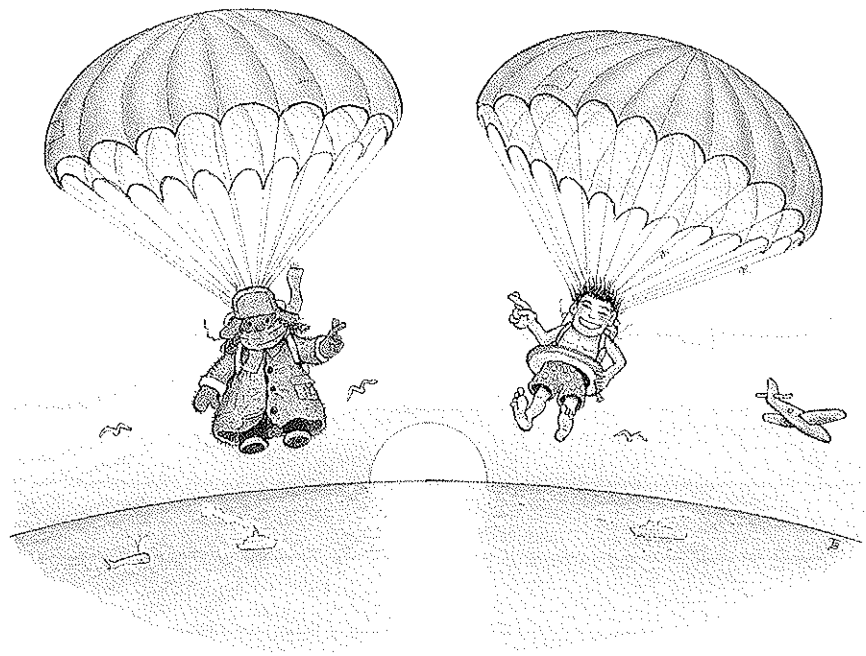
Activity 4 El Niño and Ocean Circulation



Goals

In this activity you will:

- Understand how sea surface temperatures vary during an El Niño event.
- Understand how to use data on sea surface temperatures to make inferences about changes in ocean circulation.
- Use remote-sensing data to determine the extent and duration of the 1997 El Niño event.

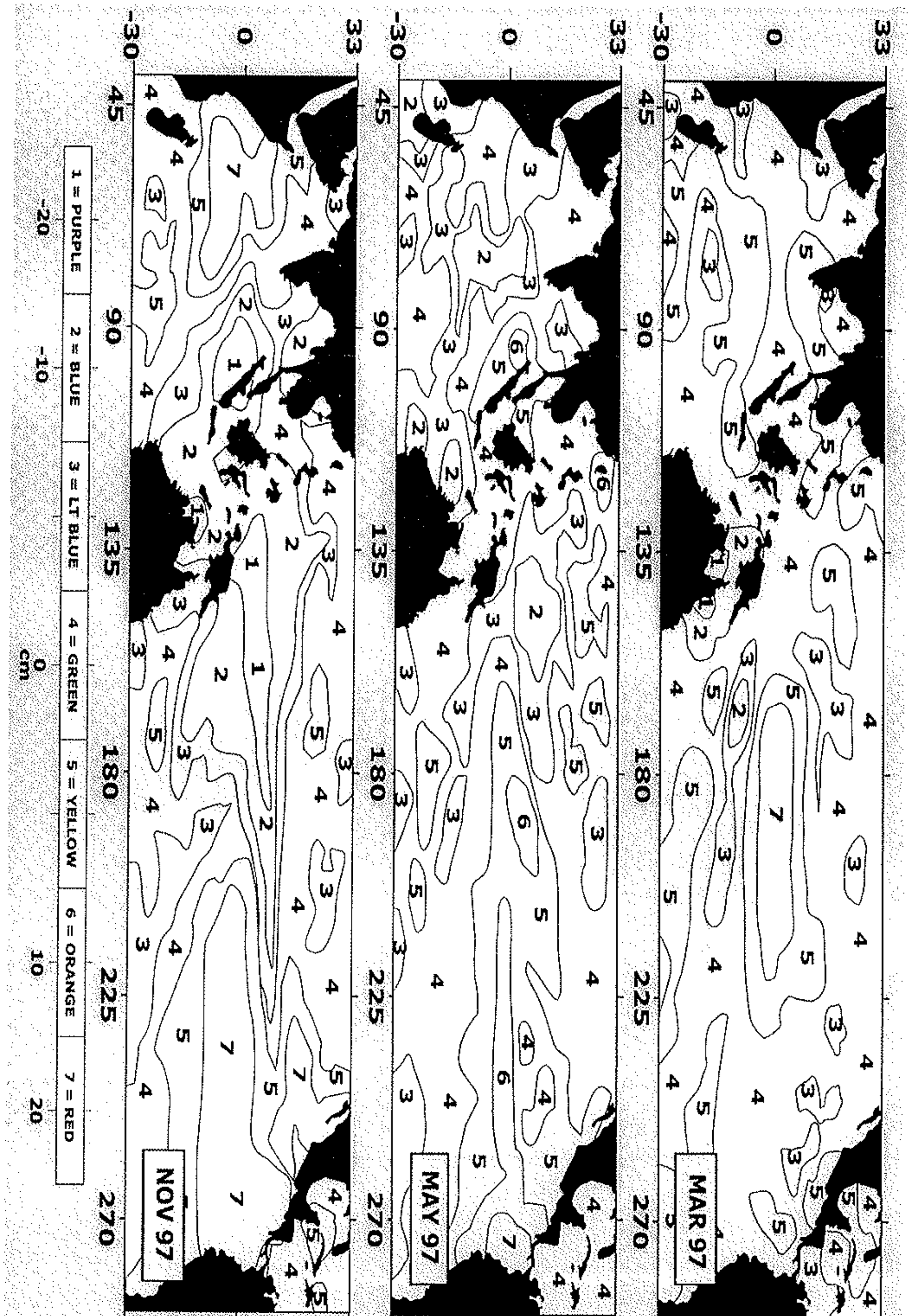
Think about It

Imagine that you and your friends have to make a nighttime parachute jump into unfamiliar waters.

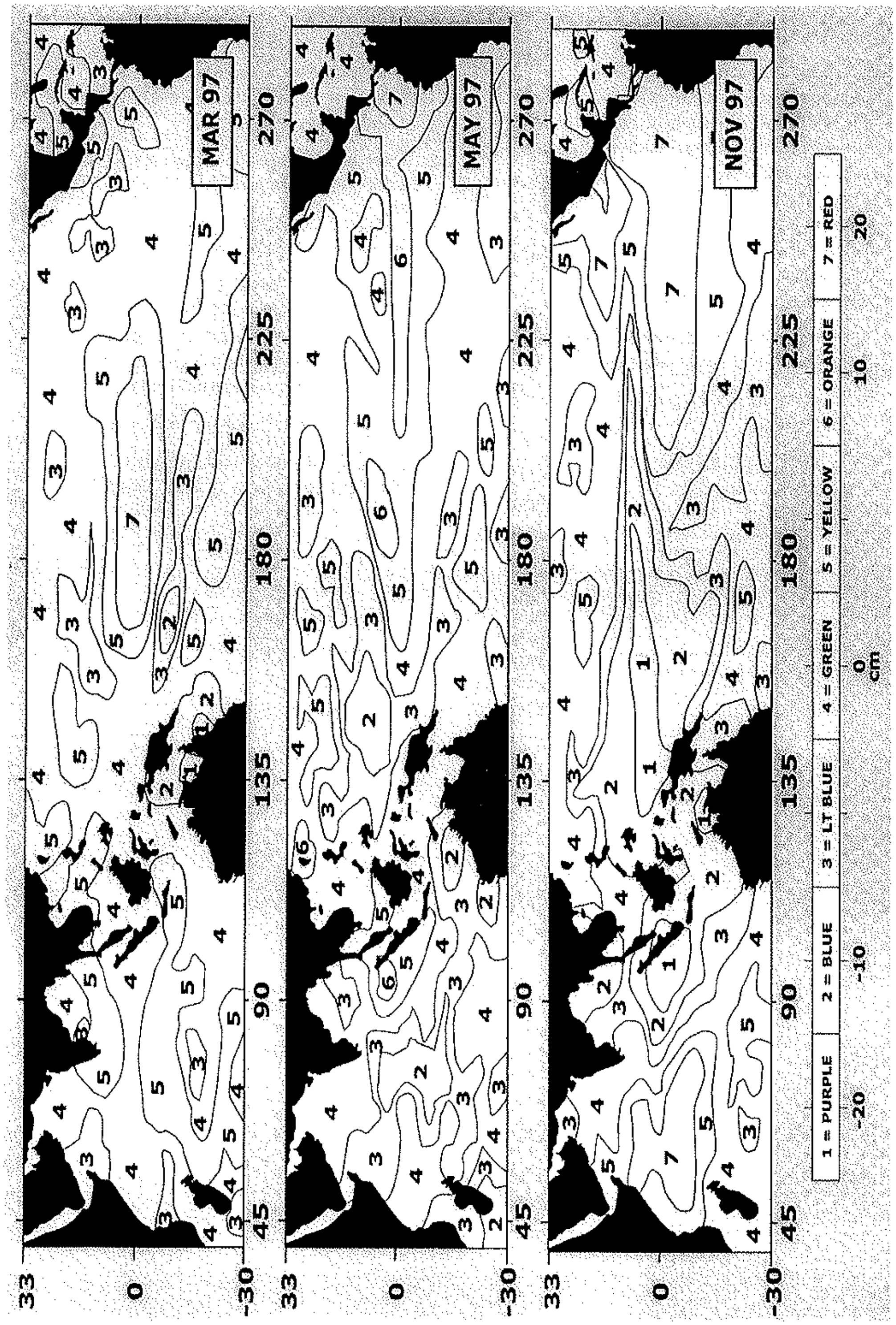
- What are some ways of learning about the distance to the water surface, the depth of the water, and the water temperature, without actually touching the water?

What do you think? In your group, brainstorm some of the methods that could be used. Record your ideas in your *EarthComm* notebook. Be prepared to discuss your responses with your small group and the class.

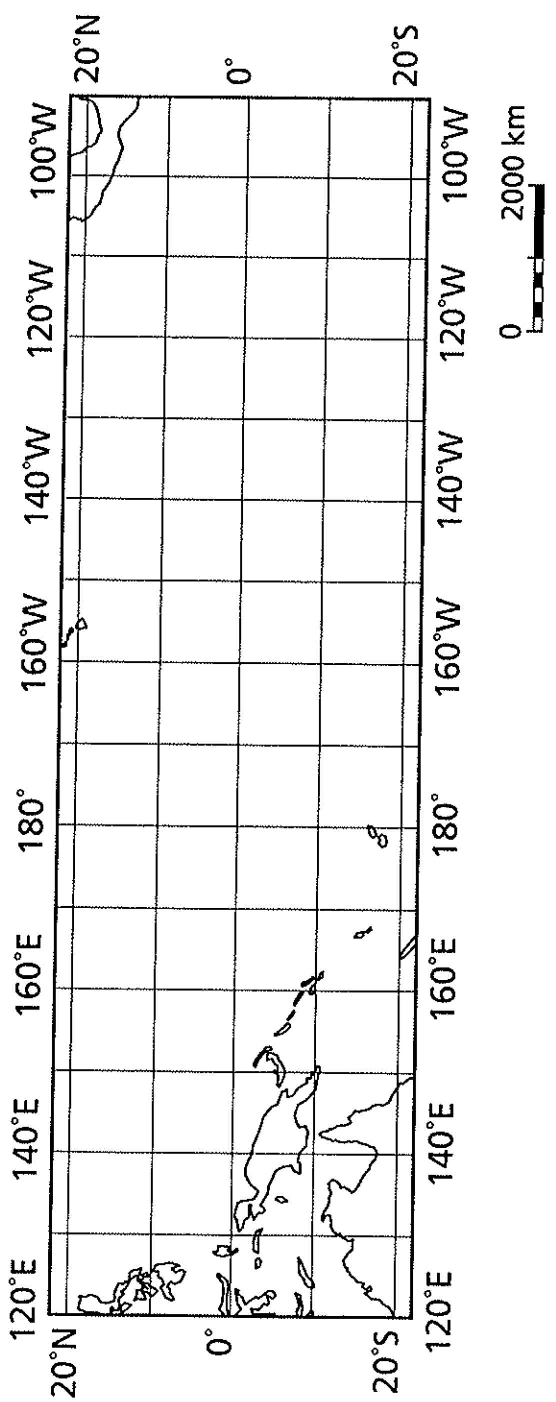
Blackline Master Oceans 4.2 Part 1
Maps of TOPEX/Poseidon Satellite Data



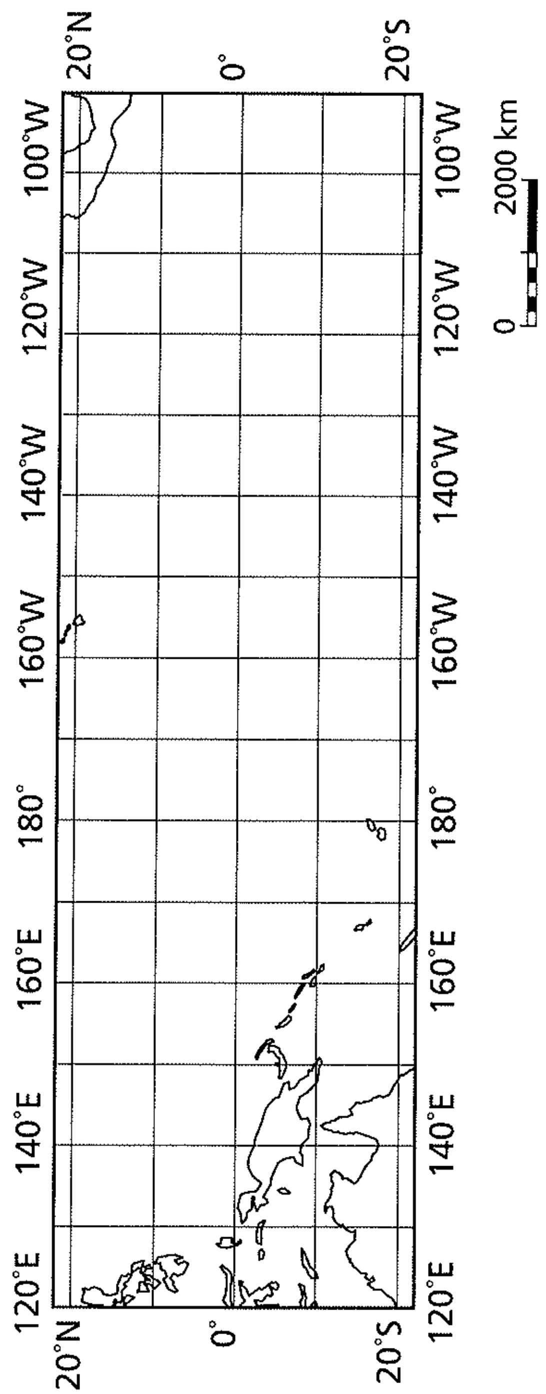
Blackline Master Oceans 4.2 Part 2
Maps of TOPEX/Poseidon Satellite Data



Blackline Master Oceans 4.1
Map of Pacific Ocean



Blackline Master Oceans 4.1
Map of Pacific Ocean



Investigate

Part A: Sea Surface Temperature

1. Examine the two data sets on these pages. Think about how you would represent this data so that it is easier to understand and can be communicated to a wide variety of people. Discuss your ideas with members of your group. In your discussion, consider the following questions:

   a) What is the fundamental difference between the two data sets?

   b) How would you communicate this difference?

   c) Why is it important to communicate data clearly and efficiently?

   d) What patterns can you see? How would the patterns be easily recognizable?

   e) What is the highest temperature in the two data sets?

   f) What kind of scale or key would you develop to include all the data?

   g) If colors were used to represent the data, how many different colors would you use for this data set? (Too many might be confusing; too few might misrepresent the data.)

   h) What would the colors represent?

   i) Can the way data is represented affect the way data is interpreted?

Data Set 1. Sea surface temperatures (degrees Celsius) in the Equatorial Pacific in August during a normal (non–El Niño) year.

	125°E	137°E	149°E	161°E	173°E	175°W	163°W	151°W	139°W	127°W	115°W	103°W
11°N	29.0	29.1	29.1	28.9	28.5	28.0	27.4	27.5	27.4	27.4	27.5	28.1
9°N	29.0	29.1	29.1	28.9	28.5	28.1	27.7	27.7	27.6	27.3	27.2	27.6
7°N	29.0	29.2	29.2	28.9	28.6	28.1	27.9	27.7	27.4	27.0	26.7	26.9
5°N	28.9	29.3	29.2	28.9	28.6	28.1	27.9	27.4	27.1	26.5	26.0	25.9
3°N	28.8	29.3	29.2	28.8	28.5	28.0	27.9	27.1	26.7	25.9	25.1	24.7
1°N	28.6	29.1	29.1	28.7	28.2	27.9	27.8	26.8	26.2	25.3	24.3	23.5
1°S	28.2	28.9	29.0	28.5	28.2	27.8	27.7	26.8	26.0	25.0	23.8	22.6
3°S	27.7	27.9	28.9	28.5	28.2	27.8	27.7	27.0	26.2	25.1	23.7	22.4
5°S	27.5	26.8	28.6	28.5	28.4	27.9	27.8	27.2	26.4	25.3	23.9	22.5
7°S	27.3	26.6	28.1	28.4	28.5	28.1	27.8	27.4	26.5	25.5	24.1	22.8
9°S	27.2	26.4	27.3	28.2	28.2	28.2	27.9	27.4	26.5	25.4	24.3	23.0
11°S	27.0	26.3	26.6	27.8	27.8	28.2	27.8	27.3	26.4	25.3	24.2	22.9

Data Set 2. Sea surface temperatures (degrees Celsius) in the Equatorial Pacific in August during an El Niño year.

	125°E	137°E	149°E	161°E	173°E	175°W	163°W	151°W	139°W	127°W	115°W	103°W
11°N	28.9	29.2	29.0	29.2	28.8	28.4	28.0	27.7	27.9	27.8	28.2	28.6
9°N	28.7	29.1	28.9	29.1	29.0	28.5	28.4	28.1	28.2	28.0	28.1	28.2
7°N	28.6	29.0	28.8	29.1	29.2	28.7	28.7	28.3	28.3	28.0	27.8	27.8
5°N	28.5	28.8	28.8	29.1	29.3	28.9	28.8	28.3	28.2	27.7	27.3	27.2
3°N	28.2	28.6	28.8	29.1	29.4	29.1	28.8	28.0	27.9	27.2	26.6	26.2
1°N	27.8	28.4	28.8	29.2	29.6	29.2	28.8	27.7	27.6	26.7	25.8	25.2
1°S	27.4	28.3	28.7	29.2	29.7	29.2	28.8	27.7	27.5	26.4	25.3	24.5
3°S	27.0	27.7	28.5	29.2	29.7	29.2	28.8	27.9	27.6	26.3	25.2	24.3
5°S	26.8	26.1	27.9	29.0	29.6	29.2	28.7	28.0	27.6	26.3	25.3	24.3
7°S	26.6	25.7	27.1	28.7	28.9	29.0	28.6	28.2	27.6	26.3	25.4	24.3
9°S	26.6	25.6	26.5	28.2	28.4	28.8	28.3	28.2	27.4	26.3	25.3	24.1
11°S	26.4	25.6	25.8	27.5	28.0	28.3	28.0	28.0	27.2	26.2	25.1	23.7

2. Typically, red is used to represent the warmest temperature and purple or dark blue is used for the coldest temperature.

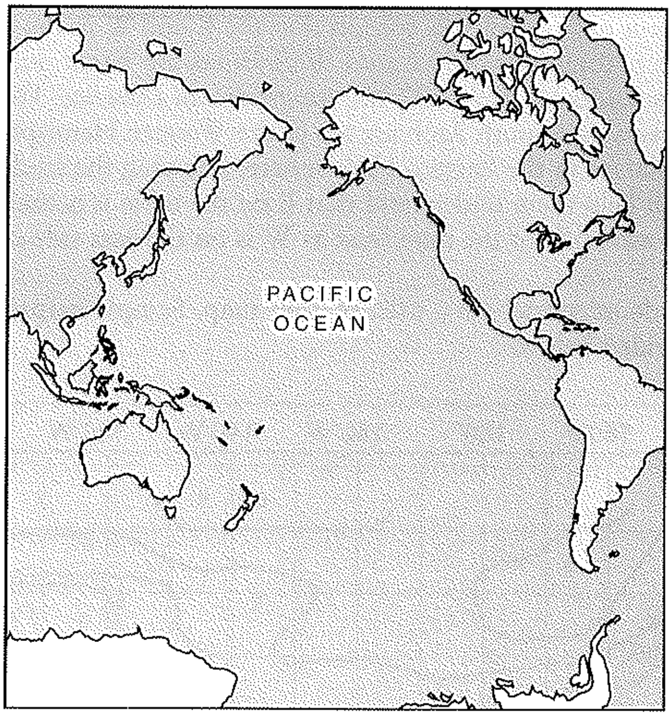
   a) Make a color scale to represent the sea surface temperatures given for the Pacific Ocean. You must have a color that can be used to plot every data point in the two data sets, from the lowest temperature to the highest temperature. If you wish, you may round the data to the nearest whole number. For example, 21.9 becomes 22, and 18.4 becomes 18. Draw your scale on two separate copies of the Pacific Ocean, similar to the one shown on the following page.

3. Use Data Set 1.

   a) Plot this data on a map of the Pacific Ocean. If available, a clear plastic ruler might be useful for plotting. Use the appropriate colored pencil for plotting.

   b) Where data points of the same color are located next to each other, lightly shade in that area with the corresponding colored pencil. When you are finished doing these for all the data points, you will have a map that is almost completely colored in the area between 11°N and 11°S.

   c) Give this map the title "Sea Surface Temperatures in August during a non–El Niño Year."



4. Use Data Set 2.
   a) Plot this data on a second copy of the map of the Pacific Ocean.
   b) Shade in the map and label it appropriately.
   c) Give this map the title "Sea Surface Temperatures in August during an El Niño Year."
5. When you have completed your map, answer the following questions:
   a) At what latitude and longitude do the warmest sea surface temperatures occur in August during a non–El Niño year?
   b) At what latitude and longitude do the warmest sea surface temperatures occur in August during an El Niño year?
   c) In general, what happens to sea surface temperatures in the equatorial Pacific Ocean during an El Niño event?
   d) During an El Niño event, what are the surface currents bringing to the eastern edge of the Pacific Ocean?
   e) In which direction are surface currents in the equatorial Pacific moving during an El Niño event?

f) Think carefully about where the surface ocean currents are pushing the water during an El Niño event. Which side of the equatorial Pacific Ocean would you expect to have higher sea level during an El Niño event?

g) From the differences that you noted in the data, would you infer that surface circulation is in the same direction during El Niño and non–El Niño years? Explain.

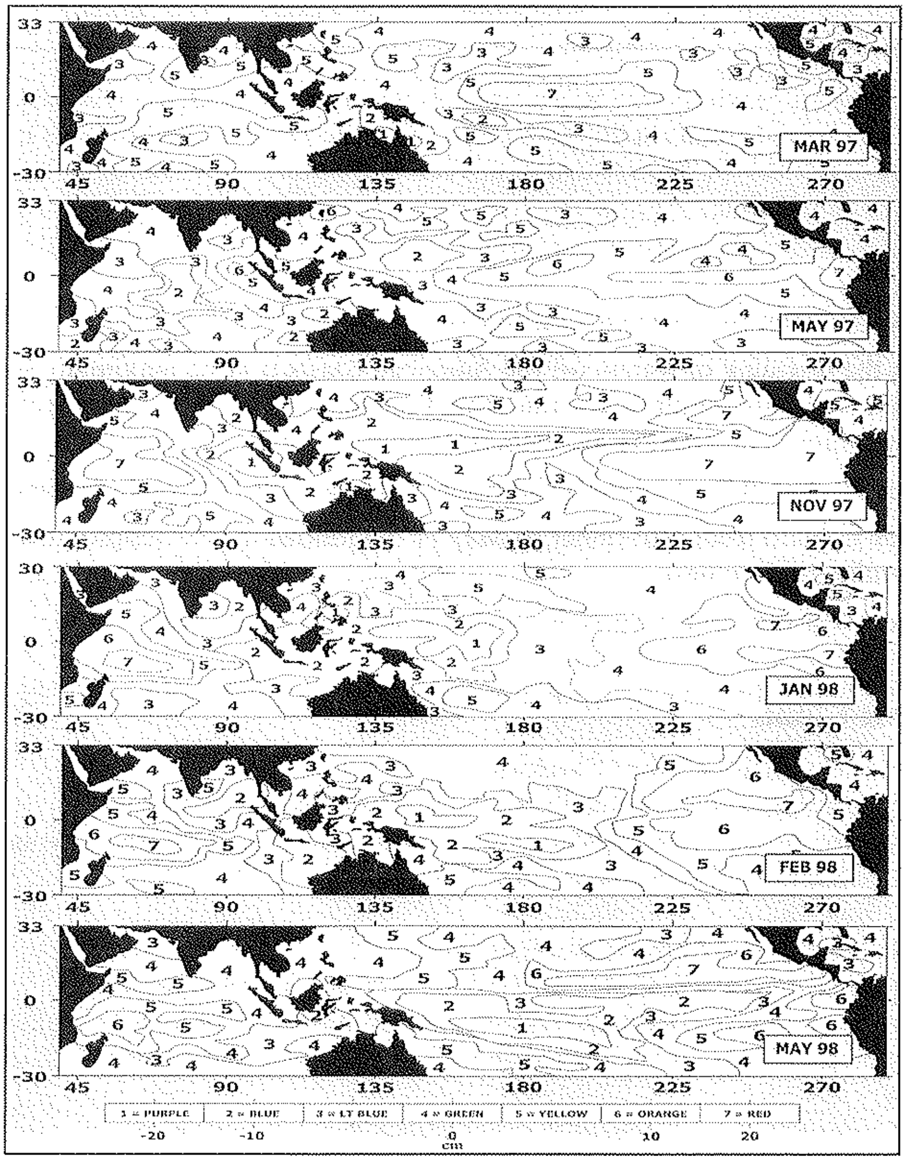
h) Are these maps easier to interpret than the data table?

i) In what ways are the colored maps inferior to the data table?

j) Is it important for scientists to have access to the map and the data table? Why or why not?

Part B: Extent and Duration of an El Niño Event

1. The following maps illustrate data collected by the TOPEX/Poseidon satellite, launched on behalf of NASA. TOPEX stands for Topography Experiment, and Poseidon was the Greek god of the sea. The TOPEX/Poseidon satellite actually measures sea level rather than water temperature. A number on one of your map sections is 10 cm higher or lower than the next. However, scientists have found when mapping the TOPEX satellite data that the highest sea levels match the warmest water, and the lowest are indeed the coolest. These bulges, or hills and valleys of water, are easily tracked.
   a) Color a copy of the maps using the color scheme found at the bottom of the maps. (Remember: the higher the number the warmer the temperature.)
2. After your maps are complete, answer the following questions:
   a) Which way did the warm water move?
   b) The El Niño was at maximum in November. How do you know?
   c) How long did it take for the El Niño to reach maximum?
   d) How long did it take El Niño to disappear?
   e) Look at the size of the area affected by El Niño. How does this compare to the size of your state?



TOPEX/Poseidon data, March 1997–May 1998.

Reflecting on the Activity and the Challenge

In this activity you saw that the El Niño conditions changed the surface of the equatorial Pacific Ocean considerably compared to "normal" (non–El Niño) conditions. These conditions lasted for several months and affected the entire west coast of the United States, where El Niño pushed warm water especially close to Mexico and California. Indian Ocean temperatures were also increased, but water temperatures in Southeast Asia were cooler. This should help you understand why El Niño could affect the weather and climate. You will learn more about this in the next activity.

Digging Deeper

El Niño Conditions and Non–El Niño Conditions

During most of the time along the Peruvian coast of South America, a strong northwest-flowing current causes upwelling, bringing deeper water that is rich in nutrients up to the surface (*Figure 1*). These cold waters support a rich population of fish. An El Niño is a condition, lasting one to three years, when the sea surface temperatures in the eastern equatorial Pacific Ocean, off the coast of Peru, are much higher than during other times. During these times the fish population is much smaller, because cold, nutrient-rich waters are no longer brought up to the surface.

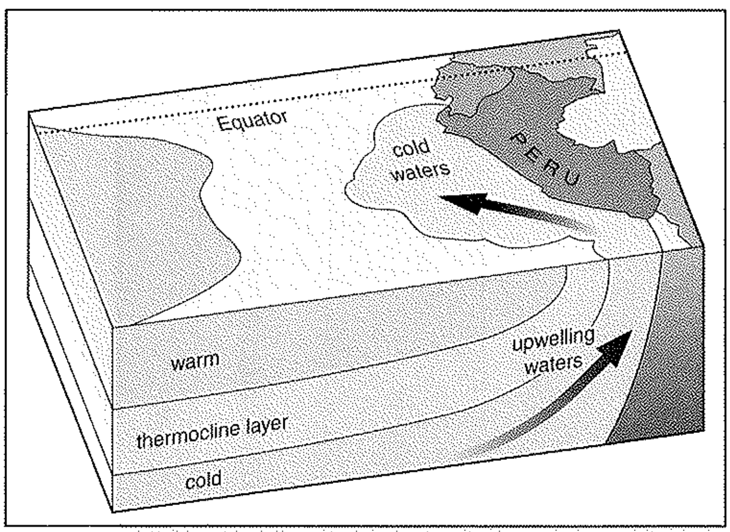


Figure 1 Upwelling off the coast of Peru.

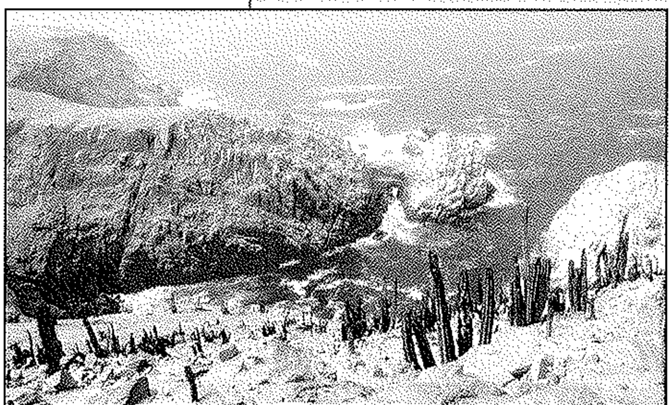


Figure 2 The waters along the Peruvian coast of South America receive nutrients via upwelling.

El Niño conditions have been known to Peruvians for centuries. It has only been in the past 100 years, however, that geoscientists have recognized that an El Niño involves changes in ocean circulation, sea surface temperatures, and climate throughout the entire equatorial Pacific. This is an area that stretches a quarter of the way around the world.

An El Niño is usually called an "event," and it is contrasted with "normal" conditions in the equatorial Pacific. It's more realistic, however, to think of El Niño conditions and non–El Niño conditions as two different states of the ocean and the atmosphere, which alternate with each other irregularly as the years go by. An El Niño lasts one to three years, and non–El Niño conditions usually last about five to ten years. The equatorial Pacific is in the "El Niño state" about 20% of the time. Geoscientists still don't have a clear understanding of what causes the switch between non–El Niño conditions and El Niño conditions.

The Southern Oscillation

Most of the time, the eastern equatorial Pacific has a very dry climate, and the western equatorial Pacific, in the area of Australia and Indonesia, has a very humid and rainy climate. Long ago, a climatologist named G.T. Walker recognized that this difference in climate was a reflection of a gigantic circulation cell. Air rises up in the western Pacific, causing abundant rainfall, and then flows eastward at high altitudes to the eastern Pacific. It then slowly sinks back to low altitudes and moves back to the western Pacific as easterly surface winds. The reason the eastern Pacific is usually so dry is that the sinking air prevents condensation and rainfall. This circulation cell in the equatorial Pacific is now called the **Walker circulation**. See *Figure 3*.

During El Niño conditions, the atmospheric circulation in the equatorial Pacific changes drastically. The area of humid, rising air and abundant rainfall shifts eastward, to the central Pacific and even the eastern Pacific. The western area is unusually dry. Sometimes there is extreme drought there, and sometimes there are torrential rains and flooding in the normally arid areas along the west coast of South America. The easterly winds that blow near the Equator weaken, and sometimes even reverse.

Geo Words

Walker circulation: circulation cells within the equatorial atmosphere caused by differences in climate.

The Equatorial Pacific Ocean

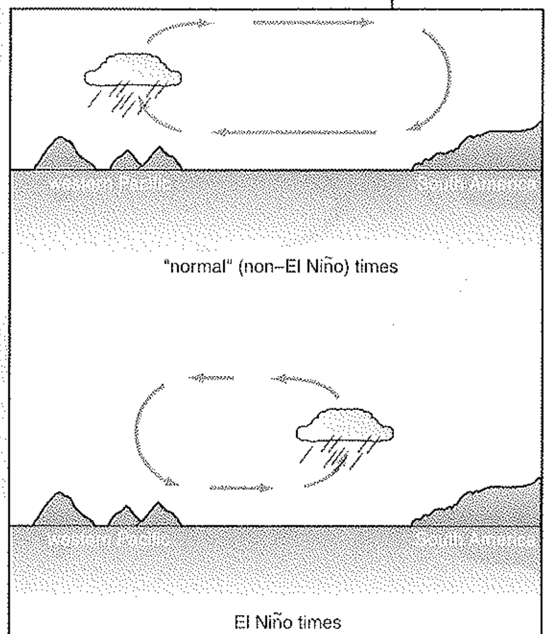


Figure 3 Normal (top) oceanic and atmospheric conditions in the equatorial Pacific, illustrating Walker circulation cells. During El Niño (bottom), shifts in atmospheric pressure result in a weakening of the trade winds and a shift in precipitation.

During non–El Niño years, the easterly winds move warm surface water toward the western boundary of the Pacific. Sea level is then slightly higher along the western boundary of the Pacific, partly because of the push of the wind on the water but also because the water is much warmer. You know that water expands when it is raised to a higher temperature, and that raises the sea surface temperature slightly because of the expansion of the water in the upper layer of the ocean. Also, the thermocline (go back and review the material in Activity 1) is much deeper in the western Pacific than in the eastern Pacific. The reason that upwelling along the coast of South America causes the ocean surface to be so cold is that thermocline is very shallow, allowing the upwelling to tap cold water from below.

During El Niño years, the equatorial Pacific Ocean is very different. The weakening of the easterly winds causes warm water to move eastward from the western Pacific area, all the way to the west coast of South America. At the same time, the thermocline gradually deepens from west to east, in a kind of wavelike motion. Upwelling continues along the west coast of South America, but because the thermocline is now much deeper there, warm water instead of cold water is brought up to the surface.

Cause and Effect

Which comes first, the change in atmospheric circulation or changes in the equatorial ocean? The changes in the atmosphere and the ocean that are involved in the beginning of an El Niño event seem to develop at about the same time. There is therefore no easy way to decide which is the cause and which is the effect. Geoscientists are still not sure about this. One way of thinking about this is that the ocean and the atmosphere in the equatorial