

National Aeronautics and Space Administration



Introduction to Geostationary AQ Observations, Tools, and Data Access

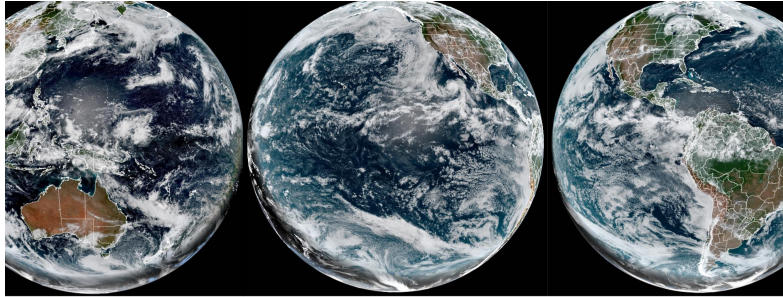
Pawan Gupta, Melanie Follette-Cook, and Sarah Strode

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



Training Outline

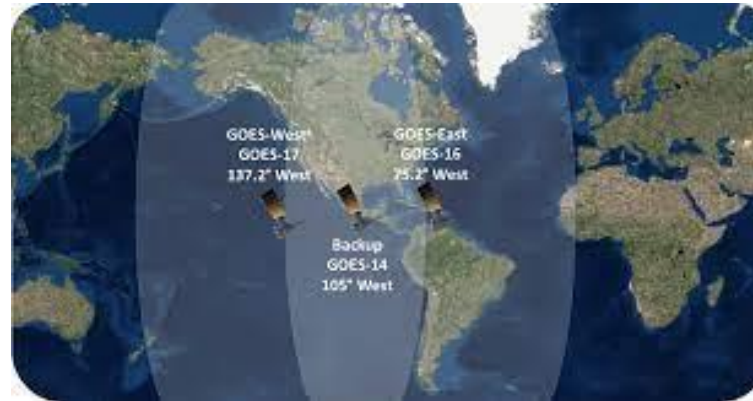
Part 1: October 11, 2022



Introduction to Geostationary AQ Observations, Tools, and Data Access

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

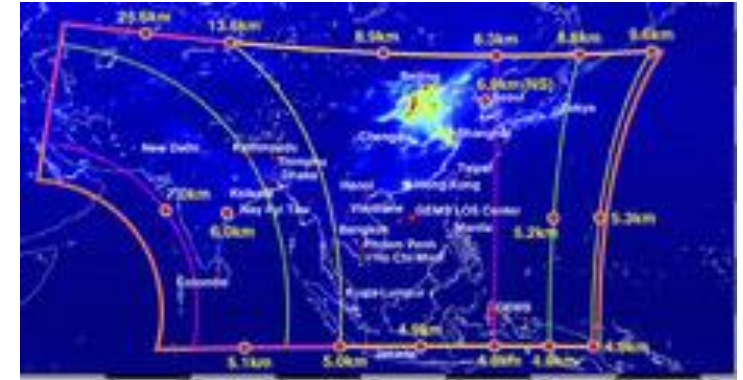
Part 2: October 18, 2022



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)

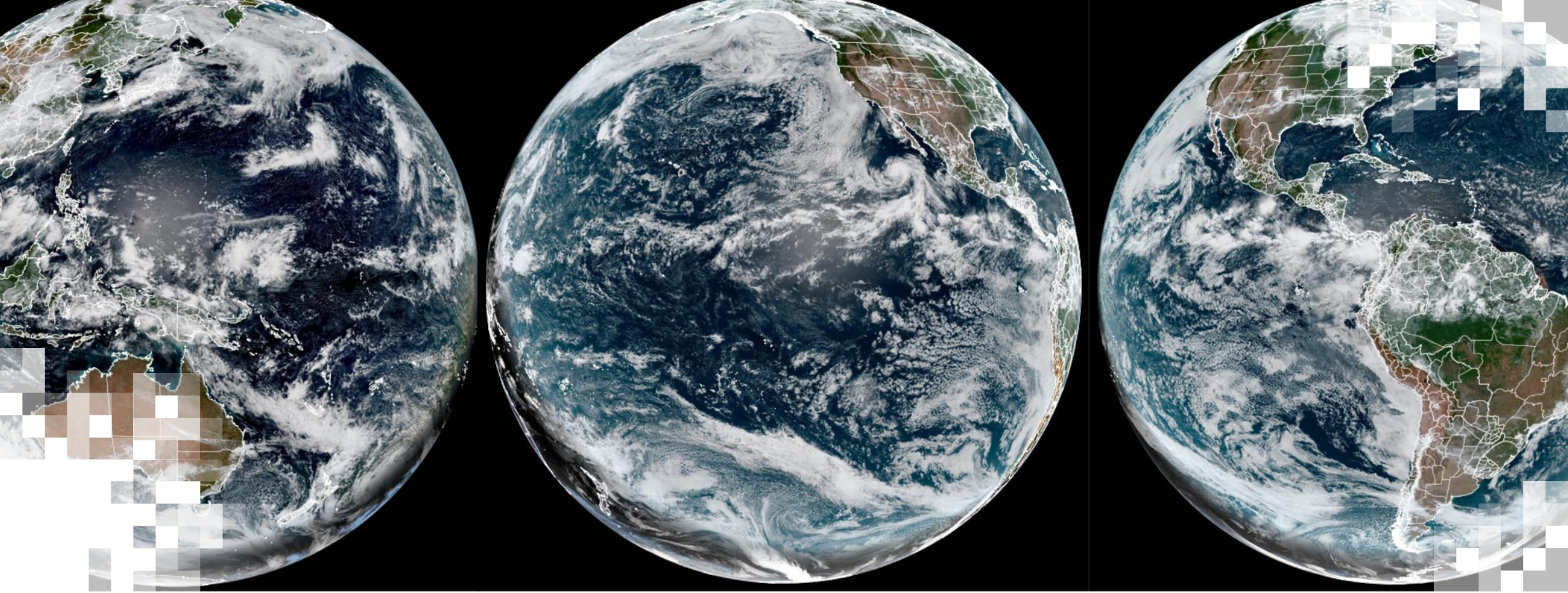


Learning Objectives

By the end of this session, participants will:

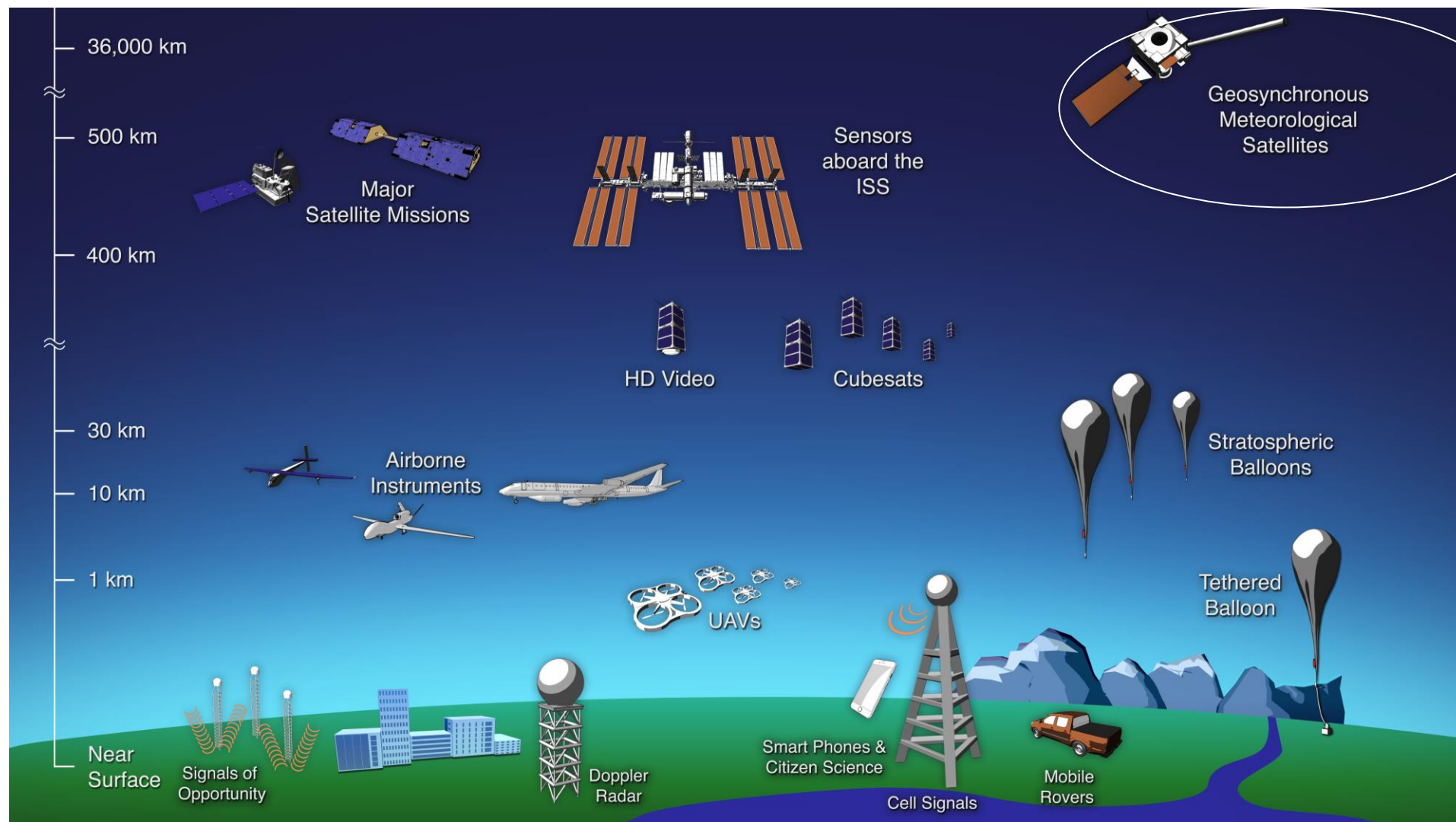
- Understand the fundamentals of geostationary orbit (GEO) remote sensing
- Understand the difference between low Earth orbit (LEO) and GEO observations
- Understand true color imagery and applications
- Locate and access GEO imagery from NASA Worldview, GEOslider websites
- Be introduced to the upcoming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



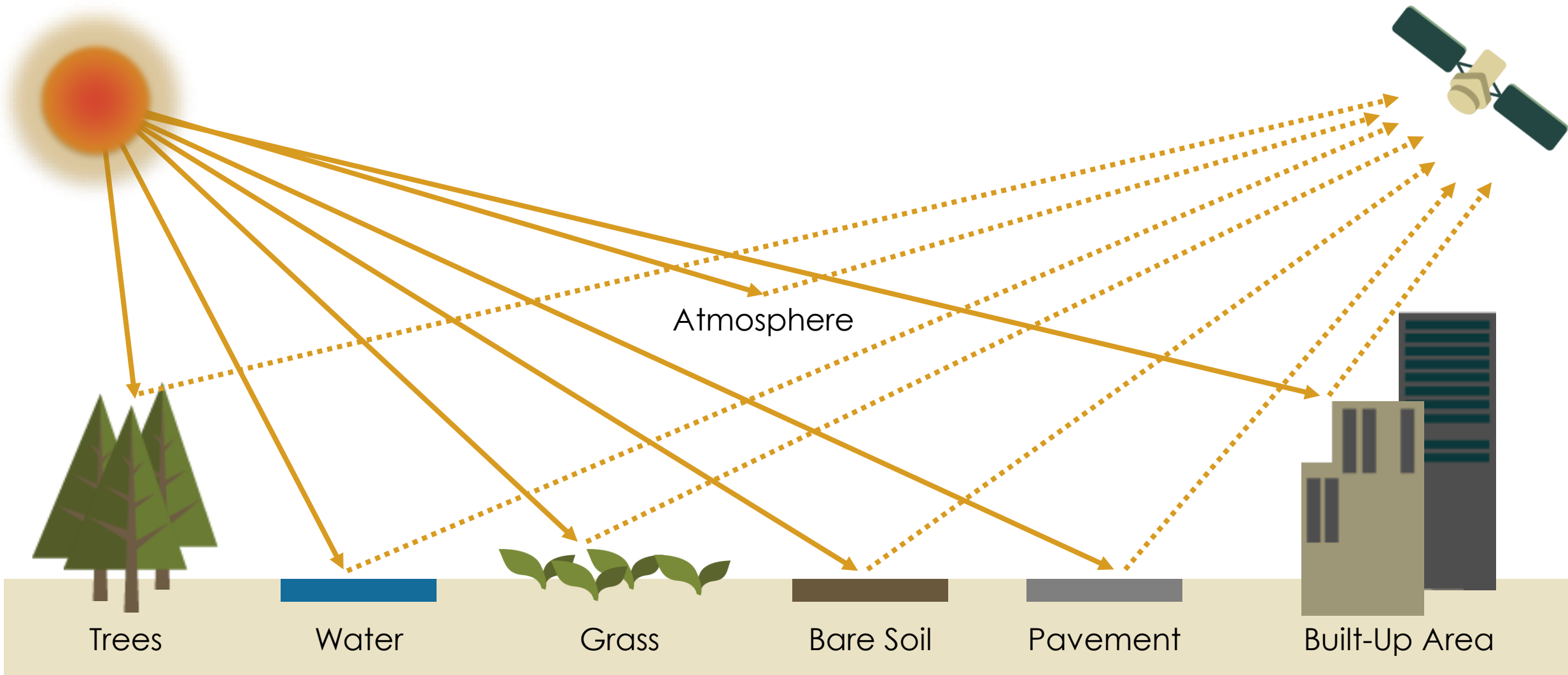


Review of Key Remote Sensing Concepts

Remote Sensing of Our Planet

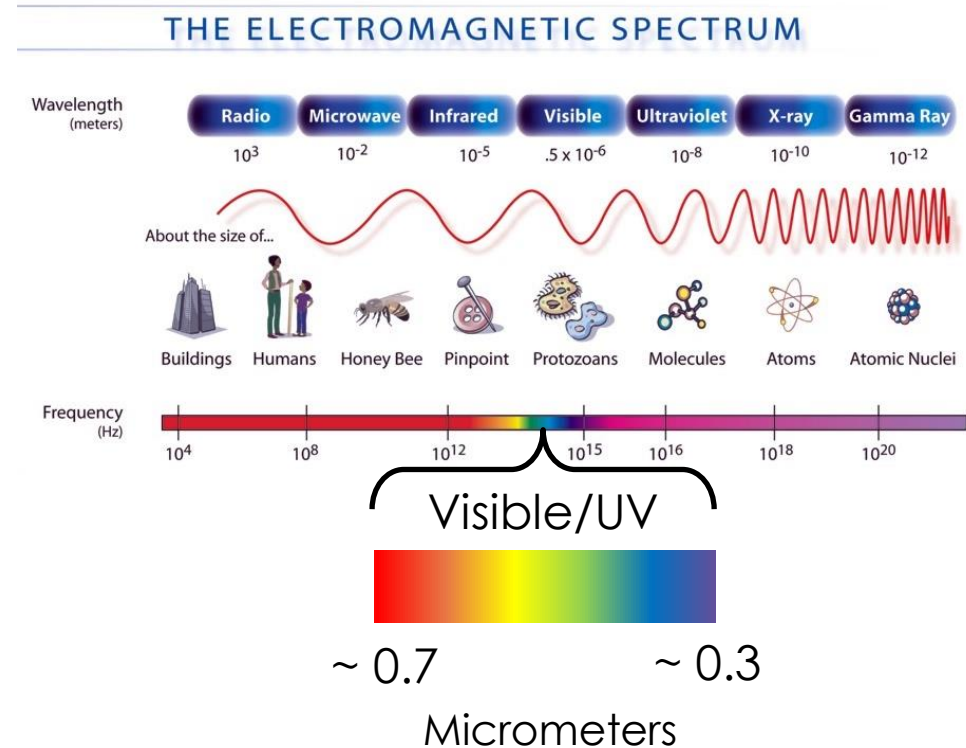
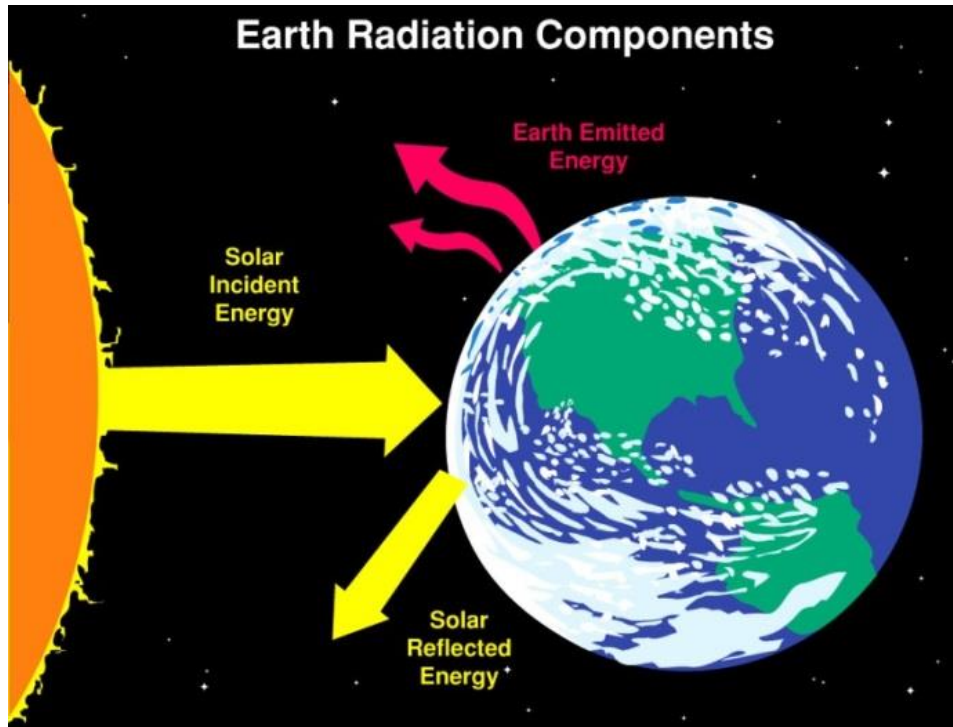


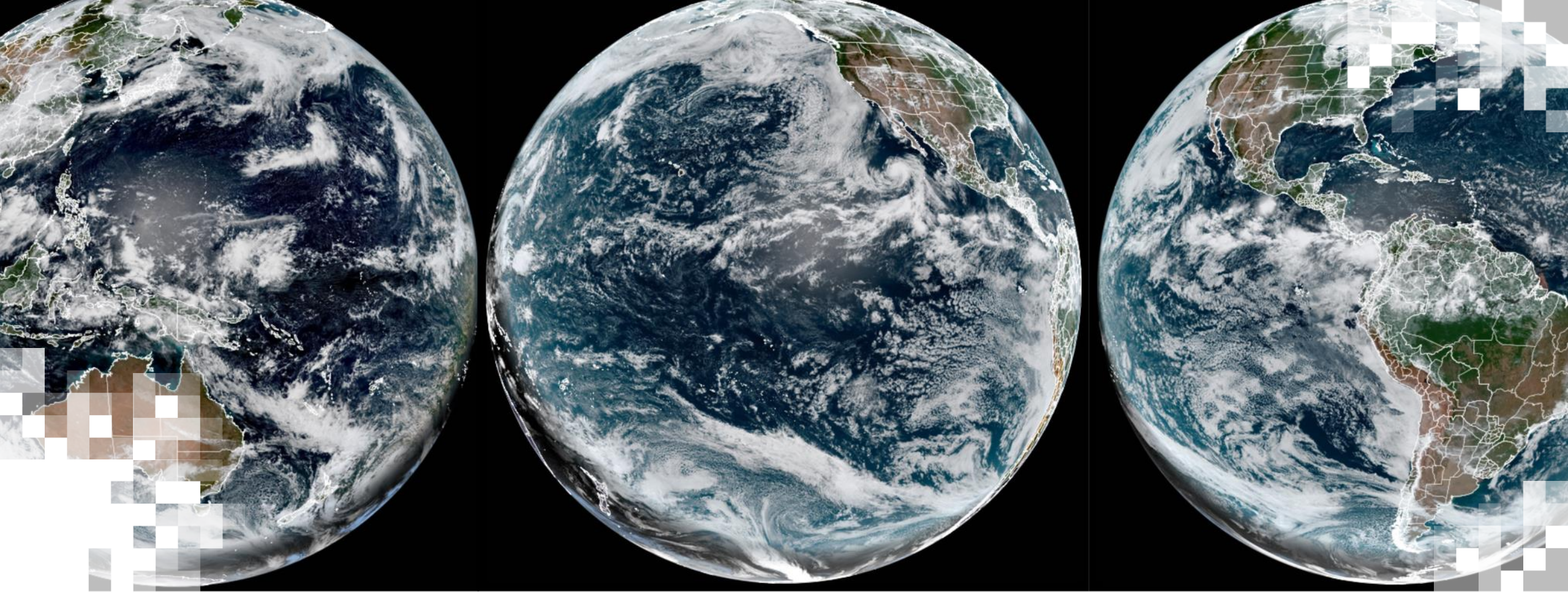
What do satellites measure?



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

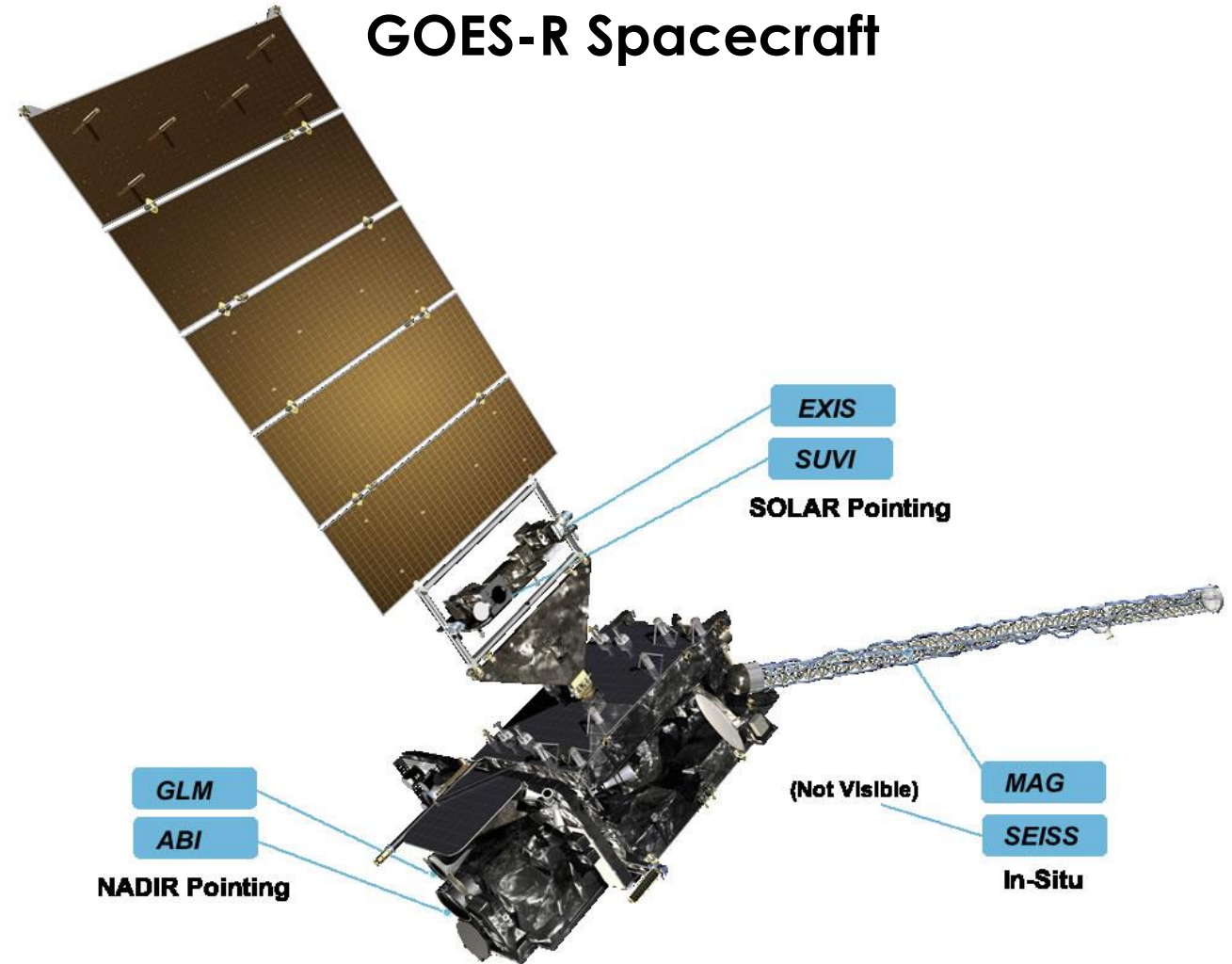
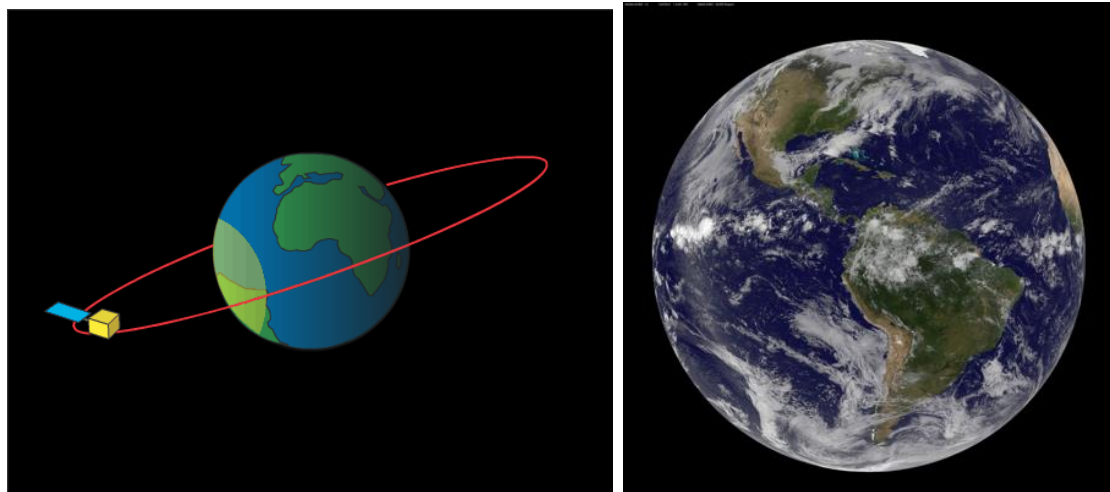


Image Credit: [NASA/NOAA](https://www.nasa.gov/)

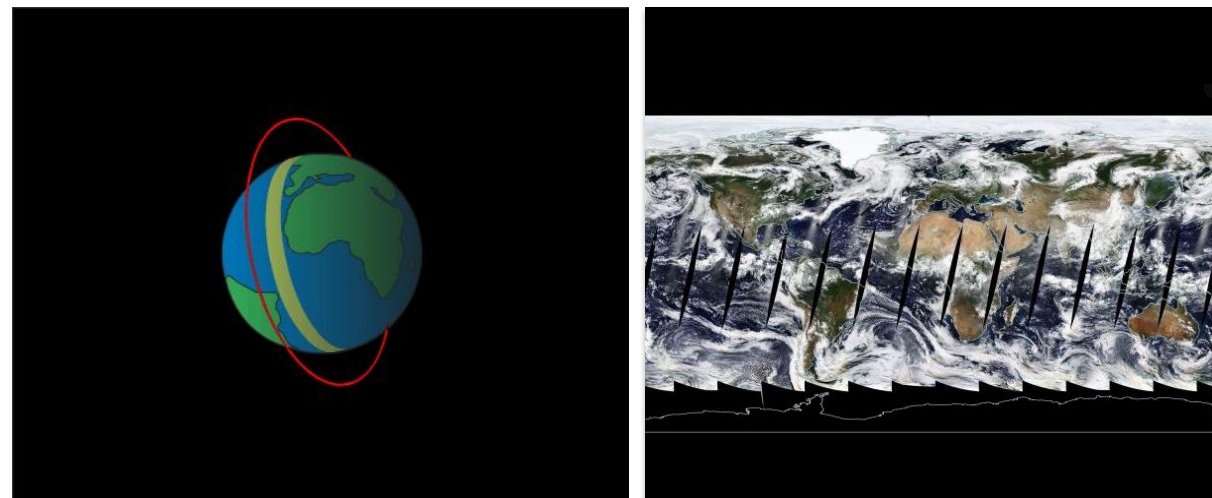


Common Orbit Types



Geostationary Orbit (GEO)

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



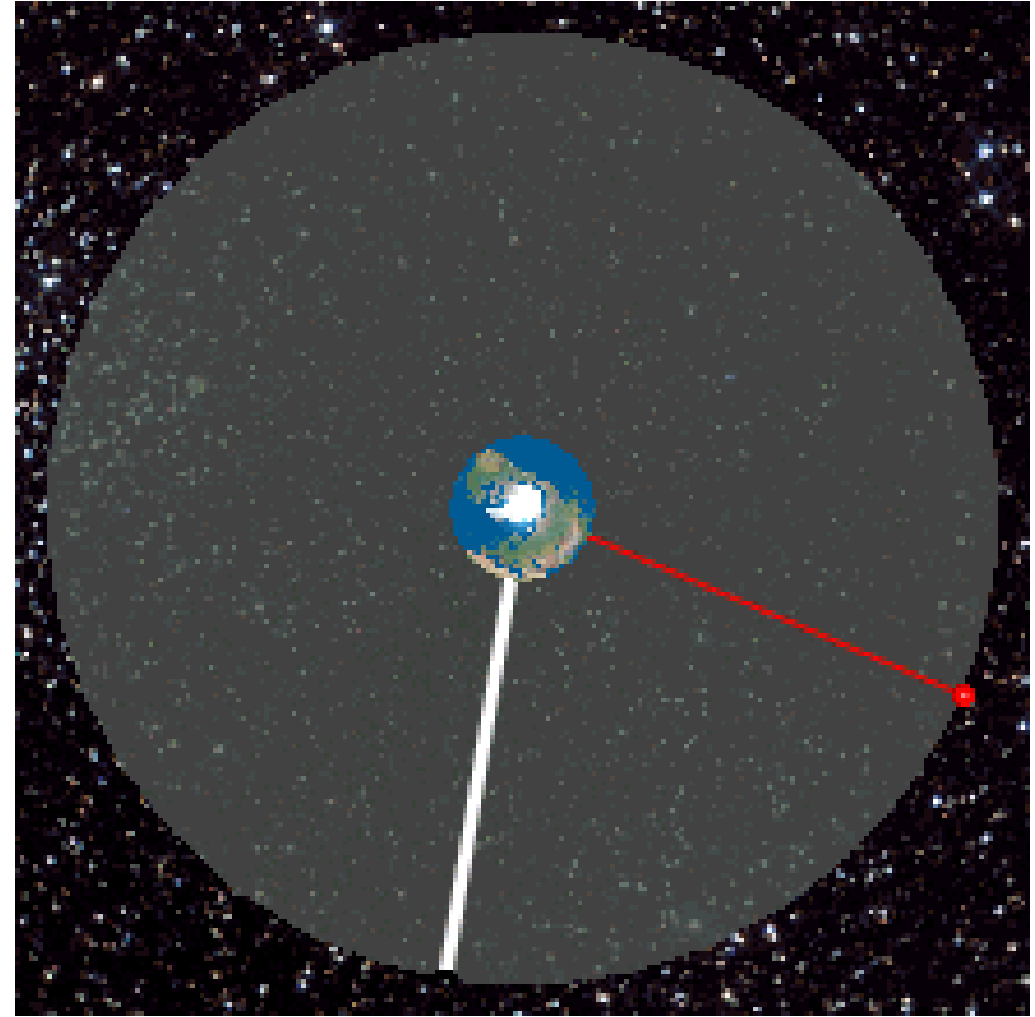
Polar Orbit (LEO)

- 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.

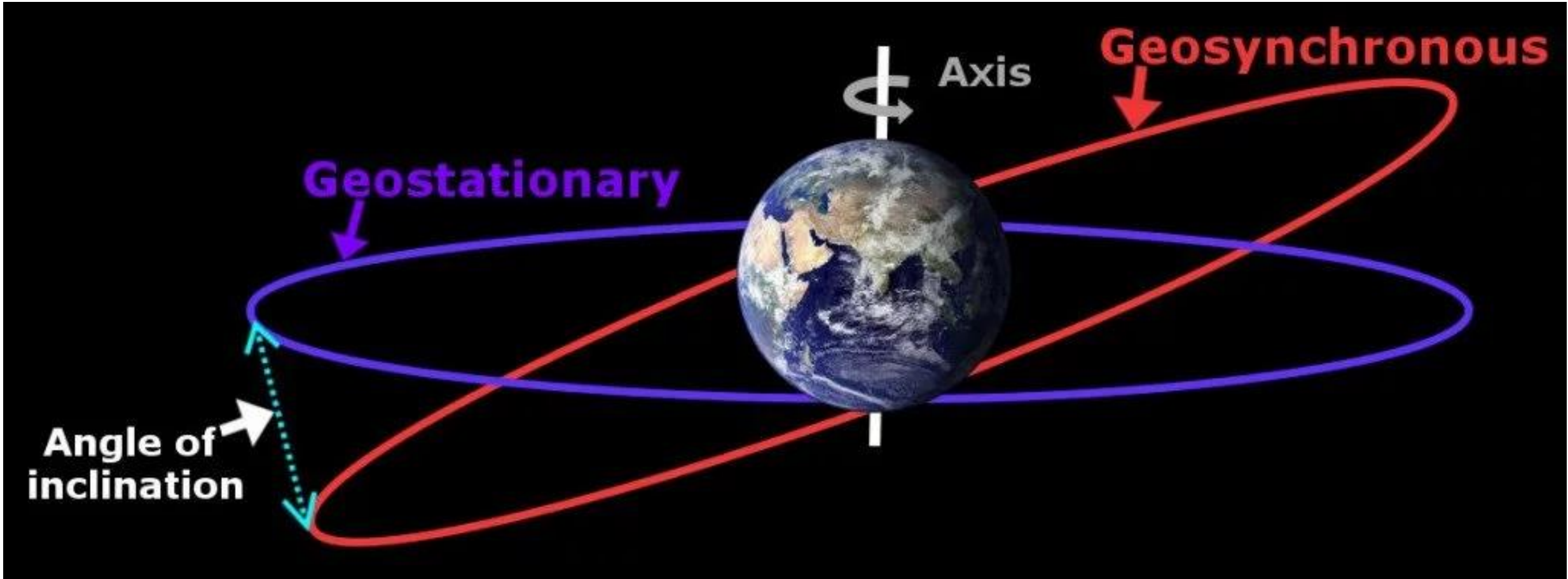


Source: [Wikipedia](#)

NASA's Applied Remote Sensing Training Program



Geostationary vs. Geosynchronous



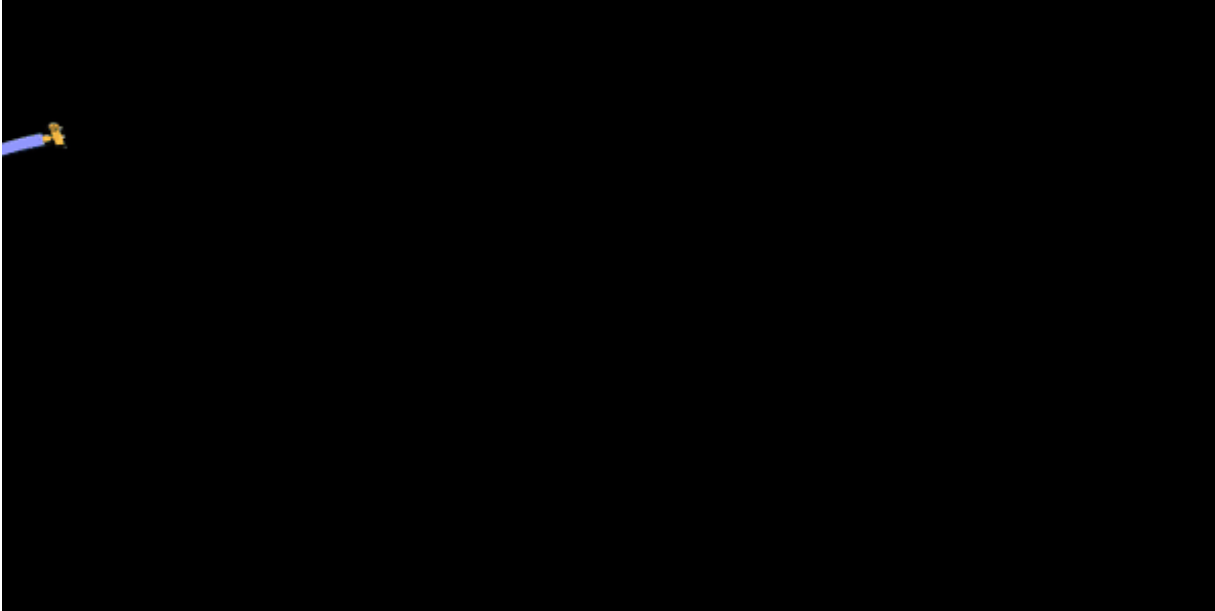
Geostationary orbit is a special type of geosynchronous satellite at the equator.

Image Credit: [ScienceABC](#)

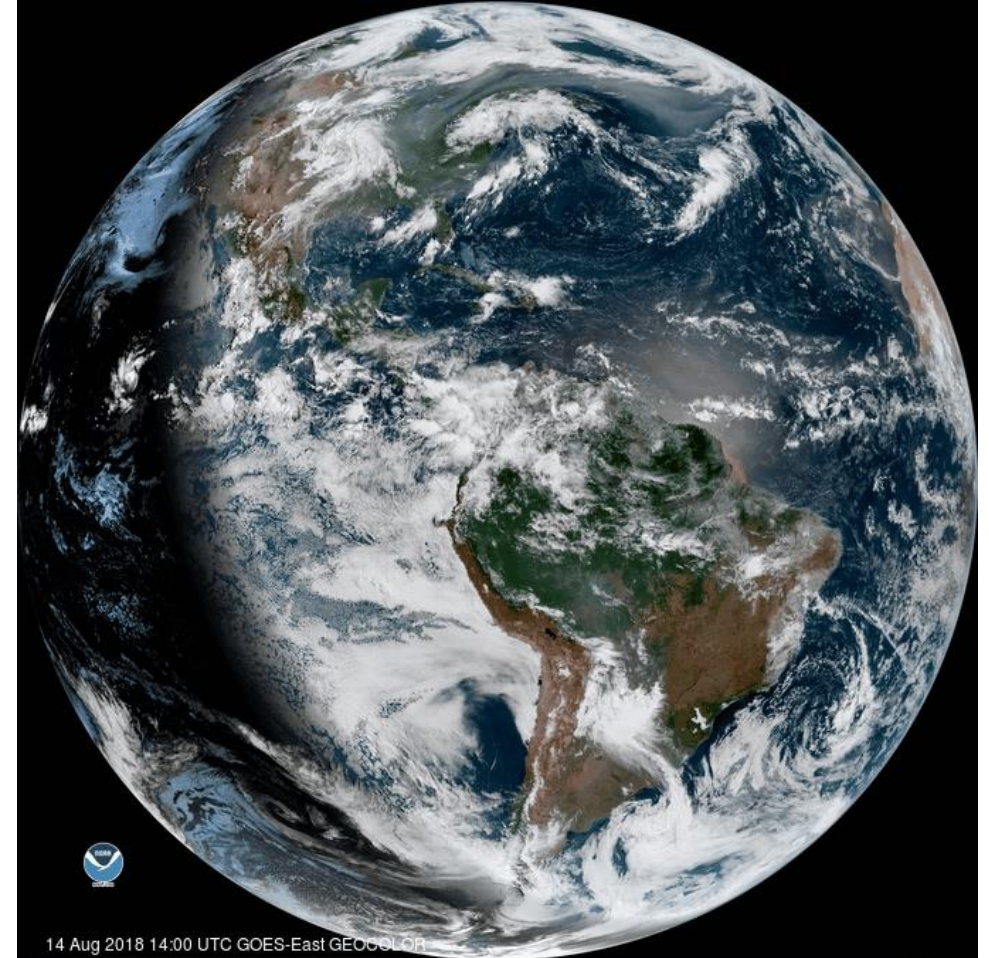


Low Earth Orbit (LEO) & Geostationary (GEO) Satellites Orbiting the Earth

LEO Orbit

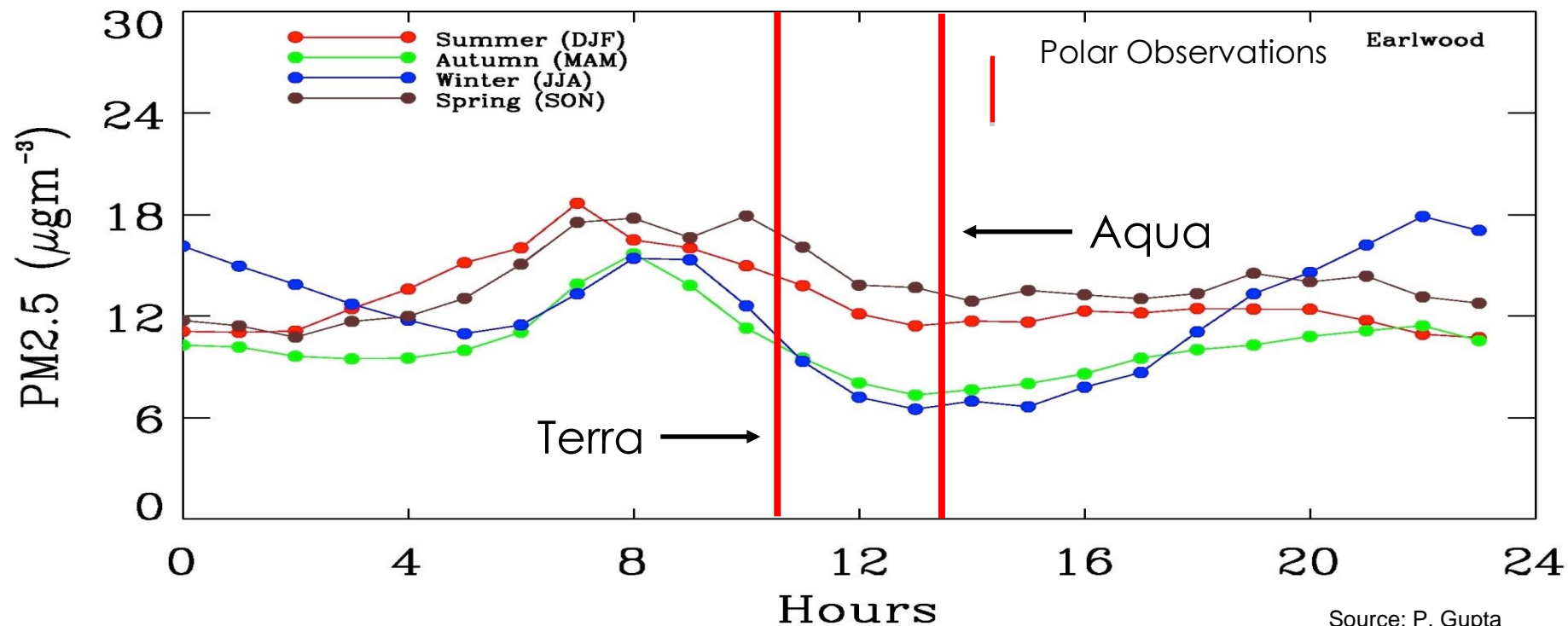


GEO Orbit



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)

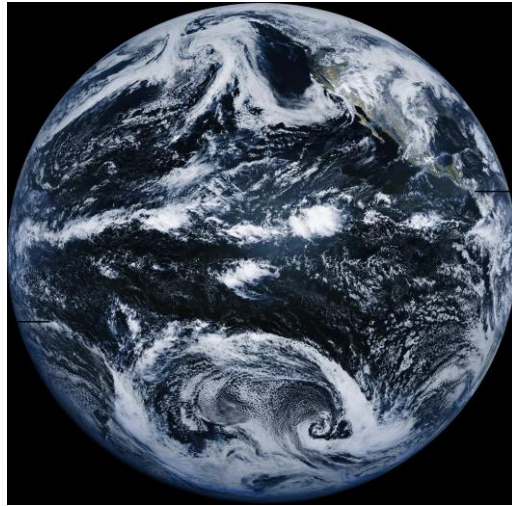
Future Geo satellites: TEMPO, Sentinel-4



Satellite Coverage - GEO



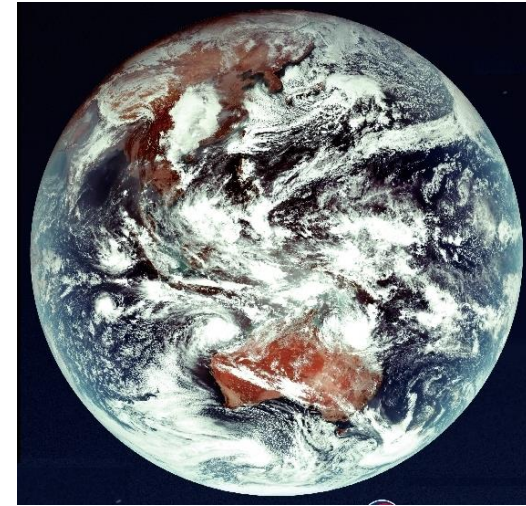
GOES-R



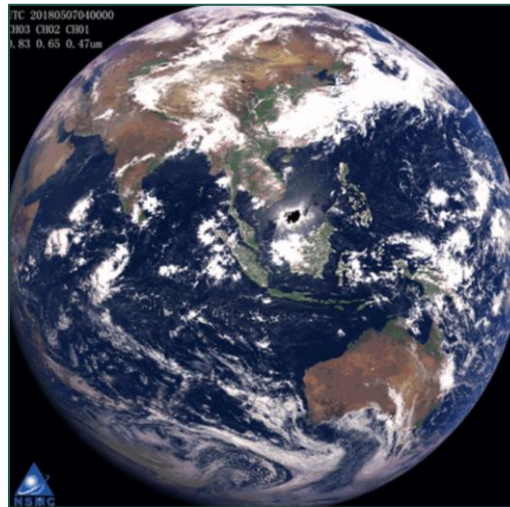
GOES-S/T



Himawari -8/9



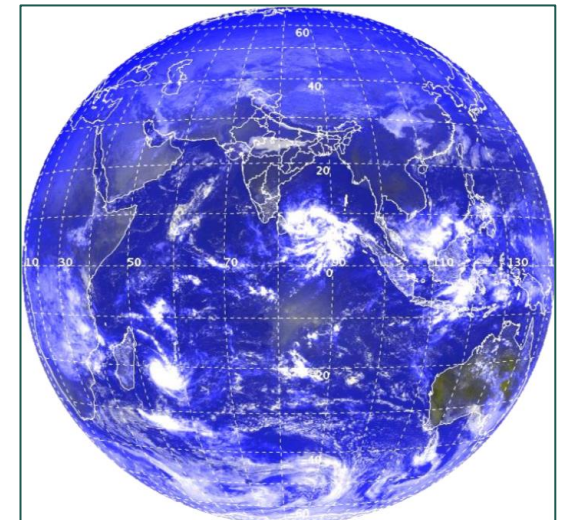
AMI-GK-2A



Fengyun-4



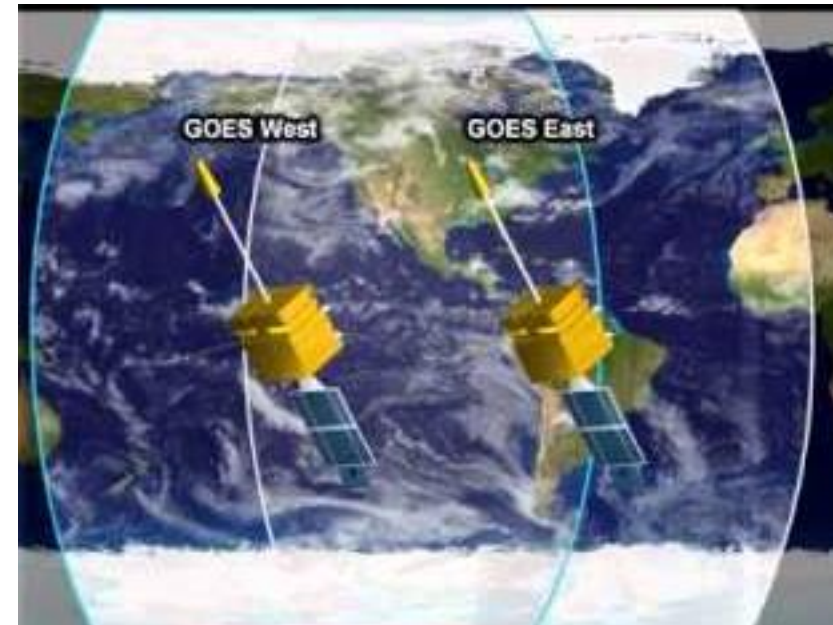
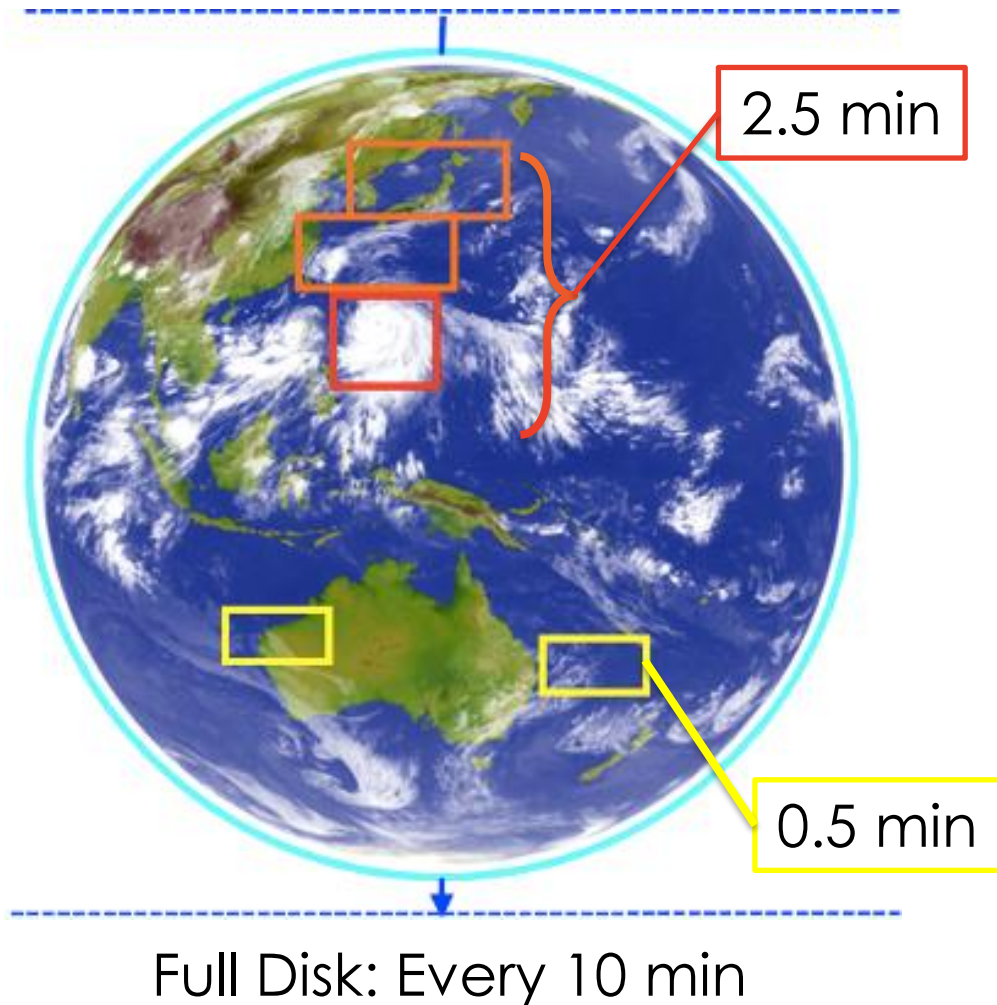
MST - (FCI)



INSAT - (GISAT)



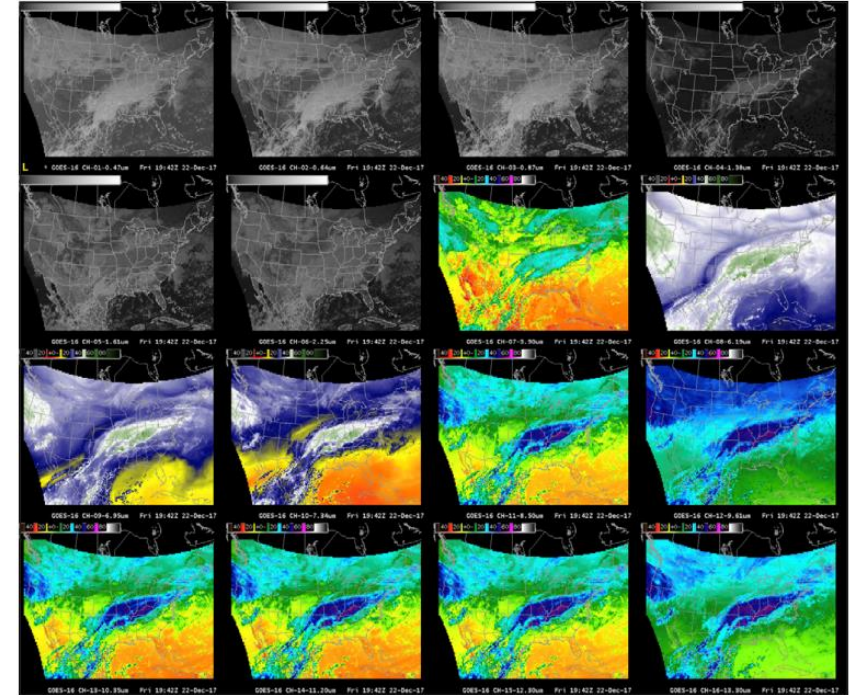
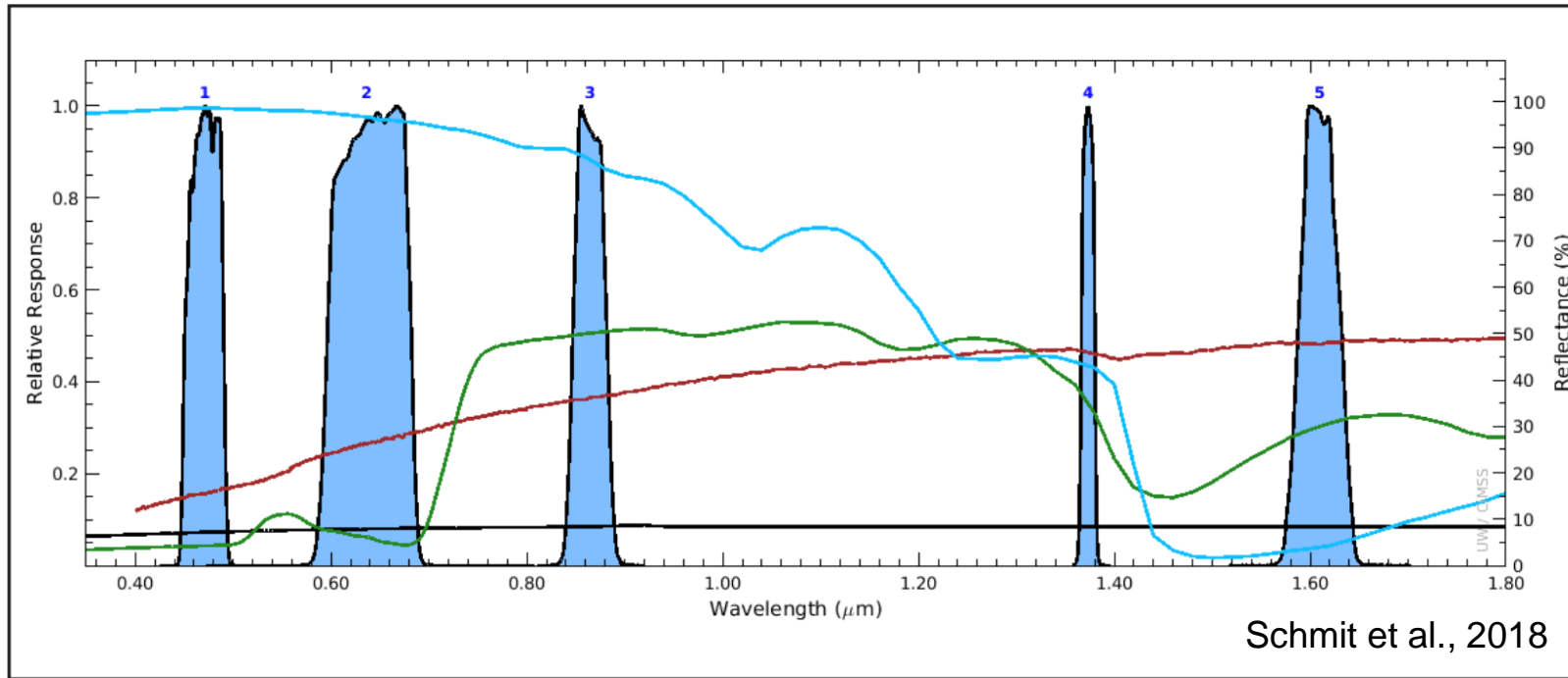
Advanced Himawari Imager (AHI) & Advanced Baseline Imager (ABI): Spatial Coverage and Temporal Resolution



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



Spectral Bands & Atmospheric Interactions



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

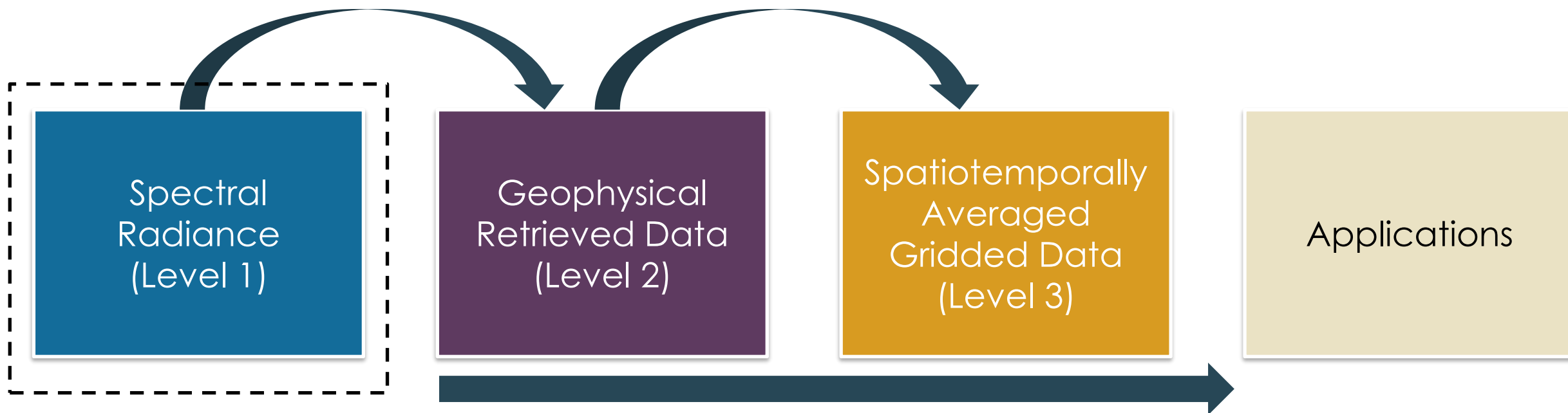
ABI

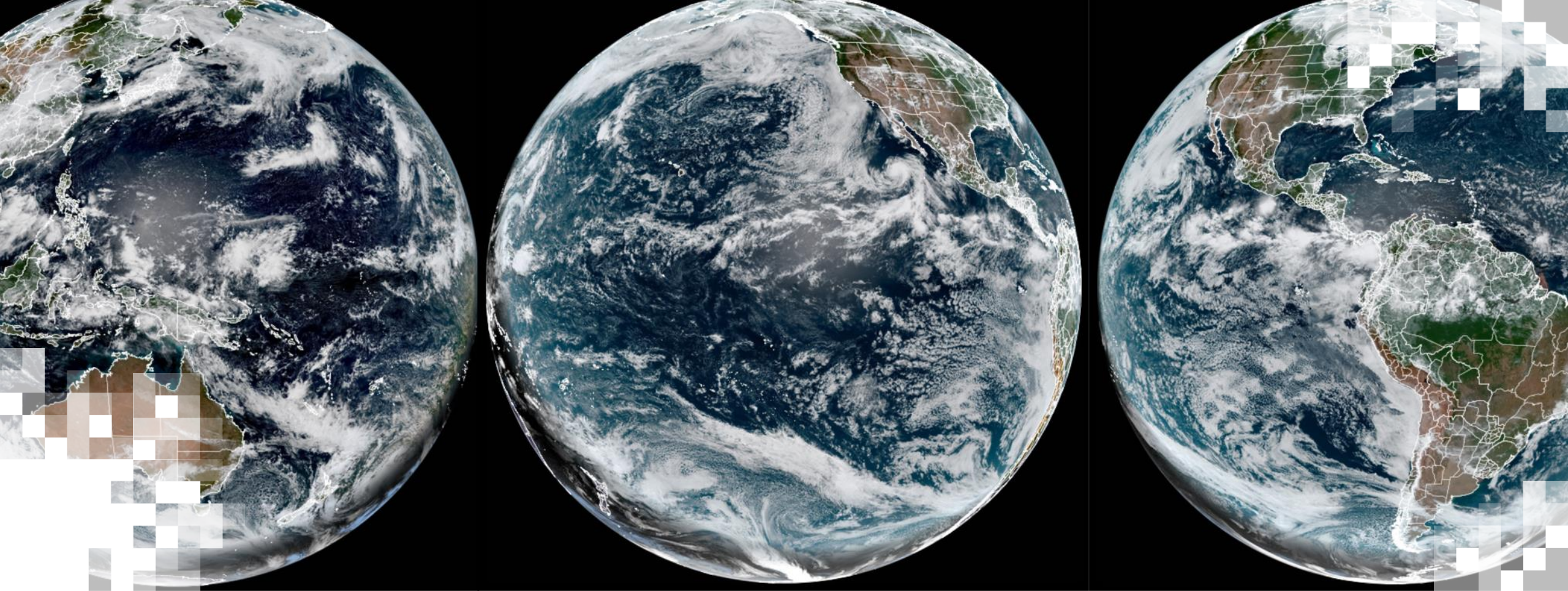
Future GOES Imager (ABI) band	Central Wavelength (μm)	Nominal Subsatellite IGFOV (km)
1	0.47	1
2	0.64	0.5
3	0.865	1
4	→ 1.378	2
5	1.61	1
6	2.25	2
7	3.90	2
8	6.19	2
9	6.95	2
10	7.34	2
11	8.5	2
12	9.61	2
13	10.35	2
14	11.2	2
15	12.3	2
16	13.3	2

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



Data Products

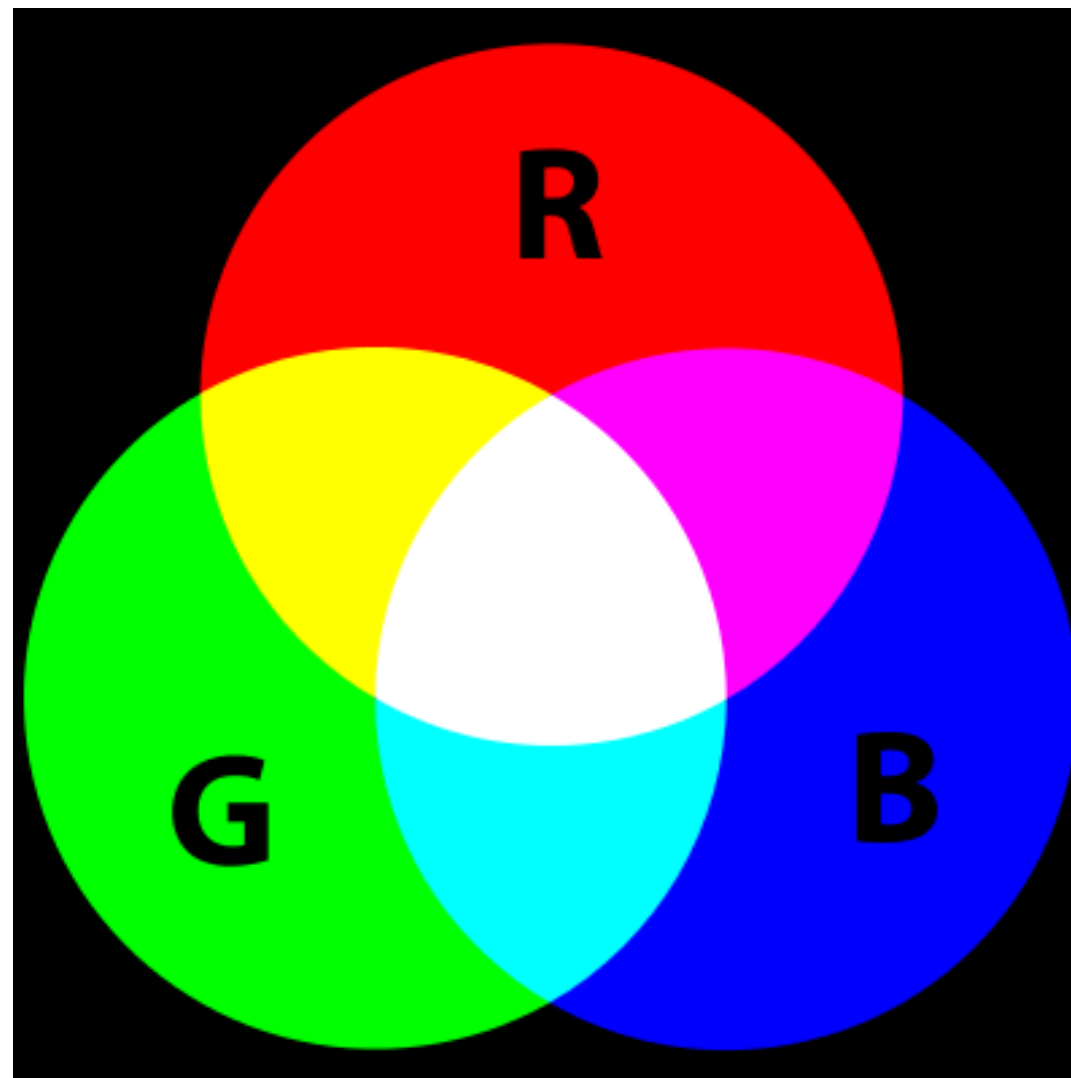




True Color Imagery (RGB, Level 1)

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)

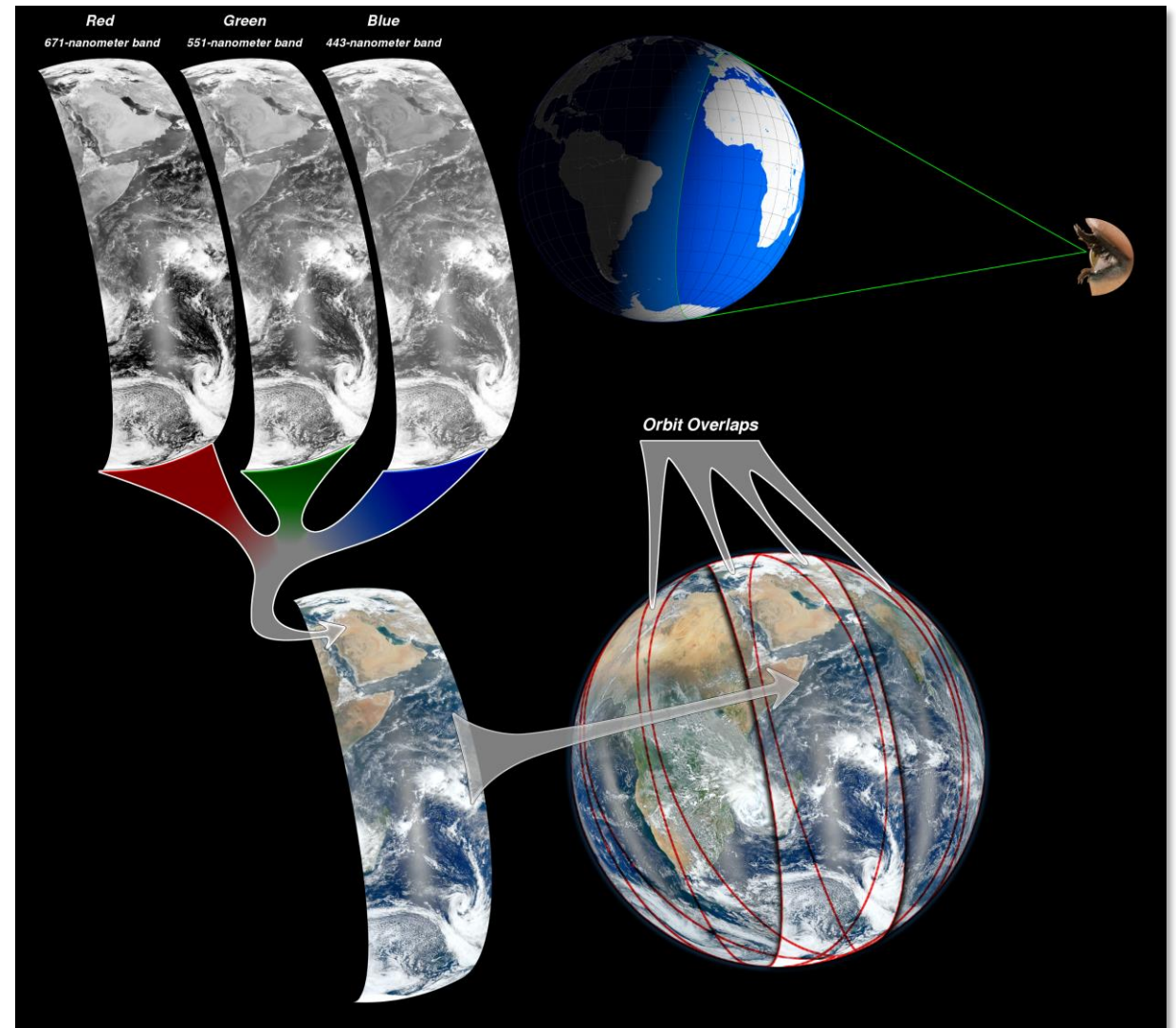
B = 0.47 μm (0.488)

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

R = 0.64 μm (0.64)

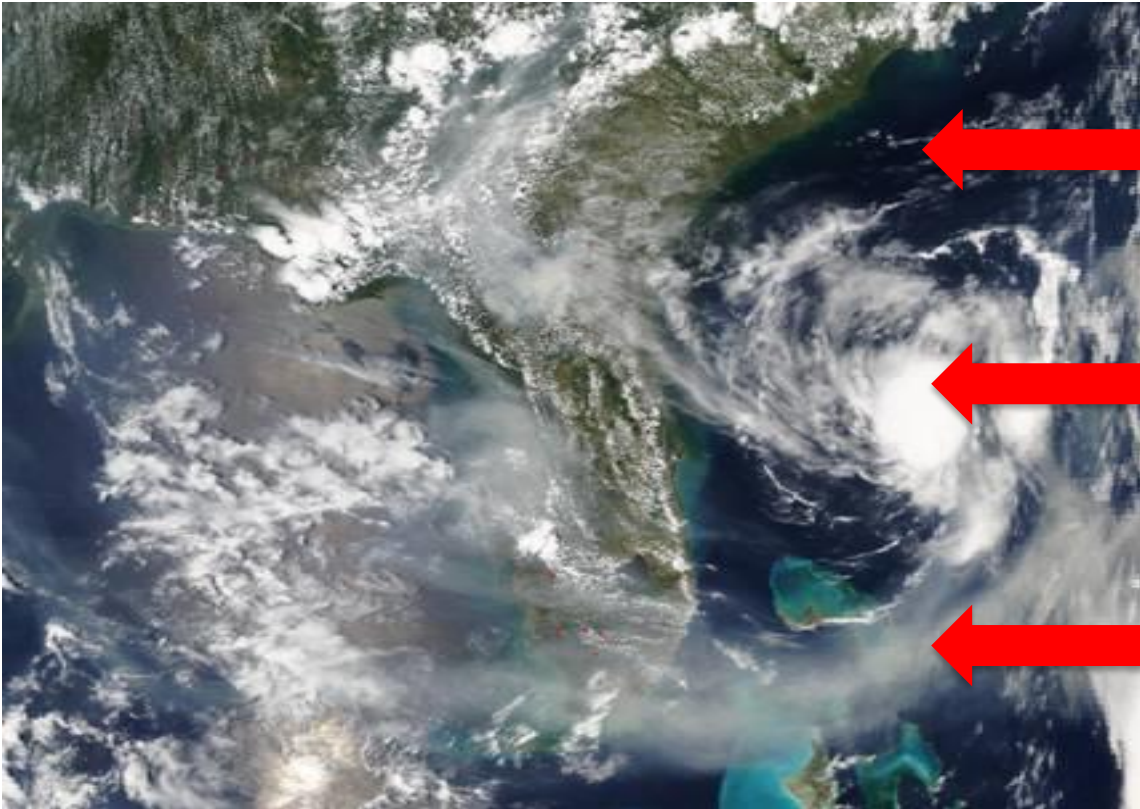
G = 0.51 μm (not available)

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.



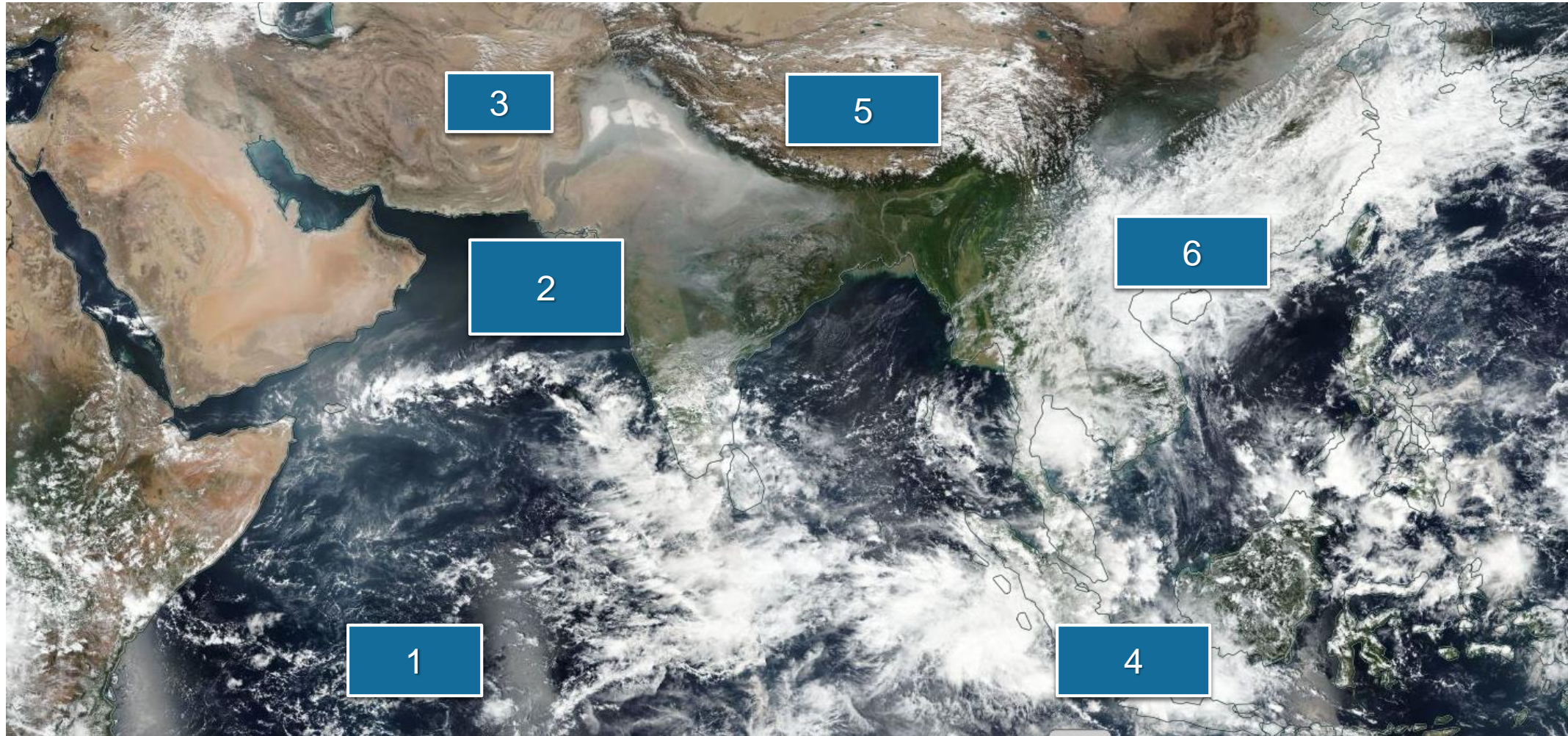
What can we learn from true color imagery?



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



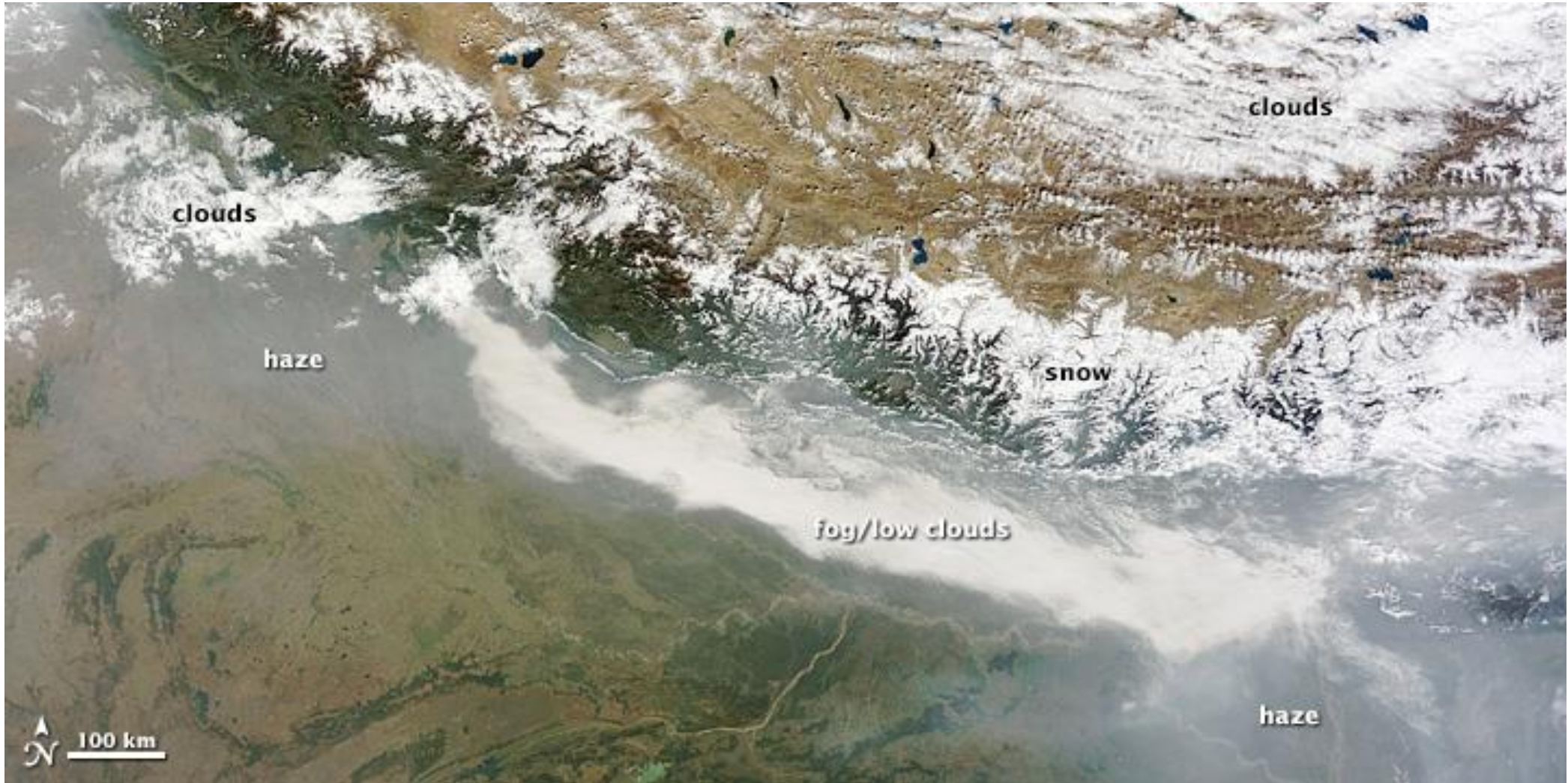
What can we learn from true color imagery?



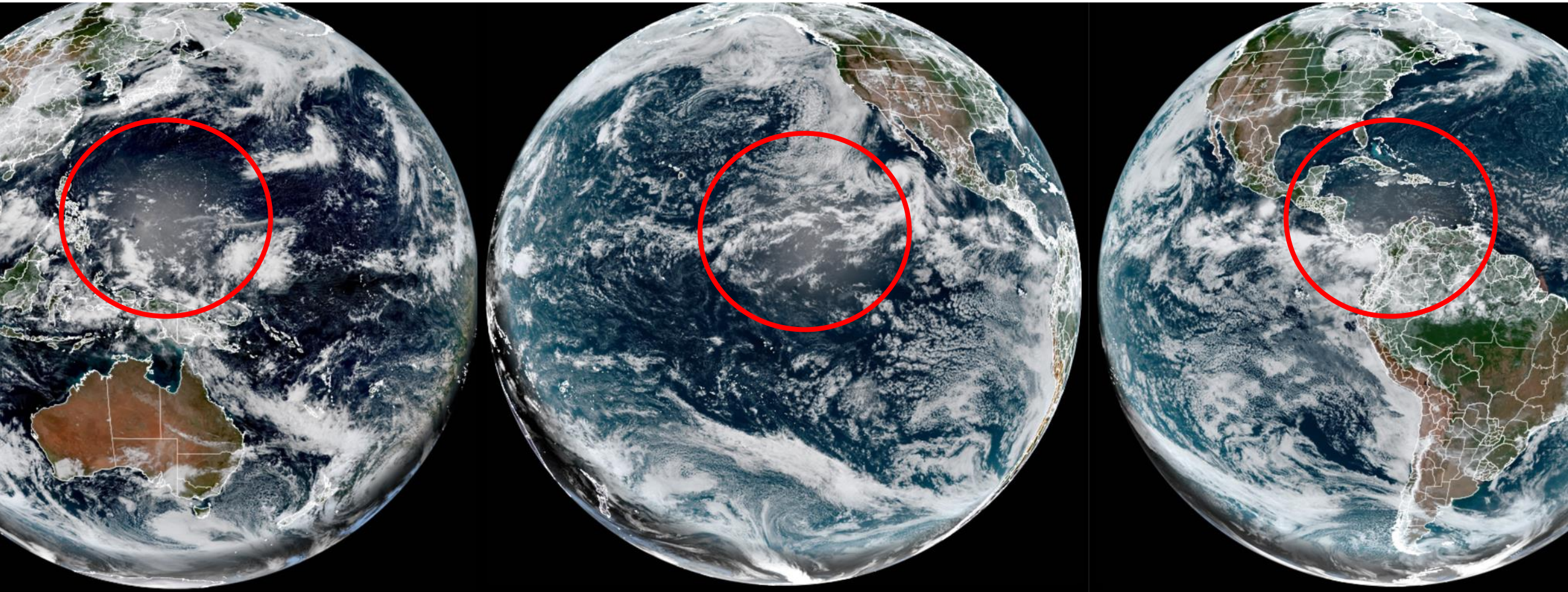
(Possible) Identification of Land, Ocean, and Atmosphere Features



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

Saharan Dust



Wildfire Smoke



Oil Fires in Iraq



Smoke from Alaskan Wildfires (2004)



GOES-16: Smoke Transport over the Northwest

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

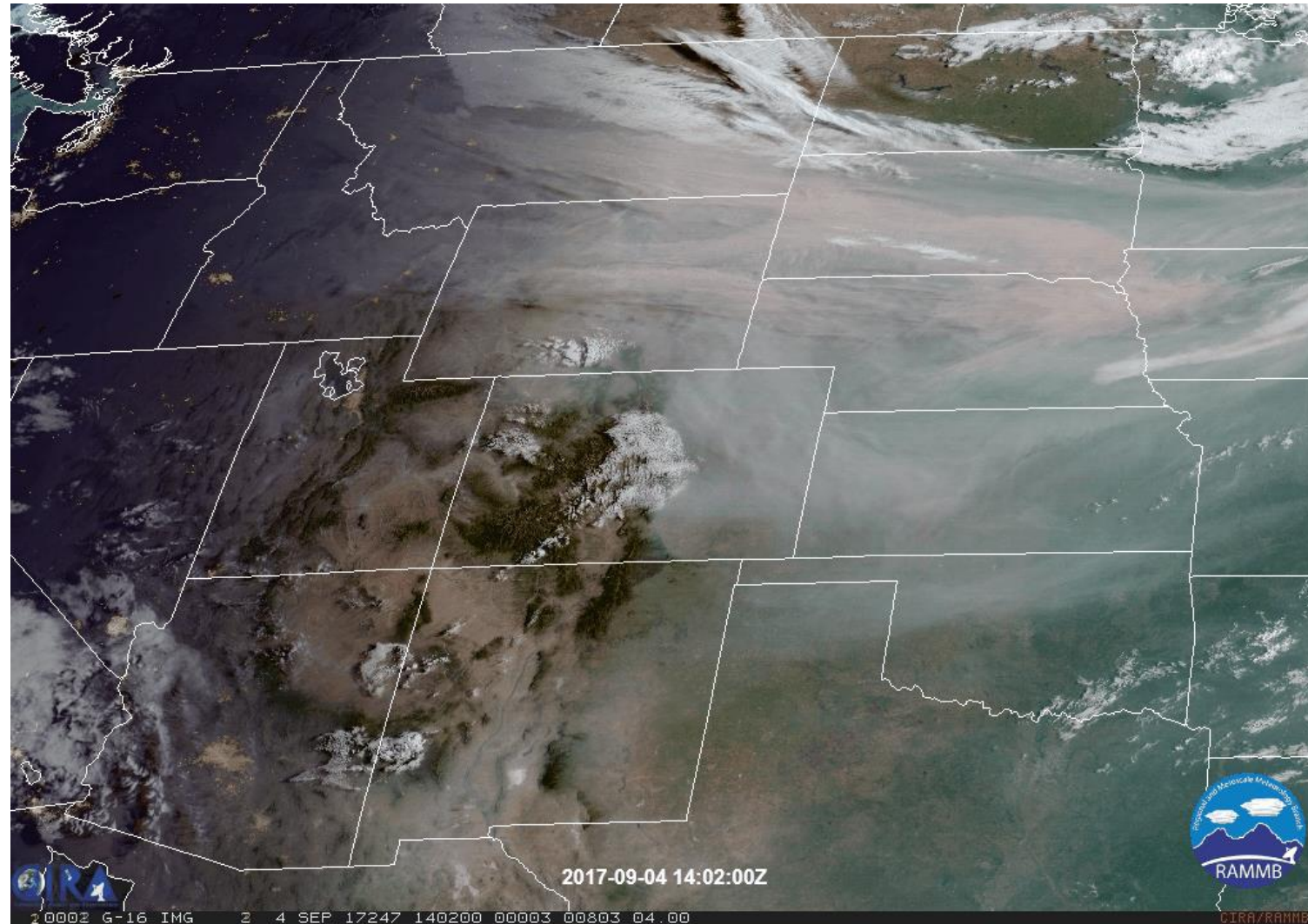


Image: [RAMMB](#)



GOES-16 Loop: Dust

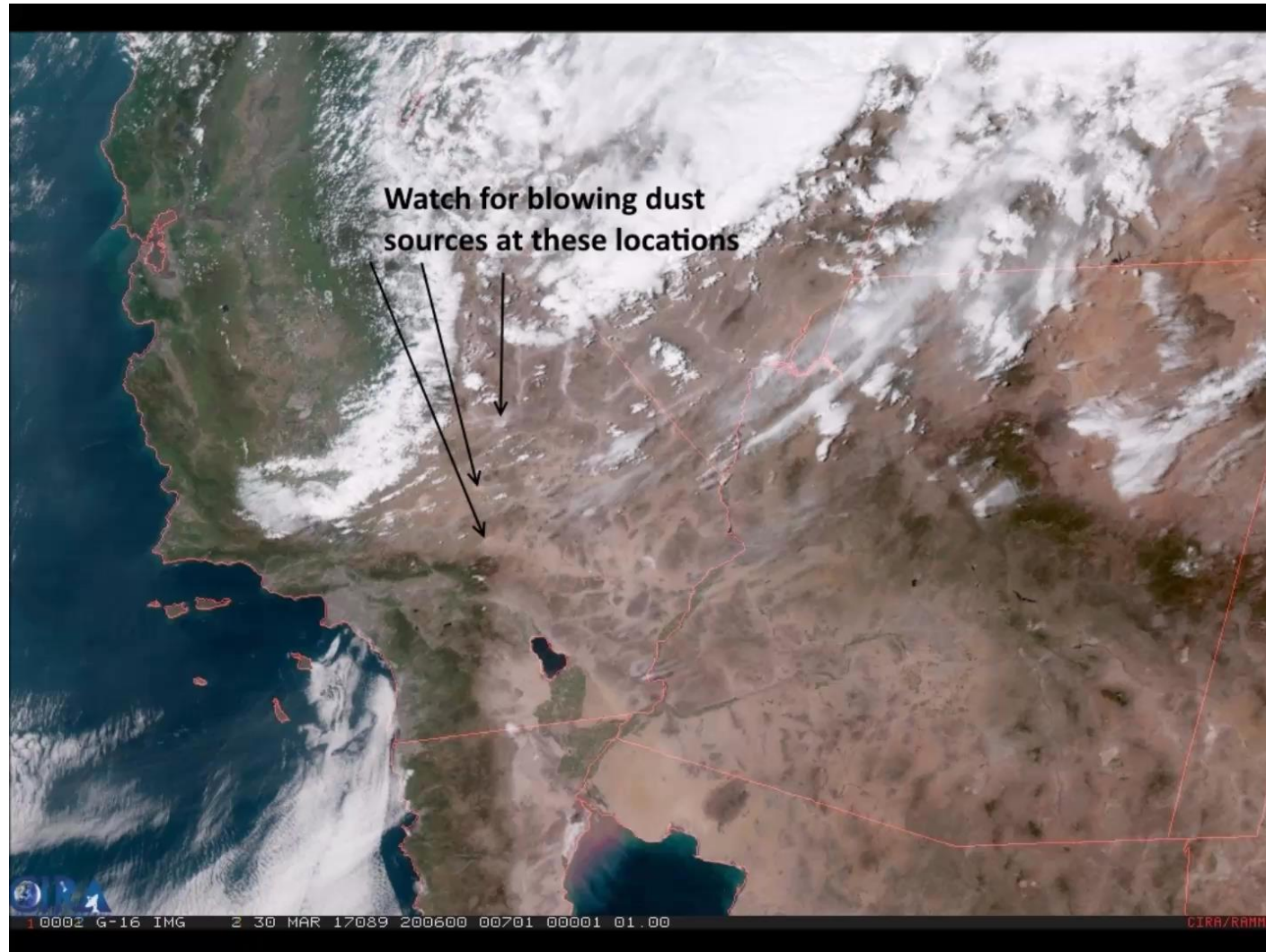


Image: [RMMB](#)



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

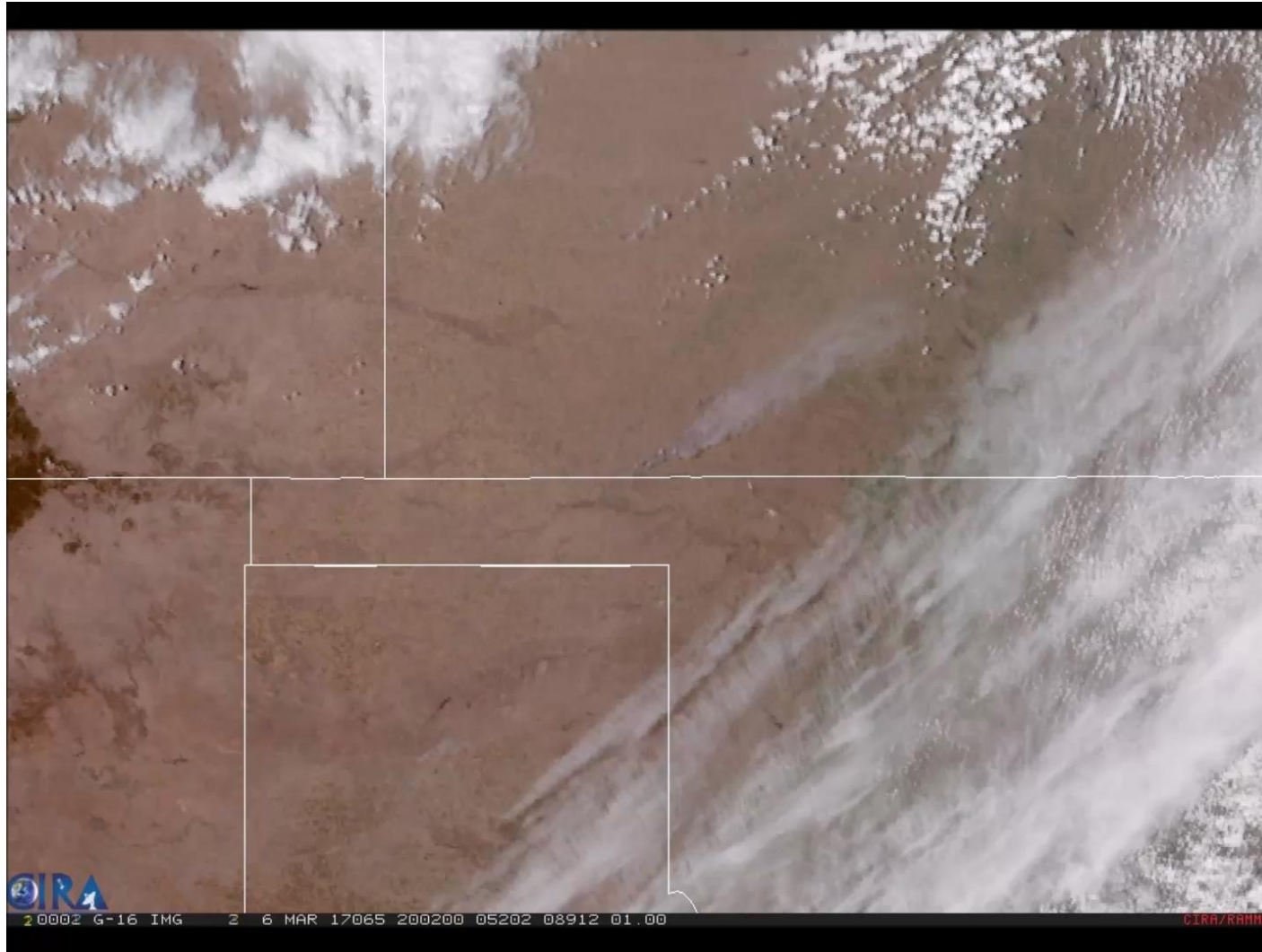


Image: [RMMB](#)



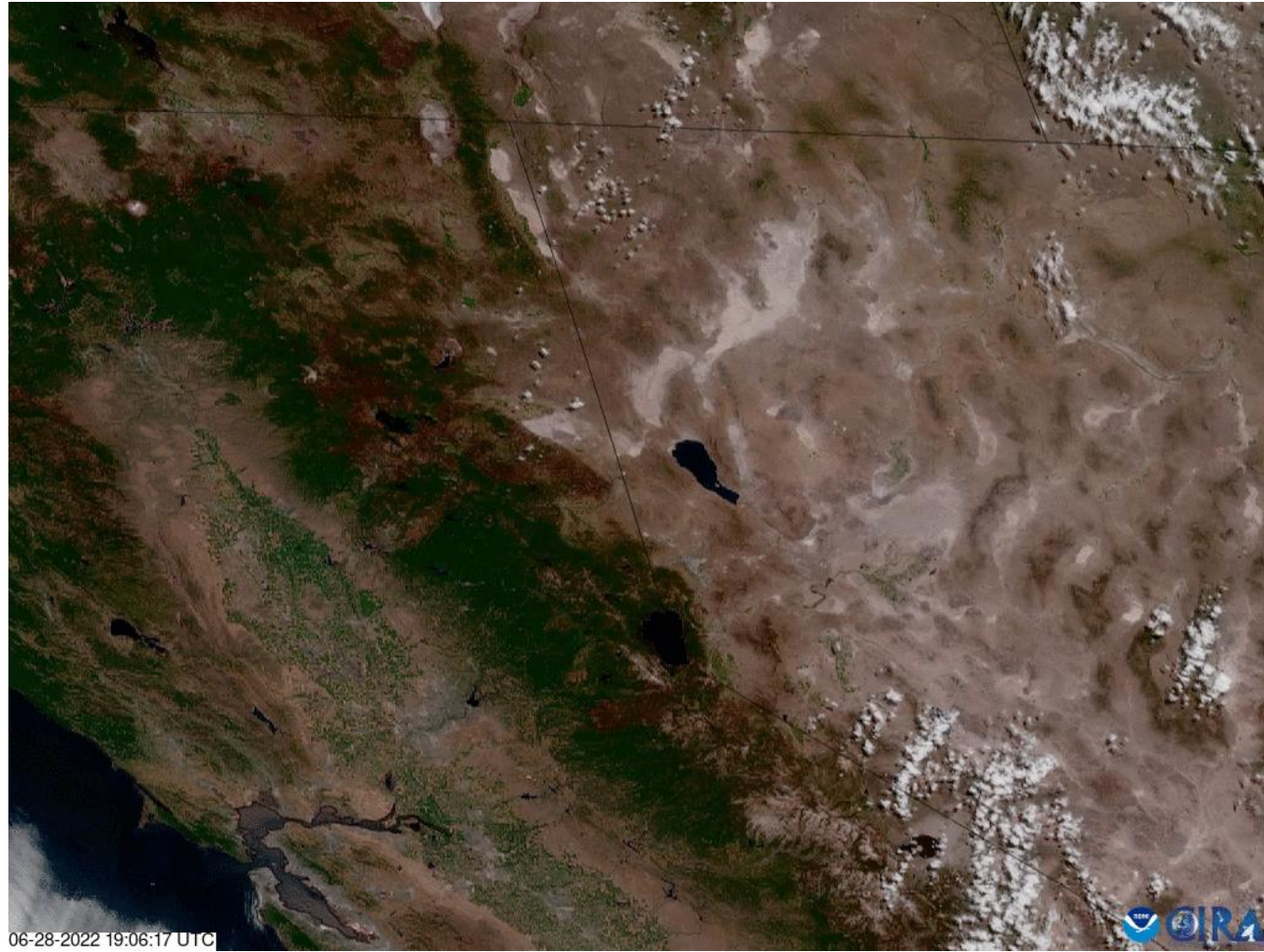
McKinney Fire (US) – GOES-17 (GeoColor)



07-30-2022 14:31:17 UTC

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

Rices Fire (US) – GOES-17 (GeoColor)

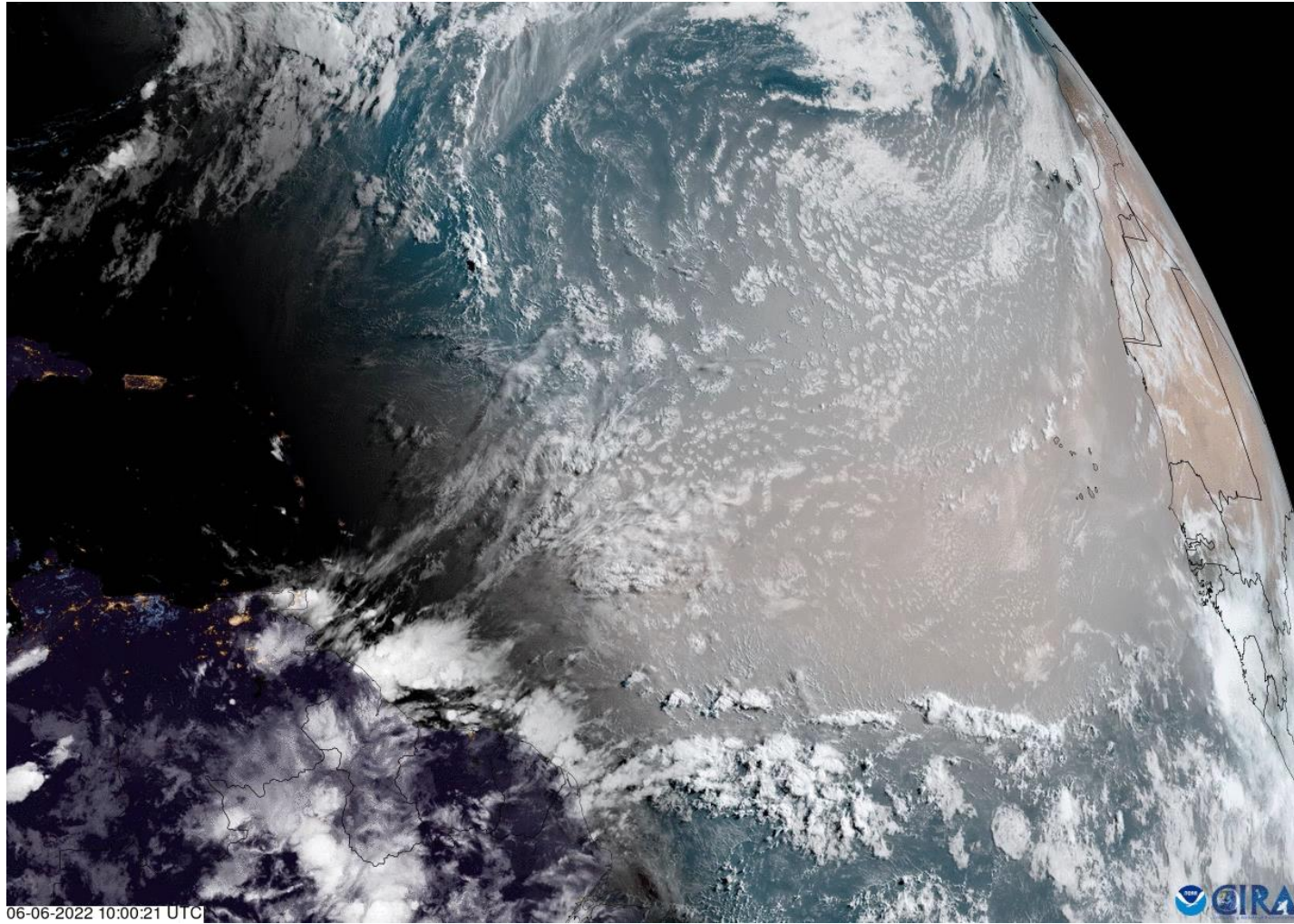


06-28-2022 19:06:17 UTC

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



GOES-East (Dust over the Atlantic)



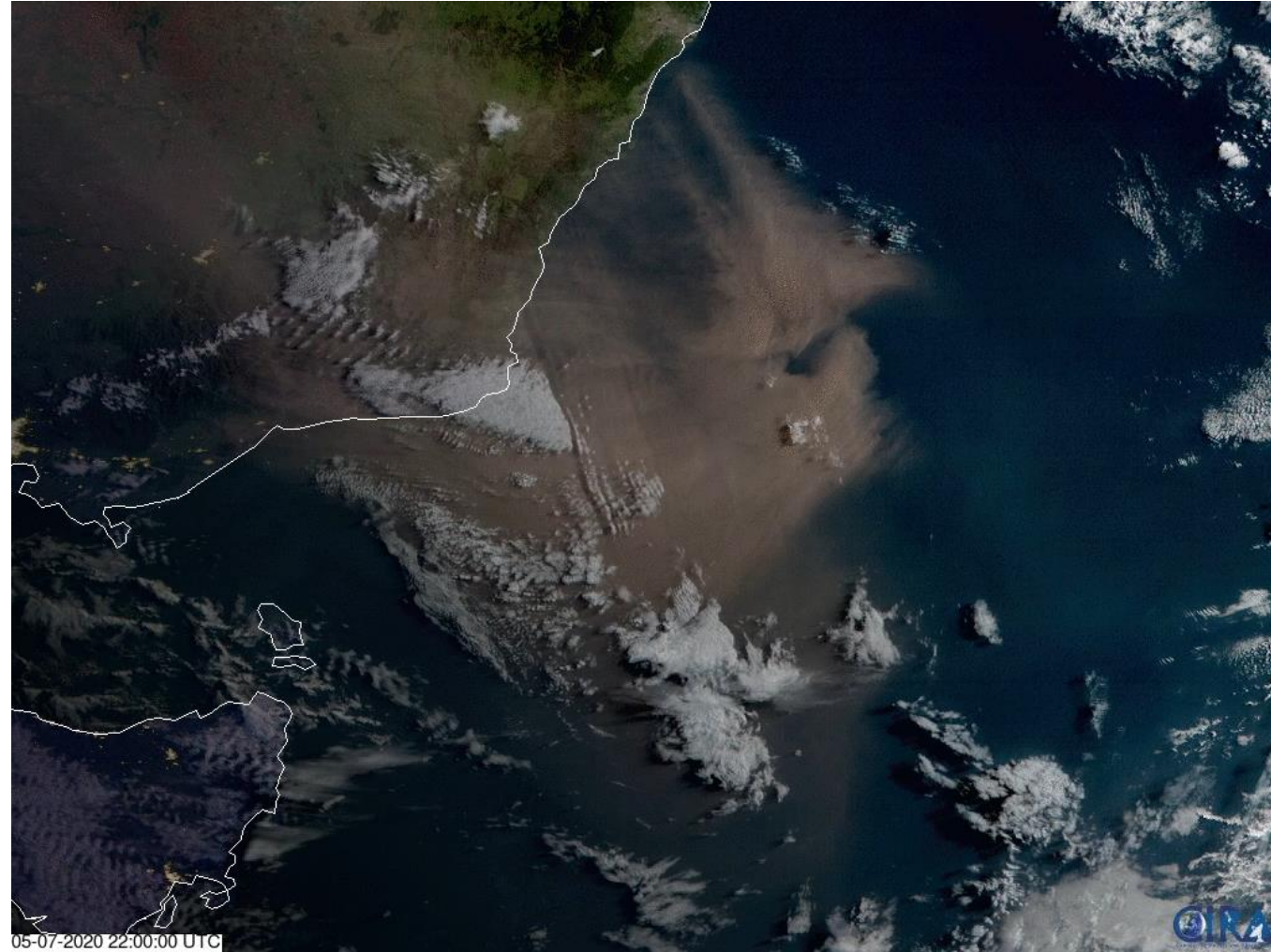
06-06-2022 10:00:21 UTC



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

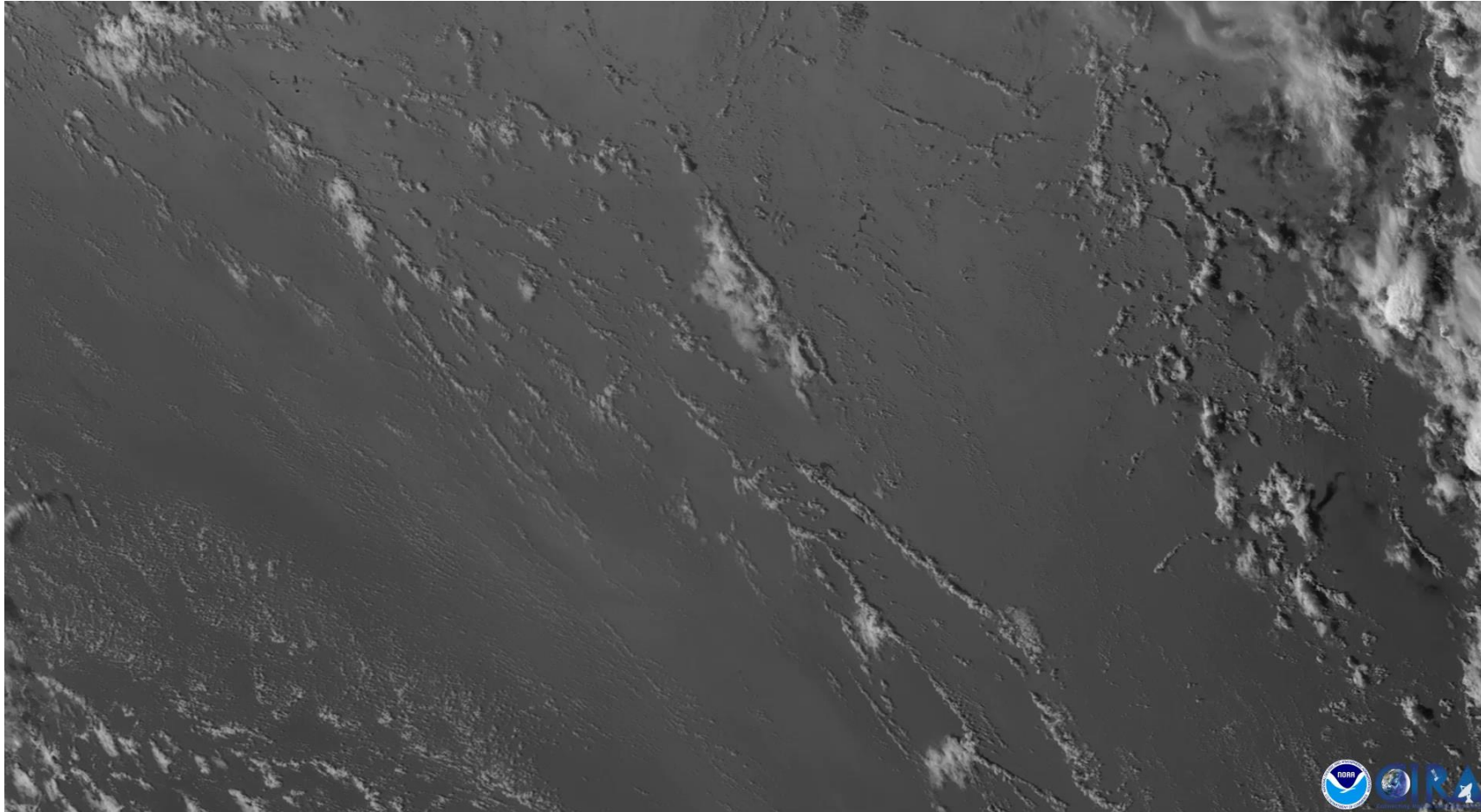


Himawari-08 (AHI) – Dust over Australia (May 8th, 2020)



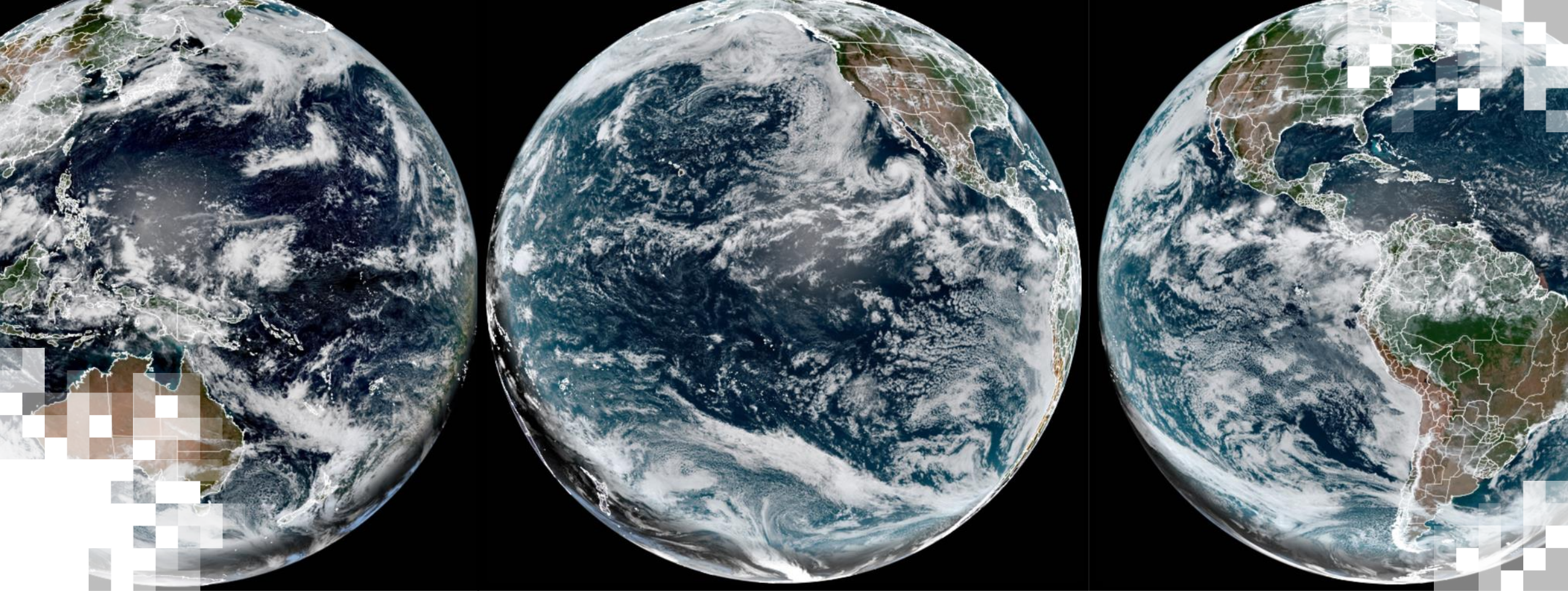
Hunga Tonga-Hunga Ha'apai's Eruption

January 15th, 2022 in the South Pacific



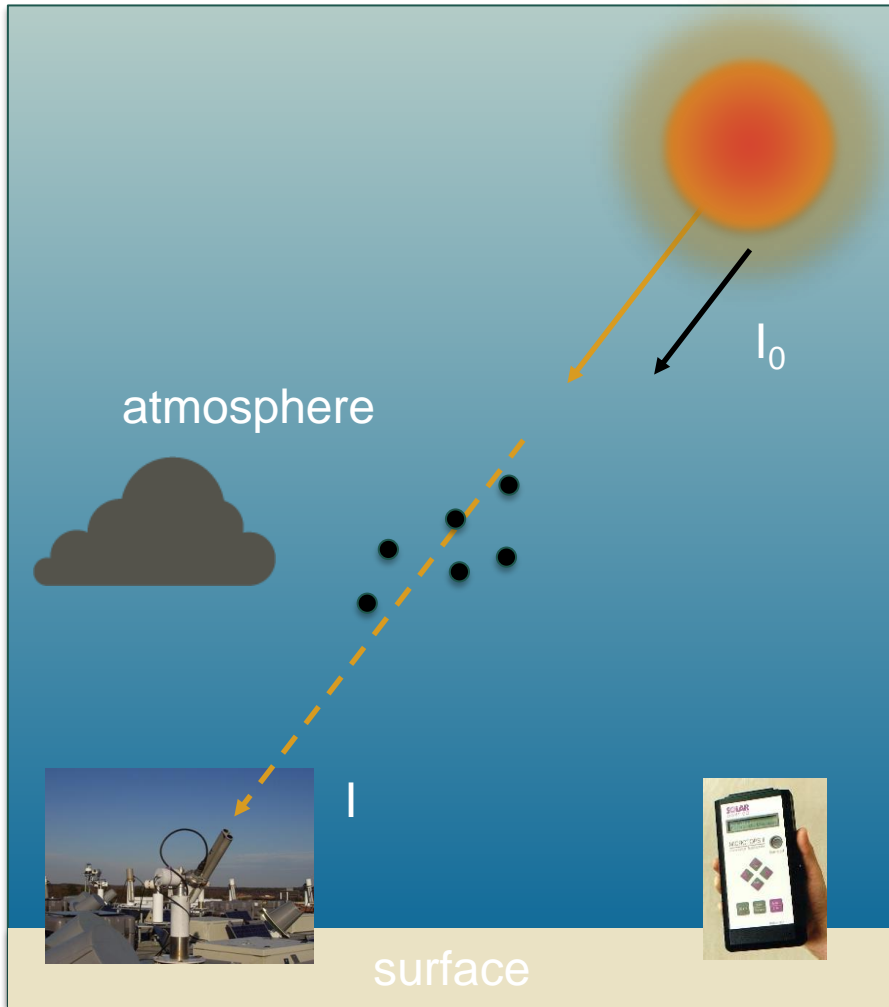
01-15-2022 | 03:10:32 UTC | GOES-17 | Visible (Band 2)





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:

$$I = I_0 e^{-m\tau}$$

$$m = \sec \theta_0$$

$$\tau = \tau_{Rayl} + \tau_{aer} + \tau_{gas}$$

Inferring AOD and PM_{2.5} 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

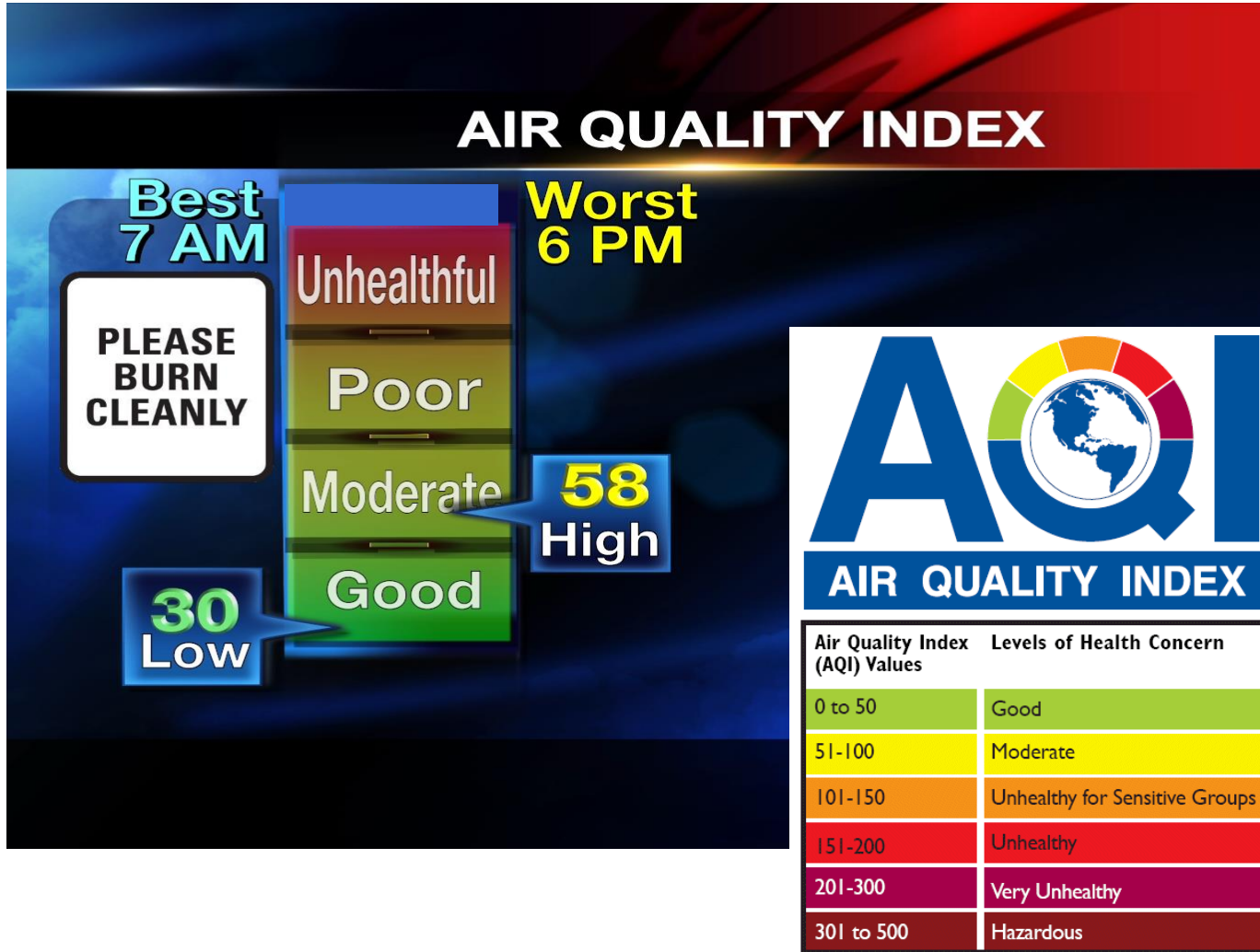


Image Credit: AirNow map, USEPA. <http://www.airnow.gov>

Spatial Gaps

PM2.5 AQI Values by site on 10/08/2017

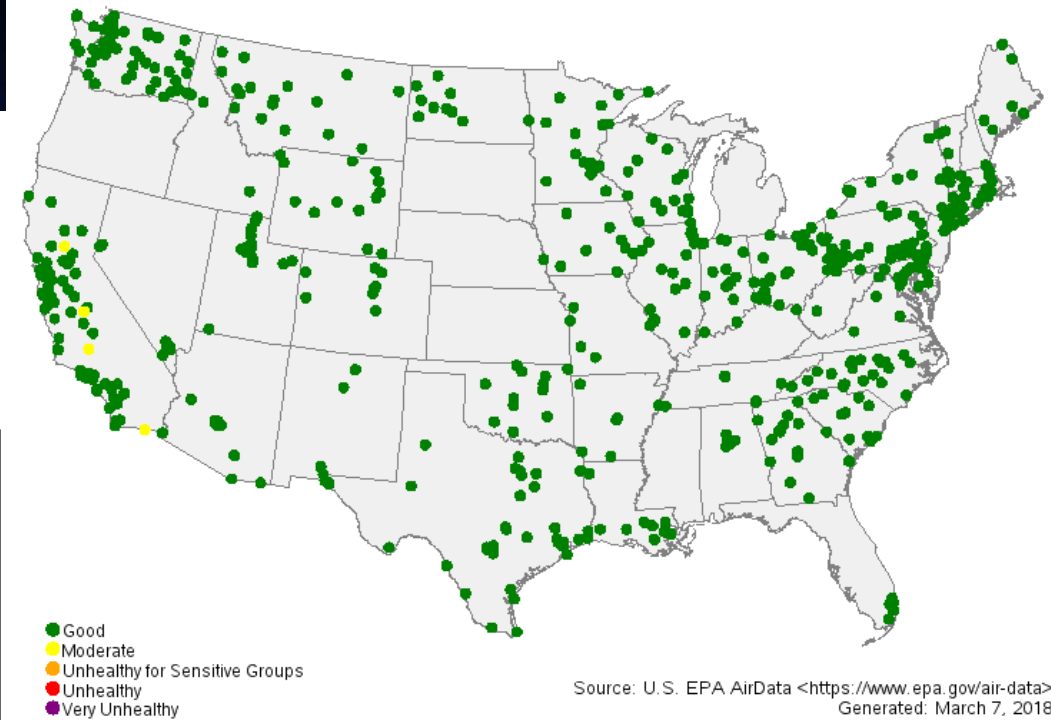


Image Archive and Gallery Links

- 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.

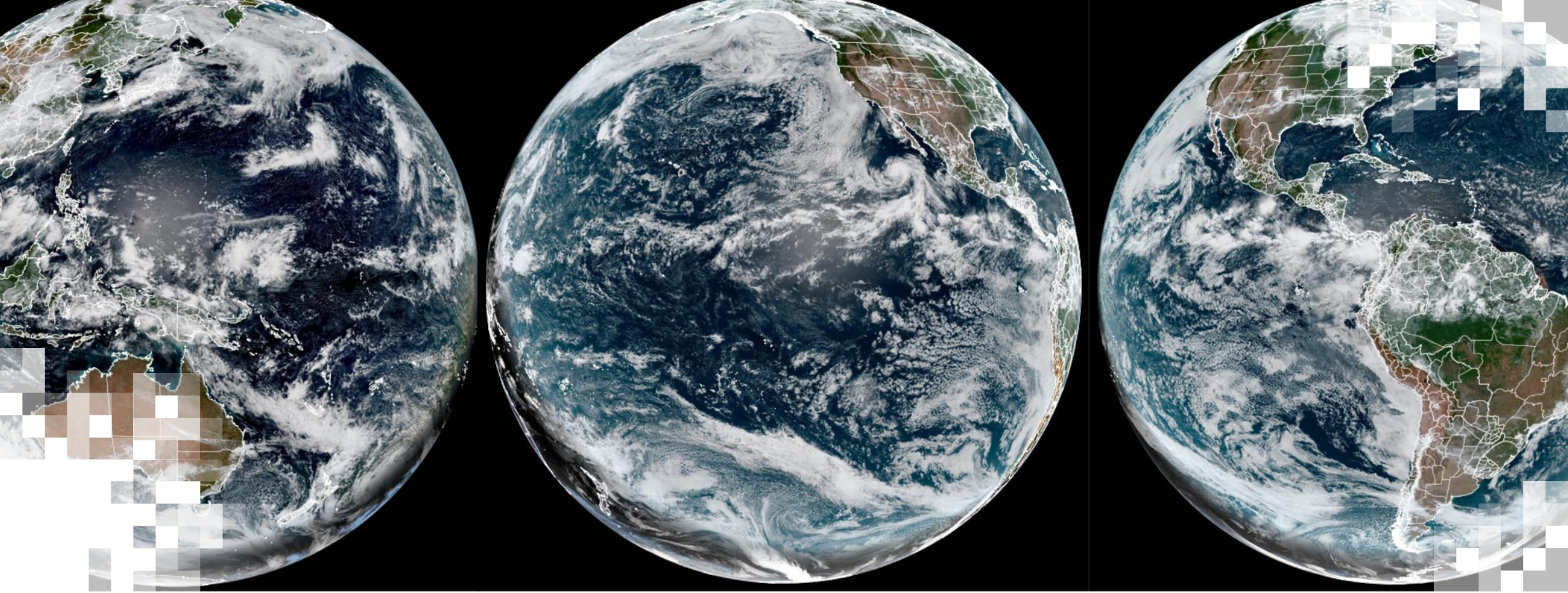
The era of imaging the Earth from the geostationary perspective began on 6 December 1966 with the launch of an experimental sensor (Spin-Scan Cloudcover Camera) on board *Application Technology Satellite-1 (ATS-1)*; Suomi and Parent 1968). The first operational follow-on satellite was the *Geostationary 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

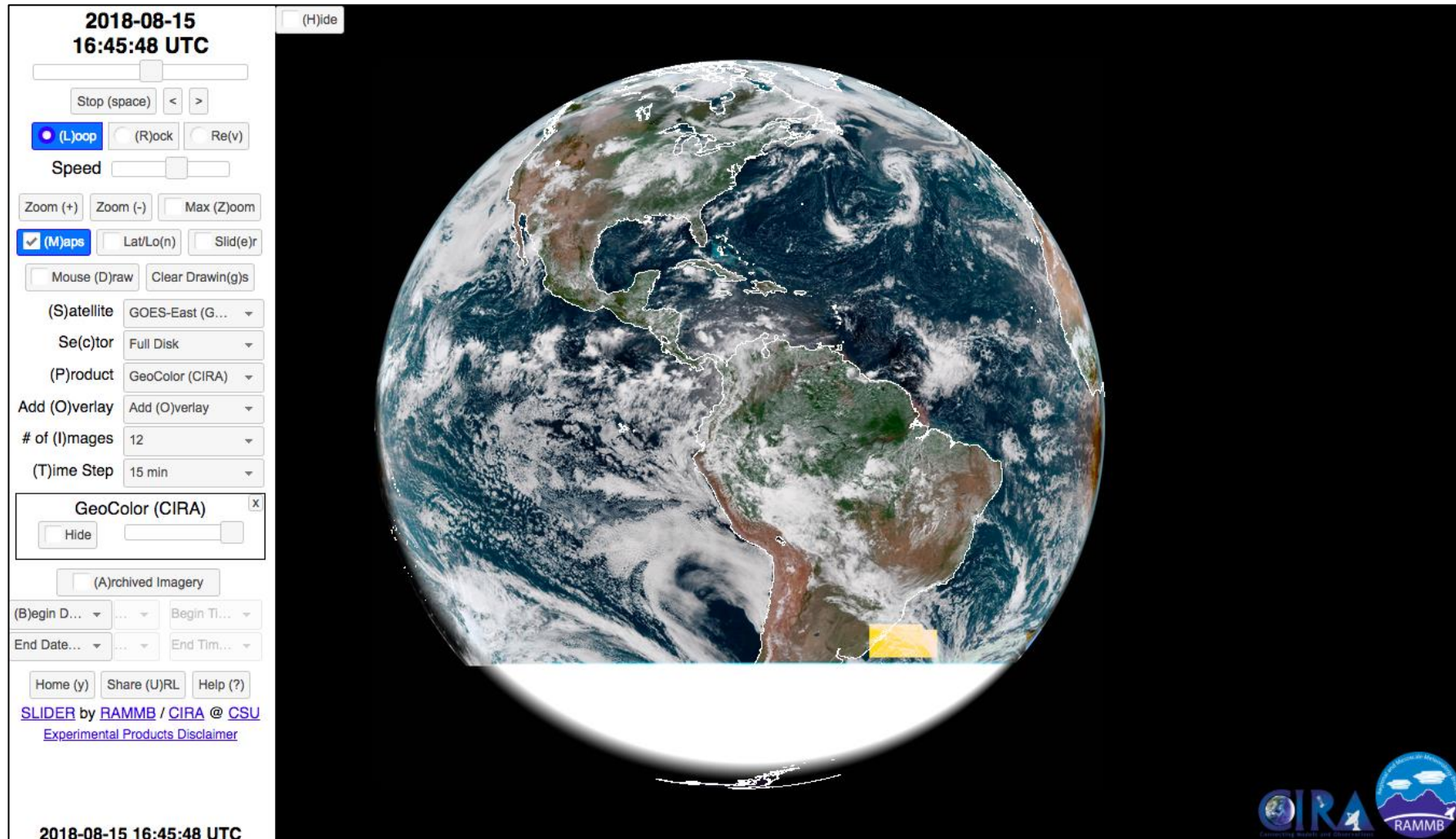
<https://satlib.cira.colostate.edu/>

The screenshot displays the RAMMB-CIRA Satellite Library website interface. On the left is a blue navigation sidebar with icons and text for 'Menu', 'Home', 'Events', 'Archive', and 'info'. The main content area features the RAMMB logo (Regional and Mesoscale Meteorology Branch) and the CIRA logo (Connecting Models and Observations). The central focus is a video player showing a satellite image of Hurricane Ian, with a play button in the top right corner. A white text box on the left of the video reads: 'Hurricane Ian' followed by 'Ian was a major hurricane in the Atlantic basin.'



ABI & AHI Sliders

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



The screenshot displays the RAMMB Slider web interface. On the left is a control panel with the following elements:

- Timestamp: 2018-08-15 16:45:48 UTC
- Navigation: Stop (space), <, >
- Mode: (L)oop (selected), (R)ock, Re(v)
- Speed: slider
- Zoom: Zoom (+), Zoom (-), Max (Z)oom
- Map: (M)aps (checked), Lat/Lo(n), Slid(e)r
- Interaction: Mouse (D)raw, Clear Drawin(g)s
- Satellite: (S)atellite GOES-East (G...)
- Sector: Se(c)tor Full Disk
- Product: (P)roduct GeoColor (CIRA)
- Overlay: Add (O)verlay Add (O)verlay
- Images: # of (I)mages 12
- Time Step: (T)ime Step 15 min
- GeoColor (CIRA) panel: Hide
- Archived Imagery: (A)rchived Imagery
- Time Range: (B)egin D..., End Date..., Begin Ti..., End Tim...
- Buttons: Home (y), Share (U)RL, Help (?)
- Footer: SLIDER by RAMMB / CIRA @ CSU, Experimental Products Disclaimer

The main display shows a satellite view of Earth centered on the Americas. A yellow box highlights a region in the southern United States. The interface includes a 'Hide' button for the control panel and a 'Show' button for the archived imagery. Logos for CIRA and RAMMB are visible in the bottom right corner.



AHI Viewer – P-Tree

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

JAXA Himawari Monitor
P-Tree System

日本語 Last Update: 15 Aug 2018 18:23:25 UTC

Date: 2018 / 8 / 15 3 : 00~09 UTC Search

-1day -1hour -10min Latest Image +10min +1hour +1day

10 min

Layer Menu

Overlay:

- Coastline (1:50m)
- Coastline (1:10m)
- Latitude/Longitude
- Major River

JAXA Products:

- Sea Surface Temperature
- Sea Surface Temperature (Night Mode)
- Aerosol Optical Thickness
- Short Wave Radiation
- Chlorophyll-a
- Wild Fire
- Photovoltaic Power
- Cloud Optical Thickness

RGB (Himawari)

Layer Opacity Control

Full Screen

What's New

Aug/10/'18 **NEW**

We have released new version of HIMAWARI-8 Aerosol Property products (version 2.1 for L2, version 3.0 for L3). We newly started distribution of daily, monthly dataset for Wild Fire and Aerosol Property products, and monthly dataset for Sea Surface Temperature products. PLEASE NOTE that the previous version of the updated products (L2 and L3 Aerosol) will stop its distribution from 13 August 2018. The new version of these products during the past observation period will be processed and provided as soon



NASA Worldview

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

The screenshot displays the NASA Worldview web application interface. At the top left, the NASA logo and 'WORLDVIEW' text are visible. Below this, there are navigation tabs for 'Layers', 'Events', and 'Data'. A search bar at the top right contains the text 'Search for places or enter coordinates' and includes icons for search, location, share, refresh, camera, and help.

The main display area shows a global map with several data layers overlaid. The layers panel on the left lists the following overlays:

- GeoColor (True Color (Day), Multispectral IR (Night)) GOES-East/ABI
- GeoColor (True Color (Day), Multispectral IR (Night)) GOES-West/ABI
- Air Mass (10 minute) Himawari-8/AHI
- Fires and Thermal Anomalies (Day and Night) Terra / MODIS (with a red 'Fire' indicator)
- Fires and Thermal Anomalies (Day and Night, 375m) Suomi NPP / VIIRS (with a red 'Fire' indicator)

At the bottom of the interface, there is a timeline showing the date and time: '2022 OCT 05 17:02'. The timeline includes navigation arrows and a '10 MINUTE' interval. A scale bar at the bottom right indicates '5000 km' and '2000 mi'.



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!

