Paleoclimate and Other Data

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Paleoclimate Data

- Some References
- Time Scales of Climate Change
- Types of Data, Dating Methods
- Focus on the last 1000 yrs
- Hockey Stick Curve, Esper Flap
- Signal Detection and its Philosophy

Both of these books are fairly recent and very good

The Holocene

An Environmental History

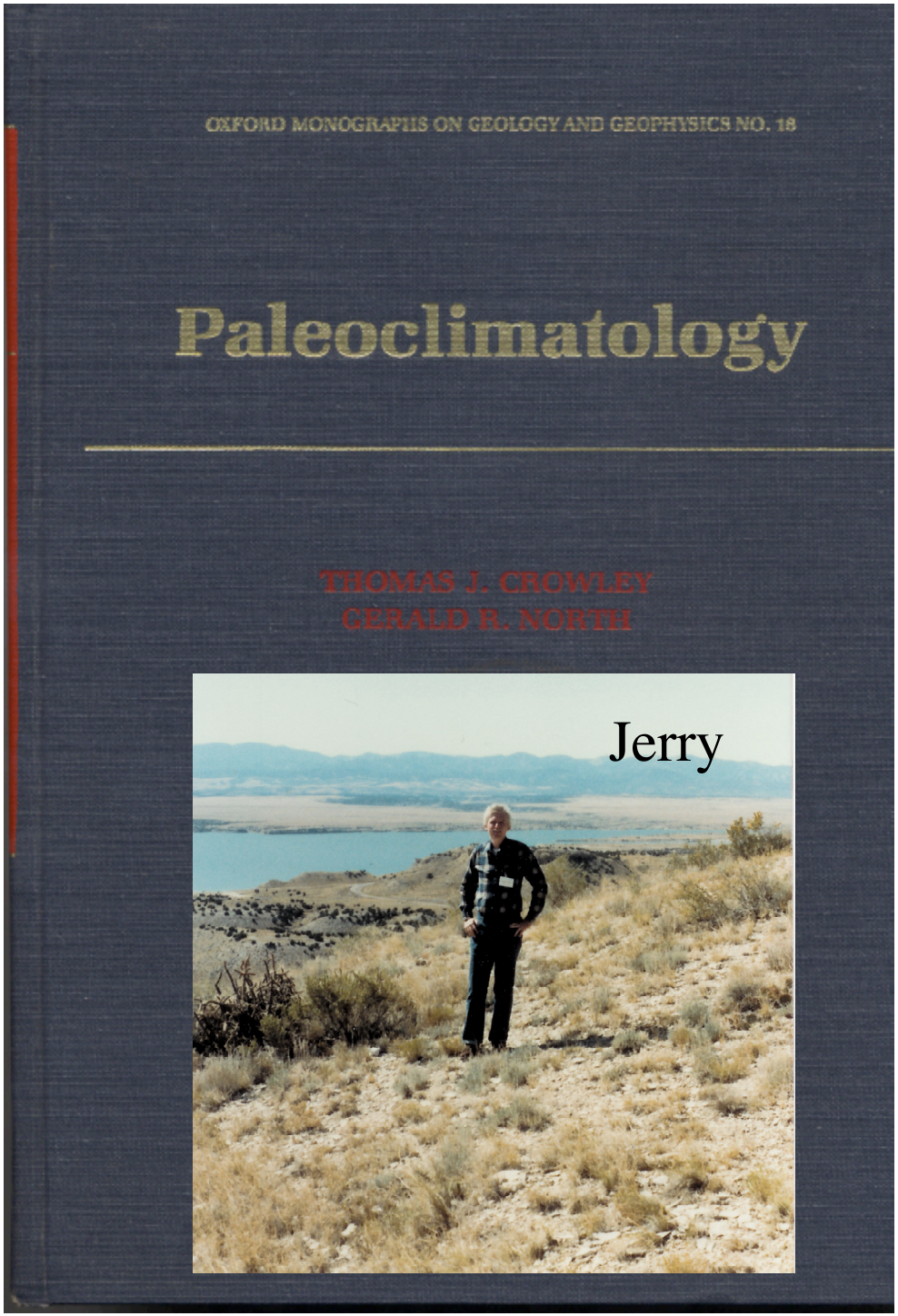
SECOND EDITION

Neil Roberts

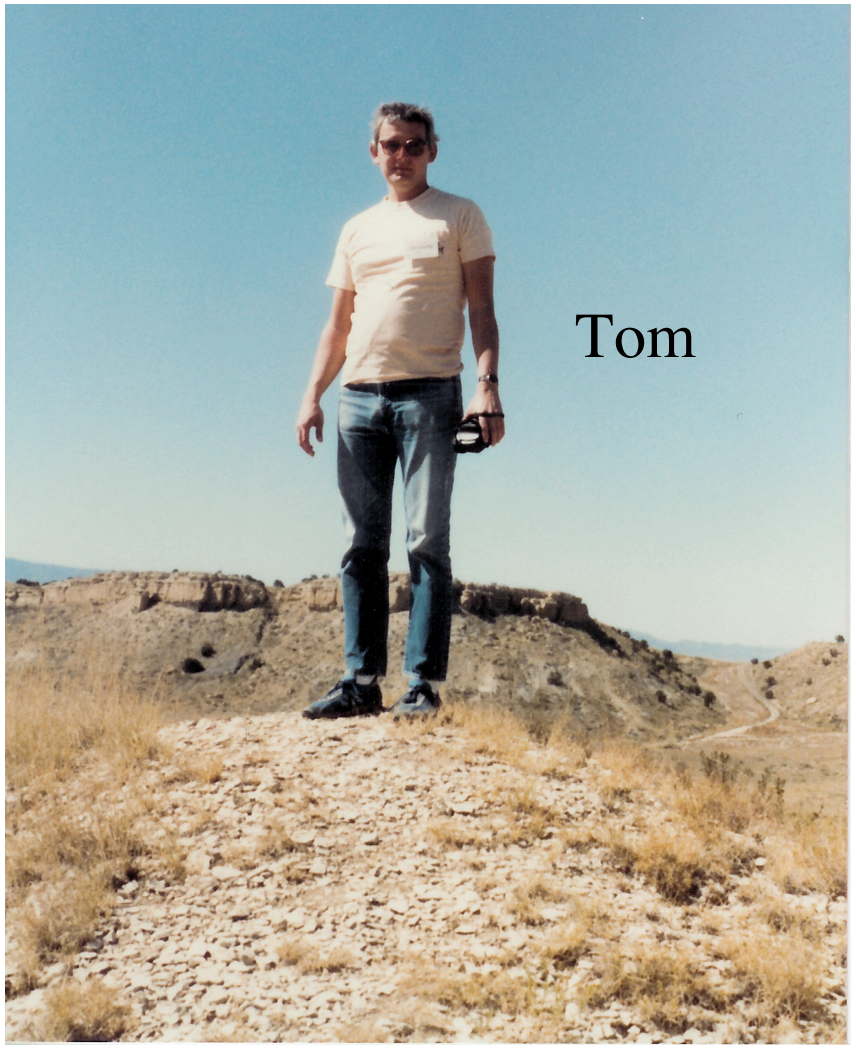
(1998)

BLACKWELL Publishers

(1999)



This is a good overview, but slightly out of date- GRN



At an AGU Chapman Conference in COLO *ca*. 1990

Dating Methods

- Carbon 14 Dating
- Long Lived Isotopes (e.g., Uranium, ..)
- Magnetic Field Changes

Carbon 14 Dating

- Produced by Cosmic Rays on N

$$^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + ^{1}_{1}H$$

$$^{14}_{6}C \rightarrow ^{14}_{7}N + \beta + \text{neutrino}$$

Half life ~ 5730yr

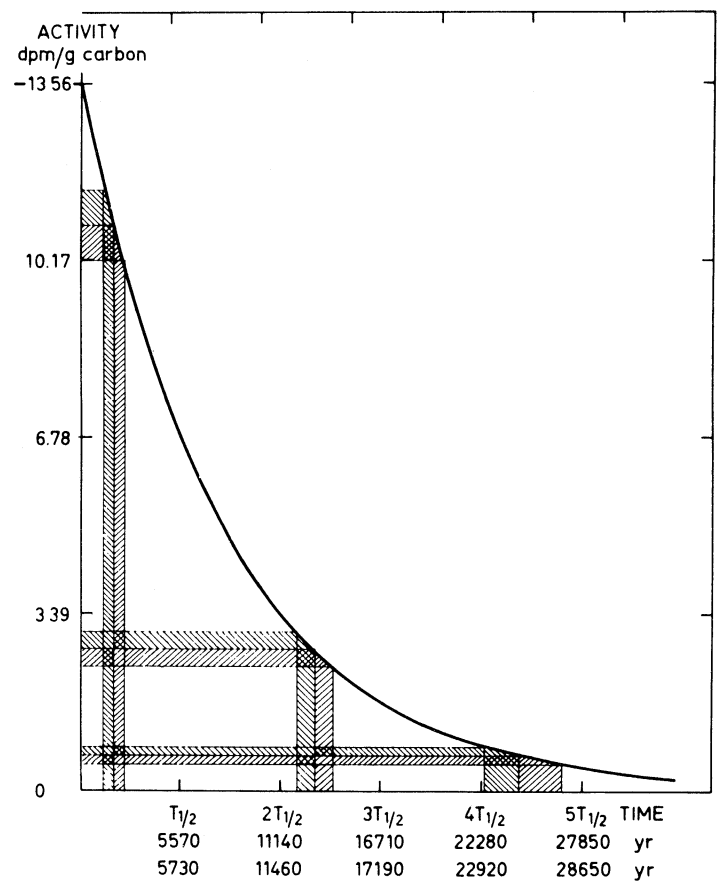


Figure 3.3 The decay of radiocarbon with time. Both the Libby and revised half-lives ($T\frac{1}{2}$) are shown on the abscissa. The ordinate scale is in disintegrations per minute per gram of carbon (after Olsson 1968).

Correcting the C^{14} time scale by tree rings

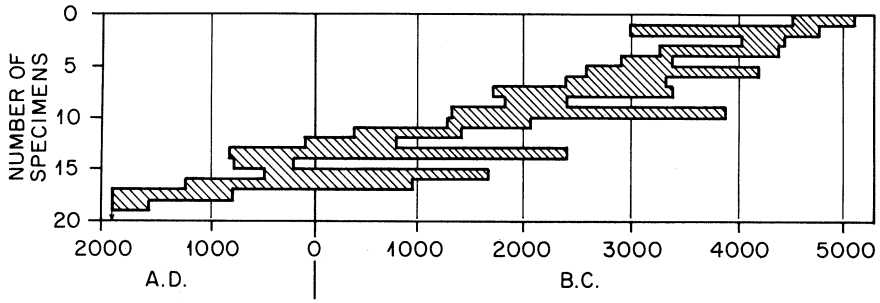


Figure 3.8 Construction of the bristlecone pine master chronology, showing time intervals

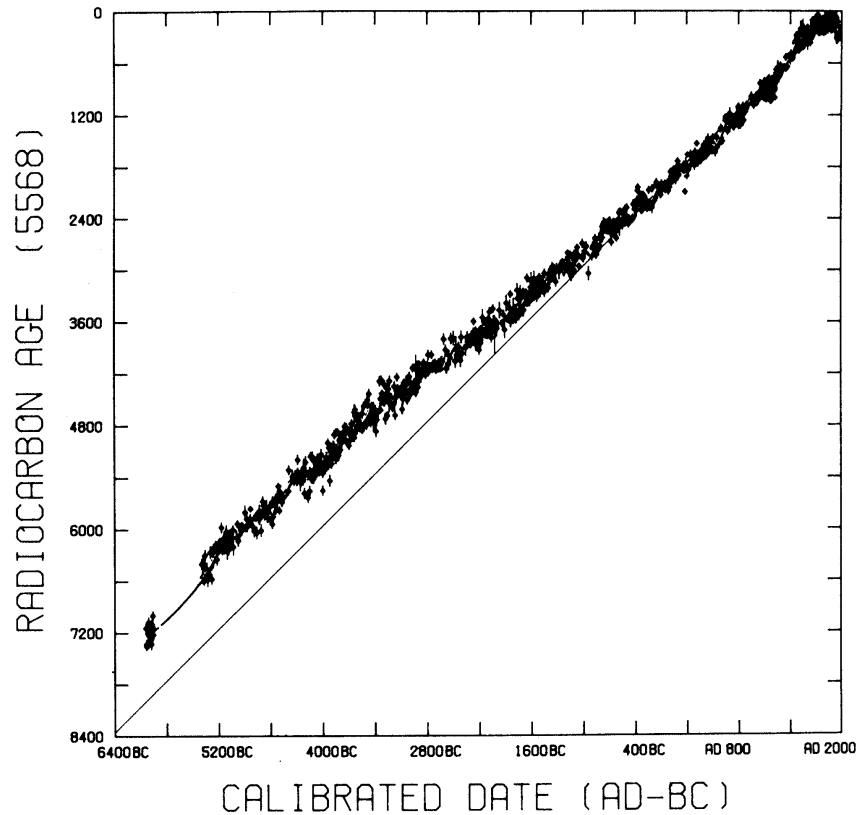


Figure 3.9 Radiocarbon dates (years BP) in relation to tree-ring dates (calendar years). Absolute correspondence is represented by the straight line. Note the systematic drift in the relationship (with ^{14}C age underestimating calendar year age) particularly before ~2500 years BP (from Klein *et al.* 1982).

Temperatures from old snow using $^{18}O/^{16}O$

Model of how O^{18}/O^{16} Changes in Polar Air

(These ideas are based on the O^{18} in H_2O not in air molecules, O_2)

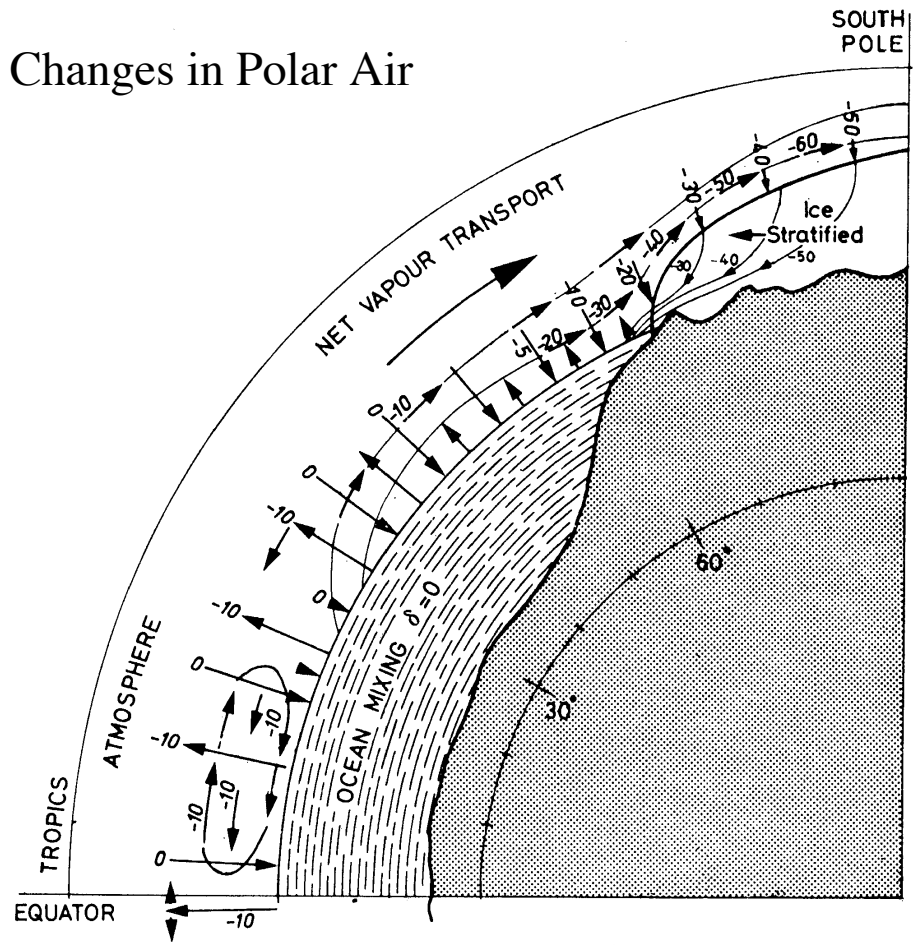


Figure 5.4 Schematic diagram to illustrate isotopic depletion of water vapor en route to Greenland ice sheet. As air mass cools, precipitation produced is preferentially enriched in ^{18}O, leaving the remaining vapor relatively depleted. Consequently, with further condensation, the precipitation contains less and less ^{18}O (i.e. lower $\delta^{18}O$ values). This isobaric effect is accentuated by uplift (adiabatic) effects over the ice sheet itself, so that lowest $\delta^{18}O$ values are found in the ice-sheet interior (after Dansgaard *et al.* 1971, Robin 1977).

Vostok site

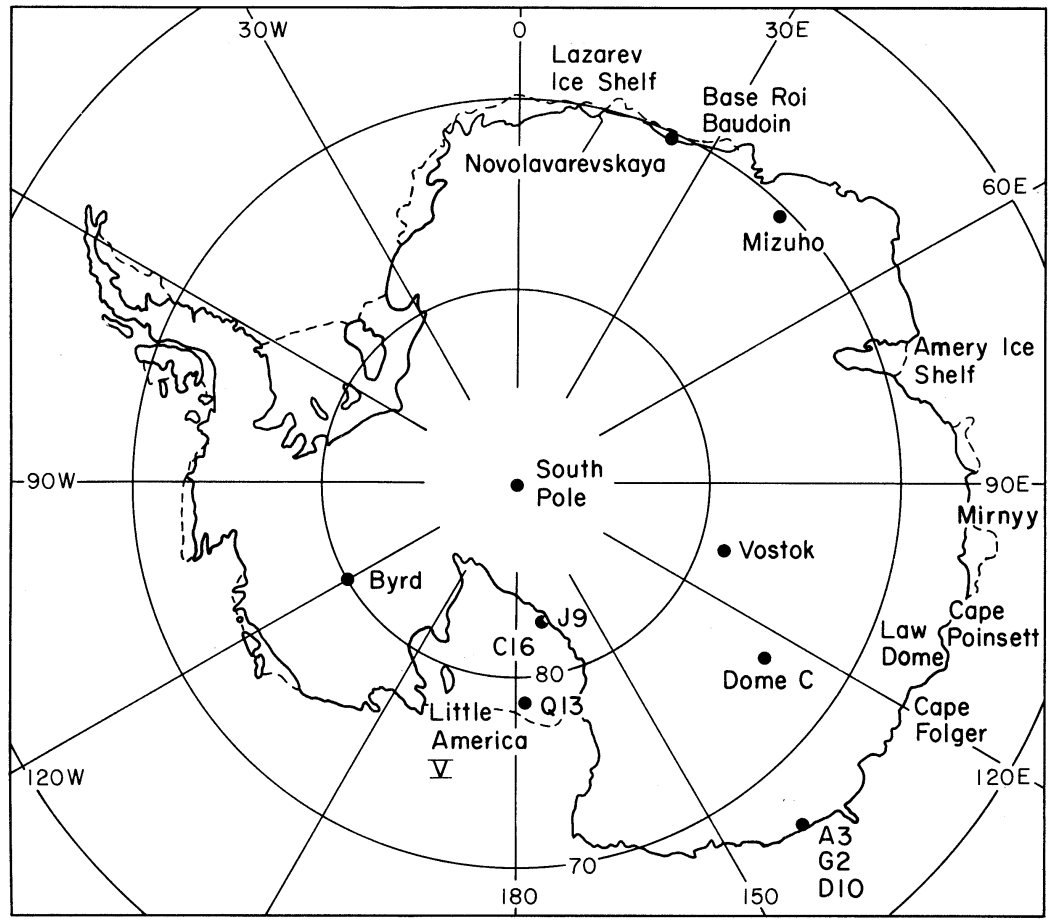


Figure 5.2 Principal ice coring sites of Antarctica.

Other Holocene Data: Pollen from Peat Bogs, Lake Beds

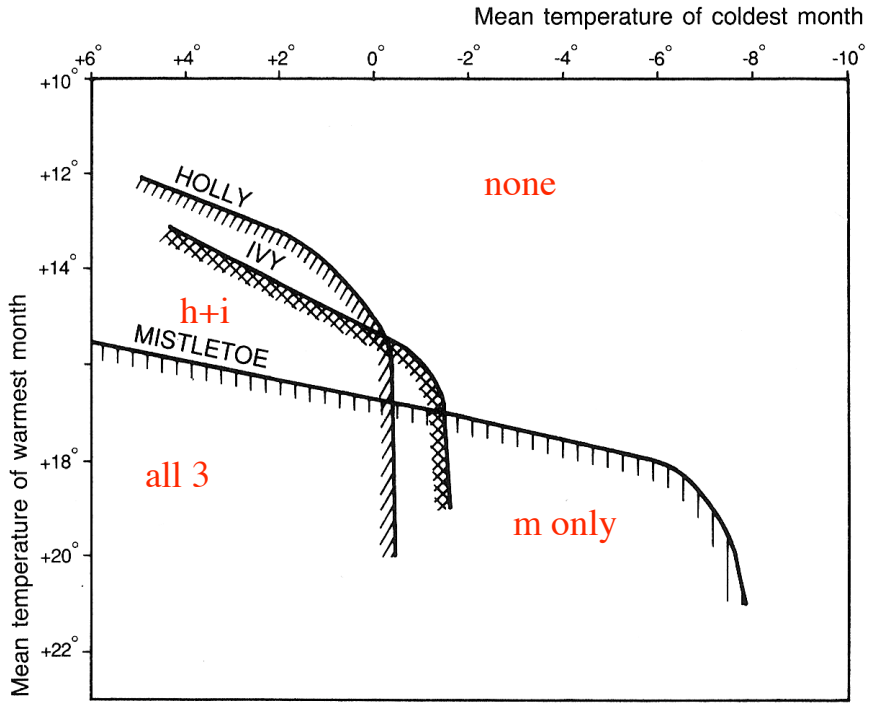


Figure 2.7 The thermal limits of holly, ivy and mistletoe (after Iversen, 1944)

By using these data you can infer past temperatures based on assemblages of plants

This works for Beetles, too.

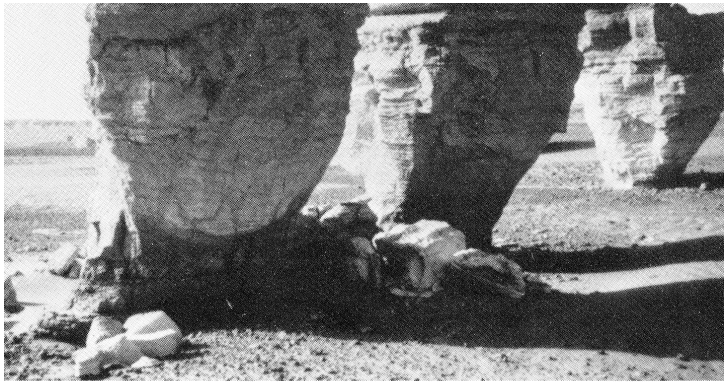


Plate 4.4 Early Holocene lake sediments (10 m thick) from Taoudenni in the central Sahara, subsequently eroded by the wind to form pillars

20 000 and 10 000 yr BP. However, when the Fre
Hugue Faure sent off samples of freshwater ca
diatomite from lake basins in the Sahel he receive
younger ^{14}C ages, between 9240 and 6900 yr BP
1963). Not surprisingly this encouraged further r
which similarly yielded ^{14}C dates in the first half of t
By 1972 Karl Butzer and others were able to put
results from a number of East African lakes and sh

Plate 4.4 Early Holocene lake sediments (10 m thick) from Taoudenni in the central Sahara, subsequently eroded by the wind to form pillars

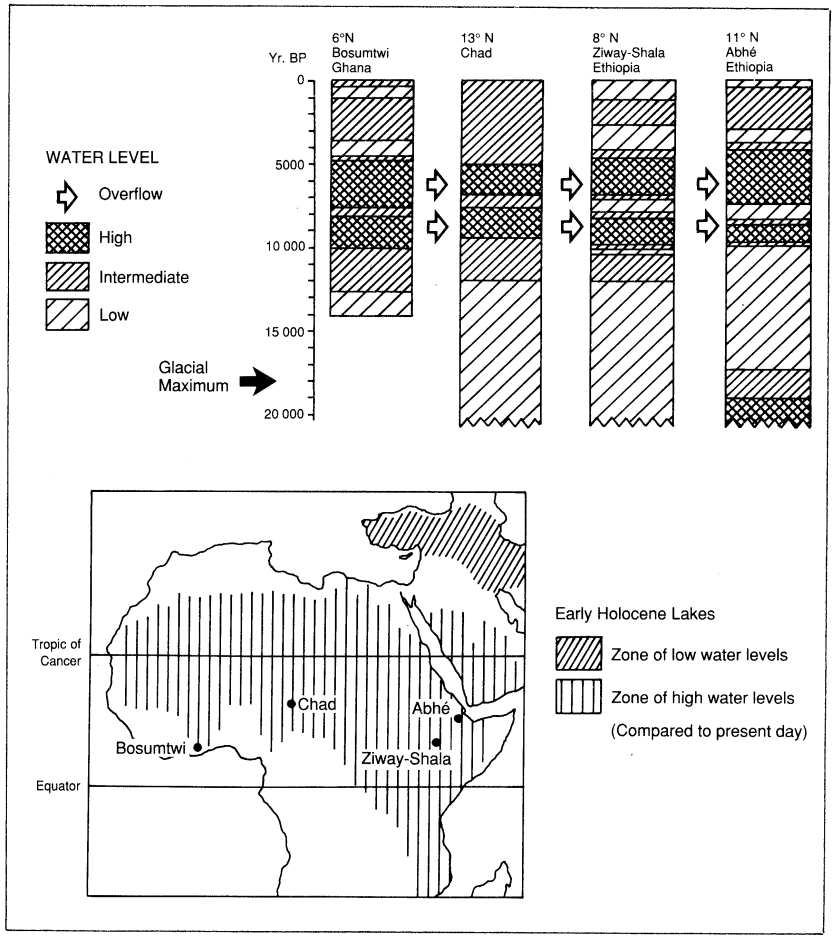


Figure 4.8 Holocene lake-level records from northern intertropical Africa and southwest Asia, showing sequences from four lake basins (above) and zones of high and low water levels at *c.* 9000 yr BP (below) (partly based on Street–Perrott *et al.*, 1985)

Data on past temperatures, conditions, can be infered from lake sediments. E.g., here are some examples from the Sahara.

Tree Rings

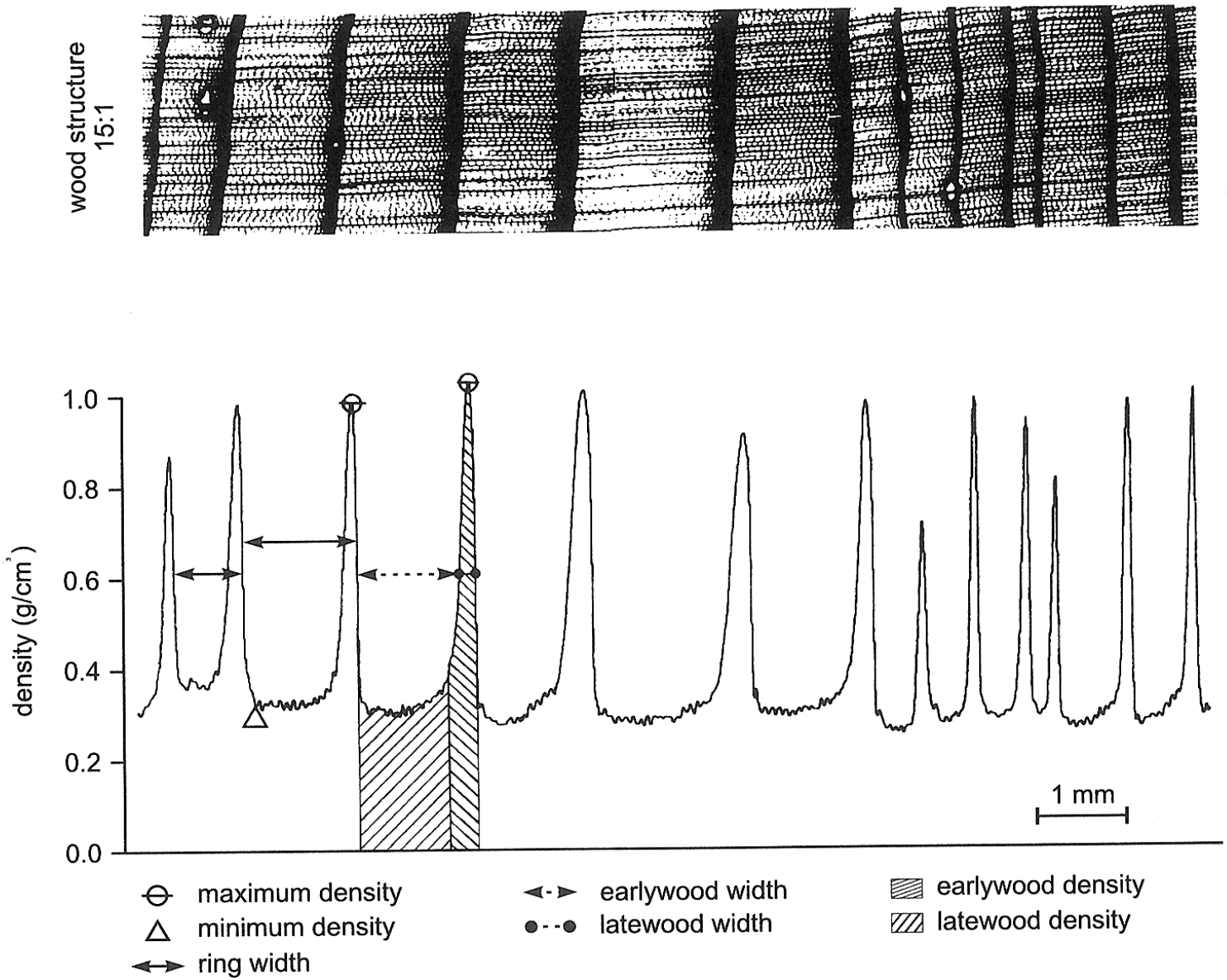
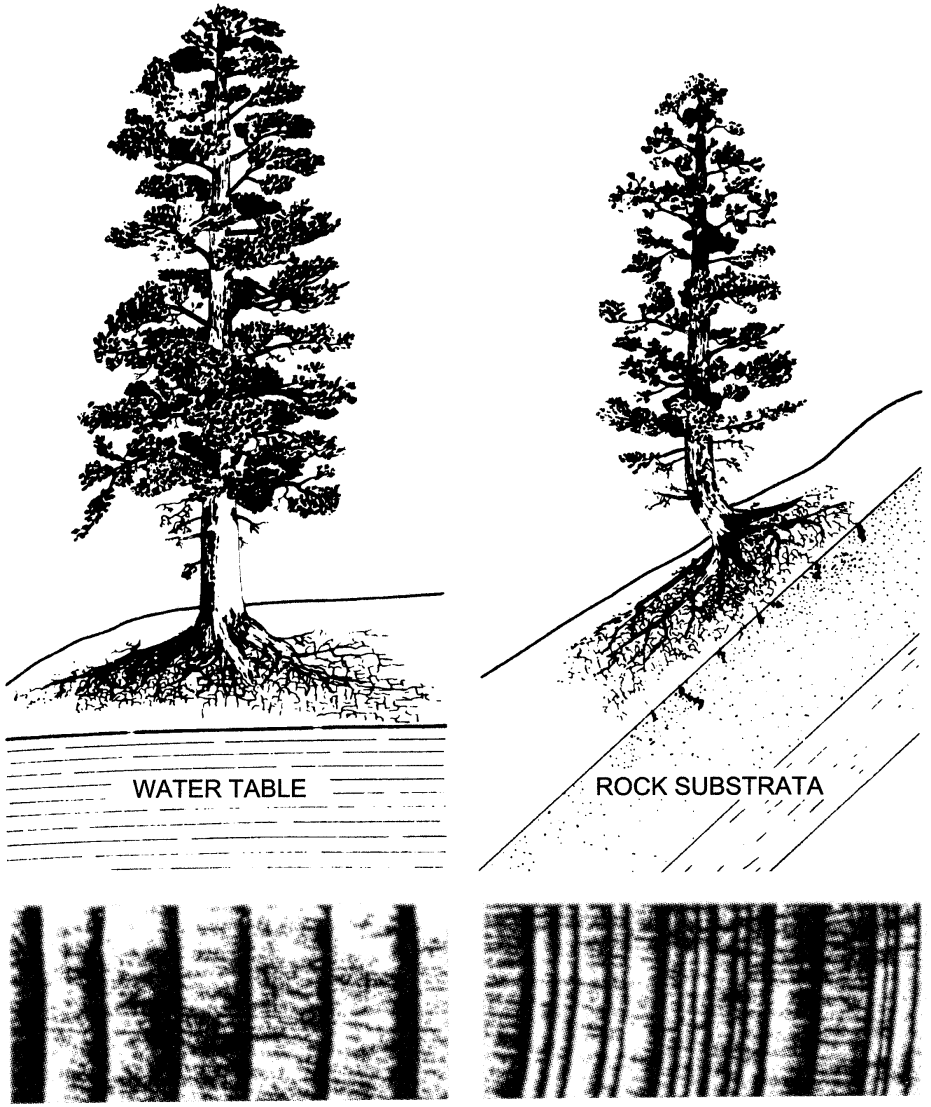


FIGURE 10.2 Example of a tree-ring density plot based on an x-ray negative of a section of wood (top of figure). Minimum and maximum densities in each annual ring are clearly seen, enabling the annual ring width to be measured as well as the width of both the earlywood and latewood (courtesy of F. Schweingruber).



Rings of uniform width provide little or no record of variations in climate.

Rings of varying width provide a record of variations in climate.

FIGURE 10.3 Trees growing on sites where climate seldom limits growth processes produce rings that are uniformly wide **(left)**. Such rings provide little or no record of variations in climate and are termed *complacent*. **(right)**: Trees growing on sites where climatic factors are frequently limiting produce rings that vary in width from year to year depending on how severely limiting climate has been to growth. These are termed *sensitive* (Fritts, 1971).

You need to find trees that are "living on the edge"

This will amplify the response to change.

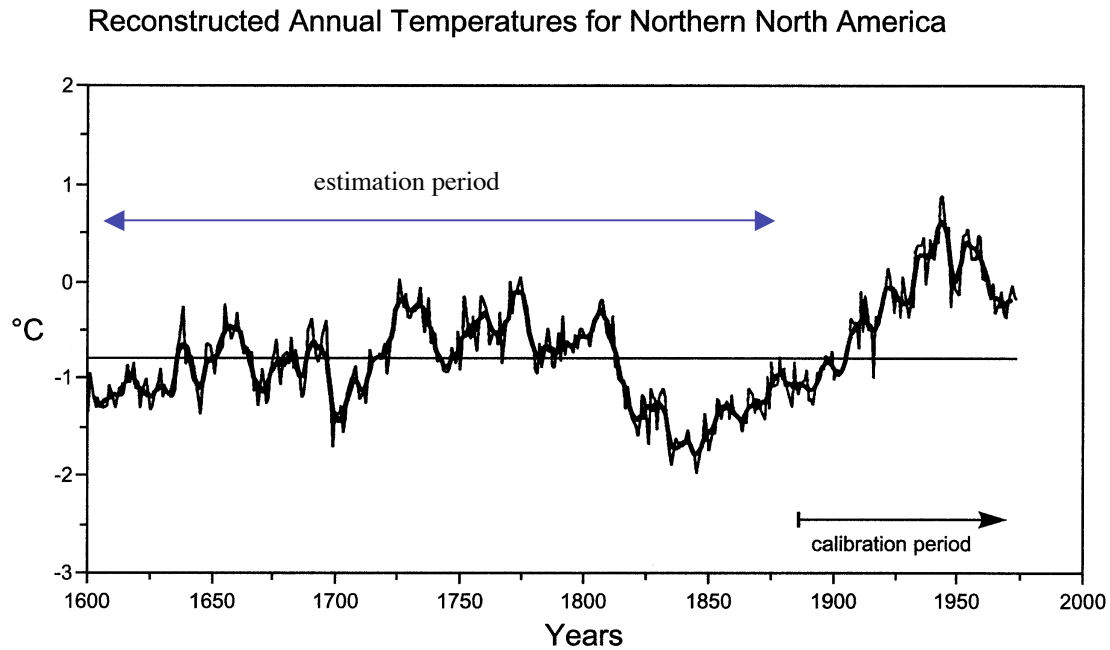


FIGURE 10.22 Reconstruction of annual temperature across northern North America for 1601–1974, based on a set of 7 tree-ring width chronologies from Alaska to Quebec; 5-yr smoothed values also shown by darker line (D'Arrigo and Jacoby, 1992).

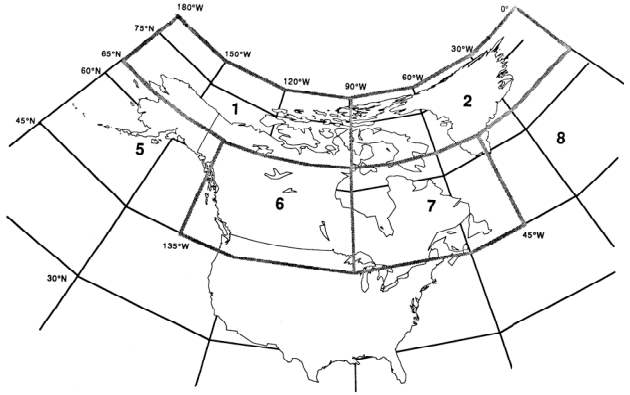
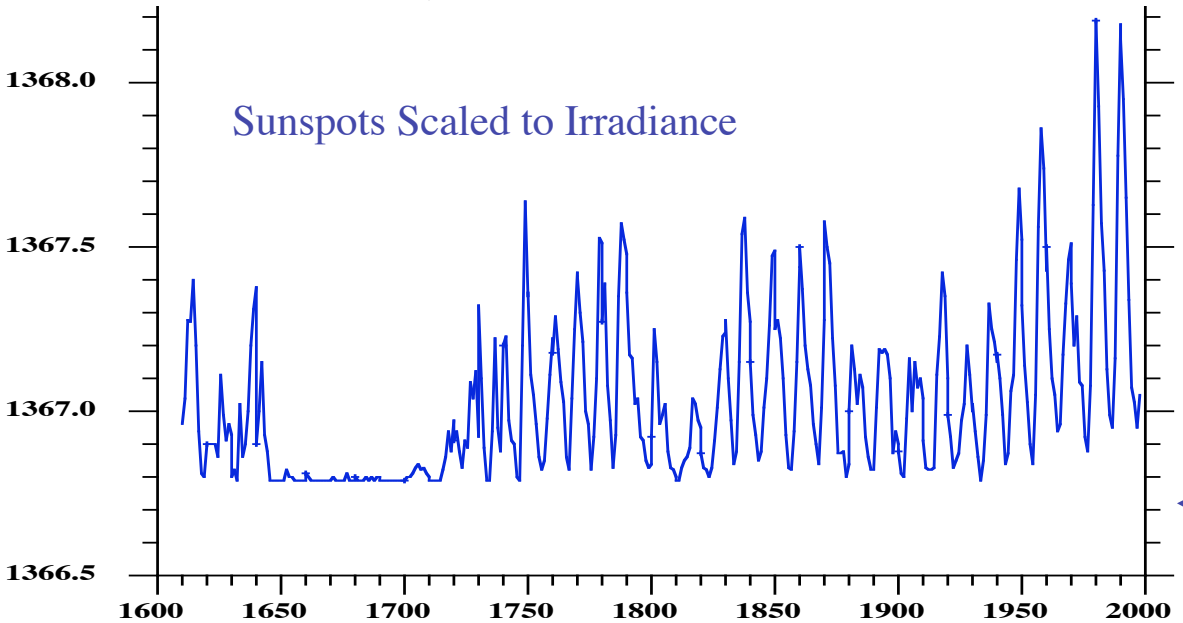


Figure 15.2 Portion of the grid of 80 equal-area temperature boxes for the globe from the Hansen and Lebedeff (1987) data set showing boxes 1, 2, 6 and 7 which have been averaged to represent the area of northern North America.

This record of Northern NA tree rings is calibrated over the last century to instruments, then used to extrapolate back.



Crowley sent me this one

Controversy:

There is a variation of tree ring width with the age of the tree. There are issues about how this affects the low frequency (centennial) variability of the record of temperatures inferred.

See the recent paper by Esper & Frank in *EOS*

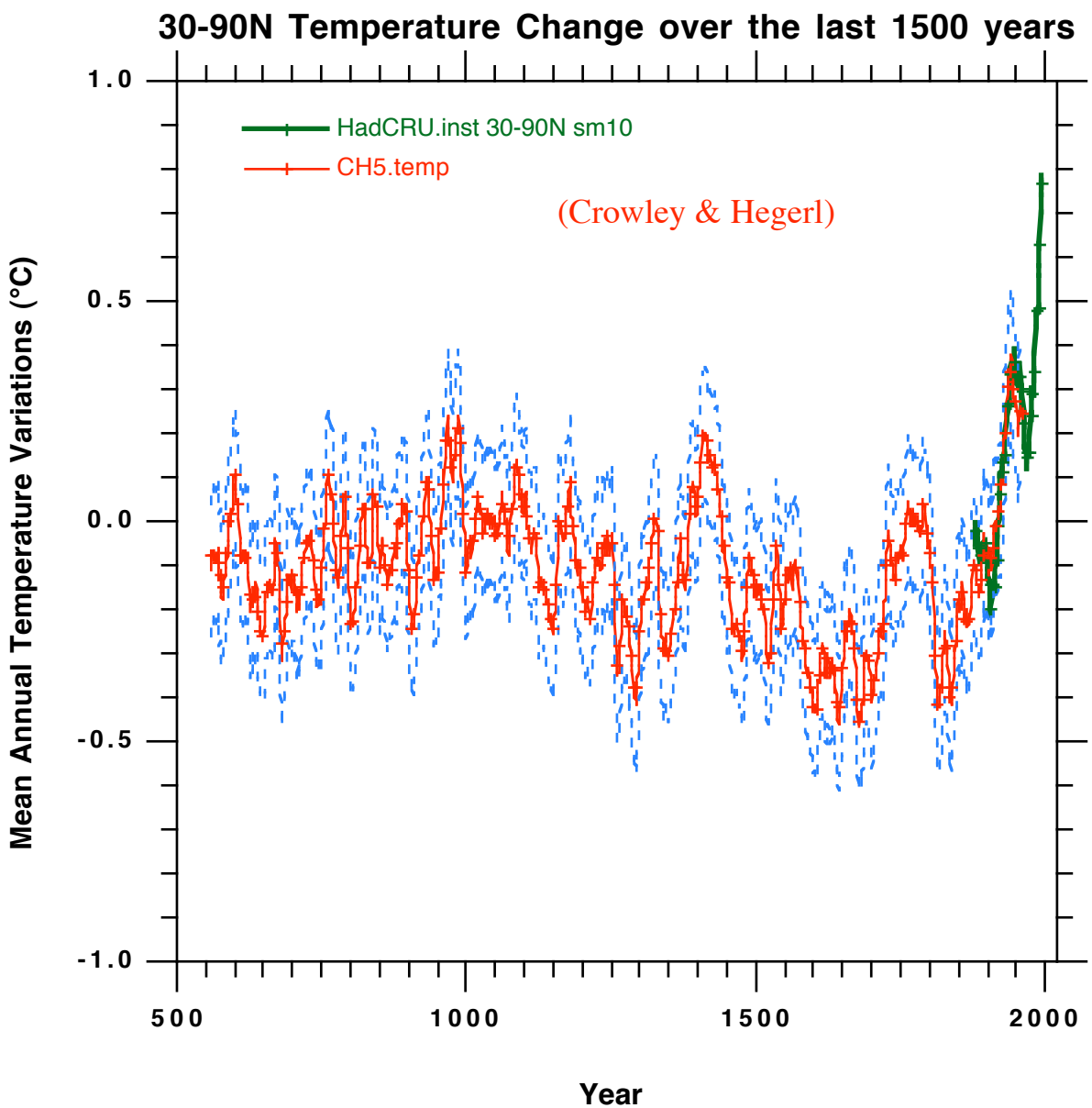
Climate Reconstructions: Low-Frequency Ambition and High-Frequency Ratification

Eos, Vol. 85, No. 12, 23 March 2004

Jan Esper and David C. Frank, Swiss Federal Research Institute WSL, Birmensdorf; and Robert J. S. Wilson, Edinburgh University, U.K.
For more information, contact Jan Esper via e-mail at esper@wsl.ch.

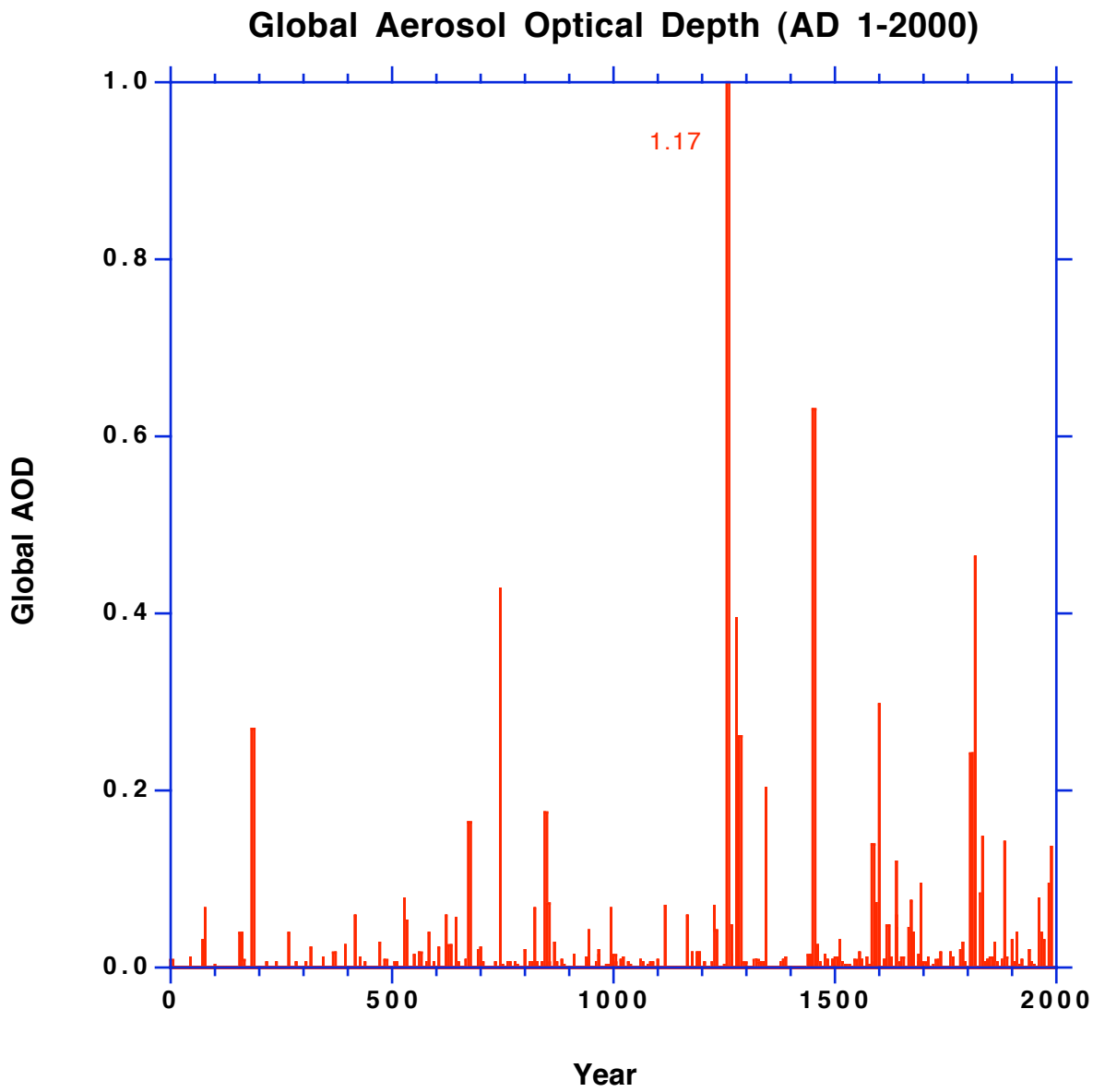
Esper's reconstructions over the last 1000yrs disagree with earlier analyses by Mann, Crowley and others. But only in low (centennial) frequencies. (important for solar issues)

Crowley & Hegerl Reconstruction (private communication, 2004)

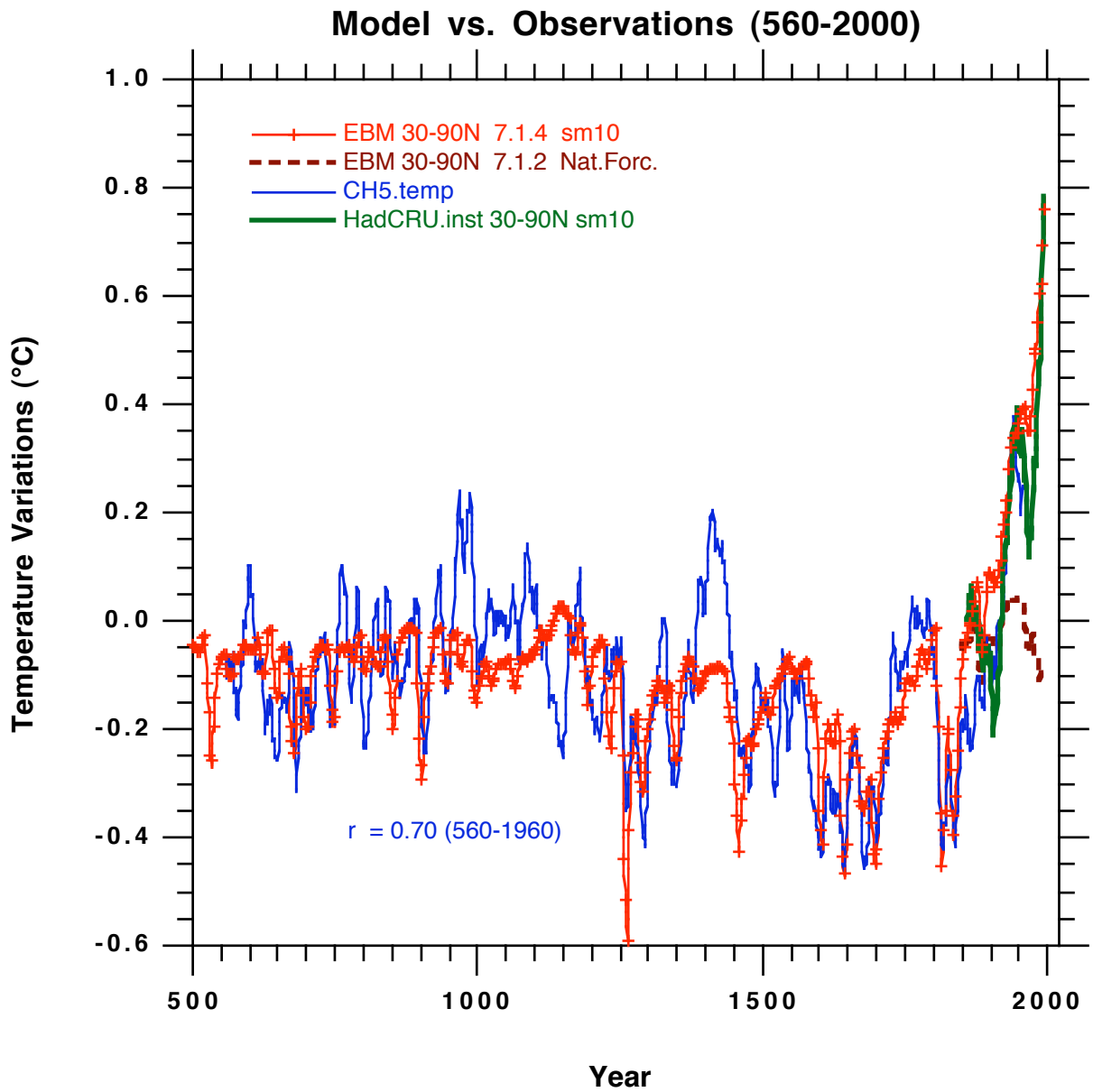


Volcanoes as derived from ice cores

(from Tom Crowley)

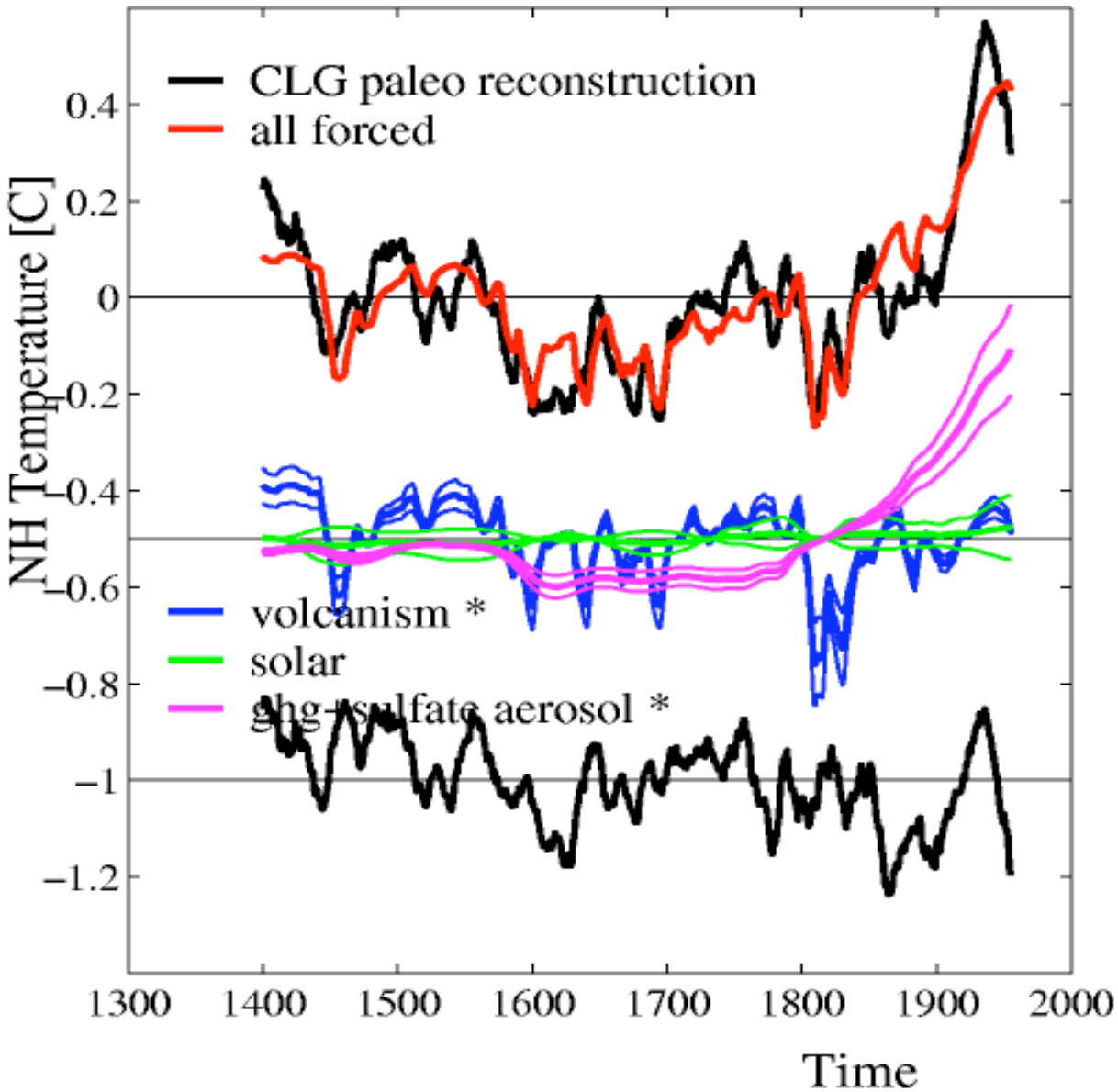


Hegerl & Crowley, 2003 (GRL)



The model is a 2D EBCM with upwelling diffusion ocean (a la North-Kim)

Hegerl & Crowley, 2003 (GRL)



Hegerl & Crowley, 2003 (GRL)

Note: Long term solar is really not detectable

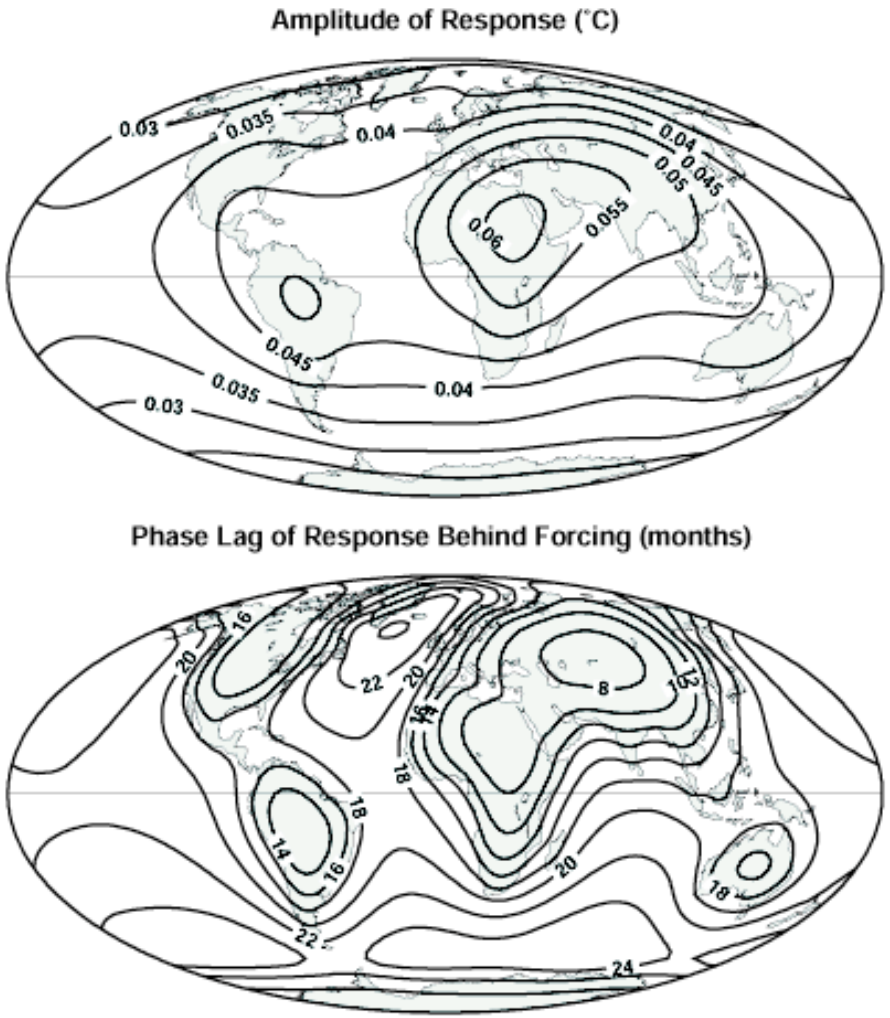
record	Briffa	CLH	Mann	Esper	CLH
period	**1400-1940**	**1400-1960**	**1400-1960**	**1400-1960**	**1000-1960**
volc	Y	Y	Y small	Y	Y
solar	N small	N small	N **(Y periods)**	N small	N **(Y 1100on)**
Ghg+aer	Y	Y	N small (y 1980)	Y, large	Y
Res std	0.09 (57%)	0.08 (77%)	0.07 (49%)	0.13 (67%)	0.10 (57%)

Detecting the 11yr Solar Cycle in the Surface Temperature Field

by G. R. North[1], Q. Wu[2] and M. J. Stevens[3]

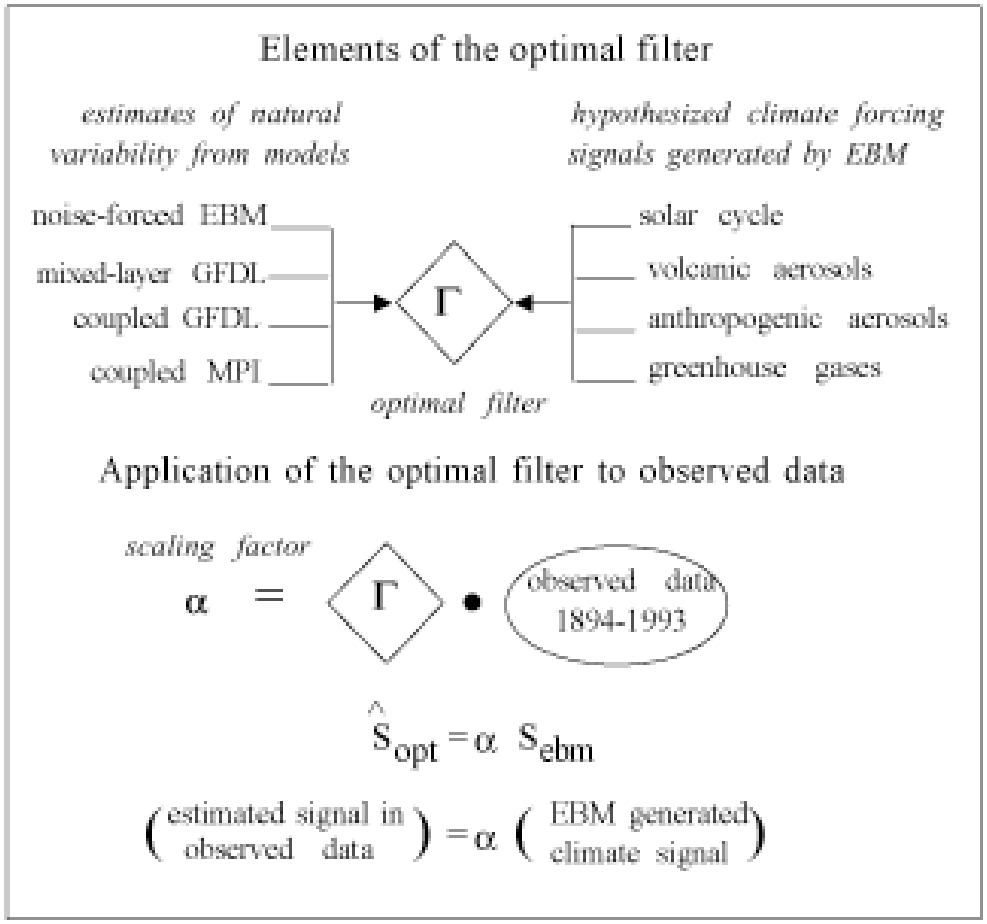
In the AGU Monograph edited by J. Pap et al., 2004

What's New: This model-study employs the seasonal cycle to improve the signal to noise ratio. There is enough gain to claim the 11-yr solar cycle is detectable at the 95 % CL using 100yrs of surface temperature data.



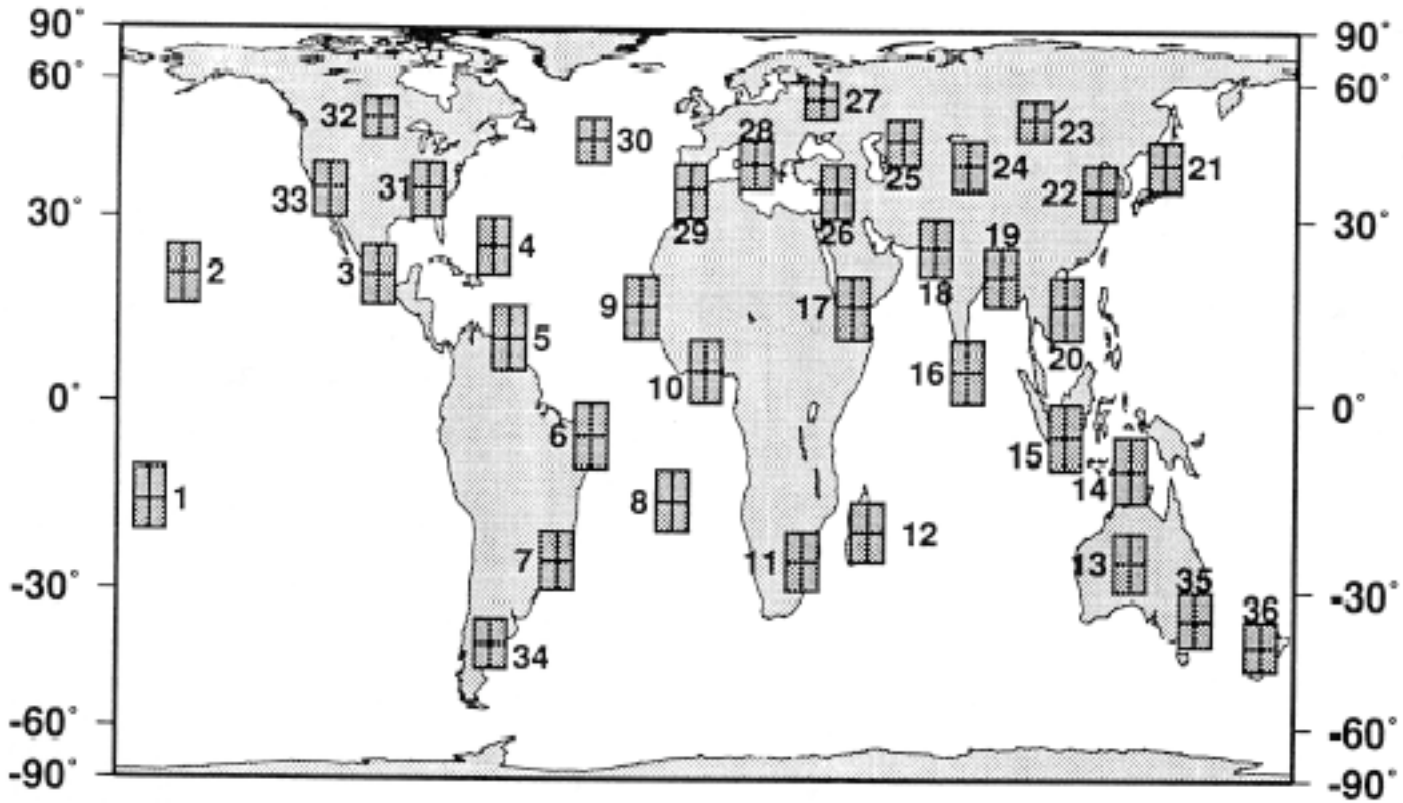
This shows how the surf temp responds to a sinusoidal solar constant variation of amplitude 0.10%. It is very faint, but possibly detectable. It can be used to test climate models.

This is a schematic of the procedure used in the detection scheme.



Natural variability comes from long control runs of GCMs. Signals come from EBCM simulations. We want to ‘detect’ the strength of signals embedded in the noise. We detect all four signals simultaneously.

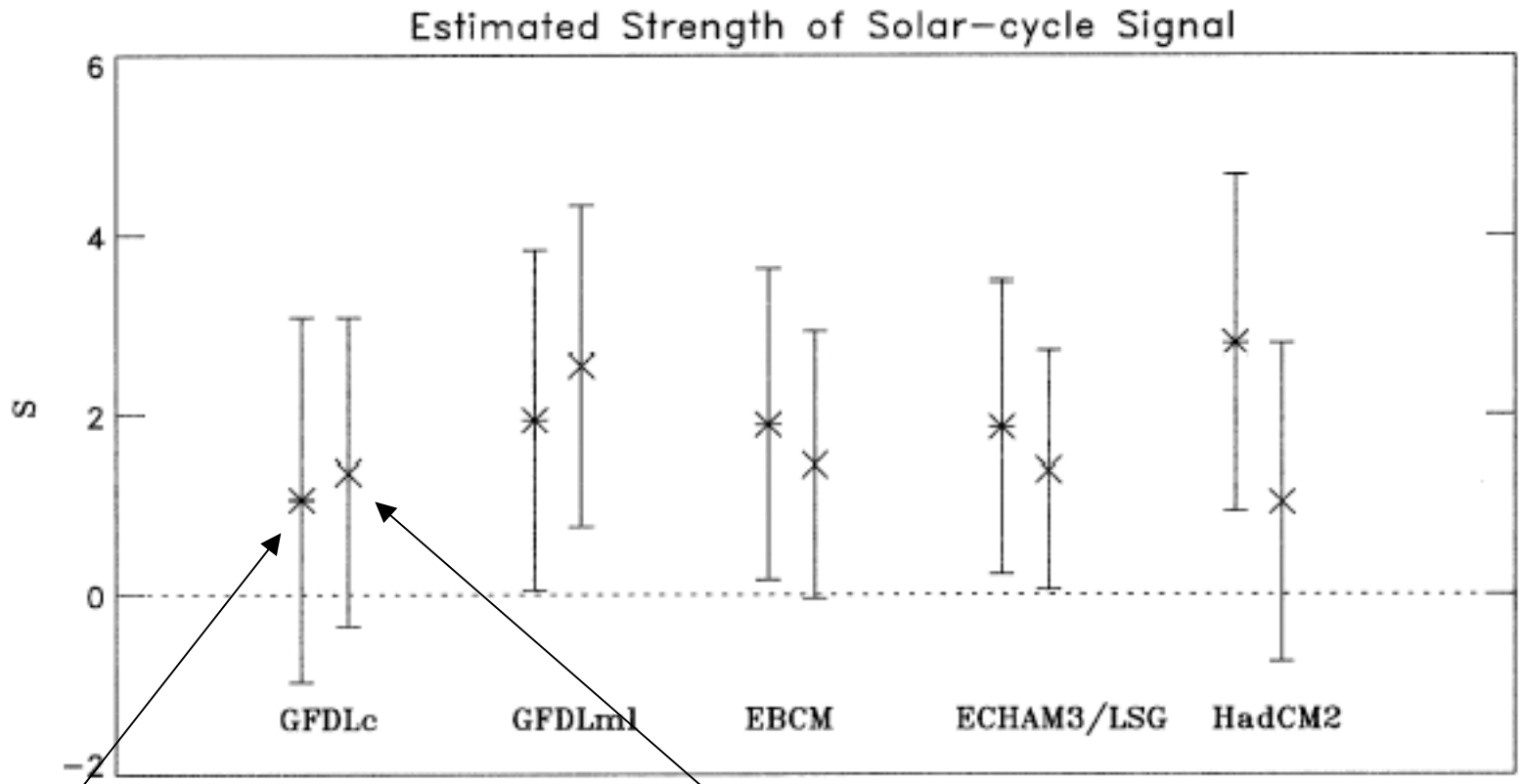
36 sites used in North/Wu/Stevens signal detection study



Chosen for coverage, quality, representativeness, each site is a 10 by10 deg box with at least 4 records extending 100yrs.

95% Confidence Level for the 11-yr Solar Signal

These different models are used to establish the 'noise'



Uses 20 tropical-only sites

Uses all 36 sites (noise reduced)

Moral: Taken across all of these noise models, it appears we have 95% confidence

Conclusions

- *Paleoclimate Data* is Controversial but Rapidly Improving
  - *Watch:* dendro, pollen, beetle, ice core, corals
- *Detection* of Solar Signals:
  - Not so obvious on longer time scales

    (see following speakers)
- *Detection* of 11yr cycle in Surf Temp Data
  - is pretty secure (~95% CL)
  - possibly good as a solar cycle detector