Status of GOES-16 and GOES-17 Advanced Baseline Imager (ABI) Aerosol Products

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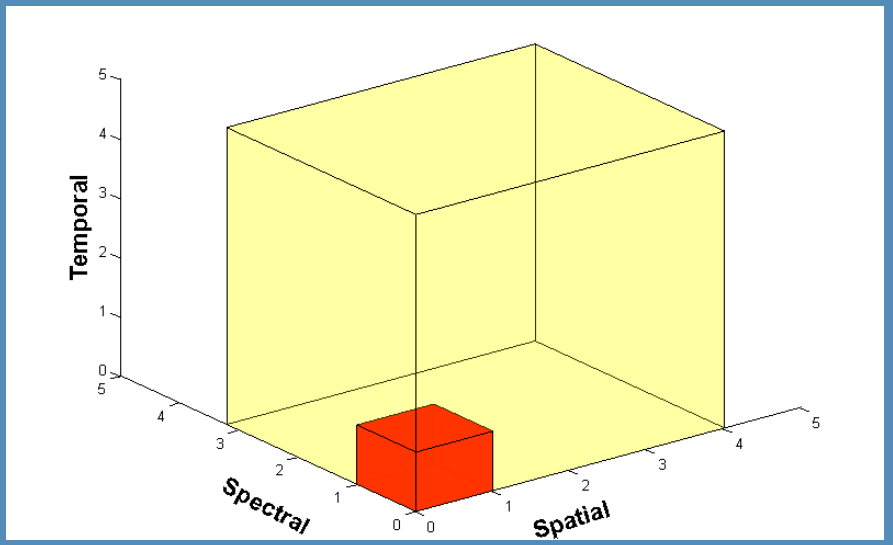
GOES-R Aerosols/Atmospheric Chemistry/Air Quality Application Team

Name	Organization	Major Task
Pubu Ciren	IMSG	Aerosol detection product development and validation
Amy Huff	PSU	Product assessment & User (forecasters) feedback, outreach
Shobha Kondragunta	NOAA	Lead and PI for aerosol detection
Istvan Laszlo	NOAA	PI for aerosol optical depth
Hongqing Liu	IMSG	Algorithm development, validation, visualization
Arthur Russakoff	IMSG	Algorithm integration/transition to operations
Chuanyu Xu	IMSG	Data analysis and miscellaneous tasks
Hai Zhang	IMSG	Data analysis, surface PM2.5, AerosolWatch development and maintenance
Mi Zhou	IMSG	Aerosol Optical Depth algorithm development and validation

GOES-R ABI



5x Faster coverage (5-minute full disk vs. 25-minute)

4x Improved spatial resolution (2 km IR vs. 4 km)

3x More spectral bands (16 on ABI vs. 5 on the current imager)

0.47
0.64
0.86
1.6
1.38
2.2
3.9
6.2
6.7
7.3
8.5
9.7
10.3
11.2
12.3
13.3

Domain	Legacy GOES			
	AOD	Geo Color RGB	Dust RGB	Smoke/Dust Mask
CONUS	X			
Full Disk				
Mesoscale				

Domain	GOES-R/S			
	AOD	Geo Color RGB	Dust RGB	Smoke/Dust Mask
CONUS	X	X	X	X
Full Disk	X	X	X	X
Mesoscale		X	X	X

Onboard calibration * Better navigation * On demand mesoscale

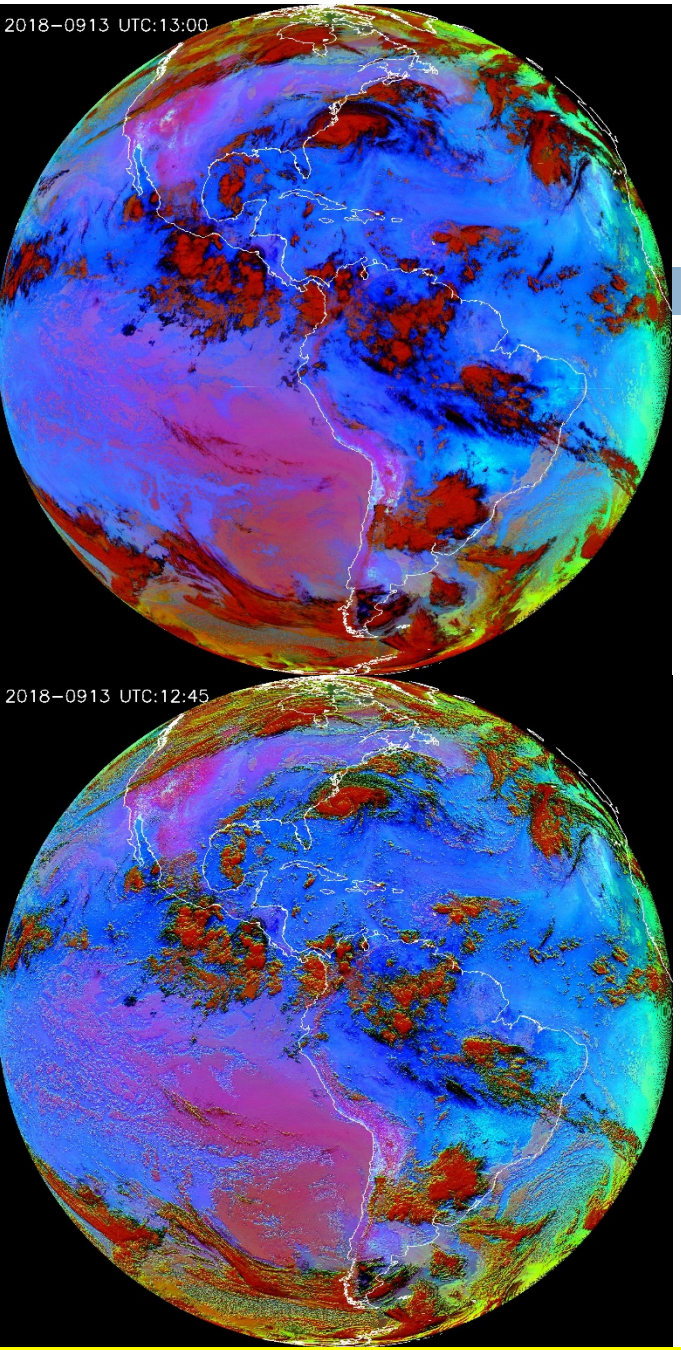
GOES-16 ABI

- GOES-16 launched on November 19, 2016
- AOD product became provisional on September 14, 2018
- ADP product will be provisional in October 2018
  - Algorithm updates have been made and to be implemented end of September 2018
- AerosolWatch is providing the following products
  - CONUS and Full Disk
    - AOD, GeoColor, dust RGB, Fire hot spots, smoke/dust mask*, AOD composite, 48-hr trajectories
- CONUS AOD data files are available via STAR FTP site but for historic data please go to CLASS

ftp://ftp.star.nesdis.noaa.gov/pub/smcd/hzhang/GOES-16/NRT/

*product will have better coverage after October 2018

GOES-17 ABI



- GOES-17 launched on March 1, 2018
- Satellite still in its test position of 89°W
- Instrument has an anomaly – cooling pipe has an issue due to which detectors are not cooled to lower temperature as needed. This happens in the night time and mostly affects thermal bands
  - AOD and ADP products are day time products only and should be ok. But various analyses are currently underway to understand the impact of the problem
- Thermal bands had band to band registration issue that got fixed on September 13, 2018
- No imagery or products are made available. Product availability TBD

ADP Algorithm

- Algorithm relies on differential spectral absorption of dust and smoke, and spatial variability tests to derive smoke and dust mask

GOES Imager (ABI) Band	Nominal Wavelength Range (μm)	Nominal Central Wavelength (μm)	Nominal Central Wavenumber (cm-1)	Nominal sub-satellite IGFOV (km)	Product Use
1	0.45-0.49	0.47	21277	1	Dust/Smoke
2	0.59-0.69	0.64	15625	0.5	Dust/Smoke
3	0.846-0.885	0.865	11561	1	Smoke
4	1.371-1.386	1.378	7257	2	Dust
6	2.225 - 2.275	2.25	4444	2	Smoke
7	3.80-4.00	3.90	2564	2	Dust/Smoke
13	10.1-10.6	10.35	966	2	Dust
14	10.8-11.6	11.2	893	2	Dust/Smoke
15	11.8-12.8	12.3	813	2	Dust/Smoke

A New Era for Aerosol Measurements

- First attempt to derive dust and smoke mask from a geostationary satellite sensor
- *JAXA launched Himawari-8/9 ahead of NOAA and algorithms similar to ABI have been adapted by KMA and others in Korea for air quality applications*

Probability of correct detection over land

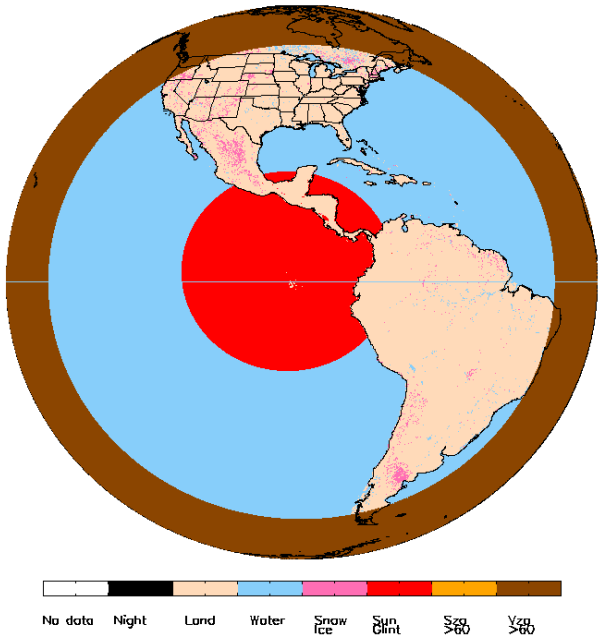
Smoke	80%
Dust	80%

Probability of correct detection over water

Smoke	70%
Dust	80%

Retrievals generated with a specific target for requirements

ADP Product Output File Content



Smoke	Determined/undetermined
Dust	Determined/undetermined
Smoke confidence	High/Medium/Low
Dust confidence	High/Medium/Low
Sunglint	Inside/Outside
Solar angles	Valid (<60°)
View angles	Valid (<70°)

Undetermined: clouds, snow/ice, turbid water, bad input reflectences, and fires.

ADP Algorithm Updates

Dust

- Update thresholds for spectral difference tests
  - Current values in baseline algorithm are based on MODIS and need an update, especially to identify thin dust

Test	Threshold (Old)	Threshold (New)
BTD1: $BT_{11.2\mu m}$-$BT_{12.3\mu m}$	-0.2	0.4
BTD2: $BT_{3.7\mu m}$-$BT_{11.2\mu m}$	10.0	5.0
$R_{1.38\mu m}$	0.0035	0.055

- Redefine the confidence level
  - only use one crucial Brightness Temperature Difference test (BTD) test ($BT_{11.2\mu m}$-$BT_{12.3\mu m}$) to determine confidence level by BTD closeness to threshold.

low confidence: 0.2<BTD1<0.4 or SZA>60 or VZA>70

Medium confidence: 0.0<BTD1<0.2

High confidence: BTD1<0.0

ADP Algorithm Updates

Dust

- Do not use bits from ABI cloud mask
  - Dust is mis-identified as cloud
- New approach
  - Run dust detection algorithm everywhere and use MNDVI to remove false dust detection/missed clouds

$$NDVI = \frac{(\rho_{0.86} - \rho_{0.64})}{(\rho_{0.86} + \rho_{0.64})}$$

$$MNDVI = \frac{NDVI^2}{\rho_{0.64}}$$

ADP Algorithm Updates

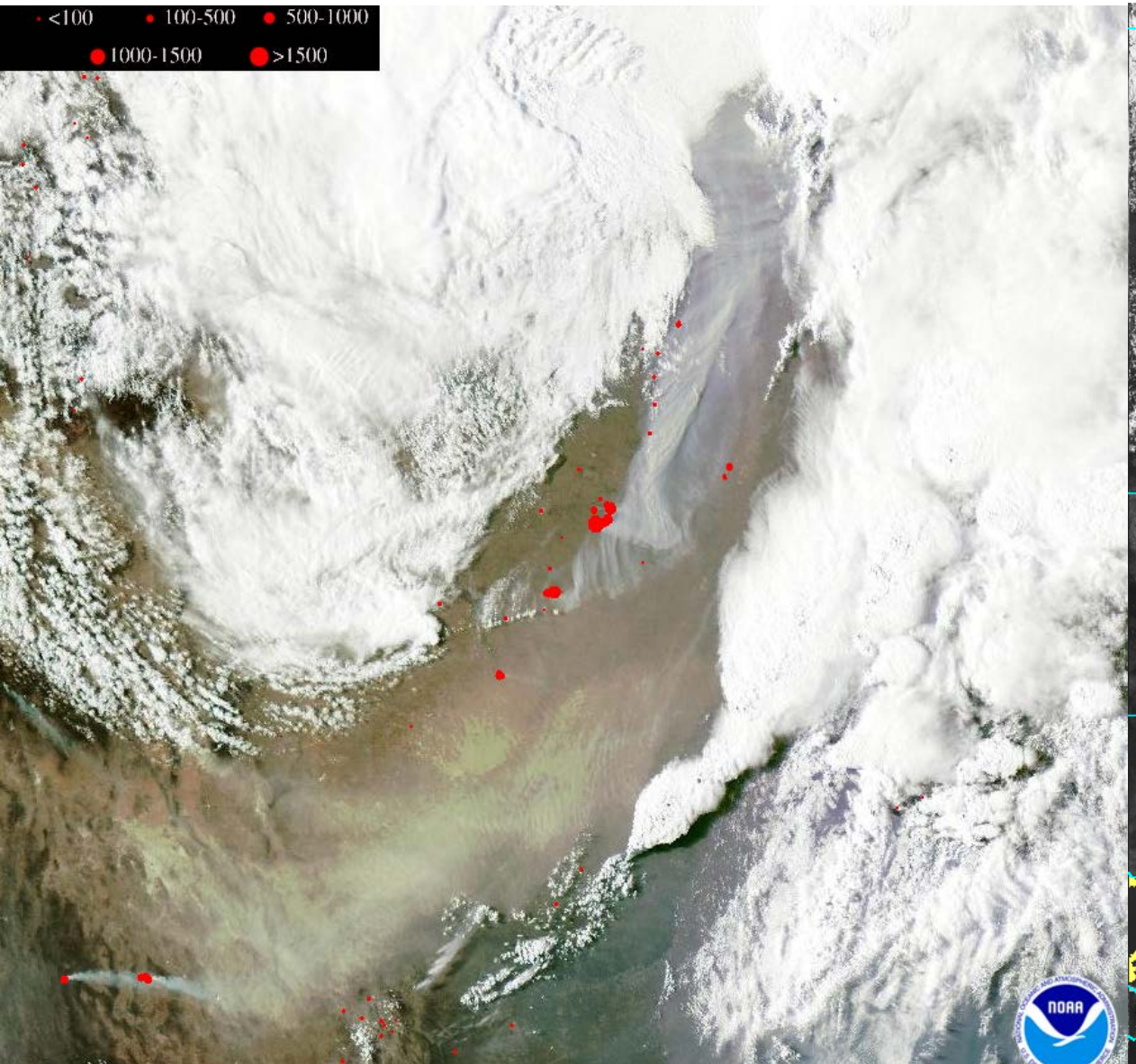
Smoke

- No cirrus test bit and EMISS4 test bits from cloud mask applied

- Over land, a new surface reflectance relationship between 0.64 µm and 2.25 µm based on ABI observations (solar zenith angle and surface type dependent)

$$\rho_{0.64} = (c_1 + c_2\theta) + (c_3 + c_4\theta)\rho_{2.25}$$

GOES-16 ABI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1000-1500
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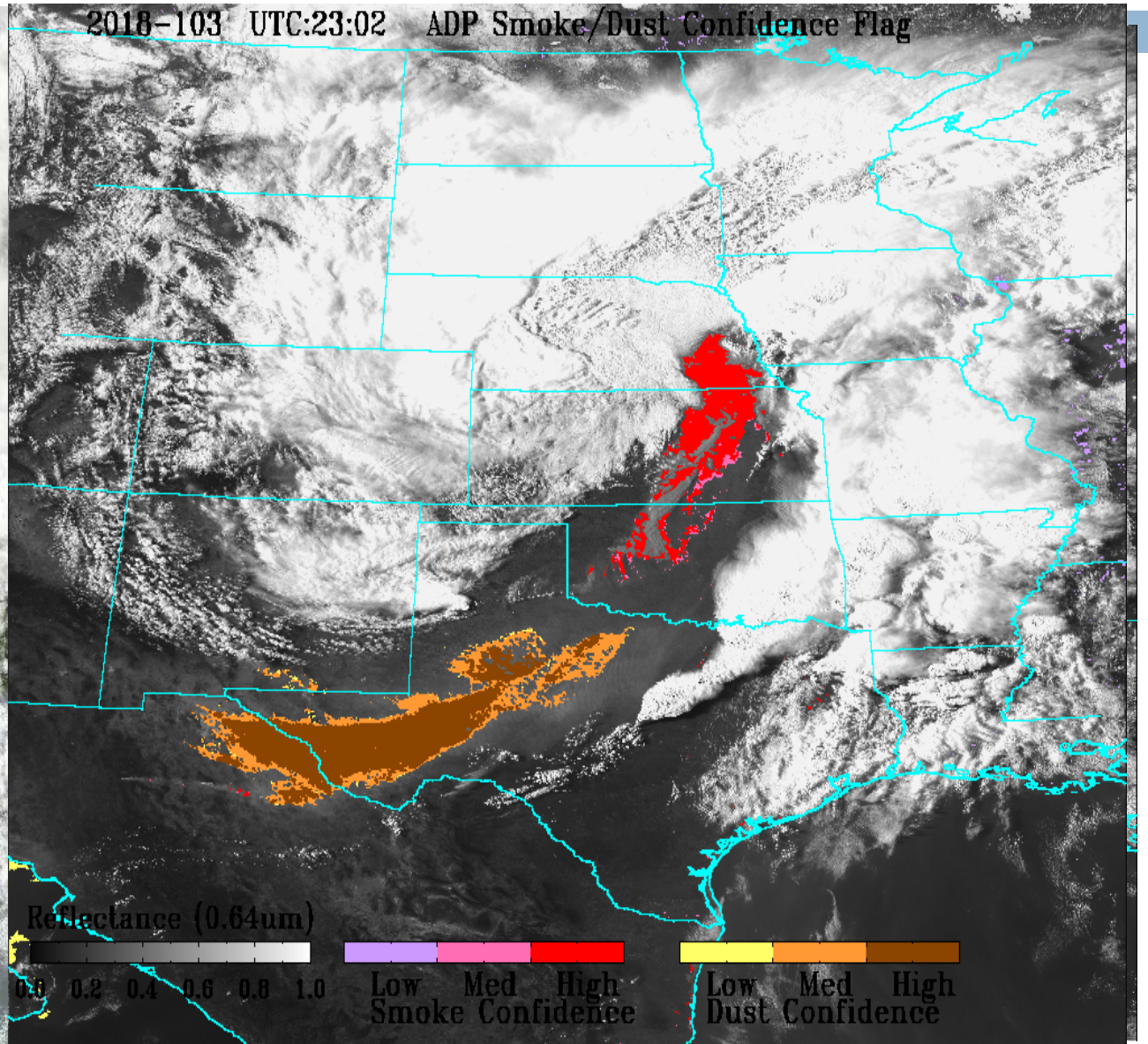
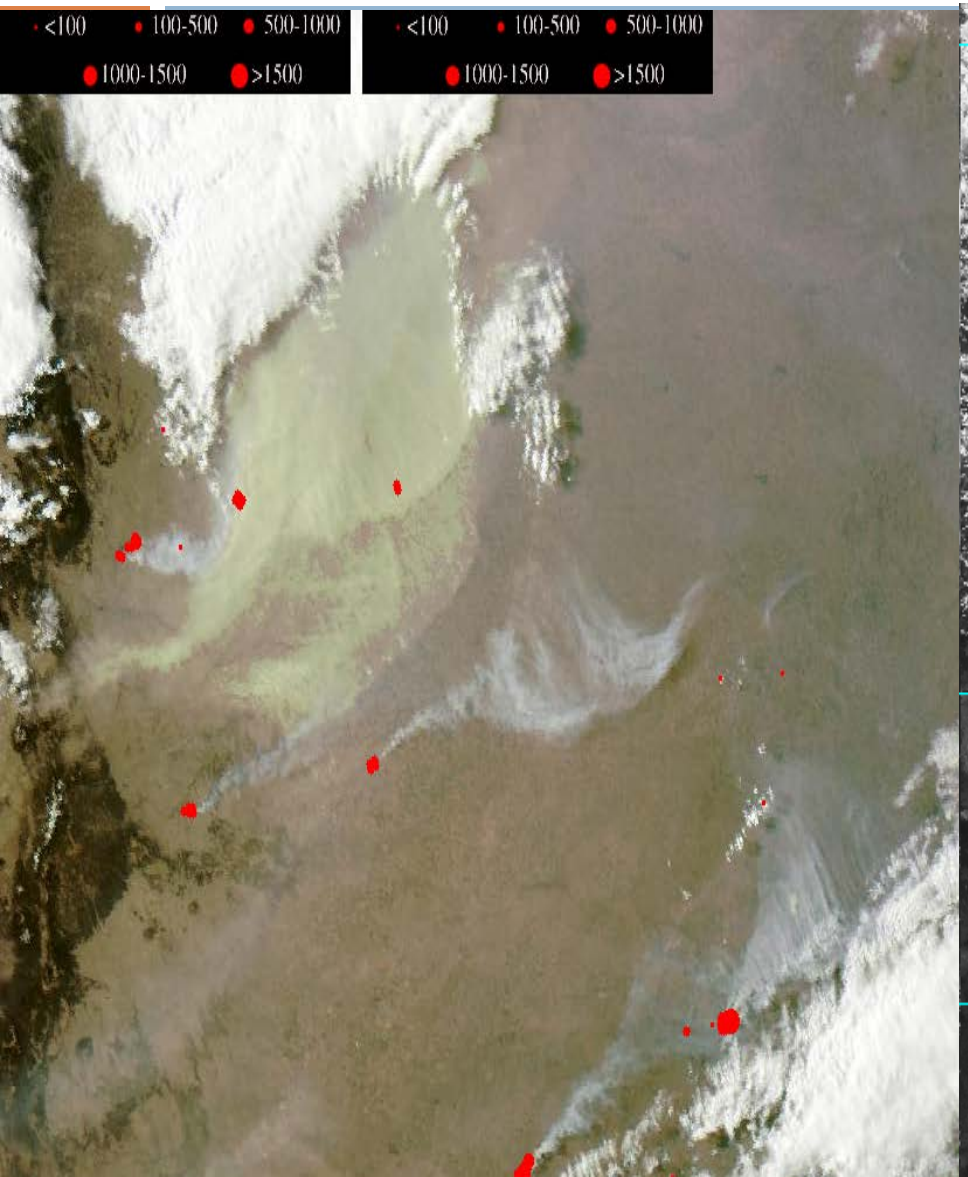

2018-103 UTC:23:02 ADP Smoke/Dust Confidence Flag
Reflectance (0.64um)
0.0 0.2 0.4 0.6 0.8 1.0
Low Med High
Smoke Confidence
Low Med High
Dust Confidence

GOES-16 ABI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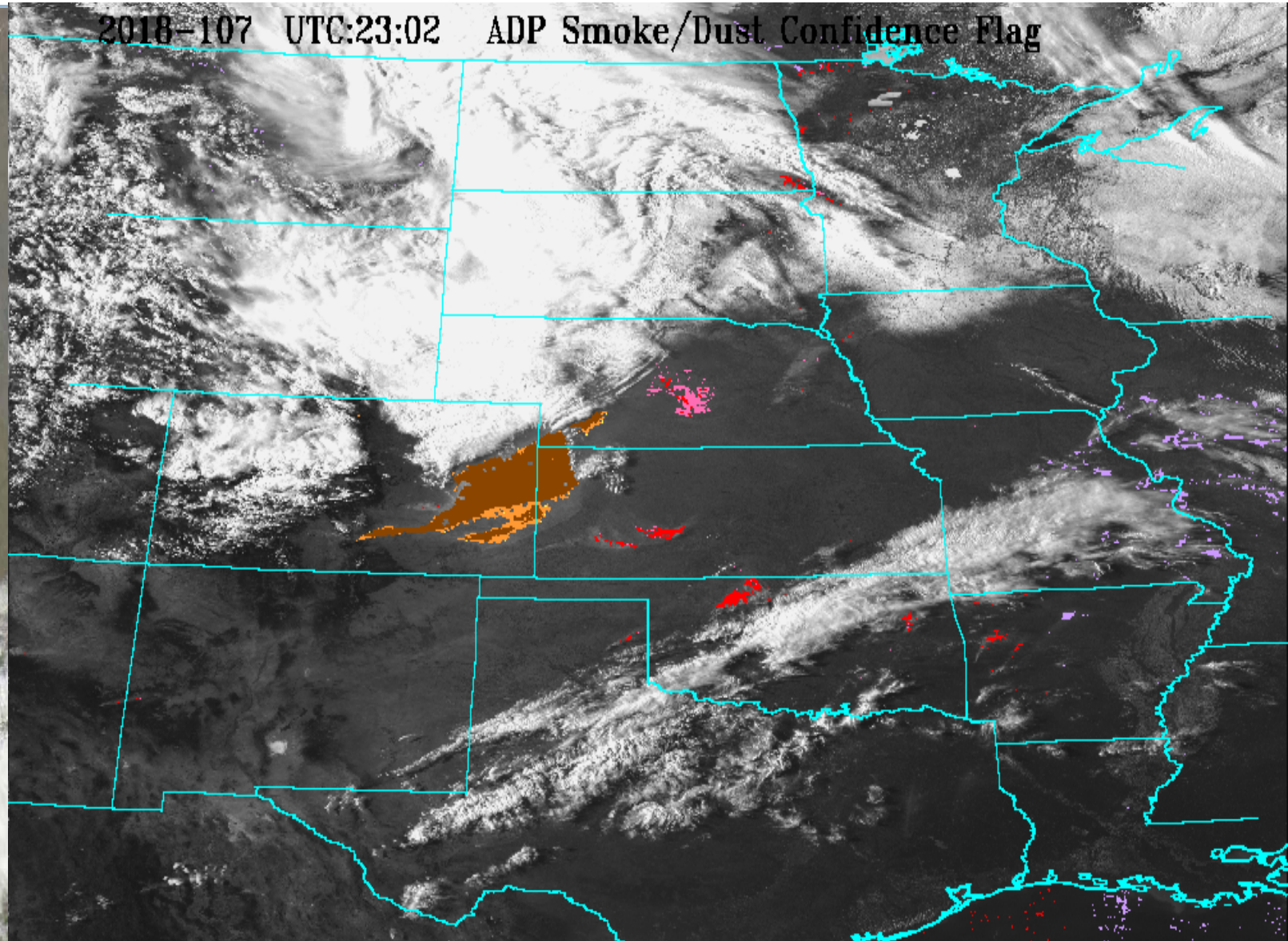
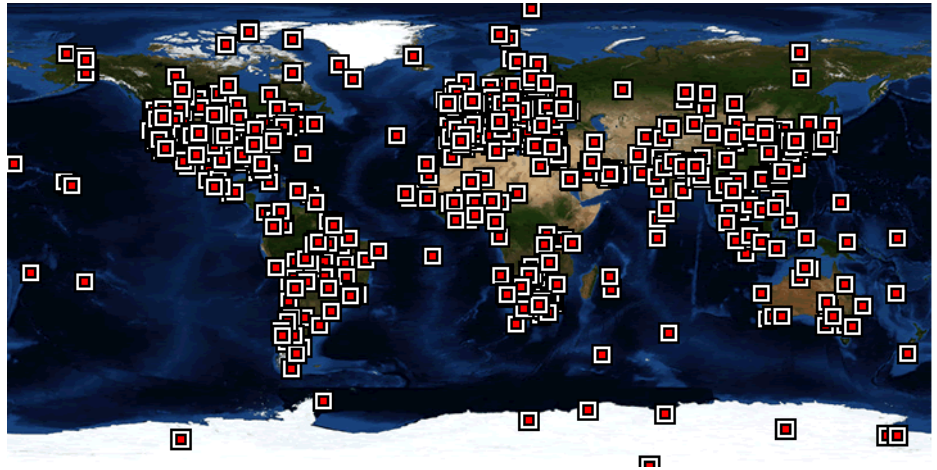
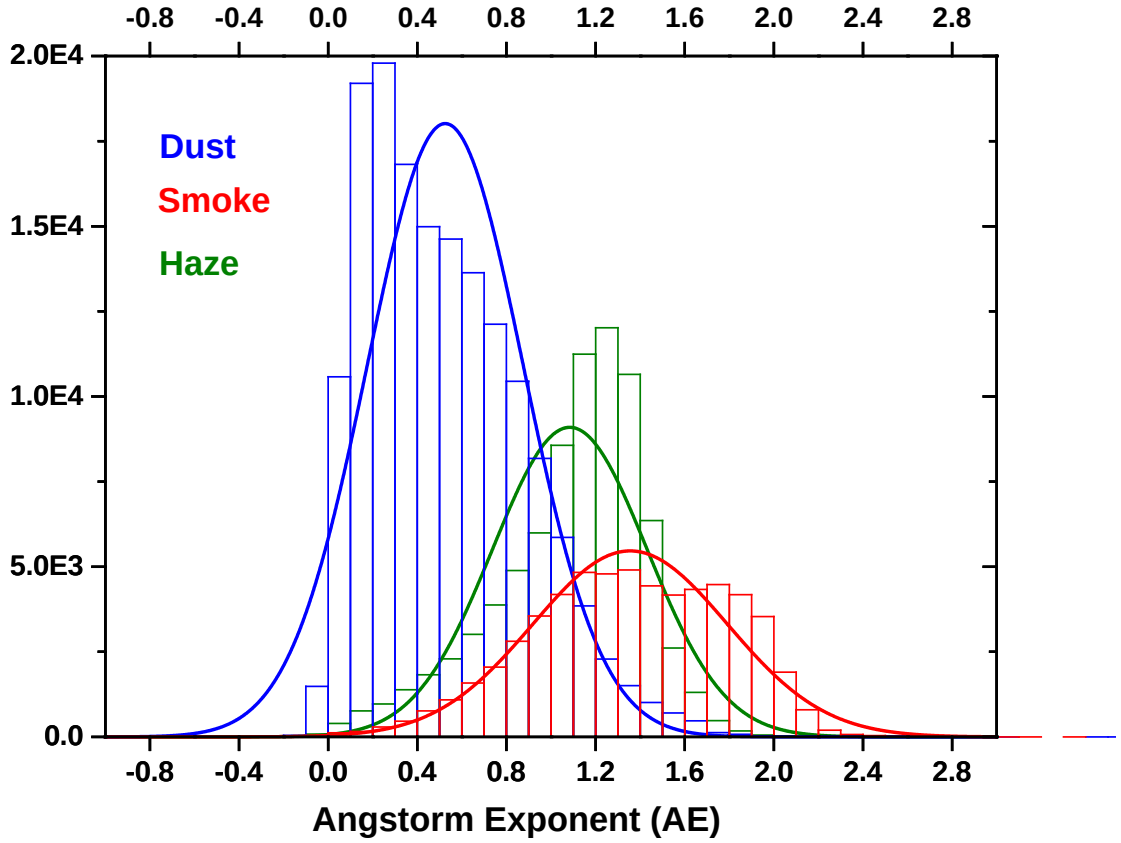

2018-107 UTC:23:02 ADP Smoke/Dust Confidence Flag

GOES-16 Validation





Matchup Criteria:
±30 min
ABI pixels within 27.5^{o} radius

AERONET Smoke: AOD > 0.2 and Angstrom Exponent > 1.0
AERONET Dust: AOD > 0.2 and Angstrom Exponent < 0.5

Smoke

Time Period	True positive	False positive	False negative	True negative	Accuracy	POCD	POFD
*Dec 14,2017 – May 10, 2018	313	143	69	20874	97.5	81.9	31.3

Dust

Time Period	True positive	False positive	False negative	True negative	Accuracy	POCD	POFD
*Dec 14,2017 – May 10, 2018	106	43	22	19367	99.1	82.8	28.8

A New Era for Aerosol Measurements

- First multi-channel AOD retrieval from a geostationary satellite covering the western hemisphere. *JAXA launched Himawari-8/9 ahead of GOES-R but instrument technology is the same as ABI*
- First time on-board visible channel calibration for a GOES sensor
  - ABI 0.64 µm has a 7% positive bias

AOD over Land

AOD	Accuracy	Precision
<0.04	0.06	0.13
0.04 – 0.80	0.04	0.25
>0.8	0.12	0.35

AOD over Water

AOD	Accuracy	Precision
<0.4	0.02	0.15
>0.4	0.10	0.23

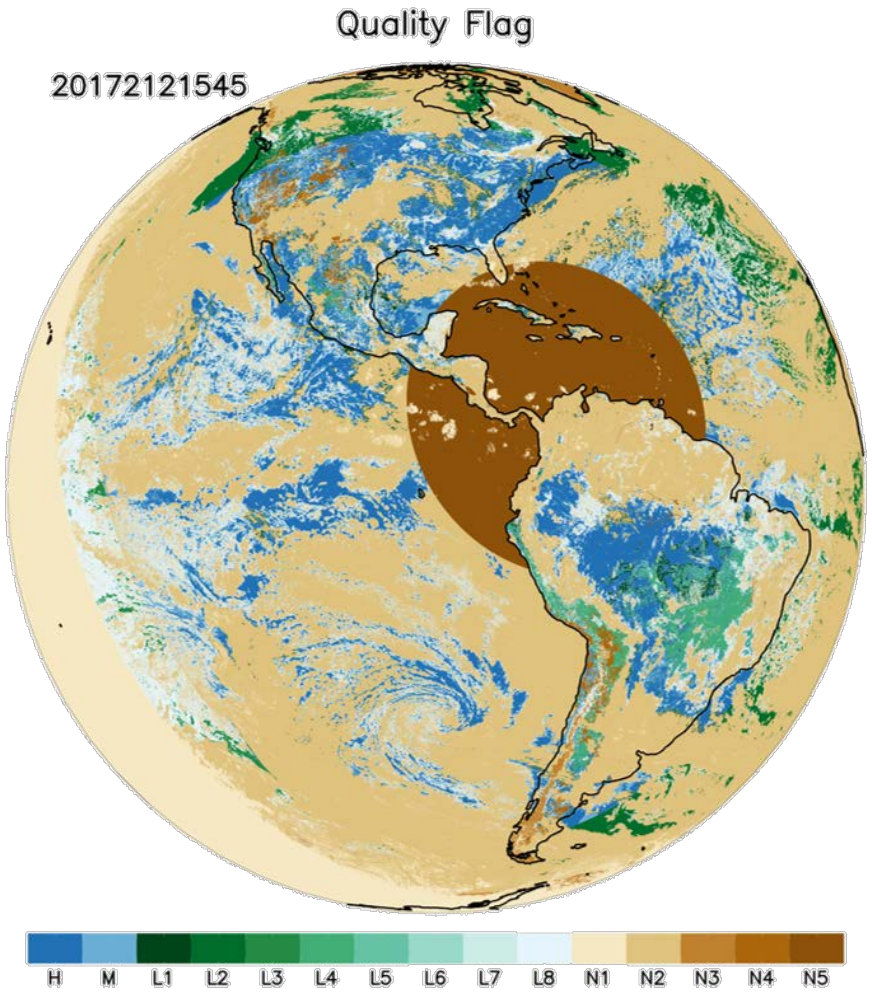
Retrievals generated with a specific target for requirements

AOD Product

- **Products in file:**
  - 550-nm Aerosol Optical Depth for Full Disk and CONUS in range -0.05 to +5
  - Quality flag (0=good; 1=medium, 2=low, 3=not produced)
  - Mean, max, min and standard deviation of 550-nm AOD (and in bands used for AOD retrieval
- **Passed provisional maturity review on September 14, 2018**
  - Will become available at CLASS
  - ***Disclaimer: The GOES-16 data are ready to be used in operational applications and scientific studies***
  - NOAA's Comprehensive Large Array-Data Stewardship System at https://www.class.ncdc.noaa.gov after product passed Provisional Review

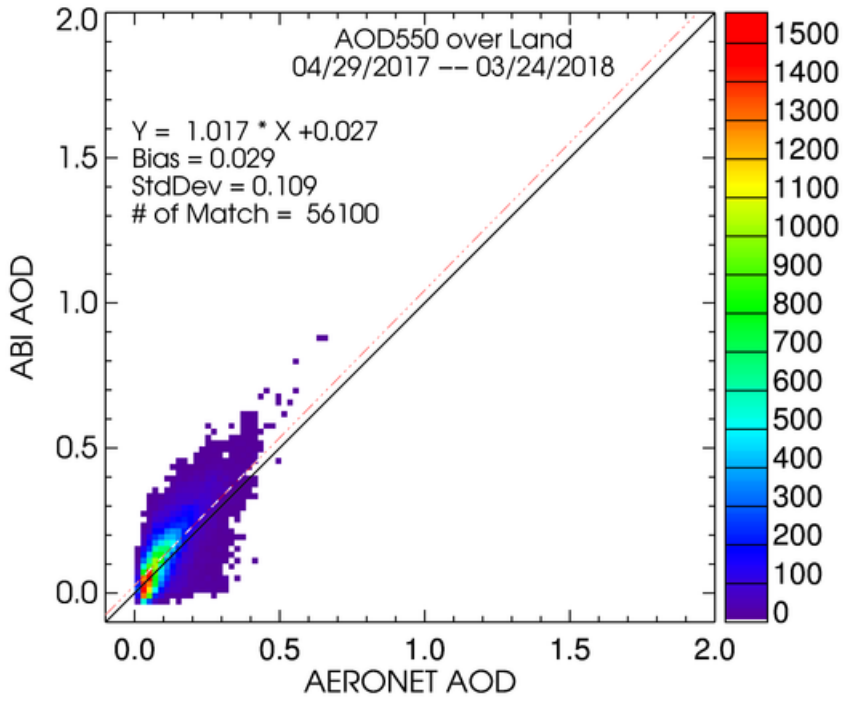
Quality Flags (Example)

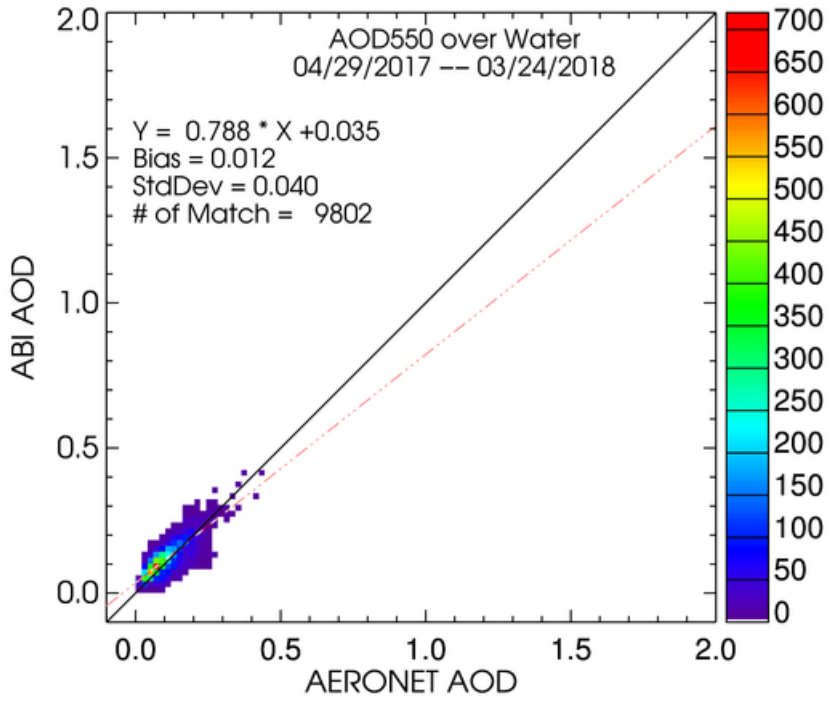
07/31/2017 at 15:45 UTC



H	High
M	Medium
L	Low
L1	Contradicting Cloud Masks
L2	Low Satellite Angle
L3	Low Sun Angle
L4	Out of Spec Range
L5	Coastal Area
L6	Shallow Inland Water
L7	High Residual
L8	High Inhomogeneity
N	No Retrieval
N1	Invalid Input
N2	Cloud
N3	Snow
N4	Bright Land Surface
N5	Sun Glint

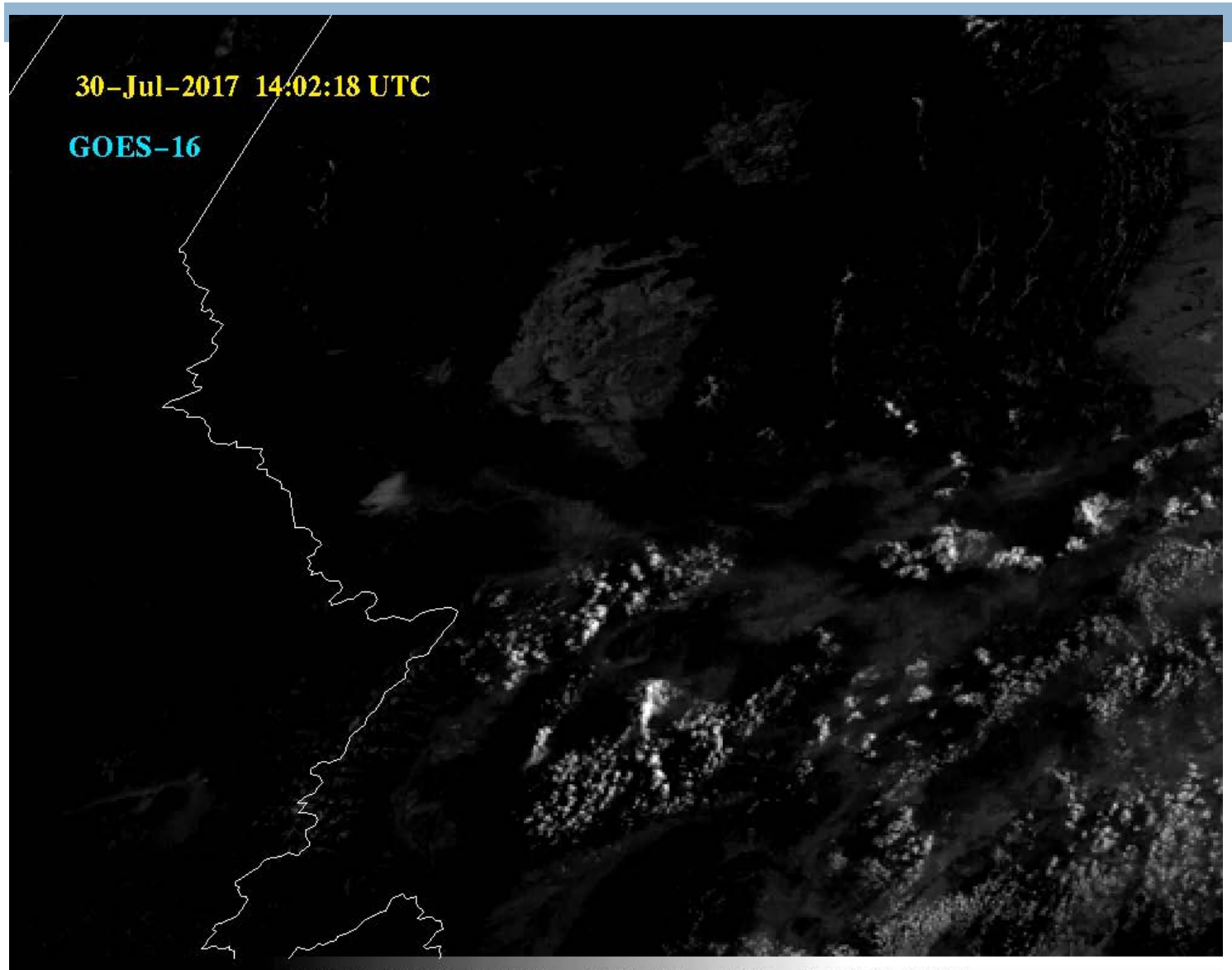
Validation with AERONET





- Time period: 04/29/2017 – 03/24/2018
- **High quality AOD**
- Bias and StDev: mean and standard deviation of ABI-AERONET differences

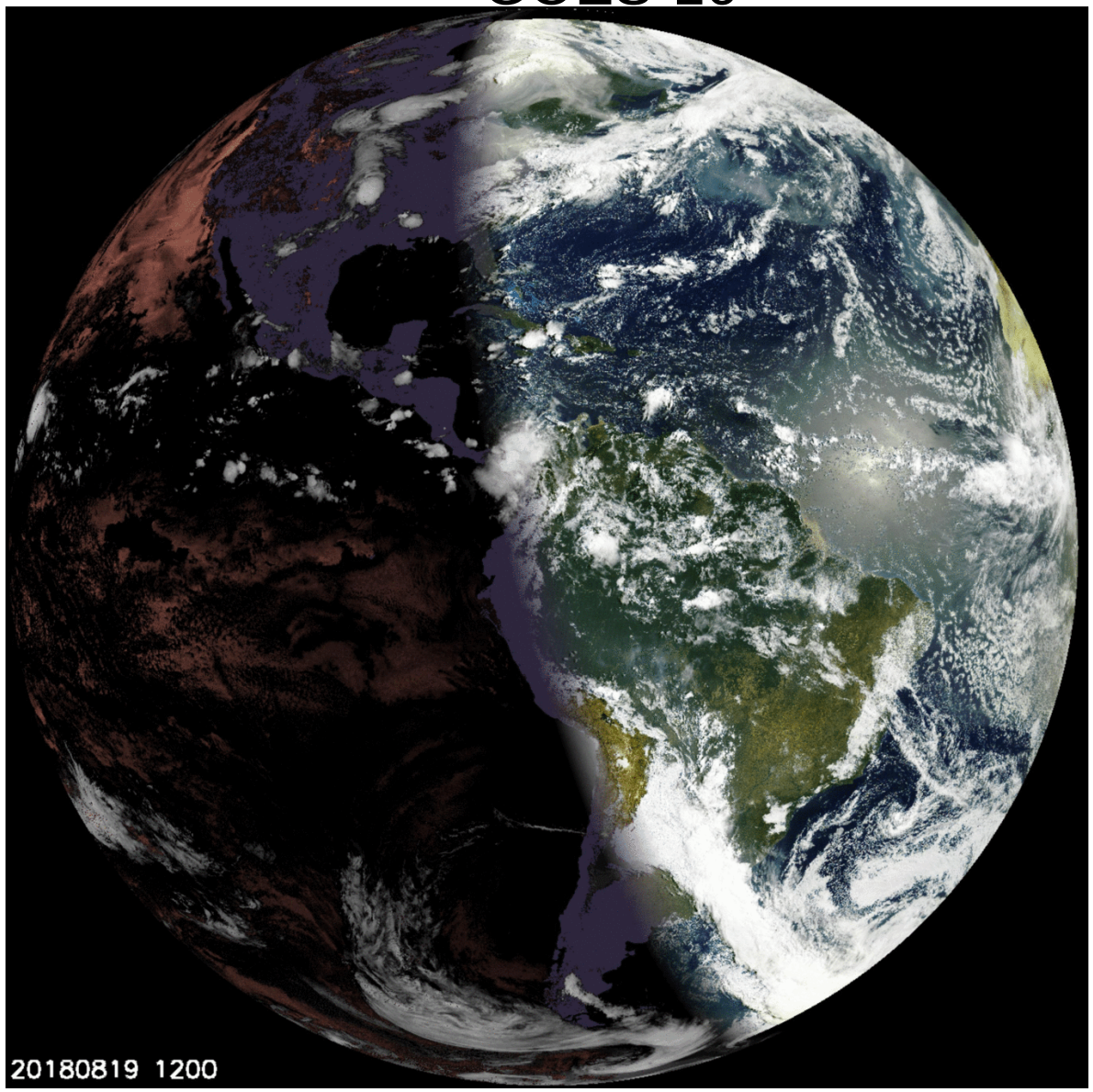
GOES-R ABI New Capabilities: 0.5 km Visible band every 5 minutes



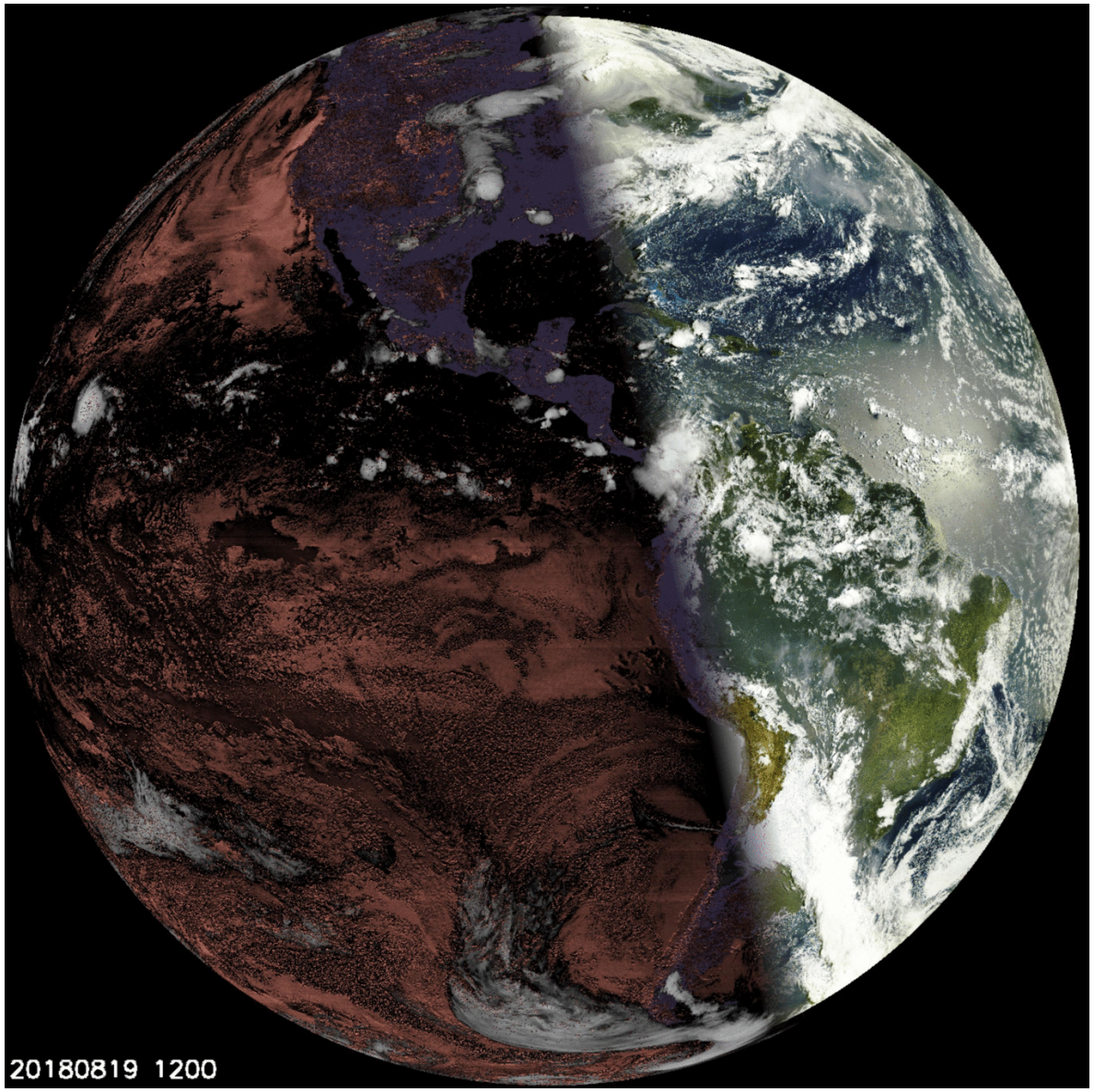
Smoke from several small plumes blend together and become one large plume.

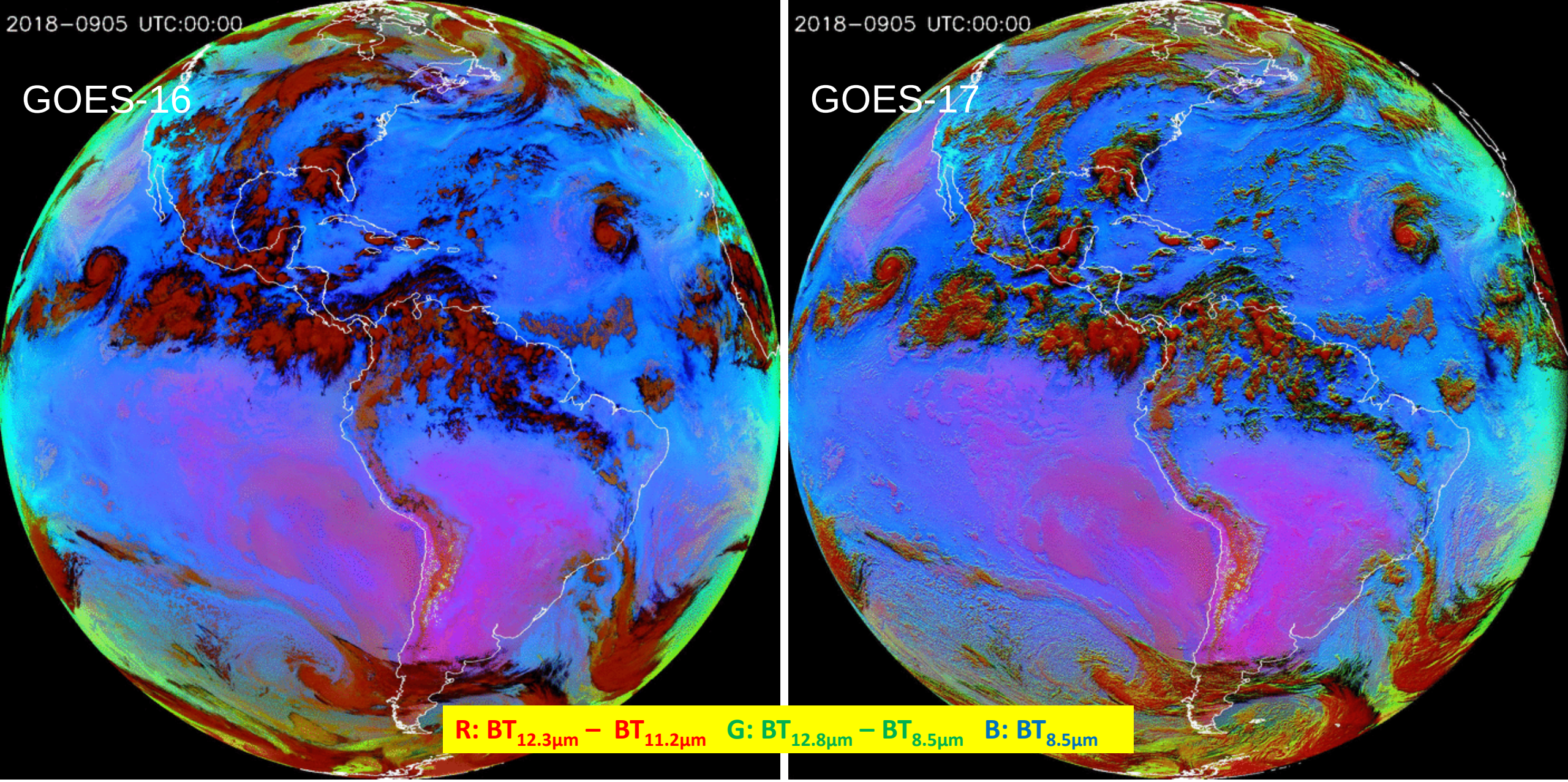
Tim Schmidt, NOAA

GOES-16

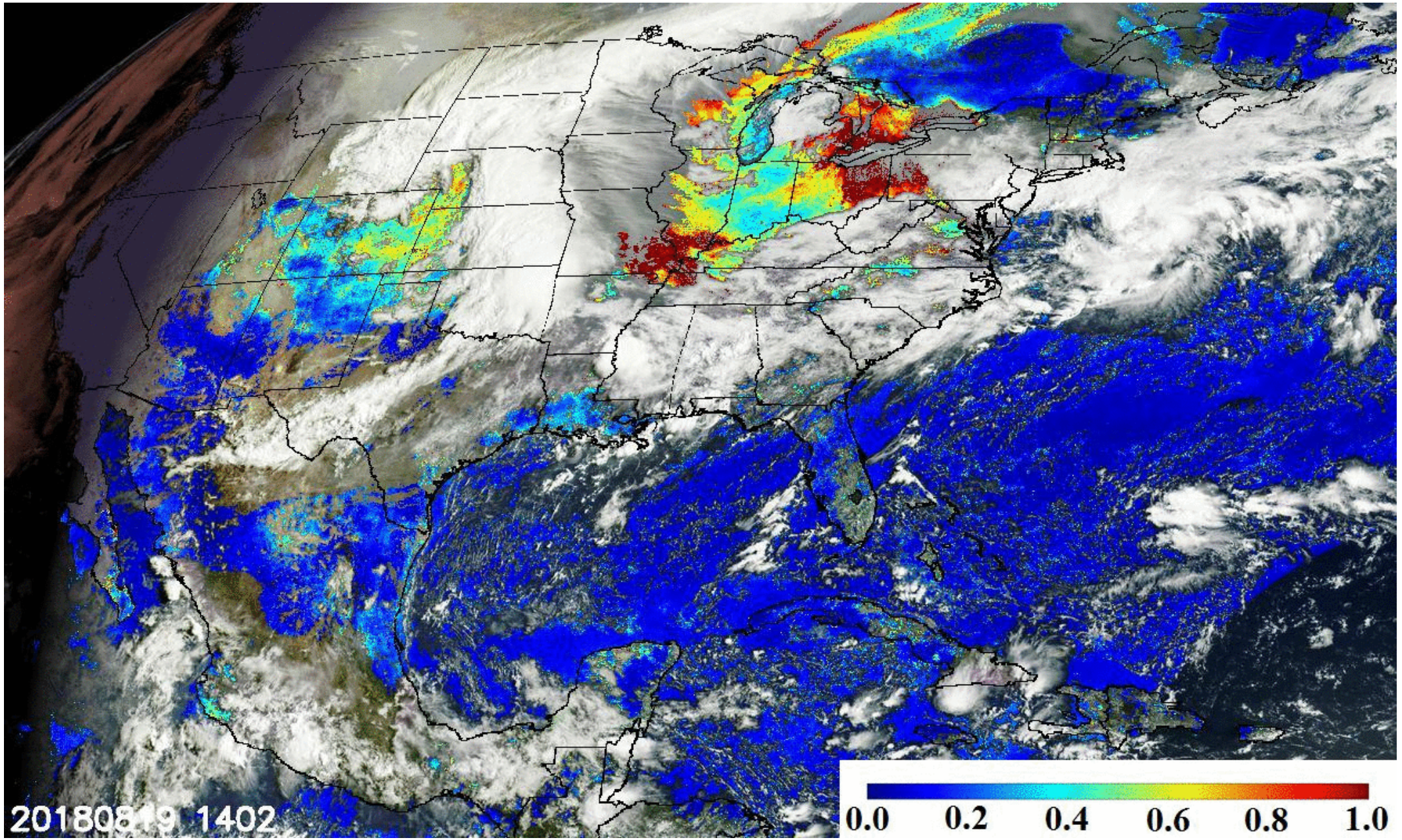


GOES-17

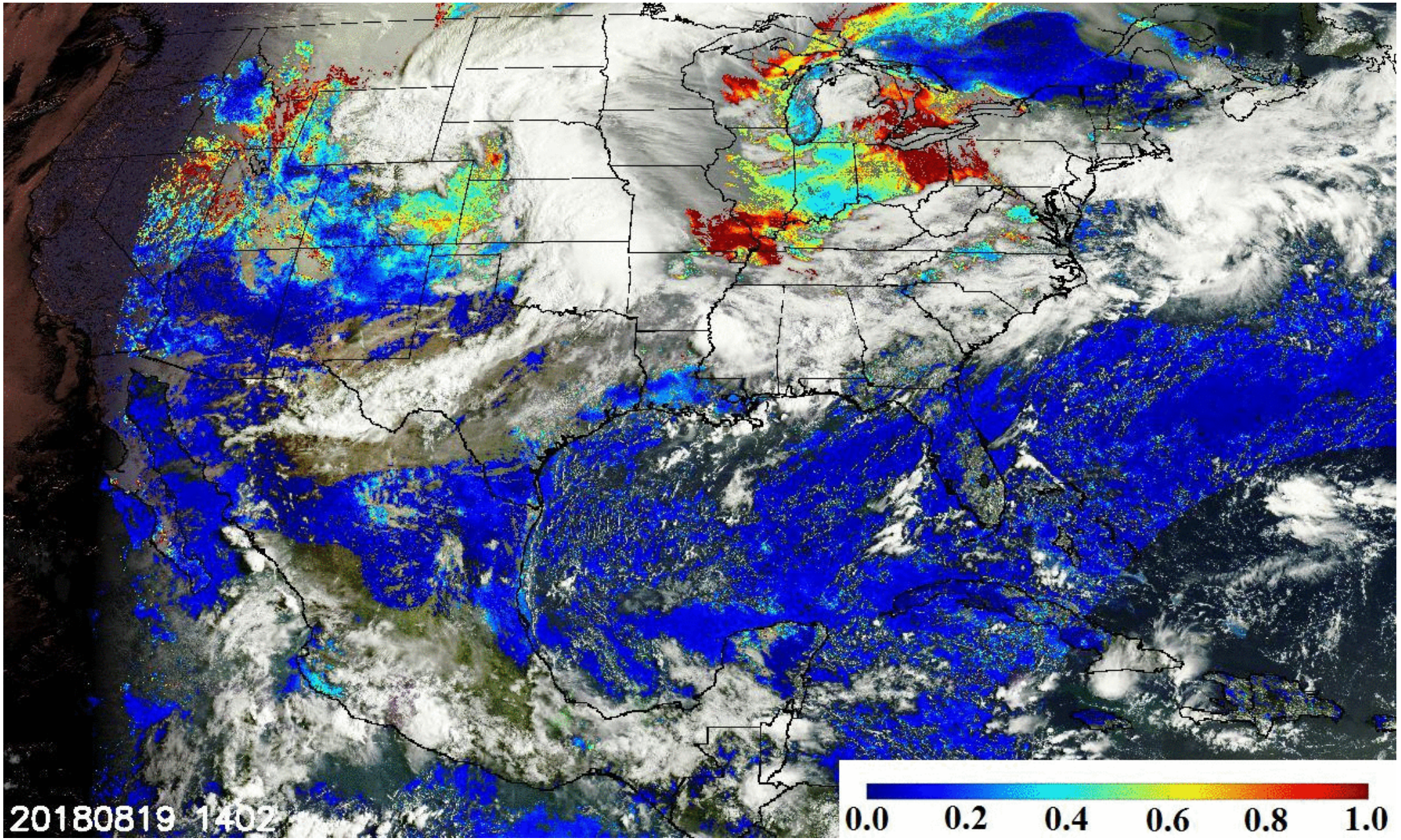


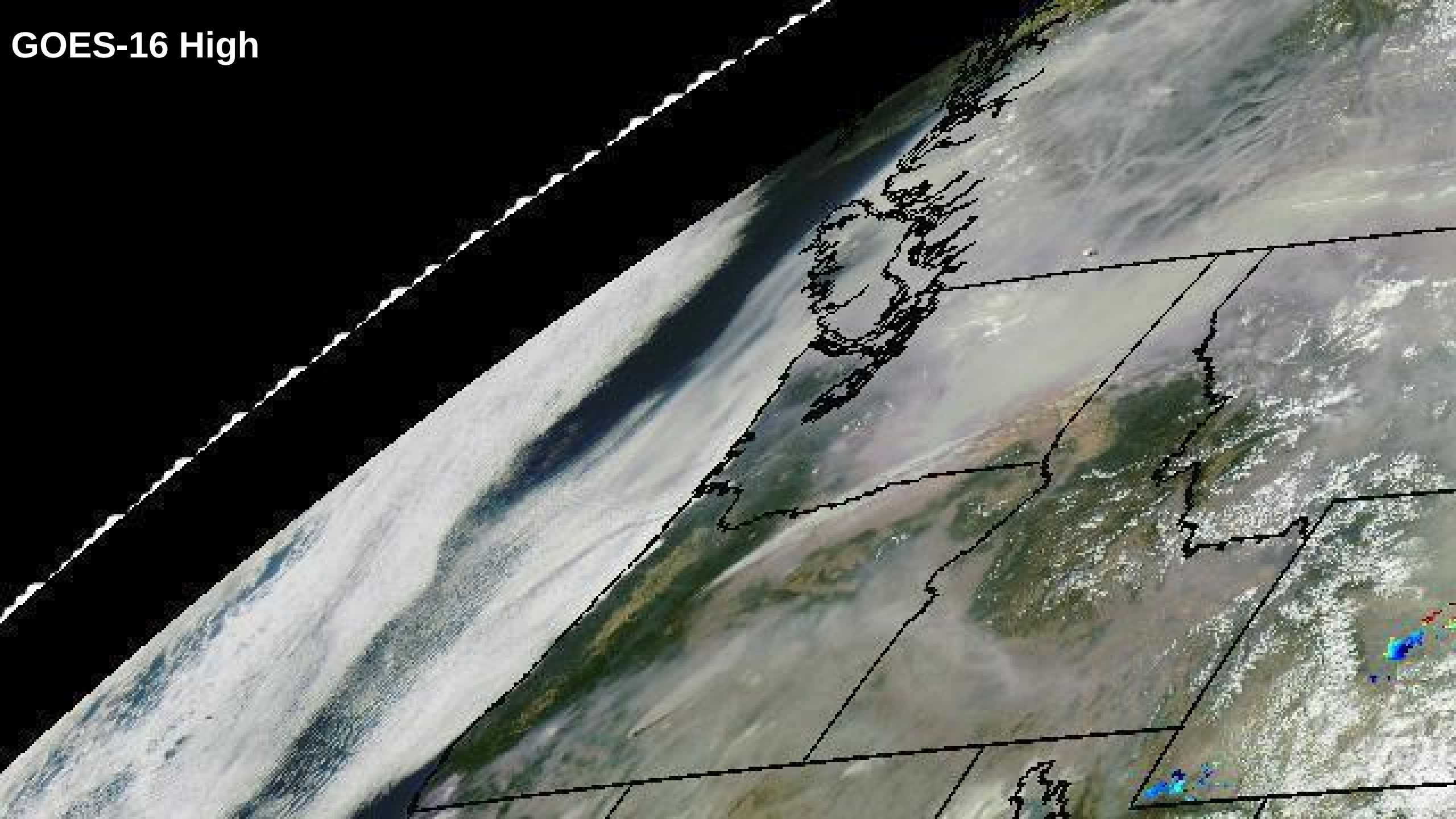

2018–0905 UTC:00:00
GOES-16
2018–0905 UTC:00:00
GOES-17
R: BT12.3µm – BT11.2µm G: BT12.8µm – BT8.5µm B: BT8.5µm

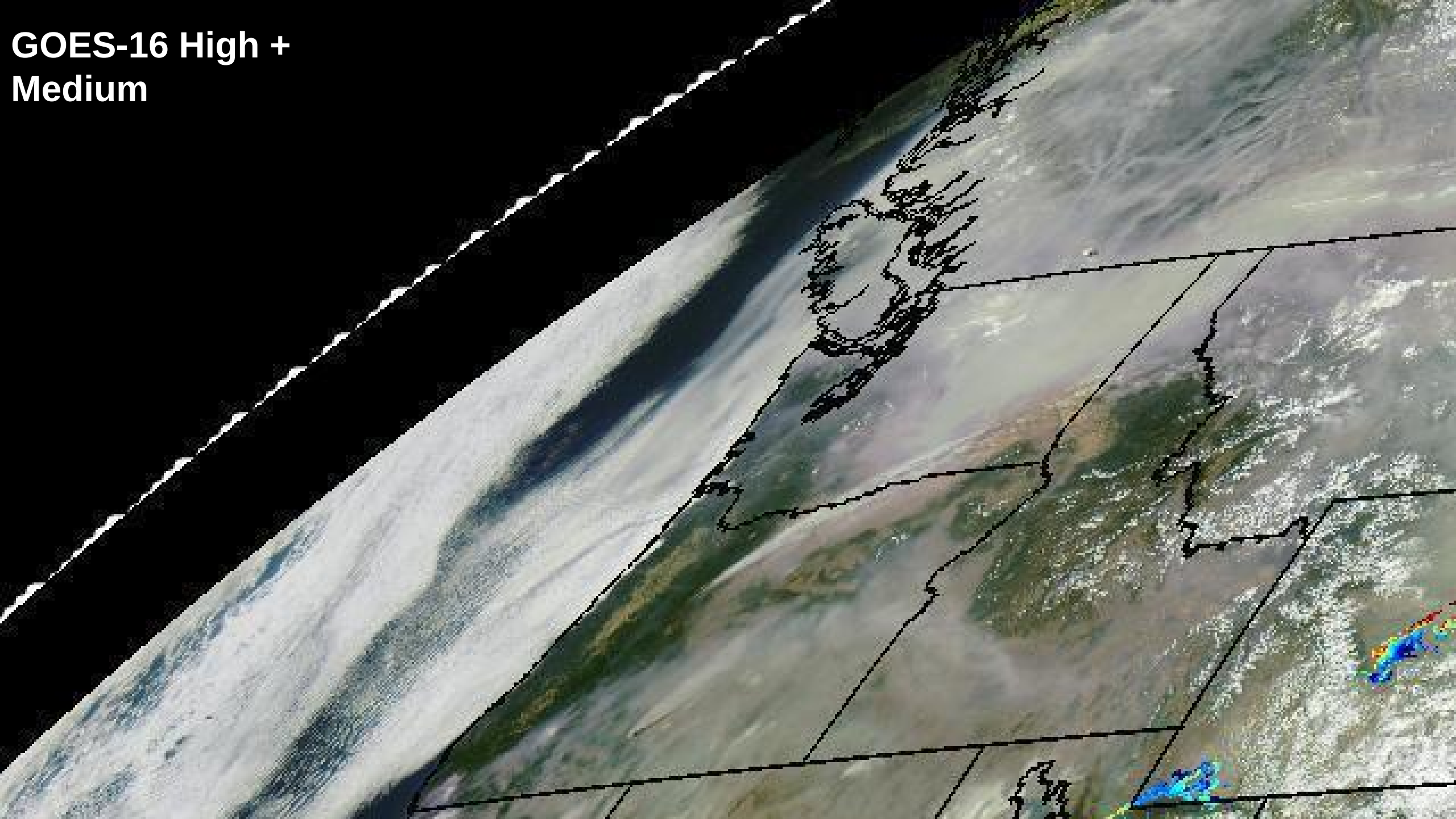
GOES-16 AOD

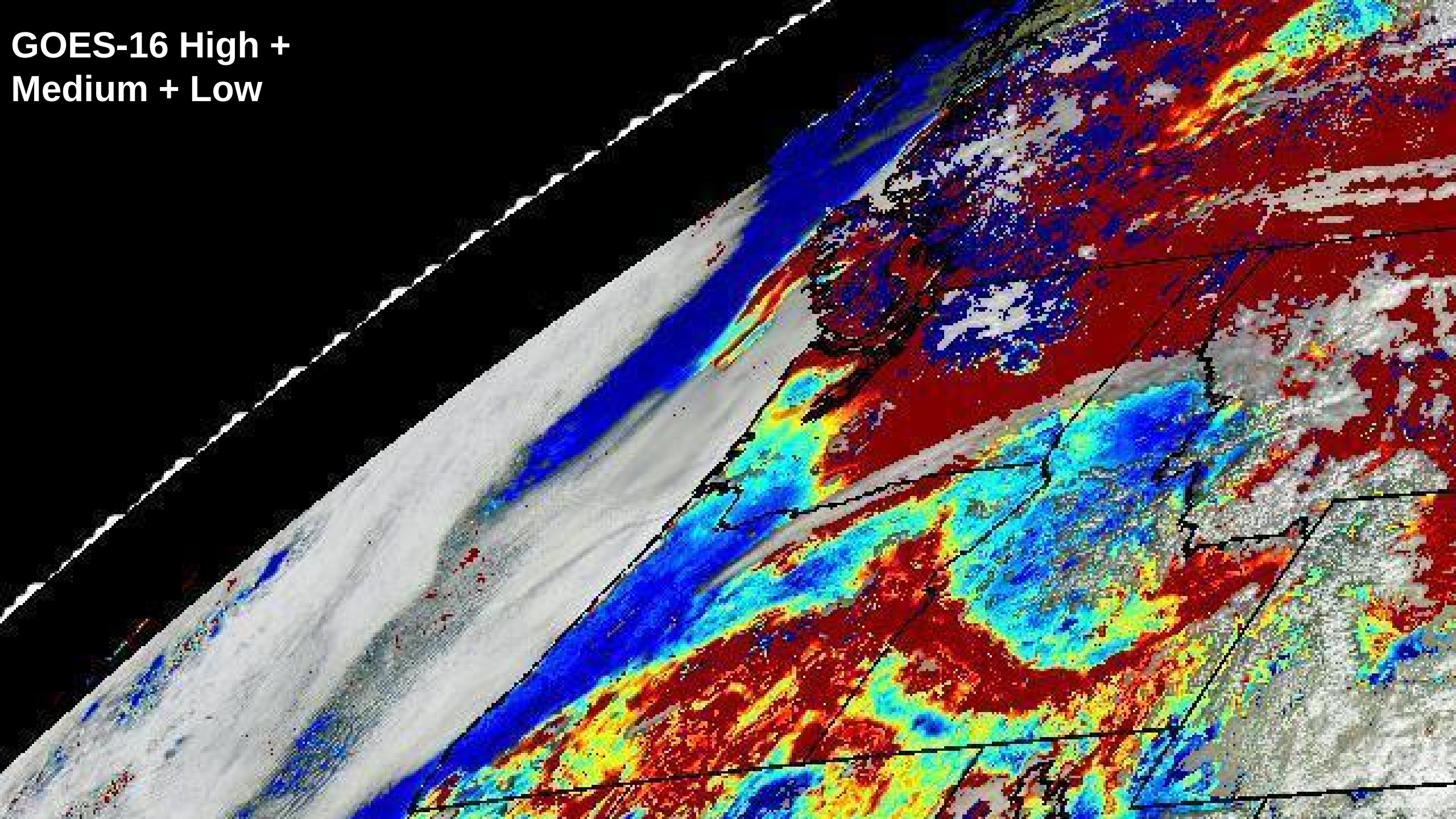


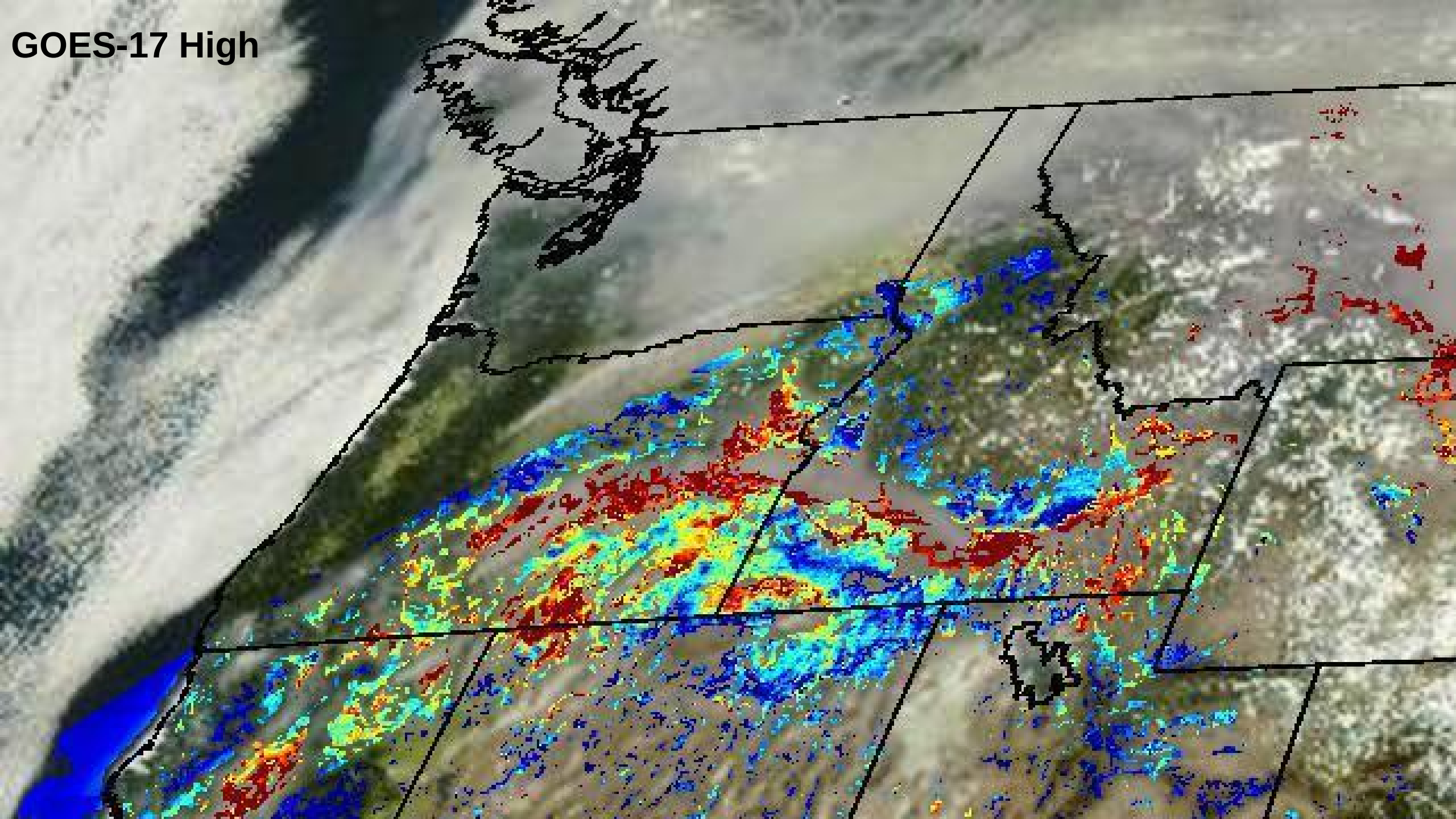
GOES-17 AOD

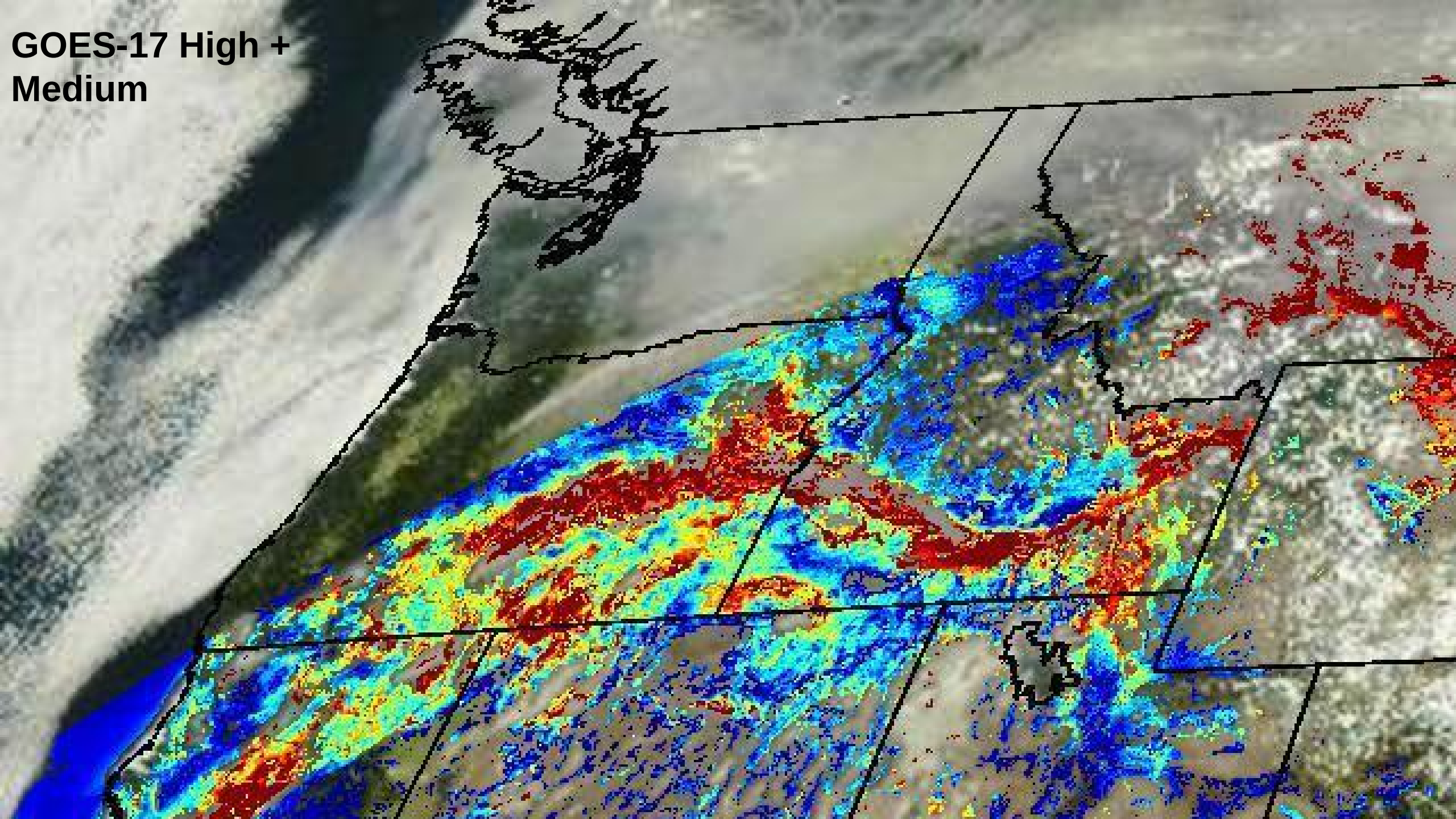


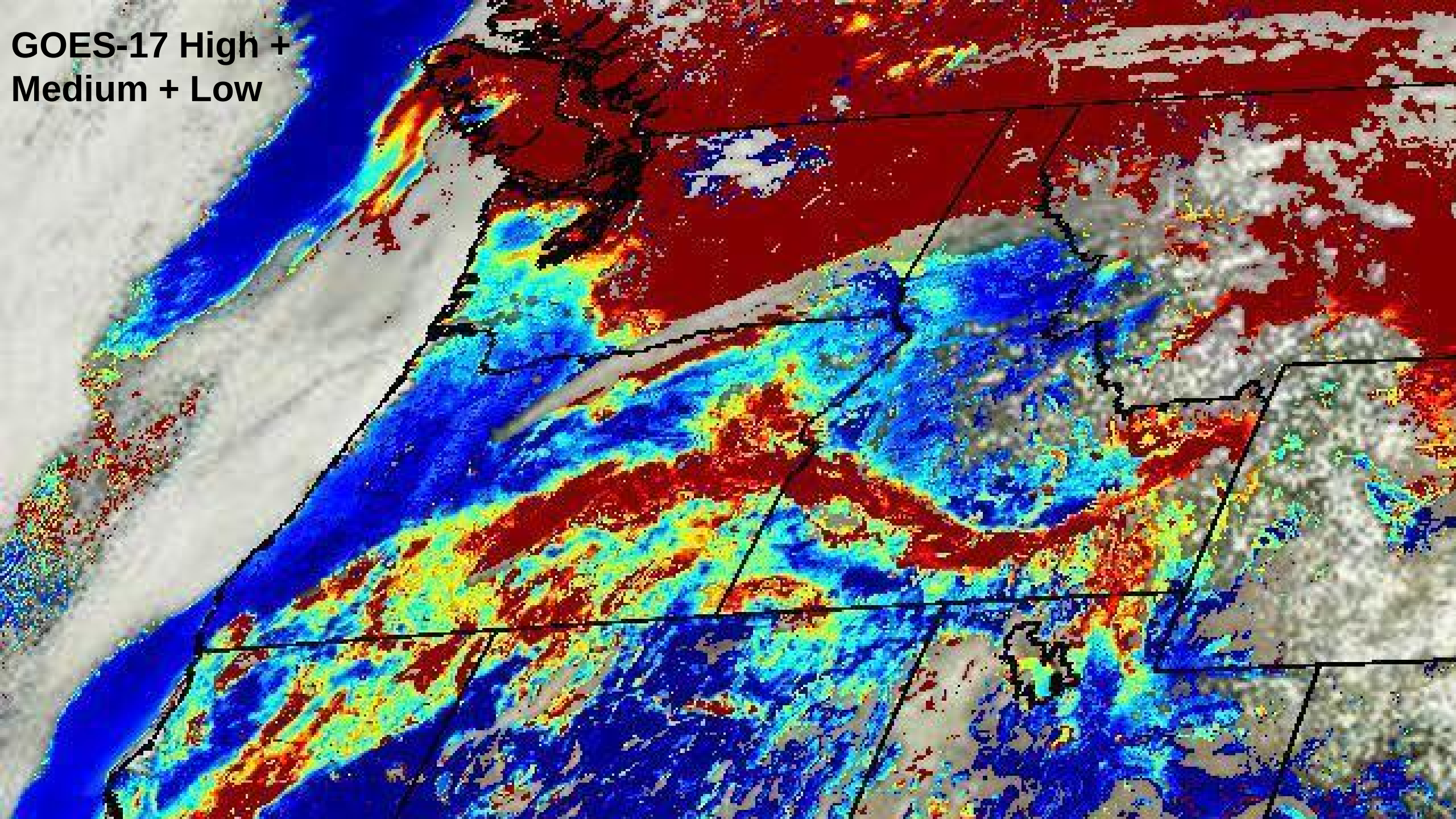

GOES-16 High

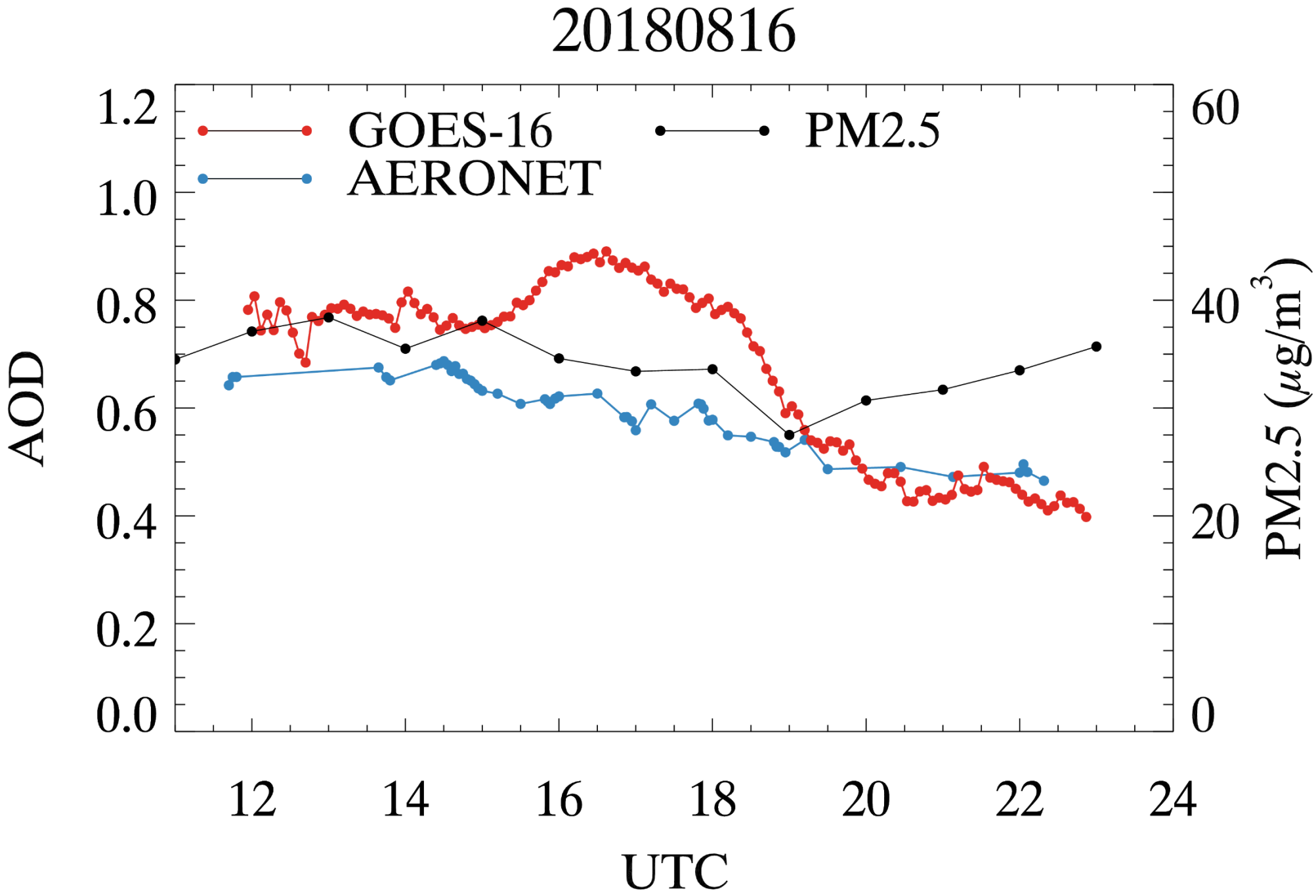

GOES-16 High +
Medium

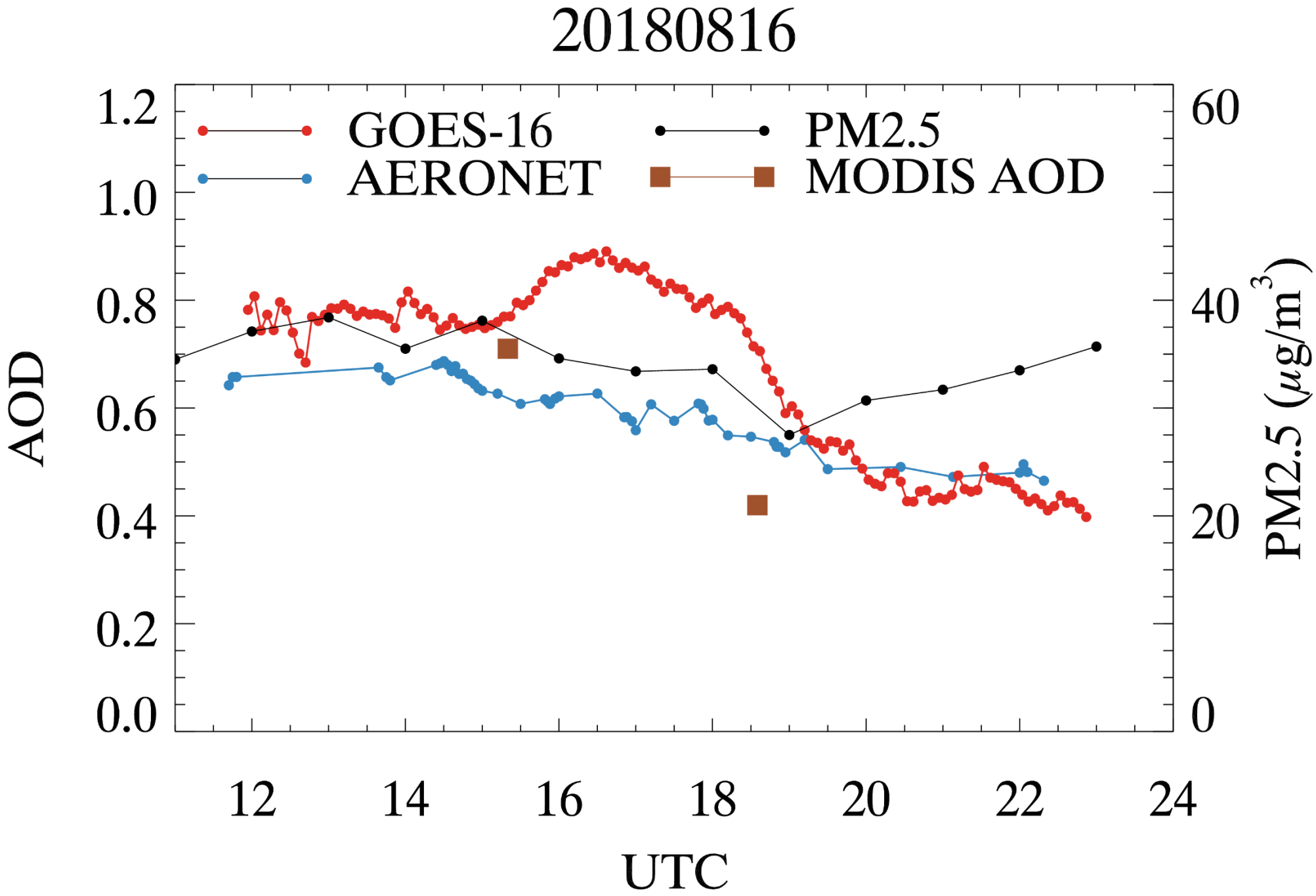

GOES-16 High +
Medium + Low


GOES-17 High


GOES-17 High +
Medium


GOES-17 High +
Medium + Low


20180816
GOES-16
AERONET
PM2.5
AOD
PM2.5 (μg/m3)
UTC
1.2
1.0
0.8
0.6
0.4
0.2
0.0
60
40
20
0
12
14
16
18
20
22
24


20180816
GOES-16
AERONET
PM2.5
MODIS AOD
AOD
PM2.5 (μg/m3)
UTC
0.0
0.2
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20
40
60
12
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16
18
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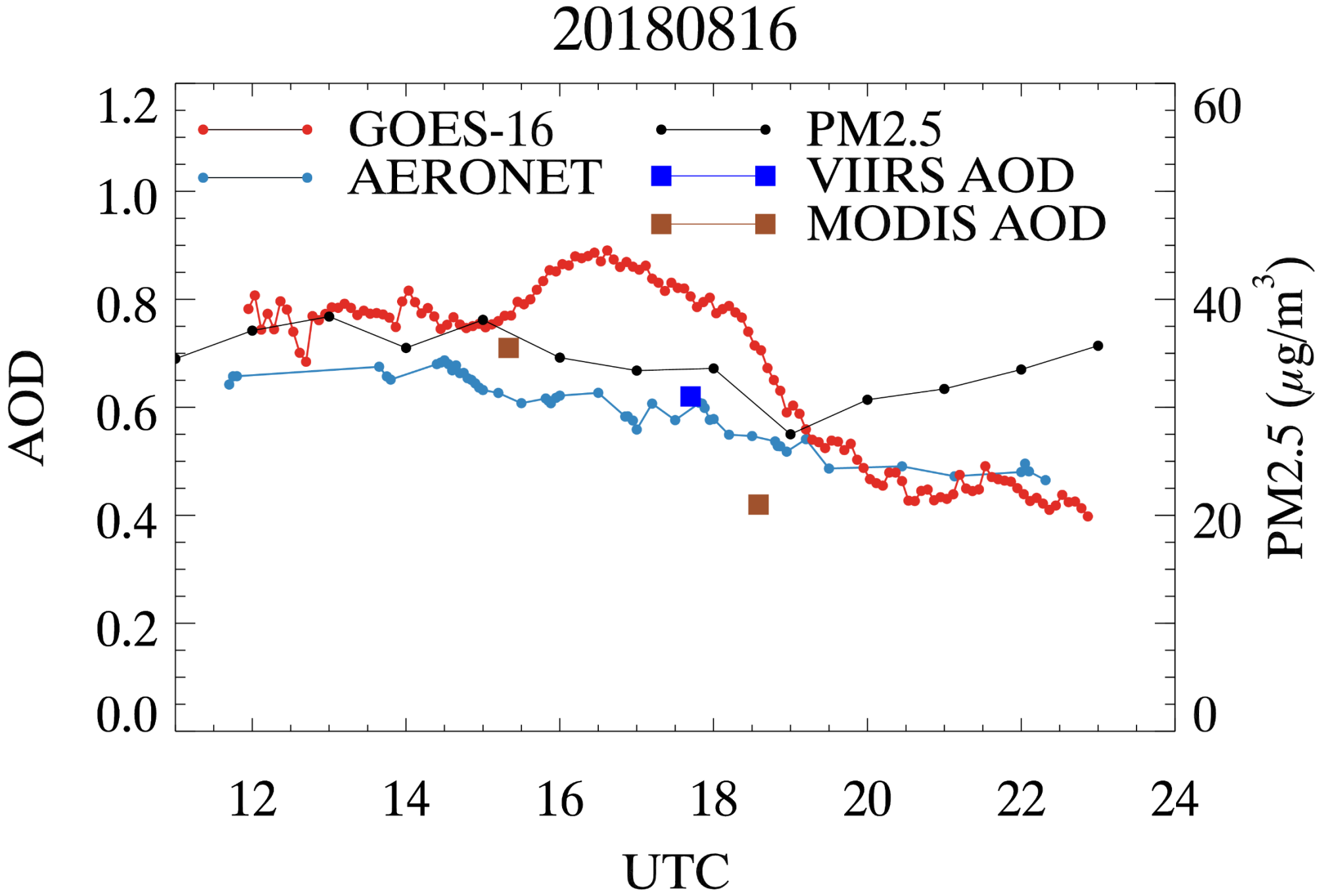
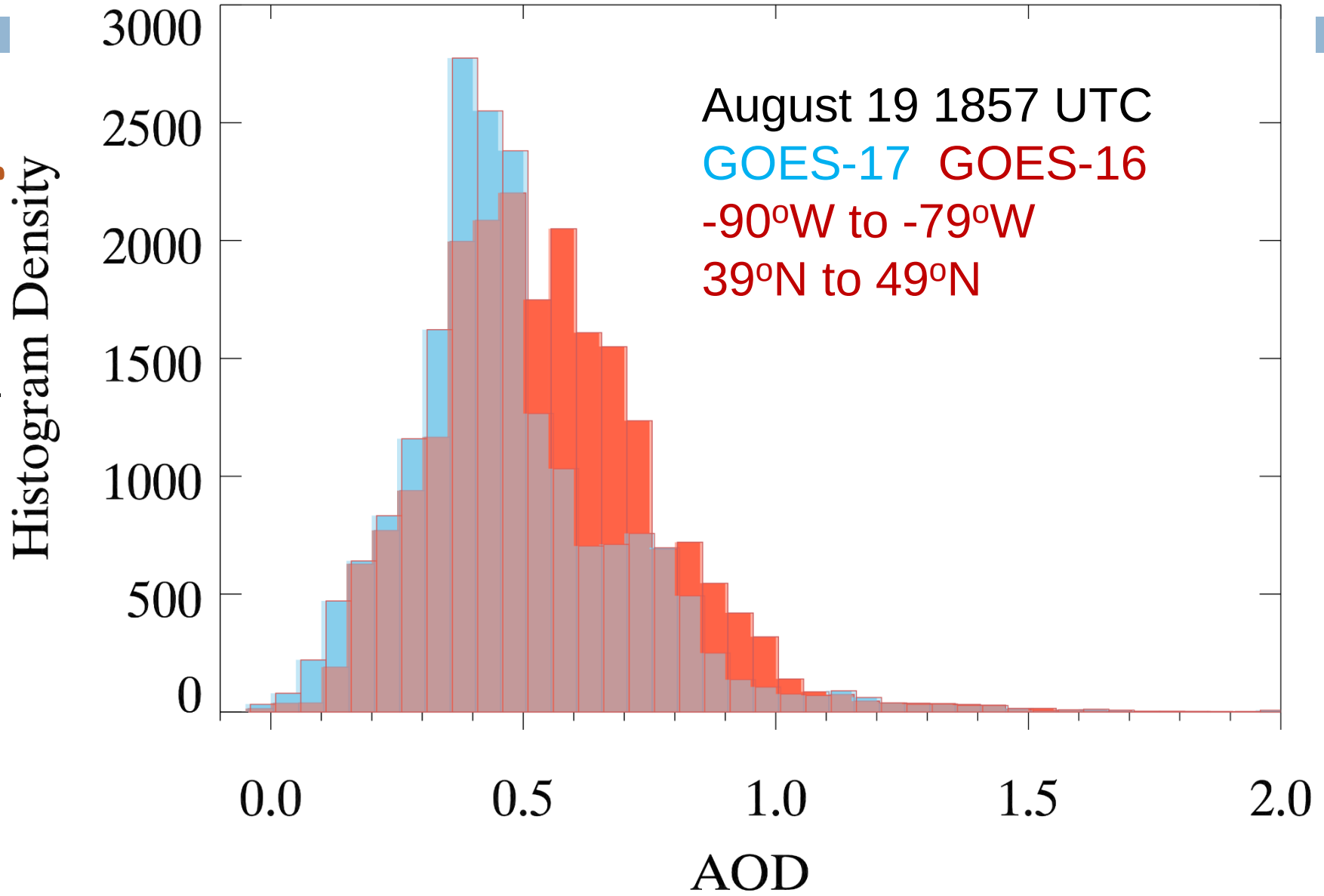
22
24


20180816
GOES-16
AERONET
PM2.5
VIIRS AOD
MODIS AOD
AOD
PM2.5 (μg/m3)
UTC
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
20
40
60
12
14
16
18
20
22
24

Concluding Remarks

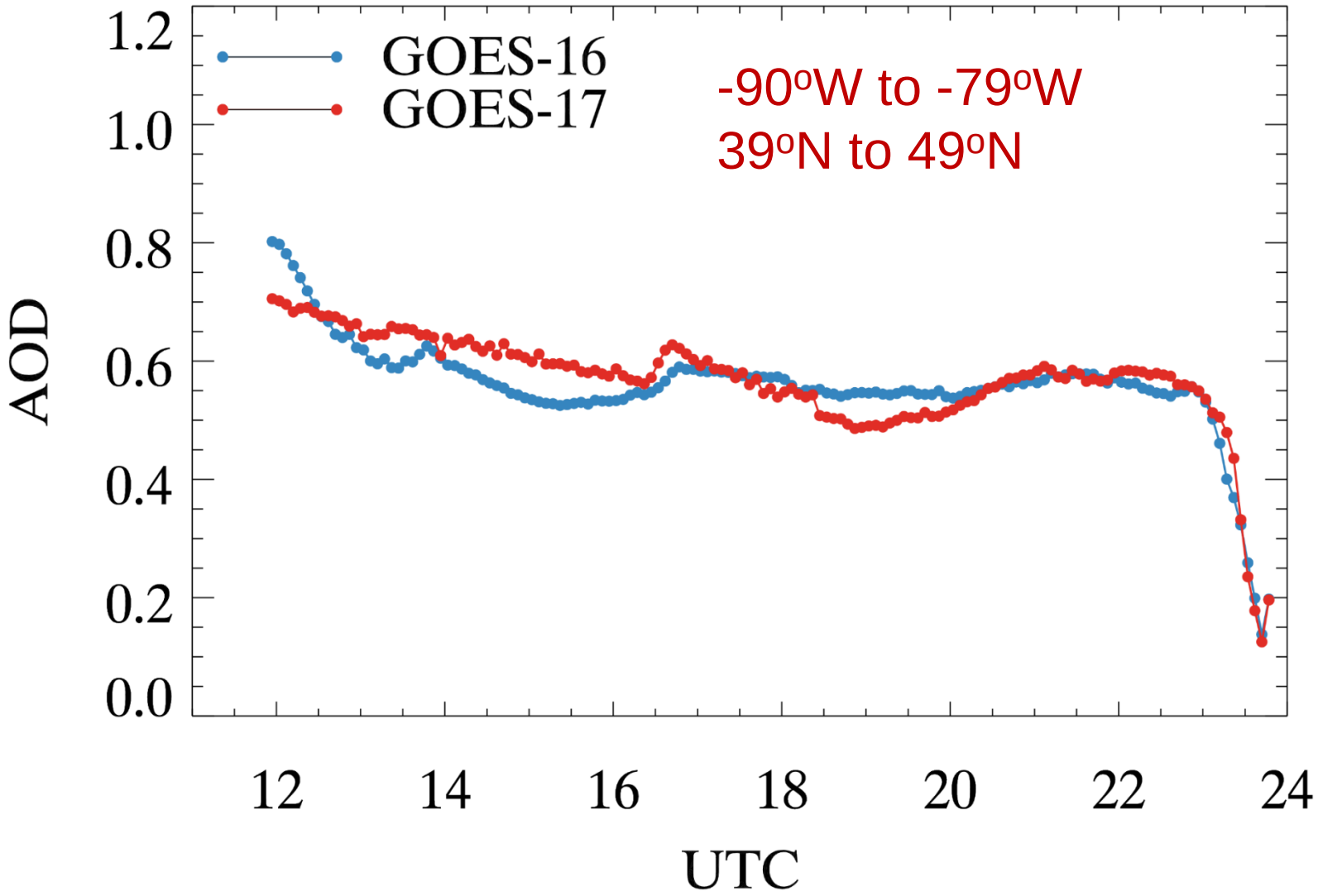
Breaking the Temporal Barrier

Viewing geometries different from GOES-E and GOES-W locations as well as from polar-orbiting satellites. Need to understand AOD bias as a function of geometry



Concluding Remarks

- Requirements are to be met for a statistically large sample.
  - ➢ Uncertain how performance metrics will be as a function of time of the day ---> important for air quality



Concluding Remarks

- Data volume is enormous
  - Users need to be ready for the “fire hose of information”. Product tailoring is required.

GOES-16 data are ready for operational use !!!

Today 3 PM Amy Huff presentation
https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/