Ocean Color

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NOAA CoastWatch Satellite Course

Anchorage, Alaska

April 7-9, 2020

Versioning

-Wilson, 2017, WCN

-Tomlinson and Vogel, 2018, ECN

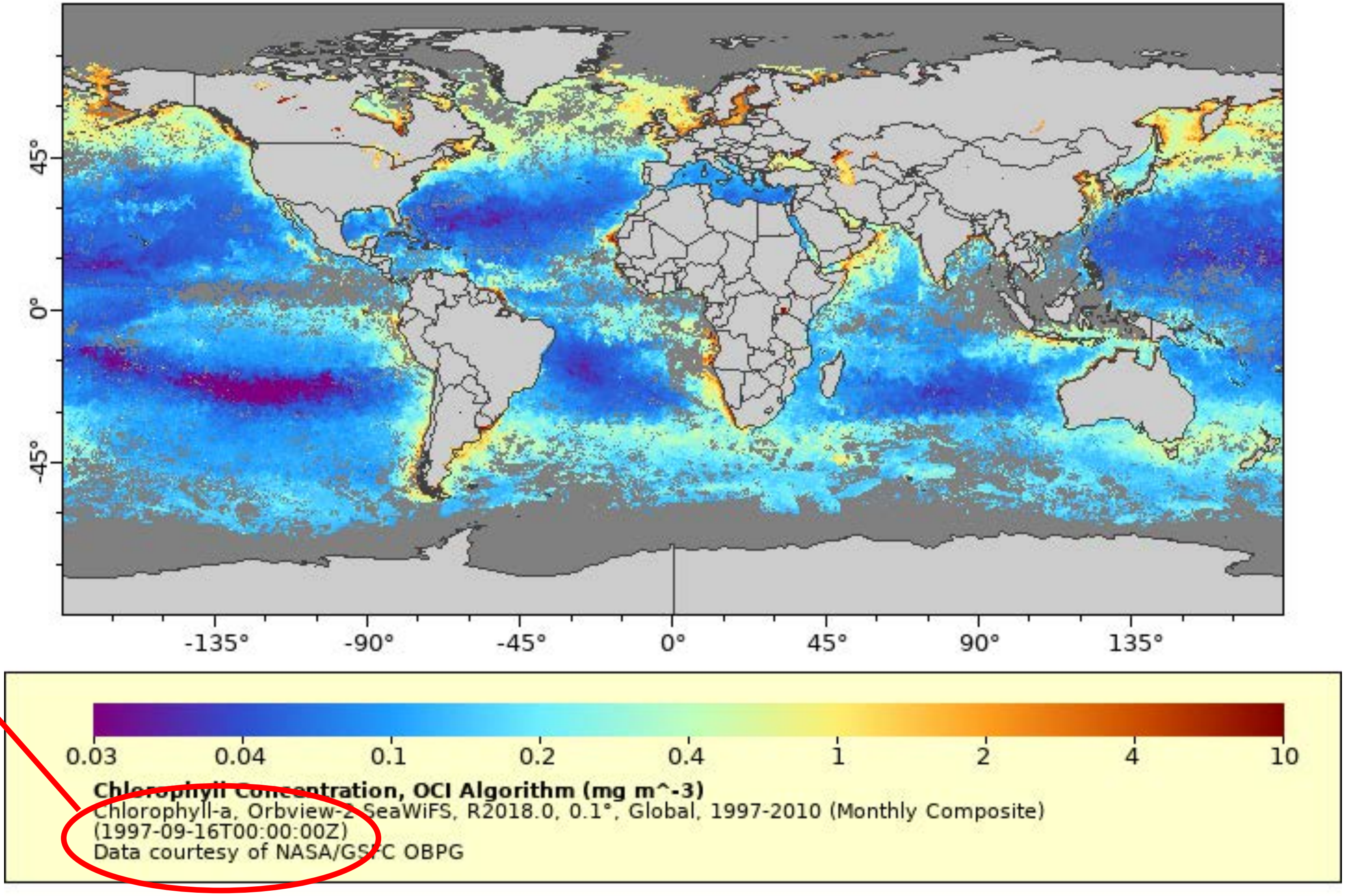
-Abecassis and Howell, 2018, PIN

-Wilson and Robinson, 2019, WCN

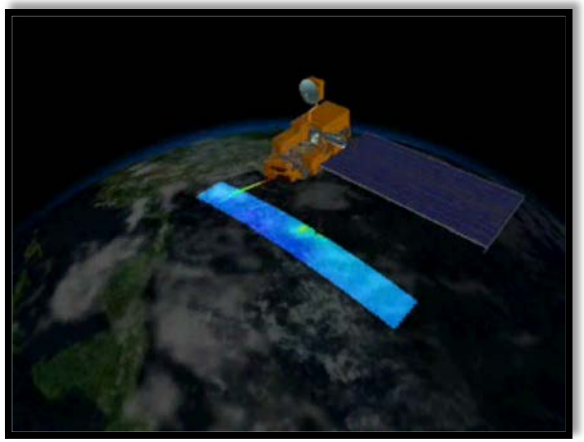
Ocean Color

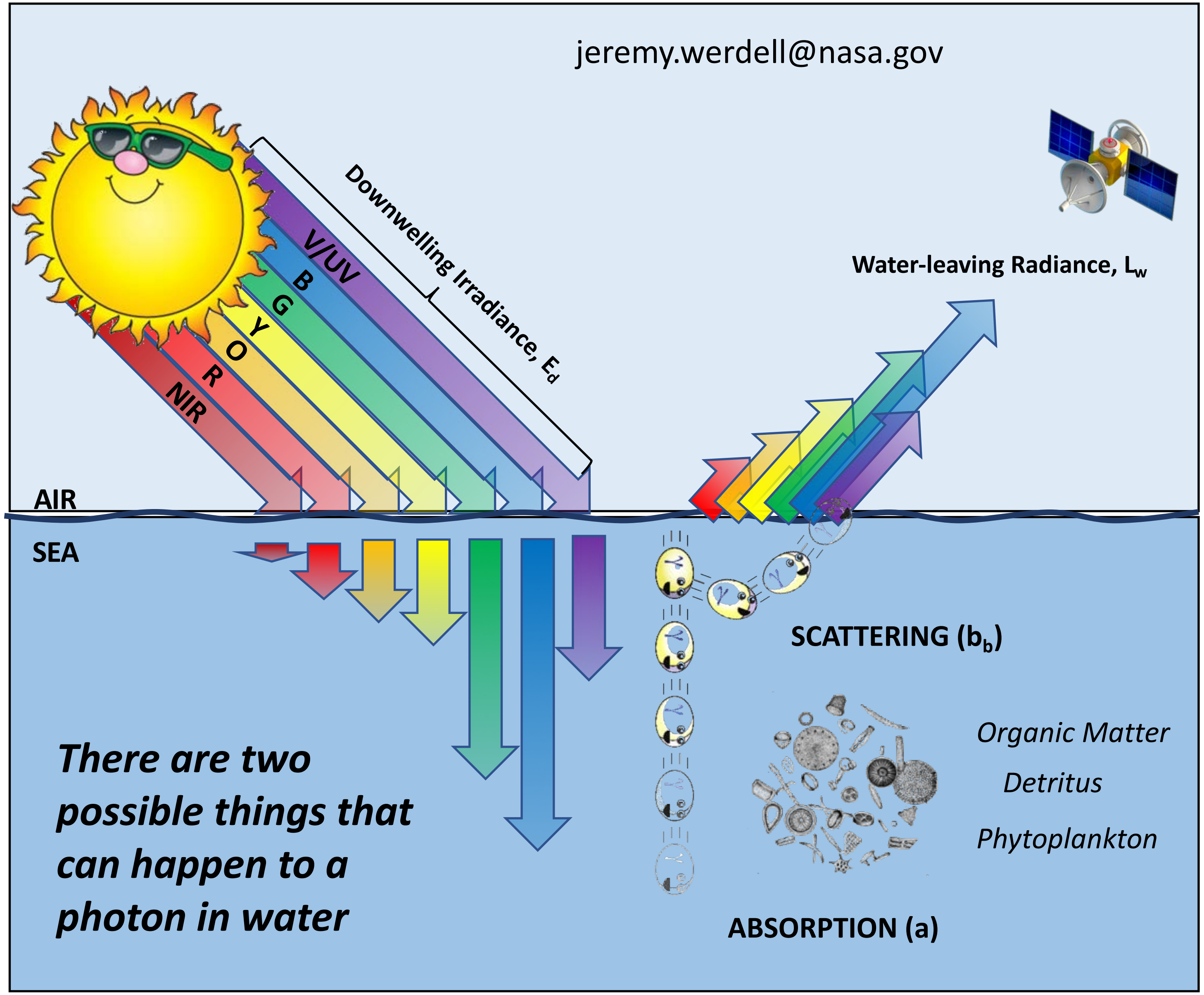
The continuous record of Ocean Color goes back to Sept 1997

CZCS flew from 1978-1986



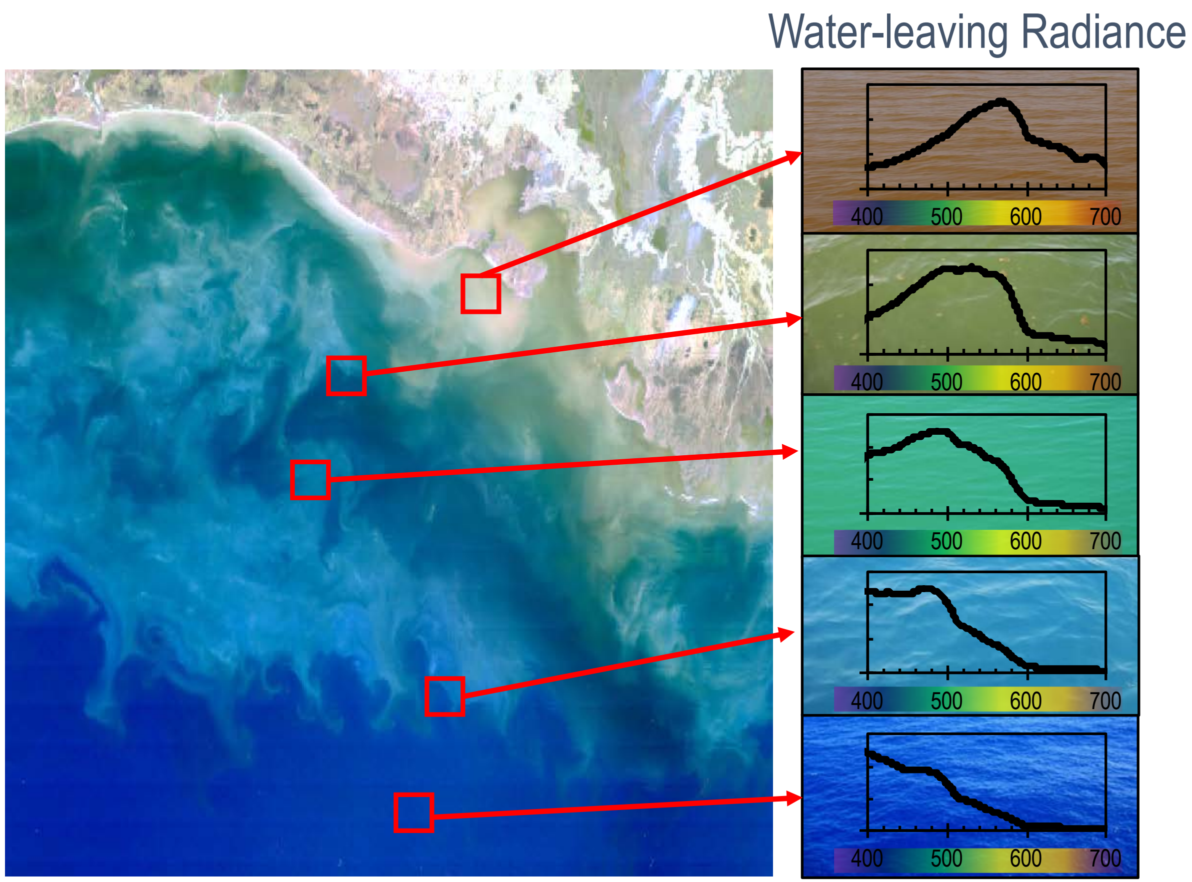
Measurements of ocean color are based on electromagnetic energy emitted by sunlight, transmitted through atmosphere, and ***reflected*** *by Earth's surface.*





There are two possible things that can happen to a photon in water

What causes variation in the color of the ocean?



The color of the ocean is a function of light that is absorbed or scattered as a result of constituents in the water.

- Phytoplankton and pigments, Dissolved organic matter
- Detritus (fecal pellets, dead cells), Inorganic particles (sediment)
- Water absorption

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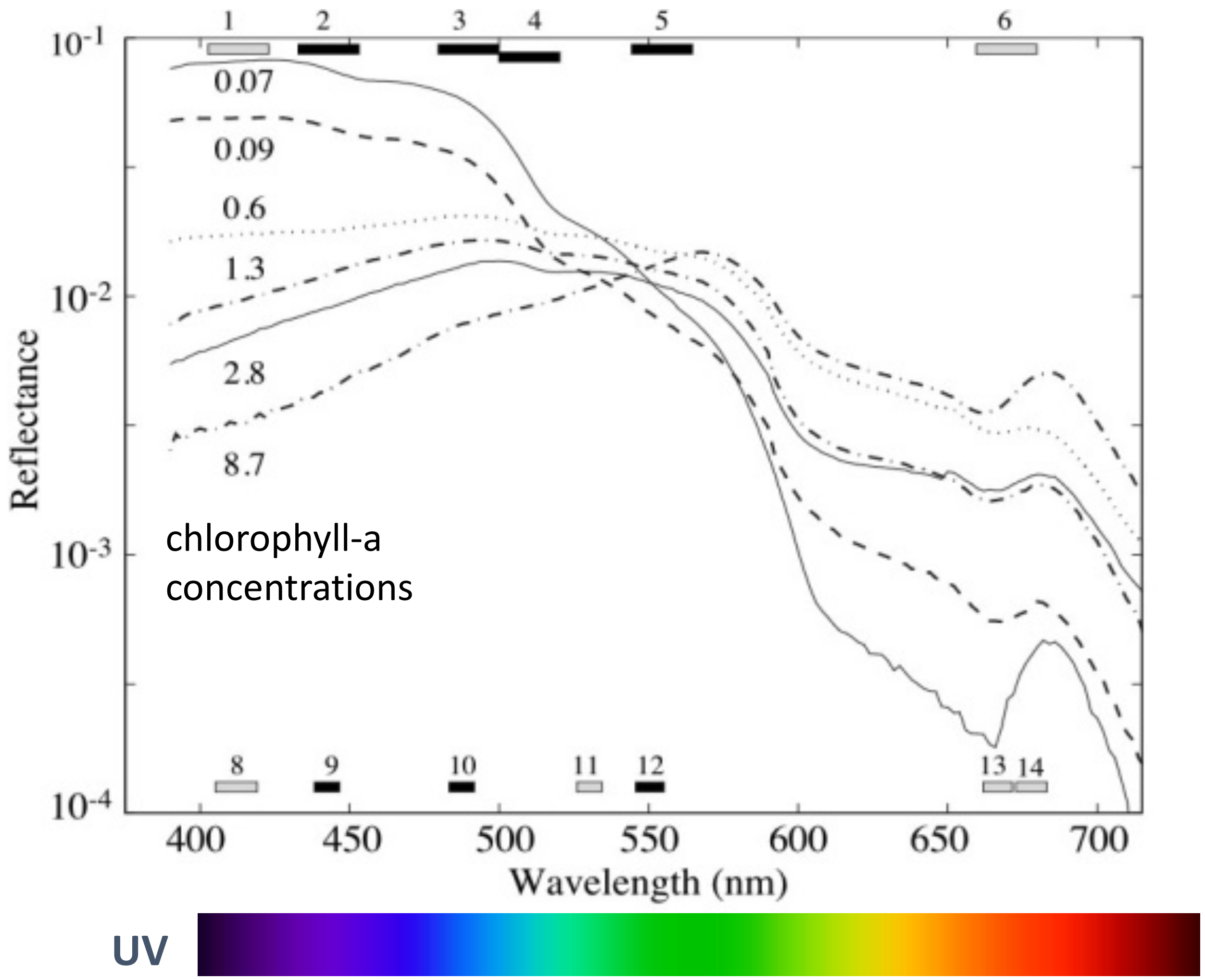
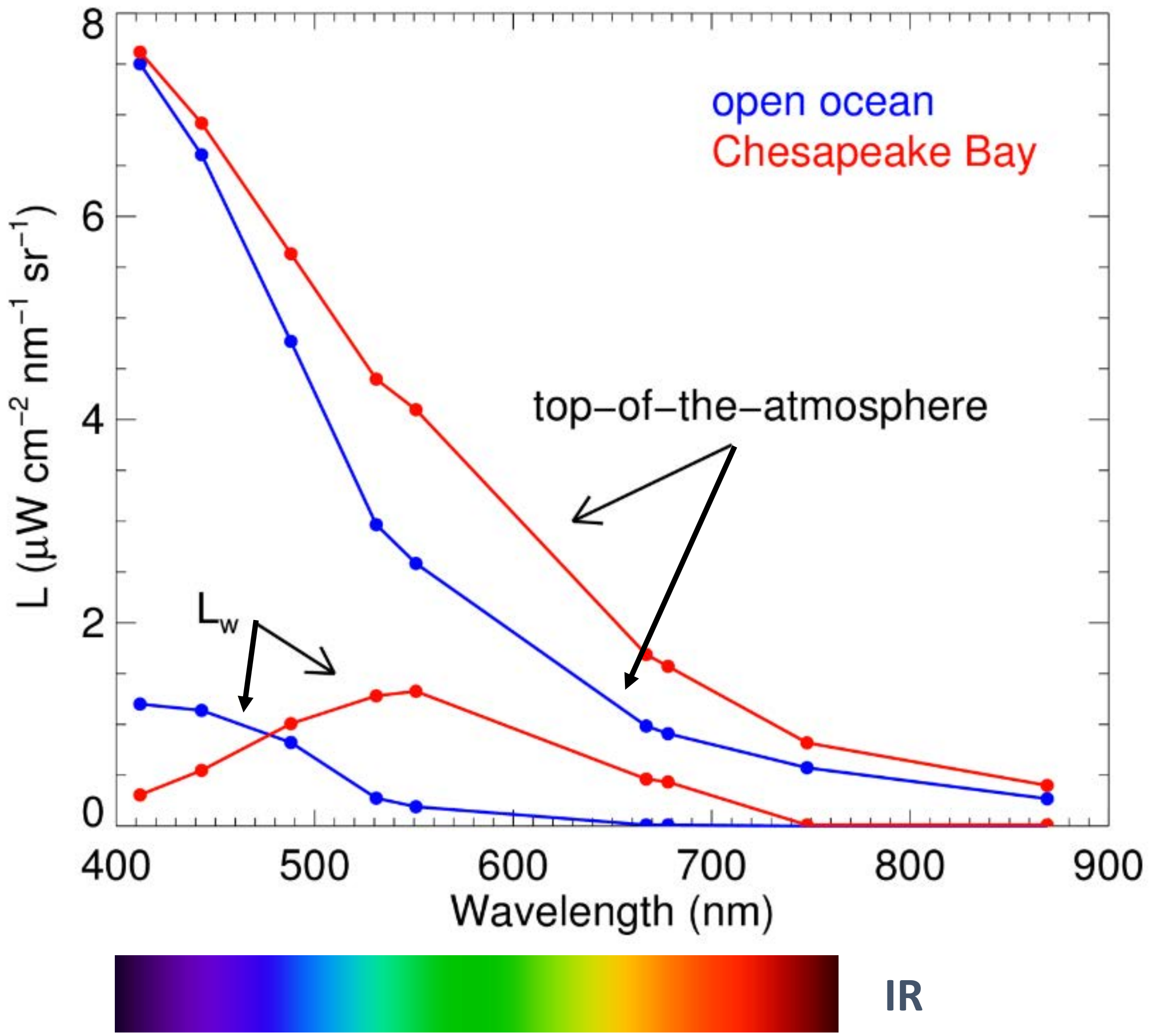
Chlorophyll Concentration and Reflectance

Reflectance is affected by the concentration of pigments in the water



Atmospheric correction



The water signal is often less than 10% of the total signal measured by the sensor

good atmospheric correction is critical

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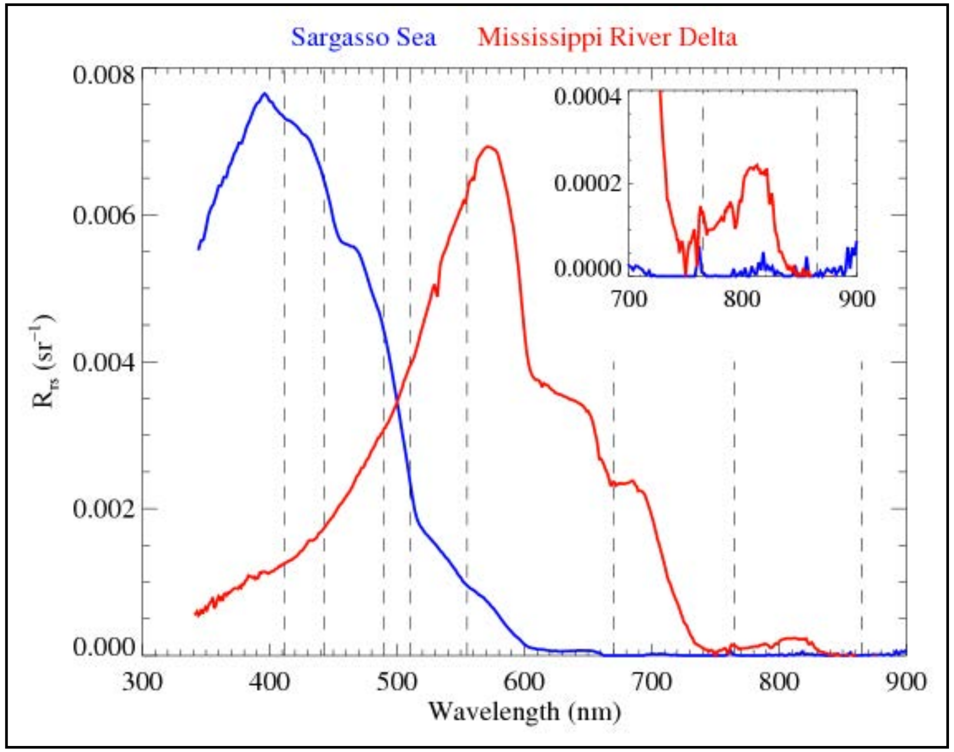
Case-1 versus Case-2 waters

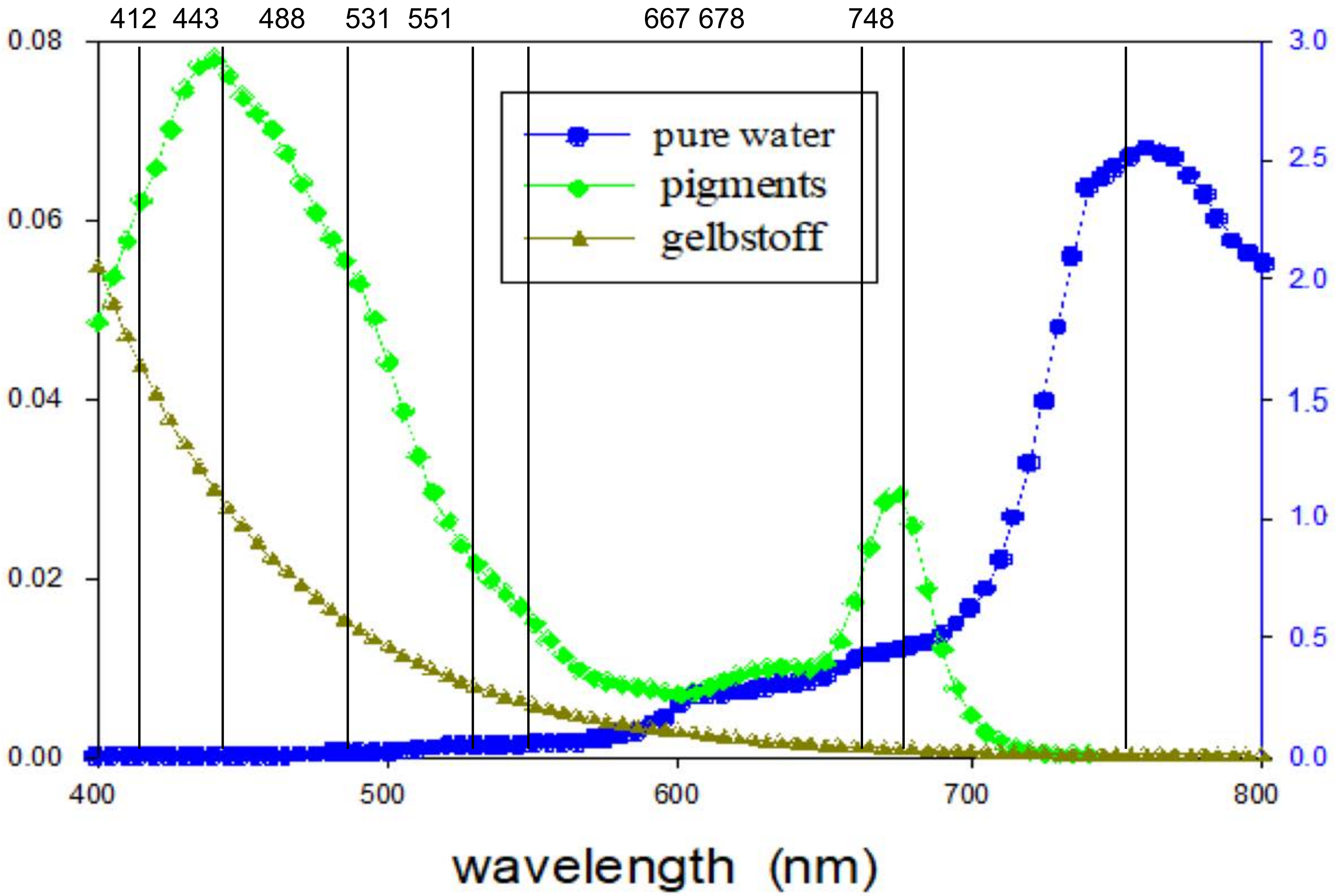
Case 1 (open ocean)
water where the optical properties are determined primarily by phytoplankton and their derivative products



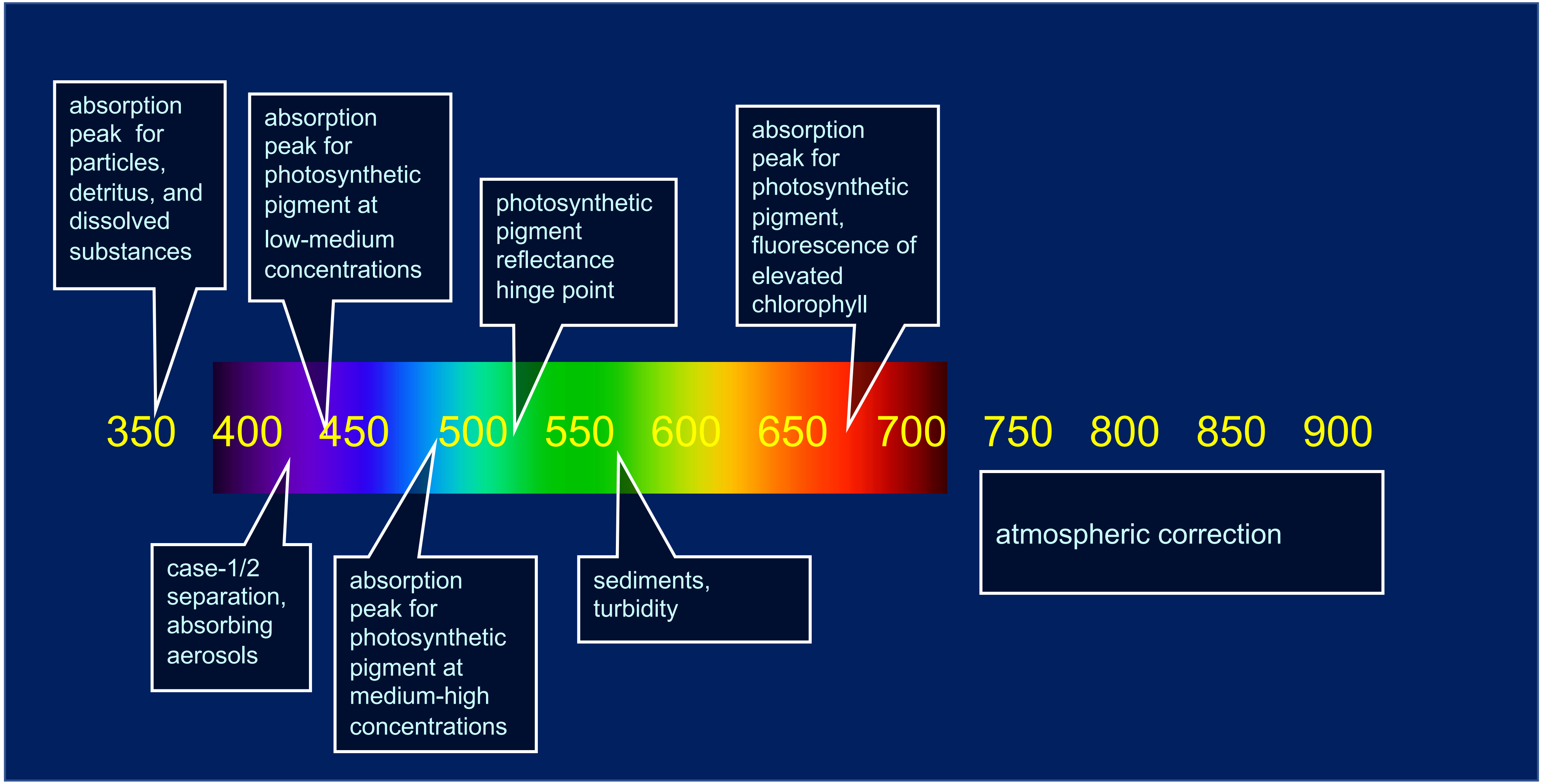
Case 2
everything else, namely water where the optical properties are significantly influenced by other constituents, such as mineral particles, CDOM, or microbubbles, whose concentrations do not covary with the phytoplankton concentration

Absorption Spectra and MODIS bands

SENSOR BANDS ARE CHOSEN TO TARGET SPECIFIC PEAKS IN ABSORPTION SPECTRA.



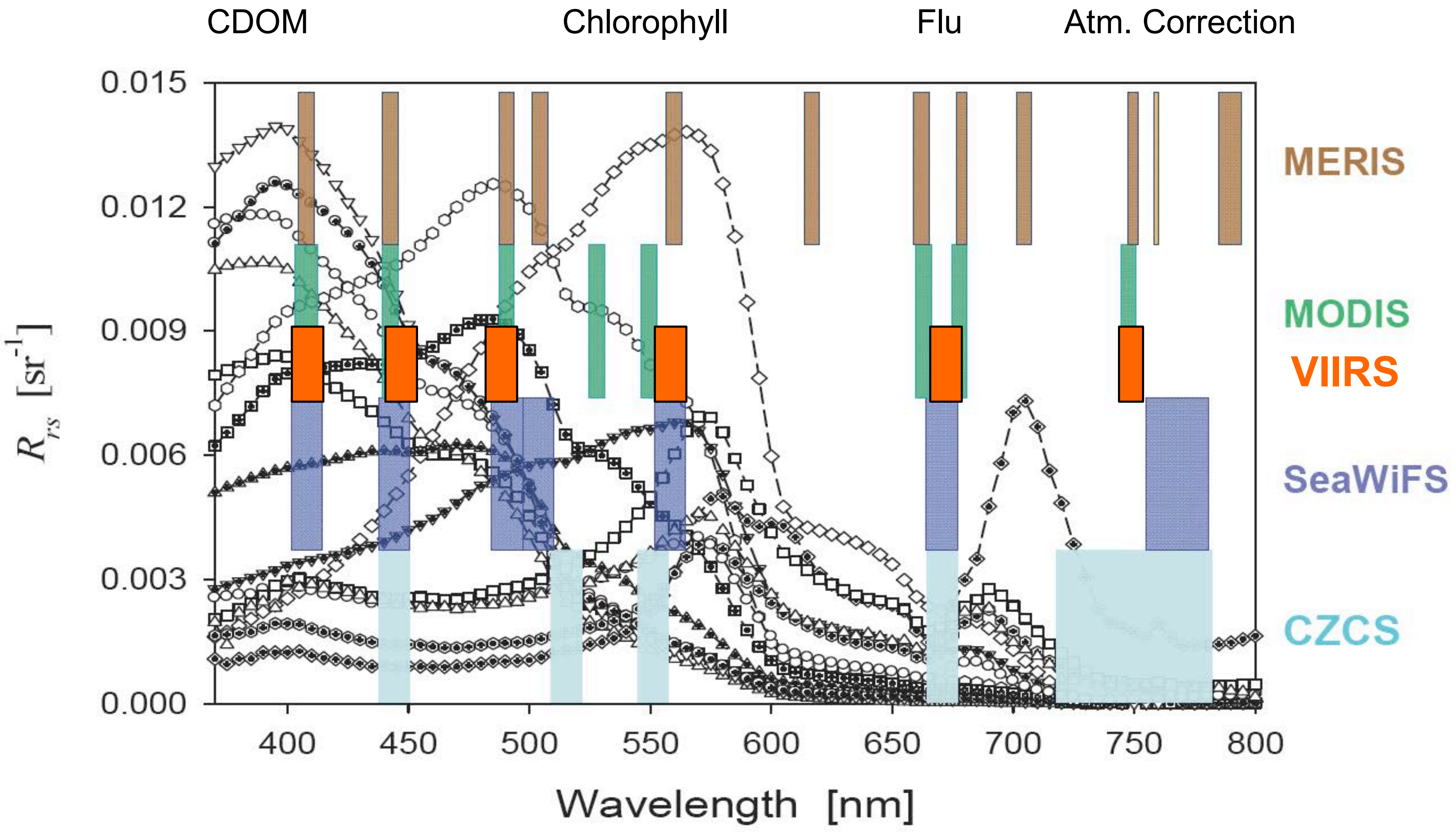
Spectral characteristics of oceanic waters



Sensor band comparison

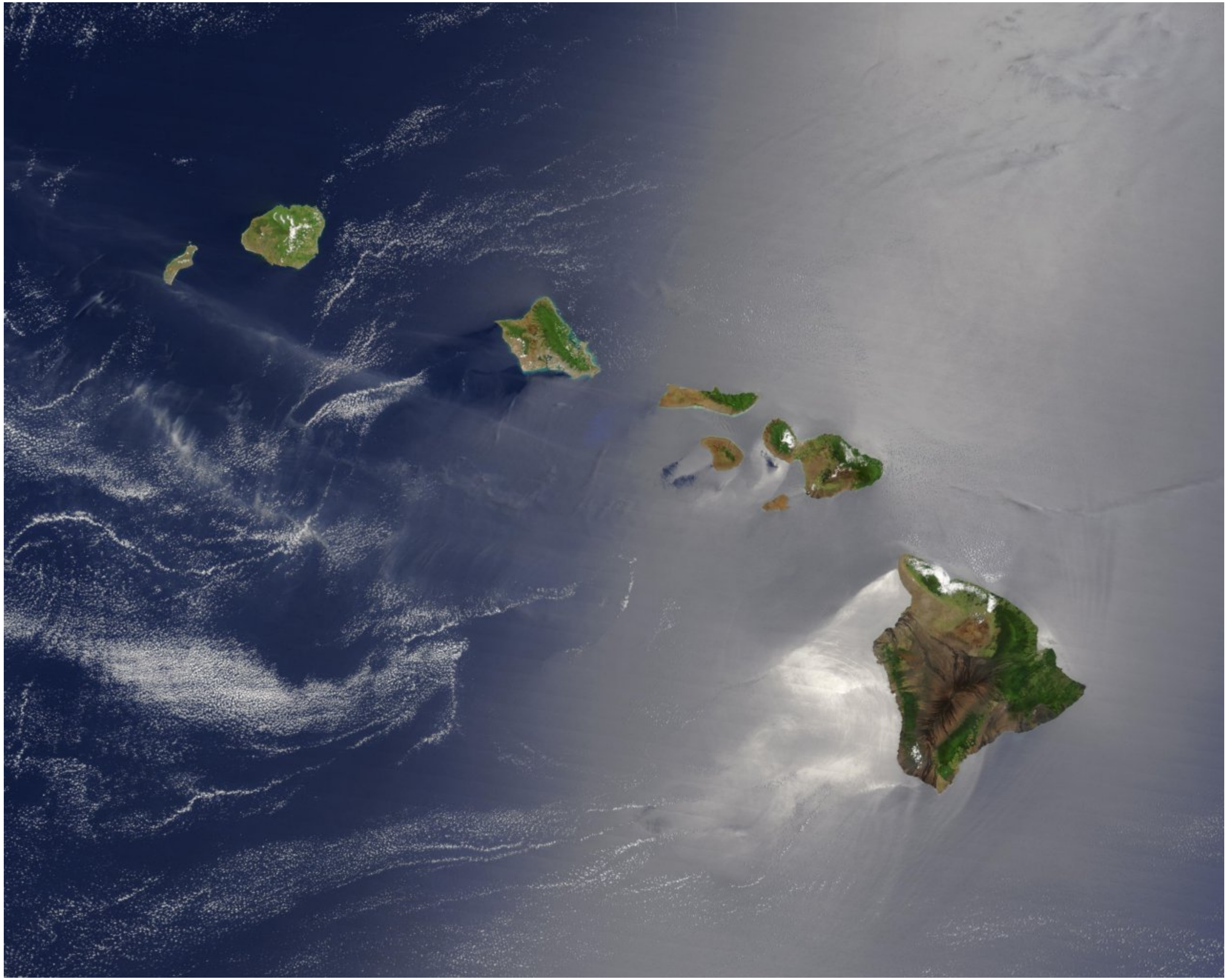
Examples of different measured spectral remote-sensing reflectance, overlain wit different sensor bands.

Modified from Lee et al. Sensors (2007).



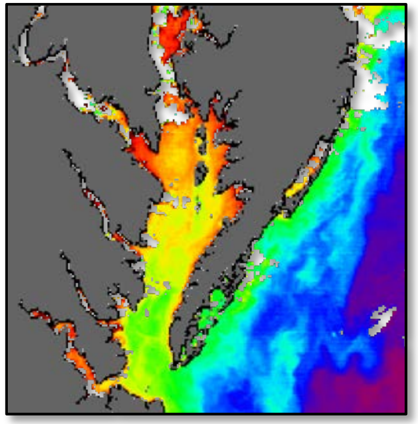
Sunglint

- Sunglint is the mirror reflection of sunlight off the sea surface.
- With strong sunglint the OC measurement can severely compromised, often impossible.
- However sunglint is very effective for detecting oil spills

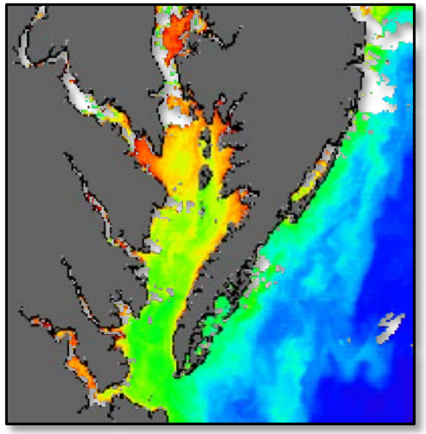


Ocean color data products

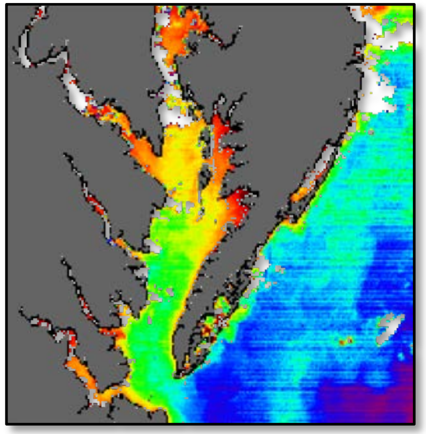
chlorophyll-a
(*algal biomass*)



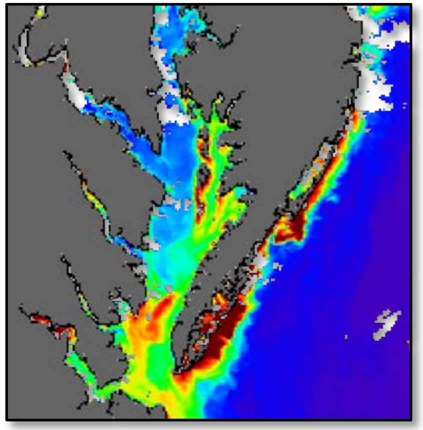
diffuse light
attenuation
(*water clarity, turbidity*)

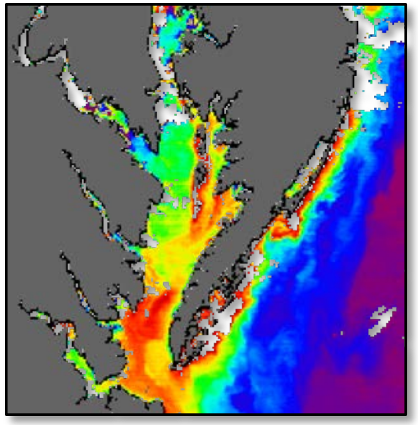


dissolved organic
matter absorption
(*runoff*)



red light reflectance
(*sediment load*)





particle backscattering
(*sediment load*)

and, many others, including:

- phytoplankton community composition (*including HABs*)
- particle size distributions (*water composition*)
- particulate (in)organic carbon (*productivity*)
- euphotic depth (*visibility, water clarity*)
- water temperature (MODIS, VIIRS)

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Kd490

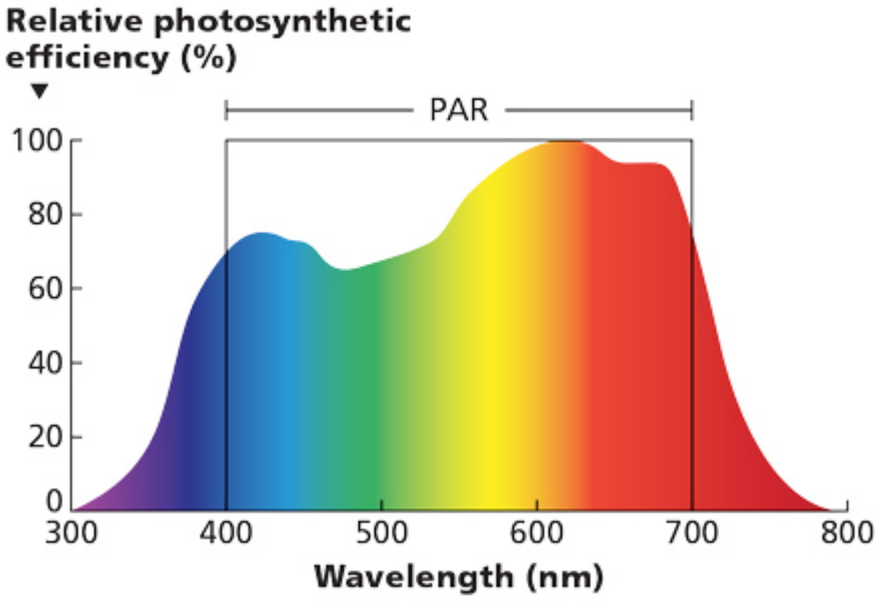
- The diffuse attenuation coefficient is a measure of the attenuation of light in the water column.

- Kd490 is an indicator of turbidity. Particles absorb in the blue, so when there are a lot of particles in the water the attenuation at 490 nm is greater,.

- Higher Kd490 value means smaller attenuation depth, and lower clarity of ocean water.

PAR

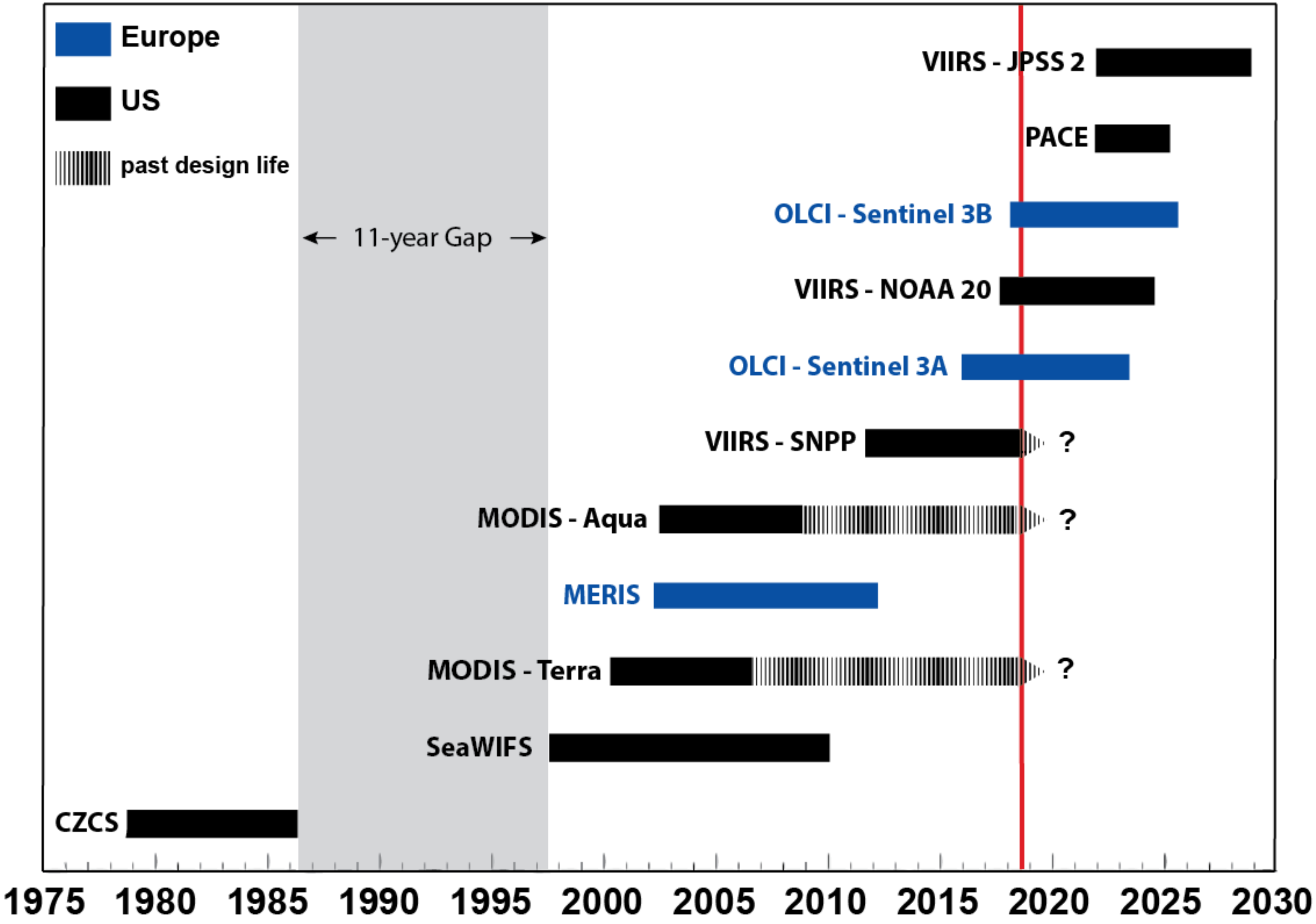
- Photosynthetically available radiation (PAR), is light from 400 to 700 nm, the range of wavelengths used in photosynthesis.
- With Kd490, surface PAR from satellites, and some assumptions, we can calculate PAR at depth
- PAR is a common input used in modeling marine primary productivity.



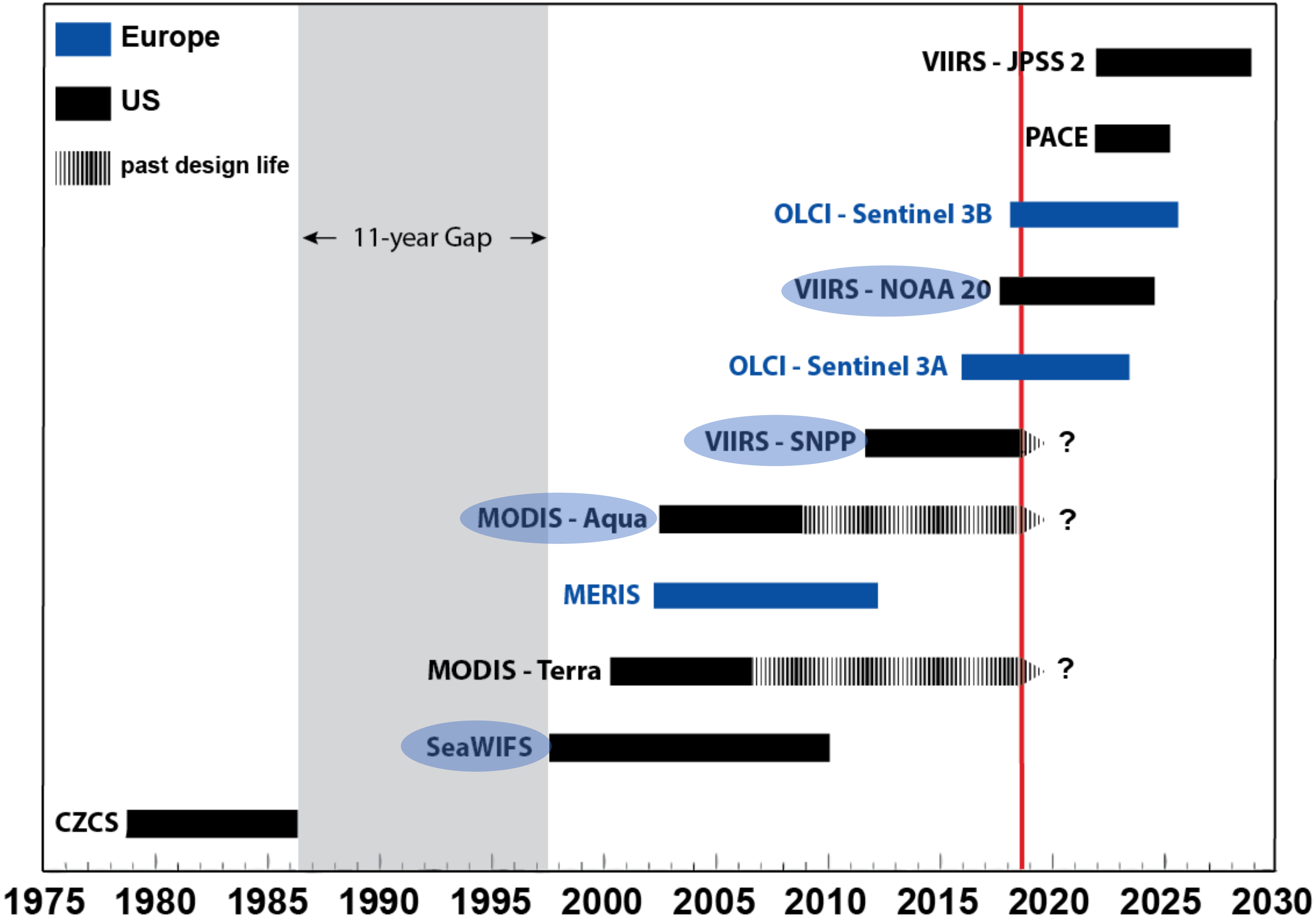
Primary Productivity (PP)

- Primary production is the rate of production of phytoplankton.
- PP can be estimated globally from satellite data using chlorophyll, PAR, SST and daylength.
- Many different models exist.
  http://www.science.oregonstate.edu/ocean.productivity/vgpm.model.php
  http://www.science.oregonstate.edu/ocean.productivity/references/L&O%201997a.pdf
  http://www.ifado.eu/wp-content/uploads/2018/08/Lobanova_etal_RemoteSensing_2018-1.pdf
- The PP products on the WCN ERDDAP use the Falkowski & Behrenfeld algorithm:
  https://coastwatch.pfeg.noaa.gov/erddap/search/index.html?page=1&itemsPerPage=1000&searchFor=Primary+productivity

Global Ocean Color Sensors



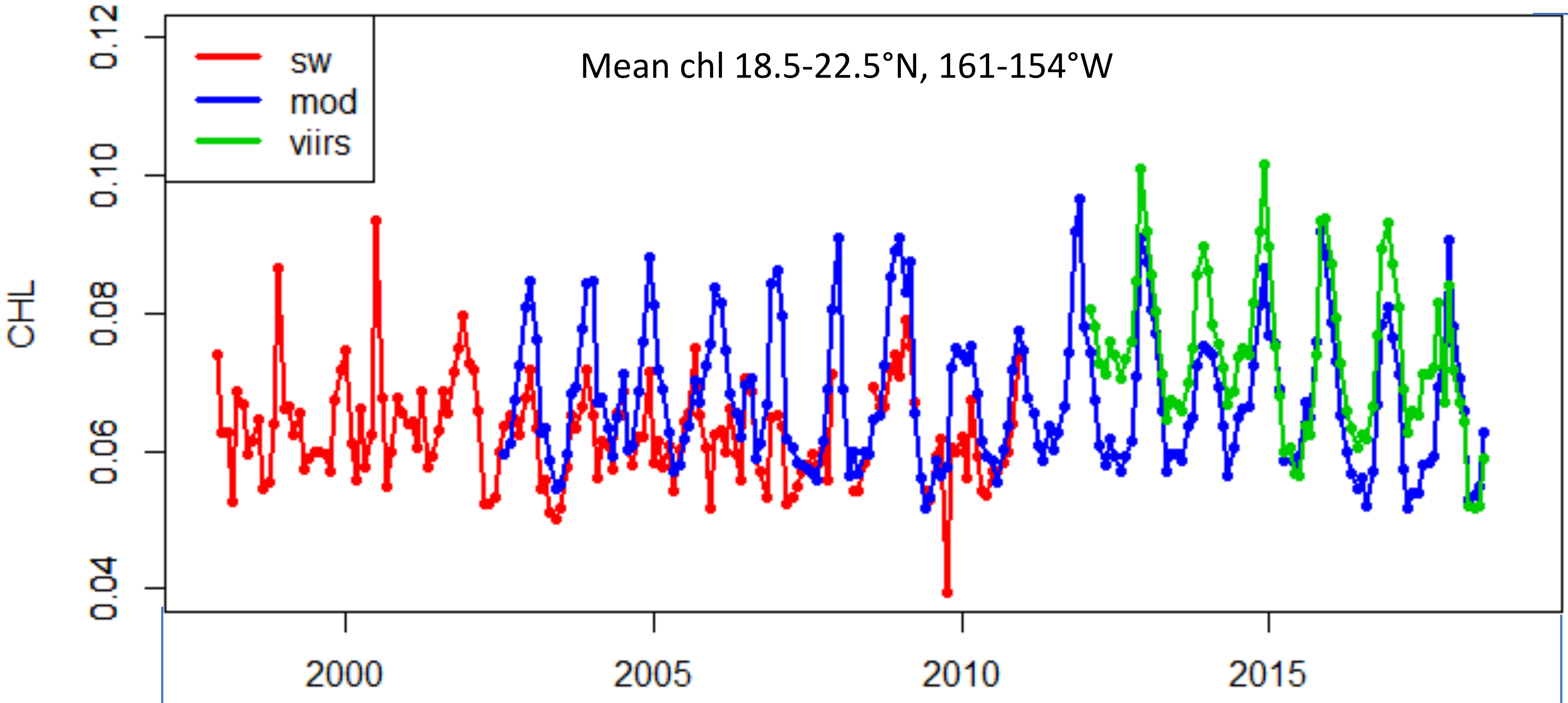
Global Ocean Color Sensors

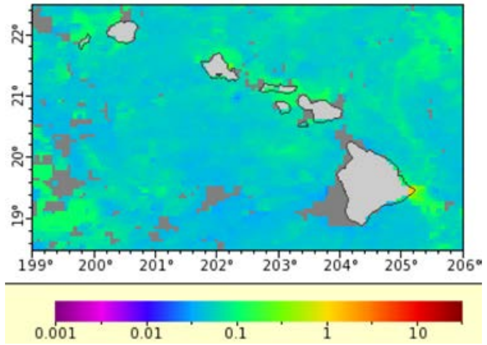


Blended Ocean Color dataset: ESA CCI dataset

- European Space Agency's Climate Change Initiative (CCI) produces merged satellite products for assessing long-term trends.
- Merged MERIS, Aqua-MODIS, SeaWiFS and VIIRS data with associated per-pixel uncertainties
- Date from 1997 through 2018.
- Daily, weekly & monthly data are available the WCN ERDDAP

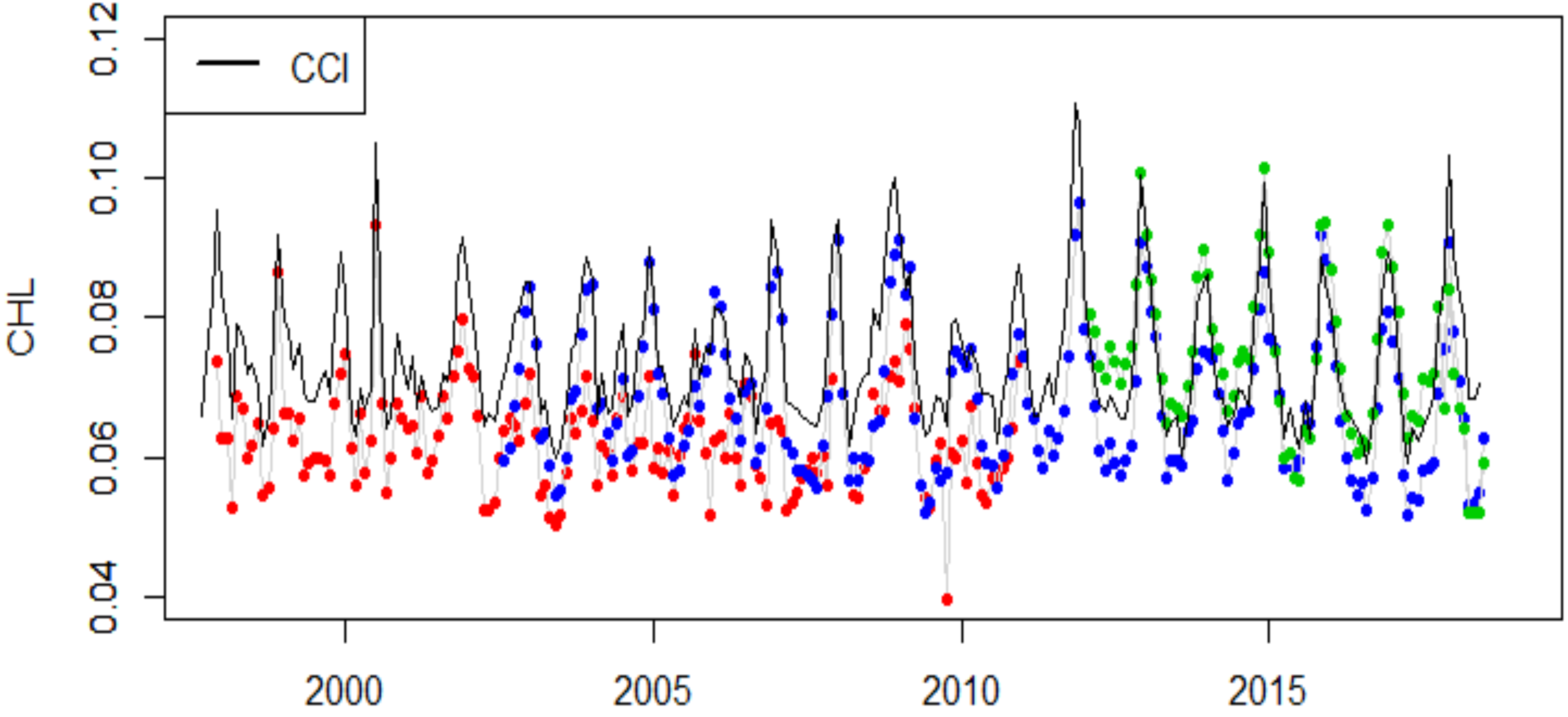
Looking at OC time-series

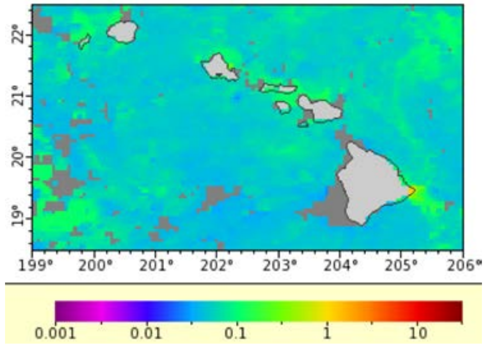




Different sensors don't always match during their periods of overlap, making it challenging to study long-term trends.

Time-series of ESA CCI Dataset



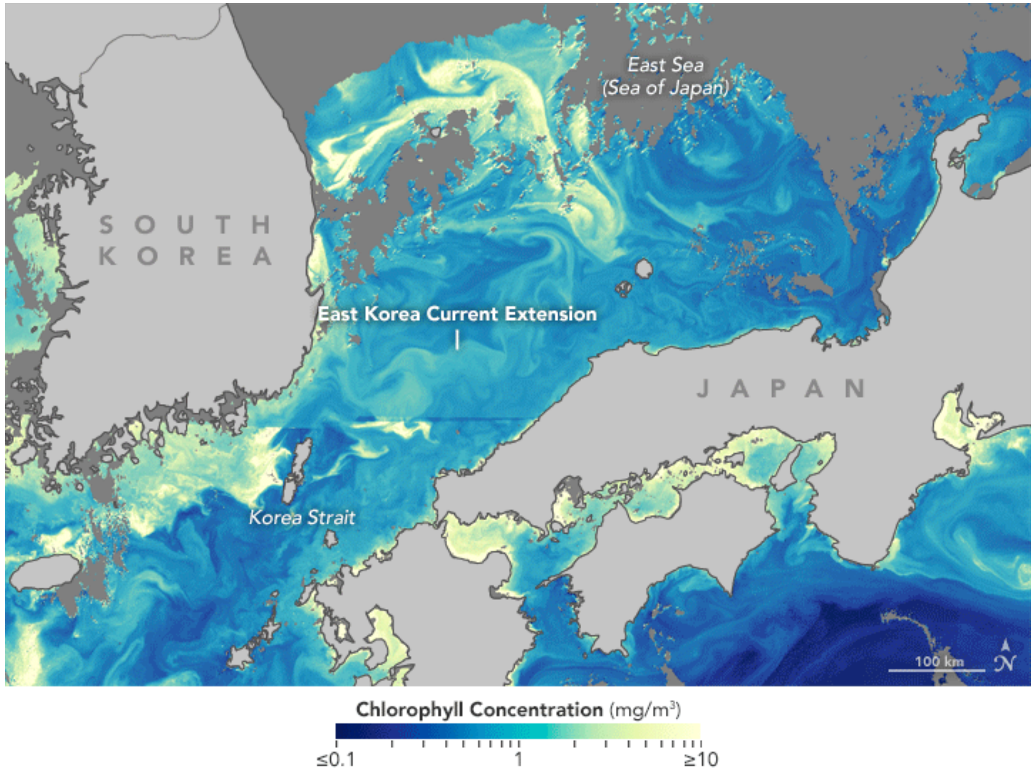


With the ESA CCI dataset overlain

Geostationary Ocean Color Sensors

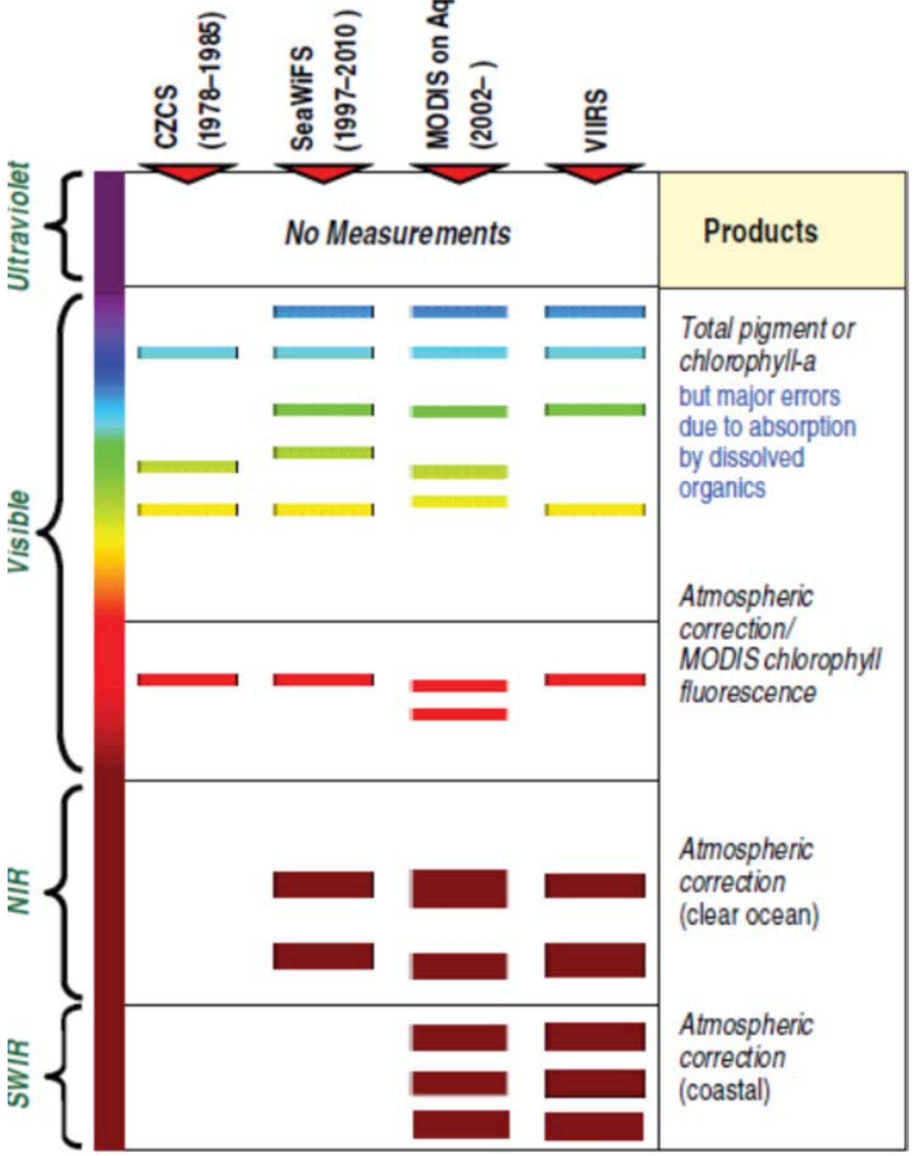
- Almost all of the OC sensors are on polar-orbiting satellites, providing one observation per day, if there are no clouds.
- GOCI is the only geo-stationary OC sensor operating. S. Korea launched it in 2010, and it only observes the region around S. Korea.
- In the US, GLIMR (Geosynchronous Littoral Imaging and Monitoring Radiometer) is planned for 2027.

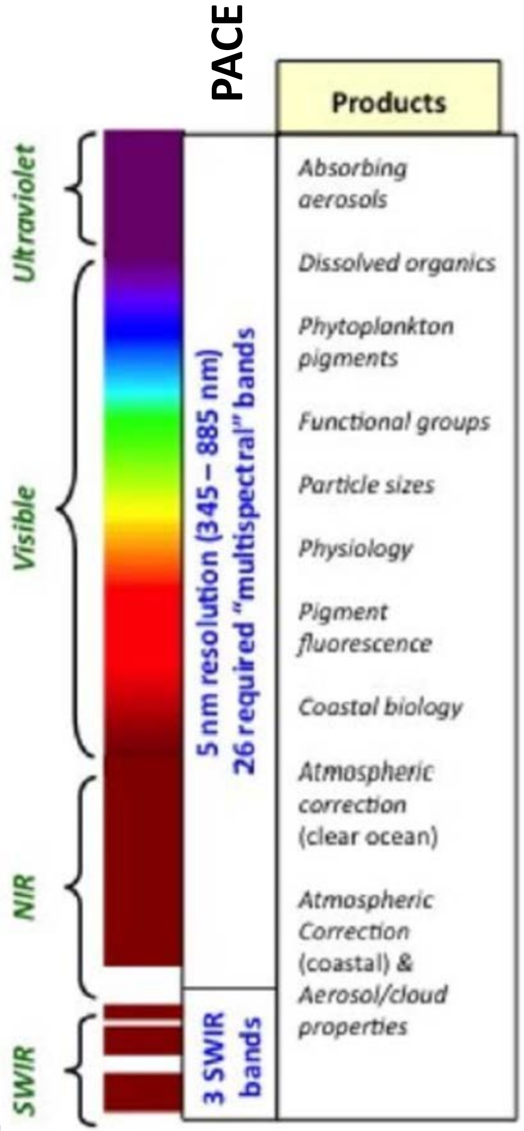
A Day in the East Korea Current, from GOCI



May 12, 2016
https://earthobservatory.nasa.gov

Towards hyperspectral sensors





2022 ?

Ocean Color Summary

- Measurements are made in the visible portion of the spectrum and can not be made through clouds or at night.
- **Atmospheric correction is extremely important!**
- There are a suite of products measured by "ocean color" satellites. Chlorophyll is the most commonly used product, other derived products include CDOM (Colored Dissolved Organic Matter), primary productivity, water clarity, fluorescence, and Photosynthetically Available Radiation (PAR), among others.
- Algorithms were developed for Case-1 (open ocean) waters. Care must be taken when using data from Case-2 (coastal) waters.
- The most recently launched U.S. OC sensor is VIIRS, a joint NASA/NOAA mission launched Oct. 2011 (SNPP) and Nov 2017 (NOAA-20).
- Primary satellites: SeaWiFS (1997-2010), MODIS/Aqua (2002➔), and VIIRS (2011➔)
- European satellites MERIS (2002-2012), OLCI (April 2016-present)