Climate Signals from stable water isotope records for the last millennium from northern Greenland

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Background

The ice cores presented here were drilled during the AWI -North -Greenland-Traverse (NGT) from 1993 to 1995. In total, 13 ice cores (B16-B23, B26-B30) from 12 different sites were drilled along the traverse route. B21 and B23 as well as B26 to B30 are located on ice divides while B16-B20 are located east of the main ice divide. The ice cores cover the last 500-1000 years.
High resolution $\delta^{18}O$ data (2-5 cm depth resolution) from all drill sites were annually dated using volcanic horizons as match points. The $\delta^{18}O$-stack (NGT+NGRIP) is used as temperatur proxy with improved signal-to-noise ratio compared to single records.

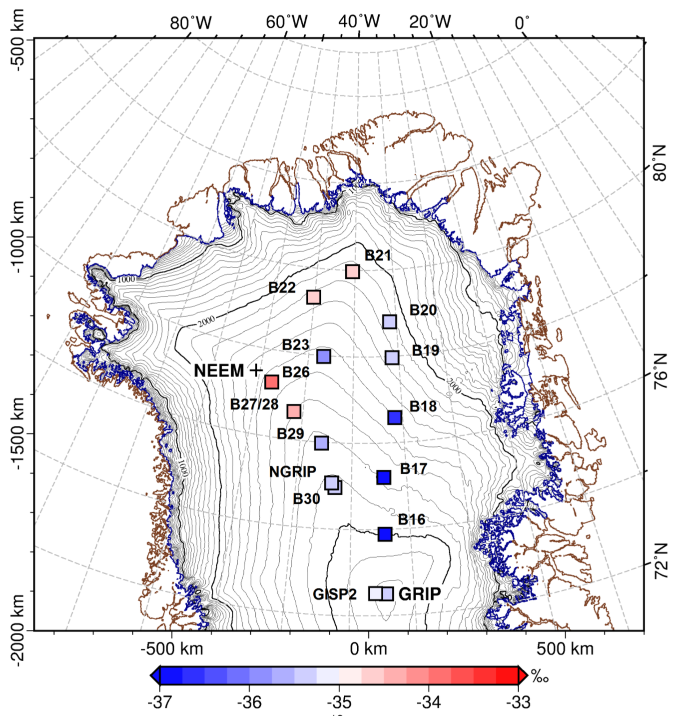

Fig. 1. Mean $\delta^{18}O$ values of the ice cores in their common time window (1505-1953 AD) given with color coded squares. Blue colors representing lighter values (colder), red colors heavier values (warmer).

Objectives

1) To investigate the spatial variability of $\delta^{18}O$ in northern Greenland (NG) using this new set of $\delta^{18}O$ data and to evaluate the influence of isotopic noise on a single record
2) To assess whether stable water isotope records from sites with very low accumulation rates can be interpreted as climate signals
3) To present a new stacked robust $\delta^{18}O$ record for northern Greenland covering the past millennium
4) To interpret this record in terms of paleoclimate with respect to temporal variability and relation to large scale climate information from other proxy records

Stacked $\delta^{18}O$ data

1928 AD is the warmest year in the record. There is a warming trend since 1870 AD. The most recent years (until 1995 AD) are not the warmest years since1900 AD.
Distinct Little Ice Age (LIA) cooling is recorded.
Abnormal warm years 1420 +/-20 AD and periodic (50-70 a) anomalies between 1100 and 1600 AD are conspicuous.

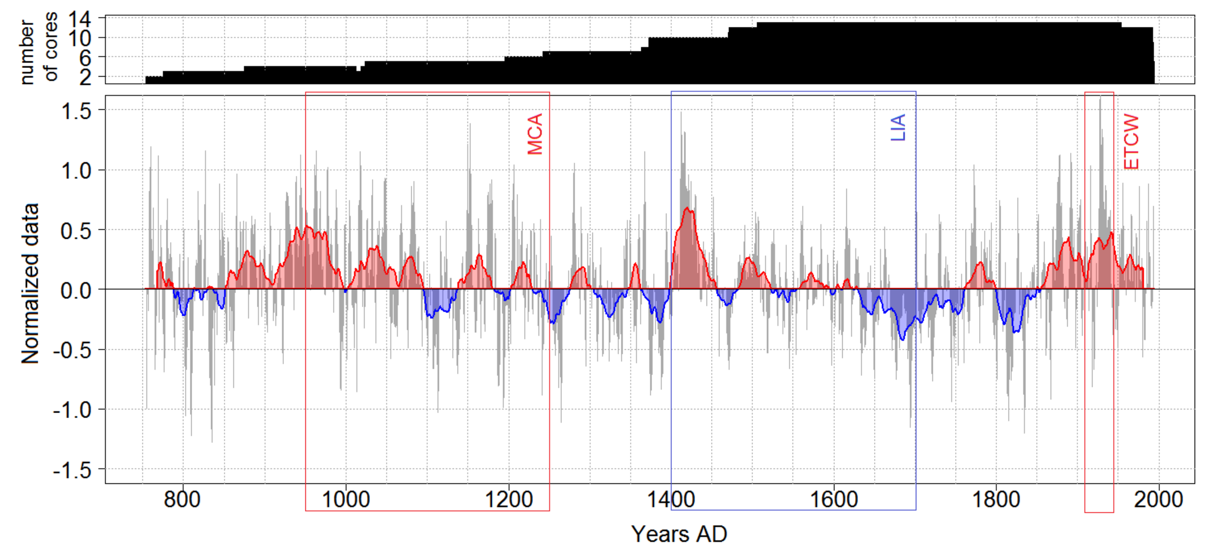

Fig. 2. Top: The number of cores used for the stack (NGT+NGRIP). Bottom: Annual stacked $\delta^{18}O$ (grey) and their smoothed record (30 years running mean). Values warmer than the mean (1953-1505 AD) are red, values colder are shown in blue color. Distinct climate periods are marked: Medieval Climate Anomaly (MCA, 950 - 1250 AD (Mann et al., 2009)), the Little Ice Age (LIA, 1400- 1700 AD (Mann et al., 2009)), Early Twentieth Century Warming (ETCW 1920 – 1940)(Semenov and Latif, 2012; Wood and Overland, 2010).

Summary

- East to west difference in $\delta^{18}O$ and accumulation rate due to the Greenland ice sheet topography (main ice divide and summit)
- $\delta^{18}O$ stack improves signal-to-noise ratio
- $\delta^{18}O$ records in northern Greenland differ from results in southern Greenland
- No clear direct volcanic influence observed from NGT $\delta^{18}O$ records
- Abnormal warming around 1420 AD
- Internal Arctic dynamic (sea ice extent) is assumed to have influence on $\delta^{18}O$ in northern Greenland (e.g. 1420 AD)
- Warming trend since 1870 AD

Mean NGT accumulation rates*

B16	B17	B18	B19	B20	B21	B22	B23	B26	B27	B29	B30
141	114	103	94	98	109	145	121	176	180	149	166

* Mean over core length, mm/a

Spatial $\delta^{18}O$ distribution

Clear east to west gradient due to Greenland ice sheet topography. Main ice divide (north to south) is blocking cyclones coming from west and summit is blocking those from south.
Very low accumulation rates in Greenland's northeast due to their position in the lee site of the main ice divide.

Accumulation, latitude, longitude and altitude are influencing $\delta^{18}O$. They are not independent of each other and to derive clear relationship to $\delta^{18}O$ values is more complex.

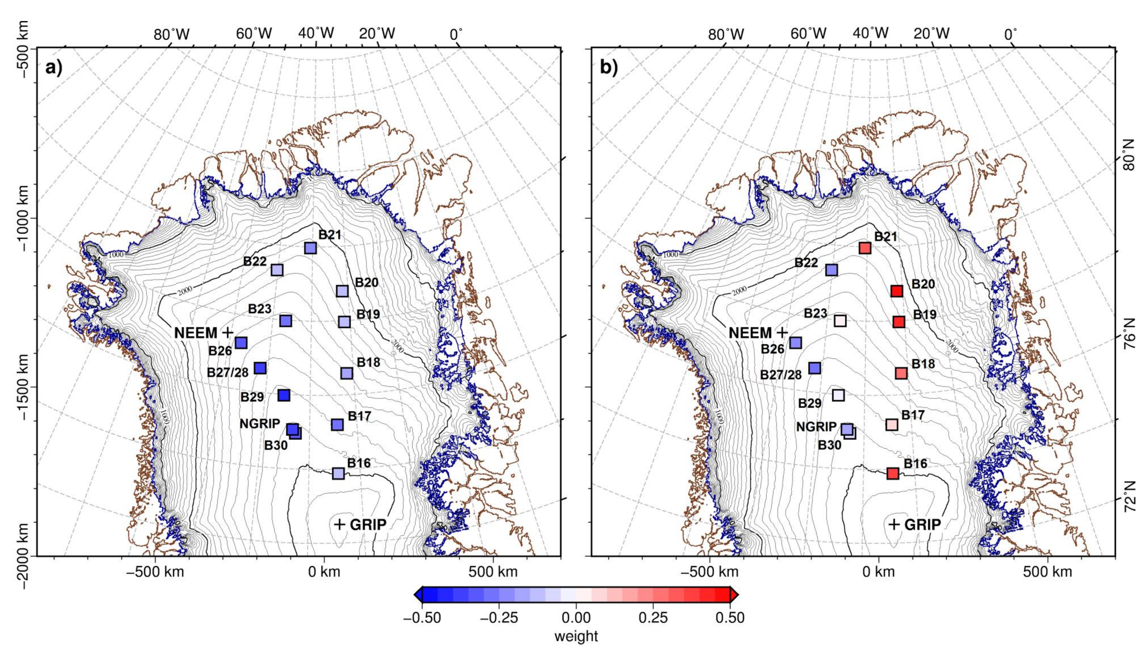

Fig. 3. Map of loading for the first a) and second b) principal component on the annual northern Greenland $\delta^{18}O$ values between 1505 and 1953 AD.

Annual $\delta^{18}O$ of single ice cores

There are differences in $\delta^{18}O$ ranges and means of the individual cores.
Heavier (colder) mean values at southern and eastern NG.
B16-B18 (east of main divide and north of Summit) have the coldest mean values.
Records have common signals (e.g.1420 AD event).

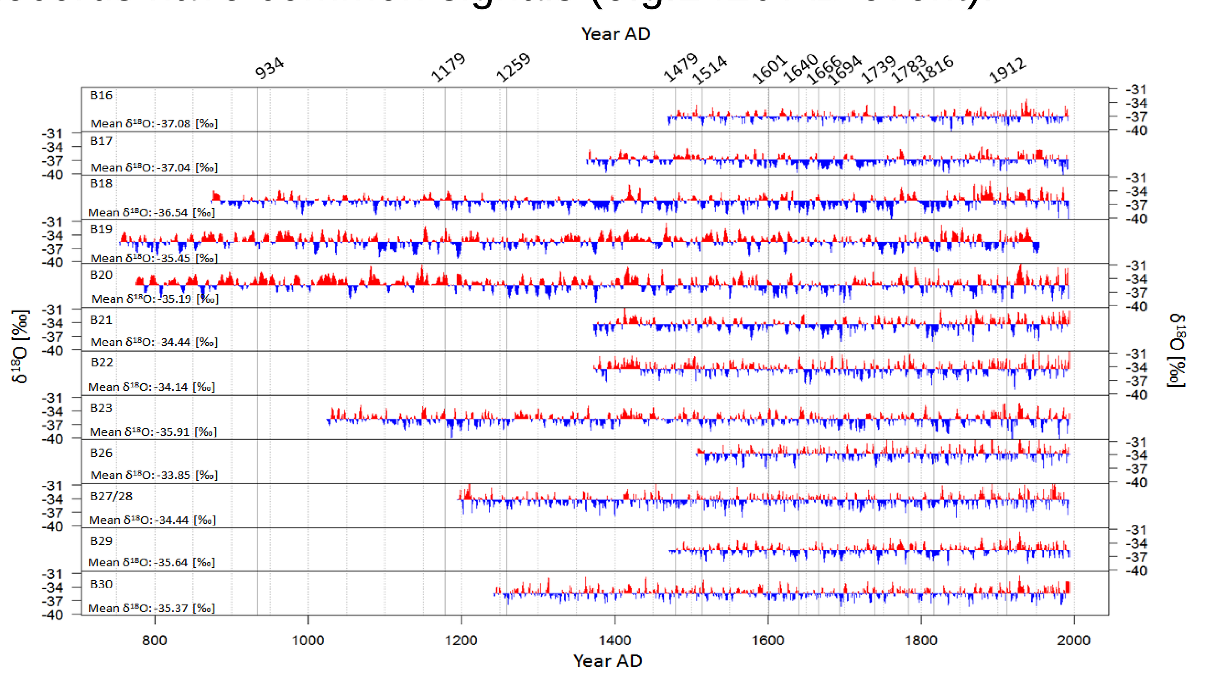

Fig. 4. Annual $\delta^{18}O$ records at the 12 NGT sites. Values below (above) the 19th century mean are marked in blue (red). Dark grey vertical lines mark volcanic eruptions (years given at top) used as time markers. The $\delta^{18}O$ mean over the whole core length is given.

Dating:
Volcanic events had been picked as marker horizons (DEP, ECM, sulfate data). The annual mean accumulation rate was calculated between this markers with the assumption of constant accumulation rate between the markers.
Annual mean values from high resolution $\delta^{18}O$ data had been calculated.

Northern Greenland in the Arctic

The abnormal warm event 1420 +/- 20 AD is most obvious from NG $\delta^{18}O$.
Strongest correlation to arctic temperature mean (Arctic 2k) and $\delta^{18}O$ from Agassiz ice cores.
Most recent years (from 1995AD) are not the warmest years in NG.
NG $\delta^{18}O$ anomalies differ from those of southern Greenland (e.g. 1420 AD, 1600-1800 AD).

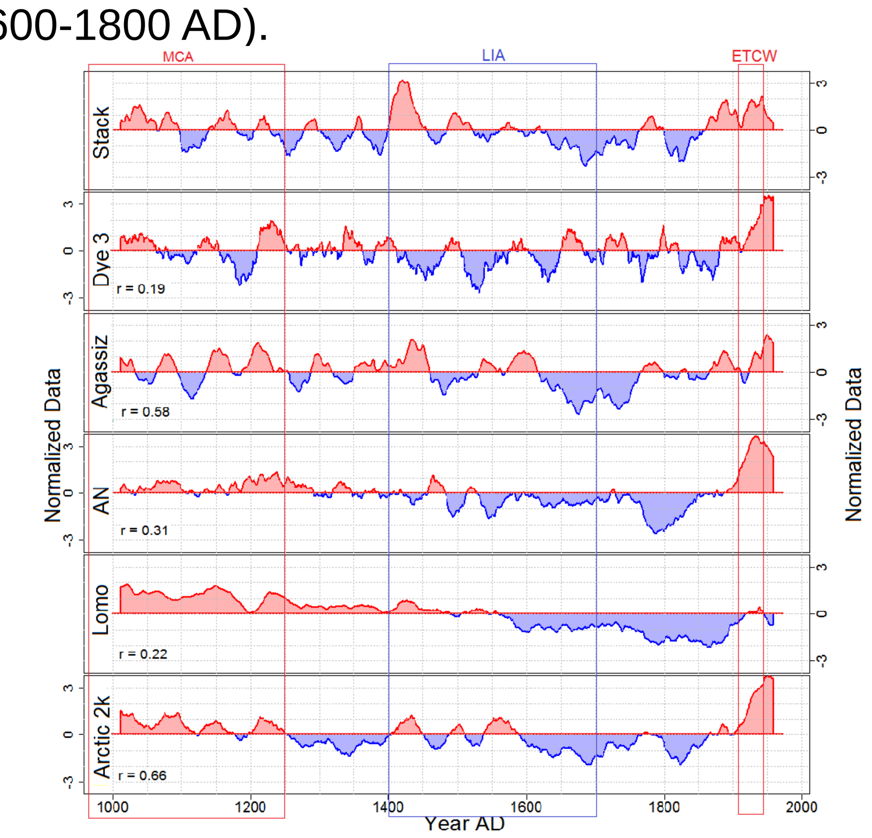

Fig. 5. 30-years running mean for $\delta^{18}O$-values from different arctic regions: northern Greenland (stack, this study), southern Greenland (Dye3, Vinther et al., 2006b), Canada (Agassiz Ice Cap, Agassiz, Vinther et al., 2008), Siberia (Akademii Nauk, AN, Opel et al., 2013), Svalbard (Lomonosovfonna, Lomo, Divine et al., 2011) and a reconstructed record (Arctic2k, Pages2k Consortium, 2013). All records are given on z-level scales (centered and normalized data). Also the correlation coefficient for the smoothed values to our stack is given.

Forcing

Minor direct effect of volcanic eruptions on $\delta^{18}O$ values in NG.
Anti-correlation between arctic sea-ice extent and $\delta^{18}O$ values around 1420 AD which indicates regional internal variability.
Solar activity causes anomalies in NG $\delta^{18}O$ values. However, there is no solar anomaly around 1420 AD.
No clear volcanic influence in NG $\delta^{18}O$ values.
Weak correlation of NG $\delta^{18}O$ stack and NAO (r = 0.2) although single NG cores (e.g. B21) assumed to be out of cyclonic track and are not correlated to NAO index.
Assumed AMO influence likely causing quasi-periodic anomalies between MCA and LIA (Fig. 2).

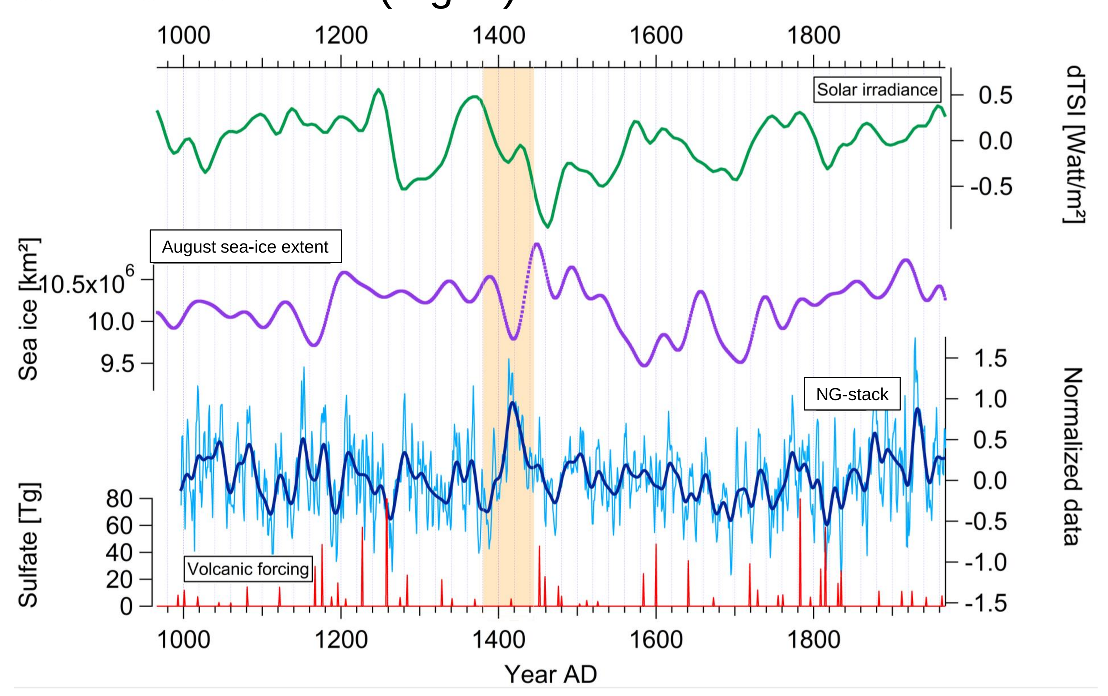

Fig. 6. The northern Greenland stack (blue: annual, dark blue: smoothed) is shown with possible forcing factors: In green the reconstructed total solar irradiance (dTSI, Steinhilber et al., 2009), in purple the reconstructed August arctic sea- ice extent (Kinnard et al., 2011) and in the stratospheric sulfate aerosol injection for the northern hemisphere (Gao et al., 2008). All values are 40- year- low-pass filtered. The discussed 1420 AD event is marked with beige colored stack.

References

Divine, D., Isaksson, E., Martma, T., Meijer, H. A. J., Moore, J., Pohjola, V., van de Wal, R. S. W., and Godtliebsen, F.: Thousand years of winter surface air temperature variations in Svalbard and northern Norway reconstructed from ice core data, 2011, doi: 10.3402/polar.v30i0.7379, 2011. 2011.
Gao, C., Robock, A., and Ammann, C.: Volcanic forcing of climate over the past 1500 years: An improved ice core-based index for climate models, JGR Atmos., 113, D23111, 2008.
Kinnard, C., Zdanowicz, C. M., Fisher, D. A., Isaksson, E., de Vernal, A., and Thompson, L. G.: Reconstructed changes in Arctic sea ice over the past 1,450 years, Nature, 479, 509-512, 2011
Mann, M. E., Zhang, Z., Rutherford, S., Bradley, R. S., Hughes, M. K., Shindell, D., Ammann, C., Faluvegi, G., and Ni, F.: Global Signatures and Dynamical Origins of the Little Ice Age and Medieval Climate Anomaly, Science, 326, 1256-1260, 2009.
Opel, T., Fritzsche, D., and Meyer, H.: Eurasian Arctic climate over the past millennium as recorded in the Akademii Nauk ice core (Severnaya Zemlya), Clim. Past, 9, 2379-2389, 2013.
Semenov, V. A. and Latif, M.: The early twentieth century warming and winter Arctic sea ice, The Cryosphere, 6, 1231-1237, 2012.
Steinhilber, F., Beer, J., and Fröhlich, C.: Total solar irradiance during the Holocene, Geophys. Res. Lett., 36, L19704, 2009.
Vinther, B. M., Andersen, K. K., Hansen, A. W., Schmith, T., and Jones, P. D.: Improving the Gibraltar/Reykjavik NAO index, Geophys. Res. Lett., 30, 2222, 2003.
Vinther, B. M., Clausen, H. B., Johnsen, S. J., Rasmussen, S. O., Andersen, K. K., Buchardt, S. L., Dahl-Jensen, D., Seierstad, I. K., Siggaard-Andersen, M. L., Steffensen, J. P., Svensson, A., Olsen, J., and Heinemeier, J.: A synchronized dating of three Greenland ice cores throughout the Holocene, JGR Atmos., 111, D13102, 2006.
Wood, K. R. and Overland, J. E.: Early 20th century Arctic warming in retrospect, International Journal of Climatology, 30, 1269-1279, 2010.

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