WATER QUALITY from Space

Dr. Ana B. Ruescas and Dr. Carsten Brockmann

25-29 September 2023

BROCKMANN CONSULT

IPL IMAGE PROCESSING LABORATORY

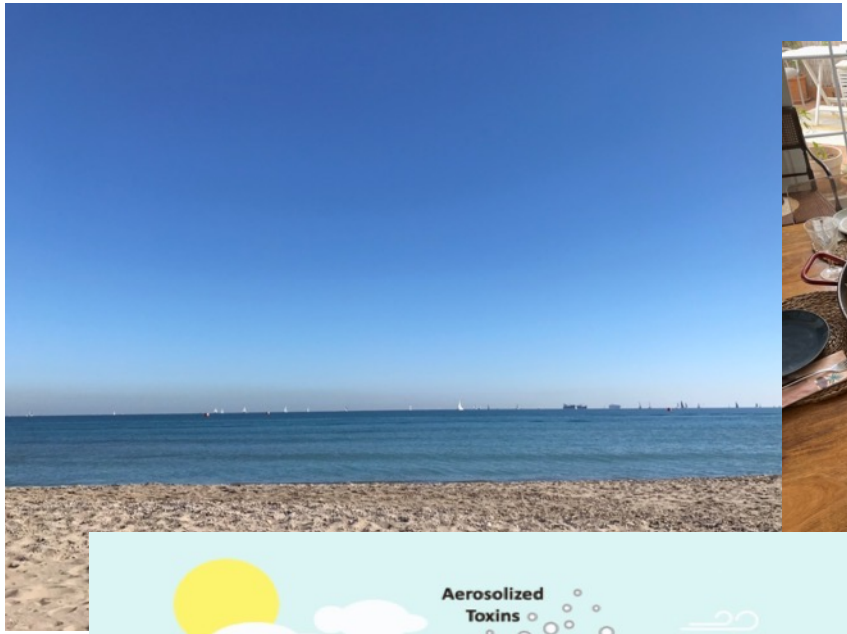
Water quality and human health

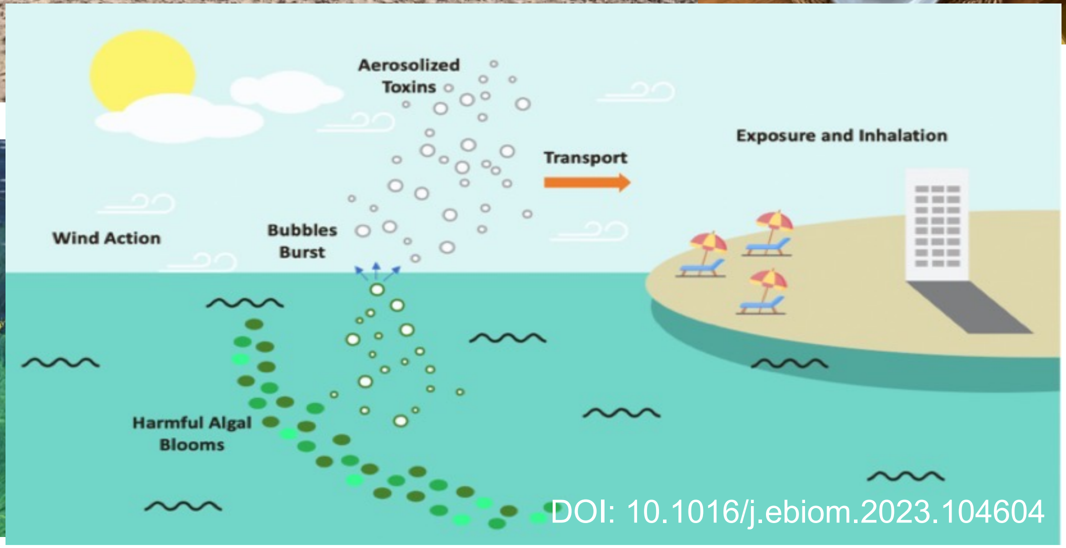
Why do we need good water quality:

- Health benefits of the environment
- High quality food

What happens when we do not have good water quality:

- Harmful algal blooms
- Infectious diseases

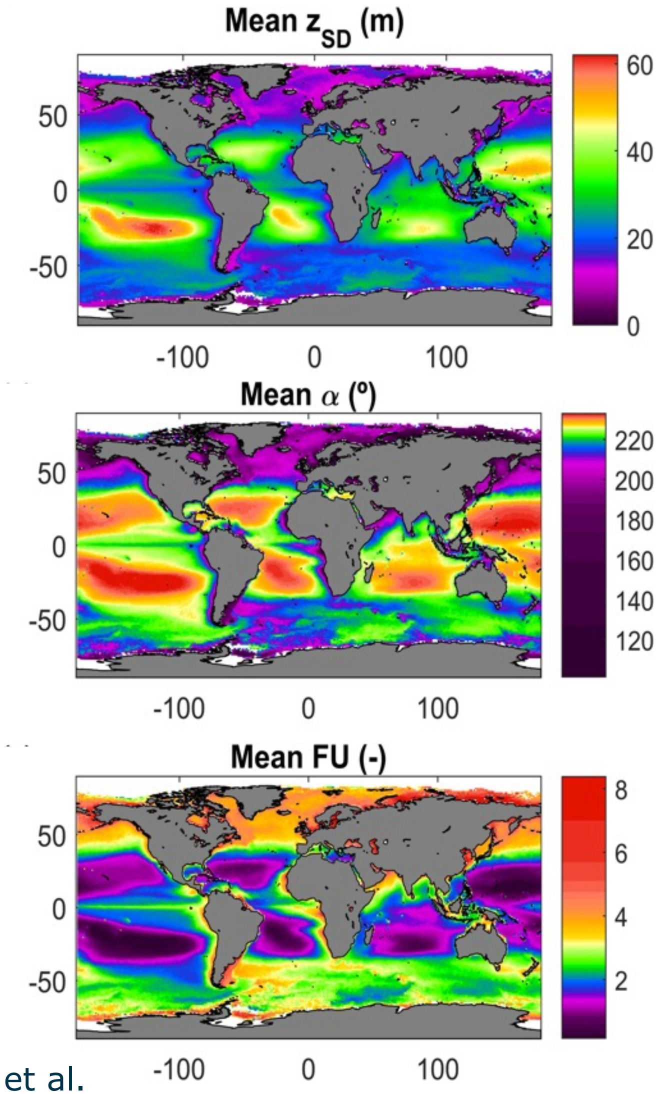




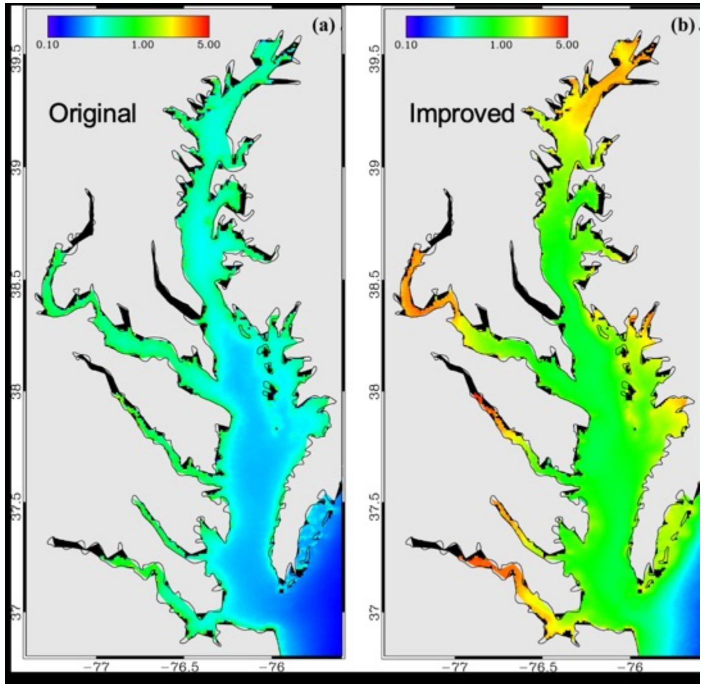
DOI: 10.1016/j.ebiom.2023.104604

Water quality indicators from space

Indicators of water quality	Some References
Diffuse attenuation coefficient (K_d)	Lee et al. (2005), Wang et al. (2009)
Turbidity	Nechad et al. (2009), Son and Wang (2019), Dogliotti et al. (2015)
Water colour (Forel-Ule scale)	Woerd et al. (2015); Pitarch et al. (2021)
Water clarity (Secchi Depth)	Pitarch et al. (2021), Son and Wang (2020)
Suspended sediment load	Volpe et al. (2011), Son and Wang (2012)
Euphotic zone	Lee et al. (2007)

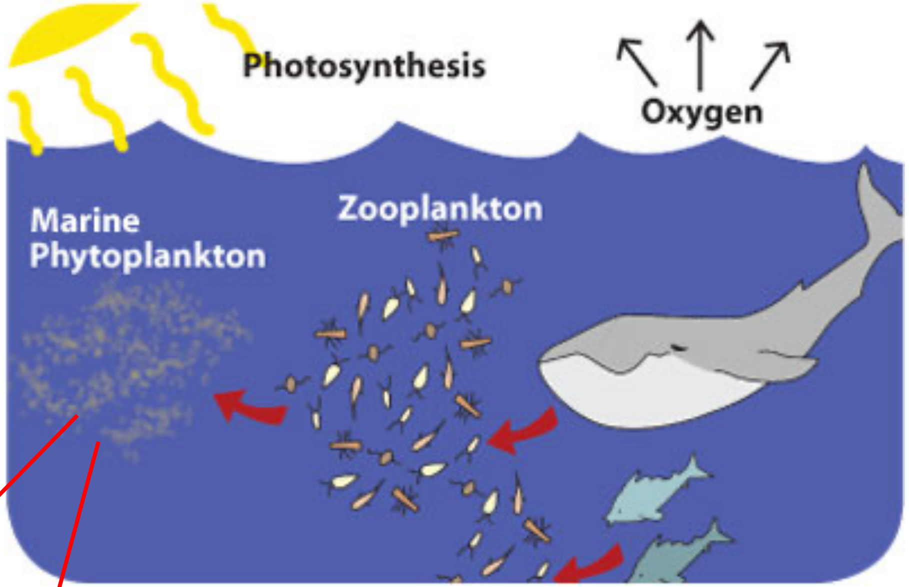


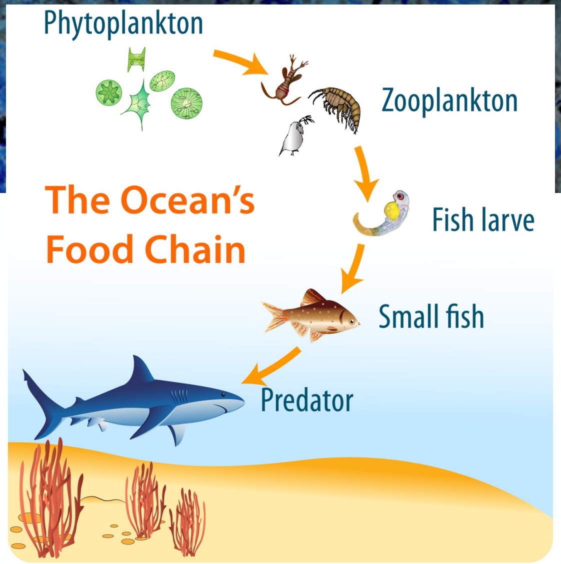
Global Scale. Pitarch et al. (2021)

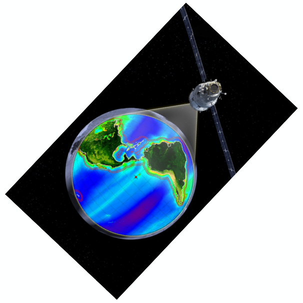


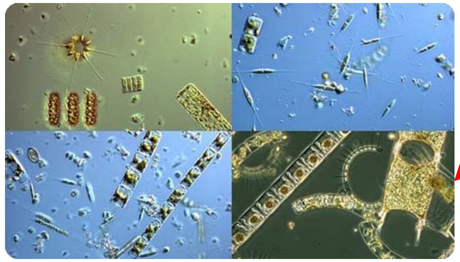
Regional scale. Chesapeake Bay K_d (490) Wang et al. (2009)

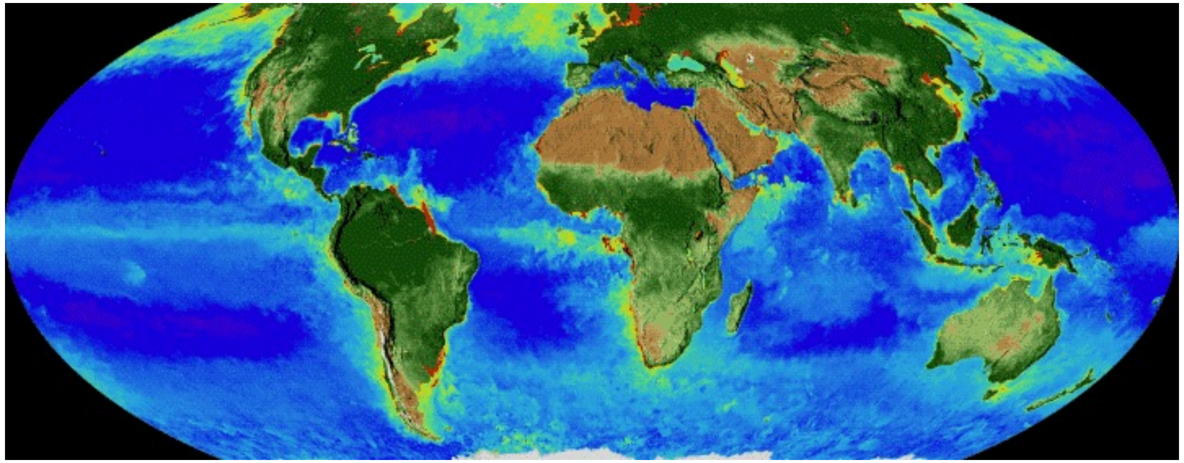
Why phytoplankton?











- live in every aquatic environment
- integral part of the earth's ecosystem
- base of the marine food chain
  - Fish, Marine mammals
- global biogeochemical cycling & climate processes
  - Oxygen (~50% of earth's O2)
  - Affects the Climate (CO2, DMS)

D. Raitsos

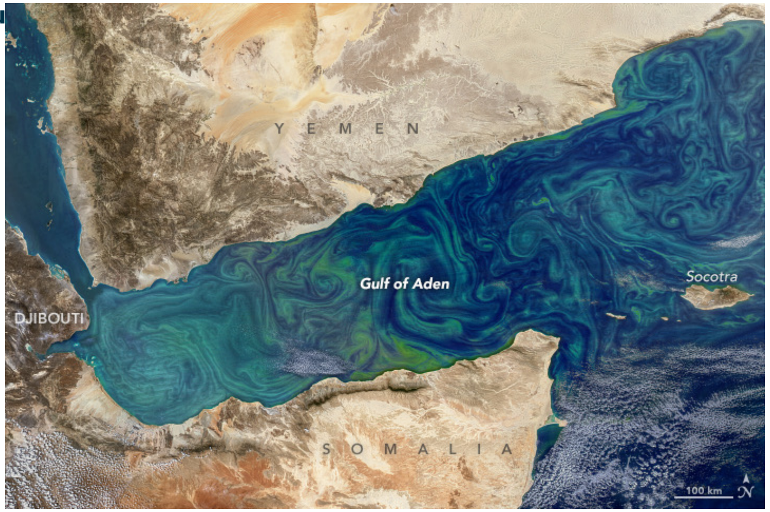
Ecological indicators

Quantifiable metrics that characterise ecosystem structure, composition or function

May serve as early-warning signals of ecological disturbances and gauges of long-term trends

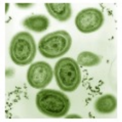
Typically based on the presence of phytoplankton

https://www.uts.edu.au/research-and-teaching/our-research/climate-change-cluster/events/c3-colloquium-fu



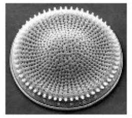
https://earthobservatory.nasa.gov/images/91937/bloom-in-the-gulf-of-aden

- Phytoplankton Biomass
- Primary production
- Phytoplankton Size/Community structure
- Phenology (timing of phytoplankton growth)



Pico
0.2 – 2 μm

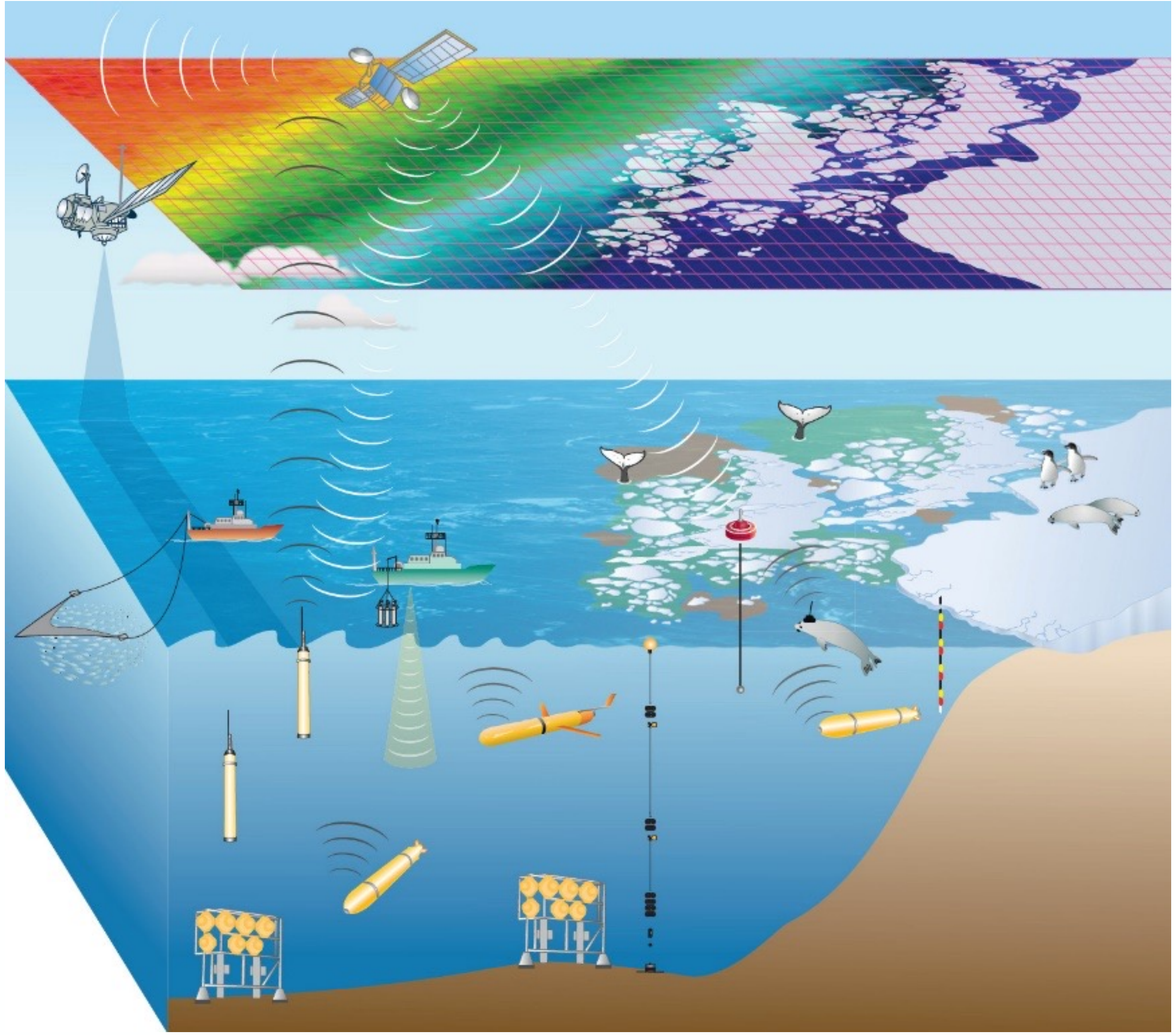
Nano
2 – 20 μm



Micro
20 – 200 μm

D. Raitsos

How to measure phytoplankton



Long-term and large-scale biological dynamics in many marine ecosystems remain poorly understood, due to limited in-water measurements

Primary production of the global ocean

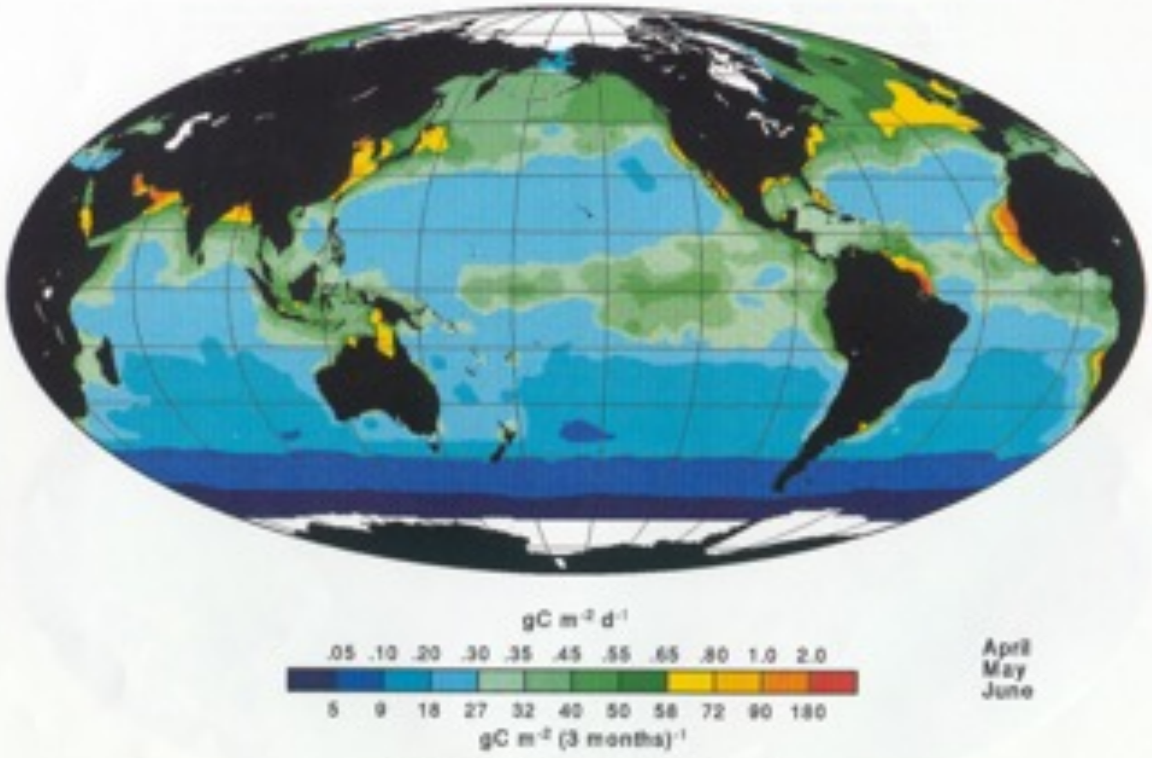


Plate 1b. As in Plate 1a, but for the April - May - June period.

(Antoine et al. 1996)

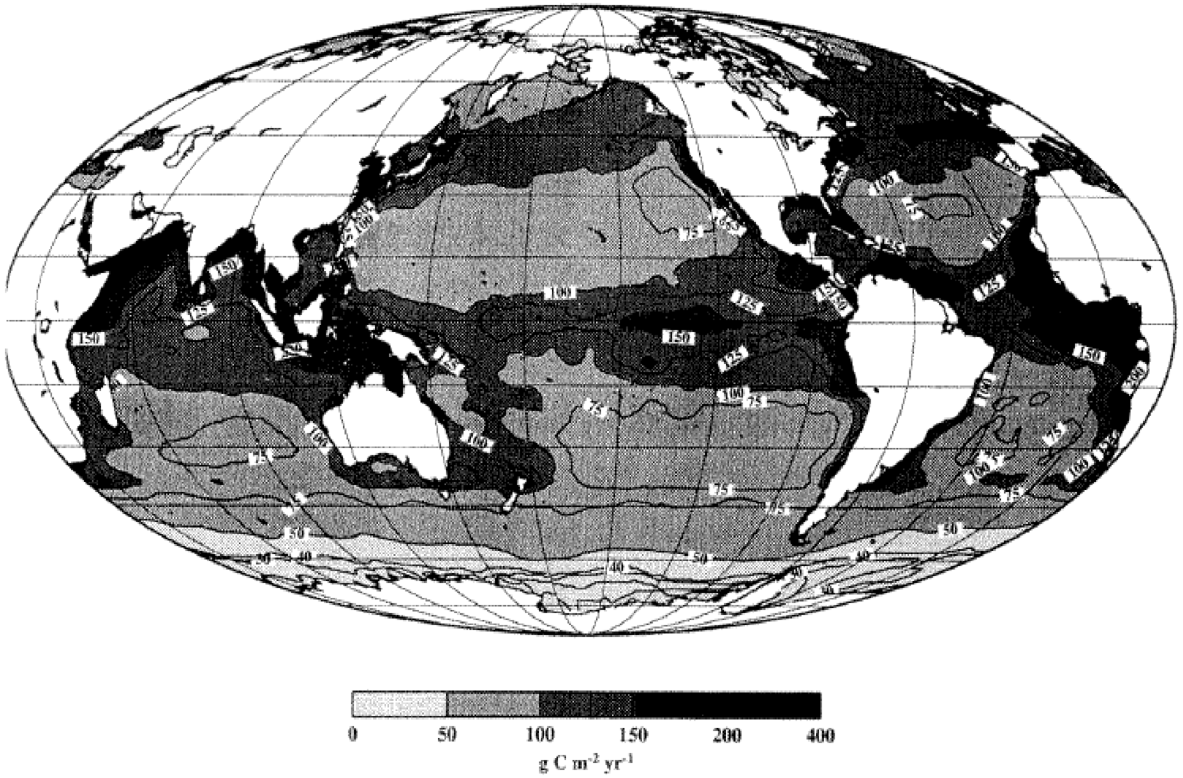
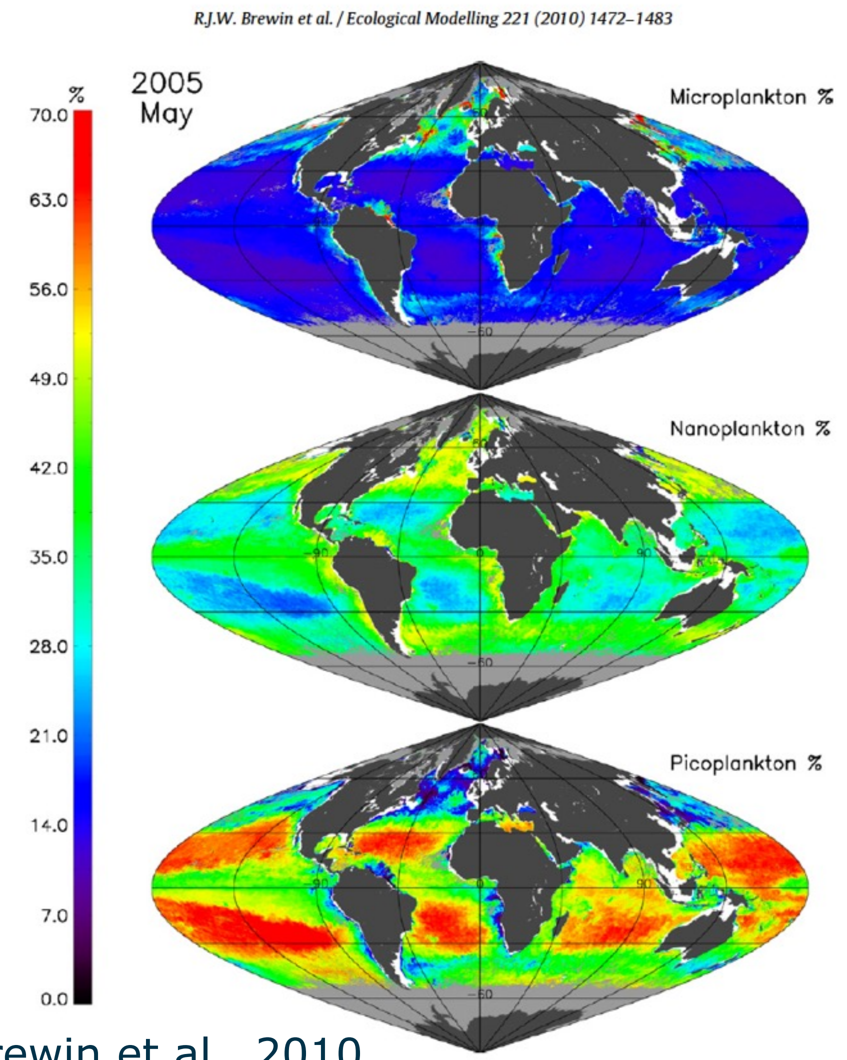
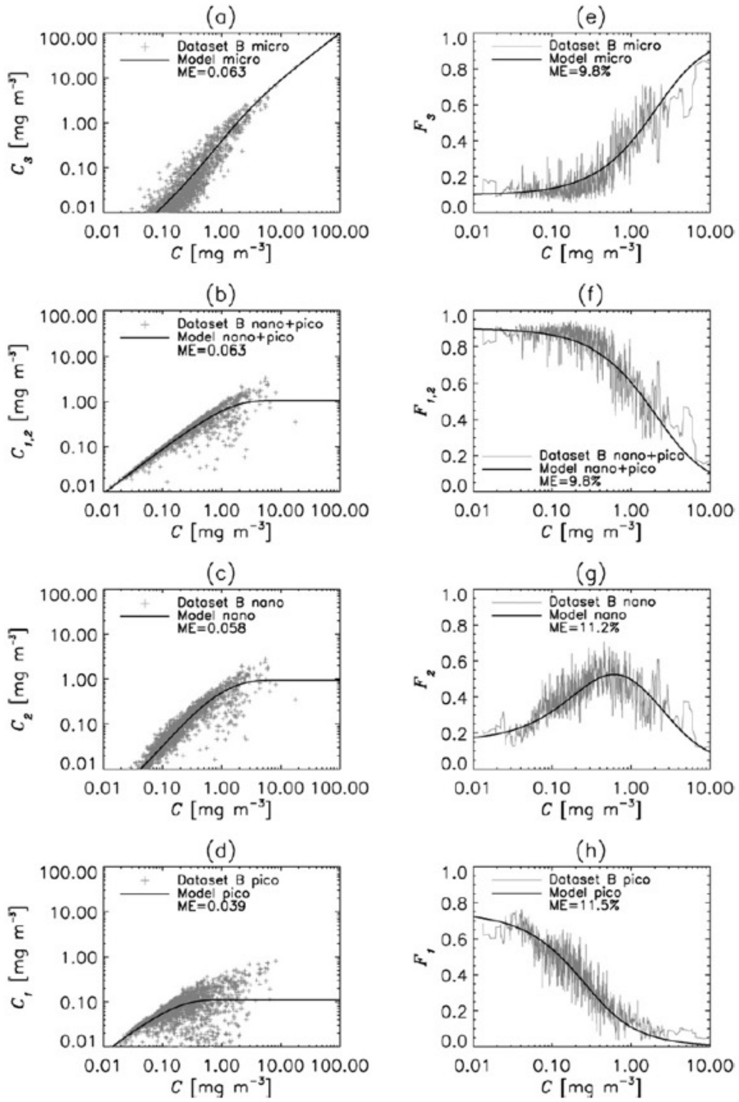


Figure 3. Annual primary production within the world ocean (equal surface "Mollweide" projection), obtained by summing the 12 monthly maps. This map shows the values obtained through the "standard" computation, which leads to a global annual carbon fixation of 36.5 Gt C yr^{-1} (Table 1, line 1). This map can be compared to the historical primary production maps, as derived from compilations of in situ carbon fixation [e.g., *Koblentz-Mishke et al.*, 1970; *Berger et al.*, 1987].

Phytoplankton communities





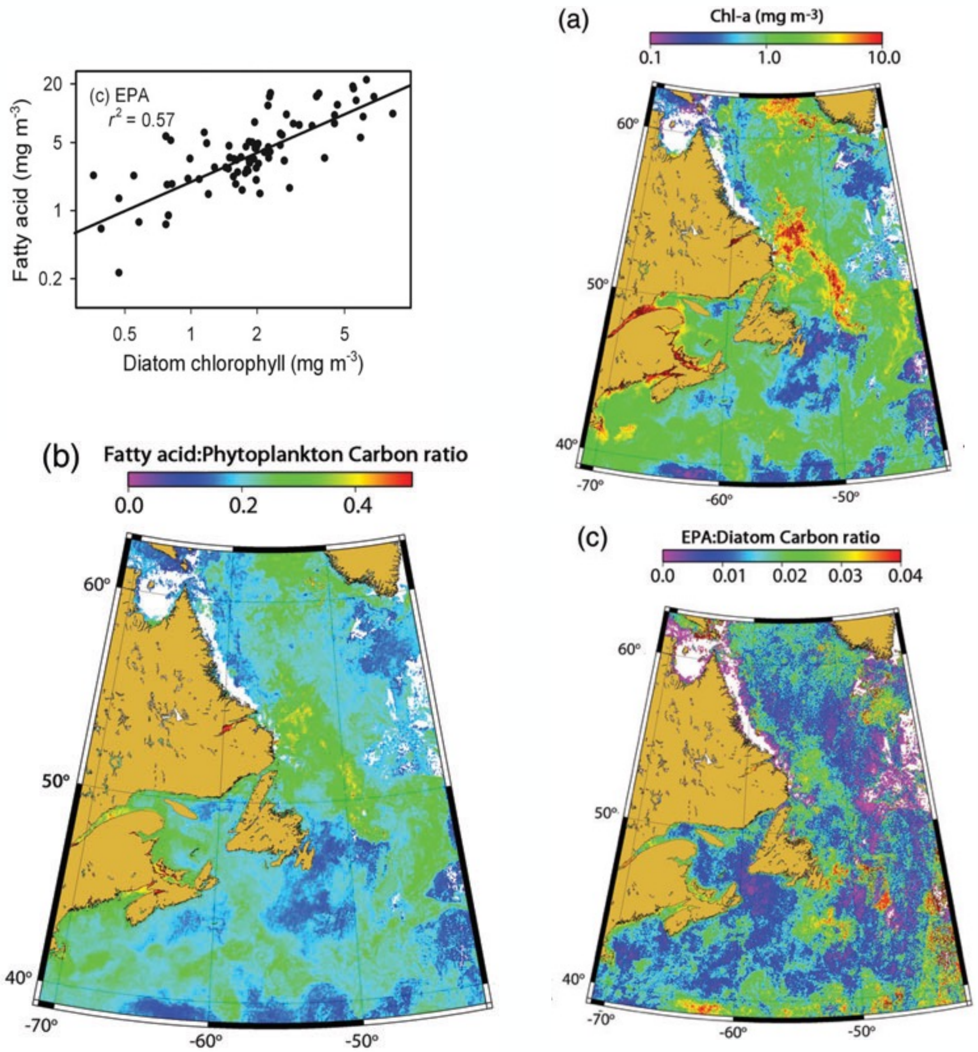
Brewin et al., 2010

- Phytoplankton: basis of trophic chain
- Shifts in community will have effects on trophic chain
- Increase in SST will increase stratification and reduce mixing at the surface (less nutrients)
- The meridional overturning circulation slows and shallows, which means less macronutrients from depth (reduction of chl).
- Sea ice retreats, which increase productivity in polar regions
- Other high latitudes will see productivity decreasing (less nutrients), but higher growth rates (+ and - responses)

Fisheries and aquaculture industries

Phytoplankton are a source of Essential Fatty Acids

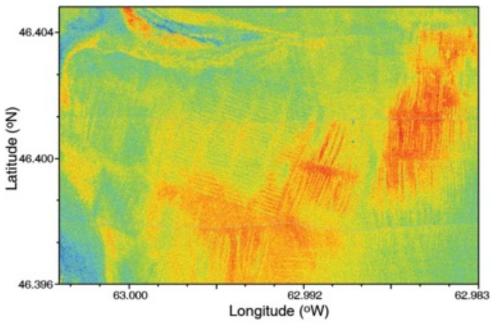
- Essential for health and survival of vertebrates.
- Different classes of phytoplankton produce FAs with differing structures
- For example, 16:4n-1 is synthesized almost exclusively by diatoms
- Diatoms also produce EPA (Eicosapentaenoic Acid), an essential omega-3 FA
- Climate-induced fish community transitions could be linked to availability of essential FAs in the ocean (Litzow et al., 2006).



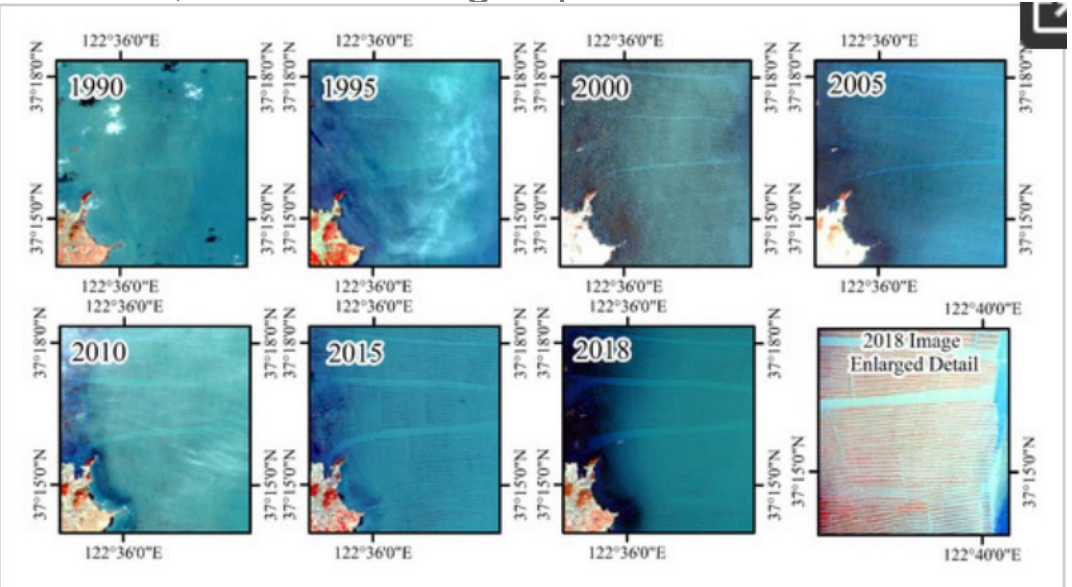
Remote sensing: chlorophyll-diatom-to-EPA

Fisheries and aquaculture industries

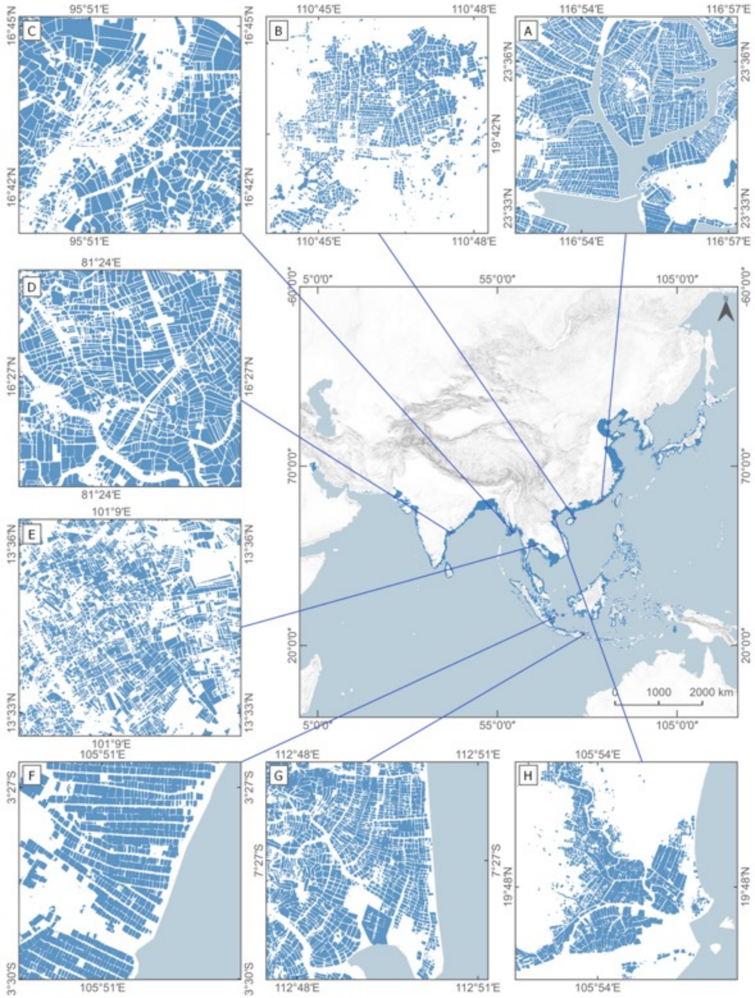
- Harmful algal bloom detection and warning
- Hypoxic events
- Carrying capacity of habitat for shellfish culture
- Water quality (for site selection, for monitoring impact



Local depletion of chlorophyll by cultured mussels
Mussel Rafts in Tracadie Bay, Prince Edward Island



Zoomed Landsat satellite images showing detail of marine aquaculture areas from 1990–2018 (data source: https://glovis.usgs.gov/, *Remote Sens.* **2022**, *14*(3), 732; https://doi.org/10.3390/rs14030732

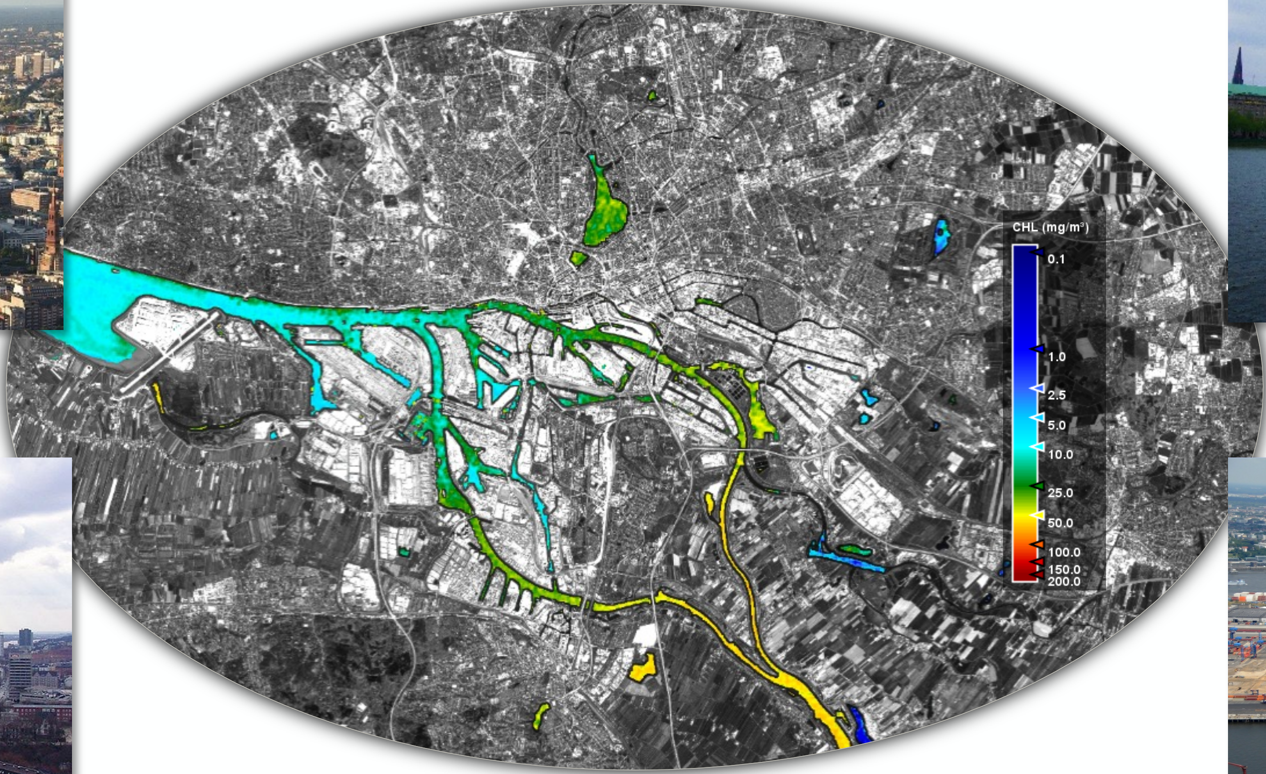


Remote Sens. **2022**, *14*(1), 153; https://doi.org/10.3390/rs14010153

S. Sathyendranath

Water quality in urban waters - Hamburg

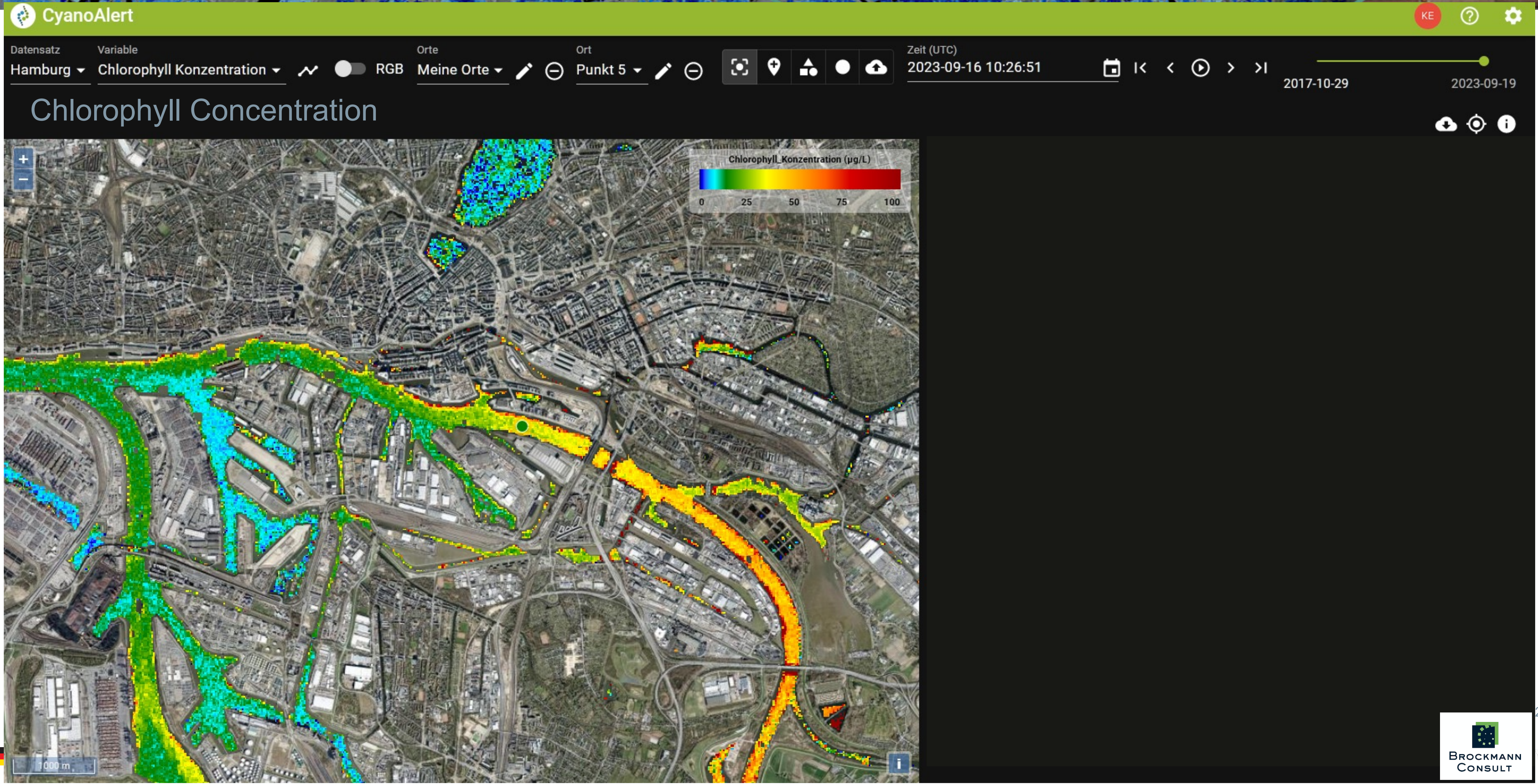
Alster



Harbour / Elbe River

NRT Service for Water quality in urban waters - Hamburg

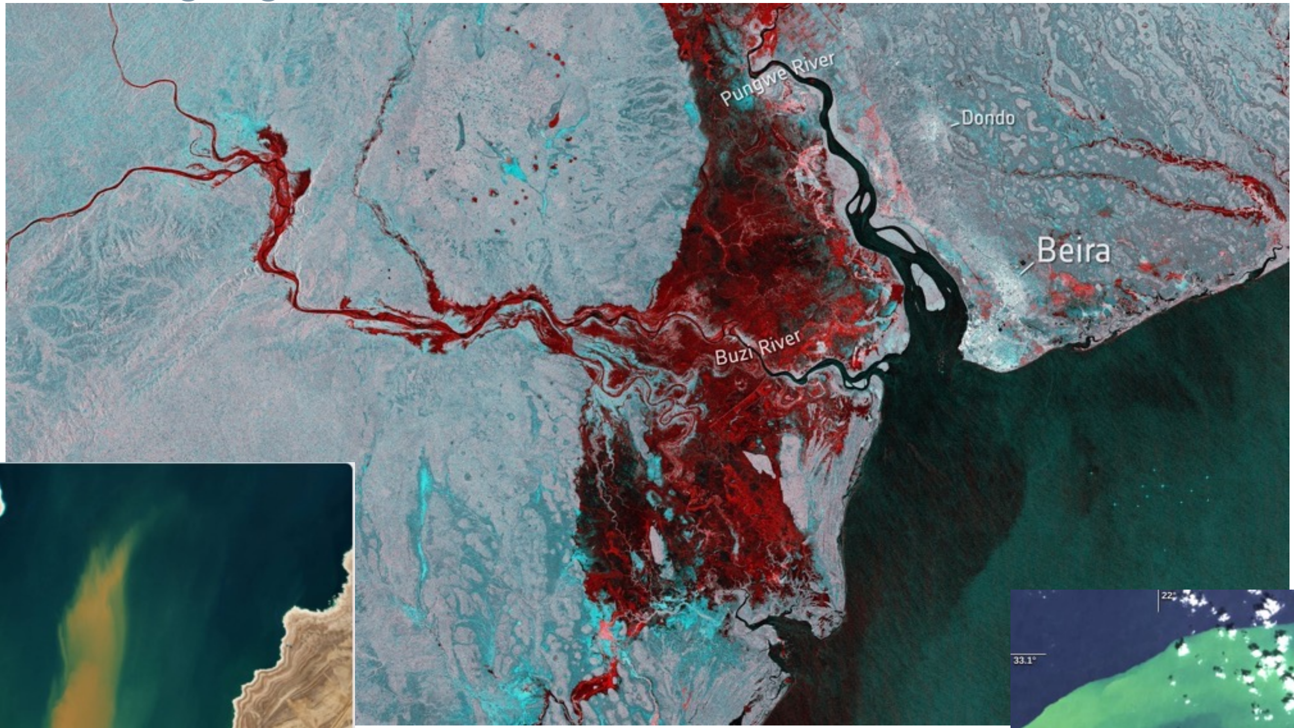
esa



Brockmann Consult

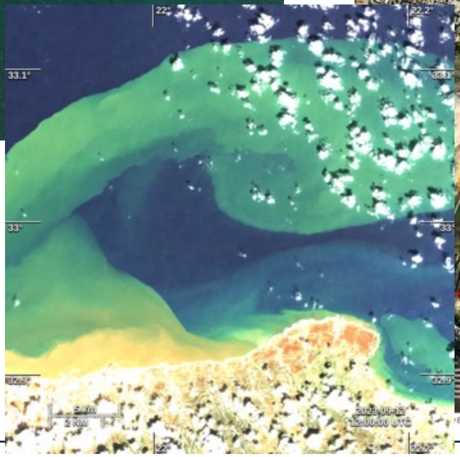
Hazards related to water: flooding

Sentinels working together: S1-SAR; S2-MSI; S3-OLCI

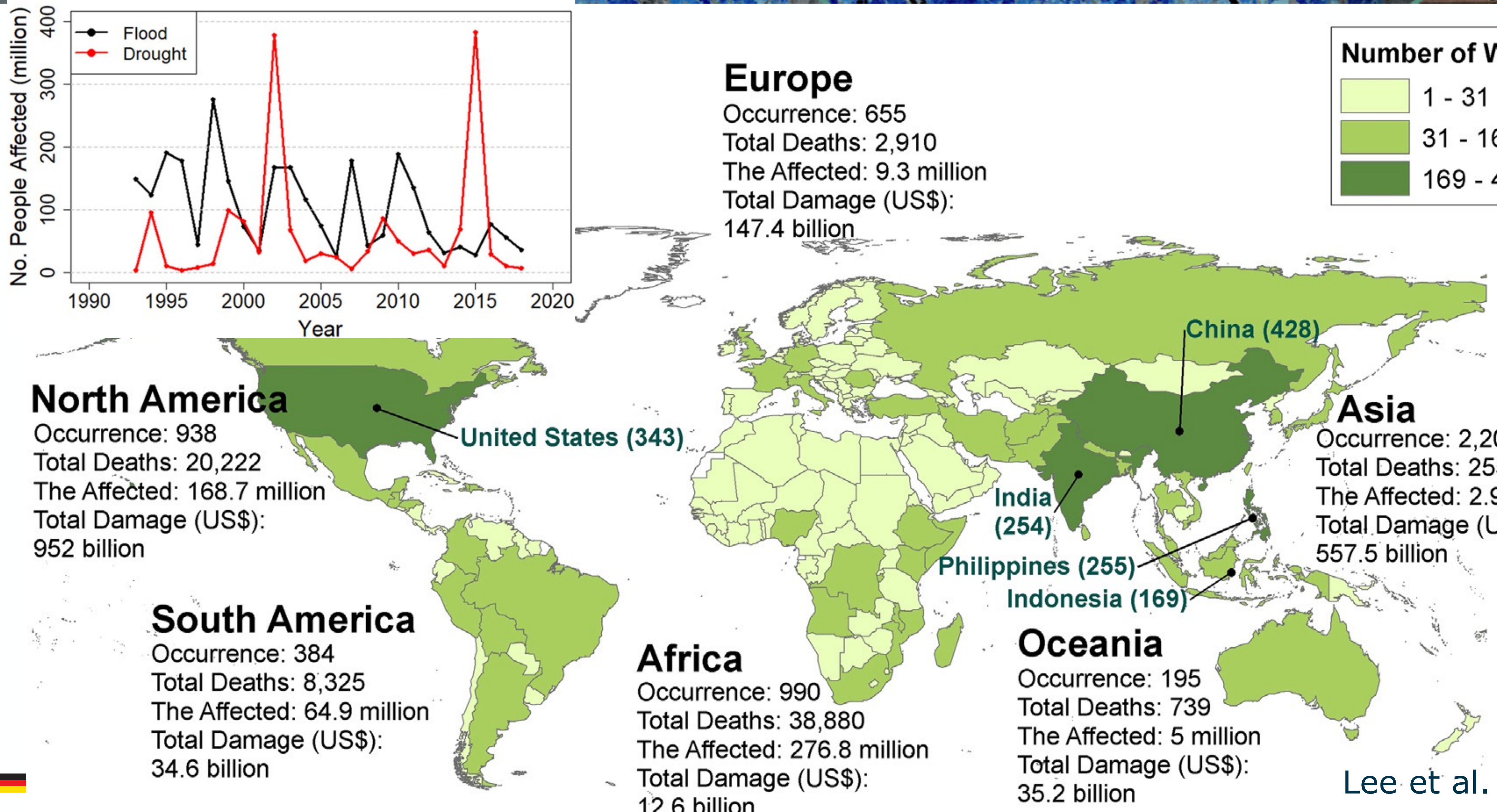


Mozambique,
2019

Arava (Israel),
2023

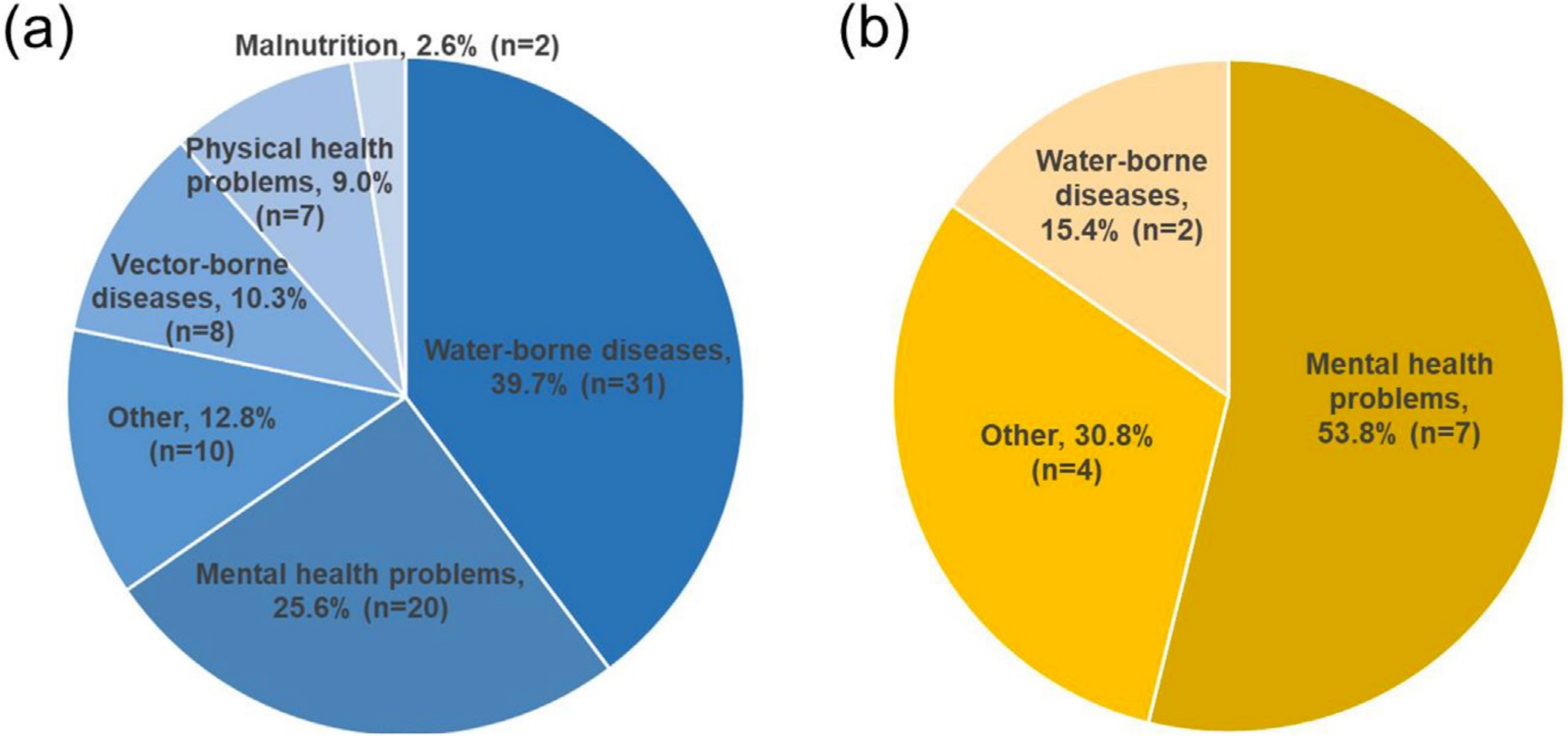


Water-Related Disasters 2001–2018



Lee et al. 2020

Health Impacts of Water-Related Disasters



Number of case studies for each health category following
(a) floods
(b) droughts

Lee et al. 2020

A case study: phytoplankton and cholera

One hypothesis: Indirect link *via* zooplankton

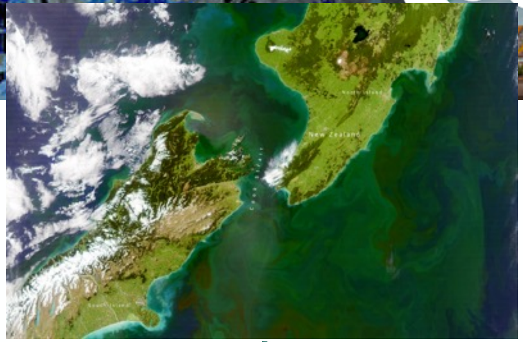
- Explains why there is often a lag of several weeks between chlorophyll blooms and cholera outbreaks (Huq et al. 2005)

- Chitin contained in the carapace of zooplankton serve as food to *V. cholerae.*

- Many lab experiments provide evidence that V. cholerae can grow successfully on copepods.

Images courtesy:
NASA
Wikipedia
Huq et al. 1984
Colwell and Huq

First step:
Phytoplankton bloom

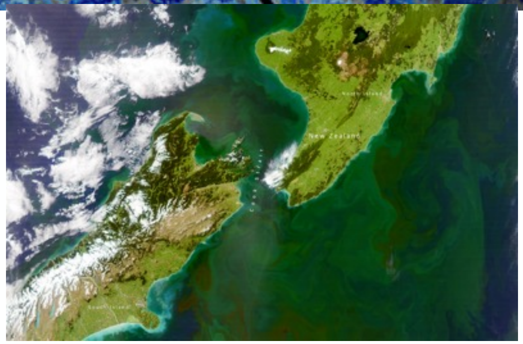


Second step:
Zooplankton follow (delay 1-2 months)

Vibrio cholerae attach themselves to zooplankton in high densities

S. Sathyendranath

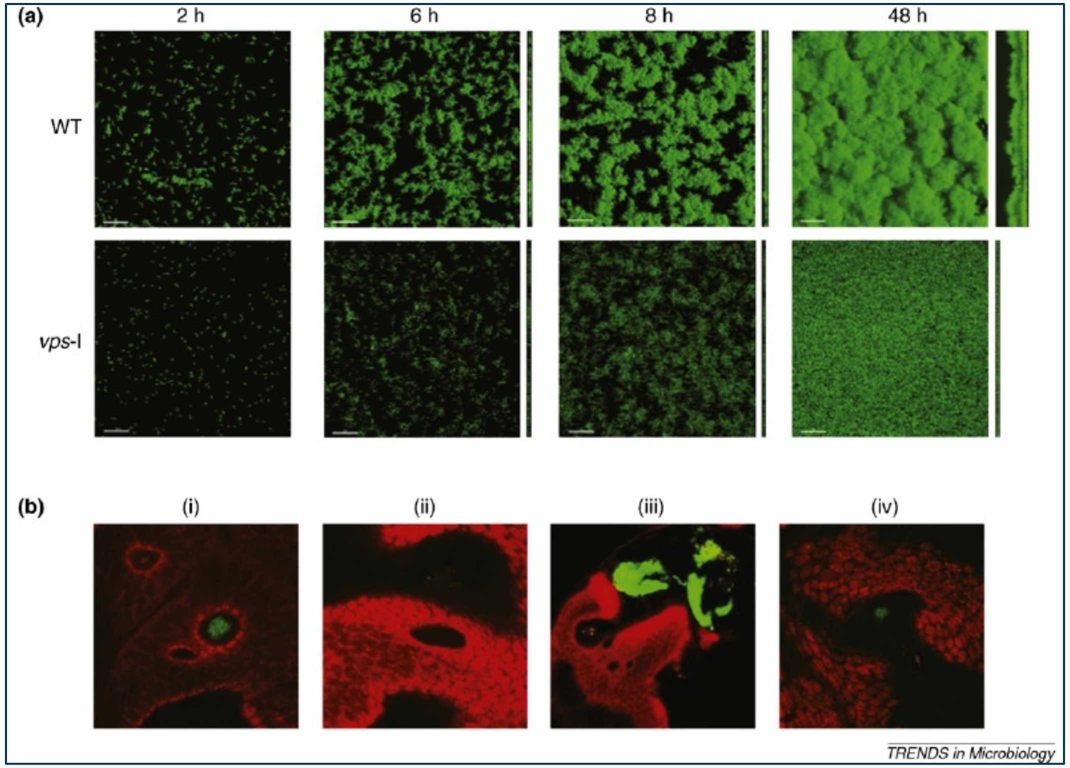
A case study: phytoplankton and cholera



Another hypothesis: Link *via* biofilms formed by *V. cholerae* around phytoplankton

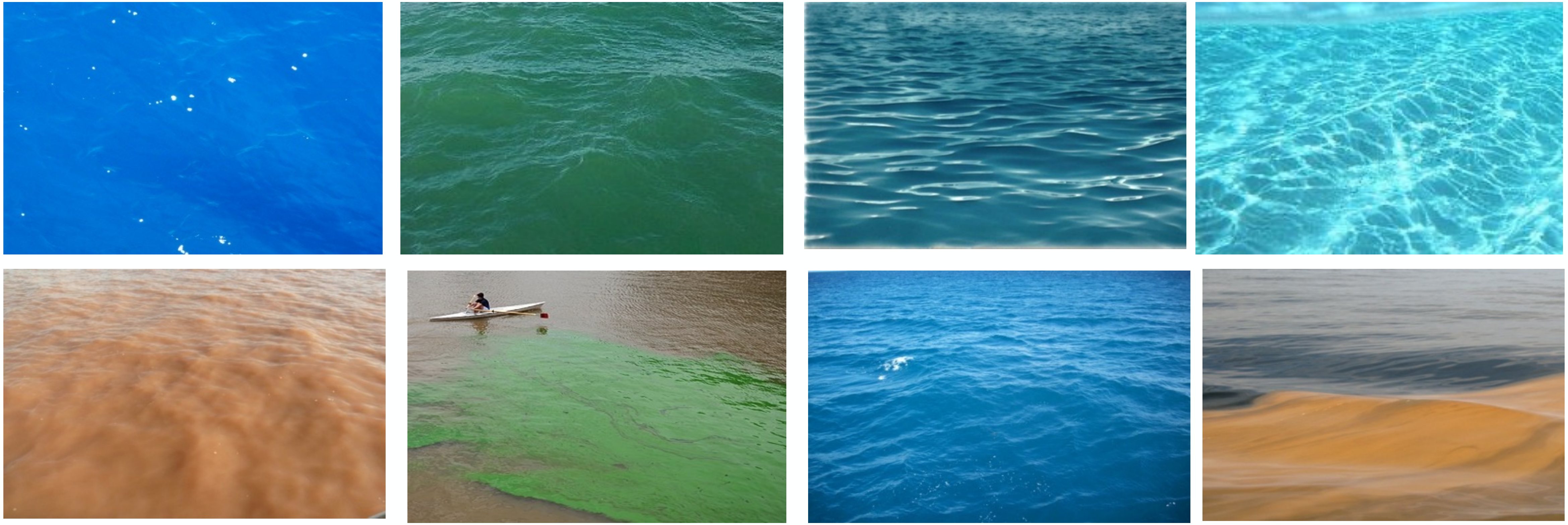
- Vibrio cholerae have the ability to form biofilms around many biotic and abiotic surfaces to access nutrients and avoid predators.

- Formation of biofilms (Yildiz and Visick 2009) or many other direct interactions could underpin strong association between *V. cholerae* and phytoplankton (Asplund *et al.* 2011, Anas *et al.* 2021).



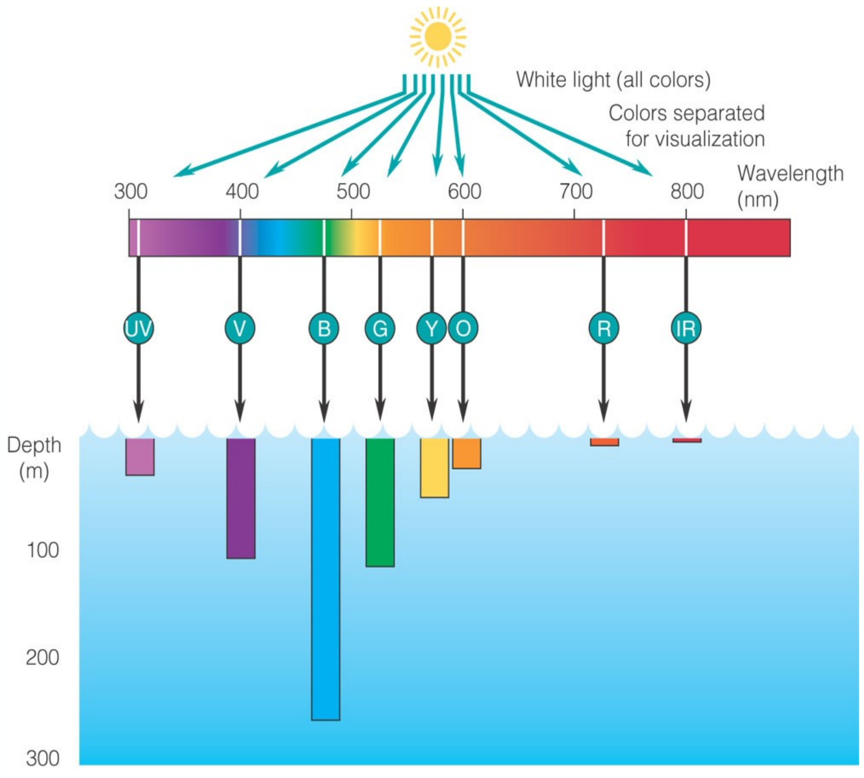
Images courtesy:
NASA
Yildiz and Visick, 2009

What is the colour of the water?

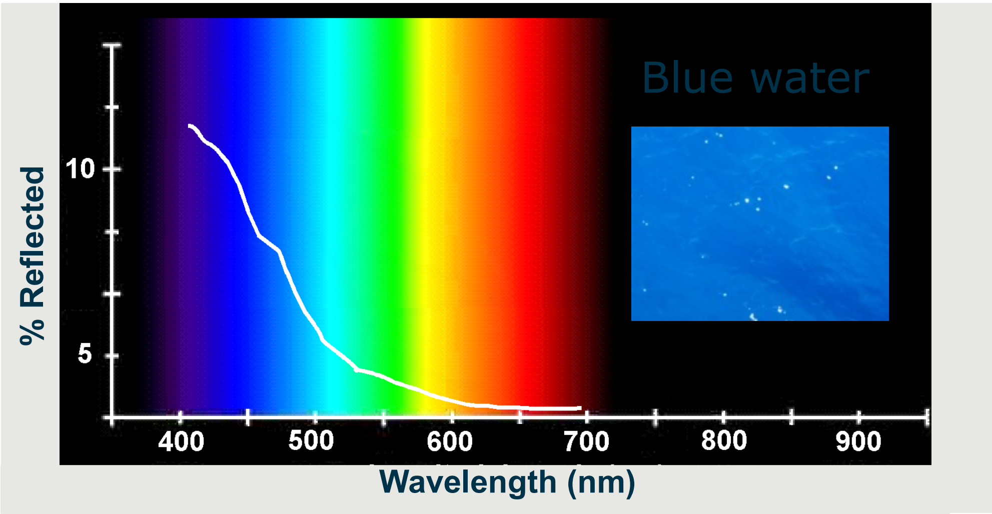


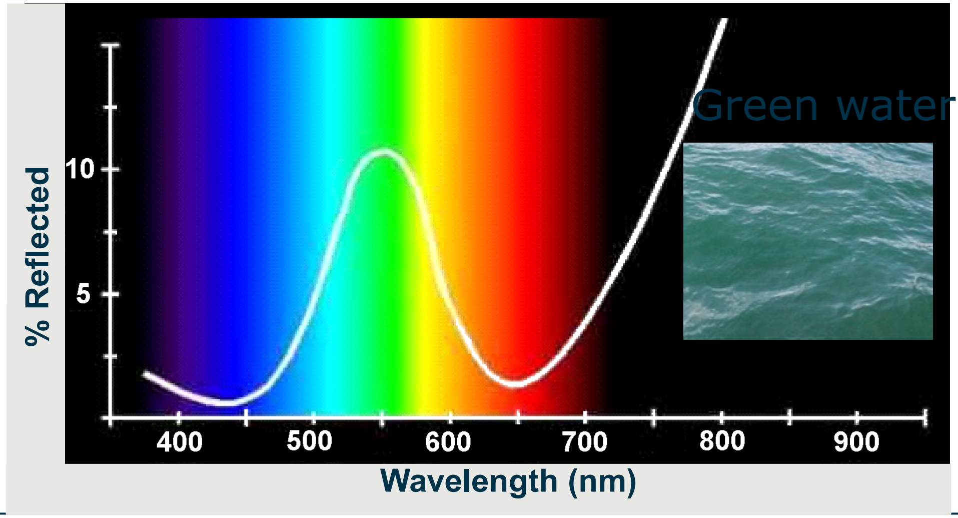
Ana Dogliotti

What is the colour of the water?

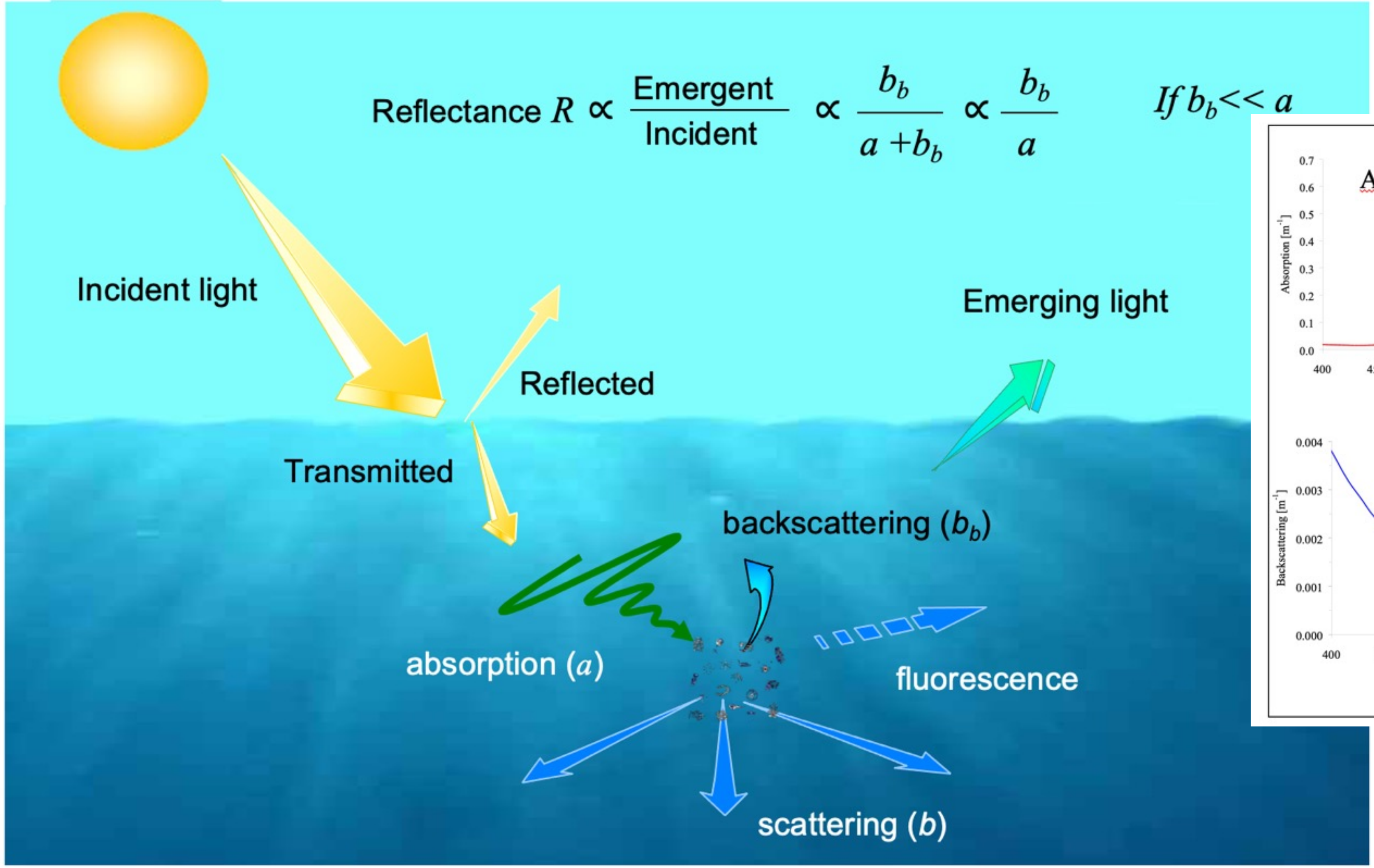


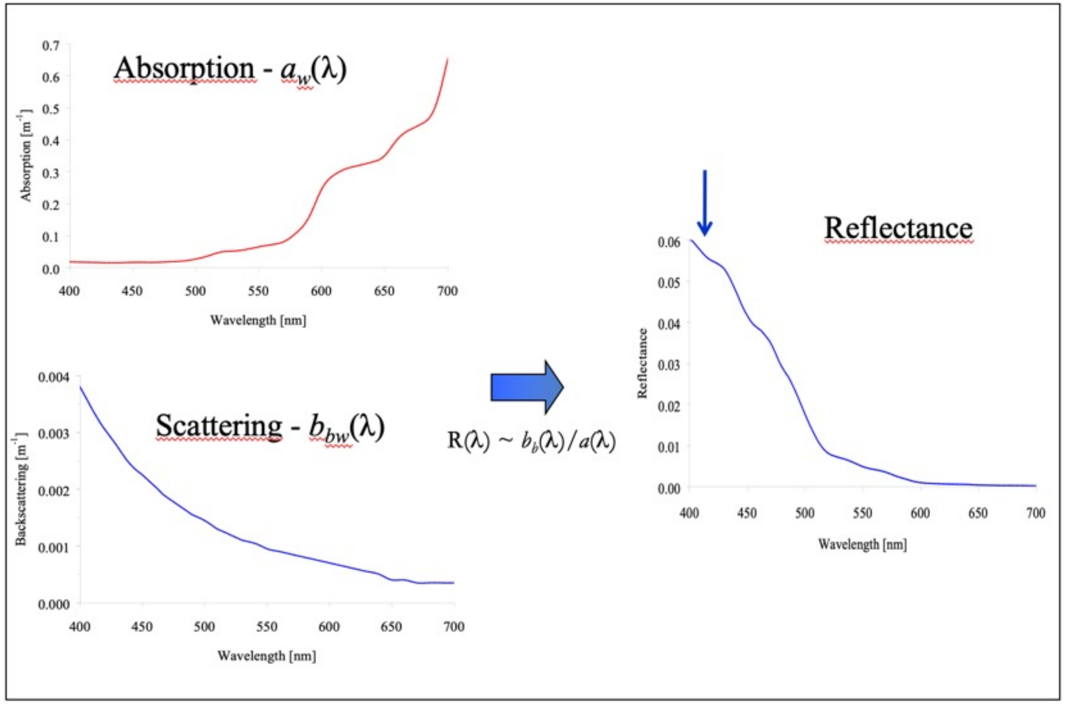
- When sunlight hits the ocean, some is reflected back, but most penetrates the surface and interacts with water molecules.
- Longer wavelengths of light (green → NIR) are absorbed
- The remaining light we see is composed of the shorter wavelengths (**blue**).





What does the colour of water depend on?



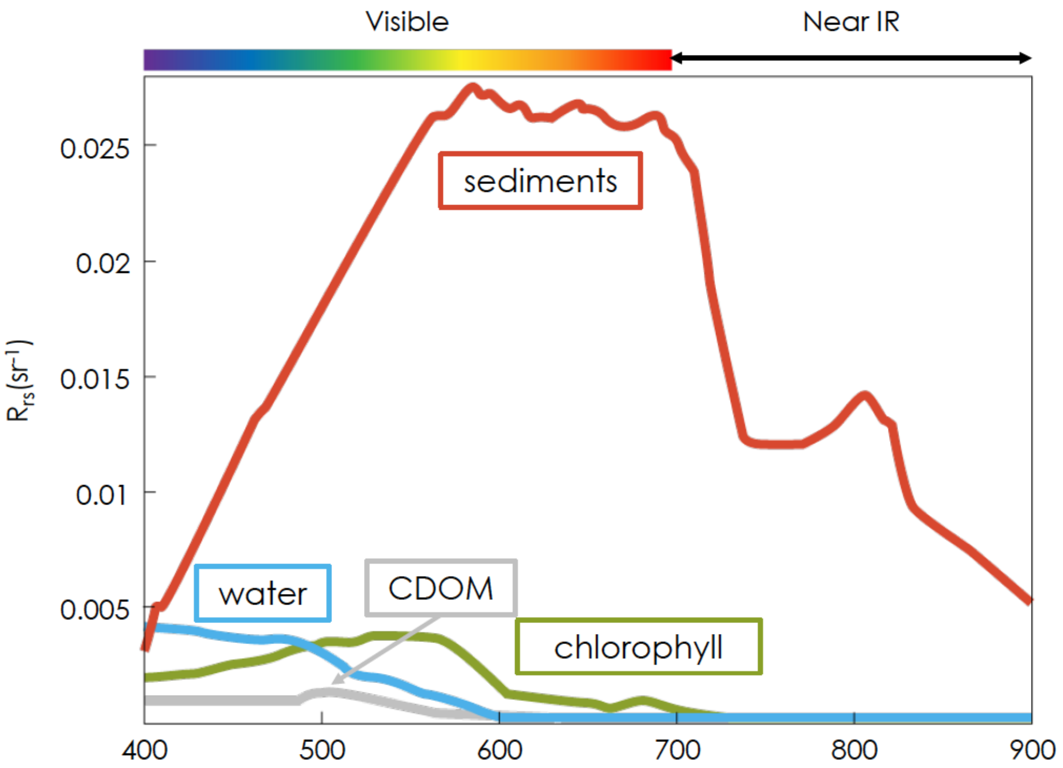


Ana Dogliotti

Optically active substances

- Particles suspended in water increases scattering of incoming sunlight.
  - Runoff from land / rivers.
  - Coloured Dissolved Organic Matter (CDOM) aka Gelbstoff.
  - Resuspended sediment.
  - **Phytoplankton!**

Microscopic, unicellular drifting plants



Optical properties

IOP (Inherent Optical Properties)

Medium properties that depend only on the composition of this medium, regardless of light conditions.

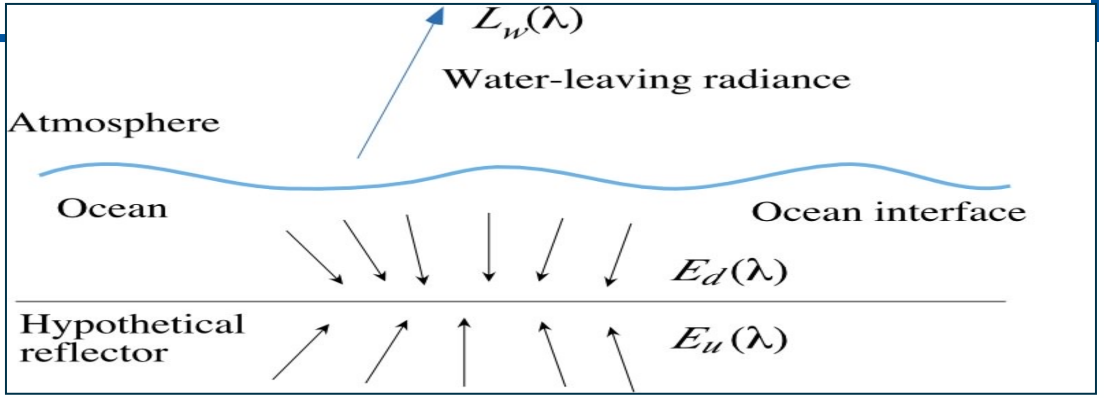
Examples are scattering (b), absorption (a), and fluorescence.

In a multi-component medium, the total inherent optical properties can be obtained by a simple addition of the individual contribution.

AOP (Apparent Optical Properties)

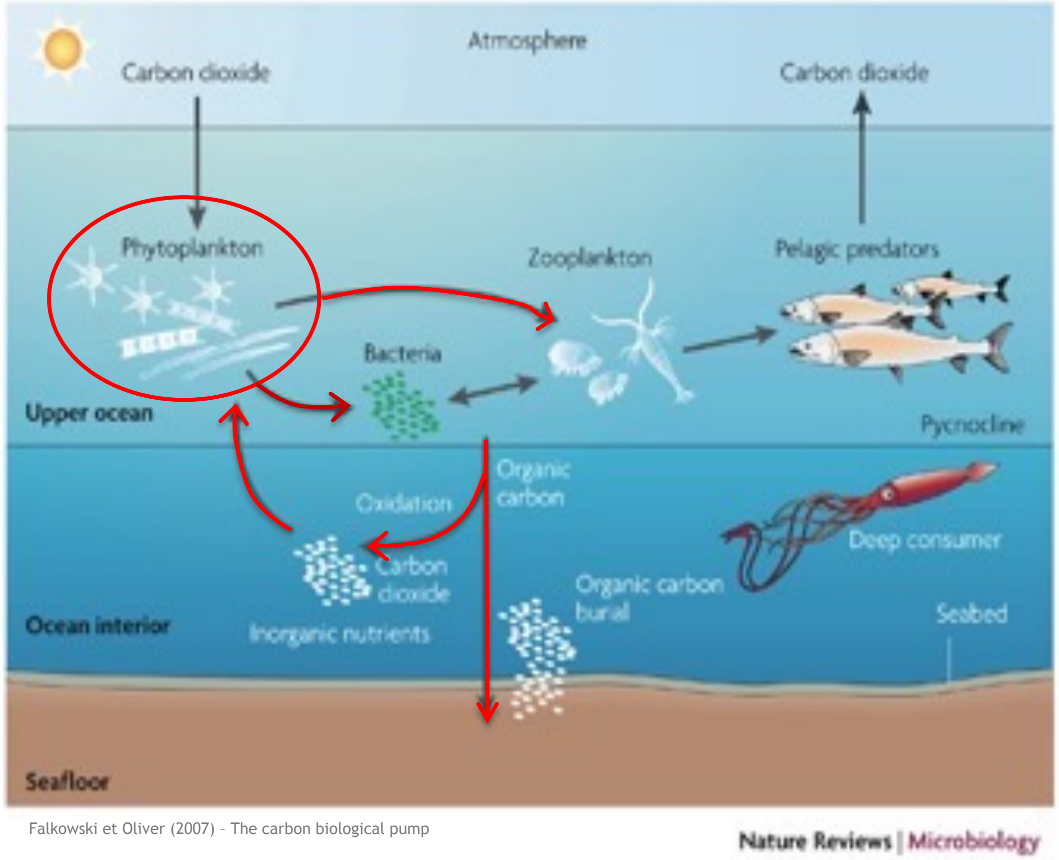
Characteristics of the medium dependent on geometric distribution of the light field and on the medium IOPs. They change with varying illumination conditions, such as solar zenith and azimuth angles.

Examples are irradiance (E), radiance (L), reflectance (R), diffuse attenuation coefficient (K), which depend on the surface boundary conditions.



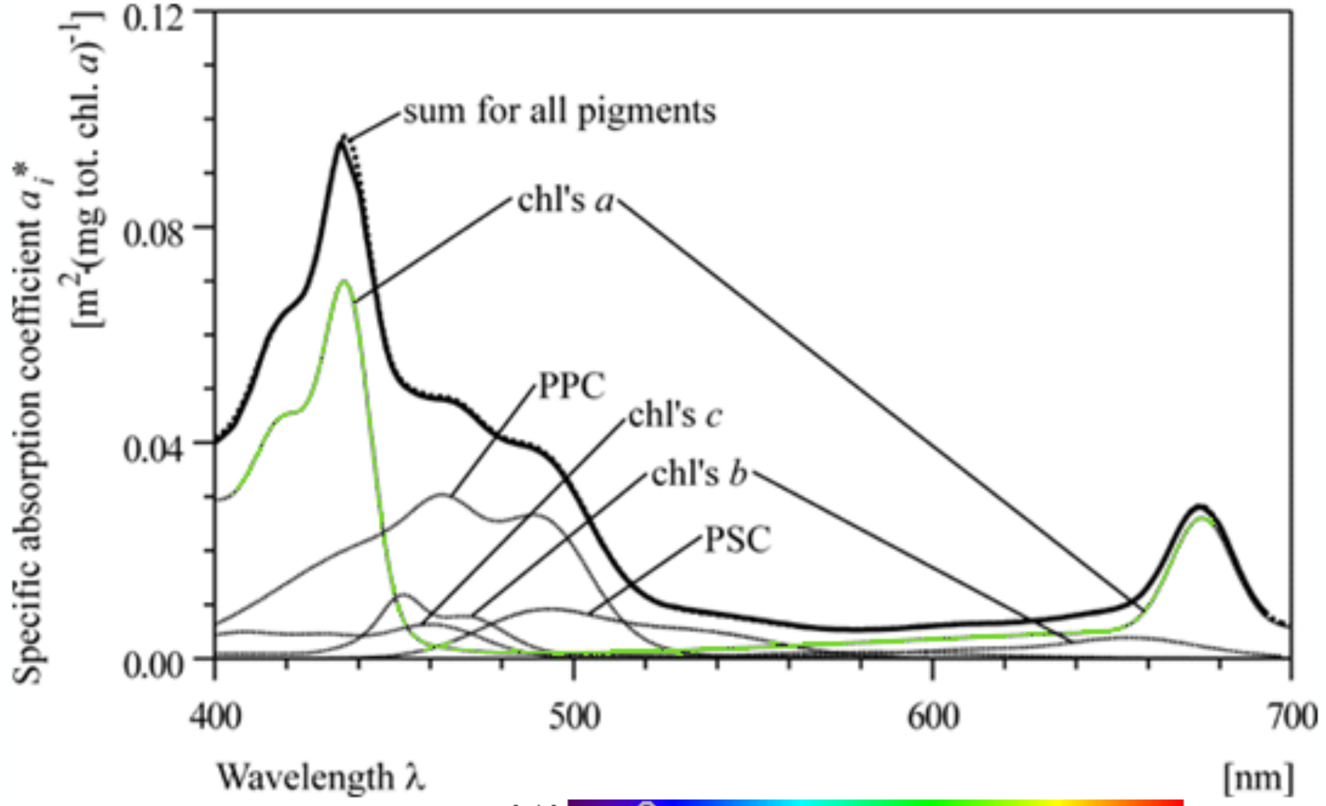
Biogeochemical significance of phytoplankton

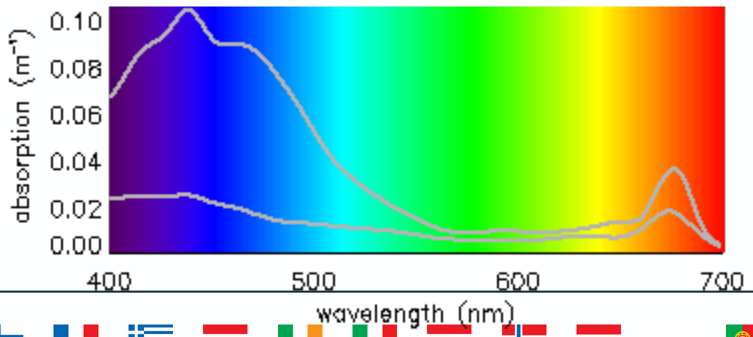
- Phytoplankton are key players in the ocean's carbon pump
- Phytoplankton diversity is an important factor that affects carbon cycling
- What's the role of phytoplankton in today's oceans?
- How will phytoplankton respond to future climate changes with interactions between climate and biogeochemistry?
- We need observations of phytoplankton and associated processes on appropriate spatial and temporal scales

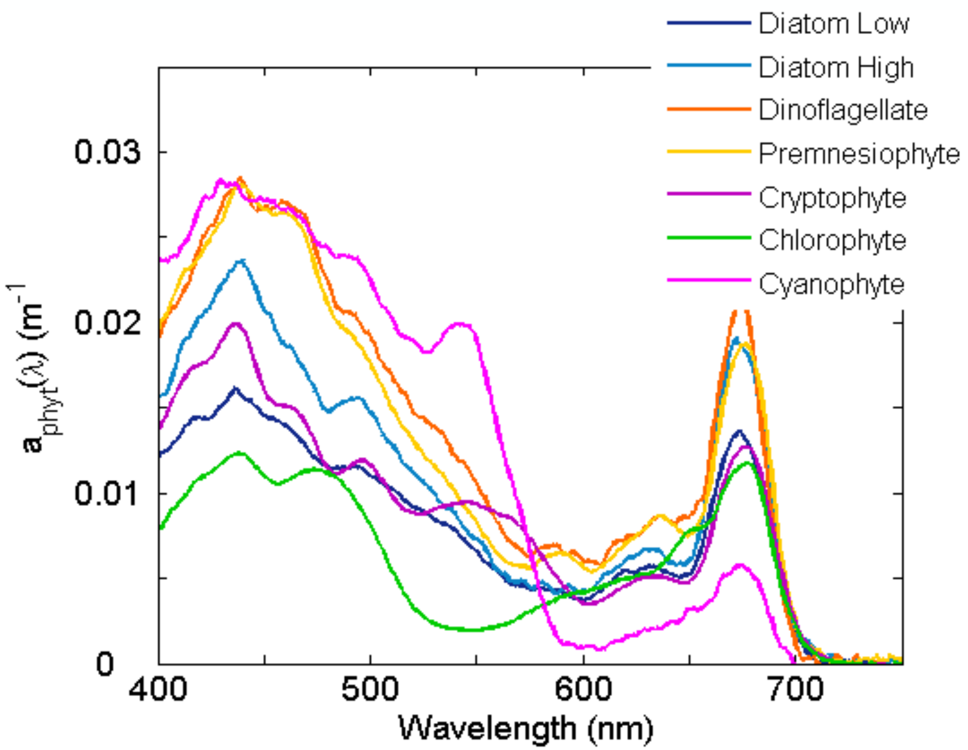


Falkowski et Oliver (2007) - The carbon biological pump

Phytoplankton optical properties: absorption





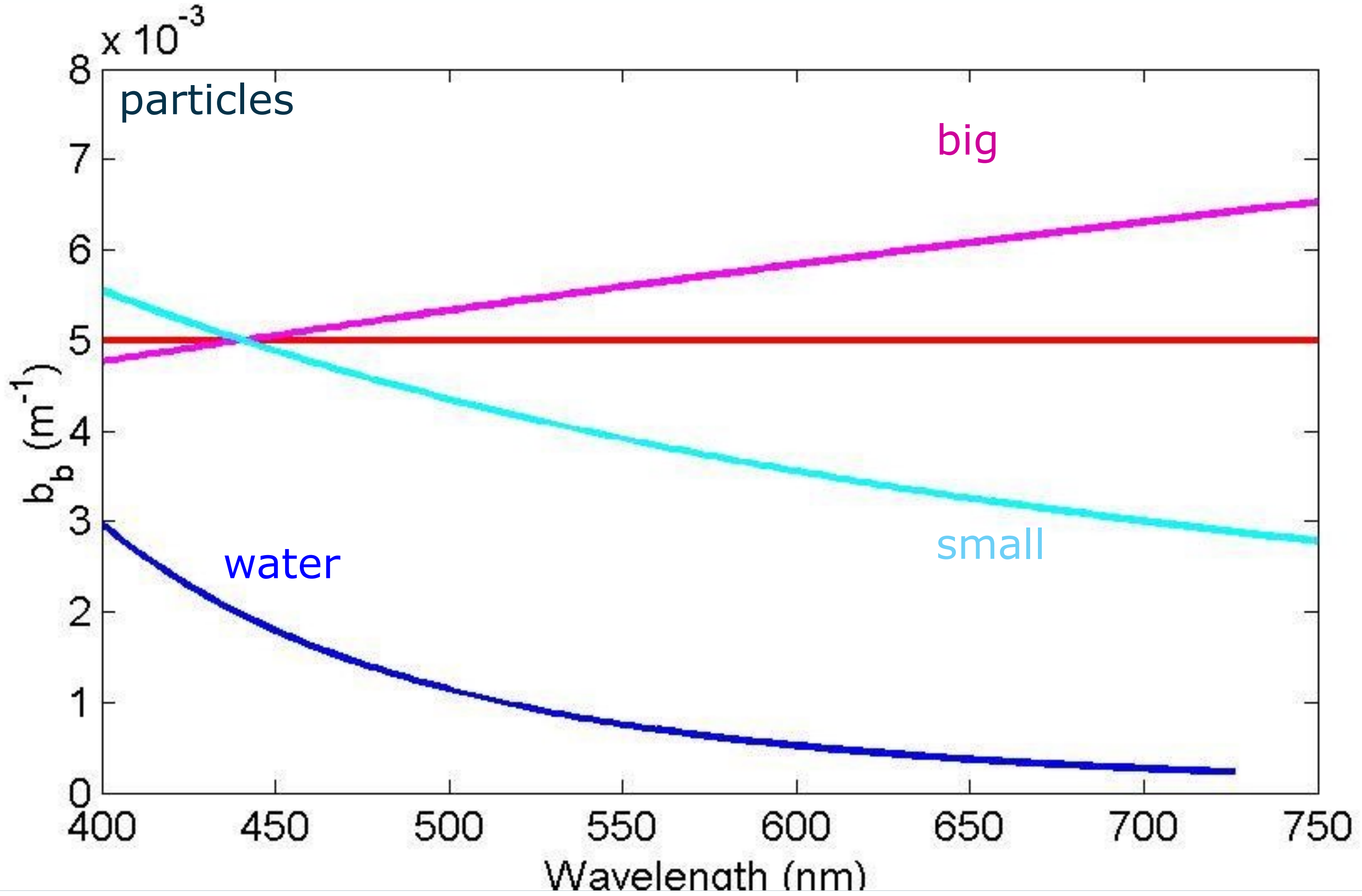


http://www.oceanopticsbook.info/view/absorption/absorption_by_oceanic_constituents

Phytoplankton optical properties: backscatter

$$b_{b\phi} = 0.3\left(\frac{550}{\lambda}\right)[Cla]^{0.62}$$

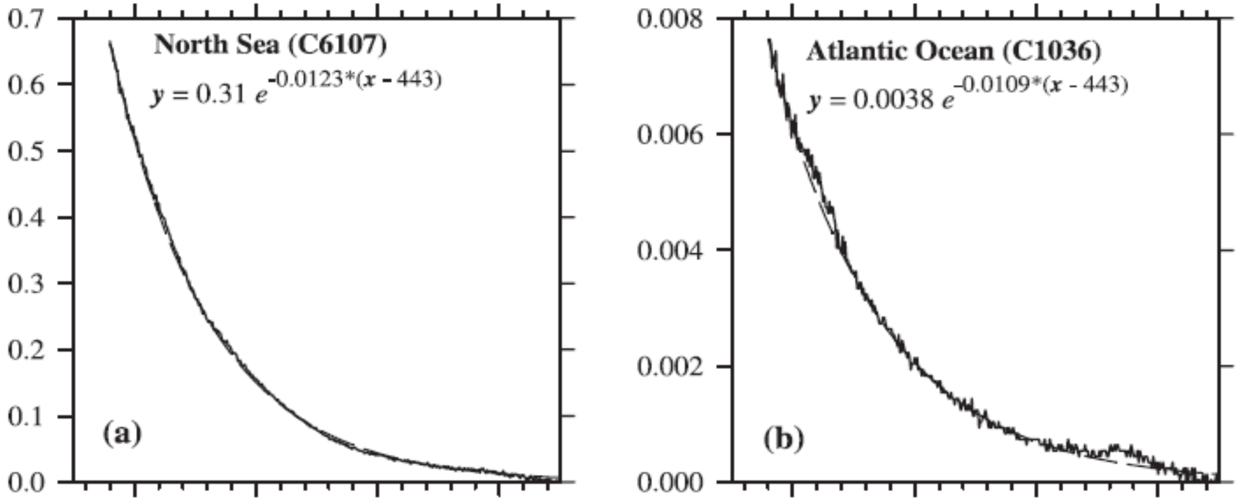
(Gordon & Morel, 198



Suspended material or Non-Algal Particles

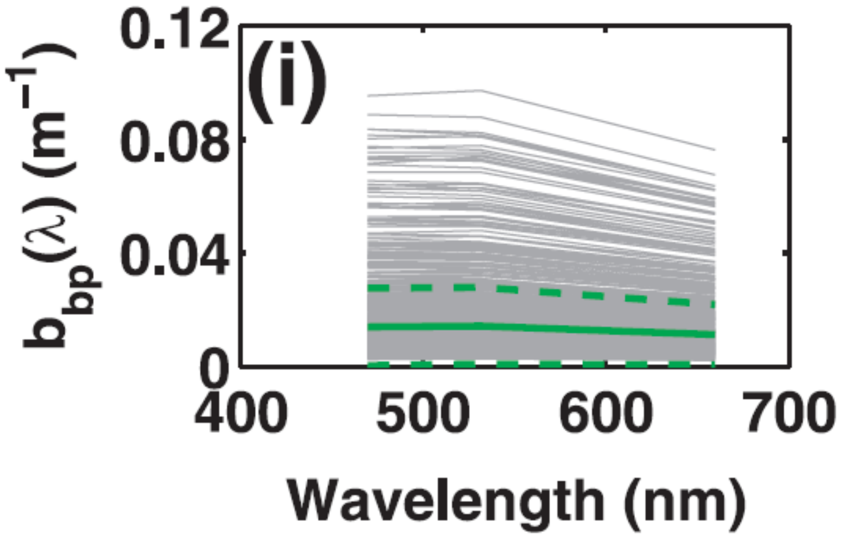
Absorption

$$a_{NAP}(\lambda) = a_{NAP}(443)e^{[-S_{NAP}(\lambda - 443)]}$$



Backscatter

$$b_{bNAP}(\lambda) = b_{bNAP}(555)\left(\frac{\lambda}{555}\right)^{\gamma_{bb}}$$



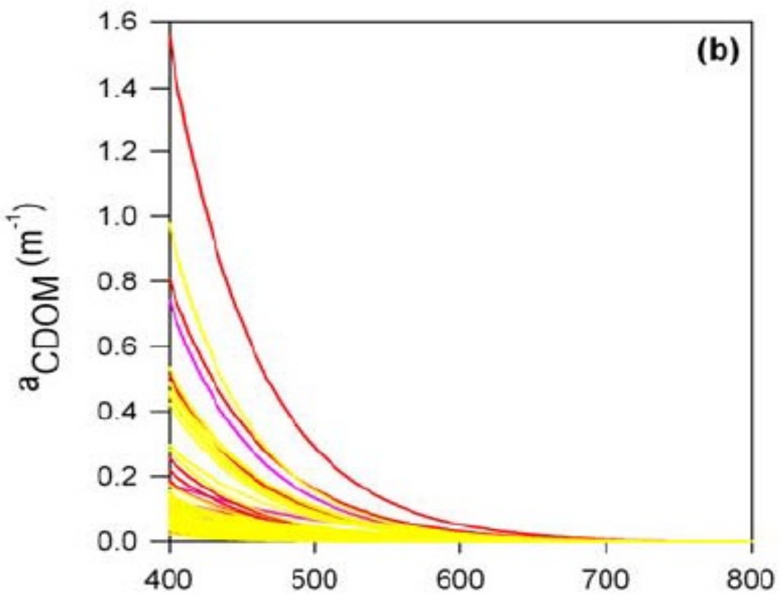
Ana Dogliotti

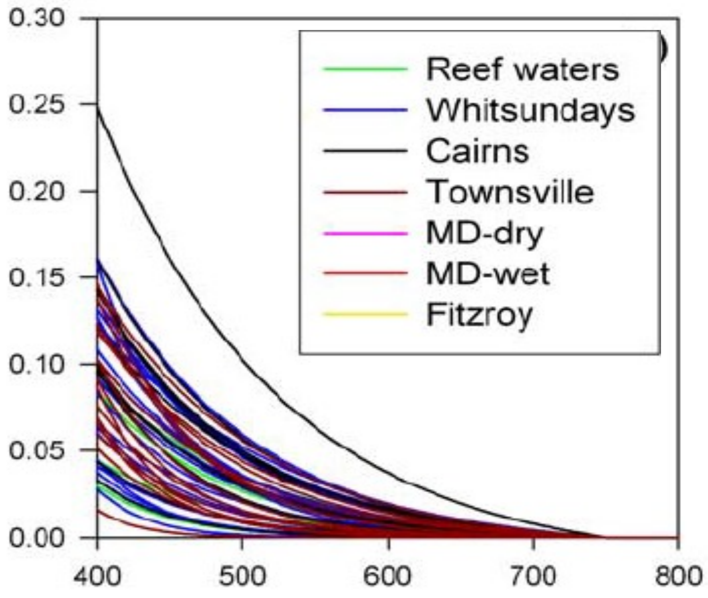
Coloured Dissolved Organic Matter

Absorption

$$a_{CDOM}(\lambda) = a_{CDOM}(\lambda_0)e^{(-S_{CDOM}(\lambda_0-\lambda))}$$

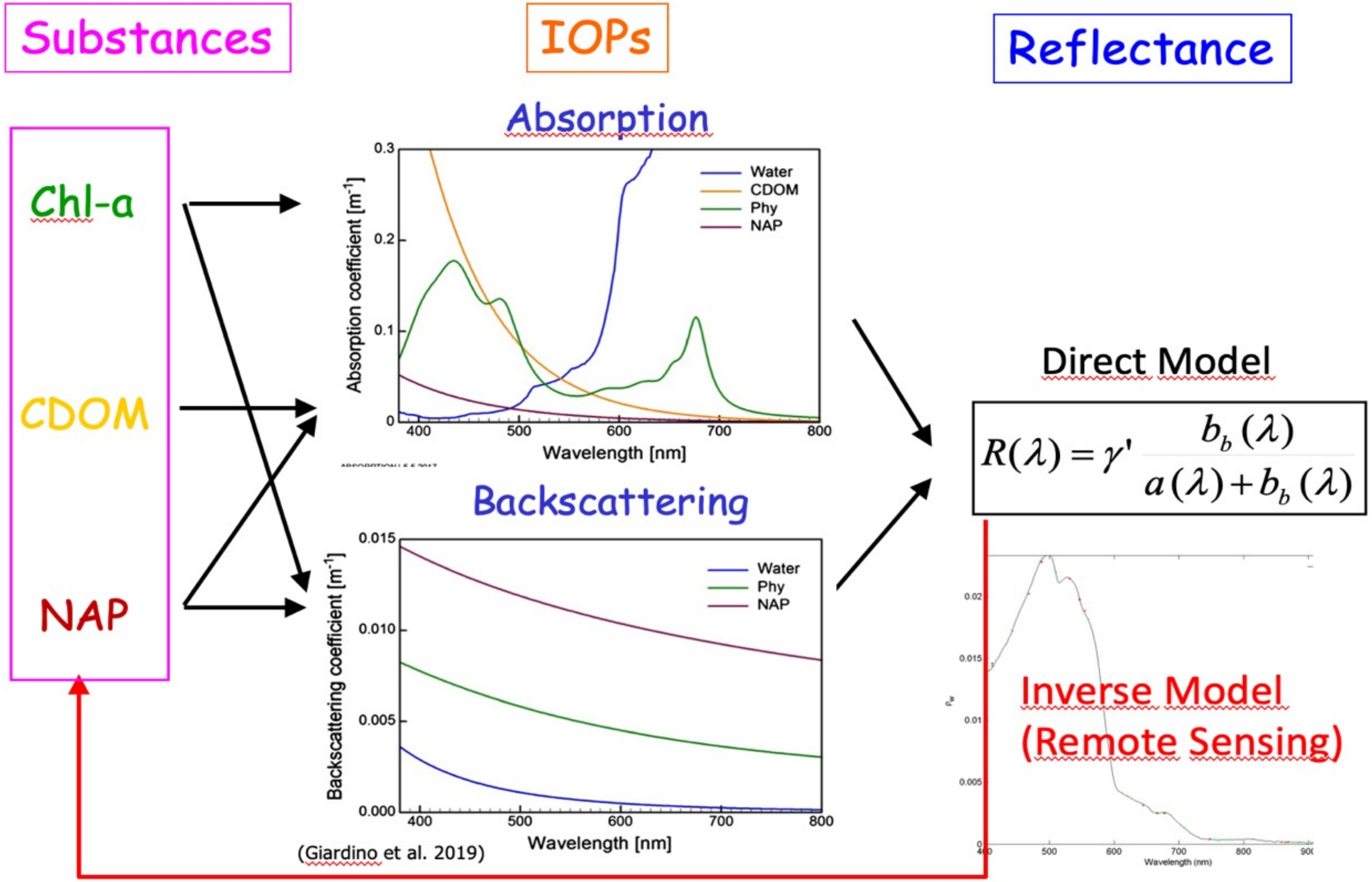
S_{CDOM} : slope (0.0114 – 0.0251 nm^{-1})





(Blondeau-Patissier et al. 2009)

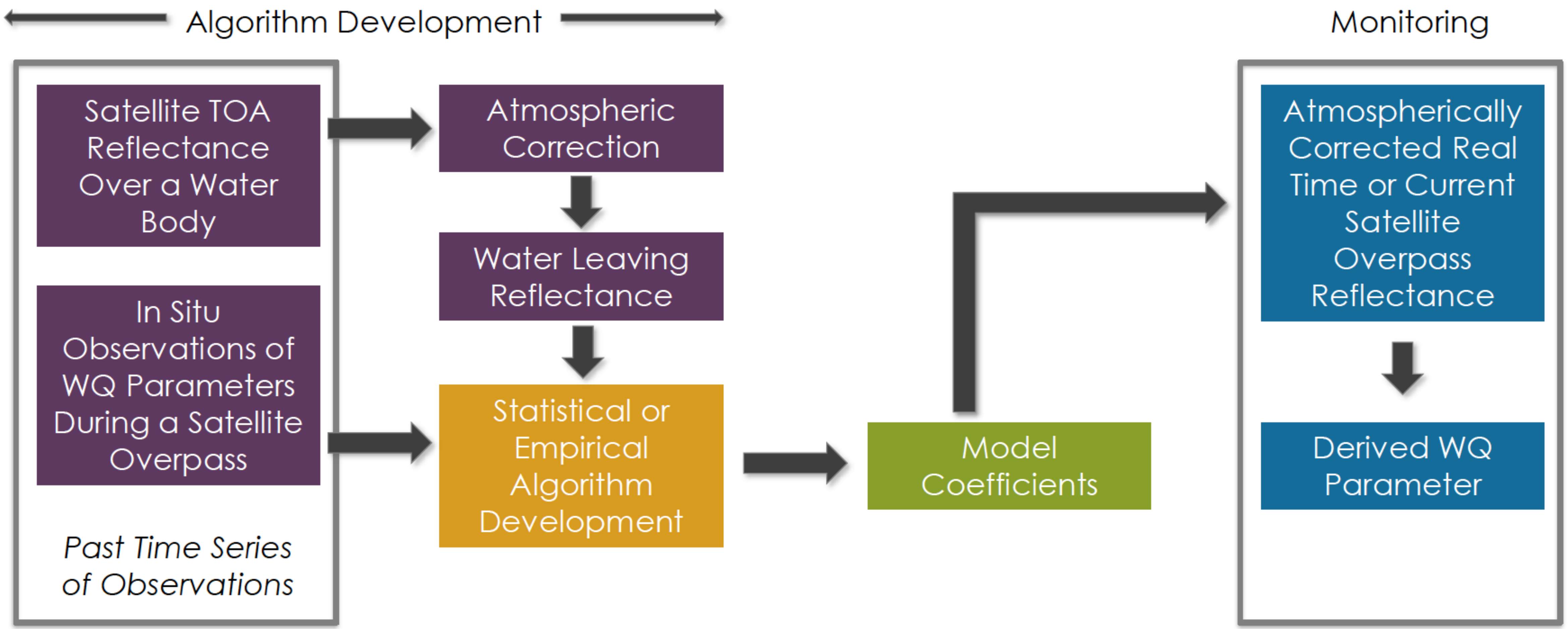
From substances to IOPs to Reflectance



$$R(\lambda) = \gamma' \frac{b_b(\lambda)}{a(\lambda) + b_b(\lambda)}$$

Ana Dogliotti

Reflectance algorithms



NASA's Applied Remote Sensing Training Program

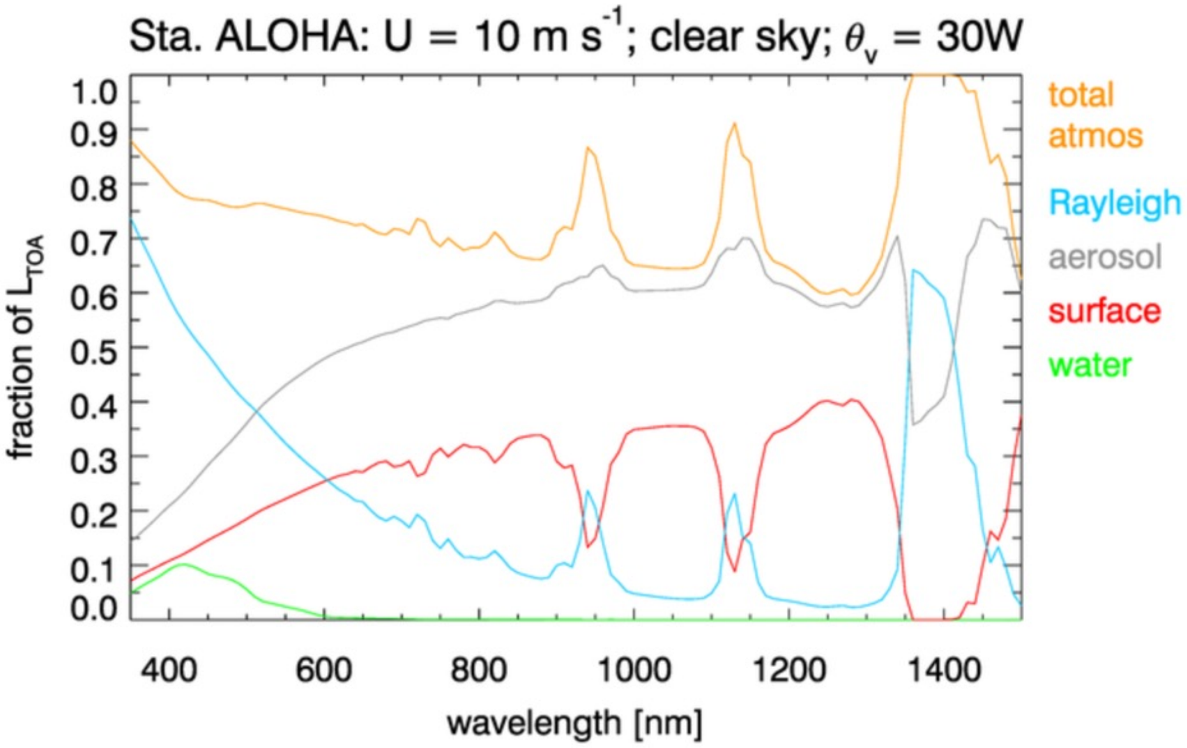
Atmospheric Correction

Ocean Colour sensors measure the upwelling radiances at the Top Of Atmosphere (L_u).

Lu comes from the water leaving radiance (L_w), the radiance reflected by the atmosphere (L_r) and the radiance scattered into the viewing direction by the atmosphere (L_a).

To obtain Lw is necessary to remove the contributions from

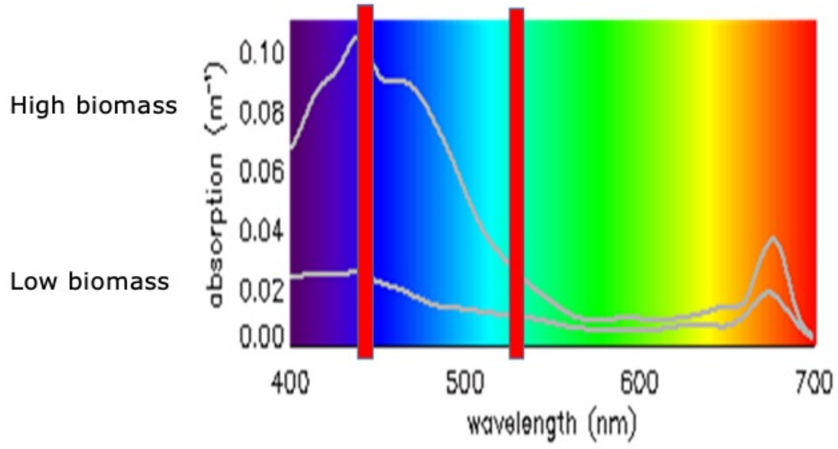
L_a and L_r = atmospheric correction.



Ocean Optics Web Book

Phytoplankton using Chl-a as proxy

Empirical algorithms



Remote-sensing reflectance maximum band ratio ([443,490,510]/555) as a function of chlorophyll-a concentration.

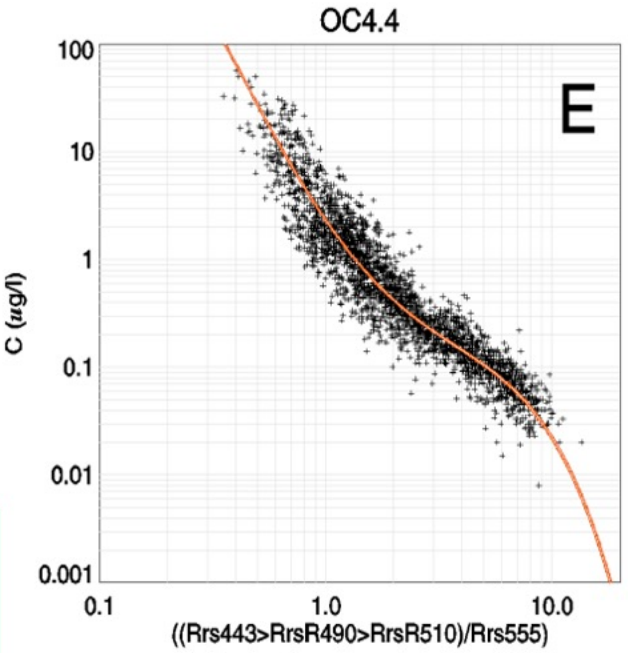


Figure from Valente et al 2016, Earth Syst. Sci. Data, 8, 235-252, doi:10.5194/essd-8-235-2016.

OC4 version 4

C = 10.0^(a(0) + a(1)*R + a(2)*R^2 + a(3)*R^3 + a(4)*R^4)

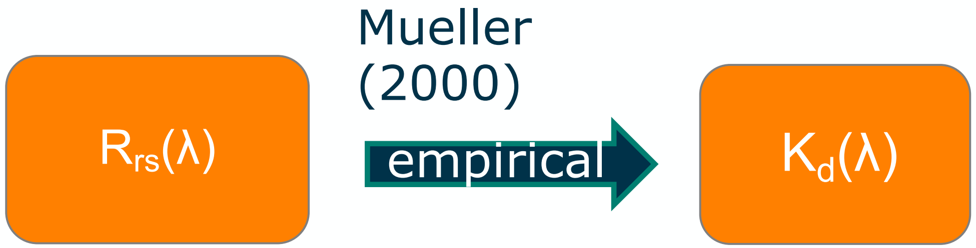
R = ALOG10((Rrs443>Rrs490>Rrs510)/Rrs555)

a = [0.366,-3.067,1.930,0.649,-1.532]

NASA OC4 and OC4E v64 operational standard algorithms, http://oceancolor.gsfc.nasa.gov/cms/atbd/chlor_a)
.

AOPS then IOPS

1. Atmospheric corrections & directional effects



2. Semi-analytical relationships:

$$R_{rs} = g_0\left(\frac{b_b}{a+b_b}\right) + g_1\left(\frac{b_b}{a+b_b}\right)^2$$

$$a(\lambda) = a_w(\lambda) + a_{dg}(443)\, e^{-S(\lambda - 443)} + \mathbf{a}_\phi^*(\lambda)\, Chl$$

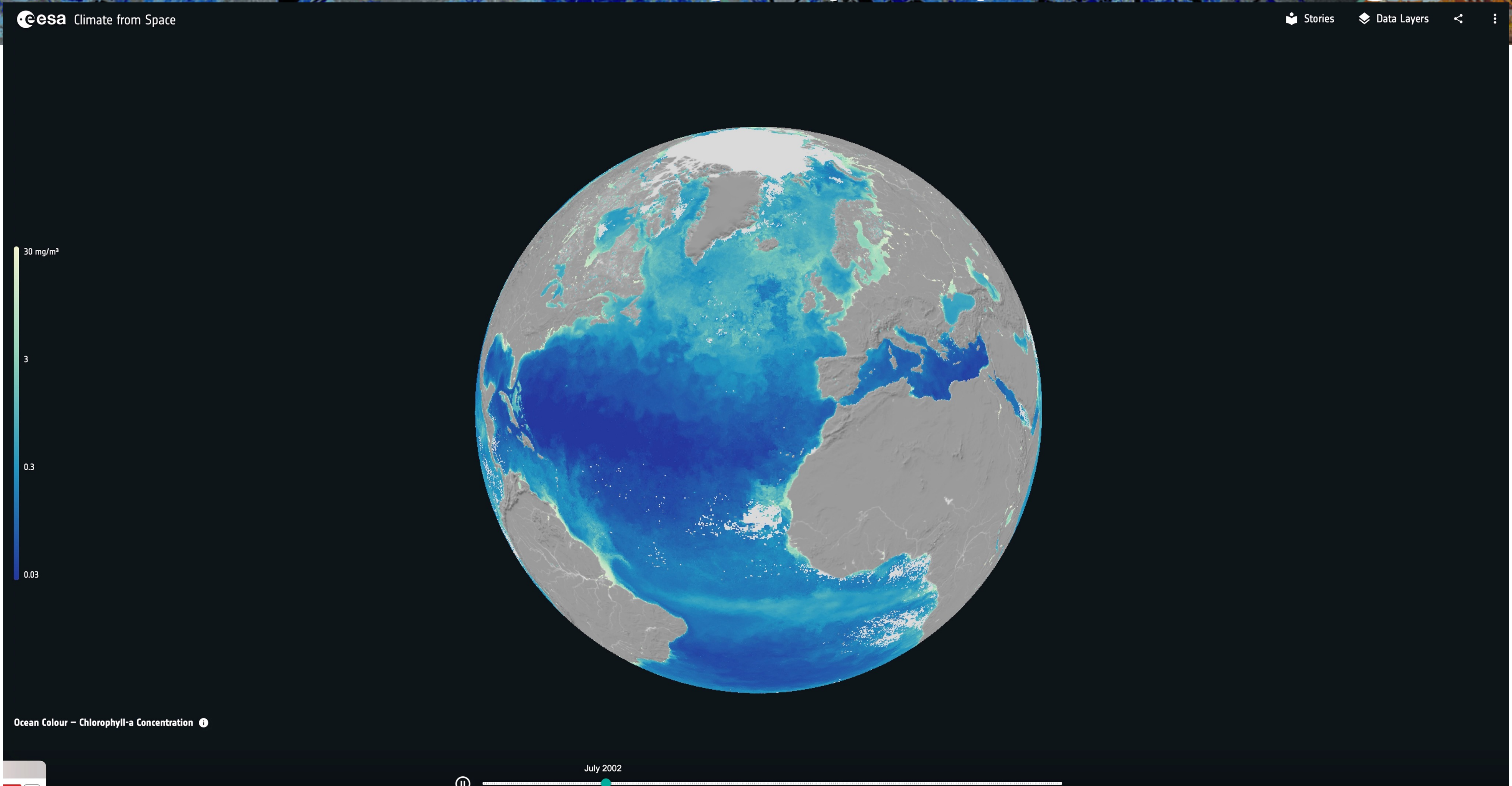
$$b_b(\lambda) = b_{bw}(\lambda) + b_{bp}(443)\left(\frac{443}{\lambda}\right)^{\eta}$$

$R_{rs}(\lambda)$ from satellite(s)

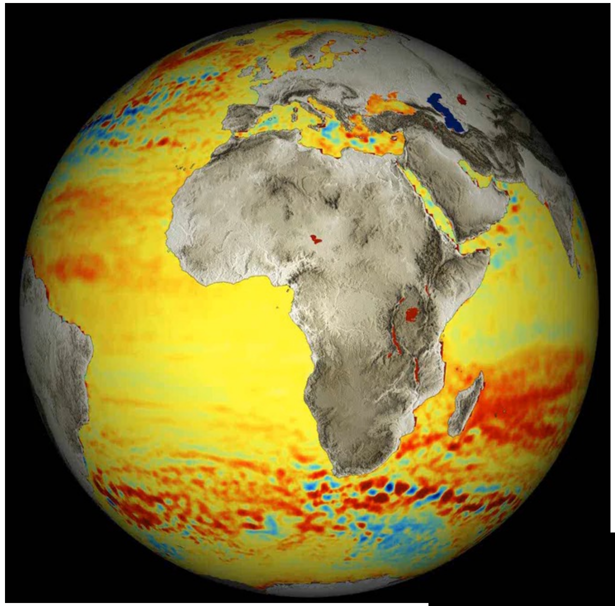
S, η, g_0, g_1, & $\mathbf{a}_\phi^*(\lambda)$ are constants

$a_{dg}(443)$, $b_{bp}(443)$, & Chl are unknown

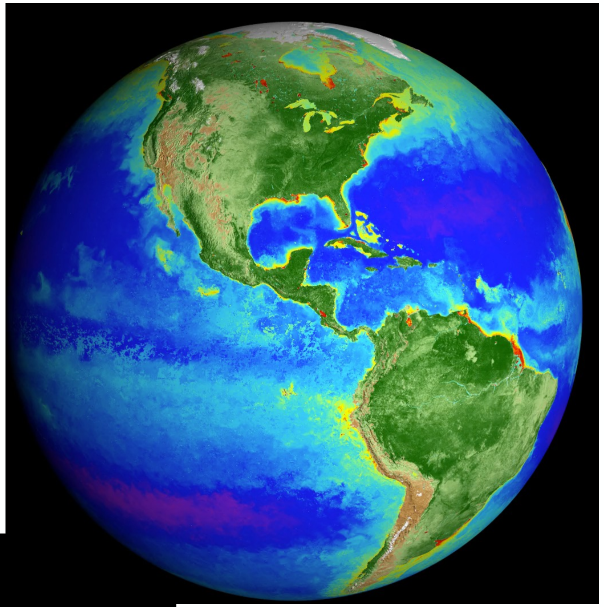
Ocean Colour Remote Sensing: why is key?

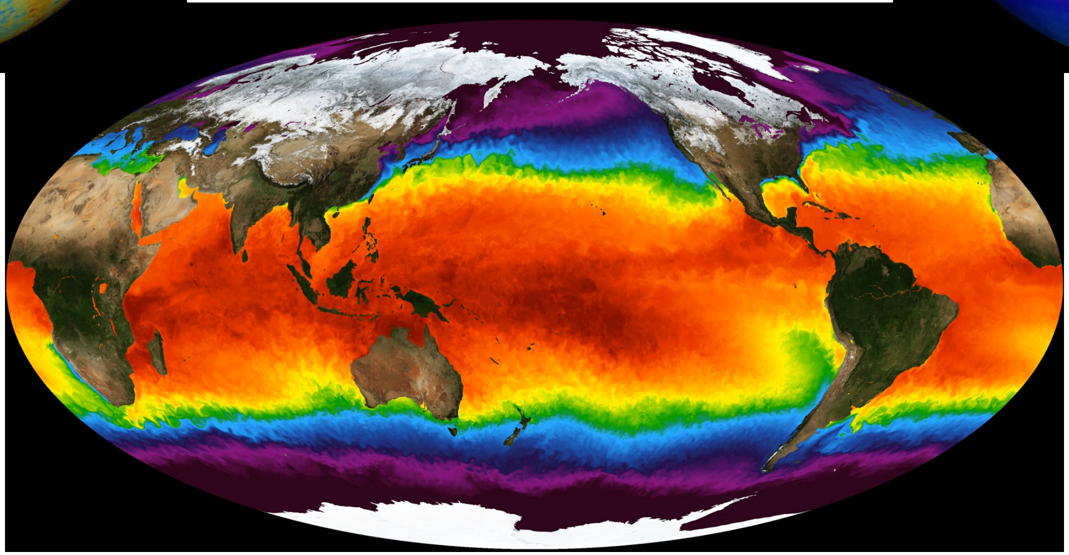


Why to combine with other variables

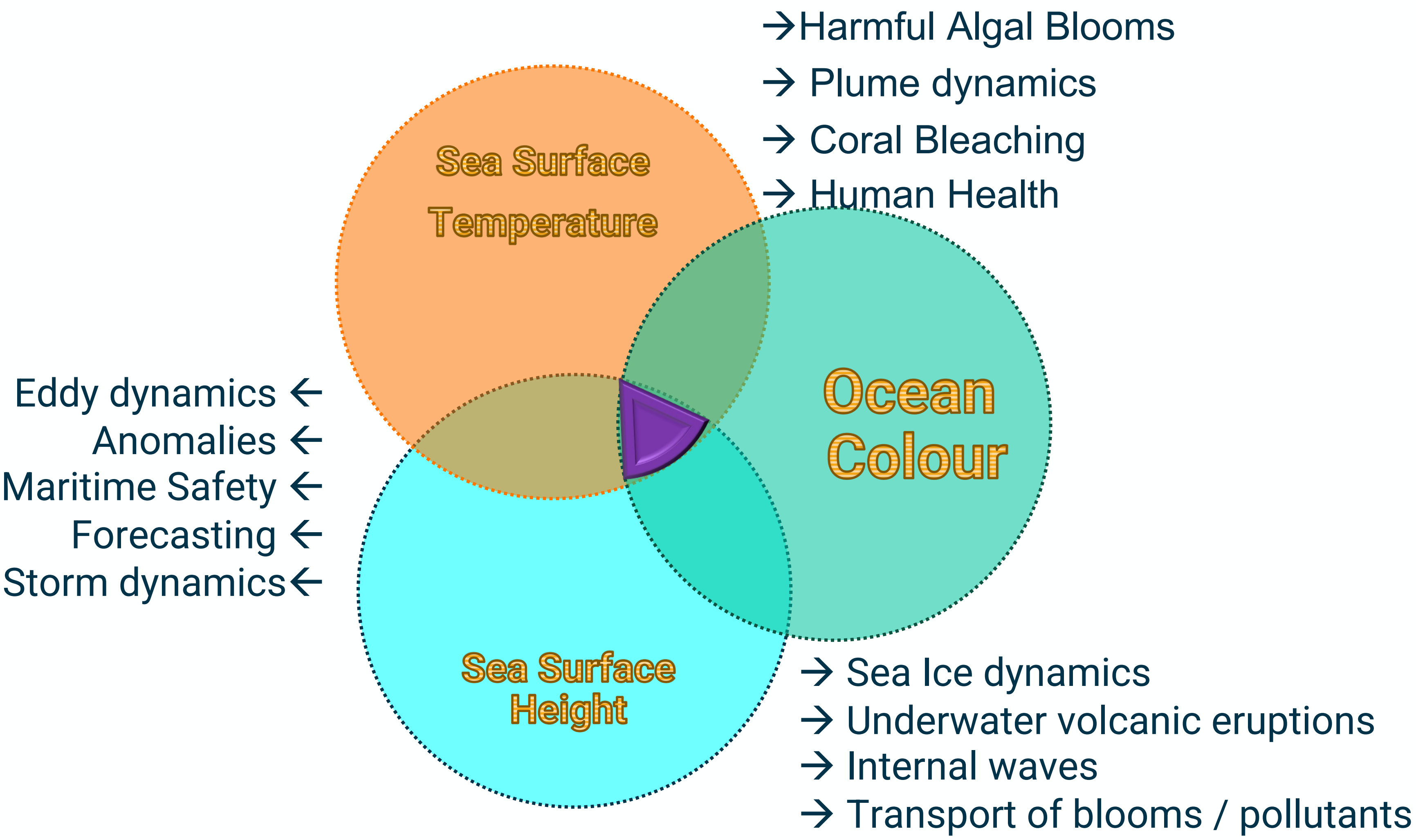


Ecosystem Monitoring





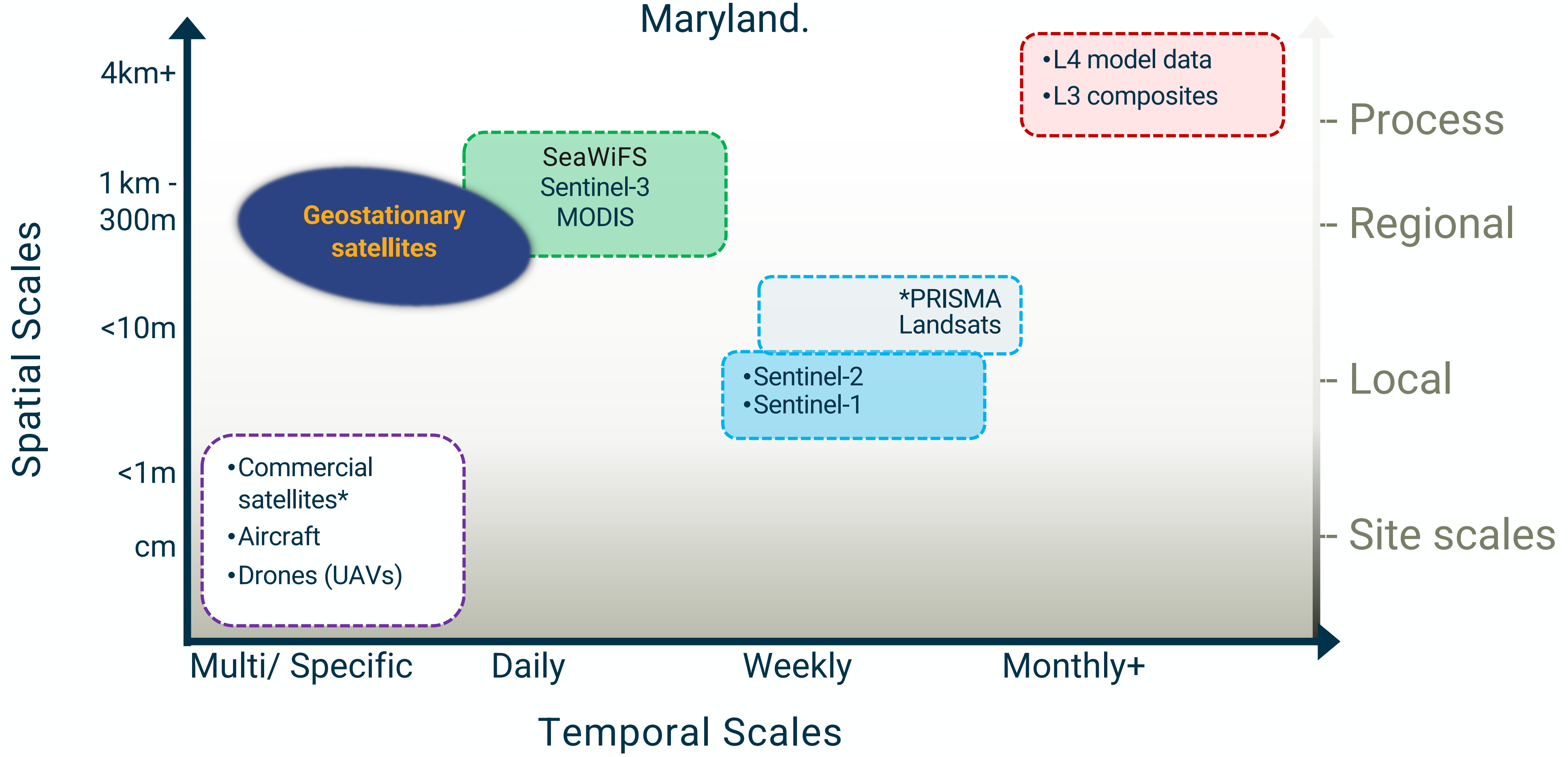
Why to combine with other variables



You cannot have everything

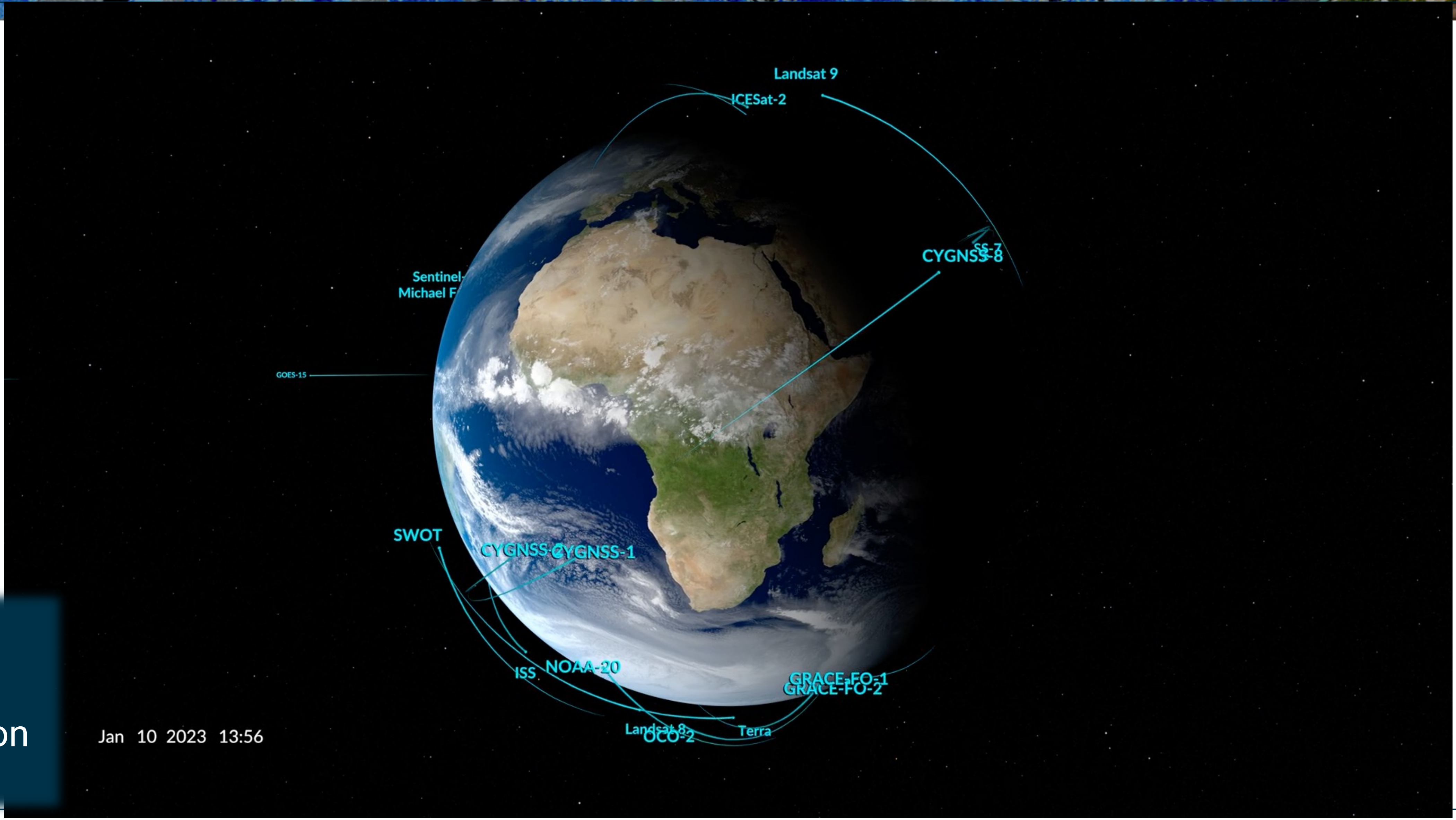
Define temporal and spatial scale

Phinn, S.R, Roelfsema, C.M. and Stumpf, R. (2010). Remote sensing: the promise and the reality. In: Dennison, W., (Ed.) Coastal Assessment Handbook, Chapter 15, University of Maryland.



L. Biermann

Swarm of satellites



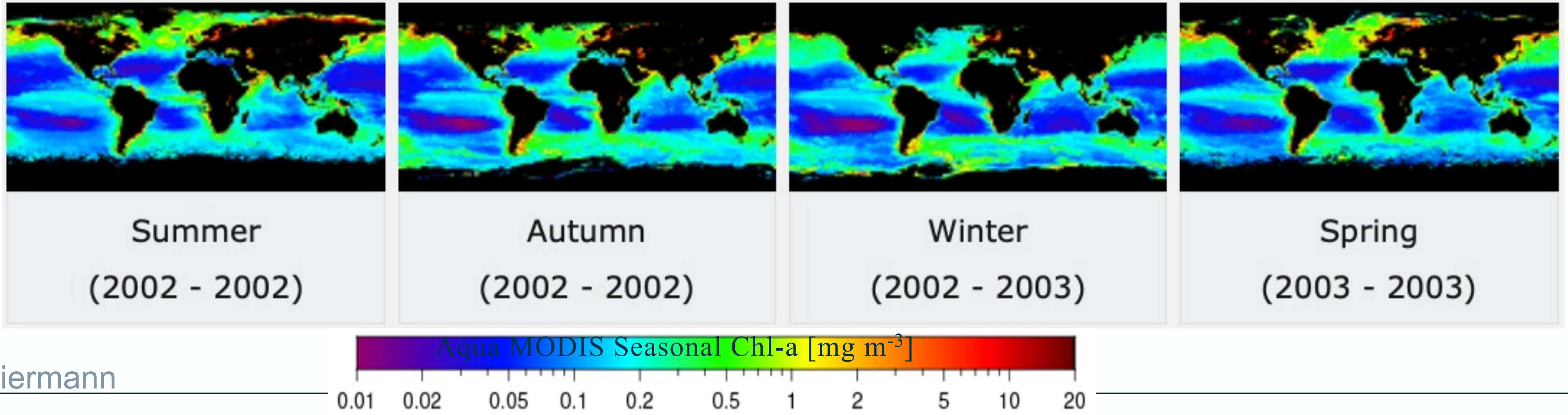
Animation:

NASA Visualisation Studio

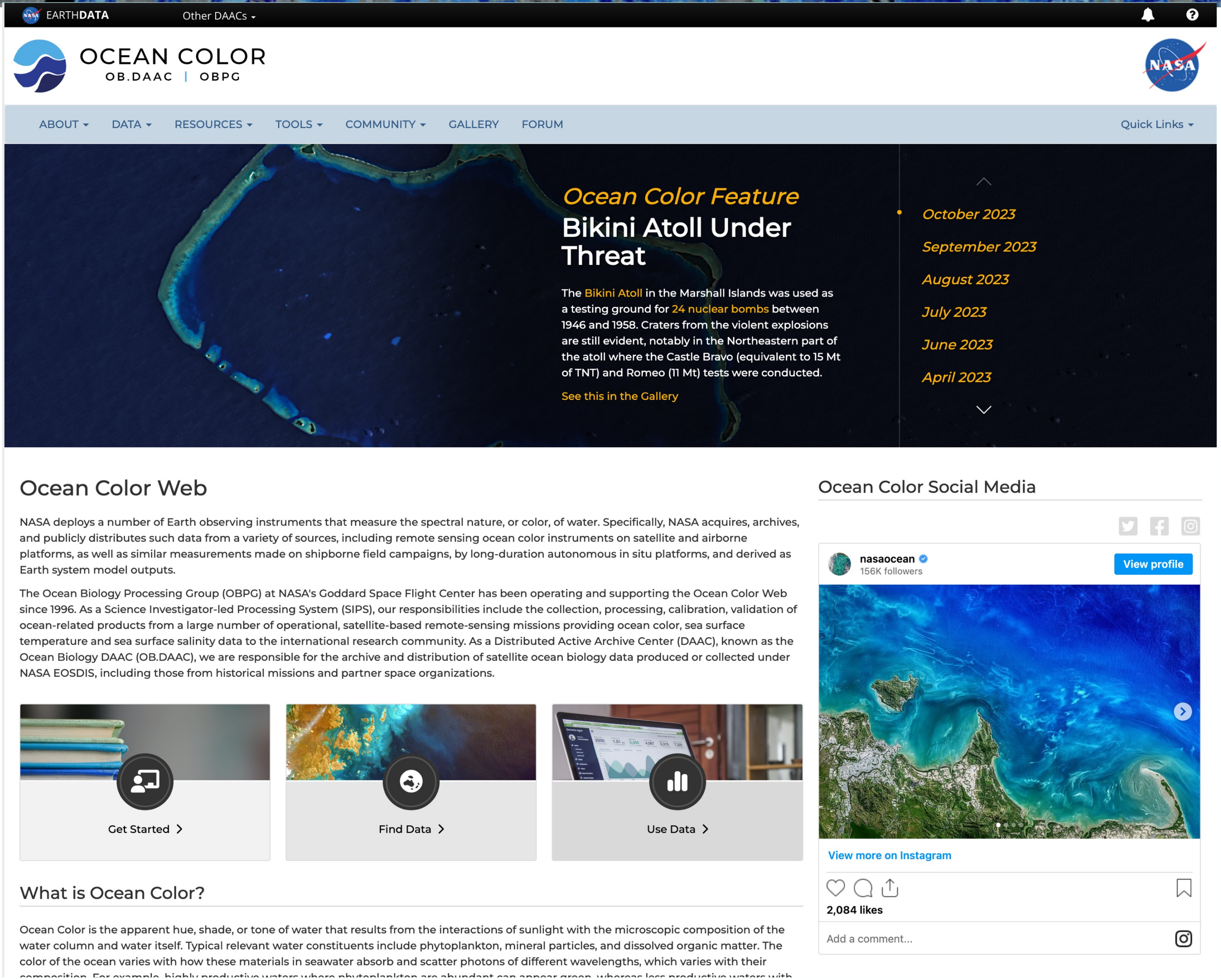
NASA's MODIS (MODerate resolution Imaging Spectroradiometer) sensors aboard Terra & Aqua satellites.

Coverage of Earth's surface every 2 days with data acquired in 36 bands at 300 m resolution.

Launched in July 2002 to present day – over 20 years!



OBPG NASA


EARTHDATA Other DAACs

OCEAN COLOR
OB.DAAC | OBPG

ABOUT DATA RESOURCES TOOLS COMMUNITY GALLERY FORUM Quick Links

Ocean Color Feature

Bikini Atoll Under Threat

The Bikini Atoll in the Marshall Islands was used as a testing ground for 24 nuclear bombs between 1946 and 1958. Craters from the violent explosions are still evident, notably in the Northeastern part of the atoll where the Castle Bravo (equivalent to 15 Mt of TNT) and Romeo (11 Mt) tests were conducted.

See this in the Gallery

October 2023
September 2023
August 2023
July 2023
June 2023
April 2023

Ocean Color Web

NASA deploys a number of Earth observing instruments that measure the spectral nature, or color, of water. Specifically, NASA acquires, archives, and publicly distributes such data from a variety of sources, including remote sensing ocean color instruments on satellite and airborne platforms, as well as similar measurements made on shipborne field campaigns, by long-duration autonomous in situ platforms, and derived as Earth system model outputs.

The Ocean Biology Processing Group (OBPG) at NASA's Goddard Space Flight Center has been operating and supporting the Ocean Color Web since 1996. As a Science Investigator-led Processing System (SIPS), our responsibilities include the collection, processing, calibration, validation of ocean-related products from a large number of operational, satellite-based remote-sensing missions providing ocean color, sea surface temperature and sea surface salinity data to the international research community. As a Distributed Active Archive Center (DAAC), known as the Ocean Biology DAAC (OB.DAAC), we are responsible for the archive and distribution of satellite ocean biology data produced or collected under NASA EOSDIS, including those from historical missions and partner space organizations.

Get Started
Find Data
Use Data

What is Ocean Color?

Ocean Color is the apparent hue, shade, or tone of water that results from the interactions of sunlight with the microscopic composition of the water column and water itself. Typical relevant water constituents include phytoplankton, mineral particles, and dissolved organic matter. The color of the ocean varies with how these materials in seawater absorb and scatter photons of different wavelengths, which varies with their

Ocean Color Social Media

nasaocean
156K followers
View profile
View more on Instagram
2,084 likes
Add a comment...

PACE

Plankton, Aerosol, Cloud, ocean Ecosystem

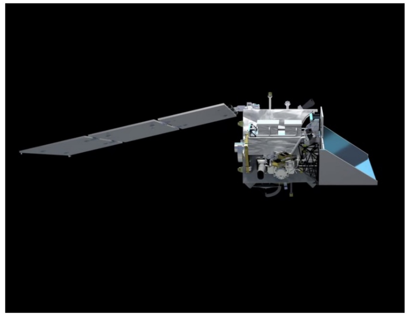
HOME · ABOUT · MISSION · SCIENCE · APPLICATIONS · DATA · LEARN MORE · NEWS · EVENTS · GALLERY · DOCUMENTS

Mission

Building on lessons learned from previous ocean color studies, a team of dedicated people is bringing PACE to life. PACE will face a series of important milestones during its mission development. The Development Team at Goddard Space Flight Center (GSFC) will guide PACE through each phase as the instruments, spacecraft, and observatory are built, tested, and flown.

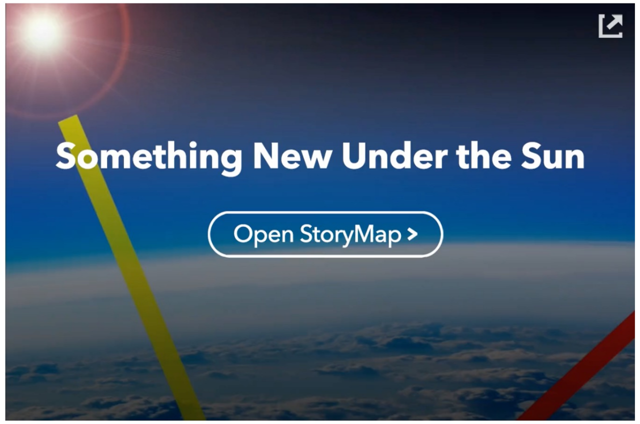
Observatory

GSFC is responsible for the principal mission elements, including the design and fabrication of the spacecraft, development of scientific instrumentation.



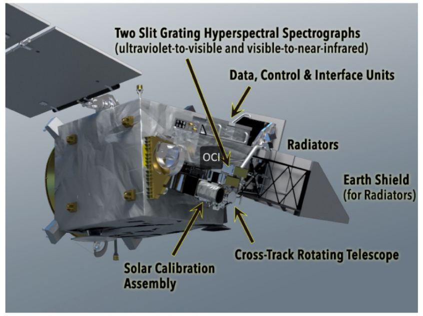
Build your own PACE!

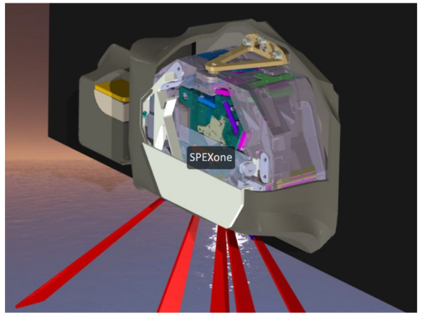
PACE StoryMap



Observatory Overview	
Mass with fuel	Not to exceed 1700 kg (3748 lb)
Dimensions	1.5 m x 1.5 m x 3.2 m (4.9 ft x 4.9 ft x 10.5 ft)
Power	1000 Watts
Communications	S-Band - Command & Telemetry Ka-Band - Science Data

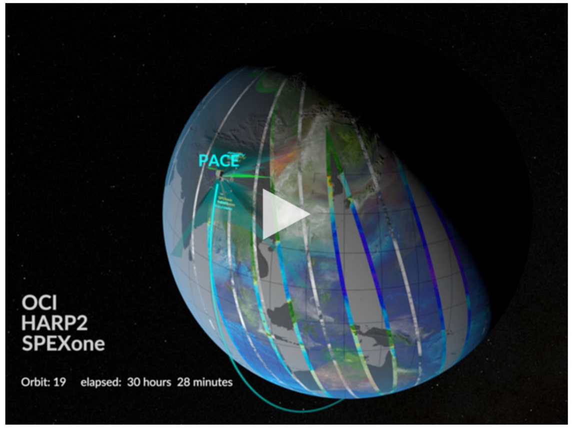
Instruments





Click on any image for a closer view.

Visualizations of PACE in Orbit



Click image to view movie. Credit: NASA Scientific Visualization Studio.

The primary science instrument planned for PACE is the Ocean Color Instrument (OCI) which will be capable of measuring the color of the ocean from ultraviolet to shortwave infrared. Learn more about the OCI »

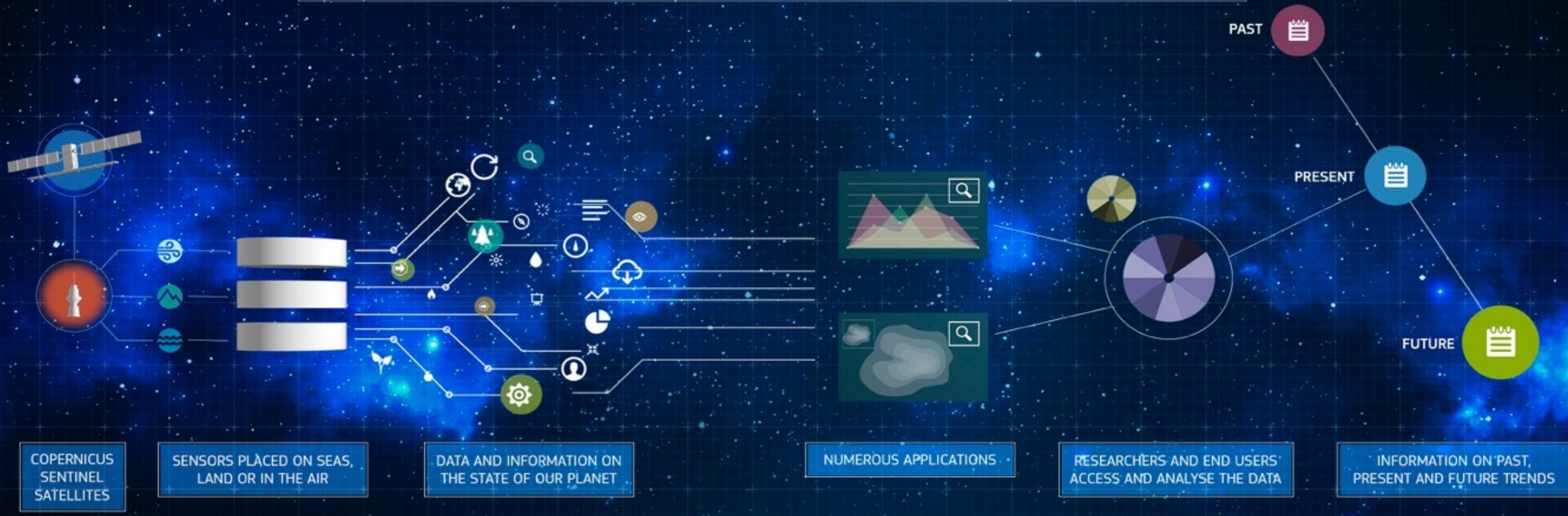
PACE will also include two polarimeters. Such instruments are used to measure how the oscillation of sunlight within a geometric plane - known as its polarization - is changed by passing through clouds, aerosols, and the ocean.

The Copernicus Programme

- European Commission funds and manages the Copernicus Programme – **all** EO data are freely available to **any users**.
- Satellite operation & data services shared between:

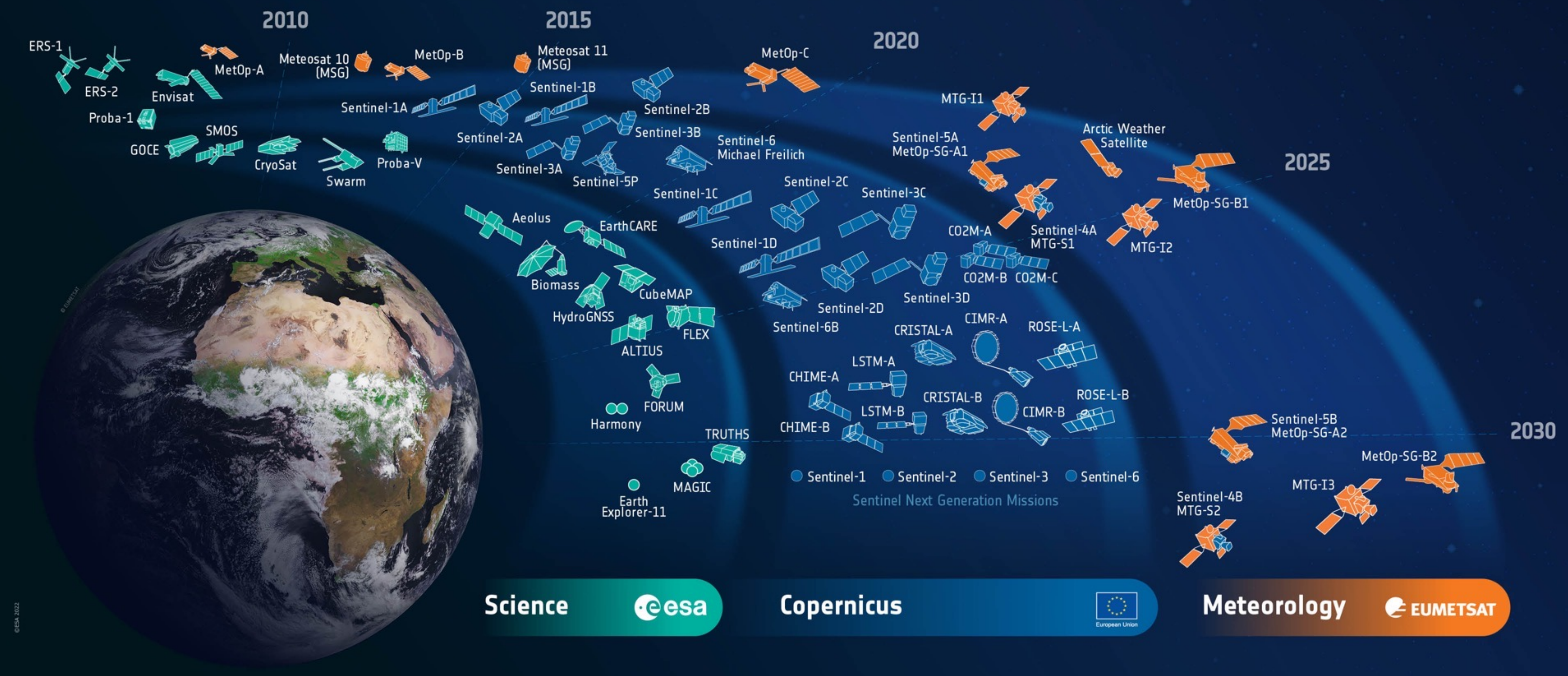
1. European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)
2. European Space Agency (ESA)

COPERNICUS DATA AND APPLICATIONS



DATA IS COLLECTED BY COPERNICUS SENTINEL SATELLITES THAT SOMETIMES OPERATE ALONE AND SOMETIMES COMBINED WITH SENSORS PLACED ON THE SEAS, LAND OR IN THE AIR. THIS DATA HELPS TO PROVIDE A LARGE AMOUNT OF RELIABLE AND UP-TO-DATE INFORMATION ON THE STATUS OF OUR PLANET AND CAN BE USED TO CREATE DIFFERENT KIND OF PRODUCTS SUCH AS STATISTICS AND TOPOGRAPHIC MAPS. THE DATA IS ANALYSED IN A WAY THAT GENERATES INDICATORS USEFUL FOR RESEARCHERS AND END USERS, PROVIDING INFORMATION ON PAST, PRESENT AND FUTURE TRENDS.

ESA developed Earth Observation missions



Sentinel 3

esa

Sentinel-3A was launched in Feb 2016 and Sentinel-3B followed in April 2018

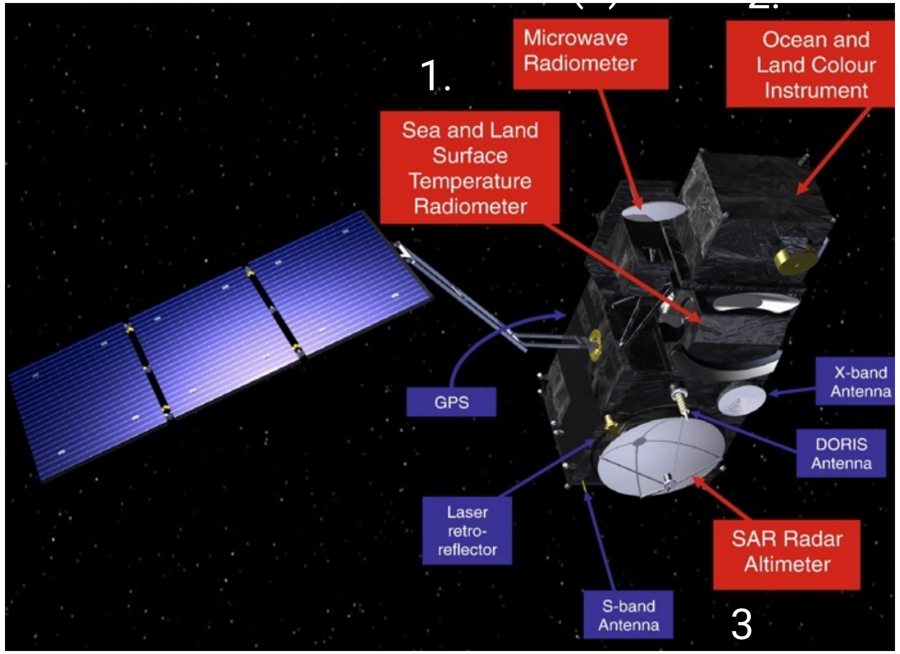
Sentinel-3 (and all Sentinels) fly in pairs (constellations).

Two-day global coverage of optical data.

Mission's main objective is to deliver measurements of sea-surface height, surface temperature, and chlorophyll.

Fondly known as the 'Blue Sentinel' thanks to its suite of ocean observing instruments.

- Sentinel-3 carries 3 sensors:
  1. SLSTR (Temperature)
  2. OLCI   (Chlorophyll)
  3. SRAL   (Surface Height)
- EUMETSAT operates   Sentinel-3 satellites.
- Copernicus Marine Data   Service conducts marine data processing and dissemination.



OLCI for HABs

OLCI sensor – Algal Pigment Chlorophyll-a Concentrations:

Full Resolution (FR) 300m

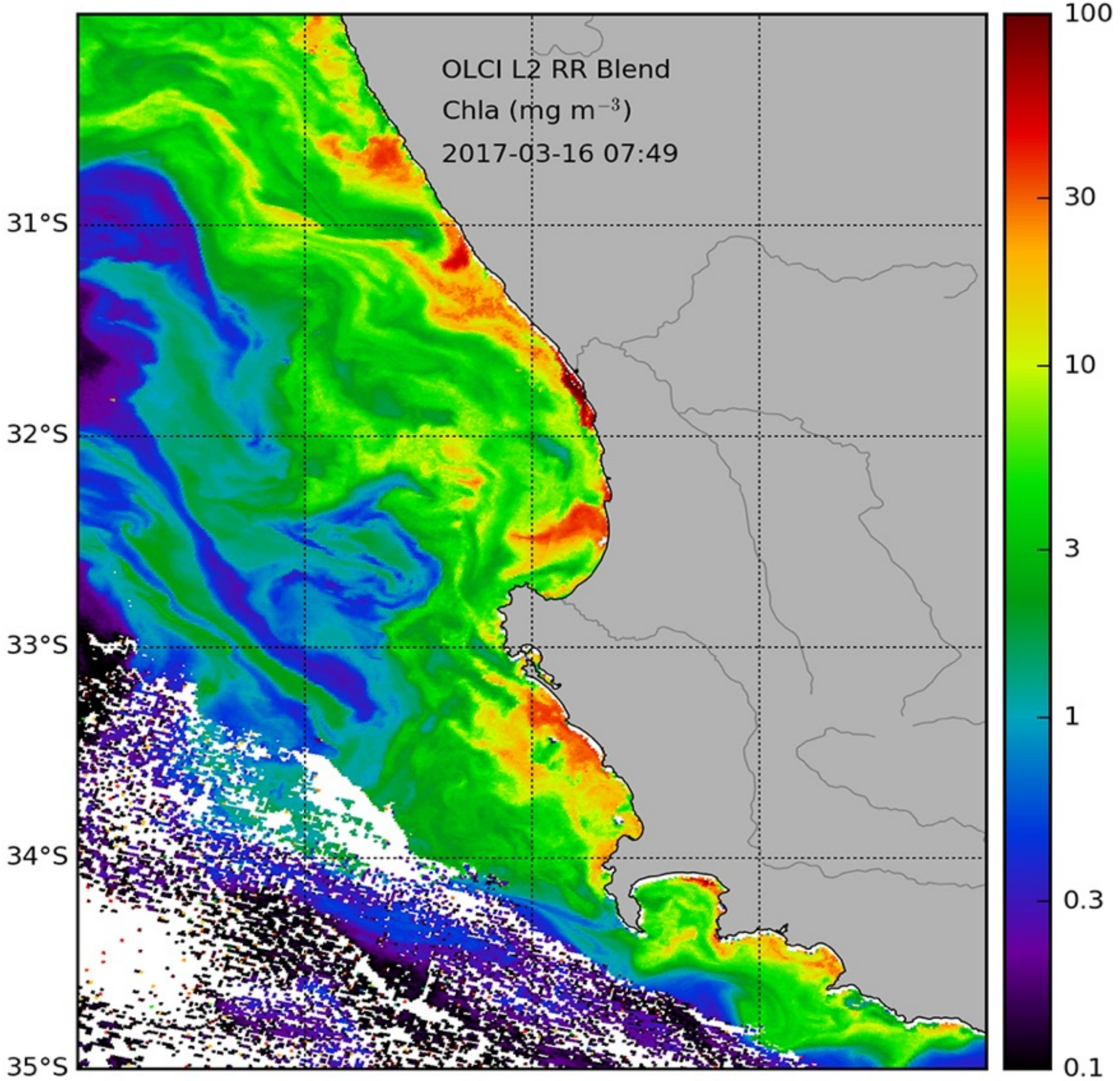
21 spectral bands (RGB - SWIR)

Excellent Signal to Noise Ratio.

Measures to 1 optical depth; determi
what is suspended in surface waters
much).

OLCI:

- Swath width: 1 270 km.
- Spatial resolution: 300m full resolution (FR) granules, 1km reduced resolution (RR).



L. Biermann

Sentinel 2: Coastal and Inland Waters

- Terrestrial mission with **some marine applications**.
- Passive Optical sensor.
- Max 10 m spatial resolution.
- **Derived Ocean Colour.**
- Level 1C and Level 2 data.

Brown hills speckle the eastern part of Australia's Lake MacKay (ESA)

Sentinel 2: Coastal and Inland Waters

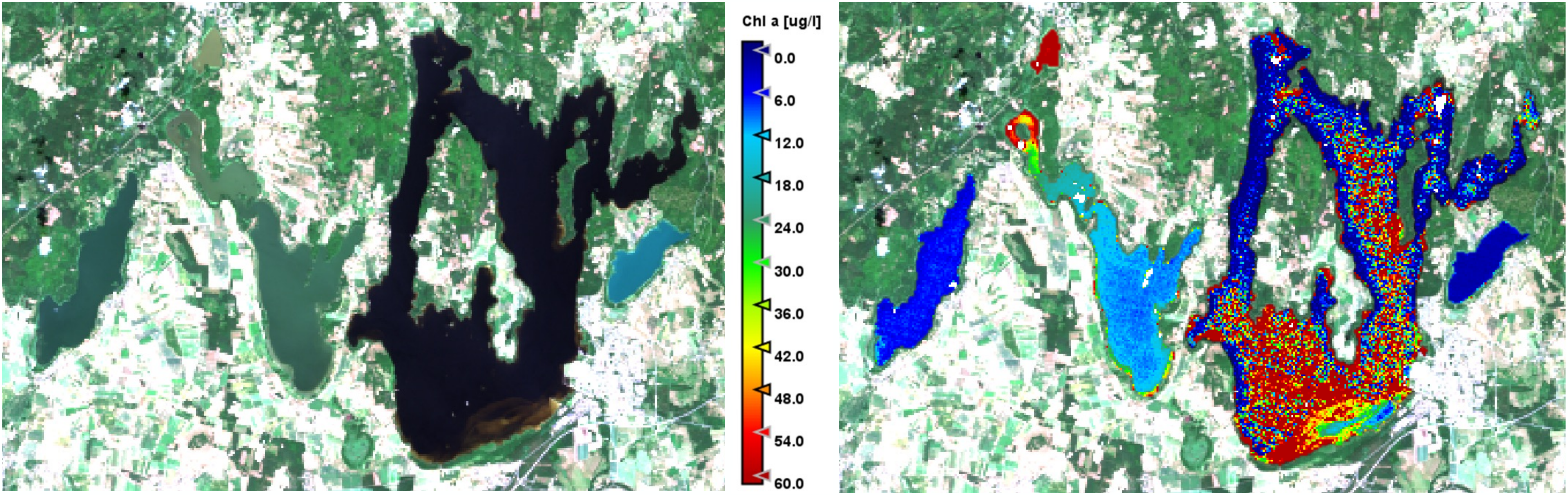
Thanks to the high spatial resolution (10m) of its VIS & NIR bands, Sentinel-2 is still useful for:

- ✓Observing surface blooms.
- ✓Monitoring water quality, including inland waters.
- ✓Monitoring aquaculture farms.
- ✓Validating radar applications.
- ✓Marine Spatial Planning.
- ✓Detecting floating debris.

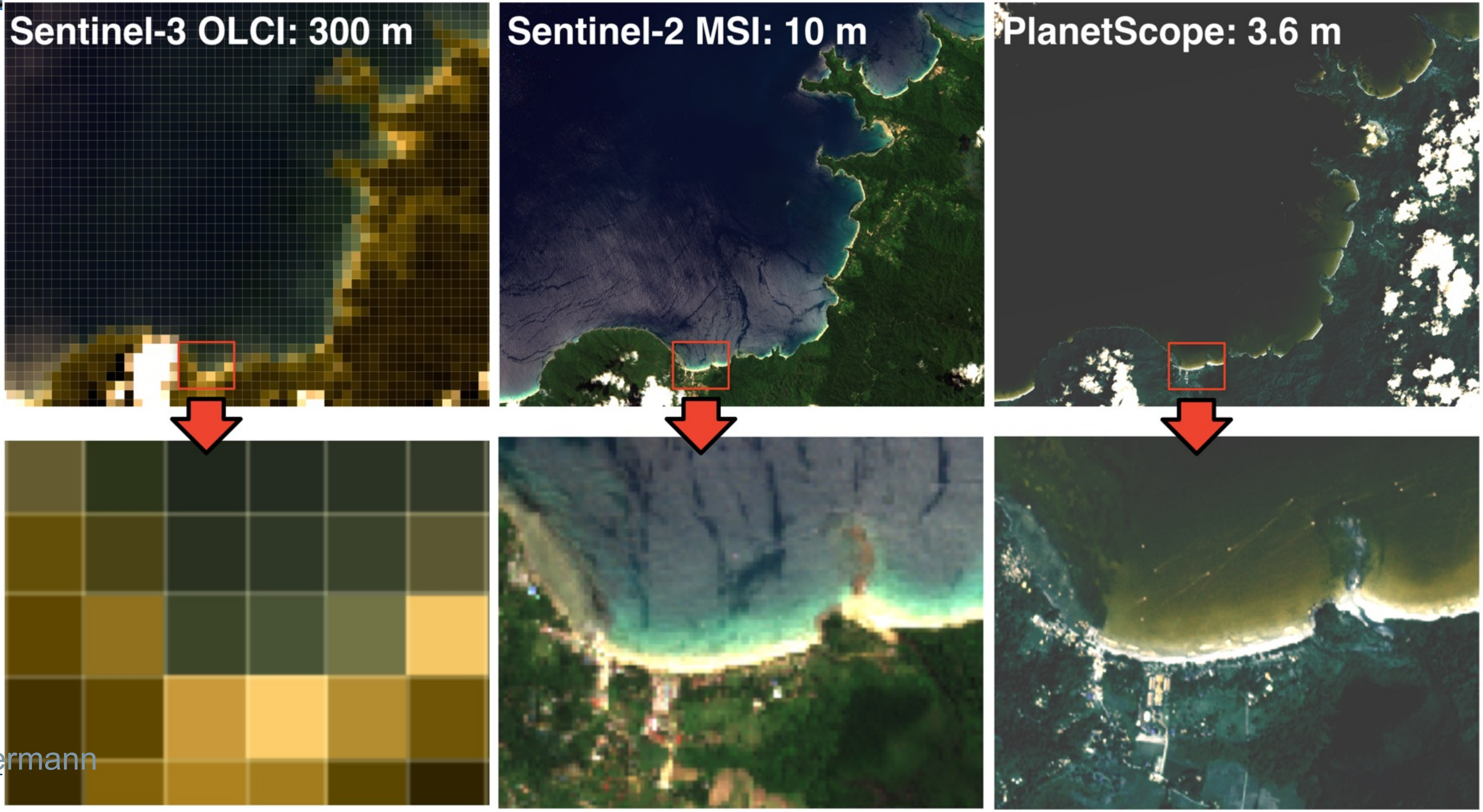
Florida: Floods Oct 2022

CyanoAlert Service - Sweden

Vattenriket - a UNESCO biosphere reserve area monitored with Sentinel-2. Reflectance and Chl a retrieval fails over dark humic



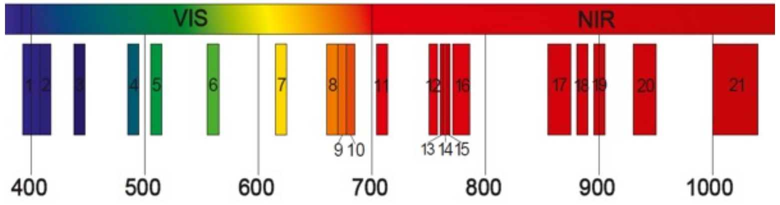
Spatial vs. Spectral



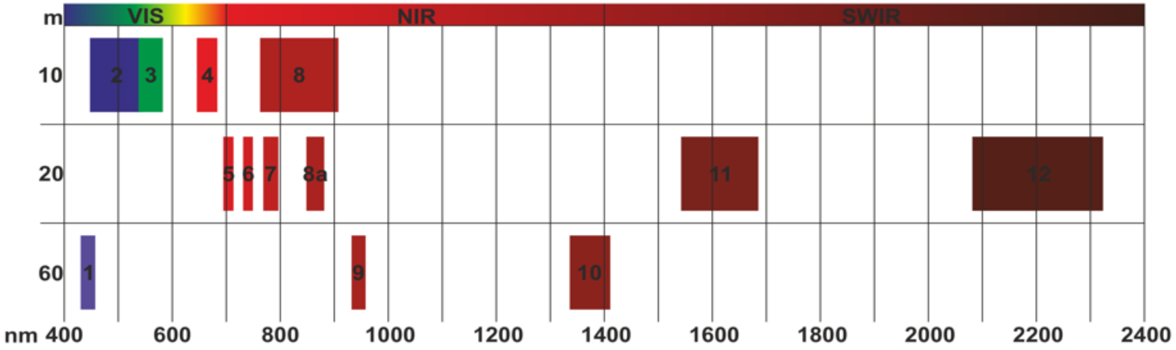
L. Biermann

Spatial vs. Spectral

Sentinel-3
OLCI:

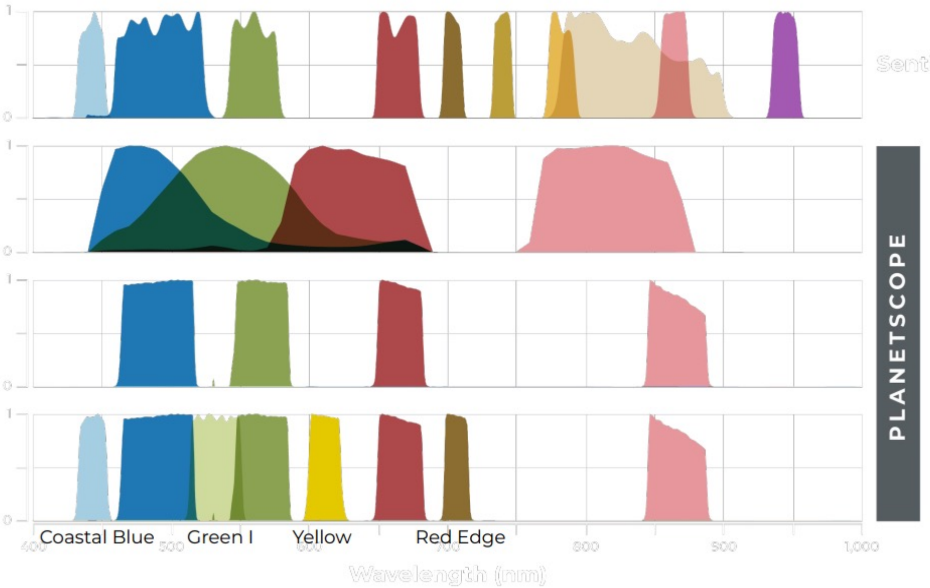


Sentinel-2
MSI:



Decreasing signal to noise ratio

Commercial satellites

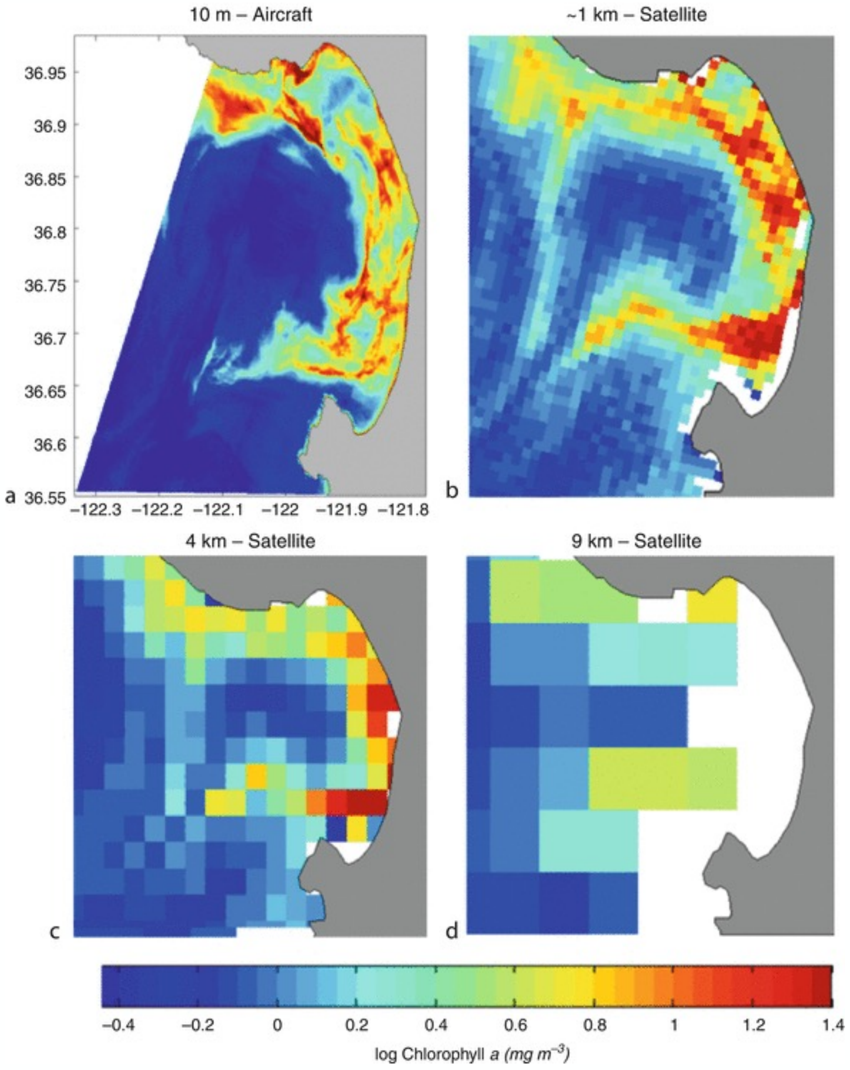


Dove Classic
Blue: 455 - 515 nm
Green: 500 - 590 nm
Red: 590 - 670 nm
NIR: 780 - 860 nm

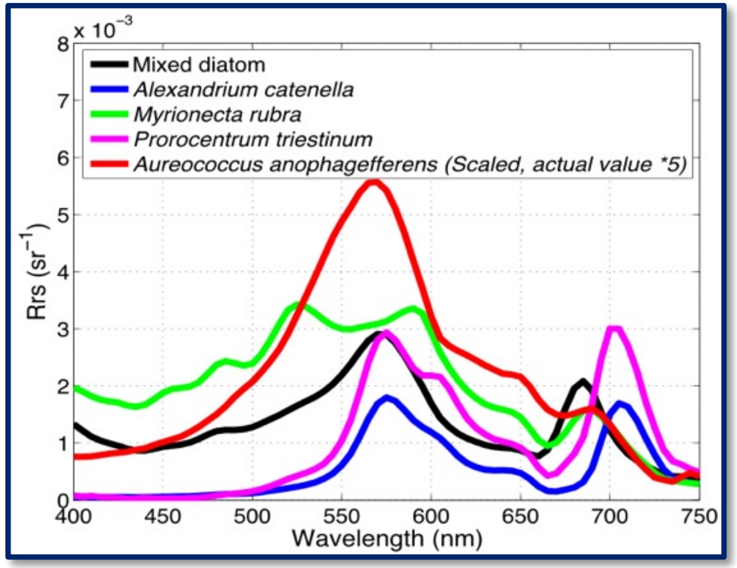
Dove-R
Blue: 464 - 517 nm
Green: 547 - 585 nm
Red: 650 - 682 nm
NIR: 846 - 888 nm

SuperDove
Coastal Blue 431-452 nm*
Blue: 465-515 nm
Green I: 513. - 549 nm
Green II: 547. - 583 nm*
Yellow: 600-620 nm*
Red: 650 - 680 nm
Red-Edge: 697 - 713 nm
NIR: 845 - 885 nm
(avail. after 8-band release)*

Spatial vs. Spectral



Important characteristics for Ocean Colour sensors



1. Spectral Resolution
2. Spatial Resolution…
3. SENSITIVITY!

What data are relevant to us?

Things we usually know when we ask this;

- What variables (we think!) we want
- What area and time period we want to cover

But, with satellite data, there many other things we should also take into consideration. We need to be specific about our "ask" before we start.

Because;

- Data is massive....really massive!
- Data is usually in different places
- Acquisition/download can be time consuming, so good to get it right!

What data are relevant to us?

Some additional considerations before you go looking for data (not exhaustive!);

- Spatial coverage; does a satellite cover your area
- Spatial resolution; does a satellite give you the spatial detail we need (not always simple with S:N!)
- Spectral resolution; does a satellite have the radiometric channels you need?
- [CHL1] ≠ [CHL2] ≠ [CHL3]; are standard algorithms suitable for your needs?
- Temporal revisit; how often is your region sampled?
- Temporal resolution; is a time-average suitable or do you need a specific time?
- Quality vs availability; Reprocessings? Operational? Near real-time?
- Flagging; how much data is “lost” in your region? Is it really lost?
- Synergy; is a single-sensor or a multi-sensor product more appropriate?
- Format; can you “easily” work with the data?
- License; can you get the data?

Answers to these questions will determine where you should look for your data or interest!

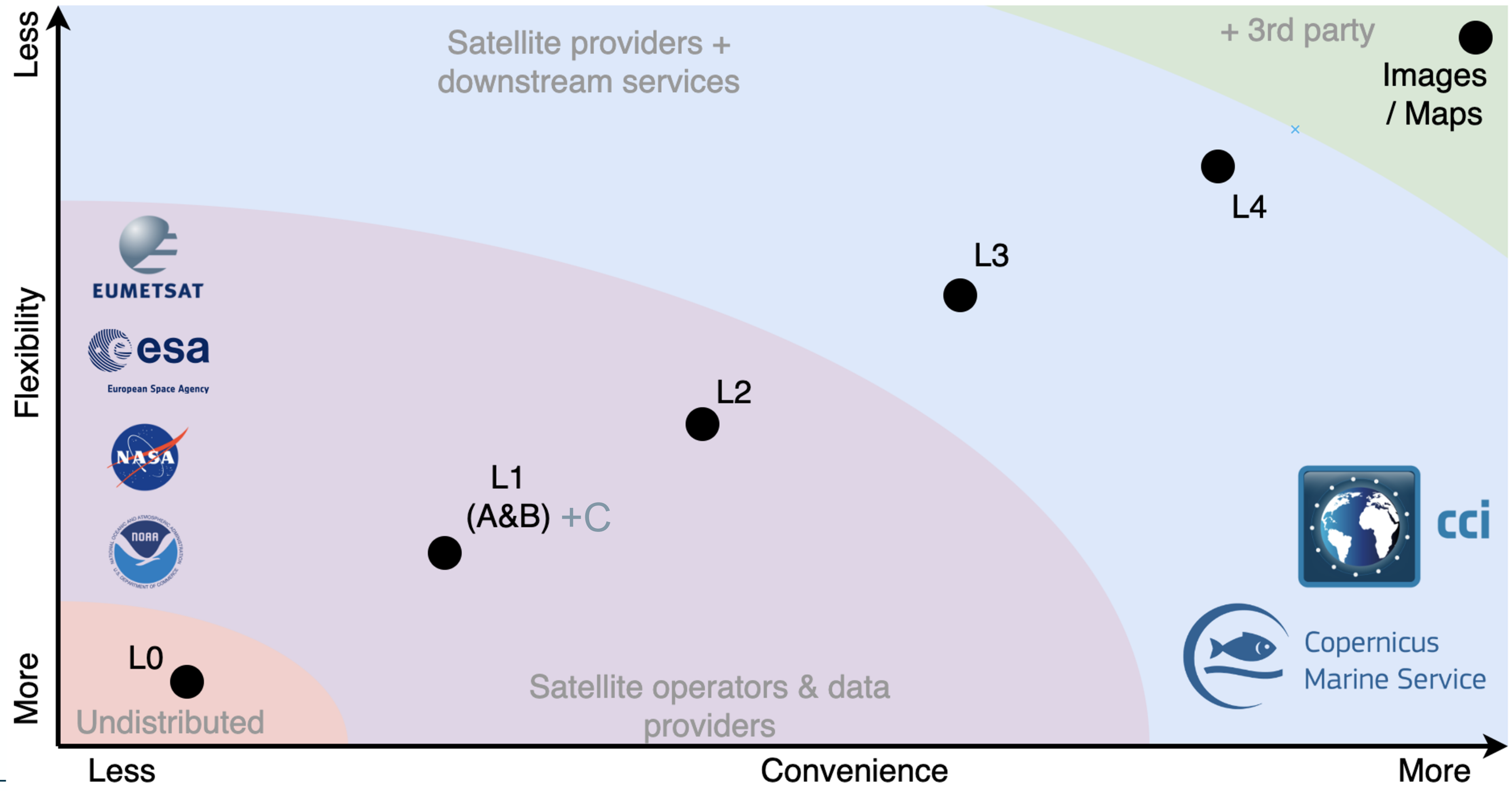
Much depends on the “level” of data you can or need to use

Satellite product levels

Processing Level	Description
Level 0	Reconstructed, unprocessed instrument and payload data at full resolution, with communications artefacts removed. Not distributed.
Level 1 (a+b)	Reconstructed, unprocessed, top-of-atmopshere instrument data at full resolution, time-referenced, and annotated with ancillary information.
Level 2 (+p)	Derived geophysical variables at the same resolution and location as Level 1 source data. Usually atmospherically corrected.
Level 3	Variables mapped on **uniform space-time grid scales**, usually with some completeness and consistency. Except topography (L4)
Level 4	Model output or results from analyses of lower-level data (e.g., variables derived from multiple measurements, gap filled, temorally aggregated)

Data provision

- Convenience: how easy is the data for you to use?
- Flexibility: how many decisions have already been made in processing the data?



B. Loveday

Data providers

copernicus.eumetsat.int

Completely non-exhaustive!.... Lots of organisation – agencies (development, launch, operations, data processing and provision)...

EUMETSAT

NASA

esa
European Space Agency

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

KIOST

planet.

cnes

JAXA

ICEYE

DLR

USGS

इसरो isro

DigitalGlobe

B. Loveday

Programmes

copernicus.eumetsat.int

Completely non-exhaustive!.... Lots of organisation – agencies (development, launch, operations, data processing and provision), strategic programes, downstream providers, scientific organisations, data & cloud services...

Copernicus Europe's eyes on Earth

cci

WEkEO

Copernicus Marine Service

AVISO+ Satellite Altimetry Data

SINERGISE

GHRSST GROUP FOR HIGH RESOLUTION SEA SURFACE TEMPERATURE

aws

NOAA COASTWATCH

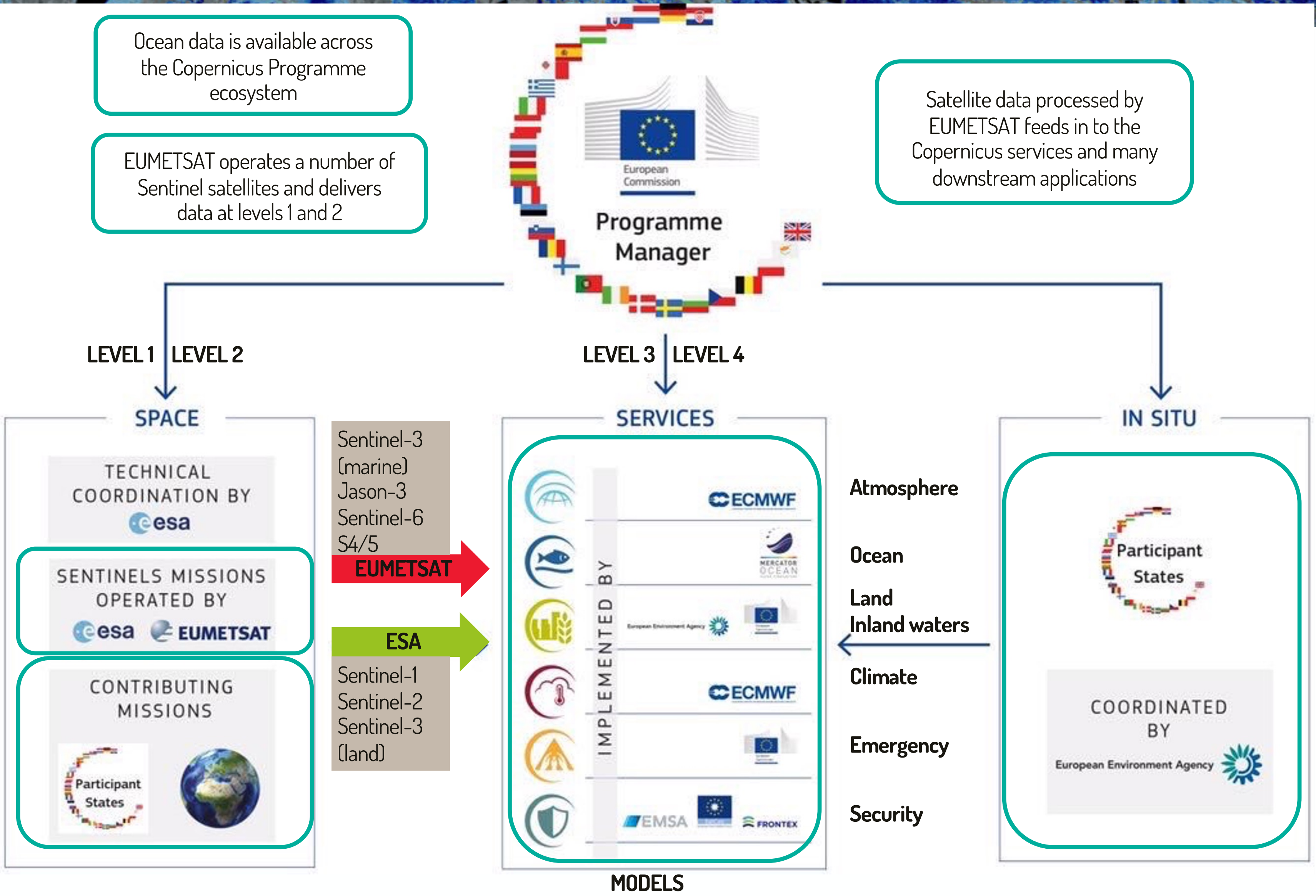
ECMWF

EUMETSAT SAF

GMES AND AFRICA

B. Loveday

The Copernicus Programme



GMES AND AFRICA

2 marine consortia (nominally N/W & S/E)

User driven data delivery and services for the marine environment

Partnerships with government and industry

B. Loveday

Data repositories

EUMETSAT

Data Store (GUI, API)

Data Centre (GUI, offline)

EUMETCast (Push)

EUMETView (WebGIS)

Copernicus Marine Service

CMEMS Marine Data Store (GUI, API)

MyOcean Viewer (WebGIS)

NASA

EarthData (GUI, API)

DAAC network (Browsers, GUI, API)

EOSDIS WorldView (WebGIS)

ECMWF

Climate Data Store (WebGIS, Toolbox, API)

Atmospheric Data Store (WEbGIS, API)

EUMETSAT OSI SAF OCEAN AND SEA ICE

Various (API, FTP)

SINERGISE

SentinelHub EO Browser

esa European Space Agency

Copernicus Data Space Ecosystem (GUI, API)

CCI Open Data Portal (links)

Ocean Virtual Laboratory

New cloud data service mechanisms coming soon...

WEkEO

WEkEO viewer (GUI)

Harmonised data access API

Cloud services

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

CoastWatch Data Portal (WebGIS, API)

Who has it?

- Here are some of the most likely sources for most of what you need (but probably nowhere near all!)

	Stream				
Processing Level	Ocean colour	Sea surface temperature	Surface topography	Radar	Ice
Level 1	• EUMETSAT Data Store (OLCI) • WEkEO (OLCI, MSI) • NASA EarthData portal (MODIS+) • ESA COAH (MSI)	• EUMETSAT Data Store (SLSTR, AVHRR) • WEkEO (SLSTR)	• EUMETSAT Data Store (SRAL, S6) • WEkEO (SRAL, S6)	• ESA COAH (S1) • WEkEO (S1)	
Level 2 (+p)	• EUMETSAT Data Store (OLCI) • WEkEO (OLCI) • NASA EarthData portal (MODIS+) • NOAA CoastWatch (VIIRS+)	• EUMETSAT Data Store (SLSTR, AVHRR) • WEkEO (SLSTR)	• EUMETSAT Data Store (SRAL, S6) • WEkEO (SRAL, S6)	• ESA COAH (S1) • WEkEO (S1)	• EUMETSAT OSI SAF
Level 3	• CMEMS Marine Data Store • WEkEO • ESA CCI Open Data Portal	• CMEMS Marine Data Store • WEkEO • ESA CCI Open Data Portal	• CMEMS Marine Data Store • WEkEO	• CMEMS Marine Data Store • WEkEO	• EUMETSAT OSI SAF • CMEMS Marine Data Store • WEkEO
Level 4	• CMEMS Marine Data Store • WEkEO • ESA CCI Open Data Portal • NOAA CoastWatch (VIIRS+)	• CMEMS Marine Data Store • WEkEO • ESA CCI Open Data Portal • NASA EarthData Hub • NOAA CoastWatch	• CMEMS Marine Data Store • WEkEO • ESA CCI portal	• CMEMS Marine Data Store • WEkEO	• EUMETSAT OSI SAF • CMEMS Marine Data Store • WEkEO • ESA CCI portal

B. Loveday

Where to obtain images?

Some things to be aware of when “data shopping”;

- Who has what is not always well advertised (but getting better!)
- Collections and products are not always 100% described (test first!)
- There is replication, and it is not always transparent (cloud services are particularly bad at this; ask questions of the provider!)

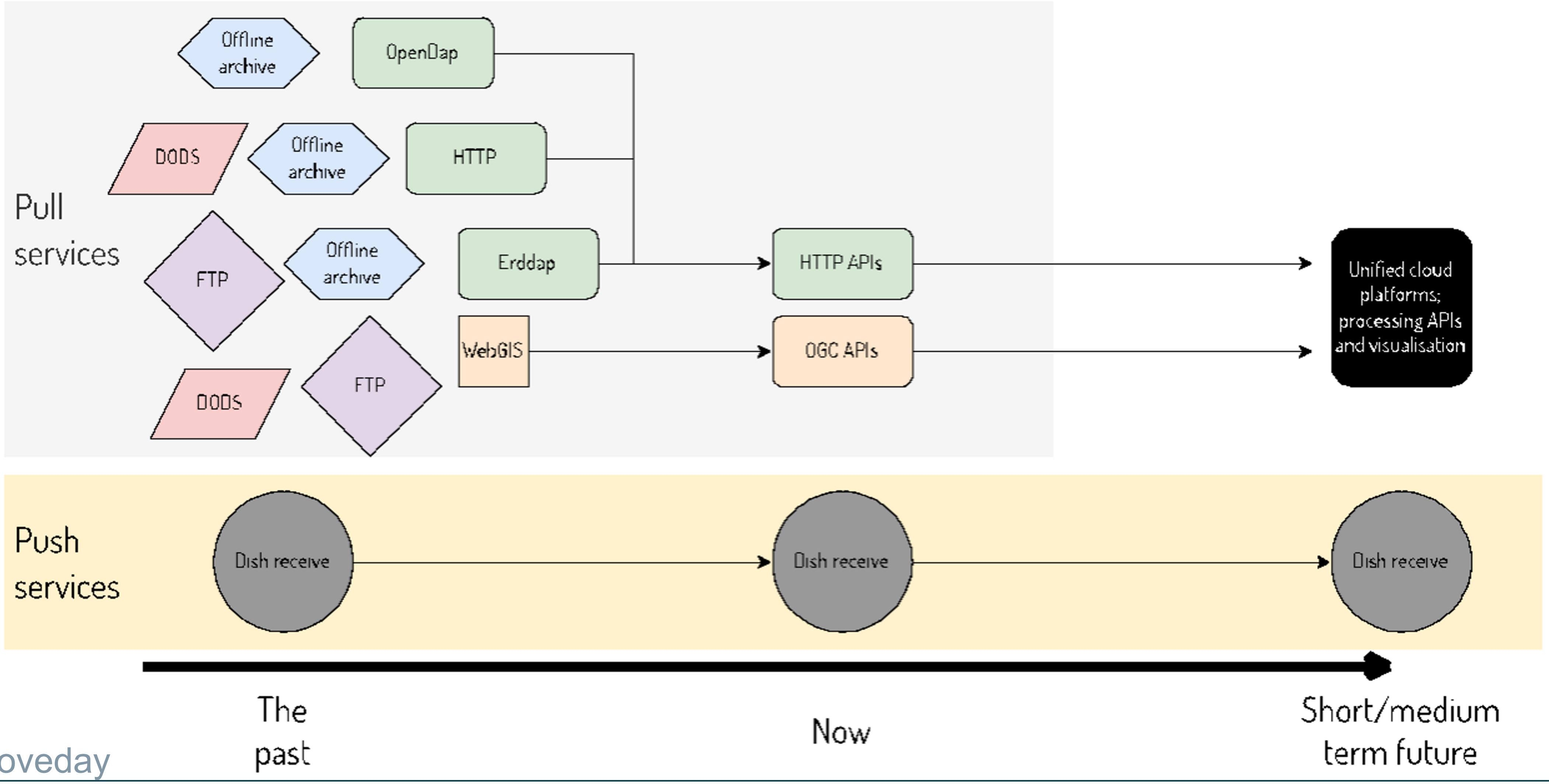
Formats are starting to change:

- For now, mostly netCDF (including Sentinel SAFE format)
- Future moves to CoG or ZARR for better cloud optimisation and new access methods.

Storage architecture is starting to change:

- Object storage (e.g. S3 buckets)
- New ways to catalogue data (e.g. STAC)

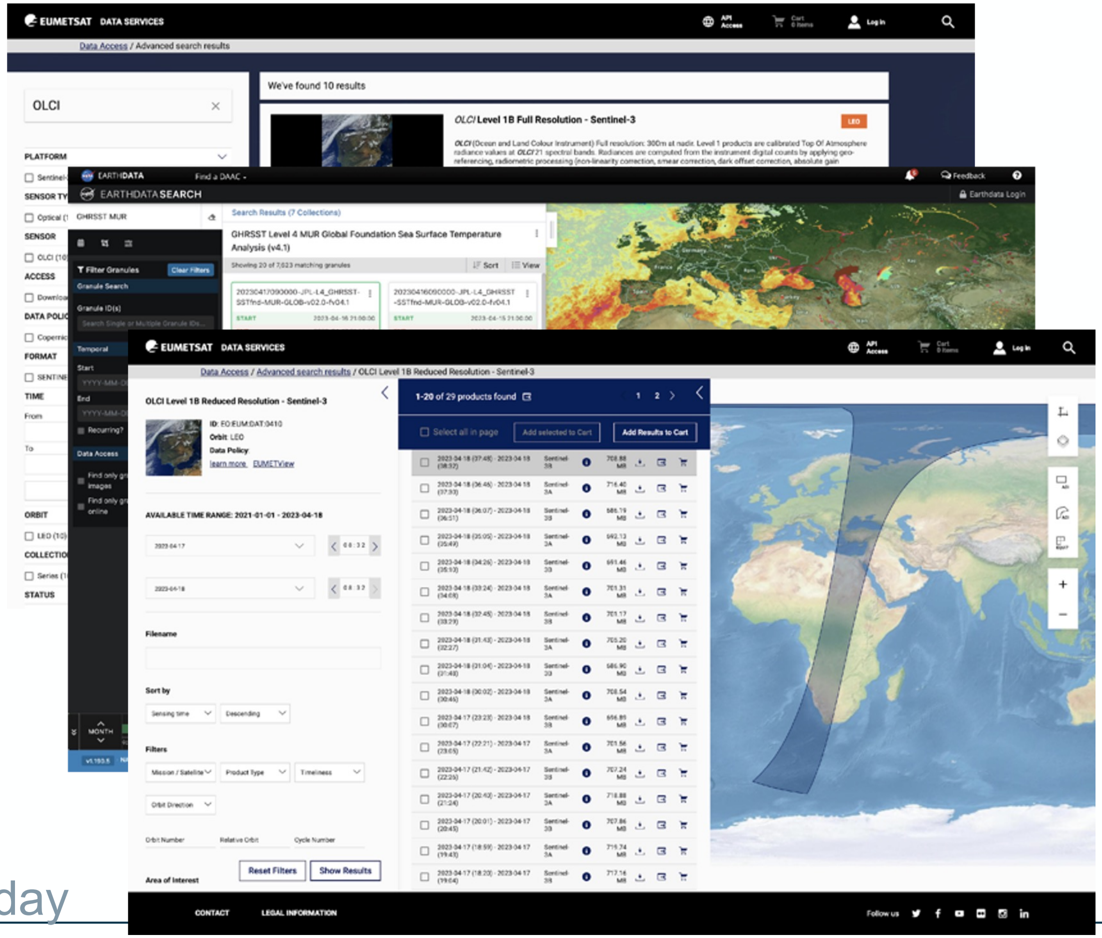
How the data delivery landscape is changing



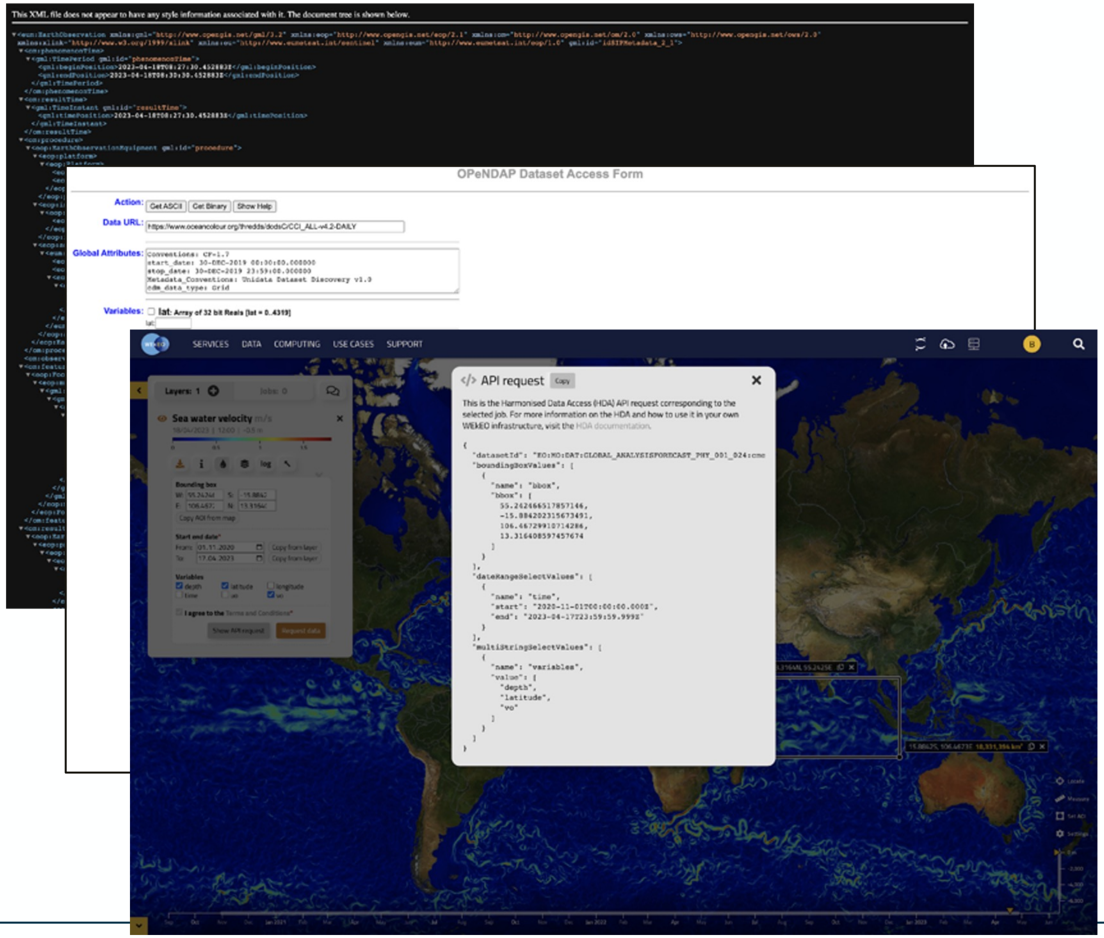
B. Loveday

How to get the data

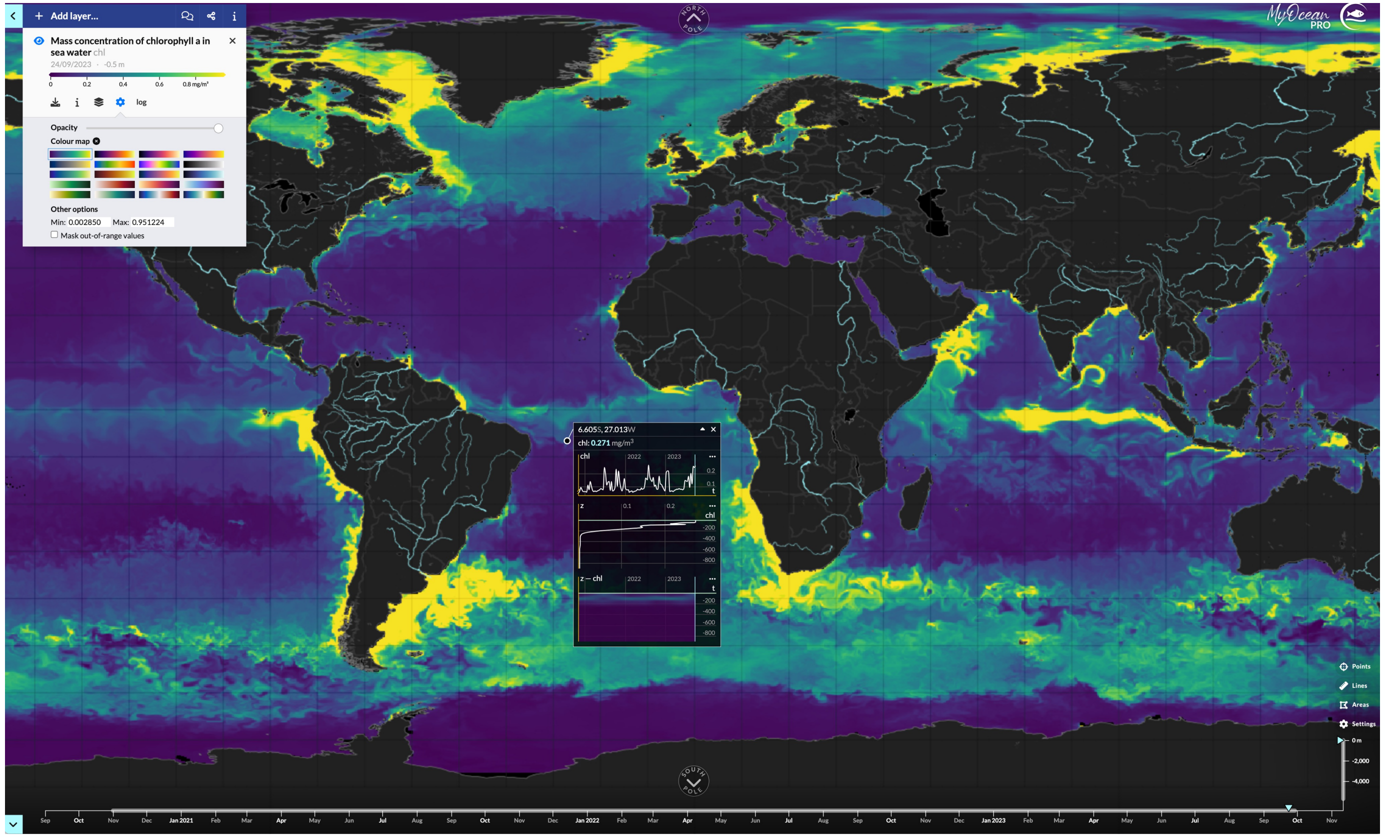
WebUI: machine to human

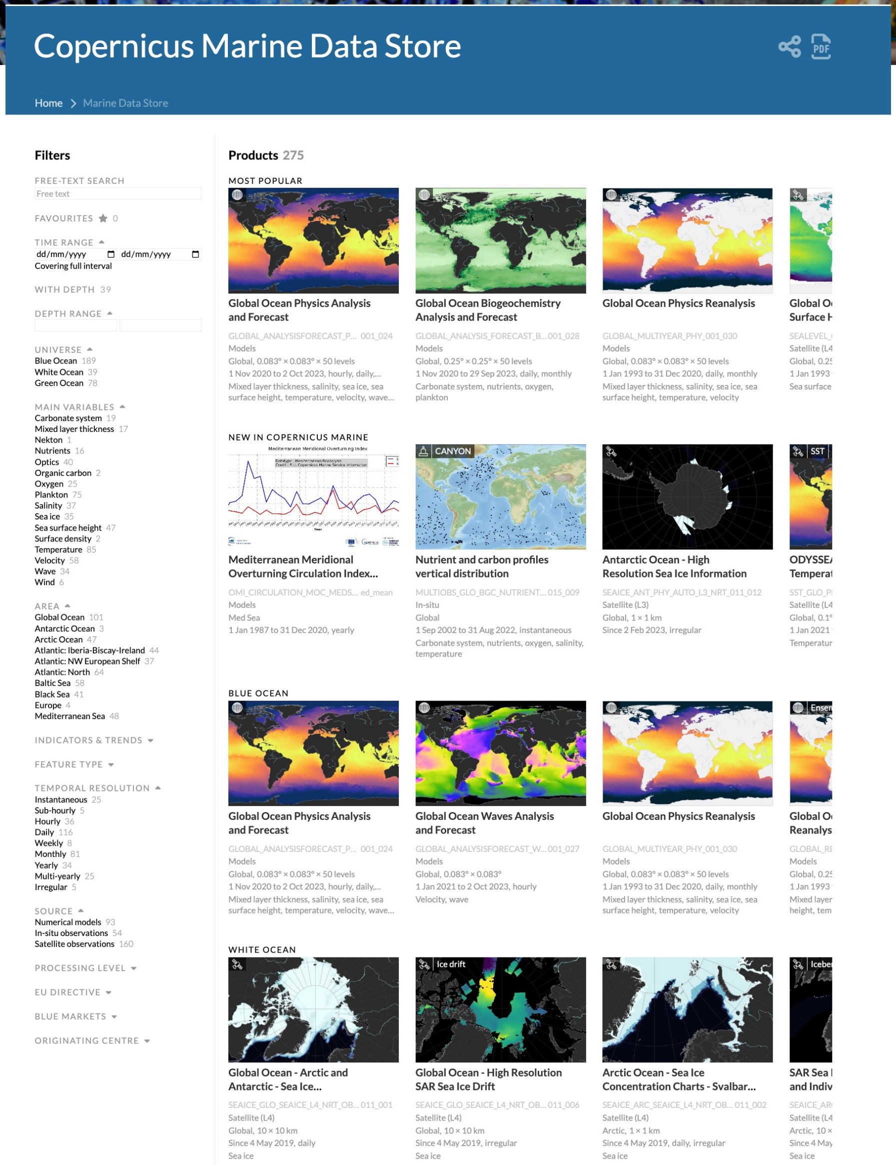


API: machine to machine



Copernicus Products: ocean in CMEMS



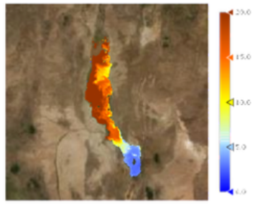


Copernicus Products: inland and coastal in CLMS

Lake Water Quality 2016-present (raster 300 m), global, 10-daily – version 1

General Info

Download



Provides semi-continuous observations for a large number of medium and large-sized lakes, according to the Global Lakes and Wetlands Database (GLWD) or otherwise of specific environmental monitoring interest. 10-daily observations are available in near real time in the spatial resolution of 300 m and and with the temporal extent from 2016 to present.

Validation status

Validated

See the Quality section for detailed information.

Dataset citation

You can find instructions on how to cite CLMS data in our Data policy section.

Characteristics

Spatial coverage: Global

Spatial resolution: 300 m

Spatial representation: Grid

Temporal extent: 2016-present

Temporal usability: Archive with regular updates

Update frequency: AsNeeded

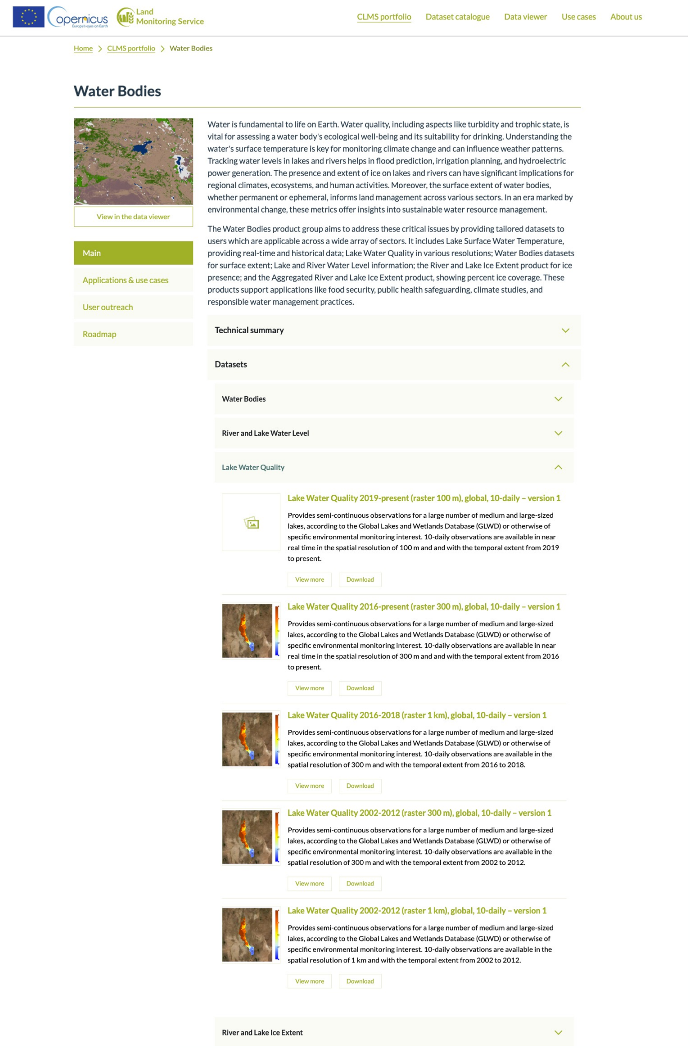
Timeliness: Within 3 days after the end of the synthesis period

Type: Satellite observations

Sensor: Sentinel-3 OLCI

Access full metadata here

- Lake Water Quality: global 10-daily Near-Real Time (raster 300m) - version 1, May 2018 - PDF - XML

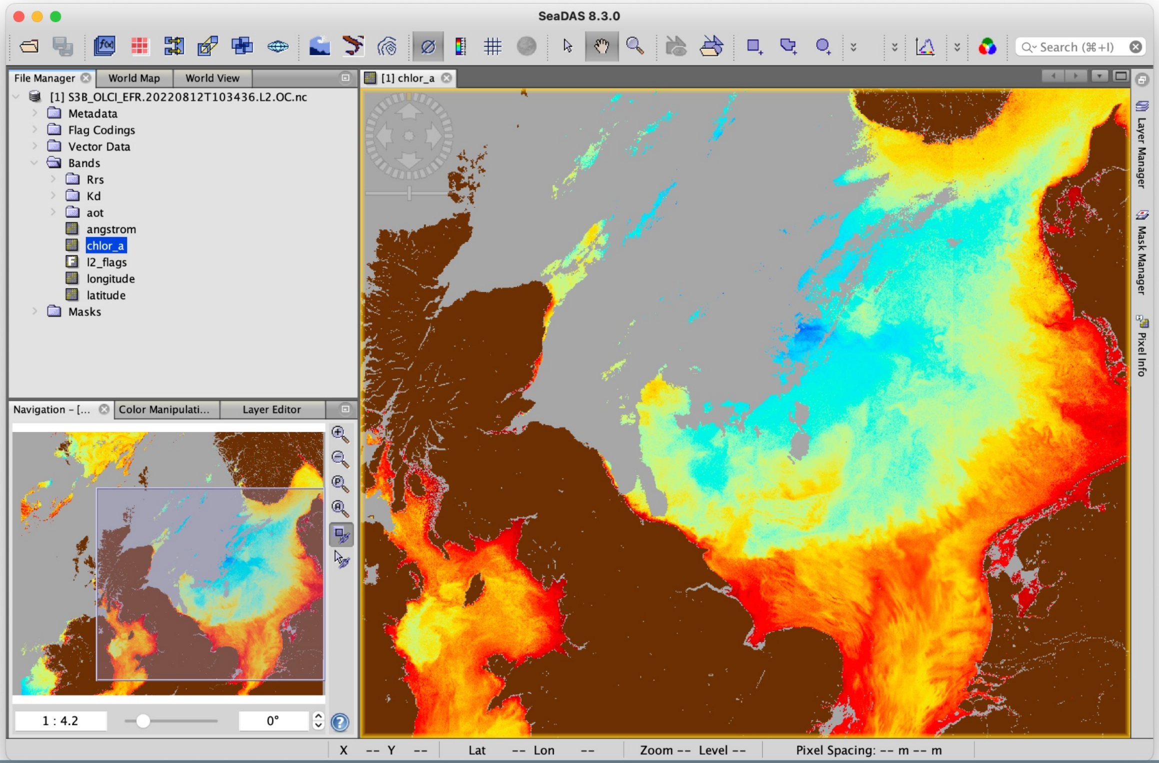


How to process data: SeaDAS

Temporary Release Available: SeaDAS 8.3.10 (Mac OS only) release fixes incompatibility issue with MacOS 13 Ventura

The Official NASA/OB.DAAC Data Analysis Software

Last update: SeaDAS 8.3.0 (December 12, 2022), SeaDAS 8.3.10 (June 14, 2023)



Sentinel-3B OLCI Chlorophyll image during heat wave over North Sea (Aug 12, 2022)

SeaDAS is a comprehensive software package for the processing, display, analysis, and quality control of ocean color data. While the primary focus of SeaDAS is

Features

- Visualization
- Science Processing
- Statistics

Requirements

Operating Systems

- Linux: tested on Ubuntu (16.04 LTS)
- Intel Mac: OS X 10.12
- Windows: 10

View the complete list of suggested hardware & configuration requirements for supported systems.

Version History

View release notes and download historical versions of the SeaDAS software package.

- Latest Release: 8.3.10 (Mac only)
- Previous versions

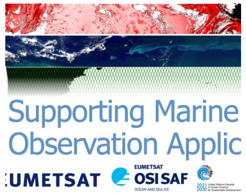
How to process data: programming languages

Some examples and demos can be found in the following links (among many others):

Python: https://youtu.be/ZyCkVI7k3eo?si=I93ltnDNDQtjerV4

Julia: https://youtu.be/BT0lA_59jAU?si=i3Gu4520ocQWnKCN

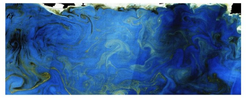
EUMETSAT Supporting Marine Earth Observation Applications (SMA) training course 2022



The EUMETSAT Supporting Marine Earth Observation Applications (SMA) training course, conducted in partnership with the Oceanography & Earth Observation Group of the National and Kapodistrian University of Athens, will share knowledge, skills, resources and code so attendees are able to independently access and process data from the EUMETSAT product catalogue for their marine work-flows and applications. The SMA course will support data streams from EUMETSATs Copernicus marine missions (Sentinel-3; Sentinel-6) and derived downstream products, those derived from Copernicus supporting missions, and those made available by the Ocean and Sea-Ice Satellite Application Facility (OSI-SAF).

Self-Paced phase: 31 Oct - 18 Nov 2022, online
Classroom phase: 21 - 25 November 2022, online

Using the Copernicus Marine Data Stream for Ocean Applications – Summer Course



CMDS Summer Course

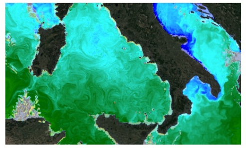
31 May - 25 June 2021

CMDS for Operational Services - Ocean Applications (2021)

The purpose of this EUMETSAT Copernicus Marine Data Stream (CMDS) training workshop is to share knowledge, skills, resources and code so that attendees are independently able to access and process Sentinel-3 data for their marine workflows and applications.

26 April - 7 May 2021

Operational Satellite Oceanography symposium 2021



This course will offer an overview of the operational aspects of the Copernicus Marine Data Stream (CMDS) and the NOAA CoastWatch program. Topics covered will include ocean satellite data products (SST, ocean colour, salinity, altimetry, winds, …), how CMEMS assimilates data into operational models and Level 4 multi sensor products, Data download APIs and ways in which data retrieval and processing can be scripted, and an overview of the ERDDAP data platform and CoastWatch data portal.

28 May 2021

CMDS Essentials Pack for Ocean Applications | self-paced learning


esa
SNAP
SeNtinel
Applications
Platform

SeNtinel Application Platform

SNAP is

- an ecosystem to analyse, process and communicate Earth Observation data
- an Open-Source Project - github.com/senbox-org
- scalable to run on notebooks up to large production clusters
- used for scientific analysis, operational production and training
- easy to use

SNAP can

- access many satellite-based Earth Observation data products as well as generic raster formats directly in the cloud
- visualise the data in many ways
- analyse data using statistical functions, mathematical operations, correlation, comparison with point and vector data
- process satellite data with instrument specific as well as generic raster data operations
- save sessions and export results in various raster and non-raster formats
- be extended using Java and Python API

SNAP has

- comprehensive documentation - step.esa.int
- > 1 Million users and active community, > 10 000 forum users – forum.step.esa.int
- a long-term commitment of the European Space Agency

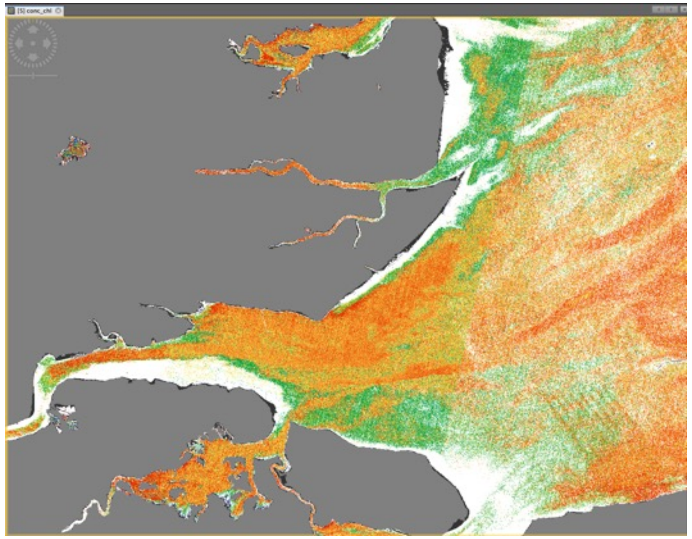
Brockmann Consult GmbH   SKYWATCH   CS GROUP   CS GROUP

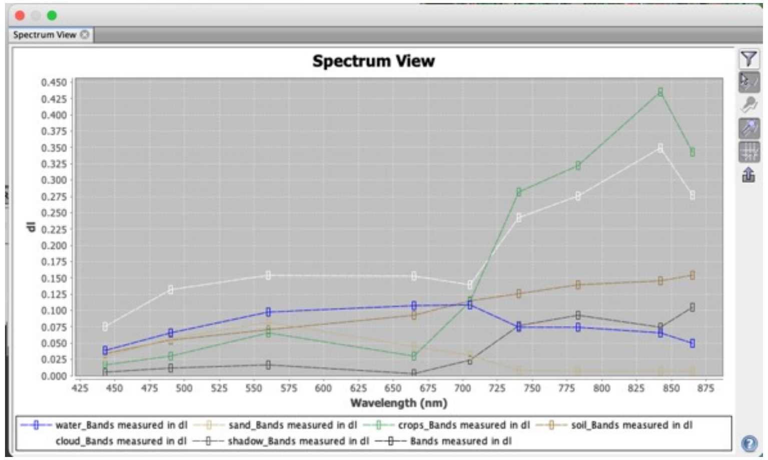
SNAP data visualization

SNAP Desktop is the GUI application which allows access to a large number of EO and generic raster data.

It provides various tools to display the data, and to visually analyse them.

The figure on the right shows an RGB of a Sentinel 2 product together with a visualisation of a water quality parameter (right panel). Bottom right show the spectral plots at places marked by PINs.

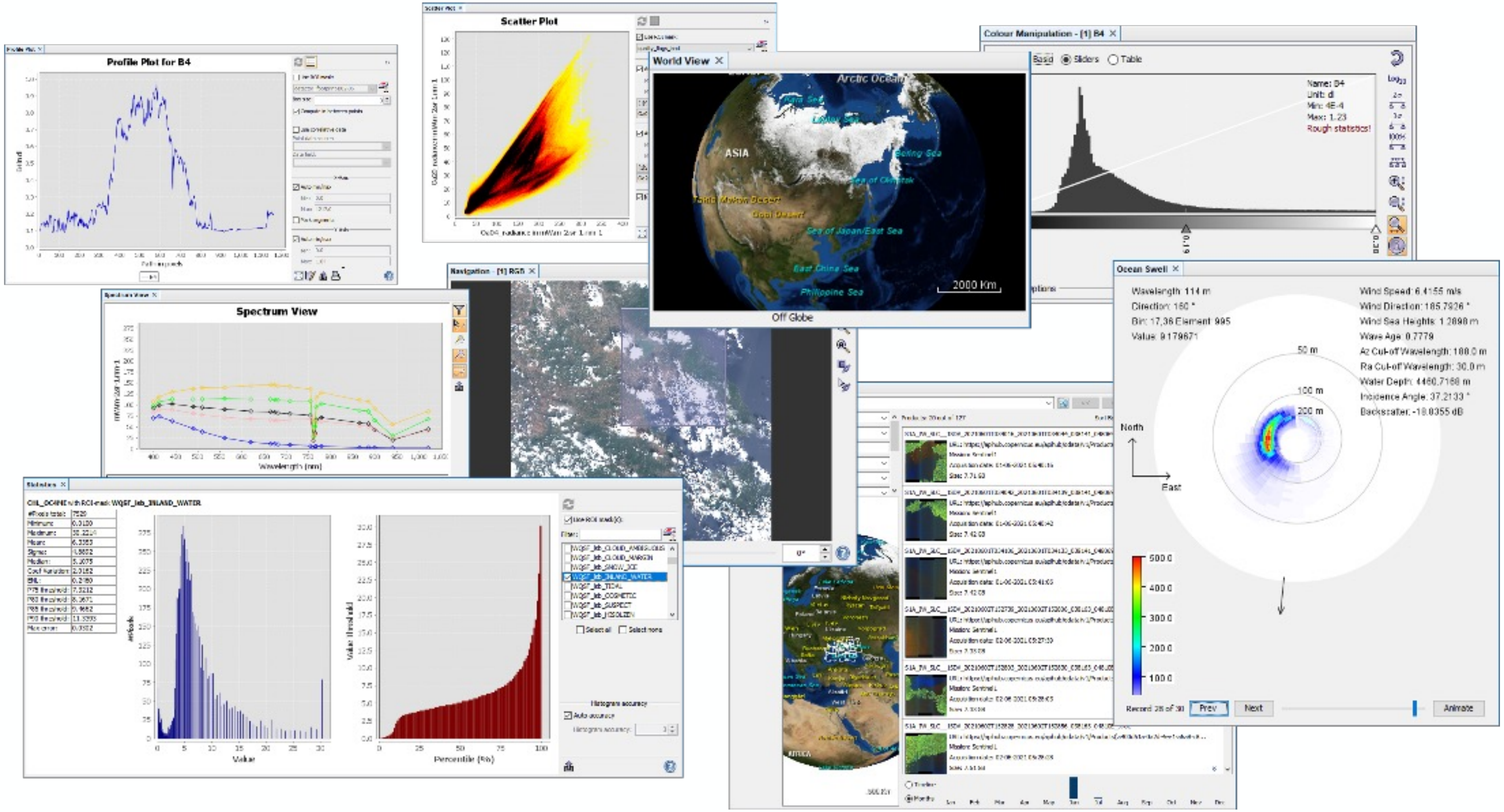




SNAP data analysis

SNAP provides a rich suite of tools for data analysis, including profile and spectrum plots, statistical analysis, extraction of points through time series, and comparison with reference data (match-ups).

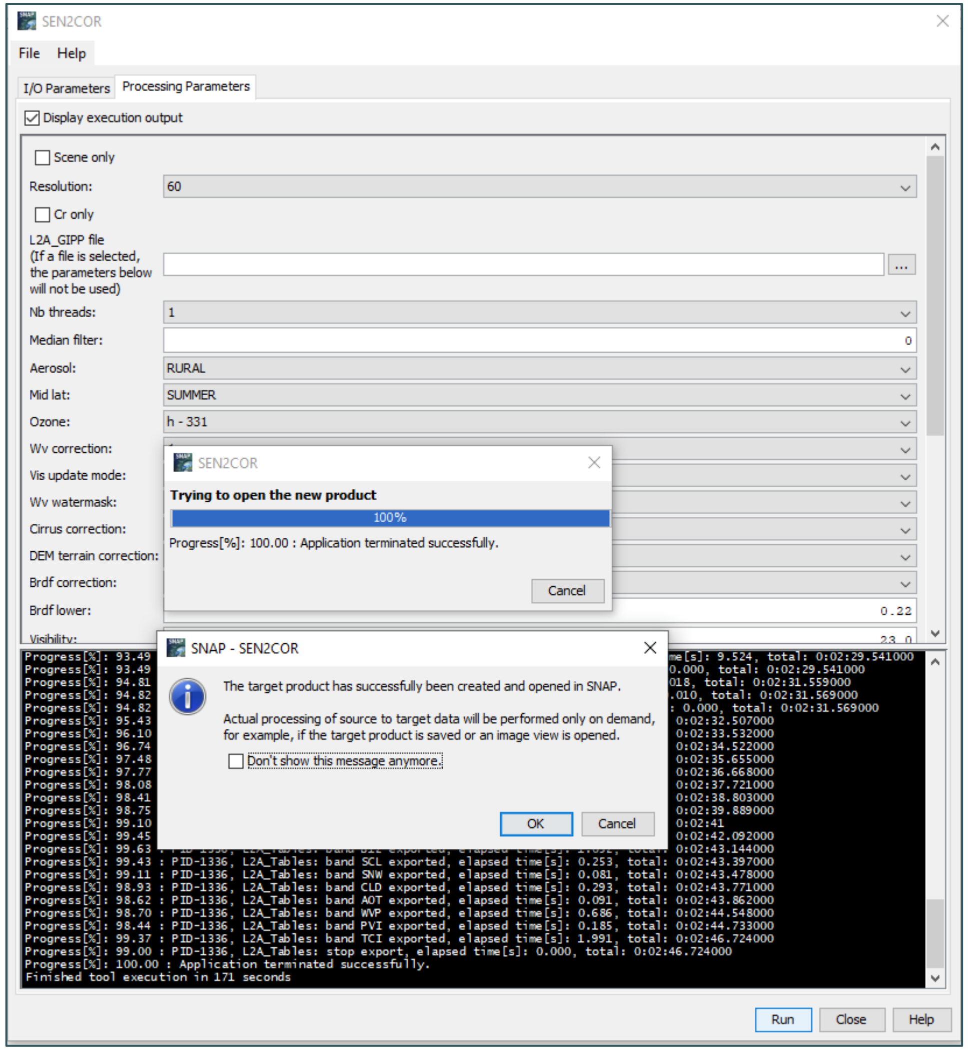
The figure shows some of the graphical analysis tools included in SNAP.



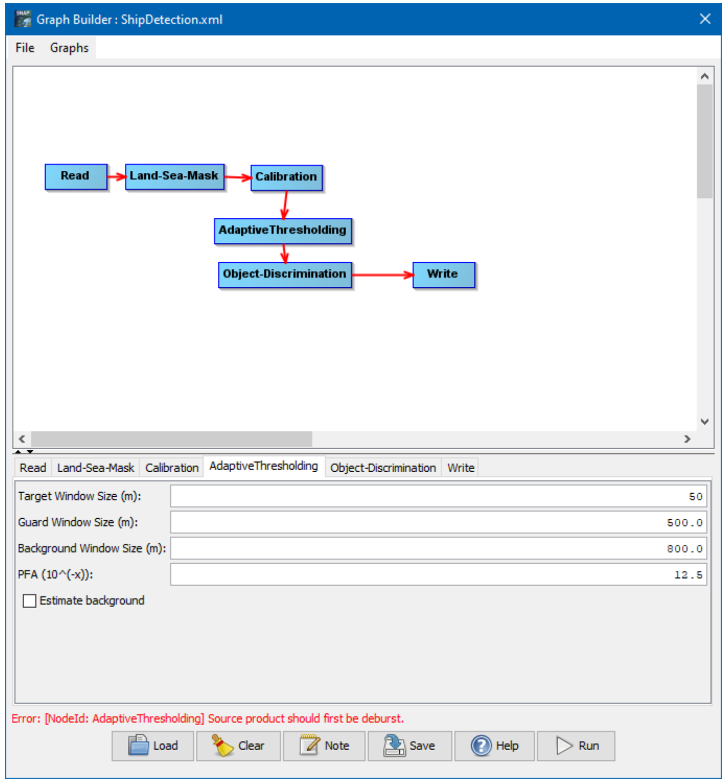
SNAP data processing

SNAP Data Processors analyse one or more input products and generate a new output product. Processors exist for generic operations such as band arithmetic, map projection or temporal aggregation. SNAP also provides a very large number of thematic processors, e.g. for atmospheric correction, biophysical indices calculation or retrieval of water quality. And SNAP supports special calibration of correction of satellite instruments with dedicated processors.

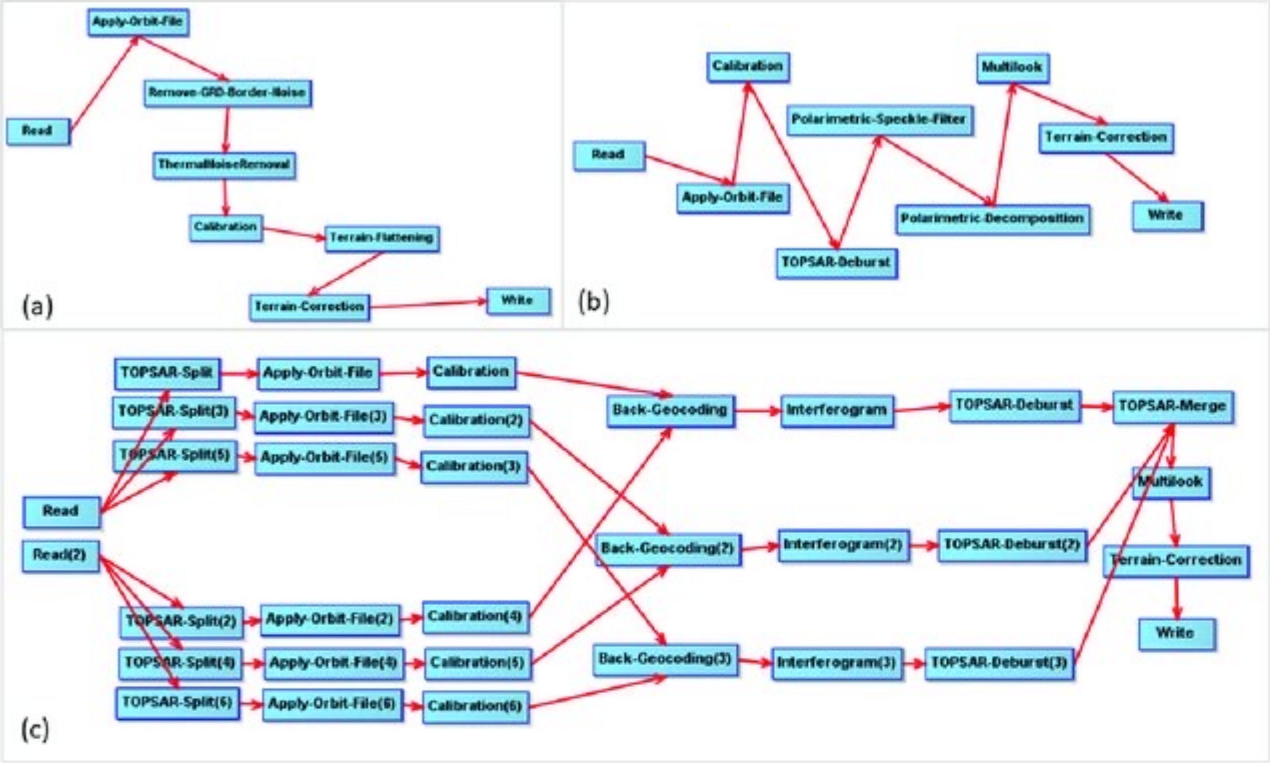
The figure shows the GUI for the Sentinel-2 Atmospheric Correction Processor sen2cor. The screenshot was taken when the processor was successfully executed. The black background shows the logging information during execution of the processor.



SNAP Batch Processing



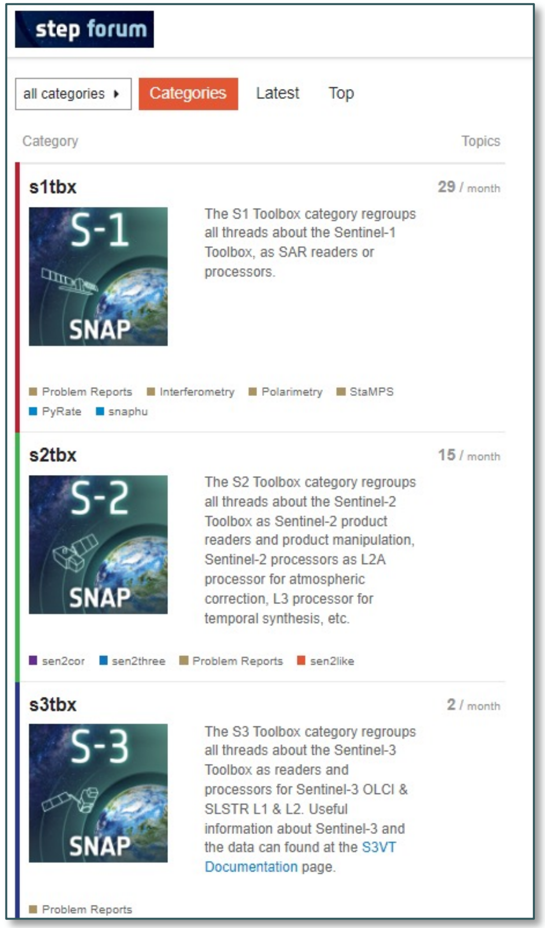
The SNAP graph builder allows to connect SNAP operators in processing graphs. These can be executed locally or in large clusters and cloud systems.



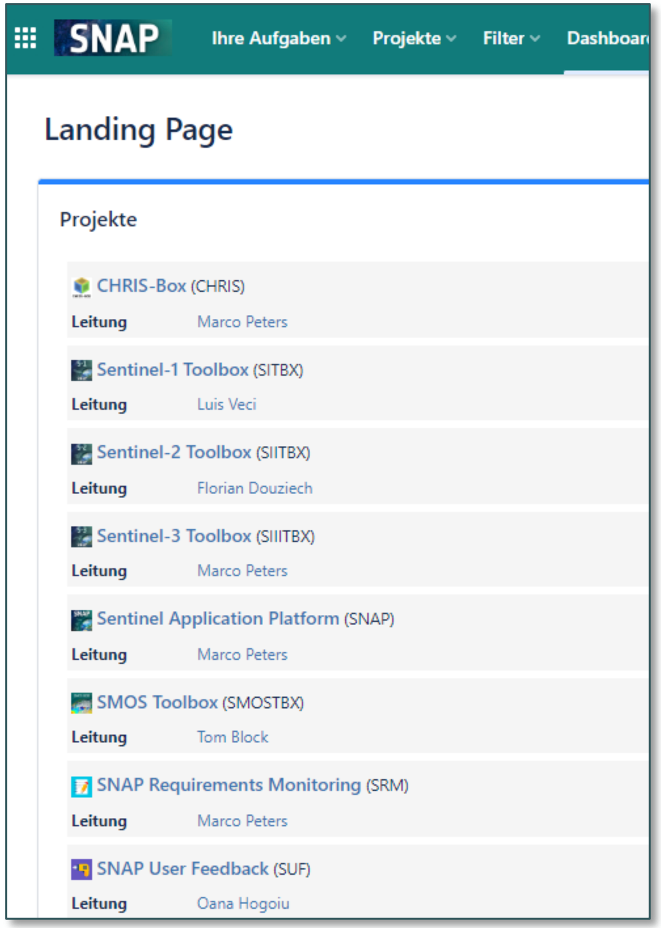
Example: Workflows in the SNAP graph builder tool for producing Synthetic Aperture Radar (SAR) analysis ready data (ARD) products. From Ticehurst, et al (2019). Building a SAR-Enabled Data Cube Capability in Australia Using SAR Analysis Ready Data. Data. 4. 100. 10.3390/data4030100.

SNAP User Support

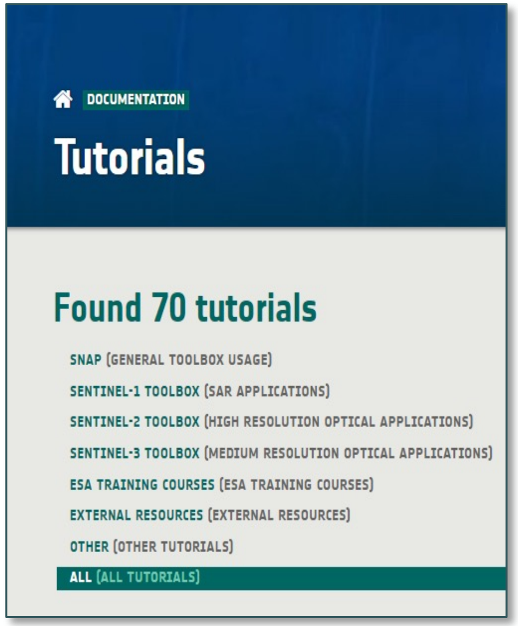
User Forum



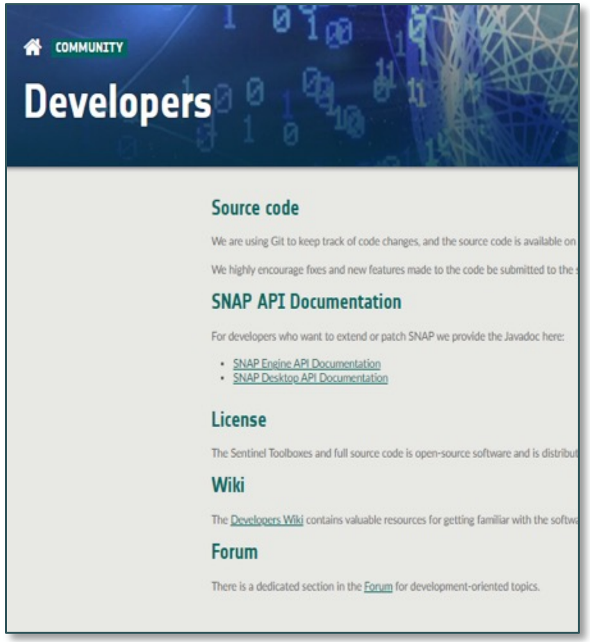
Issue Tracker



Tutorials

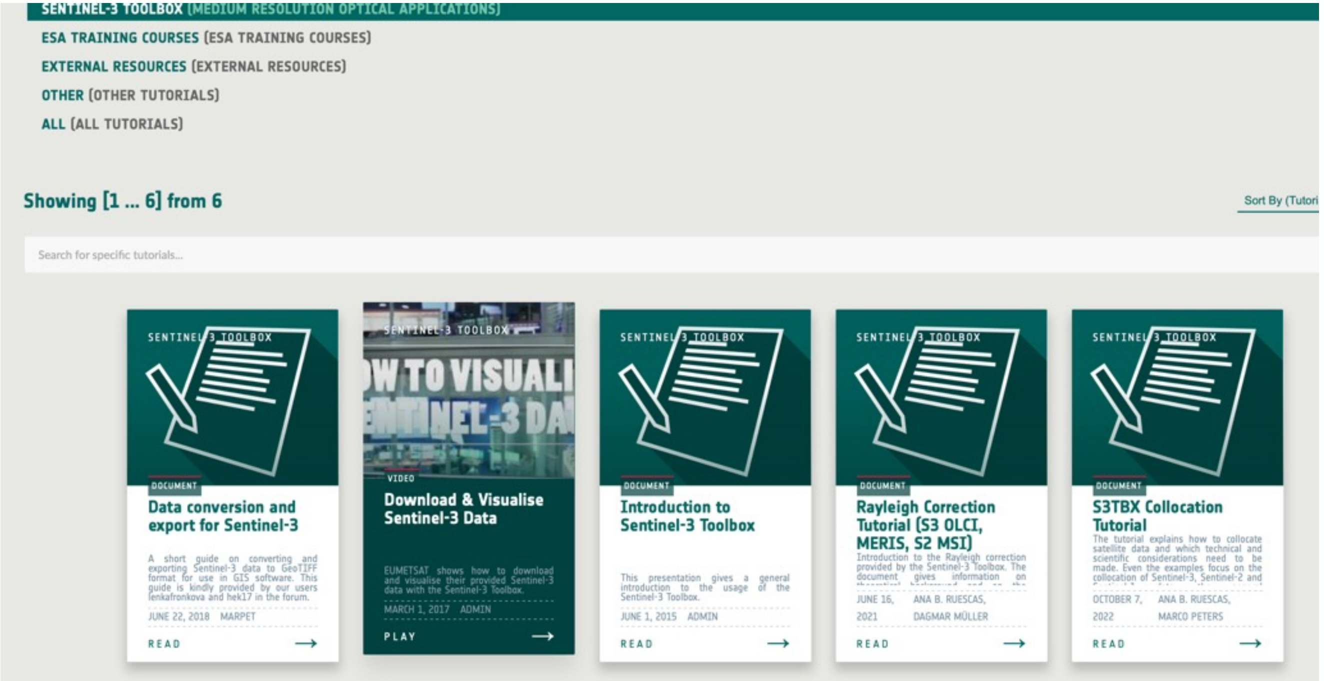


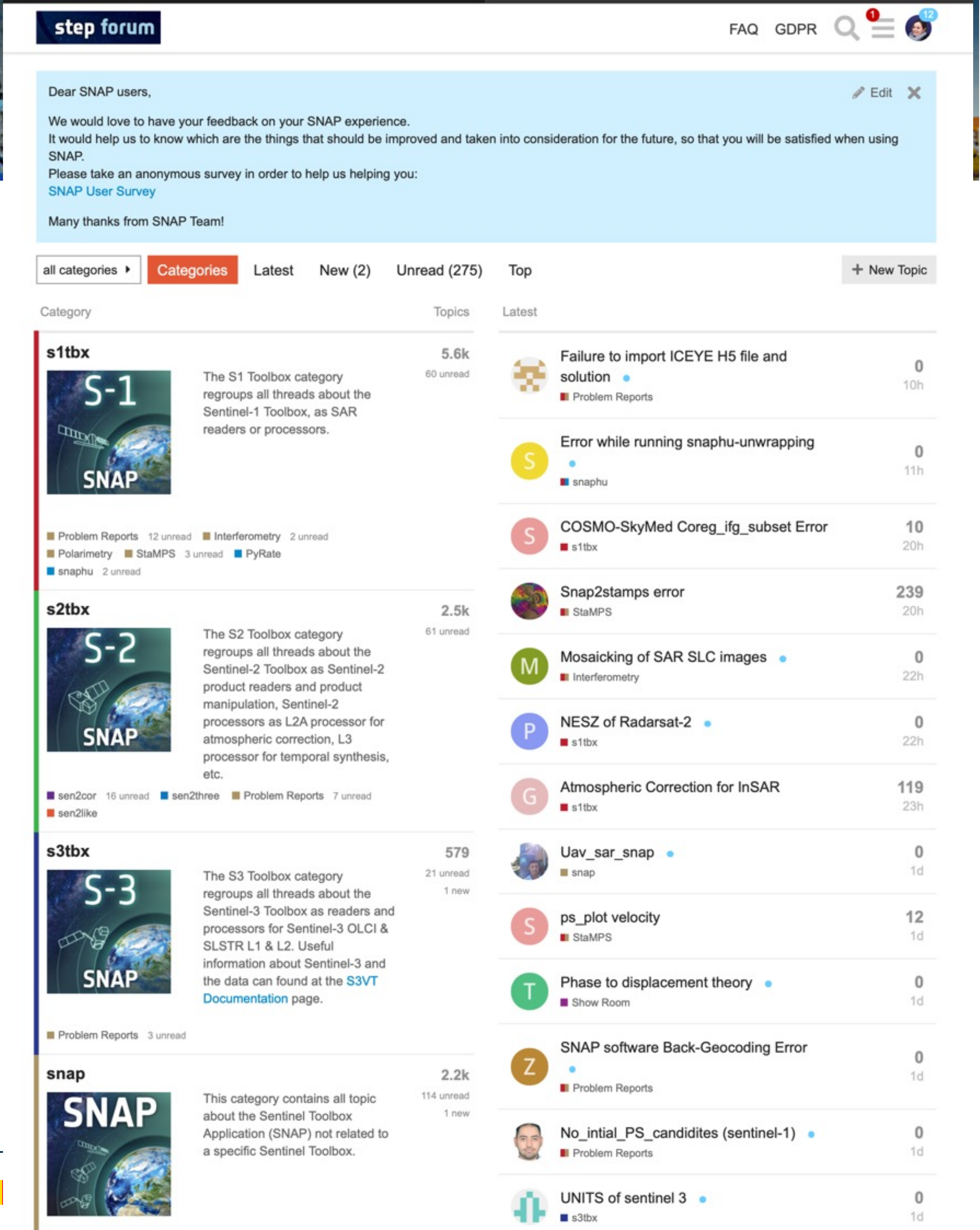
For Developers



SNAP Community and Tutorials

http://forum.step.esa.int/c/s3tbx
http://step.esa.int/main/doc/tutorials/
https://senbox.atlassian.net/wiki/spaces/SNAP/pages/1898053693/SNAP+FAQs





SNAP roadmap

06/2023 – SNAP 10

Optical and Microwave Toolboxes
Large software renovation
Documentation update
Making it technologically future proof

12/2023 – SNAP 11

Product Groups
STAC support (Spatio-Temporal Asset Catalogue)
Preparing for hyperspectral CHIME and microwave CIMR

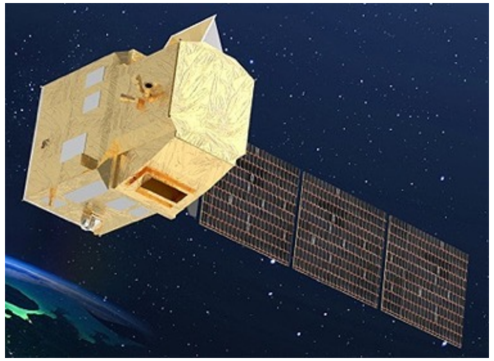
06/2024 – SNAP 12

Change detection Toolbox

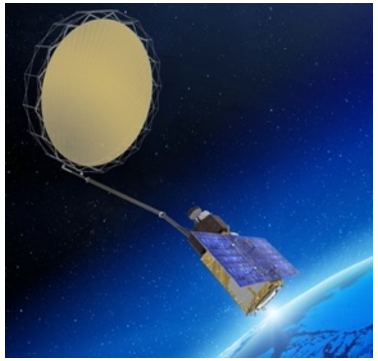
12/2024 – SNAP 13

Support NISAR, BIOMASS
Time series tools

Optical Toolbox
With future CHIME support



Microwave Toolbox
with future CIMR support



Thank you!

Questions are welcome.

Contact and further information

ana.ruescas@brockmann-consult.de