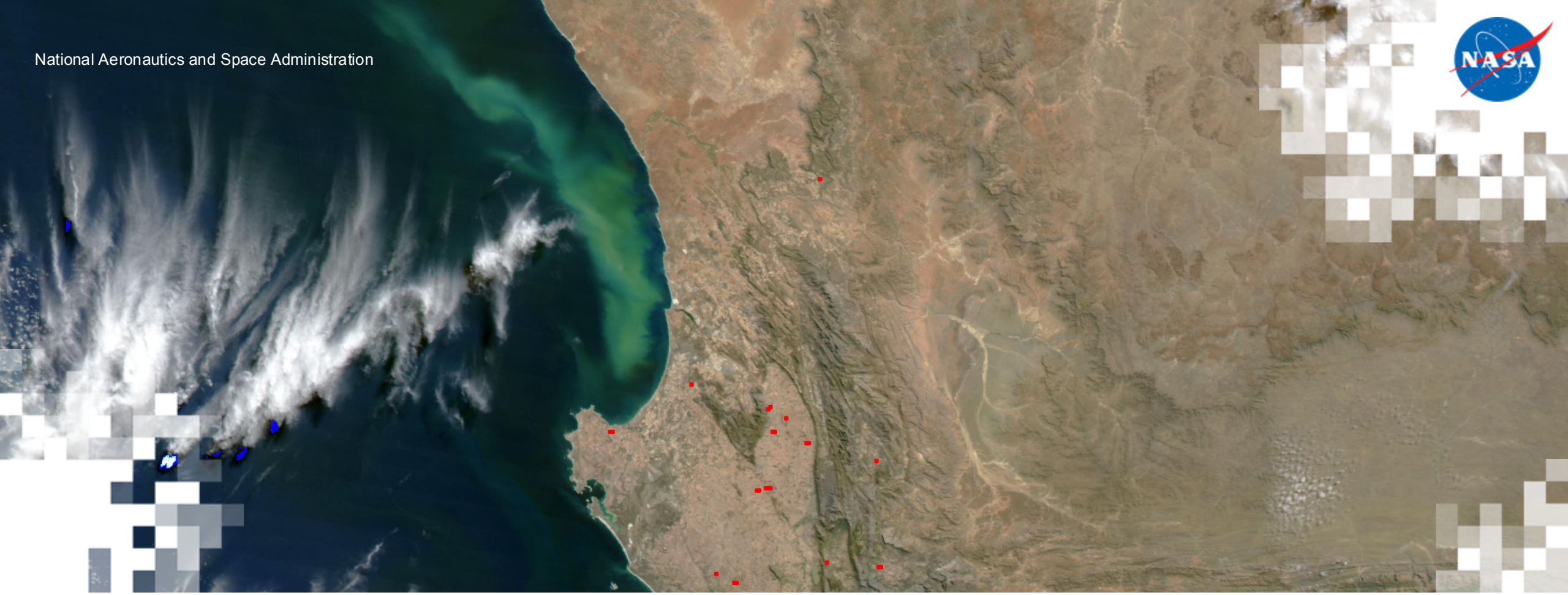
National Aeronautics and Space Administration



Hands-On Field Spectroscopy Training and Data Skills Workshop – An Introduction to NASA Satellite and Airborne Optical Sensors

Cape Town, South Africa

Juan Torres-Pérez (NASA Ames), Sativa Cruz (BAERI/NASA Ames), and Justin Fain (BAERI/NASA Ames)

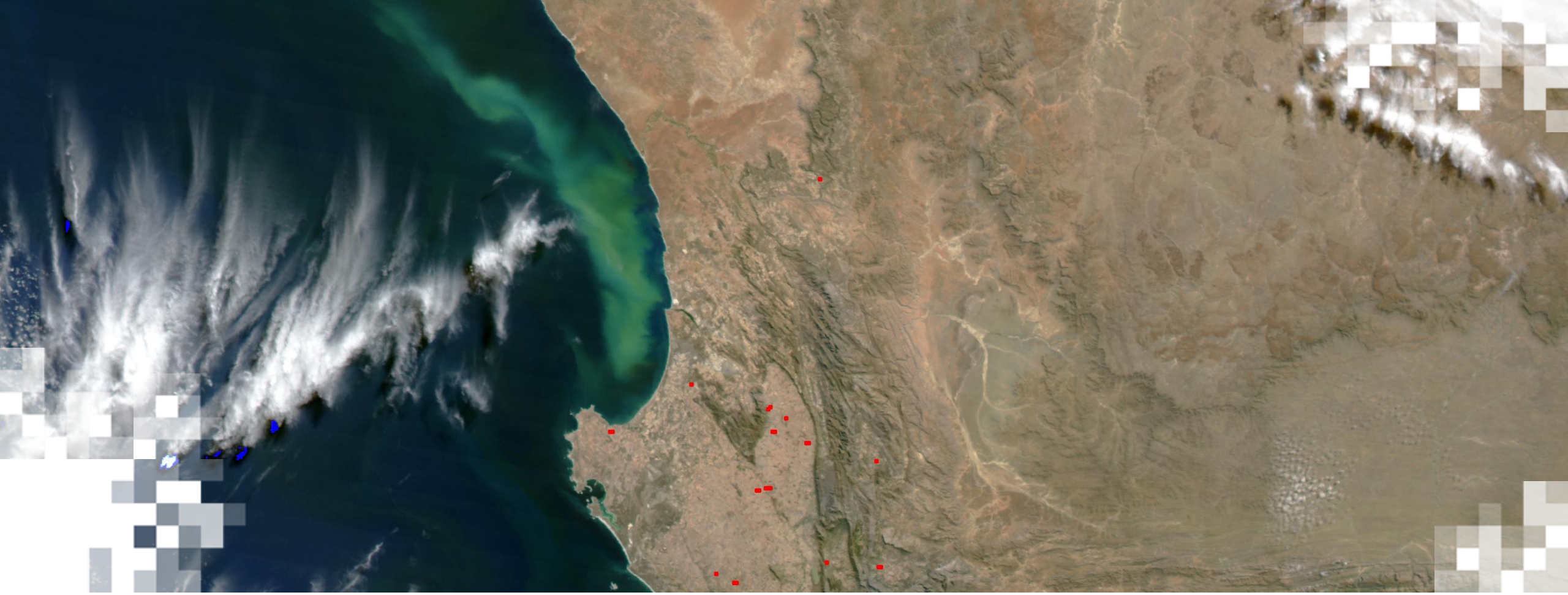
October 7-11, 2024

BIOSCAPE
Biodiversity Survey of the Cape

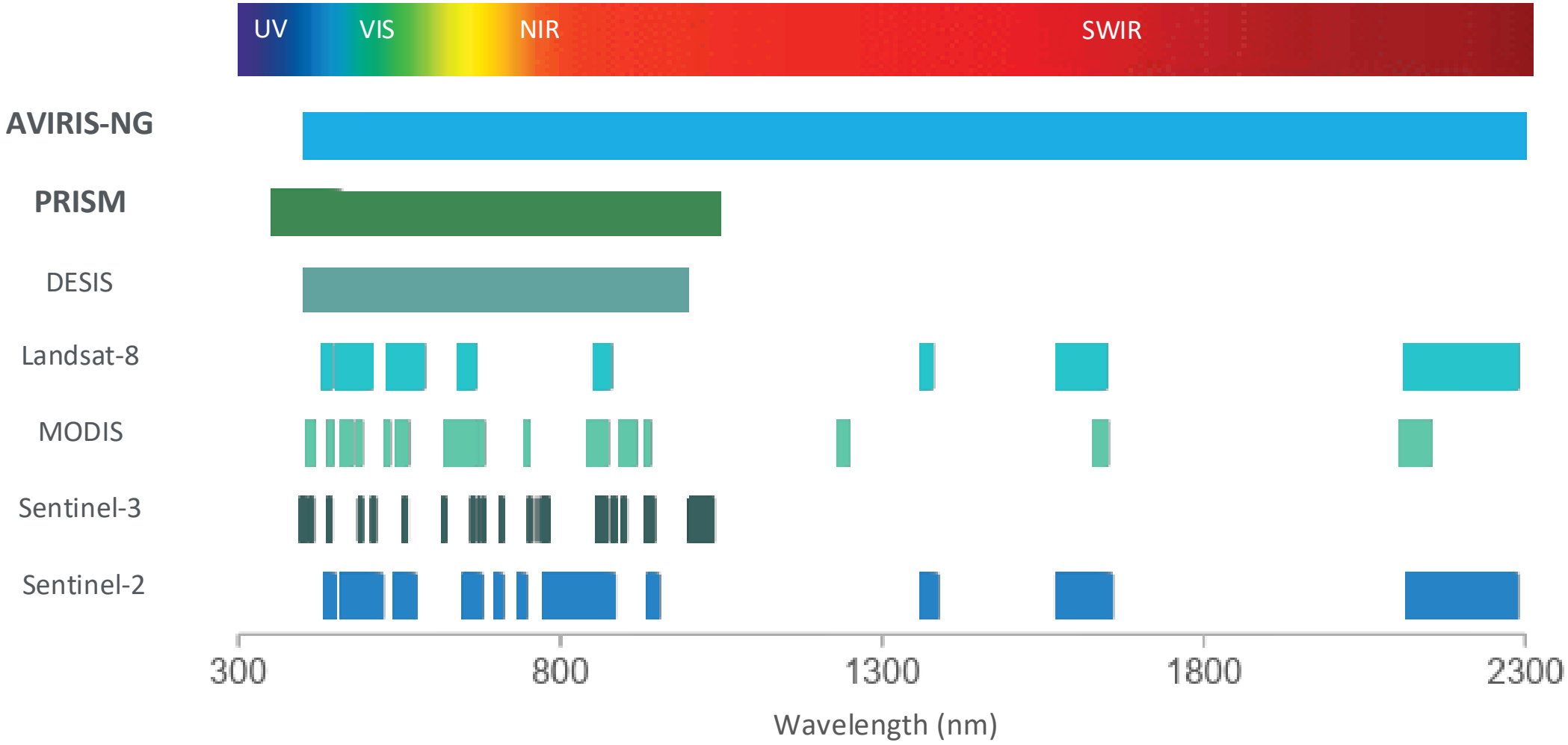
Training Learning Objectives

By the end of this training, participants will:

- Familiarize with legacy, current, and upcoming NASA satellite missions useful for studying land and aquatic ecosystems.
- Familiarize with airborne sensors flown during the 2023 BioSCape Campaign, particularly the optical sensors (AVIRIS-NG and PRISM).



Applications and Sources of Airborne VSWIR Data

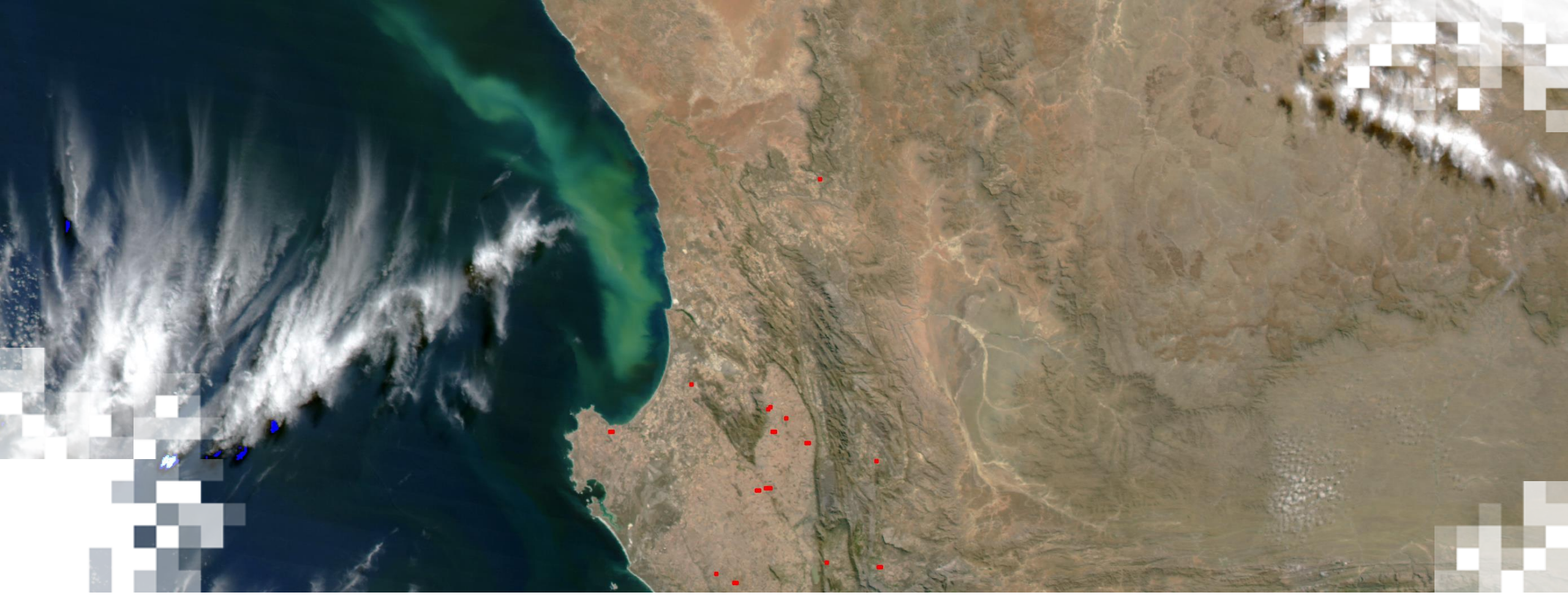


Adapted from: Wilson, A., Hestir, E., Slingsby, J., Cardoso, A. (2022). Biodiversity Survey of the Cape (BioSCape).

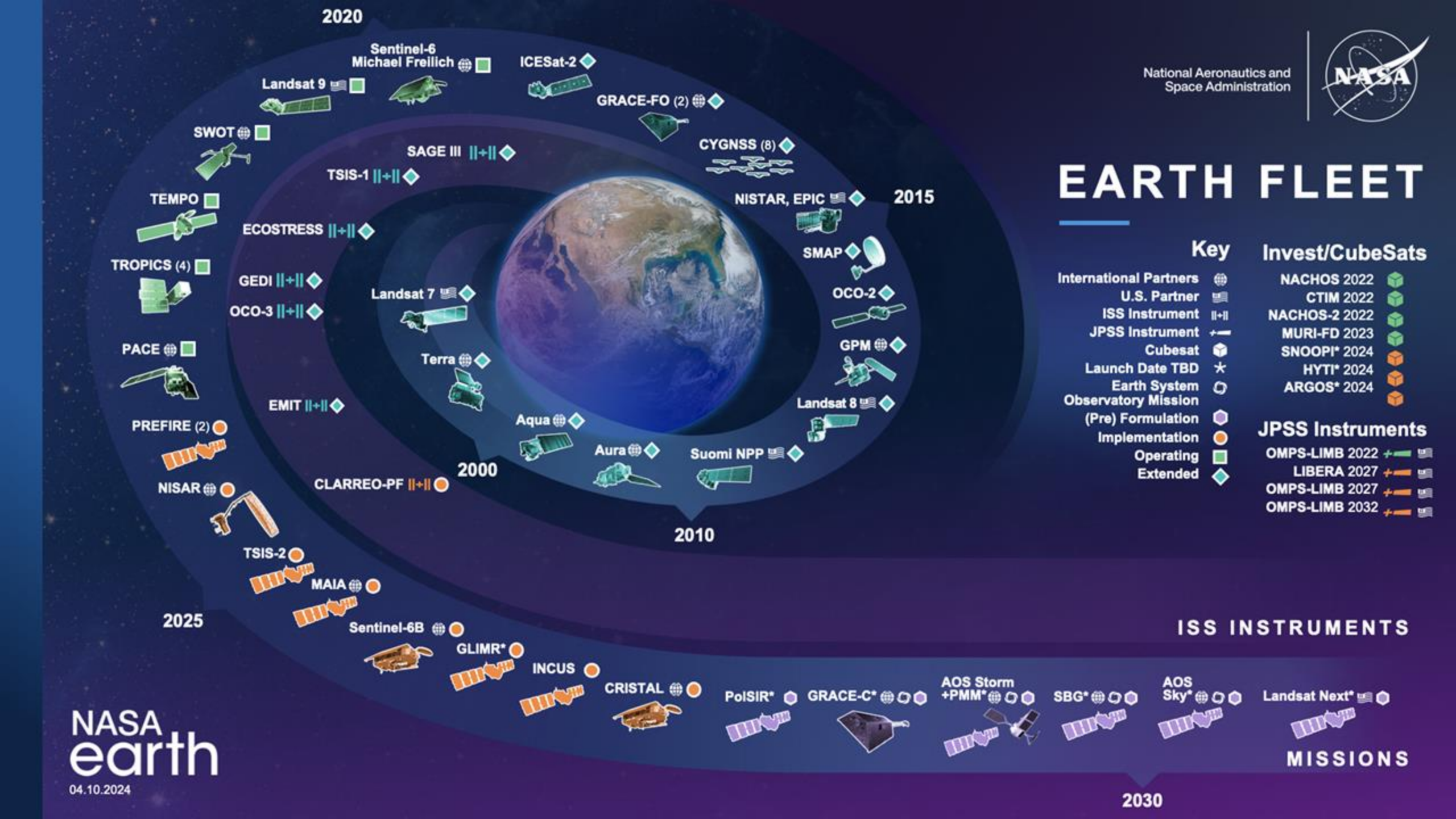
Applications of Airborne VSWIR Data

- Hyperspectral visible to shortwave infrared imaging spectroscopy data can be used to monitor and measure a wide array of environmental parameters such as climate variability, land cover distribution, seasonal cycles, and much more.
- Common sources of this data include AVIRIS-NG and PRISM.

Source: NASA JPL



Overview of Commonly Used NASA Satellite Sensors



National Aeronautics and Space Administration

NASA

EARTH FLEET

Key

- International Partners
- U.S. Partner
- ISS Instrument
- JPSS Instrument
- Cubesat
- Launch Date TBD
- Earth System Observatory Mission
- (Pre) Formulation
- Implementation
- Operating
- Extended

Invest/CubeSats

- NACHOS 2022
- CTIM 2022
- NACHOS-2 2022
- MURI-FD 2023
- SNOOPI* 2024
- HYTI* 2024
- ARGOS* 2024

JPSS Instruments

- OMPS-LIMB 2022
- LIBERA 2027
- OMPS-LIMB 2027
- OMPS-LIMB 2032

ISS INSTRUMENTS

MISSIONS

NASA earth

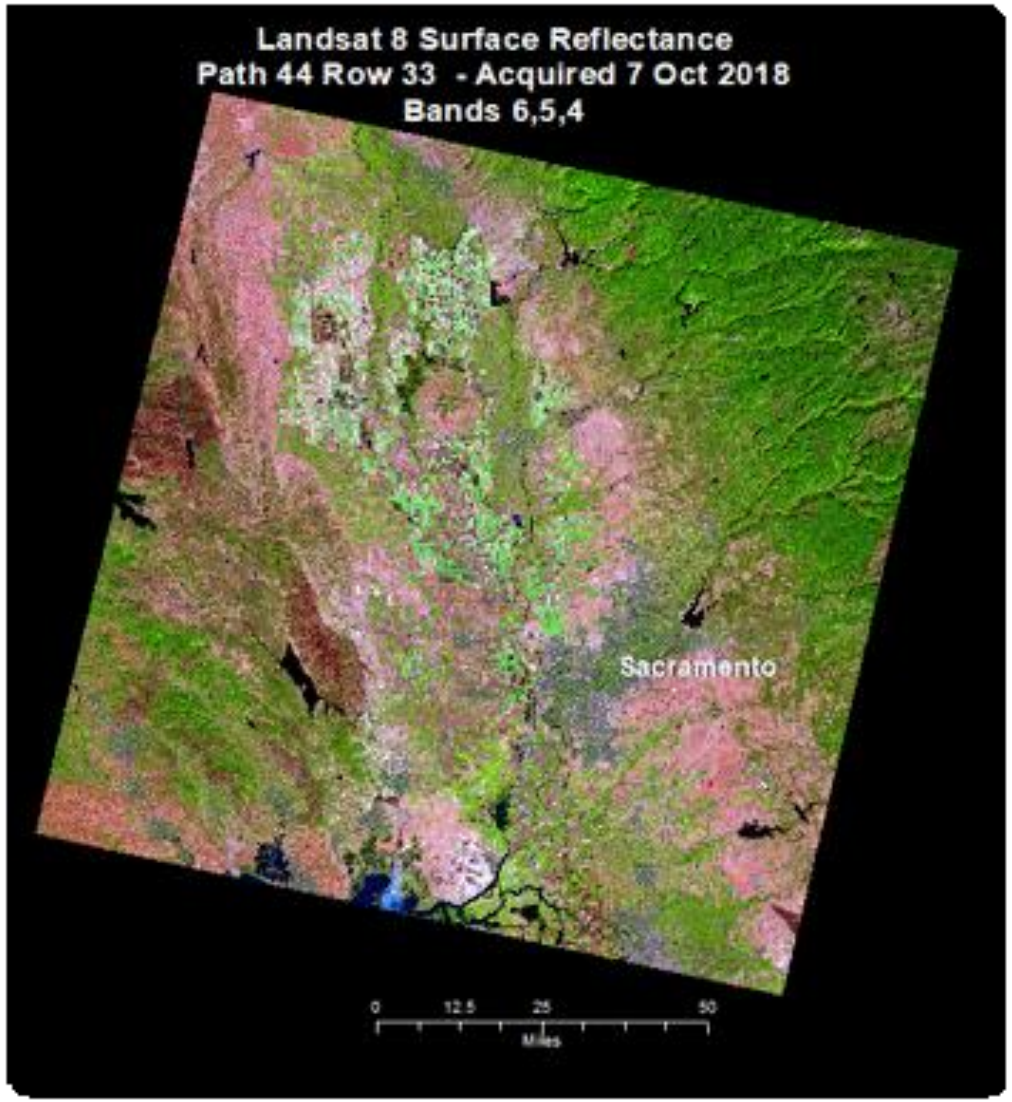
04.10.2024

Landsat Series

- First Landsat launched in 1972
- NASA created and launched
- USGS maintains data
- Passive Sensor – Obtains values of reflectance from Earth's surface
- 30-meter pixels
- Image of the entire Earth every 16 days

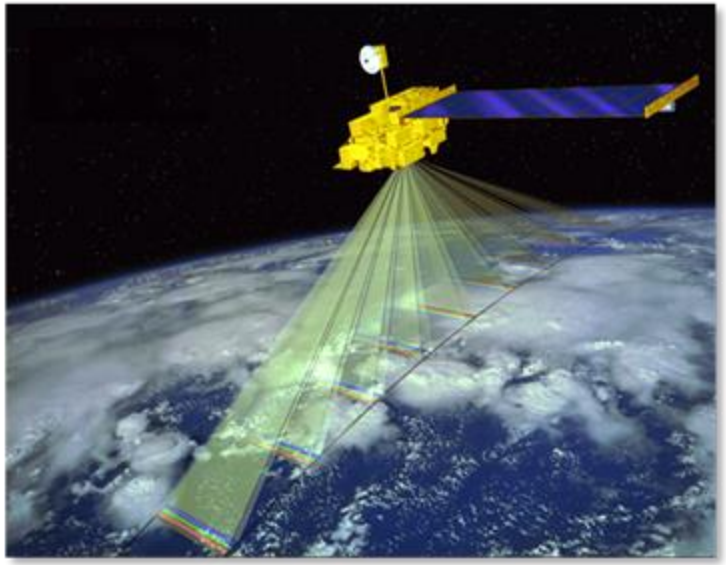
Applications:

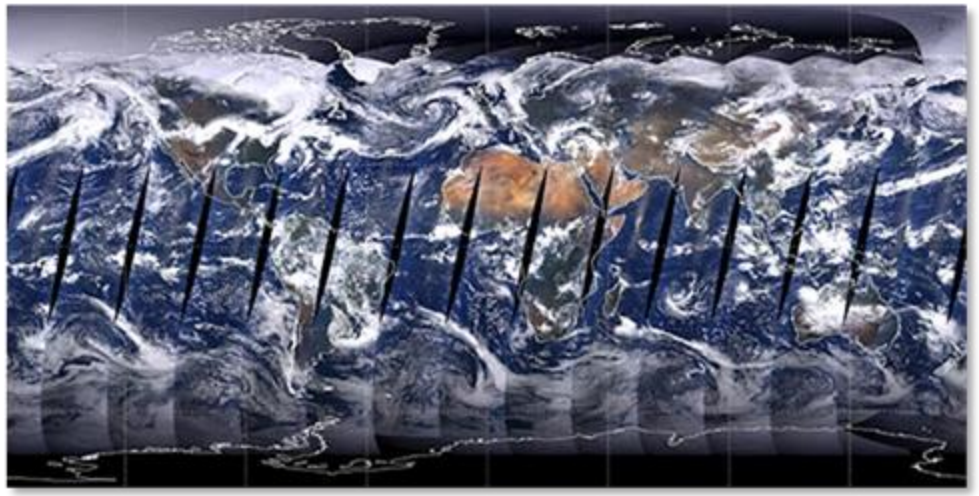
- Vegetation Health
- Deforestation
- Fires
- Agriculture
- Species Habitats
- Water Quality



Moderate Resolution Imaging Spectroradiometer (MODIS)

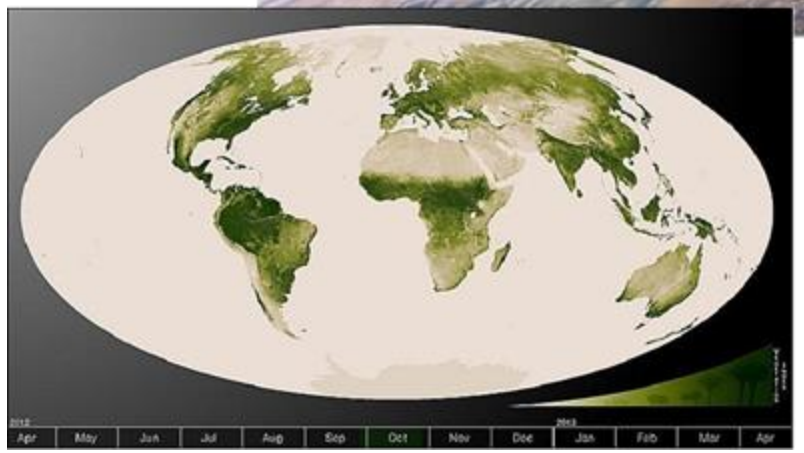
- Spatial Resolution:
  - 250 m, 500 m, 1 km
- Temporal Resolution:
  - Daily, 8-day, 16-day, monthly, quarterly, yearly
  - 2000 – Present
- Data Format:
  - Hierarchical Data Format – Earth Observing System Format (HDF–EO8)
- Spectral Coverage:
  - 36 bands (major bands include blue, green, red, IR, NIR, MIR)
    - Bands 1-2: 250 m
    - Bands 3-7: 500 m
    - Bands 8-36: 1000 m



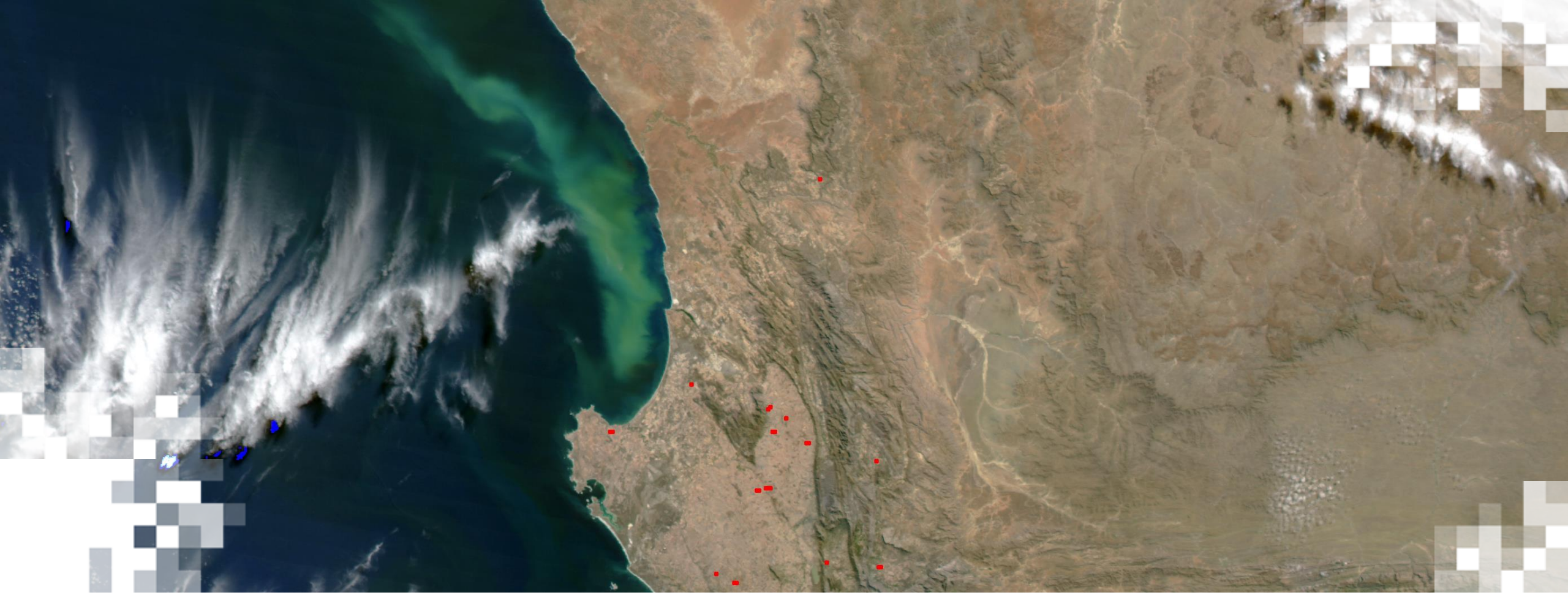


Visible Infrared Imaging Radiometer Suite (VIIRS)

- A sensor onboard the Suomi National Polar-Orbiting Partnership (NPP)
- Data available globally from January 2012 to present
- Revisit Time: 1 day
- Spatial Resolution: 375 m and 750 m
- Similar to MODIS (with some differences)
- Visible, near-infrared channels (reflectance)
- Shortwave and longwave infrared (brightness temperature)
- Products:
  - Surface Reflectance
  - Vegetation Indices
  - Thermal Anomalies



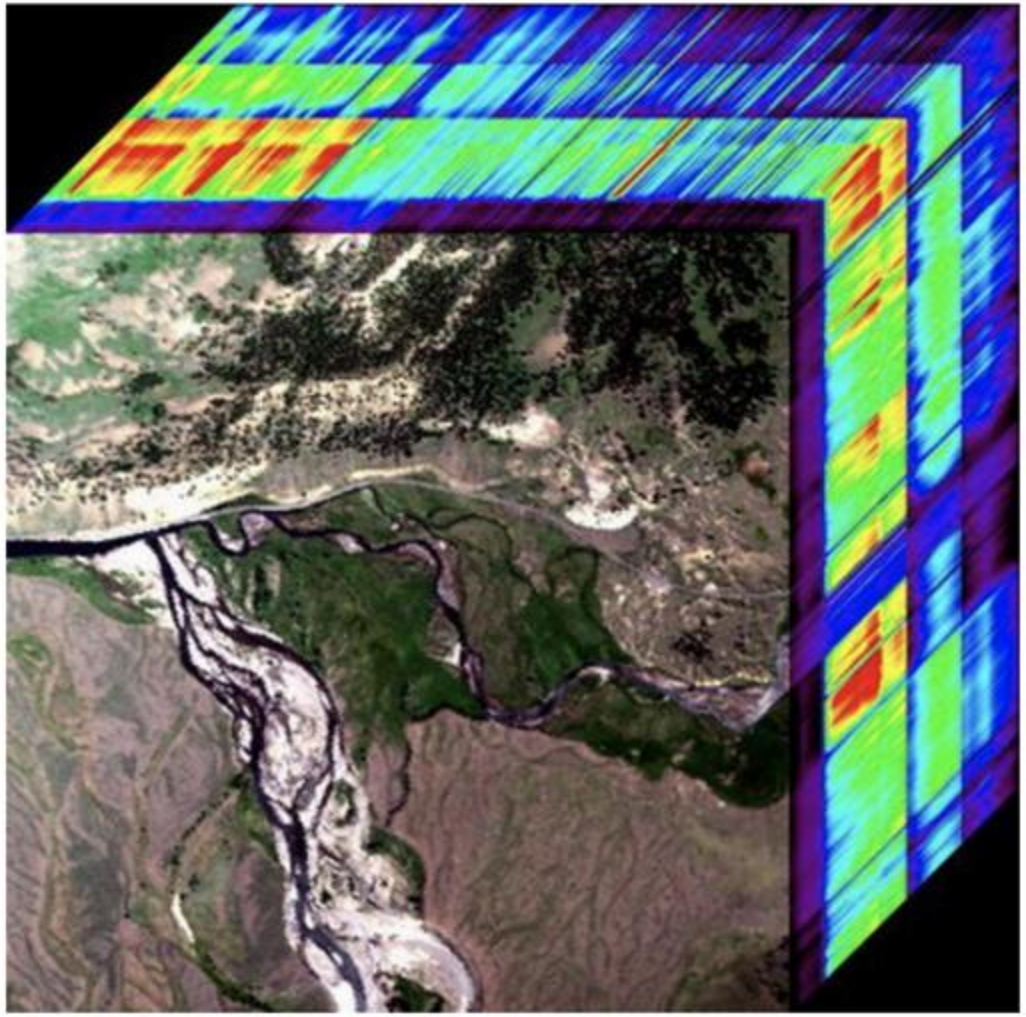
Suomi NPP satellite (above); Global vegetation map (left). Image Credit: NASA/NOAA)



Commonly Used NASA Airborne Optical Sensors

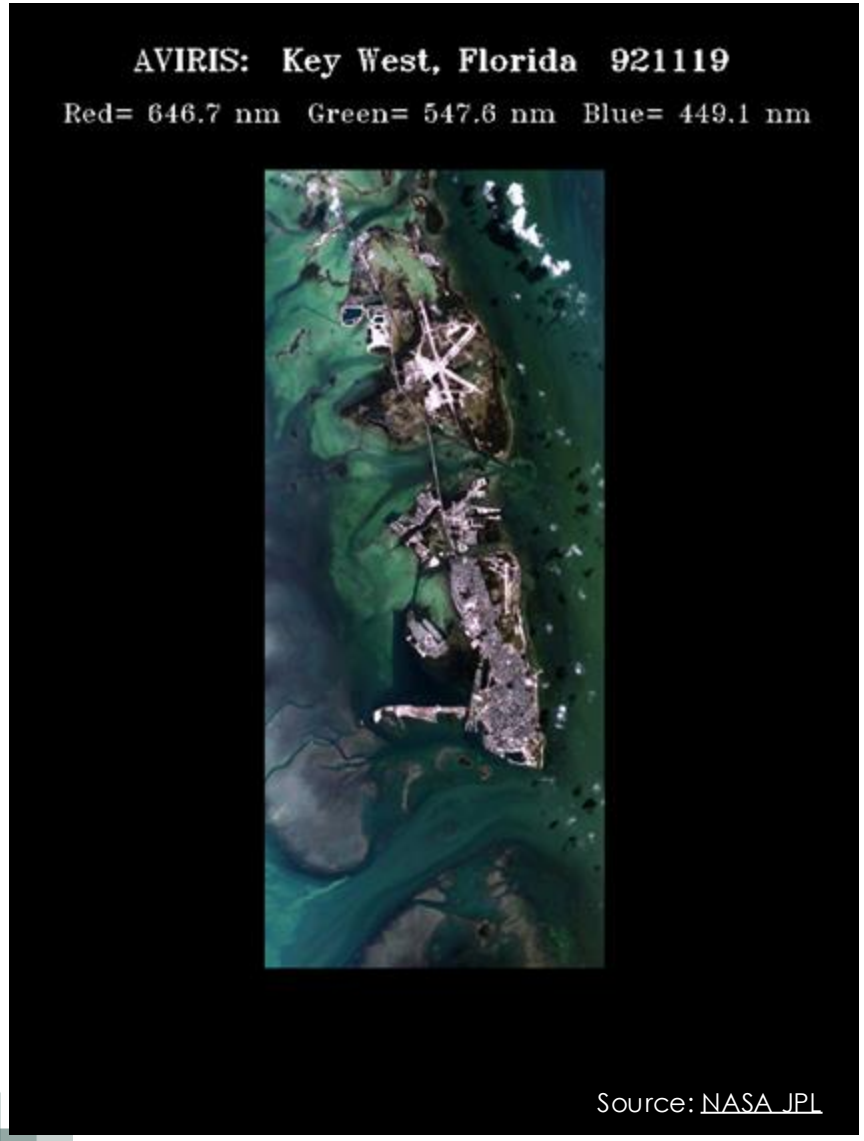
Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)

- Objective: Identify, measure, and monitor constituents of Earth's surface and atmosphere based on molecular absorption and particle scattering signatures
- Sometimes referred to as AVIRIS-C "Classic"
- Flown in North America, Europe, portions of South America, and Argentina
- Flown on Four Aircraft Platforms: NASA's ER-2 Jet, Twin Otter International's Turboprop, Scaled Composites' Proteus, and NASA's WB-57
- Active since 1986



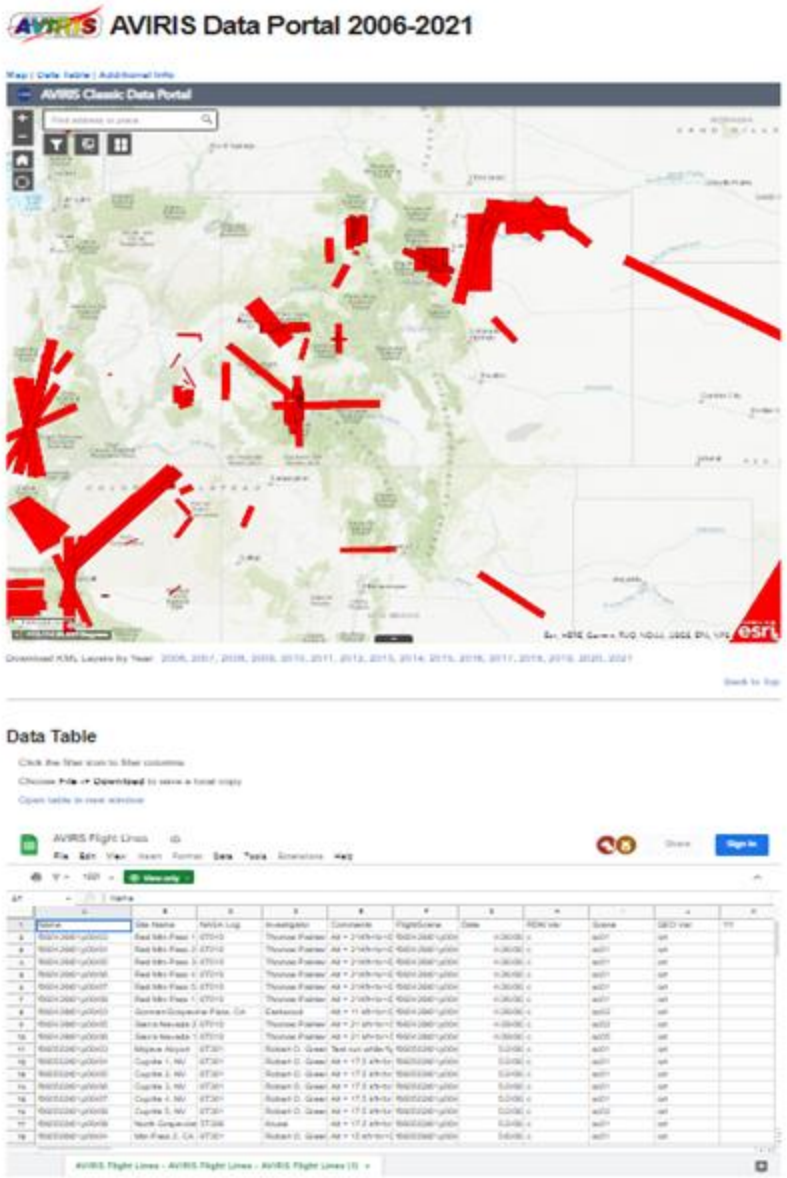
Source: Lu et al., 2020

Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)



- 224 continuous spectral bands
- Spectral Coverage: 380 to 2500 nm
- Bandwidth: < 10 nm
- Pixel size based on altitude:
  - 20 km Above Ground Level (AGL) for 20 m pixel resolution
  - 4 km AGL for 4 m pixel resolution

Accessing and Using AVIRIS-C Data



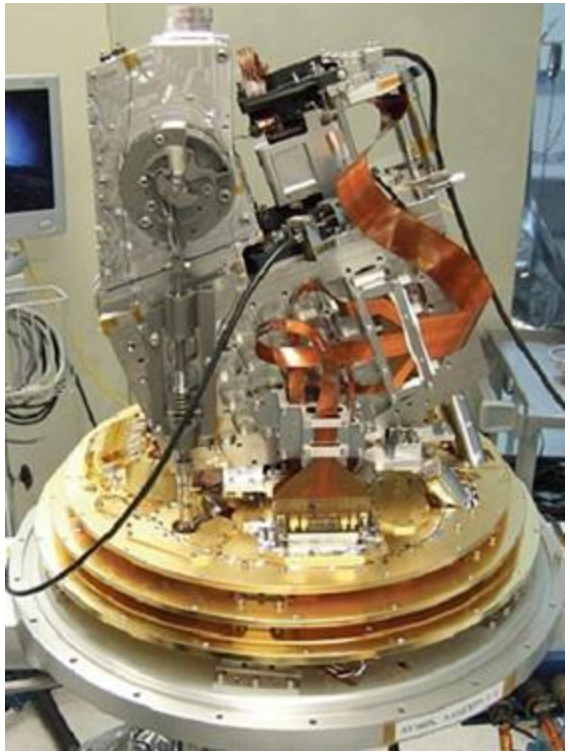
- 2006 – 2021 data is available to download from AVIRIS Data Portal
  - Many filtering options
  - Each flightline uses a specific base filename prefix
- To access pre-2006 data, users must fill out a request form
- Data Types:
  - .KML
  - .JPEG
  - .dat
- Compatible with ENVI, QGIS, ESRI products, etc.
- Preprocessing tutorial is provided

Previous AVIRIS Campaigns

2006–2021 Campaigns

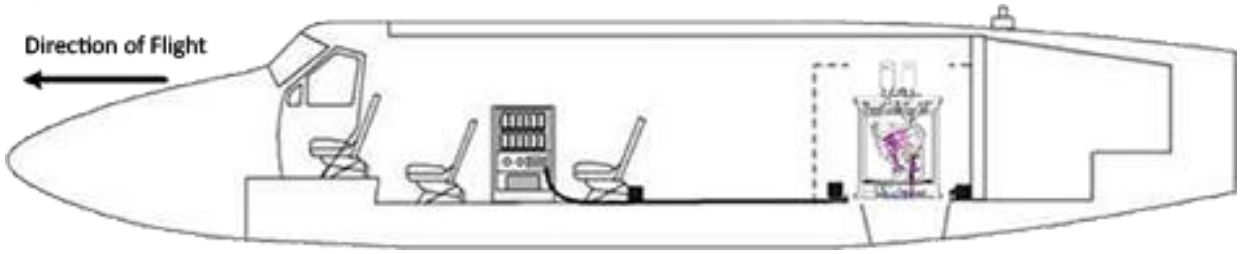
Airborne Visible InfraRed Imaging Spectrometer – Next Generation (AVIRIS-NG)

- Objective: To support NASA science and applications by measuring spectra as images that record the interaction of light with matter. These spectra are used to identify, measure, and monitor constituents of the Earth's surface and atmosphere.
- Flown on Several Aircraft Platforms: NASA's ER-2 Jet, the Twin Otter Turboprop, B200 King Air, and NASA's Gulfstream III and V
- Flown in North America, Europe, and India, and South Africa
- Active since 2009



Source: NASA JPL

Airborne Visible InfraRed Imaging Spectrometer – Next Generation (AVIRIS-NG)

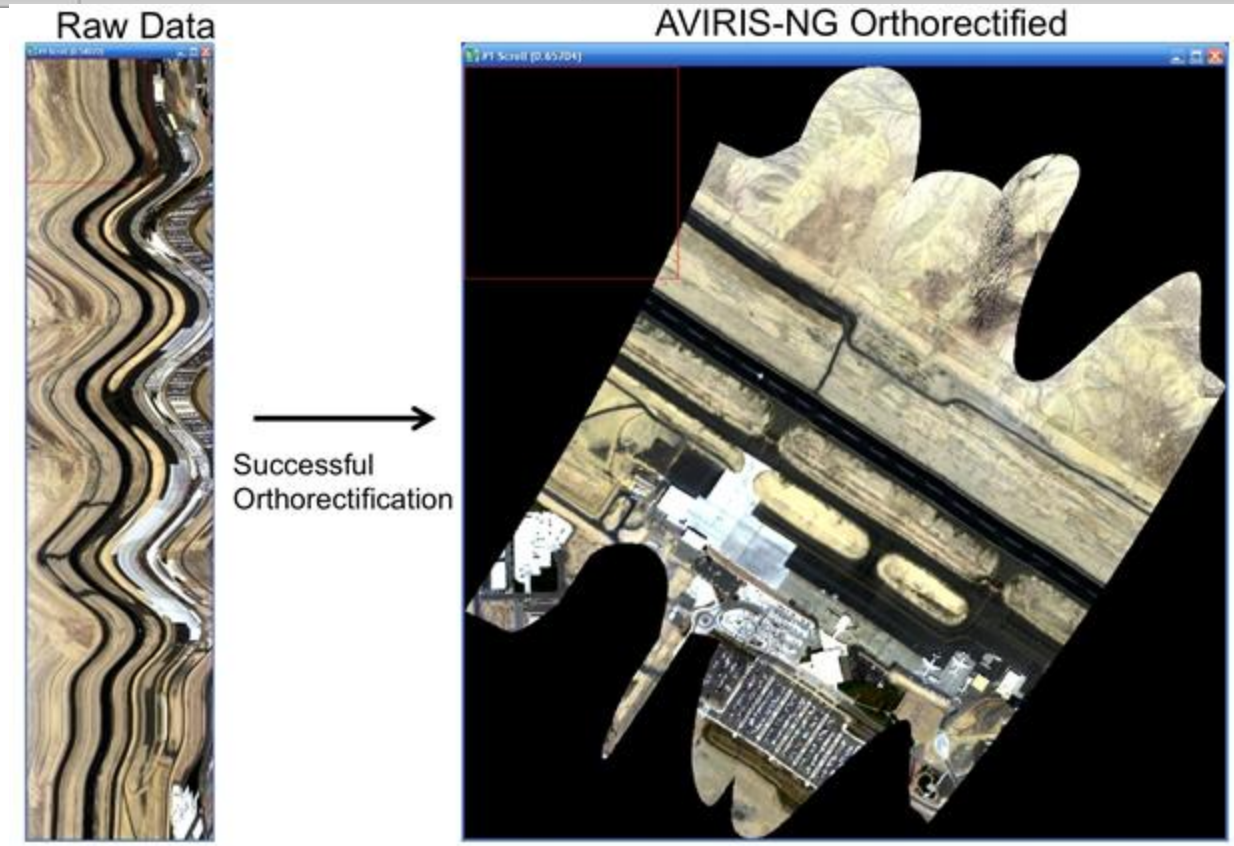


Source: NASA JPL

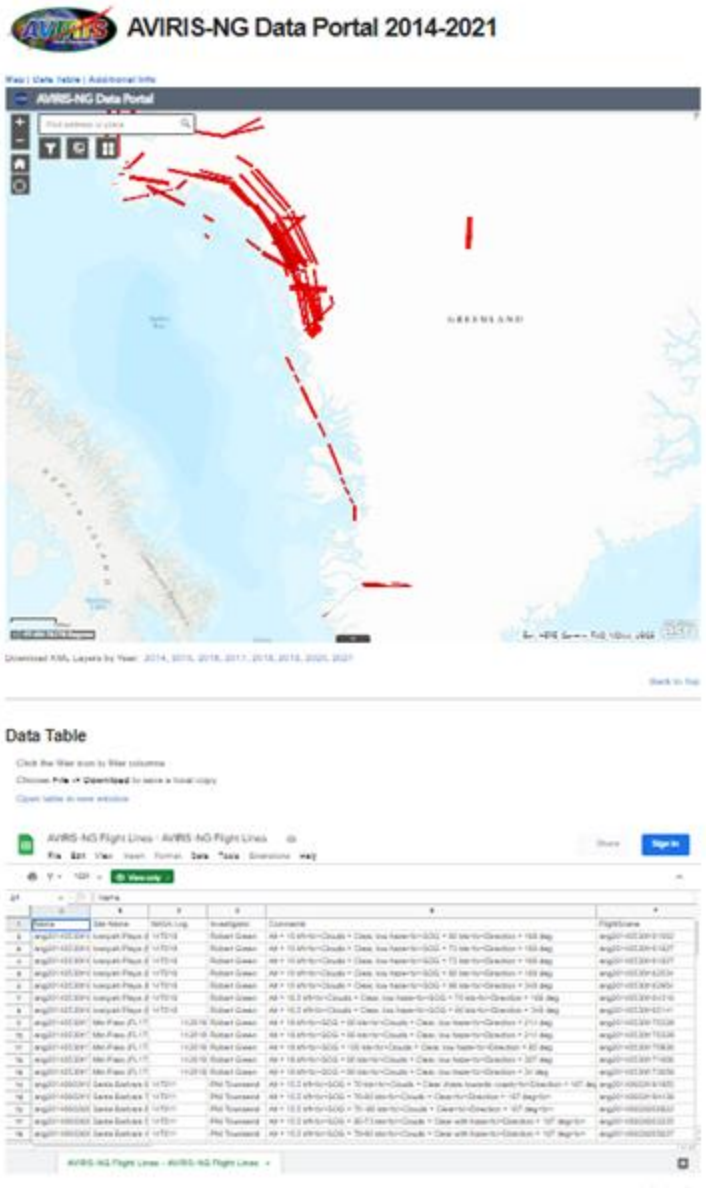
- 481 contiguous spectral bands
- Spectral Coverage: 380 to 2510 nm
- Spectral Resolution: 5 nm ± 0.5 nm
- Pixel Size Based on Altitude:
  - 6,500 ft AGL for 2 m pixel resolution
  - 13,000 ft AGL for 4 m pixel resolution
  - 20,000 ft AGL for 6 m pixel resolution

AVIRIS-NG Data Products

Product Name	Product Description
L1B	Resampled calibrated data in units of spectral radiance as well as observational geometry and illumination parameters.
L2	Orthocorrected and atmospherically corrected reflectance data (32-bit floating point quantities from 0 to 1) as well as retrieved column water vapor and optical absorption paths for liquid H2O and ice.



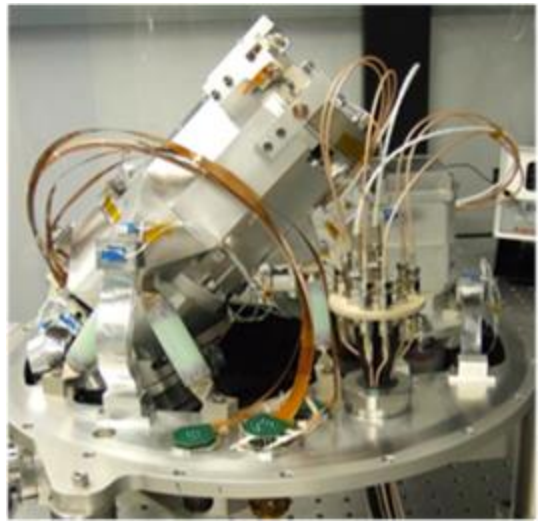
Accessing and Using AVIRIS-NG Data



- 2014–2021 data is available to download from [AVIRIS-NG Data Portal]
  - Many filtering options
  - Each flightline uses a specific base filename prefix
- Data Types:
  - .KML
  - .JPEG
  - .dat
- Compatible with ENVI, QGIS, ESRI products, etc.

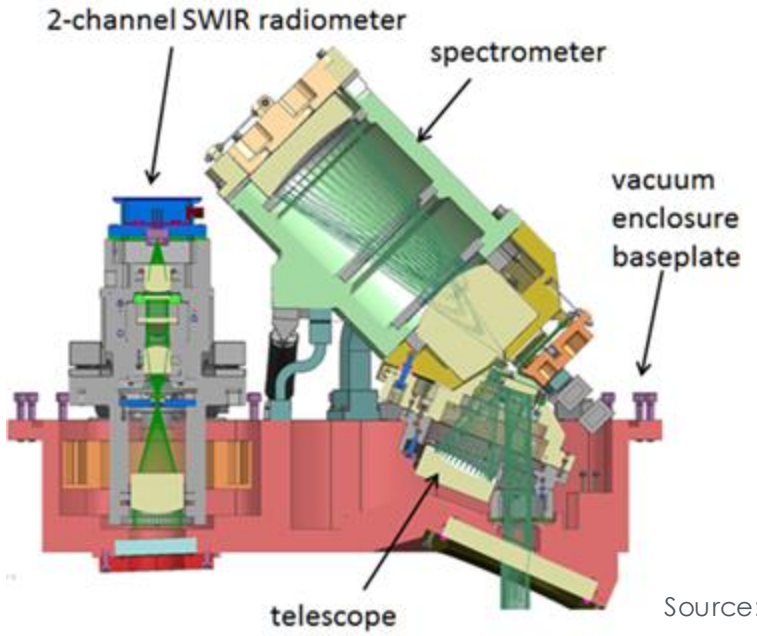
Portable Remote Imaging SpectroMeter (PRISM)

- Application: To serve as a UV-NIR (350 nm to 1050 nm) Coastal Ocean Science Instrument.
- Flown on Four Aircraft Platforms: NASA's ER-2 Jet, Twin Otter Aircraft, Gulfstream GIII and GV
- Flown in Western United States, South America, the Southern Ocean, and South Africa
- Active since 2012



Source: NASA JPL

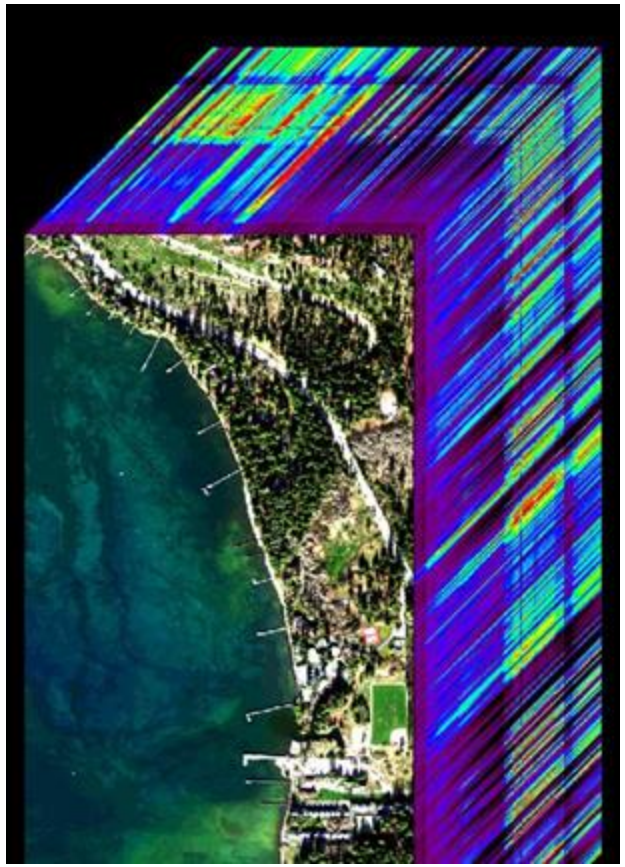
Portable Remote Imaging SpectroMeter (PRISM)



Source: NASA JPL

- Pushbroom imaging spectrometer with 246 contiguous spectral bands
- Spectral Coverage: 350–1050 nm
- Spectral Resolution: 3.5 nm
- Two short wave infrared (SWIR) bands at 1240 and 1610 nm
  - Bandwidth: 22 nm and 56 nm
- The spatial resolution depends on the altitude and plane speed, but ranges from 0.3 to 16 m.

PRISM Data Products



Product Name	Product Description
L1B	Resampled calibrated data in units of spectral radiance as well as observational geometry and illumination parameters.
L2	Orthocorrected and atmospherically corrected reflectance data (32-bit floating point quantities from 0 to 1) as well as retrieved column water vapor and optical absorption paths for liquid H2O and ice.

L1B Data Products

Grass Line, FL - View quicklook | Download data (4.5 GB)

Island Line, FL - View quicklook | Download data (4 GB)

Elkhorn, CA - View quicklook | Download data (9 GB)

Elkhorn, CA - View quicklook | Download data (10 GB)

Elkhorn, CA - View quicklook | Download data (10 GB)

L2 Data Products

Grass Line, FL - View quicklook | Download data (4.8 GB)

Island Line, FL - View quicklook | Download data (4.1 GB)

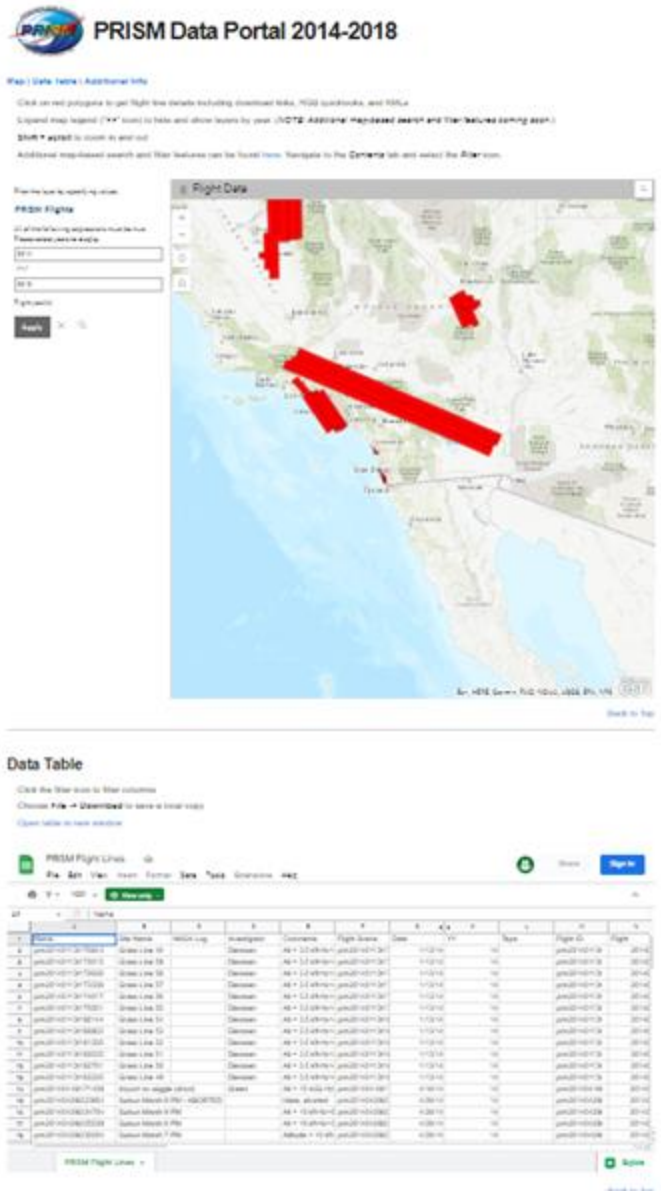
Elkhorn, CA - View quicklook | Download data (7.4 GB)

Elkhorn, CA - View quicklook | Download data (8.2 GB)

Elkhorn, CA - View quicklook | Download data (8.1 GB)

Source: NASA JPL

Accessing and Using PRISM Data



- 2014–2018 data is available to download from [PRISM Data Portal]
  - Many filtering options
  - Each flightline uses a specific base filename prefix
- Data Types:
  - .KML
  - .JPEG
  - .dat
- Compatible with ENVI, QGIS, ESRI products, etc.

Comparing Airborne Systems: Specifications

AVIRIS-C:

- Active since 1986
- 224 continuous spectral bands
- Spectral Coverage: 380 to 2500 nm
- Spectral Resolution: 10 nm
- Spatial Resolution: 4–20 m

AVIRIS-NG:

- Active since 2009
- 481 contiguous spectral bands
- Spectral Coverage: 380 to 2510 nm
- Spectral Resolution: 5 nm
- Spatial Resolution: 2–6 m

PRISM:

- Active since 2012
- 256 contiguous spectral bands and 2 SWIR bands: 1240 and 1610 nm
- Spectral Coverage: 350 - 1050 nm
- Spectral Resolution: 3.5 nm
- Spatial Resolution: 0.3 to 16 m

Comparing Airborne Systems: Access and Use

AVIRIS-C:

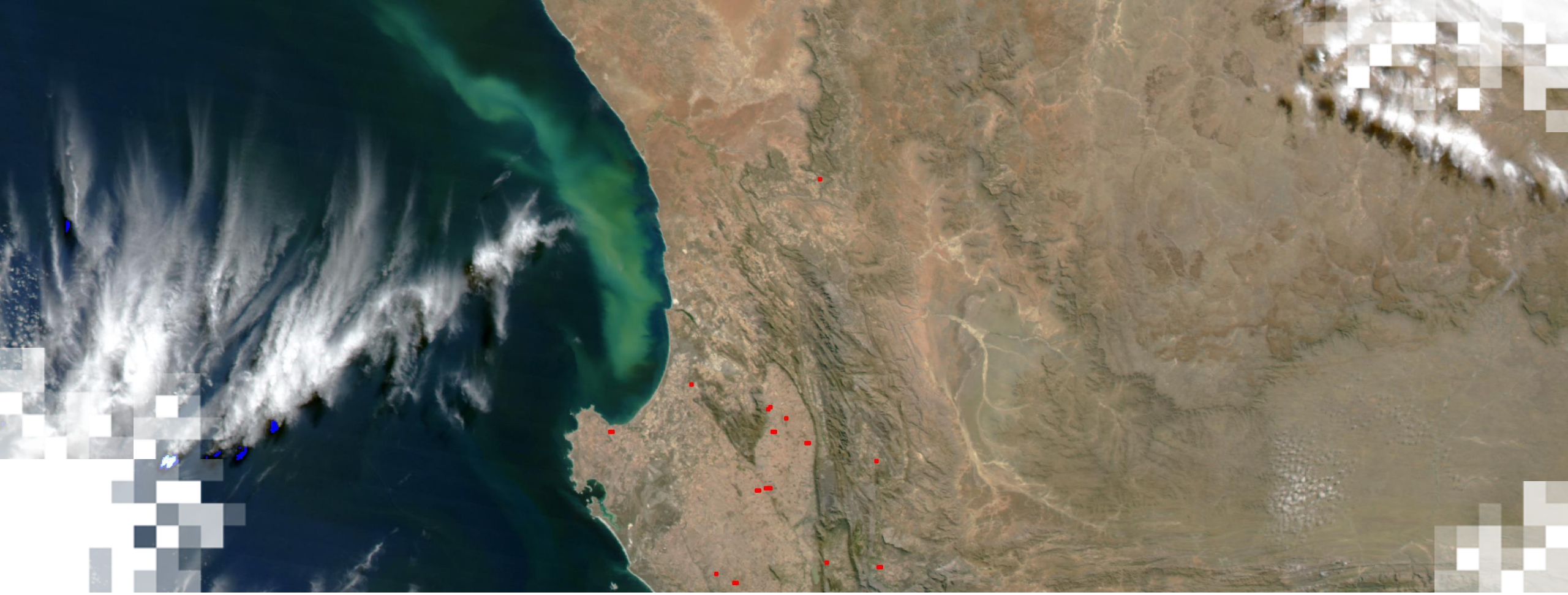
- Data Access:
  - Data portal
  - 2006–2021
  - Pre-2006 form
- Data Products:
  - Up to Level 1B for 1993 to 2012
  - Up to Level 2 for data collected 2013 to present
- Data Types:
  - .KML
  - .JPEG
  - .dat

AVIRIS-NG:

- Data Access:
  - Data portal
  - 2014–2021
- Data Products: Level 1B and L2
- Data Types:
  - .KML
  - .JPEG
  - .dat

PRISM:

- Data Access:
  - Data portal
  - 2014–2018
- Data Products: Level 1B and L2
- Data Types:
  - .KML
  - .JPEG
  - .dat

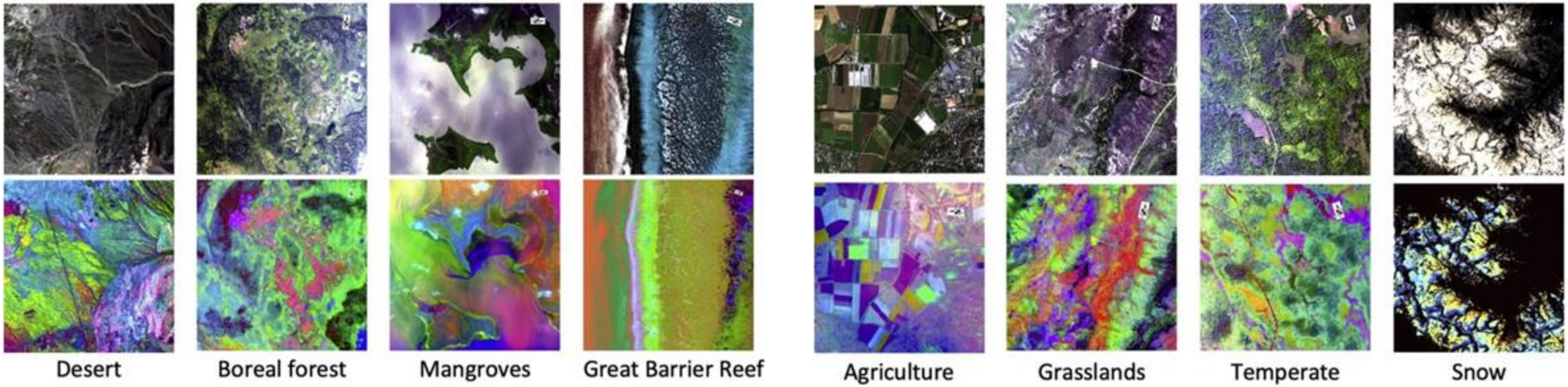


Upcoming Mission Highlights

Paving the Way for Future Missions

The design and data from these airborne instruments have been essential in the development of upcoming satellite missions and future science initiatives.

- Mission objectives and spectrometer specifications are based off the successful implementation of previous airborne campaigns.



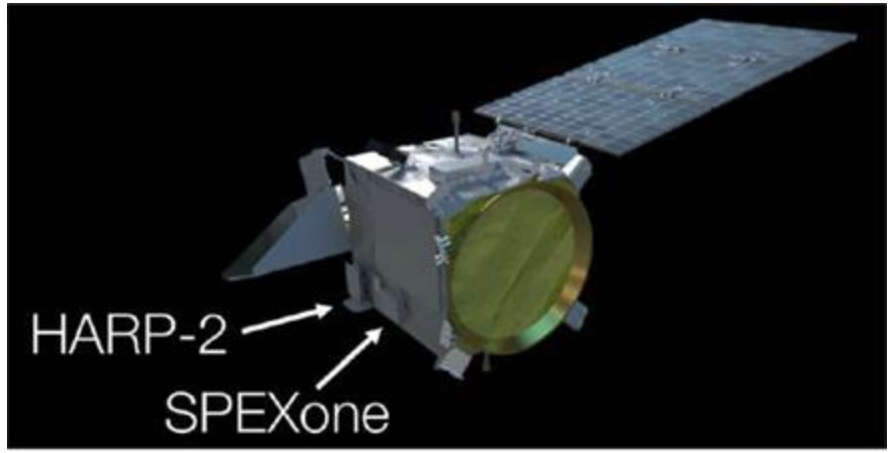
Imagery from HyTES, AVIRIS-NG, AVIRIS-C, and PRISM campaigns used for the development of NASA's SBG mission. Credit: Cawse-Nicholson, et al., 2021.

Plankton, Aerosol, Cloud, and Ocean Ecosystem (PACE)

PACE is NASA's next great investment in hyperspectral earth imagery and multi-angle polarimetry.

- Launch Date: **Feb 8, 2024**
- 3-year design life; 10-year propellant

- Hyperspectral Imager: **Ocean Color Instrument (OCI)**
  - Spectral Resolution: UV to SWIR (340-890 nm every 2.5 nm, with 940, 1038, 1250, 1378, 1615, 2130, & 2250 nm)
  - Temporal Resolution: 2 days
  - Spatial Resolution: 1-km2 at nadir
- Two Multi-Angle Polarimeters
  - **HARP-2**: Wide swath, hyper-angular, 4 bands across the VIS & NIR
  - **SPEXone**: Narrow swath, hyperspectral (UVNIR), 5 viewing angles



Extend key systematic **ocean** biological, ecological, & biogeochemical climate data records, as well as **cloud** & **aerosol climate data records**.

Make **new global measurements of ocean color** that are essential for understanding the global carbon cycle & ocean ecosystem responses to a changing climate.

Collect **global observations of aerosol & cloud properties**, focusing on reducing the largest uncertainties in climate & radiative forcing models of the Earth system.

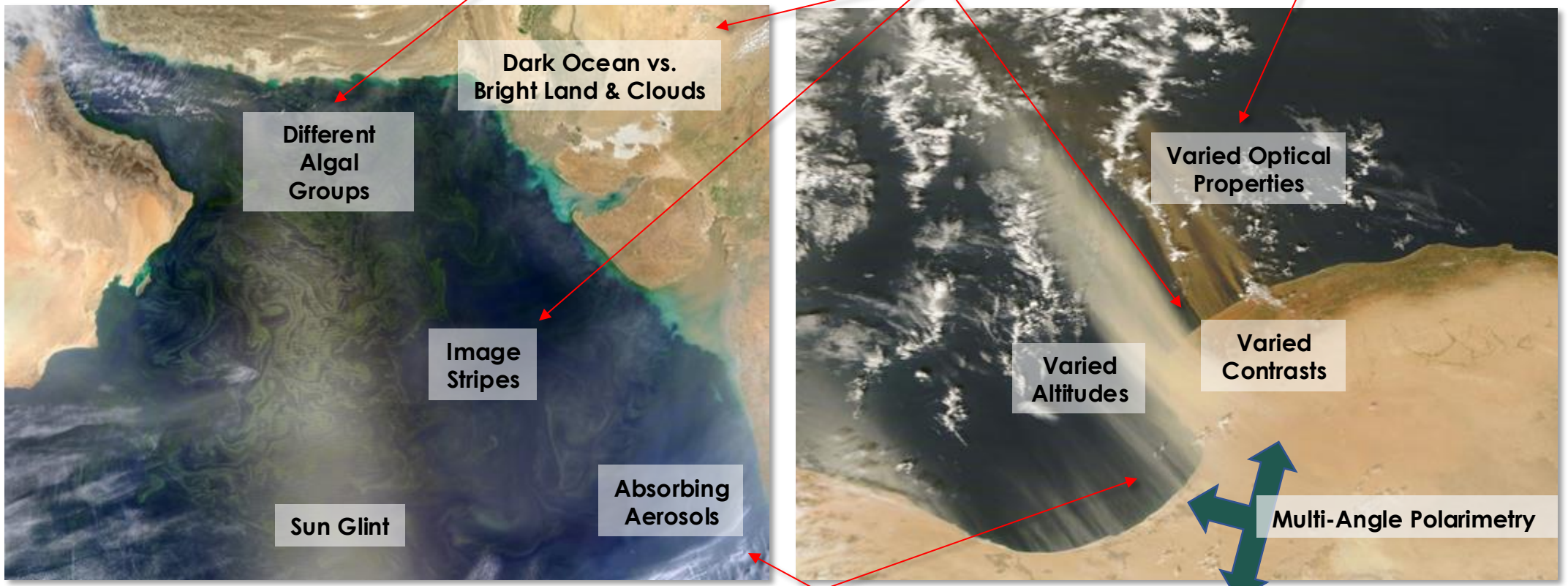
GSD of 1 ± 0.1 km² at nadir

Twice-monthly lunar calibration & onboard solar calibration (daily, monthly, dim)

Spectral Range from 350-865 @ 5 nm

940, 1038, 1250, 1378, 1615, 2130, 2260 nm

Instrument Performance Requirements

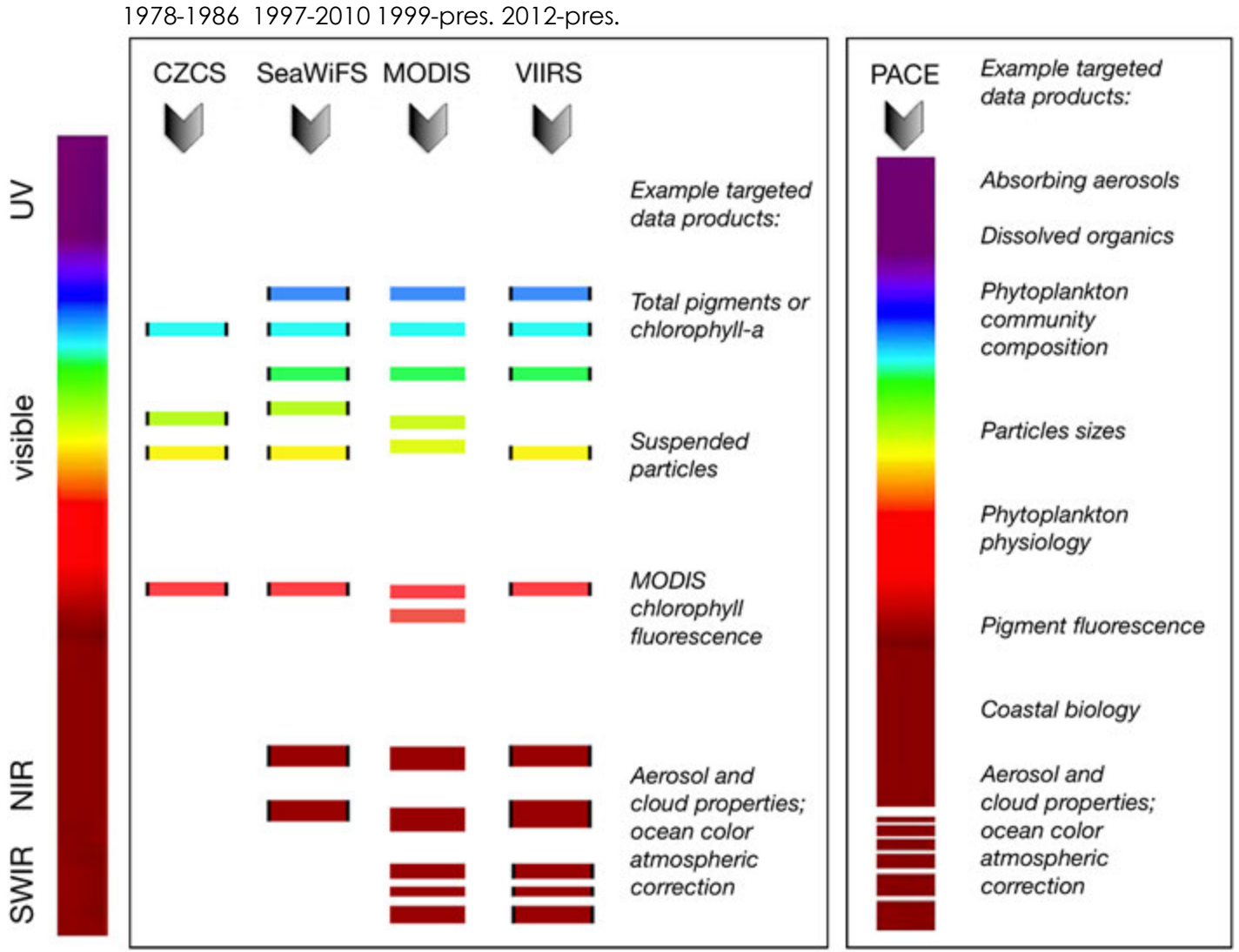


Tilt ± 20°

Spectral Range Goal of 320-865 @ 5 nm

Improve our understanding of how **aerosols influence ocean ecosystems & biogeochemical cycles** and how **ocean biological & photochemical processes affect the atmosphere.**

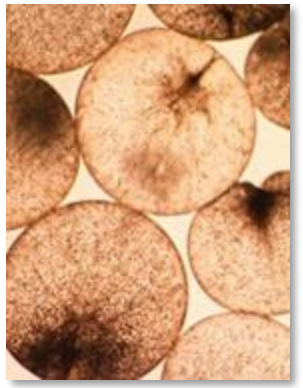
Moving from Multispectral Radiometry to Spectroscopy



Example diatom

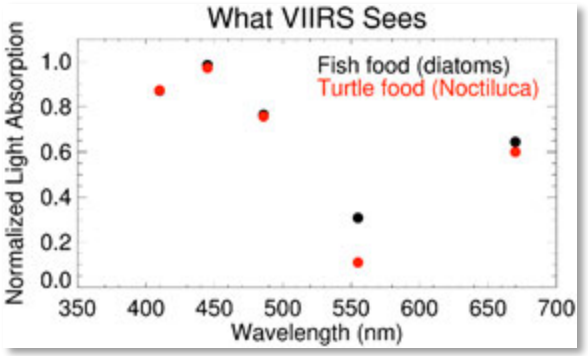
Linda Armbrecht, abc.com.au

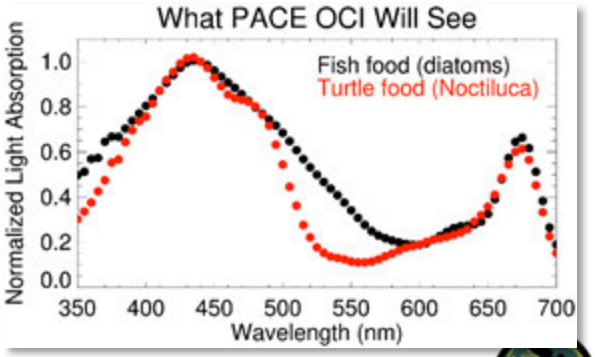
Example Noctiluca



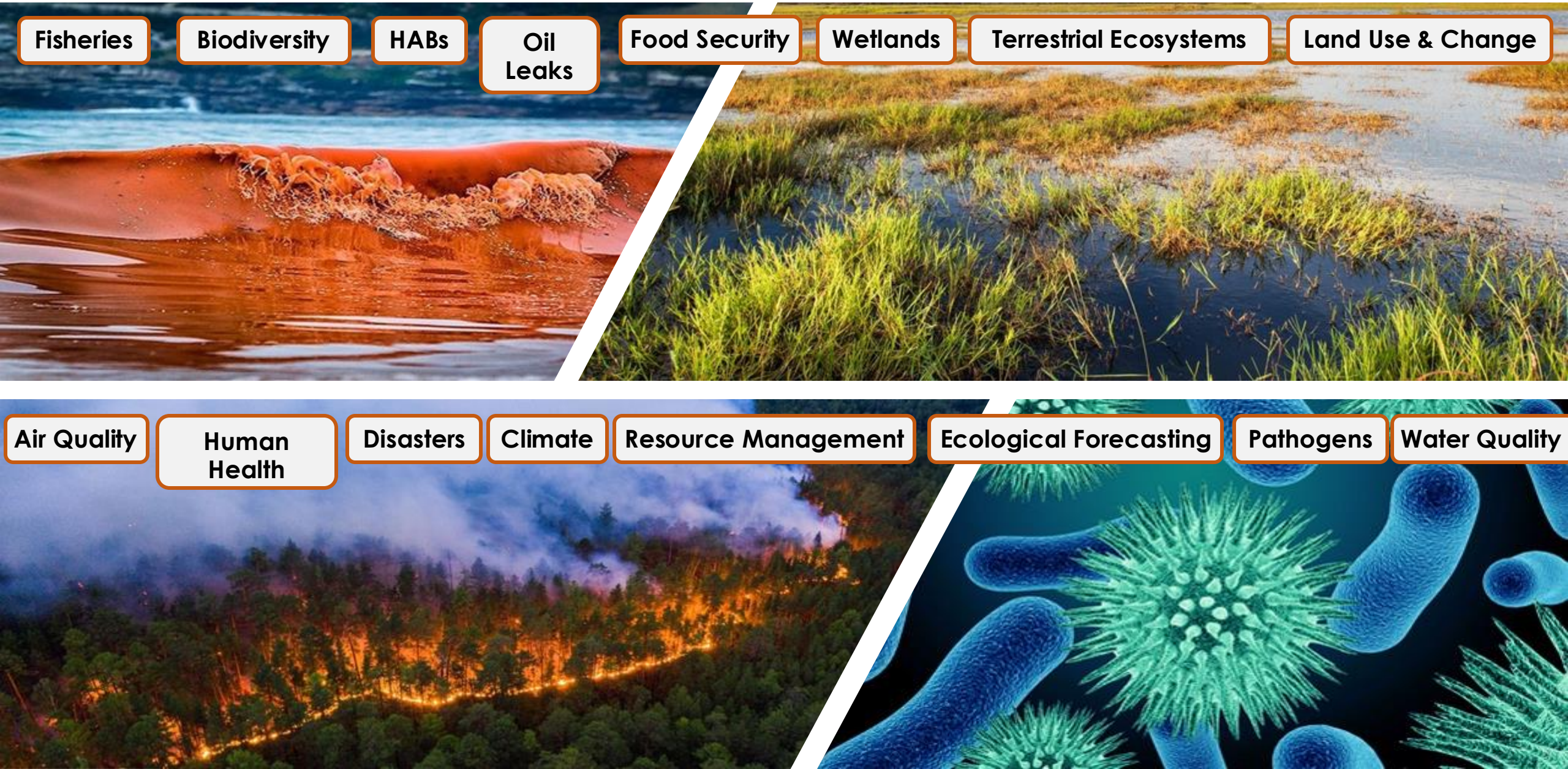
Joaquim Goes, LDEO

Signals from the ocean are small & differentiating between constituents requires additional information relative to what we have today.

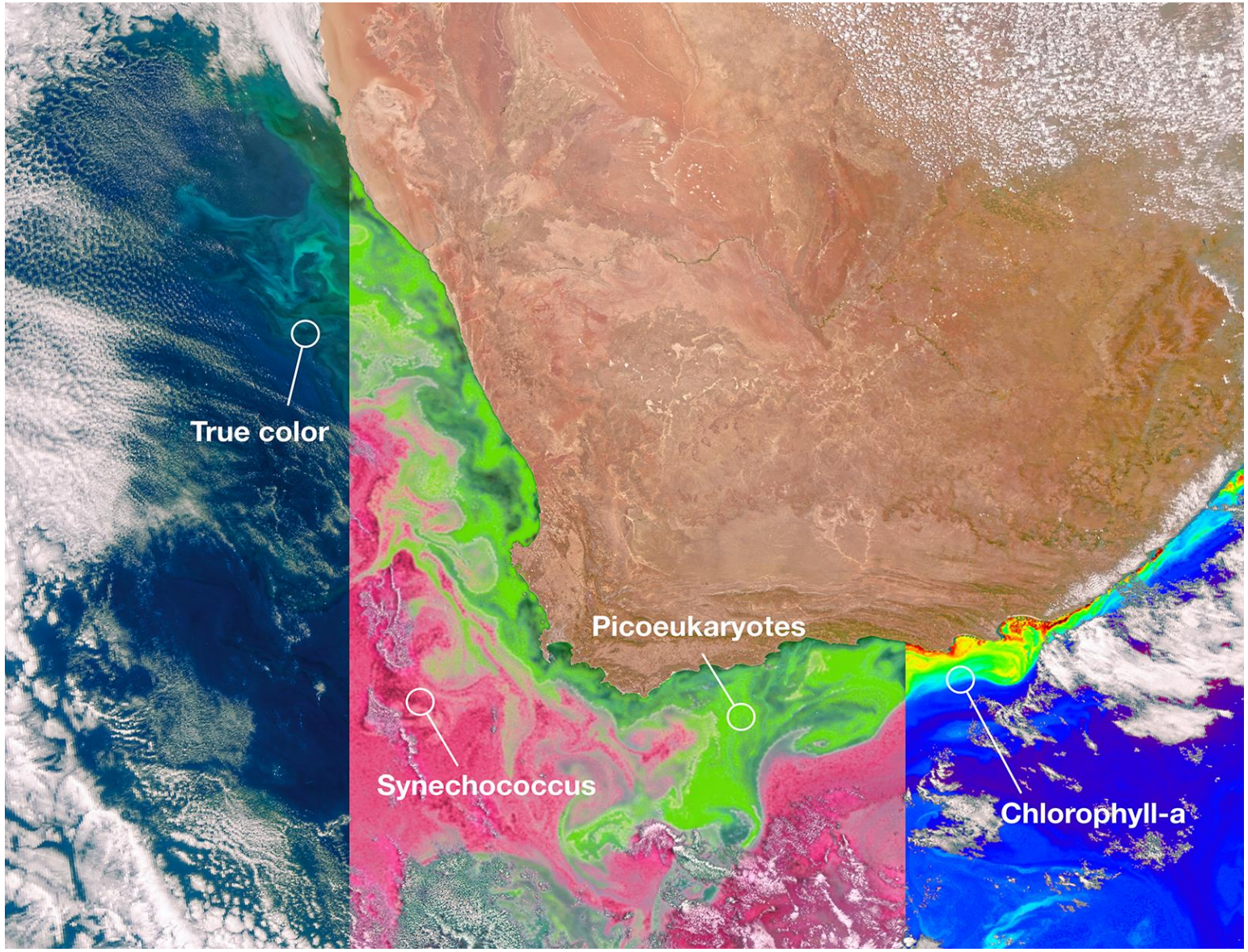




PACE: Interdisciplinary Applied Science Objectives



PACE “First Light” Image – South Africa Feb 28, 2024!!



Credit: NASA PACE – Timeline (oceansciences.org)

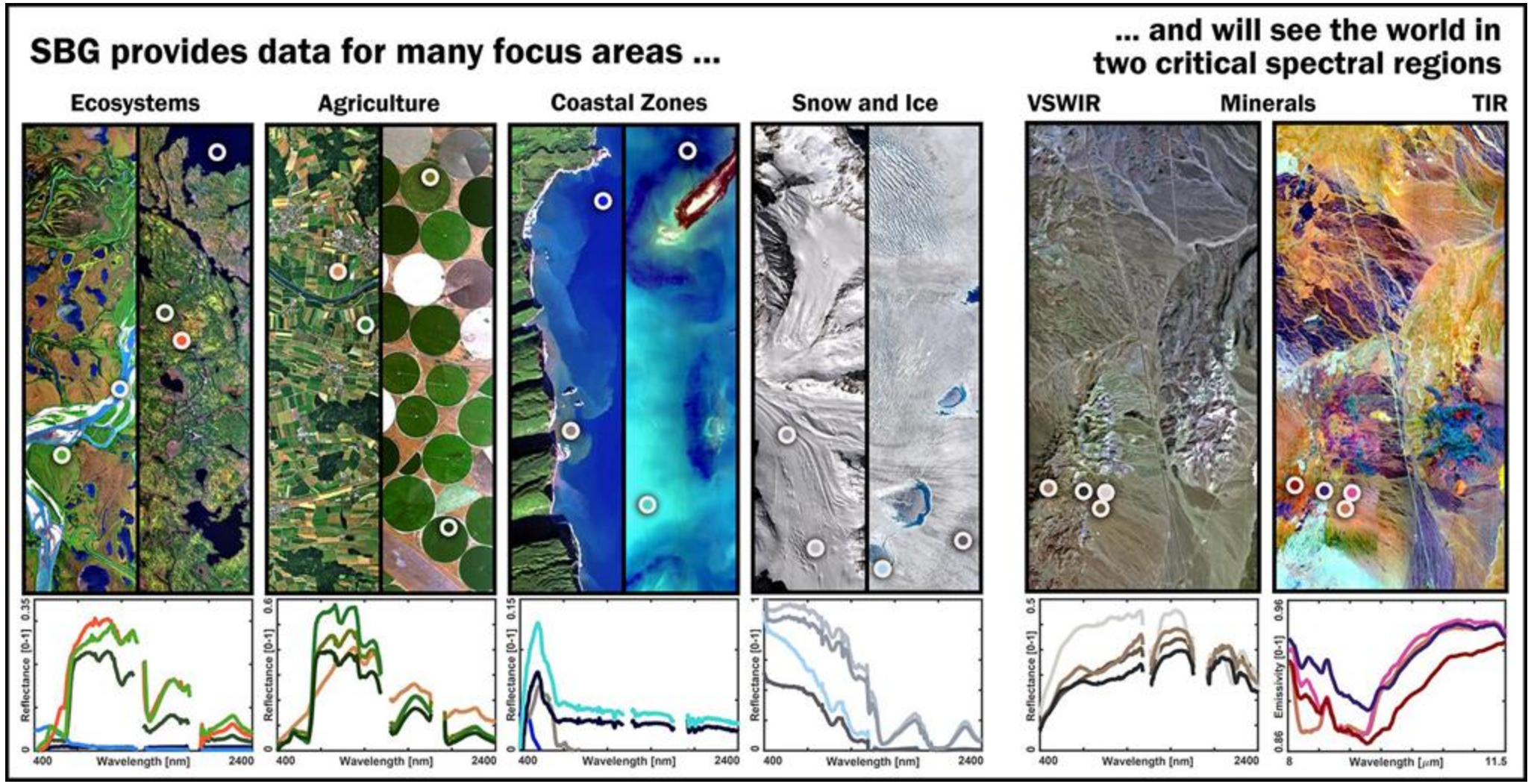
Surface Biology and Geology (SBG) Mission

https://sbg.jpl.nasa.gov/

- In development via guidance from the 2018 Decadal Survey
- Potential Parameters:
  - Visible to Shortwave Infrared Bands:
    - Spectral Range: 350 or 400–2,500 nm
    - Spectral Resolution: 10 nm or better
    - Global with 2- to 16-day revisit times
  - Thermal Bands:
    - Spectral Range: 8,000–12,000 or 3,000–5,000 nm
    - Spectral Resolution: Greater than 5 bands
    - Global with 1- to 70-day revisit times

Mount Kilimanjaro Image Credit: JPL SBG

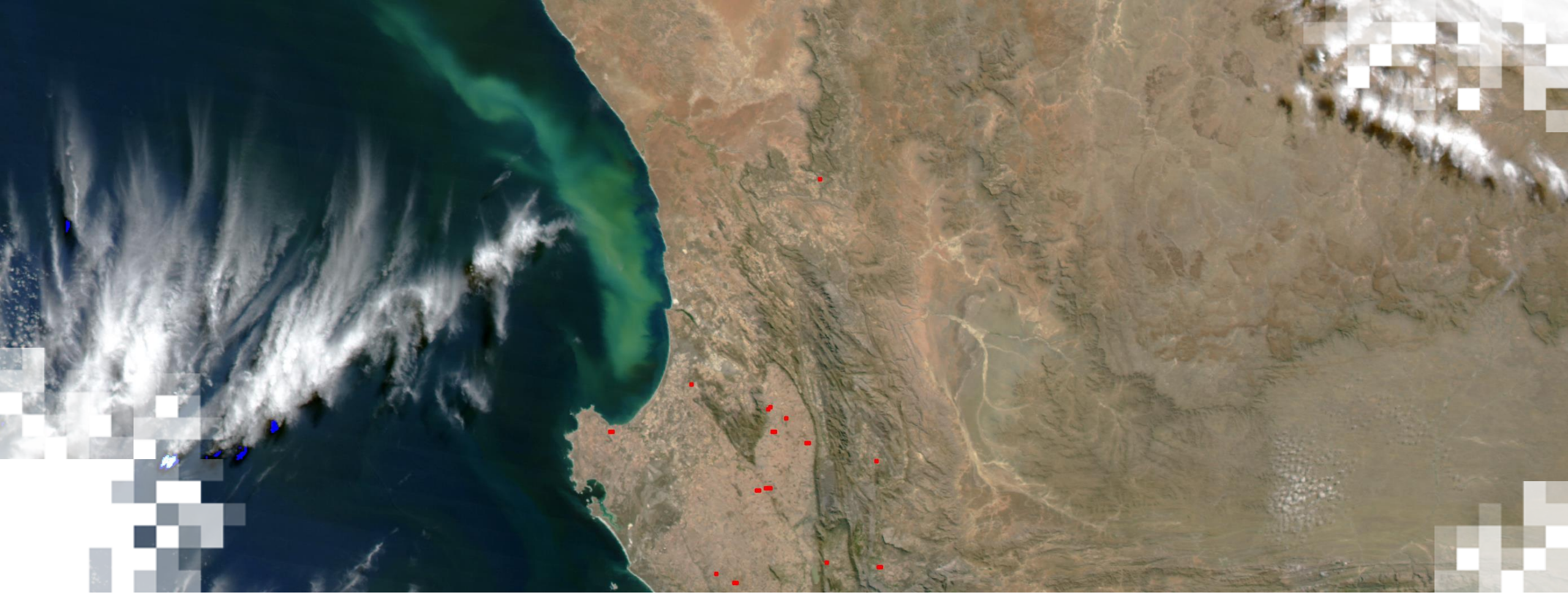
SBG Mission



SBG Potential Applications; Image Credit: JPL SBG

Resources

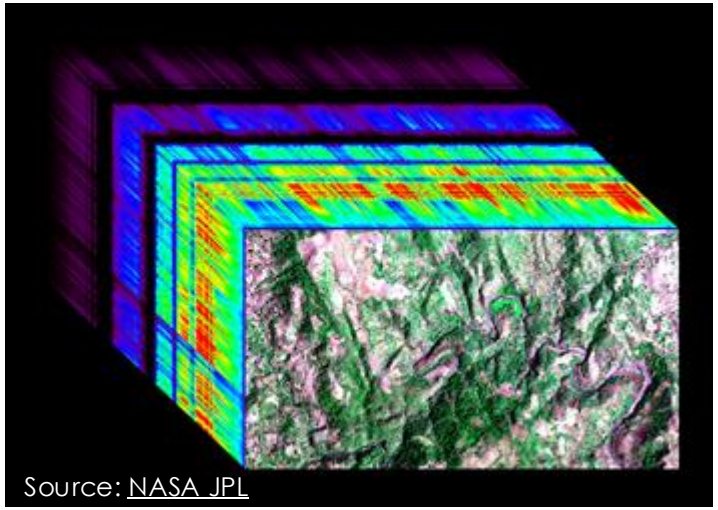
- https://airbornescience.nasa.gov/
- https://aviris.jpl.nasa.gov/
- https://prism.jpl.nasa.gov/
- https://www.bioscape.io/
- https://airbornescience.jpl.nasa.gov/campaign/coral
- https://sbg.jpl.nasa.gov/
- https://pace.gsfc.nasa.gov/



Summary

Summary

- Hyperspectral visible to short wave infrared (VSWIR) data refers to wavelengths within the visible and infrared portions of the electromagnetic spectrum (380- 2500 nm).
- The increased spectral resolution from hyperspectral data can provide users with additional data that multispectral data cannot measure.
- Airborne Visible/Infrared Imaging Spectrometer (AVIRIS), Airborne Visible InfraRed Imaging Spectrometer – Next Generation (AVIRIS-NG), and Portable Remote Imaging SpectroMeter (PRISM) airborne campaigns provide us with hyperspectral VSWIR data.
- Recent and future hyperspectral missions include Plankton, Aerosol, Cloud, and Ocean Ecosystem (PACE), Airborne Visible InfraRed Imaging Spectrometer 3 (AVIRIS-3), and Surface Biology and Geology (SBG).



Source: NASA JPL


APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!