U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Marine Fisheries Service

Lesson 11: *El Niño*

Overview

Lesson 11 applies the information students have already learned about oceanic-atmospheric interactions to explain and explore the *El Niño* phenomenon. The lecture describes the physical mechanisms behind *El Niño* and explains how scientists determine whether an *El Niño* event is occurring. In the activity, students then interpret real NOAA data to decide whether they think 2009-2010 was an *El Niño* year.

Lesson Objectives

Students will:

1. Define *El Niño* and describe its effects on global weather patterns
2. Read and interpret sea surface temperature graphs
3. Identify trends in patterns in real temperature data sets that indicate an *El Niño* year is occurring

Lesson Contents

1. Teaching Lesson 11
    a. Introduction
    b. Lecture Notes
    c. Additional Resources
2. Teacher's Edition: Can You Predict *El Niño*?
3. Student Activity: Can You Predict *El Niño*?
4. Student Handout
5. Mock Bowl Quiz

Standards Addressed

National Science Education Standards, Grades 9-12

Unifying concepts and processes
Physical science
Science in personal and social perspectives

Ocean Literacy Principles

The ocean is a major influence on weather and climate

DCPS, High School

Environmental Science
E.1.10. Select and use appropriate tools and technology to perform tests, collect data, analyze relationships, and display data
E.1.14. Observe natural phenomena and analyze their location, sequence, or time intervals (e.g., relative ages of rocks and succession of species in an ecosystem)
E.6.8. Explain the dynamics of oceanic currents, including upwelling, density, and deep water currents, the local Labrador Current and the Gulf Stream, and their relationship to global circulation within the marine environment and climate

Lesson Outline[1]

I. Introduction

Introduce the *El Niño* lesson using the demonstration below[2]. You will need the following materials:

- hot water
- cold water
- clear plastic rectangular container
- blue and red food coloring
- hair dryer **(Note: You could have students blow with straws as an alternative.)**

Note: If you are unable to obtain very hot or very cold water, you could use room temperature tap water in place of the cold water and baby oil in place of the hot water. If you want to color the baby oil, you will need to use oil-based paint rather than food coloring.

1. Fill the container about ¾ full with cold tap water. It will work best if the water is refrigerated or kept on ice immediately prior to the demonstration. Place the container on a table in front of the class so that students can see through the side of the container. The water in the tub represents a cross-section of the Pacific Ocean. Place signs on either side that represent Peru and Indonesia (see diagram).

2. Add blue food coloring to the cold water until some dye starts to settle out at the bottom.

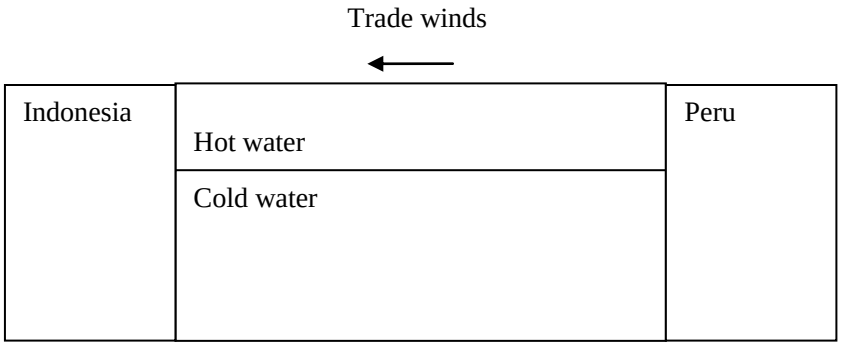
3. Fill a beaker with very hot tap water. Color this water with red dye.

4. Very gently pour the hot water into the plastic tub. This represents the surface water layer that has been heated by the sun.

5. Aim a hair dryer from the side of the tub that represents Peru toward Indonesia. The hair dryer represents the trade winds. Turn the dryer on a very low setting to avoid splashing and ask your students to describe what they see. The red water should "pile up" against Indonesia, which is then replaced by cool water moving to the surface near Peru. Remind students that this process of upwelling brings nutrients to the surface.

[1] Unless otherwise indicated, all websites provided or referenced in this guide were last accessed in November 2010.

6. During an *El Niño* event, the trade winds weaken. Demonstrate this by turning off the hair dryer, and ask your students to closely observe what happens. The red water should "pulse" back toward Peru, changing the sea surface temperature distribution of the equatorial Pacific and reducing upwelling near Peru. Ask your students what effects they think this phenomenon will have on weather and marine life.



II. Lecture Notes

Use the PowerPoint for Lesson 11 (File: Lesson 11 – El Nino.ppt) to present the following information. Distribute the Student Handout before you begin for students to take notes on key information.

Interactions between the air and the sea are important (slides 3 and 4)

1. Interactions between the atmosphere and the ocean affect climate and weather patterns. Some of these interactions, like the Gulf Stream's impact on Europe's climate, are consistent and predictable. Other interactions like *El Niño* and *La Niña* are variable and difficult to predict.

2. During an *El Niño* event, warm water builds up in the equatorial Pacific, leading to severe weather events and impacts on marine life.

How does an El Niño occur? (slides 5 and 6)

1. The exact causes of *El Niño* are not completely understood. They are related to the weakening of the trade winds, which blow from Peru toward Indonesia.

2. When these winds weaken, upwelling of cold-nutrient rich water decreases and warm water that has piled up along the coast of Indonesia moves back toward Peru.

How do you think scientists can predict El Niño events? (slide 8)

1. Scientists monitor sea surface temperature (SST) for anomalies that indicate warmer SSTs near Peru.

III. Additional Resources

1. Background information:
   http://www.elnino.noaa.gov/

Can You Predict *El Niño*?

Overview

In this activity, students interpret data from NOAA to determine if 2009-2010 was an *El Niño* year. They examine historical records of *El Niño* events and then look at sea surface temperature anomaly data from 2008-2009 in different parts of the ocean. They should notice that waters are warmer than normal in the equatorial Pacific off the northern coast of South America and indicate that this is one indicator of *El Niño* conditions.

Background

In 2009, scientists were concerned that 2009-2010 could be an *El Niño* year. Students play the role of scientists working at NOAA. Other scientists and the media would like to know their opinion about the possibility of an *El Niño* year and what this will mean for global weather. Students should review graphs as designated and answer questions in parts I and II.

Answer key

Part I. The Historical Record

Figure 1A shows sea surface temperature (SST) anomalies over time for a specific region of the eastern equatorial Pacific Ocean basin (region 3.4 as referred to in the figure title). A temperature anomaly (shown on the y axis) refers to the amount the temperature is above or below a normal or average temperature, not the actual temperature itself. Figure 1B shows the Southern Oscillation Index (SOI), a measure of large-scale air pressure differences that occur between the eastern and western tropical Pacific Ocean basins, as measured between Tahiti and Darwin, Australia. Students answer questions 1-5 below related to each figure[3].

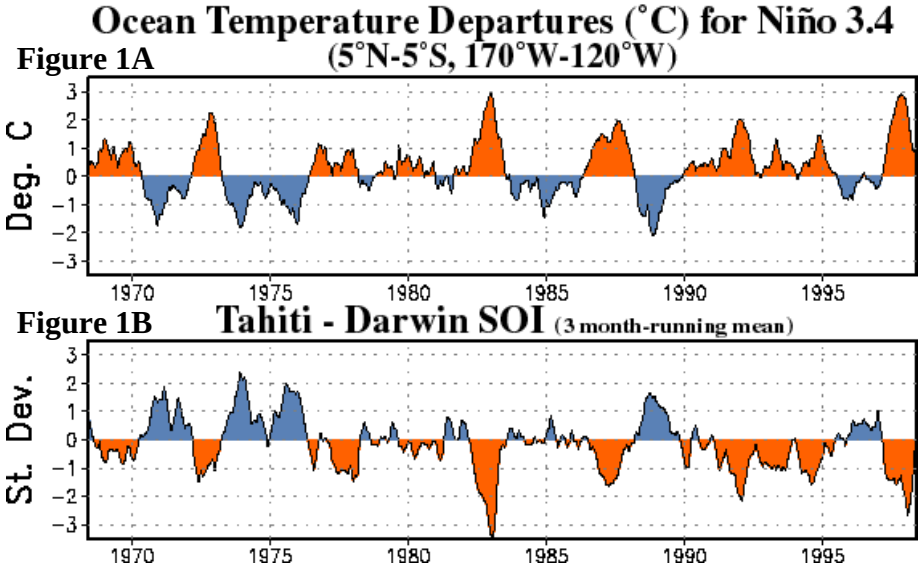


Figure 1A

Figure 1B

[3] Photo: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/soi.shtml

1. What does SST stand for?
   Sea Surface Temperature

2. Explain what SST anomaly means. Indicate what it means when the anomaly is positive and when the anomaly is negative.
   Students' answers should indicate that a SST anomaly means that temperatures are either higher or lower than average ("normal"). If the SSTs are positive, the temperatures are warmer than normal. If they are negative, it means that temperatures are lower than normal.

3. In Figure 1A, the area before 1970, were ocean temperatures recorded as warmer or cooler than average? In 1975?
   Warmer than average before 1970, cooler than average in 1975.

4. In Figure 1A, determine which sets of years had the five highest, positive SST anomalies in the eastern equatorial Pacific. Do you think these years are *El Niño* or *La Niña* years? Explain. **Students' answers should include the years: 1972-1973, 1982-1983, 1986-1987, 1991-1992, 1997-1998. These are *El Niño* years as indicated by the higher than average water temperatures.**

5. Examine Figure 1B for the same years you selected in question (3). What do you notice about the sign (positive or negative) and magnitude of the values of SOI on the y-axis? How do these values compare to the corresponding sea surface temperatures in Figure 1A?
   Students should indicate that the SOI values are negative but similar in magnitude to the sea surface temperature anomalies. They should note that when sea surface temperature anomalies are positive the SOI is negative and vice versa. They should also note that when peaks occur on the sea surface temperature graph, peaks also occur in the SOI graph but with an opposite sign.

Part II. Is 2009-2010 an *El Niño* year? You decide!

Next, students look at data to determine whether they think an *El Niño* event is occurring in 2009-2010.

1. Interpret the color scheme of Figure 2 (next page). What do the numbers next to each color represent? What does it mean if a place on the map is colored red, yellow or orange? What about if a place is colored blue?
   The numbers tell you how much above or below normal (average) the ocean temperature was in 2009. The places of the map that are yellow, orange or red were warmer than normal in 2009. The places that are colored blue were colder in 2009.

2. South America is located in the black box on the map in Figure 2. Look at the temperature of the Pacific Ocean off the west coast of the Northern part of South America **at the equator** (line labeled EQ). Was it hotter or colder than normal in September 2009?
   Hotter than normal.

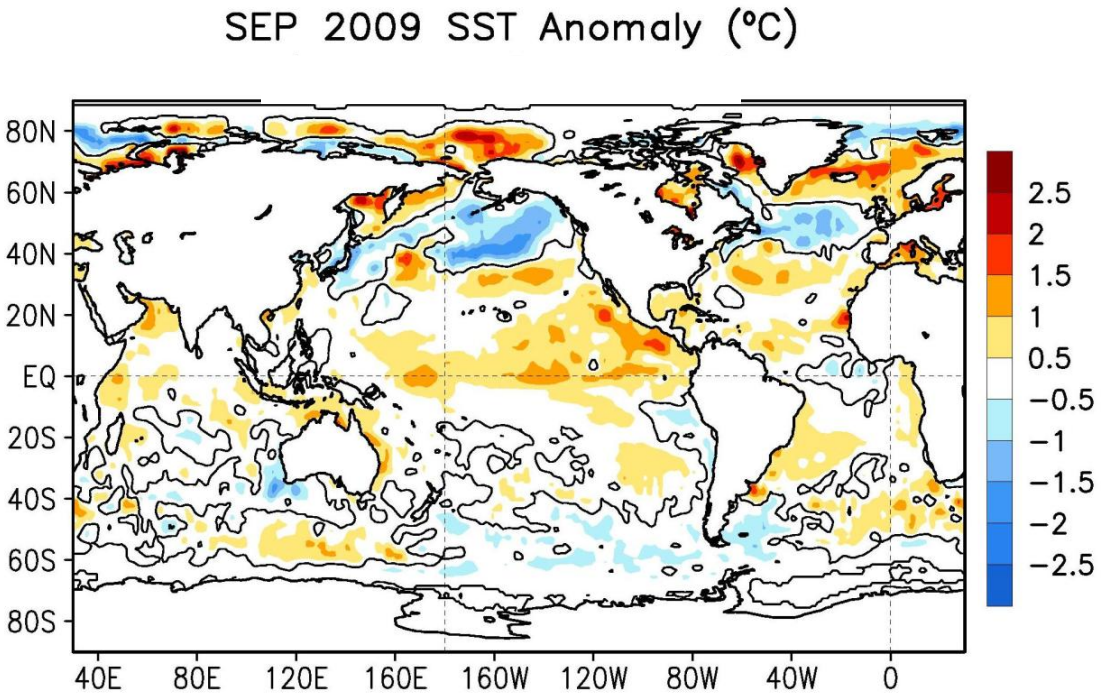


Figure 2. This graph shows temperature anomalies for the equatorial Pacific during September 2009. The horizontal axis represents the latitude of earth – the map is showing the ocean between the Americas (black square) and Western Pacific Islands (red square). The color key shows sea surface temperature anomalies.

3. Locate the lightly dotted line that corresponds to the equator in Figure 2 (labeled EQ). Trace this line all the way across the Pacific Ocean from South America until you hit Indonesia (in the red box). Is the water you pass through for the most part hotter or colder than normal?
   Hotter than normal all the way through the equatorial Pacific Ocean.

4. Does this temperature anomaly map in Figure 2 (Sept 2009) look more like you would expect for a normal year or an *El Niño* year? Why?
   An *El Niño* year because the equatorial Pacific temperature is warmer than normal all the way from South America to Australia.

Next, students use Figure 3 to answer questions 5 -11 to help further determine if they think an *El Niño* event is occurring in 2009-2010.

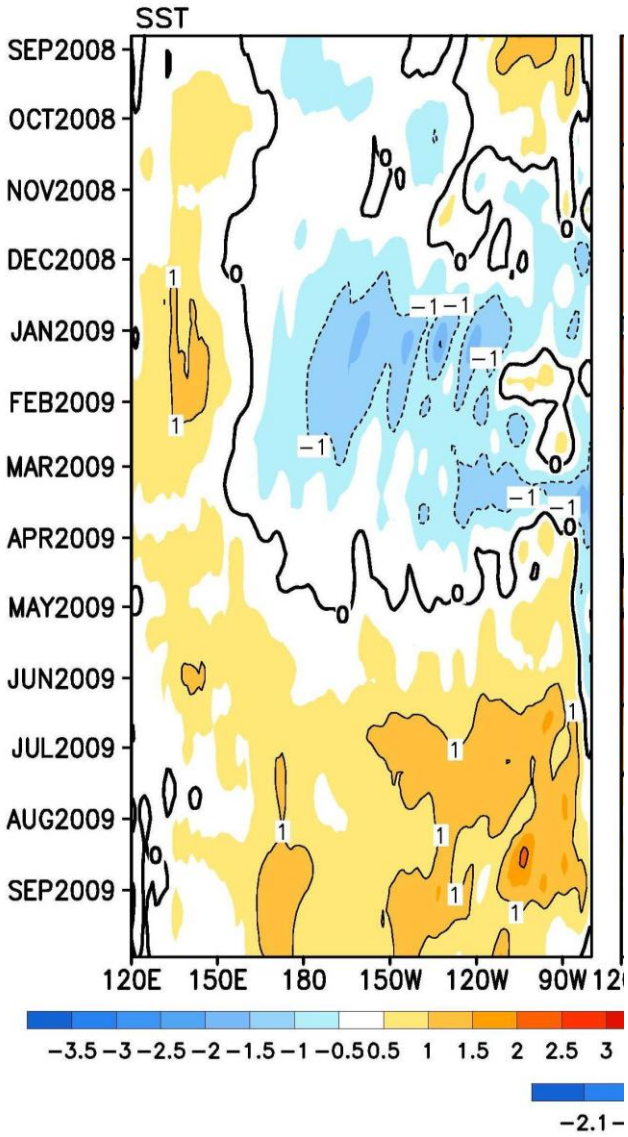


Figure 3. This graph shows temperature anomalies for the equatorial Pacific between Peru and Indonesia over the year from September 2008 to September 2009. Start at the top of the graph that says September 2008. This "row" shows the temperature distribution across the equatorial Pacific for September 2008. Temperature during that time was warm close to Indonesia and cool toward Peru (in South America).

5. Look at the part of the Figure 3 labeled JUL2009. In this month, was it mostly colder in the equatorial Pacific near South America, or mostly warmer than normal?
   Mostly colder.

6. As you move down the graph from July 2009 to Sept 2009, what do you notice about the water temperature between Indonesia and South America?
   The water gets warmer closer to South America.

7. Weakening of which wind pattern could explain the Eastward warming you are observing in Figure 3?
   Trade winds.

8. You learned that upwelling along the coast of Peru (in South America) sustains fish populations there. If upwelling is occurring, would you expect to see cold or warm water off the coast of Peru?
   You would expect to see cold water because the trade winds push the water that has been warmed by the sun toward Australia. This water is then replaced by cooler, nutrient rich water upwelling from the deeper ocean.

9. Looking at Figure 3, is upwelling occurring off the coast of Peru between July 2009 and Sept 2009?
   Upwelling is reduced.

10. Do the SSTs and presence or absence of upwelling you observed in Figures 2 and 3 suggest that 2009-2010 is a normal year or *El Niño* year?
    They suggest an *El Niño* year is occurring.

11. Prepare a brief (short paragraph) statement that the media can use in an article addressing the concern that 2009-2010 is an *El Niño* year. You should state whether you think this concern is valid and explain how you came to your conclusion. Explain what your answer means for the public.
    Answers will vary but should include the following:
    - **2009-2010 does appear to be an *El Niño* year.**
    - **Evidence includes higher than normal SST in the equatorial Pacific that indicates the trade winds may have weakened allowing warm surface water to move back toward Peru.**
    - **Effects may include more severe storms and anchovy decline off of the South American coast.**

Can You Predict *El Niño*?

In 2009, scientists were concerned that 2009-2010 could be an *El Niño* year. You and your group members are a team of scientists working at NOAA. Other scientists and the media would like to know your opinion about this possibility, and what this will mean for the global weather.

Part I. The Historical Record

Figure 1A shows sea surface temperature (SST) anomalies over time for a specific region of the eastern equatorial Pacific Ocean basin (region 3.4 as referred to in the figure title). A temperature anomaly (shown on the y axis) refers to the amount the temperature is above or below a normal or average temperature, not the actual temperature itself. Figure 1B shows the Southern Oscillation Index (SOI), a measure of large-scale air pressure differences that occur between the eastern and western tropical Pacific Ocean basins, as measured between Tahiti and Darwin, Australia. Answer questions 1-5 below related to each figure.

Figure 1A

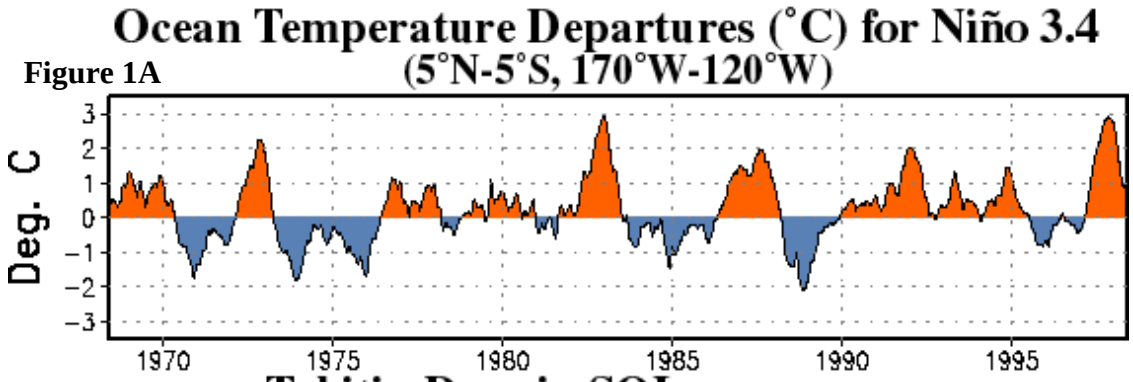
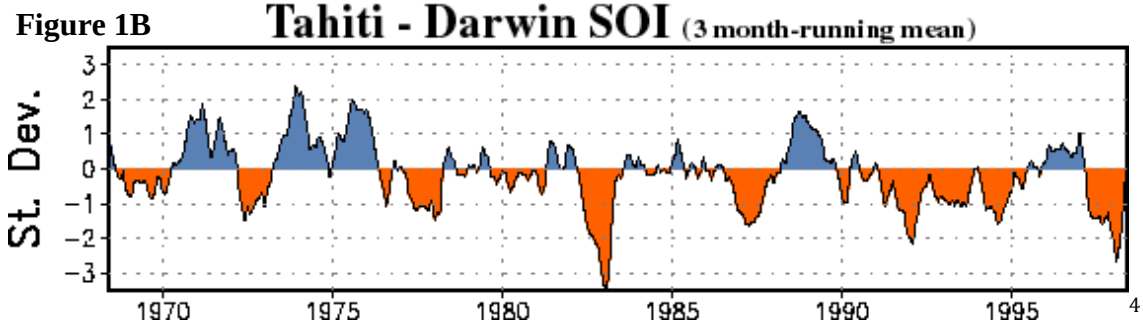


Figure 1B



[4]

[4] Photo: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/soi.shtml; Accessed, April 2011

1. What does SST stand for?

2. Explain what SST anomaly means. Indicate what it means when the anomaly is positive and when the anomaly is negative.

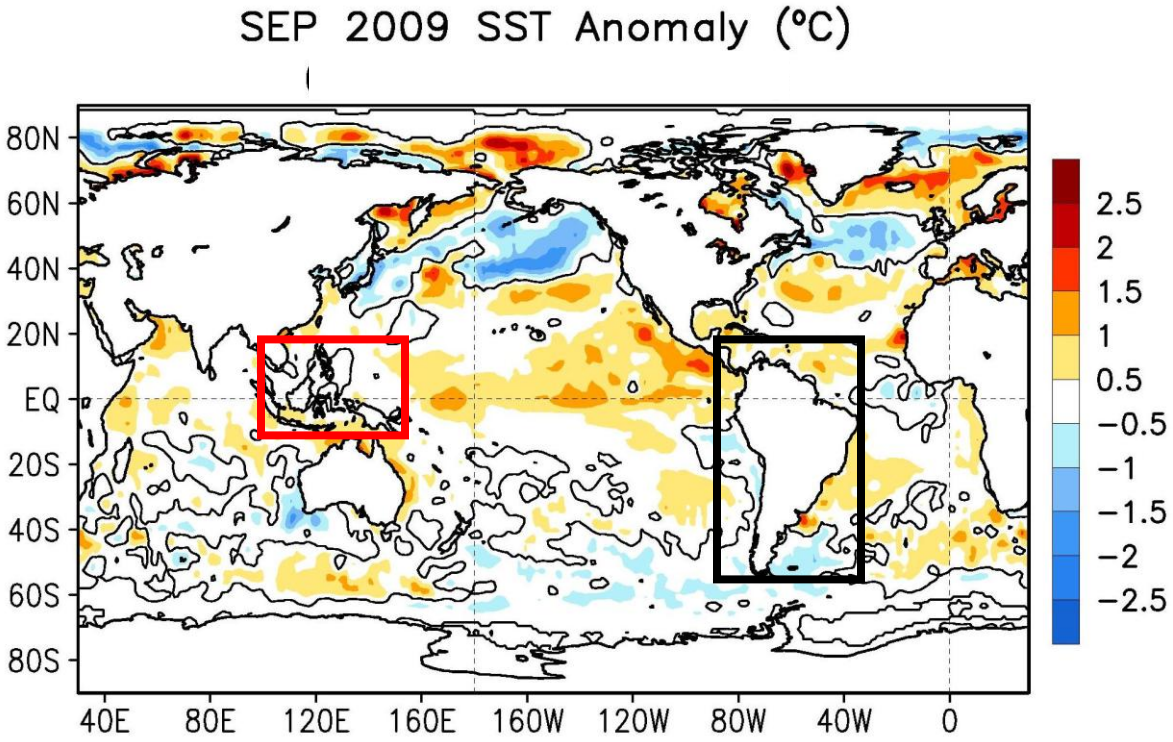
3. In Figure 1A, the area before 1970, were ocean temperatures recorded as warmer or cooler than average? In 1975?

4. In Figure 1A, determine which sets of years had the five highest, positive SST anomalies in the eastern equatorial Pacific. Do you think these years are *El Niño or La Niña* years? Explain.

5. Examine Figure 1B for the same years you selected in question (3). What do you notice about the sign (positive or negative) and magnitude of the values of SOI on the y-axis? How do these values compare to the corresponding sea surface temperatures in Figure 1A?

Part II. Is 2009-2010 an *El Niño* year? You decide!

Next you will want to look at some data to determine whether you think an *El Niño* event is occurring in 2009-2010. Remembering what you learned earlier today, look at the SST data below you've collected at NOAA and answer the questions.



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2. South America is located in the black box on the map in Figure 2. Look at the temperature of the Pacific Ocean off the west coast of the Northern part of South America **at the equator** (line labeled EQ). Was it hotter or colder than normal in September 2009?

3. Locate the lightly dotted line that corresponds to the equator in Figure 2 (labeled EQ). Trace this line all the way across the Pacific Ocean from South America until you hit Indonesia (in the red box). Is the water you pass through for the most part hotter or colder than normal?

4. Does this temperature anomaly map in Figure 2 (Sept 2009) look more like you would expect for a normal year or an *El Niño* year? Why?

Next, use figure 3 (next page) to answer questions 5 -11 to help further determine if you think an *El Niño* event is occurring in 2009-2010.

5. Look at the part of the Figure 3 labeled JUL2009. In this month, was it mostly colder in the equatorial Pacific near South America, or mostly warmer than normal?

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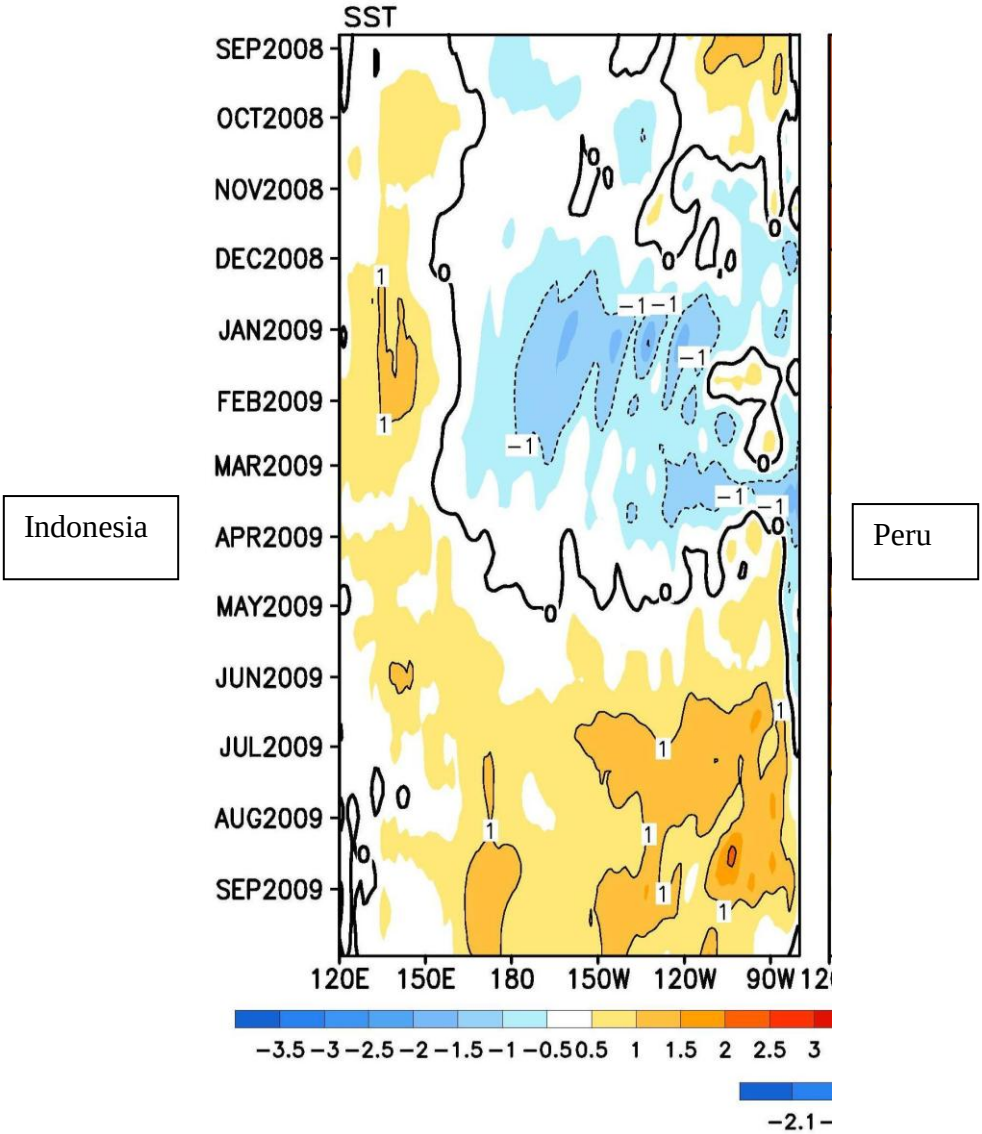

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8. You learned that upwelling along the coast of Peru (in South America) sustains fish populations there. If upwelling is occurring, would you expect to see cold or warm water off the coast of Peru?

9. Looking at Figure 3, is upwelling occurring off the coast of Peru between July 2009 and Sept 2009?

10. Do the SSTs and presence or absence of upwelling you observed in Figures 2 and 3 suggest that 2009-2010 is normal or *El Niño* year?

11. Prepare a brief (short paragraph) statement that the media can use in an article addressing the concern that 2009-2010 is an *El Niño* year. You should state whether you think this concern is valid and explain how you came to your conclusion. Explain what your answer means for the public.

Tips for the Bowl – *El Niño* [5]

What is *El Niño*?: *El Niño* is characterized by warmer than normal sea-surface temperatures (SSTs) in the tropical Pacific Ocean that impact global weather patterns. This deviation from normal SSTs can have large scale impacts, not only on ocean processes, but also on the atmosphere.

The Southern Oscillation: The Southern Oscillation is the see-saw pattern of reversing surface air pressure between the eastern (near Tahiti) and western (near Darwin, Australia) tropical Pacific; when the surface pressure is high in the eastern tropical Pacific it is low in the western tropical Pacific, and vice-versa. The Southern Oscillation Index (SOI) is calculated based on sea level pressure differences between Tahiti and Darwin. In general a negative SOI corresponds to El Niño and occurs when air pressure values are below normal in Tahiti and above normal in Darwin. A positive SOI typically corresponds to *La Niña*. Because ocean warming and pressure reversals are essentially simultaneous, scientists call this phenomenon the El Niño /Southern Oscillation or **ENSO** for short. For more information: http://lwf.ncdc.noaa.gov/teleconnections/enso/indicators/soi.php.

What is *La Niña*? Although the lesson focused on *El Niño*, you should also know about *La Niña.*

- *La Niña* causes mostly the opposite effects of *El Niño*, for example, *El Niño* would cause a wet period in the Midwestern U.S., while *La Niña* would typically cause a dry period in this area.

- *La Niña* is thought to occur due to increases in the strength of the normal patterns of trade wind circulation (unlike *El Niño* which occurs with reductions in the strength of these trade winds.)

- These trade winds increase upwelling off the coast of South America, bringing cool water to the surface and reducing SSTs.

- Impacts of *La Niña* include increased rainfall in the Western tropical Pacific (e.g., torrential rains and flooding in Southeast Asia, wet weather in Eastern Australia).

- *La Niña* is characterized by unusually cold ocean temperatures in the eastern equatorial Pacific, as compared to *El Niño*, which is characterized by unusually warm ocean temperatures in the Equatorial Pacific.

[5] National Marine Educators Association. 2010. *Life on an Ocean Planet*. Current Publishing Corps, Santa Margarita, CA. 598pp.

El Niño

1. Which of the following properties do scientists use to determine if *El Niño* is present and its strength?
    w. Carbon isotopes in deep sea sediments
    x. pH levels of Arctic waters
    y. Southern Oscillation Index
    z. Sea ice coverage in Greenland

2. In an *El Niño* year, which set of the following conditions would you expect:
    w. A cooling of Pacific Ocean SSTs near South America and a warming of SSTs to the northeast of Australia
    x. A warming of Pacific Ocean SSTs near South America and a cooling of SSTs to the northeast of Australia
    y. A warming of the oceans near the northeast of Australia only
    z. A cooling of Pacific Ocean water near South America only

3. During an *El Niño* year, rainfall in (Eastern) Australia would likely be:
    w. Greater than normal
    x. Less than normal
    y. About the same as in a non *El Niño* year
    z. It is impossible to determine because there is no known relationship between *El Niño* conditions and rainfall

4. Typically there are trade winds that blow along the equator in the Pacific Ocean from East to West. In an *El Niño* year the trade winds:
    w. Increase in strength
    x. Weaken
    y. Do not change
    z. Reverse direction

5. Short answer: During an *El Niño* year, what is most likely to happen to the Peruvian Anchovy population?
    Answer: The population will decline

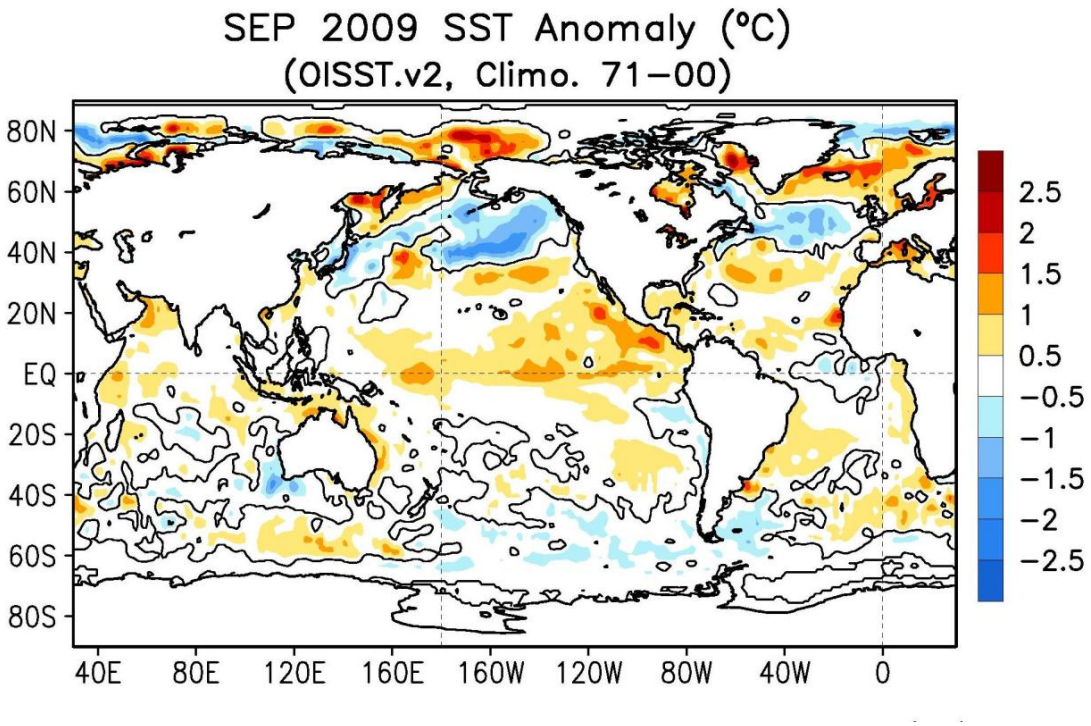
6. Reminder question: The difference in the height of the water surface between high and low tides is:
    w. Neap tide
    x. Spring tide
    y. Tidal range
    z. Tidal current

7. Reminder question: Tidal range is typically the highest during which types of tide?
    Answer: Spring tides

8. What is upwelling?
    w. A surge in fish populations like Peruvian Anchovy
    x. The rising of a cold, nutrient rich current from deep in the ocean
    y. A temperature cell in the atmosphere that rises rapidly
    z. A hurricane that forms rapidly

9. During *El Niño*, upwelling in the Pacific Ocean off the coast of South America:
    w. Increases
    x. Decreases
    y. Shows no change
    z. It is impossible to determine because there is no known relationship between *El Niño* conditions and upwelling

10. Team Challenge Question



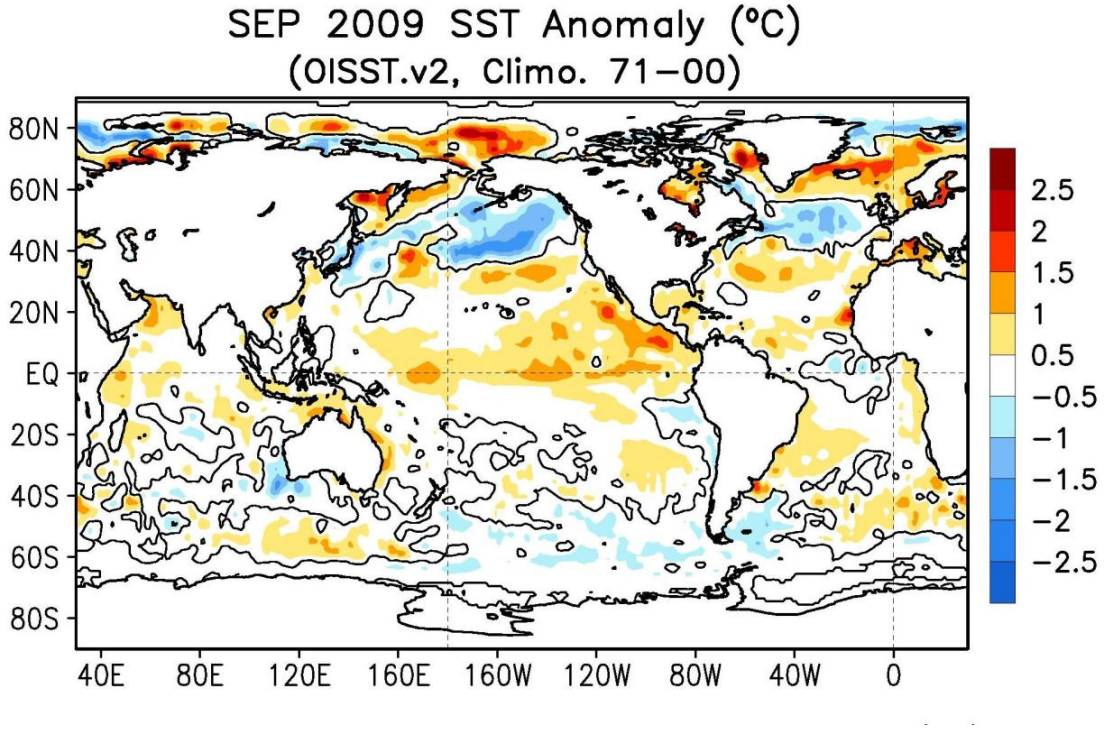
Above is a graph of Sea Surface Anomaly data from September 2009. Use the graph to answer the following questions.

1. Explain what is meant by "SST Anomaly." (2pt)

2. Does this graph provide evidence to suggest that 2009 is an *El Niño* year? Why or why not? (2pt)

3. Name one likely effect of an *El Niño* year on: 1) marine life and 2) humans. (2pt)

ANSWER



Above is a graph of Sea Surface Anomaly data from September 2009. Use the graph to answer the following questions.

1. Explain what is meant by "SST Anomaly." (2pt)
   The graph shows Sea Surface Temperature (SST) (1pt) anomalies, which refer to how different SSTs were from average temperatures during Sept 2009. Negative (blue) values correspond to values below average and positive values (orange and red) to values above average (1pt).

2. Does this graph provide evidence to suggest that 2009 is an *El Niño* year? Why or why not? (2pt)
   This graph does provide possible evidence of an *El Niño* year (1pt) because SST in the eastern tropical Pacific ocean (along the equator) near South America is warmer than average (1pt).

3. Name one likely effect of an *El Niño* year on: 1) marine life and 2) humans. (2pt)
   Answers vary but include:
   Marine life: Fish populations near South America may decline because of reduced upwelling (1pt).
   Humans: Loss of economic productivity due to commercial fish decline, more intense precipitation/storms in some areas of the world (1pt).