States' most definitive statement on climate change science.

The White House put out a statement Friday that seemed to undercut the high level of confidence of the report's findings.

"The climate has changed and is always changing," Raj Shah, a White House spokesman, said in the statement. "As the Climate Science Special Report states, the magnitude of future climate change depends significantly on 'remaining uncertainty in the sensitivity of Earth's climate'" to greenhouse gas emissions, he added.

Despite the scientific consensus presented in the report, the Environmental

Global Change Biology

Global Change Biology (2015) 21, 2206–2214, doi: 10.1111/gcb.12854

# Decrease in water clarity of the southern and central North Sea during the 20th century

ELISA CAPUZZO[1], DAVID STEPHENS[1], TIAGO SILVA[1], JON BARRY[1] and RODNEY M. FORSTER[1,2]

Received: 18 May 2017 | Revised: 27 August 2017 | Accepted: 29 August 2017

DOI: 10.1111/gcb.13916

PRIMARY RESEARCH ARTICLE

WILEY Global Change Biology

# A decline in primary production in the North Sea over 25 years, associated with reductions in zooplankton abundance and fish stock recruitment

Elisa Capuzzo[1] | Christopher P. Lynam[1] | Jon Barry[1] | David Stephens[2] | Rodney M. Forster[3] | Naomi Greenwood[1,4] | Abigail McQuatters-Gollop[5] | Tiago Silva[1] | Sonja M. van Leeuwen[1] | Georg H. Engelhard[1,4]

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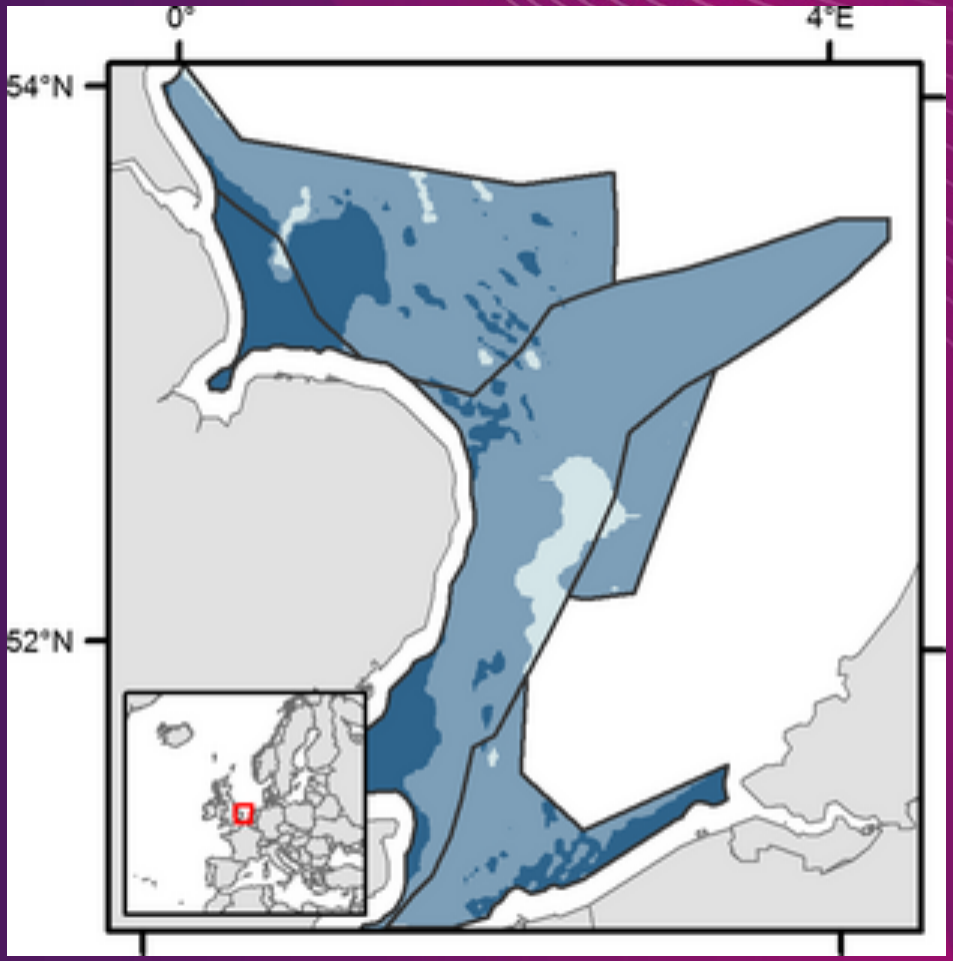
# The water is now darker




Comparison of sea floor area within photic zone pre- and post-1950 for PMX and EAP during summer (May–August). The dark areas indicate part of the sea floor which were in the photic zone in summer pre-1950 and in post-1950; lighter areas used to be within the photic zone in summer pre-1950 but not in post-1950; very light areas of sea floor were not in the photic zone in summer pre-1950 nor in post-1950

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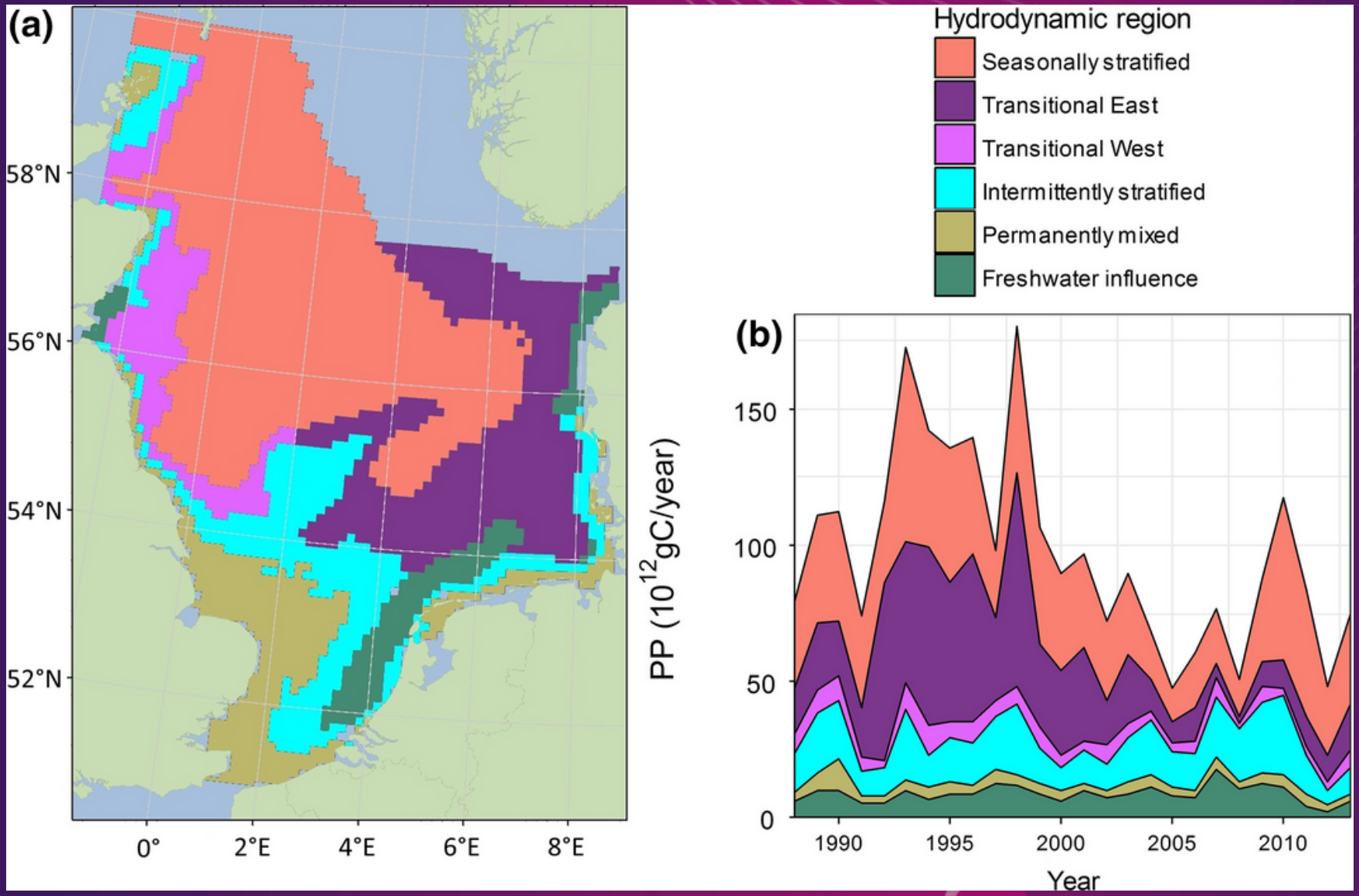
# Production is now lower



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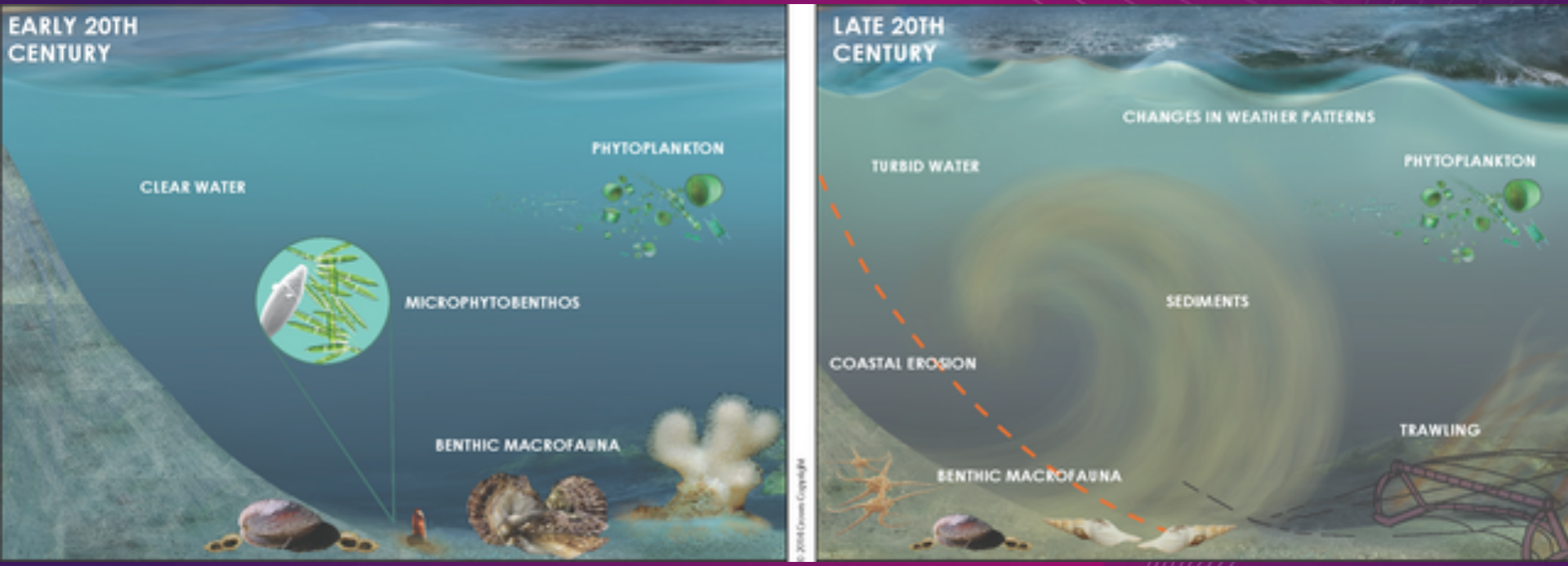
# Causes of North Sea change



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# Developments in satellite mapping of the intertidal zone and coastal seas

**Rodney Forster**
**IECS**
**University of Hull, UK**

**Keynote 3**

## COAST Bordeaux 2017

Evolution systémique et de la biodiversité des environnements côtiers et littoraux sous la pression du changement climatique, des facteurs naturels et anthropiques locaux

**Du 7 au 10 novembre 2017 - Domaine du Haut Carré**

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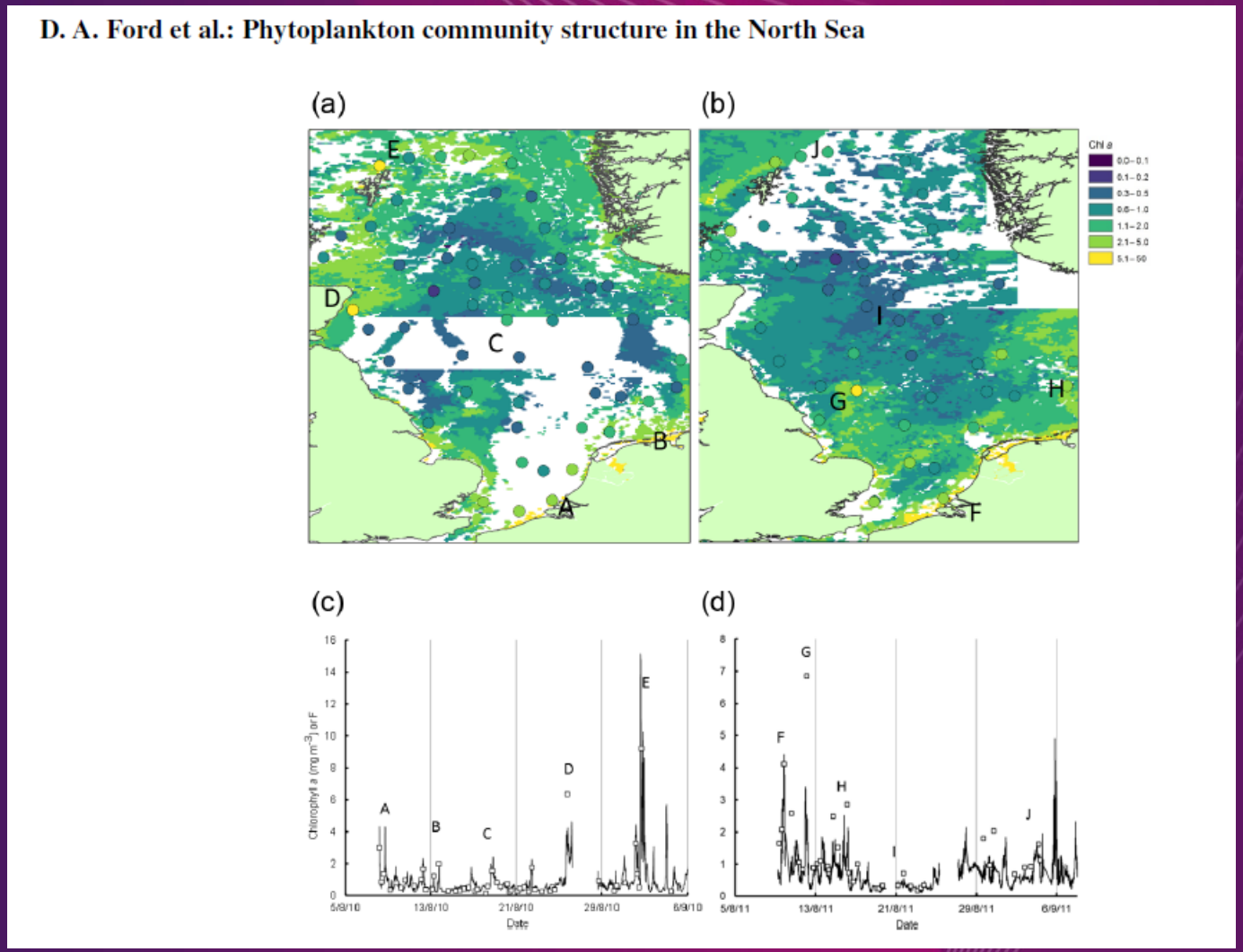
# Remote sensing of phytoplankton




Observing and modelling phytoplankton community structure in the North Sea
Ford et al. (2017) Biogeosciences 14: 1419-1444.

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# Satellite ocean colour

Routinely in use for marine assessment and policy purposes:

- is easy to download and use
- has a harmonised time series since 1997
- has 1 – 4 km spatial resolution
- correlates well with *in situ* measurements in offshore waters


Optically deep
[water+phyto+cDOM]
Complex coastal waters
Optically deep
[cDOM]
Optically shallow
[Scattering sediments]
Optically shallow
[phyto rich]

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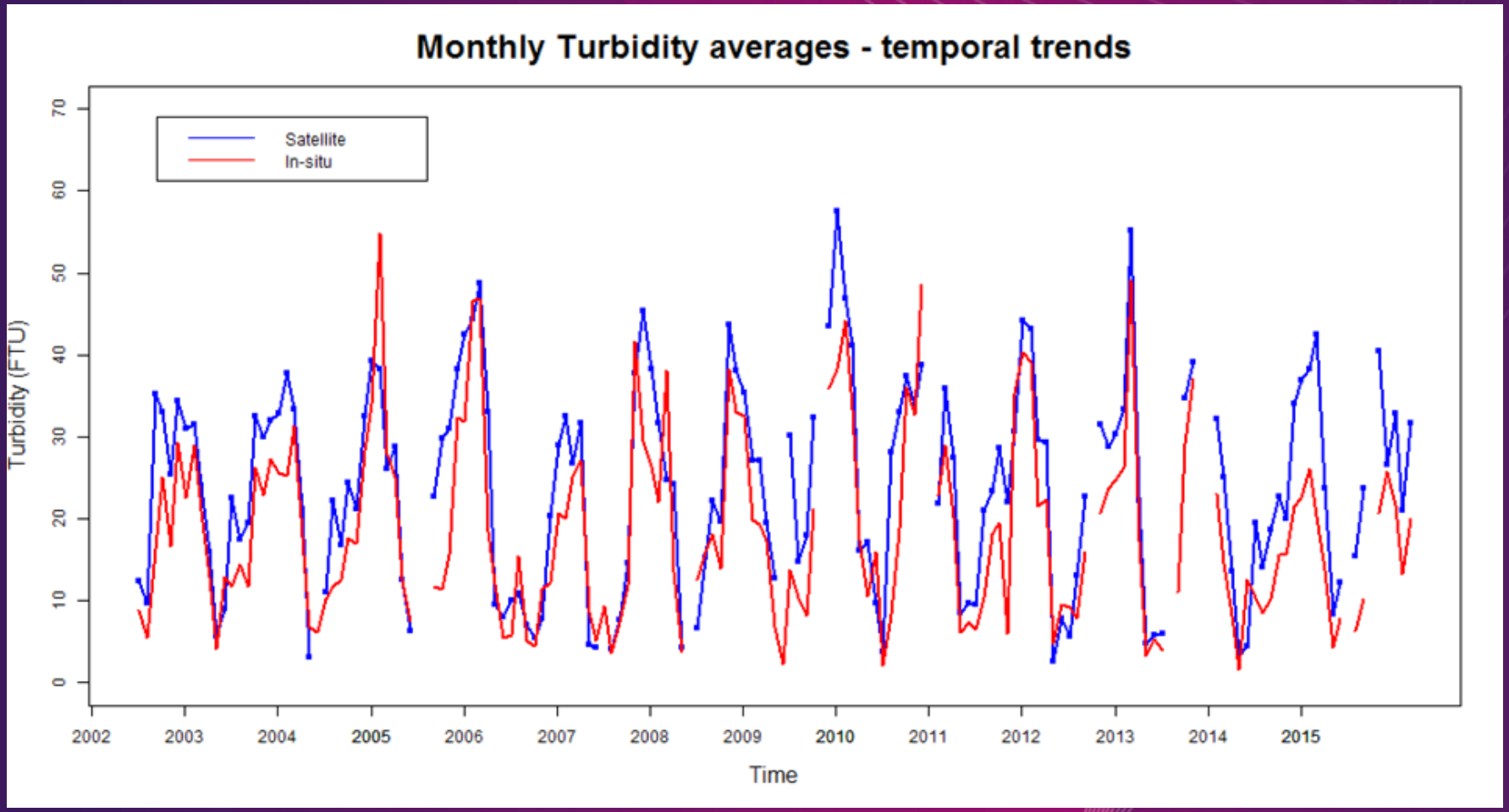
# Validation versus in situ



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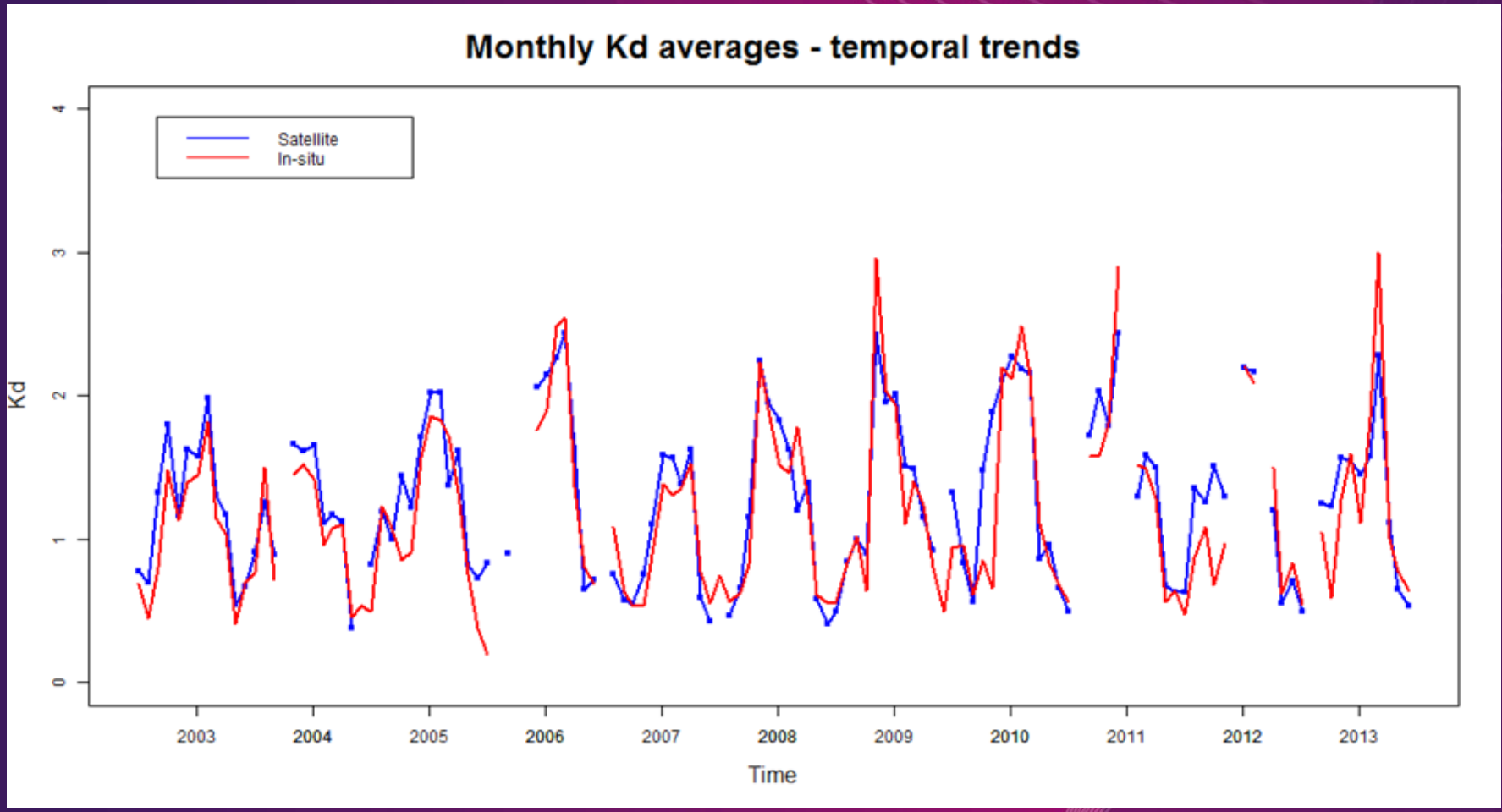
# Validation versus in situ



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# Understanding coastal ecosystem response

Problems:

wide range of habitats to sample
access can be difficult
traditional monitoring programmes are expensive

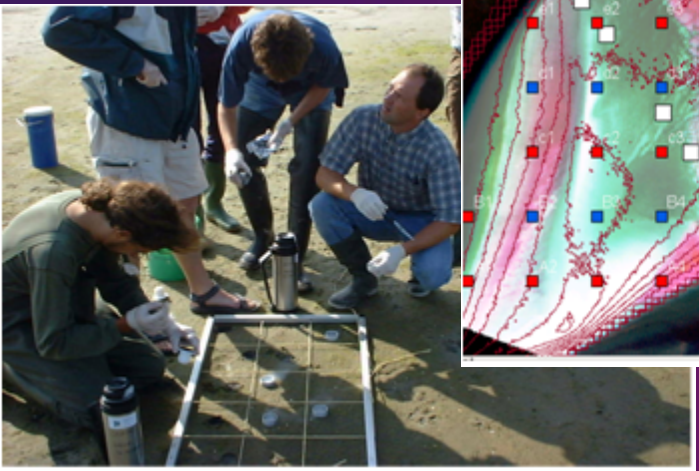
Can remote sensing be of use?

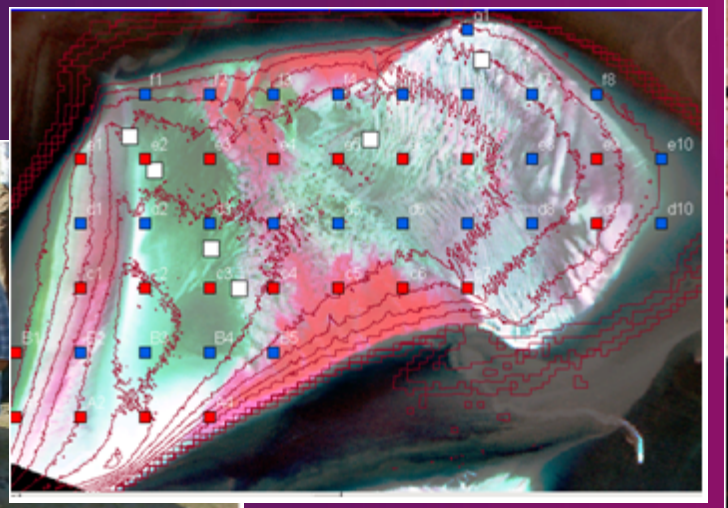
HIMOM

Site studies

New methods

Intercalibration





RS and GIS tools

# Remote sensing of the Westerschelde estuary

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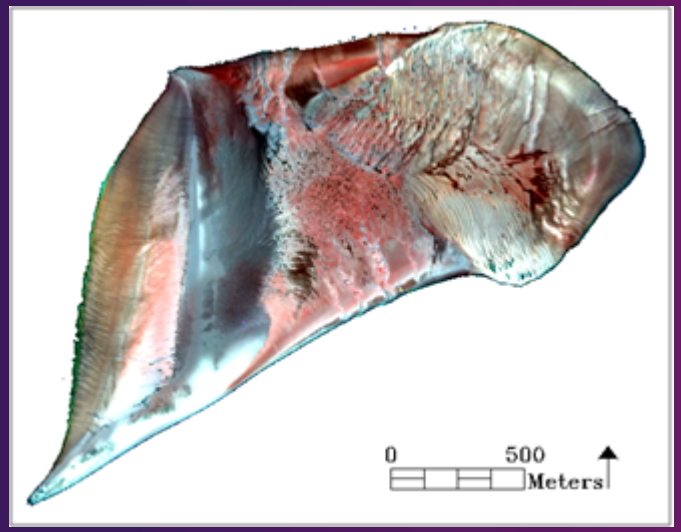


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# Sentinel-2 for inshore waters

Copernicus
Europe's eyes on Earth

Sentinel satellites + in situ component

S2A June 2015

S2B March 2017

HIGH spatial and temporal Resolution Ocean Colour products and services (2014-2017)

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# Intertidal sediment surfaces

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# Time series of NDVI for The Wash

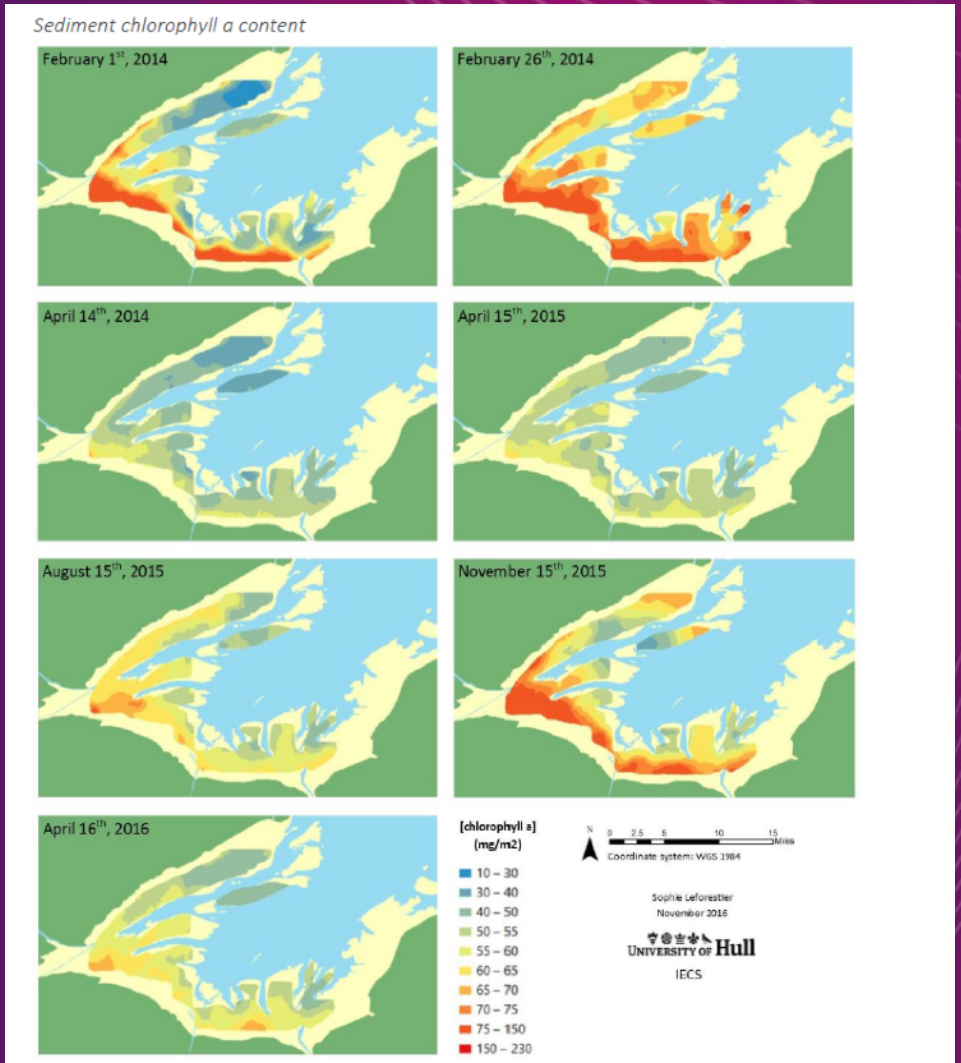


*Figure 11: Evolution of the spatial distribution of sediment chlorophyll a concentration from February 2014 to April 2016, in The Wash.*

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# Sentinel-2 RGB

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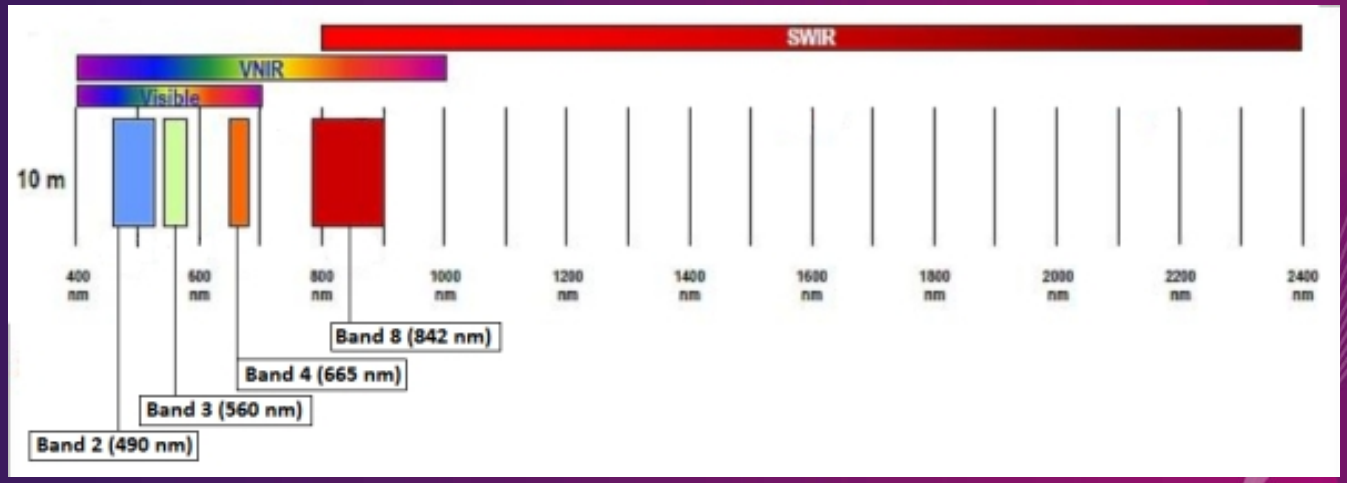
# Sentinel-2 IR false colour



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# Satellite revisit time for Landsat and Sentinel-2

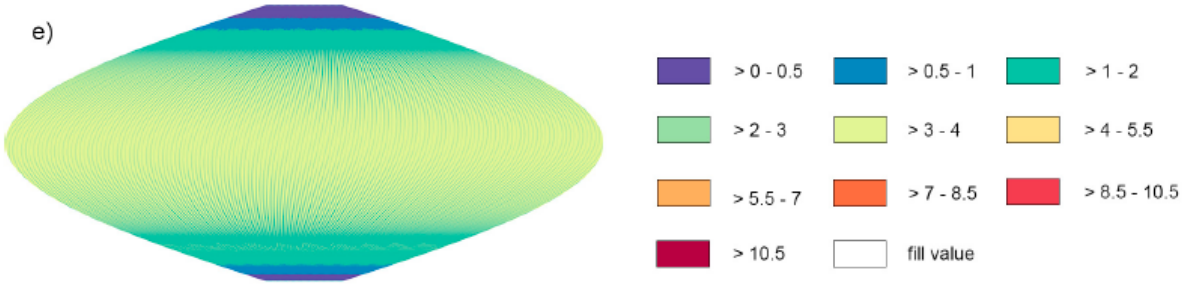


**Figure 5.** The average satellite revisit interval (days) from 1 January to 31 December 2016 for: (**a**) Sentinel-2A; (**b**) Landsat-8; (**c**) Landsat-8 and Sentinel-2A; (**d**) Sentinel-2A and Sentinel-2B; and (**e**) Landsat-8, Sentinel-2A and Sentinel-2B. Global results derived at 7201 × 3601 points spaced every 5.559752 km, equivalent to 0.05° at the Equator, in the equal area sinusoidal projection.

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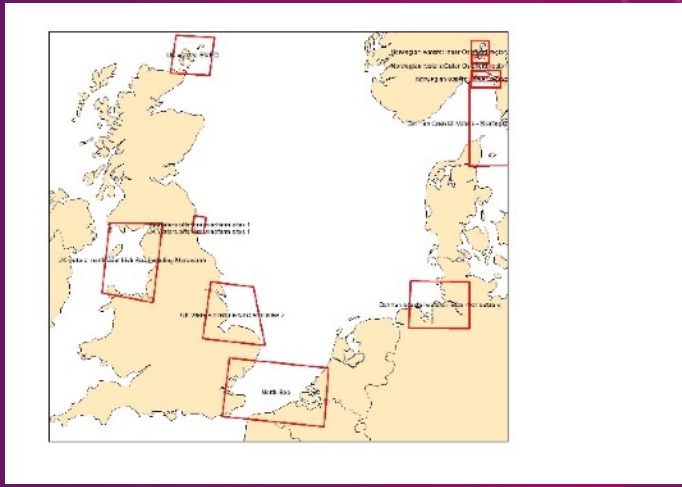
# Automated processing chain

Download module → Formatting → Pre-processor IDEPIX → Adjacency correction SIMEC → Atmospheric correction ACOLITE → L2W



# On demand processing

Download module → Atmospheric correction ACOLITE → Products for user

highroc.eu

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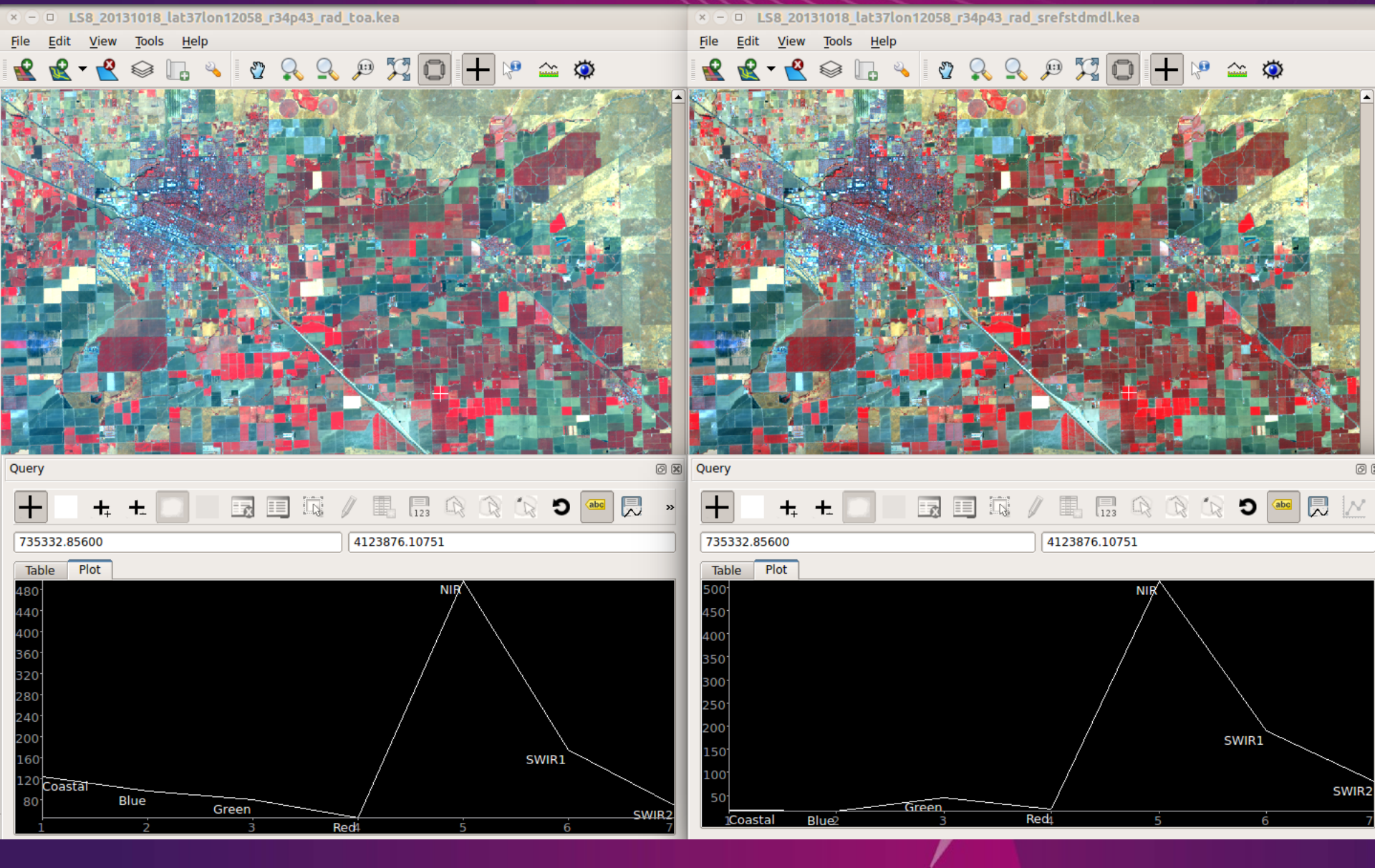
# Atmospheric correction



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# L2 Products

| Parameter (units) | Symbol | Type |
|---|---|---|
| Remote sensing reflectance spectrum ($sr^{-1}$) at water level | Rrs | L2R |
| Aerosol reflectance spectrum | RHOa | L2R (aux) |
| Aerosol reflectance Angstrom exponent | ANG | L2R (aux) |
| Aerosol optical thickness | AOT | L2R (aux) |
| Suspended Particulate Matter (g $m^{-3}$) | SPM | L2W/S |
| Turbidity (FNU) | TUR | L2W/S |
| Particulate backscatter at 555nm ($m^{-1}$) | bbp555 | L2W/S (aux) |
| Chlorophyll a (mg $m^{-3}$) | CHL | L2W/C |
| Algal pigment absorption coefficient at 443nm ($m^{-1}$) | apig443 | L2W/C (aux) |
| Diffuse attenuation coefficient spectrum ($m^{-1}$) | Kd | L2W/K |
| Diffuse attenuation coefficient of PAR ($m^{-1}$) | KdPAR | L2W/K |
| Euphotic depth (m) | Ze | L2W/K |
| CDOM absorption coefficient at 443nm ($m^{-1}$) | aCDOM443 | L2W |
| Secchi Depth (m) | SD | L2W |
| RGB Image (Rayleigh corrected) | RGB | L1 |

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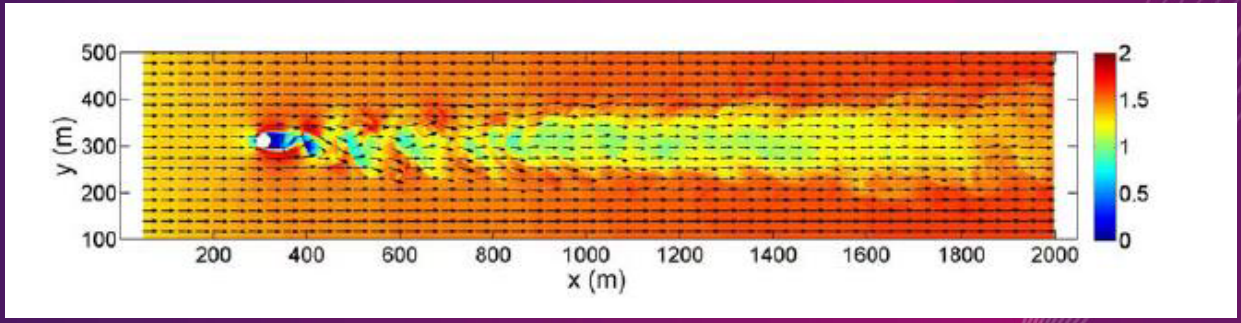
# Sentinel-2 case study – offshore wind

Turbid wake formation downstream of wind turbine monopiles



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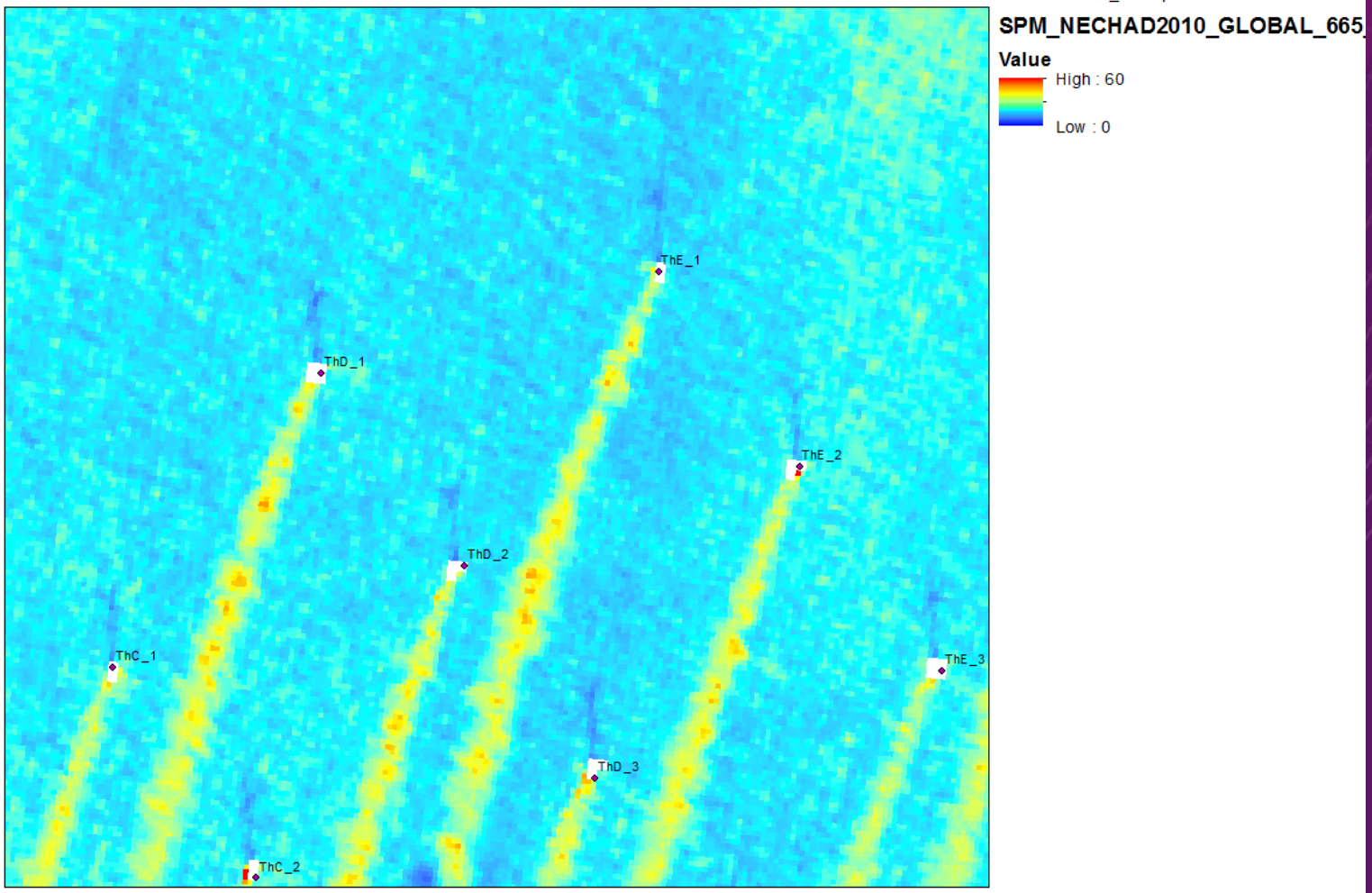
# L2W product for Suspended Particulate Matter



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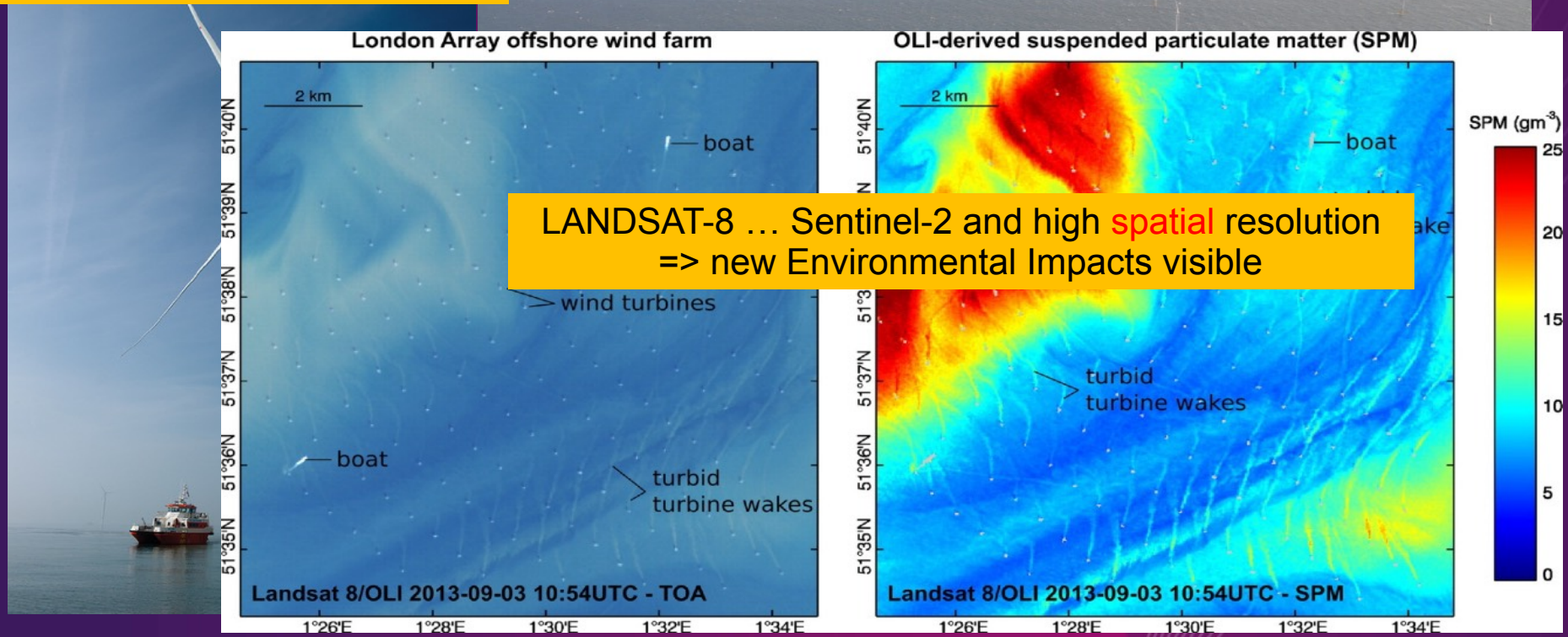
# Sentinel-2 case study – offshore wind

Environmental Impacts Assessment
legal obligation for offshore wind farm construction




LANDSAT-8 … Sentinel-2 and high spatial resolution
=> new Environmental Impacts visible

[Vanhellemont Q & Ruddick K (2014). Turbid wakes associated with offshore wind turbines obser
with Landsat 8. Remote Sensing of Environment, 145, pp. 105–115. Open Access]

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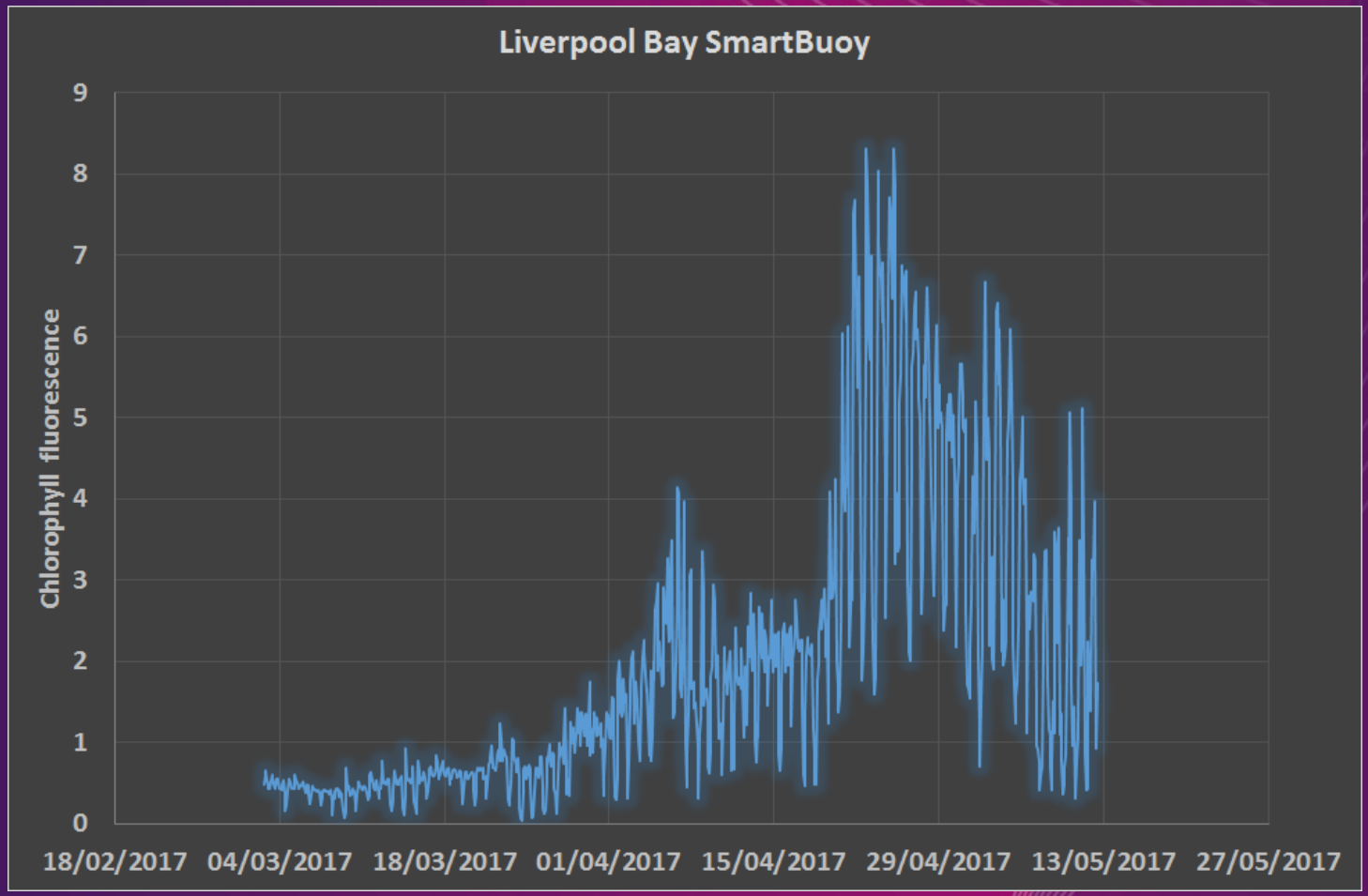
# Chlorophyll detection **in situ** observation



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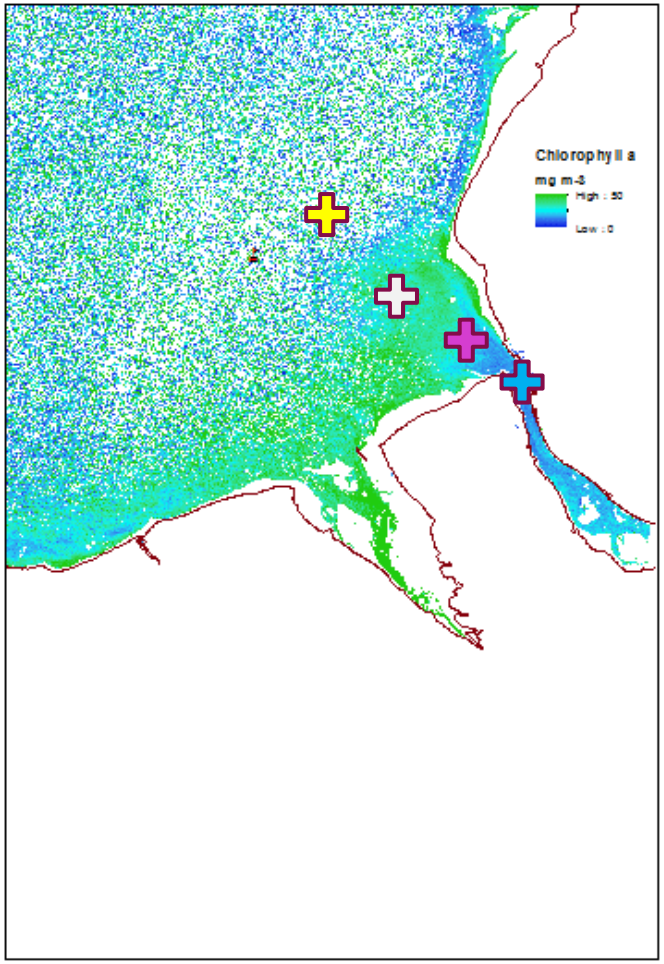
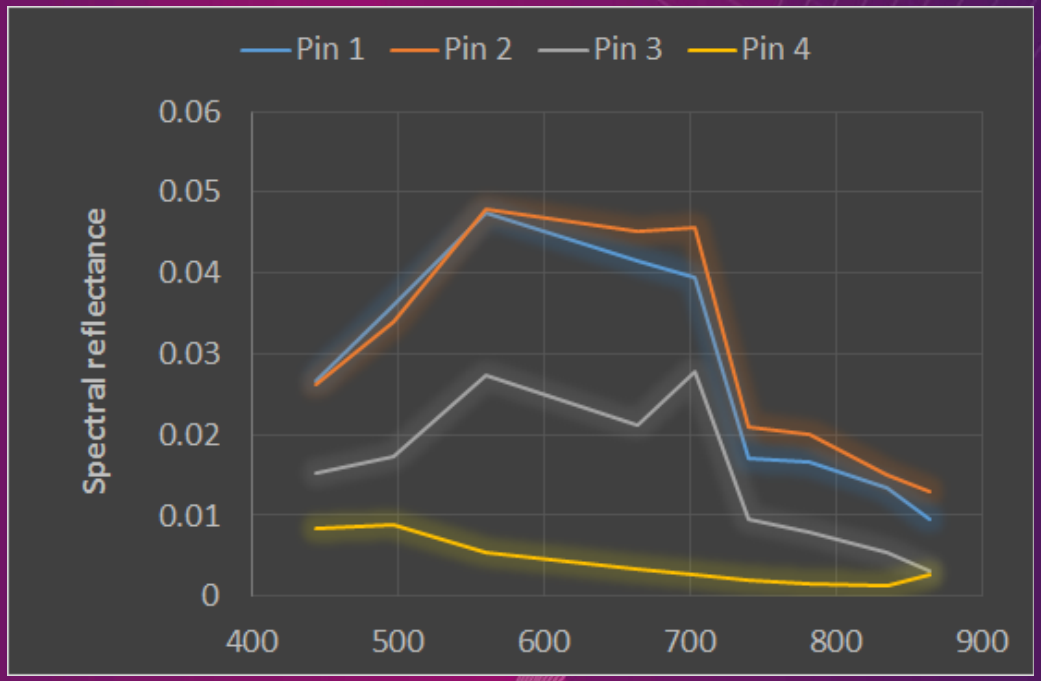
# Red / NIR Bloom detection



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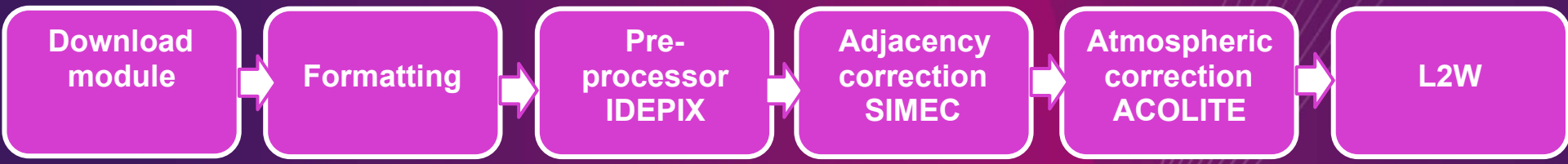
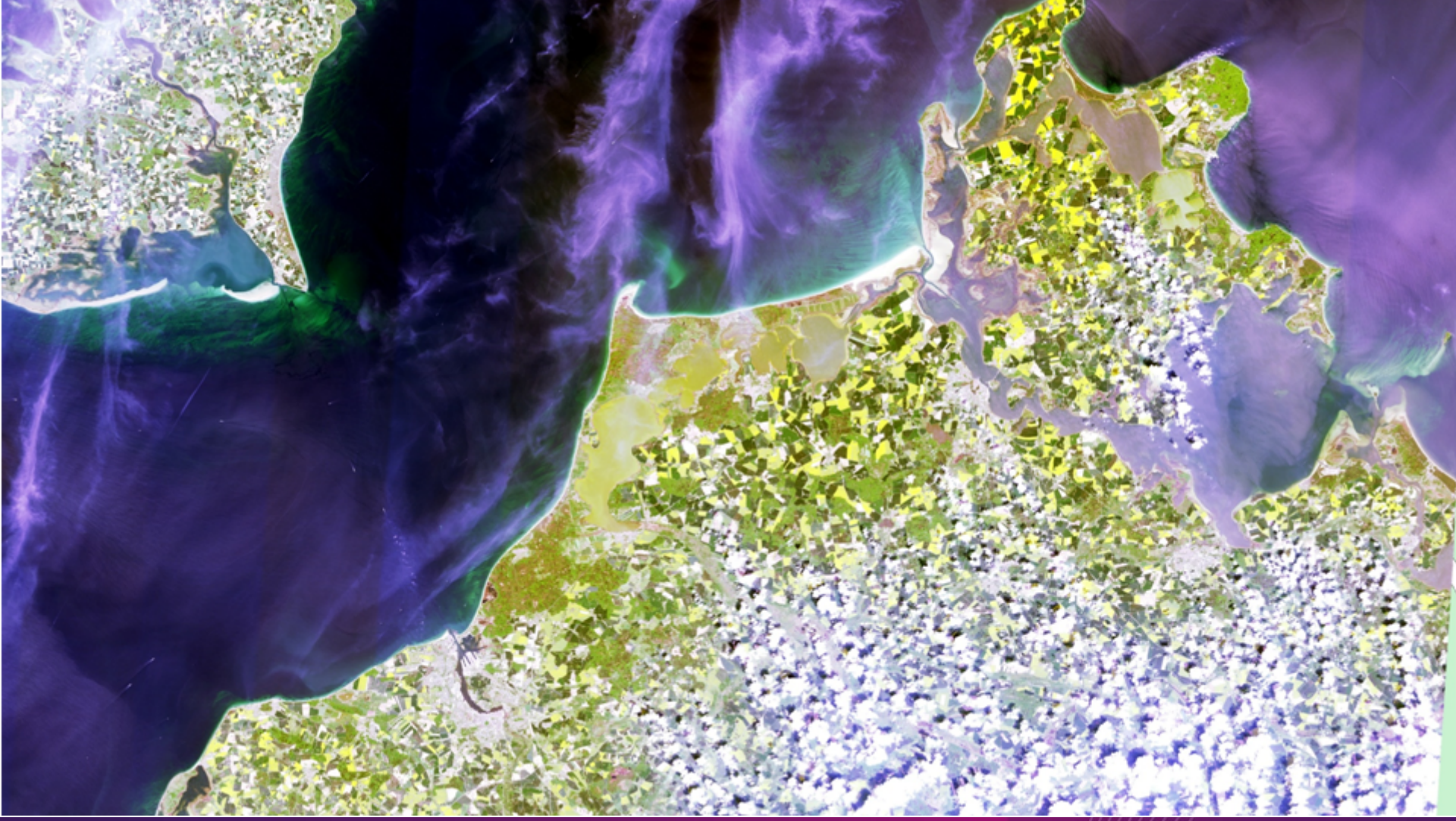
# Red / NIR Bloom detection

$$Chl = \frac{1}{a_{phy}{}^{*}} \left( \frac{R_{705}}{R_{665}} (a_{w705} - b_b) + a_{w665} - b_b{}^{p} \right)$$

## Gons, 1999 RED/NIR algorithm

Work in progress: (1) test R/NIR algorithms (2) incorporate into processing chain (3) develop user case studies





Darss-Zingst bodden chain

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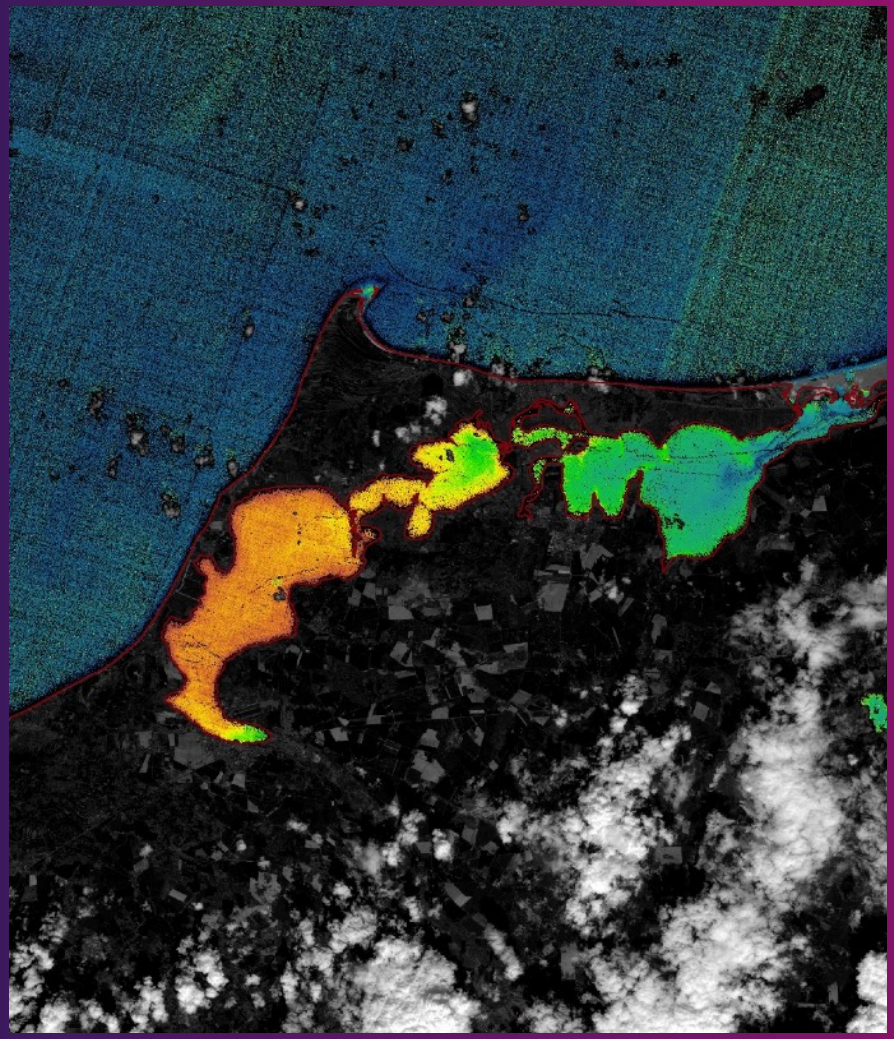
# Processing to estimate chlorophyll concentration (mg m-3)



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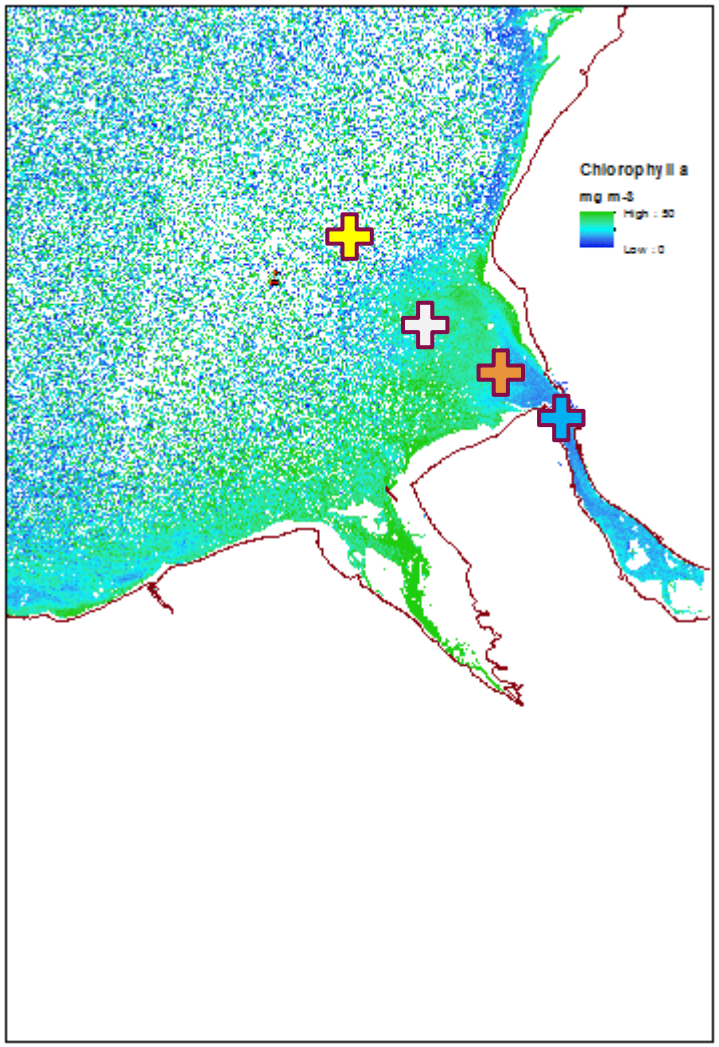
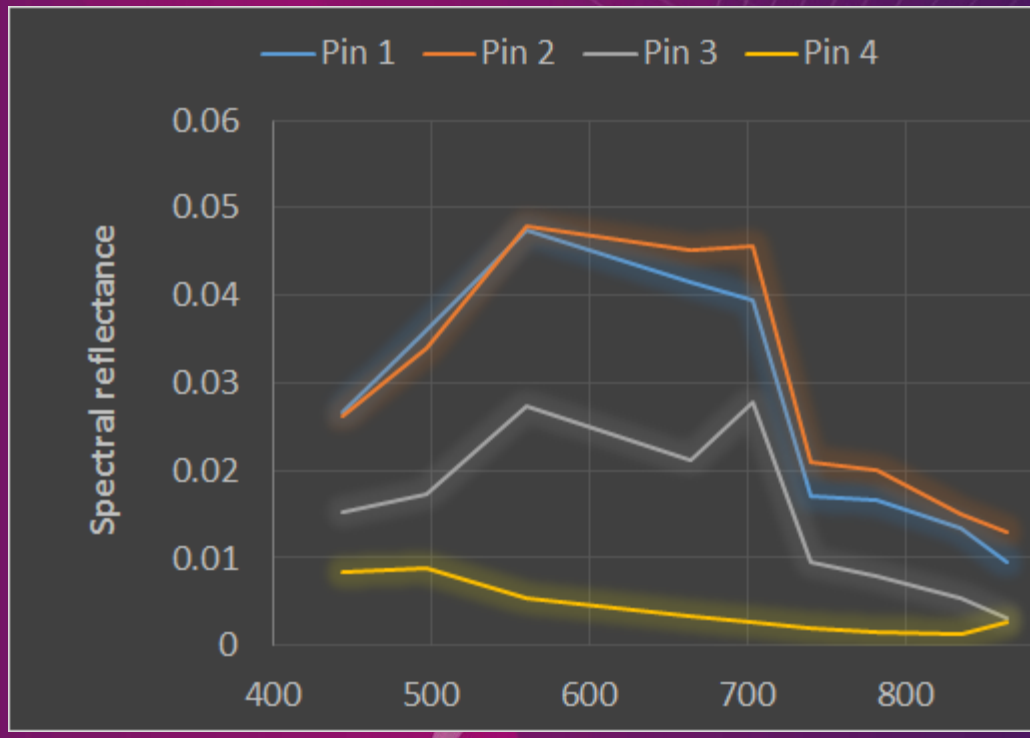
# Build confidence in ocean colour




HIGHROC user case studies: offshore wind, dredging, aquaculture, water quality



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# Validation

Ferryboxes

Reflectance, CHL-F, etc.

R/V Belgica


AERONET-OC (Blyth)

Mesurho Buoy


Smartbuoy network

Cruises/Experiments:
AOP+IOP

Turbidity
Kd
CHL-F

Reflectance Validation

AERONET-OC (Thornton)

AERONET-OC (Zeebrugge)

Significant contribution to Validation of Sentinel-3, Sentinel-2 (and Landsat-8, MODIS, PROBA-V, etc.)

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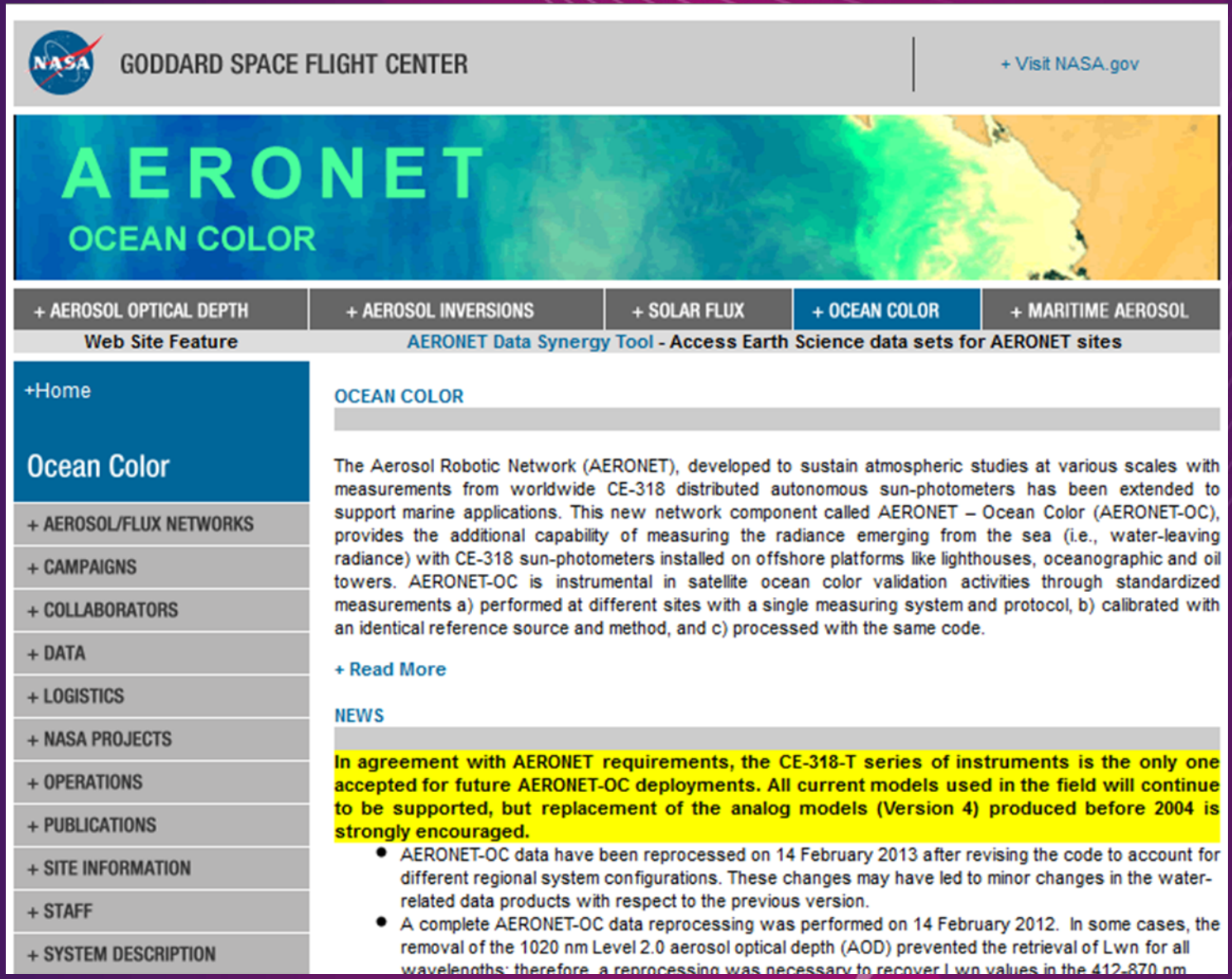
# Ocean colour validation



GODDARD SPACE FLIGHT CENTER

+ Visit NASA.gov

AERONET

OCEAN COLOR

+ AEROSOL OPTICAL DEPTH | + AEROSOL INVERSIONS | + SOLAR FLUX | + OCEAN COLOR | + MARITIME AEROSOL

Web Site Feature

AERONET Data Synergy Tool - Access Earth Science data sets for AERONET sites

+Home

Ocean Color

+ AEROSOL/FLUX NETWORKS
+ CAMPAIGNS
+ COLLABORATORS
+ DATA
+ LOGISTICS
+ NASA PROJECTS
+ OPERATIONS
+ PUBLICATIONS
+ SITE INFORMATION
+ STAFF
+ SYSTEM DESCRIPTION

OCEAN COLOR

The Aerosol Robotic Network (AERONET), developed to sustain atmospheric studies at various scales with measurements from worldwide CE-318 distributed autonomous sun-photometers has been extended to support marine applications. This new network component called AERONET – Ocean Color (AERONET-OC), provides the additional capability of measuring the radiance emerging from the sea (i.e., water-leaving radiance) with CE-318 sun-photometers installed on offshore platforms like lighthouses, oceanographic and oil towers. AERONET-OC is instrumental in satellite ocean color validation activities through standardized measurements a) performed at different sites with a single measuring system and protocol, b) calibrated with an identical reference source and method, and c) processed with the same code.

+ Read More

NEWS

**In agreement with AERONET requirements, the CE-318-T series of instruments is the only one accepted for future AERONET-OC deployments. All current models used in the field will continue to be supported, but replacement of the analog models (Version 4) produced before 2004 is strongly encouraged.**

- AERONET-OC data have been reprocessed on 14 February 2013 after revising the code to account for different regional system configurations. These changes may have led to minor changes in the water-related data products with respect to the previous version.
- A complete AERONET-OC data reprocessing was performed on 14 February 2012. In some cases, the removal of the 1020 nm Level 2.0 aerosol optical depth (AOD) prevented the retrieval of Lwn for all wavelengths; therefore, a reprocessing was necessary to recover Lwn values in the 412-870 nm

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# Search for a UK site (1)

Tower Roughs, Thames

Haile Sand, Humber

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# Search for a UK site (2)

NOAH met mast, off Blyth, Northumberland

Detailed wind measurements for OWF


Deck at 21 m

**24V power supply**
**Internet comms**

CATAPULT
Offshore Renewable Energy

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# Layout


robot

Control box

UPS 12V battery

Panel PC

12V battery for AERONET

U.P.S.

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# Maintenance

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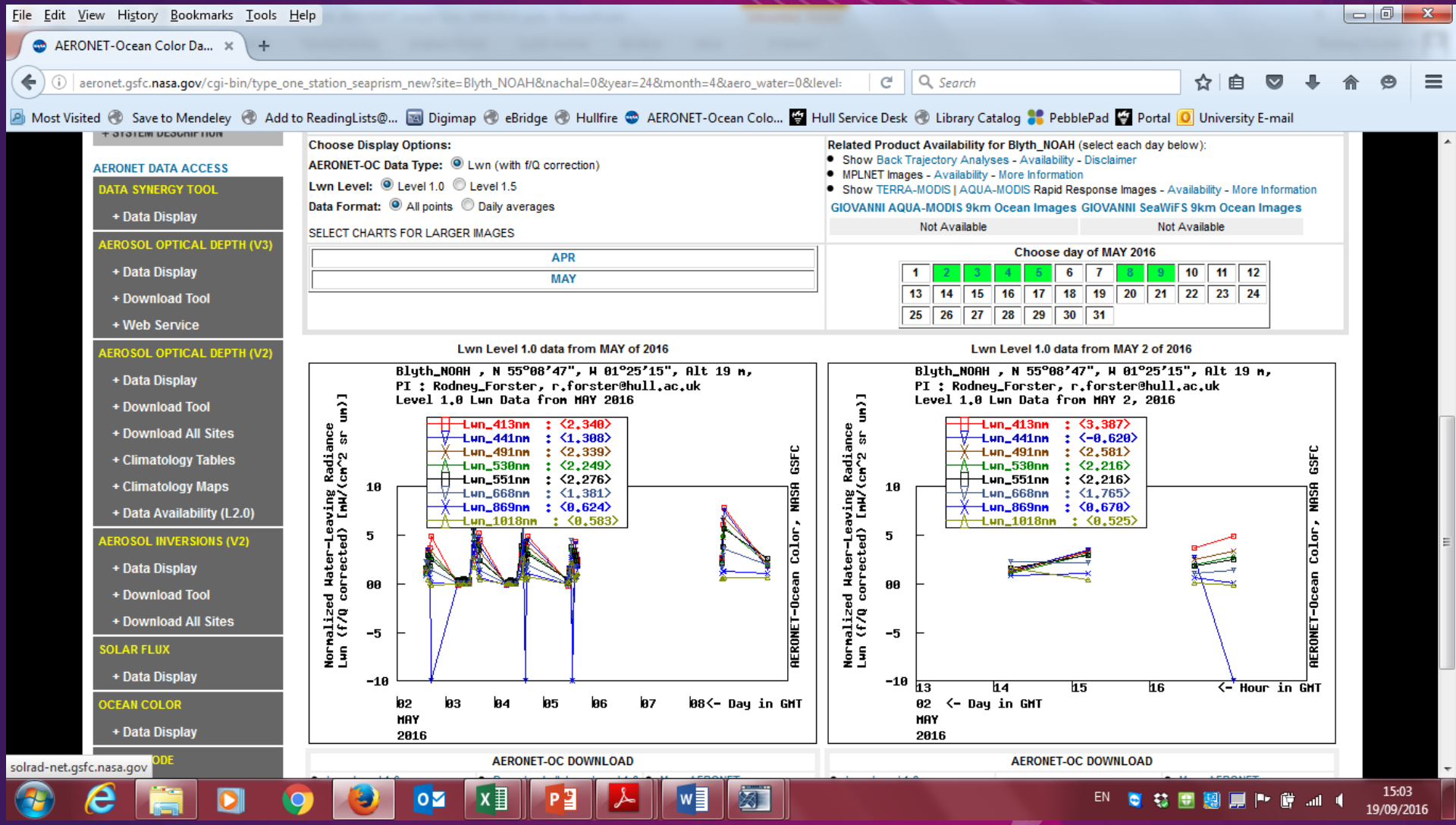
# First data at NASA GSFC



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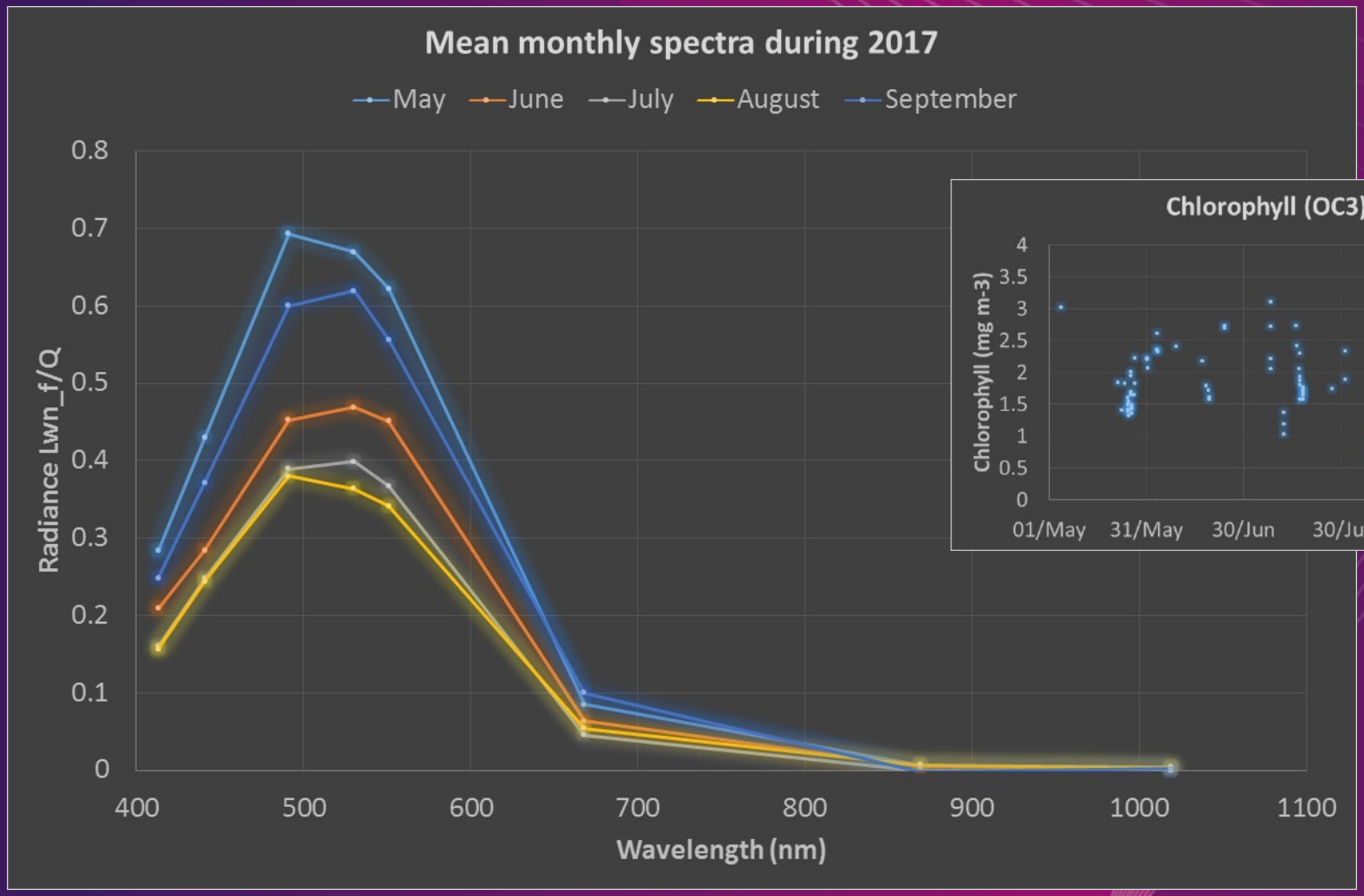
# Surface reflectance



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# Thank you!

HIGHROC: www.highroc.eu

New H2020: **DSC4COP** – I need a postdoc (datacubes, Jupyter notebooks, HPC…)

Sentinels:
About: http://www.copernicus.eu/main/sentinels
Viewer: http://apps.sentinel-hub.com/eo-browser/