Observing trends and extreme events impacts on lakes using ESA CCI Climate Research Data Package

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Lakes are integrators of environmental and climatic changes occurring within their contributing basins. Factors driving lake condition vary widely across space and time, and lakes, in turn, play an important role in local and global climate regulation, with positive and negative feedback depending on the catchment.

Understanding the complex behaviour of lakes in a changing environment is essential to effective water resource management and mitigation of climate change effects. Lakes integrate responses over time and studies of globally distributed lakes can capture different aspects of climate change. A globally harmonized observation approach is needed to identify climate signals in lake physical, hydrological and biogeochemical change and to feed lake state into numerical models.

The objective of Lakes_cci is to exploit satellite Earth Observation data to create the largest and longest possible consistent, global record of the five lake climate variables: Lake Water Level (LWL), Lake Water Extent (LWE), Lake Surface Water Temperature (LSWT), Lake Water-Leaving Reflectance (LWLR), and Lake Ice Cover (LIC).

Lakes_cci represents a unique framework to provide consistent and homogenous data to the multiple communities of lake scientists. The project actively engages with this community to assess the utility and future improvement of Lakes_cci products.

The first phase of the project has recently been completed with the release of the last version (v2.0.2) of the dataset, which is comprised of processed satellite observations at the global scale, over the period 1992-2020, for over 2000 inland water bodies, where and when data quality appropriate for climate studies can be achieved. Phase 2 of the project started in July 2022, with the inclusion of the Lake Ice Thickness variable. One scope of the project is the integration of different satellite-derived products across ESA CCI projects (e.g., Fire, Land). In this study potential of the CCI dataset is explored in three different case studies in the Eurasian region.

Lake_cci data summary

CEDA Archive

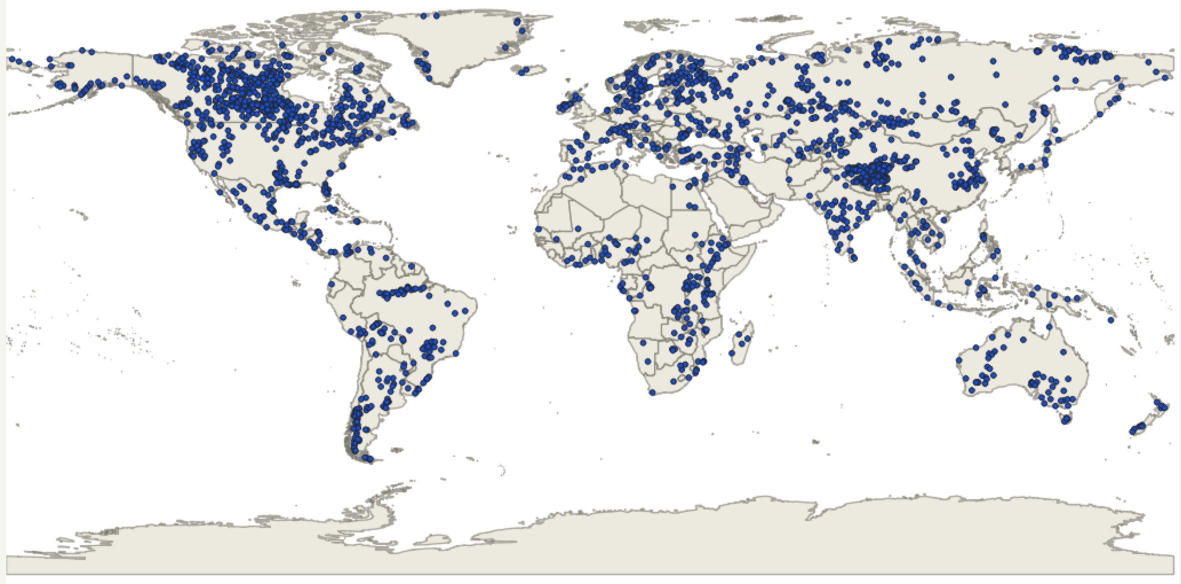

Figure 1. The first Climate Research Data Package (CRDP V2.0.2, 2022) was recently created.

The main characteristics of this data set are:
- Spatial coverage: **2024 globally distributed lakes**
- Spatial resolution: 1/120 degree global grid
- Temporal resolution: **daily netCDF files** containing all thematic variables including **uncertainty**
- Temporal coverage: **from 1992 up to 2020**

Temporal coverage
1992-2020 LWL, LWE;
1995-2020 LSWT
2000-2020 LIC
2002-2020 LWLR

The latest version 2.0.2 of the dataset is available here: https://catalogue.ceda.ac.uk/uuid/a07deacaffb8453e93d57ee214676304

Lake_cci project github to download only one area of the dataset by boundaries or by lake_id: https://github.com/cci-lakes/lakes_cci_tools

Survey

A new questionnaire is addressed to climate scientists, lake scientists and the wider scientific and expert user community interested in observing lakes. This survey forms the third user consultation of the project, collecting feedback and requirements to align the project with user needs in the Phase 2 of the project. It is focused on the use of the dataset produced in the Phase I. The link to this new survey is available on our website: https://climate.esa.int/en/projects/lakes/news-and-events/news/a-new-survey-for-users/ or with **QRcode**:

I. Long-term trends in the Lakes ECV

The **dataset** was explored for two Italian lakes (lake Trasimeno and Garda) and one Swedish lake (lake Erken) with different morphological, trophic and climate ecoregion characteristics.

Time-series of satellite data were then explored to examine trends in the context of key meteo-climatic variables. LSWT, chlorophyll-a (Chl-a), turbidity and ice cover data covering **16 years** (2003-2018) were extracted.

The analyses revealed variations in the water quality variables, including a significant alteration in the concentrations of **Chl-a** in the lakes under study.

In Lake Trasimeno (shallow-eutrophic) Chl-a was higher with more positive values of the NAO, lower lake levels and warmer temperatures. In Lake Garda (deep oligotrophic) a shift was found in the timing of the traditional Chl-a peak from a concave shape (spring peak, clear phase, summer/autumn peak) to a convex shape (dominant summer concentrations), after 2015 (Fig. 2). The Erken lake time series indicated a significant increase in Chl-a and air temperature.

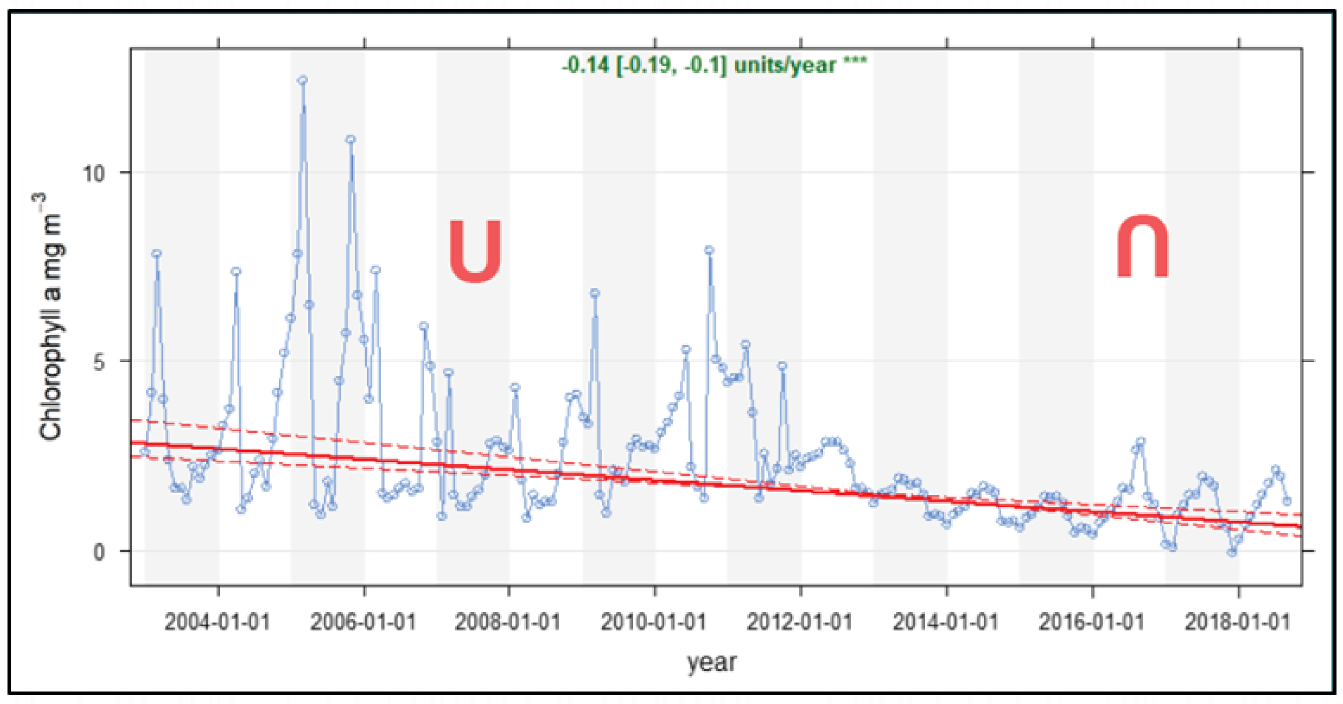

Figure 2. Trend in chlorophyll-a concentration for the period 2003-2018 in Lake Garda. Source: Free et al. 2021.

II. Heatwave and storm events impact on lakes

Chl-a data were examined for any potential responses during the **2019 double heatwave** period for 36 European lakes, evaluating how the response varies depending on latitude, total concentration of phosphorus and the average depth of the lake.

The results show that the timing and magnitude of the **response to the heatwave** events depends on lake depth and nutrients (Fig. 3).

Deeper lakes respond **sooner** probably because of higher temperatures leading to stronger stratification thereby improving the light climate but with the response strength dependent on nutrient status. In contrast, **shallower lakes** and lakes at lower latitudes showed more **asynchrony** with a greater response after the heatwave event probably as a result of internal and external loading.

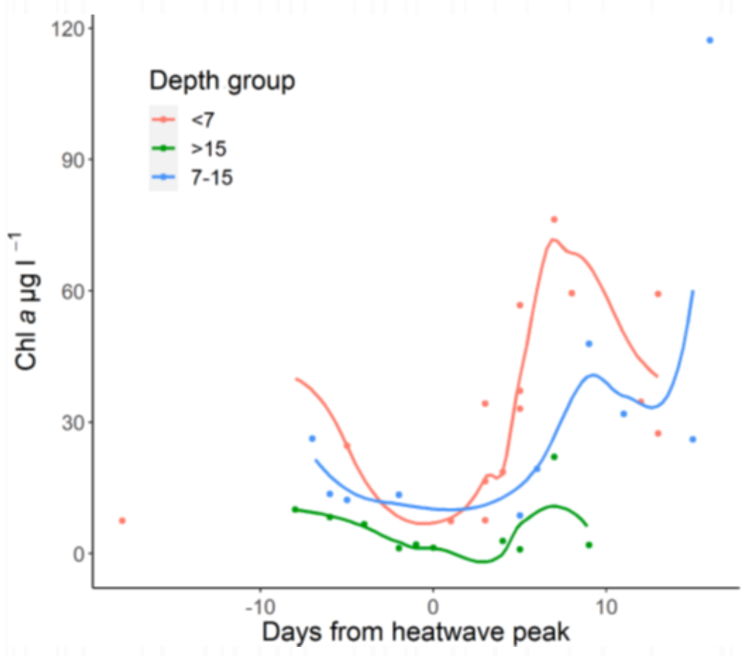

Figure 3. Timing and concentration of peak chlorophyll-a with respect to the second 2019 heatwave. Lakes coloured and lowess smoother (a locally weighted non-parametric smoothing method) applied by mean depth group. Source: Free et al. 2022.

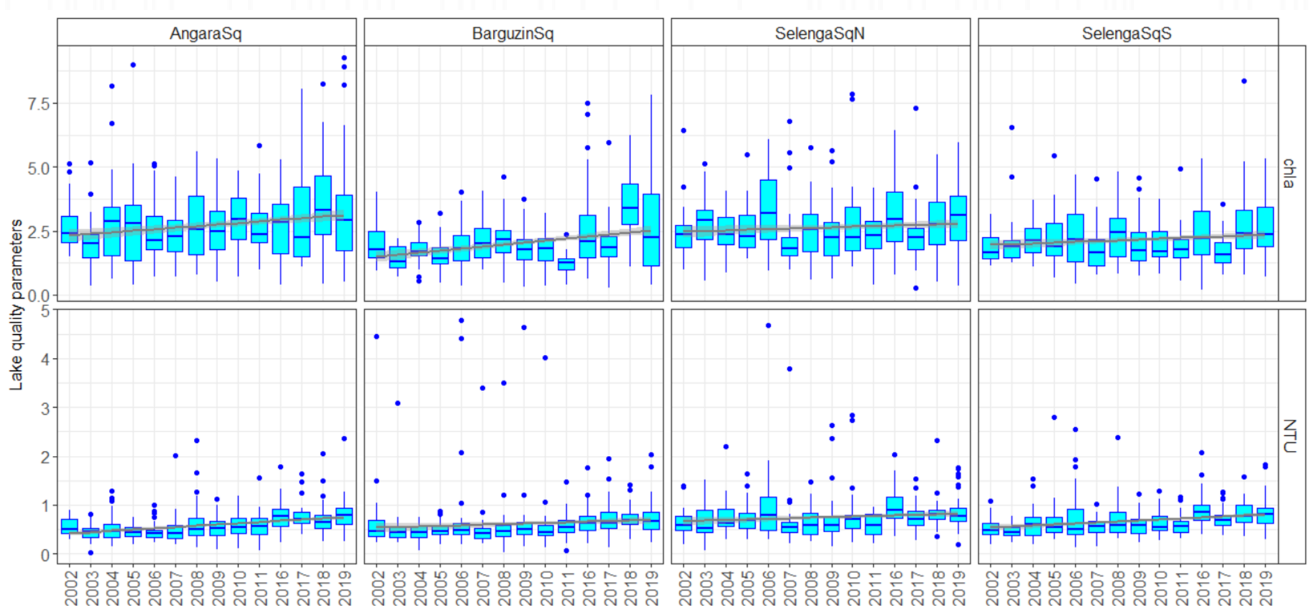

Figure 5. Trends of chlorophyll-a (chla), turbidity (NTU) in the four ROIs (Region of Interests; Angara Sq, Barguzin, SelengaSqN and Selenga SqS) close to the inflow of the main tributaries into the Lake Baikal.

III. Effects of wildfires on Lake Baikal

One scope of the Lakes_cci project is the integration of different satellite-derived products across **ESA CCI projects**. For this reason, a study on wildfire and lakes is ongoing aiming to investigate the relationship between fires and lakes water quality over a wide range of geographical regions and fire regimes.

Fire_cci and **Lakes_cci datasets** were explored to highlight any spatial-temporal relationships of burned area, meteo-climatic and water quality parameters for three sub-basins in correspondence to the inflows of the major tributaries into Lake Baikal (Fig. 4). The products were extracted for the period 2003-2019.

Results showed trends in the burned area, and an **increase** trend in chlorophyll-a and turbidity in the summer months, over the 16-year period (Fig. 5). On such a deep, pristine and large lake local effects of wildfires on water variables were detected.

The **spatial-temporal analysis** conducted in some years (2003, 2006, 2011 and 2018) of significant interest, because they represent extreme conditions of fires and precipitation, showed an increase in both Chl-a and turbidity following fire events that resulted in a significant burned area and without significant precipitation events observed in the central portion of the lake for the year 2003 (Fig. 6).

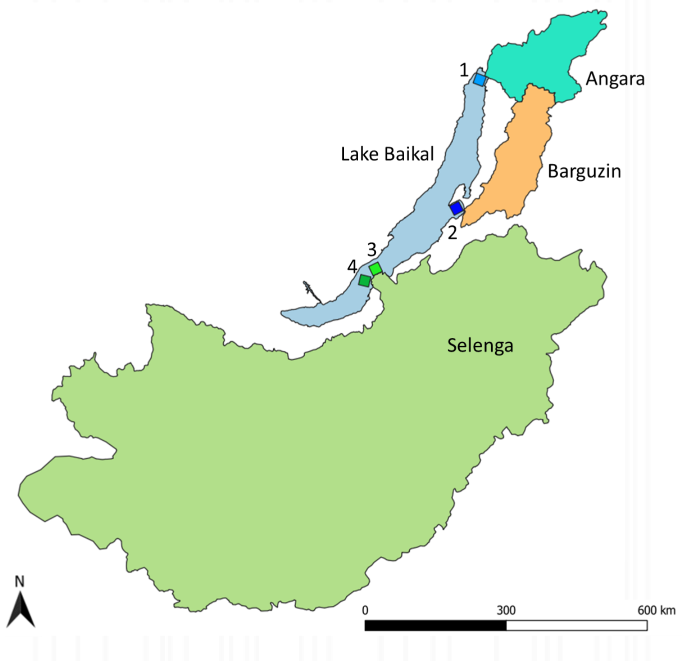

Figure 4. Lake Baikal with the three river sub-basins: Angara, Barguzin and Selenga; and the four ROIs Angara Sq (1), Barguzin (2), SelengaSqN (3) and Selenga SqS (4).

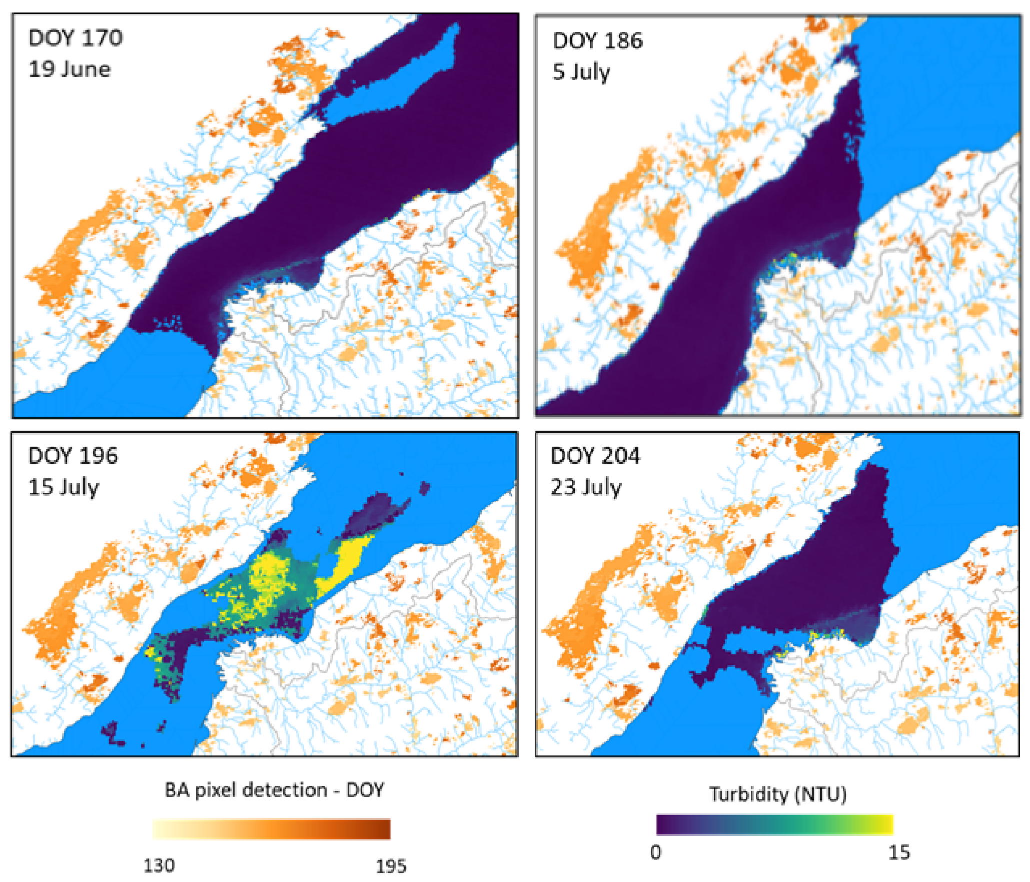

Figure 6. Maps of turbidity (NTU) and burned area (BA) in relation to the day of year (DOY) in 2003 for the central portion of Lake Baikal.

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