

PML

Plymouth Marine
Laboratory

Listen to the ocean

Harmful Algal Blooms: Challenges and opportunities for remote sensing

Dr Hayley Evers-King

(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



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
 - NH₄ 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

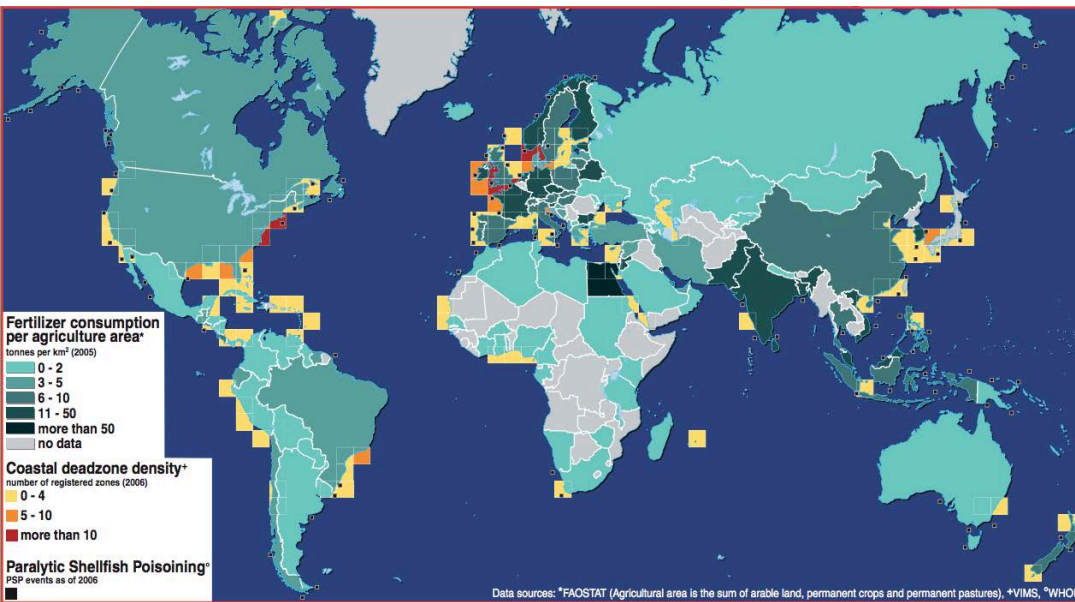
- Spatio-temporal resolution
 - Often coastal so higher spatial resolution is beneficial
 - Temporal resolution need to be frequent, but long duration to investigate event scale but also place in wider context

- 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?)



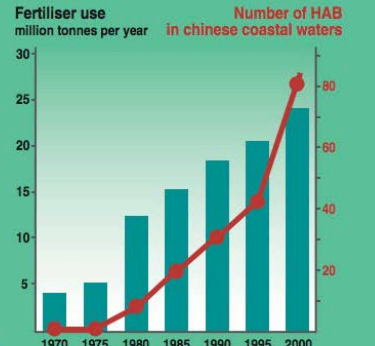
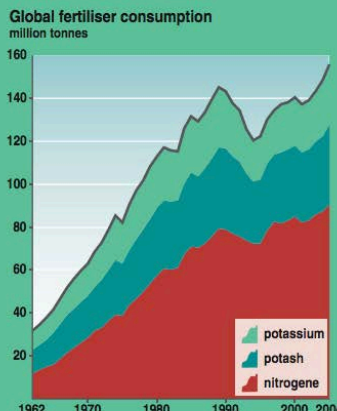
What drives HABs?

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

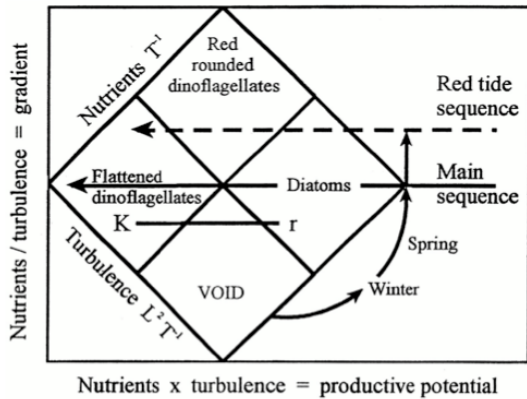


Marine water pollution has been identified as a factor in some HABs. Primary production, such as algal cell division, increases with eutrophication which is often fueled by untreated sewage water discharge. Notice on the graph how much water treatment needs improvement worldwide!

A link between the trends in fertilizer use and the number of red tides for Chinese coastal waters has been reported. Annual fertilizer use has climbed to 156 million tonnes, almost fivefold rise over the last 40 years. Stronger natural buffer zones (forest, wetlands) and diminished runoff of nutrients have the potential to decrease the number and intensity of HABs worldwide.



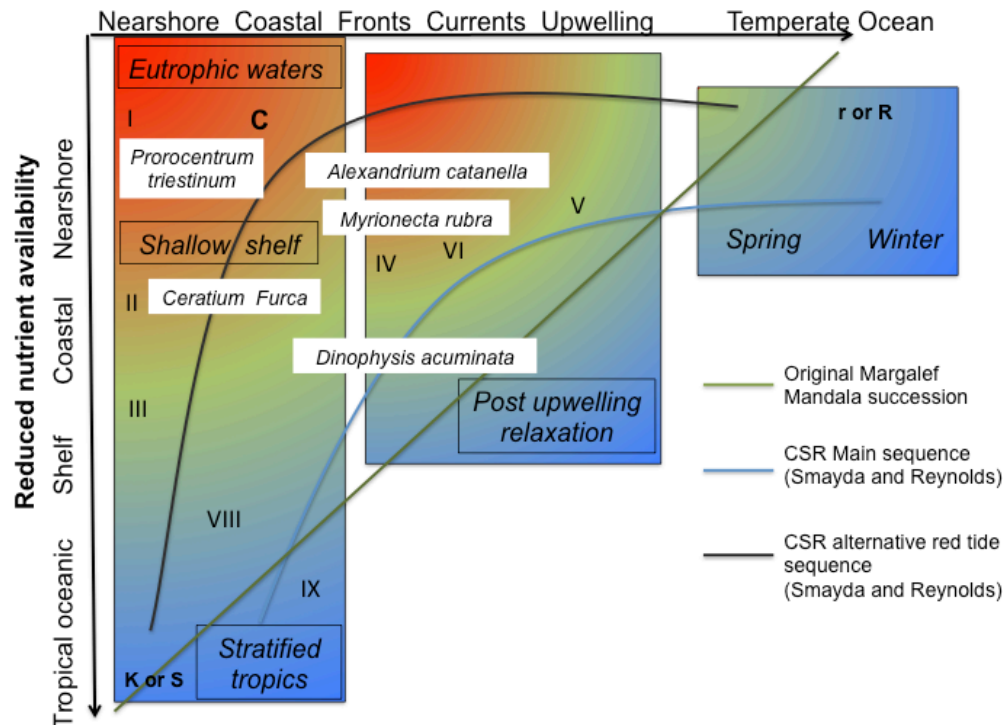
Data sources: The International Fertilizer Industry Association⁽¹⁾, Earth Policy Institute⁽²⁾, UNEP 2006⁽³⁾, Smil 2001⁽²⁾, Zhang 1994⁽⁴⁾



What drives HABs?

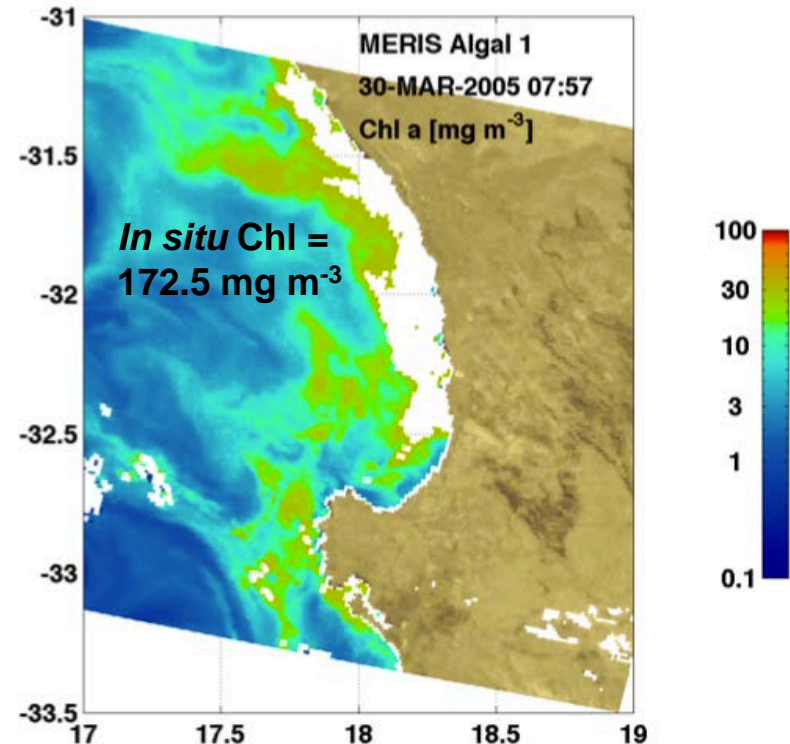
- Introduction of nutrients in to the marine environment from natural forces:
 - Wind (upwelling)
- Balance between nutrient influx and stratification, and grazing pressure
- Species competition

Reduced irradiance received, deeper mixed layer



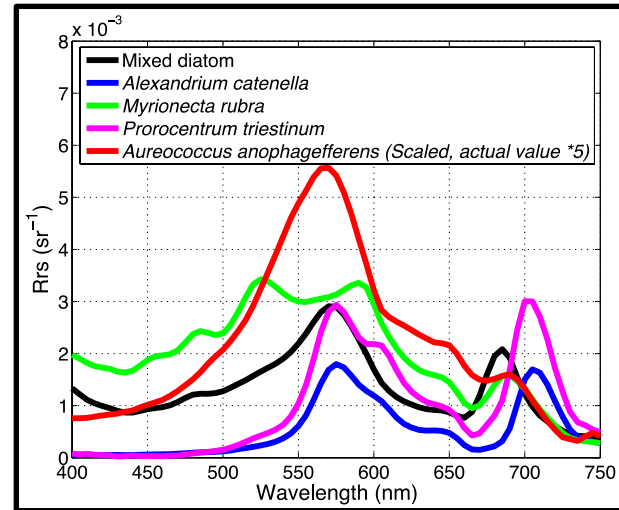
Challenges for remote sensing (general)

- 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)

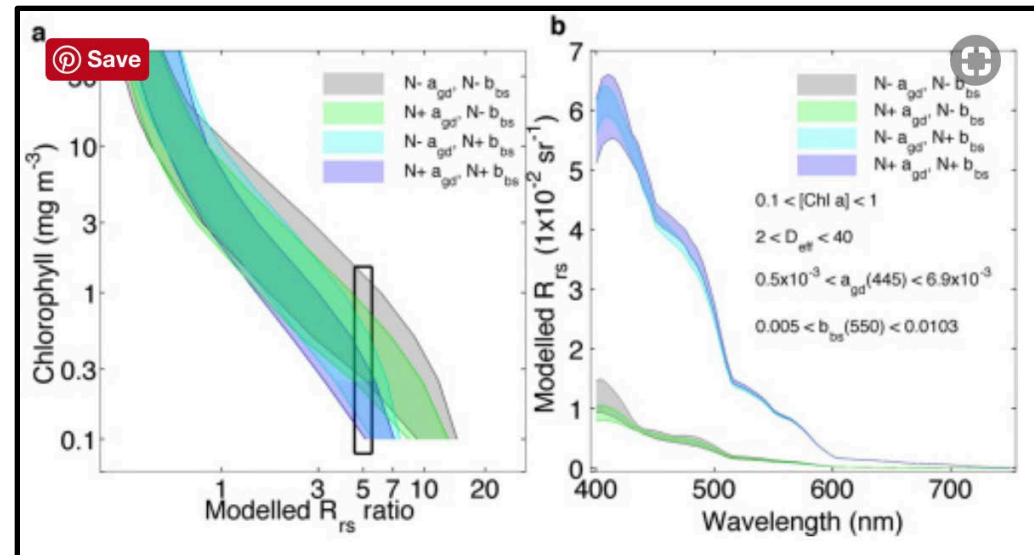
- Spectral resolution/bandwidth/S:N
 - enough for species detection?
- Ambiguity:
 - In the ocean colour problem (multiple ways to make the same spectra) (see Defoin-Platel and Chami, 2007)
 - Sensitivity (see Evers-King et al., 2014)



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



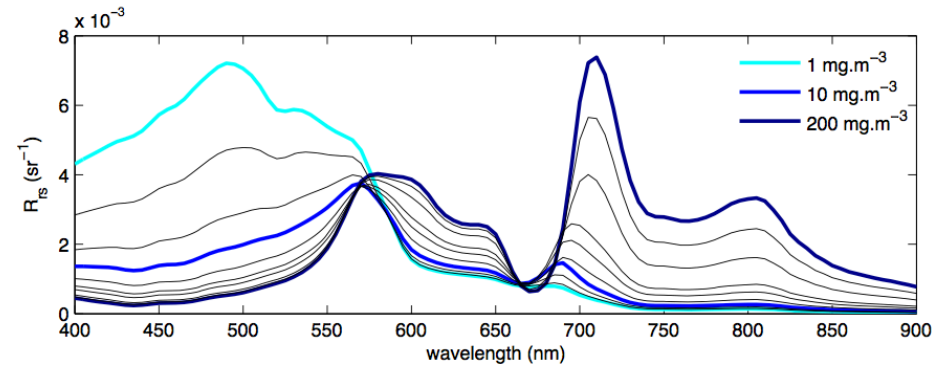
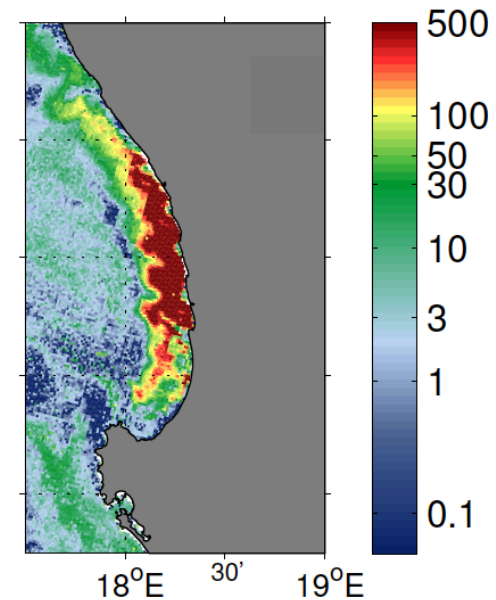
Examples of approaches: High Biomass algos

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

- 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.

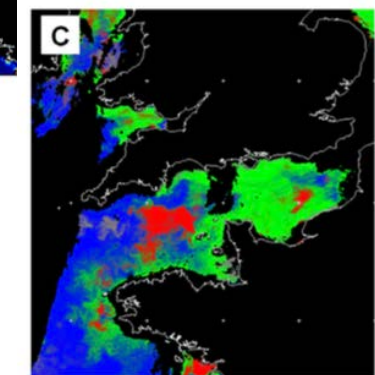
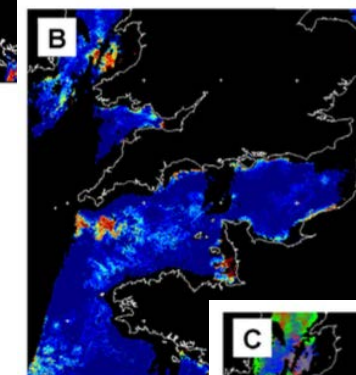
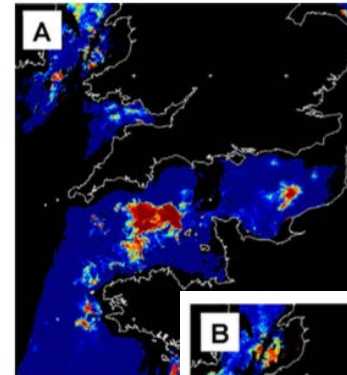
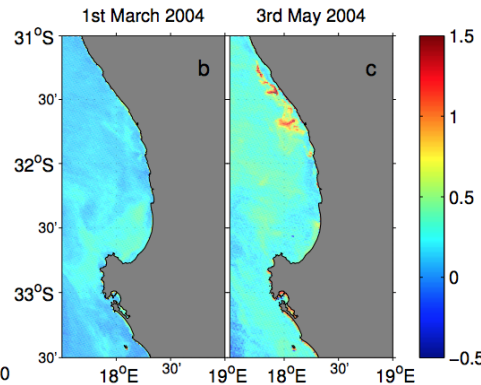
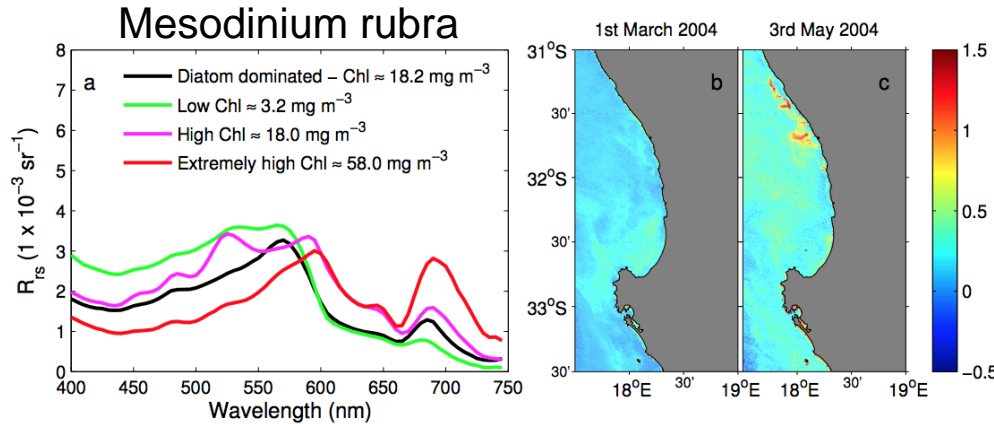
2nd April 2012



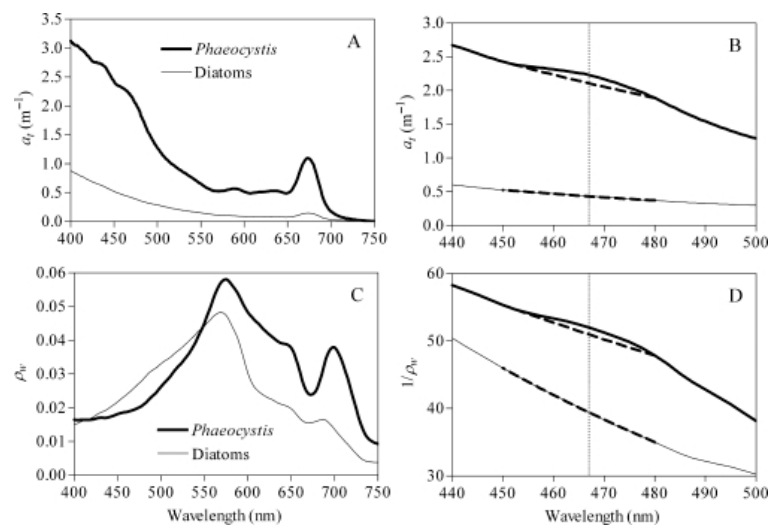
See Robertson Lain et al., 2014

Examples of approaches: Species detection

Band ratios/spectral features



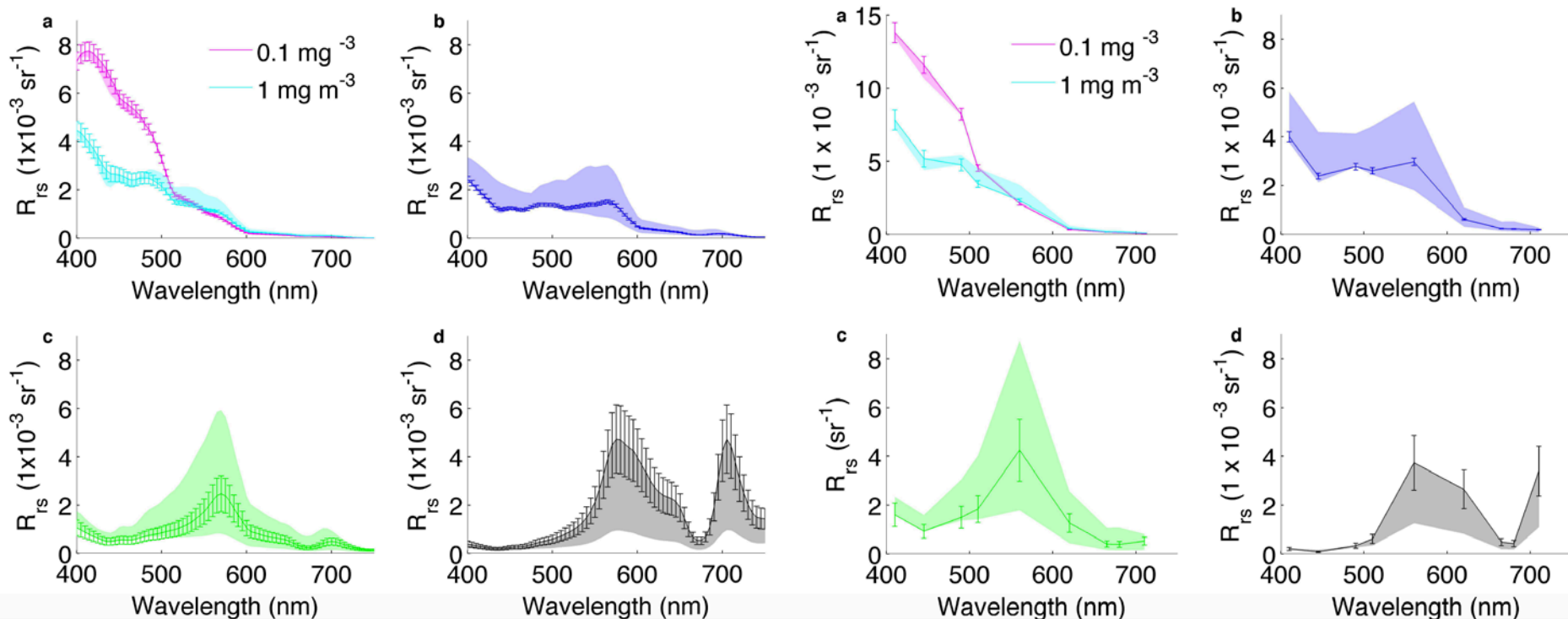
Karenia mikimotoi,
Phaeocystis,
Pseudonitzschia
 classifiers from
 Kurekin et al., 2014



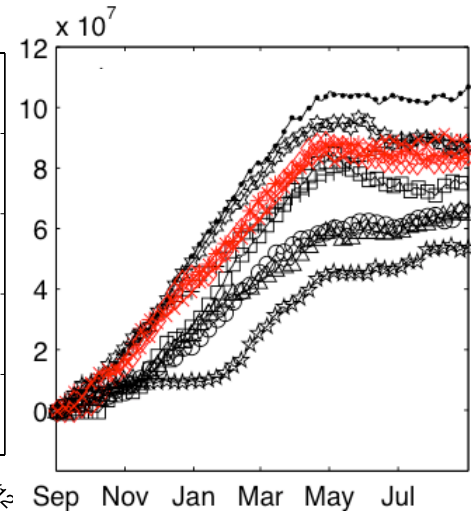
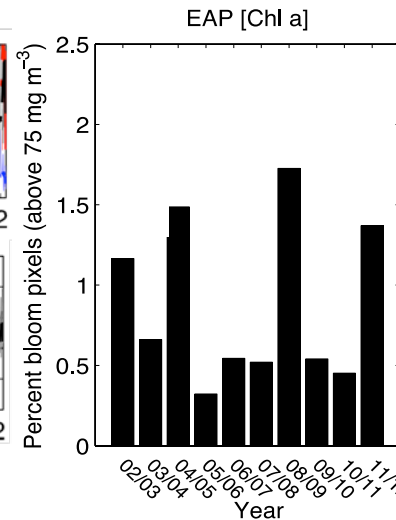
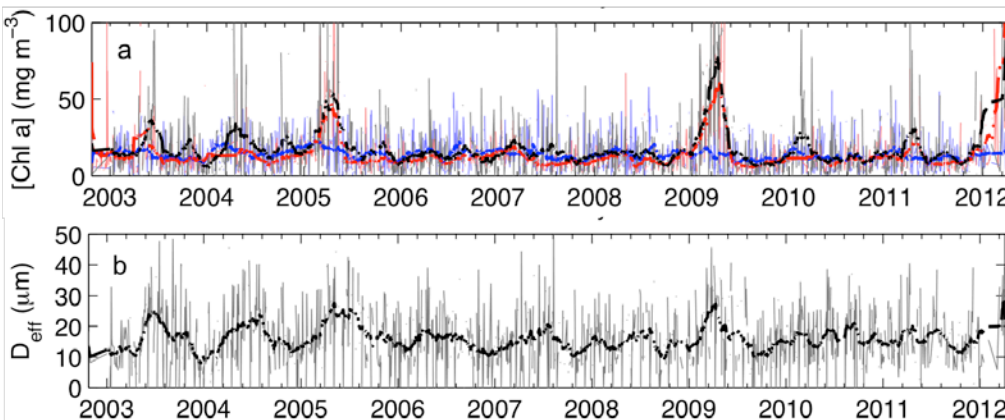
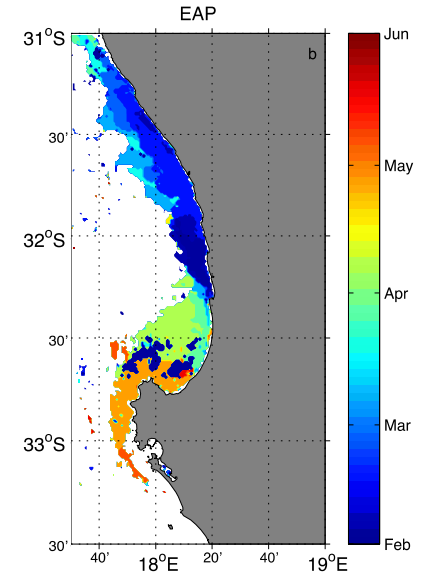
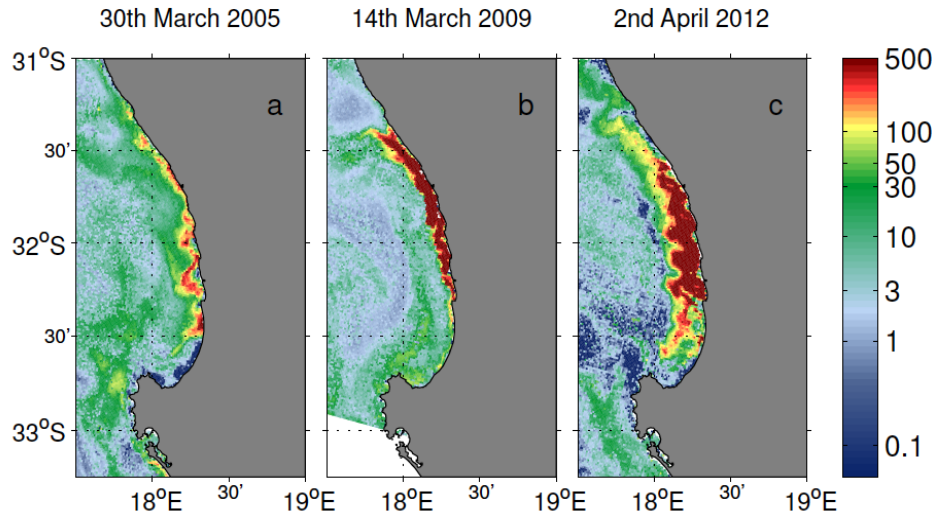
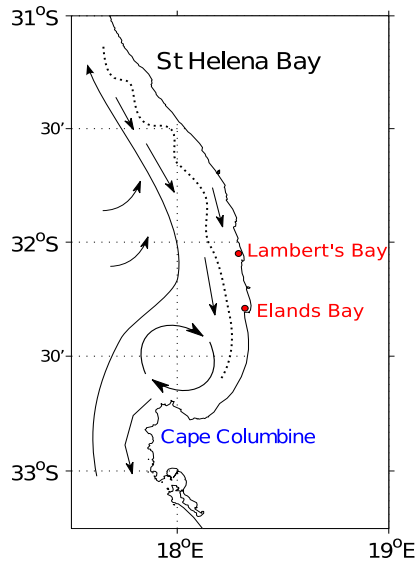
Astoreca et al., 2009

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

NOAA HAB-OFS Conditions Report

Click on the icon of Adobe Acrobat Reader link to download the PDF reader - 

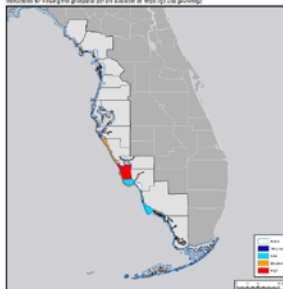
Gulf of Mexico Harmful Algal Bloom Bulletin
Monday, July 2, 2018
NOAA National Ocean Service
NOAA Satellite and Information Service
NOAA National Weather Service

Region: Southwest Florida

Conditions Report
Not assessed: High concentrations of Karenia brevis (commonly known as red tide) are present along and offshore portions of southwest Florida, and not present in the Florida Keys. K. brevis concentrations are patchy in nature and levels of respiratory irritation will vary widely based upon weather, algal concentration, ocean currents, and wind speed and direction.

Recently Reported Impacts (Sorted by County):
Respiratory Irritation: Scissors and Lee
Dead Fish: Scissors and Lee
Discarded water: None

Additional Resources
Health Information:
Florida Department of Health: <http://www.floridahealth.gov/environmental-health/aquatic-toxicology/>
Other resources: <http://go.usa.gov/qW9p>
Recent Local Observations and Data:
State Marine Laboratory Daily Beach Conditions: <http://www.floridamarine.org/>
Florida Fish and Wildlife Conservation Commission: <http://myfwc.com/conservation/>



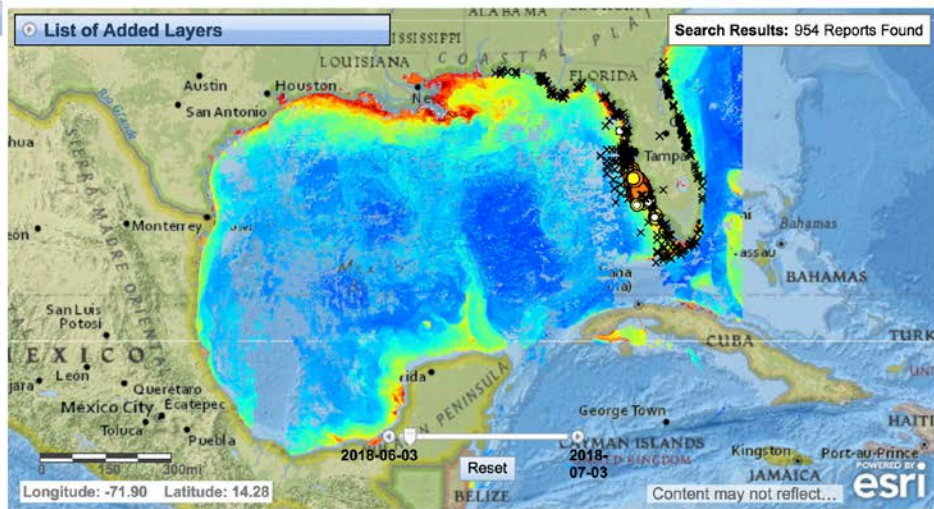
NOAA Harmful Algal Blooms Observing System

Zoom In Zoom Out Full Extent Prev Extent Next Extent Pan Stop Zoom Metadata Map Information HABSOS Main Page

List of Added Layers Search Results: 954 Reports Found

Search Add Layers Legend Tools

- Foundation Layers
- Remotely Sensed Imagery
 - Chlorophyll - Monthly Climatology January
 - Enhanced True Color (RGB)
 - Normalized Fluorescence Line Height
 - Sea Surface Temperature
- Oceanography
- Meteorology



Longitude: -71.90 Latitude: 14.28

2018-06-03 2018-07-03

Reset

Content may not reflect... esri

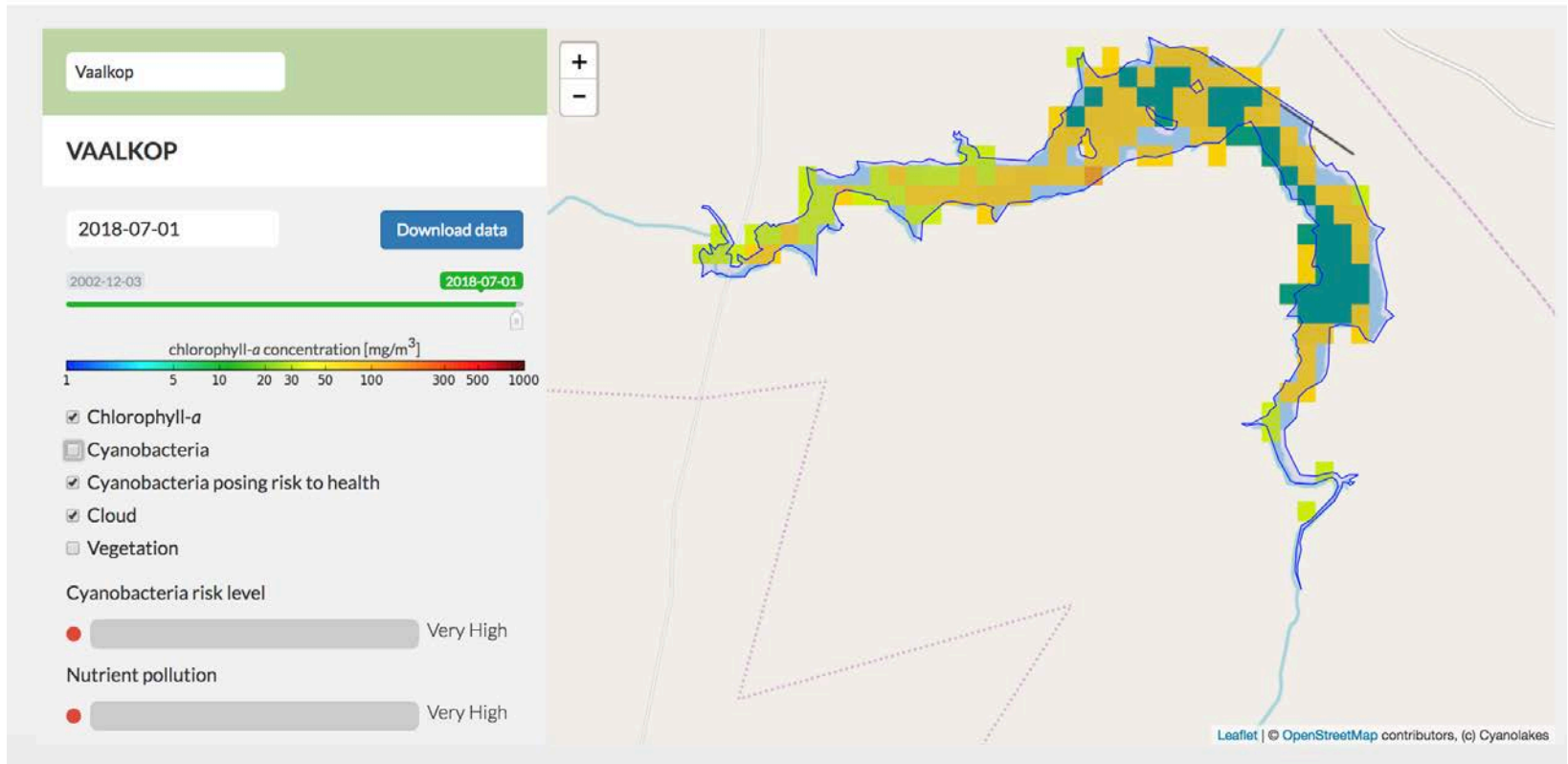
U.S. Department of Commerce | NOAA | NESDIS | NCEI
Disclaimer | Privacy Policy | Copyright Notice | USA.gov

Information Quality | Freedom of Information Act (FOIA)
Customer Service | NCEI.Info@noaa.gov

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



For more information see: www.cyanolakes.com
and <https://cyanolakes.chpc.ac.za/>

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.

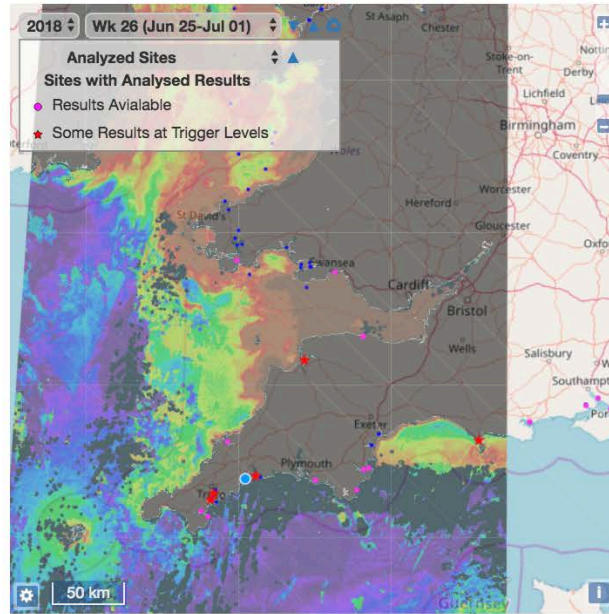
Sites within current map extent:
 B70AE: Ropehaven Outer (St. Austell Bay) zoom to site

B70AE
 8 Week history from current on map
 (Click on parameter name for a long term chart history)

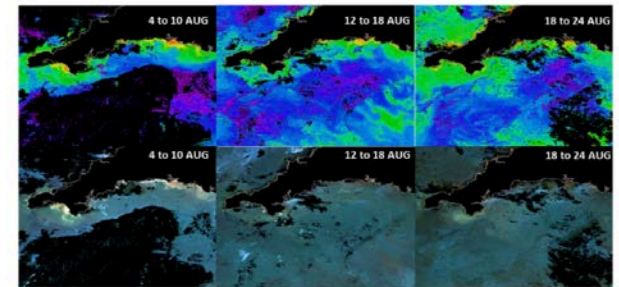
Parameter	2018	2018	2018	2018	2018	2018	2018
year/wk ->	19	20	21	22	23	24	25
PSP	x	●	●	●	●	●	●
OA/DTXs/PTXs	x	●	●	●	●	●	●
AZAs	x	x	x	x	x	x	x
YTXs	x	x	x	x	x	x	x
ASP	x	●	●	●	●	●	●
Karenia mikimotoi	x	x	x	x	x	x	x
Alexandrium Sp	x	●	●	●	●	●	●

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)

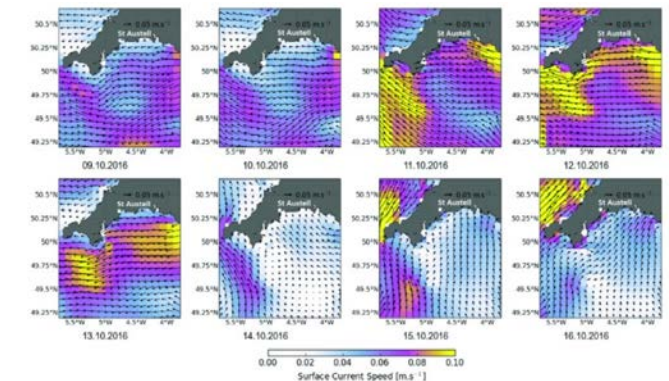


Temporal evolution of the bloom



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

- Smayda et al., (2003): https://aslopubs.onlinelibrary.wiley.com/doi/abs/10.4319/lo.1997.42.5_part_2.113
- Dierssen et al., (2006): <https://aslopubs.onlinelibrary.wiley.com/doi/abs/10.4319/lo.2006.51.6.2646>
- Defoin-Platel and Chami (2007): <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2006JC003847>
- Evers-King et al., (2014): https://www.osapublishing.org/DirectPDFAccess/B7BA5E7F-F0F7-5725-9294E1A837A0CC72_284439/oe-22-10-11536.pdf?da=1&id=284439&seq=0&mobile=no
- Kudela et al., (2017): https://www.researchgate.net/profile/Clarissa_Anderson/publication/323497462_Designing_an_observing_system_for_early_detection_of_harmful_algal_blooms/links/5a985693aca27214056d48ac/Designing-an-observing-system-for-early-detection-of-harmful-algal-blooms.pdf#page=118
- Astoreca et al., (2009): <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2639444/>
- Kurekin et al., (2014): <https://www.ncbi.nlm.nih.gov/pubmed/28040105>
- 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

