

Satellite Tools for Aviation Safety

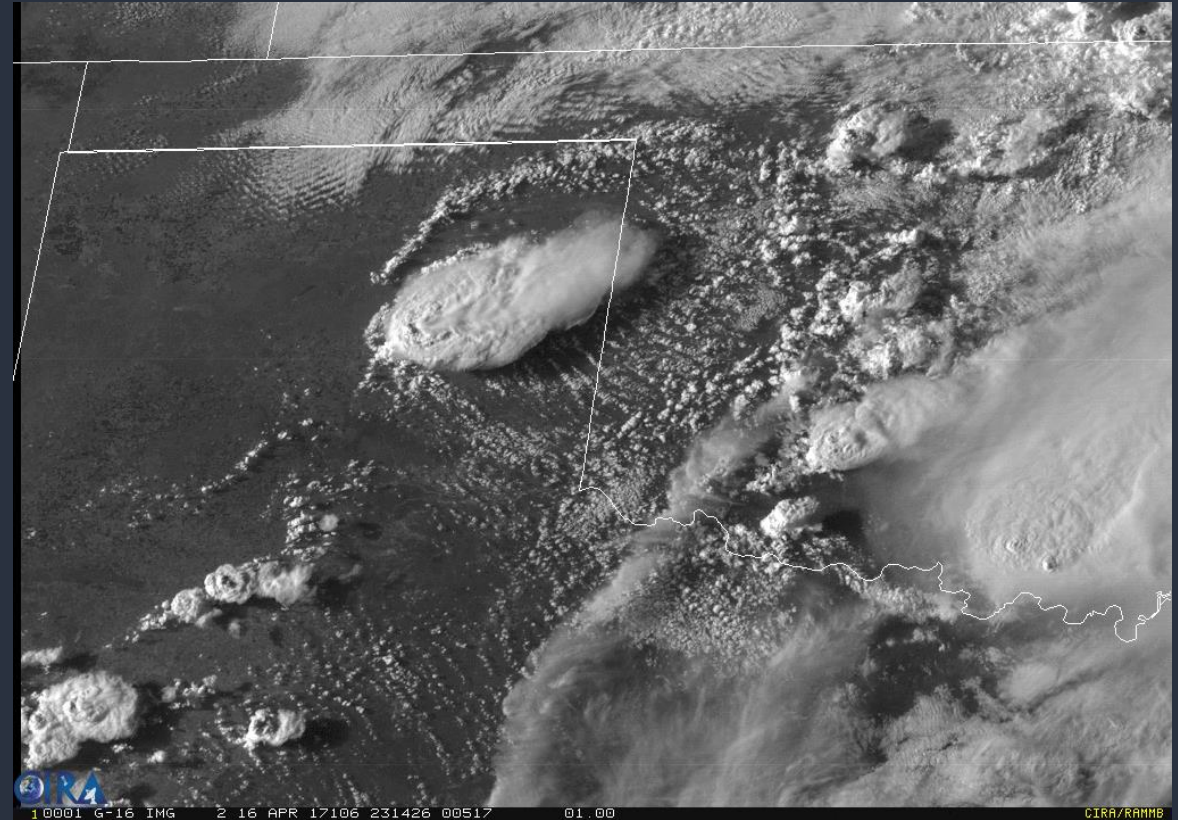
Dan Lindsey
NOAA/NESDIS GOES-R Program Scientist

Contributions from Tony Wimmers and Scott Lindstrom (CIMSS), YJ Noh (CIRA), and Mike Pavolonis (NOAA/NESDIS)

NOAA
National Environmental Satellite,
Data, and Information Service

The GOES-R Series Geostationary Satellites

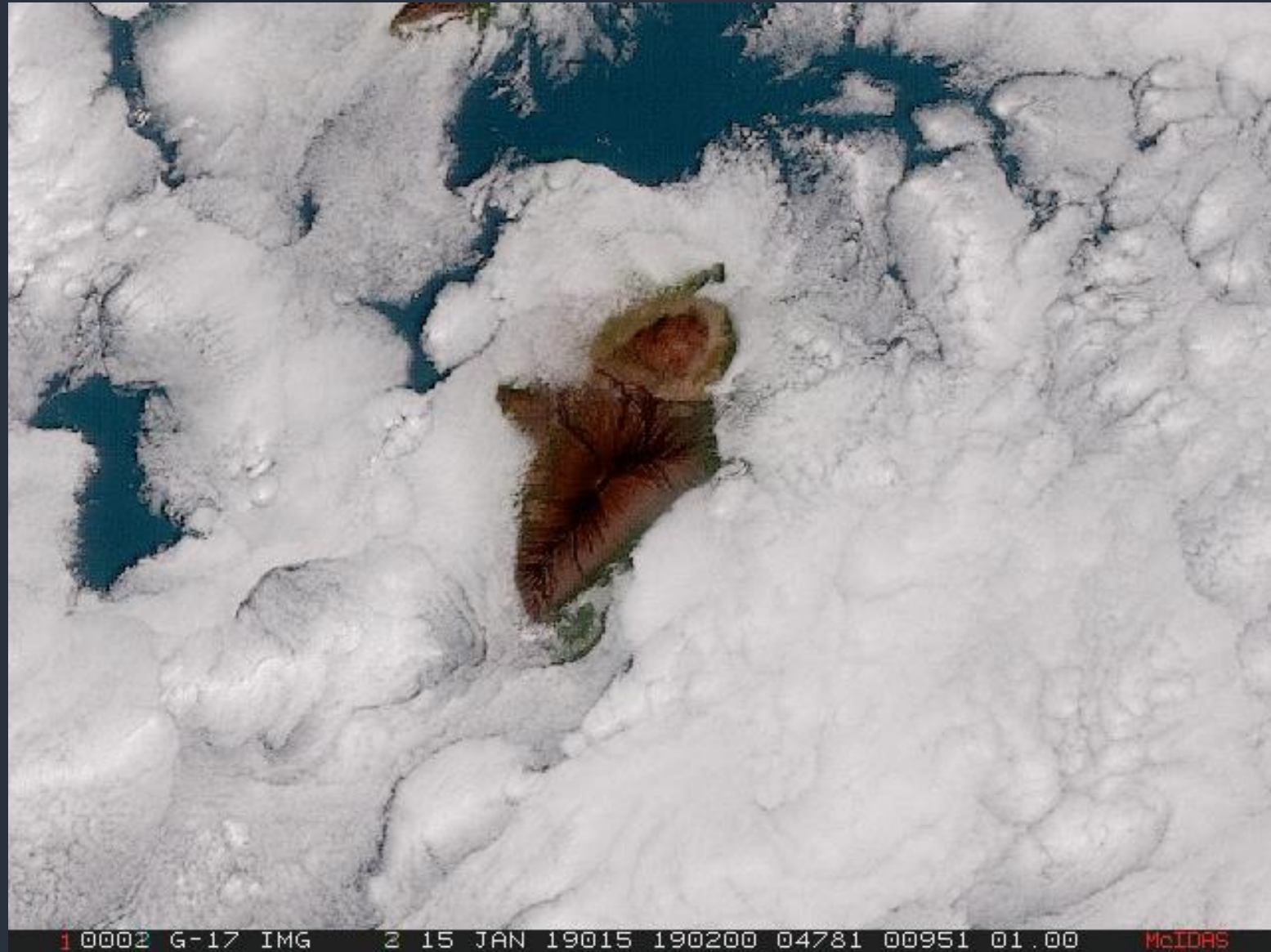
- GOES-R is NOAA's operational geostationary satellite program
- Provides geostationary coverage from GOES-East and GOES-West, covering from the coast of Africa to New Zealand
- The Advanced Baseline Imager (ABI) provides 2 km IR data and 500 m VIS data in 16 spectral channels
- Full Disk imagery every 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

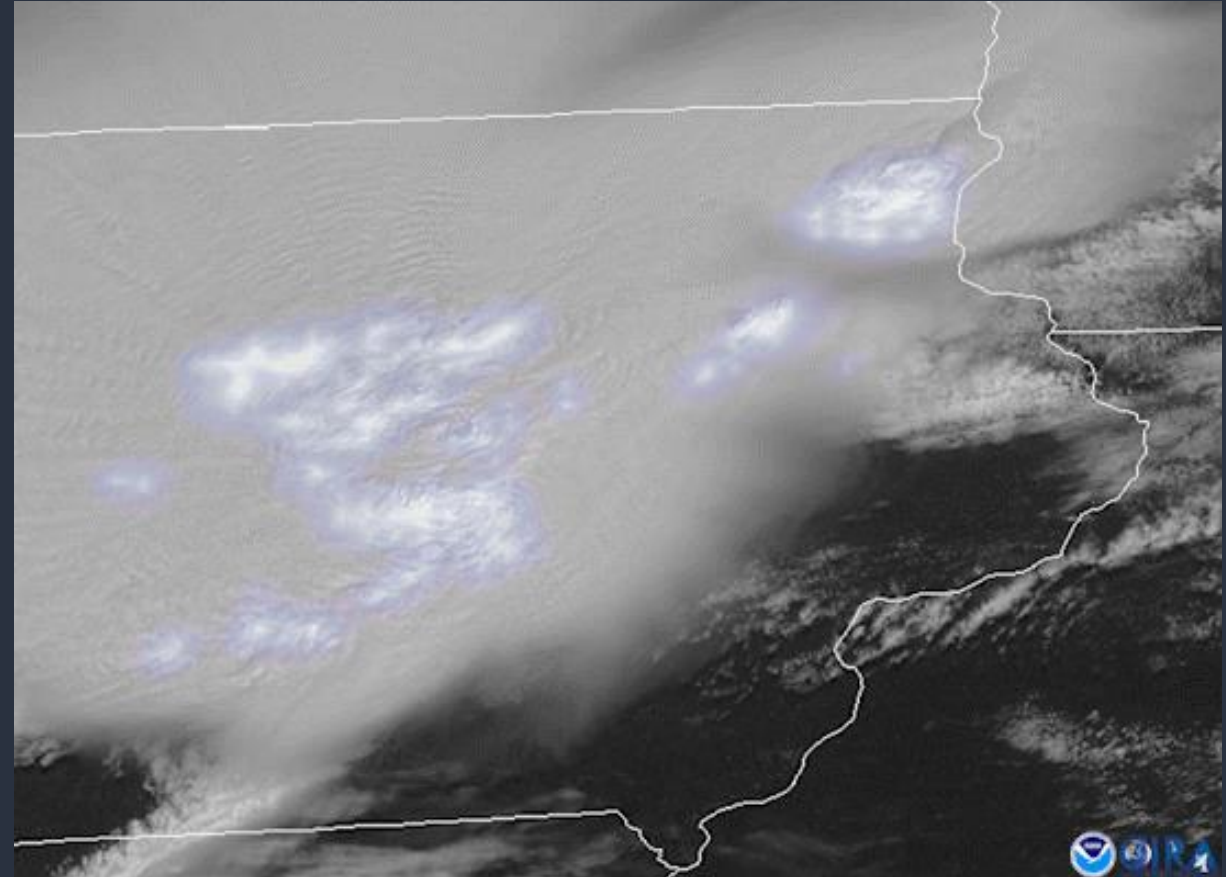
GOES-West

- GOES-17 was replaced by GOES-18 in the GOES-West position near 137 W longitude in Jan. 2023
- Provides coverage of the western CONUS, Alaska, and much of the Pacific Ocean (coverage examples coming later)
- Provides very high resolution imagery of Hawaii!



Lightning Detection from Space

- 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
- Forecasters from the NWS Aviation Weather Center have told us they get great value from GLM data for international SIGMETS within its domain



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

GOES-R Satellite Aviation Safety 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

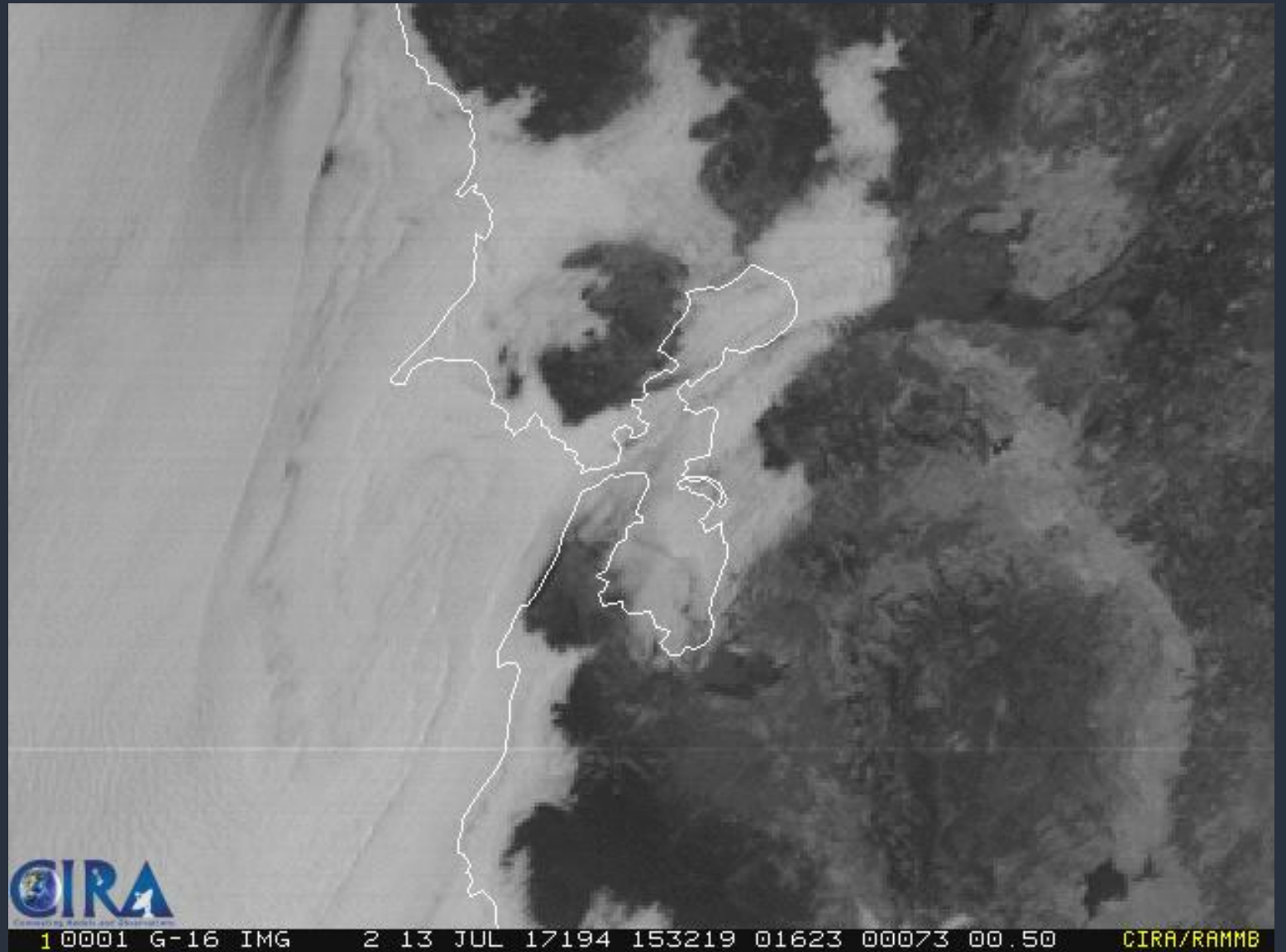
Two types of GOES-R products

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



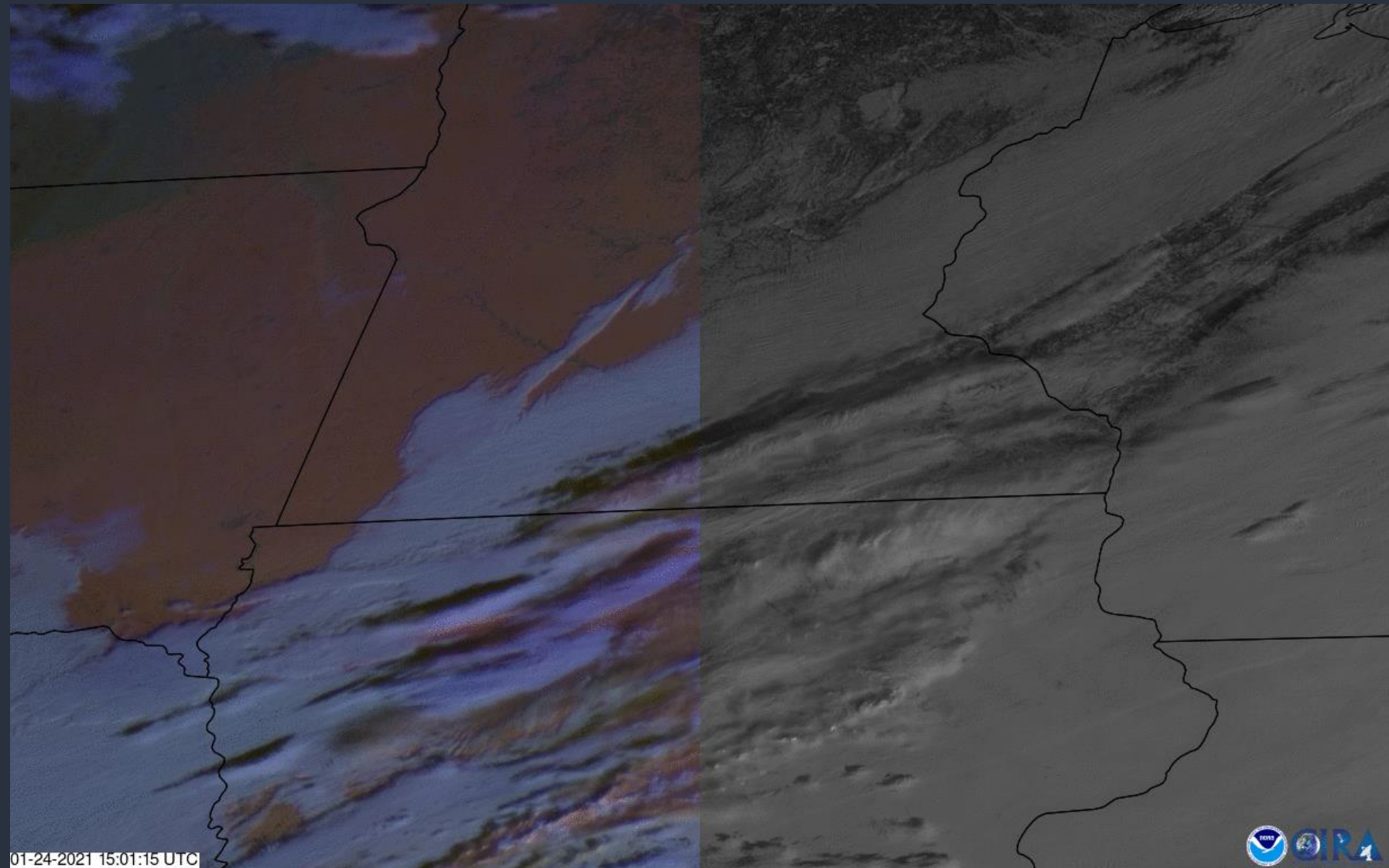
Low Cloud Monitoring – 13 July 2017 – SF Bay Area

- 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



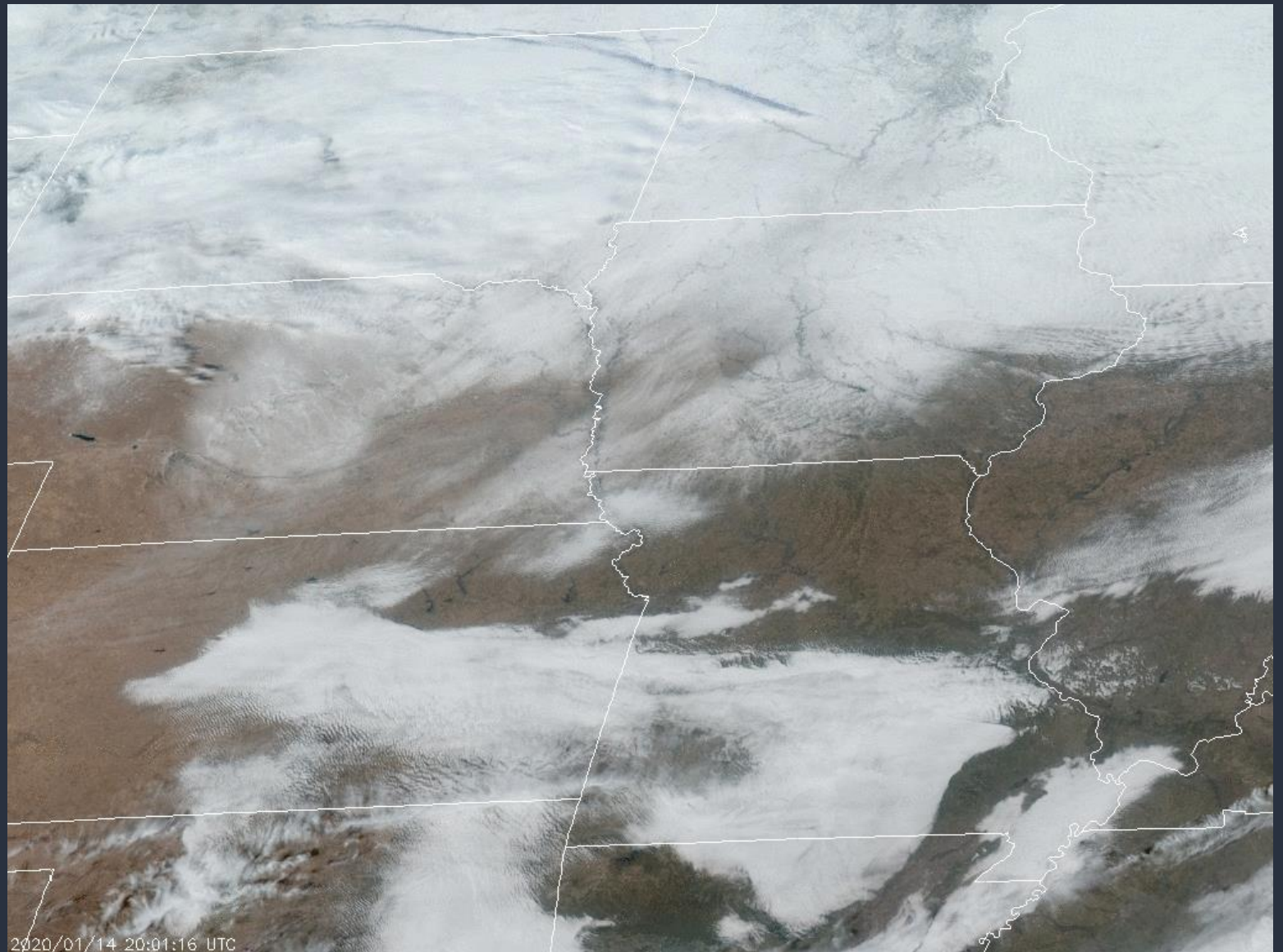
Low Clouds over Snow – 24 Jan. 2021 – Minnesota/Iowa

- 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 CIRA's SLIDER page: <http://rammb-slider.cira.colostate.edu>



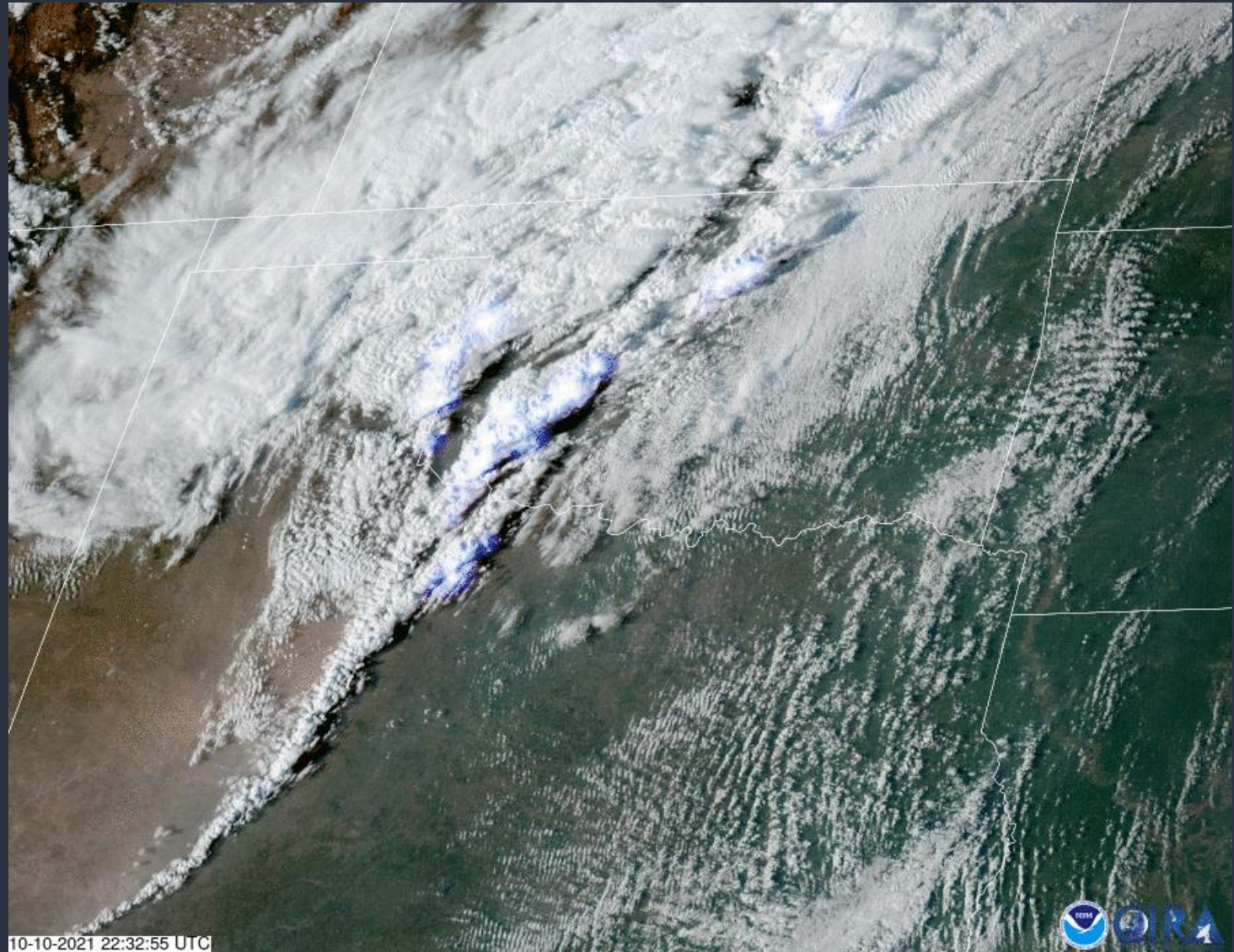
Low Clouds at night – 14 Jan. 2020 – Missouri Valley

- 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



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



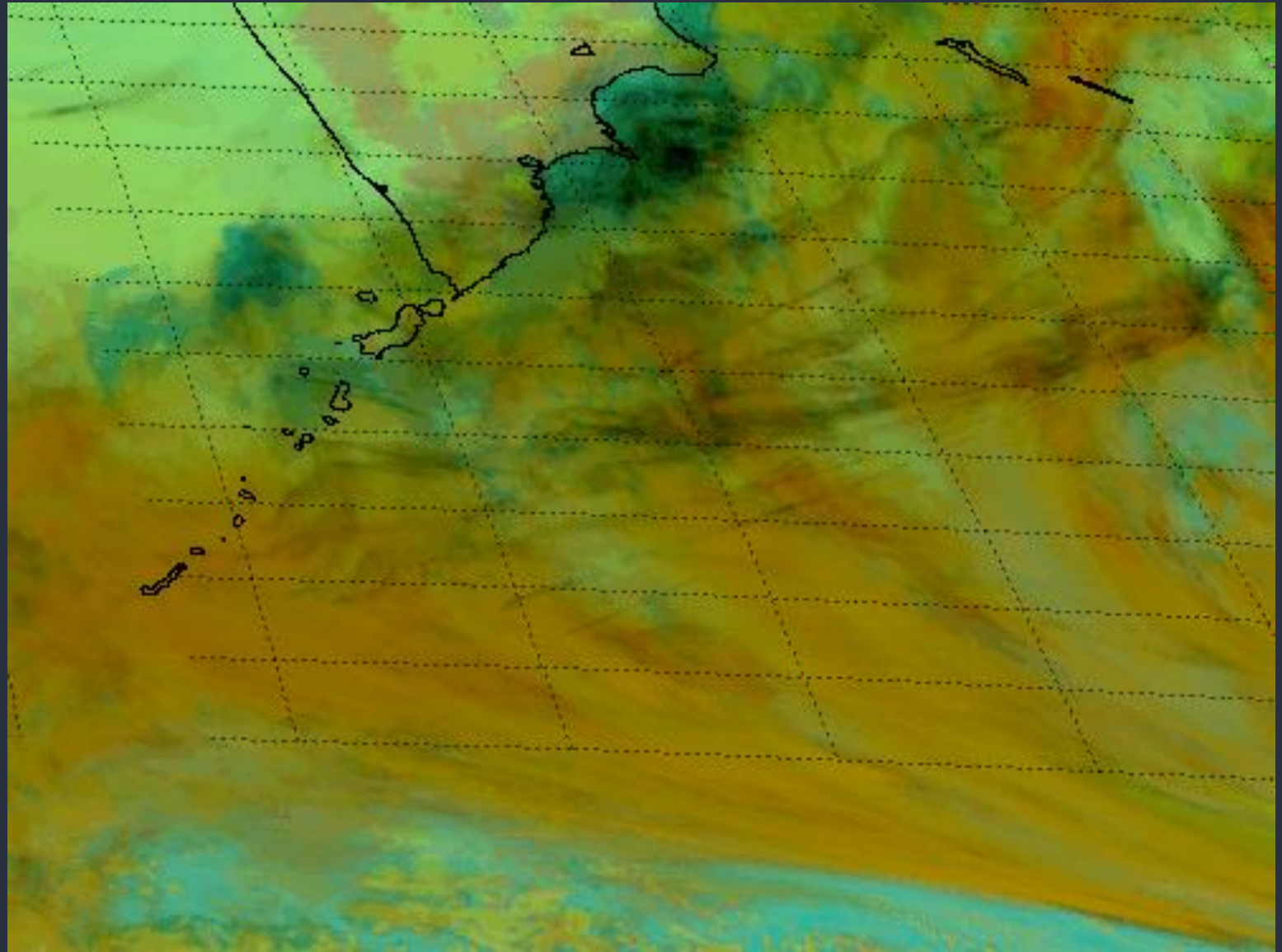
Eruption of Raikoke – June 2019 – NW Pacific – Himawari-8

- 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



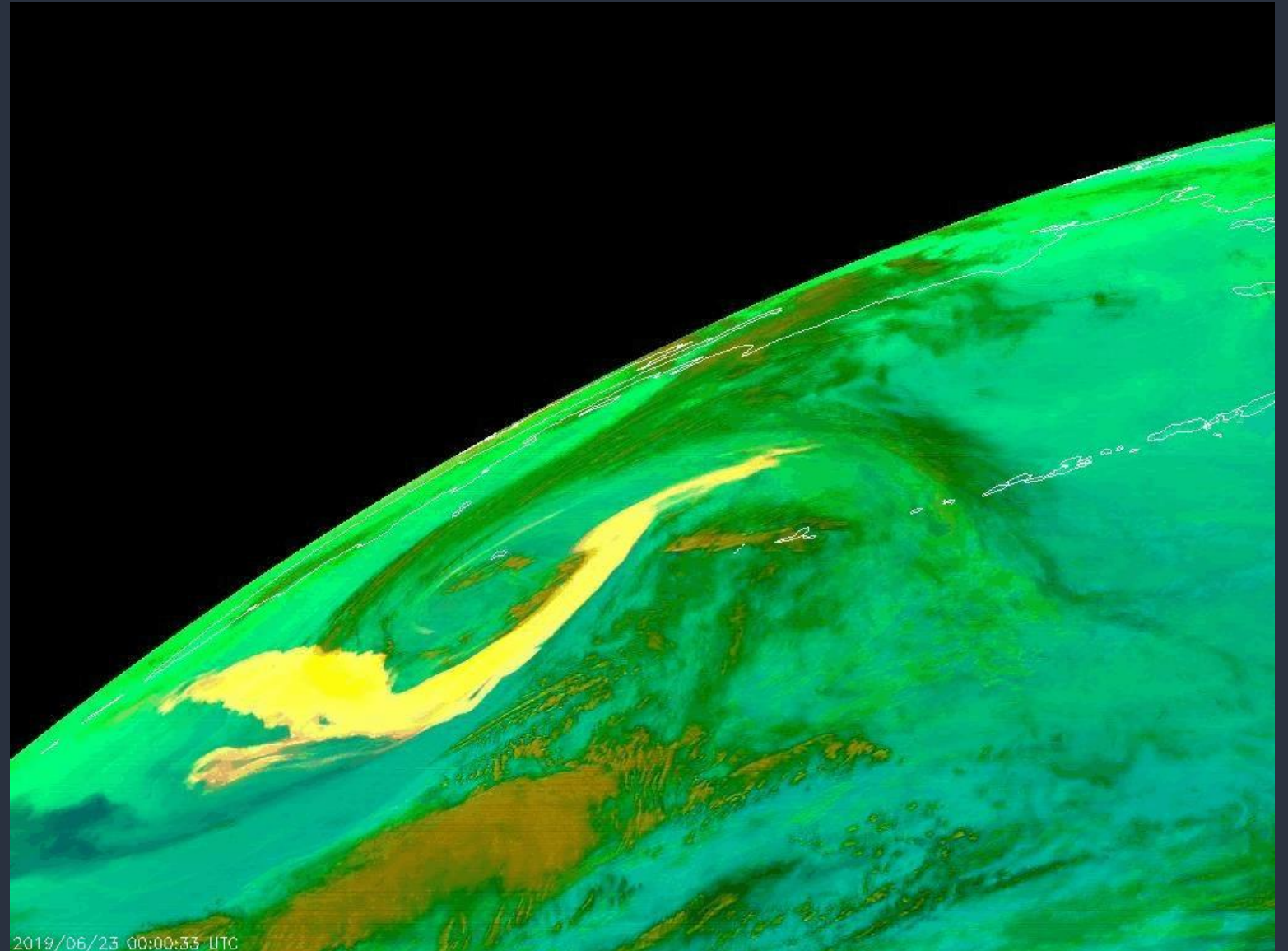
Eruption of Kambalny – March 2017 – Kamchatka – Himawari-8

- The Ash RGB uses IR bands, so is available 24/7
- Ash appears red/pink and sulfur dioxide (SO₂) has a greenish tint
- This example also picks up on aircraft contrails

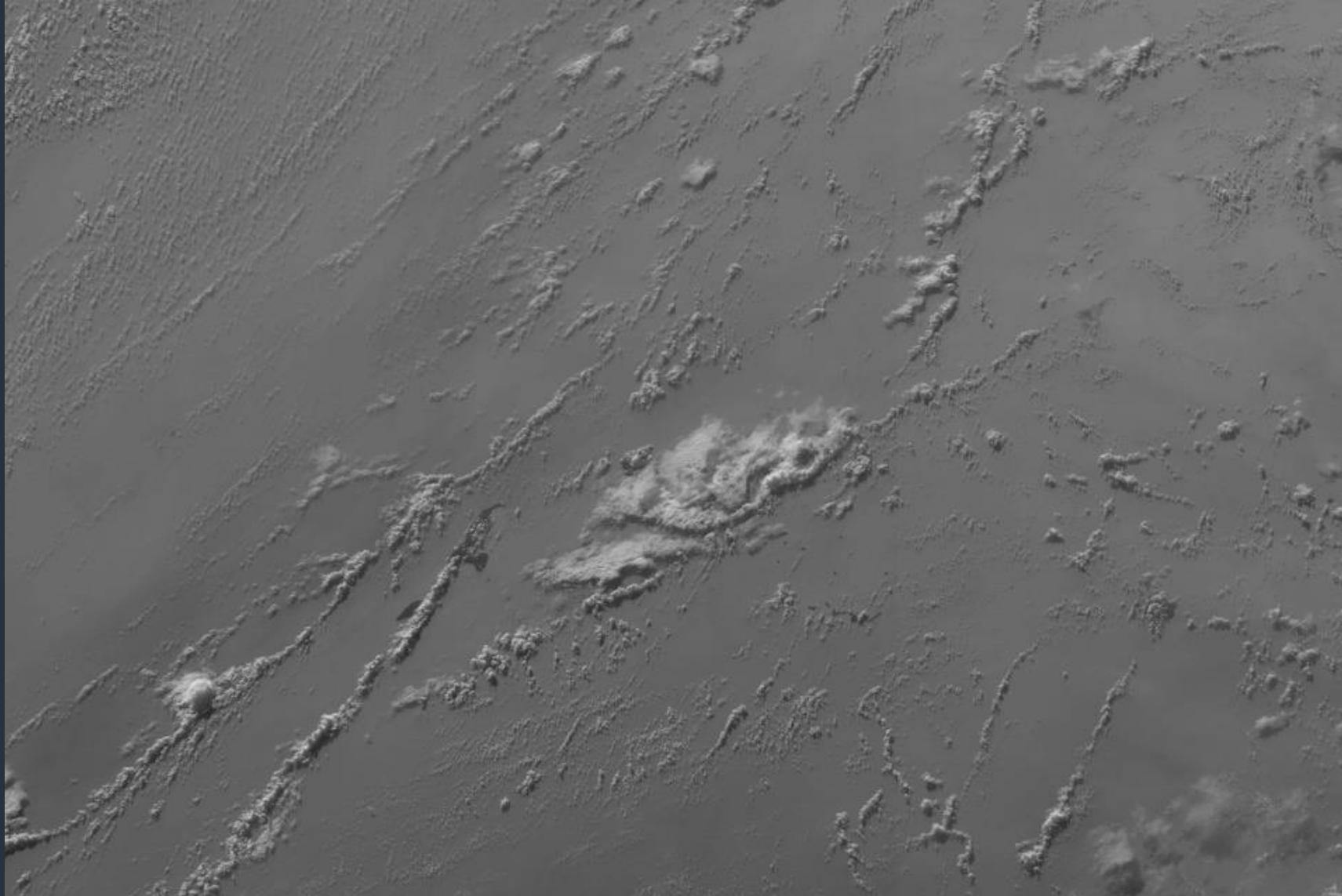


Raikoke Plume over the Aleutians – June 2019 - GOES-17 SO2 RGB

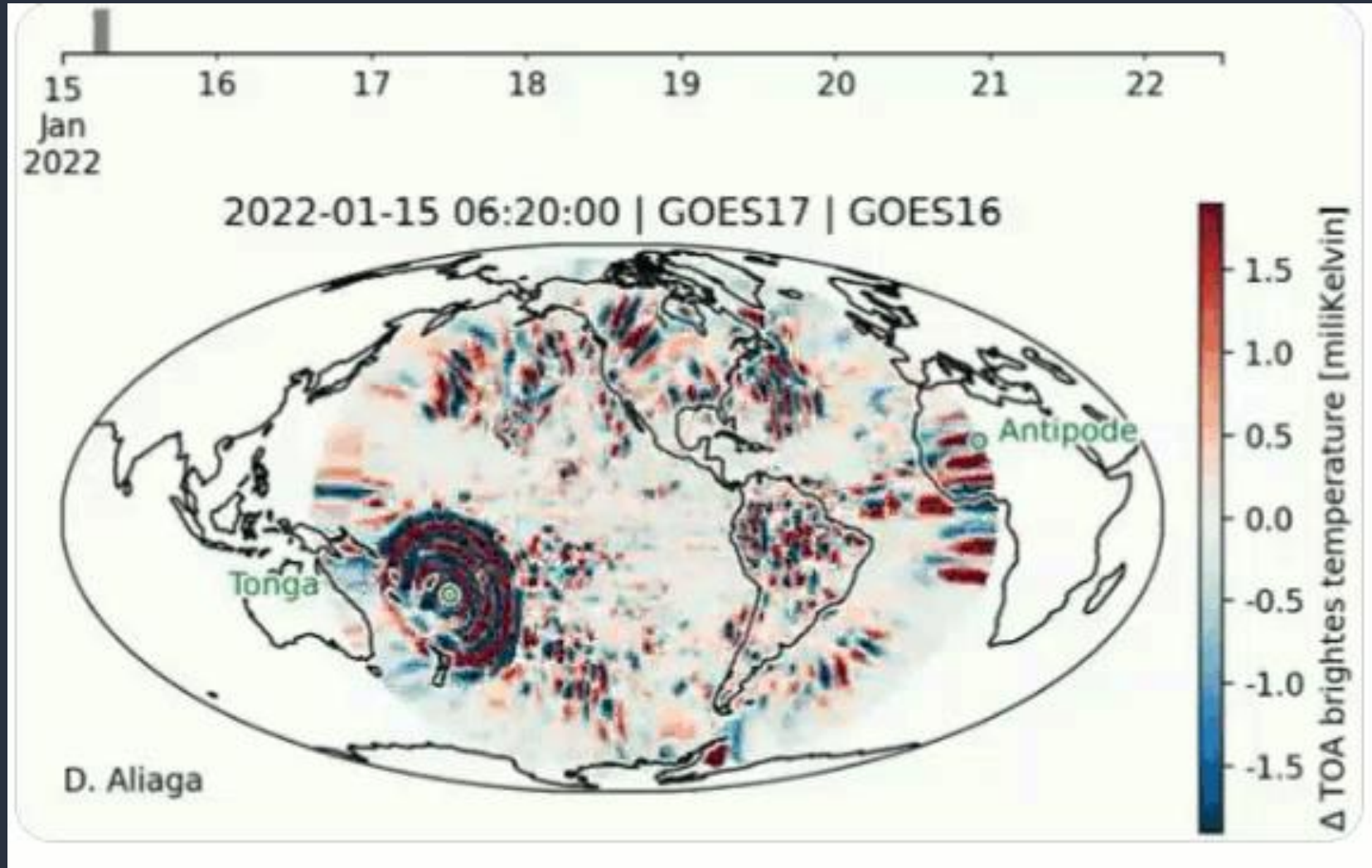
- In this SO2 RGB, SO2 and sulfate aerosols appear orange or yellow



Eruption of the Tonga Volcano – 15 Jan. 2022 – GOES-17 ABI VIS



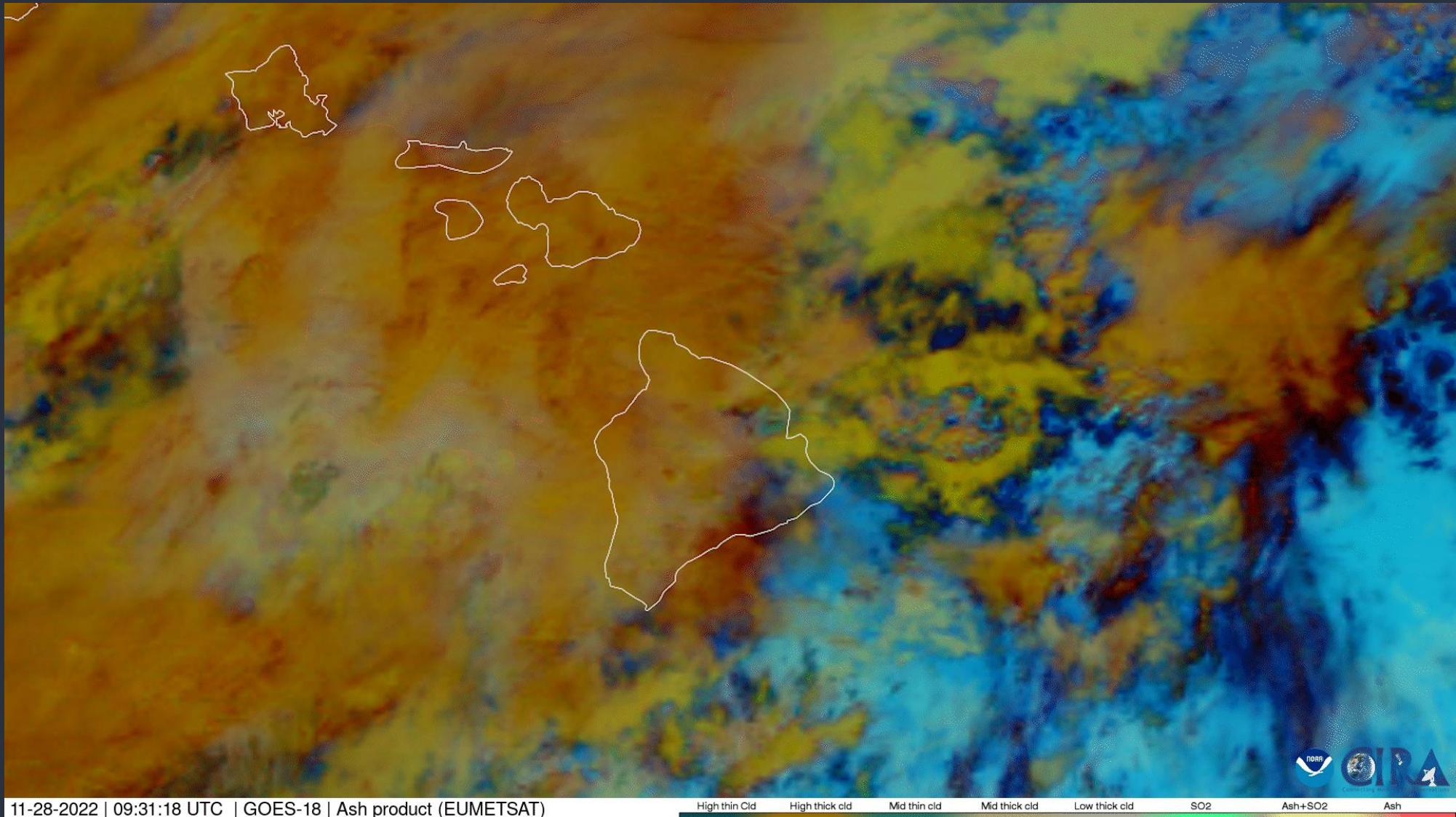
Filtered GOES-16/17 ABI Time Differences



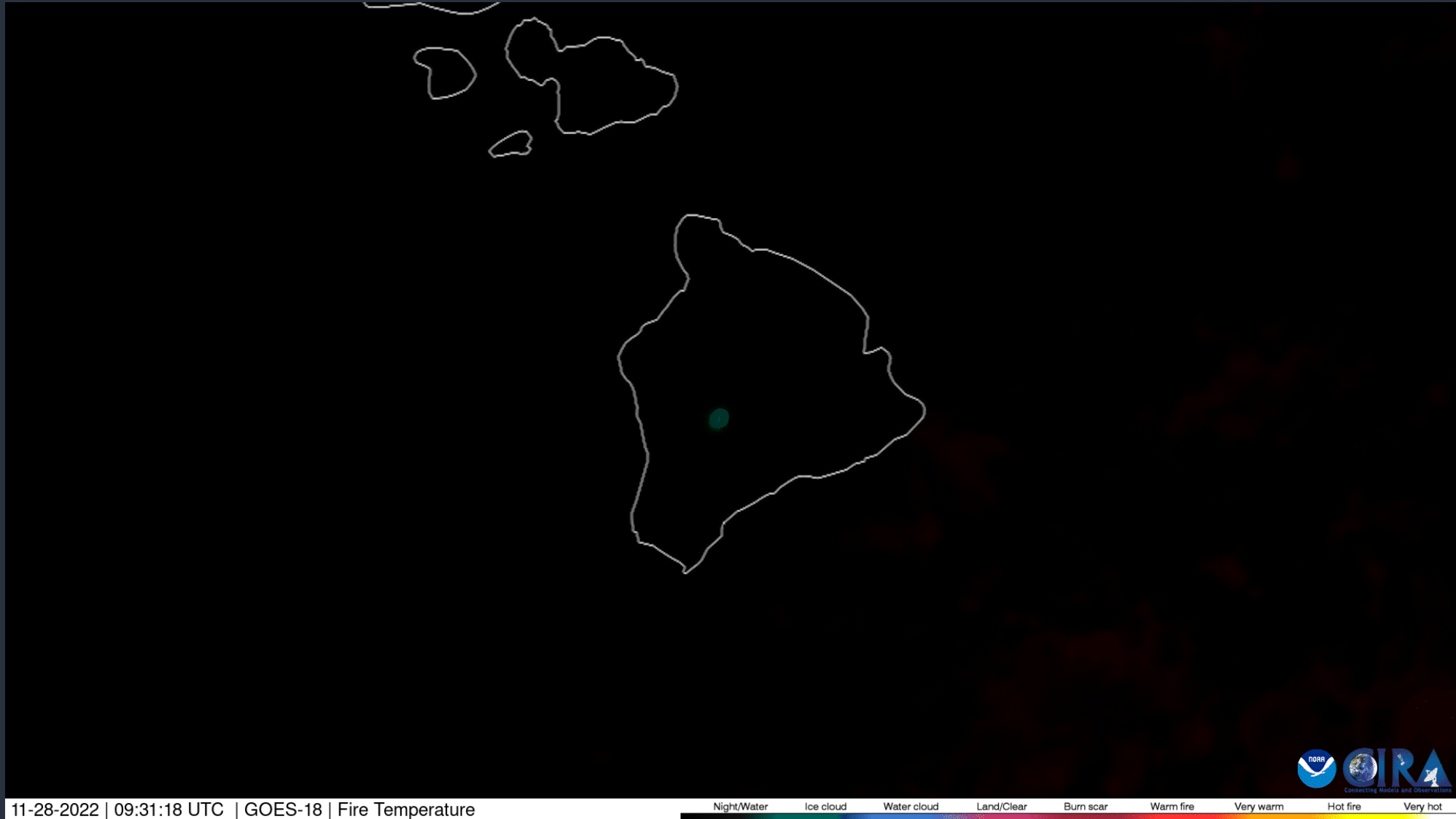
From Diego Aliaga via Twitter: <https://twitter.com/diegoaliaga2/status/1485469621327069185>



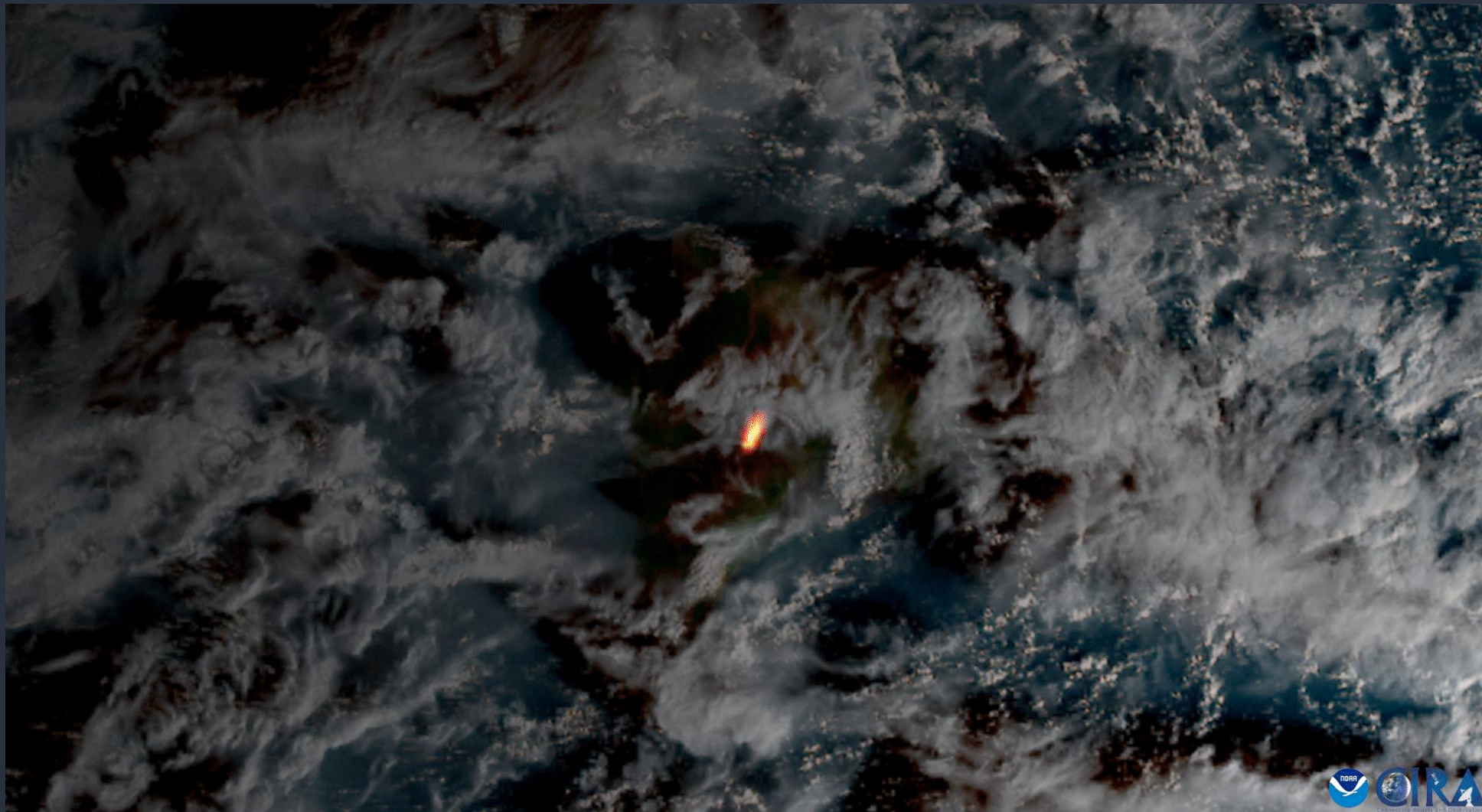
Mauna Loa Eruption – Nov. 28 2022



Mauna Loa Eruption – Nov. 28 2022



Mauna Loa Eruption – Dec. 7 2022



12-07-2022 | 17:41:17 UTC | GOES-18 | GeoColor + Fire Temperature

Night/Water Ice cloud Water cloud Land/Clear Burn scar Warm fire Very warm Hot fire Very hot

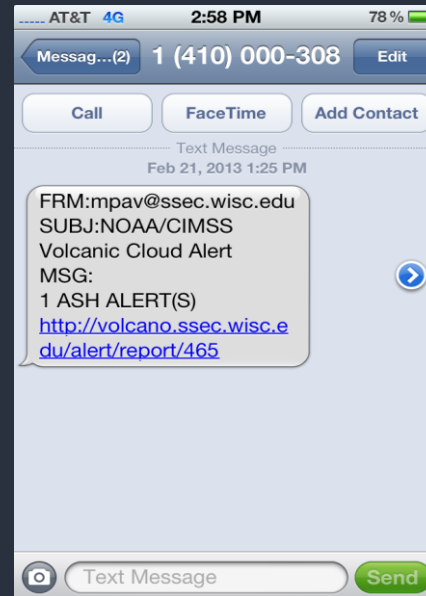


The VOLcanic Cloud Analysis Toolkit (VOLCAT)

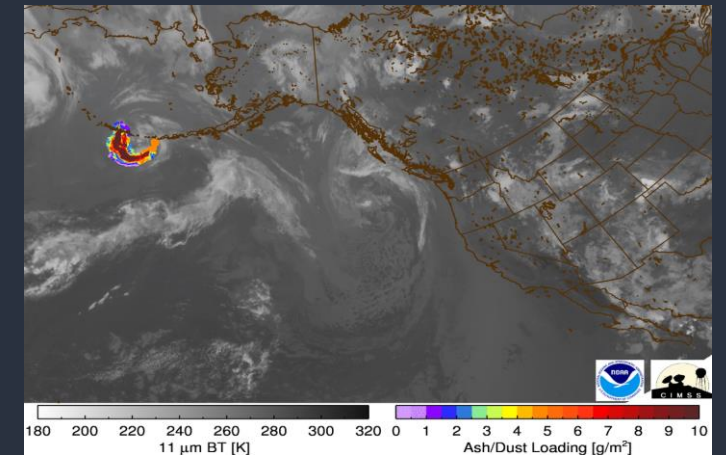
Thermal Monitoring



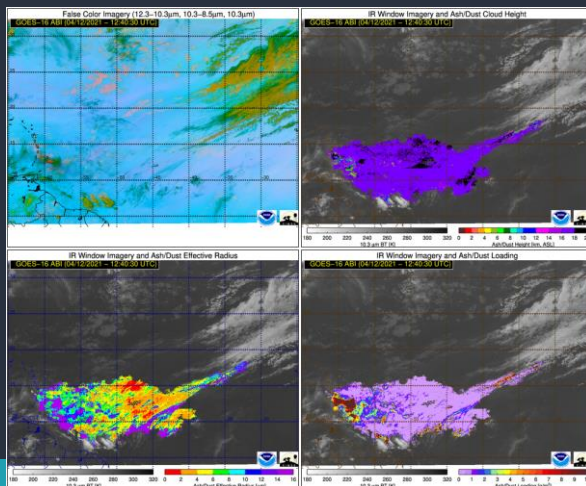
Eruption Alerts



Volcanic Cloud Tracking

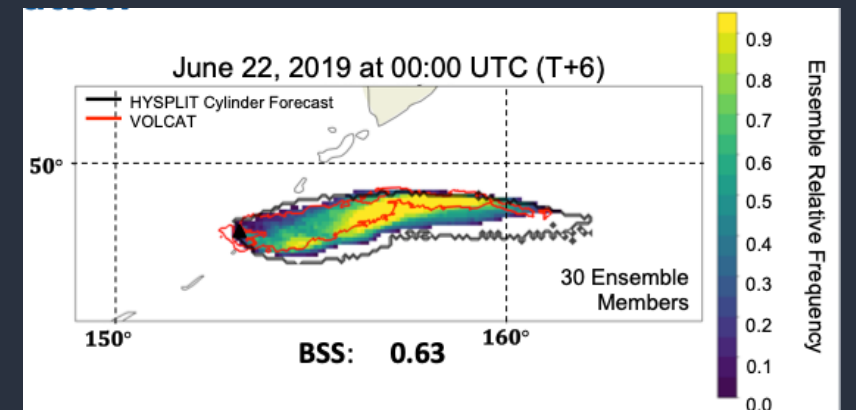


Volcanic Cloud Characterization



- 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

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

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 13:08:28 UTC
 Primary Instrument: GOES-16 ABI

Possible Volcanic Cb

Basic Information

Volcanic Region(s)	West Indies
Country/Countries	Saint Vincent and the Grenadin
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 [AMSL]	10.40 km ; 34121 ft
Maximum Height (opaque assumption) [AMSL]	13.10 km ; 42979 ft
Minimum IR Window BT	215.20 K

Show More ▲ View all event imagery ▶

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
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AREA: W_INDIES

SUMMIT ELEV: 3865 FT (1178 M)
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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



Turbulence Probability – Tony Wimmers (CIMSS)

- Subject Matter Expert: **Tony Wimmers**
- ABI and AHI have sufficient spatial and temporal resolution to infer many turbulent episodes
 - Some features in clear sky, some in clouds (often *over* clouds)
- Machine Learning is used to relate satellite observations to the likelihood of **Moderate or Greater (MOG)** turbulence
 - Thousands of turbulent and non-turbulent cases are used to create the predictive model.
 - Infrared Window Channel (10.3 mm), (upper-level) Water Vapor imagery (6.2 mm), and mid/upper-level GFS soundings
 - Aircraft-based observations of turbulence (at 30000 – 41000 feet) are used to train and validate the model

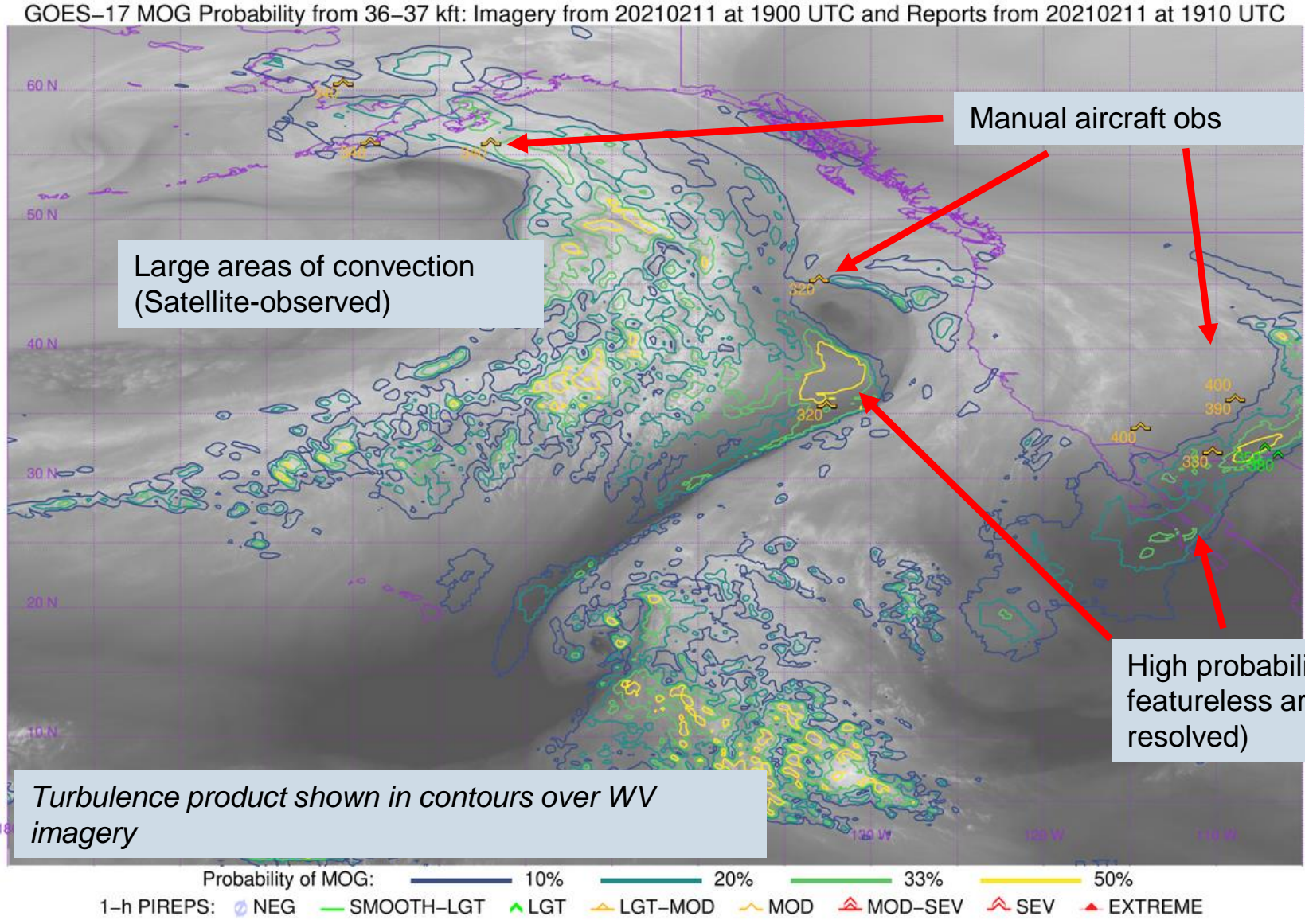


Turbulence Probability – Tony Wimmers (CIMSS)

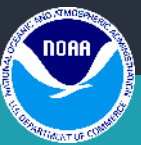
- The turbulence product is probabilistic (percentage). Interpret this as the probability of MOG...
 - For 'medium' (eg. 737) and 'large' (eg. 777) aircraft (mainly commercial passenger airliners)
 - At least once during a 10-minute period
 - Within different layers at typical cruising altitudes:
(30-31, 32-33, 34-35, 36-37, 38-39, 40-41 x 1000 ft)
- For NWS users, AWIPS display has layers of 30-33 / 34-37 / 38-41 kft.



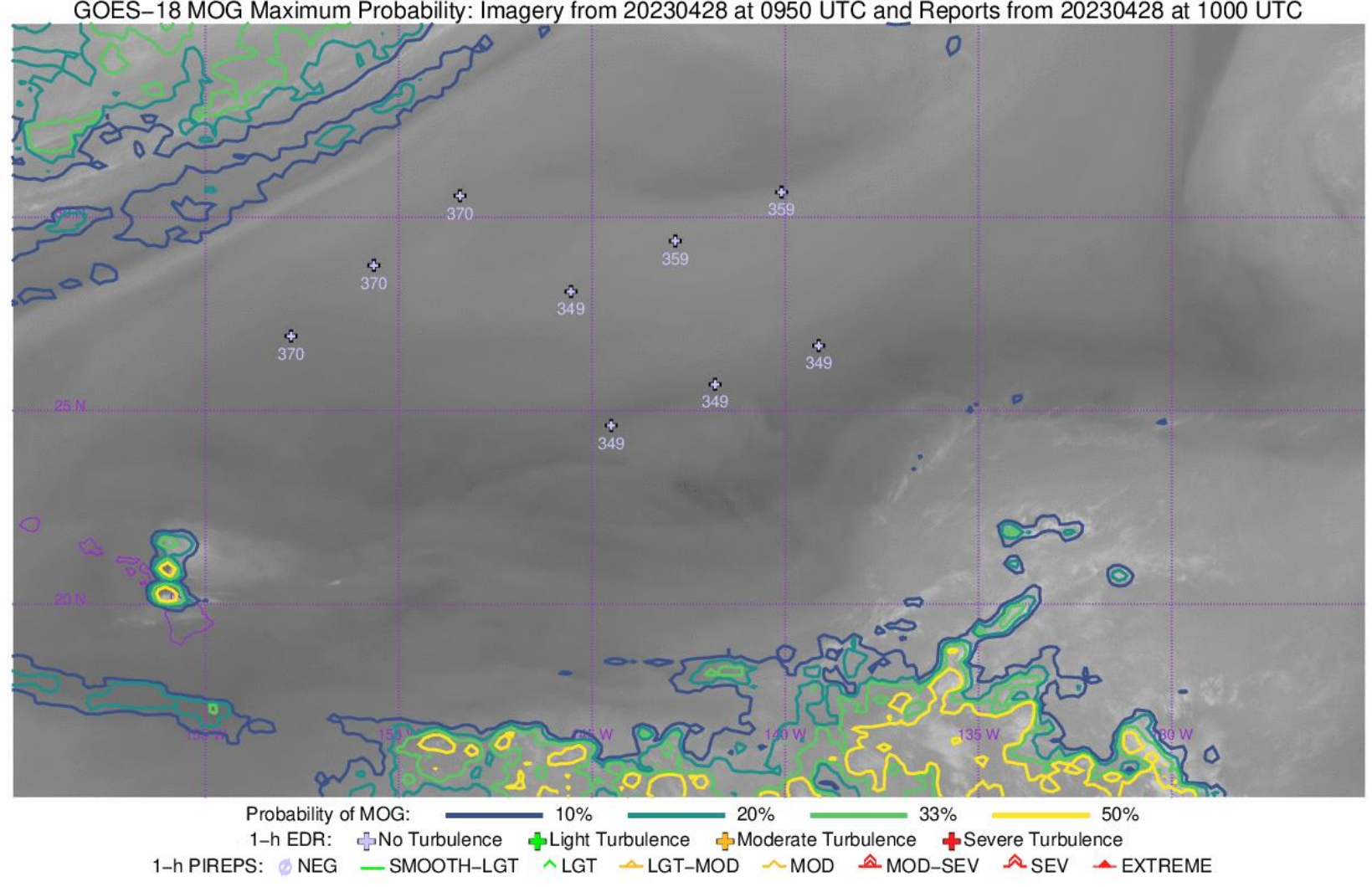
Turbulence Probability – Tony Wimmers (CIMSS)



This example is for the 36-37 kft level



Turbulence Probability – Tony Wimmers (CIMSS)



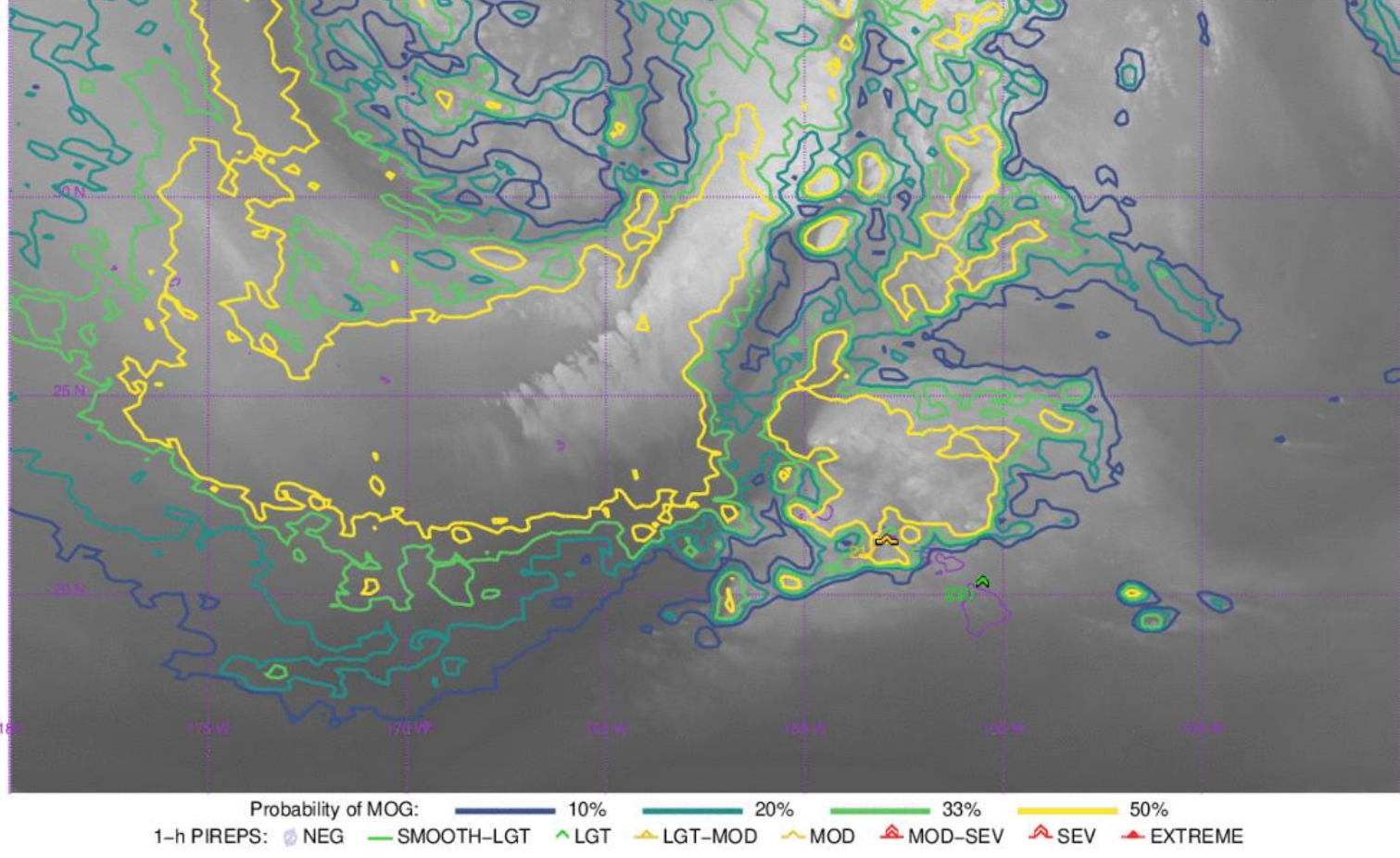
This example is for the 30-41 kft level

<https://cimss.ssec.wisc.edu/turbulence> or google "CIMSS turbulence"



Recent High-Impact event: HAL 35, from Phoenix to Honolulu, 18 December 2022

GOES-17 MOG Maximum Probability: Imagery from 20221218 at 1800 UTC and Reports from 20221218 at 1810 UTC



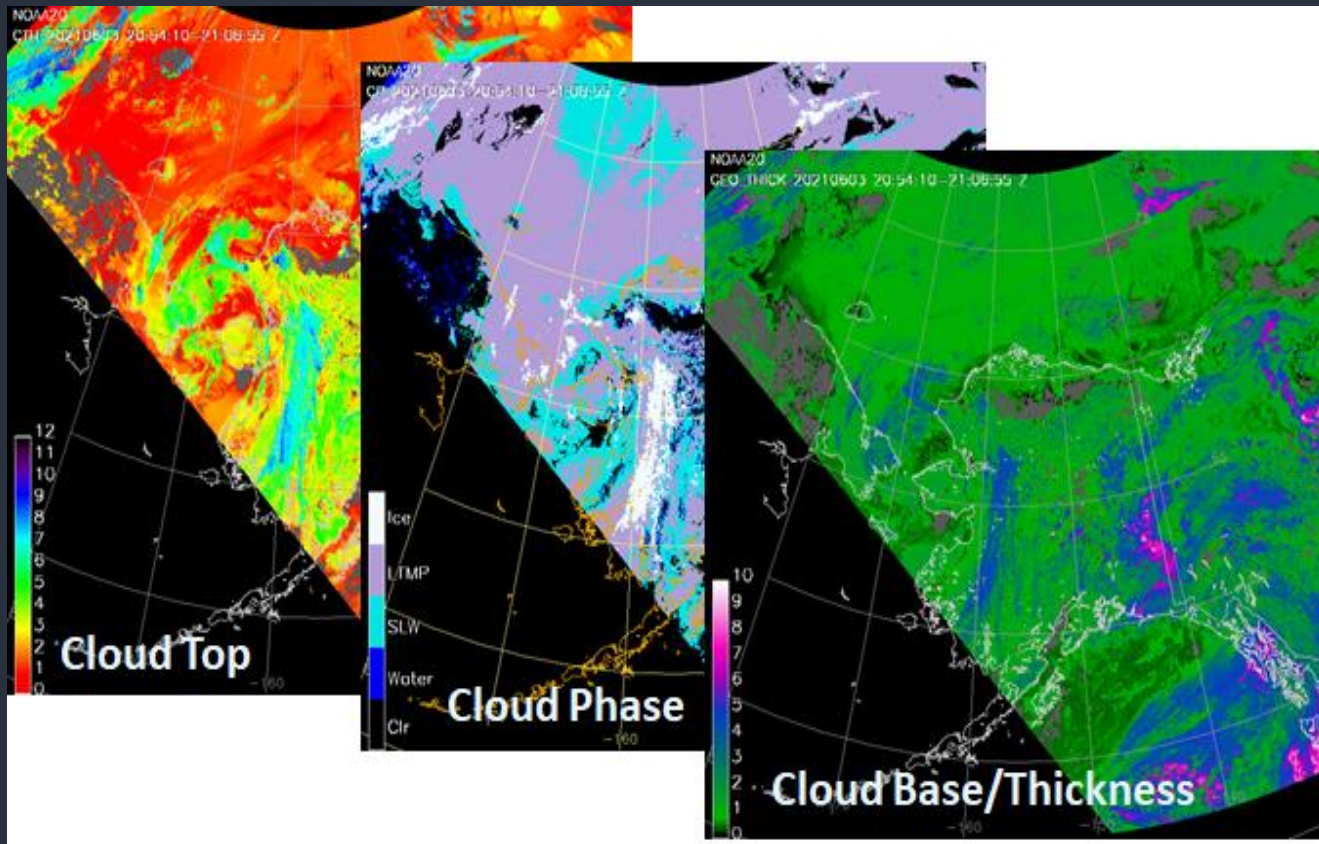
- 36 injuries
- Further analysis showed that the PIREP, filed after the event, was displaced from the actual event
- This is why you don't train Turbulence Detection models on PIREPs but rather on EDR observations

<https://cimss.ssec.wisc.edu/turbulence> or google "CIMSS turbulence"



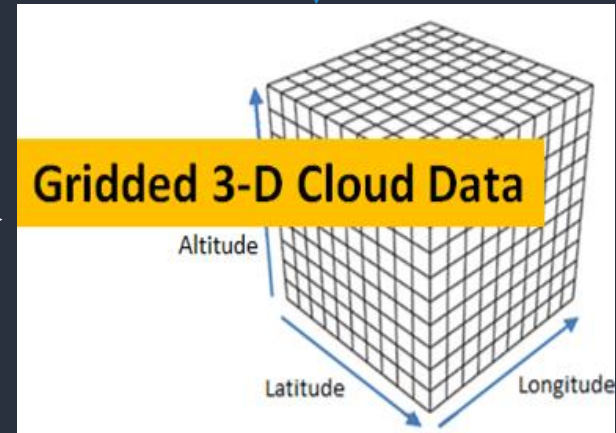
Satellite 3D Cloud Data for Aviation – YJ Noh (CIRA)

NOAA Enterprise Cloud products
(2D pixel data for the individual granules)

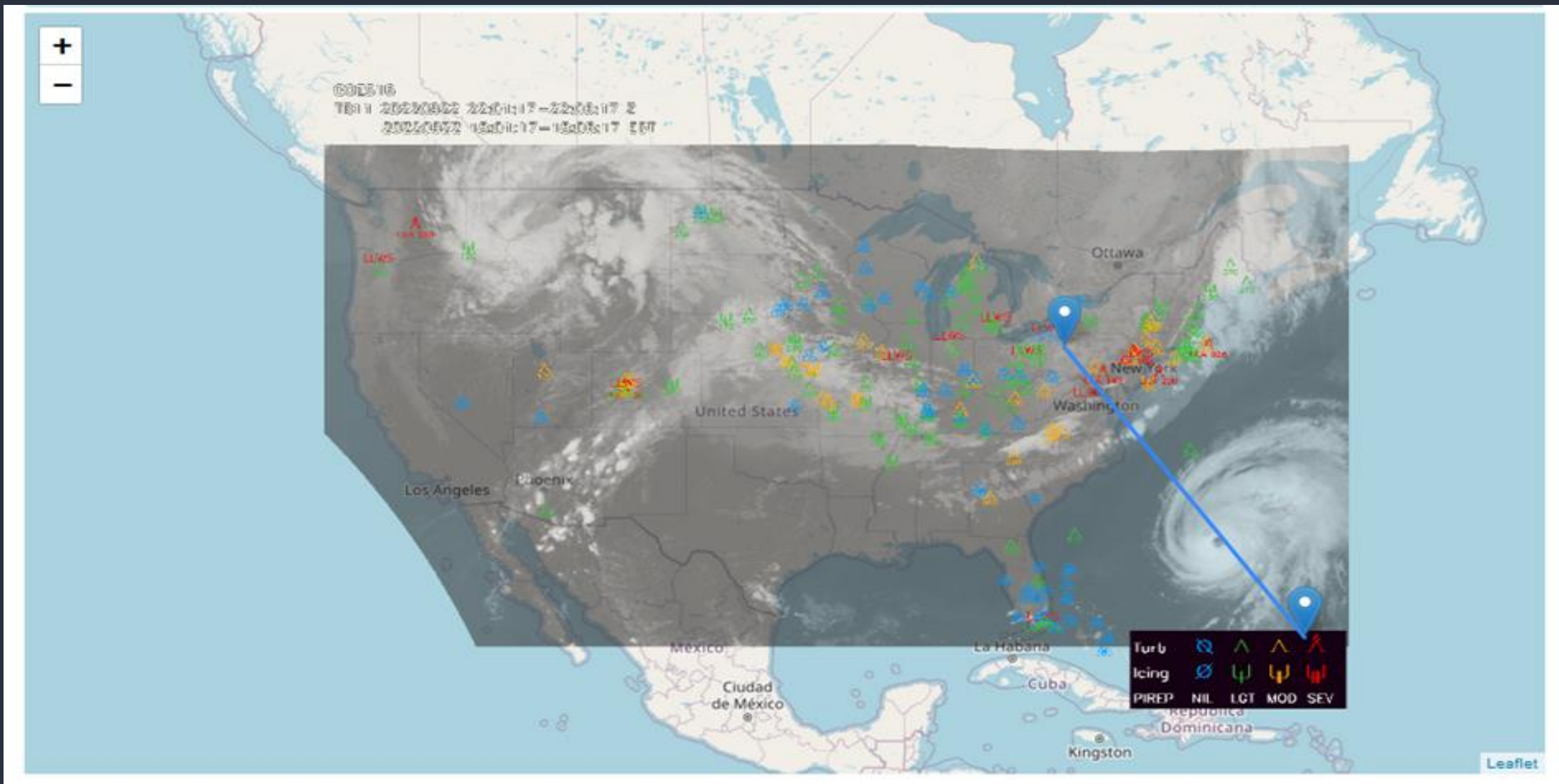


Additional information

- Temperatures (NUCAPS/NWP)
- PIREPs (Icing/Turb)
- Terrain



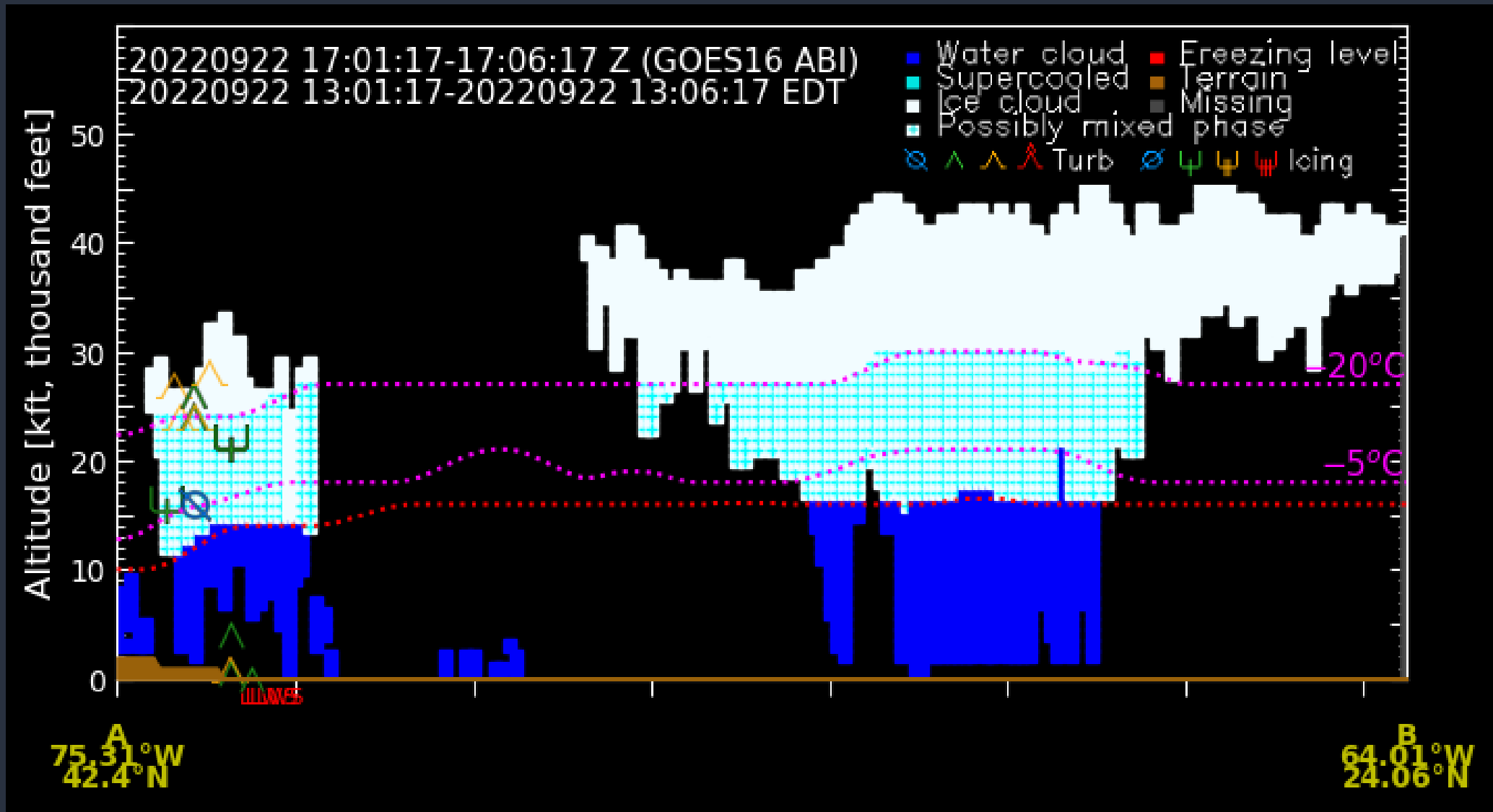
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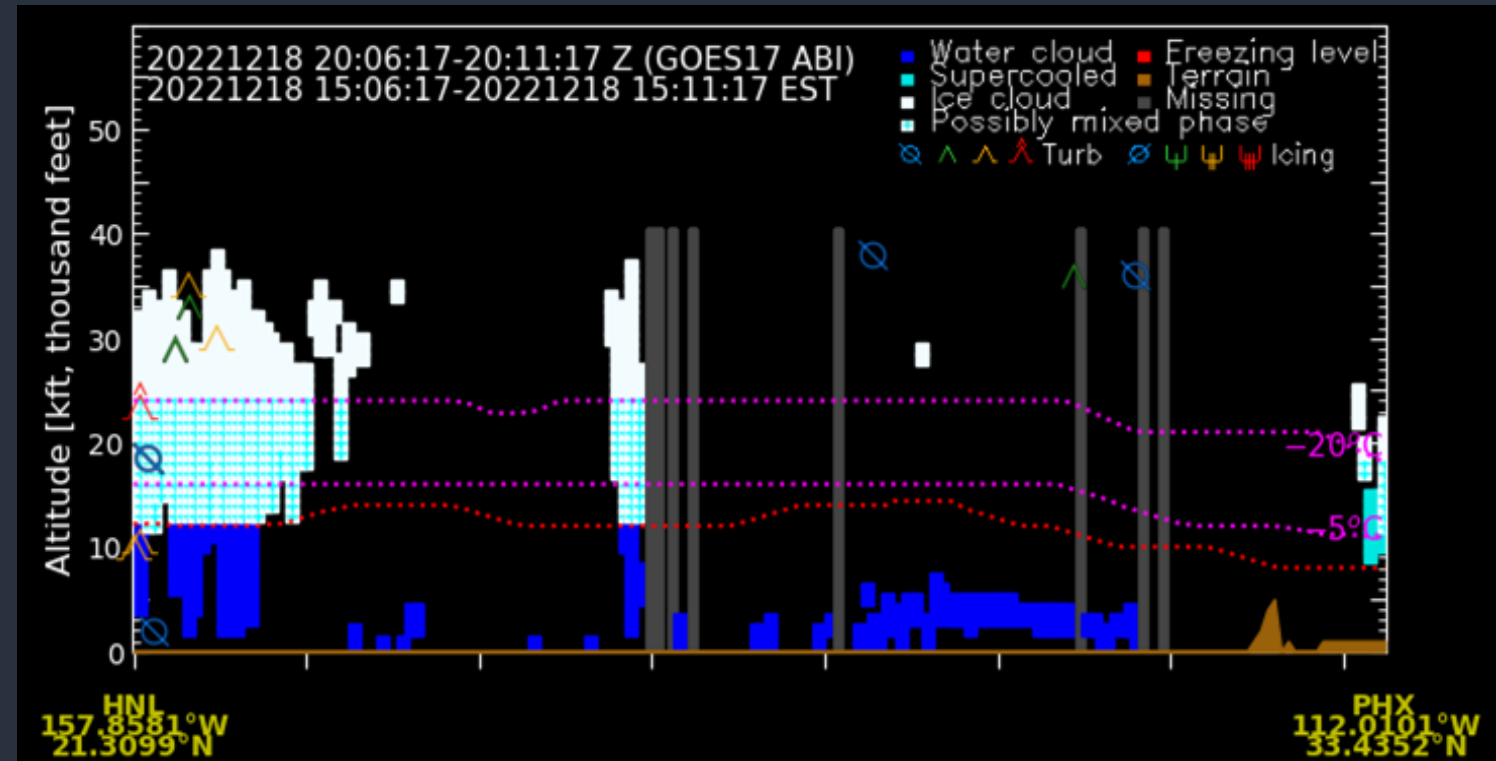
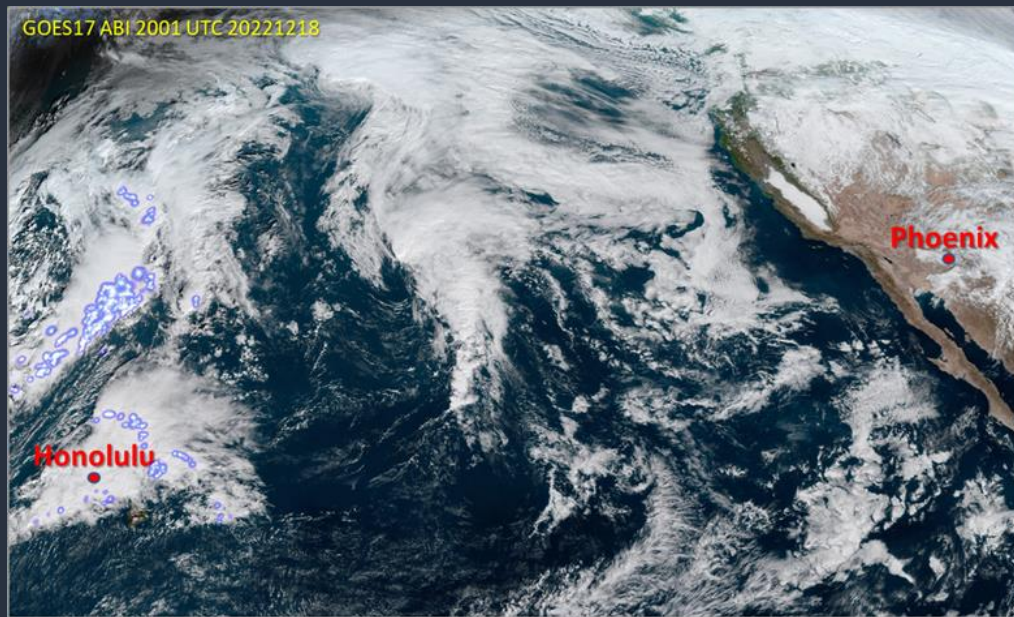
<https://aviation.cira.colostate.edu>



Satellite 3D Cloud Data for Aviation – YJ Noh (CIRA)



Coming soon: cross sections over the GOES-18 domain, including Hawaii



Resources on the Web

- GOES-16/18 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://aviation.cira.colostate.edu/>

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