# **Satellite-assisted monitoring of water quality to support the implementation of the Water Framework Directive**

# Introduction

# Water Framework Directive (WFD)

# Satellite observation derived metrics can help fill these gaps, particularly with regard to biological quality elements of medium (several km2) to large-sized surface waters

# (short-lived phytoplankton blooms; short-term changes in angiosperm abundance in intertidal areas) (all four biological quality elements BQE1-1 to BQE1-4) (transparency)

# A growing use of satellite observation for water quality

# Additional information from satellite observations

# The biomass of phytoplankton can be produced using satellite observations using Chl-a as a proxy. Recently, the Centre for Limnology in Estonia used data from the Sentinel-2 multispectral instrument (MSI) at 10 m spatial resolution to observe phytoplankton biomass in Estonian lakes.

# monitor the frequency and intensity of phytoplankton blooms. Currently, only bloom intensity is measured8,9 because measuring the frequency of blooms has been considered too costly. Revision of the WFD provides an opportunity to address this by explicitly including reference to satellite-derived Chl-a as a cost-effective method to address this component of the legislation. Diagnostic information on the presence of cyanobacteria in surface waters from satellite observations would likely provide additional value.

# Improving spatial and temporal observation coverage

# Towards a standardised and harmonised approach

# Standardisation should include elements of how observation methodologies (algorithms) are assessed, how observations from multiple sensors are combined, and how product uncertainties compare with currently used methods. Harmonisation efforts should include the fusion of in situ and remote observations as well as the merging of results originating from complementary methodologies (algorithms), all the while upholding standards of measurement.

# Holistic assessment and implementation of Programme of Measures

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# Potential barriers to uptake

# The Water Framework Directive requires that multiple biological, chemical and physical elements be measured.

# ##Satellite observation cannot provide all quality elements required by the WFD. Therefore, in situ sampling is necessary and, strictly speaking, makes the satellite products (such as Chl-a, turbidity, macrophytes and angiosperms) surplus to requirement.

# ##Lack of trust in satellite products compared to conventional assessment methods, where the latter have been inter[1]calibrated. Laboratory methods can be quality controlled using lab standards and replication, whereas satellite products are validated by comparison to in situ observation and may have hidden bias.

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# **AI for Earth Observation**

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# **Week 1&2:** Copernicus satellite data

# **Week 4:** Monitoring the Oceans

* + **Topic 4d:**

# **Part 1:** Habitat mapping of fish

# **Part 2&3:** Sea surface temperature, food, season, length of day,

# **Topic 4f:** Using ML to Differentiate Between Sediment and Chlorophyll

# **Topic 4g:** Using ML To Combine Water Quality Data From Different Satellites

# **Climate change and AI report**

[climate-change-and-ai.pdf (gpai.ai)](https://gpai.ai/projects/responsible-ai/environment/climate-change-and-ai.pdf)

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# **Key areas where AI can facilitate climate action**

# **#Distilling raw data into actionable information**

# **#Improving predictions**

# **#Optimizing complex systems**

# **#Accelerating scientific modeling and discovery.**

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# Copernicus website Data Extraction

* [What is OPeNDAP and how to access Copernicus Marine data?](https://help.marine.copernicus.eu/en/articles/6522070-what-is-opendap-and-how-to-access-copernicus-marine-data)
* [How to Consume the OPeNDAP API and CAS SSO using python](https://help.marine.copernicus.eu/en/articles/5182598-how-to-consume-the-opendap-api-and-cas-sso-using-python)
* [Good Explanation of OPeNDAP for Copernicus Marine Data](https://marine.copernicus.eu/news/access-data-opendap-erddap-api#ThenewOPeNDAPfunctionality)

What to extract?

* Data along UK shoreline

Surfers Against Sewage

* Bathing water data
  + Yearly classification("excellent", "good", "sufficient" or "poor")
  + Escherichia coli & Intestinal Enterococci colonies

Preliminary Ideas

* Collect the following data along the UK shoreline:
  + 1. The ‘y’ variable: Lab tested measures for sewage pollution which we hope to be able to predict from satellite images
  + 2. The ‘X’ variables: Measures from products in the Copernicus Marine Data Store
    - 3 or 4 dimensions for most measurements: latitude, longitude, time (depth)
    - Filter and extract data based on datapoints available from 1.
    - Instead of directly using raw satellite images data, we take processed data from satellites which gives predictions of certain properties of ocean water, and we hope to use this processed data to make more timely predictions on whether there has been sewage pollution
    - Managed to make successful API call
* Correlation analysis / research to inform what are some potential satellite-measurable proxies for sewage pollution
* Run machine learning model to isolate effect of sewage pollution specifically on these satellite-measurable proxies at a cross-sectional level (removing dimension of time)

| Ocean properties related to Sewage Pollution | Relationship to Sewage Pollution (Supporting Research) | Satellite-derived Proxies for the property, as suggested by Whitepaper | Dataset with Satellite-derived Proxies |
| --- | --- | --- | --- |
| Phytoplankton and chlorophyll-a concentration / biovolume | Phytoplankton production and chlorophyll a increased proportionally with sewage effluent enrichment (<https://www.sciencedirect.com/science/article/pii/S0025326X9700115X>) | Chlorophyll-a concentration from  in vivo pigment absorption | Global Ocean Biogeochemistry Analysis and Forecast -  Mass concentration of chlorophyll a in sea water (CHL)  <https://data.marine.copernicus.eu/product/GLOBAL_ANALYSIS_FORECAST_BIO_001_028/description> |
| Macrophyte | High concentration of sewage degrades and eliminates macrophytes rapidly (<https://rcin.org.pl/Content/75201/WA058_86959_P2840-T26_Eko-Pol-A-Nr-1.pdf>) | Areal cover of floating vegetation | North West Shelf Region, Bio-Geo-Chemical, L4, monthly means and interpolated daily observation - Mass concentration of suspended matter in sea water (SPM)  <https://data.marine.copernicus.eu/product/OCEANCOLOUR_NWS_BGC_HR_L4_NRT_009_209/description> |
| Water Transparency | More sewage pollution = lower water transparency | Secchi depth | Global Ocean Colour (Copernicus-GlobColour), Bio-Geo-Chemical, L3 (daily) from Satellite Observations (1997-ongoing) - Secchi depth of sea water (ZSD)  <https://data.marine.copernicus.eu/product/OCEANCOLOUR_GLO_BGC_L3_MY_009_103/description> |
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# **Sentinel-3: global ocean**

Instruments & applications

* OLCI - ocean color
  + Chlorophyll concentration - ratios of blue light and green light exists in the open ocean
* SLSTR - sea surface temperature
* SAR - sea surface height and sea surface topography

# **Sentinel-2: some coastal domain**

* High-resolution image - anomaly detection i.e. sewage discharge

# Questions / Problems:

* **Signal may not be very strong as likely many other factors impact the satellite measures that is not sewage pollution**
* **Measures of success for the project**
* A bit lost on how we can proceed from here in terms of **model building: Time series models? How to take into account the spatial dimension? Is there a potential for unsupervised learning or not really?**