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Harmful Algal Blooms: Challenges and opportunities for remote sensing

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(with thanks and apologies to the wide community of people involved in HAB research, including Stewart Bernard, Raphael Kudela, Richard Stumpf, Mark Matthews, many many more!)

IOCCG Summer Lecture Series 2018

European Commission

Copernicus Europe's eyes on Earth

EUMETSAT

Overview

- What are HABs?
- What are the monitoring requirements?
- Challenges for remote sensing
- Examples of approaches
- Practicals to explore HAB remote sensing concepts

Harmful Algal Blooms

- "Bloom" itself is quite a loosely defined term (see Smayda et al., 2003)

- Important to think about this, particularly in terms of HABs because it relates to two key factors:
  - What impact they have?
  - How we are able to quantify them using metrics applied to data.

- Critical questions around relationships between harm and biomass (bloom typically related to increase in biomass).

- Timing and frequency also important considerations.

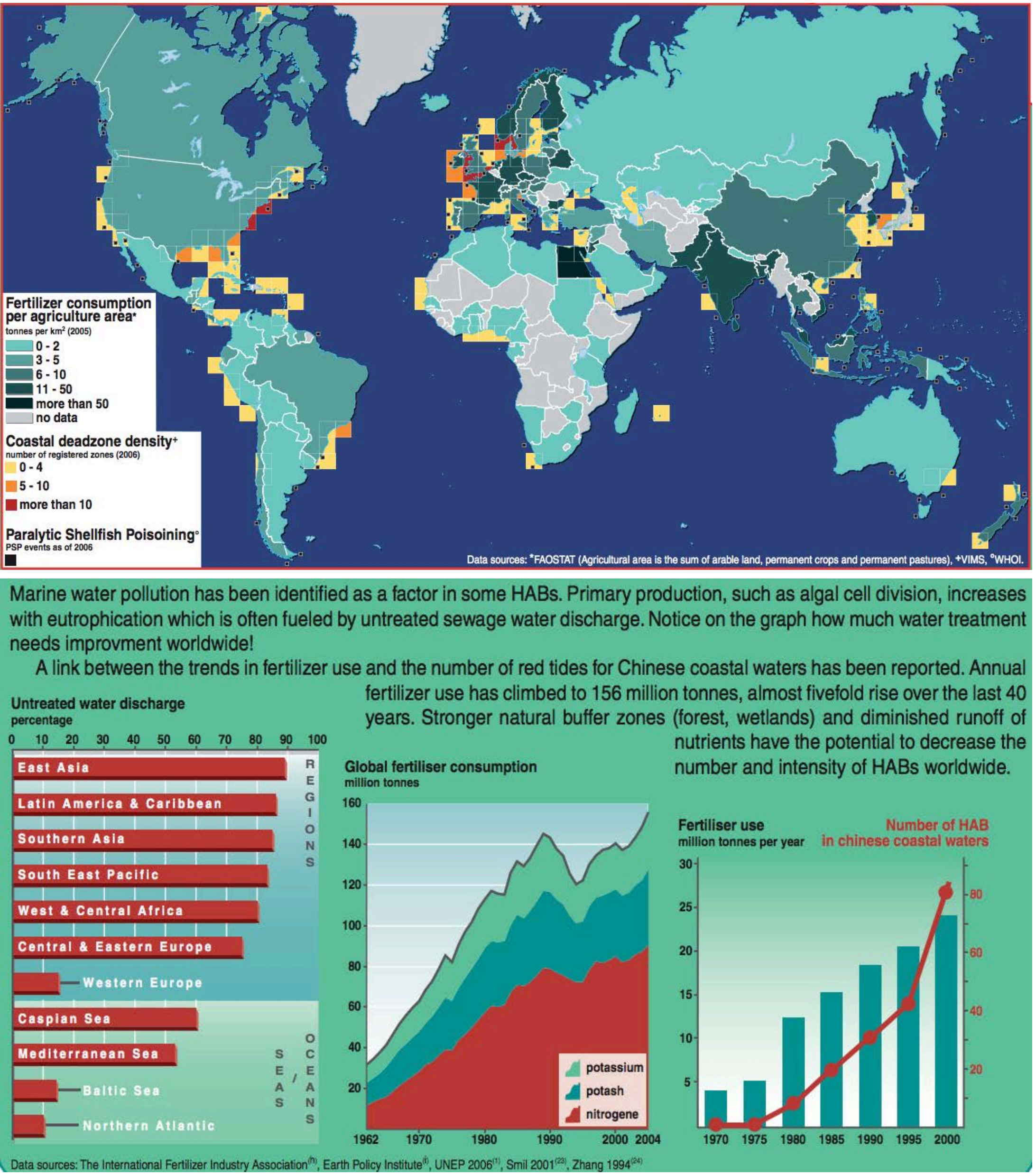
Impacts of Harmful Algal Blooms

- "At least 8 different ways a bloom could be 'Harmful'"
  - Starvation
  - Mechanical
  - Physical
  - Anoxia
  - NH_4 toxicity
  - Phycotoxins
  - Allelopathic (growth inhibition)
  - Ambush predation
- Generalise:
  - **Anoxic** (associated with high biomass)
  - **Toxic** (causing harm to humans, may not be biomass dependent)
  - **Ecological** (with some cross over)

Monitoring requirements for HABs

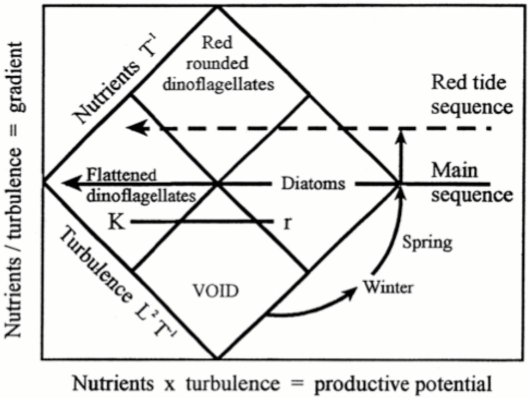
- Spatio-temporal resolution
  - Often coastal so higher spatial resolution is beneficial
  - Temporal resolution need to be frequent, but long duration to investigate event scale but also place in wider context

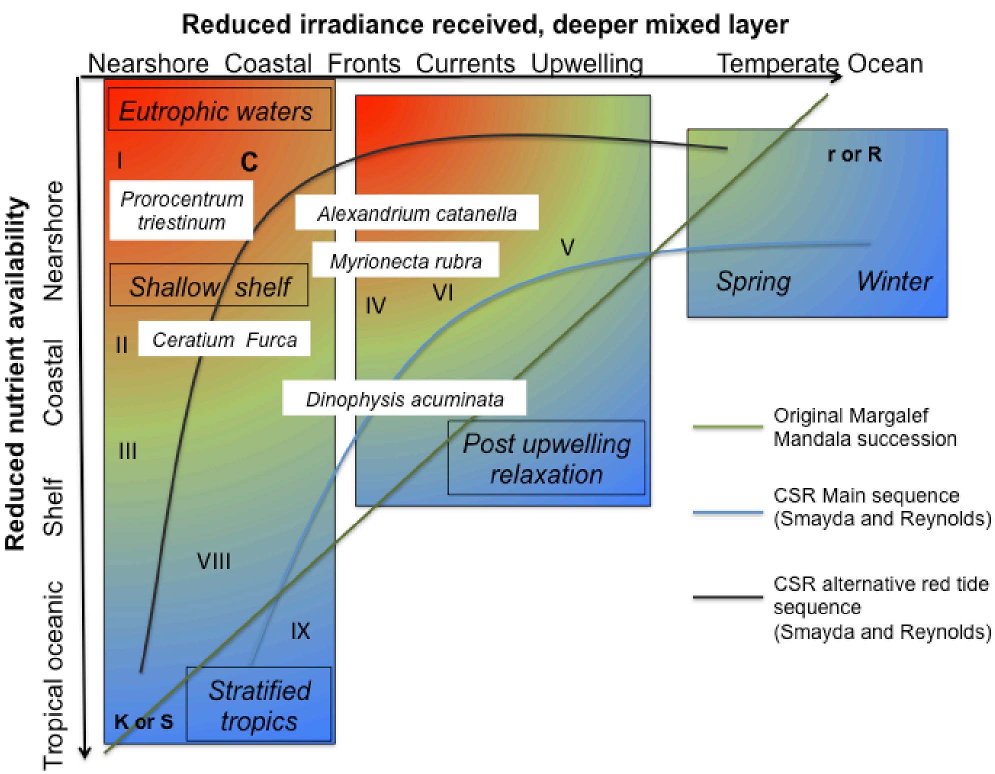
- Capture characteristics that can link to impact:
  - High biomass
  - Types of species
    - What are we detecting?
      - Individual species?
      - Functional types?
      - Size structure?
      - Colour (see Dierssen et al., 2006)
  - Bloom formation/transport
    - Drivers (natural, unnatural?)



What drives HABs?

- Introduction of nutrients in to the marine environment from anthropogenic activities:
  - Sewage
  - Fertilisers



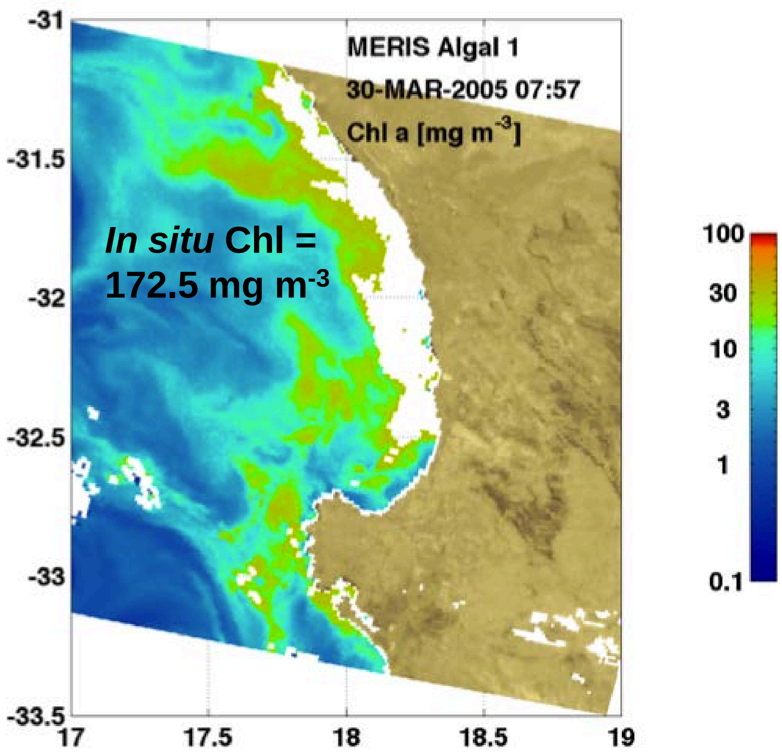


What drives HABs?

- Introduction of nutrients in to the marine environment from natural forces:
  - Wind (upwelling)
- Balance between nutrient influx and stratification, and grazing pressure
- Species competition

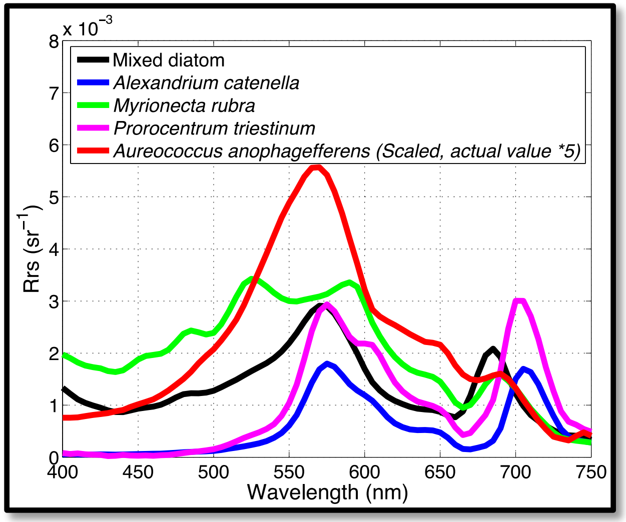
Challenges for remote sensing (general)

- Balance between spatial/temporal resolution is challenging even with modern sensors
- Sensor sensitivity
  - Higher resolution land sensors not ideal for ocean waters (S2/L8)
- Coastal complexity
  - Atmospheric correction
  - Adjacency
  - Outside scope of standard [Chl] algorithms
  - Ambiguity…



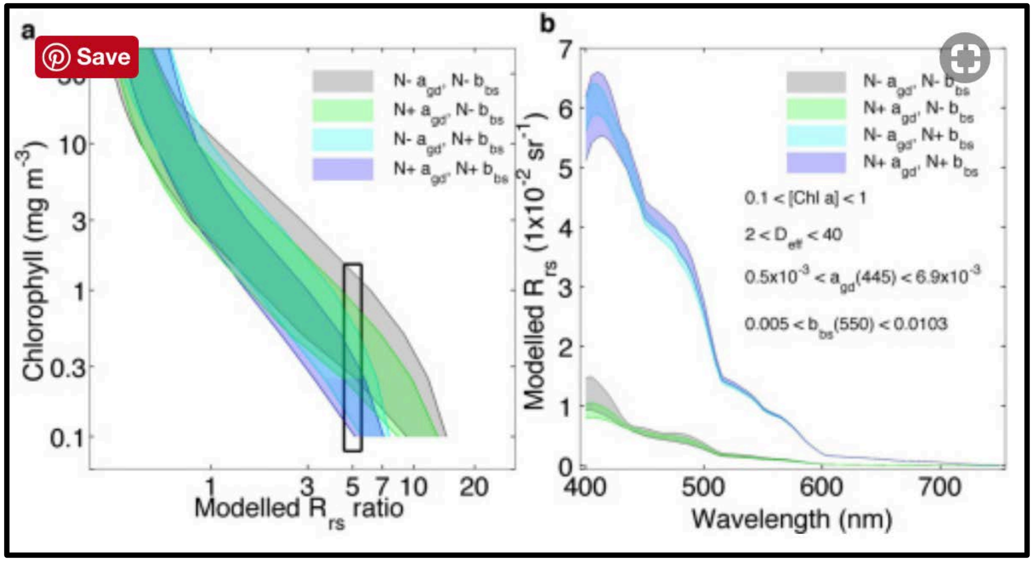
Challenges for remote sensing (specific)

- Spectral resolution/bandwidth/S:N – enough for species detection?
- Ambiguity:
  - In the ocean colour problem (multiple ways to make the same spectra) (see Defoin-Platel and Chami, 2007)
  - Sensitivity (see Evers-King et al., 2014)



Best approaches are likely to combine data:

- *In situ* monitoring
- Modelling



No 'one size fits all' solution

Opportunities from HABs research

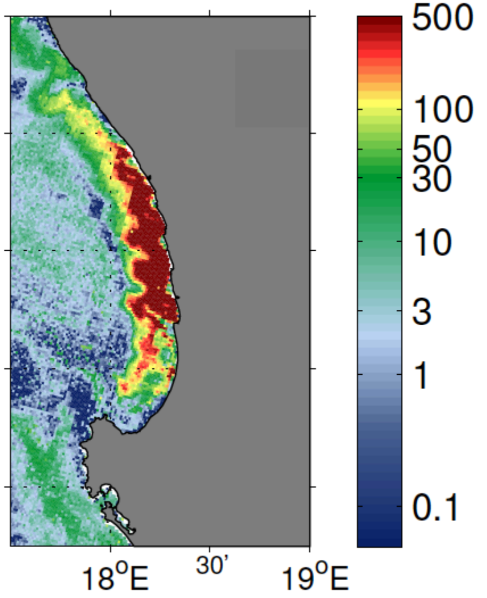
- For those interested in phytoplankton – HABs are probably one of the best natural circumstances to investigate their properties from space!
- Many opportunities for synergistic RS techniques:
  - Understanding HAB formation through relationships with SST, wind, currents etc.
- Many benefits to be had:
  - Aquaculture is a growth industry
    - Huge losses ($80 million from single event!)
  - Tourism/health
  - Commercial contexts

Examples of approaches: High Biomass algos

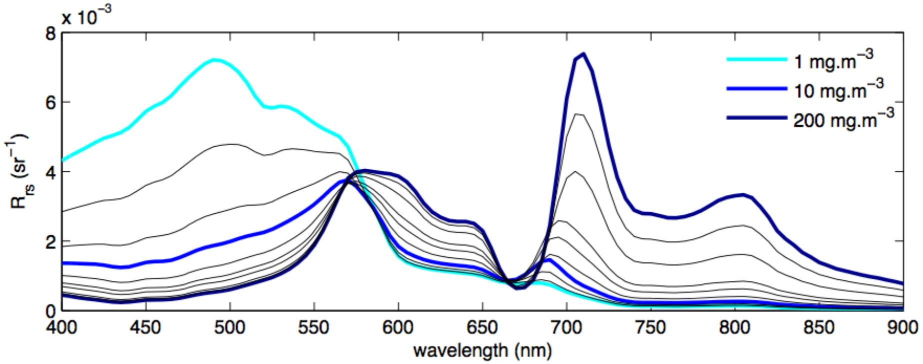
Target	*Method*	*Reference*
Biomass	Chlorophyll	*Standard product*
Chlorophyll fluorescence	Fluorescence line height (FLH), normalized fluorescence line height (nFLH)	*Standard product*
True-color image	Red-Green-Blue (RGB), Enhanced Red-Green-Blue (ERGB)	*Standard Product*
High biomass	Maximum chlorophyll index (MCI), Red band difference (RBD), maximum peak height (MPH)	Gower et al. 2005, Ryan et al. 2014; Amin et al. 2012; Matthews et al. 2012
High biomass	250 m band subtraction	Kahru et al. 2008
Floating Algae	Floating Algae Index (FAI)	Hu, 2009

See Kudela et al., 2017

2nd April 2012



- Often use spectral shape rather than magnitude (reduce influence of acorr errors/need for it)
- Other approaches are semi-analytical with underlying assumptions (SIOPs etc) more suitable for these waters.

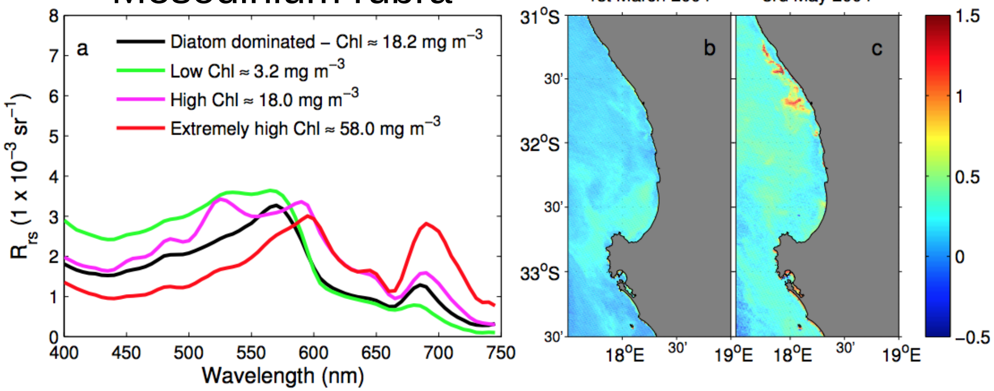


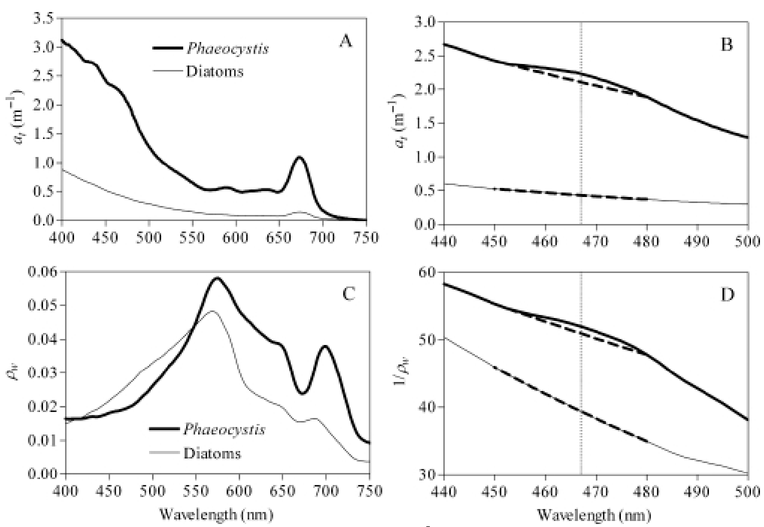
See Robertson Lain et al., 2014

Examples of approaches: Species detection

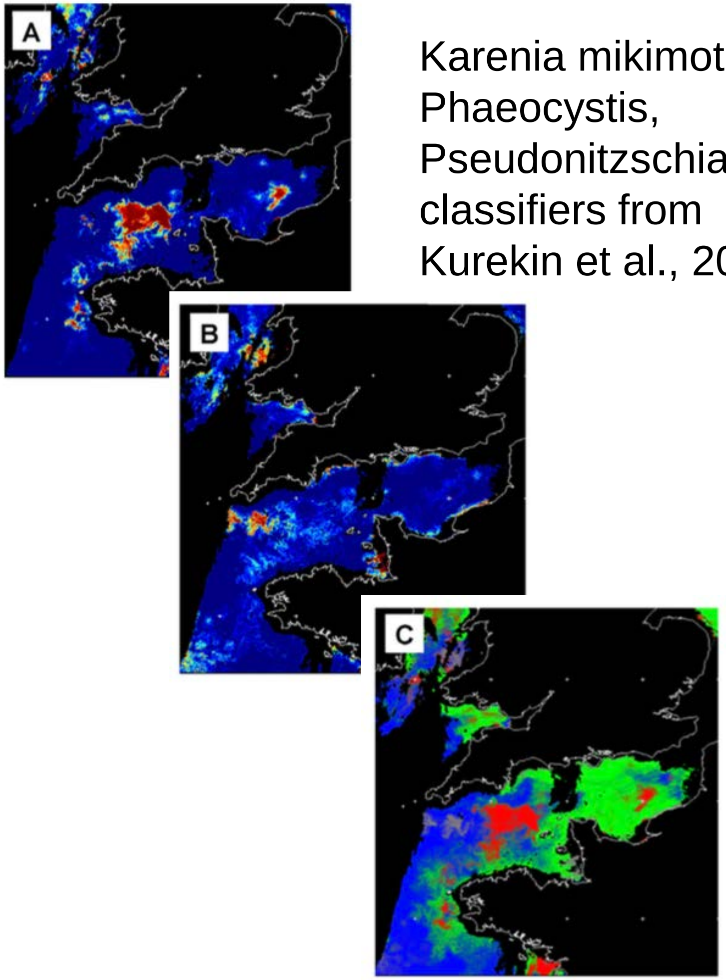
Band ratios/spectral features

Mesodinium rubra





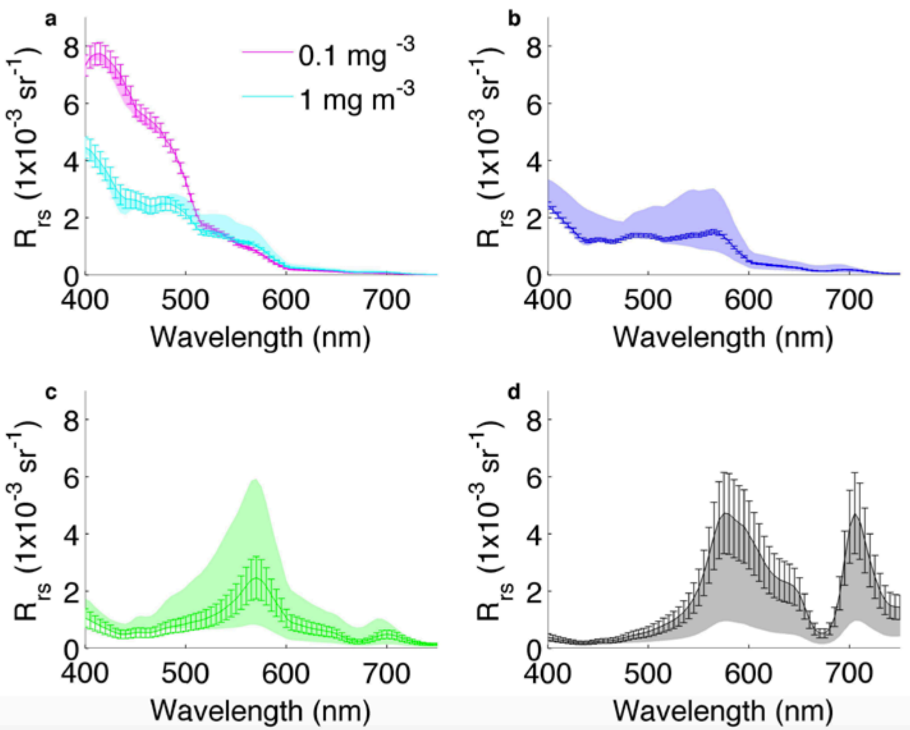
Astoreca et al., 2009

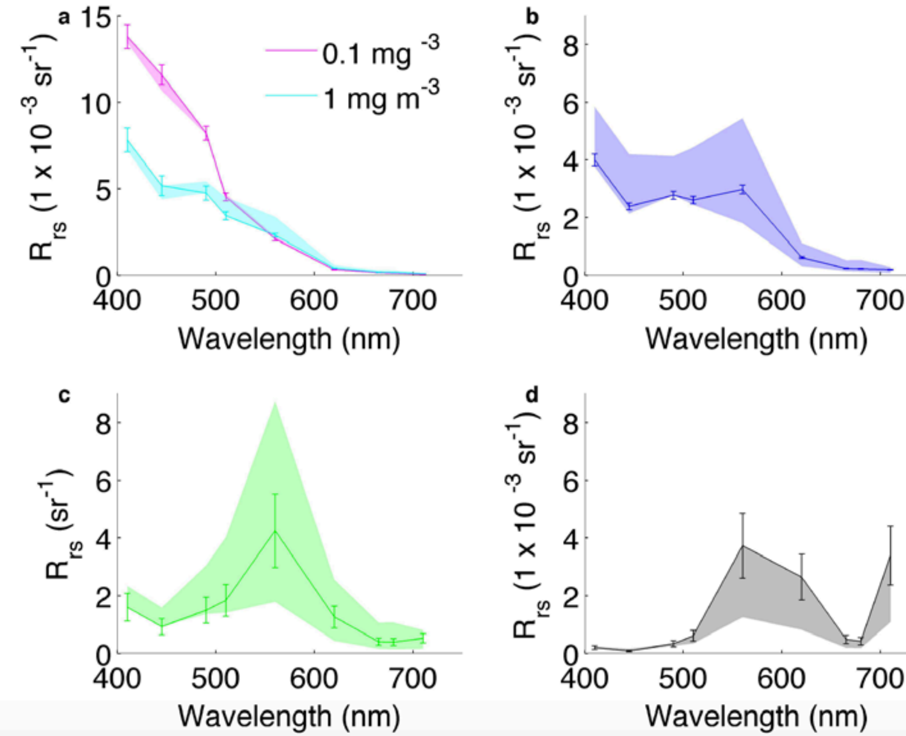


Karenia mikimotoi, Phaeocystis, Pseudonitzschia classifiers from Kurekin et al., 2014

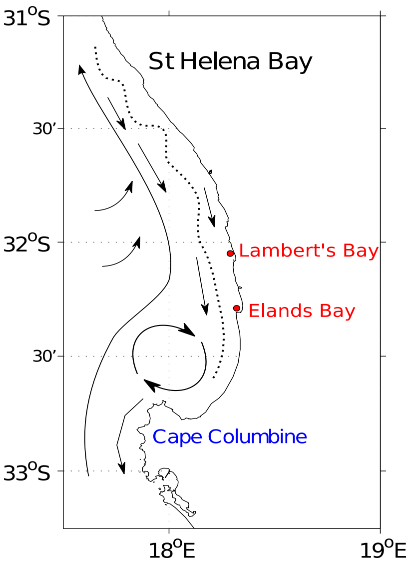
Examples of approaches: Species detection

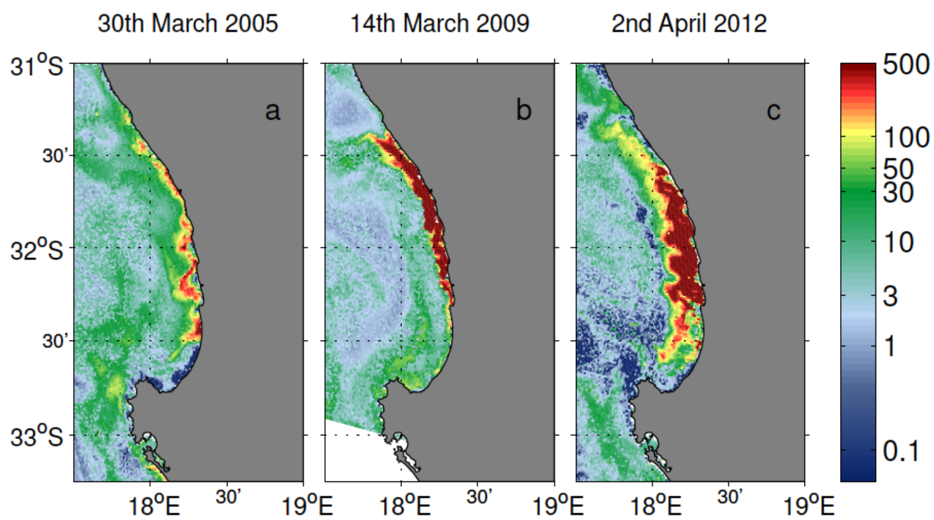
- Things to think about:
  - Assumptions in the models that underly the data…
  - Ambiguity – how distinct are the properties?
  - Relative sensitivity of the signal from the phytoplankton (and their characteristics) vs total IOP budget.
  - Error and uncertainty in your measurements (in situ or satellite)

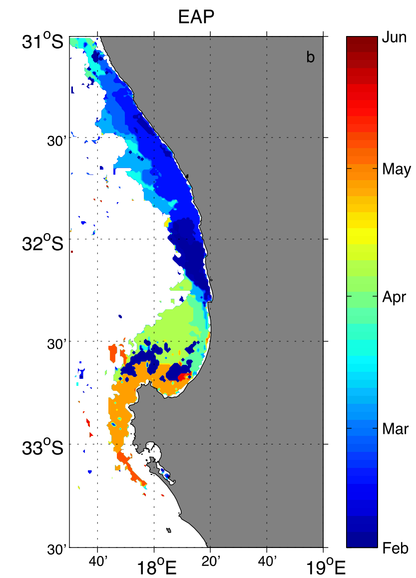


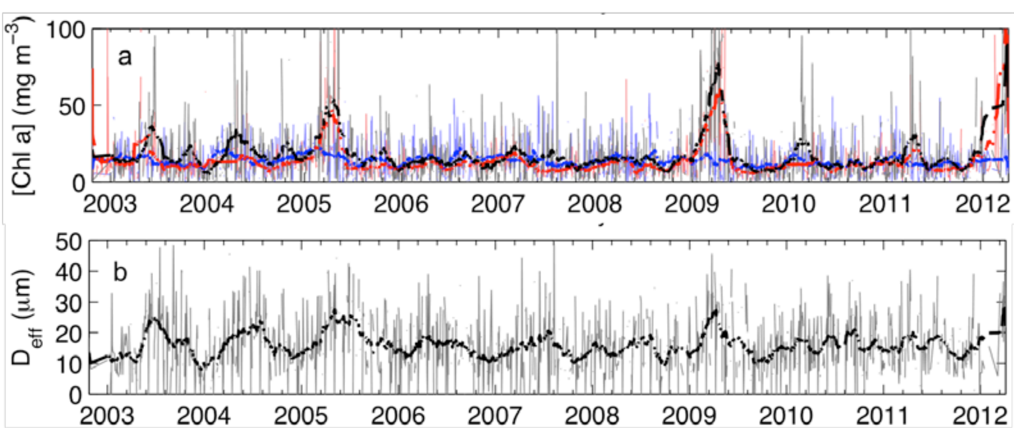


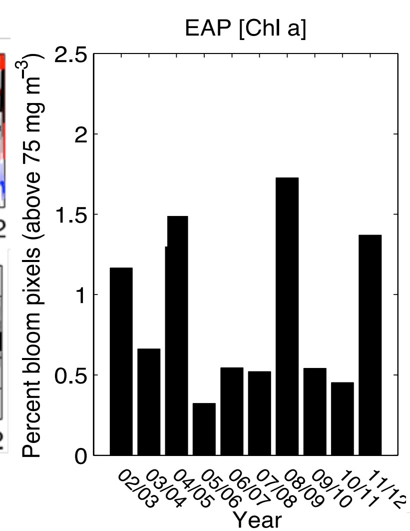
Examples of approaches: Benguela dynamics

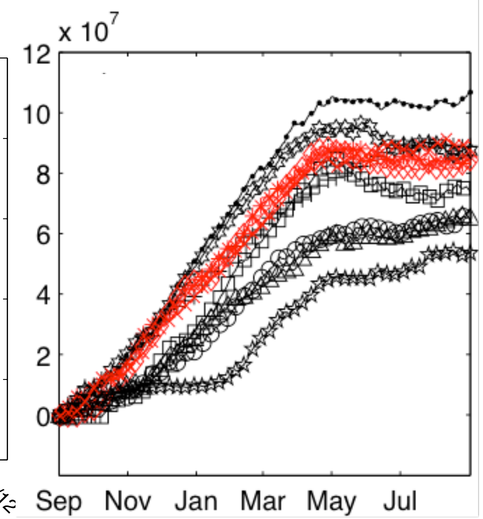




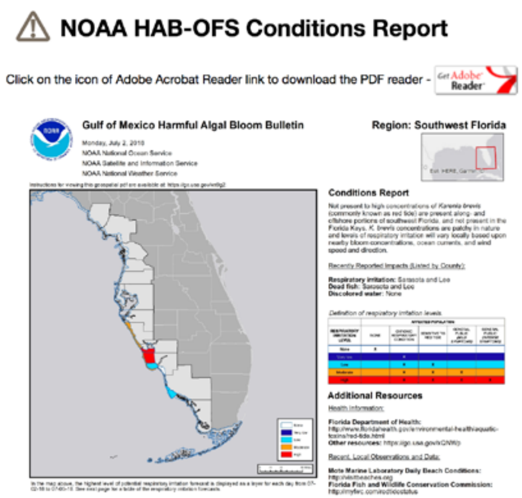


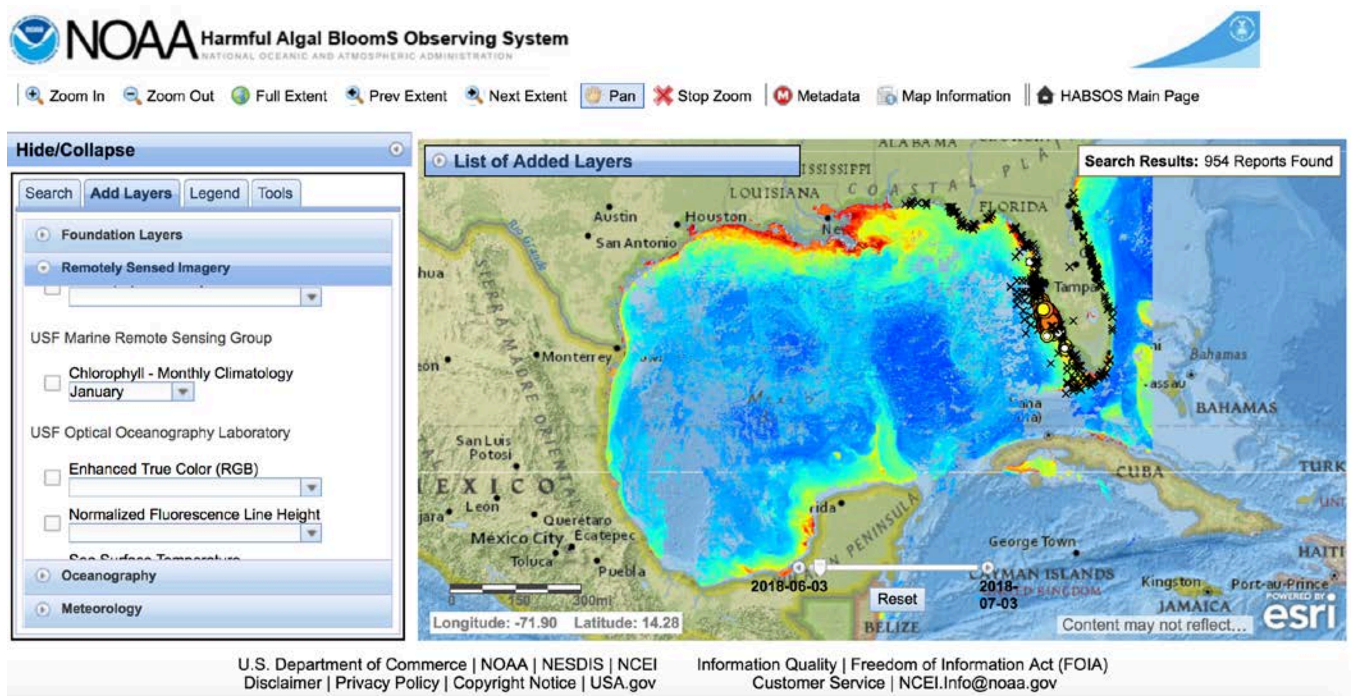






Examples of approaches: NOAA HAB Services

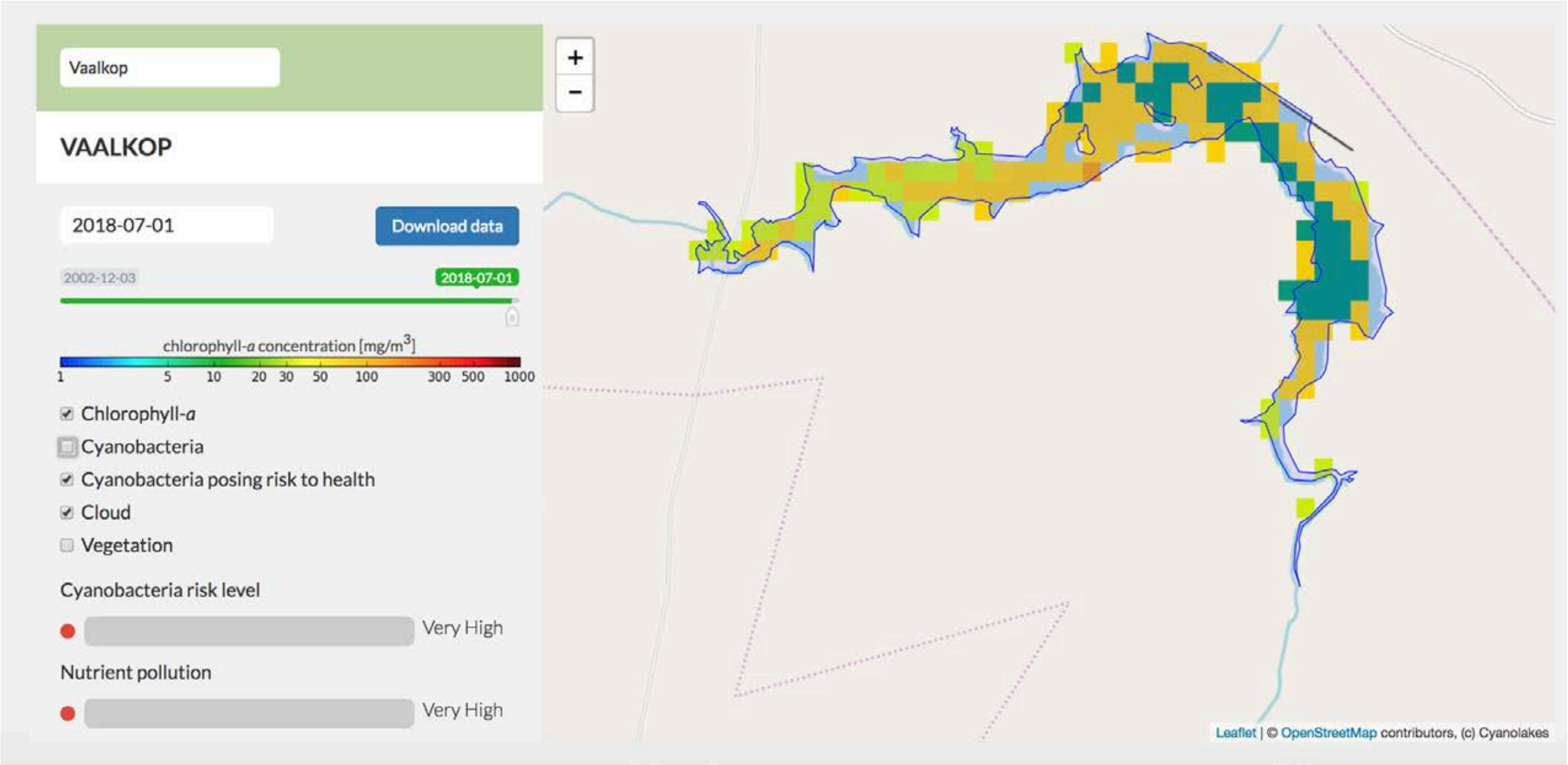




More information at: https://tidesandcurrents.noaa.gov/hab_info.html
And: https://service.ncddc.noaa.gov/website/AGSViewers/HABSOS/maps.htm

Examples of approaches: Cyanolakes

cyanolakes MAKING YOUR WATER SAFER | EO-NEMP THE EARTH OBSERVATION NATIONAL EUTROPHICATION MONITORING PROGRAMME | South African WATER RESEARCH COMMISSION



For more information see: www.cyanolakes.com

and https://cyanolakes.chpc.ac.za/

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Examples of approaches: UK HAB bulletins

ShellEye Water Quality Event Map

Welcome to the ShellEye Water Quality Event Map, providing data on harmful algal bloom events and microbiological hazards around the UK. Through this tool you can search water quality events by location, harmful algal bloom species, toxin or alert status.

We would very much value your feedback on this tool so please contact Kelly-Marie Davidson (ShellEye Communications Officer) at **kdav@pml.ac.uk** to submit any comments you may have.

For further information about this tool or the developing ShellEye service in general, please contact Ruth Calder-Potts (ShellEye Project Manager) at **ruca@pml.ac.uk**.

Sites within current map extent:

B70AE: Ropehaven Outer (St. Austell Bay)

zoom to site

B70AE

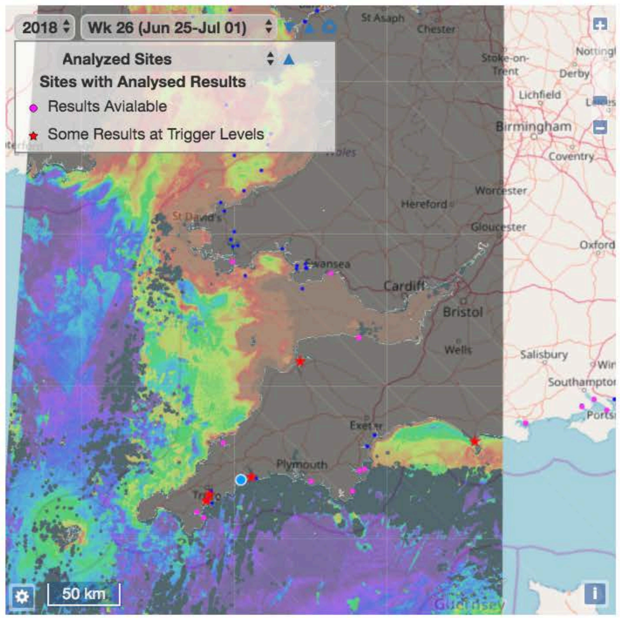
8 Week history from current on map

(Click on parameter name for a long term chart history)

Parameter	2018	2018	2018	2018	2018	2018	2018
year/wk ->	19	20	21	22	23	24	25
PSP	x	green	blue	blue	green	blue	green
OA/DTXs/PTXs	x	yellow	yellow	yellow	orange	yellow	red
AZAs	x	x	x	x	x	x	x
YTXs	x	x	x	x	x	x	x
ASP	x	green	blue	blue	green	blue	blue
Karenia mikimotoi	x	x	x	x	x	x	x
Alexandrium Sp	x	green	green	red	green	red	green

Proof of concept Image Overlay

Select ShellEye Report:
- 10-Jan-2018(St Austell)
- 13-Nov-2018(Morecambe Bay)
- 13-Nov-2018(Menai Strait>
- 10-Nov-2018 (Loch Ryan)



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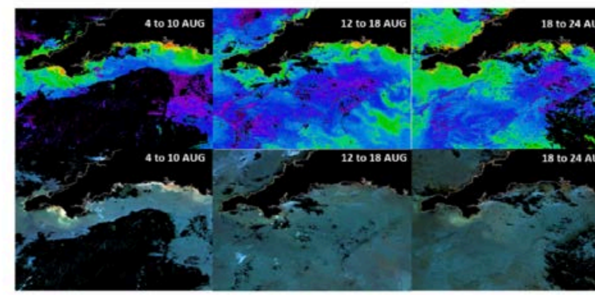
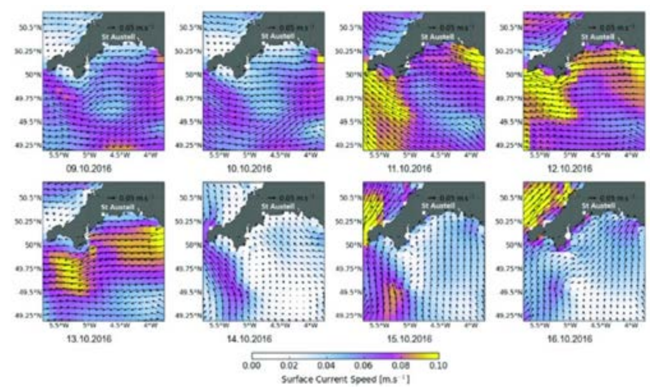
Temporal evolution of the bloom



Chlorophyll concentration (top): showing the bloom growth and increase in concentration over the previous three weeks, since 4 August 2017.

Enhanced ocean colour (bottom): for the same dates.



PML/SAMS/CEFAS/UoEx collaborations

See www.shelleye.org for more information

References

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- Robertson Lain et al., (2014): https://www.ncbi.nlm.nih.gov/pubmed/25090493

Practical session

Two practicals:

1. Understanding forward modelling, semi-analytical algorithms, phytoplankton cell size, and signal ambiguity (Generic_SA_prac)
   - Similar to model from Kevin but with different model for phytoplankton IOPs (compare!).

1. Working with coastal ocean colour data for high biomass HABs (OC_Sat_prac)

Both in Google drive folder here: http://bit.ly/HABIOCCG

Thank you