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GEOL 162 Lab exercise: Exploring El Niño

Objectives:

- Exploring what characterizes the El Niño Southern Oscillation (ENSO), and how conditions in the tropical Pacific Ocean are tracked.
- To analyze and interpret data from the TAO array to explore changes in the tropical Pacific Ocean associated with recent El Niño and La Niña events.
- To interpret oxygen isotopic data from corals which hold a record of past ENSO events.

Directions: This lab exercise is designed to explore the ocean-atmospheric phenomenon known as El Niño. Although El Niño events have been occurring for thousands of years the phenomenon has only received significant attention in the past 30 years during which two particularly damaging events (1982-83 and 1997-98) have had global impact through changes in weather resulting in floods, droughts, and other extreme weather events that have had estimated costs in the billions of dollars. **For all parts (A – C) of this lab, please answer questions directly on your lab handout.**

A. What happens in the ocean during an El Niño and how do we monitor the events? (~30 min.)
Instructions: While viewing a portion of the NOVA program, "Chasing El Niño", please take notes on the following questions:

1. **What changes from "normal" conditions in the tropical Pacific Ocean (in terms of winds and distribution of ocean temperatures) occur during El Niño years?**

2. **Much of this program is devoted to describing a system used by oceanographers to track changes in the tropical Pacific Ocean. Describe this system.**

3. **Desribe the impacts of El Niño on climate and weather for both the western Pacific (such as Indonesia and Australia) and the eastern Pacific (such as Peru and Ecuador) as illustrated in this program. What impacts can this have on the West coast of the U.S.?**

Immediately following the program I will illustrate some of the key changes between El Niño and normal conditions on the board.

4. In the space below make a sketch of a <u>cross section</u> of the ocean from the surface to 500 m depth extending from the Western Pacific (coast of Australia) to the eastern Pacific (coast of S. America) during a <u>"normal" year and an El Niño year</u>. Draw arrows (and label them) to illustrate (1) the direction of the prevailing winds, (2) the direction of movement of the surface water that would create upwelling currents off the coast of Peru, (3) the relative thickness of the well-mixed surface water layer across the basin, and (4) the slope/shape of the thermocline.

"Normal" conditions

El Niño conditions

B. Using the TAO web site to explore El Niño (about 1 hour)

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The Tropical Atmosphere Ocean project (TAO) has produced amazing results in its exploration of El Niño and other phenomena in the equatorial Pacific Ocean.
The success of this program is based on oceanographic measurements of temperature, winds, sea height, and other meteorological characteristics using an array of 70 **moorings** that form a transect across the Pacific Ocean. A mooring is an anchored line which vertically extends through the water column and holds a variety of instruments that are spaced to make measurements at specific intervals.

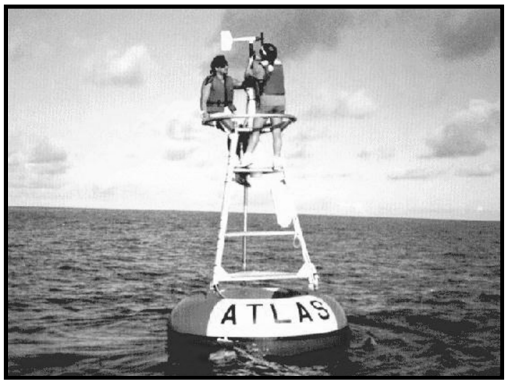

Figure 1. Technicians working on a TAO buoy. (Source: TAO project website)

Instructions:
Throughout this part of the lab, PLEASE READ EVERYTHING CAREFULLY. Questions that you should respond to are in **bold** type.

1. First, open the TAO homepage using the link on the course Blackboard page under "Labs".

2. Now, Take the **"Virtual Tour"** (link found on the Project overview page) and answer the following questions:

3. **What range of latitudes and longitudes are covered by the TAO mooring array?**

Latitudes:

Longitudes:

4. **El Niño has a global influence on climate. Describe 3 geographic regions that tend to be notably warm during the Northern hemisphere winter months of El Niño events and 3 geographic regions that tend to be notably dry.**

Warm:

Dry:

5. Now return to the Project overview page. Click Moorings under the Technical Information heading. View the diagram of the **Standard ATLAS mooring** and read the description of this instrument.

6. **Scroll down on the moorings page. What is the range of depths where temperature measurements are made on each mooring in the Pacific?**

7. **Let's look at some data**. Click the **Data Display** tab at the top of the homepage. We can produce various types of data plots from the TAO database.

8. First, click on the image for the Sea Surface temperature and winds to enlarge. It is particularly important to get a sense of how these current conditions compare to those historically seen across the array. The upper panel of this figure (entitled "Means") shows a map ("birds-eye") view of the tropical Pacific Ocean mean surface temperatures for a 5-day period across the array. The second panel, entitled "Anomalies" will be especially important in this exercise. The word **anomaly** is commonly used in oceanographic studies and is defined as, "A deviation or departure from the normal or common order, form, or rule." In our case, the anomaly is a measurement of the deviation from long-term average temperatures across the Pacific. **Save (or minimize and keep) a copy of this plot for later reference*****

9. **Are there any temperature anomalies at the sea surface across the Pacific currently? Consider any anomaly of + or – 1 degree Celsius to be a potentially significant anomaly. If so, where are the anomalies approximately located?**

10. Now, click the Assorted plots button and enlarge the image that appears on your screen. This is a figure entitled "TAO-Triton 5-day Temperature (°C)" which should show today's date as the ending date. The upper panel of this figure (entitled "Means") shows a cross-section view of average temperatures at each mooring depth across the array on the equator for the last 5 days (actually averaged between 2° N and 2° S). ***Again, save (or minimize and keep) a copy of this plot for later reference*****

11. **Briefly summarize what the data shown in the upper panel indicates about <u>current conditions</u> across the Pacific: Where is the warm surface layer of water at its thickest and thinnest, how does the position and thickness of the <u>thermocline</u> change across the basin?**

12. . Are there any significant (>+/- 1°C) temperature anomalies <u>below the ocean surface</u> in the tropical Pacific Ocean currently? If so, describe where (give approximate range of latitude/longitude and depths):

13. Think about the changes that occur in the ocean during an El Niño event. Refer to the diagram you made on the second page of this lab handout if necessary. Where would you expect to find anomalies during an El Niño event?

14. Let's now explore the 1997 El Niño event, which was particularly large.

- Return to the Data Display page and click the Lat Long Plot button.
- For Plot type, select <u>Sea Surface Temperatures</u> (this should be the default)
- For Time Range select Monthly
- Choose 1997 and January

15. Note the Sea Surface Temperatures (SSTs), (both averages and anomalies) and wind directions in the eastern and western Pacific in the space below. *Save or minimize this plot.

16. Now make the same type of plot for September 1997.
Describe changes in the SSTs and winds that occurred over the 9 month period between January and September 1997.

17. Let's now examine temperatures at all depths across the Pacific.
- Return to the Data Display page and click the Section Plot button.
- Under the select plot type heading choose Depth and Choose Monthly averaging.
- Next select 1997 as the year and September for the Month.
- ***Save or minimize this plot.**

18. At which depths did the greatest temperature anomalies occur in the eastern Pacific?

19. How much warmer were water temperatures in the eastern Pacific compared to normal years (i.e. what is the anomaly)?

20. Look at the plots of current conditions you made earlier to get a sense of the differences between current conditions and the 1997 El Niño. Based on your comparison, what state is the tropical Pacific Ocean in right now (El Niño, normal, or La Niña)?

21. Let's see how the Tropical Pacific has varied over the past 23 years.
Within the Section Plot heading choose Time for Plot Type and select Monthly averaging.
For the Time range use 1991 and the Default and 2014 and Latest as your inputs. Both the first and second plot panels should be "SST" with the first plot panel as "Mean" and the second as "anomaly"

22. View this plot carefully and think about what it is showing you. Over this time period how many individual El Niño events can you identify and what years do they occur in? How many La Niña events and in what years do they occur? (Hint: remember to refer to the Anomalies to get a sense of the deviation from normal conditions. Assume that anomalies of greater than ~+/- 1° C are significant)

El Niño events (years):

La Niña events (years):

Put an asterix (*) next to the year of the strongest El Niño and La Niña events.

C. The Record of Past Sea Surface Temperatures in the Eastern Tropical Pacific (about 30 minutes)

Has El Niño occurred in past centuries and further into the past? One way to test this is to measure the oxygen isotopic values in corals. Like trees, corals have growth bands which they add seasonally (i.e. twice a year) or even over intervals of less than a month. By carefully analyzing each millimeter-thick band one can get a record of temperature changes in the shallow ocean where the corals live. These records extend back centuries to millennia.

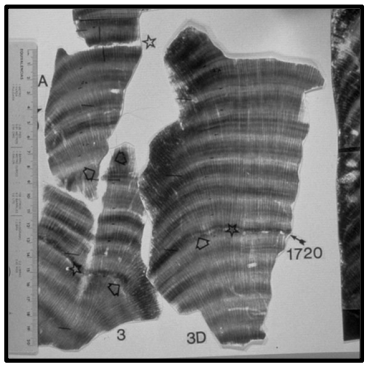

Figure 2. X-radiograph of Galapagos coral. (Photo by Jerry Wellington) Available online http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_231_slide.html

1. Using the Excel file in the Blackboard folder for this lab, plot and neatly label the Urvina Bay coral record of $\delta^{18}O$. Your plot should display changes in $\delta^{18}O$ vs. time. This record was collected in Urvina Bay, Galapagos Islands, 00° 24.52' S, 91° 14.04'W and shows the average $\delta^{18}O$ value from 1854-1981 (with some small gaps).

2. Look at this location on a map of the Pacific that I will post on screen. Why do you think the researchers chose this location to look at the question of past El Niño events (that is, why this location vs. other areas of the Pacific)?

3. Look at the plot. Recall the influence of temperature on $\delta^{18}O$ values in seawater (which are recorded in the calcite of the coral). For review, what is the relationship between sea temperature and $\delta^{18}O$ values?

4. With this in mind, note 3 years of especially warm temps. (possible El Niños) and 3 years of especially cold temps. (possible La Niñas) recorded in the coral.

Warm years:

Cold years:

5. Based on previous studies, a 1 ‰ (1 part per thousand) change in $\delta^{18}O$ values = 4° C change in temperature.
For the Urvina Bay record during what years does the largest change in temperature (over a 2 year period or less) take place? Also, make a calculation to determine approximately how much the seawater temperatures change over this period.

6. There also appears to be a significant change in Urvina Bay temperatures during the most recent part of the record (1961-1981). **Explain the character of this change.**