Ocean Variations During an El Niño

Objective

Students will analyze satellite images of sea surface temperature, sea surface topography, and wind data from an *El Niño* period and compare and contrast these data with non-El Niño conditions.

Concepts

- An El Niño is thought to be triggered when steady westward blowing *trade winds* weaken and even reverse direction in the western Pacific Ocean, near New Guinea and Australia.
- This change in the winds allows the large mass of warm water that is normally located in the western Pacific to move eastward along the equator until it reaches the coast of South America.
- This displaced pool of unusually warm water affects evaporation and where rain clouds form. This alters the typical atmospheric jet stream patterns around the world.
- Scientists are studying information from satellites and in-water buoys to better understand the causes and effects of an El Niño.

Materials

- Data images from an El Niño year (included for March, May, and September 1997)
  1. *Sea surface height* anomaly
  2. Sea surface winds *mean* and *anomaly*
  3. *Sea surface temperature* mean and anomaly
- Data images from a non-El Niño year (included for March, May, and September 1996)

Note: Images for #1 are from http://podaac.jpl.nasa.gov/topex/www/cycle_archive.html
Images for #2 and #3 are available from http://www.pmel.noaa.gov/toga-tao/realtime.html

Preparation

Each group of students should have either a set of color-coded figures, or time on the computer to study the images on screen. Alternatively, you can conduct this lesson as a class discussion and use a large monitor or an overhead projector with color transparencies of the satellite images.

You may choose to have students research, before or after this activity, more about the background of El Niño and its effects, including in the Expedition section of this CD-ROM, on these World Wide Web sites:

- “An El Niño Theme Page: What is El Niño?” http://www.pmel.noaa.gov/toga-tao/el-nino/home.html
- “ENSO Primer” http://nsipp.gsfc.nasa.gov/primer/englishprimer1.html

Procedure

Engagement

During the late 16th century, Spanish colonists who settled along the coasts of Peru and Ecuador first wrote of the warm *current* that occurred around Christmas time (El Niño is Spanish for the Christ child).

When this exceptionally warm current appeared, fish catches suffered because the *upwelling* of cold, plankton-rich offshore water was suppressed. Modern-day researchers use the term El Niño to describe not only displaced warm ocean waters along the equator but also related shifts in atmospheric conditions in the tropics and throughout the world. When El Niño occurs, some parts of the globe suffer from drought, while others experience too much rain.

Scientists use satellite and in-water buoy data to detect and track El Niño along the equatorial Pacific Ocean, including:

1. Sea surface height anomaly
2. Sea surface winds mean and anomaly
3. Sea surface temperature mean and anomaly

Sea Surface Height and Anomaly

Sea surface height that is caused by ocean circulation is shown in Figure 1.

However, there are slight deviations from this long-term, “basic” pattern that are mostly caused by short-term changes in ocean heat storage and ocean winds.

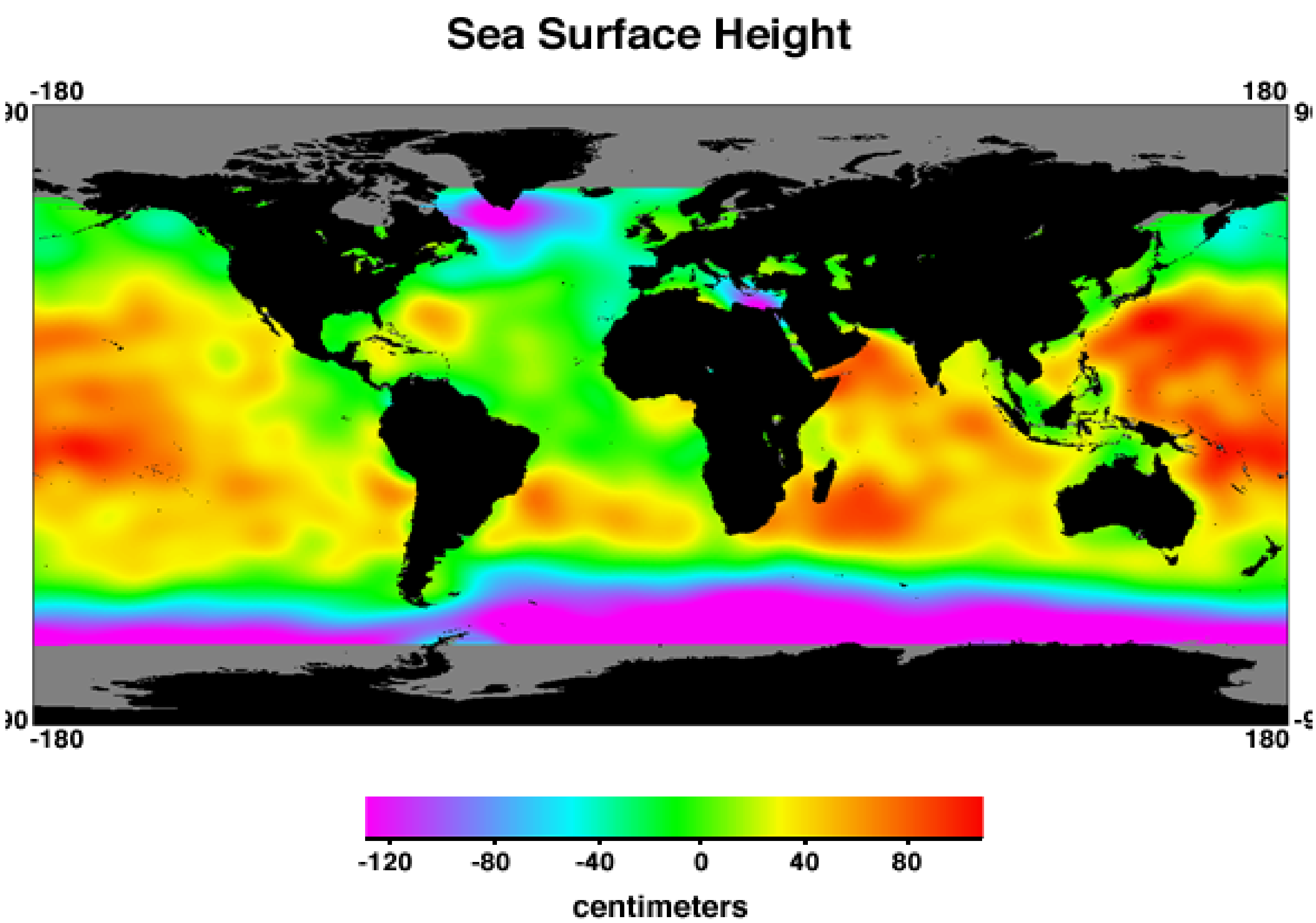

Figure 1. **Sea Surface Height**. Ocean currents are associated with “hills” and “valleys” in sea level. These long-lived features show some change through time, called sea surface height anomaly. Data shown are from the TOPEX/Poseidon satellite.

Sea surface anomaly maps help scientists easily see how short-term sea surface height deviates from long-term circulation patterns. Figure 2 shows sea surface height anomaly maps for 10-day periods in March, May, and September of 1996 and 1997.

Sea Surface Temperature Mean and Anomaly

Suppose that sea surface temperature is taken daily at a certain station in the Pacific during June 1997. Furthermore, suppose that the temperatures at this station stay fairly constant over the 30-day period. When all the temperatures are added together and divided by 30 they are found to be 27°C (Celsius). In this simple example, 27°C is the *mean* temperature for that month.

Suppose that the mean surface water temperature during June, **when averaged over many years**, is 25°C. Then, June 1997 would have a sea surface temperature anomaly of +2°C when compared to a "normal" month of June. Likewise, if June 1997's data averaged to 23°C, its sea surface temperature anomaly would be -2°C. Scientists use data from many stations or locations and "difference" the mean data to make anomaly maps. This makes it simple to spot unusual trends over large areas. Figure 3 shows color-coded mean and anomaly maps for sea surface temperature.

Ocean Surface Winds Mean and Anomaly

Data maps such as Figures 2 and 3 help scientists see the tell-tale signs of well-developed El Niño conditions, including above-average sea surface height and higher-than-normal sea surface temperatures in the central and eastern Pacific. Arrows in Figure 3 show mean and anomaly data for ocean surface winds. These data are important because El Niño is triggered by a breakdown of usually strong and steady easterly winds in the western Pacific Ocean. This "breakdown" occurs as either weaker-than-normal easterly or, in some instances, westerly winds.

Activity

Sea Surface Height Anomaly

1. Look at the color-coded bar at the bottom of the images of sea surface anomaly in Figure 2. Note that yellow and orange show where sea level is **above** normal, and blue and purple show sea level that is **below** normal.
2. Focus on the tropical Pacific Ocean data during 1996. Do you see a significant difference in these maps from month-to-month? How does the anomaly of sea level in the western Pacific compare with the anomaly in eastern Pacific?
3. Now look at the maps for 1997, again focussing on the tropical Pacific. Do you see a difference in these maps from month-to-month? How does sea level change in the equatorial Pacific over these months?

Sea Surface Temperature

1. In Figure 3, the top images show mean (or near average) data and the bottom shows anomaly data for each month.
2. Mean sea surface temperatures (top maps) are color-coded such that red shows areas of warmer water and blue indicates cooler water. Sea surface temperature anomalies (bottom maps) show how each month's conditions compared to average: green shows where sea surface temperatures during that month were near average, red reveals where the temperatures were **above** average,

and blue indicates where they were **below** average.

3. Look at the sea surface temperature (color-coded) data for 1996. From the mean data maps (top), did sea surface temperature change from March through September? Consider the anomaly maps (bottom), how did sea surface temperature during these months compare to normal conditions?
4. Repeat this exercise for 1997.
5. What conclusions can you make when you compare sea surface temperature data for these months in 1996 versus the same months during 1997? Which year was more average?

Ocean Surface Winds

1. Again, in Figure 3, the top images show mean (or near average) data and the bottom shows anomaly data for each month.
2. Ocean surface wind direction and strength are shown as arrows. Short arrows on the maps of mean wind (top maps), indicate lighter winds and longer arrows show stronger winds. The anomaly data (bottom maps) show how winds during that month compared with normal conditions. For example, when long “anomaly” arrows point to the right it indicates that winds were blowing toward the east much more strongly than usual. Very short arrows, regardless of direction, show where winds were blowing fairly normally.
3. Look at the surface wind data (arrows) for 1996, especially in the western Pacific near New Guinea. From the mean data maps (top), did surface winds change significantly from March through September 1996? Was there a dominant wind direction in the western Pacific during this time? If so, from what direction were the winds blowing? Consider the anomaly maps (bottom), how did wind strength and direction during these months compare to normal conditions?
4. Repeat this exercise for 1997.

- Summarize the changes in wind, temperature and sea height you see in the data. What conclusions can you make when you compare ocean wind data for these months in 1996 versus the same months during 1997? Which year showed more stability in wind direction and strength?
- Based on your observation of all data sets, which year was closer to normal? Which year showed warmer than normal water in the East Pacific? Can you determine which was an El Niño year?
- The upwelling of cold water off the west coast of South America favors abundant fish harvests. Which year was better for Peruvian fisheries?
- Think about the relationship between trade winds, sea surface height, and sea surface temperature. How are west-blowing trade winds in western Pacific tied to sea surface height along the equator? What happens to sea levels along the equator when the trade winds weaken or reverse direction? How do the areas of high sea level anomaly compare with sea surface temperature data?

Explanation

Under normal conditions, strong easterly trade winds in the equatorial Pacific push warm surface water toward Indonesia. This produces a large pool of 84°F (about 30°C) water in the western Pacific. During an El Niño, the trade winds weaken and warm water moves eastward along the equator toward South America. This warms the central and eastern equatorial Pacific over many months.

As warm surface waters move eastward in the tropics, heavy rains normally found near Indonesia shift into the central and eastern Pacific. This alters atmospheric patterns around the globe. El Niño related weather shifts have been felt as far north as Canada and as far south as central Chile. Scientists are only beginning to understand the far-reaching effects of this phenomenon.

TOPEX/Poseidon satellite and in-water buoy data are helping scientists to better understand the how El Niño forms. The hope is to better predict future events. This is critical because there was a noticeable increase El Niño occurrences during the 1990's.

Extension

Many fisheries are impacted by the presence of an El Niño. Fisheries depend on upwelling conditions to provide food for the fish they catch. In an El Niño year upwelling stops along the eastern Pacific. Research the locations and types of fisheries in the Pacific Ocean. Determine which areas and fisheries are likely to be most impacted by El Niño.

Links to Related CD Activities, Images, and Movies

Image of *Global fisheries*
Image of *El Niño change in winds near New Guinea*
Movie of *El Niño sea surface height time sequence*
Movie of *El Niño temperature time sequence*
Movie of *Coastal upwelling*

Vocabulary

anomaly	*current*	*El Niño*
mean	*sea surface height*	*sea surface temperature*
trade winds	*upwelling*	

Source

Adapted by Orange County Marine Institute/San Juan Institute and NASA/Jet Propulsion Laboratory from Gulf of Maine Aquarium activity at http://octopus.gma.org/surfing/weather/elnino.html.

Figure 2 (next page). **Sea Surface Anomaly.** The left column shows sea surface anomaly data for 1996. The right column shows data from about the same periods during 1997. Each map has 10 days worth of data - the time it takes the TOPEX/Poseidon satellite to map the global oceans.

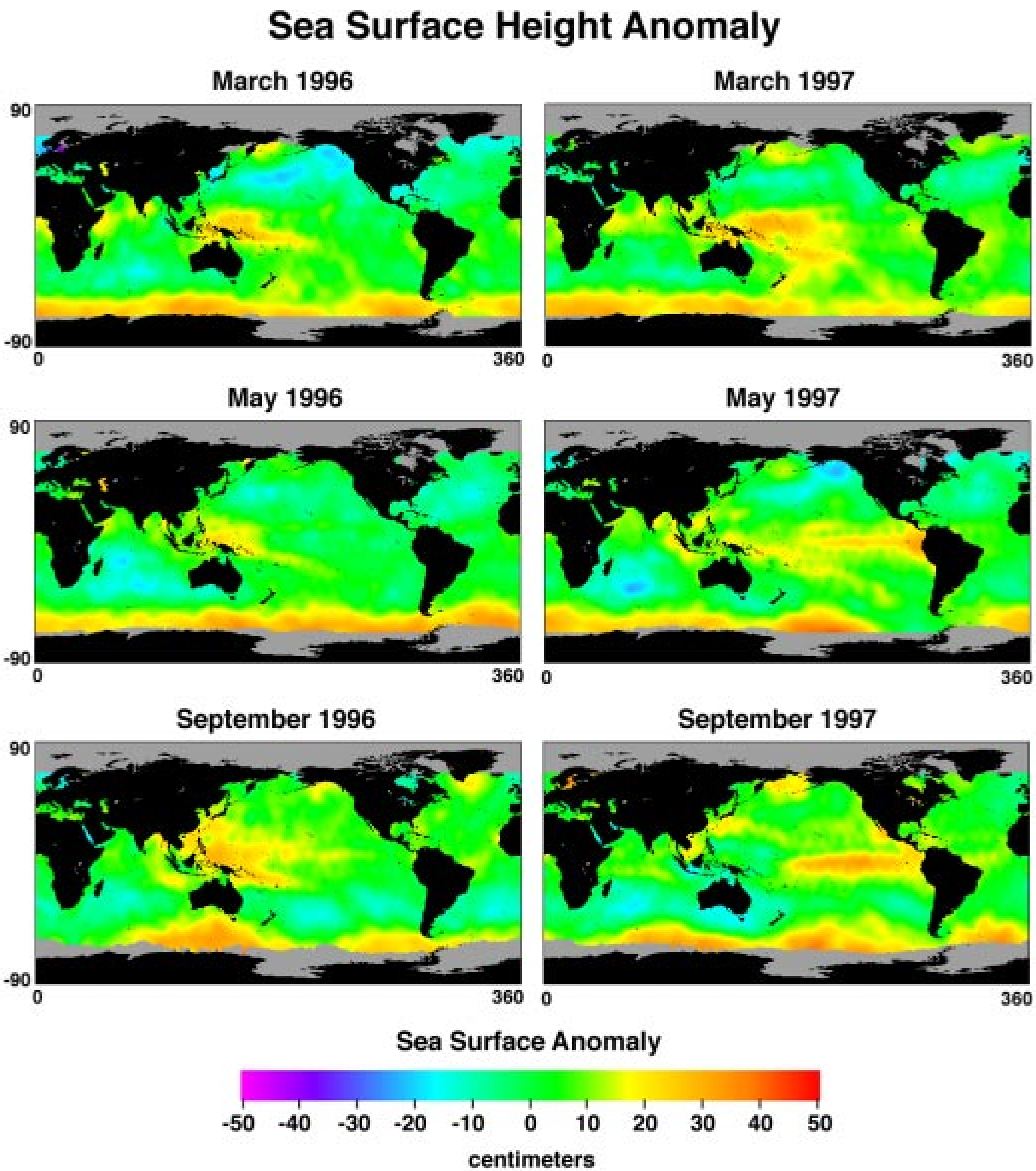

Figure 2. Sea surface height anomaly data. The left column shows color-coded sea surface height anomaly data sets from March, May, and September 1996. The right column shows data from the same months during 1997. [Data courtesy of NASA / Jet Propulsion Laboratory]

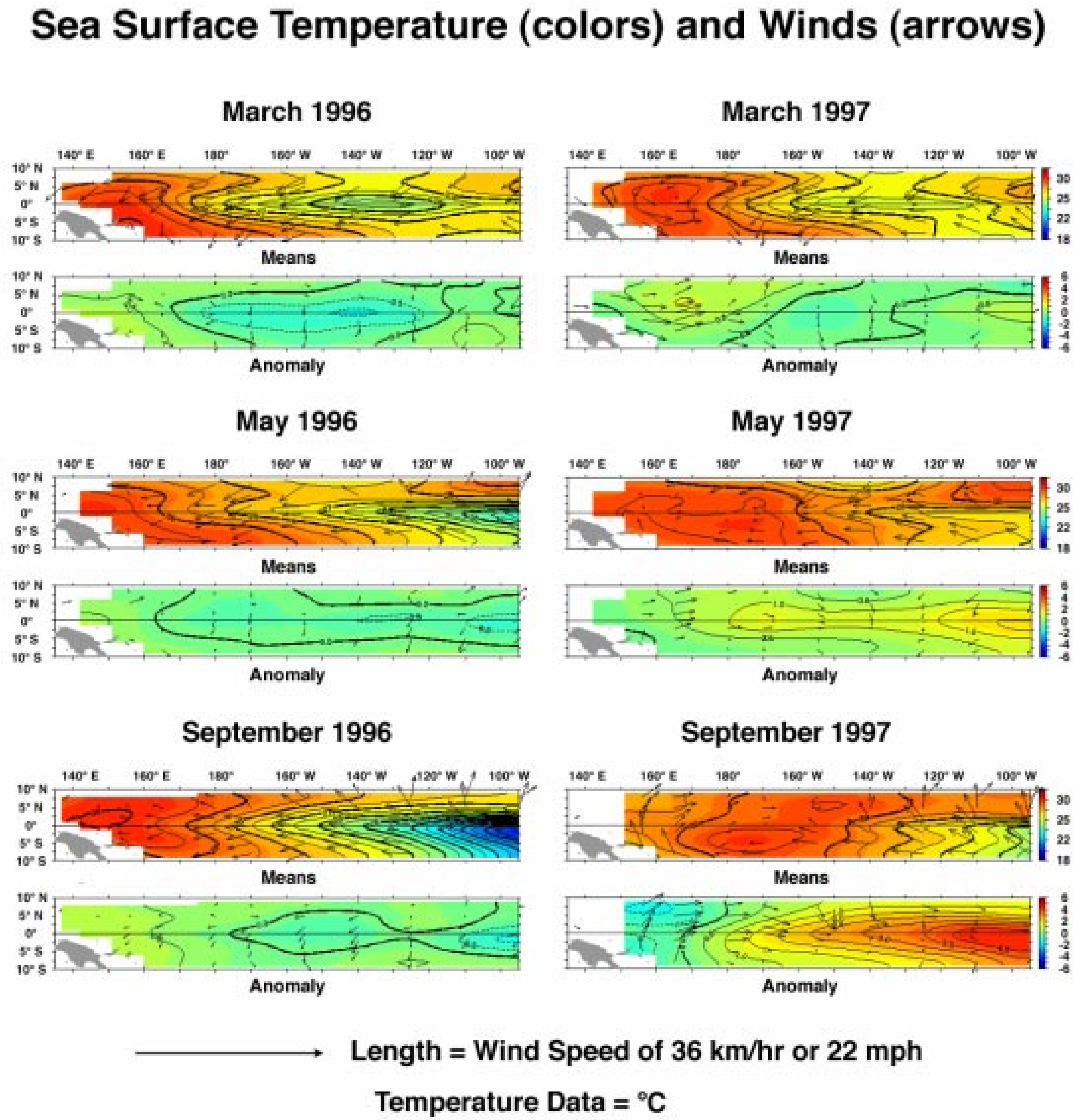

Figure 3. **Sea Surface Temperature and Winds from buoy data**. The left column shows sea surface temperature (color-coded) and wind (arrows) data sets from March, May, and September 1996. The right column shows data from the same months during 1997. In each data set, data means are shown at top and data anomalies are at bottom. [Data courtesy of NOAA, Pacific Marine Environmental Laboratory]