

Paleoclimate, Part 1

1. Evidence of past climate change

- dendrochronology
- lichenometry
- pollen in lake sediments
- fossil corals, sea sediments
- radiocarbon dating (half-life 5370 years)
- isostatic rebound and shoreline
- glacial melting and shoreline shelves
- ice-rafted rock debris (Heinrich events)
- aolean dust

2. The paleoclimatic record



4.3. The Paleoclimate Record

Paleoclimate phenomena and corresponding time scales of interest include

- the *faint young sun paradox* (billions of years),
- periodic extinctions and the *Oort cloud* (27 million-year periodicity),
- the *Cretaceous warm period* (145-65 Mybp),
- Antarctic continental drift (10 Mybp),
- glacial /interglacial cycles (last million years),
- the *Emian interglacial* (130-115 kybp),
- *Wisconsin glacial maximum* (20 kybp),
- the *Bolling/Allerod* warm period (14.6-12.9 kybp)
- the *Younger Dryas* cold event (12.9-11.6 kybp),
- Heinrich and *Dansgaard-Oeschger events* (millennial cycles),
- the *Holocene maximum* (2-8 kybp),
- the *Medieval Optimum* (600-1100 ypb; 900-1400 A.D.),
- and the *Little Ice Age* (130-620 ybp; 1400-1890 A.D.)

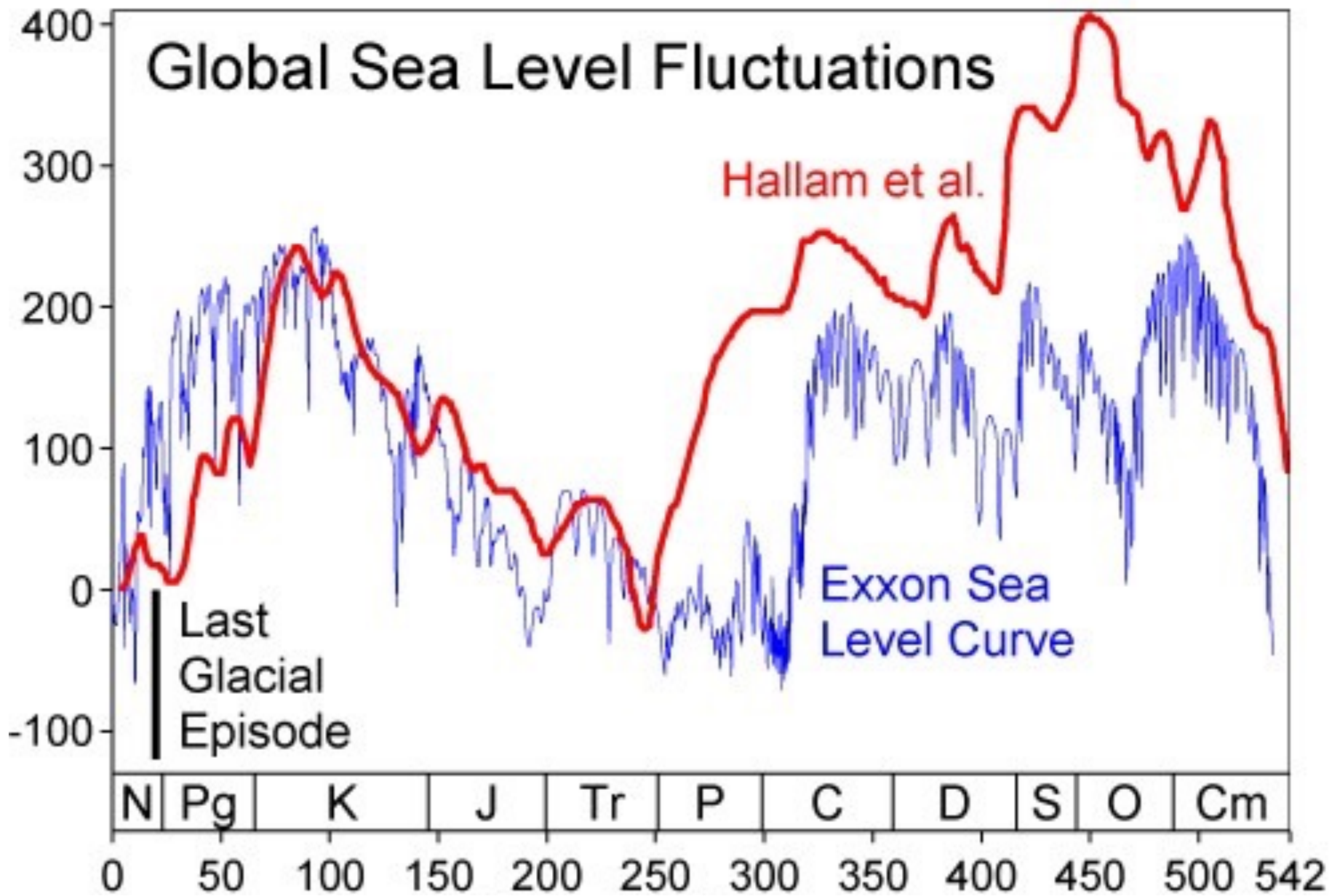


Figure 4.1. Variations in sea level (meters) over the past 500 million years [IPCC 2007].

Paleocene – Eocene Thermal Maximum

56 Mybp

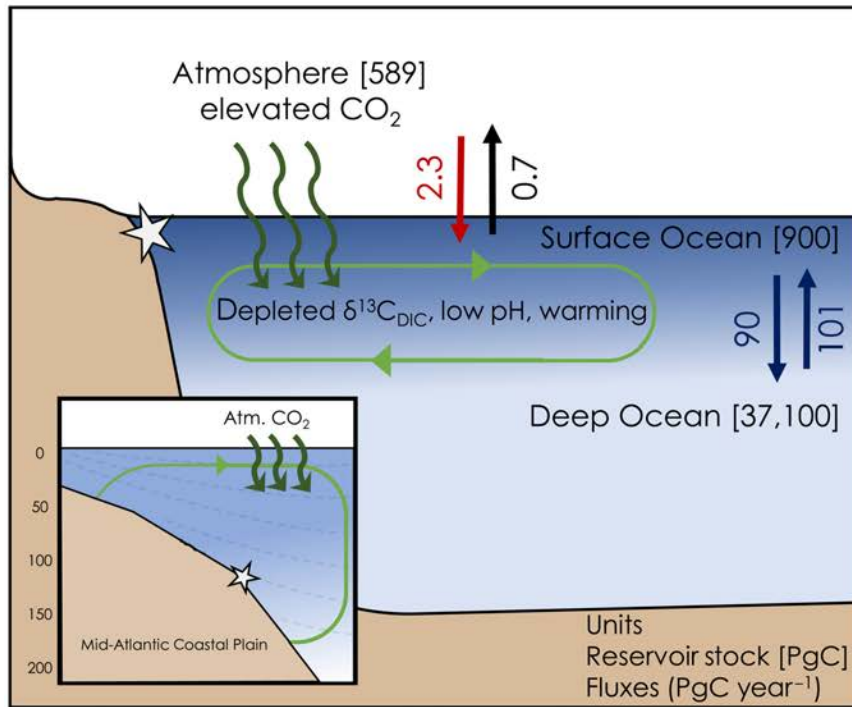
CO₂ trigger

amplified by continental margin CH₄ hydrates evaporating

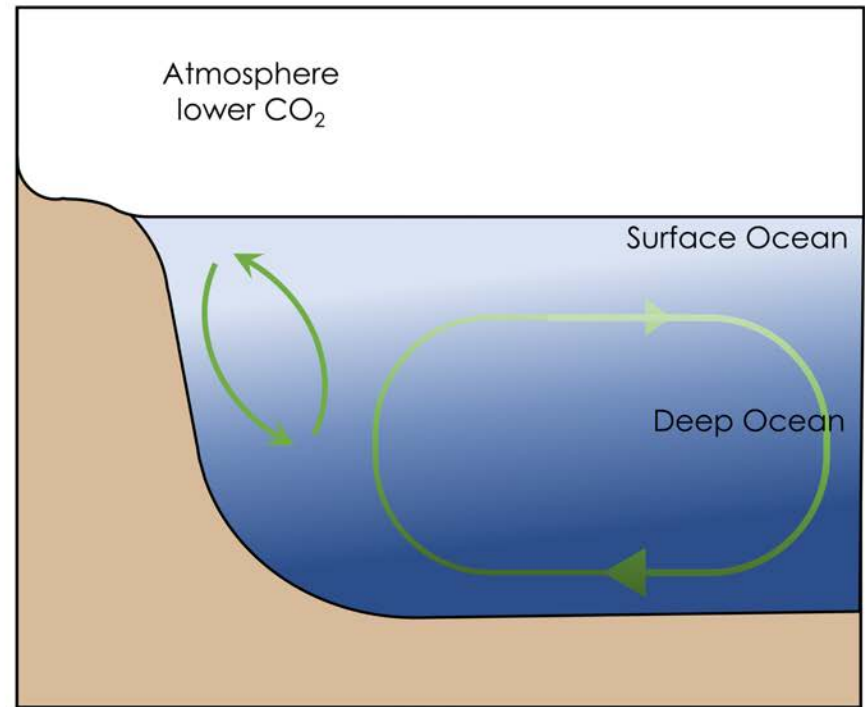
Ocean acidification

Proto-mammals in treed swamps on Baffin Island with dark winter

POE onset



POE recovery



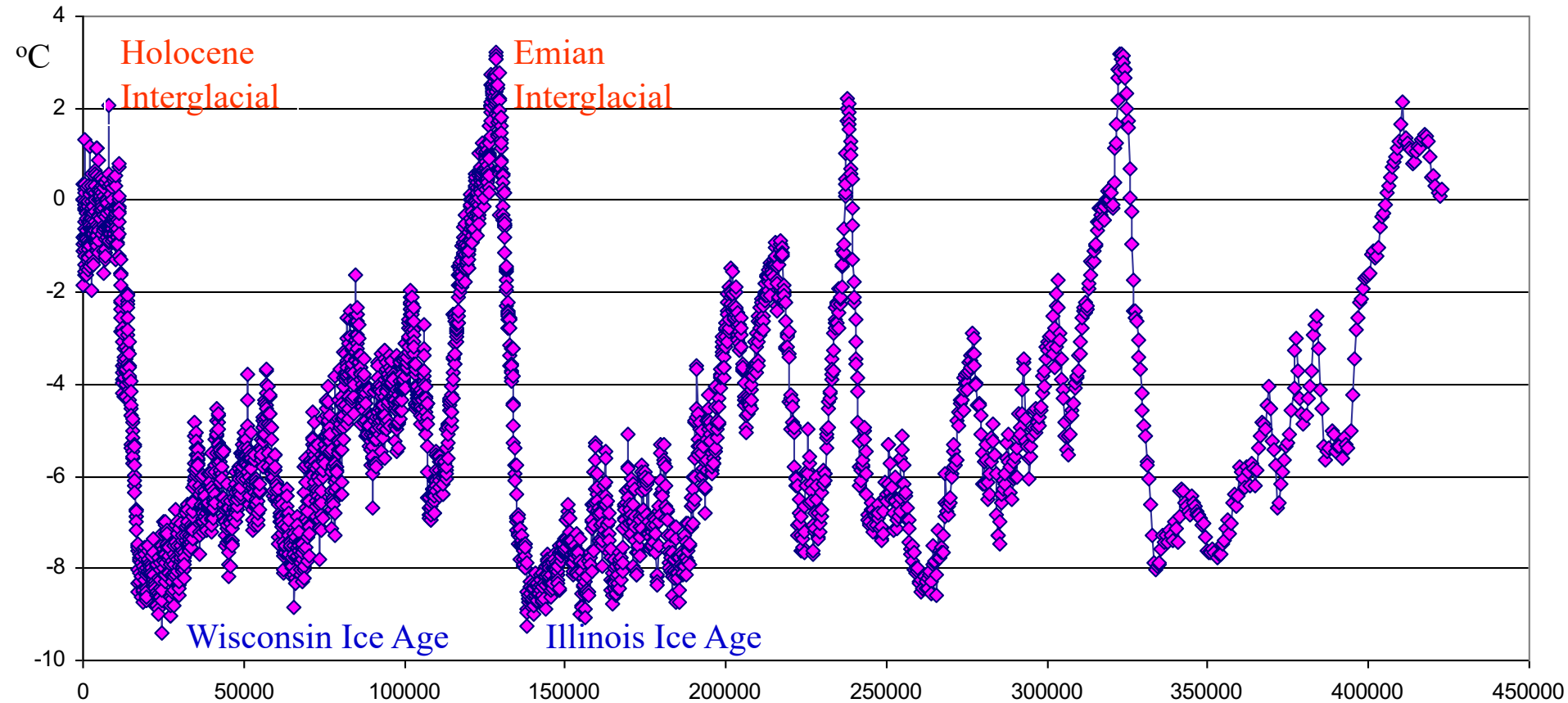


Figure 4.2. Global temperature variations over the last four glacial / interglacial cycles inferred from Vostok deuterium [Petit et al. 2001; data from www.ncdc.noaa.gov/paleo].

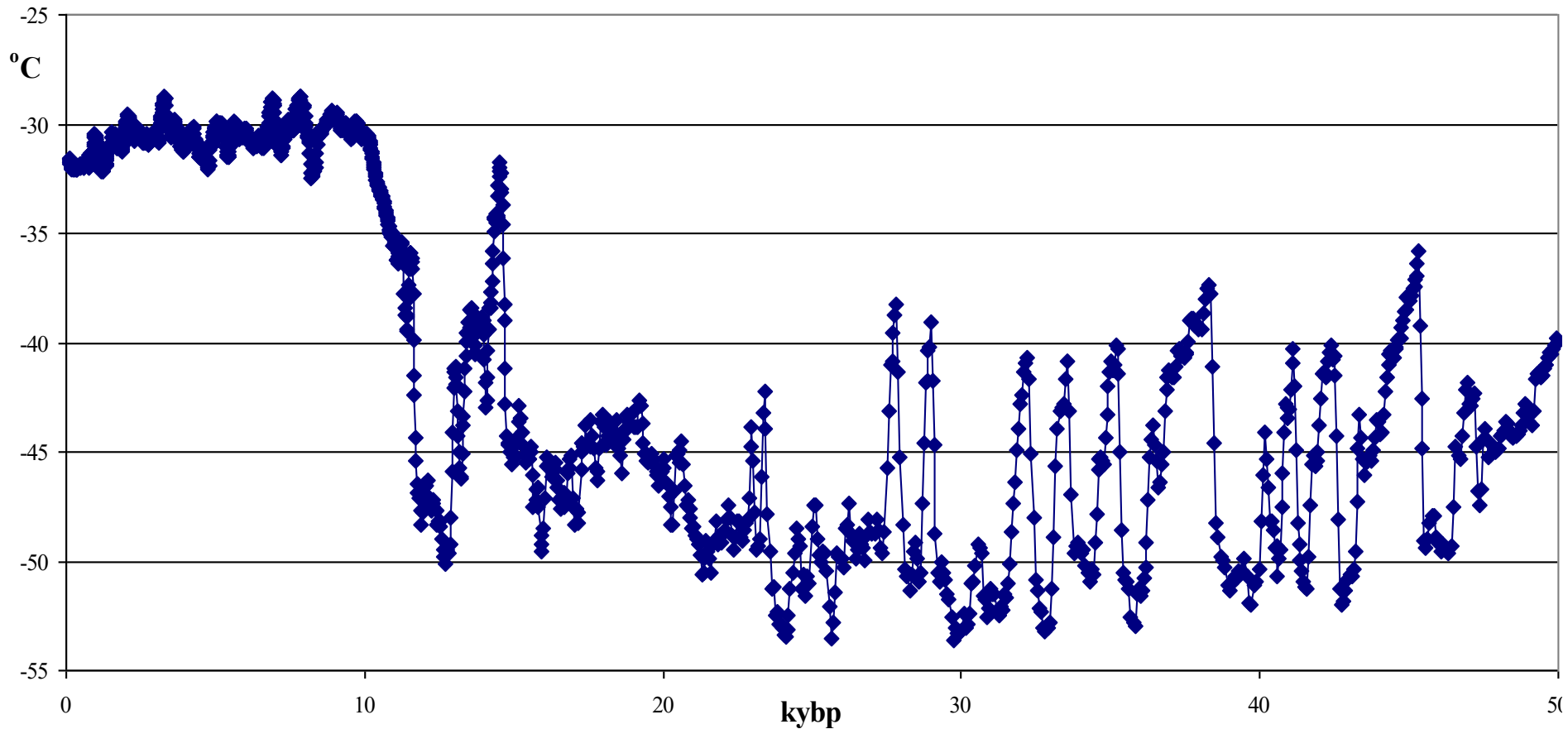


Figure 4.3. Variations in Greenland surface temperature (°C) at GISP2 over the past 50,000 years. Note the common occurrence of Dansgaard-Oeschger events during the Wisconsin Ice Age, but not during the Holocene [Alley et al. 2000, 2004, www.ncdc.noaa.gov/paleo].

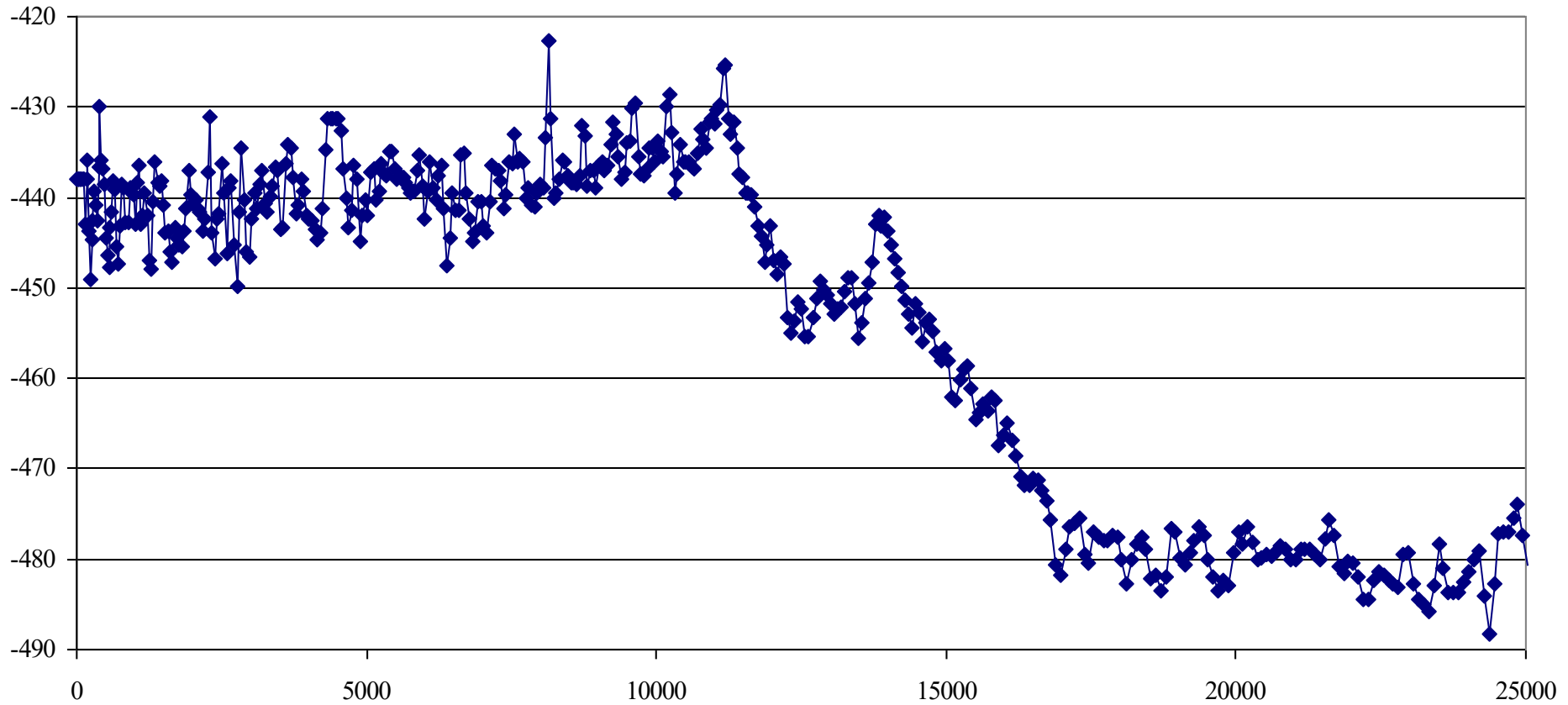


Figure 4.4a. Variation of deuterium (ppt departure from ocean mean) at Vostok, Antarctica over the past 25,000 years [Petit et al. 2001; data from www.ncdc.noaa.gov/paleo].

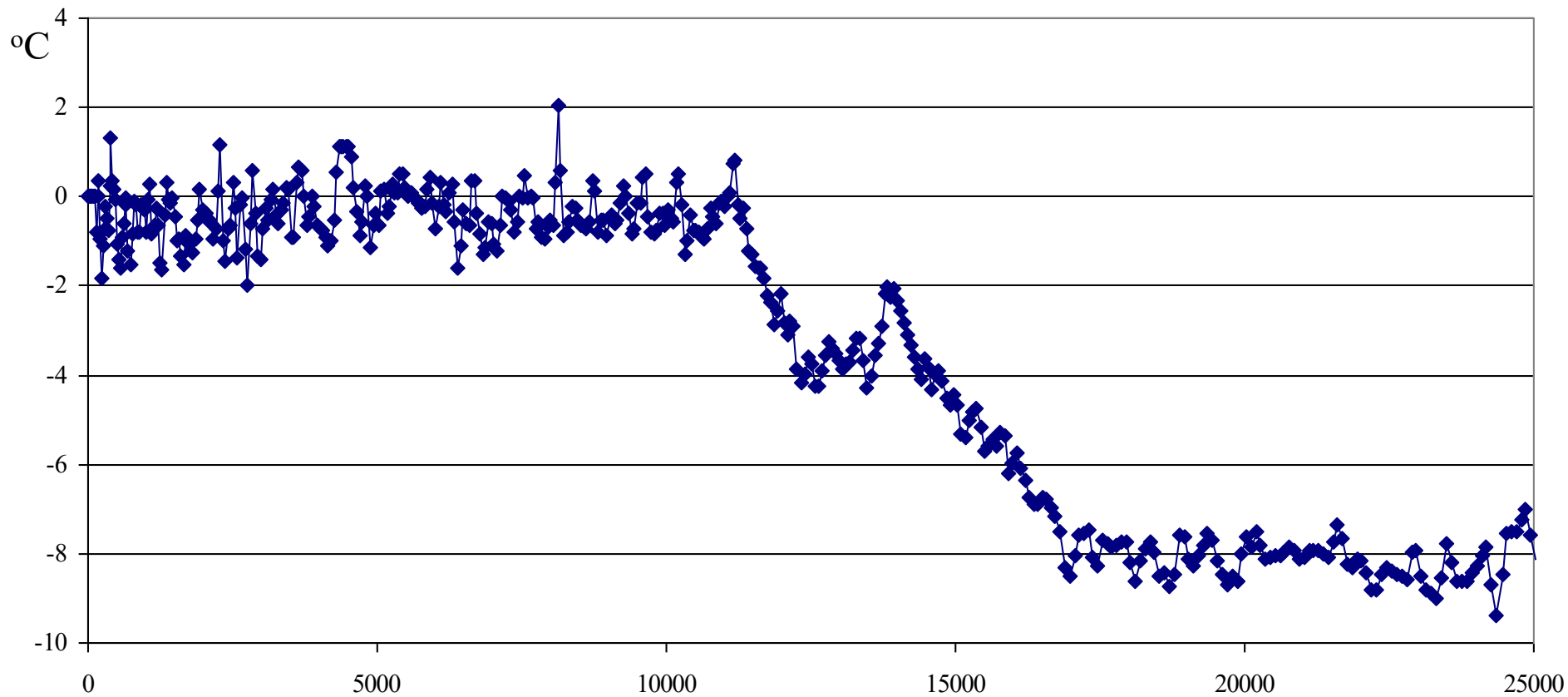


Figure 4.4b. Variation of global temperature over the past 25,000 years estimated from Vostok deuterium [Petit et al. 2001; data from www.ncdc.noaa.gov/paleo].

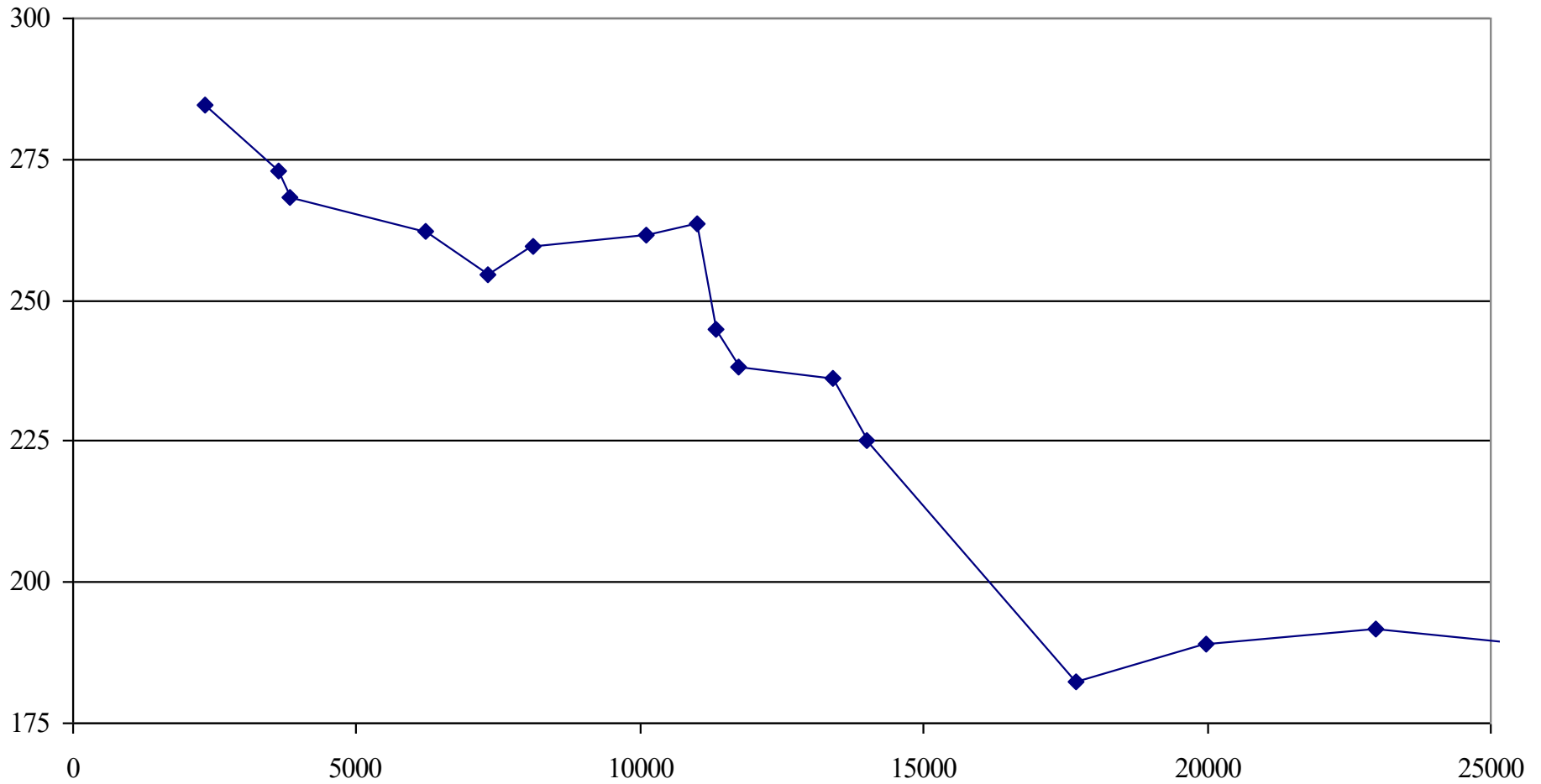


Figure 4.4d. Variation of CO₂ (ppmv) at Vostok, Antarctica over the past 25,000 years [Petit et al. 2001; data from www.ncdc.noaa.gov/paleo].

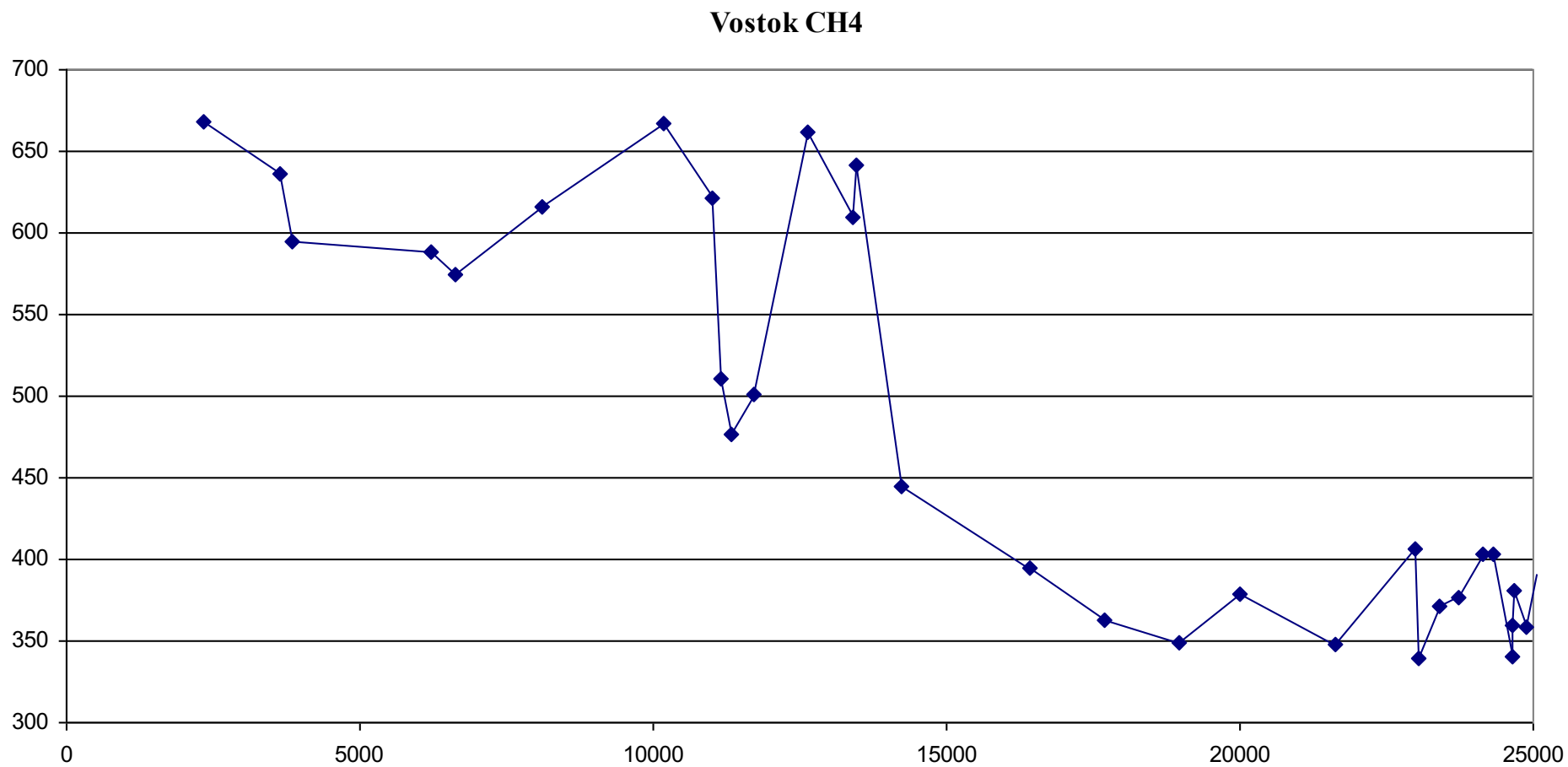


Figure 4.4e. Variation of CH₄ (ppbv) at Vostok, Antarctica over the past 25,000 years [Petit et al. 2001; data from www.ncdc.noaa.gov/paleo].

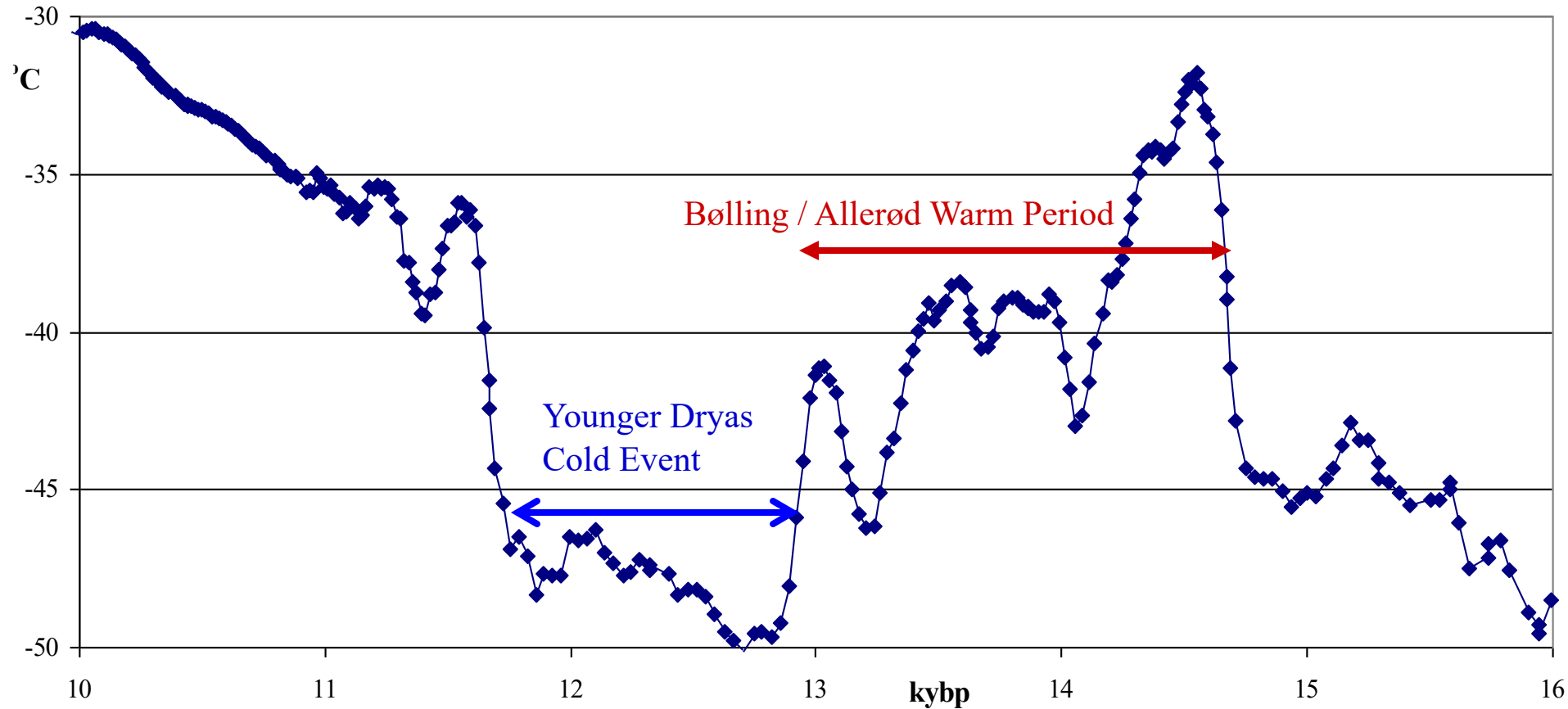


Figure 4.5. Variation in Greenland surface temperature during 16 – 10 kybp [Alley et al. 2000, 2004, www.ncdc.noaa.gov/paleo]. The Bølling / Allerød period (14.6 – 12.9 kybp) began with, and the Younger Dryas period (12.9 - 11.6 kybp) ended with rapid warming.

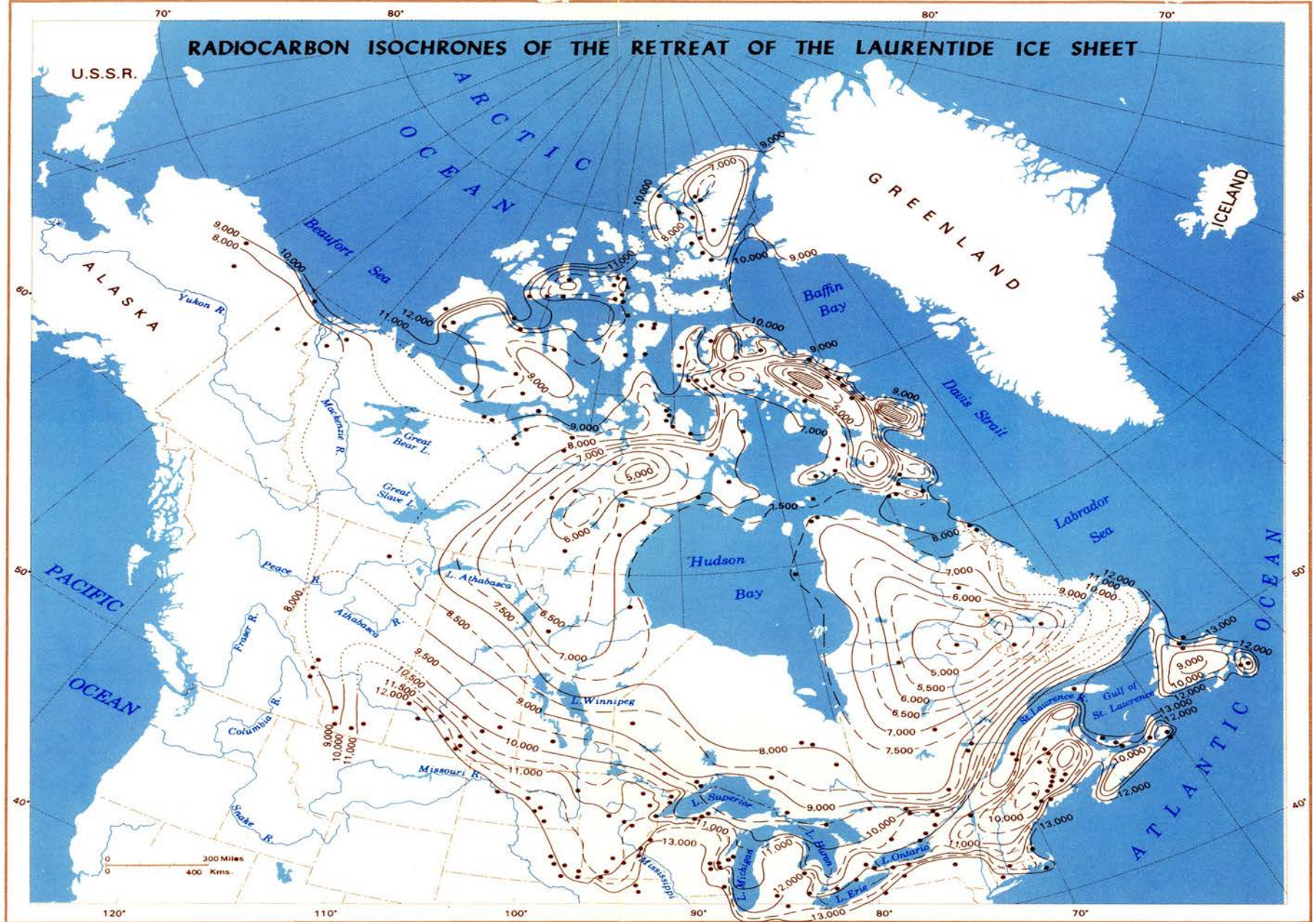


Figure 4.6. Radiocarbon isochrones of the retreat of the Laurentide Ice Sheet [Reid Bryson, personal communication].



Figure 4.7.

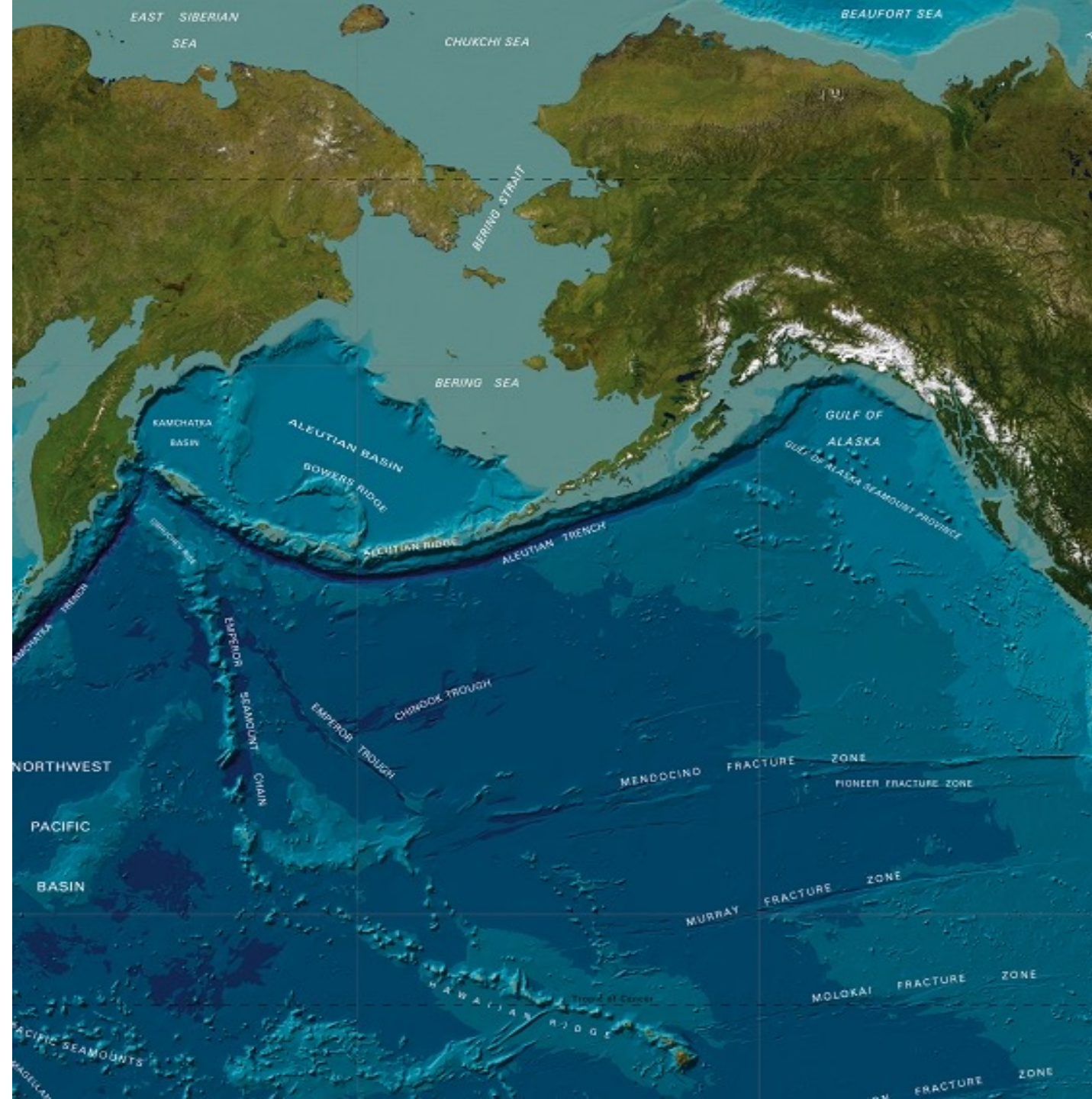


Figure 4.8.

Post-Glacial Sea Level Rise

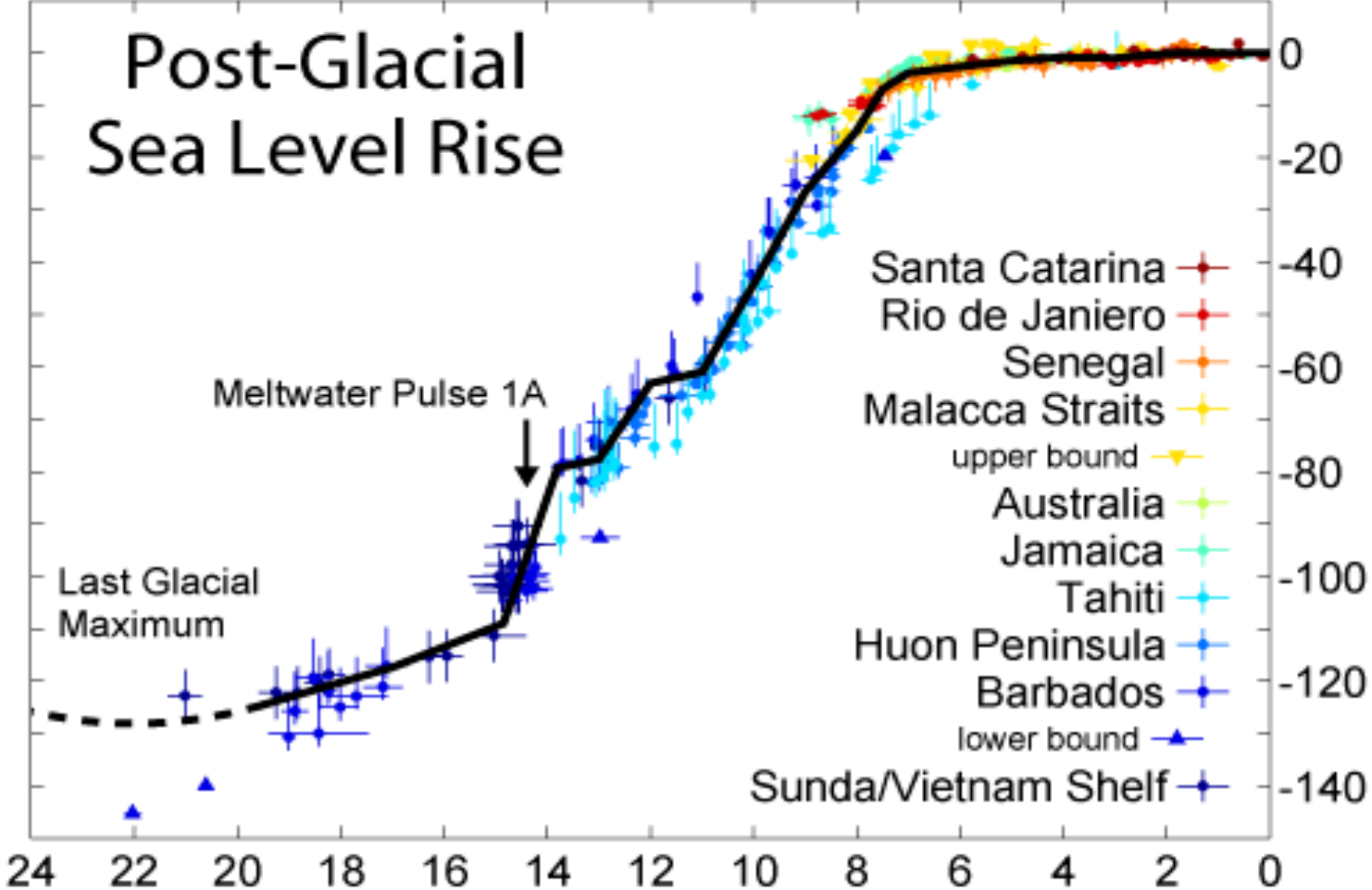


Figure 4.9a. Change in sea level (meters) from 22 kybp to the present. Note the meltwater pulse near 14.5 kybp that ushered in the Bølling / Allerød period [IPCC 2007].

Gobekli Tepe

11,500 – 10,000 ybp



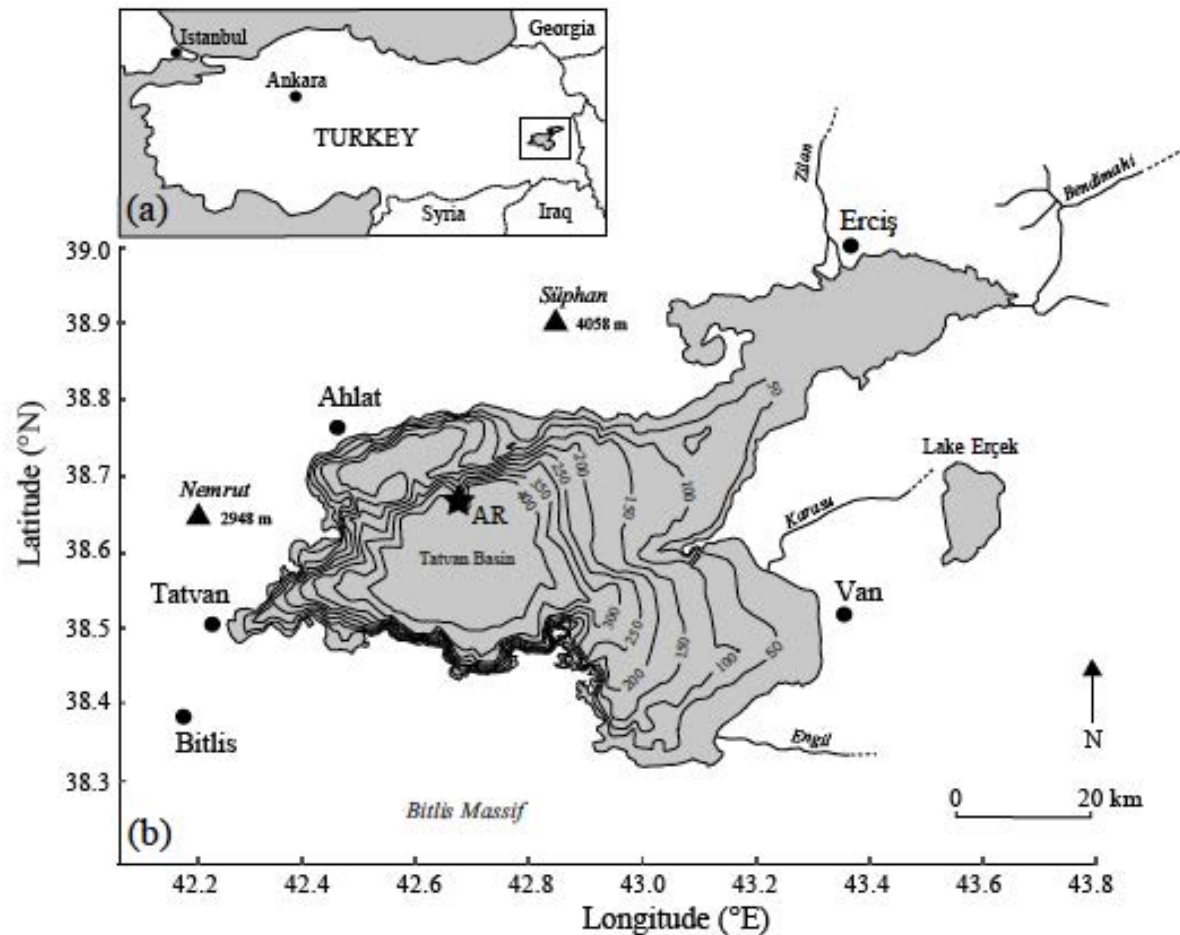
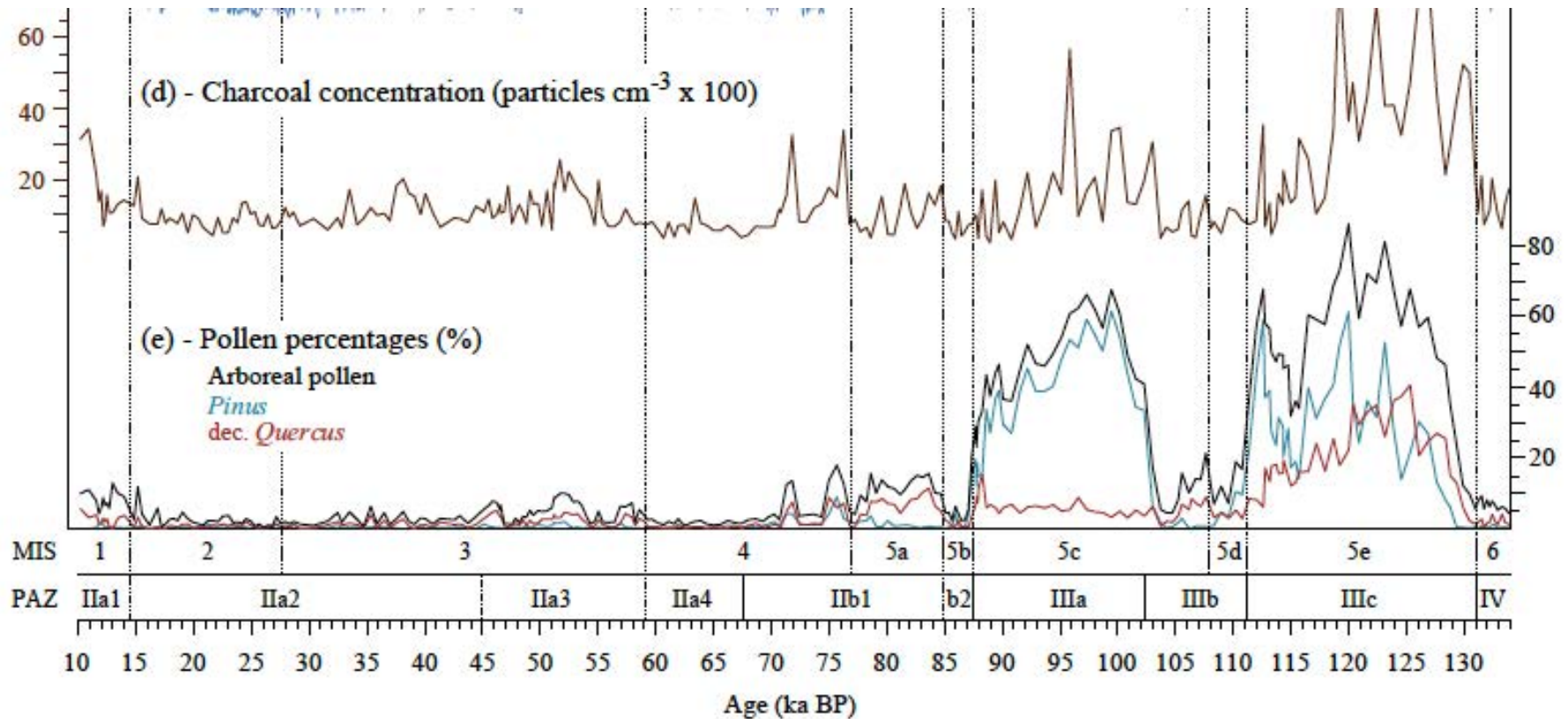


Figure 1. (a) Location of Lake Van in eastern Anatolia (Turkey) and (b) the bathymetry of Lake Van including the main ICDP drill site Ahlat Ridge (AR, black star). Major cities (black dots) and rivers are represented. The black triangle indicates the positions of the active volcanoes Nemrut and Süphan. The Bitlis Massif in the south reaches up to 3500 m a.s.l.

> 600,000-year record of lake varve pollen!



Emerging from the Younger Dryas ~11,600 ybp, Anatolia became moister and warmer, supporting pine and oak forests, with a range of other species.

Holocene Sea Level

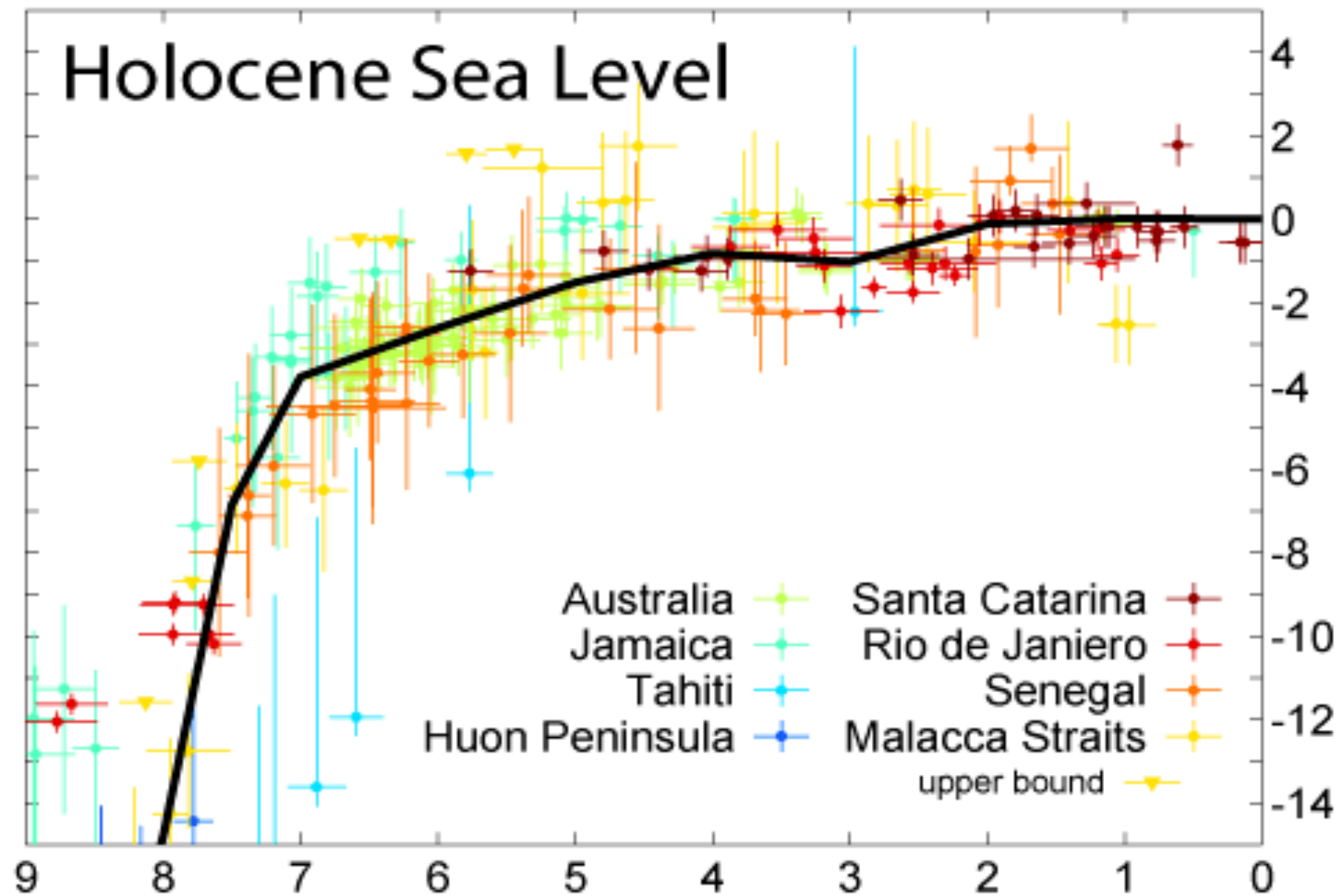


Figure 4.9b. Change in sea level (meters) from 8 kybp to the present. Note the stability of sea level during the rise of civilization [IPCC 2007].

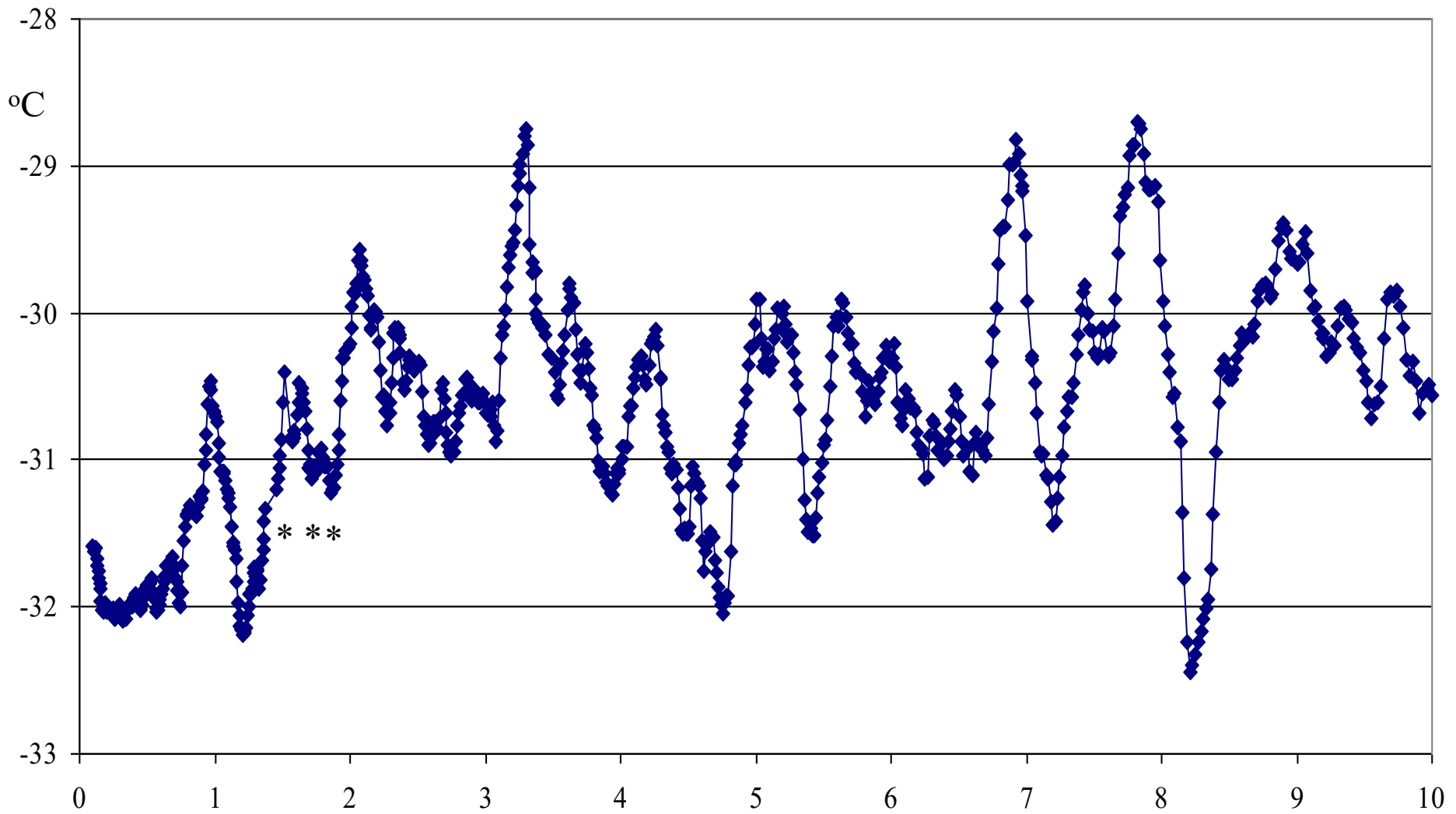


Figure 4.10. Variations in Greenland surface temperature ($^{\circ}\text{C}$) at GISP2 over the past 10,000 years. Note the interesting variability at millennial time scales [Alley et al. 2000, 2004, www.ncdc.noaa.gov/paleo].

160 AD Antonine Plague 250 AD Plague of Cyprian 543 AD Plague of Justinian

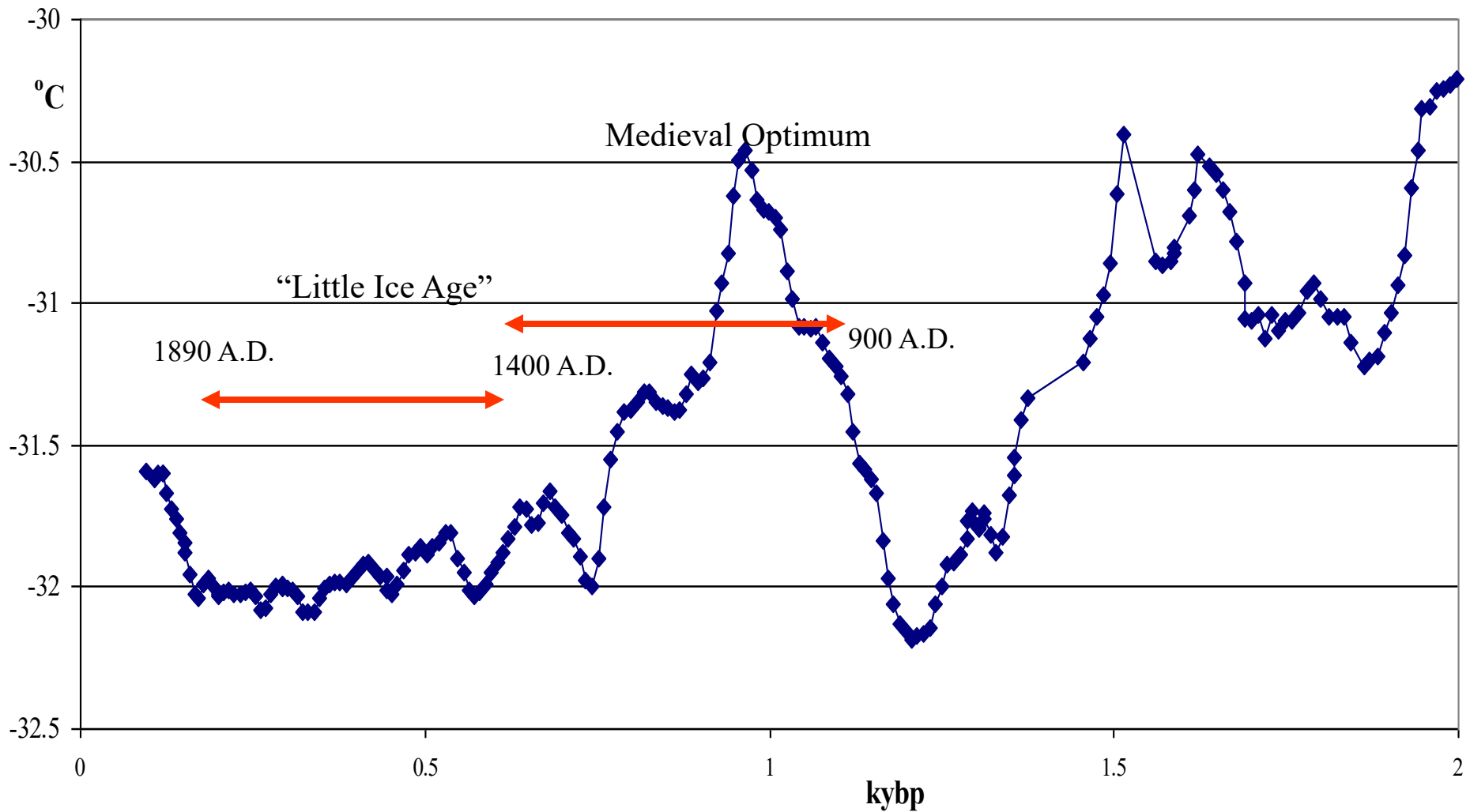


Figure 4.11. Variations in Greenland surface temperature (°C) at GISP2 over the past 2,000 years. Note the relatively warm period during 900 – 1400 A.D. (1100 – 600 ybp) and the cool period during 1400 – 1890 A.D. (600 – 120 ybp) [Alley et al. 2000, 2004, www.ncdc.noaa.gov/paleo].

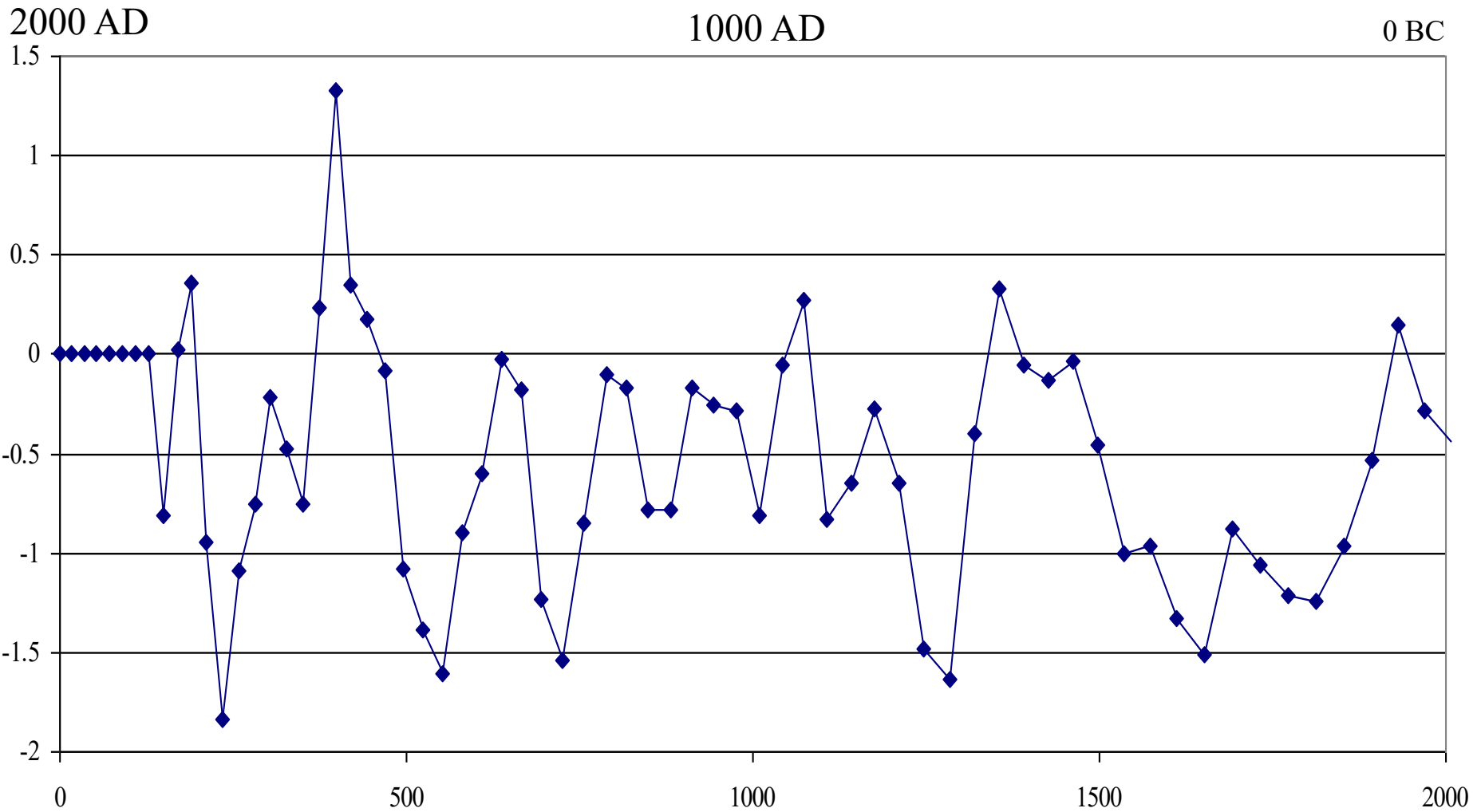


Figure 4.12. Variation of temperature derived from deuterium at Vostok, Antarctica From 2000 ybp to the present (left) [Petit et al. 2001; data from www.ncdc.noaa.gov/paleo].

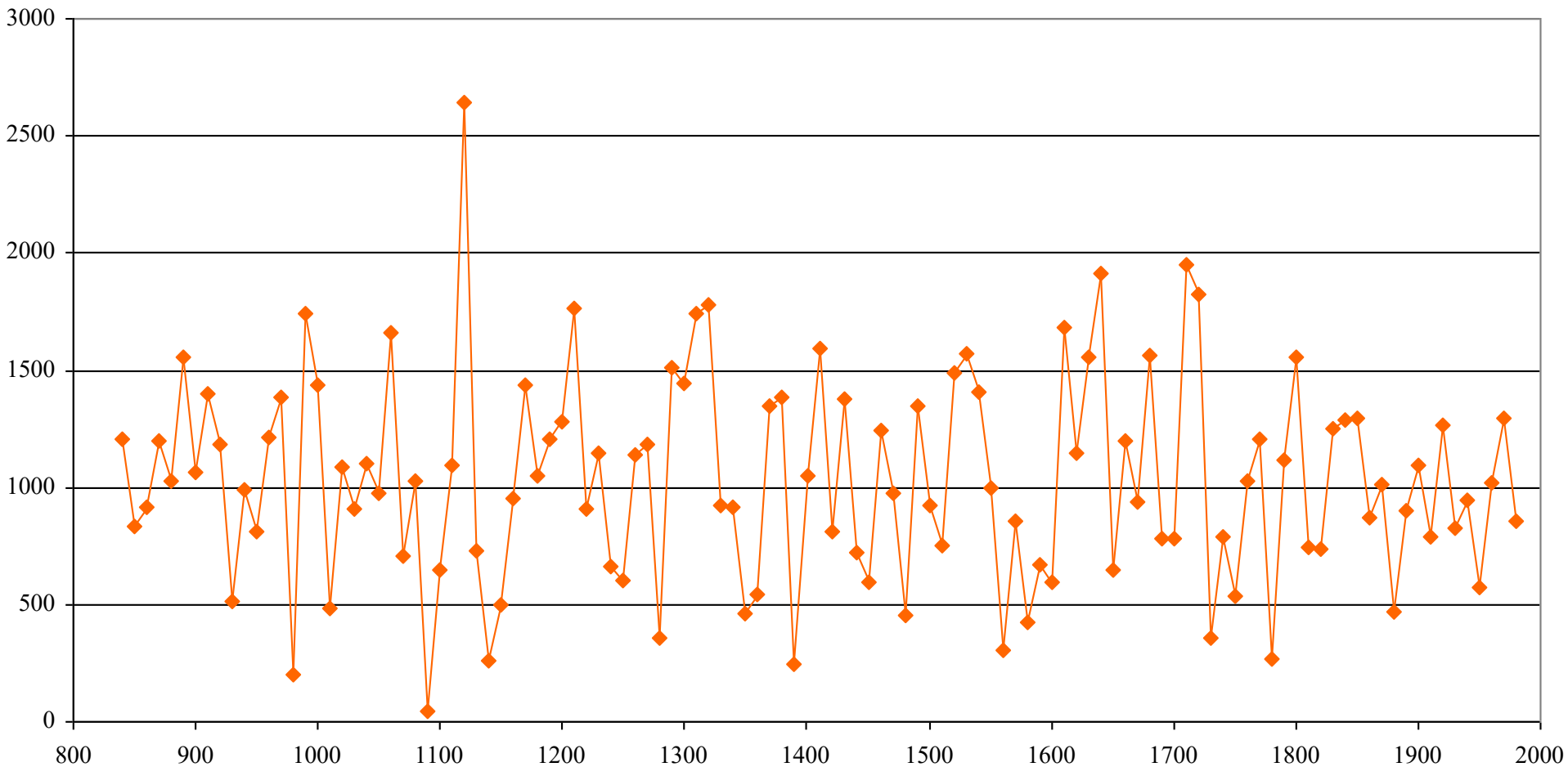


Figure 4.13. Decadal averages of limber pine tree ring width at Italian Canyon, NM (36.4°N, 105.3°W), 2894 m elevation, during AD687-1987 [Swetnam et al. 1989, www.ncdc.noaa.gov/paleo].

Sunspot Number 1749 - 2009

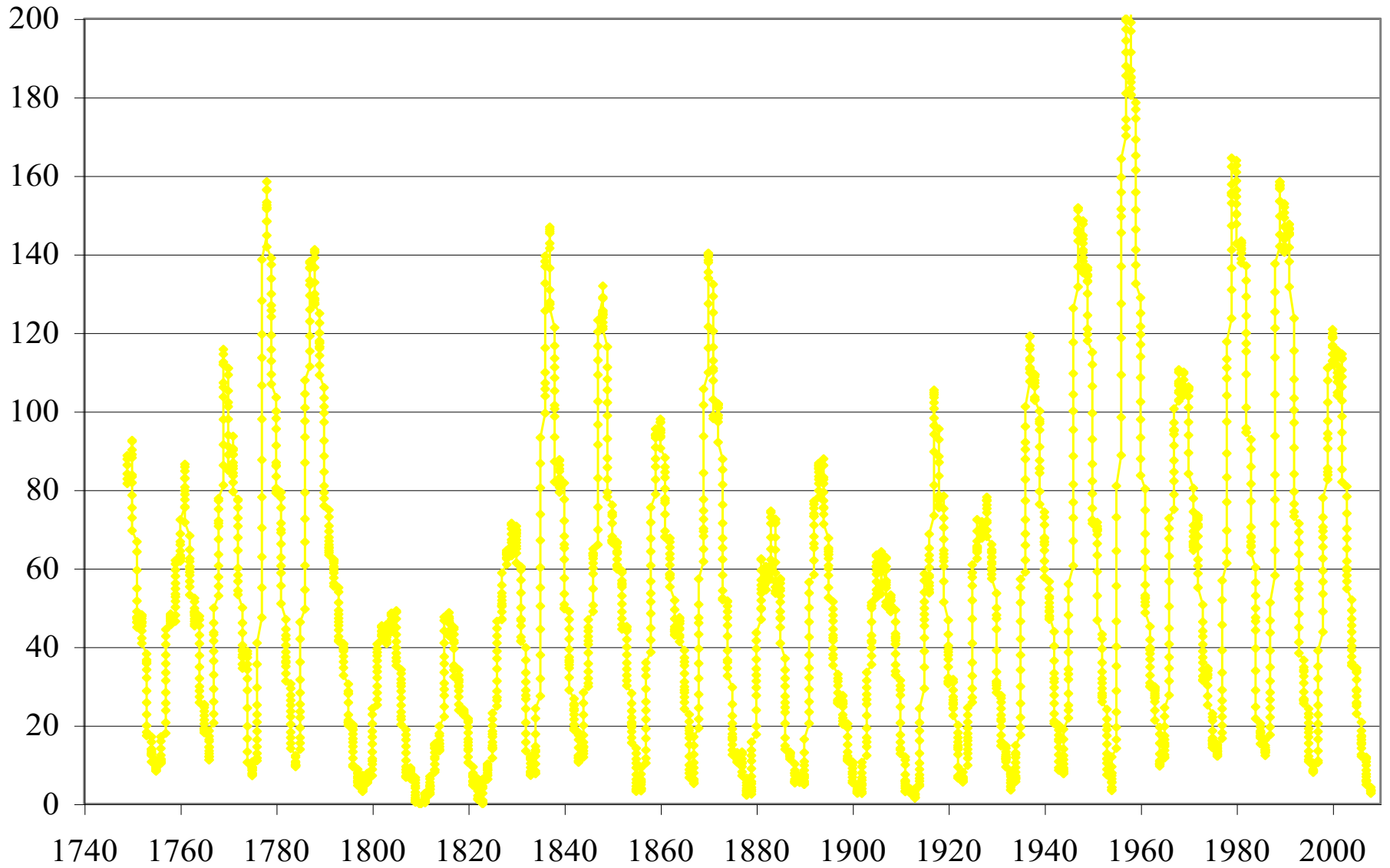


Figure 4.14a. Variation in sunspot number during 1749 – 2009 [from www.ngdc.noaa.gov].

Duration of sunspot cycle (yrs)

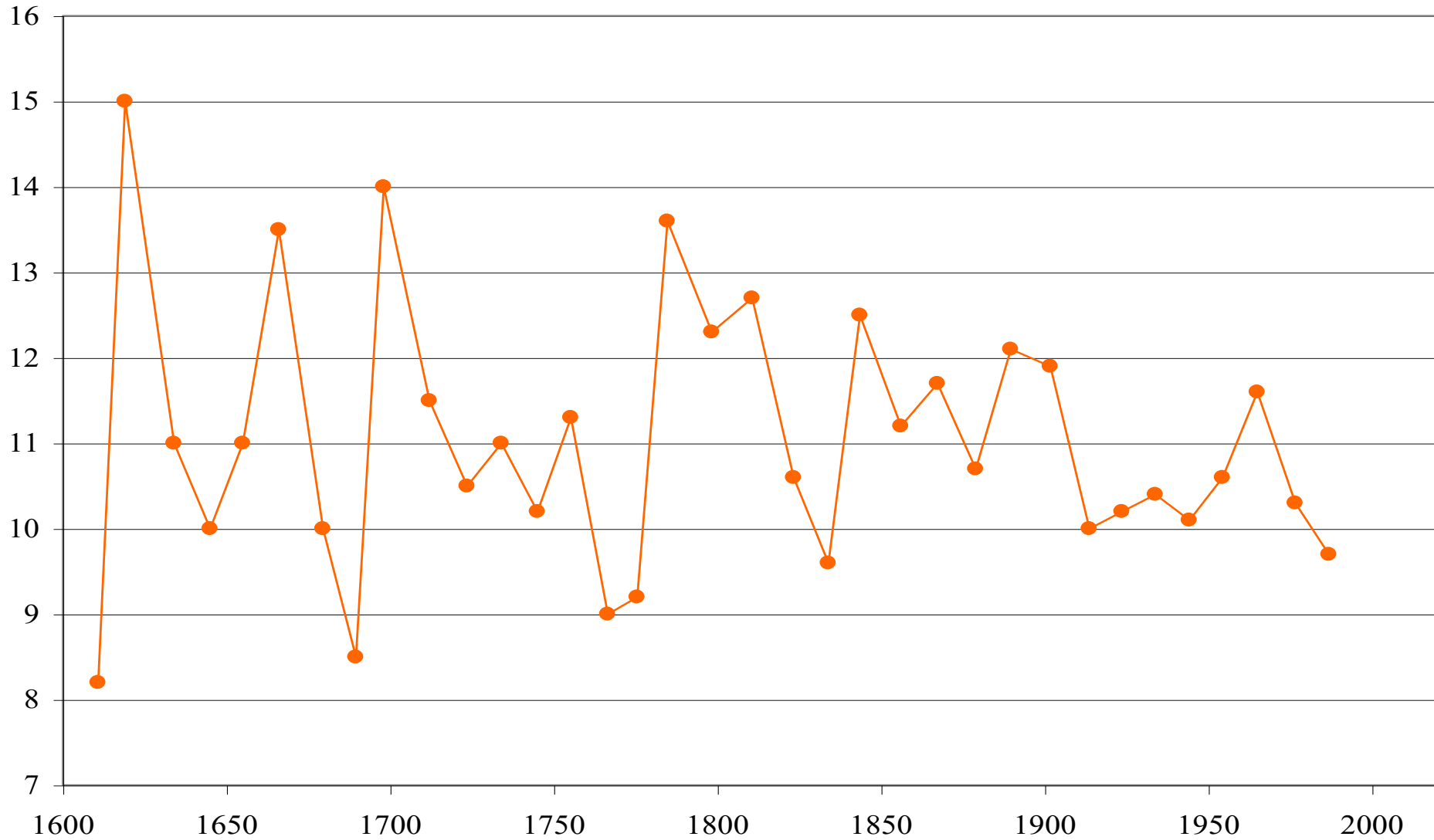


Figure 4.14b. Variation in length of solar cycle during 1600 - 2000 [from www.ngdc.noaa.gov].

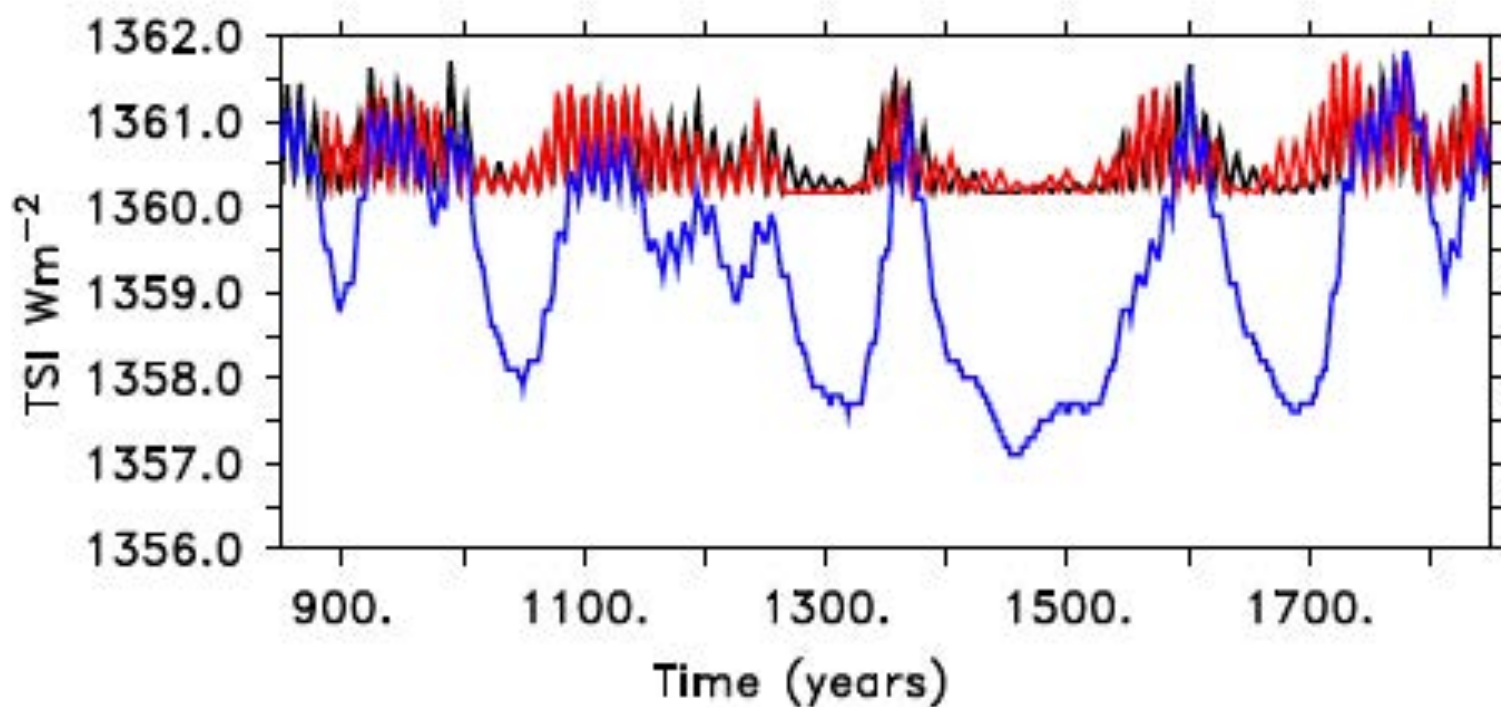
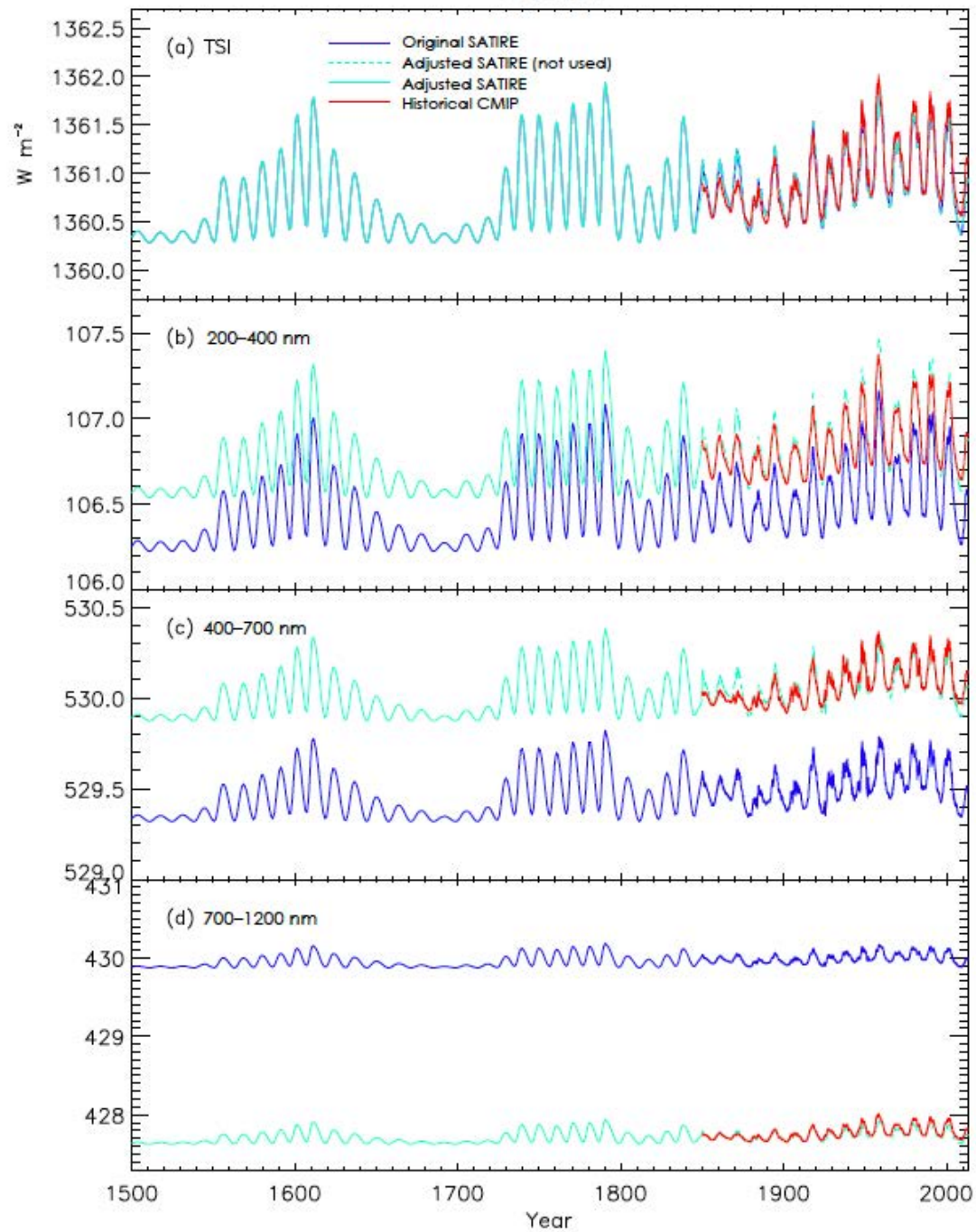


Figure 3. Reconstructions of total solar irradiance based on two different isotope data sets and two different irradiance models. The ^{14}C -based reconstruction of sunspot numbers is converted to TSI using (black line) the SATIRE-M model and (blue line) the updated Shapiro et al. (2011) model. The ^{10}Be -based TSI reconstruction is constructed using the SATIRE-M model (red line).

¹⁴C based



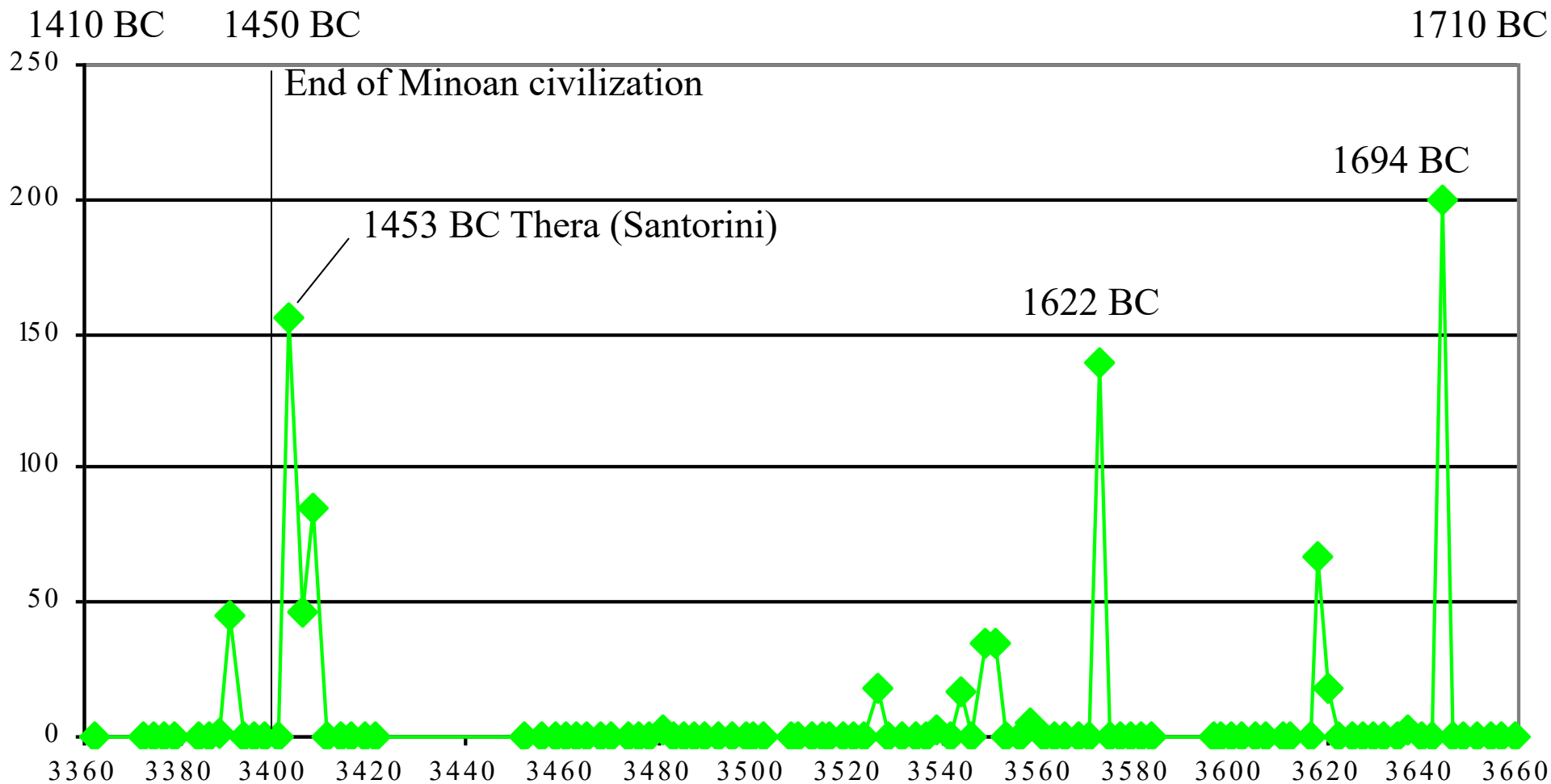


Figure 4.15a. GISP2 volcanic sulfate (ppb) during 3360-3660 years before 1950 AD (1410-1710 BC) [Zielinski et al 1993].

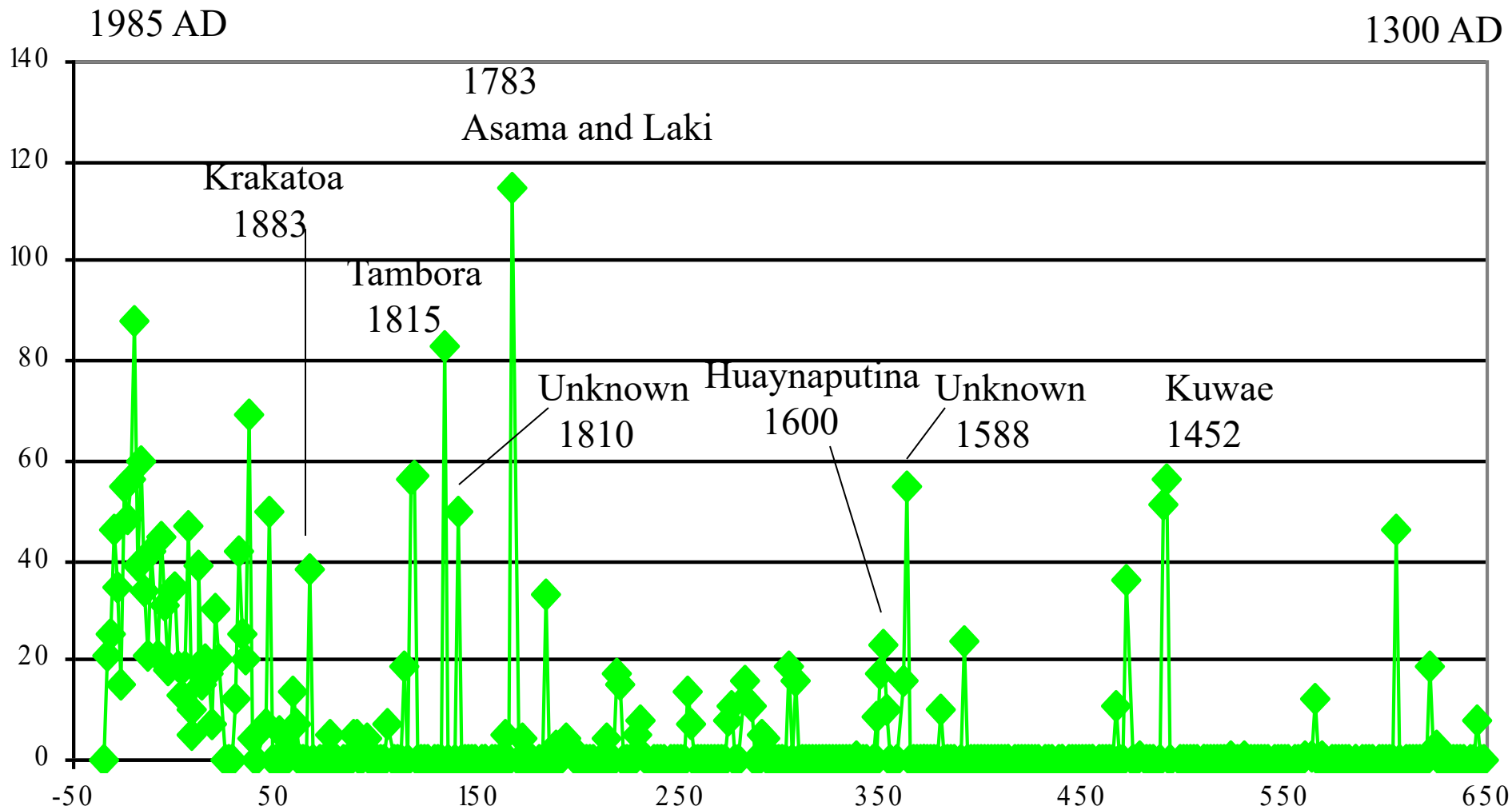
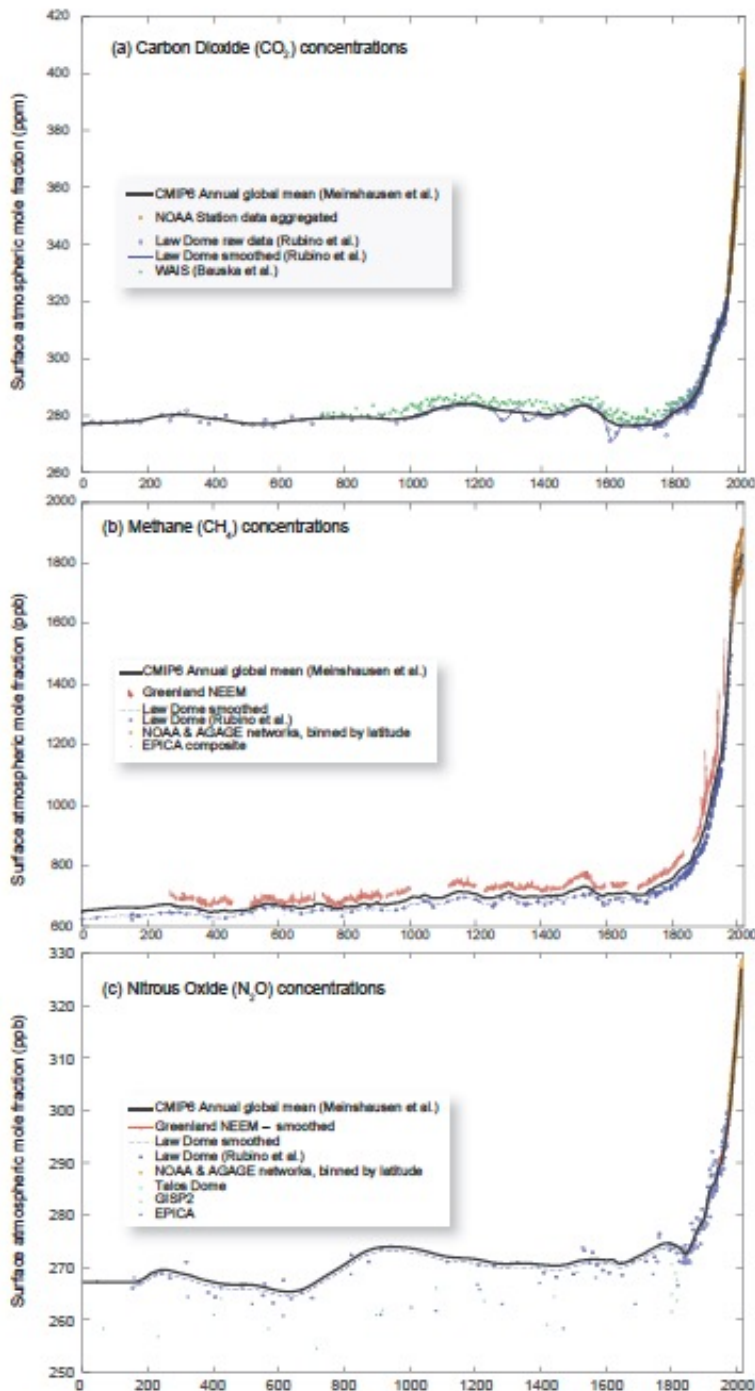


Figure 4.15b. GISP2 volcanic sulfate (ppb) during 650 to -35 years before 1950 AD (1300-1985 AD) [Zielinski et al 1993].



Jungclaus et al. 2017

→ Climate Dynamics Theory

(What will the Superinterglacial be like?)