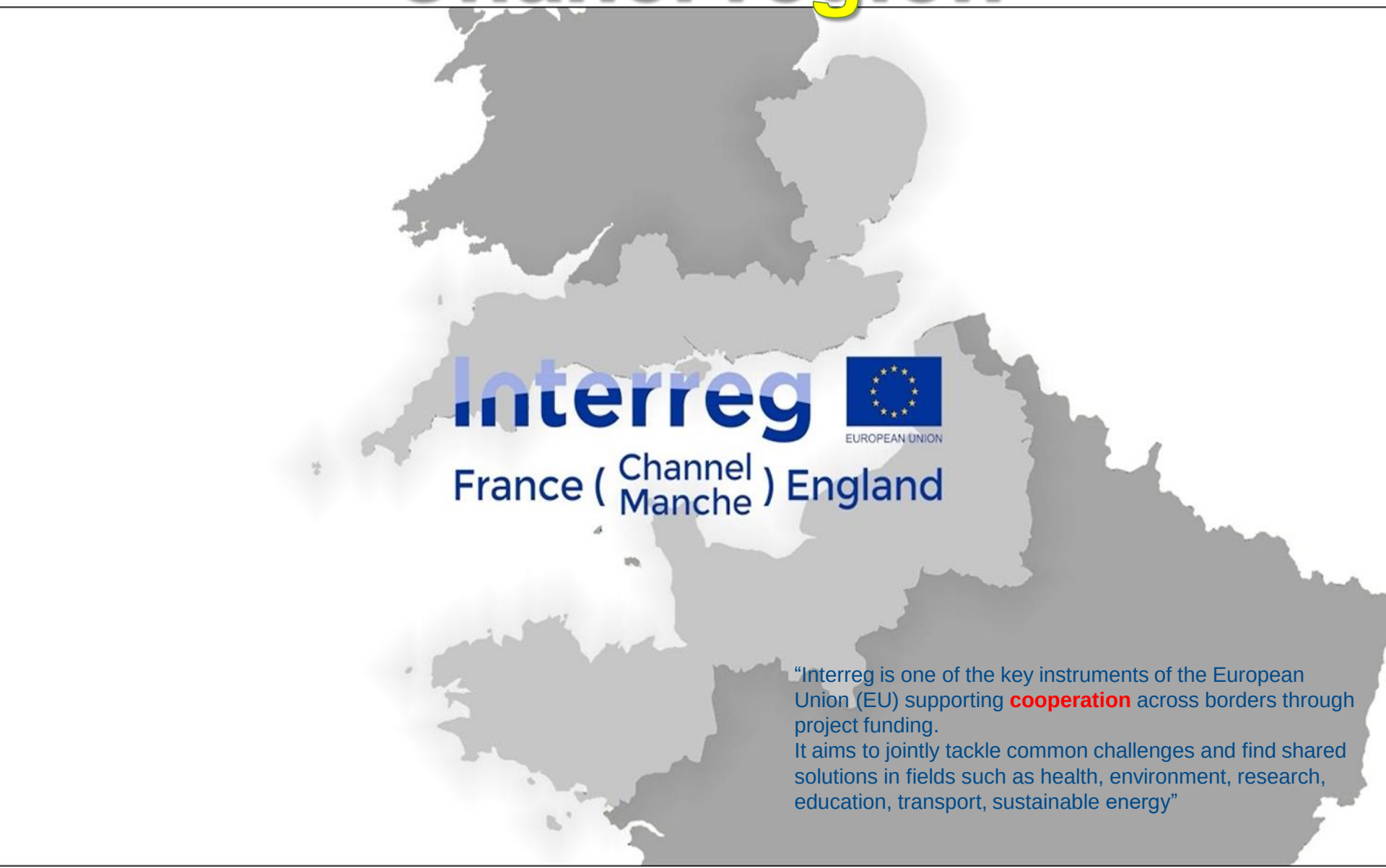
Sentinel-3 products for detecting EUtROphication and Harmful Algal Bloom (HAB) events in the French-English Channel (S-3 EUROHAB).

www.s3eurohab.eu

An Interreg Project for the Chanel region



"Interreg is one of the key instruments of the European Union (EU) supporting **cooperation** across borders through project funding.
It aims to jointly tackle common challenges and find shared solutions in fields such as health, environment, research, education, transport, sustainable energy"

Project Objectives

- ***To create a cross-border monitoring network and data portal for assessing Good Environmental Status of the common waters between the French-English Channel.***
- ***To produce a Web based alert system for the detection of water quality and harmful algal blooms using the latest European Space Agency / Copernicus satellite data.***
- ***To conduct a socio-economic analysis of the impact of Harmful Algal Blooms in the French-English Channel.***

Environment Agency

https://www.s3eurohab.eu/

A sexy project ?

- Satellites
- Toxic algae
  - Food poisoning
  - Neurotoxins
- Shellfish industry
  - Spin off Bathing Waters ?
- Alert service
- Saving Money ?£?

EA FW and Marine Incidents	FSA List	Eurohab list	*Extended List*	Combined List
Alexandrium tamarense	Alexandrium spp.		Alexandrium spp.	Alexandrium spp.
			Azadinium spinosum	Alexandrium tamarense
Dinophysis spp.	Dinophysiaceae	Dinophysis spp.	Dinophysis spp.	Azadinium spinosum
			Gonyaulax spinifera	Dinophysis spp.
Gymnodinium catenatum			Gymnodinium spp.	Gonyaulax spinifera
		Karenia mikimotoi		Gymnodinium spp.
		Lepidodinium chlorophorum		Gymnodinium catenatum
	Lingulodinium polyedrum		Lingulodinium polyedrum	Karenia mikimotoi
Pfiesteria spp.				Lepidodinium chlorophorum
		Phaeocystis globosa		Lingulodinium polyedrum
	Prorocentrum cordatum			Pfiesteria spp.
Prorocentrum lima	Prorocentrum lima		Prorcentrum spp.	Phaeocystis globosa
	Protoceratium reticulatum		Protoceratium reticulatum	Prorcentrum spp.
Pseudo-nitzschia spp.	Pseudo-nitzschia spp.	Pseudo-nitzschia spp.	Pseudo-nitzschia	Protoceratium reticulatum

PML | Plymouth Marine Laboratory

Plymouth Marine Laboratory

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Environment Agency

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NORMANDIE

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European Union

S-3 EUROHAB Work Packages.

WP 1: Management

WP 1: Communication, outreach, promotion

WP 3: Cross border monitoring network & data portal for assessing Good Ecological Status. Lead PML; Partners IFREMER-Brest, -PenB, -Boul, EA, UoS

WP 4: Web based alert system for the detection of water quality and harmful algal blooms. Lead IFREMER-Brest; Partners PML, -PenB, EA, UoS, CRPM, D&S IFCA

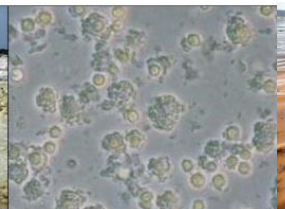
WP 5: Socio-economic analysis of impact of Harmful Algal Blooms in the FCE. Lead PML; Partners UBO, EA, CRPM, D&S IFCA

S-3 EUROHAB Stakeholders:

- Marine managers:
  - FSA, DEFRA, CEFAS, AEAP, AESN, AELB, Marine Scotland, SPHA, ABP, AFBI…
- Fishery and Shellfishery end users:
  - Southern-IFCA, CRCBN, OS-UK…
- Marine policy makers eg: DG-ENV, DG-MARE, OSPAR, ICES, OSPAR ICG COBAM Pelagic Habitats Expert Group…
- Wildlife conservation groups: DWT, CWT.

Harmful Algal blooms (HABs)

- "Societal" term
  - What harms us or things we value
    - Shellfish bed closures, recalls
    - Nuisance scum on beaches
  - Potential cost to industry & health
    - £18K - £87M wider industry
    - £300,000 hospital costs

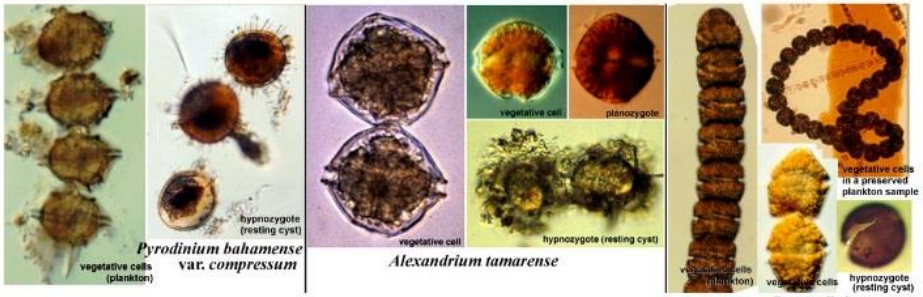


A Rogues Gallery

Toxic Microalgae

WESTPAC/IOC/UNESCO
Ver. 2.2 2000.1.1
ed. by Yasuwo Fukuyo (ufukuyo@mail.ecc.u-tokyo.ac.jp)

Species Responsible for Paralytic Shellfish Poisoning



Pyrodinium bahamense var. *compressum*

Alexandrium tamarense

Gymnodinium catenatum

Species Responsible for Diarrhetic Shellfish Poisoning

Dinophysis fortii *Dinophysis acuminata* *Dinophysis mitra*

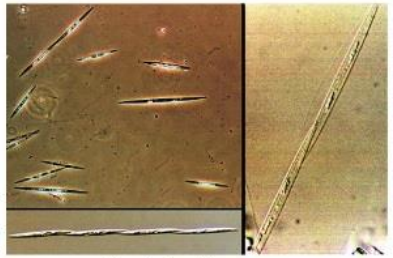
Dinophysis caudata

Dinophysis miles

Species Responsible for Neurotoxic Shellfish Poisoning

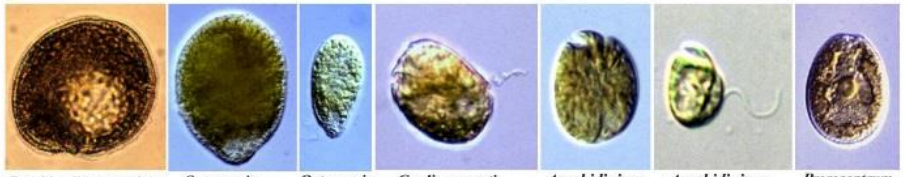
Gymnodinium breve

Species Responsible for Amnesic Shellfish Poisoning



Pseudonitzschia spp.

Species Responsible for and implicated in Ciguatera Fish Poisoning



Gambierdiscus toxicus *Ostreopsis lenticularis* *Ostreopsis ovata* *Coolia monotis* *Amphidinium klebsii* *Amphidinium carterae* *Prorocentrum lima*

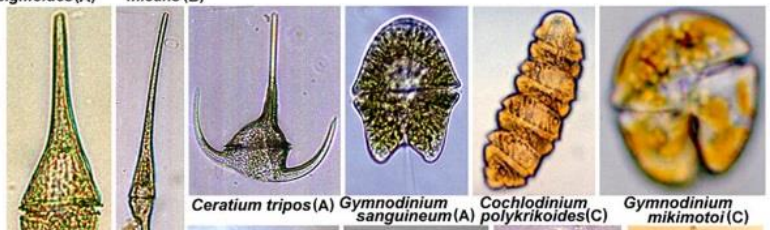
Red Tide Microalgae

WESTPAC/IOC/UNESCO
Ver. 1.4 2000.1.1
ed. by Yasuwo Fukuyo (ufukuyo@mail.ecc.u-tokyo.ac.jp)

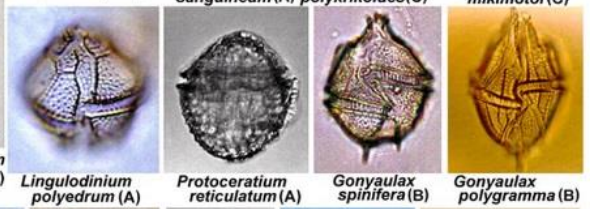
A: Useful, mostly harmless B: Potentially harmful by oxygen depletion C: Harmful, responsible for fish mass mortality

Trichodesmium thiebautii (B) *Skeletonema costatum* (B) *Chaetoceros sociale* (A) *Thalassiossira mala* (B) *Eucampia zodiacus* (A)

Prorocentrum sigmoides (A) *Prorocentrum micans* (B) *Dinophysis caudata* (B) *Noctiluca scintillans* (B)



Ceratium furca (A) *Ceratium fusus* (A) *Ceratium tripos* (A) *Gymnodinium sanguineum* (A) *Cochlodinium polykrikoides* (C) *Gymnodinium mikimotoi* (C)



Lingulodinium polyedrum (A) *Protoceratium reticulatum* (A) *Gonyaulax spinifera* (B) *Gonyaulax polygramma* (B)

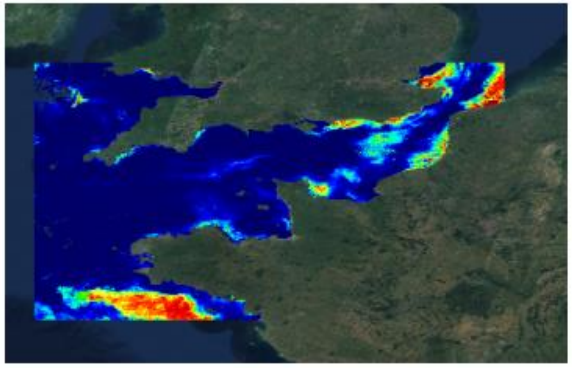
Alexandrium affine (A) *Peridinium quinquecorne* (A) *Heterocapsa triquetra* (A) *Heterosigma akashiwo* (B) *Scrippsiella trochoidea* (A) *Heterocapsa circularisquama* (C) *Fibrocapsa japonica* (C) *Chattonella antiqua* (C)

Table 1 Toxin syndromes and symptoms within UK waters

	Toxin	Causal species	Symptoms
PSP	Saxitoxin and gonyautoxin	*Alexandrium spp.* *Gymnodinium spp.* *Pyrodinium spp.*	Tingling and numbness Drowsiness Incoherence **In high doses** - respiratory arrest or cardiovascular shock or death
DSP	Okadaic acid and Dinophysis toxin (1,2 and3)	*Dinophysis spp.* *Prorcentrum spp.*	Nausea Vomiting
ASP	Domonic acid	*Pseudo-nitzschia*	Nausea Vomiting Diarrhoea Abdominal cramps Loss of short term memory

Paralytic Shellfish poisoning

Amnesic Shellfish poisoning



Web Alert System

S-3 EUROHAB has produced a web based alert system for a selection of the most important Harmful Algal Bloom Species. Currently the system provides data covering:

- Karenia - responsible for reducing oxygen in the water column
- Phaeocystis - responsible for producing foam
- Pseudo-nitzschia - responsible for Amnesic Shellfish Poisoning

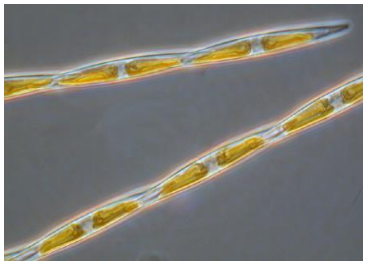
Images in the portal are provided in near real time so data up to a few days ago should be available.

For more information on the Web Alert System please see the documentation here

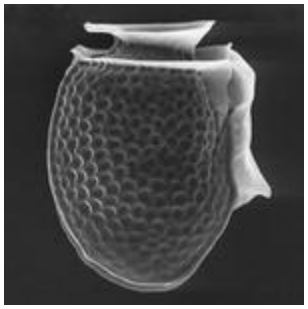
WP3. Env driving factors that lead to HABs in WCE.

Activity 3.2. Assessment of environmental drivers of HABs and WQ. **Lead - UoS.**

Five Target Species:



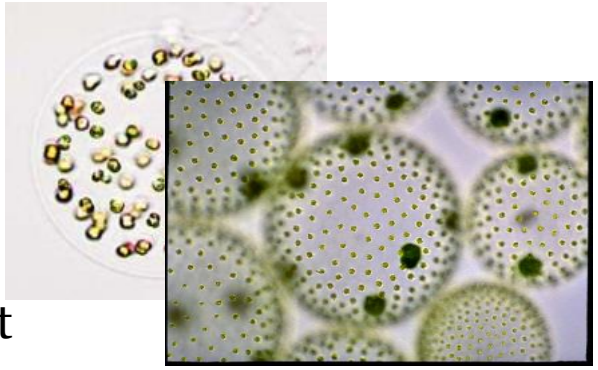
Pseudo-nitzschia sp. release domoic acid that can causes Amnesic Shellfish Poisoning.

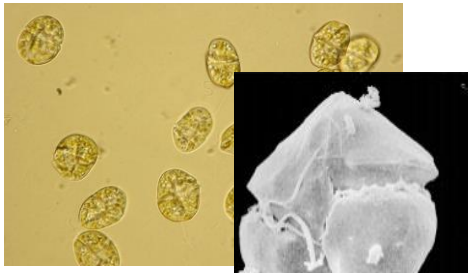


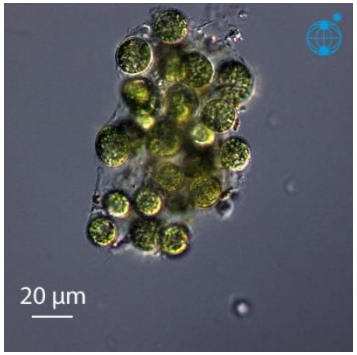
Dinophysis spp., produce toxins that result in diarrheic shellfish poisoning causing severe human gastrointestinal problems.

Karenia mikimotoi and *Lepidodinium chlorophorum* can lead to oxygen deficiency in the water column causing fish and shellfish mortality.

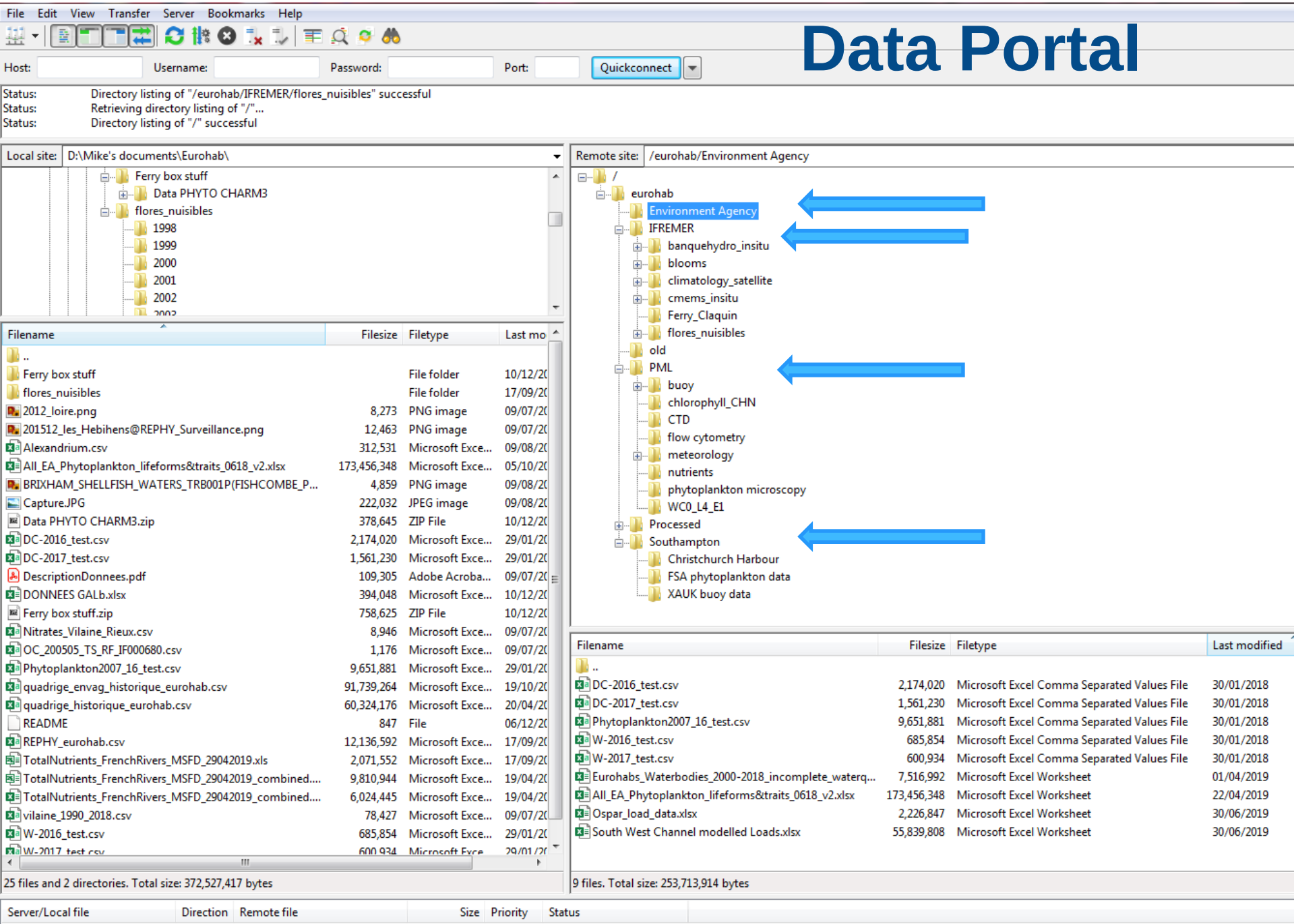
Phaeocystis globosa produces foam that can clogg the gills of fish and shellfish, lead to anoxic conditions and has a negative impact on tourist beaches.







Data Portal


File Edit View Transfer Server Bookmarks Help
Host: Username: Password: Port: Quickconnect
Status: Directory listing of "/eurohab/IFREMER/flores_nuisibles" successful
Status: Retrieving directory listing of "/"...
Status: Directory listing of "/" successful
Local site: D:\Mike's documents\Eurohab\
Ferry box stuff
Data PHYTO CHARM3
flores_nuisibles
1998
1999
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2002
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2012_loire.png 8,273 PNG image 09/07/2(
201512_Ies_Hebihens@REPHY_Surveillance.png 12,463 PNG image 09/07/2(
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DC-2017_test.csv 1,561,230 Microsoft Exce... 29/01/2(
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vilaine_1990_2018.csv 78,427 Microsoft Exce... 09/07/2(
W-2016_test.csv 685,854 Microsoft Exce... 29/01/2(
W-2017_test.csv 600,934 Microsoft Exce... 29/01/2(
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Remote site: /eurohab/Environment Agency
/
eurohab
Environment Agency
IFREMER
banquehydro_insitu
blooms
climatology_satellite
cmems_insitu
Ferry_Claquin
flores_nuisibles
old
PML
buoy
chlorophyll_CHN
CTD
flow cytometry
meteorology
nutrients
phytoplankton microscopy
WC0_L4_E1
Processed
Southampton
Christchurch Harbour
FSA phytoplankton data
XAUK buoy data
Filename Filesize Filetype Last modified
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Ospar_load_data.xlsx 2,226,847 Microsoft Excel Worksheet 30/06/2019
South West Channel modelled Loads.xlsx 55,839,808 Microsoft Excel Worksheet 30/06/2019
9 files. Total size: 253,713,914 bytes
Server/Local file Direction Remote file Size Priority Status

in situ data

REPHY sampling stations

All phytoplankton species
on 55 stations

Only dominant and harmful species
on 93 other stations

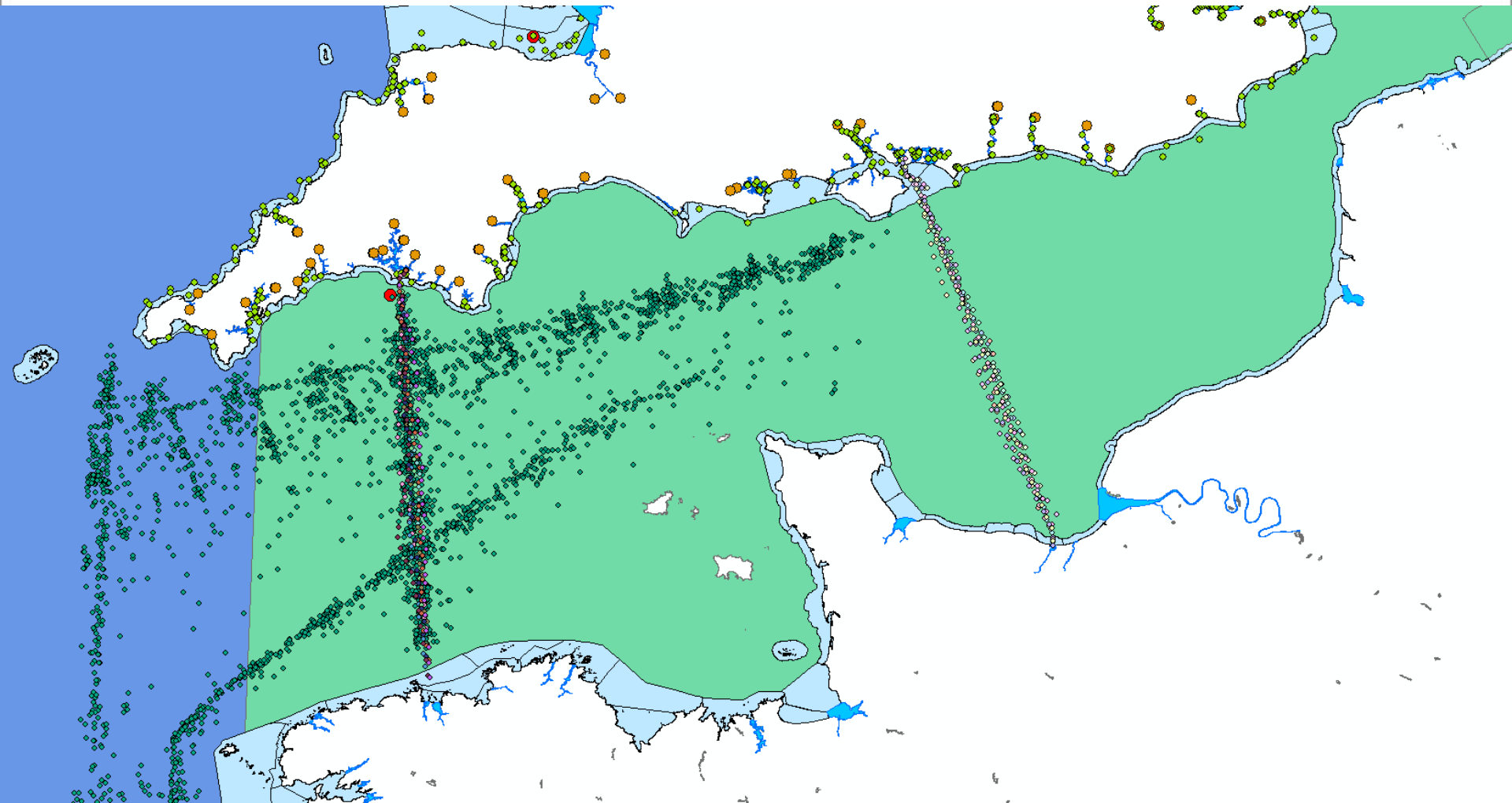
Time series

25 years
on ~ 20 stations

10-20 years
on numerous stations

Environ
Agency

Ferry box and continuous plankton recorder (CPR) data



Some results:

Environmental Driving factors

	Factor							
Taxa	Hydrography (water column structure)	Salinity	Water temperature	Rainfall	Wind speed and direction	Surface irradiance	Nutrients	Biological interactions
Dinophysis spp	✓✓✓				✓✓			✓
Phaeocystis globosa						✓✓✓	✓✓✓	✓
Pseudo-nitzschia spp	✓	✓✓	✓	✓		✓✓✓	✓	
Karenia mikimotoi	✓✓✓	✓	✓✓	✓		✓✓	✓✓	
Lepidodinium chlorophorum	✓	✓		✓				

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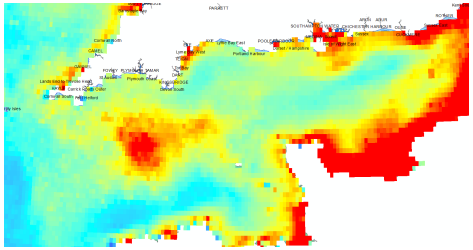
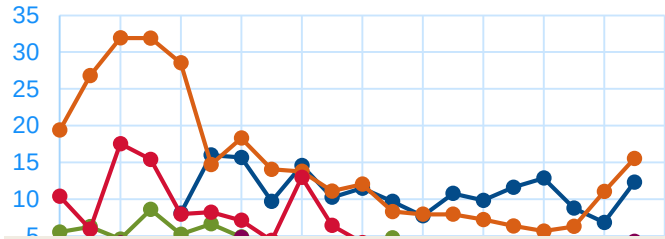
Some results:
GES & Food Web Worries inshore

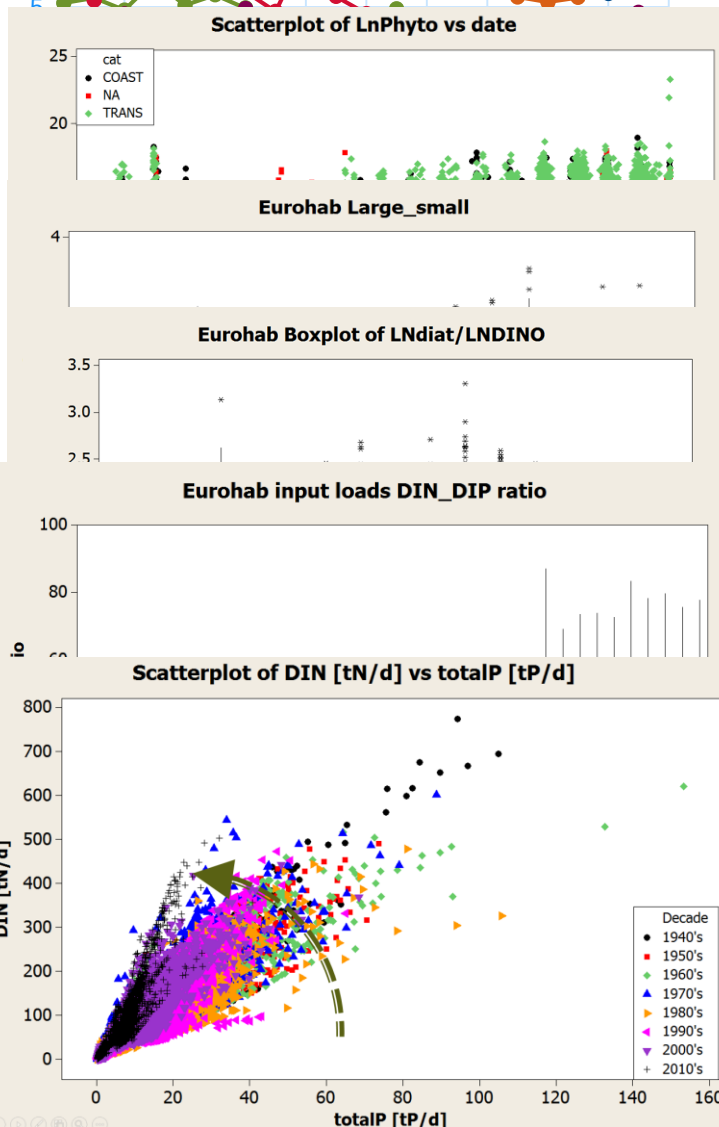
- General improvement in Chl
- But …
- Increase in cell numbers
- Increase in proportion of small cells
- Increase in proportion of dinoflagellates
- This …
- Correlates with change in Nutrient ratio
- Signal weakens as you go offshore



- Offshore different…
  - Chl & PP decreasing
  - Life form climate change signals
    - Not strong in Eurohab area

Annual Average Chlorophyll





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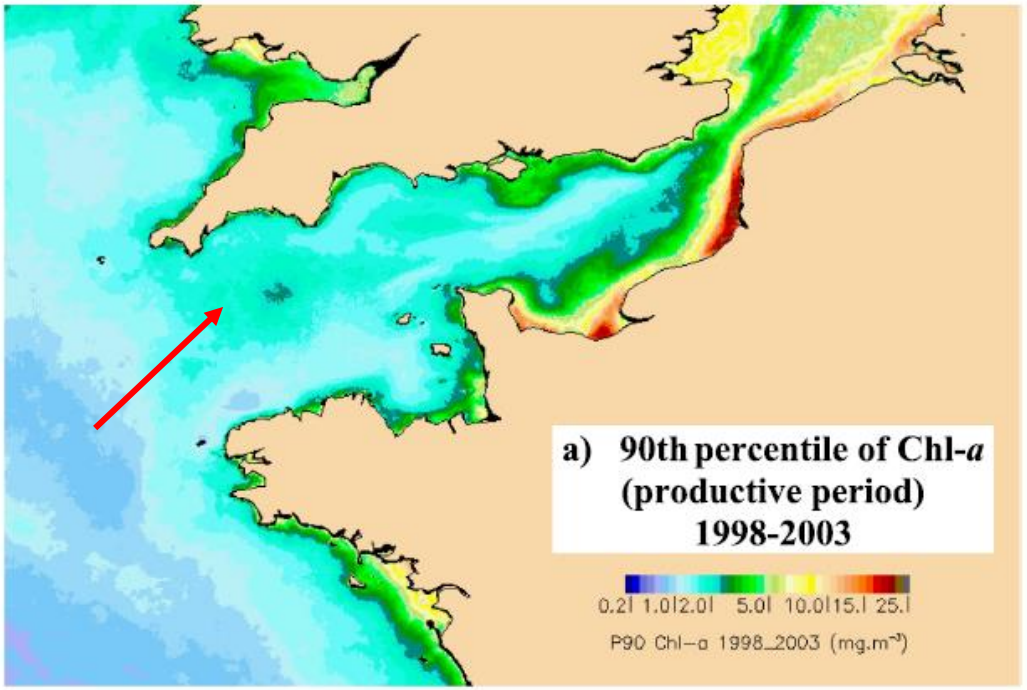
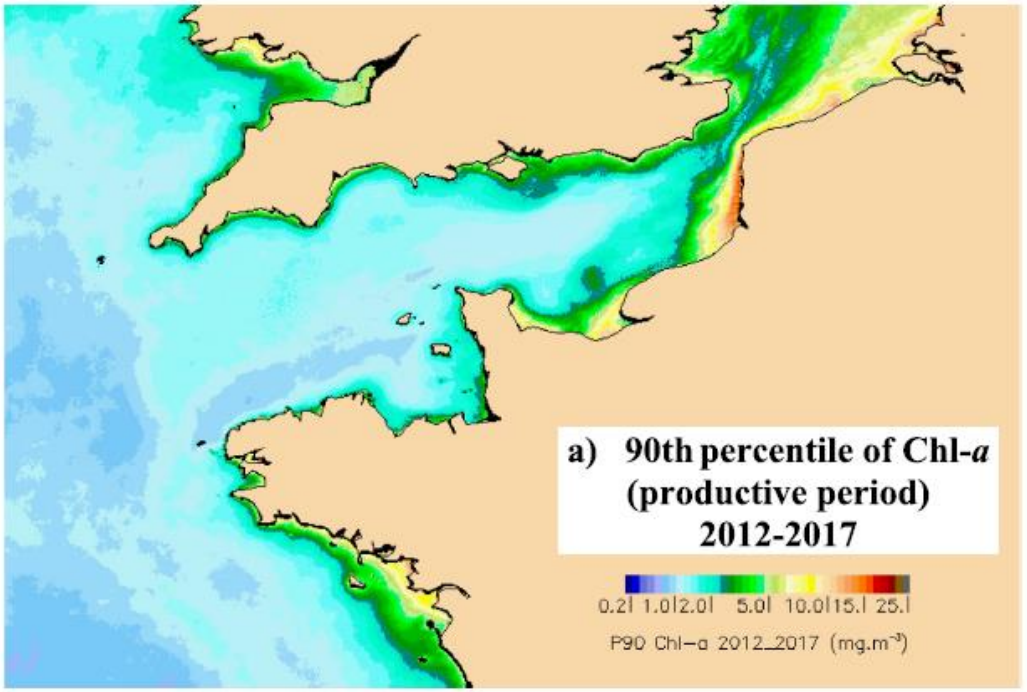
Effect basically in area of Fresh Water influence

Chlorophyll Changes over 20 years





Gohin *et al.* (2019).Twenty years of satellite and *in situ* observations of surface chlorophyll-*a* from the northern Bay of Biscay to the eastern English Channel. Is the water quality improving? Rem Sen Env. 233

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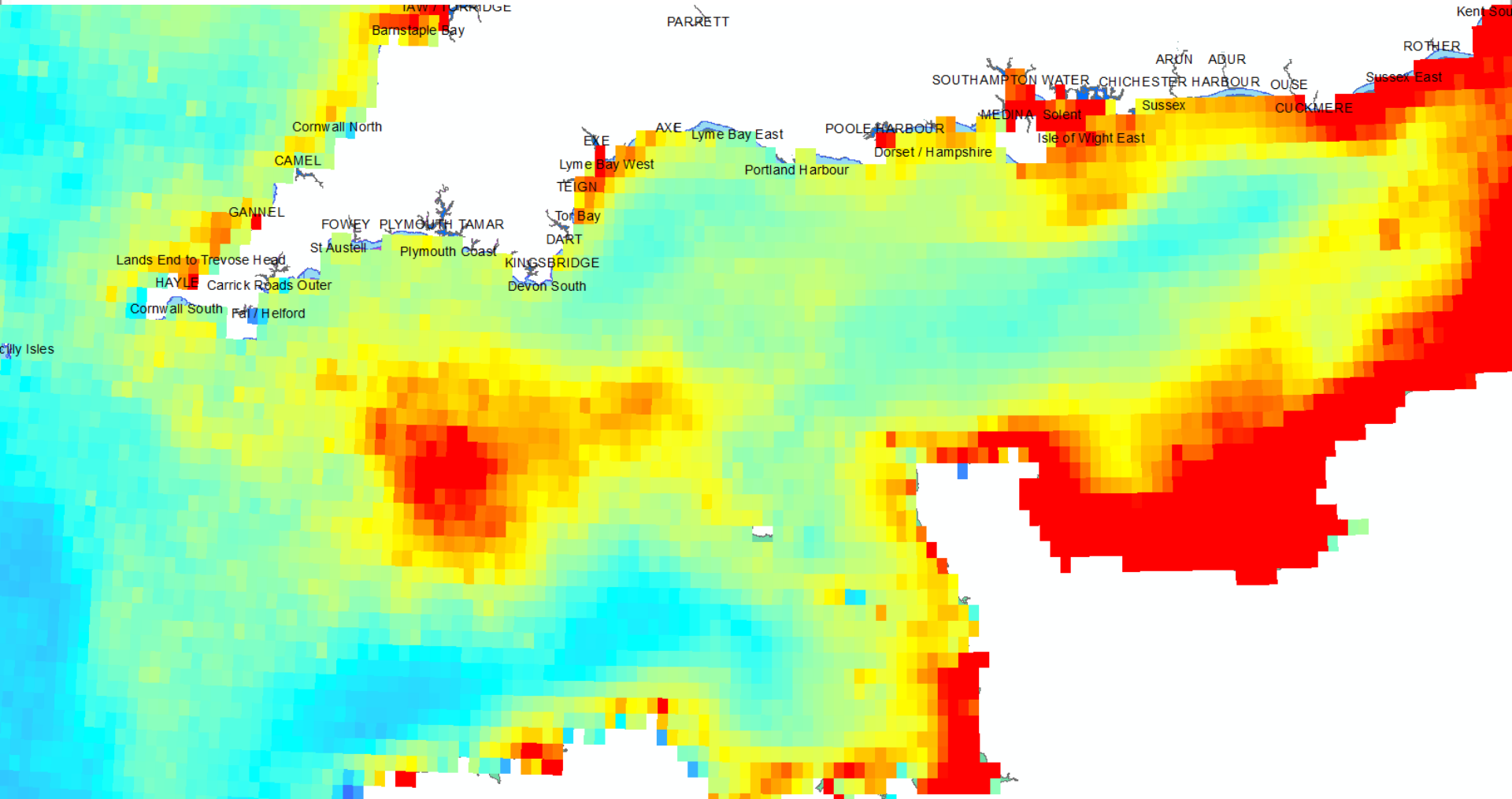
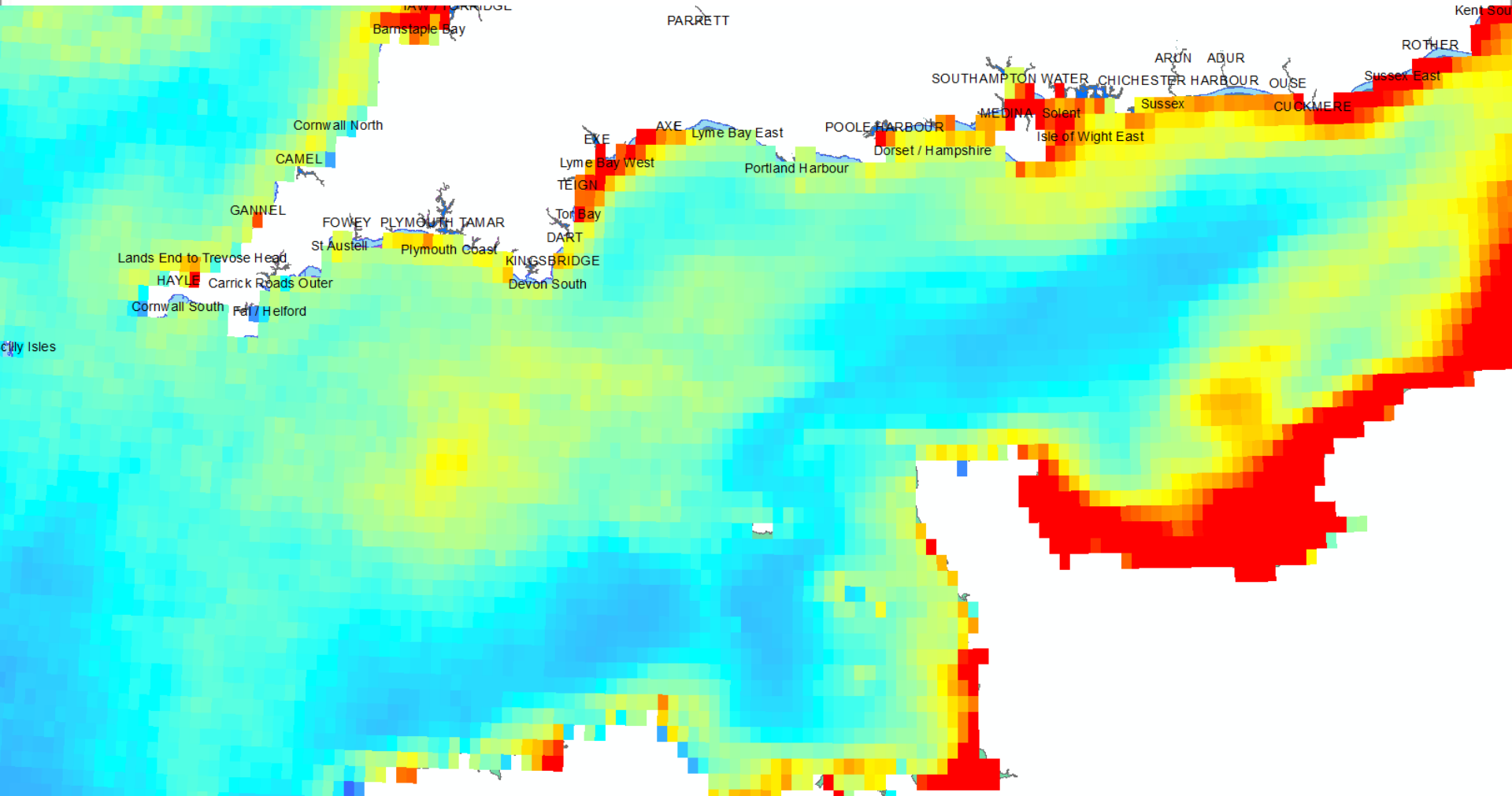
90%ile Primary Prod :1997-2005



90%ile Primary Prod: 2006-2016

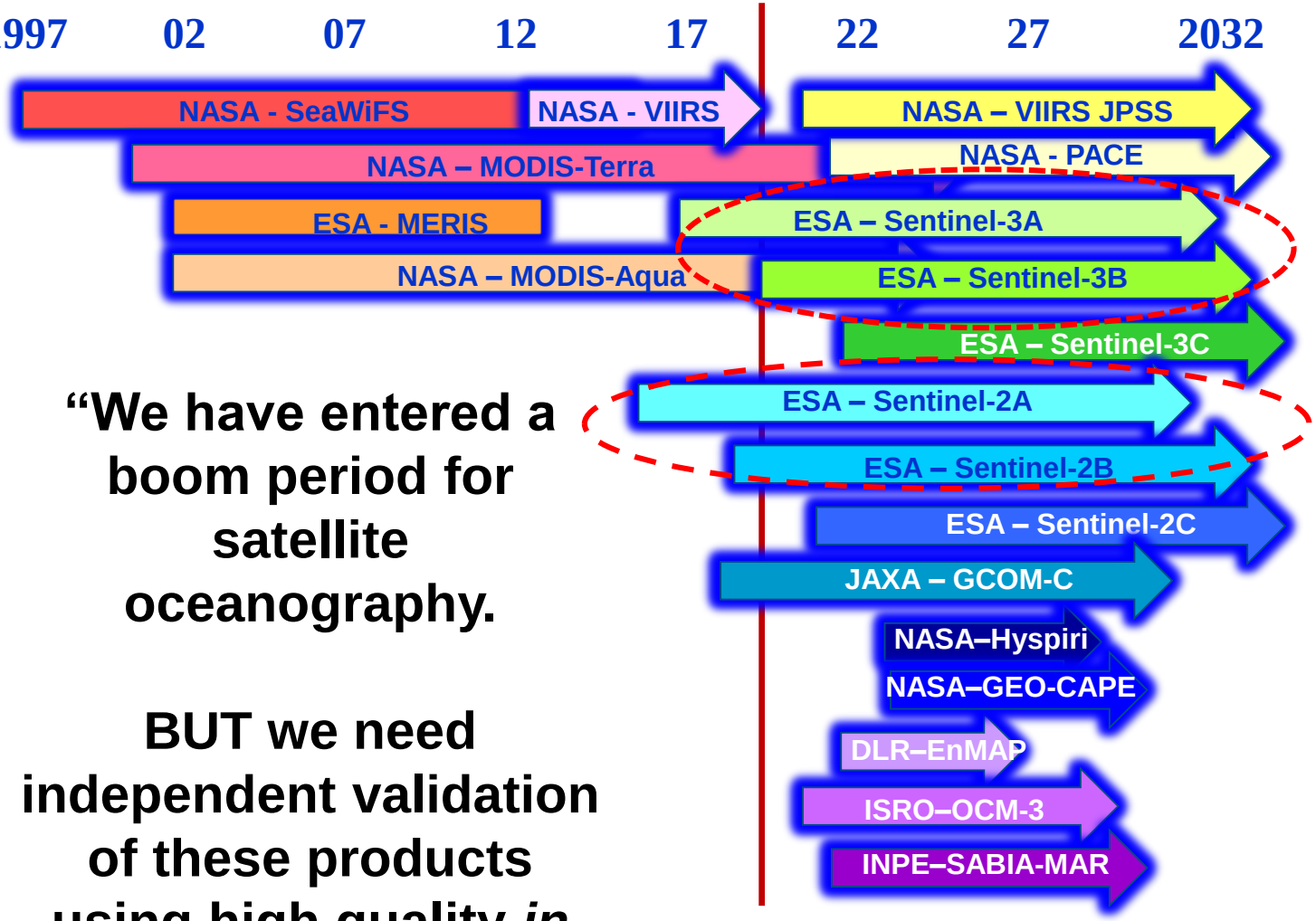


Context set …

Bloomin’ Marvellous

Ocean Colour validation.

Global Ocean Colour satellite constellation: 1997 - current.



"We have entered a boom period for satellite oceanography.

BUT we need independent validation of these products using high quality *in situ* data."

Since 2015 and over the next 5 years, 16 more ocean colour satellites will be launched.

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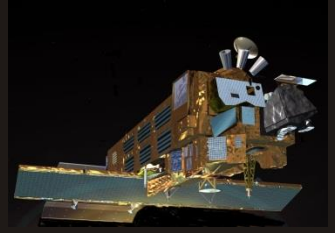
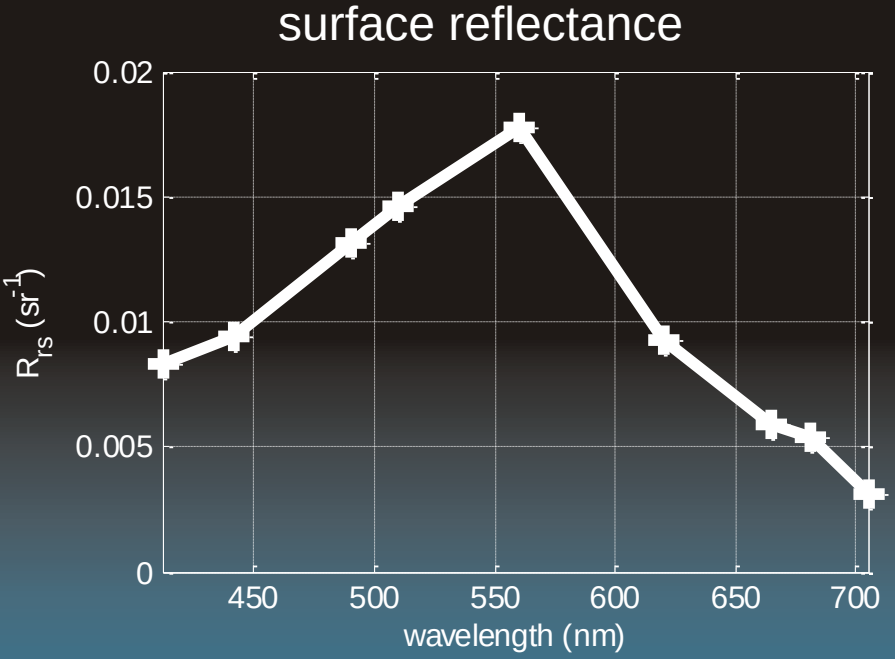




Aerosols
Aerosols
Rayleigh scattering

Foam
Freshwater

Algae
Minerals
Organic material
Dissolved matter

- Chla, a_{ph}
- TSM, a_{NAP}
- a_{CDOM}

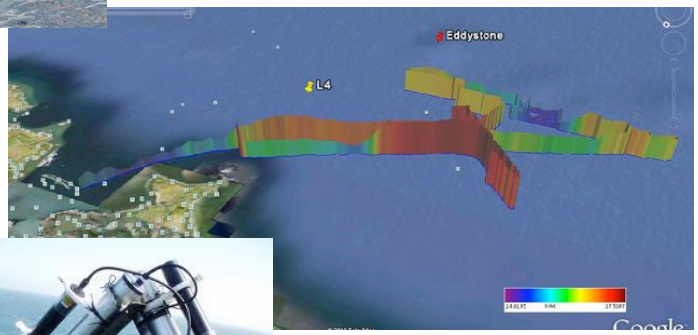
CHALLENGE. Evaluate the most accurate atmospheric correction processor for Sentinel-3A Ocean Colour products in the Fr-En Channel.

$R_{rs}(\lambda)$ - Western English Channel Observatory.

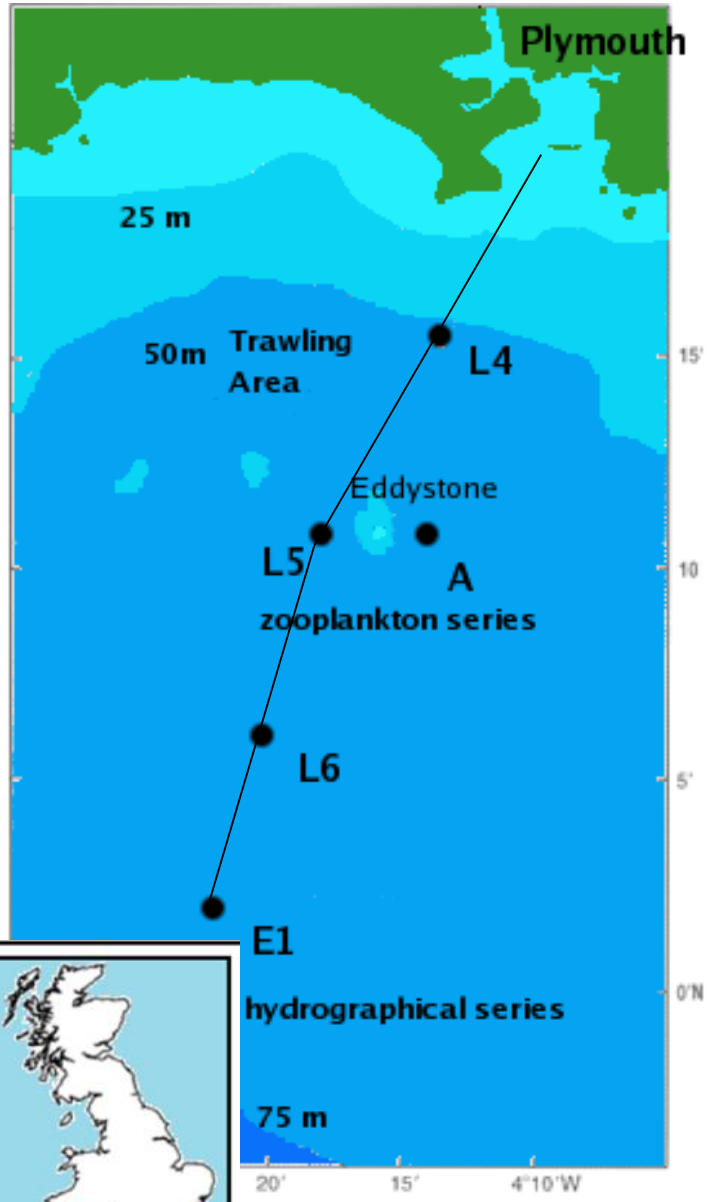
English Channel transect & stations: Case 1 (May-Oct); Case 2 (Nov-April).

Three **SATLANTIC HyperSAS spectro-radiometers** mounted on bow of **R/V Quest**.

Stepper motor platform to compensate for solar azimuth and vessel heading. 3.3 nm spectral resolution and a field-of-view of 7° at 15-s intervals.



Along-track SATLANTIC HyperSAS system



Spectra measured from April-Dec 2016.

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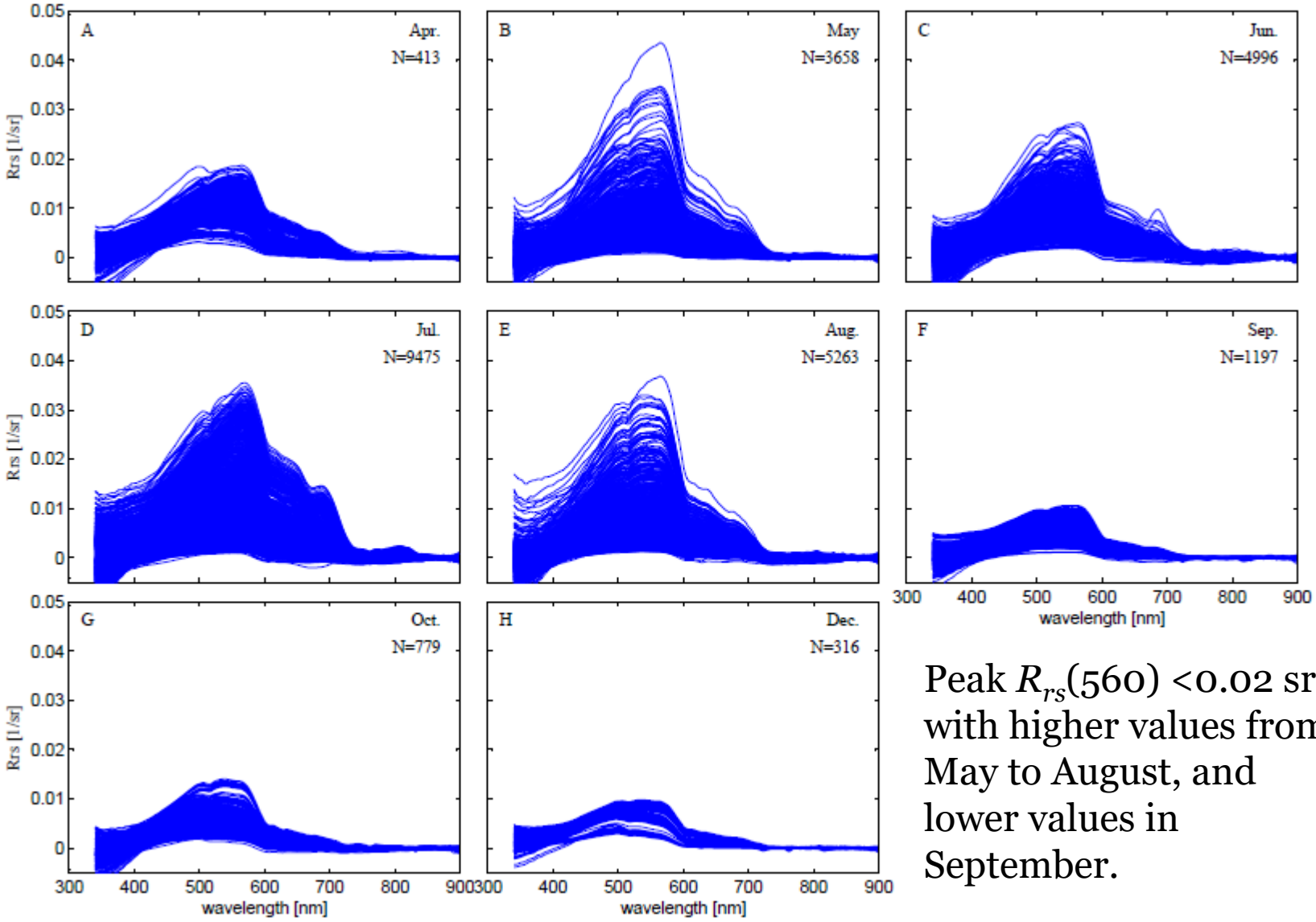
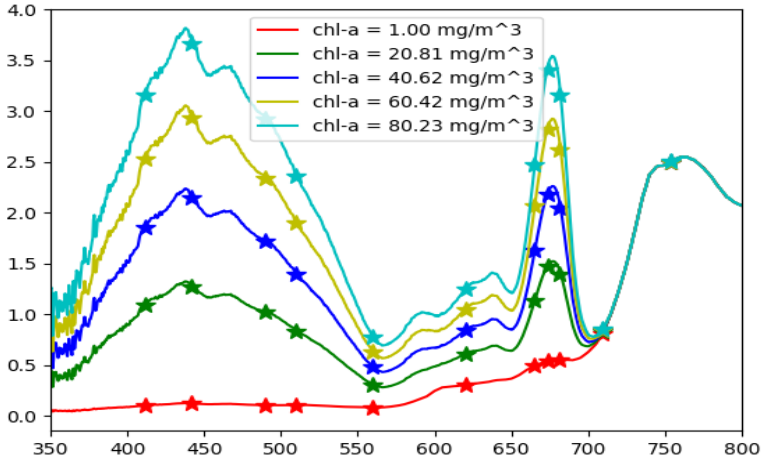
$R_{rs}(\lambda)$ measurements in the English Channel.

26000 spectra in the Western English Channel from April-Dec 2016.

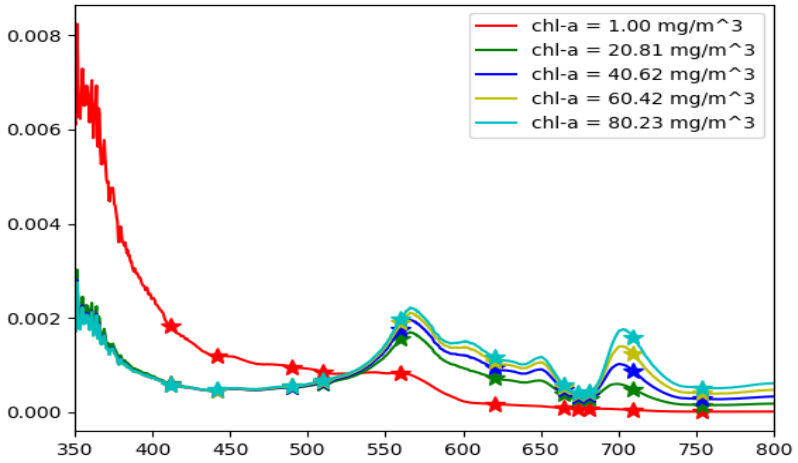


Peak $R_{rs}(560)$ <0.02 sr^{-1} with higher values from May to August, and lower values in September.

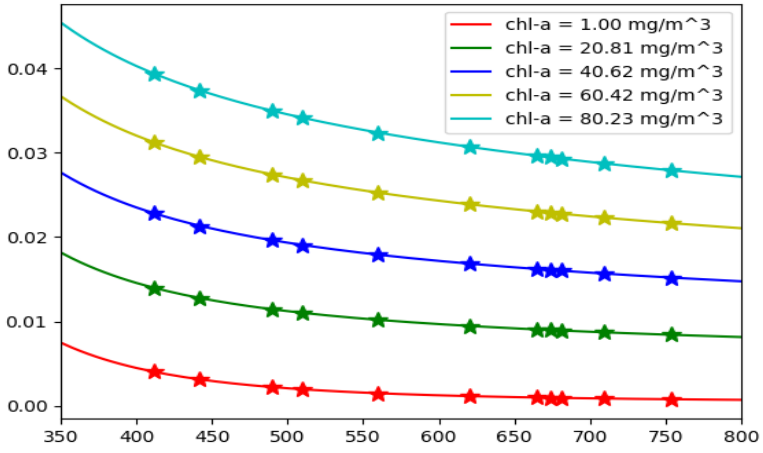
Lab experiment



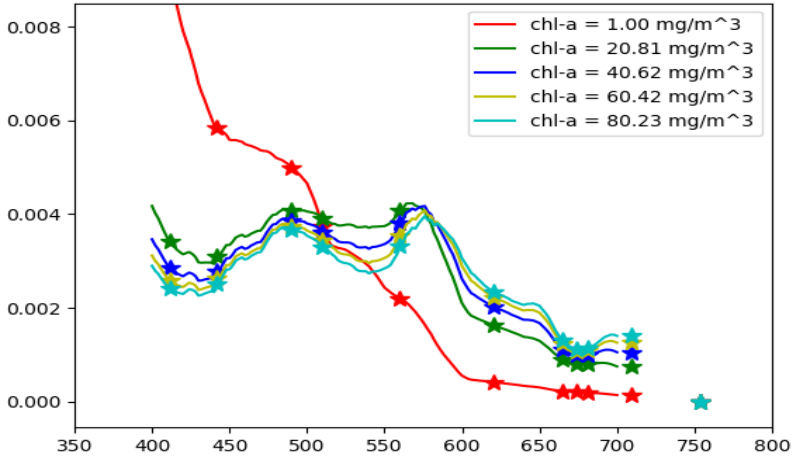
Karenia absorption



Karenia bloom Rrs



Karenia backscatter



Non-harmful bloom Rrs

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Then create your algorithms

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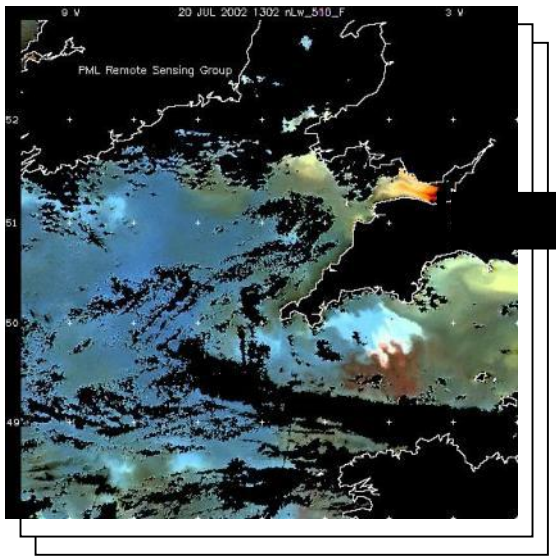
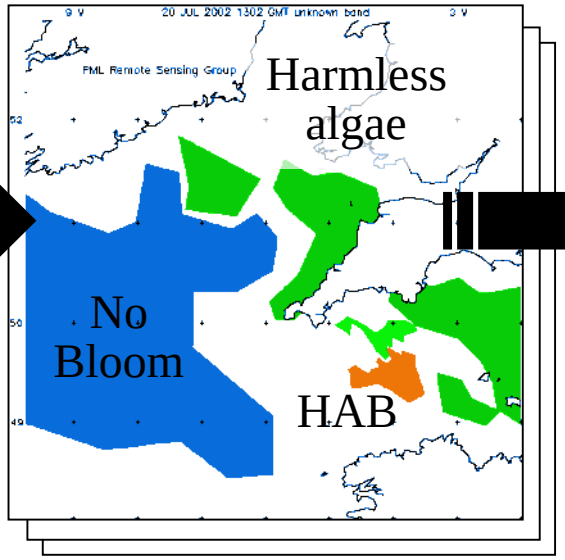
Multivariate HAB discrimination method

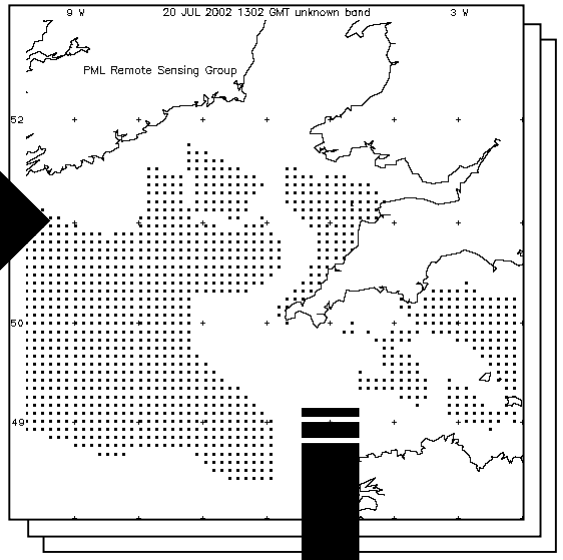
Ocean colour scenes

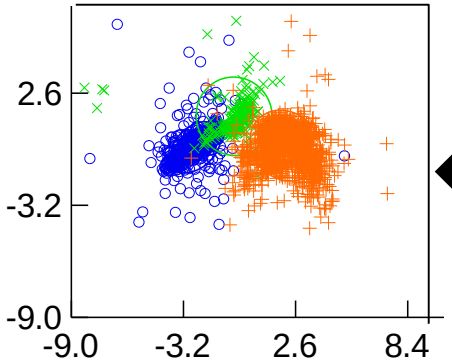
Manual training

Training samples









Classifier

R Stats

Multivariate analysis

Lwn(λ)
a(λ)
bb(λ)

Ocean properties

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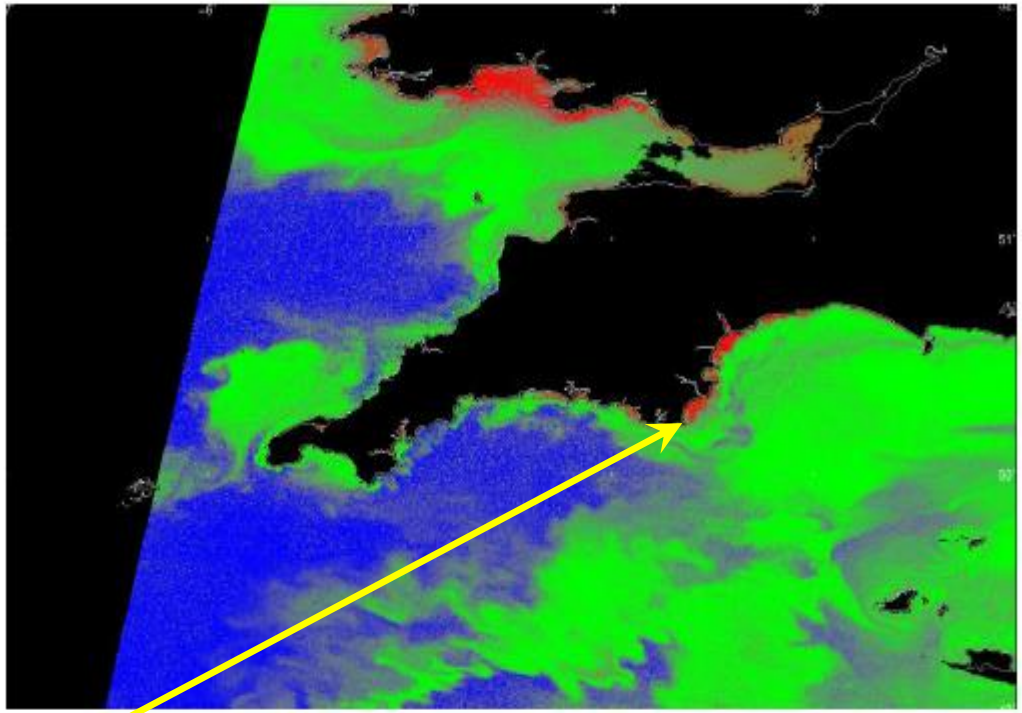
HABS chasing

Pseudo-nitzschia HAB map

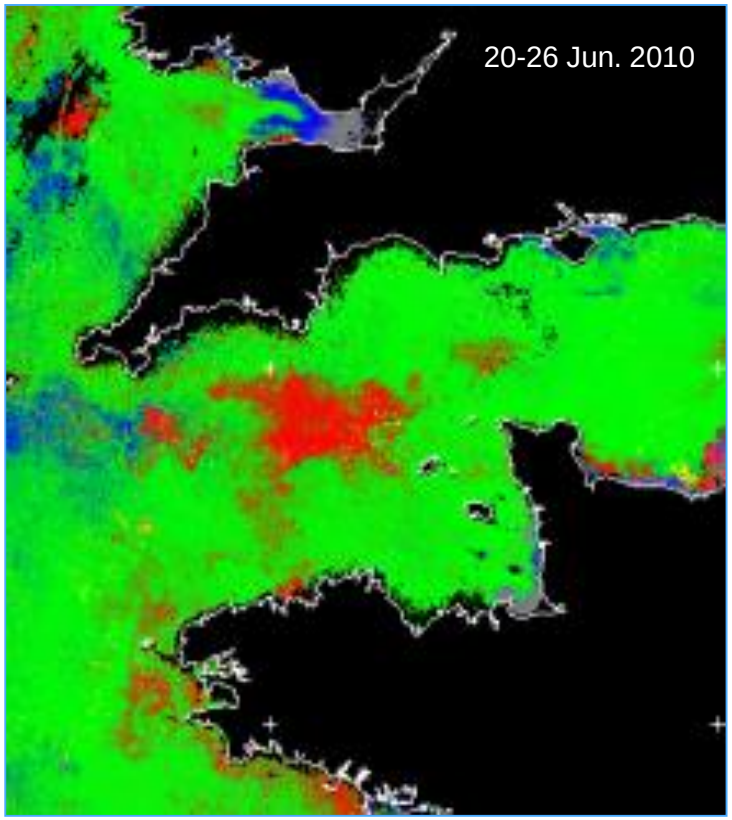


- HAB risk
- harmless
- no bloom
- not classified

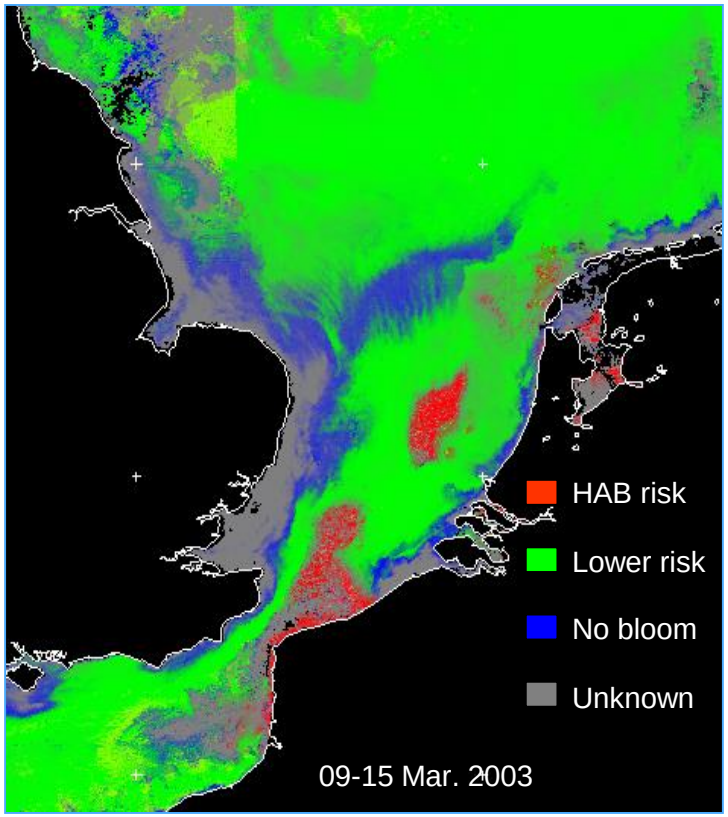
Also Dinophysis and Azadinium

Environment Agency

Harmful Algal Bloom risk maps



Weekly HAB risk maps of *Karenia mikimotoi* algal bloom in the Western English Channel in summer 2010



Phaeocystis globosa bloom in the Southern North Sea in spring 2003

- HAB risk - harmless - no bloom - not classified

Environment

Kurekin, A.A., Miller, P.I. & Woerd, H.J.V.D. (2014) Satellite discrimination of *Karenia mikimotoi* and *Phaeocystis* harmful algal blooms in European coastal waters: merged classification of ocean colour data. *Harmful Algae*.

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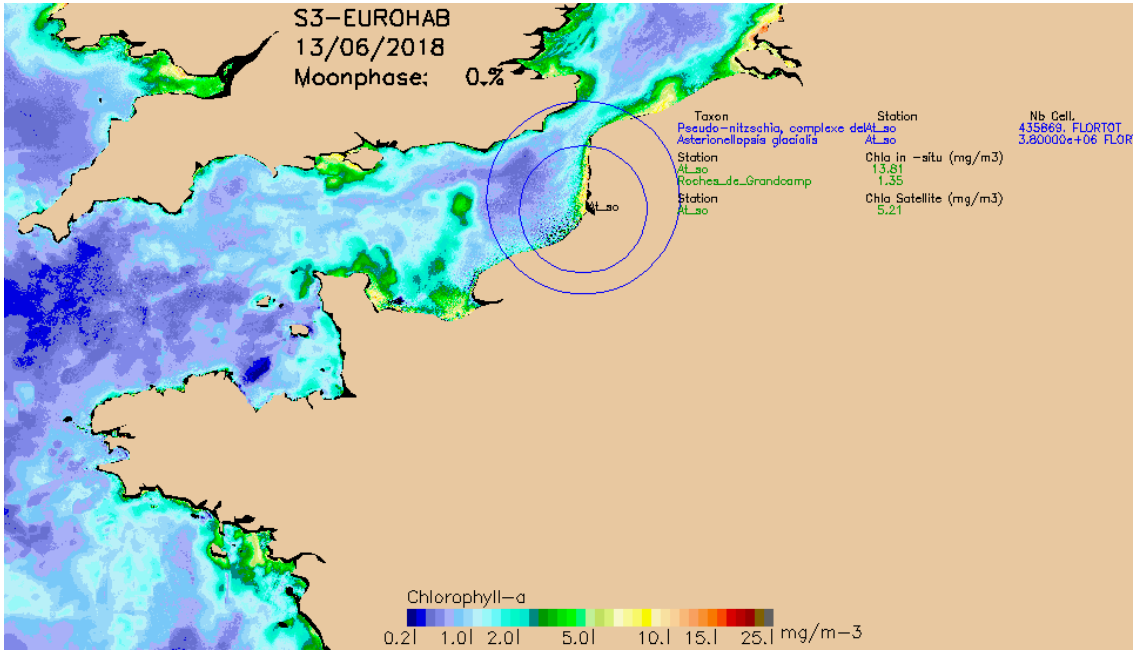
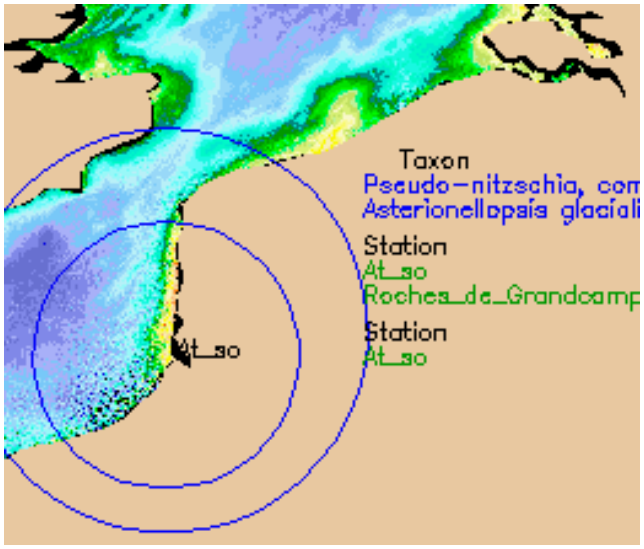
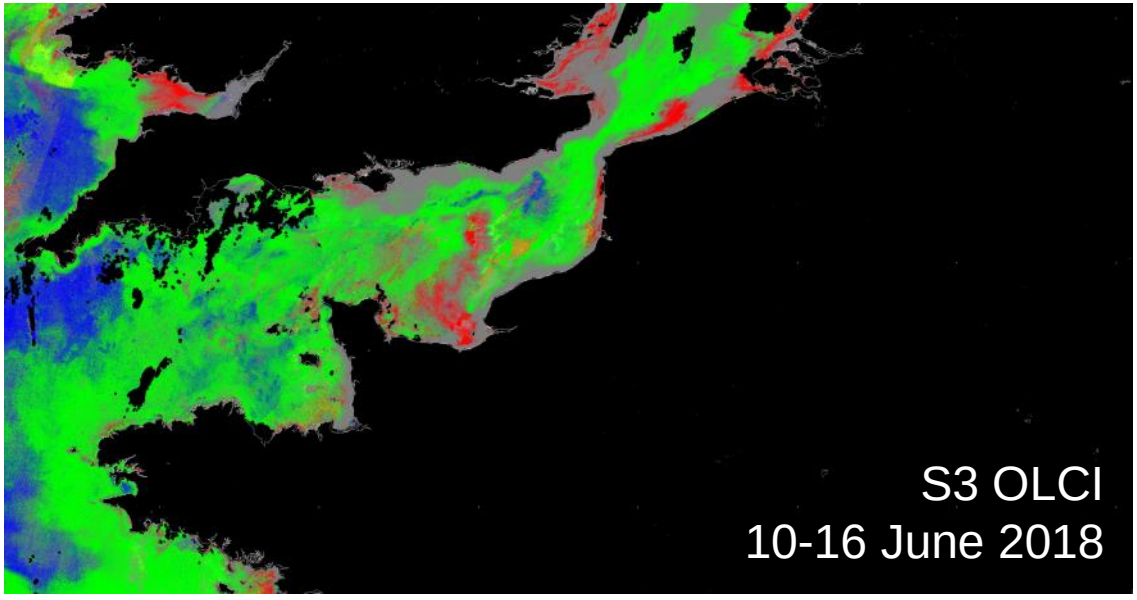
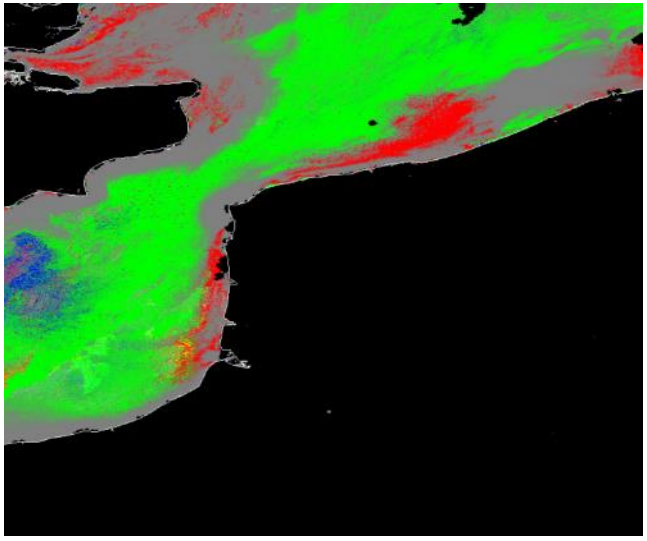
Pseudo-nizschia EO vs. IFREMER in-situ data









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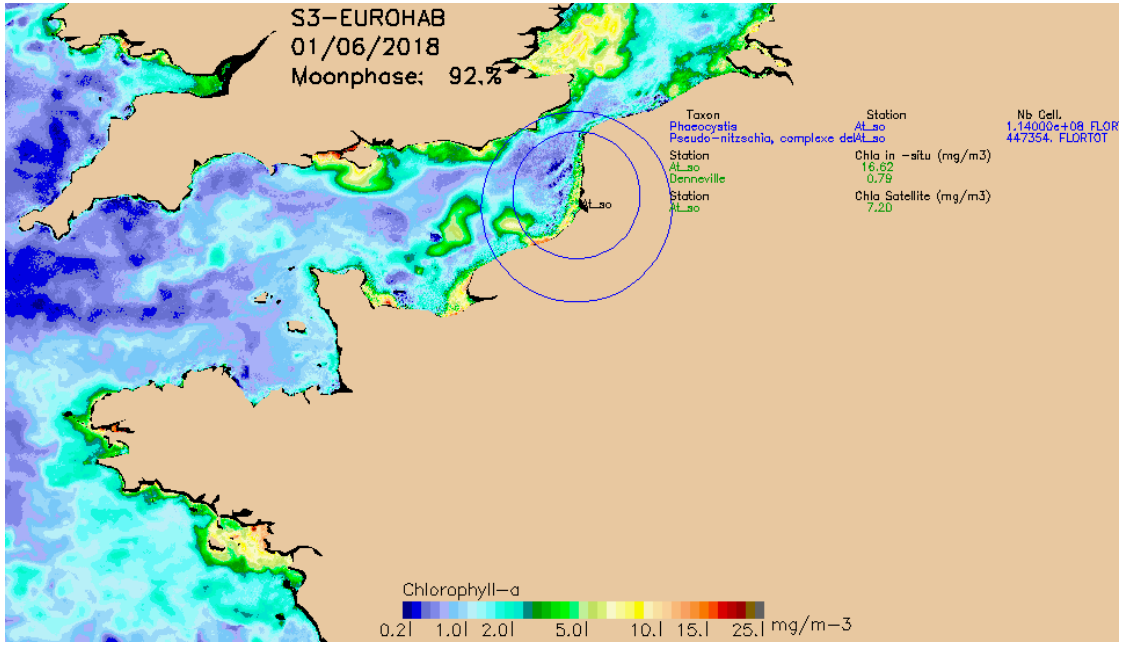
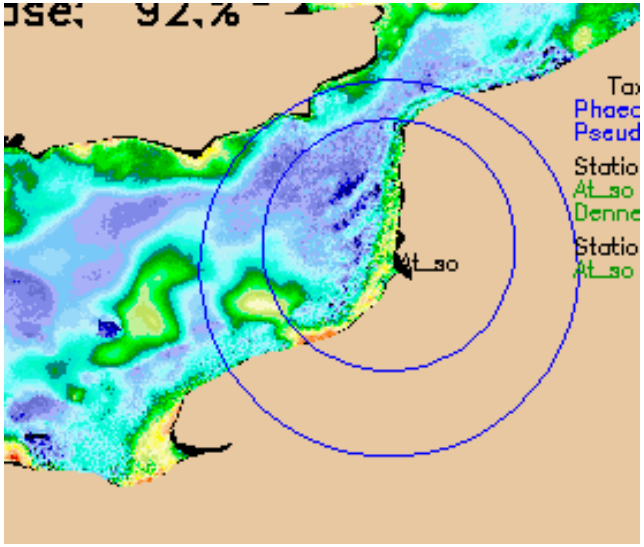
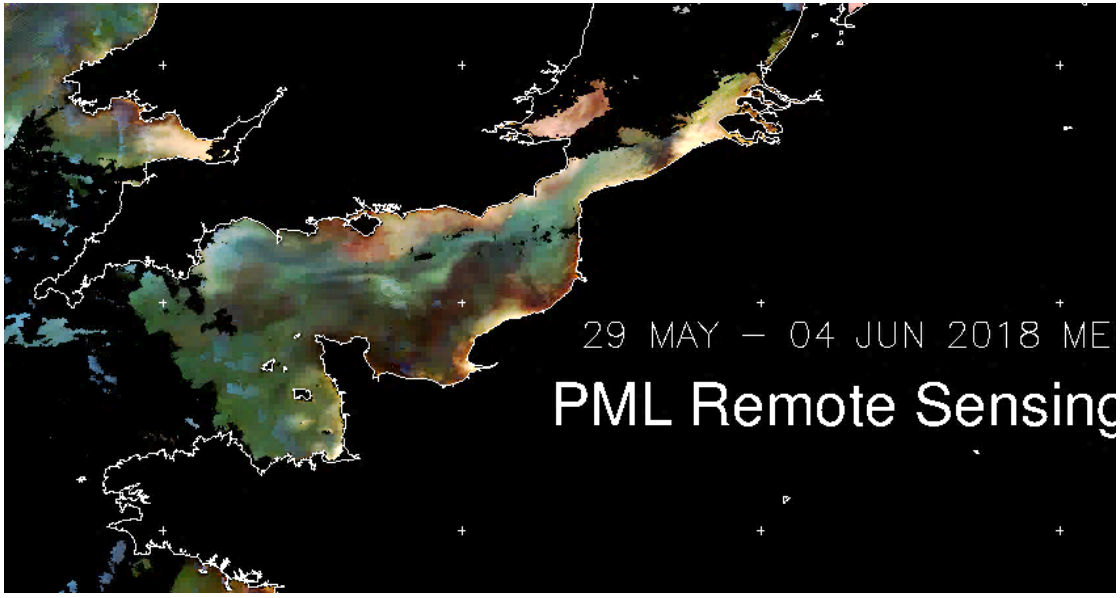
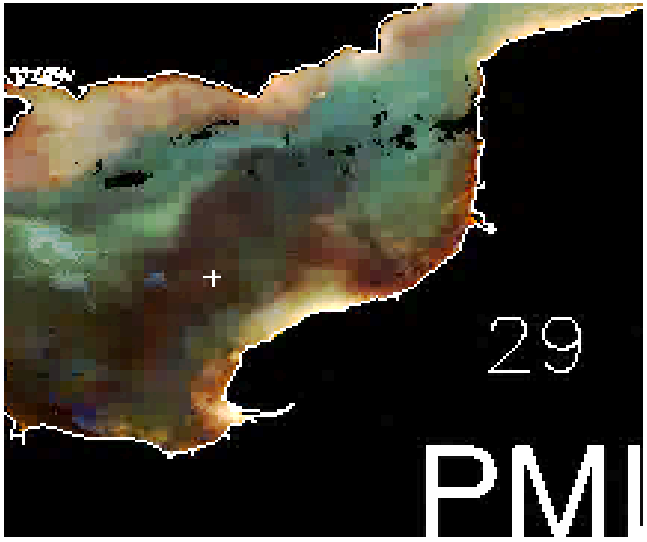
Phaeocystis EO vs. IFREMER in-situ data









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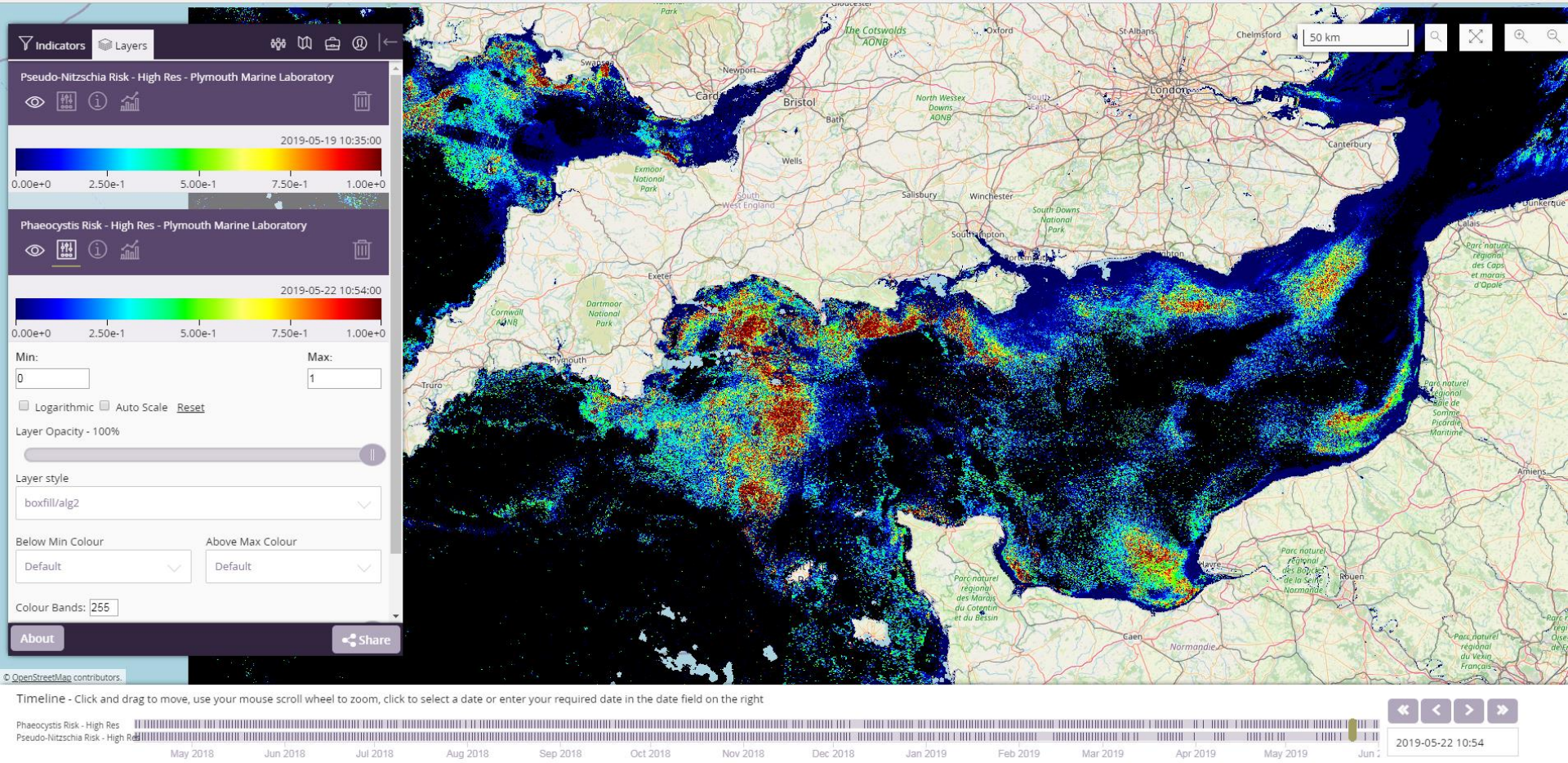
Web Portal - https://www.s3eurohab.eu/portal/

- Timeline
- Risk
- Taxa



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Summer 2020: Things were blooming

- *Karenia mikimotoi*
- Coccolithophores

Sentinel 2 preview image

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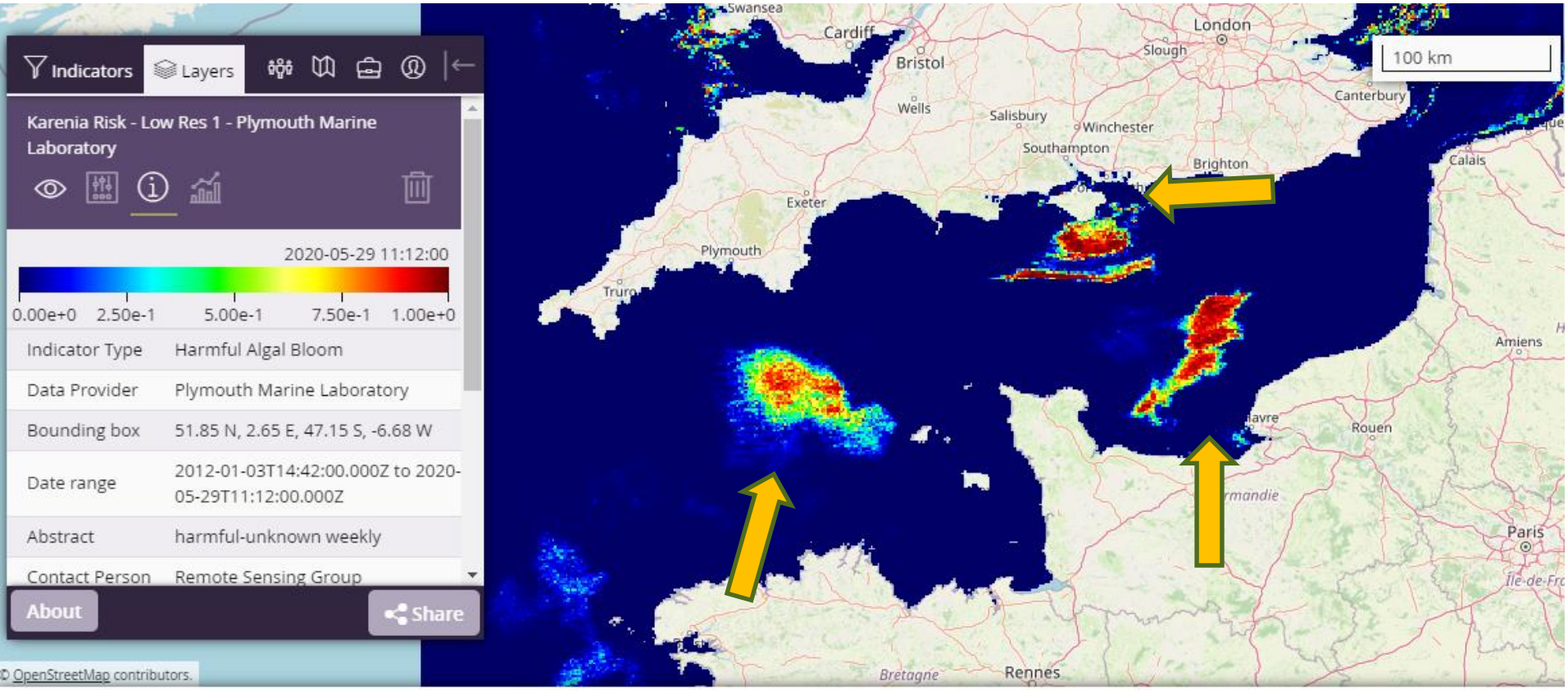
Karenia Risk and likelihood assessment



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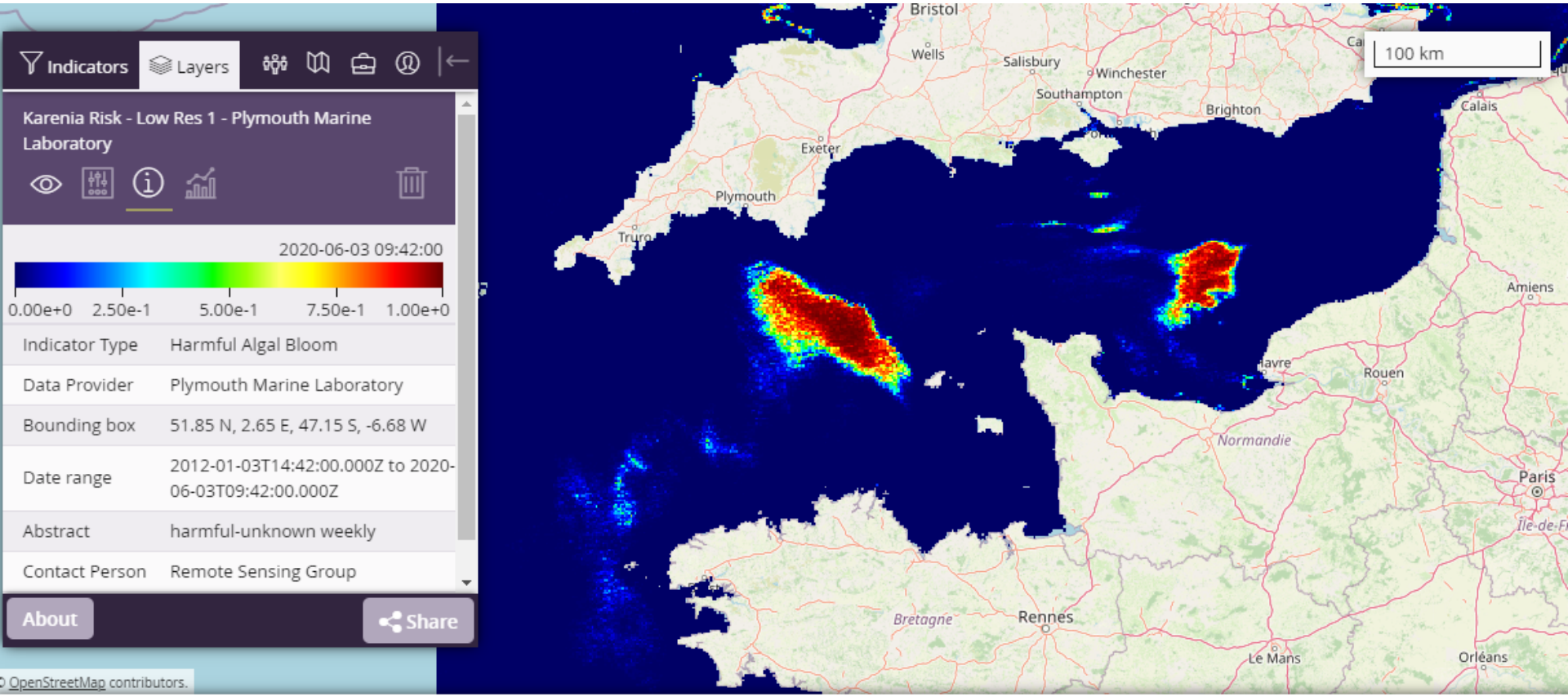
Changes rapidly



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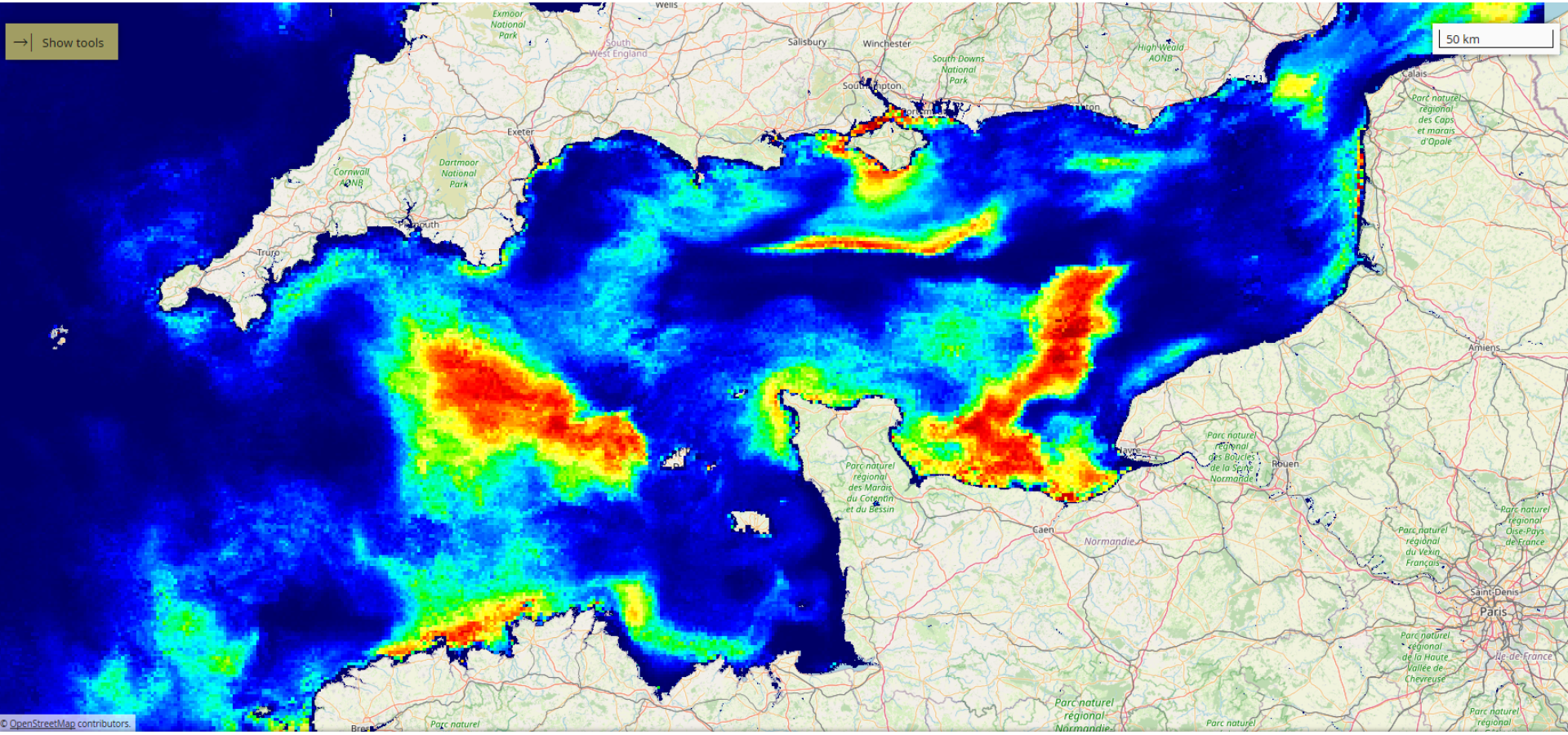
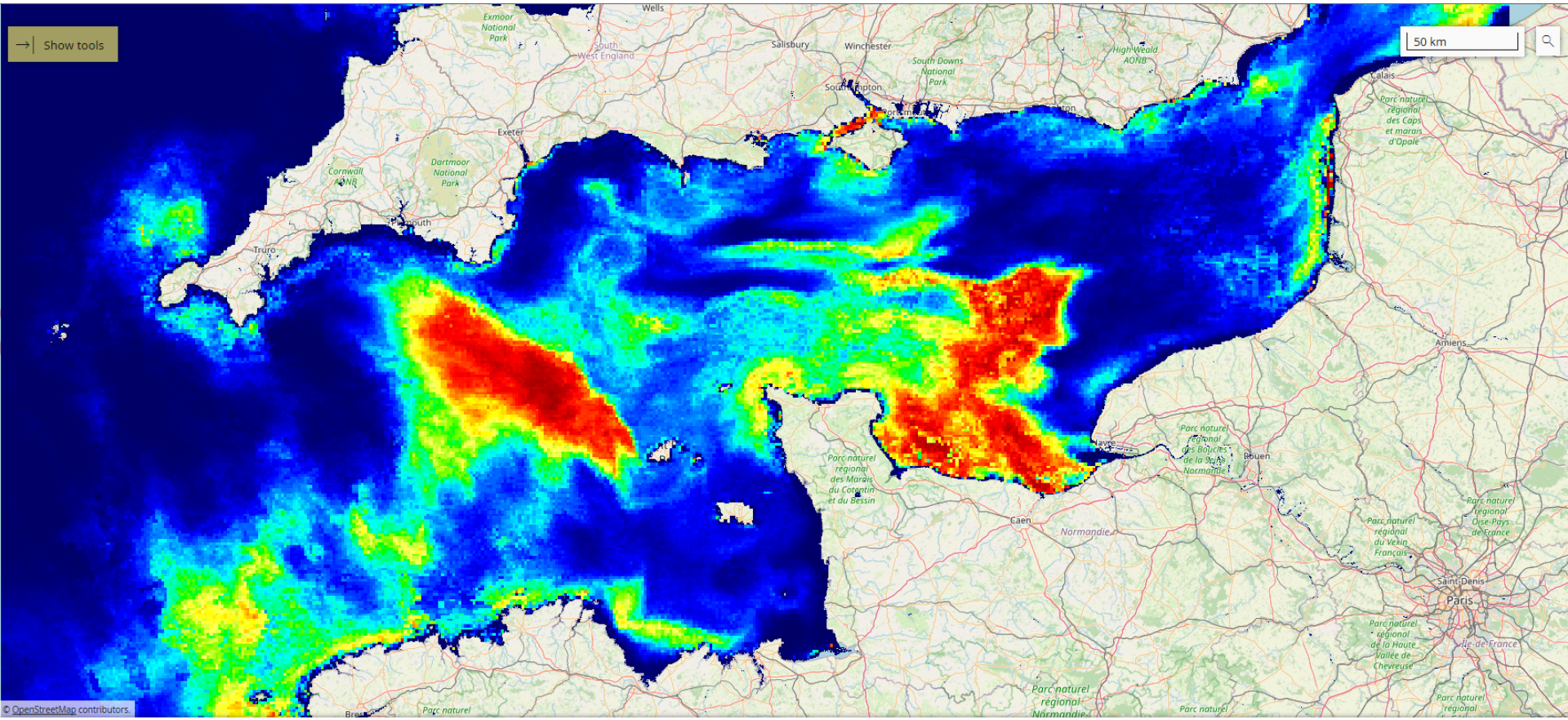
High Res 31st May



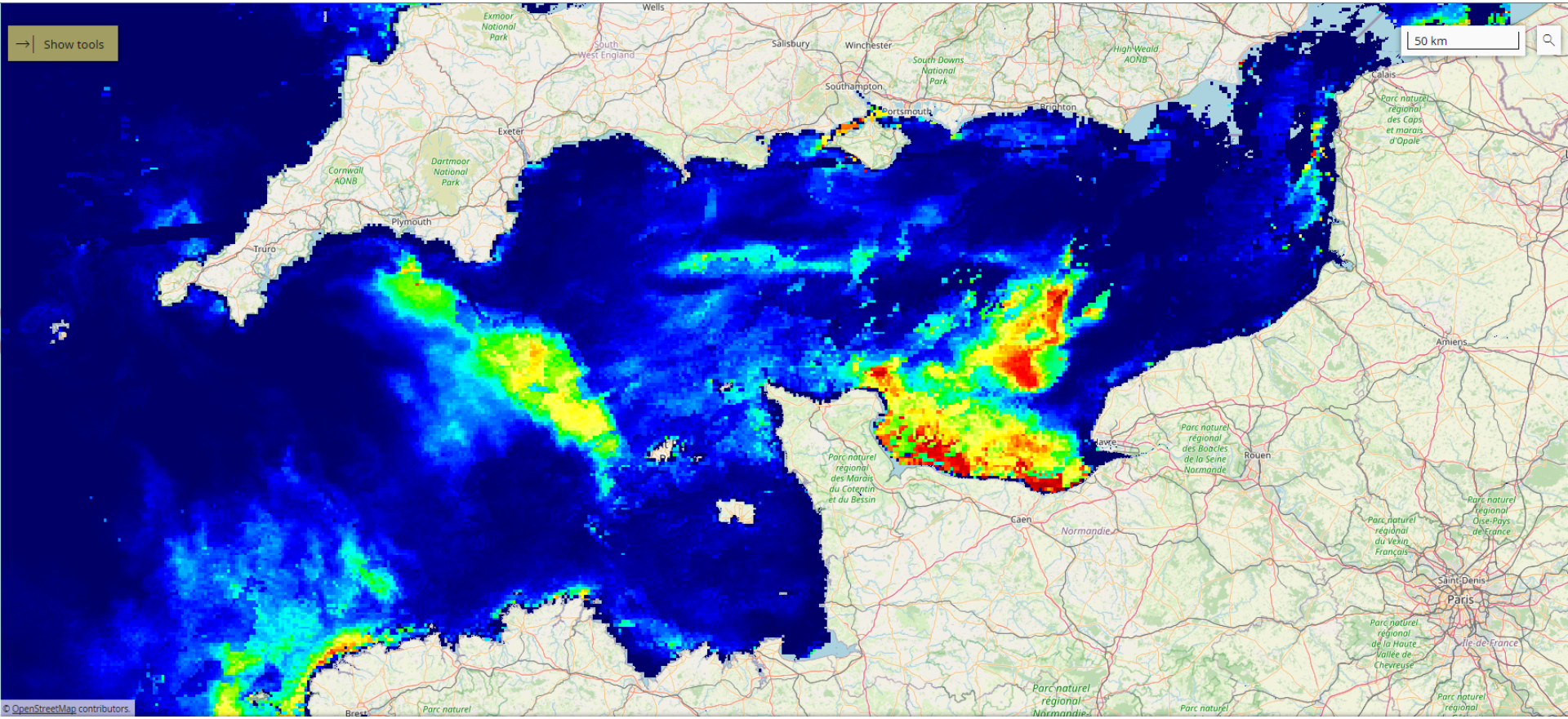
Environment Agency

High Res 4th June



Environment Agency

High Res 9th June



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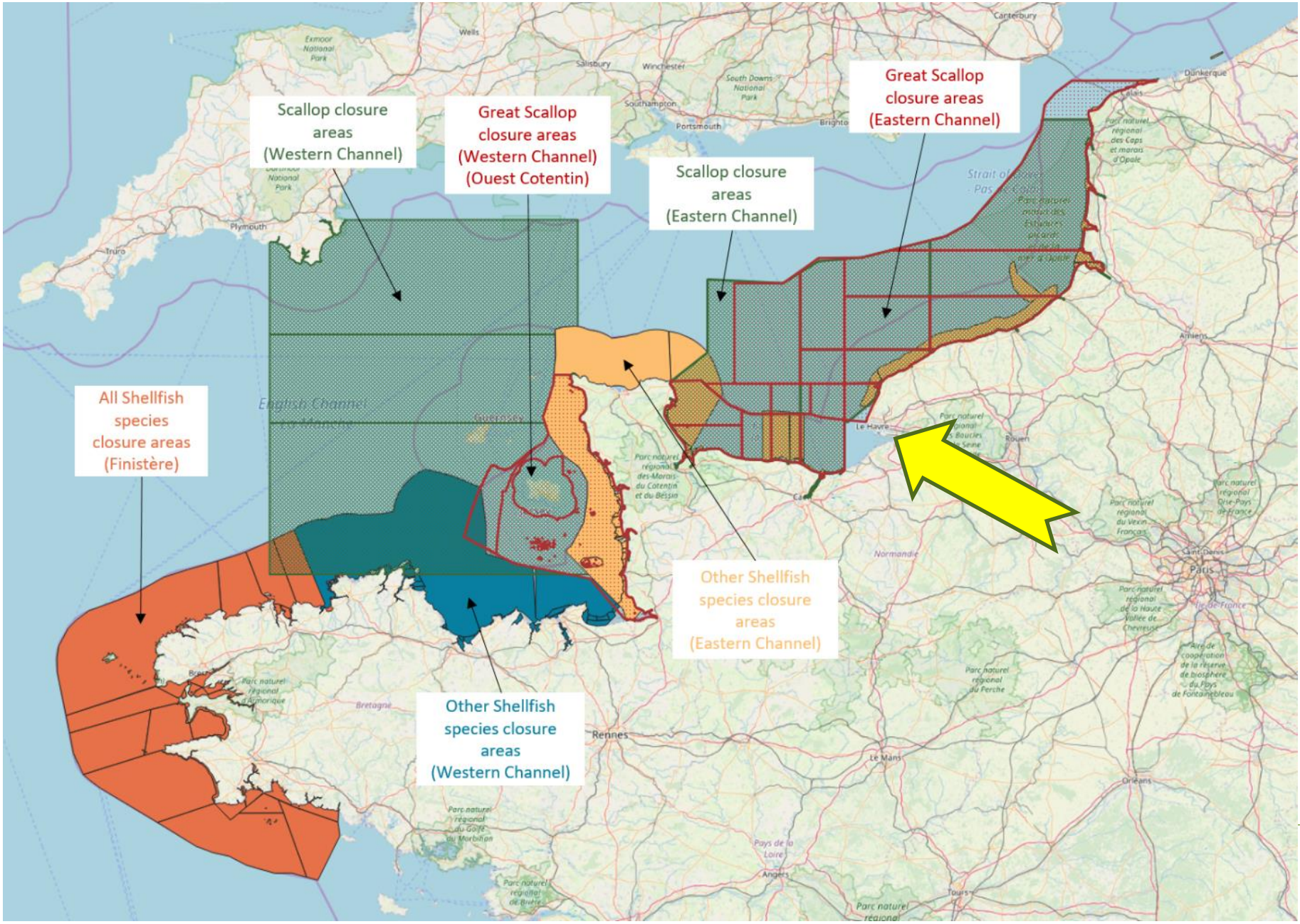
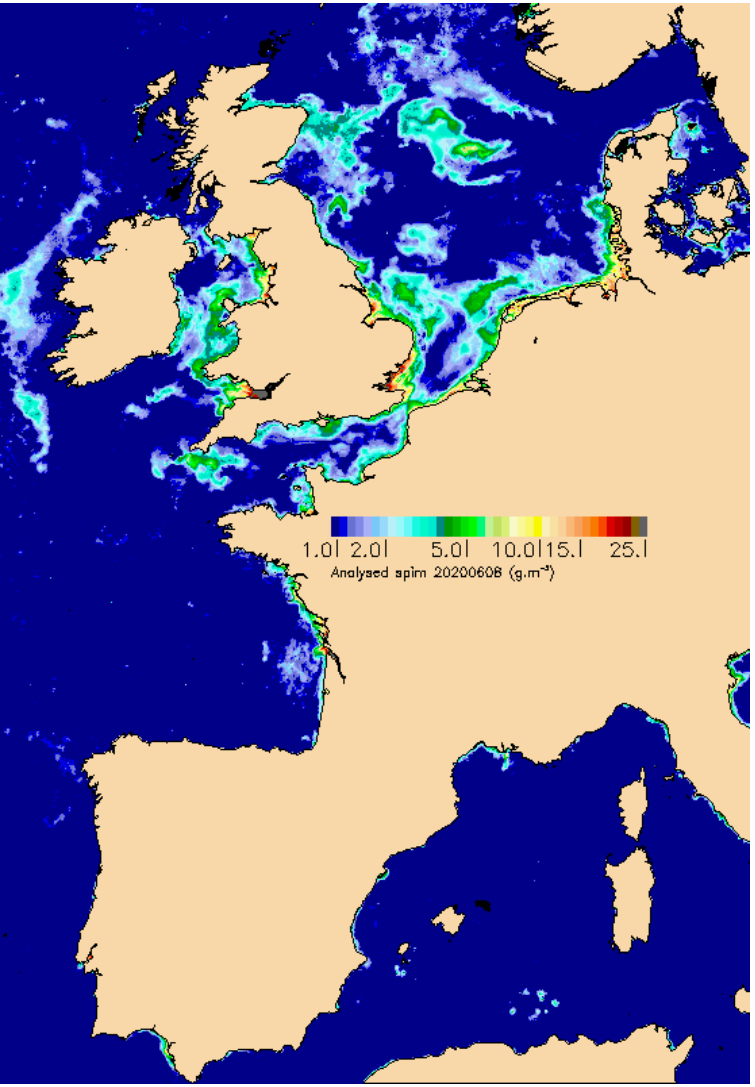

Scallop closure areas (Western Channel)
Great Scallop closure areas (Western Channel) (Ouest Cotentin)
Scallop closure areas (Eastern Channel)
Great Scallop closure areas (Eastern Channel)
All Shellfish species closure areas (Finistère)
Other Shellfish species closure areas (Eastern Channel)
Other Shellfish species closure areas (Western Channel)
English Channel
La Manche
Normandie
Bretagne
Pays de la Loire
Paris
Rennes
Le Mans
Orléans
Tours
Angers
Le Havre
Rouen
Caen
Amiens
Dunkerque
Calais
Canterbury
Brighton
Portsmouth
Southampton
Winchester
Salisbury
Wells
Plymouth
Truro
Guernsey
Jersey

What’s the cause ?

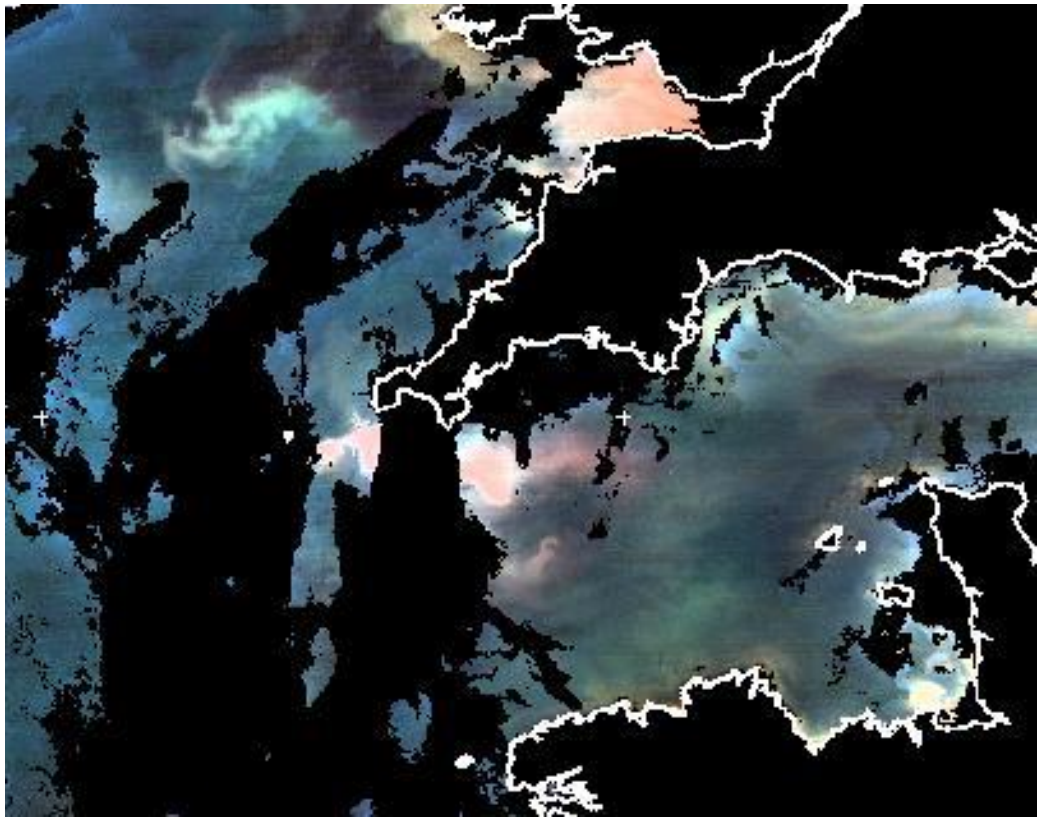
- *Karenia* - dinoflagellate

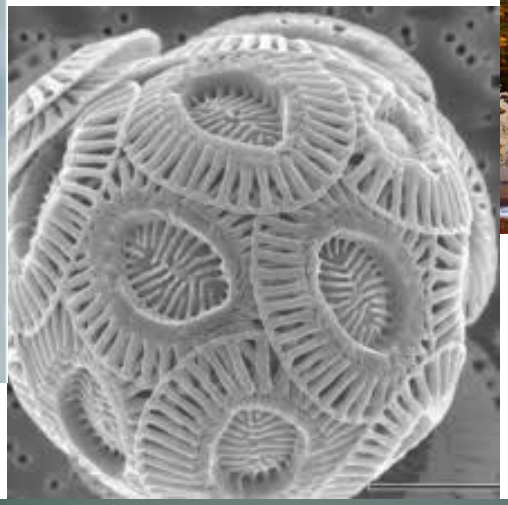
Environment Agency

Environment Agency

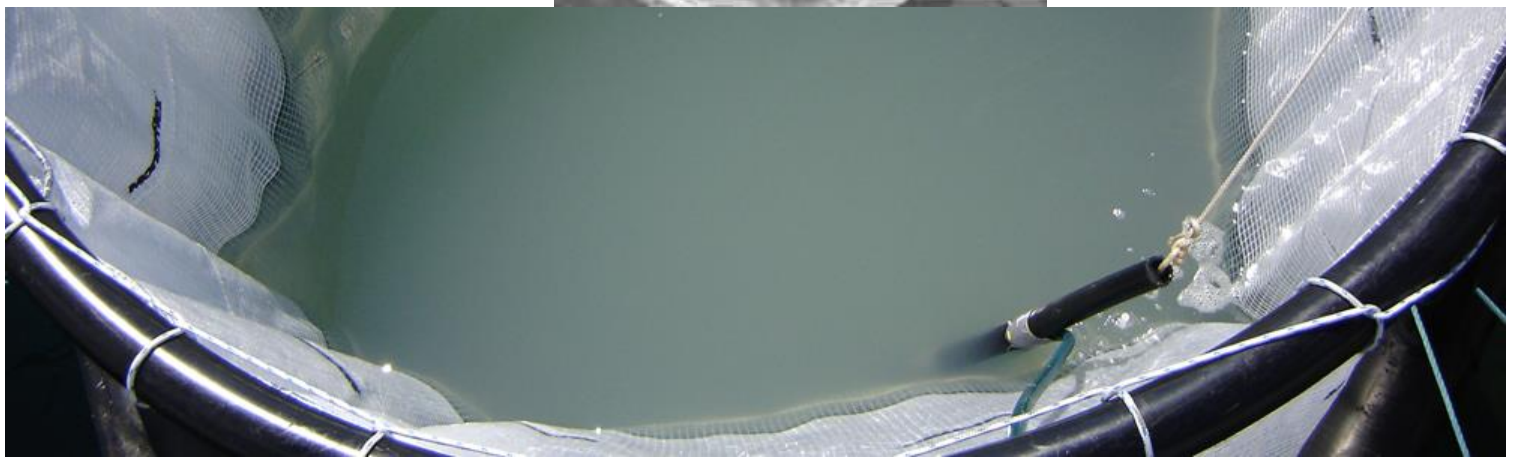


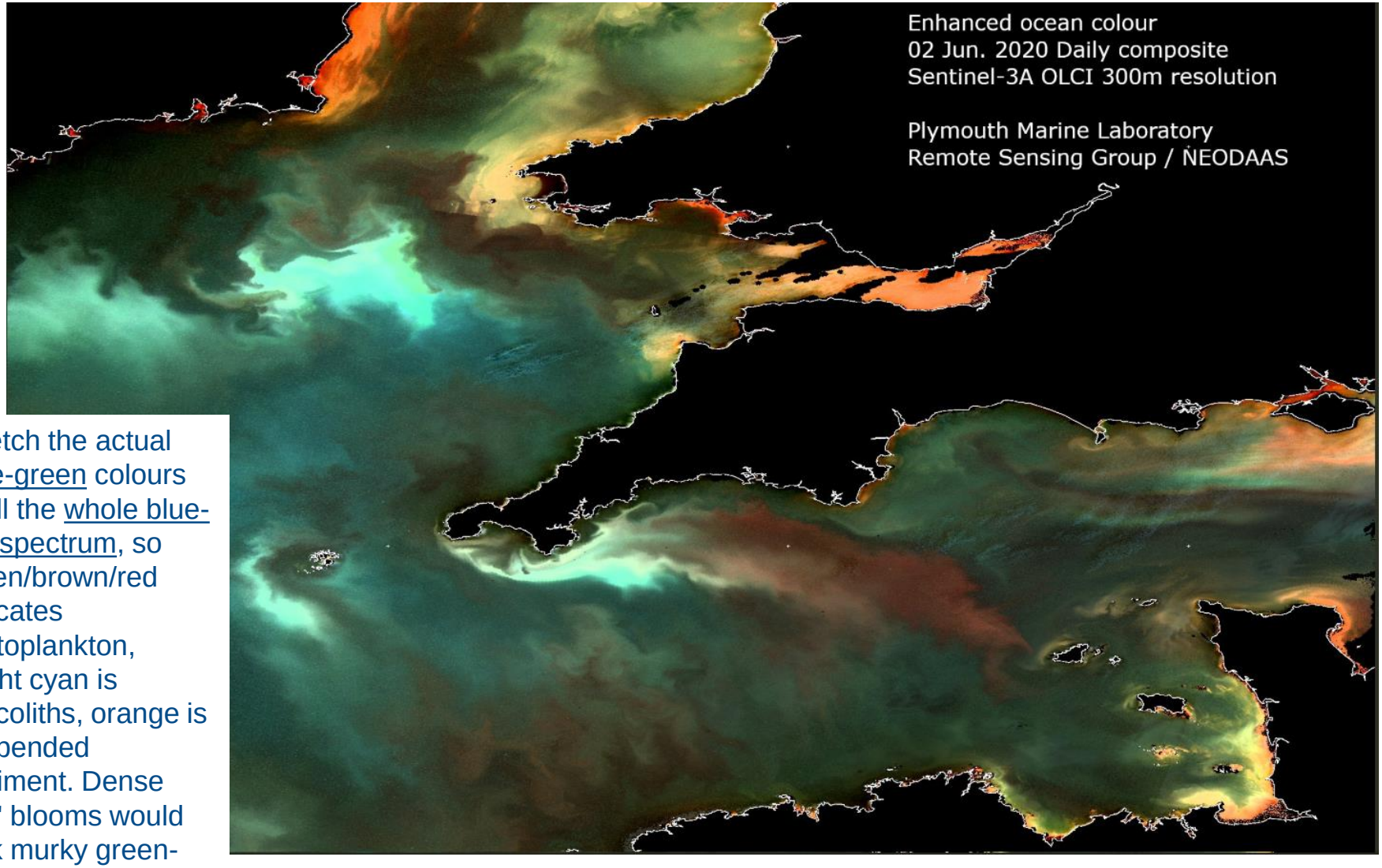
Coccolithophores





Emiliania huxleyi





Stretch the actual blue-green colours to fill the whole blue-red spectrum, so green/brown/red indicates phytoplankton, bright cyan is coccoliths, orange is suspended sediment. Dense 'red' blooms would look murky green-brown in reality

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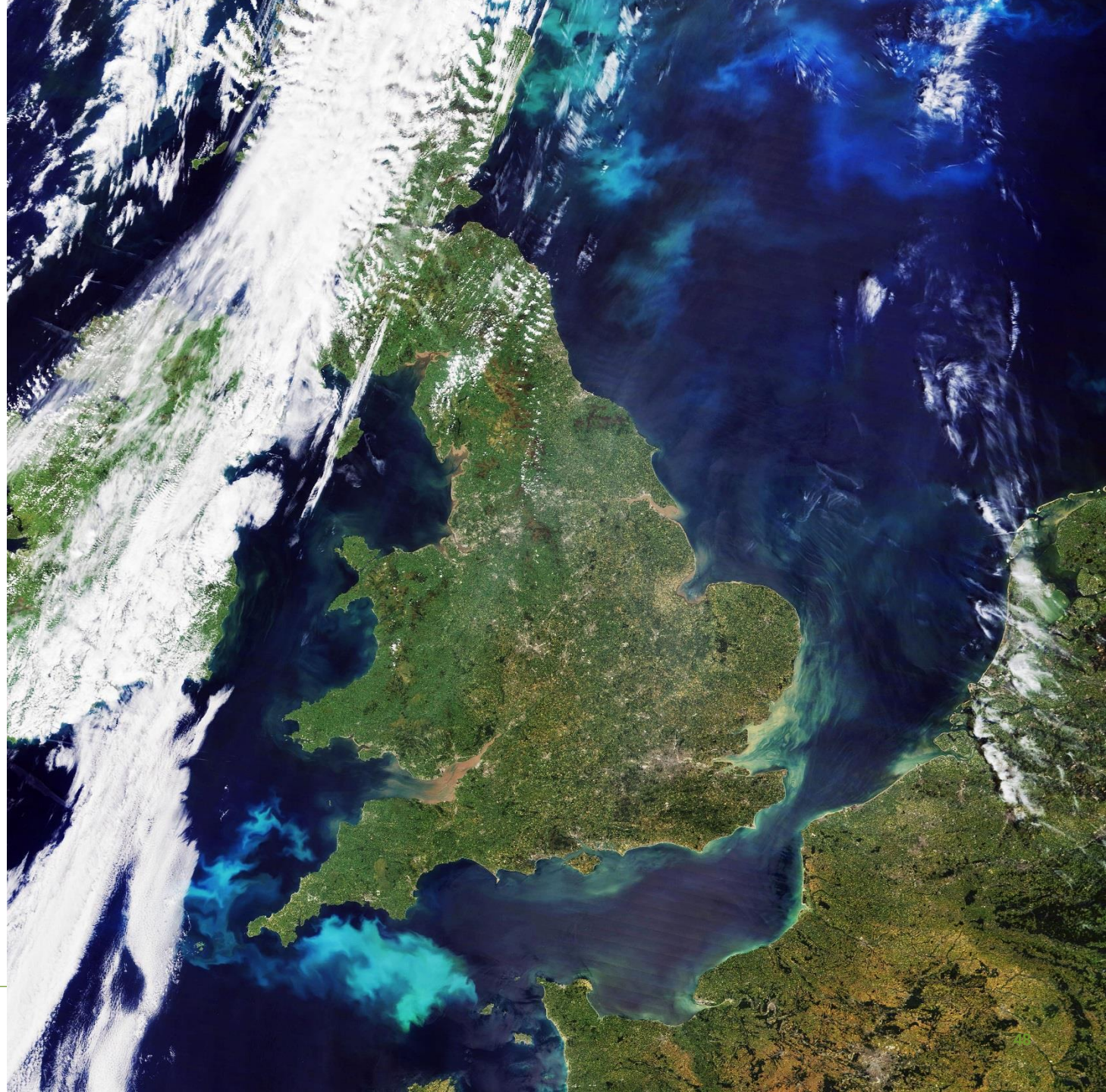

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Some of Our Spinoffs

- Inform our shellfish waters
  - Why more toxic events of French side?
- Web Alerts added Bathing waters tool ?
- Coloured water alerts ?
- Better inshore Chlorophyll algorithms
- Test bed for Lifeforms tool (MSFD)
- Data portal and stats tools (calibrate our results with others)
- Our data analysis is influencing academic thinking
- Money for monitoring
  - EO is not “a simple innovation”

Interreg

EUROPEAN UNION

France (Channel Manche) England

S-3 EUROHAB

European Regional Development Fund

Sentinel products for detecting EUtROphication and Harmful Algal Bloom events in the French-English Channel

The project will use data from the recently launched European satellite, Copernicus Sentinel 3, to track the growth and spread of harmful algal blooms in the Channel. This data will then be used to create a web based alert system, the first of its kind in Europe, to alert marine managers and fishing industries of the growth of potentially damaging algal blooms.

Budget received from the France (Channel) England Programme:

€2.6 million ERDF

Project Duration	Total Project Budget
4 years	€3.76 million

Environment Agency

Thankyou

www.s3eurohab.eu

Interreg

EUROPEAN UNION

France (Channel Manche) England

S-3 EUROHAB

European Regional Development Fund