GOES-R Overview of Aviation and Nowcasting Applications Current Status and a Look into Future

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Cooperative Institute for Meteorological Satellite Studies (CIMSS),
University of Wisconsin – Madison, U. S. A.

Environment Canada, Toronto/Montreal
April 28-29, 2011

Thank you for inviting me!

- 19 years at UW-Madison
- Research interests: Nowcasting, uplooking passive thermodyamic profiling, validation, NWP satellite simulations
- Principal Investigator: NASA ASAP, NASA ROSES, NOAA GIMPAP, NOAA GOES-R AWG/PG, NOAA/NRC Network of Networks study
- GOES-R Aviation Algorithm Working Group Co-Chair 2007-present
- AMS SatMet Committee (2007- current)
- AMS Journal of Atmospheric and Oceanic Technology Editor 2009-present

Outline

- National Aviation Transportation System
- GOES-R R3/AWG/PG programs
- Aviation Hazard Overview
- GOES-R Aviation Application Overview
  - Validation
  - Path to current Proving Grounds and operational use on current imager technology
- Convection
- Turbulence
- Summary

GOES-R Program

Risk Reduction

↓

Algorithm Working Group

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Proving Ground Exercises

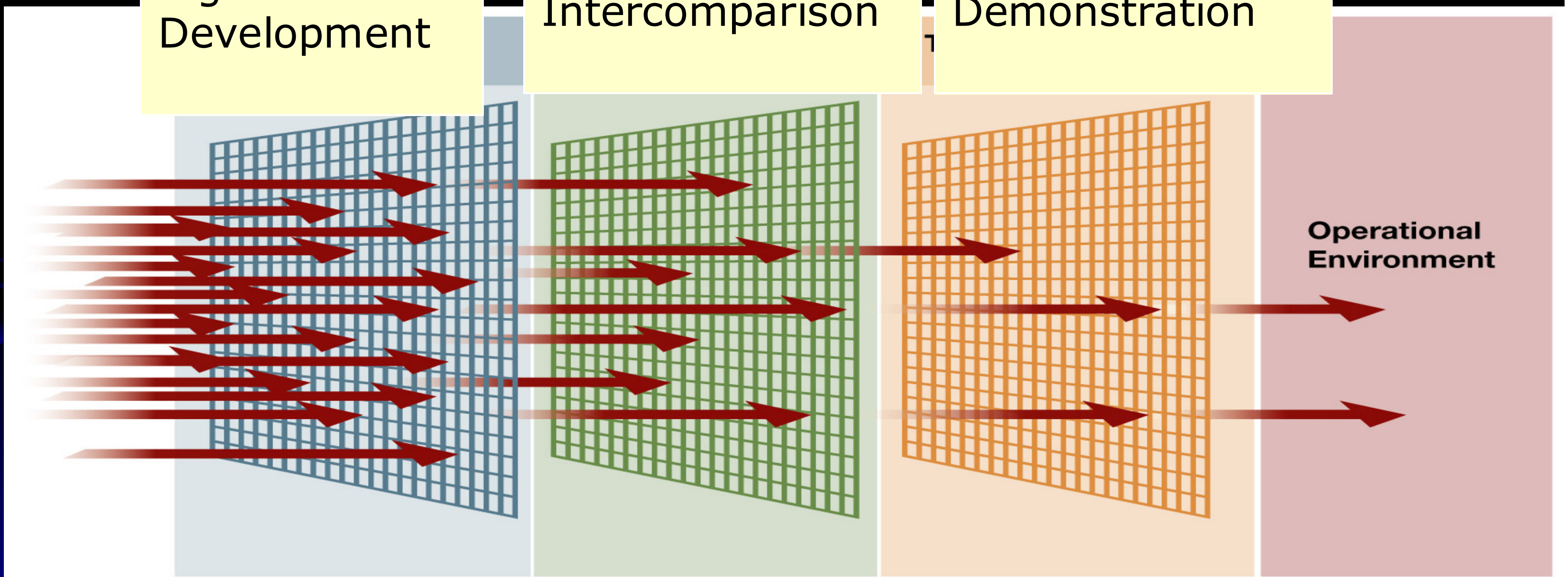
First Light Decision Support Products

Algorithm Research to Operations Process

GOES-R Risk Reduction Exploratory Algorithm Development

AWG Algorithm Candidate Development & Intercomparison

AWG Algorithm Selection and Proving Ground Demonstration



GOES-R AWG Application Teams

SSEC AWG Involvement in Yellow
AWG Chair listed first
Local SSEC/CIMSS POC underlined/italics

- **Soundings (*Tim Schmit*)**
- **Winds (Jaime Daniels, *Chris Velden*)**
- **Clouds (*Andy Heidinger*)**
- **Aviation (Ken Pryor, *Wayne Feltz*)**
- **Aerosols / Air Quality / Atmospheric Chemistry (Shobha Kondragunta, *Steve Ackerman/Chris Schmidt/Brad Pierce*)**
- **Land Surface (Dan Tarpley, *Chris Schmidt/Elaine Prins*)**
- **Cryosphere (*Jeff Key*)**
- **Visualization and Imagery (*Tim Schmit*)**
- SST and Ocean Dynamics (Alexander Ignatov)
- Radiation Budget (Istvan Lazslo)
- Lightning (Steve Goodman)
- Space Environment (Steven Hill)
- Hydrology (Robert Kuligowski)

- **Proxy Data (Fuzhong Weng, *Allen Huang/Tom Greenwald*)**
- **Algorithm Integration (Walter Wolf, *Ray Garcia/Graeme Martin*)**
- **Cal/Val (Changyong Cao, *Dave Tobin*)**

GOES-R-Baseline and Option 2 Products

(by inclusion into geocat)

GOES-R Baseline Products	GOES-R Option 2 Products
Aerosol Detection (Including Smoke and Dust)	Aerosol Particle Size
Aerosol Optical Depth: AOD & Suspended Matter	**Aircraft Icing Threat**
Volcanic Ash: Detection and Height	**Cloud Ice Water Path**
Cloud and Moisture Imagery	**Cloud Layers/Heights**
Cloud Optical Depth	**Cloud Liquid Water**
Cloud Particle Size Distribution	**Cloud Type**
Cloud Top Phase	**Convective Initiation**
Cloud Top Height	**Enhanced "V" / Overshooting Top Detection**
Cloud Top Pressure	**Low Cloud and Fog**
Cloud Top Temperature	**Tropopause Folding Turbulence Prediction**
Hurricane Intensity	**Visibility**
Lightning Detection: Events, Groups & Flashes	Probability of Rainfall
Rainfall Rate / QPE	Rainfall Potential
Legacy Vertical Moisture Profile	Absorbed Shortwave Radiation: Surface
Legacy Vertical Temperature Profile	Downward Longwave Radiation: Surface
Derived Stability Indices	Upward Longwave Radiation: Surface
Total Precipitable Water	Upward Longwave Radiation : TOA
Clear Sky Masks	**Ozone Total**
Downward Shortwave Radiation: Surface	**SO_2 Detection**
Reflected Shortwave Radiation: TOA	Flood/Standing Water
Derived Motion Winds	Ice Cover
Fire/Hot Spot Characterization	Snow Depth (over Plains)
Land Surface (Skin) Temperature	Surface Albedo
Snow Cover	**Surface Emissivity**
Seas Surface Temperature (Skin)	Vegetation Fraction: Green
	Vegetation Index
	Currents
	Currents: Offshore
	Sea and Lake Ice: Age
	Sea and Lake Ice: Concentration
	Sea and Lake Ice: Motion

In GEOCAT (from CIMSS)

No known plans for GEOCAT

Near-term plans for GEOCAT (from CIMSS)

GLM Product

No Current plans for GEOCAT (from CIMSS)

Of the 25 Baseline products, 15 are in GEOCAT

Revised 6/30/2009

Satellite-based Nowcasting and Aviation APplication (SNAAP) Team

- Primarily NASA/NOAA funded through Advanced Satellite Aviation-weather Products (ASAP) and GOES/GOES-R/Polar initiatives working with NOAA, FAA, and NCAR
- 8th Year of Existence with UW-CIMSS Research Focus
  - Convection, Mesoscale winds
  - Turbulence
  - Volcanic Ash
- Team continues to explore satellite- based aviation weather applications with emphasis on the 0-3 hour forecast problem

UW-CIMSS SNAAP Team

PI/Lead: Wayne Feltz

NOAA Collaborators: Michael Pavolonis, Bradley Pierce, and Tim Schmit

- Convective Initiation
  - Justin Sieglaff
  - Lee Cronce
  - Kris Bedka (formerly CIMSS)
- Enhanced-V/Overshooting top detection
  - Jason Brunner
  - Kristopher Bedka
  - Richard Dworak
- Turbulence
  - Anthony Wimmers
  - Wayne Feltz
- Volcanic ash/SO_2
  - Mike Pavolonis (NOAA STAR)
  - Andrew Parker
- Fog/Low Cloud
  - Mike Pavolonis (NOAA STAR)
  - Corey Calvert
- Visibility
  - Brad Pierce (NOAA STAR)
  - Wayne Feltz
- Current Graduate Students
  - Sarah Monette (Tropical Genesis using OTTC)
  - Caitlin Hart (WDSS-II object tracking of satellite-based convection)

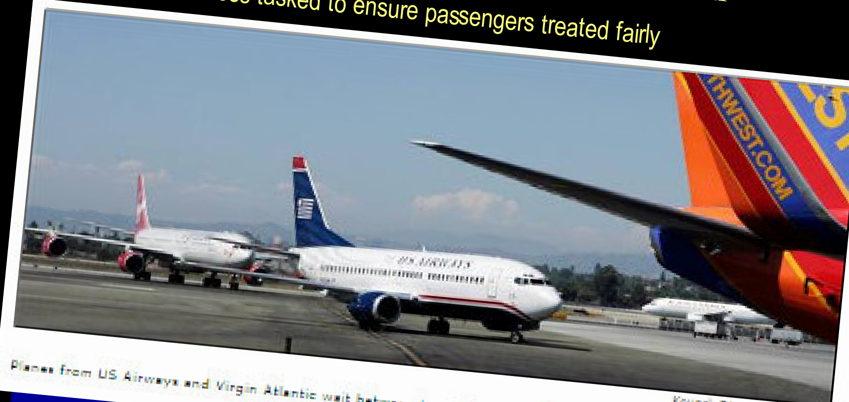
Why satellite-based nowcasting/aviation applications (0-6 hour range)?

- Aviation Community demands high temporal and spatial resolution
- Aviation weather hazard information is relevant on very short time scales
- Geostationary satellites provide the temporal resolution but do not provide data at high latitudes where “great circle” commercial aviation routes are common
- Polar-orbiting satellites provide higher spatial resolution with more advanced weather research instrumentation but many times do not provide the temporal information need for short term high impact weather nowcasts in the mid-latitudes and tropics
- Satellites data provide the primary information over data sparse oceanic, arctic, and high terrain regions where commercial and general aviation aircraft operate

The Current System is not Performing Adequately

The New York Times
Airport Delays Worsen
By MATTHEW L. WALD
July 10, 2008
…delays at Newark Liberty and La Guardia are worse.

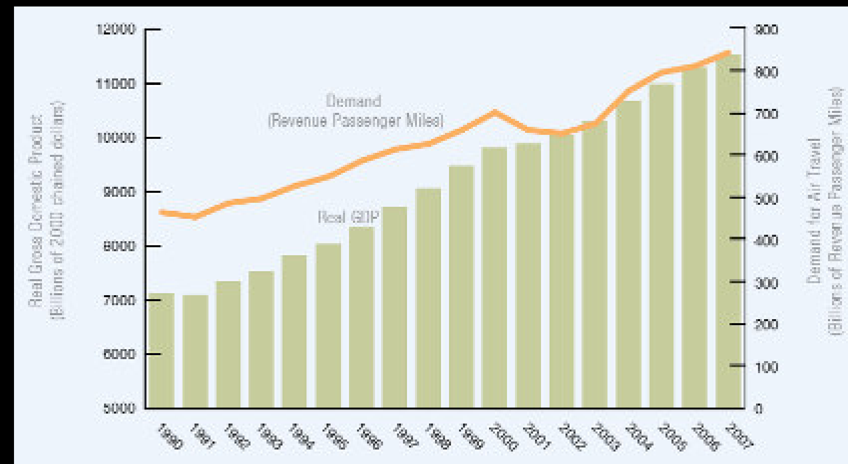
Travel woes continue: 'We've got a problem'
Transportation boss tasked to ensure passengers treated fairly



Kevork Djansezian / AP file
Planes from US Airways and Virgin Atlantic wait between terminals one and two to taxi at LAX last month.

- Demand remains high in already congested markets
- Our air traffic system does not utilize current available technologies to:
  - Support aviation's role in the national economy
  - Address aviation's environmental impact

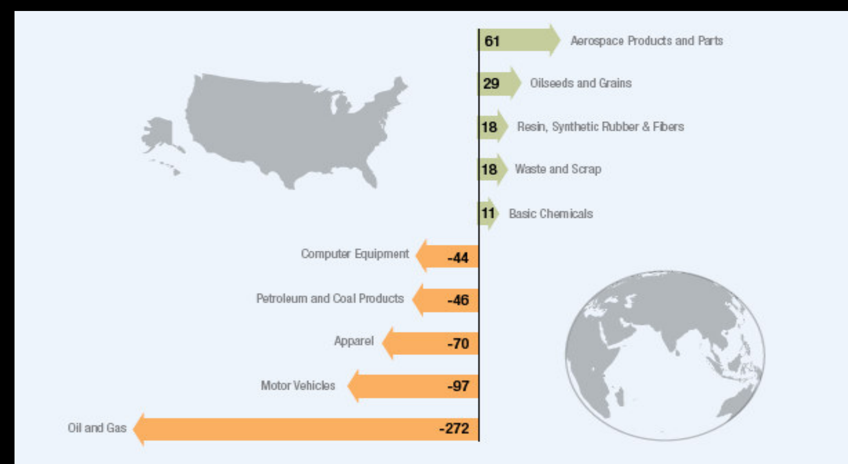
Impact of Aviation on the U.S. Economy

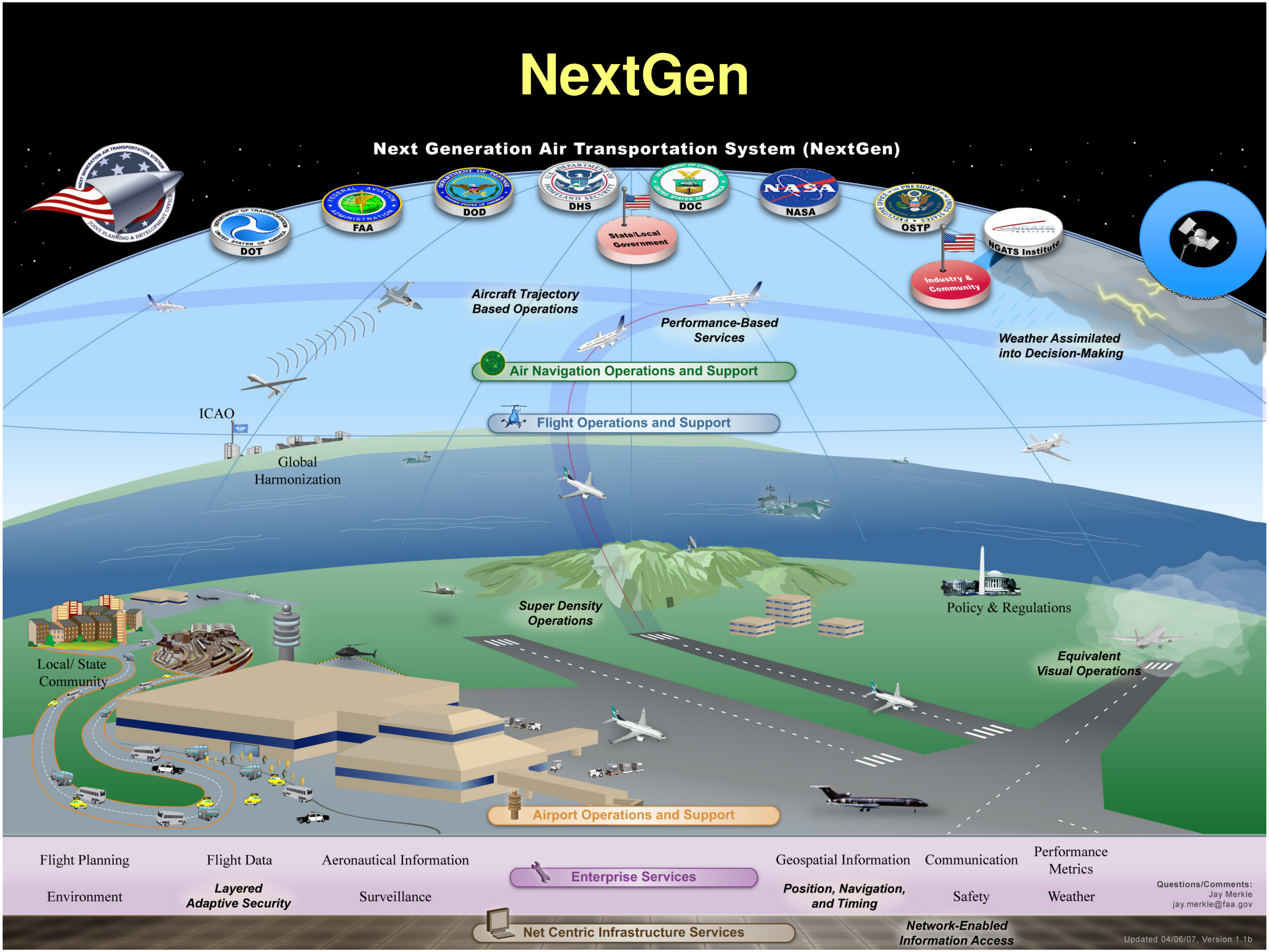


The Aviation Industry contributes to the U.S. Economy and International Trade

Aviation accounts for:

- 11 million aviation-related jobs
- $1.2 trillion in economic activity
- 5.6 Percent Contribution to Gross Domestic Product
- Adds $61 Billion to the US Trade Balance

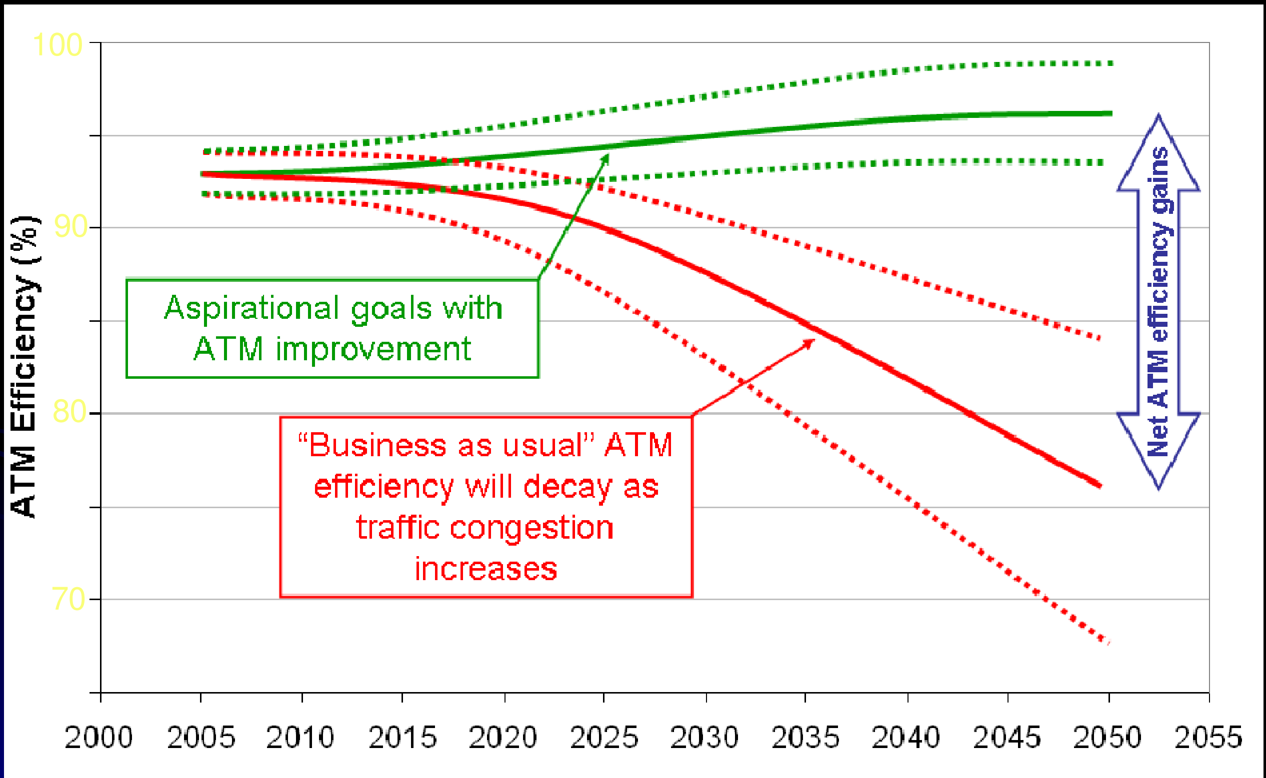




NextGen
Next Generation Air Transportation System (NextGen)
DOT
FAA
DOD
DHS
State/Local Government
DOC
NASA
OSTP
Industry & Community
NGATS Institute
Aircraft Trajectory Based Operations
Performance-Based Services
Weather Assimilated into Decision-Making
Air Navigation Operations and Support
Flight Operations and Support
ICAO
Global Harmonization
Super Density Operations
Policy & Regulations
Local/ State Community
Equivalent Visual Operations
Airport Operations and Support
Flight Planning
Flight Data
Aeronautical Information
Enterprise Services
Geospatial Information
Communication
Performance Metrics
Environment
Layered Adaptive Security
Surveillance
Position, Navigation, and Timing
Safety
Weather
Questions/Comments:
Jay Merkle
jay.merkle@faa.gov
Net Centric Infrastructure Services
Network-Enabled Information Access
Updated 04/06/07, Version 1.1b

Environmental Impact

Trends show that environmental impacts from aircraft noise and emissions will be a critical constraint on airspace capacity and flexibility -- unless managed & mitigated



Increased efficiency with NextGen will lead to reduced fuel consumption, resulting in lower carbon emissions.

NextGen: Improving Efficiency and Capacity

Today's National Airspace System	NextGen
Ground-based Navigation and Surveillance	Satellite-based Navigation and Surveillance
Air Traffic Control Communications By Voice	Routine Information Sent Digitally
Disconnected Information Systems	Information More Readily Accessible
Air Traffic "Control"	Air Traffic "Management"
Fragmented Weather Forecasting	Forecasts Embedded into Decisions
Airport Operations Limited By Visibility Conditions	Operations Continue Into Lower Visibility Conditions
Forensic Safety Systems	Prognostic Safety Systems

The transition to NextGen has already begun.

NextGen Weather: Improving Efficiency and Capacity

Provides advanced weather Information as requested by users to enable collaborative planning and efficient utilization of airspace routes from end to end through entire trajectory

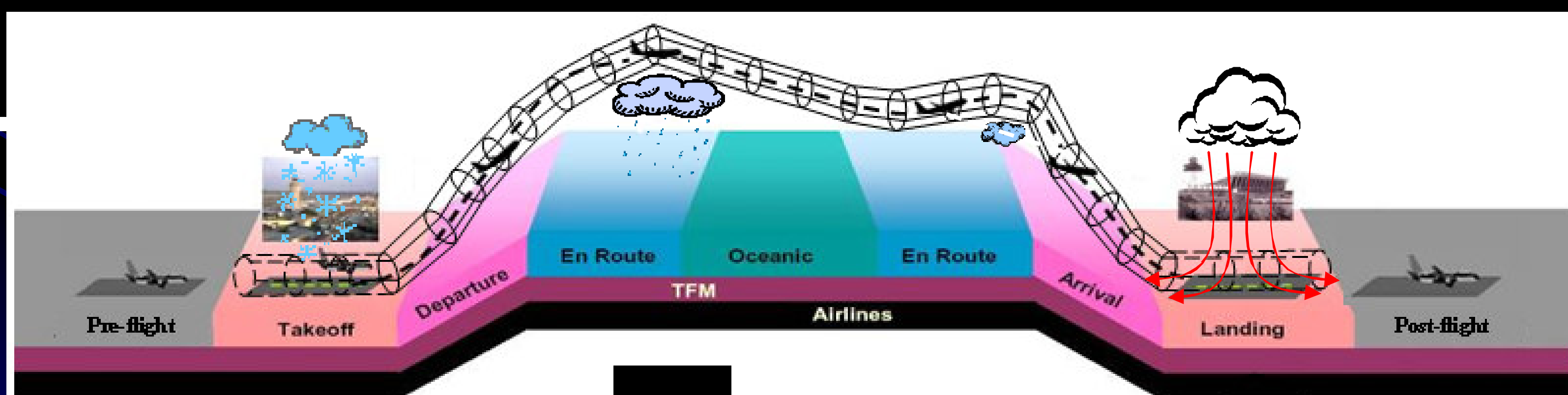
Arrival Forecast Weather
Alternate Forecast Weather
Flight Winds

Thunderstorms
Lightning
Crosswinds
Wind Shear
Freezing/Frozen Precip
Low Ceiling & Visibility
Surface Icing

Thunderstorms, Jet Stream,
Volcanic Ash, Turbulence,
In-Flight Icing, Winds,
Mountain Waves

Thunderstorms
Lightning
Crosswinds
Wind Shear
Freezing/Frozen Precip
Low Ceiling & Visibility
Surface Icing

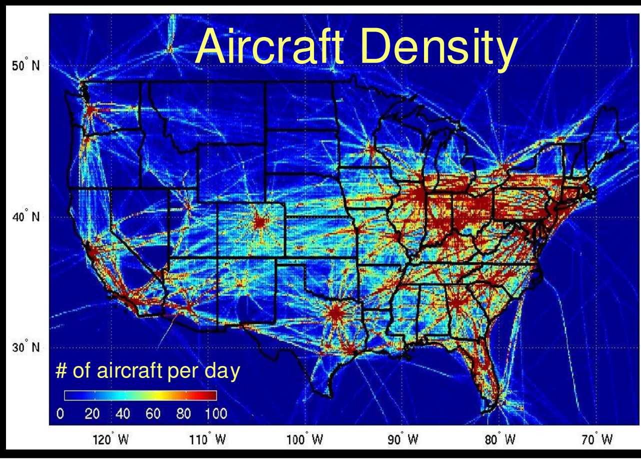
Post-flight observed weather archives

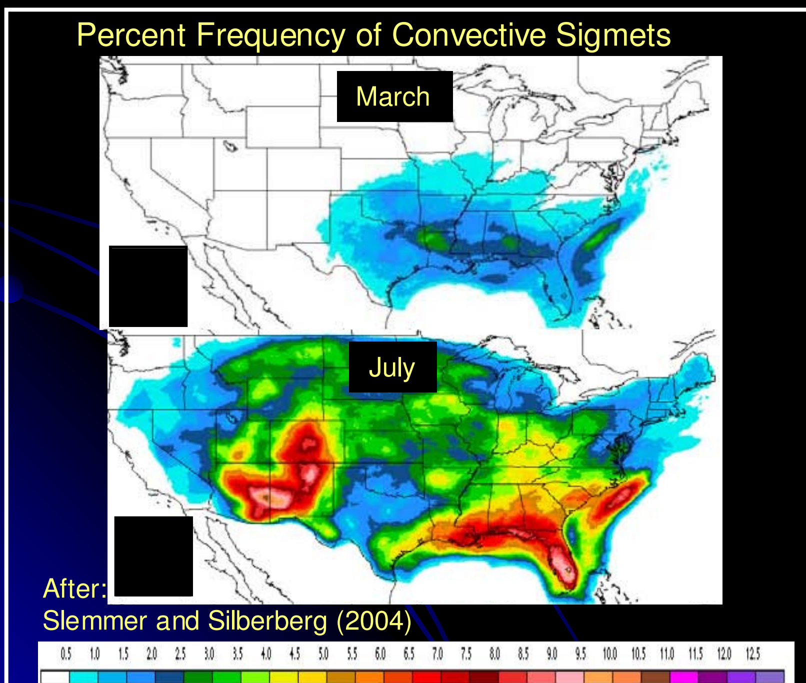


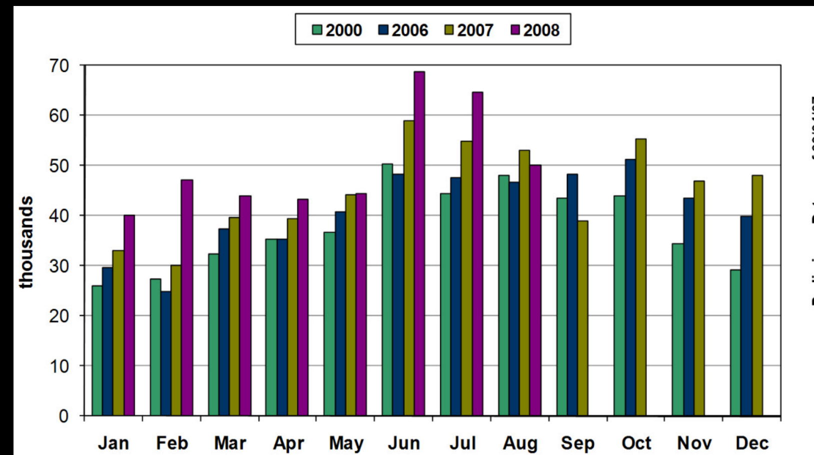
Primary Aviation Weather Hazards

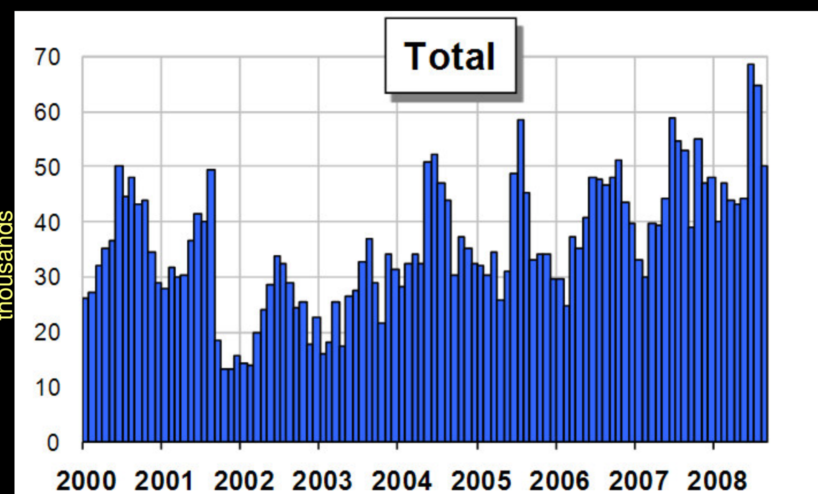
- Convective weather and strong storms (#1 cause of delays/cancellations)
- Turbulence and wake vortices (#1 safety hazard at cruise altitudes)
- Icing (ground, in-flight and engine ice accretion)
- Reduced visibility (VFR pilots in IFR conditions)
- Volcanic ash and gas (Rare but potentially catastrophic)

Aviation Summertime Delays





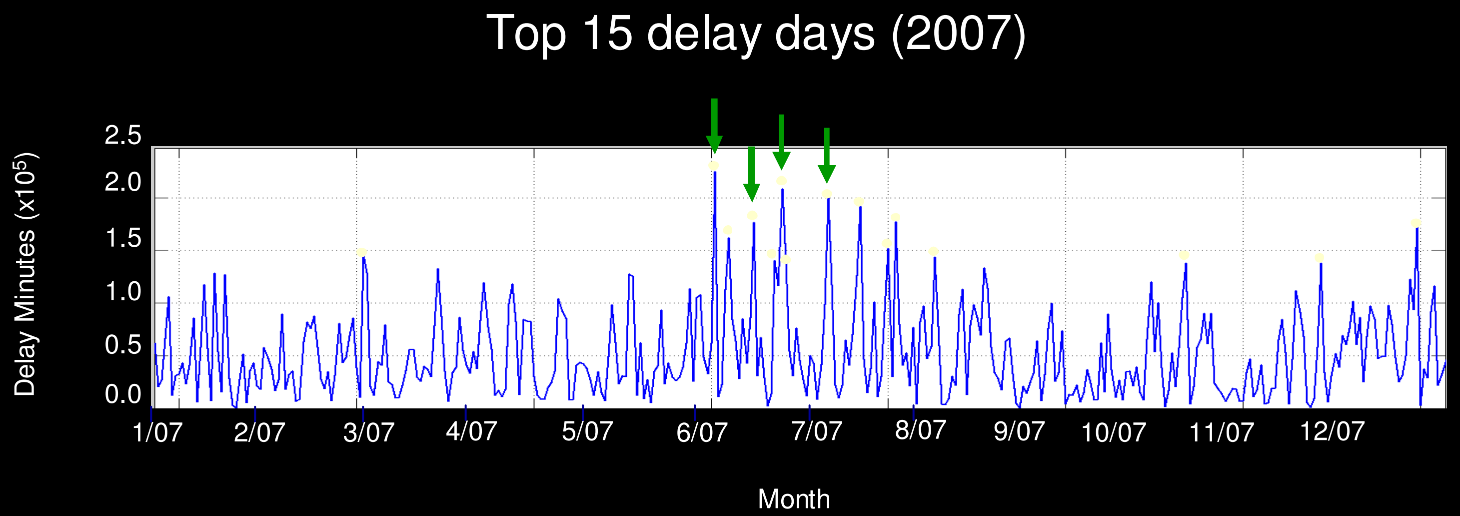


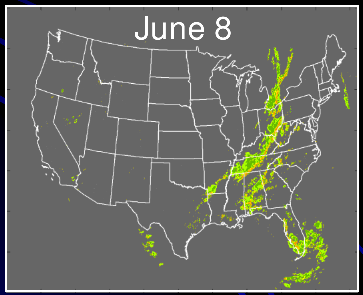


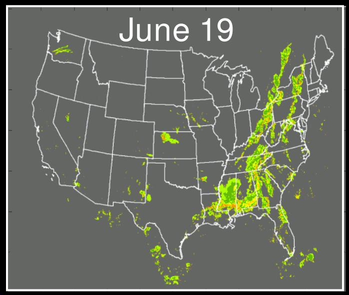
Courtesy: MITRE Corp.

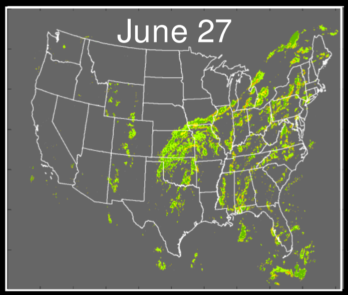
Convective Weather Impact on High Density Operations

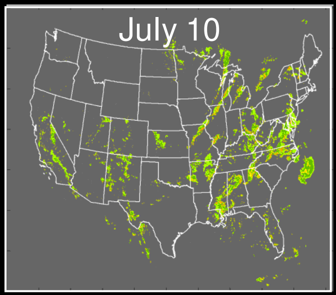
Examples of Aviation Delay Days

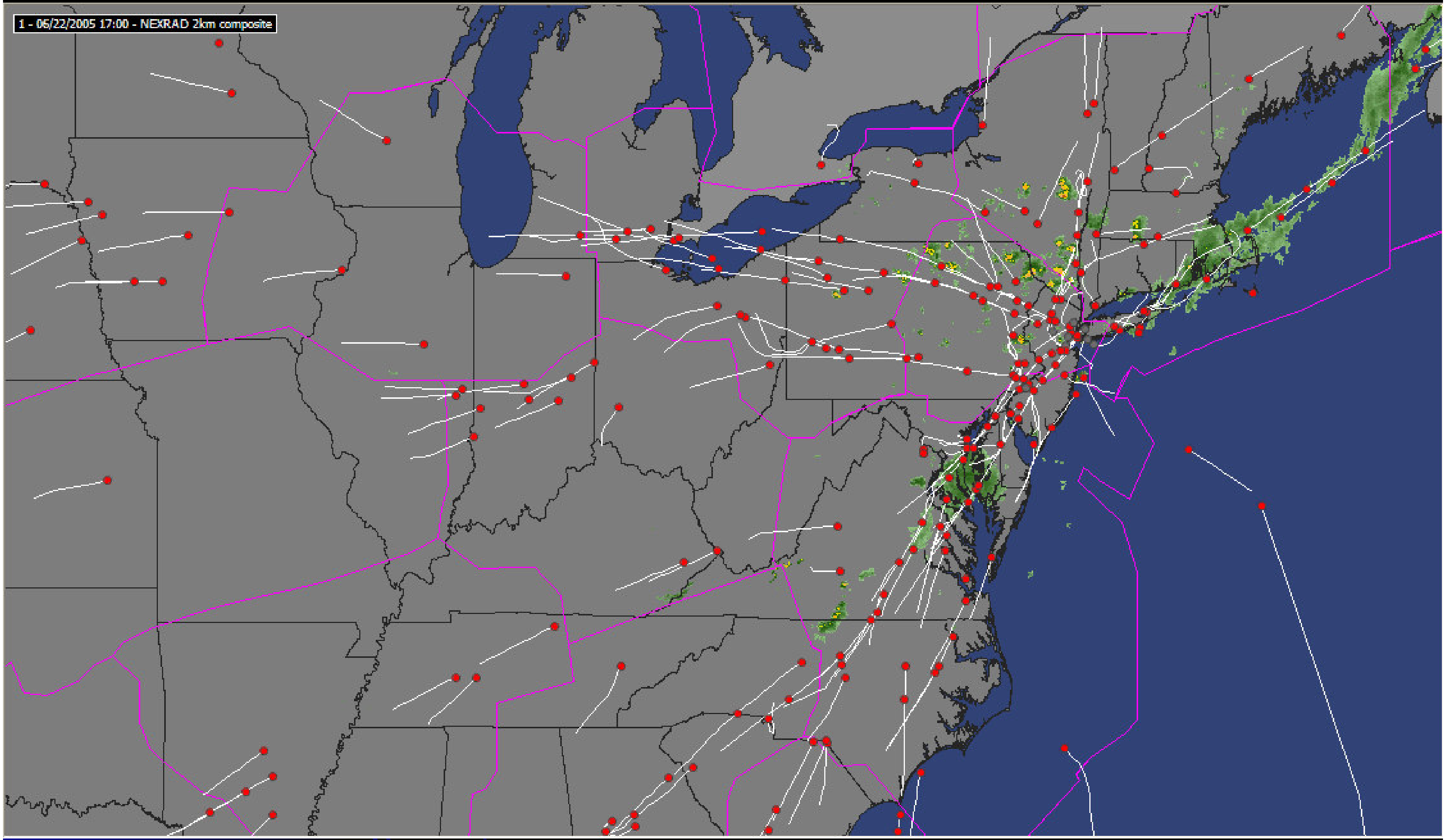












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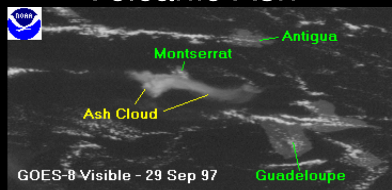
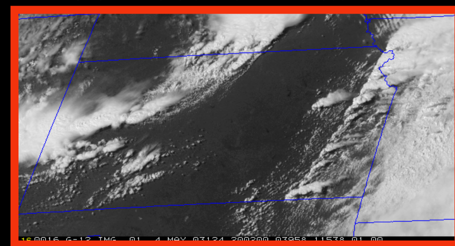
Aviation Weather Real Implications

Satellite-based Advanced Aviation Applications

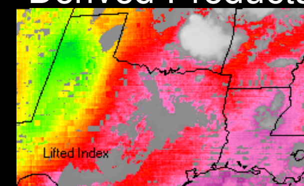
Volcanic Ash



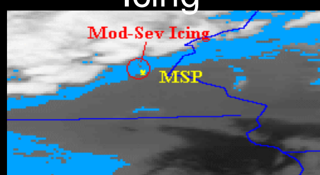
Convective Initiation



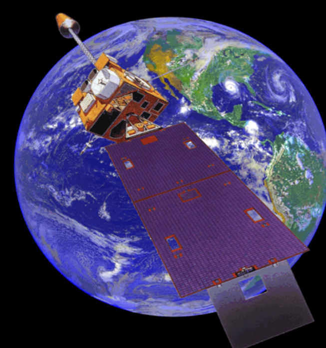
Derived Products



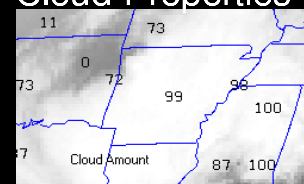
Icing



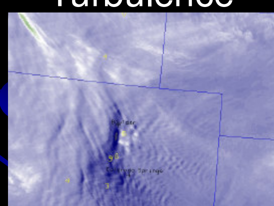
GOES Satellite



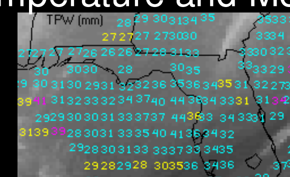
Cloud Properties



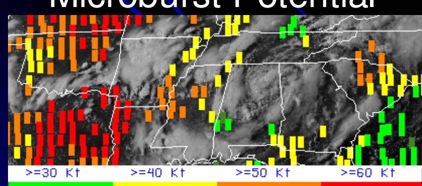
Turbulence



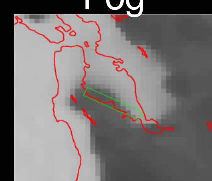
Temperature and Moisture



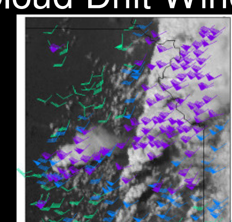
Microburst Potential



Fog



Cloud Drift Winds



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GOES-R AWG Aviation Team

AWG Aviation Team Chairs : Ken Pryor, Wayne Feltz

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

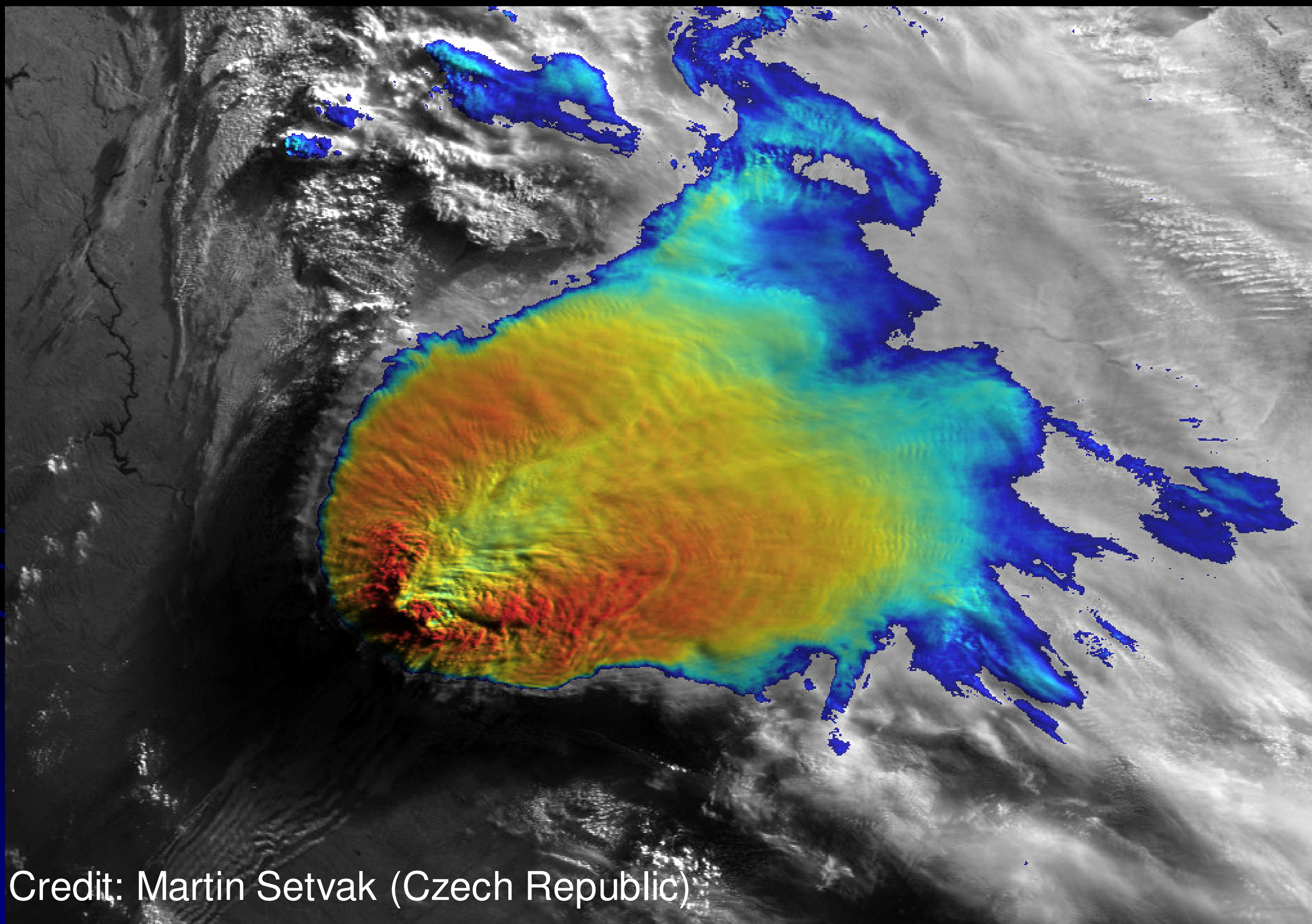
Convective Initiation and Overshooting-top/Enhanced-V

Overshooting-Top/Enhanced-V Detecion

Lead: Kristopher Bedka NASA LaRC SSAI

Jason Brunner (SSEC/CIMSS)

GOES-R Overshooting-Top



Overshooting Top Algorithm Design Overview

Reasons Overshooting Tops are Important

Overshooting Top: A domelike protrusion above a cumulonimbus anvil, representing the intrusion of an updraft though its equilibrium level or the tropopause (from the AMS Glossary)

1)Indicates a storm with a very strong updraft, hazardous for aviation operations if a plane were to fly through an OT

2)Correlates well with radar reflectivity/lightning maxima and storm severity

3)Interaction of updraft with stable tropopause layer generates turbulent gravity waves which can propagate far away from their source region

4)Responsible for obstructing upper-level jet stream flow, producing the enhanced-V signature

Overshooting Top Detection Processing Schematic

(Bedka et al, 2010)

INPUT: BT_{14} and NWP Tropopause

↓

Find Pixels Colder Than 215 K and NWP Tropopause

↓

Filter List of Cold Pixels To Identify Regional BT Minima: Overshoot Candidates

↓

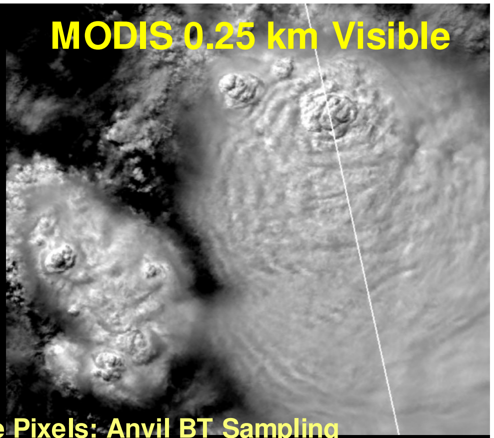
Compute BT Difference Between Candidates and Surrounding Anvil Cloud

↓

Pixels With BT > 6.5 K Colder Than Mean Surrounding Anvil Are Overshooting Tops, Flag Remaining Pixels That Compose The Entire Top

↓

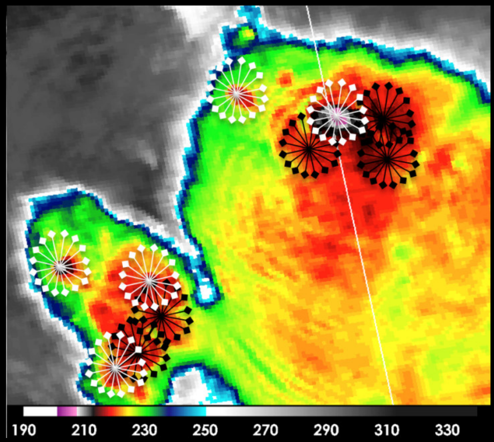
Output Overshooting Top Mask

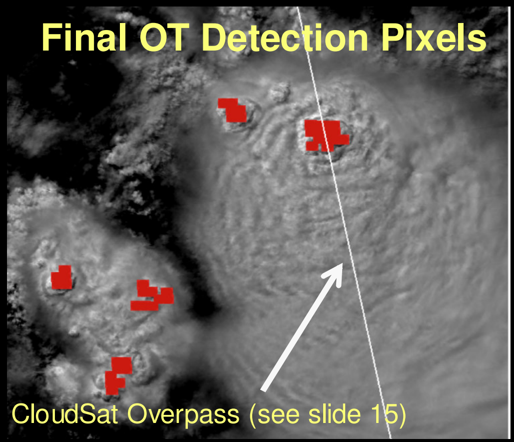


IRW-Texture Candidate Pixels: Anvil BT Sampling

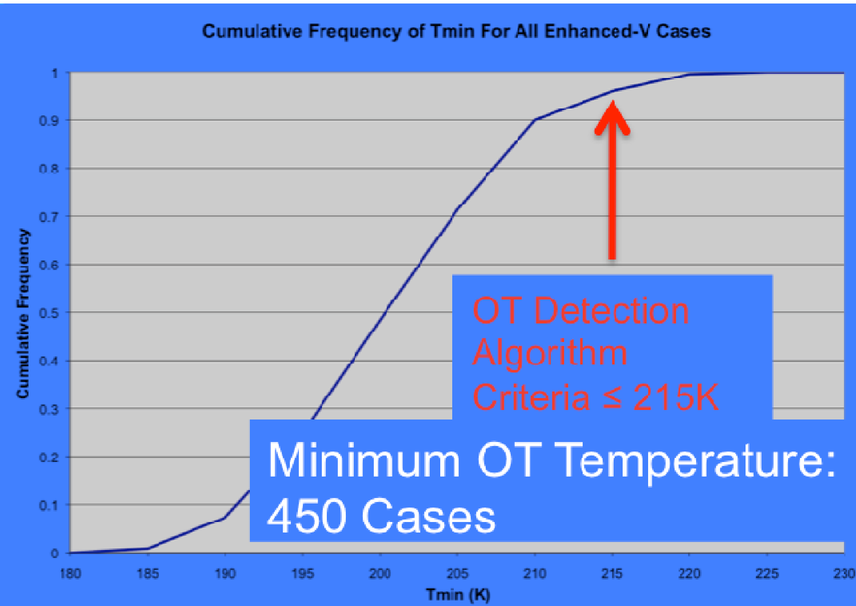
White Pinwheels: Candidate OT Significantly Colder Than Anvil

Black Pinwheels: Cloud Top BT Pattern Too Uniform=Not an OT

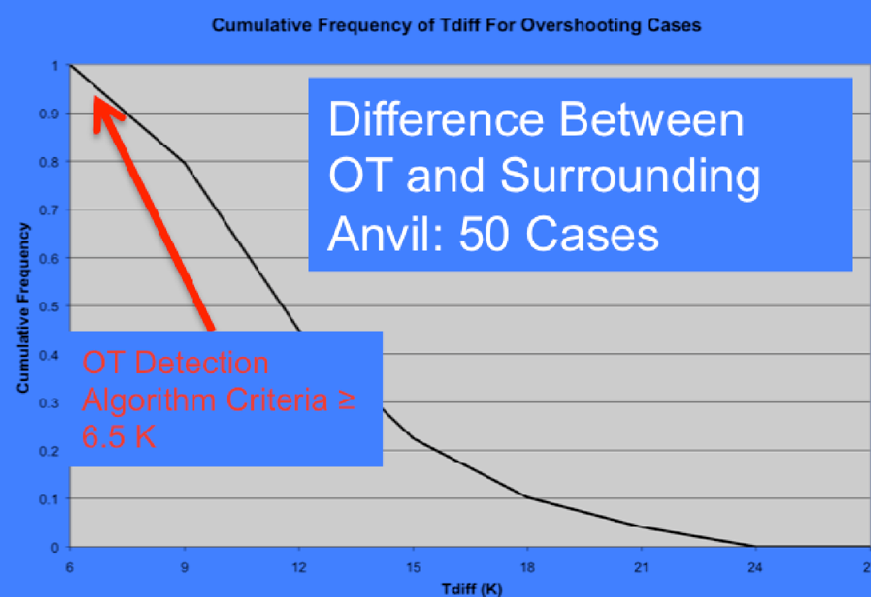


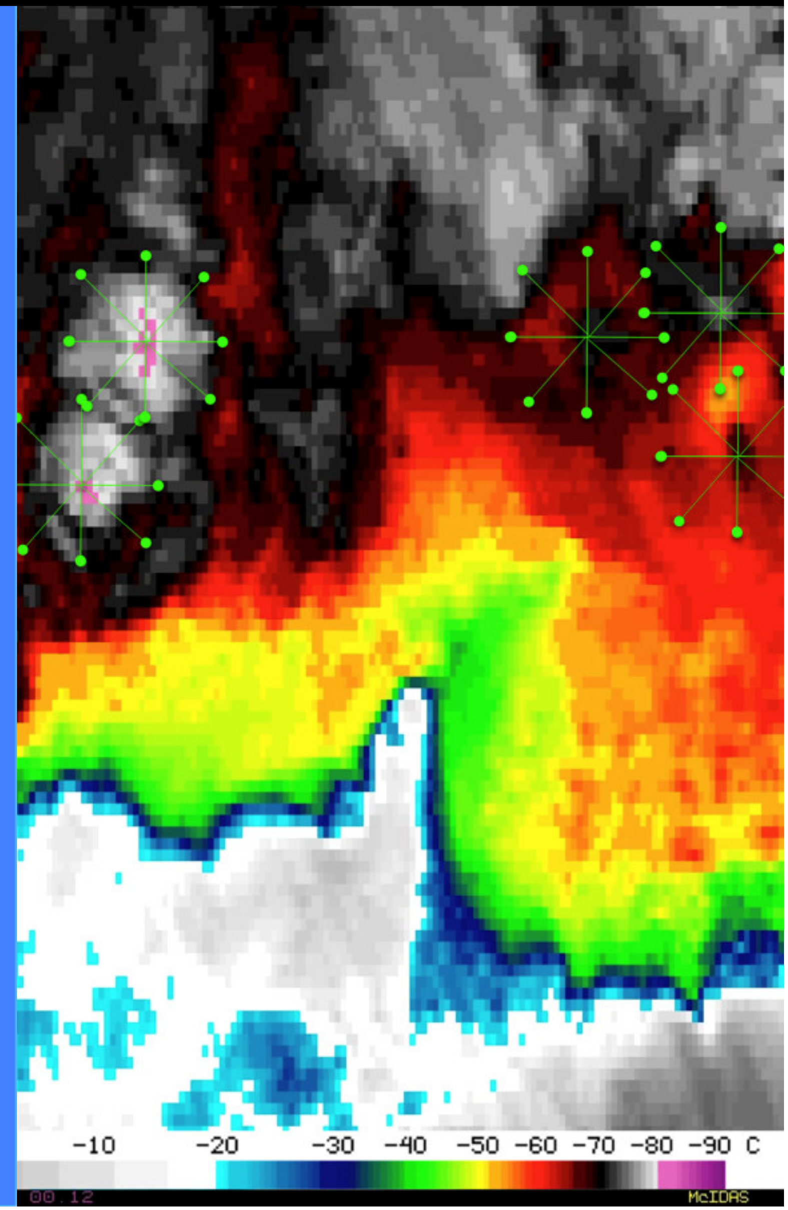


OT Algorithm Design Overview



Relies solely on 10.7 um channel therefore day/night!

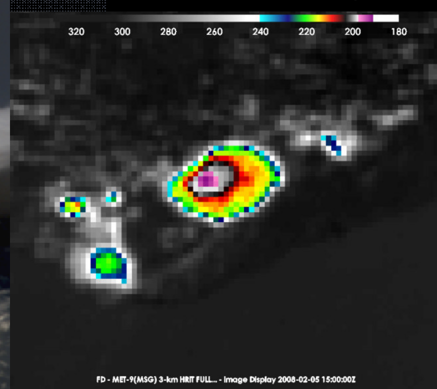




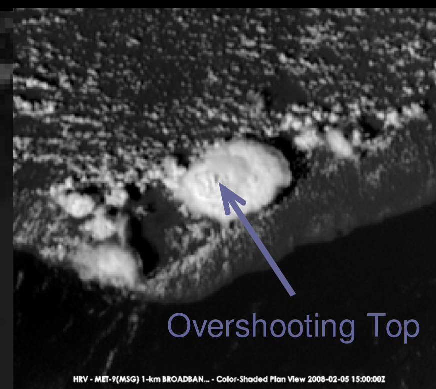
Convective Overshooting-top

Photo From International Space Station

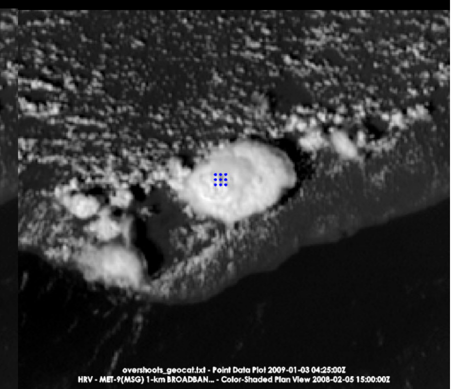
3 km MSG SEVIRI 10.8 µm



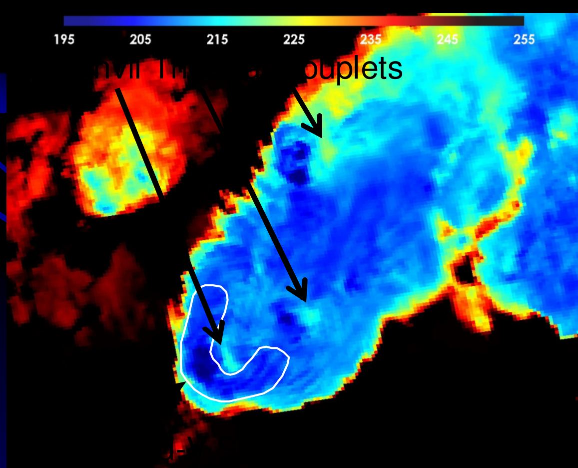
1 km MSG SEVIRI Visible



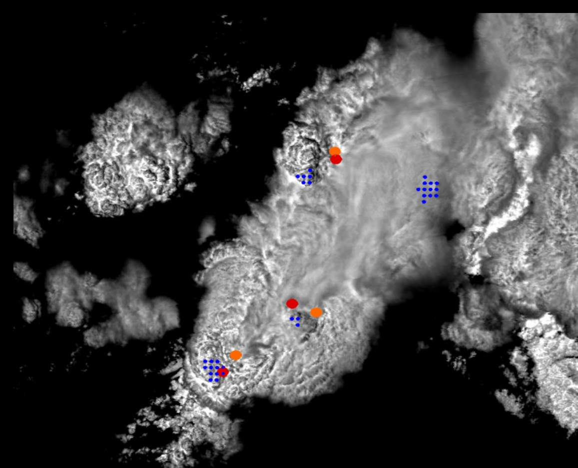
1 km MSG SEVIRI Visible
With Overshooting Detection



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

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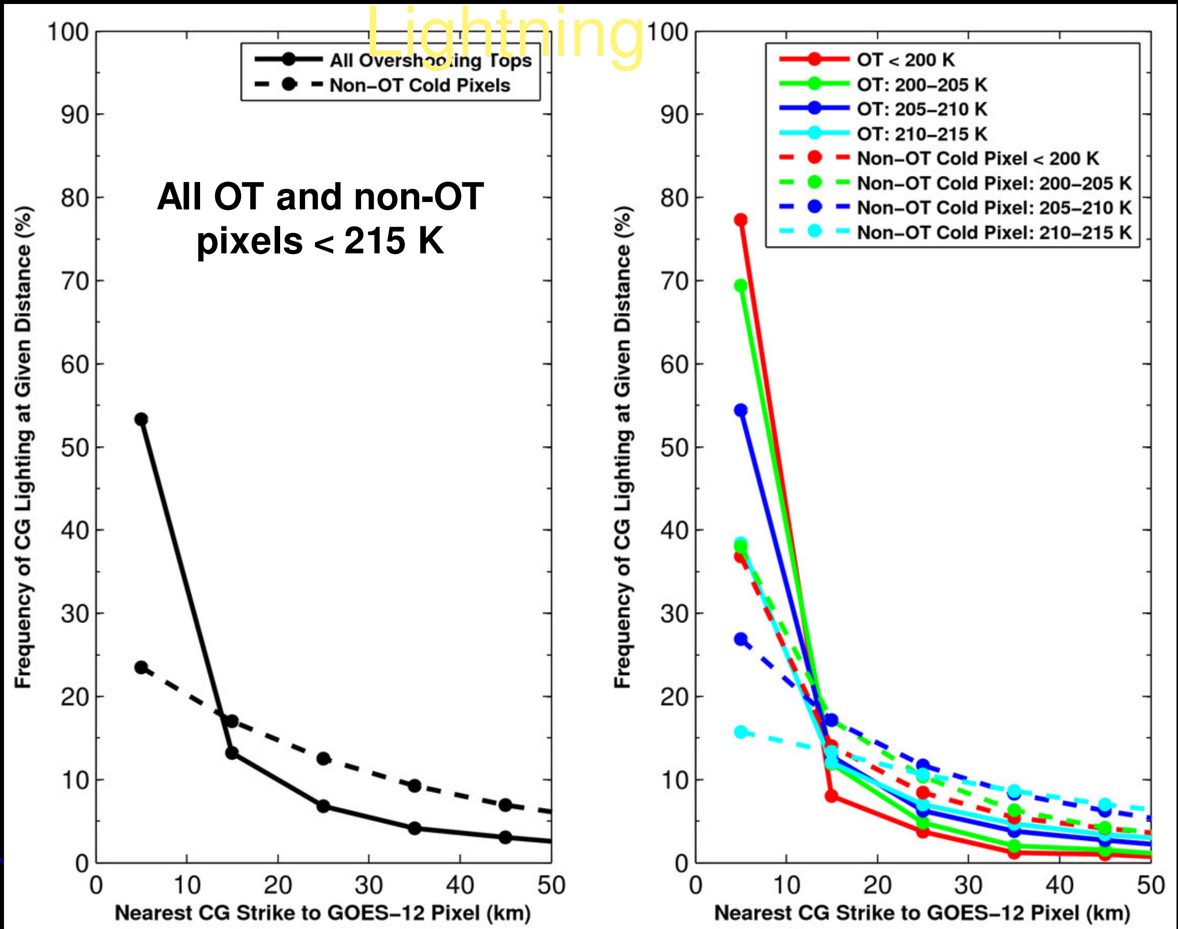
OT Applications

- Inference of turbulence
- Inference of cloud-to-ground lightning
- Climatology -> ENSO
- Tropical storm genesis
- More investigations occurring

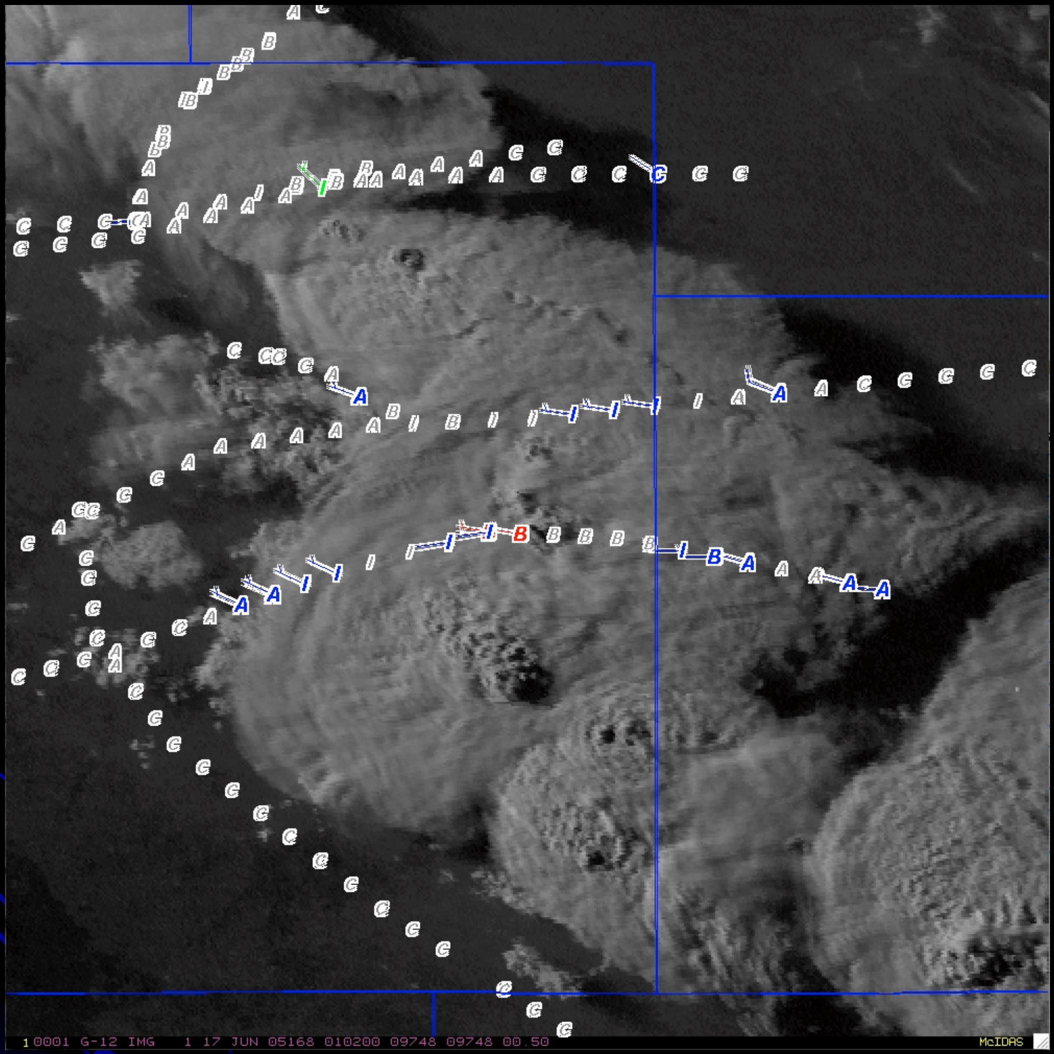
GOES-12 Overshooting Top Relationships with Cloud-to-Ground Lightning



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

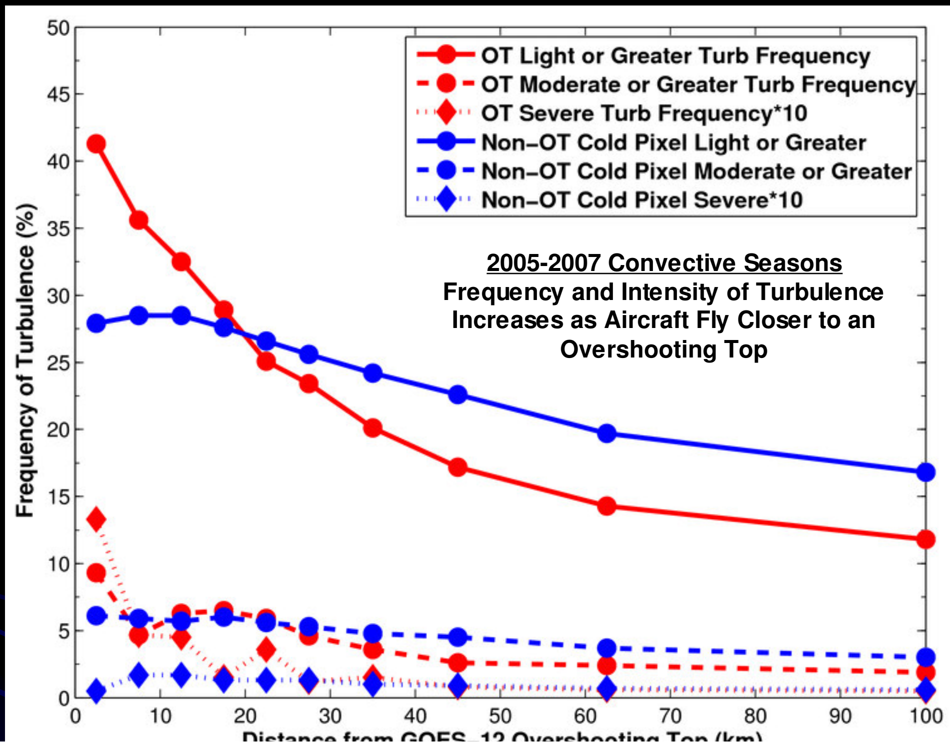
OTs with very cold BTs represent a significant lightning hazard

Objective Turbulence Reporting is Key

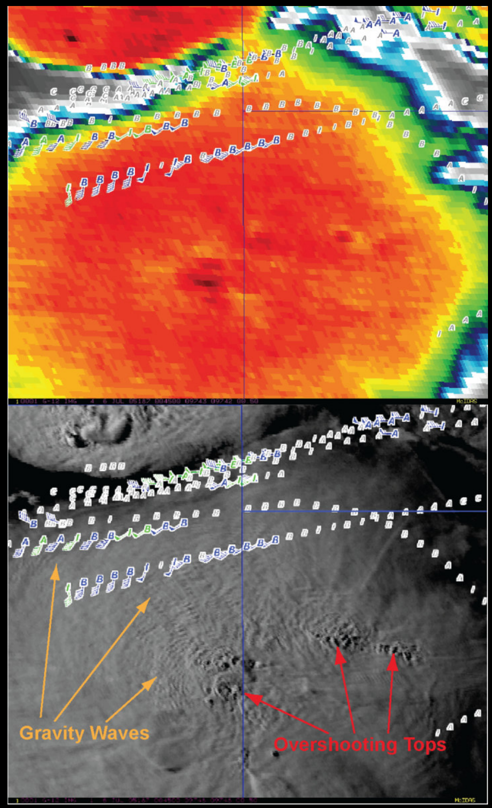


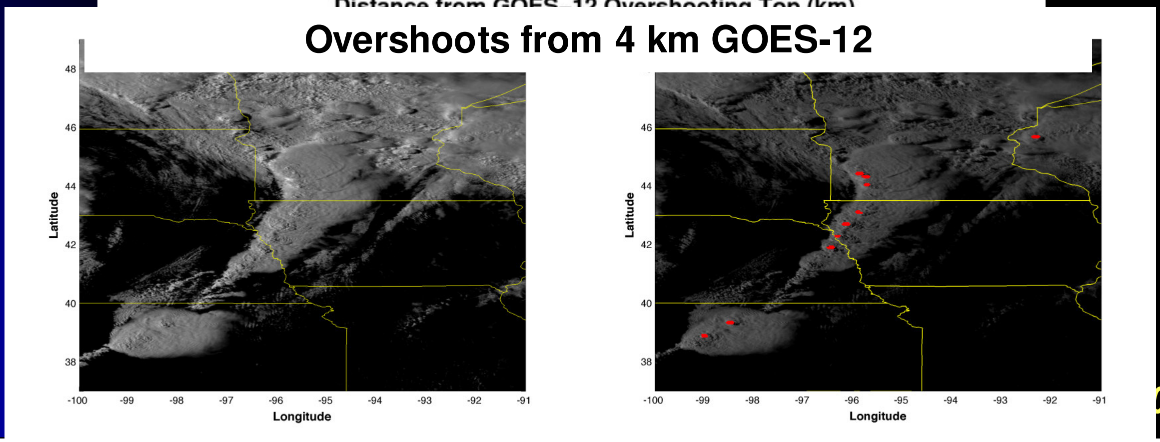
Environment Canada 28-29 April 2011

Deep Convection Characteristics and Turbulence Signatures: Overshooting Tops



Light Intensity Turbulence from EDR
Moderate Intensity Turbulence from EDR

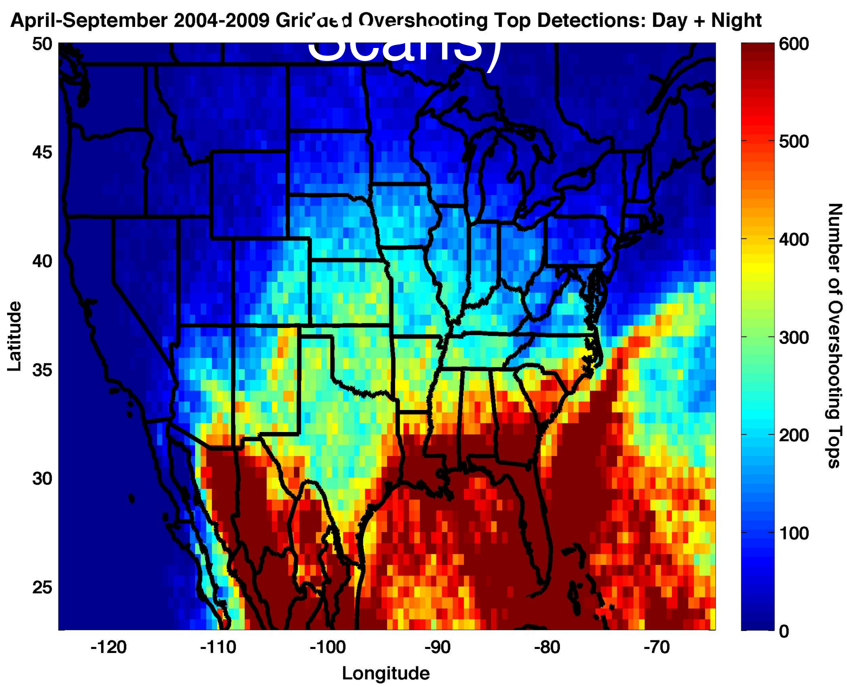




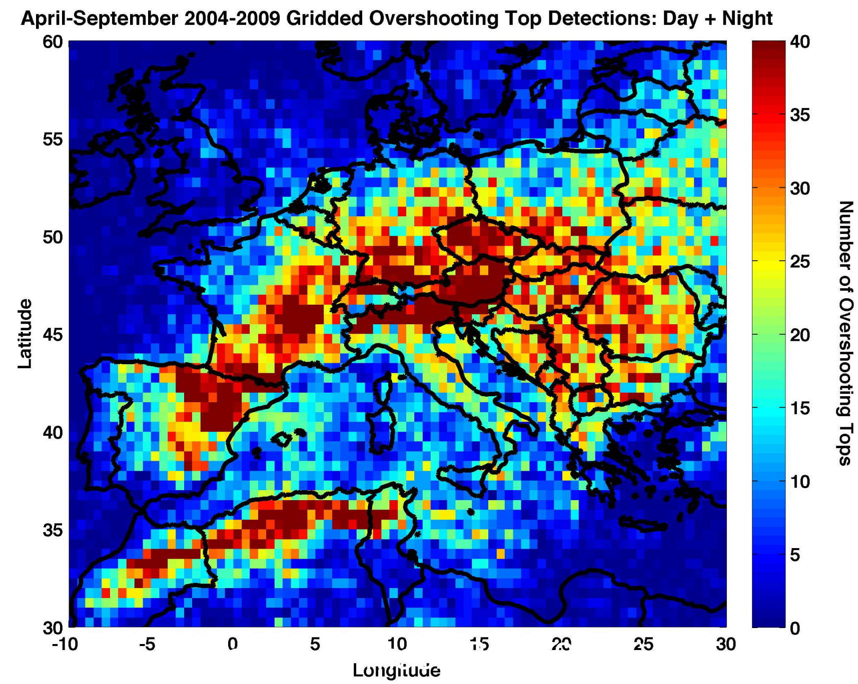
011

6-Year GOES and MSG SEVIRI OT Detections

GOES-12 (Includes Rapid Scans)



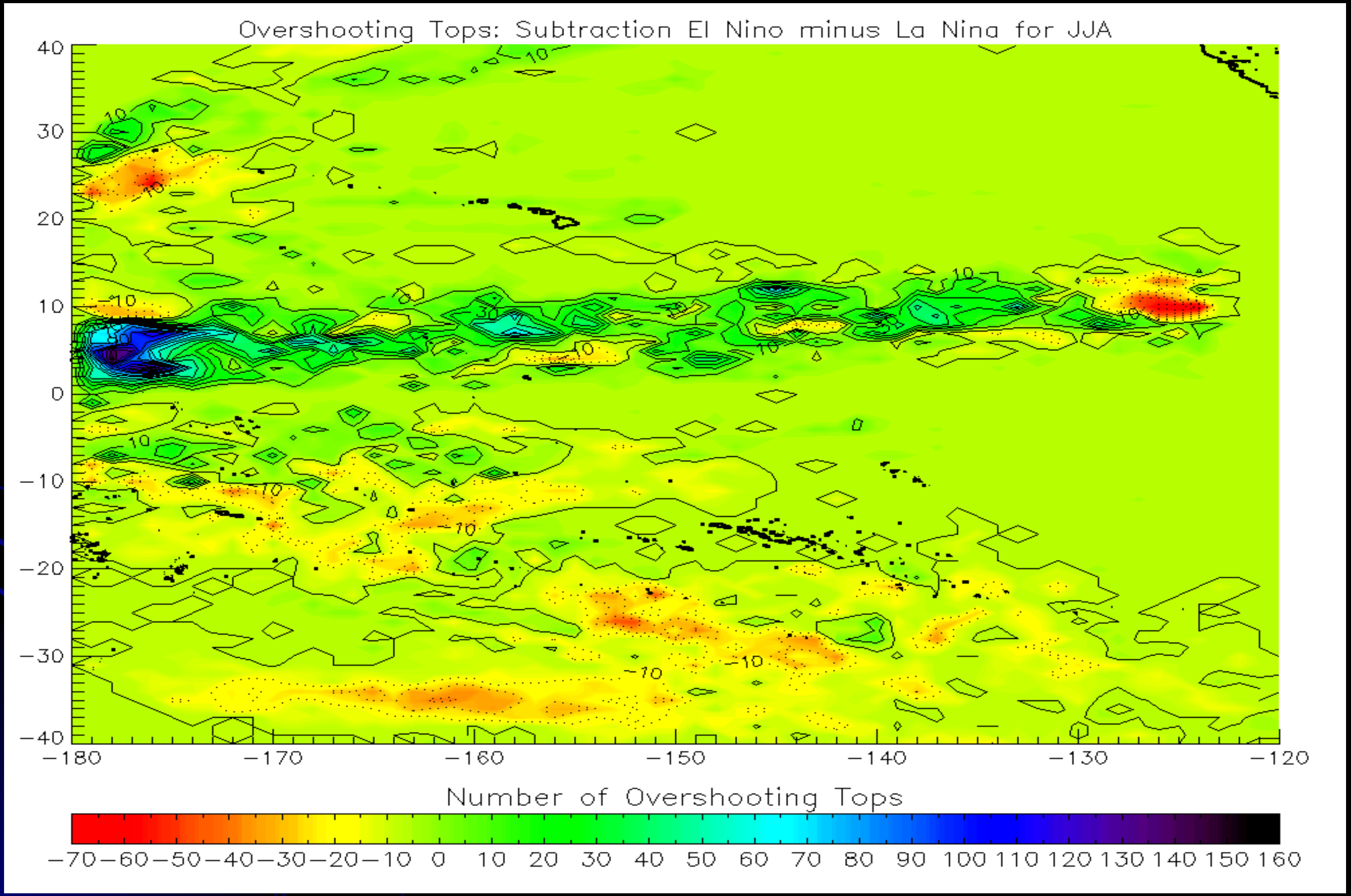
SEVIRI (15 min Scans Only)



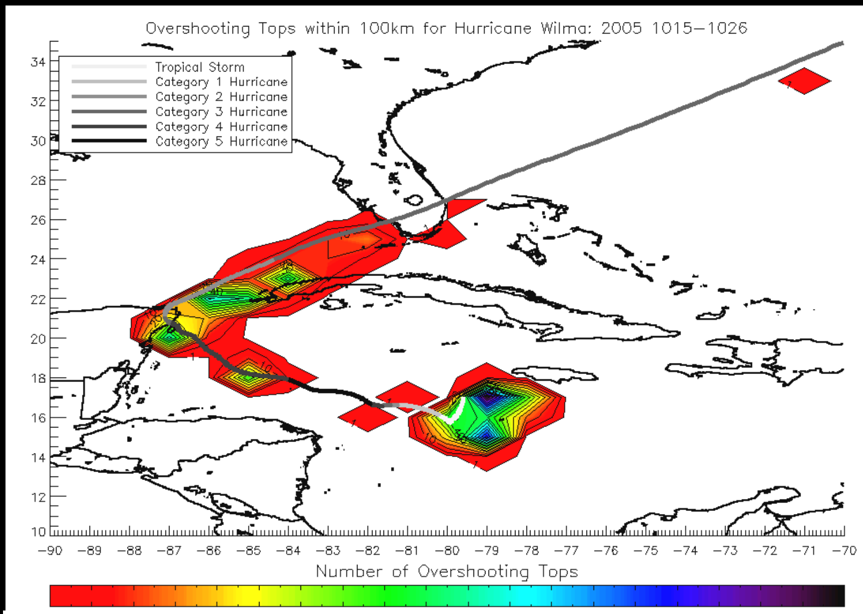
Bedka et al (*JAMC*, 2010)

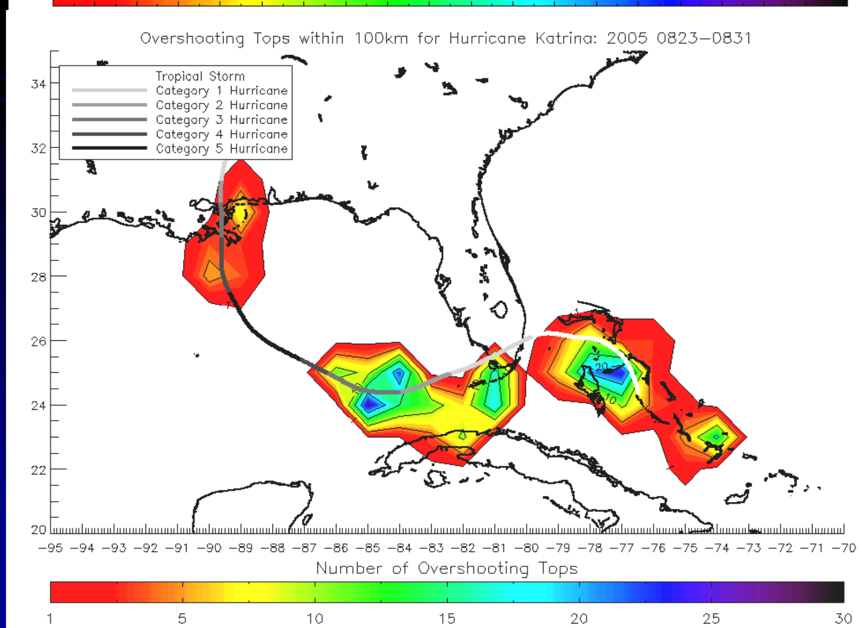
NOTE: Color Table Ranges Do Not Match

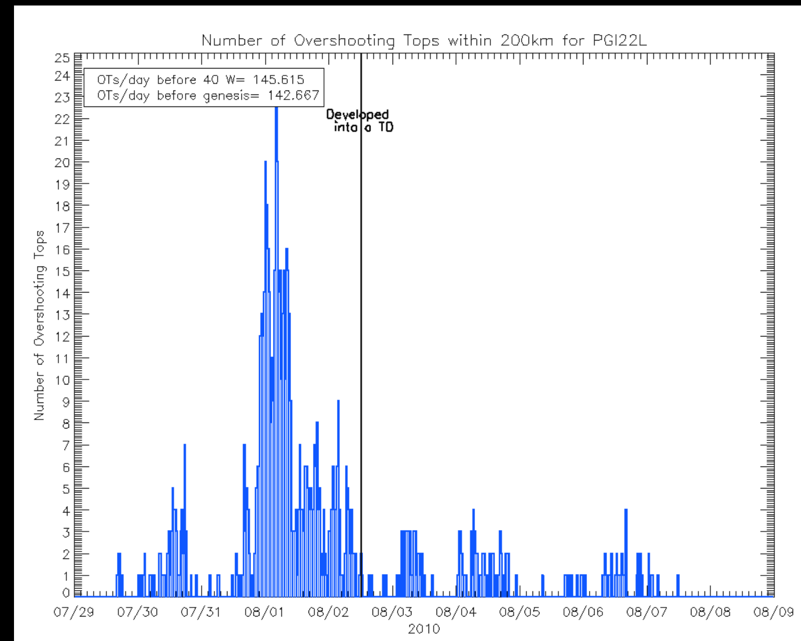
Difference in Number of OT between El Nino and La Nina



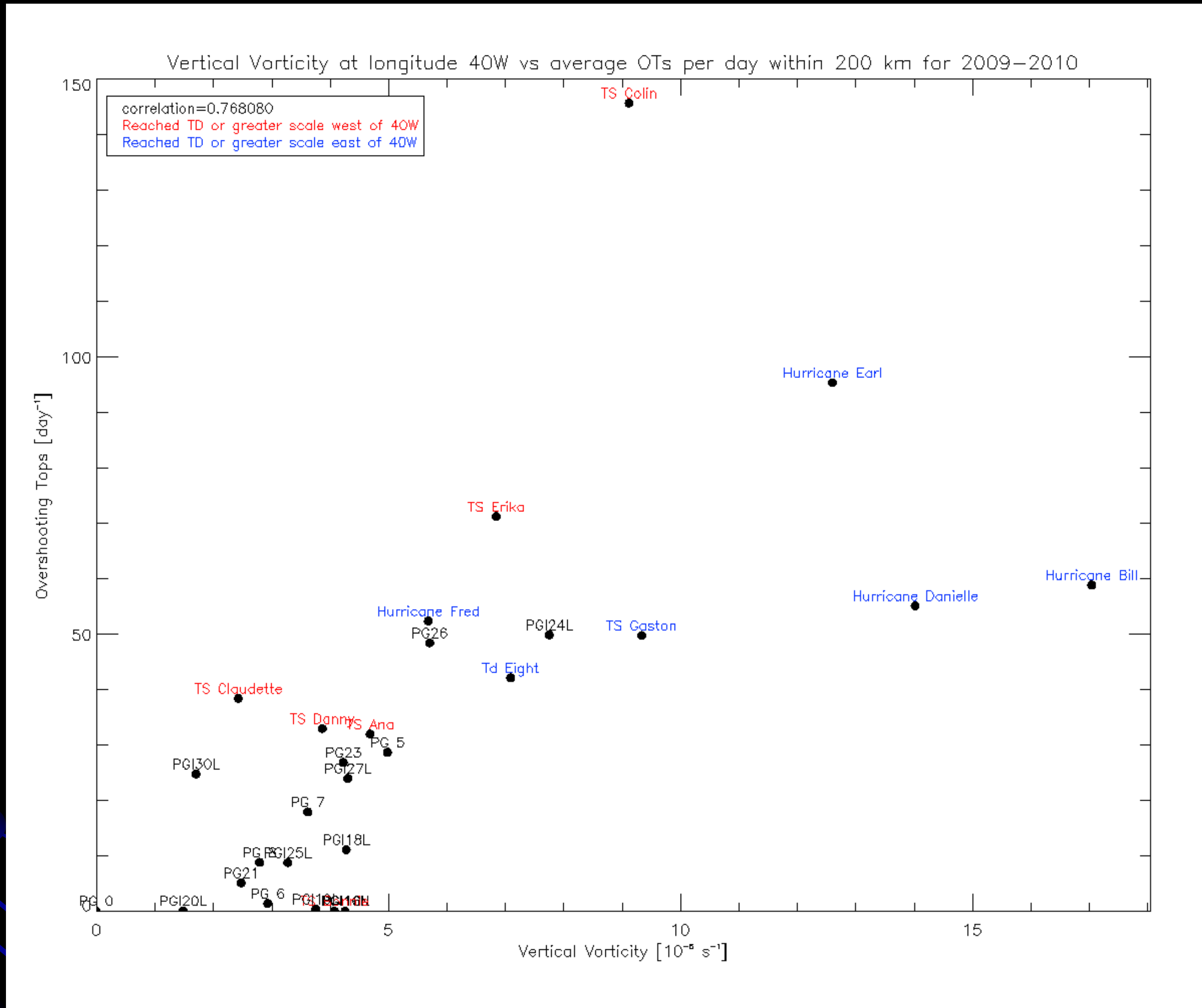
Tropical Storm Genesis





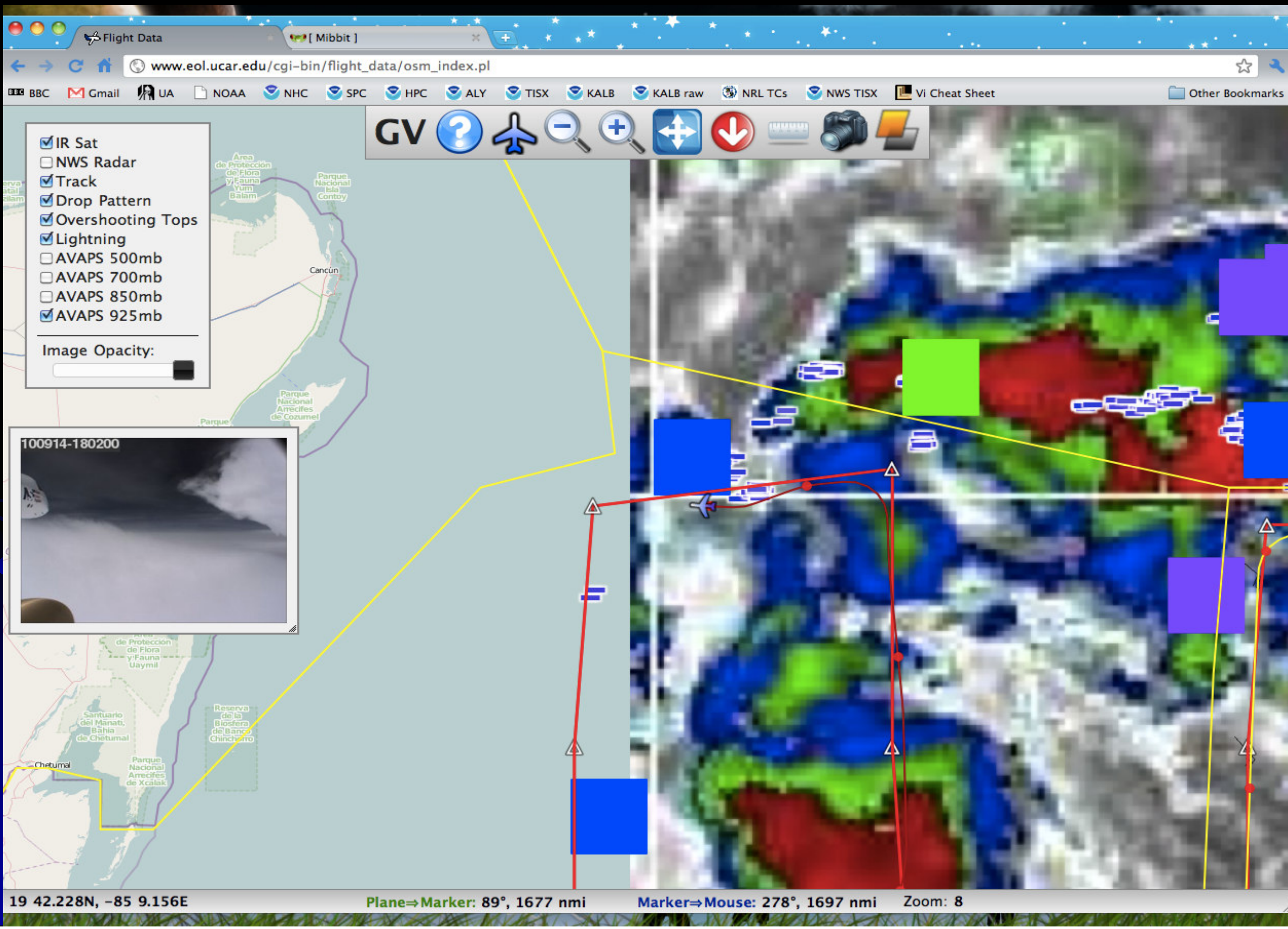


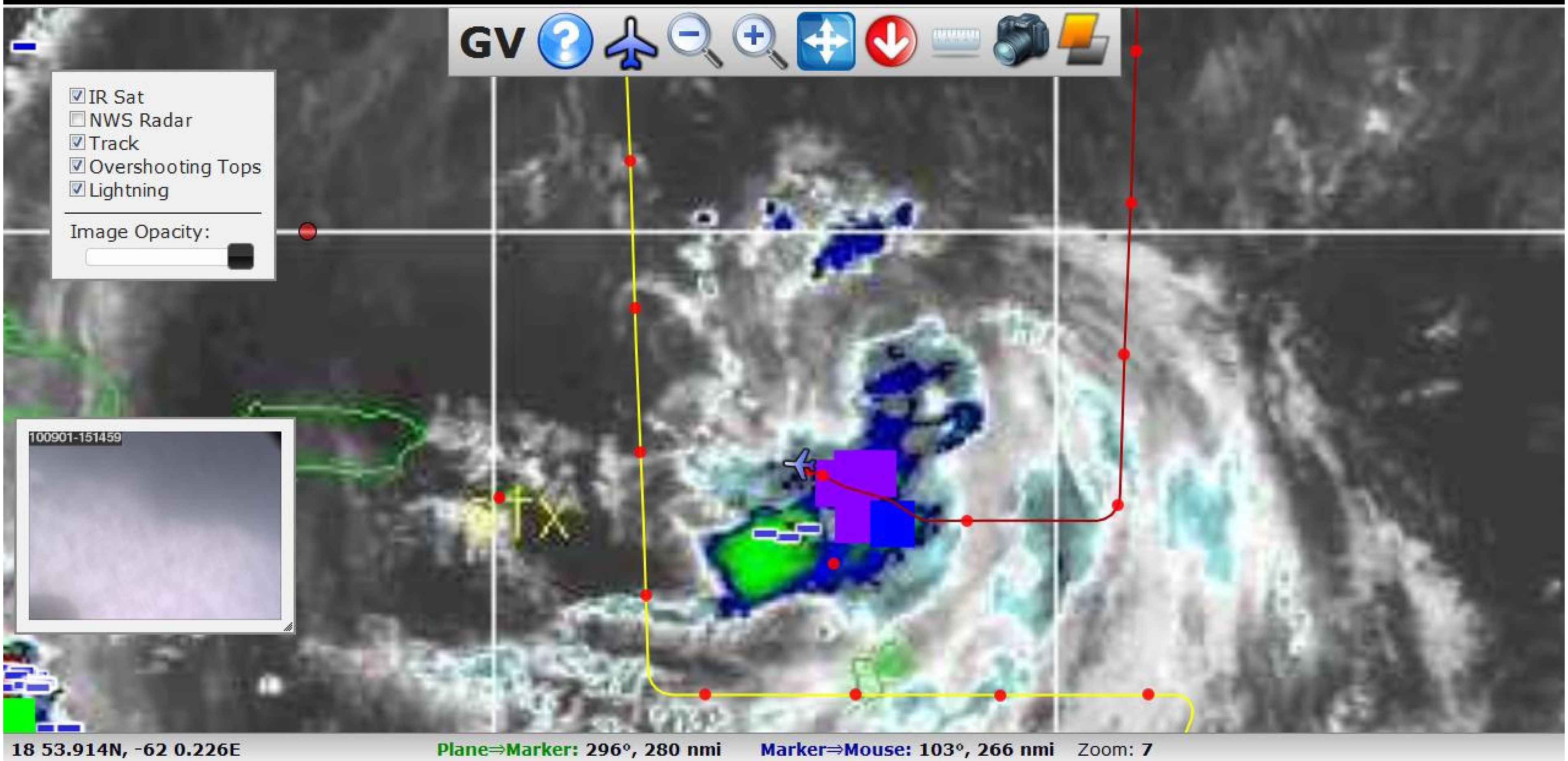
Number of overshooting tops within 200 km of pre-Tropical Storm Colin. Note the sharp increase before genesis.



Approximately 93% of pouches averaging 35 OTs per day or less before 40W experience development.

SEVIRI/GOES OT Algorithm used in PREDICT (Tropical Cyclone Experiment)





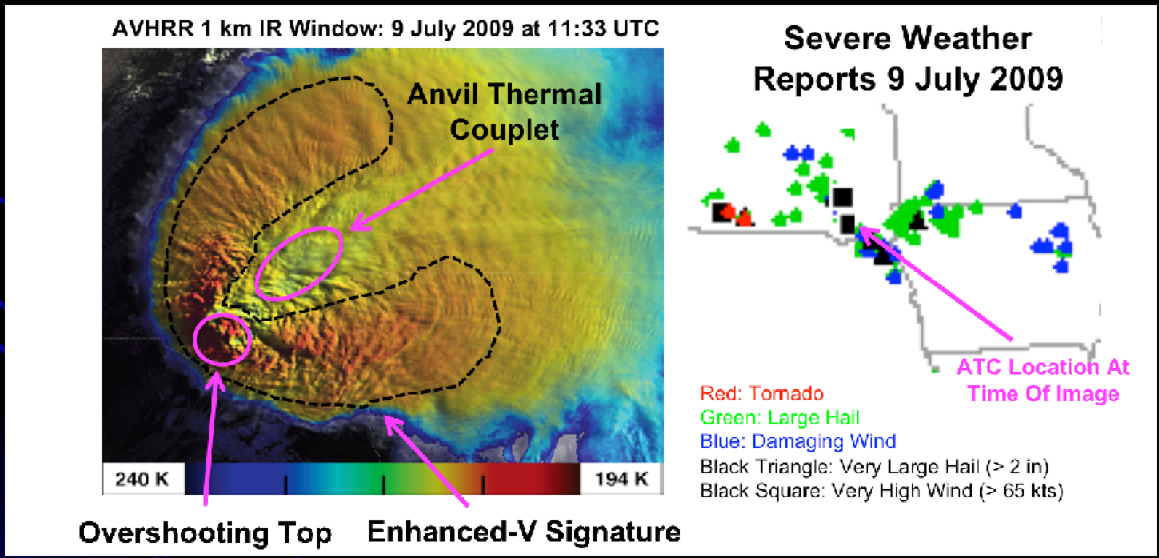
Aircraft incre


2010/9/2 17:21

What Is An Enhanced-V?
(Brunner et al, 2007)

The appearance of an enhanced-V in infrared imagery resembles a V- or boomerang-shaped area of cold IR window channel BTs bordering an area of warm BT downwind. (From *Meteorology: Understanding the Atmosphere* (Ackerman and Knox, 2001))

- **The enhanced-V is often seen in infrared satellite imagery before the onset of severe weather (damaging winds, hail, and/or tornadoes) and is an important indicator of a severe thunderstorm**
  - **McCann (MWR, 1983) found that the median lead time (time from the initial identification of the feature on satellite imagery to the first reports of severe weather on the ground) is about 30 minutes.**
  - **Brunner et al. (WAF, 2007) found that ~92% of enhanced-V storms with a specified set of temperature parameters produced severe weather during summers 2003 and 2004**



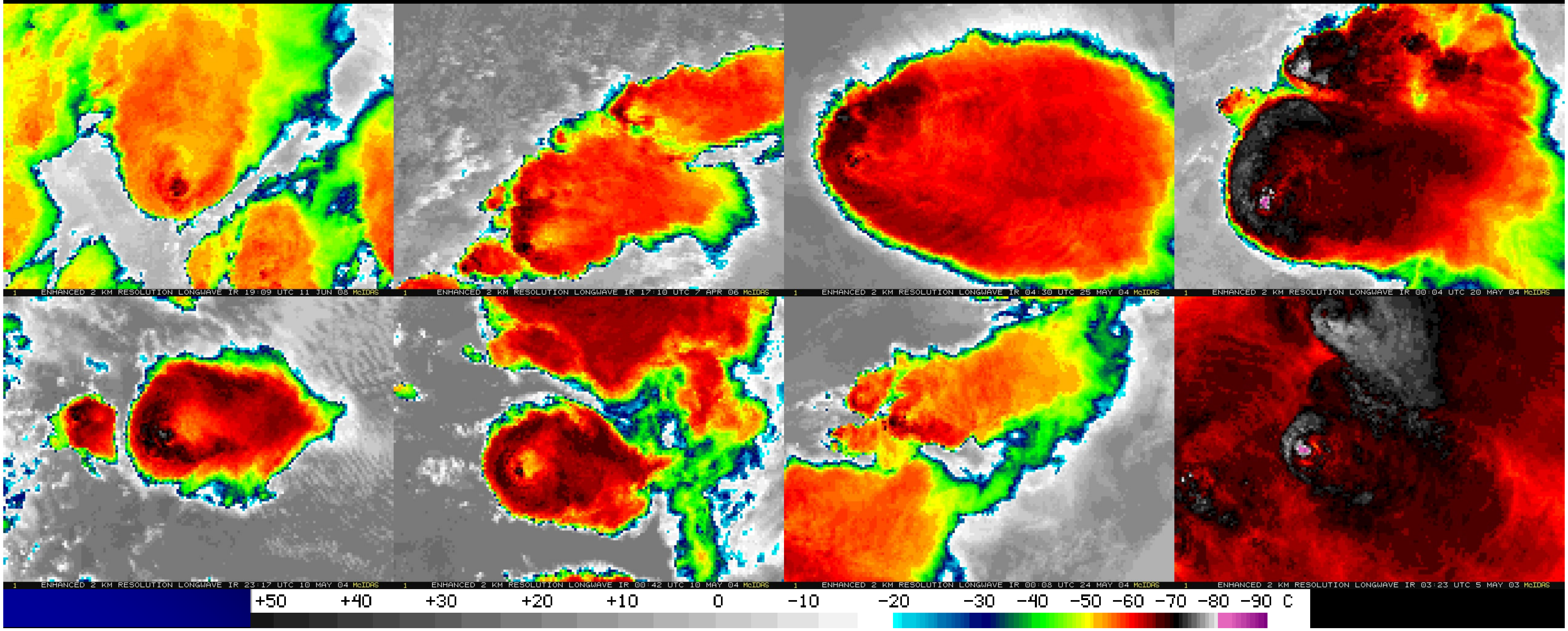
AVHRR image courtesy of Martin Setvak (CHMI)

V-Signature vs. Anvil Thermal Couplet Detection

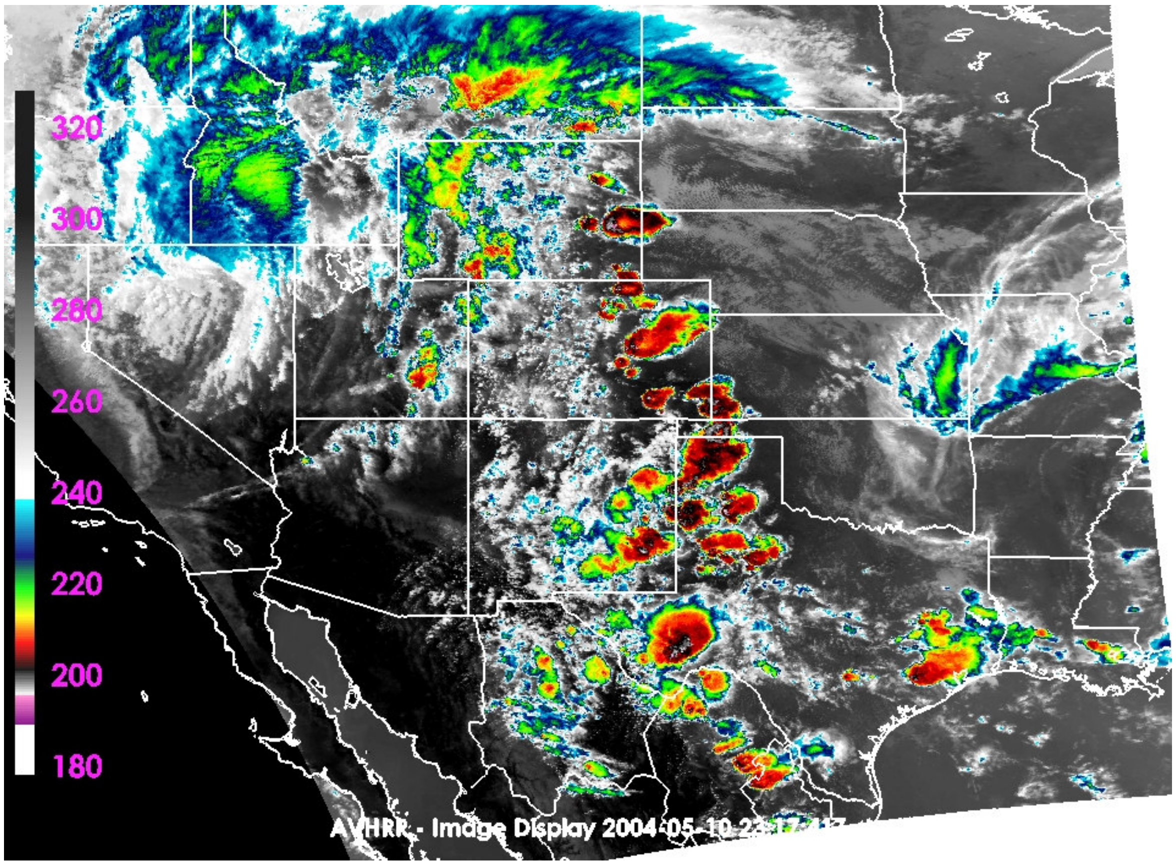
Though the enhanced-V signature can appear quite differently in many cases, the anvil thermal couplet (ATC) is (almost) always present, making accurate detection of the ATC and thus the V-signature, far more attainable

MODIS & AVHRR IR Window Degraded to 2 km ABI Resolution

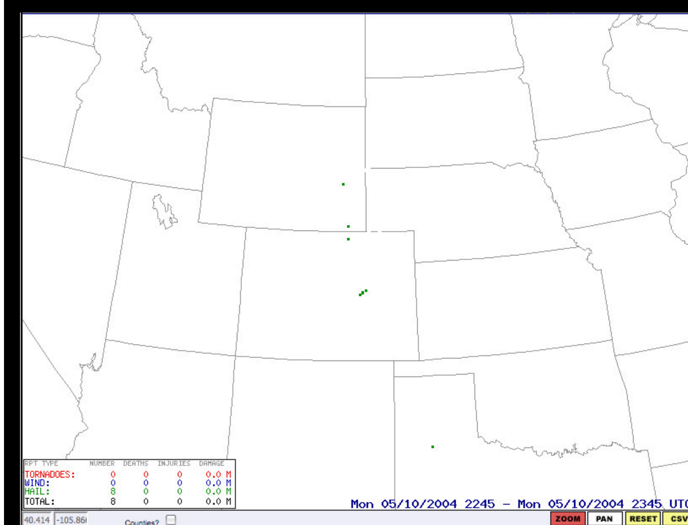
All Images Cover the Same Horizontal Distance and Use Same Color Enhancement, Illustrating Variations in the V-signature Across Events



Overshooting Top and Thermal Couplet Product Output



Severe Storm Reports +/- 30 Mins
From Image Time
Numbers Correspond To The Storms
Labeled In the Left Panels



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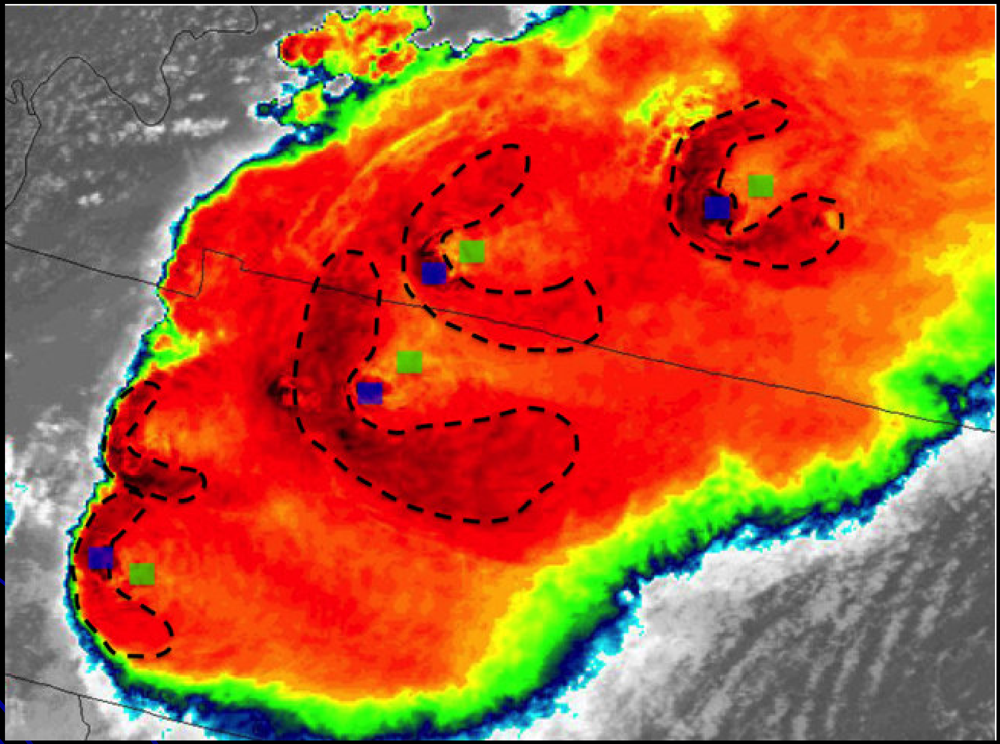
Overshooting Top and Thermal Couplet Detection Product Output

2 km Proxy ABI From 1 km MODIS 10.7 μ m Imagery 4/7/2006 at 1825 UTC



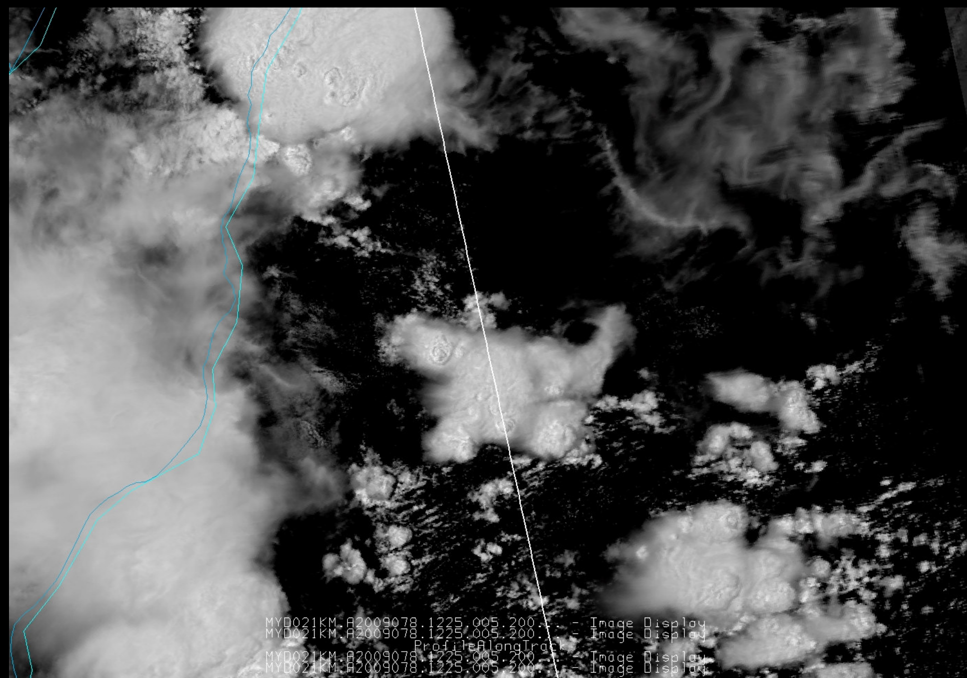
* Overshooting top location indicated by blue symbol (only OTs with thermal couplets are shown)

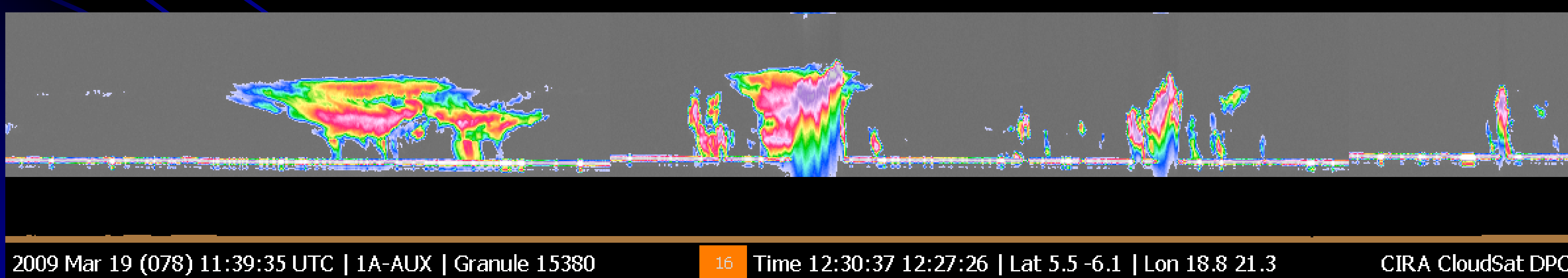
* Enhanced-V ATC detections indicated by green symbol

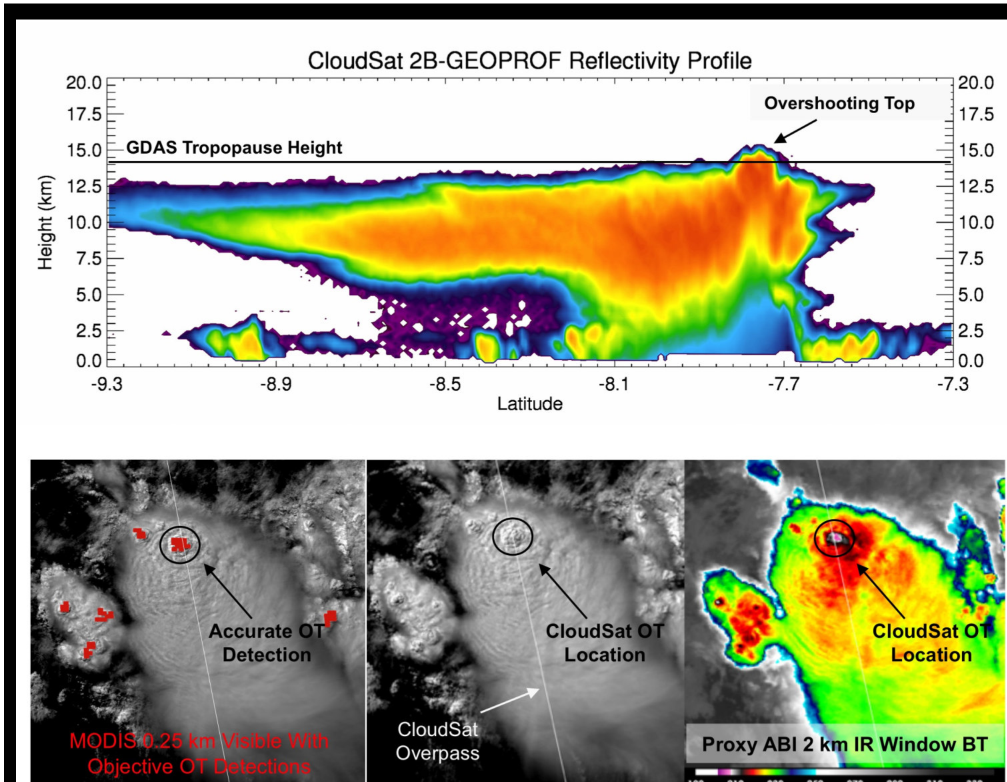
* 4 of 5 possible enhanced-V ATCs are detected accurately in this MODIS case

Validation Results

CloudSat/Calipso Validation is Crucial







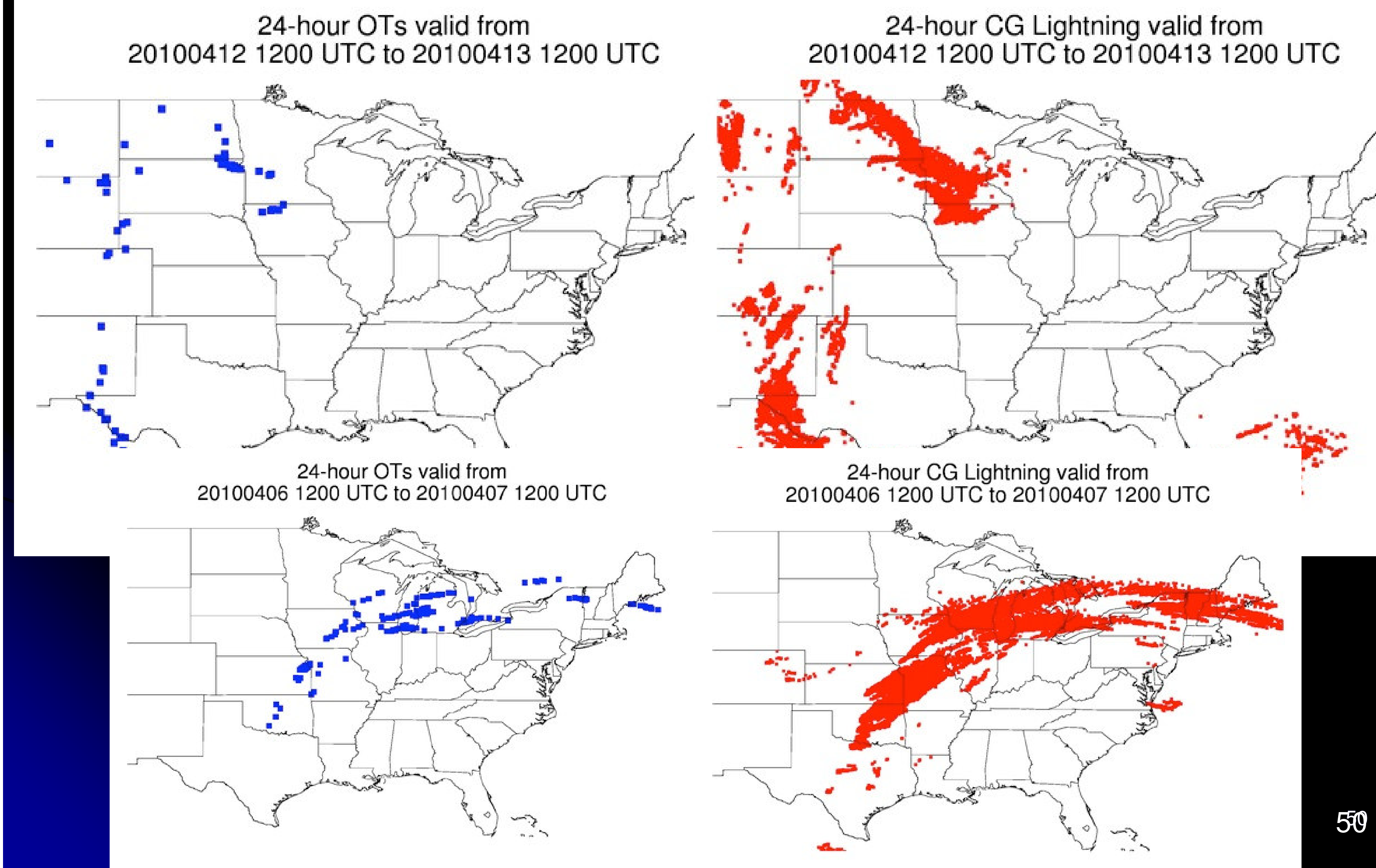
- **Overshooting tops (OTs) are the product of deep convective storm updrafts with sufficient strength to rise above the storms' equilibrium level and penetrate into the lower stratosphere**

- **OTs appear as small clusters of very cold pixels relative to the surrounding thunderstorm anvil**
  - Infrared (IR) temperature gradients (i.e. texture) are combined with NWP information to accurately detect OTs during day/night using current and future satellite sensors (Bedka et al. 2010)

- **Detection product being evaluated within the 2010 SPC Spring Experiment via the GOES-R Proving Ground and the NCAR Global Atmospheric Turbulence Decision Support System for Aviation**

OT Detection Method	OT Pixel FAR	ABI OT Detection Product Maximum Acceptable FAR Requirement	OT Top Region POD	Number of OT Detection Pixels Along CloudSat Track
IR-Texture (Applied to Synthetic ABI)	16.1%	25%	74.6%	940 *(114 Global OT Events)*
IR-Texture (Applied to Current GOES and SEVIRI)	18.3%	N/A	57.6%	252 *(59 OT Events)*
WV-IR BT Diff > 0 K (Currently Operational At Aviation Weather Center)	81.2%	25%	99.1%	15079 *(114 Global OT Events)*

Overshooting-top Validation



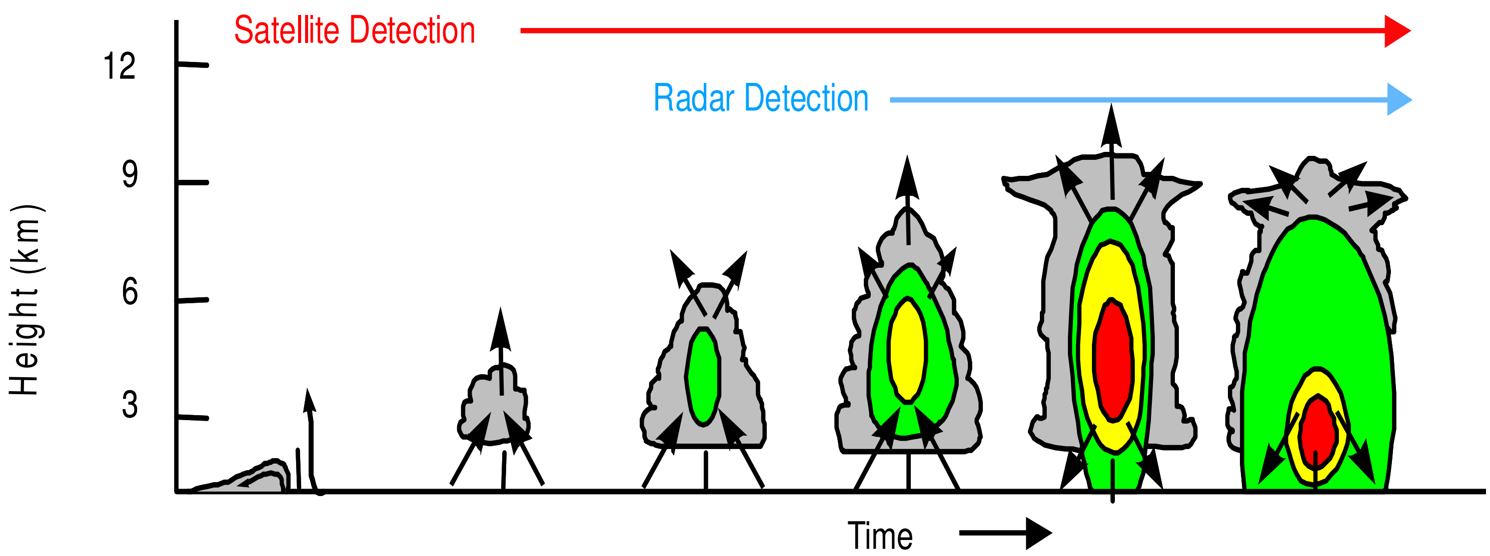
Anvil Thermal Couplet Detection Performance Relative to Brunner et al. V-Signature Database

Probability Of Detection	False Alarm Ratio	Accuracy Requirement
62% (126 accurately detected / 203 V-signature events)	24% (40 false detected / (40 false detected + 126 accurately detected))	25%

- 76% of all detected enhanced V anvil thermal couplets were associated with severe weather.
- 66% of non-detected enhanced V anvil thermal couplets were associated with severe weather, indicating that the ABI algorithm focuses on high impact events
- Spatial resolution has significant impact on thermal couplet detection. Current GOES POD: 12.8%, current GOES FAR: 5.9%

Convective Initiation

What does satellite data add to convective detection?



Source of Confusion: More than one CI algorithm exists!

- CI from CIMSS (UWCI)
  - 24-hour coverage
  - Uses cloud-typing algorithm to detect phase changes
  - Uses multispectral GOES IR data
  - Not computational intensive
  - Being extended via object tracking

- CI from UAH (SatCast)
  - Daytime Only
  - Uses pixel-based mesoscale Atmospheric Motion Vectors
  - Uses multispectral GOES IR data
  - Computationally intense (esp. to compute vectors)
  - Being extended via object tracking

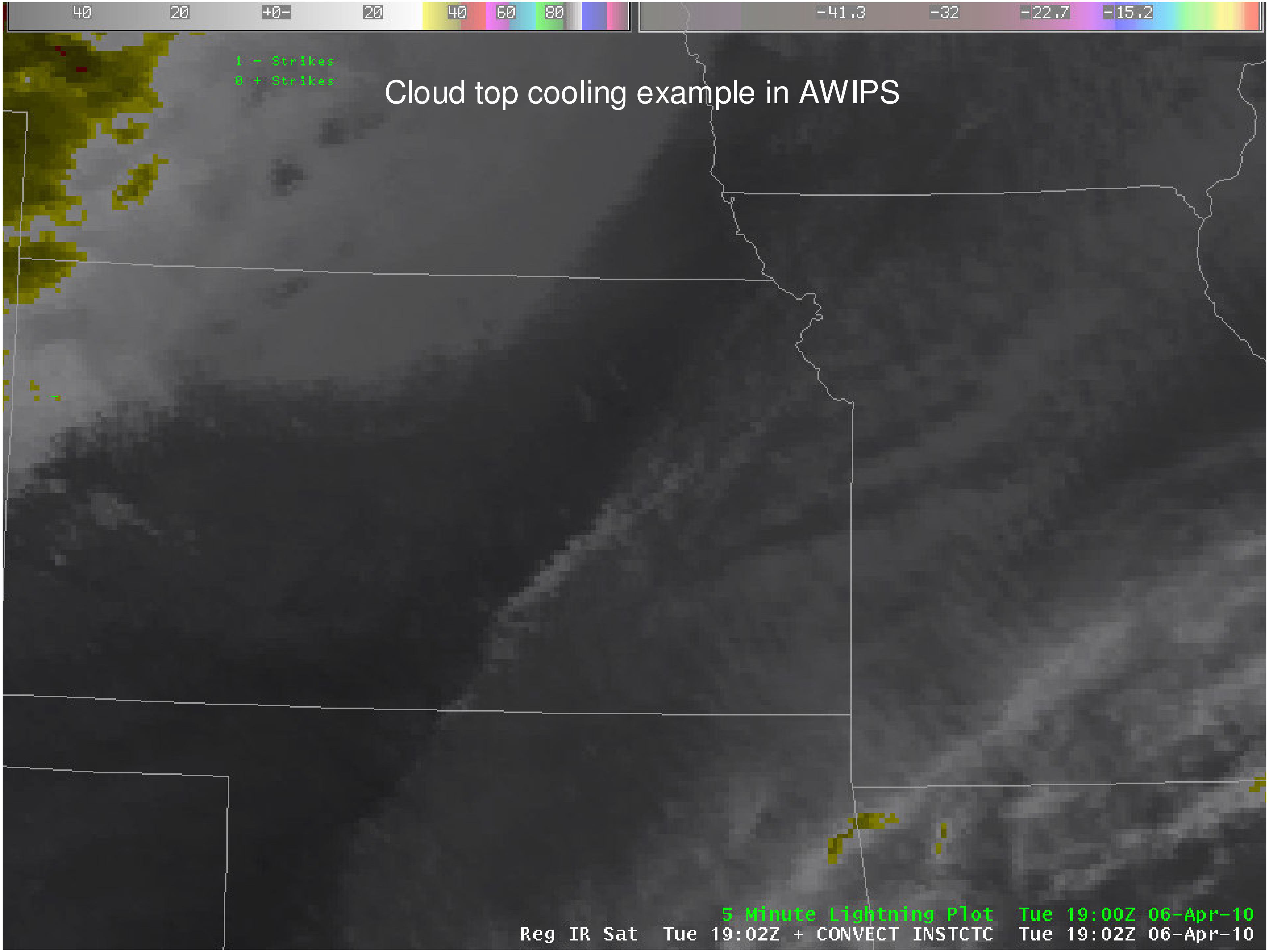
UWCI Objectives

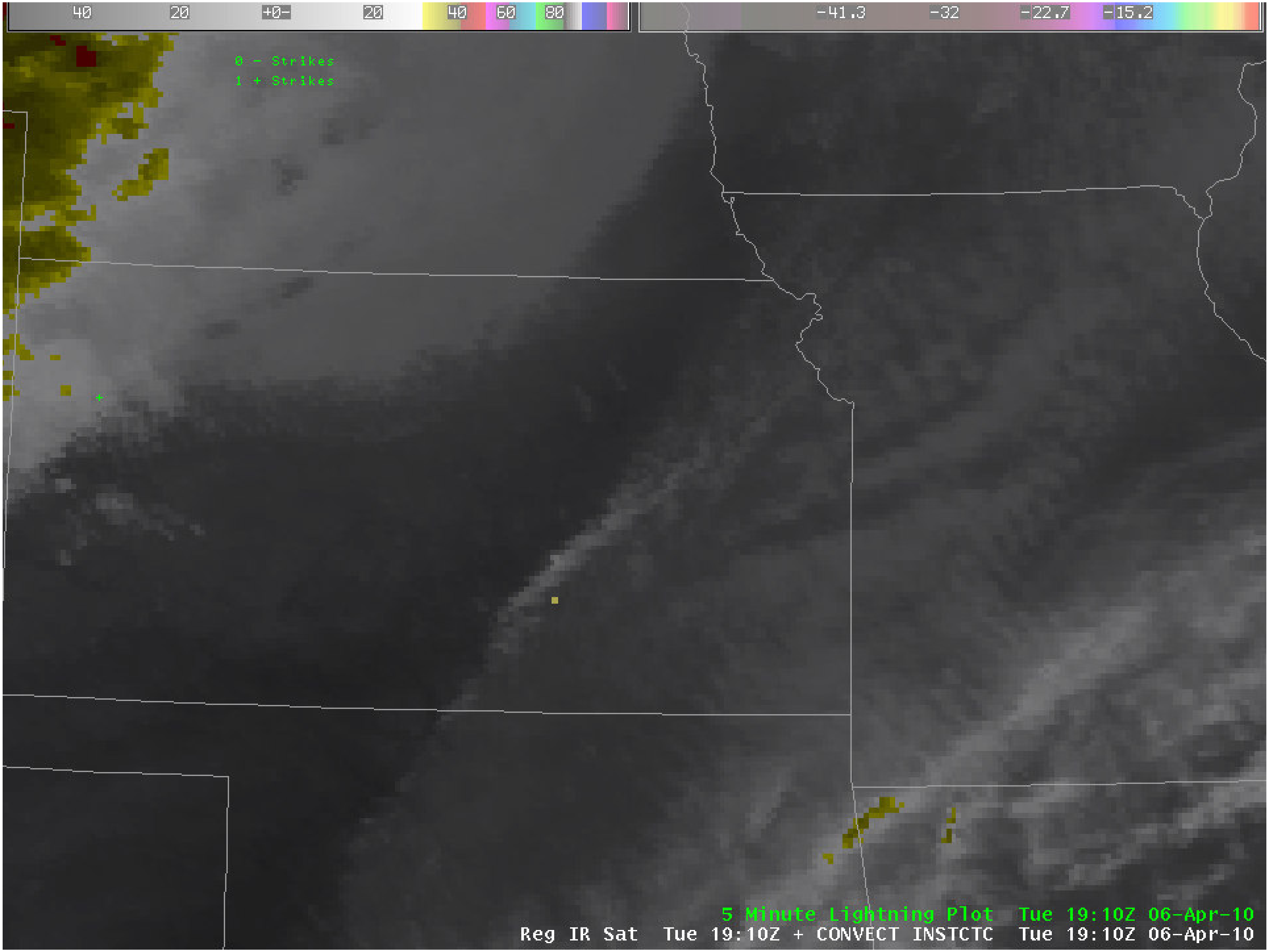
- Provide a CI nowcast signal during day and night
- Minimize false alarm at the expense of some probability of detection
- Use alternative method for time trend computation (non-AMV) to minimize pixelation
- Provide coherent radar-like satellite-based CI signal as direct AWIPS/N-AWIPS satellite convective initiation decision support aid in field

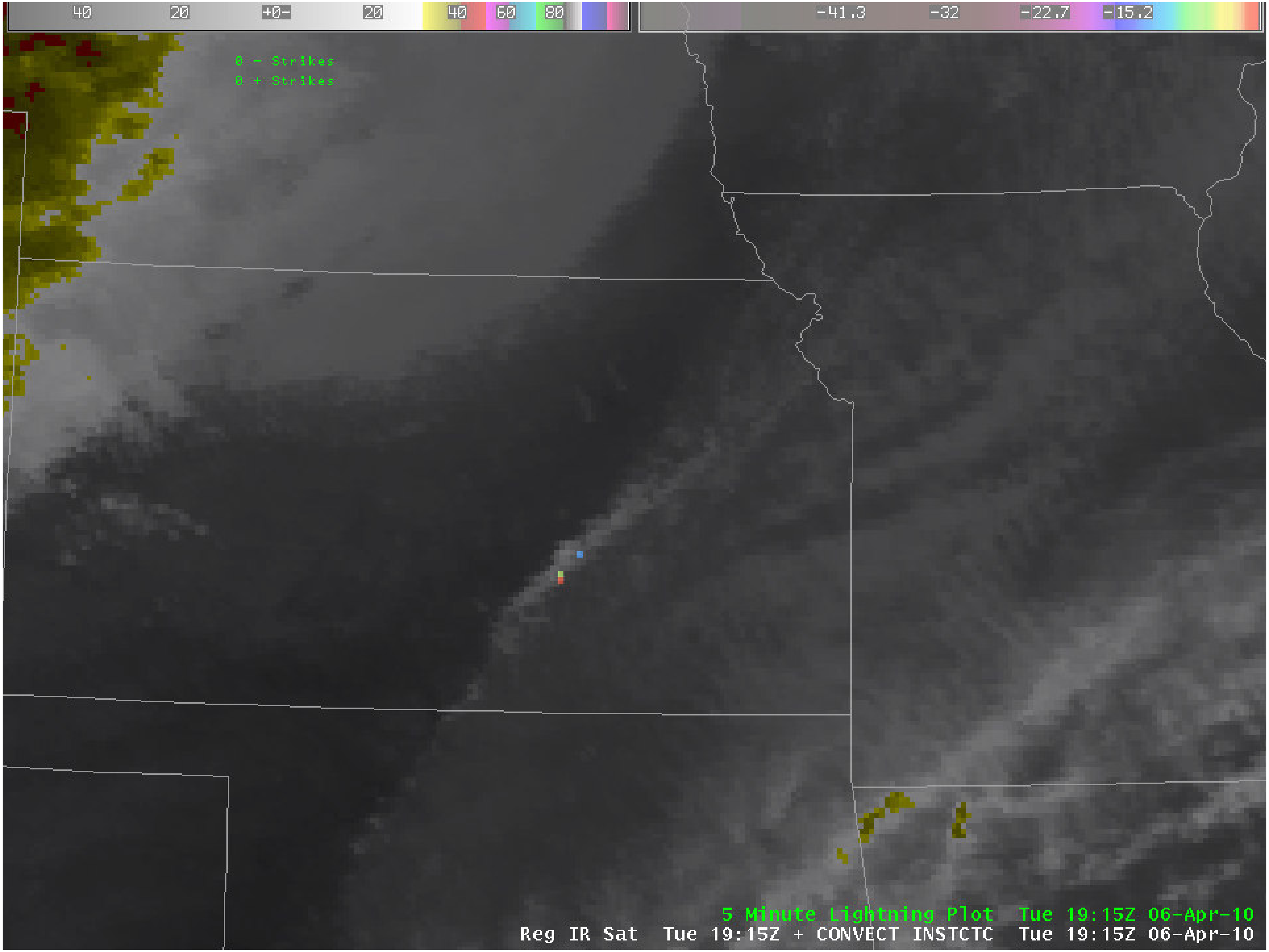
Thunderstorm Initiation Algorithm Description

- Cloud top cooling by monitoring infrared temperature measurements from image to image
- Monitoring cloud top water phase transitions (warm water -> mixed phase/supercooled water vapor -> icing/glaciation) from scene to scene
- Day/Night UW Cloud typing product
- Goal: Pre-radar nowcast of imminent convection (lead time up to 45 minutes)

Cloud top cooling example in AWIPS




40 20 +0- 20 40 60 80
-41.3 -32 -22.7 -15.2
0 – Strikes
1 + Strikes
5 Minute Lightning Plot Tue 19:10Z 06-Apr-10
Reg IR Sat Tue 19:10Z + CONVECT INSTCTC Tue 19:10Z 06-Apr-10


40
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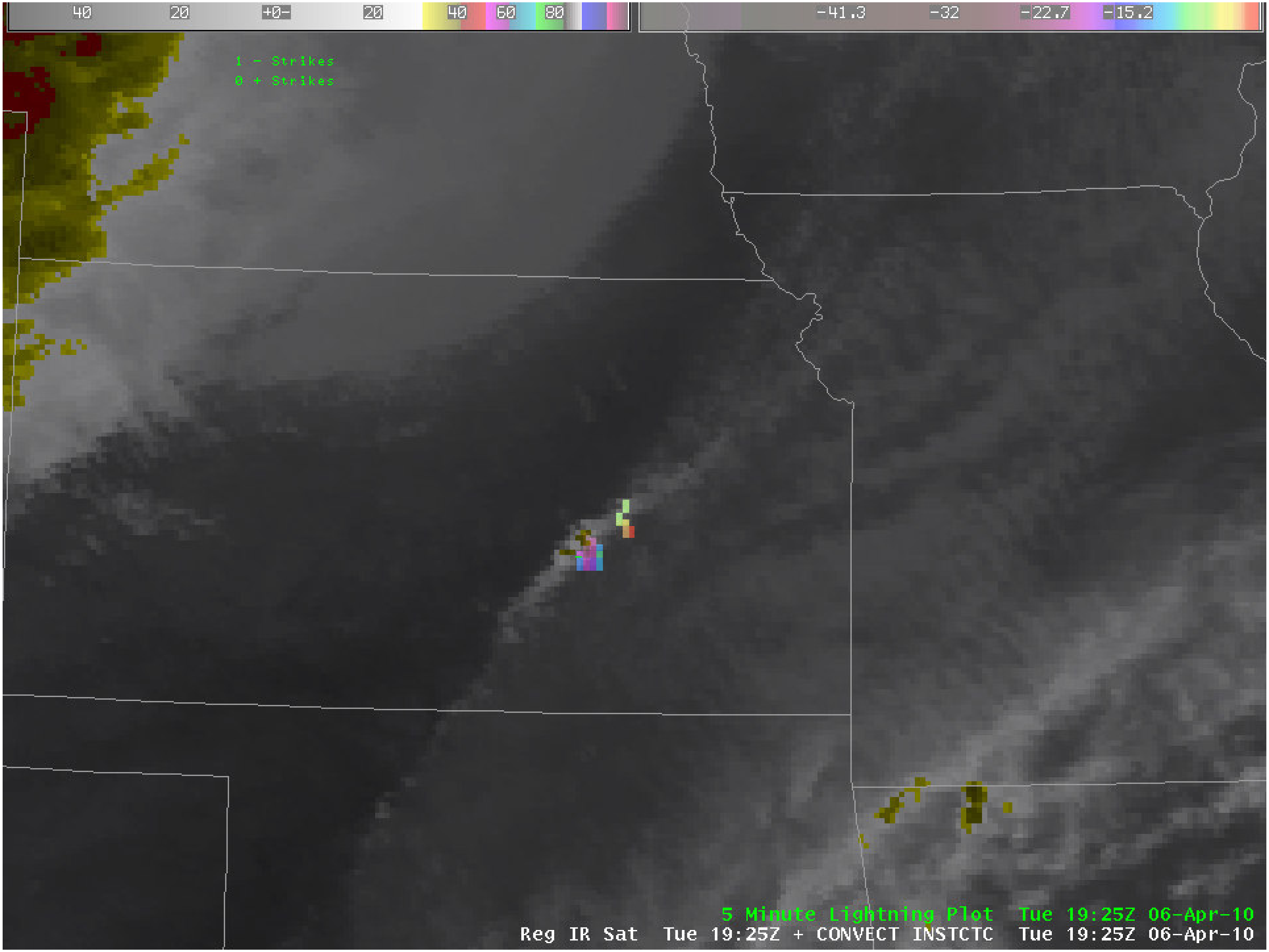
-41.3
-32
-22.7
-15.2
0 - Strikes
0 + Strikes
5 Minute Lightning Plot Tue 19:15Z 06-Apr-10
Reg IR Sat Tue 19:15Z + CONVECT INSTCTC Tue 19:15Z 06-Apr-10



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-41.3 -32 -22.7 -15.2
1 - Strikes
0 + Strikes
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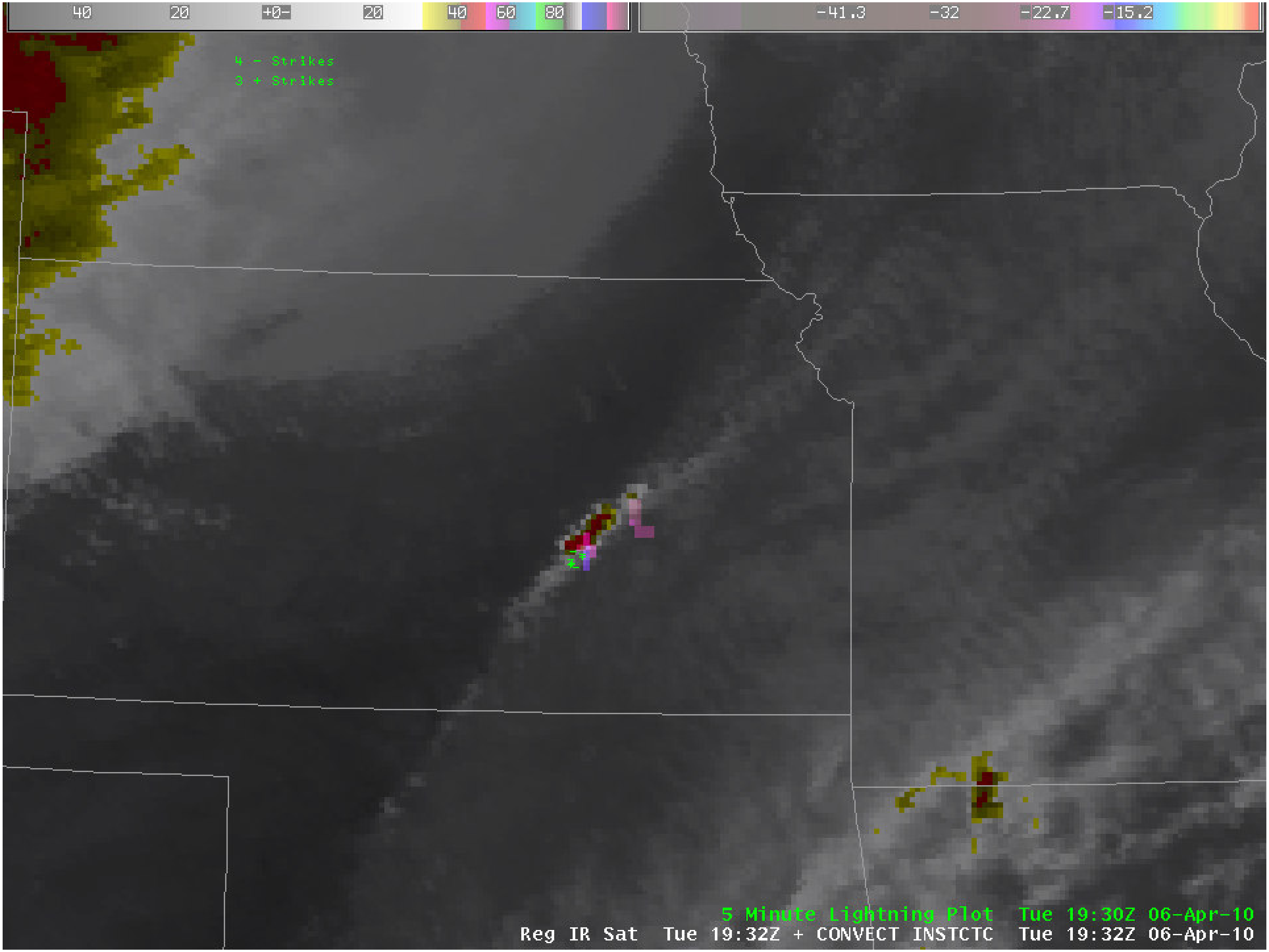
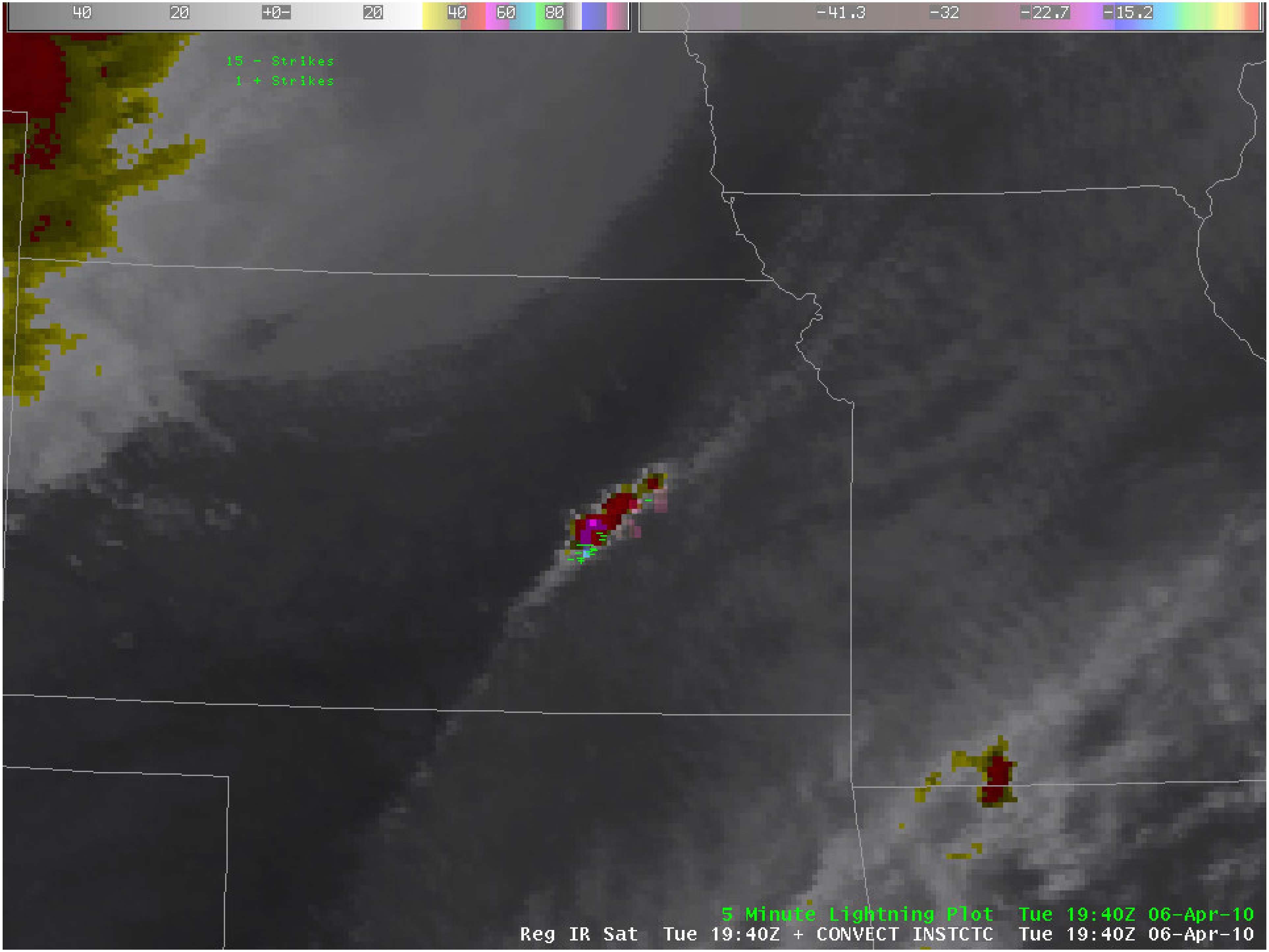
Reg IR Sat Tue 19:25Z + CONVECT INSTCTC Tue 19:25Z 06-Apr-10



40 20 +0- 20 40 60 80
-41.3 -32 -22.7 -15.2
4 - Strikes
3 + Strikes
5 Minute Lightning Plot Tue 19:30Z 06-Apr-10
Reg IR Sat Tue 19:32Z + CONVECT INSTCTC Tue 19:32Z 06-Apr-10


40 20 +0- 20 40 60 80
-41.3 -32 -22.7 -15.2
15 - Strikes
1 + Strikes
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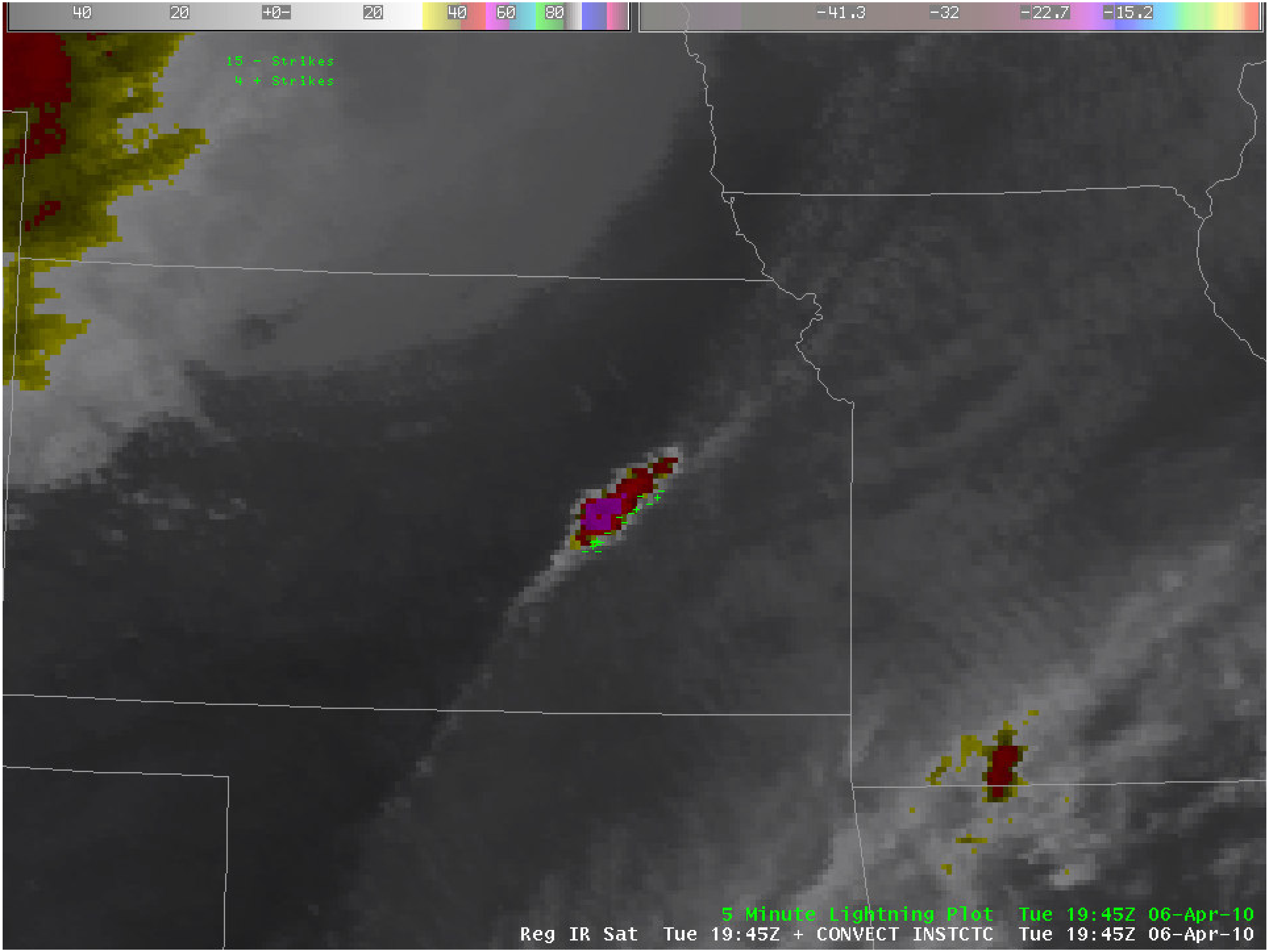
Reg IR Sat Tue 19:40Z + CONVECT INSTCTC Tue 19:40Z 06-Apr-10



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15 - Strikes
4 + Strikes
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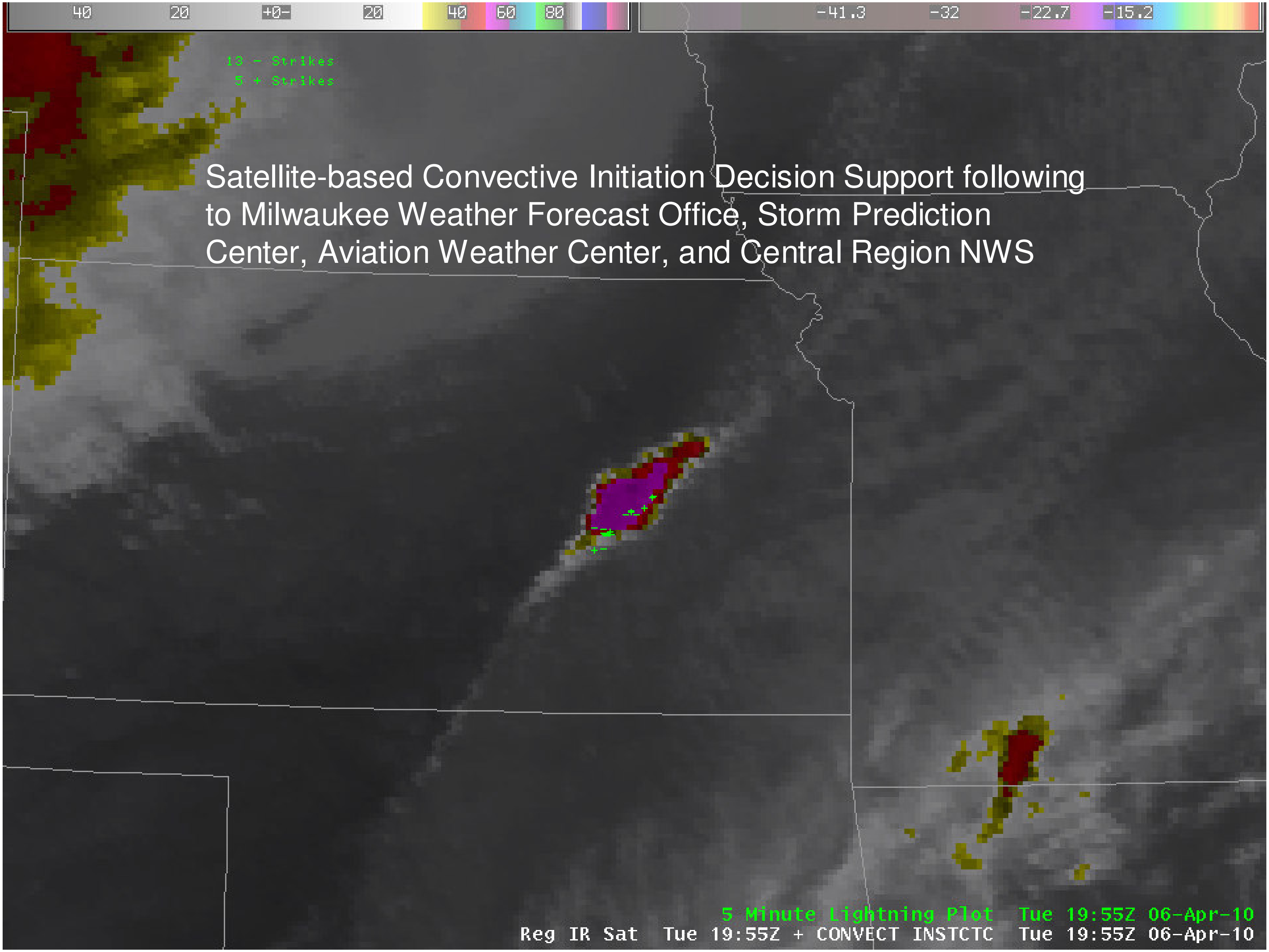
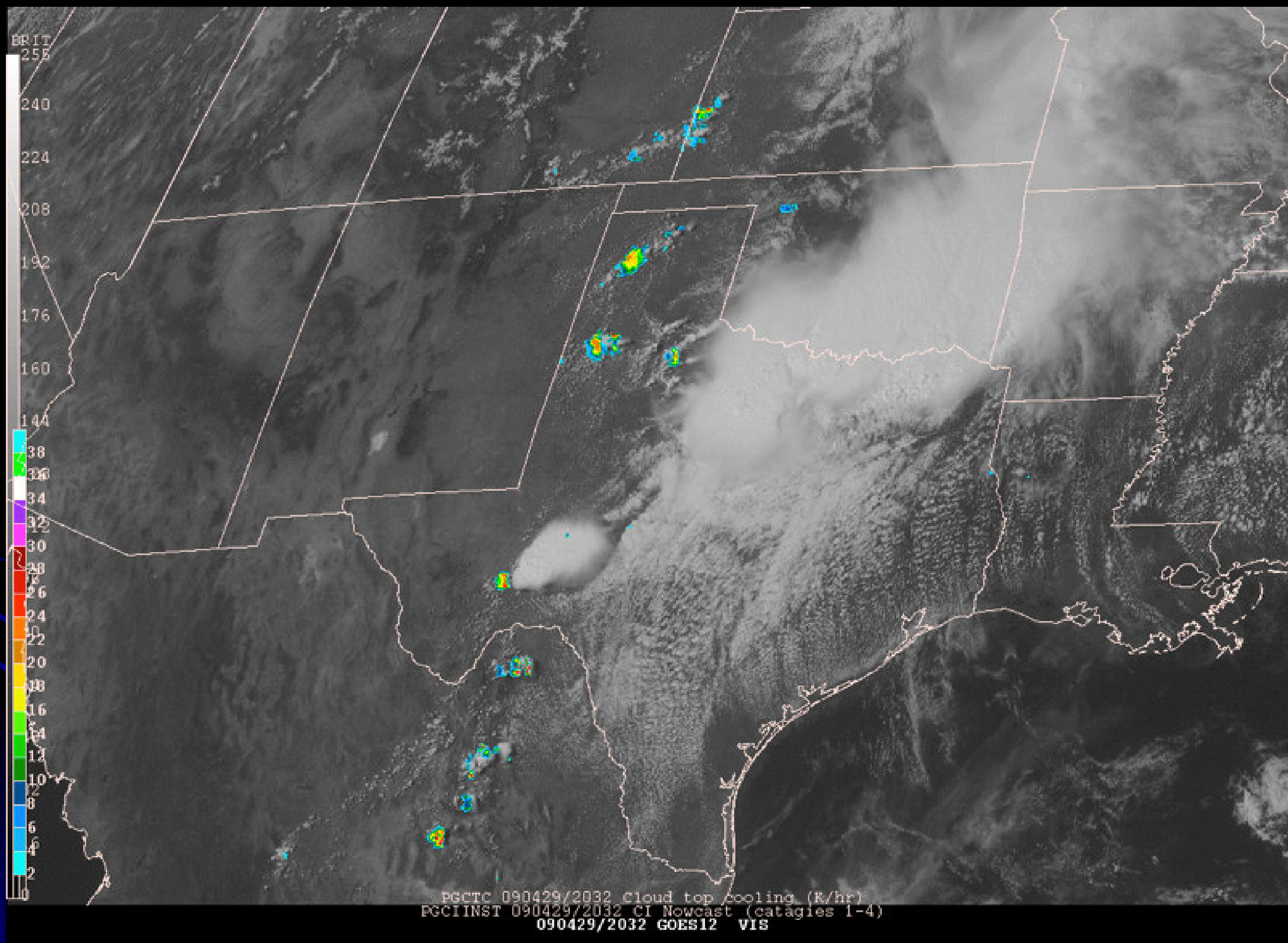
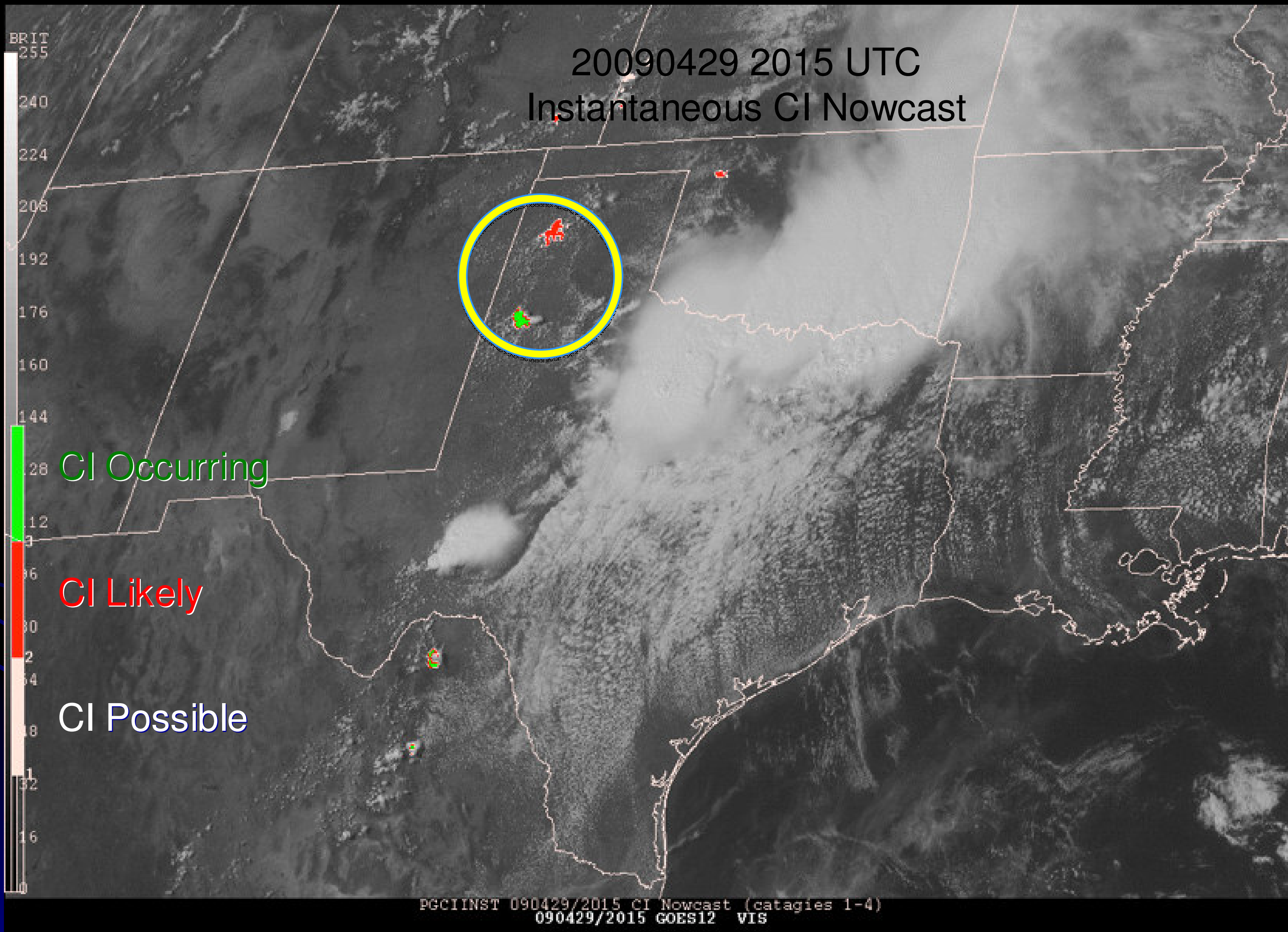

40 20 +0- 20 40 60 80
-41.3 -32 -22.7 -15.2
13 - Strikes
5 + Strikes
Satellite-based Convective Initiation Decision Support following to Milwaukee Weather Forecast Office, Storm Prediction Center, Aviation Weather Center, and Central Region NWS
5 Minute Lightning Plot Tue 19:55Z 06-Apr-10
Reg IR Sat Tue 19:55Z + CONVECT INSTCTC Tue 19:55Z 06-Apr-10

20090429 Dryline CI Case

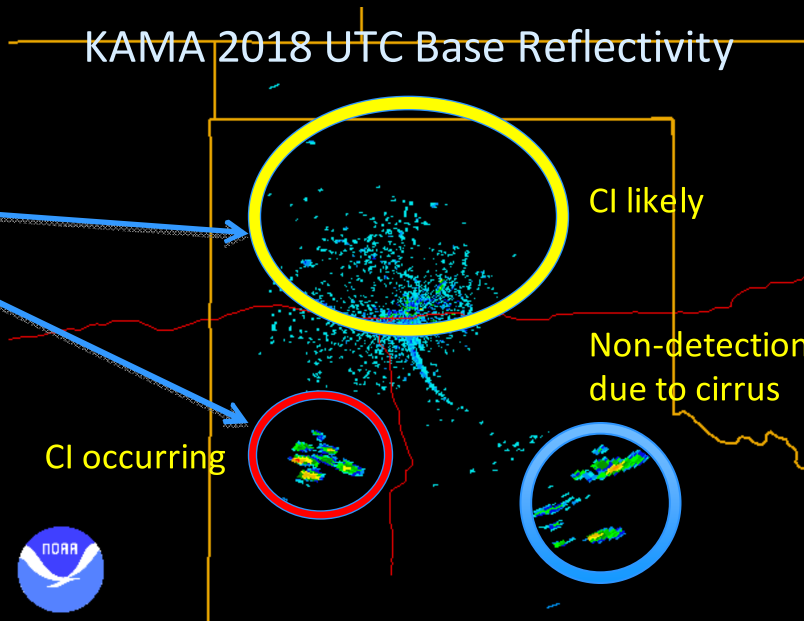


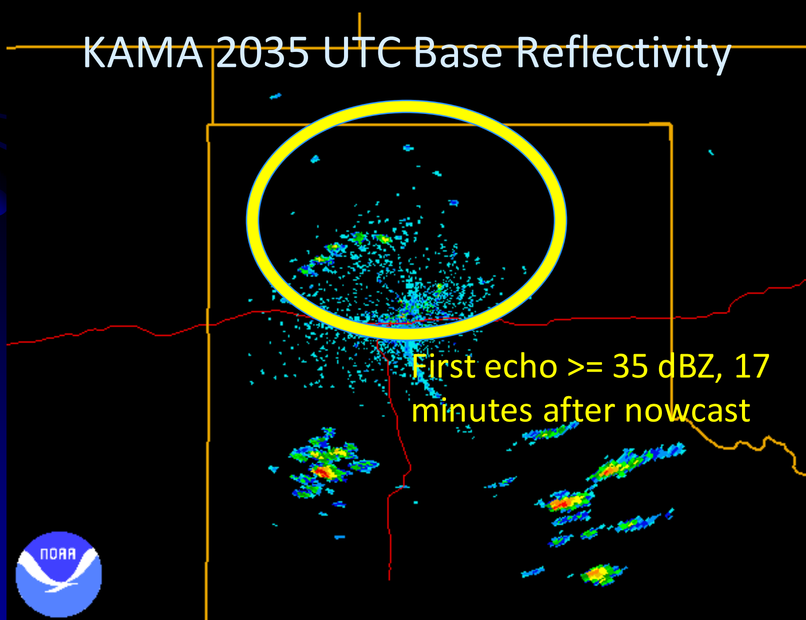


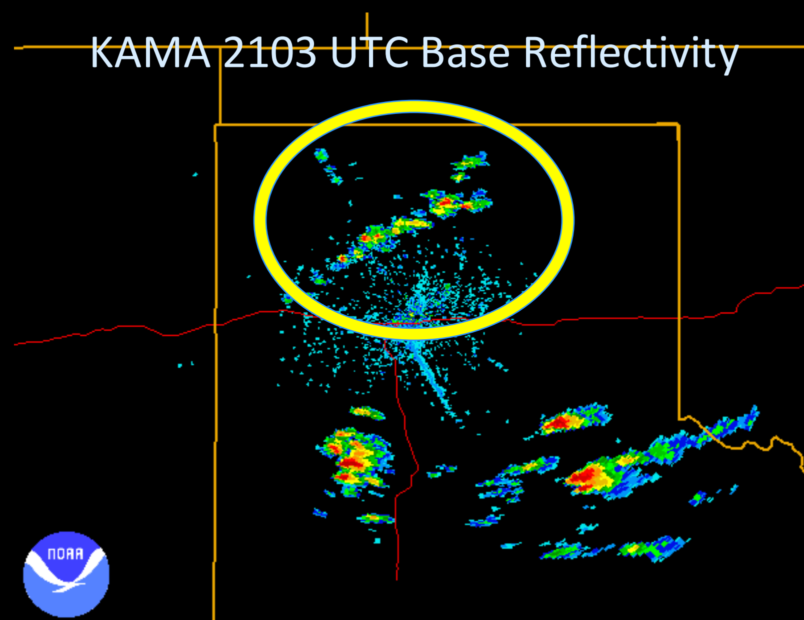
20090429 2015 UTC
Instantaneous CI Nowcast
CI Occurring
CI Likely
CI Possible
BRIT
255
240
224
208
192
176
160
144
PGCIINST 090429/2015 CI Nowcast (catagies 1-4)
090429/2015 GOES12 VIS

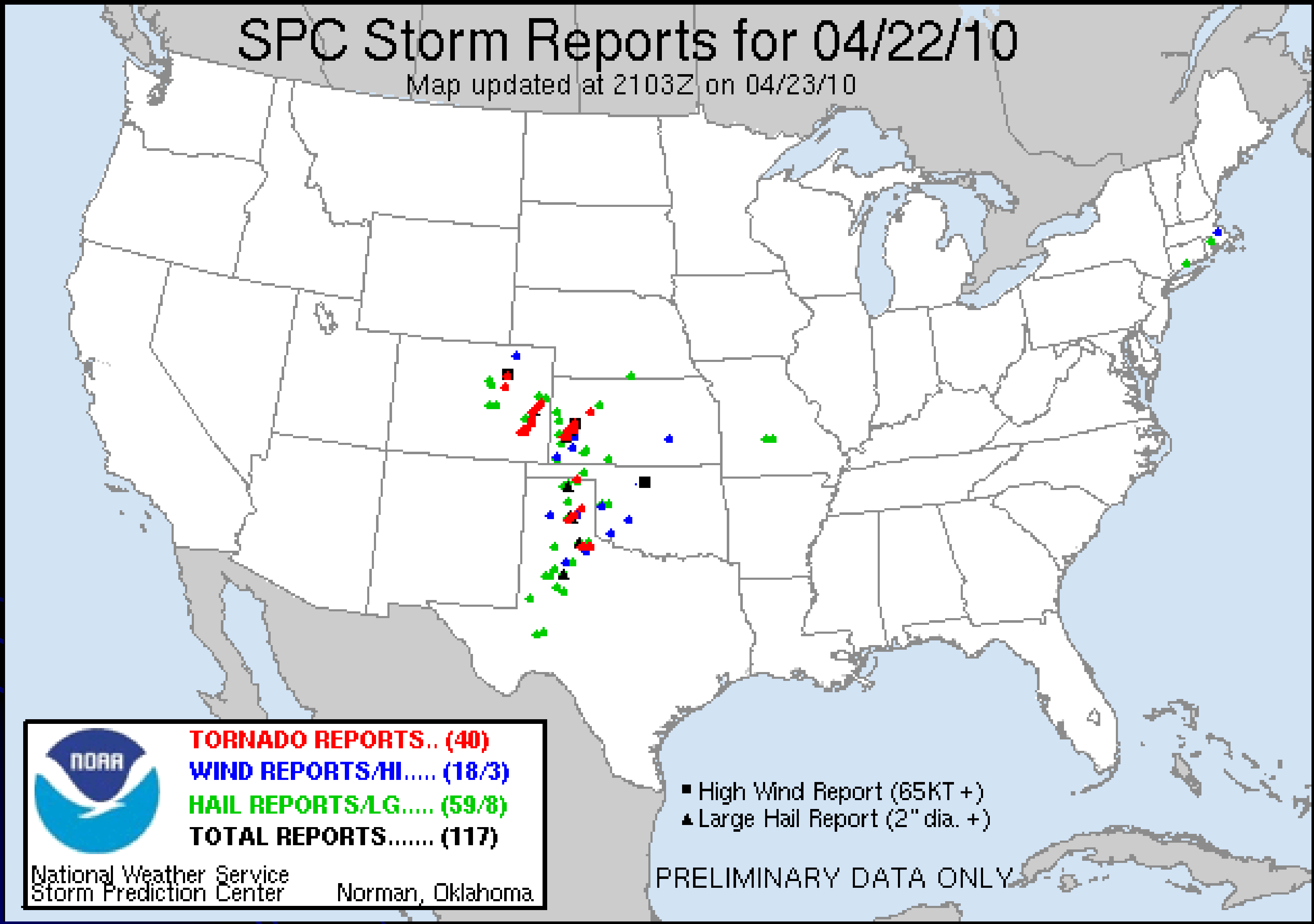
CI nowcast at 2015 UTC

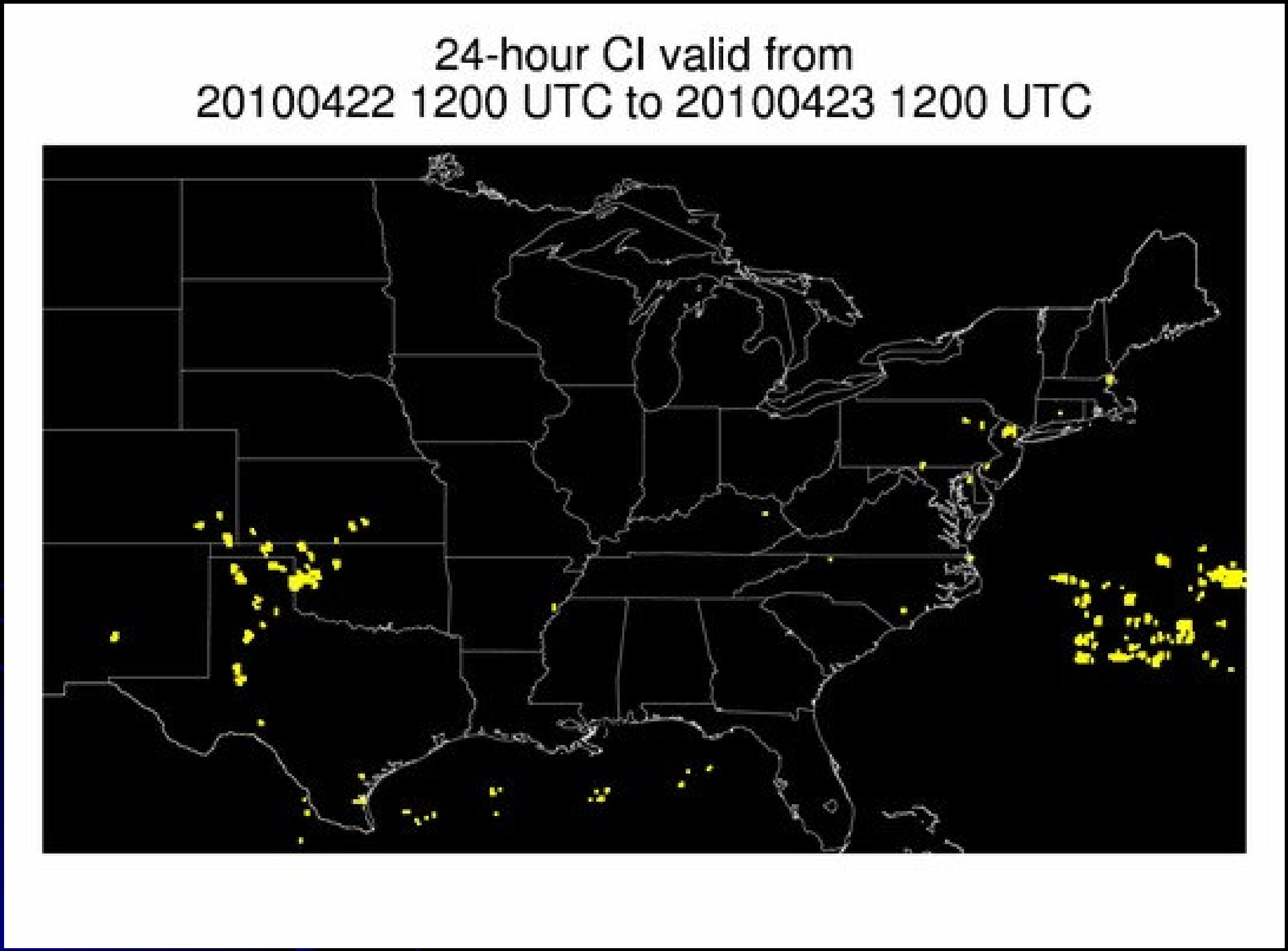
29 April 2009








SPC Storm Reports for 04/22/10
Map updated at 2103Z on 04/23/10
TORNADO REPORTS.. (40)
WIND REPORTS/HI..... (18/3)
HAIL REPORTS/LG..... (59/8)
TOTAL REPORTS....... (117)
National Weather Service
Storm Prediction Center
Norman, Oklahoma
■ High Wind Report (65KT +)
▲ Large Hail Report (2" dia. +)
PRELIMINARY DATA ONLY


24-hour CI valid from
20100422 1200 UTC to 20100423 1200 UTC

- Algorithm considers both cloud-top temperature changes and cloud type changes
- Works day and night
- Lead time of up 45 minutes before 35 dbZ echoes is common
- Several checks to minimize false alarms: When CI says convection is initiating, it usually is (POD: 55.6%; FAR: 26.0%)

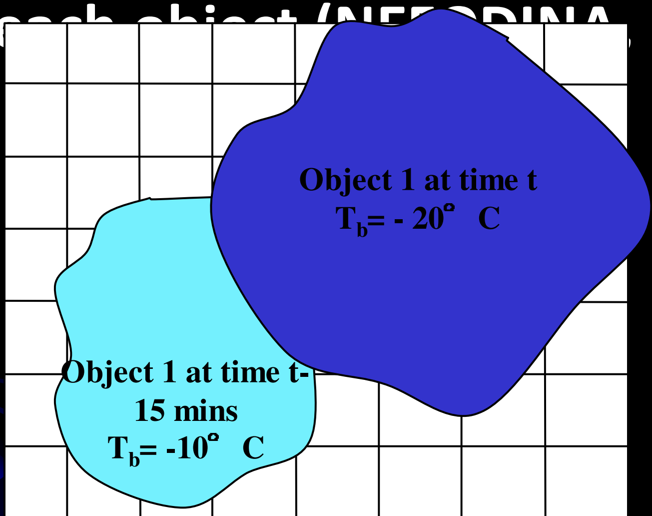
Nowcast forecasts more than half the storms that develop

Forecaster can trust that 3 out of 4 forecasts verifies

- …-top …d type
- Works day an…
- Lead time of 3… echoes is com…
- Several checks to minimize false alarms: When CI says convection is initiating, it usually is (POD: 55.6%; FAR: 26.0%)
- Ongoing study to connect radar to UWCI using WDSS-II

Object Tracking Approach for Nowcasting Convective Storm Development Using Geostationary Imagery

Develop method to group cumulus cloud pixels into coherent "objects", which can then be objectively tracked over time (cloud overlap, cross-correlation?) to determine IRW T_B cooling rate for each object (NEFODINA, Nowcast SAF RDT, WDSS-II)



Cumulus objects overlap (or "look" very similar) in 2 images…so they must be the same cloud!!!

Identify properties such as object size, temperature, mean cloud particle size and microphysical phase changes

Advantages

Explictly tracks cumulus cloud motion, producing accurate time trends of numerous cloud properties

Allows for easier and more comprehensive validation of nowcast products

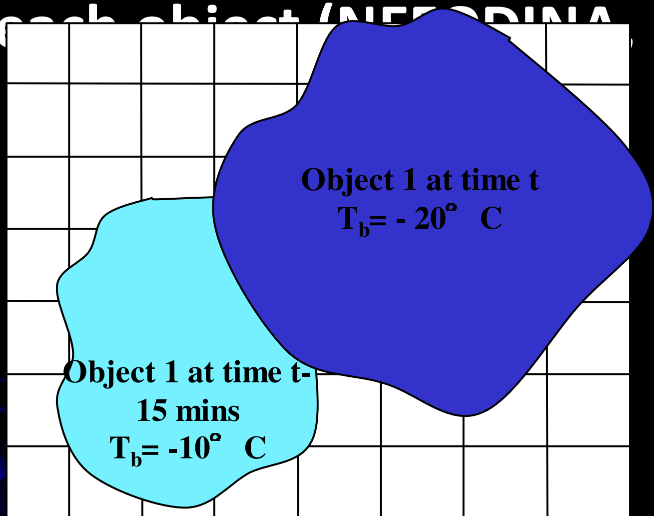
Disadvantages

Can be very computationally expensive

Some current generation methods focus on tracking colder objects (NEFODINA T_B < 260 K), missing the initiation phase. RDT is much warmer with max T_B suggested to be 278 K.

Object Tracking Approach for Nowcasting Convective Storm Development Using Geostation ry Im agery

Develop method to group cumulus cl ... nt "objects", which can then be objecti ... (cloud overlap, cross-correlation?) to dete ... for each object (NEFODINA, Nowcas ...



Cumulus objects overlap (or "look" very similar) in 2 images…so they must be the same cloud!!!

Identify properties such as object size, temperature, mean cloud particle size and microphysical phase changes

Coming Soon using WDSS-II!

F ... g
acc ... oud

Allows for e sier an ore co prehensive validation of no wcast products

Disadvantages

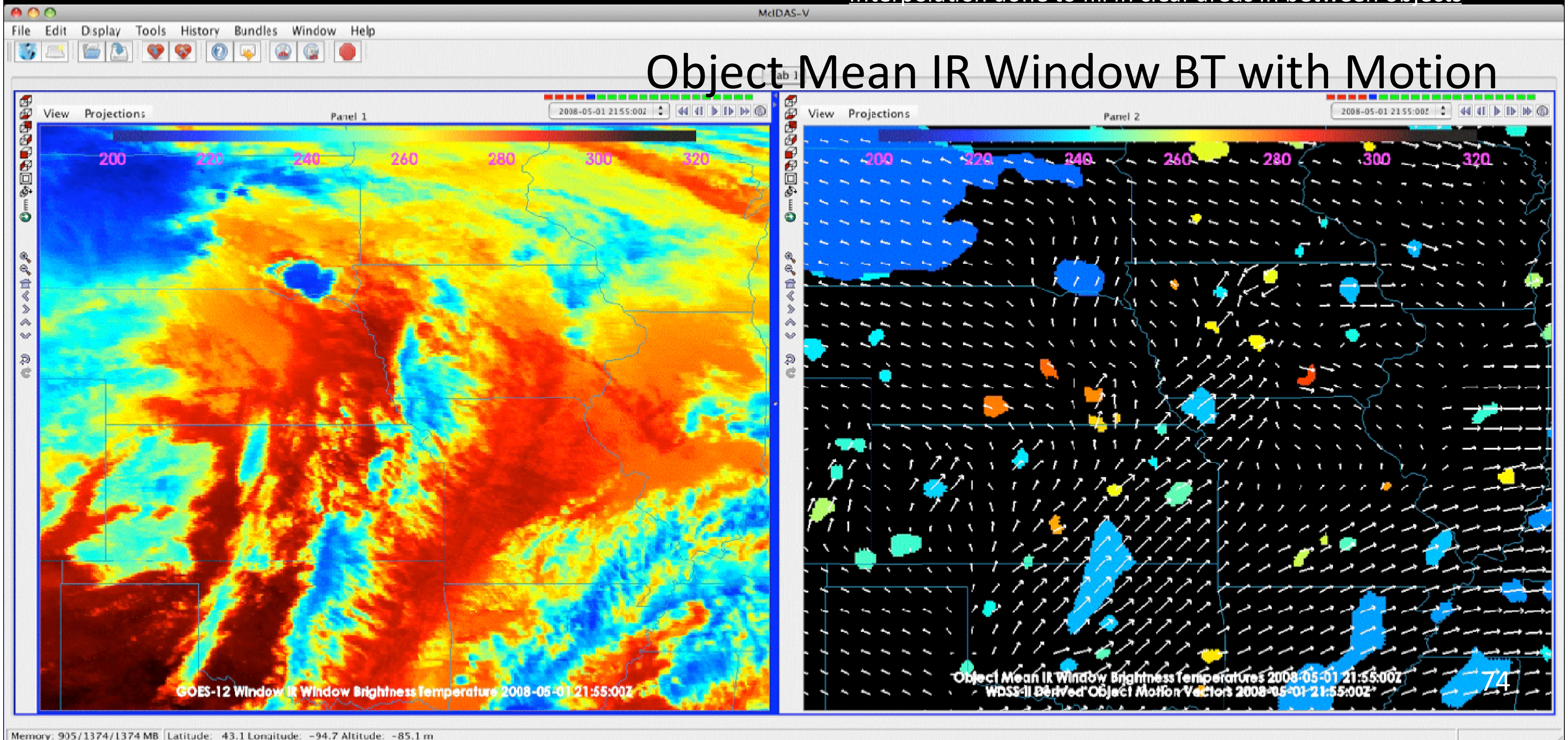
Can be very computationally expensive

Some current generation methods focus on tracking colder objects (NEFODINA T_B < 260 K), missing the initiation phase. RDT is much warmer with max T_B suggested to be 278 K.

- Used Warning Decision Support System – Integrated Information (WDSS-II, Lakshmanan et al. (*WAF*, 2007)) to define cloud ***objects*** based on normalized IR temperature and compute their motion across an image sequence
- Our experience using the WDSS-II framework is still evolving, so these results are preliminary, but demonstrating the object tracking concept is the primary focus here

Motion field generated entirely from object motion and interpolation done to fill in clear areas in between objects

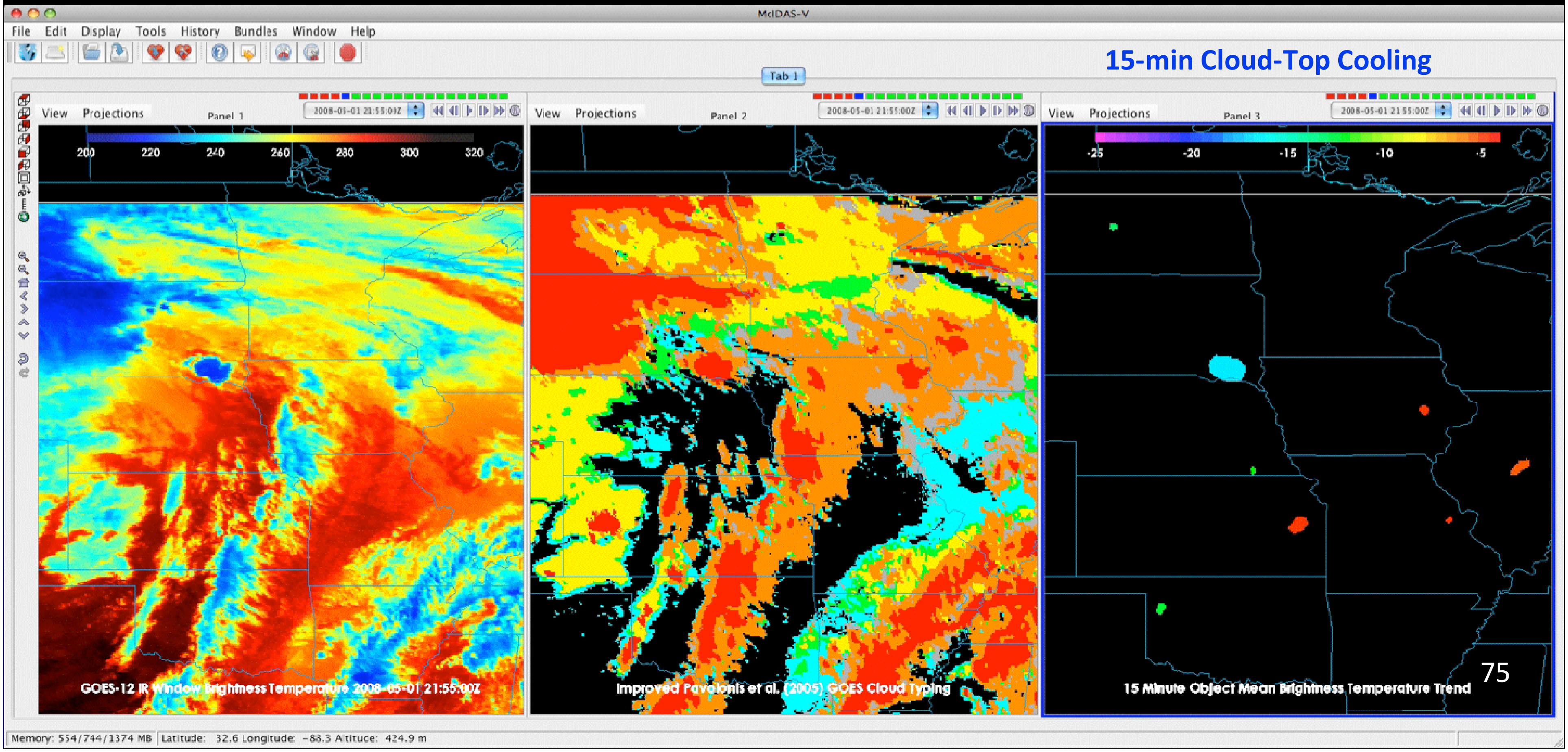
Object Mean IR Window BT with Motion



Based upon cloud object motion, compute cloud-top cooling rates to identify rapid growing cumulus

Combine persistent cloud-top cooling with cloud microphysical type changes to identify new convective storm initiation

Pavolonis et al. (2005) GOES Cloud Typing
Cyan: Liquid Water Cloud
Green: Supercooled Water Cloud
Yellow: Mixed Phase Cloud
Red: Thick Cirrus Ice Cloud
Orange: Thin Cirrus Ice Cloud



Additional Resources

UWCI Qualitative Automated Validation Page
http://cimss.ssec.wisc.edu/snaap/convinit/validation/

UWCI/OTTC Data access and Training:
http://cimss.ssec.wisc.edu/goes_r/proving-ground/SPC/SPC.html

Satellite-based Turbulence Applications

Background – known turbulence sources

Clear-air Turbulence (CAT)

Mountain wave Turbulence (MWT)

Low level Terrain-induced Turbulence (LLT)

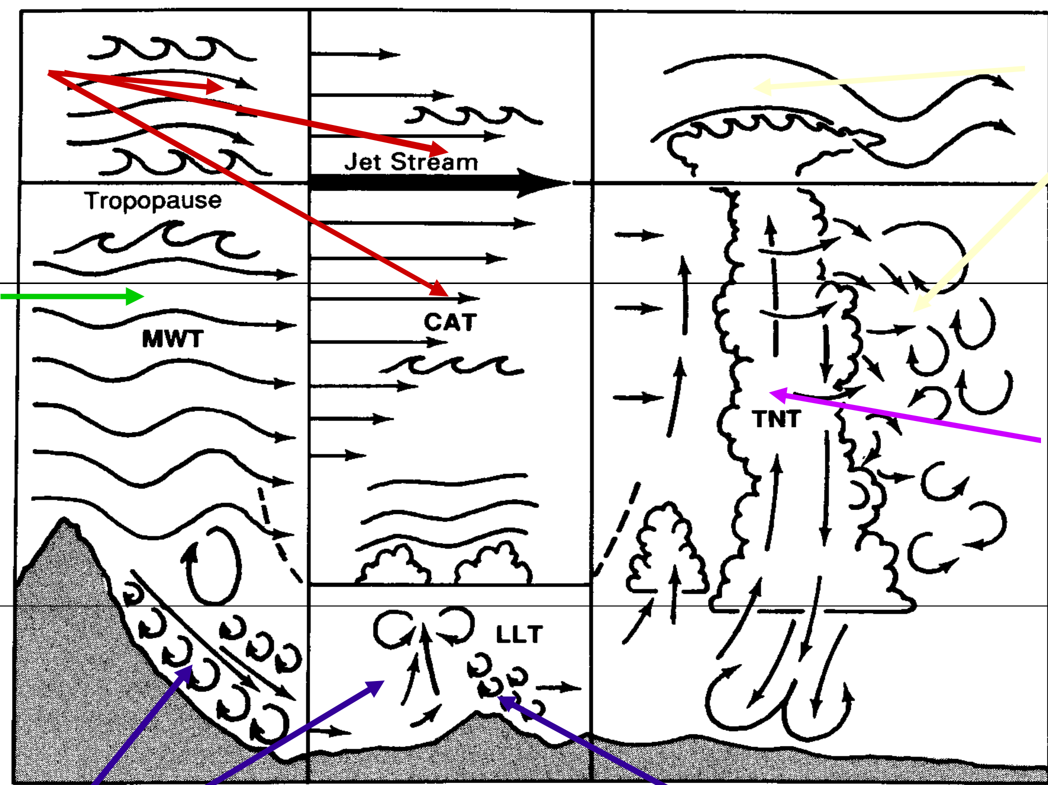


Figure 1-16. Aviation turbulence classifications. This figure is a pictorial summary of the turbulence-producing phenomena that may occur in each turbulence classification.

Cloud-induced or Convectively-induced Turbulence (CIT)

In-cloud turbulence

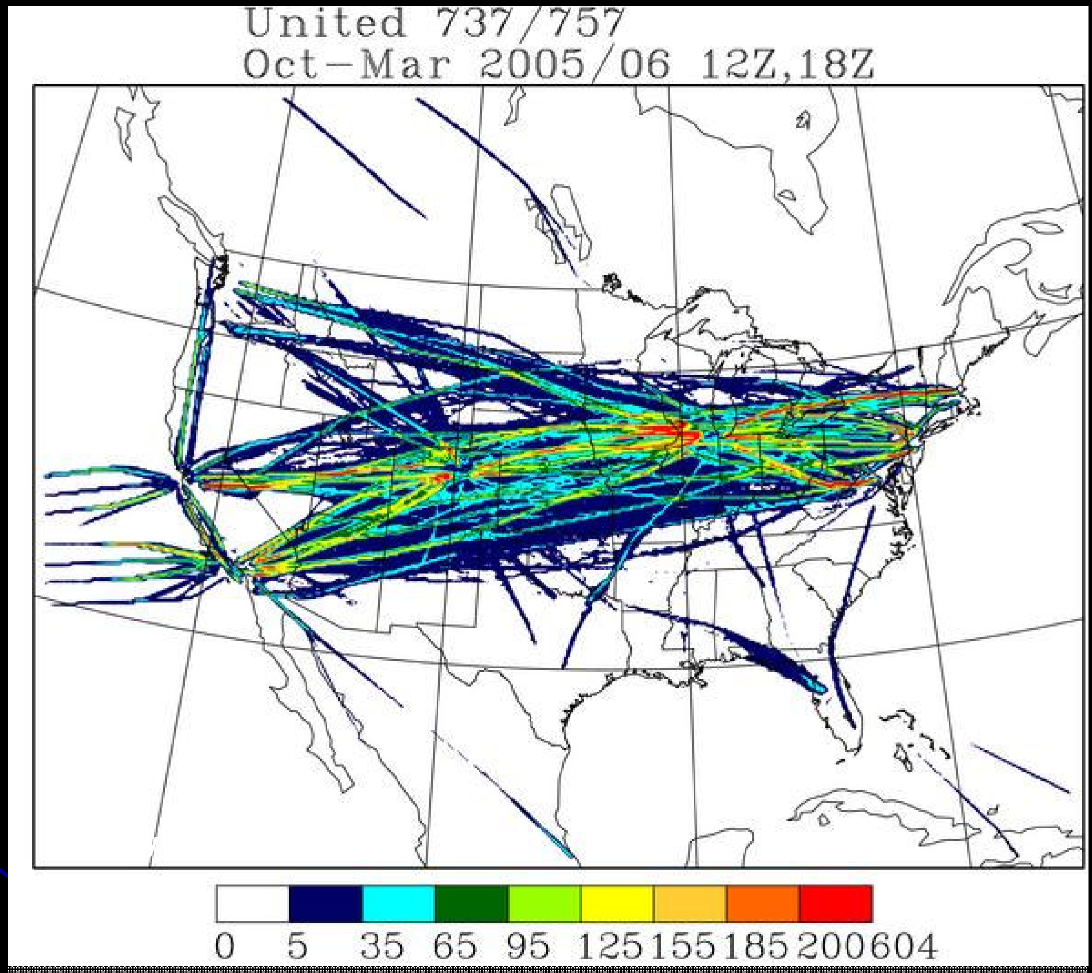
Convective boundary Layer turbulence

Source: P. Lester, "Turbulence – A new perspective for pilots," Jeppesen, 1994

Adapting to aircraft hazard awareness

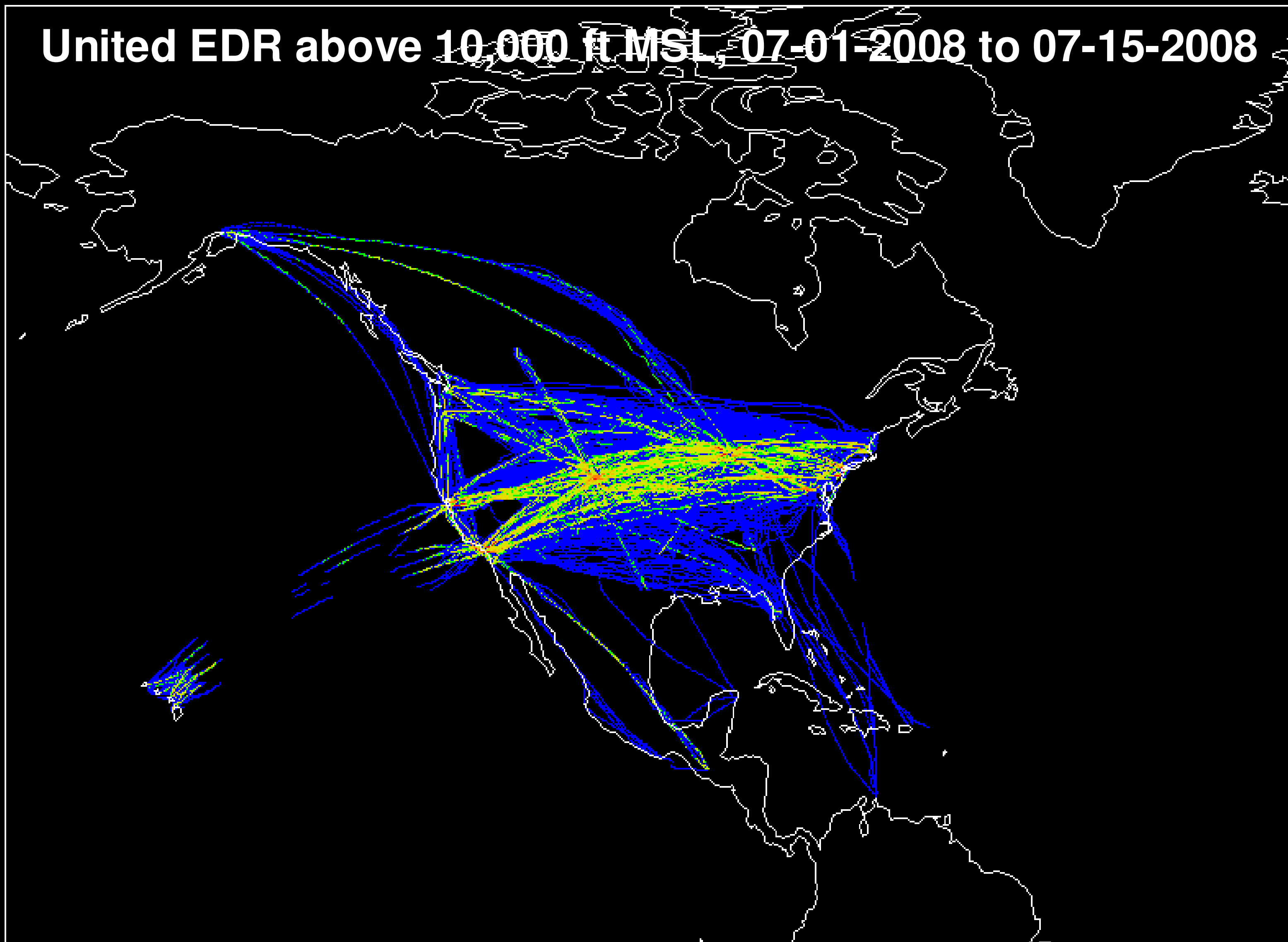
- **Validation data - Eddy Dissipation Rate**
  - Automated reporting of inertial disturbance on commercial aircraft
  - 3-minute integration time per measurement (short). This indicates several measurements through any single turbulent region.
  - Collected and quality-checked by NCAR
  - ~ 1 month latency

EDR Turbulence Observations

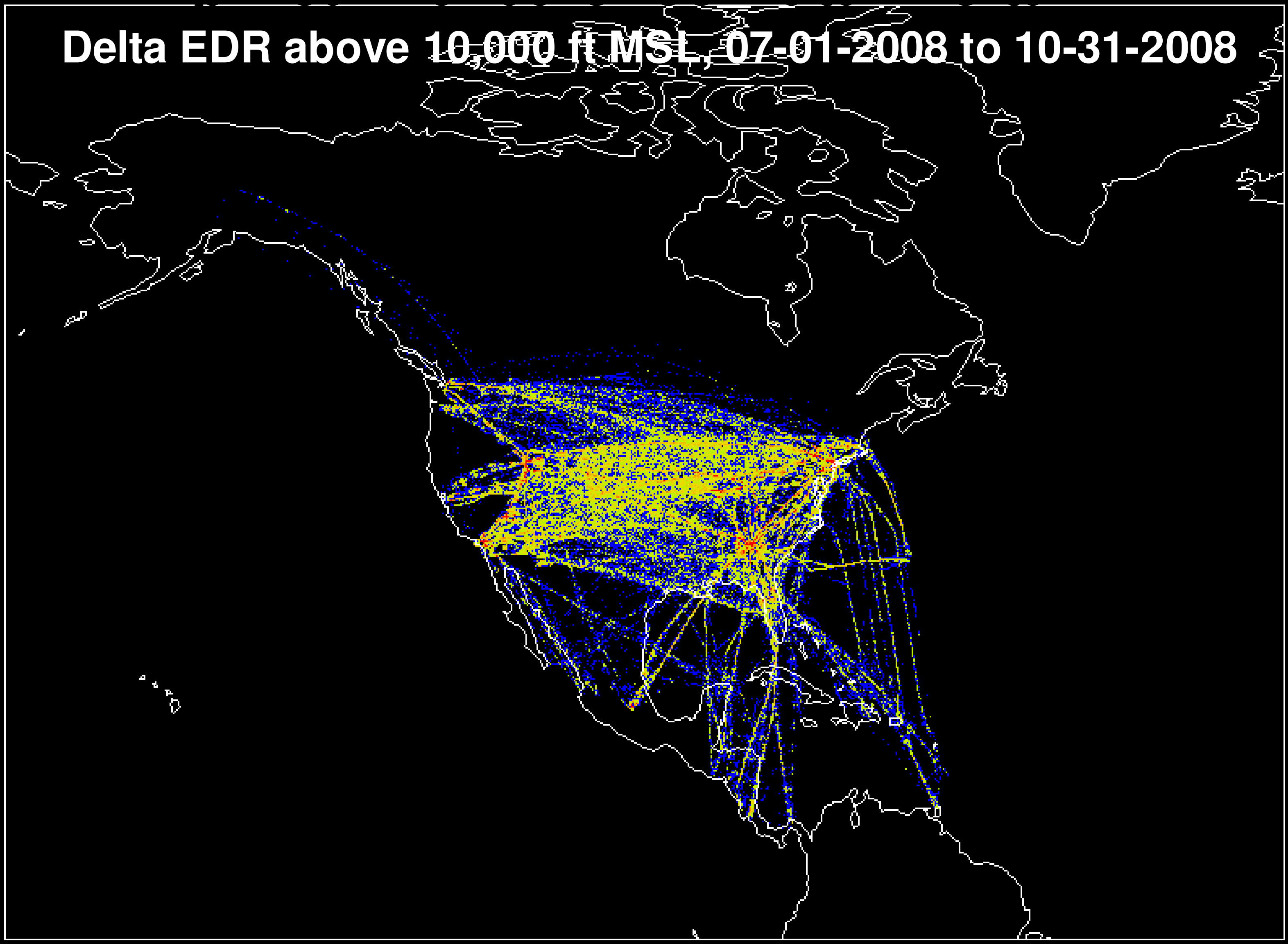


- Many United Airlines Boeing 757 aircraft are collecting Eddy Dissipation Rate (EDR) observations, an objective measure of aircraft turbulence (Cornman et al., *J. Aircraft*, 1995)
  - *Delta and Southwest Airlines EDR observations are now availabie as of 2009*
- EDR provides a significant advantage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

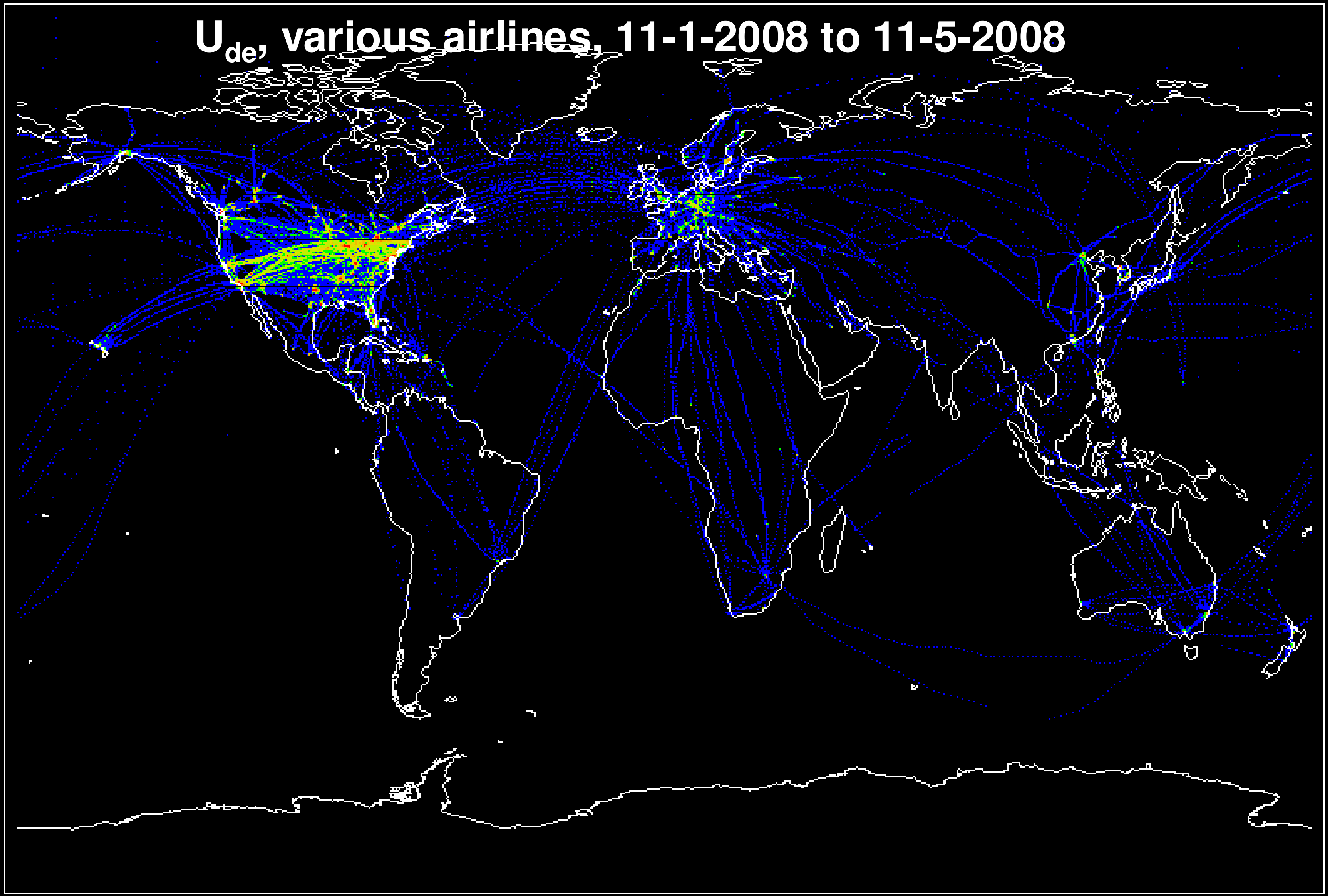
EDR = Treasure Chest!



Delta EDR above 10,000 ft MSL, 07-01-2008 to 10-31-2008

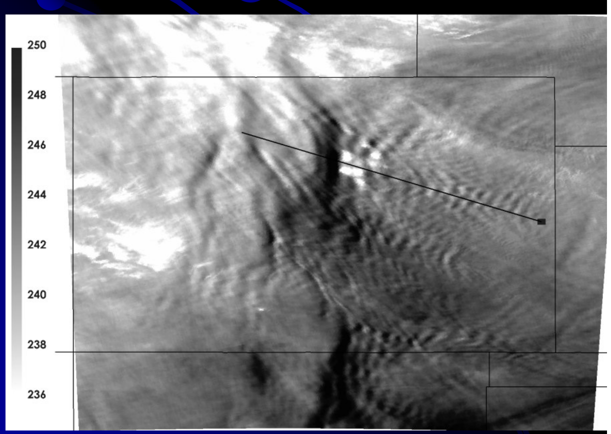


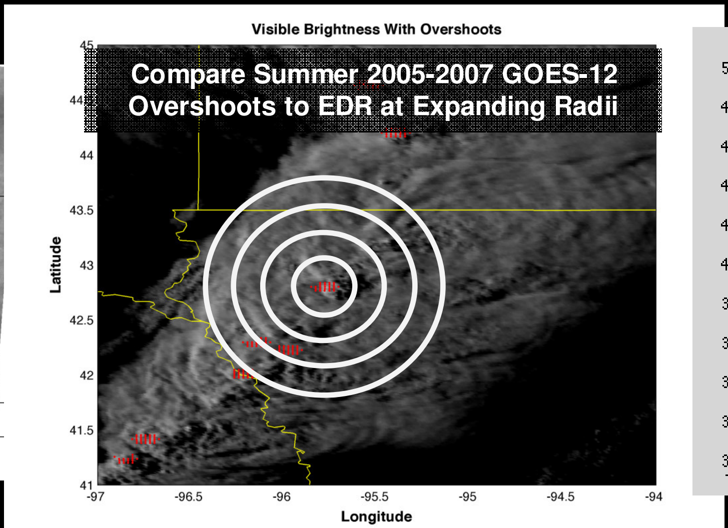
Empirical Turbulence Data: U_{de}

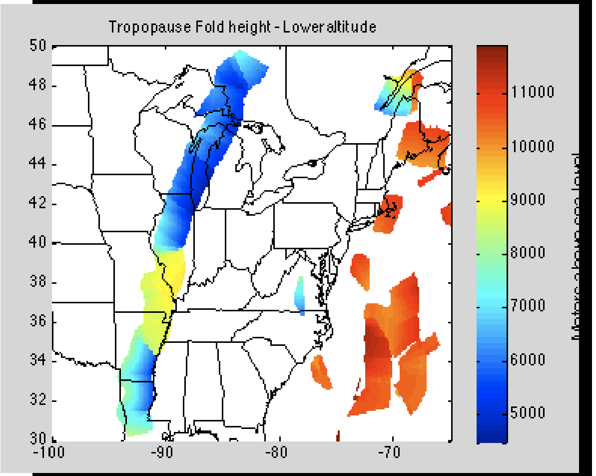


Satellite-based Turbulence Interest Field Detection

- Convectively Induced Turbulence
- Tropopause Folding
- Mountain Wave Turbulence





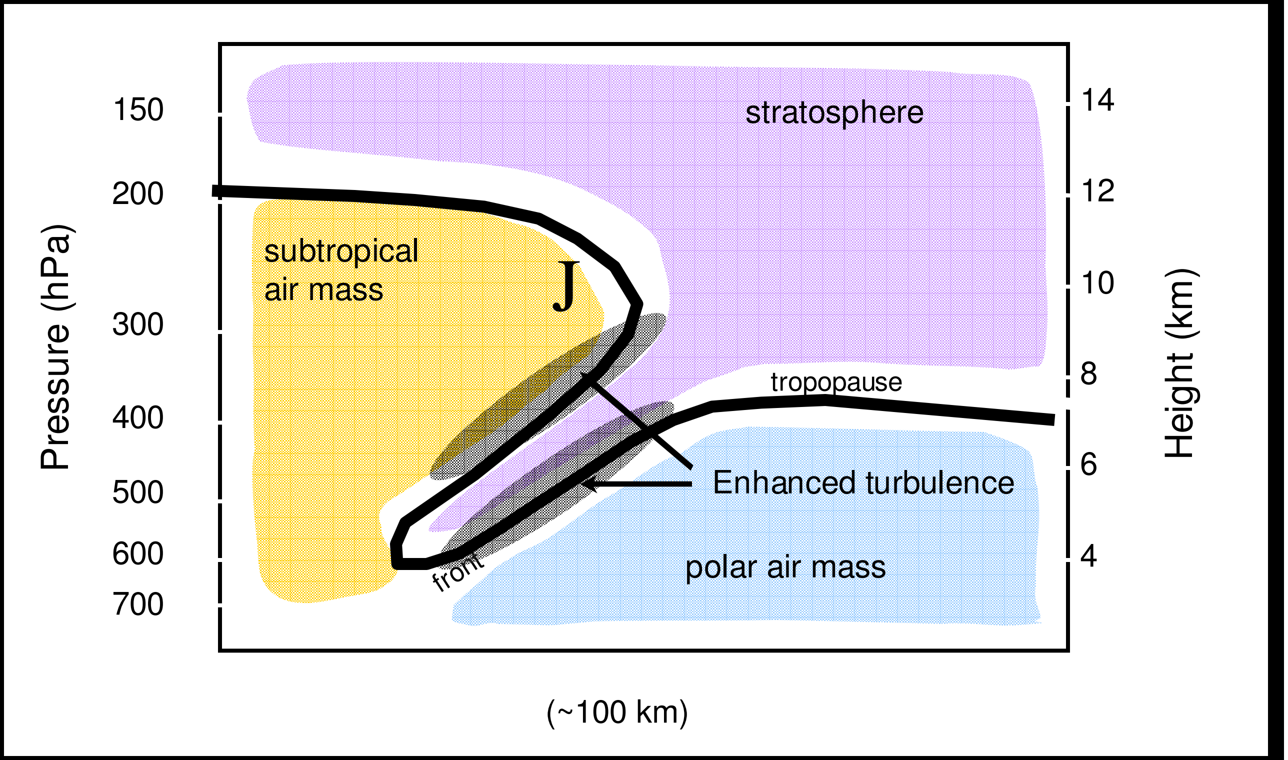


What Is a Tropopause Fold?

- Tropopause folding describes an event at the tropopause break in which the tropopause folds into the troposphere due to ageostrophic flow around the jet stream.

- This frequently leads to dynamical instability (enhanced turbulence) because of high levels of vertical shear across the boundary of the tropopause fold, which contains elevated potential vorticity.

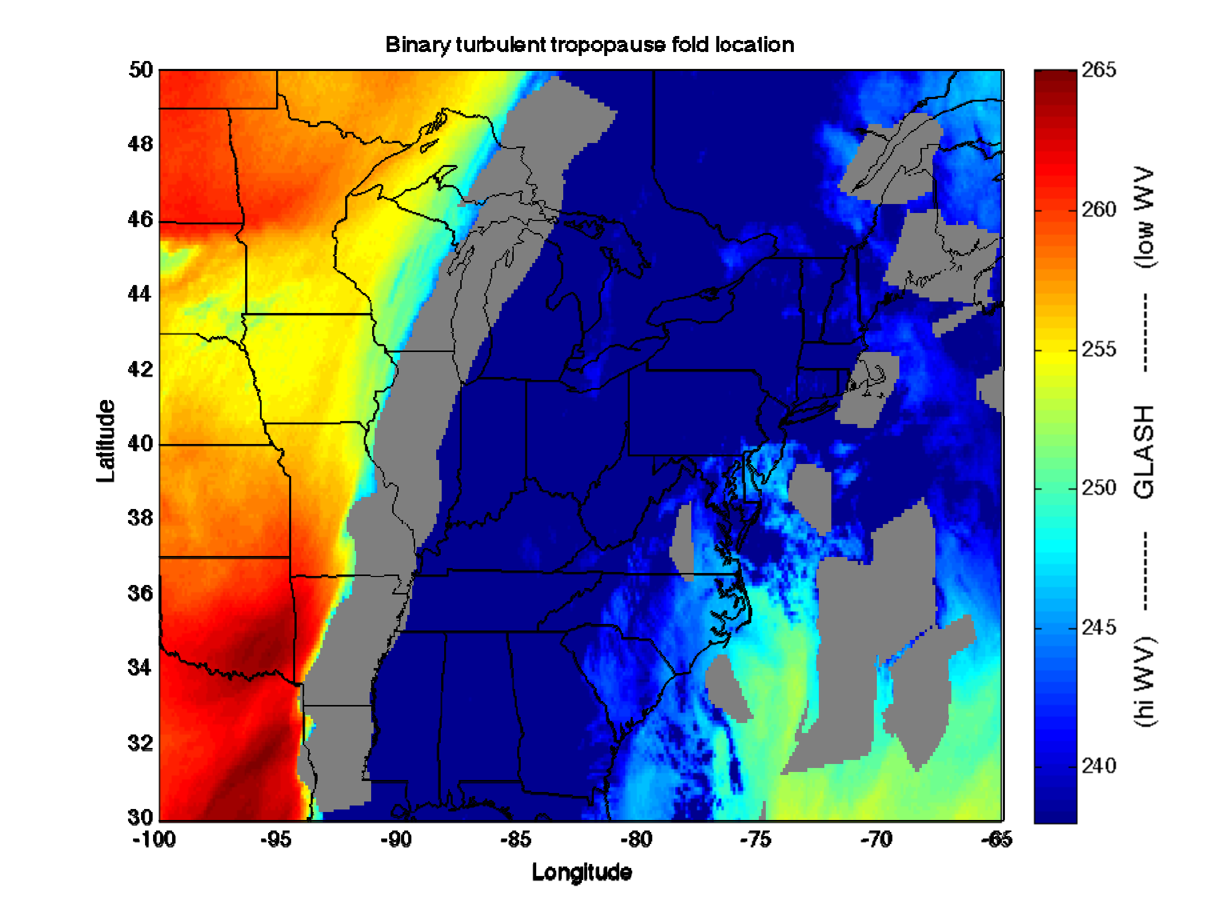
Upper-air front

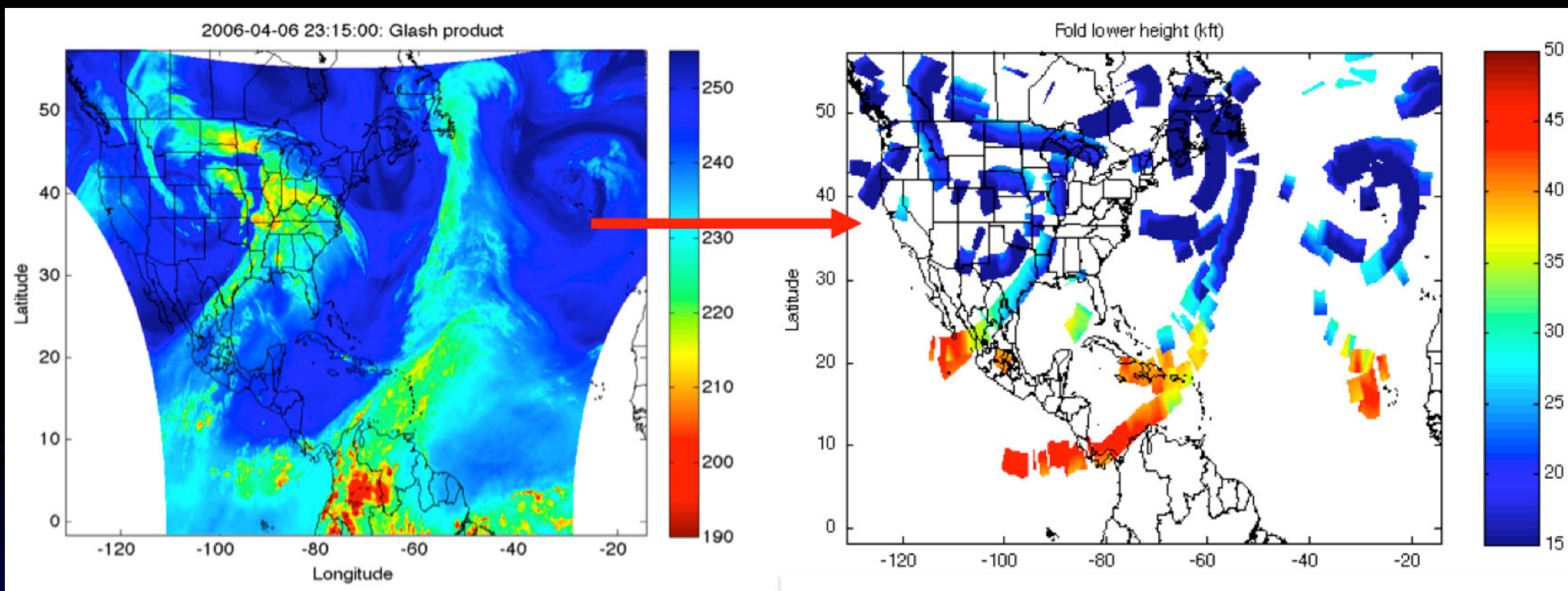


GOES-R Aviation: Tropopause Fold Turbulence Prediction (TFTP) product

Uses gradients in ABI water vapor (upper troposphere) to find regions of turbulent tropopause folds in upper-level air mass boundaries

Product consists of tropopause fold location (right, in gray), vertical boundaries and the ranges of vulnerable flight directions.

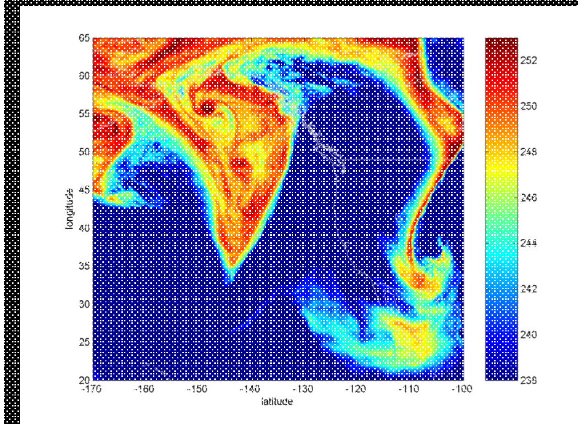




2006-04-06 23:15:00: Glash product
Latitude
Longitude
50
40
30
20
10
0
-120
-100
-80
-60
-40
-20
250
240
230
220
210
200
190
Fold lower height (kft)
Latitude
45
35
25
15

Tropopause Folding Turbulence Prediction (TFTP)

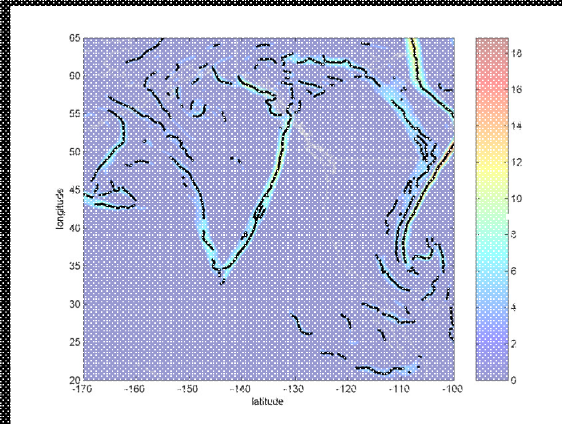
"Tropopause folding" is the entrainment of high-vorticity stratospheric air underneath a warm air mass, along a front. It creates eddy circulations and unstable flow around the jet stream, causing CAT.



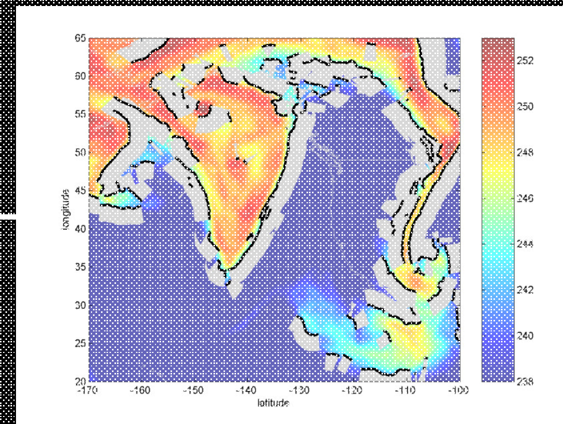
GOES Water Vapor

(low WV)

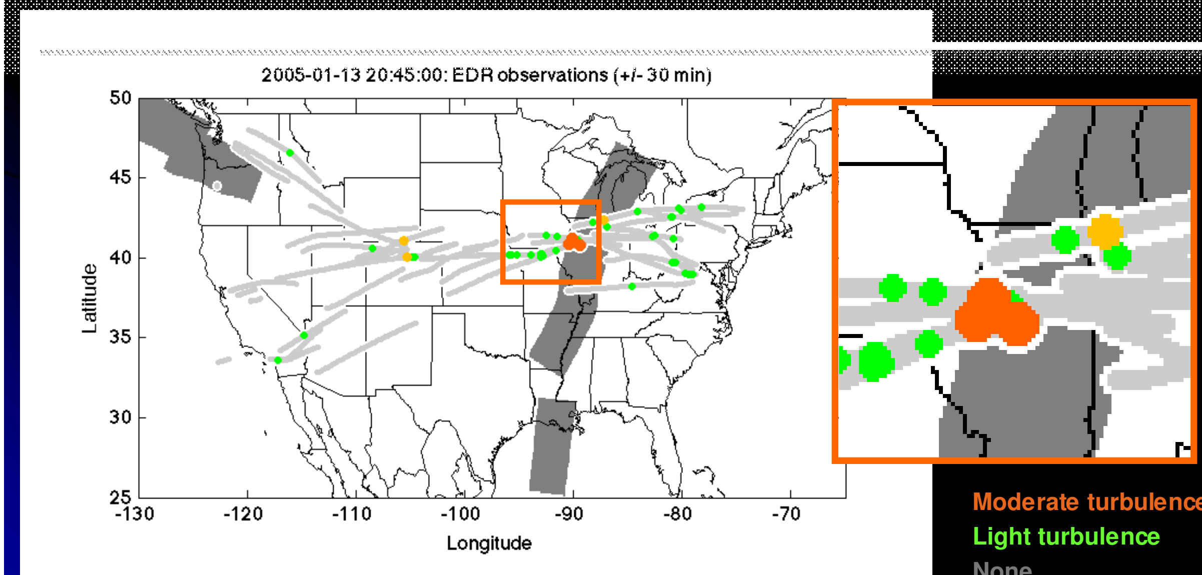
(high WV)



Edge Detection



Tropopause fold layer

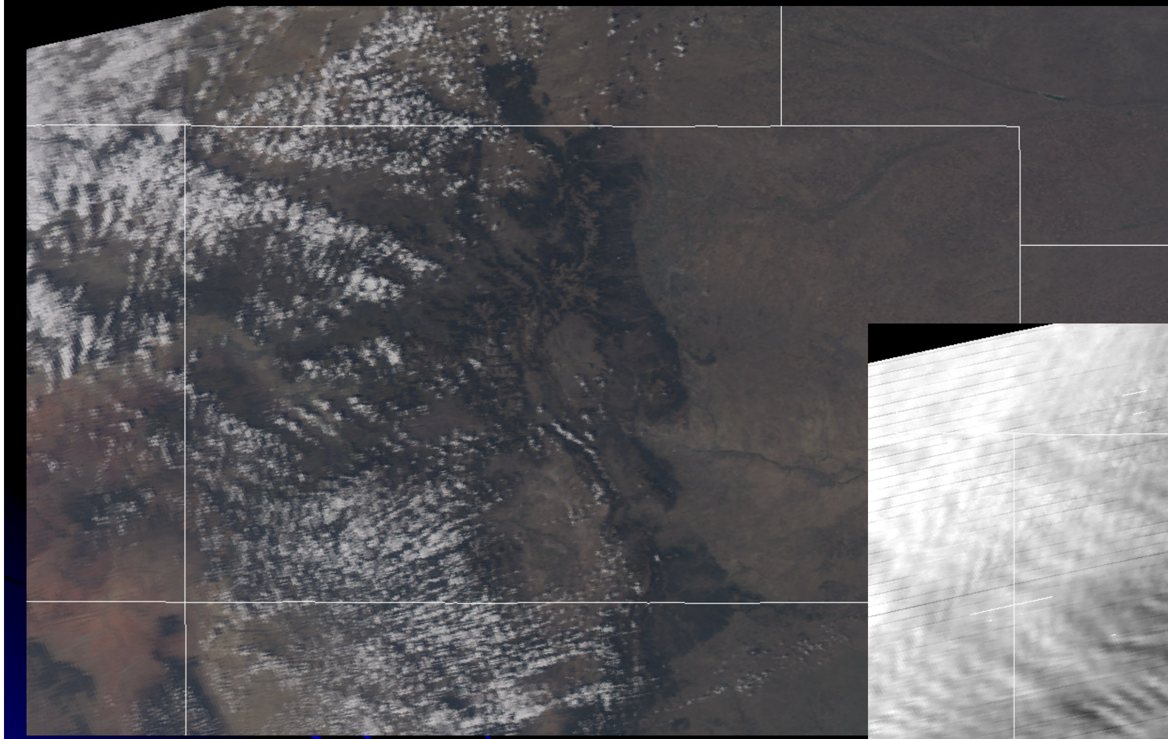


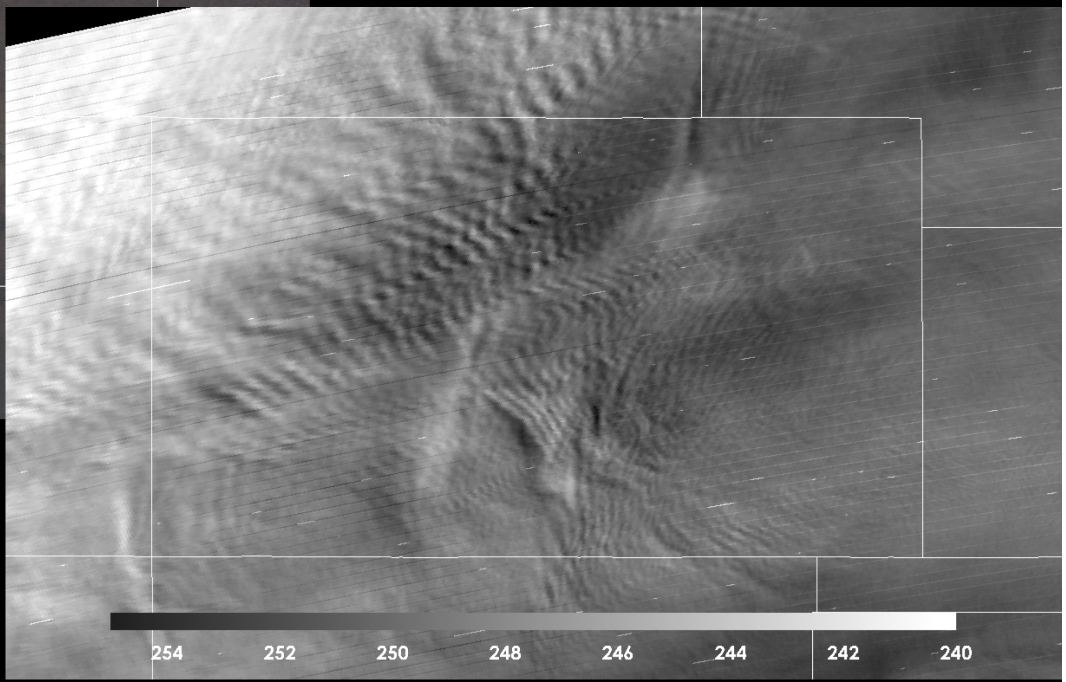
Trop folding product with EDR observations

Key attributes, status

- Can be produced from any satellite water vapor channel.
- Performing at 50% accurate detection of Moderate turbulence
- TFTP is being integrated into the GTG project with global geostationary coverage.
- TFTP will be available as a GOES-R product in 2014

Mountain Wave Turbulence

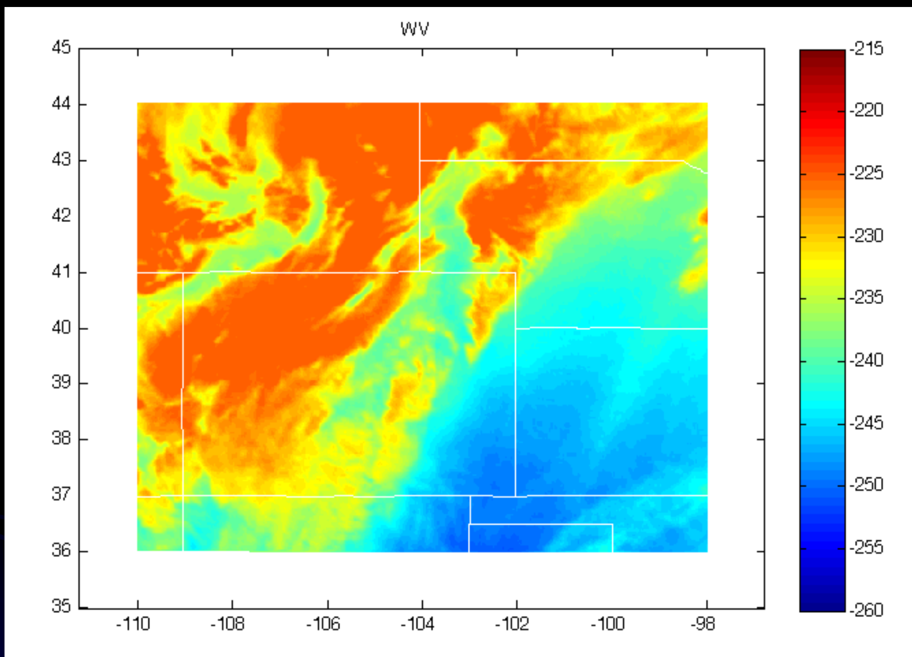




Environment Canada 28-29 April 2011

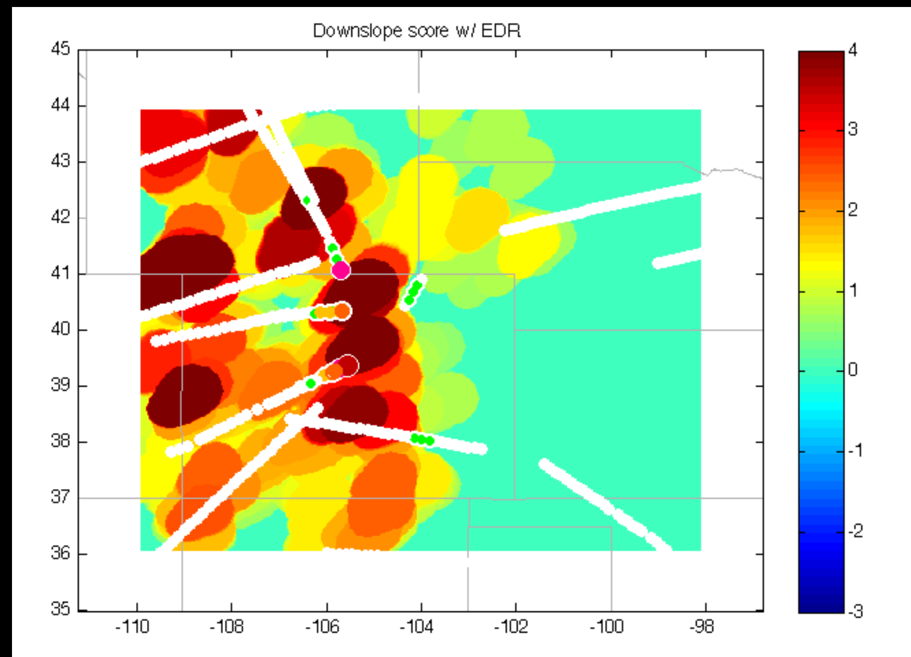
Detecting sources of mountain wave turbulence

Tony Wimmers, Wayne Feltz
Graphical Turbulence Guidance Project



GOES-12 WV over Colorado
(Input to downslope turbulence product)

• Turbulence tends to occur where water vapor decreases down elevation gradients (associated with downslope winds)

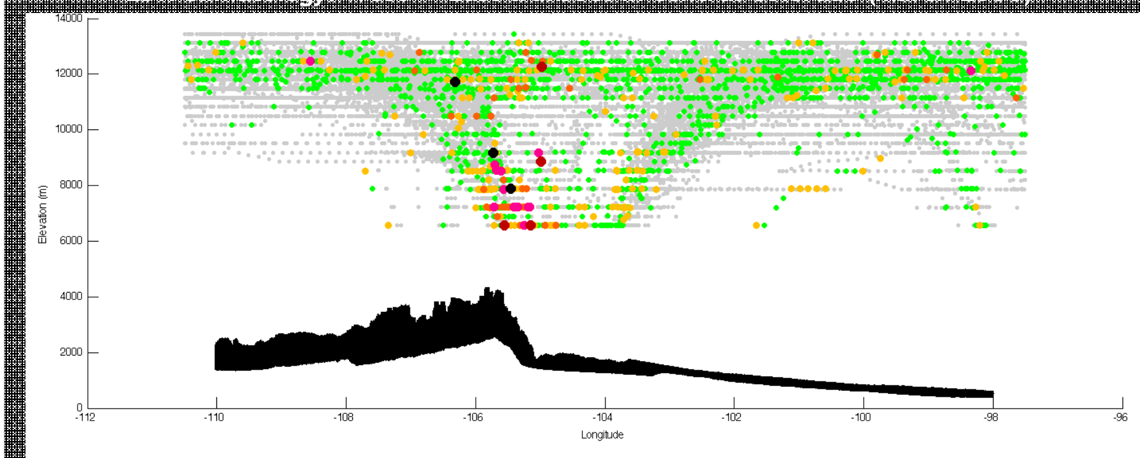


Downslope turbulence product

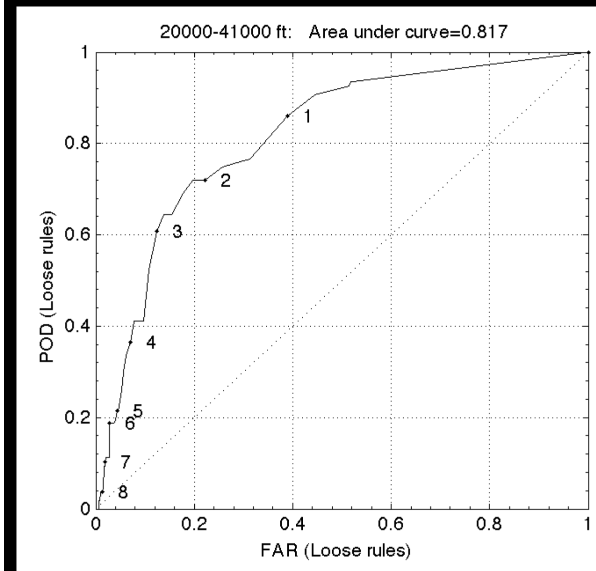
- Hot colors predict turbulence
- Overlaid with automated aircraft reports:
  - Green: Light Turbulence
  - Orange: Moderate
  - Red: Severe

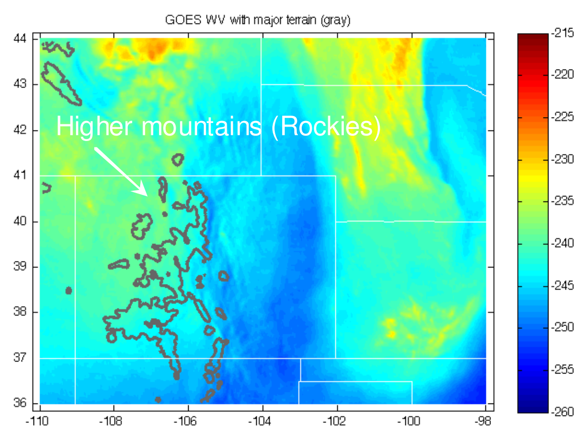
NEW: Mountain Wave Turbulence (MWT) detection

EDR Climatology: West -> East transect in central Colorado (March 2006)

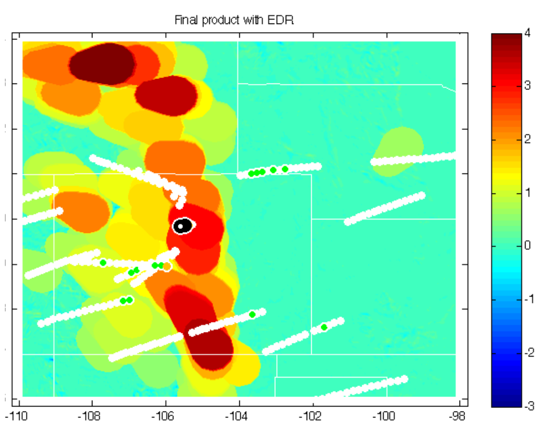


- According to the EDR record, MWT is concentrated predominantly around area of the the strongest downslope winds





GOES-12 WV for 12 Nov 2005 1745 UTC

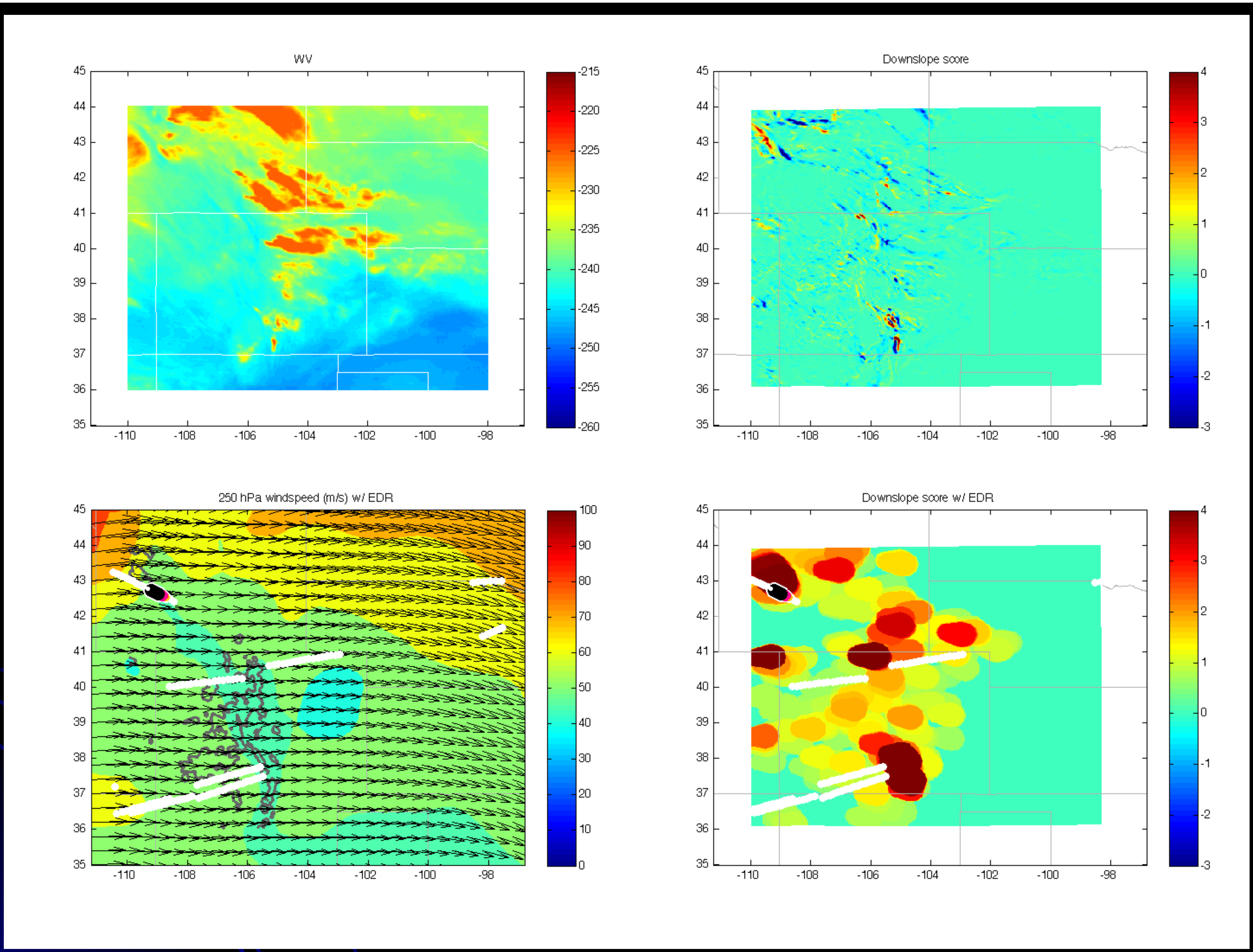


Corresponding downslope MWT product

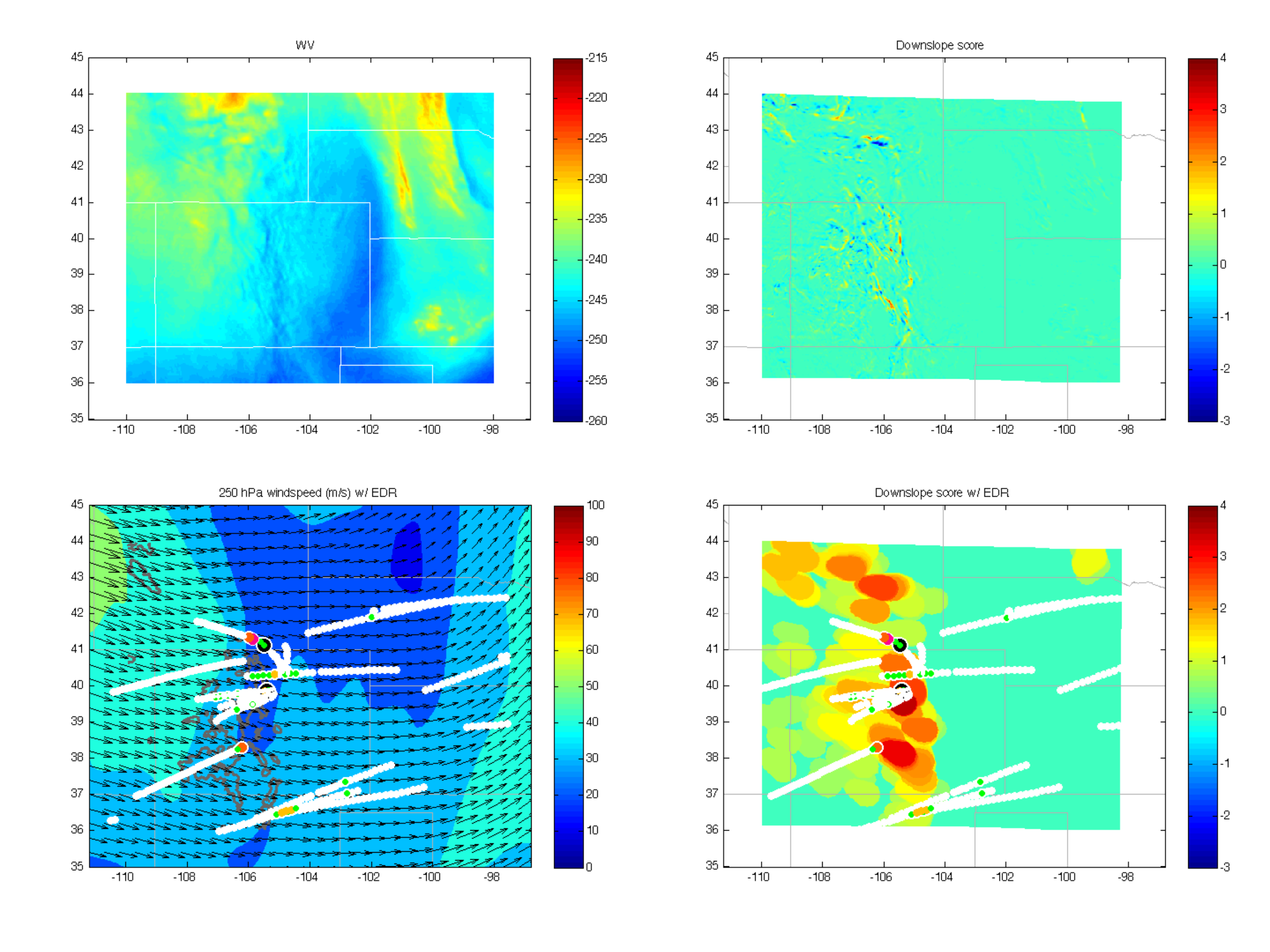
- The downslope MWT product identifies the regions in the mid-to-upper troposphere influenced directly by downslope vertical winds evident in the WV imagery

Key attributes, status

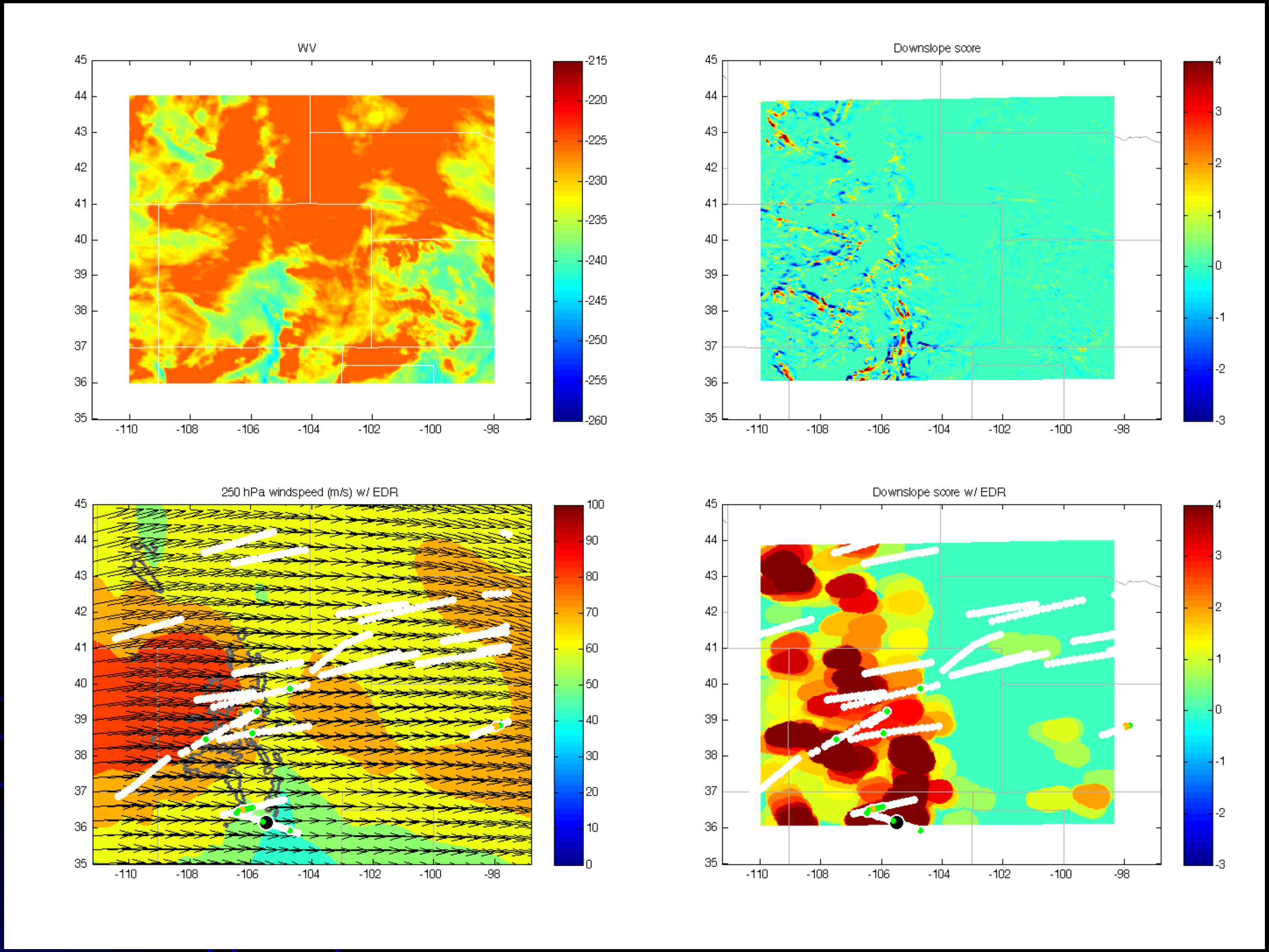
- **Can be produced from any satellite water vapor channel.**
- **Optimum: POD: 70% / FAR: 20%**
- **Forecast capability of 0-3 hrs.**
- **Downslope MWT product is being integrated into the GTG project with global geostationary coverage.**



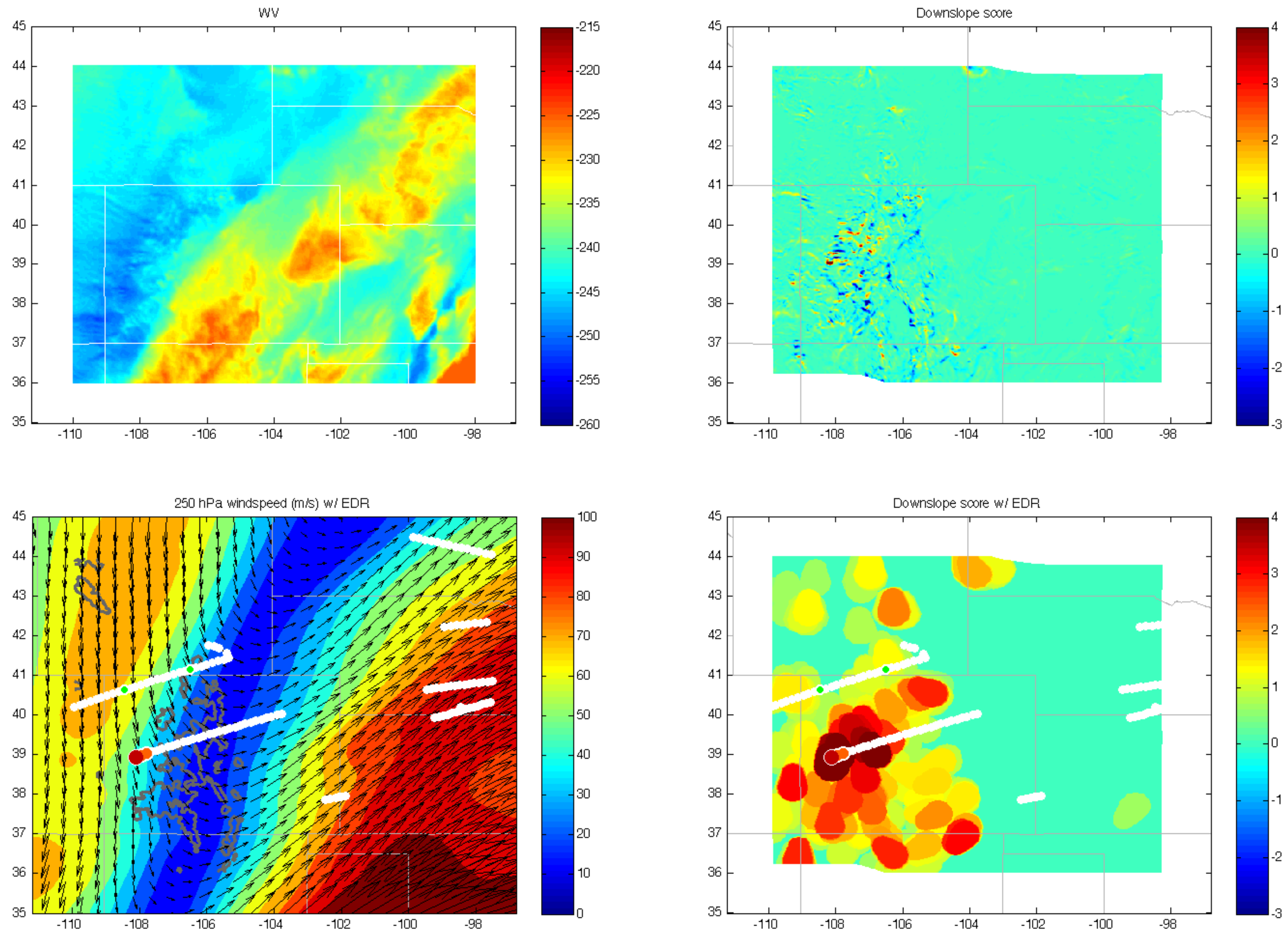
Dot product of water vapor gradient and elevation: Extreme Turbulence at Wind River Range



Extreme turbulence with low model winds at the Front Range (and north)

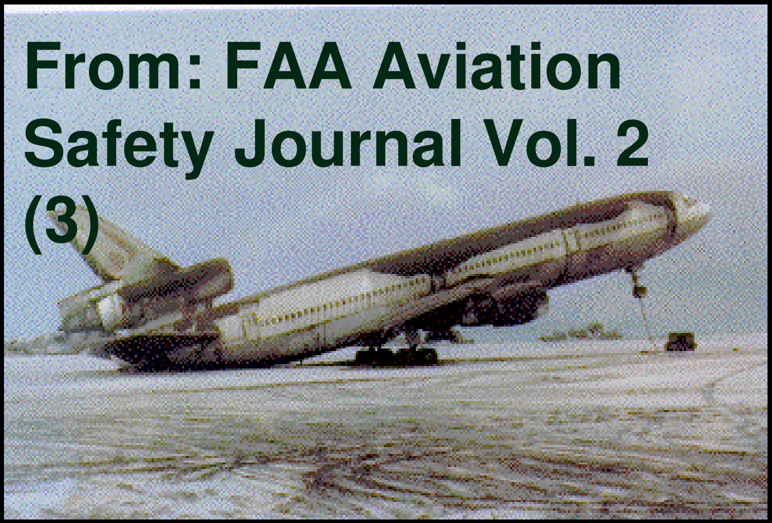


Extreme turbulence in northern New Mexico



Severe turbulence: Northerly wind over Grand Mesa

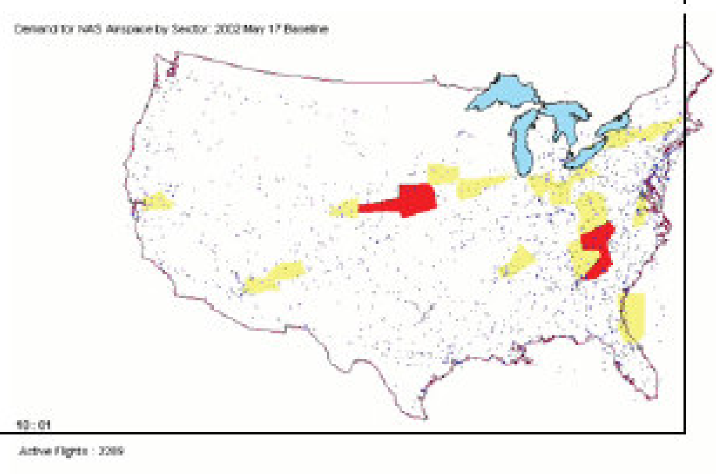
The Future



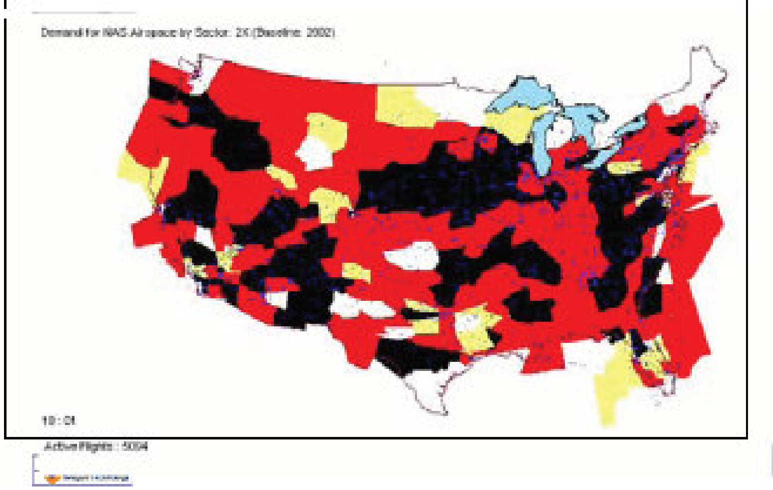
Airspace Loading: Mid-Day EST Demand for Airspace

Snapshot at ~1pm EDT

Baseline Demand (2002)



Future 2X Demand



VAMS ACES Simulation B 2.0.3
Unconstrained Airports & Airspace
250 Airports, 24 hour simulation
Future growth based on Terminal Area Forecast (TAF)

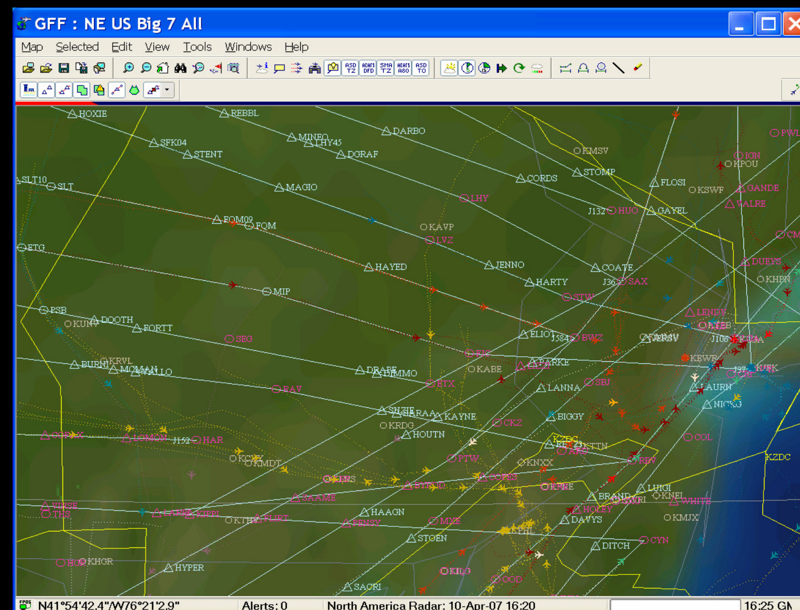
2002: ~27K flights total
Future 2X: ~54K flights total

Sector Color Loading index:

- **Yellow:** 80 – 125% of sector capacity
- **Red:** 125 - 200% of sector capacity
- **Black:** > 200% of sector capacity

National Airspace System is unable to respond to weather impacts

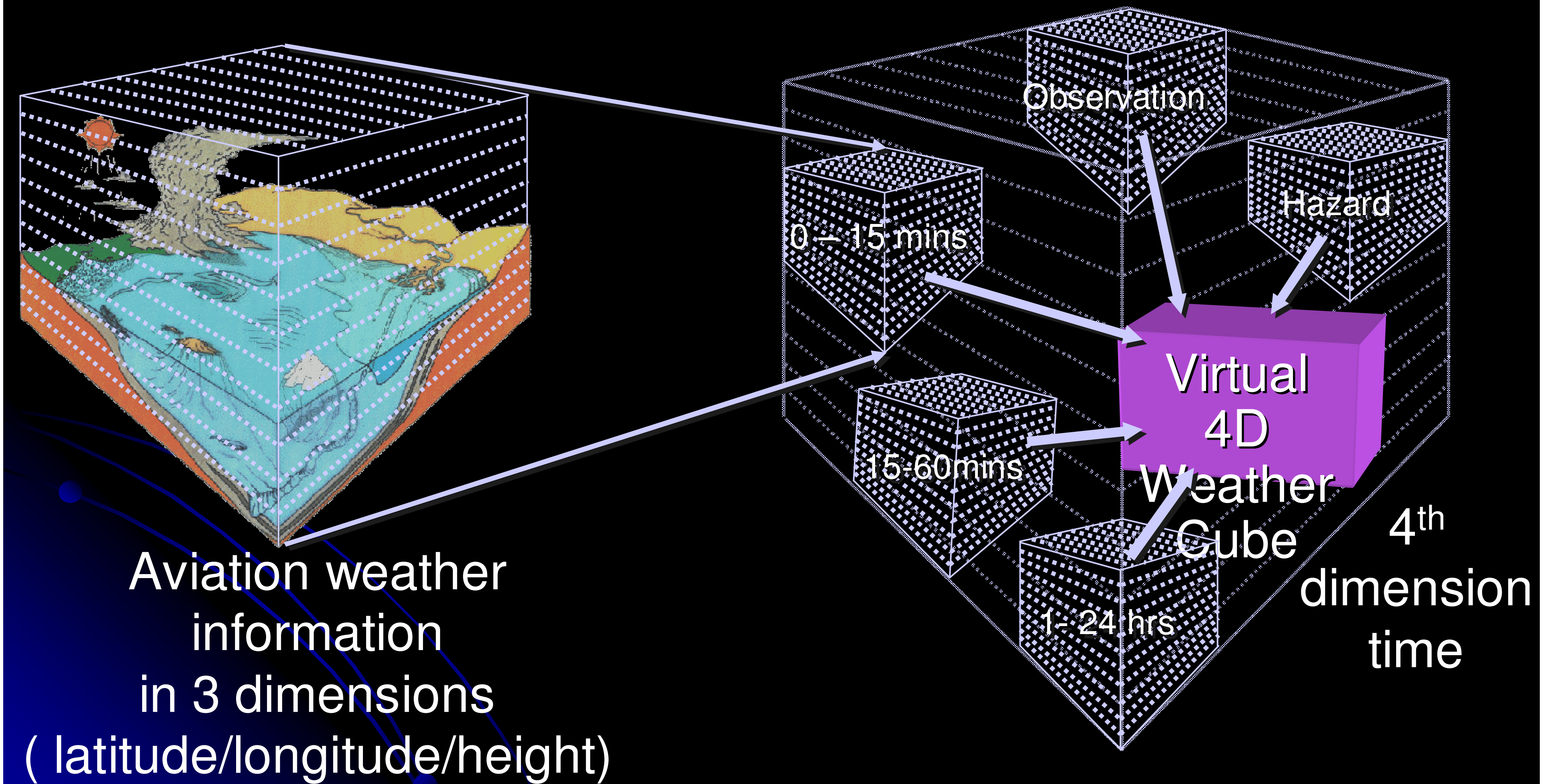
- **Highly-structured**
- **Rigid networks of routes**
- **Complex Coordination**



Research is underway to create flexible airspace designs that can adapt to weather impacts

NextGen Weather

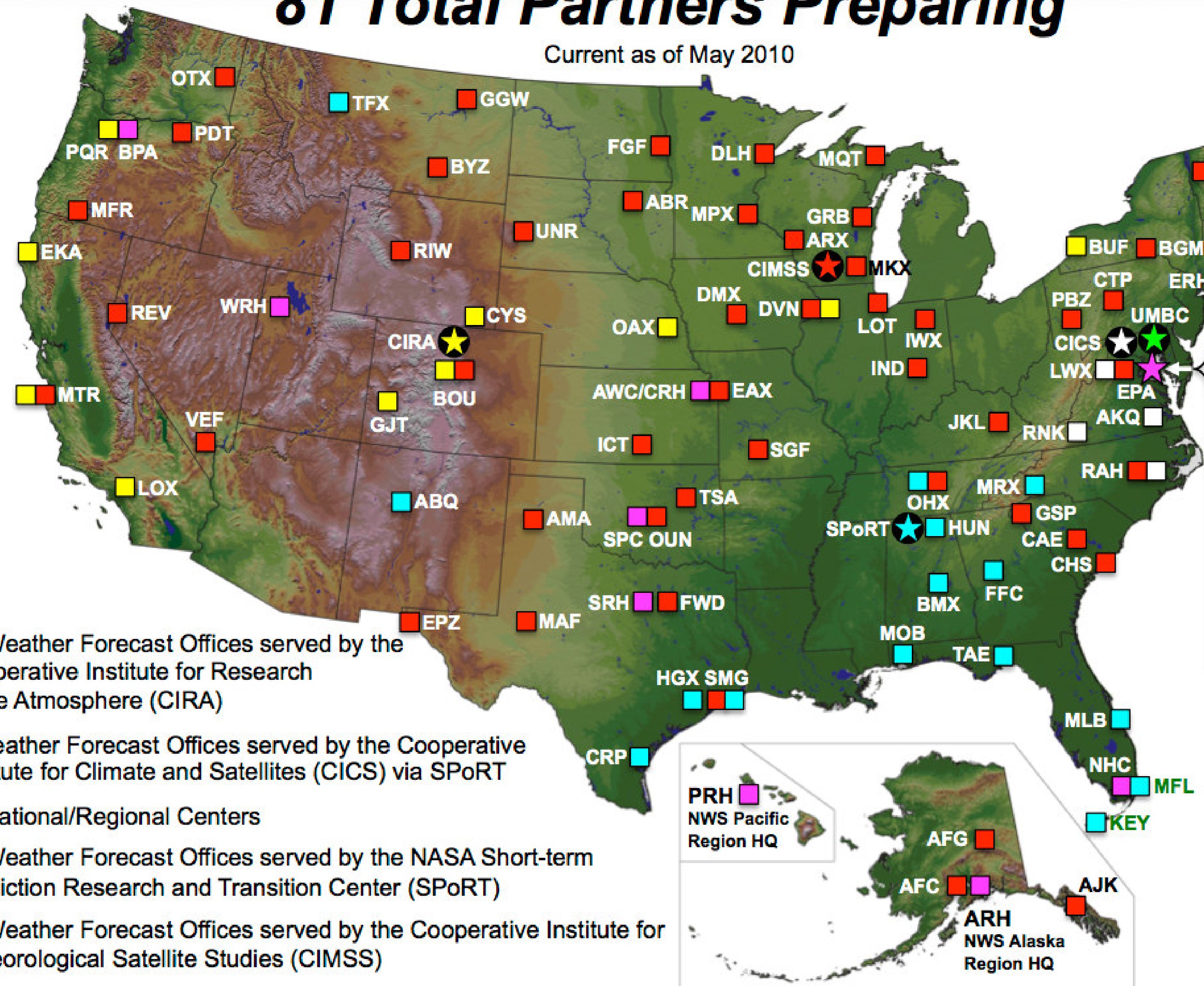
Virtual 4D Weather Cube



GOES-R Proving Ground Partners

81 Total Partners Preparing

Current as of May 2010



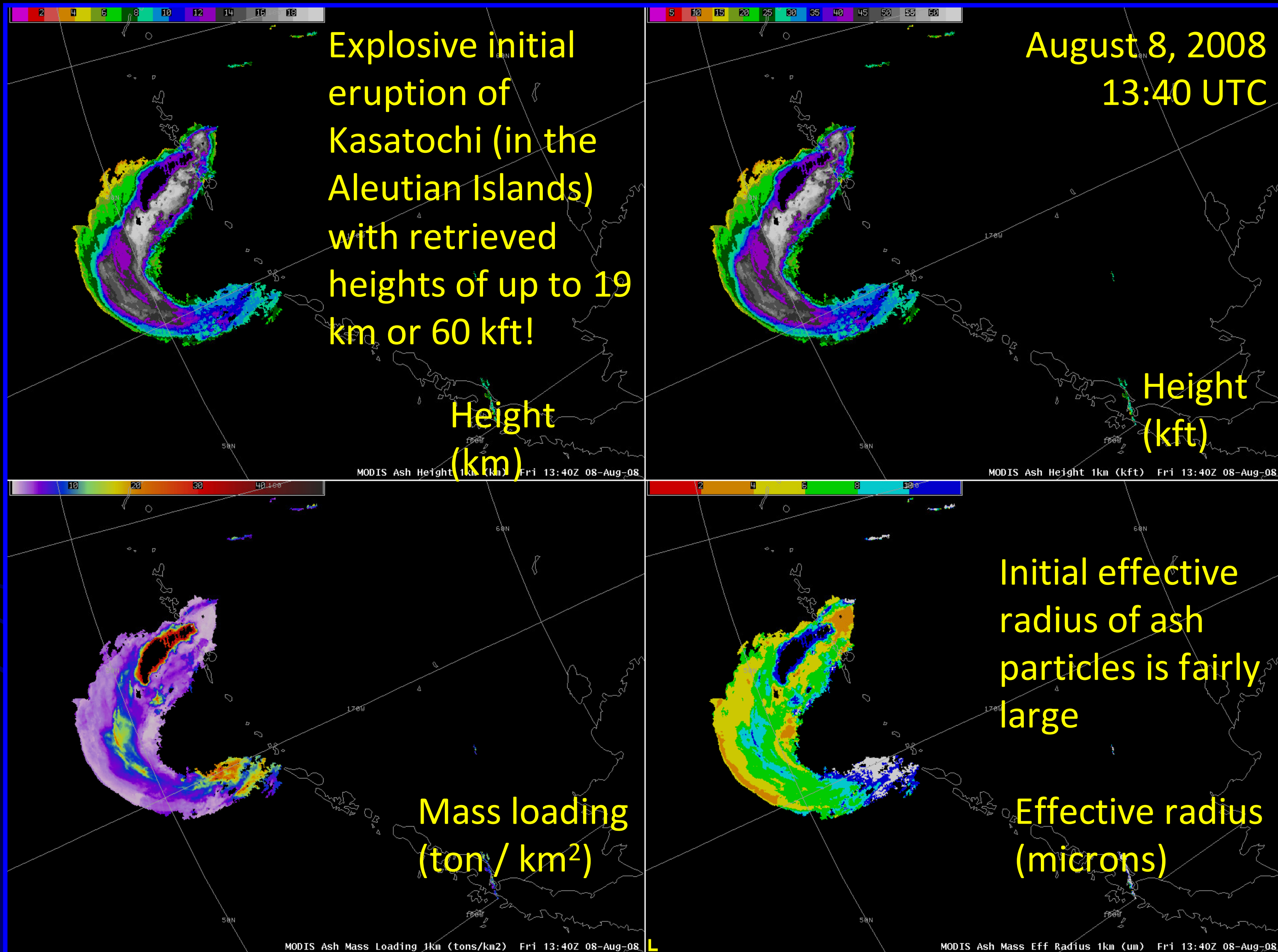
NOAA/NWS Headquarters (Silver Spring, MD); Center for Satellite Applications and Research; Office of Satellite Data Processing and Distribution.

GOES-R Program Office (Greenbelt, MD).

- ***10*** Weather Forecast Offices served by the Cooperative Institute for Research in the Atmosphere (CIRA)
- ***4*** Weather Forecast Offices served by the Cooperative Institute for Climate and Satellites (CICS) via SPoRT
- ***11*** National/Regional Centers
- ***15*** Weather Forecast Offices served by the NASA Short-term Prediction Research and Transition Center (SPoRT)
- ***48*** Weather Forecast Offices served by the Cooperative Institute for Meteorological Satellite Studies (CIMSS)

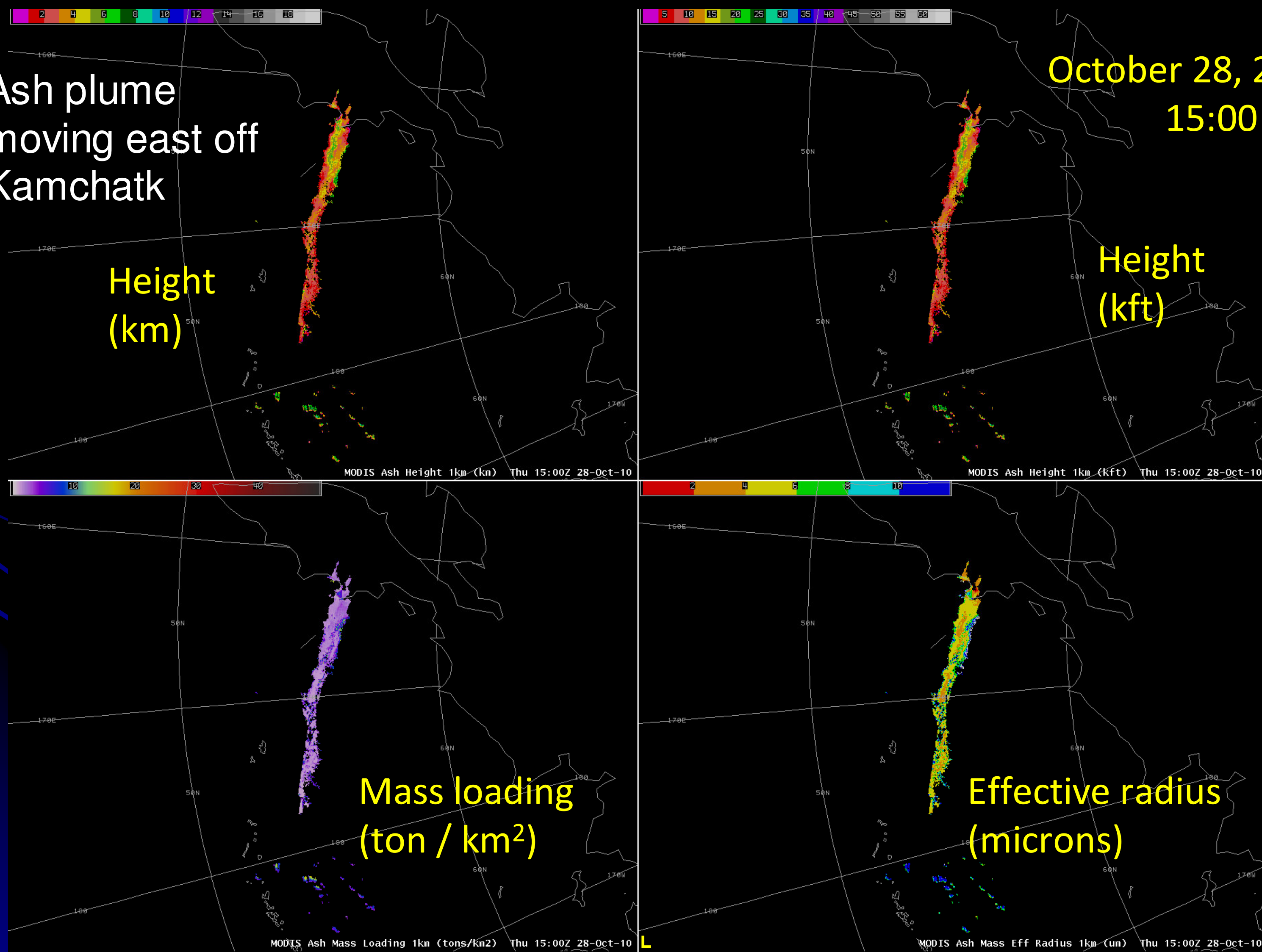
Volcanic Ash/SO_2

GOES-R (MODIS Proxy) Volcanic Ash



GOES-R (MODIS Proxy) Volcanic Ash

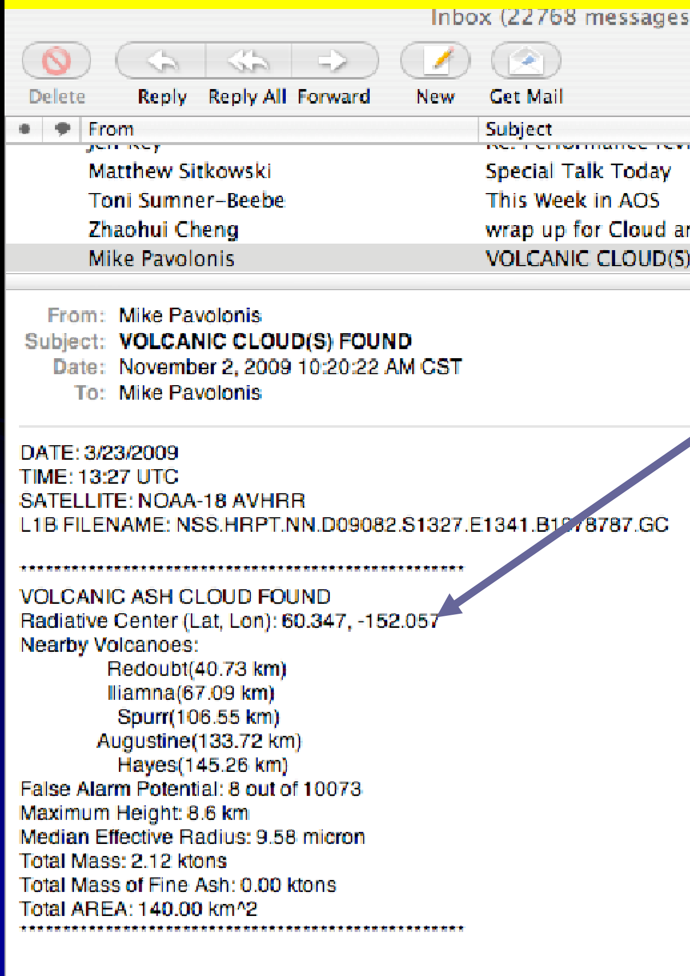
Products being evaluated by Anchorage Volcanic Ash Advisory Center as part of GOES-R PG



AVHRR automated ash cloud warning system

- The warning criteria is fully user configurable.
- In addition to the text message, an automatically generated, pre-analyzed false color image along with product images are supplied to the user.

Text Warning


Inbox (22768 messages

Delete Reply Reply All Forward New Get Mail

From	Subject
Matthew Sitkowski	Special Talk Today
Toni Sumner-Beebe	This Week in AOS
Zhaohui Cheng	wrap up for Cloud ar
Mike Pavolonis	VOLCANIC CLOUD(S)

From: Mike Pavolonis
Subject: VOLCANIC CLOUD(S) FOUND
Date: November 2, 2009 10:20:22 AM CST
To: Mike Pavolonis

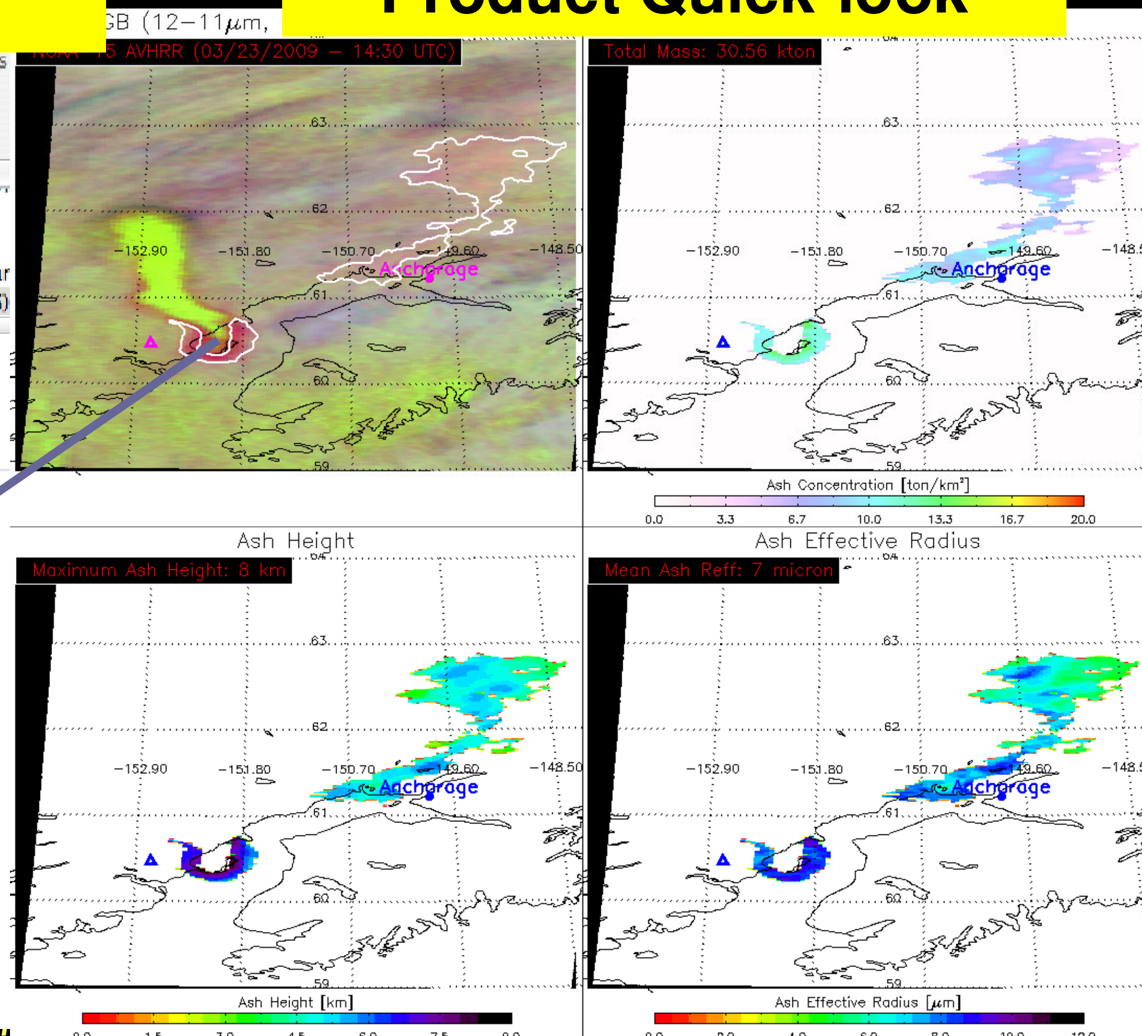
DATE: 3/23/2009
TIME: 13:27 UTC
SATELLITE: NOAA-18 AVHRR
L1B FILENAME: NSS.HRPT.NN.D09082.S1327.E1341.B1978787.GC

`**************************************************`

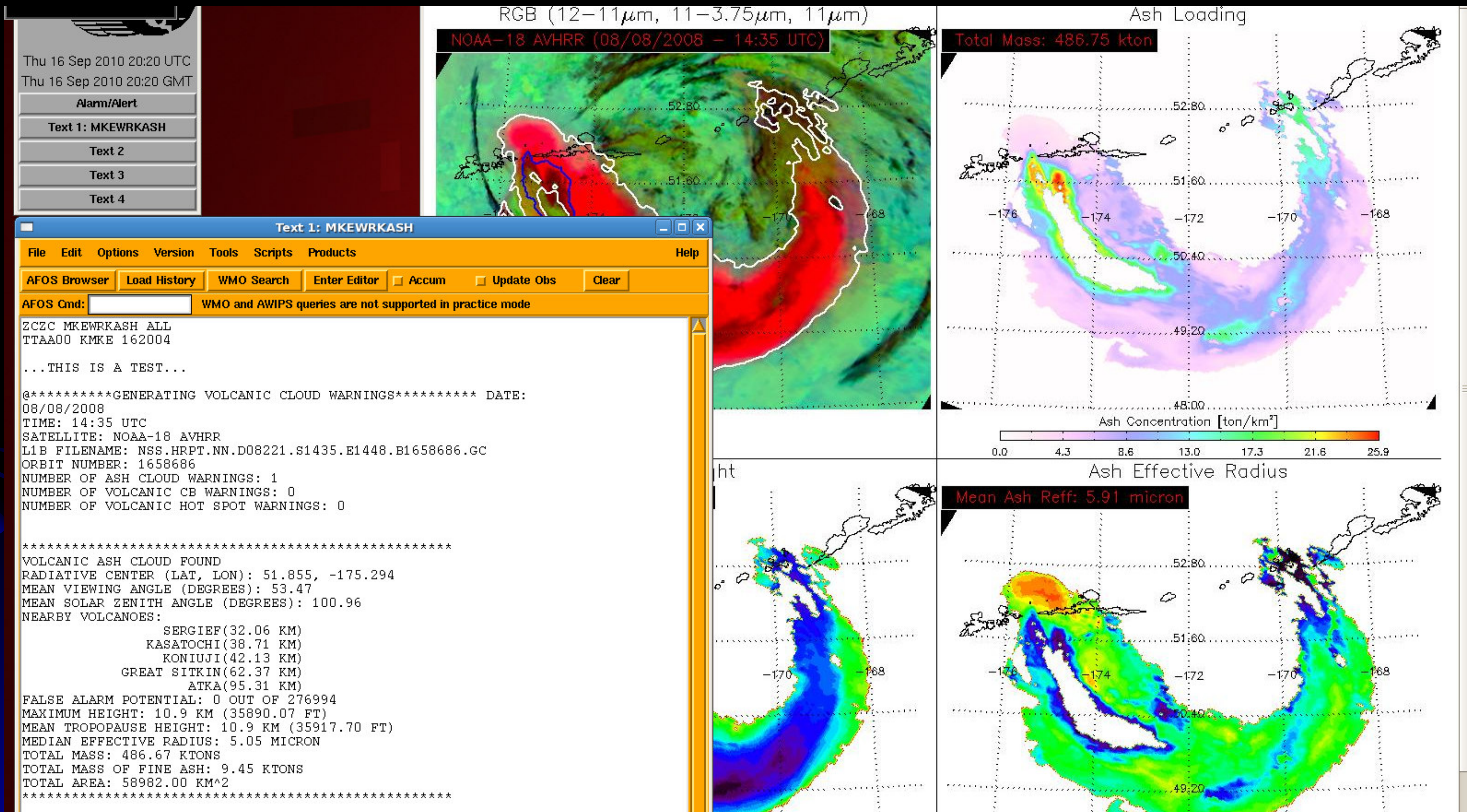
VOLCANIC ASH CLOUD FOUND
Radiative Center (Lat, Lon): 60.347, -152.057
Nearby Volcanoes:
Redoubt(40.73 km)
Iliamna(67.09 km)
Spurr(106.55 km)
Augustine(133.72 km)
Hayes(145.26 km)
False Alarm Potential: 8 out of 10073
Maximum Height: 8.6 km
Median Effective Radius: 9.58 micron
Total Mass: 2.12 ktons
Total Mass of Fine Ash: 0.00 ktons
Total AREA: 140.00 km^2

`**************************************************`

Product Quick-look

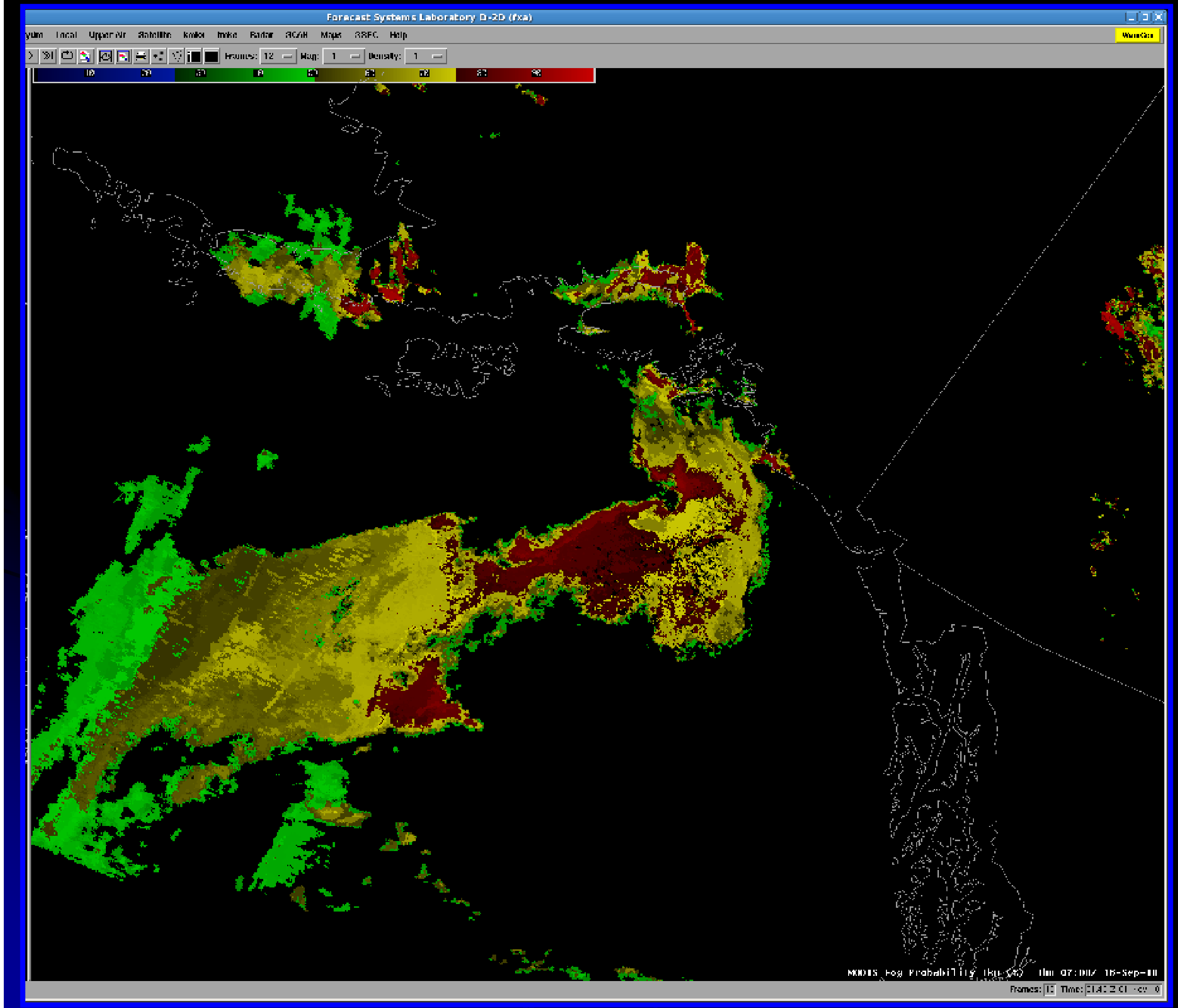


Automated Warning



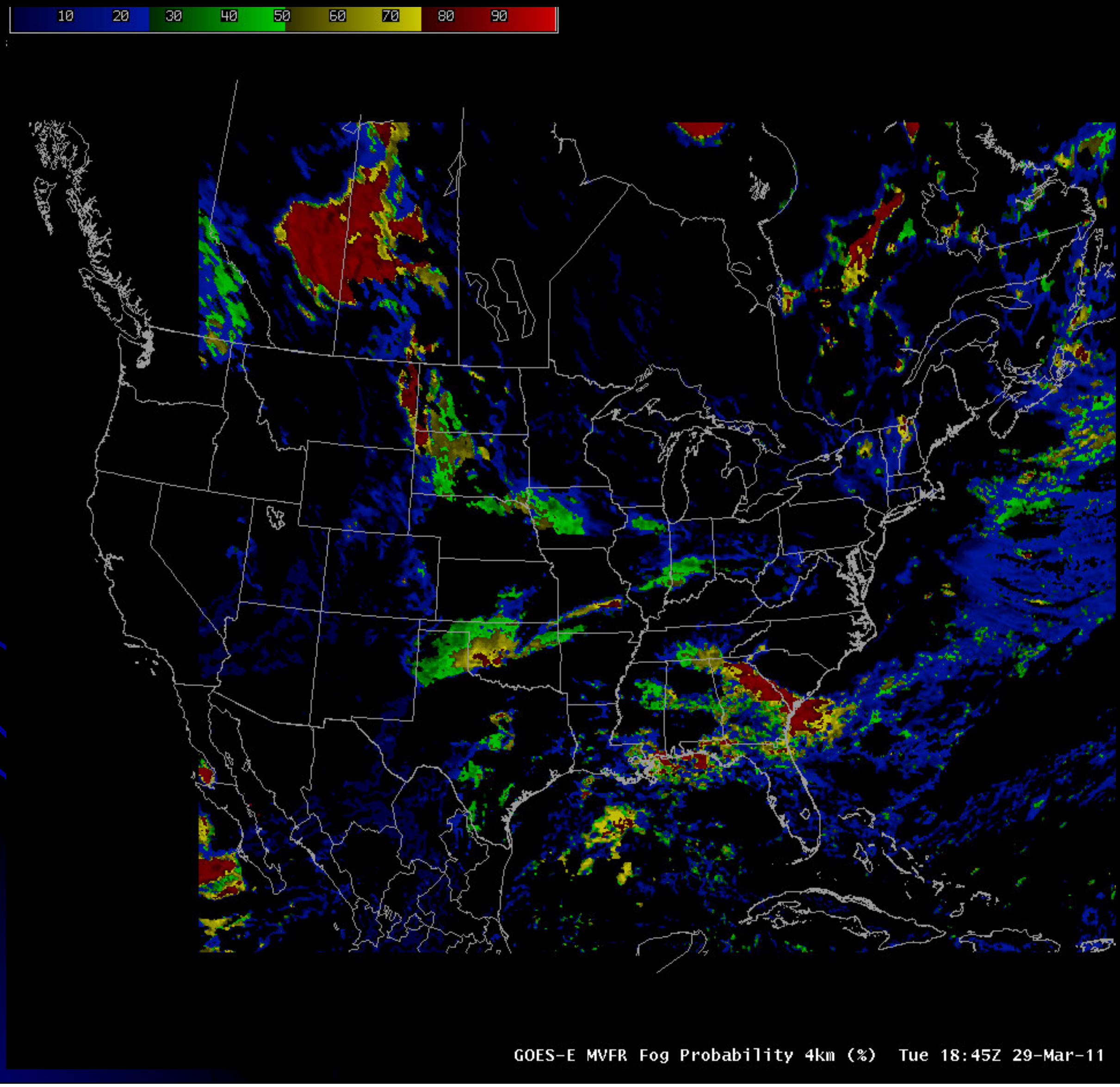
Low Cloud/Fog

High Latitude Testbed/AK Example Fog Probability (MODIS)

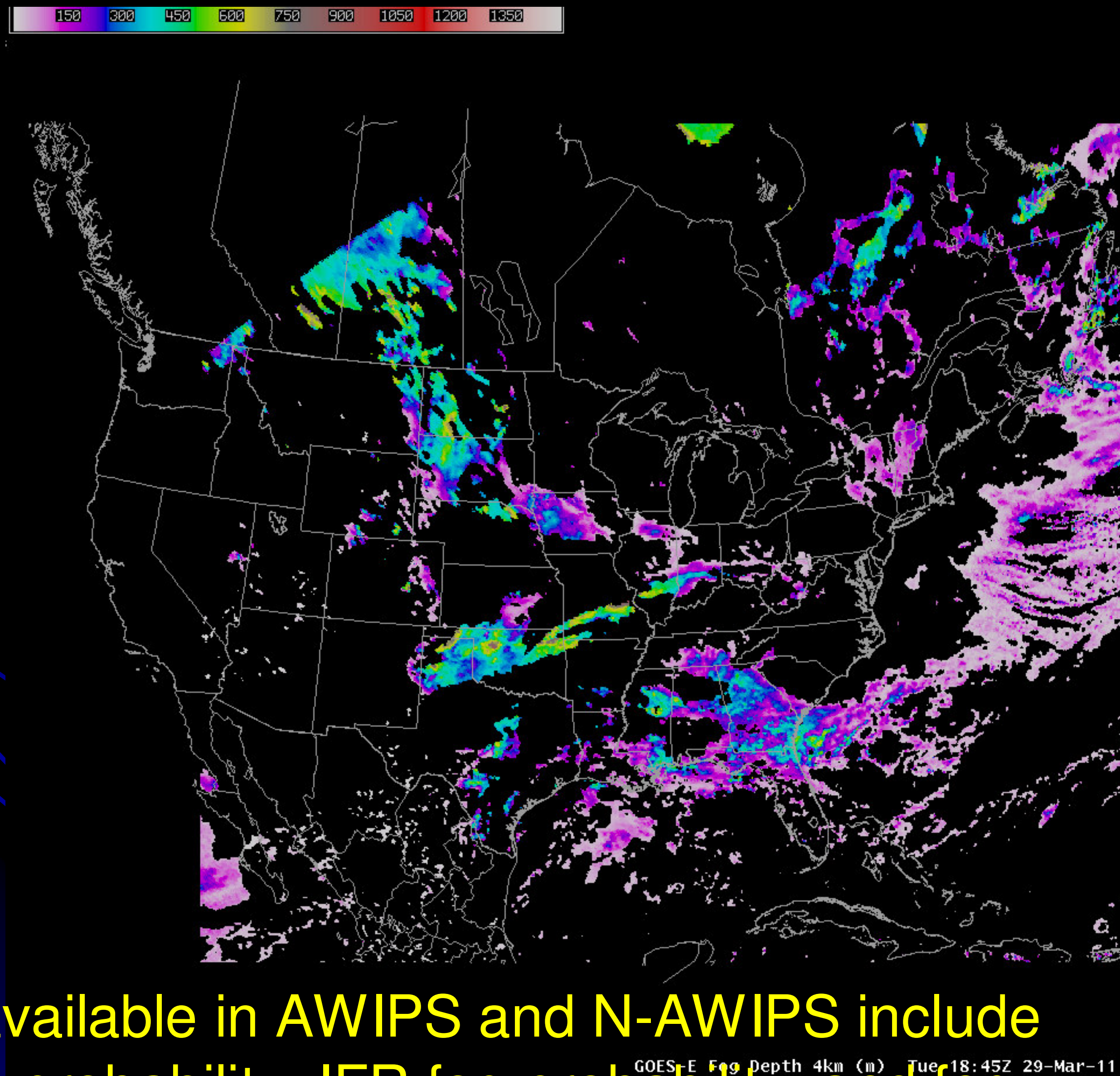


GOES-R (MODIS Proxy) Fog Probability Product in AWIPS September 16, 2010 – 07:00 UTC

AWIPS GOES-EAST MVFR Fog Probability at 1845 UTC 29 March 2011

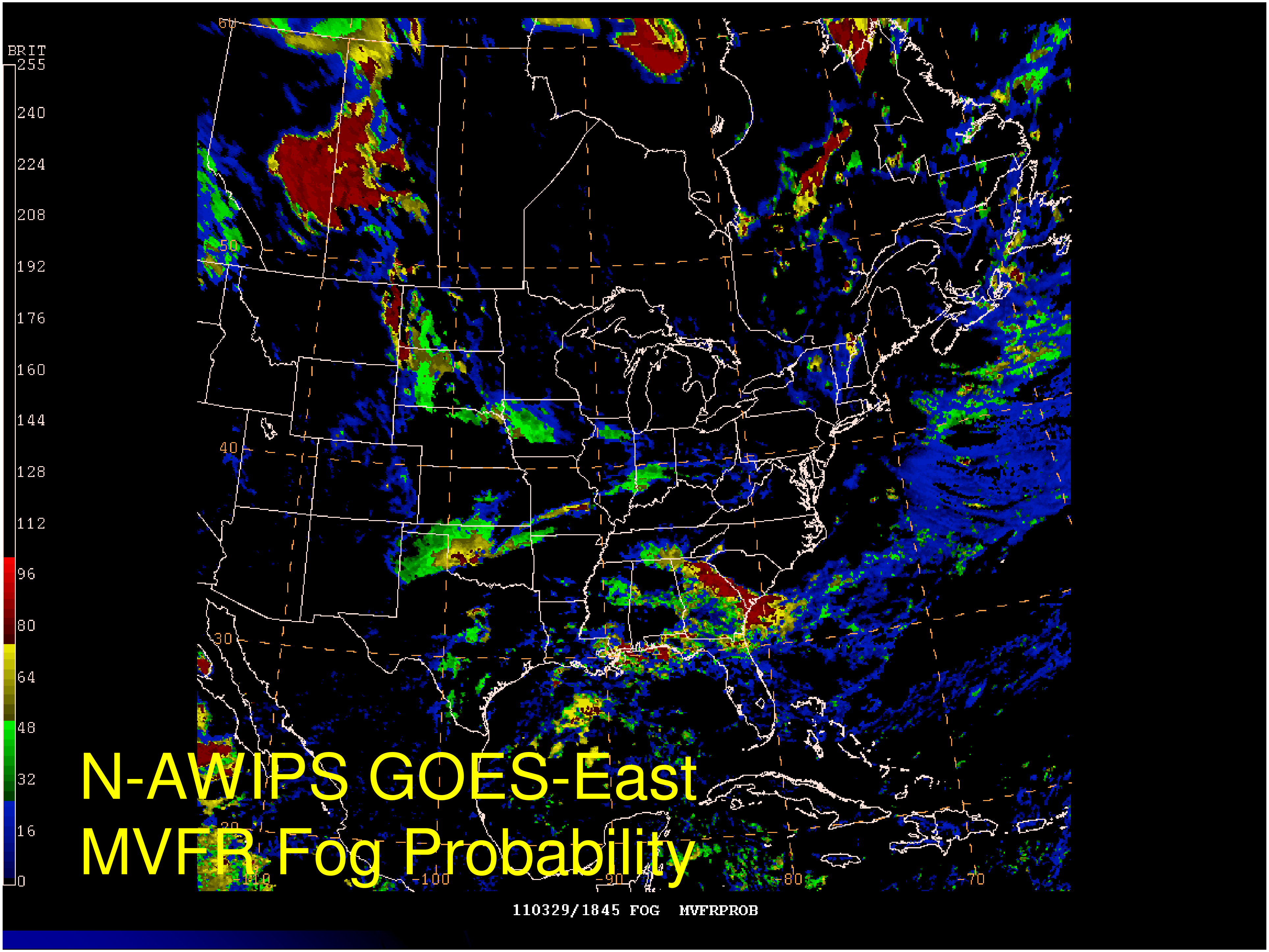


AWIPS GOES-EAST Fog Depth (meters) at 1845 UTC 29 March 2011.

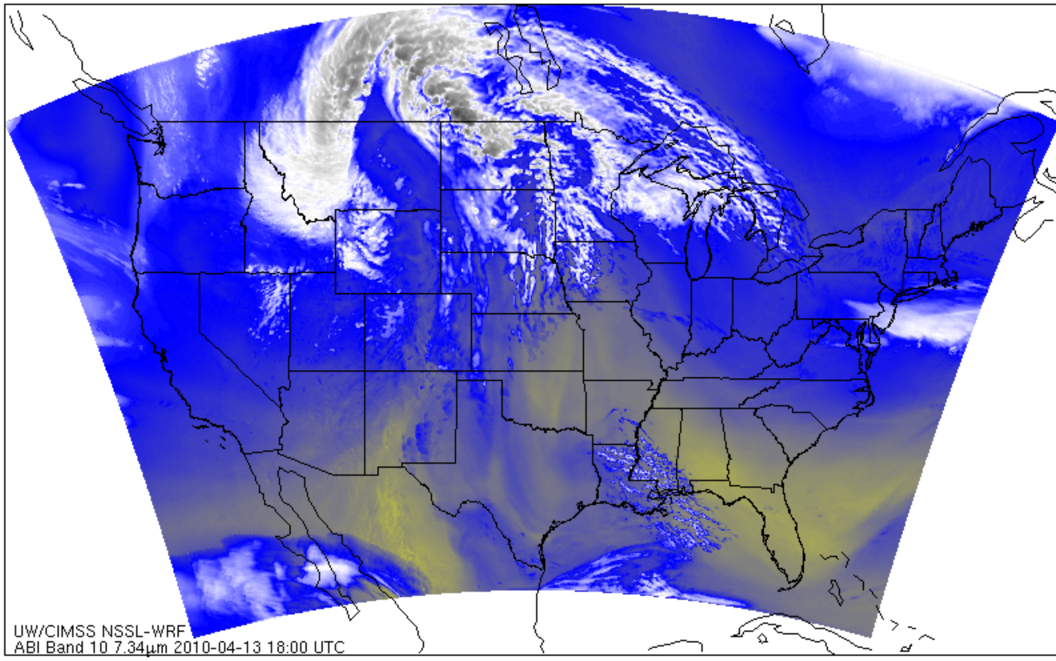


Products available in AWIPS and N-AWIPS include MVFR Fog probability, IFR fog probability, and fog

N-AWIPS GOES-East MVFR Fog Probability



NSSL WRF ARW Simulated ABI Imagery



UW/CIMSS is generating simulated ABI Bands 8-16 using NSSL-WRF once daily

Webpage is updated by 11am for 11 time steps.

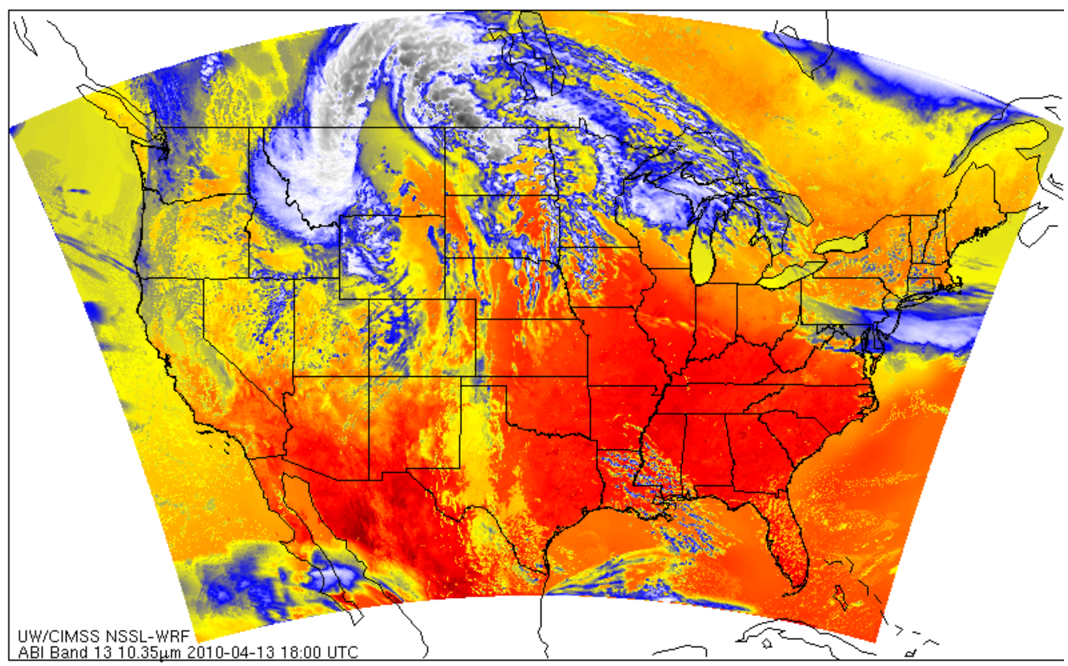
McIDAS areas for N-AWIPS display

ABI Band 10
(7.34 µm)

ABI Band 13
(10.35 µm)

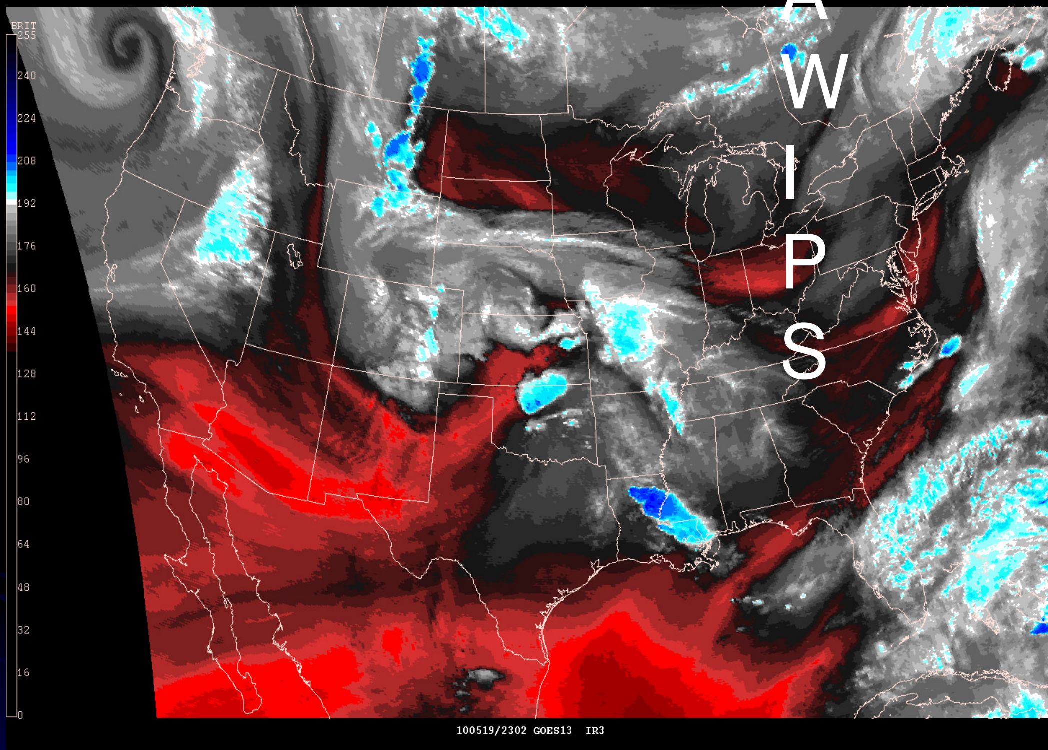
http://cimss.ssec.wisc.edu/goes_r/proving-ground/nssl_abi/nssl_abi_rt.html

Environmen

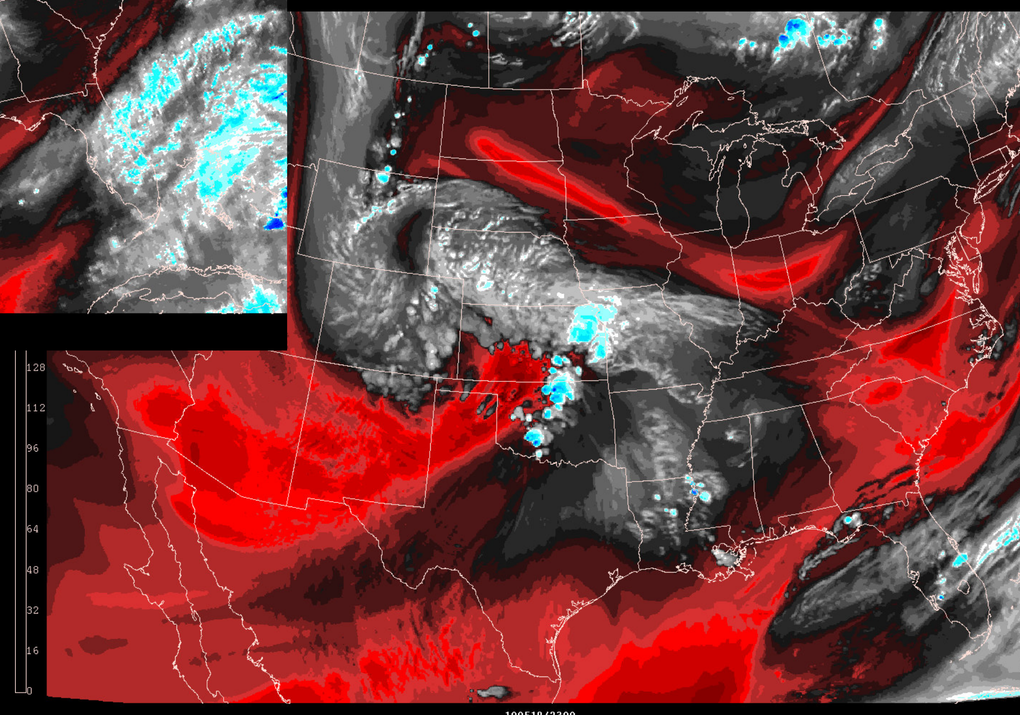


Simulated

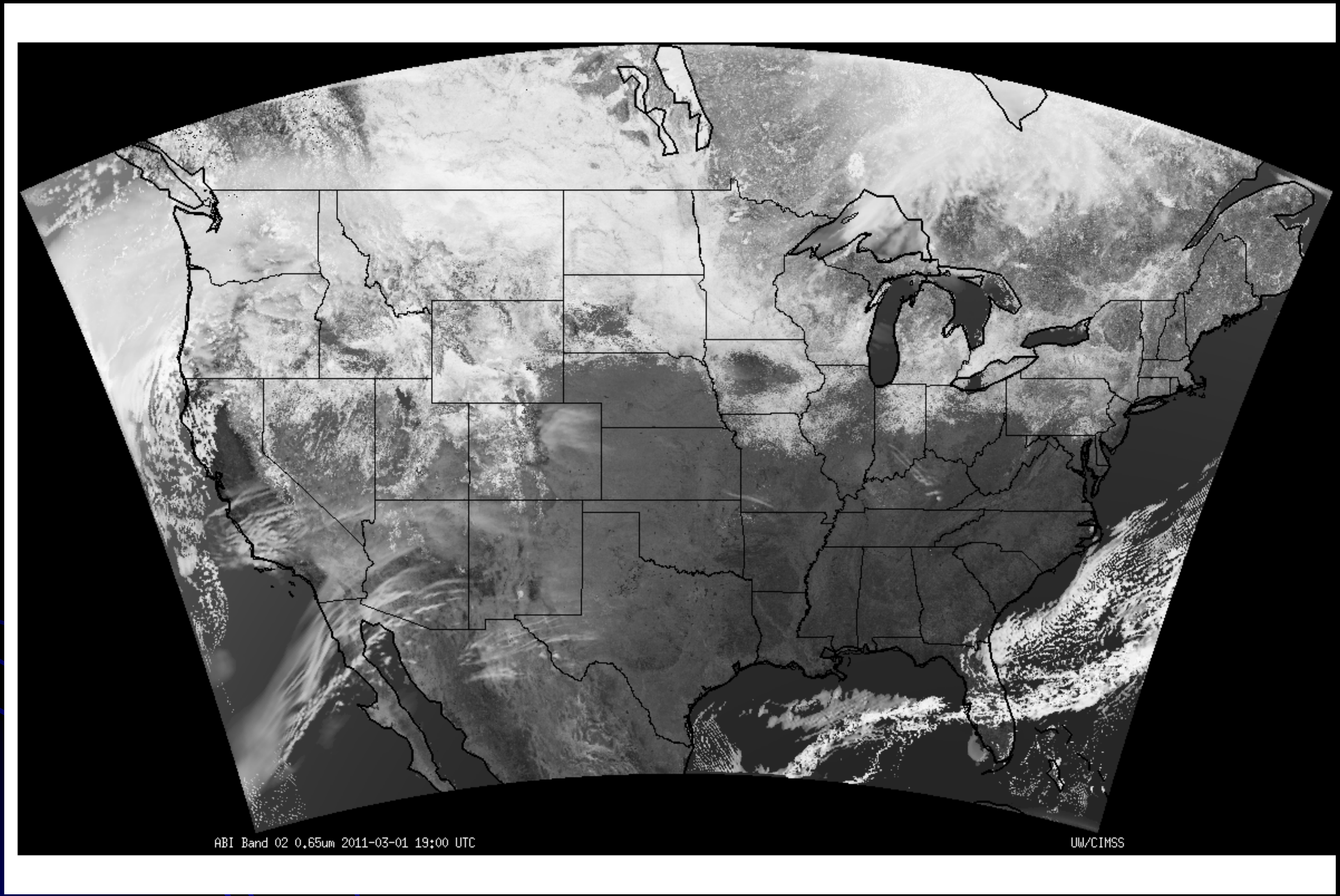
N-AWIPS



GOES-13 Observed



New near real-time visible channel simulation (HWT 2011)



http://cimss.ssec.wisc.edu/goes_r/proving-ground/nssl_abi/animations/abi_band02.html

NSSL WRF ABI Band 2 Simulated by UW/CIMSS using 'fast' solar RTM
1900 UTC -- 01 March 2011

Avoid Stovepiping

Most of these science product requirements are being dovetailed into operational venue (examples below), other avenues to operations are becoming apparent (DOD AFWA)

- Turbulence – GTG-N
- Convective initiation - CoSPA
- Icing - CIP
- Volcanic Ash – VAACs

Summary

- Transition of National Airspace to NextGen environment will heavily use various satellite based weather information

- The GOES-R AWG teams are working toward algorithms ready to produce level-2 data at first light (~2015)

- New validation resources have provided decision support confidence that was non-existent a decade before, therefore we are still learning how to use current GOES imager technology

- GOES-R algorithm development has fostered new decision support applications with current imager technology

Summary

- GOES-R science requirement algorithms have a valid use in operations with current (proxy) imager radiances and are finding new decision support value as methodology matures

- With transition to future operational satellite sensors such as NPOESS and GOES-R, reliance on this information for operational support decisions

- Successful research to operations requires diversity in agency objectives and funding requirements =
COOPERATIVE INSTITUTES!!

Acknowledgments

- NASA Applied Sciences Program through the Advanced Satellite Aviation Weather Products (ASAP) initiative and NASA ROSES Decision Support resources

- NOAA GIMPAP and GOES-R AWG, R3, and PG Research Program Support

Turbulence 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
- 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
- Lenz, A., 2008: Identification of Aviation Turbulence Signatures from Mesoscale Convective Features using Satellite Imagery. UW-Madison Senior Undergraduate Thesis, Atmospheric Oceanic Sciences Department
- Lenz, A., K. Bedka, W. Feltz, and S. Ackerman, 2009: Convectively-Induced Transverse Band Signatures in Satellite Imagery. Accepted for publication in J. of Weather and Forecasting.
- Uhlenbrock, N. L., K. M. Bedka, W. F. Feltz, and S. A. Ackerman, 2007: Mountain Wave Signatures in MODIS 6.7- μ m Imagery and Their Relation to Pilot Reports of Turbulence. Wea. Forecasting, 22, 662–670.

Convection References

- Bedka, K. M., J. Brunner, R. Dworak, W. Feltz, J. Otkin, and Thomas Greenwald, 2010. Objective Satellite-Based Overshooting Top Detection Using Infrared Window Channel Brightness Temperature Gradients, Jour. of Appl. Meteor. and Clima, 49, 2, 181-202.
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Questions?

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