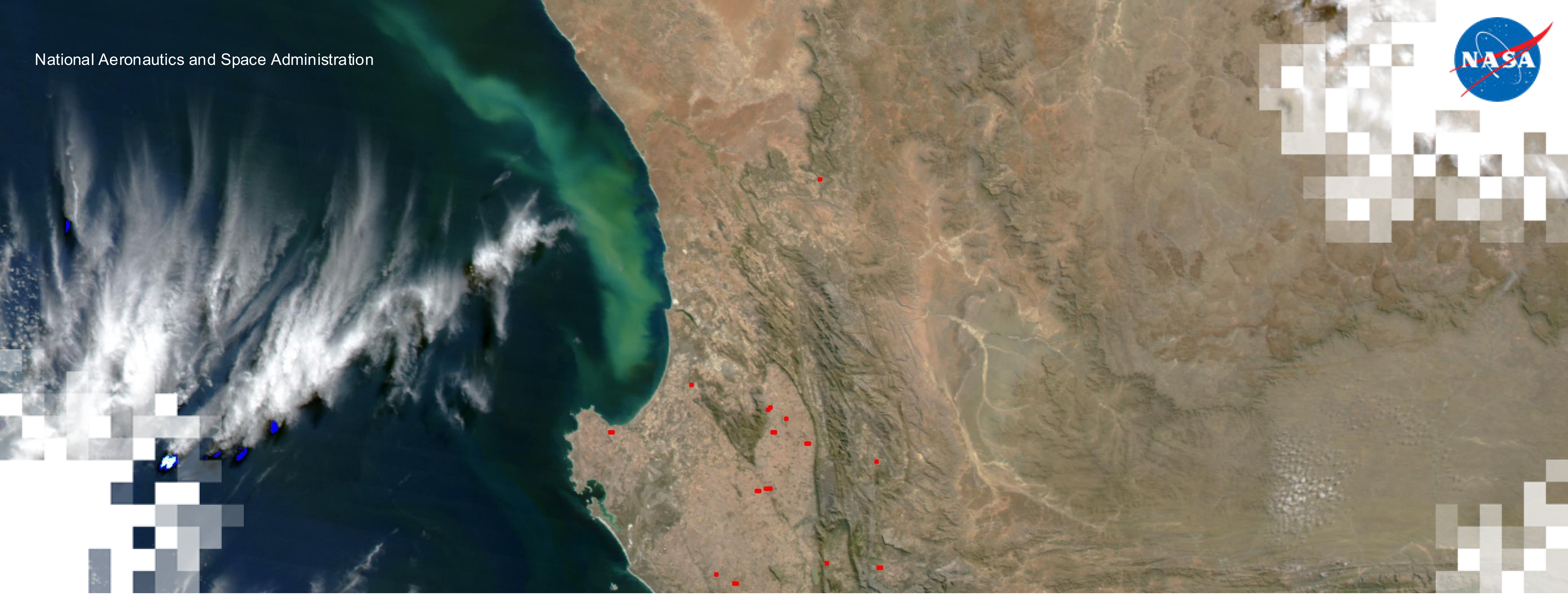
National Aeronautics and Space Administration



Hands-On Field Spectroscopy Training and Data Skills Workshop

Basic Considerations with Field Spectroscopy

Cape Town, South Africa

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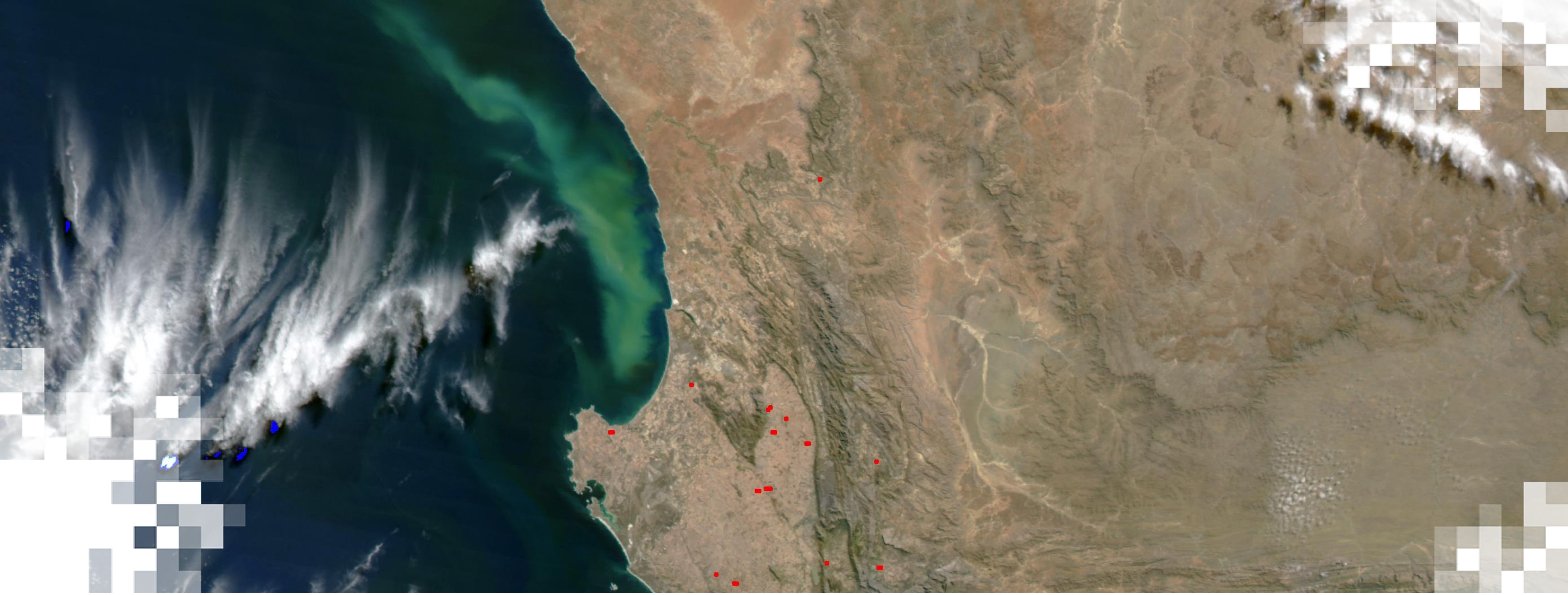
and Justin Fain (BAERI/NASA Ames)

October 7-11, 2024

Training Learning Objectives: Presentation and Hands-on Activities

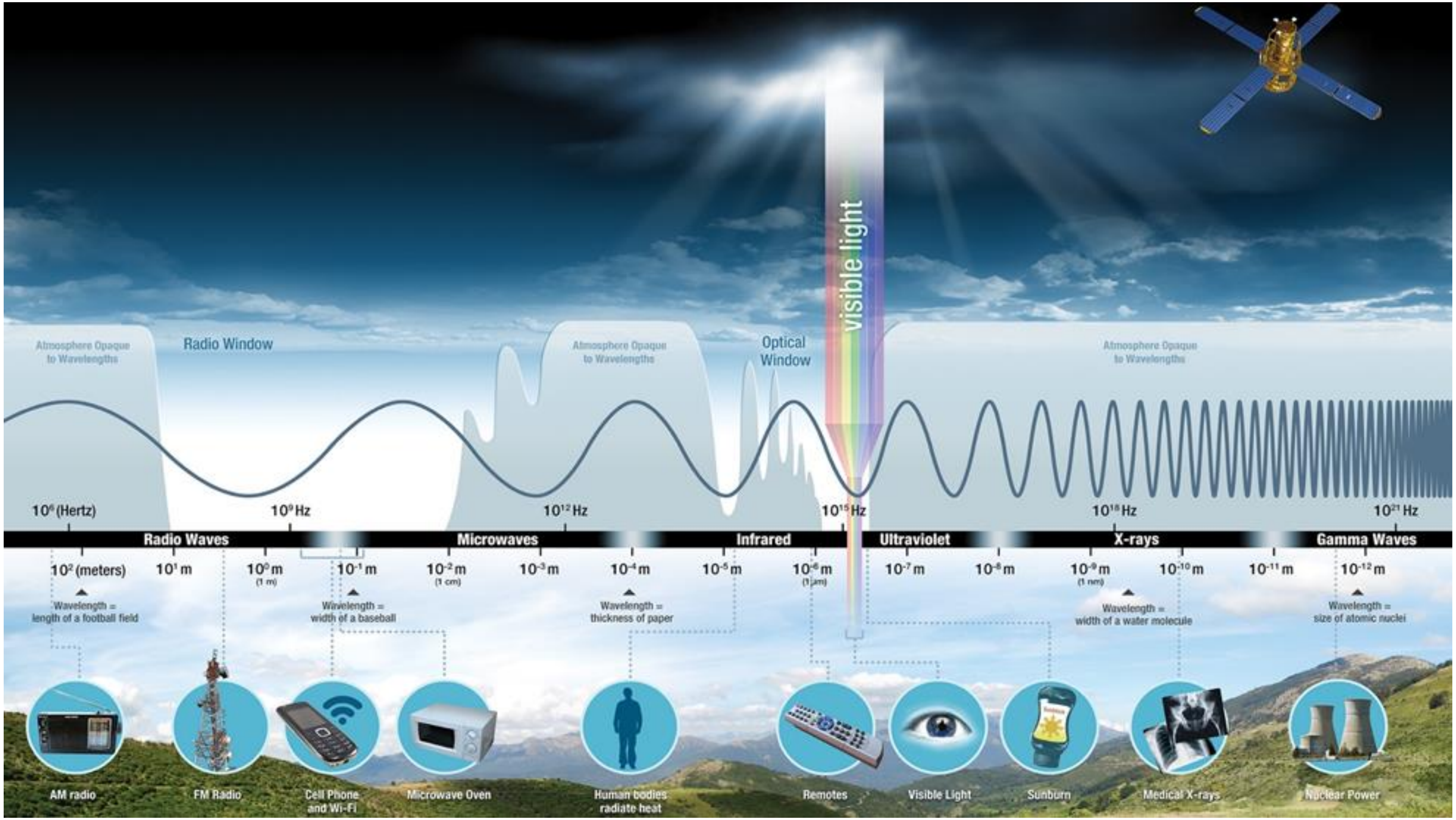
By the end of this training, participants will be able to:

- Identify typical spectral signatures of water bodies and their characteristic features
- Identify factors that may affect data collection in the field
- List considerations to take into account when conducting field spectroscopy
- Compare common radiometer models used in field spectroscopy
- Experiment with a hand-held spectroradiometer and become familiarized with its features
- Take part in a hands-on field activity on spectral data collection from a water target using the HR-512i spectroradiometer
- Compare spectral datasets from diverse South African lakes and reservoirs, the features of their characteristic spectral signatures, and contrast differences or similarities



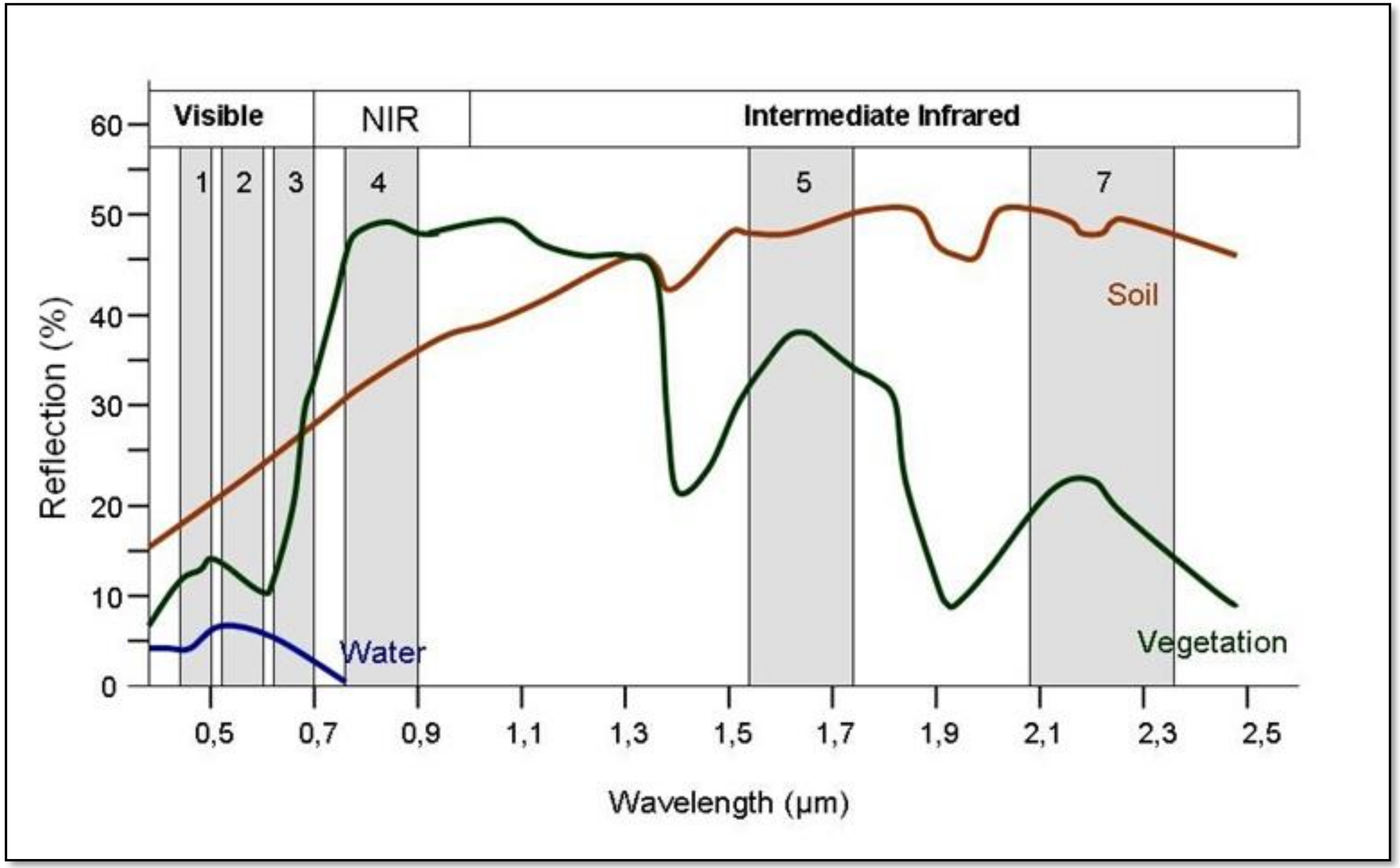
Short Review on Properties of the Water Column and Interaction of Light

Electromagnetic Spectrum



Spectral Signatures

- Every surface on Earth reflects and absorbs energy in different ways.
- Different surfaces have different spectral signatures.
- In this example, you can see the differences between Water, Vegetation, and Soil signatures.



Interaction with Earth's Surface: Vegetation

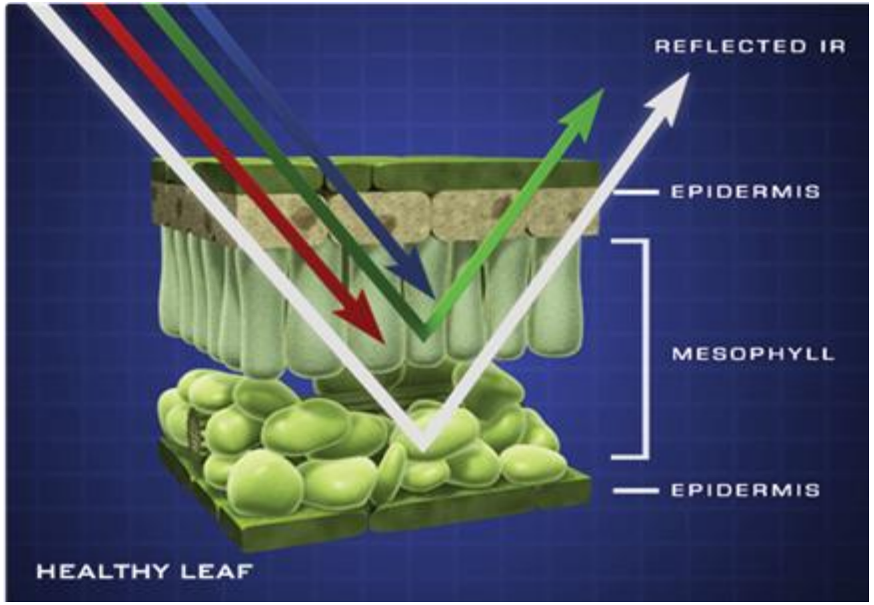
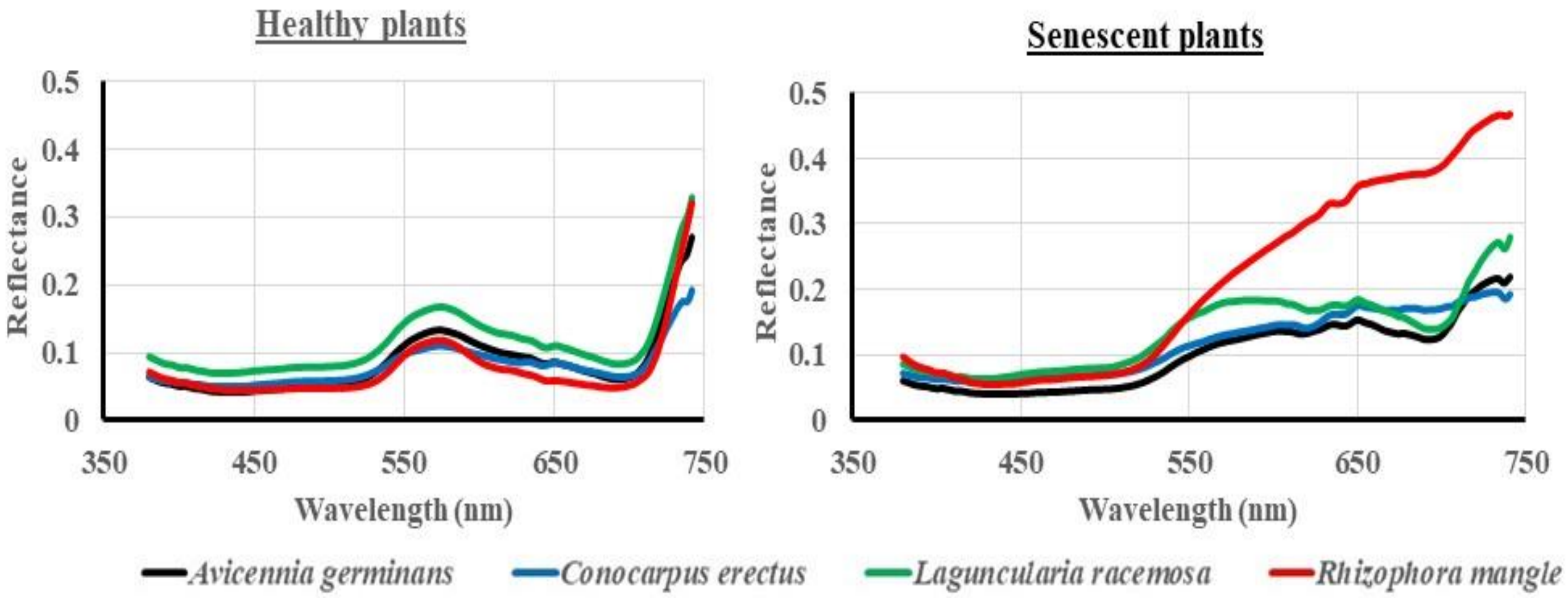


Image Credits: NASA/Jeff Carns & Ginger Butcher

- Example: Healthy, green vegetation **absorbs Blue and Red** wavelengths (used by chlorophyll for photosynthesis) and **reflects Green and Infrared**.
- Since we cannot see infrared radiation, we see healthy vegetation as green.
- The amount of reflected energy is dependent on the health of the vegetation, water content, and phenological stage.

Mangrove Forests

- Species are spectrally similar.
- Spectral data can be used for discriminating between healthy and non-healthy (or senescent) canopies.



Torres-Pérez (Unpublished)

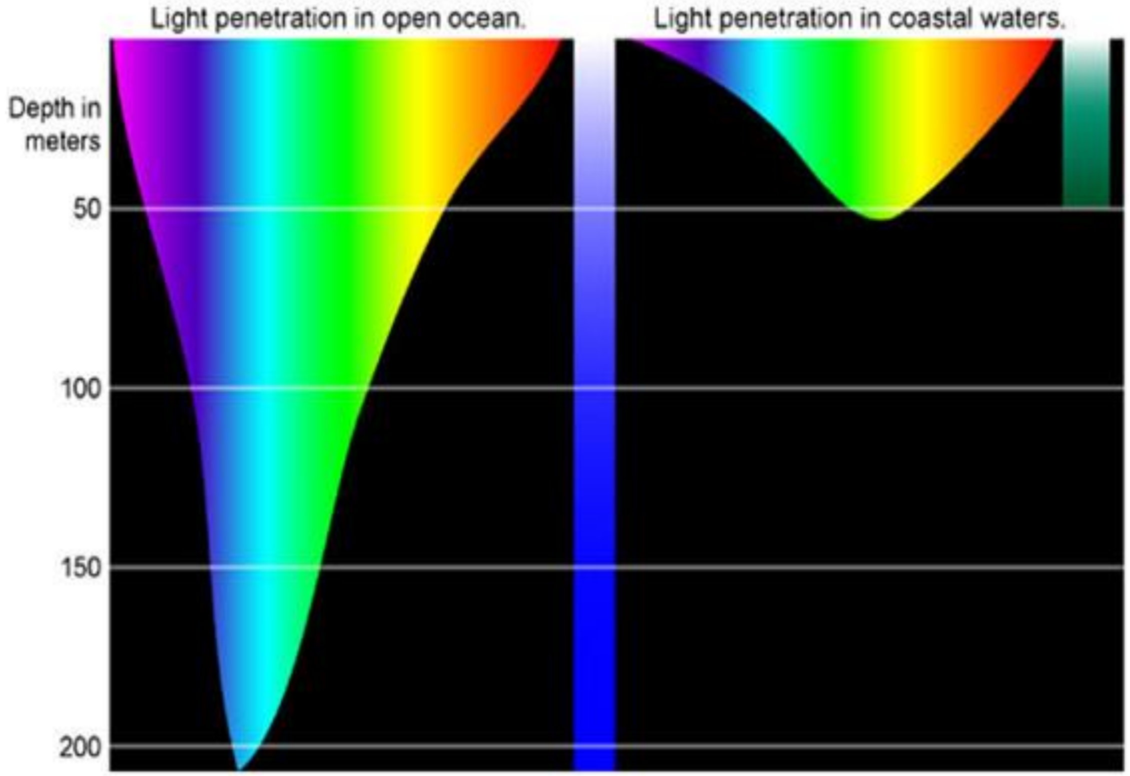
Spectral Signature: Water

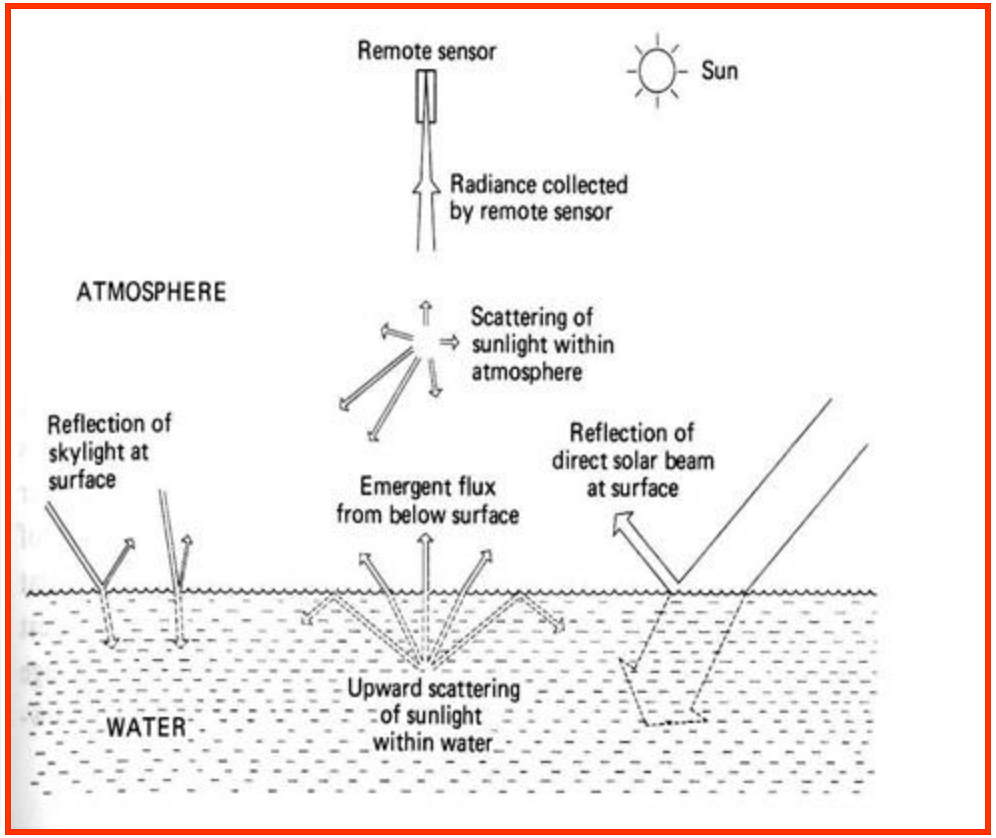
Image Credit: NASA Earth Observatory, using Landsat data courtesy of USGS.

- Longer visible wavelengths (green and red) and near-infrared radiation are absorbed more by water than shorter visible wavelengths (blue) – so water usually looks blue or blue-green.
- Satellites provide the capability to map optically active components of upper water column in inland and near-shore waters.

Water Quality Affects Water Optical Properties

Natural water contains material that is optically active. Monitoring light **reflectance** from the water surface with remote sensing can indicate the quality of the water.





How Light Interacts with Water

Remote Sensing Reflectance (Rrs) or Ocean Color

$$\mathrm{Rrs}\left(\lambda,0^{+}\right) \cong C\,\frac{b_b(\lambda)}{a(\lambda)+b_b(\lambda)} = \frac{L_w(\lambda)}{E_d\left(\lambda,0^{+}\right)}$$

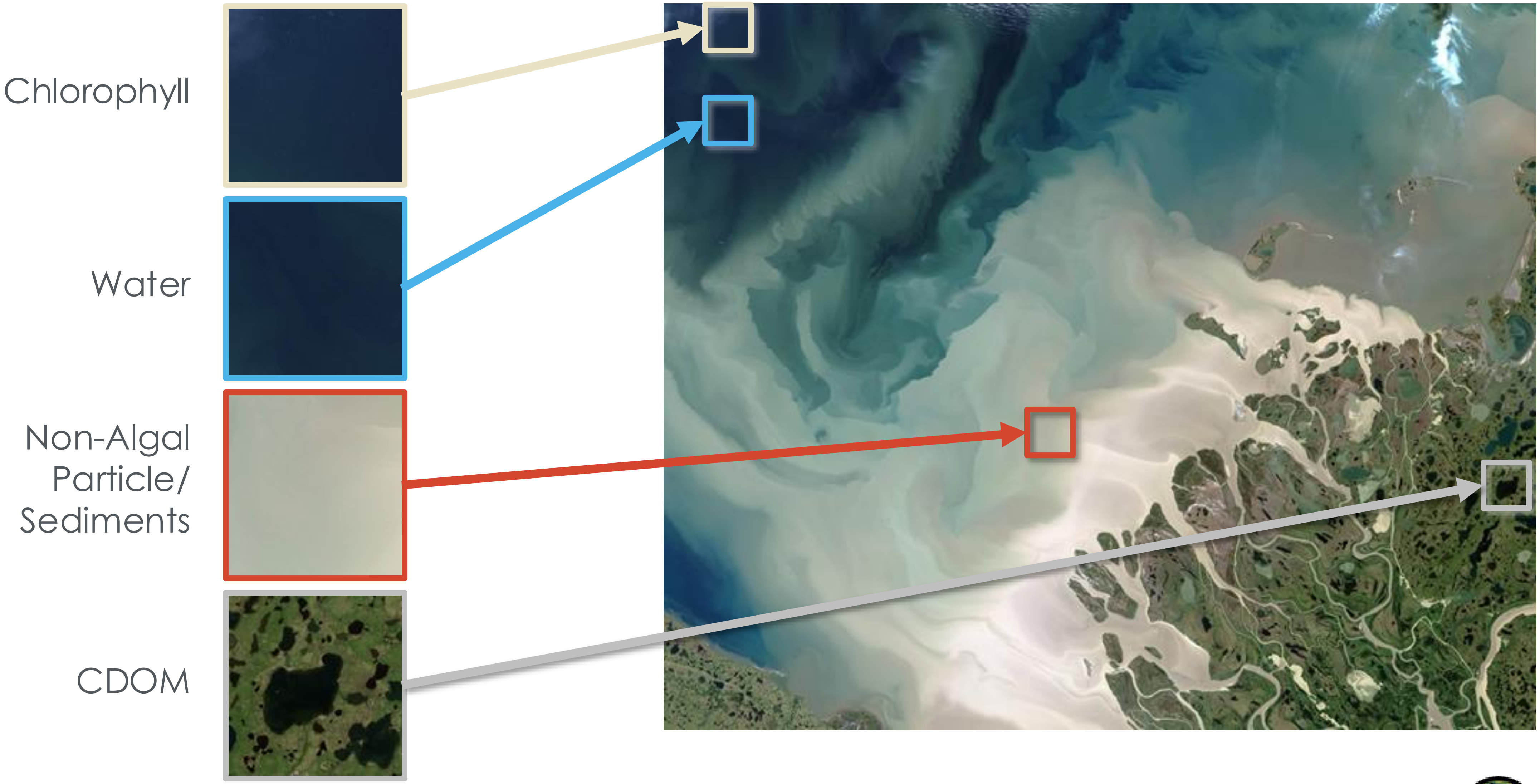
Inherent Optical Properties:

- *a* = Absorption by…
  - Phytoplankton (ph)
  - Non-Algal Particles (nap)
  - Colored Dissolved Organic Matter (CDOM)
  - Water (w)
- *b* = Scattering in forward (f) and backward (b) directions

Apparent Optical Properties:

- L_w = Water Leaving Radiance
- L_u = Upwelling Radiance
- E_d = Downwelling Irradiance
- R_{rs} = Remote Sensing (rs) Reflectance

Inherent Optical Properties (IOPs) and the 'Color' of Water



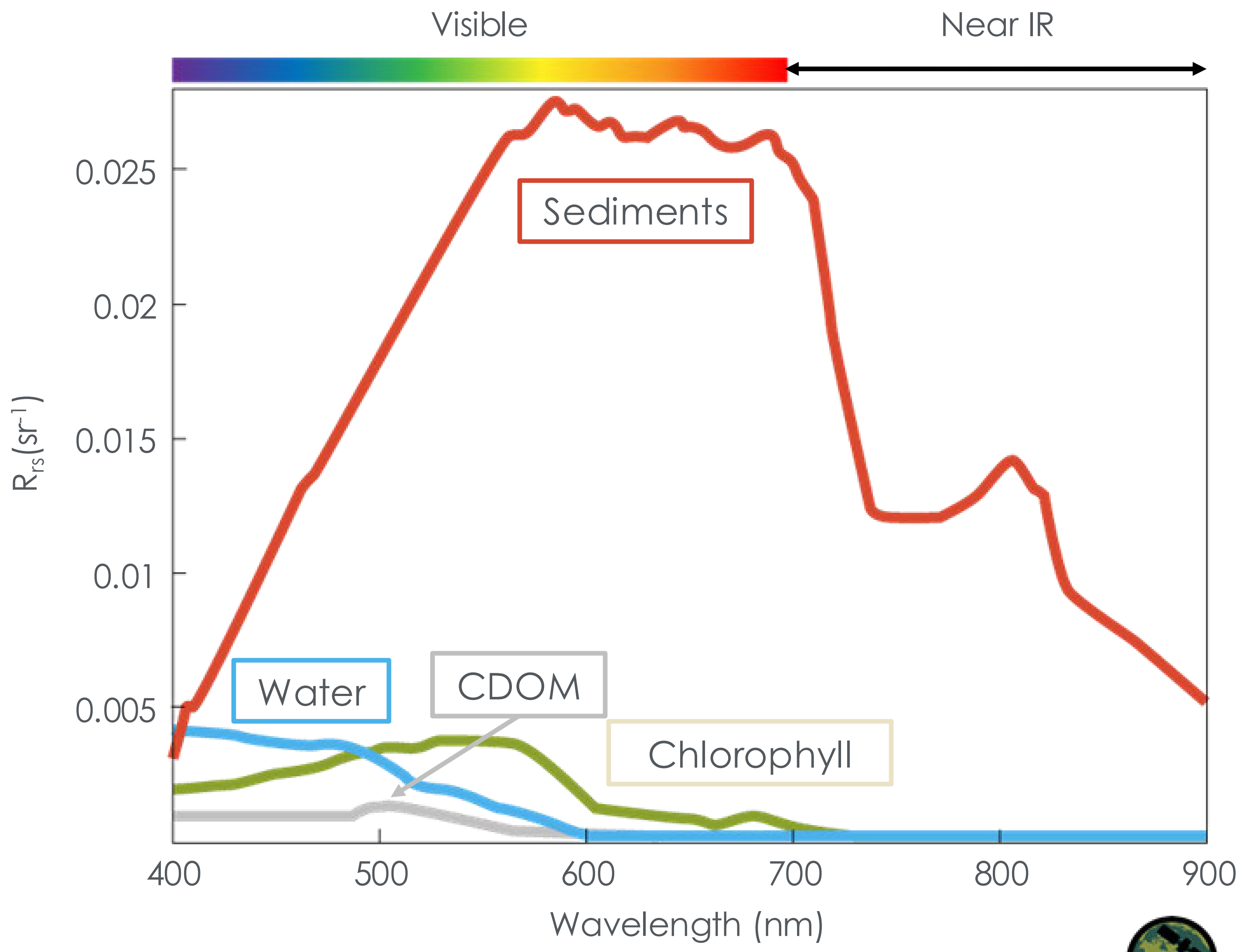
Inherent Optical Properties (IOPs) and the 'Color' of Water

Chlorophyll

Water

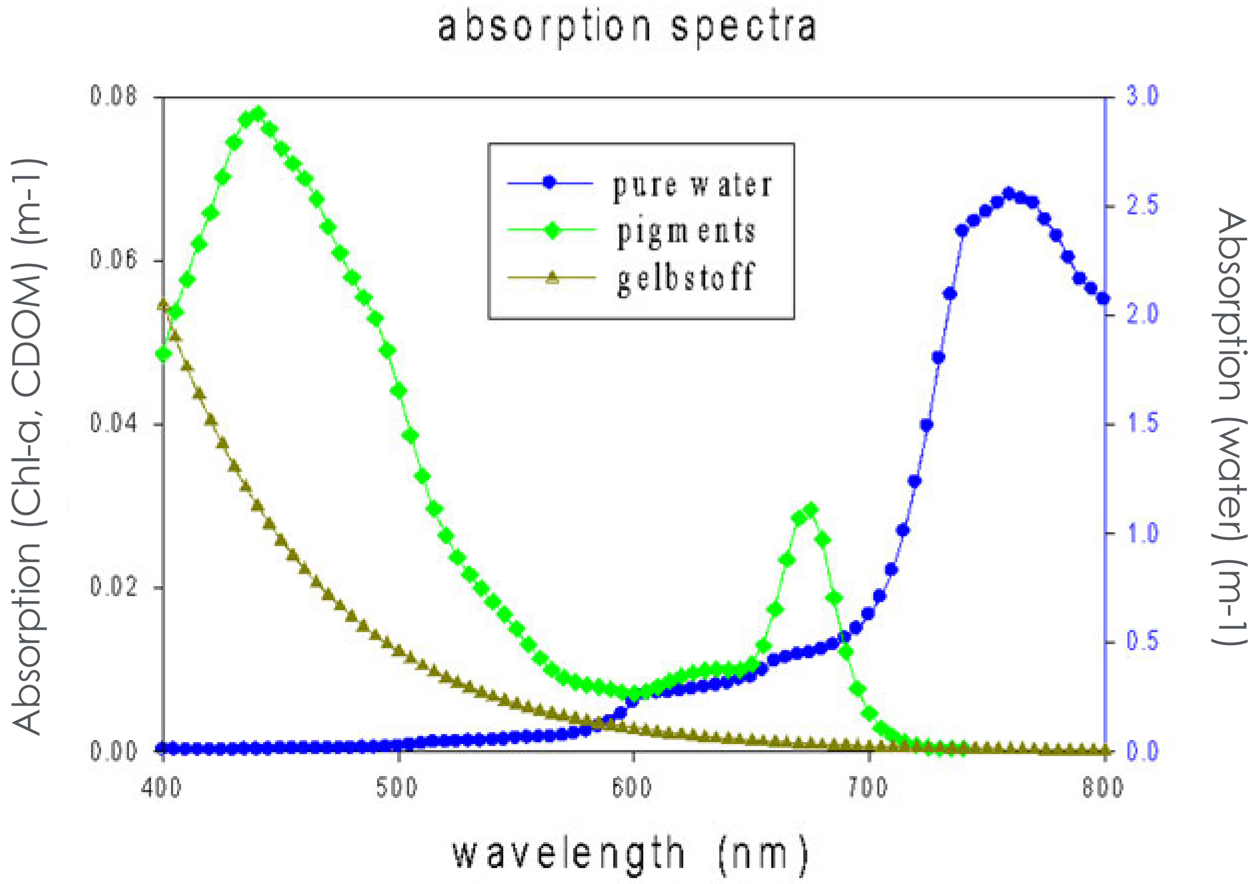
Non-Algal Particle/ Sediments

CDOM



Absorption of Water, CDOM, and Phytoplankton

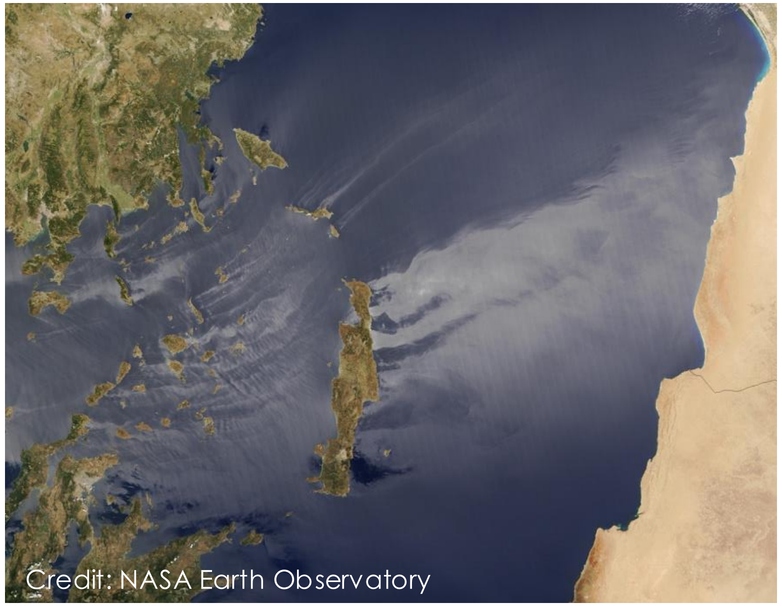
- Water absorbs strongly in the red, NIR, and SWIR.
- CDOM absorbs strongly in the blue region.
- Phytoplankton (Chl a) absorbs strongly in the blue and red regions of the spectrum.



Credit: Univ. PR Bio-Optical Oceanography Lab

Now… water-leaving radiance (Lw) is affected by IOPs but also by light from the sky.

- One thing to carefully consider is water **sun glint**!
- Caused by specular reflection of the sun from capillary waves formed when the wind blows over a water body.
- Occurs when the sun light reflects at the same angle that the sensor views it.



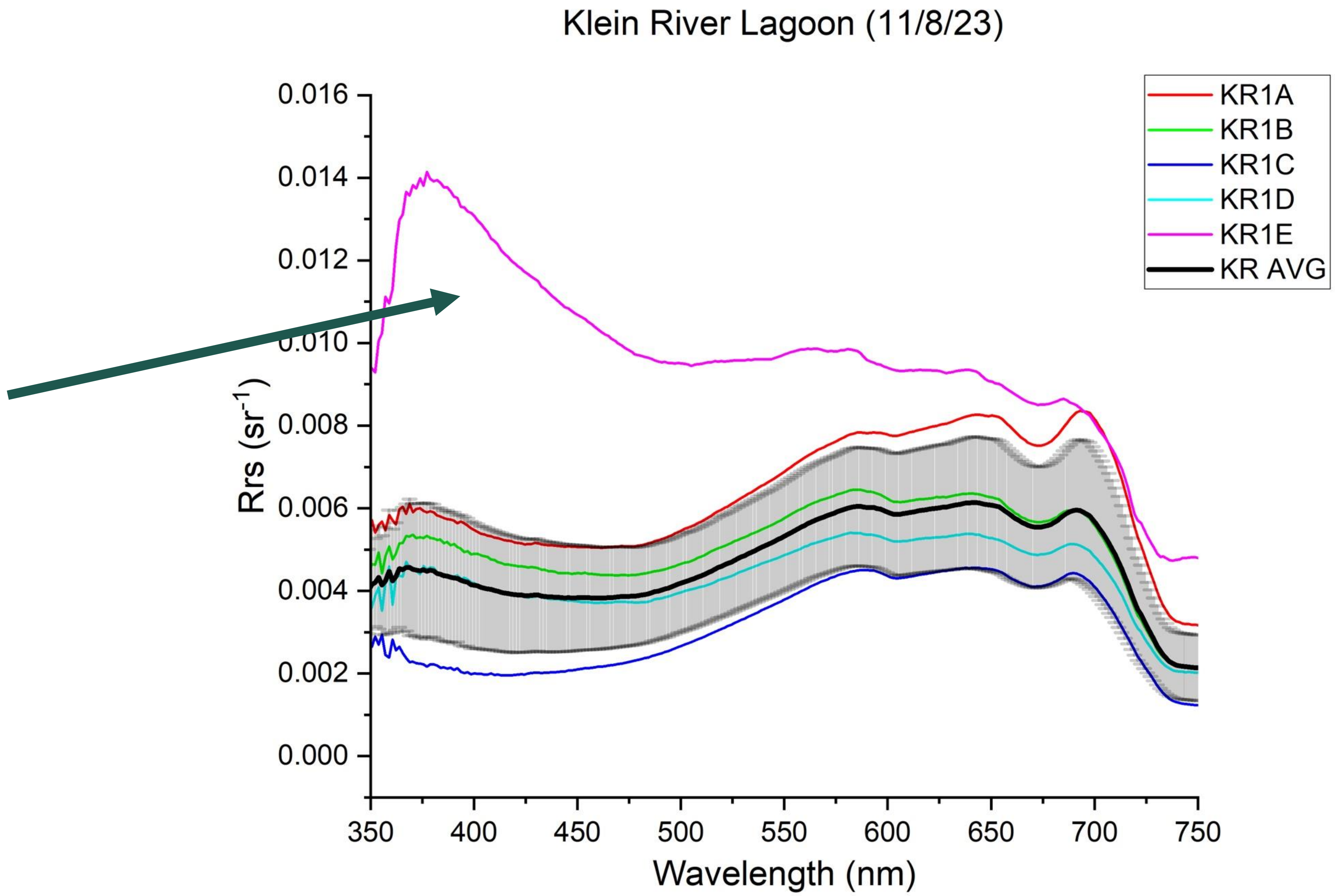
Credit: NASA Earth Observatory

From: Shaw & Vollmer (2017) Blue sun glints on water viewed through a polarizer. Appl. Optics. 56(19): G36-41. https://doi.org/10.1364/AO.56.000G36

But, we can work around this in field spectroscopy…

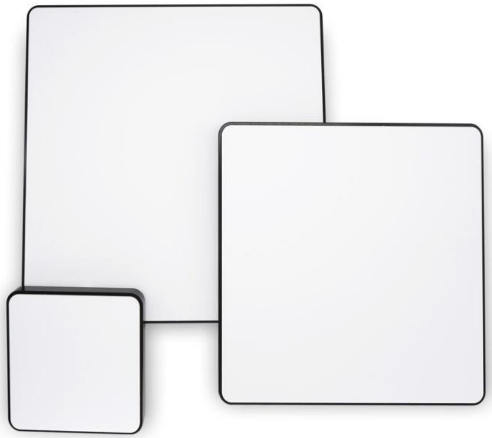
- Know where to point the instrument (direction, sun angle).
- For instance, to reduce sun glint, point the instrument at **~40-45º** angles towards the target (i.e., water surface) and the sky.
- Keep the viewing azimuth (horizontal plane) between **90-180º**.
- Oh, don't forget to take photos of the target and sky for later reference.
- Take notes on sun angle (there are several free apps that can help), sky conditions (% cloud cover and types of clouds), and of course, water color and conditions (visible presence of cyanobacterial (or other type) blooms.
- And, take photos of team collecting data!

When working in the water, the movement of the boat can affect too!



The "Plaque Method"

1) Measure Lw @ 40-45°
2) Measure Lsky @ 40-45°
3) Measure Ed using a calibrated and homogeneous surface
   - ❖ Should be at nadir but it can be @ 20-60°
   - ❖ Usually, a Spectralon® panel 50 or 99% white

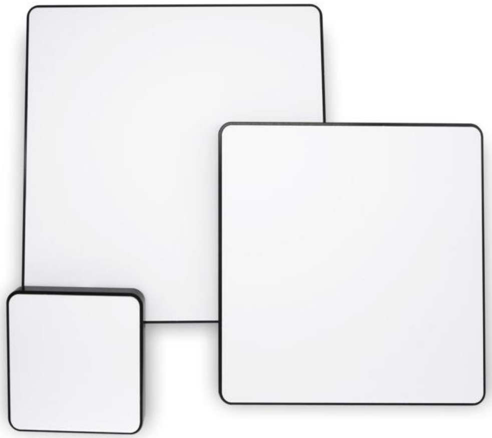


Credit: Labsphere

Credit: NASA OCEANOS

The "Plaque Method:" Some Additional Considerations

- Make sure there are no shadows over the panel when collecting the data.
- Panel has to be as horizontal as possible.
- If possible, use a tripod to keep it at a certain height
- **Keep the panel clean!**

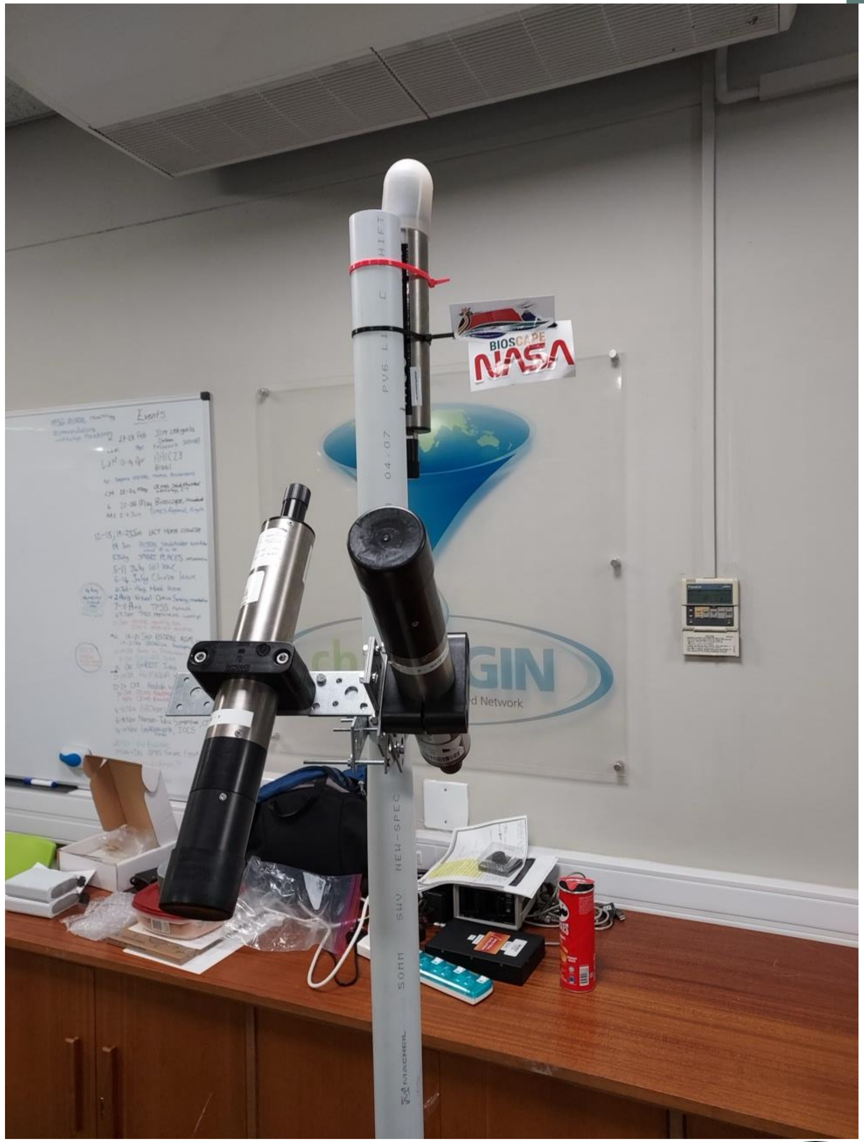


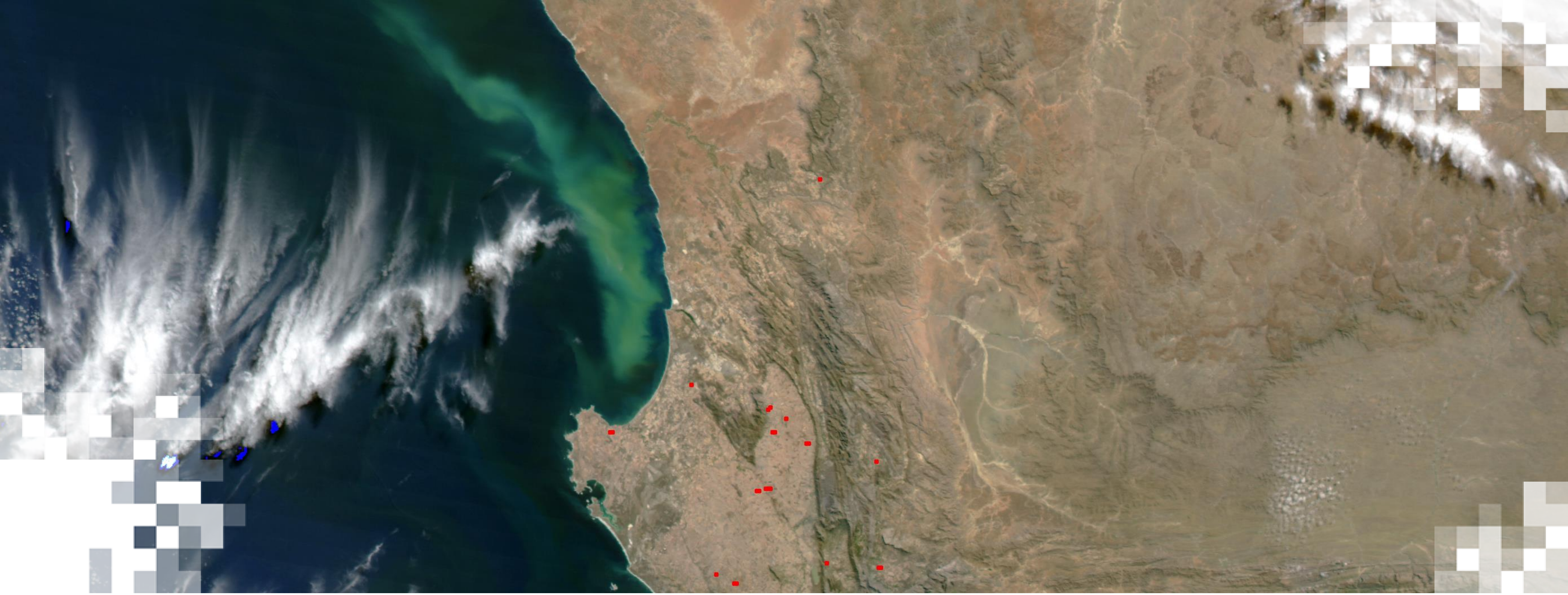
Credit: Labsphere

Credit: NASA OCEANOS

Sometimes (or frequently!), we have to be creative in the field.

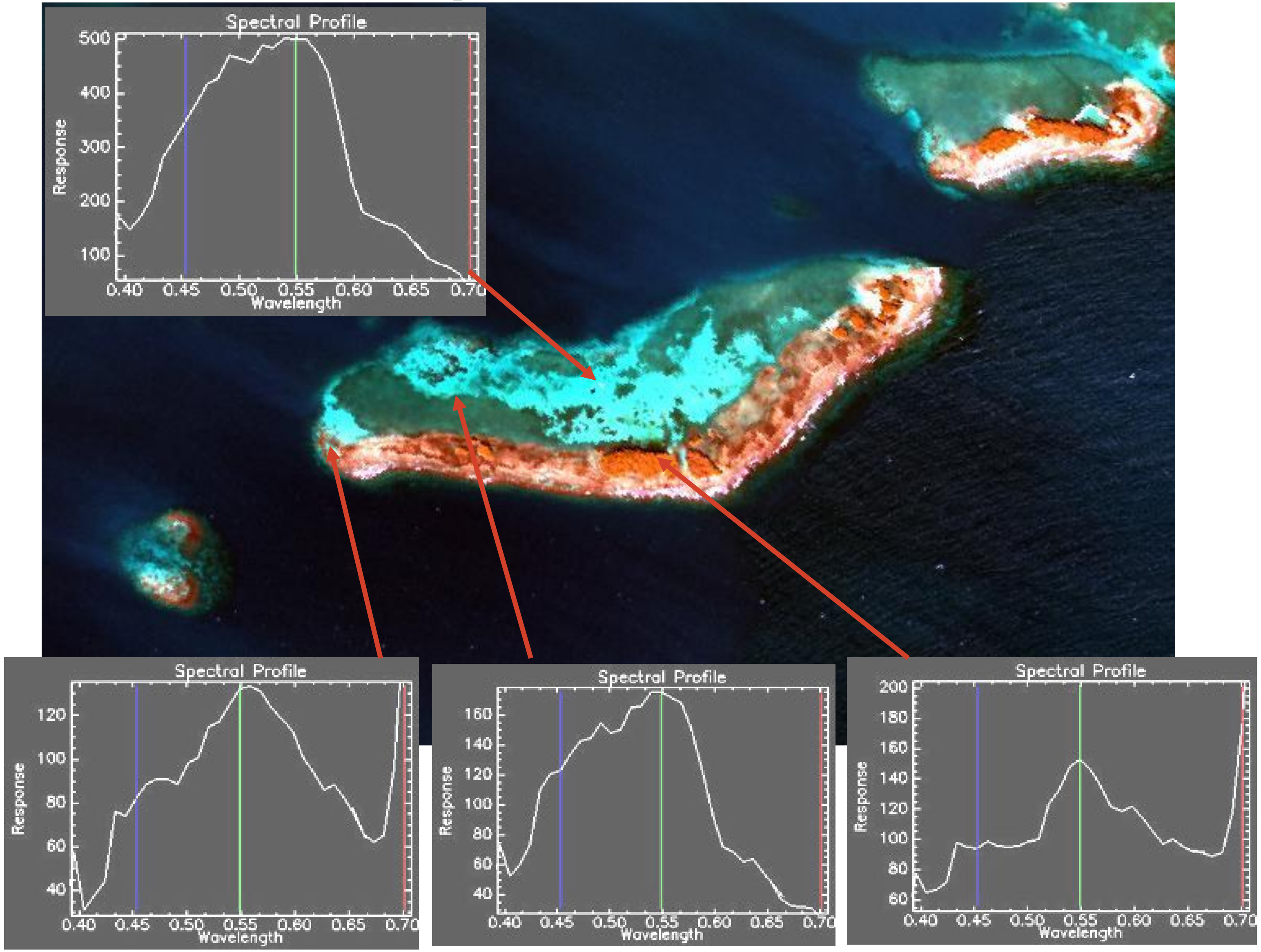
Photos: JL Torres-Pérez





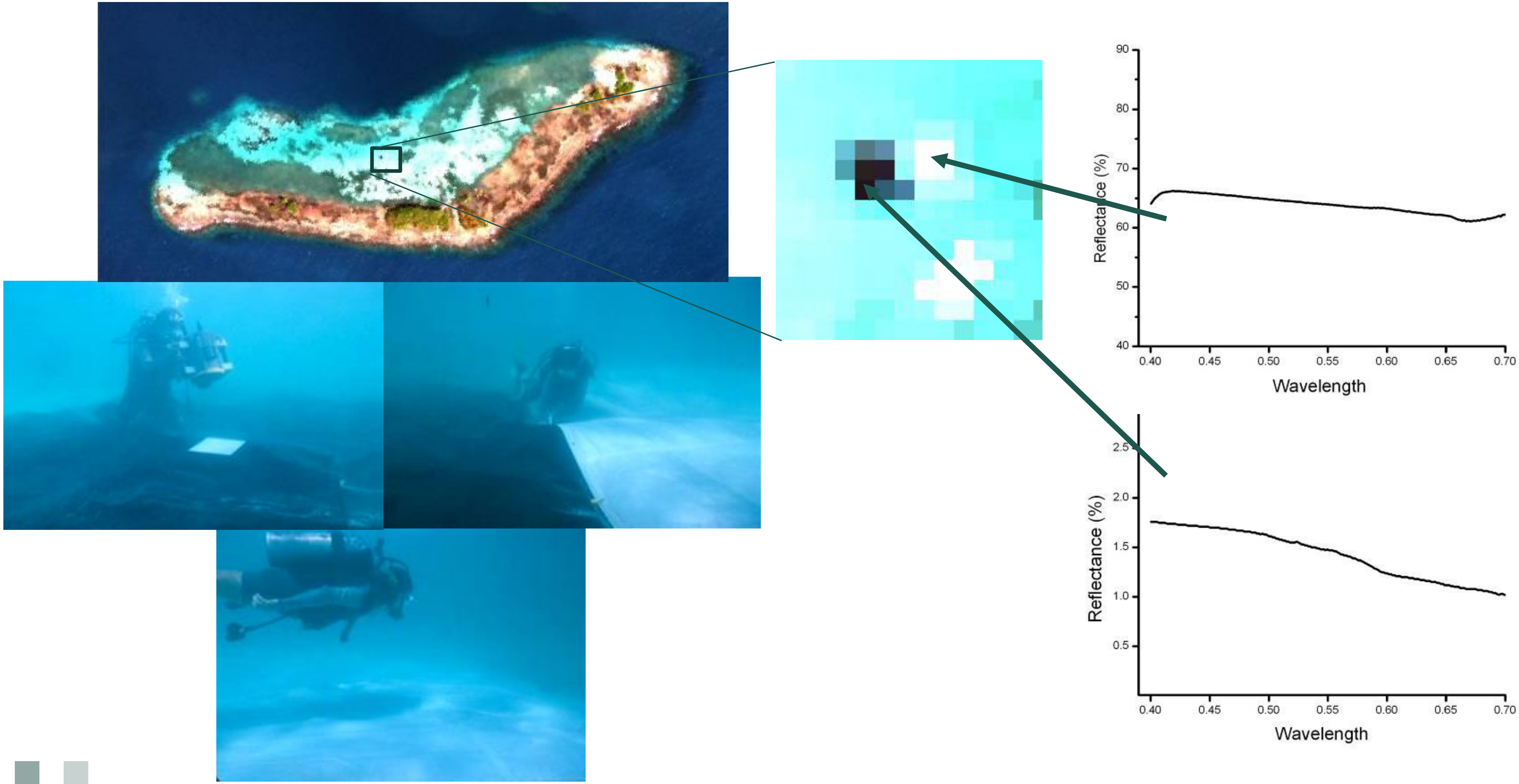
Benthic Feature ID with Field Spectroscopy

Atmospherically Corrected AVIRIS (Hyperspectral) Image (Before Water Column Correction)



Credit: Univ. PR Bio-Optical Oceanography Lab

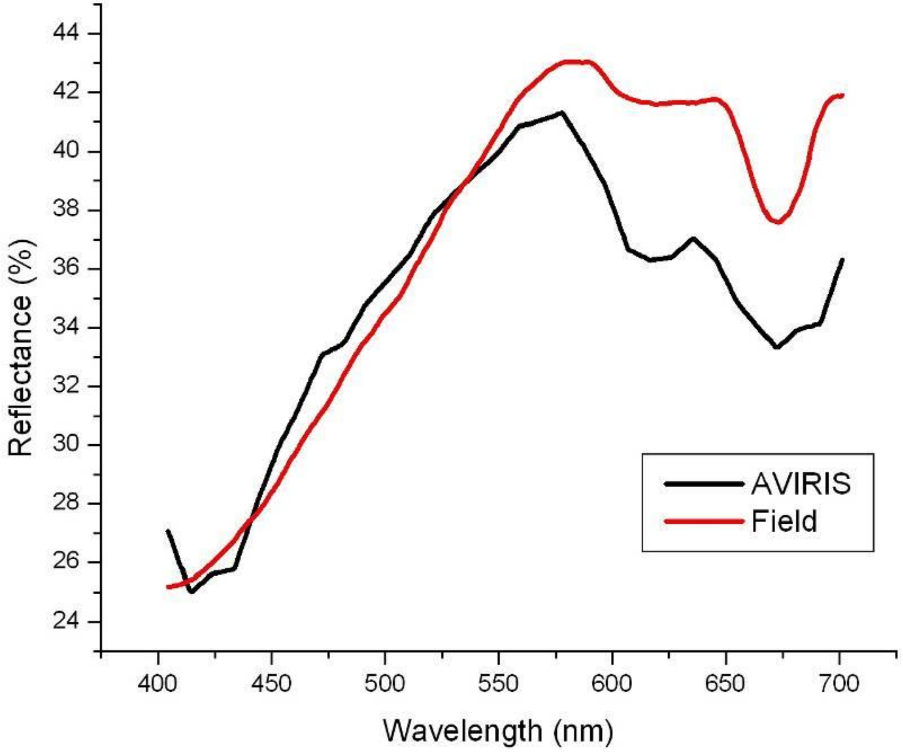
Underwater Flat-Field Calibration Targets for Water Column Correction



Credit: Univ. PR Bio-Optical Oceanography Lab

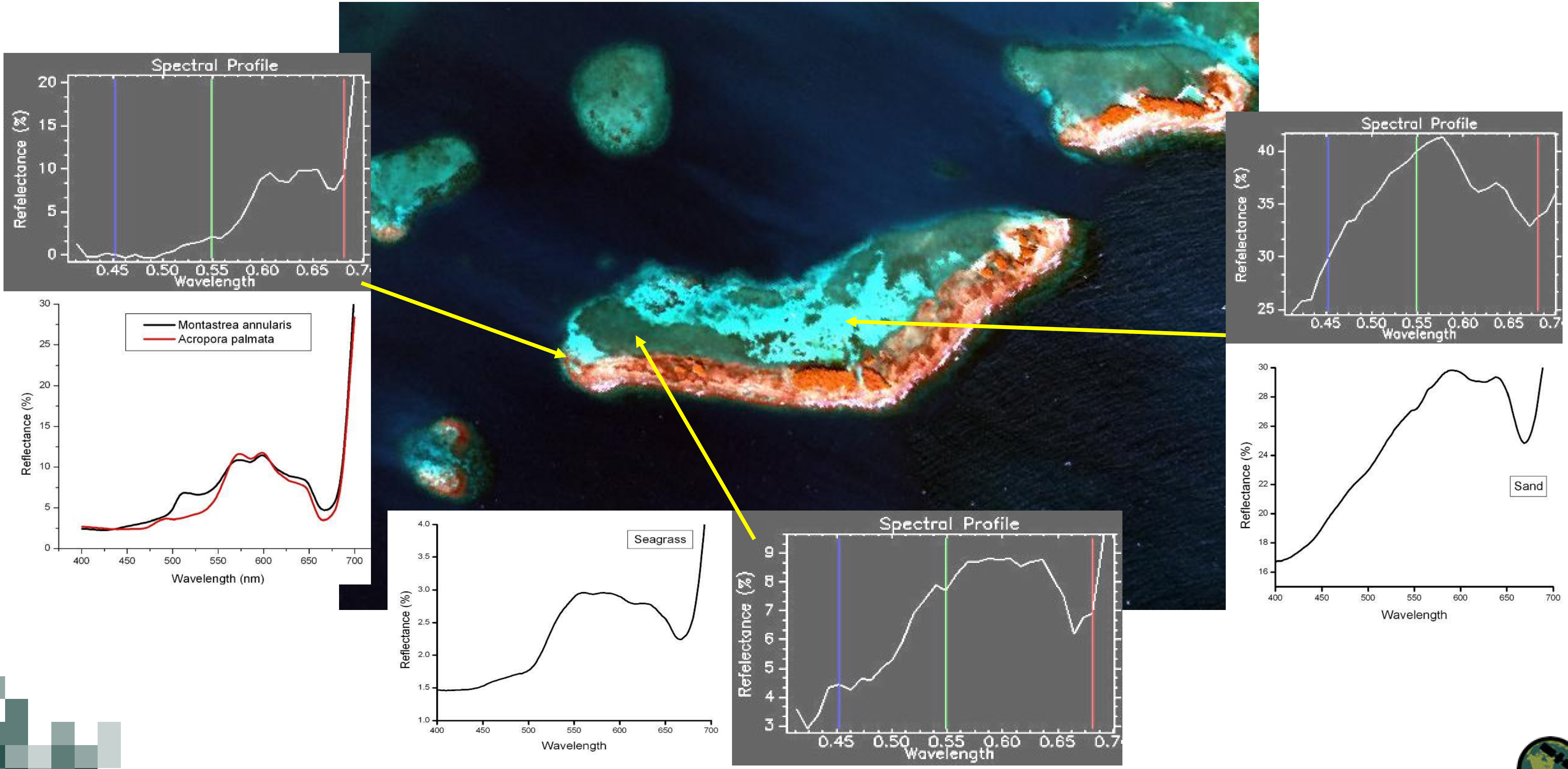
Water Column Correction Validation

- AVIRIS agrees with field values within 10% from 400-600 nm and up to 18% between 600-700 nm.
- Spectral features are preserved, mostly corresponding to pigment absorption by microbial layers.



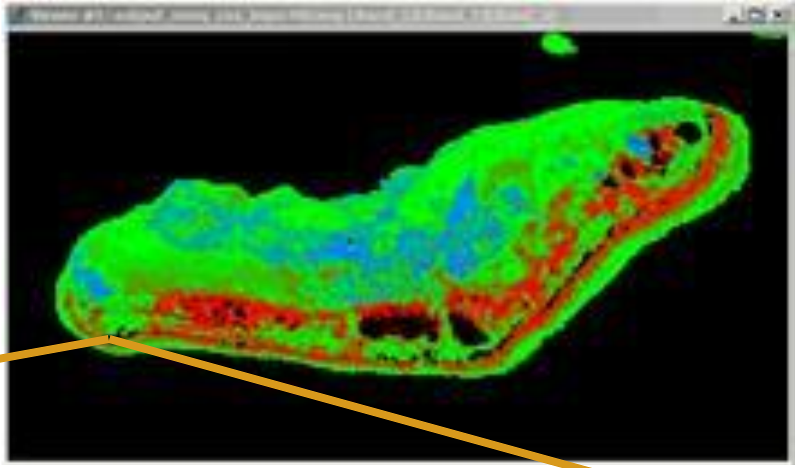
Credit: Univ. PR Bio-Optical Oceanography Lab

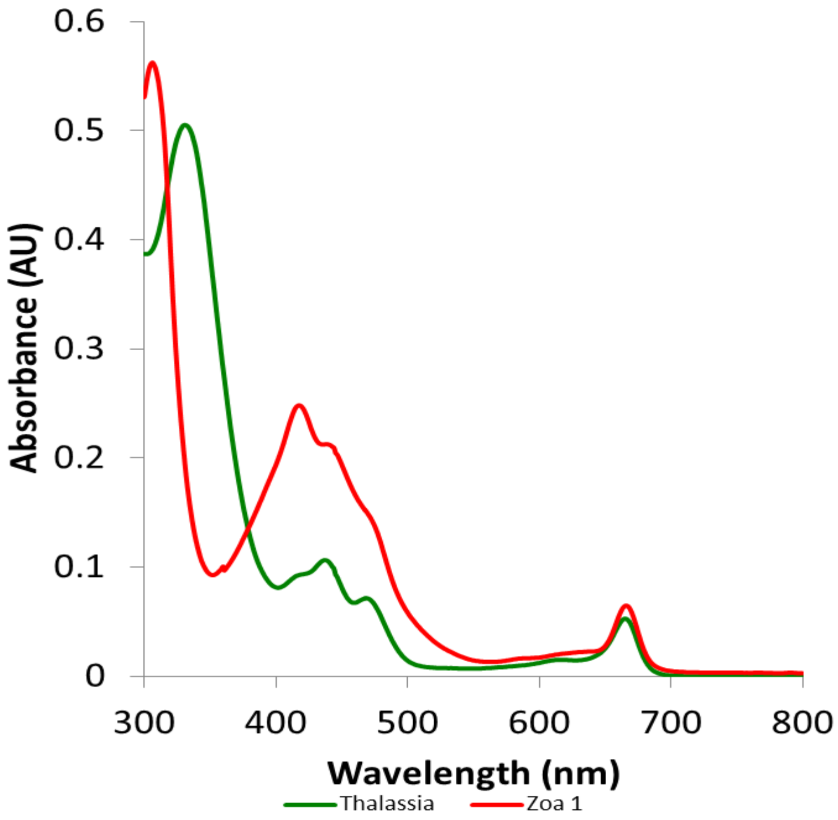
Atmospherically Corrected AVIRIS (Hyperspectral) Image (After Water Column Correction)



Credit: Univ. PR Bio-Optical Oceanography Lab

Some features may have very similar colors, but can be spectrally different.



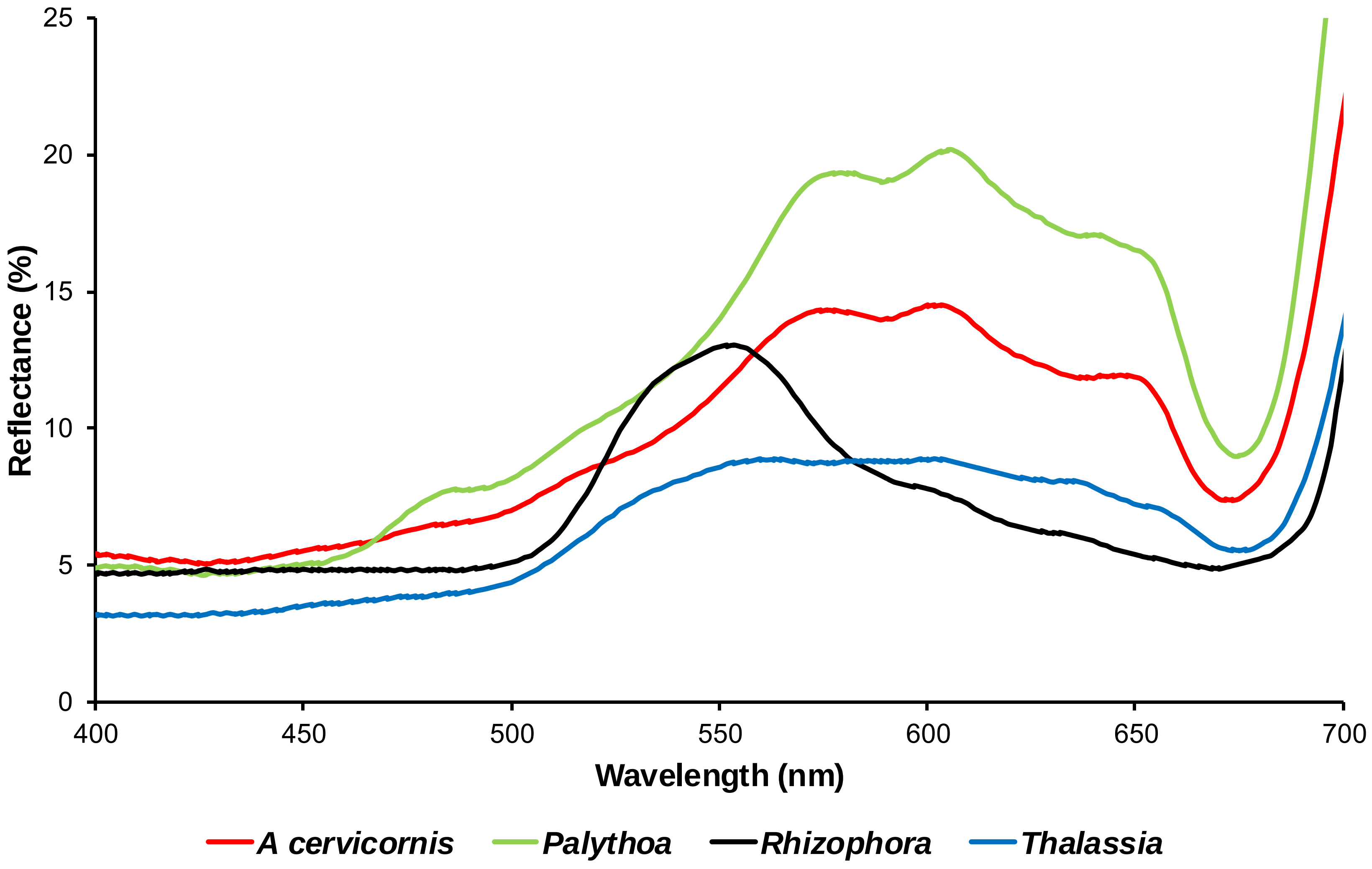


Spectral Comparison of Different Caribbean Coastal Components

A. cervicornis

Rhizophora mangle

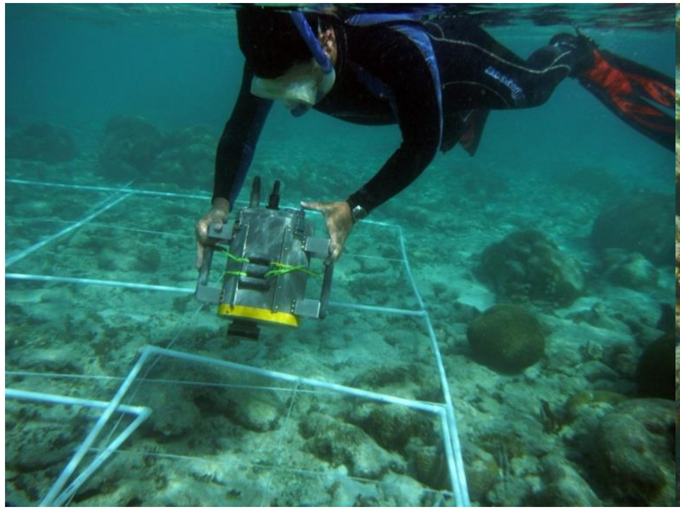
Thalassia

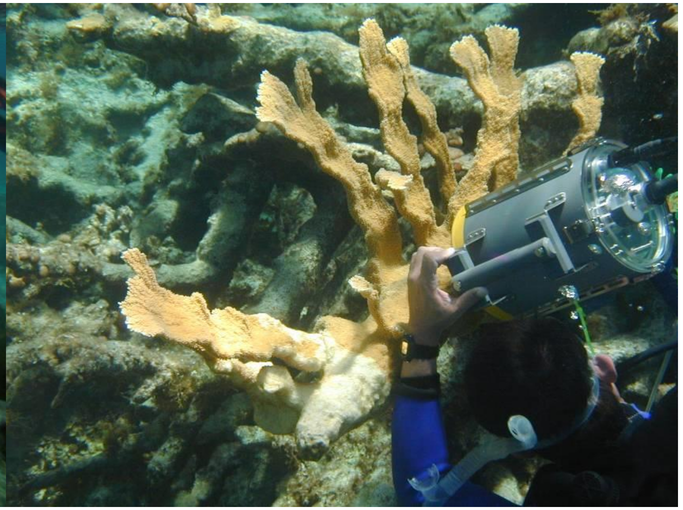


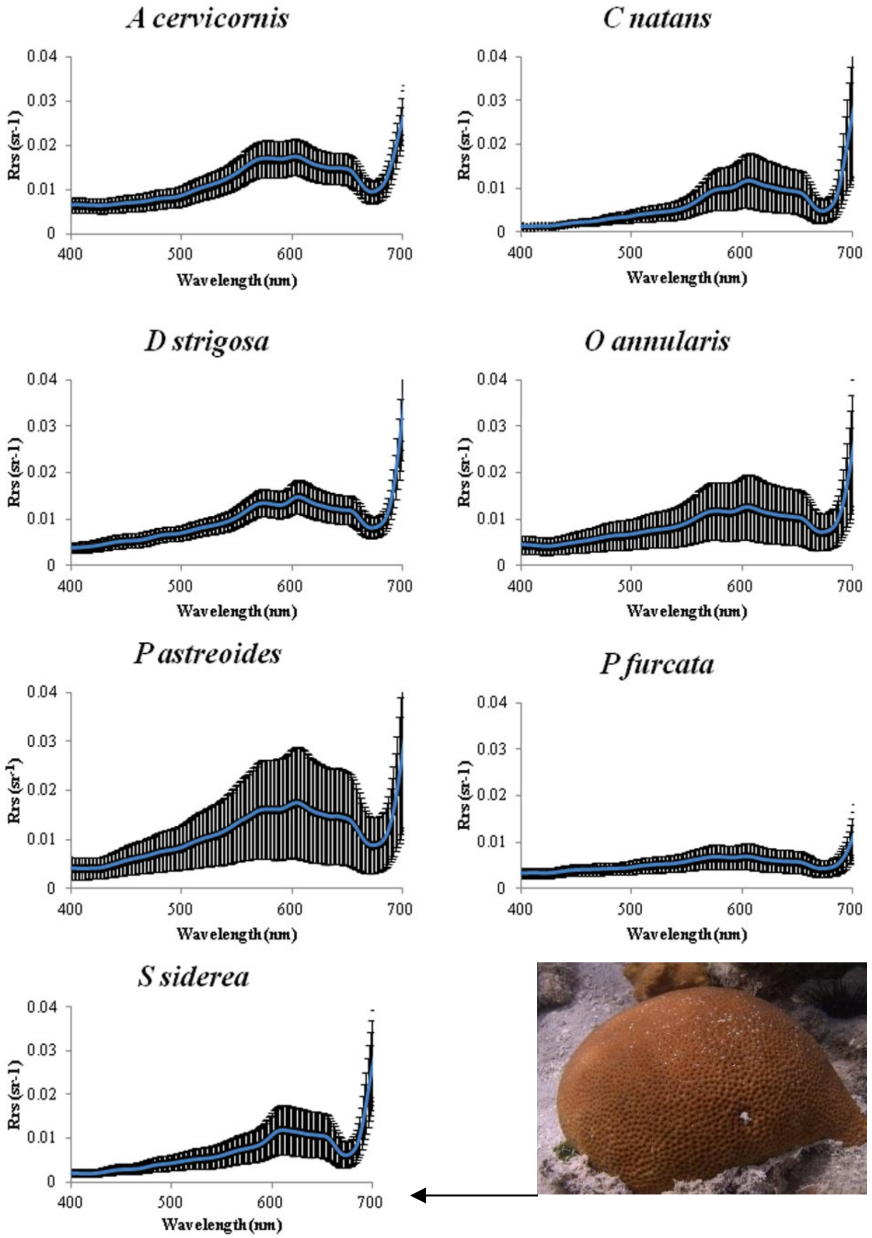
Torres-Pérez (Unpublished)

Spectroscopy to Study Coral Reefs

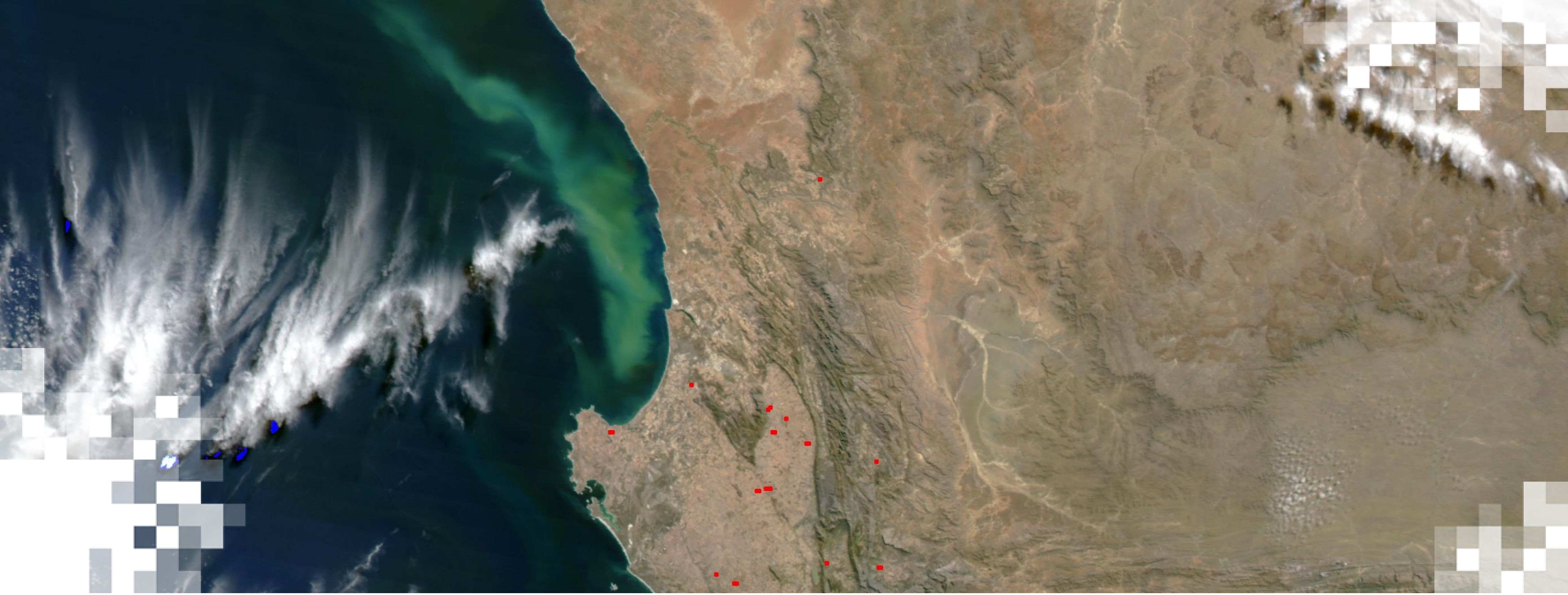
- Provides for a non-invasive tool to assess the health of reef corals.
- Can be used to follow the development of a potentially devastating event such as bleaching or disease outbreaks.







Torres-Pérez et al. (2015) PLoSONE



Some Commonly Used Field Spectroradiometers

Malvern Panalytical's ASD FieldSpec

Credit: Samatha Sharp (CyanoSCape)

Feature	Range
Spectral Range	350-2500 nm
Channels (Bands)	2151 (512 in VNIR [350-1000nm])
Spectral Resolution (FWHM)	3 nm, 700 nm
Bandwidth (Nominal)	1.4 nm @ 700 nm; 1.1 @ 1400 nm; 1.1 @ 2100 nm
Minimum Integration	100 milliseconds
FOV	25° (Fiber Optic)
Controller	Laptop Computer

Other Features:

- Data Collection Speed: 2 spectra/second
- Several Models Available
- Permanent Fiber Optic Cable
- Ergonomic Backpack

Spectral Evolution's RS-8800

Feature	Range
Spectral Range	350-2500 nm
Channels (Bands)	512
Spectral Resolution (FWHM)	2.8 nm, 700 nm
Bandwidth (Nominal)	1.3 nm @ 700 nm; 3.5 @ 1500 nm; 2.3 @ 2100 nm
Minimum Integration	100 milliseconds
FOV	1, 2, 3, 4, 5, 8, and 10° Lenses
Internal Memory	Integrated Computer

Other Features:

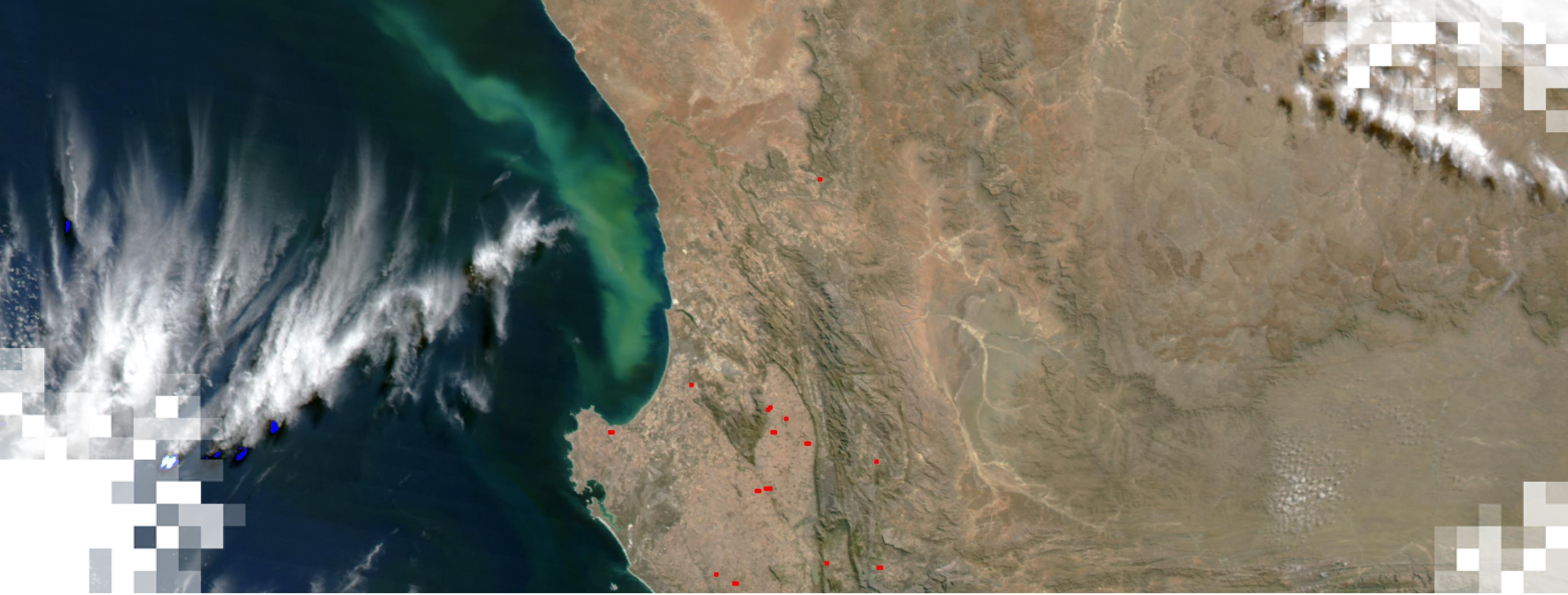
- USB/Bluetooth Connectivity
- Internal GPS
- Software has some very nice capabilities:
  - Can calculate 19 different spectral indices (NDVI, SAVI, EVI, etc.)
  - Build your own spectral libraries

SVC's HR-512i Spectroradiometer (Previously GER-1500)

Feature	Range
Spectral Range	350-1050 nm
Channels (Bands)	512
Spectral Resolution (FWHM)	3.2 nm, 700 nm
Bandwidth (Nominal)	1.5 nm, 350-1050 nm
Minimum Integration	10 milliseconds
FOV	4° (Standard), 8°, 25° (Optional Fiber Optics)
Internal Memory	1,000 Scans

Other Features:

- Standalone Measurements (NO need for a laptop.)
- Internal Digital Camera (But with very bad resolution!)
- Internal GPS
- Optional Underwater Enclosure (Can be submerged up to ~40m.)



Summary

Summary

- Terrestrial and water targets have specific spectral features that can be used to identify them and monitor their variability spatially and temporally.
- This is affected by the presence/absence of particular components such as photosynthetic pigments, UV-absorbing compounds, dissolved and particulate constituents, the medium itself, etc.
- There are considerations to take into account when collecting field spectra.
- Nowadays, there are a number of field spectroradiometers available. The selection of a specific spectroradiometer will be dependent on your type of study, research question, and budget, among others.

Thank You!