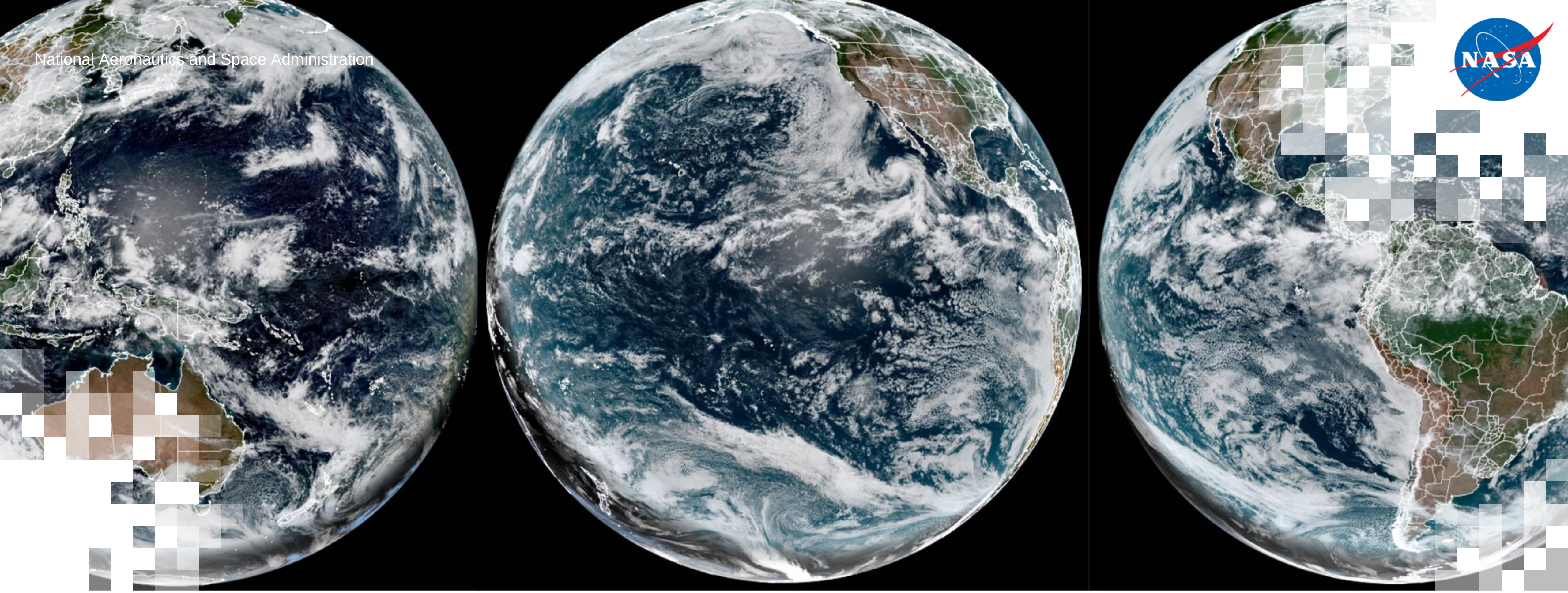


Introduction to Geostationary AQ Observations, Tools, and Data Access

Pawan Gupta, Melanie Follette-Cook, and Sarah Strode

Accessing and Analyzing Air Quality Data from Geostationary Satellites – Oct 11, 2022

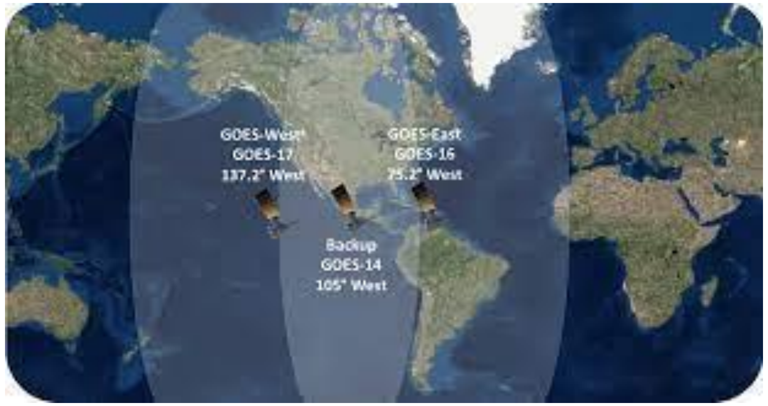
Training Outline

Part 1: October 11, 2022

Introduction to Geostationary AQ Observations, Tools, and Data Access

Pawan Gupta (USRA/MSFC) & Aaron Naegar (UAH/MSFC)

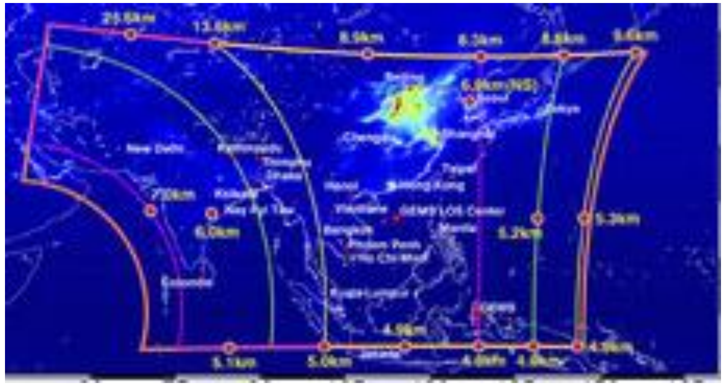
Part 2: October 18, 2022



Air Quality Products from the GOES-R Series

Amy Huff (IMSG/NOAA)

Part 3: October 25, 2022



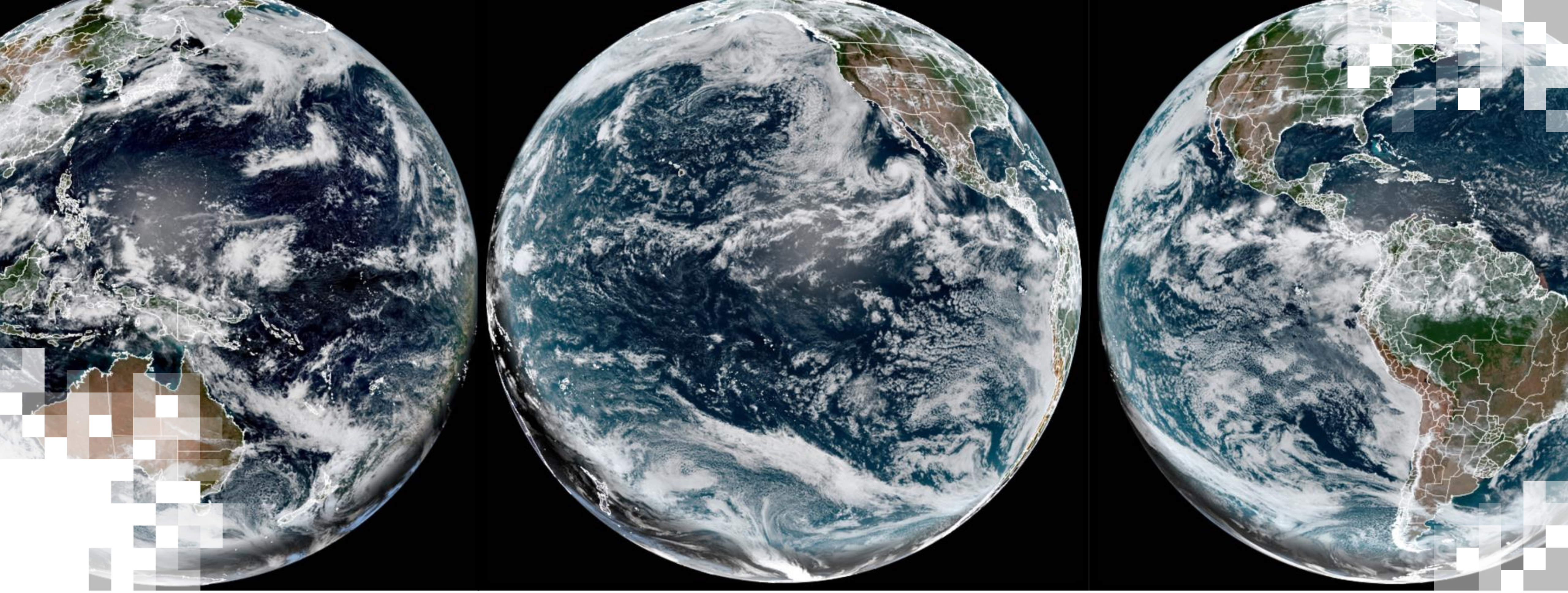
Air Quality Products from GEMS

Su Jung Go (UMBC/GSFC)

Learning Objectives

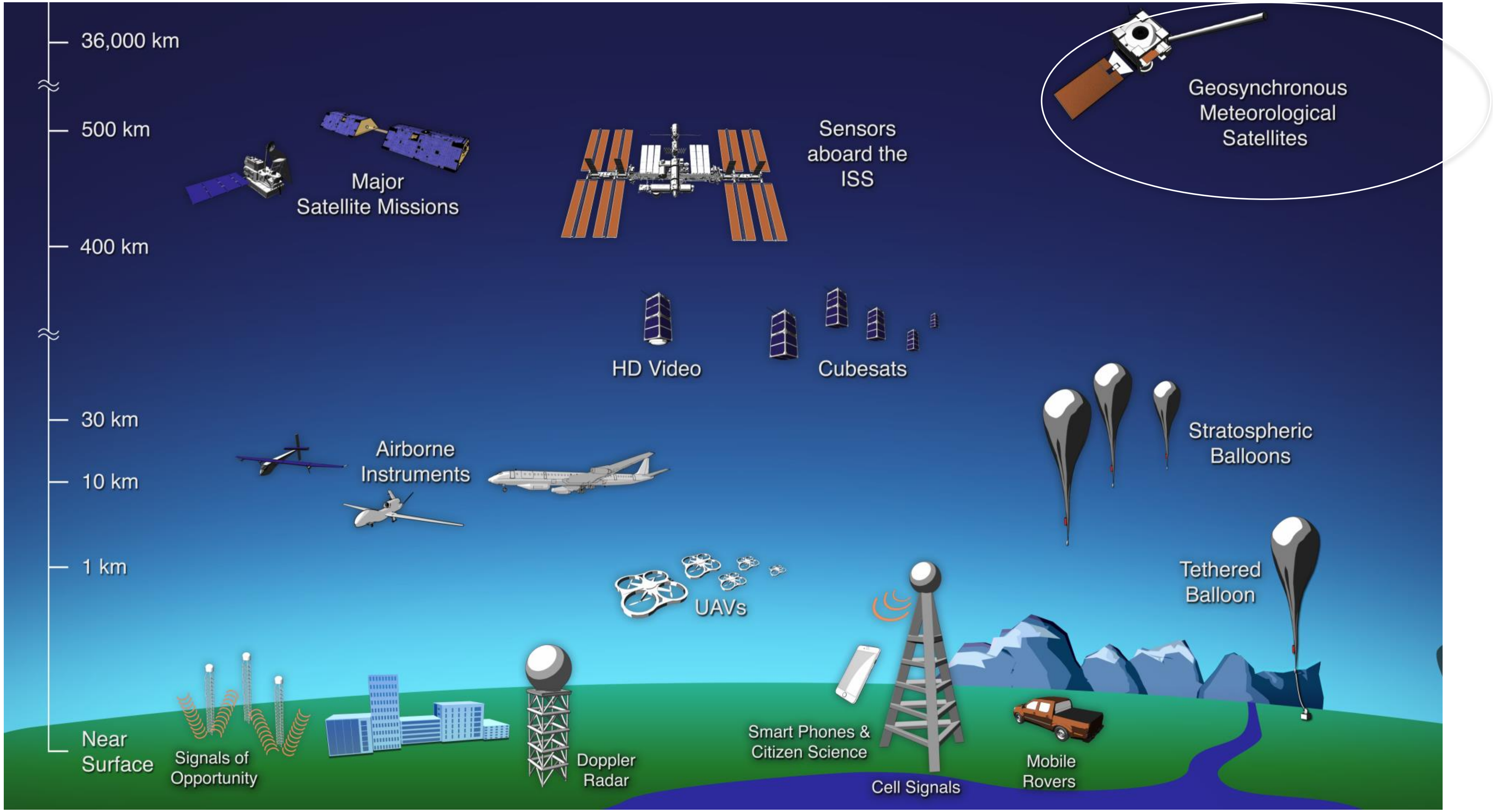
By the end of this session, participants will:

- Understand the fundamentals of geostationary orbit (GEO) remote sensing
- Understand the difference between low Earth orbit (LEO) and GEO observations
- Understand true color imagery and applications
- Locate and access GEO imagery from NASA Worldview, GEOslider websites
- Be introduced to the upcoming Air Quality mission, TEMPO

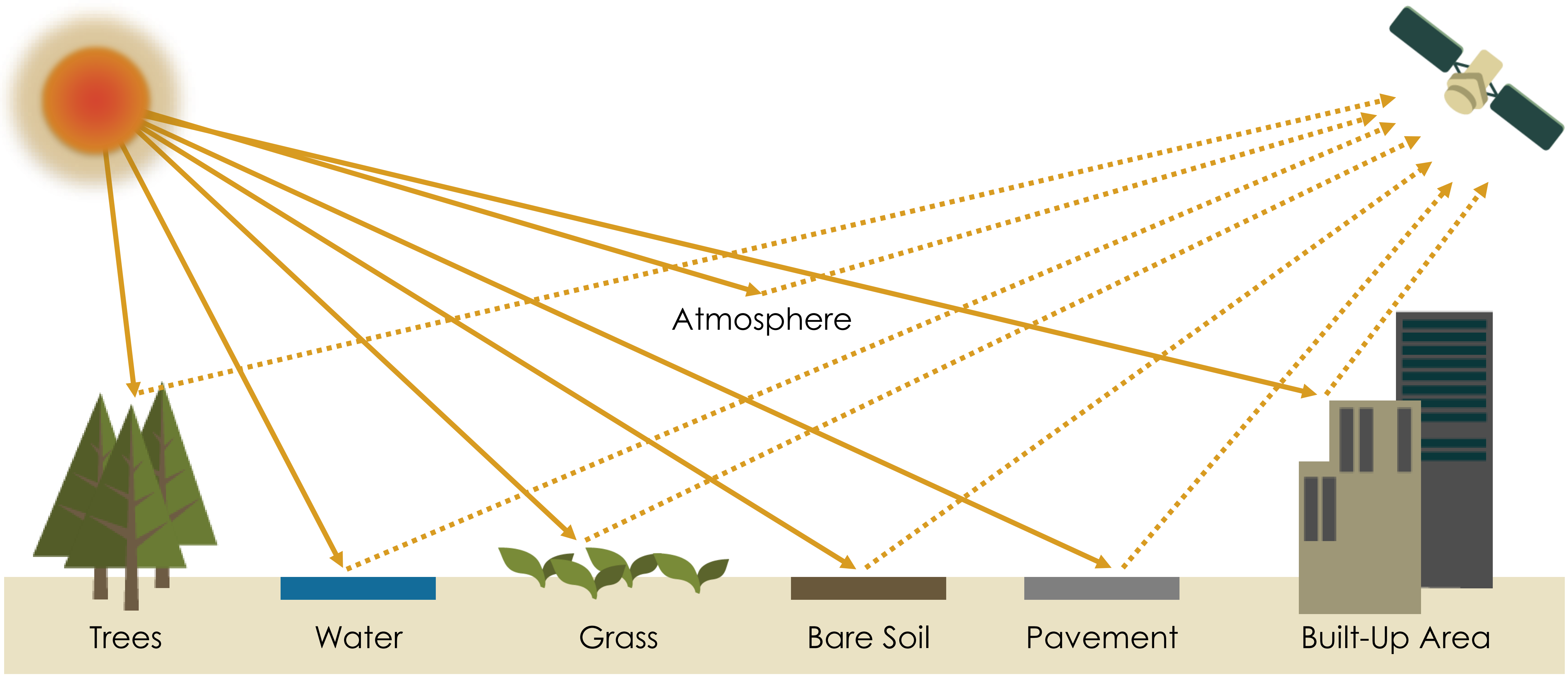


Review of Key Remote Sensing Concepts

Remote Sensing of Our Planet

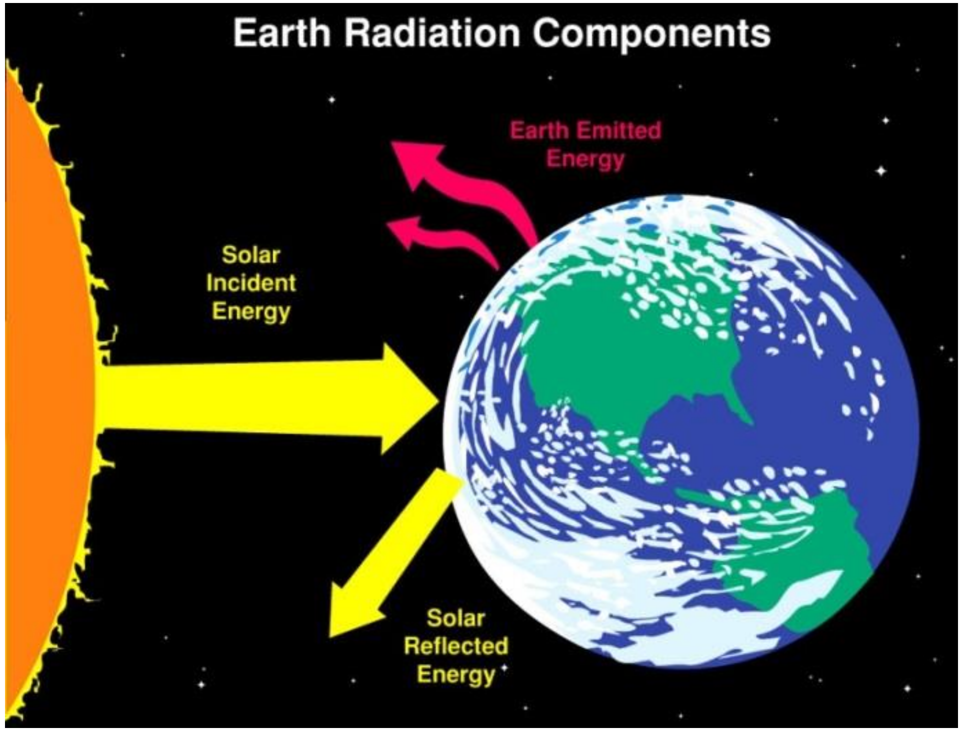


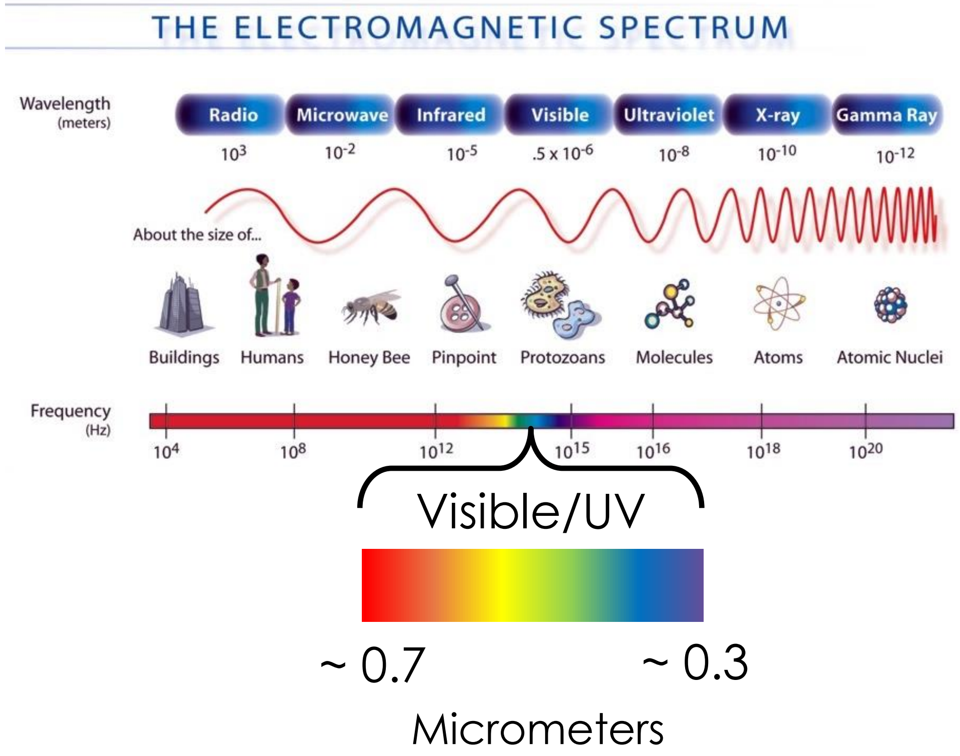
What do satellites measure?

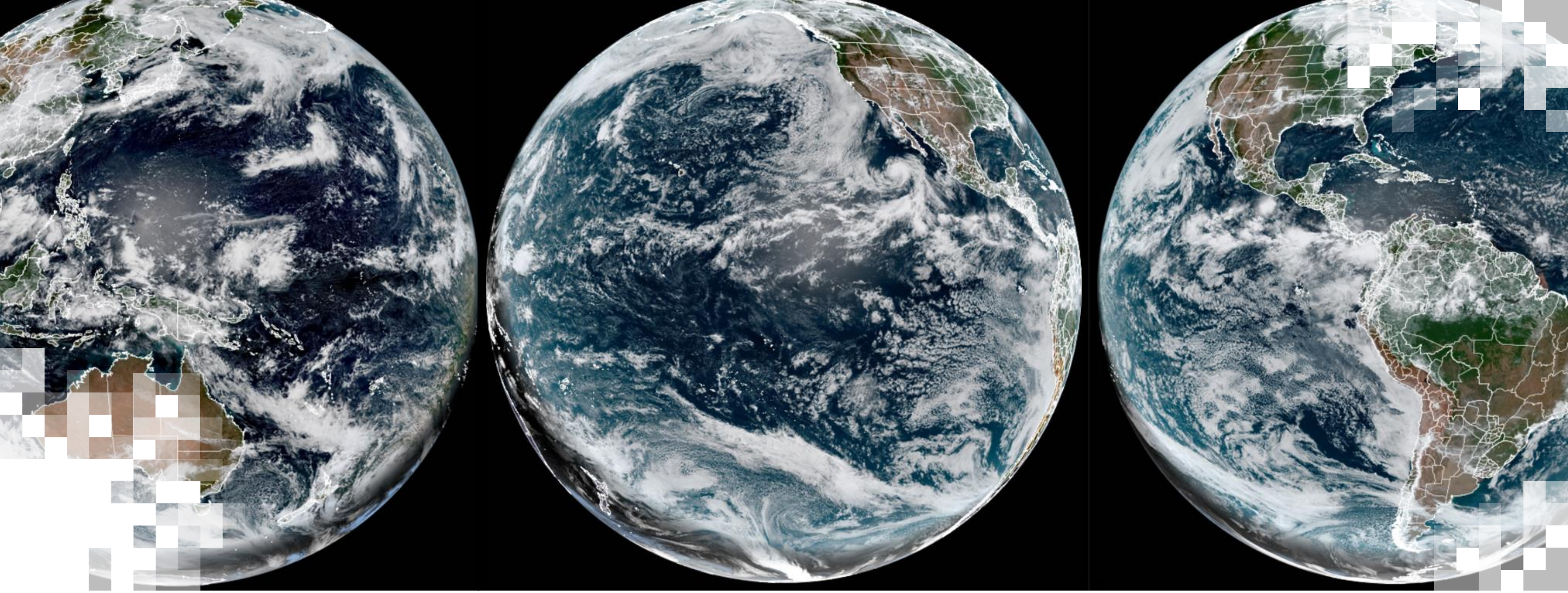


Electromagnetic Radiation

- Earth-Ocean-Land-Atmosphere System
  - Reflects solar radiation back into space
  - Emits infrared and microwave radiation into space







Satellites, Sensors, and Orbits

Satellites vs. Sensors

Earth observing satellite remote sensing instruments are named according to:

1. The satellite (platform)
2. The instrument (sensor)

Naming Convention

- Before Launch: GOES-R & GOES-S
- After Launch: GOES-16 & GOES-17
- Operational in final orbit/position: GOES-East & GOES-West

GOES-R Spacecraft

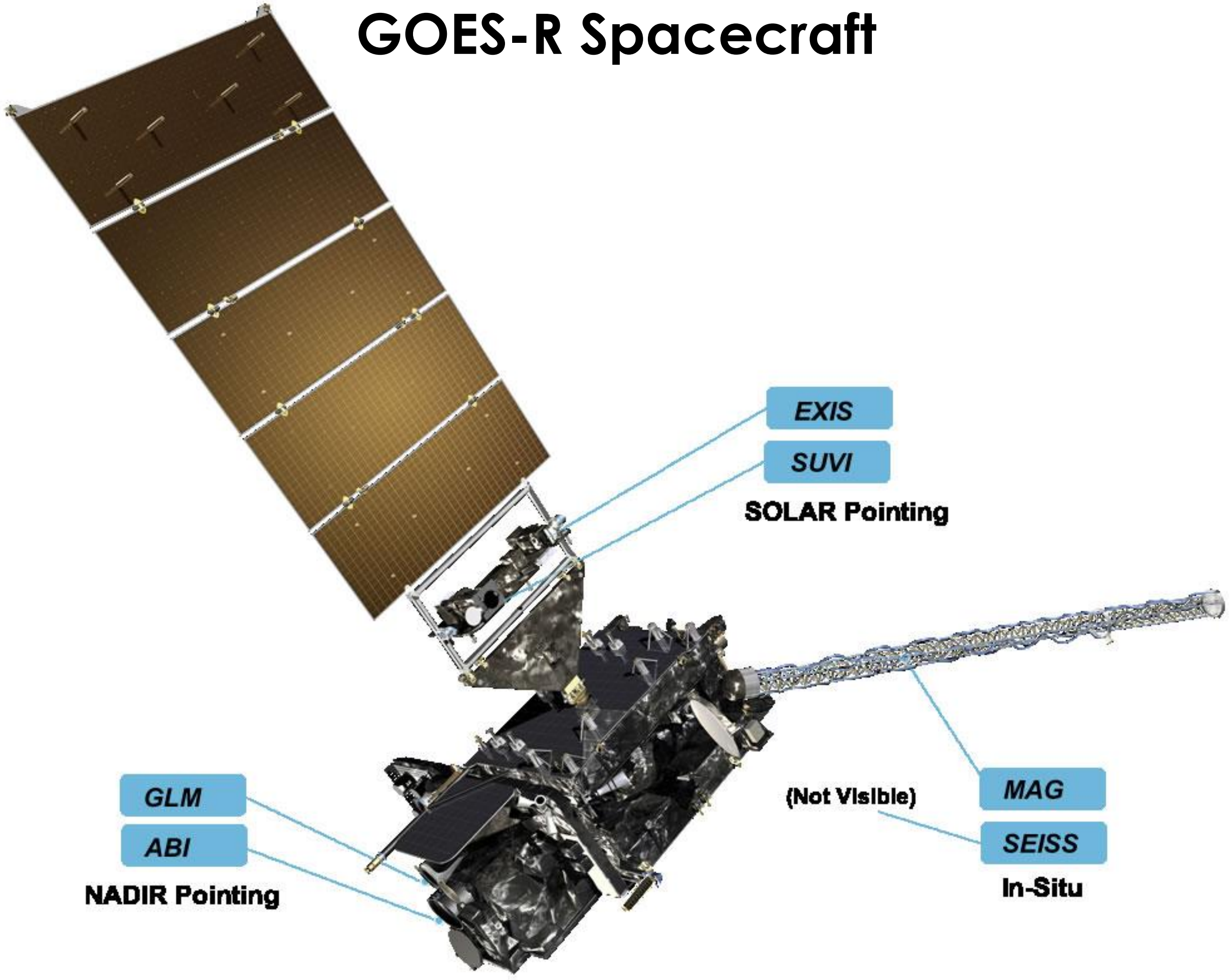
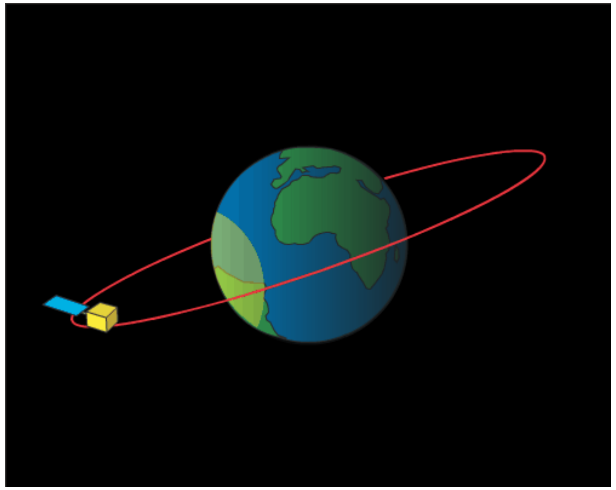
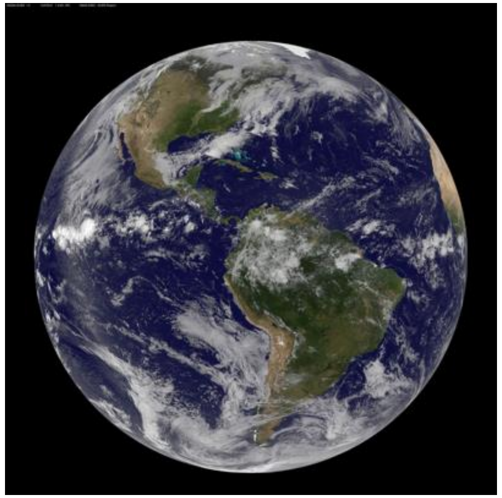
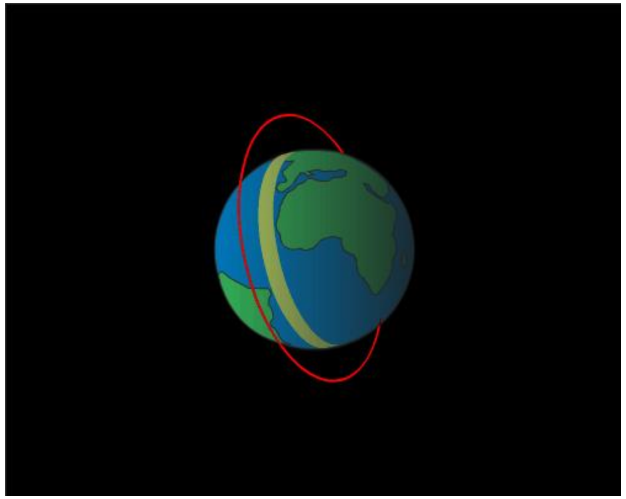


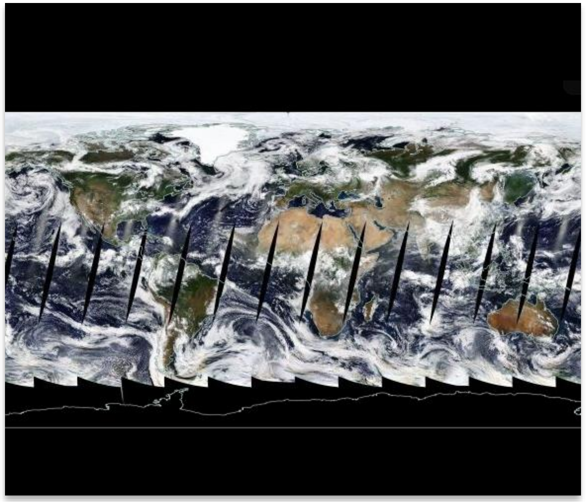
Image Credit: NASA/NOAA

Common Orbit Types









Geostationary Orbit (GEO)

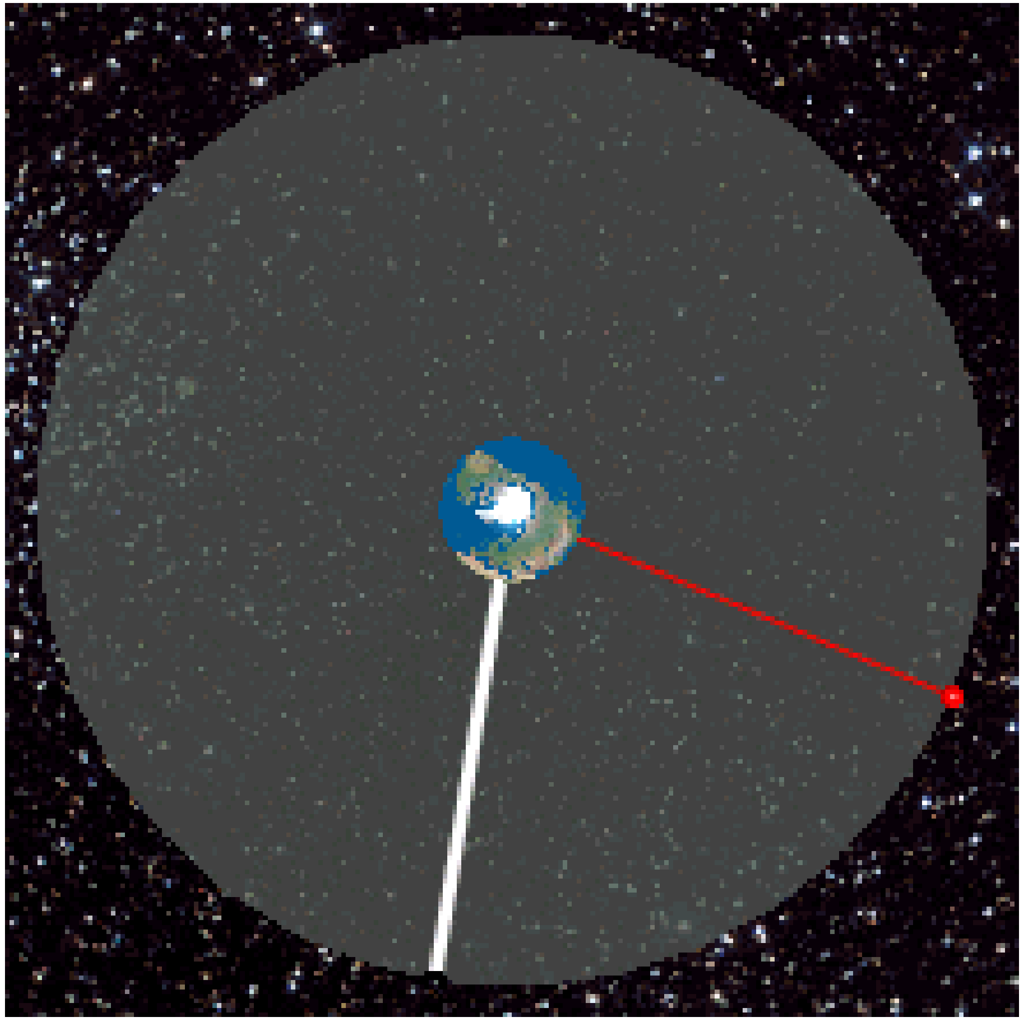
- Has the same rotational period as Earth
- Appears 'fixed' above Earth
- Orbits ~36,000 km above the Equator

Polar Orbit (LEO)

- Fixed, circular orbit above Earth
- Sun synchronous orbit ~600-1,000 km above Earth with orbital passes at about the same **local solar time** each day

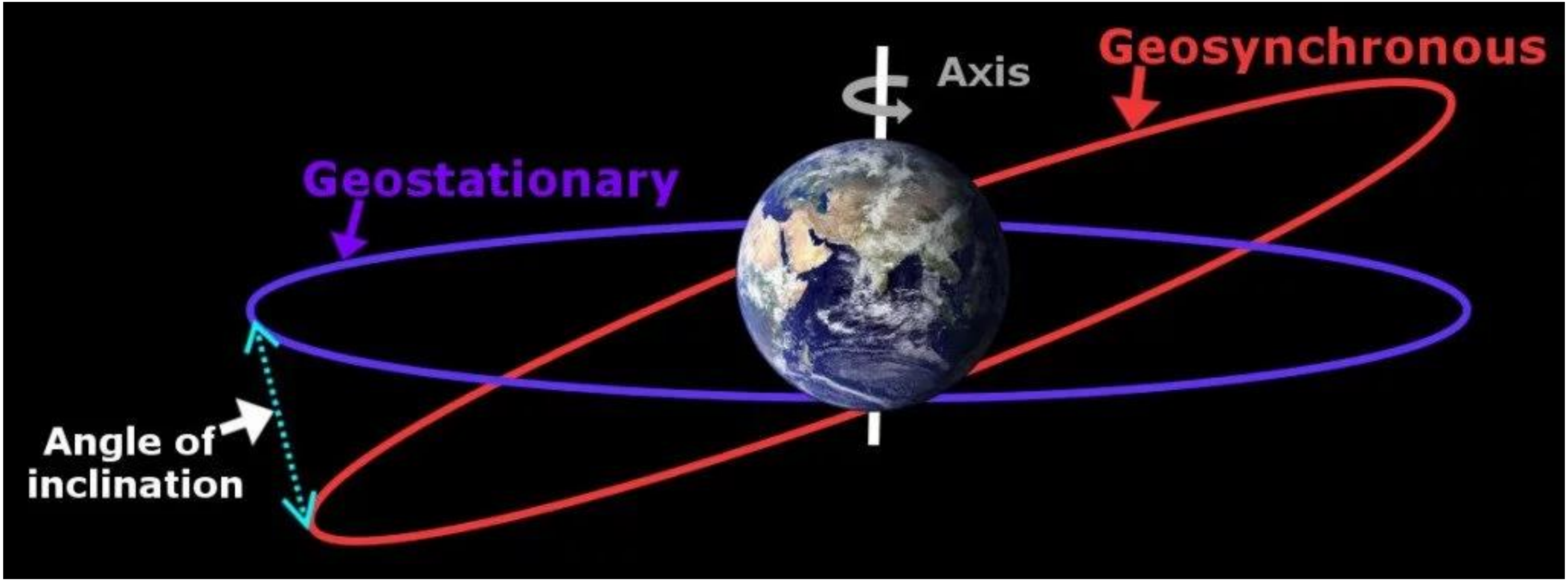
Some Facts About Geostationary Orbits

- Above the Earth's Surface - 35,786 km (or 22,236 mi)
- Orbital velocity of 3.07 km/s (1.91 mi/s)
- Circular orbit at 0-degree inclination with Equator
- This allows the satellite to match Earth's rotation period.



Source: [Wikipedia]

Geostationary vs. Geosynchronous



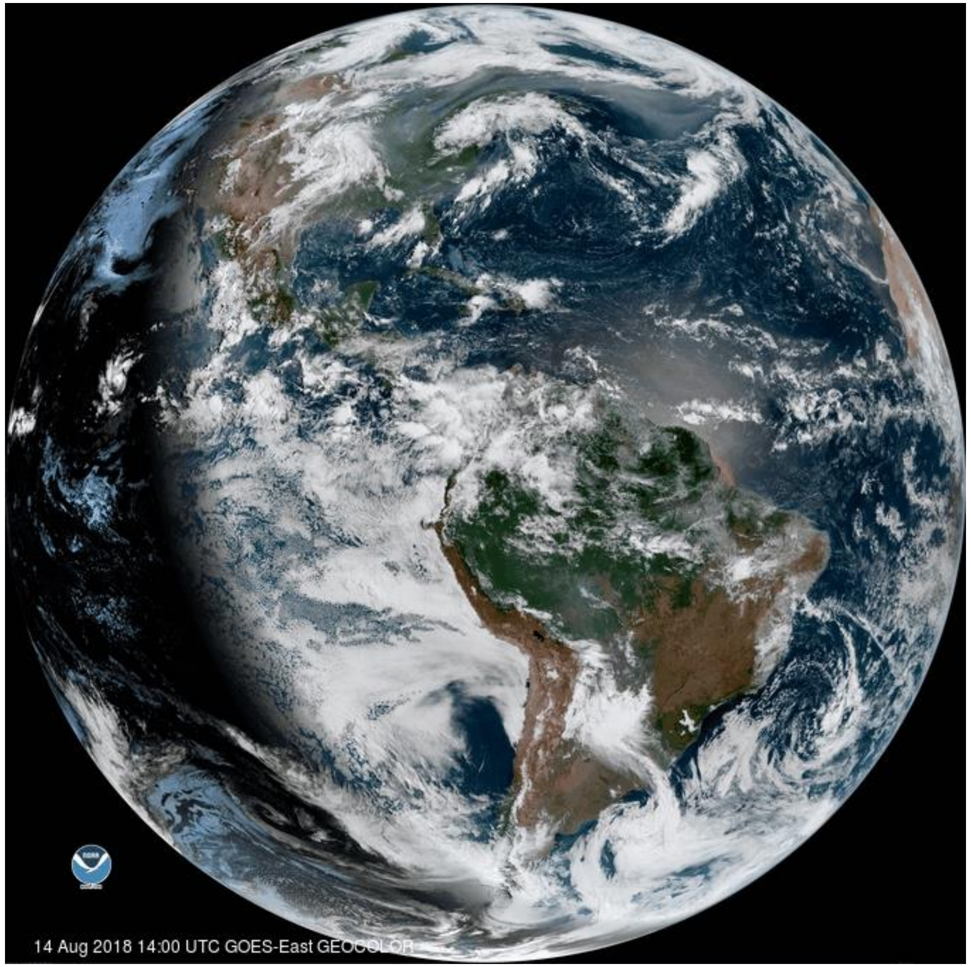
Geostationary orbit is a special type of geosynchronous satellite at the equator.

Image Credit: ScienceABC

Low Earth Orbit (LEO) & Geostationary (GEO) Satellites Orbiting the Earth

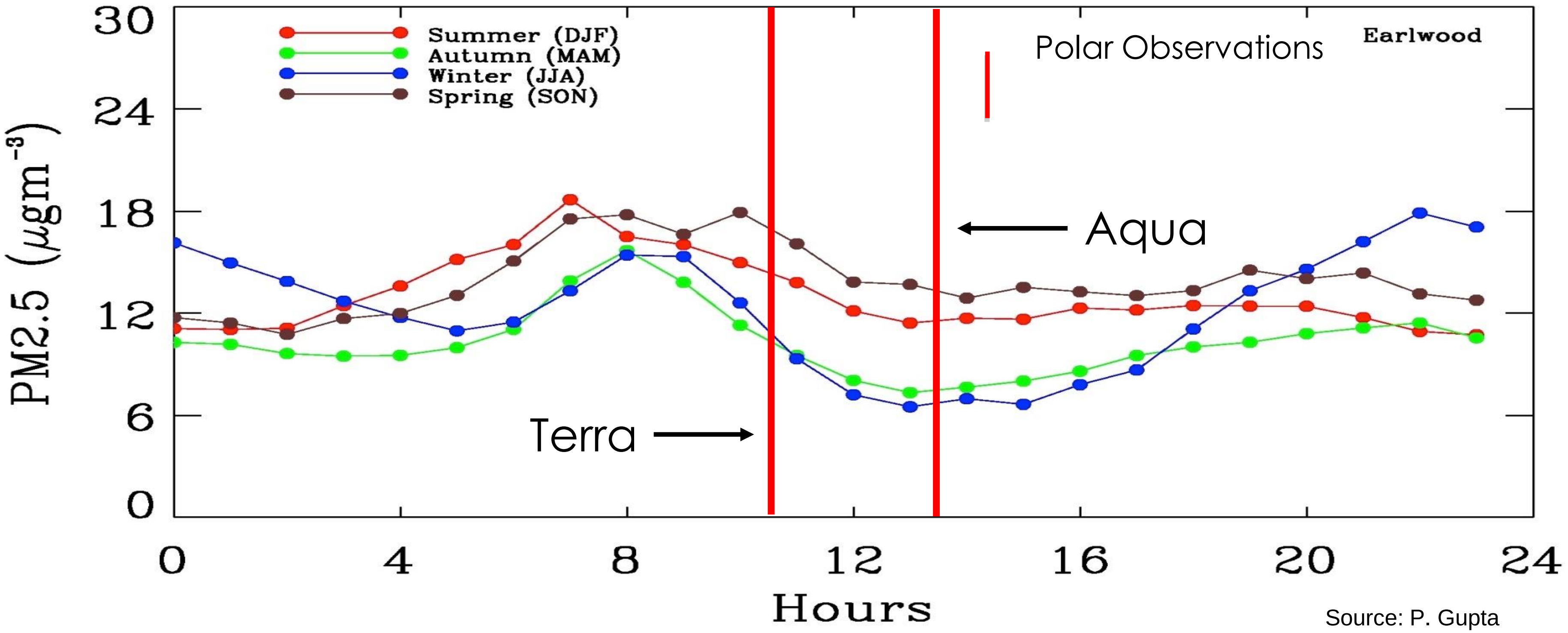
LEO Orbit

GEO Orbit



Observation Frequency

Polar Orbiting Satellites: 1-3 observations per day, per sensor

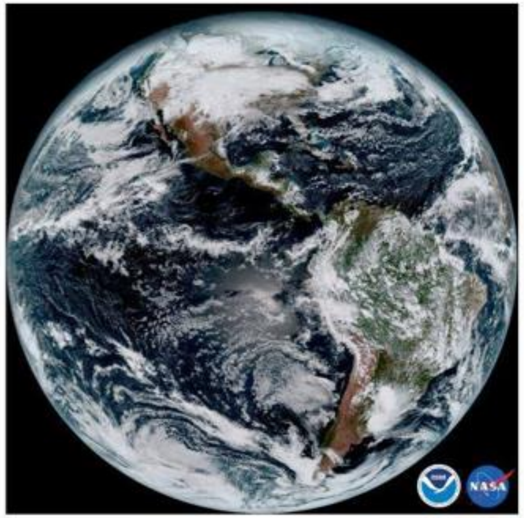


Source: P. Gupta

Geostationary Satellites: Every 30 sec. to 60 min. (ABI, AHI, AMI, GEMS)

Future Geo satellites: TEMPO, Sentinel-4

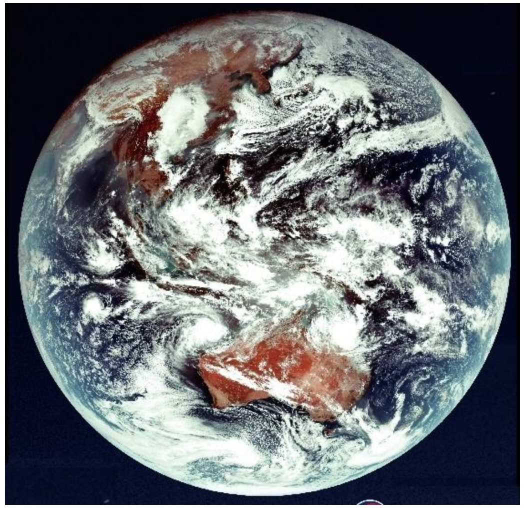
Satellite Coverage - GEO



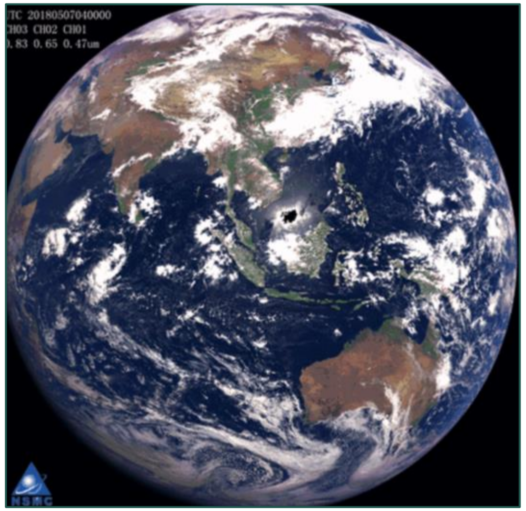
GOES-R

GOES-S/T

Himawari -8/9

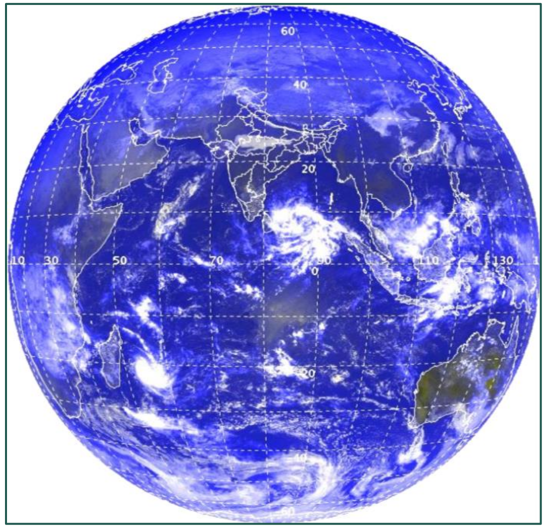


AMI-GK-2A



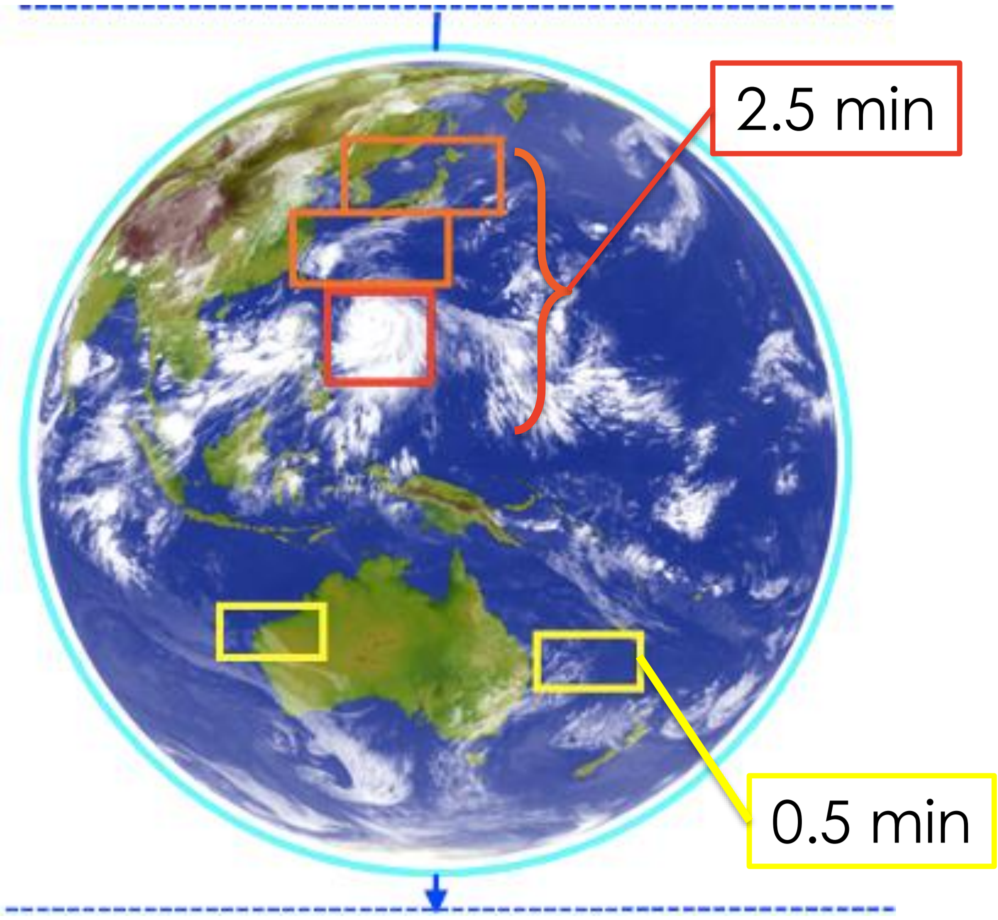
Fengyun-4

MST – (FCI)

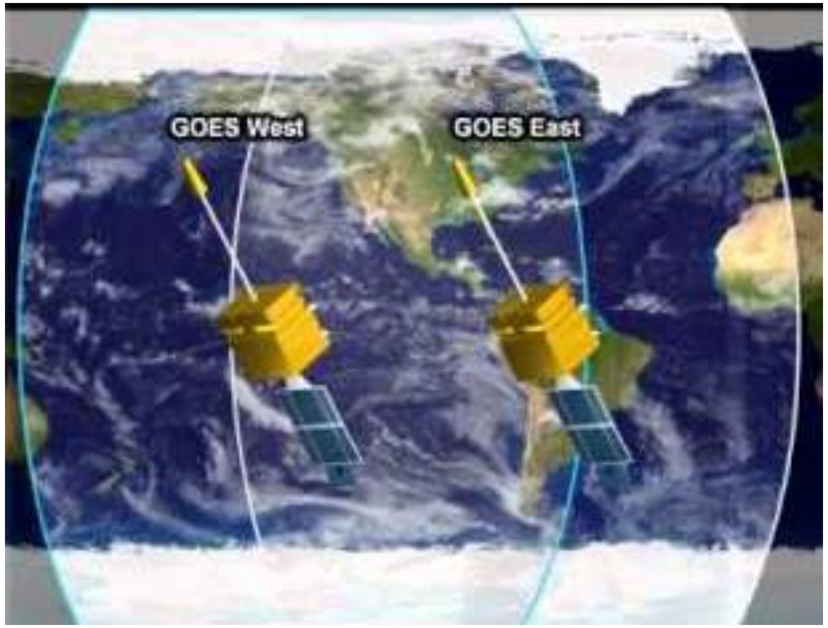


INSAT – (GISAT)

Advanced Himawari Imager (AHI) & Advanced Baseline Imager (ABI): Spatial Coverage and Temporal Resolution

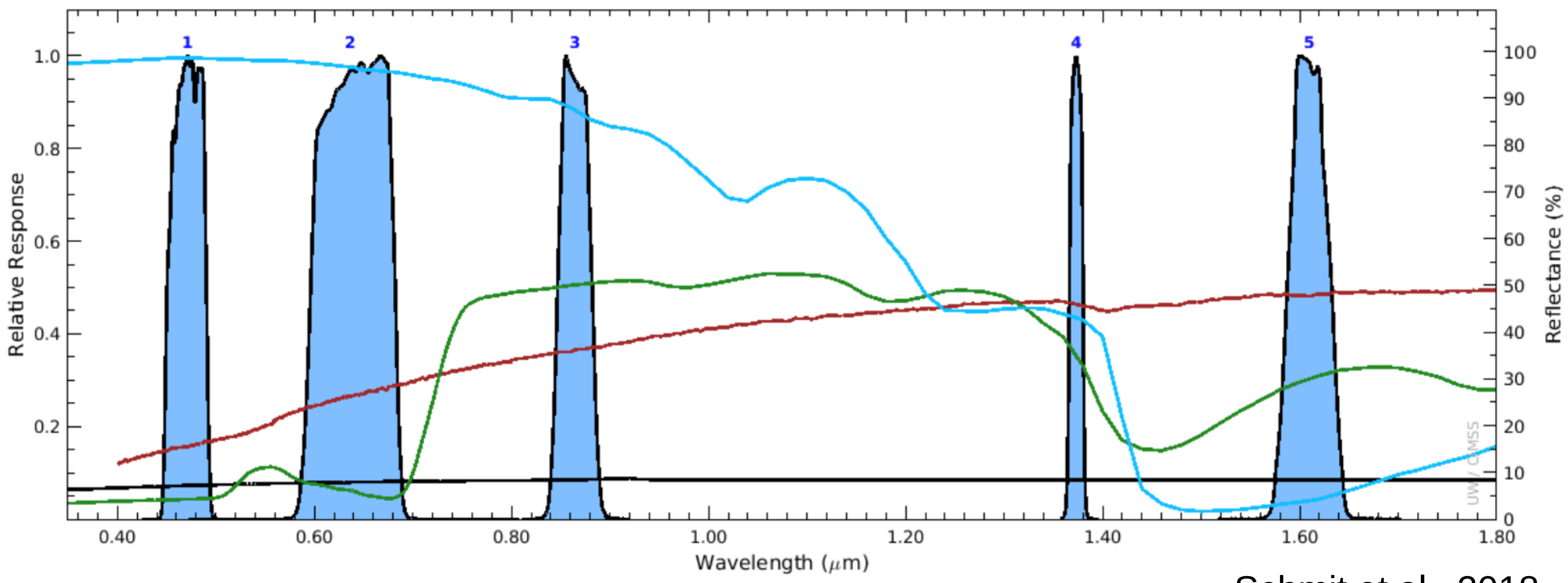


Full Disk: Every 10 min

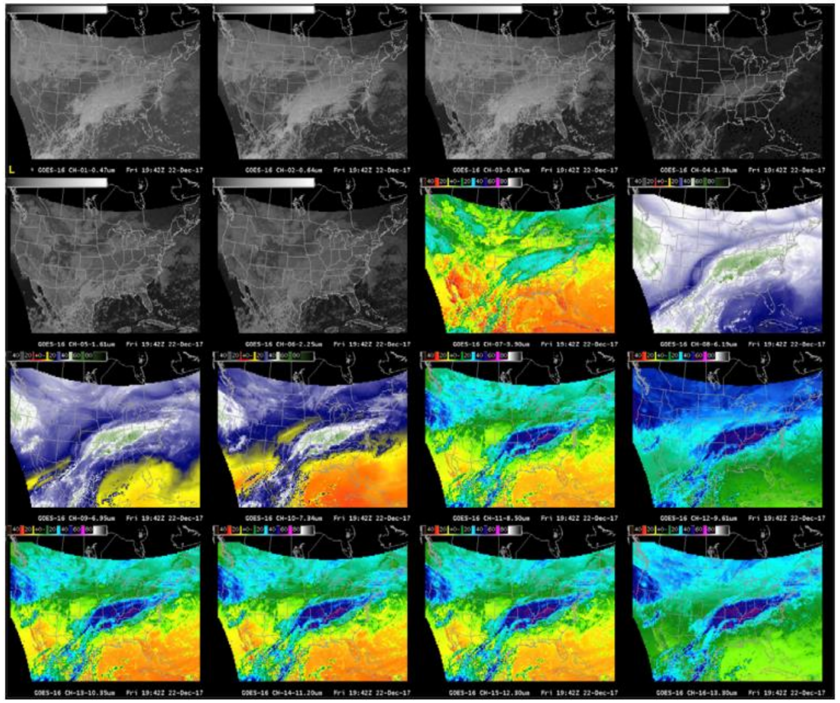


Full Disk: Every 10 min
CONUS: Every 5 min
Mesoscale: Every 0.5 min

Spectral Bands & Atmospheric Interactions



Schmit et al., 2018



Source: http://nwafiles.nwas.org/jom/articles/2018/2018-JOM4/2018-JOM4.pdf

AHI & ABI: Spectral Coverage

AHI

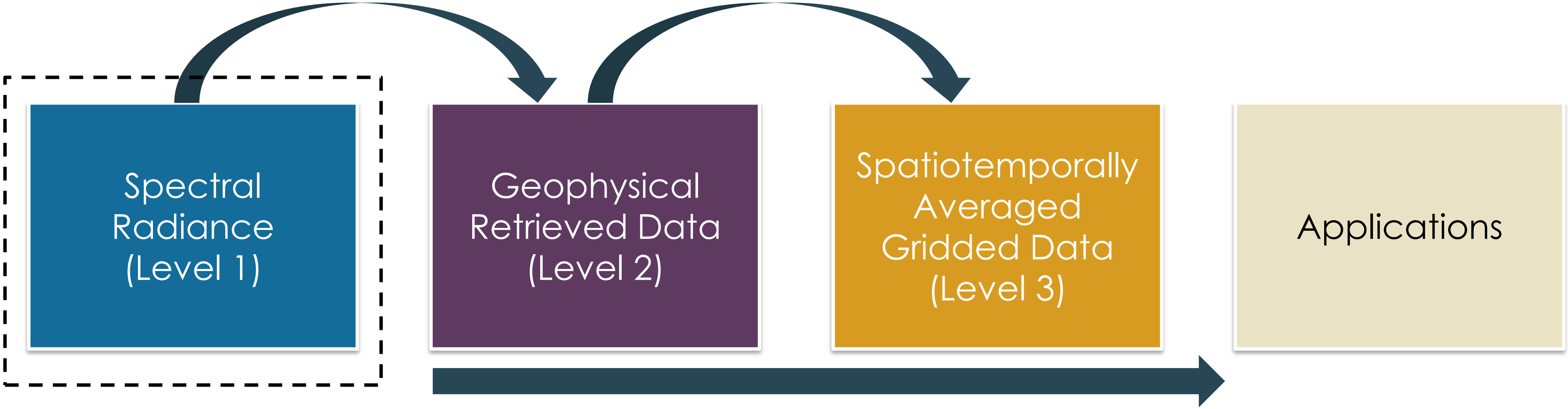
Band	Wavelength (µm)	Spatial Resolution (km)
1	0.46	1
2	→ 0.51	1
3	0.64	0.5
4	0.86	0.5
5	1.6	2
6	2.3	2
7	3.9	2
8	6.2	2
9	7.0	2
10	7.3	2
11	8.6	2
12	9.6	2
13	10.4	2
14	11.2	2
15	12.3	2
16	13.3	2

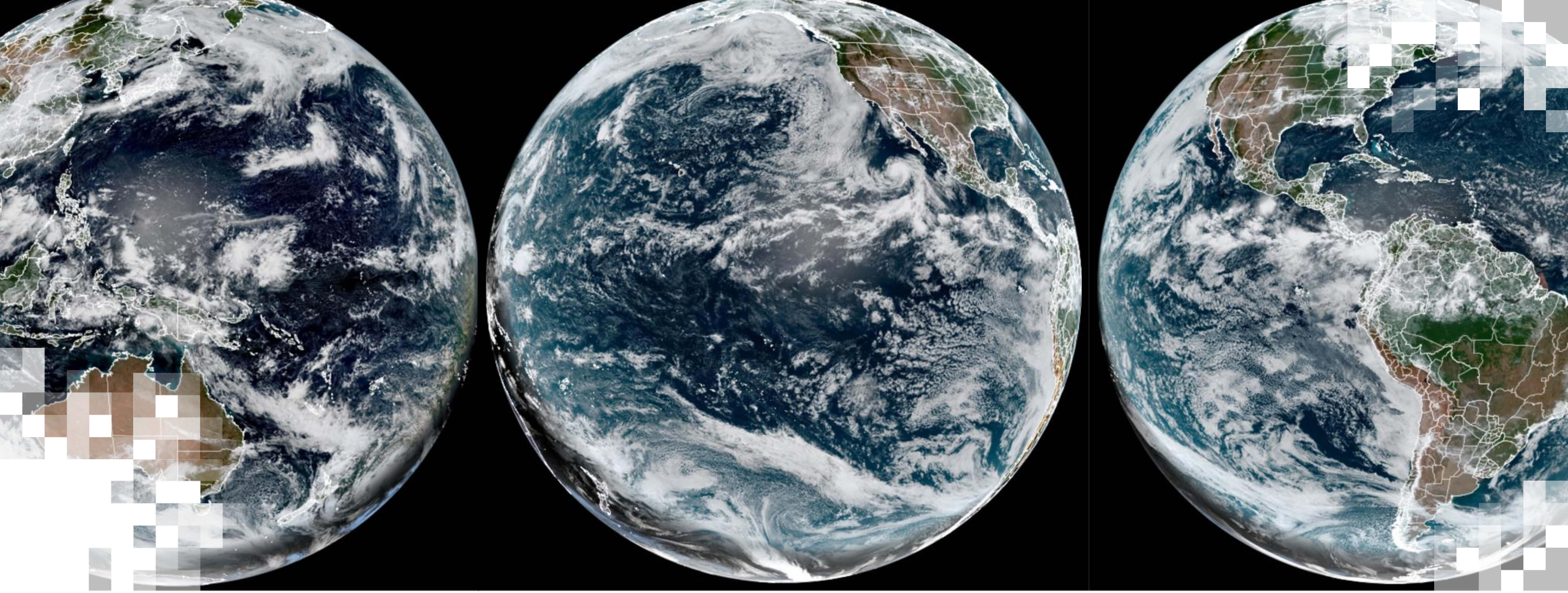
ABI

Future GOES Imager (ABI) band	Central Wavelength (µm)	Nominal Subsatellite IGFOV (km)
1	0.47	1
2	0.64	0.5
3	0.865	1
4	→ 1.378	2
5	1.61	1
6	2.25	2
7	3.90	2
8	6.19	2
9	6.95	2
10	7.34	2
11	8.5	2
12	9.61	2
13	10.35	2
14	11.2	2
15	12.3	2
16	13.3	2

Source: http://www.data.jma.go.jp/

Data Products

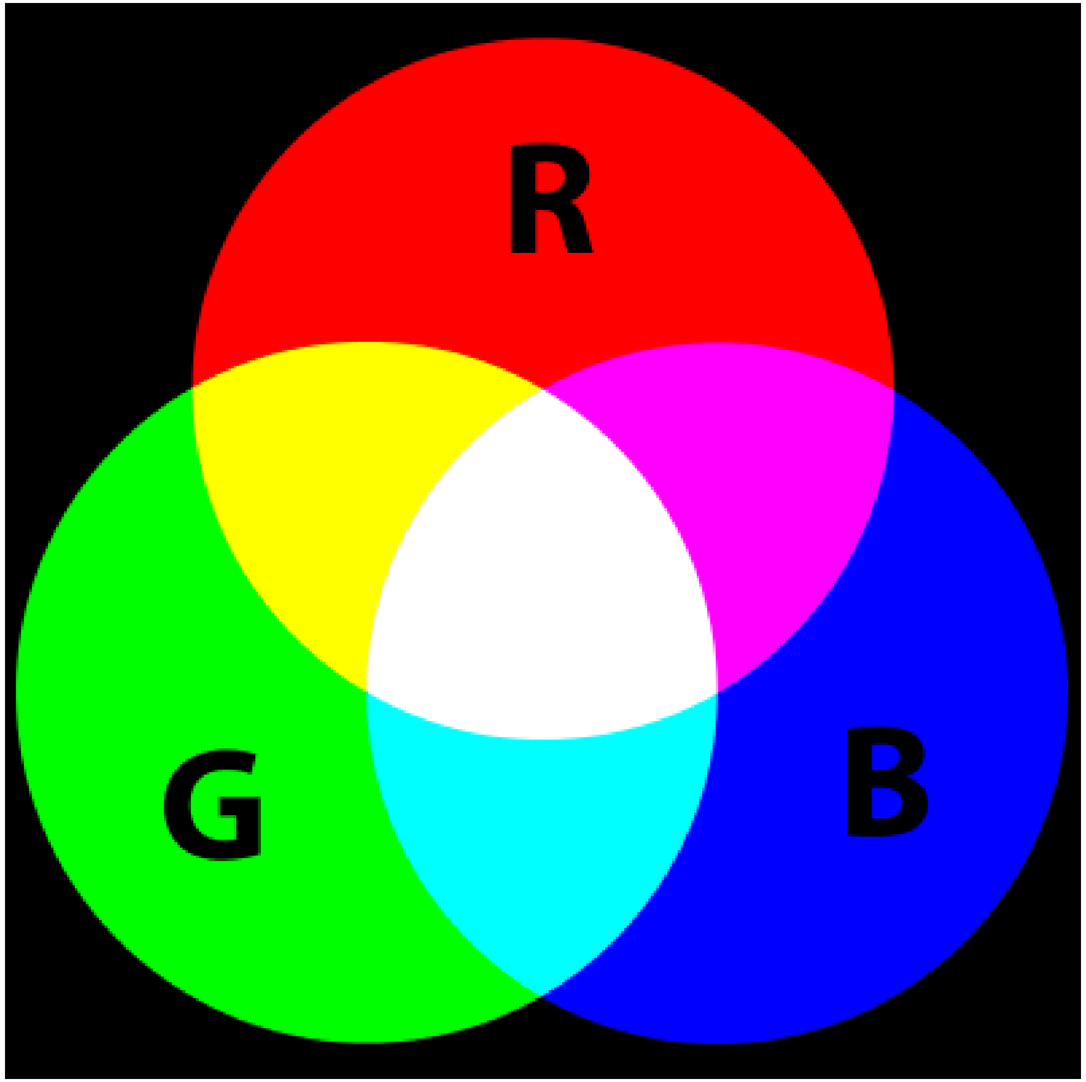




True Color Imagery (RGB, Level 1)

RGB Imagery

- Create an image using any 3 bands
- Load red, green, and blue satellite bands into corresponding display channels
- Simulates what the human eye sees



True Color Image (or RGB) for Visible Smoke

A MODIS (VIIRS) "true color image" uses visible wavelength bands.

R = 0.66 µm (0.640)

G = 0.55 µm (0.555)

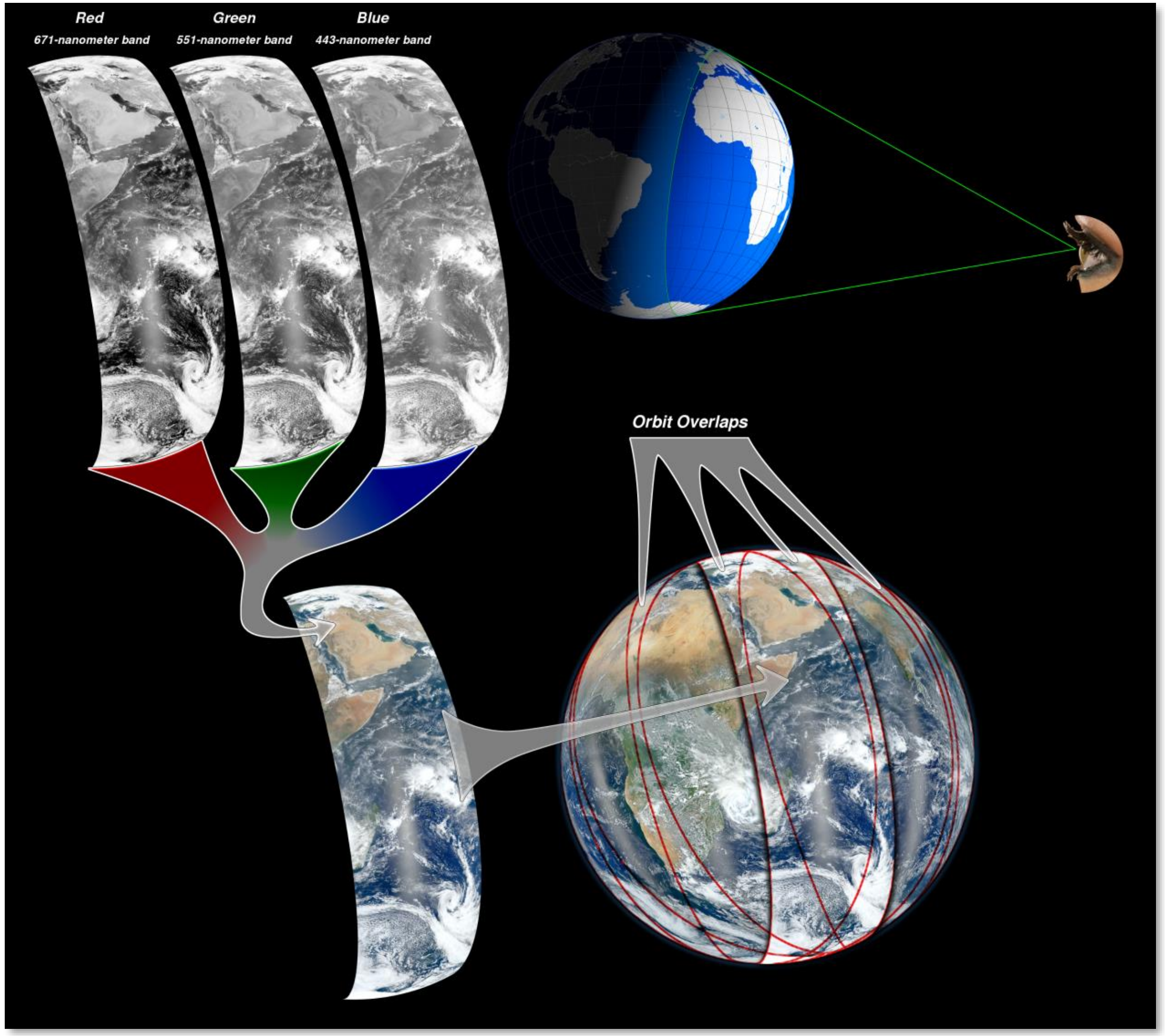
B = 0.47 µm (0.488)

An AHI (ABI) "true color image" uses visible wavelength bands.

R = 0.64 µm (0.64)

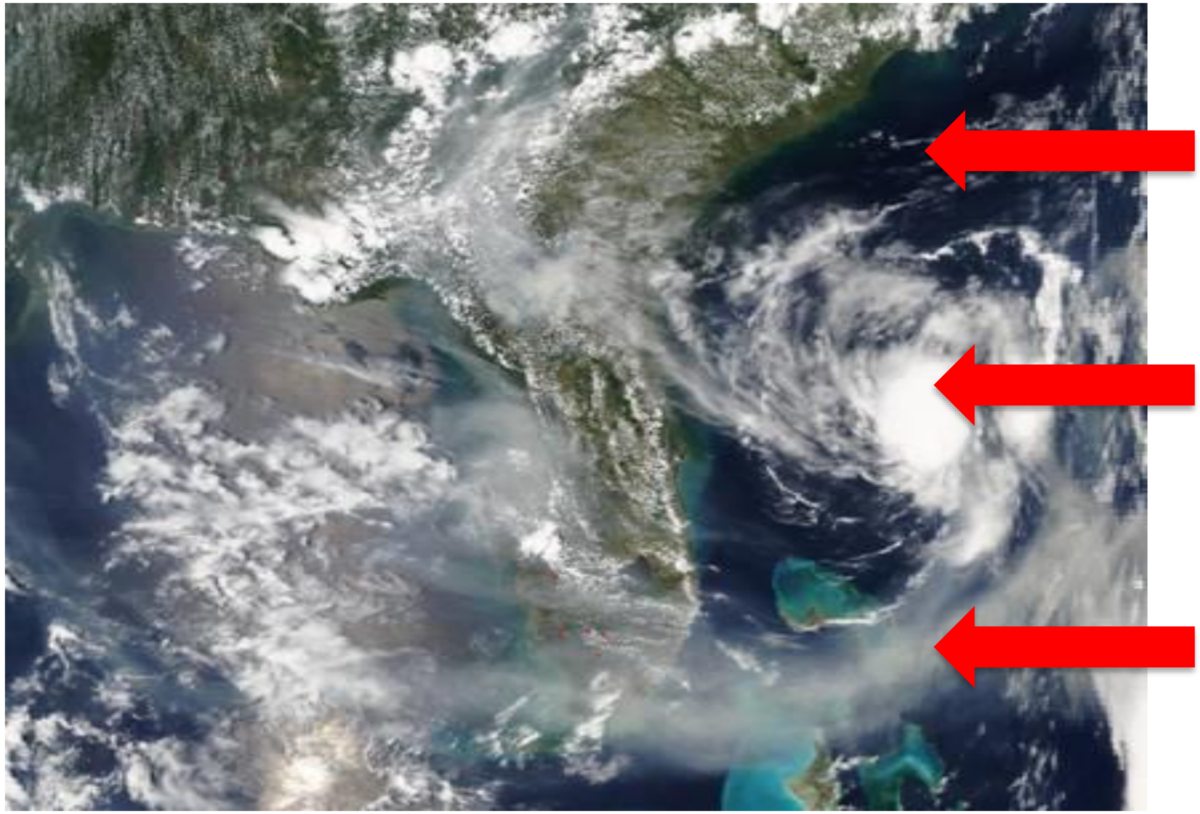
G = 0.51 µm (not available)

B = 0.46 µm (0.47)



Doing More with Satellite Imagery

If we understand the physics of how particular wavelengths interact with objects, we can create images to emphasize what we want to see.



Visible imagery water is dark because it absorbs most of the energy.

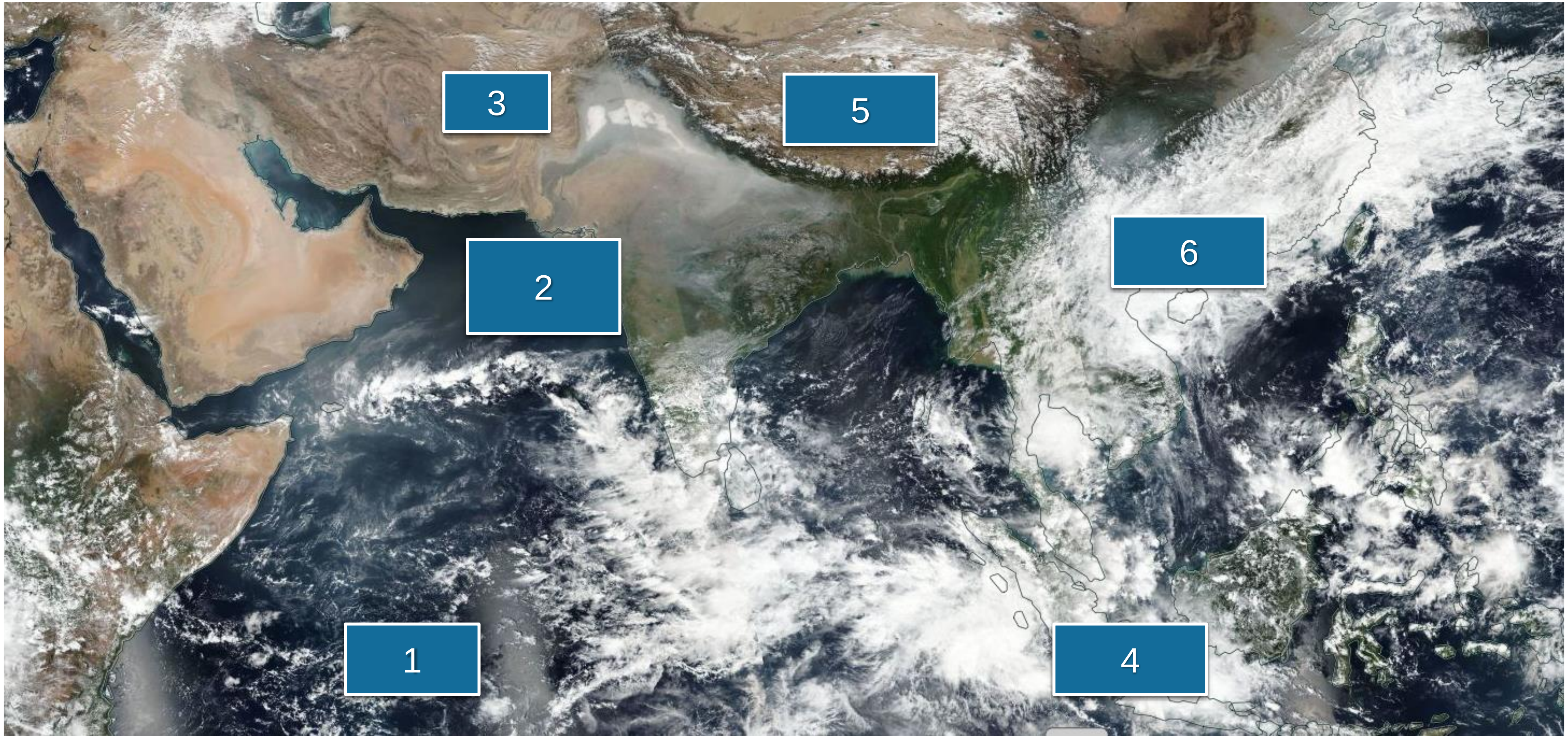
Clouds are white because they reflect most of the incoming energy.

Pollution is hazy depending on its absorption properties.

What can we learn from true color imagery?

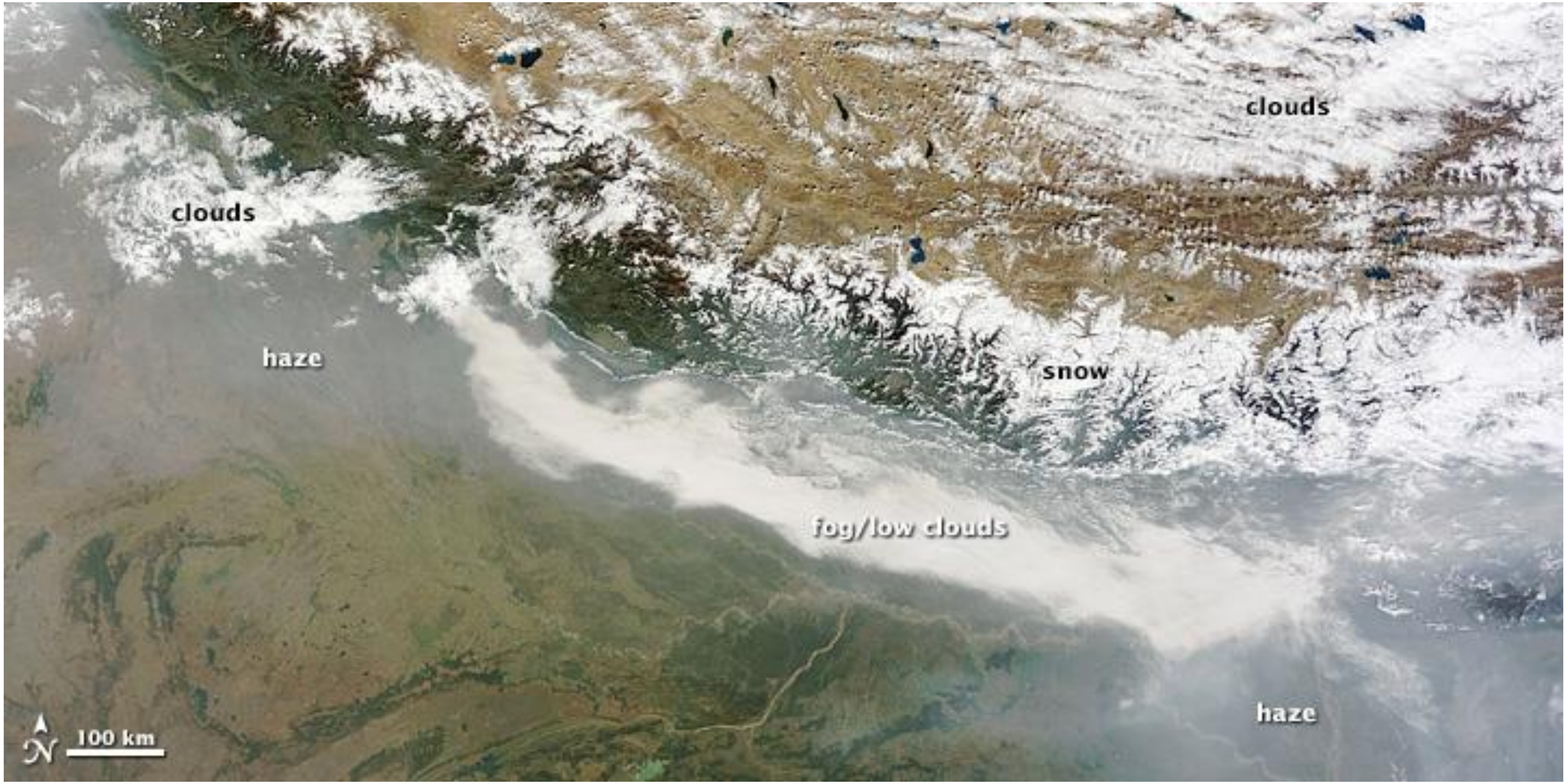
(Possible) Identification of Land, Ocean, and Atmosphere Features

What can we learn from true color imagery?

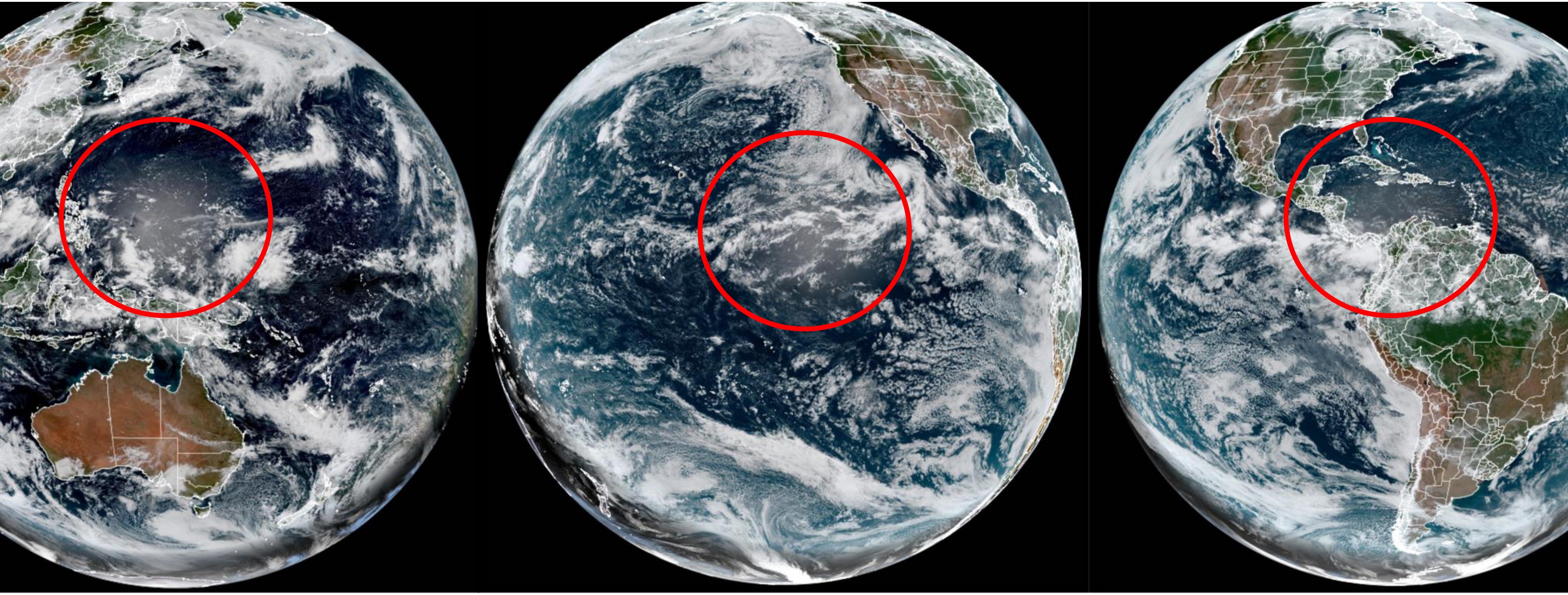


(Possible) Identification of Land, Ocean, and Atmosphere Features

Features in True Color (Atmosphere)

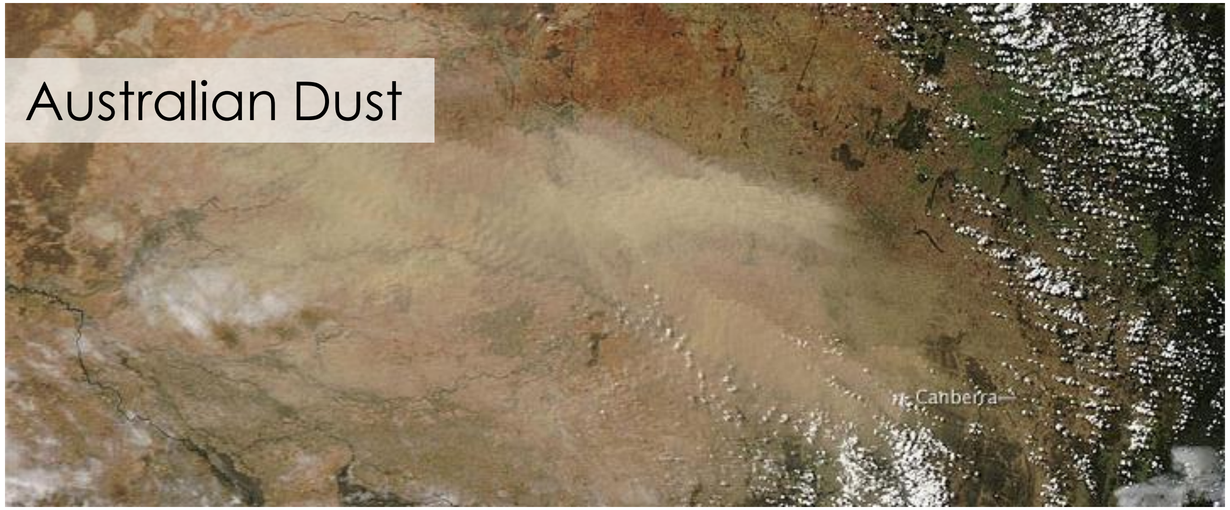


Glint



Feature Identification

More reliable when a clear source is in the image



Feature Identification

More reliable when a clear source is in the image

GOES-16: Smoke Transport over the Northwest

Fast changing air quality due to smoke transport can be captured by GEO sensors

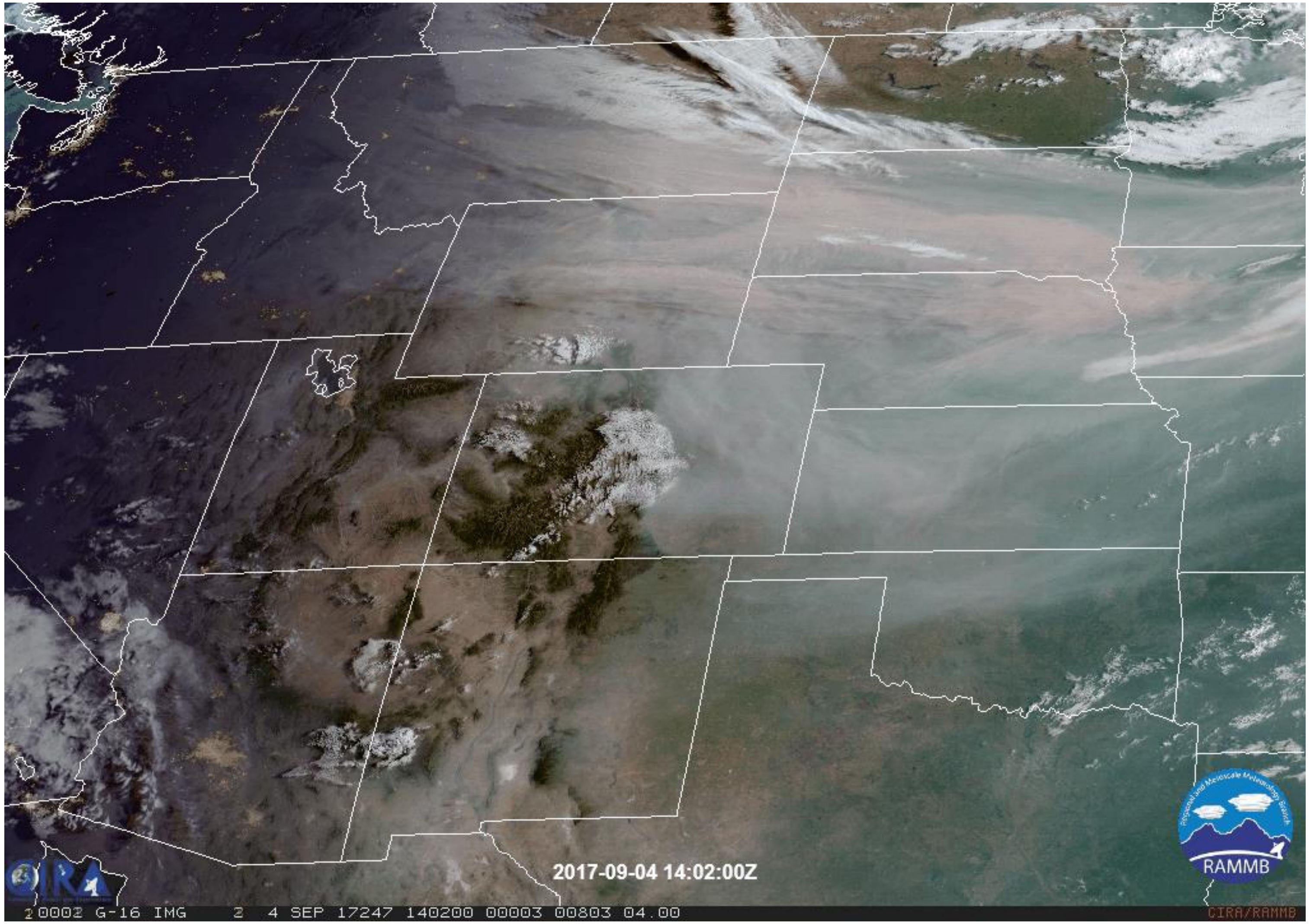


Image: [RMMB]

GOES-16 Loop: Dust

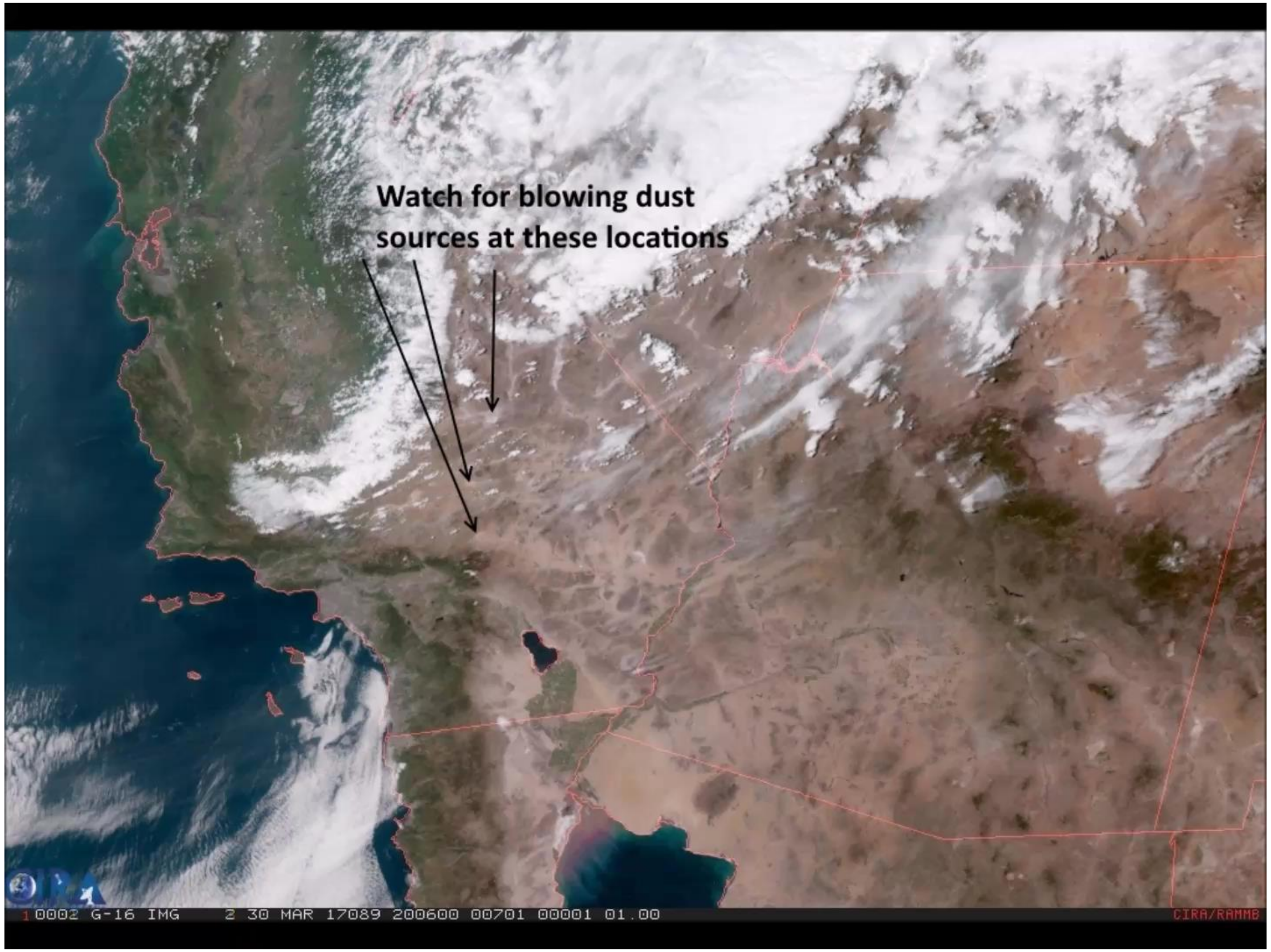


Image: [RMMB]

GOES-16 Loop: Smoke Over the Southeast U.S.

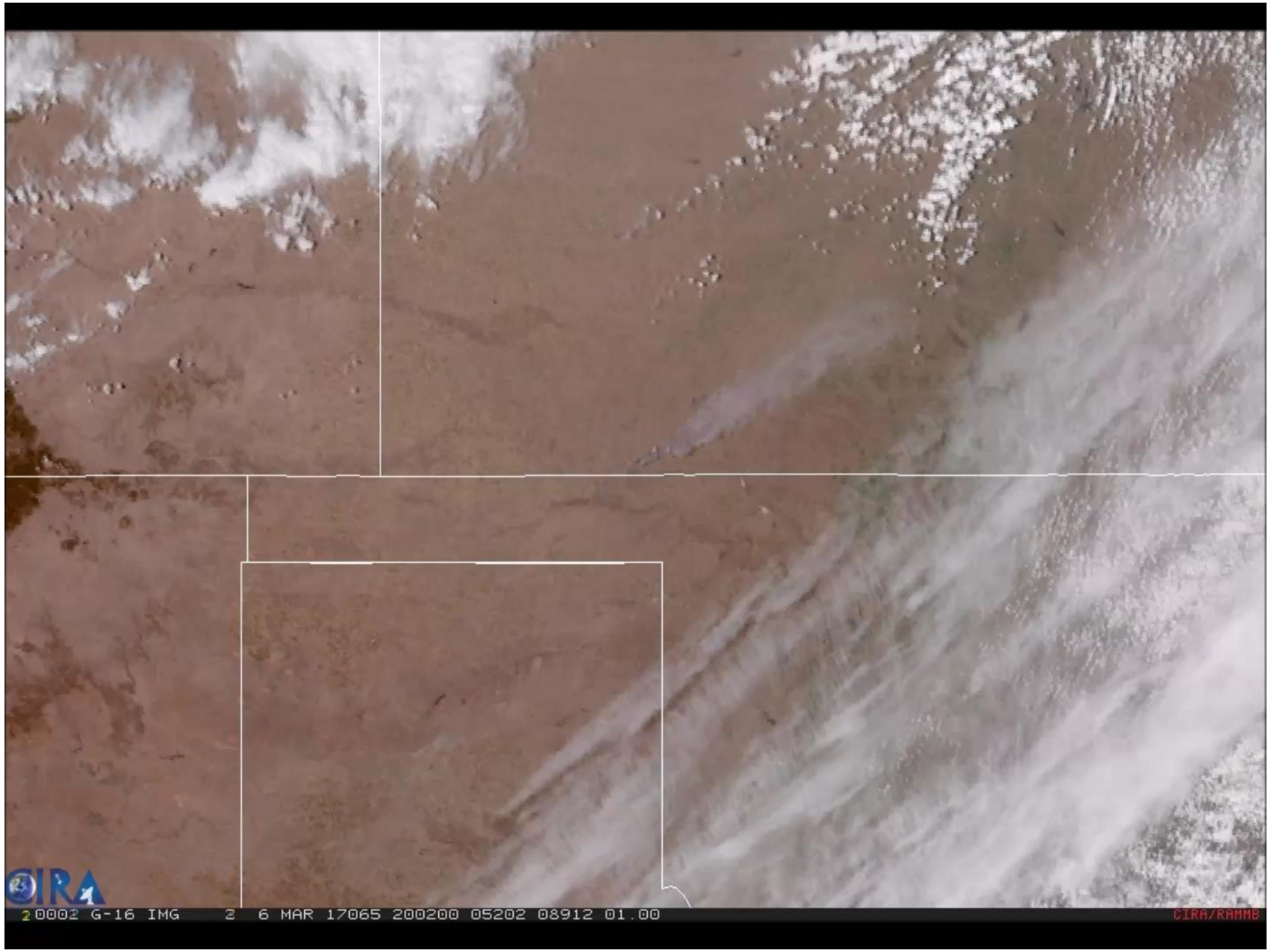
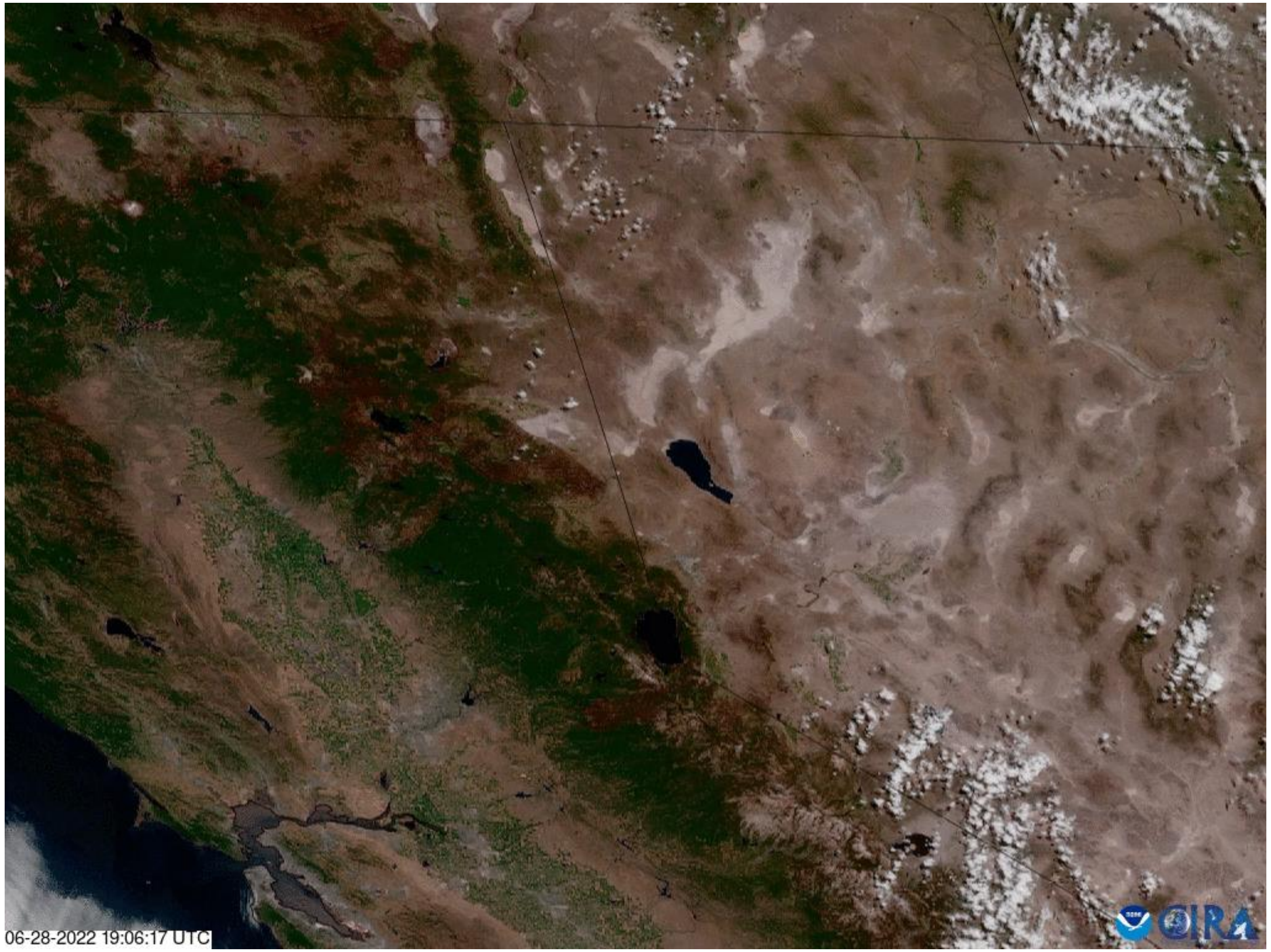


Image: RMMB

McKinney Fire (US) – GOES-17 (GeoColor)

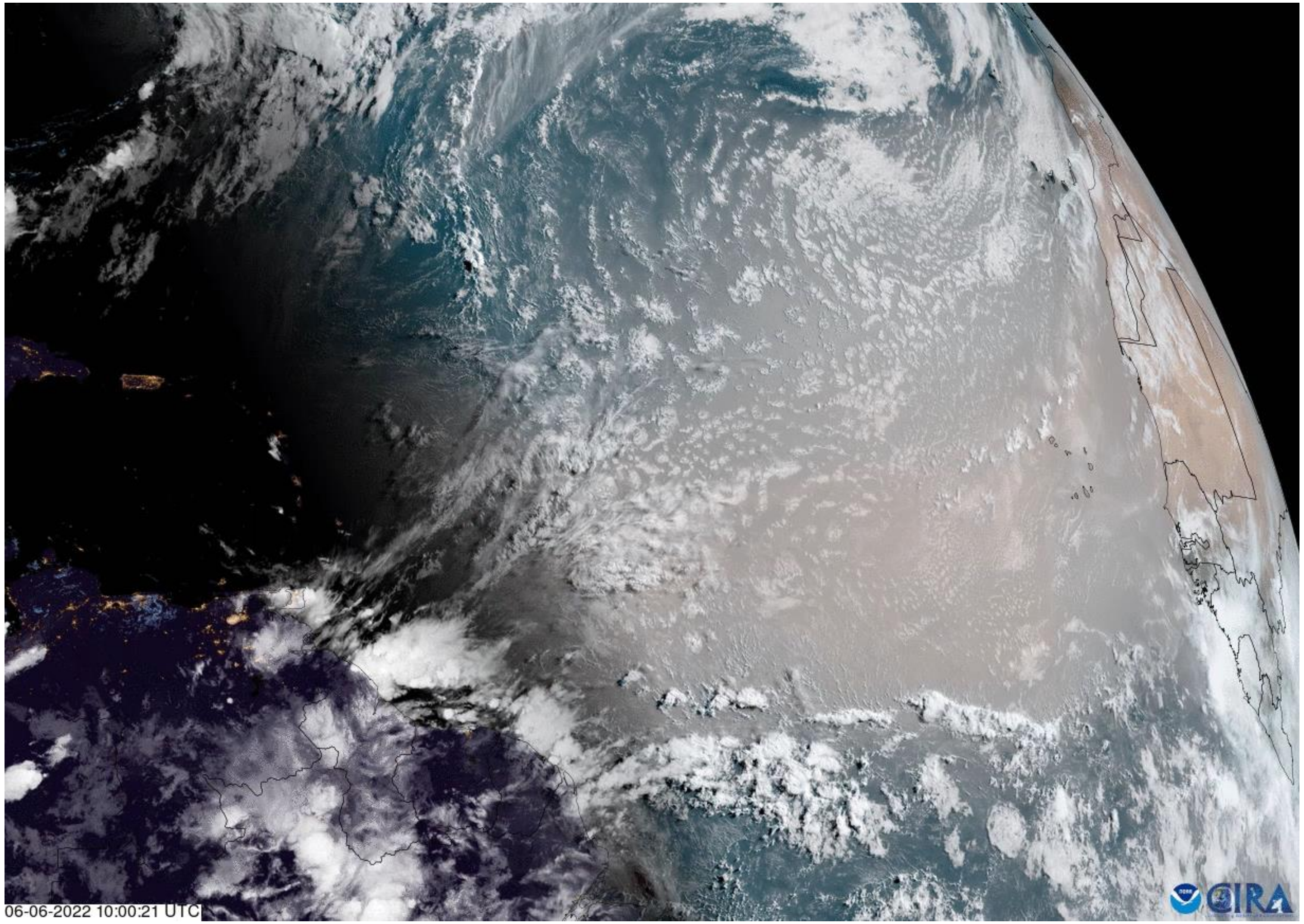
https://rammb.cira.colostate.edu/ramsdis/online/loop_of_the_day/

Rices Fire (US) – GOES-17 (GeoColor)



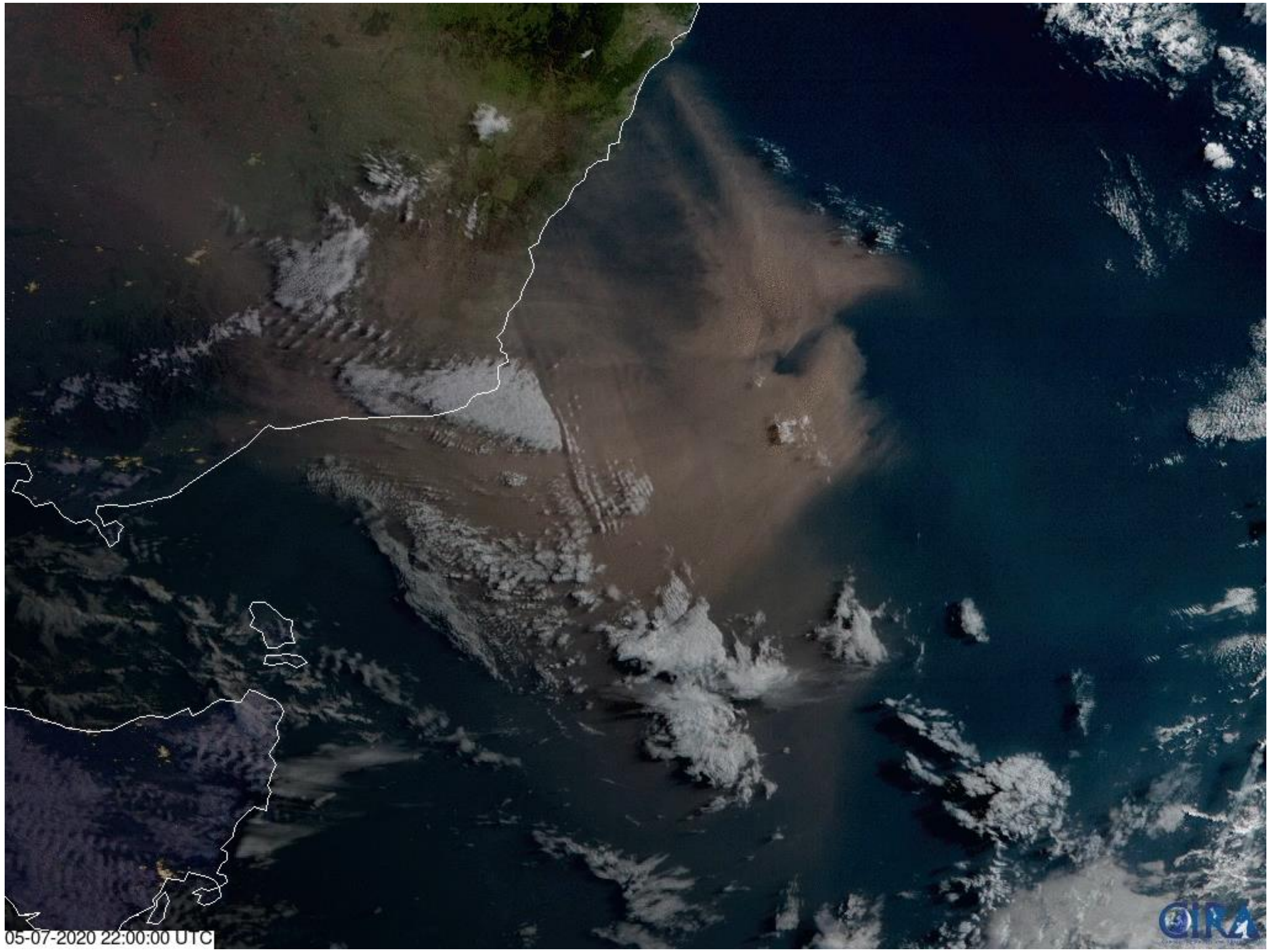
https://rammb.cira.colostate.edu/ramsdis/online/loop_of_the_day/

GOES-East (Dust over the Atlantic)



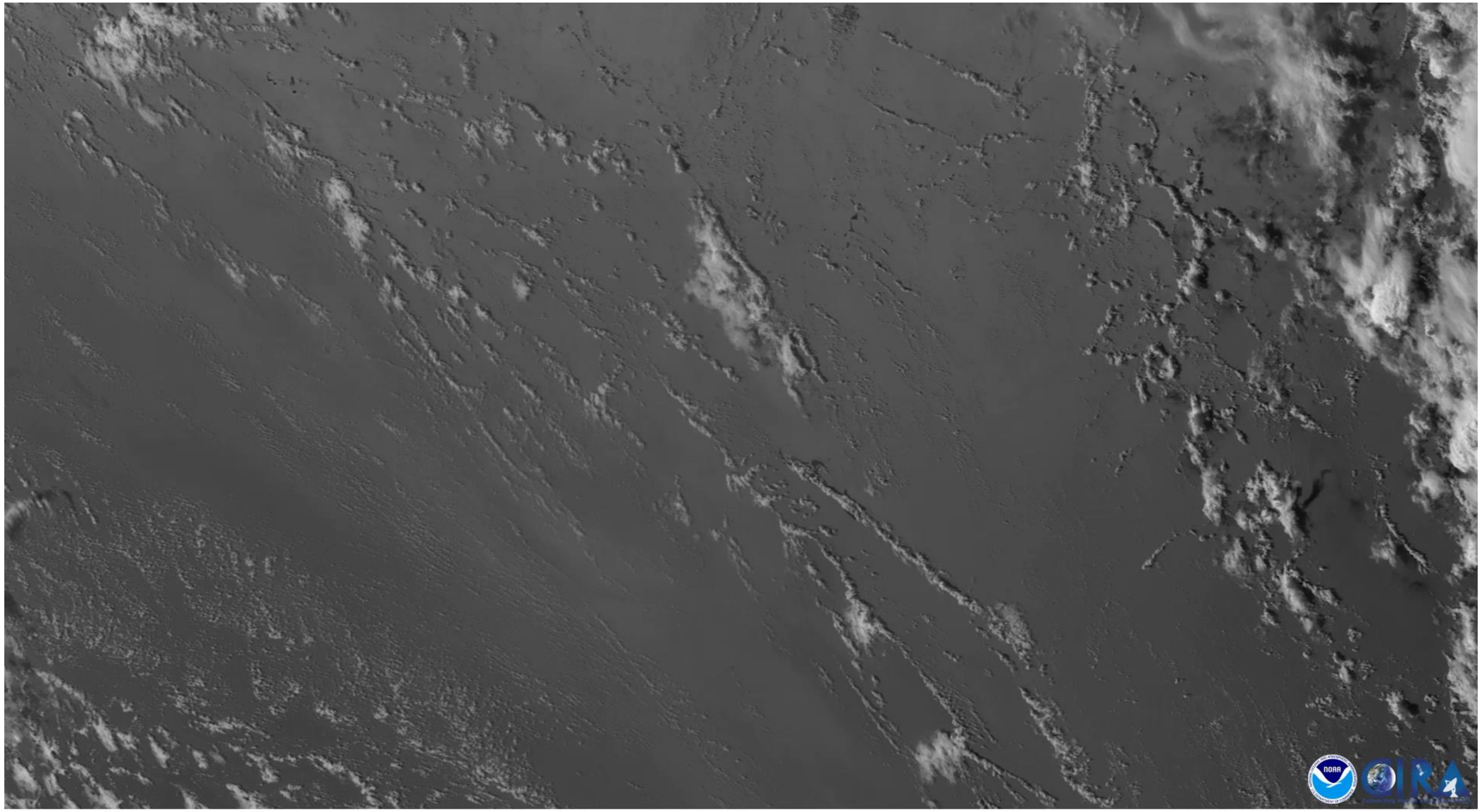
https://rammb.cira.colostate.edu/ramsdis/online/loop_of_the_day/

Himawari-08 (AHI) – Dust over Australia (May 8th, 2020)

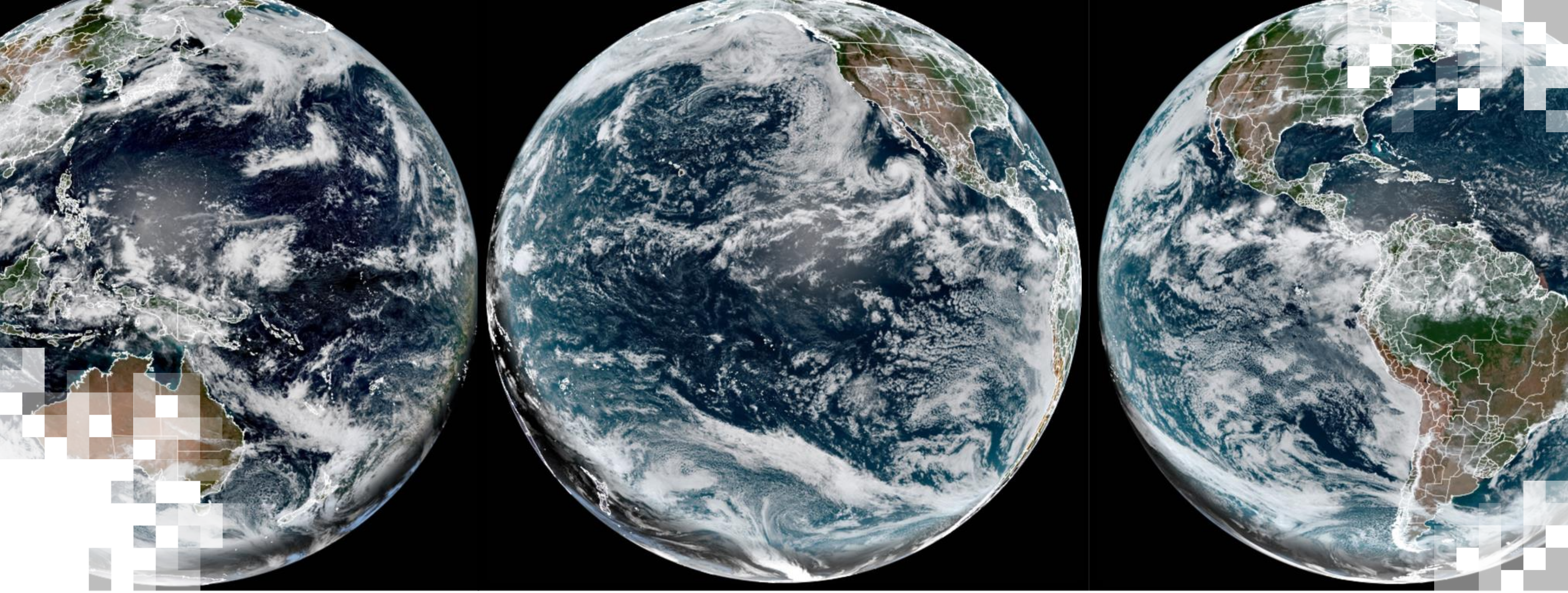


Hunga Tonga-Hunga Ha'apai's Eruption

January 15th, 2022 in the South Pacific

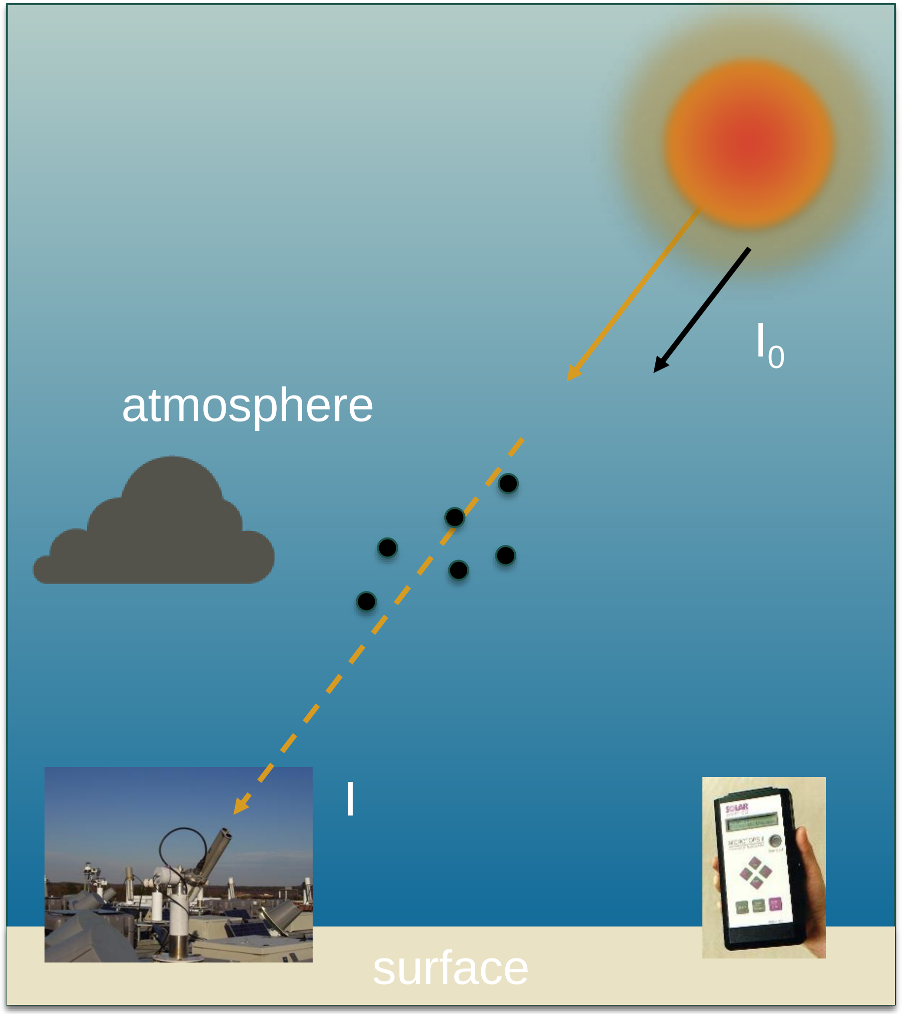


01-15-2022 | 03:10:32 UTC | GOES-17 | Visible (Band 2)



Satellite Data and AQ

Optical Depth



The optical depth expresses the quantity of light removed from a beam by **scattering** or/and **absorption** during its path through a medium

optical depth τ as:

$$I = I_o e^{-m\tau}$$
$$m = \sec\theta_0$$
$$\tau = \tau_{Rayl} + \tau_{aer} + \tau_{gas}$$

Inferring AOD and PM2.5 from Visuals

Pittsburgh

$PM_{2.5}$ = 45 µgm^{-3}

$PM_{2.5}$ = 4 µgm^{-3}

Pictures are taken from the same location, at the same time of day, on two different days

AOD = ~0.8

AOD = ~0.1

Image Credit: Learning with CLEAR: Introduction to Aerosols - What Are Aerosols? http://caice.ucsd.edu/index.php/education/clear/learning-with-clear/introduction-to-aerosols/

Air Quality Monitoring and Reporting

AQI
AIR QUALITY INDEX

Air Quality Index (AQI) Values	Levels of Health Concern
0 to 50	Good
51-100	Moderate
101-150	Unhealthy for Sensitive Groups
151-200	Unhealthy
201-300	Very Unhealthy
301 to 500	Hazardous

Spatial Gaps

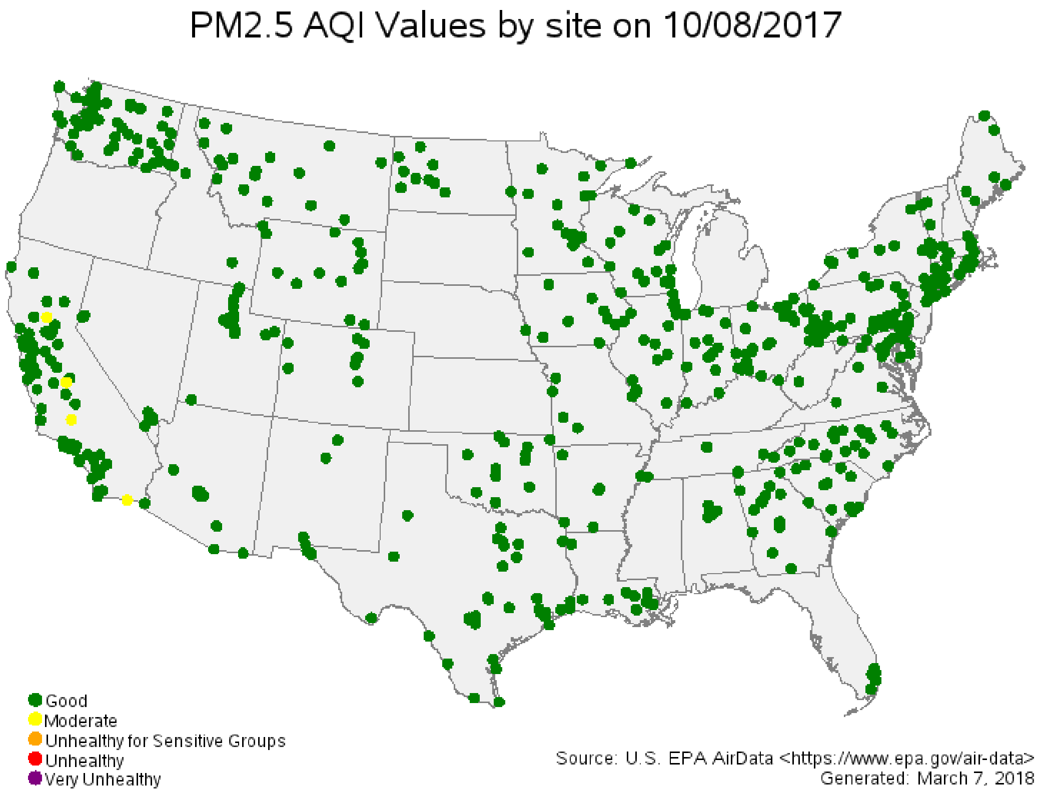


Image Credit: AirNow map, USEPA. http://www.airnow.gov

Image Archive and Gallery Links

- ARSET Satellite Imagery Overview and links
  - http://airquality.gsfc.nasa.gov/
- MODIS Rapid Response Site
  - http://earthdata.nasa.gov/data/near-real-time-data/rapid-response
- NASA's Visible Earth
  - http://visibleearth.nasa.gov
- NASA's Earth Observatory
  - http://earthobservatory.nasa.gov
- NASA's Earth Observations (NEO)
  - http://neo.sci.gsfc.nasa.gov
- MODIS-Atmos (MODIS Atmosphere Product Reference Site)
  - http://modis-atmos.gsfc.nasa.gov/IMAGES/index.html
- GLIDER Tool
  - http://www.ssec.wisc.edu/hydra

Reference Paper

A CLOSER LOOK AT THE ABI ON THE GOES-R SERIES

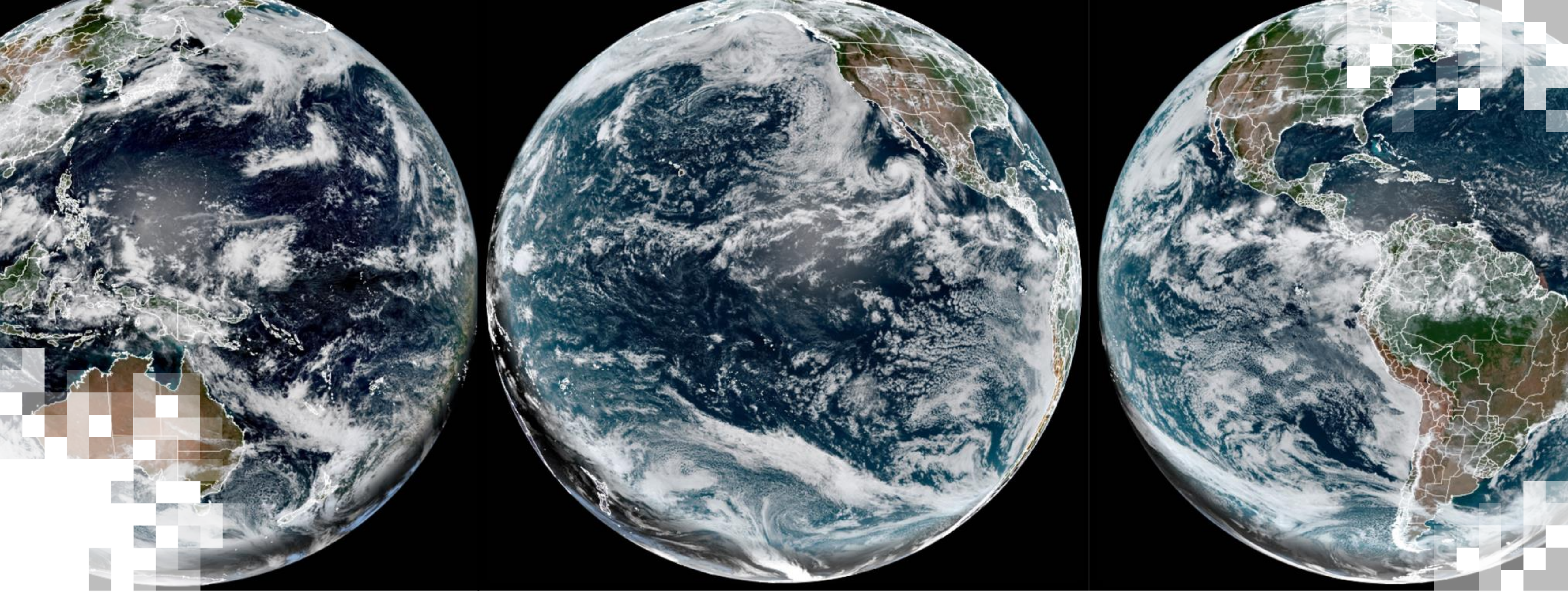
Timothy J. Schmit, Paul Griffith, Mathew M. Gunshor, Jaime M. Daniels,
Steven J. Goodman, and William J. Lebair

The ABI on the GOES-R series is America's next-generation geostationary advanced imager and will dramatically improve the monitoring of many phenomena at improved time and space scales.

The era of imaging the Earth from the geostationary perspective began on 6 December 1966 with the launch of an experimental sensor (Spin-Scan Cloudcover Camera) on board *Application Technology Satellite-1* (*ATS-1*; Suomi and Parent 1968). The first operational follow-on satellite was the *Geostationary Operational Environmental Satellite-1* (*GOES-1*), launched in October 1975 (Davis 2007). *ATS-1* had only visible sensors, while *GOES-1* had both visible and infrared (IR) sensors, allowing for monitoring clouds at night. Subsequent generations of sensors improved the spectral coverage, added an operational sounder, and many other improvements (Menzel and Purdom 1994). The Advanced Baseline Imager (ABI) on the GOES-R series continues this coverage, with a greatly improved sensor. The mission of the ABI is to measure Earth's radiant and reflective solar energy at moderate spatial and spectral resolution and high temporal and radiometric resolution. The first satellite in the GOES-R series was launched on 19 November 2016. The ABI is a state-of-the-art 16-band radiometer, with spectral bands covering the visible, near-infrared, and IR portions of the electromagnetic spectrum (Table 1). Many attributes

AFFILIATIONS: Schmit—NOAA/NESDIS/Center for Satellite Applications and Research/Advanced Satellite Products Branch, Madison, Wisconsin; Griffith—Space and Intelligence Systems, Harris Corporation, Fort Wayne, Indiana; Gunshor—Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin–Madison, Madison, Wisconsin; Daniels—NOAA/NESDIS/Center for Satellite Applications and Research, Operational Products Development Branch, College Park, Maryland;

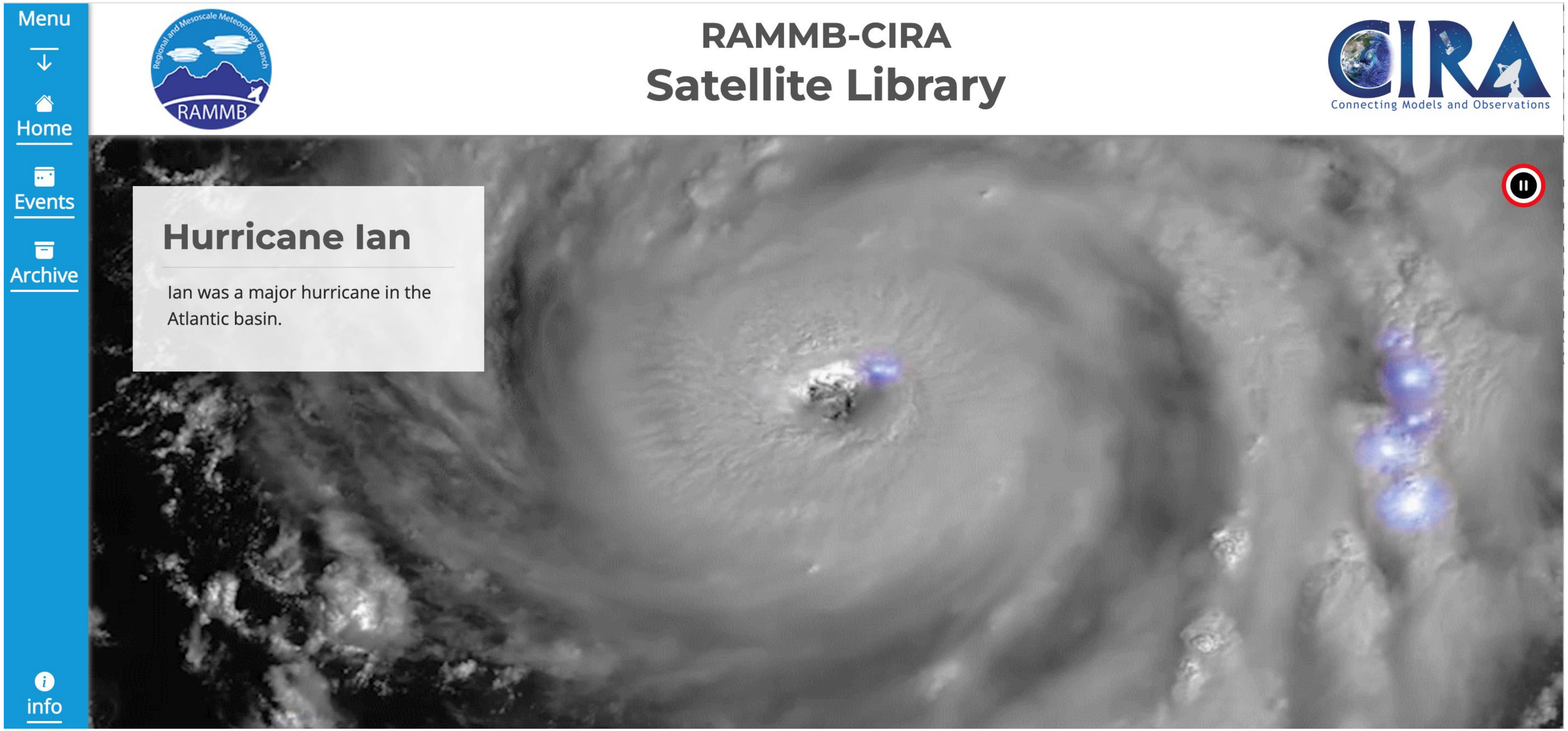
- https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-15-00230.1



Online Tools

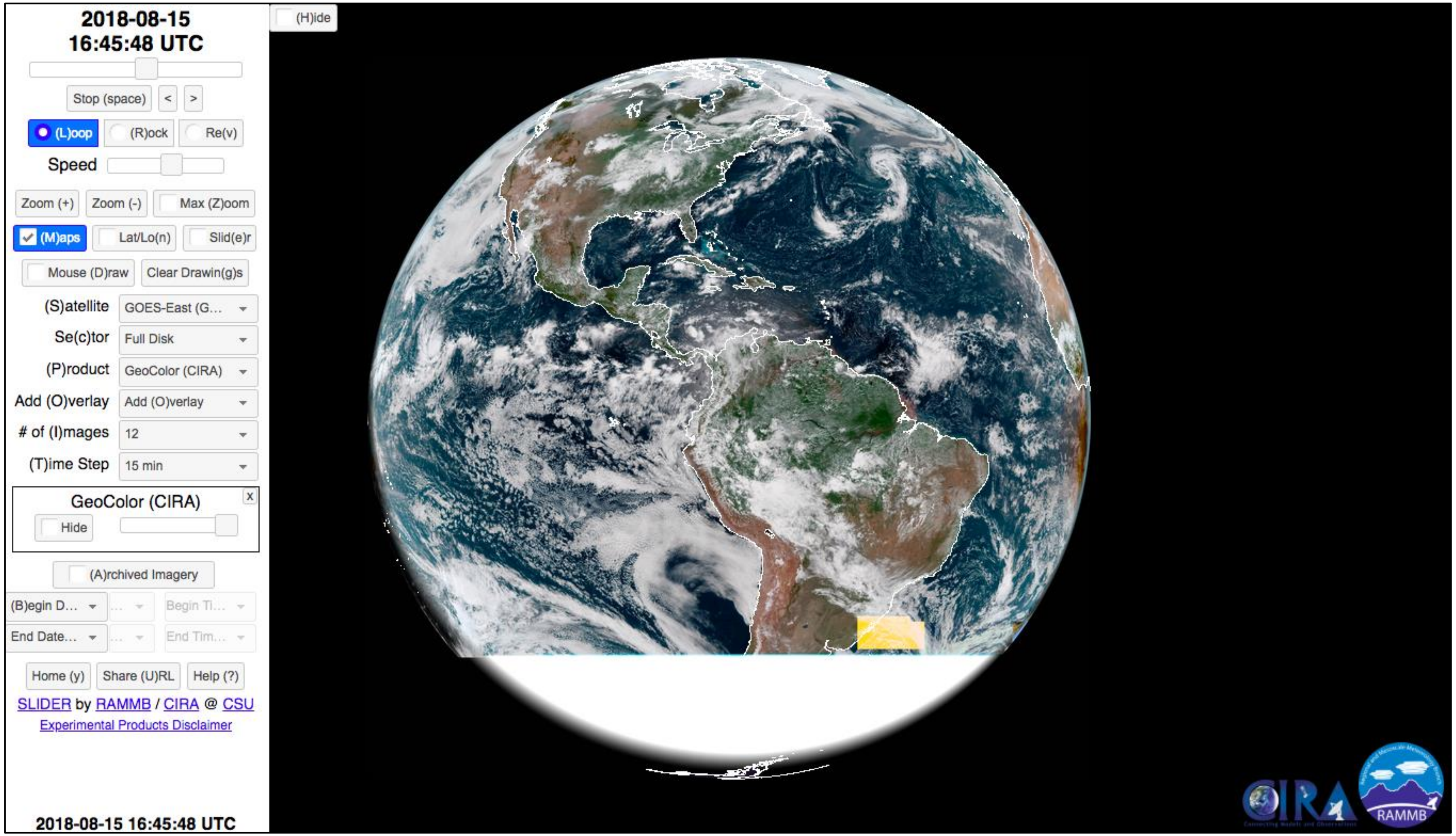
Satellite Library

https://satlib.cira.colostate.edu/



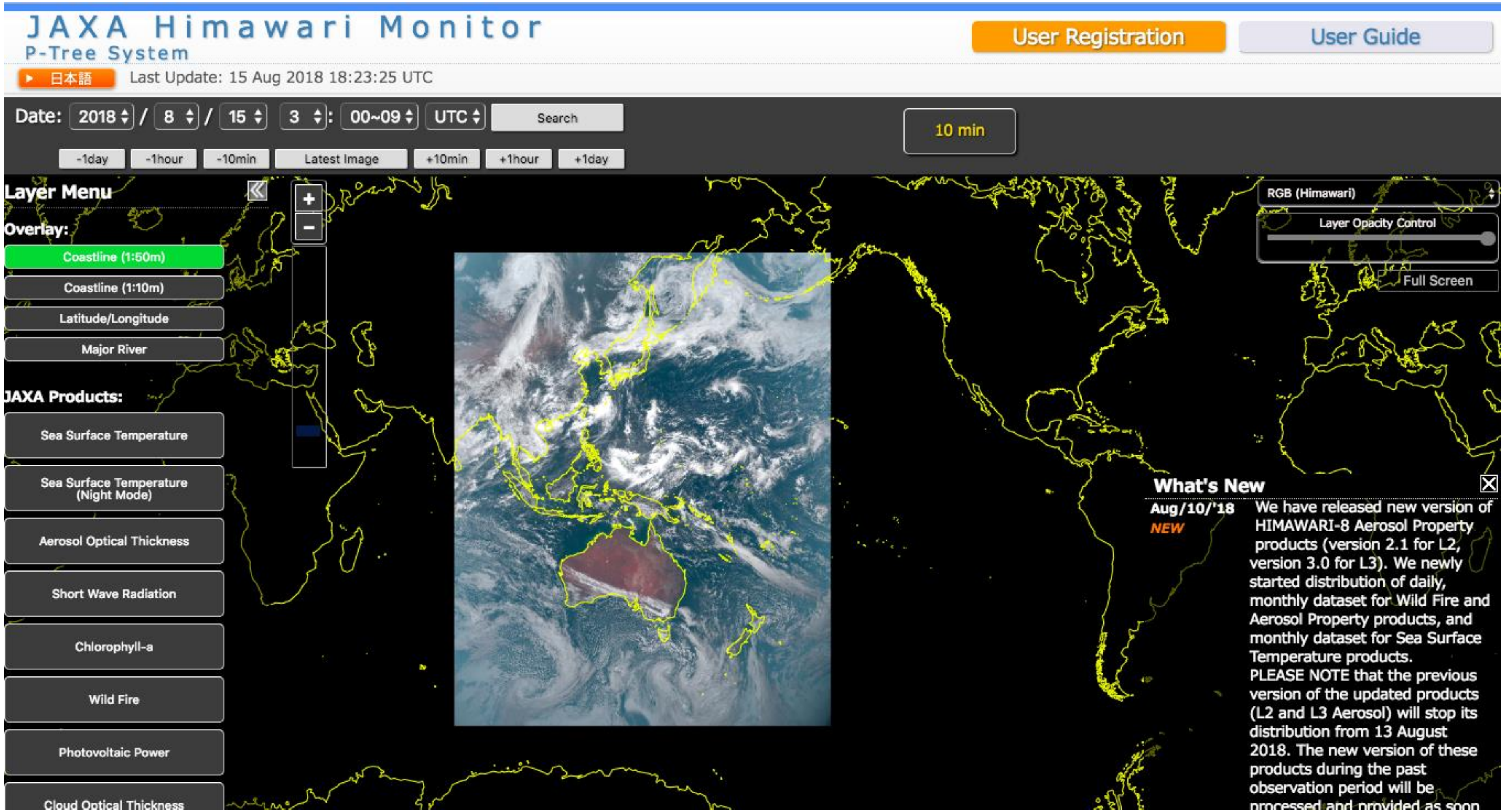
ABI & AHI Sliders

http://rammb-slider.cira.colostate.edu/



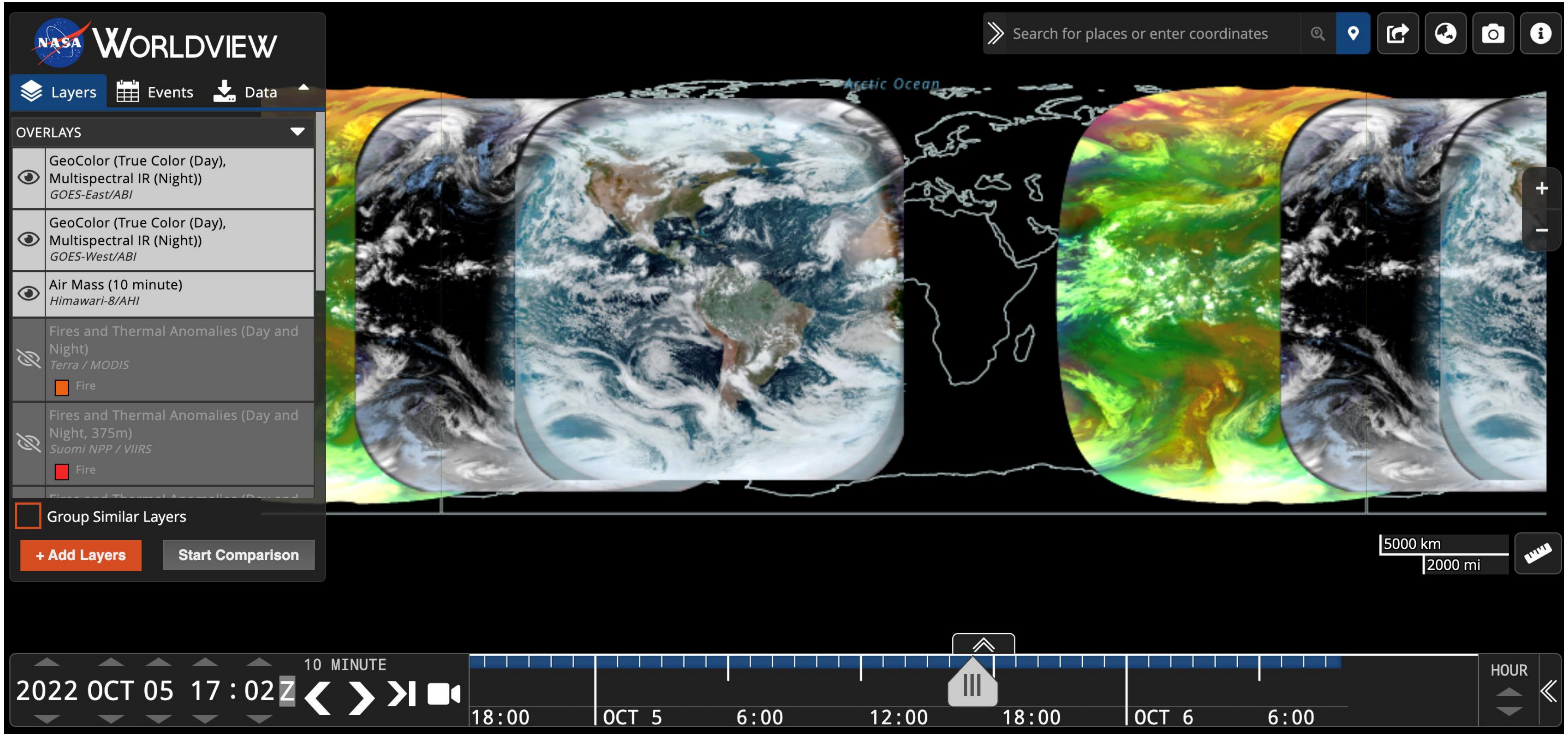
AHI Viewer – P-Tree

http://www.eorc.jaxa.jp/ptree/



NASA Worldview

https://worldview.earthdata.nasa.gov/



Events to Tour

- Jan 15th, 2022 – 3 UTC Onward (https://satlib.cira.colostate.edu/event/hunga-tonga-hunga-haapai-eruption/) - https://go.nasa.gov/3ym16NE
  - South Pacific Ocean, GOES-West
- March 15, 2021 (https://acp.copernicus.org/articles/22/6393/2022/acp-22-6393-2022.pdf) -
- Sep 6-15, 2022 - (https://satlib.cira.colostate.edu/event/mosquito-fire/) –
  - Sacramento, CA, GOES-East

Thank You!