

## LAB

# Paleoclimate Reconstruction from Oxygen Isotopes in a Coral Skeleton from East Africa

### TIPS ON HOW TO COMPLETE THIS LAB

1. This lab requires you to use Microsoft Excel or some other spreadsheet software that has the required functionality. If you are doing something overly repetitive in Excel, you are not using the software properly and should ask for help.
2. Answers to the questions should be typed in a Microsoft Word or some other word processor document (with a proper header). Include your last name in the filename when saving the document and email it to your instructor.
3. Always use leading zeros: Example: 0.5 versus .5.
4. All figures (or graphs) should be numbered consecutively (Figure 1, Figure 2, etc.). Add a caption below the figure that gives a brief description of the information in the figure; the caption should include the source of the data. Make sure all graphs look professional (use the graphs presented in lectures as examples and ask your instructor to check your graphs prior to copying them to your text document).

### OBTAINING THE DATA

For this lab, you will need to find the NOAA Paleoclimatology database on the Internet. Once there, find the coral data set from Malindi, Kenya, published by J.E. Cole, R.B. Dunbar, T.R. McClanahan, and N. Muthiga in 2000 (you want the oxygen isotope data set). Note that there are two files of interest: the “Malindi (2000) annual data README file” and the “Malindi (2000) annual O18 Data.” Save the data set to your computer and then open it from within Excel (open Excel and then open the file, making sure “open all file types” is selected). All the data should be in separate cells (do not do this manually!). In the end, you should have three columns: date, oxygen isotope values (O18), and local SST. Note also that the O18 data are the same as the  $\delta^{18}\text{O}$  data discussed in the class lecture and are given in ‰ units (pronounced “per mil”). SST stands for sea surface temperature and is given in degrees Celsius ( $^{\circ}\text{C}$ ).

### Task 1

Research the background of the data by reading the README file. Type the answers to the following questions into a Word document under a header labeled Task 1.

- (a) At what water depth did the coral grow? Is this considered deep or shallow water?
- (b) How did the researchers assign dates to each of the  $\delta^{18}\text{O}$  data points?
- (c) Which ocean is this coral record from?
- (d) Why are some SST data missing between 1951 and 1989?

### Task 2: Calibration

Your goal is to reconstruct past SST from the coral  $\delta^{18}\text{O}$  data. You have some SST data between 1951 and 1989 and  $\delta^{18}\text{O}$  data going back to 1801. Plot (graph)  $\delta^{18}\text{O}$  vs. SST, then fit a regression line (trendline) through the data (Hint: Excel Charts layouts will do this for you). Select the options to display the equation and the  $R^2$  value on the graph. Remember what types of data belong on the x- versus y-axes (i.e., dependent vs. independent variables).

You can read about regressions here: [http://graphpad.com/guides/prism/6/curve-fitting/index.htm?reg\\_linearreg.htm](http://graphpad.com/guides/prism/6/curve-fitting/index.htm?reg_linearreg.htm).

After your graph is finalized and approved by your instructor, follow these steps:

- (a) Copy and paste your graph into your Word document under a header labeled Task 2A and add a brief figure caption (see Tips on How to Complete this Lab above).
- (b) In your Word document, under the header Task 2B, explain what  $R^2$  means in the context of your regression. What is the change in  $\delta^{18}\text{O}$  value per  $^{\circ}\text{C}$ ?
- (c) In your Word document, under the header Task 2C, rewrite your regression equation so that you can calculate SST from  $\delta^{18}\text{O}$  (i.e., solve for x). Write it out using SST and  $\delta^{18}\text{O}$  in place of x and y. This is your *paleotemperature equation*.

### Task 3: Validation

Paleoclimatologists usually validate their paleotemperature equations using sections of the coral data not used in making the paleotemperature equation. Here, for simplicity, and to help learn about regression statistics, we will use all of the SST data to make the paleotemperature equation and then validate it on the same data.

Using your paleotemperature equation, calculate SST for each year from the  $\delta^{18}\text{O}$  data you used to develop the equation (do not use any of the  $\delta^{18}\text{O}$  data not used to make the equation). Plot the calculated SST vs. measured SST. Copy and paste your graph into your Word document (use the header “Task 3”) and write a caption for your figure.

Next, type the answers to the following questions in your Word document under Task 3.

- Examine your slope and intercept. What do they mean? What would you expect them to be?
- Has the  $R^2$  value improved from the calibration graph? Why/why not?

### Task 4: Error Estimation

For this task, you will calculate the error on your temperature reconstruction. Again, paleoclimatologists typically do this on a section of data not used in the calibration, but here you will use all data for which we have paired measured SST and calculated SST. You will calculate the root mean square error (RMSE), which is an error estimation technique used widely in paleoclimatology. To do this, first calculate the difference between the measured SST and calculated SST. Next, square this difference, then calculate the average of the squared differences. Finally, to get RMSE, calculate the square root of this average.

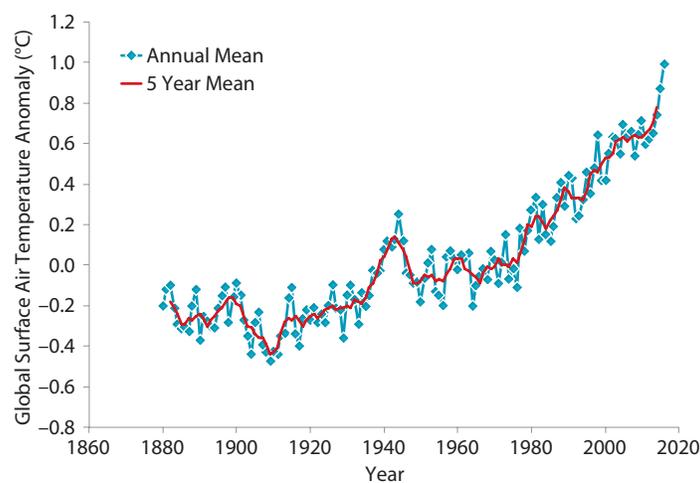
Doing these calculations in Excel is simple. Add a column for each of the operations listed above, starting with the difference between measured SST and the calculated SST (use a formula similar to  $=A2-B2$ , where A2 and B2 are the cells of observed and calculated SST, respectively). To square data, add another column and enter a formula similar to  $=C2^2$ , where C2 is the cell with “observed-calculated SST.” Next, calculate the average of the data in the “squared difference” column using  $=\text{average}(D2:D12)$ , where D2:D12 is the range of data in the last calculation. You, of course, only calculate one average. Finally, to take the square root of this, use  $=\text{sqrt}(E2)$ , where E2 is the cell with the average squared difference. This is your RMSE, which gives a good indication of the error associated with your calculated SST (in  $^{\circ}\text{C}$ ). Variations smaller than the RMSE cannot be considered detectable.

### Task 5: Climate Reconstruction

Now, use your paleotemperature equation to calculate SST for all years from 1801 to 1994. Make a plot of calculated SST vs. year. Copy and paste your graph into your Word document, label it Figure 3, and write a brief caption describing the data used in the figure.

### Task 6: Comparison with Other Climate Records

Visually compare the data you generated (your Figure 3) to Figure A below. How do they compare? When comparing, use  $R^2$  and RMSE in your argument. Do you consider your paleotemperature equation to be robust? Discuss your data with these questions in mind and write a succinct (five to six sentences) abstract.



**FIGURE A.** A line plot of global annual mean surface air temperature change from 1880 to 2016, with the base period 1951–1980 (the average value subtracted from the data), derived from the meteorological station network. Data from the US National Aeronautics and Space Administration ([http://data.giss.nasa.gov/gistemp/graphs\\_v3](http://data.giss.nasa.gov/gistemp/graphs_v3))