



"Ice out": the contribution of citizen scientists to our understanding of climate change

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Long-term trends in spring 'ice out' dates (1836–2013) for twelve lakes in Maine, New Brunswick and New Hampshire, in eastern North America reveal a remarkable coherency across the region ($r_s=0.462-0.933$, $p<0.01$). These data have been compiled since the early 19th century, primarily by amateur citizen scientists, for a variety of purposes, including determining fishing seasons, estimating the spring opening of ferry boat routes, community contests, and general curiosity. Ice out dates correlate closely with late-winter/early-spring, March–April (MA), instrumental temperature records from across the region ($r_s=0.488-0.816$, $p<0.01$). This correlation permits use of ice out dates as a proxy to extend the shorter MA instrumental record (1876–2013). Mean ice out dates trended progressively earlier during the recovery from the Little Ice Age through to the 1940s, and gradually became later again through to the late 1970s, when ice out dates had returned to values more typical of the late nineteenth century. Post-1970's ice out dates resumed trending toward earlier dates, with the twenty-first century being characterized by the earliest ice out dates on record. Spectral and wavelet time series analysis indicate that ice out is influenced by several teleconnections including the Quasi-biennial Oscillation, El Niño-Southern Oscillation, North Atlantic Oscillation, Atlantic Multidecadal Oscillation as well as a significant correlation between inland lake records and the Arctic Oscillation. The relative influence of these teleconnections is variable with notable shifts occurring after ~ 1870 , ~ 1925 , and $\sim 1980-2000$. The intermittent expression of these cycles in the ice out and MA instrumental record is not only influenced by absolute changes in the intensity of the various teleconnections and other climate drivers, but by phase interference between teleconnections, which periodically damps the various signals.