Satellite remote sensing supporting surface water ecological status monitoring

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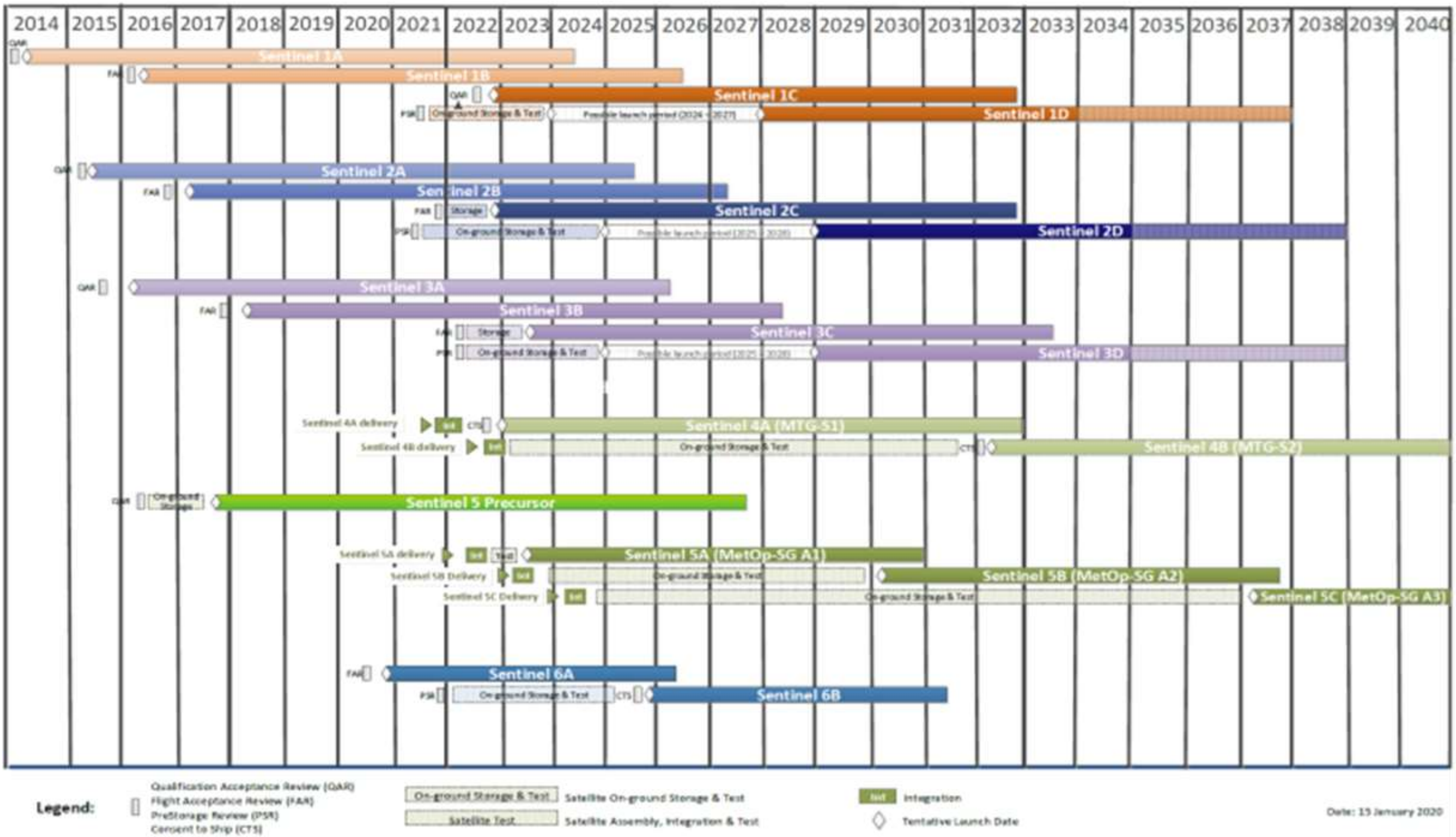
+ co-authors of the EOMORES/CoastObs white paper

This work has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreements 776480, 730066, 101004186

The European satellite observation infrastructure is fully operational (open and free)



Key messages

There is complementary value in **optical water quality observations from satellite sensors** and this is relevant to the goals of the **WFD** wrt surface waters to achieve good ecological status by 2027

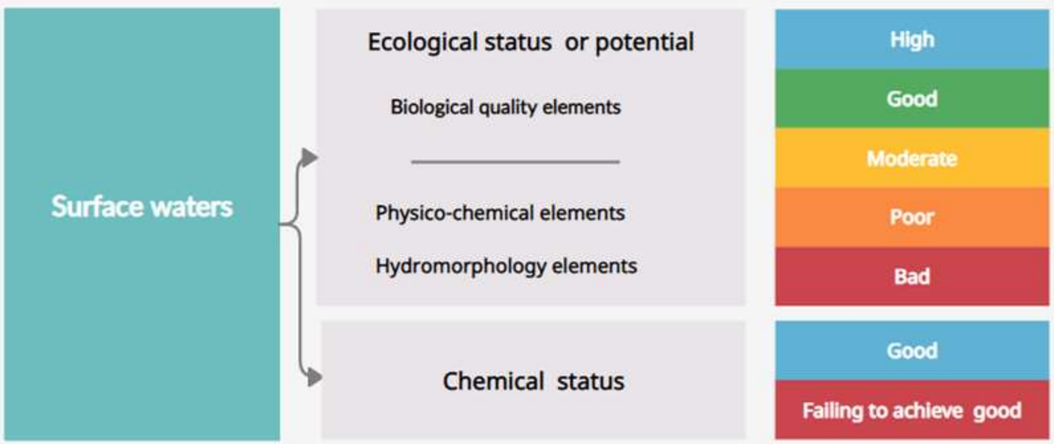


FIGURE 1

Assessment of status of surface waters and groundwater according to the WFD

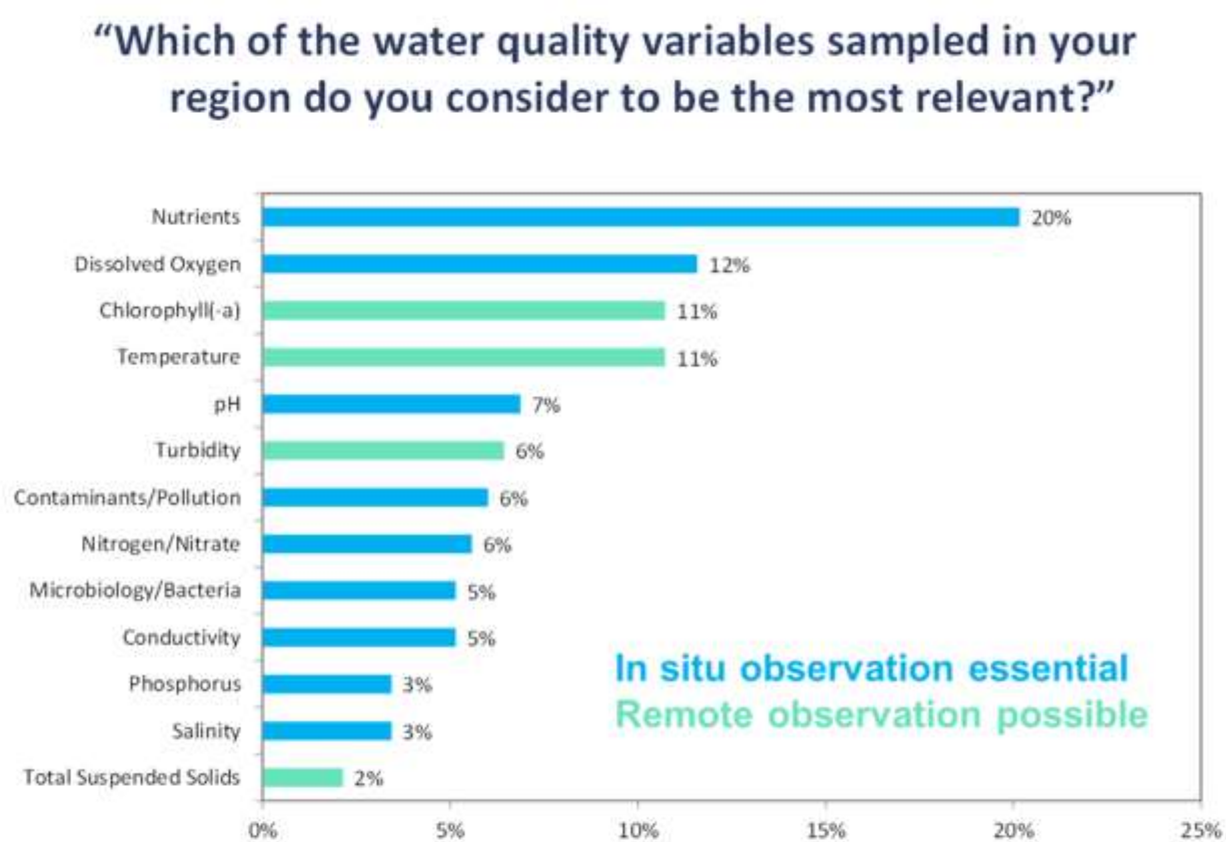
Source: European waters. Assessment of status and pressures 2018. EEA Report No 7/2018

But need to:

- align in situ and satellite remote sensing strategies to achieve the best complementary value
- integrate satellite and in situ observations into policy frameworks

Key messages

Optical water quality observation can complement (and does not replace) *in situ* sampling efforts

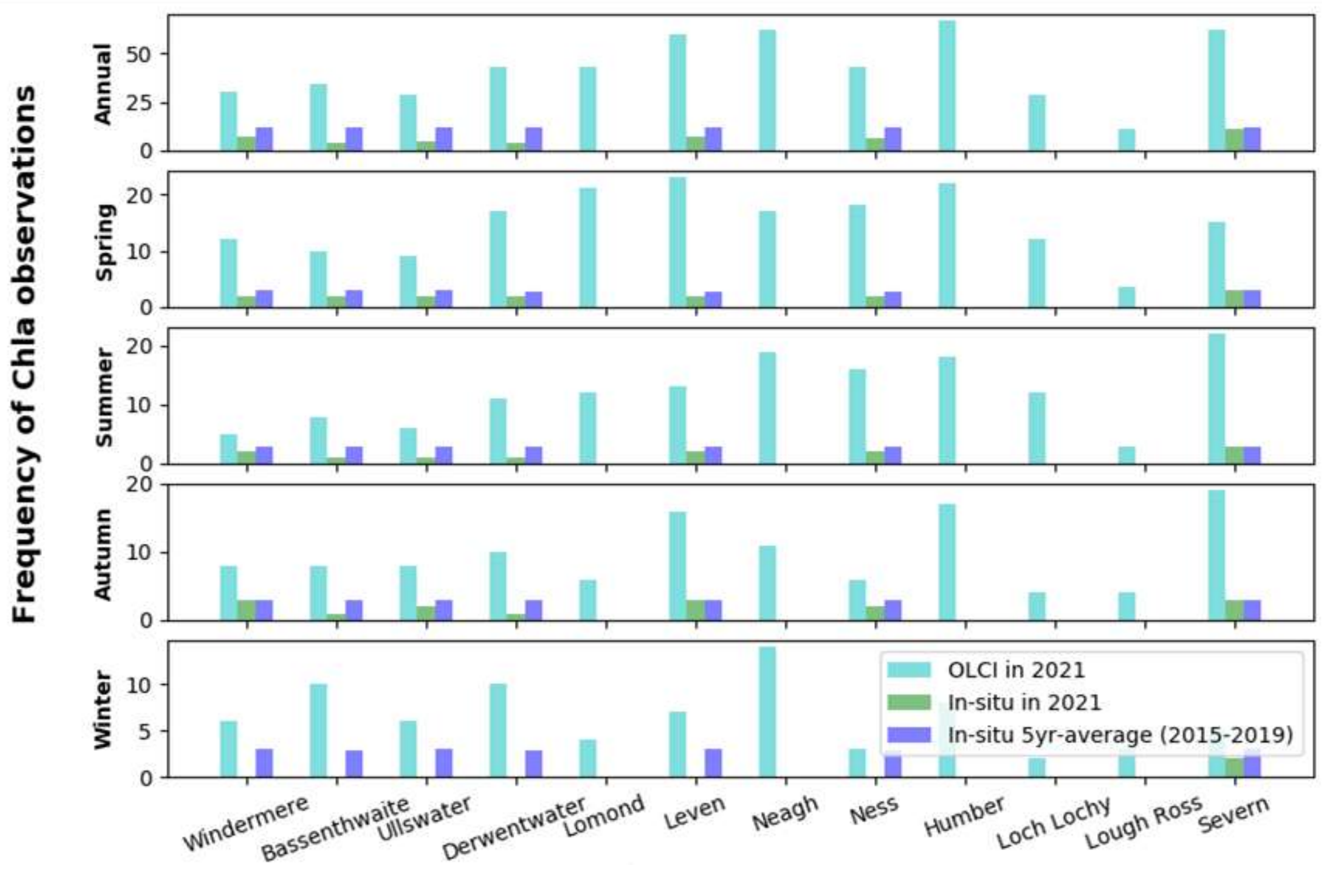


https://monocle-h2020.eu/Resources

In situ reporting gaps

Reporting gaps became more evident during the Covid-19 pandemic affecting the current reporting period

Medium-sized lakes and two estuaries in the United Kingdom



Satellite*

In situ 2021

In situ <2020

*using Sentinel-3A/B OLCI sensors at 300m resolution

Analysis, Showcase & Recommendations

EOMORES White Paper – 2019


EOMORES

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

White Paper | November 2019

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	All versions	This version
Views	1,836	650
Downloads	1,272	396
Data volume	10.7 GB	3.3 GB
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Unique downloads	1,071	354

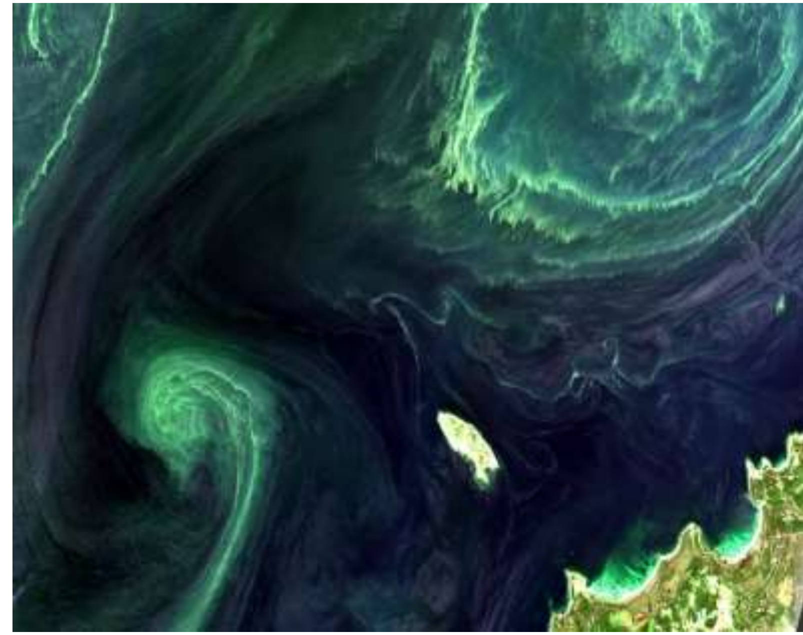
The white paper looks at current satellite-based opportunities through a WFD lens

E Papathanasopoulou, S Simis, K Alikas, A Ansper, S Anttila, J Attila, … M L Zoffoli. (2019, September 30). Satellite-assisted monitoring of water quality to support the implementation of the Water Framework Directive (Version 1.2). Zenodo. http://doi.org/10.5281/zenodo.3903776

Complementary value

Table 1: Current in situ metrics and corresponding satellite-derived quality metrics to be considered

WFD requirements	National Systems	Satellite-derived proxies to be considered
QE1 Biological elements		
QE1-1. Phytoplankton		
Abundance and biomass	Extracted chlorophyll-a concentration[i] Biovolume of phytoplankton[i]	Chlorophyll-a concentration from in vivo pigment absorption[ii,iii] Trophic State Index derived from Chlorophyll-a
Composition	Biovolume of cyanobacteria[i] % of cyanobacteria of total biovolume[i] Various other metrics, trophic indices	Phycocyanin (cyanobacterial pigment) concentration[v] Functional size classes (only in oceanic waters)[iv]
Frequency and intensity of planktonic blooms	Not reported / not possible using conventional monitoring	Chlorophyll-a concentration[ii,iii] Phycocyanin (cyanobacterial pigment) concentration[v] Surface accumulations of cyanobacteria[vi]
QE1-2 Other aquatic flora		
Macrophyte abundance	Various trophic indices; Submerged vegetation cover[i] Total areal coverage[i]	Areal cover of floating vegetation
Macrophyte composition	Proportion of taxa	Not from current satellite sensors, but from airborne surveys[vii]
Macroalgal cover and angiosperm abundance	Combination of spatial extent and relative abundance (measured as density) of macrophytes Abundance of macrophytes[viii,ix]	Spatial extent In intertidal areas[x,xi,xii]: spatial distribution of seagrass density of sea grass, total surface area of seagrass beds
QE3. Chemical and physico-chemical elements		
QE3-1. General		
QE3-1-1. Transparency	Secchi disk depth (Dissolved organic carbon also used to characterise lake typology)	Satellite backscatter as turbidity, suspended particulate matter weight or vertical transparency (extinction or Secchi depth)[xiii,xiv]
QE3-1-2. Thermal conditions	Mean water temperature Water temperature range Air temperature	Surface water temperature[xv] (in open water >2 km from land)



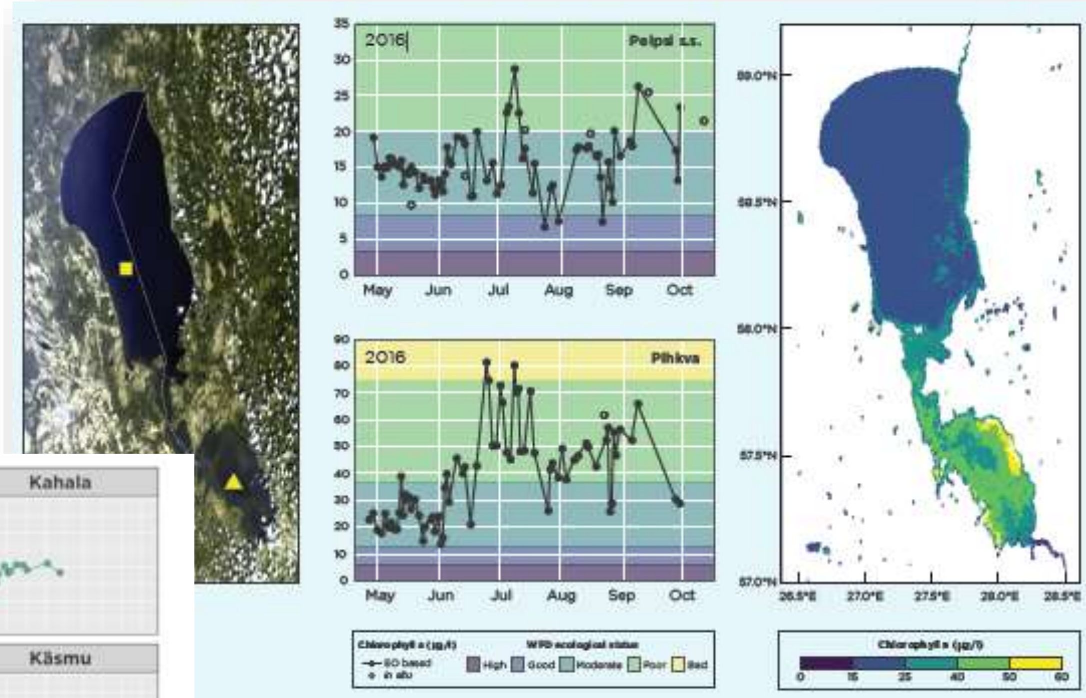
Optical satellite observation can be considered in seven biological and physico-chemical elements.

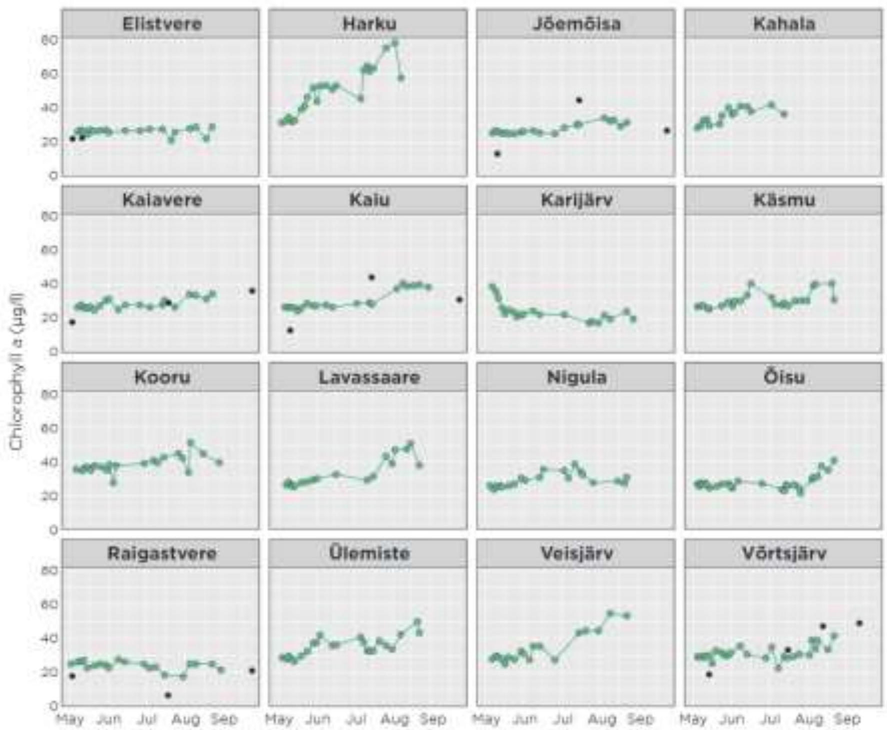
Major improvements possible for *frequency of blooms* because this requires high spatio-temporal coverage.

E Papathanasopoulou, S Simis, K Alikas, A Ansper, S Anttila, J Attila, … M L Zoffoli. (2019, September 30). Satellite-assisted monitoring of water quality to support the implementation of the Water Framework Directive (Version 1.2). Zenodo. http://doi.org/10.5281/zenodo.3903776

Estonia

Analysing satellite observations of lakes and coastal waterbodies.





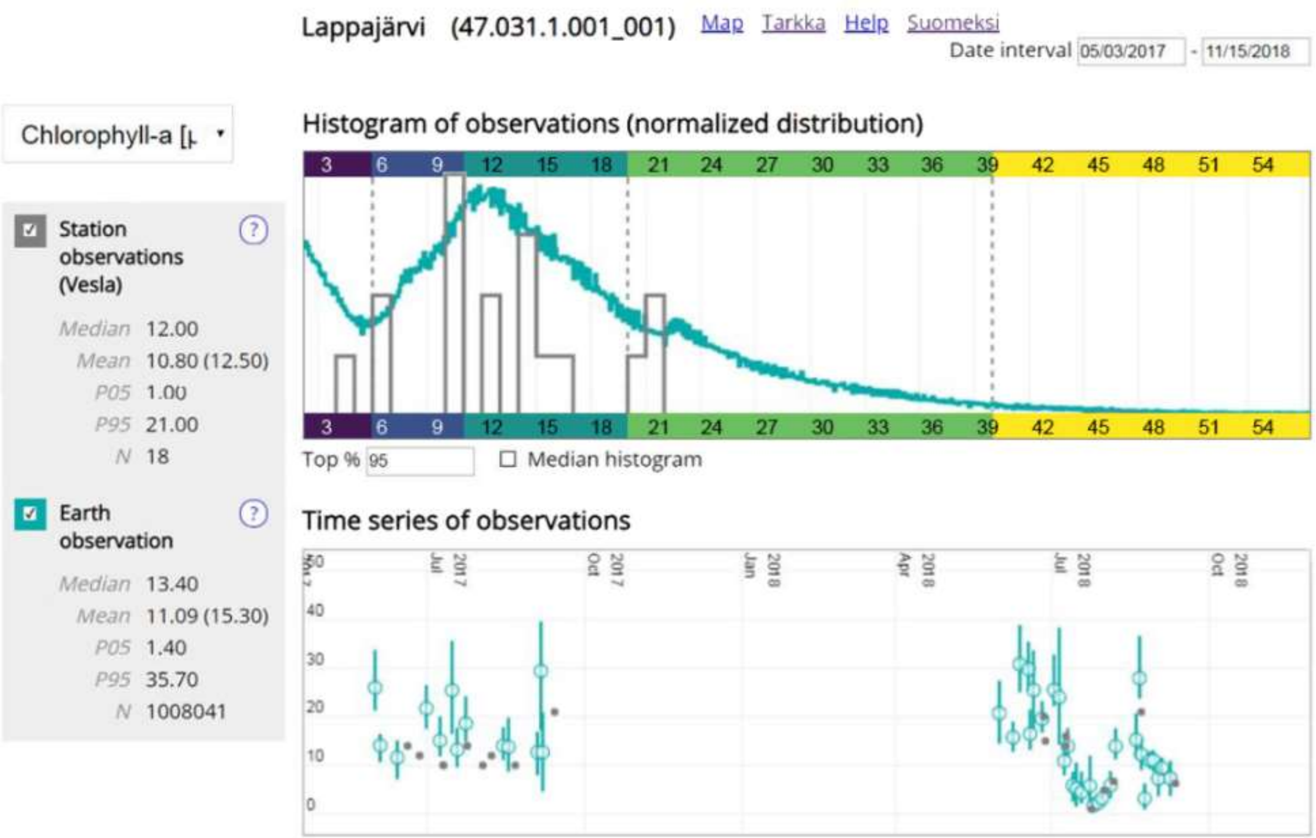
Seasonal dynamics of chlorophyll-a in selected Estonian lakes under WFD reporting obligations from Sentinel-2 satellite during 2018. Black dots denote spectrophotometrically measured (in situ) chlorophyll-a.

Using medium and high-resolution sensors, temporal data coverage is > 10x improved. Validation is good on the basis of WFD classes.

Note: colour-coding of WFD classes uses a colour-blind friendly palette in the EOMORES White paper: particularly useful in maps!

Finland

Satellite products provide complementary information on 87% of the area of Finnish WFD lakes and nearly all coastal waterbodies (4,617 lakes and 276 coastal in the WFD). **Satellite products were already included in the last two reporting periods**.
Classification accuracy was within 23% (cf. ±20% uncertainty for laboratory-based Chl-a).



Waterbody statistics include each individual observation in the classification:
N = 18 samples in situ versus >1M from satellite.

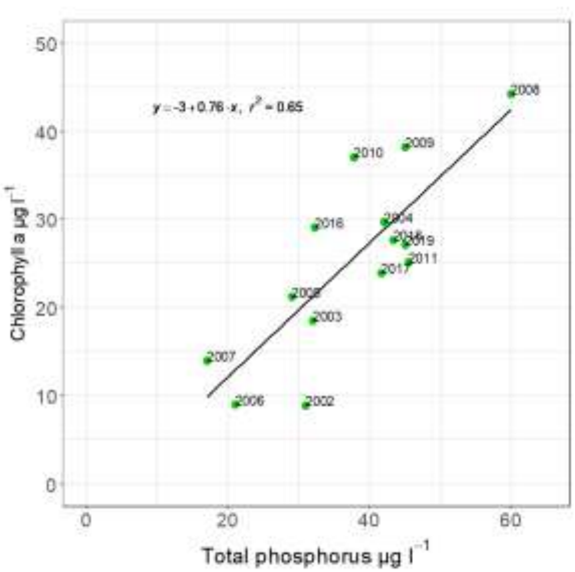
A view of the web application showing statistics, data distributions (histograms) and time series of station and satellite-derived chlorophyll-a of a coastal WFD region. In the histogram, WFD status classes are indicated by colours (purple: excellent, blue: good, teal: moderate, green: poor, yellow: bad).

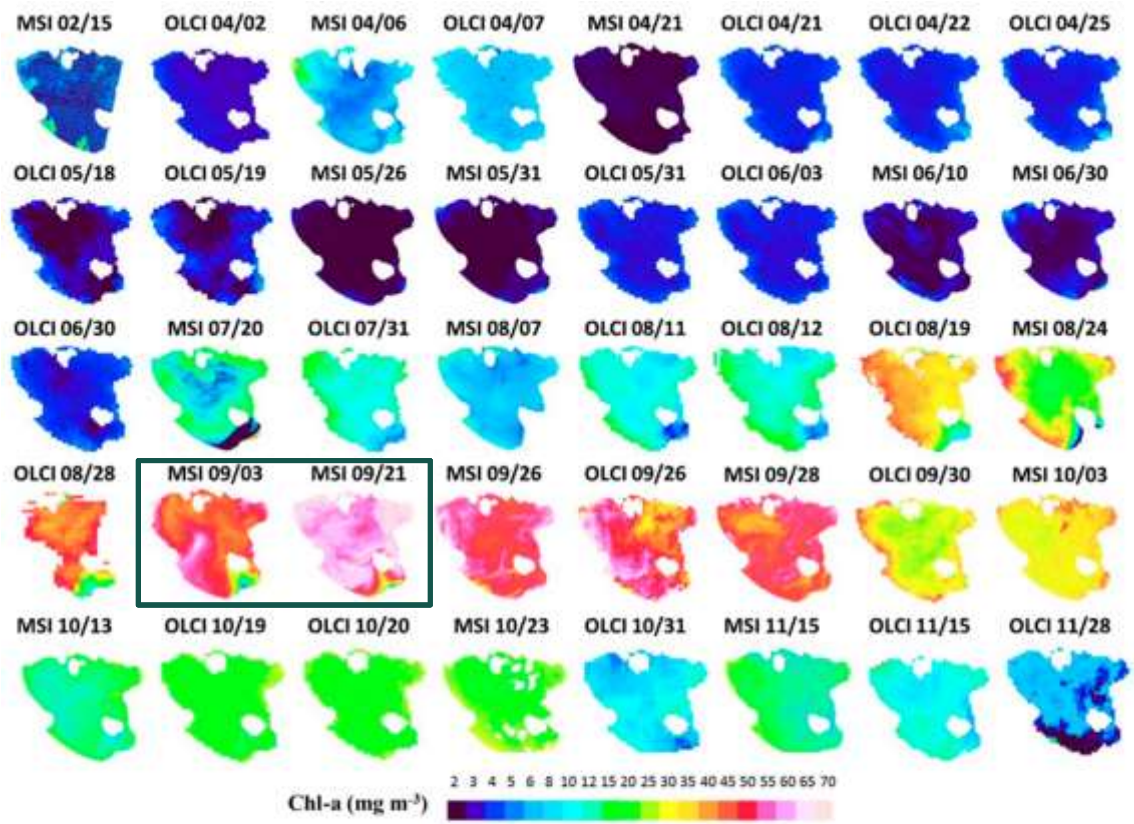
Italy

Chlorophyll *a* in Lake Trasimeno (data from Lakes CCI)

Seasonal monitoring is possible, here combining results from high and medium resolution sensors.

Results compare well to Total Phosphorus:



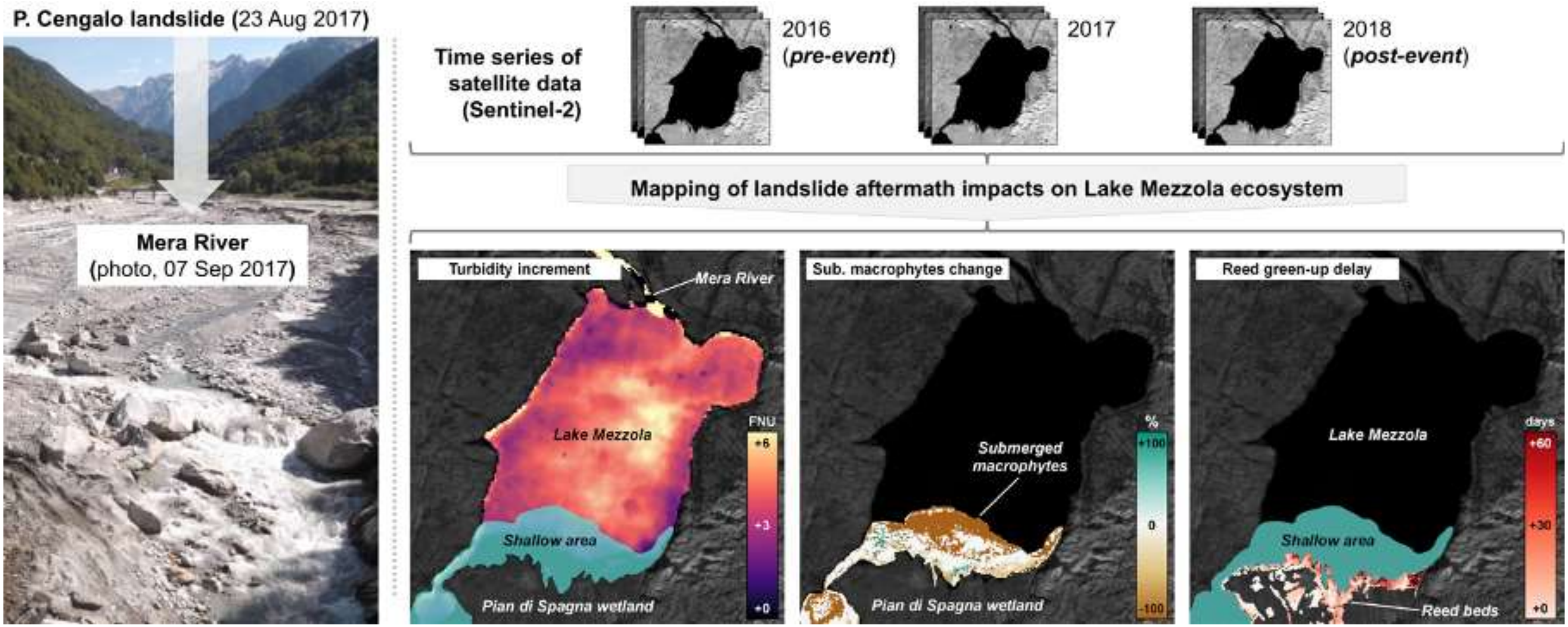


Bresciani *et al*., 2020 https://doi.org/10.3390/w12010284

Italy

Macrophytes: natural hazards

Assessing temporal evolution of key ecosystem variables after an upstream landslide in perialpine Lake Mezzola (northern Italy)

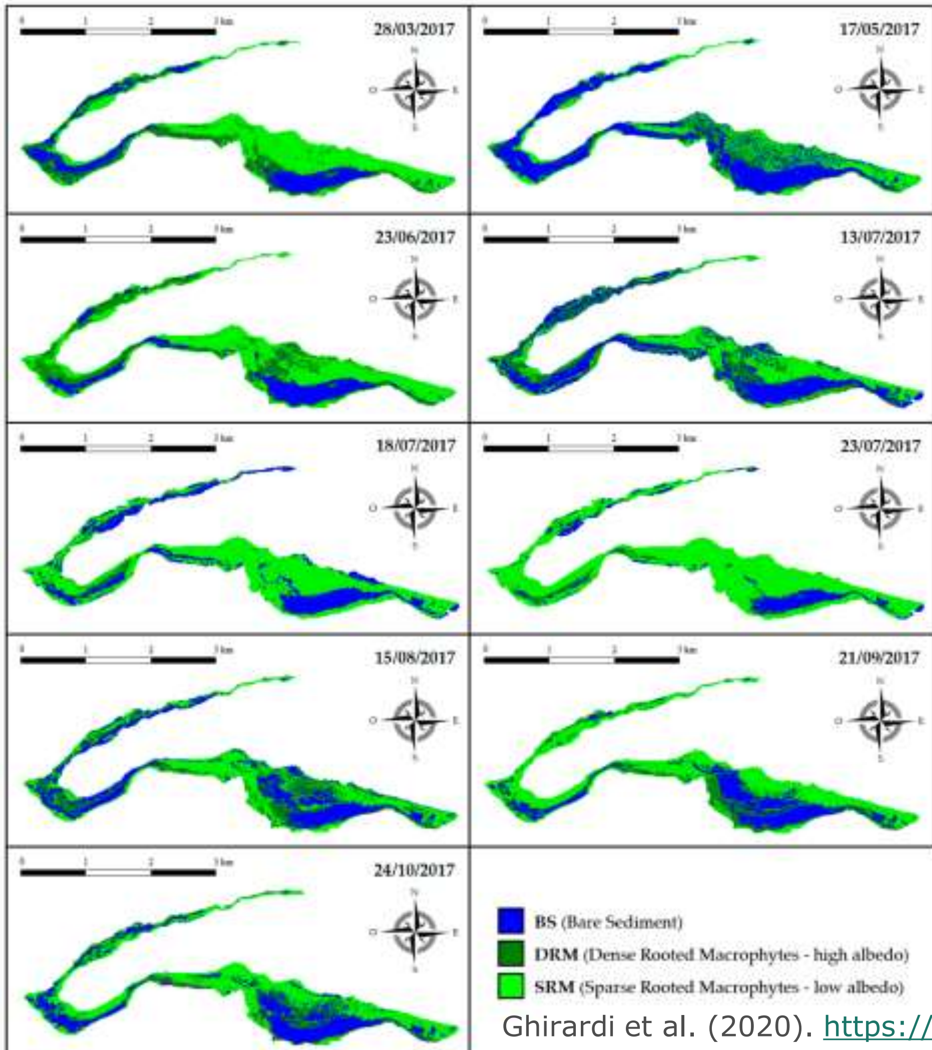


Villa et al. (2020). https://www.sciencedirect.com/science/article/pii/S0048969720311384

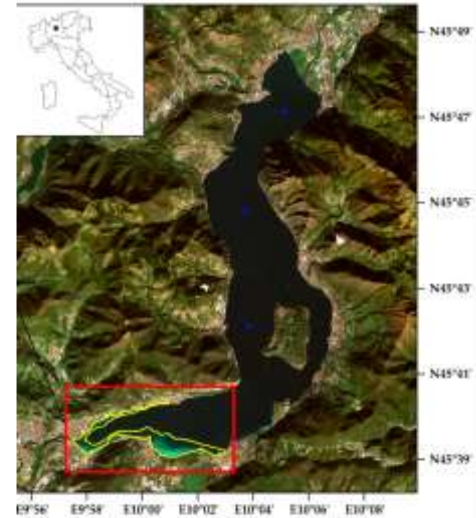
Italy

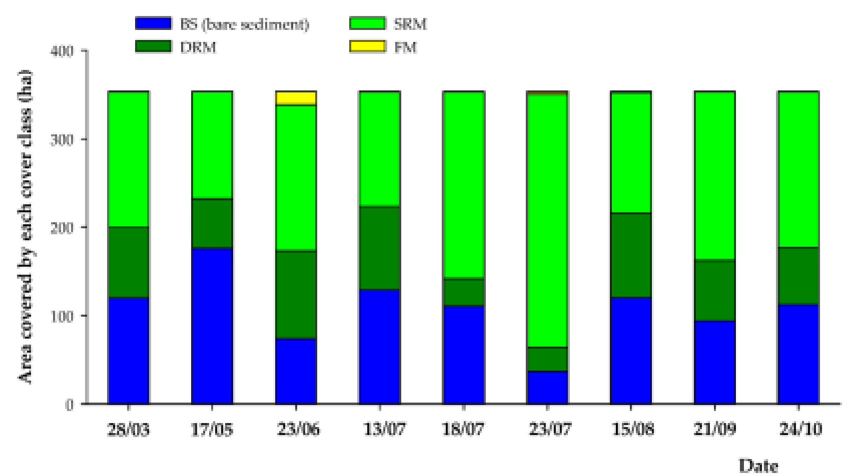
Macrophytes: submerged

Mapping lakes substrates colonised by submerged macrophyte communities



BS (Bare Sediment)
DRM (Dense Rooted Macrophytes - high albedo)
SRM (Sparse Rooted Macrophytes - low albedo)

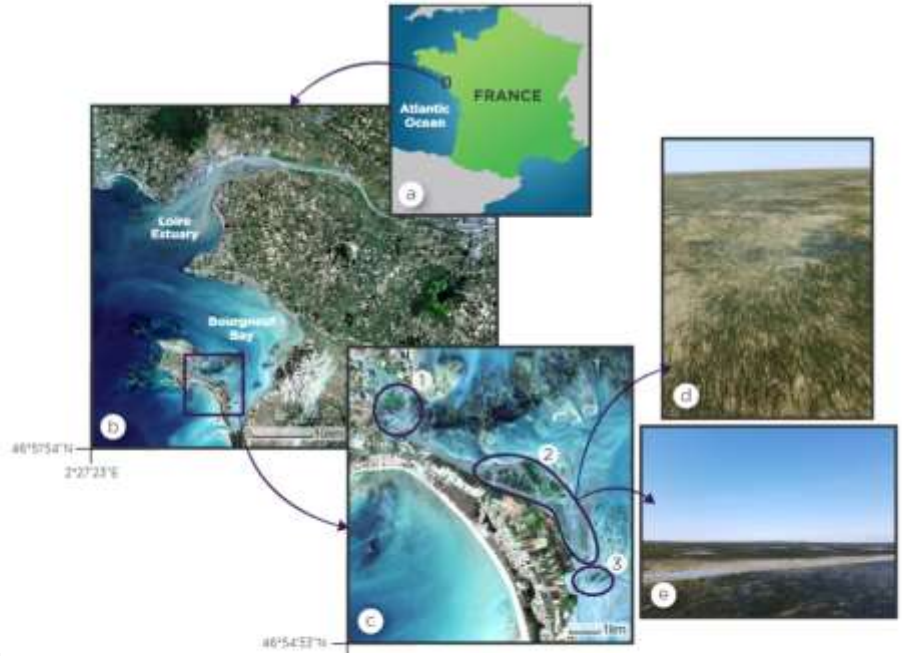


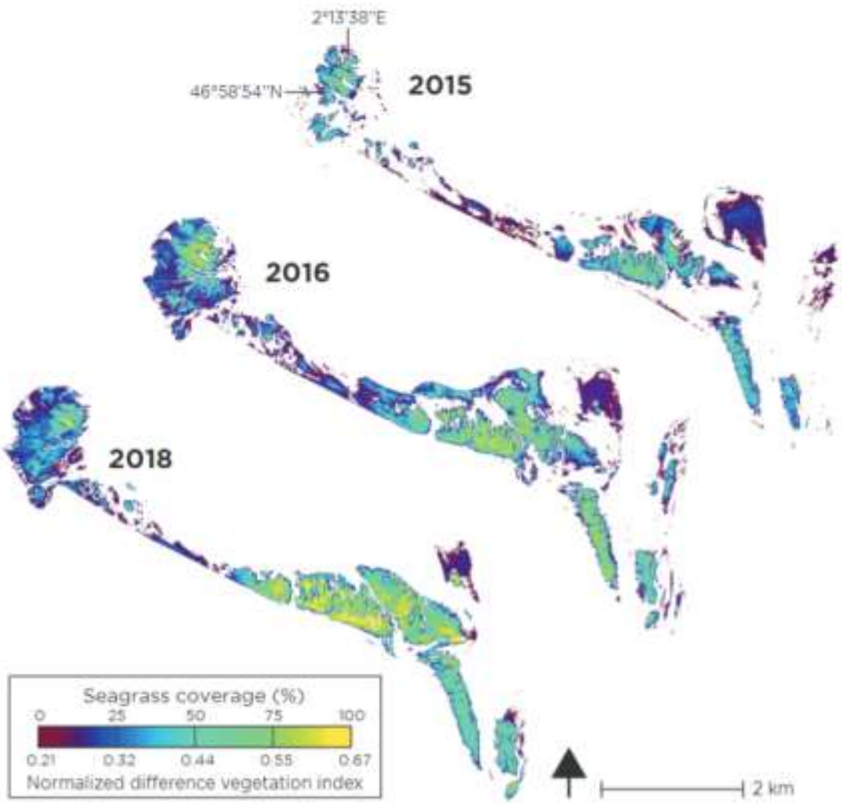


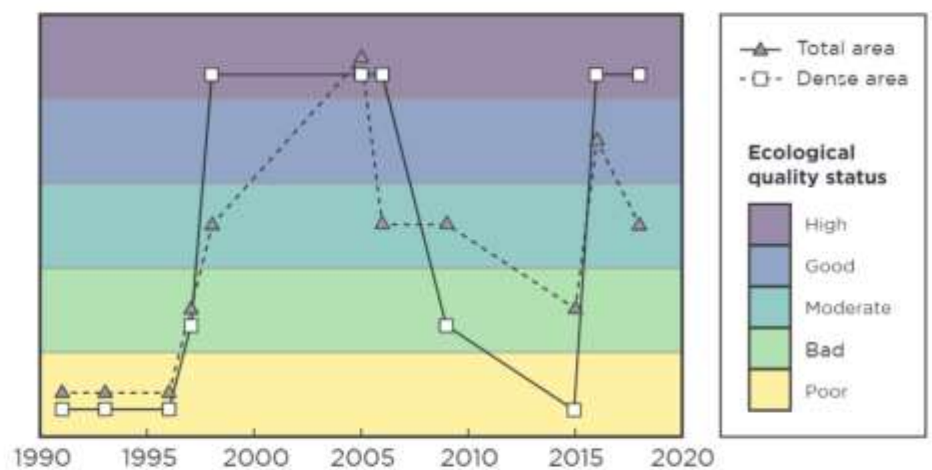
Ghirardi et al. (2020). https://www.mdpi.com/2073-4441/11/3/563

France

Seagrass mapping from high-resolution satellite provides **seasonal dynamics**. The total area is observed rather than average %cover in quadrats -> different approach but more robust interannual results.







Ireland

THE IRISH TIMES

LATEST NEWS MOST READ MEDIA IRELAND WORLD SPORT

Pollution police look to space to monitor over 800 Irish lakes

Environmental body says use of satellites a major step forward when checking water quality

Lough Ree, one of 812 Irish lakes now being monitored from space.

Brian Hutton

Mon, Nov 19, 2018, 01:00

Assessing ecological status

Until now, only about a quarter of these have been actively monitored

Gary Free, an aquatic environment expert with the EPA, said the new technology would not entirely replace the traditional testing methods, but should help them **monitor many lakes which currently go unchecked because of cost constraints**.

“It is fascinating the images you get back,” he said of the real-time pictures beamed down every time the satellites pass over the State.

“The main thing for us is the layers and layers of information – all the different wavelengths – are reported back by the satellites. It is not a simple snapshot, there are layers of data within it. It can tell you an awful lot about the environment.”

Ecological status predicted from Sentinel-2 for the Glyde-Proules catchment

https://blog.vito.be/remotesensing/an-eye-on-european-waters

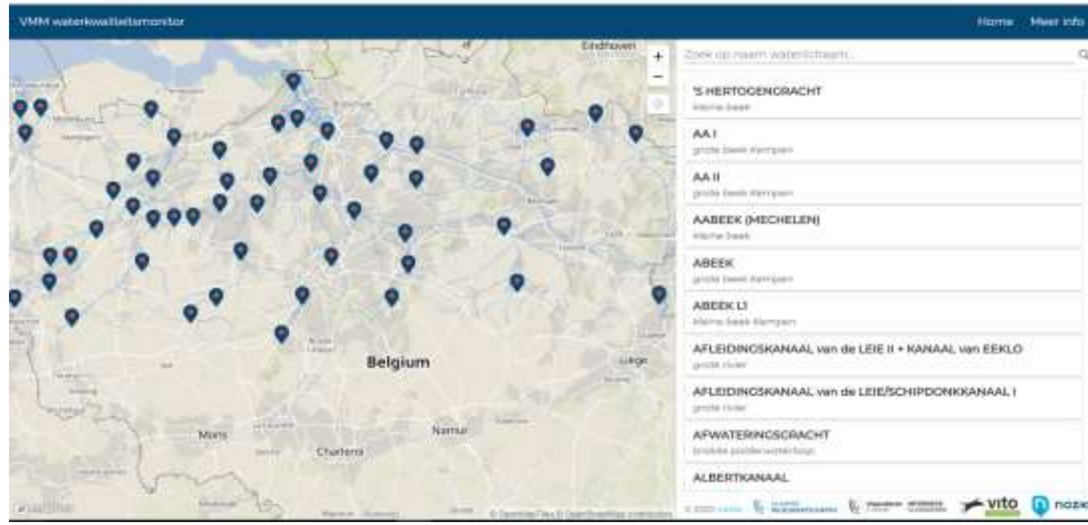
Flanders

Watermonitor for Flanders Environment Agency (VMM)

Demo (2020-2021) NRT Sentinel-2 based Chl-a + in situ Chl-a

WFD classes/colour code (max Chl-a and summer average Chl-a)

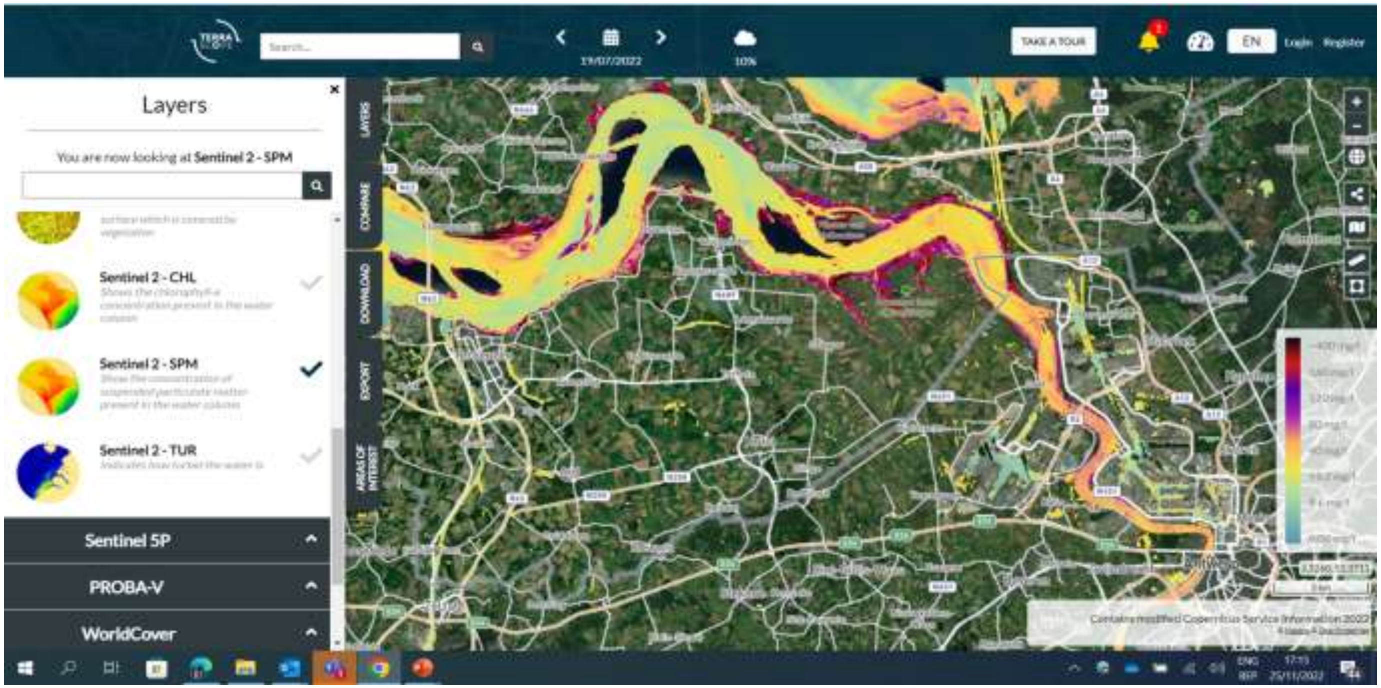
Exceedance alert



https://remotesensing.vito.be/case/watermonitor

Flanders

Suspended Particulate Matter and Turbidity



https://viewer.terrascope.be/

Model to predict habitat suitability for spawning and larval development of Twaite Shad in Sea Scheldt

The Netherlands

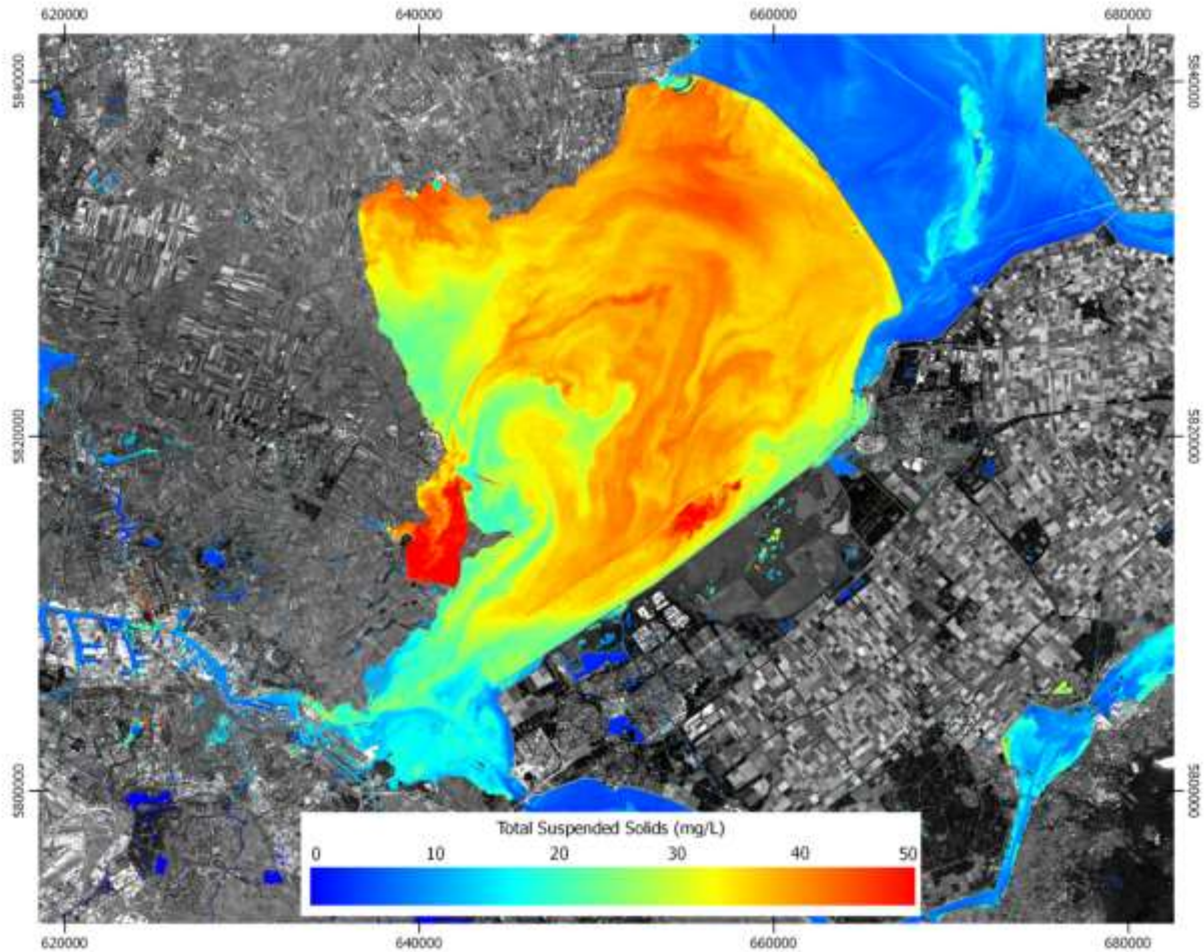
Lake Marken

2016: Because of silt dynamics growth of plants and Zebra mussel population decreased (less food for birds)

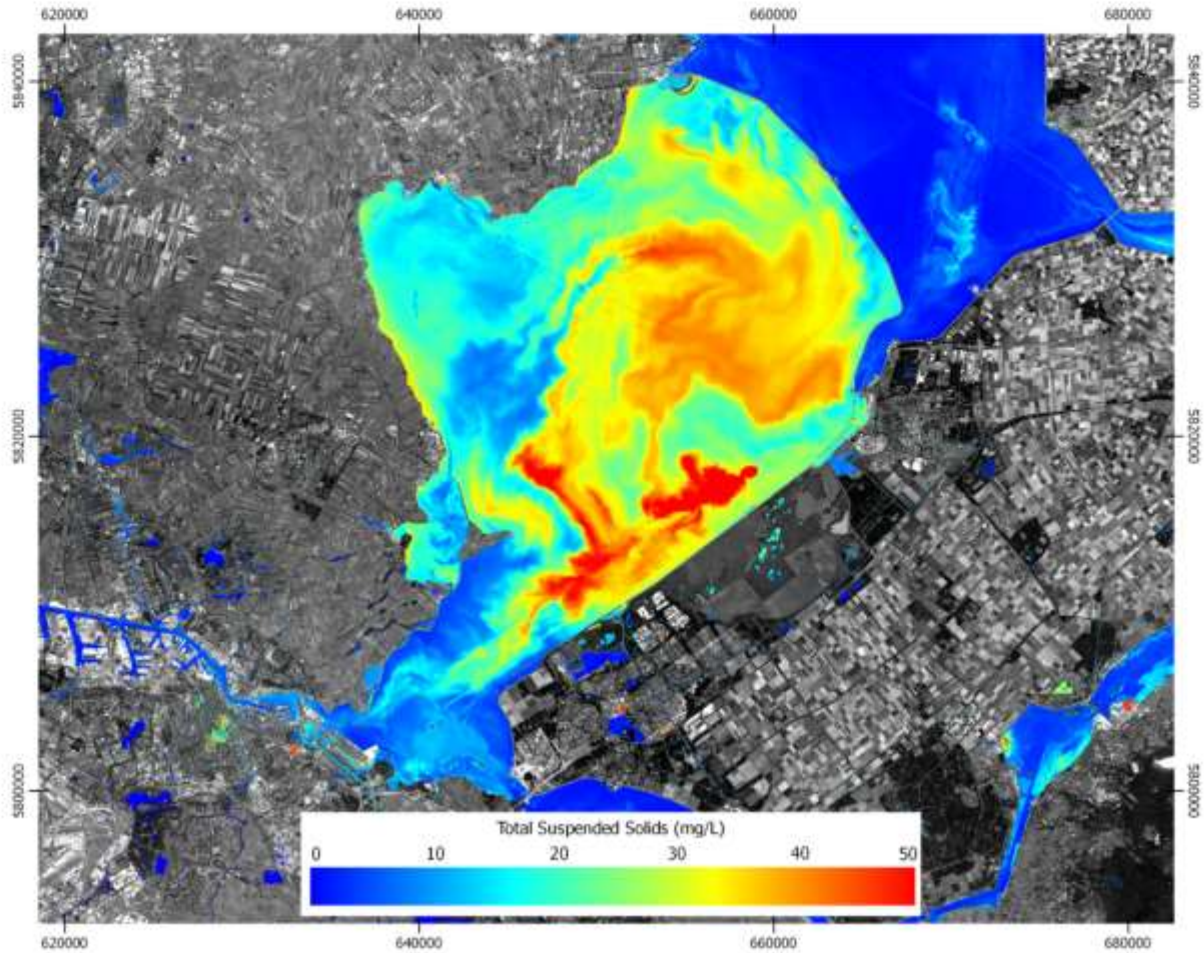
Silt used to create Marken Wadden islands

De ingenieur: eerste eiland

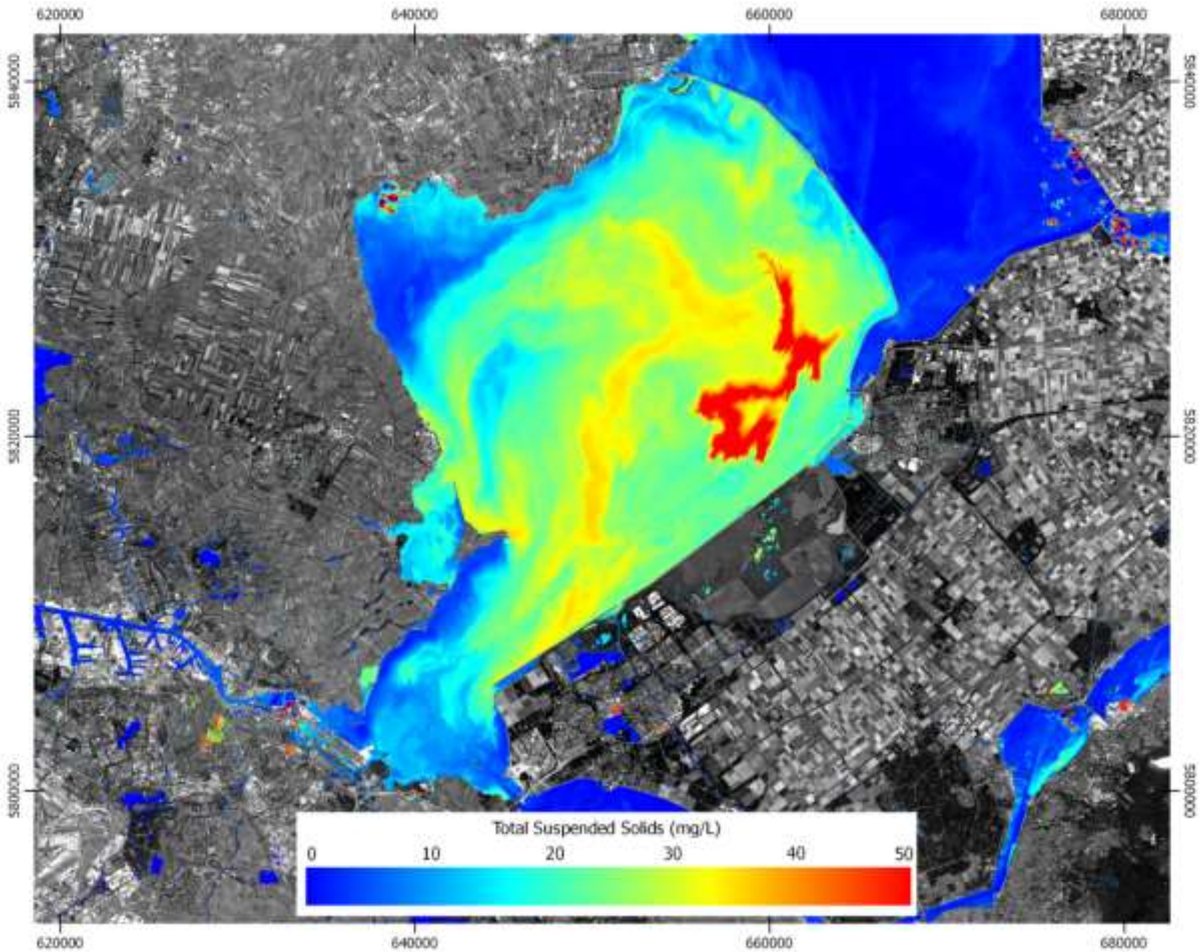
Sentinel-2 image Copernicus Sentinel data (2016)



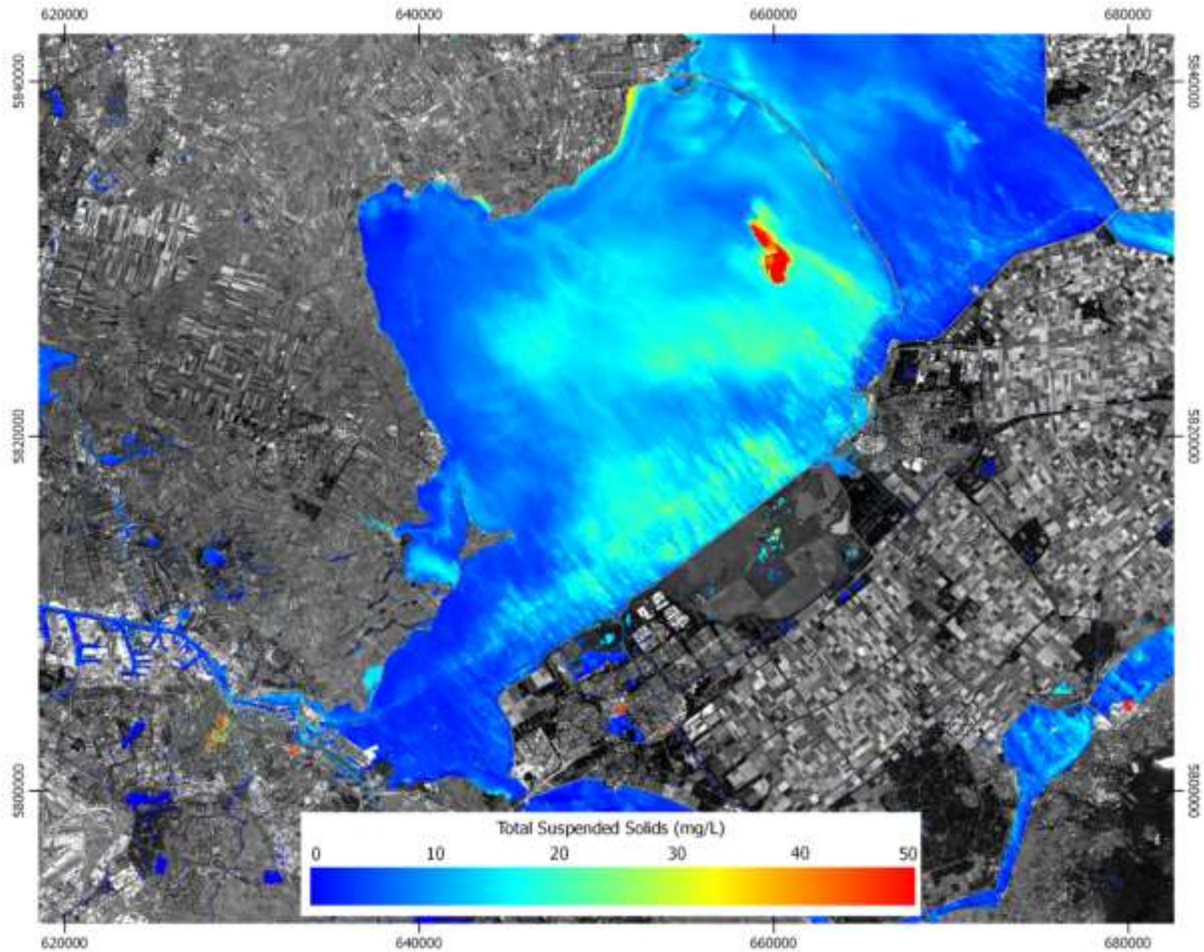
Total Suspended Solids map for Lake Marken, the Netherlands (Landsat-8, 7 January 2015)



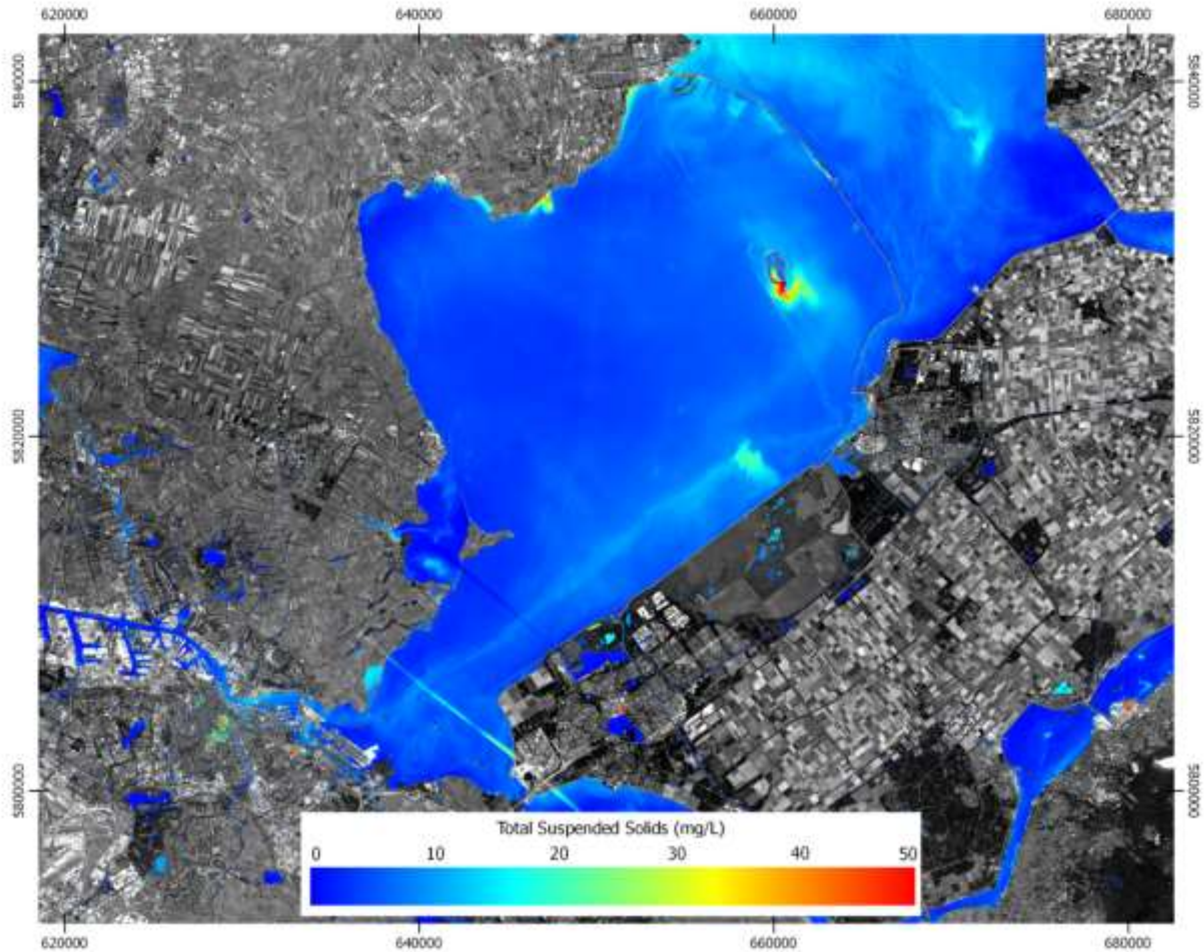
Total Suspended Solids map for Lake Marken, the Netherlands (Landsat-8, 12 March 2015)



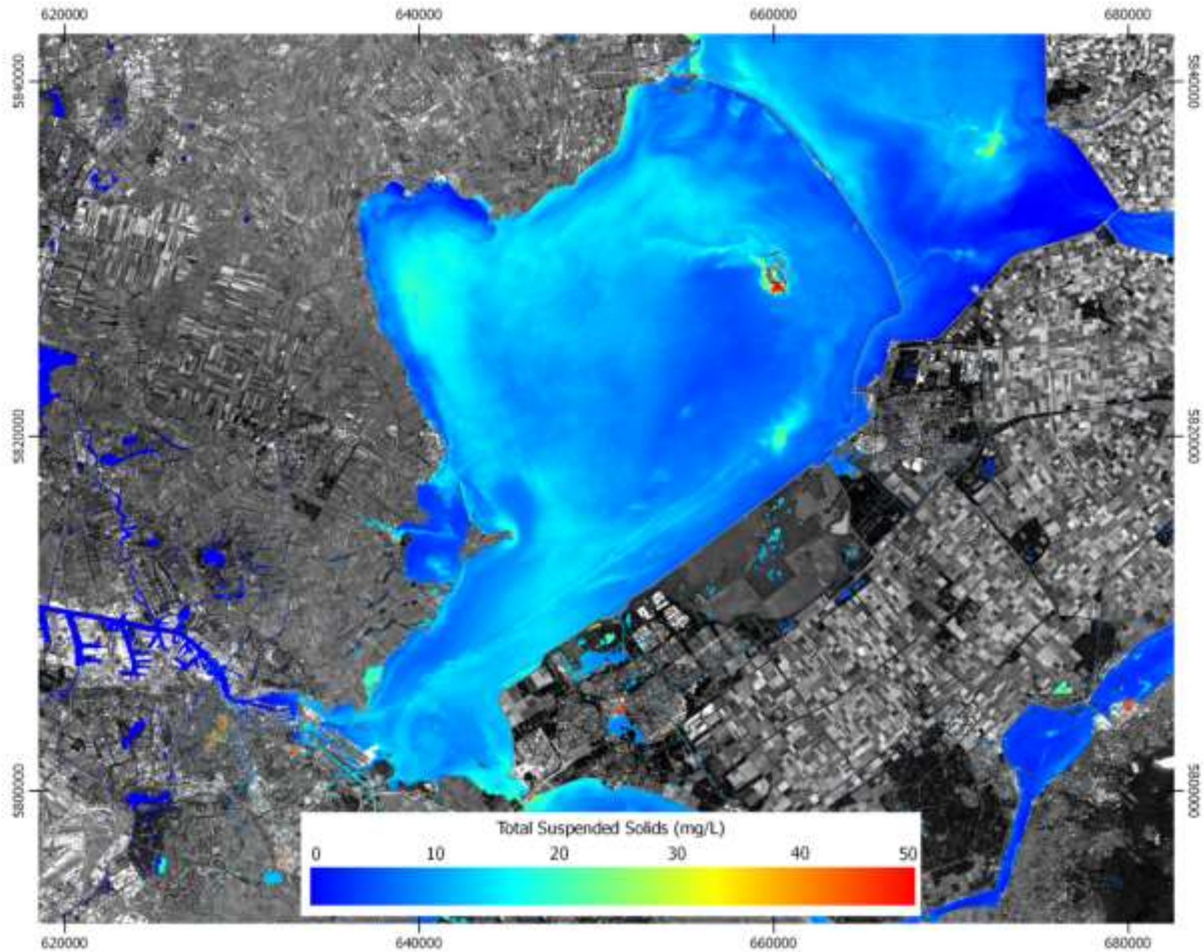
Total Suspended Solids map for Lake Marken, the Netherlands (Landsat-8, 1 May 2016)



Total Suspended Solids map for Lake Marken, the Netherlands (Landsat-8, 20 July 2016)



Total Suspended Solids map for Lake Marken, the Netherlands (Sentinel-2A, 8 September 2016)



Total Suspended Solids map for Lake Marken, the Netherlands (Sentinel-2A, 15 September 2016)

Roadmap for the Copernicus services

Water-ForCE

Developing a Roadmap for Copernicus Water Services

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004186

Introduction

Inland and coastal waters play a crucial role in human health and wellbeing, in the global carbon and nutrient cycles, as well as supporting high levels of biodiversity. The **Copernicus Programme** is an European contribution improving our understanding of the Earth system, including water quantity and quality at regional and global scale.

Scope

The Horizon 2020 project "Water scenarios For Copernicus Exploitation", **Water-ForCE**, will analyse the needs of different users from policy makers, researchers and industry to businesses, NGOs and general public, determine gaps in current Copernicus WATER portfolio, evaluate technical capabilities of present and future Copernicus sensors in providing the necessary information about water quantity and quality. The recommendations on the evolution of water services will be summarised in a **Roadmap.**

Want to contribute to how the future Copernicus water services will look?

Go to our web page **waterforce.eu**, register in one of the relevant international working groups and participate in the development of the **Roadmap**

Six **Copernicus Services** (Atmosphere, Marine, Land, Climate Change, Security, Energy) deliver water and hydrology related services from Earth Observation, in situ and modelled data.

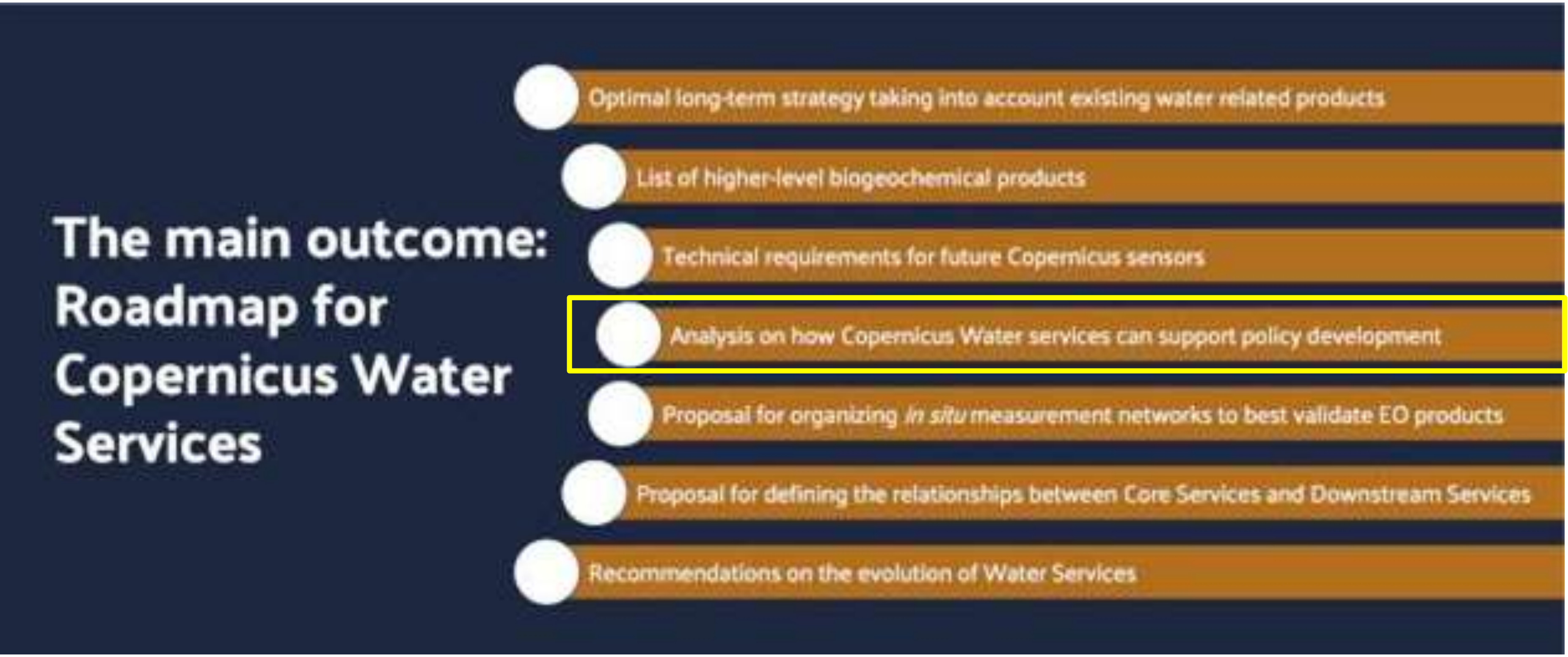
However, the current Services have some shortcomings:

- **difficulties in getting comprehensive understanding of the global water cycle** (water products provided by different Services)
- **gaps in water related products**
- **unclear which Service should fill which gap**
- **duplication aspects**
- **finding relevant Copernicus products not easy for users**

The main outcome: Roadmap for Copernicus Water Services

- Optimal long-term strategy taking into account existing water related products
- List of higher-level biogeochemical products
- Technical requirements for future Copernicus sensors
- Analysis on how Copernicus Water services can support policy development
- Proposal for organizing *in situ* measurement networks to best validate EO products
- Proposal for defining the relationships between Core Services and Downstream Services
- Recommendations on the evolution of Water Services

Roadmap for the Copernicus services



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