

# The Medieval Climate Anomaly in Greenland ice core data

Bo M. VINThER

Center for Ice and Climate, University of Copenhagen, Denmark; bo@gfy.ku.dk

## Temperature signals in ice core data

Greenland ice core data can be used to derive information on past climatic conditions in the Greenland area. Recently, Vinther et al. (2010) demonstrated a high correlation between  $\delta^{18}\text{O}$  data and Greenland coastal temperature observations even on seasonal timescales, reaffirming the ability of ice core  $\delta^{18}\text{O}$  to capture local temperatures, first proposed by Dansgaard (1954).

The Vinther et al. (2010) analysis of the seasonal ice core  $\delta^{18}\text{O}$  data showed that the winter  $\delta^{18}\text{O}$  contains the strongest temperature signal, and that even annual average Greenland temperatures are more accurately captured in the winter  $\delta^{18}\text{O}$  rather than annual average  $\delta^{18}\text{O}$  data. This surprising fact is partly explained by the observation that Greenland winter temperatures are much more variable than summer temperatures and thus dominate the annual average variability (Vinther et al., 2010). Past Greenland climatic conditions can also be derived directly from Greenland ice core borehole temperature observations, by solving the equation of heat conduction in moving ice and firn (Dahl-Jensen et al., 1998). Using a Monte Carlo inversion technique, Dahl-Jensen et al. (1998) derived temperature histories from both southern and central Greenland from high precision borehole temperature measurements obtained at the DYE-3 and GRIP ice core drill sites. A third way of estimating past Greenland temperature conditions is to measure isotopes on nitrogen and argon trapped in air-bubbles within the ice (Severinghaus et al., 1998). These gases undergo a temperature dependent mass fractionation in the snow column before the air-bubbles are formed in the ice, thus retaining a retrievable temperature signal.

## Greenland temperature conditions during the past two millennia

The Dahl-Jensen et al. (1998) inversions of two Greenland ice core borehole temperature profiles are shown in the top panel of Figure 1. Looking at the inversions it is important to remember that temperature signals in the ice sheet diffuse with time, meaning that the inversions will lose more and more high frequency information as we move back in time. Even so, it is clear from both the DYE-3 and the GRIP borehole temperature inversions that a warm Medieval Climate Anomaly (MCA) can be observed with peak temperatures from 800 to 1000 AD being some 1.3K warmer than the 1881-

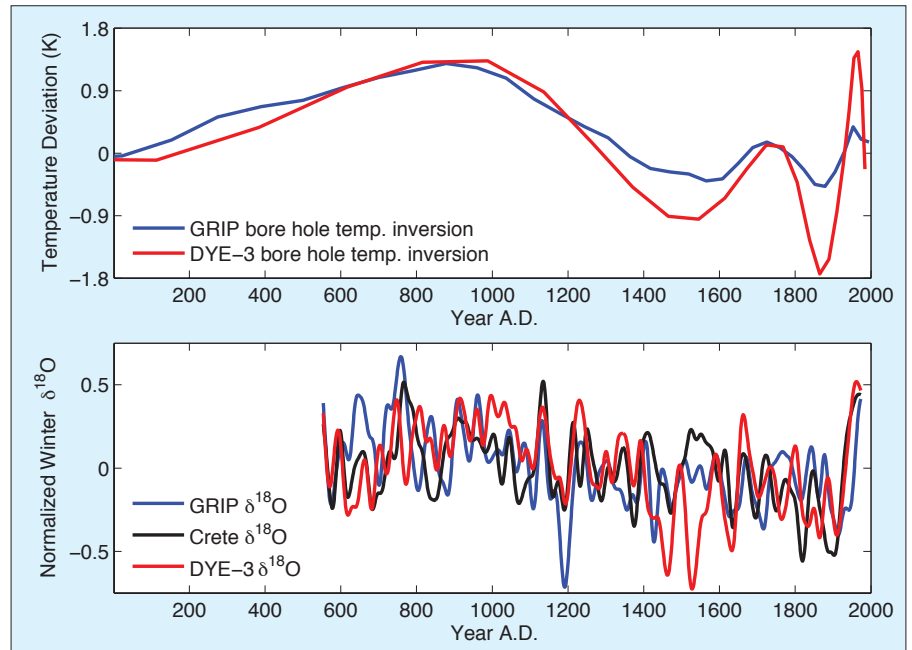


Figure 1: Two Greenland ice core temperature proxies. **Top:** Bore hole temperature inversions from central (GRIP) and southern (DYE-3) Greenland (from Dahl-Jensen et al., 1998). Temperature deviations are given with respect to the period 1881-1980 AD. **Bottom:** Normalized winter  $\delta^{18}\text{O}$  from central (Crete, GRIP) and southern (DYE-3) Greenland smoothed with a Gaussian filter with a 50-year half-width (from Vinther et al., 2010).

1980 AD reference period. From 1000-1400 AD a general cooling is observed at both drill sites, followed by two cold periods culminating around 1500 and 1860 AD, respectively. A recent warming culminating in the 1950s is also seen in both records. One noteworthy difference between the DYE-3 and GRIP temperature inversions is the amplitude of the most recent temperature oscillations. While some of the difference is probably climatic, it is also possible that the much higher accumulation rate at the DYE-3 drill site allowed for a better preservation of the recent temperature signals in the DYE-3 borehole, thus contributing to the higher amplitudes in the DYE-3 inversion. In the bottom panel of Figure 1, winter  $\delta^{18}\text{O}$  records from three Greenland ice cores all spanning the past 1450 years are presented (Vinther et al., 2010). To ease comparison with the borehole inversions, the records have all been smoothed with a Gaussian filter (tuned to have 50% damping of a signal with a 50-year cycle). The MCA warmth is also seen in the winter  $\delta^{18}\text{O}$  data and it seems to coincide with the warmth observed in the borehole inversions. The first cold spells around 1500 AD are only clearly identifiable in the DYE-3 winter  $\delta^{18}\text{O}$  data, while the 1860 AD cold period and the warming culminating in the 1950s are seen in all three winter  $\delta^{18}\text{O}$  records.

It is noteworthy that the winter  $\delta^{18}\text{O}$  records and the DYE-3 borehole temperature inversion all suggest that the warm-

ing culmination in the 1950s resulted in Greenland temperatures comparable to or only slightly cooler than peak MCA warmth. This observation is supported by a recent study spanning the last millennium by Kobashi et al. (2010). Using the gas fractionation technique on ice cores, they found that peak Greenland temperature conditions in the 12<sup>th</sup> century were just 0.3K warmer than those observed during the 1950s. The GRIP borehole inversion is therefore the only data set suggesting significantly higher temperatures during the MCA than during the 1950s, lending further support to the speculation that the quite low accumulation rate at the GRIP drill site did hamper the inversion of this recent short-lived climatic warming.

## References

- Dahl-Jensen, D., Mosegaard, K., Gundestrup, N., Clow, G.D., Johnsen, S.J., Hansen, A.W. and Balling, N., 1998: Past temperatures directly from the Greenland ice sheet, *Science*, **282**: 268-271.
- Dansgaard, W., 1954: The  $\text{O}^{18}$ -abundance in fresh water, *Geochimica et Cosmochimica Acta*, **6**: 241-260.
- Kobashi, T., Severinghaus, J.P., Barnola, J.-M., Kawamura, K., Carter, T. and Nakaegawa, T., 2010: Persistent multi-decadal Greenland temperature fluctuation through the last millennium, *Climatic Change*, **100**(3-4): 733-756.
- Severinghaus, J.P., Sowers, T., Brook, E.J., Alley, R.B. and Bender, M.L., 1998: Timing of abrupt climate change at the end of the Younger Dryas interval from thermally fractionated gases in polar ice, *Nature*, **391**: 141-146.
- Vinther, B.M., Jones, P.D., Briffa, K.R., Clausen, H.B., Andersen, K.K., Dahl-Jensen, D. and Johnsen, S.J., 2010: Climatic signals in multiple highly resolved stable isotope records from Greenland, *Quaternary Science Reviews*, **29**: 522-538.

