Geophysical Research Abstracts
Vol. 15, EGU2013-8406, 2013
EGU General Assembly 2013

On the impact of climate change on surface water temperature of Lake Garda

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Lakes have been widely recognized as important sentinels for climate change. Indeed, physical, chemical, and biological properties of limnic systems have been observed to respond rapidly to climate-related modifications. Inspired by studies on climate change, during the last decades a lot of research has been conducted to investigate past and predict future responses of lakes to changing climate and environmental conditions. In particular, a major concern is to assess and quantify the effect of climate on water temperature, which represents one of the key parameters determining ecological conditions within a lake, as it influences both chemical and biological processes. In turn, lake's thermal budget is strongly controlled by the temperature of surface water (i.e. epilimnion), which is regulated by climate conditions.

In this work, a simple physically-based, semi-empirical lumped model is used to estimate surface water temperature (SWT). It requires only air temperature as input information and accounts for the overall heat exchanges with the atmosphere and the deeper layer of the lake (i.e. hypolimnion) by means of simplified relationships, which contain a few parameters to be calibrated. The model has been shown to be capable of reproducing both seasonal and inter-annual fluctuations with high performances (Nash-Sutcliffe efficiency index $\simeq 0.9$), over long-term simulation periods (i.e. decades). These results and the physical interpretation of the model parameters suggest this semi-empirical model as a valuable tool for climate change applications as well.

The model has been applied to Lake Garda, the largest lake in Italy (surface area: $370\ km^2$, volume: $50\ km^3$ and maximum depth: $346\ m$). A Monte Carlo approach has been used for calibration, in which 10^8 different sets of parameters have been randomly chosen and tested. The calibration period ranges from 2004 to 2010, during which air temperature and SWT data are available. Air temperature is provided by a Regional Circulation Model (RCM) for the Alpine region of Northern Italy (Züger J., Knoflacher M., AIT Austrian Institute of Technology GmbH, Uncertainties of scenarios - Regional climate change scenario, Deliverable 4.3.3, Project EULAKES, 2012), whilst SWT refer to estimates from satellite imagery derived from MODIS data. Once calibrated, the model has been adopted to assess the impact on SWT using a future projection of climate change provided by the RCM for the next century.