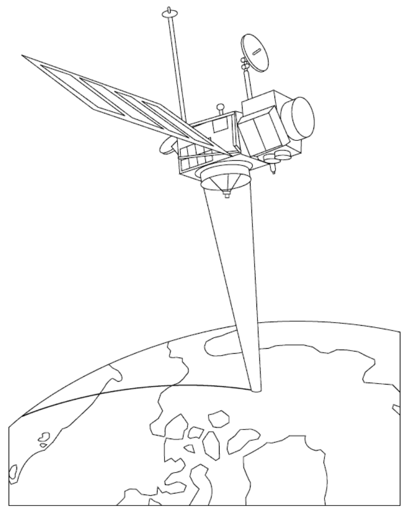
Lesson IV. TOPEX/Poseidon Measuring Currents from Space



The goal of this unit is to explain in detail the various measurements taken by the TOPEX/Poseidon satellite.

Keywords*: ocean topography, geoid, and sea surface variability*

Science Objectives and Goals

The objective of the TOPEX/Poseidon mission is to obtain an ongoing global view of Earth's **ocean topography** with sufficient accuracy to improve models designed to forecast global ocean circulation.

By meeting this objective, scientists are: determining ocean circulation and variability; learning to understand the wind's role in circulation; developing the descriptions of the nature of ocean dynamics; contributing to the understanding of the transport of heat, mass, nutrients and salt through the oceans; determining geocentric ocean tides; investigating the interactions of currents with waves; improving our knowledge of the marine geoid and increasing our understanding of lithospheric and mantle processes.

Ocean Topography

Ocean topography is a measure of sea level in relation to Earth's **geoid**, the shape the ocean surface would have if it were covered with water at relative rest to a rotating Earth. The geoid will be pulled away from a perfect sphere due to mass concentrations. Note also that the rotation rate of the Earth affects the geoid. The geoid is the sum of gravity effects and rotational effects.

Ocean topography is the changing height of sea level relative to the Earth's geoid after various corrections due to tides have been subtracted. While patterns of the oceans currents have been charted for hundreds of years, TOPEX/Poseidon is the first space mission that allows scientists to use ocean topography to calculate the speed and direction of ocean currents almost everywhere in the ocean. With maps of ocean topography, scientists can observe in detail the movement of water through the world's oceans. In the Northern Hemisphere, ocean currents flow clockwise around the highs of ocean topography and counterclockwise around the lows; this process is reversed in the Southern Hemisphere. These highs and lows are the oceanic counterparts of similar circulation systems in the atmosphere.

Oceanographers use ocean topography maps to calculate the speed and direction of ocean currents in the same way meteorologists use maps of atmospheric pressure to calculate the speed and direction of winds. TOPEX/Poseidon is the first space mission that allows scientists to map ocean topography with sufficient accuracy to study the large-scale current systems of the world's oceans.

Global Ocean Circulation

Ocean circulation is the large-scale movement of waters in the ocean basins. Winds drive surface circulation, and the cooling and sinking of waters in the polar regions drive deep circulation.

Surface circulation carries the warm upper waters pole ward from the tropics. Heat is dispersed along the way from the waters to the atmosphere. At the poles, the water is further cooled during winter and sinks to the deep ocean. This is especially true in the North Atlantic and along Antarctica. Deep ocean water gradually returns to the surface nearly everywhere in the ocean. Once at the surface, it is carried back to the tropics and the cycle begins again.

The more efficient the cycle, the more heat is transferred, and the warmer the climate.

Due to the rotation of the Earth currents are deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. This effect is known as the **Coriolis Effect**. The deflection leads to highs and lows of sea level directly proportional to the speed of the surface currents. The changes in sea level due to currents are the ocean topography observed by TOPEX/Poseidon.

Observations of ocean topography and a knowledge of the Coriolis force permit scientists to map ocean currents using data from the satellite. Every ten days, TOPEX/Poseidon produces maps of the currents everywhere in the ocean.

Variations in the ocean circulation can lead to variations in heat transport and to variations in weather patterns. One important variation in the circulation is the change in the equatorial circulation known as El Niño, which occurs with an irregular period of 2-5 years. TOPEX/Poseidon has observed the most recent El Niños with unprecedented accuracy.

Sea Surface Variability

Sea surface variability refers to any change in sea level relative to some average sea level, usually a multi-year average. By comparing recorded sea levels to the established averages, scientists can observe the variability of the world's oceans from 10-day cycle to 10-day cycle, season to season and year to year.

From the tropics to the poles, seasonal sea level changes are dominated by the heating and cooling of the upper layer of the oceans.

Larger ocean masses tend to have more moderate seasonal changes. The Southern Hemisphere has less landmass and more ocean mass than the Northern Hemisphere. As a result, the seasonal sea level change in the south is about half as large as in the north.

Around the equator, sea level changes can be observed in one of their more dramatic forms during an event known as El Niño. The higher sea surface height reflects an excessive amount of unusually warm water in the upper ocean.

The sea surface temperature reflects the temperature in the top inch or so of water, and the temperature can change dramatically with depth in some cases. The sea surface measured by altimetry is related to the temperature at all depths, as well as other parameters, such as the water salinity and ocean currents.

There is no direct relationship to convert sea surface temperature to sea surface topography, or vice versa. Although a change in sea surface temperature will cause a change in sea surface topography, and this can be computed approximately via an equation, one can't compute the total topography from the temperature. If this were possible, no one would be interested in satellite altimetry.

Significant Wave Height and Wind Speed

Significant wave height is determined from the shape of the return radar pulse of the altimeter. A calm sea with low waves returns a sharp pulse, whereas a rough sea with high waves returns a stretched pulse.

In general, there is a high degree of correlation between wind speed and wave height. As a result, wind speed is determined from the strength of the return pulse of the radar altimeter. A calm sea is a good reflector and returns a strong pulse whereas a rough sea tends to scatter the signal and return a weak pulse.

The strongest winds are found in the southern oceans. Accordingly, the highest waves are also found in the southern oceans and can rise to over six meters in height. The lowest waves are found primarily in the tropical and subtropical oceans where the wind speeds are the lowest.

The simultaneous observations of wind speed and wave height by TOPEX/Poseidon will help improve the ability to forecast ocean waves.
Source: TOPEX/Poseidon
Perspectives on an Ocean Planet

Activities

Activity IV-1. How Does Sea Surface Temperature Change With Latitude?

Modified from: http://athena.wednet..edu/curric/ocean/index.html

The following table shows AVHRR Sea Surface Temperature measurements taken in July 1997 for several different latitudes along 135° West longitude in the Pacific Ocean. Plot the sea surface temperature vs. the latitude.

Oceanographers use diagrams of satellite measurements to figure out what is happening in the ocean. After you complete your plot, use it to determine how sea surface temperature changes with latitude.

Sea Surface Temperature at 135° West

Latitude	SST
50° South	10.9°C
40° South	12.4°C
30° South	18.9°C
20° South	25.5°C
10° South	27.4°C
0° (equator)	28.8°C
10° North	27.9°C
20° North	23.4°C
30° North	21.6°C
40° North	16.8°C
50° North	12.9°C

Help With Plotting:

Draw a rectangle. Make eleven tick marks (little lines) along the left, right, top and bottom of the rectangle. Make sure that the distances between the left and right tick marks are the same and that the distances between the top and bottom tick marks are the same. Along the left side of the rectangle, "Sea Surface Temperature in Degrees Celsius". Label the bottom of the diagram "Latitude in Degrees".

From bottom to top label the left tick marks: 10, 12,14,16,18,20,22,24,26,28,30. From left to right, label the bottom tick marks using the latitudes given in the above table. 50° South should be the tick mark furthest to the left and 50° North should be the tick mark furthest to the right.

You are now ready to plot the values of the sea surface temperature vs. latitude. The first value, 10.9° C, occurs at 50° South. Find 50° South at the bottom of the graph. Using your ruler, draw a straight line from the 50° South tick mark on the bottom of the graph to the 50° South tick mark on the top of the graph. Now find 10.9°C on the left side of the graph. Note that a sea surface temperature of 11.0°C will be half way between 10 and 12. Therefore, a sea surface temperature of 10.9°C will be almost, but not quite halfway between 10 and 12. Draw a straight line from this place to the right side of the graph. At the point where your two lines intersect, make a dot. Do this for the rest of the values in the table. Then connect the dots. Once your graph is complete, don't forget to try to figure out how sea surface temperature changes with latitude.

Answer

As you can see by the students work, the temperature of the sea surface is warmest at the equator and decreases to the north and south (toward the poles). The temperature of the air also changes the same way. For example, if you drive your car all the way from Southern California to Alaska, the temperature of the air also gets cooler. Why does this occur?

As you probably know, the sun directly affects the temperature of the sea surface. The strong rays of the overhead sun hit the Earth in the equatorial region (from the Tropic of Cancer to the Tropic of Capricorn) throughout the year. Thus, the warmest sea surface temperatures usually occur in this region. This is shown very well on your graph between 10° North and 10° South. However, at high latitudes, the amount of sunlight that reaches the surface is greatly affected by the time of year. During Northern Hemisphere summer, the tilt of the Earth allows a latitude in the Northern Hemisphere to receive more sunlight for more hours during the day than the same line of latitude in the Southern Hemisphere. In fact, the difference in sunlight between hemispheres is so great that the Southern Hemisphere experiences winter during the Northern Hemisphere summer. Therefore, the sea surface temperatures should be greater for Northern latitudes during the Northern Hemisphere summer. Your graph shows sea surface temperatures during July 1997 (Northern Hemisphere summer). By comparing the temperatures of 50° North to

50° South, 40° North to 40° South and 30° North to 30° South, you can see that the sea surface temperatures are, in fact, warmer in the Northern Hemisphere during its summer months. During Northern Hemisphere winter, the tilt of the Earth allows the Southern Hemisphere to receive more sunlight. Therefore, a plot of the sea surface temperature for December should show warmer values in the Southern Hemisphere.

Questions:
1. Is there any equation to correlate sea surface temperature to sea surface topography?

Answer:
1. No, there is no direct relationship to convert sea surface temperature to sea surface topography, or vice versa. Although a CHANGE in sea surface temperature will cause a CHANGE in the topography, and this can be computed approximately via an equation, one can't compute the total topography from the temperature. If this were possible, no one would be interested in satellite altimetry.

The sea surface temperature reflects the temperature in the top inch or so of water, and the temperature can change dramatically with depth in some cases. The sea surface measured by altimetry is related to the temperature at ALL depths, as well as other parameters, such as the water salinity and ocean currents.

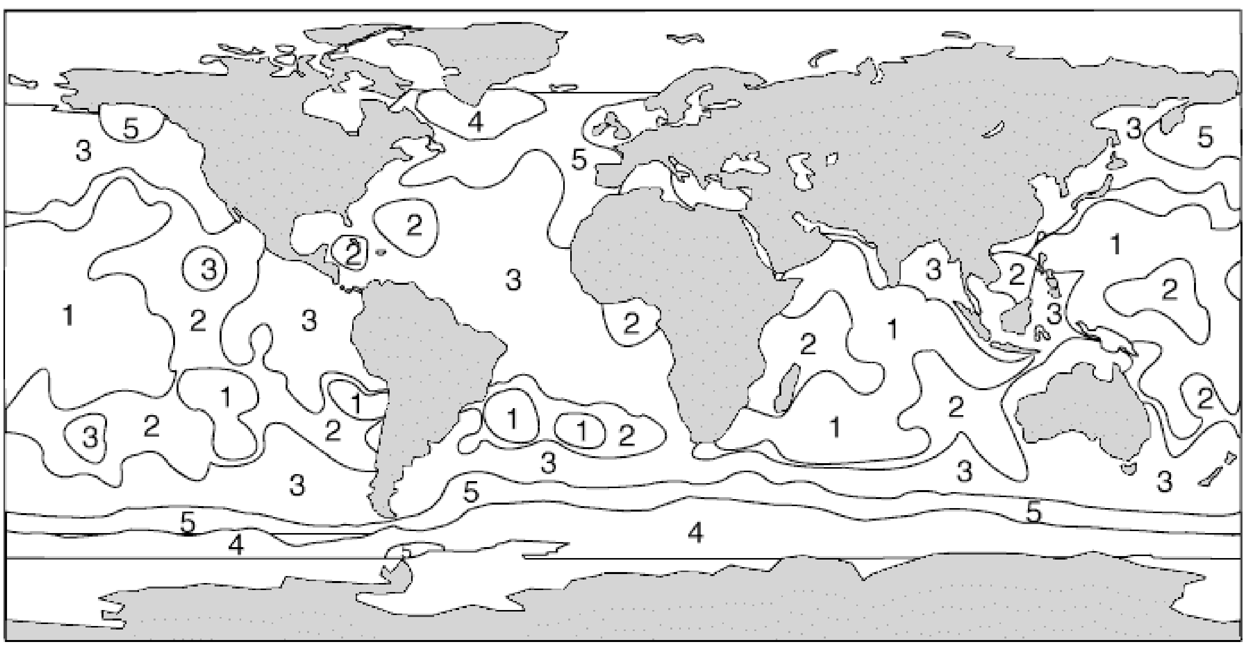
Activity IV-2 Coloring Sea Surface

Used with permission from *http:///www.csr.utexas.edu/tsgc/topex/html***.**   Have the students the color the picture according to the date of the lesson

The TOPEX/Poseidon satellite created this picture. It tells scientists the heights of the oceans.

Color in the picture using the following color guide.
The TOPEX/Poseidon satellite created this picture. It tells scientists the heights of the oceans.

1: Red
2: Yellow
3: Green
4: Purple
5: Blue



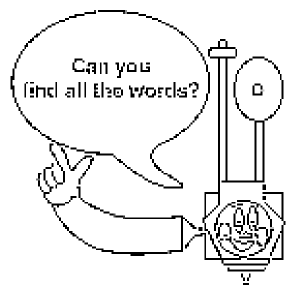
1=RED   2=YELLOW   3=GREEN   4=PURPLE   5=BLUE

TOPEX/Poseidon Word Search
(HARD)

J	Q	O	C	H	Y	D	Z	D	J	N	K	E	R	N	A
X	T	Y	H	P	A	R	G	O	P	O	T	A	T	J	N
E	B	N	U	F	H	V	X	C	Y	I	I	N	Y	Q	T
Y	O	L	P	E	D	D	W	H	L	Z	R	E	G	B	E
X	E	R	U	S	A	E	M	L	C	E	D	L	R	A	N
C	Z	R	A	D	A	R	E	E	R	K	H	Z	E	R	N
X	C	L	I	M	A	T	E	U	L	U	F	Z	N	E	A
E	O	R	Z	N	A	Q	T	A	M	N	T	P	E	T	C
P	M	T	C	S	S	A	X	I	D	E	I	Y	L	E	N
O	W	V	S	E	R	T	D	C	K	V	O	N	L	M	Y
T	L	E	A	E	M	I	R	C	G	C	N	Q	O	I	G
I	N	R	P	K	T	S	O	U	E	C	X	O	C	T	D
C	T	M	T	Y	P	R	U	A	M	D	K	D	N	L	G
H	E	I	H	P	Z	S	N	U	M	E	P	O	A	A	I
T	N	O	I	S	L	U	P	O	R	P	N	N	S	I	B
A	N	T	H	G	I	E	H	K	I	K	G	T	A	W	B

Words to Find:

TEMPERATURE	INSTRUMENT	PROPULSION
TOPOGRAPHY	SATELLITE	ALTIMETER
HUMIDITY	ANTENNA	MEASURE
CLIMATE	HEIGHT	ELNINO
ENERGY	DEPLOY	ROCKET
OCEAN	EARTH	TOPEX
RADAR	NASA	CNES



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Student Information Sheet
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