Earth/Environmental Science Grades 9-12

COMPETENCY GOAL 5: The learner will build an understanding of the dynamics and composition of the atmosphere and its local and global processes influencing climate and air quality.

Objectives

5.01 Analyze air masses and the life cycle of weather systems:
- Planetary wind belts.
- Air masses.
- Frontal systems.
- Cyclonic systems.

5.02 Evaluate meteorological observing, analysis, and prediction:
- Worldwide observing systems.
- Meteorological data depiction.

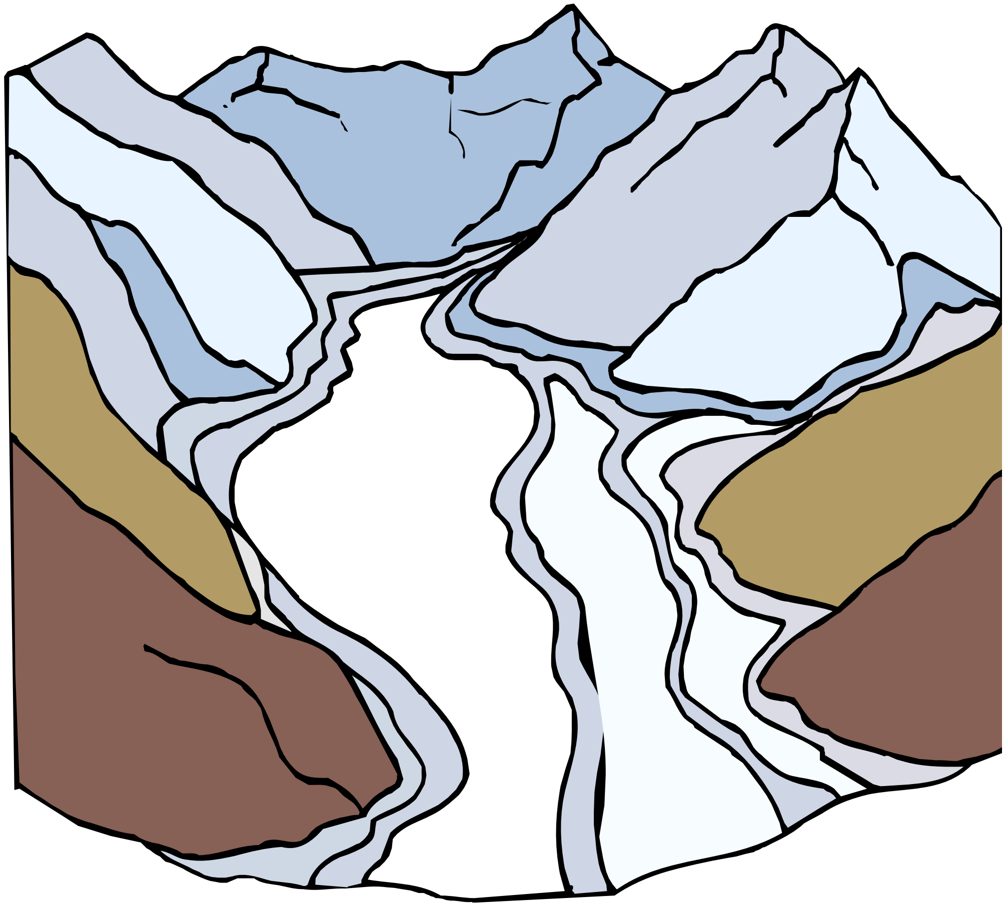
5.03 Analyze global atmospheric changes including changes in $\mathbf{CO}_2$, $\mathbf{CH}_4$, and stratosheric $\mathbf{O}_3$ and the consequences of these changes:
- Climate change.
- Changes in weather patterns.
- Increasing ultraviolet radiation.
- Sea level changes.

NOAA serves the nation by providing information on past changes in climate and the environment, and by providing estimates of future change. Tree rings are one of the few sources of information on the large changes (temperature, drought, and the hydrologic cycle) that have occurred over hundreds and thousands of years. The information obtained from these natural recorders of earth history play a valuable role in helping societies understand and live with our changing environment.

For more visit http://www.ncdc.noaa.gov/paleo/

NOAA

NOAA Paleoclimatology Program

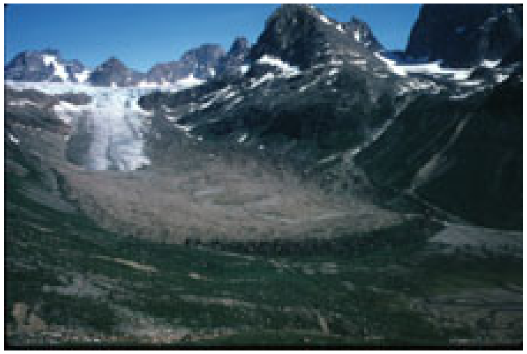


Arctic Environmental Change of the Last Four Centuries

NATIONAL CLIMATIC DATA CENTER
Protecting the Past, Revealing the Future
NCDC
National Oceanic & Atmospheric Administration

Arctic Environmental Change of the Last Four Centuries

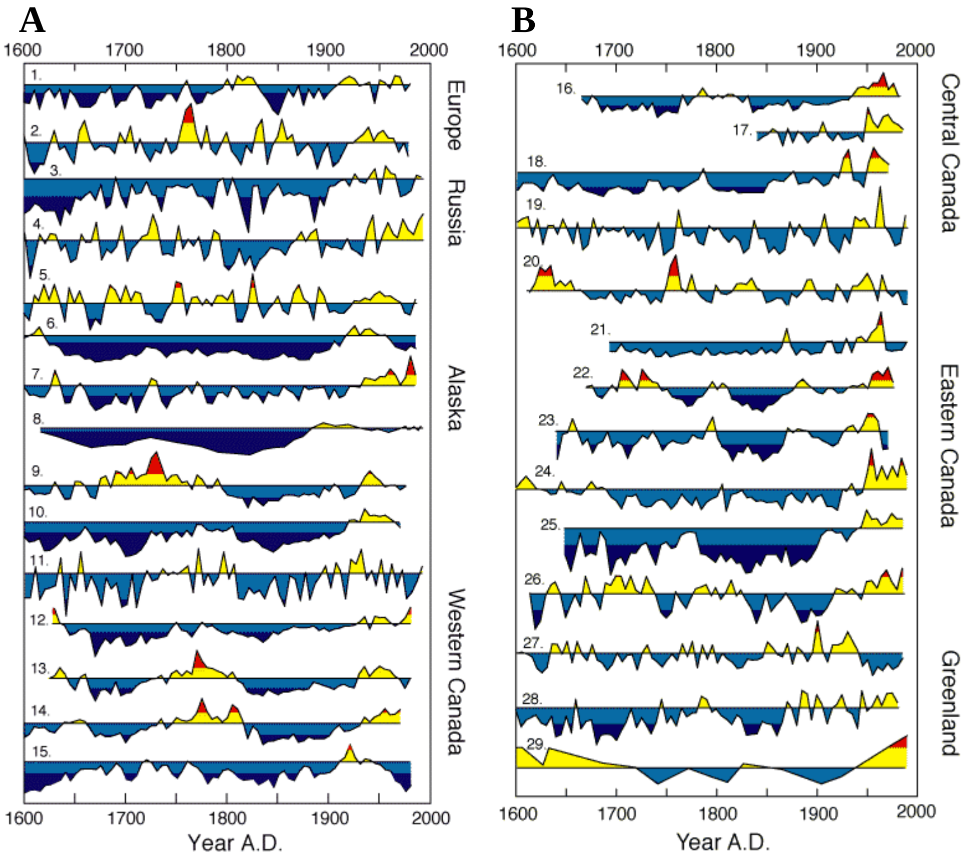
In this article, we use the paleoenvironmental record to asses the climate events of this century from the perspective of the last four centuries. We build on previous work (8-10) by compiling a variety of complementary paleoenvironmental indicators of climate from around the entire Arctic. This perspective permits the visualization of natural subdecadal to century-scale climate variability in the circum-Arctic region and allows us to examine the role that natural forcing mechanisms play in driving Arctic climate. Given the growing focus on Arctic environmental dynamics (4), we also examine the centuries-long paleoenvironmental perspective to determine whether the climate change we infer have resulted in changes to the natural Arctic ecosystem.



Receding glacier, southern Greenland. One of many glaciers on southern Greenland that has retreated (melted) dramatically since the end of the Little Ice Age (about 1850). In front of the present ice margin is the large brown unvegetated region formerly occupied by ice and bounded by the “end moraine,” or rocky ridge that marks the maximum Little Ice Age extent of the glacier. Photo credit: Jonathan Overpeck.

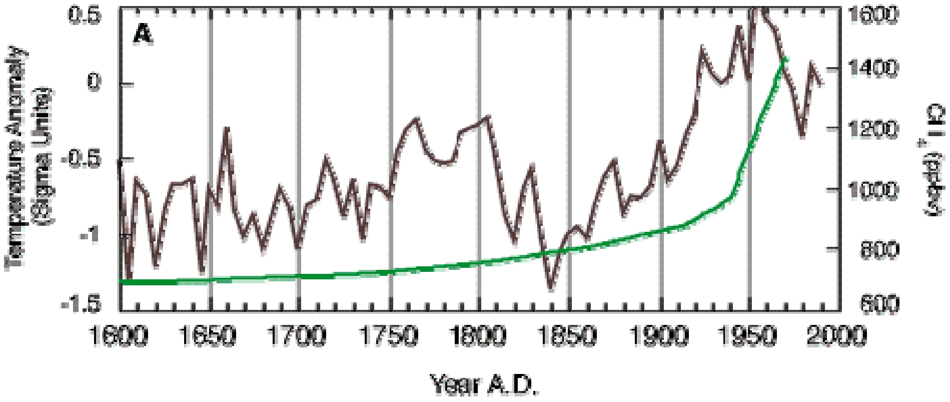
Muskox on Greenland. Arctic wildlife undoubtedly have been, and will be, affected by Arctic climate and vegetation change. Photo credit: Jonathan Overpeck.

(**A**) Standardized 400-year proxy climate records reflecting surface air temperature for sites from Arctic Europe east to western Canada (Fig. 1 and Table 1) (18). Red indicates temperatures greater then one standard deviation warmer than average for the reference period (1901-1960), whereas dark blue indicates at least one standard deviation colder than this average. (**B**) Same as (**A**) but for sites in Canada east to Greenland. All series are presented as 5-year averages except for sites 8 and 29, which are plotted at their original lower resolution. All time series represent surface air temperature expect for site 29, which represents STT. All time series shown will be available at http://www.ncdc.noaa.gov/paleo/paleo.html.

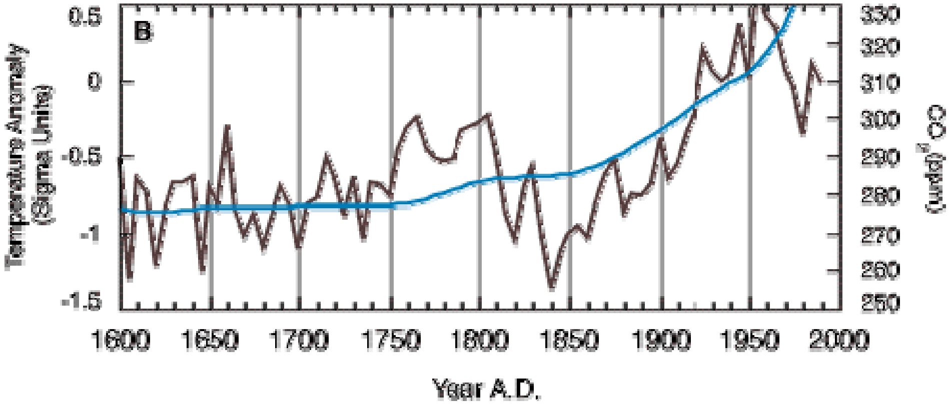


Comparison of hypothesized external climate forcing (colored lines) and standardized proxy Arctic-wide summer-weighted annual temperature (gray lines, plotted as sigma units: see paper for explaination next page).

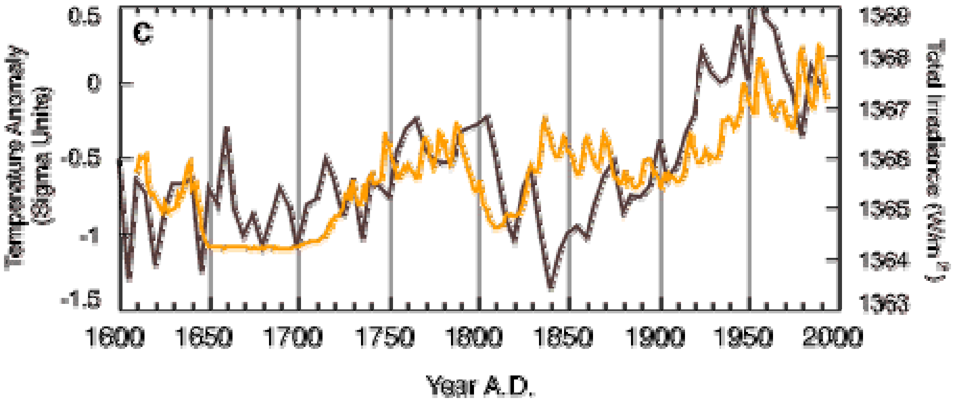
(**A**) atmospheric CH_4 (T. Nikazawa et al., Geophys. Res. Lett. 20,943 (1993))



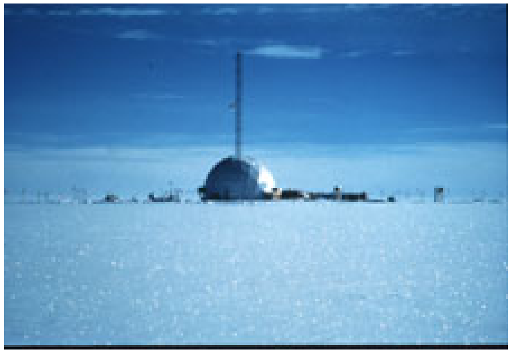
(**B**) reconstructed atmospheric CO_2 (D.M. Etheridge et al., Geophys. Res. Lett. 22, 4115 (1996))



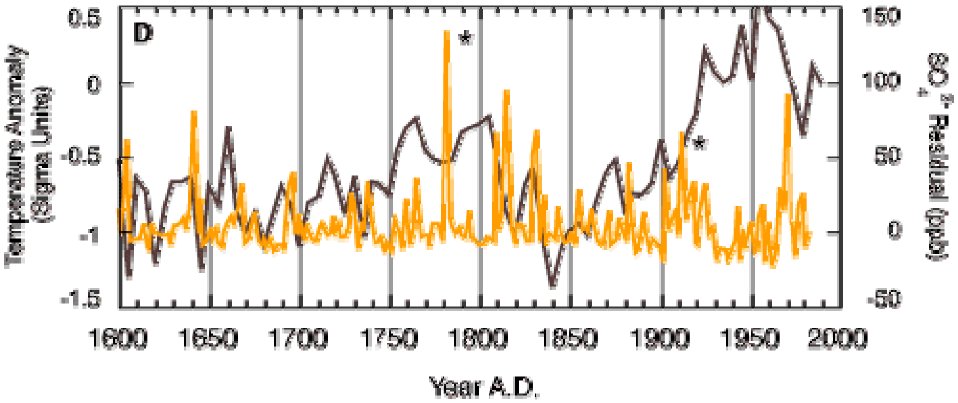
(**C**) solar irradiance (J. Lean et al., Geophys. Res. Lett. 22, 3195 (1995))



(**D**) standardized Greenland (GISP2) ice-core volcanic sulfate (Zielinski et al., Science 264, 948 (1994))



The GISP2 Ice Core drill dome at the summit of Greenland. The Greenland Ice Sheet Project 2 (GISP2) ice cores have revealed much about past environmental change, including the nature of Arctic stratospheric volcanic aerosol loading over the past four centuries. Photo credit: Mark Twickler.

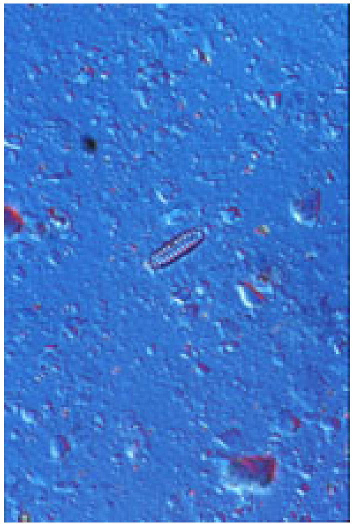


Eruptions known to be over-represented in the GISP2 record are marked with an asterisk.

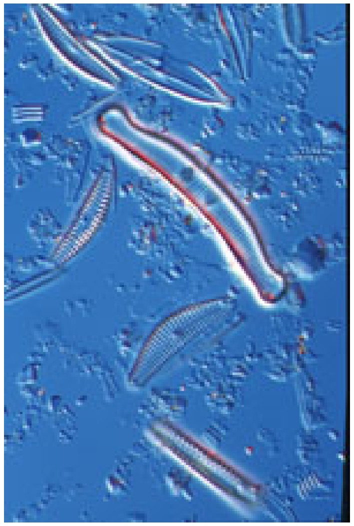
Figure 4 illustrates lake sediment records from climatically and limnologically contrasting regions of Ellesmere Island (M.S.V. Douglas, J.P. Smol, W. Blake Jr., Science 226, 416 (1994); N.C. Doubleday, M.S.V. Douglas and J.P. Smol, The Science of the Total Environment 160/161, 661 (1995); A.P. Wolfe, in Climate Change in the High Arctic, M. Garneau, Ed. (Geological Survey of Canada Memoir) in press., The inflection between unsupported and background (in situ production) ^{210}Pb activities in the Col Pond and Elison Lake cores indicates apporximately 1850 AD, which coincides with the onset of major diatom shifts in these cores. The Solstice Lake chronology is based on a linear interpolation between calendar-age-calibrated radiocarbon ages. This model place the major diatom changes within the last 120 years. The Lower Dumbell Lake core is without a radiometric chronology, but also suggests that substantial floristic change occured within the last 100 to 150 years.), each showing abrupt changes in the composition of fossil diatom assemblages deposited within approximately the last 150 years. These biostratigraphic changes are unrelated to differential silica preservation and represent the greatest floristic shifts of the middle to late Holocene.

Taxonomic diversification with greater representations of littoral and periphytic taxa (**A**-**C**), increased diatom algal biomass (**C**), and recent diatom (re) colonization (**D**) are all consistent with the abrupt 19th- to 20th-century shift towards longer summer growing seasons, reduced lake-ice severity, and greater habitat availability. The limnological consequences of the 19th to 20th century warming appear to be unprecedented in the context of pre-18th century natural variability.

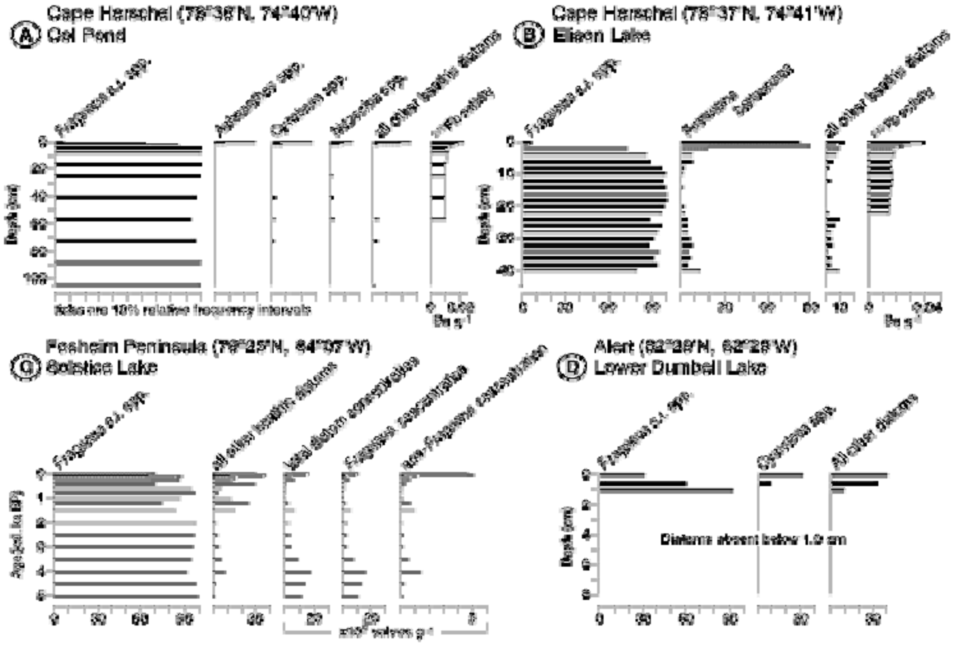
Ellesmere Island, Canada. The ecology (limnology) of this small Arctic lake is has recently undergone profound change, as recorded by the diatom fossils observed in the sediments. Photo credit: Marianne Douglas.



Photomicrograph of pre-1850 Elison Lake sediment sample, Ellesmere Island, Canada. Shows scarcity of diatoms before the post-1850 Arctic warming event. Photo credit: Marianne Douglas



Photomicrograph of present-day Elison Lake sediment sample, Ellesmere Island, Canada. Shows abundance of diatoms that characterizes sediment samples younger than 1850. Photo credit: Marianne Douglas.



Lake sediment records from climatically and limnalogically contrasting regions of Ellesmere Island (62, 68), each showing abrupt changes in the composition of fossil diatom assemblages deposited within approximately the last 50 years. These biostratigraphic changes are unrelated to differential silica preservation and represent the greatest floristic shifts of the middle to late Holocene. Taxonomic diversification with greater representations of littoral and periphytic taxa (**A** to **C**), increased diatom algal biomass (**C**), and and recent diatom recolonization (**D**) are all consistent with the abrupt 19th– to 20th-century shift toward longer summer growing seasons, reduced lake-ice severity, and greater habitat availability. The limnological consequences of the 19th– to 20th-century warming appear to be unprecedented in the context o pre-18th century natural variability. Except where noted, tick marks on horizontal axes represent 10% relative frequency intervals.

Implications for the Future

Our reconstruction of past environmental change in the Arctic suggests that natural variability is large in this region and is working together with human forcing (through increased concentrations of atmospheric trace gases) to drive unprecedented changes in the Arctic environment. The complexity of natural and anthropogenic forcing highlights the probability that assumptions of climate stability, or efforts to simply extrapolate past patterns of change into the future, will ultimately fail to anticipate future Arctic climate change and its impacts. Reliable predictions of future change will require climate system models that prove effective in simulating past changes such as those reconstructed here. Even as these models are being developed and tested, however, the Arctic environment is likely to continue its pace of change.

J. Overpeck, K. Hughen, D. Hardy, R. Bradley, R. Case, M. Douglas, B. Finney, K. Gajewski, G. Jacoby, A. Jennings, S. Lamoureux, A. Lasca, G. MacDonald, J. Moore, M. Retelle, S. Smith, A. Wolfe, & G. Zielinski.

Science, v. 278, n. 5341 p. 1251-1256, 1997.

Authors affiliations

Abstract a compilation of paleoclimate records from lake sediments, trees, glaciers, and marine sediments provides a view of circum-Arctic environmental variability over the last 400 years. From 1840 to the mid-20th century, the Arctic warmed to the highest levels in four centuries. This warming ended the Little Ice Age in the Arctic and has caused dramatic retreats of glaciers, melting of permafrost and sea-ice, and alteration of terrestrial and lake ecosystems. Although significant warming, particularly after 1920, was likely due to increases in atmospheric trace-gases, the initiation of the warming in the mid-19th century suggests that increased solar irradiance, decreased volcanic activity, and feedbacks internal to the climate system played roles.