Time	Agenda
09:30 – 11:00	Introduction to course and PML remote sensing group
11:00 – 11:30	**Coffee break**
11:30 – 13:00	Intro to EO and choosing the right data for your application
13:00 – 14:00	**Lunch break**
14:00 – 15:30	Introduction to the satellites and EO for coastal ecosystems EO for debris detection
15:30 – 16:00	**Coffee break**
16:00 – 17:30	Introduction to MAGEO Data access and plotting practical

PML | Plymouth Marine Laboratory

Research excellence supporting a sustainable ocean

Introduction to the satellites

PORTWIMS

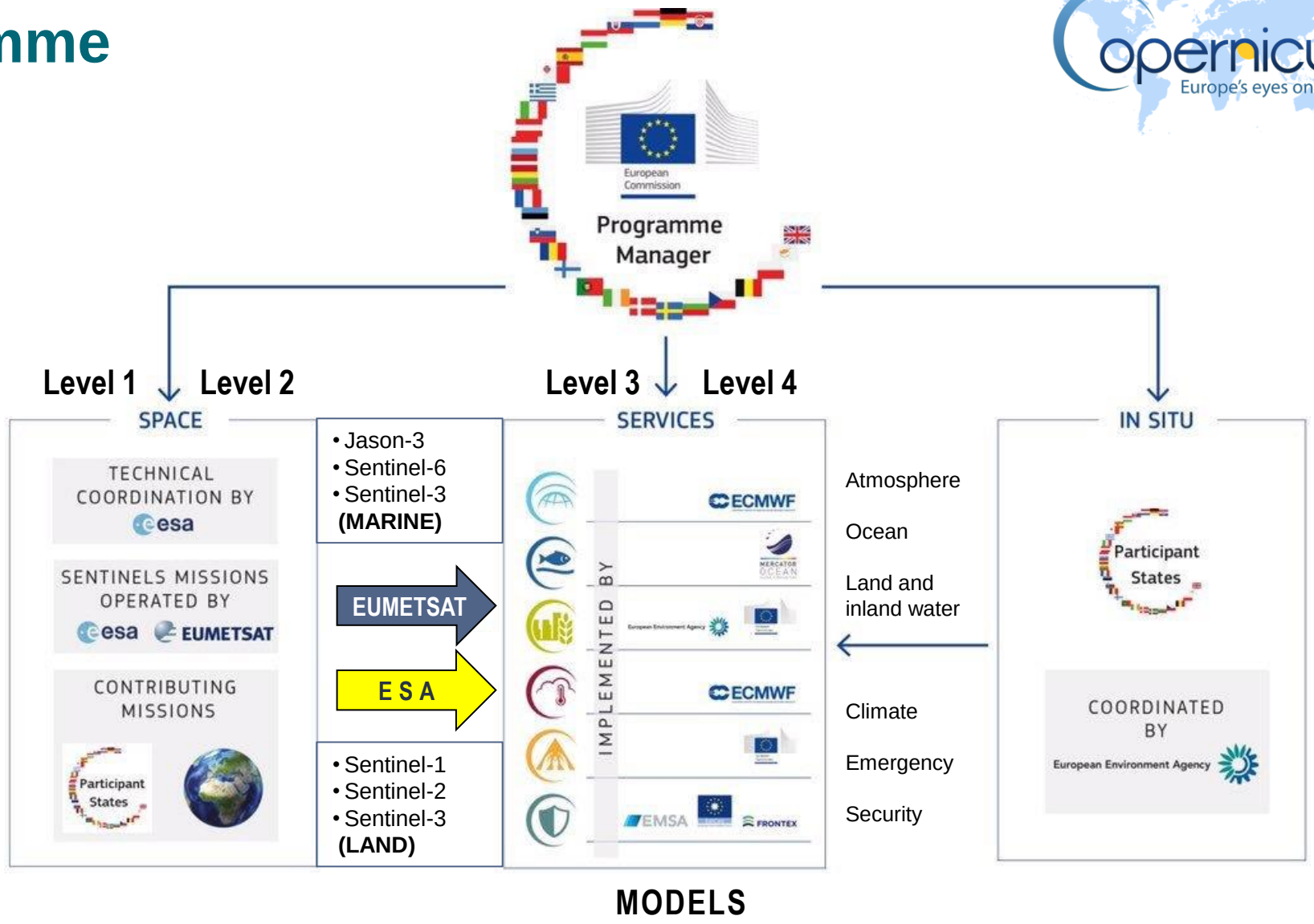
Introduction

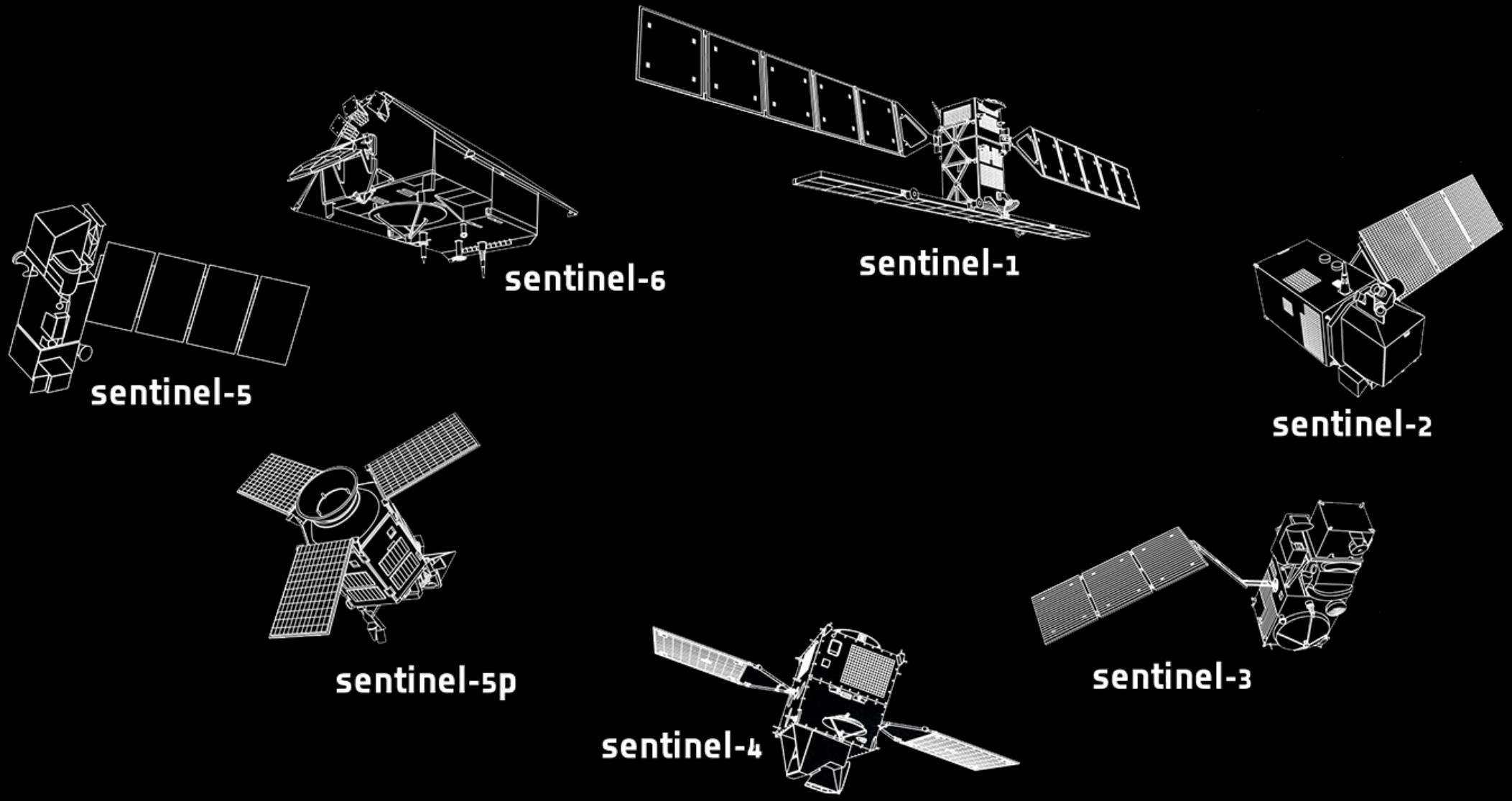
- This session will introduce a few satellites and sensors in more detail
  - Sentinels 1, 2 & 3
  - Landsat
- Applications to study coastal ecosystems

Bazaruto Island from Sentinel 2

Copernicus Programme

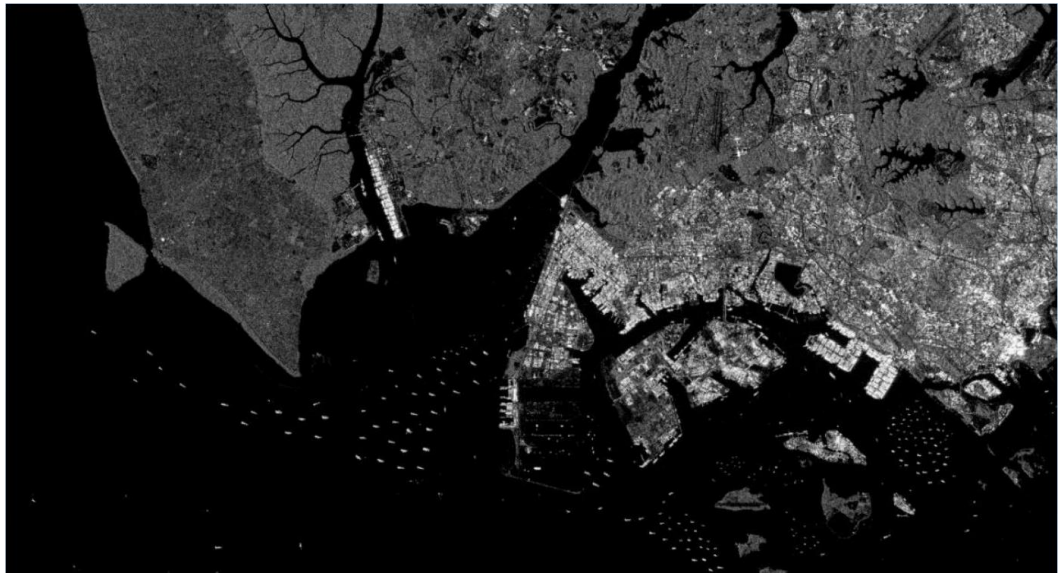
- European Union's Earth observation program
- Funded and managed by the European Commission




sentinel-6
sentinel-1
sentinel-5
sentinel-2
sentinel-5p
sentinel-3
sentinel-4

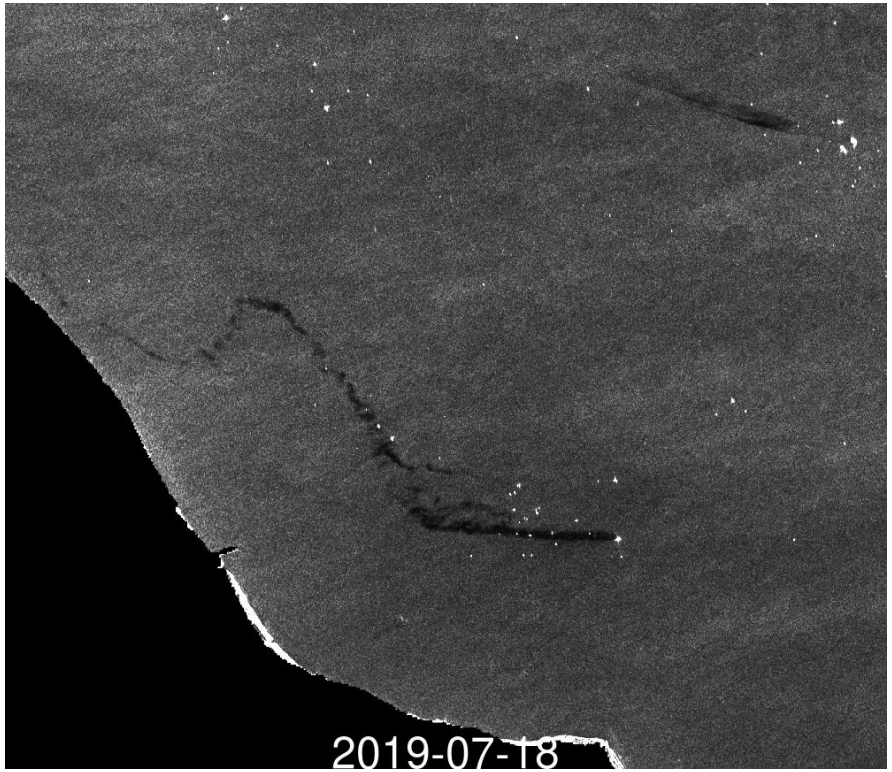
Sentinel-1

- C-band synthetic-aperture radar (SAR) instrument
- Active sensor measuring radar backscatter
- Resolution depends on acquisition mode
- Sentinel-1A launched in April 2014, Sentinel-1B launched in April 2016.
- Image every ~~6 days~~ 12 days
- Applications: land use, deforestation, oil spill detection, wind/wave information, iceberg tracking, shipping and offshore infrastructure, emergency response



Sentinel-1 for marine monitoring:

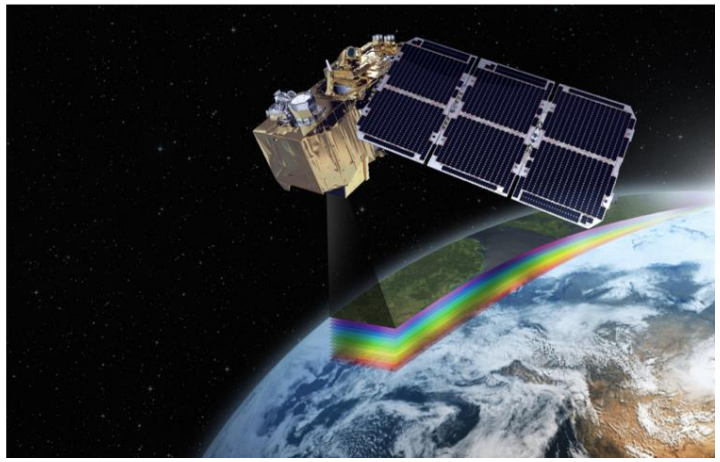
- **Oil spill detection and polluter identification** – illegal discharges of oil are visible in SAR imagery as characteristic dark features.
- **Wind / wave information** – vital for maritime safety and rescue operations, measurements can be extracted directly from SAR surface roughness.
- **Sea-ice and iceberg monitoring** – covers safety of shipping / offshore operations, climate monitoring, and polar species habitat monitoring.

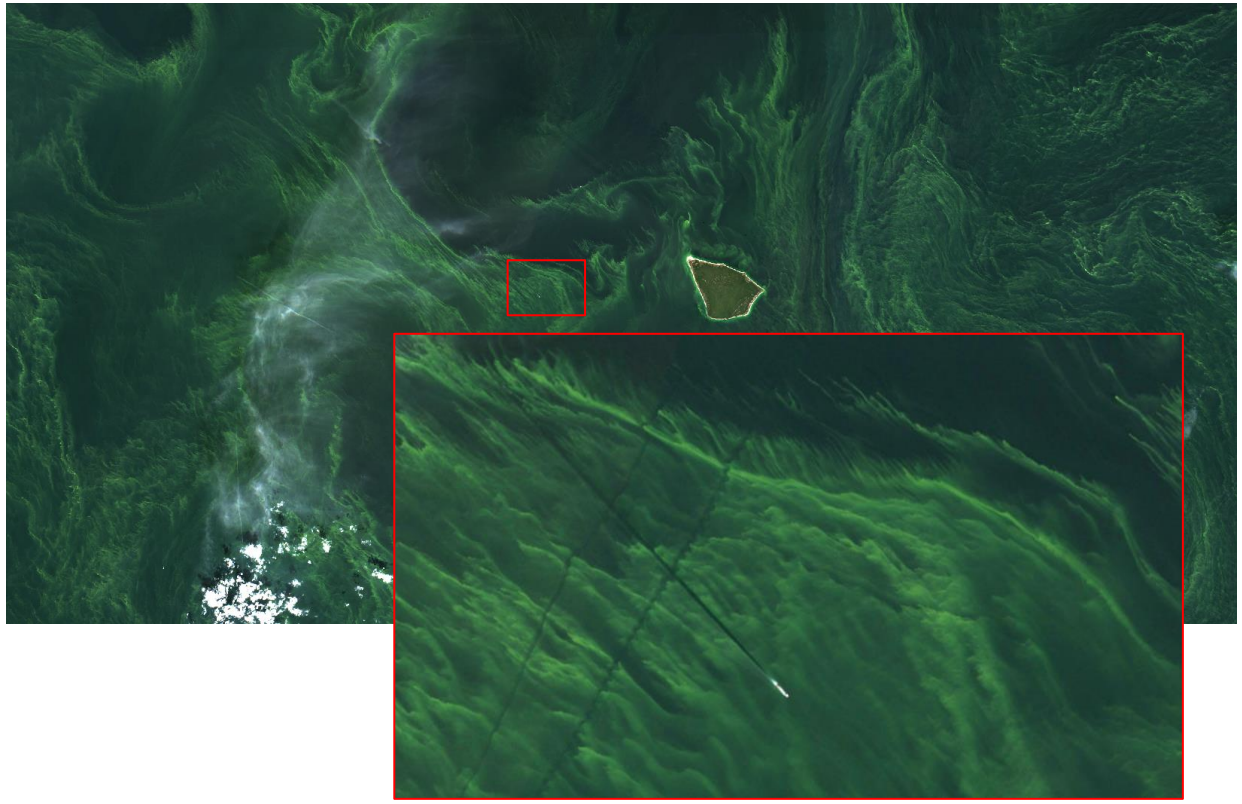


Images of an oil spill off Indonesia from Sentinel 1 SAR

Sentinel-2

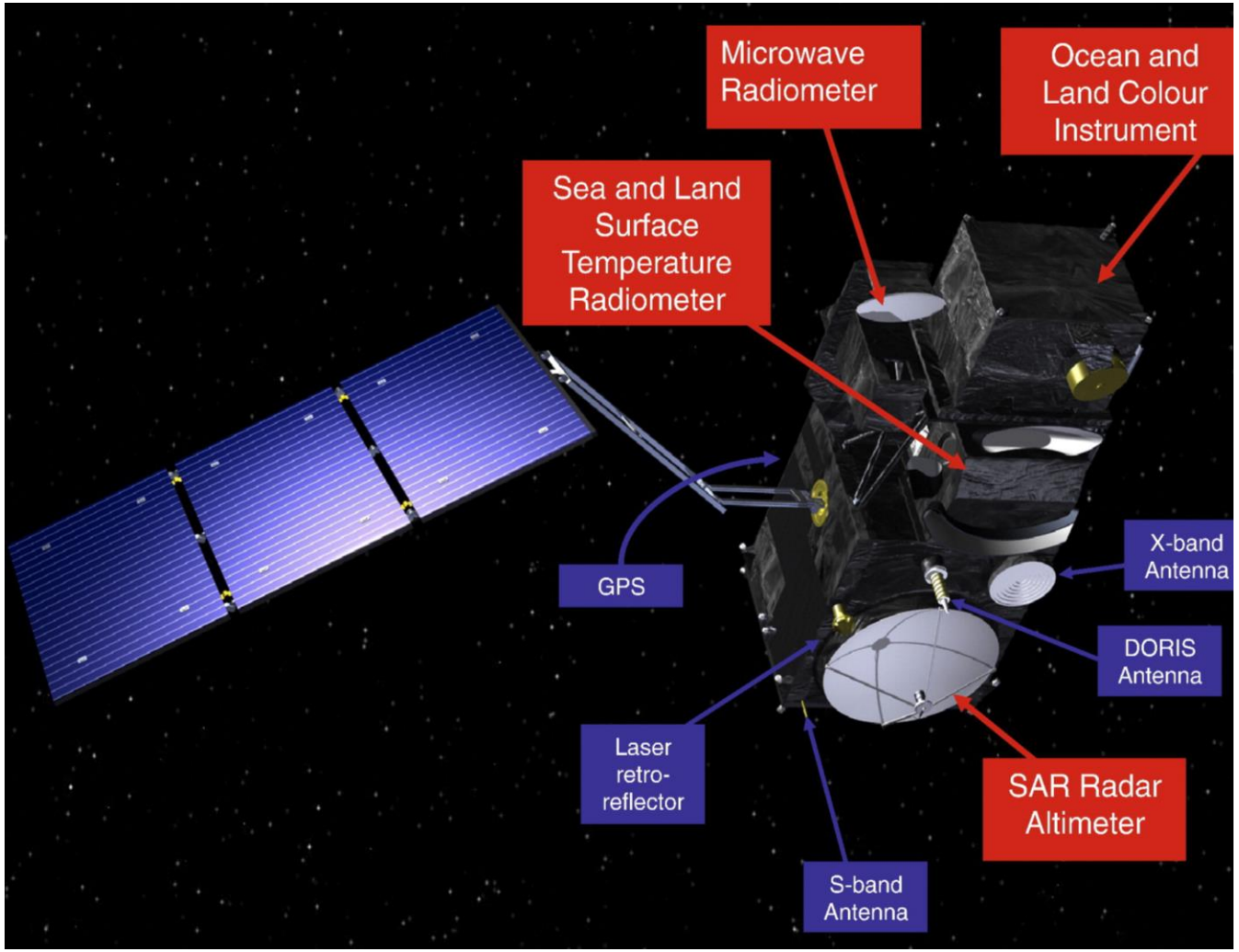
- Multi-Spectral Instrument (MSI) – passive optical sensor (resolution 10 m, 20 m and 60 m, 13 spectral bands)
- Passive sensor observing visible, NIR, SWIR
- Sentinel-2A was launched 2015, Sentinel-2B was launched in 2017
- Image every 5 days
- Applications: land and agriculture monitoring, land cover classification, emergency management, water quality and floating debris.





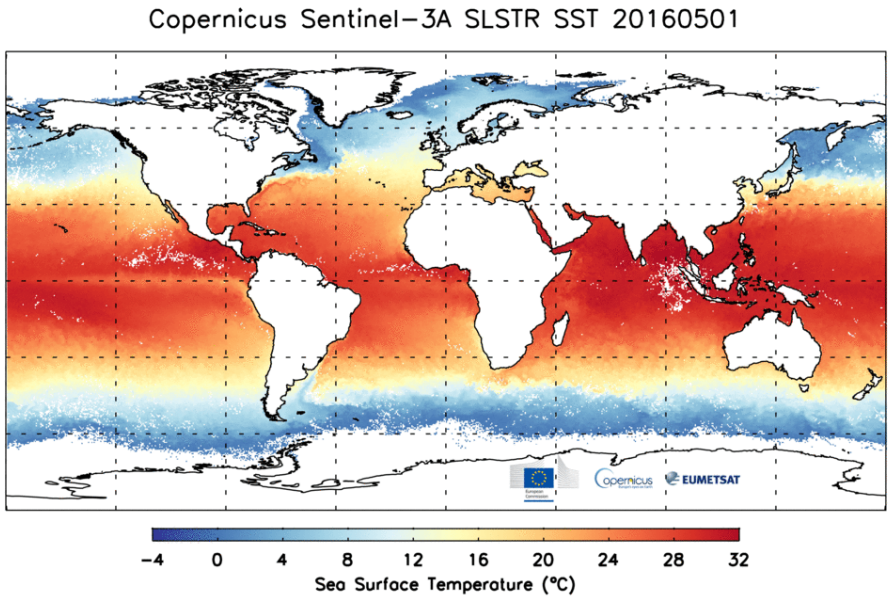
Sentinel-3

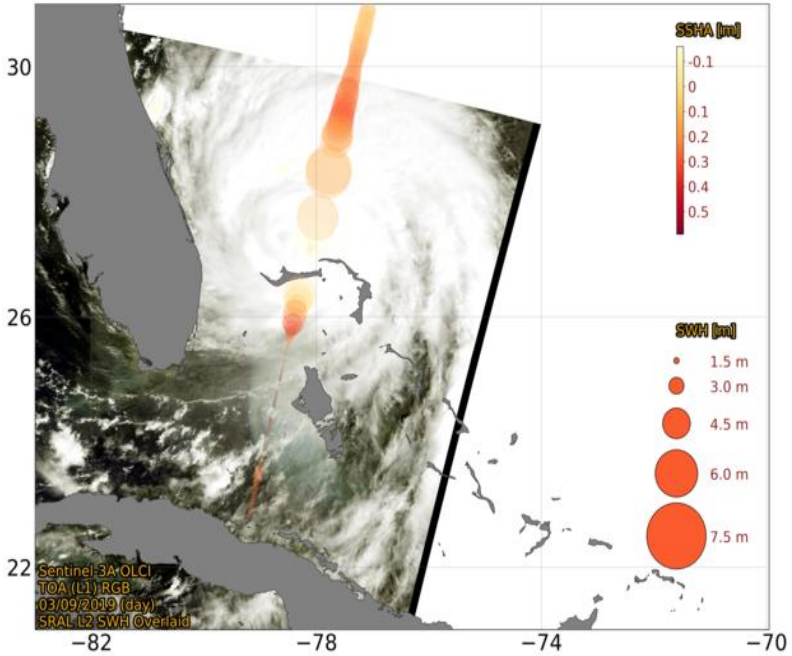
- Marine mission – the ‘Blue’ Sentinel
- Mix of passive and active sensors
- Sentinel-3A launched Feb 2016, Sentinel-3B launched in April 2018.
- EUMETSAT operates the Sentinel-3 satellites
- 3 ocean observing instruments: OLCI, SLSTR and SRAL

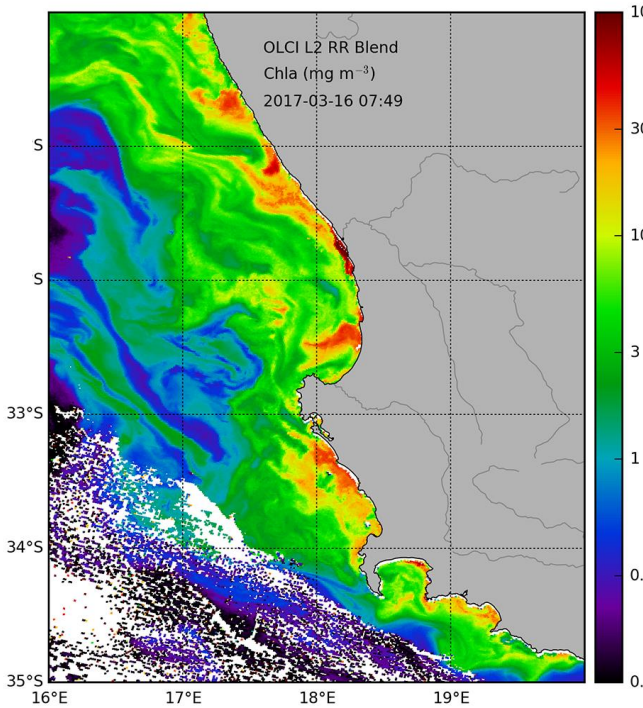


Sentinel-3

- SLSTR (SST)
  - Passive IR radiometer
  - Applications: land and sea surface (skin) temperature
- OLCI (Ocean Colour)
  - passive optical sensor (300m full resolution (FR) granules, 1km reduced resolution (RR), good signal to noise ratio)
  - 21 bands in visible to SWIR
  - Applications: Chlorophyll-a (phytoplankton), harmful algal blooms, suspended sediment concentration
- SRAL (Altimetry)
  - Active Radar altimeter
  - Applications: Sea surface height, wave height, tides, ocean currents, sea ice, eddies

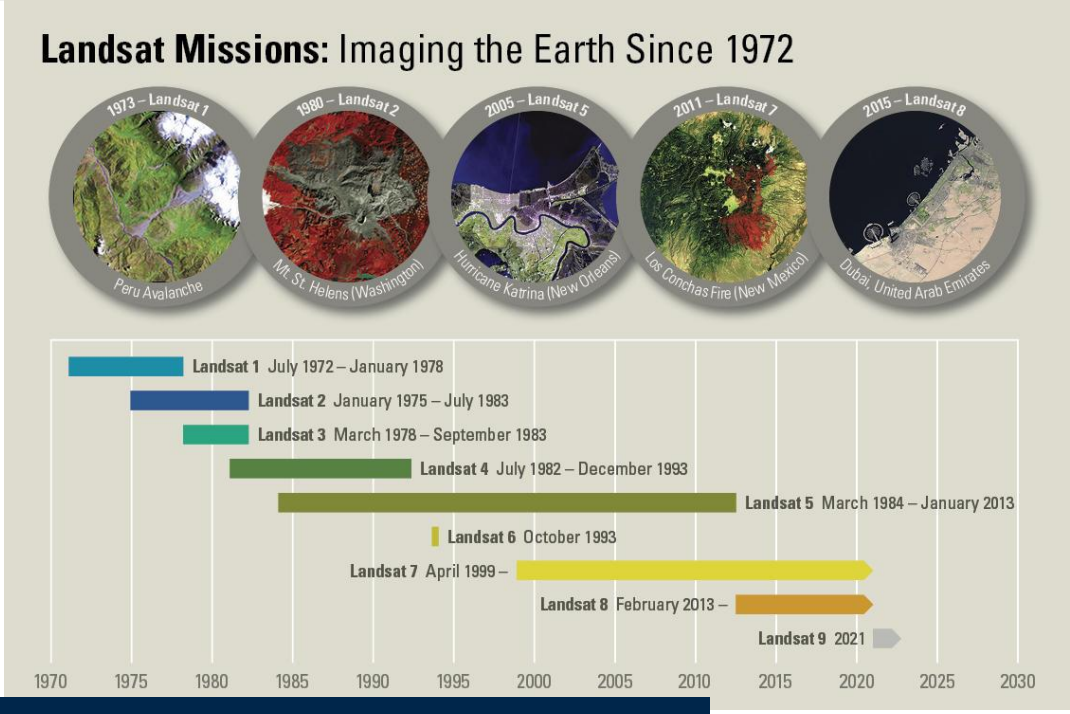


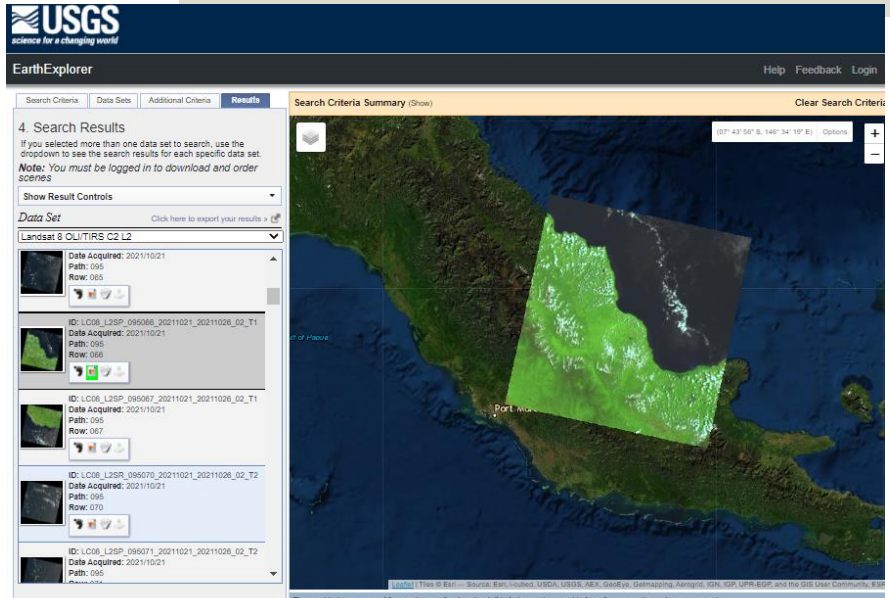




Landsat programme

- Series of missions (Landsat 1 to Landsat 9) jointly led by USGS and NASA
- Longest-running series of satellites for moderate-resolution optical remote sensing of earth
- Passive sensor observing visible, NIR, SWIR (30 m resolution, 11 spectral bands)
- Image every 16 days (8 days with Landsat 8 & 9)
- Applications: Land cover change monitoring, drought, fire, urbanization.
- USGS EarthExplorer - https://earthexplorer.usgs.gov/





Remote sensing of coastal ecosystems

- Healthy coastal environments are important reservoirs of biodiversity and support human livelihoods and wellbeing.
- Remote sensing is a cost-effective method for collecting environmental data on a range of spatial scales.

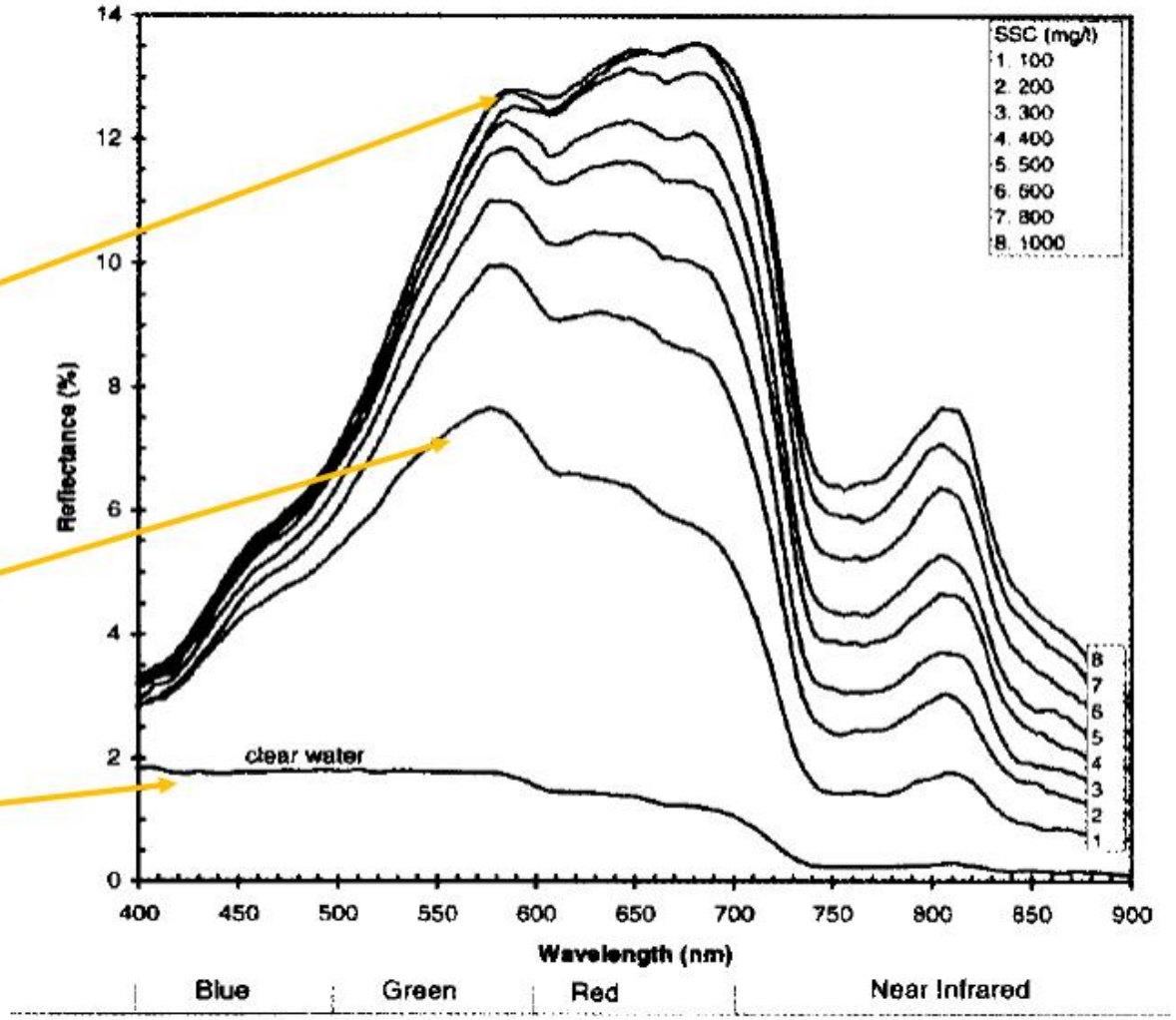
What does the colour of the water tell us?

- Ocean colour provides information on substances within the water that alter the absorption and reflection of light.
  - Chlorophyll
  - Sediments
  - Coloured dissolved organic matter (CDOM)

Figure courtesy of Trevor Platt

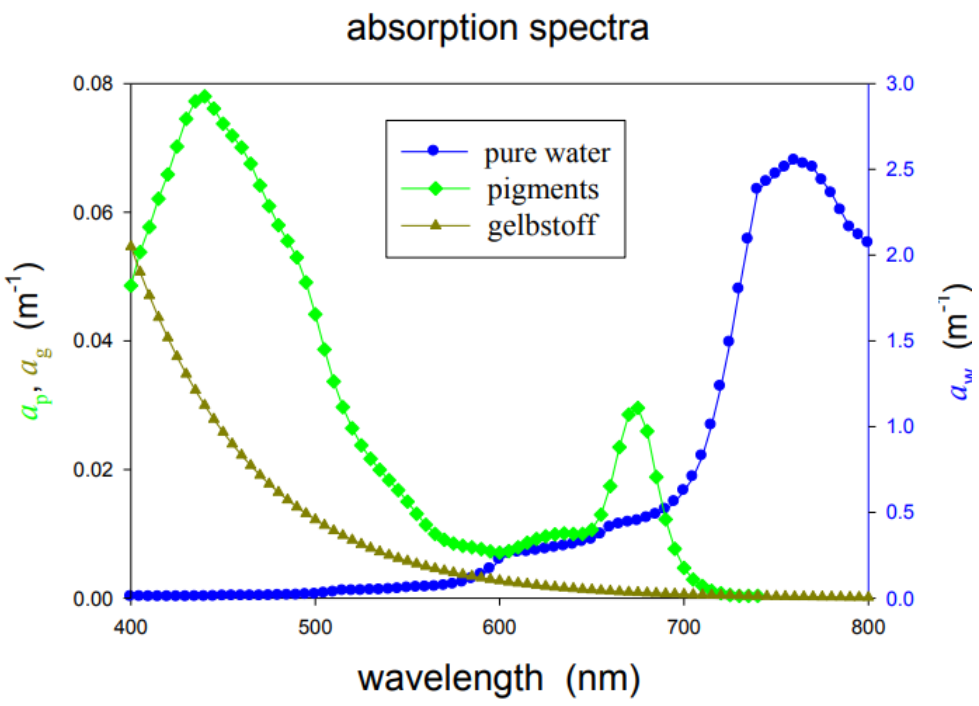
- Suspended sediment usually has a strong reflectance in the yellow-red and NIR
- But this is impacted by sediment type and composition…

IKONOS image Añasco River plume (West Coast PR). Credit: Univ. PR Bio-optical Oceanography Lab

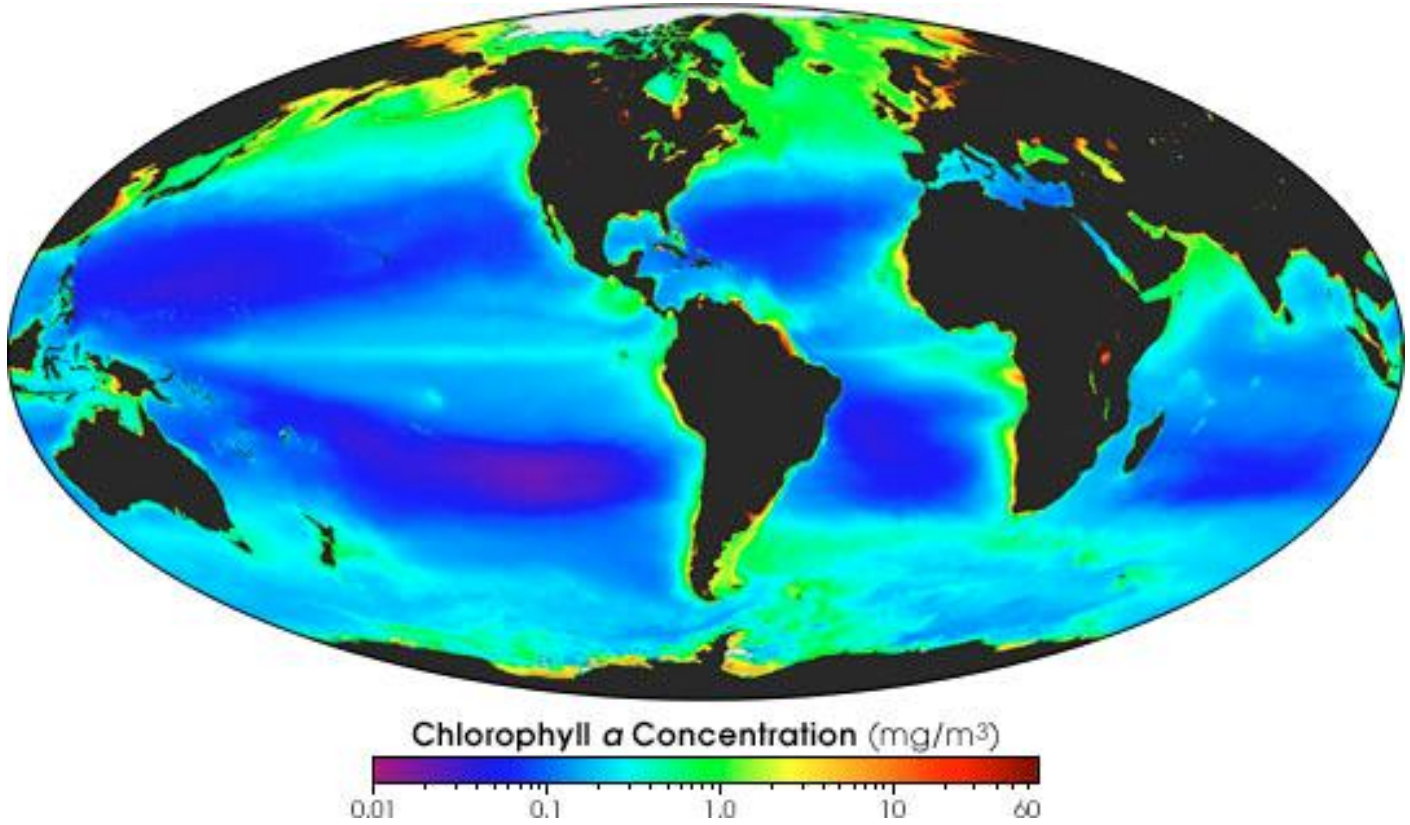


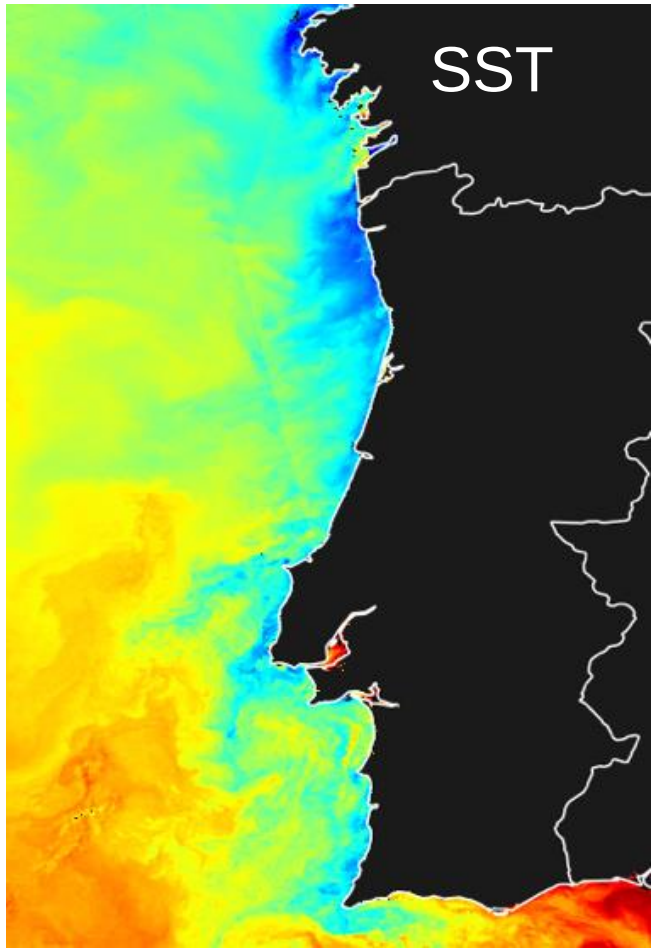
From Lodhi et al. 1998

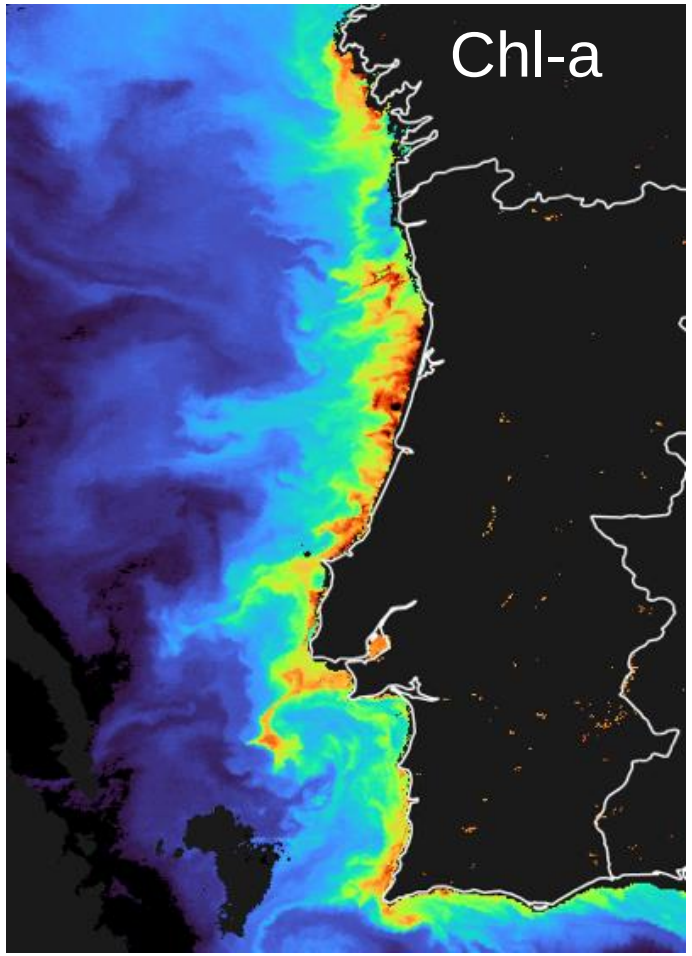
Global maps show productive coastal waters and ocean “deserts”



Credit: Univ. PR Bio-optical Oceanography Lab



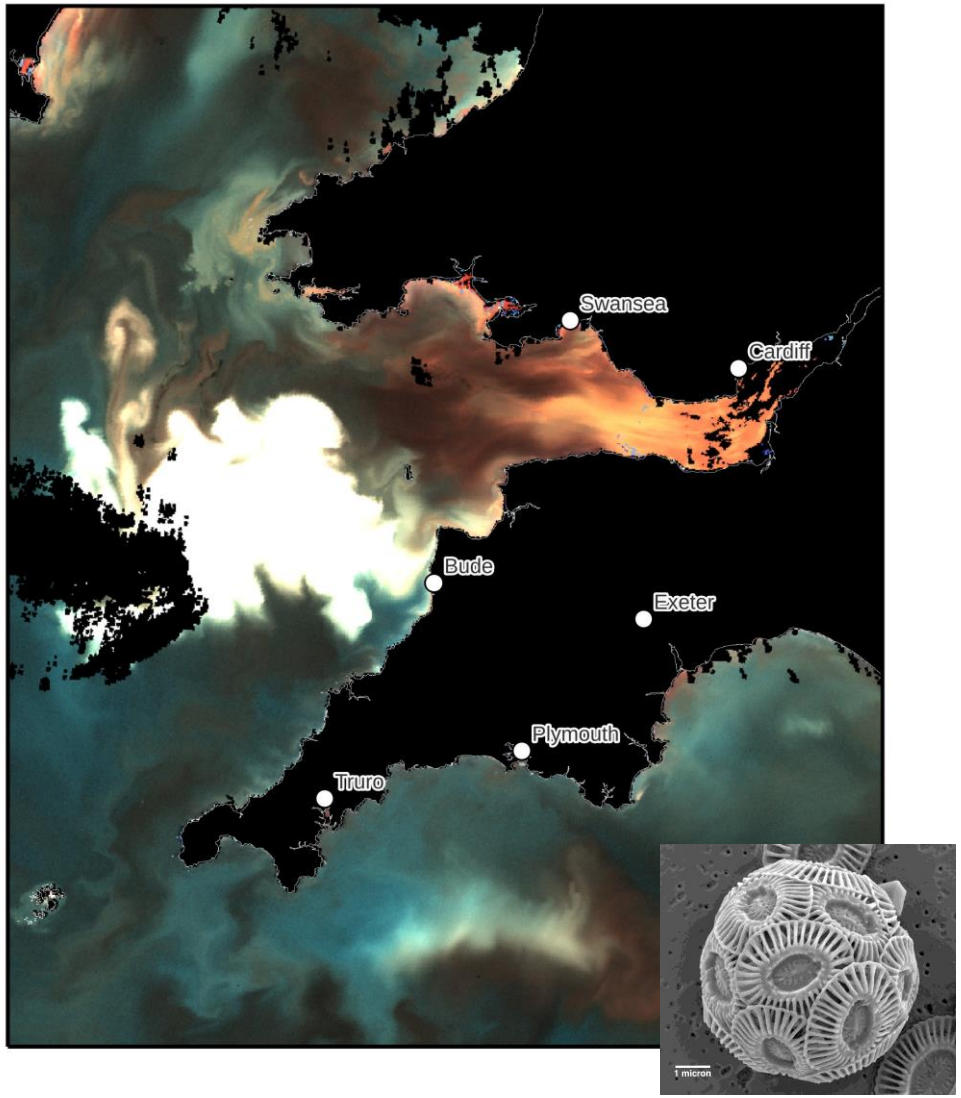




Sentinel 3 chl-a and SST west of Spain/Portugal

Upwelling brings cooler/deeper waters to the surface with high nutrients supports higher levels of phytoplankton

NRT Sentinel 3a OLCI, enhanced ocean colour
2022-05-28 - 2022-05-28
Processed by NEODAAS

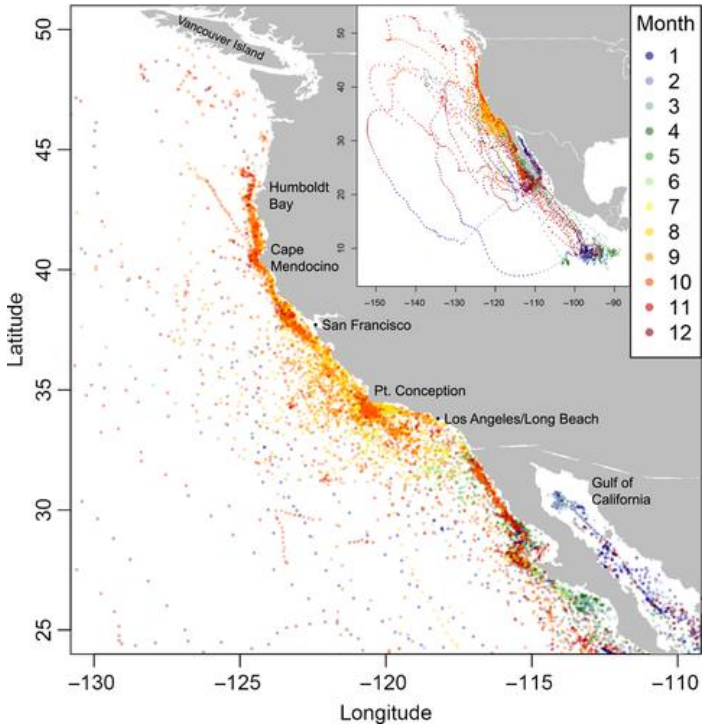


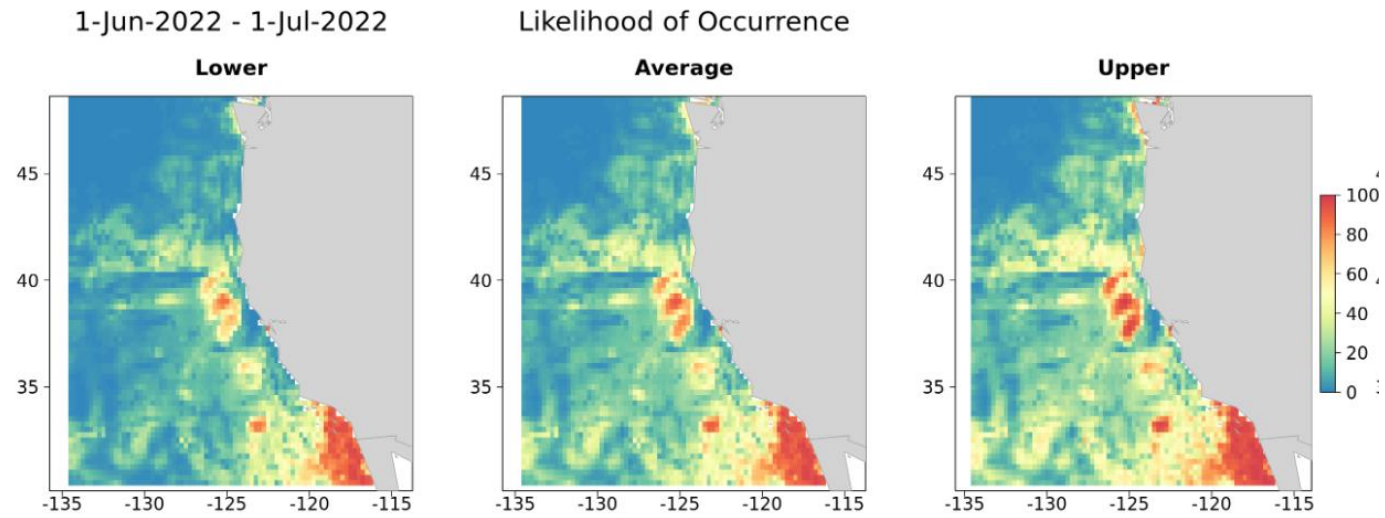
WhaleWatch

- Automated tool to help decrease Eastern North Pacific blue whales mortality due to collisions with shipping and fishing gear
- Matched whale tag data with satellite measurements SST, chlorophyll concentration and surface height anomaly
- Use a telemetry-based habitat model to calculate the likelihood of where whales will be

→ Map of blue whale tag data set highlighting seasonal migration in and out of the California Current.

↓ Monthly estimates of likelihood of Whale occurrence from WhaleWatch

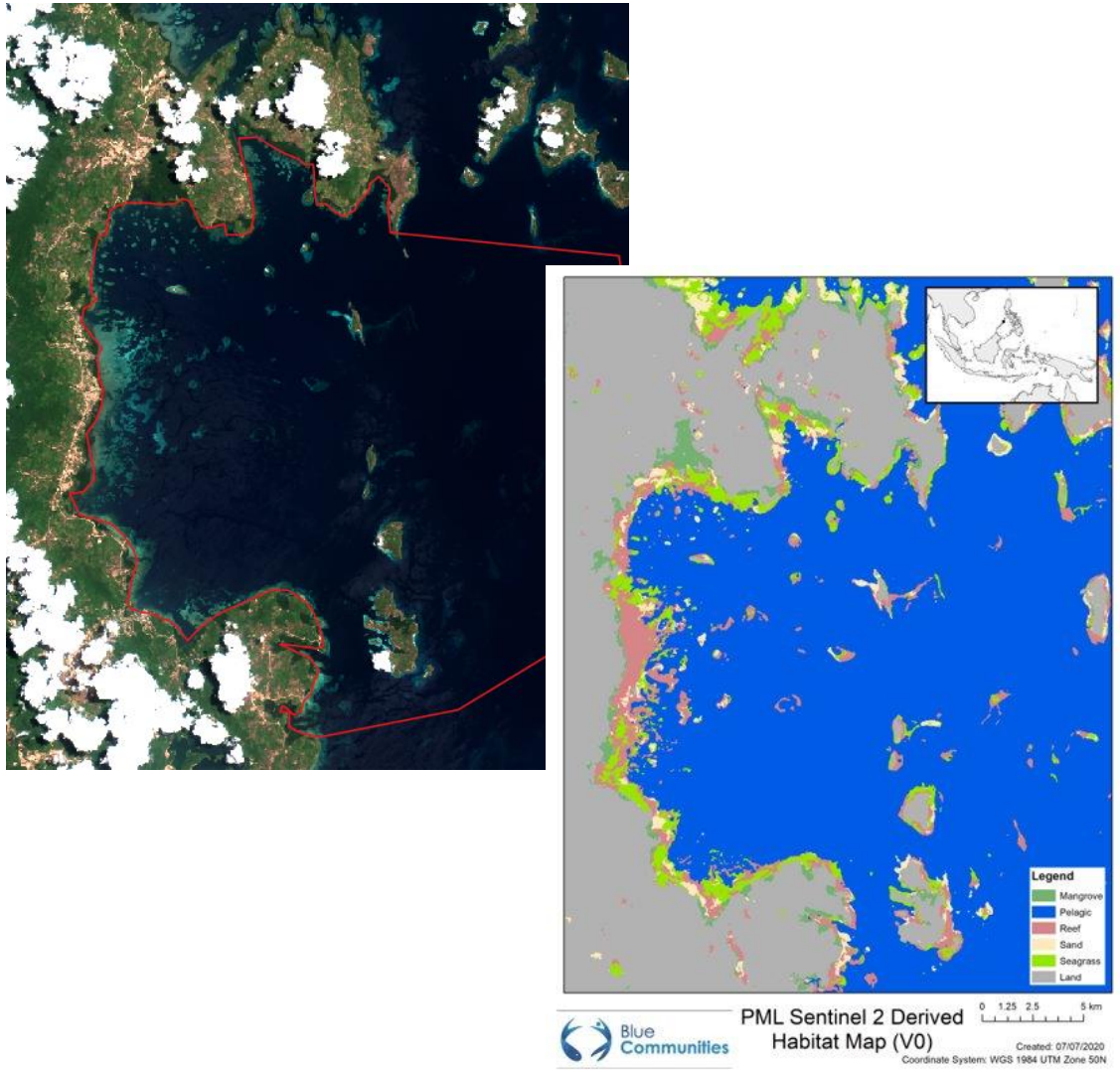




Hazen et al. 2017. https://doi.org/10.1111/1365-2664.12820

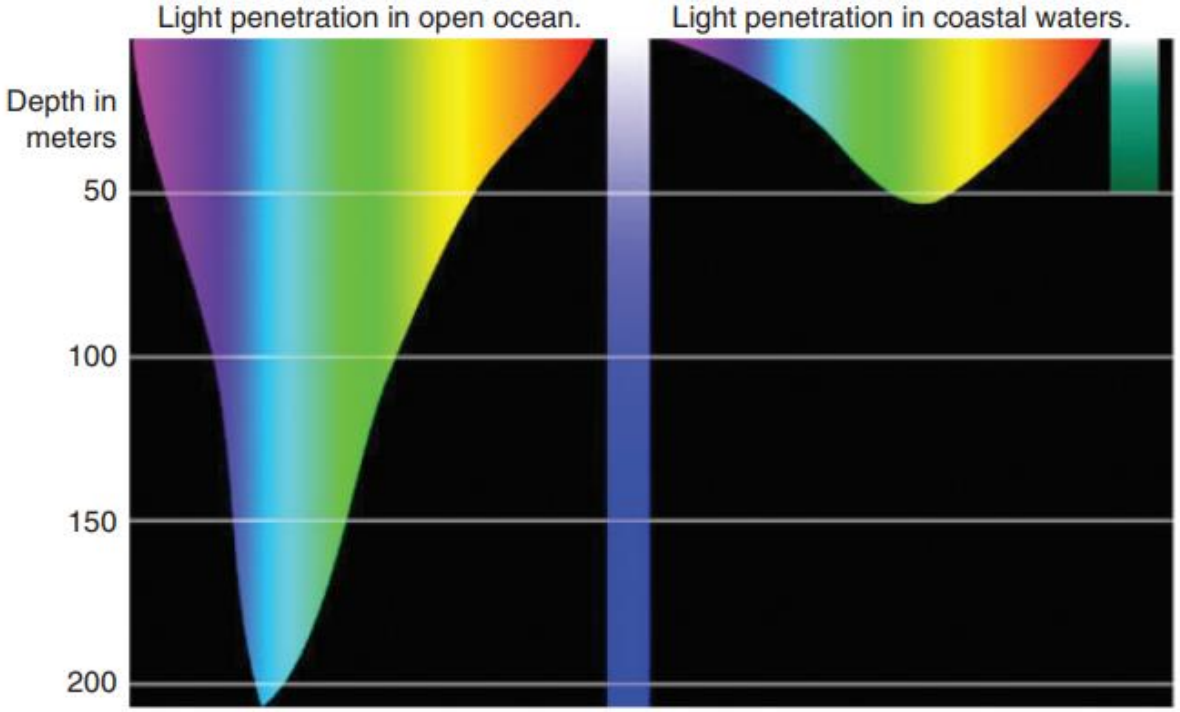
Mapping shallow coastal ecosystems using satellite imagery

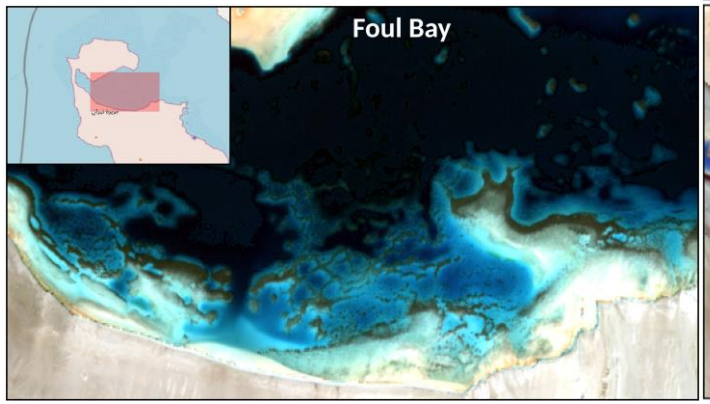
- Medium to very high resolution optical imagery can be used for mapping benthic habitats based on their spectral signature.
- However due to the water column benthic classification becomes more challenging.
  - Water surface roughness, glint
  - Water clarity & light attenuation
  - Similarity of spectral signatures
  - Benthic heterogeneity

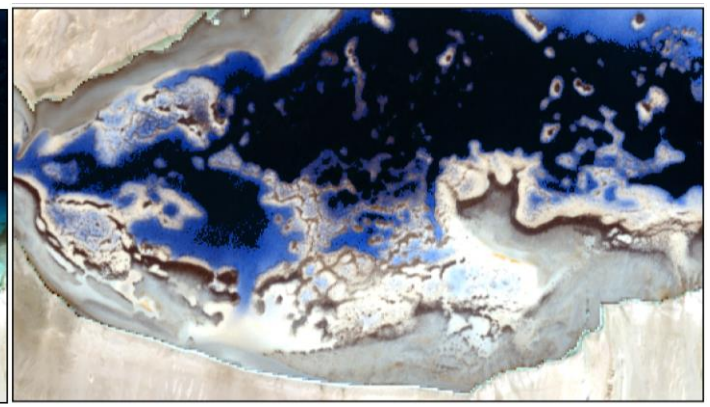


Penetration of light in the water column

- Penetration of light is wavelength dependent.
- Suspended or dissolved constituents in coastal waters will scatter and absorb light.
- The spectral signature recorded by a sensor is dependent on both the reflectance of the seafloor and the water column depth and clarity.
- Depth correction methods are available (e.g. Lyzenga's depth invariant indices).

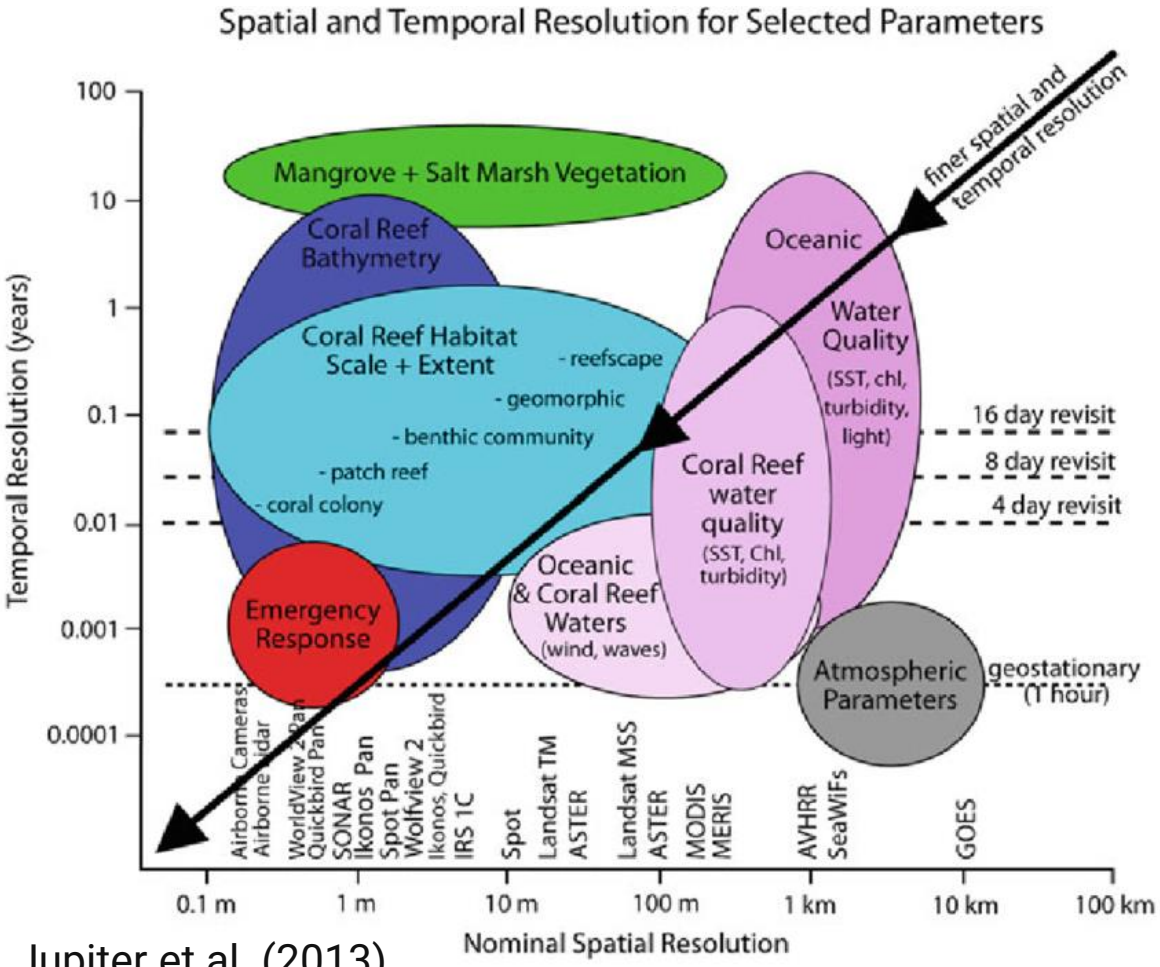






Coastal ecosystems are complex

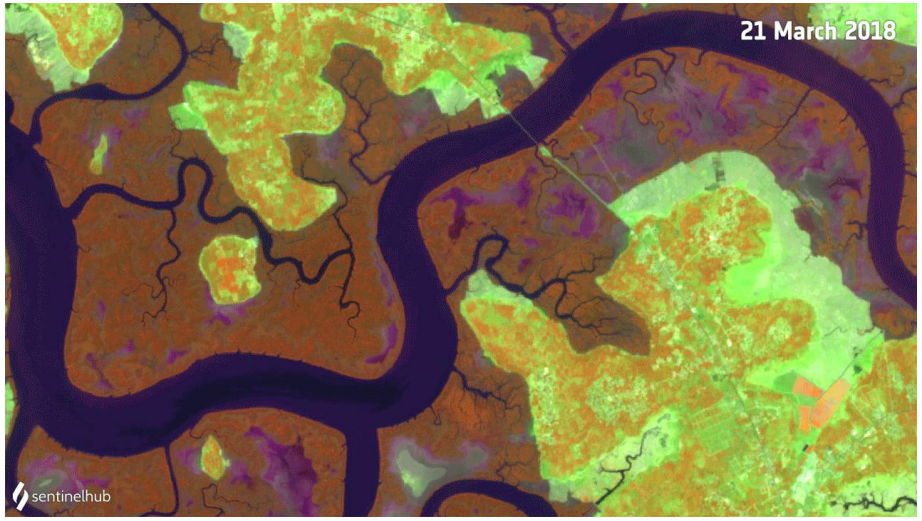
- Medium resolution optical satellite imagery is sufficient to get an overview of seabed character
- Highly heterogeneous ecosystems – within one pixel may be:
  - Hard corals
  - Seagrass
  - Sand
  - Algae
  - Dead coral rubble etc.
- Higher resolution imagery needed to capture more detailed classes.

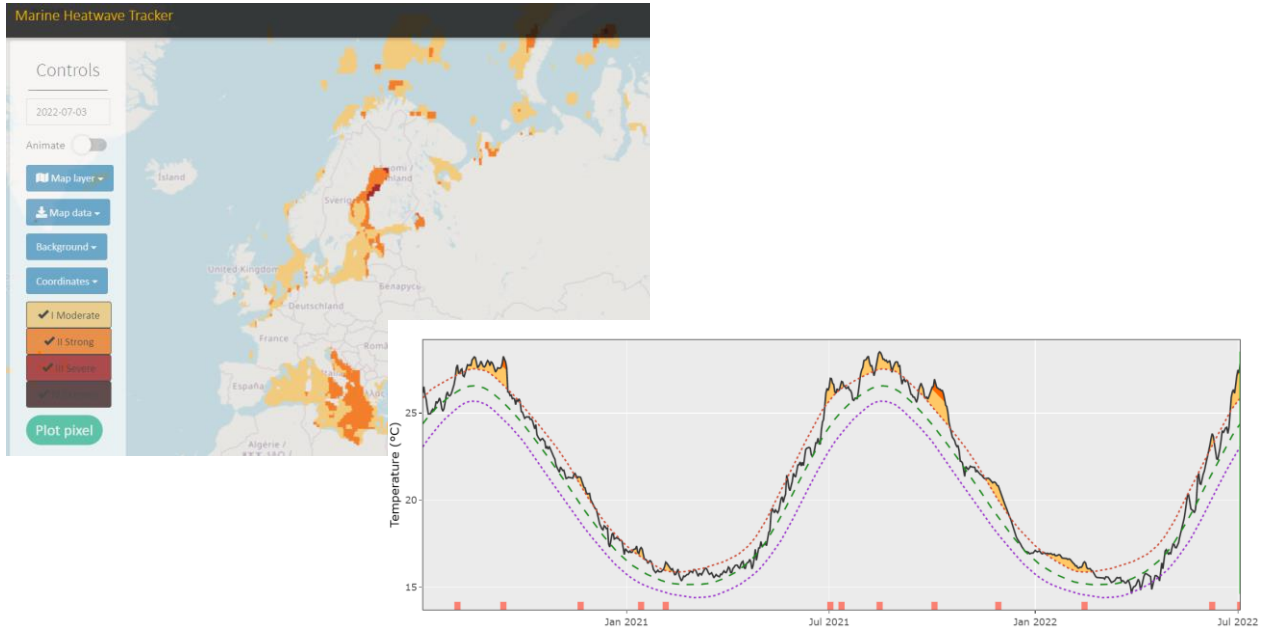


Jupiter et al. (2013)

Monitoring coastal ecosystems

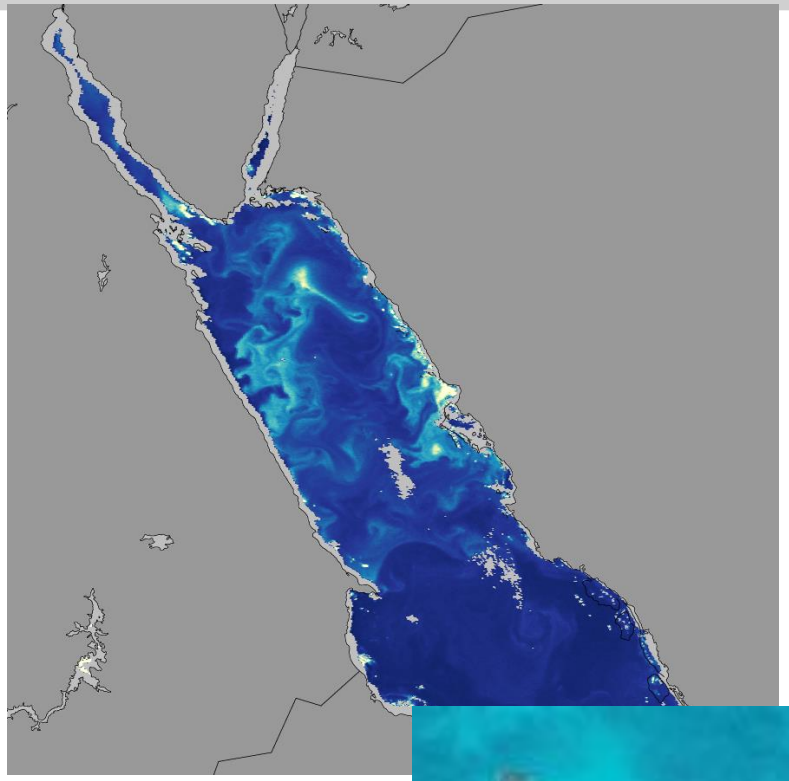
- **Direct** – The reef, seagrass, mangrove forest etc. is the target of remote sensing.
  - Benthic cover, mangrove cover, geomorphological features, habitat complexity, etc.
  - Monitoring changes in status (e.g. changes in vegetation health, disturbance)
- **Indirect** – Focuses on the oceanic and atmospheric environment around the ecosystem. For example:
  - SST and bleaching events
  - Water quality (CDOM, Chl-a, turbidity)





Summary

- Huge range of applications of applications of EO data for marine and coastal environments!
- Ocean colour sensors (inc. Sentinel 3 OLCI) can provide a lot of information on the composition of dissolved and suspended materials in the water column.
- Optical and SAR sensors can be used for land cover mapping for mangroves and wetlands.
- Even in clear waters, light attenuation occurs fast in the water column. This, and the complexity of benthic habitats can mean benthic classification is more challenging.
- EO data can be used to monitor coastal ecosystems directly and indirectly and feed into modelling approaches.



↑ Chlorophyll concentration in the Red Sea from SeaWiFS, NASA earth observatory

→ Drone imagery from the Red Sea, KAUST