Fri. Feb. 16, 2018

- Reading:
  - Jump ahead to first part of Ch. 8 -- Digital Image Processing for lab next week.
    - Pg. 255 - 269 except
    - Skip over map projections -- we'll cover that in more detail later
    - Just skim descriptions of old scanning/digitizing technology
    - DO understand DN (Data Number, Digitial Numbers) and Histograms / Contrast Stretch

- Today Ch. 4 Other Satellite Systems
  - Most other satellite systems in book are OLD
  - I'll cover newer ones in lecture

Figure 3-24 Landsat MSS band 4 image of the Peninsular Ranges, southern California. From Lamar and Merifield (1975, Figure 3). Courtesy P. M. Merifield, UCLA.

Linear Features

- Linear: Adjective
- Lineation: 1-D fabric in a rock
- Lineament: Linear or curvilinear feature on a map or image

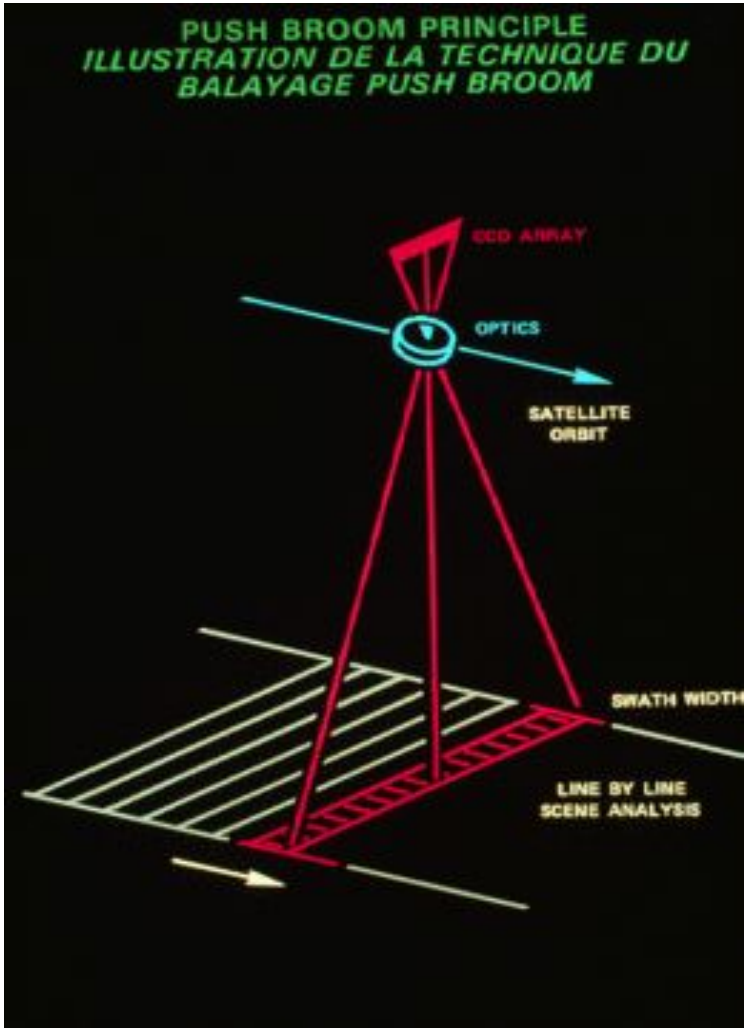
Other Satellite Systems

- Spot satellite overview
- NASA "Earth Observing System"
  - Terra, Aqua, Aura, etc.
    - MODIS on Terra and Aqua
    - ASTER on Terra
- POES and GOES
- Private companies such as DigitalGlobe
  - WorldView (up to ~20 cm resolution) and GeoEye (0.5 m resolution) satellites
  - Most of Google Earth images are by them
  - USGS also purchasing some data from them

SPOT

- European Spacecraft
- Higher spatial resolution, less spectral coverage than Landsat
  - 10 m resolution Panchromatic (vs TM 30,15 m)
  - 20 m in 3 VNIR bands
- Can look “off nadir” (to side) for stereo
- 832 km sun-synchronous
  - 10 am south-bound track
  - 26 day repeat cycle

SPOT



SPOT 10-meter panchromatic Toulous, France

Earth Observing System

- Terra (AM) and Aqua (PM)
  - Terra
    - Launched Dec. 1999
    - ASTER, MODIS, other instruments
      - Advanced Spaceborne Thermal Emission and Reflection Radiometer
        - » Targeted observations (not whole earth coverage) VNIR, SWIR(failed 2008), TIR
      - MODerate-resolution Imaging Spectroradiometer
  - Aqua
    - Launched May 2002
    - MODIS, other instruments
  - Aura
    - Launched May 2004
    - Atmosphere oriented
  - Glory
    - Launch failure on Mar. 4, 2011
    - Energy balance (solar irradiance, scattered & reflected sunlight, clouds)
  - A-Train (Afternoon pass): Aqua, Cloudsat, CALIPSO, AURA, (~~GLORY~~, GCOM-W1)

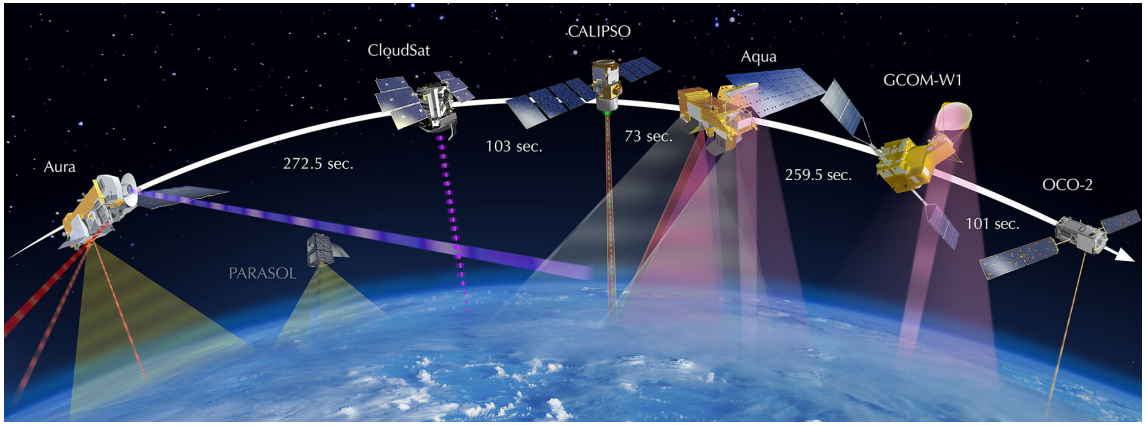
OCO and Glory

- Orbiting Carbon Observatory — Launch failure Feb. 24, 2009
- Glory — Launch failure Mar. 4, 2011

- Both launched by Taurus XL rockets from Vandenburg AFB
- In both cases payload fairing failed to separate once it left atmosphere

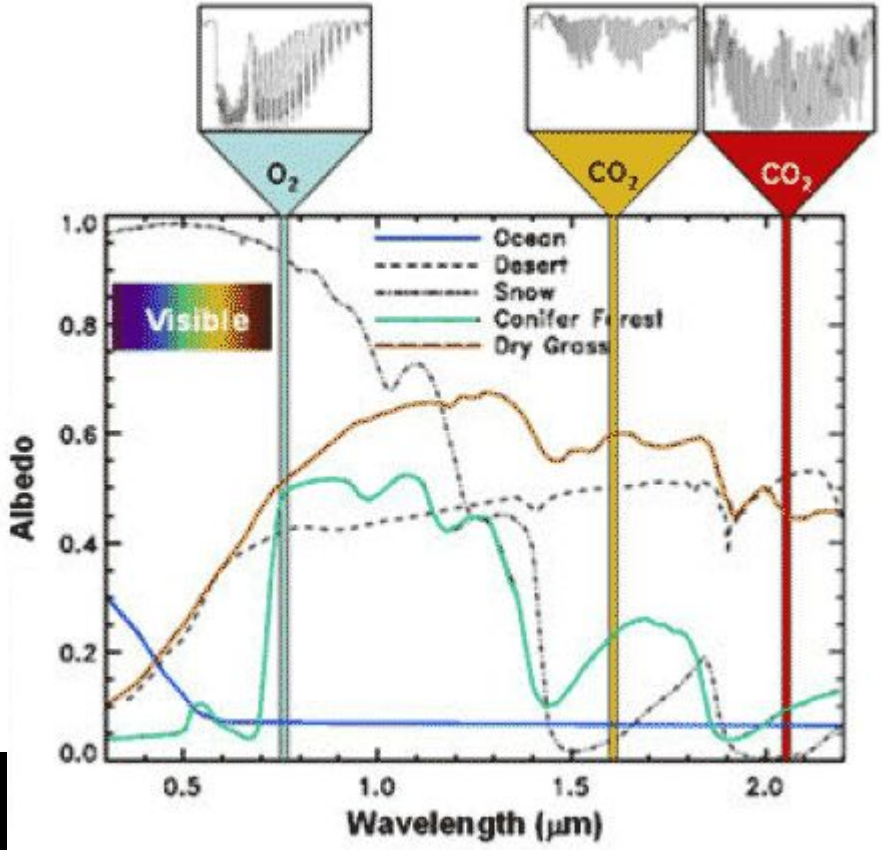
- With payload fairing still attached rocket to heavy to reach orbit -- reentered over the South Pacific

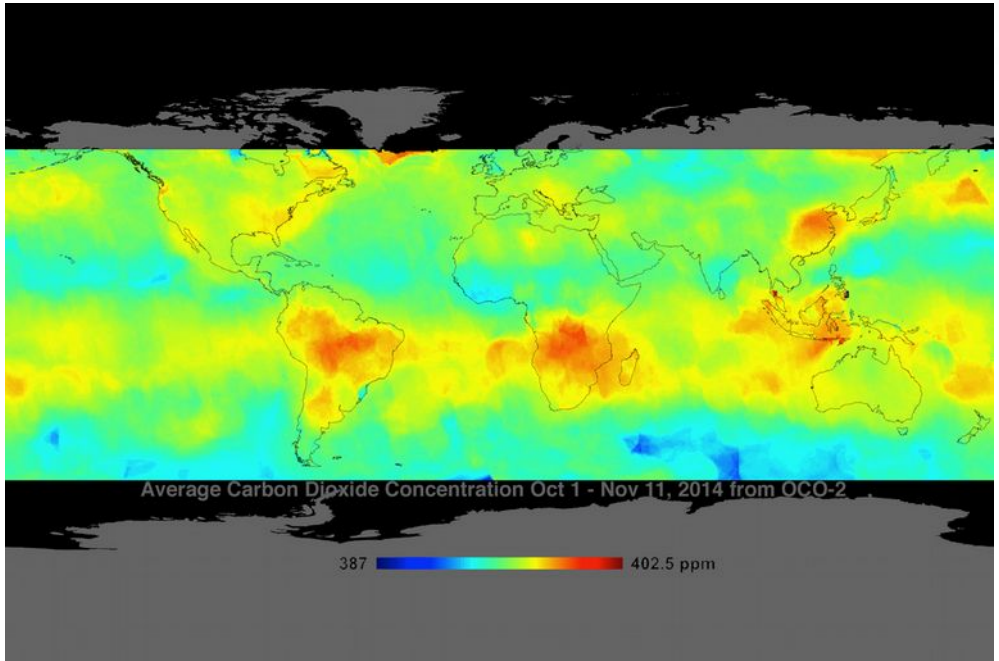
- Replacement OCO-2 launched successfully July 2, 2014 on a Delta II
  - Flies in Afternoon "A-Train" constellation



OCO-2

- Observes O2 and CO2 absorption at 0.76, 1.61, and 2.06 μm
- Measures CO2 mole fraction in the atmosphere
- Goal is to watch variations in that, to determine CO2 sources and sinks
- <http://oco.jpl.nasa.gov/>

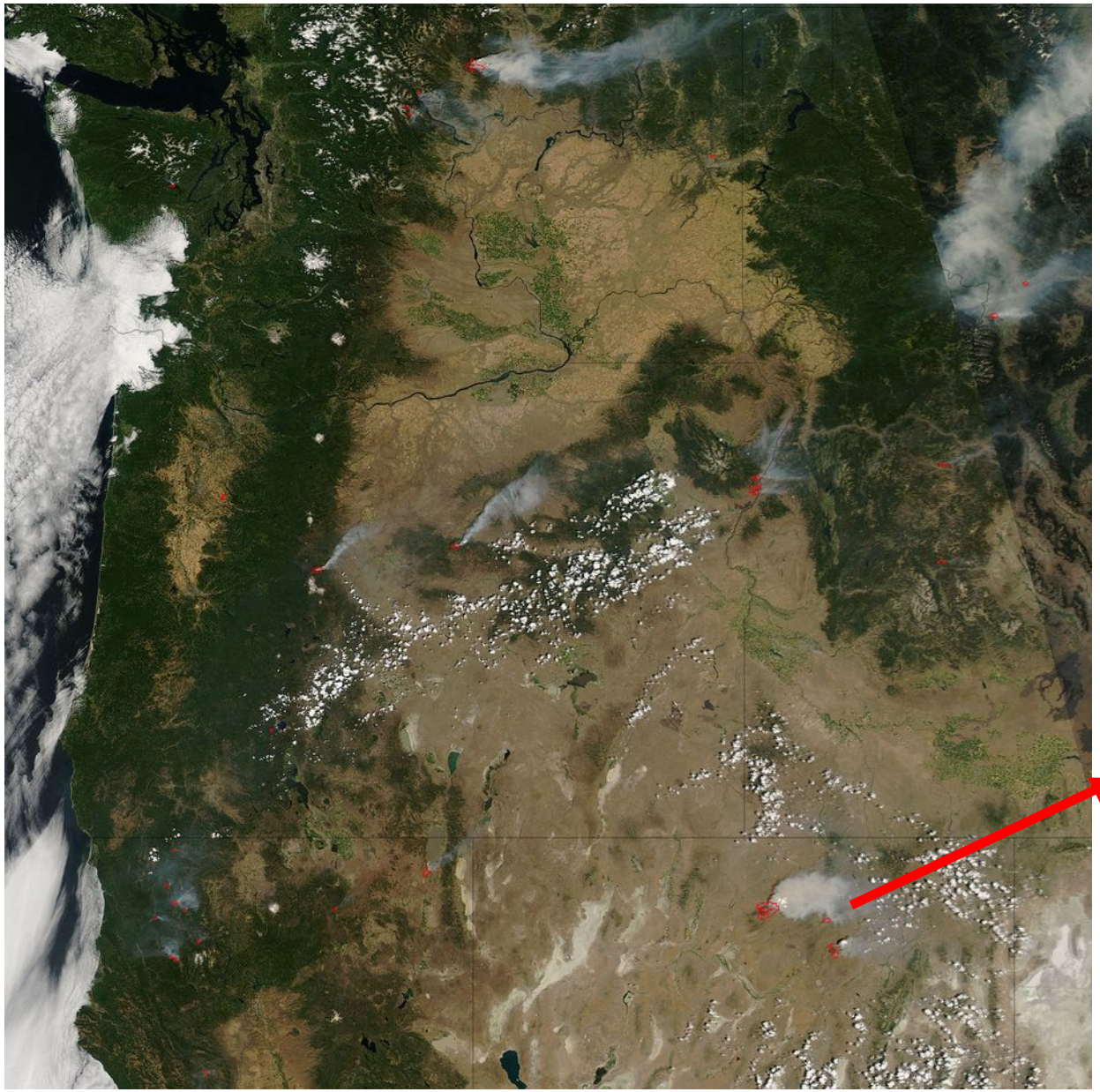




MODIS

- Moderate Resolution Imaging Spectrometer
- On both EOS Satellites:
  - Terra (AM) and Aqua (PM)
- 36 Spectral Bands 0.4 – 14.4 μm
  - spat. res.: 2 @ 500m; 5 @ 500m; 29 @1km
- Wide swath width
  - ±55^{o} from 705 km altitude ⇒2330 km
  - 1 or 2 day repeat cycle
- Info at: http://modis.gsfc.nasa.gov

MODIS: Fire Detection



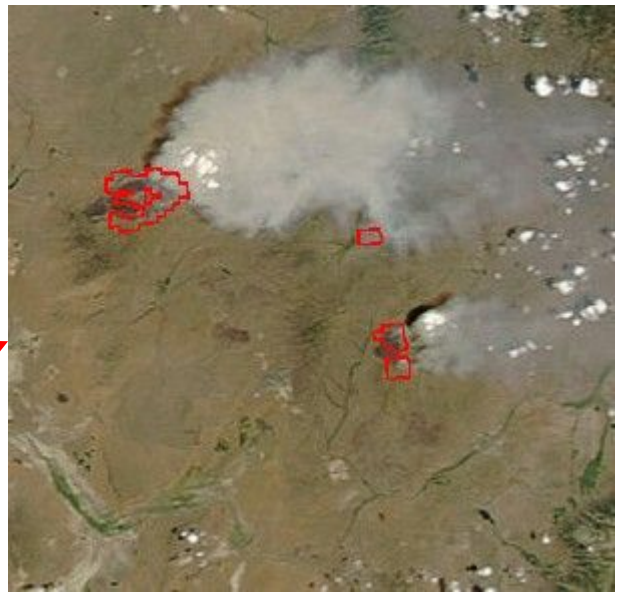
RGB Image Bands:

1: 620 – 670 nm

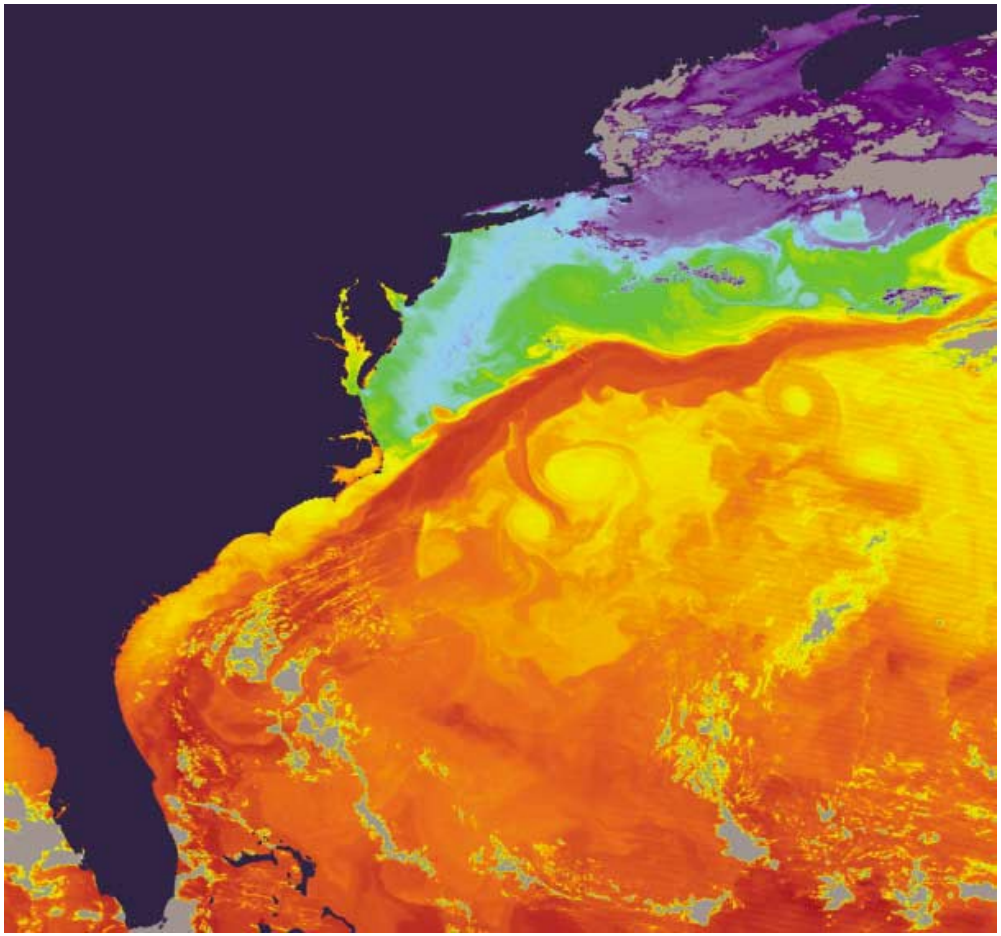
4: 545 – 565 nm

3: 459 – 479 nm

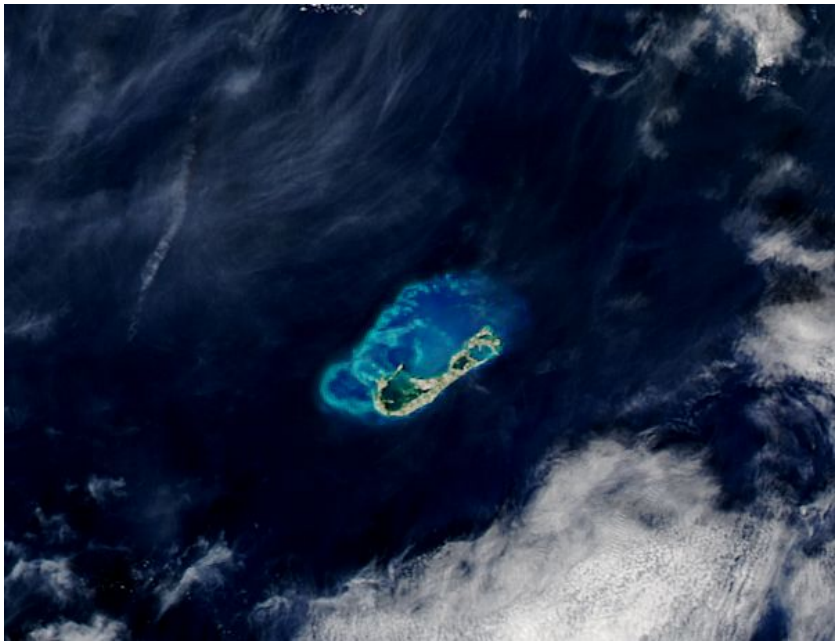
\+ 4 μm fire detection



MODIS: Ocean Temperatures, Plankton

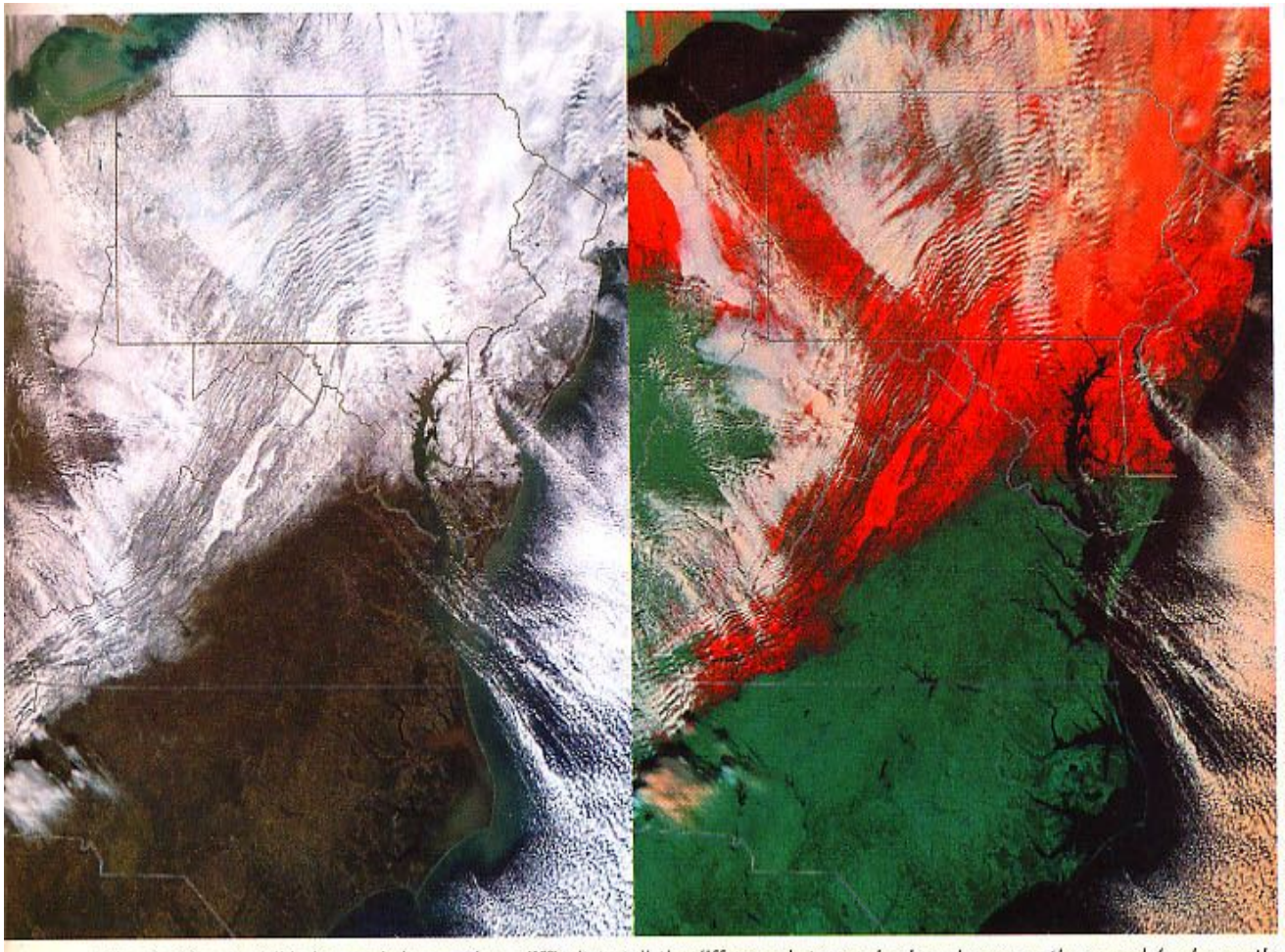


Gulf Stream Temperatures



Bermuda Phytoplankton Boom

Snow and clouds spectrally discriminated (Modis)



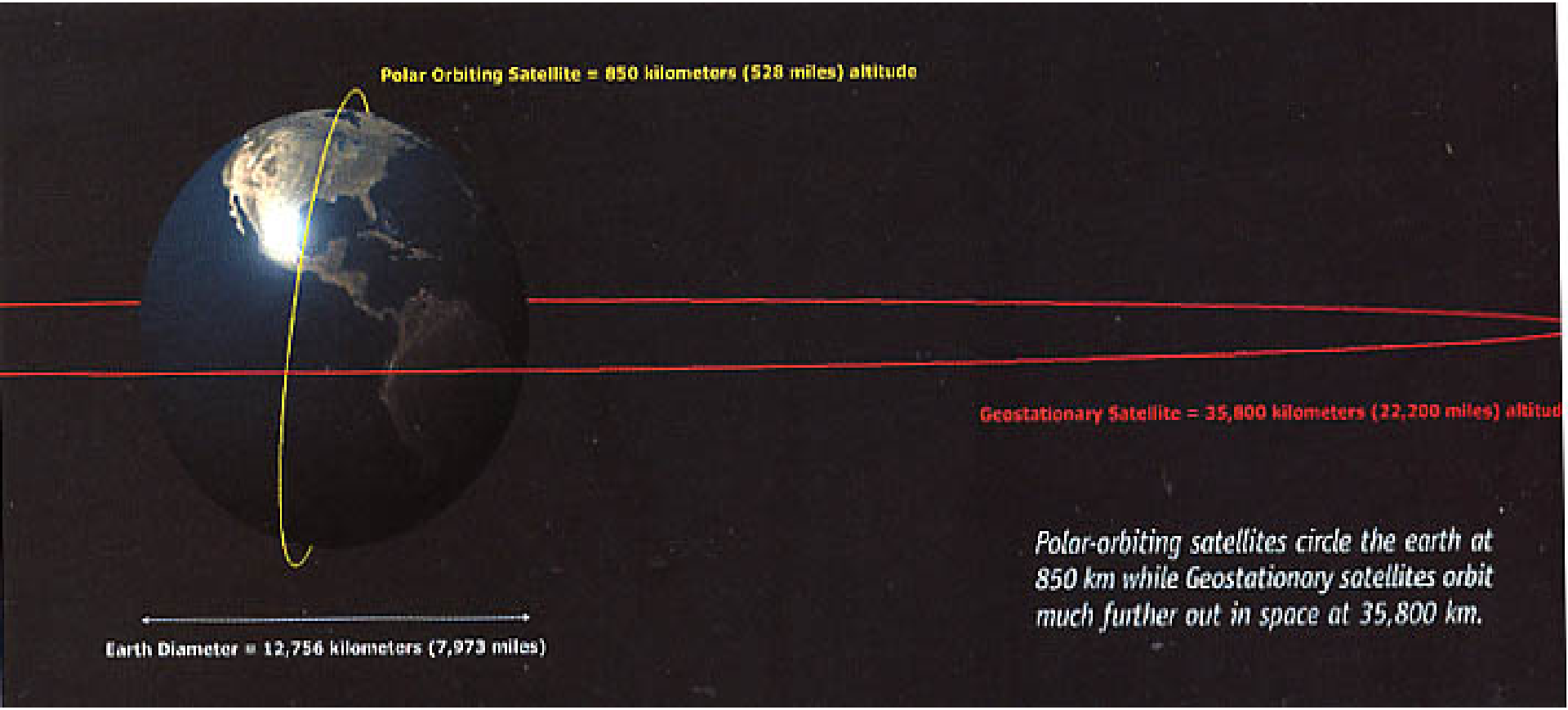
When looking at visible images it is sometimes difficult to tell the difference between clouds and snow on the ground (under mostly clear skies). The false color image (right) allows meteorologists to quickly determine the difference between clouds (white), water (black) and snow cover (orange). Bare ground and vegetation is green. This image was taken from the NASA MODIS sensor on board the Terra satellite. NODIS is a precursor to VIIRS that will fly on NPOESS.

POES and GOES

- "POES" and GOES
  (Polar/Geostationary Operational Environmental Satellites)

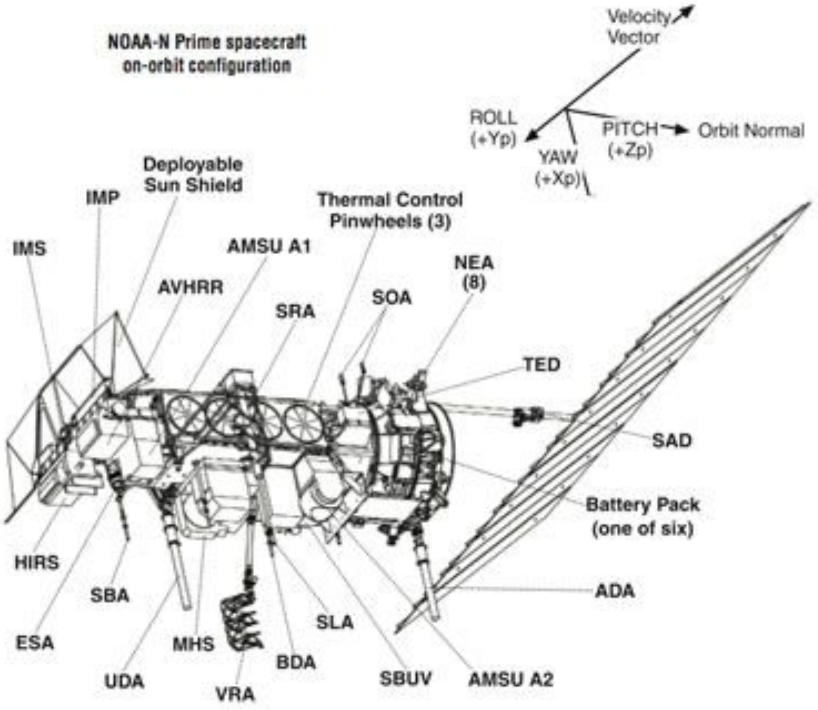
- GOES program:
  - 3 active satellites: E. US, W. US, S. America, plus 1 spare
  - First of new generation, GOES-R (GOES-16) launched Oct. 2016
  - GOES-S (to become GOES-17) scheduled to launch Mar. 2018
- POES program restructured after several canceled "next generation versions". New versions now finally launching
  - Last "regular" POES was NOAA-19, Feb. 6, 2009
  - "NPP" (prototype "National Polar-orbiting Partnership) satellite (renamed Suomi) launched Oct. 2011
  - JPSS-1 (now NOAA-20) launched Nov. 2017

POES and GOES



- http://goes-n-o-p.ndc.nasa.gov/ (P Launched 2010)

Satellite Properties



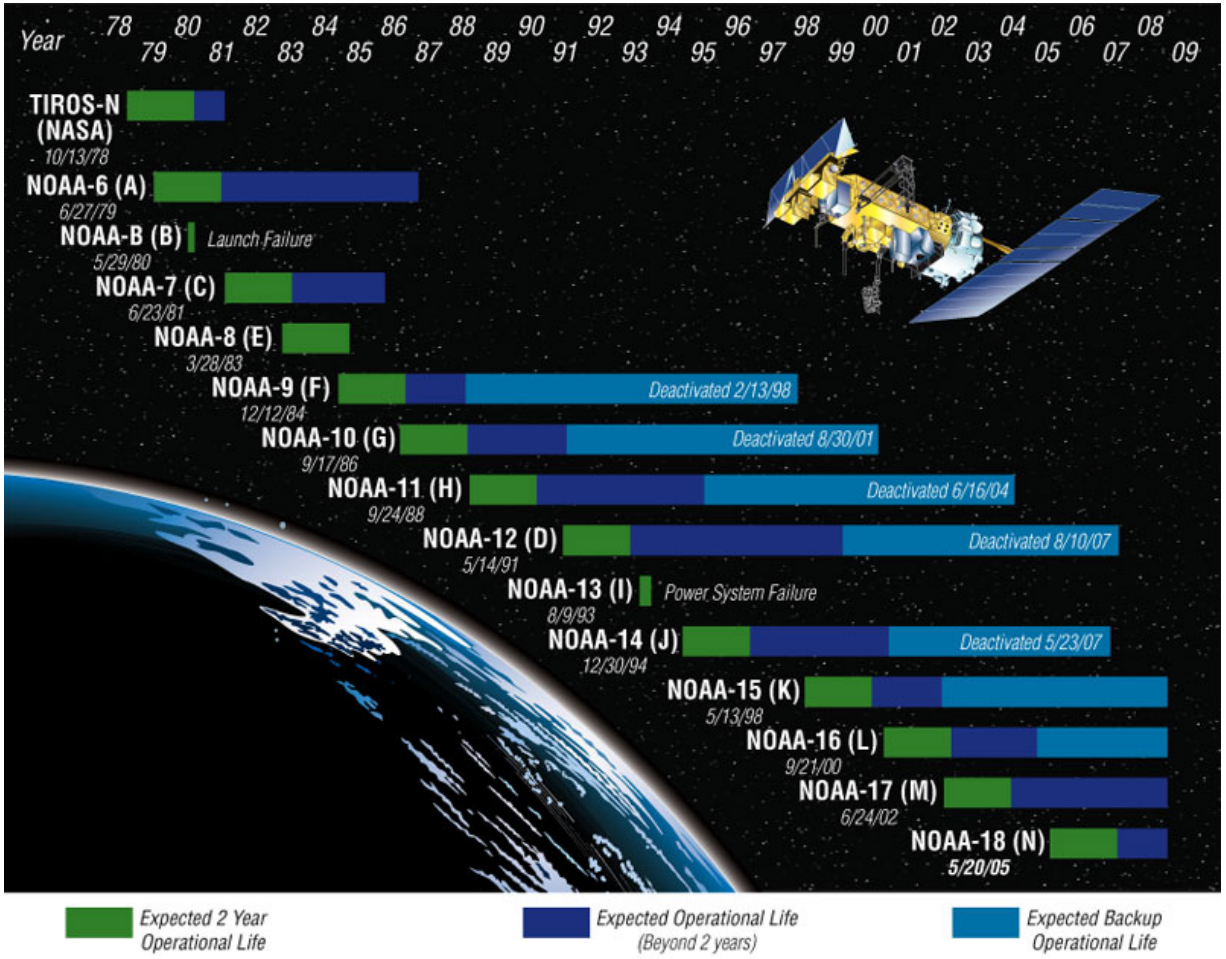
LEGEND

ADA	ADCS Deployable Antenna	SAD	Solar Array Drive
*ADCS	Advanced Data Collection System	*SARR	Search and Rescue Repeater
		*SARP3	Search and Rescue Processor 3
AMSU	Advanced Microwave Sounding Unit	SBA	S-Band Antenna
		SBUV	Solar Backscatter Ultraviolet Spectral Radiometer
AVHRR	Advanced Very High Resolution Radiometer	SLA	Search and Rescue Transmitting Antenna (L-Band)
BDA	Beacon Dipole Antenna		
ESA	Earth Sensor Assembly	SOA	S-Band Omni Antenna (2 of 6 shown)
HIRS	High Resolution Infrared Radiation Sounder	SRA	Search-and-Rescue Receiving Antenna
IMP	Instrument Mounting Platform		
IMS	Inertial Measurement System	TED	Total Energy Detector
*MEPED	Medium Energy Proton/Electron Detector	UDA	Ultra-High Frequency Data Collection System Antenna
MHS	Microwave Humidity Sounder	VRA	Very High Frequency Real-time Antenna
NEA	Nitrogen Engine Assembly		

*Not shown in this view

- Sun Synchronous Orbit
  - 852 km altitude
  - 100 minute period
  - S→N pass at 2 PM
- AVHRR (radiometer)
- AMSU (microwave sounder)
- HIRS (IR sounder)
- HMS (humidity sounder)
- SBUV (ozone measurements)
- SAR Repeater

POES History (since 1978)

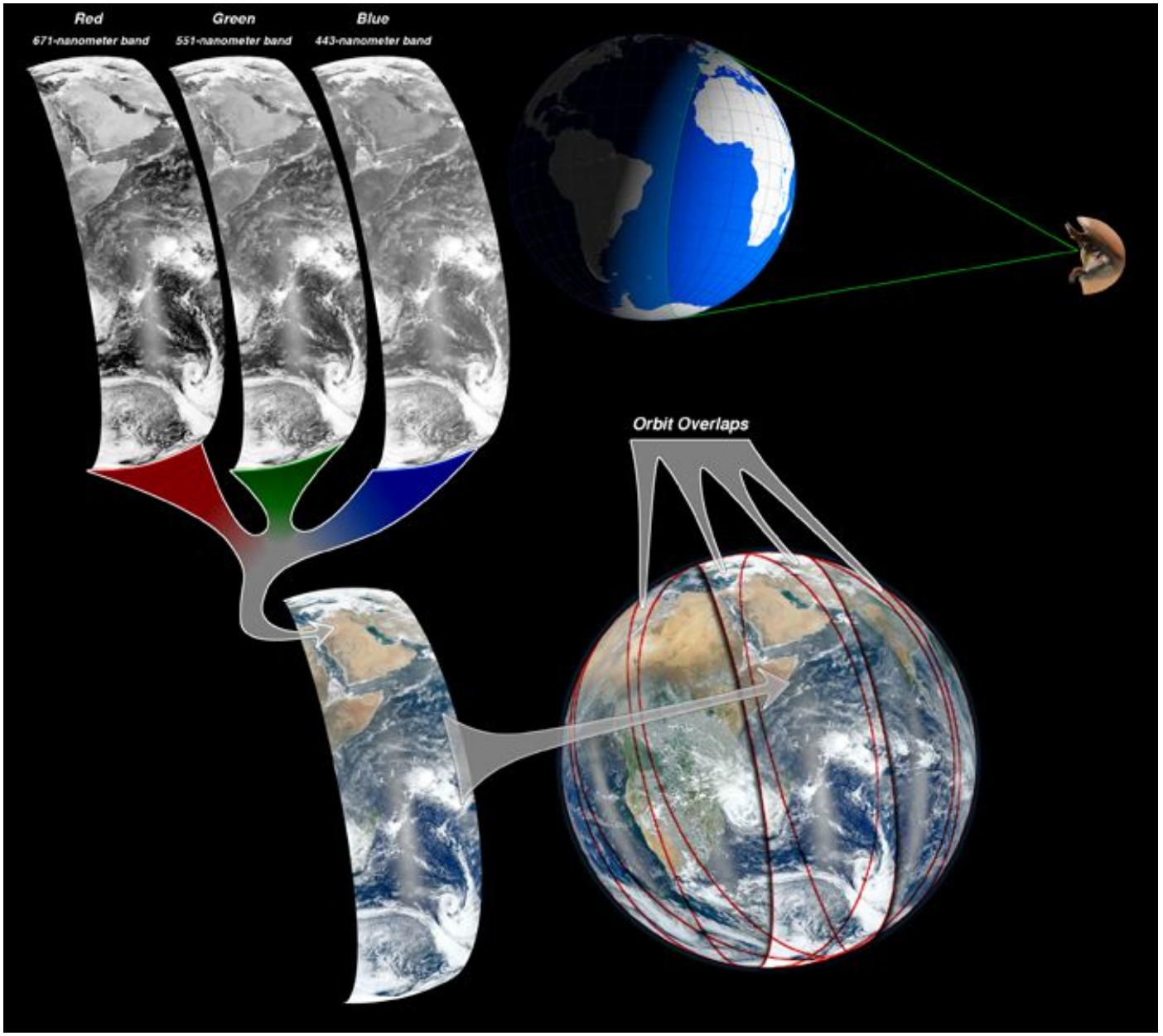


- "Final" satellite in series launched in 2009 NOAA-19
- In 2013 advanced "NPOESS" was to start replacing existing ones but cancelled because of budget overruns, problems, etc.
- Finally being replaced by JPSS (Joint Polar Satellite System) versions

- http://npp.gsfc.nasa.gov/

Suomi NPP

- Suomi NPP VIIRS instrument
  - <http://npp.gsfc.nasa.gov/index.html>
  - Vernon E. Suomi = U. Wisc. prof involved in early satellite meteorology
  - VIIRS: Visual/Infrared Imager Radiometer Suite
    - Enhanced version of the AVHRR we'll discuss in a minute
    - More bands, higher precision, similar spatial resolution
  - Several other "weather" specific instruments



Making the Blue-Marble Image

- Really made from 3 swaths from ~800 km high sun-synchronous orbit
- Remapped to appear to be from 7000 km perspective
- VIIRS is an enhanced replacement for AVIRIS

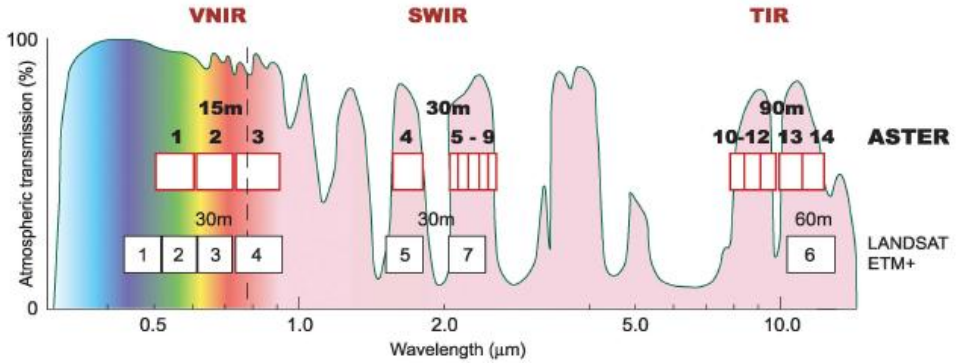
AVHRR Specs

NOAA Advanced Very High Resolution Radiometer (AVHRR) Sensor System Characteristics

Band	NOAA 6, 8, 10 Spectral Resolution (μm)[a]	NOAA 7, 9, 11, 12, 13, 14, 15 Spectral Resolution (μm)[a]	Band Characteristics
1	0.580 – 0.68	0.580 – 0.68	Daytime cloud, snow, ice, and vegetation mapping; used to compute NDVI
2	0.725 – 1.10	0.725 – 1.10	Land–water interface delineation; snow, ice, and vegetation mapping; used to compute NDVI
3	3.55 – 3.93	3.55 – 3.93	Monitoring hot targets (volcanoes, forest fires), nighttime cloud mapping
4	10.50 – 11.50	10.30 – 11.30	Day-and-night cloud and surface-temperature mapping
5	None	11.50 – 12.50	Cloud and surface temperature, day and night cloud mapping; removal of atmospheric water vapor path radiance
IFOV at nadir	1.1 × 1.1 km		
Swath width	2700 km at nadir		

AVHRR Imagery

Multispectral vs. Hyperspectral



AVIRS: Airborne Visible / Infrared Spectrometer

(don't confuse with AVHRR – radiometer on weather satellites.)

Flown on NASA U2 at 20 km altitude

Swath width 10.5 km, spatial resolution 20 m

0.4 – 2.5 µm, 224 bands, 0.010 µm = 10 nm resolution

Images for ~1/5 of bands shown on pg. 24 and Plate 1B

Hyperion: On board EO-1 (NASA 2001 experimental satellite)

0.4 – 2.5 µm, 220 bands 7.5 km by 100 km images

Mineral Spectra

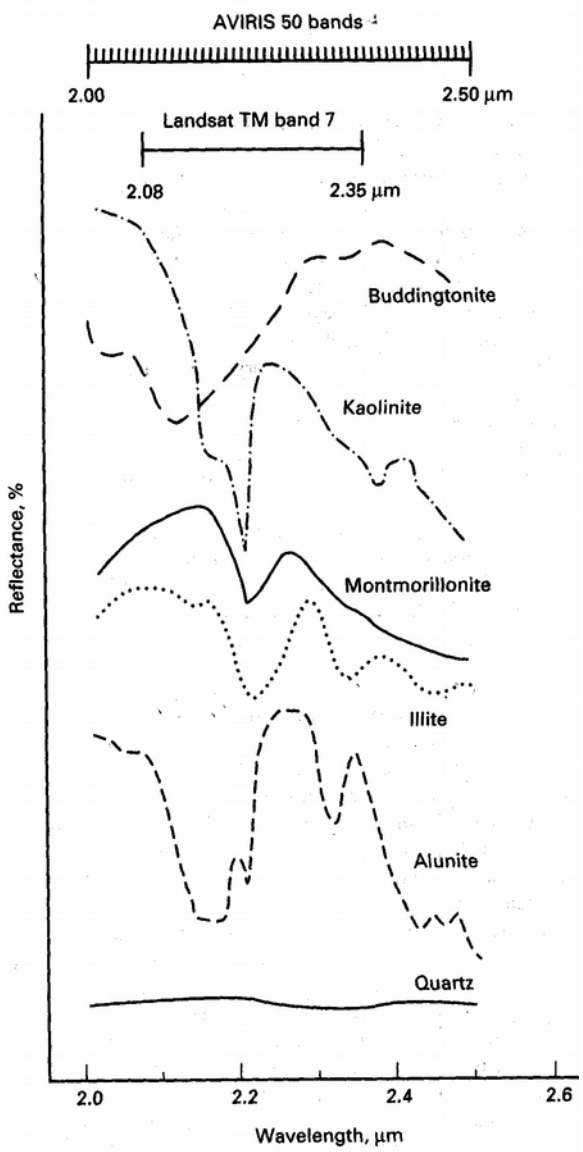


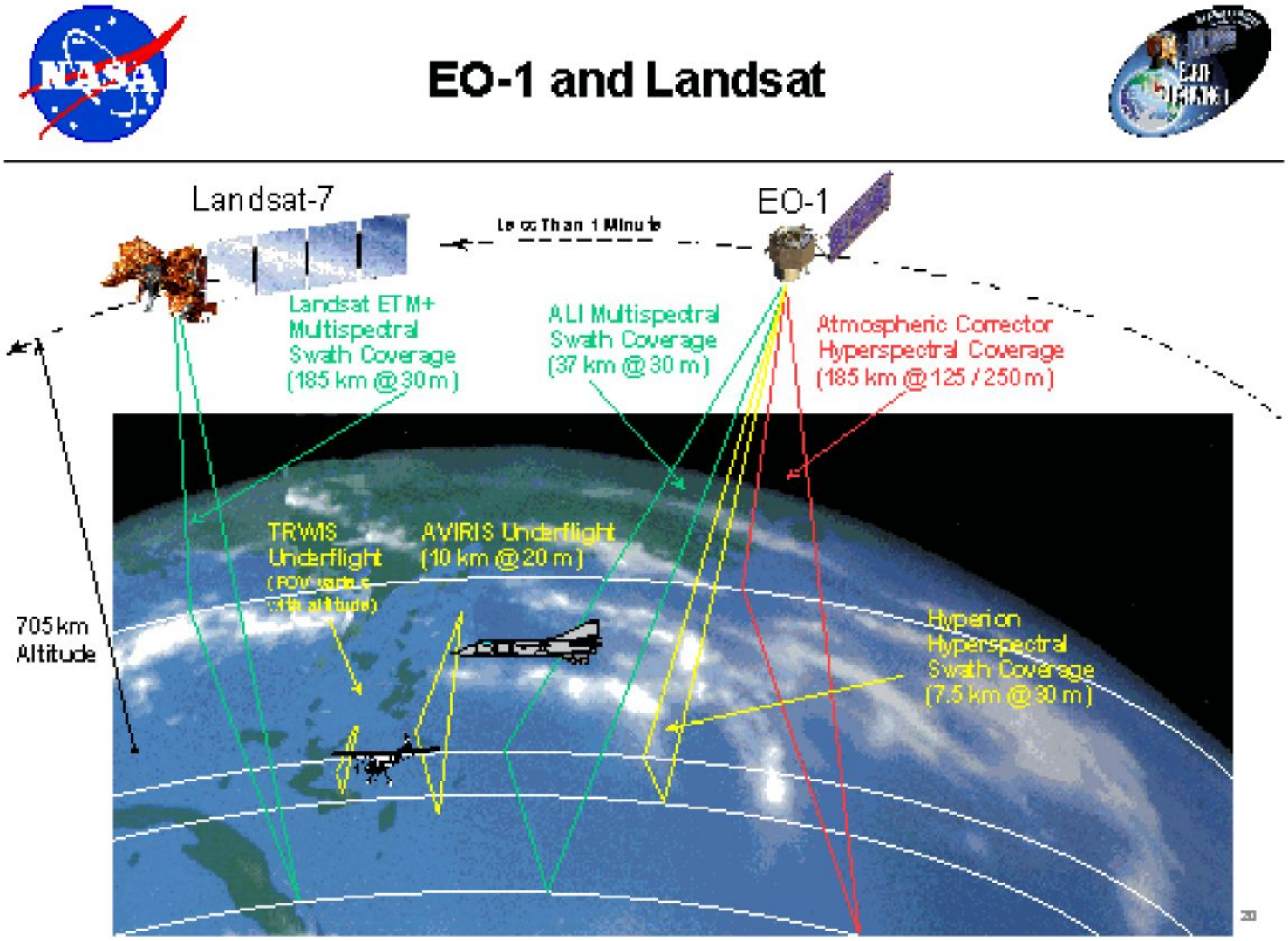
Figure 11-17 Laboratory spectra of alteration minerals in the atmospheric window from 2.0 to 2.5 µm. Spectra are offset vertically for clarity. Bandpasses of AVIRIS and TM band 7 are shown.

Clays have OH incorporated in structure

Generally darken towards 3µm where water absorbs strongly.

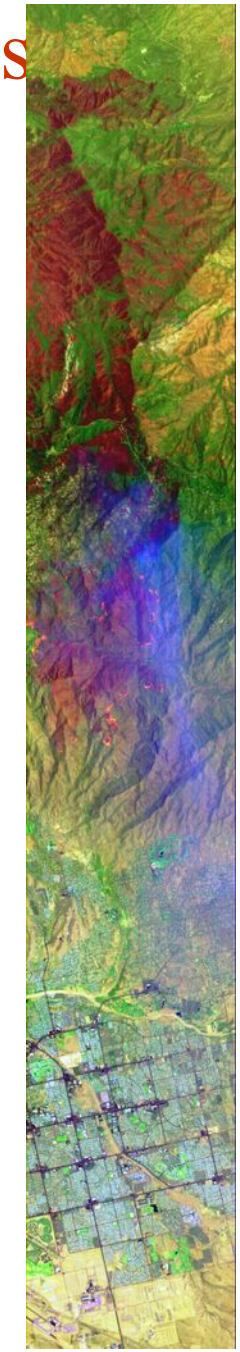
Detailed structure of 2.0 – 2.5 bands depends upon detailed mineral structure.

Hyperion (EO-1) orbit



Hyperion Images

Cuprite, NV



Tucson – Aspen fire