Introduction to Remote Sensing

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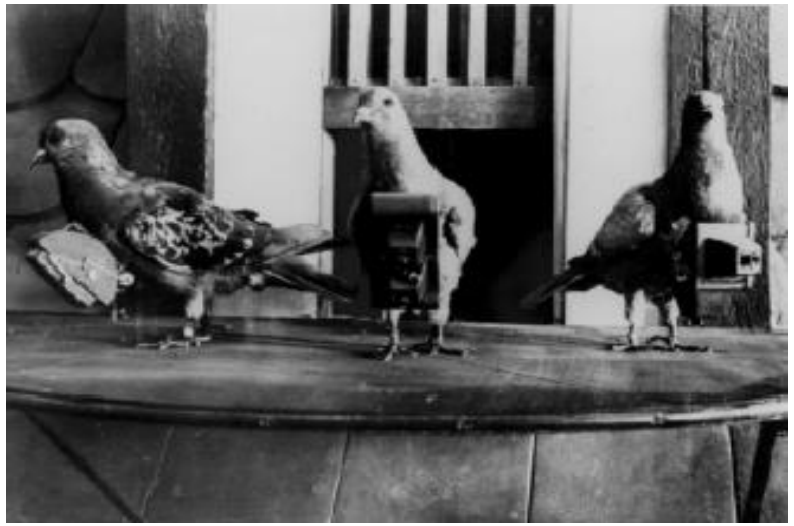
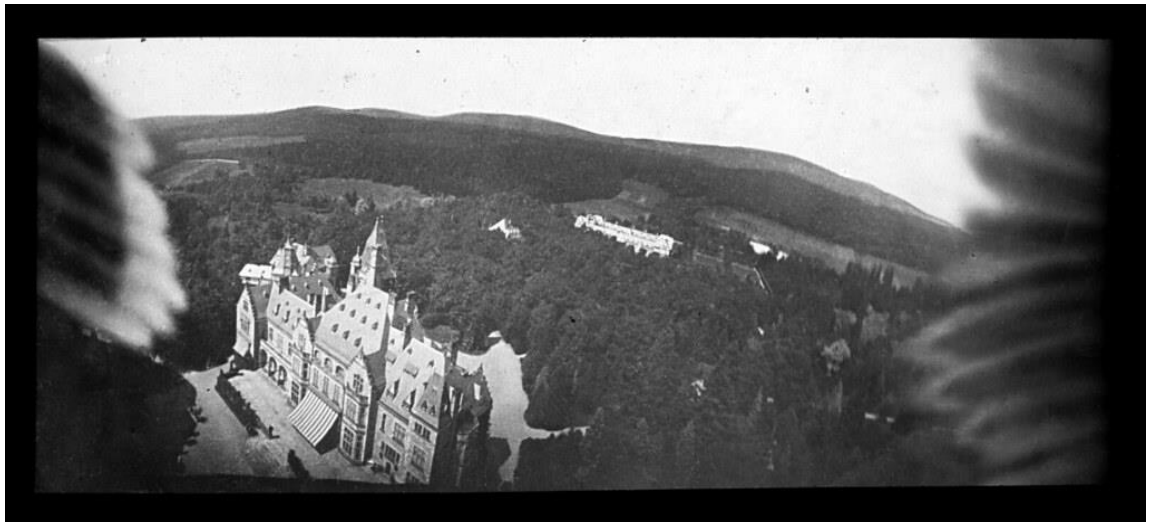
What is remote sensing?

'Remote sensing is the science of making inferences about objects from measurements, made at a distance, without coming in contact with the objects under study' (Joseph, 2005)

Besides balloons and kites, pigeons were used to carry cameras and could be trained to fly over targets

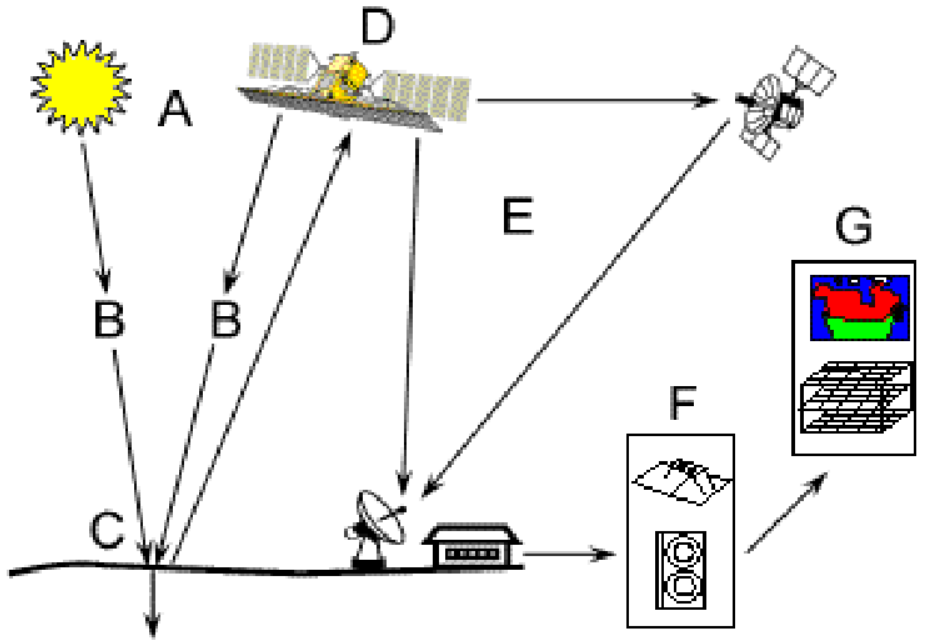


German scientist
Dr. Julius Neubronner



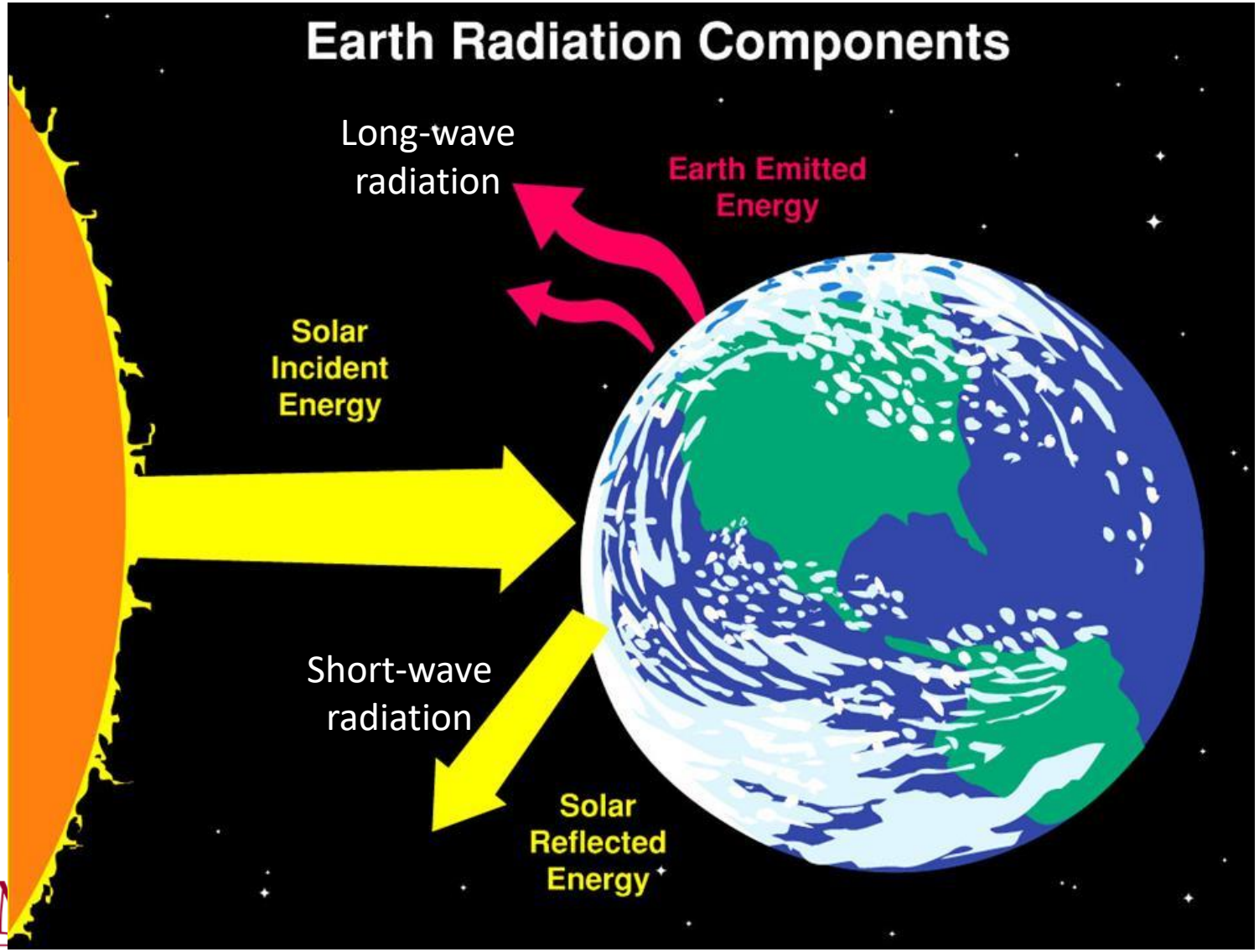
Components of remote sensing

1. Energy source or illumination (A)
2. Radiation and the atmosphere (B)
3. Interaction with the target (C)
4. Energy recording by sensor (D)
5. Transmission, receiving, processing (E)
6. Interpretation and analysis (F)
7. Application (G)



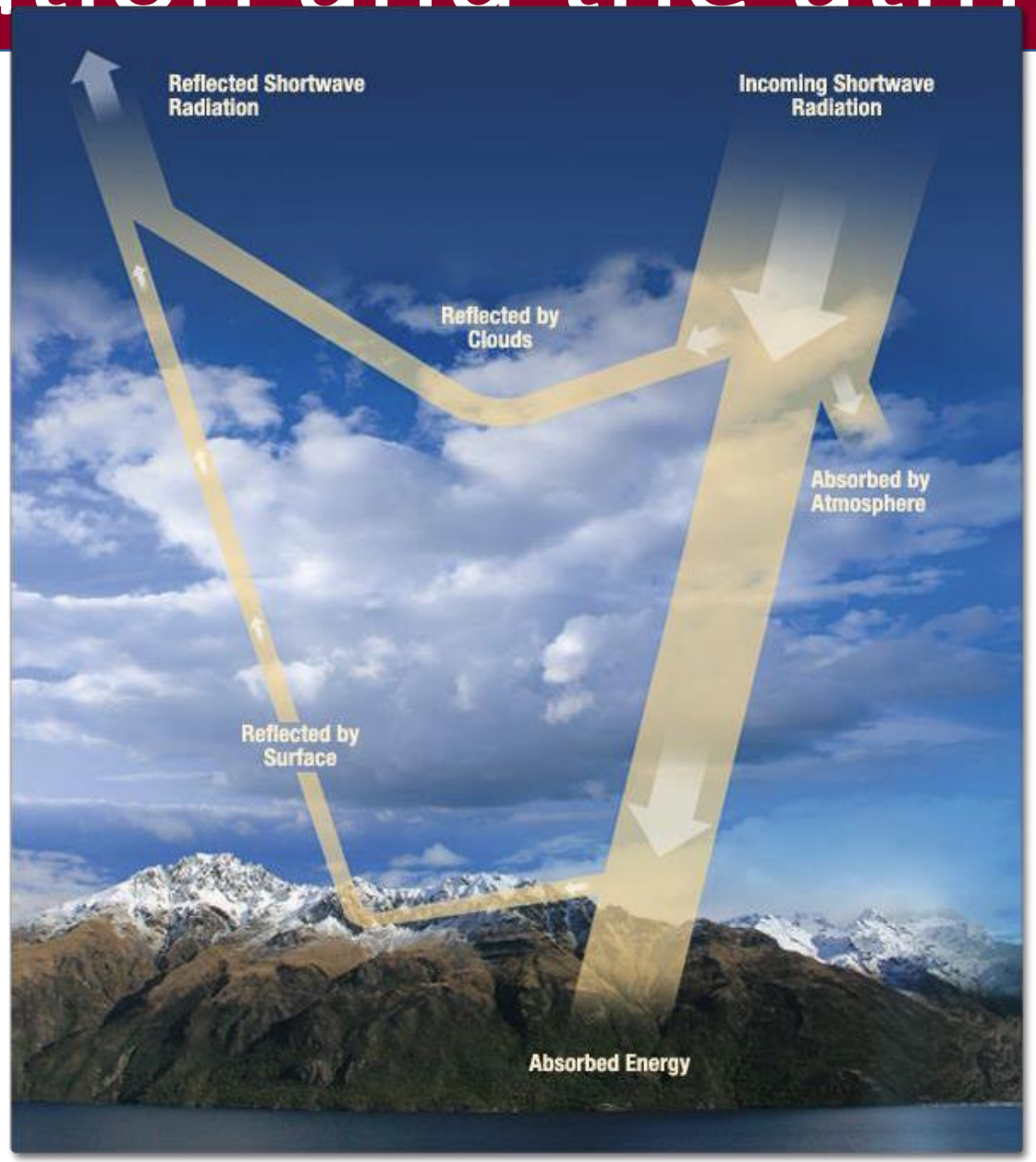
Credit:
De Sherbinin et al. (2002)

Energy source



Credit: NASA Applied Sciences

Radiation and the atmosphere



Credit:
NASA Applied Sciences

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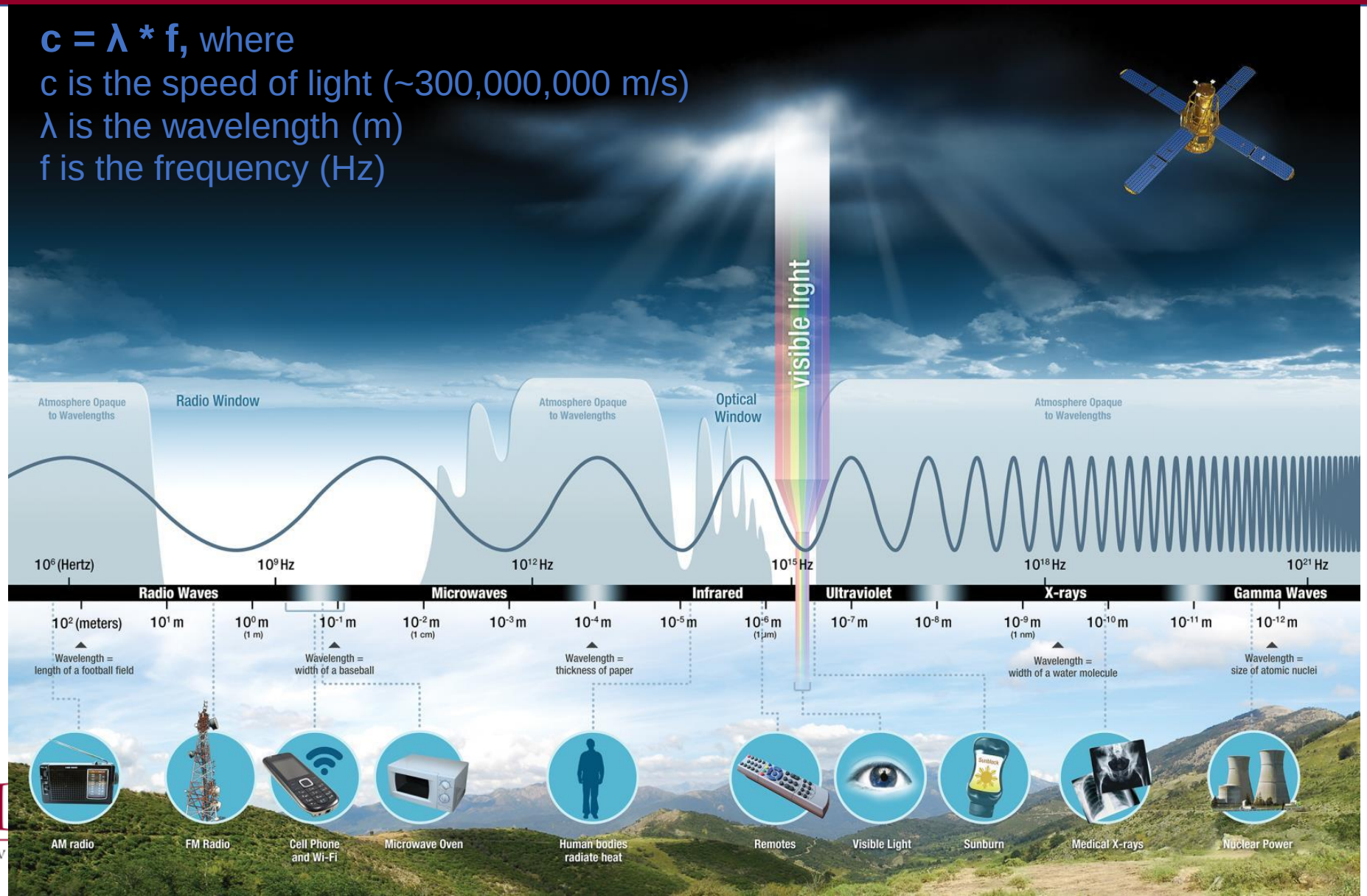
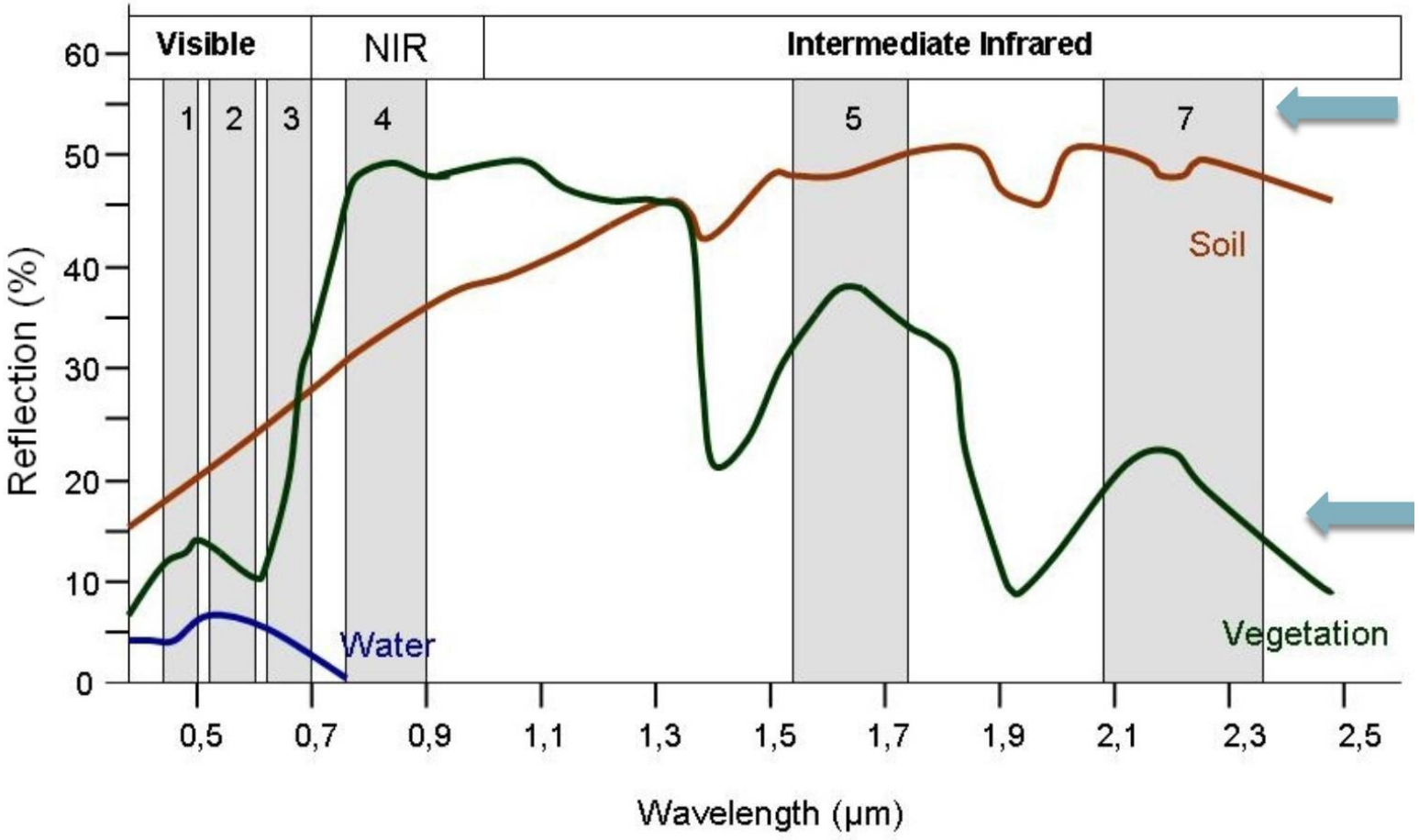
Electromagnetic spectrum

c = λ * f, where
c is the speed of light (~300,000,000 m/s)
λ is the wavelength (m)
f is the frequency (Hz)



Wavelength interaction with target

Spectral Signatures



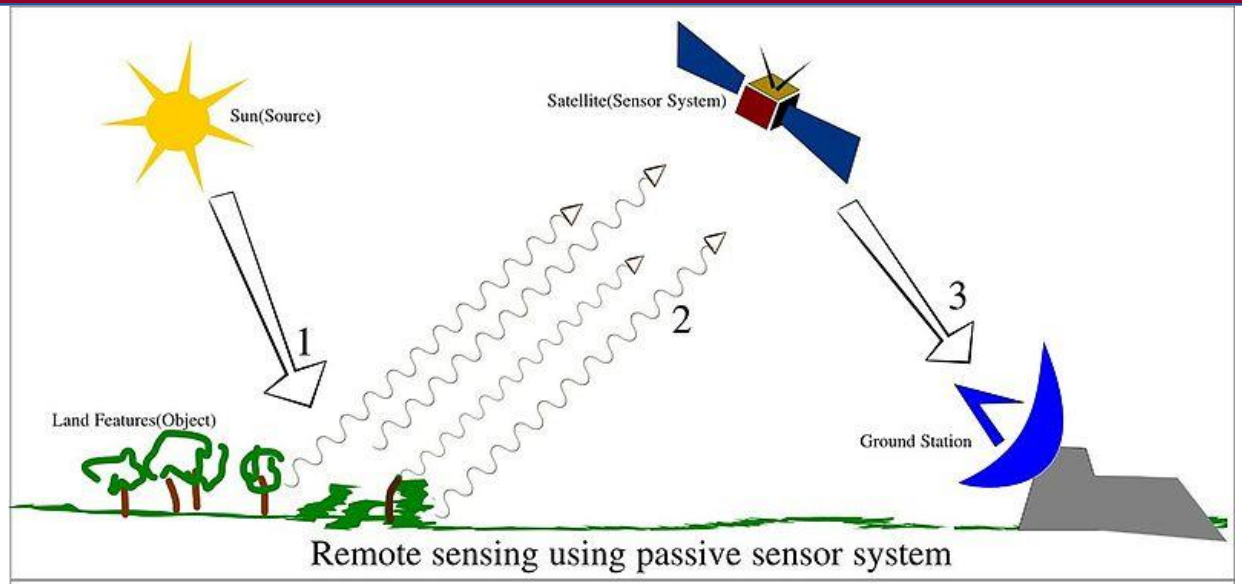
Landsat bands

Spectral signatures

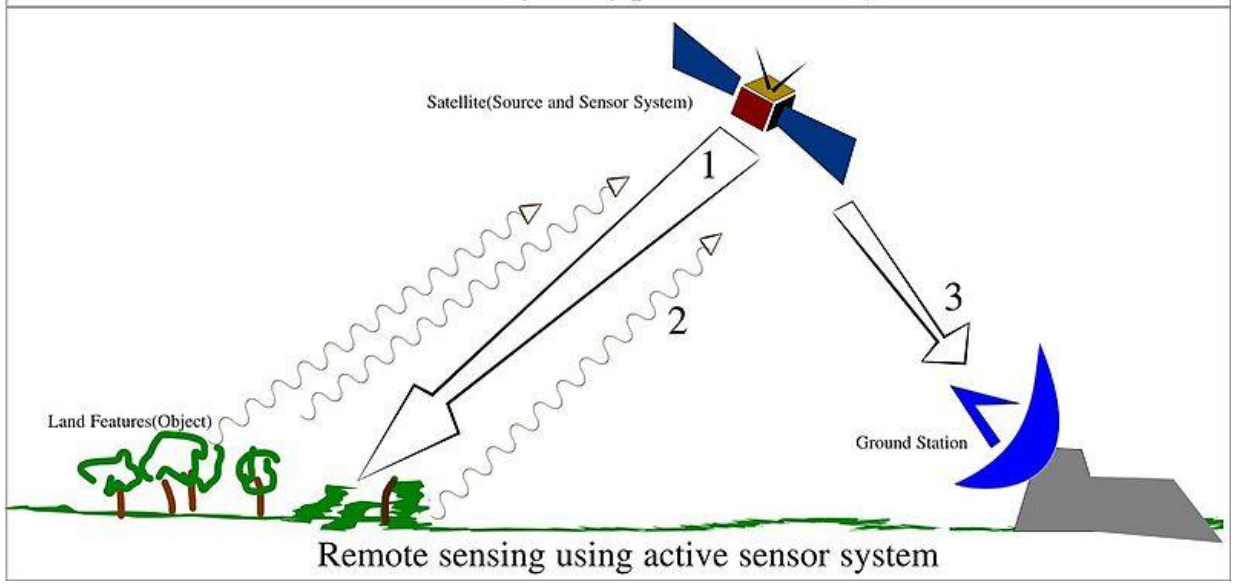
Credit: NASA Applied Sciences

Sensor recording

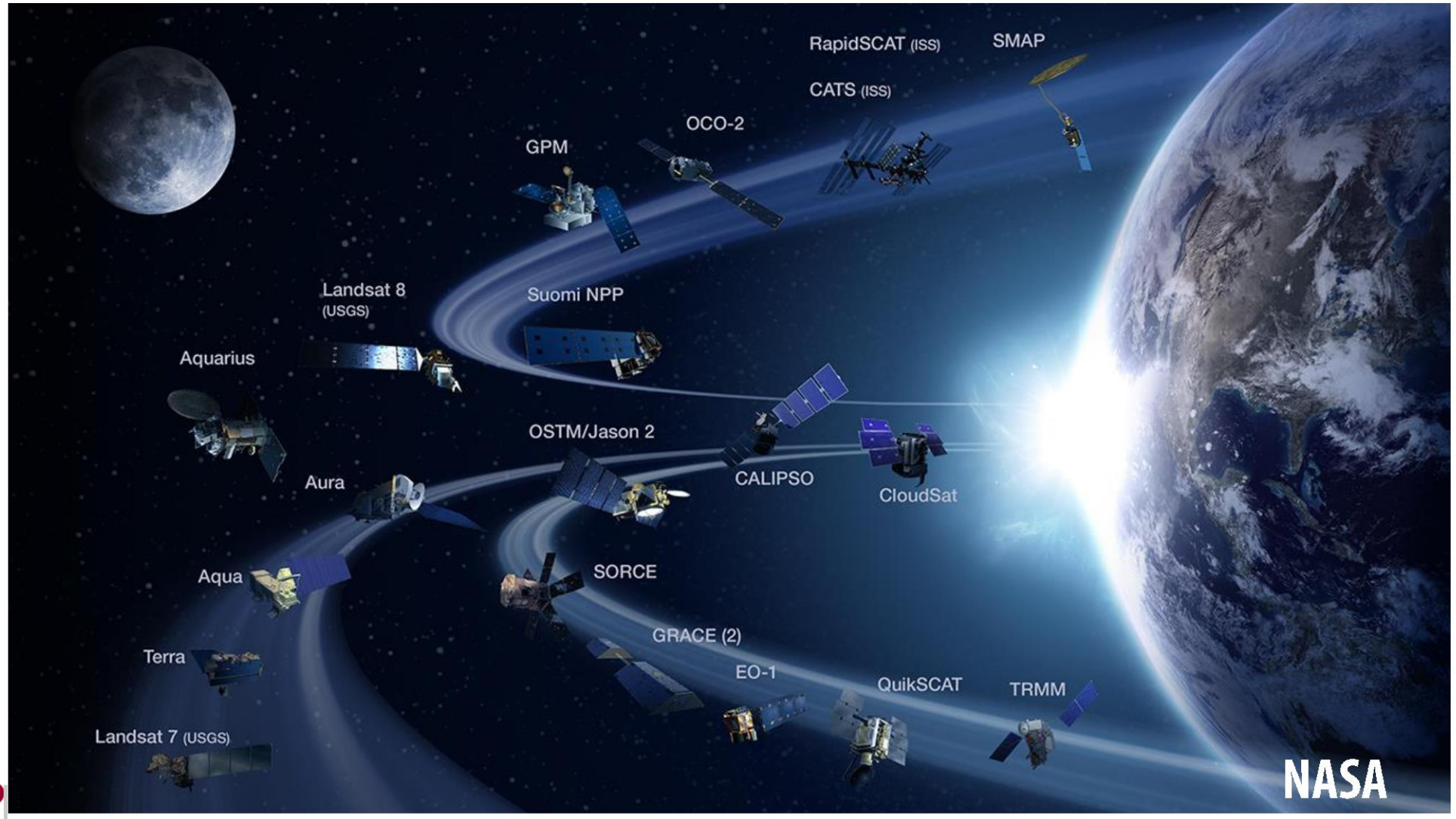
Passive sensor



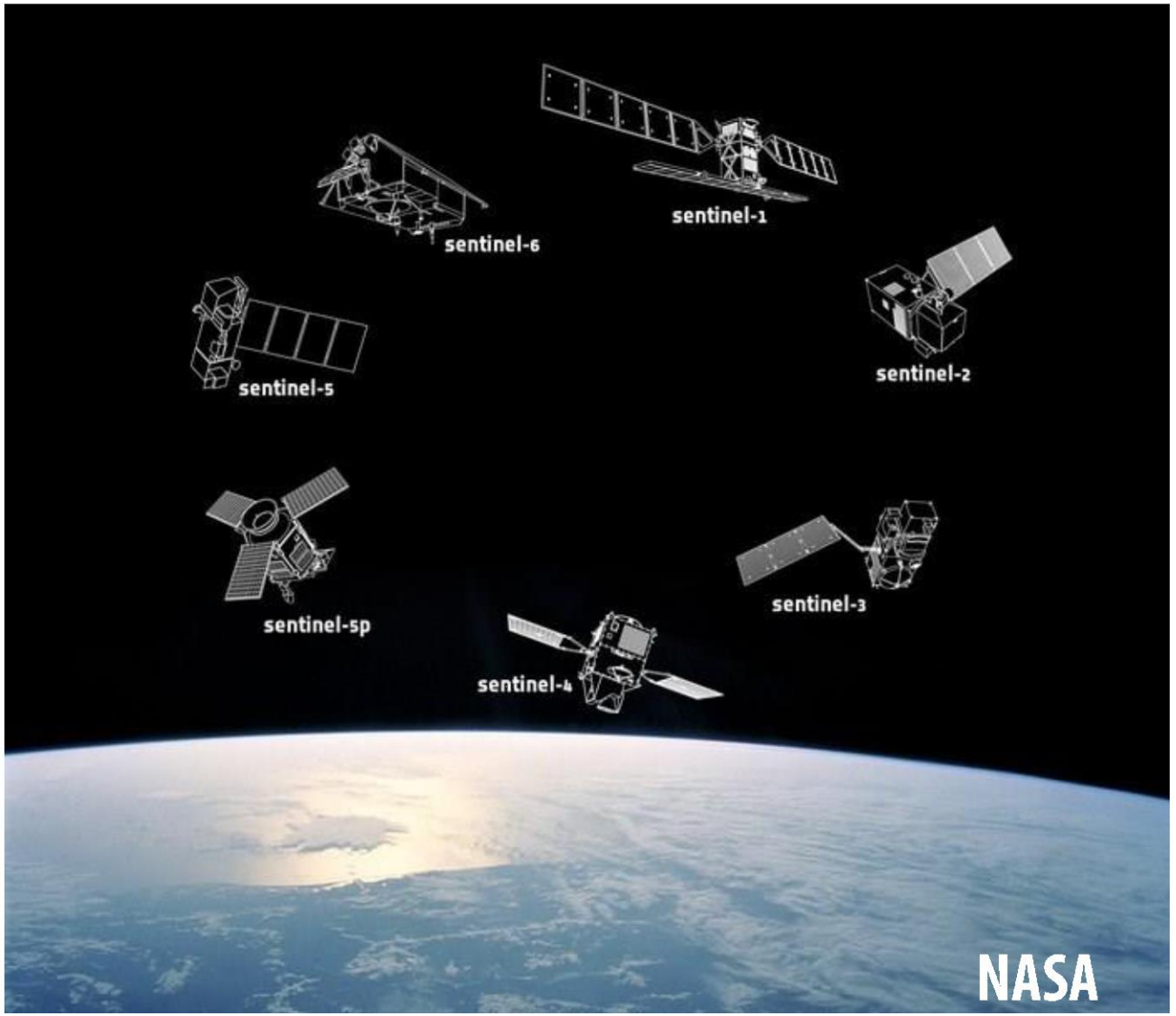
Active sensor



NASA Satellite Constellation



ESA Sentinel Missions



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Satellite systems

	IKONOS[1†]	SPOT[2]	Landsat[1†]	TERRA (MODIS) [1†]	AVHRR[1† †]	RADARSAT[3r]
Type:	Sun-synchronous	Sun-synchronous	Sun synchronous	Sun Synchronous	Sun Synchronous	Sun-Synchronous
Descending Pass:	10:30 a.m.	10:30 a.m.	9:45 a.m. * 10:00 a.m. **	10:30 a.m.		
Altitude:	681 km	832 km	920 km * 705 **	705 km,	833km	798 km
Inclination:	98.1 degrees	98.7		98.2 degrees	98.8 degrees	98.6 degrees
Period:		101.4 minutes	100	90 minutes	102 minutes	100 minutes
Repeat Cycle:	2.9 days at 1 m res. 1.5 days at 1.5 m res.	26 days	18 days * 16 days **	2 days	Twice daily	24 days
Spatial Resolution (in Square Meters)	1-4	10 - Panchromatic 20 - Multispectral	15 - panchromatic 30 - TM 80 - MSS	250 (bands 1-2) 500 (bands 3-7) 1000 (bands 8-36)	1,100 LAC 4,000 GAC	8-100
Swath Width	11 km	60 km	185 km	2330 km	2700 km	50-500 km
Archive	1999	1986	1972	1999	1978	1995

De Sherbinin et al. (2002)

Satellite imagery

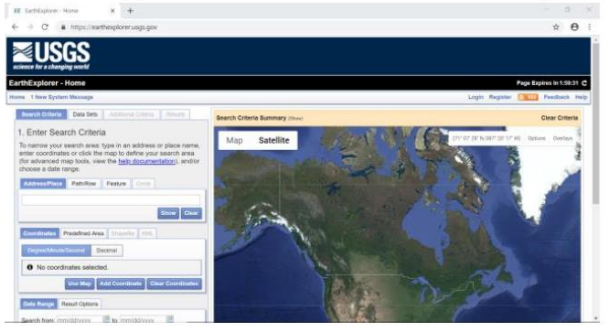
Data Portals

- NASA EarthData Search – Landsat, VIIRS, MODIS, etc.
https://search.earthdata.nasa.gov/search

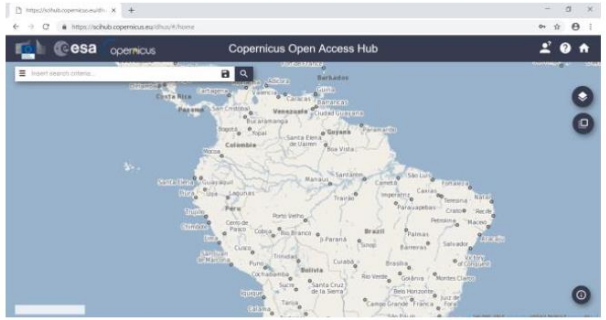
- USGS / NASA AppEEARS – Land Processes Distributed Active Archive Center (LP DAAC).
https://lpdaac.usgs.gov/tools/appeears/

- ESA Sentinel Hub – Sentinel-1, 2, 3 and 5P
https://scihub.copernicus.eu/

- University of Maryland – Global Forest Change data (produced by Hansen et al. 2013)
https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.2.html



Earth Explorer



Sentinel Data Hub

Satellite Imagery

Open Source Software & Resources

- QGIS
  - https://qgis.org/en/site/forusers/download.html

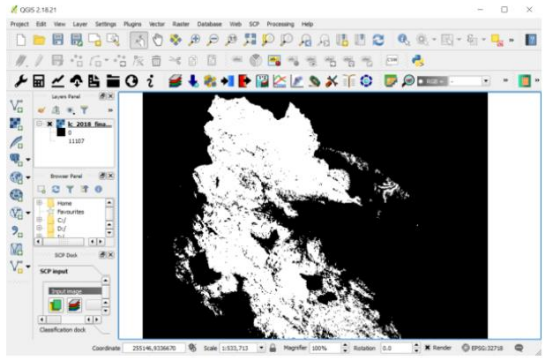
- Remote Sensing Image Analysis with R
  - https://rspatial.org/raster/rs/1-introduction.html\

- Google Earth – visualizations
  - https://earth.google.com/web/

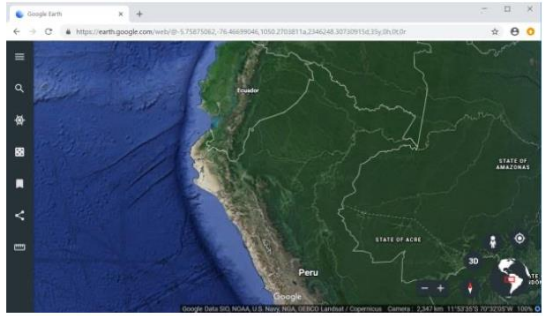
- SNAP – for ESA data and radar
  - http://step.esa.int/main/toolboxes/snap/

- Landsat explorer app
  - http://landsatexplorer.esri.com/

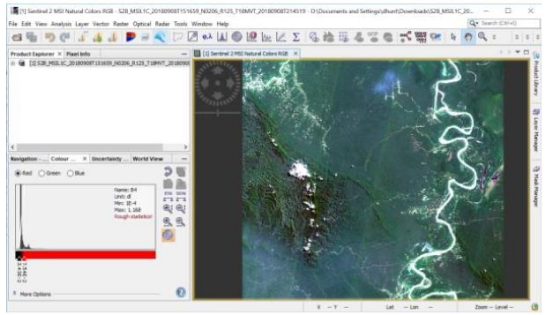
- Advanced ARSET training
  - https://arset.gsfc.nasa.gov/



QGIS



Google Earth



SNAP

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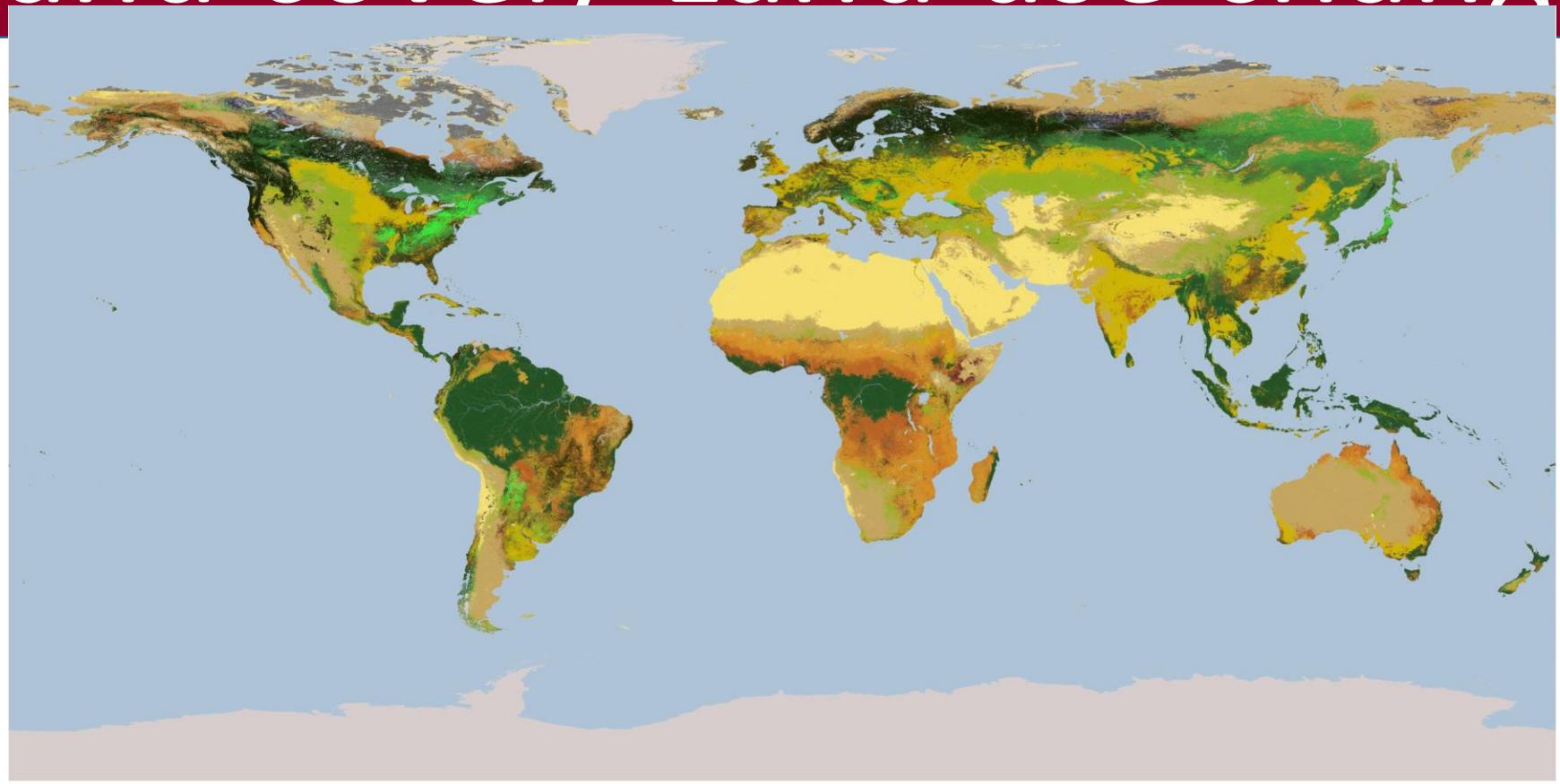
Remote Sensing Applications

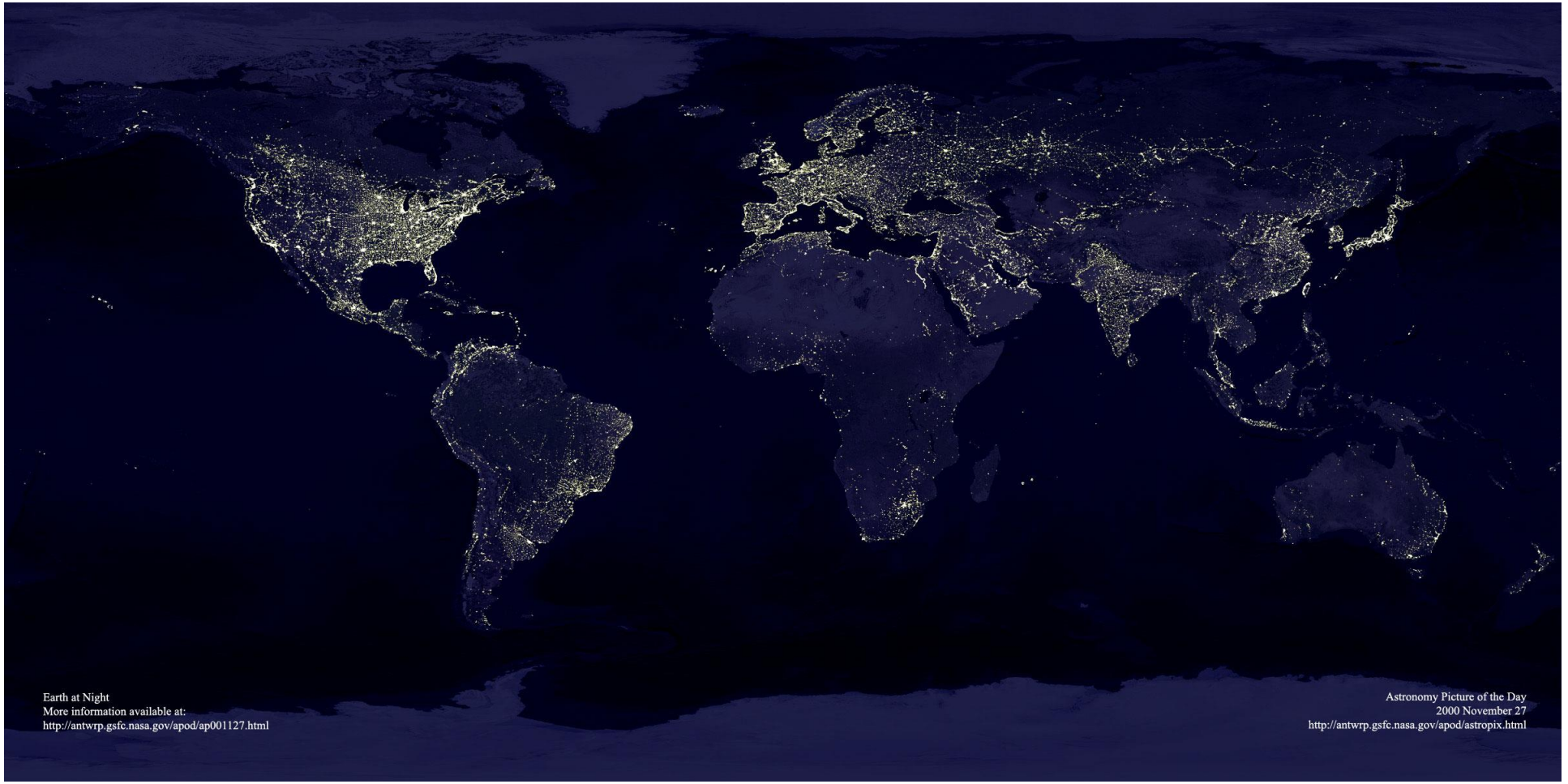
- Land cover / land use change
- Population mapping
- Air quality
- Aquatic ecosystems
- Hydrology
- Weather and climate
- Disaster monitoring and response
- (Many more…)

Land cover/ Land use change

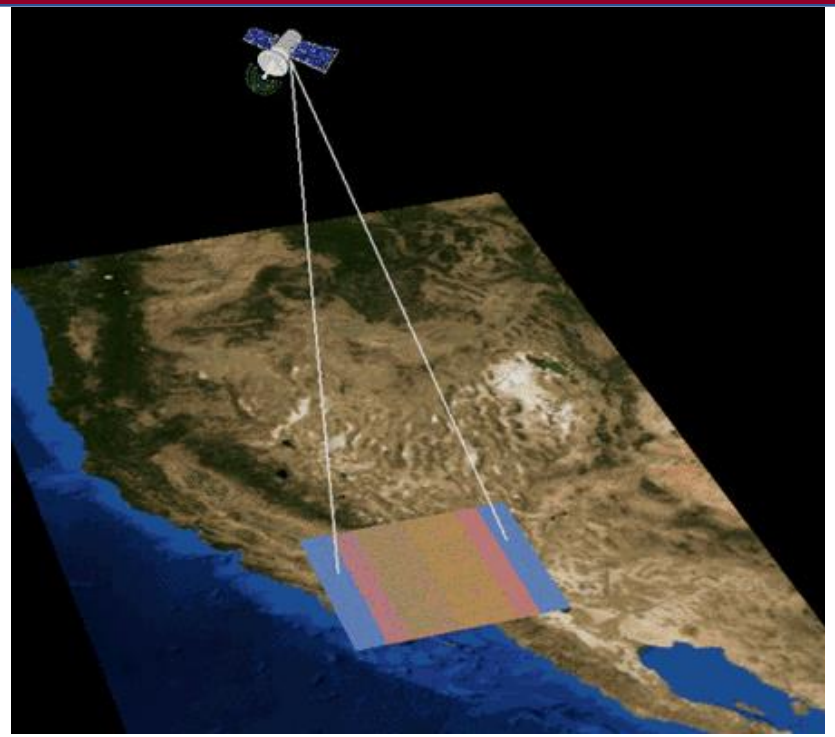


- 0 Water
- 1 Evergreen Needleleaf Forest
- 2 Evergreen Broadleaf Forest
- 3 Deciduous Needleleaf Forest
- 4 Deciduous Broadleaf Forest
- 5 Mixed Forests
- 6 Closed Shrublands
- 7 Open Shrublands
- 8 Woody Savannas
- 9 Savannas
- 10 Grasslands
- 11 Permanent Wetlands
- 12 Croplands
- 13 Urban and Built-Up
- 14 Cropland/Natural Veg. Mosaic
- 15 Snow and Ice
- 16 Barren or Sparsely Vegetated
- 17 Tundra

Population Mapping



Air quality



Multi-Angle Imager for Aerosols (MAIA)

- Scheduled to launch in 2022

MAPS

- Measures distribution of CO 3-10km above the earth's surface
  - Near global CO database

TOMS

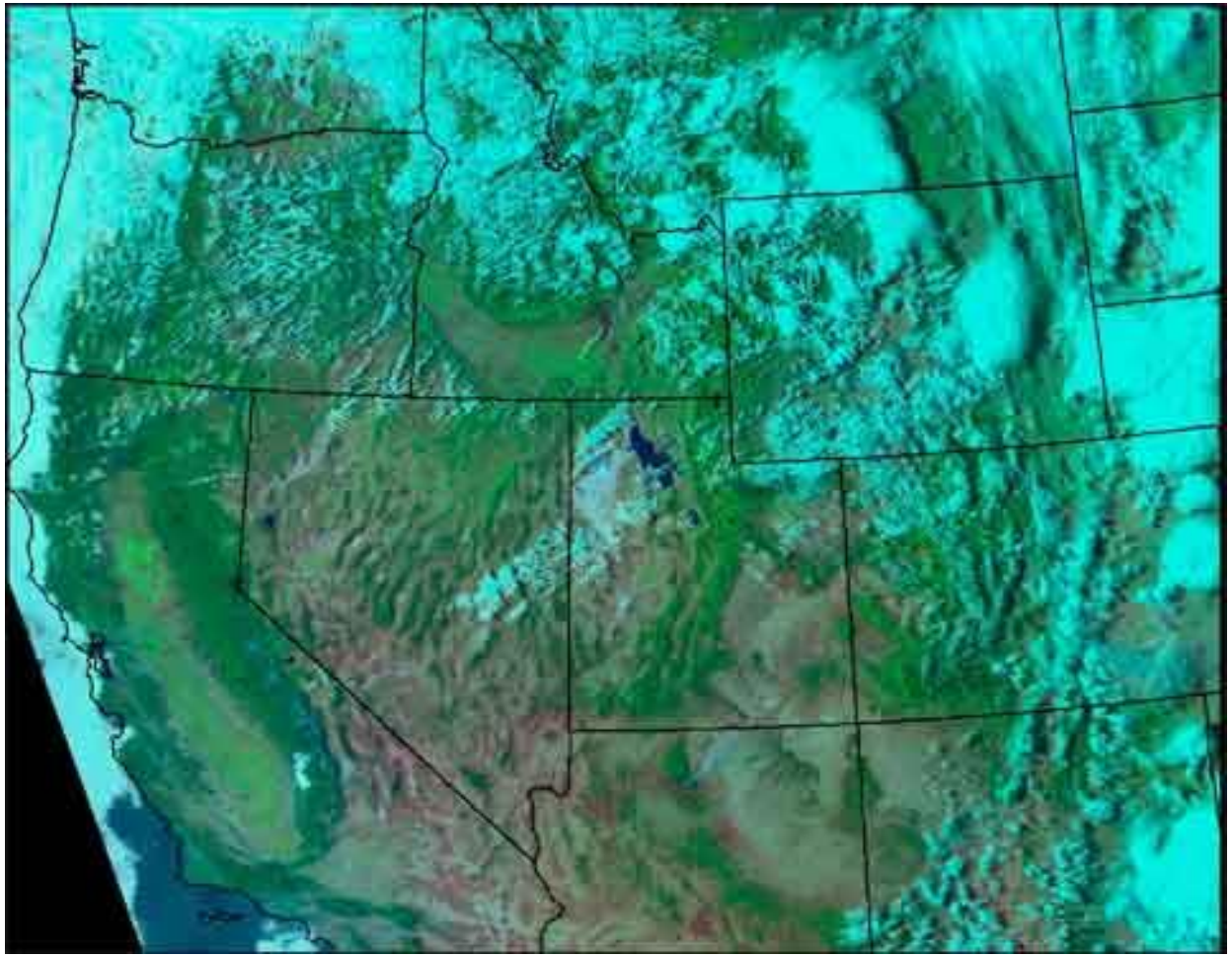
- Measures ozone, UV, aerosols, and volcanic ash emissions

Landsat 7 and Calipso

- Air Pollution Monitoring
  - Ozone, CO, Sulfur Dioxide, Nitrogen Dioxide
- Measure proportion of light blocked by particulate matter for atmospheric modeling

Weather and Climate Modeling

- Instantaneous data on local, regional conditions
- Longer-term climatological summaries
- Changes in mean, variance



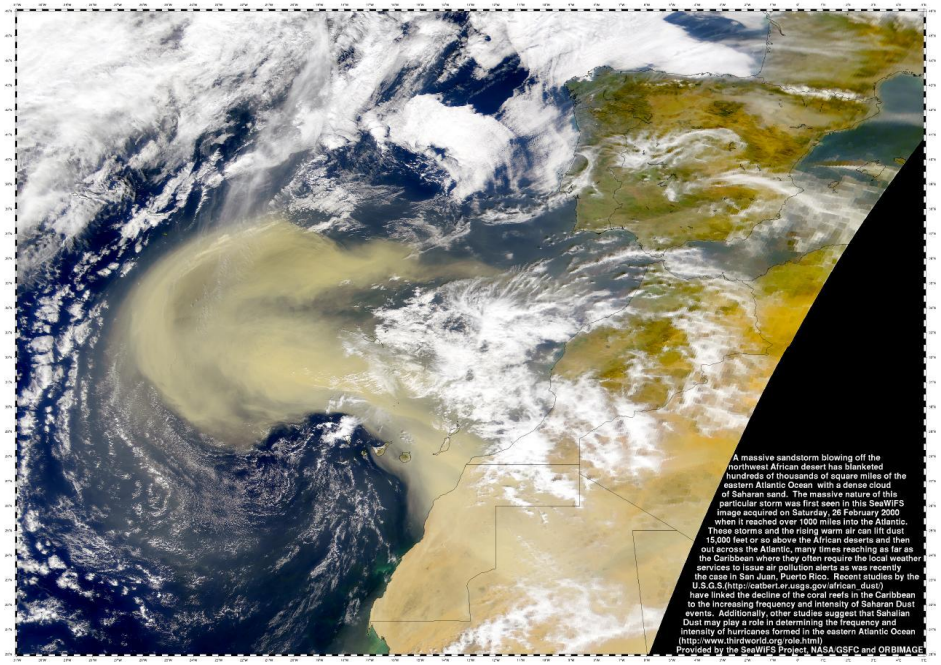
source: U.S. Forest Service

Disaster Monitoring and Response

Hurricane Katrina

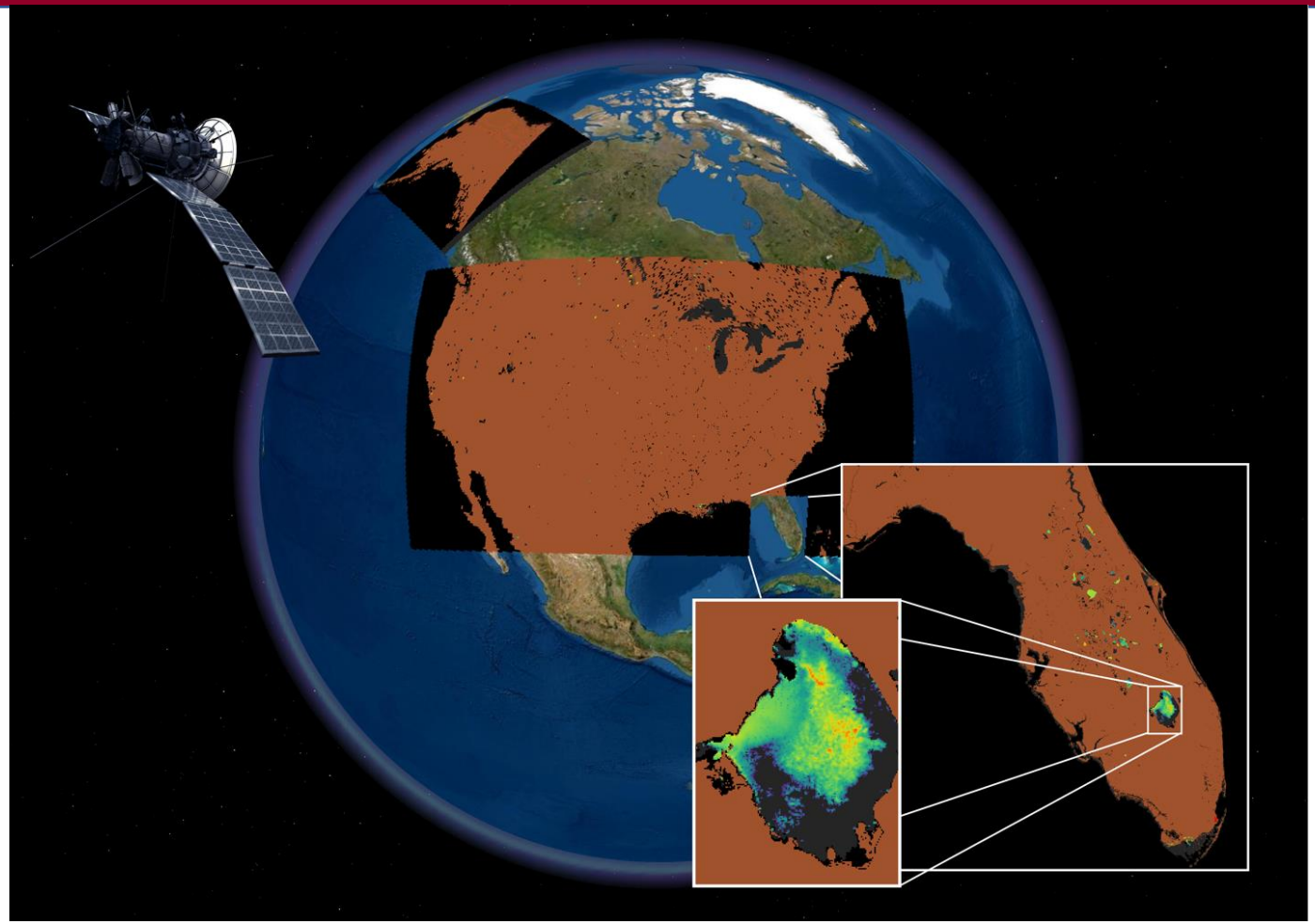
Source: NOAA

African Dust storm



Source: NASA

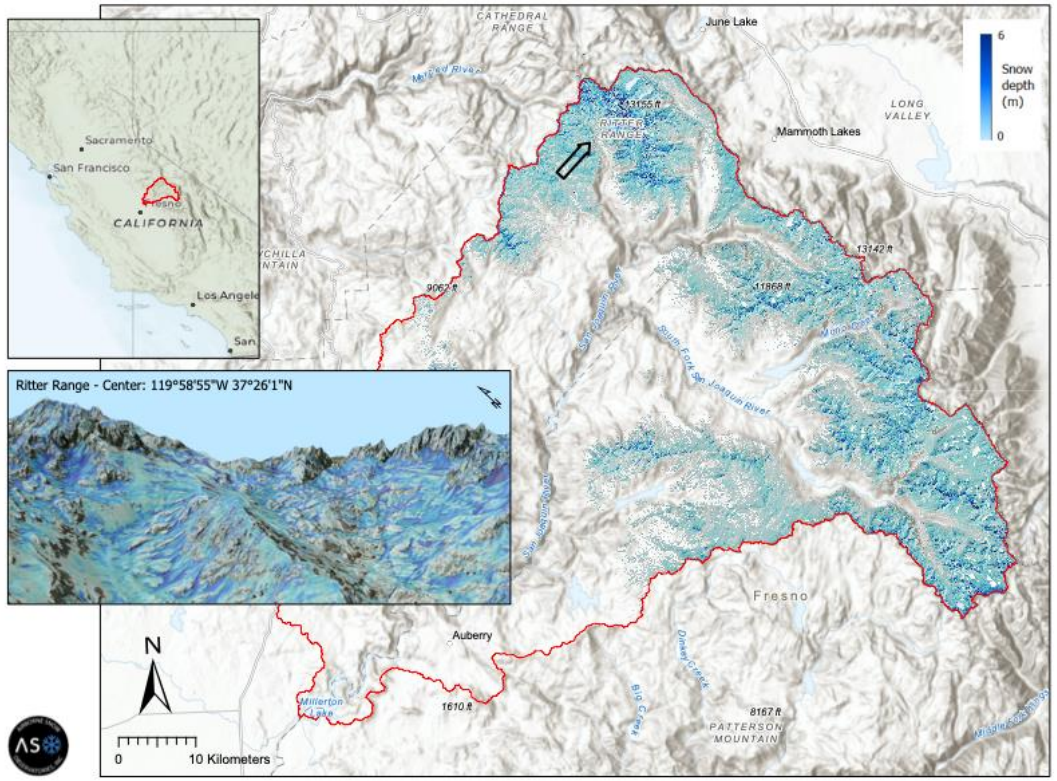
Aquatic Ecosystems



- Runoff
- Flooding
- **Water quality**
- Water body extent
- River flow rates
- Wetlands mapping
- Water surface elevation and depth
- Ocean color
- Coral reef mapping
- Benthic habitat
- Oil spill monitoring

Cooley, S., Jenkins, A., Schaeffer, B., Abdallah, A., Granger, S., & Friedl, L. (*in review*). Research to Operations: Pathways to Success for Research-Driven Decision-Making. Journal of *Technology Transfer*.

Hydrology



Spatially-distributed snow depth observations collected on May 4-5, 2020 by the Airborne Snow Observatory (ASO) are shown for the San Joaquin River Basin, CA. ASO measured the entire snowpack within the 4,500 km^2 watershed area and provided snow depth products at a spatial resolution of 3 x 3 m and snow water equivalent (SWE) products at 50 x 50 m spatial resolution (not shown) within 72 hours of the survey.

Hydrologic Modeling:

- Watershed geometry
- Drainage network
- Empirical Equations

  Annual runoff, Flood peak, Low flow

Runoff Modeling:

- Land use
- Soil moisture
- Topography

Water Quality:

- Suspended sediments
- Estimate chlorophyll
- Temperature
- Turbidity
- Eutrophication

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Advantages of RS

- Cost-effective method of monitoring land cover and use
- Allow monitoring of global processes
- Can observe remote areas
- Enable the integration of many different types of data
- Encourage better information management
- Facilitate historical comparisons
- Create a clear and striking visual product
- Develop and compare options for future land use

Limitations of RS

- Cost of satellite images, software and equipment
- Cloud cover
- Error in data interpretation
- Satellite coverage
- Lack of visible light
- Large data storage needs
- Limited historical data
- Lack of good species data