

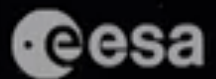


# Ocean Colour Short Course:

Introducing the Sentinel-3 satellites and their applications for marine monitoring.

Lauren Biermann & Olly Clements





**Copernicus**  
Europe's eyes on Earth

# The Copernicus Programme:

- The **European Commission** funds & manages the Copernicus Programme.
- Segments shared by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the European Space Agency (ESA):
  1. Space
  2. Services
  3. In situ



# Marine data are available across all aspects of the Copernicus Landscape:



## Level 1 Level 2 SPACE



### MARINE:

- Jason-3
- Sentinel-3
- Sentinel-6



### LAND:

- Sentinel-1
- Sentinel-2
- Sentinel-3

## Level 3 Level 4 SERVICES



Atmosphere

Ocean

Climate

Land and inland water

Emergency

Security

## IN SITU



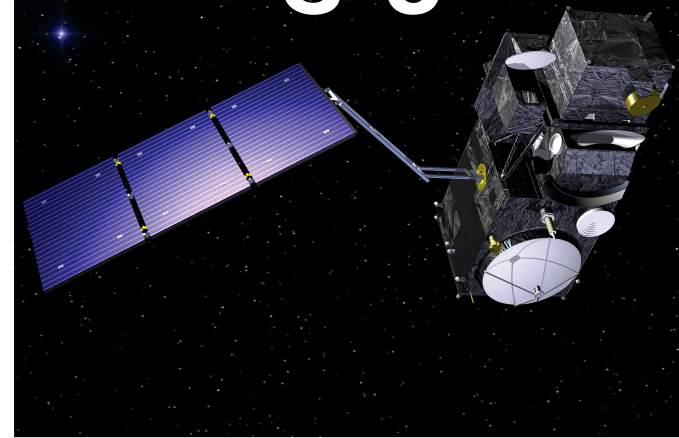
## S-1



## S-2



## S-3



- **Terrestrial mission** with some marine applications.
- Active sensor.
- Radar.
- Max ~10 m spatial resolution.
- No ocean colour!
- Level 1 data, Level 2 products.

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

- **Dedicated Marine Mission.**
- Mix of passive & active sensors.
- Optical, IR radiometer, plus radar altimeter.
- Ocean Colour 300 m spatial resolution data.
- Level 1 data as well as Level 2 data and products.

# sentinel-3

→ A BIGGER PICTURE  
FOR COPERNICUS



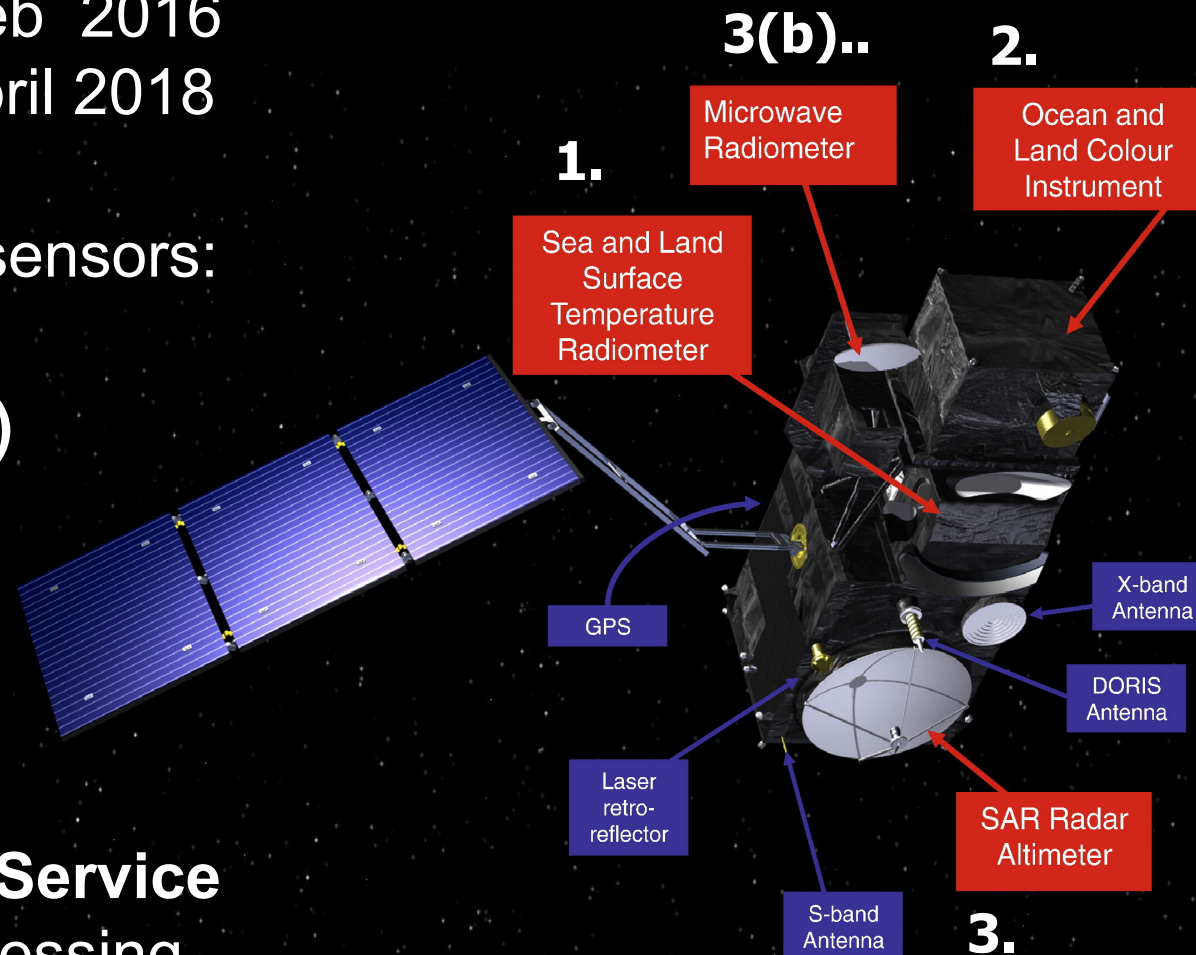
# Marine Mission Sentinel-3

Sentinel-3 is the '**Blue Sentinel**' thanks to its suite of ocean observing instruments.

- The mission's main objective is to deliver sea-surface topography, sea-surface temperature and **ocean colour**.
- Sentinel-3 (and all Sentinels) fly in pairs (constellation).
- Two-day global coverage of optical data.

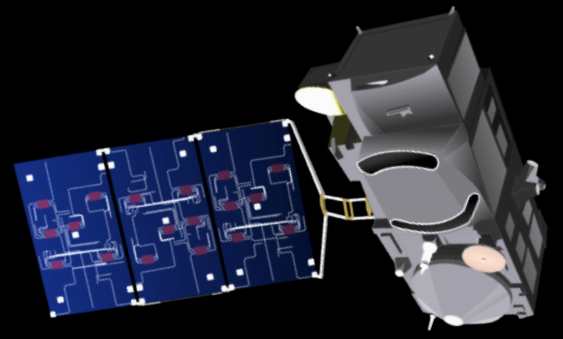
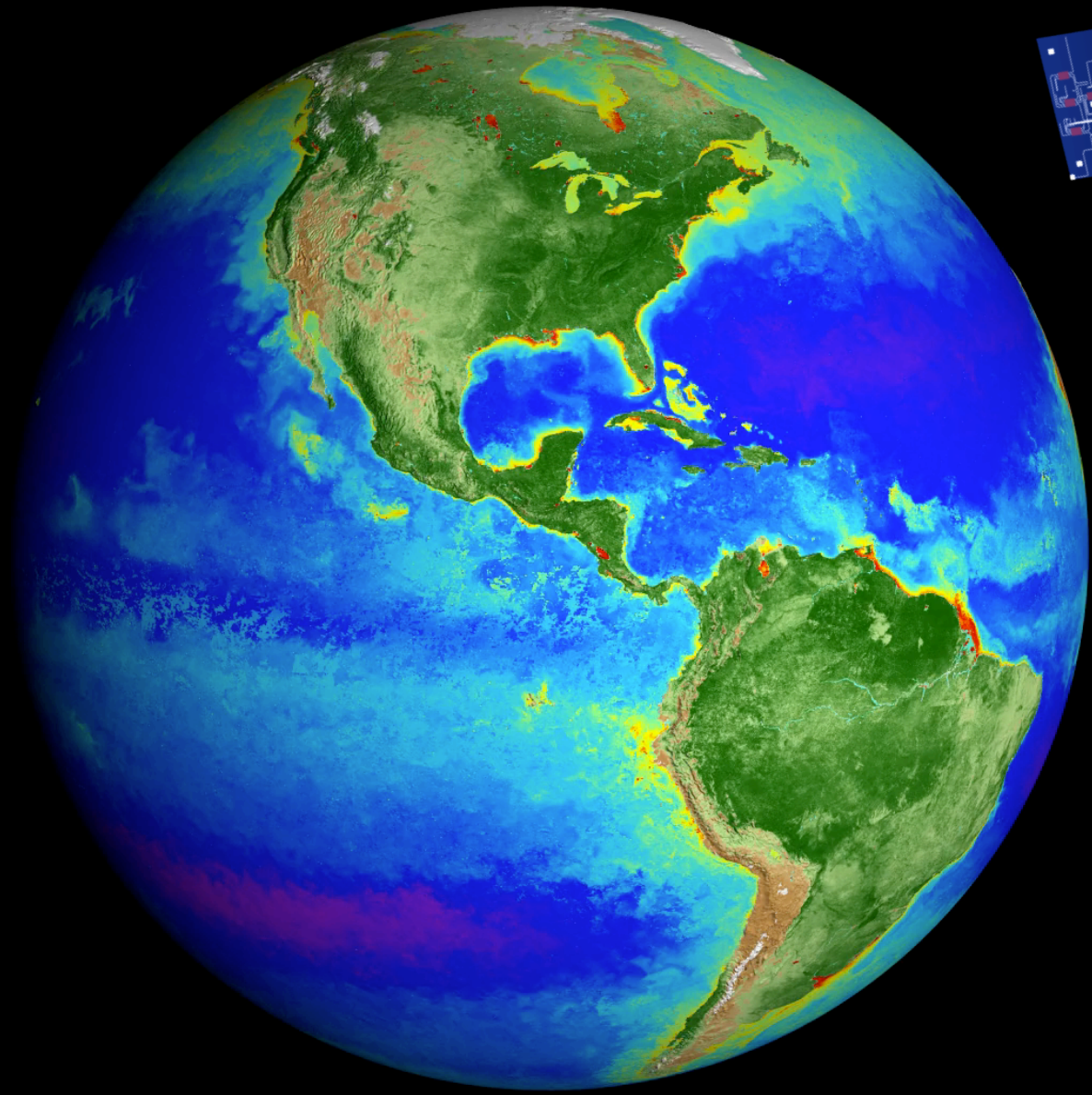
# EUMETSAT Sentinel-3: Our 'Blue Sentinel'

- Sentinel-3A launched in Feb 2016 & Sentinel-3B launched April 2018
- Sentinel-3 has 3 EO data sensors:
  1. SLSTR (SST)
  2. OLCI (Ocean Colour)
  3. SRAL (Altimetry)
- EUMETSAT operates the Sentinel-3 satellites.
- Copernicus Marine Data Service conducts marine data processing and dissemination.



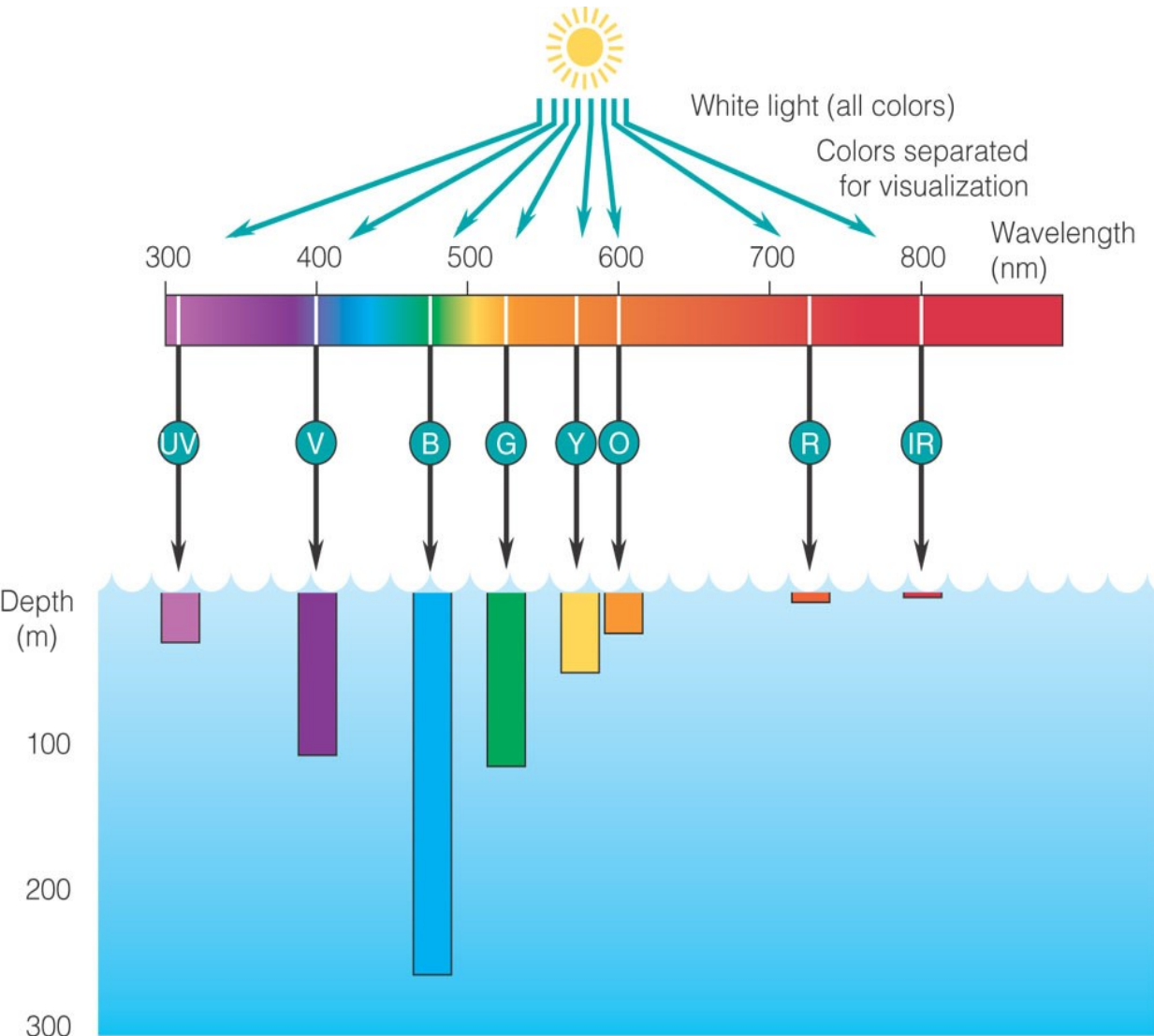


# Ocean Colour



Animation:  
NASA Visualisation Studio

# What is Ocean Colour?



- 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**).

A close-up photograph of water in a river estuary, showing a thick, turbid, yellowish-brown color with a mottled, textured surface.

**River Estuary**

A photograph of the Atlantic Ocean, showing deep blue water with small, rhythmic waves and a clear surface.

**Atlantic Ocean**

A photograph of water in the North Sea during a bloom, showing a vibrant green color with white foam from breaking waves.

**North Sea Bloom**

A photograph of Florida Red Tide, showing a reddish-pink color in the water near a sandy beach, with the sand visible at the bottom.

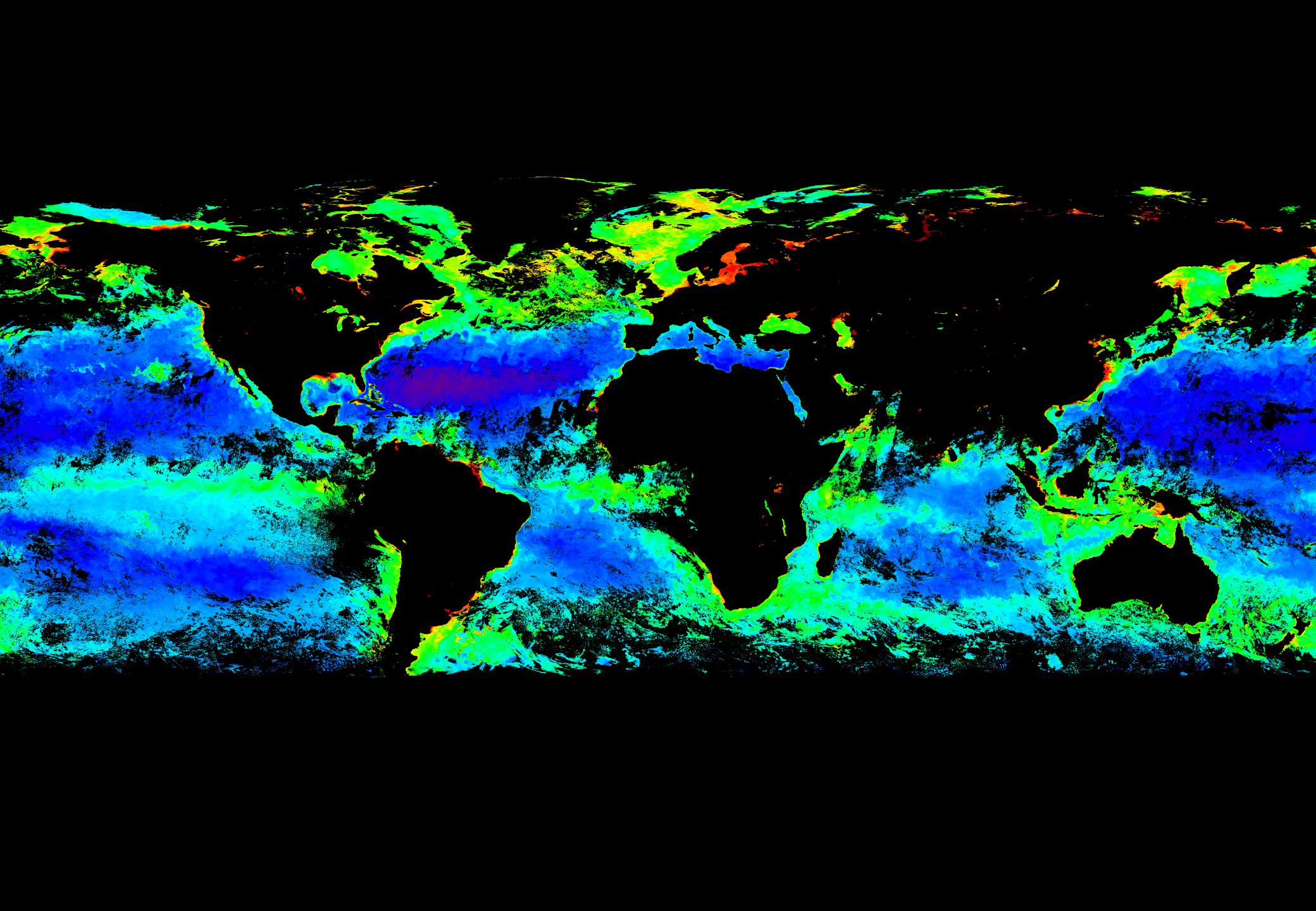
**Florida Red Tide**

# Ocean Colour – Inherent Optical Properties

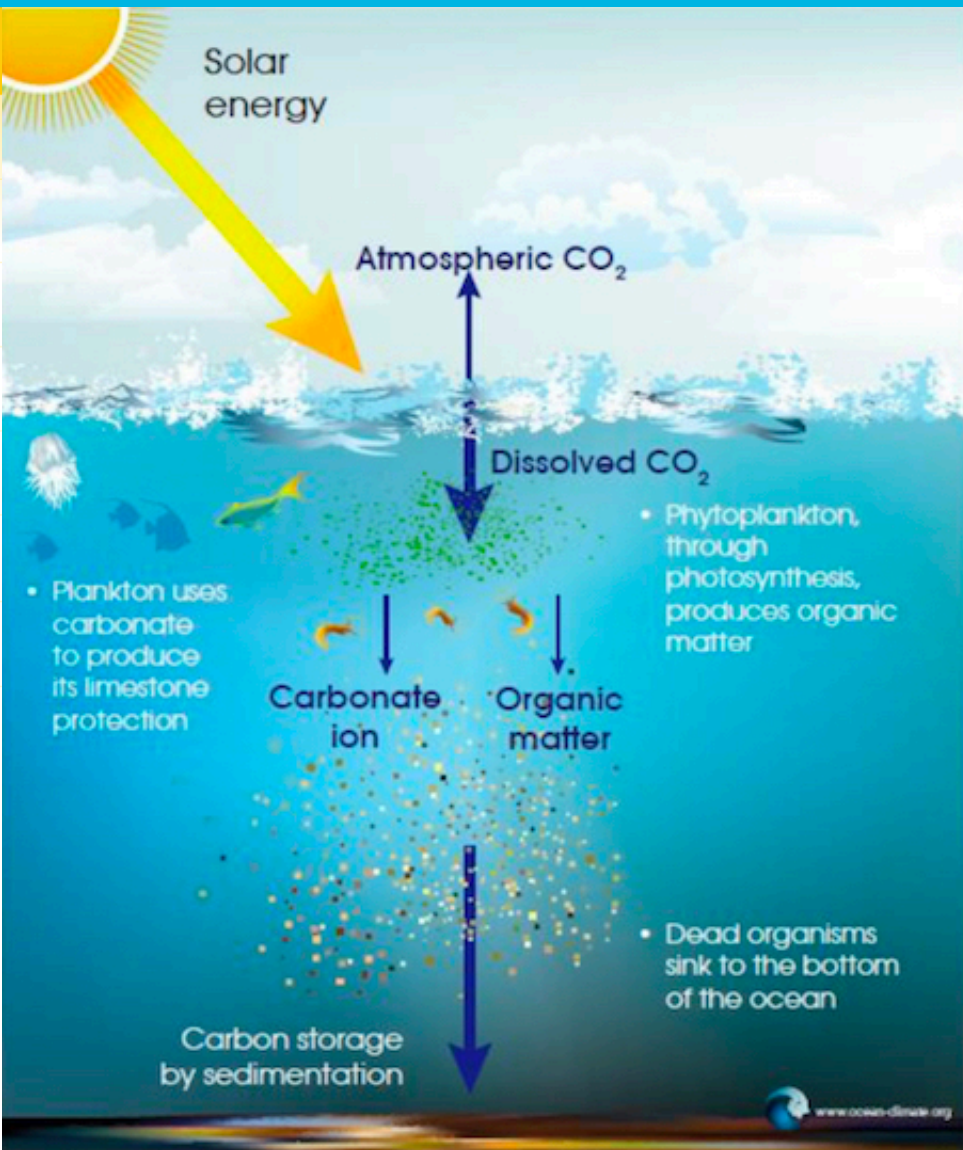
- Particles suspended in water increases scattering of incoming sunlight.
  - Runoff from land / rivers.
  - Coloured Dissolved Organic Matter (CDOM) aka Gelbstoff.
  - Resuspended sediment.
  - **Phytoplankton!**



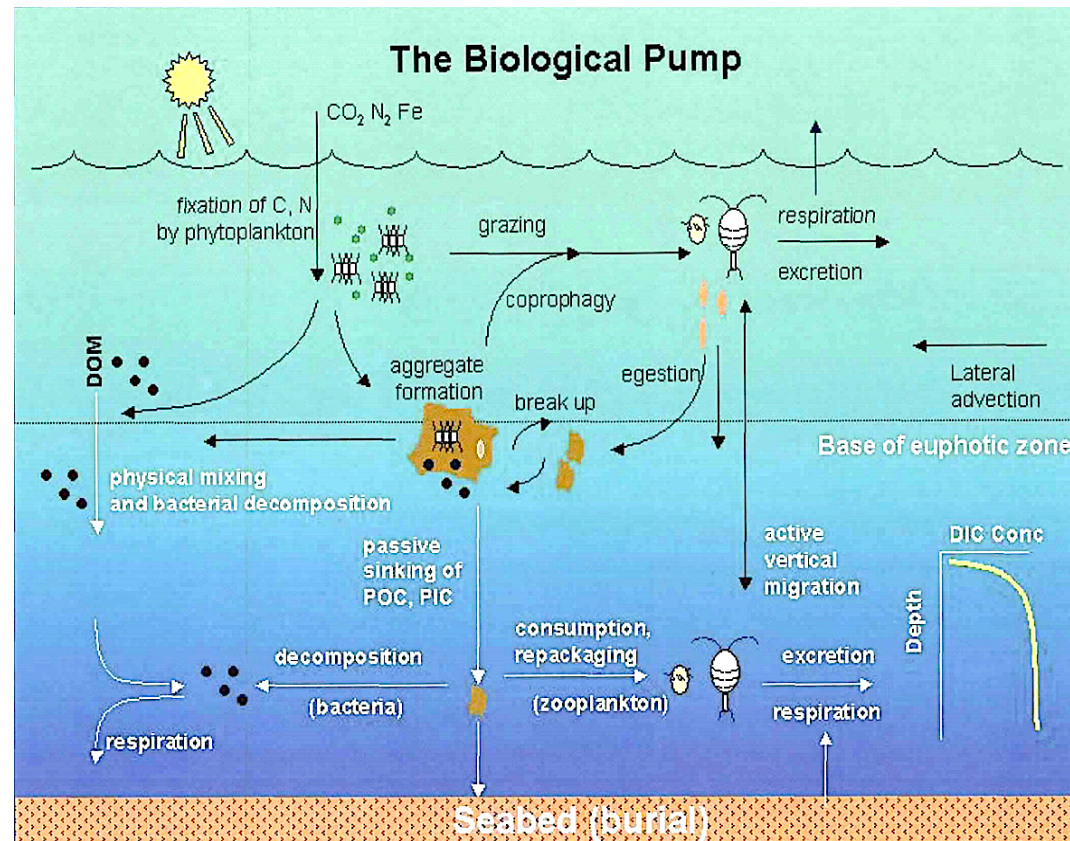
Microscopic, unicellular drifting plants

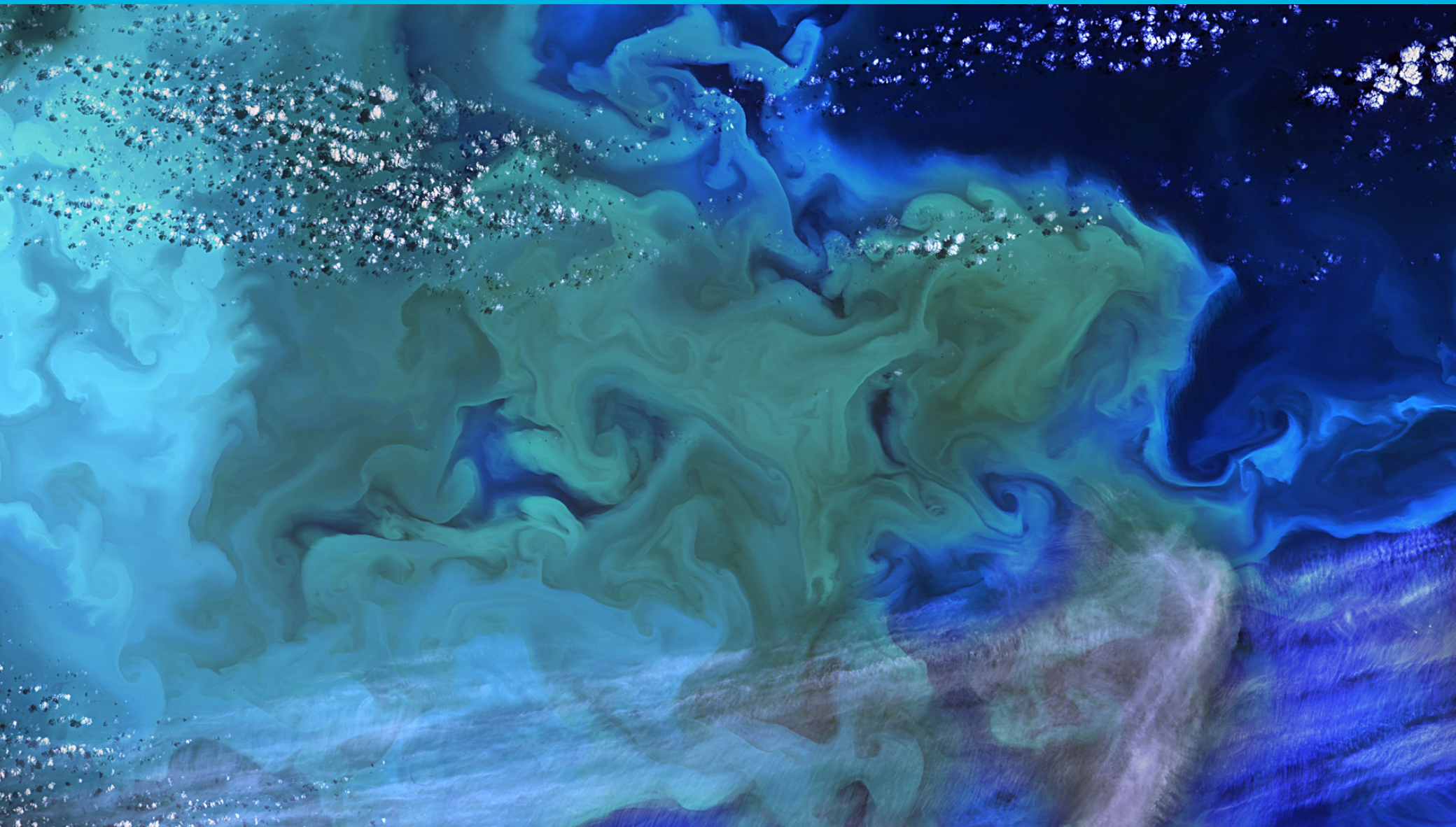


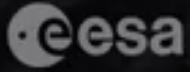
# Simplified Biological Carbon Pump



- Phytoplankton transfer CO<sub>2</sub> from the atmosphere to the ocean.







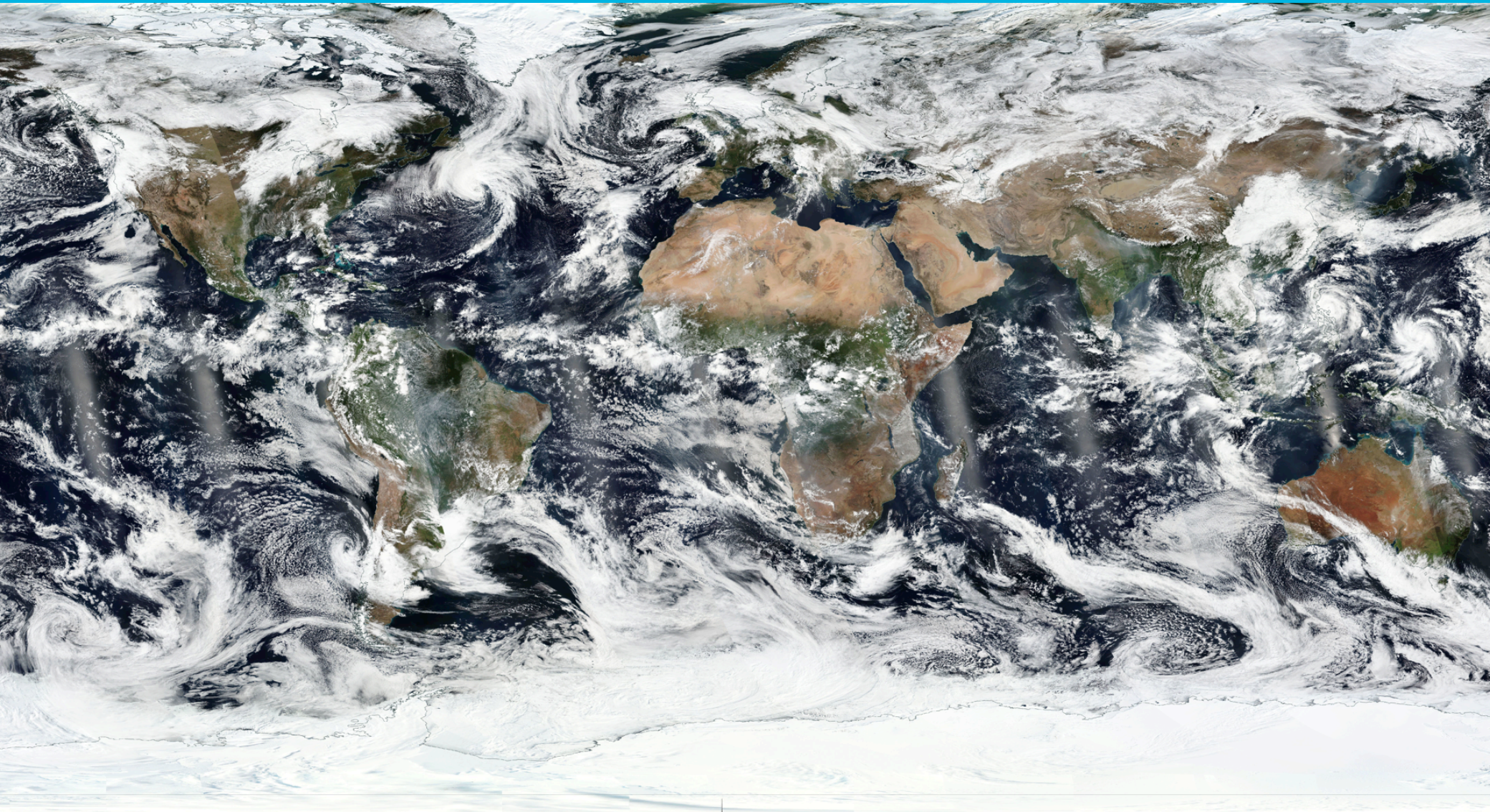
- Spectral resolution: 21 spectral bands from visible into SWIR.
- Good Signal to Noise Ratio (SNR) for ocean applications.
- Push-broom imaging spectrometer with 5 cameras.

## OLCI ocean colour Instrument:

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

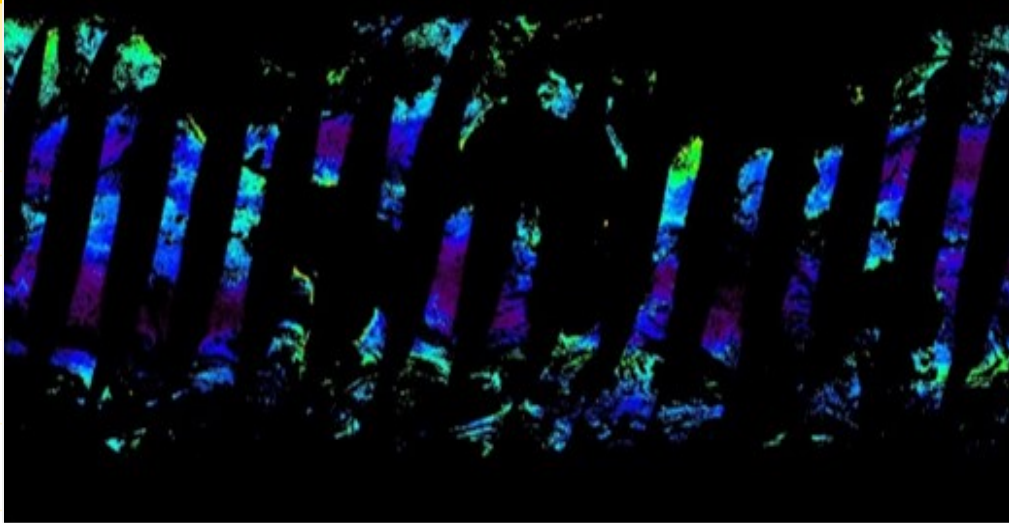


# Earth is Cloudy!



# The Sentinel-3A & S-3B constellation:

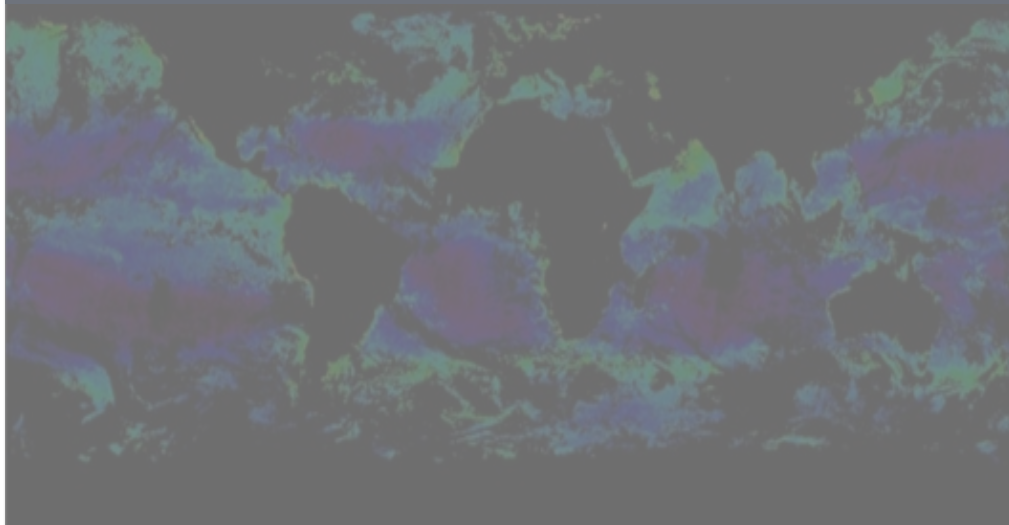
Sentinel-3A only – 1 day OLCI



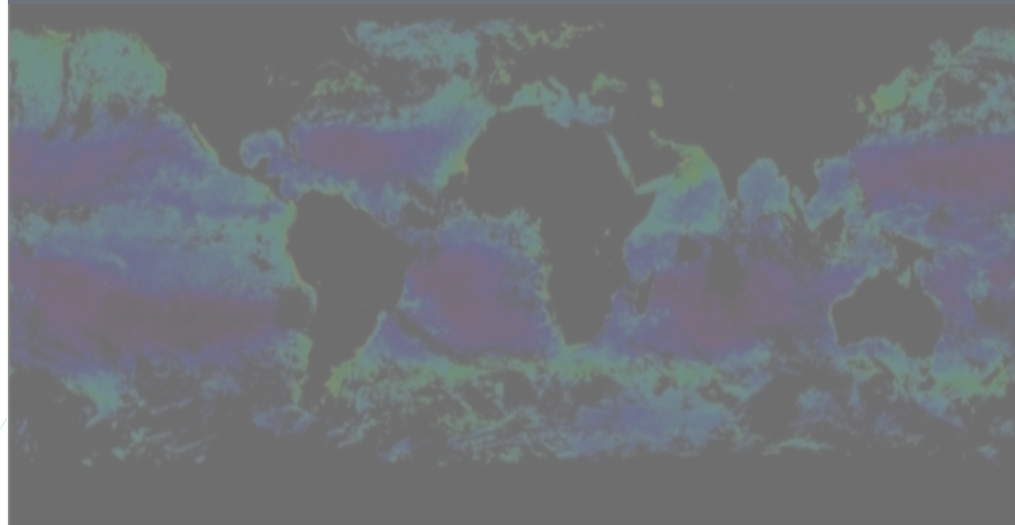
S-3A plus S-3B – 1 day OLCI



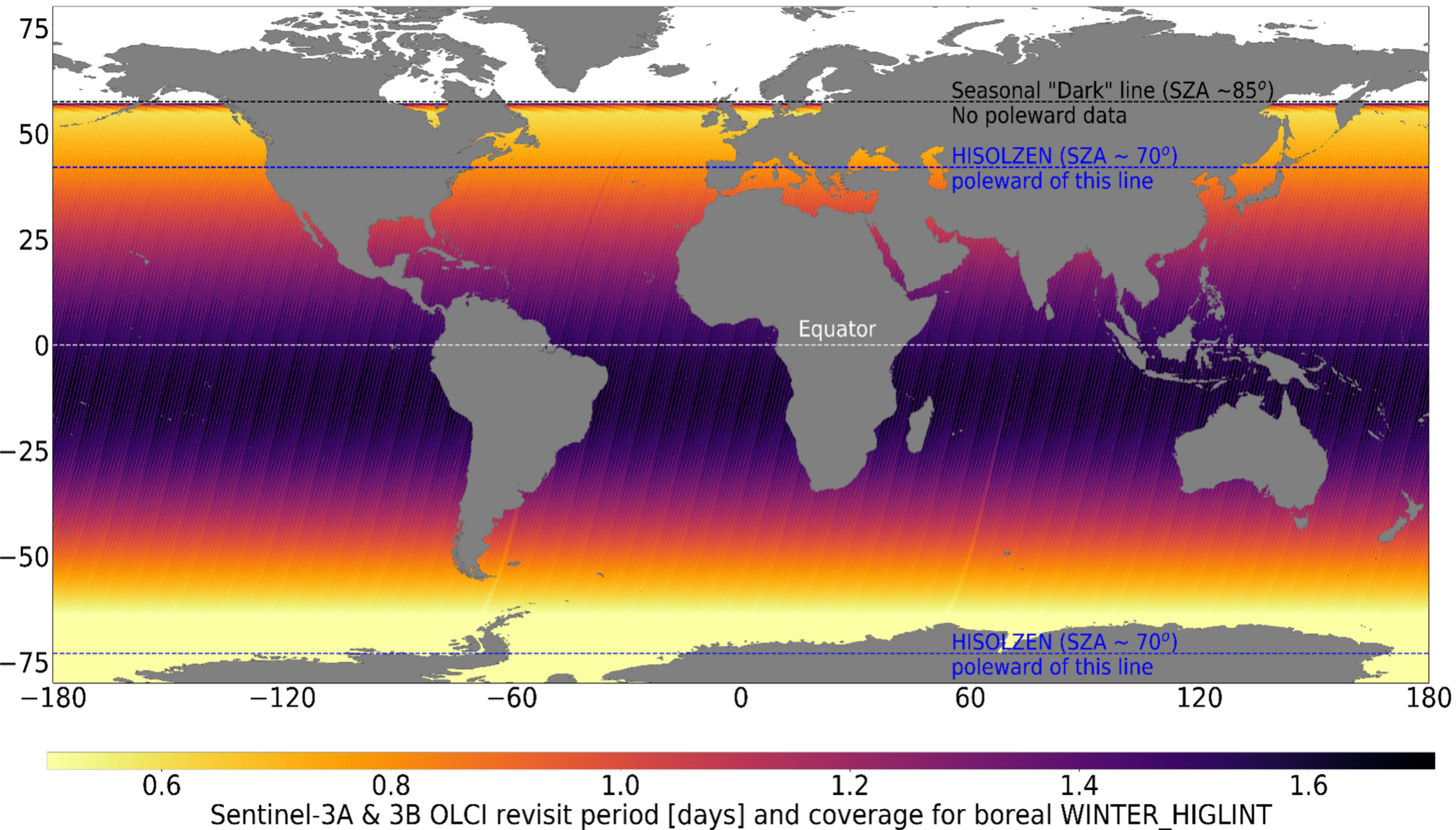
S-3A + S-3B – 2 day OLCI



S-3A + S-3B – 3 day OLCI

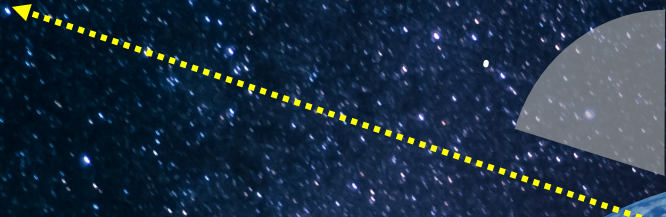
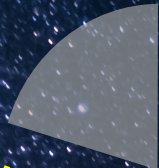


# Coverage maps: OLCI Northern Hemisphere winter

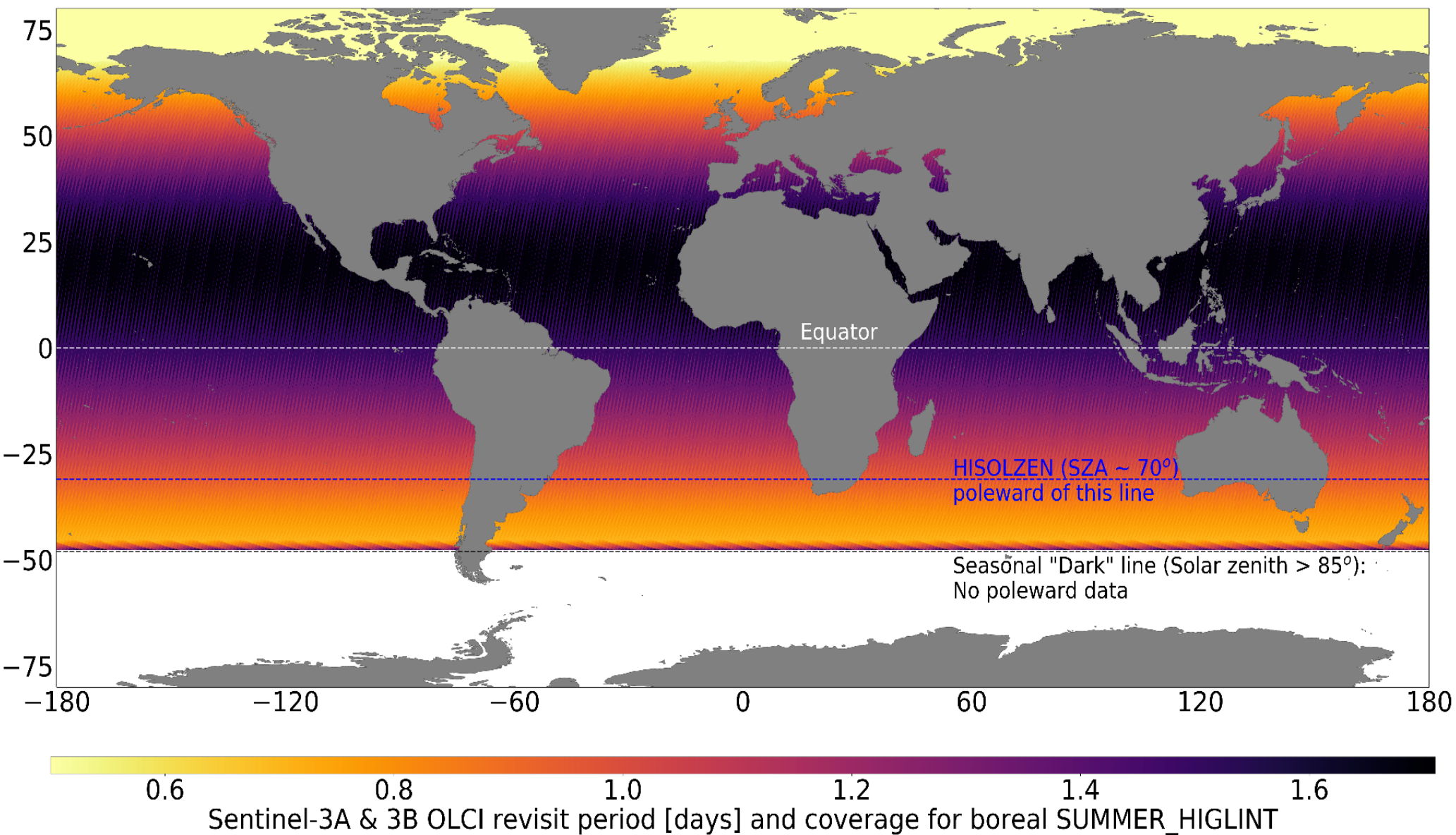




Zenith

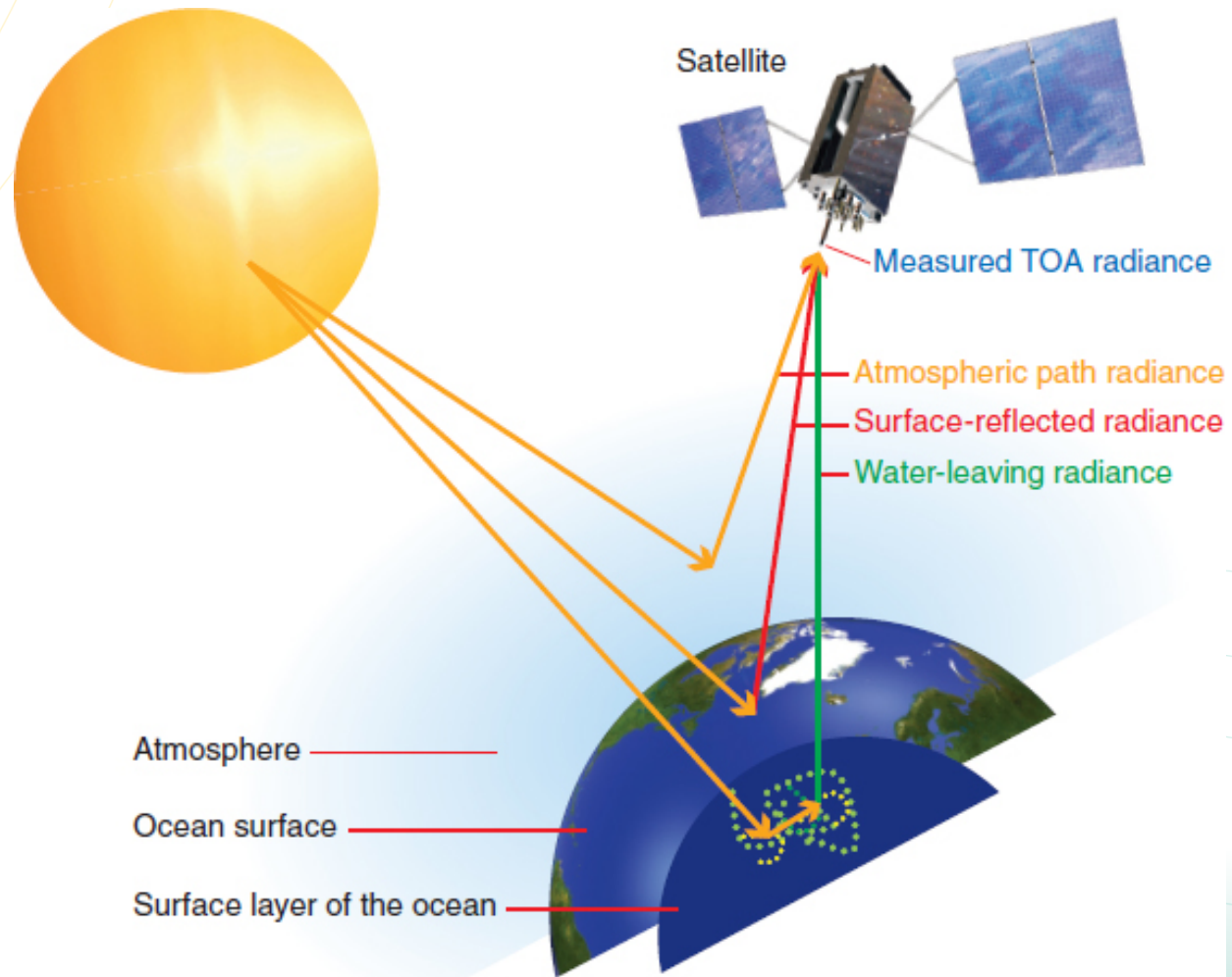


# Coverage maps: OLCI Northern Hemisphere summer



# Remote Sensing of Water-Leaving Radiance

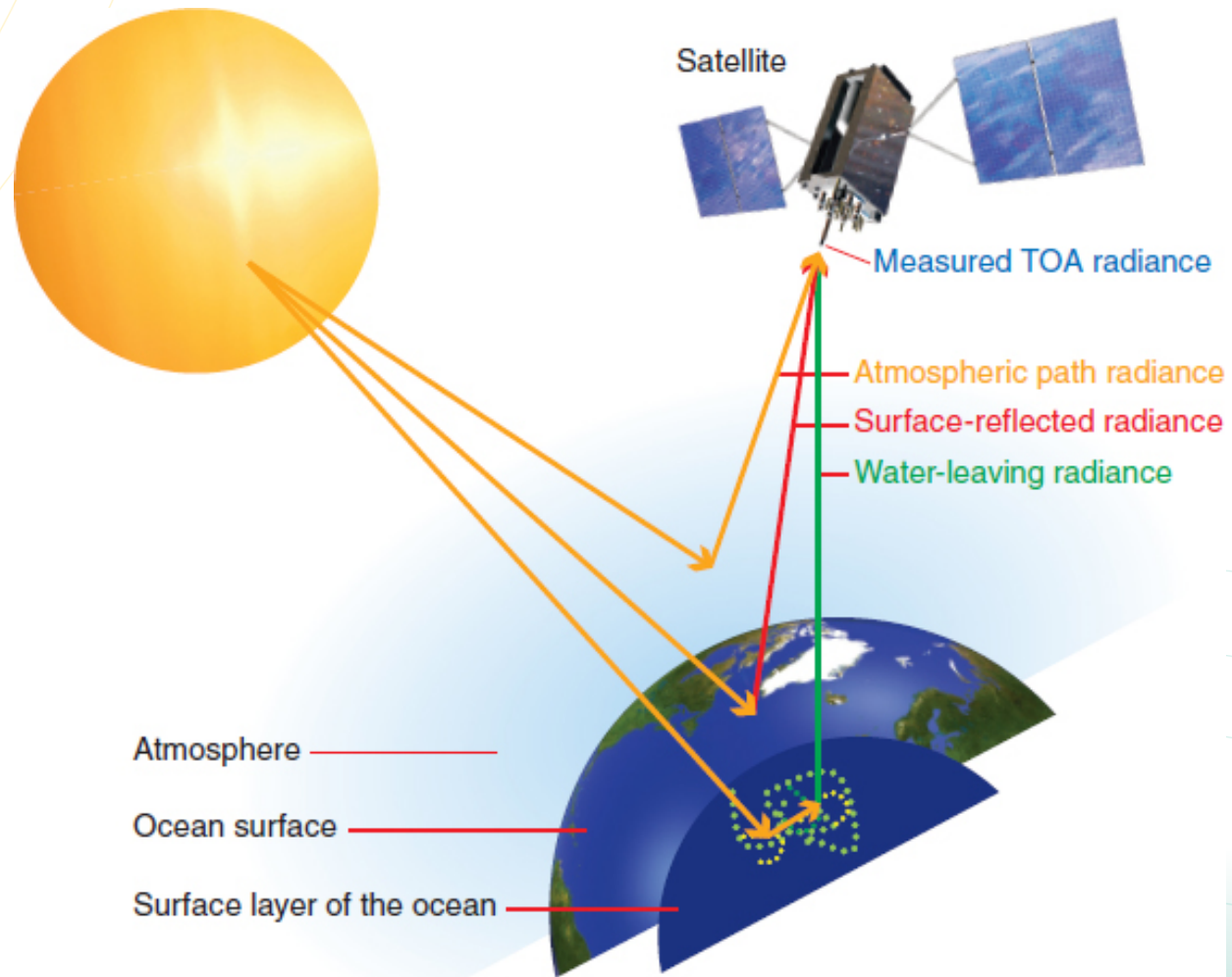
- Deriving biological parameters from ocean color measurements is a multi-stage process.
- Ocean colour sensors measure the upwelling radiance at the top of the atmosphere (LTOA).



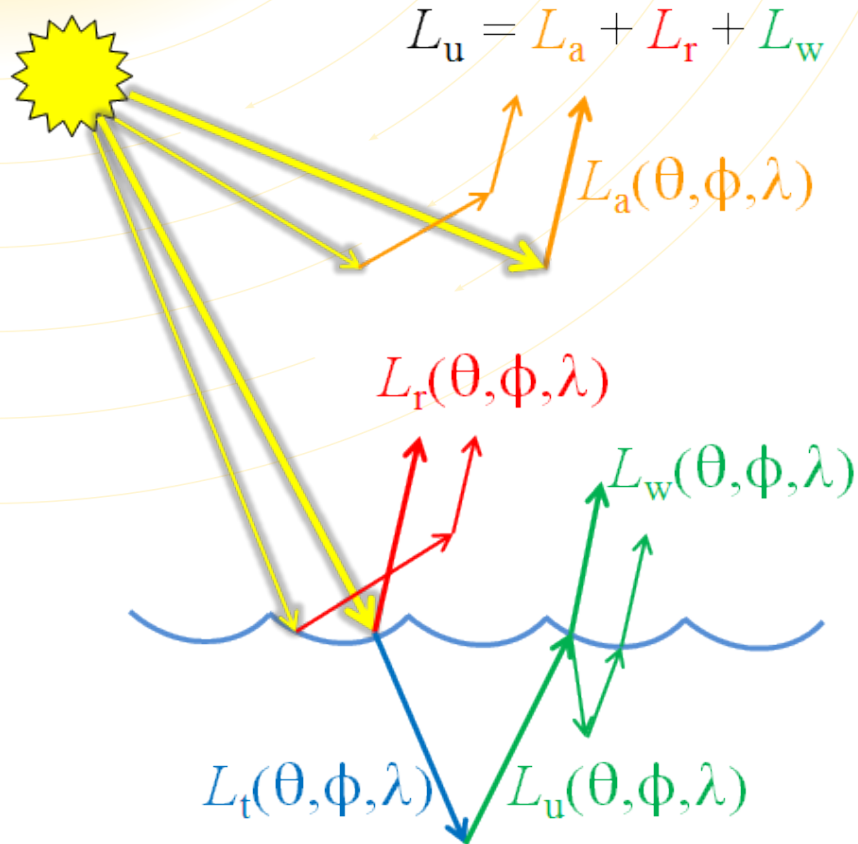
# Atmospheric Correction:

LTOA is the total radiances from three sources:

1. Water-leaving radiance ( $L_w$ ).
2. Radiance reflected from the sea surface.
3. Radiance scattered into the viewing direction by the atmosphere.



# Atmospheric Correction:



- Desired measurement is **L<sub>w</sub>** = ocean color = information on biological and chemical constituents in near-surface waters.
- To obtain L<sub>w</sub>, it is necessary to remove the contributions of surface reflection and atmospheric path radiance from the measured total
- This is the **atmospheric correction**.



# EUMETSAT Copernicus Marine Data Service

Earth Observation is complicated for many reasons...

Earth is cloudy, has seasons, and it has an atmosphere.

## Sentinel-3A and 3B

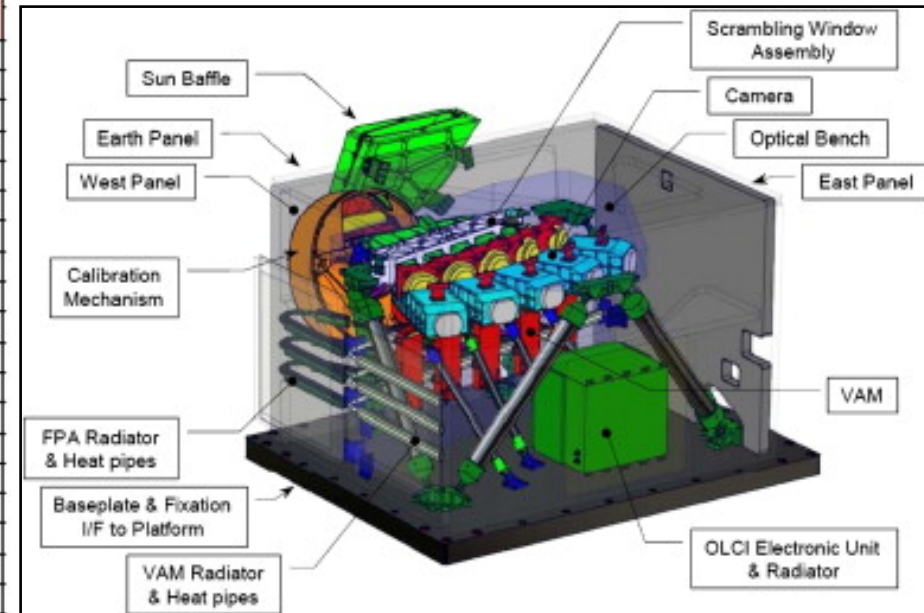
- Operation of satellite
- Ground segment for:
  - Data processing
  - Data to services



# Ocean Colour from Sentinel-3 OLCI

- Spatial resolution: 300 m full resolution (FR) granules, 1km reduced resolution (RR) half-orbit dumps
- Good SNR for ocean applications with 21 spectral bands
- With S-3A and S-3B < 3 day revisit

Band #	$\lambda$ center	Width	Lmin	Lref	Lsat	SNR@Lref
	nm	nm	W/(m <sup>2</sup> .sr.μm)	W/(m <sup>2</sup> .sr.μm)	W/(m <sup>2</sup> .sr.μm)	
Oa1	400	15	21.60	62.95	413.5	2188
Oa2	412.5	10	25.93	74.14	501.3	2061
Oa3	442.5	10	23.96	65.61	466.1	1811
Oa4	490	10	19.78	51.21	483.3	1541
Oa5	510	10	17.45	44.39	449.6	1488
Oa6	560	10	12.73	31.49	524.5	1280
Oa7	620	10	8.86	21.14	397.9	997
Oa8	665	10	7.12	16.38	364.9	883
Oa9	673.75	7.5	6.87	15.70	443.1	707
Oa10	681.25	7.5	6.65	15.11	350.3	745
Oa11	708.75	10	5.66	12.73	332.4	785
Oa12	753.75	7.5	4.70	10.33	377.7	605
Oa13	761.25	2.5	2.53	6.09	369.5	232
Oa14	764.375	3.75	3.00	7.13	373.4	305
Oa15	767.5	2.5	3.27	7.58	250.0	330
Oa16	778.75	15	4.22	9.18	277.5	812
Oa17	865	20	2.88	6.17	229.5	666
Oa18	885	10	2.80	6.00	281.0	395
Oa19	900	10	2.05	4.73	237.6	308
Oa20	940	20	0.94	2.39	171.7	203
Oa21	1020	40	1.81	3.86	163.7	152



# EUMETSAT Copernicus Marine Data Service

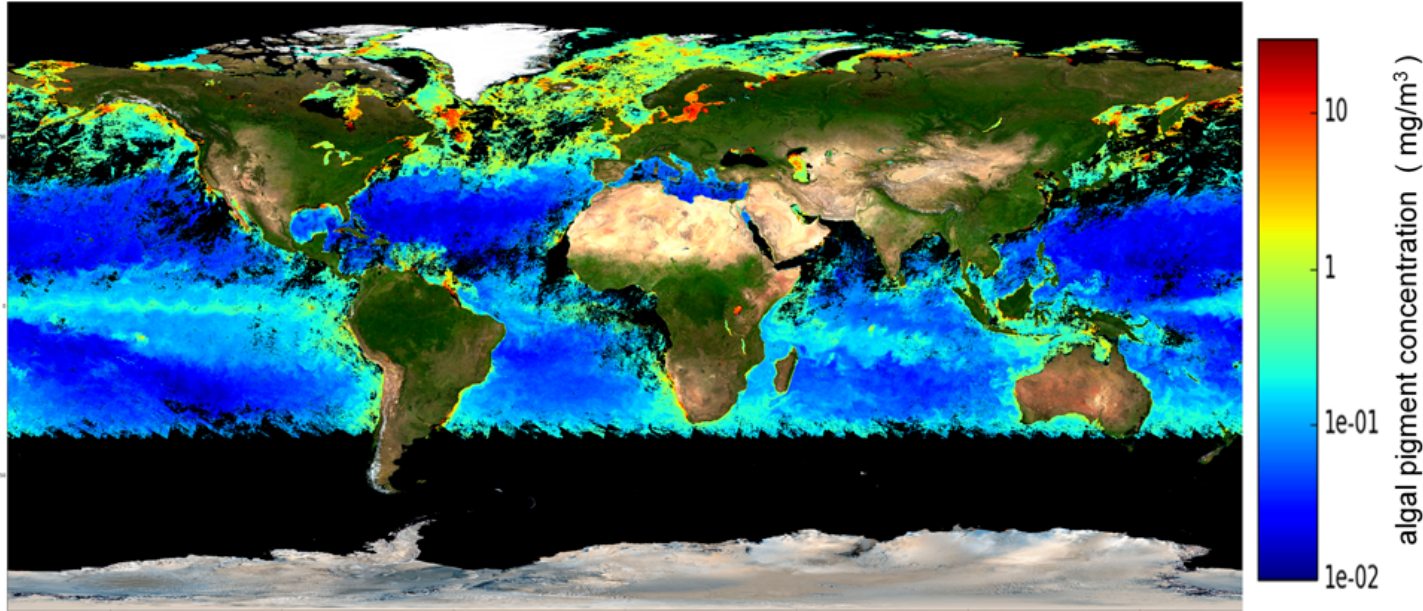
## Global Level 1 data & Marine Level 2 data products

- Daily, highest resolution (sensor specific, native).
- NRT/ STC/ NTC
- Level 1: allows user to implement custom processing.
- Level 2: atmospheric correction applied, and geophysical products are provided as standard.



# OLCI L2 products available through CMD5:

Sentinel-3A OLCI algal pigment concentration  
14-27 June 2017, 14-day composite, OC4ME clear water algorithm



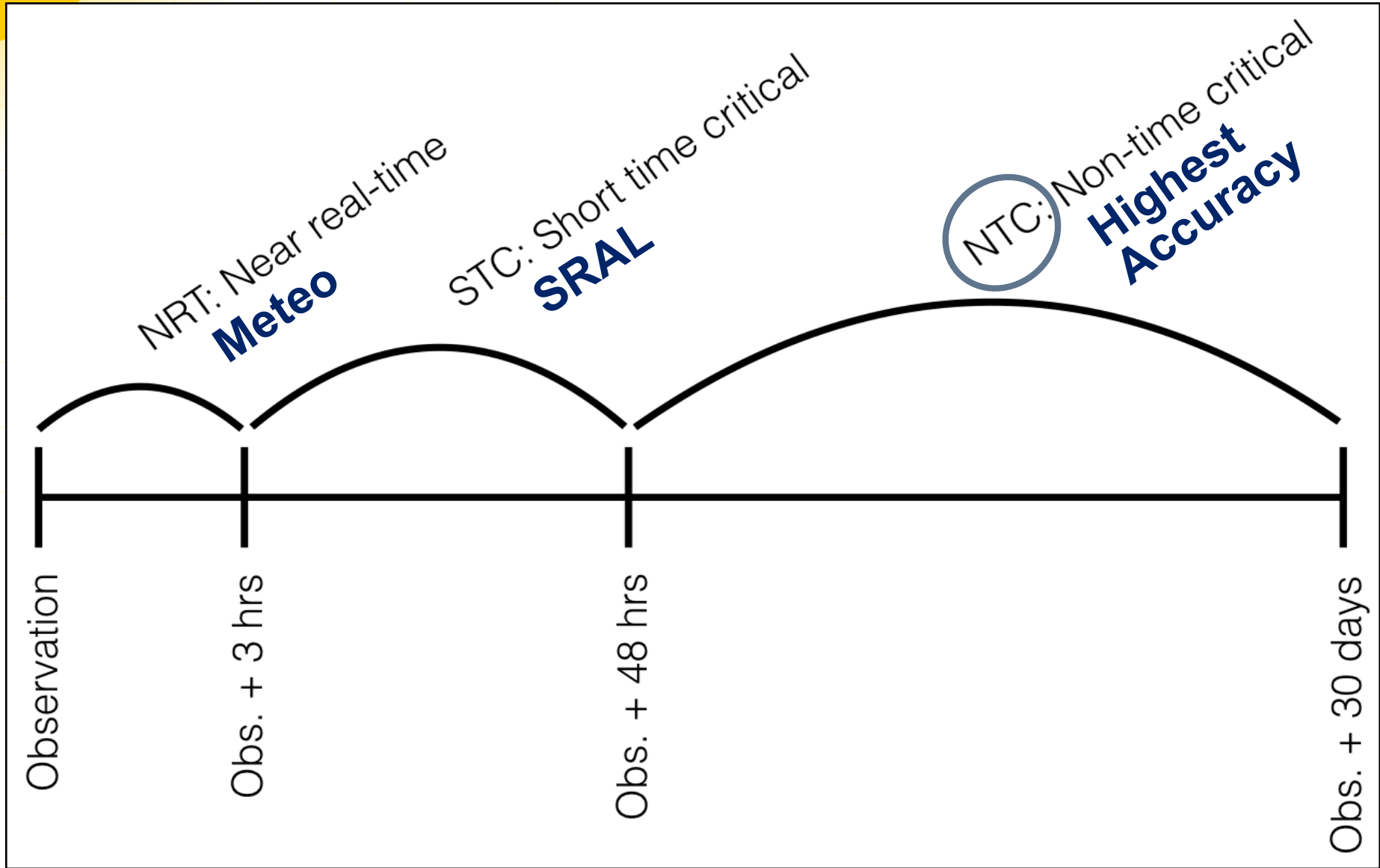
- Chlorophyll-a concentration (CHL)
- Total Suspended Matter (TSM)
- Absorption of Gelbstoff & detritus (a<sub>dg</sub>)
- Diffuse attenuation coefficient (K<sub>d\_490</sub>)
- Photosynthetically active radiation (PAR)

# Sentinel-3 Data Processing Levels

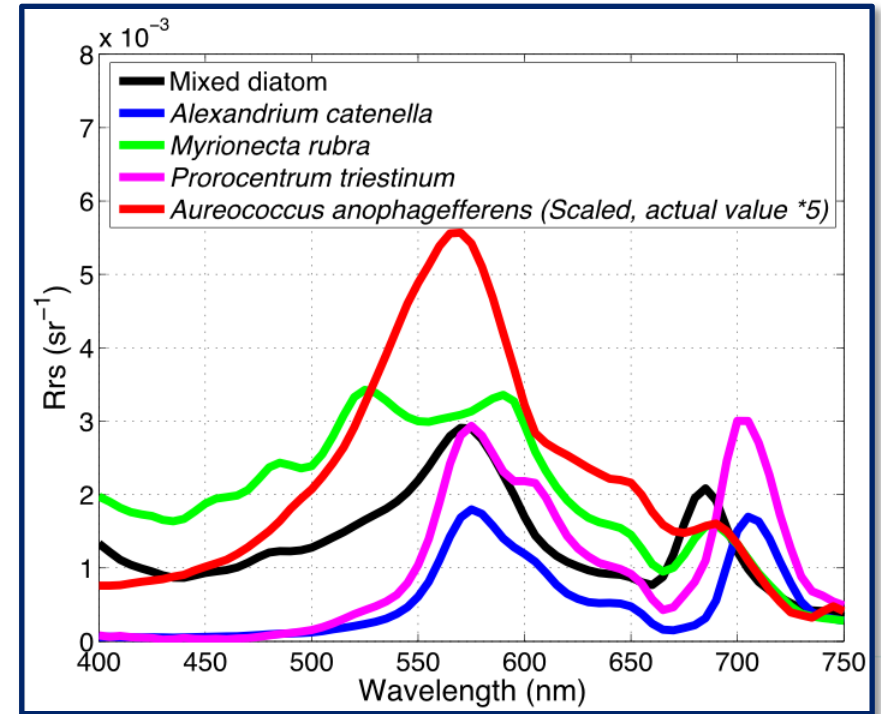
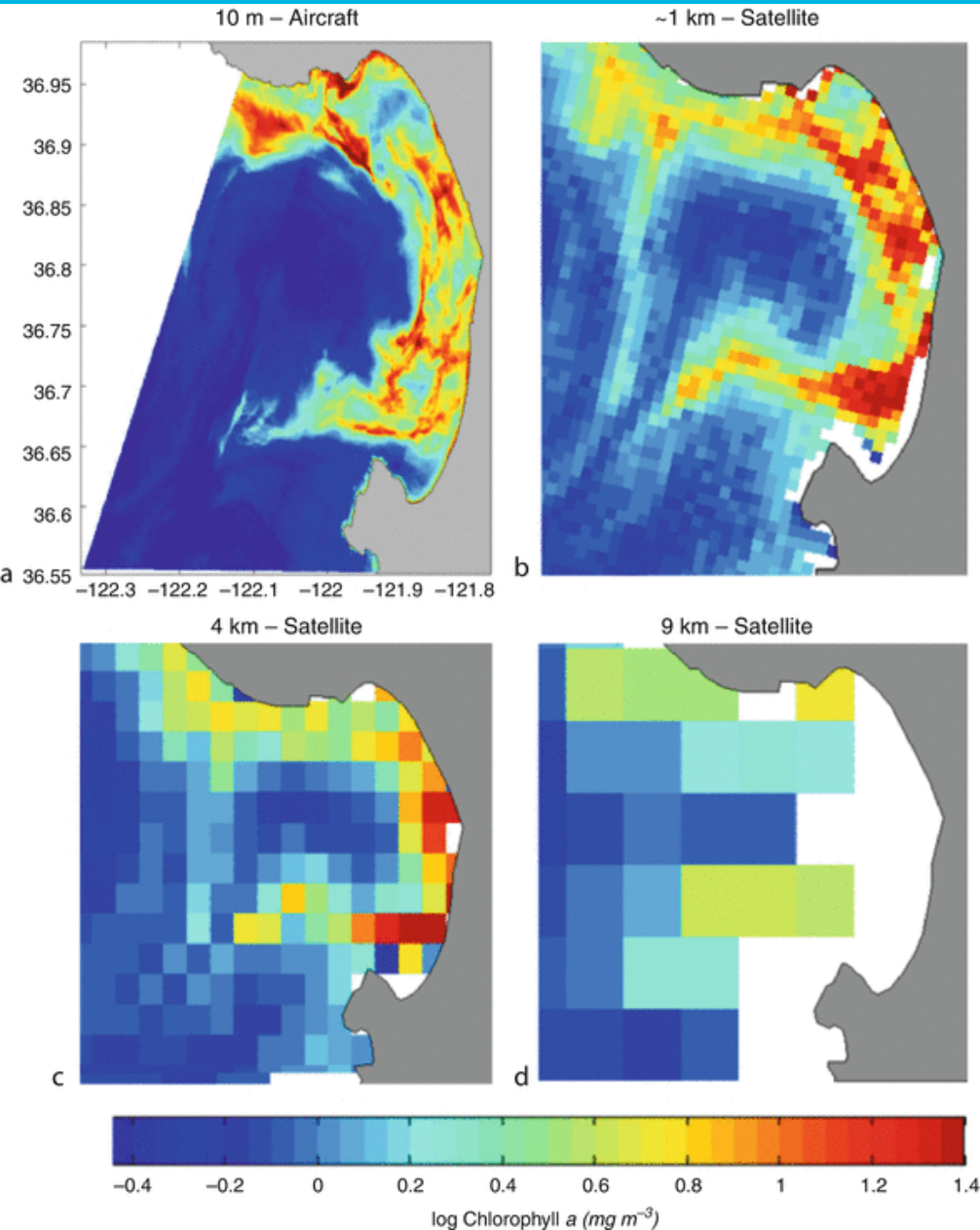
Level	Description
Level 0	Reconstructed, unprocessed instrument and payload data at full resolution, with communications artefacts removed.
Level 1	Reconstructed, unprocessed instrument data at full resolution, time-referenced, and annotated with ancillary information.
Level 2	Derived geophysical variables at the same resolution and location as Level 1 source data. Often involves atmospheric correction.
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).

**NOTE: There are differences in how parts of the remote sensing community define processing levels.**

# Timeliness and Data Accuracy

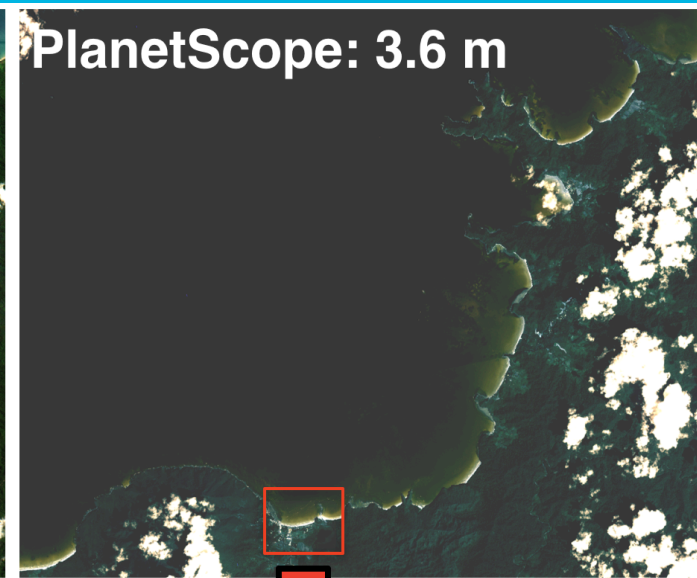
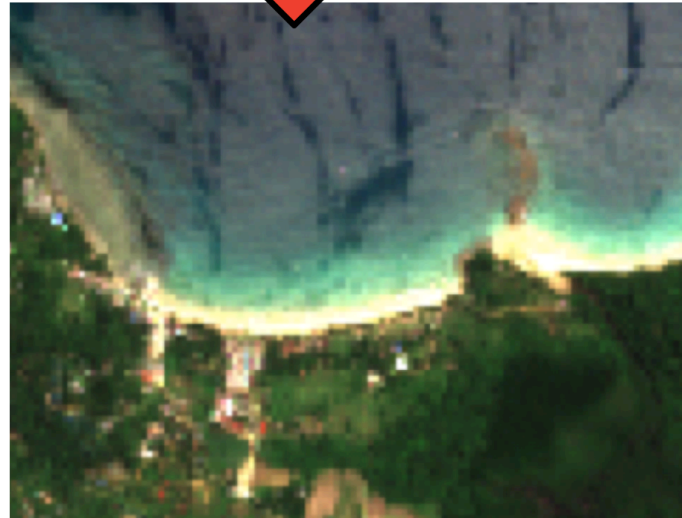
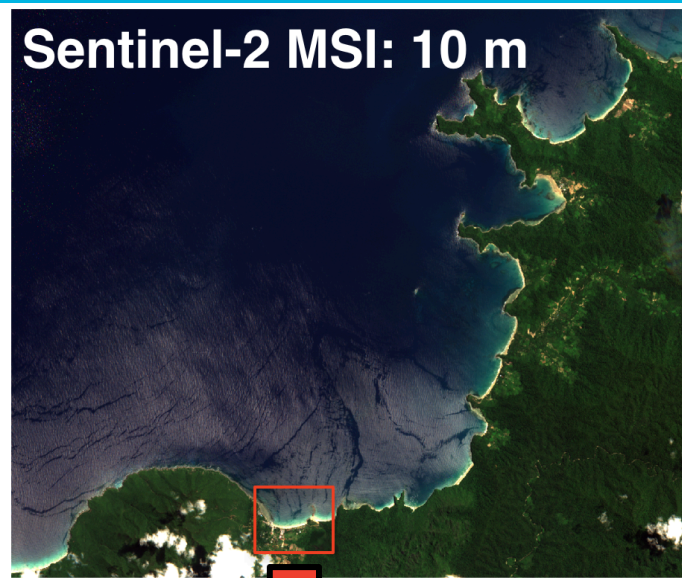
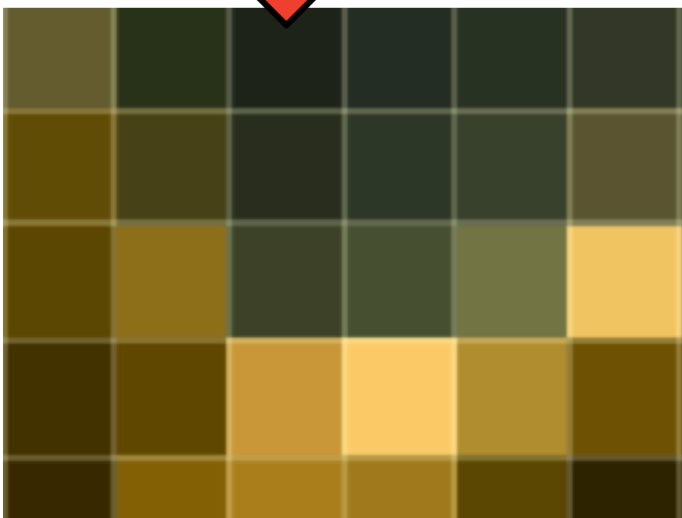
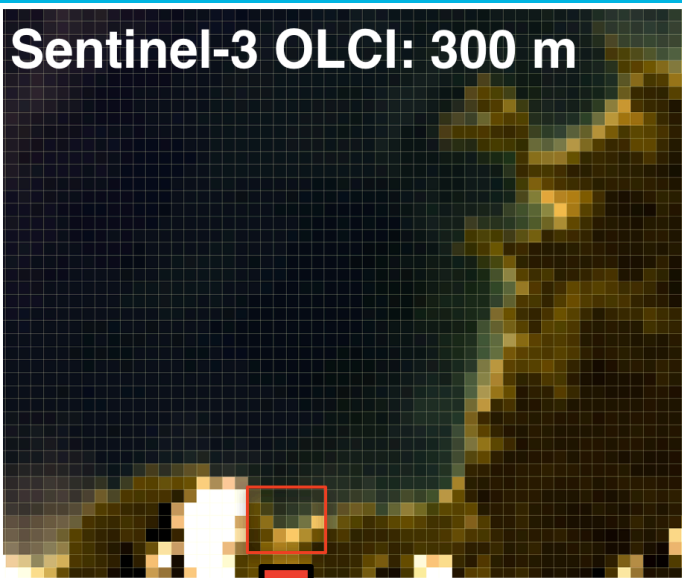


# Important characteristics for OC sensors



**RESOLUTION,  
RESOLUTION....  
SENSITIVITY!**

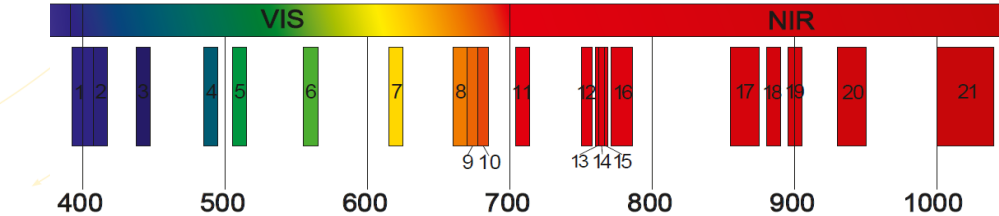
# Spatial and spectral resolution



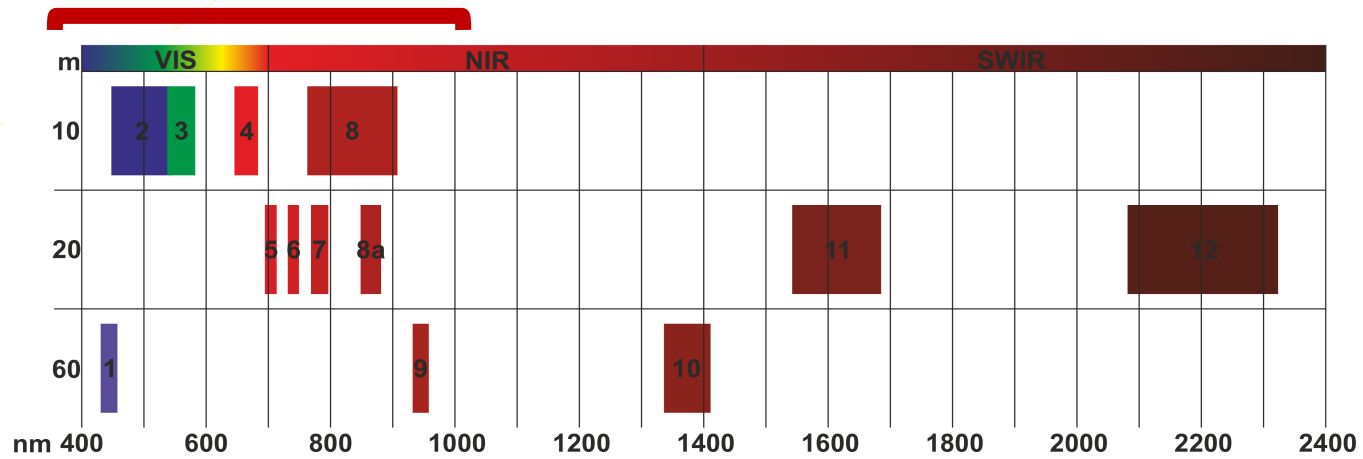


# Spatial & spectral resolution: comparisons

**Sentinel-3  
OLCI:**



**Sentinel-2  
MSI:**

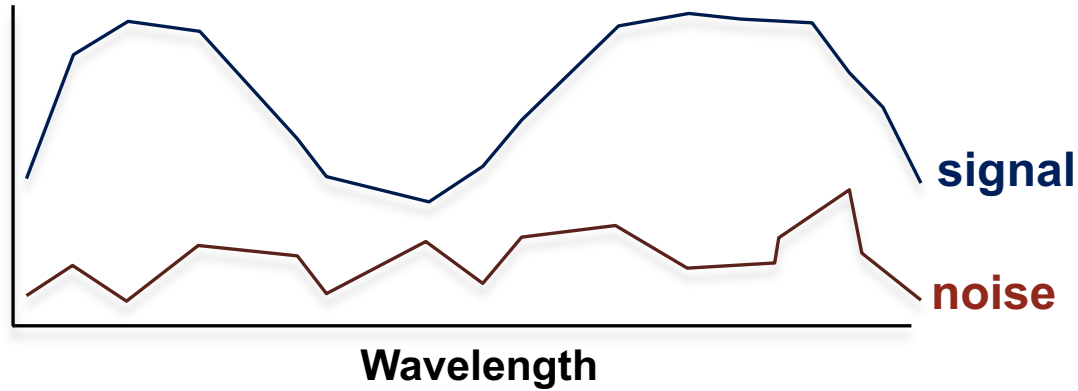


Decreasing signal to noise ratio

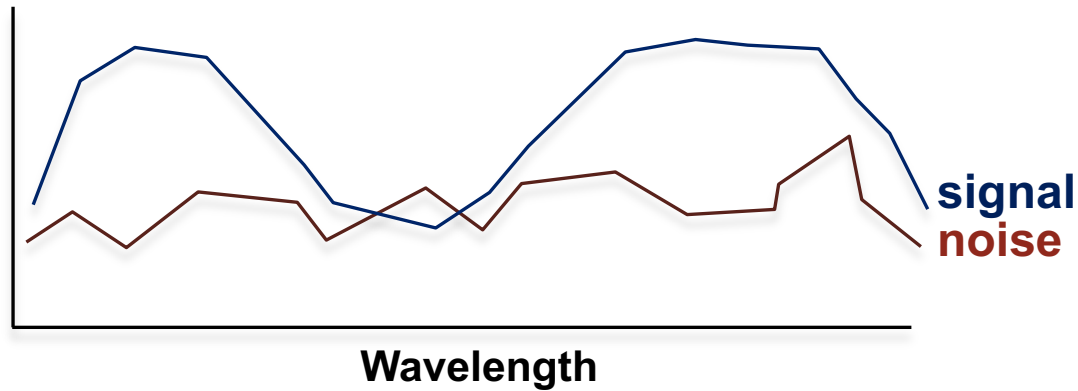
**Commercial PlanetScope: Red, Green, Blue, (1 x NIR)**

# Spatial and spectral resolution: comparisons

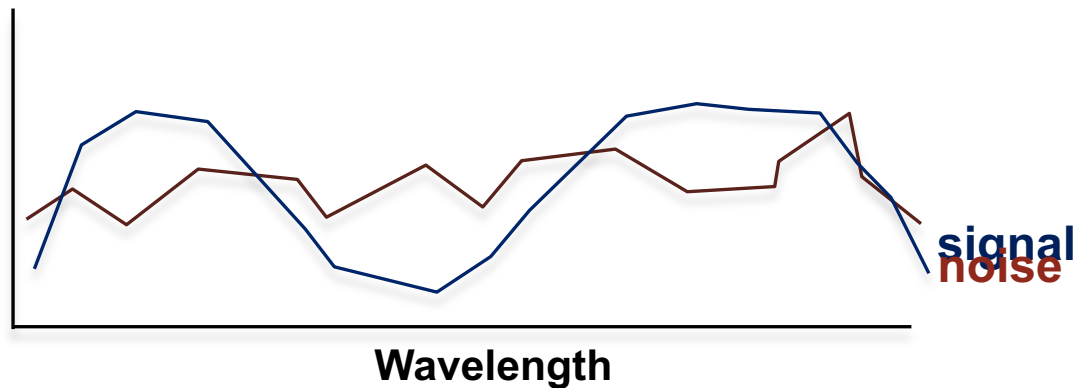
Sentinel-3 OLCI:



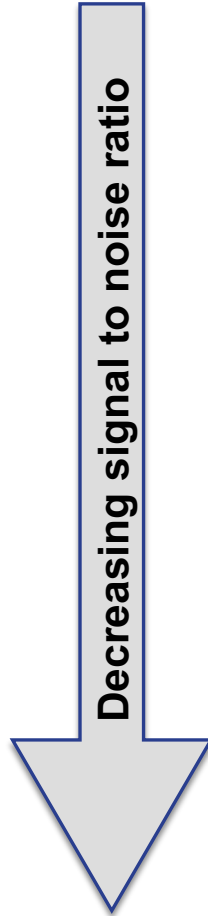
Sentinel-2 MSI:



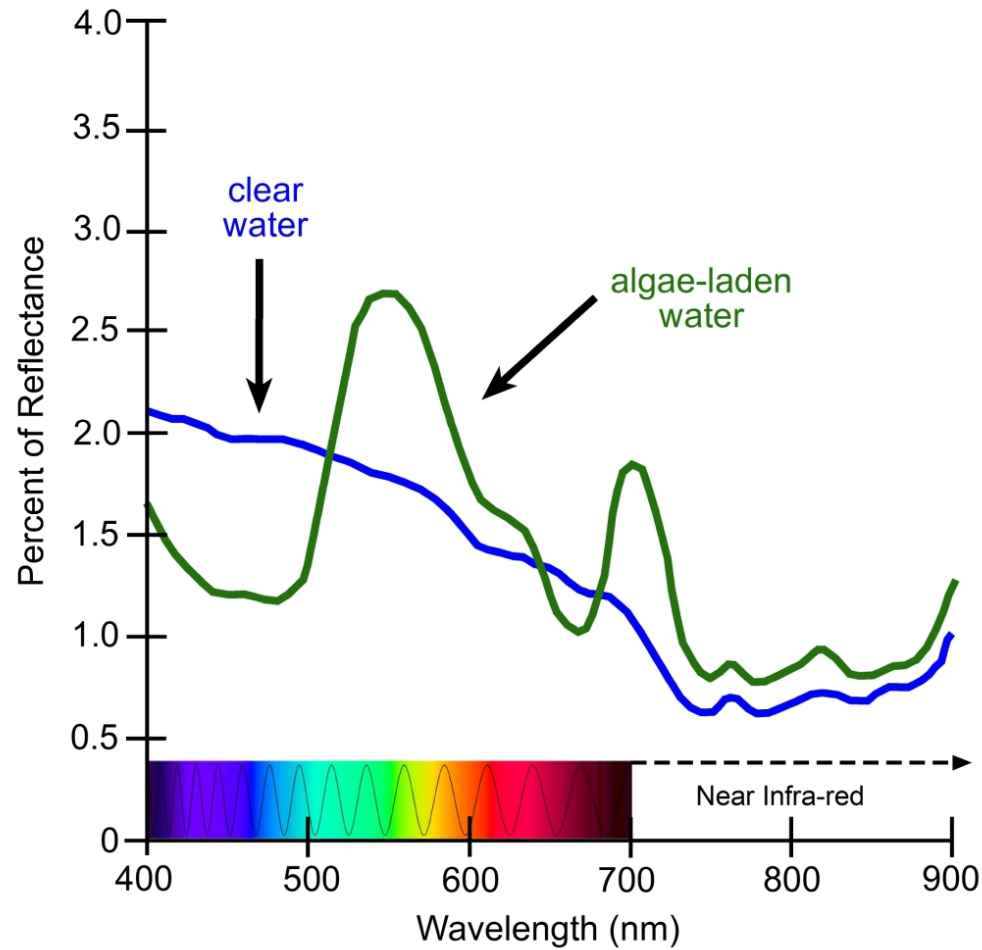
Planet Scope:



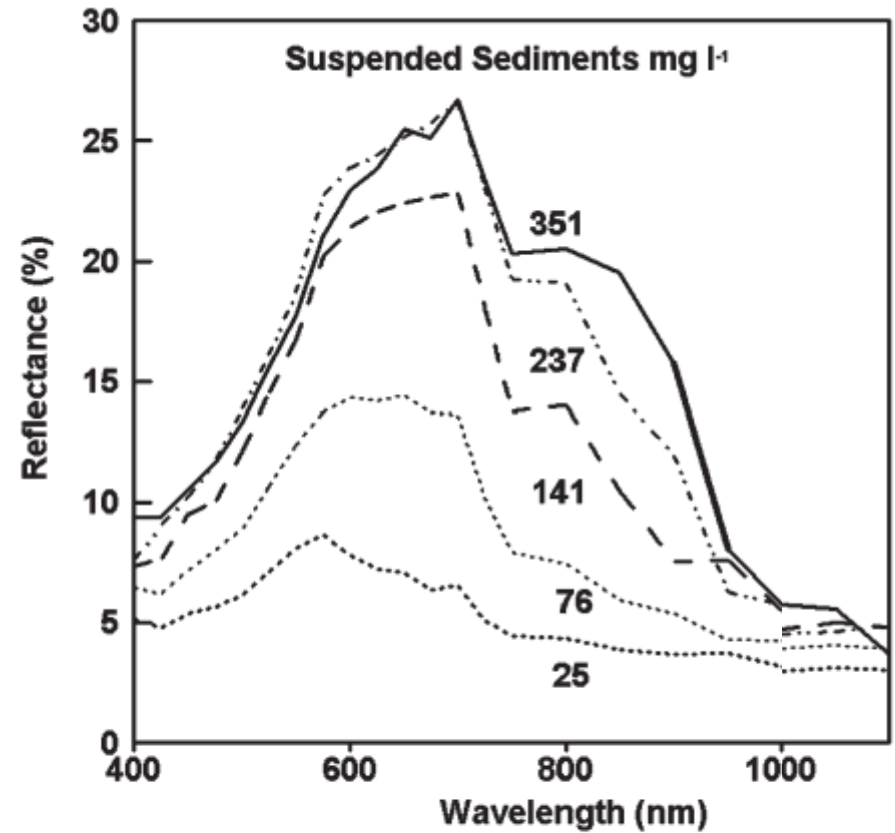
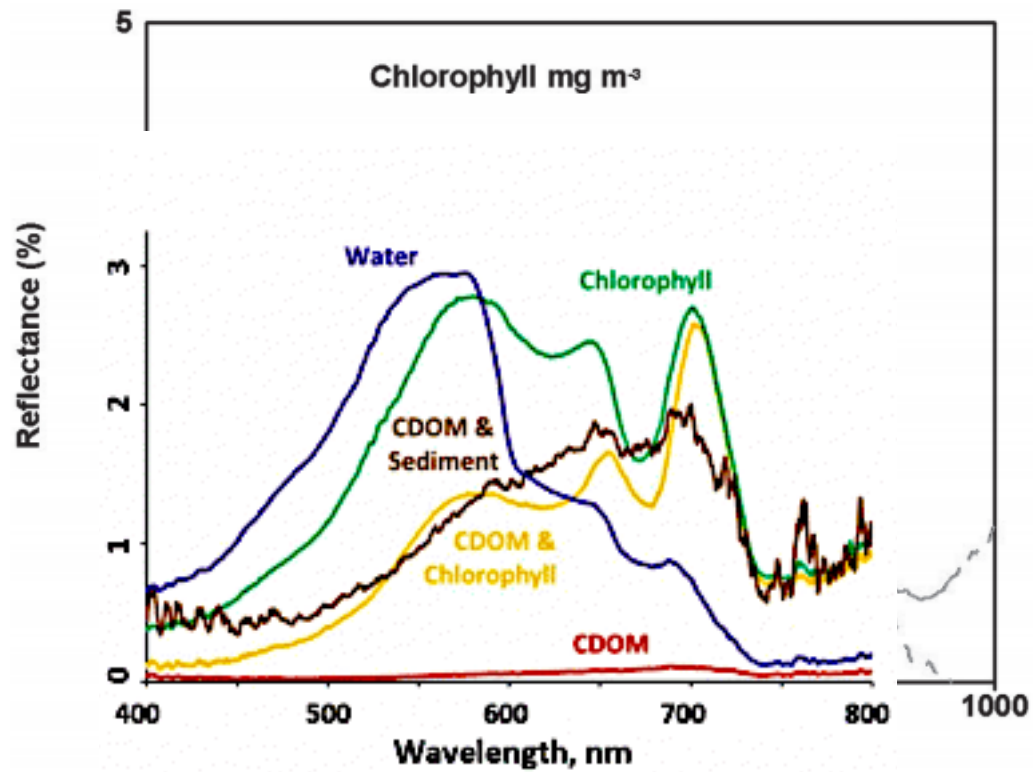
Decreasing signal to noise ratio



# Spectral Signatures of in-water Constituents:



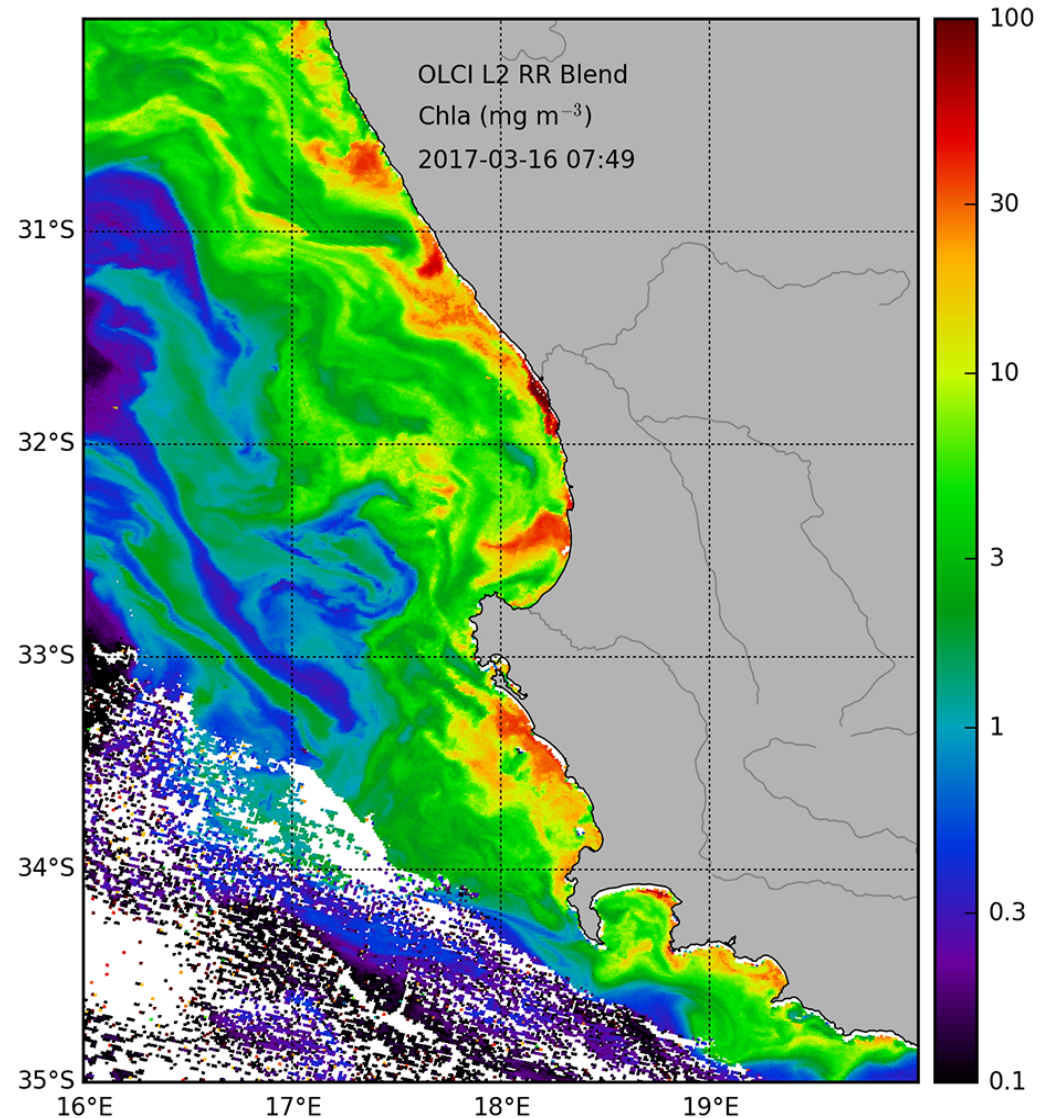
# Spectral Signatures of in-water Constituents:



# Monitoring Harmful Algal Blooms (HABs)

## OLCI [Chlorophyll-a]

- Full Resolution (FR) 300m  
Reduced Resolution 1km.
- 21 spectral bands (RGB to SWIR) .
- Good Signal to Noise Ratio.
- >3 day revisit time with paired S-3A and S-3B.
- Measures to 1 optical depth - determined by what is mixed in the surface waters.



# Marine Environment Monitoring Service

- Copernicus Marine Environment Monitoring Service: CMEMS
- CMEMS provides products and services for marine applications, using data from:
  - The Sentinels
  - Historic and third-party missions
  - Physical and biogeochemical models
  - *in situ* data.
- Other services also support the marine domain, including the Emergency, Climate & Security Services.



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# https://tra

Our training activities support users in the member states and asso services, including Copernicus data provided by EUMETSAT.

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A small number of past courses are now open for access (guest ac available to you upon log in. Please note that discussion forums and access include:

- Atmospheric Composition Data (2019)
- GMES & Africa and Copernicus Marine Earth Observation (2019)
- Workshop on the Use of the Copernicus Marine Data Stream for O
- The Use of Satellite Data for Climate Services in Europe (2019)
- Meteorological Satellite Applications course on Identifying African
- International School on Applications with the Newest Multi-spectra

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There are no upcoming events  
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Announcements

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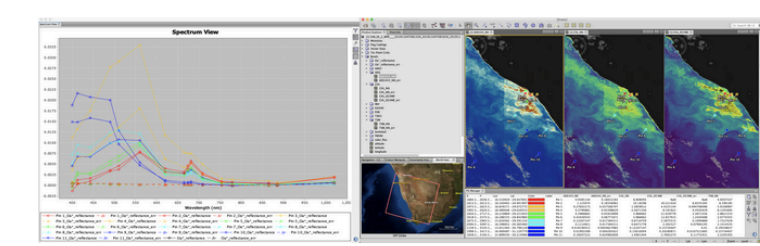
Activity since Sunday, 22 November 2020, 3:05 PM  
Full report of recent activity...  
No recent activity

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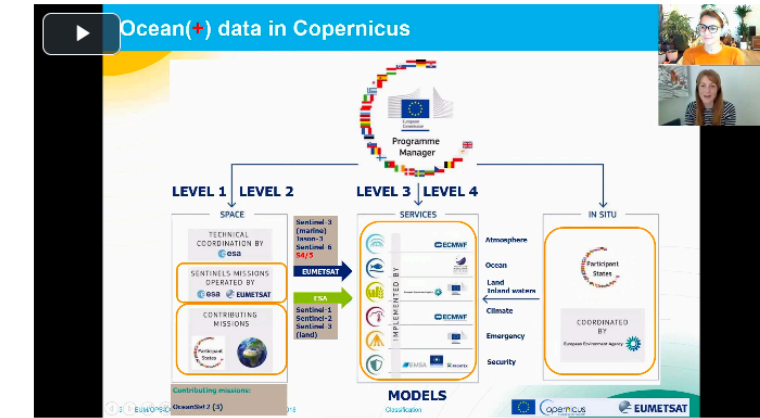
## Technical Guide to Installing Software for working with CMDS data:



## Announcements

### Introduction: EUMETSAT and the Copernicus Marine Data Stream (CMDS)

This topic provides an overview of the Copernicus programme, EUMETSAT's role within Copernicus, and the Copernicus Marine Data Stream (CMDS). It's worth getting a clear idea of the Copernicus Marine Landscape here - the information will prove highly relevant when it comes to your workflows, in terms of who collects the marine data you want and where you can find it.



Hayley Evers-King joins Lauren Biemann for an informal discussion to help simplify the Copernicus Marine Landscape, talking us through the different missions, mechanisms and agencies working together under the Copernicus Programme and European Commission banner.

# SEA SURFACE HEIGHT

# SEA SURFACE TEMP

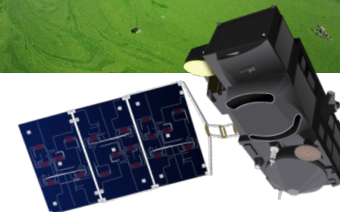
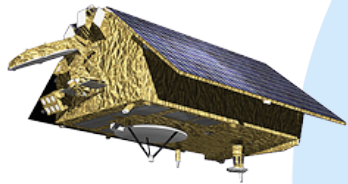
Eddies  
Ocean currents  
Storm dynamics  
Maritime safety  
Thermocline  
Weather forecasting

Essential Climate Variables  
Climate Model Assimilation  
Marine Spatial Planning  
Disaster response  
Insurance Risk  
ENSO

Pollutant transport  
Ice detection  
Oil pollution  
Internal waves  
Biological transport (blooms, genetics)

HAB formation  
Plume dynamics  
Aquaculture productivity  
Coral bleaching  
Human health  
Bio-toxins

# OCEAN COLOUR





# Thank you!

