Training handbook

"How to use Satellite-based Water Quality Information available at the UNESCO-IHP IIWQ World Water Quality Portal"

Comments from the UNESCO-IHP IIWQ Expert Advisory Group members and IHP Secretariat staff are gratefully acknowledged.

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Executive Summary

Practical experience on the advantages, interpretation and usage of satellite-based water quality information is not yet disseminated widely to environmental managers, although the demand on such information is high. This handbook shall improve this understanding in a nutshell to a general public, supporting water experts, politicians and individuals.

Worldwide information for lakes and rivers, derived by various satellite data is provided free and open by the UNESCO-IHP IIWQ World Water Quality Portal:

www.worldwaterquality.org

The portal and its global water quality information products are easily accessible, to support practical experience and training for anybody.

A brief guide on handling of this online web application using computers or mobile devices is provided in the portal's help section. Complementary information on the technical background can also be found on the portal.

This training handbook addresses practical questions that may come across when using satellite-based information products.

These questions are structured into thematic focus areas around product understanding, ways to access data, use scenarios, and getting supported.

1. Global water quality challenges

Water quality is one of the main challenges in the 21st century. The rising level of water pollution and increasing government funding for pollution monitoring and control are two major factors to increase global awareness of water quality measurements. Water quality is becoming a global concern due to the significant role that it plays in economic and social development. The world is faced with numerous water quality concerns such as eutrophication, salinization, sedimentation, microbial pollution as well as toxic pollution problems. Poor water quality is accompanied with economic costs in the form of health-related costs, the degradation of ecosystem functions, high water treatment costs, reduced property values, as well as impacts on economic activities such as agriculture and manufacturing.

Monitoring of inland and marine coastal waters for the evaluation of the ecological, chemical and hydro-morphological status is one of the most relevant areas of responsibility of water resources management and protection authorities worldwide. Several water monitoring related directives exist, like the Water Framework Directive (WFD) in Europe, for which the Member States have to assess the status of their water bodies and report it to the European Commission. But the monitoring capabilities of water authorities assigned with the monitoring tasks are nowadays restricted within their financial and logistical capacities.

In addition, billions are invested yearly to increase hydropower and global water storage capacities -nevertheless the net water capacity is continuously decreasing due to sedimentation in reservoirs. On the other hand, aquaculture farming has evolved into a global industry of approx. 10 bill USD/year with doubling production rate in the past years (FAO yearbook 2012), accordingly an increasing demand on intensive water monitoring in basins, inlet and discharge areas. This doubling rate of the water market annual turnover for the next decade is also expected by the WssTP Position paper on H2020, COM (2011)808-811 from 375 billion in 2011 to 720 billion Euro in 2020.

2. Satellite based water quality products

2.1 What kind of satellite-based information products are available?

The information products provided by the UNESCO-IHP IIWQ portal are listed under the section 'Parameters' of the menu bar: Turbidity, Chlorophyll, HAB indicating harmful algae bloom or Cyanobacteria appearance, Organic Absorption, and water surface temperature. Units and further short descriptions are also made accessible. The parameters produced on the portal are based on *eoWater* products provided by EOMAP GmbH & Co. KG, an optical remote sensing company in the aquatic sector. The parameters are physics-based parameters with a direct reference to globally harmonized optical properties.

There is a large variety of service providers, research organizations and projects, which provide also other water quality information products. For example, the publication of … includes a comprehensive list, and a number of recent or actual projects also focus on the provision of water quality products (list to be completed). For practical applications, users should be aware that the majority is based on analysis tools, which are applicable to one or few satellite sensors. The limitation to specific sensors means that you should check, if your specific requirements on temporal or spatial resolutions are satisfied.

Because of methodological reasons, satellite-based information products can be accessed only for the upper water column, where the majority of light is absorbed and reflected back to the satellite sensor. This are typically the first 0.1 to 30 meters. This light penetration depth is close to the so called Secchi disk depth and can be provided as information product as well. See further explanations available after the next question.

2.2 What are the key benefits and challenges using satellite derived products?

Key benefits:

- Availability over most water bodies worldwide and time periods, where no ground-based measurements are available
- Costs, logistical effort and time span to access information is a fractional amount, typically several magnitudes below ground sampling approaches.

Further strength under these main advantages include: Spatially resolved information at various levels, including millions of single measurements for each day of observation and, temporally resolved information from current status information up to historic observations.

Key challenges:

- The independent accessible products are limited to those listed in question 1.1.
- The individual uncertainties are higher than in comparison to particular laboratory measurements. Further information is available at the Booklet.

Overall, the significant information gain and cost-efficiency of using satellite-based data is the major benefit, which balances also higher uncertainties in comparison with laboratory measurements. This is especially relevant when considering the natural temporal and spatial variability of water quality parameters within a single water body (typically larger then factor 10) or on a national scale (typical factor 10 000).

However, methodological differences need to be known and accounted in the interpretation and usage of the data.

Are the satellite-based products being all comparable?

No, not yet. Standardization and quality standards of satellite-based products are still under development. The UNESCO therefore selected a state-of-the art physics-based approach, which provides products that are comparable on a physical level, as the products are linked to specific absorption and scattering units.

2.3 What is the difference between satellite derived water quality measures and laboratory or in-situ measures?

As a whole, the term water quality is used by very different user groups and industries for a large variety of measures. This includes many measures, which cannot at all, or not directly accessed by the optical earth observation and satellite instruments. Examples include specific trace organics in the water cycle, parameters such as the Chemical or Biochemical Oxygen Demand COD and BOD used for water analysis. Also, phosphor bonds cannot be detected directly through measurements in the visible and infrared region of the satellite observations. However, in some cases, there exist empirical or substantial relations. Some may serve as a global proxy already if the accuracy of each individual measure is not of relevance. Others are restricted to a certain region or certain seasonal conditions.

Optical satellite measurements can instead access information on water quality parameters, which are based on absorption, scattering and also fluorescent properties of water constituents. These include the parameters listed under question 1.1.

Laboratory or in-situ measurements of the parameters accessible from space follow typically a very different analysis protocol, such as the ISO normed photometric Chlorophyll-a standards or are calibrated to those (e.g. fluorescence-based instruments or HPLC analysis). Only few are methodological relative comparable to the satellite measurement. In-situ measured turbidity for example is usually measured by 90-degree side scattering of selected light frequencies, while the satellite-based methodology is based on the approx. 180° backscattering signal from the water column at a broader wavelength range.

Methodological differences therefore have to be taken into account when comparing the different approaches, or when using and interpreting satellite-based data (see X). These differences include also

- Sampling depth, which might be distinct or mixed depth for in-situ samples, but always integrated in the upper water column (approx. within the Secchi disk depth or 90% of the euphotic zone) for satellite-based measurements.
- Location, which might impact large differences in comparisons and also introduced by
- Sampling time, which again has a significant impact on measured values

- Sampling area, which usually can be treated as point measurement for water sampling, and area integrated sampling for satellite measurements, covering few m2 for very high-resolution sensors up to km2 for coarse resolution sensors.

How accurate are the products?

For comparisons with ground-based and laboratory data, the previous listed methodological differences need to be reflected. Sampling related differences through varying sampling depth, time shifts of few hours or days, shifts in the spatial location typically result in uncertainties of factor 0.5 and higher. In relation to these impacts, the accuracy of satellite based products is higher, see details in the validation overview presentation, with a set of selected validation results from previous studies.

3. Application fields

3.1 What are typical application cases?

Directive Monitoring:
With provision of customized products and reports for their monitoring obligations, cost effective monitoring of essential water quality parameters for inland water bodies for environmental assessments, e.g. for the Water Framework Directive, support governmental authorities on local, regional and national level.

Water industry:
With fast and high-resolution satellite-based water quality data provision an increase of the responsiveness level of water managers against possible short to medium term changes of the quality of the water like increased turbidity or algae blooms and thus enabling proactive informed decision making on an operational level can be achieved. Main profiteers are e.g. water treatment plant operators of drinking water reservoirs or hydropower operators.

Aquaculture:
Daily spatial monitoring of e.g. shrimp ponds and the related coastal water conditions, comprising several water quality parameters such as turbidity, chlorophyll, the detection of water quality anomalies and Harmful Algae Blooms (HAB's), and Surface Temperature reduce costs for treatment activities in Aquaculture farms. Also, site location decisions can be supported by evaluating time series of water quality data.

River management:
Information of sediment transports for better understanding the transport processes of suspended sediments in waterways is essential to reduce river engineering expenses such as dredging and can be gained using satellite water quality products.

Desalination plants
Provision of high resolution water temperature mapping can support impact assessment for desalination plants planning and maintenance.

Dredge Monitoring:
With satellite-based products environmental impact of dredging activities can assessed, e.g. through change monitoring for evaluation of ecological status, independent of in situ measures.

Tourism:
Up-to-date water quality data for bathing waters or recent turbidity status for planning of diving activities can be of great usage for both tourists, but also for stakeholders in the tourism industry (hotels, diving schools etc.)

4. Access to satellite-based information

4.1 How can I find and access the water bodies I am interested in?

Information for worldwide lakes and rivers worldwide by the IIWQ World Water Quality Portal is online, open and free accessible at

www.worldwaterquality.org

This web page is accessible through computers or mobile devices. It opens a web application, which allows you to browse to any location worldwide, and access information on satellite derived water quality parameters.

A brief guide on the handling of this web application is provided in its help section, while complementary information on the technical background is available with the Booklet on Water Quality Monitoring.

- If you do not find suitable information products for your area of interest, there might be a number of underlying reasons. For example, the requested water body might be too small for the satellites used here, or it was occasionally covered by cloud, to shallow, or other reasons. Several aspects are addressed in the Whitepaper in the chapter 2 'Supported Spatial and Temporal Resolutions'
- There are several options to get help, which are listed below in the support section. E.g., in case you need a higher spatial resolution to detect your water bodies, you might contact service providers who can access and process to high resolution satellites with a spatial resolution of up to 1m per measurement point.

4.2 Can I get information of past years or continuous up-to-date data?

Yes, historic satellite records allow to go back in time for more than 30 years. Using transferable processing technologies, water quality information can be generated independently also for historic conditions. Just keep in mind, that the quality of the information products might be lower for previous satellite sensors in comparison to current systems, as well as the temporal or spatial resolution.

And yes, also actual information and continuous monitoring is possible with up to several records per week nowadays under cloud free conditions and spatial resolutions up to 10m. Commercial satellite sensors and data analytics services will support soon also multiple records per day at a resolution of less than 10m, at least for products such as turbidity.

At the IIWQ portal, we provided for demonstration purposes one complete global layer in 90m. Due to the importance of the temporal dynamics, UNESCO provided time series data in 30m resolution, for one full year 2016 in selected demo regions at the portal. These time series are based on observations from three different satellite sensors to provide a good temporal resolution. The same sensors – Landsat 8, Landsat-7 and Sentinel-2A – were used for the global layer.

5 Support

5.1 How to share my experience, propose improvements, and exchange experience with other organizations worldwide?

More information and documents are made available at the UNESO IHP-IIWQ World Water Quality Portal soon.

Knowledge Transfer:

To access valuable information on water quality measurements and to identify key issues and challenges, training workshops and webinars will be made available soon worldwide.

Exchanging ideas and promoting best practice on water quality issues is vital for generating a knowledge base that can be shared among all stakeholders.

Expert trainers will lead interactive workshops or closed workshops tailored towards special needs.

5.2 Where can I receive support?

Please contact Dr. Sarantuyaa Zandaryaa, Programme Specialist, Division of Water Sciences, UNESCO-IHP IIWQ, Paris, France.

or

Karin Schenk, Water Quality Project Manager, EOMAP GmbH & Co. KG, Seefeld, Germany.

Help and support

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