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Final Project

Teleconnections

This unit is an introduction/survey of teleconnections. Throughout this course I have learned that what happens in one location may influence the conditions somewhere else. Atmospheric pressure determines the wind patterns and also influences the sea surface temperature (SST) as well as precipitation patterns. Different regions of the earth have their local weather patterns determined by events thousands of kilometers away.

Living and teaching on the western Pacific coast of the United States (US), I chose to concentrate my final project on what happens in the community where I teach in. El Nino and La Nina can have a definite impact on my students as far as how weather impacts their lives. Many of my students that are avid snowboarders, and this past winter was a total bust for this activity because of the lack of precipitation and snow in the mountains in the Pacific Northwest. Many of my students also enjoy sports fishing for salmon, which seems to be definitely affected by ENSO events. This unit is intended as an “eye opener” for how what is happening thousands of kilometers away in the Equatorial Pacific influences events in the Pacific Northwest (PNW) as well as other in the US. Weather affects natural resources, and natural resources are necessary for economies to grow and build. (I’ve never taken an Econ class, but it sounds good ☺)

We can predict the future from events that occurred in the past. The study of teleconnection involves looking for patterns in the past as well as present conditions in certain locations. The unit involves looking at data from the past and present to determine of an event is occurring. Proxy data can be used to reconstruct past climates. This proxy data is a preserved physical characteristic of the environment that can be substituted for direct measurements. Examples include ice cores, tree rings, sediment deposits and pollen. By analyzing proxy data, a climatologist can reach beyond the instrumental record of the last few hundred years to understand climate millions of years ago. Future plans for this unit would include using proxy data to study teleconnections.

This unit focuses on teleconnections in the Pacific Ocean, specifically El Nino Southern Oscillation (ENSO) and will be expanded at a later time to include the Pacific Decadal Oscillation (PDO). Students will use a variety of data sources to investigate relationships among variables involved in climate oscillations.

Learners
-High School juniors and seniors enrolled in Oceanography 101 and/or Atmospheric Science 111 in the University of Washington in the High School Program
-The majority of the learners will be self-motivated and in a college prep track of study
-Lessons will consist of whole group instruction, pairs/small group and individual work.

Next Generation Science Standards

HS-ESS2-4 *Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.*

HS-ESS3-5 *Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems*

Topic

Teleconnections study how events/conditions in one location affect the climate/weather in a distant location.

Curriculum Links

This unit will be incorporated in my oceanography course when we are studying currents and upwelling. I would like to create an additional activity where students will look at the data for ENSO and upwelling by using data for chlorophyll levels. Following this unit would be a study of boundary currents, the study of eastern boundary currents versus western boundary currents. I would love to teach my oceanography and atmospheric sciences courses with more technology. This takes time, and I am only going to teach in the US for four more years. My cost-benefit analysis says that I am doing enough by agreeing to teach another University of Washington in the High School (UWHS) course for the last four years I teach.

Objectives

1) Students will be able to explain the term "teleconnection" means in the study of climate
2) Students will be able to identify the locations and characteristics of a given climate oscillation
3) Students will be able to use data to determine the stage of a climate oscillation
4) Students will use data to determine correlation between data sets

Materials

-Computer with internet access and projector (for teacher)

-Computer with internet access and MS Excel

Time

-Each lesson is planned for 50 minutes

Scope and Sequence

Day 1-What is a teleconnection?

1) Teacher will introduce the concept of a teleconnection through a brief MS PowerPoint presentation. [Teleconnections PowerPoint (Slides 1- 4)]
2) Teacher will ask clarifying questions of the students during the presentation.
3) After lecture/discussion the teacher will assist the students in completing the worksheet "Teleconnections"
4) Students will use the internet to find information about various teleconnections and complete Web Search Worksheet-Teleconnections.

5) We will discuss the students' findings at the beginning of the period the next day. I use this type of activity often in my Oceanography class instead of just straight "lecture" method. It gets the students in a discussion, and I can ask questions during their web quest as well.

Day 2-Characteristics and Effects of ENSO

1) Lesson will begin with a discussion of yesterday's activity about Teleconnections.
2) Teacher will discuss how conditions in one location can affect a location very far away. [Teleconnections PowerPoint (Slides 5- 9)]
3) The students will use data obtained from maps of the US for monthly temperature and precipitation anomalies and compare their data analysis to NOAA maps showing location of certain conditions during El Nino and La Nina.
4) The class will come together and discuss their findings, and see if they can come to a consensus about the analysis of the data in the activity

ENSO Worksheet 1-Characteristics and Effects of ENSO

Day 3-ENSO

In this study of ENSO we will look at data in the Equatorial Pacific Ocean from 1989 until 2000. We will be using the following parameters: Sea Surface Temperature Anomalies, Precipitation Anomalies, Wind direction and Air Pressure. During this decade there were El Nino events in 1991-1992, 1994-1995, and 1997-1998. La Nina events occurred in 1995-1996, 1998-1999, and 1999-2000. The outcome of this activity would be for the students to be able to recognize conditions for El Nina and La Nina events in the Equatorial Pacific. In the discussion the next class period, we will see if we can come to a consensus about conditions that determine the occurrence of an ENSO event.

ENSO Worksheet 2-Patterns in the Pacific-"A Decade of Oscillation"

Day 4-ENSO

1) The teacher will lead a discussion about conditions in Equatorial Pacific for ENSO using the worksheet-"A Decade of Oscillation" from yesterday. The intended outcome would be for the class to come to a consensus for each year about is it normal, El Nino or La Nina event?

2) Begin SOI/PNW Weather Excel Activity (if time allows)

Teleconnections PowerPoint (Slides 10-11)

Day 5 and 6-SOI and PNW Weather

This lesson engage students in a hands-on learning experience analyzing sea surface temperature data collected over a number of years using MS Excel. This data will be used to determine if the year was a normal, El Niño or La Niña episode. During this activity students will be able to:
a) Contrast conditions in the equatorial Pacific during El Niño, La Niña and normal years.
b) Analyze precipitation data for the Pacific Northwest during El Niño and La Niña years
c) Use Excel to calculate and interpret correlation coefficients between Southern Oscillation Index (SOI) and precipitation

SOI/PNW Weather Excel Activity

Supplementary Materials

Unit Pre-Assessment

Teleconnections Web Search Worksheet

Students will use the internet (with suggested sites) to complete a worksheet about climate oscillations.

ENSO Worksheet 1-Characteristics and Effects of ENSO

Students will look at temperature and precipitation anomalies using maps for different locations in the US during both El Nino and La Nina phases, and determine what the effects of El Nino and La Nina are in these different locations.

ENSO Worksheet 2-Patterns in the Pacific-"A Decade of Oscillations"

Students will look at data in the equatorial Pacific for Sea Surface Temperature (SST), precipitation, wind direction, and surface air pressure to look for patterns in El Nino Southern Oscillation (ENSO) events. After gathering data, there will be a discussion about if there was an El Nino, or La Nina event for a given year in the data.

SOI/PNW Weather Excel

Students will graph data for the Southern Oscillation Index (SOI) and local (Chehalis, WA) precipitation. The students will analyze the data to see if a correlation exists between SOI and local precipitation.

Unit Post-Assessment

Note: The Post-Assessment is the same assessment as the Pre-Assessment.

Assessment of Students

Students will be given a pre- and post-assessment over topics covered in the unit. I have to do this during my normal teaching assignment at my high school, so I am used to it. We are required to measure "student growth" as part of our evaluation in Washington State. Most of the activities I have designed in this unit are "seek, find, analyze and discuss". I give them some data source to explore; the students record the data with the provided worksheet, and then analyze the data. After the students have analyzed the data, we will have a whole class discussion about their results. I will also be able to assess their skills in using Excel by looking at their final product for the SOI/PNW Weather Excel activity.

Evaluation of the Lessons

My evaluation of the lesson would include how well the students seemed to enjoy the lesson as well as their level of participation and involvement. Were they engaged? Did they ask clarifying questions? Was there active participation during the discussions?

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Conclusion

This project seemed very daunting at first, but in the end I think it was very doable in the time allotted. I have not taken a formal course where I must earn a “grade” since 1997, when I finished my master’s degree in curriculum and instruction. Our lesson plans and outlines were not required to be so detailed back in the last century. Most of what the students need to do is outlined on the worksheets, so I did not include “detailed” instructions in my scope and sequence. I feel this is a bit redundant, but I will do so if required. This has been a good brain exercise for me. I have four years until I retire from teaching high school math and science at my current position. I have developed curriculum since 1997, but much less detailed that what I need to do now. I have also not had any deadlines…except to make sure I stay ahead of my students. ☺

Teleconnections Unit **Name _____**

Pre-Assessment

1) Define the term ***teleconnection*** as it relates to atmospheric science.

Mark the correct choice for each question is the space provided.

____ 2) Which of the following is not a teleconnection?

a) ENSO b) NAO c) NOAA d) PDO

3) During an El Nino event which of the following conditions generally occur in the Equatorial Pacific? Check the true statements.

____There is increased upwelling of the coast of Peru

____There is no upwelling off the coast of Peru

____There is a high pressure zone in the eastern Equatorial Pacific

____There is a low pressure zone in the eastern Equatorial Pacific

_____There is a warm water pool along the equator in the Pacific Ocean

_____There is a warm water pool in the western equatorial Pacific

_____ There are heavy rains in southeast Asia

____ There are drought conditions in southeast Asia

____ The trade winds blow from east to west

____ The trade winds blow from west to east

____ 4) During a La Nina event which of the following conditions generally occur in the Equatorial Pacific? Check the true statements.

_____There is increased upwelling of the coast of Peru

_____There is no upwelling off the coast of Peru

_____There is a high pressure zone in the eastern Equatorial Pacific

_____There is a low pressure zone in the eastern Equatorial Pacific

_____ There is a warm water pool along the equator in the Pacific Ocean

_____ There is a warm water pool in the western equatorial Pacific

_____ There are heavy rains in southeast Asia

____ There are drought conditions in southeast Asia

____ The trade winds blow from east to west

____ The trade winds blow from west to east

_____ 5) During an El Nino event, which of the following is true of the weather in North America? Check the true statements.

____ There is unusually dry weather in California

____ There is unusually wet weather in California

____ There is a unusually cold weather in the northern United States

____ There is a unusually warm weather in the northern United States

____ The southern United States is abnormally warm and dry

____ The southern United States is abnormally cool and wet

____ There is abnormally cold weather in the western United States and Canada

____ There is abnormally wet weather in the Pacific Northwest

_____ 6) During a La Nina event, which of the following is true of the weather in North America? Check the true statements.

____ There is unusually dry weather in California

____ There is unusually wet weather in California

____ There is a unusually cold weather in the northern United States

____ There is a unusually warm weather in the northern United States

____ The southern United States is abnormally warm and dry

____ The southern United States is abnormally cool and wet

____ There is abnormally cold weather in the western United States and Canada

____ There is abnormally wet weather in the Pacific Northwest

Teleconnections Unit **Name __KEY_____**

Assessment

2) Define the term ***teleconnection*** as it relates to atmospheric science.

The term refers to a recurring and persistent, large-scale pattern of pressure and circulation anomalies that span vast geographical areas.

Mark the correct choice for each question is the space provided.

__c_ 2) Which of the following is not a teleconnection?

b) ENSO b) NAO c) NOAA d) PDO

3) During an El Nino event which of the following conditions generally occur in the Equatorial Pacific? Check the true statements.

____There is increased upwelling of the coast of Peru

__X__There is no upwelling off the coast of Peru

____There is a high pressure zone in the eastern Equatorial Pacific

__X__There is a low pressure zone in the eastern Equatorial Pacific

__X___There is a warm water pool along the equator in the Pacific Ocean

_____There is a warm water pool in the western equatorial Pacific

_____ There are heavy rains in southeast Asia

__X__ There are drought conditions in southeast Asia

____ The trade winds blow from east to west

_X___ The trade winds blow from west to east

____ 4) During a La Nina event which of the following conditions generally occur in the Equatorial Pacific? Check the true statements.

__X___There is increased upwelling of the coast of Peru

_____There is no upwelling off the coast of Peru

__X___There is a high pressure zone in the eastern Equatorial Pacific

_____There is a low pressure zone in the eastern Equatorial Pacific

_____ There is a warm water pool along the equator in the Pacific Ocean

___X__ There is a warm water pool in the western equatorial Pacific

__X___ There are heavy rains in southeast Asia

____ There are drought conditions in southeast Asia

__X__ The trade winds blow from east to west

____ The trade winds blow from west to east

_____ 5) During an El Nino event, which of the following is true of the weather in North America? Check the true statements.

____ There is unusually dry weather in California

__X__ There is unusually wet weather in California

____ There is a unusually cold weather in the northern United States

_X___ There is a unusually warm weather in the northern United States

____ The southern United States is abnormally warm and dry

__X__ The southern United States is abnormally cool and wet

____ There is abnormally cold weather in the western United States and Canada

____ There is abnormally wet weather in the Pacific Northwest

_____ 6) During a La Nina event, which of the following is true of the weather in North America? Check the true statements.

____ There is unusually dry weather in California

____ There is unusually wet weather in California

___X_ There is a unusually cold weather in the northern United States

____ There is a unusually warm weather in the northern United States

_X___ The southern United States is abnormally warm and dry

____ The southern United States is abnormally cool and wet

___X_ There is abnormally cold weather in the western United States and Canada

__X__ There is abnormally wet weather in the Pacific Northwest

Teleconnections

This lesson serves as an introduction to the Teleconnections unit. This lesson engages students in a web based research activity to explore the various aspects of teleconnections.

Objectives

Compare and contrast conditions in the following teleconnections based on location, variable which is being measured, time scale and description of each phase.

Go to: https://www2.ucar.edu/news/backgrounders/weather-maker-patterns-interactive-map

Use this website as a starting point for your research on teleconnections.

Teleconnections Conditions

Meaning of Acronym	Location	Measurement	Time Scale
AO/NAM			
Description of each phase			
Meaning of Acronym	Location	Measurement	Time Scale
NAO			
Description of each phase			

Meaning of Acronym	Location	Measurement	Time Scale
AMO			
Description of each phase			
Meaning of Acronym	Location	Measurement	Time Scale
PDO			
Description of each phase			
Meaning of Acronym	Location	Measurement	Time Scale
ENSO			
Description of each phase			

Meaning of Acronym	Location	Measurement	Time Scale
SAM			
Description of each phase			
Meaning of Acronym	Location	Measurement	Time Scale
IOD			
Description of each phase			

Teleconnections_KEY

This lesson serves as an introduction to the Teleconnections unit. This lesson engages students in a web based research activity to explore the various aspects of teleconnections.

Objectives

Compare and contrast conditions in the following teleconnections based on location, variable which is being measured, time scale and description of each phase.

Go to: https://www2.ucar.edu/news/backgrounders/weather-maker-patterns-interactive-map

Use this website as a starting point for your research on teleconnections.

Teleconnections Conditions

Meaning of Acronym	Location	Measurement	Time Scale
AO/NAM Arctic Oscillation/Northern Annular Mode	**Arctic Ocean**	**Wind**	**Weeks to Months**

Description of each phase

Positive Phase	Negative Phase
-Colder stratosphere	-less cold stratosphere
-Stronger westerly winds	-less strong westerly winds
-NE Canada cold	-NE US cold
-N. Europe warm and wet	-Europe Cold
-Stronger trade winds	-Weaker trade winds

Meaning of Acronym	Location	Measurement	Time Scale
NAO North Atlantic Oscillation	**North Atlantic**	**Atmospheric Pressure**	**Weeks to Months**

Description of each phase

Positive Phase	Negative Phase
-Jet stream further south	-Jet stream further north
-Eastern US & Scandinavia warm and wet	-Eastern US Cold & Snowy/Scandinavia Cold & Dry
-N. Canada Cold/Mediterranean Cold and Dry	-N.Canada warm/Mediterranean Warm & wet
Strong Low pressure	Weak Low pressure
Strong High pressure	Weak High pressure

Meaning of Acronym	Location	Measurement	Time Scale
AMO Atlantic Multidecadal Oscillation	**North Atlantic**	**Sea Surface Temperature (SST)**	**Several Decades**

Description of each phase

Atlantic hurricane activity increases as SST increases

Meaning of Acronym	Location	Measurement	Time Scale
PDO Pacific Decadal Oscillation	**North Pacific**	**Sea Surface Temperature**	**40-60 years**

Description of each phase

Positive Phase (Warm)

-Temperatures warm on the west coast of North America and eastern tropical pacific

Cool in north Pacific

Negative Phase (Cold)

-Warm in the north Pacific and Antarctica

-Cool along eastern Pacific

Meaning of Acronym	Location	Measurement	Time Scale
ENSO **El Nino-Southern Oscillation**	**Equatorial Pacific**	**Atmospheric Pressure and Sea Surface Temperature**	**2-6 years**

Description of each phase

El Nino
-Warm water off of Peru and Low pressure in Eastern pacific
-Precipitation over the equatorial Pacific
-Shallow Thermocline in Eastern Pacific

La Nina

Warm water in western Pacific
Wet with Low Pressure in Eastern Pacific

Deep Thermocline in Eastern Pacific

Meaning of Acronym	Location	Measurement	Time Scale
SAM **Southern Annular Mode**	**Southern Ocean**	**Winds**	**Weeks to Months**

Description of each phase

Positive Phase	Negative Phase
Ring of westerly winds is strong and further south	Ring of westerly winds is weaker and further north
Inhibiting Antarctic airbreaks	Antarctic air spills north more easily

Meaning of Acronym	Location	Measurement	Time Scale
IOD **Indian Ocean Dipole**	**Indian Ocean**	**Winds** **Sea Surface Temperature**	**2+ years**

Description of each phase

Positive Phase	Negative Phase
Trade winds strionger than normal	Trade winds weaker than normal
Cold Water in Eastern Indian Ocean	Cold Water in Western Indian Ocean
Warm Water in Western Indian Ocean	Warm Water in Eastern Indian Ocean
Drought in Eastern Indian Ocean	Drought in Western Indian Ocean
Rain in Western Indian Ocean	Rain in Eastern Indian Ocean

A Decade of Oscillation

In this study of ENSO we will look at data in the Equatorial Pacific Ocean from 1989 until 2000. We will be using the following parameters:

- Sea Surface Temperature Anomalies
- Precipitation
- Wind direction
- Air Pressure

Go the website: http://iridl.ldeo.columbia.edu/maproom/

You will find a plethora of data which will allow you to answer the questions for each year. The maps are clickable to select a certain region. You will want to select near 20° N and S, and 100° E and 60° W.

1) Find **Three Month Standardized Monthly SST Anomaly Persistence**

Draw a Solid Circle (+) with a + sign inside around areas of above normal SST

Draw a Solid Circle (-) with a - sign inside around areas of below normal SST

2) Find **Seasonal Precipitation Anomalies**

Draw a Dashed Circle (+) with a + sign around areas of above normal precipitation

Draw a Dashed Circle (-) with a - sign around areas of above normal precipitation

3) Go to Atmospheric Circulation -→ **Monthly Tropical Wind Anomalies: Pacific Ocean Sector**

Use arrows ⟶ to show general wind direction

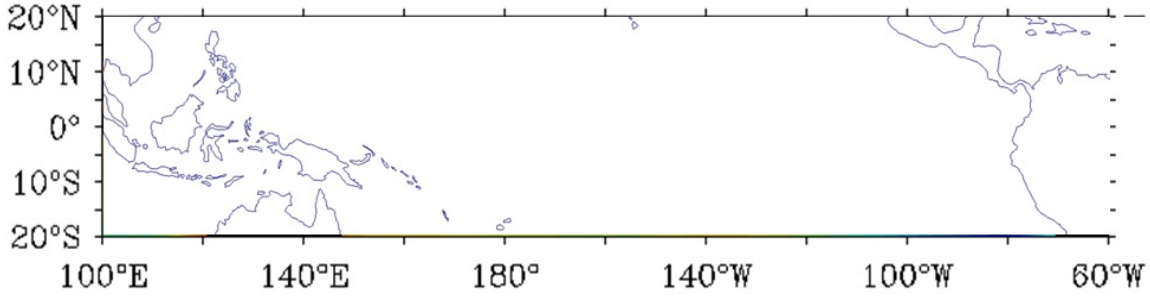
4) Go to Atmospheric Circulation -→ **Monthly Sea Level Pressure Standardized Anomaly**

Indicate Air Pressure anomalies by writing **H** for high and **L** for low pressure in the areas where this is occurring

On steps 3 and 4 you will have to analyze all three months, and "visualize" a "mean" for these values.

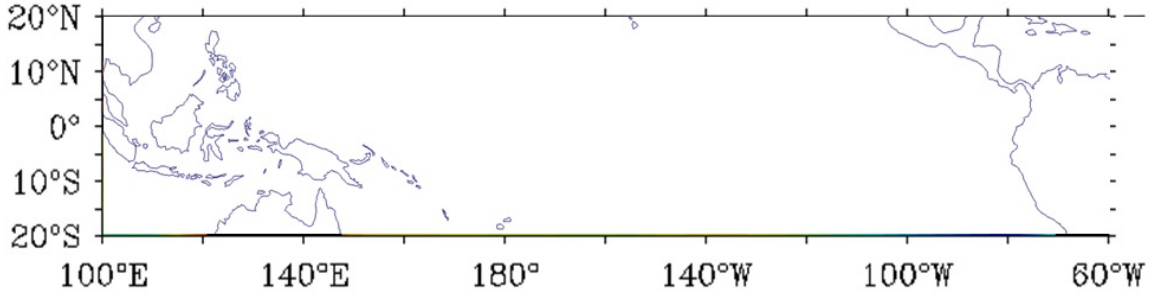
Use you maps to do an analysis of the conditions in the Equatorial Pacific. Circle the conditions you believe to be happening during this time. Be ready to justify you answer to your teacher and your classmates.

Nov 1989- Jan 90



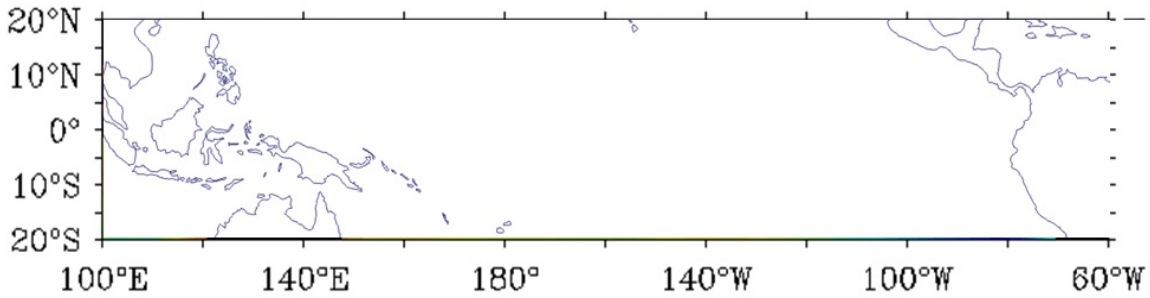
Normal **El Niño** **La Niña**

Nov 1990- Jan 91



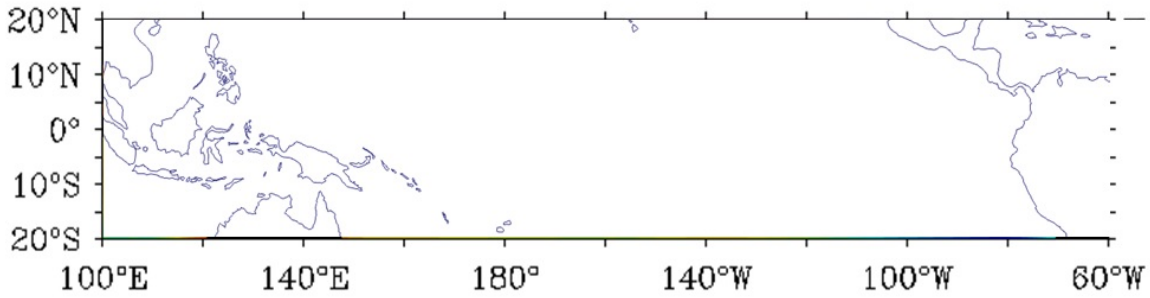
Normal **El Niño** **La Niña**

Nov 1991- Jan 92



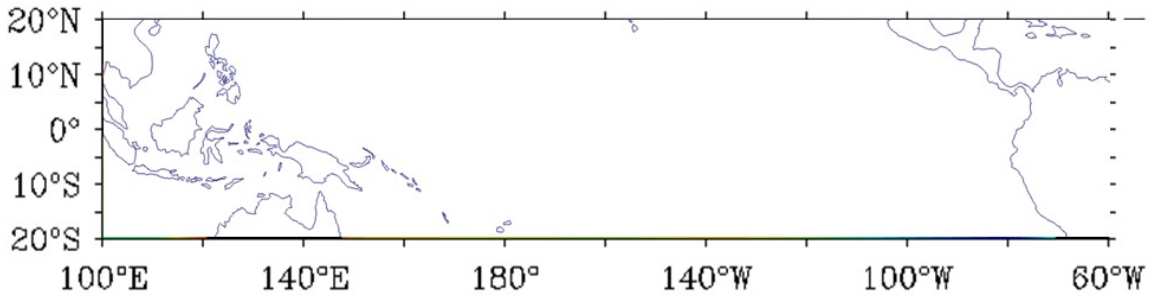
Normal **El Niño** **La Niña**

Nov 1992- Jan 93



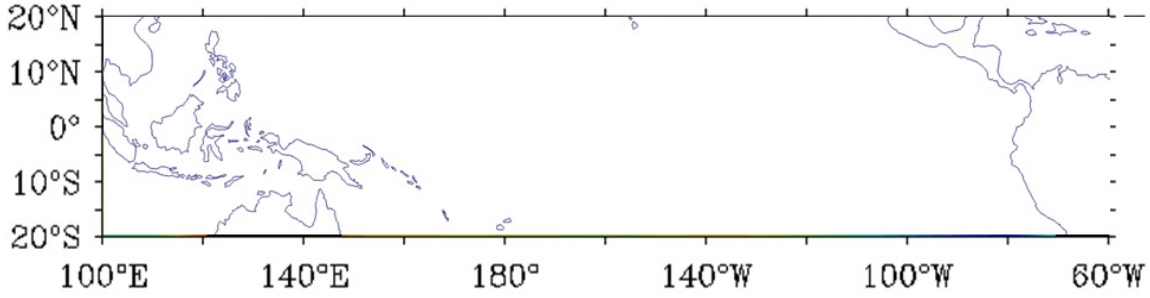
Normal **El Niño** **La Niña**

Nov 1993- Jan 94



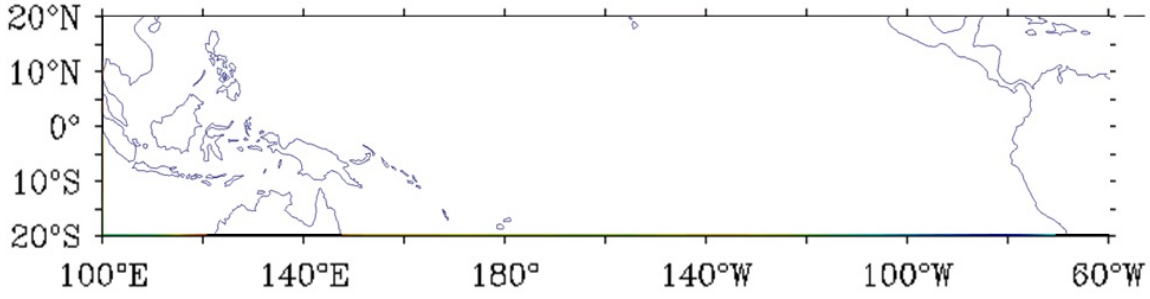
Normal **El Niño** **La Niña**

Nov 1994-Jan 95



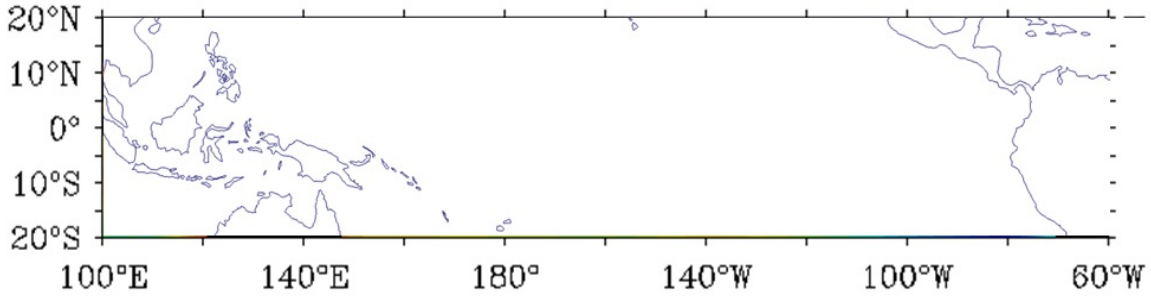
Normal **El Niño** **La Niña**

Nov 1995- Jan 96



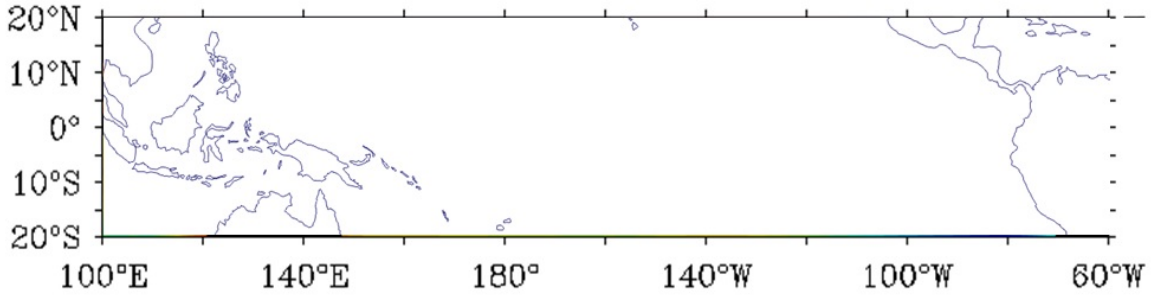
Normal **El Niño** **La Niña**

Nov 1996- Jan 97



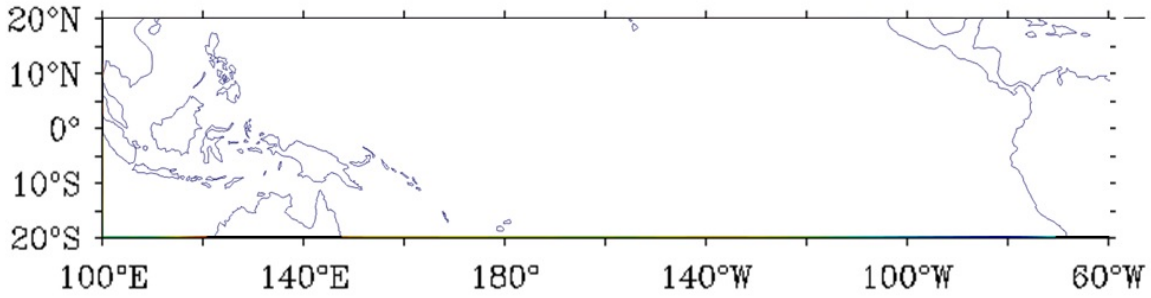
Normal **El Niño** **La Niña**

Nov 1997- Jan 98



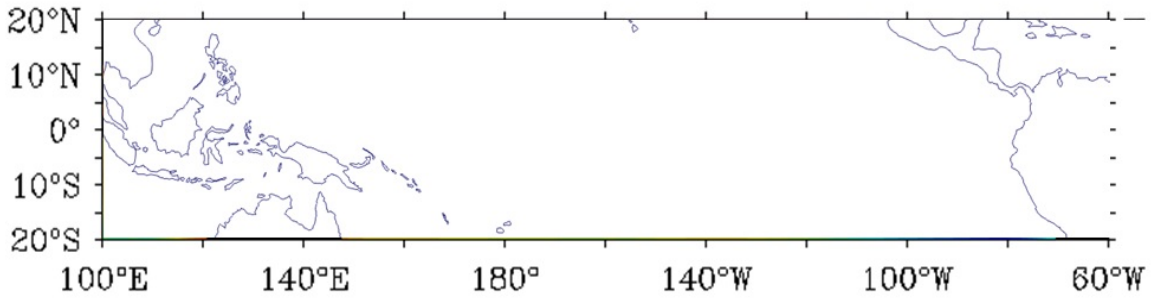
Normal **El Niño** **La Niña**

Nov 1998- Jan 99



Normal **El Niño** **La Niña**

Nov 1999- Jan 2000



Normal **El Niño** **La Niña**

Characteristics and Effects of ENSO

You will compare the effects of ENSO in four different locations in the United States during the El Nino year of 2002-2003 and a La Nina year of 2010-2011.

Location 1: Los Angeles, CA
Location 2: Seattle, WA
Location 3: Minneapolis, MN
Location 4: Miami, FL

Go to
http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/1-month-archive.shtml
You will use the monthly maps for Percentage of Monthly Precipitation and Temperature Departure to determine anomalies for both of these variables.
For each month in the table indicate the anomaly percentage with either a plus (+) or minus (–) along with the range of above or below normal.

2002-2003 El Nino Chart								
	Average Monthly Temperature Anomaly				Precipitation Anomaly			
	Seattle	Los Angeles	Minneapolis	Miami	Seattle	Los Angeles	Minneapolis	Miami
July								
August								
September								
October								
November								
December								
January								
February								
March								
April								
May								
June								

2010-2011 La Nina Chart

	Average Monthly Temperature Anomaly				Precipitation Anomaly			
	Seattle	Los Angeles	Minneapolis	Miami	Seattle	Los Angeles	Minneapolis	Miami
July								
August								
September								
October								
November								
December								
January								
February								
March								
April								
May								
June								

Data Analysis

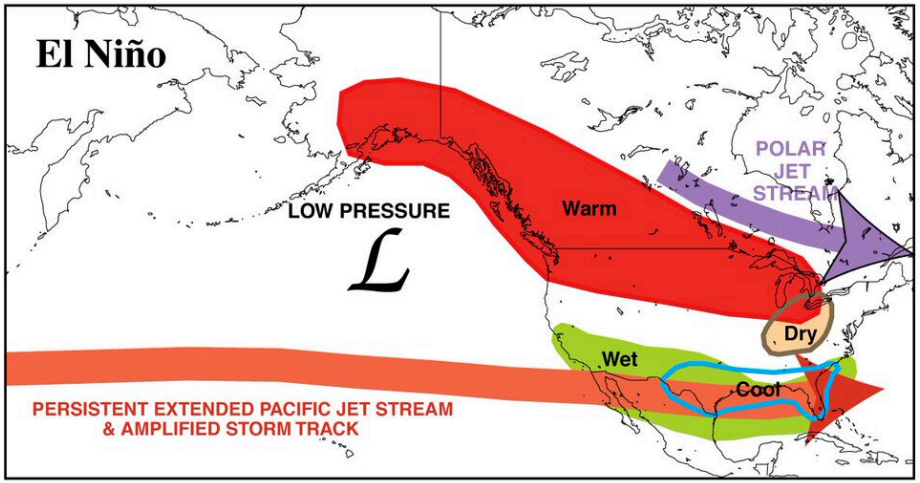
1) During an El Nino event where are the major precipitation anomalies? List the anomaly as being positive or negative, and during the months which it is observed.

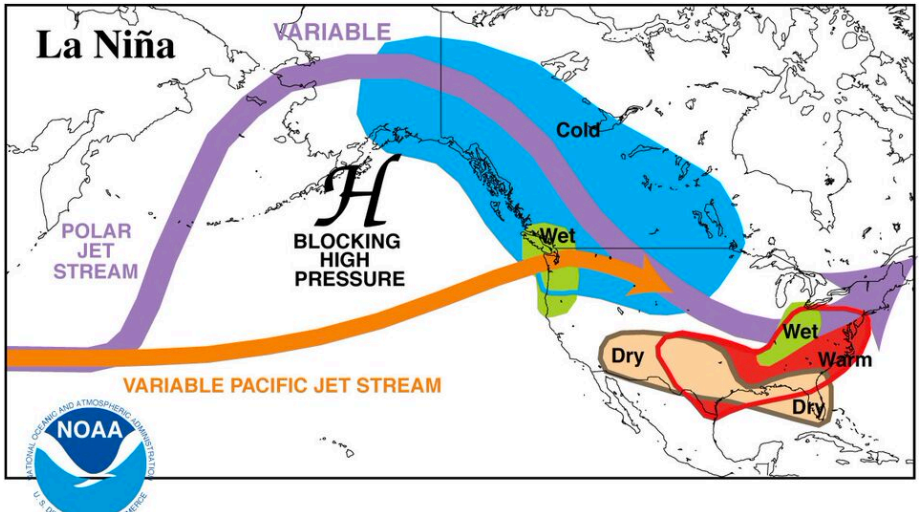
2) During an El Nino event where are the major temperature anomalies? List the anomaly as being positive or negative, and during the months which it is observed.

3) During an La Nina event where are the major precipitation anomalies? List the anomaly as being positive or negative, and during the months which it is observed.

4) During an La Nina event where are the major temperature anomalies? List the anomaly as being positive or negative, and during the months which it is observed.

TYPICAL JANUARY-MARCH WEATHER ANOMALIES AND ATMOSPHERIC CIRCULATION DURING MODERATE TO STRONG EL NIÑO & LA NIÑA





5) Using the maps to the left describe the correlation between your data and the anomalies show on the map.

El Nino

La Nina

6) What are the limitations of analyzing the data the way you did in this activity?

ENSO Investigation 1 Name _____

Conditions for Normal, El Niño, and La Niña Years

Using your text or the internet to complete the table.

Factor	Normal	El Niño	La Niña
Location of warm pool of surface water (Western, Eastern or mid-Pacific)			
Location of Low Pressure Zone and associated rainfall (Western, Eastern or mid-Pacific)			
Amount of upwelling along the western coast of S. America (Strong, weak, normal)			
Coastal winds along the west coast of South America (compass direction and relative strength)			
Position of thermocline (deep, shallow or normal)			

Analyzing Data

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

1. 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.

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

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

Southern Oscillation Index

The Southern Oscillation Index (SOI) is an index based on the observed sea level pressure differences between Tahiti and Darwin, Australia. The SOI measures the fluctuations in air pressure occurring between the western and eastern tropical Pacific during El Niño and La Niña episodes. The negative phase of the SOI represents above normal air pressure at Darwin and below normal air pressure at Tahiti. Periods of negative SOI values coincide with abnormally warm ocean waters across the eastern tropical Pacific typical of El Niño episodes. Periods of positive SOI values coincide with abnormally cool ocean waters across the eastern tropical Pacific typical of La Niña episodes.

1. Open and SAVE the ENSO investigation spreadsheet. Click on the first tab—SOI. Select cells A1-B61, and make a scatter plot of year vs. Southern Oscillation Index (SOI), inserting the graph on the worksheet next to the data set. Based on SOI values shown in the data set and on the graph, identify the following years as El Niño or La Niña years.

Year	Southern Oscillation Index (SOI)	El Nino or La Nina?
1955		
1983		
1998		
2000		

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 SOI 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 High SOI is associated with more or less rainfall? Is this what you expected, based on your answer to question 2a?

b. Is a low SOI 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 SOI 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 SOI 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 SOI and Indonesia rainfall. Is the relationship direct or inverse? Strong or weak?

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 Chehalis 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.

2. Procedure

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

1. Select cells A1-C61, then make a scatter plot of SOI 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 SOI 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 SOI and Chehalis Precipitation, October-March. Cut the graph and paste onto the Graphs tab. Enlarge by dragging to the right. Right-click on the blue SOI graph line and select Format Data Series, then Secondary Axis.

3. Ask your instructor to verify your two graphs by checking the box. ☐

4. Calculate the correlation coefficients for SOI/Paradise Snowfall and SOI/Chehalis Precipitation in cells C64 and C66. Follow the same procedure you learned earlier in this investigation, BUT note that the data sets and cells B6

SOI/Paradise Snowfall	B6:B61, C6:C61
SOI/Chehalis Rainfall	B6:B58, D6:D58

Analysis

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

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

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

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

ENSO Investigation 1 Name _KEY___

Conditions for Normal, El Niño, and La Niña Years

Using your text or the internet to complete the table.

Factor	Normal	El Niño	La Niña
Location of warm pool of surface water (Western, Eastern or mid-Pacific)	**Western**	**Mid**	**Western**
Location of Low Pressure Zone and associated rainfall (Western, Eastern or mid-Pacific)	**North/normal**	**Weak**	**North, strong**
Amount of upwelling along the western coast of S. America (Strong, weak, normal)	**Normal**	**Weak**	**Strong**
Coastal winds along the west coast of South America (compass direction and relative strength)	**Normal**	**Deep**	**Shallow**
Position of thermocline (deep, shallow or normal)	**Western-mid**	**Eastern-mid**	**Western**

Analyzing Data

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

1. 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.

It looks like a La Niña year, based on the cool sea surface temperatures (SST) along the equator.

2. Perform the same analysis for December 1997. Based on your results, was 1997 a La Niña or El Niño year? How can you tell?
This was an El Niño year, with much warmer SST and winds going east instead of the typical trade winds blowing towards the west.

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

Answers vary

Southern Oscillation Index

The Southern Oscillation Index (SOI) is an index based on the observed sea level pressure differences between Tahiti and Darwin, Australia. The SOI measures the fluctuations in air pressure occurring between the western and eastern tropical Pacific during El Niño and La Niña episodes. The negative phase of the SOI represents above normal air pressure at Darwin and below normal air pressure at Tahiti. Periods of negative SOI values coincide with abnormally warm ocean waters across the eastern tropical Pacific typical of El Niño episodes. Periods of positive SOI values coincide with abnormally cool ocean waters across the eastern tropical Pacific typical of La Niña episodes.

1. Open and SAVE the ENSO investigation spreadsheet. Click on the first tab—SOI. Select cells A1-B61, and make a scatter plot of year vs. Southern Oscillation Index (SOI), inserting the graph on the worksheet next to the data set. Based on SOI values shown in the data set and on the graph, identify the following years as El Niño or La Niña years.

Year	Southern Oscillation Index (SOI)	El Nino or La Nina?
1955	0.60	La Niña
1983	-2.10	El Niño
1998	-1.90	El Niño
2000	5.60	La Niña

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?

Rainfall should be lower than normal during an El Niño year

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

3. Click and drag to select cells A1-C61. Insert a Scatter Plot next to the data. You should see the SOI 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 positive SOI is associated with more or less rainfall? Is this what you expected, based on your answer to question 2a?

Rainfall should be higher with a positive SOI

b. Is a low SOI associated with more or less rainfall? Is this what you expected?

Rainfall should be less with a negative SOI

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 SOI 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 SOI and Indonesia Precipitation from 1979-2006 should appear in cell F57. Record the correlation coefficient value here **-1.81**

5. In a short paragraph, summarize what you learned about the correlation between SOI and Indonesia rainfall. Is the relationship direct or inverse? Strong or weak?

It is a weak inverse correlation. A positive SOI is found during La Niña years, and a negative SOI is found during El Niño years

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 Chehalis 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?

During La Niña, we expect wetter than normal conditions. During El Niño, conditions should be drier than normal.

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.

Snowfall should be greater than average due to colder winter temperatures. More of the precipitation should fall as snow rather than rain.

2. Procedure

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

1. Select cells A1-C61, then make a scatter plot of SOI 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 SOI 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 SOI and Chehalis Precipitation, October-March. Cut the graph and paste onto the Graphs tab. Enlarge by dragging to the right. Right-click on the blue SOI graph line and select Format Data Series, then Secondary Axis.

3. Ask your instructor to verify your two graphs by checking the box. ☐

4. Calculate the correlation coefficients for SOI/Paradise Snowfall and SOI/Chehalis Precipitation in cells C64 and C66. Follow the same procedure you learned earlier in this investigation, BUT note that the data sets and cells B6

SOI/Paradise Snowfall B6:B61, C6:C61
SOI/Chehalis Rainfall B6:B58, D6:D58

Analysis

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

The correlation coefficient between SOI and Paradise snowfall is -.115, a weak inverse correlation.

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

The correlation is very weak.

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

The correlation coefficient between SOI and Chehalis Precipitation is 0.166, a weak correlation.

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

The correlation is very weak.