High Arctic lakes as sentinel ecosystems: Cascading regime shifts in climate, ice cover, and mixing

Mueller, Derek R., Patrick Van Hove, Dermot Antoniades, Martin O. Jeffries, Warwick F. Vincent

Limnol. Oceanogr., 54(6_part_2), 2009, 2371-2385 | DOI: 10.4319/lo.2009.54.6_part_2.2371

ABSTRACT: Climate and cryospheric observations have shown that the high Arctic has experienced several decades of rapid environmental change, with warming rates well above the global average. In this study, we address the hypothesis that this climatic warming affects deep, ice-covered lakes in the region by causing abrupt, threshold-dependent shifts rather than slow, continuous responses. Synthetic aperture radar (SAR) data show that lakes (one freshwater and four permanently stratified) on Ellesmere Island at the far northern coastline of Canada have experienced significant reductions in summer ice cover over the last decade. The stratified lakes were characterized by strong biogeochemical gradients, yet temperature and salinity profiles of their upper water columns (5-20 m) indicated recent mixing, consistent with loss of their perennial ice and exposure to wind. Although subject to six decades of warming at a rate of 0.5° C decade^{-1}, these lakes were largely unaffected until a regime shift in air temperature in the 1980s and 1990s, when warming crossed a critical threshold forcing the loss of ice cover. This transition from perennial to annual ice cover caused another regime shift whereby previously stable upper water columns were subjected to mixing. Far northern lakes are responding discontinuously to climate-driven change via a cascade of regime shifts and have an indicator value beyond the regional scale.