EAS 8001 Climate Seminar : The Hockey Stick.
Lab session : Uncertainties in proxy records

October 22nd, 2007

Due Nov 5th, 2007.

1 Introduction

In the past 4 weeks, you have seen what proxies are used in studies like MBH98, their strengths and their weaknesses. The aim of this lab is to acquire a first-hand account of the difficulties arising in processing and interpreting paleoproxy data.

You may work in groups of 2 or 3 provided each student turns in a report. Please all label axes on figures (one figure per section should suffice). Undergraduates are only required to complete the sections marked by an asterisk (*).

Instructions are in *slanted* font :

- *launch Matlab*
- *In your home directory, move to the EAS8001_lab folder.*

2 Coral records : an example from Palmyra

Load `CORAL.mat` . The relevant structures, `Palmyra, NINO34 and nearest_SST` are now in the workspace. Palmyra is the δ^{18}O data from *Cobb et al.* [2003] and NINO34 is from the *Kaplan et al.* [1998] dataset.

- Inspect the METADATA : `http://www.ncdc.noaa.gov/paleo/pubs/cobb2003/cobb2003.html`. What are dating uncertainties for the most recent coral timeseries (twentieth century) ? For earlier portions ?
- Do the same thing for the NINO34 index from the Kaplan dataset `http://iridl.ldeo.columbia.edu/SOURCES/.Indices/.nino/.EXTENDED/.NINO34/`. What does NINO34 represent ?
- Standardize both series using `standardize.m`. Compute correlations (hint : use `corrcoef.m`). Plot NINO34 and δ^{18}O against their respective time axis.
- Bandpass the series in the [2;8] years range (using `wavelet_filter.m`). Plot and compute correlation coefficients as above.
- Bandpass the series in the [9;30] years range. Plot and compute correlation coefficients as above. You may want to present three plots on one figure using `subplot.m`)
- **Question 2.1** : Is Palmyra δ^{18}O a good proxy for NINO34 ? On which timescales ?

- **Question 2.2** : Imagine you had 1000 years of δ^{18}O data, performed the δ^{18}O /NINO34 calibration over the past 30 years of data and tried to extrapolate back in time. How would this "band-specific" correlation affect your reconstruction ?

3 Tree rings : the divergence problem *

Load `TREE.mat` , which is the data in figure 6 of the *Briffa et al.* [1998] article (time, maximum latewood density (MXD) and Apr-Sep temperature at high-northern latitudes). Let us investigate the non-stationarity of the relationship with Northern Hemisphere temperature.

- **Question 3.1** : Plot `MXD` and `Temp` vs `tt`. Compute correlations before and after 1950. Is MXD a useful temperature proxy ? Why and why not ?
- **Question 3.2** : Now imagine you perform a calibration of the MXD-temperature relationship over 1940-1980. Would this effect tend to over or under-estimate past temperatures in high Northern latitudes ?
- **Question 3.3** : Would this increase or decrease the 'shaft' of the hockey-stick ?

4 Sediments records : non-linearity of climate proxies

You have seen in the article by *Rein et al.* [2004] that one can use sediments to reconstruct El Niño-related floods in Peru. This proxy is clearly non-linear, as the amount of lithic grains in the core will record droughts or floods very differently (how ?). It is, moreover, affected by noise like any other proxy.

Imagine that the fraction of lithic grains in this core is a quantity Y, related to the intensity of El Niño-Southern Oscillation by a nonlinear relationship. Further assume this relationship writes :

$$Y = \alpha NINO34^{\beta} + \gamma\epsilon \tag{1}$$

where $\epsilon \rightarrow N(0,1)$ is a model for the non-climatic information or "noise" in the proxy. Let us assume this error to be a Gaussian random variable with 0 mean and unit standard deviation. In Matlab, one can generate a realization of this stochastic process using `randn.m`. In `SEDIMENT.mat` you will find the same NINO34 timeseries as before.

- **Question 4.1** (NONLINEARITY) : For parameters $(\alpha, \beta, \gamma) = (0.4108, 2, 0.5)$,generate Y and plot it vs t along NINO34. Say one defines El Niño events as periods where NINO34 $> 2\sigma$ for at least 3 months. How many events can you find in the NINO34 series ? How many in the Y timeseries ? Is it possible to reconstruct La Niña episodes (NINO34 $< -\sigma$ for more than 3 months)? Why ?
- **Question 4.2** (NOISE LEVEL) : Now $(\alpha, \beta, \gamma) = (0.2896, 2, 0.8)$. Repeat the previous exercise. Given a measurement of Y, what can you say about NINO34 ?
- **Question 4.3** (ALIASING) : Let $(\alpha, \beta, \gamma) = (0.4108, 2, 0.5)$ again. Now imagine the sediment deposition process is akin to a subsampling of Y(t) every 5 years. Resample the series accordingly, and plot the corresponding timeseries Y_a (for 'aliased') on the same graph as Y. What can you say about NINO34 given Y_a ?

5 Ice Core and borehole records *

Load `ICE.mat` , which is the ice core δ^{18}O data from Quelccaya (Peru), used in MBH99.

- Read the metadata in http://www.ncdc.noaa.gov/paleo/icecore/trop/quelccaya/quelccaya_data.html. What is the chronological uncertainty in these ice core measurements ?
- Plot the raw data `d` vs `t`.
- In order to verify the claim that δ^{18}O is a proxy for local temperature, look at the structure `NCEP`, which contains temperature from the NCEP/NCAR Reanalysis (http://ingrid.ldeo.columbia.edu/description.ncep-ncarreanalysis.html) at 11 pressure levels (P) throughout the atmosphere. The lowest, 1000 mb, is around sea-level. The highest, 150 mb, is near the stratosphere.
- Plot `NCEP.Ta` vs t at 1000, 500 and 250mb. What do you notice ?
- Compute correlations of δ^{18}O with temperature at all 11 levels [you may want to write a loop]. What pressure level has the highest correlation ? Can you think of a reason why ? (assume that the correlations are all significant at the 95% level).
- Now imagine we want to use to groundtruth Quelccaya δ^{18}O as a proxy for Northern Hemisphere temperature. The latter is available from 1881 onwards from http://data.giss.nasa.gov/gistemp/ (structure `NH` in your workspace). Plot `NH.temp` vs t. What do you notice ?
- Correlate NH temperature and Quelccaya δ^{18}O . What do you notice ?

  Based on the above observations, answer the following questions :

- **Question 5.1**: Is Quelccaya δ^{18}O a good of proxy local temperature ? Of local *surface* temperature ? (explain)
- **Question 5.2**: Is Quelccaya δ^{18}O a good of proxy of some other quantity ?
- **Question 5.3** Is it one you would include in a multiproxy-recontruction of northern hemisphere temperature ?

6 Conclusion

Question 6 (unrated) So, which proxy do you trust the most? Why ?