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Response of ice cover on large northern lakes, as observed through the synergy of spaceborne microwave and optical measurements

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Lake ice is an important component of the high-latitude terrestrial cryosphere with the long period of ice cover playing both a significant role in and responding to regional climate. Dates of complete freeze-over (CFO) and of water clear of ice (WCI) have shown to be strongly correlated with air temperature and are therefore sensitive indicators of climate variability and change. Monitoring changes in CFO, WCI and ice duration is important since ice cover impacts on physical, limnological, and hydrological processes as well as ecological and socio-economic implications at high latitudes. Furthermore, understanding the interactions of lake ice with the overlying atmosphere is essential for climate modeling and weather forecasting as the presence/absence of seasonal lake ice has an effect on heat and energy transfers across the lake-atmosphere interface. Unfortunately, ground-based lake ice networks in most countries of the Northern Hemisphere have diminished to the point where they can no longer form the main source of observations necessary for climate monitoring and atmospheric/hydrological modeling. Remote sensing has long been seen as the technology that would supersede traditional ground-based observations. However, much development still must take place to make remote sensing the primary data source for operational lake ice monitoring.

In this research, we present and contrast ice phenology algorithms derived from the Quick Scatterometer (QuikSCAT), the Advanced Microwave Scanning Radiometer (AMSR-E), and the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments (Lake Surface Temperature and Normalized Difference Snow Index products) for large northern lakes. The newly developed ice cover algorithms are tested over Great Bear Lake (GBL) and Great Slave Lake (GSL) in Canada as well as Lake Ladoga and Lake Onega in Europe. The microwave and optical measurements from spaceborne sensors show that signals emanating from lake ice are affected by different ice cover characteristics (i.e. emissivity change of ice/snow and freshwater, surface roughness, snow cover, and the existence of melting ponds). It is shown that satellite-derived ice phenology is useful for analyzing the spatial and intra-/inter-annual variability in ice cover in response to climate. The synergistic use of data from both microwave and optical sensors presents a high potential for monitoring lake ice phenological events on large northern lakes.