

# Satellite Imagery Access, Interpretation, and Tools for Dust, Smoke, and Pollution Monitoring

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Satellite Remote Sensing of Dust, Fires, Smoke, and Air Quality, July 10-12, 2018



# Learning Objectives

By the end of this presentation, you will be able to:

- Recognize satellite imagery, label features, and recite applications of satellite imagery
- Access and perform basic analysis of satellite imagery

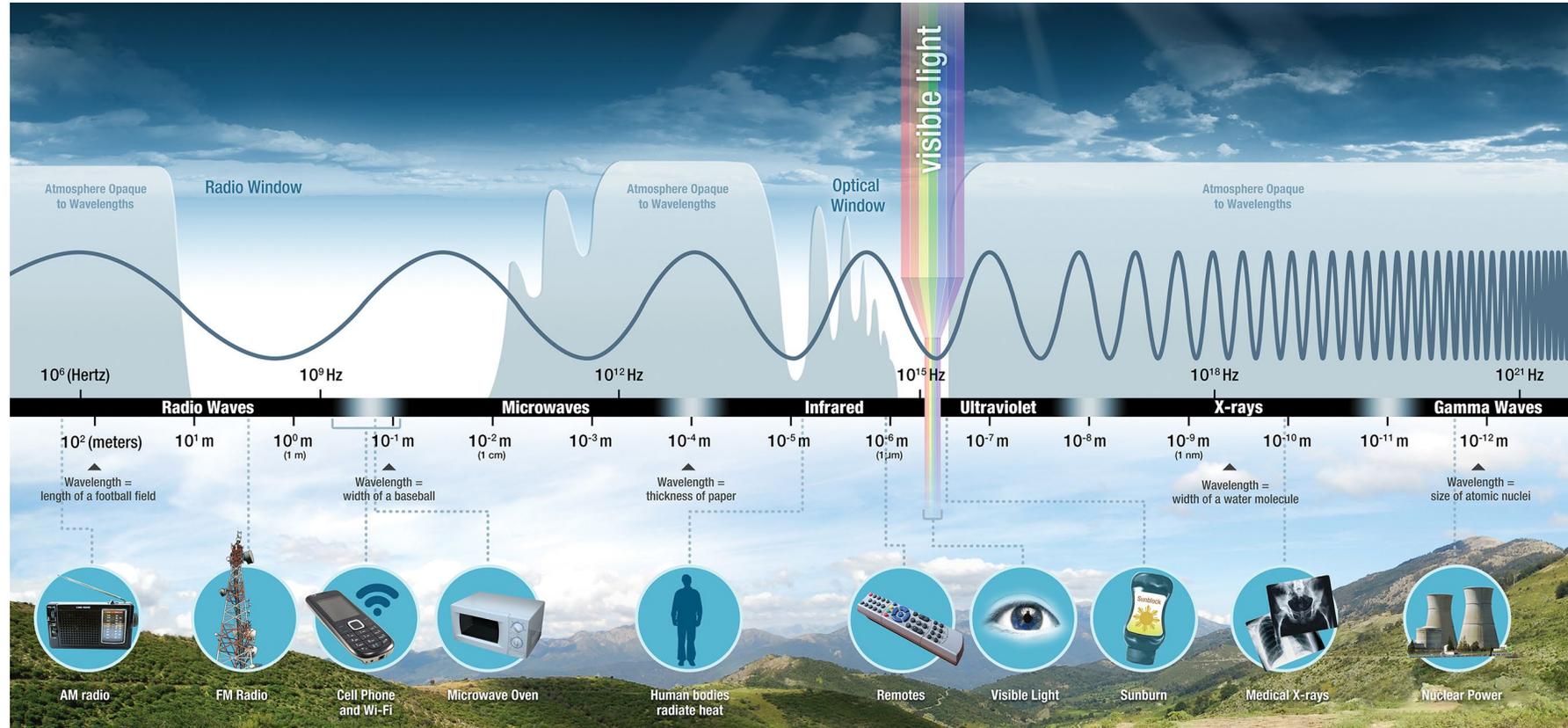


# Visible Image Science

- Visible satellite images are essentially photographs
- All the energy collected by the visible sensors (cameras) onboard the satellite is light energy from the sun, reflected by the Earth
- The reflectance is a measure of albedo, which is the percentage of light energy reflected by the Earth
- The higher the albedo, the more light reflected back into space (i.e. clouds appear bright)
- The lower the albedo, the more light energy is absorbed (i.e. water appears dark)



# Wavelength Selection

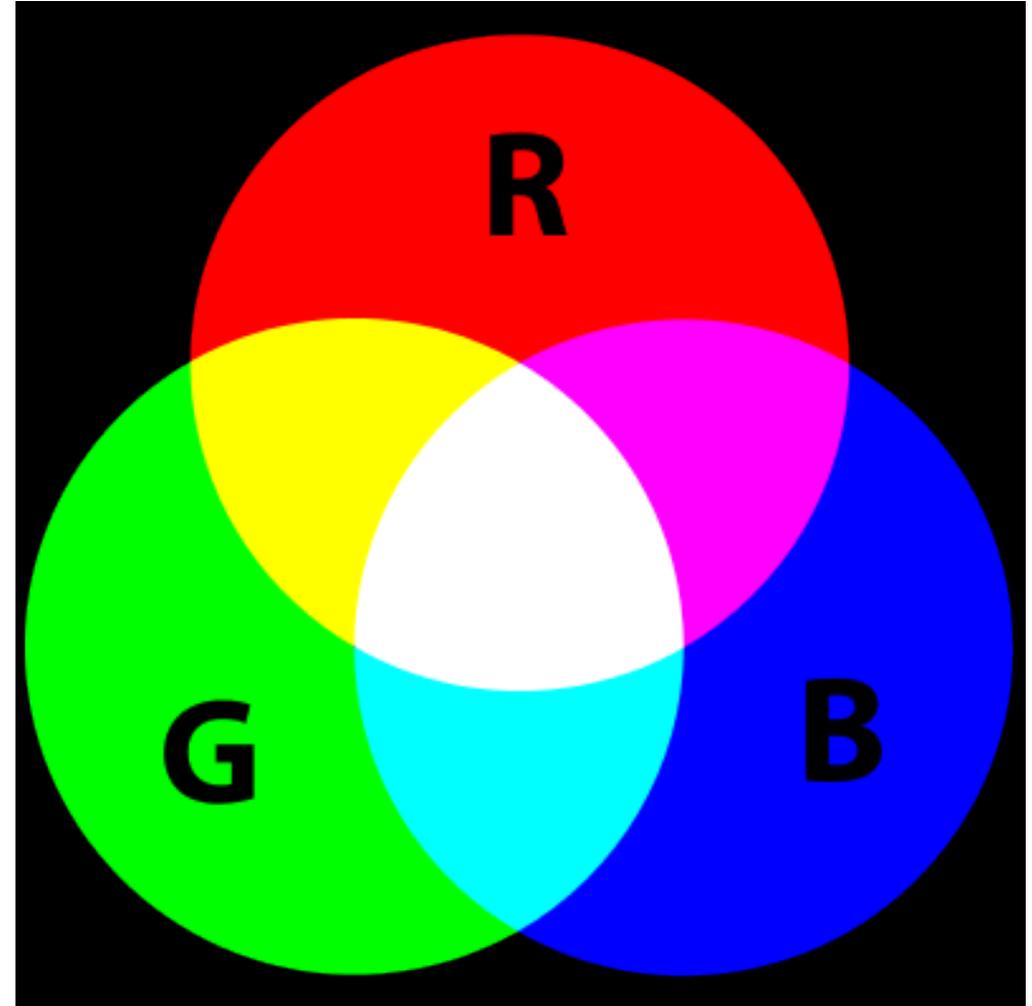


Earth observing satellite remote sensing instruments typically make observations at many discrete wavelengths, or **wavelength bands**



# 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



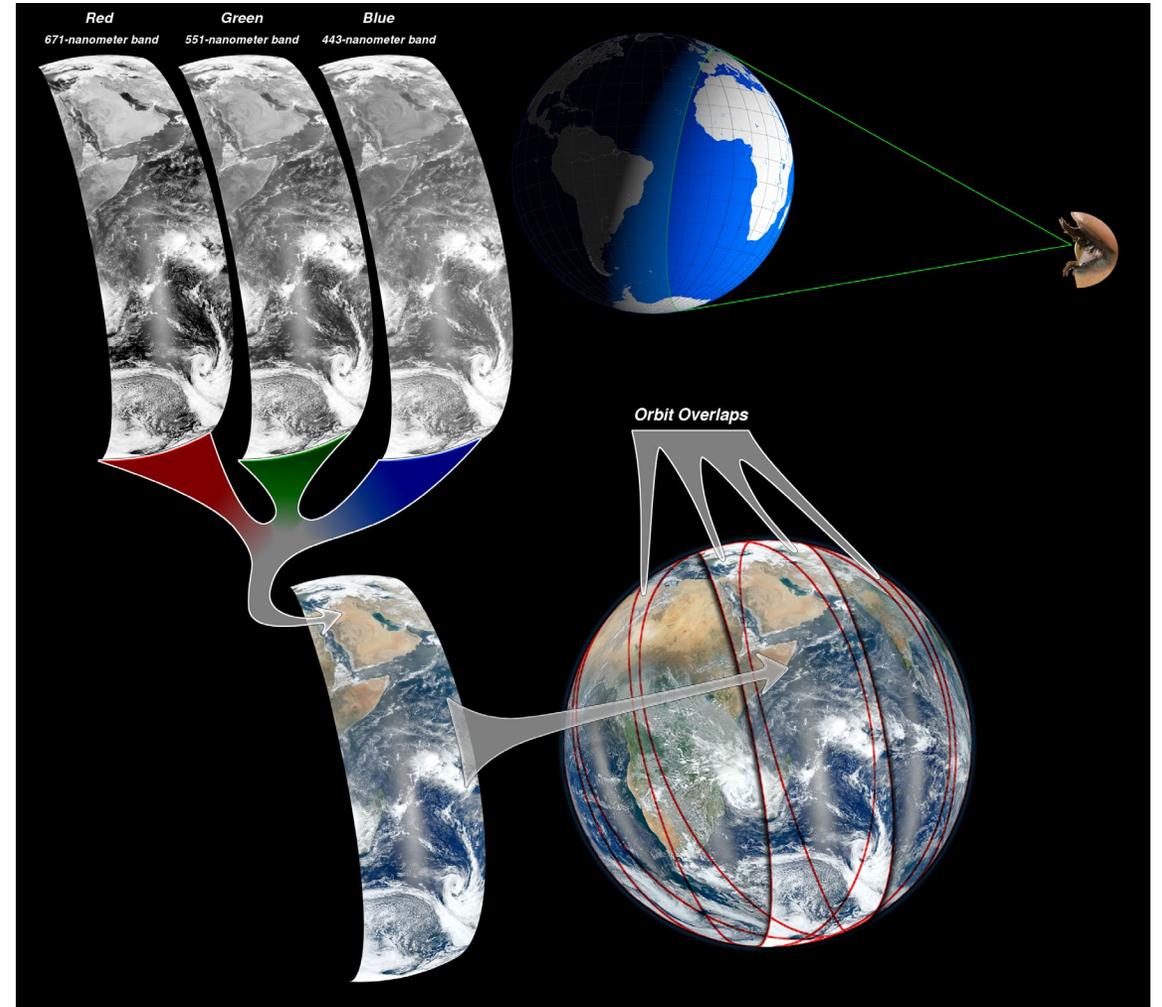
# True Color Image (or RGB)

A MODIS “true color image” will use MODIS visible wavelength bands 1, 4, 3

R = 0.66  $\mu\text{m}$

G = 0.55  $\mu\text{m}$

B = 0.47  $\mu\text{m}$



# Moderate Resolution Imaging Spectroradiometer

## MODIS

- Spatial Resolution
  - 250 m, 500 m, 1 km
- Platform
  - Terra & Aqua
- Temporal Resolution
  - 2000 – present
  - Daily, 8-day, 16-day, monthly, quarterly, yearly
- Data Format
  - Hierarchical Data Format – Earth Observing System (HDF-EOS)



- Spectral Coverage
  - 36 bands (major bands include red, blue, IR, NIR, MIR)
    - Bands 1-2: 250 m
    - Bands 3-7: 500 m
    - Bands 8-36: 1,000 m

# MODIS Reflected Solar Bands

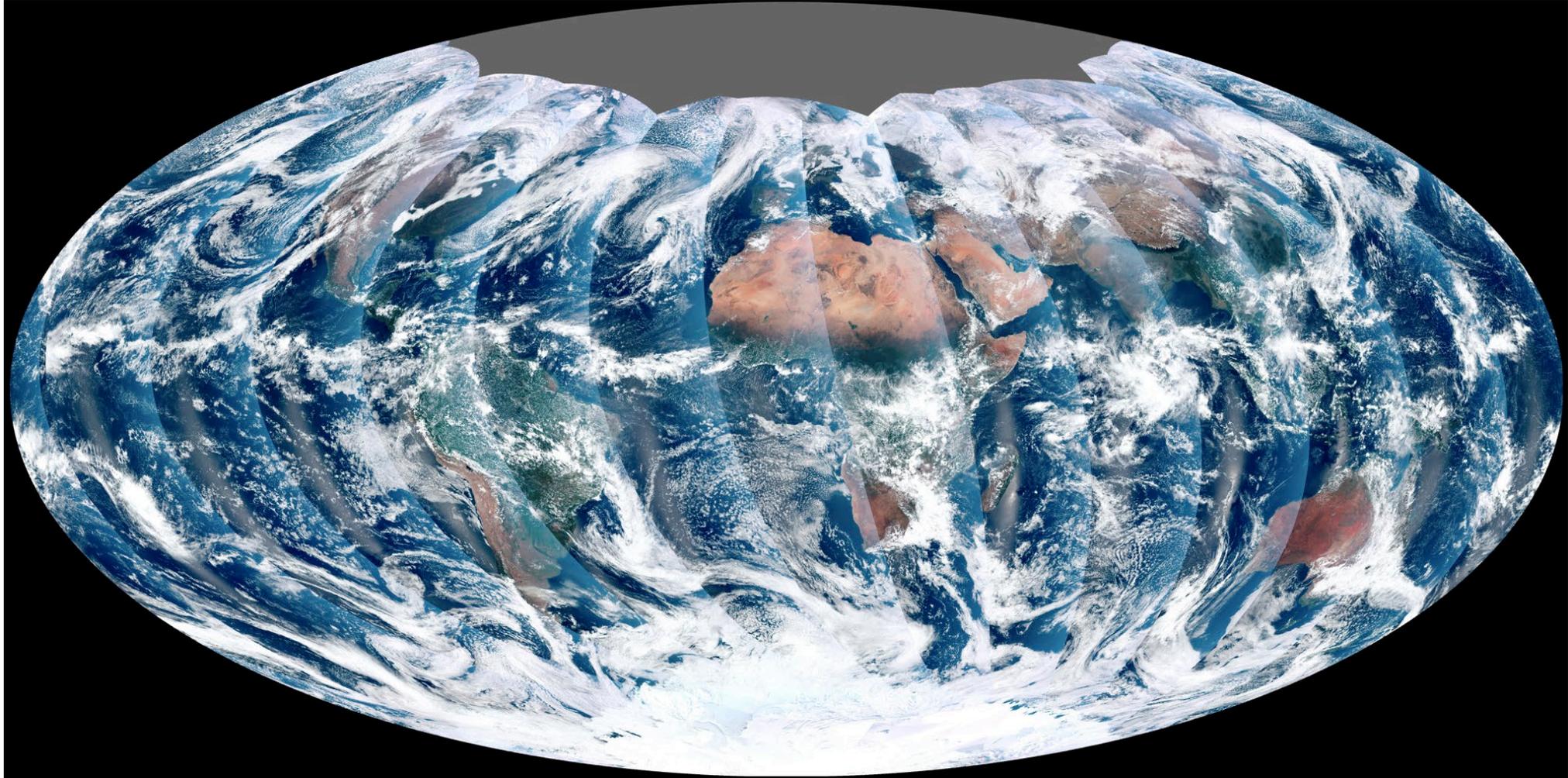
	Primary Use	Band No.	Bandwidth (nm)
250 m	Land/Cloud Boundaries	1**	620-670
		2**	841-876
500 m	Land/Cloud Properties	3*	459-479
		4*	545-565
		5*	1230-1250
		6*	1628-1652
		7*	2105-2155
	Ocean Color/ Phytoplankton/ Biogeochemistry	8	405-420
		9	438-448
		10	483-493
		11	526-536
		12	546-556
		13	662-672
		14	673-683
		15	743-753
	16	862-877	
	Atmospheric Water Vapor	17	890-920
		18	931-941
		19	915-965

\* 500m Spatial Resolution

\*\* 250m Spatial Resolution

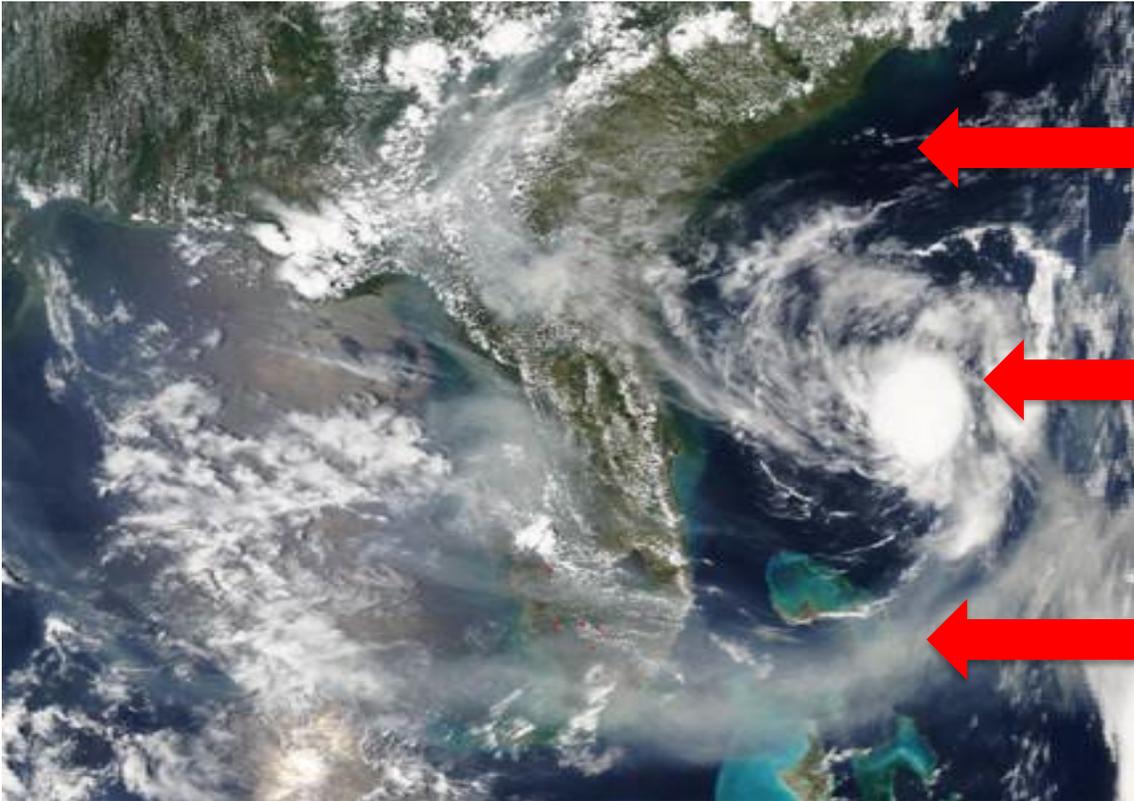


# VIIRS Image



# 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



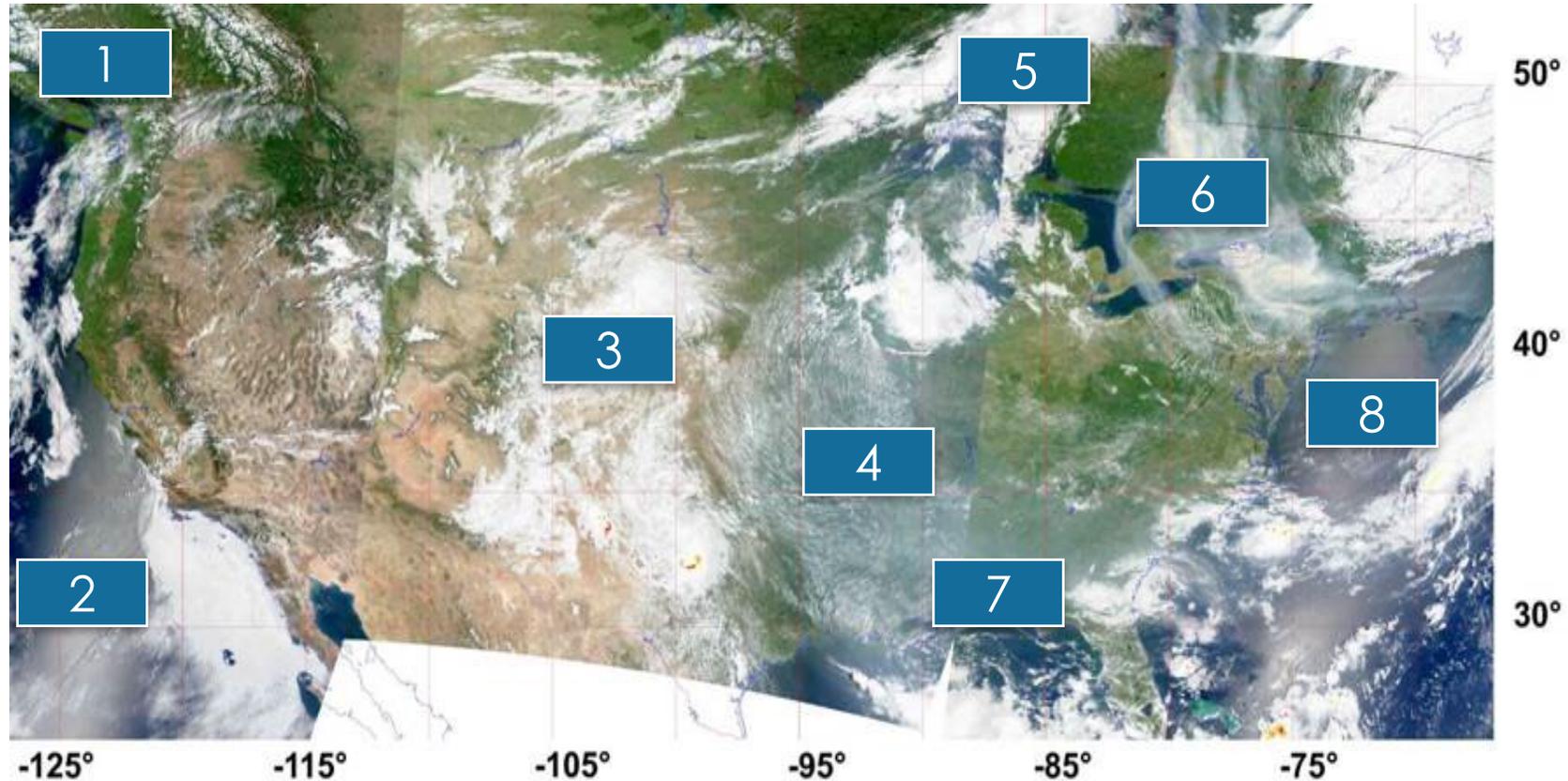
Visible imagery water is dark because it absorbs most of the energy

Clouds are white because they reflect most incoming energy

Pollution is hazy depending on its absorption properties



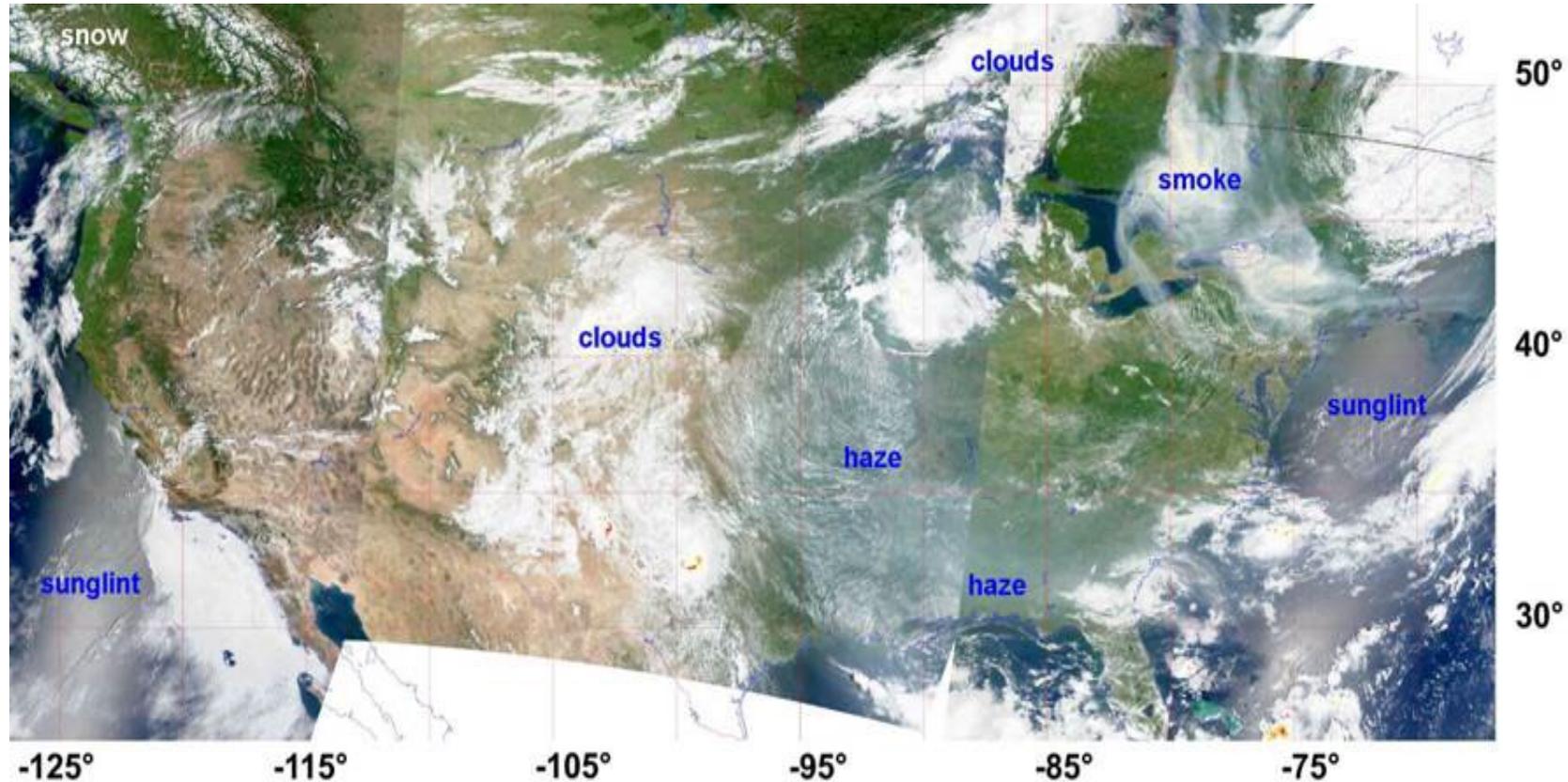
# What can we learn from true color imagery?



(Possible) identification of land, ocean, and atmosphere features



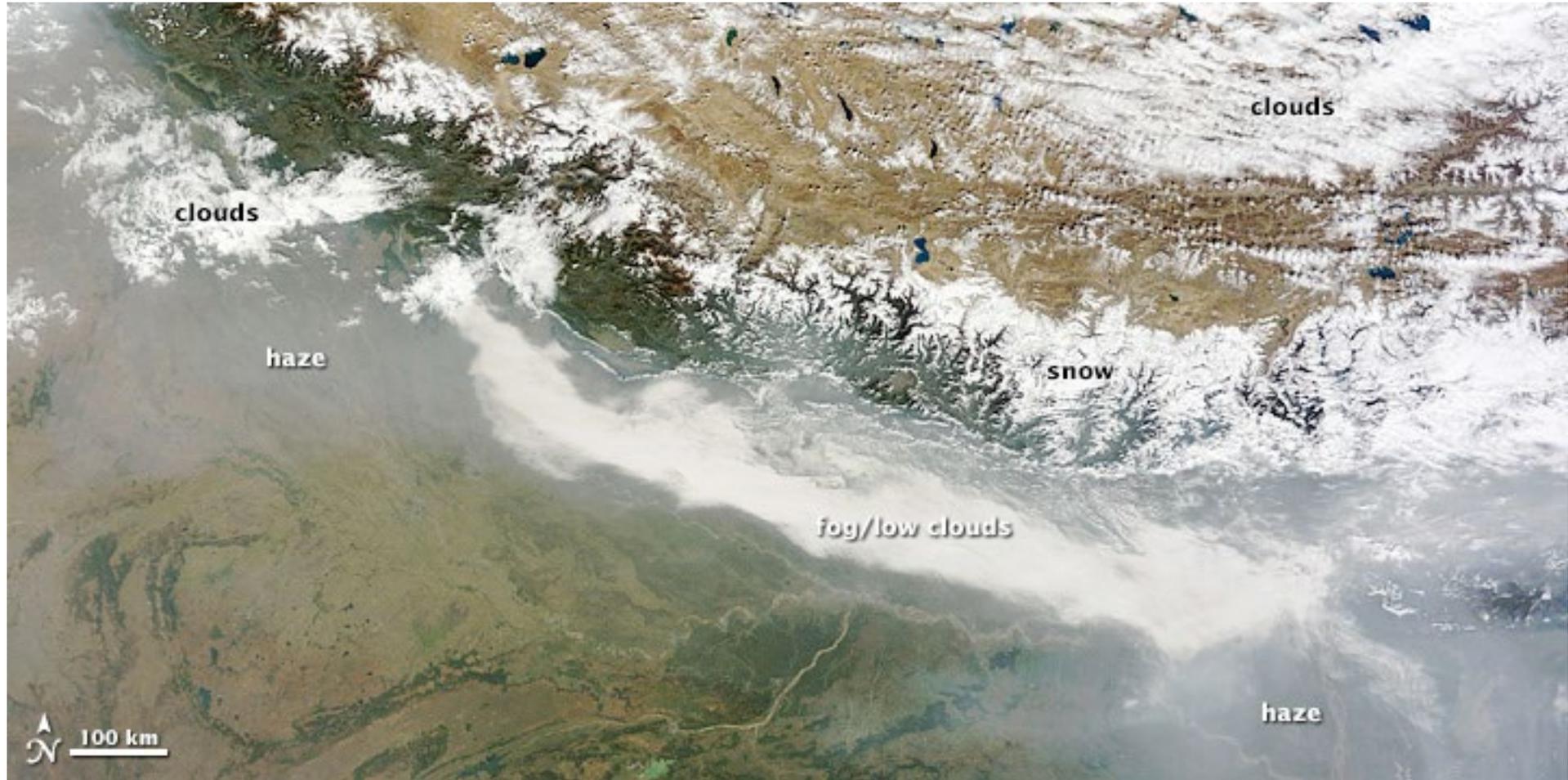
# What can we learn from true color imagery?



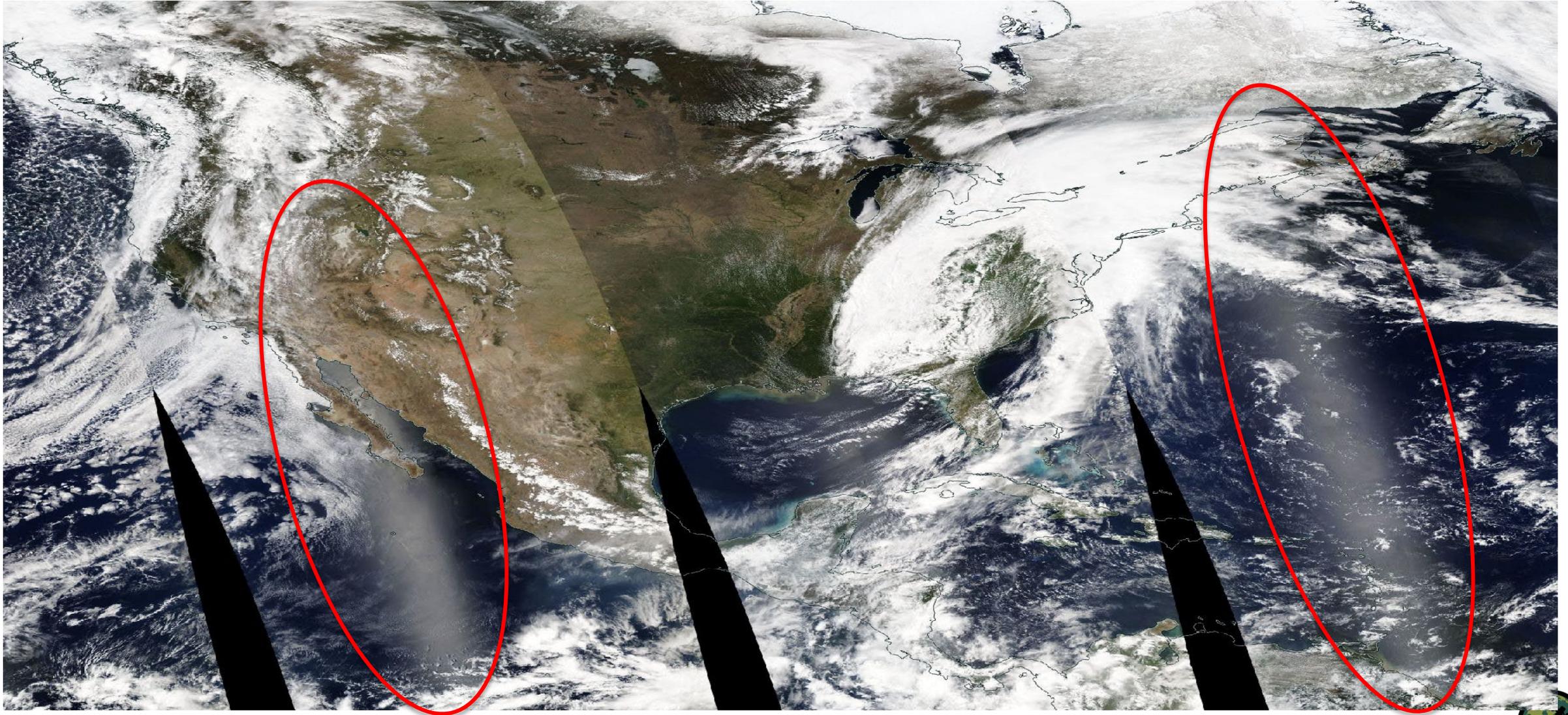
(Possible) identification of land, ocean, and atmosphere features



# Features in True Color (Atmosphere)



# Glint



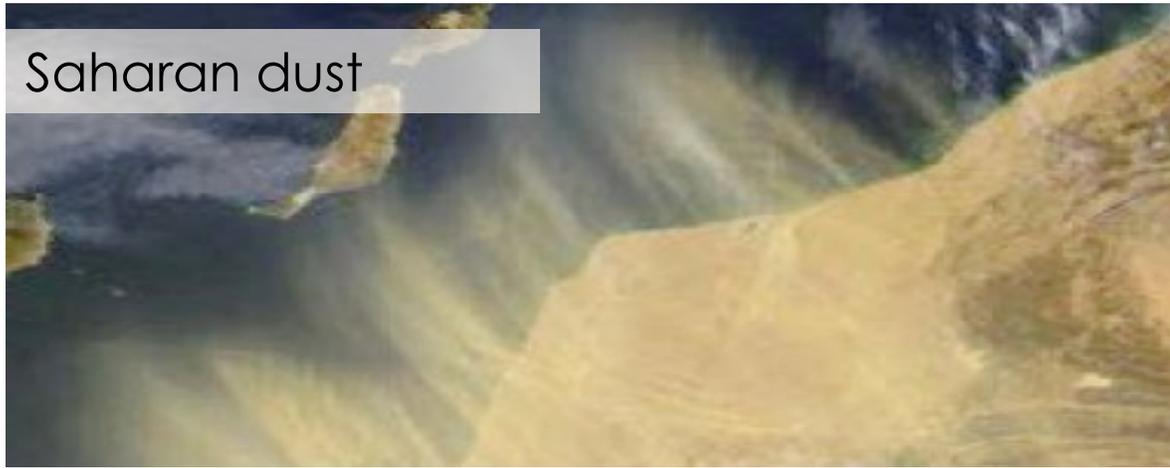
# Feature Identification

More reliable with clear source in image



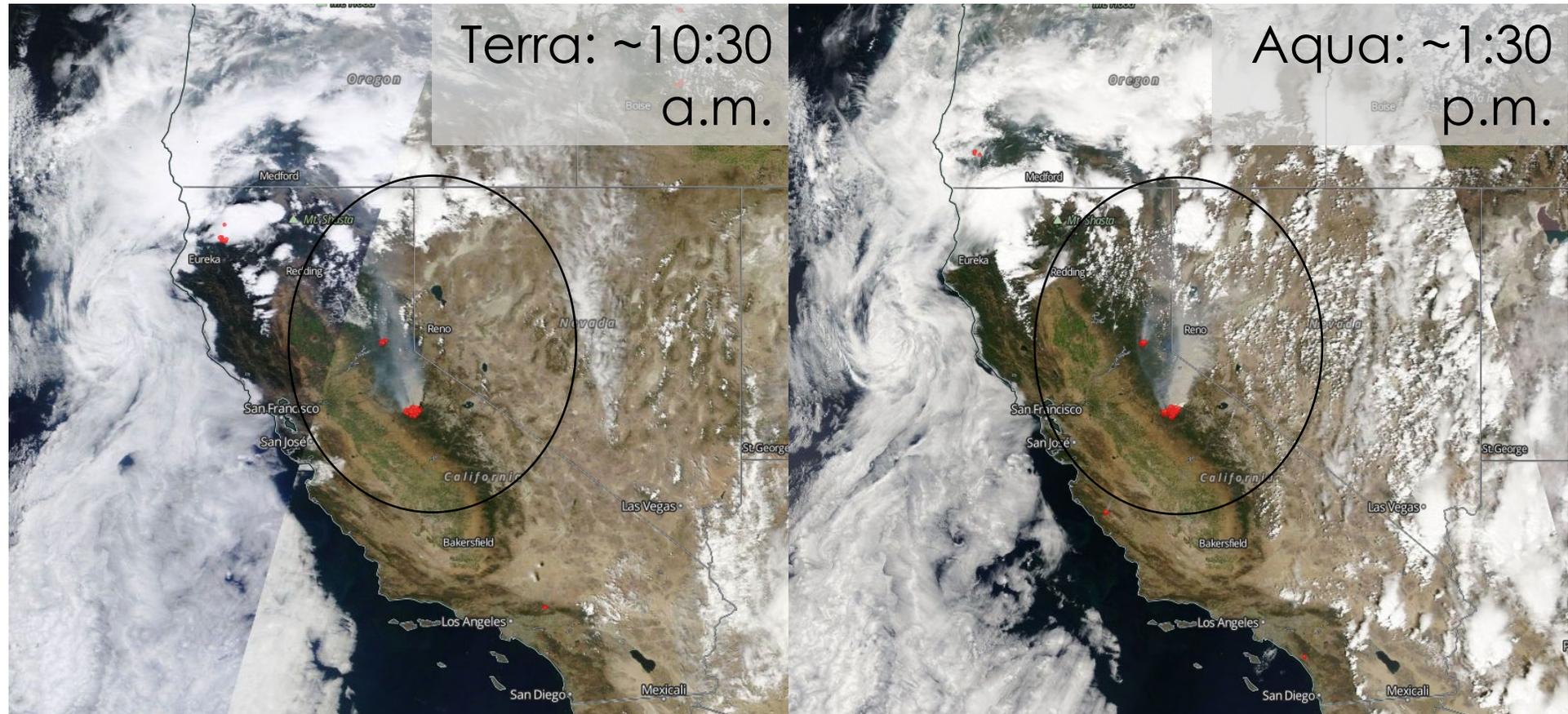
# Feature Identification

More reliable when a clear source is in the image



# Using Time Series Imagery

## Smoke Transport – Rim Fire

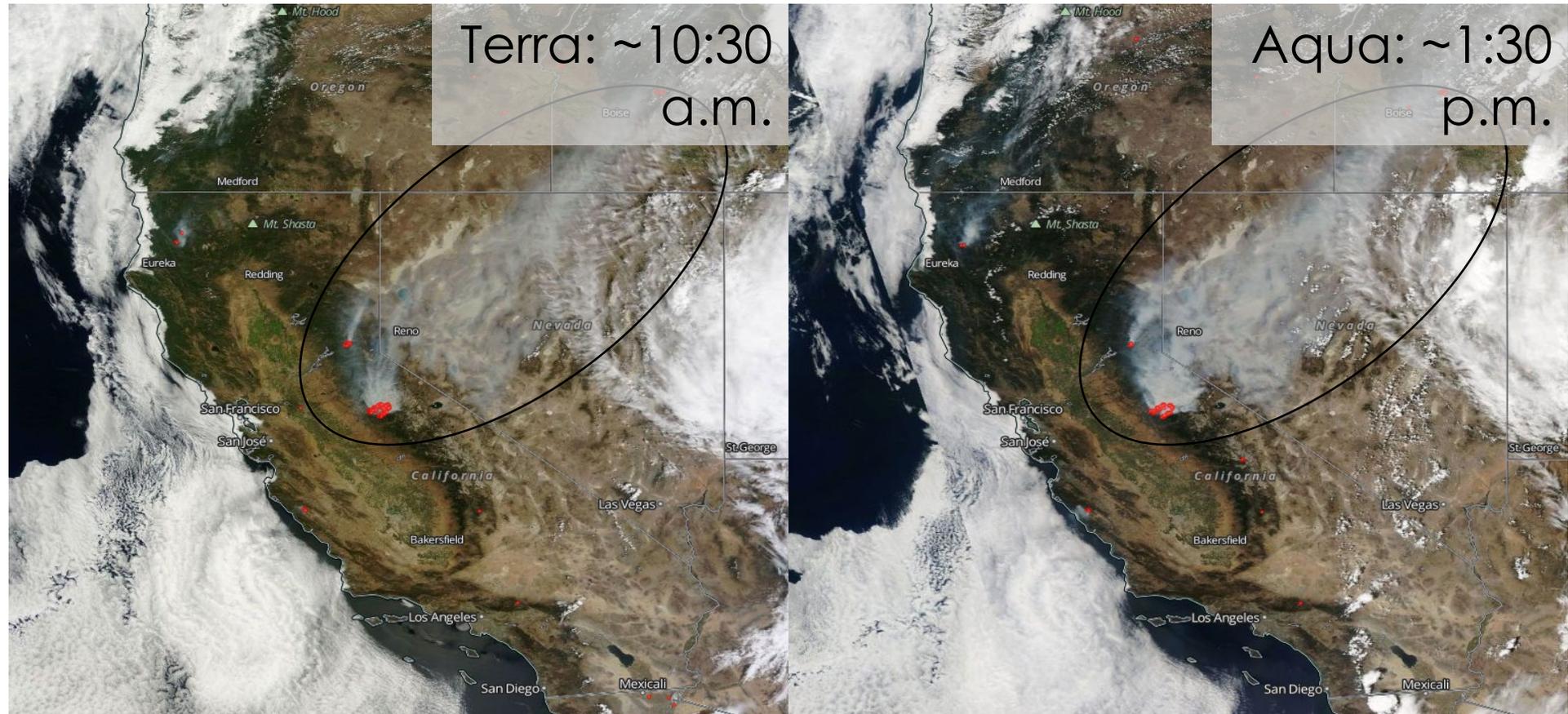


August 22, 2013; Images from NASA Worldview



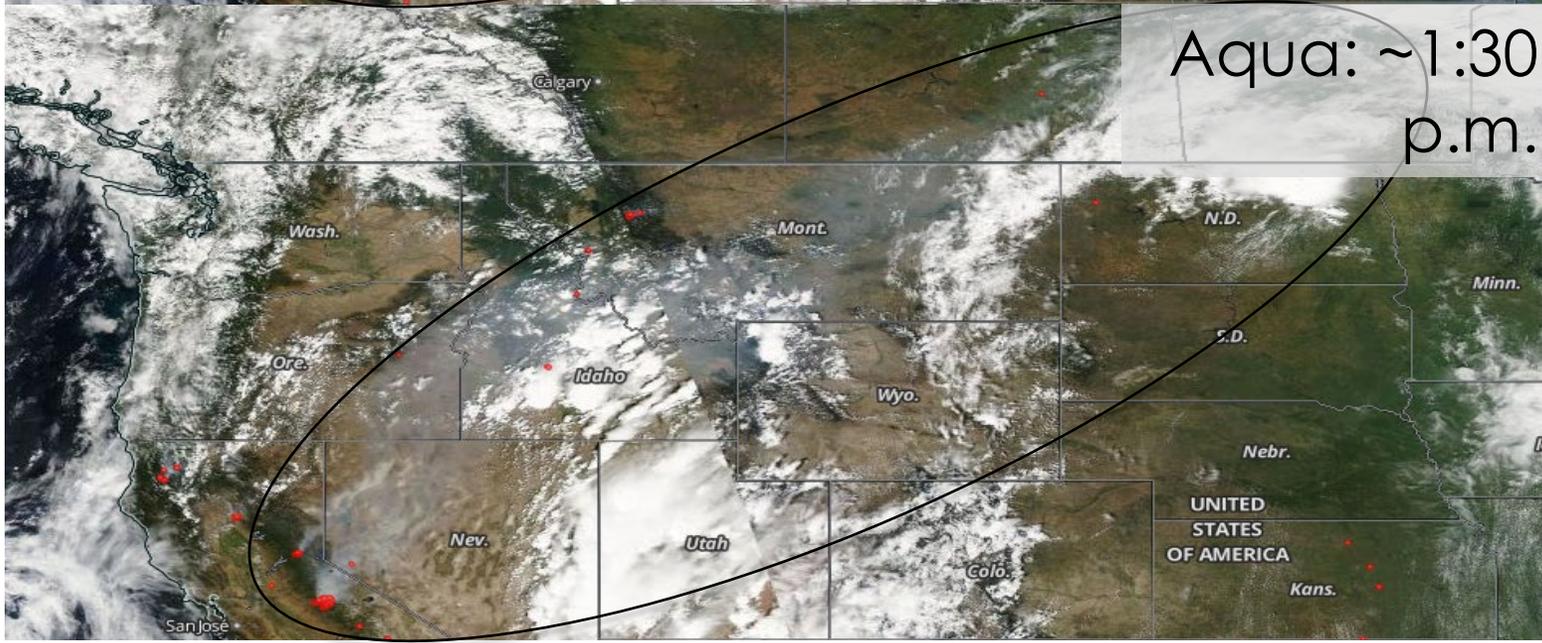
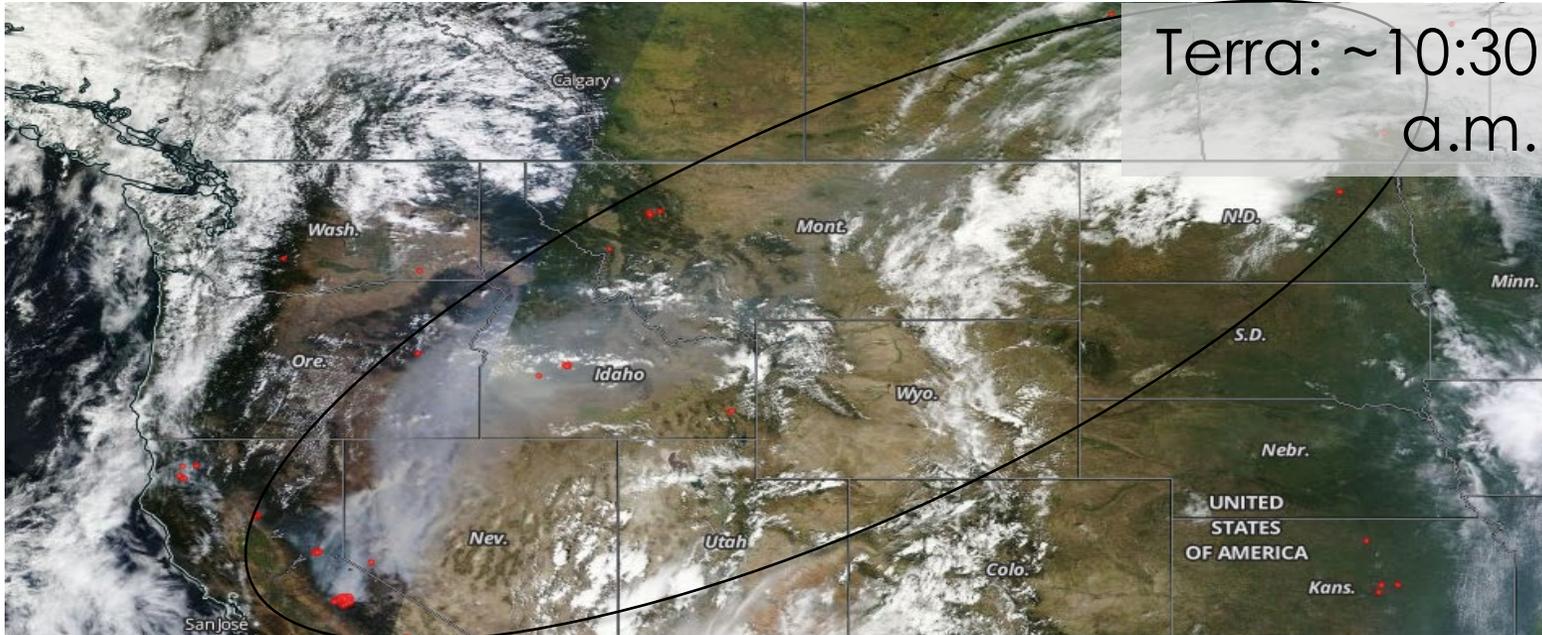
# Using Time Series Imagery

## Smoke Transport – Rim Fire



August 23, 2013; Images from NASA Worldview

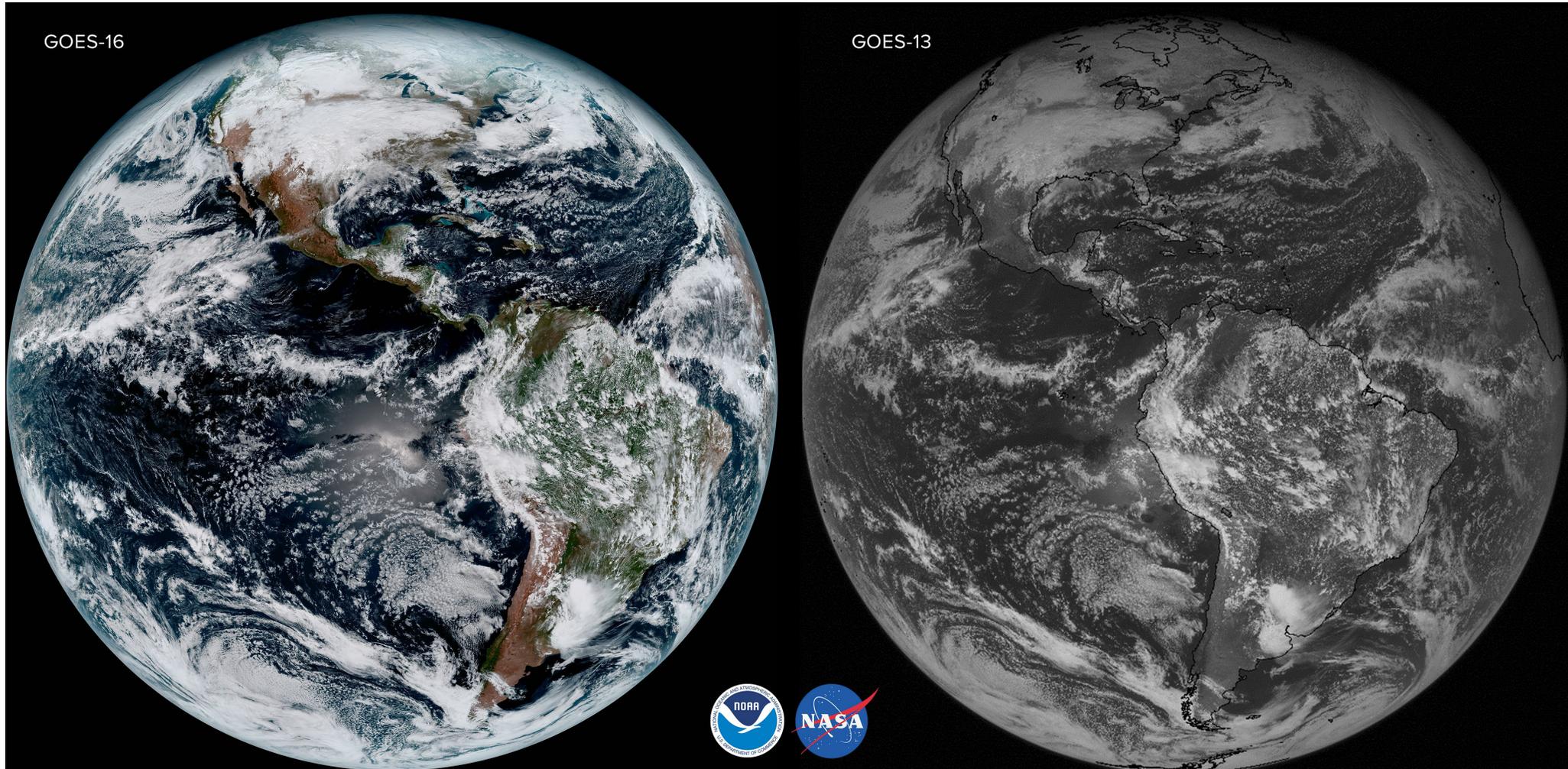




## August 24, 2013; Images from NASA Worldview



# Geostationary Observations – GOES-16 (East)



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



# GOES-16 Loop: Dust

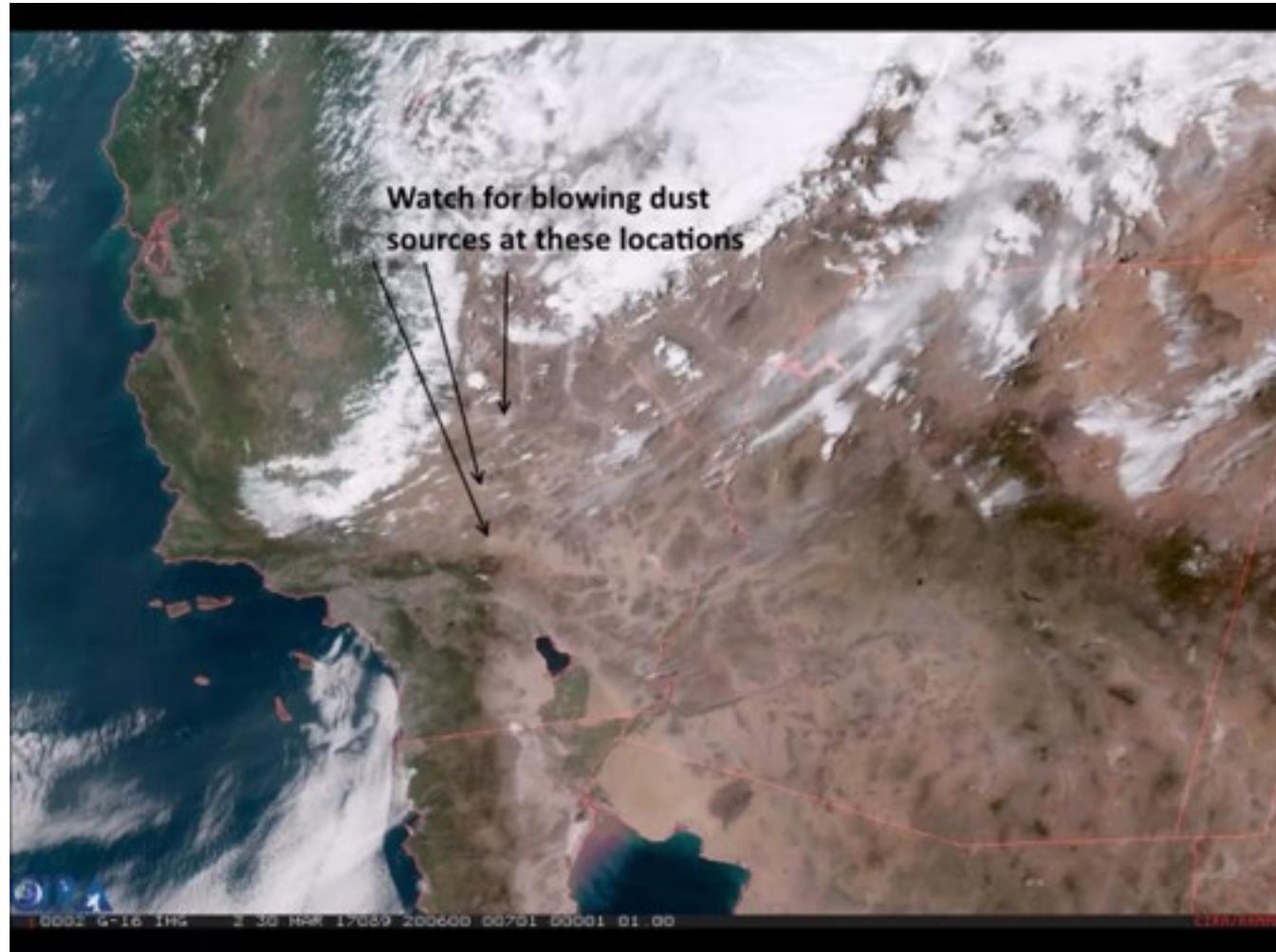


Image: NOAA CoRP, STAR: [http://rammb.cira.colostate.edu/ramsd/online/loop.asp?data\\_folder=loop\\_of\\_the\\_day/goes-16/20170330000000&number\\_of\\_images\\_to\\_display=100&loop\\_speed\\_ms=100](http://rammb.cira.colostate.edu/ramsd/online/loop.asp?data_folder=loop_of_the_day/goes-16/20170330000000&number_of_images_to_display=100&loop_speed_ms=100)



# GOES-16: Smoke Transport over the Northwest

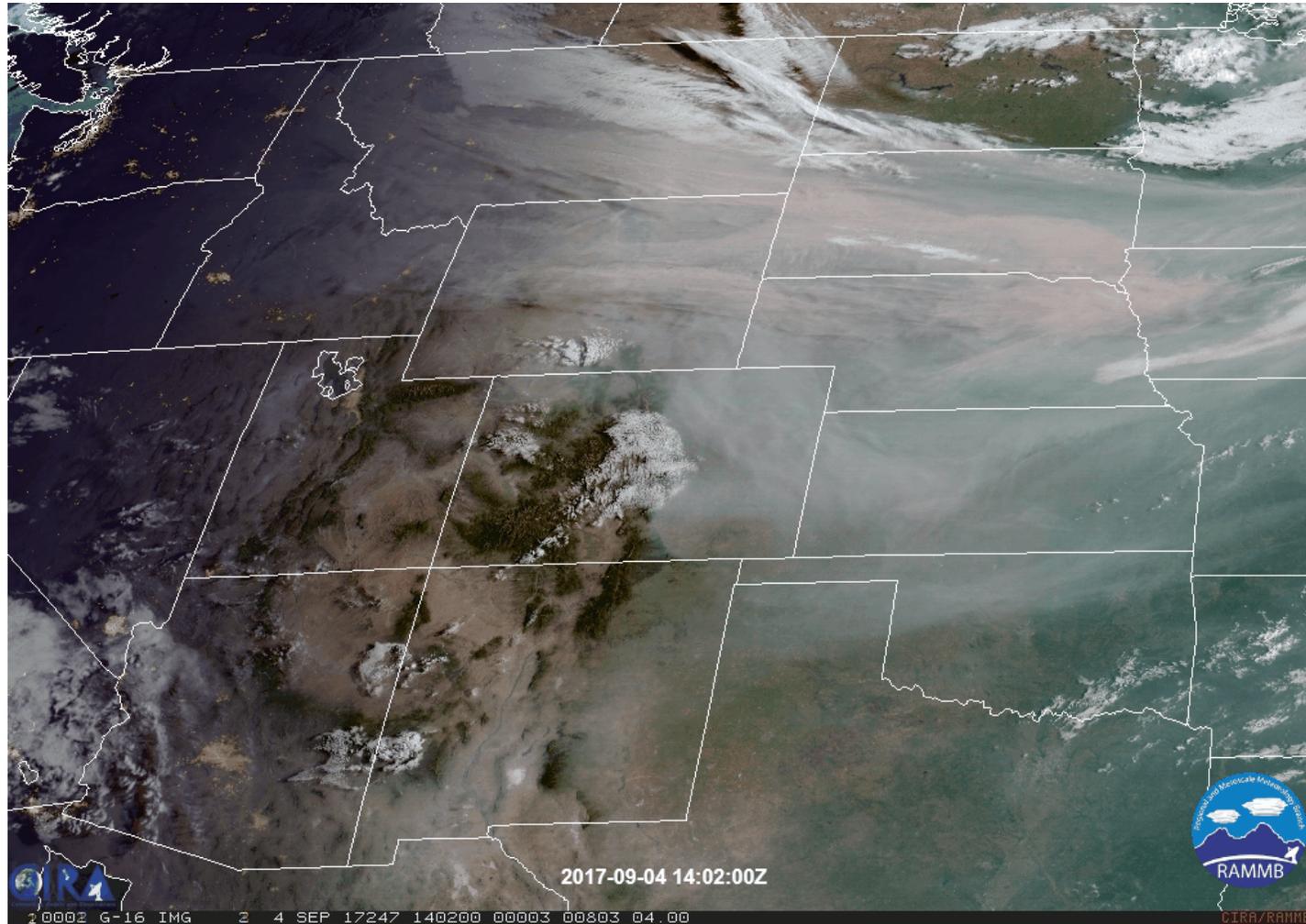


Image: [http://rammb.cira.colostate.edu/ramdis/online/loop.asp?data\\_folder=loop\\_of\\_the\\_day/goes-16/20170904000000&number\\_of\\_images\\_to\\_display=200&loop\\_speed\\_ms=80](http://rammb.cira.colostate.edu/ramdis/online/loop.asp?data_folder=loop_of_the_day/goes-16/20170904000000&number_of_images_to_display=200&loop_speed_ms=80)



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

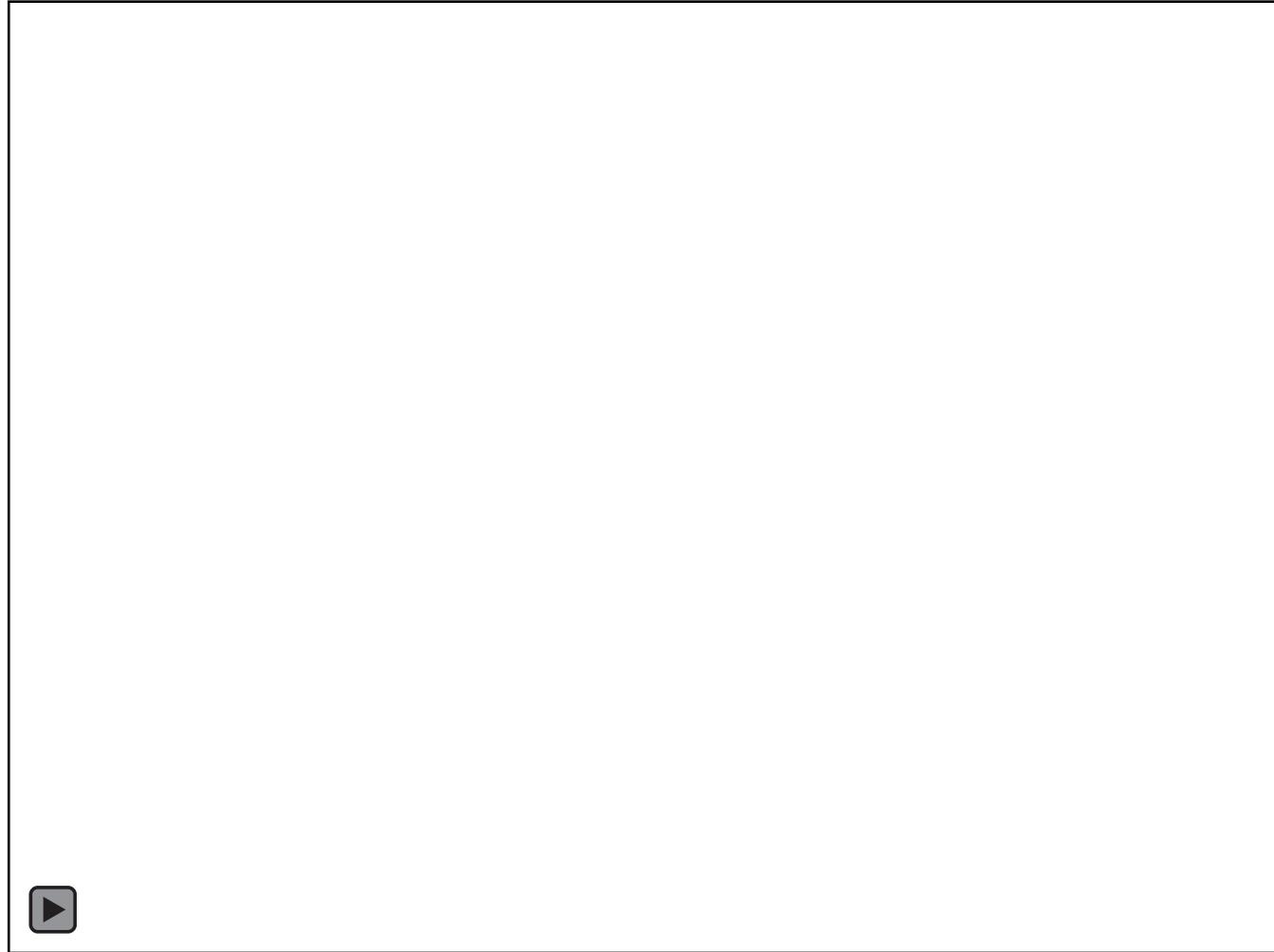


Image: NOAA CoRP, STAR: [http://rammb.cira.colostate.edu/ramsd/online/loop.asp?data\\_folder=loop\\_of\\_the\\_day/goes-16/20170306000000&number\\_of\\_images\\_to\\_display=100&loop\\_speed\\_ms=100](http://rammb.cira.colostate.edu/ramsd/online/loop.asp?data_folder=loop_of_the_day/goes-16/20170306000000&number_of_images_to_display=100&loop_speed_ms=100)



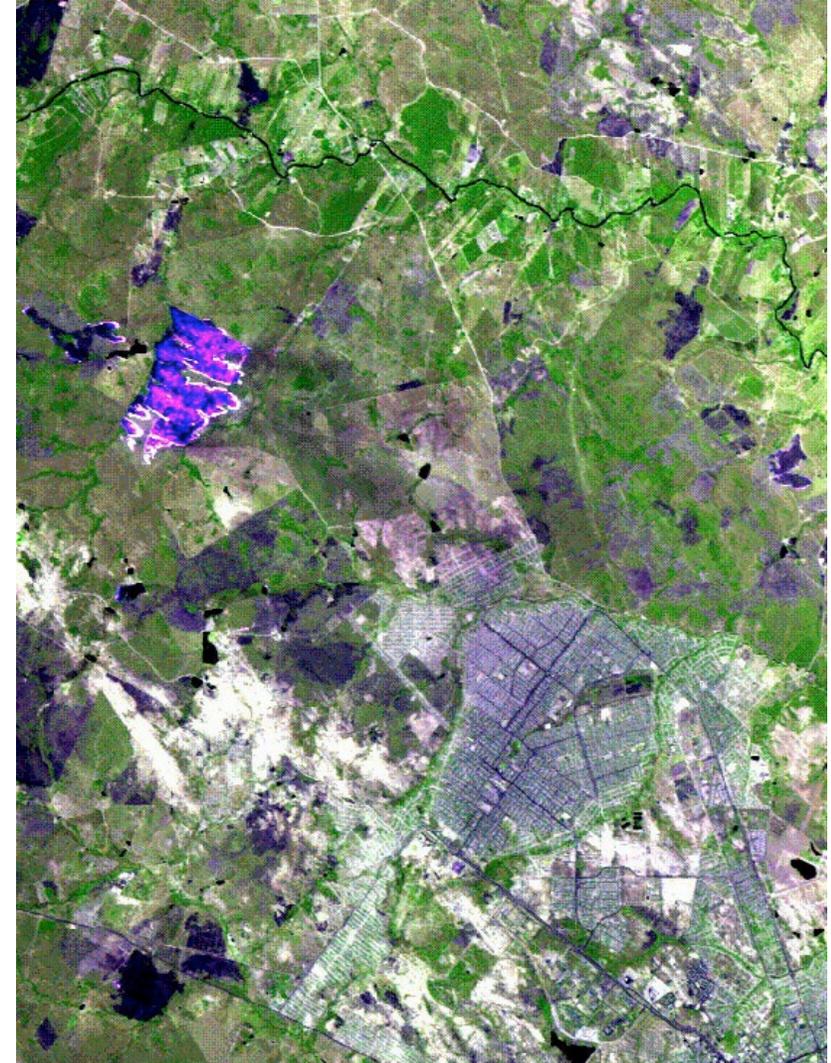
# False Color Images

- Load bands into the red, green, and blue display channels
- Do not correspond to the visible red, green, and blue wavelengths

R = 1.6  $\mu\text{m}$

G = 1.2  $\mu\text{m}$

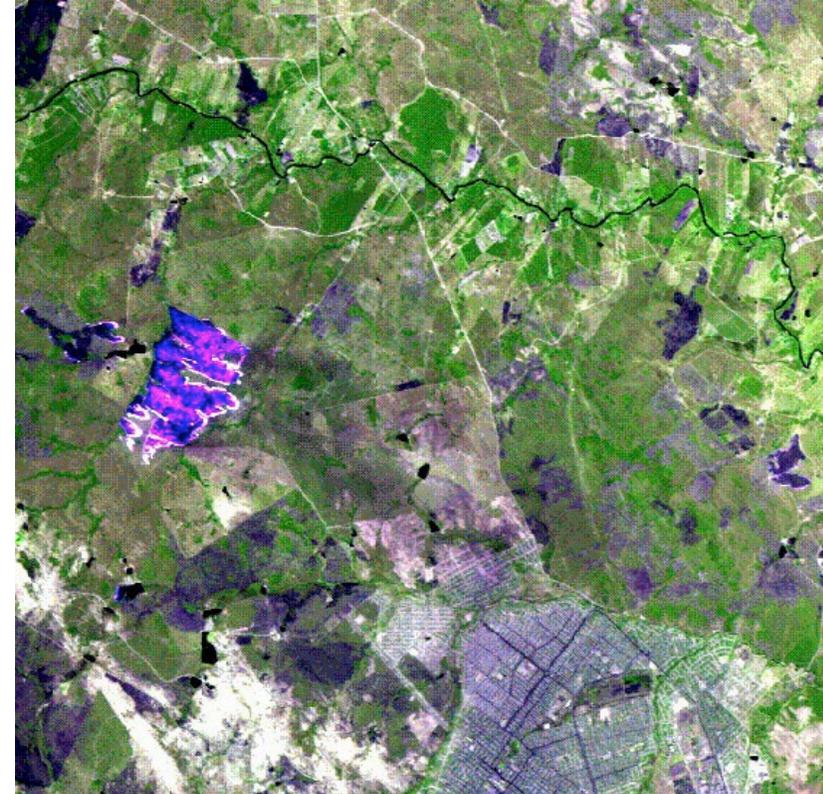
B = 2.1  $\mu\text{m}$



# True vs. False Color Images



R = 0.66  $\mu\text{m}$   
G = 0.55  $\mu\text{m}$   
B = 0.47  $\mu\text{m}$



R = 1.6  $\mu\text{m}$   
G = 1.2  $\mu\text{m}$   
B = 2.1  $\mu\text{m}$



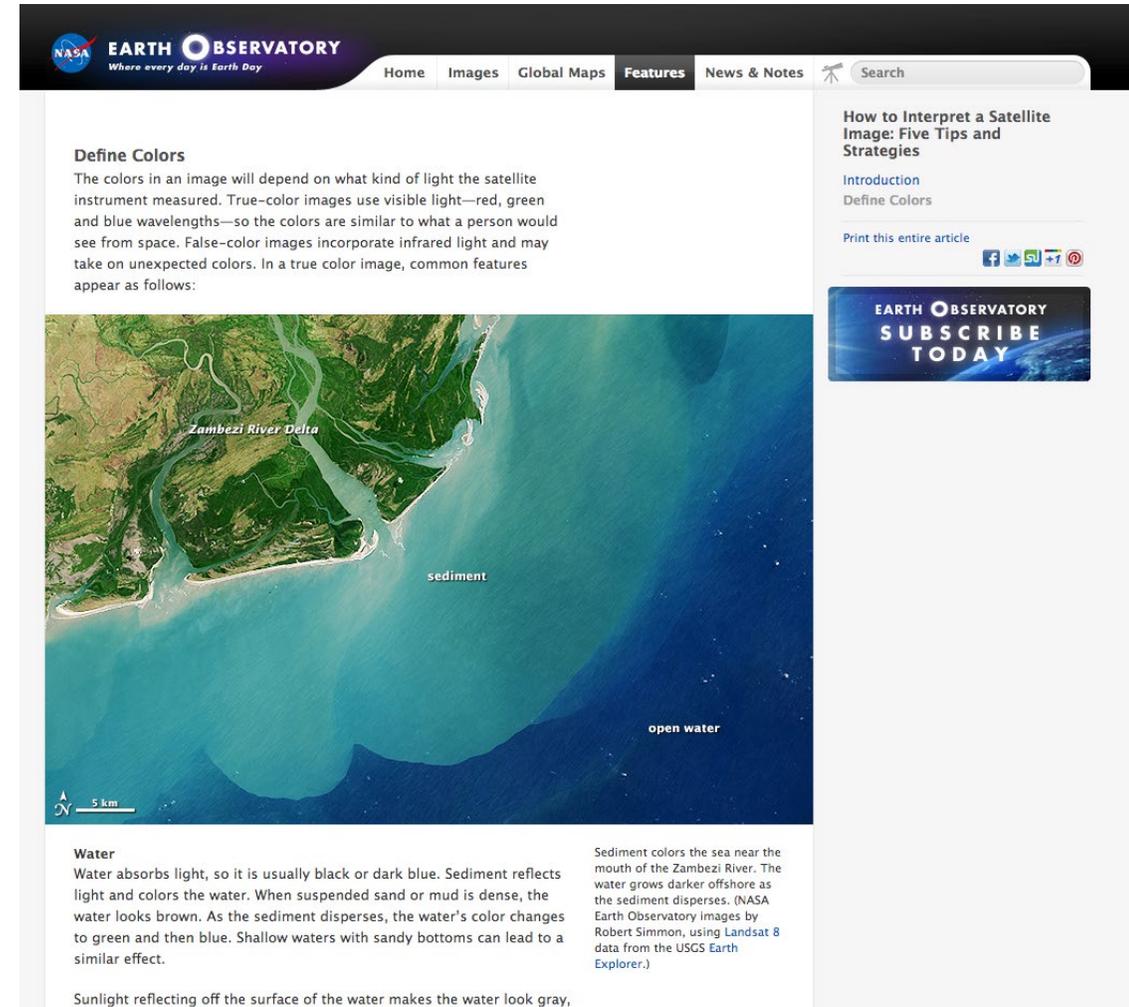
# Change in Vegetation Color from Space



# Earth Observatory Story

An article on feature detection in an image:

<http://earthobservatory.nasa.gov/Features/ColorImage/page2.php>



The screenshot shows the NASA Earth Observatory website. The header includes the NASA logo, the text "EARTH OBSERVATORY Where every day is Earth Day", and navigation links for Home, Images, Global Maps, Features, News & Notes, and a search bar. The main content area is titled "Define Colors" and contains the following text: "The colors in an image will depend on what kind of light the satellite instrument measured. True-color images use visible light—red, green and blue wavelengths—so the colors are similar to what a person would see from space. False-color images incorporate infrared light and may take on unexpected colors. In a true color image, common features appear as follows:" Below this text is a satellite image of the Zambezi River Delta. The image shows the river flowing into the ocean, with a large area of sediment-colored water near the mouth. Labels "Zambezi River Delta", "sediment", and "open water" are overlaid on the image. A scale bar indicates 5 km. Below the image, there are two columns of text: "Water" and "Sediment". The "Water" section explains that water absorbs light, making it dark blue, and that sediment reflects light, making the water appear brown, green, or blue. The "Sediment" section explains that sediment colors the sea near the mouth of the Zambezi River, and that the water grows darker offshore as the sediment disperses. On the right side of the page, there is a sidebar with the title "How to Interpret a Satellite Image: Five Tips and Strategies", a "Print this entire article" link, social media icons, and a "SUBSCRIBE TODAY" button.

**Define Colors**

The colors in an image will depend on what kind of light the satellite instrument measured. True-color images use visible light—red, green and blue wavelengths—so the colors are similar to what a person would see from space. False-color images incorporate infrared light and may take on unexpected colors. In a true color image, common features appear as follows:



**Water**

Water absorbs light, so it is usually black or dark blue. Sediment reflects light and colors the water. When suspended sand or mud is dense, the water looks brown. As the sediment disperses, the water's color changes to green and then blue. Shallow waters with sandy bottoms can lead to a similar effect.

**Sediment**

Sediment colors the sea near the mouth of the Zambezi River. The water grows darker offshore as the sediment disperses. (NASA Earth Observatory images by Robert Simmon, using Landsat 8 data from the USGS Earth Explorer.)

Sunlight reflecting off the surface of the water makes the water look gray,



# Image Archive and Gallery Links

- ARSET Satellite Imagery Overview and links
  - <http://airquality.gsfc.nasa.gov/index.php?section=64>
- 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>



# Tour of Some Useful Image Archives

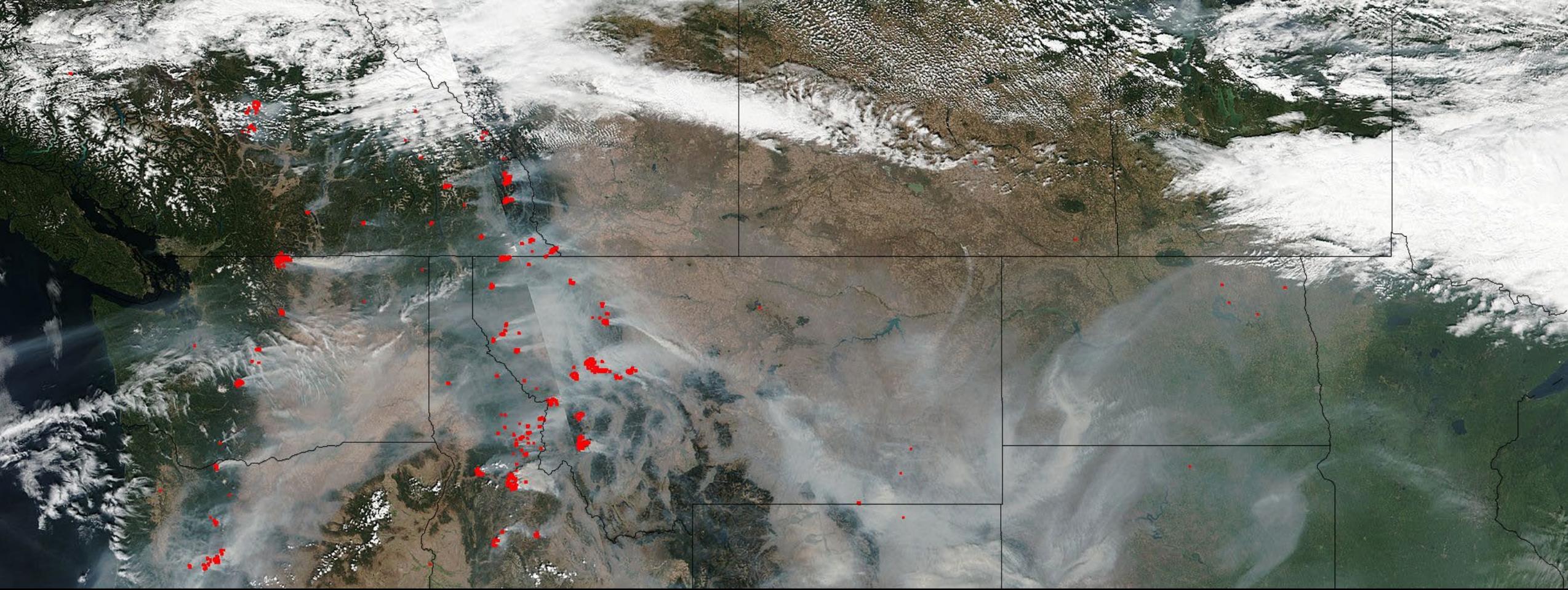
- Earth Observatory: Events & More
  - <http://earthobservatory.nasa.gov>
- Worldview: Near Real-Time
  - <http://earthdata.nasa.gov/labs/worldview>



# Questions & Discussion Prompts

- What are the differences between true color and false color images?
- What are three applications of true color images for air quality monitoring?
- Does access of near real-time, true color imagery provide any useful information to air quality forecasters?





Questions?