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A satellite-based climatology (1989–2012) of lake surface water temperature from AVHRR 1-km for Central European water bodies

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The temperature of lakes is an important parameter for lake ecosystems influencing the speed of physio-chemical reactions, the concentration of dissolved gazes (e.g. oxygen), and vertical mixing. Even small temperature changes might have irreversible effects on the lacustrine system due to the high specific heat capacity of water. These effects could alter the quality of lake water depending on parameters like lake size and volume. Numerous studies mention lake water temperature as an indicator of climate change and in the Global Climate Observing System (GCOS) requirements it is listed as an essential climate variable.

In contrast to in situ observations, satellite imagery offers the possibility to derive spatial patterns of lake surface water temperature (LSWT) and their variability. Moreover, although for some European lakes long in situ time series are available, the temperatures of many lakes are not measured or only on a non-regular basis making these observations insufficient for climate monitoring. However, only few satellite sensors offer the possibility to analyze time series which cover more than 20 years. The Advanced Very High Resolution Radiometer (AVHRR) is among these and has been flown on the National Oceanic and Atmospheric Administration (NOAA) Polar Operational Environmental Satellites (POES) and on the Meteorological Operational Satellites (MetOp) from the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) as a heritage instrument for almost 35 years. It will be carried on for at least ten more years finally offering a unique opportunity for satellite-based climate studies.

Herein we present the results from a study initiated by the Swiss GCOS office to generate a satellite-based LSWT climatology for the pre-alpine water bodies in Switzerland. It relies on the extensive AVHRR 1-km data record (1985–2012) of the Remote Sensing Research Group at the University of Bern (RSGB) and has been derived from the AVHRR/2 (NOAA-11, -14) and AVHRR/3 (NOAA-16, -17, -18, -19 and Metop-A). A high accuracy is needed for climate related studies, which requires a careful pre-processing and consideration of the atmospheric state. Especially data from NOAA-16 and prior satellites were prone to unwanted noise, e.g., due to transmission errors or fluctuations in the instrument's thermal state. This has resulted in partly corrupted thermal calibration data and may cause errors of up to several Kelvin in the final brightness temperatures. Therefore, a multistage correction scheme has been applied to the data, in order to minimize these artefacts in the satellite observations.

For the LSWT retrieval we have tested three different methods. First, we applied the operational NOAA National Environmental Satellite, Data, and Information Service (NESDIS) and NOAA Pathfinder global sea surface temperature (SST) algorithms to our data set. In addition, we developed an optimized simulation-based scheme making use of the Radiative Transfer for TOVS (RTTOV) Version 10 together with operational analysis and reanalysis data from the European Centre for Medium Range Weather Forecasts (ECMWF). All methods were validated extensively using in situ measurements from lakes with various sizes between 14 km^2 (Lake Sempach) and 580 km^2 (Lake Geneva). The simulation-based algorithm reduces the RMSE and Bias for the lakes in the study region of Switzerland compared to the global SST algorithms and even small lakes yield good results.

Following these successful outcome, the model-based LSWT retrieval shall be expanded to all European lakes covered and recorded by the AVHRR data receiving station at the RSGB.