

ESTIMATION OF WATER PARAMETERS FROM OCEAN REMOTE SENSING

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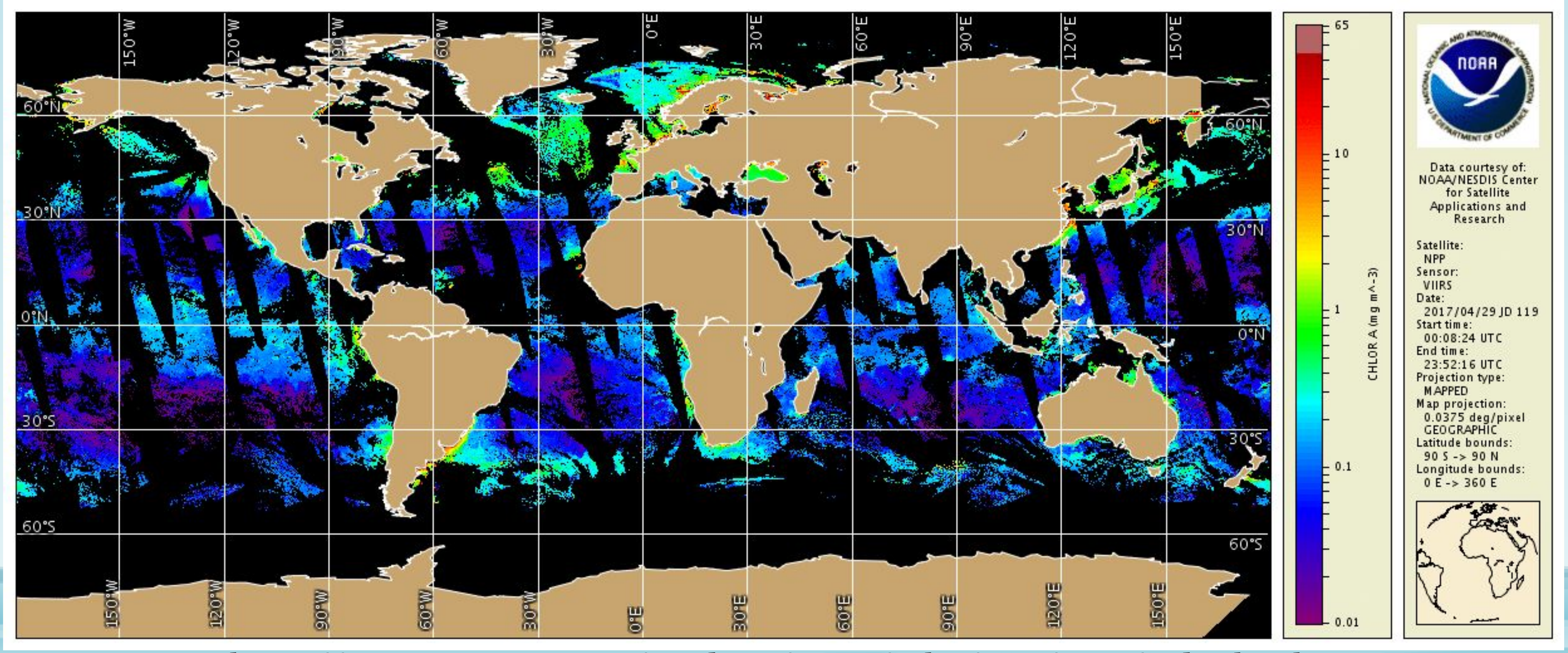
What is ocean color?

Ocean color (OC) studies the interaction between the visible light coming from the sun and aquatic environments (Dierssen and Randolph, 2012). OC studies aid scientists to gain a better understanding of photosynthetic organisms such as phytoplankton and their impact on the Earth system (NASA, 2020).

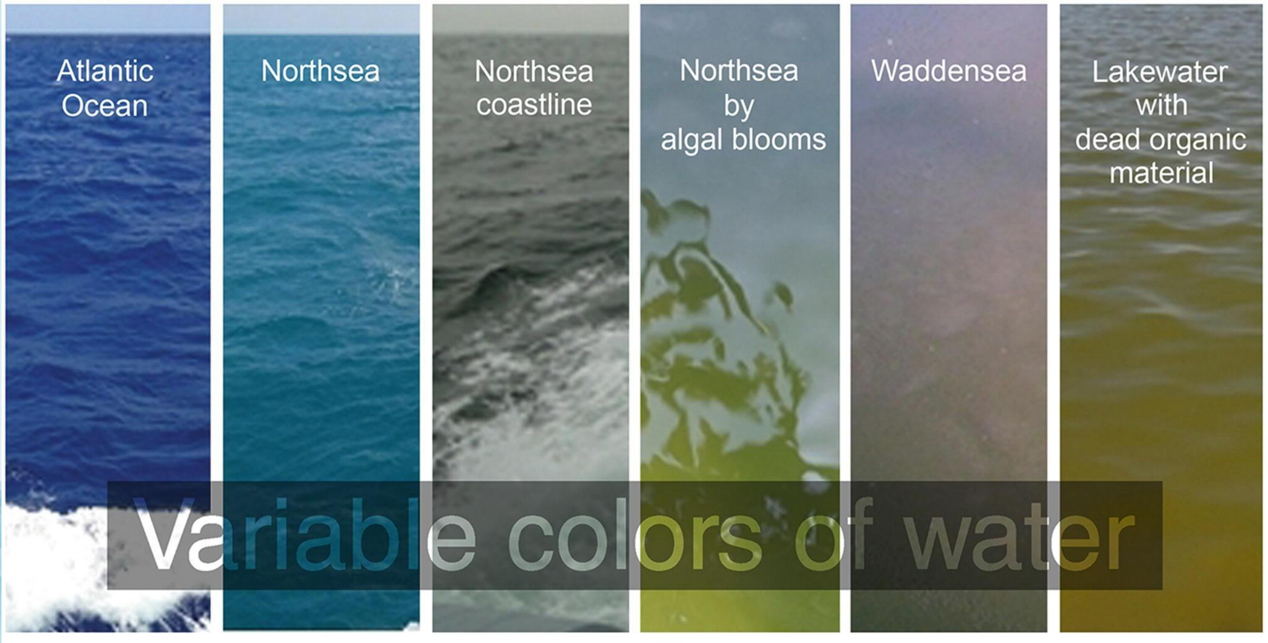


Source: https://www.ospo.noaa.gov/Products/ocean/color/viirs/snpp/index.html

Why is important Ocean Color to Us?

The color of a water body is determined by scattering and absorption by pure water and its natural constituents, such as phytoplankton, detritus, inorganic particles, and colored dissolved organic matter (CDOM) (Mobley, 1994).

Some phytoplankton species form harmful algal blooms, which can negatively affect human and marine life and often have severe repercussions on a range of industries (IOCCG, 2021).



Source: Marine optics and ocean color remote sensing, Figure 1. Various colors observed in fresh and marine waters influenced by the presence of varying optically active constituents. (https://link.springer.com/chapter/10.1007/978-3-319-93284-2_4/figures/1)

Importance and Specifics of Coastal Water Remote Sensing

- Majority of human population lives near the coast
- Influenced by oceanic and terrestrial processes
- Account for nearly 90% of global fish
- Extreme events: hypoxia (deficit of oxygen), Harmful Algal Blooms
- Necessity of active coastal management

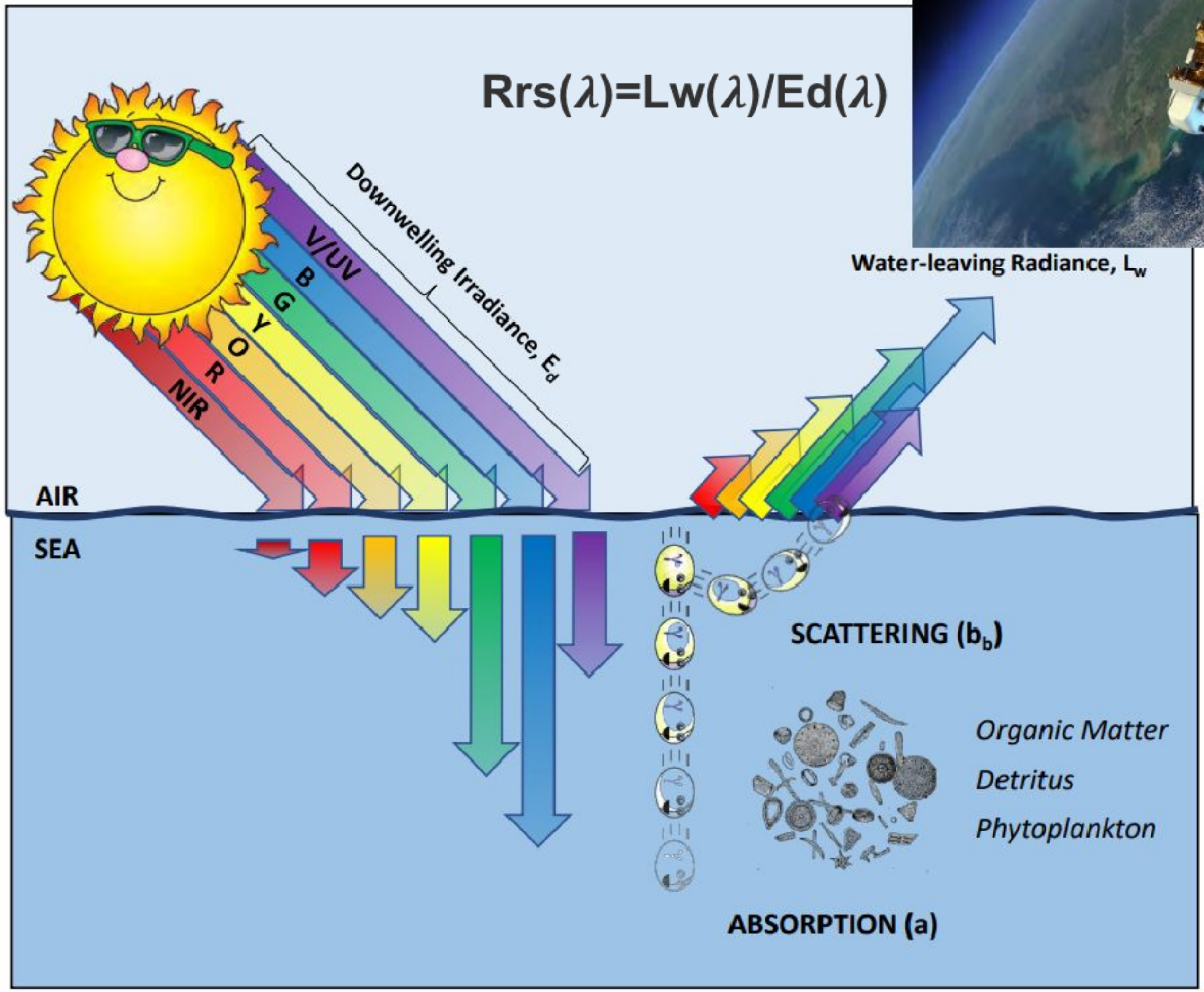
Source: https:// [illegible] in-florida-is -big-sugar-to-blame/

Source: https://www.gainesville.com/story/opinion/2021/04/06/alejandro-andres -munoz-florida-risk-more-toxic-algae-blooms/4842009001/

Algae alert photo courtesy Calusa Waterkeeper (https://www.biologicaldiversity.org/)

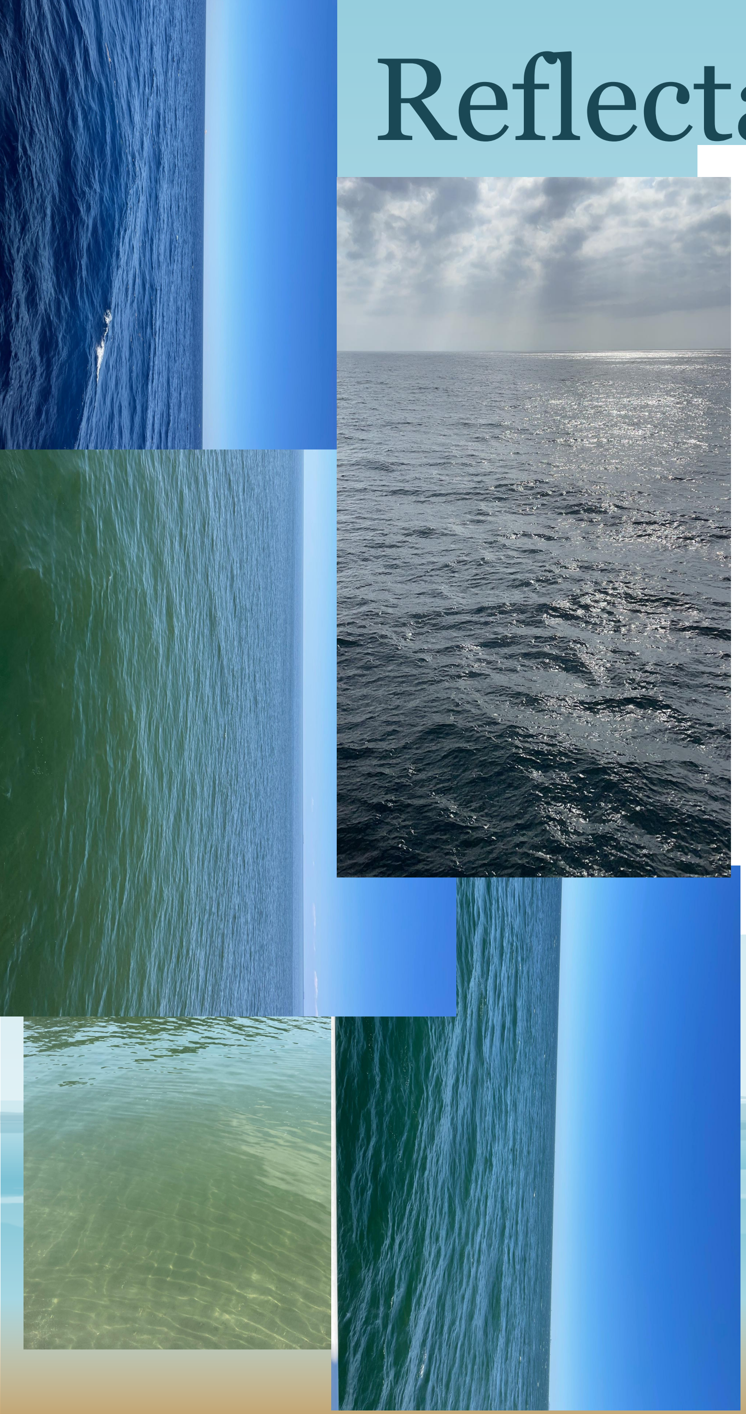
How Remote sensing works over the ocean

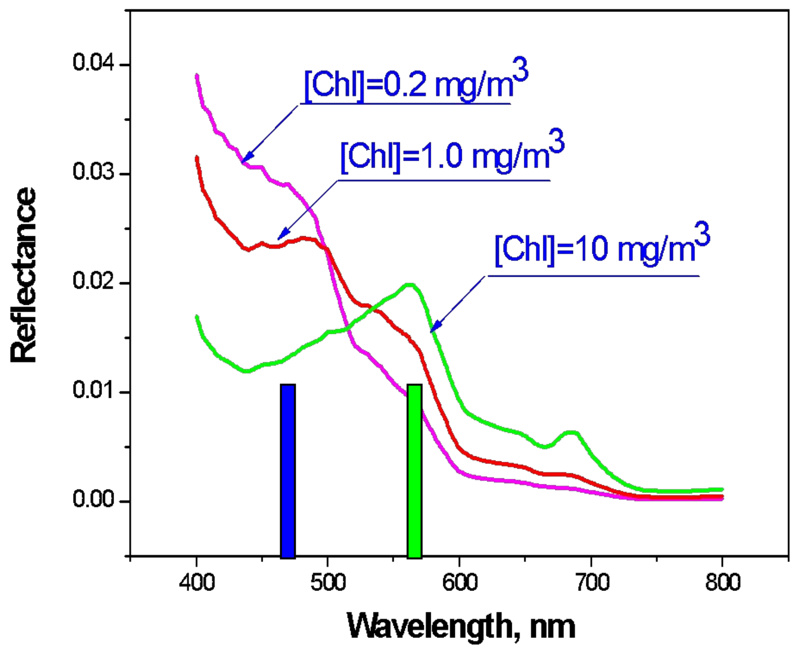
A large part of the radiance at the top of the atmosphere (TOA) is originated from scattering processes in the atmosphere and reflections of the Sun and sky on the wave-roughened water surface, and **less than ten percent** is due to the water signal at sea level (Gordon et al, 1983).



Source: Ocean Optics 21 class, lecture 20 (http://misclab.umeoce.maine.edu/OceanOpticsClass2021/wp-content/uploads/2021/07/Lecture_20_atm_corr_Mobley.pdf)

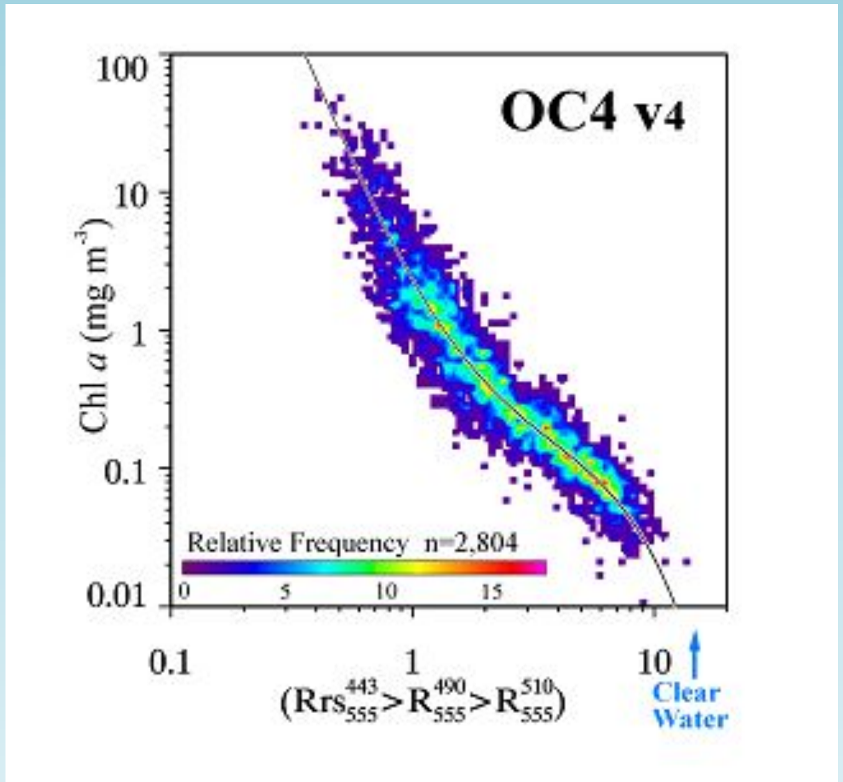
Reflectance spectra for the open ocean





[Chl] can be well characterized by blue-green ratio

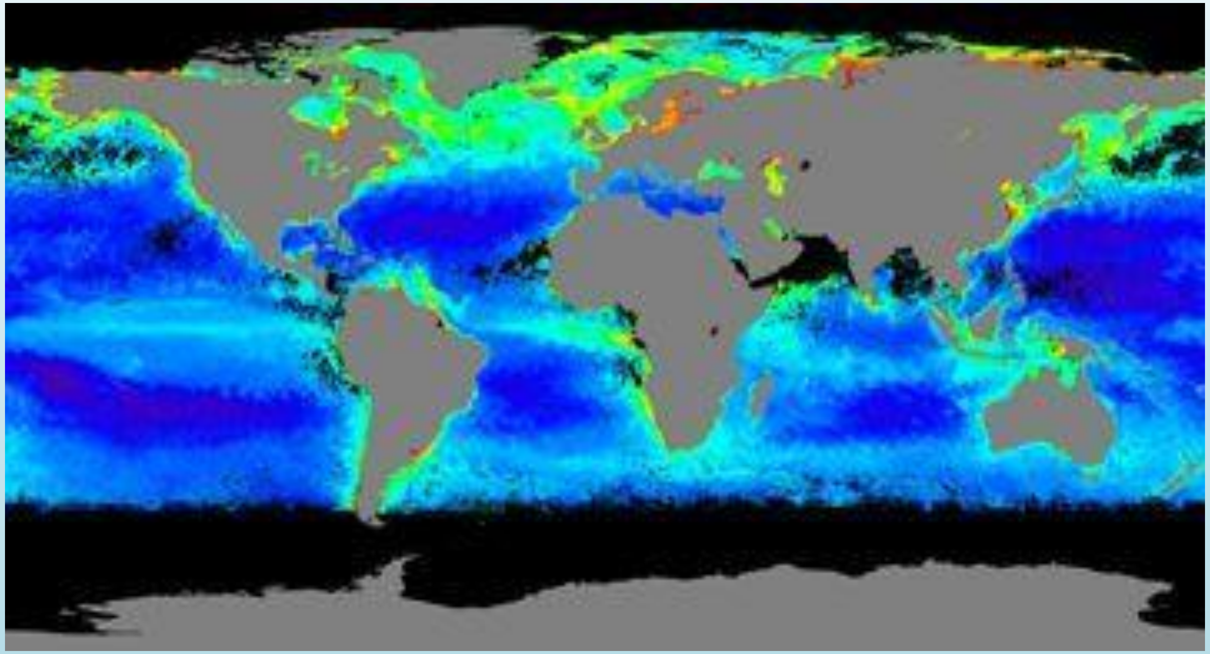
With increasing [Chl] water changes its color from blue to green

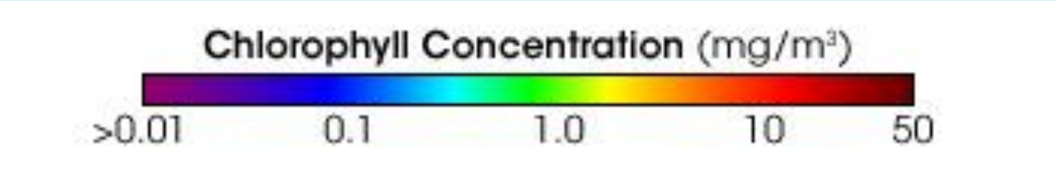


SeaWiFS Blue-Green Ratio Algorithm

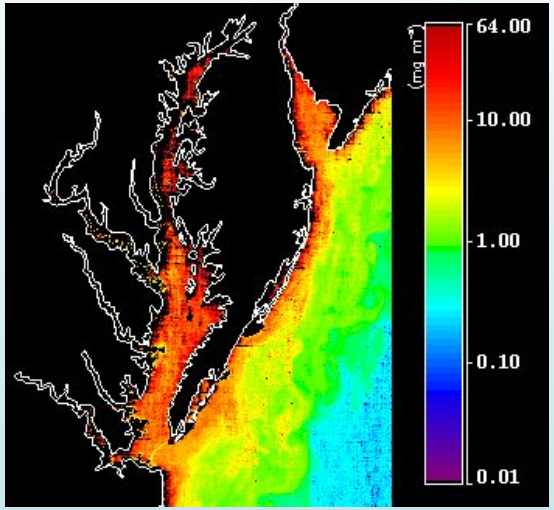
From K. Carder, et al. ,2003

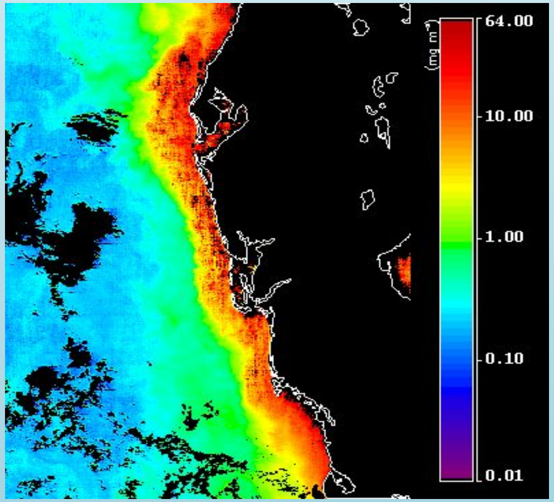
Chlorophyll Global and Regional Maps





SeaWiFS, July 2006





MODIS, NE and Florida coasts

Main goals in retrieval from ocean color imagery

CHL CONCENTRATION

IN ADDITION, ESPECIALLY IN COASTAL WATERS:

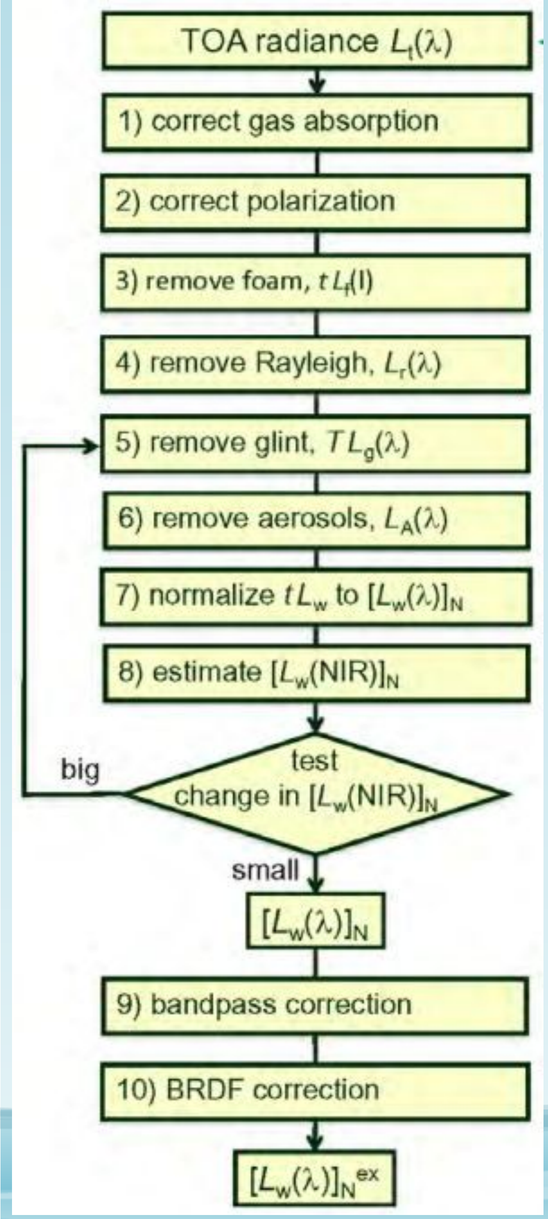
CDOM CONCENTRATION

CONCENTRATION OF MINERALS

PARTICLE SIZE DISTRIBUTIONS

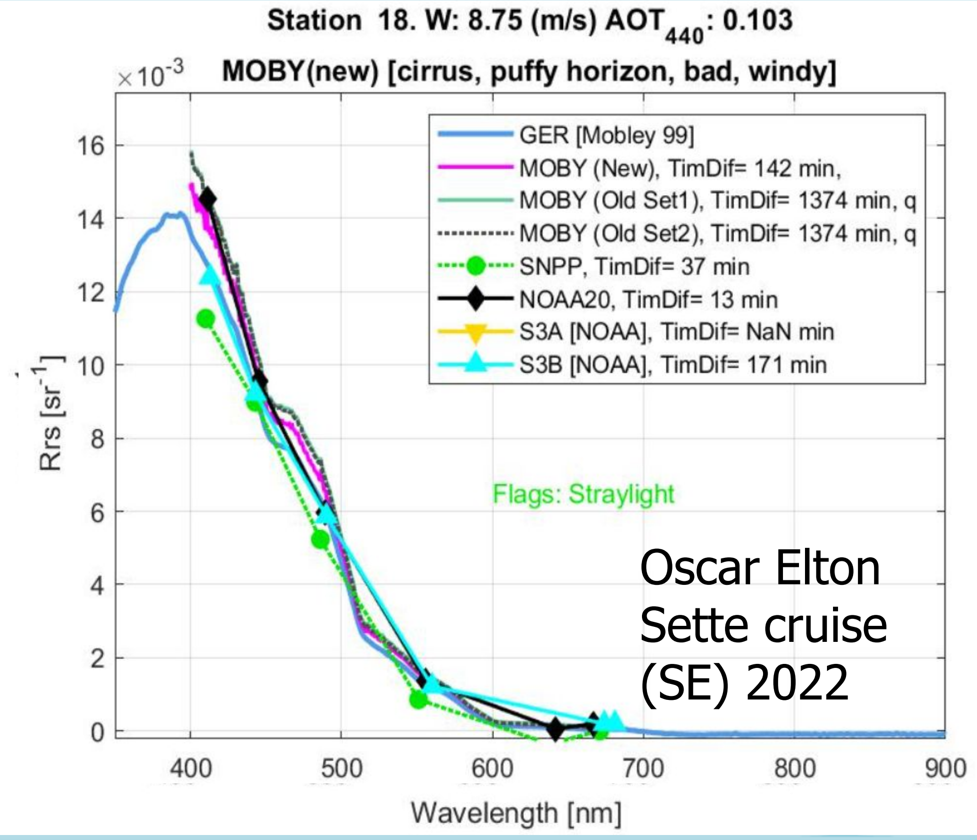
TYPES OF PHYTOPLANKTON SPECIES

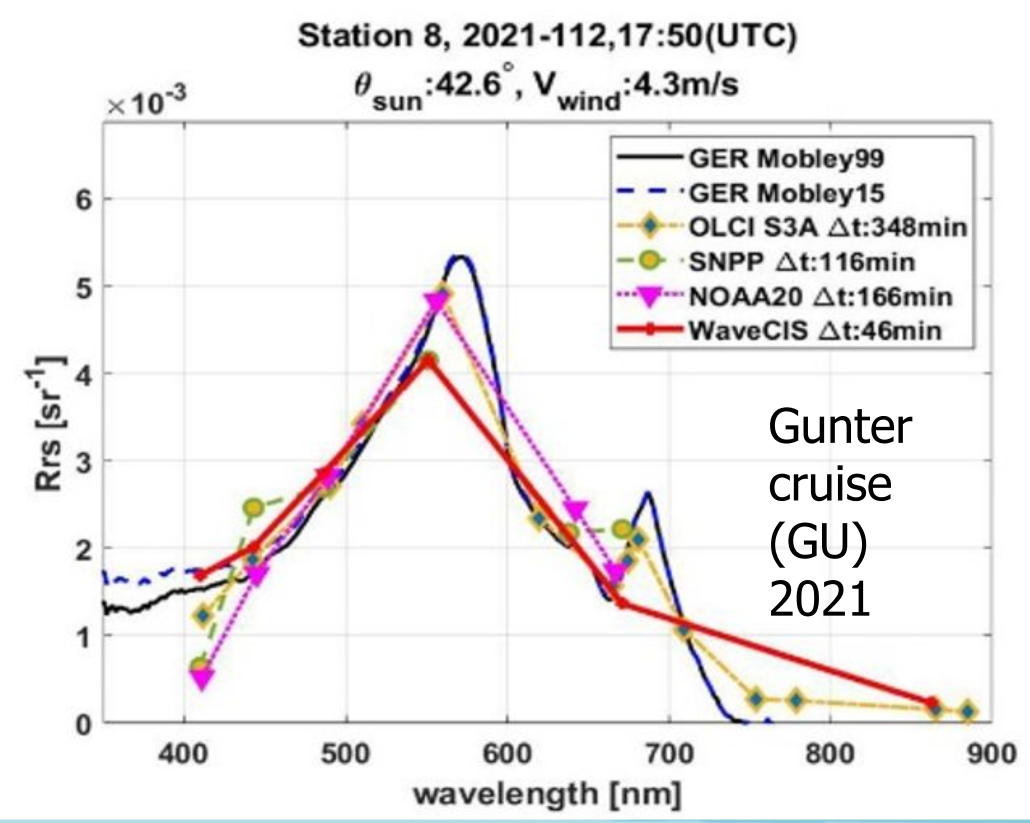
ATMOSPHERIC CORRECTION BY NASA



$$L_{t\_TOA}(\lambda) = L_r(\lambda) + L_a(\lambda) + L_g(\lambda) + tL_w(\lambda)$$

In situ and satellite-derived *Rrs* from the VIIRS cal/val cruise





The bidirectional reflectance distribution function (BRDF)

In situ - AERONET-OC data processing

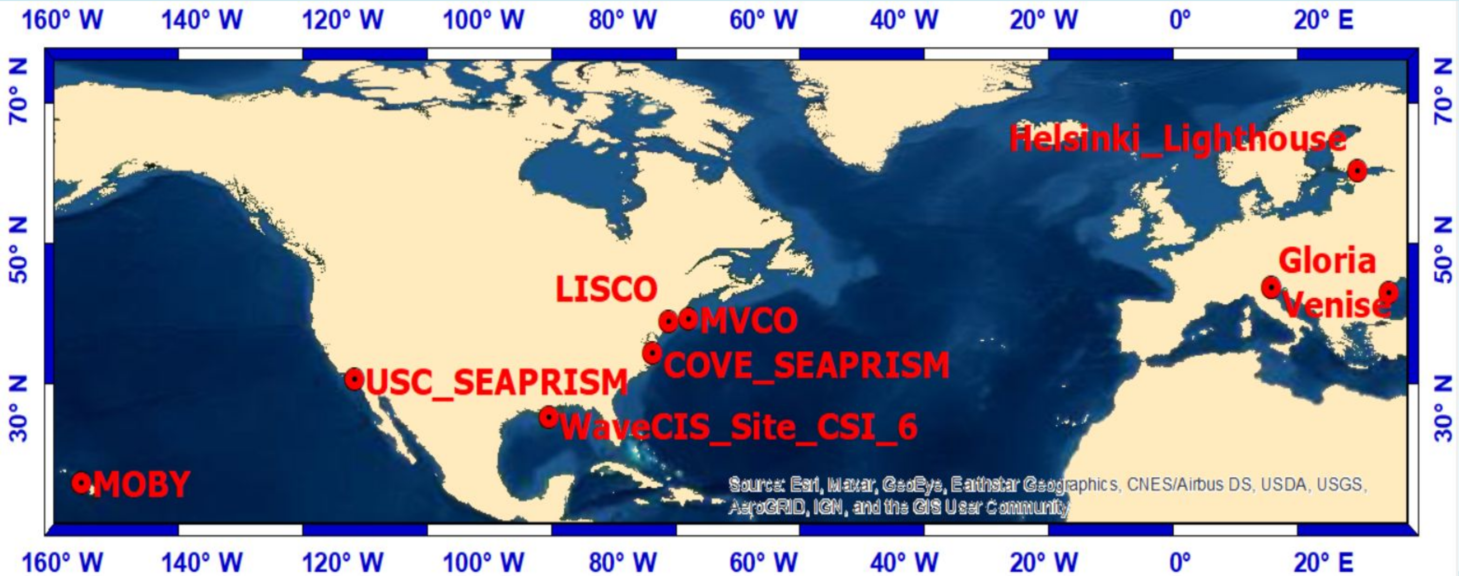
For the rest of the AERONET-OC stations used in this study, the elevation, distance to shore, and environmental conditions vary. Table below presents a brief description of the other AERONET-OC sites used in this research.

All in-situ data used in the quantitative match-up comparison analysis are selected and averaged from the measurements made within a ±2-hour time window of the satellite overpass time of the locations of the sites for Rrs, and AOD. This approach ensures that the in-situ data set is minimally affected by the natural temporal changes in the atmosphere and water (Zibordi et al., 2009).

In addition, we also obtain data from the Marine Optical BuoY (MOBY) located offshore of Lanai, Hawaii (Clark et al., 1997).

Station name	Location	Distance to shore (km)	Latitude (°)	Longitude (°)	Height above water (m)
LISCO	Long Island Sound near Northport, NY, USA	3.00	N 40.955	W 73.342	12.0
WaveCIS Site CSI 6	Timbalier Bay area, MS, USA	18.00	N 28.867	W 90.483	32.7
MVCO	Near South Beach in Edgartown, MA, USA	5.00	N 41.300	W 70.550	10.0
COVE SeaPRISM	Near Virginia Beach, VA, USA	25.00	N 36.900	W 75.710	24.0
USC SeaPRISM	Near Newport Beach, CA, USA	18.00	N 33.564	W 118.118	31.0
Helsinki Lighthouse	Gulf of Finland	27.78	N 59.949	E 24.926	20.0
Gloria	Near Constanta, Romania	22.22	N 44.599	E 29.360	30.0
Venice	Venice Lagoon, Italy	14.82	N 45.314	E 12.508	10.0

AERONET-OC sites : Location, distance to shore, and height above water



AERONET-OC site location in the Northern Hemisphere, and MOBY are presented with red dots.

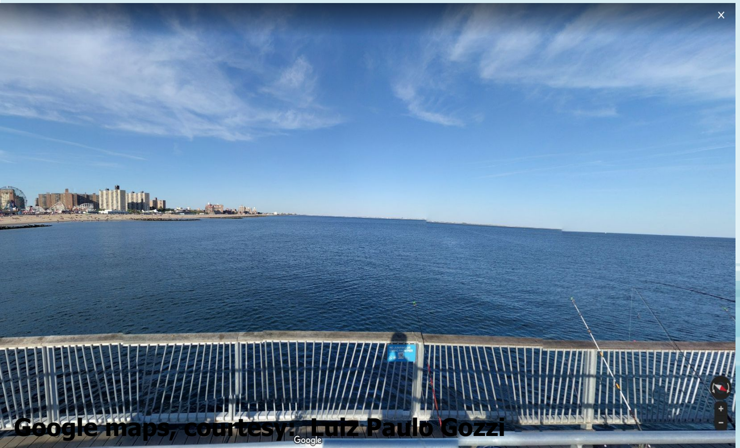
In situ - fieldwork

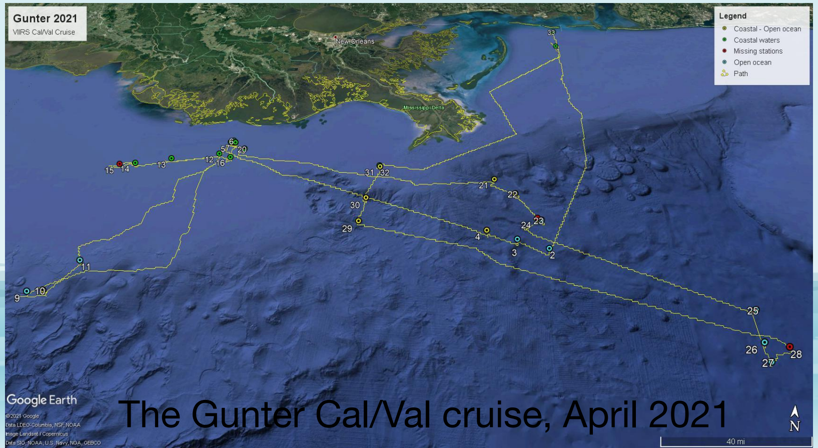
We collect data from Brooklyn in the New York City area and from the VIIRS Cal/Val cruises performed by the National Oceanic and Atmospheric Administration (NOAA) and US Navy annually since 2012.

We take measurements in a diversity of water conditions along the Atlantic and Pacific coasts of the United States.

A Spectravista GER-1500 spectroradiometer for a spectral range of 350 - 1050 nm, and a spectral resolution of 1.5 nm,

A hyperspectral snapshot imager (Cubert 285). This sensor facilitates the study of the visible spectrum and NIR spectrum. Currently, we also added a new hyperspectral snapshot imager (Cubert, ULTRIS X20) with a wavelength range from 380 nm to 1000 nm


Google maps, courtesy: Luiz Paulo Gozzi

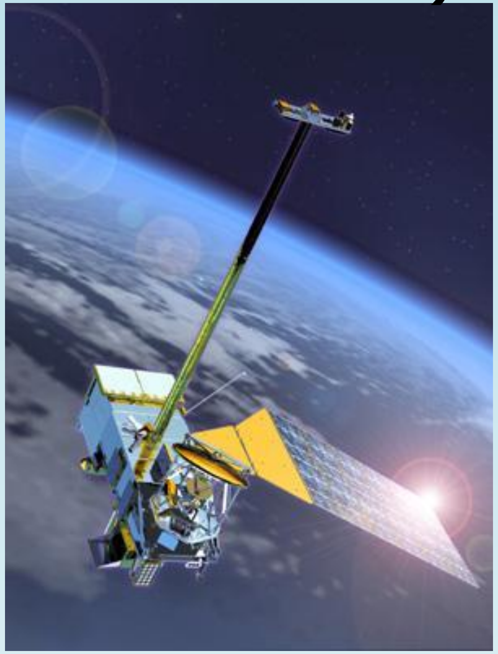


The Gunter Cal/Val cruise, April 2021

GER spectroradiometer

Satellite sensors

VIIRS
(Visible Infrared Imaging Radiometer Suite)



- Launched in October 2011
- The Visible/Infrared Imager/Radiometer Suite is a part of JPSS project.
- It collects visible/infrared imagery and radiometric data. Data types include atmospheric, clouds, earth radiation budget, clear-air land/water surfaces, sea surface temperature, ocean color, and low light visible imagery. Nadir resolution of 750 m.
- It partially combines MODIS and AVHRR (for sea surface temperature) capabilities.

Band Name	λ(nm)	(nm) **	Wavelength Type
M1	412	20	VIS
M2	445	18	VIS
M3	488	20	VIS
M4	555	20	VIS
M5	672	20	VIS
M6	746	15	NIR
M7	865	39	NIR
M8	1240	20	SWIR
M9	1378	15	SWIR
M10	1610	60	SWIR
M11	2250	50	SWIR
M12	3700	180	MWIR
M13	4050	155	MWIR
M14	8550	300	LWIR
M15	10763	1000	LWIR
M16	12013	950	LWIR
DNB	700	400	VIS
I1	640	80	VIS
I2	865	39	NIR
I3	1610	60	SWIR
I4	3740	380	MWIR
I5	11450	1900	LWIR

Satellite sensors

Landsat 8
(Provisional Aquatic Reflectance product)

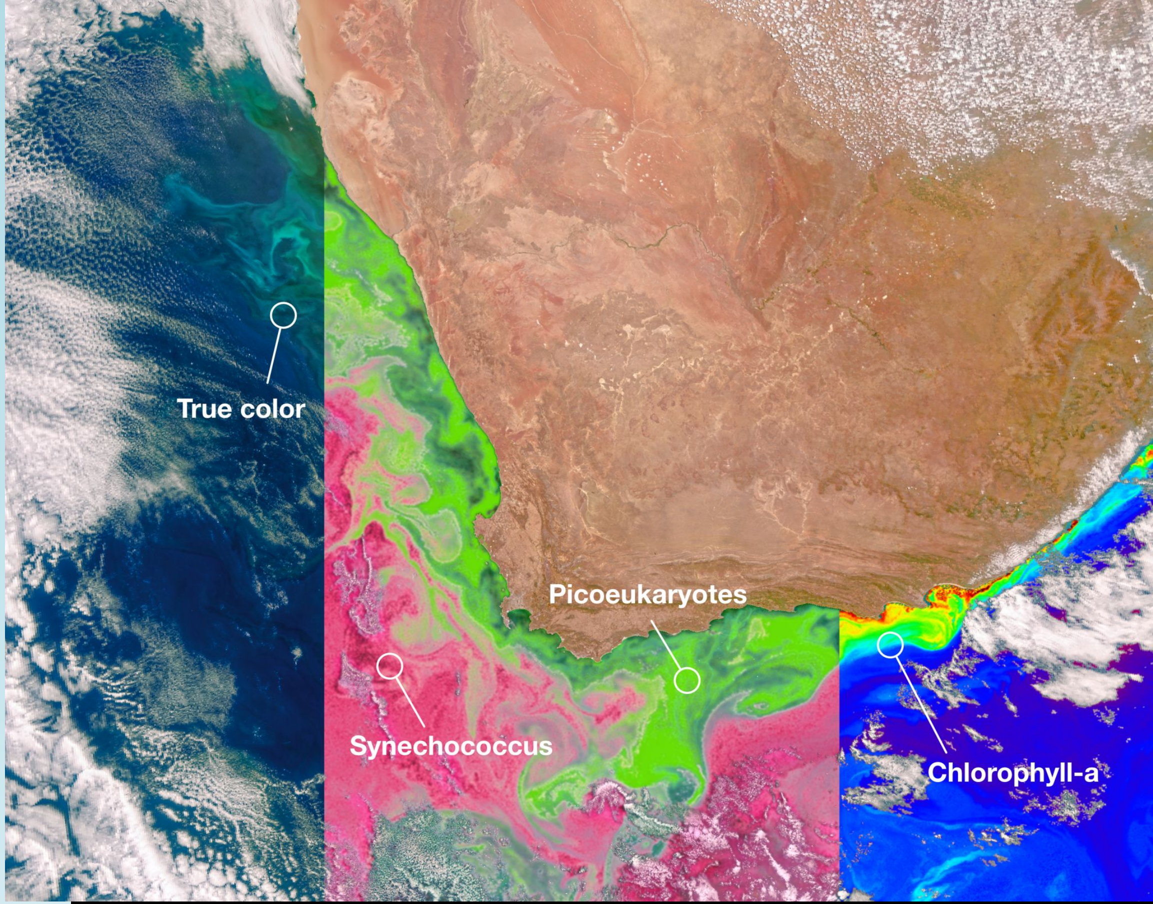
- Launched in February 2013
- A collaboration between NASA and the U.S. Geological Survey (USGS).
- Two science instruments: the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). Nadir resolution of 30 m.
- Provisional Aquatic Reflectance product is derived from Landsat 8 Level-1 reflective visible spectral bands over inland water bodies and nearshore coastal regions.

Landsat-8 OLI and *TIRS* Bands (μm)		
30 m Coastal/Aerosol	0.435 - 0.451	Band 1
30 m Blue	0.452 - 0.512	Band 2
30 m Green	0.533 - 0.590	Band 3
30 m Red	0.636 - 0.673	Band 4
30 m NIR	0.851 - 0.879	Band 5
30 m SWIR-1	1.566 - 1.651	Band 6
100 m TIR-1	*10.60 – 11.19*	Band 10
100 m TIR-2	*11.50 – 12.51*	Band 11
30 m SWIR-2	2.107 - 2.294	Band 7
15 m Pan	0.503 - 0.676	Band 8
30 m Cirrus	1.363 - 1.384	Band 9

Satellite sensors

PACE
(Plankton, Aerosol, Cloud, ocean Ecosystem)

- Launched in February 2024
- A NASA Earth-observing satellite mission that will continue and advance observations of global ocean color, biogeochemistry, ecology, carbon cycle, aerosols and clouds.
- 3 science instruments: Ocean Color Instrument (OCI), Spectro-Polarimeter for Planetary Exploration (SPEXone) and the Hyper-Angular Rainbow Polarimeter #2 (HARP2).



Methods

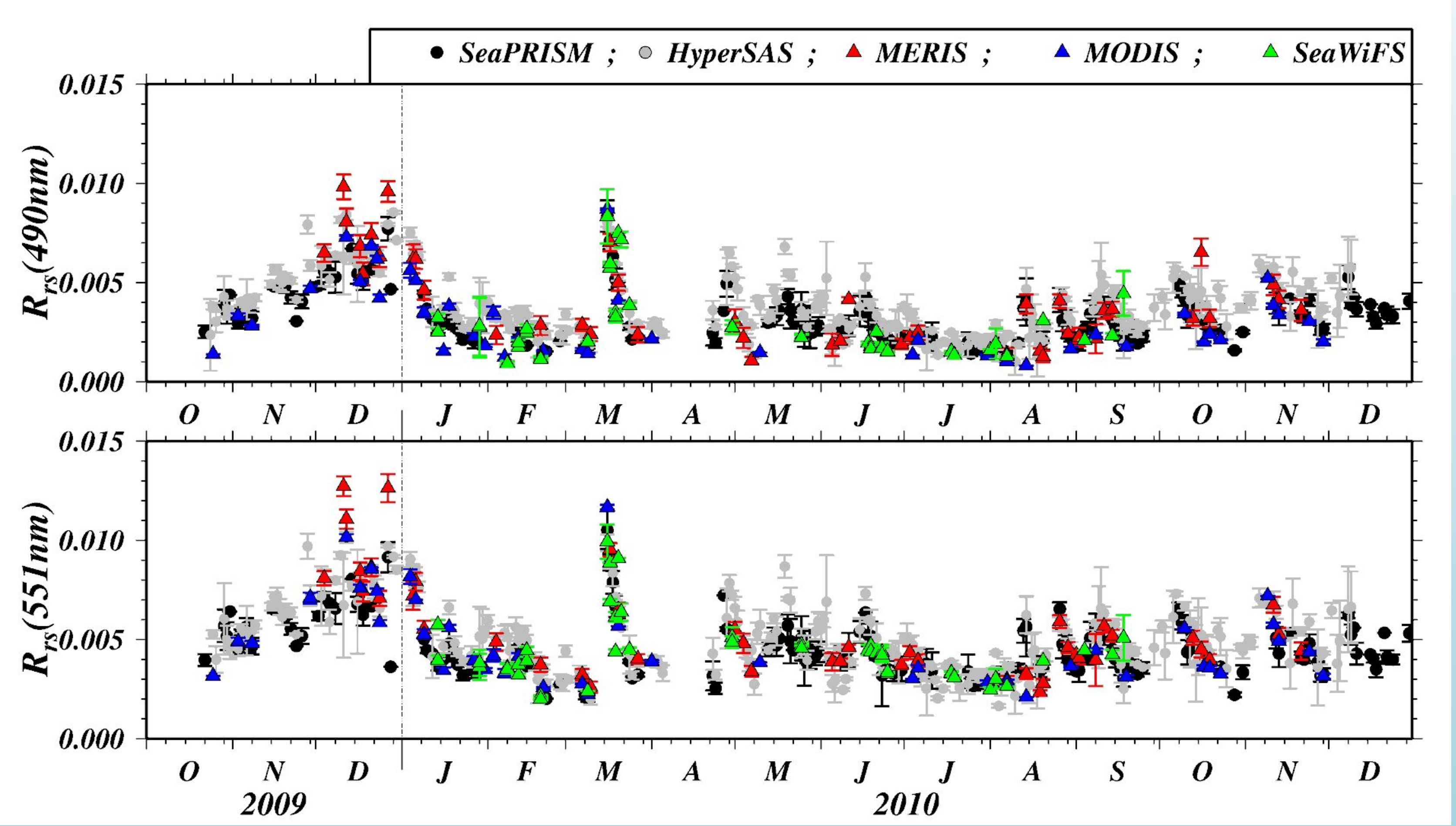
The students will become familiar with:

- instrumentation,
- processing of data from satellite sensors and the ocean platform thus evaluating the quality of data from satellite sensors operated by NASA, NOAA, and the European Space Agency (ESA), including data from the new NASA PACE mission.
- They will also work with algorithms to estimate water parameters from remote sensing data.

Outcomes

Satellite Validation

Time Series Remote Sensing Reflectance (R_{rs}) [sr^{-1}]



 Consistency in seasonal variations observed from the platform and from space

Estimation of water parameters from Ocean Remote Sensing

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