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Lake Surface Temperatures in the European Alps from 1880 to 2100 – Reconstructions and Projections derived at twelve lakes located within the complex topography of Austria

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This study is devoted to the development of long-term time-series for Lake Surface Temperatures (LSTs) in the Central Alps. This endeavor comprises three steps: (i) the reconstruction of LSTs from 1949 back to 1880, (ii) the homogenization of records from 1950 to 2012 and (iii) the derivation of climate change projections from 2013 to 2100 driven by two different Representative Concentration Pathways (RCP8.5, indicating a 'business as usual' scenario, and RCP4.5, representing a more climate-friendly pathway).

The generation of LST reconstructions is obtained by digitizing monthly LSTs at twelve selected lakes from hydrographic yearbooks and by merging them with corresponding time-series covering most recent decades, which are available in already digitized form from the ministry of water resources (BMLFUW). Based on results achieved by the application of (i) a Rotated Empirical Orthogonal Functions (REOFs) Analysis and (ii) hierarchical clustering methods two groups of lakes are specified. Homogeneous LST time series from 1950 to 2012 are established through applying a homogenization procedure called HOMER (Mestre et al. 2013) to LST time-series within these two groups and additional appropriate amendments.

In order to reconstruct seasonal LST developments back to 1880, we make use of the so-called HISTALP database (Auer et al. 2007) comprising regularly updated, homogeneous, monthly time-series of various atmospheric elements at 133 stations across the European Alps back to 1762. Throughout the period shared by HISTALP and our LSTs (1950-2012), Multiple Linear Regression (MLR) Models are established for each lake and every season, using air-temperature, precipitation totals and air-pressure as covariates. Based on extensive validation experiments, the three best-performing MLR-models are applied to reconstruct LSTs back to 1880.

In order to derive ensembles of LST projections at each lake until 2100, 60 Global Climate Model (GCM) simulations driven by the above mentioned RCP-pathways are refined via empirical, statistical downscaling (ESD) techniques, which have been thoroughly evaluated in various validation experiments. In total there are 30 climate-change projections for each RCP-pathway available at every HISTALP station. These ensembles are subsequently transferred to the lakes via the aforementioned MLR-models. Hence, 30 LST projections from 2013 until 2100 are available at each lake for each RCP-pathway and each (of three) MLR-model. These extensive ensembles of LST-projections are utilized to sketch out probable future LST corridors until the end of this century.

This study attempts (i) to contribute to a better understanding of lake ecosystems by providing long-term LST time-series throughout the past - through which direct measurements and proxy-data describing biological activity and associated processes impacted by LSTs are available as well as (ii) to foster the implementation of efficient and effective protection measures according to the derived corridors within the European Alps. Findings will also support decision-makers in ecosystem protection, tourism and water resource management.

Mestre et al., 2013: HOMER: A homogenization software – methods and applications, Idöjárás, 117, 47-67.
Auer et al., 2007: HISTALP Historical Instrumental Climatological Surface Time Series of the Greater Alpine Region, International Journal of Climatology, 17, 14-46.