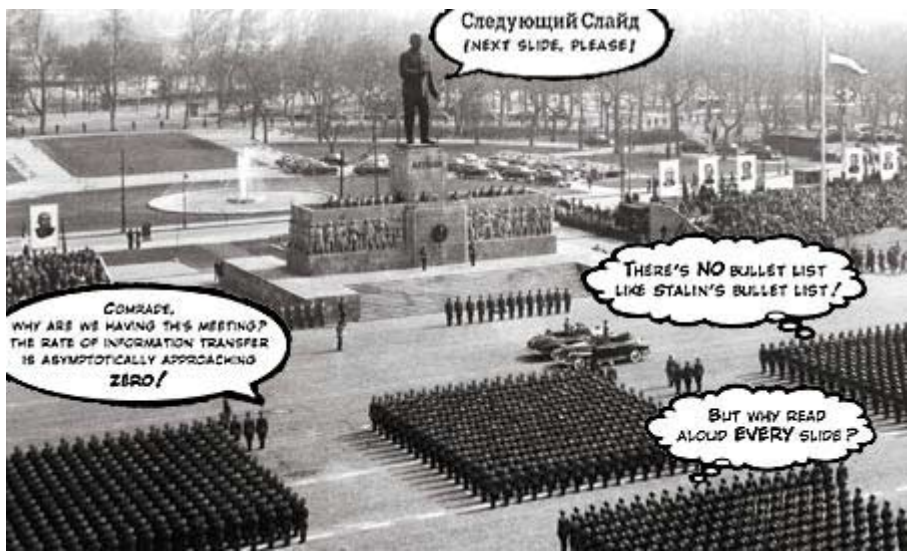
PowerPoint Is Evil

Power Corrupts.
PowerPoint Corrupts Absolutely.

By Edward Tufte



A potential bias in coral reconstruction of sea surface temperature

Andrew Solow & Amit Huppert

Why Do We Need Ecological Proxies Of Climate?

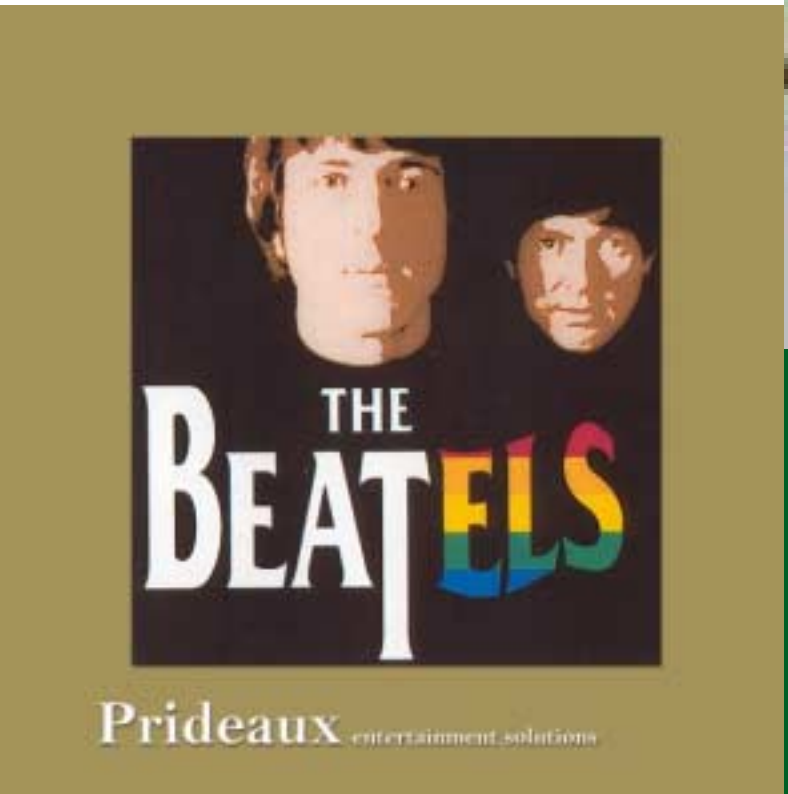
•"The farther backward you can look, the farther forward you are likely to see"

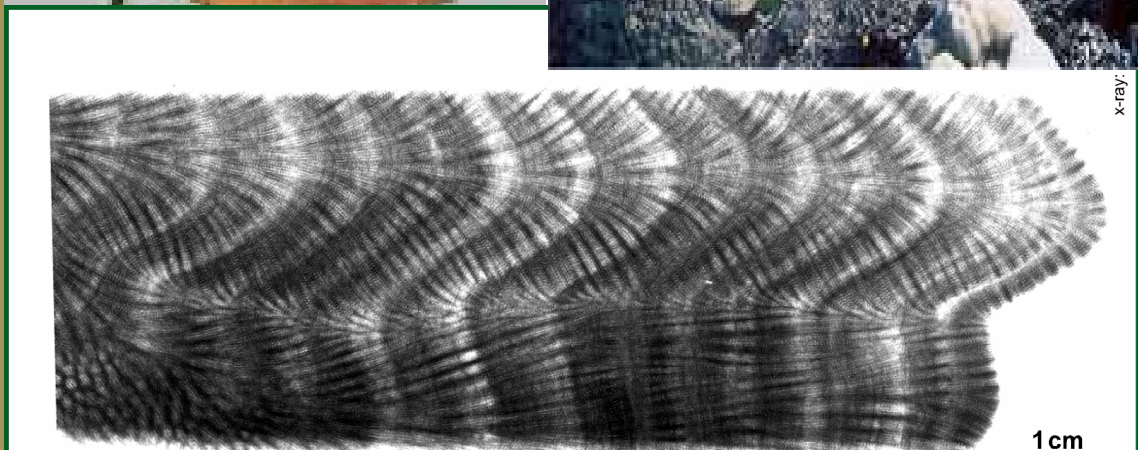
•Paleoclimate resea lied scientific objectives.

•The coverage of in space and time were poor before th g from space and non-existent before truments.

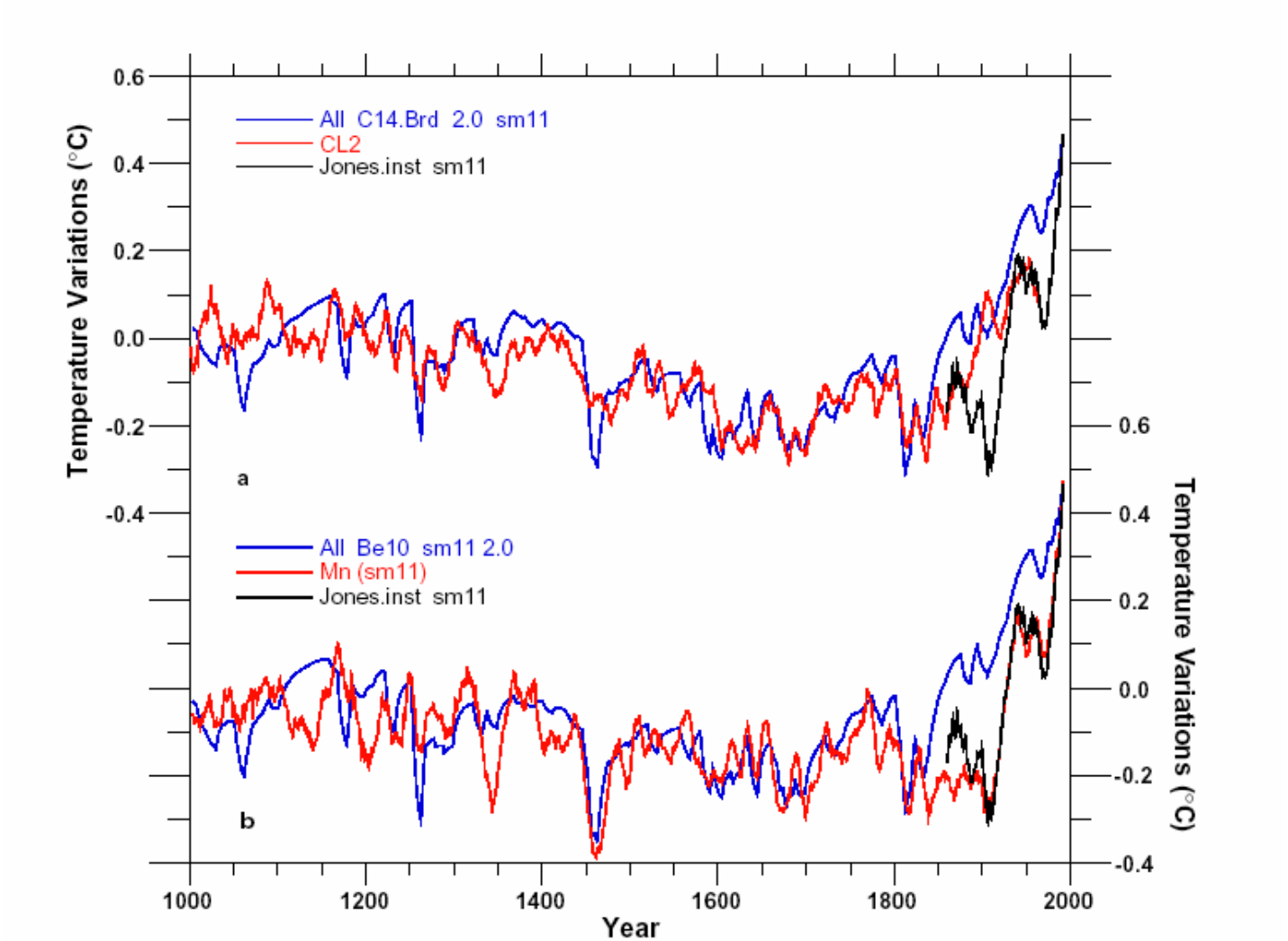
Paleoclimate

In order to study climatic changes over decades or even centuries time scale we have to rely on reconstruction using natural archives (e.g. tree rings, corals, beetles, pollen, ice cores, and laminated lake/ocean sediments) as proxies.



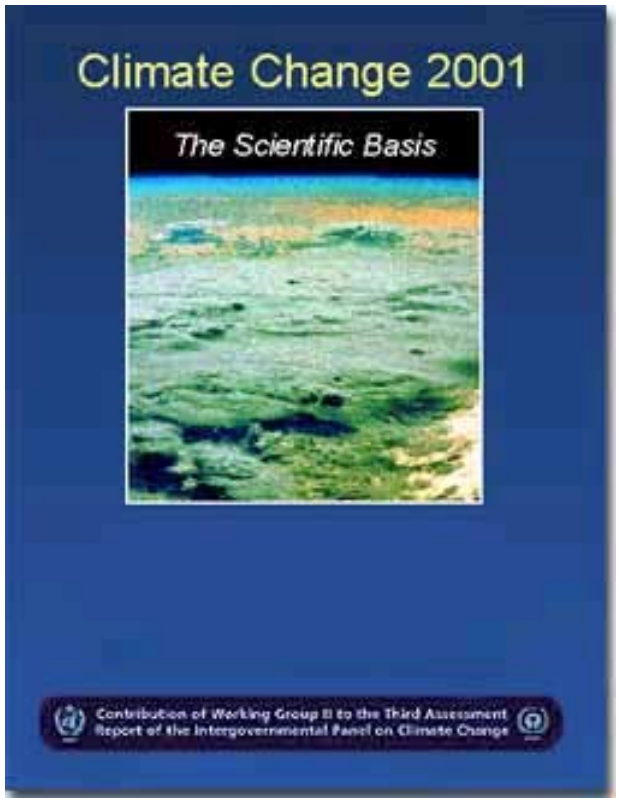


Validation of Climate Models



CLIMATE COLLAPSE
The Pentagon's Weather Nightmare

The climate could change radically, and fast. That would be the mother of all national security issues.



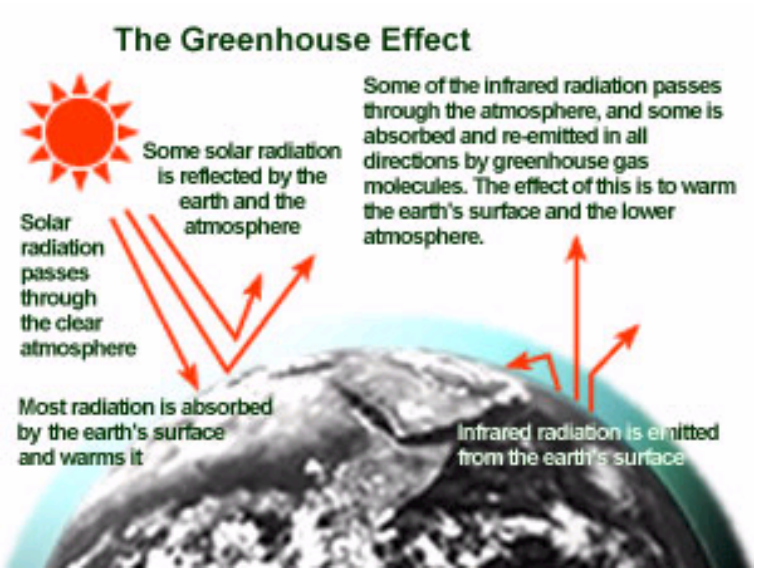
Early Civilizations Casualties of Rapid Climate Change

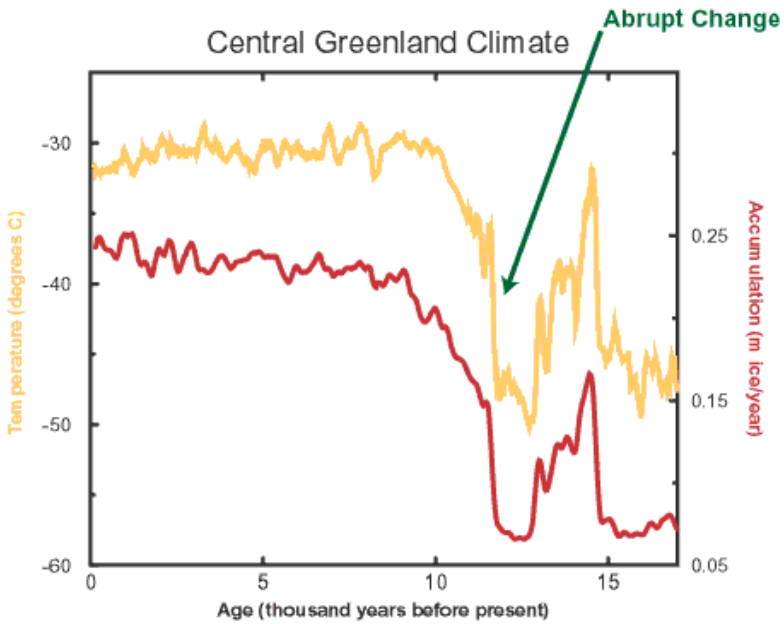
ARCHAEOLOGY:

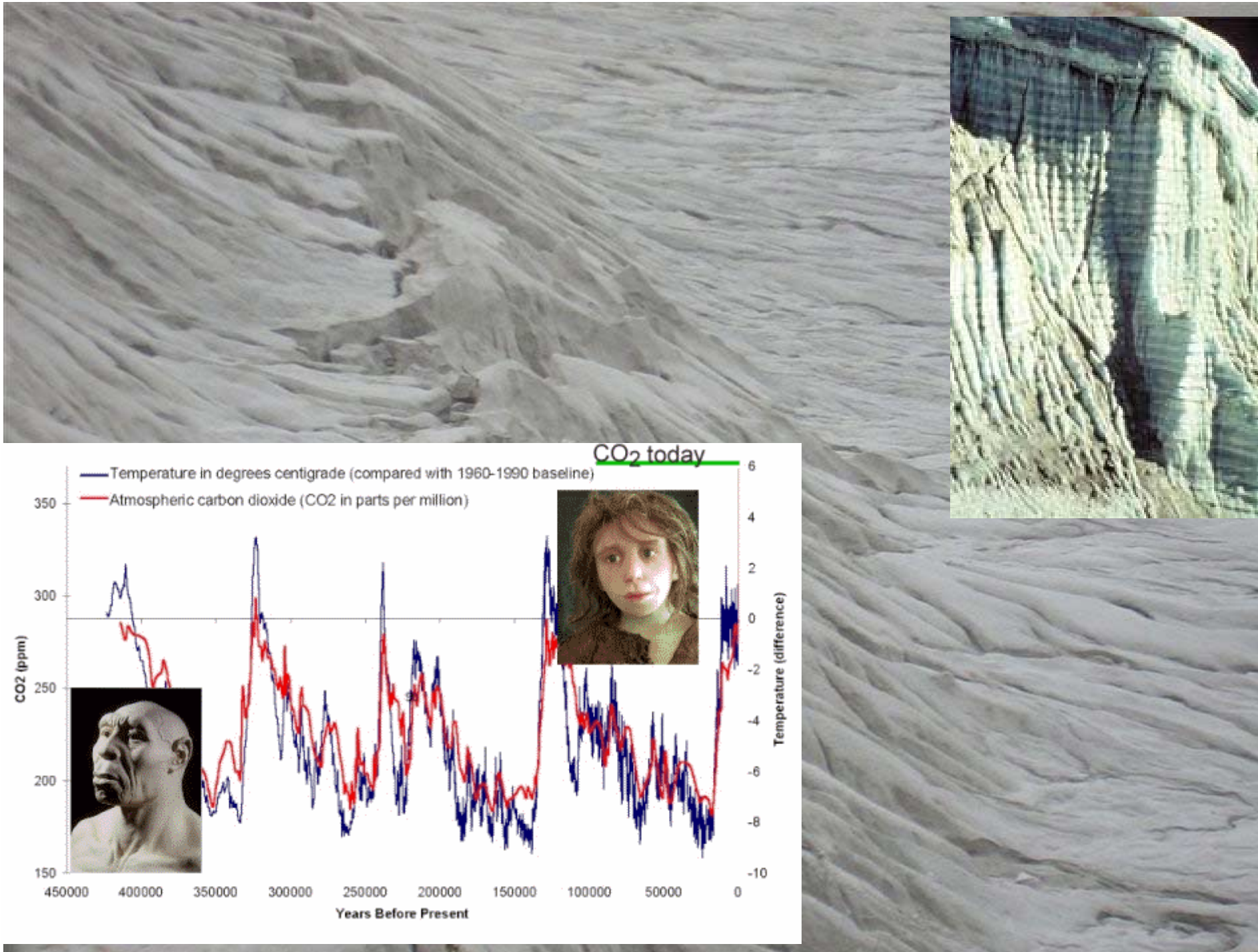
What Drives Societal Collapse?

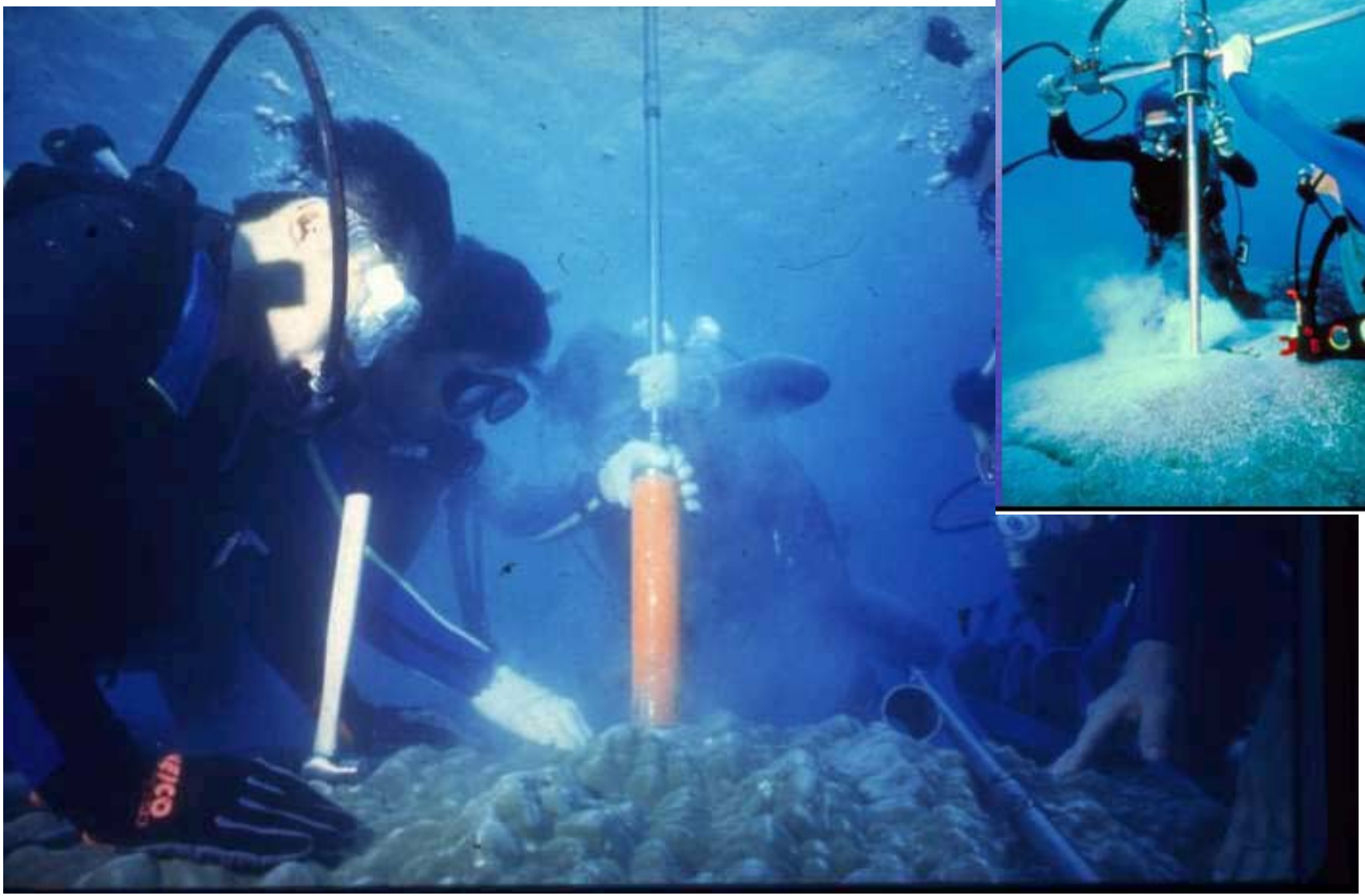
Science, Jan. 26, 2001

Paleoclimate studies help us to quantify properties of Earth's climate, including the forces that drive climate change and the sensitivity of the earth's climate to those forcing (e.g. the potential effects of human-induced climatic change.)

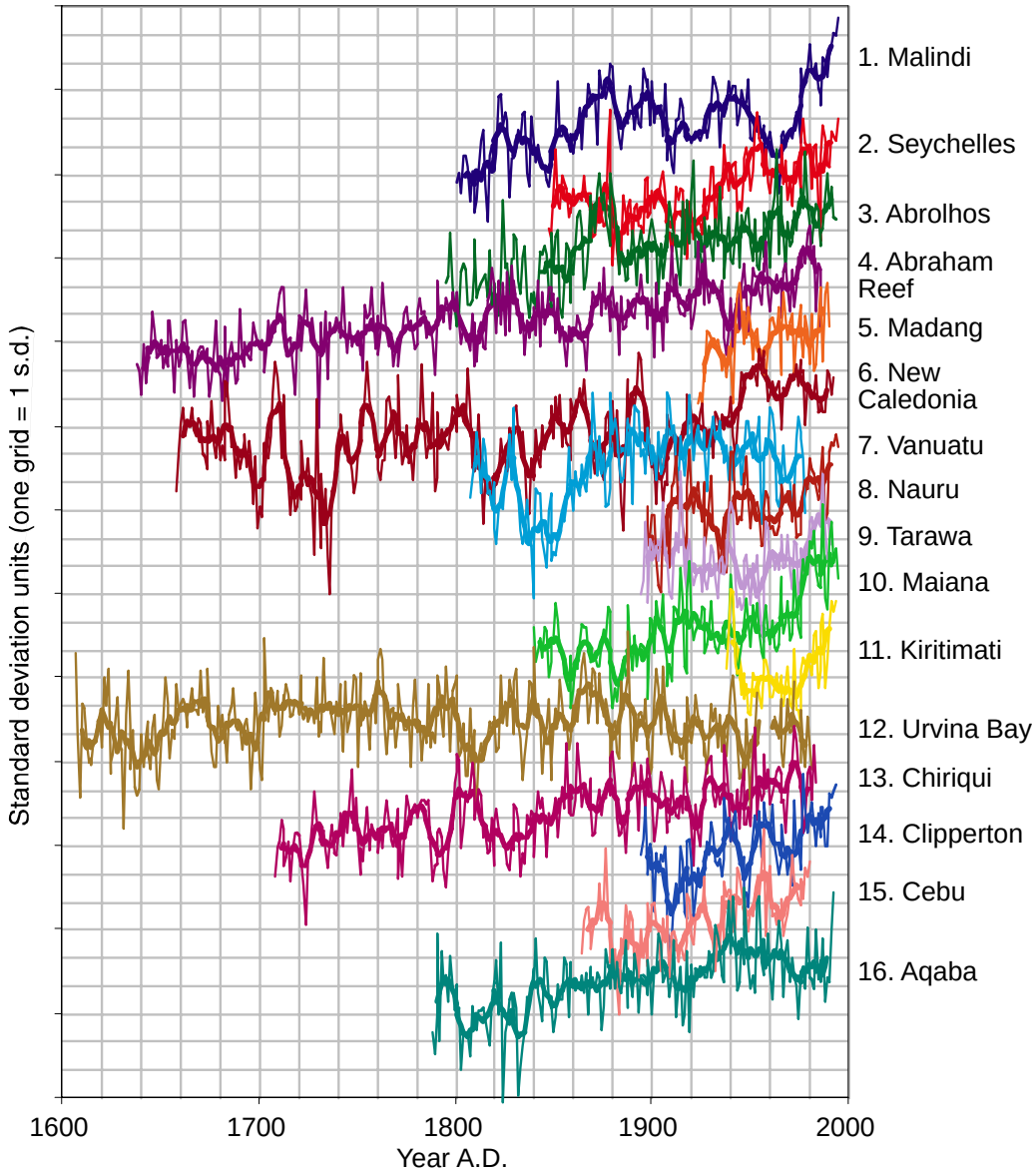





CO_2 today
Temperature in degrees centigrade (compared with 1960-1990 baseline)
Atmospheric carbon dioxide (CO2 in parts per million)
CO2 (ppm)
Temperature (difference)
350
300
250
200
150
6
4
2
0
-2
-4
-6
-8
-10
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Years Before Present

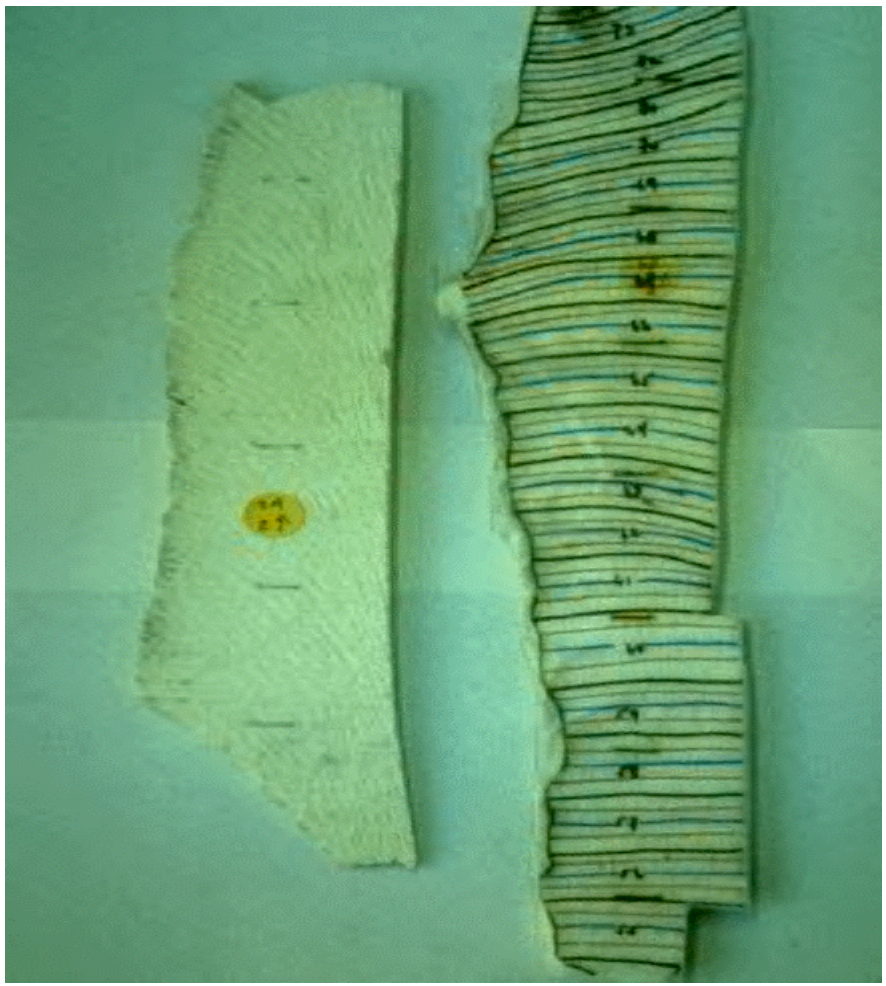


• The corals used for palaeoclimate reconstruction grow throughout the tropics in relatively shallow waters, often living for several centuries. Accurate annual age estimates are possible for most sites using a combination of annual variations in skeletal density and geochemical parameters.



google et al 2005

Corals, like tree rings, also form layers on an annual basis. Corals can live for centuries, and they deposit bands of calcium carbonate at a rate of 10-20 mm/yr on their skeletons.



How to reconstruct temperature using coral isotopic measurements

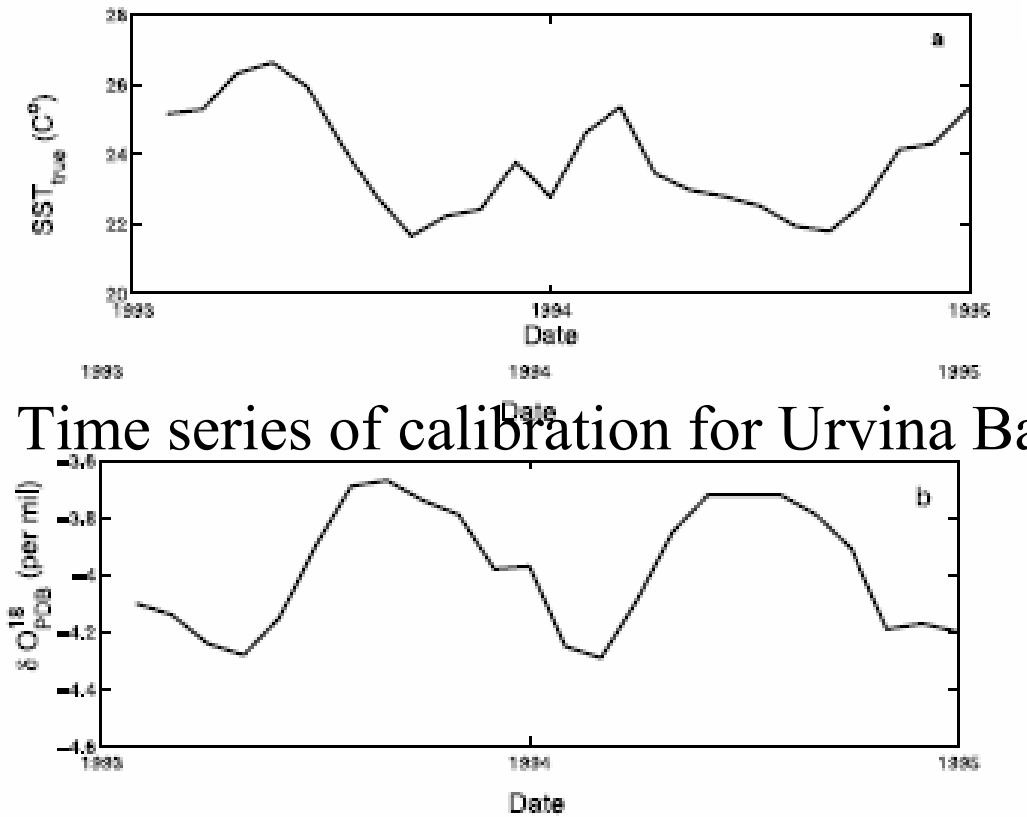
Let *Y* denote an isotopic measurement in a coral and let *SST* denote the corresponding sea surface temperature. These quantities are assumed to be related through the simple linear regression model:

$$Y = \beta_o + \beta_1 SST + \varepsilon$$

where β_o , β_1 and are unknown regression parameters and ε is an error with mean 0 and unknown variance σ_ε^2 . This error includes both error in the isotopic measurement and variability in *Y* unrelated to variability in *SST*.

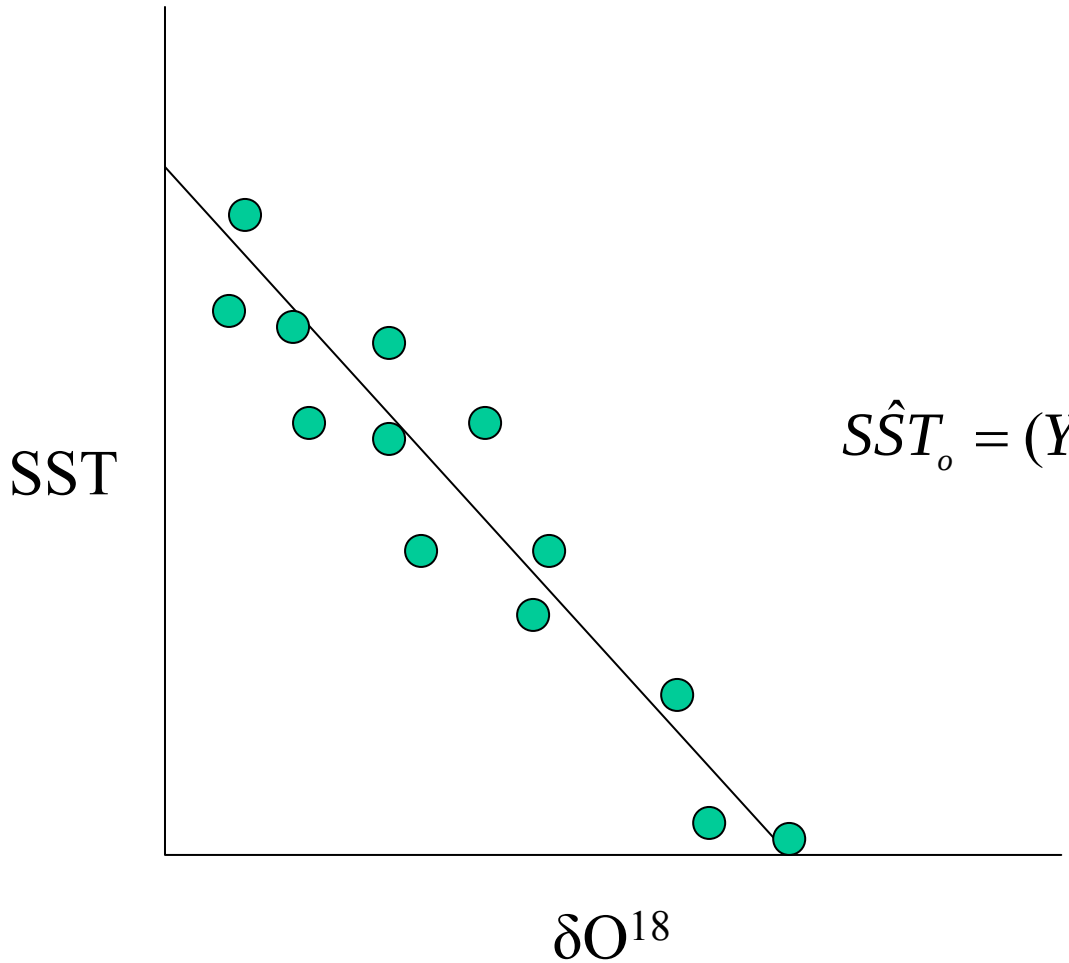
Let $\hat{\beta}_o$ and $\hat{\beta}_1$ be the estimates of β_o and β_1 , respectively.

$$\hat{SST}_o = (Y_o - \hat{\beta}_o) / \hat{\beta}_1$$



Time series of calibration for Urvina Bay

Figure 1. Time series of calibration $\delta^{18}O$ values for two Urvina Bay corals (a) Ur-1 and (b) Ur-3.



$$\hat{\beta}_o = -0.44$$

$$\hat{\beta}_1 = -0.15$$

$$\hat{SST}_o = (Y_o - \hat{\beta}_o) / \hat{\beta}_1$$

The Problem

- The model is fit by regression using a calibration sample consisting of paired isotopic and sea surface temperature measurements.

- This fitting assumes that sea surface temperature is measured without error during the calibration period.

- **This assumption is not always realistic. For example, error can arise when sea surface temperature is not measured at the location of the coral or when the pairing of sea surface temperature and isotopic measurements is imperfect.**

The Effect of Measurement Error in SST

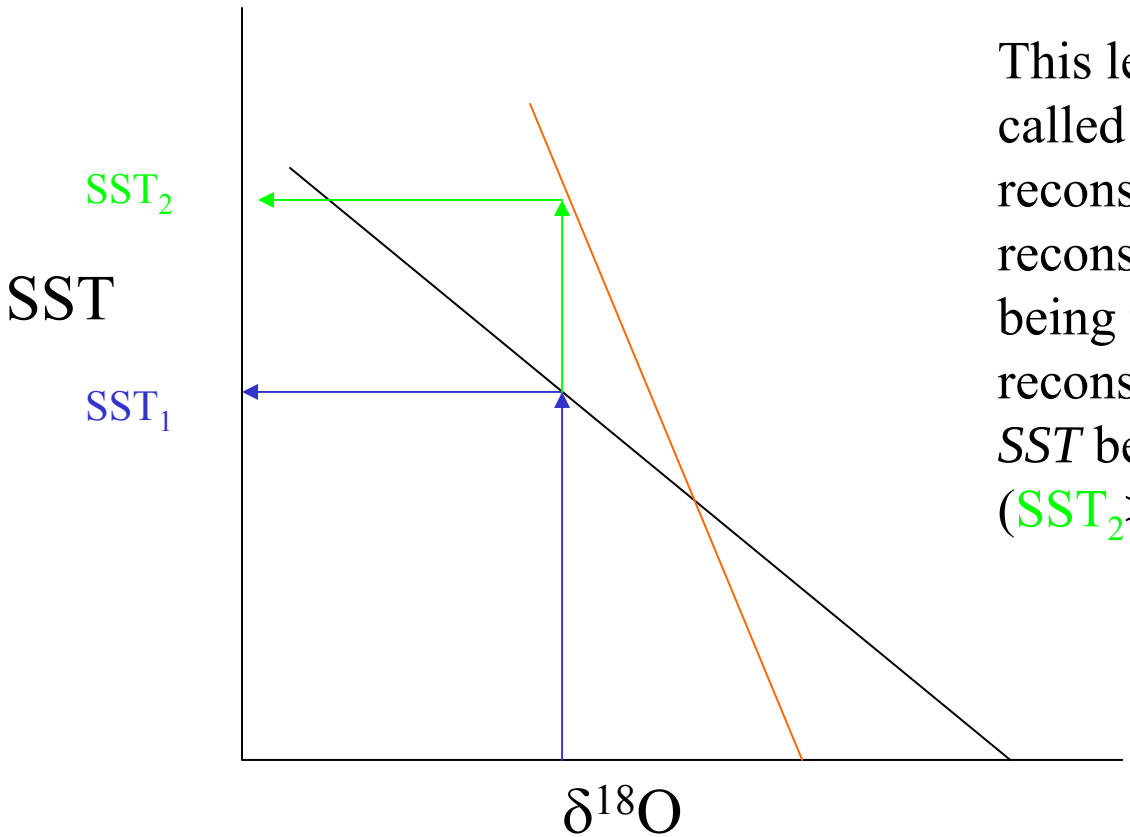
Suppose that, in addition to measurement error in *Y*, there is measurement error in *SST*. Specifically, suppose that:

$$SST_{meas} = SST_{true} + \eta$$

where SST_{meas} is measured sea surface temperature, SST_{true} is the true sea surface temperature, η and is a measurement error with mean 0 and variance σ_{η}^{2} .

In this case, the estimates $\hat{\beta}_o$ and $\hat{\beta}_1$ are biased. In qualitative terms, the effect of measurement error in *SST* is to attenuate the fitted regression model (i.e. on average, $\hat{\beta}_1$ is closer to 0 than β_1).

Accentuation in SST reconstruction



This leads to what might be called accentuation in *SST* reconstruction, with the reconstruction of a cold *SST* being too cold and the reconstruction of a warm *SST* being too warm ($SST_2 > SST_1$).

Bias Correction

$$Y = \beta_o + \beta_1 SST + \varepsilon$$

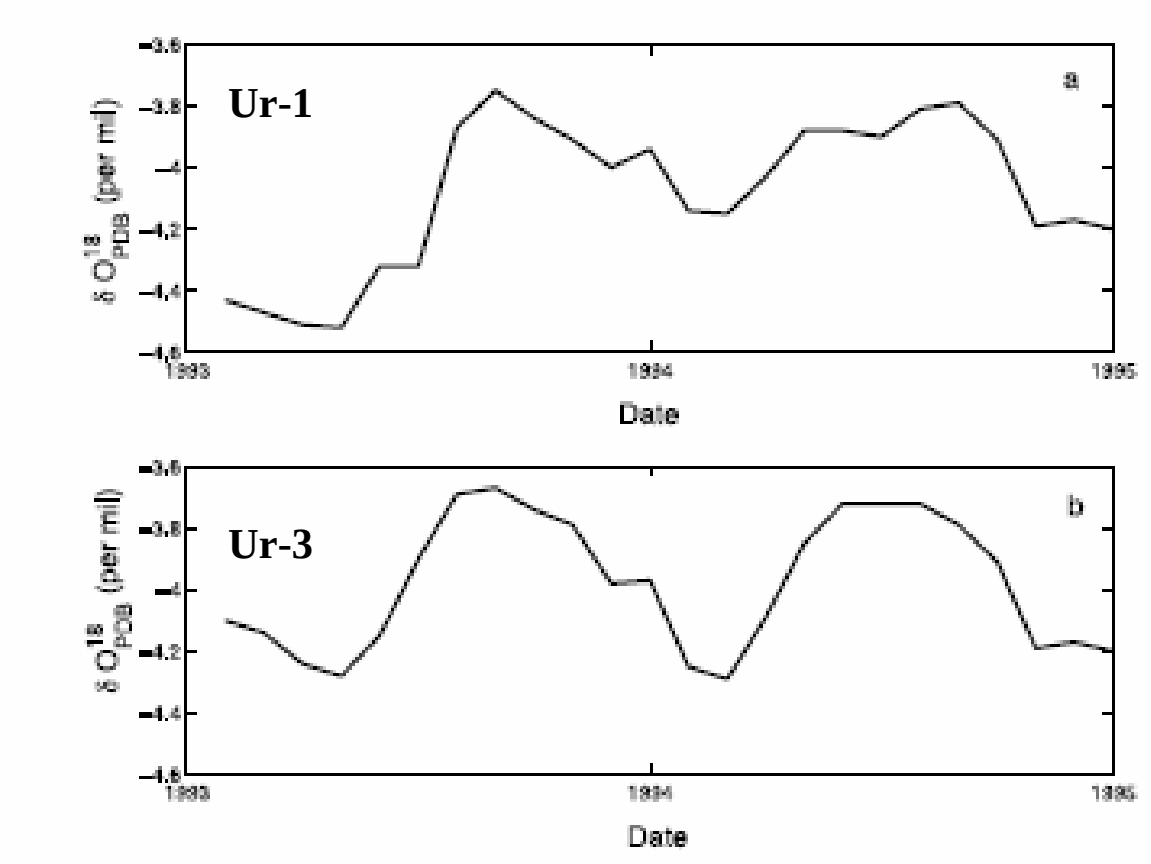
The bias-corrected estimates of β_o and β_1 :

$$\tilde{\beta}_1 = \hat{\beta}_1 / \hat{\lambda}$$
$$\tilde{\beta}_o = \bar{Y} - \tilde{\beta}_1 \overline{SST}_{meas}$$

Here $$\hat{\lambda} = \frac{\sigma^2_{meas} - \sigma^2_{\eta}}{\sigma^2_{meas}}$$

where σ^2_{meas} is the sample variance of the measured SST values in the calibration sample, σ^2_{η} is the variance of SST measurement error and $\overline{SST}$, $\bar{Y}$ is the mean of SST_{meas} and isotopic measurments in the calibration sample.

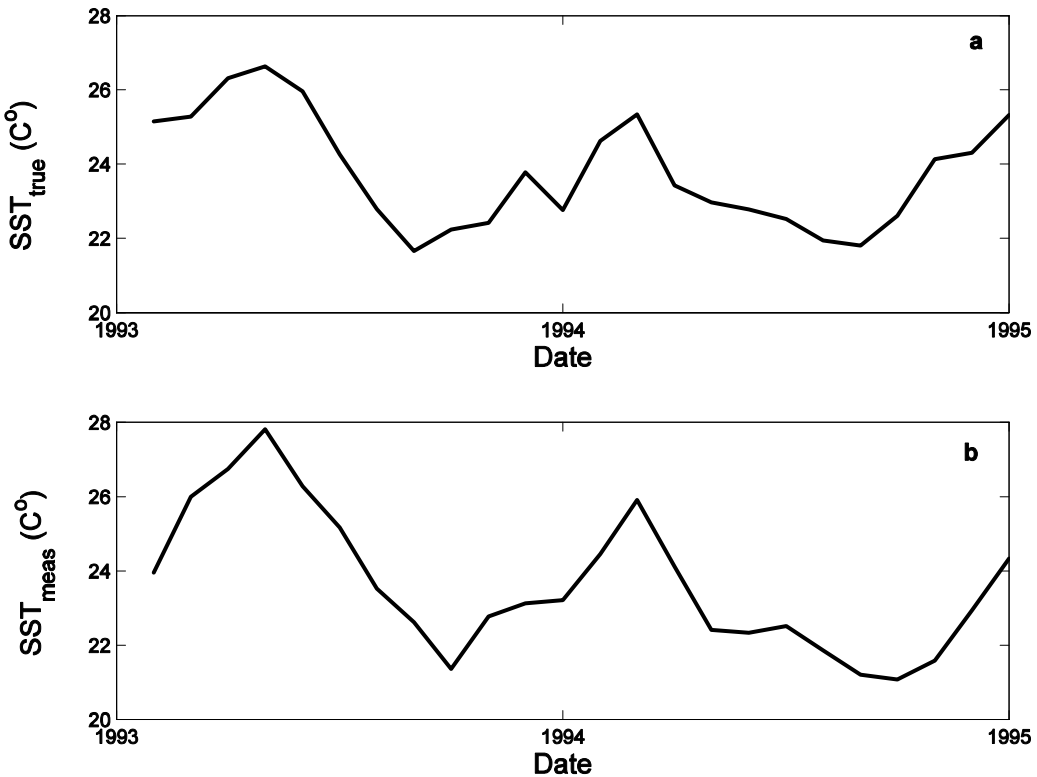
An Illustration



Data from Wellington et al 1996

Pavona clavus from Urvina Bay Galapagos Islands

Bias calculation for Ur-1



$$\beta_0 = -0.44$$
$$\beta_1 = -0.15$$

$$\beta_0 = -1.54$$
$$\beta_1 = -0.11$$

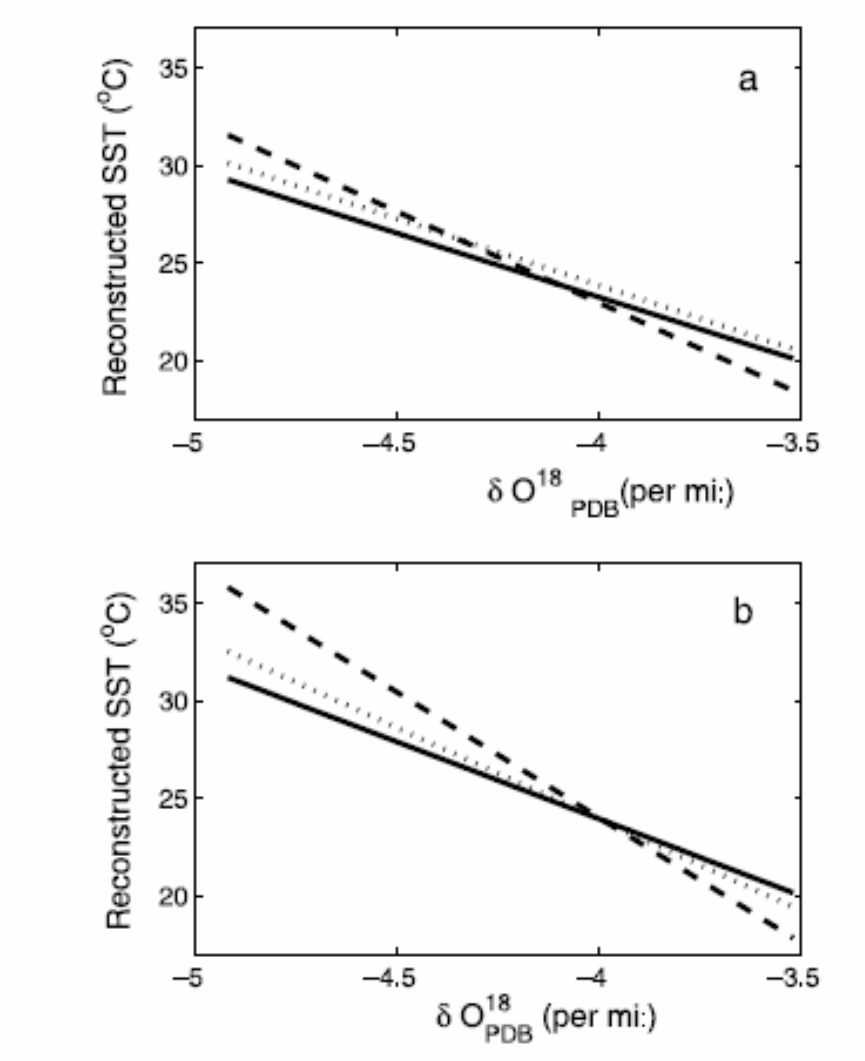
Time series of calibration *SST* values for (a) Urvina Bay and (b) Bartolomé.

$$SST_{true} - SST_{meas}$$

$$S\hat{S}T_o = (Y_o - \hat{\beta}_o) / \hat{\beta}_1$$

$$\sigma_\eta = 0.92^0 C$$

$$\mu = 0.15^0 C$$



SST reconstruction plots for (a) Ur-1 and (b) Ur-3. In each case, the solid line is based on SST_{true}, the dashed line is based on SST_{meas}, and the dotted line is based on bias correction.

$$\hat{SST}_o = (Y_o - \hat{\beta}_o) / \hat{\beta}_1$$

	estimate of β_o	estimate of β_1
Ur-1		
using SST_{true}	-0.44	-0.15
using SST_{meas}	- 1.54	-0.11
bias-corrected	-0.49	-0.15
Ur-3		
using SST_{true}	-0.96	-0.13
using SST_{meas}	-2.13	-0.08
bias-corrected	-1.44	-0.11

Conclusions

The basic result, shown here, is that even relatively **modest** measurement error can lead to a relatively **large accentuation bias**, particularly at and beyond the range of conditions during the calibration period.

Good News

Provided the variance σ_η^2 of the measurement error can be estimated, the bias-corrected reconstruction we developed provides a simple way to correct for this bias.

Bad News

It is Worth pointing out that the use of a poor estimate of σ_η^2 could lead to a bias-corrected reconstruction whose bias is actually greater than that of the uncorrected reconstruction.

Is the reconstruction bias important?

- There is an inconsistency between climate reconstruction using foraminifera and corals.

  (temperatures reconstructions using corals yield higher temperatures of about 2^{o} C.)

- An unbiased climate reconstruction is crucial for estimating the true magnitude of global climate change.