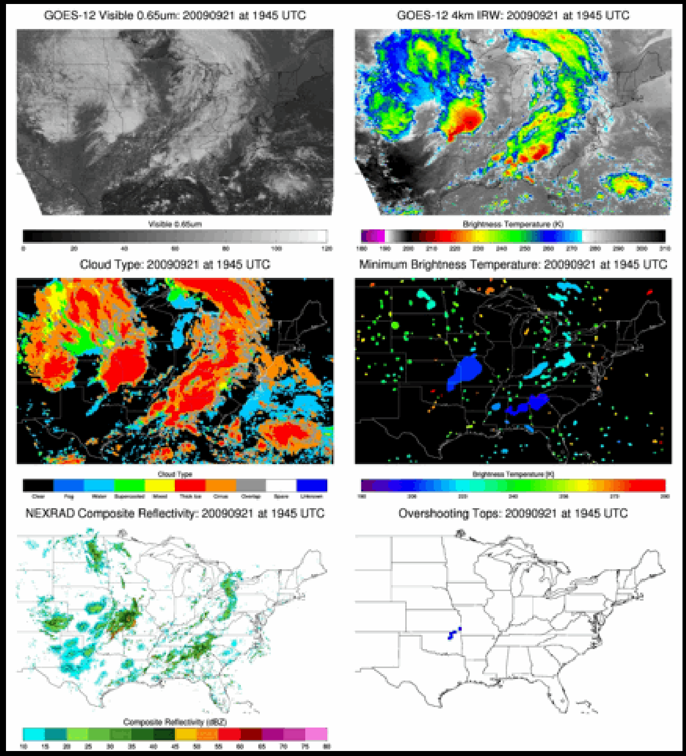


Denotes radar location.

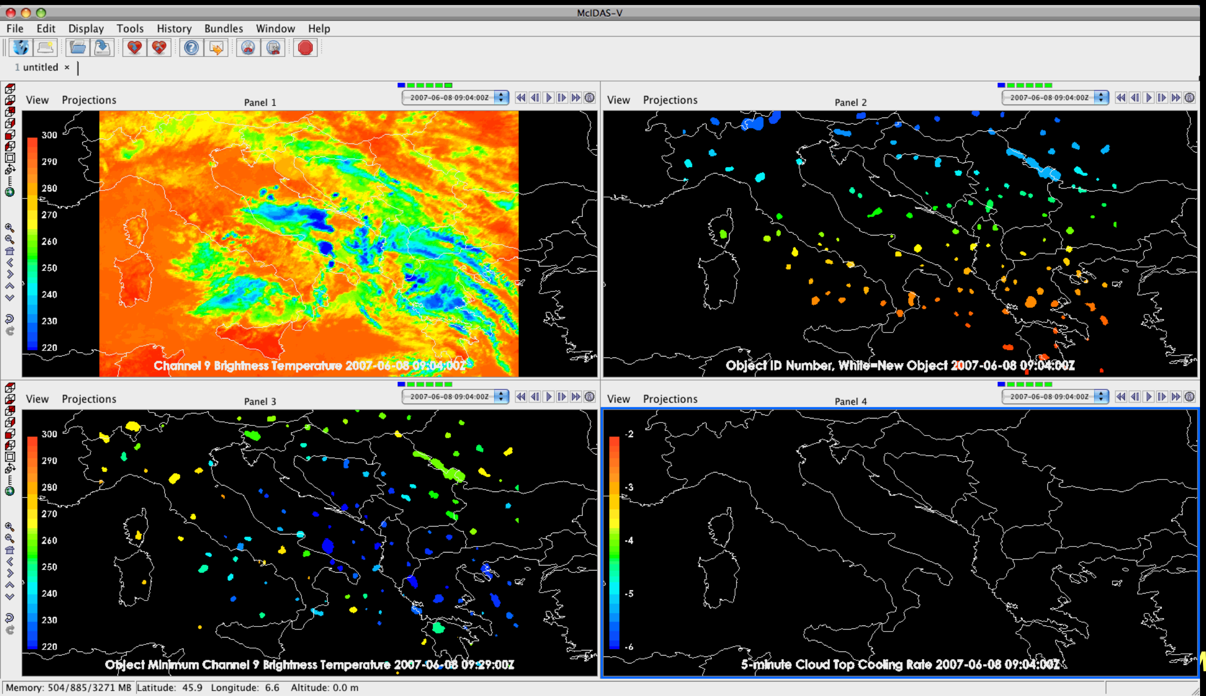
Exploring the Use of Object Tracking for CI Nowcasting

- UW-CIMSS and the University of Alabama in Huntsville (UAH) are working toward development of object-based methods for CI nowcasting in the GOES-R ABI era, using current GOES-12 and MSG SEVIRI as proxies for GOES-R
- UW-CIMSS is experimenting with the Warning Decision Support System-Integrated Information (WDSS-II, Lakshmanan et al. (*J. Tech*., 2009), (*WAF*, 2007)) to compute cloud-top cooling rates, which can be used with cloud-top microphysical trends to produce CI nowcasts
- Radar reflectivity can be remapped to the satellite resolution/projection and carried along with the satellite-derived objects for reliable product validation. (funded with GOES GIMPAP 2010-2011)
    - This capability is not available with current pixel-based CI nowcast methods which causes significant difficulty in evaluating current product accuracy over large scenes and numerous cases

GOES-12 Example



MSG SEVIRI Example



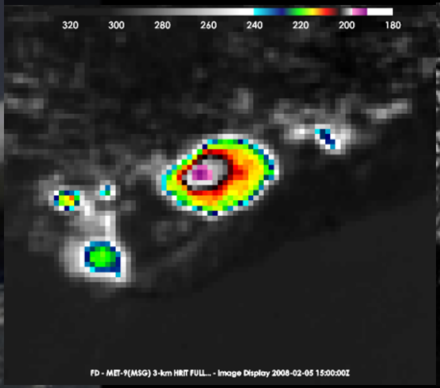
Convective Overshooting-top/Enhanced-V

Overshooting-Top and Convective Initiation

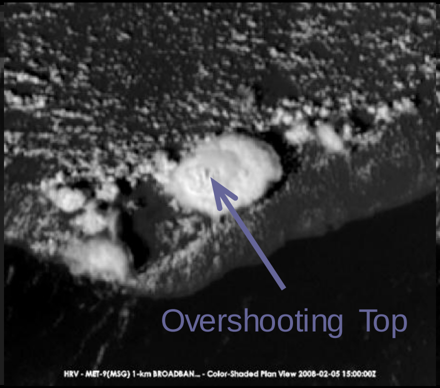
Convective Overshooting-top

Photo From International Space Station

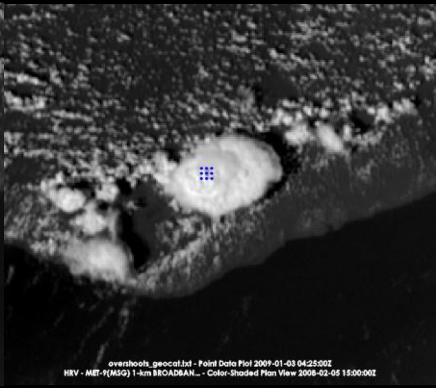
3 km MSG SEVIRI 10.8 µm



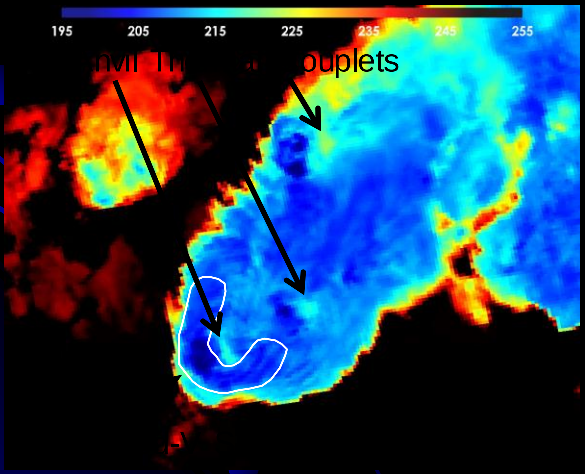
1 km MSG SEVIRI Visible



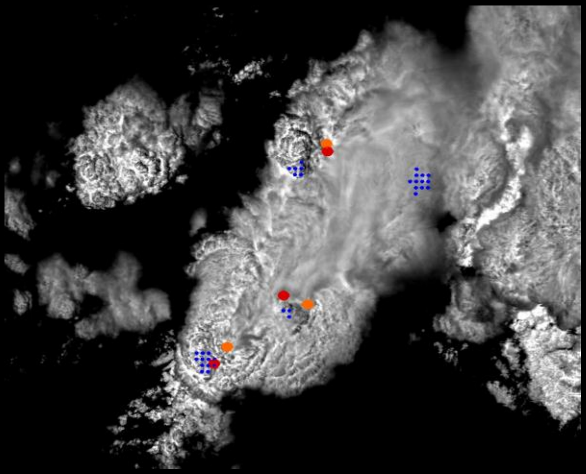
1 km MSG SEVIRI Visible
With Overshooting Detection



1 km MODIS 11 µm



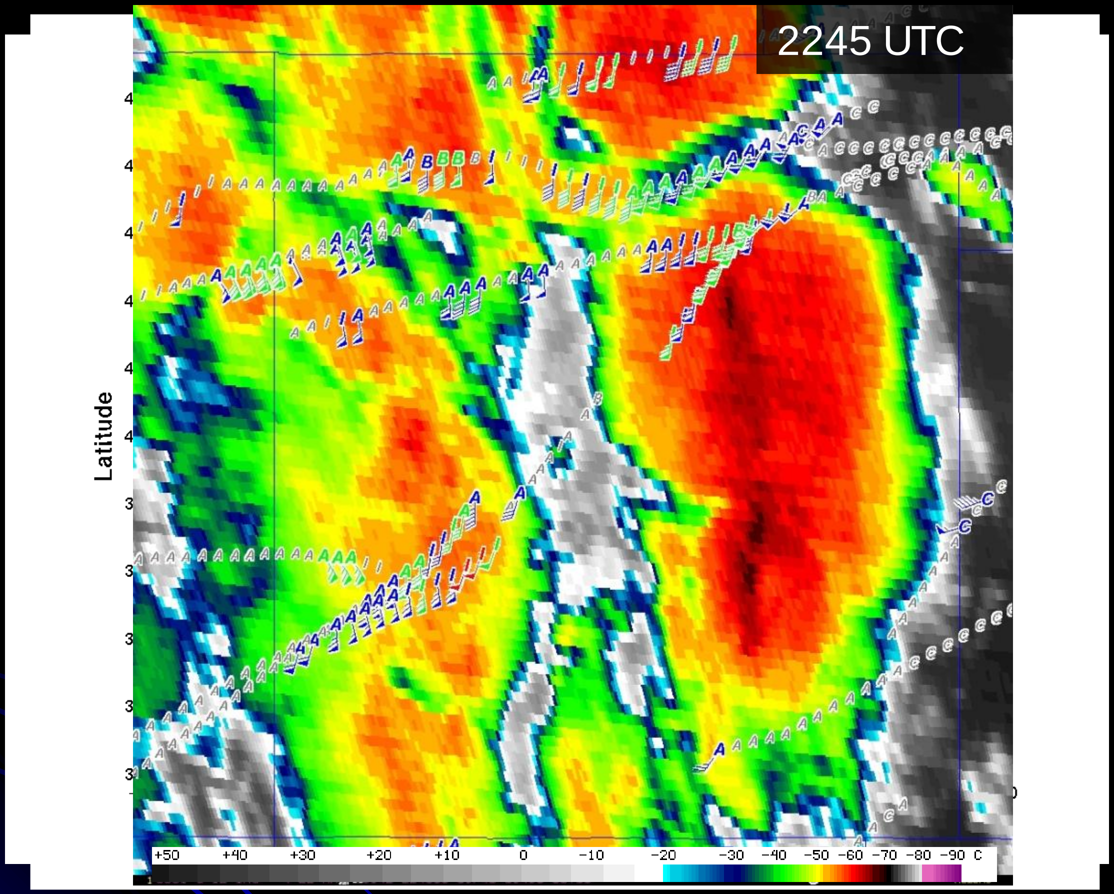
Overshooting Top Detections, Enhanced-V/Thermal Couplet Detections, and Severe Hail Reports Atop MODIS 250 m Visible



Algorithm Developers: Kristopher Bedka, Jason Brunner, and Wayne Feltz

GOES-R Lightning AWG/R3 Review

Identification of Significant Turbulence Events



Null: Peak EDR=.05

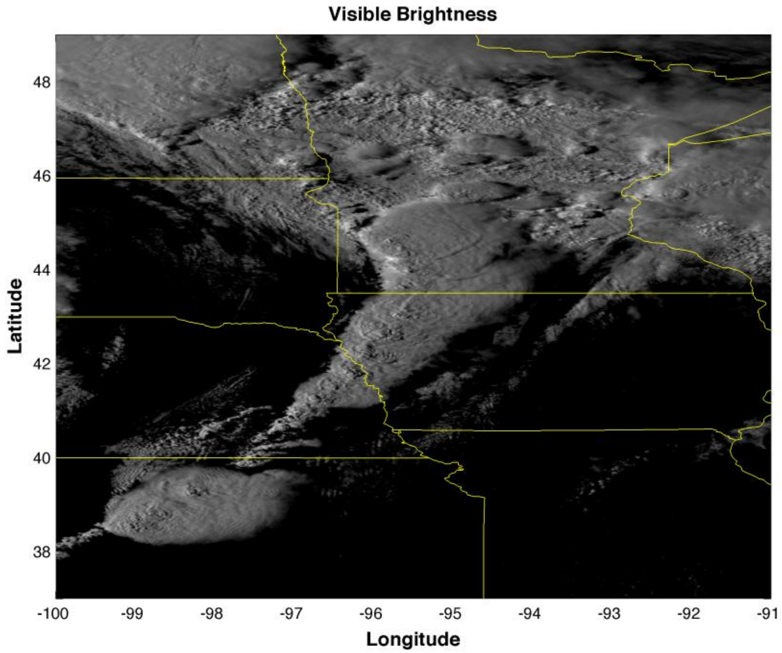
Light: Peak EDR=.15

Moderate: Peak EDR .25-.45

Severe: Peak EDR ≥ .55

- EDR observations are grouped from 1200-1159 UTC during winter (Nov-Mar) and convective (Apr-Oct) season days to identify significant turbulence events
  - Significant event=Event having a # of MOD and SVR observations exceeding 2 std. dev. from the seasonal mean
- We collect and analyze all available GOES, MODIS, and AVHRR imagery around times with a high concentration of MOD to SVR reports

Objective Day/Night Overshooting Top Detection Using Current and Future GOES



IR window imagery is used to identify overshooting tops occurring during both day and night

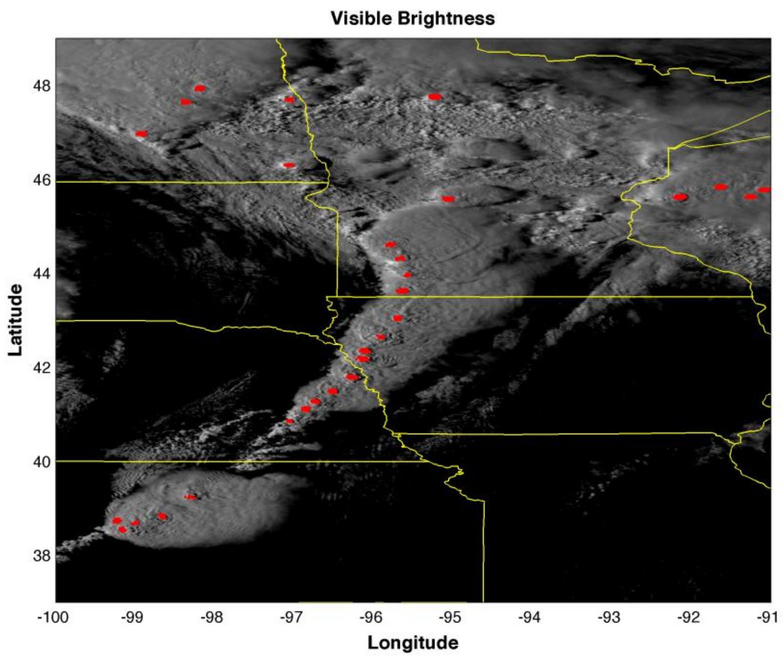
A study of 450 enhanced-V producing overshooting top cases (Brunner et al. (WAF, 2007)) shows that tops are:

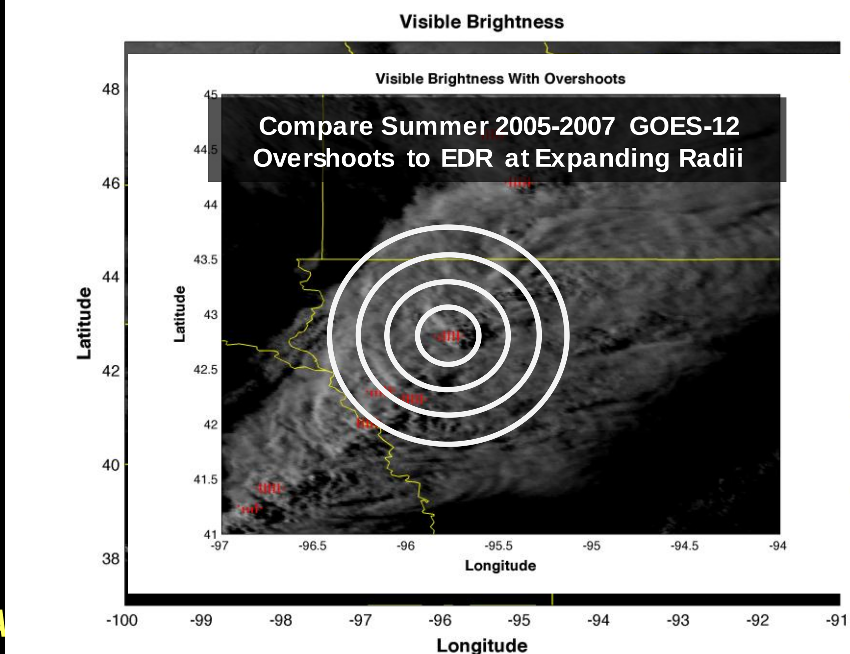
1) isolated clusters of pixels (< 12 km^2 area) colder than 215 K and the GFS tropopause temp
2) significantly colder (> 6.5 K) than the surrounding anvil cloud

Higher ABI spatial resolution leads to better observation of cold BT minima and improved overshooting detection

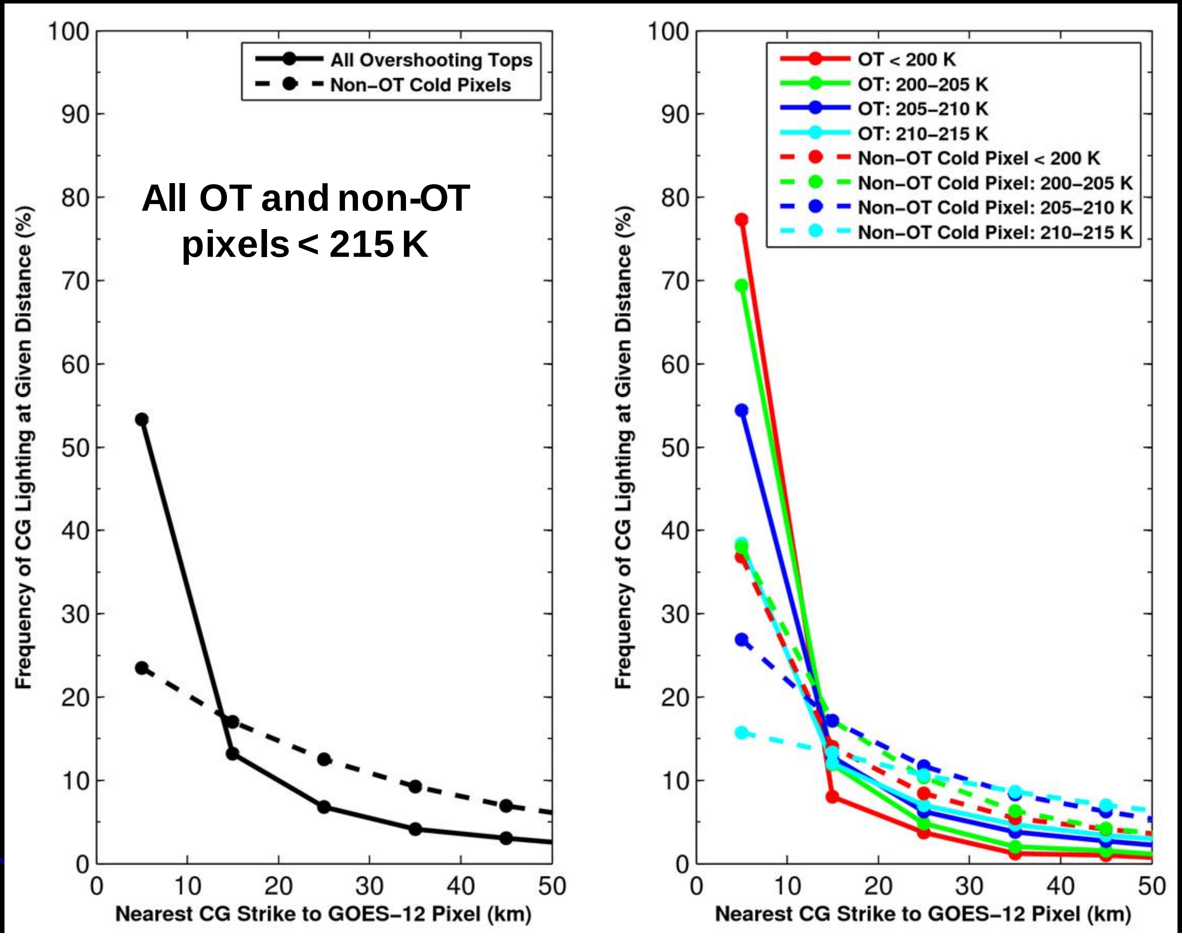
AVHRR 2 km (or GOES-R ABI)

4 km GOES-12





GOES-12 Overshooting Top Relationships with Cloud-to-Ground Lightning

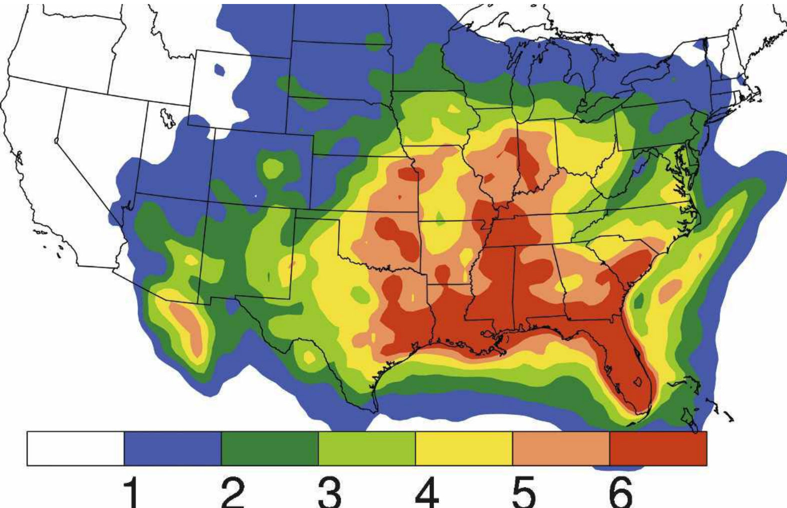


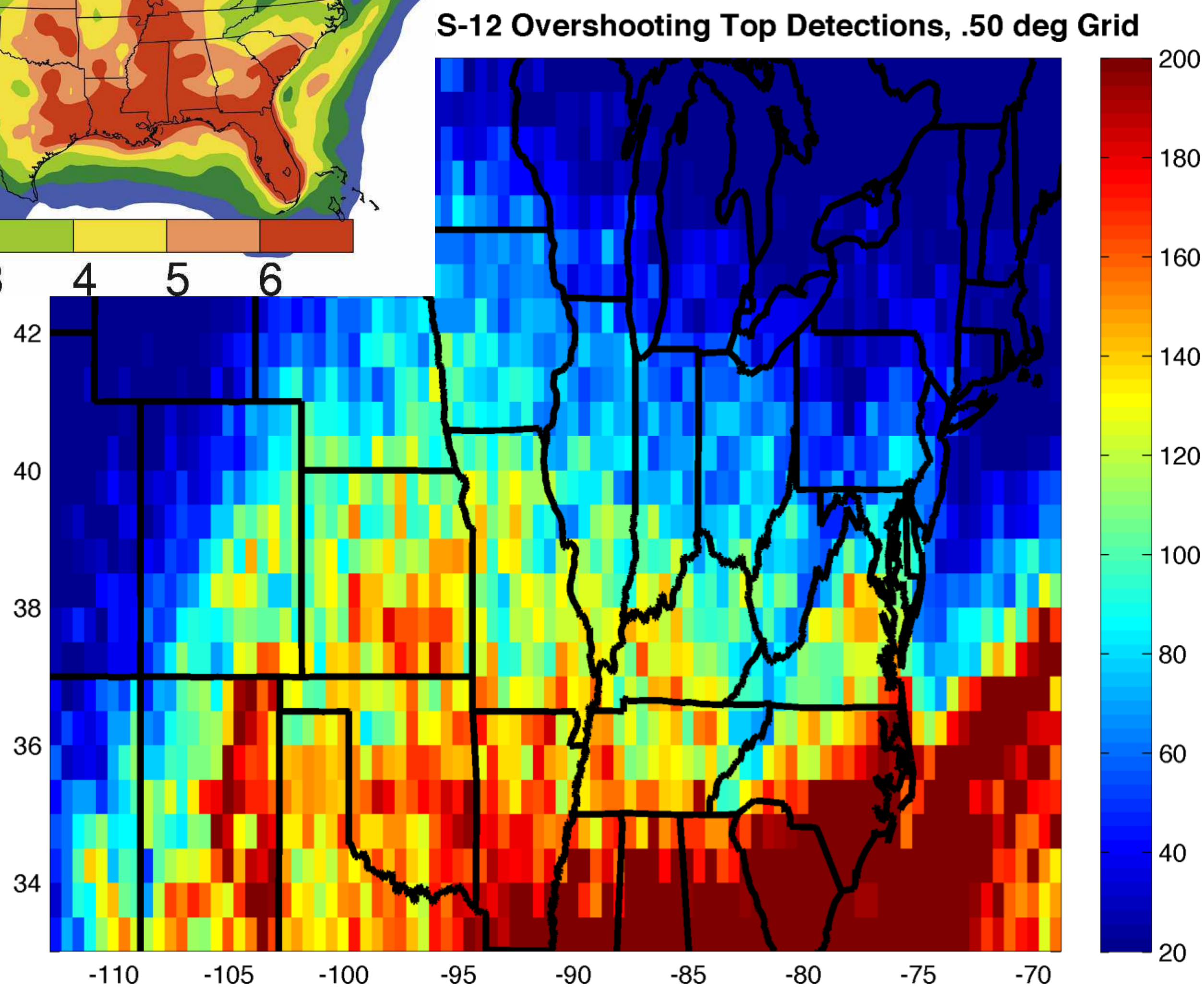
CG lightning is 30% more likely to be found very near (0-10 km) to GOES-12 OT's than non-overshooting cold pixels

OTs with very cold BTs represent a significant lightning hazard (Bedka et al, 2009)

rshooting Top Climatology:
mers 2004-2008

5-Year CG Lightning Climatology

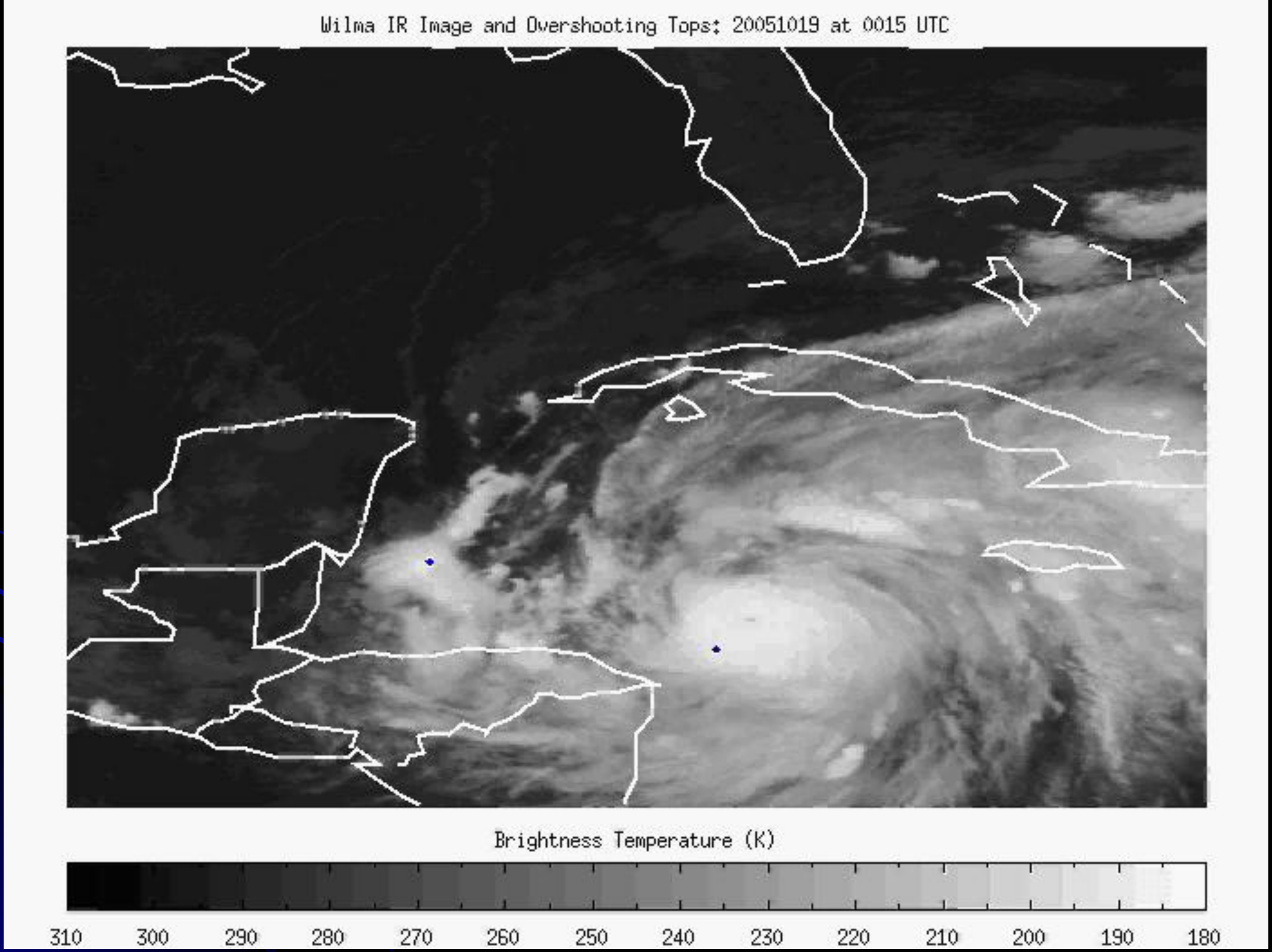




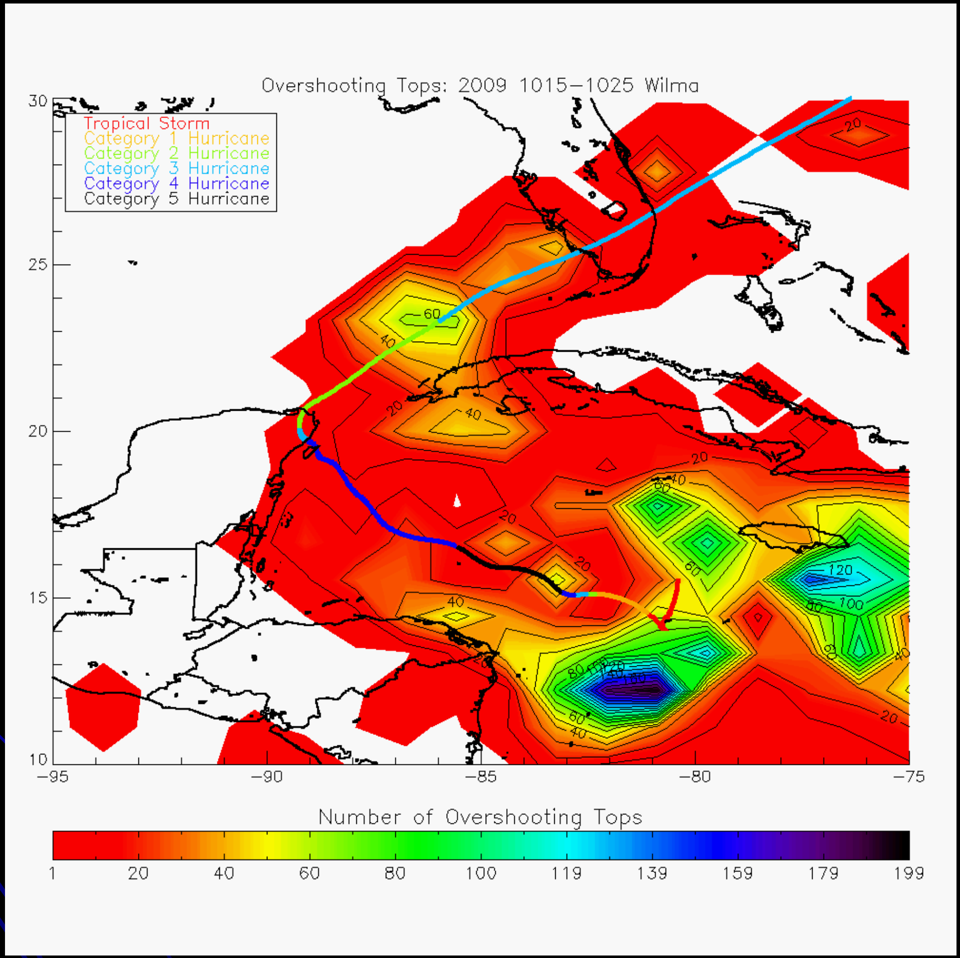
(Bedka et al, 2009)

Credit to Kris Bedka (SSAI NASA LaRC)

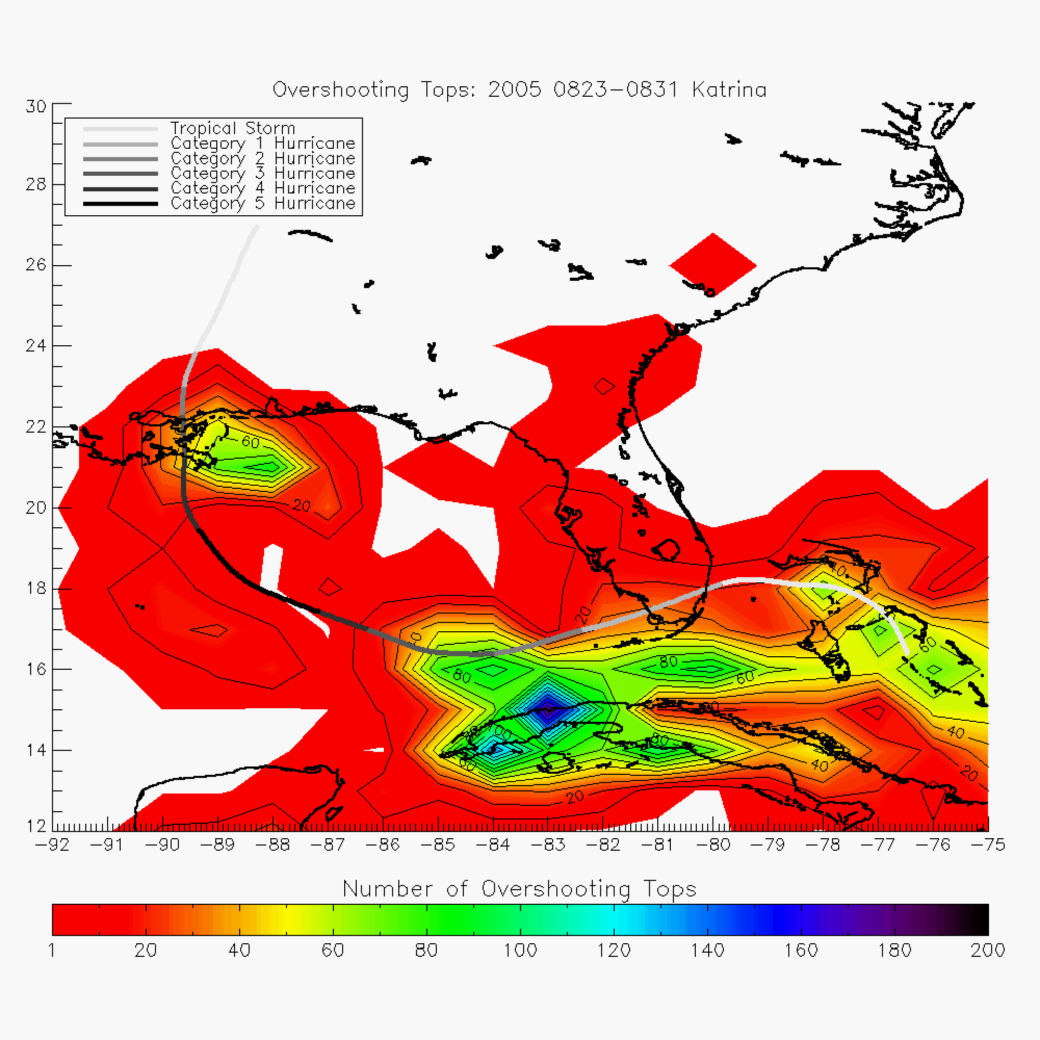
Convective Overshooting-tops for Hurricane Wilma



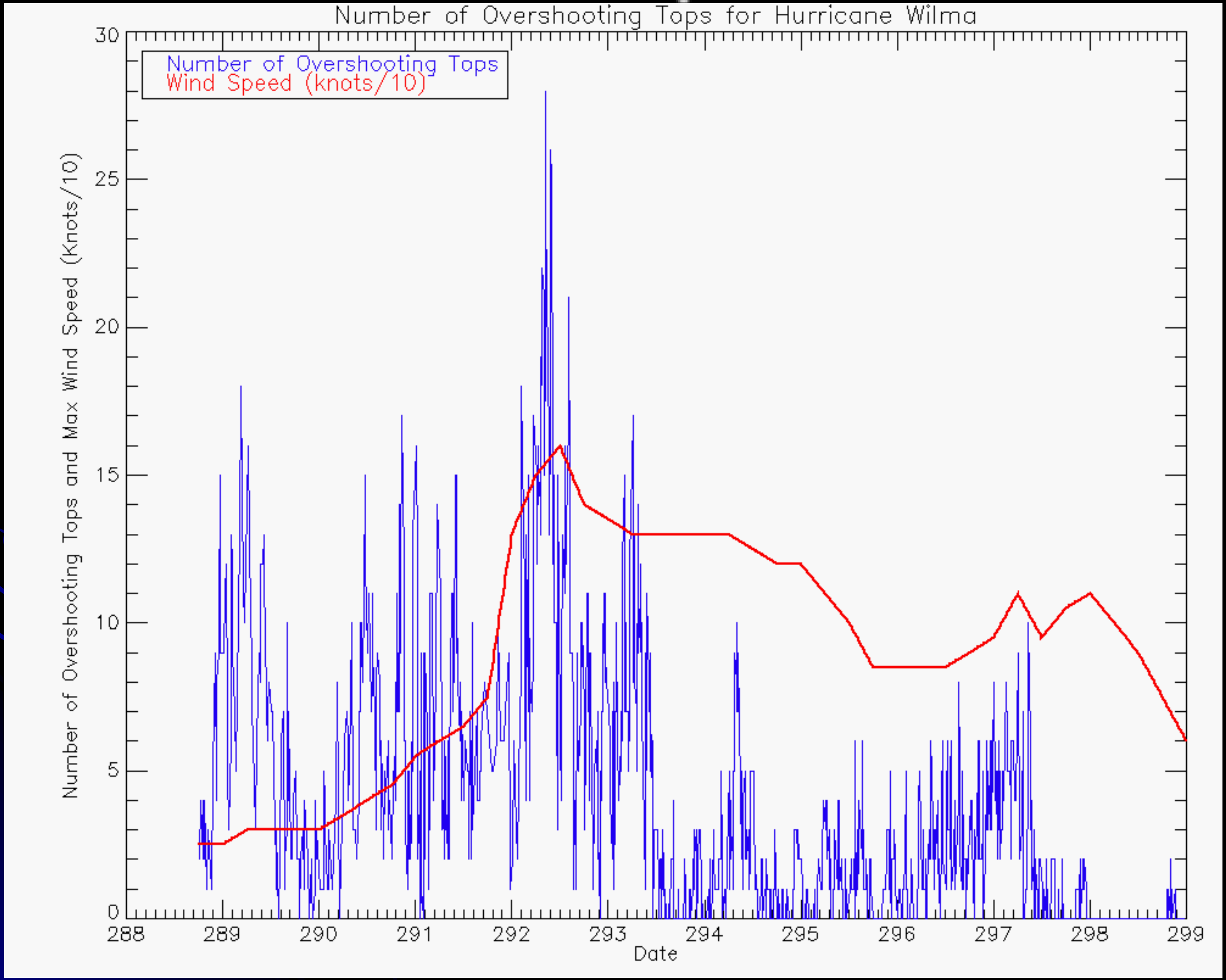
Convective Overshooting-tops for Hurricane Wilma



Hurricane Katrina Overshoot-top Frequency



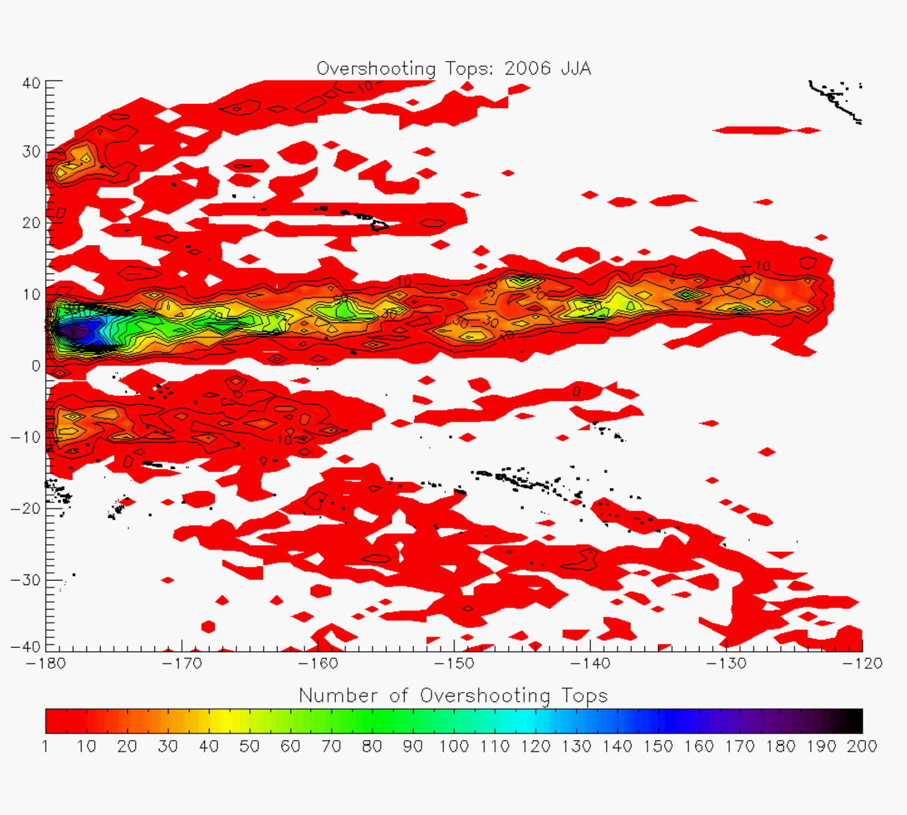
Overshoot Frequency vs Wilma Wind Speed

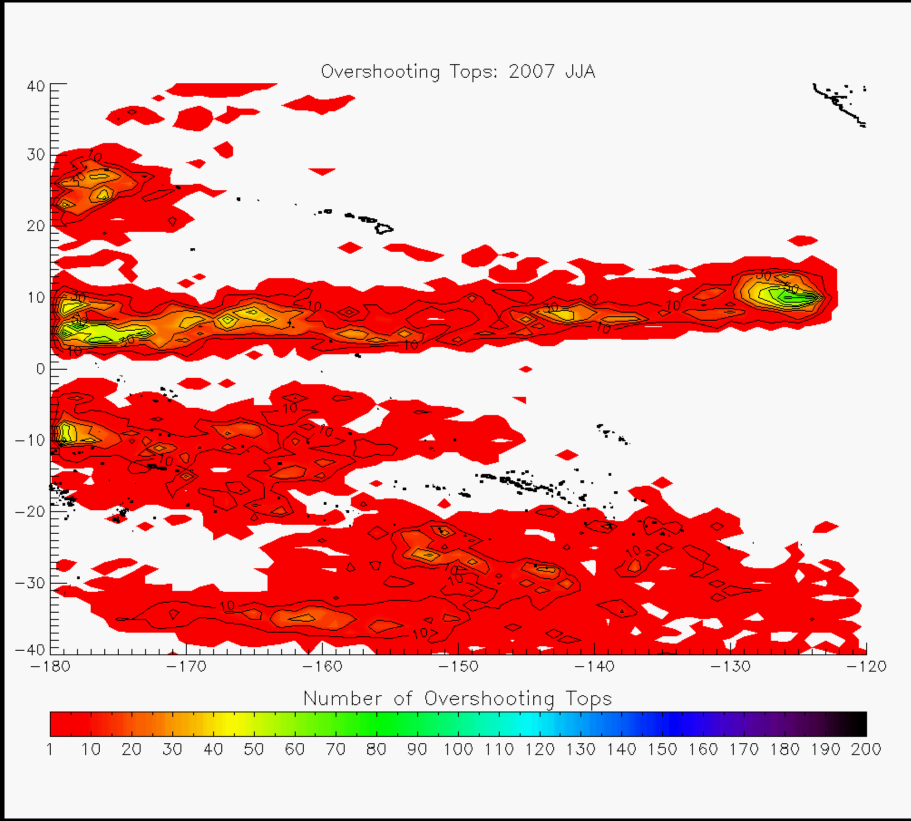


OT Frequency for Climate Phase Signal (ENSO)

GOES-10/11 OT Frequency 2006

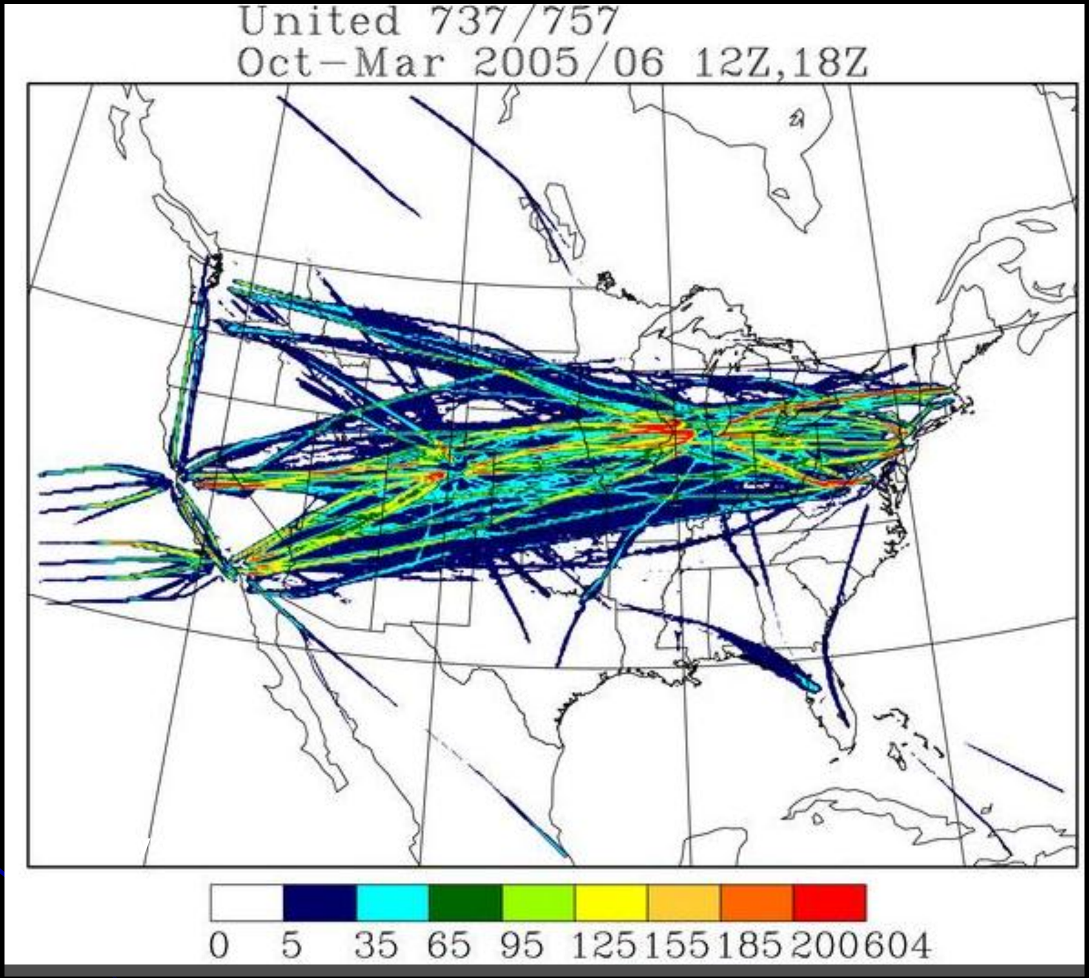
GOES-10/11 OT Frequency 2007





Convectively Induced Turbulence

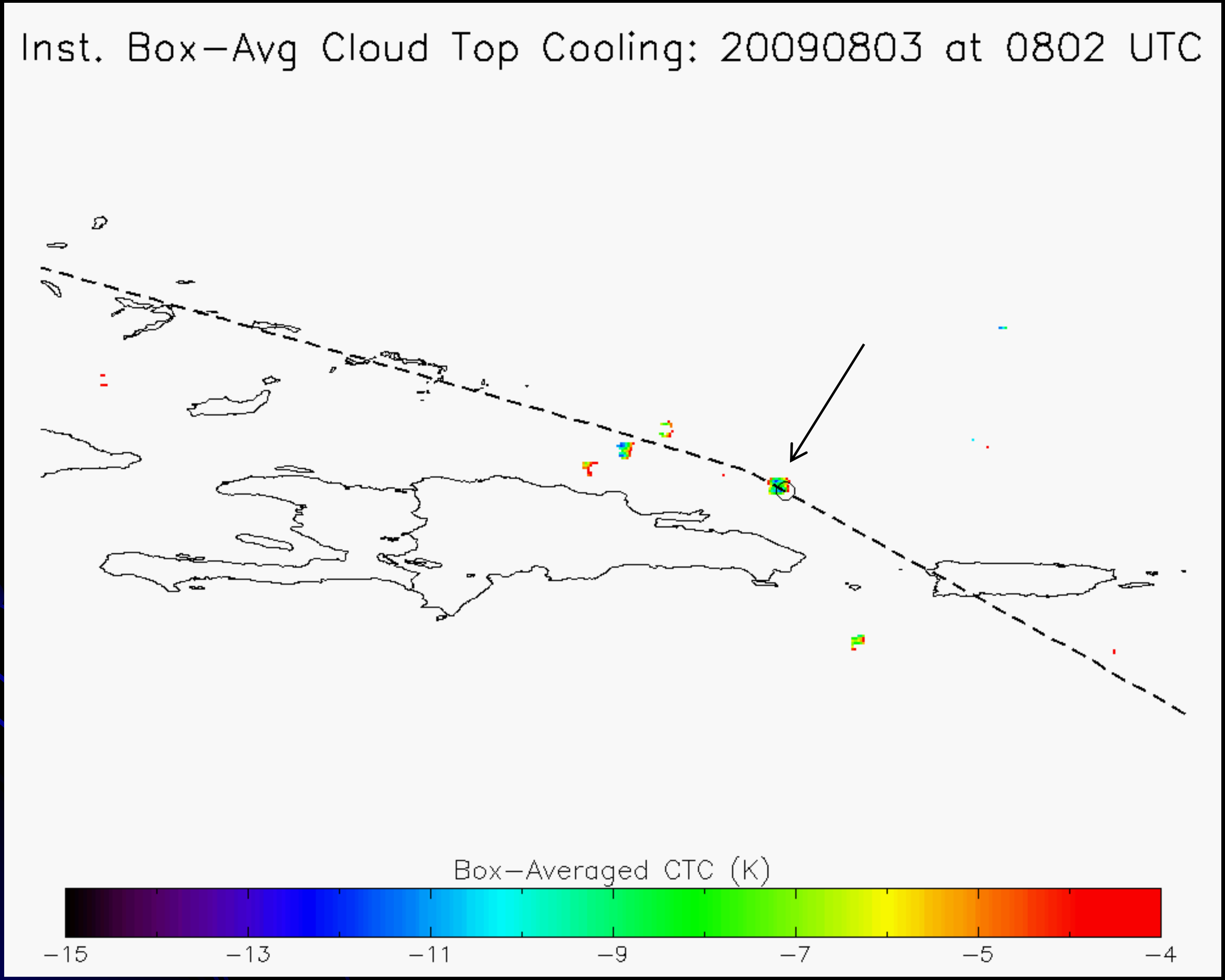
EDR Turbulence Observations



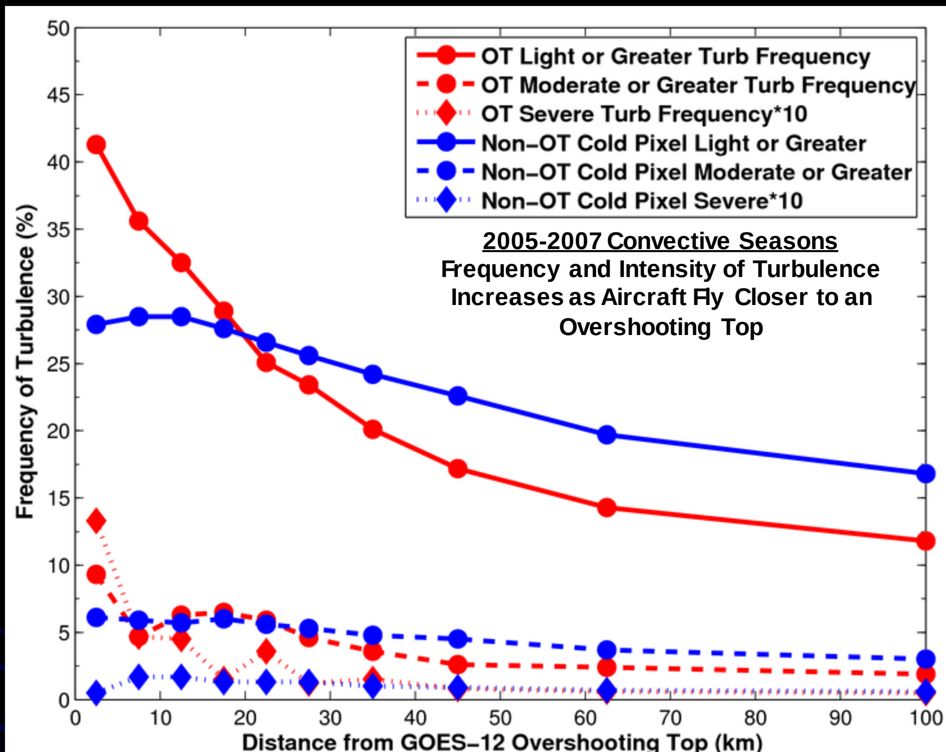
- Many United Airlines Boeing 757 aircraft are collecting Eddy Dissipation Rate (EDR) observations, an objective measure of aircraft turbulence (Cornman et al., *J. Aircraft*, 1995)
  - *Delta and Southwest Airlines EDR observations will be collected in 2009*
- EDR provides a significant advantage over PIREPS in their: 1) objectivity, 2) positional accuracy, and 3) frequency of turbulent + null reporting (every minute)

August 3, 2009 Turbulence Event

10.7 um animation

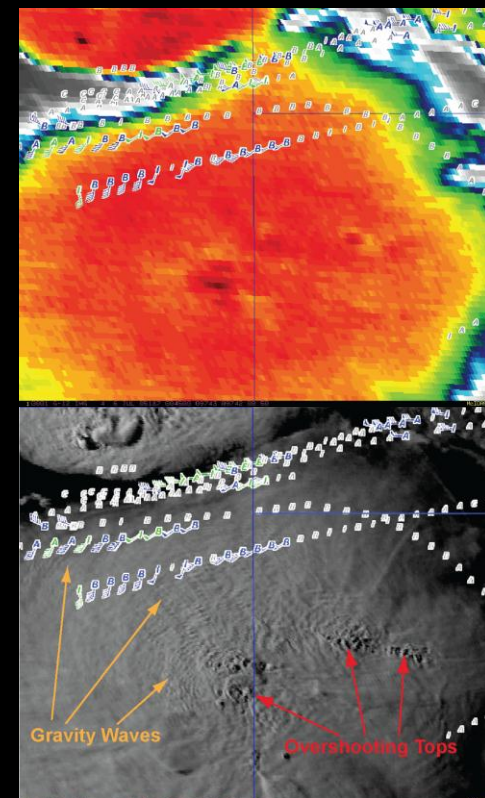


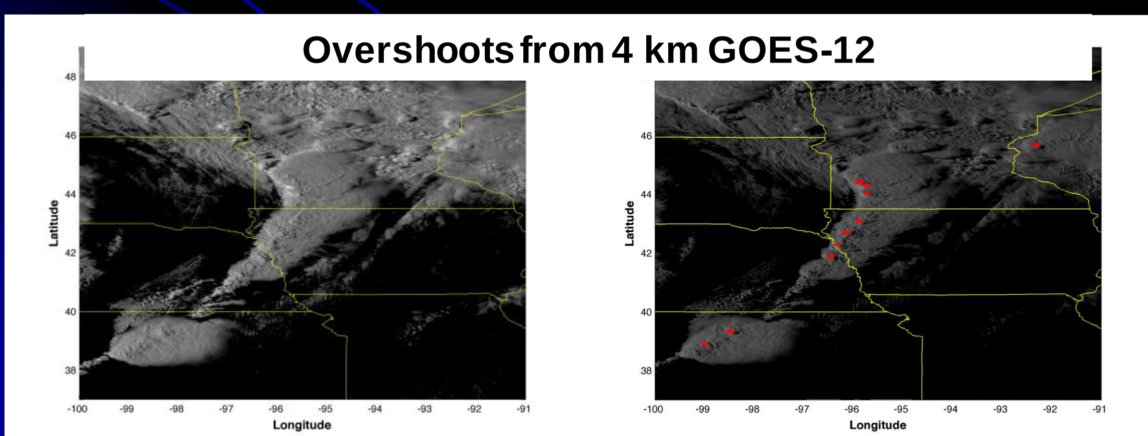
Deep Convection Characteristics and Turbulence Signatures: Overshooting Tops



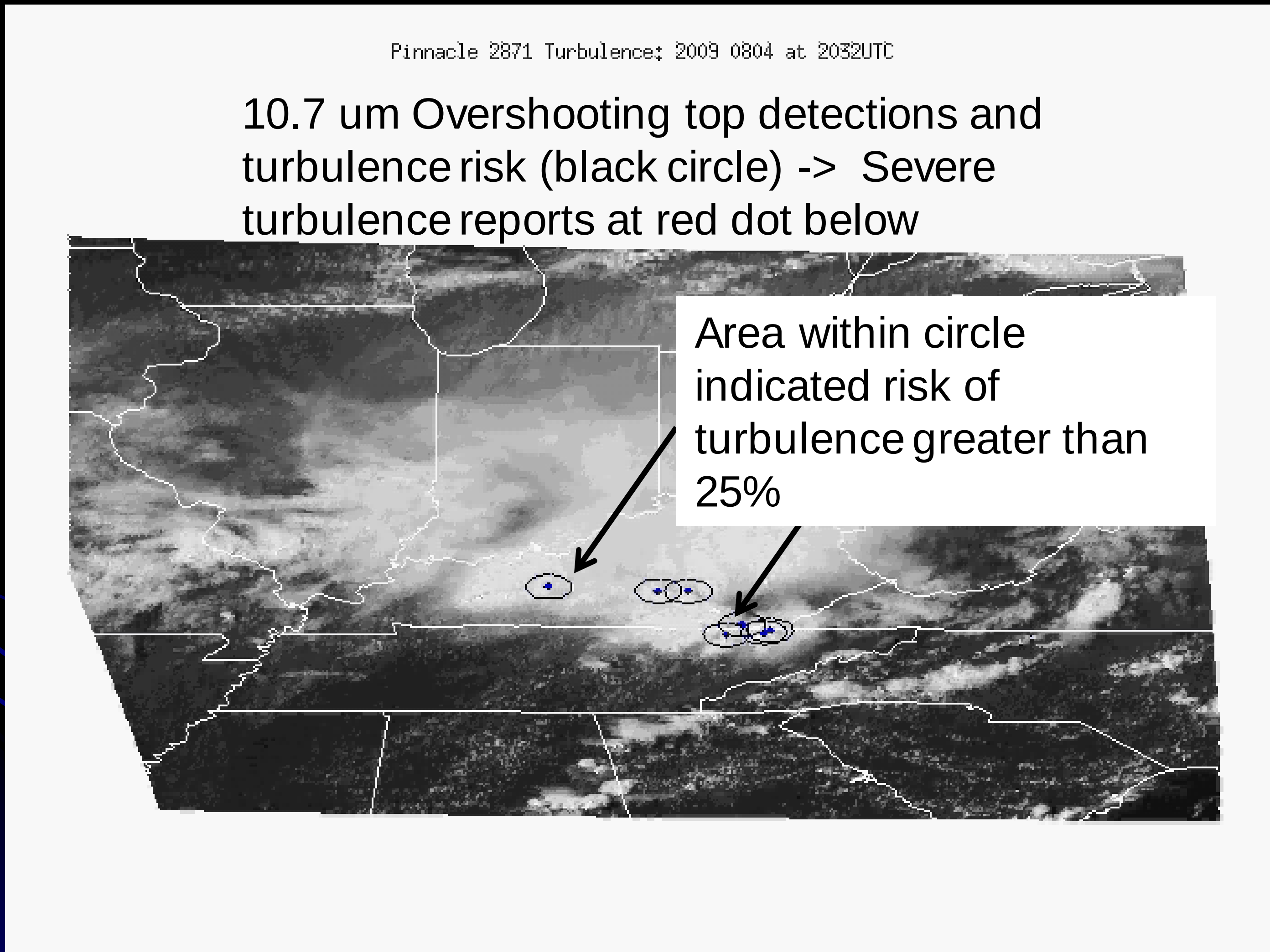
Light Intensity Turbulence from EDR

Moderate Intensity Turbulence from EDR





Overshooting-top -> Inference of Turbulence Pinnacle Flight 2871 on August 4, 2009



Summary

- Plentiful Aviation AWG – Lightning AWG bridges to create

  - Over ocean convective detection and relationship to turbulence important to aviation community
  - Climate indices??
  - Hurricane intensification signals?
  - UAH Lightning Initiation R3 effort

- R3/Proving Ground Testbeds Path to Optimal Synergy?
  - SPC HWT -> Overshooting-top/CTC + Lightning
  - NHC -> Tropical Cyclone Genesis Intensity Nowcast/Monitoring
  - AWC -> Turbulence
  - Climate Testbed -> ENSO phase monitoring

References

- Bedka, K. M., J. Brunner, R. Dworak, W. Feltz, J. Otkin, and Thomas Greenwald, 2009. Objective Satellite-Based Overshooting Top Detection Using Infrared Window Channel Brightness Temperature Gradients, Accepted for publication within JAMC
- Brunner, J.C., S.A. Ackerman, A.S. Bachmeier, and R.M. Rabin, 2007: A quantitative analysis of the enhanced-V feature in relation to severe weather. *Wea. Forecasting, 22, 853-872*
- Feltz, W. F.; Bedka, K. M.; Otkin, J. A.; Greenwald, T. and Ackerman, S. A., 2009. Understanding satellite-observed mountain-wave signatures using high-resolution numerical model data. Weather and Forecasting, Volume 24, Issue 1, 2009, pp.76-86. Call Number: Reprint # 6016
- Mecikalski, J.R., and K.M. Bedka, 2006: Forecasting Convective Initiation by Monitoring the Evolution of Moving Cumulus in Daytime GOES Imagery. Mon. Wea. Rev., 134, 49–78.
- Mecikalski, J.R., W.F. Feltz, J.J. Murray, D.B. Johnson, K.M. Bedka, S.T. Bedka, A.J. Wimmers, M. Pavolonis, T.A. Berendes, J. Haggerty, P. Minnis, B. Bernstein, and E. Williams, 2007: Aviation Applications for Satellite-Based Observations of Cloud Properties, Convection Initiation, In-Flight Icing, Turbulence, and Volcanic Ash. Bull. Amer. Meteor. Soc., 88, 1589–1607.