UWHS Climate Science

Unit 3: Natural Variability

Chapter 5 in Kump et al

Nancy Flowers

ENSO Investigation

Overview

This module provides a hands-on learning experience where students will analyze sea surface temperature data collected over half a century. They will then use this data to determine if the year was an El Niño, La Niña, or normal year. The objective of this module is to have students learn about climate variability, data analysis, and be able to understand the content well enough to create predictions.

Learning Goals

1. To understand and identify the differences between El Niño, La Niña, and normal climate patterns
2. To be able to analyze precipitation data for the Pacific Northwest during El Niño and La Niña years
3. To use Excel to analyze and display data

Prior Knowledge

Students will be asked to perform some basic statistics on a real data set. It is expected that students have some prior experience in either a math or science class of finding the average, standard deviation and linear line of best fit. Students must also know about climate variability (such as El Niño and La Niña events), understand terminology and vocabulary used (such as upwelling), have basic knowledge of geography, and understand and know how to read contour maps.

Grade Level

10-12

Time Required

Part I

- 30 minutes

Part II

- 2+ hours

Part III

- 2+ hours

Materials Needed

Textbook

- Pg. 221-225 (Garrison, Oceanography)
- Pg. 92-96 (Kump, Earth System)

Computer

- Excel
- Internet Access
- Printer
- ENSO Investigation Spreadsheet

Websites

- **El Niño and La Niña animation:** http://esminfo.prenhall.com/science/geoanimations/animations/26_NinoNina.html
- **PMEL Data:** http://www.pmel.noaa.gov/tao/jsdisplay

ENSO (El Niño/Southern Oscillation) Investigation Worksheet

Objectives

- Contrast conditions in the equatorial Pacific during El Niño, La Niña and normal years
- Calculate and interpret correlation coefficients between Cold Tongue Index (CTI) and precipitation data
- Analyze precipitation data from the Pacific Northwest during El Niño and La Niña years

Part I: ENSO Background

✪Textbook references: pages 221-225 (Garrison, Oceanography) and pages 92-96 (Kump, Earth System).

1. **Watch** the El Niño and La Niña animation (http://esminfo.prenhall.com/science/geoanimations/animations/26_NinoNina.html). Pay attention to the labels on the arrows. Describe the following factors during normal, El Niño and La Niña conditions.

Factor	Normal	El Niño	La Niña
Location of low pressure system, generating rainfall (eastern, mid or western Pacific)			
Coastal winds along the west coast of South America (compass direction and relative strength)			
Relative strength of upwelling off the coast of South America (weak, normal, strong)			
Position of thermocline (shallow, deep, normal)			
Location of warm surface water (eastern, mid or western Pacific)			

2. **Analyzing PMEL Data**

✪ Go to http://www.pmel.noaa.gov/tao/jsdisplay/

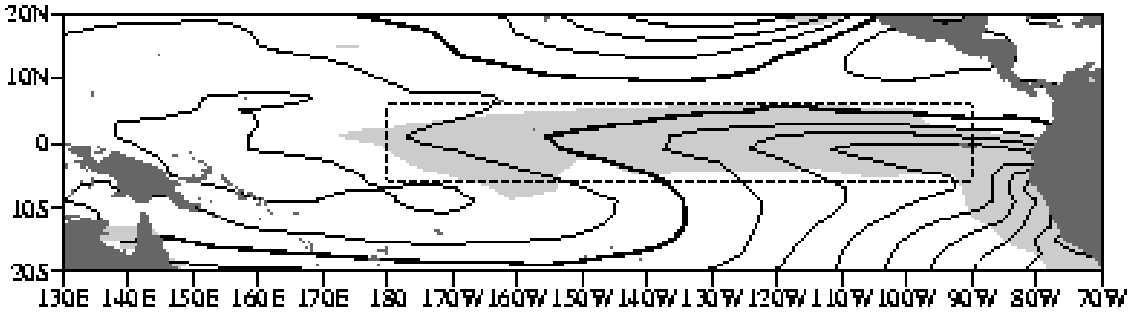
a. Click on the lat/lon plots tab. Click on Monthly for time range, and choose 2011, December. Click on the Make Plot button. Click on the plot to see a larger version. Focus on Temperature (color-coded). Two plots are produced: the upper plot shows mean temperature for December, 2011 and the lower plot shows temperature anomalies (deviations from the long-term mean). Based on your results and your work with the animation in part I, was 2011 a La Niña or El Niño year? Be sure to state your evidence.

b. Perform the same analysis for December 1997. Based on your results, was 1997 a La Niña or El Niño year? How can you tell?

c. Do the same analysis for this (latest) year, this (latest) month. Is this a La Niña, El Niño or neutral year? State your evidence.

Part II: Investigating the Cold Tongue Index

Tropical Pacific sea surface temperatures (SSTs) are characterized by cold SSTs (usually less than 26 °C) in a narrow band centered on the equator in the central and eastern Pacific, and warm SSTs (greater than 27 °C) in the western equatorial Pacific and extending north and eastward to Central America. These features can be seen in the annual mean SST map shown below (contour interval is 1 °C; note that the 27 °C contour is the darkest one). The region of equatorial cold SSTs is commonly referred to as the "cold tongue."



Large year-to-year fluctuations in tropical Pacific SSTs, shown by the shading, are centered in the cold tongue and along the South American coast. These fluctuations are associated with the El Niño/Southern Oscillation (ENSO) phenomenon. The Cold Tongue Index (CTI) is defined as the SST anomaly from 6 °N-6 °S and 180-90 °W (the dotted box on the map) minus the global mean SST. A positive CTI means that SSTs in the region are warmer than normal (El Niño condition) and a negative CTI indicates that SSTs in the region are colder than normal (La Niña condition).

1. Open and SAVE the ENSO investigation spreadsheet, available for download on Moodle. Click on the first tab—Cold Tongue, Indonesia. Select cells A1-B61, and make a scatter plot of year vs. cold tongue index, inserting the graph on the worksheet next to the data set. Based on CTI values shown in the data set and on the graph, identify the following years as El Niño or La Niña years.

Year	CTI Index	El Niño or La Niña?
1951		
1955		
1982		
1997		
2000		
2007		

2. Look at the spreadsheet tab labeled El Niño/La Niña conditions for the months of December-February.
   a. During an El Niño year, would you expect rainfall in Indonesia to be higher or lower than a normal year?

   b. During a La Niña year, would you expect rainfall in Indonesia to be higher or lower than a normal year?

3. Click and drag to select cells A1-C61. Insert a Scatter Plot next to the data. You should see the CTI and Indonesia Precipitation plotted on the same graph. Right-click on the red Indonesia line and select "Secondary Axis". This will add a second y-axis for the Indonesia precipitation values, and you will notice that the Indonesia data has been rescaled. Stretch the graph out to the right to make it easier to read.
   a. Would you say that a low CTI (colder SST than normal, La Niña conditions) is associated with more or less rainfall? Is this what you expected, based on your answer to question 2a?

   b. Is a high CTI (warmer SST than normal, El Niño conditions) associated with more or less rainfall? Is this what you expected?

4. In addition to visual inspection of the graph, you can perform a statistical calculation to get a better idea of the relationship between two variables. In this step, you will calculate the correlation coefficient between the CTI and Indonesia Precipitation. The correlation coefficient value varies from 1 (strong direct relationship) to -1 (strong inverse relationship). A value of 0 indicates no relationship between the two variables. Click on cell F57 and enter the following formula exactly as printed:

   =correl(B31:B52,C31:C52)

   When you hit ENTER, the correlation coefficient between CTI and Indonesia Precipitation from 1979-2006 should appear in cell F57. Record the correlation coefficient value here_____.

5. In a short paragraph, summarize what you learned about the correlation between CTI and Indonesia rainfall. Is the relationship direct or inverse? Strong or weak? Be sure to include discussion of what CTI actually means in terms of equatorial Pacific sea surface temperature.

Part III: Pacific Northwest Data

✪ In Part III, you will first predict climate patterns during El Niño and La Niña events, and then analyze precipitation data from Everett and Mt. Rainier over the last 60 years.

1. **Predictions**:

a. According to the climate impacts described on the map on the second tab of the spreadsheet, what are the expected winter precipitation conditions in the Pacific Northwest during a La Niña year? What about during an El Niño year?

b. During a La Niña year, would you expect the yearly snowfall amount at Mt. Rainier to be less than or greater than average? Explain your reasoning.

c. How would an El Niño year affect the yearly snowfall amount at Mt. Rainier? Explain your thinking.

2. Procedure

✪The third tab of the spreadsheet contains the CTI index, and precipitation data for Paradise, Mt. Rainier and Everett. The fourth tab is a blank worksheet for pasting the graphs you create.

1. Select cells A1-C61, then make a scatter plot of CTI and Paradise snowfall. Cut the graph and paste it onto the Graphs tab worksheet. Enlarge the graph by dragging to the right. Right-click on the blue CTI graph line and select Format Data Series, then Secondary Axis.

2. Select cells A1-B61. Hold down the CTRL key and select D1-D61. Make a scatter plot of CTI and Everett Precipitation, October-March. Cut the graph and paste onto the Graphs tab. Enlarge by dragging to the right. Right-click on the blue CTI graph line and select Format Data Series, then Secondary Axis.

3. Ask your instructor to sign off on your two graphs _____

4. Calculate the correlation coefficients for CTI/Paradise Snowfall and CTI/Everett Precipitation in cells C64 and C66. Follow the same procedure you learned earlier in this investigation, BUT note that the data sets and cells are:

Correlation	Cells
CTI/Paradise Snowfall	B6:B61,C6:C61
CTI/Everett Rainfall	B6:B58,D6:D58

Analysis

a. What was the correlation coefficient between CTI and Paradise Snowfall? Does this indicate a strong or weak, direct or inverse relationship between these two variables?

b. Does the CTI/Snowfall correlation coefficient confirm your original predictions about snowfall during El Niño and La Niña years?

c. What was the correlation coefficient between CTI and Everett Precipitation? What can you conclude about the relationship between the two variables?

d. Does the CTI/Everett Precipitation correlation coefficient confirm your predictions about precipitation during El Niño and La Niña years?

Conclusion

After looking at the Everett and Paradise data, are you convinced that El Niño and La Niña affect rainfall and snowfall in a consistent way? What would you need to do to make the data more convincing?