

Using Earth Observation for Water Quality Monitoring: Resources and Information

This is a selection of resources and links to accompany our workshop on ‘Using Earth Observation for Water Quality Monitoring’ 13-14 October 2020. It is not intended to be a comprehensive list, and links to service providers are not endorsements. We hope you find it useful!

Copernicus platforms and sensors

Sentinel-1	C-Band Synthetic Aperture Radar (SAR) imaging mission. Acquire imagery in all weather conditions. ESA Online Information Sentinel-1
Sentinel-2	Multi-spectral imaging mission. Wide swath and high revisit time making its products suitable for monitoring Earth’s surface changes. ESA Online Information Sentinel-2
Sentinel-3	Multi-instrument satellite developed to provide information about the oceans including sea surface topography, ocean & land surface colour, forecasting, environmental & climate monitoring, and ocean & land surface temperature. ESA Online Information Sentinel-3
Overview of other missions	Sentinel-4 focusses on air quality monitoring of Europe at high temporal and spatial resolution, measuring trace gases and aerosols. Sentinel-5 is also dedicated to air quality monitoring but focuses on the composition of the atmosphere including Carbon monoxide, Methane and Ozone. Sentinel-5P is Copernicus’ precursor mission which aims to fill the gap between the retirement of the Envisat satellite and NASA’s Aura mission and the launch of Sentinel-5. It performs atmospheric measurements including UV radiation, climate forecasting and ozone.

Accessing Data and Products

Sentinel-Hub	Sentinel Hub allows users to easily access Earth observation imagery from a variety of satellite missions and process the information via a user-friendly interface.
Copernicus Marine Environment Monitoring Service (CMEMS)	Provides reference datasets and information from both Copernicus satellites and in-situ measurements. The three categories of information are ocean products, ocean indicators and ocean state reports.
Copernicus Land Monitoring Service	The Global Land Service systematically produces a series of qualified bio-geophysical products on the status and evolution of the land surface, at global scale and at mid to low spatial resolution, complemented by the constitution of long-term time series. The products are used to monitor the vegetation, the water cycle, the energy budget and the terrestrial cryosphere.

Copernicus Global Land Service	An operational, recent data service including inland water products (temperature, quality, water level). CGLS is a component of the Land Monitoring Core Service of Copernicus.
Copernicus Climate Change Service	Provides information about the past, present and future climates and tools to enable mitigation and adaptation of climate change by policy makers and businesses. Key services include bulletins, data store, data application examples and focus snapshots.
European Organisation for the Exploitation of Meteorological Satellites (EUMetSat)	Intergovernmental organisation supplying satellite derived data of weather and climate to the meteorological services of the member states in Europe and users worldwide. It manages a fleet of satellites which measure variables of the atmosphere and ocean & land surfaces.
NERC Earth Observation Data Acquisition and Analysis Service (NEODAAS)	Offers key services to support the use of Earth observation within the UK research community and other users. Services include development of products, satellite data processing, airborne data processing, near real-time support & rapid response, support & training and the Massive GPU Cluster for Earth Observation (MAGEO).
European Space Agency (ESA)	Manages the Sentinel missions for applications associated with Earth observation as well as advancing communications, navigation, exploration of space and innovative new technologies.
Copernicus Open Access Hub	Also known as the Sentinels Scientific Data Hub, it provides free and open access to Sentinel user products. Data can be accessed through the Open Hub interface, the API Hub or via the Copernicus Data and Information Access Services (DIAS) platforms .
Cefas Data Hub	The Cefas open data portal containing 2088 metadata records and 5627 data sets available for users to download and use. This contains records on remote sensing, water column parameters, fisheries and plankton.
Mercator Ocean International	A private non-profit company which implements and operates the Copernicus Marine Service
Cefas Marine Assessment Tool (CefMAT)	A service which uses satellite and modelling data from CMEMS to provide data products associated with water quality, eutrophication, marine food webs, biodiversity and marine assessments.
Global Earth Observation System of Systems (GEOSS)	Several Earth observation processing systems which interact and provide access to diverse information for a broad range of users in both public and private sectors. A hosted portal provides a single point of access to data, imagery and software packages.
Environment Agency Water Quality Archive	Provides data on <i>in situ</i> water quality measurements taken at sampling points from coastal, estuarine and inland waters in England.
NERC Earth Observation Data Centre (NEODC) at the Centre for Environmental Data Analysis (CEDA)	Archive of Earth observation data and derived products from many platforms and sensors – includes datasets on sea and lake surface temperature, phytoplankton size classes, coastal zone colour, Sentinel-3 and MERIS.
ESA's Climate Change Initiative Open Data Portal	Provides access to climate data records for over 20 essential climate variables, including lakes and oceans products.

Tools and Software

Sentinel Application Platform (SNAP) software	<p>SNAP is a platform with functions including a Modular Rich Client Platform, Graph Processing framework, Portability and Titled Memory Management amongst others. These features make it suitable for Earth Observation processing and analysis. The SNAP architecture is used across the Sentinel 1, 2 and 3 toolboxes.</p> <p>SNAP download from ESA SNAP release notes SNAP on GitHub</p>
WEKEO platform	<p>Offers access to Copernicus data and information and the Copernicus services (e.g. Climate, Land and Marine). Cloud-based processing & tools. Ready to use virtual machines, including SNAP. Also contains user support mechanisms.</p>
Scientific Toolbox Exploitation Platform (STEP)	<p>A community platform for accessing software, training materials, liaising with developers & the scientific community and promoting results & achievements. Use STEP to access the ESA toolboxes.</p>
Case-2 Regional CoastColour (C2RCC)	<p>The C2RCC processor carries out numerous functions to interpret light scattering and absorption. In optically complex waters determining the colour of water is useful for detecting eutrophication and sediment-loaded water bodies amongst other applications. The processor corrects for atmospheric effects. It can be accessed through the SNAP toolbox.</p>

Collaboration and Innovation

GloboLakes LIMNADES database	<p>The Global Observatory of Lake Responses to Environmental Change. The GloboLakes programme investigates the state of lakes and their response to climatic and other environmental drivers of change at a global scale using long-term satellite observations.</p> <p>Associated with GloboLakes is the Lake Bio-optical Measurements and Matchup Date for Remote Sensing (LIMNADES) database. It was formed during the GloboLakes project and is still maintained by Stirling University.</p>
CERTO	<p>Copernicus Evolution: Research for harmonised Transitional water Observation (CERTO) aims to increase harmonisation of the marine, freshwater and transition zones by integrating water quality data from the Copernicus Marine, Copernicus Climate Change and Copernicus Land services.</p>
CoastObs	<p>An EU H2020 funded project which uses satellite data (Sentinel-3 and Sentinel-2) to monitor coastal water environments and develop a platform providing validated products to users. Products include monitoring of phytoplankton size classes, primary production, harmful algae, seagrass and macroalgae and indicators.</p>
Living Laboratory	<p>Led by the University of Stirling, Living Laboratory is an environmental monitoring system providing information on water quality and quantity such as in reservoirs, bathing water, early warning monitoring of flooding, and water temperature. The system will use Artificial Intelligence, Satellite data and sensors to provide this information, integrated using EE's 5G network, across the Forth Valley in Scotland.</p>
MONOCLE project	<p>Multiscale Observation Networks for Optical monitoring of Coastal waters, Lakes and Estuaries. An EU H2020 funded project which creates</p>

Global user requirements survey among water quality practitioners	sustainable <i>in situ</i> solutions to support satellite Earth Observation of optical water quality for inland and transitional waters. A global user requirements survey was carried out among water quality practitioners early in the MONOCLE project, looking at issues of cost, responsibility and security. The slide pack of the results is available under a creative commons license.
GEO AquaWatch	AquaWatch is an initiative within the Group on Earth Observations (GEO) with the aim to develop and build the global capacity and utility of Earth observation-derived water quality data, products and information to support water resources management and decision making.
Data Cubes for Copernicus	DCS4COP is a service with aids users handling large volumes of data by integrating data streams from a variety of sources. Sources are the Copernicus Water DataCube Service (CoWaDaCS), Sentinel data, Copernicus Service data and user supplied data. DCS4COP provides users with processing capability, software and training.
UK Lakes Observatory	A satellite-based climate service producing weekly Chlorophyll products for 933 UK lakes using a dynamic selection of algorithms based on lake optical water types. The platform is due to go live in 2020/2021.

Case Studies / References - by application

Earth Observation Overview	
The Blue Book: Copernicus for a Sustainable Ocean	Free downloadable book published in November 2019 telling the story of the Copernicus Marine Service, its impact and benefits.
From Observation to Information and Users: The Copernicus Marine Service Perspective, Le Traon et al. (2019)	An overview of the Copernicus Marine Environment Monitoring Service (CMEMS), and the benefits of high-level products ready to use in applications and services (Open Access)
Defra Earth Observation Centre of Excellence	Examples of some of the projects conducted with the Defra Earth Observation Centre of Excellence
Litter and plastic pollution	
Finding Plastic Patches in Coastal Waters using Optical Satellite Data, Biermann et al. (2020)	Detecting marine macroplastics using optical data collected by the European Space Agency Sentinel-2 satellites. (Open Access)
CMEMS Use Case - DHI Italia supporting ARPAL with marine litter and water quality monitoring	Utilises the Mediterranean Sea Physics Analysis and Forecast product.
CMEMS Use Case - Modelling plastic pollution in the Mediterranean Sea.	Utilises the Mediterranean Sea daily analysis with a hydrodynamic-wave modelling system.
Water quality Management	
Copernicus Use Cases - High-resolution modelling tool to improve water quality management.	Focuses on the coastal area where there are interactions of both physical ocean processes and high occurrence of human activity.
CMEMS Use Case - Monitoring and forecasting nearshore water quality.	Tools and services provided by the Estonian Marine Systems Institute (MSI), here use the Analysis and Forecast model.

CMEMS Use Case - SkyFISH:	Water quality monitoring tool advises users on the availability of the fish resources and their sustainability in the Black Sea. This project uses products integrated within the platform and as added-value products combined with the modelled outputs.
Satellite-assisted monitoring of water quality to support the implementation of the Water Framework Directive, Papathanasopoulou et al. (2019)	This paper makes recommendations to promote and support the use of satellite-based water quality metrics in WFD statutory monitoring and reporting activities. (Open Access)
Oil Spill monitoring	
CMEMS Use Cases - Oil spill drift monitoring in the Maltese Waters	A forecasting tool developed by the University of Malta to assist decision making concerning oil spills around the Malta Island. Uses the Marine Analysis and Forecast model and Physics Model providing hydrodynamic forecasting.
EASOS (Earth and Sea Observing System) Marine Watch	Application using radar satellite imagery to automatically detect potential oil spills. Provides decision support for containment and cleaning efforts, reducing environmental damage. Development led by Plymouth Marine Laboratory and funded by the UK Space Agency.
Eutrophication - harmful algal blooms	
CMEMS Use Cases- Harmful algae bloom monitoring for aquaculture farms in Ireland	The Marine Institute in Ireland releases weekly Harmful Algae Bloom (HAB) bulletins. Uses the Marine Analysis and Forecast model and Physics Model providing hydrodynamic forecasting. In situ and satellite data from CMEMS is also used.
Bloomin' Algae Citizen Science app	Bloomin' Algae is a Citizen Science app for reporting the presence of harmful algal blooms of blue-green algae. The app helps speed up public health warnings and can help teach you how to recognise the risks to you, children and animals.
S-3 EUROHAB- Sentinel products for detecting EUtROphication and Harmful Algal Bloom events	Focussing on the way water quality and harmful algal blooms (HABs) are monitored in the English Channel. The project uses data from Copernicus Sentinel 3 to create a web-based alert system.
MACROMAN project- National University of Ireland	Project aiming to implement methods to quickly identify the main pressures in estuaries in Ireland which are affected by blooms, look at the response to blooms to management measures and identify solutions.
Coastal & inland waters	
Moving towards global satellite-based products for monitoring of inland and coastal waters. Regional examples from Europe and South America, Spyarakos et al. (2020)	This study provides an overview of the challenges and solutions of developing a global observation platform, including the diverse and complex optical properties of inland waters and guided algorithm selection procedure required to deliver reliable data.

Assessment of atmospheric correction algorithms for the Sentinel-2A MultiSpectral Imager over coastal and inland waters, Warren et al. (2019)	A comparison of publicly available atmospheric correction algorithms to optical in-situ measurements within the Baltic Sea and Western Channel (Open Access)
DANUBIUS-RI Documentary	DANUBIUS-RI's Mission is to facilitate and contribute excellent science on understanding the continuum from river source to sea to provide interdisciplinary knowledge and data for sustainable management, use and protection of River-Sea Systems.
Priority Habitats in England	A citizen science initiative to contribute observations on a range of lake habitat parameters for priority habitats in England.
Optical types of inland and coastal waters, Spyrakos et al. (2017)	In this study, a comprehensive dataset from more than 250 aquatic systems, representing a wide range of conditions, were analysed in order to develop a typology of optical water types (OWTs) for inland and coastal waters. (Open Access)
Seabed Habitat mapping	
Estimation of the diffuse attenuation coefficient KdPAR using MERIS and application to seabed habitat mapping, Saulgiun et al. (2013)	Comparison of the most common models of satellite derived K_{d490} to an in-situ dataset, for clear and turbid waters using MERIS reflectances. (Open Access)

Case Studies / References - by product

Chlorophyll-a	
A global approach for chlorophyll-a retrieval across optically complex inland waters based on optical water types, Neil et al. (2019)	An evaluation of the performance of chlorophyll retrieval algorithms for remote sensing applications. Algorithms are tested in water bodies of varying optical properties and recommends an optical water type framework to provide overall accuracy.
Seamless retrievals of chlorophyll-a from Sentinel-2 (MSI) and Sentinel-3 (OLCI) in inland and coastal waters: A machine-learning approach, Pahlevan et al. (2020)	The Mixture Density Network (MDN) machine-learning model which is an algorithm able to be applied to different bio-optical regimes in inland and coastal waters. (Open Access)
Applicability of Earth Observation chlorophyll-a data in assessment of water status via MERIS — With implications for the use of OLCI sensors, Attila et al. (2018)	An analysis of the benefits of using chl-a concentrations derived from EO (MERIS or OLCI) data for Water Framework Directive status assessments. MERIS enabled reliable estimates for 65% of the coastal water bodies studied. (Open Access)
Ocean Colour	
Satellite Ocean Colour: Current Status and Future Perspective, Groom et al. (2019)	This paper describes the current status and future prospects in the field of ocean colour focusing on large to medium resolution observations of oceans and coastal seas. It reviews the user requirements in terms of products and uncertainty characteristics and then describes

	features of current and future satellite ocean-colour sensors, both operational and innovative. (Open Access)
Special Issue on Remote Sensing of Ocean Color: Theory and Applications, Platt et al. (2020)	Current developments in Ocean Colour Remote Sensing (OCRS) including advances in the application of the technology, the understanding of the underpinning science and its relevance in monitoring climate change and engaging the public. (Open Access)
Ocean Colour- Climate Change Initiative (OC_CCI)	The project focusses on the Ocean Colour ECV encompassing water-leaving radiance in the visible domain, derived chlorophyll and optical properties. Data can be extracted and downloaded from the website.
Primary Production, an Index of Climate Change in the Ocean: Satellite-Based Estimates over Two Decades, Kulk et al. (2020)	In situ measurements of photosynthesis of phytoplankton were compared to irradiance parameters and a 20-year record of climate quality satellite observations to assess primary productivity on a global scale, seasonally and over multiple years. (Open Access)
Trends in Winter Light Environment Over the Arctic Ocean: A Perspective From Two Decades of Ocean Color Data, Sathyendranath et al. (2020)	This paper investigates the Arctic open-water season and the effects of cloud cover by using masks of valid-invalid ocean colour pixels and comparing to sea ice products from satellites. (Open Access)