Delivering the Lake Essential Climate Variable
An update from ESA CCI Lakes

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Perspectives and aims

Lakes are sentinels, regulators and integrators **of climate change**:

- many lake hydrological and biophysical variables are potential **indicators of current climate change**
- lakes **regulate GhG** but potentially may be important source of re-emission to the atmosphere
- lake sediments are **archives** of **past climate**
- the **parameters** needed to understand their role in **climate change** are numerous: level, extent, temperatures, ice, water colour
- remote sensing techniques are very suitable to examine the role of lakes in climate change at the global scale

The **first release of the Lakes ECV data set** is expected in **January 2020**, **including > 200 lakes**

The **Lakes CCI** project is part of the Climate Change Initiative (CCI) European Space Agency (ESA) and run for three years. Main **objective** is **to exploit satellite data** to create the **largest** and **longest** possible **consistent**, **global** record of the five lake variables: **lake water level (LWL), extent (LWE), temperature (LSWT), surface-leaving reflectance (LWLR),** and **ice cover (LIC)**.

The project extends the state-of-the-art in **altimetry**, **thermal**, **optical** and **SAR**, drawing from over 30 satellite sensors. **Research priorities** include **extending current methodologies** to both older sensors and the latest Sentinels, **improved uncertainty** characterization and product inter-consistency checks.

Target Users

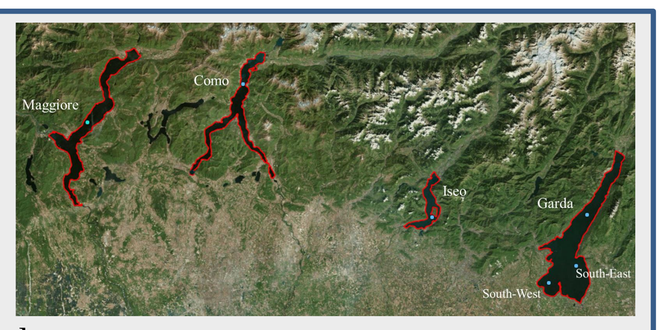
- Climate modelers
- Lake scientists
- Catchment modelers
- Lake stakeholders

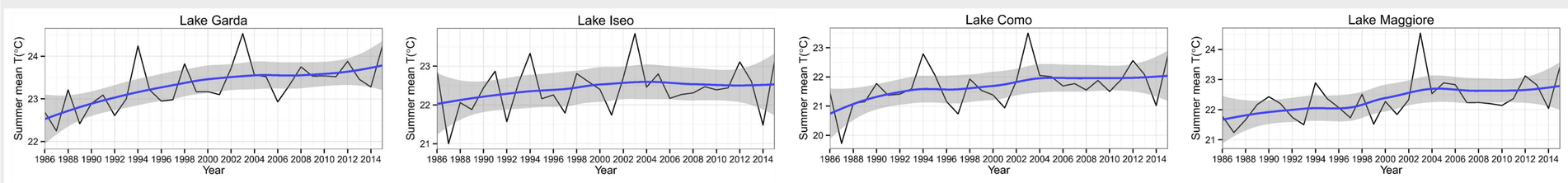
Are these variables measurable from remote sensing with sufficient confidence to address climate questions?
Please visit our website and provide your inputs to us!

cci.esa.int/lakes

A preliminary analysis on Subalpine lakes

The major lakes in the Italian subalpine ecoregion are part of a Use Case to be developed in the Lakes CCI in synergy with LTER (Long Term Ecological Research Network).
Water quality of these lakes is in danger due to the increasing demand for freshwater, the effect of climate change and the anthropogenic pressure.
Lake Surface Water Temperature (LSWT) for subalpine lakes were derived by Pareeth et al. (2017); while in this panel results based on Lake Water Leaving Reflectance (LWLR), and the derived Chlorophyll-a (Chl-a) concentrations products, are presented.

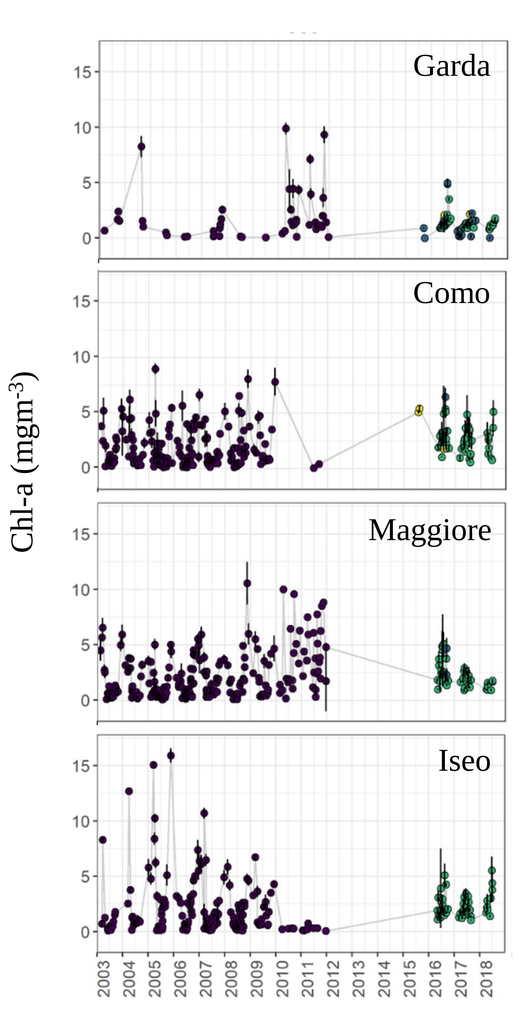




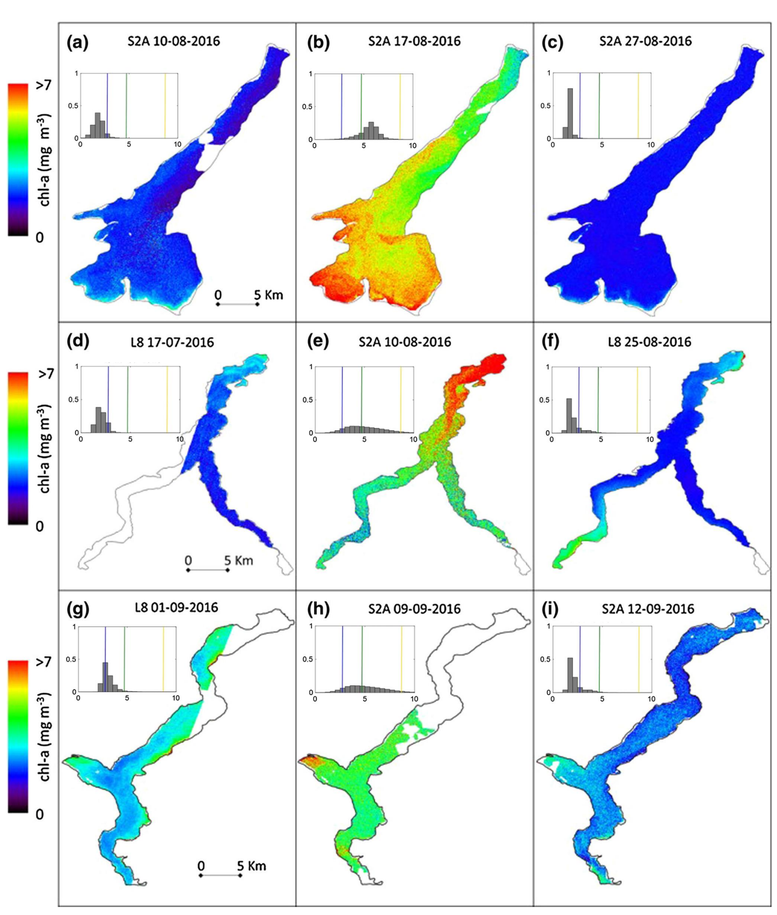
Summer mean LSWT from 1986 to 2015; data were smoothed using the LOESS interpolation (blue line). The grey area depicts the 95% confidence interval. (Pareeth et al., 2017)

Methods – Earth Observation (EO) data from different satellite sensors (MERIS, OLI, MSI, OLCI) were used for acquiring timely, frequent synoptic information of Garda, Iseo, Como and Maggiore lakes with a focus on phytoplankton abundance (**Chl-a concentration)** in the period **2003-2018**.
Imagery were processed for radiometric and atmospheric correction, and bio-optical models (C2R, BOMBER) were applied to retrieve Chl-a. The products were validated against field data as in Odermatt et al., 2010, Giardino et al., 2014, and Bresciani et al., 2018.
Trend analysis was conducted with Seasonal Kendall test, and Sen Slope estimator was calculated as estimation of median annual slope. Trend was considered meaningful if $p < 0.05$ and if the Sen's Slope was at least 1% of the median value.

Results - Trends show a slight tendency to increase of Chl-a concentrations during the period considered, particularly for Iseo and Maggiore lakes. From these time-series products was then possible to extrapolate phenology data such as the start of season of phytoplankton.



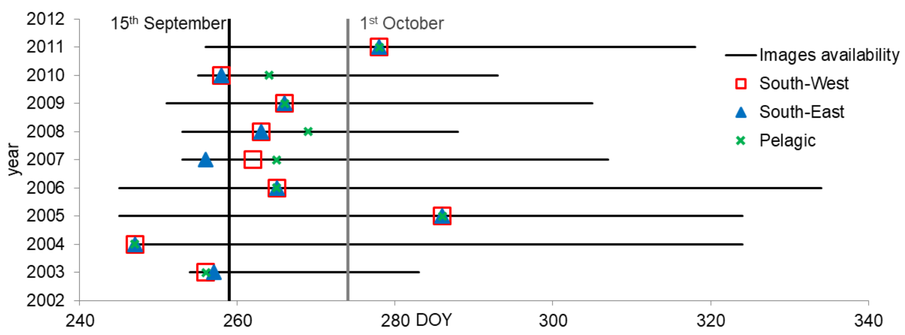
Chl-a concentrations from multiple satellites observations from 2003 to 2018



Maps: Chl-a concentrations for the time window of algal bloom events in 2016 in: Garda (a–c), Como (d–f), Maggiore (g–i). Histograms: Chl-a concentration on x-axis and fraction of total pixel on y-axis. Vertical lines indicate WFD boundaries for water quality status classification based on Chl-a concentration (Bresciani et al., 2018)

Lake	Median value (mgm^{-3})	Median annual Sen slope (mgm^{-3})
Garda	1.18	0.053
Iseo	1.52	0.109
Como	1.03	0.073
Maggiore	1.34	0.111

Seasonal Kendall and Sen slope test results (according to seasons) from 2003-2018 EO-derived Chl-a values (average value for the all lake area)



On set of phytoplankton for Garda from MERIS: cover of satellite images from September to October (showed as black line) and day-of-the year of Chl-a onset in three lake's sub-basins. Vertical lines facilitate interpretation

Conclusions

- The multi-temporal analysis on LSWT and LWLR and related Chl-a products highlighted the contribute of satellite data for a synoptic long-term and continuous monitoring of lakes at regional scale.
- Further activities are planned need to combine EO with LTER data for analyzing patterns and trends in a climate change scenario.

References *- Bresciani et al., 2018, Hydrobiologia, 824, 197-214. Giardino et al., 2014, Sensors, 14, 24116-24131. Odermatt et al., 2010. Remote Sens Envir, 114, 607-617. Pareeth et al., 2017, Sci of the Tot Environ, 578, 417-426.*

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