Overview of Satellite Support for SEAC^{4}RS

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SEAC4RS Science Team Meeting
Boulder, CO, 29-30 Apr – 1 May 2012

OBJECTIVES

- Provide satellite complement to in situ, ground, and modeling studies
  - Provide high temporal resolution imagery
  - Provide consistent retrievals of cloud properties
- Provide real-time support in field
  - Real-time imagery and interactive analysis
    - mission planning & execution
  - Near-real time cloud retrievals

Data

- GOES-E 4-km resolution (15 min, possible 1-min RS)
  - *0.65, 3.9, 6.7, 10.8, 13.3 µm*
- GOES-W 4-km resolution (15 min, possible 1-min RS)
  - *0.65, 3.9, 6.7, 10.8, 13.3 µm*

Support work horses

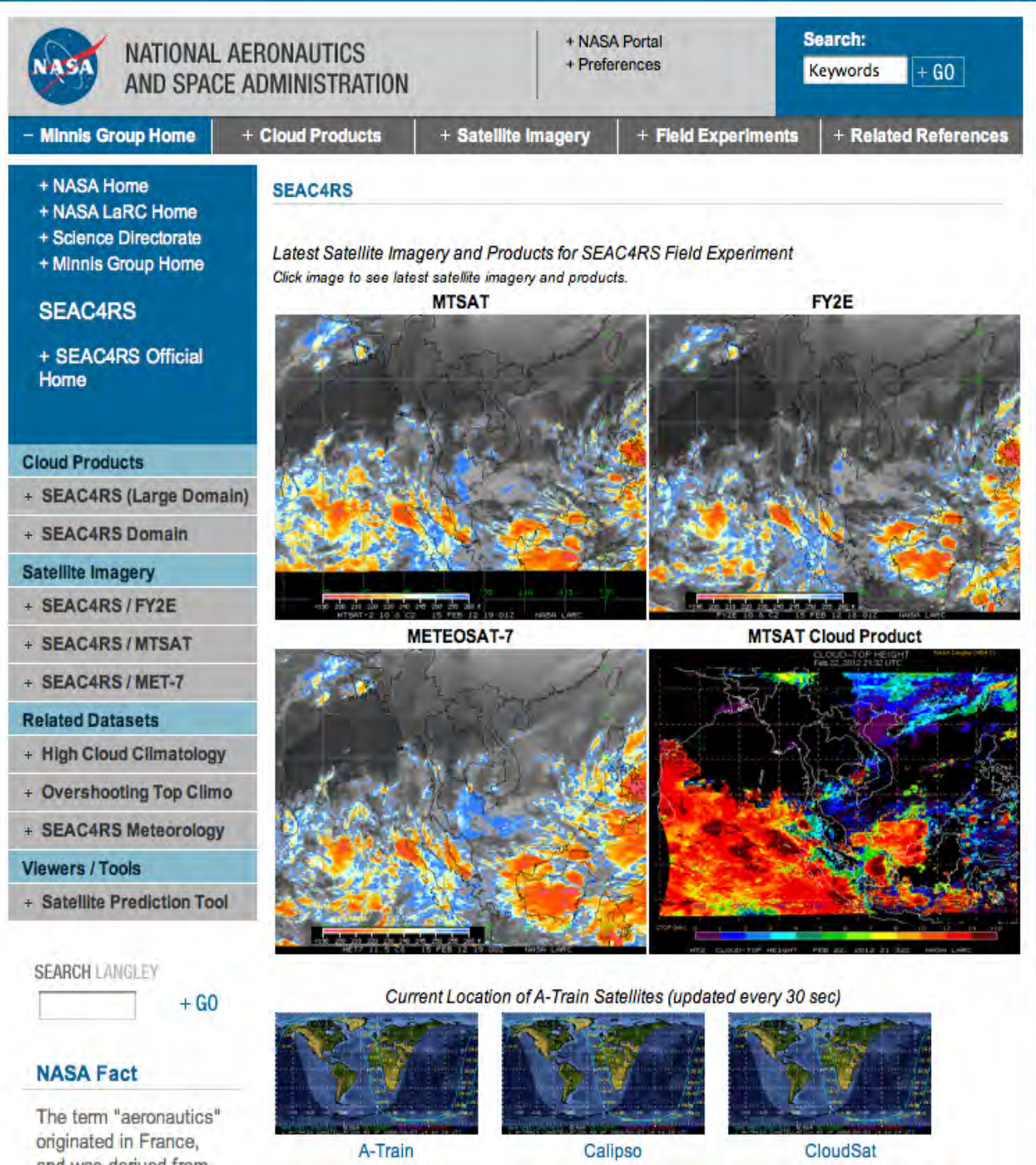
- MODIS, twice daily (Terra & Aqua [A-train]), 1-km
  - multispectral
- NPP VIIRS, 1-km multispectral 1330 LT
- NOAA-15/16/18/19 AVHRR; TRMM VIRS, TMI

Langley SEAC4RS Web Page

http://
cloudsgate2.larc.nasa.gov

Click on "SEAC4RS" on sidebar
or from main SEAC4RS page

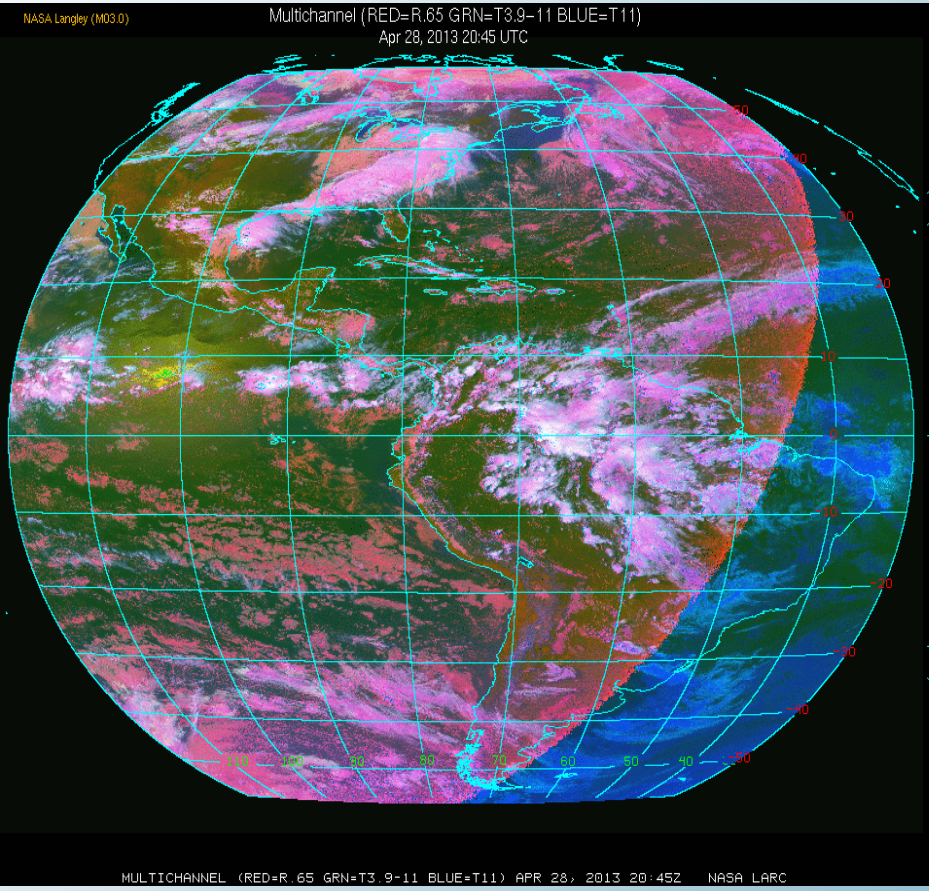
Still focused on SE Asia
Need to decide on domains before revising

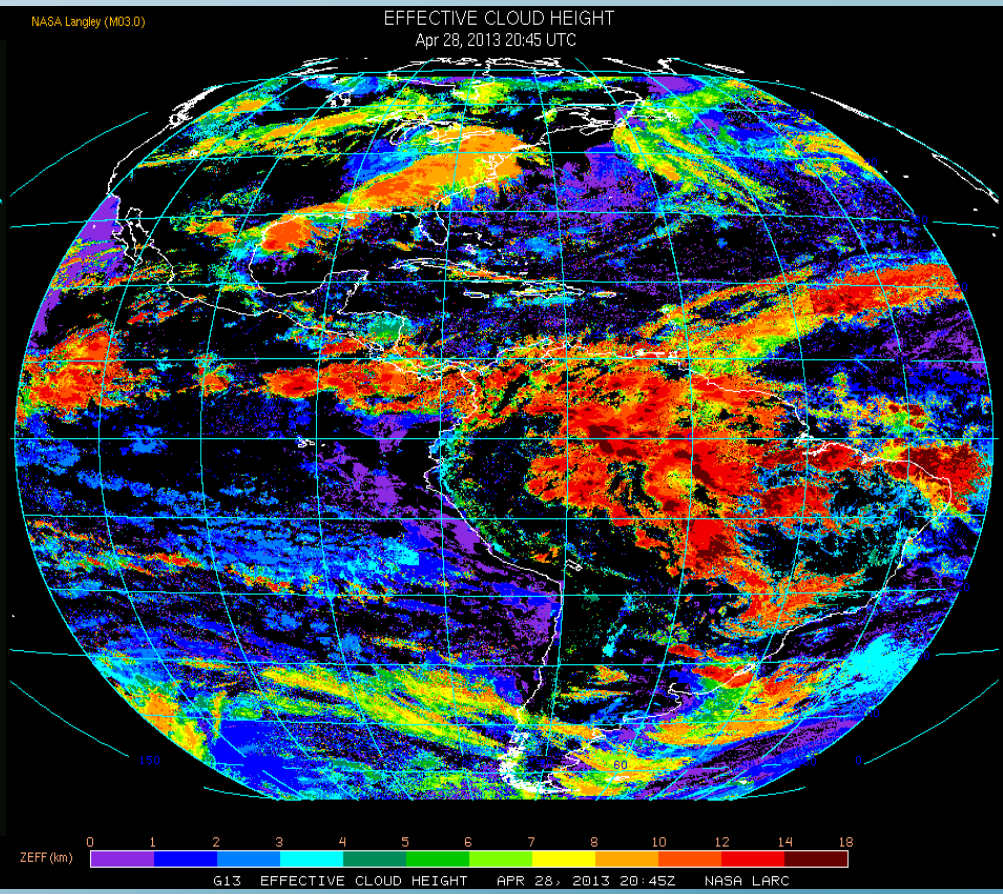


GOES Retrieval Domains
2045 UTC, 28 Apr 2013

North American Domain (8-km,1.0 hr)

Cloud Height (km)

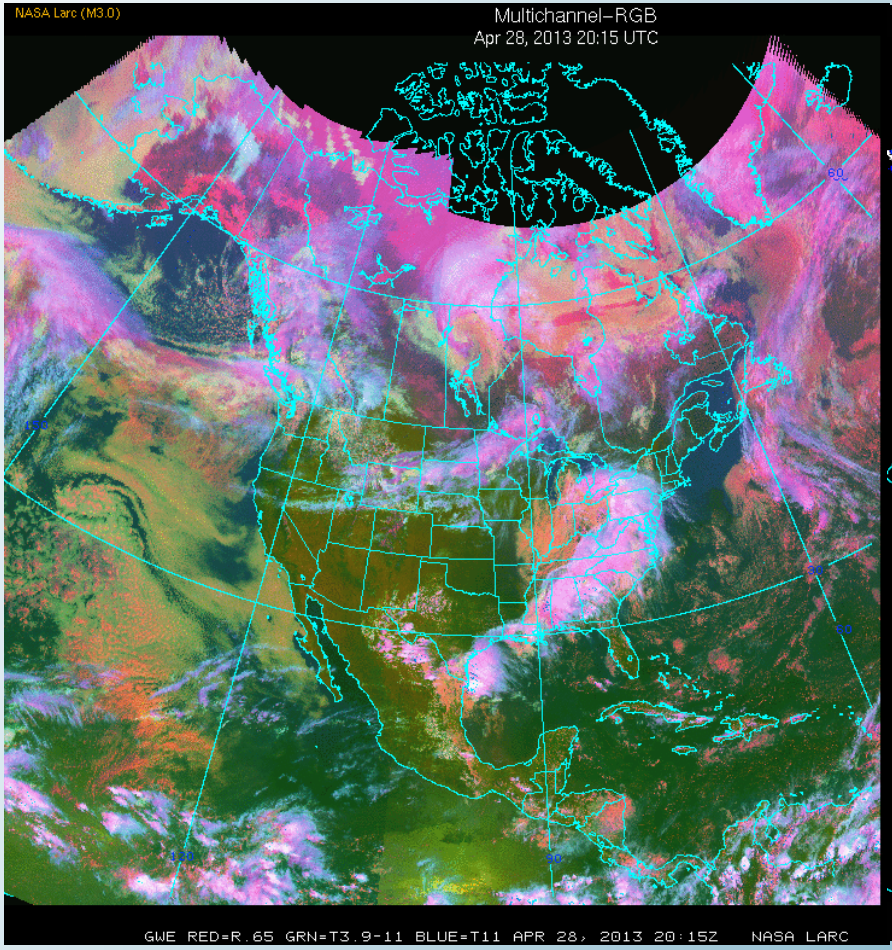




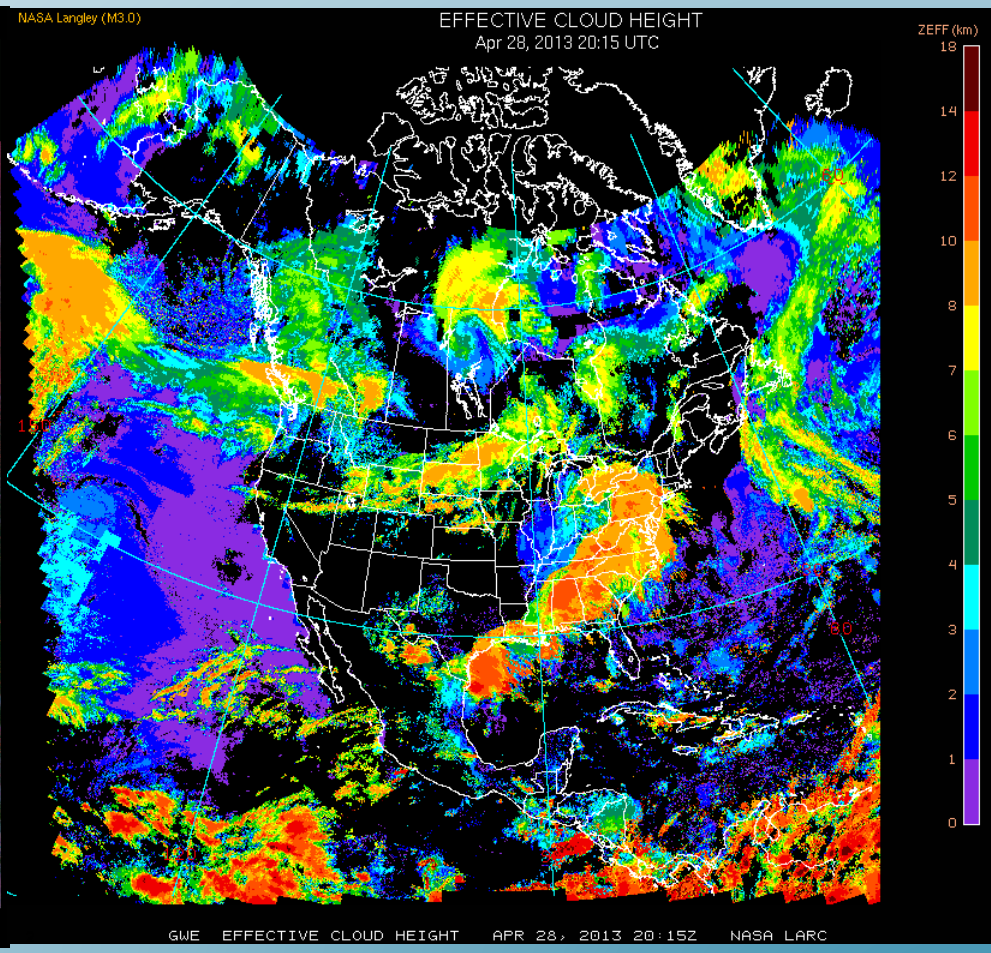
Products generated for all GEOSats, each hour

GOES North American Retrieval Domain
2015 UTC, 28 Apr 2013

RGB (8-km, 0.5 hr)

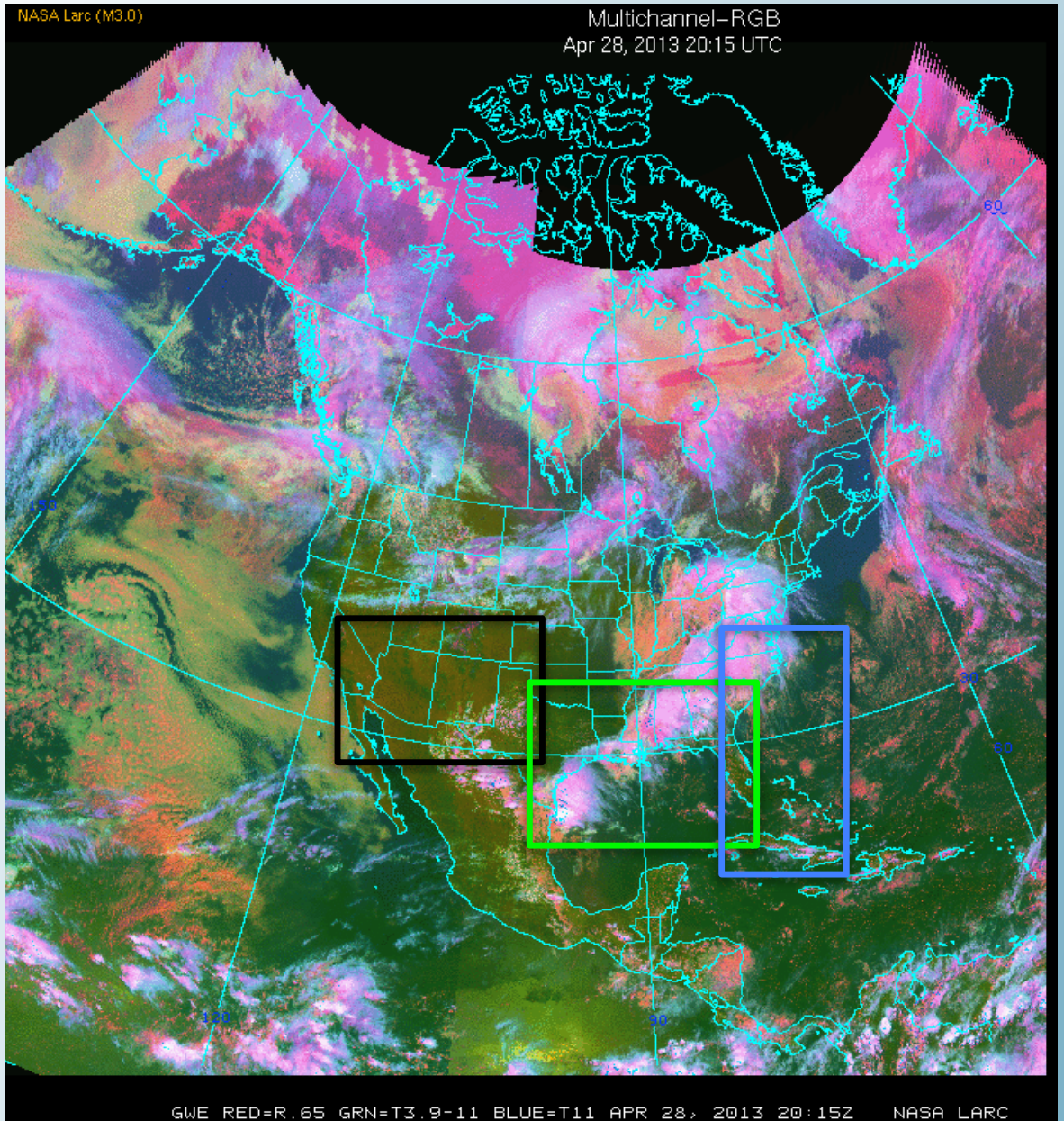


Cloud Height (km)



Products available < 30 min after image time
Supplied to NCEP for Rapid Refresh Model

GOES Retrieval Domains? SEAC4RS 2015 UTC, 28 Apr 2013



- Hi temporal & spatial resolution
  - 1-km VIS, 4-km other
  - 15 min + RS
- Fixed domains?
  - Monsoon
  - SE US pollution
  - Atlantic hurricane?
- Floating domain?
  - build around flight plan
  - use subsets of NA domain for modeling studies?

NASA Langley Cloud Products

Standard, Single-Layer VISST/SIST

0.65, 1.6 μm Reflectances	**Cloud**
3.7, 6.7, 10.8 μm Temp	Mask, Phase
12 or 13.3 μm Temp	Optical Depth, IR emissivity
Broadband TOA Albedo	Cloud effective particle size
Broadband OLR	Liquid/Ice Water Path
Clear-sky Skin Temperature	Effective Temp, height, pressure
Icing Potential**	Top/ Bottom Pressure
Pixel Lat, Lon	Top/ Bottom Height
Pixel SZA, VZA, RAZ	**Overshooting tops** (new)

Multi-Layer, CIRT, CO_2 channel only (GOES-12 & later)

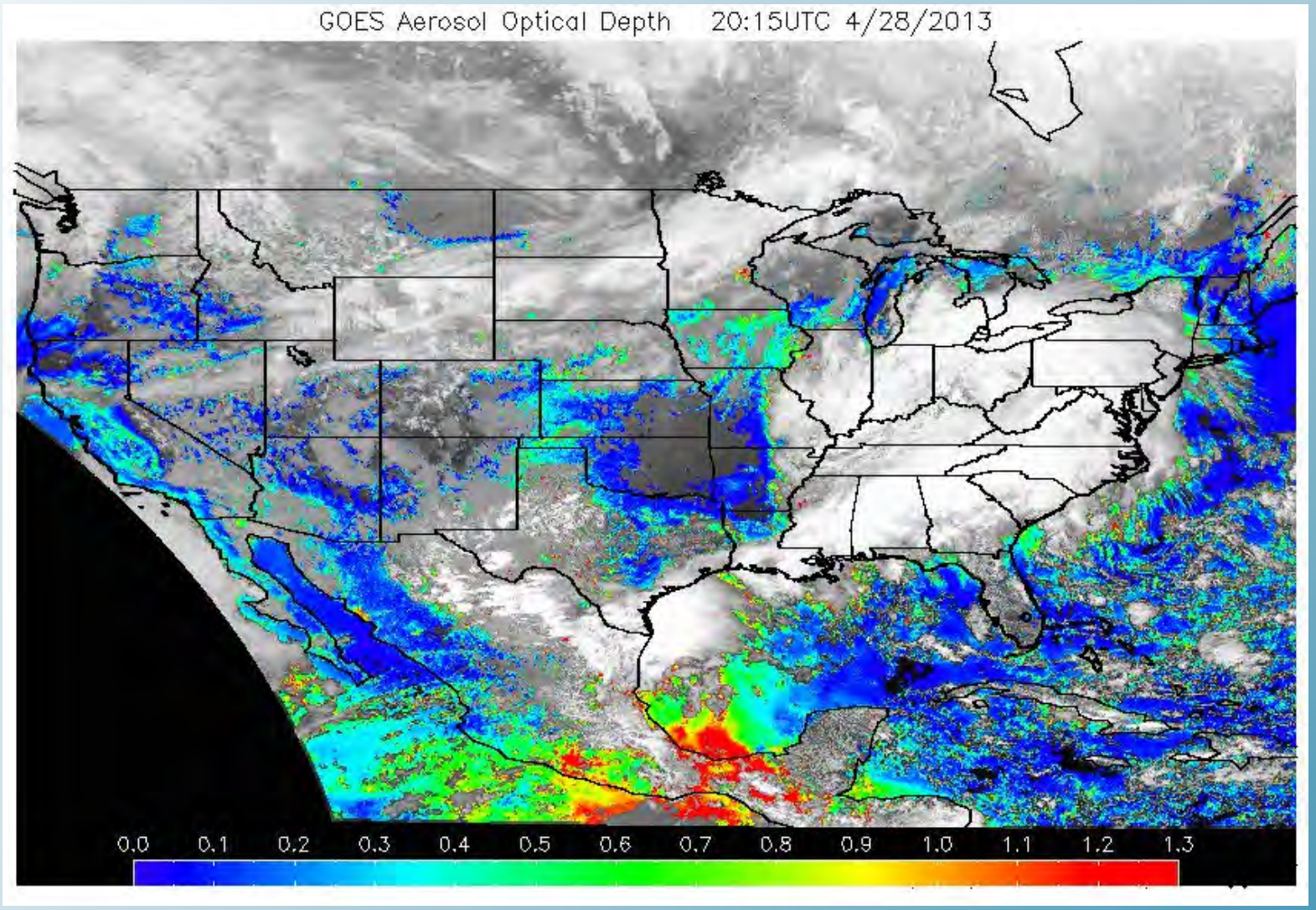
Upper & lower cloud

Multilayer ID (single or 2-layer)

effective temperature	optical depth, thickness
effective particle size	ice or liquid water path
height, top/base height	pressure

NOAA GASP Half-hourly Aerosol Product

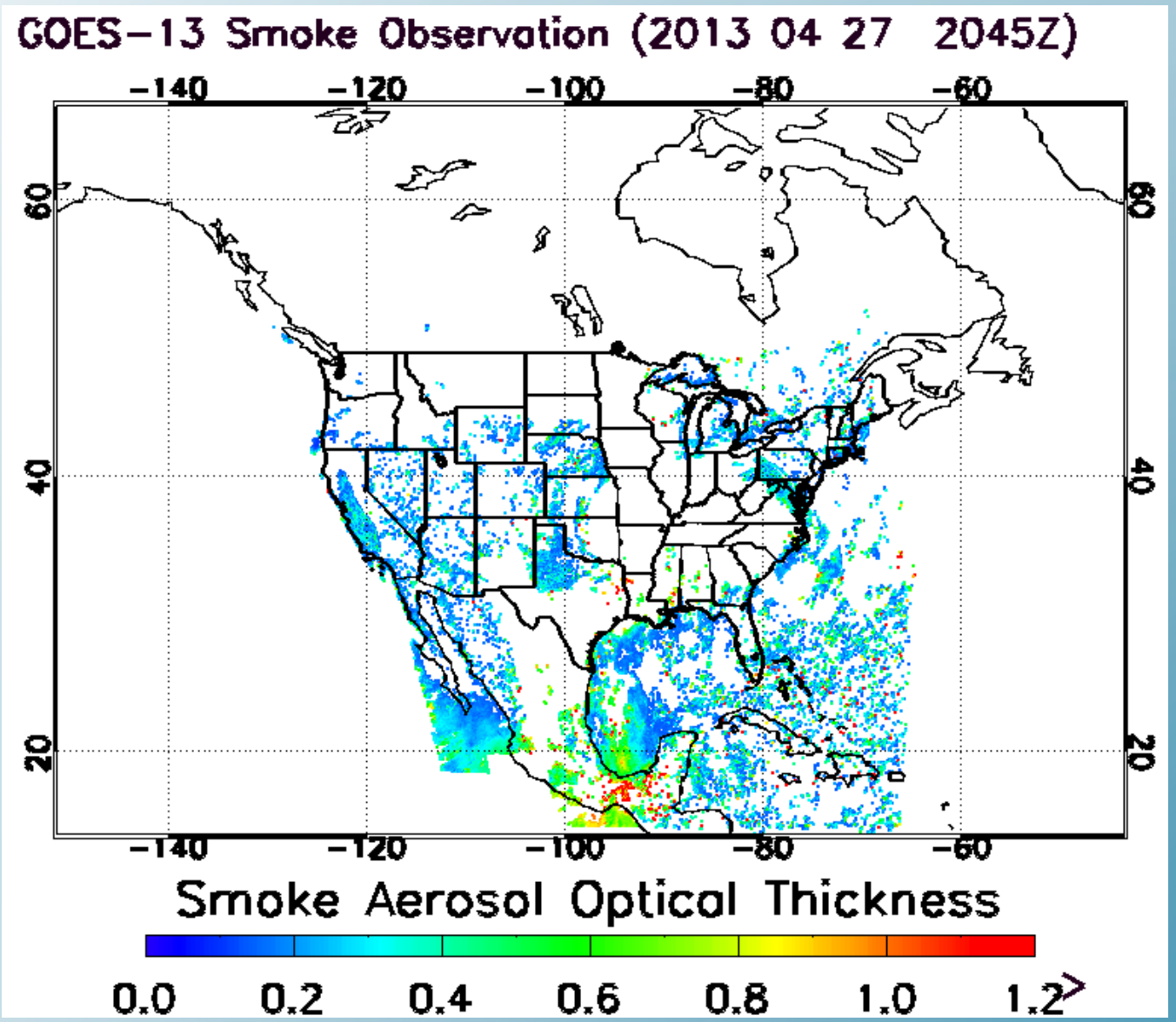
4-km, half-hourly, 2015 UTC, Apr 2013



- Will also bring in daily MODIS AOD data

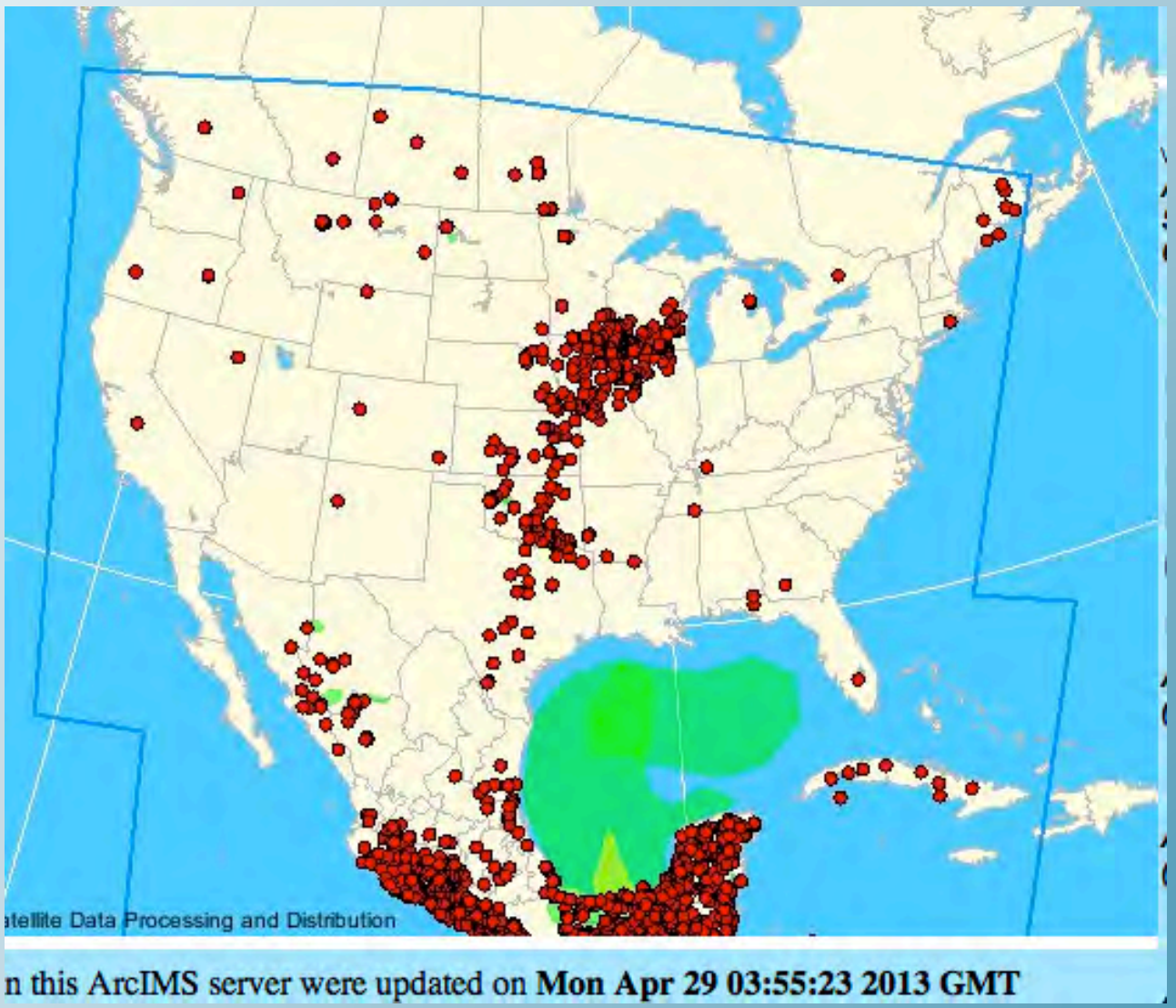
NOAA GASP Half-hourly Smoke AOD Product

4-km, half-hourly, 2015 UTC, Apr 2013



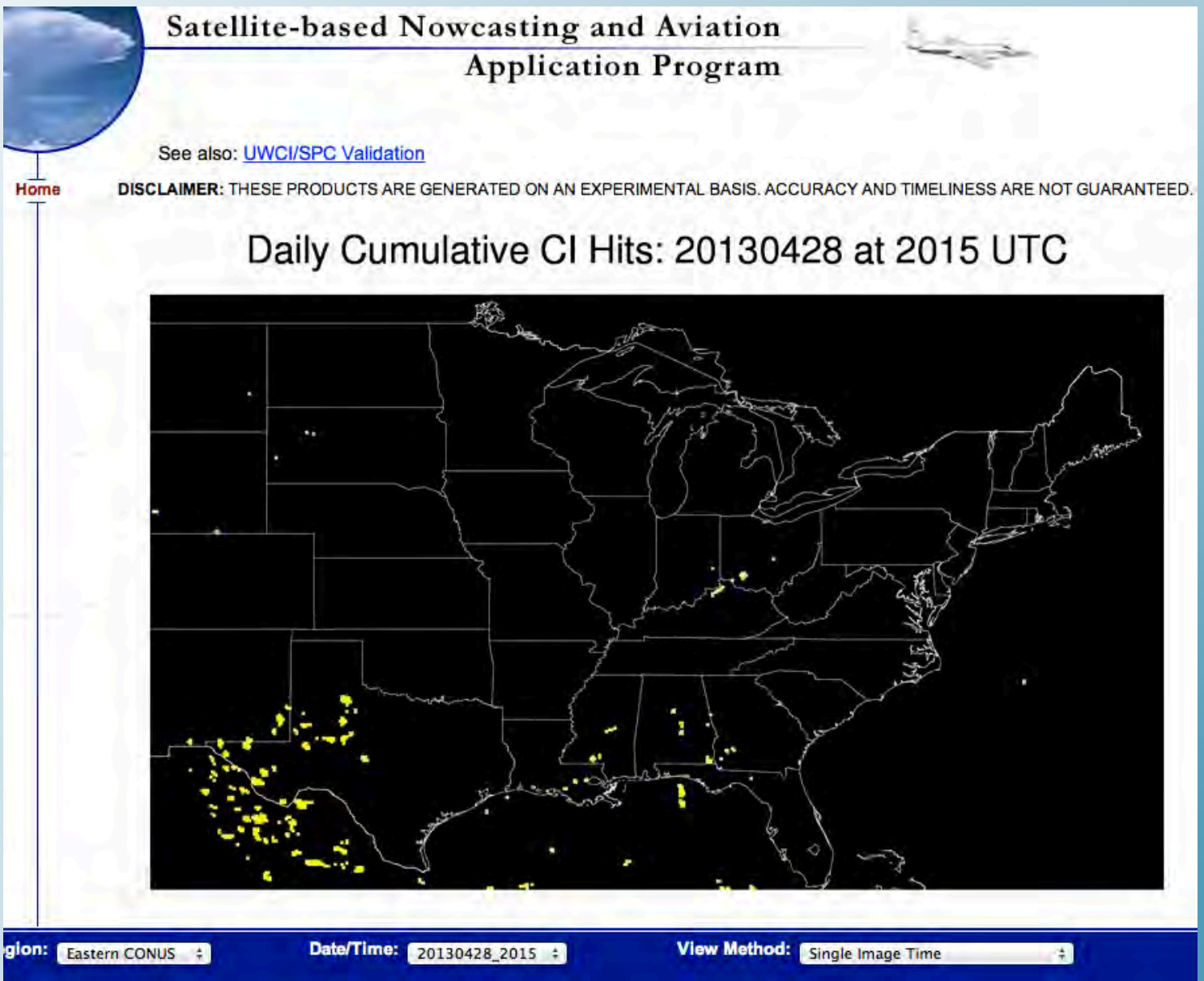
NOAA Fire Product

Analyzed fires and smoke (green) 0400 UTC, 29 Apr 2013



CIMSS 15-min Convective Initiation Product

- Could aid in-flight route modification, experimental



Summary

- Capabilities on site will be much enhanced compared to online data
  - change resolution, satellite, and domain as desired
  - provide exact locations of objects as needed
  - variety of loops and model overlays as needed
  - flight tracks in near real time (given the nav data)
- Add additional satellites or links to web page
  - MODIS, NPP, AVHRR, CALIPSO, CloudSat, TRMM
  - pursue acquisition of other NRT products
    - convective initiation
    - fires
    - aerosols, GOES & MODIS
- Matching of data with flights and ground sites as it comes in
  - cloud products & radiances
- New algorithms to retrieve thin cirrus & ML clouds to be employed
    - nowcast cloud curtains
- Add features as requested, if possible

Objective Overshooting Convective Cloud Top Detection

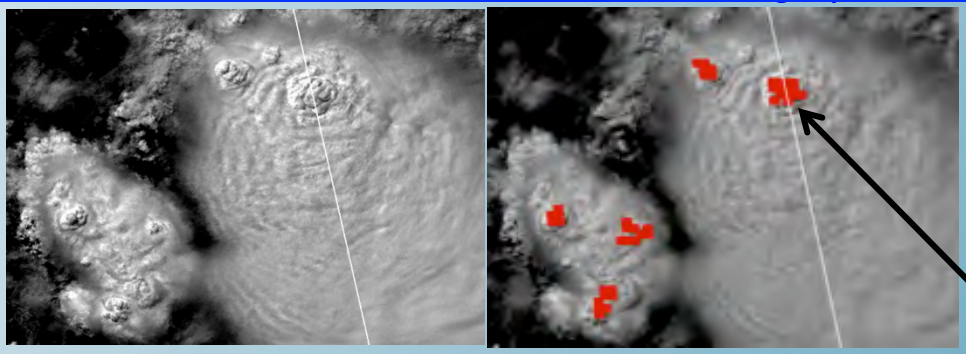
• A method to objectively detect overshooting convective cloud tops and the enhanced-V signature has been recently developed within the GOES-R Aviation Algorithm Working Group

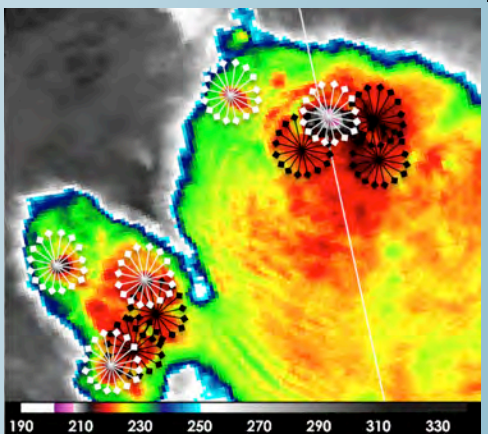
• Overshooting convective cloud tops represent deep convective updrafts that have penetrated through the local equilibrium level and into the UTLS region

• Adiabatic cooling induced by strong vertical ascent causes overshooting tops (OTs) to appear as a small regions (< 15 km diameter) of anomalously cold IR brightness temperatures surrounded by a warmer cirrus anvil cloud

• An objective OT detection algorithm utilizes IR brightness temperature and spatial gradient thresholding with NWP tropopause temperature information to identify OTs at their characteristic spatial scale

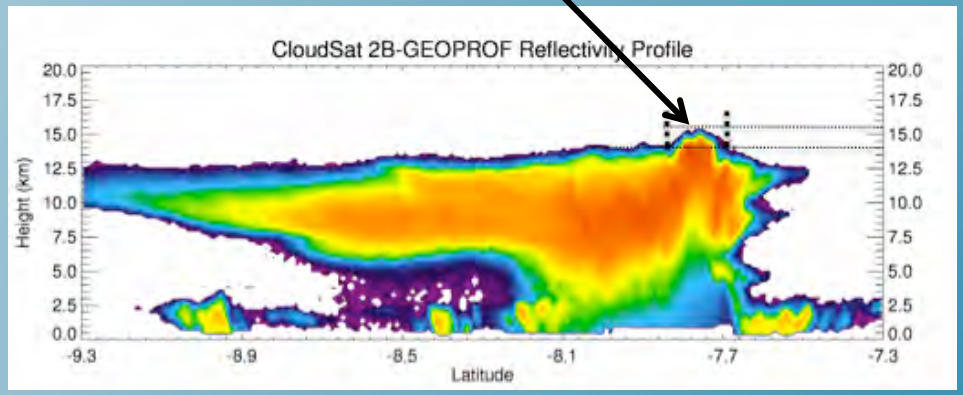
MODIS 250 m Visible and 1 km IR Window With Overshooting Top Detections

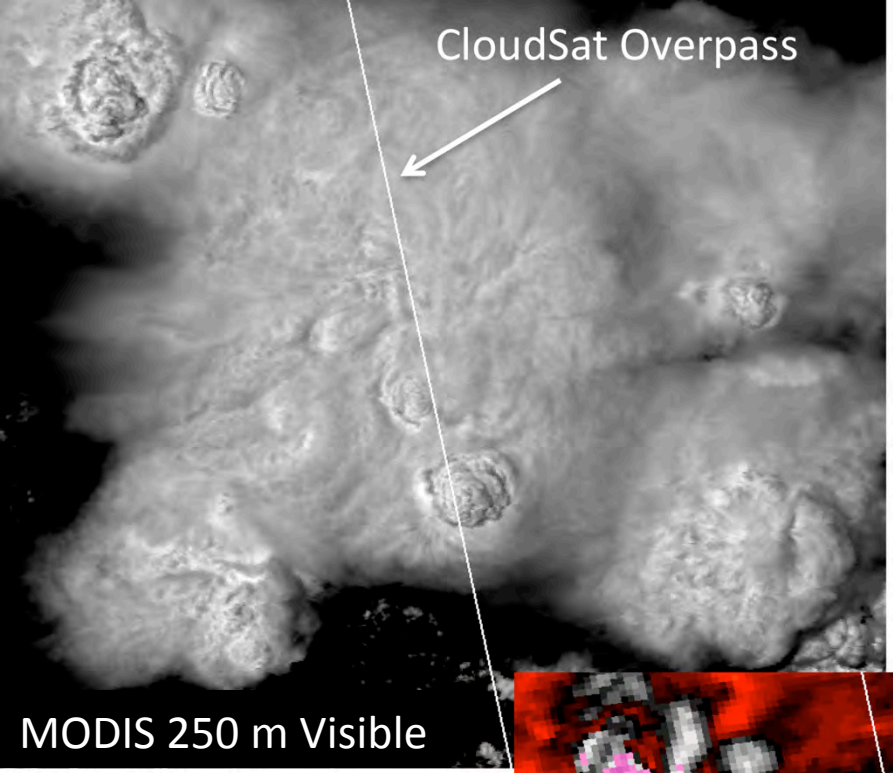


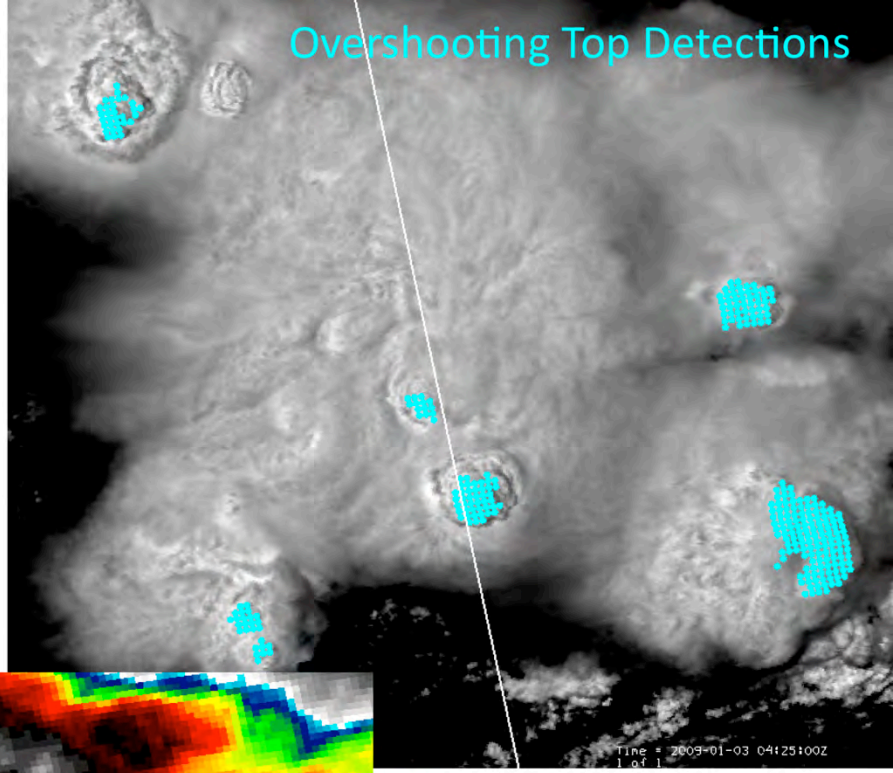


White: Region meets OT detection criteria

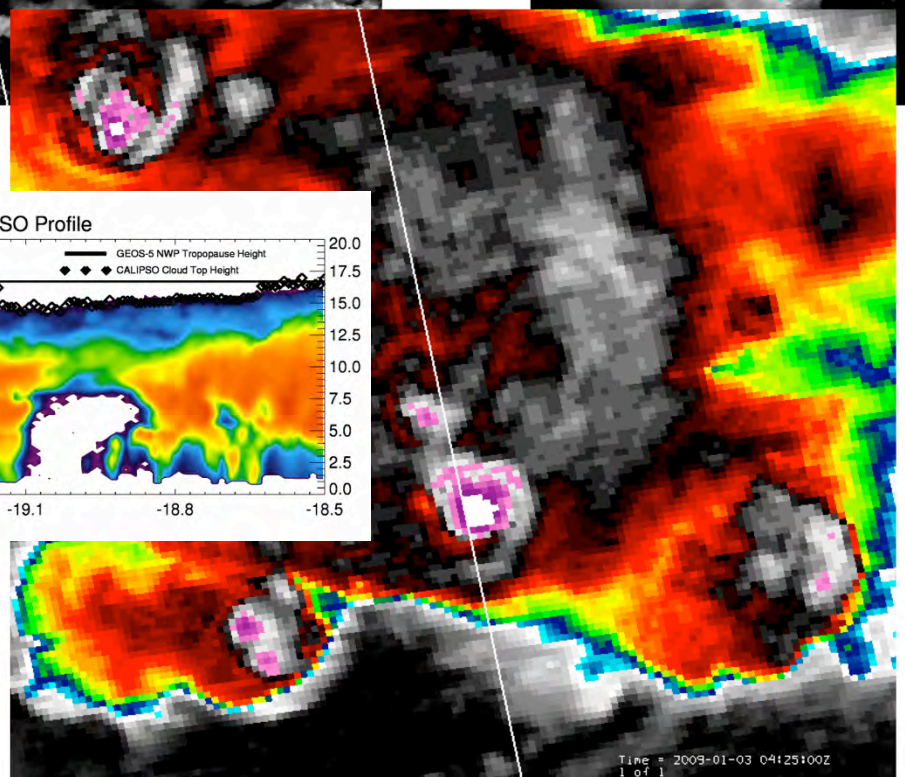
Black: Region not cold enough relative to surrounding anvil

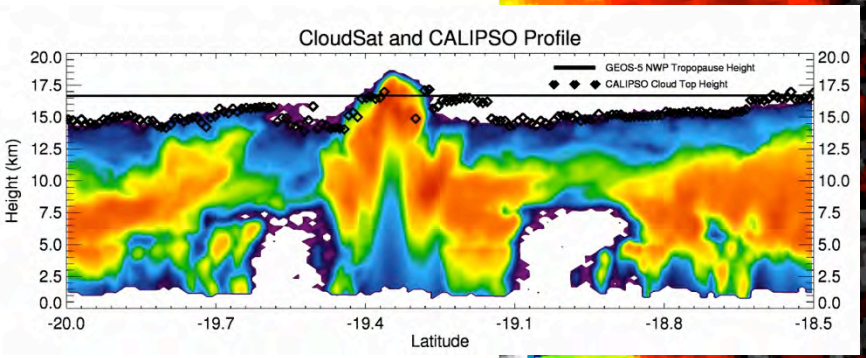






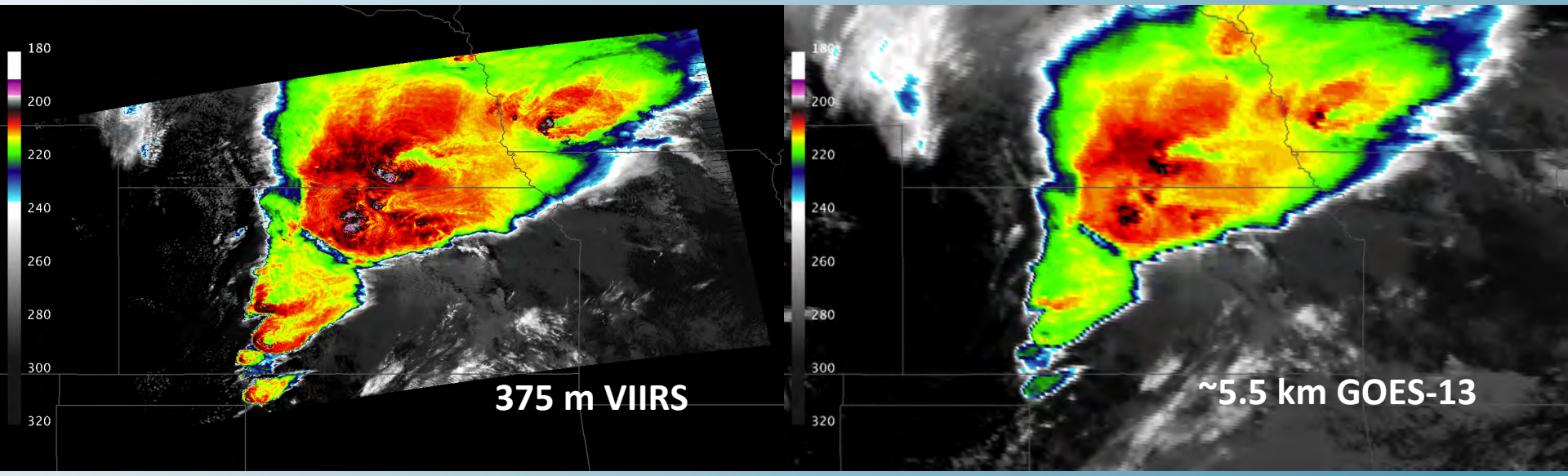
MODIS 250 m Visible





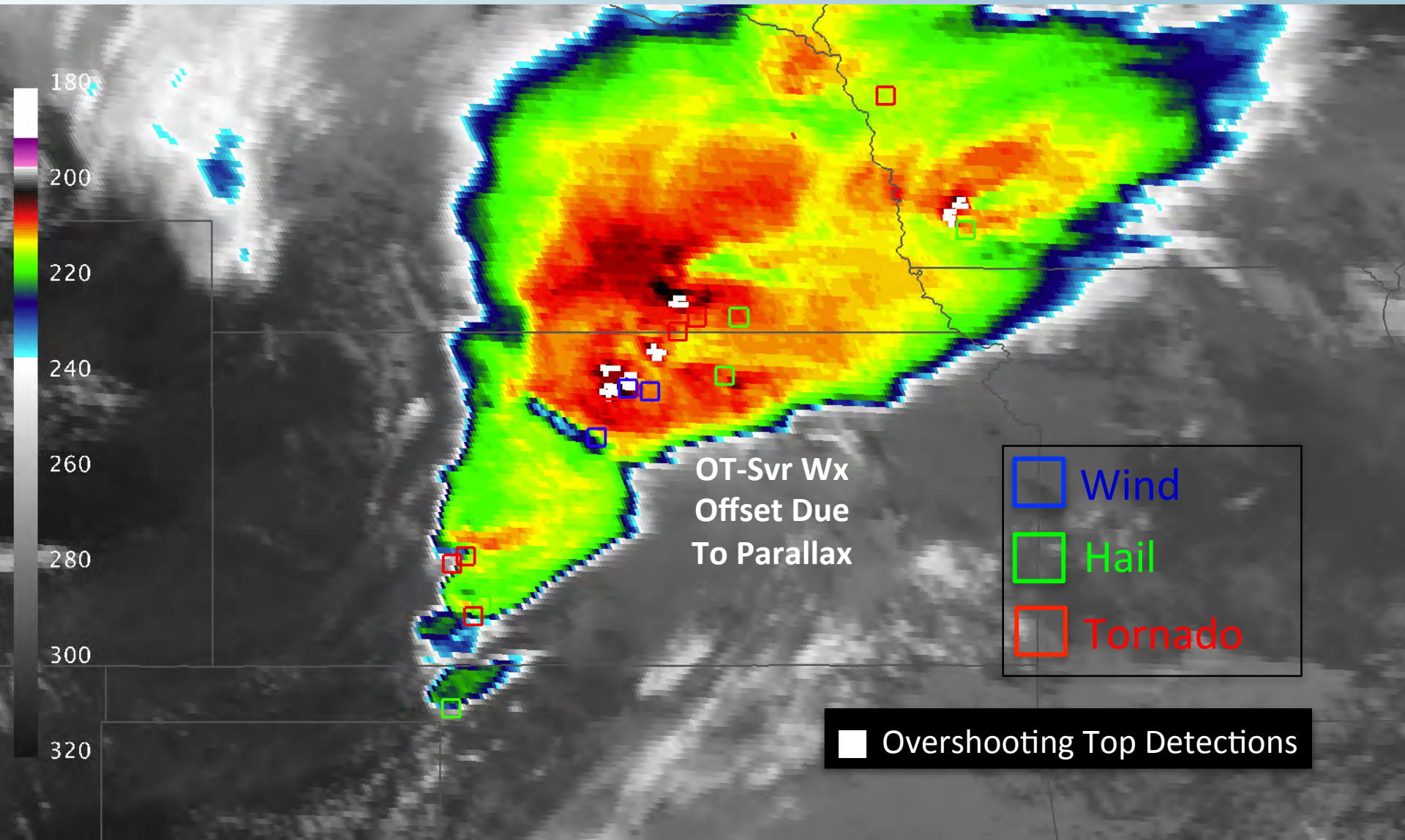
375 m VIIRS vs. ~5.5 km GOES-13 Imagery

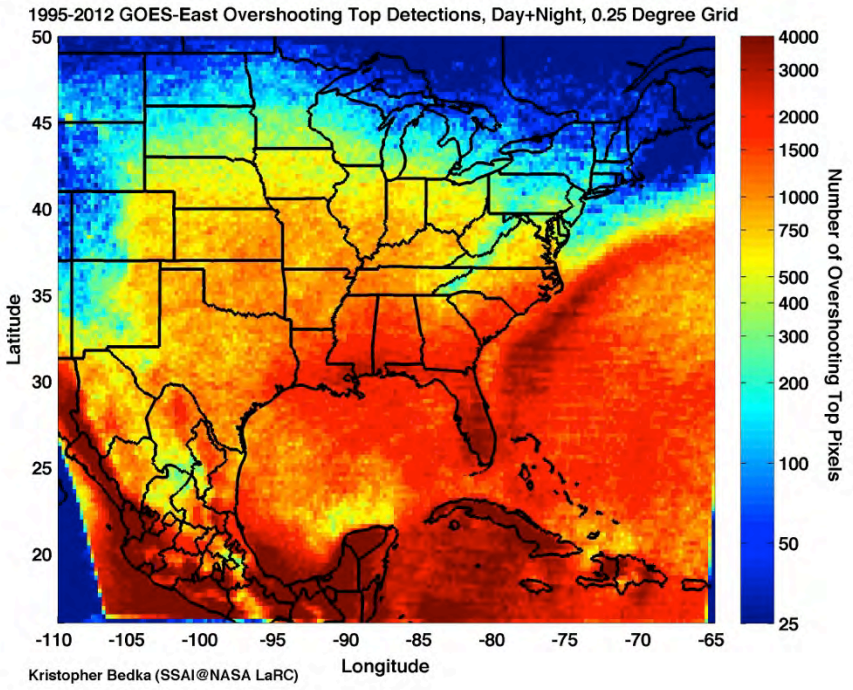
- **High spatial resolution data is critical for resolving the coldest IR BTs present within severe convective storm tops and detection of overshooting tops**
- IRW BTs within the coldest portion of the cloud top were found to be 12 K colder in polar orbiting imagery than matching geostationary data (based on 200+ cases)
- VIIRS IR BTs are ~20 K colder than GOES for the most intense storms in this case

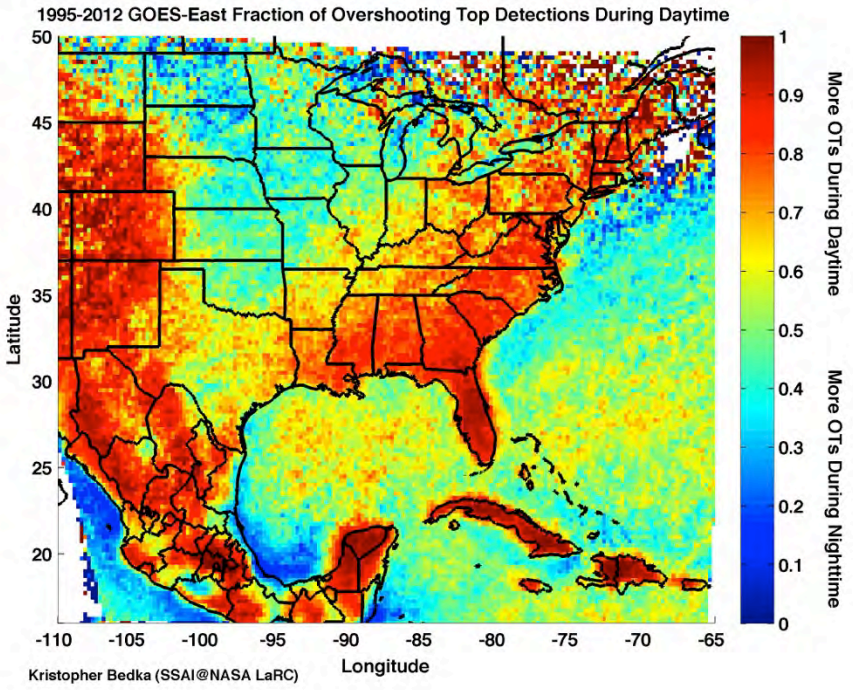


GOES Overshooting Convective Cloud Top Detection

- Many of the newer severe storms in the southwest portion of the domain are not identified with GOES-13 imagery via this method because their minimum IR BTs are not significantly colder than the anvil





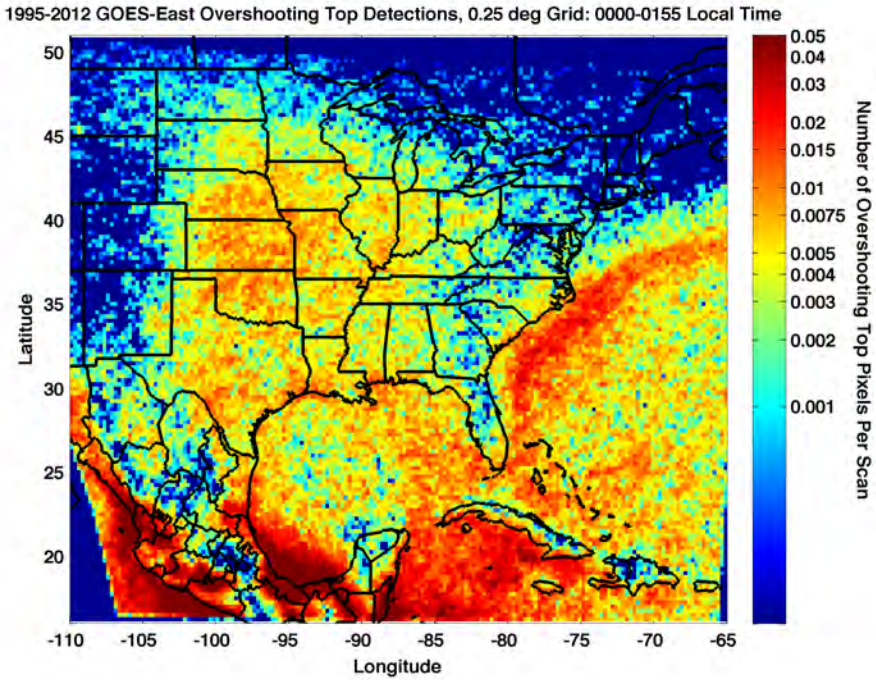


1995-2012 GOES-East OT Detections Using Full Spatial Resolution (4-6 km) and Two Images Per Hour

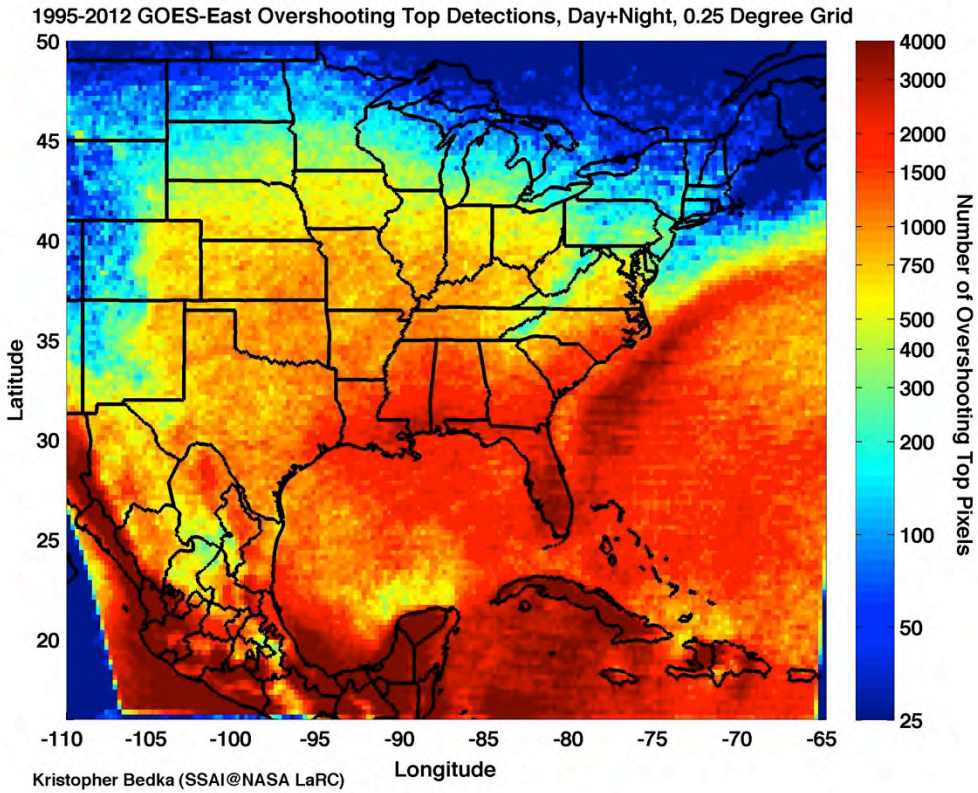
OT Detections Assigned To 0.25 Degree Resolution Grid

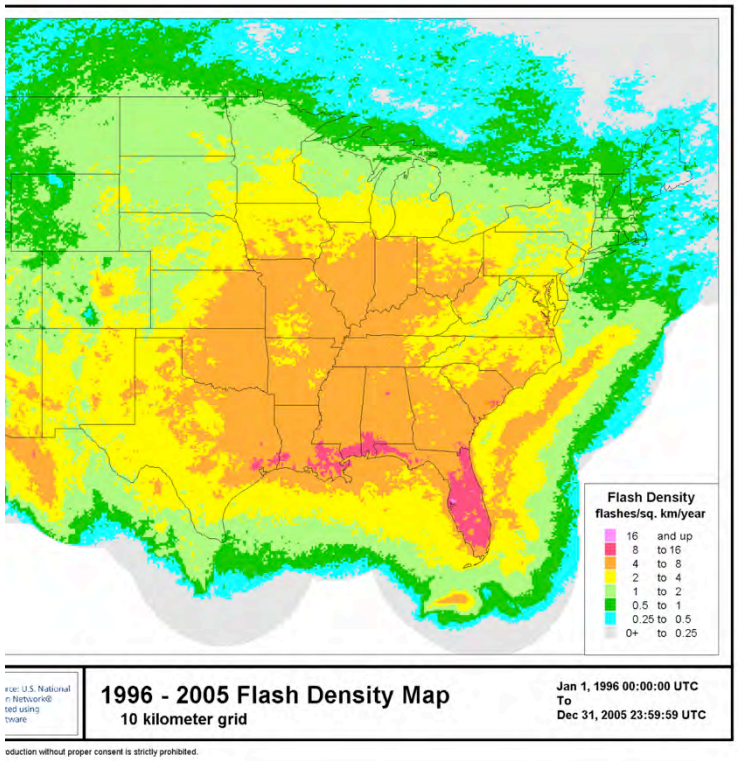
OT Detections Grouped Into 2-Hour Segments In The Animation

Animation Available Here:
http://www-angler.larc.nasa.gov/site/people/data/kbedka//OTclimatology_1995-2011_houranim.gif



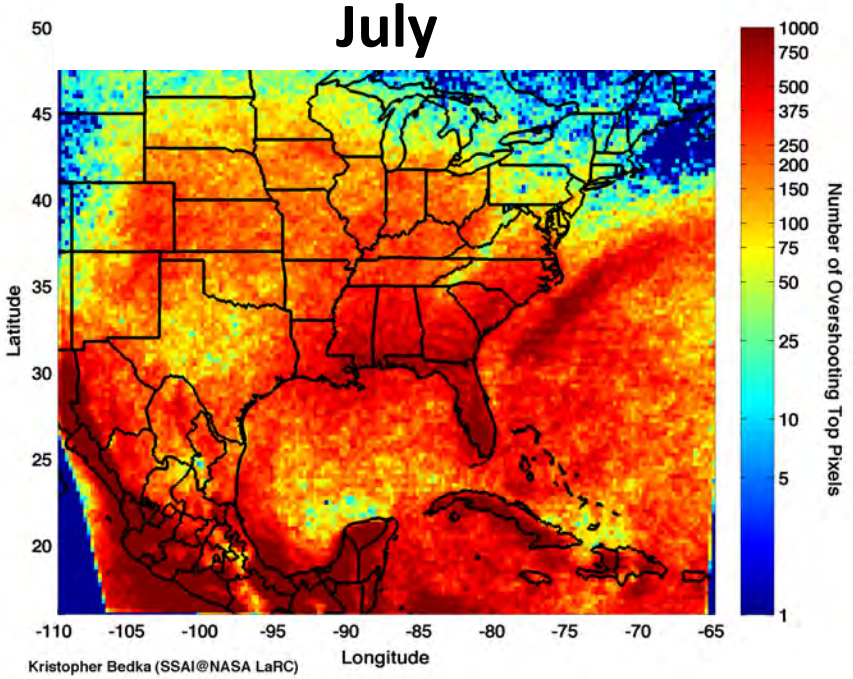
GOES OT Detection vs. NLDN Flash Density Database



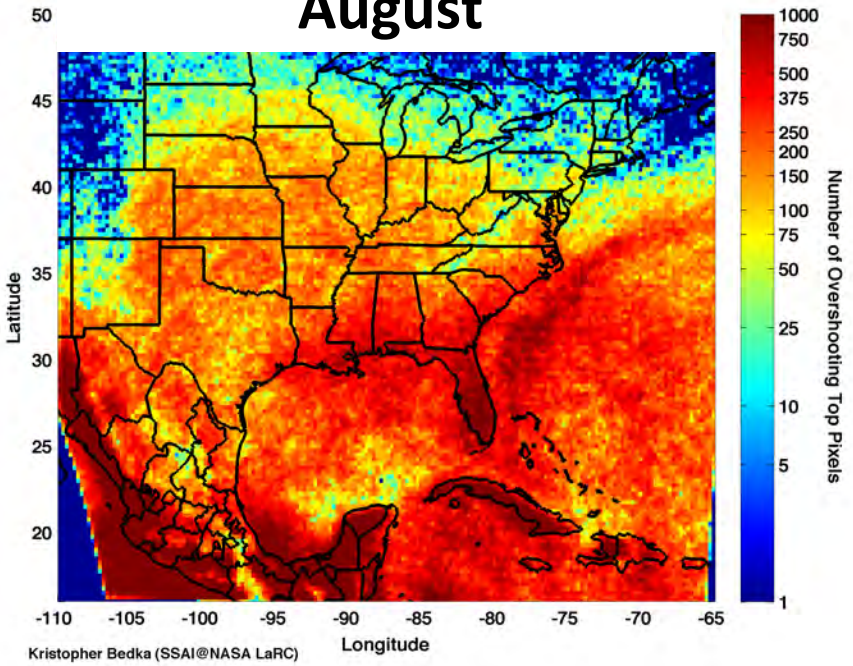


Monthly GOES OT Detection Distributions During SEAC4RS: 1995-2012

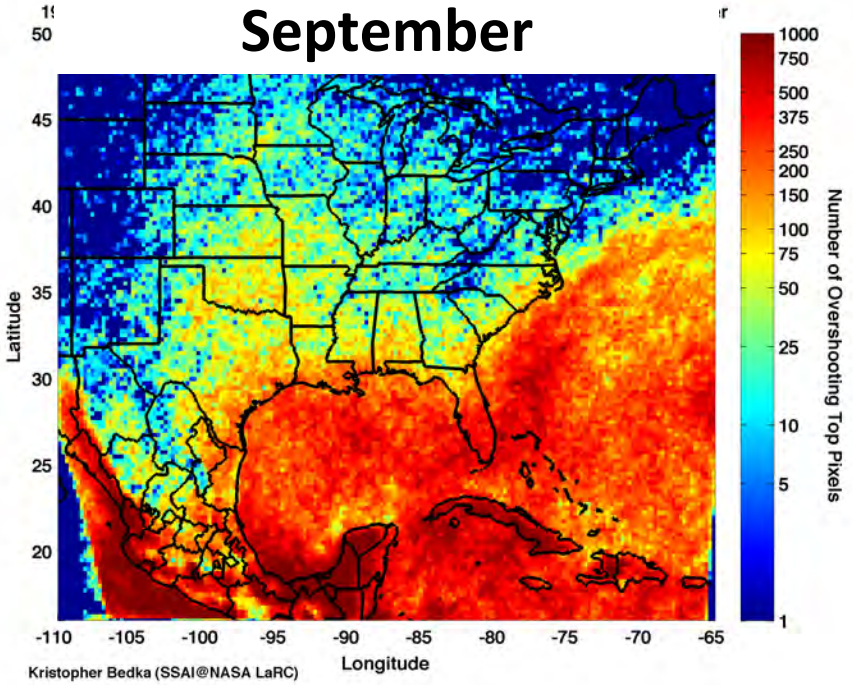
July



August

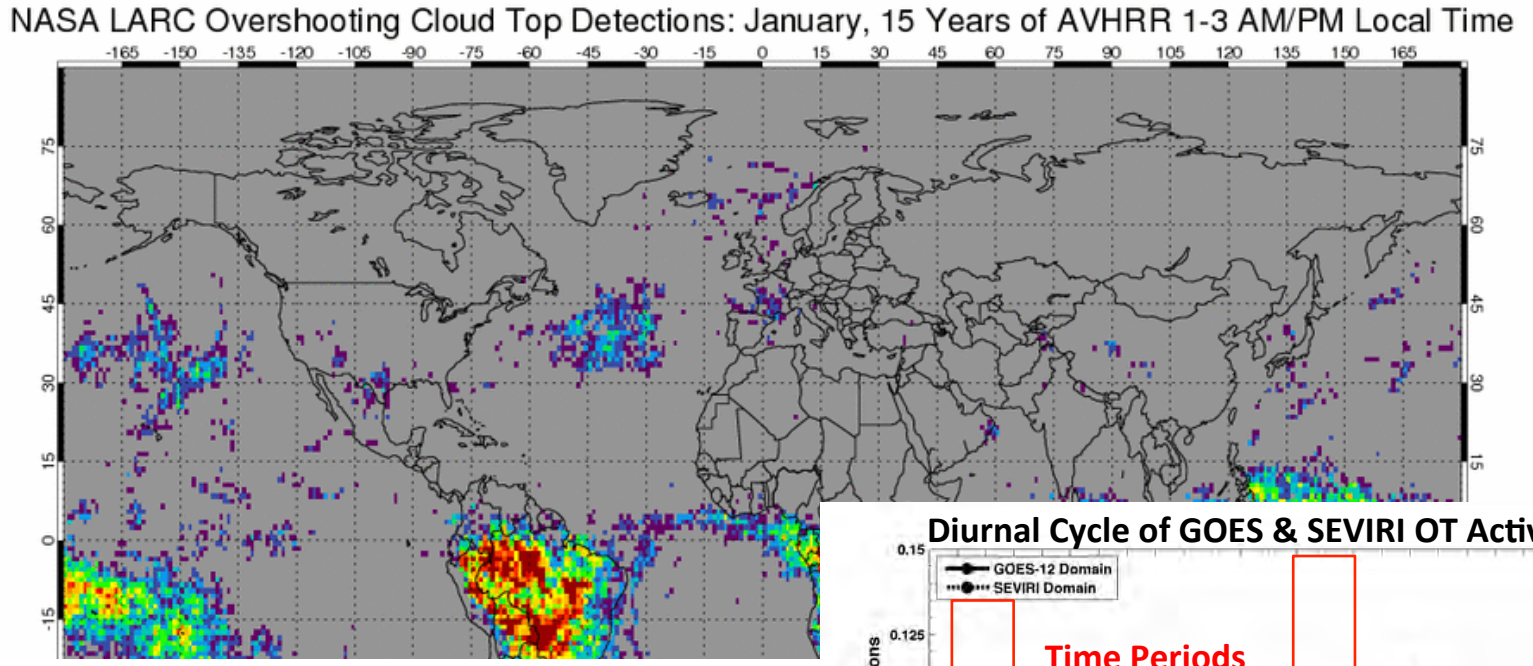


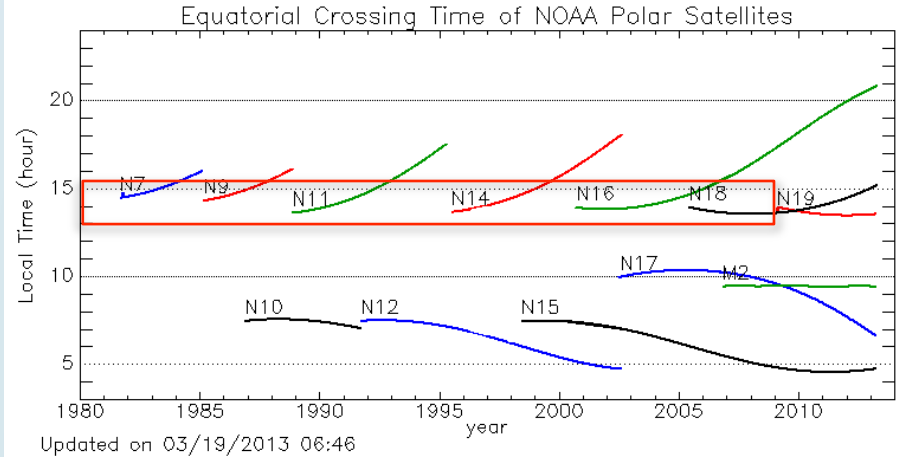
September

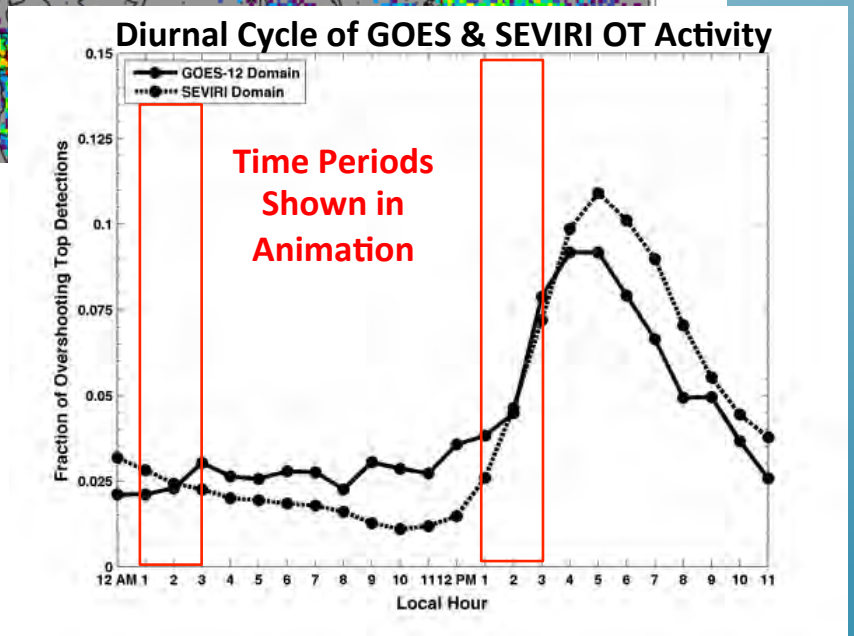


NOAA AVHRR Global Gridded Overshooting Top Detections 0100-0300 AM/PM Local Time, 10 Years of Orbits

OT detections will be produced for all AVHRR observations from 1978-present within a AVHRR Cloud Property Climate Data Record being developed at NASA LaRC







Convective Cycle Summary Inferred from OT Statistics

- Monsoon area
  - Most frequent occurrence during July, fades out in September
  - Peak convection 3-4 PM over mountains, later over plains

- Southeast – Gulf domain
  - Most frequent occurrence during July, fades out in September
  - Early morning peak convection over gulf
  - Near noon relatively frequent along coastal land in gulf
  - Peak convection 3-4 PM inland, later further inland

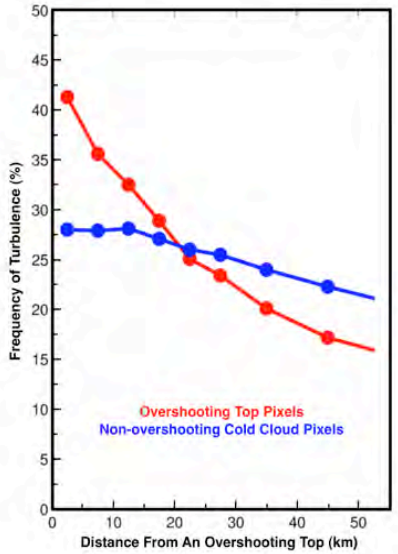
- Southeast – Atlantic domain
  - Very similar to Gulf seasonal and diurnal variations

Relevance of OT Detection to SEAC4RS Flight Operations and Post-Experiment Analysis

Turbulence Risk Near Overshooting Cloud Tops

- **Comparison of objective GOES overshooting top (OT) detections with objective in-situ turbulence observations from 2005-2008 shows an increased probability of turbulence during flight near OTs versus cloud tops with spatially uniform IR temperatures**

- **The following cases show that commercial aircraft can often encounter moderate to severe turbulence during flight near OTs in regions with adequate NEXRAD coverage**



The frequency of turbulence observed when United Airlines EDR-equipped aircraft fly within varying distance from 1) detected overshooting tops (red) and 2) cold pixels (IR temperature < 215 K) that do not meet the overshooting top detection criteria (blue). Turbulence is observed significantly more often when aircraft fly very close to overshooting tops.

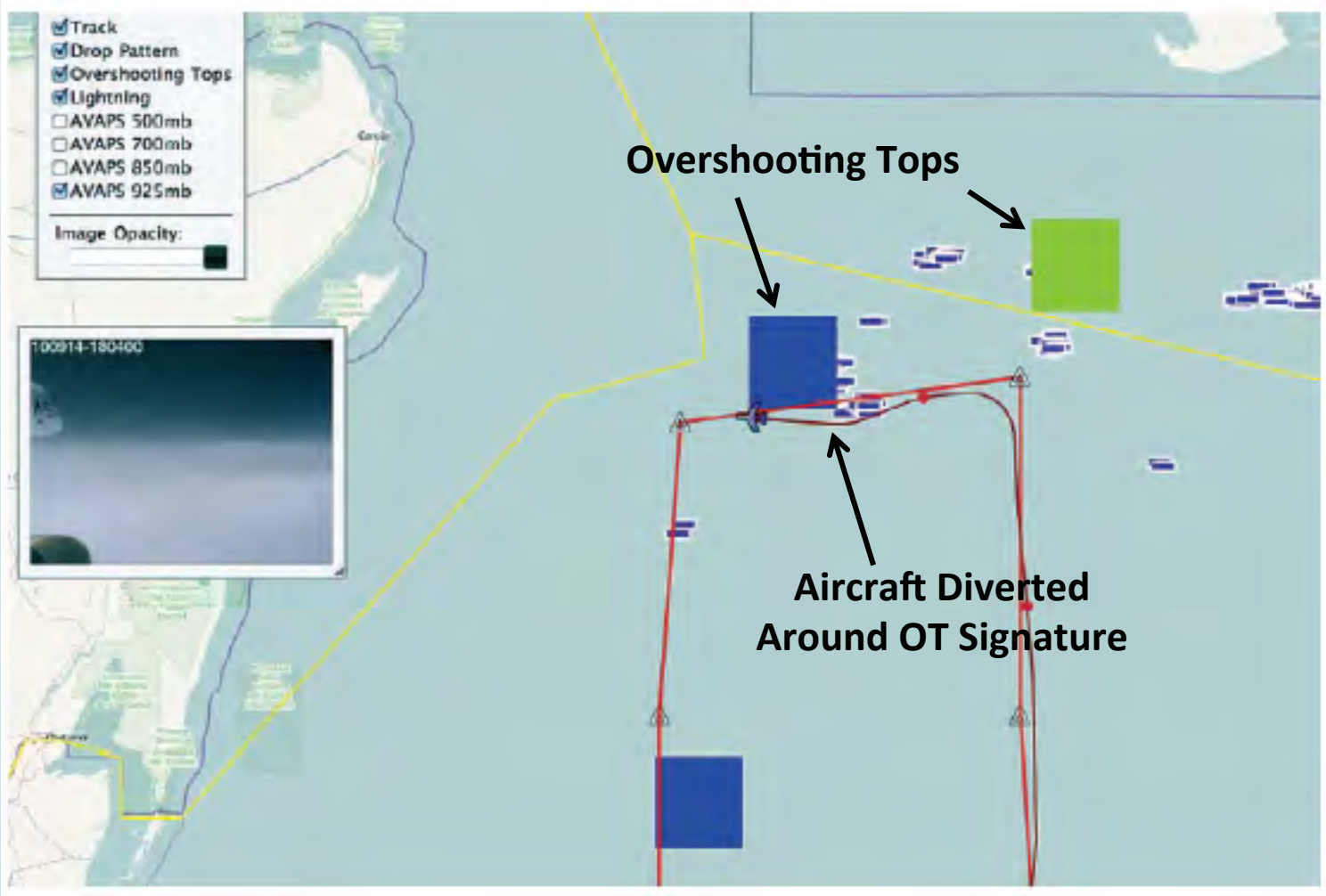
13 Moderate and 3 Severe Turbulence Observations During Flight Near 3 Overshooting Tops

12 Moderate and 1 Severe Turbulence Observations During Flight Downstream Of Overshooting Tops Within Convectively-Induced Gravity Waves

A: ABOVE CLOUD TOP
B: BELOW CLOUD TOP
I: IN CLOUD
C: CLEAR SKY

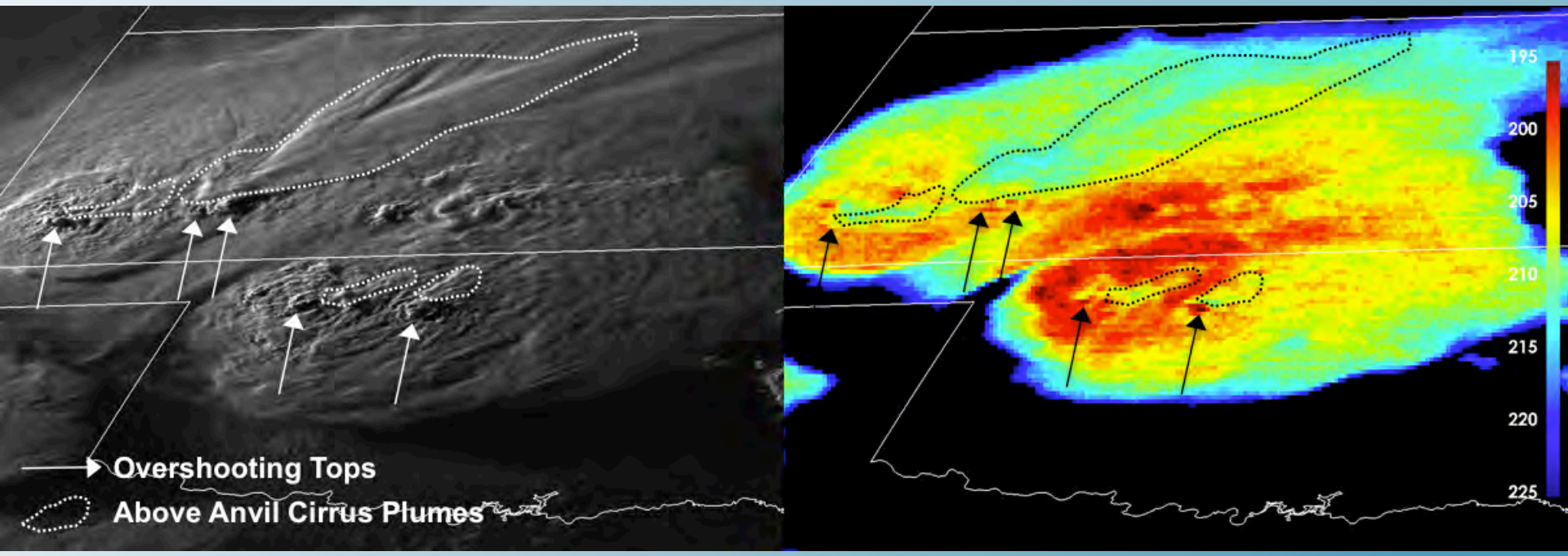
RED: SEVERE
GREEN: MODERATE
BLUE: LIGHT
GREY: NULL

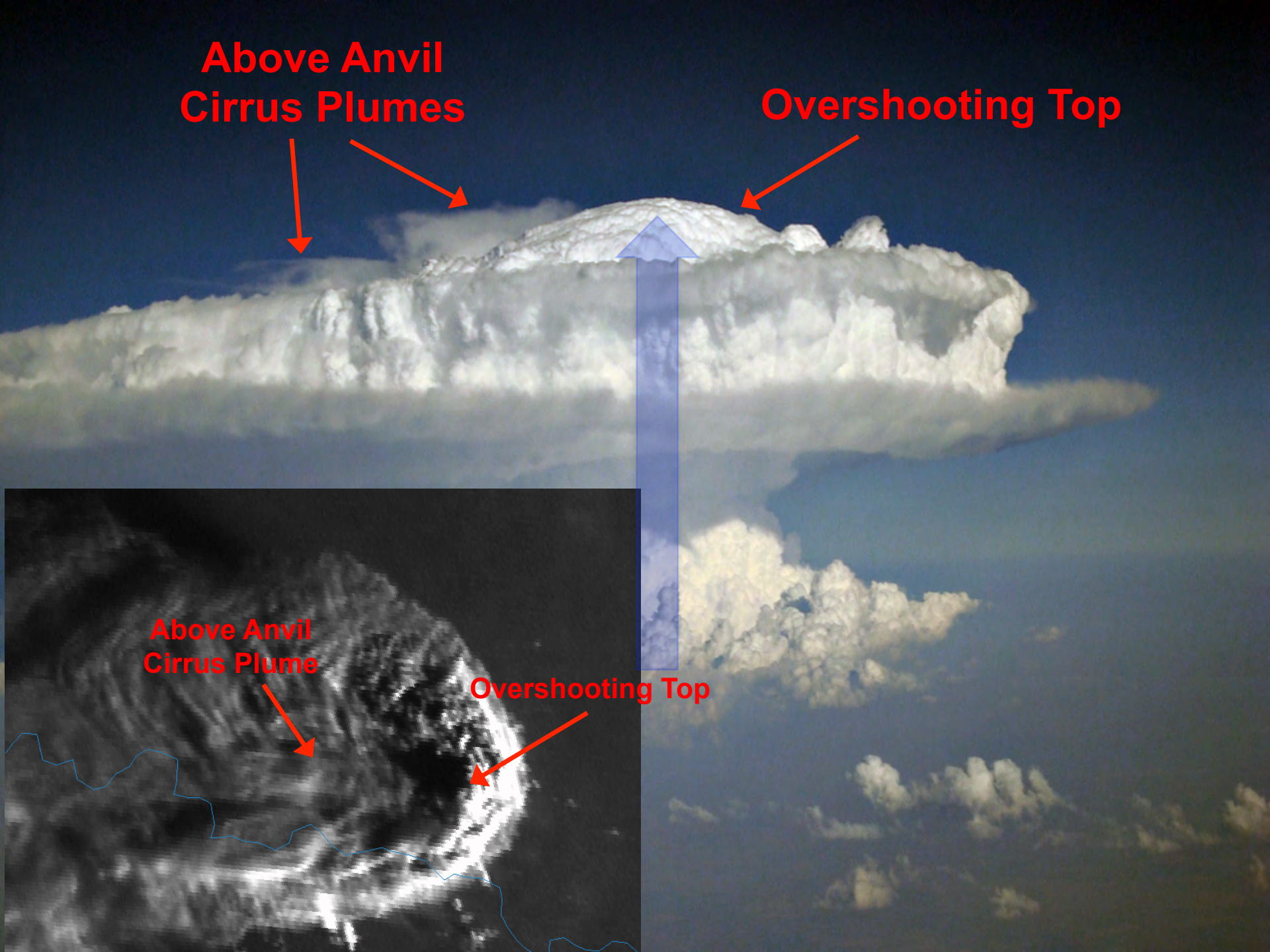
Overshooting Cloud Top Detection Use In Real-Time Flight Routing During PREDICT/GRIP



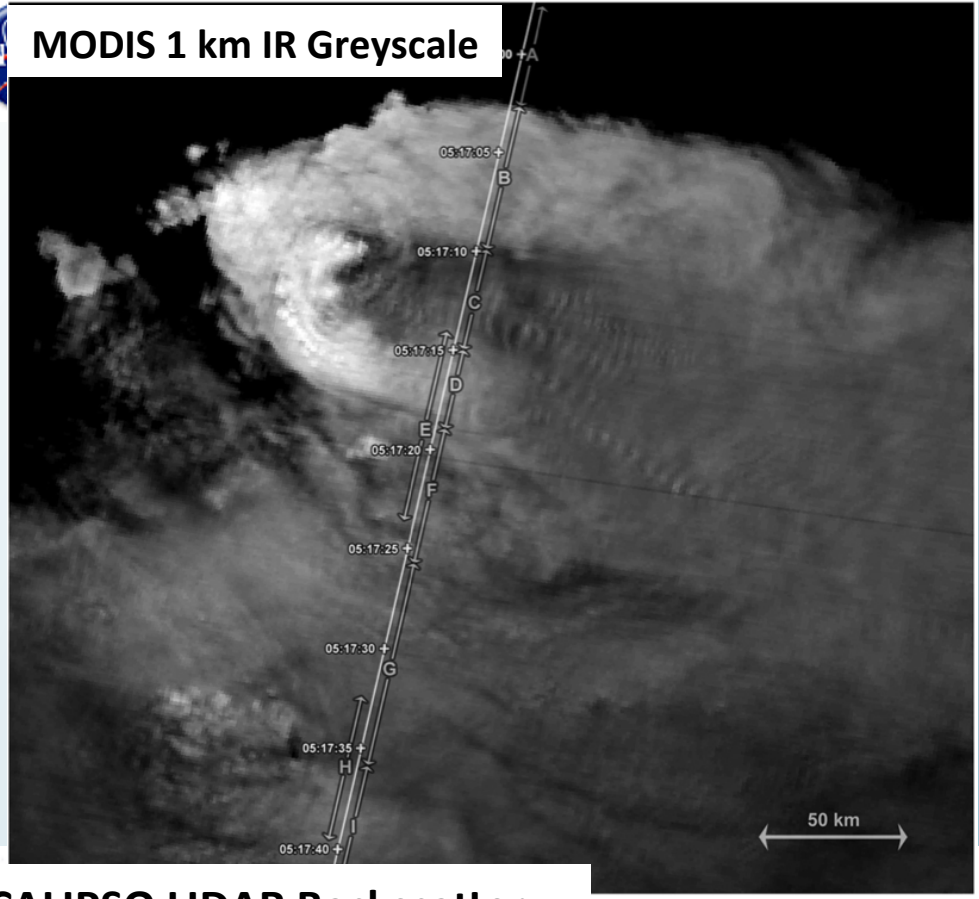
OT Injections of Water Vapor and Ice into the UTLS

- Overshooting tops inject significant quantities of water vapor and ice into the UTLS region
- Some storms with especially strong updrafts can produce a cirrus layer up to 3 km above the primary anvil cloud. This cloud radiates at the warmer stratospheric temperature and appears as a warm anomaly in IR satellite imagery



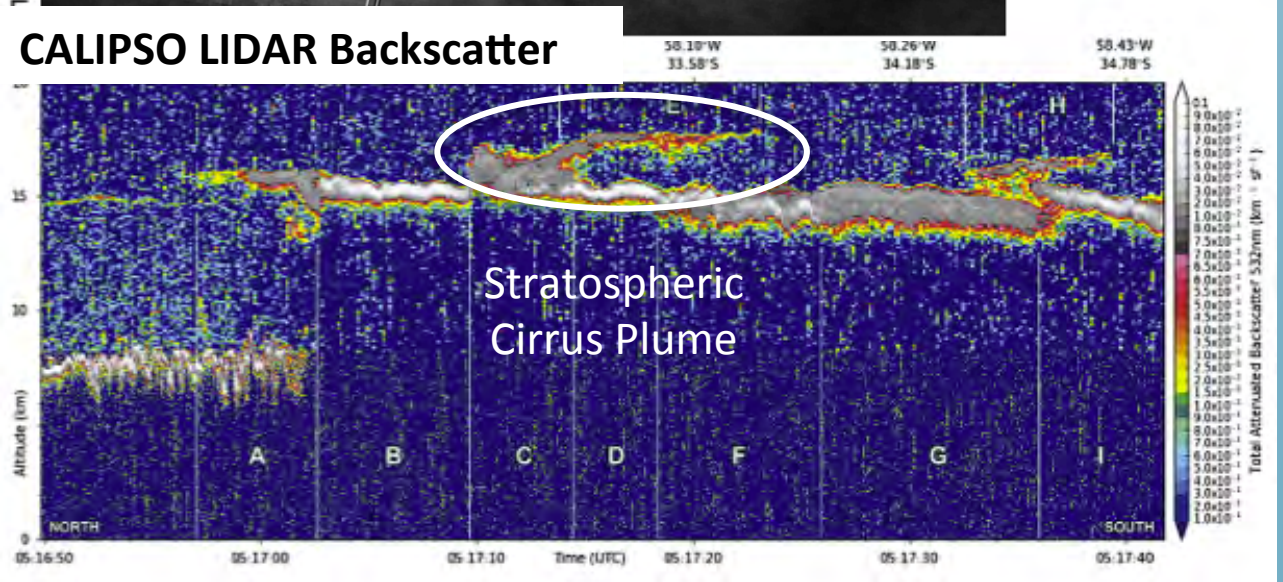

Above Anvil
Cirrus Plumes
Overshooting Top
Above Anvil
Cirrus Plume
Overshooting Top

OT Injections of Water Vapor and Ice into the UTLS



- Observational evidence suggests that stratospheric ice/moisture plumes are a relatively common feature above OT-producing storms whenever there is strong vertical wind shear which favors gravity wave breaking (*Setvak; Wang; Lane; Hassim*)

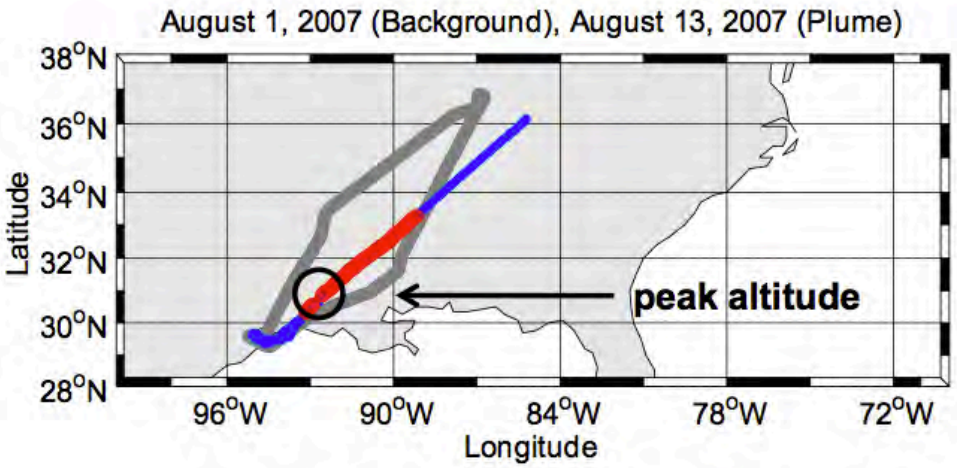
- This CALIPSO lidar profile shows a stratospheric cirrus plume within and near to an enhanced-V signature present up to 2 km above the primary anvil cloud



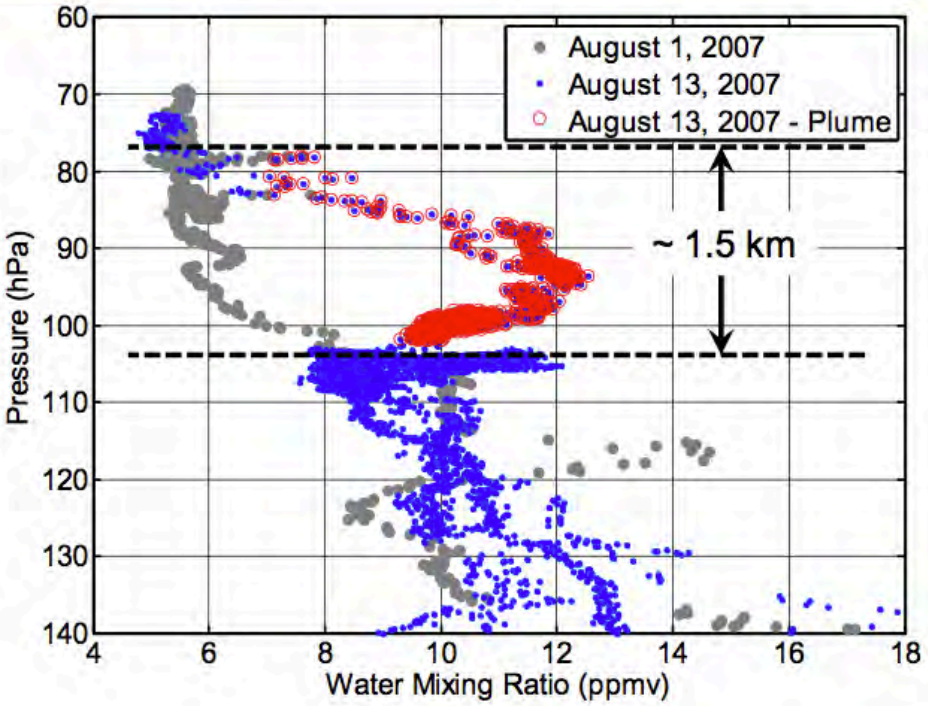
Setvak, Bedka, et al. (Atmos. Res. 2013)

Extensive Plume Encountered on Aug. 13, 2007

Background VMR, Plume VMR



~40 min segment, ~480 km

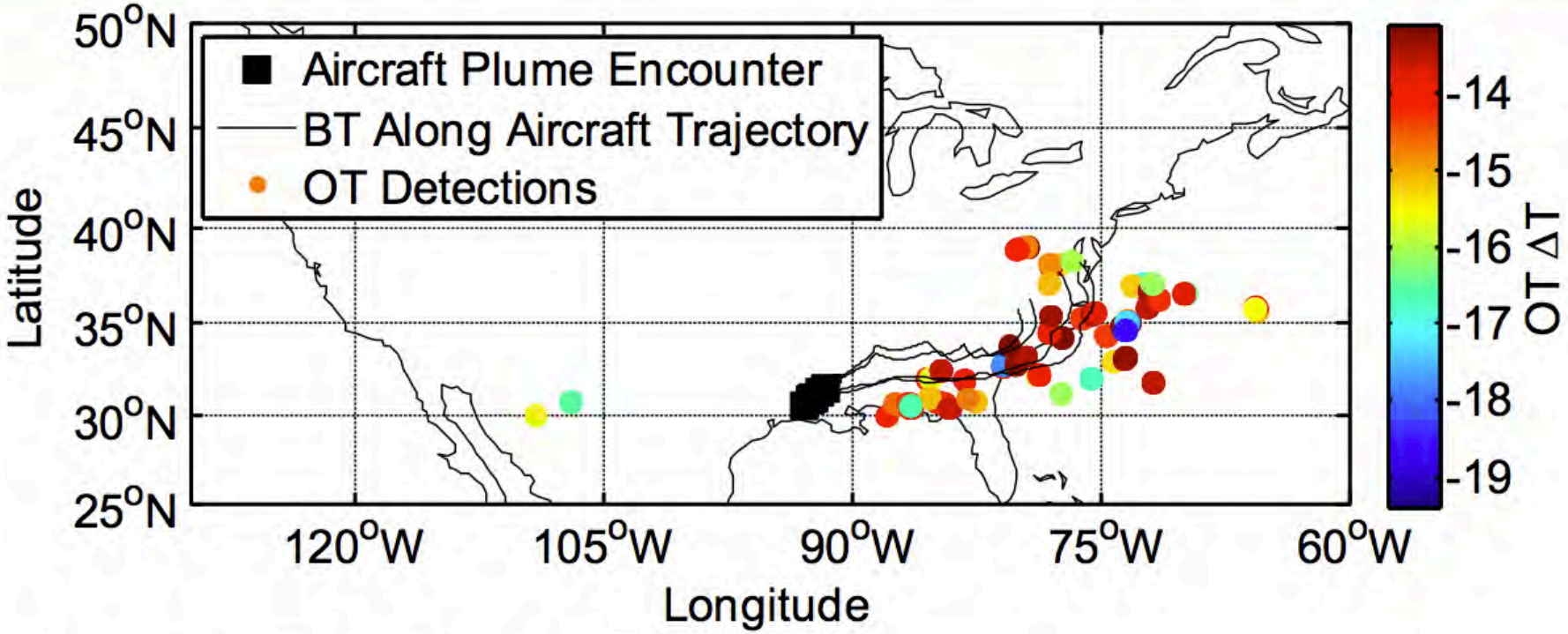


- Horizontal extent ~3°N/S or 300 km & ~4° E/W or 400 km
- Vertical extent ~1.5 km, from 16 km to 17.5 km
- Enhancement of ≥6 ppmv over background values

J. B. Smith et al., 2013, An analysis of convectively sourced water vapor in the overworld stratosphere at northern mid-latitudes, *in preparation*

Overshooting Tops (OTs) & Back-Trajectories

HWV Encounter on August 13, 2007



- OT detection includes entire eastern US domain
- OT detection run for three full days prior to plume encounter
- Difference between OT and surrounding anvil ≥ 13°K – selection criterion
- BTs using GSFC Back-Trajectory Model Output from TC4 Archive

OT Detection Algorithm by Kristopher Bedka, NASA Langley

J. B. Smith et al., 2013, An analysis of convectively sourced water vapor in the overworld stratosphere at northern mid-latitudes, *in preparation*

On-site Satellite Support

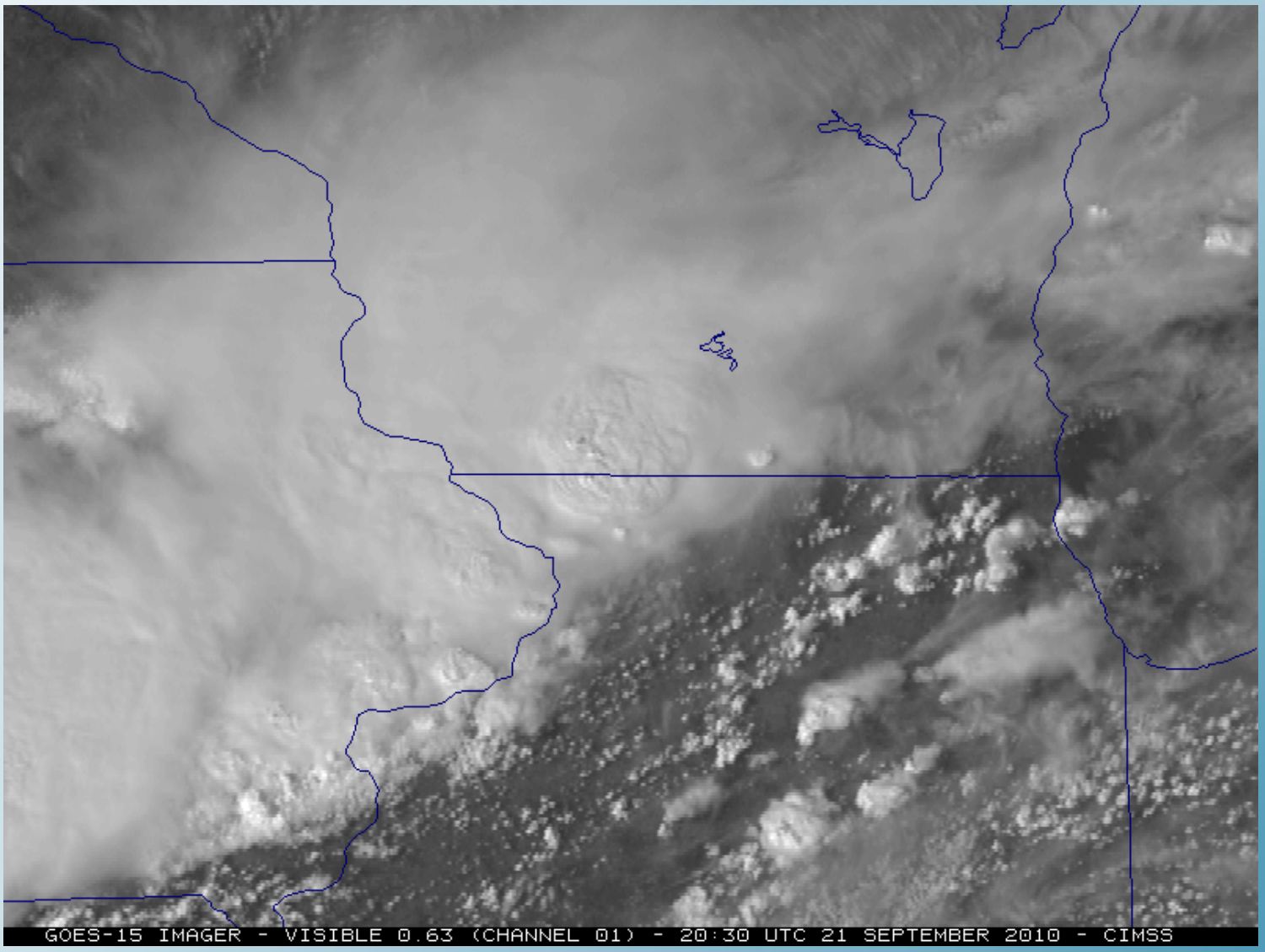
- Computer system with McIDAS Satellite Displays
- Integrated System
  - Real-time Access to GOES with < 1m latency
  - Full temporal and spatial, multi-band
  - Access LEO satellite data with latency
  - Interactive, enhancement, multi-views
  - Langley's Cloud Products, Overshooting Tops
- Provide real-time aircraft tracking on satellite display
- Tools for predicting satellite track for aircraft underpass

Satellite Data Coverage for SEAC4RS (N. Am)

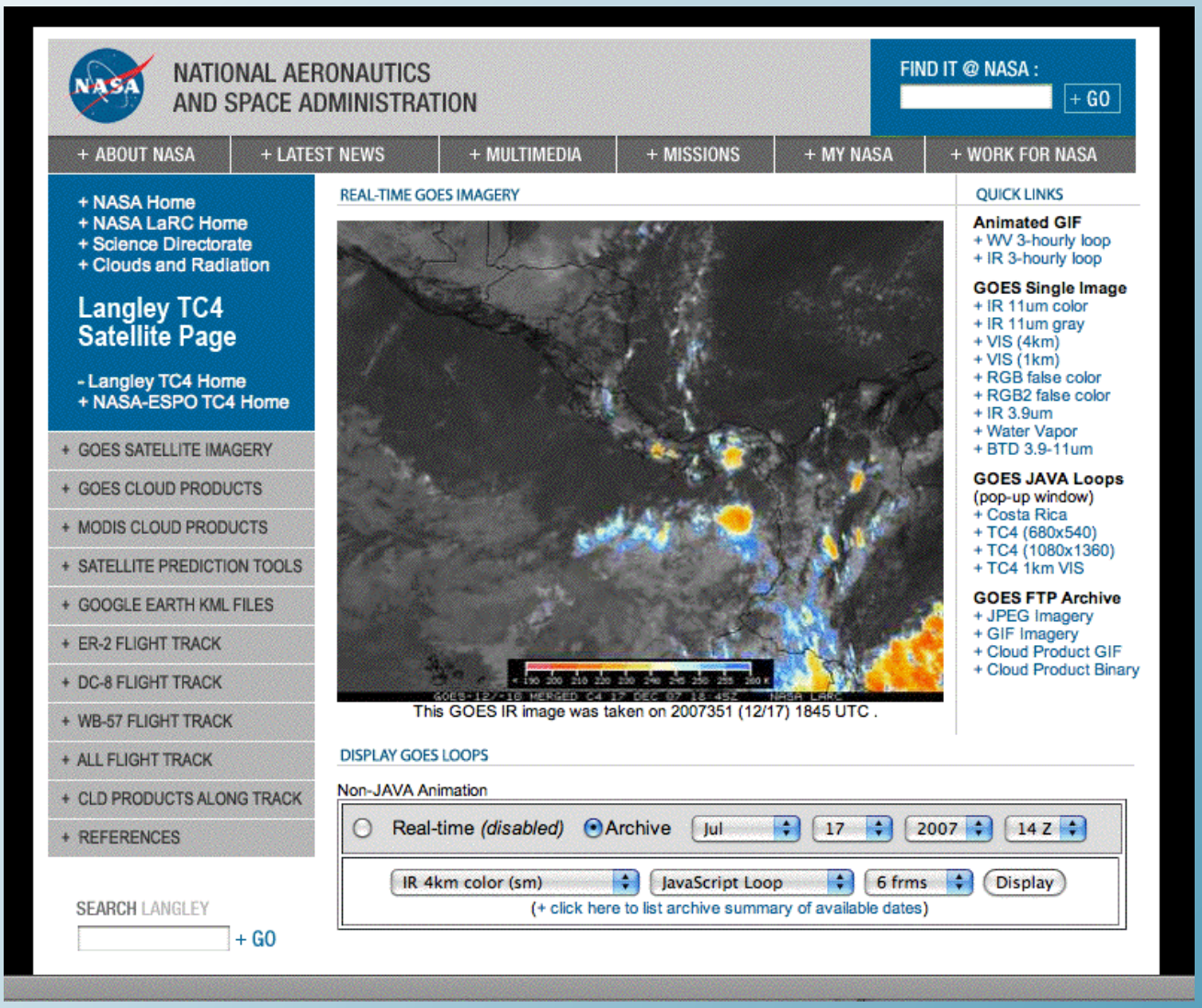
- GOES-15 (West) and GOES-13 (East)
  - Nominal schedule: 15min, 1km vis 4km ir
  - Rapid Scan Operations (RSO, 2-8min)
  - Will work on request for SRSO (1min)
    - Possibility of using GOES-14 (Standby)
- CALIPSO, Cloudsat
- AQUA/TERRA MODIS
- NOAA-19, METOP-A
- NPP VIIRS

Satellite Data Coverage for SEAC4RS (N. Am)

GOES Super Rapid Scan Operation (SRSO)



Satellite Support Web Page during TC4



Flight Track Summary And Quicklooks

ER2 Flight Track Overlay on GOES Ima

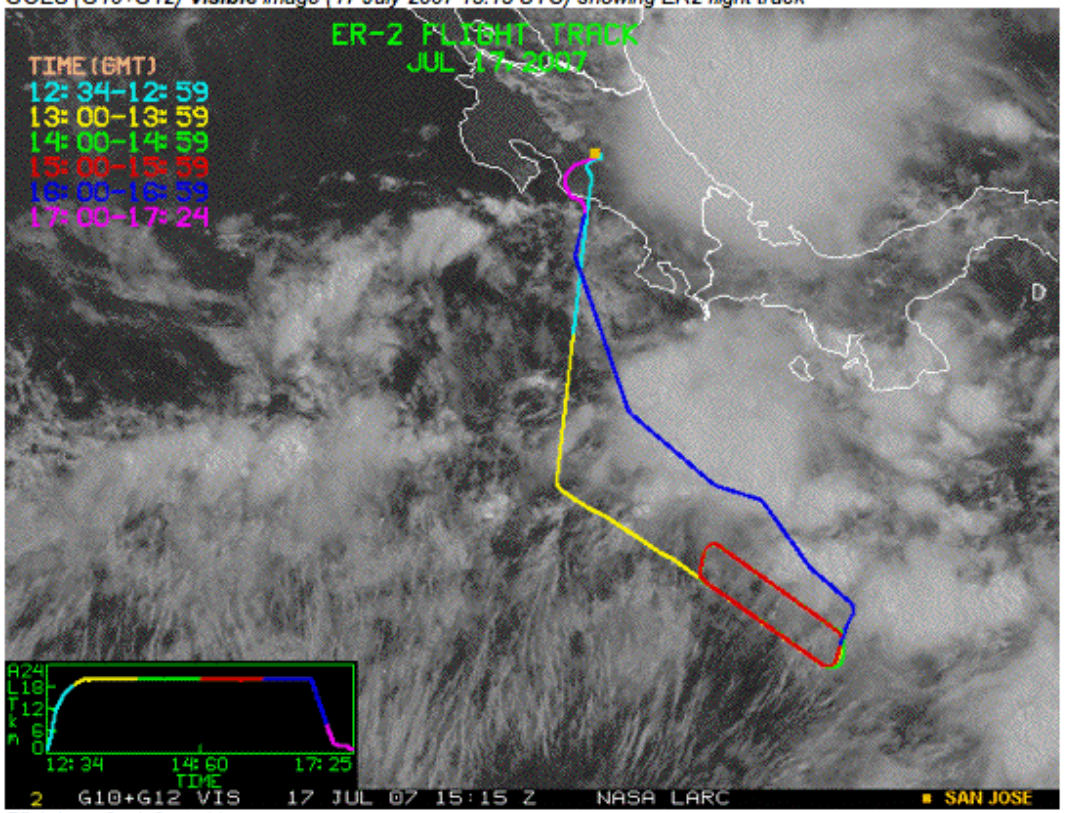
Select a flight day.

Jul-Aug 2007						
Su	Mo	Tu	We	Th	Fr	Sa
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	01	02	03	04
05	06	07	08	09	10	11

Available 2-3 hours after landing

Flight Tracks for July 17, 2007

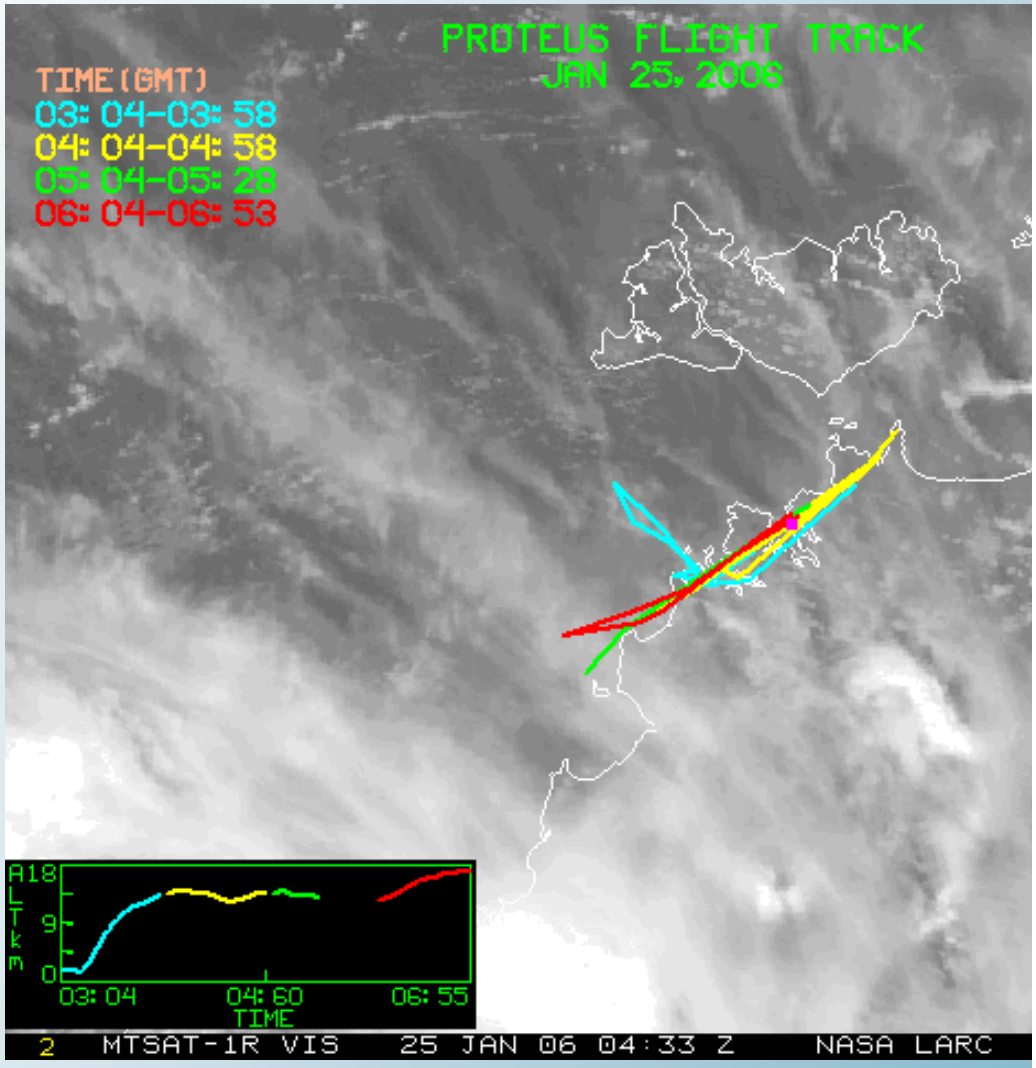
*GOES (G10+G12) **Visible** image (17 July 2007 15:15 UTC) showing ER2 flight track*

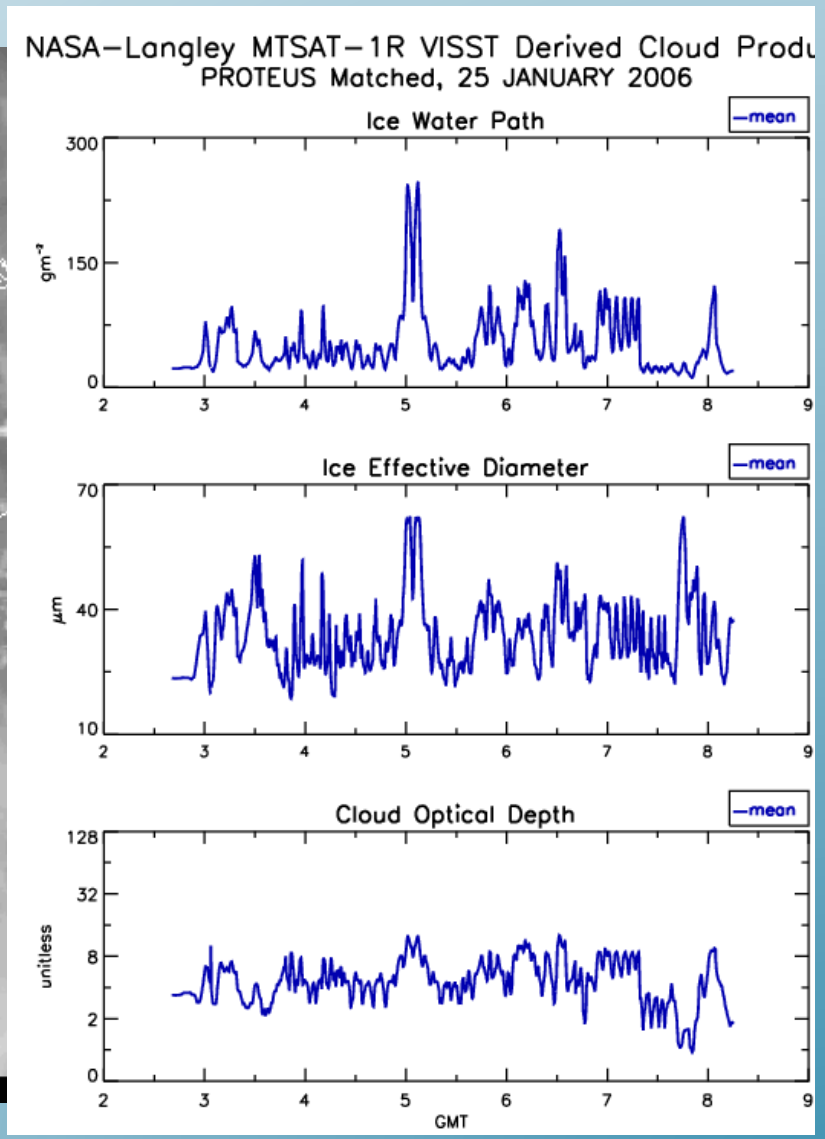


Click here for Infrared Image

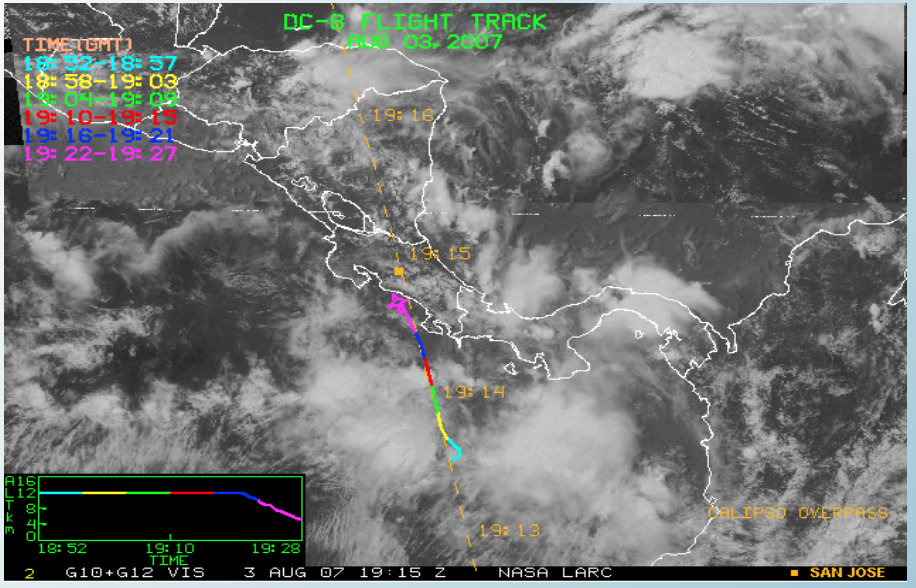
- **ER2 Flight Tracks overlayed on G10+G12 Imagery**
  - JavaScript Loop: Visible, Infrared
  - Animated GIF Loop: Visible, Infrared
  - VIS Images: 12:28, 12:45, 12:58, 13:15, 13:28, 13:45, 13:58, 14:15, 14:28, 14:45, 15:15, 15:28, 15:45, 15:58, 16:15, 16:28, 16:45, 16:58, 17:15, 17:28
  - IR Images: 12:28, 12:45, 12:58, 13:15, 13:28, 13:45, 13:58, 14:15, 14:28, 15:15, 15:28, 15:45, 15:58, 16:15, 16:28, 16:45, 16:58, 17:15, 17:28
  - **Aircraft Navigation Data:**
    - ER2 navigation file

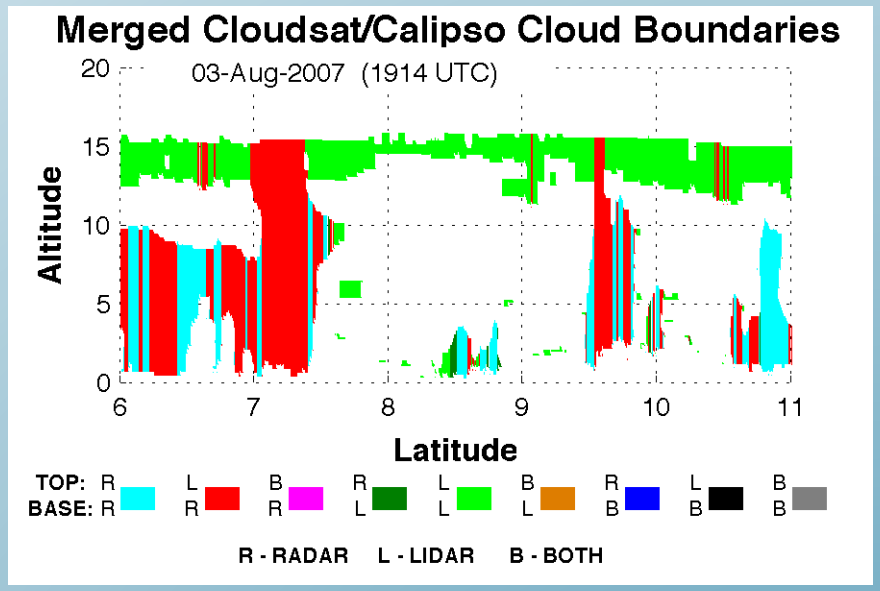
Cloud Product along Aircraft Track, TWP-ICE 2006

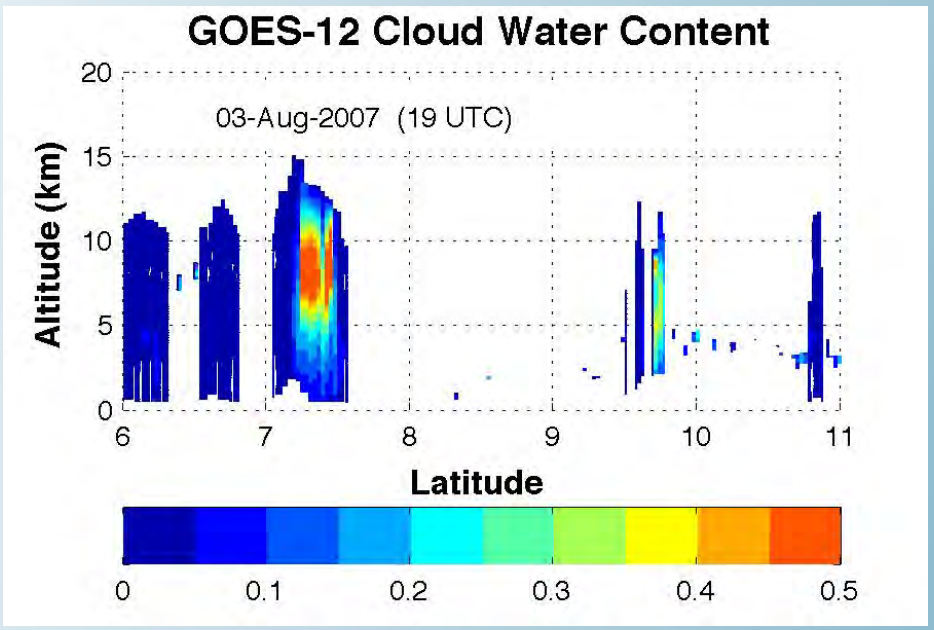


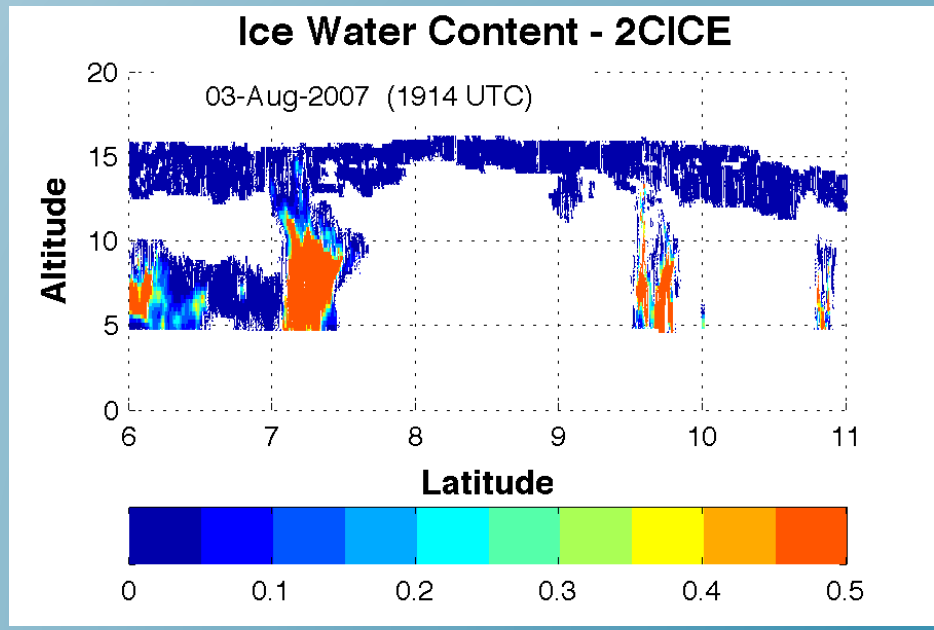


Nowcasting Flight Path Cloud Profiles

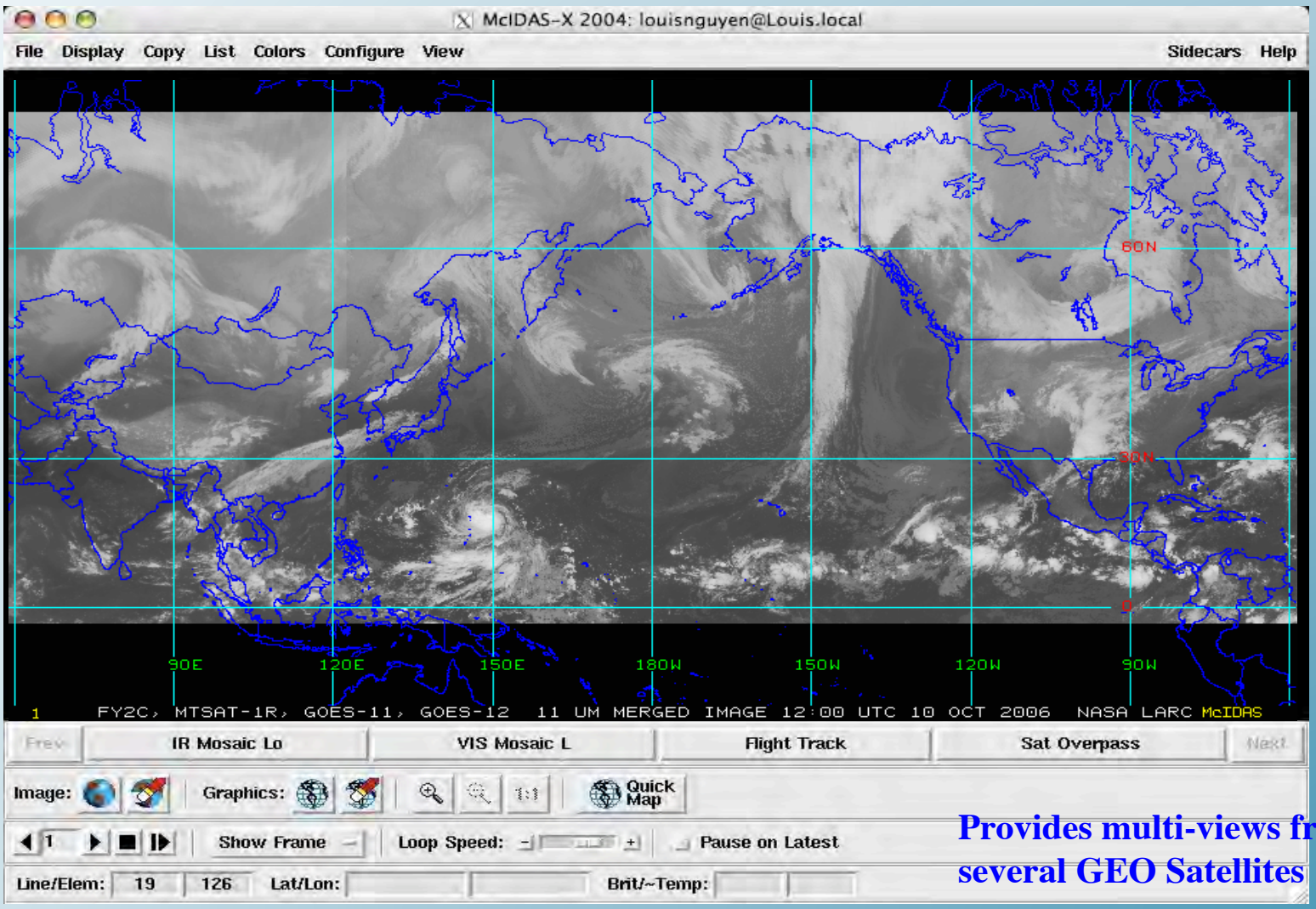






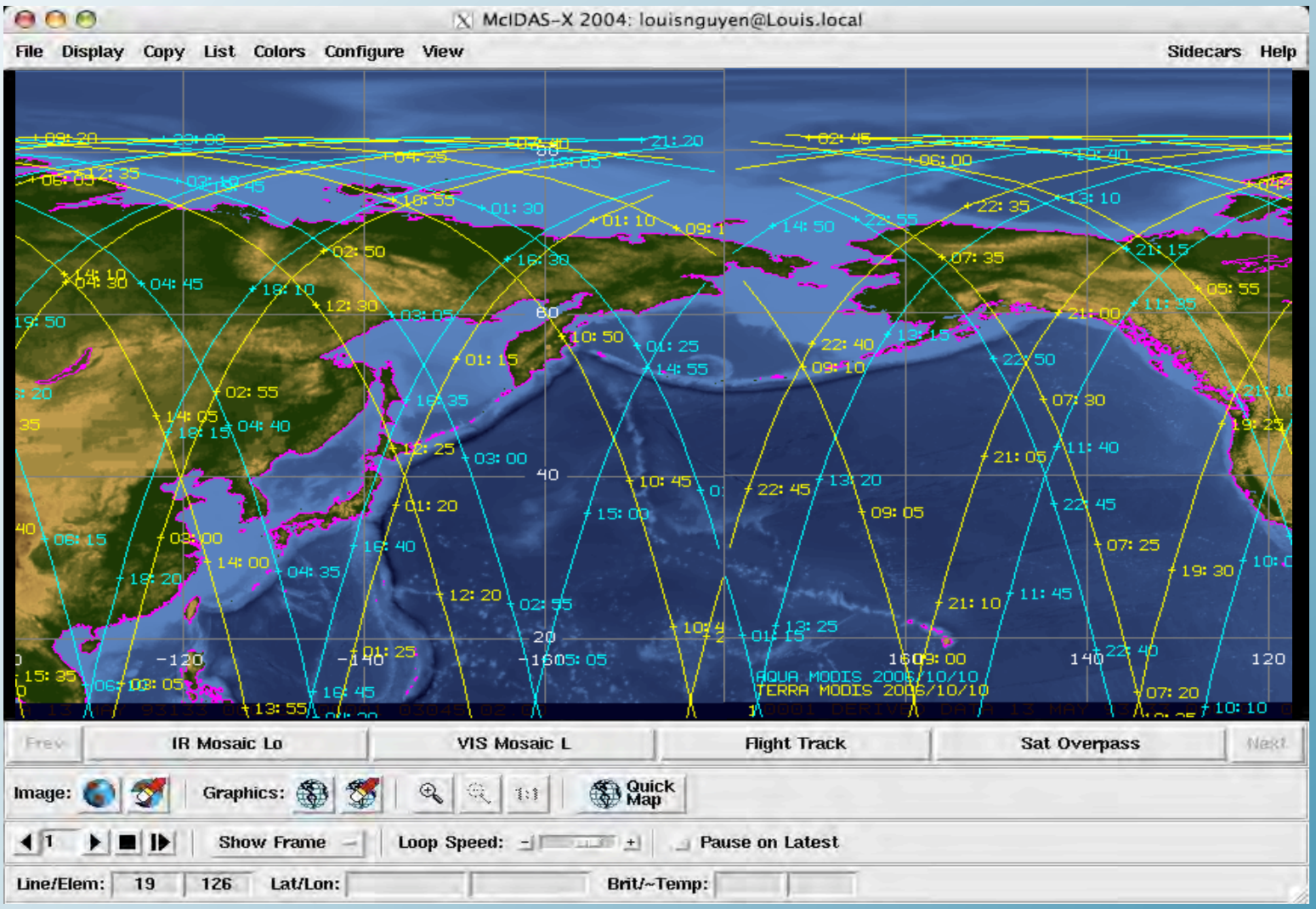


McIDAS Satellite Display System



Provides multi-views from several GEO Satellites

Satellite Predictions for Aircraft Underpass Flight



Calipso/Cloudsat Prediction for Aircraft Coordination via Goggle Map and Earth

NASA LANGLEY CLOUD AND RADIATION GROUP

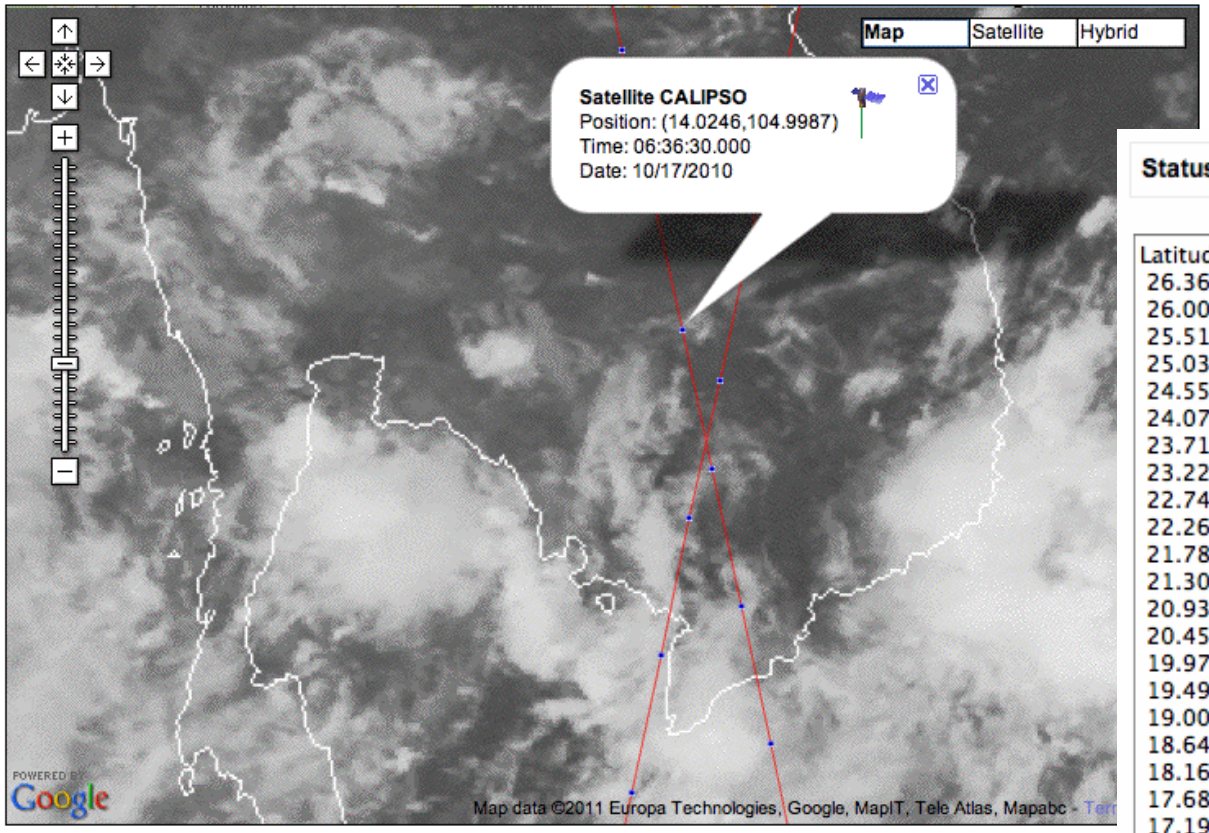
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

+ NASA Portal
+ Preferences

Search: Keywords + GO

− Cloud Radiation Home | + LaRC ICESat/GLAS Home | + Satellite Products | + GSFC ICESat / GLAS Home

Satellite Orbital Prediction *Warning: this application is under development and is not ready for general use!



Show Current Satellite Position

Satellite: CALIPSO Display Stop

Plot Satellite Track

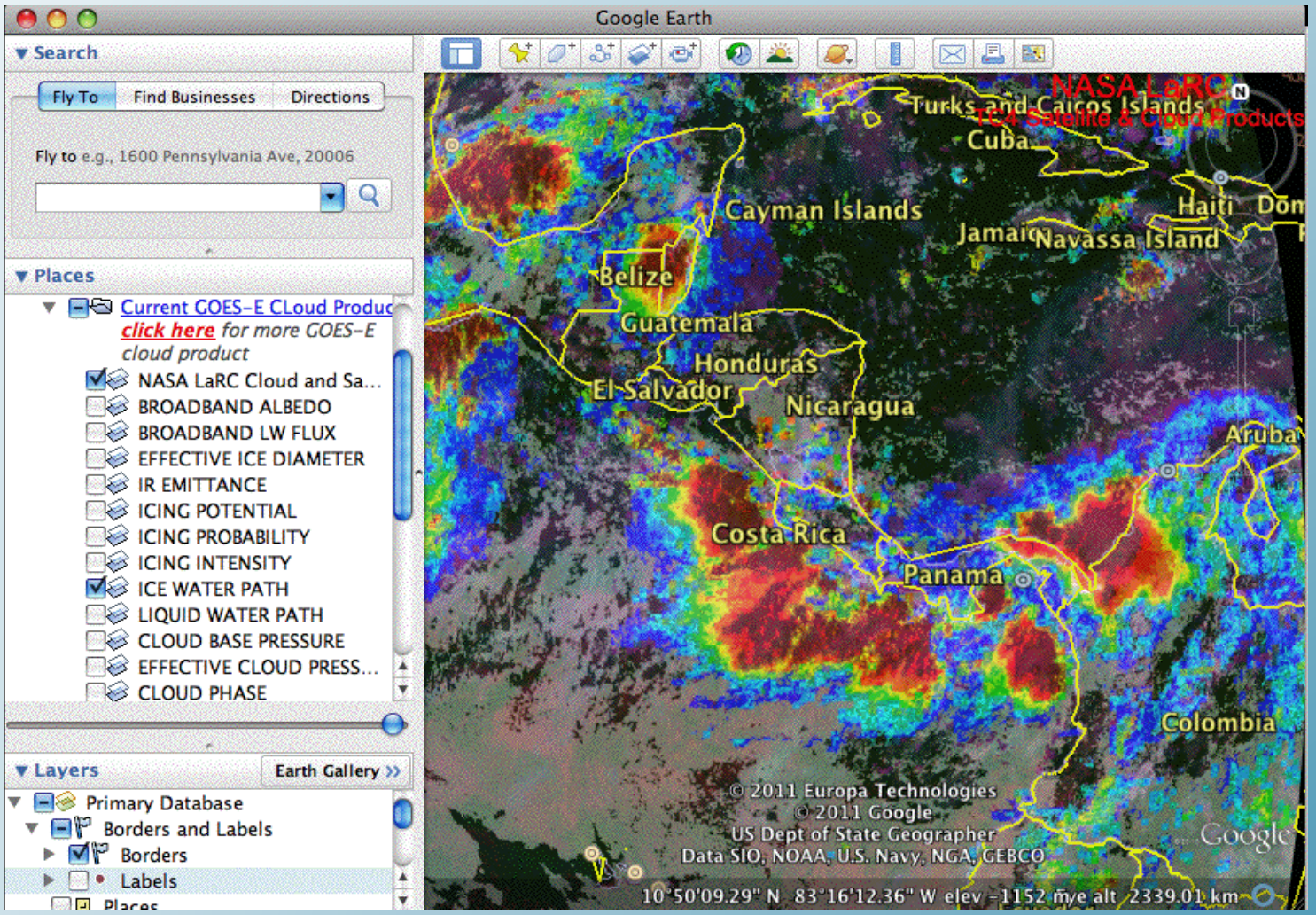
Satellite: CALIPSO Steps: 30 sec Year: 2010 Mon: Oct Day: 17 Display

Starting Time: 00 : 00 Ending Time 22 : 00

Status: Completed processing all 600 points successfu

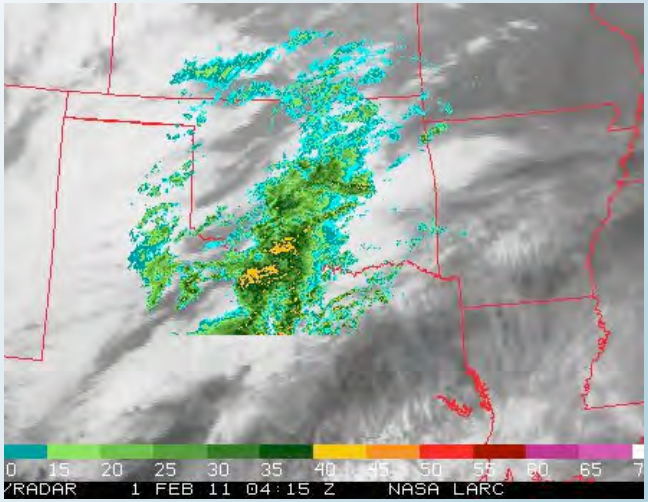
Latitude	Longitude	Year	Month	Day	Hour	Min	
26.3619,	97.4363,	2012,	08,	24,	06,	59,	58.000
26.0007,	97.5258,	2012,	08,	24,	06,	59,	52.000
25.5190,	97.6444,	2012,	08,	24,	06,	59,	44.000
25.0372,	97.7624,	2012,	08,	24,	06,	59,	36.000
24.5553,	97.8797,	2012,	08,	24,	06,	59,	28.000
24.0734,	97.9963,	2012,	08,	24,	06,	59,	20.000
23.7119,	98.0834,	2012,	08,	24,	06,	59,	14.000
23.2298,	98.1990,	2012,	08,	24,	06,	59,	6.000
22.7477,	98.3140,	2012,	08,	24,	06,	58,	58.000
22.2655,	98.4285,	2012,	08,	24,	06,	58,	50.000
21.7832,	98.5424,	2012,	08,	24,	06,	58,	42.000
21.3009,	98.6557,	2012,	08,	24,	06,	58,	34.000
20.9391,	98.7404,	2012,	08,	24,	06,	58,	28.000
20.4566,	98.8528,	2012,	08,	24,	06,	58,	20.000
19.9741,	98.9648,	2012,	08,	24,	06,	58,	12.000
19.4916,	99.0763,	2012,	08,	24,	06,	58,	4.000
19.0089,	99.1873,	2012,	08,	24,	06,	57,	56.000
18.6469,	99.2703,	2012,	08,	24,	06,	57,	50.000
18.1642,	99.3805,	2012,	08,	24,	06,	57,	42.000
17.6815,	99.4904,	2012,	08,	24,	06,	57,	34.000
17.1986,	99.5998,	2012,	08,	24,	06,	57,	26.000
16.7158,	99.7088,	2012,	08,	24,	06,	57,	18.000
16.2329,	99.8175,	2012,	08,	24,	06,	57,	10.000
15.8706,	99.8987,	2012,	08,	24,	06,	57,	4.000
15.3877,	100.0068,	2012,	08,	24,	06,	56,	56.000
14.9046,	100.1144,	2012,	08,	24,	06,	56,	48.000
14.4216,	100.2218,	2012,	08,	24,	06,	56,	40.000
13.9384,	100.3288,	2012,	08,	24,	06,	56,	32.000
13.4553,	100.4356,	2012,	08,	24,	06,	56,	24.000

Satellite Imagery and Cloud Product via Google Earth

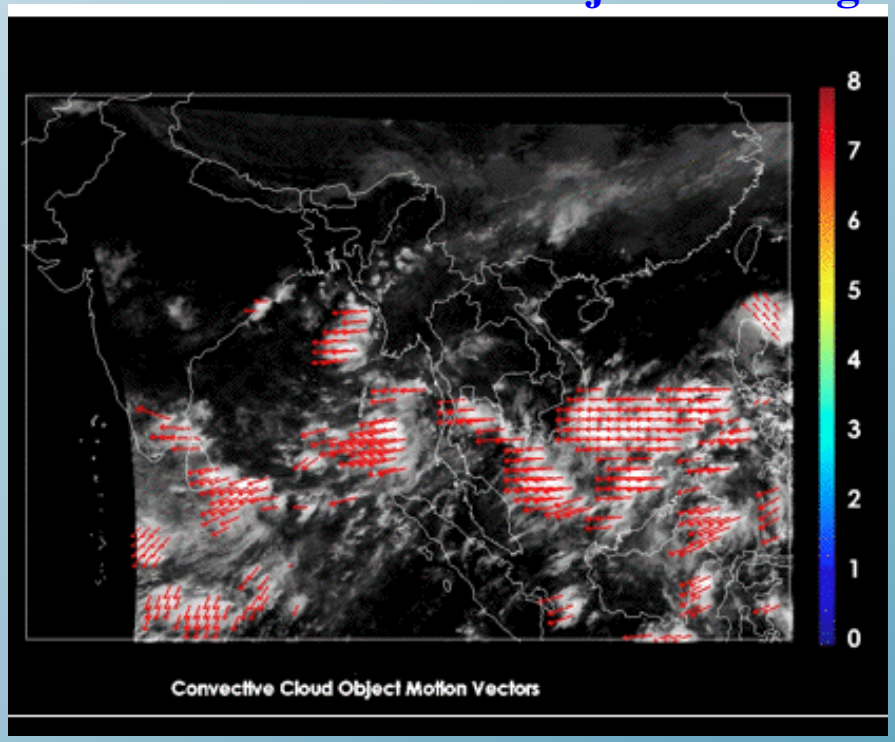


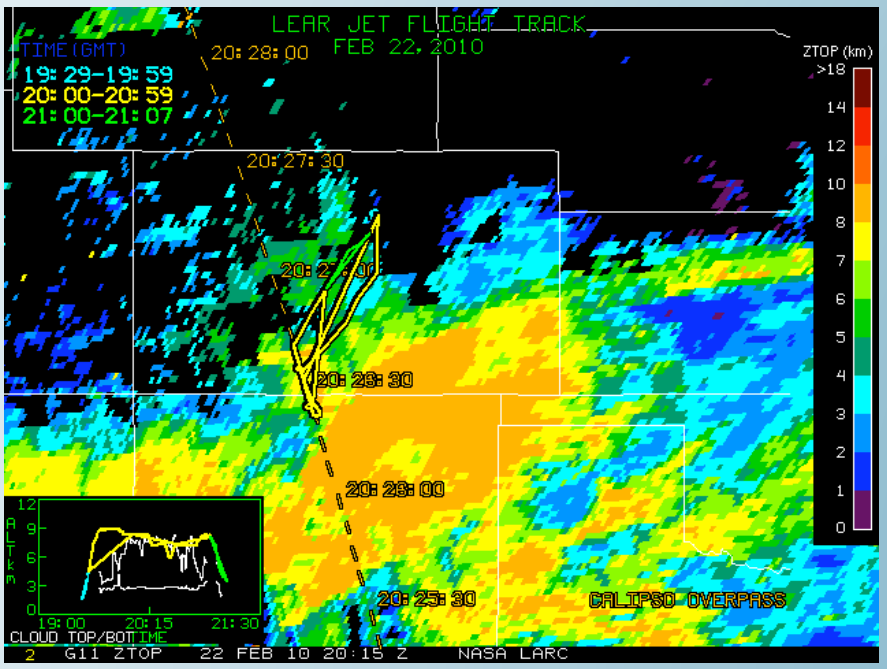
Integration of Cloud Products into McIDAS system

Nexrad Radar Overlay



Convective and Cloud Object Tracking





Lear Jet Track During SPARTICUS Field Campaign 2010

Geostationary Convective Cloud Object Tracking

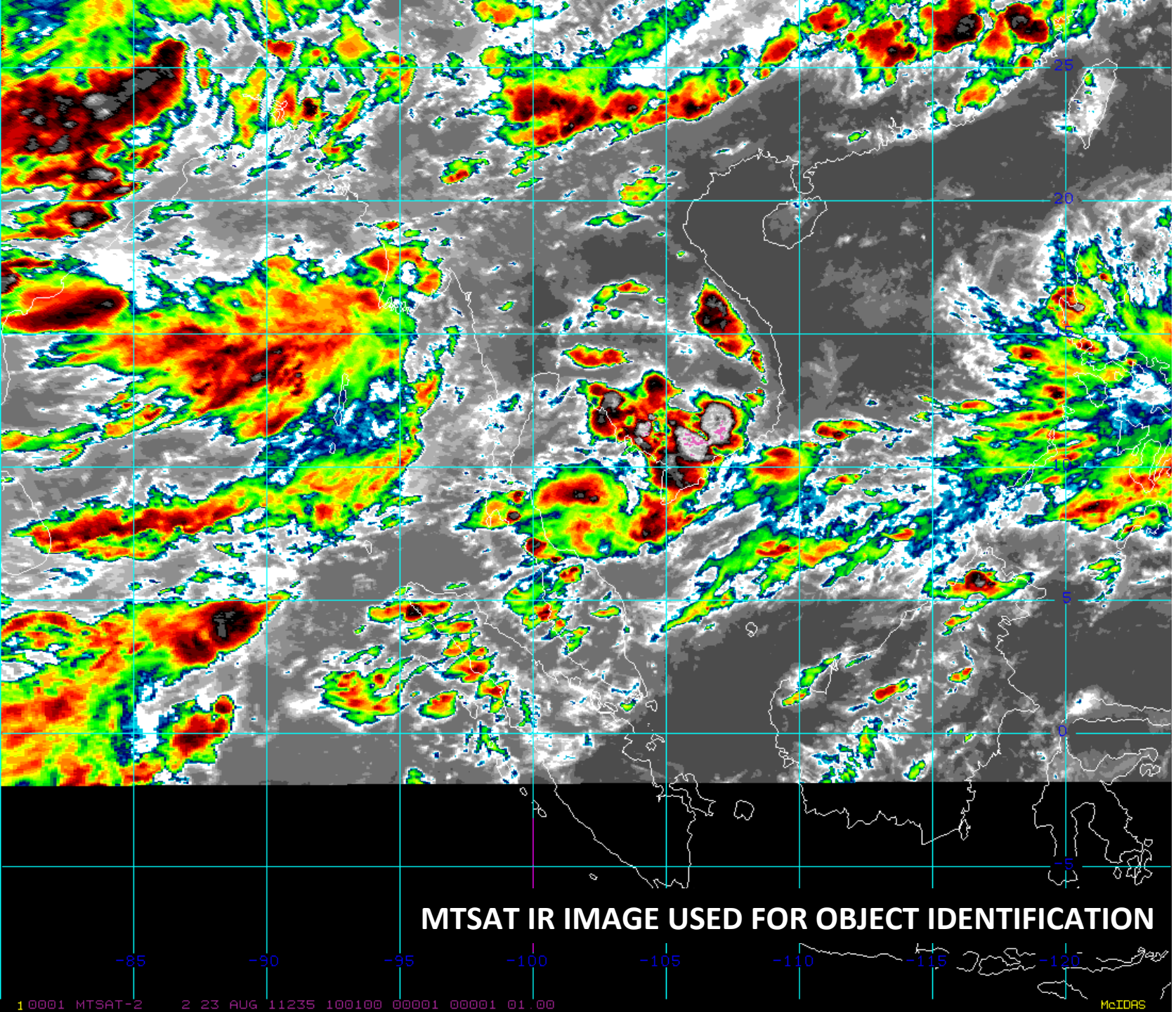
Object Advection Using Previous Object Motion + NWP Wind Field

- Objects are tracked throughout a sequence of images. Motions are derived within adjacent frames. Outflow from a stationary object can deceive the system

- An NWP 700 hPa wind field (GEOS-5 during SEAC4RS) is blended with the object-based motion analysis to produce a more reliable motion field

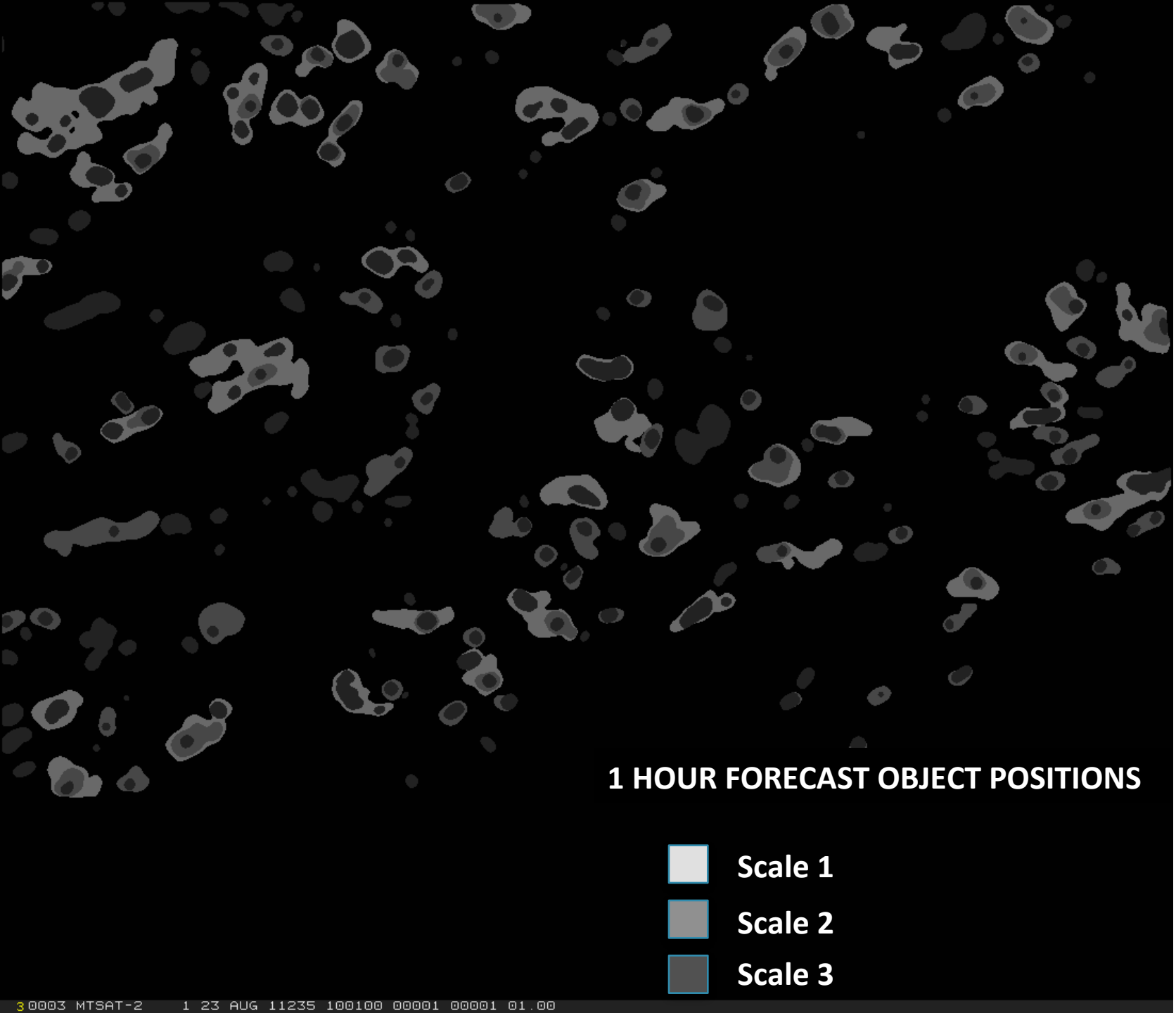
- Object locations are projected forward in time based on the wind field. The shape of the object can be distorted by the wind if the field is not constant across the object

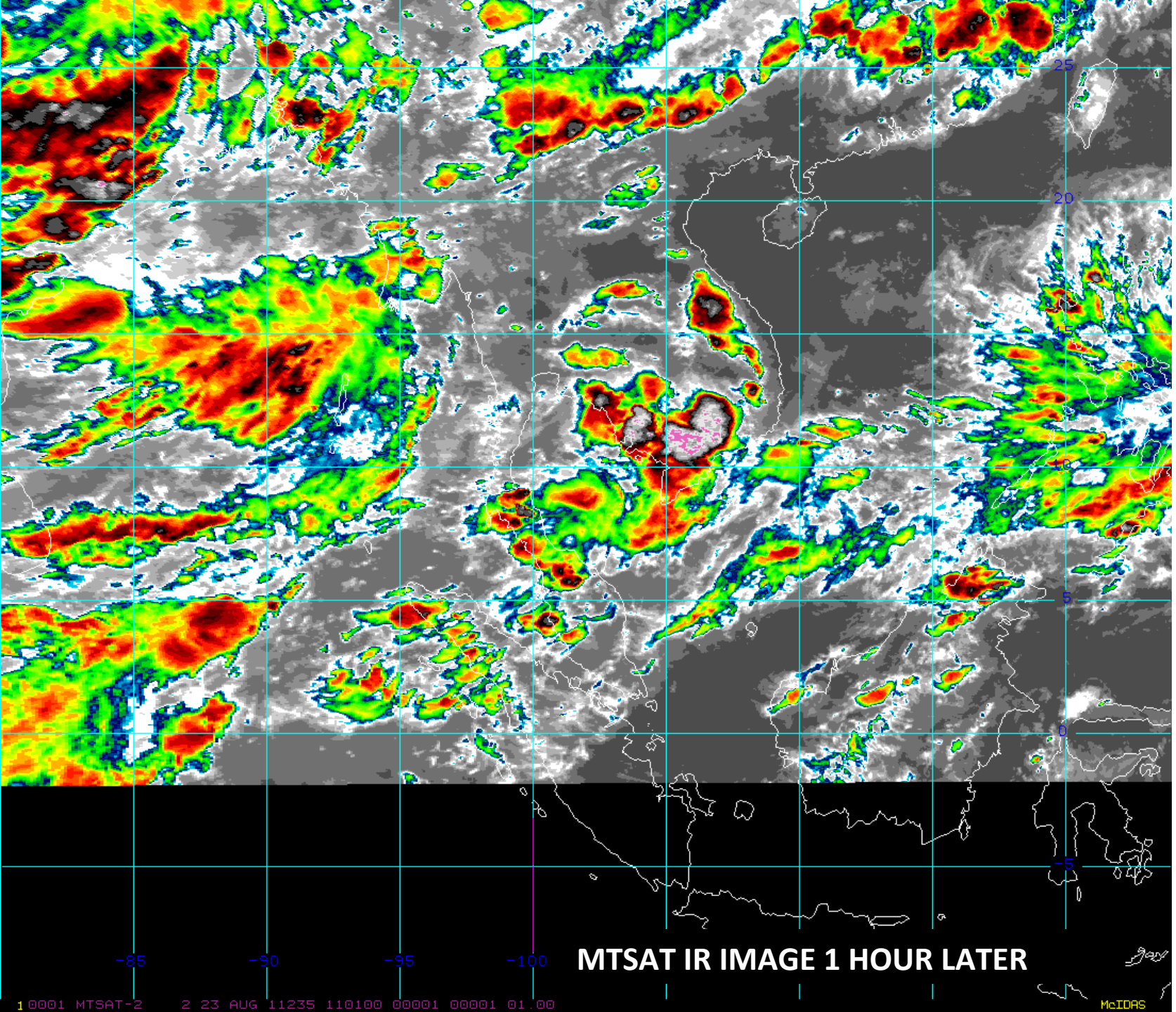
- With 30 min imagery, objects and their associated properties can be tracked for long periods of time until they have decayed to a point where there are no longer IR BTs colder than 230 K.



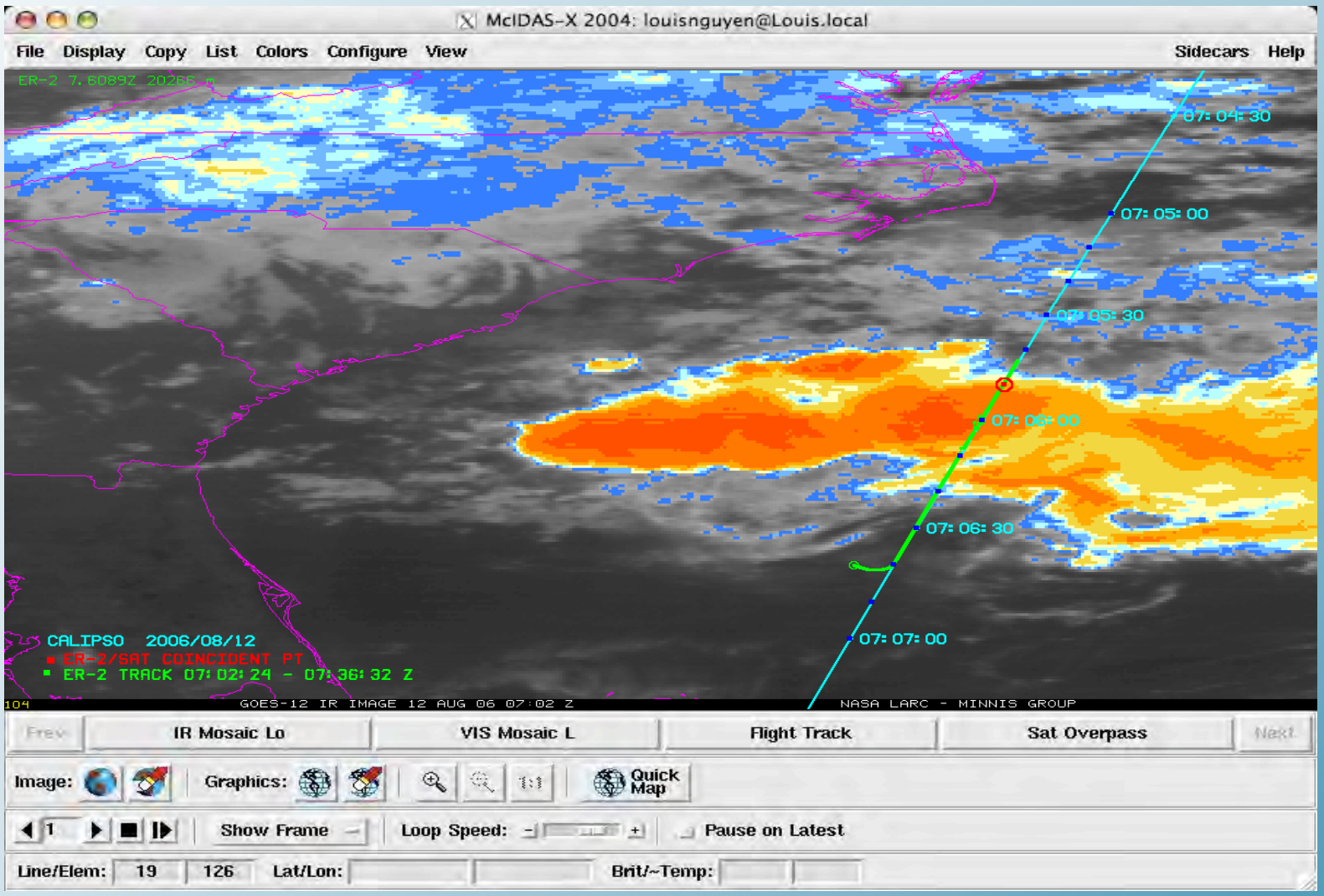
MTSAT IR IMAGE USED FOR OBJECT IDENTIFICATION


CLOUD OBJECT IDENTIFICATION
Scale 1
Scale 2
Scale 3
2 0002 MTSAT-2 1 23 AUG 11235 100100 00001 00001 01.00


1 HOUR FORECAST OBJECT POSITIONS
Scale 1
Scale 2
Scale 3
3 0003 MTSAT-2 1 23 AUG 11235 100100 00001 00001 01.00


25
20
15
10
5
0
-5
-85
-90
-95
-100
MTSAT IR IMAGE 1 HOUR LATER
1 0001 MTSAT-2 2 23 AUG 11235 110100 00001 00001 01 00
McIDAS

Real-time Aircraft Tracking

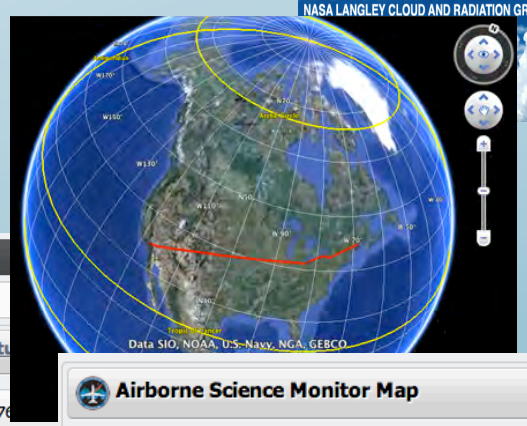


Will need Real-time access to the aircraft navigation data

Integration of Satellite Products into MTS

NASA Airborne Science Mission Tool Suite

http://airbornescience.nasa.gov/content/ASP_Mission_Tool_Suite



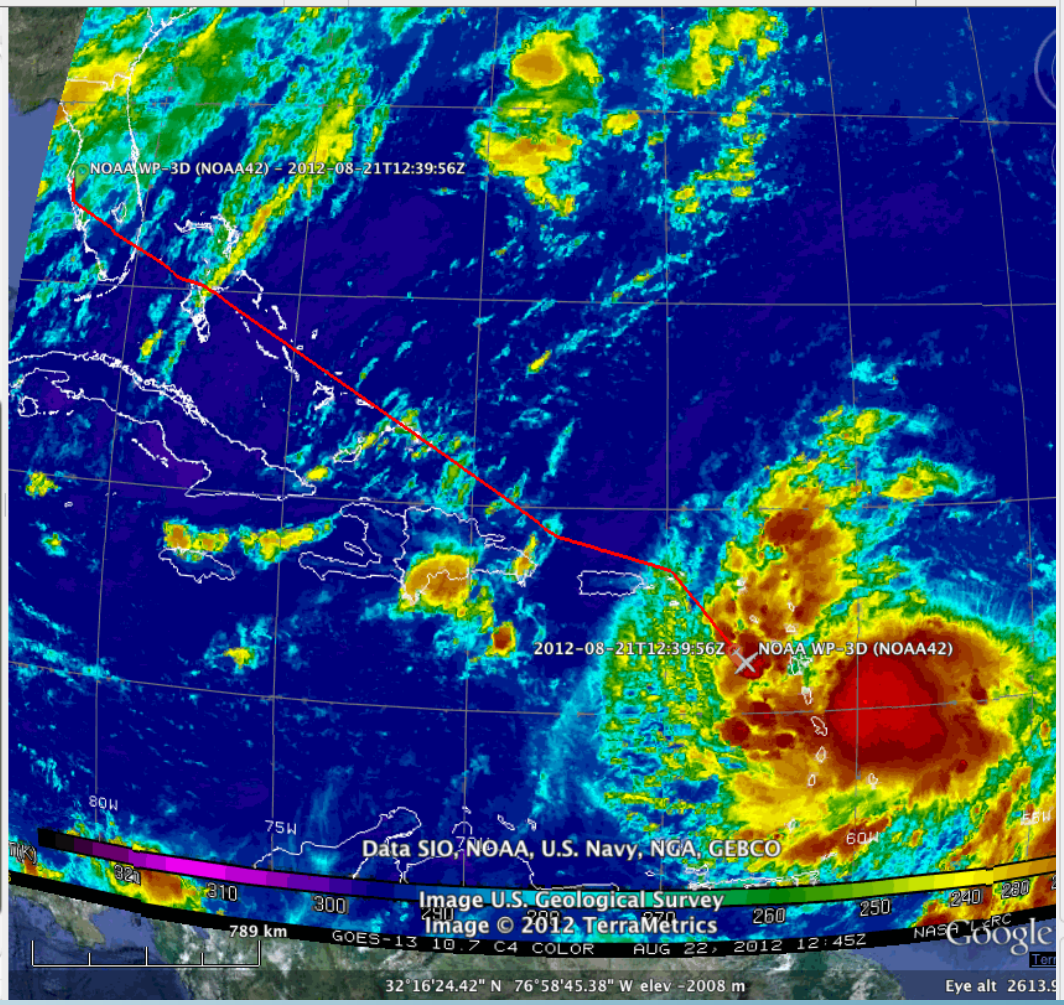
Home

NASA Airborne Science | Louis Nguyen | Home

Airborne Science Monitor Globe

NOAA WP-3D (NOAA42) | 2012-08-21T18:32:57Z (About 21 hours ago)

- NASA LaRC - HS3 Products
  - Eastern US/Atlantic
  - Atlantic
    - Visible
    - Visible Loop (Maps C
    - Water Vapor
    - Water Vapor Loop (N
    - IR 10.7um Grayscale
    - IR 10.7um Grayscale
    - IR 10.7um NOAA AV
    - IR 10.7um NOAA AV
    - IR 10.7um NOAA Ra
    - IR 10.7um NOAA Ra
  - Gulf of Mexico
  - Cloud Top Products
    - Ice Water Path
    - Liquid Water Path
    - Cloud Phase
    - Optical Depth
    - Cloud-Base Height
    - Cloud Top Height
- JPL HS3 Products
- Lightning Products
- Forecast & Model Products
- U.S. Radar Products
- Aircraft Operations and Planning



Airborne Science Monitor Map

NOAA WP-3D (NOAA42) | 2012-08-22T00:56:5

- B-200 - DFRC (NASA801)
- B-200 - LARC (NASA529)
- BAT4 (BAT401)
- C-23 Sherpa (NASA430)
- Cessna 206 (NASA504)
- DC-8 (NASA817)
- DHC-3T Otter (N226UT)
- ER-2 (NASA809)
- ER-2 (NASA806)
- Falcon (NASA525)
- Global Hawk AV1 (NASA871)
- Global Hawk AV6 (NASA872)
- Gulfstream G-3 (NASA502)
- Ikhana (NASA870)
- Learjet 25 (NASA616)
- NOAA G-IV (NOAA49)
- NOAA WP-3D (NOAA43)
- NOAA WP-3D (NOAA42)
- NSF G-V (N677F)
- P-3B (NASA426)
- S-3 Viking (NASA601)
- SIERRA (NASA707)
- T-34 (NASA608)
- Twin Otter - GRC (NASA607)
- Twin Otter - TOIL (N821AR)

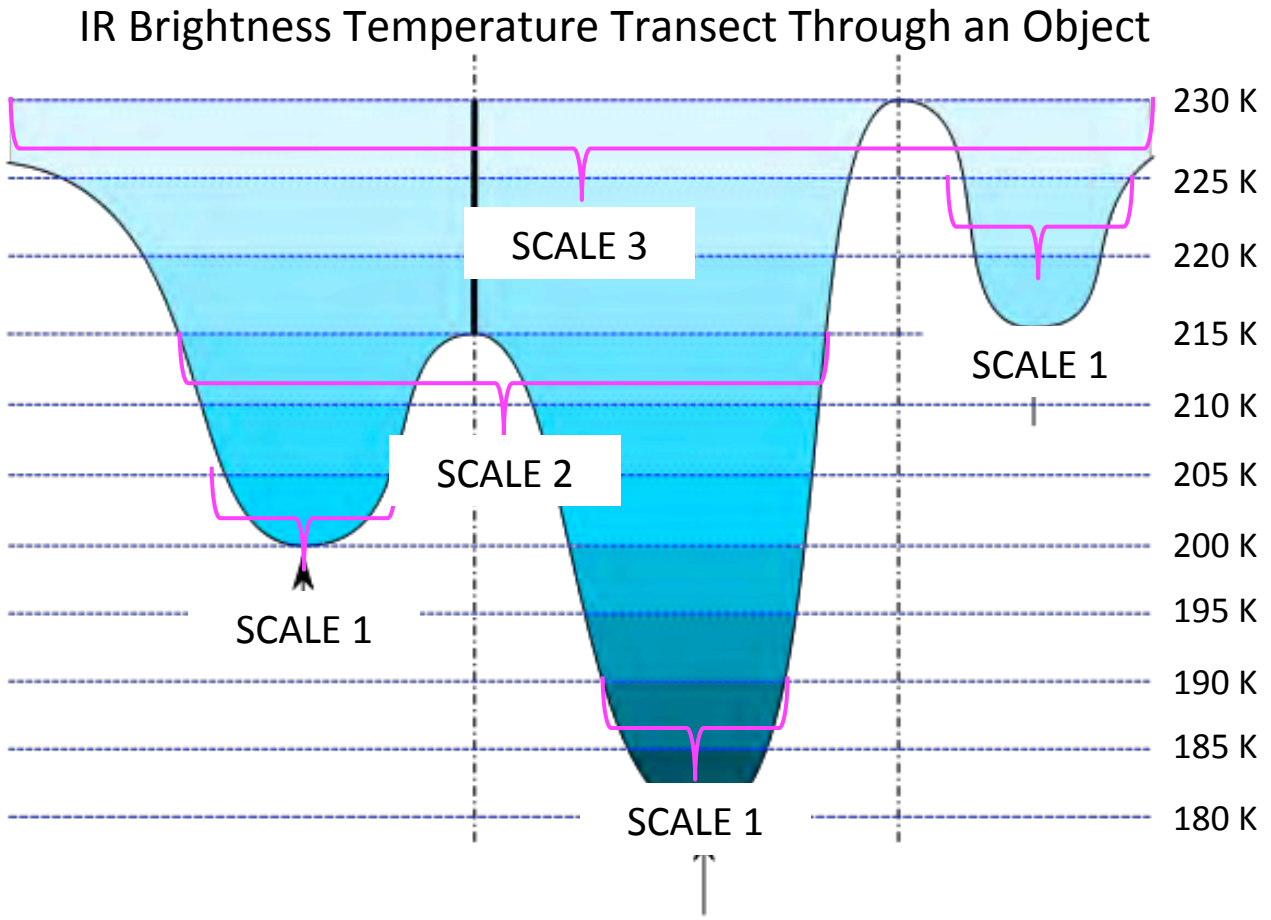
Web Service API for Accessing Data Products

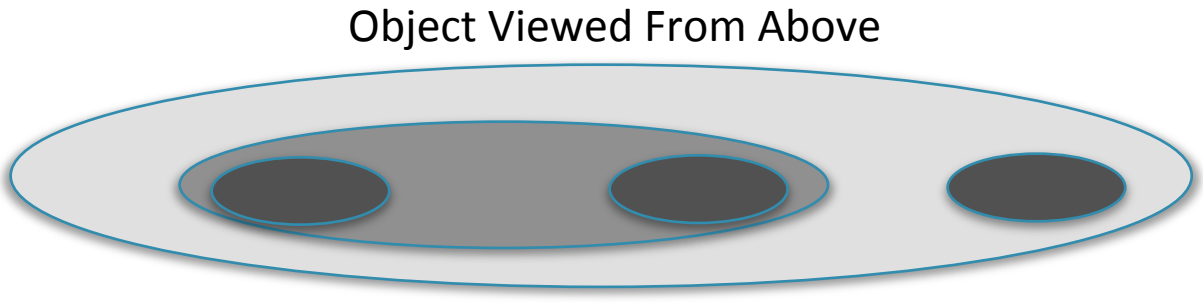
- Allow access to binary data
- Custom floating domain size and resolution
- Parameter selection
- Provides near real-time direct access via http
  - Allows integration into other application

Contact: Louis Nguyen at L.Nguyen@nasa.gov

BACKUP SLIDES

Multi-scale Object Identification Via The Watershed Transform





Objects are identified and tracked using the Warning Decision Support System – Integrated Information (WDSS-II) developed at NOAA NSSL and OU-CIMMS

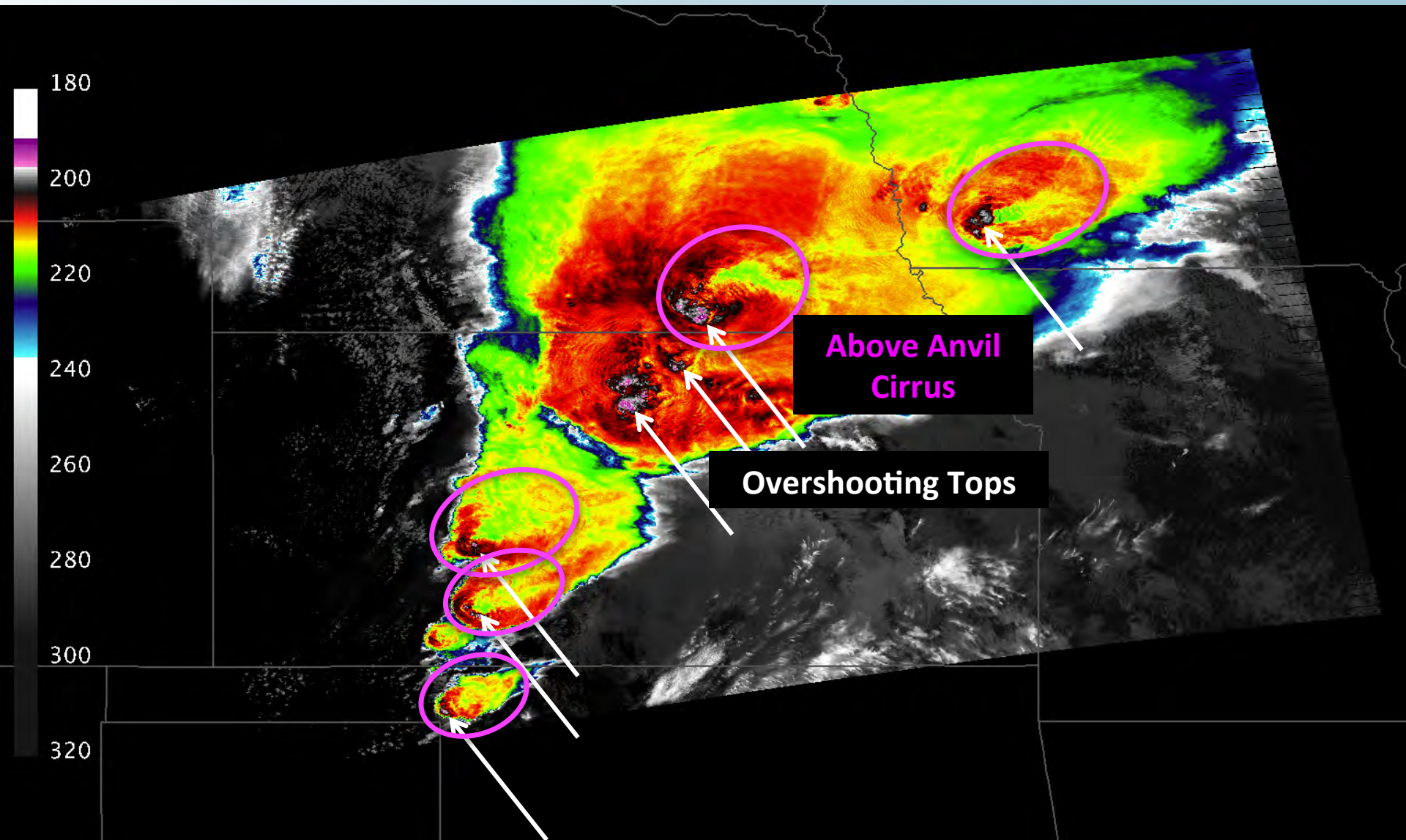
Objects are identified here at three size scales: 10, 200, and 800 pixels

Watershed Transform based on concept of "immersion". The immersion process starts at the coldest IR brightness temperature (BT, 180 K). It then progresses at 5 K increments to 230 K.

Once a sufficient number of contiguous pixels are "flooded" to reach one of the object size scales, then the object is assigned an ID number and the growth of the object stops at that time.

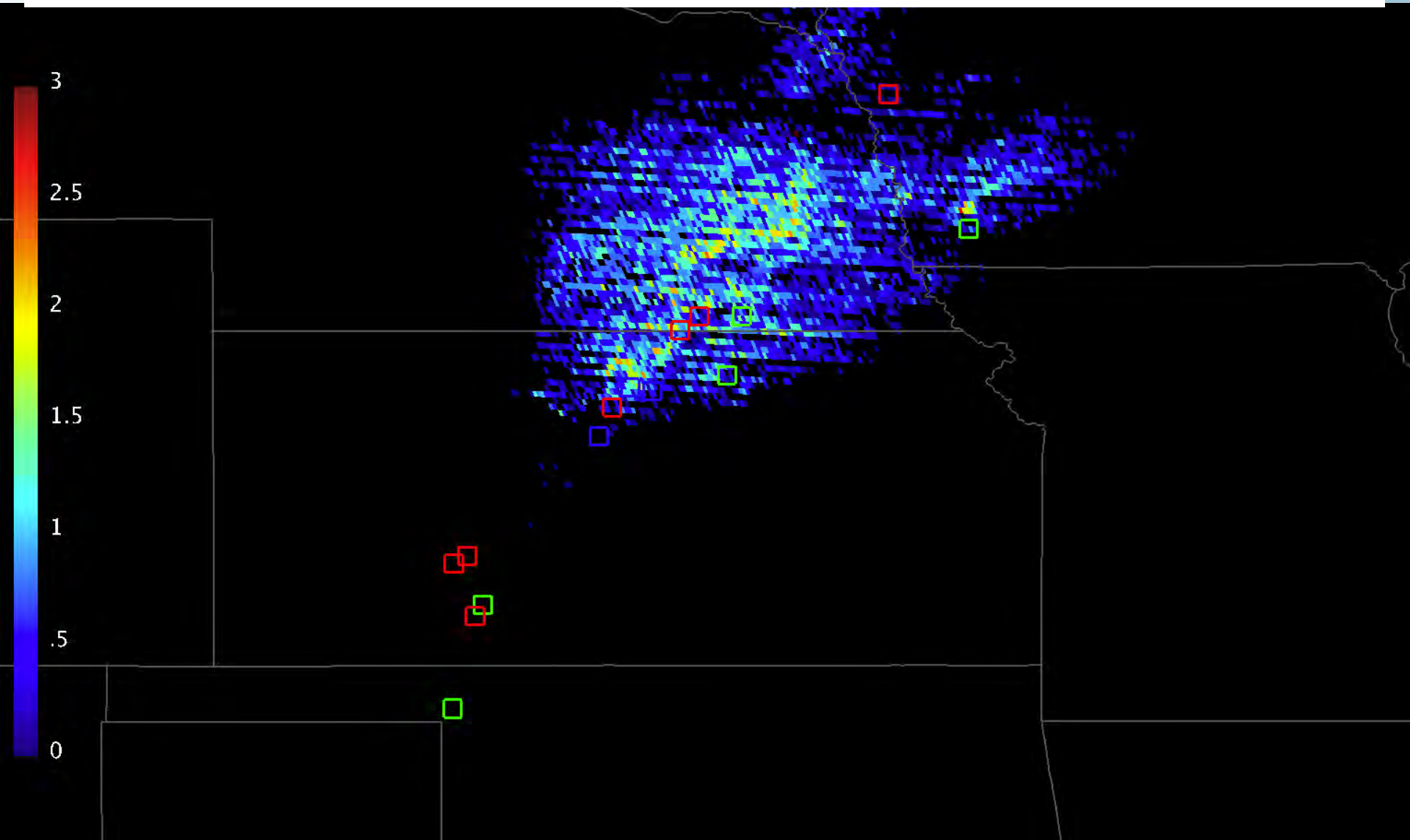
Sometimes an object may appear to be significantly larger than its size scale. This occurs when there is a large area of uniform BT that all gets absorbed into the object when the immersion progresses to the next 5 K level.

Overshooting Top and Enhanced-V Signatures Within 375 meter Suomi NPP VIIRS IR Imagery



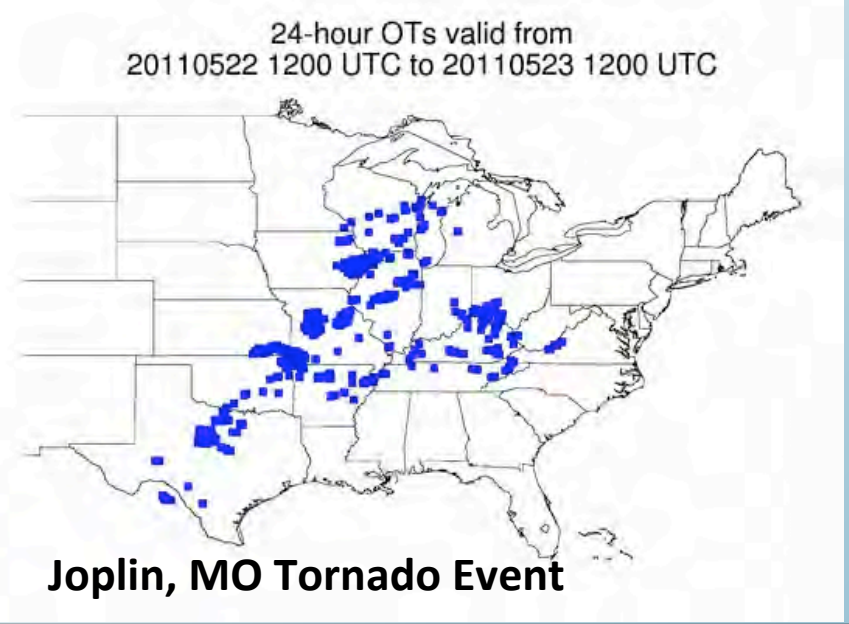
The Global Convective Diagnostic (WV-IR BTD)

- Positive BT differences (BTD) between the ~6.7 µm water vapor and 11 µm IR window channel are supposed to indicate the presence of stratospheric water vapor and convective overshooting (*Schmetz et al., Martin et al.*). Though this product has been featured in several climate studies related to overshooting convection, this and many other examples can show that much of the anvil cloud is highlighted by BTD > 0 K. There is no consistent threshold that can be used to consistently identify only the overshooting and severe portion of a storm.

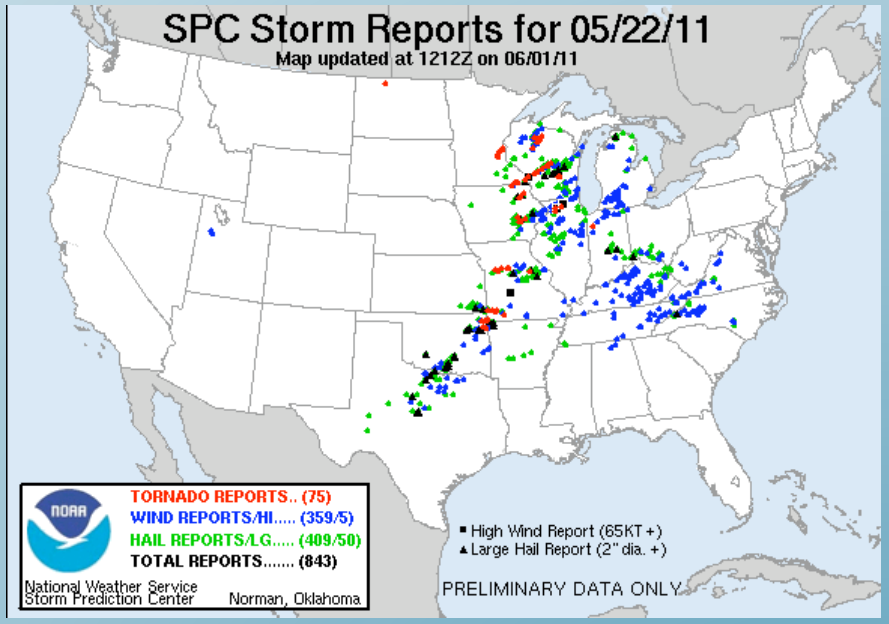


Severe Weather -> OT Comparisons

How often is an OT detected near severe weather? (+/- 30 min & km)



Joplin, MO Tornado Event



2004-2009 April-September (Dworak et al. (WAF, 2012))

Severe Weather Type	# Severe Reports	OT Match %
Tornado	4,684	56.2%
Severe Wind	52,743	58.4%
Large Hail	56,114	51.3%
Any Type	113,541	54.8%