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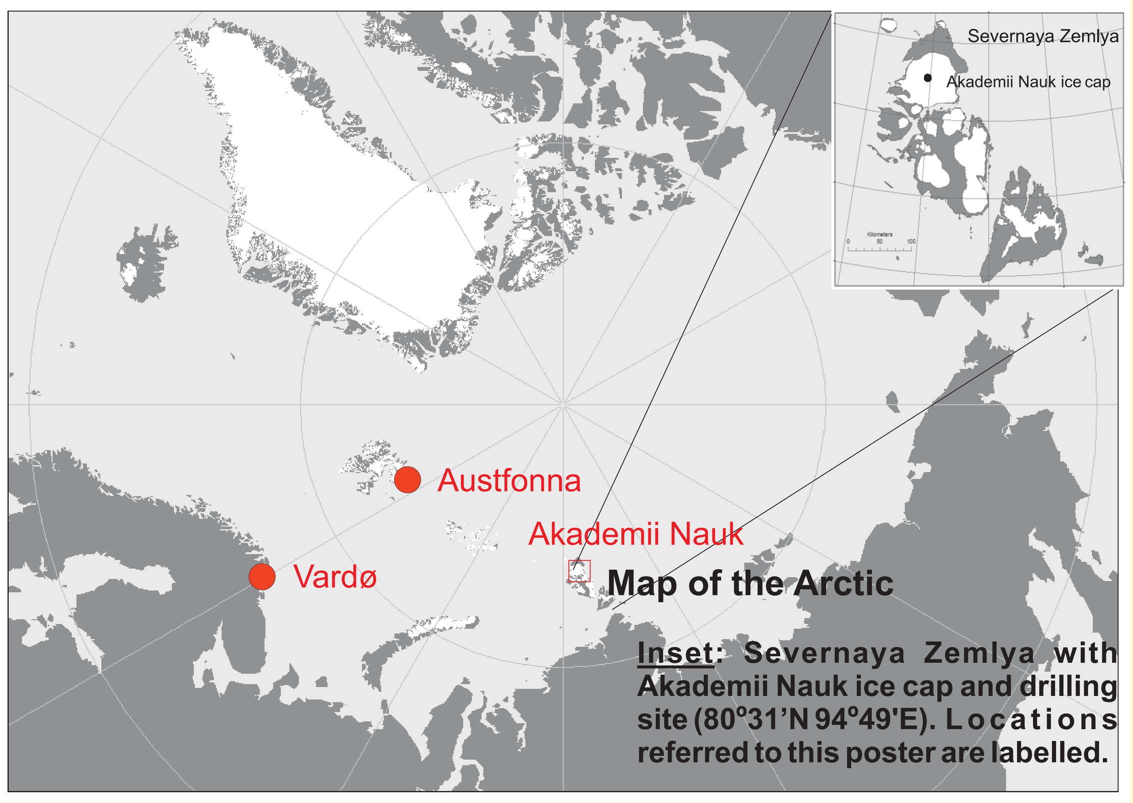
Late Holocene environmental ice core record from Akademii Nauk ice cap (Severnaya Zemlya)

Introduction



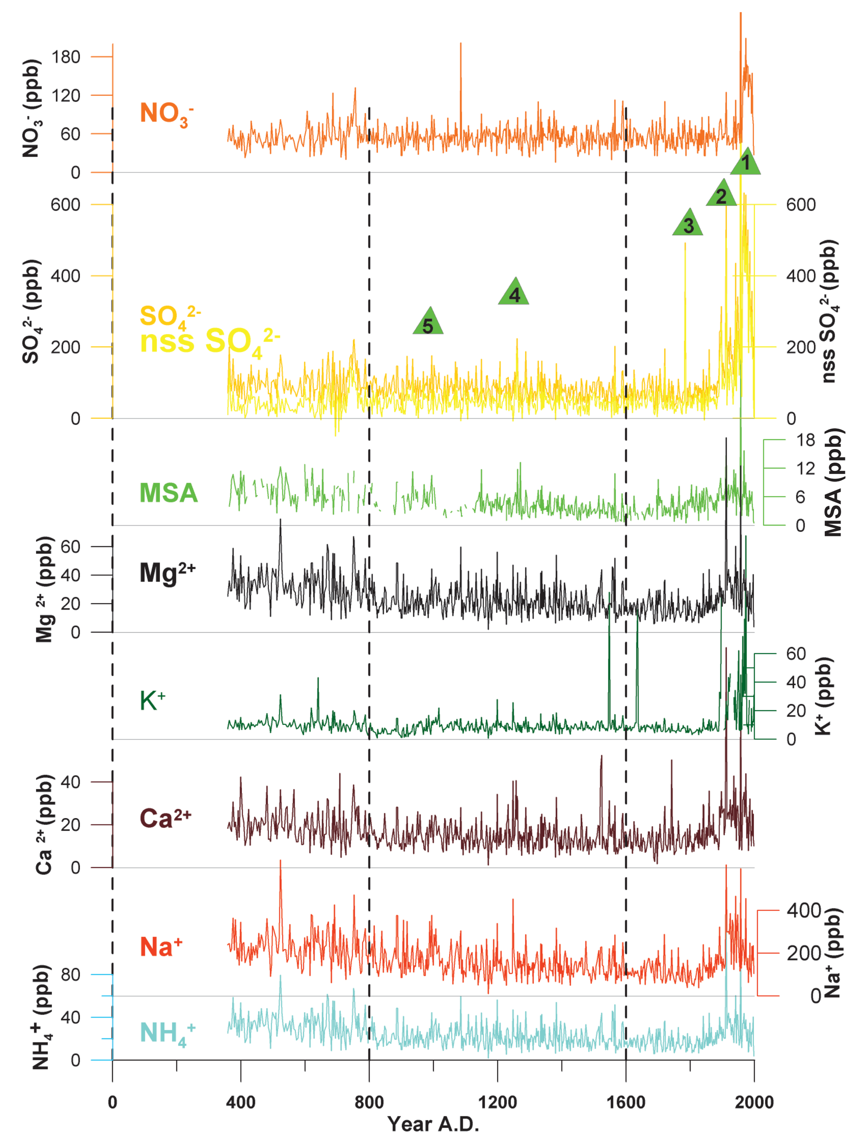
In the Arctic, a key region for the global climate system and more affected by the ongoing warming than other regions, meteorological records are relatively short, with only a few time series starting before the 20th century. Hence, climate archives, especially high-resolution ones like ice cores, are of particular importance for the assessment of past and recent climate changes.

To gain new high-resolution proxy data for the reconstruction of climate and environmental changes, a 724 m-long ice core was drilled near summit of Akademii Nauk (AN) ice cap, the largest glacier on Severnaya Zemlya (Figure above) within a joint German - Russian project in 1999-2001 [1]. In the Eurasian Arctic Severnaya Zemlya is the easternmost archipelago covered by considerable ice caps.

The AN ice cap is affected by melting in summertime. Percolating water causes alterations of original isotope and chemical signals.

Paleoclimate Proxies

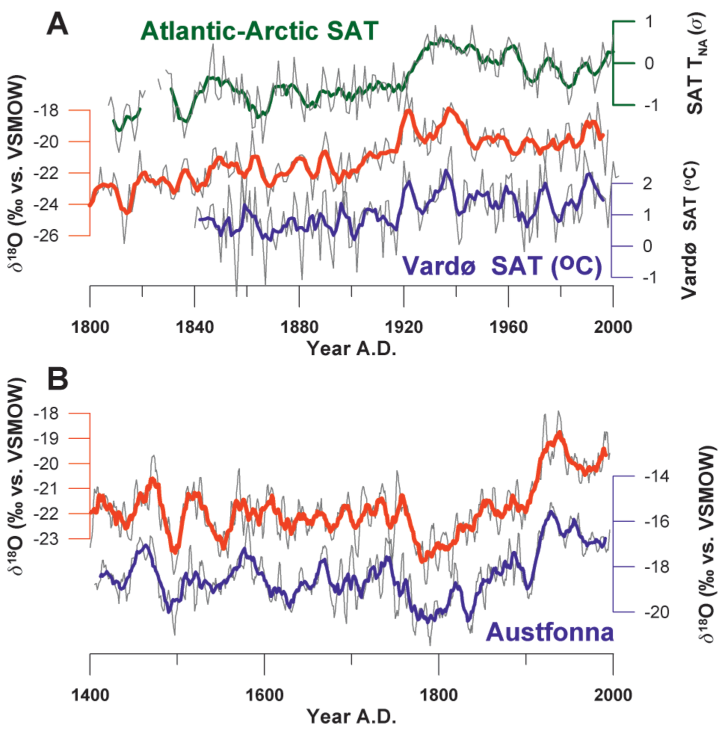
Major Ions



Record of bag-mean values of major ions

Sulphate record shows prominent peaks corresponding to volcano eruptions of Bezymianny 1956 (1), Katmai 1912 (2), Laki 1783 (3), Samalas ? 1257 (4) and Eldgja 934 (5) used as reference horizons for core dating. The 20th century pattern of sulphate and nitrate reflects anthropogenic emissions.
Sea-salt ions (e.g. Na^+, methanesulphonate MSA^-) show a decreasing trend between 300 and 1800 probably caused by the increase of surface elevation at the drilling point followed by a strong increase around 1910, indicating an abrupt shift in sea-ice atmosphere interactions (nss = none sea-salt).

Stable-water Isotopes



$\delta^{18}O$ record of AN ice core
all annual data - grey

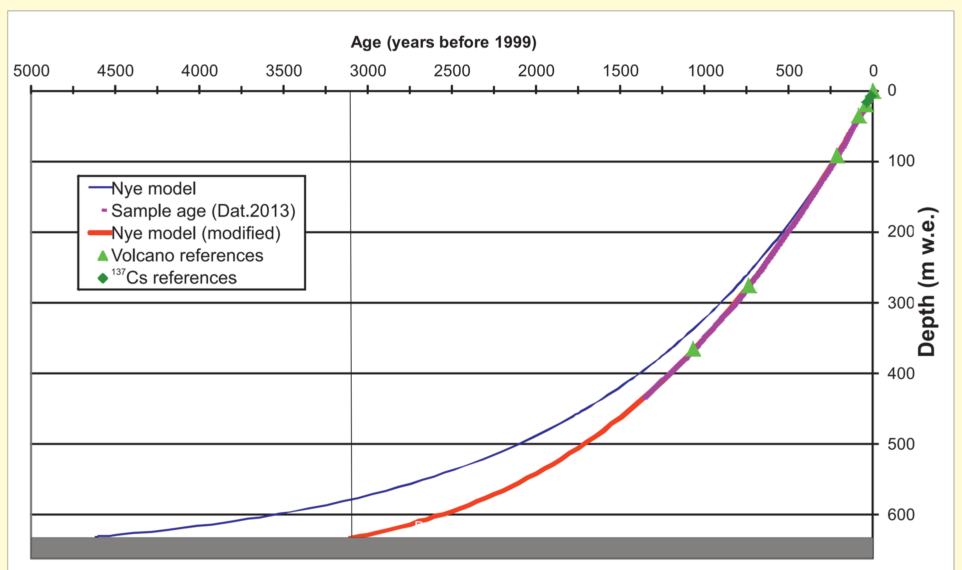
A: Surface air temperature (SAT) variations compiled for Atlantic/Arctic boundary region [4], 5 years running means (yrm) - green, AN $\delta^{18}O$, 5 yrm (red) and meteorological SAT data from Vardø/ Northern Norway, 5 yrm (blue).

B: AN $\delta^{18}O$, 15 yrm (red) and Austfonna $\delta^{18}O$ (Svalbard) [5],15 yrm (blue.)

Major ions have been analysed in low resolution only (bag-mean values - figure left). Volcanoes used for core dating are marked but are missing in the lower core part. Therefore, we tried an independent validation of our age-depth relationship using ^{10}Be concentrations (below).

The figure above shows the $\delta^{18}O$ record of the upper 255 m using our preliminary dating. We found the best correlation with Arctic meteorological time series for Vardø, Northern Norway (r_{5yrm} = 0.76). Therefore, we consider our $\delta^{18}O$ 5yrm data as a robust temperature (SAT) proxy showing features typical for the Western Eurasian Arctic. Examples are the double-peaked Early Twentieth Century warming (1920-1940) and the absolute SAT minimum just before 1800 also found in the Austfonna $\delta^{18}O$ ice core record from Svalbard [6]. The SAT reconstruction for the Atlantic-Arctic boundary region [4] shows remarkable differences.

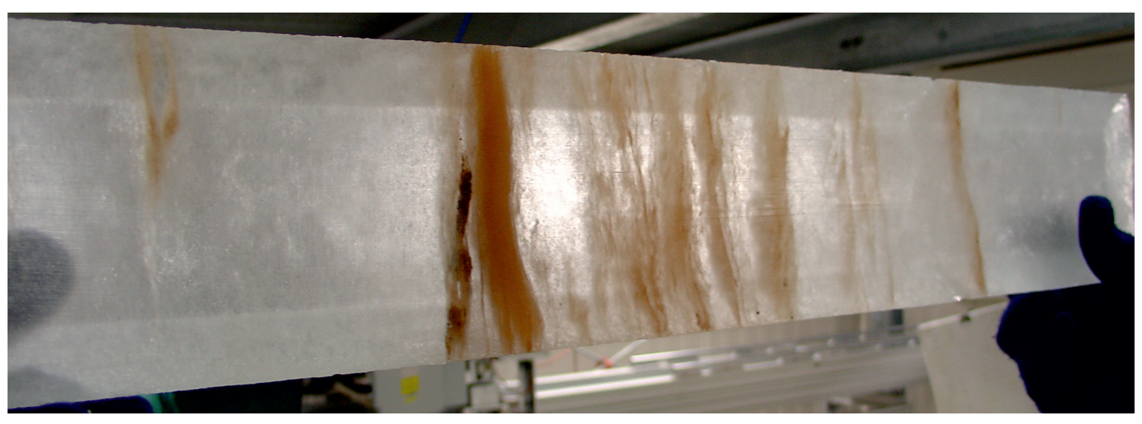
Core Dating



Age-depth relationship of the core

An exact core chronology is essential to interpret paleo-environmental signals. For the upper 479 m dating has been done by counting annual cycles of stable water isotopes (magenta in Figure above). For cross-checking we used peaks of ^{137}Cs (Chernobyl 1986), nuclear weapon tests (1963) [2] as well as 5 volcanic reference horizons (cf. Figure Major Ions).

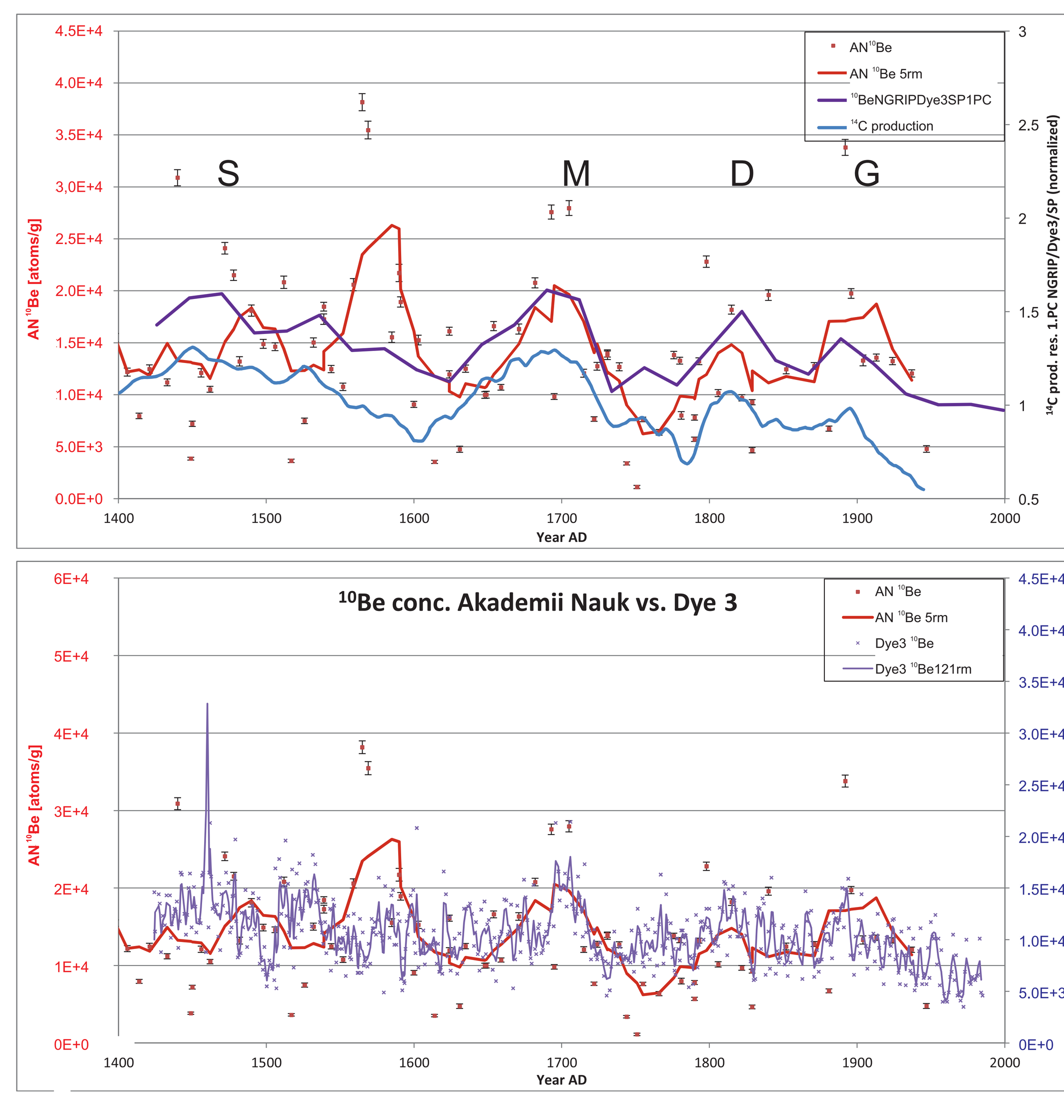
Our dating shows that the glacier has not been in dynamical steady state in the past as postulated by usual standard flow models such as Nye's [3] - blue line - but it has been growing until recent times. A modified Nye model considering the increasing surface altitude has been developed - red line - and was used for dating of deeper core sections. Our model predicts an age of about 3100 years at a depth of 690 m (630 m water equivalent - w.e.). The deepest core part (Figure below) has completely different properties hence, we suppose an unconformity at this depth.



Deepest core section with debris

^{10}Be

Validation of Core Dating

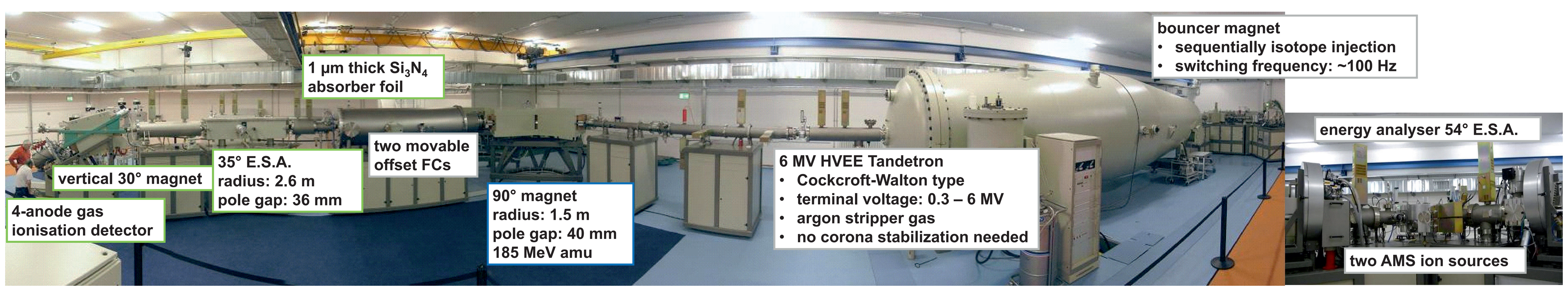


Comparison of ^{10}Be concentration in AN with 1. PC (PCA) [9] from high-resolution ^{10}Be records from NGRIP, Dye3 and South Pole ice cores (above) and ^{10}Be from Dye3 core (below).

^{10}Be is one of several radionuclides produced in the Earth's atmosphere by cosmic radiation. Because its production rate is modulated by variations of geo- and heliomagnetic fields the concentrations of these nuclides in glacier ice or tree rings are suitable to reconstruct solar activity. Vice versa an ice core age model can be verified by matching ^{10}Be concentrations with cosmogenic radionuclide records from well-dated archives. Local differences in ^{10}Be ice core records as results of different geomagnetic coordinates, transport and deposition processes and accumulation rates are known [7] and have to be considered. After 1600 AD AN ^{10}Be concentration maxima fit well with periods of relative quiet sun (known as Gleisberg (G), Dalton (D), Maunder (M) and Spörer (S) Minima) visible in ^{14}C production [8] and 1.PC derived by PCA of ^{10}Be records from NGRIP, Dye3 (both Greenland) and South Pole ice cores [9], too. An explanation for the yet obvious mismatching before 1600 needs further investigations.

AMS measurement

^{10}Be decays (beta decay) with a half-life of 1.387 $*10^6$ years, which usually requires long measuring times at low sensitivity for beta-spectroscopy. Thus only Accelerator Mass Spectrometry (AMS) is sensitive enough for the effective measure of ^{10}Be concentrations in ice cores. The Ion Beam Center of HZDR offers determination of cosmogenic radionuclides using a high-energy accelerator (voltage 6 MV, figure below). The team of DREsden AMS (DREAMS) [10] was able to measure ^{10}Be concentrations in discrete AN ice core samples of about 300 g each.



DREAMS (DREsden AMS): Machine layout (E.S.A. = electrostatic analyser)

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