The NGT and PARCA shallow ice core arrays in Greenland: A brief overview

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Introduction

Ice cores provide the most direct and highest temporal resolution record of past atmospheric and precipitation chemistry, and local to regional-scale meteorology. Such records have been used to reconstruct changes in oceanic and atmospheric circulation, to document industrial pollution and volcanic emissions, and to investigate current and past surface mass balance and net snowfall. An ice core chemical record reflects changes in both emissions from the source regions and transport pathways, so arrays of ice core records are required to distinguish between these often covarying phenomena. Moreover, arrays of ice cores offer the potential to identify spatial variability in emissions, climate, and meteorology. Extensive arrays of ice cores (Fig. 1) have been collected recently on the Greenland Ice Sheet (GIS) under two projects: the Alfred-Wegener-Institute North Greenland Traverse (NGT) (following the 1990 to 1992 German/Swiss glaciological study along the old line of the Expedition Glaciologique International au Groenland (EGIG) in central Greenland) and the U.S. Program for Arctic Regional Climate Assessment (PARCA).

North Greenland traverse

The NGT array includes 33 shallow and 13 deeper ice cores collected as part of 1993 to 1995 overland traverses in the data sparse northern GIS (Fig. 1). Isotopic and glaciochemical analyses on selected cores included discrete measurements of $\delta^{18}O$, and major and trace ions, which have been used to address a range of geophysical issues. For example, the cores were used to document the preindustrial climate variability and precipitation history in northern Greenland (see below). Fischer et al. (1998) analyzed the array to characterize deposition mechanisms for

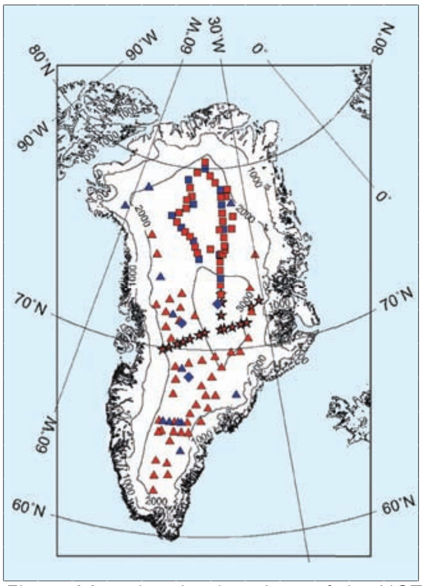

Fig. 1: Map showing locations of the NGT (shallow cores: red squares, deeper cores: blue squares) and PARCA (shallow cores: red triangles, deeper cores: blue triangles) arrays of ice cores in Greenland. Cores identified as shallow are less than 50 m in depth. Cores funded by NSF (deeper cores: blue diamonds) and EGIG (shallow cores: red stars) are shown for completeness.

nitrate and sulfate (Fig. 2) and the impact of industrial emissions on north Greenland precipitation. More recently, measurements of sea salt tracers from the NGT deeper cores were used to investigate interannual to multidecadal modes in atmosphere/ocean dynamics in the North Atlantic over the past millennium (Fischer and Mieding, 2005).

PARCA campaigns

Ice cores are the primary indicator of net snowfall over the ice sheet at all temporal scales. The PARCA array of >80 ice cores was collected during a series of primarily airborne campaigns beginning in 1995 and continuing to the present, and was designed to investigate the spatial and temporal variability in net snowfall and the meteorological changes that drive that variability. For both logistical and scientific reasons, the array includes mostly cores spanning the last few decades, with a few extending over recent centuries. The majority of the ice cores were collected from higher accumulation, data sparse areas of the central and southern GIS, where altimetry measurements indicate the most change (Fig. 1). For validation of satellite and meteorological model estimates of net snowfall, a multi-parameter approach to dating is used that includes high-resolution chemical measurements from traditional and expanded continuous flow analysis (CFA), together with discrete water isotope, beta radiation, and dust particle measurements for some cores.

Although the primary focus of PARCA has been on snowfall and mass balance, the array also pro-

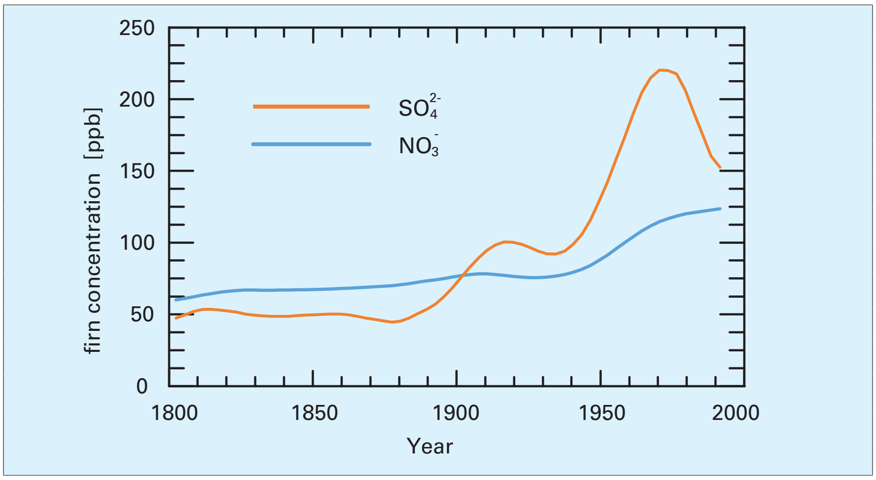

Fig. 2: Long-term trend in sulfate and nitrate concentrations in the NGT B21 (80.0°N, 41.1°W) core.

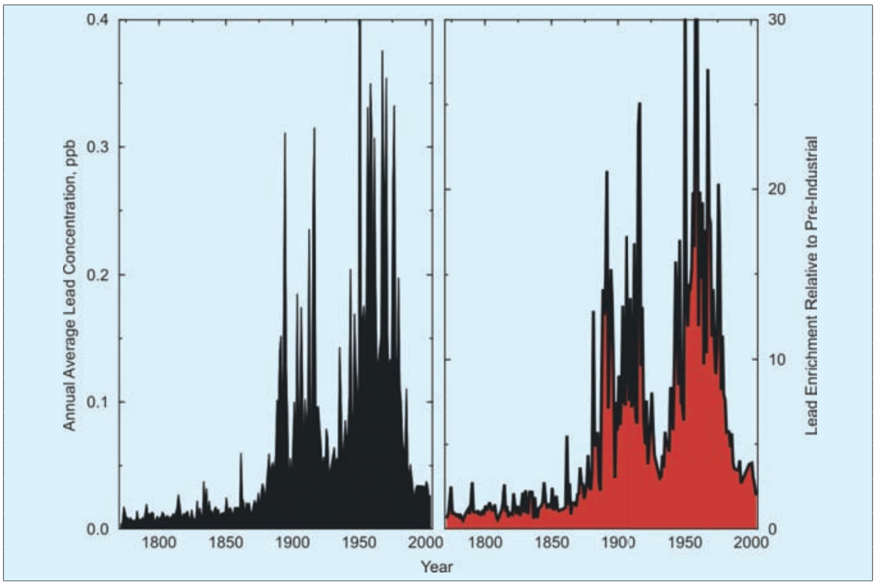

Fig. 3: High-resolution record of lead concentration and lead enrichment (relative to aluminum) measured in the PARCA ACT2 ice core (66.0°N, 45.2°W).

vides a unique spatially distributed record of precipitation and atmospheric chemistry, dust and sea salt flux, and volcanic fallout. Particularly, recently collected cores have been analyzed with a newly developed CFA system that also includes trace elements. For example, the records document dramatic changes in lead pollution in Greenland precipitation over recent decades to centuries in response to industrialization and the efficacy of subsequent government interventions in the early 1970s (Fig. 3). Interpretations of the chemical measurements from the PARCA ice core array are ongoing and will address a range of environmental and paleoclimate questions.

New GIS accumulation estimates

The Greenland Ice Sheet (GIS) contains enough ice to raise sea level by 7 m, so understanding the current and past mass balance is critical to sea level prediction. Recent repeat altimetry studies show little change in overall mass at higher elevations, although some areas have experienced significant thinning or thickening during the past few decades. However, multiple factors determine ice sheet elevation change, including changes in ice dynamics and melt, as well as short and long-term changes in net snowfall.

Ice-core accumulation measurements from the PARCA and NGT arrays provide a much better understanding of the temporal and spatial variability in net snowfall on the GIS. To date, results have been used to develop both long-term mean (e.g., Bales et al., 2001; Dethloff et al., 2002) and year-by-year maps of net snowfall for all or parts of the ice sheet, to validate meteorological model estimates of net snowfall, and to interpret repeat altimetry surveys. For example, using year-by-year accumulation records from ice cores, together with firn densification modeling, it was found that much of the 1978 to 1988 spatial pattern in ice-sheet elevation change observed by repeat altimetry could be attributed to short-term variability in snowfall (McConnell et al., 2000), with such elevation change masking any thickening and thinning associated with long-term, ice-dynamics-driven changes in mass balance. More recently, net accumulation measurements have been used to validate the ERA-40 reanalysis. Results indicate that, as with other meteorological model outputs, ERA-40 simulations capture much of the temporal variability in snowfall but not the magnitude of snowfall around the ice sheet (Hanna et al., 2005).

Project facts

PARCA - Program for Regional Climate Assessment)
Contact: Joe McConnell, jmcconn@dri.edu
Participants: Roger Bales (University of California, Merced), Joe McConnell (Desert Research Institute), Ellen Mosley-Thompson (Ohio State University)
Funding: NASA, with additional support from NSF
Where: Greenland
When: 1995-present
What: >80 shallow to intermediate ice cores spanning decades to the last millennium, Traditional CFA, dust concentration, water isotopes, beta horizons for earlier cores, Expanded CFA for more recent cores including >20 elements and chemical species measured at ~1 cm effective depth resolution.
Web Page: http://nsidc.org/data/parca/

NGT - North Greenland Traverse
Contact: Sepp Kipfstuhl, kipfstuhl@awi-bremerhaven.de
Participants: Sepp Kipfstuhl, Hubertus Fischer (Alfred-Wegener-Institute for Polar and Marine Research, Bremerhaven), Dietmar Wagenbach (Institute for Environmental Physics, University of Heidelberg), Thomas Stocker (Climate and Environmental Physics, Physics Institute, University of Bern)
Funding: National contributions from Germany and Switzerland
Where: Northern Greenland
When: 1993-95
What: Snow pits, shallow and intermediate ice cores spanning up to 1000 years, water isotopes ($\delta^{18}O$, δD, deuterium excess), major and traces, radioisotopes
Database: www.pangaea.de

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