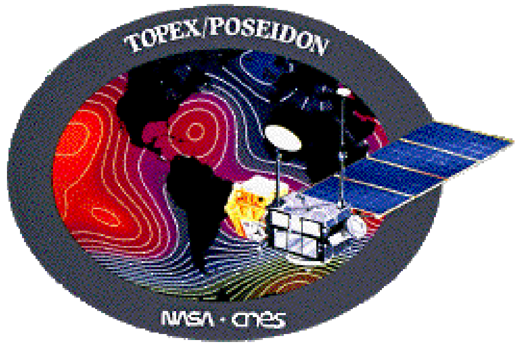
Lesson III. TOPEX /Poseidon Altimetry



The goal of this unit is to explain how altimeters on the TOPEX/Poseidon satellite obtain global sea level measurements.

Keywords: ***Altimeter, remote sensing, radiometer measurements, and ocean topography***

Measurement System

The TOPEX/Poseidon uses altimeter to provide levels of precision previously unobtainable in global sea level measurements. The measurement system is very complicated so we're just going to focus on how the satellite's measurement is optimized. To do this, we need to know: 1) where the satellite is in its orbit and 2) the distance from the satellite to the ocean. Satellite position is known relative to the center of the Earth and so we measure sea height relative to the Earth's center.

TOPEX/Poseidon makes very precise measurements of sea surface height. Let's discuss the meaning of the term "precise." You are given two rulers, each a foot long, but one has tick marks to indicate only whole inches

The position of the TOPEX/Poseidon satellite is determined using three methods. TOPEX/Poseidon has two altimeters that measure the distance from the satellite to the ocean. These **altimeters** send radar signals straight down which "bounce off" the ocean surface. The time it takes for the radar signal to return to the satellite tells us how far the satellite is from the ocean's surface. To improve the altimeter measurement, we measure the water content of the atmosphere. This is because water along the path of the signal changes the speed at which the altimeter signal travels.

and the other with tick marks every 1/16th of an inch...which would provide a more precise measurement of the length of your thumb? The more precise TOPEX/Poseidon's measurement is, the smaller the ocean feature we can measure.

Later, we'll focus on the relative heights of certain ocean features that scientists want to measure. Right now, TOPEX/Poseidon's measurement precision for sea surface height is 4.3 cm (1.7 inches). Because the satellite flies 1330 km (830 miles) above the Earth's surface, that's comparable to knowing the sea surface height to much less than the thickness of a dime while flying in a jet at 35,000 feet altitude!

Source:
http://dutlru8.lr.tudelft.nl/pages/altim.html

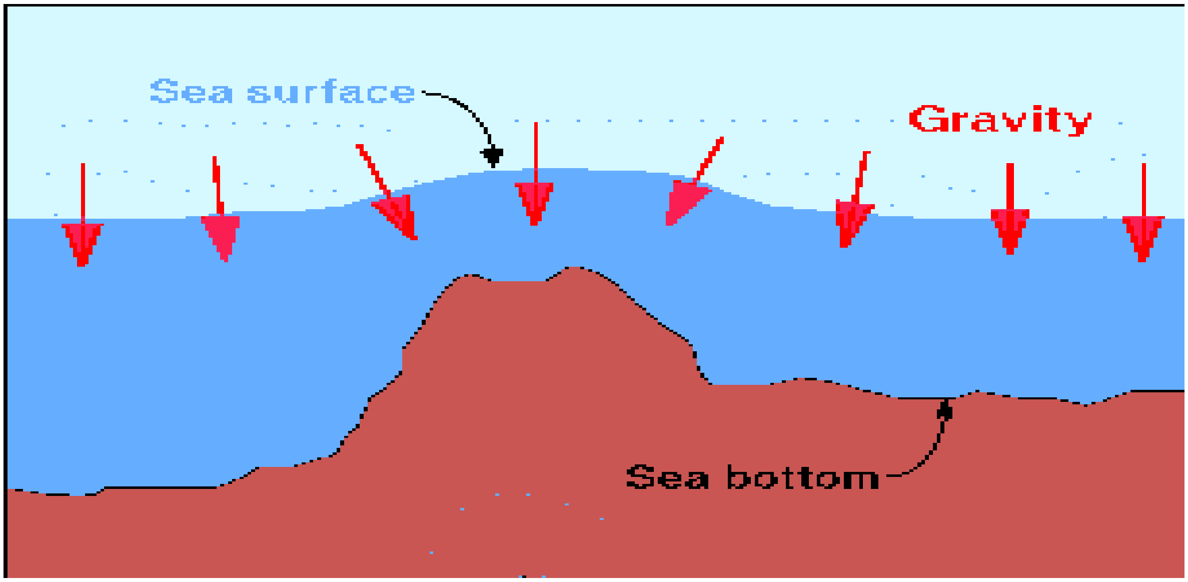
Satellite Radar Altimetry

Satellite **altimetry** offers the possibility to measure sea surface heights globally. Sea surface height is determined by measuring the distance between a satellite and the sea surface using radar. After computing the location of the satellite during the measurement and a number of atmospheric corrections are made, the sea surface height is known. Movement of water in the sea on spatial scales exceeding ~30 km and temporal scales exceeding ~1 day are manifested by deflections of the sea surface; that is, by changes in mean sea level associated with the strength and direction of the flow. This change in topography varies from the 1 meter increase in mean sea level in 100 km over the Gulf Stream to a 10 cm change over 1000 km over an El Niño event in the tropical Pacific. Given the strength of the sea surface topography signature, one can infer the magnitude and direction of the oceanic water movement**.**

Satellite altimetry is used for:

Oceanography. Since currents are detectable as slopes in the sea surface, the world's ocean currents can be detected and monitored. Small-scale features are visible as well, like eddies, which are generated by the large-scale currents (by the Gulf Stream, for example). Altimeter data is also used for tide modeling.

Geophysics. Density differences in the Earth's crust cause local differences in gravity (gravity anomalies). These affect the topography of the sea surface. The sea surface is always perpendicular to the (local) gravity so a "mountain" in local gravity shows up as a "hill" in the sea surface (see Figure below). This "mountain" can be both a real subsurface seamount or island, or it may be a local increase in density in the Earth's crust. An accurate determination of the constant part of the sea surface (as opposed to the time-dependant part, mostly due to oceanographic influences) is made by averaging as much data as possible from as many satellites as possible.



Graphic Source Unknown

So far, eight altimeters have flown on satellites. The first experiment was flown on board SKYLAB and provided many useful engineering data on which the following altimeters were further developed. The first scientific altimeter mission was the one on GEOS-3. It demonstrated how flat land and ocean surfaces could be profiled, but lacked sufficient accuracy and coverage to do serious science. SEASAT carried a better altimeter and offered global coverage; unfortunately the mission failed after only some three months. The next altimeter satellite, GEOSAT, worked for several years. The GEOSAT data set has proven the usefulness of the altimeter. In the 1990's, already four altimeters have been launched: two identical altimeters are carried on the multi-disciplinary **remote-sensing** satellites ERS-1 and ERS-2. Although ERS-1 is still in good health, it was put into hibernation a year after its successor ERS-2 was launched and carried over its operational duties. Simultaneously, the dedicated altimeter satellite TOPEX/Poseidon has been providing the most precise information to date and carries two altimeters: a French solid-state altimeter and a US dual-frequency altimeter, charting the time at a ratio of 1:9. By combining the data sets of the last four satellites, a data set with an excellent coverage can be obtained. The fact the two satellites are now carrying altimeters in orbit simultaneously greatly improves the coverage for oceanographic studies both temporal and spatial.

***Source*:http://dutlru8.lr.tudelft.nl/page/altim.html**

Measurement Process

TOPEX/Poseidon's primary instrument for measuring ocean topography is an **altimeter**. The altimeter bounces a **microwave pulse** off the surface of the ocean. By measuring how long it takes the signal to return, the altimeter determines the distance between the satellite and the ocean surface.

Air, water vapor, clouds and rain slow down the return of the microwave signal. A second instrument called a radiometer is used to correct for the influence of water in the atmosphere.

Altimeter and **radiometer measurements**, in conjunction with precise orbit determination, are used to obtain a detailed map of the **ocean's topography**. From this, scientists calculate ocean circulation and tides.

Altimeter Antenna

The **altimeter antenna** is used by the NASA /CNES radar altimeters carried in TOPEX/Poseidon's instrument module (IM). The antenna is a 1.5 meter diameter parabolic dish and is fixed on the nadir face of the IM surrounded by the laser retroreflector array.

The dual frequency NASA radar altimeter is the primary instrument aboard the spacecraft. It works by sending radio pulses at 13.6 Ghz and 5.3 Ghz toward the Earth and measuring the characteristics of the echo. By combining this measurement with data from the **microwave radiometer** and with other information from the spacecraft and ground, scientists can calculate the height of the sea surface to within 4.3 centimeters.

Altimeter Verification

TOPEX/Poseidon altimeter measures the distance from the spacecraft to the ocean surface. To verify the accuracy of the measurement made by TOPEX/Poseidon, the Precision Orbit Determination and Verification Team has a second, Earth-based way of obtaining the altimeter-to-ocean distance.

This measurement comes from sea level monitoring instruments placed on Texaco's Platform Harvest, an oil production platform located off the coast of California. The site was chosen so that land interference would not corrupt the altimeter return signal.

Measurement Systems

The TOPEX/Poseidon spacecraft uses a high precision radar altimeter to take measurements of sea surface height over 90% of the world's ice-free oceans. The satellite orbits at an altitude of 1336 km above the Earth and at an inclination of 66 degrees. One revolution around the planet is referred to as an orbit. In approximately 10 days, TOPEX/Poseidon completes 127 orbits, or a cycle. In that time, it records sea level measurements for the entire globe. TOPEX/Poseidon measures the distance from the satellite to the sea surface to within approx. 2.5 centimeters, about the diameter of a quarter.

Data Products

Scientists and engineers process measurements gathered with the radar altimeter on board TOPEX/Poseidon to produce six separate data sets focusing on: ocean temperature, sea surface variability, significant wave height, wind speed, perceptible water vapor and total electron content.

These data sets enable scientists to meet the project objective of a better understanding of global ocean circulation and its effect on the world's climate.

Science Data

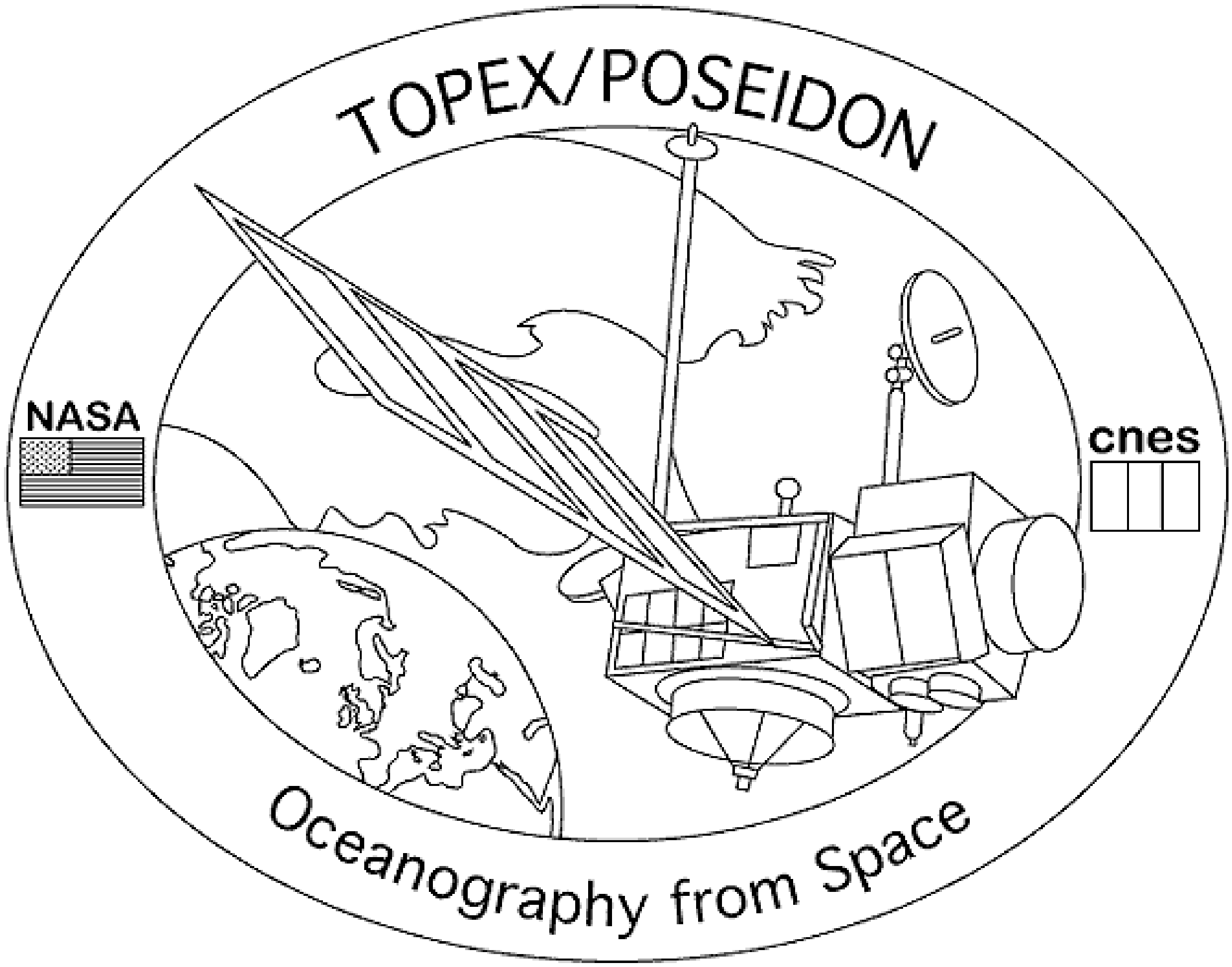
TOPEX/Poseidon's **data flow** is the process by which data are transferred from the spacecraft to the Earth and converted into useful science products such as maps and images.

The flow takes the data from the spacecraft's instruments to its tape recorders, to processing centers on two continents, and finally to members of the Science Working Team in 10 different countries.

Information pertaining to and samples of the different data sets created by these scientists are currently available to science investigators, educators, students and the general public through the TOPEX/Poseidon Educational Outreach program.

Data Flow

Data from the altimeter are stored in on-board tape recorders and played back daily to control and processing centers at the Jet Propulsion Laboratory in California and in Toulouse, France. Mission data from TOPEX/Poseidon are available for science analysis within seven days of playback. During this time, the raw data used to produce ocean topography are corrected for instrument biases, tropospheric delay, ionospheric delay, electromagnetic bias and tides. The sum of all these corrections can make a difference on the order of 2.5 meters in the measured ocean topography.


TOPEX/POSEIDON
NASA
cnes
Oceanography from Space

Discussion Questions:

1. How do the atmosphere and the ocean interact?

2. How could global warming affect sea levels? Why is global warming important?

3. What is the repeat time for the TOPEX/Poseidon satellite?

Answers

---

1. Differences in the heating and cooling rates of land and ocean affect air circulation. Land and water temperatures rise and fall at different rates because land absorbs and loses heat faster than water does. During the day, hot air rises and is replaced by cooler air. This small-scale circulation is called a sea breeze, and usually starts three or four hours after sunrise, reaching its peak by early afternoon. At night, the land is cooler than the water because the land has given up its heat to the atmosphere. The cool air flows over the warmer water and rises as it is warmed. This circulation is called a land breeze, and usually starts to form in the late evening. It reaches its peak intensity near sunrise.

2. Global warming may cause sea levels to rise by several mechanisms. Temperature increases may cause some of the ice in the polar regions to melt, which would raise sea levels. Higher water temperatures also may cause the oceans to expand. This expansion would cause a sea-level rise. Scientists are studying how global warming would affect sea levels, because a substantial rise in the sea level may flood coastal cities and other low-lying areas.

3. TOPEX/Poseidon is in a "10 day" (9.9155 d) exact repeat at an inclination of 66 degrees. The ground tracks are about 315 km apart at the equator and the orbit period is 112 minutes.

Student Information
Satellite Oceanography III

Altimeter Measurement System

The TOPEX/Poseidon uses its altimeter to provide levels of precision previously unobtainable in global sea level measurements. The measurement system is very complicated so we're just going to focus on how the satellite's measurement is optimized. To do this, we need to know: 1) where the satellite is in its orbit and 2) the distance from the satellite to the ocean. Satellite position is known relative to the center of the Earth and so we measure sea height relative to the Earth's center.

TOPEX/Poseidon makes very precise measurements of sea surface height. Let's discuss the meaning of the term "precise." You are given two rulers, each a foot long, but one has tick marks to indicate only whole inches and the other has tick marks every 1/16th of an inch...which would provide a more precise measurement of the length of your thumb? The more precise TOPEX/Poseidon's measurement is the smaller the ocean feature we can measure.

The position of the TOPEX/Poseidon satellite is determined using three methods. TOPEX/Poseidon has two altimeters that measure the distance from the satellite to the ocean. These **altimeters** send radar signals straight down which "bounce off" the ocean surface. The time it takes for the radar signal to return to the satellite tells us how far the satellite is from the ocean's surface. To improve the altimeter measurement, we measure the water content of the atmosphere. This is because water along the path of the signal changes the speed at which the altimeter signal travels.

Later, we'll focus on the relative heights of certain ocean features that scientists want to measure. Right now, TOPEX/Poseidon's measurement precision for sea surface height is 4.3 cm (1.7 inches). Because the satellite flies 1330 km (830 miles) above the Earth's surface, that's comparable to knowing the sea surface height to much less than the thickness of a dime while flying in a jet at 35,000 feet altitude!

Satellite Radar Altimetry

Satellite **altimetry** offers the possibility to measure sea surface heights globally. Sea surface height is determined by measuring the distance between a satellite and the sea surface using radar, after computing the location of the satellite during the measurement and a number of atmospheric corrections the sea surface height is known. Movement of water in the sea on spatial scales exceeding ~30 km and temporal scales exceeding ~1 day are manifested by deflections of the sea surface; that is, by changes in mean sea level associated with the strength and direction of the flow. This change in topography varies from the 1 meter increase in mean sea level in 100 km over the Gulf Stream to a 10 cm change over 1000 km over an El Niño event in the tropical Pacific. Given the strength of the sea surface topography signature, one can infer the magnitude and direction of the oceanic water movement**.**

Satellite altimetry is used for:

***Oceanography*.** Since currents are detectable as slopes in the sea surface, the world's ocean currents can be detected and monitored. Small-scale features are visible as well, like eddies, which are generated by the large-scale currents (by the Gulf Stream, for example). Altimeter data is also used for tide modeling.

***Geophysics*.** Density differences in the Earth's crust cause local differences in gravity (gravity anomalies). These affect the topography of the sea surface. The sea surface is always perpendicular to the (local) gravity so a "mountain" in local gravity shows up as a "hill" in the sea surface (see Figure below). This "mountain" can be either a real subsurface seamount or island, or it may be a local increase in density in the Earth's crust. An accurate determination of the constant part of the sea surface (as opposed to the time-dependant part, mostly due to oceanographic influences) is made by averaging as much data as possible from as many satellites as possible.

Internet Sites:

http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/seawifs_raq.html
http://topex-www.jpl.nasa.gov/
http://ferret.wrc.noaa.gov/fbin/climate_server
http://seawifs.gsfc.nasa.gov/SEAWIFS/LIVING_OCEAN/LIVING_OCEAN.html
http://www-ccar.colorado.edu/research/demos/html/demos.html