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Landsat-based Upper Great Lakes Forest Phenoclimatology, 1984-2013

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Abstract

Past studies have connected mean forest phenology from remote sensing analyses to regional climatological patterns, usually relying on long-term average temperatures and derived growing degree day accumulations. This long-term mean phenology is then used to inform land surface model vegetation dynamics in meteorological and climate modeling systems. We present a detailed, spatially-explicit examination of remotely sensed forest phenology in the region of western Lake Superior, USA, based on a comprehensive 1984-2013 climatological assessment [Garcia and Townsend, 2016] and Landsat imagery over the same period. The previous work showed that regional warming on land areas of 0.56°C during the 30-year study period contrasted with ~2.5°C warming in Lake Superior, one of the fastest-warming large lakes in the world, indicating possible long-term changes in land–lake interactions and hence vegetation phenology. As well, summer warming is accompanied by a regional precipitation decline of 0.34 cm/y across the study area, potentially leading to vegetation moisture stress that can reduce carbon uptake rates and render the forest more vulnerable to disturbance agents. Changes appear most prominent in areas exhibiting strong influences of Lake Superior. We use our climatological analysis to explain the mean annual land surface phenological cycle and its interannual variability in temperate mixed forests. Differences in phenological indicators across our study area, especially the durations of (spring) green-up and (summer) maturity, are strongly correlated with spring and summer hydroclimatology. We then depart from traditional examinations of the fitted mean phenology, using partial-least-squares regression methods to associate Landsat vegetation index residuals (departures from the mean phenological curve) with short-term departures from location-specific climatology based on our analysis. The mean phenological curve typically explains ~50-70% of observed interannual variability from long-term Landsat records; our novel, spatially-explicit and climate-sensitive mixed modeling approach may explain as much as 90% of seasonal and interannual phenological variability. These methods may improve the information provided to land surface models in operational weather and long-term climate models that depend on accurate representations of vegetation state in the land–atmosphere system.