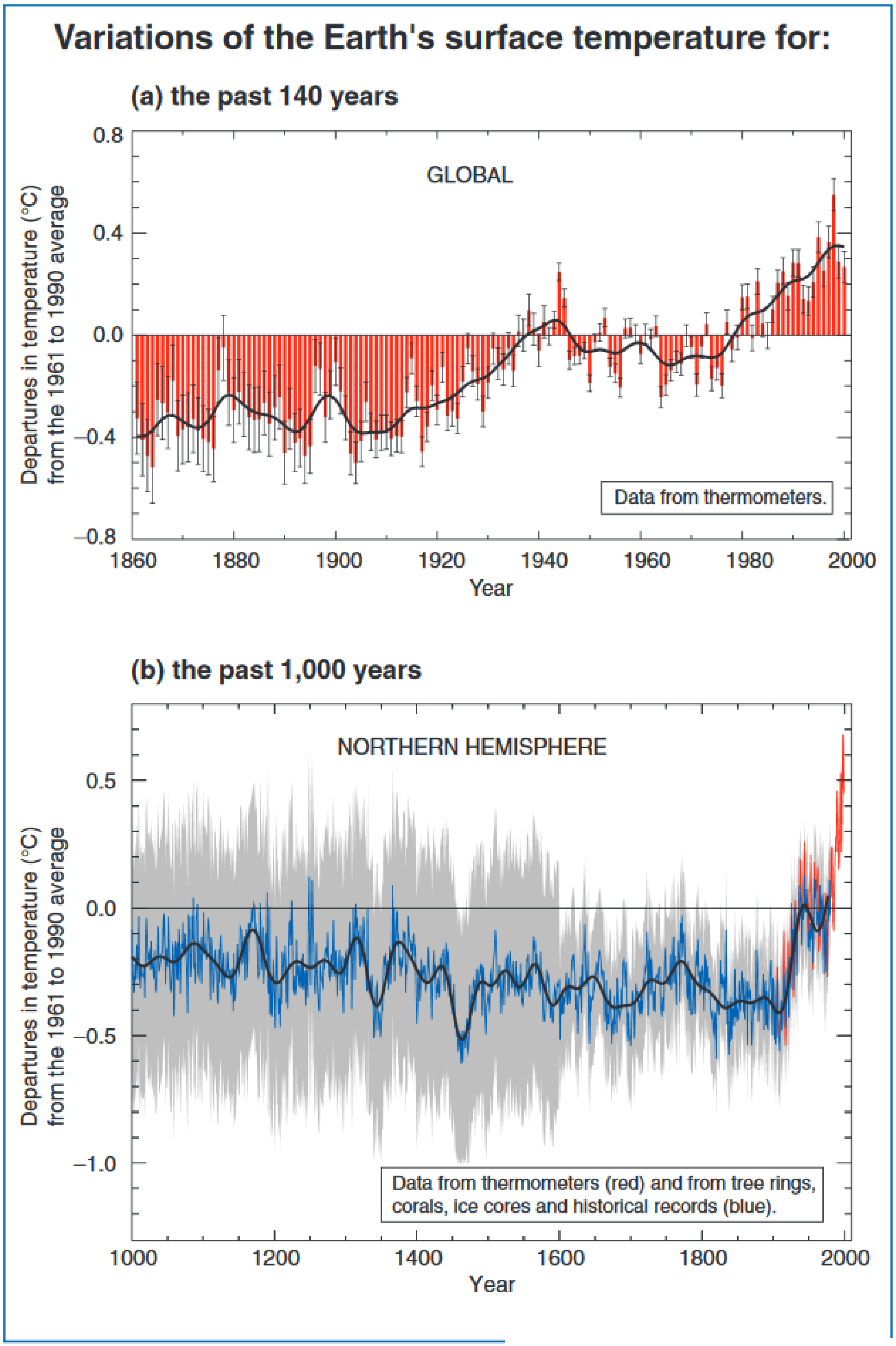
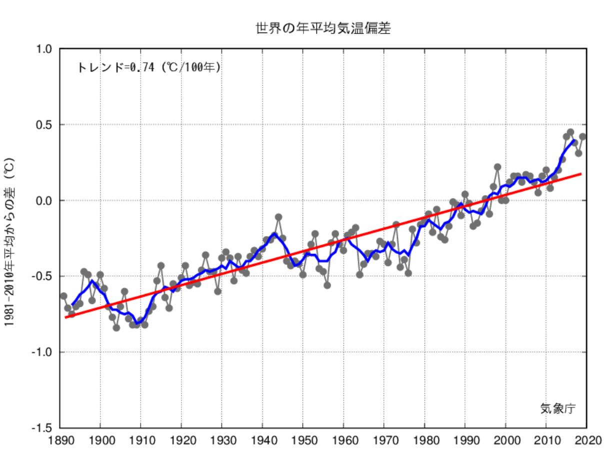


Figure 1: Variations of the Earth's surface temperature over the last 140 years and the last millennium.

(a) The Earth's surface temperature is shown year by year (red bars) and approximately decade by decade (black line, a filtered annual curve suppressing fluctuations below near decadal time-scales). There are uncertainties in the annual data (thin black whisker bars represent the 95% confidence range) due to data gaps, random instrumental errors and uncertainties, uncertainties in bias corrections in the ocean surface temperature data and also in adjustments for urbanisation over the land. Over both the last 140 years and 100 years, the best estimate is that the global average surface temperature has increased by 0.6 ± 0.2°C.

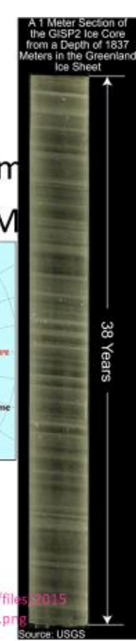
(b) Additionally, the year by year (blue curve) and 50 year average (black curve) variations of the average surface temperature of the Northern Hemisphere for the past 1000 years have been reconstructed from "proxy" data calibrated against thermometer data (see list of the main proxy data in the diagram). The 95% confidence range in the annual data is represented by the grey region. These uncertainties increase in more distant times and are always much larger than in the instrumental record due to the use of relatively sparse proxy data. Nevertheless the rate and duration of warming of the 20th century has been much greater than in any of the previous nine centuries. Similarly, it is likely[7] that the 1990s have been the warmest decade and 1998 the warmest year of the millennium.

[Based upon (a) Chapter 2, Figure 2.7c and (b) Chapter 2, Figure 2.20]



Ice-Core: the main proxy

- Antarctica and Greenland
- The annual snows turned to ice for a long tim
- The boring ice-core: annual records for 0.4 M



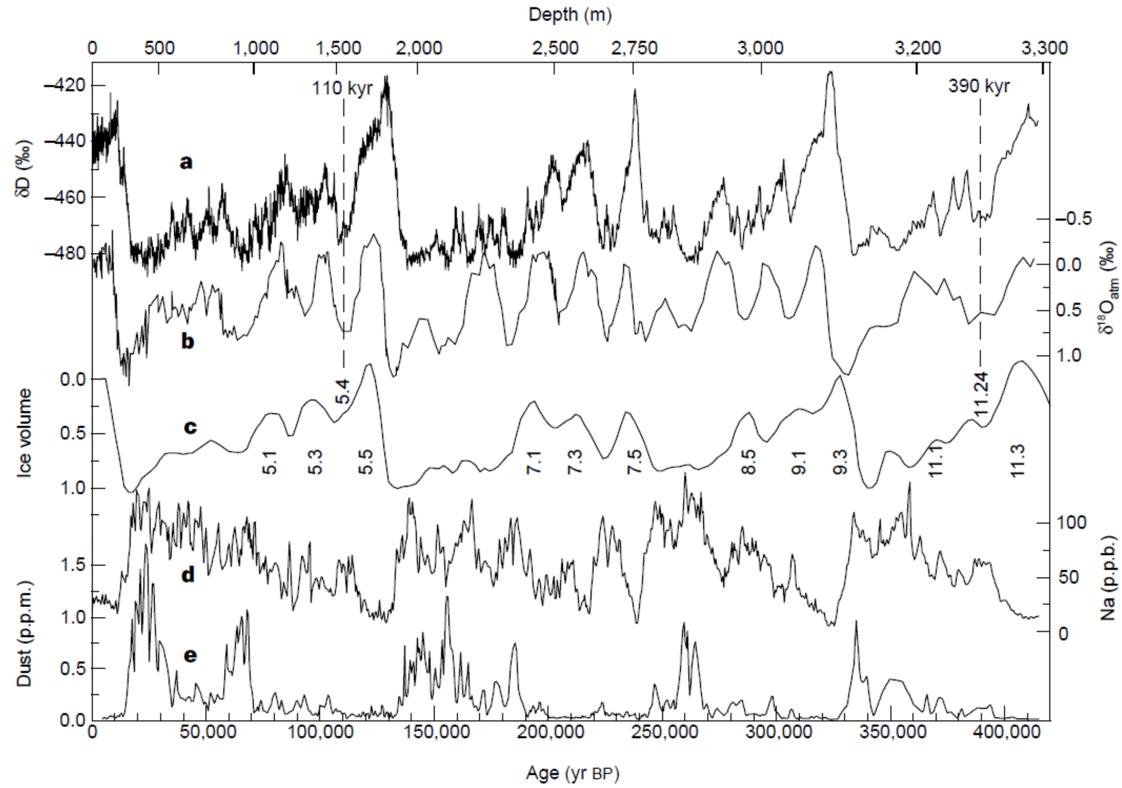


Figure 2 Vostok time series and ice volume. Time series (GT4 timescale for ice on the lower axis, with indication of corresponding depths on the top axis and indication of the two fixed points at 110 and 390 kyr) of: **a**, deuterium profile (from Fig. 1); **b**, $\delta^{18}O_{atm}$ profile obtained combining published data[11,13,30] and 81 new measurements performed below 2,760 m. The age of the gas is calculated as described in ref. 20; **c**, seawater $\delta^{18}O$ (ice volume proxy) and marine isotope stages adapted from Bassinot *et al.*[26]; **d**, sodium profile obtained by combination of published and new measurements (performed both at LGGE and RSMAS) with a mean sampling interval of 3–4 m (ng g^{-1} or p.p.b); and **e**, dust profile (volume of particles measured using a Coulter counter) combining published data[10,13] and extended below 2,760 m, every 4 m on the average (concentrations are expressed in $\mu g\, g^{-1}$ or p.p.m. assuming that Antarctic dust has a density of 2,500 kg m^{-3}). $\delta^{18}O_{atm}$ (in ‰) $= [(^{18}O/^{16}O)_{sample}/(^{18}O/^{16}O)_{standard} - 1] \times 1{,}000$; standard is modern air composition.

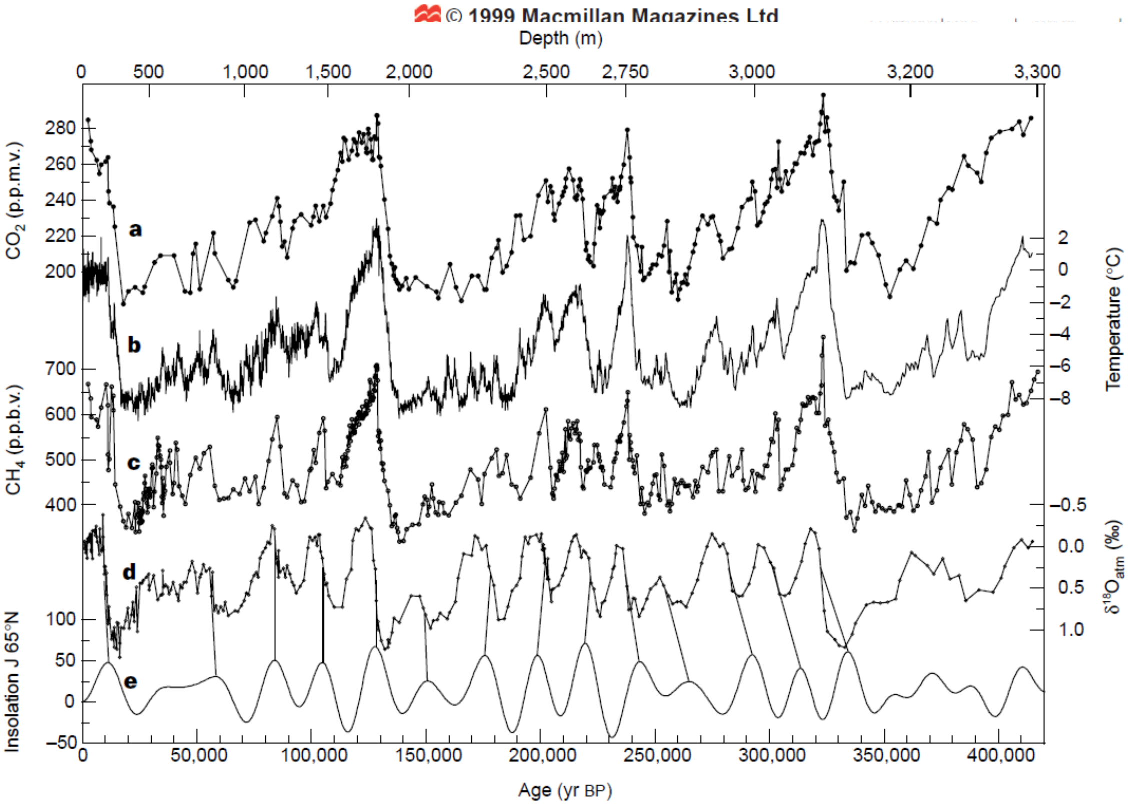
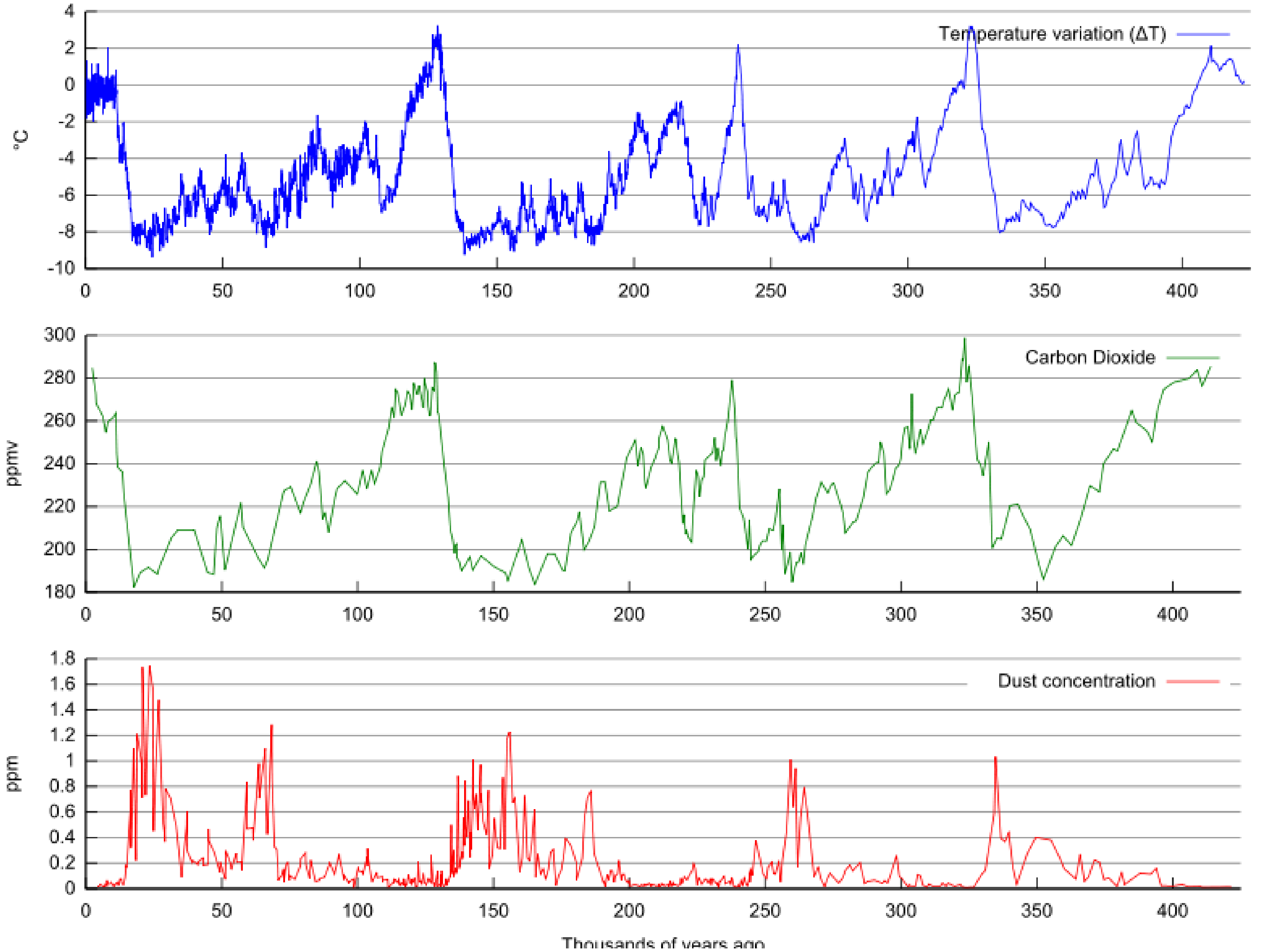
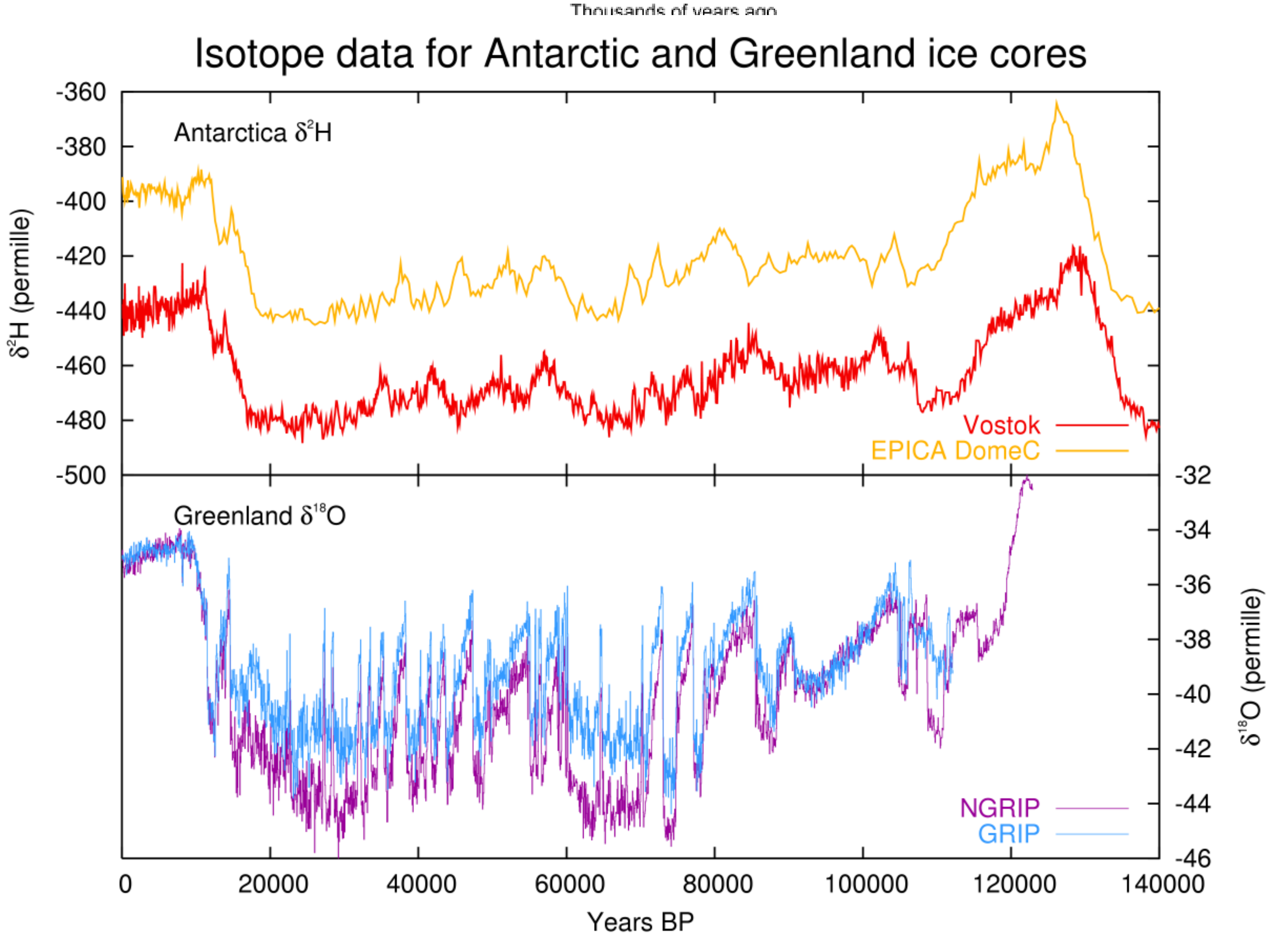


Figure 3 Vostok time series and insolation. Series with respect to time (GT4 timescale for ice on the lower axis, with indication of corresponding depths on the top axis) of: **a**, CO_2; **b**, isotopic temperature of the atmosphere (see text); **c**, CH_4; **d**, $\delta^{18}O_{atm}$; and **e**, mid-June insolation at 65° N (in W m^{-2}) (ref. 3). CO_2 and CH_4 measurements have been performed using the methods and analytical procedures previously described[5,9]. However, the CO_2 measuring system has been slightly modified in order to increase the sensitivity of the CO_2 detection. The thermal conductivity chromatographic detector has been replaced by a flame ionization detector which measures CO_2 after its transformation into CH_4. The mean resolution of the CO_2 (CH_4) profile is about 1,500 (950) years. It goes up to about 6,000 years for CO_2 in the fractured zones and in the bottom part of the record, whereas the CH_4 time resolution ranges between a few tens of years to 4,500 years. The overall accuracy for CH_4 and CO_2 measurements are ±20 p.p.b.v. and 2–3 p.p.m.v., respectively. No gravitational correction has been applied.



Temperature variation (ΔT)
°C
Carbon Dioxide
ppmv
Dust concentration
ppm
Thousands of years ago



Isotope data for Antarctic and Greenland ice cores
Antarctica δ²H
δ²H (permille)
Vostok
EPICA DomeC
Greenland δ¹⁸O
δ¹⁸O (permille)
NGRIP
GRIP
Years BP

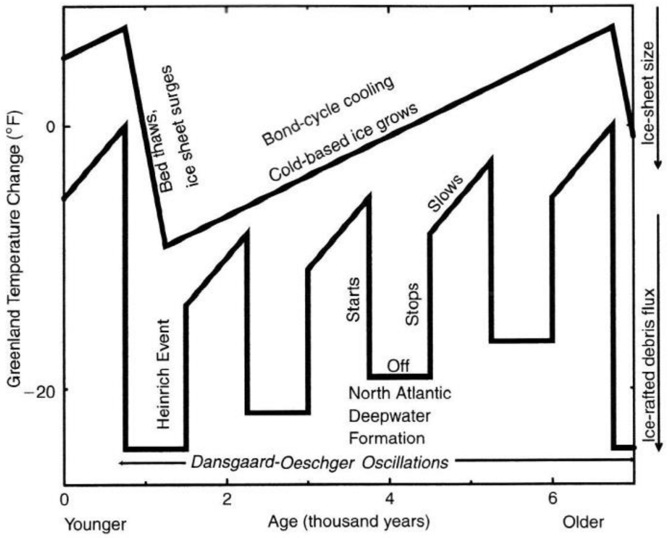


FIGURE 12.4

An idealized history of temperature and ice sheet changes in the north Atlantic region during a Bond cycle. Successive Dansgaard-Oeschger oscillations, caused by the turning on and off of the far northern sinking of waters in the north Atlantic, become progressively cooler as the cold-based ice sheet grows in Hudson Bay. Then the base of that ice thaws, and a Heinrich event surge occurs, dumping large numbers of icebergs containing rock debris into the north Atlantic. When the surge ends, the ice sheet freezes to its bed, while the ocean circulation resumes and causes an especially large warming away from the ice sheet.

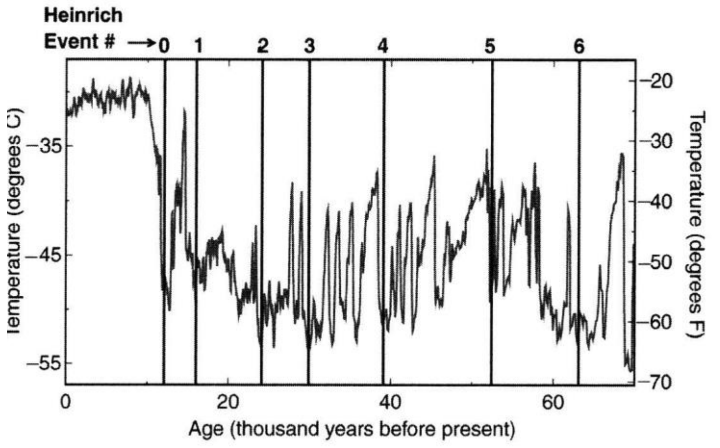


FIGURE 12.3

The history of temperature in central Greenland as in Figure 12.2, with the times of Heinrich events (numbered 1 to 6, plus the Younger Dryas, which is often referred to as Heinrich event 0 because numbers 1 through 6 had already been used and no one wanted to renumber them), as identified by Gerard Bond. Gerard also identified the cycle of progressive cooling of successive cold lumps, followed by a Heinrich event and an especially large warming, which we call the Bond cycle.

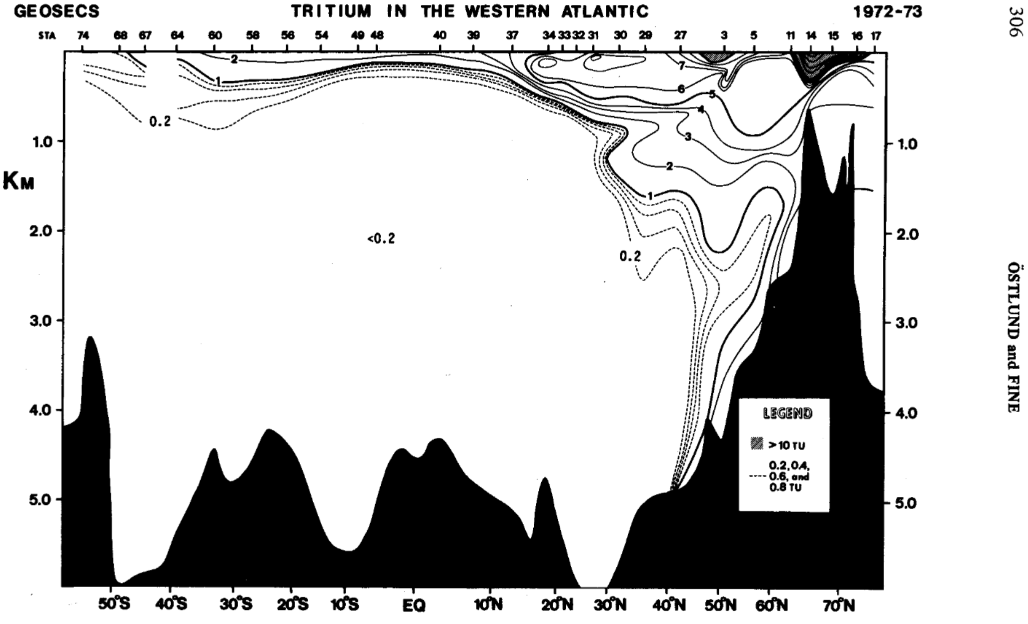


FIG.2. Tritium section of the western Atlantic in 1972 from 70° N to 50° S ve
Vertical exaggeration is 2000:1. Horizontal scale is proportional to cruise track