

# 19.3 Regional Wind Systems



## Section 19.3

### 1 FOCUS

#### Section Objectives

- 19.9** Identify the causes of local winds.
- 19.10** Describe the general movement of weather in the United States.
- 19.11** Compare and contrast weather patterns characteristic of El Niño and La Niña events.

#### Reading Focus

##### Key Concepts

- What causes local winds?
- Describe the general movement of weather in the United States.
- What happens when unusually strong, warm ocean currents flow along the coasts of Ecuador and Peru?
- How is a La Niña event triggered?

##### Vocabulary

- ◆ prevailing wind
- ◆ anemometer
- ◆ El Niño

##### Reading Strategy

**Previewing** Copy the table below. Before you read, use Figure 17 to locate examples of the driest and wettest regions on Earth. After you read, identify the dominant wind system for each location.

Precipitation	Location	Dominant Wind System
Extremely low	a. _____?	b. _____?
Extremely high	c. _____?	d. _____?

#### Reading Focus

##### Build Vocabulary

L2

**Word Parts** Explain to students that the word *anemometer* is a combination of the Greek word *anemos*, meaning “wind,” and the Latin *meter*. Have students use this information to predict the definition of *anemometer*. After they have studied the section, have them correct their predictions if necessary.

##### Reading Strategy

L2

Sample answers:

- a. Arabian Desert
- b. sinking trade winds produce tropical high
- c. Amazon rain forest
- d. rising trade winds produce equatorial low

##### Local Winds

##### Use Visuals

L1

**Figure 12** After students have examined the illustration, ask: **Does a sea breeze move toward the sea or away from the sea? (away from the sea) Why does a sea breeze usually reach its highest speeds in the late afternoon? (The heat differential between land and water increases with the number of hours the sun has been shining.)**

Visual, Logical

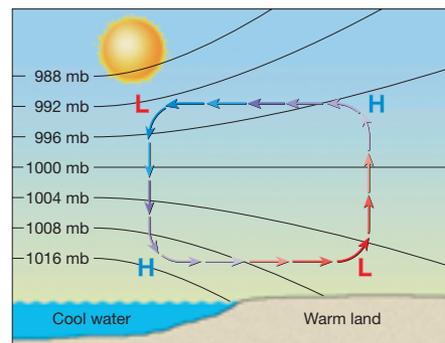
Circulation in the middle latitudes is complex and does not fit the convection system described for the tropics. Between about 30 and 60 degrees latitude, the general west-to-east flow, known as the westerlies, is interrupted by migrating cyclones and anticyclones. In the Northern Hemisphere, these pressure cells move from west to east around the globe.

### Local Winds

Small-scale winds produced by a locally generated pressure gradient are known as local winds. ➤ **The local winds are caused either by topographic effects or by variations in surface composition—land and water—in the immediate area.**

**Land and Sea Breezes** In coastal areas during the warm summer months, the land surface is heated more intensely during the daylight hours than an adjacent body of water is heated. As a result, the air above the land surface heats, expands, and rises, creating an area of lower pressure. As shown in Figure 12, a sea breeze then develops because cooler air over the water at higher pressure moves toward the warmer land and low pressure air. The breeze starts developing shortly before noon and generally reaches its greatest intensity during the mid- to late afternoon. These relatively cool winds can be a moderating influence on afternoon temperatures in coastal areas.

**Figure 12 Sea Breeze** During daylight hours, the air above land heats and rises, creating a local zone of lower air pressure.



Use Visuals

L1

**Figure 13** After students have examined the illustration, ask: **Does a land breeze move toward the land or away from the land?** (*away from the land*) **Why do land breezes usually take place at night?** (*After sunset, both land and water begin to cool, but land cools more rapidly.*) **Visual, Logical**

Build Science Skills

L2

**Comparing and Contrasting** Have students create a table that contrasts sea, land, valley, and mountain breezes.

	Direction	Day/Night	Cause
sea	toward land	day	sun heats land faster than water; air above land rises, creating low pressure zone
land	toward sea	night	land cools faster than water; air above land sinks, creating high pressure zone relative to air above water
valley	upslope	day	air along slopes heats faster than air above valley, glides up slope because it is less dense
mountain	downslope	night	air along slopes cools faster than air above valley, sinks down slope into valley

Verbal, Logical



Differential Heating

L2

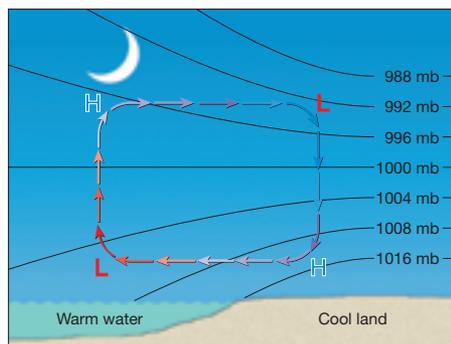
**Purpose** Students observe that soil heats faster than water.

**Materials** 2 containers, soil, water, 2 thermometers

**Procedure** Fill the two containers 2/3 full, one with water and the other with soil. Place a thermometer in each container and place both in a hot, sunny location. Read temperature measurements at the beginning of the experiment and after about 25 minutes.

**Expected Outcome** Soil heats faster than water.

Visual, Kinesthetic



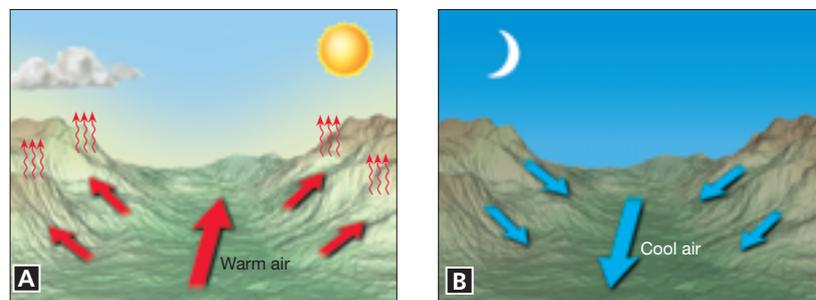
**Figure 13 Land Breeze** At night, the land cools more rapidly than the sea, generating an offshore flow called a land breeze.

**Inferring** *How would the isobar lines be oriented if there was no air pressure change across the land-water boundary?*

At night, the reverse may take place. The land cools more rapidly than the sea, and a land breeze develops, as shown in Figure 13. The cooler air at higher pressures over the land moves to the sea, where the air is warmer and at lower pressures. Small-scale sea breezes also can develop along the shores of large lakes. People who live in a city near the Great Lakes, such as Chicago, recognize this lake effect, especially in the summer. They are reminded daily by weather reports of the cool temperatures near the lake as compared to warmer outlying areas.

Valley and Mountain Breezes

A daily wind similar to land and sea breezes occurs in many mountainous regions. During daylight hours, the air along the slopes of the mountains is heated more intensely than the air at the same elevation over the valley floor. Because this warmer air on the mountain slopes is less dense, it glides up along the slope and generates a valley breeze, as shown in Figure 14A. The occurrence of these daytime upslope breezes can often be identified by the cumulus clouds that develop on adjacent mountain peaks.



**Figure 14 A Valley Breeze** Heating during the day generates warm air that rises from the valley floor. **B Mountain Breeze** After sunset, cooling of the air near mountain slopes can result in cool air moving into the valley.

After sunset, the pattern may reverse. The rapid cooling of the air along the mountain slopes produces a layer of cooler air next to the ground. Because cool air is denser than warm air, it moves downslope into the valley. Such a movement of air,

illustrated in Figure 14B, is called a mountain breeze. In the Grand Canyon at night, the sound of cold air rushing down the sides of the canyon can be louder than the sound of the Colorado River below.

The same type of cool air drainage can occur in places that have very modest slopes. The result is that the coldest pockets of air are usually found in the lowest spots. Like many other winds, mountain and valley breezes have seasonal preferences. Although valley breezes are most common during the warm season when solar heating is most intense, mountain breezes tend to be more dominant in the cold season.



**What type of local wind can form in the Grand Canyon at night?**

Customize for English Language Learners

Explain that the terms *prevailing* and *predominant* are synonyms. They are adjectives that mean “having superior strength, influence, or authority.” Have students look up the definitions of verb forms of these words and use each in a sentence. Then ask students to

look up definitions for the related verb *dominate* and the related adjective *dominant*. Students also could be asked to compare and contrast the meanings of all six words, as well as the suffix *pre-*.

## How Wind Is Measured

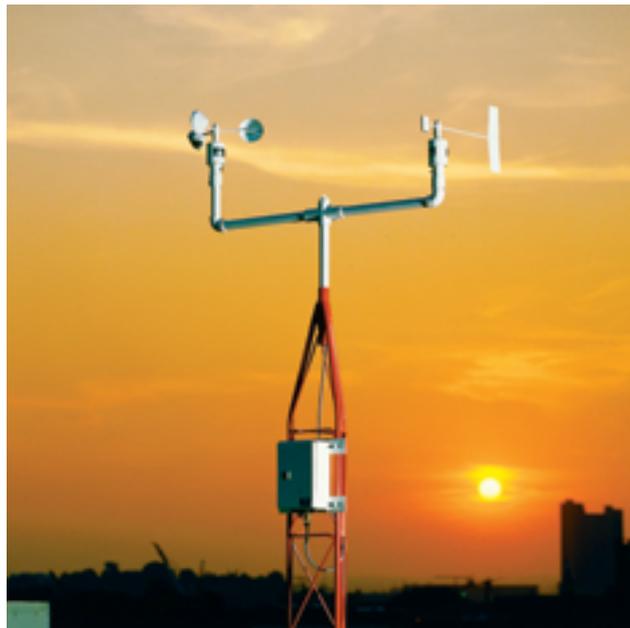
Two basic wind measurements—direction and speed—are particularly important to the weather observer. Winds are always labeled by the direction from which they blow. A north wind blows from the north toward the south. An east wind blows from the east toward the west. The instrument most commonly used to determine wind direction is the wind vane, shown in the upper right of Figure 15. Wind vanes commonly are located on buildings, and they always point into the wind. The wind direction is often shown on a dial connected to the wind vane. The dial indicates wind direction, either by points of the compass—N, NE, E, SE, etc.—or by a scale of 0° to 360°. On the degree scale, 0° or 360° are north, 90° is east, 180° is south, and 270° is west.



Toward which direction does a SE wind blow?

**Wind Direction** When the wind consistently blows more often from one direction than from any other, it is called a **prevailing wind**. Recall the prevailing westerlies that dominate circulation in the middle latitudes. 🌍 **In the United States, the westerlies consistently move weather from west to east across the continent.** Along within this general eastward flow are cells of high and low pressure with the characteristic clockwise and counterclockwise flows. As a result, the winds associated with the westerlies, as measured at the surface, often vary considerably from day to day and from place to place. In contrast, the direction of airflow associated with the trade winds is much more consistent.

**Wind Speed** Shown in the upper left of Figure 15, a cup **anemometer** (*anemo* = wind, *metron* = measuring instrument) is commonly used to measure wind speed. The wind speed is read from a dial much like the speedometer of an automobile. Places where winds are steady and speeds are relatively high are potential sites for tapping wind energy.



**Figure 15 Wind Vane and Cup Anemometer**  
**Interpreting Photographs** How can you tell which direction the wind is blowing?



**For:** Links on winds  
**Visit:** [www.SciLinks.org](http://www.SciLinks.org)  
**Web Code:** cjn-6193

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## How Wind Is Measured

### Use Visuals

L1

**Figure 15** After students have examined the photograph, ask: **What is the purpose of the cup-shaped side of the device shown in the photograph?** (to measure wind speed) **What is the purpose of the opposite end of the device?** (to indicate wind direction) **What might be the purpose of the box-shaped component on the pole beneath the anemometer and wind vane?** (could contain devices for recording wind speed and direction data, and/or transmitting the data to another location)

Visual, Logical

### Use Community Resources

L2

Take students on a field trip to visit a weather station maintained by a community member or local or government organization. Ask the person in charge to show students how wind direction and speed are measured at the station, how records are kept, and how the information is used. Interpersonal, Kinesthetic



Download a worksheet on winds for students to complete, and find additional teacher support from NSTA SciLinks.

### Answer to . . .

**Figure 13** Isobars would be horizontal.

**Figure 15** Wind vanes point into the wind.

mountain breeze

NW

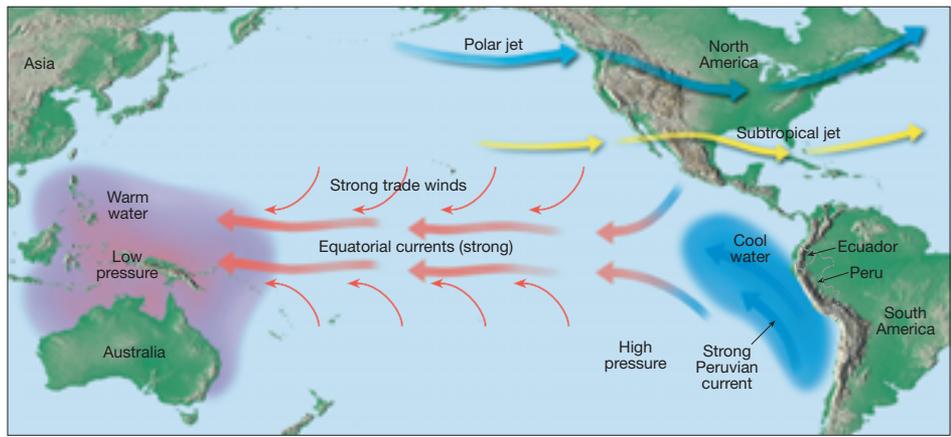
## El Niño and La Niña

### Build Reading Literacy **L1**

Refer to p. 246D in Chapter 9, which provides the guidelines for relating cause and effect.

**Relate Cause and Effect** As they read through the text on El Niño and La Niña, have students create a flowchart showing the cause-effect chain that results in an El Niño event. (Sample answer: high pressure over eastern Pacific → warm water pileup in eastern Pacific that prevents cold water upwelling and promotes formation of low air pressure zone → inland areas receive abnormal amounts of rain → trade winds weaken or may reverse direction → subtropical and mid-latitude jet streams are displaced → abnormal rainfall in Florida/southern United States and mild winter temperatures west of the Rocky Mountains)

**Verbal, Logical**



**Figure 16 Normal Conditions**  
Trade winds and strong equatorial ocean currents flow toward the west.

## El Niño and La Niña

Look at Figure 16. The cold Peruvian current flows toward the equator along the coasts of Ecuador and Peru. This flow encourages upwelling of cold nutrient-filled waters that are the primary food source for millions of fish, particularly anchovies. Near the end of the year, however, a warm current that flows southward along the coasts of Ecuador and Peru replaces the cold Peruvian current. During the nineteenth century, the local residents named this warm current El Niño (“the child”) after the Christ child because it usually appeared during the Christmas season. Normally, these warm countercurrents last for a few weeks and then give way to the cold Peruvian flow again.

**El Niño** 🌍 At irregular intervals of three to seven years, these warm countercurrents become unusually strong and replace normally cold offshore waters with warm equatorial waters. Scientists use the term **El Niño** for these episodes of ocean warming that affect the eastern tropical Pacific.

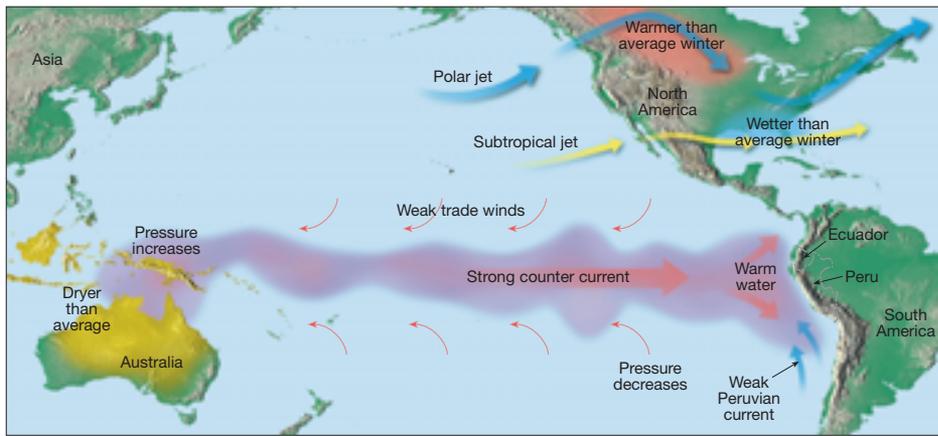
The onset of El Niño is marked by abnormal weather patterns that drastically affect the economies of Ecuador and Peru. As shown in Figure 17, these unusually strong undercurrents accumulate large quantities of warm water that block the upwelling of colder, nutrient-filled water. As a result, the anchovies starve, devastating the local fishing industry. At the same time, some inland areas that are normally arid receive an abnormal amount of rain. Here, pastures and cotton fields have yields far above the average. These climatic fluctuations have been known for years, but they were originally considered local phenomena. It now is understood that El Niño is part of the global circulation and that it affects the weather at great distances from Peru and Ecuador.

When an El Niño began in the summer of 1997, forecasters predicted that the pool of warm water over the Pacific would displace the

## Facts and Figures

The seesaw pattern of atmospheric pressure changes between the eastern and western Pacific is called the Southern Oscillation. During average years, high pressure over the eastern Pacific causes surface winds and warm equatorial waters to flow westward. The result is a pileup of warm water in the western Pacific, which promotes the lowering of air

pressure. An El Niño event begins as surface pressure increases in the western Pacific and decreases in the eastern Pacific. This air pressure reversal weakens or may even reverse the trade winds, and results in an eastward movement of the warm waters that had accumulated in the western Pacific.



paths of both the subtropical and midlatitude jet streams, as shown in Figure 17. The jet streams steer weather systems across North America. As predicted, the subtropical jet brought rain to the Gulf Coast. Tampa, Florida, received more than three times its normal winter precipitation. The mid-latitude jet pumped warm air far north into the continent. As a result, winter temperatures west of the Rocky Mountains were significantly above normal.



**What is an El Niño and what effect does it have on weather?**

**La Niña** The opposite of El Niño is an atmospheric phenomenon known as La Niña. Once thought to be the normal conditions that occur between two El Niño events, meteorologists now consider La Niña an important atmospheric phenomenon in its own right.

**Researchers have come to recognize that when surface temperatures in the eastern Pacific are colder than average, a La Niña event is triggered that has a distinctive set of weather patterns.** A typical La Niña winter blows colder than normal air over the Pacific Northwest and the northern Great Plains. At the same time, it warms much of the rest of the United States. The Northwest also experiences greater precipitation during this time. During the La Niña winter of 1998–99, a world-record snowfall for one season occurred in Washington State. La Niña impact can also increase hurricane activity. A recent study concluded that the cost of hurricane damages in the United States is 20 times greater in La Niña years as compared to El Niño years.

The effects of both El Niño and La Niña on world climate are widespread and vary greatly. These phenomena remind us that the air and ocean conditions of the tropical Pacific influence the state of weather almost everywhere.

**Figure 17 El Niño** Warm countercurrents cause reversal of pressure patterns in the western and eastern Pacific.



**For:** Links on La Niña and El Niño  
**Visit:** [www.SciLinks.org](http://www.SciLinks.org)  
**Web Code:** cjn-6211

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## Integrate Physics

**L2**

**Thermal Energy Transfer** Remind students that heat is the transfer of energy between two objects of different temperatures. Heat can be transferred directly, when the objects are in contact. It also can be transferred indirectly, by radiation and convection. Radiation is the transfer of energy via electromagnetic waves. Convection is the transfer of energy by fluid motion. In a fluid, convection works when colder, denser fluid sinks below warmer, less dense fluid. Ask: **Which of these three types of heat transfer is involved in El Niño formation and the weather patterns that result?** (All three; direct transfer takes place between ocean water and air. Radiation transfers heat from sun to land and atmosphere. Convection is the airflow that occurs between high- and low-pressure regions.)

**Verbal, Logical**



Download a worksheet on La Niña and El Niño for students to complete, and find additional teacher support from NSTA SciLinks.

## Facts and Figures

When winds blow along the surface of the ocean, the water is not pushed along directly in front of the wind. Instead, it is deflected by about 45 degrees as a result of the Coriolis effect. When surface waters are deflected, colder, deeper water rises to take its place.

This cold water is richer in nutrients than warmer surface water and promotes highly productive coastal fisheries. In years when coastal upwelling does not occur, coastal fish populations may be reduced or absent.

## Answer to . . .



An episode—occurring every three to seven years—of ocean warming that affects the eastern tropical Pacific; warm countercurrents become unusually strong and replace normally cold offshore waters with warm equatorial waters.

## Section 19.3 (continued)

# Global Distribution of Precipitation

## MAP MASTER Skills Activity

### Answers

**Using the Map Key** less than 400 mm

**Identify Causes** subtropical high pressure cells

## 3 ASSESS

### Evaluate Understanding

L2

To assess students' knowledge of section content, have them write a short description of each of the four types of local winds. Then have students write two or three sentences describing the events that give rise to an El Niño event.

### Reteach

L1

Have students draw and label their own diagrams illustrating sea, land, valley, and mountain breezes. Allow students to use Figures 12, 13, and 14 as references, if needed.

### Writing In Science

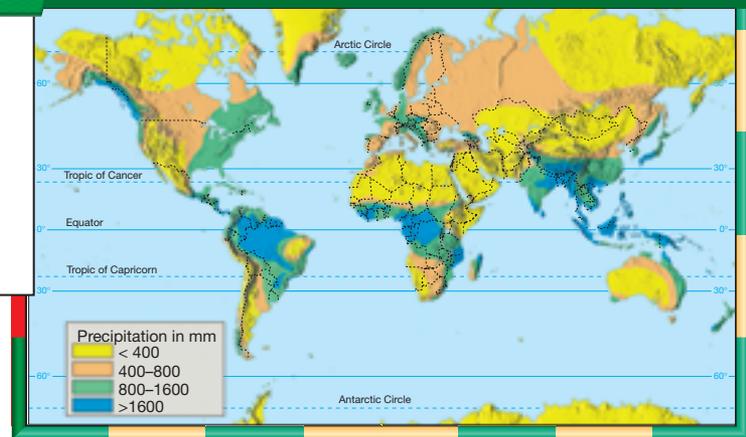
Student paragraphs should contrast the ocean water temperature conditions that trigger each phenomenon and describe how these in turn influence air pressure. Specific examples of weather associated with El Niño and La Niña also should be included in the paragraph.

## MAP MASTER Skills Activity

### Global Precipitation

Figure 18

**Regions** The map shows average annual precipitation in millimeters. **Using the Map Key** Determine the range of precipitation that dominates Northern Africa. **Identify Causes** Which weather pattern influences precipitation in this area?



## Global Distribution of Precipitation

Figure 18 shows that the tropical region dominated by the equatorial low is the rainiest region on Earth. It includes the rain forests of the Amazon basin in South America and the Congo basin in Africa. In these areas, the warm, humid trade winds converge to yield abundant rainfall throughout the year. In contrast, areas dominated by the subtropical high-pressure cells are regions of extensive deserts. Variables other than pressure and wind complicate the pattern. For example, the interiors of large land masses commonly experience decreased precipitation. However, you can explain a lot about global precipitation if you apply your knowledge of global winds and pressure systems.

## Section 19.3 Assessment

### Reviewing Concepts

1. What are local winds, and how are they caused?
2. Describe the general movement of weather in the United States.
3. What happens when strong, warm countercurrents flow along the coasts of Ecuador and Peru?
4. How is a La Niña event recognized?
5. What two factors mainly influence global precipitation?

### Critical Thinking

6. **Interpreting illustrations** Study Figure 17. How could air pressure changes influence weather patterns in this region?

### Writing In Science

**Compare-Contrast Paragraph** Write a paragraph comparing the features and effects of El Niño and La Niña. Include specific weather patterns associated with each phenomenon.

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## Section 19.3 Assessment

1. Local winds are small-scale winds caused by local variations in air pressure, which are caused by topography and unequal heating of land and water, or unequal heating of air above slopes and valleys.
2. from west to east
3. An El Niño event blocks normal upwelling of cold, nutrient-laden waters off the shores of these countries, and causes heavy precipitation inland. El Niño can have far-reaching effects

- on weather patterns of regions that are great distances from Ecuador and Peru.
4. La Niña is triggered when surface temperatures in the eastern Pacific are colder than average.
5. moisture content of air and distribution of land and water
6. Warm water near Ecuador and Peru would heat air and cause it to rise, producing lower pressure and precipitation. Regions north of Australia that normally receive more warm water would experience higher pressure, possibly leading to drought.

## Tracking El Niño from Space

The images in Figure 19 show the progression of the 1997–98 El Niño. They were derived from data collected by the satellite TOPEX/Poseidon.\* This satellite bounces radar signals off the ocean surface to precisely measure the distance between the satellite and the sea surface. When combined with high-precision data from the Global Positioning System (GPS) of satellites, maps of sea-surface

topography like these can be produced. These maps show the topography of the sea surface. The presence of hills indicates warmer-than-average water, and the areas of low topography, or valleys, indicate cooler-than-normal water. Using water topography, scientists can determine the speed and direction of surface ocean currents.

The colors in these images show sea-level height relative to the average. When you focus on the images, remember that hills are warm colors and valleys are cool colors. The white and red areas indicate places of higher-than-normal sea-surface heights. In the white areas, the sea surface is between 14 and 32 centimeters above normal. In the red areas, sea level is elevated by about 10 centimeters. Green areas indicate average conditions, whereas purple shows zones that are at least 18 centimeters below average sea level.

The images show the progression of the large warm-water mass from west to east across the equatorial Pacific Ocean. At its peak in November 1997, the surface area covered by the warm water mass was about one and one half times the size of the 48 contiguous United States. The amount of warm water added to the eastern Pacific with a temperature between 21°C and 30°C was about 30 times the combined volume of the water in all of the United States Great Lakes.

\*Source: NASA's Goddard Space Flight Center

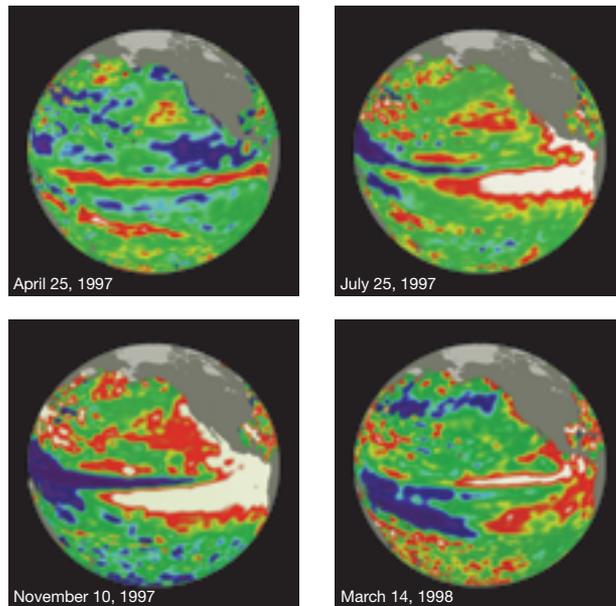


Figure 19 Progression of the 1997–98 El Niño

## Tracking El Niño from Space

L2

### Background

The image for April 25, 1997, shows the Pacific Ocean on the eve of the 1997–1998 El Niño event. By examining the images for July 25 and November 10, you can see the dramatic buildup of warm water (white and red areas) in the eastern Pacific and the enlarging region of cooler water (purple) in the western Pacific. By the time of the March 14, 1998, image, the area of warm water in the eastern Pacific was much smaller.

### Teaching Tips

- The directional terms *eastern Pacific* and *western Pacific* may give some students trouble, since the eastern Pacific Ocean borders the western coast of the United States. Ask: **What continents are bordered by the eastern Pacific Ocean?** (*North America, South America, and Central America*)
- As students examine each of the four images in Figure 19, ask: **What colors indicate warmer than average water temperatures?** (*white and red*) **What colors indicate cooler than average water temperatures?** (*purple*) **Where is the warm water mass located on April 25, 1997?** (*warm water mass not yet evident*) **Where is the warm water mass located on July 25 and November 10?** (*eastern Pacific*) **What does the map indicate about the warm water mass on March 14?** (*It is dissipating.*)