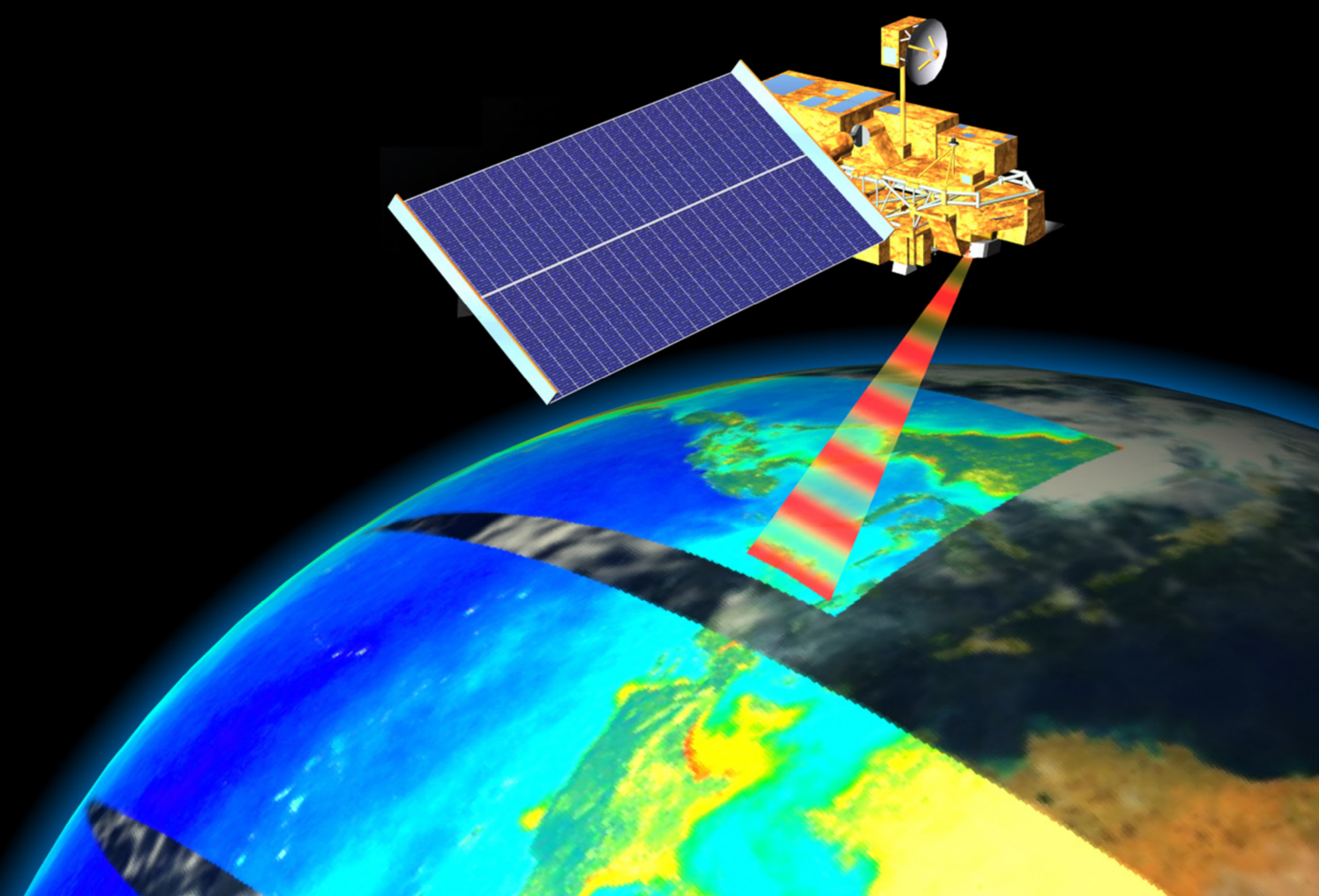
Data to Information to
Understanding El Nino

Cold are the feet and forehead of the earth,
Temperate his bosom and his knees,
But huge and hot the midriff of his girth,
Where heaves the laughter of the belted seas,
Where rolls the heavy thunder of his mirth
Around the still unstirred Hesperides.

The Belted Seas, Arthur Colton



Lesson Objectives:

To demonstrate an understanding of several satellites and the instruments they carry that collect sea surface data

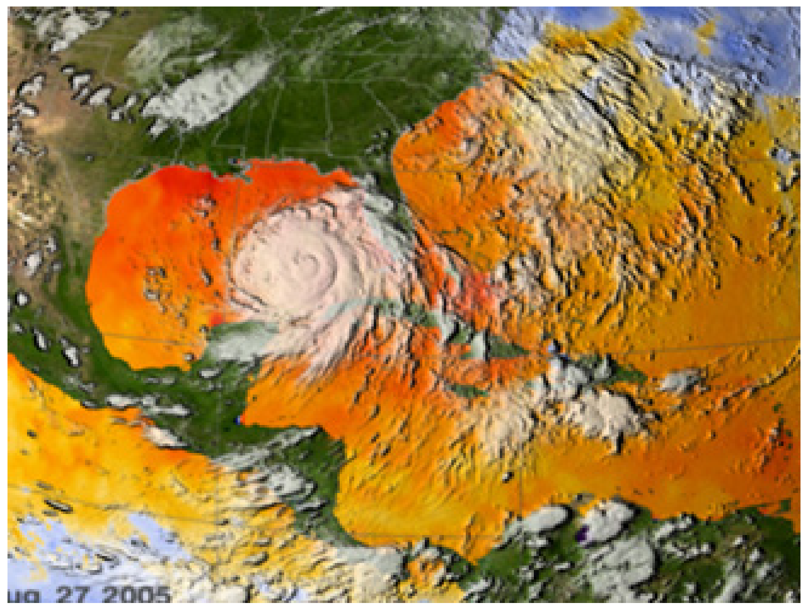
To demonstrate an understanding that the speed of ocean surface currents vary as distance from the Equator increases

To demonstrate an understanding of where the greatest sea surface temperature anomalies occur

To demonstrate an understanding of ocean surface patterns or relationships that can explain the weather phenomena, El Niño

Glossary: aerosols, buoy, chlorophyll, electromagnetic radiation, longitude, standard deviation

Introduction: Ocean Surface Currents Affect Global Weather and Climate



Hurricanes wreak havoc in the Gulf of Mexico, tornados tear apart the Midwest, winter storms move from the Pacific Ocean, across the Rockies, and into the Eastern US. Every day we see weather stories, but how are the weather data gathered? Data are collected by satellites, balloons, ships, buoys, and other methods. Study of these data helps us understand the processes that affect our global weather and climate and help meteorologists make weather forecasts. Scientists use these data to calibrate, test and adjust computer models that simulate Earth's weather and climate. Scientists model the entire globe as one connected, interacting system, including oceans, land and atmosphere.

Weather can be defined by five key variables: temperature, wind magnitude, wind direction, water vapor (humidity), and pressure. We write mathematical equations that reveal how these weather variables relate to each other and to external factors such as solar energy. Using these equations to make forecasts is more difficult and requires knowledge of atmospheric conditions everywhere at an instant in time. To make weather predictions, scientists need a global "data snapshot" of the atmosphere that tells us the value of the five key variables at all altitudes and locations. Gathering this amount of data on a planet where 73% of the surface is covered by water is a tremendous challenge. Satellites provide the most efficient means of gathering a global view that fills the voids where little or no data are collected.

Most of the solar heat absorbed by the ocean is in a belt about 23 ½ degrees above and below the Equator. Ocean temperatures at the Equator are moderated by ocean currents, which continuously circulate and distribute energy to the rest of the globe. This lesson encourages the investigation of ocean surface current patterns and their link to weather phenomena such as El Niño. You are invited to explore data visualizers to find patterns in ocean surface currents that reveal El Niño patterns from the past and potential patterns for the future.

What do you know?

Before beginning this lesson is it helpful to learn how much information you already know about the satellite data. A simple preconceptions survey has been created for you to assess your prior knowledge.

1. Click on the blue **Quiz** button below.
2. Take the quiz
3. Submit your responses online and they will be automatically scored.
4. Record your score.
5. Return to this guide and begin your exploration of the satellite data and El Niño.

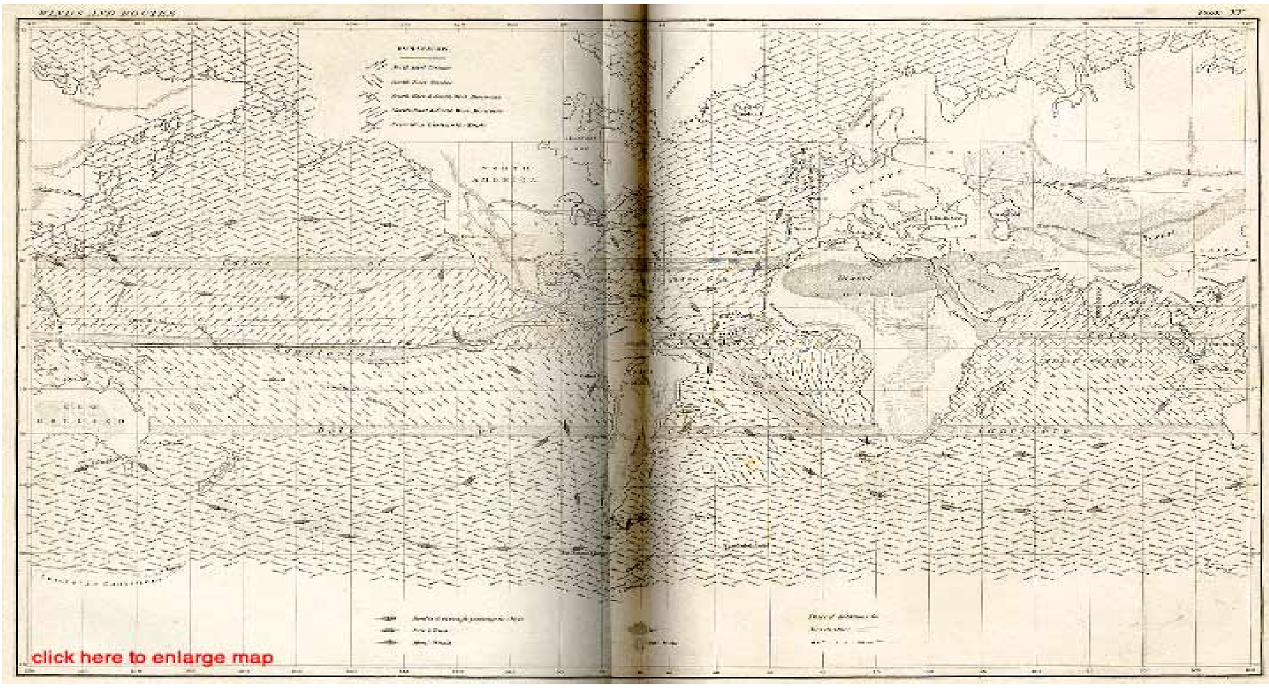
Ocean Travels Today

Could global shipping traffic collect enough data from the ocean surface to determine how currents affect weather and climate?

There is a river in the ocean. In the severest droughts it never fails, and the mightiest floods…it never overflows. Its banks and its bottoms are of cold water, while its current is of warm. The Gulf of Mexico is its fountain, and its mouth is in the Arctic Sea. It is the Gulf Stream. There is in the world no other such majestic flow of waters.

Matthew Fontaine Maury's 1855
The Physical Geography of the Sea.

Ship crews have been taking intermittent measurements of the ocean surface conditions for hundreds of years. The American naval captain, Matthew Fontaine Maury, pictured on the left, and the 1853 Brussels Maritime Conference are credited with promoting the use of a uniform system for ship-based collection of meteorological and sea surface measurements. Captain Maury's nickname was "The Pathfinder of the Seas" due to his extensive work mapping ocean and wind currents. He served in the U. S. Navy. After Virginia seceded, he served the Confederate States of America by helping to obtain ships and other vital equipment. Maury published the *Wind and Current Chart of the North Atlantic*, which showed sailors how to use the ocean's currents and winds to their advantage and drastically reduce the length of ocean voyages. His *Sailing Directions* and *Physical Geography of the Seas and Its Meteorology* remain standard. Maury's uniform system of recording oceanographic data was adopted by navies and merchant marines around the world and was used to develop charts of ocean surface currents (example on the following page) for all the major trade routes.



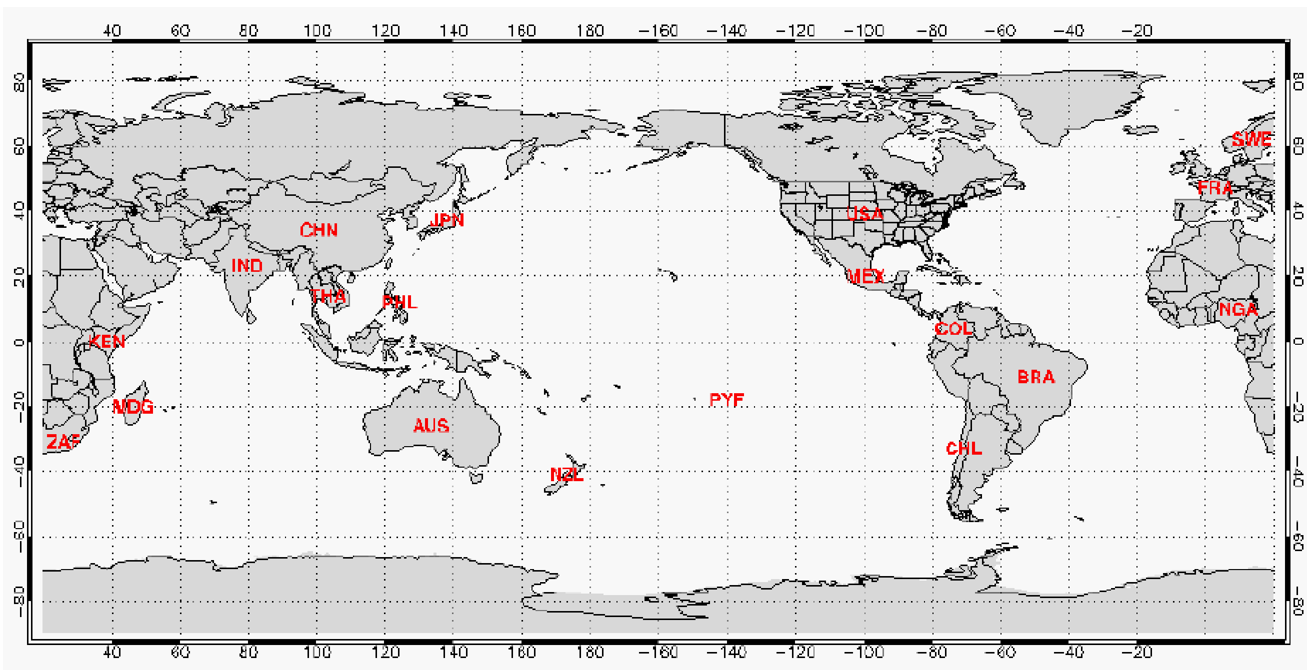
To appreciate the vastness of the oceans and the difficulty of gathering comprehensive surface current data needed to see patterns, you will trace the flow of some of the major import and export shipping traffic between countries.

1. Below is a table listing some countries and their major import and export partners. Select 10 countries from the table below and using the world map that follows the table, draw arrows showing the possible routes for goods imported and exported between countries. Refer to an atlas if you cannot identify some countries on the map.

2. Based on your route predictions, mark regions of the ocean that would have the most and the least commercial (non-fishery) ship traffic.

Country	Abbrev	Importing From…	Exporting To…
Australia	AUS	USA, China, Japan, Germany, Singapore	Japan, China, USA, Rep. of Korea
Brazil	BRA	USA, Argentina, Germany, China, Nigeria	USA, Argentina, Netherlands, China, Germany
Chile	CHL	Argentina, USA, Brazil, China, Germany	USA, Japan, China, Rep. of Korea, Netherlands
China	CHN	Japan, Rep. of Korea, USA	USA, Japan, Rep. of Korea, Germany
Colombia	COL	USA, Brazil, China, Venezuela, Mexico	USA, Venezuela, Ecuador, Peru, Mexico
France	FRA	Germany, Italy, Spain, Belgium, United Kingdom	Germany, Spain, United Kingdom, Italy, Belgium
French Polynesia	PYF	France, USA, Australia, New Caledonia, China	Japan, China, Hong Kong, USA, France, Thailand
India	IND	USA, China, Switzerland, United Arab Emirates	USA, United Arab Emirates, China, Singapore
Japan	JPN	China, USA, Rep. of Korea, Australia, Indonesia	USA, China, Rep. of Korea
Kenya	KEN	United Arab Emirates, South Africa, Saudi Arabia, United	Uganda, United Kingdom, Netherlands, United Rep. of

Country	Abbrev	Importing From…	Exporting To…
		Kingdom, Japan	Tanzania
Madagascar	MDG	France, China, Bahrain, South Africa	France, USA, Mauritius, Singapore
Mexico	MEX	USA, China, Japan, Germany, Canada	USA, Canada, Spain, Germany, Aruba
New Zealand	NZL	Australia, USA, Japan, China, Germany	Australia, USA, Japan, China, United Kingdom
Philippines	PHL	USA, Japan, Singapore, Rep. of Korea	Japan, USA, Netherlands, China
South Africa	ZAF	Germany, USA, China, Japan, United Kingdom	USA, United Kingdom, Japan, Germany, Netherlands
Sweden	SWE	Germany, Denmark, Norway, United Kingdom, Netherlands	USA, Germany, Norway, United Kingdom, Denmark
Thailand	THA	Japan, USA, China, Malaysia, Singapore	USA, Japan, Singapore, China
United States of America	USA	Canada, China, Mexico, Japan, Germany	Canada, Mexico, Japan, United Kingdom, China



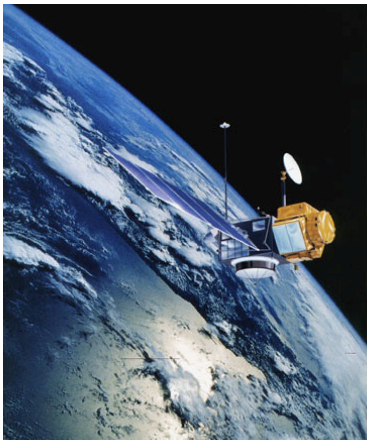
View of the Ocean from Satellites
What kind of data do satellites collect?

Although many ships sail the oceans today, depending on them to gather synoptic oceanographic data would not be an efficient way to collect these data. Earth is composed of dynamic systems that undergo change. Some changes to ocean surface currents form patterns that impact oceanic and continental weather. Continuous data collection, over a long period of time from a multitude of sites, is necessary to determine whether patterns of surface currents exist and, if so, the role they play in weather and climate.

To provide wider and more frequent data coverage of the ocean regions, scientists employ satellites that circle the Earth above the atmosphere several times a day. Various satellites and measuring instruments provide the ocean surface data you will use in your investigations. They collect the following data that help scientists track ocean surface currents and their potential impact on weather and climate:

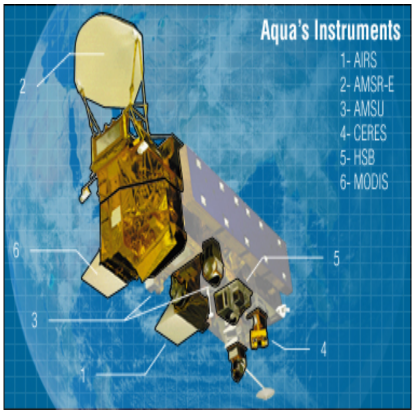
• Sea Surface Topography: The ocean surface is neither flat nor round. Changes in the sea surface height reveal clues about currents and stores of heat energy in water below the surface.
• Sea Surface Temperature: The temperature of ocean water may be used to track the flow of energy around the globe.
• Near-Surface Ocean Winds: Winds drive ocean surface currents and affect both the ocean's interaction with the atmosphere and the depth of mixing of layers at the surface of the ocean.
• Ocean Color: Microscopic ocean plant life can be detected by satellites and used to study patterns of marine life and how surface currents play a role providing nutrients, regulating temperature and dispersing populations.

Read the following information about satellites (or instrument packages on a satellite) and the data they collect. Additional information can be found by clicking on links noted in blue. Use the information to answer the questions following the reading.



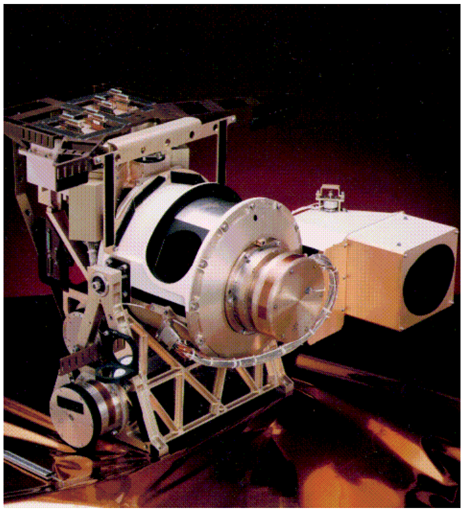
Sea Surface Topography - TOPEX/Poseidon. and Jason-1,
Scientists measure the sea surface height (SSH) to study surface currents, ocean circulation, and heat stored in the oceans, ocean and coastal tides and ocean floor topography. The satellites use a radar altimeter that sends short pulses of electromagnetic radiation downward and analyzes the returned (reflected) signal. The time difference between sent and received signals gives the distance to the sea surface. The waveform shape of the received signal measures significant wave height and wind speed. Knowing the orbit of the satellite and its distance to the sea surface allows scientists to determine changes in sea surface height to 2–3 cm. Changes in SSH may be due to variability of ocean currents, seasonal cooling and heating, evaporation and precipitation, and planetary wave/tsunami phenomena.

Sea Surface Temperature - AVHRR on NOAA satellites MODIS on AQUA and TERRA
Scientists measure the sea surface temperature (SST) to understand the ocean's affect on weather, study global climate change and visualize surface water currents, turbulence and upwelling. The satellites measure thermal infrared radiation emitted by the sea surface to estimate its temperature. To correct for aerosol absorption of the radiation, ship and buoy near-surface temperature measurements are required to calibrate the SST values. Clouds do interfere with SST measurements. Global SST maps are a composite of cloud-free data collected over week or month.



Near Surface Ocean Winds - QuikSCAT
Scientists are interested in sea surface winds because they drive surface water currents, influence air-sea exchange of energy and mass, and affect regional and global weather. The SeaWinds instrument uses microwave radar to measure near-surface wind speed and direction every 1–2 days under all weather and cloud conditions over Earth's oceans. The SeaWinds instrument has a 1-meter diameter rotating dish antenna that produces two narrow beams that sweep in a circular pattern. The dish rotates 18 revolutions per minute and radiates microwave pulses at a frequency of 13.4 gigahertz across broad regions of the Earth's surface. The return radar pulses reveal details about wave patterns at the sea surface; these patterns help compute near-surface wind speed (up to 30 m/s = 67 mph = 58 knots = 58 kt) and direction.

Ocean Color - SeaWiFS Instrument on SeaStar
MODIS on AQUA and TERRA



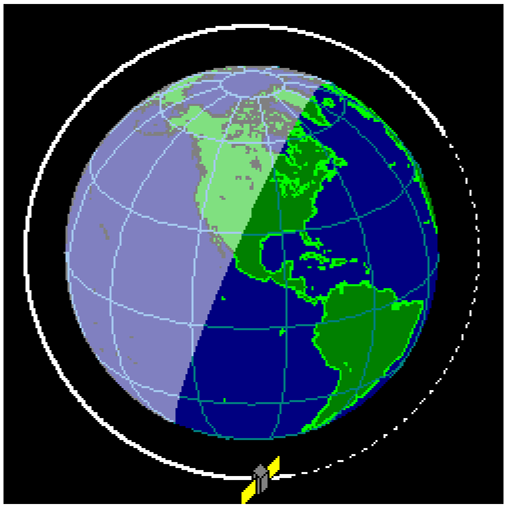
Scientists are interested in the bio-optical characteristics of the ocean surface because the color of the water can reveal the types and quantities of marine phytoplankton (microscopic marine plants) that are important to the study of the dynamics and seasonal cycles of ocean primary production and global biogeochemistry. *Primary producers* use sunlight or chemical energy rather than organic material as a source of energy. A major chemical component of primary producers is chlorophyll. SeaWiFS (**Sea**-viewing **Wi**de **F**ield-of-view **S**ensor) circles the Earth every 99 minutes and measures reflected and emitted electromagnetic radiation. The satellite is placed in a sun-synchronous orbit, which means that the satellite travels over the North and South Poles, covers the full globe and passes over the same region of the Earth at the same local time.

Ocean Surface Current Satellite Data

3. Satellites orbit at high speeds (typically near 17000 mph) above the Earth. Is it possible to place a satellite in orbit so that it does not move?

4. Satellites typically make measurements of the Earth's surface with instruments looking downwards along a path that lies directly beneath a satellite's orbit. If a satellite were placed in orbit around the Equator, what portion of the Earth's surface would it measure? If a satellite is placed in an orbit that goes over the North and South Poles, what portion of the Earth's surface would it measure?

5. The satellite shown in the figure to the right is 1330 km above the Southern Ocean. It sends a radar pulse downward at the speed of light: 300,000 km/second. Estimate the time it takes for the pulse to return to the satellite? (HINT: Distance Traveled = Speed x Time)



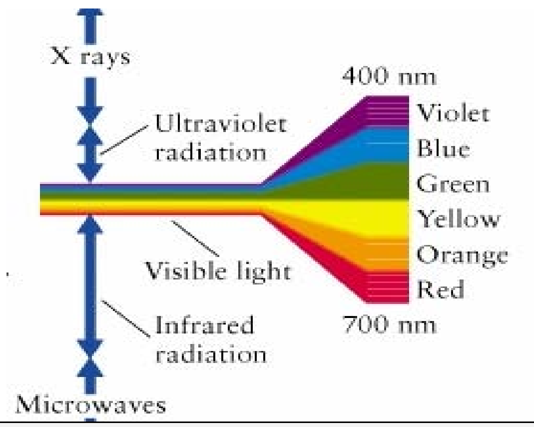
6. Radiation emitted by the ocean surface must pass through the atmosphere to reach the satellite. How would aerosols (minute particles derived from desert dust, volcano emissions, smoke from wood and fossil fuels) in the atmosphere affect the radiation received by the satellite? Would the ocean surface appear colder or warmer than it really is? "Colder" means that the satellite receives less radiation than the ocean surface emits. "Warmer" means that the satellite receives more radiation than the ocean surface emits.

7. Scientists, just like sailors, use the wave patterns of the ocean surface to estimate wind speed. When you wake up in the morning and look out a window, what clues alert you to unusual weather outside (for example, high winds, extreme cold or heat, heavy precipitation, unsteady or changing weather)?

8. Sailors know that oil spread on the ocean surface tends to reduce waves. If SeaWinds tries to measure the wind speed over a major oil slick, will it give a wind speed that is above or below the true value?

9. Can the SeaWinds satellite be used to measure winds over the land? Why or why not?

10. The SeaWiFS instrument measures reflected radiation intensity in various visible (as well as invisible) wavelength bands. Identify the colors that best match each of the following SeaWiFS visible wavelengths. Refer to this linked website for more detail about the color spectrum:



Band	Visible Wavelength (nanometers)	Relation to Substances and Processes	Nearest Color
1	443	Chlorophyll Absorption	
2	520	Chlorophyll	
3	550	Sediments	
4	670	Chlorophyll Absorption	

Gathering Data and the Scientific Method

Gathering data is not enough. Collections of data are only raw materials like words in a dictionary or bricks in a pile. A dictionary of words does not make a Shakespeare play, and a pile of bricks does not make a home. Effort is needed to use the words to write a memorable play or assemble the bricks to build a distinctive home. The Results, Conclusion and Theory steps of the scientific method require you to build your case to answer a significant question with data and decide whether your hypothesis is correct.

Scientific Method

- Question: Be curious and ask questions.

- Hypothesis: Develop and refine a hypothesis that can be tested with data.

- Experiment: Perform an experiment (or select a satellite data product) and gather data useful for testing the hypothesis.

- Results: Review experiment's results. If the results are not sufficient to test the hypothesis, return to one of the prior steps (Question, Hypothesis, Experiment) that need refinement. Otherwise, continue to the next step (Conclusion).

- Conclusion: Articulate a conclusion based on the data.

- Theory: Develop an explanation or theory that may account for data. Return to the Question step to further test your theory.

The Nature of Science, the Science of Nature

Today many of the properties and behaviors of air and water vapor are well known; this does not, however, make it easy to predict tomorrow's weather with 100% confidence. Knowing all the rules of baseball or of a video game does not allow one to predict the final outcome of a game. The vastness and changeability of the atmosphere makes it difficult to assemble a complete data set characterizing its state at any one moment. Unknowns or uncertainties about the state of the atmosphere at one time make future predictions uncertain. Imagine trying to predict the outcome of a baseball game based on a few photographs taken at random times during a game.

In this next section, you will be able to use data resources and tools to engage in your own studies of the ocean's surface. Several introductory studies have been included in this guide to help you get started. The studies are not exhaustive and focus on simple questions. The data resources and processing tools provided on this website are open-ended and can serve for many further studies. Learning one fact from data should lead to developing a better, follow-up question. This should not be discouraging. It is the process of doing science.

The explorations in this next section are open-ended and do not always lead to simple (Yes/Always or No/Never) answers. You will be using data that is rich with patterns and clues about how the ocean surface behaves. With persistence and the observant, critical eye of an explorer, you might discover some important, new facts about nature.

Tropical Pacific Surface Currents
How does the speed of ocean surface currents vary with distance from the Equator?

In the first study, you will investigate how the speed of ocean surface currents varies with distance from the Equator. The waters of the Equator are exposed to a high intensity of solar radiation throughout the year and would become very hot if there were no circulation. Circulation of warm Equatorial waters towards the Poles equalizes the surface water temperatures and the Earth's climate.

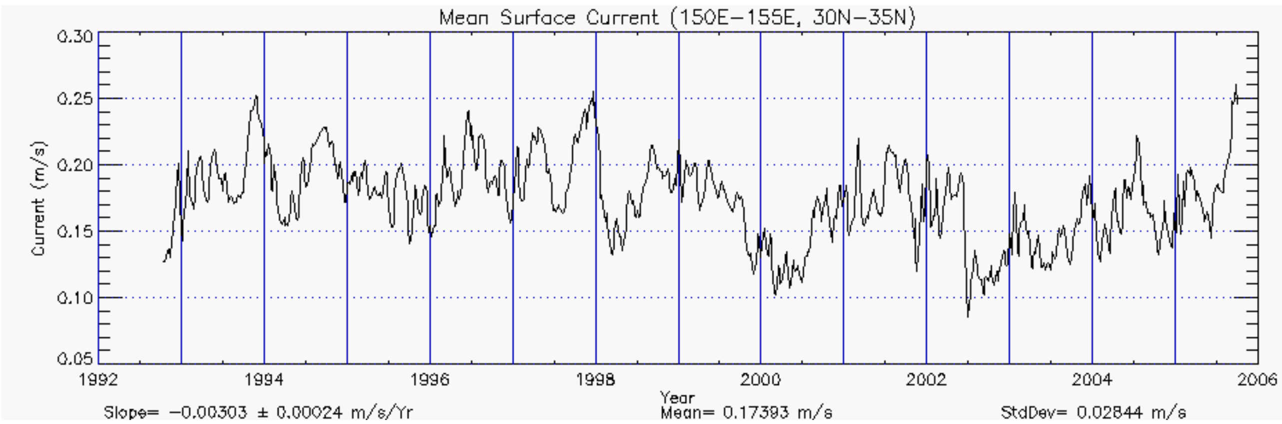
Go online to the [Ocean Surface Currents Visualizer]() and click on the following starting settings. The settings of the other controls are not important for this study. If you do not have access to the Internet, use the graphs provided on page 11 and 12 of this Guide.

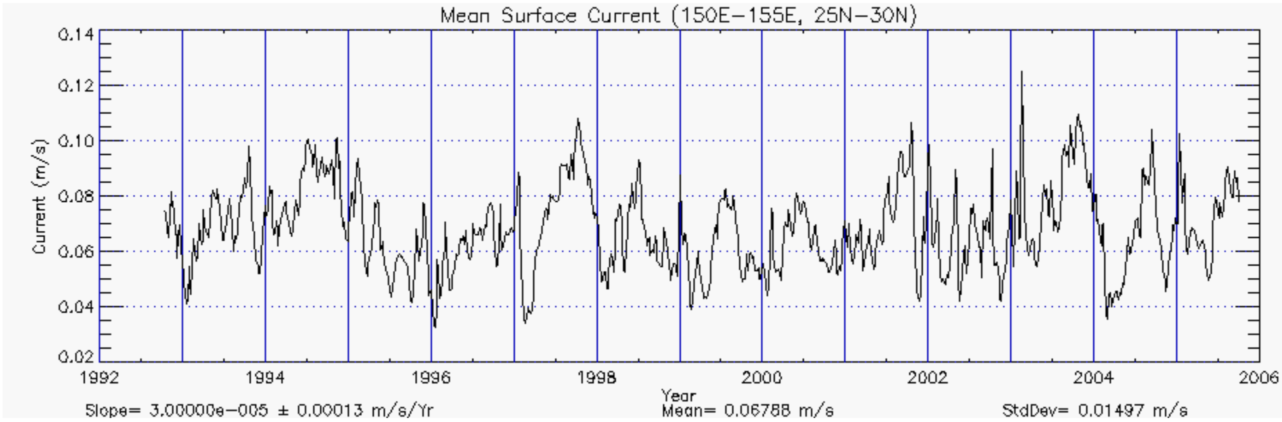
- Parameter: **speed**
- Tropical Pacific Region: **northwest**
- Click-on-Map Data: **graph**

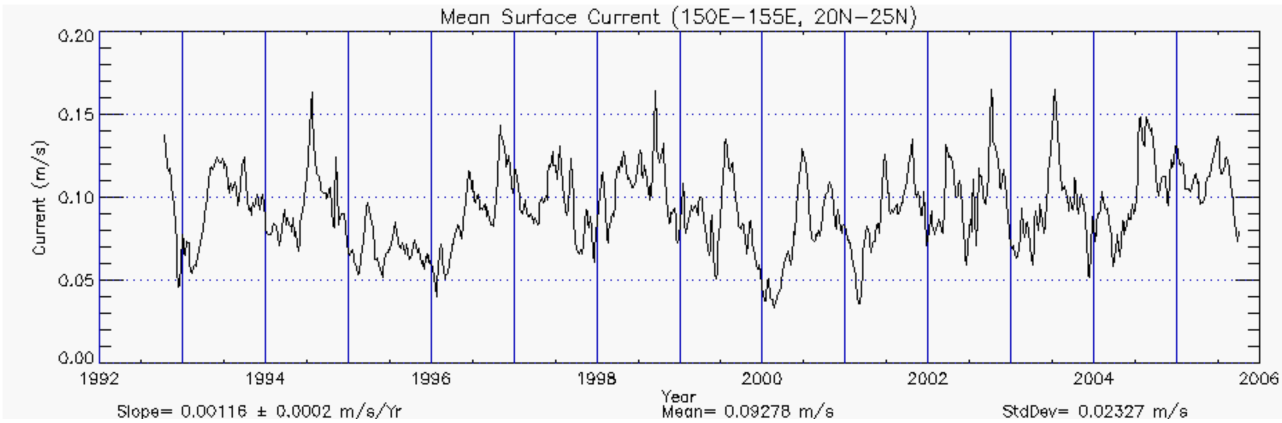
(Note: Clicking on a colored map region will display a plot of the mean current speed in the selected 5^o x 5^o region for all available years.)

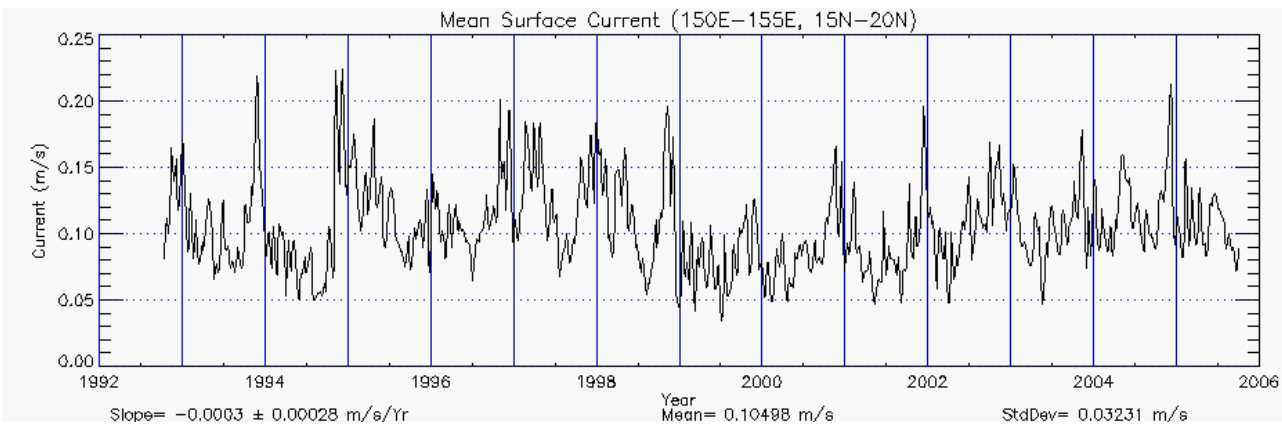
11. Locate the longitude and latitude ranges found in the following chart by moving the hand-shaped cursor over the map that appears on the visualizer. Click on the locations indicated below and a window with a plot of surface current speeds from 1992–2005 will appear. At the bottom of each graph you will find three computed values: (1) slope, (2) mean and (3) standard deviation of the surface current. You will only need the mean surface speed for this activity. Round off your values to the nearest hundredth place.

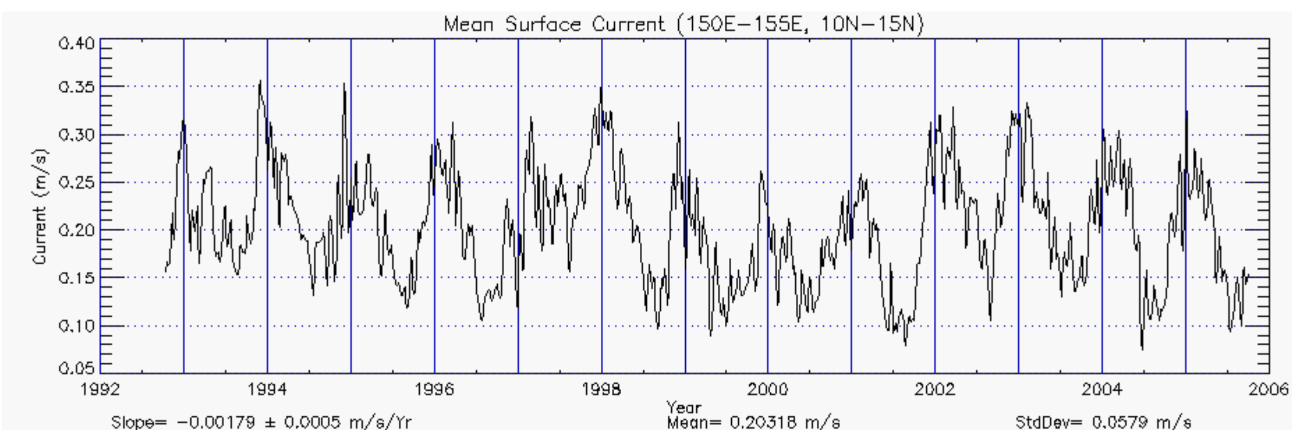
Longitude Range	Latitude Range	Mean Current Speed meters/second
150 E – 155 E	30 N–35 N	
	25 N–30 N	
	20 N–25 N	
	15 N–20 N	
	10 N–15 N	
	5 N–10 N	
	0–5 N	

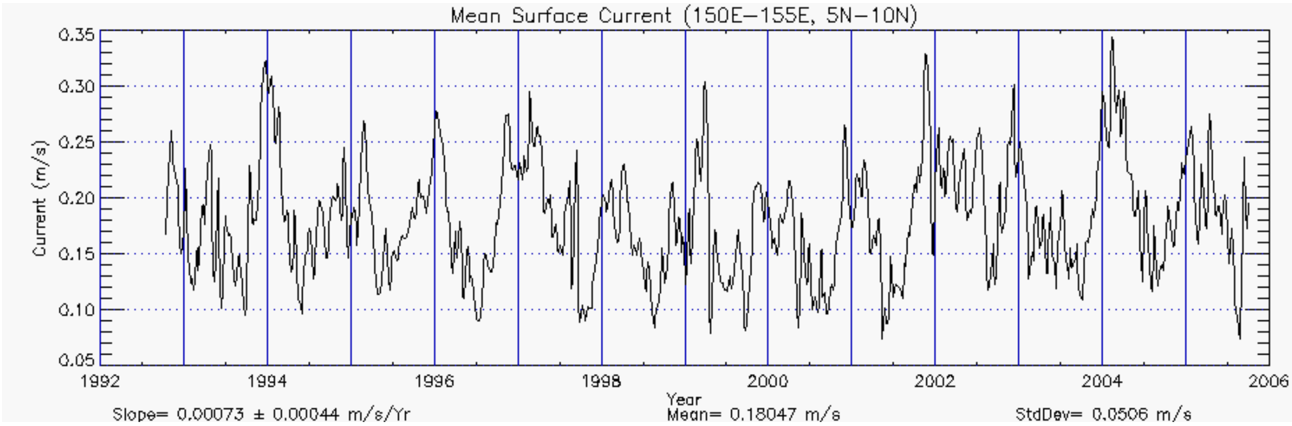


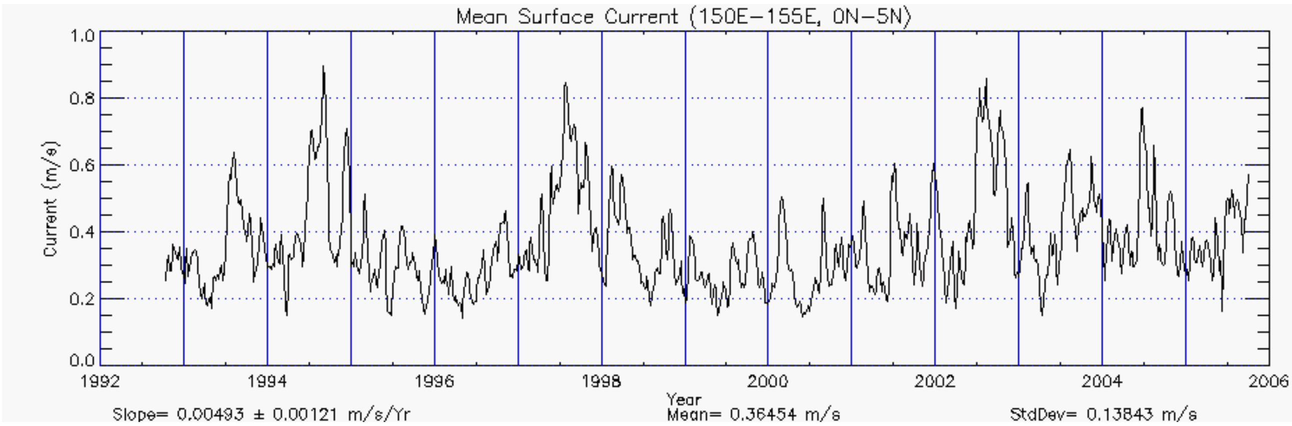

Mean Surface Current (150E−155E, 25N−30N)
Current (m/s)
Year
Slope= 3.00000e−005 ± 0.00013 m/s/Yr
Mean= 0.06788 m/s
StdDev= 0.01497 m/s


Mean Surface Current (150E−155E, 20N−25N)
Current (m/s)
Year
Slope= 0.00116 ± 0.0002 m/s/Yr
Mean= 0.09278 m/s
StdDev= 0.02327 m/s


Mean Surface Current (150E−155E, 15N−20N)
Current (m/s)
Year
Slope= −0.0003 ± 0.00028 m/s/Yr
Mean= 0.10498 m/s
StdDev= 0.03231 m/s


Mean Surface Current (150E−155E, 10N−15N)
Current (m/s)
Year
Slope= −0.00179 ± 0.0005 m/s/Yr
Mean= 0.20318 m/s
StdDev= 0.0579 m/s





12. To give you a sense of how fast these currents move, compare normal walking pace to the mean surface current speed. Measure out a fixed distance (10, 30 or 50 meters) on flat terrain. Walk at your normal speed and measure how many seconds it takes to walk the distance. Compute your walking speed. How does your walking speed compare to the movement of ocean surface currents?

13. Examine the mean values. What happens to the mean speed as currents move farther from the Equator? Where is the mean speed highest? Where is it lowest?

14. You have learned something about a particular location and should study other locations to see if they follow the same pattern. What about other longitudes in the Western (or Central or Eastern) Pacific? What about the Southern Tropical Pacific? Do other locations show the same or different behavior?

To broaden your study, select new locations and fill in the following table:

Longitude	Latitude	Mean Speed (m/sec)

15. Examine the mean values. What happens to the mean current speed as you move farther from the Equator? Where is the mean speed highest? Where is it lowest? Does this data show the same pattern as the Northwest 150E-155E data? Can you derive a conclusion and theory from your data?

More Challenging: Extend This Lesson to the Study of Patterns in the Slope and Standard Deviation

To continue this study and broaden the applicability of your conclusion, you can select more sample locations. Also you can study patterns in the slope and standard deviation values that you have accumulated. The slope estimates the change in current speed each year. The slope values are given with an estimated error (For example, 0.00236 ± 0.00082 means 0.00236 is the slope and 0.00082 is the estimated error in the slope). If the error value is close to or larger than the slope value, then the slope value is mostly error and could be zero (no significant change each year). Positive (negative) slope values would be evidence of increasing (or decreasing) surface current speed and changes in ocean circulation. Alternatively, you can set the visualizer parameter to "Direction" and make a similar study the direction of flow of Pacific currents with latitude.

Sea Surface Temperature Anomaly

What are sea surface temperature anomalies and why are they important?

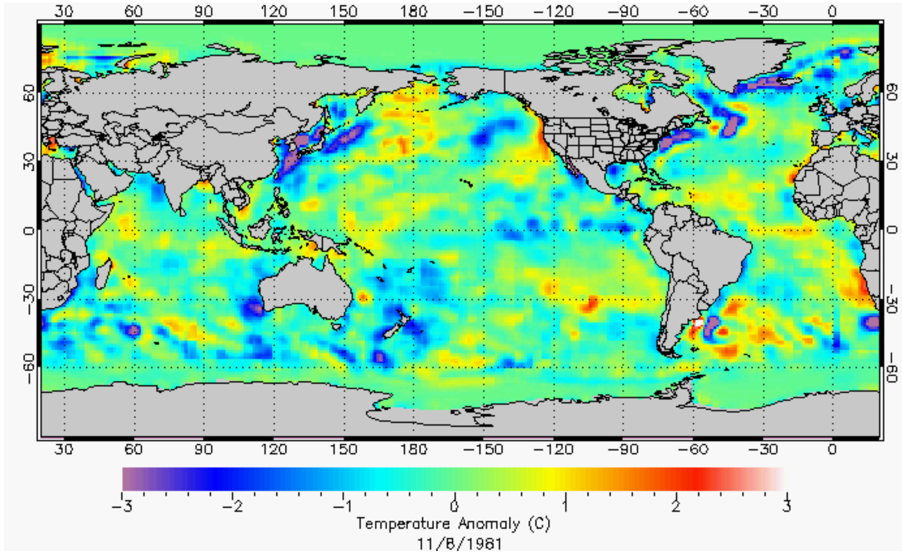
Anomalies are deviations from the normal. Large-scale anomalies can upset the state of the atmosphere. The sea surface temperature anomaly (SSTA) measures the difference between an average ("normal" or "typical") SST at a site during a specific time of year and the actual SST:
Anomaly = Actual Value – Average Value

A positive (or negative) anomaly indicates that the sea surface is warmer (or colder) than you would expect at the given time of the year. An anomaly of zero (0.0) means that the temperature is normal or typical. In this activity, you will explore the equatorial regions in the Atlantic, Indian and Pacific oceans to study anomaly variation (or variability) in these three ocean basins. To do this, you will use a measure of variation called the standard deviation. A high standard deviation in SSTA data means that that the temperatures depart more from normal than at a site where the standard deviation of SSTA is low.

Variations in the sea surface temperature can be caused by changes in surface currents, precipitation, wind speed, near-surface air temperature and upwelling. The sea surface is mostly isolated from deeper layers of very cold water by a layer of water that is thoroughly mixed (the mixed layer) and has relatively constant density and temperature. One might expect smaller sea surface temperature variations where the mixed layer is deep and larger variations where the mixed layer is shallow.

To see a map that shows the SSTAs around the world, link to the sea surface environment visualizer and click on the following settings:

• Parameter: **Temp Anomaly**
• Click-on-Map Data: **Graph**



The settings of the other controls are not important for this study.

For this study, limit your data collection to regions in the Atlantic, Indian and Pacific Oceans near the Equator. For each of the three oceans, click on the map at the Equator (0^o) for each of the six locations listed in the table. When you click on the map at each location, a pop-up window with a data plot will appear. The value of the standard deviation (StdDev) of all the data is printed at the bottom of each plot. Look at the *Measurement Protocol and Data Manipulation* in Lesson 2 for additional information about standard deviation.

16. In the table below, record the longitudes and the corresponding standard deviation for the data from the bottom of each graph.

Sea Surface Temperature Anomalies In Atlantic, Indian and Pacific Oceans at the Equator (0^o)						
	Atlantic Ocean					
Site	1	2	3	4	5	6
Longitude	40W	35W	25W	20W	5W	5E
Standard Dev.						
	Indian Ocean					
Site	1	2	3	4	5	6
Longitude	50E	55E	65E	80E	90E	95E
Standard Dev.						
	Pacific Ocean					
Site	1	2	3	4	5	6
Longitude	155E	170E	155W	145W	105W	85W
Standard Dev.						

17. Comment on any patterns that you see in your data. Where are SSTAs greatest? Where are they smallest? Which ocean has the greatest difference between West and East?

Weather Going Wild–La Corriente del Niño

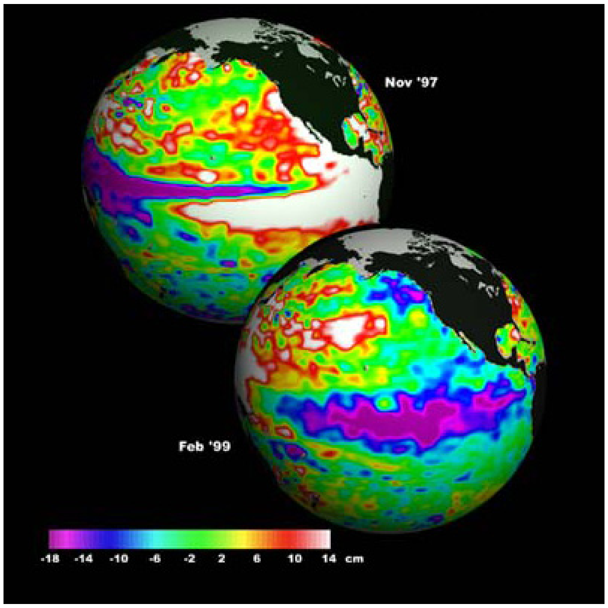
Are there patterns/anomalies in surface current data that could account for El Niño?

Over the past millennia, the climate has remained remarkably stable. Yet even the most stable climates contain variability. Regional conditions in the ocean and atmosphere shift back and forth. Natural variations in winds, currents, and ocean temperatures can temporarily change regional weather patterns. If these deviations become extreme enough, these disruptions can ripple across the globe. Such changes, especially if they are not foreseen, can devastate communities that rely on predictable weather patterns for their livelihoods.

The most infamous of these disruptions was marked by the arrival of warm currents into the chilly waters off the Peruvian coast. In the 19th century, Peruvian fishermen named this phenomenon El Niño, Spanish for "the Christ child," because the warm water typically arrived around Christmas. Normally this incursion of warm water is a short-term seasonal event. But every two to seven years, these warm waters stick around for up to 12 to 18 months, signaling a temporary shift in the interaction between the ocean and atmosphere over the tropical Pacific Ocean.

(click the image to load movie)
Transcript - Text
QuickTime - High Resolution | Low Resolution
Windows Media - High Resolution | Low Resolution

Today El Niño refers to this long-term incursion of warm water and its climatic consequences. Torrential rains that normally fall over the western tropical Pacific shift eastward, flooding the normally arid Peruvian and Ecuadorian coasts and leaving Indonesia and eastern Australia high and dry. These rainfall shifts may in turn disrupt the ocean and atmospheric circulation well beyond the tropical Pacific. During the severe El Niño events of 1982–83 and 1997–98, droughts and floods struck some of the most vulnerable areas in the world, including parts of Africa, Southeast Asia, and Central and South America. In the United States, unusually warm water made its way up the west coast, triggering torrential rains in California. Changes in the jet stream increased the frequency of floods and tornadoes in the southern states. On a brighter note, the northeast states enjoyed warmer winters and the number of Atlantic hurricanes decreased.



The TOPEX/Poseidon sea surface height anomaly satellite data, shown in the two Earth images on the right, help scientists determine the patterns of the ocean circulation - how heat stored in the ocean moves from one place to another. Since the ocean holds most of the Earth's heat from the Sun, ocean circulation is a driving force of climate. The two globes compare the 1997 El Nino (heights elevated off the Pacific coast of South America) and the 1999 La Nina (depression of heights in similar locations).

All told, floods, mud slides, crop failures, forest fires, and the spread of diseases attributed to El Niño has contributed to thousands of deaths around the world, displaced hundreds of thousands of people, and cost countries tens of billions of dollars.

With so much at stake, physical oceanographers and meteorologists have joined forces to learn what triggers El Niño, why it lasts only 12 to 18 months, and why an El Niño is often followed by a second climate anomaly called La Niña.

18. During the time of El Niño, weather- and ocean-related phenomena change. Scientists are analyzing data to find relationships between these phenomena and to better understand the dynamics taking place. In the following table, the weather- and ocean-related phenomena are listed in the left column. Develop a hypothesis to show how each of two phenomena might be related to each other.

Weather- and Ocean-Related Phenomena	**Relationship Hypothesis**
Warmer sea and air temperatures and Increased intensity and frequency of rainfall	
Slowing of the cold Peruvian (or Humboldt) current that moves up the western South America coastline and Deepening of the warm, nutrient-poor ocean surface layer	
Deepening of the warm, nutrient-poor ocean surface layer and a slowdown in the upwelling of deep water and Changes in varieties and numbers of marine life	

Scientists recognized that the influence of this weather disturbance [stretches around the globe](), so they deployed [buoys](), pictured on the right, in the tropical Pacific Ocean to continuously monitor the state of the sea surface: surface winds, air temperature, sea surface/subsurface temperatures, relative humidity and surface/subsurface water currents.

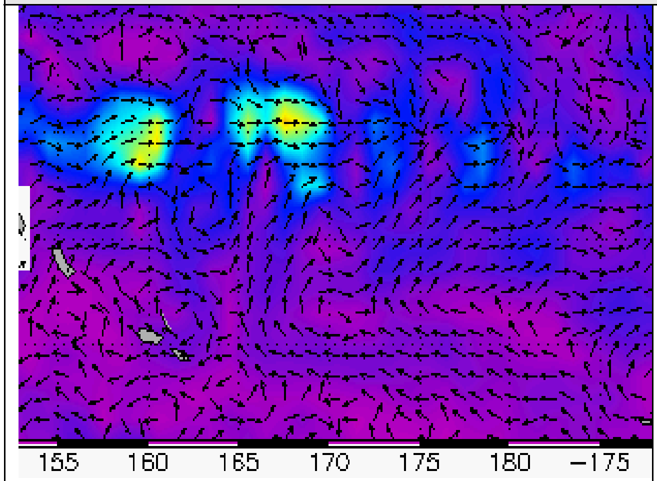
Link, again, to the [Ocean Surface Currents Visualizer]() and click the following settings:

- Year: **1997**
- Month: **FEB**
- Parameter: **Speed Anomaly**
- Tropical Pacific Region: **Equatorial West**
- Click-on-Map Data: **Graph**

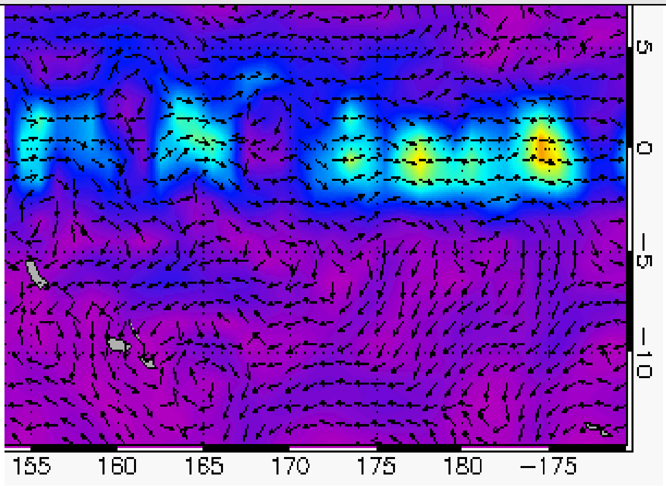
Scientists are interested in surface current changes that occur in the Equatorial Pacific Ocean. To view changes, we are displaying the surface current speed anomaly. Remember that the anomaly is the difference between the actual and average (or typical) value. Note: the Equator is indicated by the 0 on the right side of the map representing 0^o latitude. The colors shown in the image represent water current speed anomalies with a legend at the bottom of each page of maps.

19. Using the *Next* and *Back* buttons, move forward through 1997 and view the changes in current speed that occur near the equator. During which months are the anomalies highest? During which months are they lowest? Which way are the equatorial currents flowing during each high anomaly month?

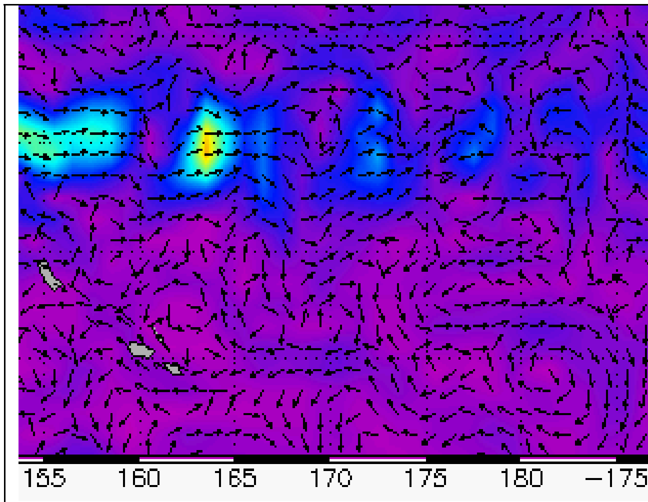
Speed Anomalies of the Equatorial West Pacific 1997



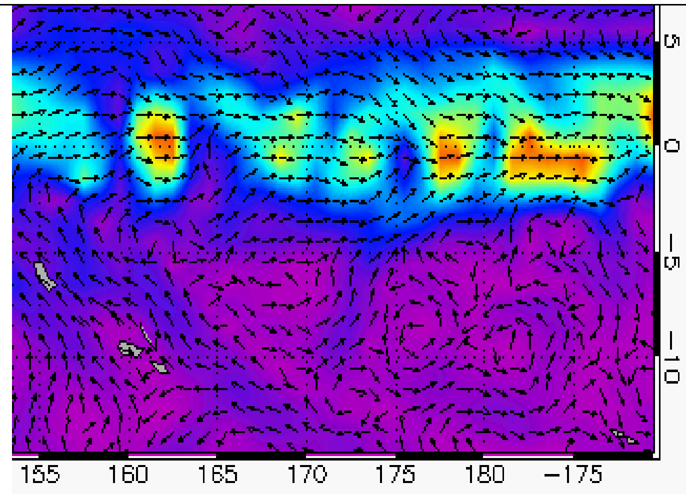
January 4, 1997



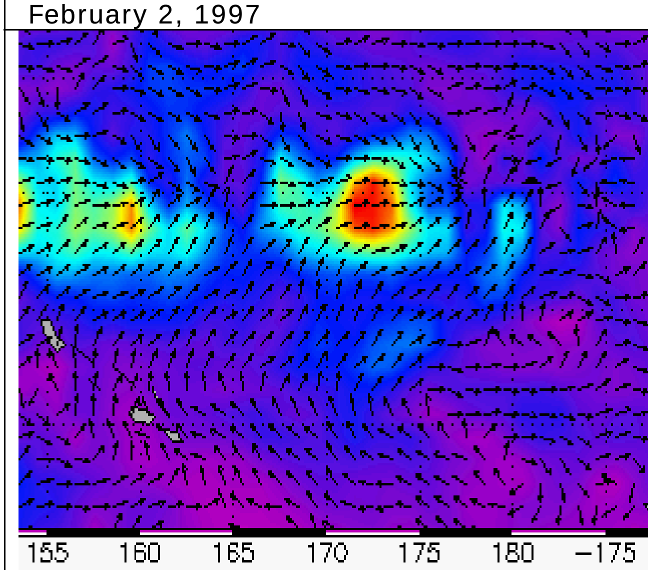
July 5, 1997



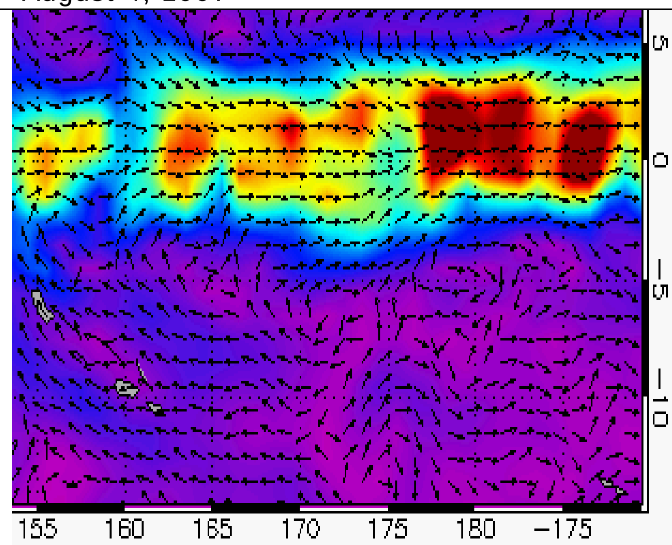
February 2, 1997



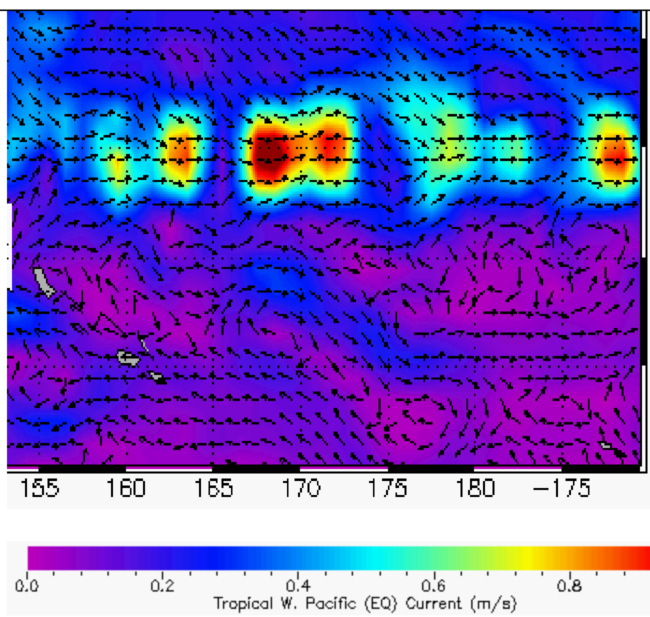
August 4, 1997



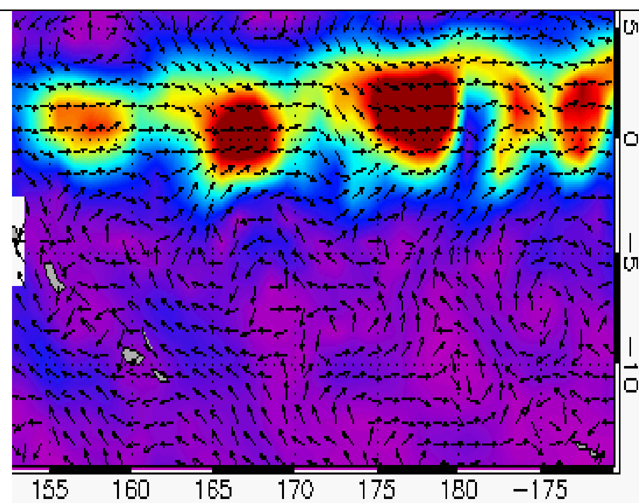
March 5, 1997



September 4, 1997

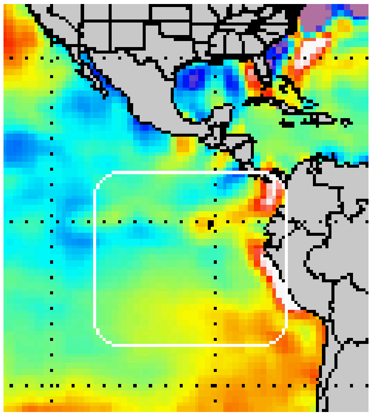


April 5, 1997



October 5, 1997

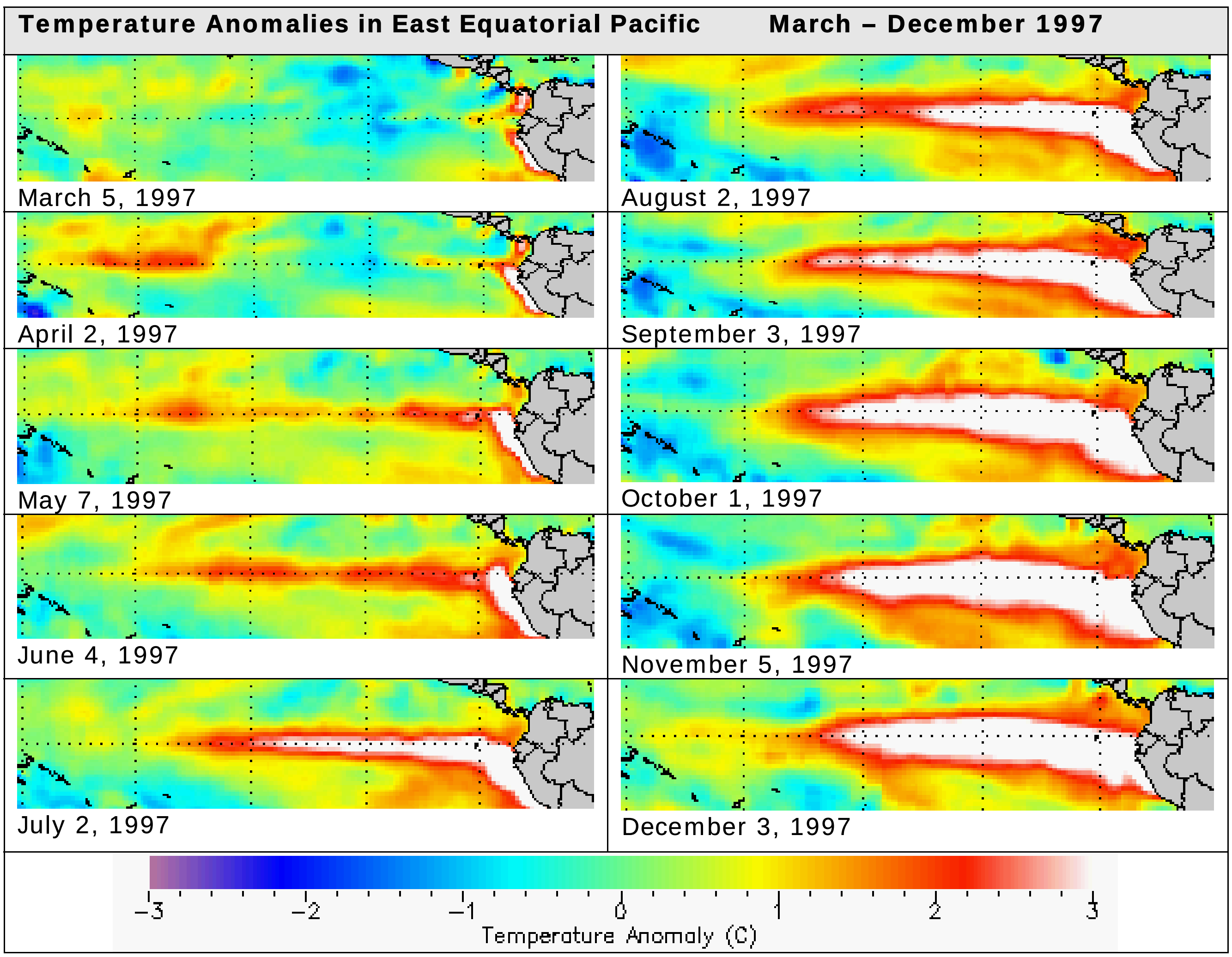
Link again to the Sea Surface Environment Visualizer and click on the following settings:



- Year: **1997**
- Month: **JAN**
- Parameter: **Temp Anomaly**
- Click-on-Map Data: **Graph**

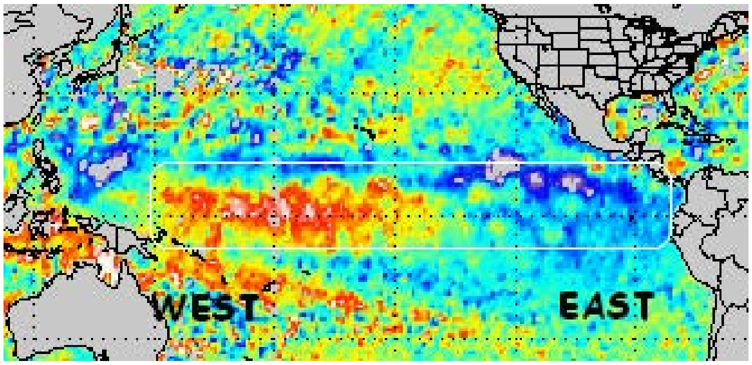
Scientists are interested in changes that occur in the SSTAs in the region indicated by the white outline box in the figure (West Coast of South America, Equatorial Eastern Pacific Ocean). Recall that the temperature anomaly gives the difference between the actual and average sea surface temperature. A high, positive anomaly means that waters are warmer than normal. A low negative anomaly means that waters are colder than normal. The colors shown in the image represent temperature anomalies.

20. Using the NEXT and BACK buttons, move forward from March 1997 and view the changes in SSTAs that occur near the equator and 90W longitude. Describe the pattern of change that you observe in the SSTA images. Continue in 1998 if necessary. When does the major anomaly start? When does it reach its peak? When does it end? Does the anomaly show the water becoming warmer or colder?



Link again to the Sea Surface Environment Visualizer and click the following settings:

- Year: **1997**
- Month: **JAN**
- Parameter: **Height Anomaly**
- Click-on-Map Data: **Graph**

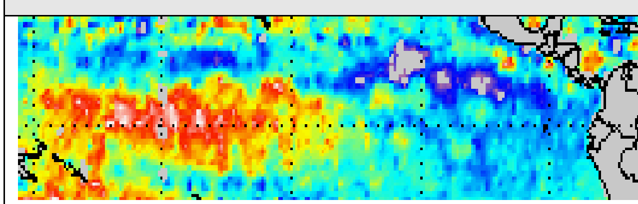
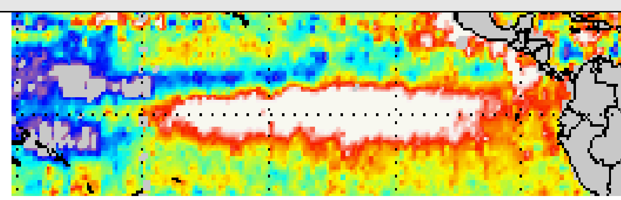
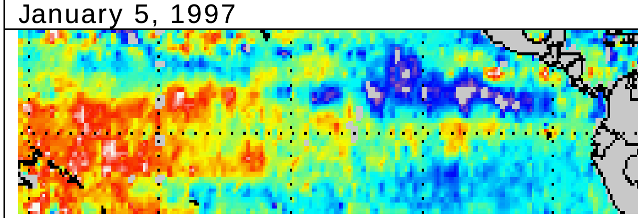
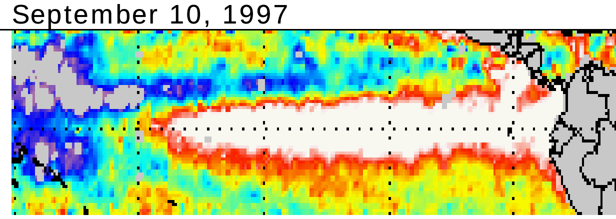


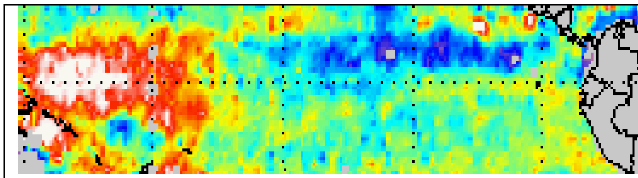
Scientists are interested in changes that occur in the sea surface height anomaly (SSHA) in the region indicated by the white outline box in the figure (Equatorial Pacific Ocean). Recall that the height anomaly gives the difference between the actual and average sea surface temperature. A high, positive anomaly (red, white) means water levels higher than normal and low, negative anomaly (blue) means water levels lower than normal.

21. Set the Months and Years controls (or step forward with the NEXT button) to determine if the water levels in the West and East Pacific are at higher (H), Lower (L) or normal (N) levels. H represents a positive anomaly and L represents a negative anomaly.

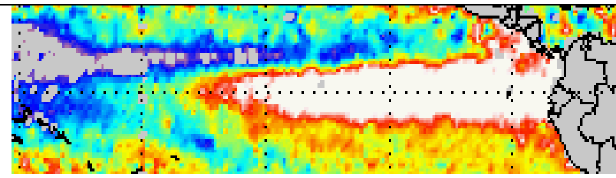
Sea Height Anomaly	**1997**												**1998**		
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**De**	**J**	**F**	**M**
West Pacific															
East Pacific															
H – High				**L – Low**				**N - Normal**							

Note on the maps below: The far right side of the map is Central America and the west coast of South America. The dotted horizontal line in the middle of each map represents the Equator (0^o Latitude).

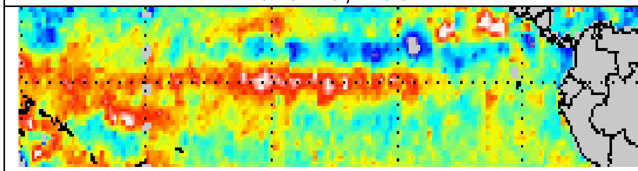
Sea Surface Height Anomalies in Equatorial Pacific Jan 1997 – April 1998	
 January 5, 1997	 September 10, 1997
 February 4, 1997	 October 10, 1997



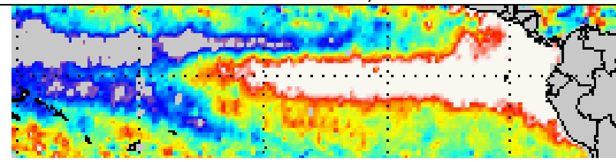
March 6, 1997



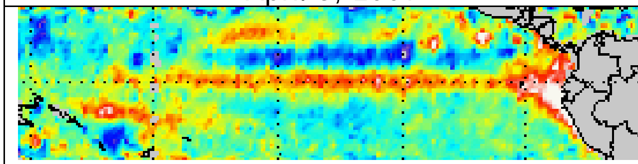
November 9, 1997



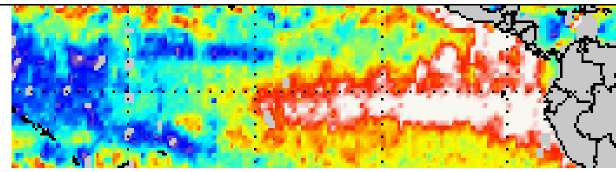
April 5, 1997



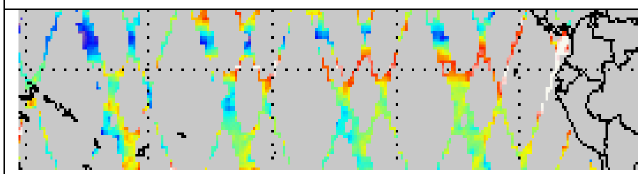
December 8, 1997



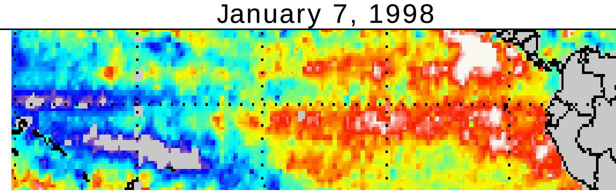
May 4, 1997



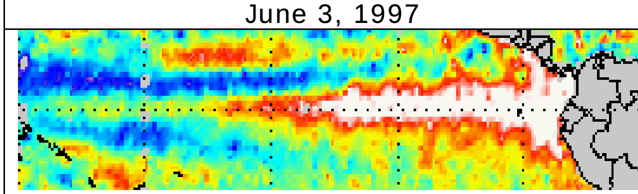
January 7, 1998



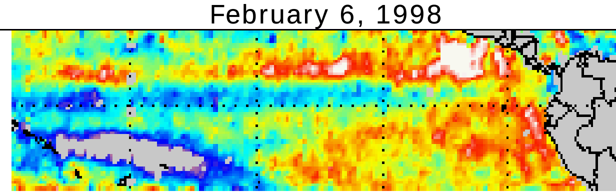
June 3, 1997



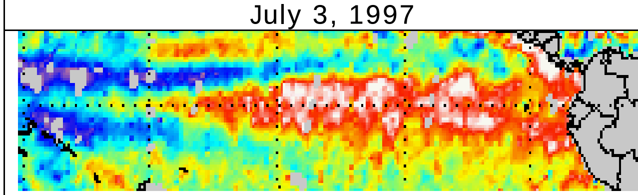
February 6, 1998



July 3, 1997

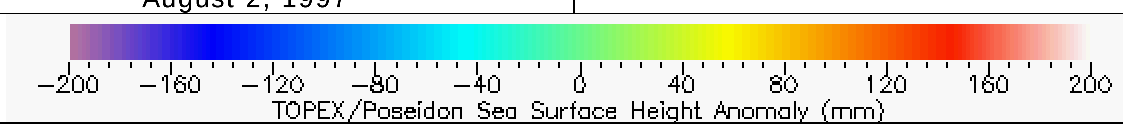


March 8, 1998



August 2, 1997

Note that the reading for June 3, 1997 is incomplete. The reason is unknown; however, it was included to reduce any confusion that might result if it were omitted.



22. Describe the pattern that you see in the SSHA data. Recall your study of Equatorial surface currents. Do your observations of the anomalous current flow agree with what you are seeing in the changes of sea surface height?

Grading Matrix for Grading Lesson 6

4 Expert	Responses show an in-depth understanding of how instruments on satellites collect data used in research to study complex interactions between the atmosphere and the ocean. Proficient manipulation of computer models to read near real-time satellite data. Analysis of data is complete and accurate and responses demonstrate an understanding of patterns in data that provide clues to phenomena such as El Niño.
3 Proficient	Responses show a solid understanding of how instruments on satellites collect data used in research to study complex interactions between the atmosphere and the ocean. Mostly proficient manipulation of computer models to read near real-time satellite data. Analysis of data is mostly complete and accurate and responses mostly demonstrate an understanding of patterns in data that provide clues to phenomena such as El Niño.
2 Emergent	Responses show a partial understanding of how instruments on satellites collect data used in research to study complex interactions between the atmosphere and the ocean. Some proficiency in manipulation of computer models to read near real-time satellite data. Analysis of data is partially complete and accurate, and responses sometimes demonstrate an understanding of patterns in data that provide clues to phenomena such as El Niño.
1 Novice	Responses show a very limited understanding of how instruments on satellites collect data used in research to study complex interactions between the atmosphere and the ocean. Little or no ability in manipulation of computer models to read near real-time satellite data. Analysis of data is partially complete, and accurate and responses demonstrate a limited understanding of patterns in data that provide clues to phenomena such as El Niño.