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A New Ice Core from the Devon Ice Cap Canadian Arctic: Continued Development of High-resolution Proxy Records to Evaluate the Regionalization of Climate in the Circum-Arctic

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Final Report for Period: 08/2000 - 07/2002

Submitted on: 11/12/2002

Principal Investigator: Zielinski, Gregory A.

Award ID: 0049096

Organization: University of Maine

Title:

A New Ice Core from the Devon Ice Cap Canadian Arctic: Continued Development of High-resolution Proxy Records to Evaluate the Regionalization of Climate in the Circum-Arctic

Project Participants

Senior Personnel

Name: Zielinski, Gregory

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Wake, Cameron

Worked for more than 160 Hours: Yes

Contribution to Project:

Post-doc

Name: Zdanowicz, Christian

Worked for more than 160 Hours: Yes

Contribution to Project:

Post-doc to work on the microparticle record. Individual eventually took a position with the Geological Survey of Canada part way through the project.

Support was full-time salary through the grant.

Graduate Student

Name: Murphy, Alison

Worked for more than 160 Hours: Yes

Contribution to Project:

Research Assistant with the project to evaluate the chemical record of snow pits and the sea salt ice core record as a proxy for past sea ice extent.

Support was through a research assistantship.

Undergraduate Student

Name: Cavillari, Benjamin

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted in core-processing and responsible for running samples for microparticle analyses.

Support via hourly rate through the grant.

Technician, Programmer

Name: Whitlow, Sally

Worked for more than 160 Hours: Yes

Contribution to Project:

laboratory assistant responsible for running all samples for glaciochemical analysis.

Support at at monthly rate via the grant.

Other Participant**Research Experience for Undergraduates****Organizational Partners****Geological Survey of Canada (GSC)**

Data were shared between the organizations, and the GSC coordinated all field logistics.

Other Collaborators or Contacts

No other collaborators

Activities and Findings**Research and Education Activities:**

The primary goal of this project was to collect an ice core from the Summit of the Devon Ice Cap, Devon Island, Canadian Arctic. A 302-m core was collected during the spring of 1998 with additional field work in 1999. Individuals supported by this grant participated in the field work, although the GSC did the actual drilling. Glacier flow models as well as physical characteristics of the ice and $\delta^{18}\text{O}$ records suggest that basal ice recovered is about 86,000 years old. The first 200 meters were collected under dry drilling conditions, whereas the final 52 meters were collected with a drilling fluid to help prevent microfractures in the core. Unfortunately, drilling fluid penetrated to the interior of the core through microfractures, thus the bottom 52 meters was unable to be measured for the parameters analyzed in this study. Ice spanning approximately the last 5000 years was analyzed. To establish base-line conditions (i.e., modern snow characteristics), four snow pits were dug during the two field seasons. The same measurements were performed on pit snow as were done for ice and firn collected in the coring process.

Two main parameters were measured, ice glaciochemistry and concentrations of insoluble microparticles. Concentrations of major anions (Cl^- , NO_3^- , SO_4^{2-}), major cations (Na^+ , NH_4^+ , K^+ , Mg^{2+} , Ca^{2+}) and MSA were determined using a Dionex Model 2010 ion chromatograph with an auto sample housed in a designated laboratory. Insoluble particle concentrations and grain-size distributions from 0.6 to 13 μm in 64 logarithmically-divided channels were determined with an Elzone 280 PC particle counter equipped with a 30 μm orifice in a Class 100 clean room. A new microparticle analyzer had to be purchased near the end of the award period, as the electronics used in the original machine are now out of date. The microparticle record has just been completed, thus the evaluation of that record has yet to be undertaken. There were no direct educational activities except for general outreach via lectures as summarized on other parts of this report.

Findings: (See PDF version submitted by PI at the end of the report)

The first major finding of this project was establishing baseline conditions for snow chemistry on the Devon ice cap. Foremost, it was important to establish whether or not the glaciochemical concentrations measured are a function of environmental conditions outside of the snow environment. In particular, it is important to determine whether or not accumulation rates are the primary control on snow chemistry or are environmental factors, such as source region, wind speed and circulation patterns, the key control on glaciochemical concentrations. Comparisons between ion concentrations and accumulation rates through linear regression analysis and an empirical orthogonal function analysis (EOF) showed that these two parameters are independent of each other. Consequently, ion concentrations are a proxy for environmental factors outside of the Devon ice cap. Moreover, there was no statistical difference in mean annual concentrations of species among the pits studied indicating that spatial variability across the summit region of the Devon ice cap is negligible. As a result, a single ice core can provide a reliable paleoenvironmental signal.

The second major finding of this study was development of a lengthy time series of variability in the North Water polynya. A detailed comparison of sea-salt Na^+ concentrations compared to recent records of past ice extent in the North Water polynya showed the inverse relationship that was expected. Satellite images of sea ice extent from northernmost Baffin Bay, location of the North Water polynya southward through Davis Strait from 1980 to 1996 allowed development of a time series of past sea ice extent by seasons. This record was compared to the annual record of sea-salt Na^+ over that same time period. The linear regression between these two parameters showed that they varied inversely as one would expect if the open water associated with less sea ice extent provide a local source for the sea salt species that are deposited on the ice sheet. An EOF analysis on these same parameters supported the conclusions drawn from the linear regression analysis.

This relationship suggested that the sea-salt Na^+ record could be used as a proxy for past extent of the North Water polynya back to about 5200 year ago, the length of the useable record from the Devon ice core.

See attached file with Figure 1

Over the last 5200 years, the extent of the North Water polynya has varied considerably. Two specific examples highlight this variability. From about 4000 to 5200 years ago, sea-salt Na⁺ concentrations are consistently among the highest above mean values. This results highly suggests that the extent of sea ice was minimal, thus a very expanded North Water polynya during the mid-Holocene. From 4000 years ago to the present, the North Water polynya was predominantly much reduced compared to the 4000-5200 year ago time period as suggested by sea-salt Na⁺ concentrations predominantly below the mean. However, when evaluating the last 1000 years in detail, a clear record of highly variable sea ice extent coinciding with overall climatic conditions exists. The period from about AD 1600 to 1000 is characterized by higher concentrations, thus less extensive sea ice conditions and a more pronounced polynya. This corresponds in a general sense to the Medieval Warm Period. However, from AD 1600 to the present, sea ice extent is greater (thus a reduced polynya) as indicated by the overall lower sea-salt Na⁺ concentrations. An interesting conclusion drawn from these results is that sea-ice extent has not been increasing dramatically with any warming in the Arctic, despite recent findings that suggest sea ice thinning over the Arctic Ocean as a whole.

See attached file with Figure 2.

The purchase of a new microparticle counter delayed the completion of that record. As all samples have only recently been analyzed, the evaluation of the microparticle time series is only now underway.

Training and Development:

Three primary opportunities for training and development existed in this project. A post-doc was employed further increasing that individual's background in ice core studies. That individual used results from the ice core collected in the Penny ice cap project for his doctoral dissertation work. This individual left the project part way through the study as he took a professional position with the Geological Survey of Canada as a direct result of his work on the Penny and this Devon ice-coring project. The second opportunity for training and development came through the research assistant employed by the grant. This student used the field and laboratory results obtained in this study to develop her M.S. thesis. Her experience in dealing with biogeochemical processes used in this study and her coursework enabled her to take a position with an environmentally-based company. She also submitted one paper from her thesis for publication in a professional journal, although it was not accepted, and developed a second paper that is close to being submitted. The third major training and development opportunity was the undergraduate student who analyzed the majority of the samples for insoluble microparticles in the core. This student has become very familiar with laboratory techniques in ice-core research and the overall methods used in scientific studies as a whole. In addition to these three primary training opportunities, this project also supported undergraduate students as laboratory assistants in sample preparation and analysis, thereby giving them experience in the scientific process.

Outreach Activities:

Results from this project were presented as part of a public forum entitled "Coastal Communities and Climate Change in the North Atlantic", Bowdoin College, Brunswick, ME. Forum was sponsored by Coastal Studies Center, Peary-MacMillan Arctic Museum and Environmental Studies Program, Bowdoin College.

Journal Publications

Books or Other One-time Publications

Alison M. Murphy, "A glaciochemical record from the Devon ice cap and late-Holocene reconstruction of past sea-ice extent in the north water polynya, eastern Canadian Arctic", (2000). Thesis, Published
Bibliography: M.S. Thesis, University of New Hampshire, 217 p.

Web/Internet Site

Other Specific Products

Product Type: abstract published

Product Description:

Murphy, A., G.A. Zielinski, C.P. Wake, C.M. Zdanowicz, R.M. Koerner, D.A. Fisher, S. Whitlow, Relationship between a Devon Ice Cap glaciochemical record and sea ice in the North Water/Baffin Bay region of the eastern Canadian Arctic. Paper presented at Circum-Arctic PaleoEnvironments (CAPE) Conference, Sea Ice in the Climate System: The Record of the North Atlantic Arctic, Kirkjubæjarklaustur, Iceland, 2-6 June 2000.

Ice collected in this project is available for additional analyses by other investigators.

Sharing Information:

Published in abstract volume for the meeting. Ice is available upon request to the PI or the National Ice Core Lab (NICL) in Denver.

Contributions

Contributions within Discipline:

The glaciochemical records available from this ice core provide new information on key aspects of the climate system in the eastern Canadian Arctic. Changes in the Arctic are critical to the overall global climate system, thus it is critical to understand how climatic and environmental conditions have fluctuated in that region both now and prior to any anthropogenic influence on climate. The results from this project provide information on how the extent of the north water polynya varied over the last 5000 years. This polynya is a vital source of heat exchange with the atmosphere in the eastern Canadian Arctic. Overall, the polynya was less extensive during the Little Ice Age, thereby reducing a heat source to the circum-polar atmosphere. This scenario would have contributed to the overall cold conditions during the Little Ice Age. Further, this study shows how climate systems have varied regionally during the Holocene.

Contributions to Other Disciplines:

The main contribution of this study has been to climatic research with minimal contributions to other scientific and engineering disciplines.

Contributions to Human Resource Development:

This study provided significant learning experience to individuals at three different levels in their careers, that is, at the post-doctoral level, the master's level, and the undergraduate level. The results may also be used in lectures on past climatic conditions, thus contributing to the overall educational system.

Contributions to Resources for Research and Education:

A new microparticle counter was purchased with this grant for the University of Maine. The older model was out of date making any attempt to repair the older instrument very cost ineffective. The grant supported students including tuition waiver for the M.S. student.

Contributions Beyond Science and Engineering:

The results for this study were presented in a lecture for the general public as part of an open forum on how climatic change may impact coastal communities in the northernmost Atlantic Ocean. In general, the results showed individuals how variable climatic conditions have been in this region of the northern hemisphere and how susceptible communities in these areas are to changes in climate. Sea ice extent is one of the key aspects of their livelihood given their dependency on hunting seals for food and other essentials. A lack of sea ice prevents individuals from traveling far from their settlements. A record of sea ice extent was the primary product of this study.

Categories for which nothing is reported:

Any Journal

Any Web/Internet Site

FIGURE 1

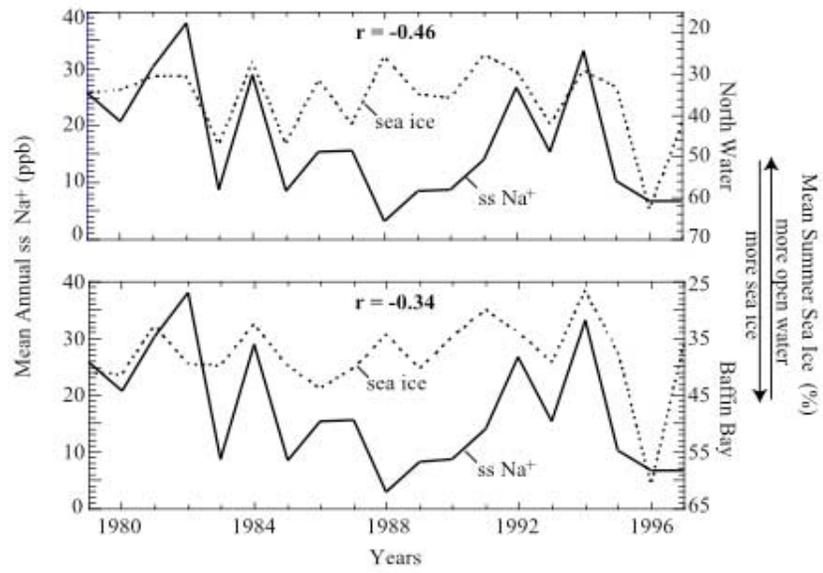


FIGURE 2

