# Contemporary Arctic change: A paleoclimate déjà vu?

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Observations of warming in the high northern latitudes provide a variety of scientific datasets to better understand the forcings and feedbacks at work in the global climate system. Instrumental data and satellites show that most of the current Arctic warming is the result of large changes in winter temperatures and that, by comparison, changes in summer temperatures have been relatively modest (1). Yet changes in seasonal temperatures are having a profound influence on glaciers, sea ice cover, snow cover, nutrient flux, and vegetation assemblages, causing shifts in both terrestrial and marine ecosystems (2, 3). Profoundly provocative is the suggestion that rapid melt rates now observed at the margins of the Greenland Ice Sheet (GIS) still lag significantly behind recent Northern Hemisphere warming (4).

How out of the ordinary are these changes? Although changes of the last few decades can be assessed in the short term against instrumental and historical data and observations, it is only paleoclimate records that provide the necessary perspective to inform these questions. Kaufman et al. (5) documented that the past decade was the warmest for the last 2,000 years by using high-resolution lake sediment, ice core, and tree ring records from multiple sites across the Arctic. The report by Axford et al. in this issue of PNAS (6) builds on this necessary paleo-perspective by comparing a lake sediment record of the last century to interglacial episodes preserved at depth in the same lake on the Clyde Forelands, Baffin Island, in the eastern Canadian Arctic.

Records of past interglacials (warm intervals) are somewhat rare in the terrestrial arctic, and finding well-preserved, organic-rich interglacial lake sediments stacked in sequence within the limits of the Laurentide Ice Sheet are even rarer. Yet Axford and colleagues (7) have previously reported discovering three interglacials [marine isotope stage (MIS) 1, substages 5a and 5e, and MIS 7] preserved between intervening glaciogenic sands.

This new study (6) of Lake CF8 on eastern Baffin Island (Fig. 1) describes a variety of proxies (including chironomids, diatoms, chlorophyll-a, % organic carbon, etc.) that collectively provide a measure of past lake temperature, productivity, and pH. Axford et al. (6) use these data to evaluate the lake system's response to changes in insolation driven by Earth's orbital forcing (8) for each interglacial episode over the past 200,000 years. The overall trends in most of the proxies follow a similar pattern for interglacial MIS 1 and 5, with MIS 7 interpreted to be the tail end of the interglacial preceding glacial onset into MIS 6. Their argument concerning the biological response for each interglacial is aimed squarely at the Holocene, the best-dated part of the record characterized by a marked peak in insolation until ≈8,000 years ago [the so-called Holocene Thermal Maximum (9)]. They then infer insolation forcing for MIS 5e and 7 notably because the dating of these intervals in their long sediment core is not so well constrained. Nevertheless, using detrended correspondence analysis (DCA), a type of ordination analysis popular in ecosystem studies, on the measured proxies averaged to achieve a common sampling resolution, they show that for both of the earlier warm interglacial sequences the proxies all fall within a relatively well-defined window described by the first and second DCA axes. In contrast, these same proxies measured on sediments representing the past century show an "ecological trajectory" away from this interglacial window, suggesting that factors causing this change are unprecedented for the past 200,000 years. Lakes throughout the Arctic document remarkable 20th-century change (10) but few can make the direct comparison to earlier interglacials. So to answer our earlier questions: yes, this has happened before but not quite like this. Having said that, some readers will agree that the comparison needs to be viewed with some caution given that the raw sampling interval of the record over the past century is better than that for earlier interglacials.

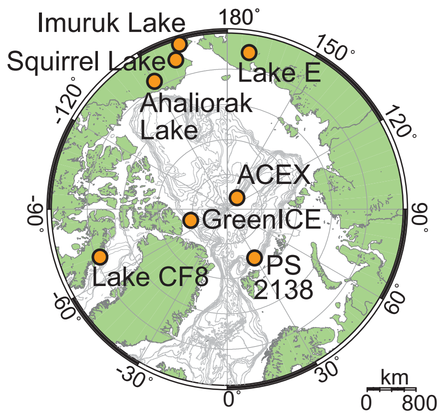


**Fig. 1.** Circumpolar projection showing the location of sites mentioned in the text and Fig. 2.

Several points highlight the significance of this work in the context of what is known about the Arctic past and present. First, although Lake CF8 shows remarkable ongoing change in summer-based proxies over the later half of this century, it is located where maps of recent (2003–2007) National Centers for Environmental Prediction surface air temperature data show little or no change in summer; in contrast, large positive anomolies of 2–3 °C occur over the region in autumn (September–November; ref. 1). In other words, it could be that later onset of winter is driving ecological change. Second, the interglacial records from Lake CF8 join a number of long lacustrine records from around the Arctic that extend to the last interglacial and beyond (11), yet very few extend to MIS 7. Lake El'gygytgyn in central Chukotka was recently drilled in spring 2009 with the expectation that it will extend continuously to 3.6 million years (12). Published records demonstrate continuous deposition to nearly 350,000 years B.P., including MIS 9 (refs. 13 and 14 and Fig. 2). Long paleoclimate records from other Arctic lakes include those from Imuruk, Squirrel, and Ahaliorak lakes in the western Arctic (11).

What do the interglacials in this and other Arctic lake records inform us about the future? In short, if it happened before, it could happen again, and it's happening now. A growing number of observations show that summer Arctic sea ice was much reduced during MIS 5e and may have been almost seasonal because of Milankovitch-driven summer insolation as much as 11–13% above present (11). Emerging records from the central Arctic Ocean [Arctic Coring Expedition (ACEX) and Greenland Arctic Shelf Ice and Climate Project (GreenICE); Figs. 1 and 2] also point to seasonally open water during MIS

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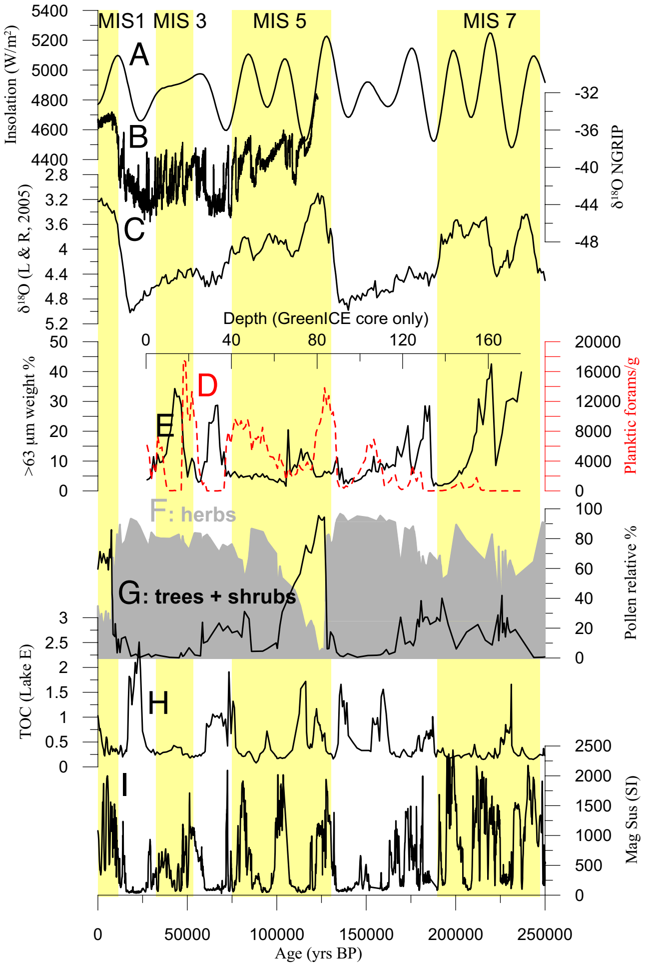


**Fig. 2.** Comparison of various global and Arctic proxy records spanning the past 250,000 years. Approximate durations of interglacial MIS are indicated by yellow bars. (*A*) June insolation values in W/m$^2$ for 65°N (8). (*B*) Greenland ice core (North Greenland Ice Core Project) $\delta^{18}$O values expressed as ‰ in relation to Vienna standard mean ocean water (22). (*C*) Global stacked benthic $\delta^{18}$O values (23). (*D*) The red dashed line indicate the number of planktic foraminifera per gram of sediment in the GreenICE core (15). (*E*) Ice-rafted debris from the GreenICE core off the coast of Greenland/Ellesmere Island measured as the weight percentage of the sediment fraction >63 $\mu$m (15). Both *D* and *E* are plotted vs. core depth instead of vs. age. The plots are stretched so that the MIS correlate with those in ref. 15. (*F–I*) Precession-driven changes from Lake El'gygytgyn (Lake E) in northern Russia. The age model for Lake E cores is same as in ref. 14. In *F* the black line indicates relative % herb pollen (24). In *G* gray lines indicate relative % tree and shrub pollen (24). (*H*) Total organic carbon (25). (*I*) Magnetic susceptibility as a proxy for seasonal lake ice cover (13).

5e (15, 16). The GIS was reduced in size and tree line advanced northward across large parts of Arctic (11). The early Holocene was another period only slightly warmer than today and forced by enhanced summer insolation approaching 10% in the high latitudes (8) that drove marked changes in tree line (9) and a significant reduction in sea ice along the Canadian Arctic (17) and northern Greenland (18). These warm periods inform us about the sensitivity of the Arctic system to warming in response to Arctic amplification (1) and provide the testing ground for climate model verification.

But modern climate change is driven largely by atmospheric $CO_2$ concentrations in the face of decreasing insolation (5). Therefore, we need only look to Arctic records of the mid-Pliocene to capture our geologic moment of déjà vu when $CO_2$ is estimated to have been in the range of 350 to 400 ppm like it is now (19). Intermittently throughout this time period sea level may have been +5 to +40 m above present (ref. 19 and references therein), driven in part by massive reductions in Antarctic ice sheets (20). Syntheses of this Pliocene interval and later interglacials (ref. 21 and www.globalchange.gov/publications/reports/scientificassessments/saps/sap1-2) leave little doubt that renewed studies in the high latitude are well justified to test and improve the chronological coherence of Arctic records. With a seasonally ice-free Arctic now projected to be only a few decades from now, perhaps Yogi Berra was right: "it's déjà vu all over again."

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