Lesson I. Satellite Oceanography Overview

The goal of this unit is to give a basic overview of satellite oceanography, its uses and applications.

Key words*: satellite, global climate, ocean circulation, altimetry, and sea level measurements*

Covering about seventy percent of the Earth's surface, the oceans are central to the continued existence of life on our planet. The oceans are where life first appeared on Earth. The largest creatures on Earth (whales) and the smallest (bacteria and viruses) live in the oceans. We rely on the ocean for many things, including: food, water transportation, recreation, minerals and energy. Oceans store energy. When ocean currents change, they cause changes in global weather patterns and can cause droughts, floods and storms.

However, our knowledge of our oceans is limited. Ships, coastlines, and islands provide places from which we can observe, sample, and study small portions of oceans. But we can only look at a very small part of the global ocean this way. We need a better place from which to study oceans.

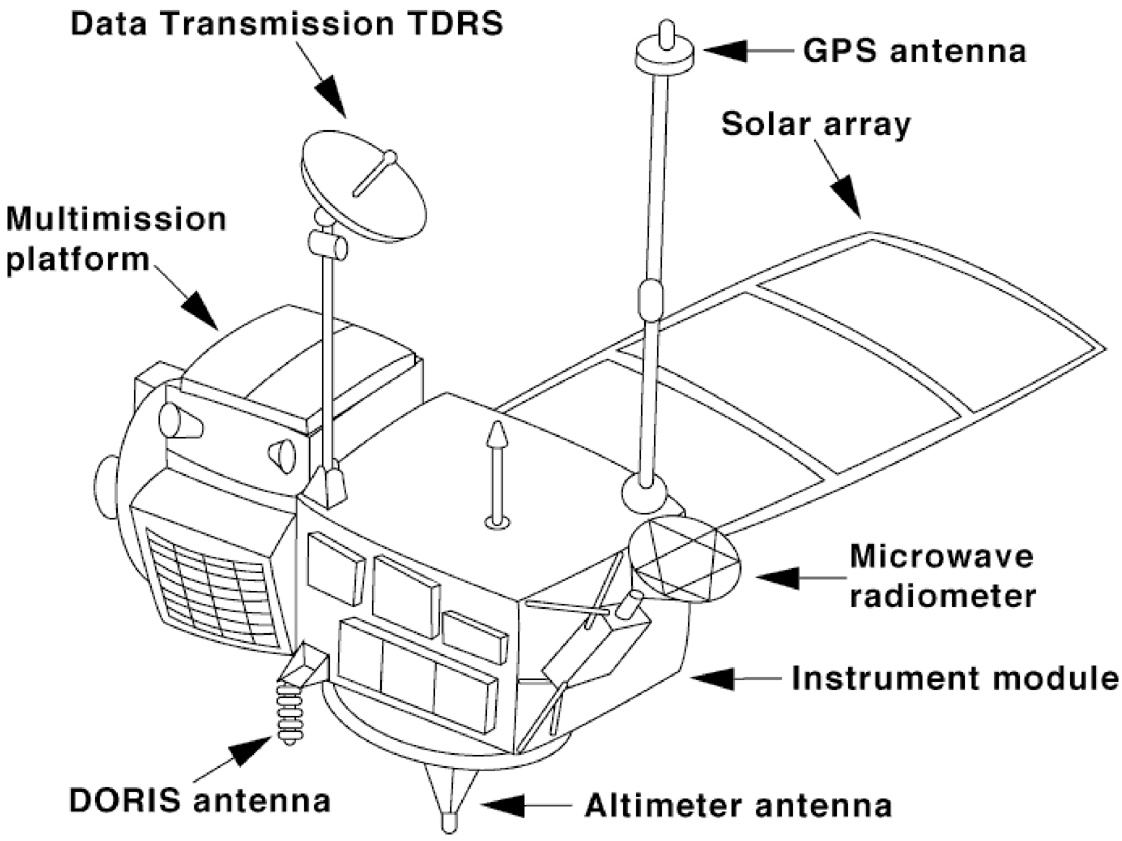
Space provides this place. Satellites circling the Earth can survey an entire ocean in less than an hour. These satellites can "look" at clouds to study the weather, or at the sea surface (when it's not cloudy) to measure the sea's surface temperature, wave heights and direction of waves. Some satellites use radar to "look" through the clouds at the sea surface.

One other important characteristic that we can see from space is the color of the ocean. Changes in the color of ocean water over time or across a distance on the surface provide valuable information.

In this series of programs, we will discover satellite imaging, TOPEX/Poseidon **altimetry**, the view of the ocean from the space shuttle, measuring currents from space, marine mammal tracking and tracking El Niño.

What is a Satellite?

A **satellite** is any object that orbits or revolves around any other object. For instance, the moon is a satellite of the Earth and the Earth is a satellite of the sun. We'll look at the man-made satellites that orbit the Earth and sun, highly specialized tools that do thousands of tasks every day.



This can be made into an overhead.

Satellite Oceanography

Satellites can orbit the Earth several times a day. By placing instruments on a satellite, an oceanographer can obtain data from all over the world in a short amount of time. These instruments are able to measure the temperature of the ocean surface, the height of the water, the speed of the wind above the water and many other things.

Satellites can take measurements over the entire Earth's surface in just a few days. As a result, oceanographers are now able to better study phenomena, which affect entire oceans or even the entire planet. This makes satellite measurements ideal for scientists who study the Earth's climate, El Niño or the monsoons in the Indian Ocean. Satellites also allow scientists to get measurements in places which are hard to reach by ship, such as Antarctica. **Oceanography** is the scientific study of the oceans. Because there are so many different things to study in the ocean, there are many different types of oceanography. The type of oceanography in which the movements of the ocean are studied is called **physical oceanography**. Many different things cause the movements of the oceans. For example, wind can create waves, the moon and the sun create tides, and the rotation of the Earth creates currents. The temperature of the water can even cause it to move. Therefore, physical oceanographers, the scientists who study the movements of the ocean, have had to develop many different instruments to study the ocean. Scientists are also coming up with many more purposes for satellite measurements. For example, the original purpose of the TOPEX/Poseidon was to measure **sea surface height**. However, oceanographers at the University of Texas have used these measurements to track whale migrations.

Space Oceanography encompasses oceanographic research and technological development resulting from manned and unmanned systems in Earth's orbit. These systems observe and measure oceanographic parameters such as **seas surface winds, sea surface temperature, waves, ocean currents** and **frontal regions**. The scope of oceanographic research embraces the sciences of physics (including acoustics), geology, biology and chemistry. The technological developments include new sensing methods and sensor systems to acquire oceanographic data with specified degrees of **resolution**, accuracy, coverage and timeliness. Some **oceanographic phenomena** were first observed and photographed by astronauts in space. Sensor technology then evolved to observe the same phenomena from unmanned spacecraft. As our scientific knowledge of the world's oceans increases, and as a consequence the accuracy of the physics in oceanographic forecasting models improves, there arises a need for real-time, global (encompassing all ocean basins), daily oceanographic observation systems.

Discussion Questions

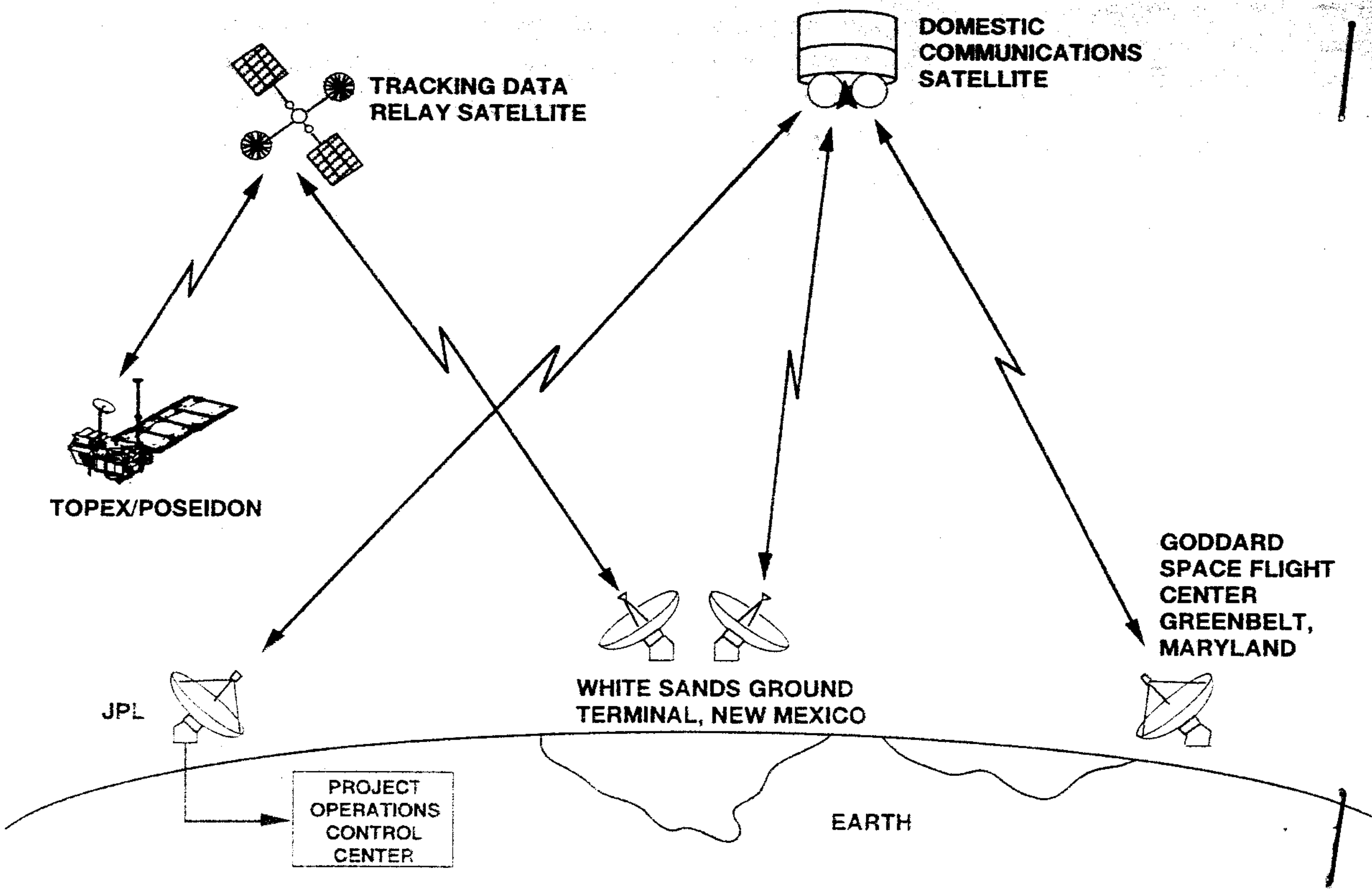
1. What is a satellite? What materials can a satellite be composed of?

2. What can create movement of the oceans?

2. How is the position of the TOPEX/Poseidon satellite determined?

4. Scientists use two types of satellites to study the environment. A geostationary satellite remains above the same spot on the Earth's equator from an altitude of about 22,500 miles and can "see" an entire hemisphere all the time. A polar orbiting satellite travels in a circular orbit, passing above the North and South Poles while the Earth rotates beneath it. This type of satellite can "see" details as small as a mile or less. Which of these satellites probably would be better for our ocean color instrument? Would one prove better than the other to track hurricanes and other large weather systems?

Answer to #4:
A polar-orbiting satellite potentially can "see" everywhere in the world in about two days, and its orbit is low enough so that it can detect smaller details than a geostationary satellite. It will pass over a certain area once daily at the same time of day, which is important for instruments that use sun illumination for measurements of ocean color or land vegetation. A geostationary orbit can view almost an entire hemisphere at the same time, is able to track hurricanes and weather systems by making measurements every half hour or so and also is used for meteorological purposes.



TDRSS and TOPEX/POSEIDON communications

Activity I-1. Design a Satellite

Source: athena.wednet.edu

Remind students that satellites are used for communication, spying, search and rescue, scientific research, meteorology, navigation, and space and exploration. The basic components of a satellite can include solar panels to generate electricity, antennae to send signals and sensors to measure temperature, wavelength, latitude and longitude, or local distress signals.

Objective: Design a satellite and invent a mission for it.

1. Discuss the following with students:
- What do satellites look like?
- What are the orbits they follow?
- How do they stay in orbit?
- What are some of the tasks they perform?

3. Look at examples of actual satellites and point out and discuss the features and designs.

3. Supply cans, egg cartons, paper or foam cups, and other materials to allow students to build their own satellite models.

4. Ask them to address these questions before they design their models:
- How is your satellite powered? (Real satellites are powered by solar panels, fuel cells that convert chemical energy to electrical energy, or by nuclear energy.)
- What is its mission?
- What kinds of remote sensing activities will you want it to perform?
- How will it acquire this data? (What kind of equipment will it use?)
- How will it communicate with people on Earth?
- What kind of orbit will you chose for it (polar or geostationary)?

5. Using a string, suspend satellites from the ceiling of the classroom.

6. Use a satellite model and a globe to illustrate how satellites orbit the Earth in a geostationary or a polar orbit.

7. Write a press release to be issued by the National Aeronautics and Space Administration (NASA) about what your satellite will do during its mission. Within it provide a brief biography of the Mission Commander (you) and any selected crewmembers. The press release should be no longer than two pages, double-spaced. The most important information should go in the first paragraph.

Materials

- Photographs or illustrations of satellites
- Cans
- Milk
- Cartons
- egg cartons
- paper or foam cups
- plastic pipe cleaners
- aluminum foil
- buttons
- coins
- wire
- cardboard
- tape
- rubber bands
- glue
- markers
- crayons
- string
- globe.

Activity I-2. Orbit Model

Source: athena.wednet.edu

Satellite orbits lie in planes that bisect the orbited body. If the Earth were not rotating, each orbiting satellite would pass over the same point on the Earth with each orbit, crossing the equator repeatedly at the same longitude. Because the Earth is constantly rotating, each orbital pass of the satellite (as indicated by the model described in this activity) appears to be to the west of the previous one. In reality, the Earth is rotating eastward as the orbital plane remains fixed.

Students will examine the factors determining the length of a satellites orbit around Earth.

Recognize that the Earth rotates 360 degrees in 24 hours, or:

$$\frac{60\text{ minutes}}{1\text{ hour}} \times \frac{24\text{ hours}}{1\text{ day}} = \frac{1440\text{ minutes}}{1\text{ day}}$$

Dividing 360 degrees by 1440 minutes shows that the Earth is rotating 0.25 degrees every minute. Here's the math:

$$\frac{360\text{ degrees}}{1440\text{ minutes}} = \frac{0.25\text{ degrees}}{1\text{ minute}}$$

The satellites that we will want to track travel around the Earth in approximately 102 minutes. Thus, we can see that if the satellite crossed the equator at 0 degrees longitude on one orbit, it would cross over 25.5 degrees longitude 102 minutes later.

$$\frac{0.25\text{ degrees}}{1\text{ minute}} = \frac{25.5\text{ degrees}}{102\text{ minutes}}$$

The extremely large size of the Earth in relation to the very modest thickness of the atmosphere leads to frequent, intentional distortions of scale in map projections. Constructing a true scale physical model of an orbiting satellite's path will lay the groundwork for insights into geographical configurations on a three-dimensional sphere, and the physical characteristics of the satellite's orbit.

Given the following information, answer the questions that follow.

If you are tracking a satellite, the following figures will be a close approximation.

	Km	Miles
Mean orbital altitude	860	534
Width of field of view	2900	1800

Orbital period….102 minutes

Determine the scale of your globe by measuring either its diameter or circumference and comparing that to the Earth's actual diameter or circumference.

The following is a series of questions to test for understanding. The answers to each question follow on an accompanying page.

Questions

1. What is the Earth's diameter? What is the diameter of the globe?
2. What is the ratio of the model diameter compared to the Earth's diameter? This is your scale measure.

Using a piece of wire (#10 works well), position the wire in such a way as to center the wire over your location on the globe. Experiment with different ways of supporting the wire slightly above the globe. With our globe, we were able to rig a support from the globe support bar already in place. The height of the globe support bar was almost the exact height as our orbital plane, which we will be discussing shortly. The globe should be able to rotate under the wire. You may want to add a piece of plastic transparency material to the wire. This will represent the width of the Earth that the satellite will image on a typical pass. Because this width is approximately 1800 miles, the scale plastic strip will be approximately 2.5" wide.

3. Just how high should we position the wire above the globe?

On a large sheet of paper, draw a circle of the same diameter as your globe.

(continued on next page)

This surface will represent the surface of the Earth. Write the scale of measure in the lower right-hand corner as a legend. Draw a circle having the same center as the first, but with a radius of 534 miles more than your first circle. This will represent the orbit of the satellite over the Earth's surface. Label point H on the inner circle (Earth's surface) as your town or city. Draw a straight line through this point. That will represent the horizon as it appears from your location.

The satellite we wish to examine can only be received while in an unobstructed straight line from the antenna; thus, it can only be received while above the horizon. The point at which we first receive a satellite's signal is known as Acquisition of Signal (AOS) and the point at which we lose the signal is referred to as Loss of Signal (LOS). A good analogy would be to think of sunrise as AOS and sunset as LOS.

On your drawing, label two points that lie directly under the points at which the satellite will come into (AOS) or go out of (LOS) receiving range.

Refer to your diagram and answer the following questions:

4. How many miles from your location are the points on Earth over which the satellite will come into or leave receiving range?
   You may wish to draw a circle on your globe to represent this range, known as the acquisition circle.

5. Knowing the period of a complete orbit, find a way to calculate the amount of time that the satellite will be in range if it passes directly overhead as you've illustrated.

Rotate the globe to position the wire so that the northbound orbit will cross the equator at 0 degrees longitude. If the Earth were not rotating, the satellite would always follow the path illustrated by the wire. Would this path ever bring the satellite over your school?

Polar orbiting weather satellites have an orbital period of about 102 minutes. This means they complete a trip around the world in approximately 1 hour and 42 minutes.

The Earth rotates 360 degrees in 24 hours.

6. How many degrees does the Earth rotate in 1 minute?
7. How many degrees does the Earth rotate in 1 hour?
8. How many degrees does the Earth rotate in 102 minutes?
9. How many orbits will the satellite complete in one day?
10. How many miles does a satellite travel during one orbit?
11. How many miles does the satellite travel during each day?
12. How many times will your location be viewed by this satellite in one day?

Answers

Question 1

The sample calculations given here are based on the use of a 12-inch diameter globe and should be proportionally adjusted for use of other materials. The diameter of a globe can be determined by first finding the circumference using a measuring tape.

	Earth	Model
Diameter	8100 miles	12 inches
Circumference	25,500 miles	37.75 inches
Path Width	1800 miles	2.5 inches
Orbit altitude	534 miles	.75 inches

Question 2

Using the circumference, a ratio can be established as follows:

$$\frac{37.75\ \text{inches}}{25{,}500\ \text{miles}} = \frac{1\ \text{inch}}{675\ \text{miles}}$$

Question 3

By the scale established above, the orbital height of 500 miles is represented by a scale distance of:

$$\frac{1\ \text{inch}}{675\ \text{miles}} = \frac{.75\ \text{inch}}{500\ \text{miles}}$$

Thus, on this model of the Earth, using a 12-inch diameter globe, the wire representing the orbital plane should be placed approximately 3/4" above the surface of the globe.

Question 4

Assume the satellite pass is directly overhead of point H (your home location). R equals the radius of our reception area (acquisition circle) and D equals the diameter of the reception area.

Having established the AOS and LOS points on the orbital curve, project lines from both the AOS and LOS points down to the center of the Earth. Label this point G (Earth's Geocenter). With these lines in place, go back and label the two points where these two lines intersect the Earth's surface. Appropriately label these points A and L. If we measure the angel formed by points AGL, we find it to be 55 degrees. This is angle D (diameter of acquisition circle). Angle R is half of angle D (R = radius of acquisition circle). Why is it important to know this angle? We are interested in knowing the size of our acquisition circle, that is, the distance from our home location (point H) that we can expect to receive the satellite signal.

We've previously determined that the circumference of the Earth is approximately 25,500 miles. Thus:

$$\frac{360 \text{ degrees}}{25{,}500 \text{ miles}} \quad x \quad \frac{55 \text{ degrees}}{3800 \text{ miles}}$$

We know that the satellite signal will be present for 55/360 of this distance. Using your calculator, 55/360 represents .1528 of the total circle. Thus, if we multiply the Earth's circumference (25,500 miles) by .1528, we can determine the distance (diameter) of our acquisition circle, which in this case is equal to 3896 miles. Half of that, or R, is 1948 miles. For a receiver in Maine, a satellite following a path as indicated on Figure A would be somewhere south of Cuba when the signal is first heard (AOS), and to the north of Hudson Bay when the signal is lost (LOS).

Question 5

Let's look at some numbers. Remember that it takes 102 minutes for a NOAA-class satellite to make one complete orbit around the Earth. We now want to determine the fractional part of the orbit, the exact time inside our acquisition circle, that the signal will be usable to us. Using the same math as before, the satellite will be available for 55/360 of one complete orbit. As previously defined, 55/360= .1528. This number times the orbital period of 102 minutes yields 15.6 minutes. This means that on an overhead pass, we expect to hear the satellites signal for approximately 15.6 minutes. Using a reliable receiver with outside antenna will in fact yield the above reception time.

Question 6

The Earth rotates 360 degrees in 1440 minutes. Thus

360/1440= .25 degrees/minute

Question 7

If the Earth rotates .25 degrees each minute, then:
.25 x 60 = 15 degrees / hour

Question 8

If the Earth rotates .25 degrees each minute, then:
.25 x 102=25.5 degrees/orbit

Question 9

The satellite will be on its 15th orbit at the end of 24 hours since it completes 14 orbits in one day and begins a 15th. More precisely:

$$\frac{1\text{ orbit}}{102\text{ minutes}} \quad x \quad \frac{1440\text{ minutes}}{1\text{ day}} = \frac{14.12\text{ orbits}}{1\text{ day}}$$

Question 10

The satellite will travel the equivalent of the circumference of each orbit, or 25,500 Earth miles. However, the circumference at orbital altitude is approximately 38,850 miles.

Question 11

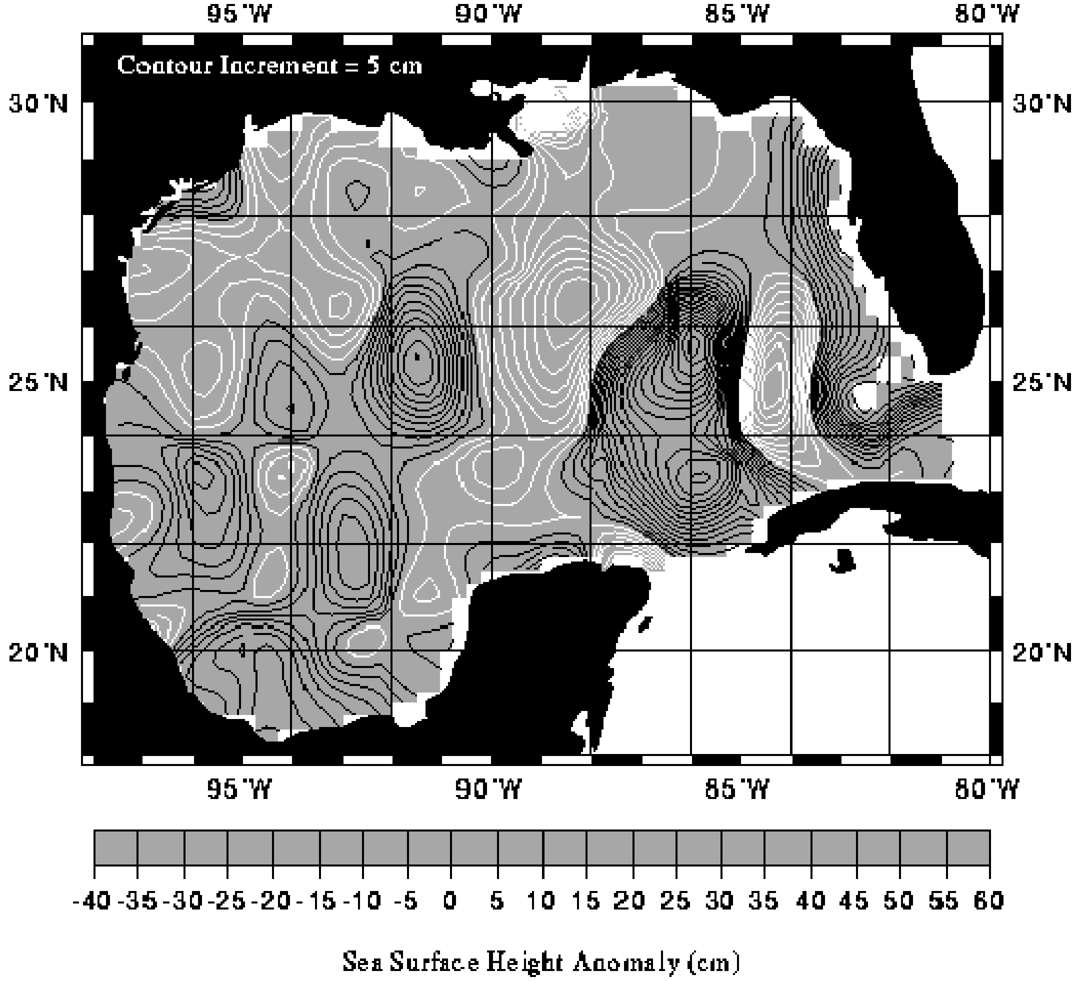
25,500 miles/orbit x 14.12=360,060 miles/day (approx.). These are miles traveled at ground level. More precisely, the circumference of the orbital circle is about 28,850 miles, thus,

28,850 miles/orbit x 14.12= 407,362 miles/day

Question 12

At least four times per day. The satellite will usually come within range on two consecutive orbits, sometimes three. Usually figure on a pass to the east of your location, nearly overhead, and then to the west. Remember that at one part of the day the satellite will be on an ascending pass (crossing the equator going north) and at another time of day the satellite will be on a descending pass (crossing the equator going south).

Gulf of Mexico Dynamic Height Anomaly
w.r.t. Corrected Rapp Mean
TOPEX Cycle 83 - Dec 15 to Dec 25, 1994



Student Information Sheet Lesson I
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