

# GOES-R Satellites: Providing Tools for Enhanced Aviation Decision Support

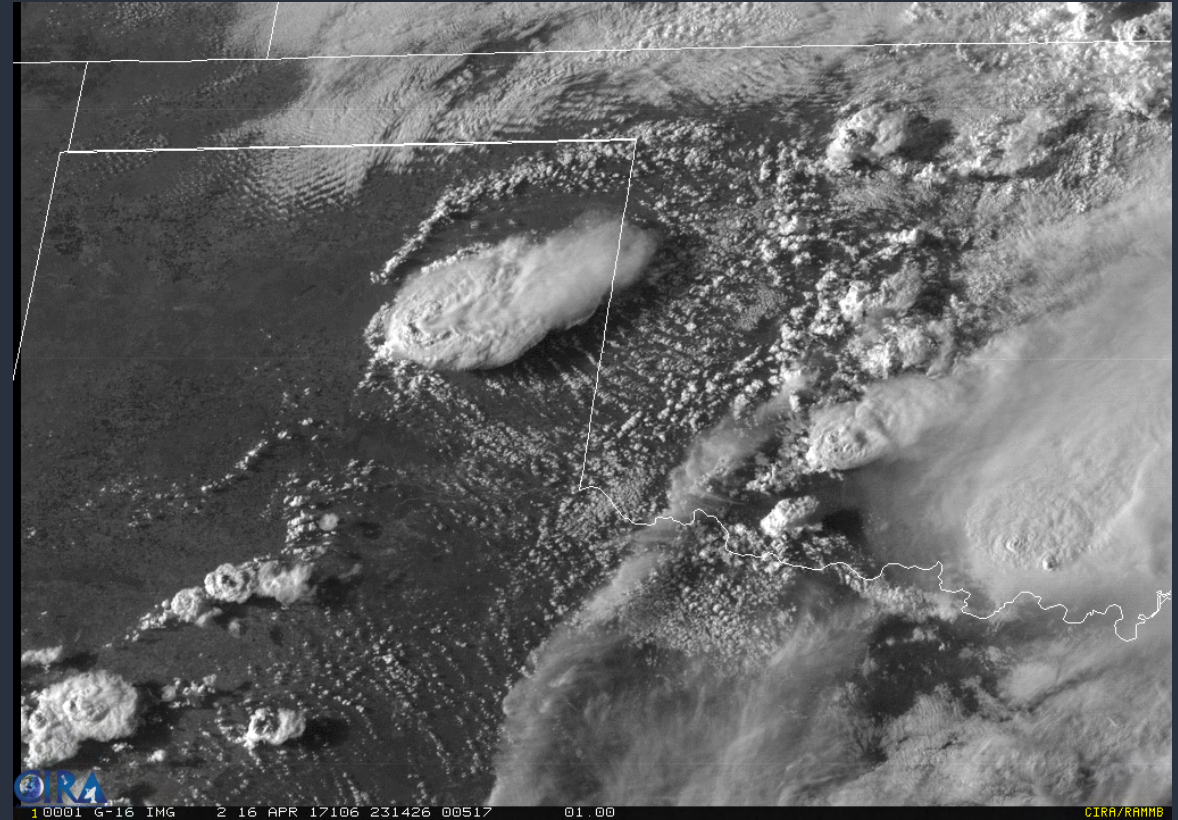
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Contributions from Tony Wimmers (CIMSS), Mike Pavolonis (NESDIS/STAR), and Yoo-Jeong Noh (CIRA)

**NOAA**  
National Environmental Satellite,  
Data, and Information Service

# What is GOES-R?

- NOAA's operational geostationary satellite program
- Provides geostationary coverage from GOES-East and GOES-West, covering from the coast of Africa to New Zealand
- The Advanced Baseline Imager (ABI) provides 2 km IR data and 500 m VIS data in 16 spectral channels
- Full Disk imagery every 10 mins, CONUS every 5 mins, and two Mesoscale sectors each with 1-min updates

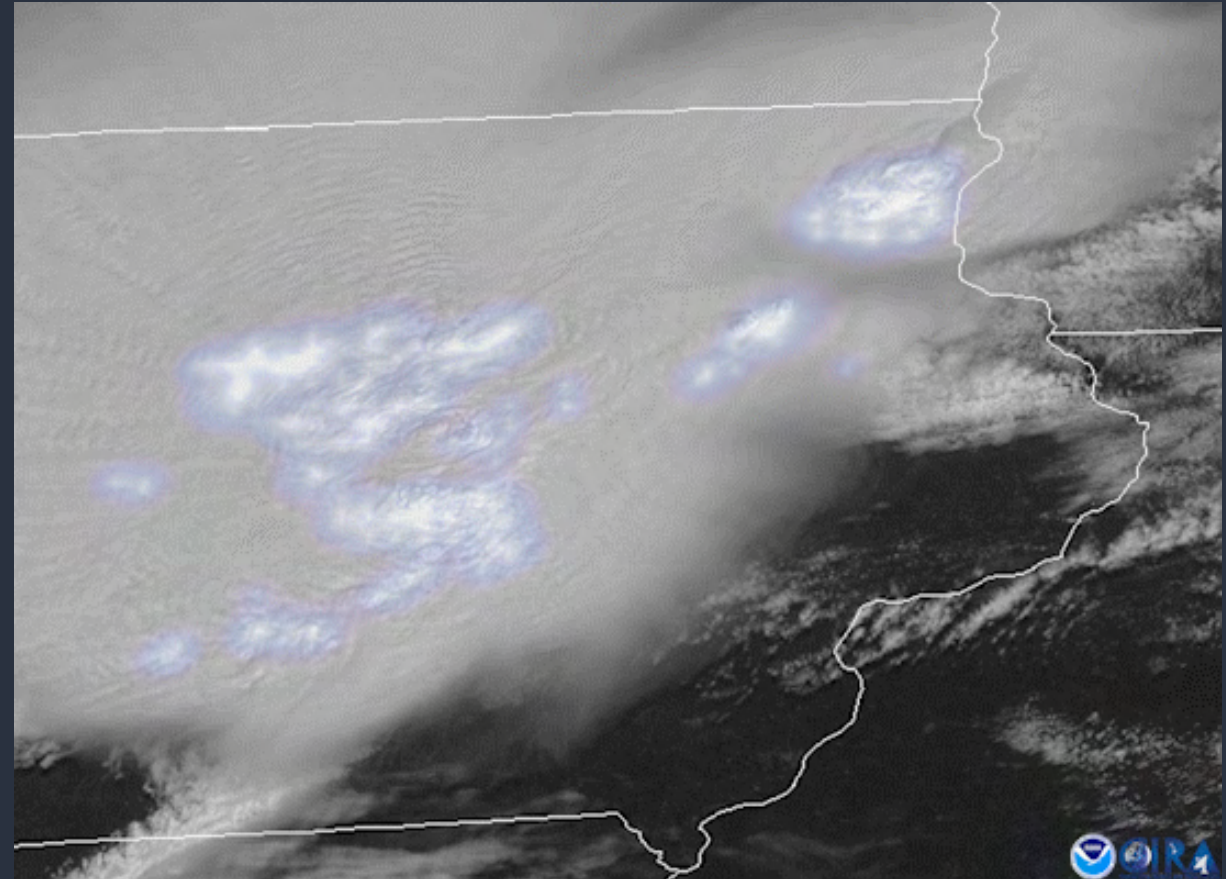


*GOES-16 ABI visible imagery in a 1-min Mesoscale sector over north Texas from 16 April 2017*



# What is GOES-R?

- GOES-R series satellites also carry the Geostationary Lightning Mapper (GLM)
- It provides continuous monitoring of lightning activity
- The domain is a little smaller than the ABI, but it still covers all of CONUS and much of the Atlantic and east Pacific oceans



*GOES-16 Visible with GLM Group Energy Density overlaid from the Midwest Derecho on 10 Aug. 2020*

# GOES-R Satellite Aviation Applications

- 1) Low cloud/fog monitoring (visibility and icing)
- 2) Volcanic ash detection and tracking
- 3) Convective storm monitoring
- 4) Turbulence detection
- 5) Three-dimensional distribution of clouds

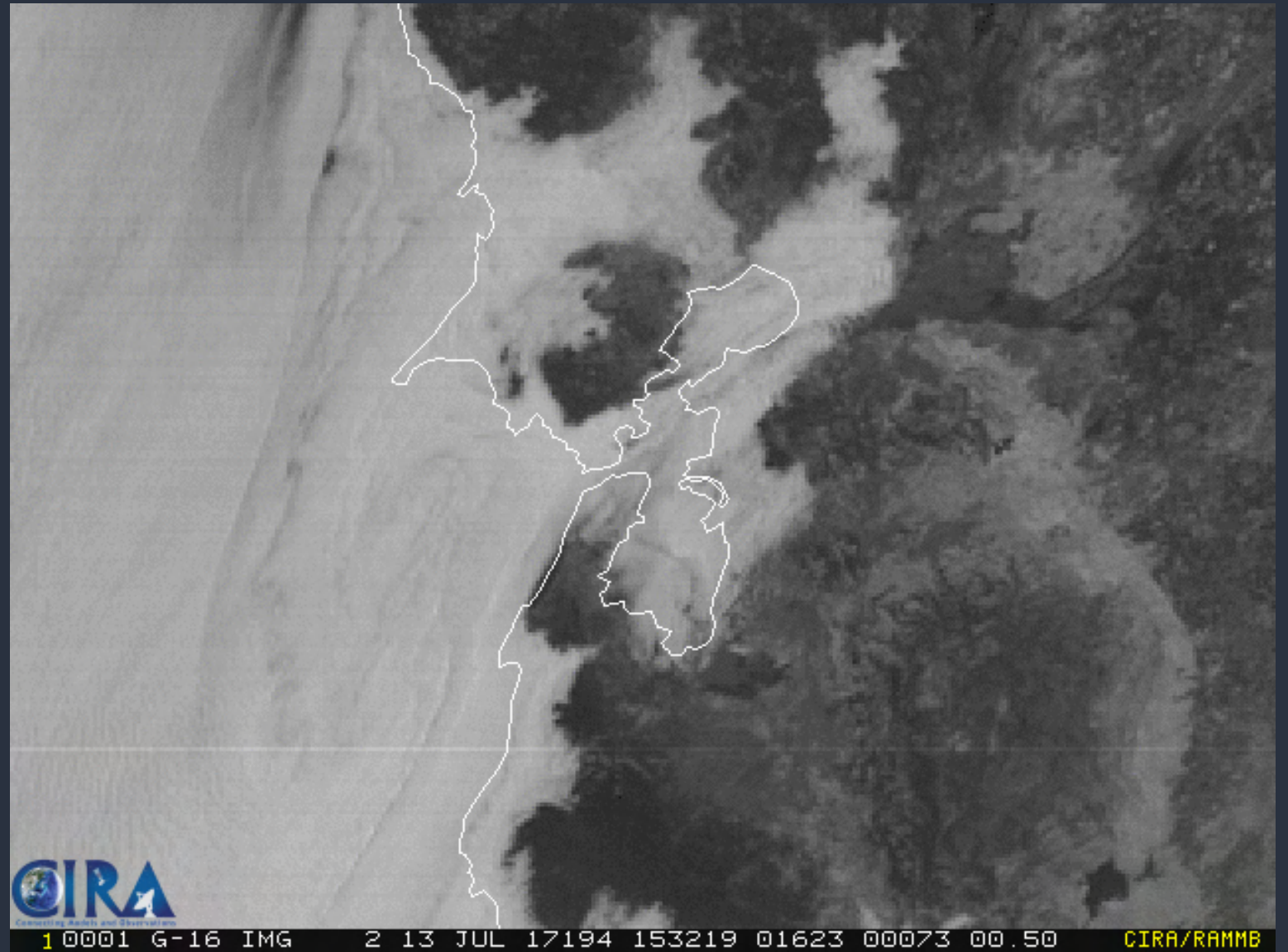
## Two types of GOES-R products

- Imagery, requiring qualitative analysis by an expert
- Quantitative products, or algorithms designed to provide value-added information to the user



# Low Cloud Monitoring – 13 July 2017 – SF Bay Area

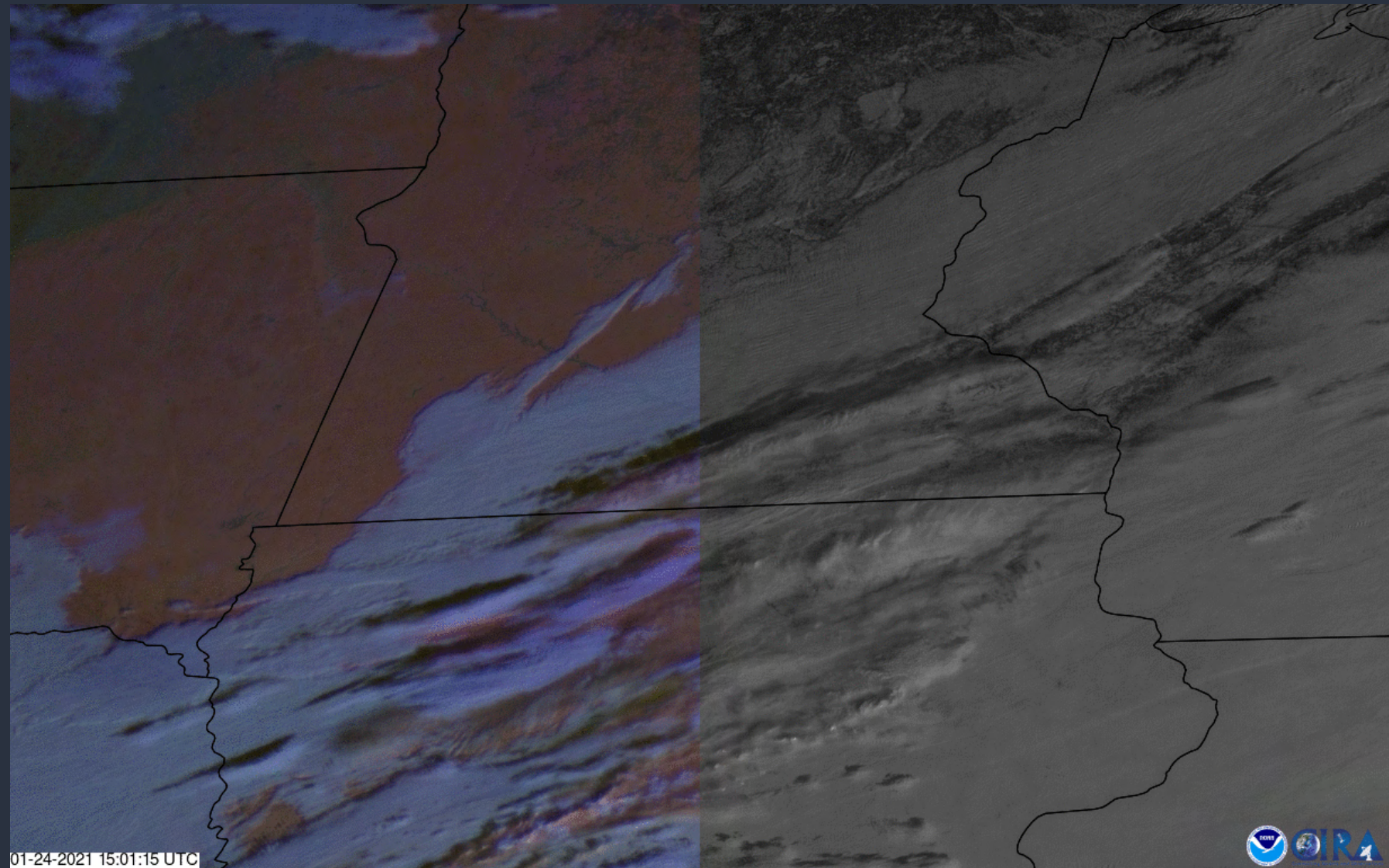
- 500 m visible band provides very good spatial resolution for monitoring low clouds and stratus
- 5 min imagery over CONUS (this example) and 1 min imagery in Meso sectors also means the latency is very low
- Here, forecasters in SFO may be able to use this imagery to anticipate stratus dissipation





# Low Clouds over Snow – 24 Jan. 2021 – Minnesota/Iowa

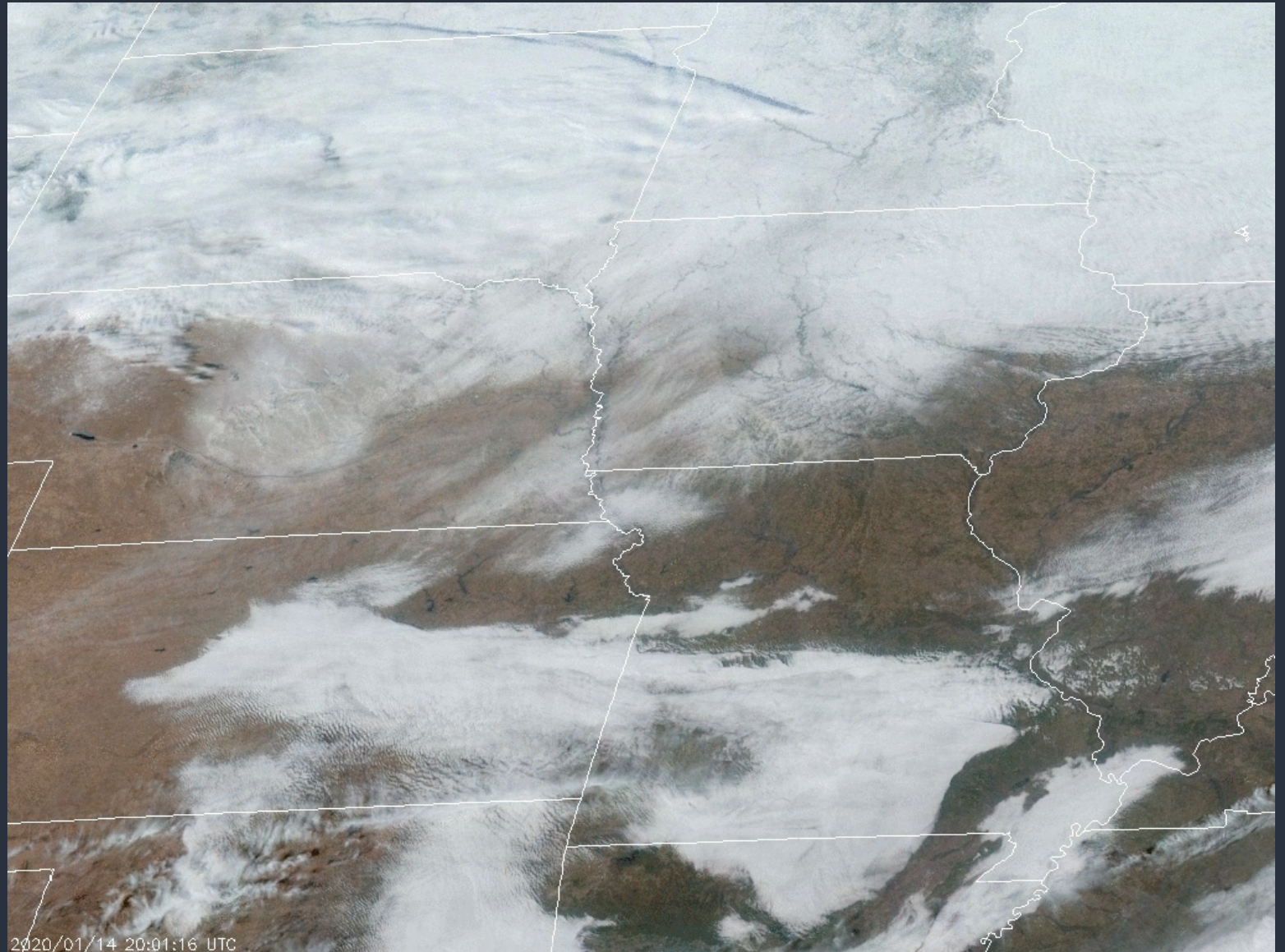
- Day Snow/Fog RGB
- RGBs like this provide easier-to-interpret scenes compared to VIS alone
- For this RGB, snow is red/pink and low clouds are white
- This and other RGBs are available on the RAMMB SLIDER page: <http://rammb-slider.cira.colostate.edu>





# Low Clouds at night – 14 Jan. 2020 – Missouri Valley

- CIRA's GeoColor product provides one method for monitoring low clouds (blue) at night
- City lights are a static background (not actually detected by GOES-R instruments) primary for geolocation assistance





# Eruption of Raikoke – June 2019 – NW Pacific – Himawari-8

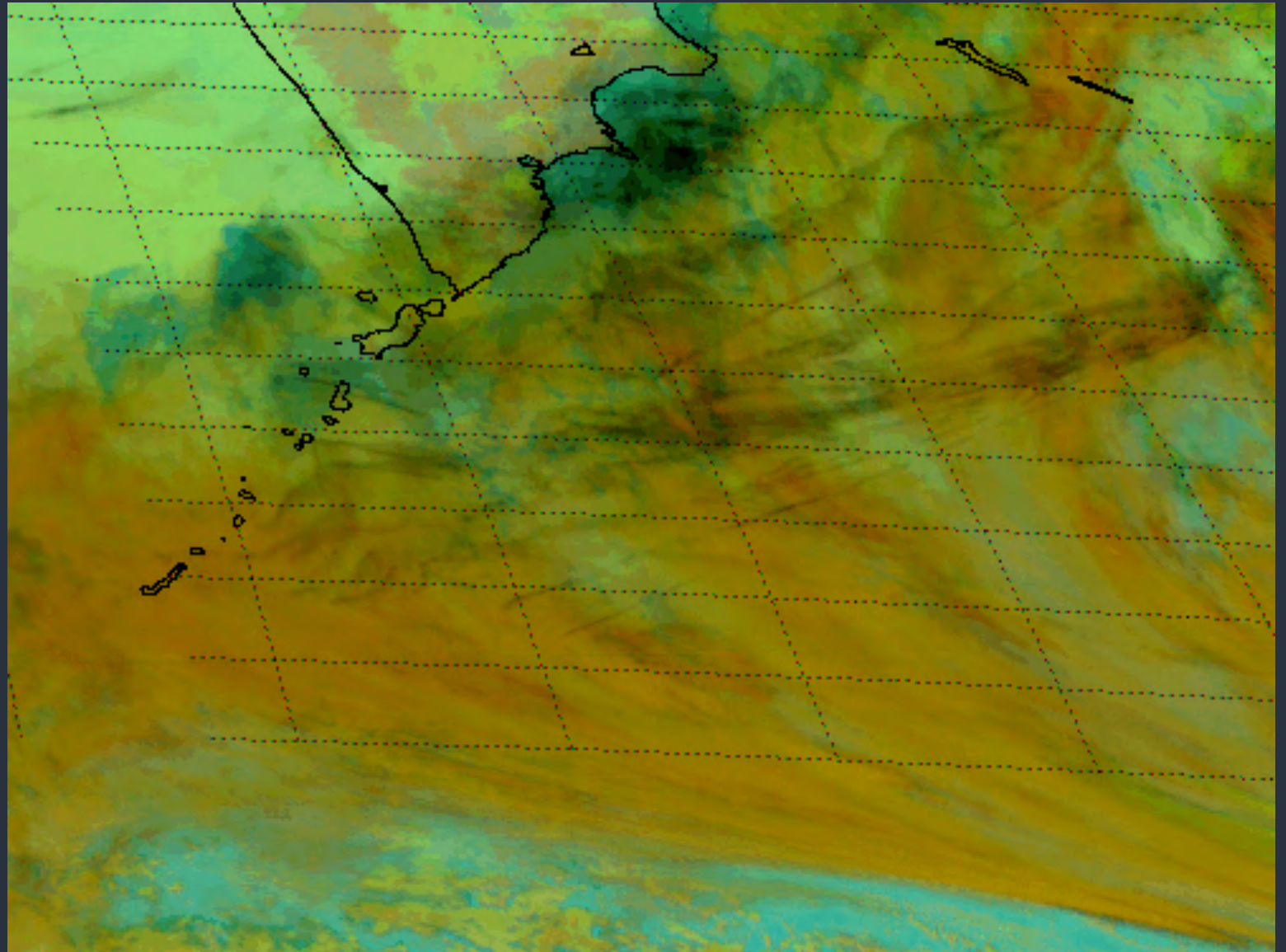
- ABI/AHI provide many tools for monitoring volcanic ash
- This GeoColor example from Himawari shows the brown ash emerging over low clouds during the day





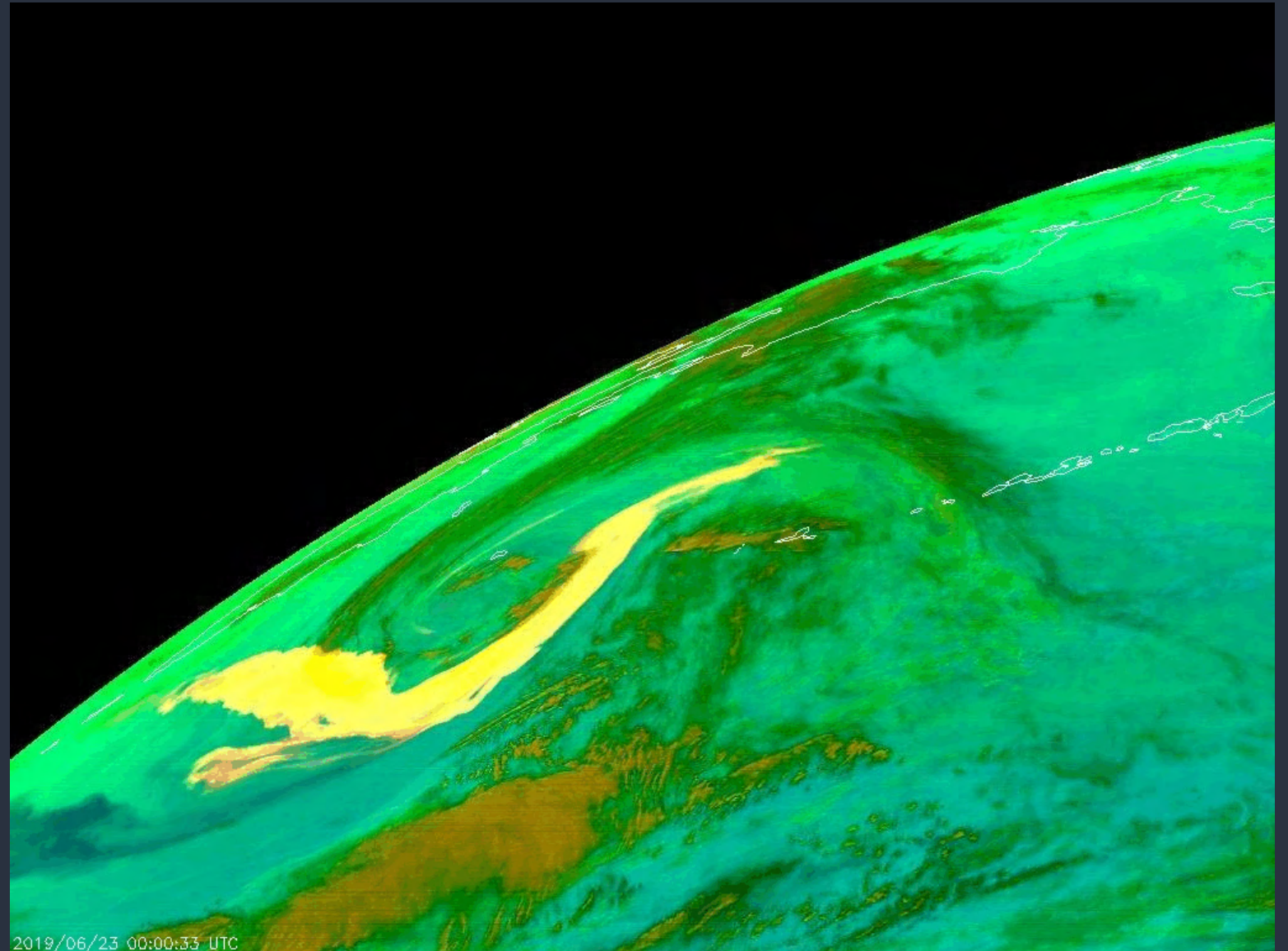
# Eruption of Kambalny – March 2017 – Kamchatka – Himawari-8

- The Ash RGB uses IR bands, so is available 24/7
- Ash appears red/pink and sulfur dioxide (SO<sub>2</sub>) has a greenish tint
- This example also picks up on aircraft contrails



# Raikoke Plume over the Aleutians – June 2019 - GOES-17 SO2 RGB

- In this SO2 RGB, SO2 and sulfate aerosols appear orange or yellow



2019/06/23 00:00:33 UTC



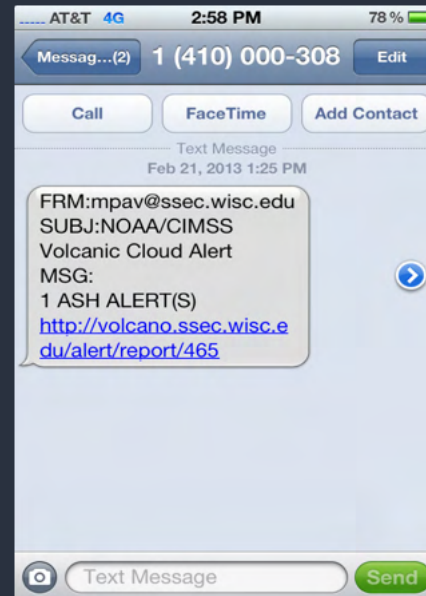


# The VOLcanic Cloud Analysis Toolkit (VOLCAT)

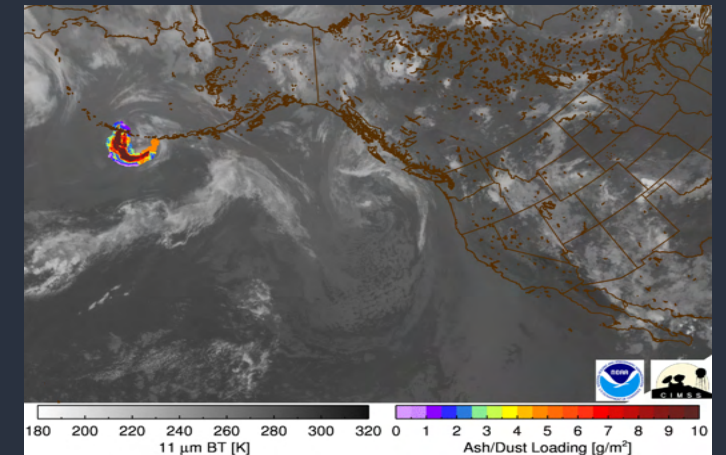
## Thermal Monitoring



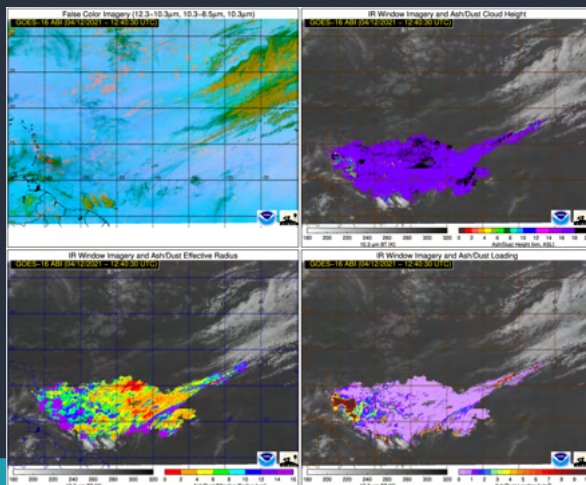
## Eruption Alerts



## Volcanic Cloud Tracking

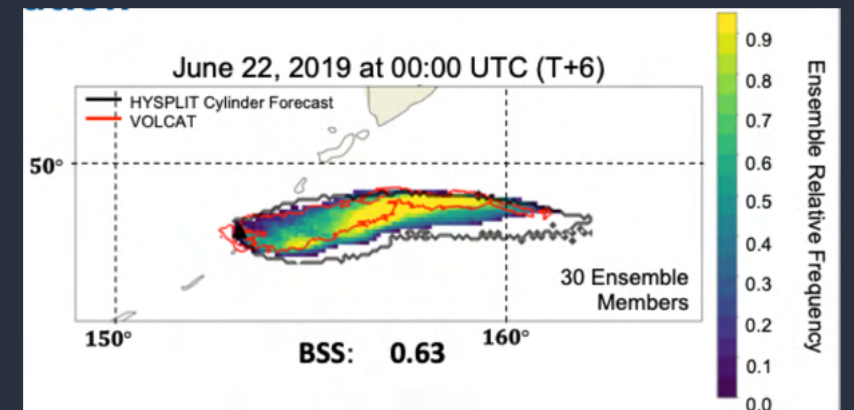


## Volcanic Cloud Characterization



- VOLCAT was developed by Mike Pavolonis (NESDIS/STAR) and operated by UW-CIMSS

## Dispersion & Transport Forecasting



# Operational Applications

## VOLCAT Event Dashboard

Last updated: 13:45:25 UTC NOAA/CIMSS VOLCAT Event Dashboard

Volcano	Country	VAAC	Most Recent	Actions
Fuego	Guatemala	VAAC Washington	18 minutes ago	X ▲
Nyiragongo	DR Congo	VAAC Toulouse	7 minutes ago	X ▲
Pacaya	Guatemala	VAAC Washington	2 hours, 9 minutes ago	X ▲
Sangay	Ecuador	VAAC Washington	1 hour, 8 minutes ago	X ▲
Soufriere St Vincent	Saint Vincent and the Grenadines	VAAC Washington	38 minutes ago	X ▼

Event Age	Event Type	Alert Detail	Imagery	Thermal Dashboard
38 minutes ago	Potential vCb with Lightning (ground-based) and Recent Strong Thermal Anomaly (GOES-16 ABI)	Alert Detail	Imagery	Thermal Dashboard
4 hours, 39 minutes ago	Volcano Radiative Power Spike (GOES-16 ABI)	Alert Detail	Imagery	Thermal Dashboard
5 hours, 59 minutes ago	Volcano Radiative Power Spike (GOES-16 ABI)	Alert Detail	Imagery	Thermal Dashboard

### Volcanic Cloud Alert Report

Date: 2021-04-09  
Time: 12:50:30  
Production Date and Time: 2021-04-09 13:06:28 UTC  
Primary Instrument: GOES-16 ABI

**Possible Volcanic Cb**

**Basic Information**

Volcanic Region(s)	West Indies
Country/Countries	Saint Vincent and the Grenadines
Volcanic Subregion(s)	West Indies
VAAC Region(s) of Nearby Volcanoes	Washington
Identification Method	Cloud Growth Anomaly (CGA)
Mean Object Date/Time	2021-04-09 12:53:38UTC
Radiative Center (Lat, Lon)	13.360°, -61.100°
Nearby Volcanoes (meeting alert criteria)	Soufriere St. Vincent (0.50 km) (Thermal Anomaly Present)
Trend in IR Brightness Temperature	-66.10 °C
Vertical Growth Rate Time Interval	10 minutes
Vertical Growth Rate Anomaly	23.30 number of stddev above mean
Maximum Height [AMSLL]	10.40 km ; 34121 ft
Maximum Height [opaque assumption] [AMSL]	13.10 km ; 42979 ft
Minimum IR Window BT	215.20 K

## VOLCAT Alert Report

## Example Volcanic Ash Advisory from the Washington VAAC

FVXX25 KNES 092346  
VA ADVISORY  
DTG: 20210409/2346Z

VAAC: WASHINGTON

VOLCANO: SOUFRIERE ST VINCENT 360150  
PSN: N1319 W06110

AREA: W\_INDIES

SUMMIT ELEV: 3865 FT (1178 M)

ADVISORY NR: 2021/007

INFO SOURCE: GOES-16. NWP MODELS. ASH3D. VOLCAT. RADIOSONDE. SOCIAL MEDIA.

ERUPTION DETAILS: CONT EXPLOSIVE ERUPTION

OBS VA DTG: 09/2320Z

OBS VA CLD: SFC/FL220 N1326 W05820 - N1215 W05842 - N1226 W05946 - N1301 W06100 - N1315 W06104 - N1314 W06106 - N1304 W06043 - N1326 W05937 - N1326 W05820 MOV SE 30KT SFC/FL420 N1459 W05807 - N1329 W05826 - N1329 W05936 - N1323 W05953 - N1407 W06026 - N1407 W06026 - N1456 W05947 - N1459 W05807 MOV E 35KT SFC/FL500 N1408 W06026 - N1323 W05952 - N1307 W06044 - N1316 W06109 - N1323 W06111 - N1408 W06026 MOV E 40KT

Automated Urgency Ranking - Warning: Automated urgency ranking may differ from human expert assessment and events should first be verified.

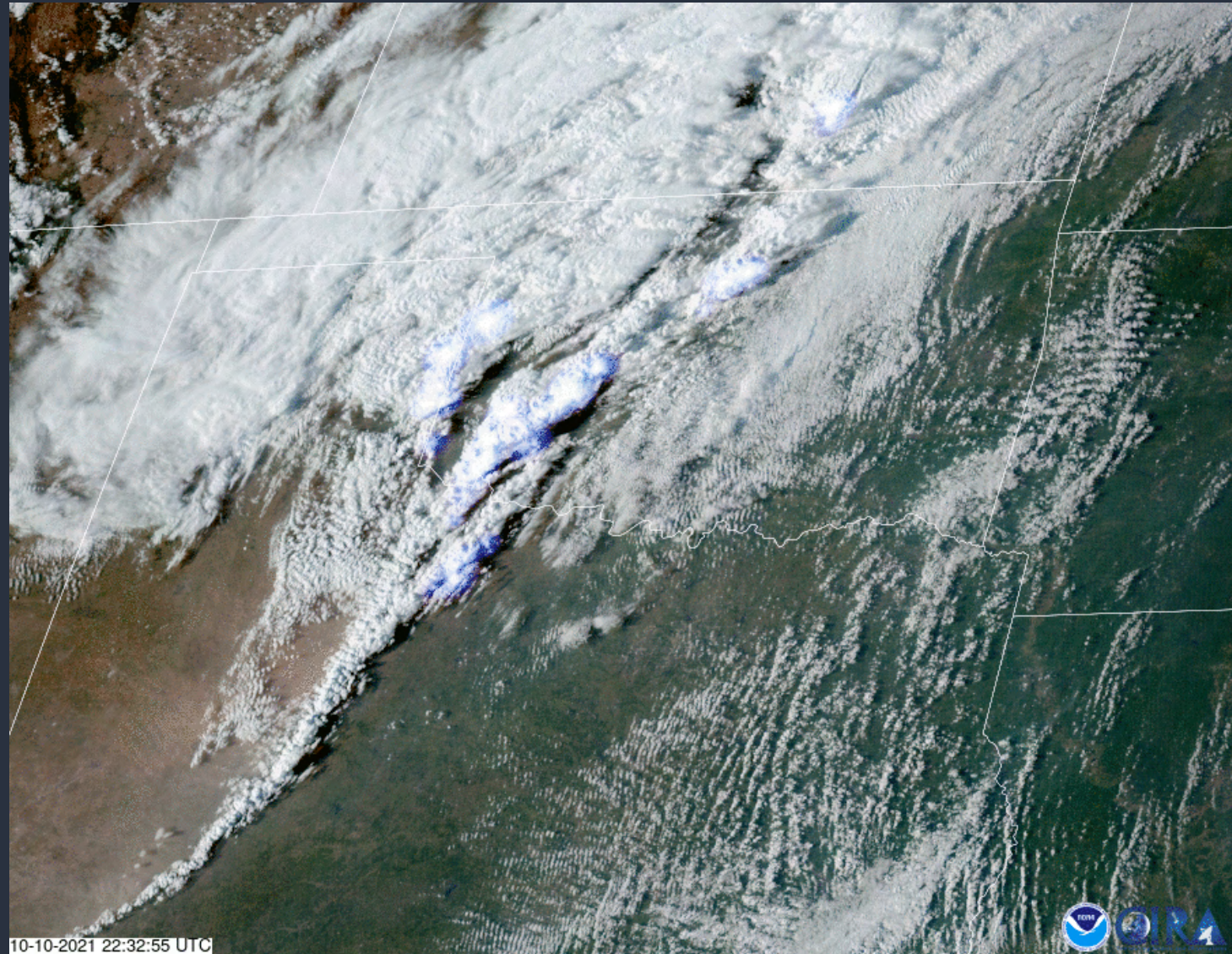
Rank 1 Rank 2 Rank 3





# Convective Storm Monitoring – 10 Oct. 2021 – TX/OK

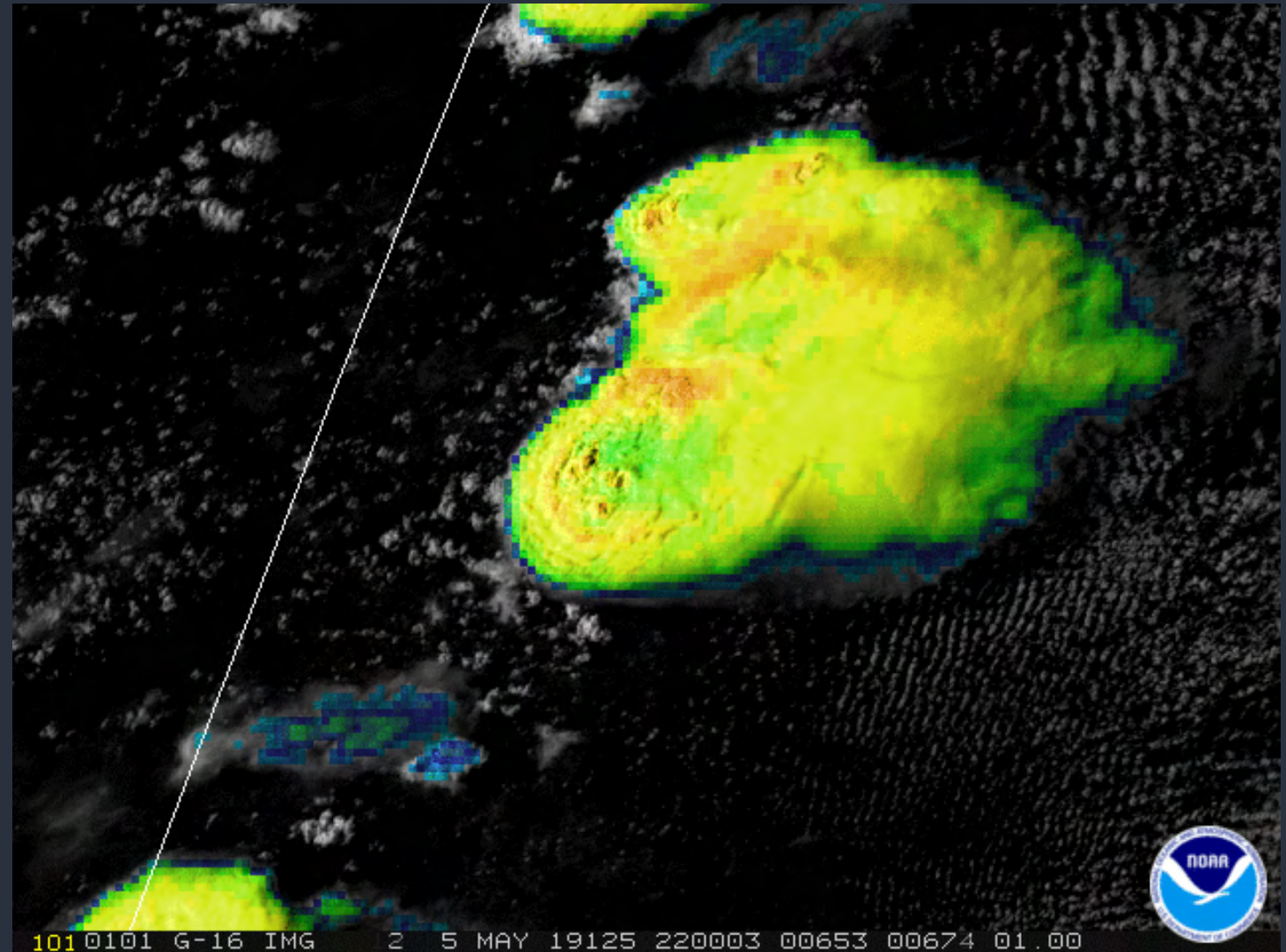
- There are many ways to monitor convection with GOES-16/17 ABI and GLM
- Overlaying GLM fields provides added value to pinpoint which clouds are producing lightning
- This example is GeoColor with GLM Group Energy Density overlaid





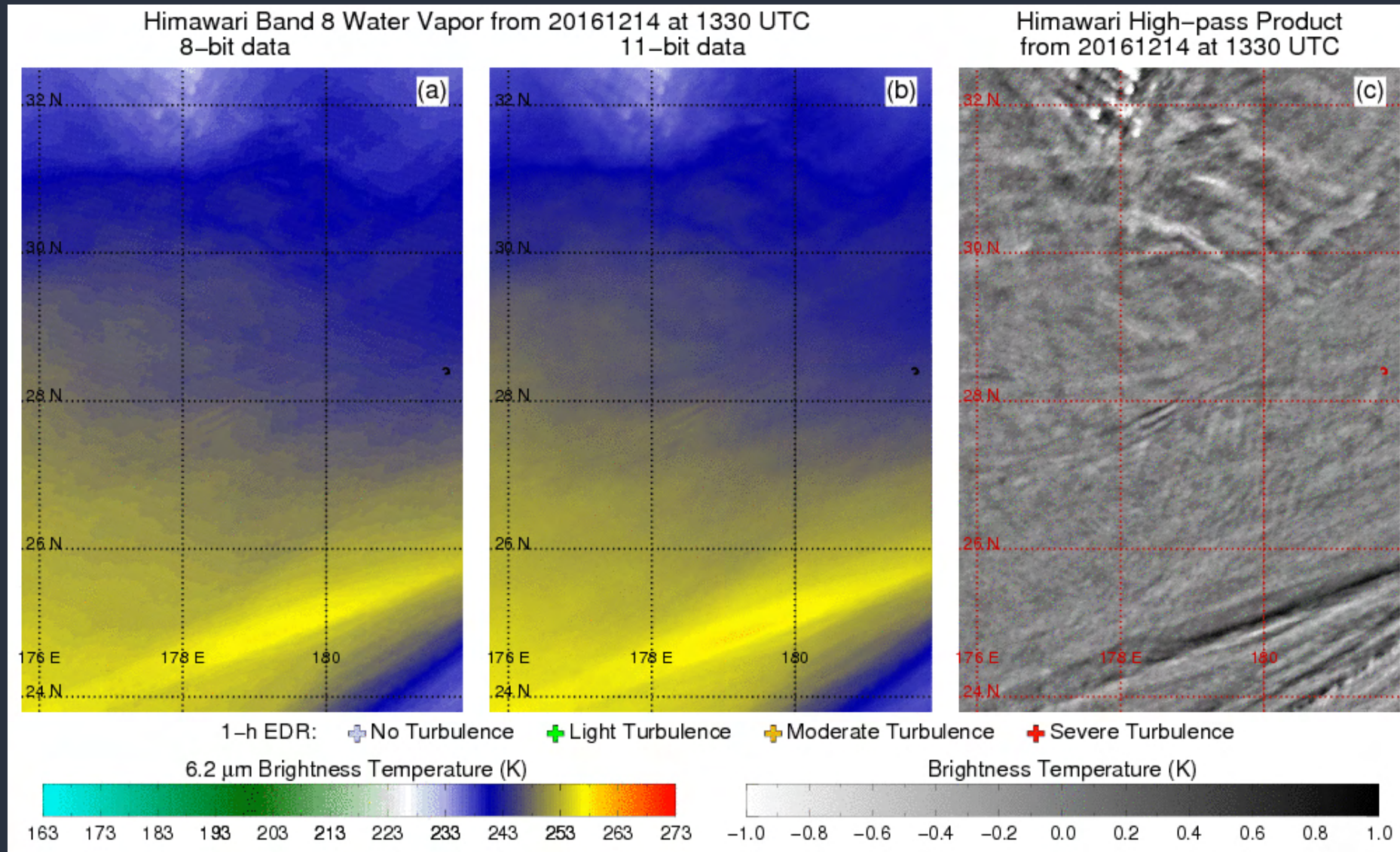
# Convective Storm Monitoring – 5 May 2019 – West TX

- Visible/Infrared “Sandwich” product provides color-enhanced cloud tops from the IR with shadows from the VIS
- Convectively-forced gravity waves are very apparent atop the anvil
- How far do the gravity waves extend beyond the edge of the anvil clouds?





# Automated turbulence detection – Tony Wimmers (CIMSS)



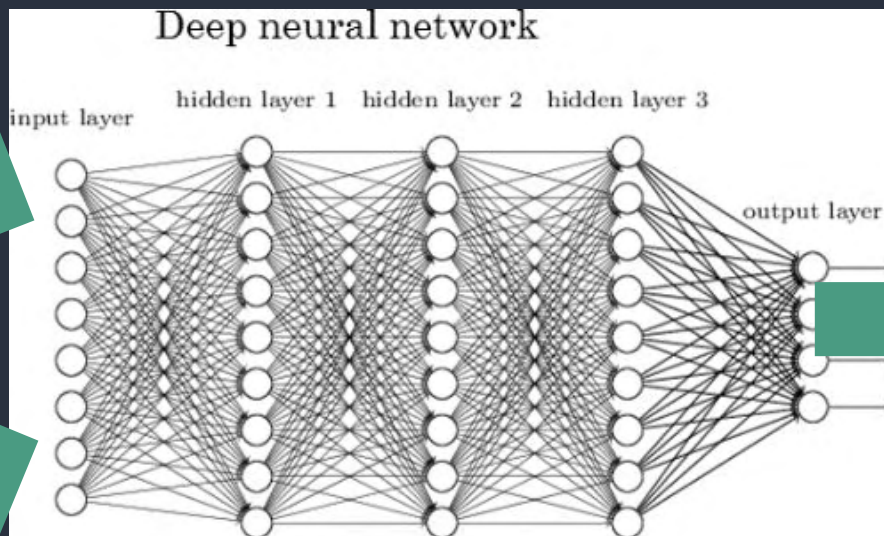
# 'CRUISENET' NEURAL NETWORK MODEL

Surrounding 64x64  
image pixels

1. WV (ch 8)
2. High-pass WV
3. IR (ch 13)
4. Surface elevation

Nearest column from  
the GFS model  
(z, t, u, v @100-700 hPa)

*For every spot on the satellite  
image...*



- Probability of MOG @ 40-41 kft
- “ @ 38-39 kft
- “
- “
- “
- “ @ 30-31 kft

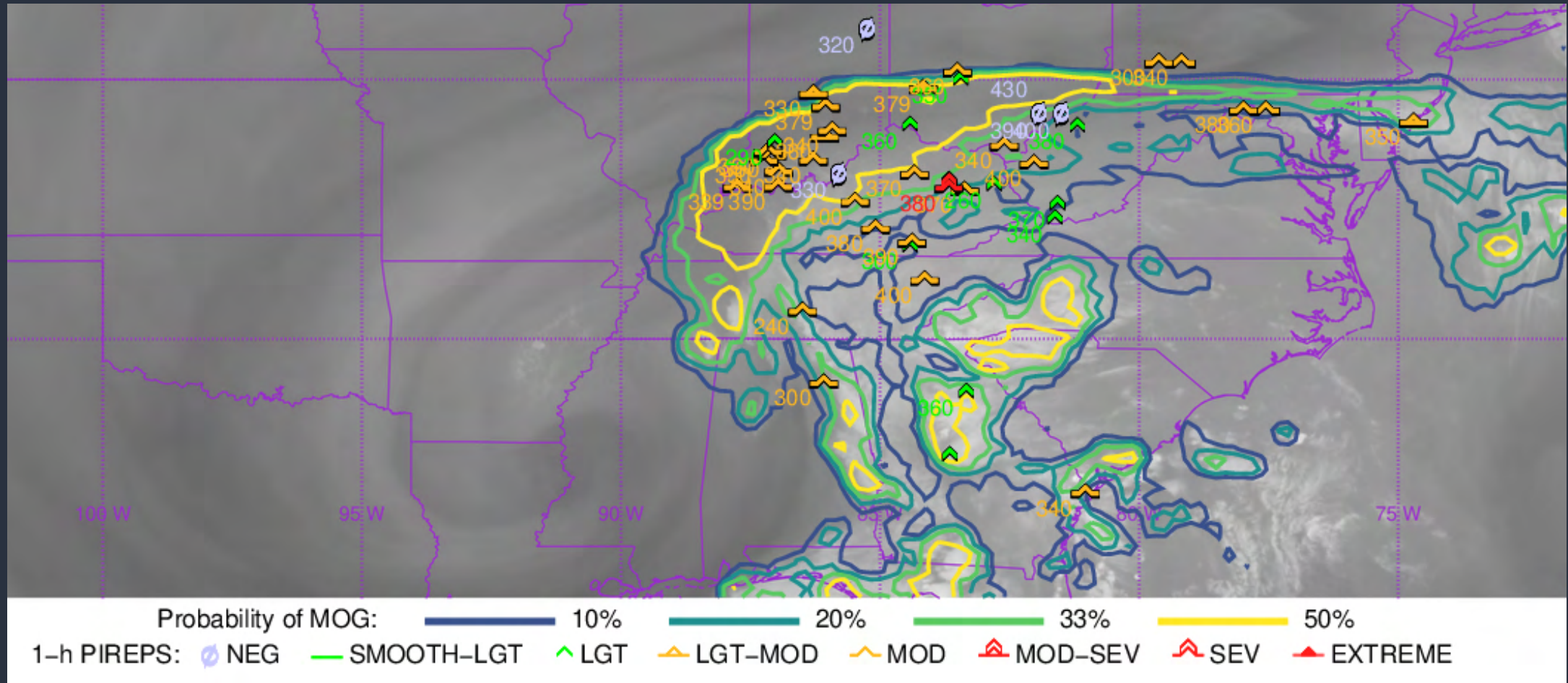
- Trained on ~30,000 EDR obs from 4 years
- Probability of MOG *over a 10-minute segment* (cruising)





# Automated turbulence detection – Tony Wimmers (CIMSS)

GOES-16 MOG Probability from 36–37 kft: Imagery from 20211005 at 1430 UTC

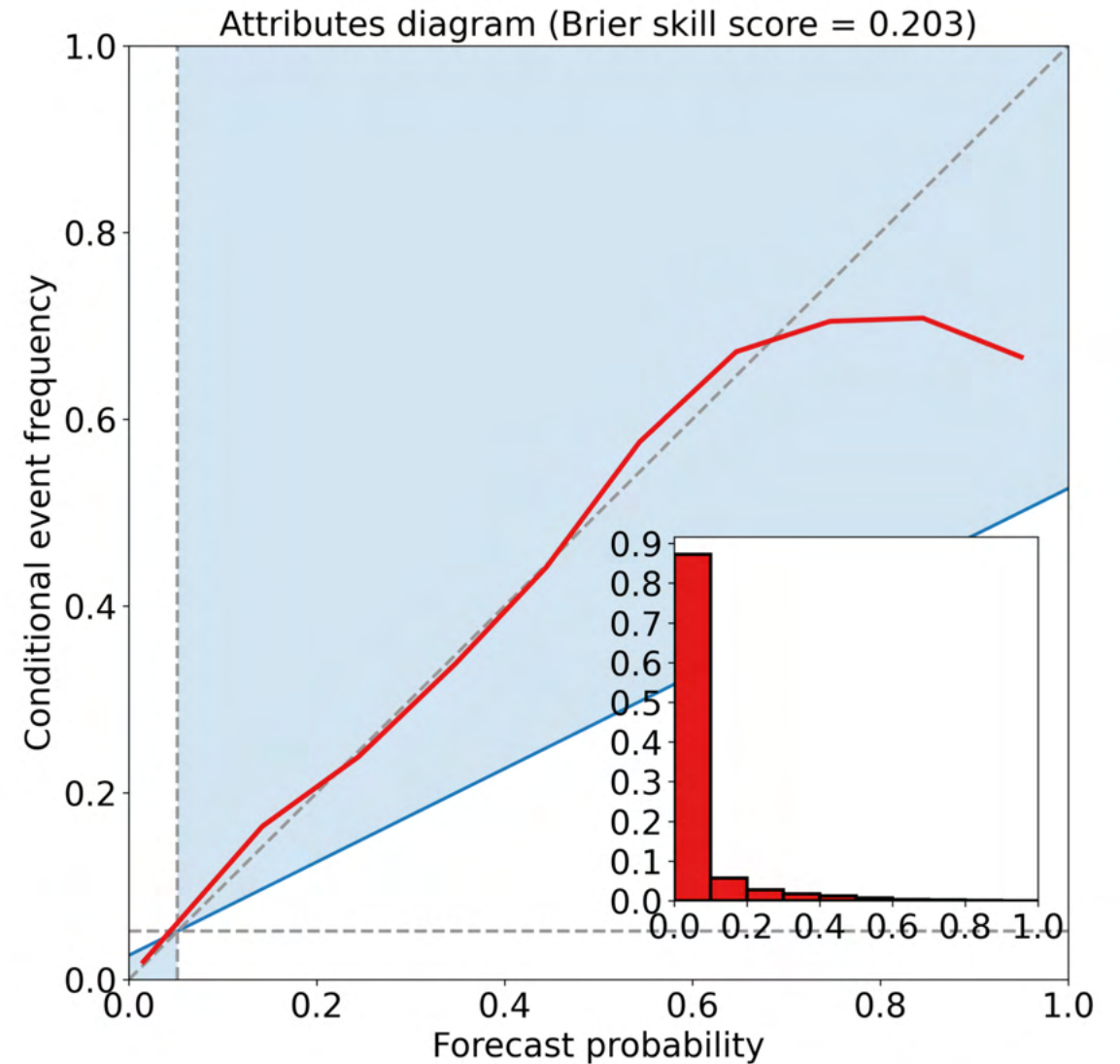


<https://cimss.ssec.wisc.edu/turbulence/>



# VALIDATION: BIAS

- Very low bias (“20%” means 20%)
- (Above 60%, the validation is so undersampled that you can disregard the values there)



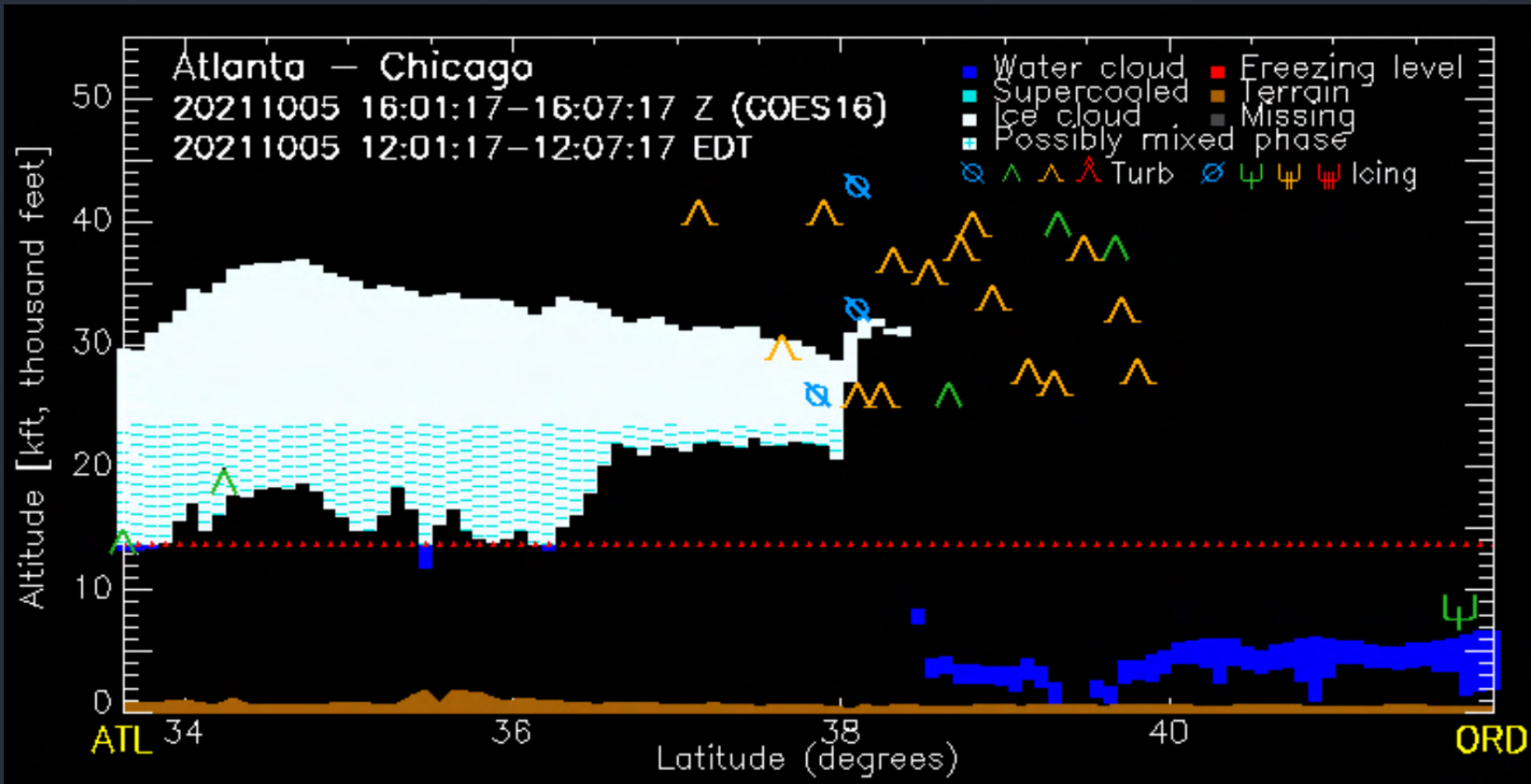


# EARLY LESSONS LEARNED

- Throw out everything we've said about this product before February 2021. Adding NWP inputs makes this product comprehensive, far more skillful, and better with IR-only imagery.
- The product performance matches the statistical validation very closely: For example, an aircraft entering a "20%" contour reports MOG turbulence 20% of the time every 10 minutes.
- Mountain Wave Turbulence (MWT) events are still a bit underestimated (both over Rockies and Appalachians)
- CIMSS Automated Turbulence detection page: <https://cimss.ssec.wisc.edu/turbulence/>



# Cloud Vertical Cross Sections – Yoo-Jeong Noh (CIRA)



[https://rammb.cira.colostate.edu/ramsdis/online/npp\\_viirs\\_conus\\_aviation.asp](https://rammb.cira.colostate.edu/ramsdis/online/npp_viirs_conus_aviation.asp)





# Resources on the Web

- GOES-16/17 ABI imagery and products: <https://rammb-slider.cira.colostate.edu/>
- Another imagery viewer that may load more quickly: <https://www.star.nesdis.noaa.gov/goes/index.php>
- VOLCAT (Volcano Monitoring) from CIMSS: <https://volcano.ssec.wisc.edu/>
- CIMSS Automated Turbulence detection page: <https://cimss.ssec.wisc.edu/turbulence/>
- CIRA Cloud Vertical Cross Section page: [https://rammb.cira.colostate.edu/ramsdis/online/npp\\_viirs\\_conus\\_aviation.asp](https://rammb.cira.colostate.edu/ramsdis/online/npp_viirs_conus_aviation.asp)

Any feedback (positive or negative) on these products is very much appreciated!

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