

e-shape solutions: Earth Observation for biodiversity and water management

14 - 15 February 2023

9.30 – 17.00 CET

The Hague - NSO Headquarter

Centre Court



e-shape

An event co-organised by

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BRIDGE SPACE AND SOCIETY

**Netherlands
Space
Office**

How services based on Earth Observation can support monitoring for the EU Water Framework Directive

e-shape pilot 5.6

Annelies Hommersom



Presentation contents

- Short intro about the Water Framework Directive (WFD)
- Water quality monitoring based on Earth Observation (EO)

- e-shape pilot in Estonia
- e-shape pilot in the Netherlands

- Conclusions: what EO can contribute to the WFD

EU water policies and regulations

- Water Framework Directive
- Floods directive
- Water Reuse Regulation
- Urban Waste Water Treatment Directive
- Nitrates Directive
- Drinking water Directive
- Bathing water Directive
- Marine Strategy Framework Directive
- Habitats and Birds Directives

Require monitoring of **surface water** quality

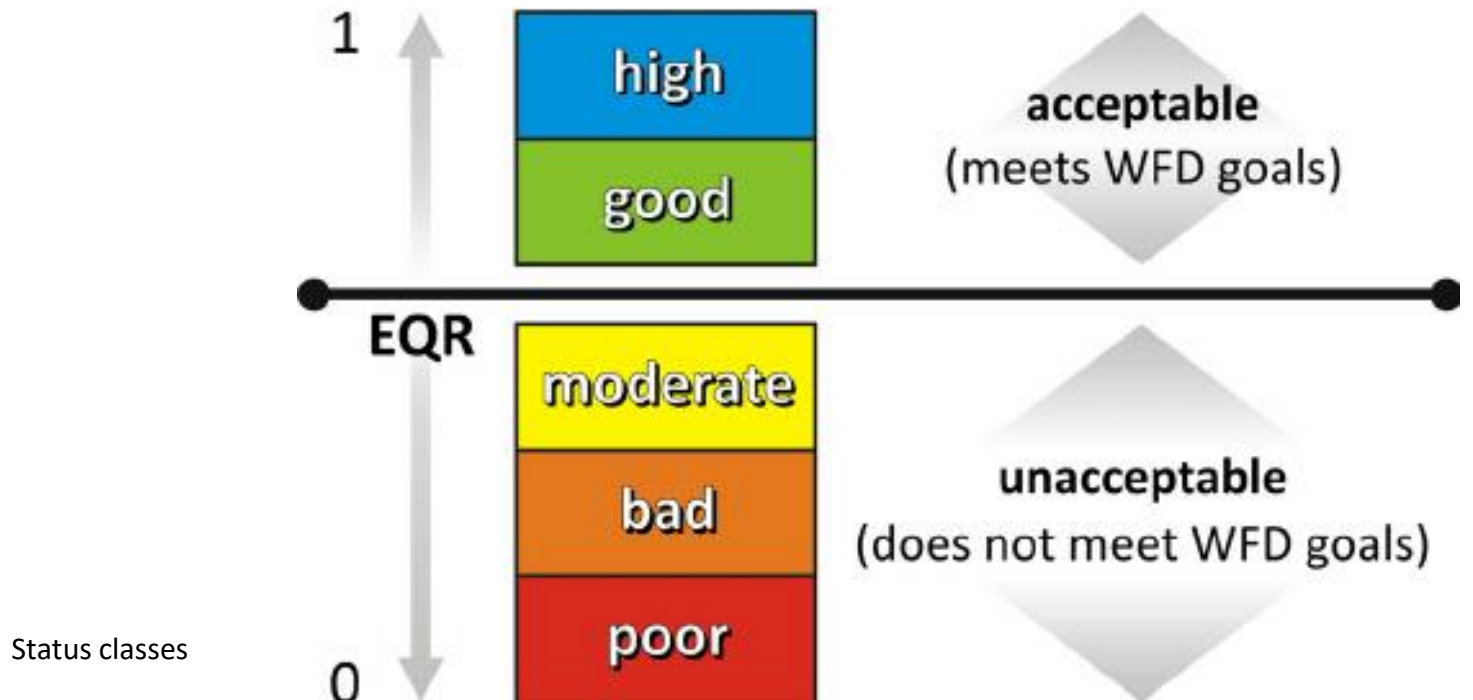
Water Framework Directive (WFD)

Purpose:

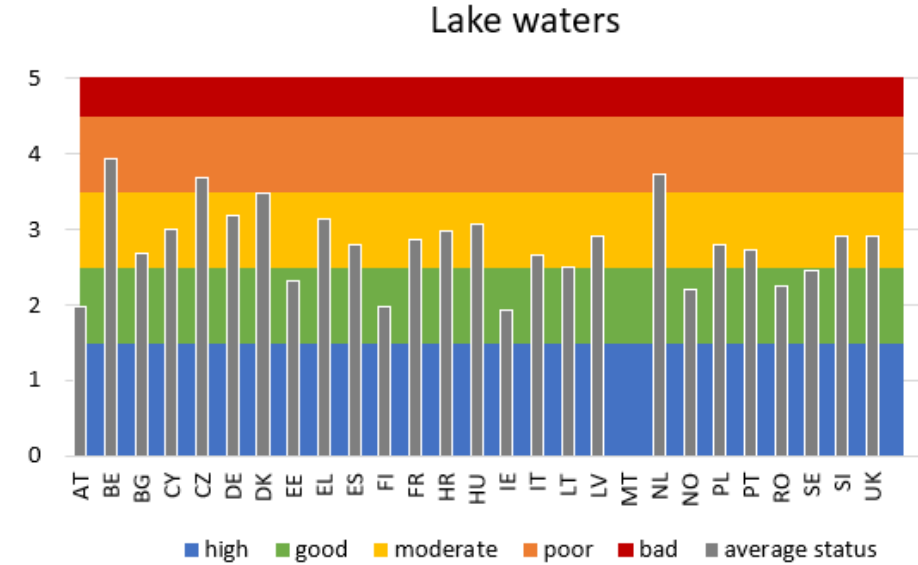
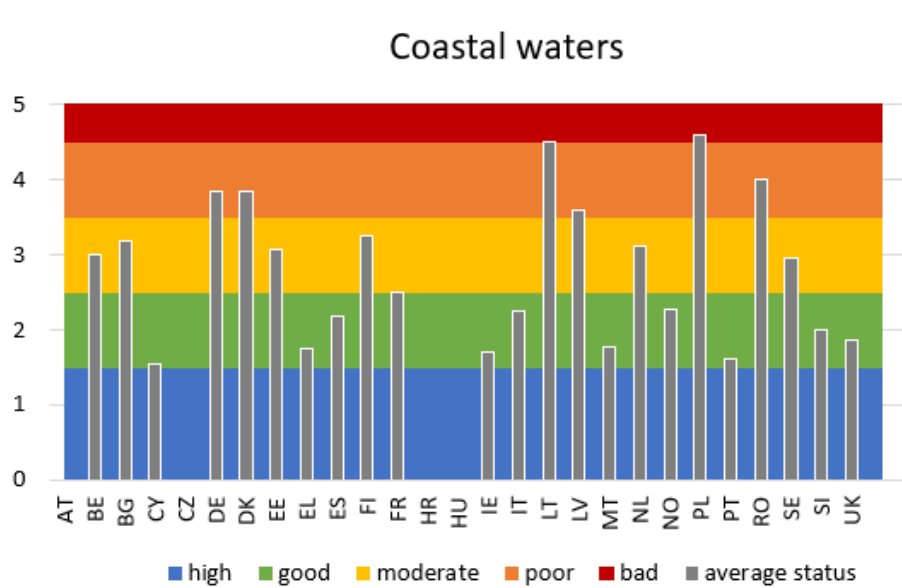
- Protection of inland surface waters, transitional waters, coastal waters and groundwater
- Achieving "good status" for all waters by a set deadline

"Good status" means that water shows only a slight change from undisturbed conditions

6-year cycles of reporting



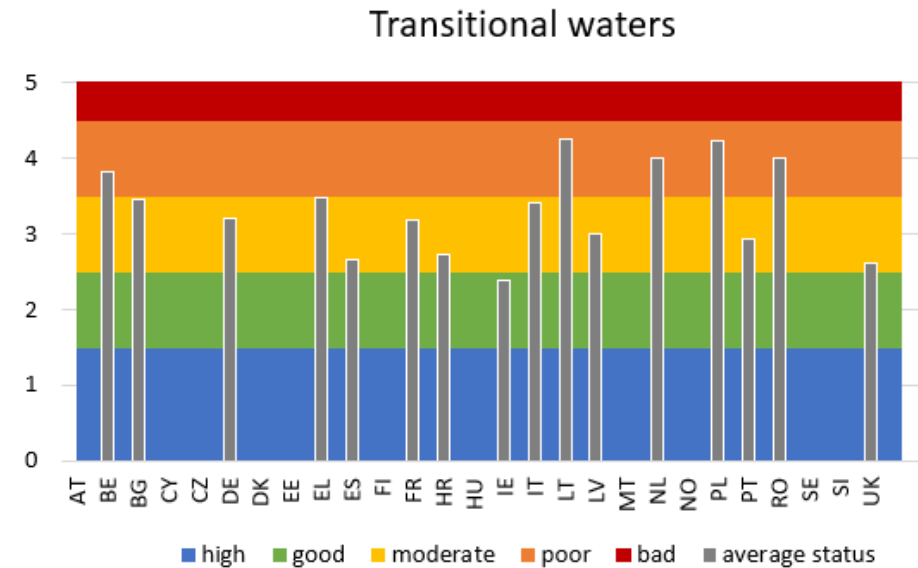
Average ecological status per country



Ecological status classes

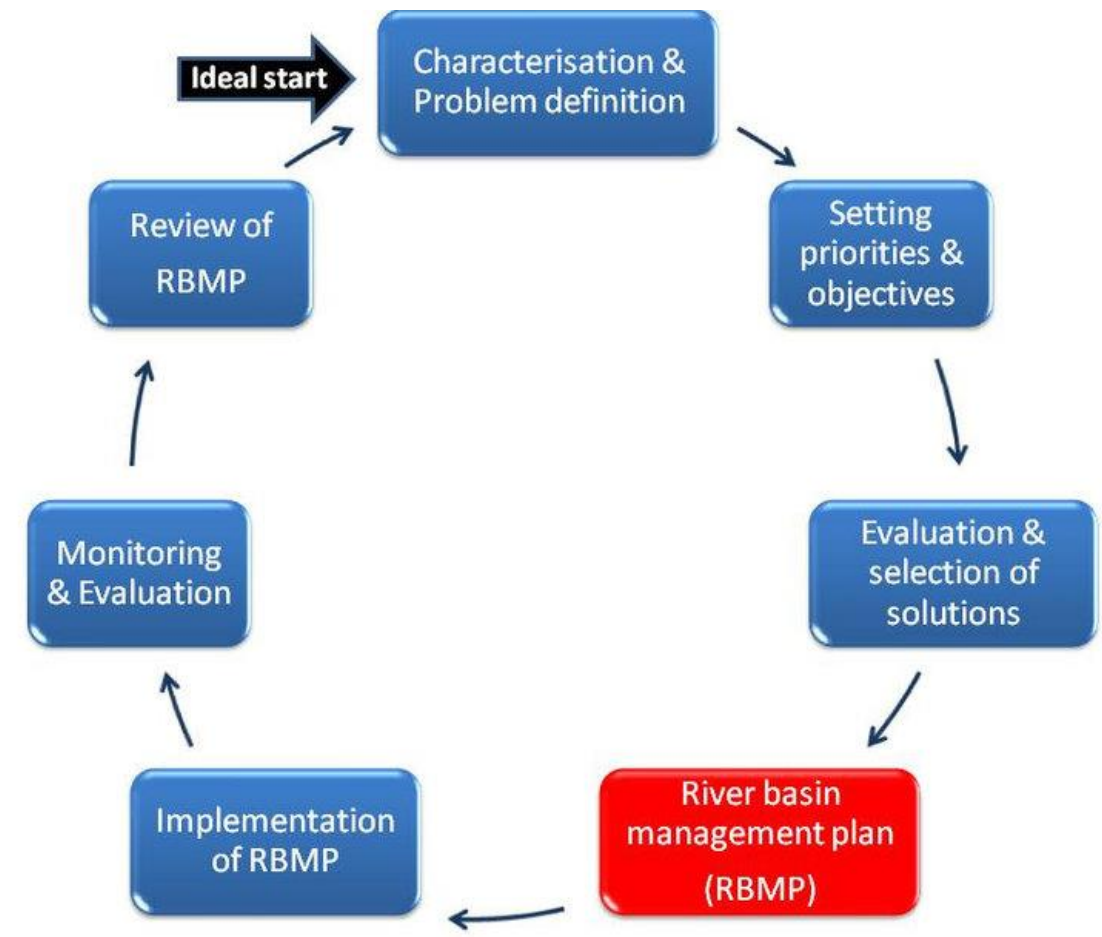
5	bad	
4	poor	
3	moderate	
2	good	
1	high	

Data from WISE-SoW database



6-Yearly cycles in the WFD

- Development of River Basin Management plans
- Define environmental objectives
- **Monitoring**
- Implementation of measures to achieve objectives
- Classification and status assessment
- Evaluation of measures (incl **monitoring**)



Earth Observation can contribute to monitoring for WFD

White paper

Table:

Column 1: WFD requirements

Column 2: implementation in national systems

Column 3: proxies from EO data to be considered



EOMORES and CoastObs white paper

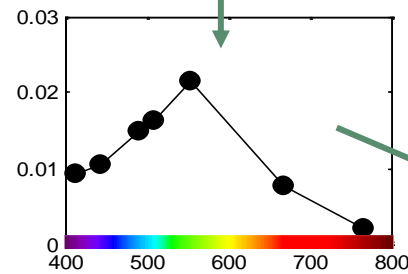
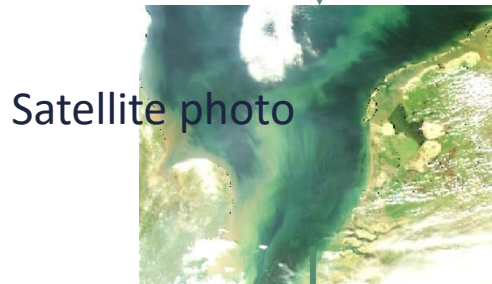
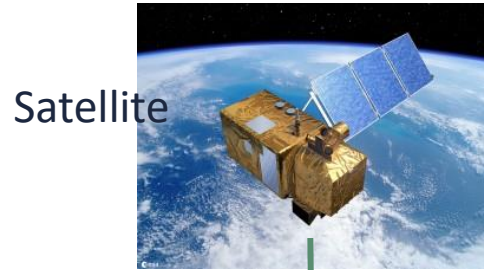
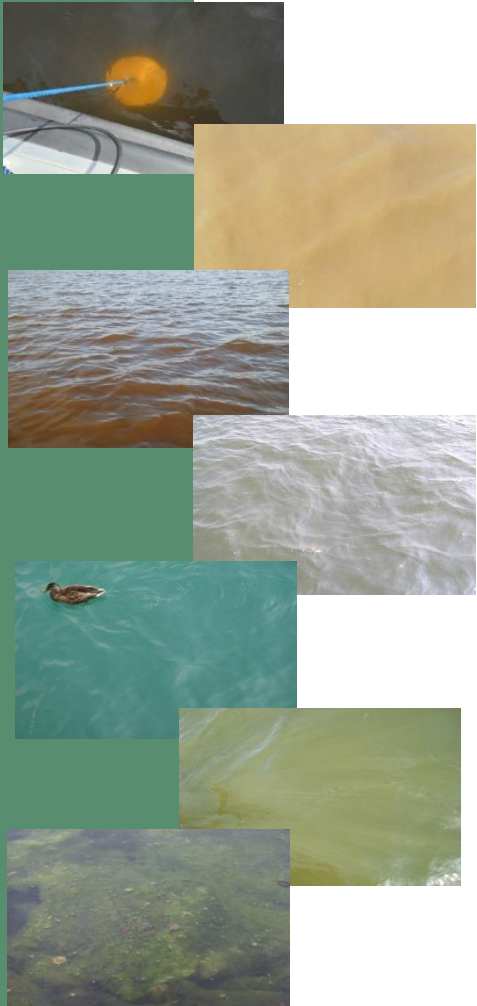
[10.5281/zenodo.3463050](https://doi.org/10.5281/zenodo.3463050)

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) ^v
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 ^{vi}
Macroalgal cover and angiosperm abundance	Combination of spatial extent and relative abundance (measured as density) of macrophytes Abundance of macrophytes ^{vii,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)
QE3-1-4. Salinity	Electrical conductivity Refractometry	Only with regionally tuned models using Coloured Dissolved Organic Matter (CDOM) as freshwater proxy. In marine/oceans: sea surface salinity
QE3-1-5. Acidification status	pH	Only in oceanic waters: from combining ocean colour, sea surface temperature, sea surface salinity ^{xvi}

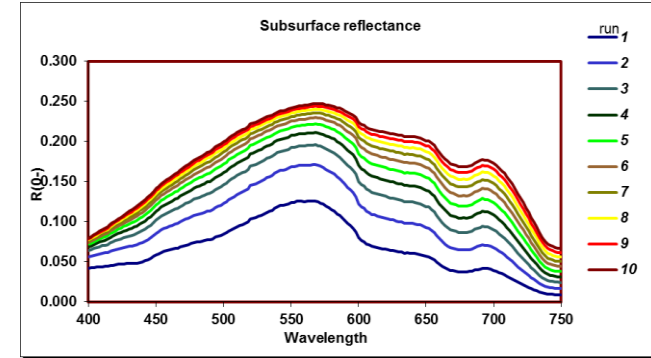
How does that work, water quality monitoring with Earth Observation?

Water colour

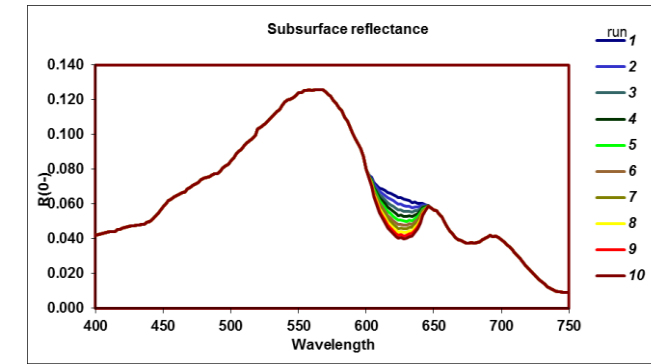


'reflectance' for each pixel: how much light is there of each colour

Modelled effect of suspended matter increase on reflectance



Modelled effect of chlorophyll increase on reflectance



Based on known effects of parameters on reflectance, algorithms can derive the parameters for each pixel



Example EO-based monitoring for the WFD

1. Map chlorophyll-a based on EO (Sentinel 2)
2. Chlorophyll-a is in the WFD used as proxy for the phytoplankton biomass
3. Apply WFD lake specific thresholds on Chl-a to derive WFD phytoplankton biomass status classes

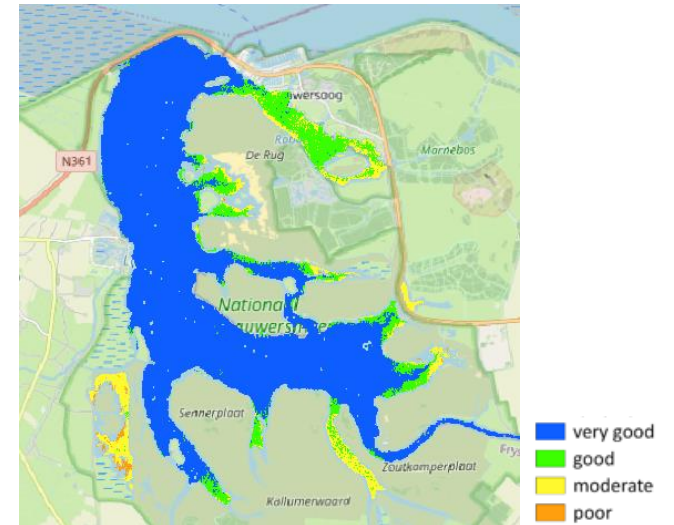
RGB



Chl-a



WFD



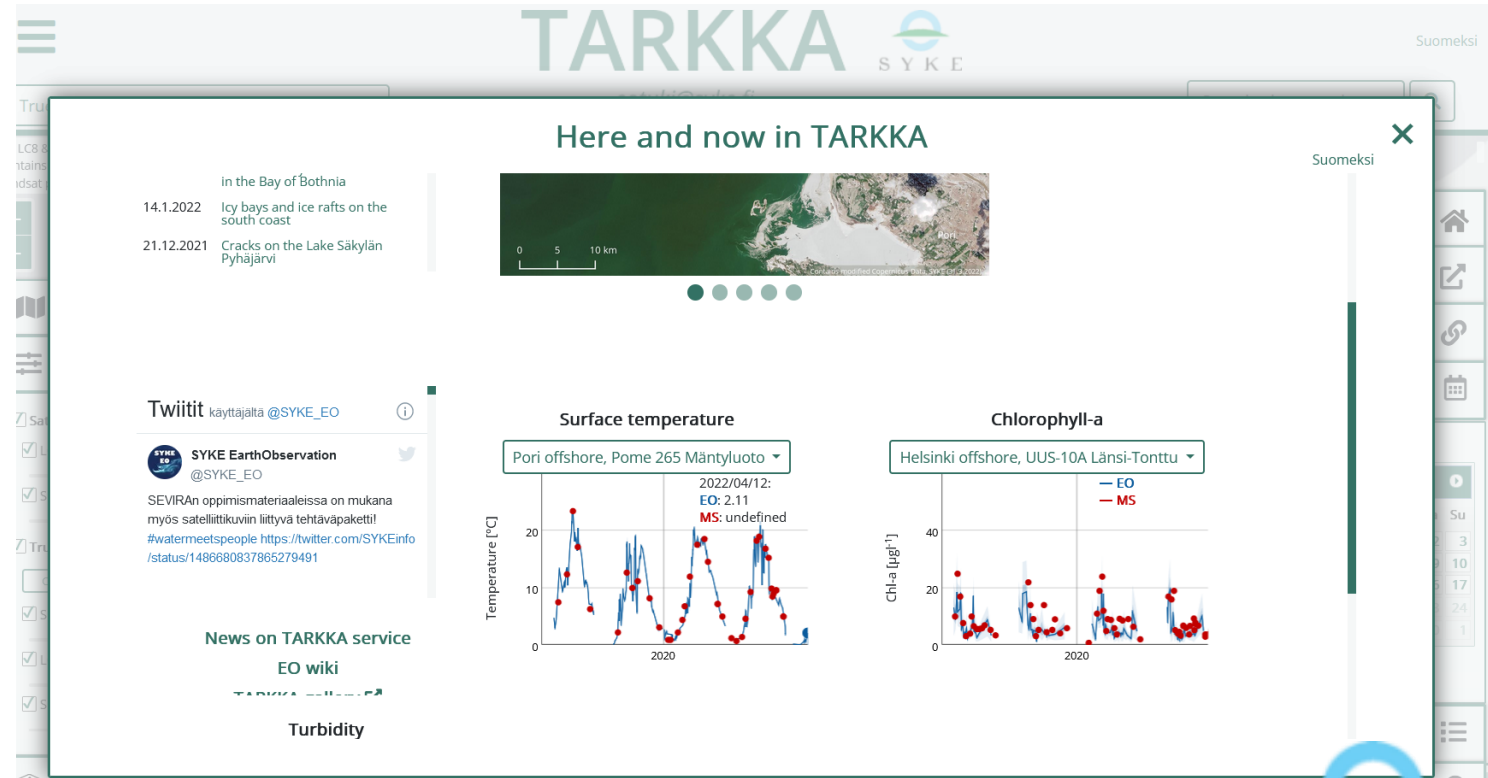
Is Earth-Observation based monitoring for WFD allowed?

For the EU Framework: yes

But national regulations differ

Often, national agencies prescribe certain methods

Use of a new data source requires re-thinking of monitoring plans and practices, additions to storage systems etc.



<https://wwwi4.ymparisto.fi/i4/eng/tarkka>

“Finland now uses operational satellite observation data in WFD reporting as complementary information for environmental status assessment. The work is carried out under direct guidance from the Ministry of Environment, and helps address the challenge of reporting on thousands of WFD waterbodies.” EOMORES and CoastObs white paper [10.5281/zenodo.3463050](https://zenodo.org/record/3463050)

e-shape pilot 5.6 Case study in Estonia



The case study

- Most lakes are still in their natural state, either eutrophic or mesotrophic
- Limited in resources, so most monitoring effort goes to
 - largest lakes
 - some small lakes based on their importance and the chances of passing WFD thresholds
- Important is to monitor also the lakes with 'good' status

Pilot together with Eesti Maaülikool (EMÜ)
(Center for Limnological research, Estonia)

e-shape pilot 5.6 Case study in Estonia



The case study

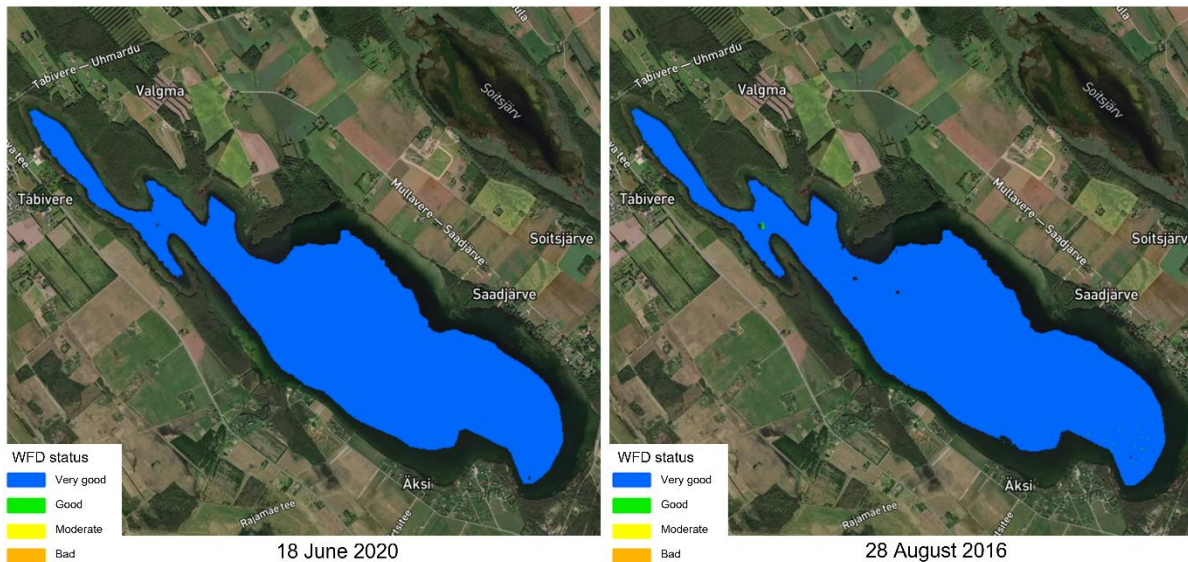
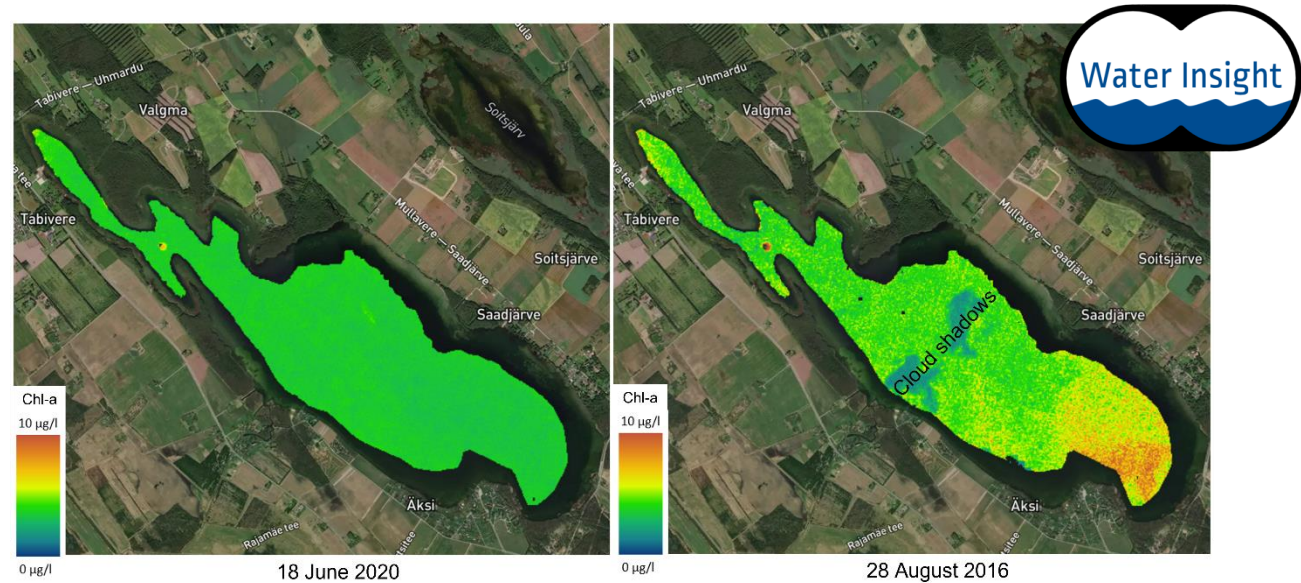
- Focus on two small clear water lakes (Saadjärv and Kuremaa järv)
- Phytoplankton biomass was mapped as Chl-a for monitoring, and WFD thresholds were applied to create status class maps
- Validation with in-situ buoy data of EMÜ



e-shape pilot 5.6 Case study in Estonia

Results

- EO confirms: Saadjärv is usually a lake with low Chl-a (example on the left)
- An example with slightly elevated concentrations of Chl-a in the south after runoff is shown (on the right)



Satellite-based WFD classification maps based on the maps of Chl-a concentrations. Although for most of the lake the WFD class is always 'very good', for a few pixels the class changed from 'very good' to 'good' on 28th August 2016

e-shape pilot 5.6 Case study in Estonia



Conclusions

- EO can be used to capture variations in phytoplankton biomass and WFD status levels even in clear-water lakes.
- EO data can therefore be used for cheap and automated monitoring for all under-sampled clear lakes, combined with targeted sampling in case of unexpected changes.



e-shape pilot 5.6 Case study in the Netherlands

The case study

- Many stakeholders involved in WFD (planning, monitoring, reporting, monitoring requirements etc)

The pilot – apply e-shape co-design methods

- Create examples
- Discuss with stakeholders
- Update examples
- Discuss the way forward



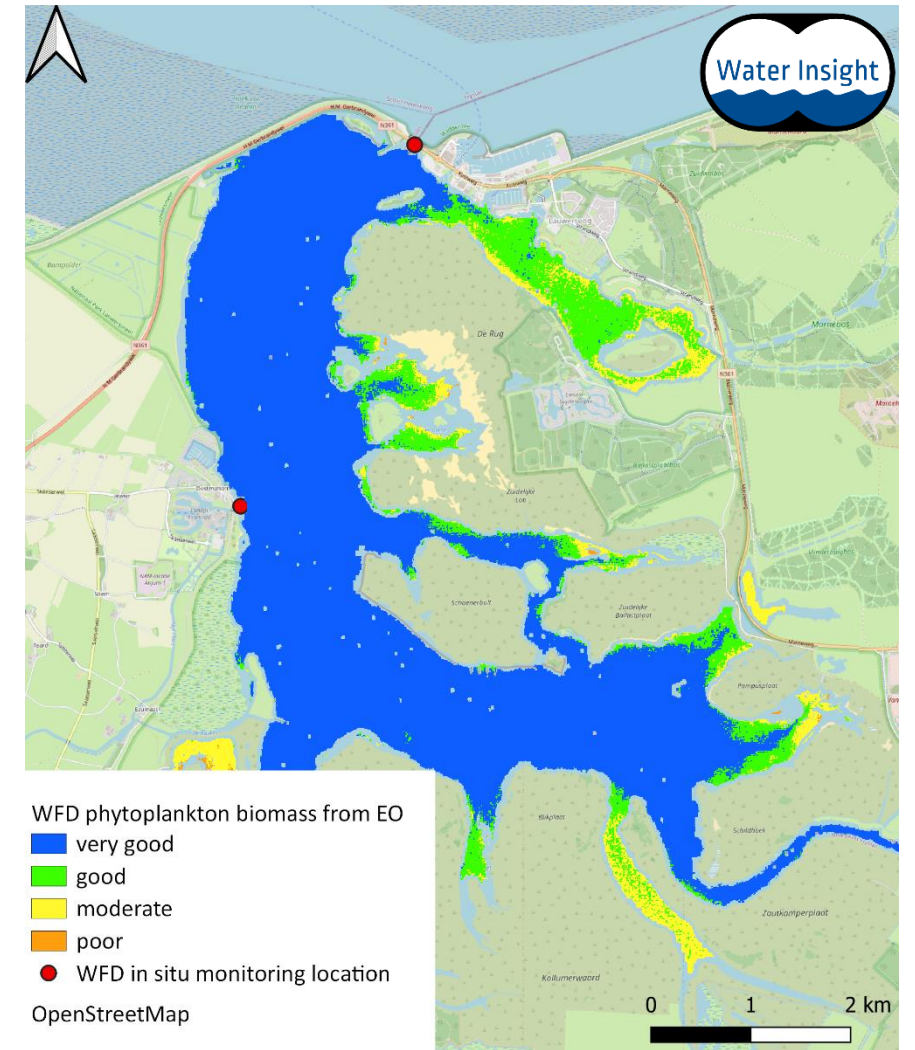
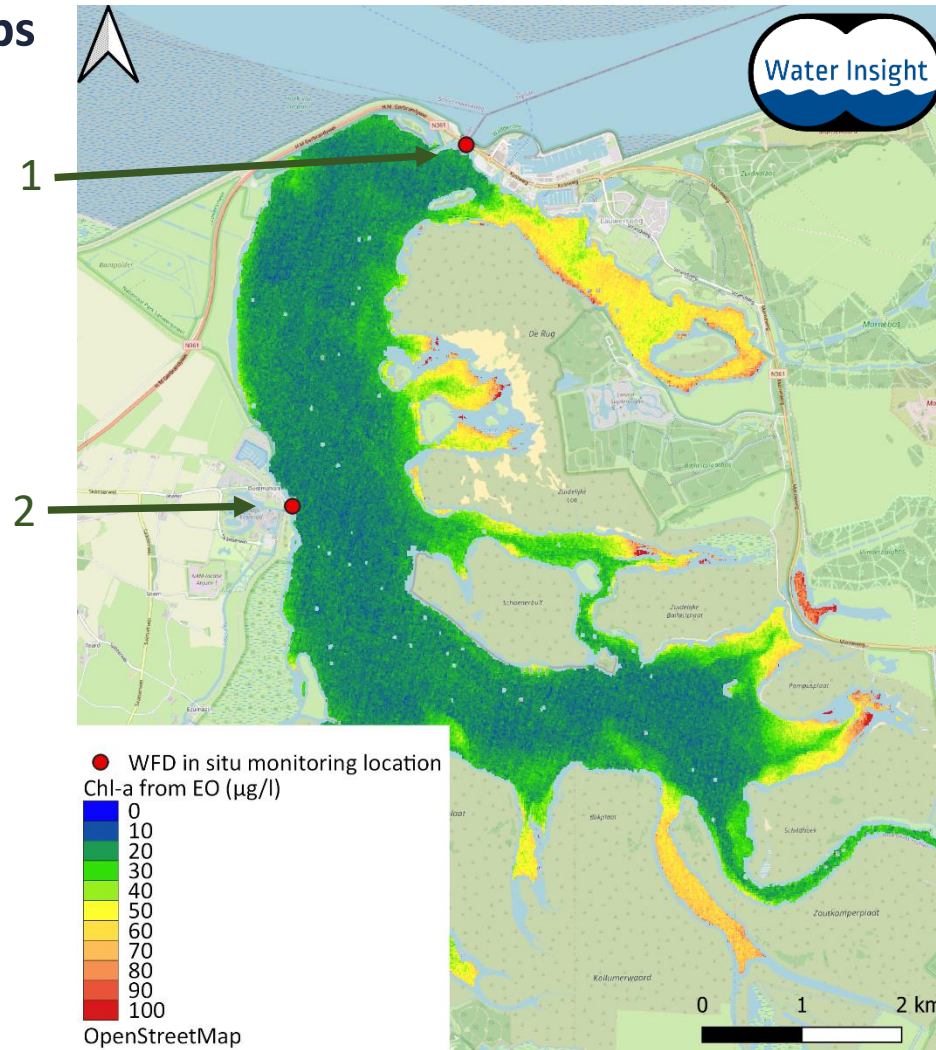
Pilot together with Waterschap Noorderzijlvest (local water authority, Netherlands)



e-shape pilot 5.6 Case study in the Netherlands

Stakeholders asked for maps to show representativeness of current stations

Results 1/3: maps





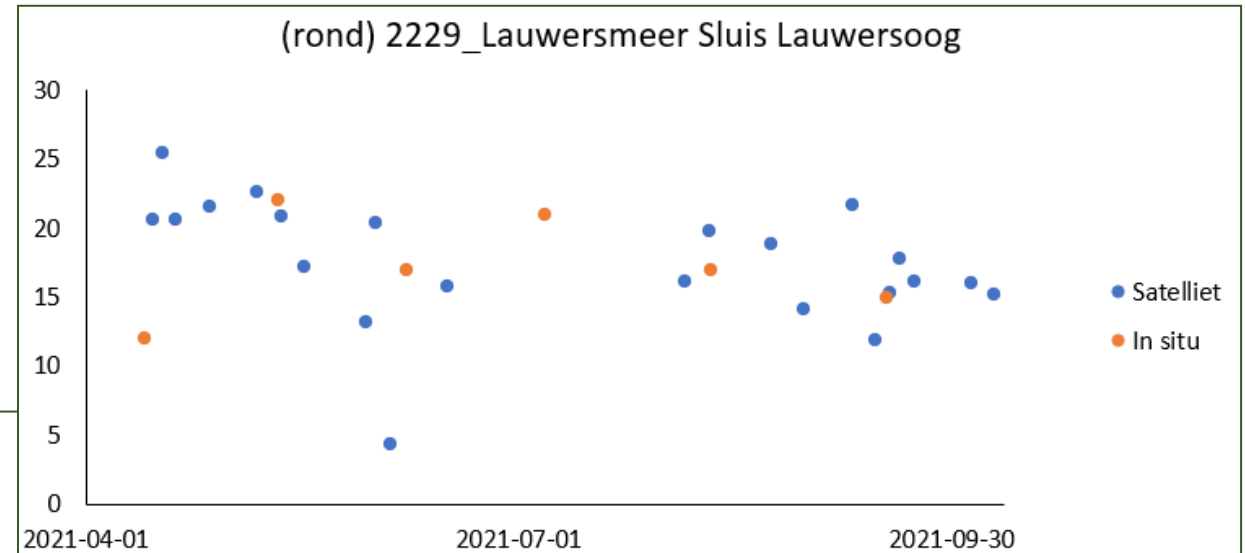
e-shape pilot 5.6 Case study in the Netherlands



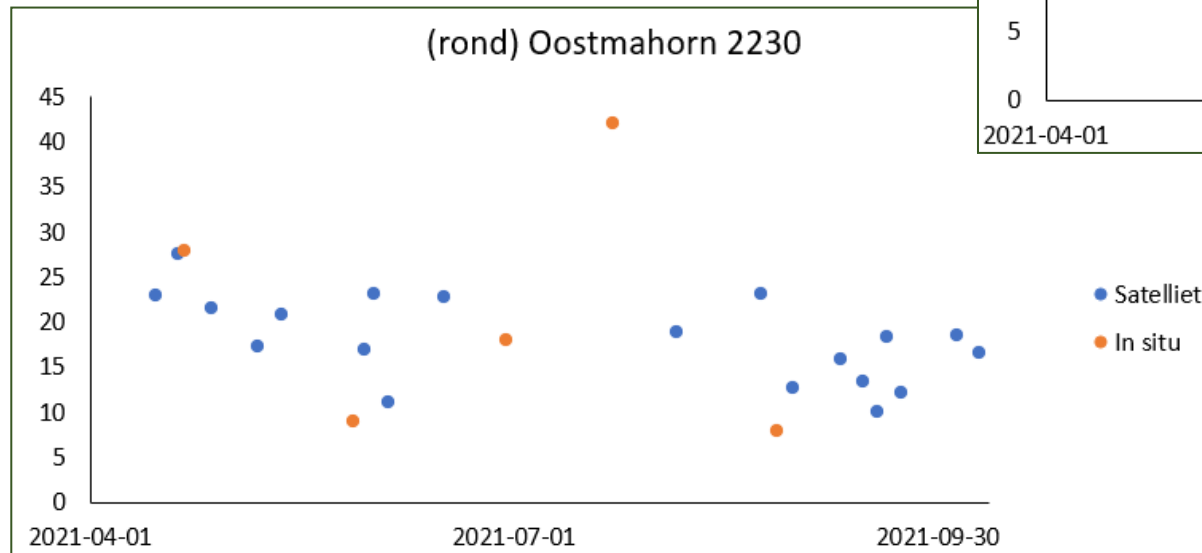
Stakeholders asked for validation in the Netherlands

Results 2/3: validation

1



2





e-shape pilot 5.6 Case study in the Netherlands

Results 3/3: Co-design



Results were discussed with stakeholders, after that the next steps. They agreed:

EO data/maps provide spatial information and can:

- help to pinpoint representative in situ locations
- be used to create additional monitoring locations
- allow to obtain this information in retrospect
- and with that fill knowledge gaps

Cost/benefit analysis seems positive



e-shape pilot 5.6 Case study in the Netherlands

Results 3/3: Co-design



It was agreed that the wealth of data from EO should be used.

The experts will:

- Start using EO-based data for e.g. systems analysis when suitable
- Involve their team, and introduce them to EO-data
- Built a community of practice to exchange experience with using EO-based data
- Communicate about the results to increase the awareness

Conclusion: What EO-based monitoring can contribute to the WFD:

- Spatial coverage
- Pinpoint representative in situ locations
- Additional monitoring data
- Obtain information in retrospect
- Cheap monitoring for lakes without issues



EO based phytoplankton biomass for WFD reporting

How satellite Earth Observation can help with monitoring for the Water Framework Directive

A good water quality is the base of a healthy ecosystem with rich biodiversity. Aquatic ecosystems provide essential services for drinking water, irrigation, recreation, aquaculture, fisheries and more. The EU Water Framework Directive (WFD) recognizes the importance of clean water, and requires member states to monitor and, if necessary, improve the water quality. Although the spatial component is key to gain insight in the processes in water, regular sample-based monitoring only provides point data.

Maps based on satellite Earth Observation (EO) can be used to get a spatial overview, and therefore obtain the necessary insights in the processes, to be able to take effective measures for improvement of the water quality. In some countries the amount of waterbodies exceeds the ordinary monitoring capabilities, so that choices need to be made on how to allocate the monitoring effort. For these countries, cheap monitoring to keep track of the lakes in good status and timely notice unexpected changes is the most important. EO is a cheaper way of monitoring; it does not require sampling personnel, ships, equipment and laboratory work, only a specialist with knowledge about EO. Results can be available the same day, so that fieldwork can be carried out soon – manual monitoring from regular targeted.

Estonia is one of the EU countries with high CH₂a concentrations. Limited in resources the largest lakes, and only some at representative and the chances of pass also the lakes with 'good' status, and EO provides a possibility there. In this pilot we therefore focussed on the small clear water lakes in Estonia. Phytoplankton biomass was mapped as CH₂a for monitoring, and ultimately WFD reporting. We demonstrate that EO can be used to capture variations in phytoplankton biomass and WFD status levels even in clear water lakes. EO data can therefore be used for cheap and automated monitoring for under-sampled clear lakes, combined with targeted sampling in case of unexpected changes.

Background information on EO data for the WFD can be found in the white paper 'Satellite-assisted monitoring of water quality to support the implementation of the Water Framework Directive' <https://doi.org/10.5281/zenodo.3103774>

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Useful links:
e-shape project www.e-shape.eu
Pilot 5.6 <https://e-shape.eu/index.php/houwaes/pilot-5-6-ao-based-phytoplankton-biomass-for-wfd-reporting>

EO based phytoplankton biomass for WFD reporting

Earth Observation for operational monitoring and system analysis of aquatic systems

The Water Framework Directive requires member states to monitor and, if necessary, improve water quality. One of the parameters to measure is the ecological status (good, moderate, poor, bad), based on phytoplankton biomass measured as chlorophyll *a* (Ch₂a).

In this pilot we developed maps of CH₂a for a lake in the Netherlands and the defined phytoplankton biomass WFD status classes maps.

Together with the local water authority (but in charge of this lake, and a group of Dutch water quality experts, we discussed the related water, cost/benefit and possibilities of the Earth Observation (EO) based maps.

Advantages

The WFD status reporting requires samples from one or a few monitoring points. In the Netherlands, sampling for reporting is well-organized and complete. However, it is often not known if the monitoring locations are representative for the whole water body.

In this pilot we developed first EO-based maps can be used for checking if the sampling stations are representative, and to check they are not representative. EO can help to pinpoint representative locations.

Samples are usually collected from the shore of the most easy to reach locations, or from one point in the middle of a lake. To understand the whole system, e.g. for a thorough system analysis, more information is needed.

EO can be used to create additional monitoring locations. Observations from EO based maps can be extracted each day, or in some locations can be used in the same way as in situ data (e.g. averaging over the season).

EO data even allows to obtain this information in retrospect, e.g. if a system change is needed now, EO data of previous years can be obtained and processed into some quality maps, so that the analysis can be retrospective without being too well for data.

When measures are taken to improve the water quality, the effect of the measures must be evaluated. To do so, it is important to obtain spatial insights, especially in lakes where some areas respond different to measures.

EO based maps can fill this knowledge gap: Maps can be made available the same day, and can therefore also be used to evaluate the results during of project, allowing the manager to adjust the plans for the response of the water body.

EO data is not seen as replacement or full in situ CH₂a measurements because: 1) over certain time periods there might be too little data because of clouds, 2) field sampling can be required for validation, 3) not all locations can be measured by EO data, e.g. small streams are too narrow for the satellite probe. This brings the question on the table: Is the additional information worth the additional costs?

With the water quality experts, the following considerations were listed:

- EO based CH₂a maps are not expensive.
- Costs can be re-allocated when the use of EO-based maps of just some regular samples are skipped.
- Measures to improve water quality are often quite costly. It is important to evaluate the effects preferably during such a project, with enough data to be able to improve and prevent unnecessary costs.
- Dutch water managers have experience with satellite monitoring with satellites, which is worth the costs. The expectation is that the same goes for surface water quality.

Possibilities

An important question we discussed was if it is allowed to use EO data for the WFD. There are two answers for this:

1. For status and trend monitoring and reporting, it is allowed to use EO data according to the WFD. However, national guidelines might prescribe the methods for each parameter. In some countries (such as Finland), methods include EO-based monitoring. In the Netherlands, this is not the case. Yet, however, the prescribed methods are subject to updates for each new WFD cycle. National water quality experts write the updates.
2. For operational monitoring for status and evaluation, water authorities can use the methods they find most suitable. The use of EO data is therefore already allowed for these purposes.

The Dutch authorities in fact were present in the meetings on EO-based maps as a very reliable additional source of information.

How the story continues

It was agreed that the results of data from EO should be used. The present experts agreed to:

- Start using EO based data for e.g. systems analysis when suitable.
- Involve their team members and organization in these projects, to introduce them to the use of EO data.
- Build a community of practice of water managers to exchange experiences with using EO-based data to full capacity.
- Communicate about the results at e.g. platform meetings, national fora and in professional magazines to increase the awareness.

Other jobs for services and contact e-shape Help Desk for more information <https://helpdesk.e-shape.eu/>

Useful links:
e-shape project www.e-shape.eu
Pilot 5.6 <https://e-shape.eu/index.php/houwaes/pilot-5-6-ao-based-phytoplankton-biomass-for-wfd-reporting>





Read more



- **e-shape** success story ‘How satellite Earth Observation can help with monitoring for the Water Framework Directive’ <https://e-shape.eu/index.php/success-stories>
- **e-shape** success story ‘Earth Observation for operational monitoring and system analysis of aquatic systems’ <https://e-shape.eu/index.php/success-stories>
- **Carvalho, L., et al.**, 2019. Protecting and restoring Europe’s waters: an analysis of the future development needs of the Water Framework Directive. *Sci. Total Environ.* 658, 1228–1238. <https://doi.org/10.1016/j.scitotenv.2018.12.255>
- **Water Insight water quality monitoring and reporting services** <https://www.waterinsight.nl/solutions/glass-global-lakes-sentinel-services>
- **EOMORES inland water monitoring services:** <https://eomores.eu>
- **CoastObs coastal monitoring services:** <https://coastobs.eu>
- dotSPACE 2022, **WaterForCE deliverable D1.3** Links between missions-services-applications
- Papathanasopoulou, E., Simis, S. et al. 2019. Satellite-assisted monitoring of water quality to support the implementation of the Water Framework Directive. **EOMORES and CoastObs white paper**. 28pp. doi: [10.5281/zenodo.3463050](https://doi.org/10.5281/zenodo.3463050)



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