McIDAS Activities at NASA Langley Research Center

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Introduction

- **The LaRC Satellite ClOud and Radiative Property Retrieval System (SatCORPS) team: Group of 10-15 people who regularly use McIDAS-X and/or McIDAS-V**

- **Primarily involved with cloud and Earth Radiation Budget studies using remote sensing data:**

  * Cloud / clear sky property retrieval
    - Cloud height, phase, particle size, optical and geometric thickness, skin temperature, broadband radiation flux)

  * Clouds and the Earth's Radiant Energy System (CERES) Mission
    - Earth Radiation Budget -> Long-term GEO+LEO cloud climate data record

  * Convection and severe storms

  * Aviation impacts and safety -> Contrails, airframe icing, engine icing

  * IR and visible imager calibration

  * Assimilation of satellite cloud property information into NWP models

  * Airborne field program support

  * NASA GLOBE: Cloud observations from citizens and students

Introduction

External customers/users of our LaRC SatCORPS products include:

* DOE ARM -> Climate studies, field campaigns
* NOAA NCEP and NSSL and NASA GMAO -> NWP Assimilation
* FAA -> Contrails, Deep Convection
* National Weather Service and NOAA National Centers
* Other NASA centers, national/international universities, international working groups
* Private industry (solar energy, reinsurance, others)

LaRC McIDAS-X Usage

- McIDAS-X: Primary software used to acquire and/or process GEO and LEO VIS/IR imager, gridded NWP, and other datasets
- McIDAS-X and SSEC Data Center archive server subscription are essential for LaRC SatCORPS and NASA CERES operations
- Cloud and radiation product generation and display
  * Shell scripts, mcenv, batch processing used to generate web graphics
- Derived product overlay on satellite imagery
- GUI used for onsite airborne field experiment support
  - Flight planning, aircraft safety, identifying desired targets for sampling
- Extract satellite data along line segments or over ground sites
- Use TLE files to plot satellite orbital predict tracks
- Calibration
  * Write gridded image data for satellite inter-comparison
  * Extracts suspected deep convective cloud and desert pixel data

McIDAS-Based Data Volumes Processed at NASA LaRC

- Files downloaded by McIDAS for real-time processing or archival
  * ~ 1000 satellite image AREA files per day
  * Model data in GRID format including analyses and forecasts from global GFS at 1.0 and 0.5 deg, and the RAP 40-km run
  * Data volume: ~64 GB/day (mostly from AREA files)

- Example Airborne Field Campaign: Data volume for ATom-4 field experiment (primary+backup system ingest)
  * ~ 1400 AREA files/day (GOES, HIM8, MSG, N15-19, METOP)
  * ~ 28 GB/day

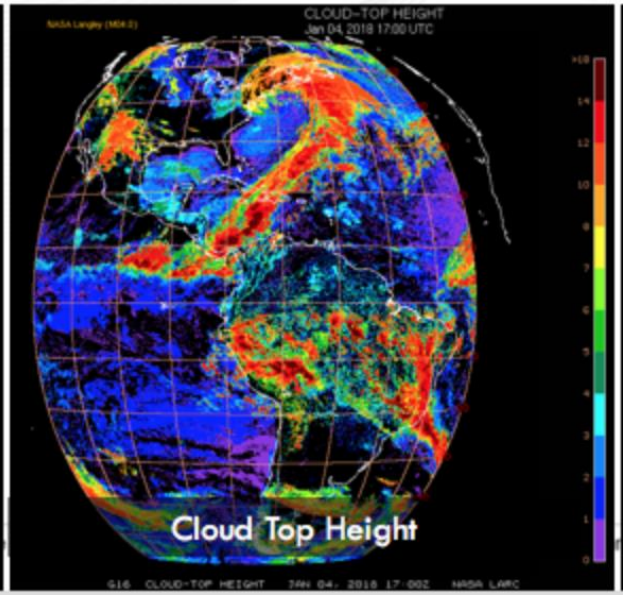
- McIDAS Data volume for global convection processing:
  * ~ 480 AREA files/hour (G13, G15, MET8, MET10, HIM8)
  * ~ 40 GB/hour

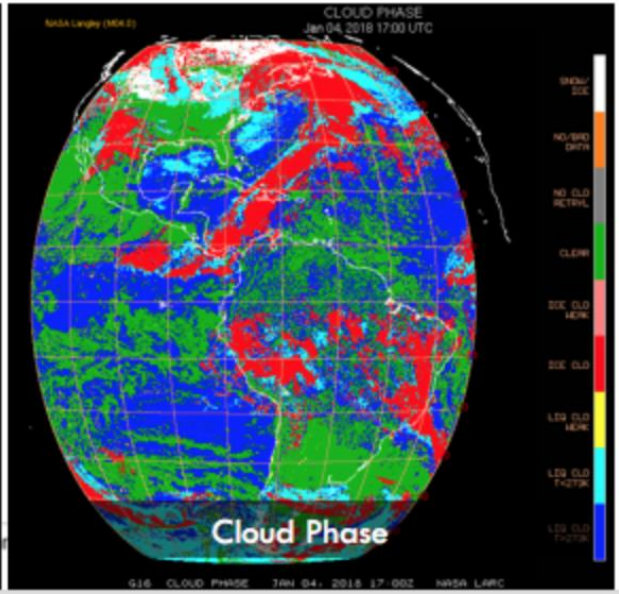
- CERES cloud property climate data record processing, ~20-year global GEO data record at 8 km resolution, ??? TB

NASA LaRC Cloud Property Retrievals

The LaRC Satellite ClOud and Radiative Property retrieval System (SatCORPS) uses methods developed within the CERES Science Team and other NASA and NOAA programs to ingest real-time satellite imagery (left image) and determine cloud properties such as:

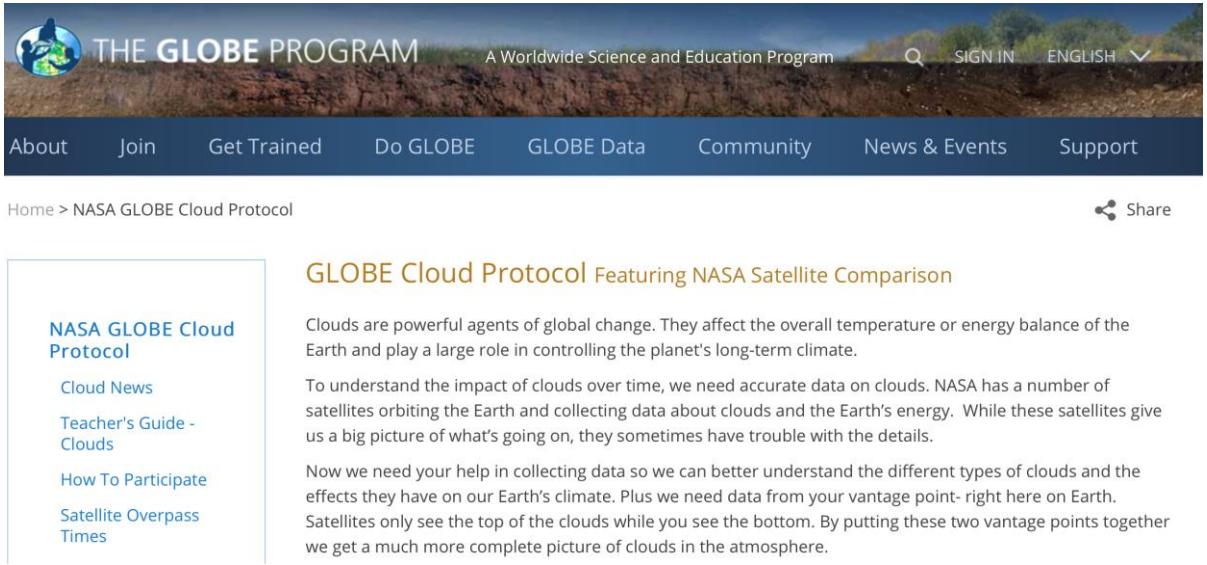
1) Cloud Top Height (middle image)
2) Cloud Top Phase (ice vs. water, right image)
3) Cloud Top Ice Crystal or Water Droplet Size
4) Cloud Optical and Geometric Thicknesses
5) Aircraft airframe and aircraft engine icing likelihood
6) Locations of hazardous thunderstorms





Citizen Scientist Cloud Observations Within the GLOBE Program

https://www.globe.gov/web/s-cool



- Produce McIDAS cloud product AREA file from netcdf data
- Extract cloud amount, phase, optical depth, height, temperature in a 40-km radius circle surrounding the observer's location
- Include matches for observations within 15-min of approximate satellite scan line time
- Use the historical McIDAS GEO server to make VIS or IR image centered on observer's lat/lon coordinates to show them their scene from a satellite perspective

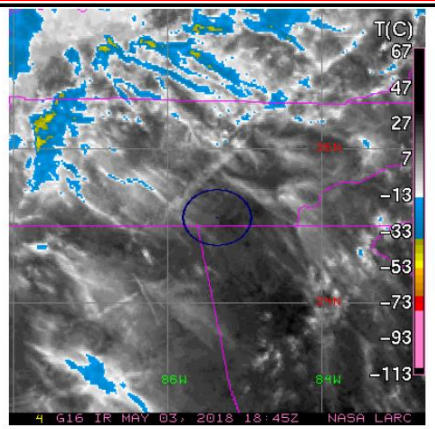
LaRC SatCORPS Cloud Property Retrieval In 40 km Radius From GLOBE Citizen Scientist Observation

* May 3, 2018 GLOBE cloud observation (18:42 GMT) matched with G16 IR image (18:45 GMT)

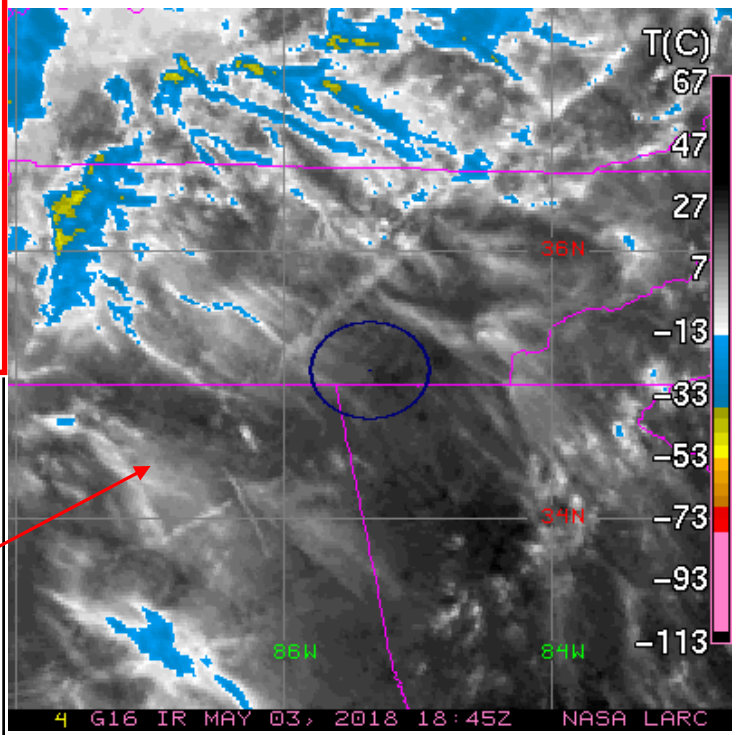
Ground Observation: 624706			GEO Satellite				
Latitude : 35.12 Longitude : -85.36			Latitude : 0.00 Longitude : -75.00				
Date: 2018-05-03		Universal Time: 18:42	Date: 2018-05-03		Universal Time: 18:48		
Opacity	Cloud Cover	Type		Altitude (km)	Opacity	Cloud Cover	Phase Temp(C)
Total Ground Cloud Cover: Broken (50-90%)			Total GEO Cloud Cover: 48.54 %				
HIGH	Contrails Non Spreading: 1						
HIGH	Translucent	Broken (50-90%)	Cirrus, Cirrocumulus, Cirrostratus	6.58	Transparent 0.89	Clear (<10%) 2.17	ice -8.32 (C)
MID	Translucent	Isolated (10-25%)	Altocumulus, Altostratus	3.68	Transparent 0.89	Scattered (25%-50%) 41.3	mixed 7.74 (C)
LOW	Translucent	Clear (<10%)	Cumulus	1.76	Transparent 0.86	Clear (<10%) 5.07	water 19.07 (C)
Sky Visibility : no report Sky Color : no report							

Surface Conditions

Snow/Ice	No
Standing Water	No
Muddy	No
Dry Ground	Yes
Leaves on Trees	Yes
Raining or Snowing	No



T(C)=Temperature(Celsius)

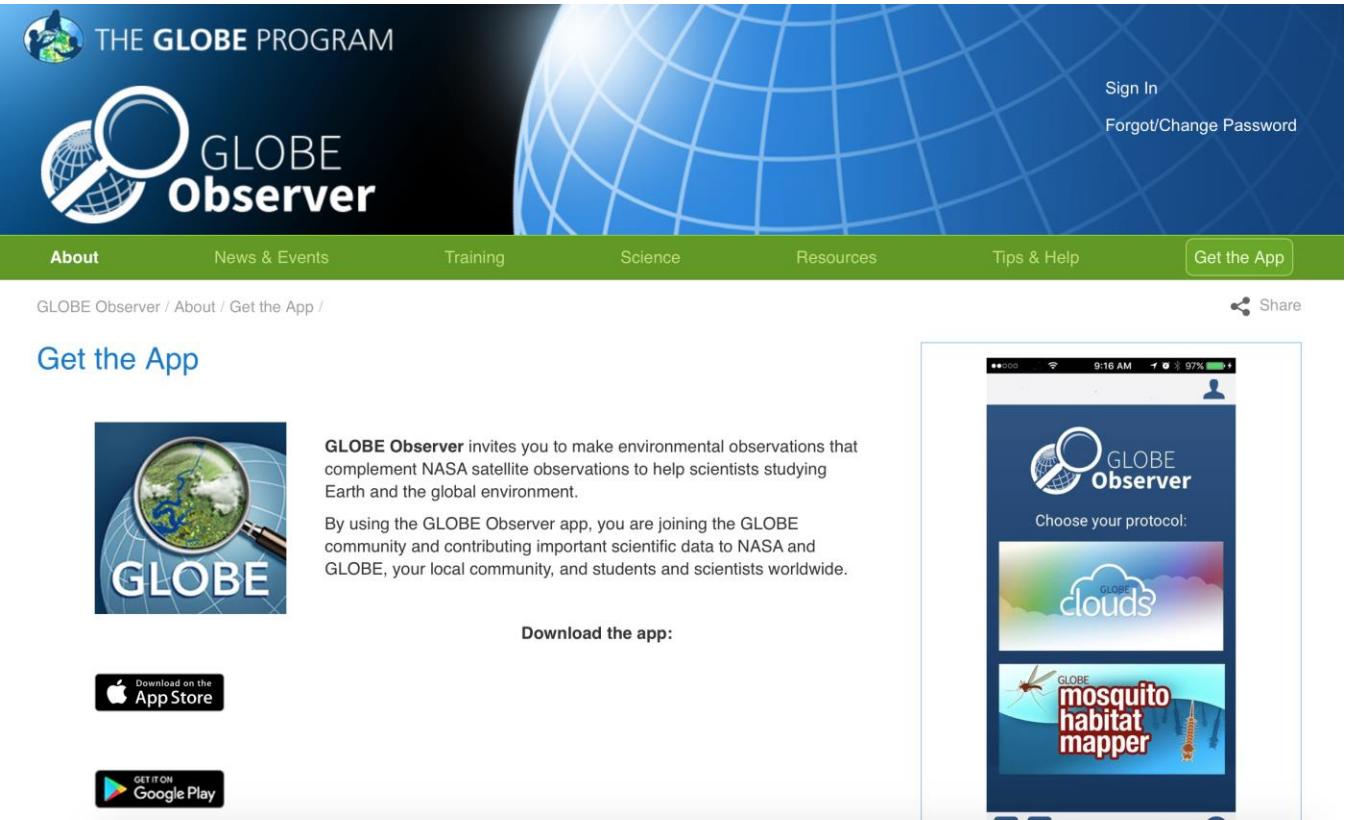


Citizen Scientist Cloud Observations Within the GLOBE Program

https://observer.globe.gov/about/get-the-app

- You too can submit observations of clouds, anywhere and anytime, with the GLOBE Observer App

- Enables photographs of clouds that are very helpful for understanding why automated NASA cloud detection/retrieval algorithms mischaracterized clouds. Data useful for NOAA cloud algorithm validation too



South

Upward

CERES Cloud Property Climate Data Record Generation

- Hourly global GEO imagery downloaded from SSEC Data Center ADDE archive server (i.e. geoarc.ssec.wisc.edu)
- Images are subsetted from 60N-60S at 6- to 8-km resolution
- GEO data acquired and processed from 2000-present
- Cloud products are currently generated one month at a time to add the existing data record. New algorithm Editions require reprocessing of the entire data record
- Long-term product generation for CERES Edition 4 complete, Edition 5 to be generated in the ~2020 timeframe

Recent Airborne Field Mission Support

- NASA 4th Atmospheric Tomography mission (ATom-4) over Western Hem
  -12 Domains running simultaneously using G15, G16, HIM8, MET11, NOAA-AVHRR, MODIS
  - High res imagery for web page and lower res uploaded to plane
  - Read into NASA MTS/Google Earth

- Southern Ocean Clouds, Radiation, Aerosol Transport Experimental Study (SOCRATES) off SE coast of Australia
  - Real time mission support using HIM8
  - Flight tracks with overlay on vis, ir, rgb imagery

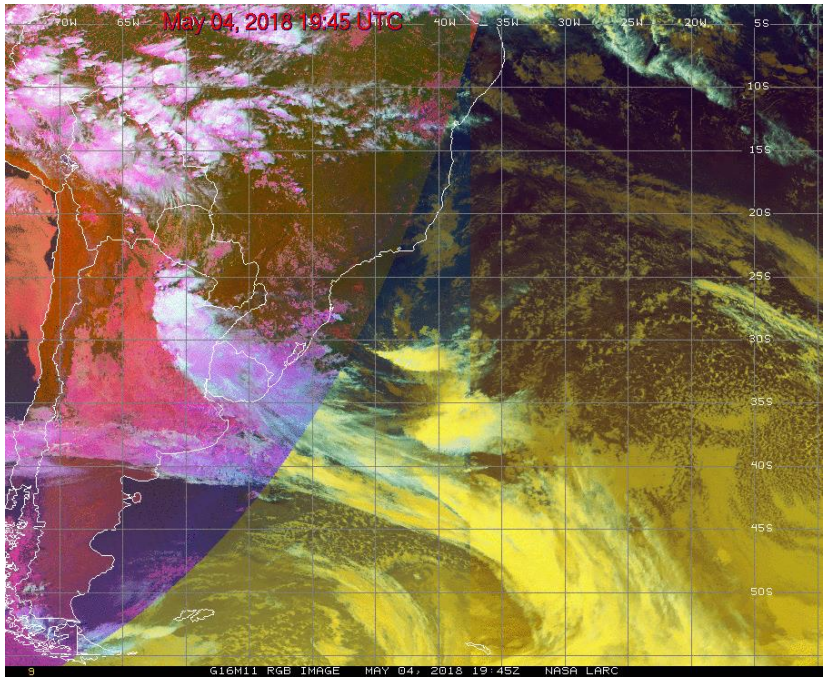
- North Atlantic Aerosol and Marine Ecosystems Study
  - Real time support using G16 imagery
  - GIF, kml files with large domain plus individual sectors provided

- Observations of Aerosols above Clouds and their IntEractionS (ORACLES) along and off SW Africa coast
  - 2 domains supported operations using MET-10 imagery
  - Image channels converted to netcdf format using LaRC programs

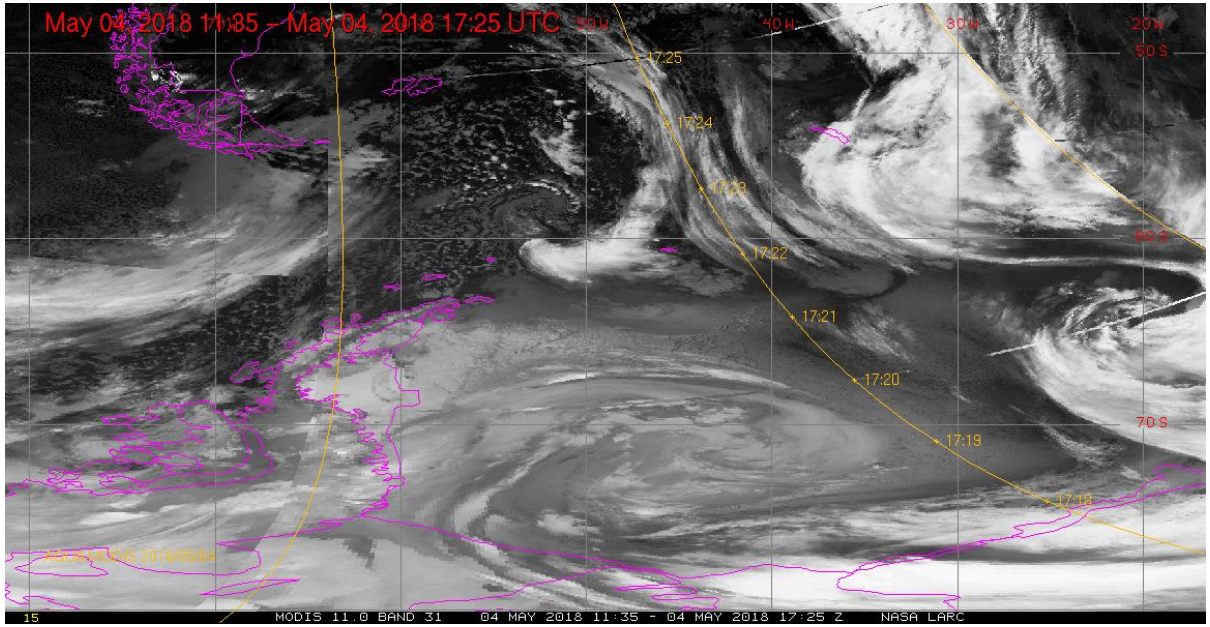
- High Ice Water Content – Radar 2 Campaign upcoming in August 2018 (ABI CONUS, MESO, GLM)

Field Mission Support

ATom-4 Imagery
from 2 Domains
04 May 2018

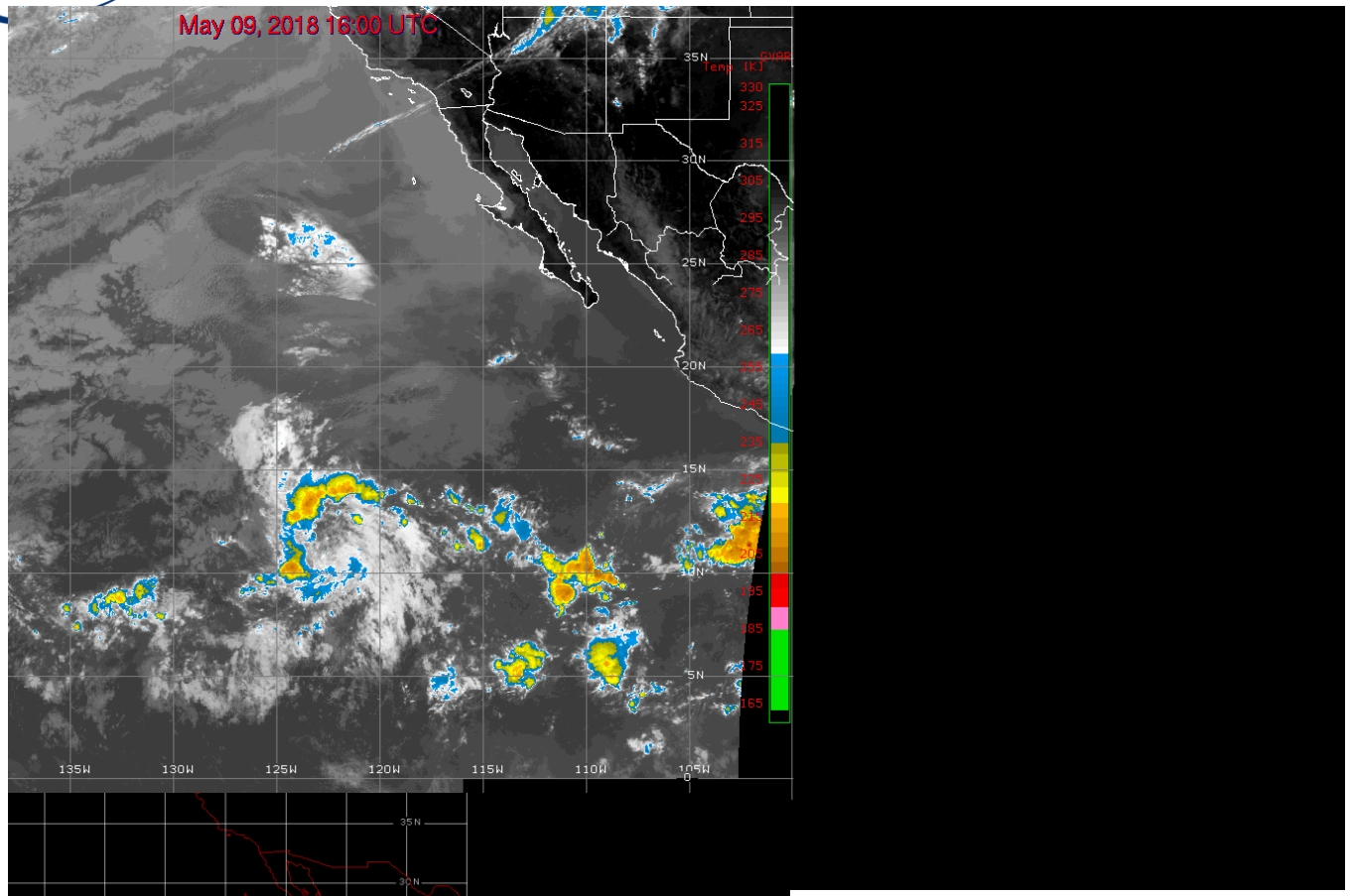


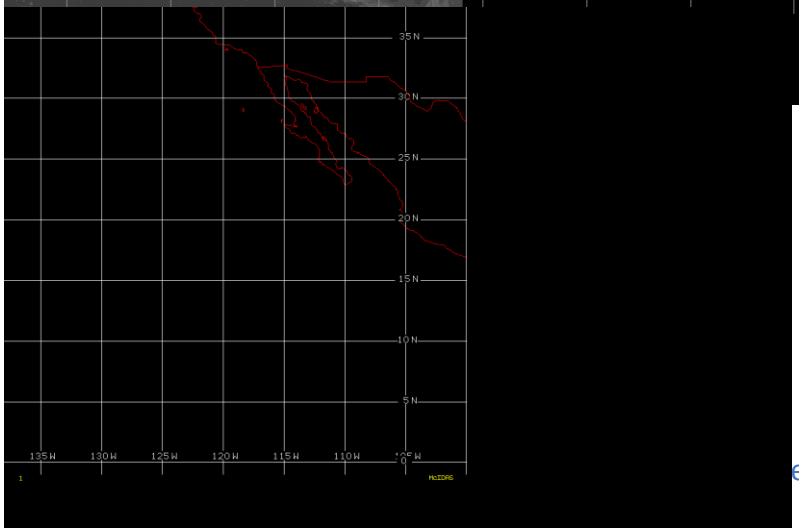
* G16, MET11 Merged RGB: South America-SW Atlantic



* Terra, Aqua MODIS Composite IR: South America-Antarctica

Field Mission Support

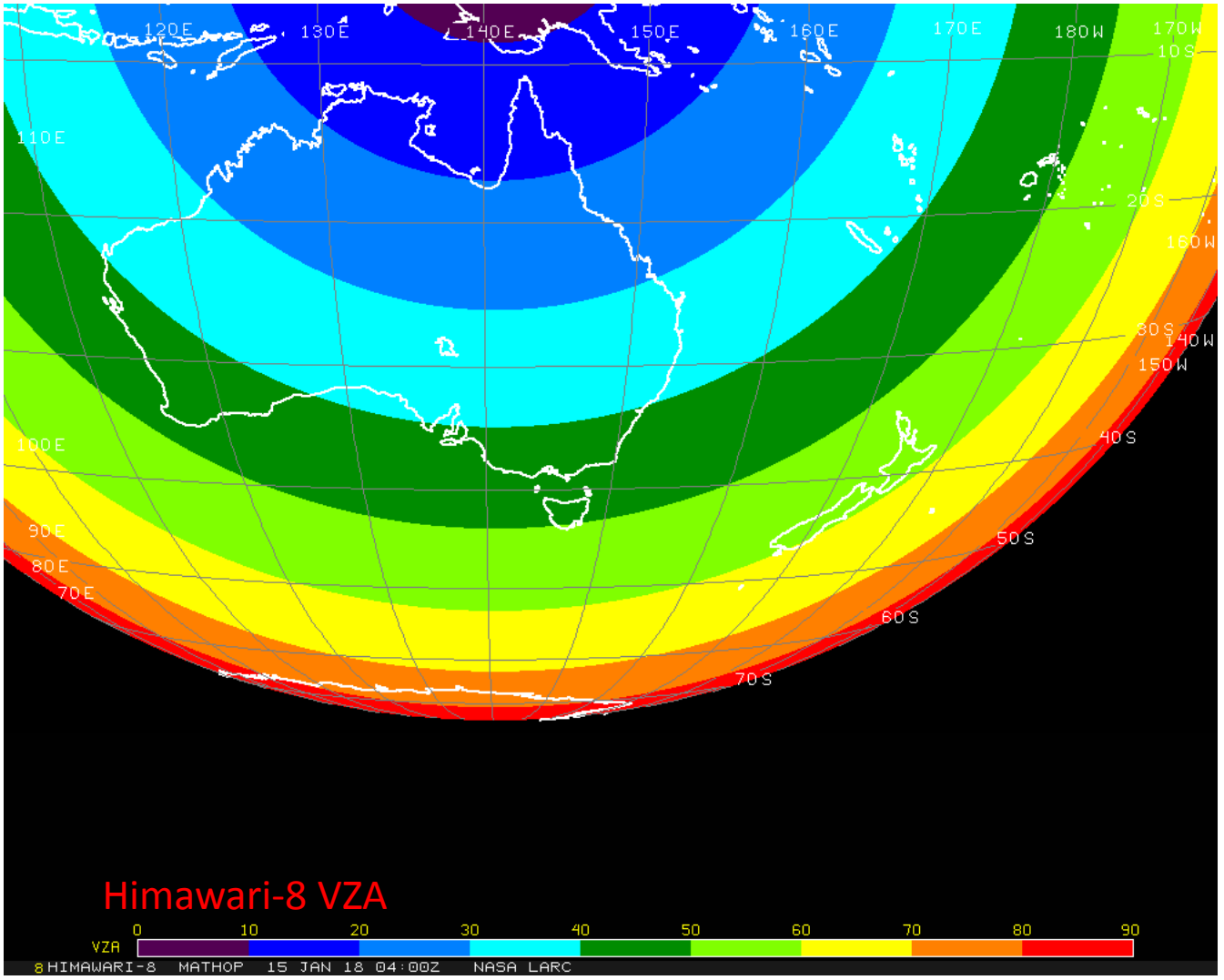




*ATom-4 Color IR Imagery and map for 11 Domains, 09 May 2018, 16:00 UTC

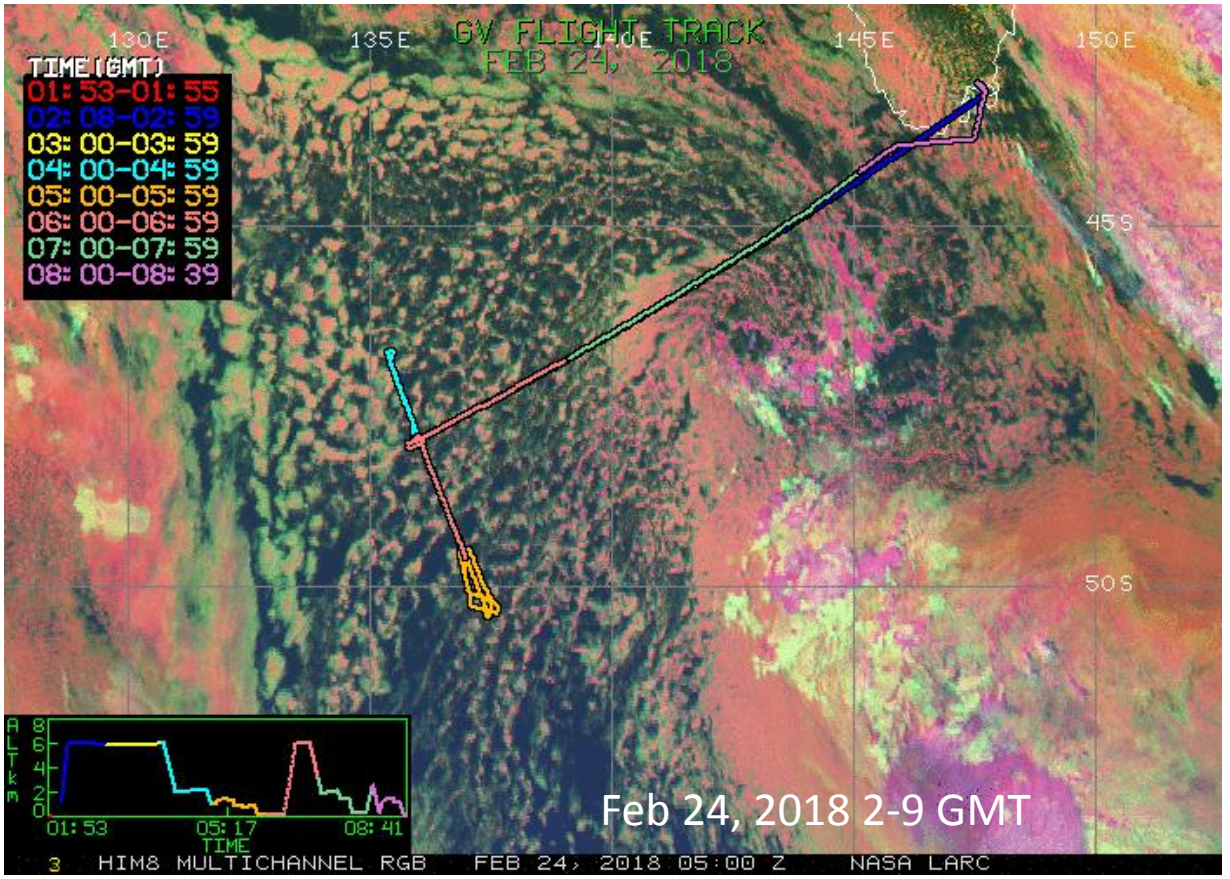
Field Mission Support

* Image of VZA used to determine how far south imagery would realistically go toward Antarctica's coast for SOCRATES



Field Mission Support

SOCRATES



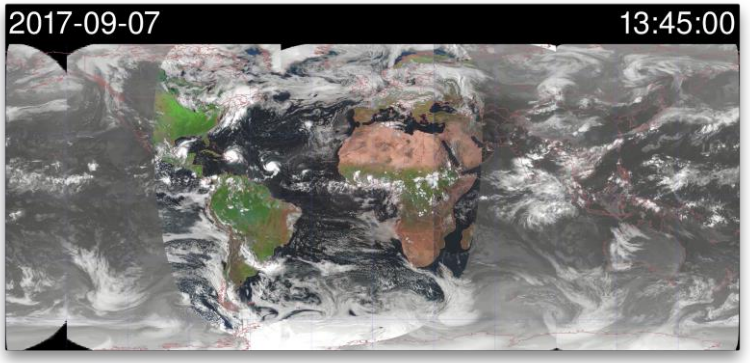
*Gulfstream-V Flight Track overlay on Himawari-8 multi-channel RGB Imagery (south of Tasmania)

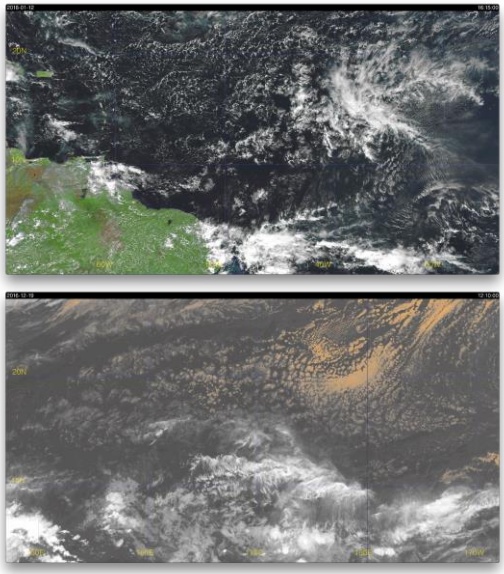
Geostationary RGB Animations Made From Archived SSEC Data Center Imagery

Initial Processing

- McIDAS-X used to download full-disk images at highest resolution:
  - GOES-16 (1 km, 15 min)
  - Himawari-8 (1 km, 10 min)
  - Meteosat-10 (3 km, 15 min)
  - Meteosat-8 (3 km, 15 min)

- After converting from AREA to NetCDF, Matlab code reads multiple wavelength bands at each image's timestamp to calculate a quasi-color representation for daytime, and (mostly) grayscale infrared for nighttime. Day and night are blended.

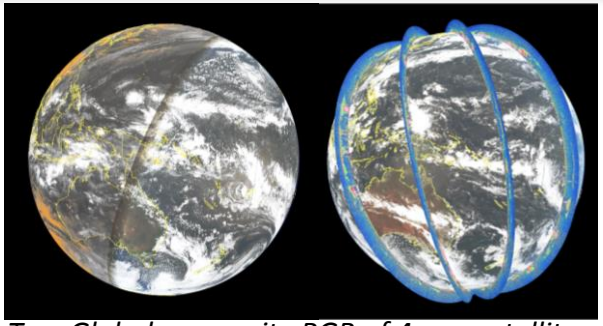




Top: GOES-16, Jan 2018. Bottom: Himawari-8, Dec 2016.

Projection / Animation

- ParaView (open-source viz. software):
  - Embedded Python shell for scripting
  - Plate Carrée or Spherical Projection
  - Matlab-generated image time series is plotted regionally or globally, then written as a stream of PNG files.
  - Can add CALIPSO/CloudSat profiles and choreograph smooth camera flybys.
- FFmpeg – Converts stream of PNG images into an MPEG-4 file.



Top: Global composite RGB of 4 geo satellites. Bottom: Spherical projection of Himawari-8 and CALIPSO/CloudSat.

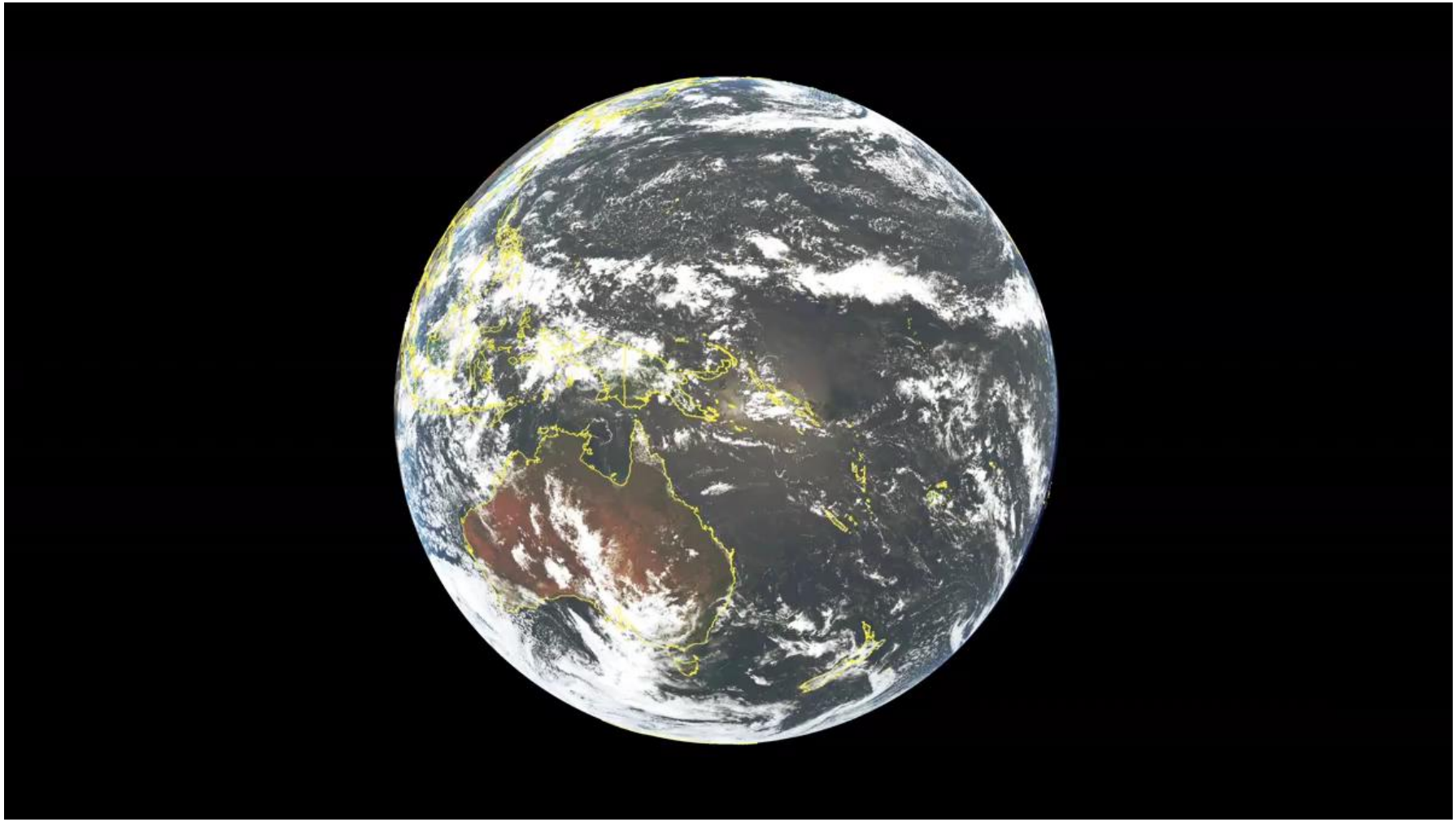
Purpose

- Gives ability to view observed atmospheric phenomena globally at high resolution.
- Adds meteorological context when analyzing individual CALIPSO/CloudSat cross-sections.
- MPEG's are portable, can be reproduced easily, and deliver detailed animations.

Slide by Roman Kowch

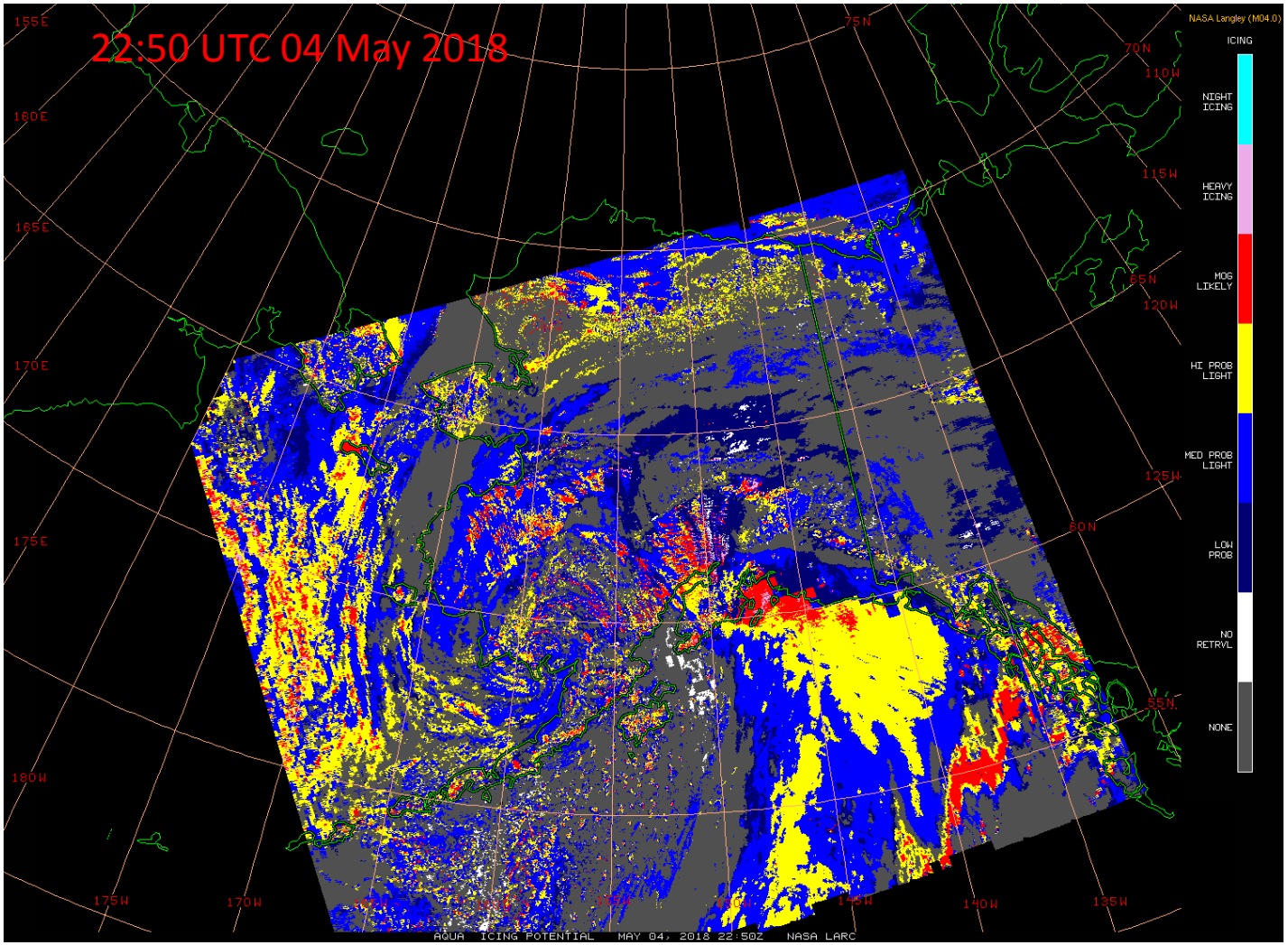
Geostationary RGB Animations Generated From AREA Acquired From SSEC Data Center Archive

* Himawari-8 imagery with CALIPSO and CloudSat data, early Dec 2016



MODIS Aircraft Airframe Icing

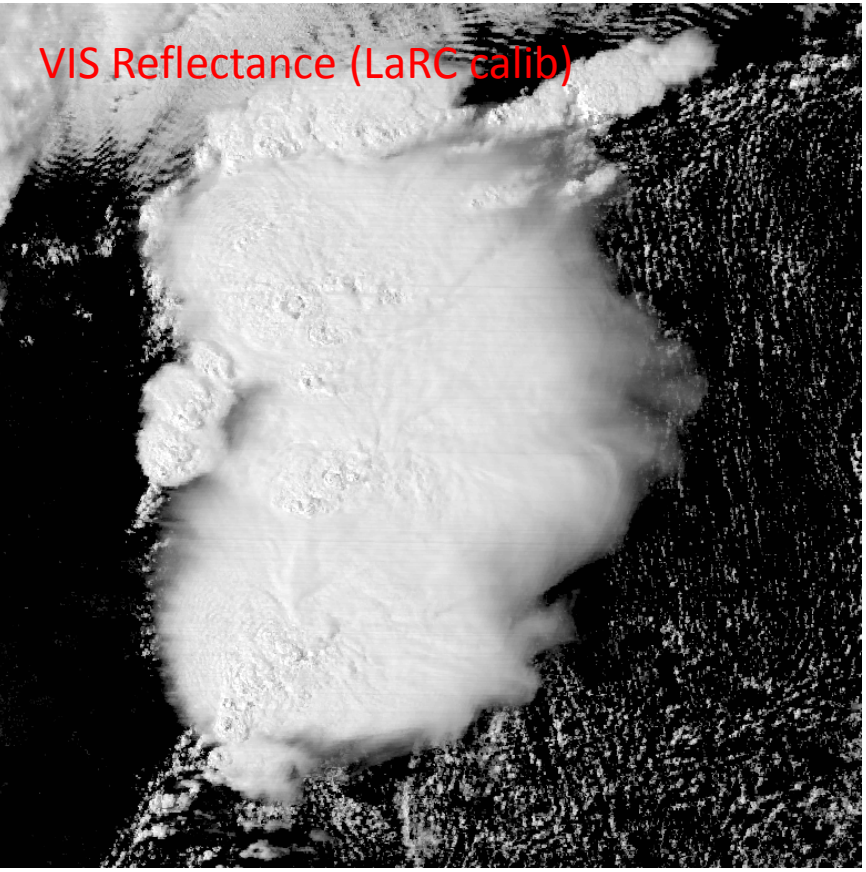
* Airframe icing derived from Aqua-MODIS over Alaska

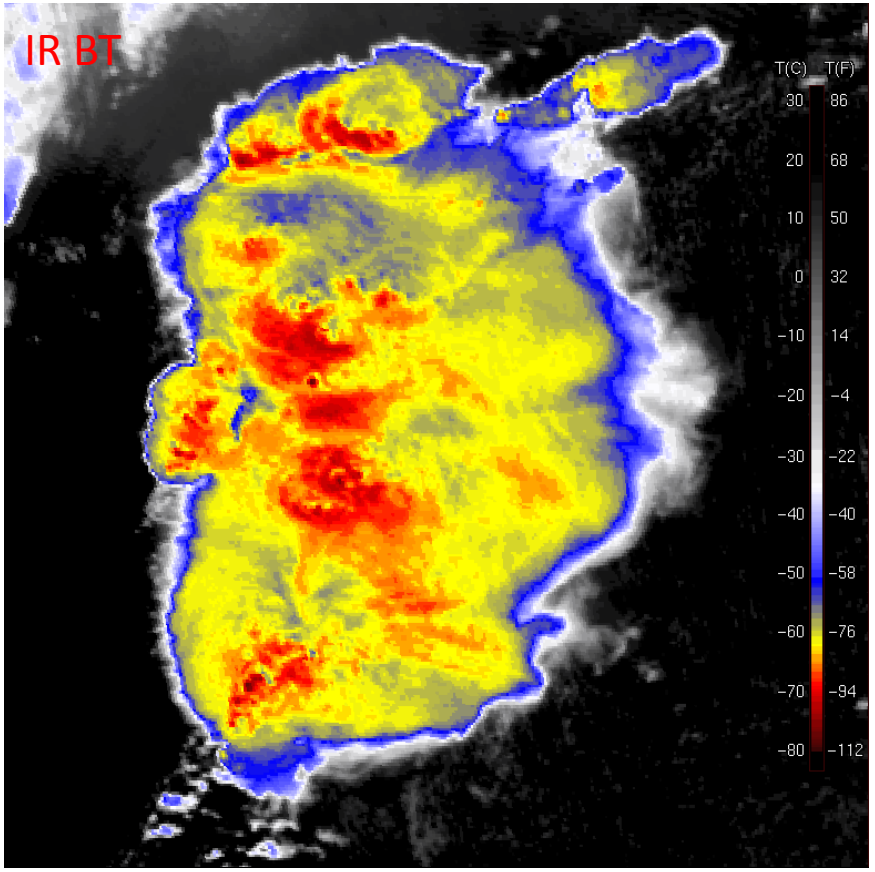


McIDAS Generation of Imagery For Citizen Scientist Analysis

- GOES-13 and GOES-16 imagery was acquired and resampled in McIDAS-X to determine if/how members of the general public can be trained to outline overshooting cloud tops using the Zooniverse platform

https://www.zooniverse.org/projects/kbedka/hazardous-thunderstorm-identification





*G16 May 18, 2017 21:27 GMT

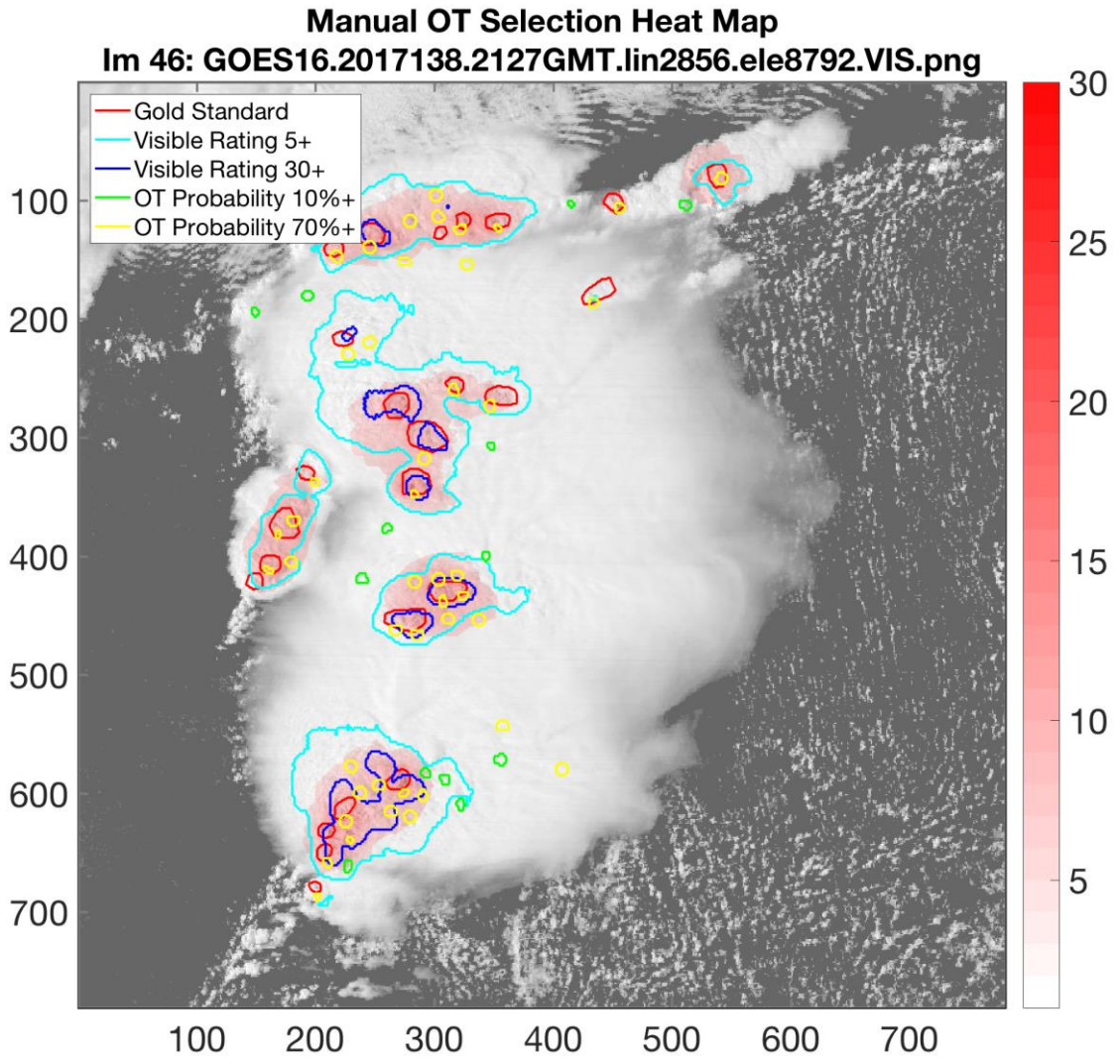
GOES Overshooting Cloud Top Human Identification and Algorithm Detection

* GOES-16 Imagery remapped to 56 pix/degree grid, facilitates comparison with automated overshooting cloud top detection output

* 50 GOES-13 and 50 GOES-16 analyzed. Over 3000 total image analyses submitted

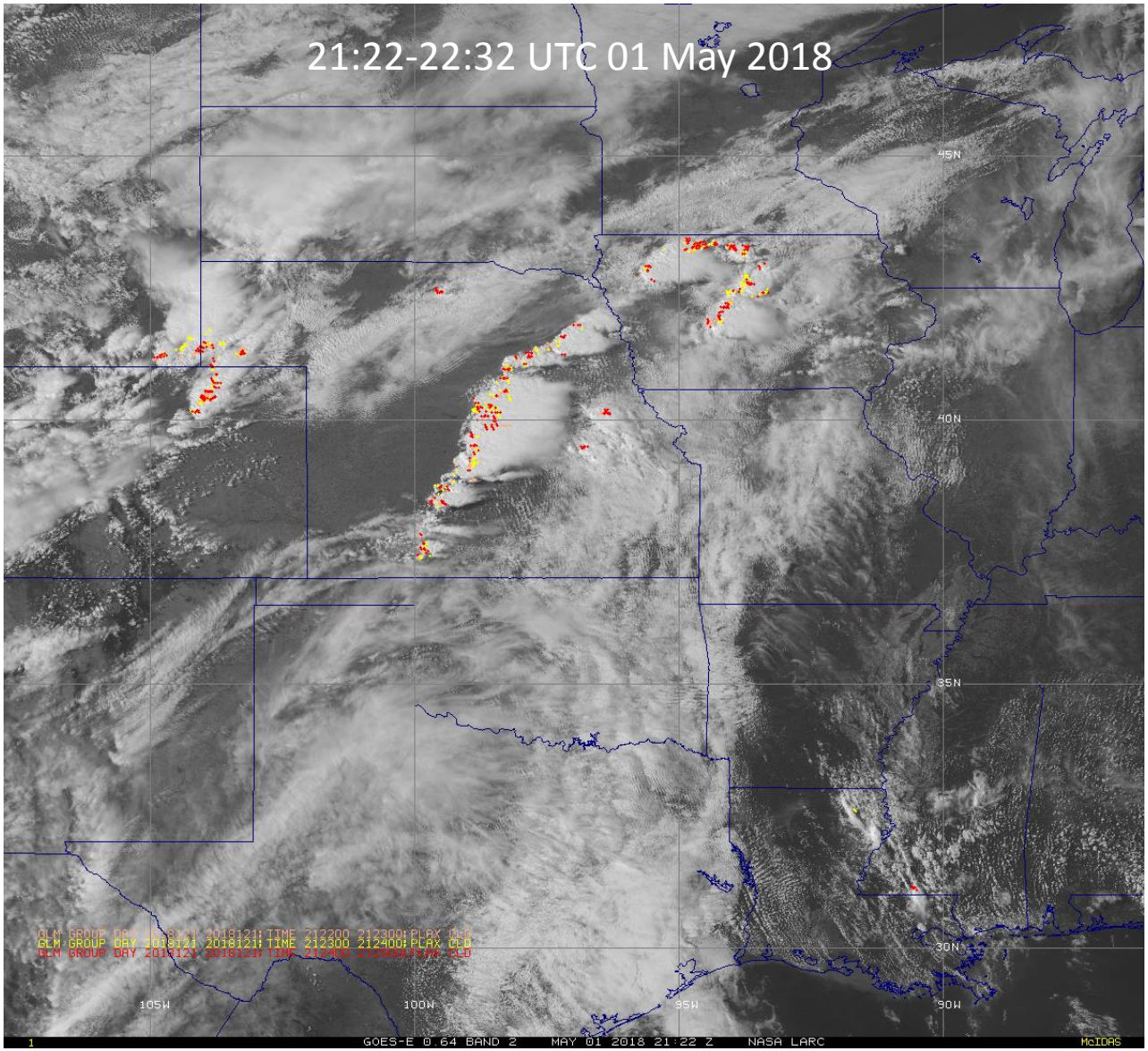
- Within minimal training, Citizen scientists performed quite well at outlining overshooting tops

- Similar engagement with the general public can help scientists develop ”truth” databases for detection algorithm training and validation



GLM Lightning Overlay Atop ABI

* G16 Real-time GLM overlay using 5-min CONUS Band-2 VIS imagery



McIDAS-V Usage

- **McIDAS-V is being used regularly (i.e. every day) by several (~5) members of the LaRC SatCORPS team**

- **Primary use cases include:**

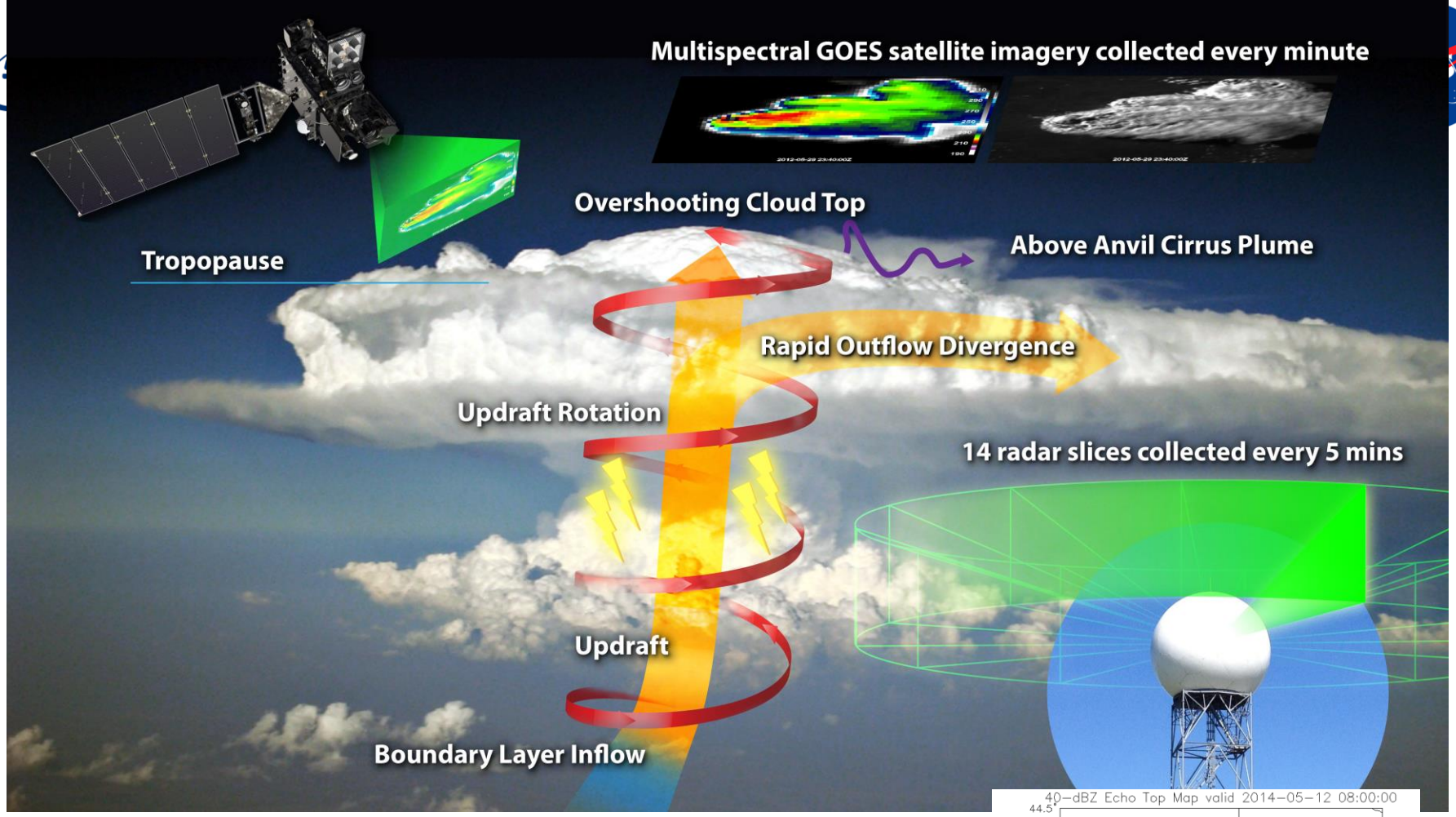
1) Analysis of LEO and GEO cloud mask and cloud property retrieval data in NetCDF

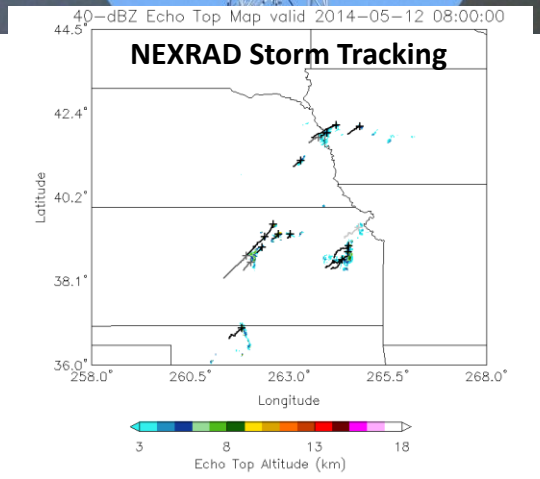
- Creation of RGB composites from user-generated formulas. Display cloud mask/retrievals on RGB and toggle. Zoom in on small regions and probe individual pixel values to assess mask/retrieval product quality
- Quick visualization QC of NetCDF product files to ensure they're being written properly
- Display daily/monthly mean gridded products for direct comparison with other climatologies

2) Analysis of deep convective cloud data in LEO and GEO satellite imagery in combination with other ground-based remote sensing, model, and severe weather reports

- Data formats: GRIB, ADDE AREA, NetCDF, HDF, and ascii text point data
- Data includes 1) ground- and space-based lightning detection, radar, severe storm reports, 2) satellite imagery, and 3) automated hazardous storm detection products

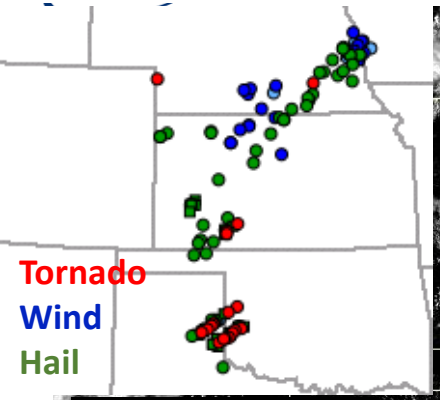
See the following slides!

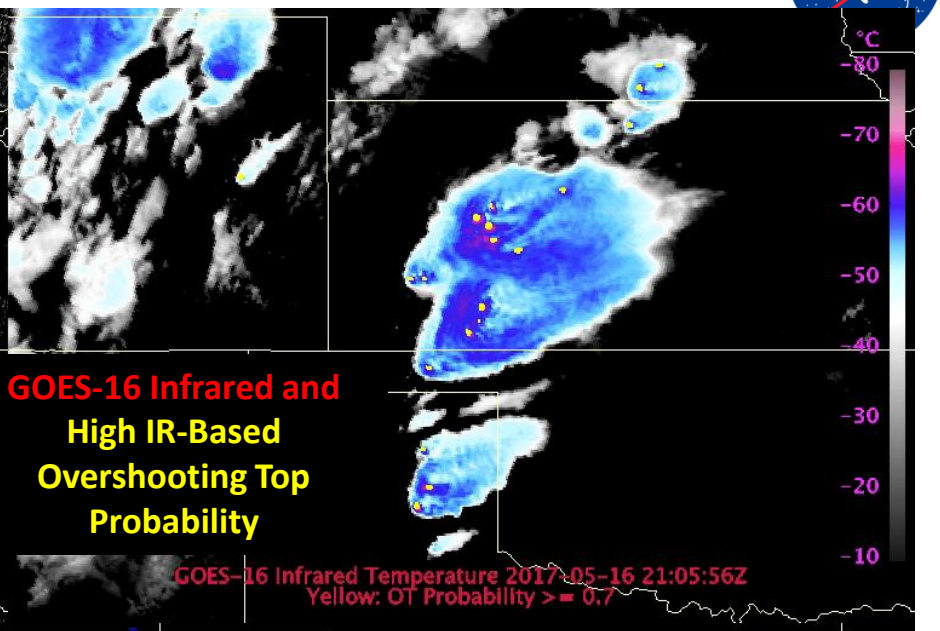


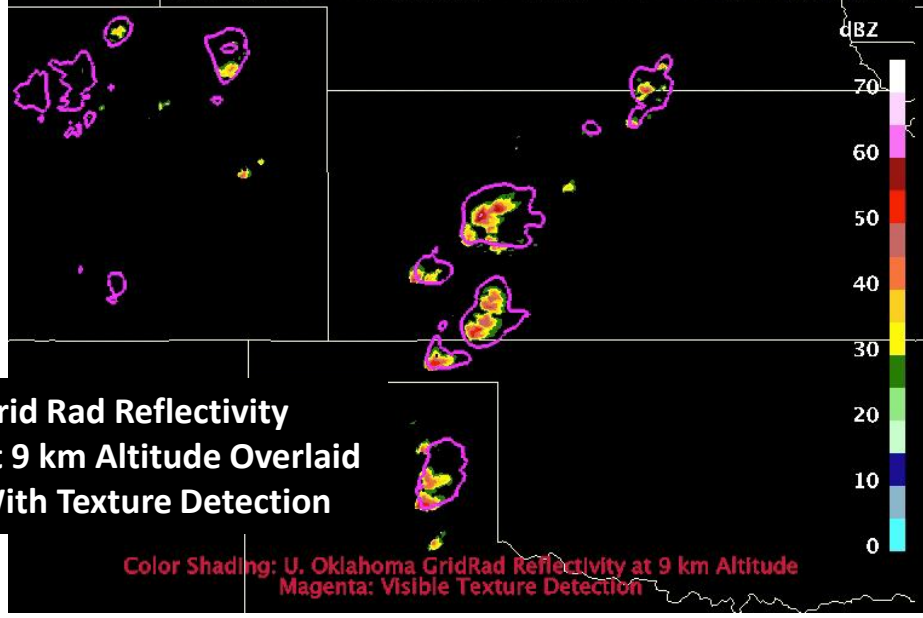


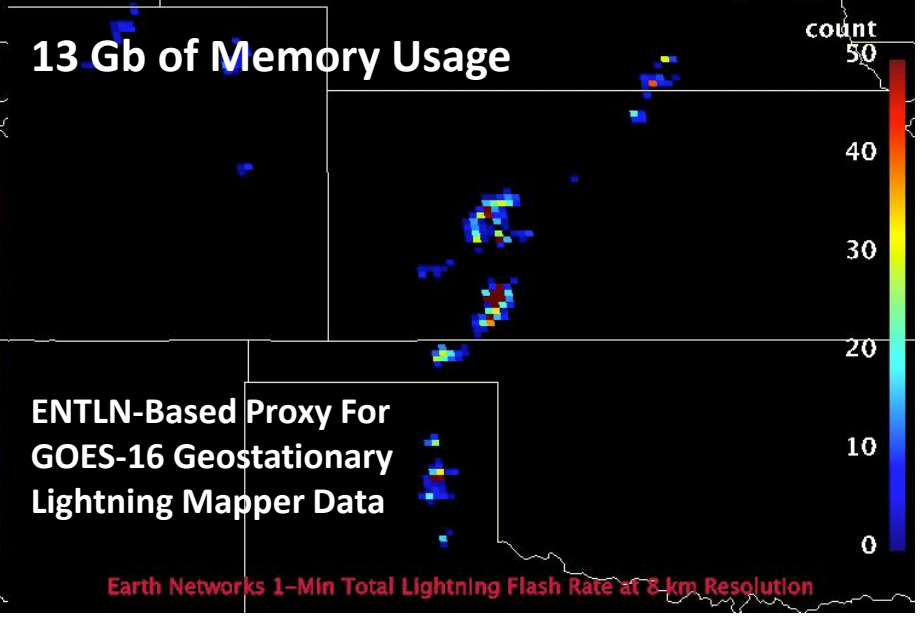
- McIDAS-V enables synchronization of diverse observations and derived products
- This helps the community to better understand severe thunderstorms and evaluate the performance of derived products

McIDAS-V: 16 May 2017 Severe Weather Outbreak, 2100-2359 UTC

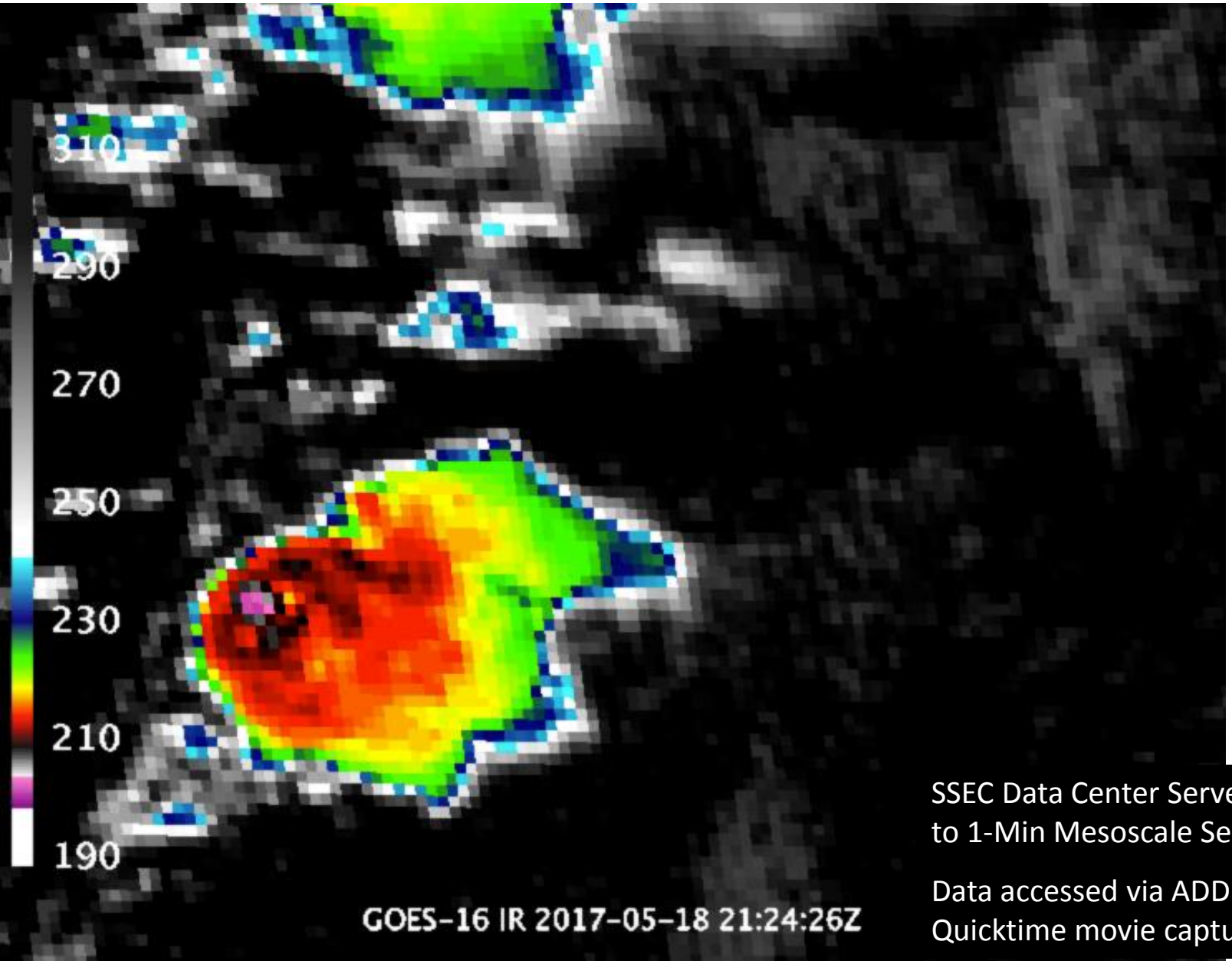








GOES-16 Above Anvil Cirrus Plume Producing Supercell Storm
18 May 2017, 2124-0100 UTC, North Texas

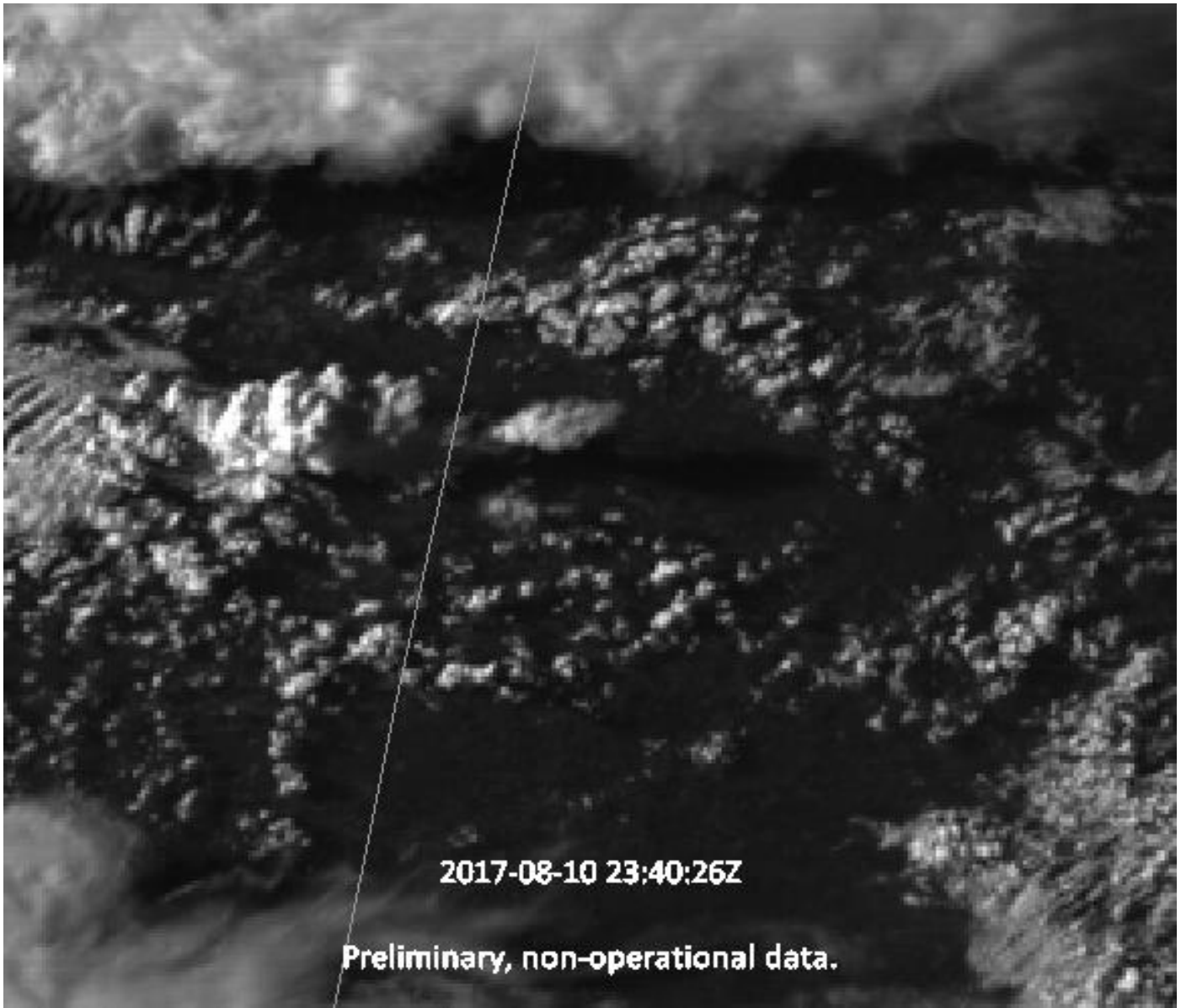


SSEC Data Center Serves GOES-16 30-s to 1-Min Mesoscale Sector Scans

Data accessed via ADDE, displayed and Quicktime movie captured in McIDAS-V

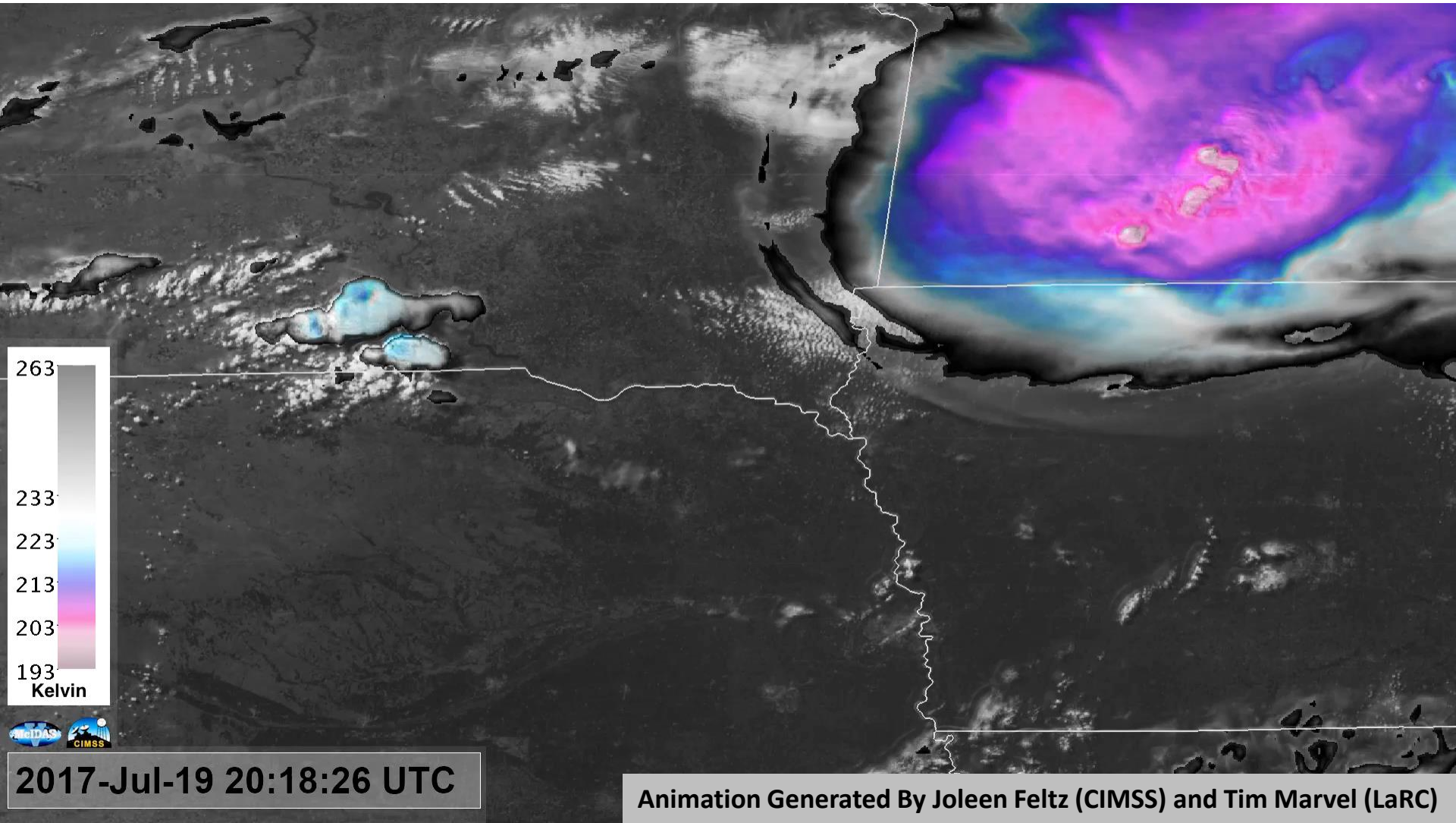
McIDAS-V Display of GOES-16 Visible
Large Hail, Above Anvil Plume Producing Storm, Colorado/Kansas Border, 10 August 2017

Prepared By: Bill Line (NWS Pueblo)

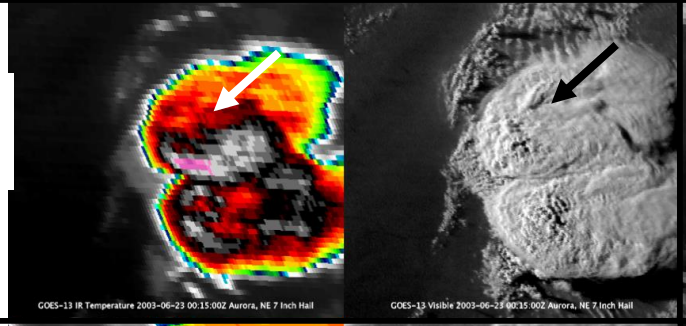


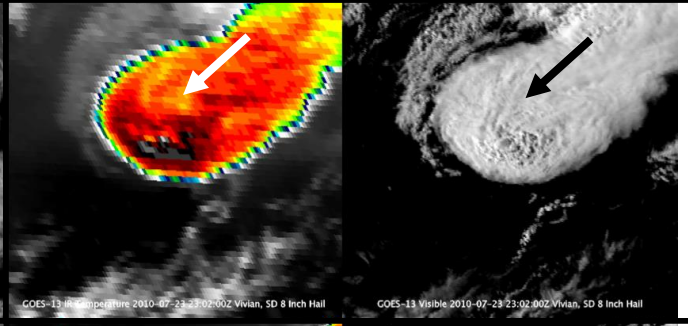
Annotated GOES-16 Sandwich Product Animation of An Above Anvil Cirrus Plume Producing Thunderstorm

- Contour identifying above anvil plume produced in video editing software (Maya). Additional Mc-V functionality to annotate imagery/animations would be desired



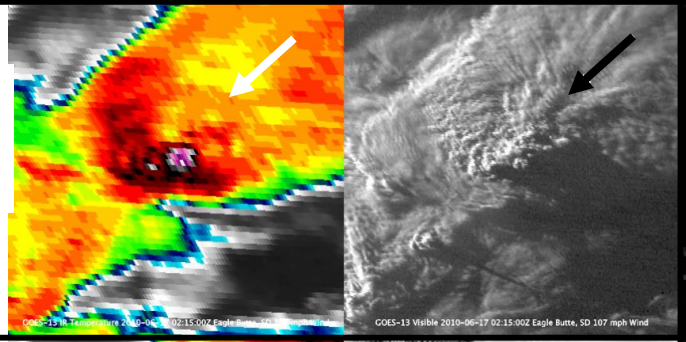
GOES-13
Aurora, NE 7 Inch Hail
23 Jun 2003

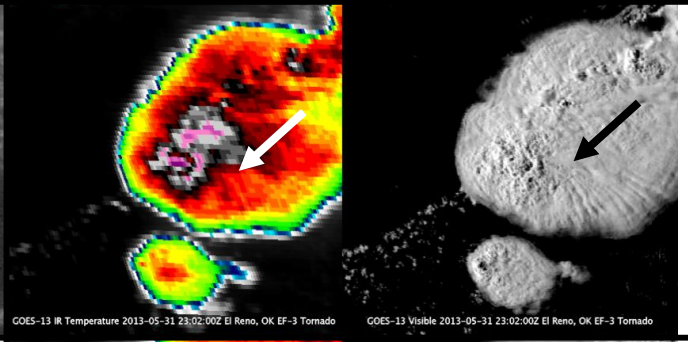




GOES-13
Vivian, SD 8 Inch Hail
23 Jul 2010

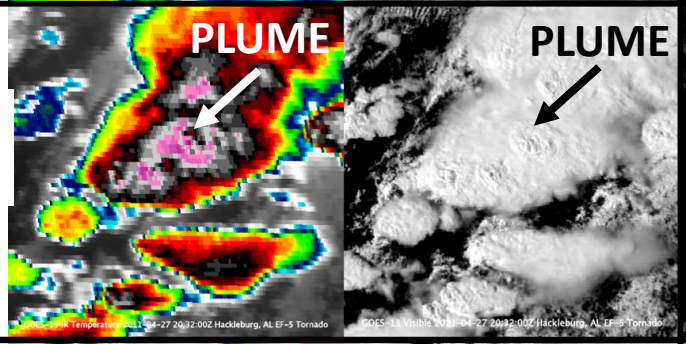
GOES-13
Eagle Butte, SD
107 mph Wind
17 Jun 2010

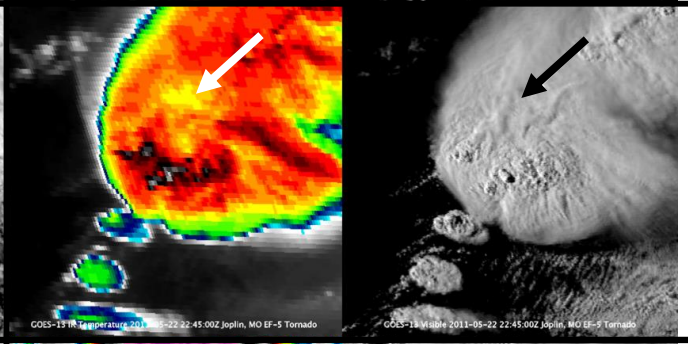




GOES-13
El Reno, OK EF-3
31 May 2013

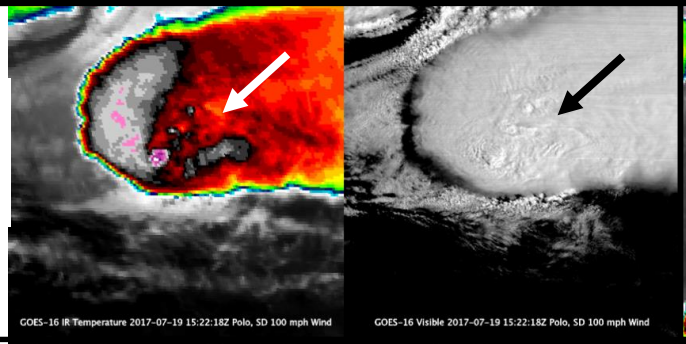
GOES-13
Hackleberg, AL EF-5
27 Apr 2011

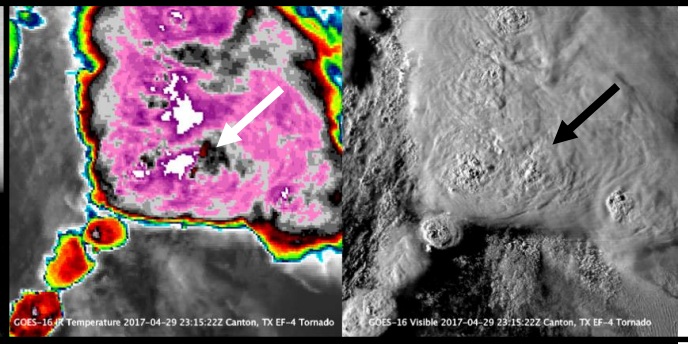




GOES-13
Joplin, MO EF-5
22 May 2011

GOES-16
Polo, SD
100 mph Wind
19 Jul 2017





GOES-16
Canton, TX EF-4
29 Apr 2017

GOES imagery accessed from SSEC Data Center and displayed over a domain of identical size using McIDAS-V scripting, centered on the severe weather report location

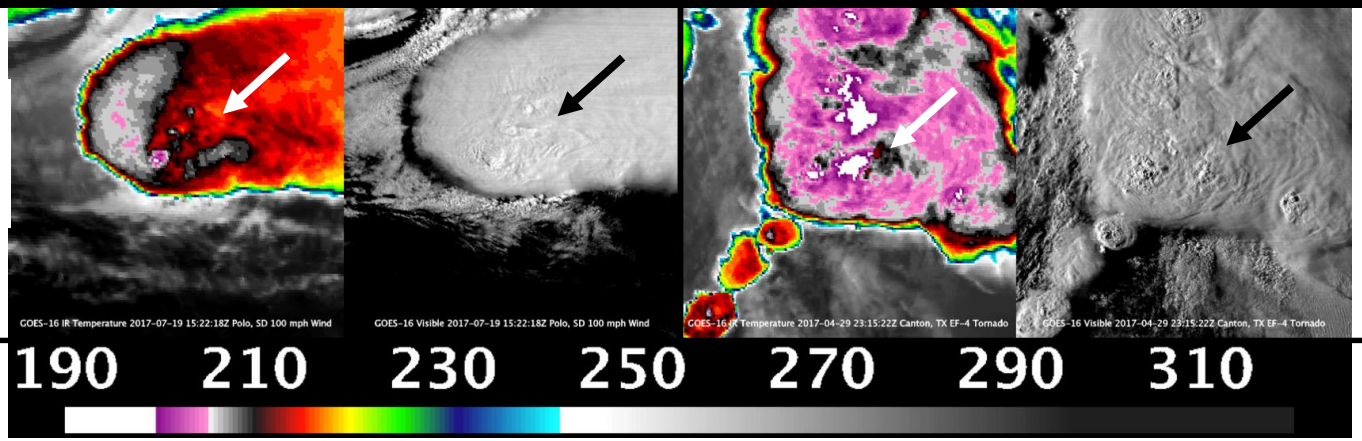
All 8 these randomly selected extremely severe storms generated an above anvil plume, also known as a “enhanced-V” or “cold-ring” signature in various published studies

245 of the most severe storms that have occurred over the US analyzed from 2010-2015, based on the NOAA SPC report database: 4.5+ inch hail, 90+ mph wind, EF-4+ tornado

Plume produced by 79% of tornado (N=58), 76% of wind (N=110), and 92% of hail (N=77) events

McIDAS-based data access, display, and analysis capabilities has enabled new understanding of storms with the plume signature and their weather and climate impacts

GOES-16
Polo, SD
100 mph Wind
19 Jul 2017

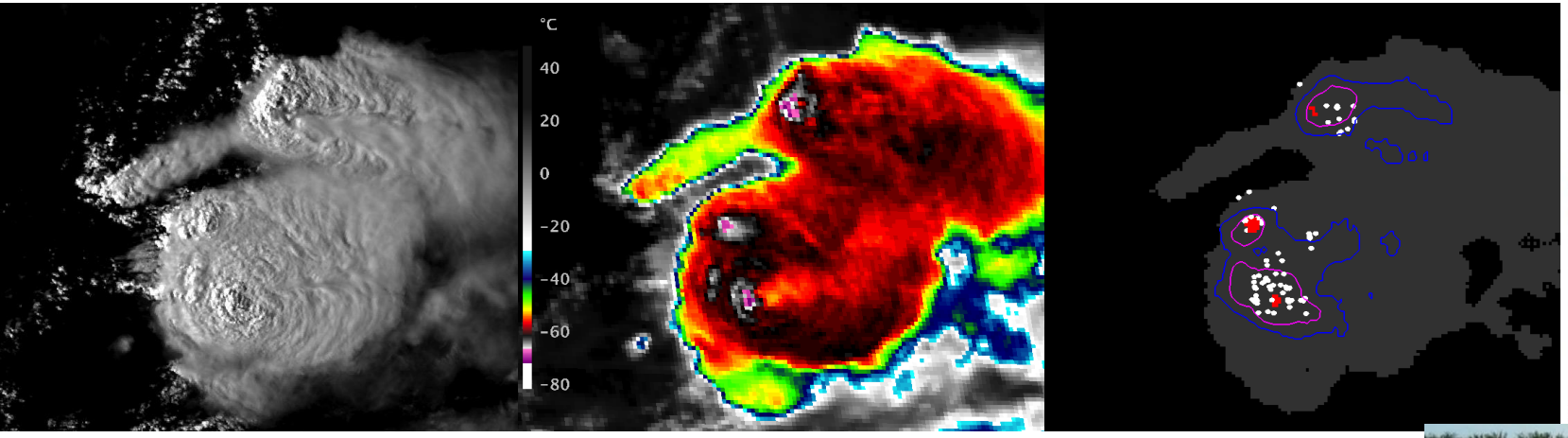


GOES-16
Canton, TX EF-4
29 Apr 2017

McIDAS Displays of Historic Hail Storms over Argentina

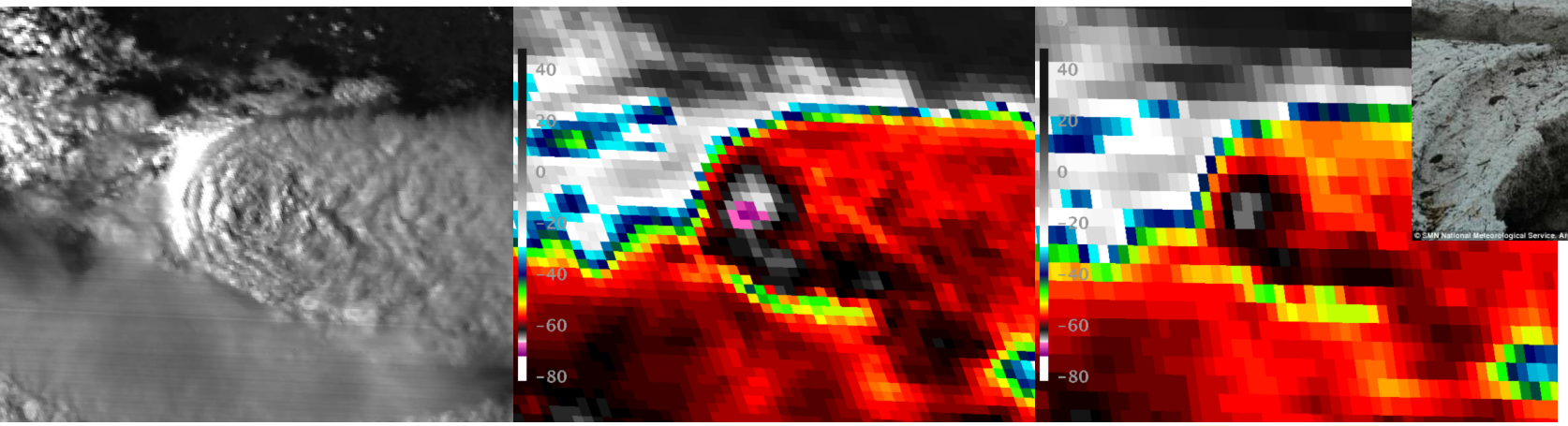
Automated LaRC Anvil Detection (Gray), Weak and Strong Visible Texture Detection (blue, pink), IR Overshooting Top Detection (Red), and GLM Lightning +/- 2 mins From Image (White)

8 February 2018: GOES-16



26 October 2017: GOES-16

GOES-13



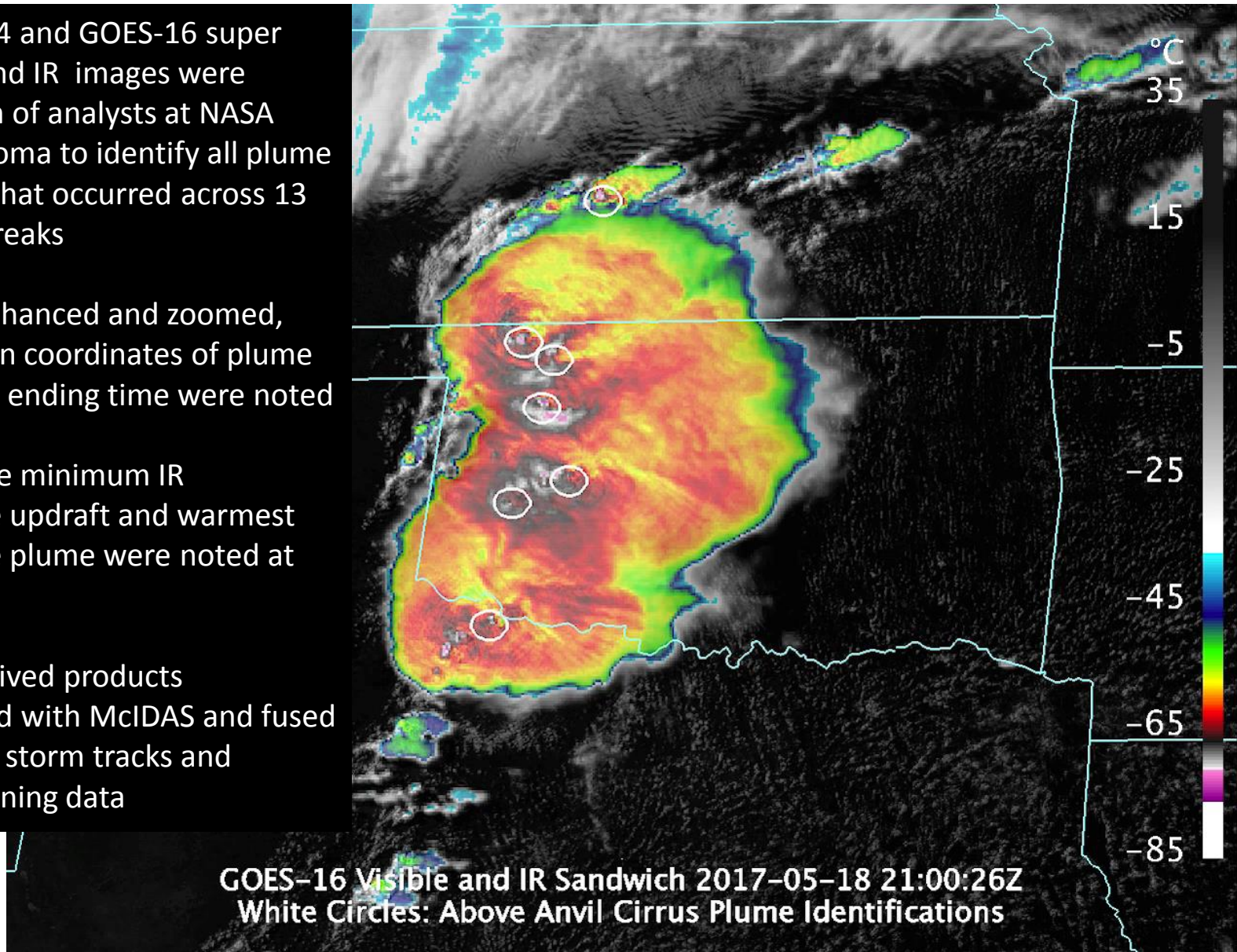
Above Anvil Cirrus Plumes Identified With GOES-16 "Sandwich Product" Data

Over 7000 GOES-14 and GOES-16 super rapid scanvisible and IR images were analyzed by a team of analysts at NASA LaRC and U. Oklahoma to identify all plume producing storms that occurred across 13 severe storm outbreaks

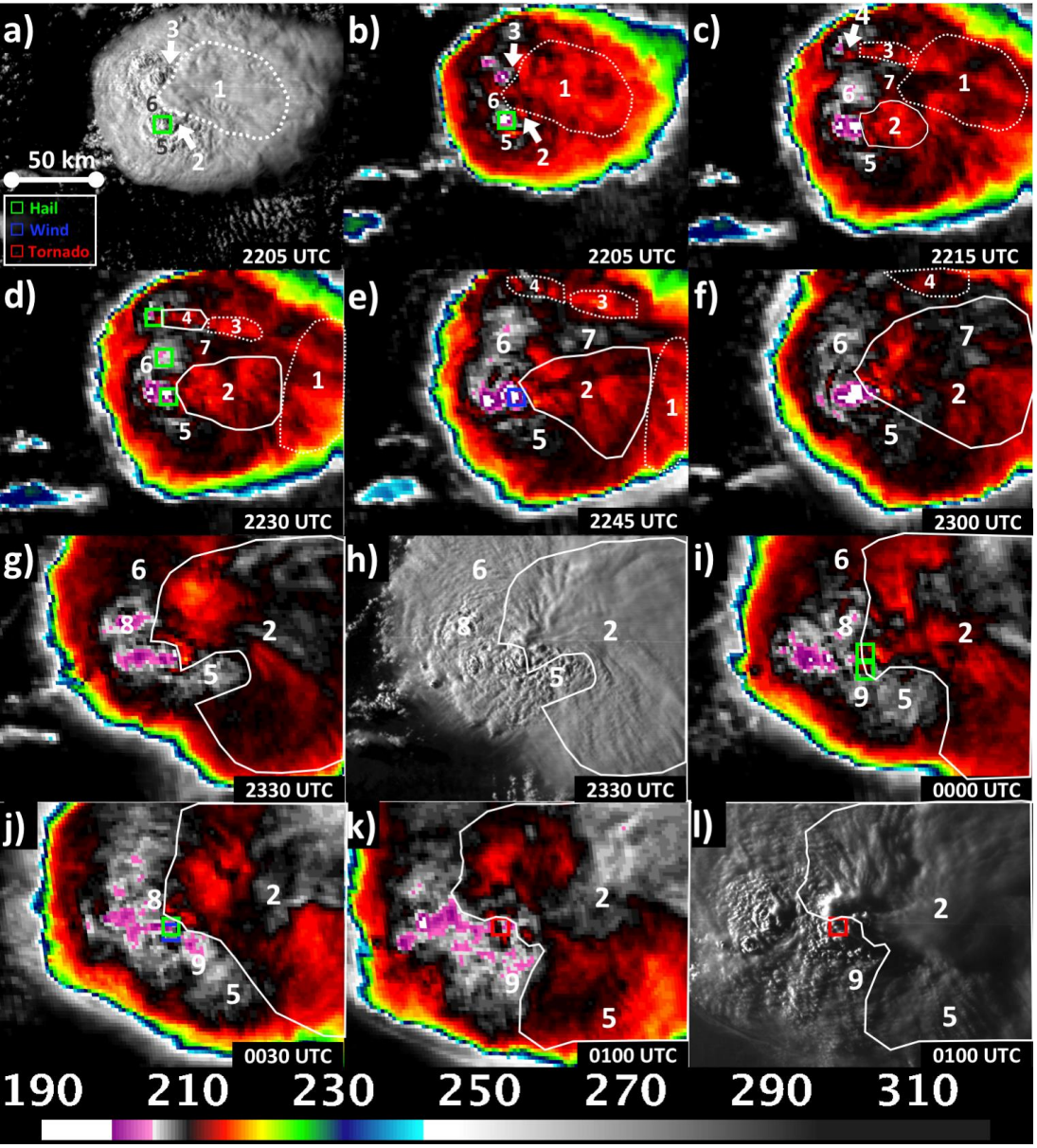
Images contrast enhanced and zoomed, the time and lat/lon coordinates of plume starting and plume ending time were noted

For some cases, the minimum IR temperature in the updraft and warmest temperature in the plume were noted at 1-min intervals

GOES data and derived products acquired/generated with McIDAS and fused with radar-derived storm tracks and ground-based lightning data



Annotated GOES-16 MultiSpectral Imagery



- GOES-16 imagery acquired via ADDE
- Text point data used to define and time-coincident severe weather reports, shifted for parallax (colored boxes)
- Arrows, user-defined curves, number labels added to point out specific features of interest in the imagery
- Done in Powerpoint but it would be helpful to have some of these capabilities infused into McIDAS-V

Suggested Areas for McIDAS-V Improvement

- Include selected NetCDF product name(s) from field selector on the image display
- Computation of viewing/solar zenith geometry to generate calibrated reflectances, normalized by solar angle, and reflected component of the 3.9 um radiance
- Parallax correction capability based on user-specified cloud height (i.e. PLAX in McIDAS-X)
- Lat/lon labels currently displaying poorly
- Annotation capability, i.e. Powerpoint-like functionality
- Improve location labels: Difficult to get desired cities/places to appear on map and in visually appealing way
- Center higher resolution visible pixels on corresponding IR pixels, currently there is an offset which blurs sandwich products and multispectral overlays
- Customization of color bar: User-controlled labels and label frequency, option for text labels instead of numbers (i.e. 1="ice cloud"), colored background for color bar
- Improved display of vertical profile (CALIPSO, CloudSat, aircraft) data in altitude dimension: Axis labels, fonts, tick mark labeling frequency
- AMSR-E and AMSR-2 Level 2 file support on Mac Mc-V. This data is displayable on Windows but problems were encountered on Mac, already posted on Forum
- McIDAS-V crashing on Mac, usually after 1 day of inactivity with relatively large memory usage (3+ Gb), already posted on Forum
- Allow the Stop Sign button to stop data downloads, currently Stop does nothing and whatever data is requested will eventually appear in addition to subsequent requests