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Toward a Lake Ice Phenology Derived from VIIRS Data

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Ice cover on lakes plays an essential role in the physical, chemical, and biological processes of freshwater systems (e.g., ice duration controls the seasonal heat budget of lakes), and it also has many economic implications (e.g., for hydroelectricity, transportation, winter tourism). The variability and trends in the seasonal cycle of lake ice (e.g., timing of freeze-up and break-up) represent robust and direct indicators of climate change; they therefore emphasize the importance of monitoring lake ice phenology.
Satellite remote sensing has proven its great potential for detecting and measuring the ice cover on lakes. Different remote sensing systems have been successfully used to collect recordings of freeze-up, break-up, and ice thickness and increase the spatial and temporal coverage of ground-based observations. Therefore, within the Global Climate Observing System (GCOS) Swiss project, "Integrated Monitoring of Ice in Selected Swiss Lakes," initiated by MeteoSwiss, satellite images from various sensors and different approaches are used and compared to perform investigations aimed at integrated monitoring of lake ice in Switzerland and contributing to the collection of lake ice phenology recordings. Within the framework of this project, the Remote Sensing Research Group of the University of Bern (RSGB) utilizes data acquired in the fine-resolution imagery (I) bands (1–5) of the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor that is mounted onboard the SUOMI-NPP. Visible and near-infrared reflectances, as well as thermal infrared-derived lake surface water temperatures (LSWT), are used to retrieve lake ice phenology dates. The VIIRS instrument, which combines a high temporal resolution ($\sim$2 times per day) with a reasonable spatial resolution (375 m), is equipped with a single broad-band thermal I-channel (I05). Thus, a single-channel LSWT retrieval algorithm is employed to correct for the atmospheric influence. The single channel algorithm applied in this study is a physical mono-window (PMW) model based on the Radiative Transfer for the Television Infrared Observation Satellite Operational Vertical Sounder code (RTTOV). RTTOV, which is a fast radiative transfer model, can be used to estimate upward and downward atmospheric path radiance and atmospheric transmittance in the thermal infrared for a specific atmospheric profile. In this study, atmospheric profiles from ECMWF ERA-interim are utilized to run RTTOV and simulate top-of-atmosphere (TOA) brightness temperatures. We present the first retrievals of LSWT and ice features from corrected clear-sky channel I05 data of the VIIRS sensor. Together with VIS and NIR reflectance values, these first LSWT retrievals are used to derive ice-on/off dates for selected Swiss lakes by applying a threshold method. After successful validation based on in-situ measurements of Swiss lakes, the method can be utilized for global application.