Using Earth Observation for Climate Change Monitoring: Resources and Information

This is a selection of resources and links to accompany our workshop on 'Using Earth Observation for Climate Change Monitoring' 04-07 October 2021. 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 NASAs 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.
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.
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	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. SNAP download from ESA

	SNAP release notes SNAP on GitHub
WEkEO platform	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.
Scientific Toolbox Exploitation Platform (STEP)	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.
Case-2 Regional CoastColour (C2RCC)	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.
JNCC GitHub page	As part of a project that that makes analysis ready Sentinel-1 and Sentinel-2 data available in the UK, JNCC have have set up a public repository for sharing code in any language for processing or analysing Sentinel data

Collaboration and Innovation

ConnectEO	The European Union's ConnectEO project aims to promote access to and long-term cooperation with international markets for European EO companies. Australia and Chile have been identified as countries of interest for maritime and agriculture sectors.
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.
GloboLakes LIMNADES database	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. 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.
MONOCLE project Global user requirements survey among water quality practitioners	Multiscale Observation Networks for Optical monitoring of Coastal waters, Lakes and Estuaries. An EU H2020 funded project which creates sustainable *in situ* 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.

Case Studies / References

Earth Observation Overview	
ESA's climate change initiative	The CCI platform provides an overview of the role of EO has in understanding Climate Change. Includes ESA missions, case studies, an open data portal and an interactive data explorer.
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. **Chapter 6 on ocean climate.**
Deglaciation and ice monitoring	
Drift+Noise Polar Services	The service provides EO based, automated mapping of sea ice and determination of safe cargo shipping routes.
Temperature and GHG	
Air pollution measurements	Detailed tutorial on the measurement of air quality with Sentinel-5P data.
Satellite measurements of air quality and greenhouse gases: application to regulatory activities	Detailed technical report from the UK's Environment Agency on the measurement of greenhouse gases with S5P.
Urban Heat	Technical report on the use of the Copernicus Climate Change Service (C3S) for the measurement of urban heat in metropolitan areas.
Forest monitoring	
Ecometrica Forests 2020	5-year program for the EO monitoring of deforestation in South America.
Sentinel script contest on deforestation	Tutorial and code for mapping deforestation with Copernicus data.
Forestry services based on C3S data	A European market study to identify and characterise the valuable climate information and services that could be generated from C3S data and infrastructure.
Peatlands	
Sentinel data for monitoring change in peatland condition	A study from JNCC on the condition of upland and lowland peatlands across England, Scotland, and Wales. Maps were using aerial photography and a time-series of Sentinel-2 imagery from 2015 to 2020.
Tropical Peatlands	The International Tropical Peatlands Centre focuses on efforts to conserve and sustainably manage peatlands throughout Southeast Asia, the Congo Basin and Peru.
Moorland Change map and The Impact of Peatland Restoration on Local Climate: Restoration of a Cool Humid Island, Worral et al. 2019	This project by Natural England uses Satellite data to produce an annual map of moorland condition and changes, including cutting and burning.

Space4Climate demo on recovery of Peatland areas	Winning project in the Space4Climate competition which demonstrates the harnessing of EO data for the monitoring of peatlands and restoration actions to reduce carbon emissions from them.
Photosynthesis capacity of restored Peatlands, Lees et al. 2019	This study presents a model for gross primary productivity of peatlands based on satellite data and suggests formerly afforested peatlands undergoing restoration regain full photosynthesis capacity after five to ten years.
The role of earth observation in an integrated framework for assessing peatland habitat condition and its impact on greenhouse gas accounting	This report describes an exploratory assessment of the potential of freely available Earth Observation (EO) data to map and monitor the condition of the UK's peatlands. A primary aim of the work was to develop methods for classifying peat condition attributes to enable peatland Greenhouse Gas (GHG) emissions and removals to be predicted for the UK GHG Emissions Inventory, however it also considers the wider potential of EO methods to support a range of peat condition mapping and monitoring requirements
Wetlands & inland waters	
Moving towards global satellite-based products for monitoring of inland and coastal waters. Regional examples from Europe and South America, Spyrakos 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.
Short-Term Change Detection in Wetlands Using Sentinel-1 Time Series, Muro et al. 2016	This study presents an automated, SAR based monitoring system to capture wetlands' high spatial and temporal variability. Two wetlands with different ecological characteristics are tested; a seasonal isolated wetland in southern Spain and a coastal wetland in the south of France.
Climate change effects on water quality	This case study uses nutrient indicators from the C3S for Water demonstrator to show the impact of climate change on nutrient loads and concentrations in Swedish lake waters for various scenarios.
Copernicus Evolution: Research for harmonised and Transitional water Observation (CERTO)	This project runs from 2020-2023 and will bring together six user-case studies with a wide variety of stakeholders to focus attention on industrial, policy, environmental issues in poorly characterised transitional waters (three lagoons and three estuaries) each with associated coastal zones. This will provide the most comprehensive in situ validation data set to undertake water type classification in all water bodies from oceans, to coasts, estuaries, lagoons and lakes.

Oceanography	
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).
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).
ESA-SOLAS - OceanFlux Greenhouse Gases and The AMT4OceanSatFlux project	The atmosphere-to-ocean exchange of greenhouse gases is a critical part of the Earth's climate system. These projects by Plymouth Marine Laboratory aim to improve air-sea exchange (flux) estimates of CO2 and other greenhouse gases using Earth Observation (EO) data.
THE COASTAL DYNAMICS MONITOR	This project uses EO data to monitor the impact of the sandscaping and track the subsequent natural movement of UK beach sediments on a monthly basis.
Flooding	
Feasibility assessment of an automated, global, satellite-based flood monitoring product for the Copernicus Emergency Management Service	Detailed technical report by the European Commission on global flood monitoring with the Copernicus Emergency Mapping Service.
European Flood Awareness System	Example of a pan-European operational warning system for flood risk and hazard.
Flood Hazard and risk mapping in Wales	Operational system for flood warning and mapping in Wales.
Sentinel-1 Flood mapping after Cyclone related flooding	Case study on the use of S1-based flood mapping in Mozambique, Zimbabwe and Malawi after triggering activation of both, the Copernicus Emergency Mapping Service and the International Charter Space and Major Disasters.
Mapping water bodies and flooding in Denmark with Sentinel-1 and Sentinel-2	Danish case study based on time-series data of S1 to map flooding and S2 to map transitional waters and lakes.
UN recommended protocol for flood mapping	Detailed technical protocol on the processing of Copernicus data for flood mapping.
Mapping Floods Using Open Source Data and Software - SENTINEL-1 and ESA SNAP	Another technical protocol on the processing of S1 data for the creation of flood maps.

Wildfires	
The Global Wildfire Information System (GWIS) and European Forest Fire Information System (EFFIS)	Based on Copernicus data, these tools support operational wildfire management from national to global scales. GWIS builds on the ongoing activities of the EFFIS with respect to wildfire information gathering.
Global Wildfire maps by NASA and their Fire information resource management system	Global operational system based on moderate resolution MODIS data.
Introduction to wildfire mapping	Detailed introduction to wildfire mapping via satellite imagery.
Duncan Blake, Muirburn Report	Technical report and code for the use of S2 data to detect wildfires, quantify their extent and monitor subsequent recovery.
Activation of International Disaster Charter to map Fires in UK	This case study provides an example for the use of the International Disaster Charter (activating Copernicus EMS) by the UK Space Agency to map fires in Manchester.
Drought	
Soil water measurements in the Pampas region	This study uses the soil water index (SWI) calculated from S2 data to assess soil moisture at different depths, taking into account the porosity of the soils (FAO data), and generating soil moisture maps in Argentina.
Blue Dot water observatory	Interactive dashboard based on Copernicus data to explore water levels of lakes, dams, reservoirs, wetlands and similar water bodies globally.
Soil moisture on coffee plantation in Guatemala	Time series data of the Soil Water Index (SWI) and the Normalized Difference Vegetation Index (NDVI) are used to monitor the impact of dry soils on coffee plant growth and health.
Agriculture	
A Natural Capital Approach to Landscape Planning: a Pilot Project in Colchagua Valley, Chile	Map and further links to the use of Copernicus data for the delivery of some of the ecosystem services vital to the viticulture industry in the Colchagua Valley area.
Food security in the Andes	Forecasting tool for local authorities and farmers to advise on crop management.
CropSat	Danish project based on S2 data for predicting fertiliser needs.
ClimaCasting	The project provides advanced climate analytics and a service suite for the agricultural insurance sector on a global scale, based on several crop specific climate indices.
Other	
Active volcano mapping	High level introduction to active volcano monitoring using different Copernicus products. Python notebooks are provided for visualising eruptions with S2 data.
Biodiversity in Costa Rica	Use of the Copernicus Climate Change Service (C3S) to identify ‘climate sensitive areas’ in Costa Rica and to inform resource management.

GeoGraph	Provides code for assessment of ecosystem fragmentation with Copernicus data.