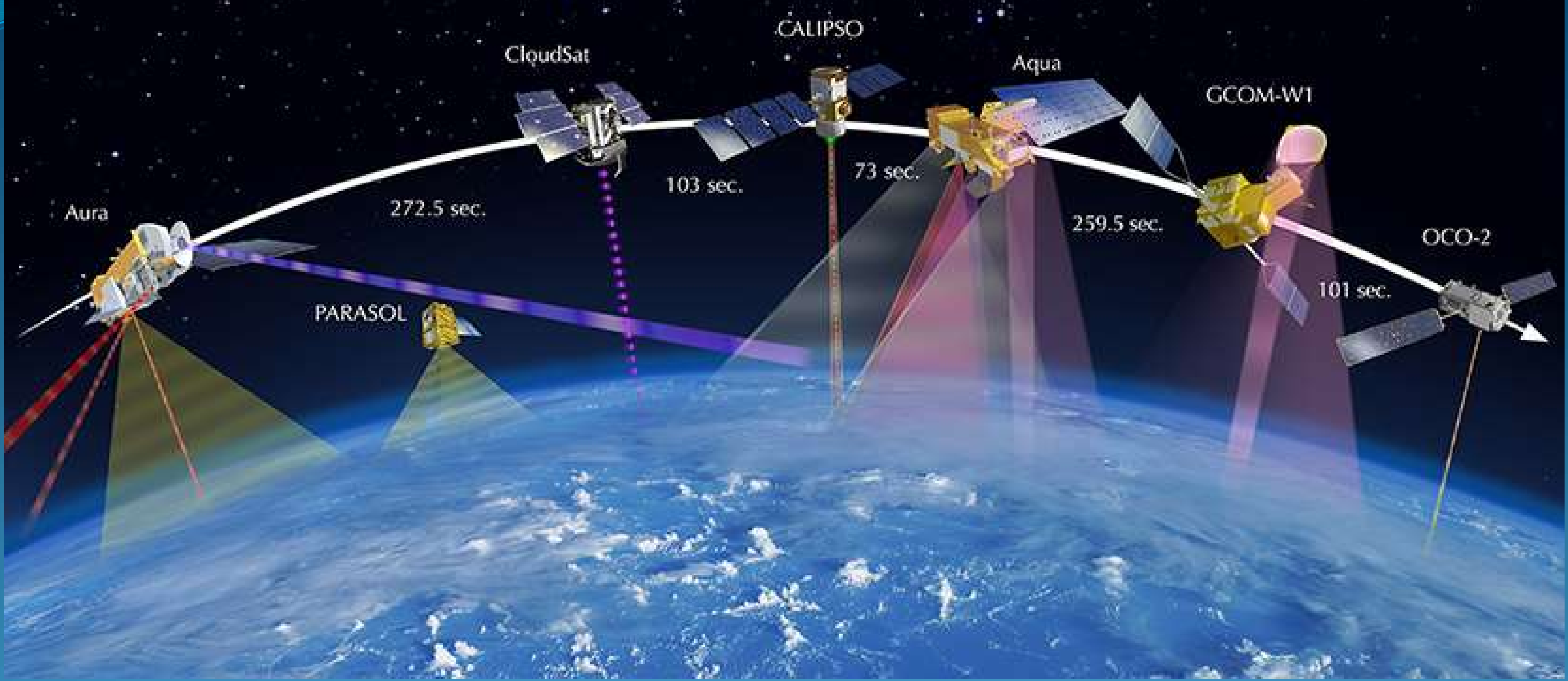
MET 611 – Satellite Data Applications



Topex/Poseidon – Sea Surface Height

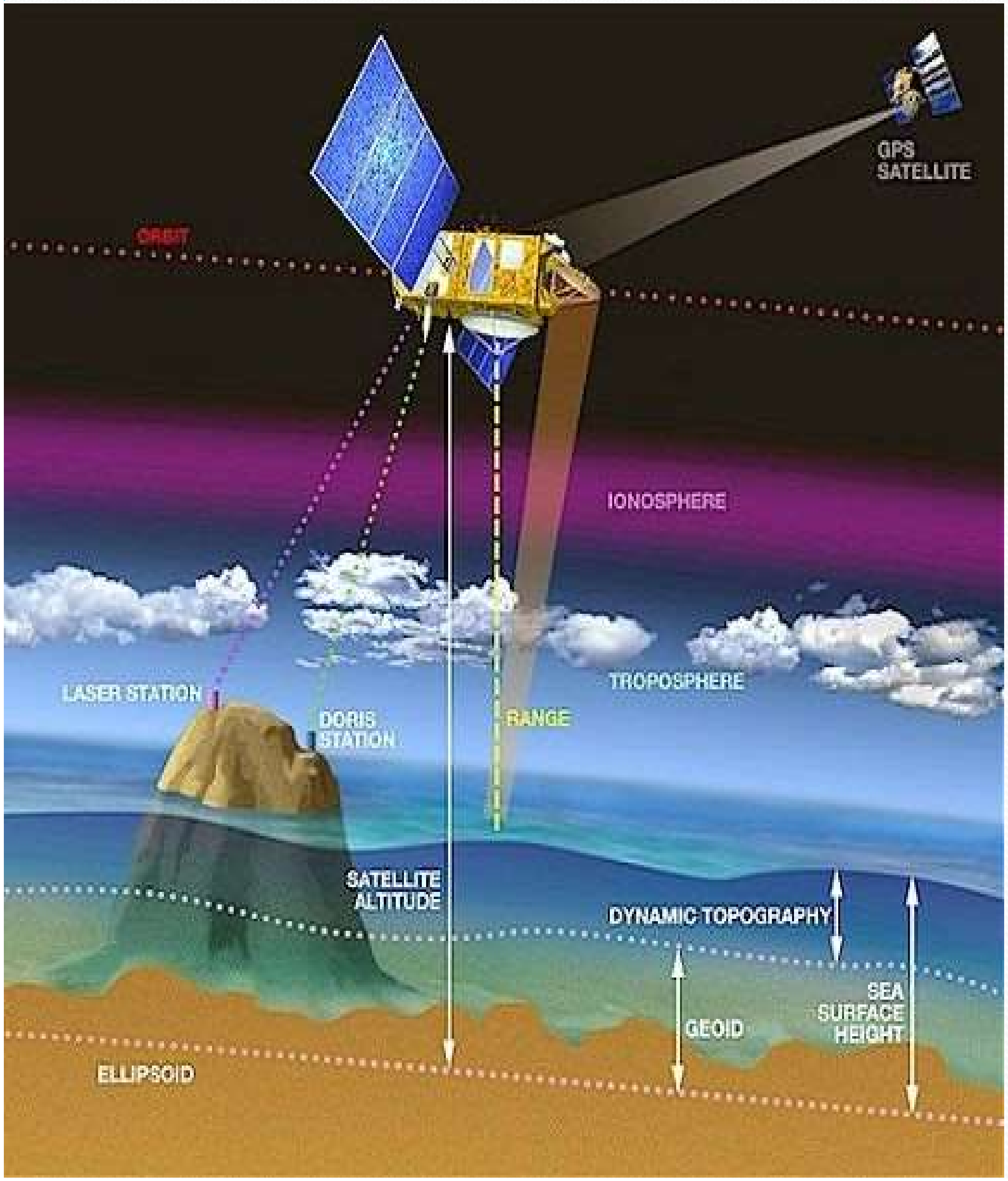
Jennifer D. S. Griswold

Lecture Outline

- Basic principles of satellite altimetry
- TOPEX/Poseidon satellite
- Sea Surface Height:
  - Geoid
  - Tides
  - Geostrophic circulation

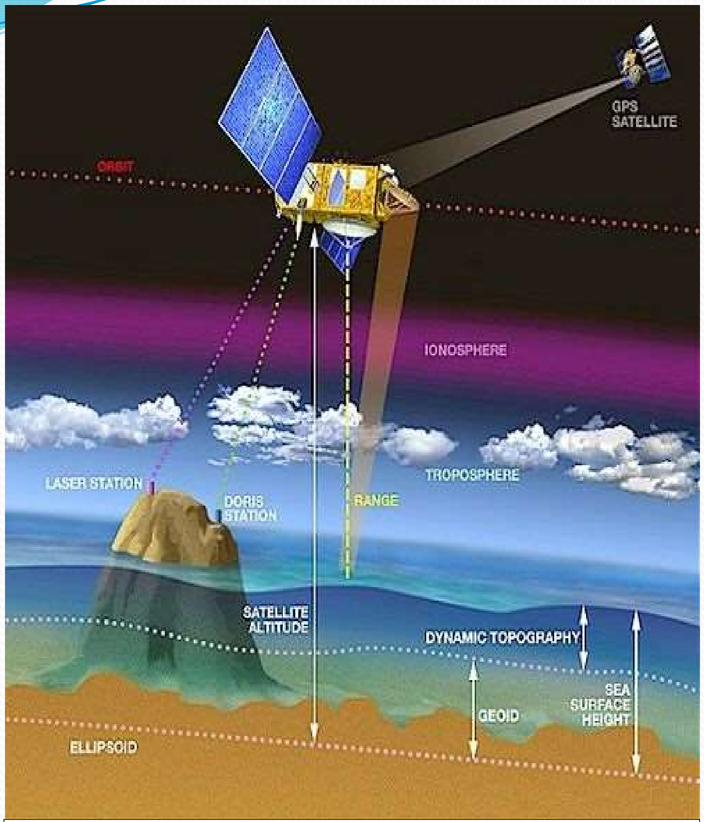
- TOPEX/Poseidon Data Access an Structure

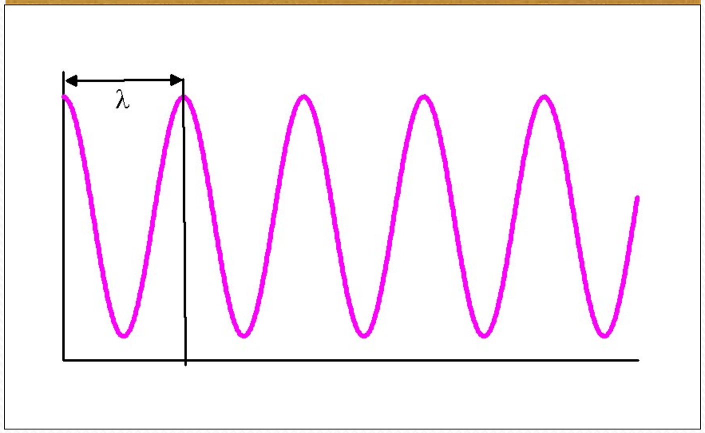
Basic Principles of Satellite Altimetry



- Radar altimeters on board the satellite permanently transmit signals at high frequency (Topex/Poseidon - over 1700 pulses per second) to Earth, and receive the echo from the sea surface.
- This is analyzed to derive a precise measurement of the round-trip time between the satellite and the sea surface.
- The time measurement, scaled by the speed of light (at which electromagnetic waves travel), yields a measurement of the satellite-to-ocean range.

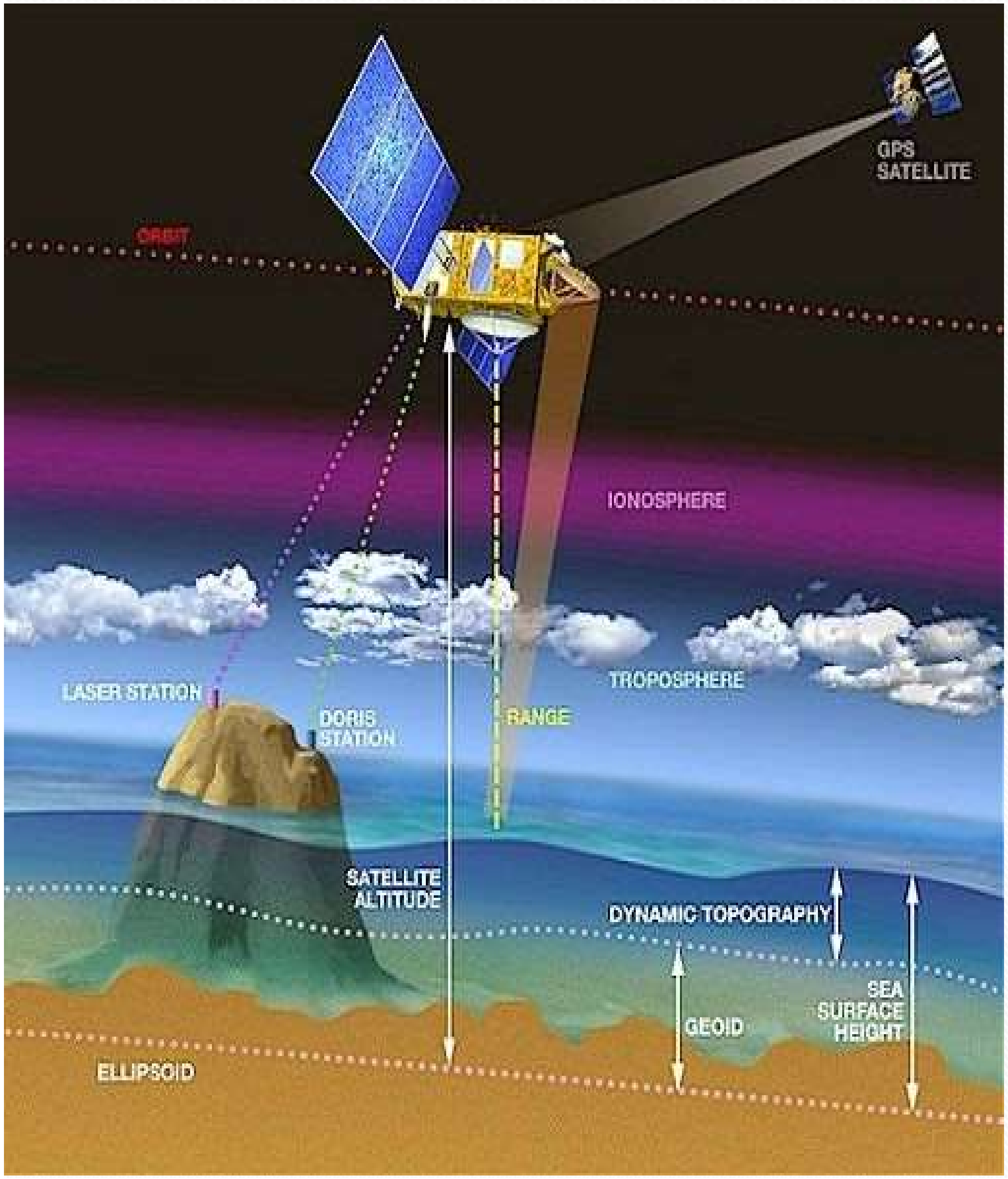
Basic Principles of Satellite Altimetry





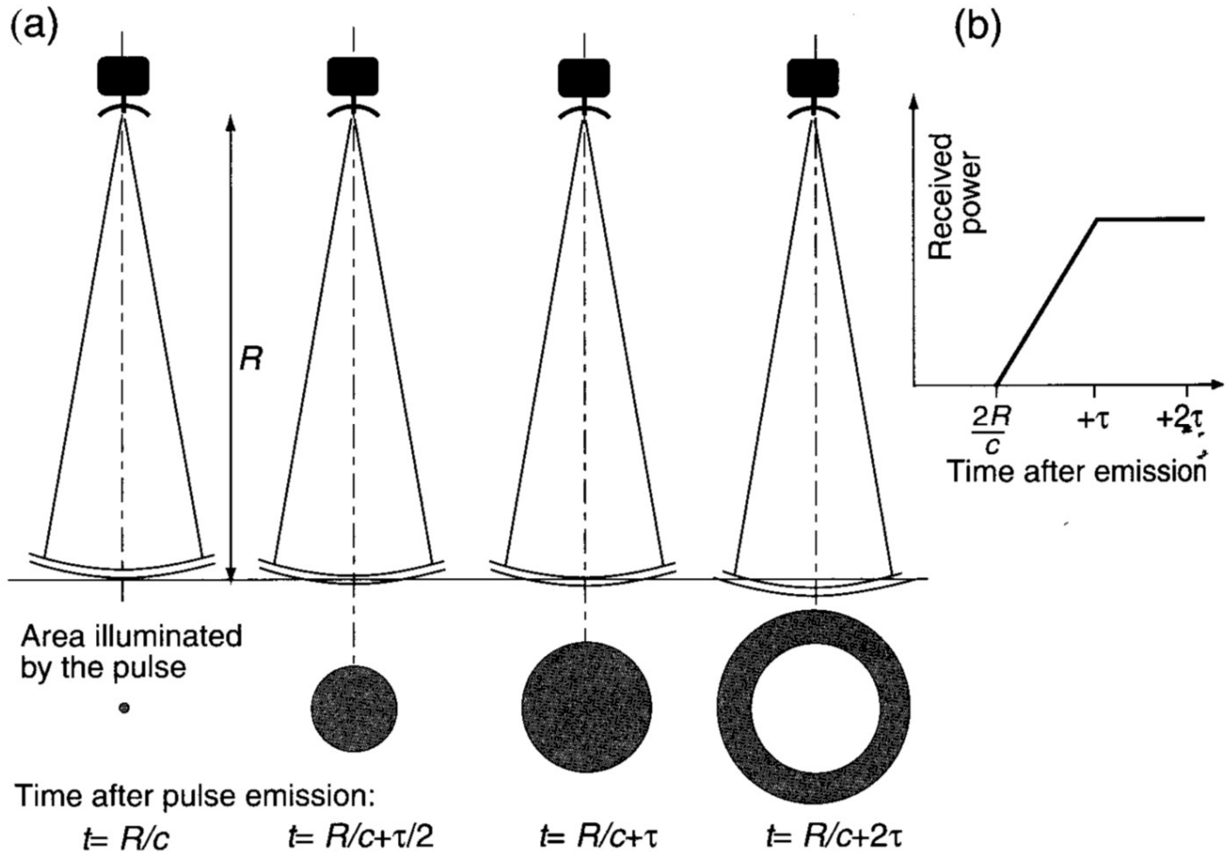
- Each signal pulse produced by a radar altimeter consists of **coherent electromagnetic energy**.
- Receiving the echo signal, the sensor measures not only the **amplitude** but also the phase of the reflected signal and the **travel time of the pulse**.
- Measuring the phase of the signal reflected from the earth surface enables measuring the travel time with very high accuracy.

Basic Principles of Satellite Altimetry



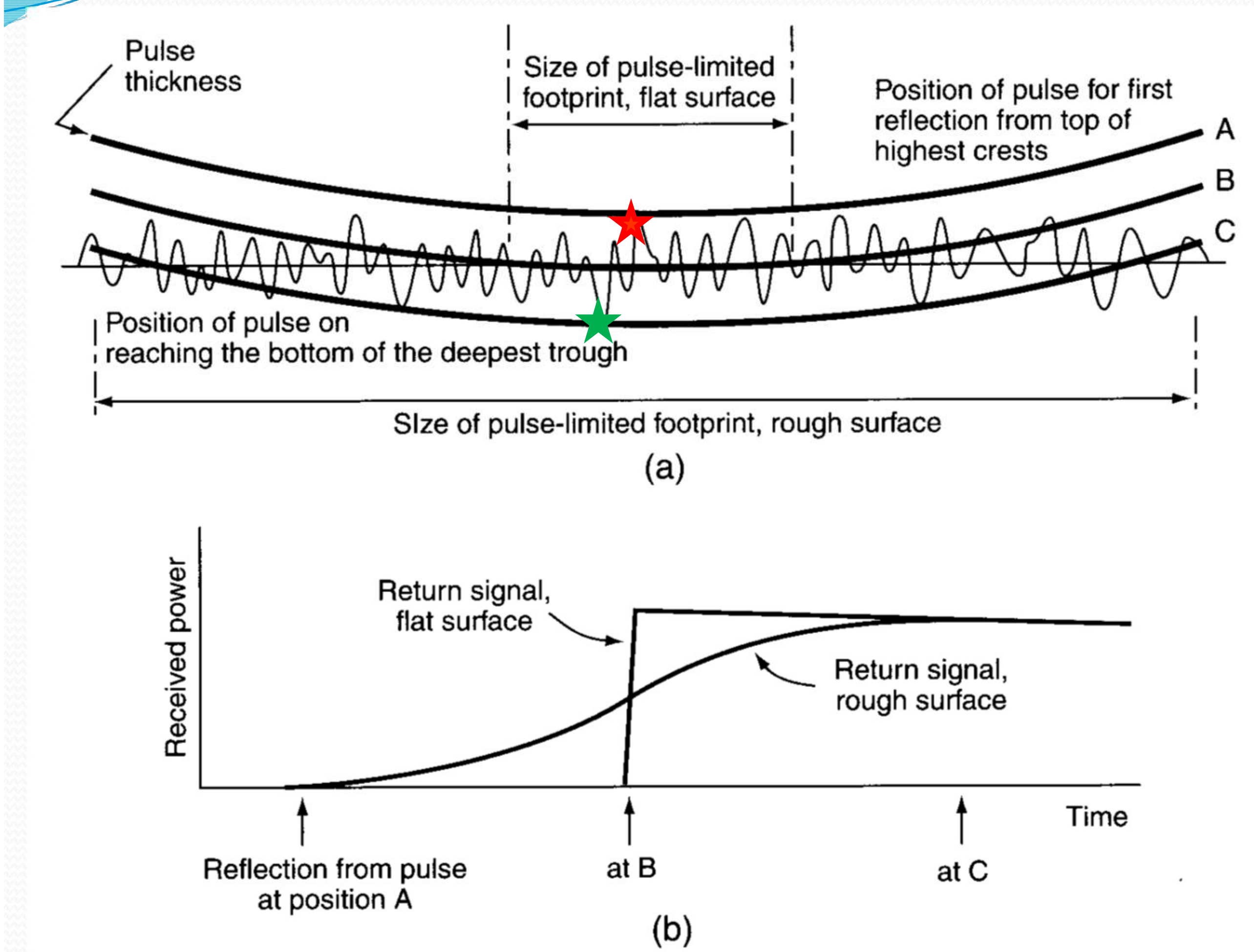
- As electromagnetic waves travel through the atmosphere, they can be **decelerated by water vapor or by ionization**.
- Once these phenomena are corrected for, the final **range "R" is estimated within 2 cm**.
- The ultimate aim is to measure the **sea level**.
- This requires independent measurements of the **satellite orbital trajectory**:
  - exact latitude
  - exact longitude
  - exact altitude coordinates.

Basic Principles of Satellite Altimetry



- Interaction of the pulse of duration τ with a **smooth sea surface**.
- For an altimeter in a 1000-km orbit a pulse duration of about **3 ns** would lead to a **footprint of diameter 2.8 km**.

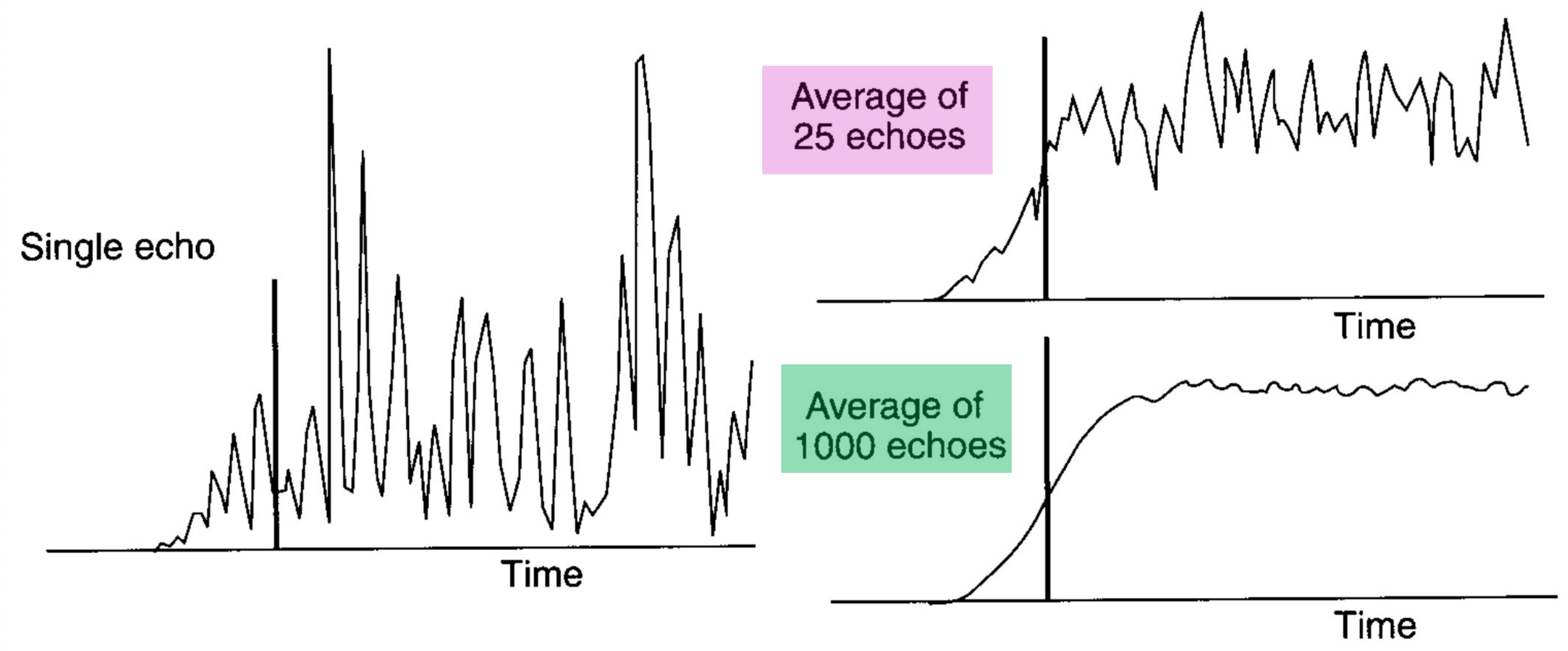
Basic Principles of Satellite Altimetry



- In practice sea surface is **rough** rather than flat.
- As a result, the first reflection of energy commences when the leading edge of the pulse reaches the **topmost crests of the waves**, earlier than for the flat surface
- The reflected energy does not achieve its maximum until the **trailing edge reaches the lowest wave trough**.

- In this way, the altimeter is able to **average out the effect of the ocean waves**. This parameter is called a **Significant Wave Height (SWH)**

Basic Principles of Satellite Altimetry

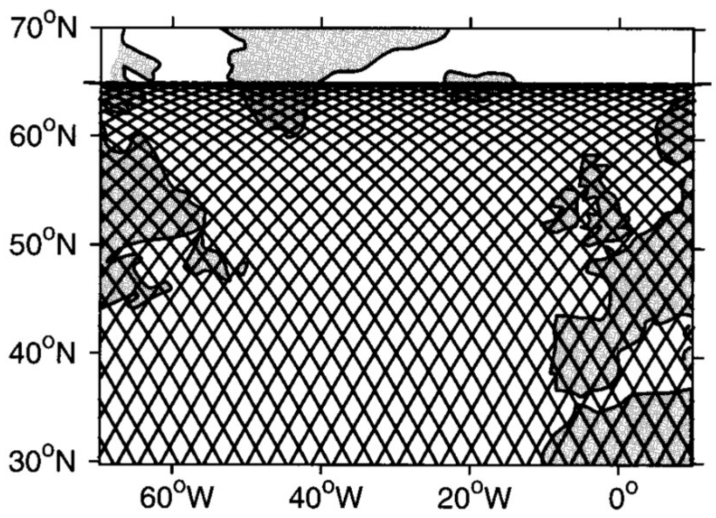


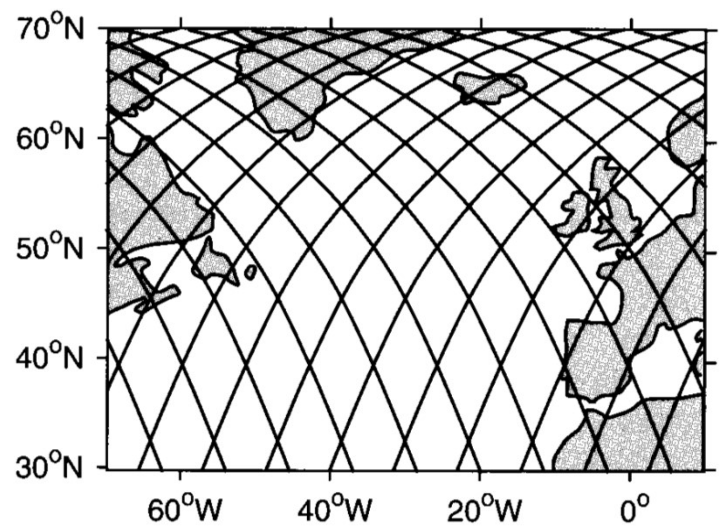
- As a result of random distribution of the ocean wave facets at any instant, **each individual return signal is very noisy!**
- but **averaging many successive pulses can reduce this**.

Basic Principles of Satellite Altimetry

- Of all sensors carried on satellites, the altimeter is most dependent upon its orbit to be capable of successful **calibration** and **interpretation**.

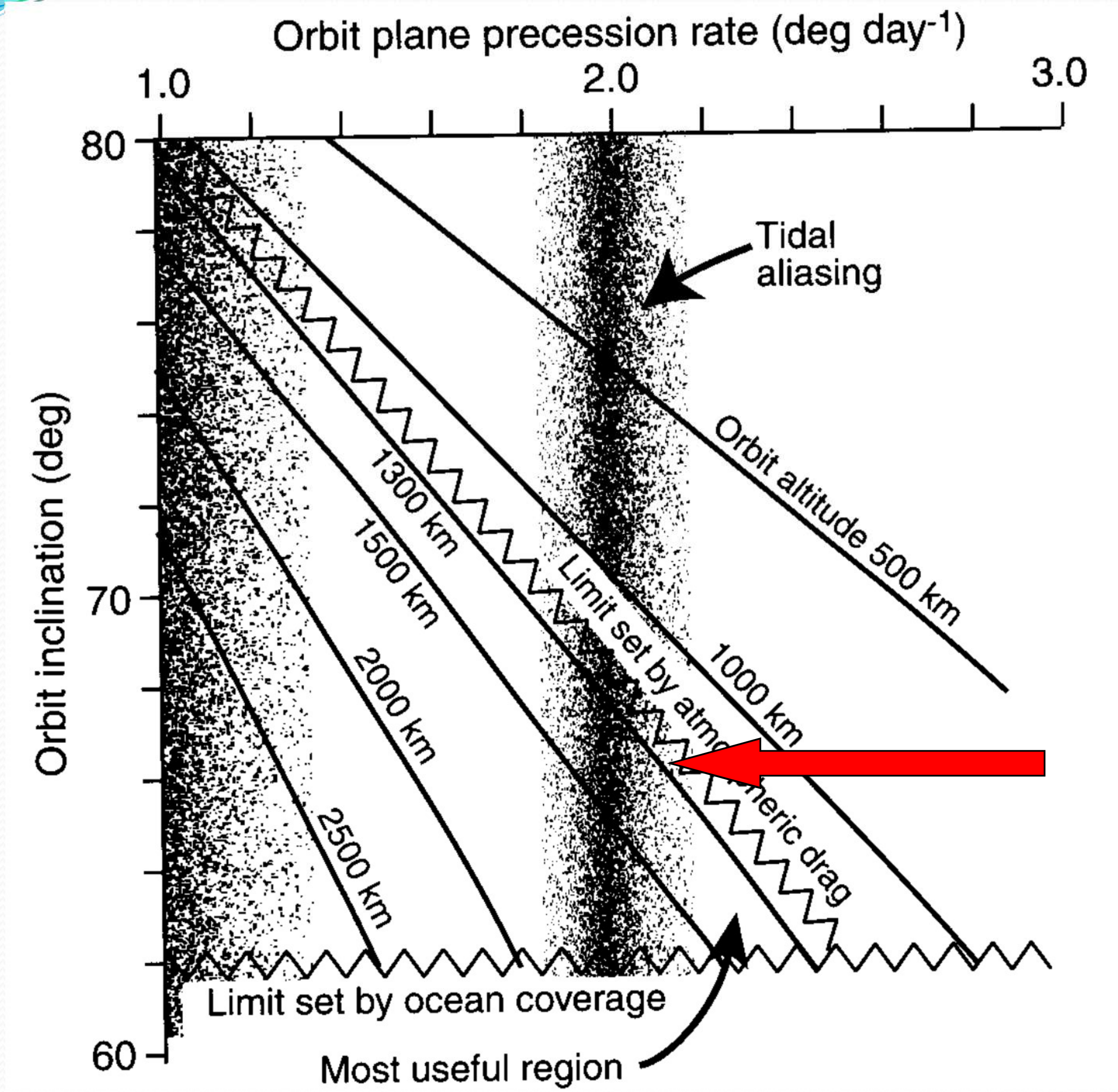
- An altitude over **1300 km** is advised, because:
  - the **atmospheric drag** there is an **order of magnitude less** than at 800 km
  - **ground stations** can much better track the satellite
  - the **satellite orbit error** resulting from irregularities of the Earth gravitation field at a high orbit is less than at a lower one.





- **Different inclination results in different repeat cycles and track separation:**
  - Topex/Poseidon (10 days/316 km at equator)
  - Seasat (3 days/800 km).

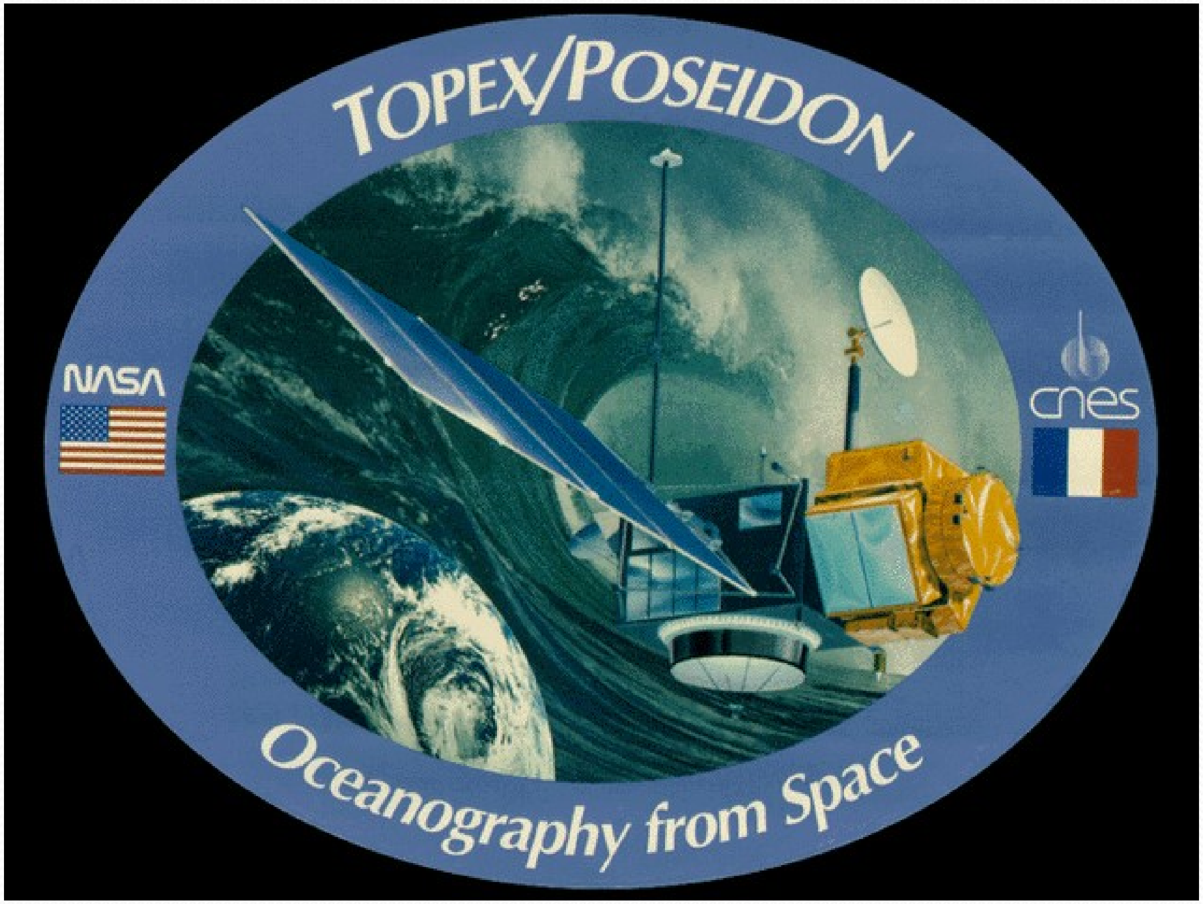
Basic Principles of satellite Altimetry



- Selecting a proper inclination, we should take into account that the precession of satellite orbit should not coincide with the harmonics of tidal cycle.

- As a result, **Topex / Poseidon** and Jason-1 satellites have **altitude 1300 km and inclination 66º.**

TOPEX/Poseidon Satellite



- **TOPEX/Poseidon** is a result of cooperation between the **NASA** and the **CNES** (France's space agency, the **Centre National d'Etudes Spatiales**)

TOPEX/Poseidon Satellite

- TOPEX/Poseidon is based on three earlier earth-orbiting satellite missions.

  1. **GEOS-3** was launched in 1975. Its altimetric system measured sea level with a precision of approximately 20 centimeters and an accuracy of better than 50 centimeters.

  2. **SEASAT** was launched in 1978. It measured the sea level with a precision of 10 centimeters at an accuracy of better than 30 centimeters. Unfortunately, the mission ended prematurely after about 100 days of operation.

  3. **GEOSAT** was launched in 1985. Its accuracy and precision were comparable to SEASAT. The mission lasted for approximately 4 years.

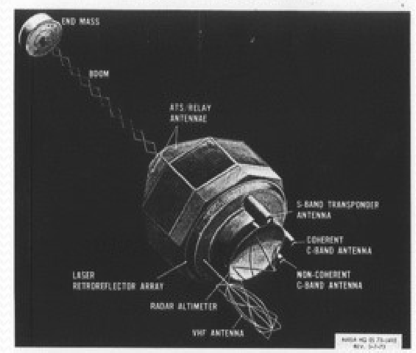
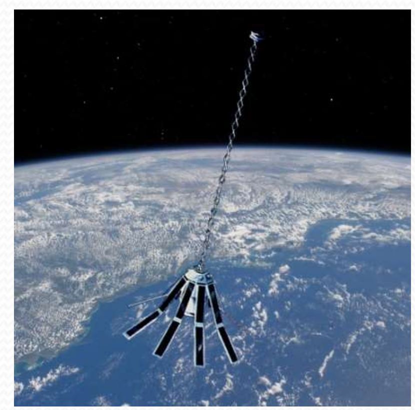
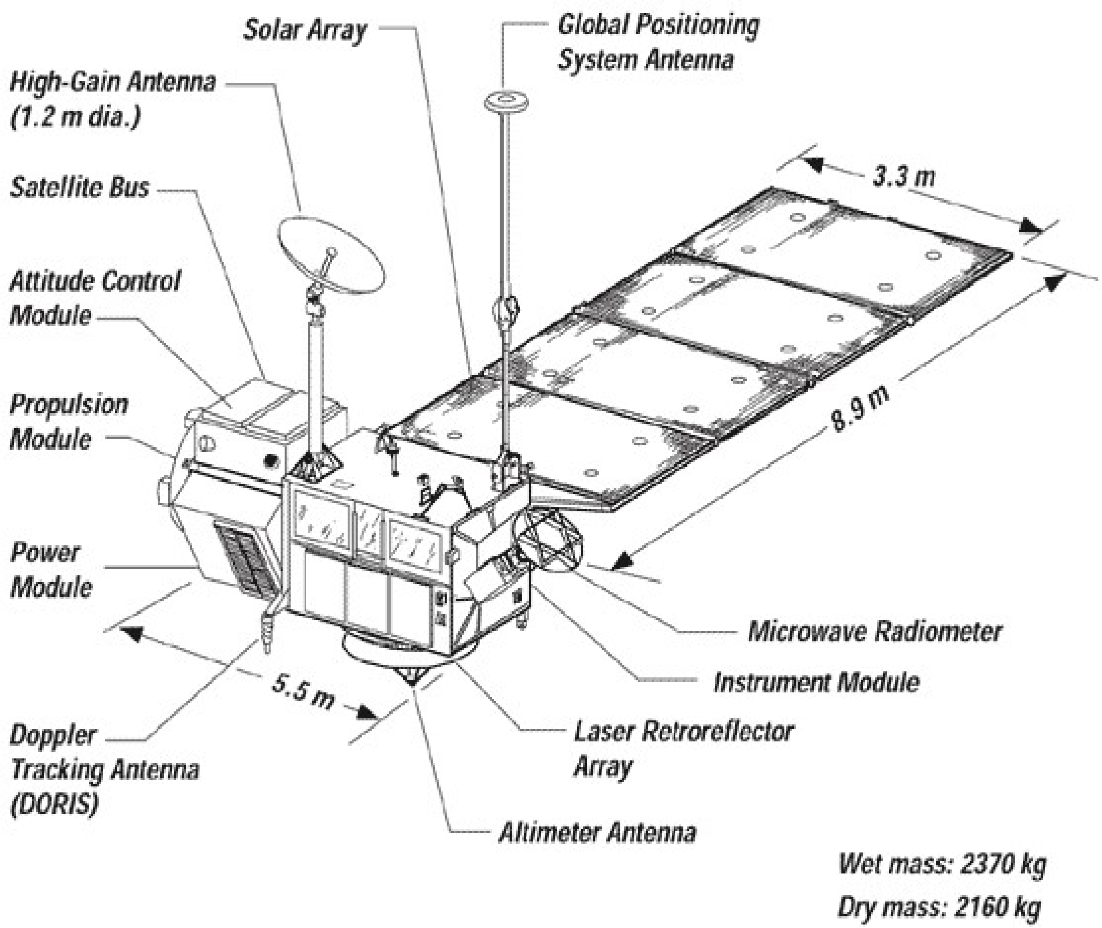


Fig. 1. Artist concept of Geos 3 spacecraft.



TOPEX/Poseidon Satellite



- In 1979, NASA's Jet Propulsion Laboratory began planning **TOPEX**
  - Ocean **Top**ography **Ex**periment that would use a satellite altimeter to measure the surface of the world's oceans.
- At the same time the French space agency **CNES** was designing an oceanographic mission called **Poseidon**, named for the Greek god of the sea.
- The two space agencies decided on a cooperative effort and pooled their resources to form a single mission.

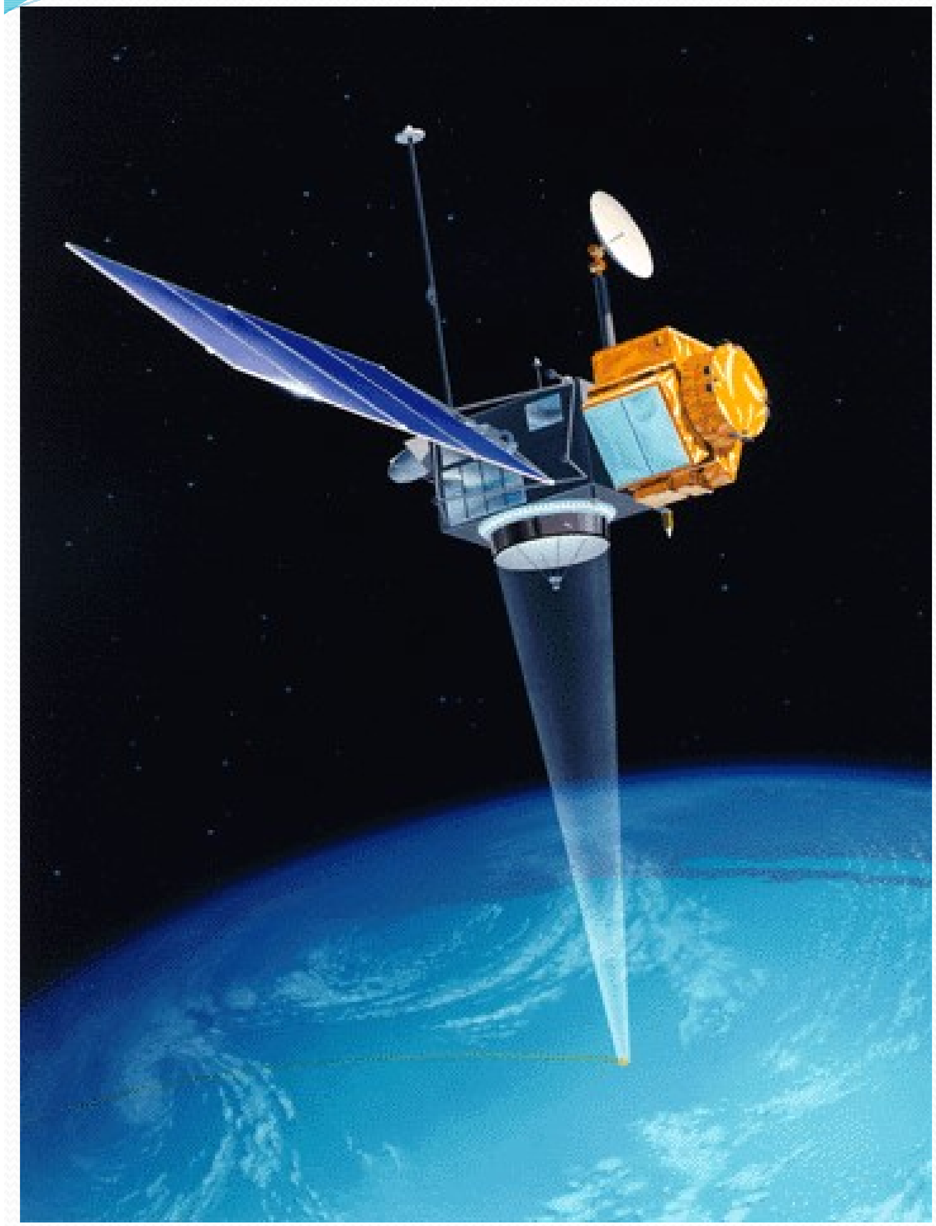
TOPEX/Podeidon Launch

- The **Ariane 42P** carrying the **TOPEX/Poseidon** spacecraft was launched from the European Space Agency's Guiana Space Center in Kourou, French Guiana, on **August 10, 1992**.
- Mass (kilograms) with dry/full tanks: 2169.4 / 2388.4
- Dimensions (meters): length: 5.5 /span: 11.5 / height: 6.6
- Solar Array: size: 29.4 sq. meters; power output (watts): 3385 (at start); 2100 (at 5 years)

Data Storage:

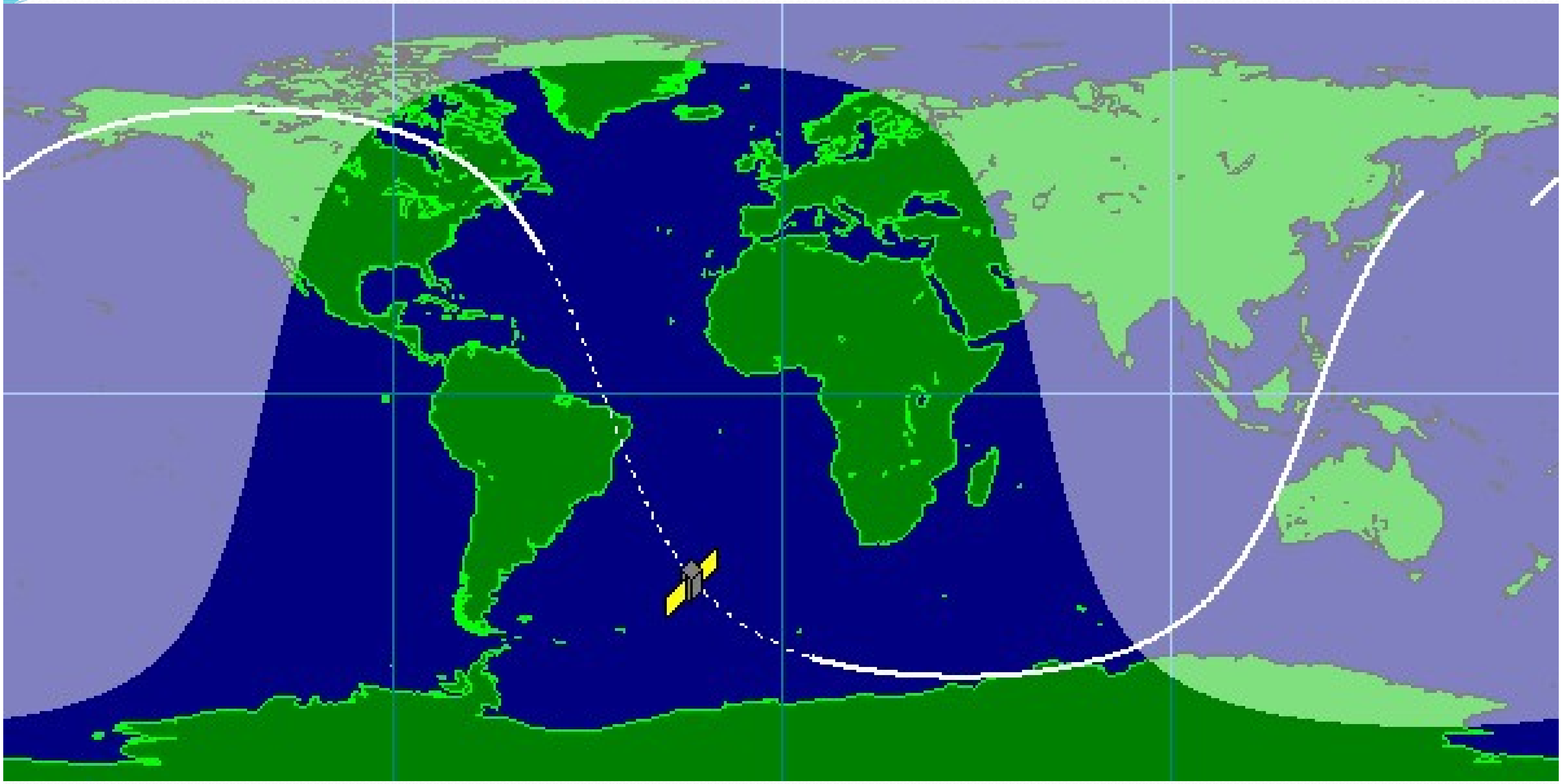
type: 3 tape recorders, 500 Mb each; record rate: 16 kb/s

TOPEX/Poseidon Orbit



- 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 kilometers** above the earth
  - inclination of **66 degrees**
- In approximately **10 days** TOPEX/Poseidon completes **127 orbits**.

TOPEX/Poseidon Satellite Cycle

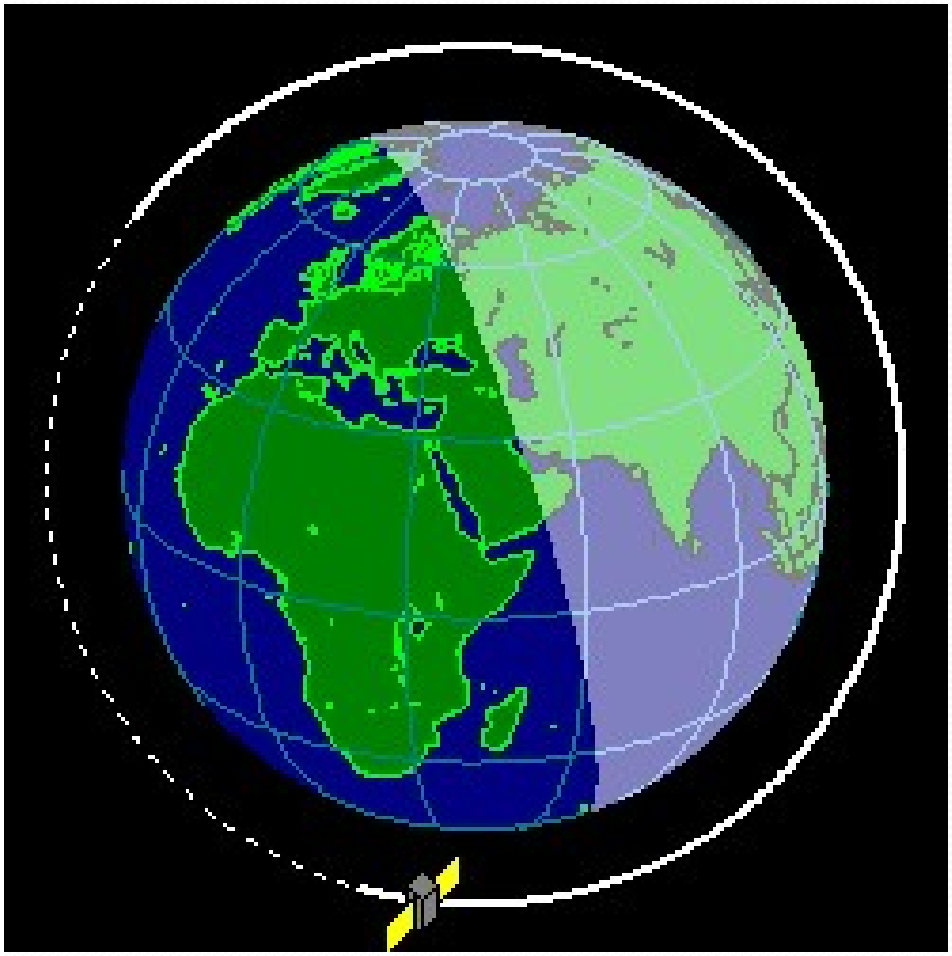


- The satellite cycles consist of 127 orbits each. The 128th orbit repeats the 1st one, etc.

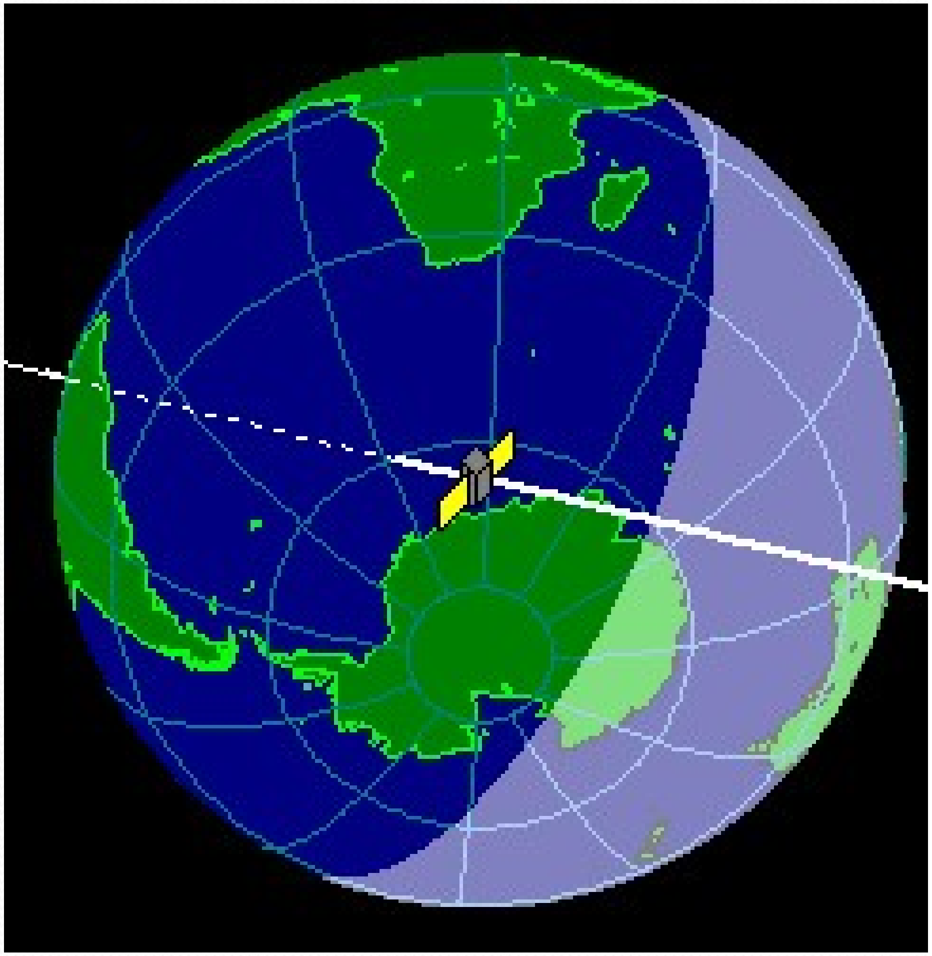
TOPEX/Poseidon Accuracy

- At the time TOPEX/Poseidon carried improved instrumentation and has the **most accurate precision orbit determination** of any earth-orbiting satellite.
- Its altimeter has a measurement **precision of approximately 2.5 centimeters**.
- After correction the resulting sea level observations are accurate to **5 centimeters**.

TOPEX/Poseidon Orbit Views

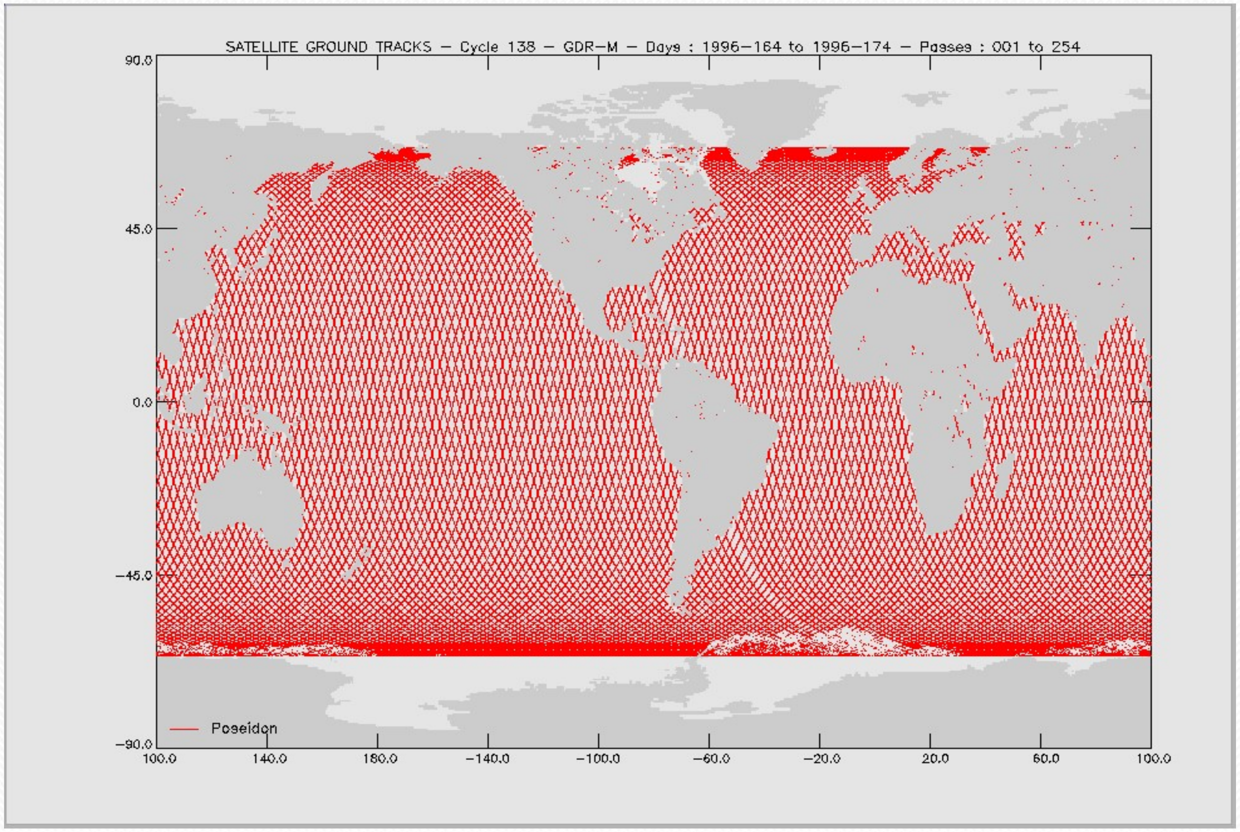


View from above orbital plane



View from above satellite

TOPEX/Poseidon Satellite Cycles



Repeat period

= 9.9156249999999977 DAYS

= 856710 seconds

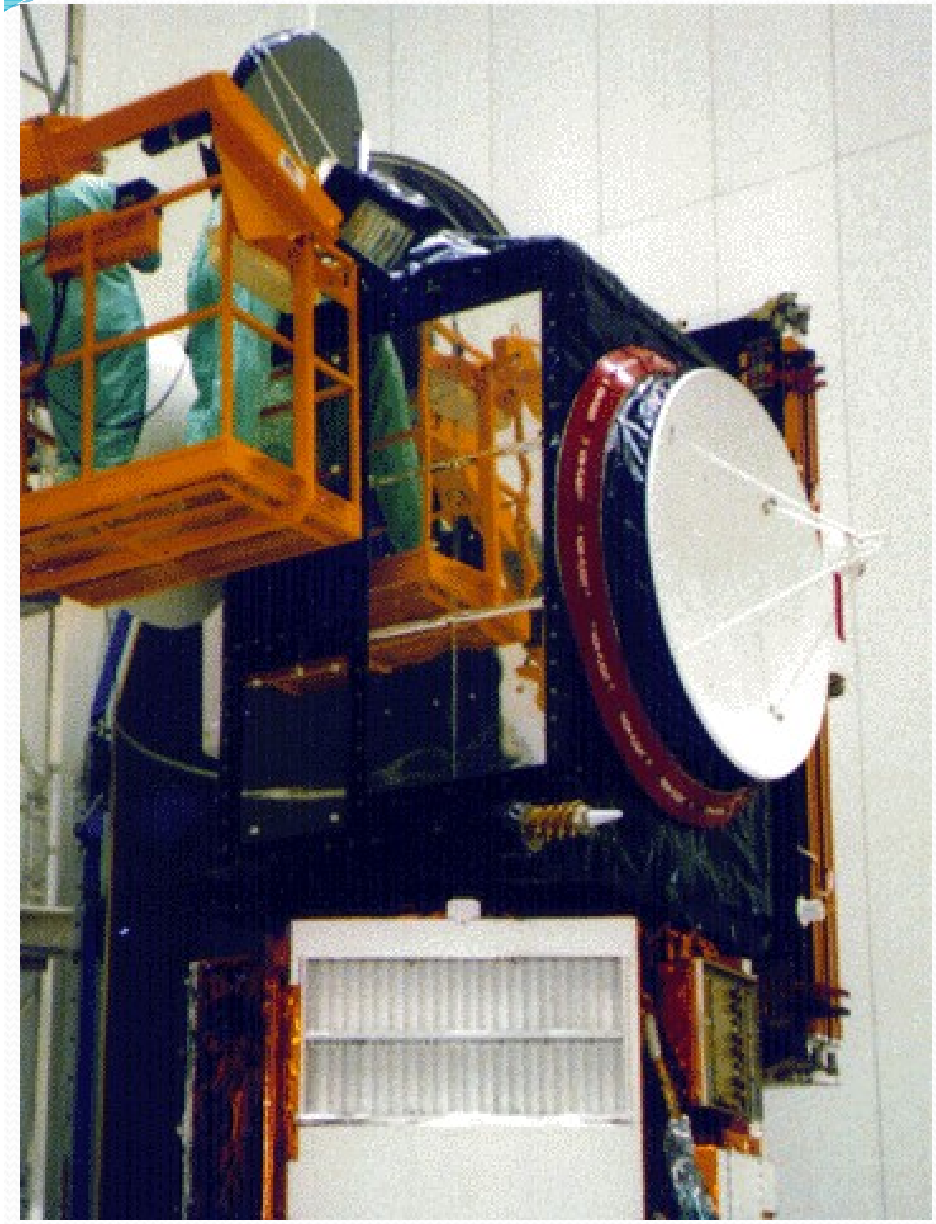
CYCLE 1 267 48888.1516204 WED 1992-SEP-23 3:38

CYCLE 2 277 48898.0672454 SAT 1992-OCT- 3 1:36

CYCLE 3 286 48907.9828704 MON 1992-OCT-12 23:35

CYCLE 4 296 48917.8984954 THU 1992-OCT-22 21:33, etc.

TOPEX/Poseidon Satellite

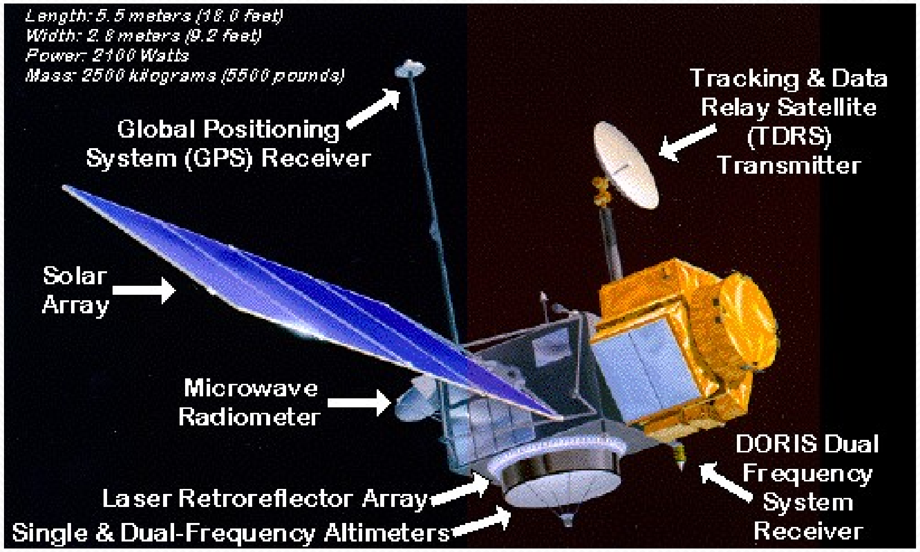


- TOPEX/Poseidon's primary instrument for measuring **ocean topography** is an **altimeter,** measuring the distance between the satellite and the ocean surface.
- Air, water vapor, clouds, and rain **slow down** the return of the **microwave signal**.
- A second instrument, a **radiometer,** is used to correct for the influence of water in the atmosphere.

TOPEX/Poseidon Satellite Info

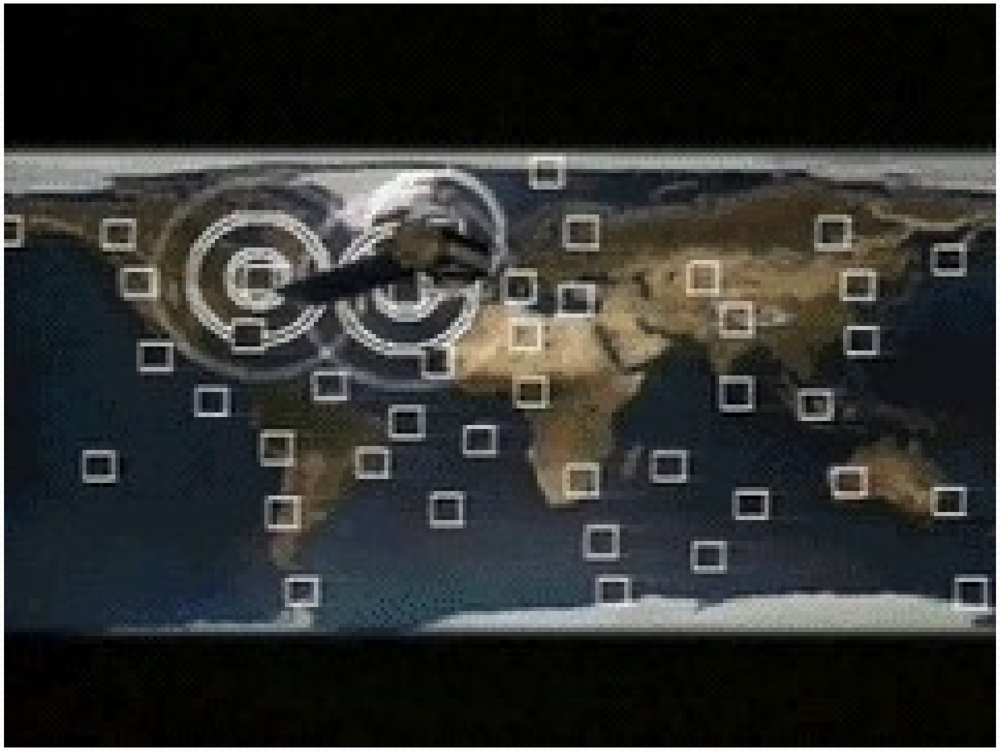
- TOPEX/Poseidon carries **two radar-altimeters**:

- 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 the ground, scientists can calculate the height of the sea surface.



- The **single-frequency CNES altimeter** is classified as an experimental sensor because TOPEX/Poseidon is the first flight to utilize this technology.
  - The CNES altimeter is a low-power, low-mass sensor which works in much the same way as the NASA altimeter. Its precision is also comparable with that of the NASA altimeter.

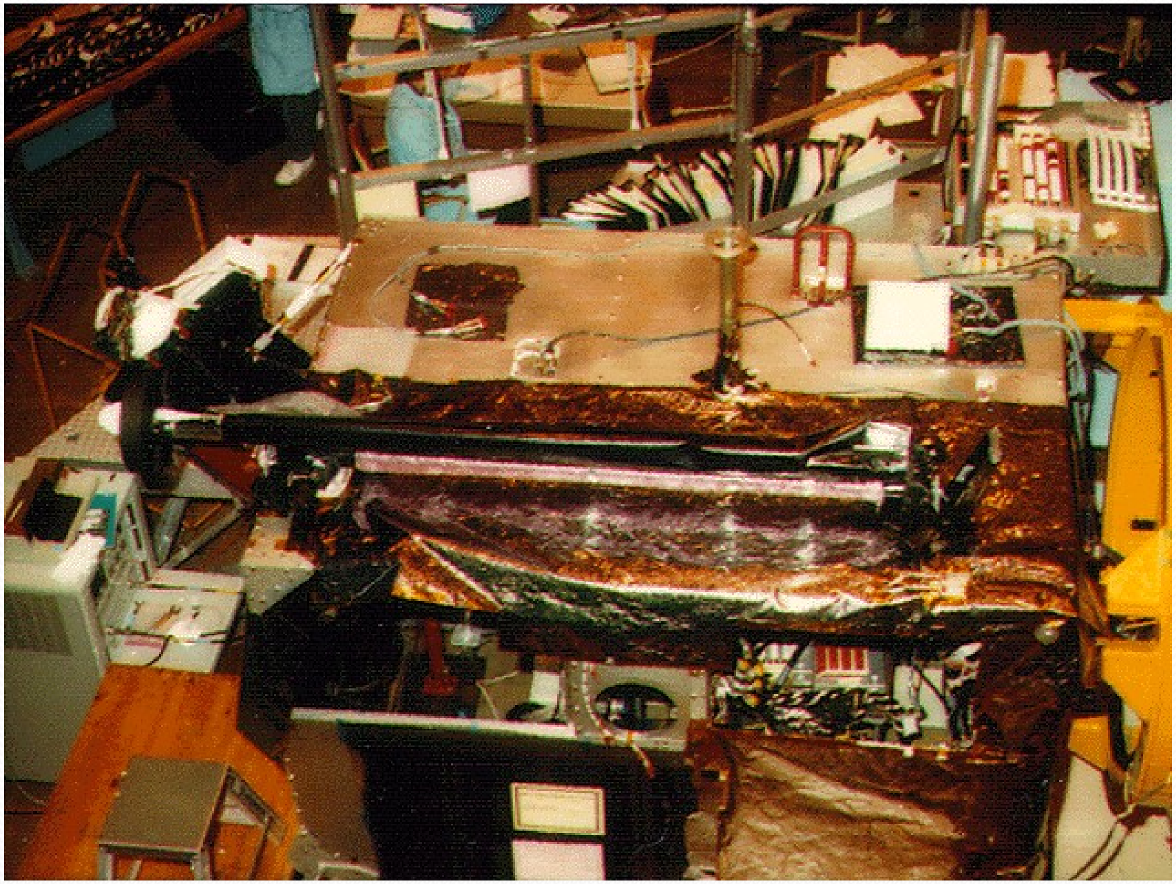
TOPEX/Poseidon Satellite



- The altimeter measurement obtained by TOPEX/Poseidon would **not be very useful** if the satellite's position in space were not well known.
- **Different systems measure** the position of TOPEX/Poseidon in space.

- Data from the **SLR (Satellite Laser Ranging)** and **DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite)** systems are used to **determine the orbit** of TOPEX/Poseidon.
  - Together these systems provide all-weather, global tracking of the satellite. There are however, some limitations in land-based systems.

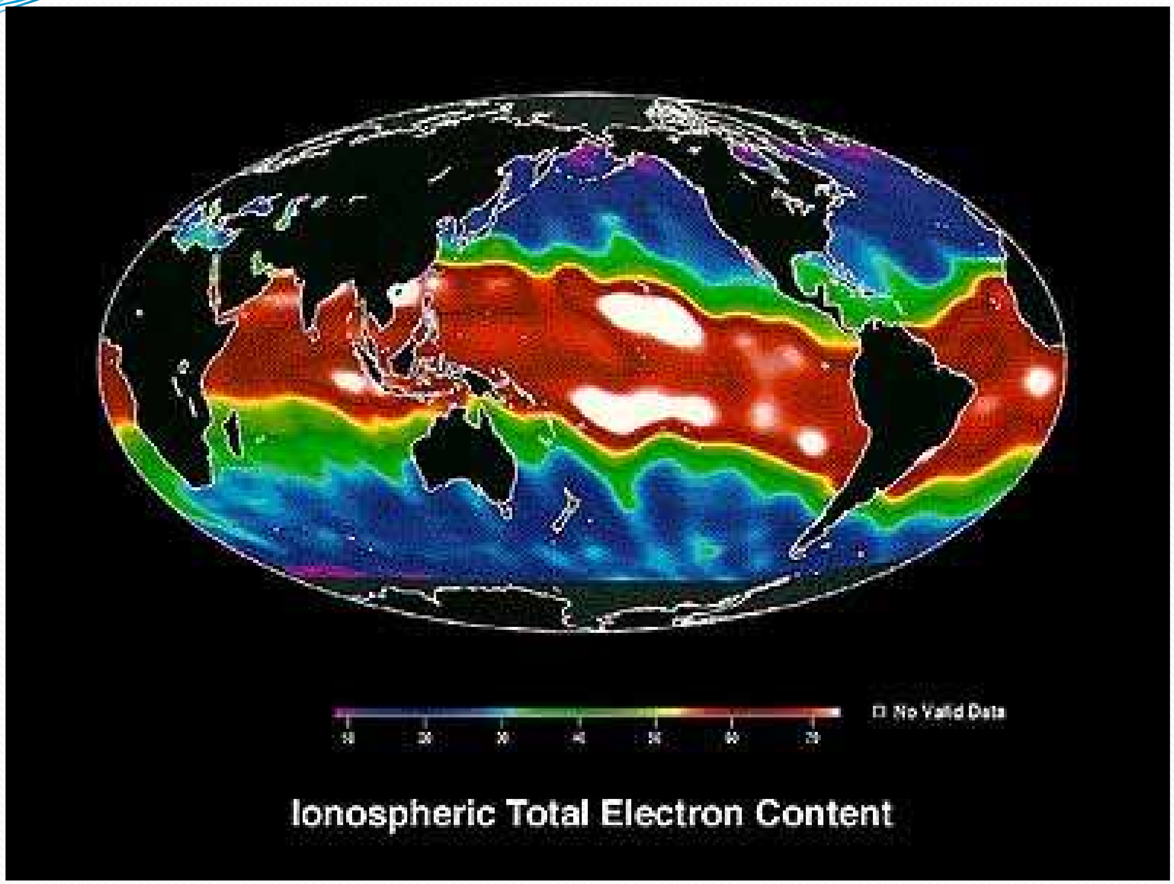
TOPEX/Poseidon Satellite



- To develop more accurate and less expensive methods of calculating orbits, the project installed a **Global Positioning System or GPS receiver** on the spacecraft as a flight experiment.

- The experiment proved a great success. During testing the GPS receiver simultaneously tracked signals from as many as 8 of the 21 GPS satellites that orbit the earth and provided the spacecraft's **radial position with an accuracy of better than 3 centimeters**.

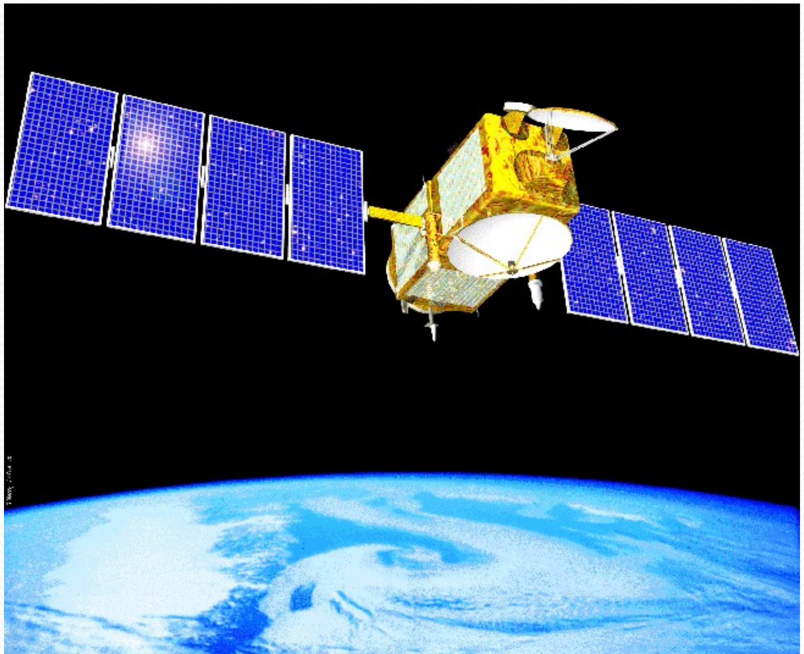
TOPEX/Poseidon Satellite



- **Free electrons** are present in the earth's ionosphere.
- As with water vapor, **these electrons delay the return of the radar pulse from the altimeter** and thus interfere with the accuracy of sea-level measurements.

- To **correct for this delay** the altimeter takes **measurements at two radio frequencies**.
  - The difference between the two measurements provides both **a measure of the electron content and a correction for the range delay**.

TOPEX/Poseidon Satellite



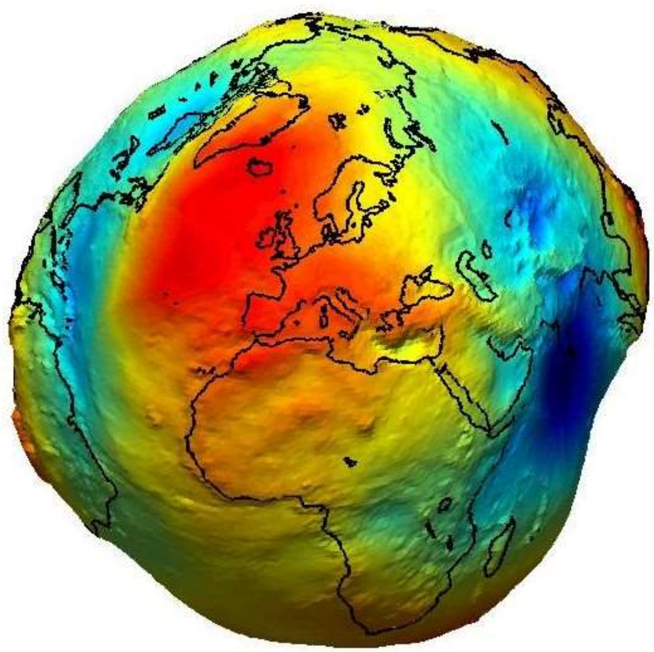
- In addition to TOPEX/Poseidon satellite, in **December 7 2001 Jason-1**, another satellite with radar-altimeter, was launched.

- Jason-1 is much smaller that TOPEX/Poseidon (weight 500 kg vs. 2400).

- **All other characteristics** of Jason-1 are similar to TOPEX/Poseidon.

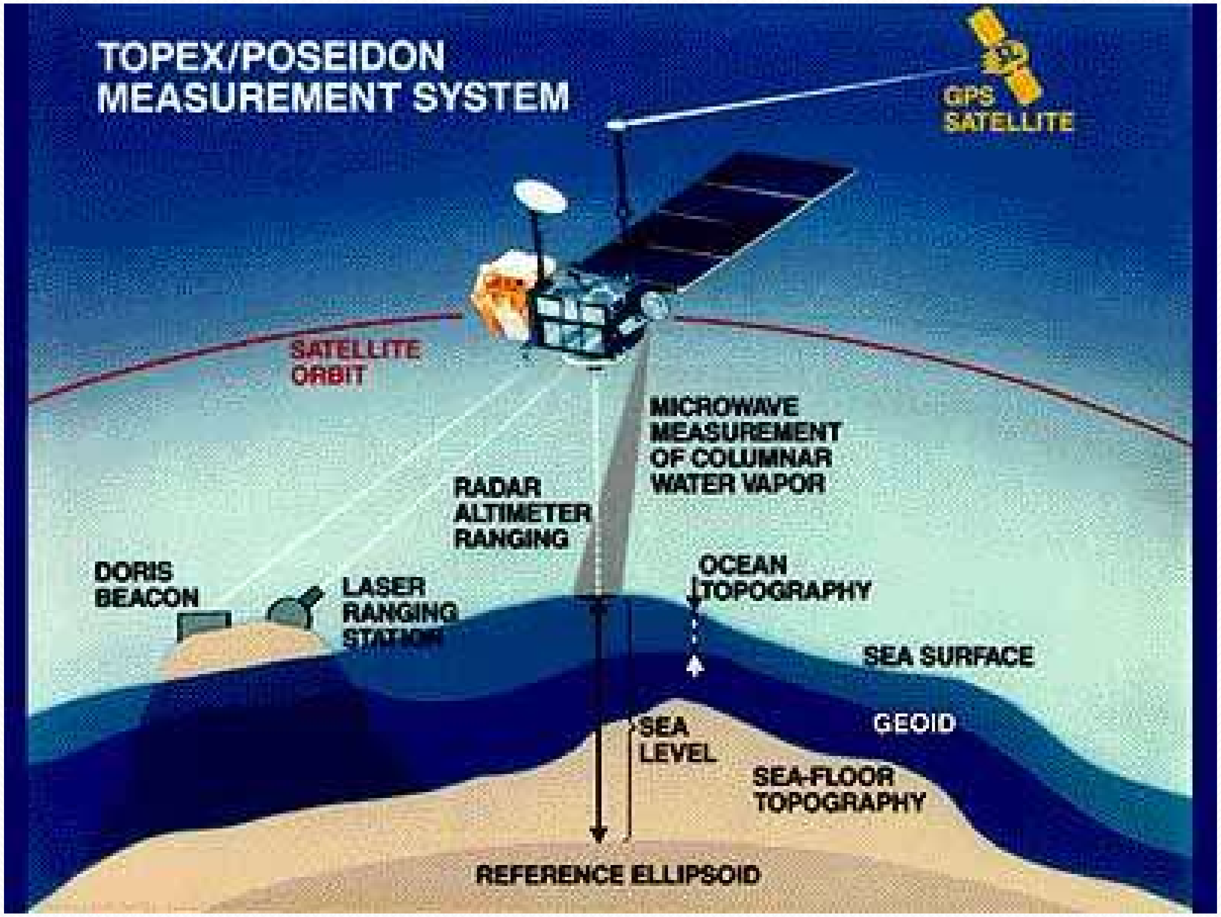
Sea Surface Height Determination

- **Sea Surface Height**, i.e., the distance between the satellite and the ocean surface, depends on five principle factors:
  1. Geoid
  2. Ocean Tides
  3. Atmospheric pressure
  4. Geostrophic circulation
  5. Ocean Waves



The **geoid** is the shape that the surface of the oceans would take **under the influence of Earth's gravitation and rotation alone**, in the absence of other influences such as winds and tides. This surface is extended through the continents (such as with very narrow hypothetical canals).

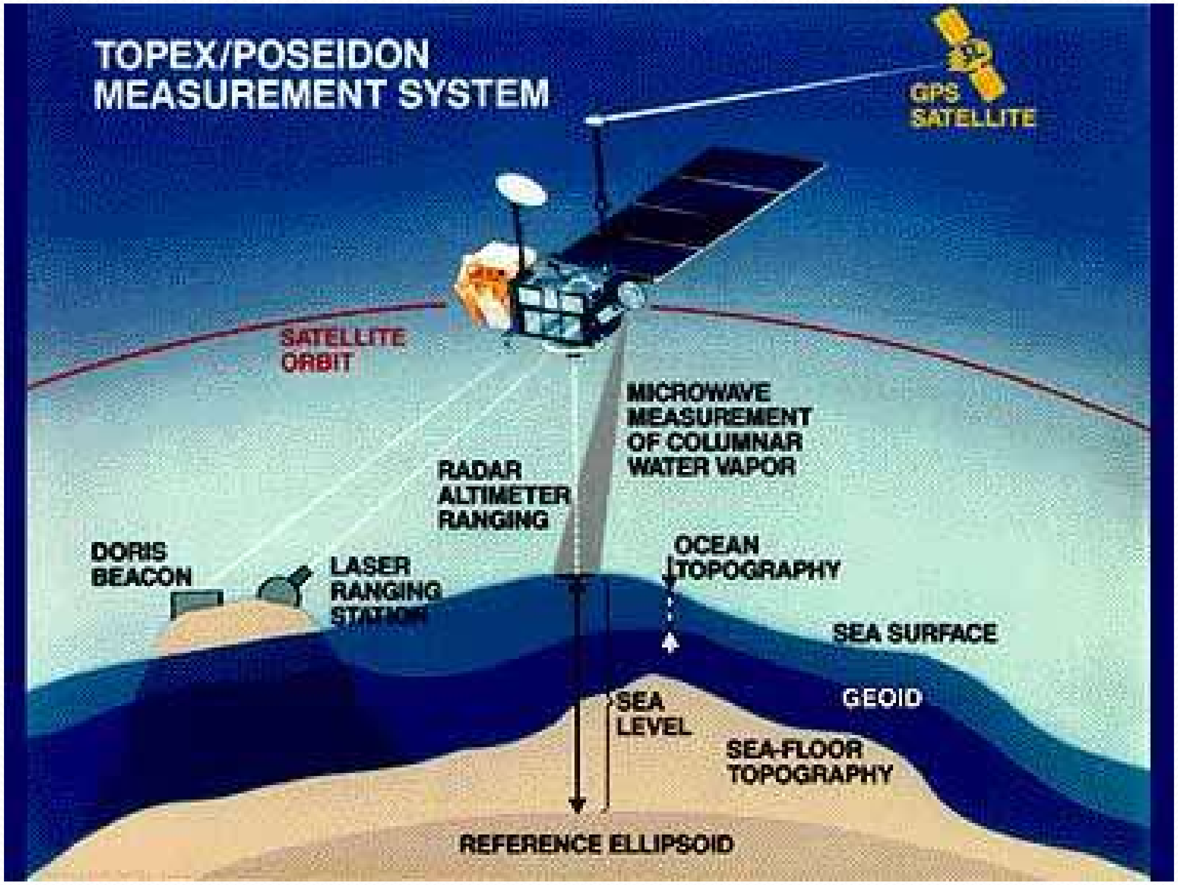
Sea Surface Height: Geoid



- We describe the Earth as an ellipsoid
  - however, in practice it is not an ellipsoid and the **distribution of the mass within the Earth is not uniform**.
  - The resulting **gravitation field of the Earth** is also **<u>not uniform</u>**.

- These **subtle variations of the gravitation field** influence both the **ocean surface** and the **satellite orbit**.

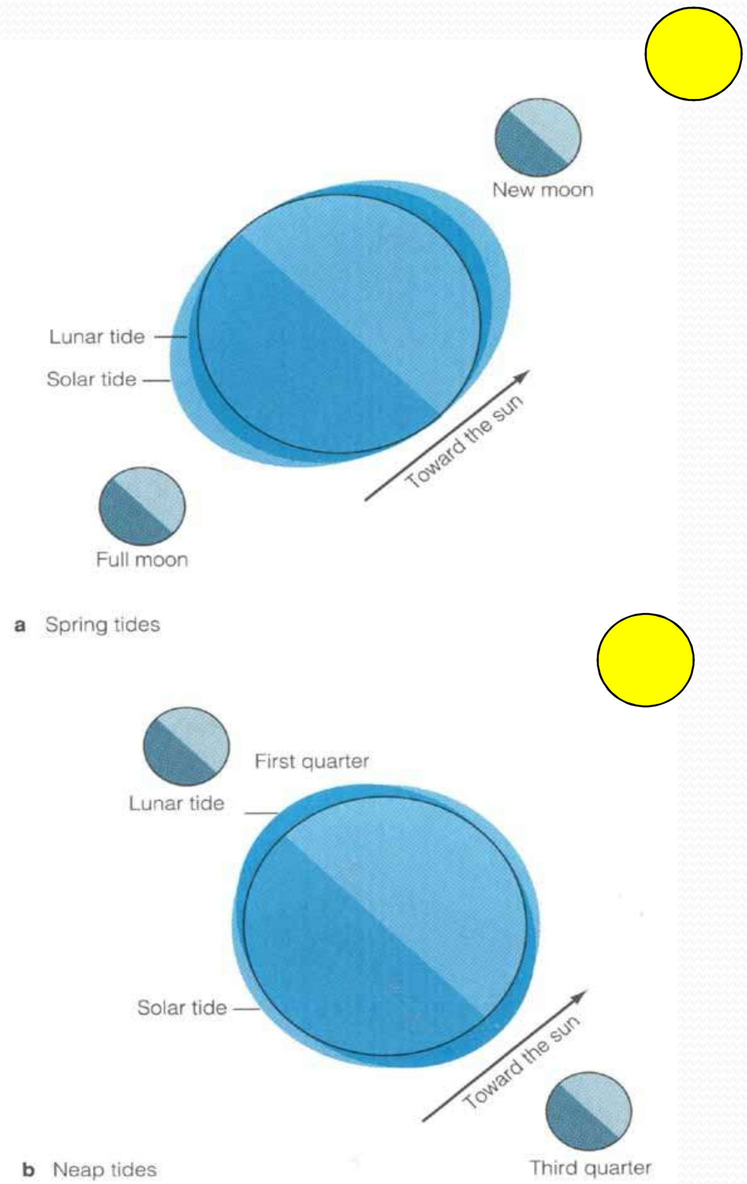
Sea Surface Height: Geoid



- The deviations of the geoid from the reference ellipsoid range from **-104 m to +64 m**.
- In areas where there are ocean trenches or ridges the **geoid height can vary by several meters over a few kilometers**.
- **At present the shape of geoid is not known**.

- Measuring the distance between the satellite and the Earth surface we can estimate the influence of the gravitation field over land, but not over the ocean. Therefore, **sea surface height is referenced to geoid**.

Sea Surface Height: Ocean Tides

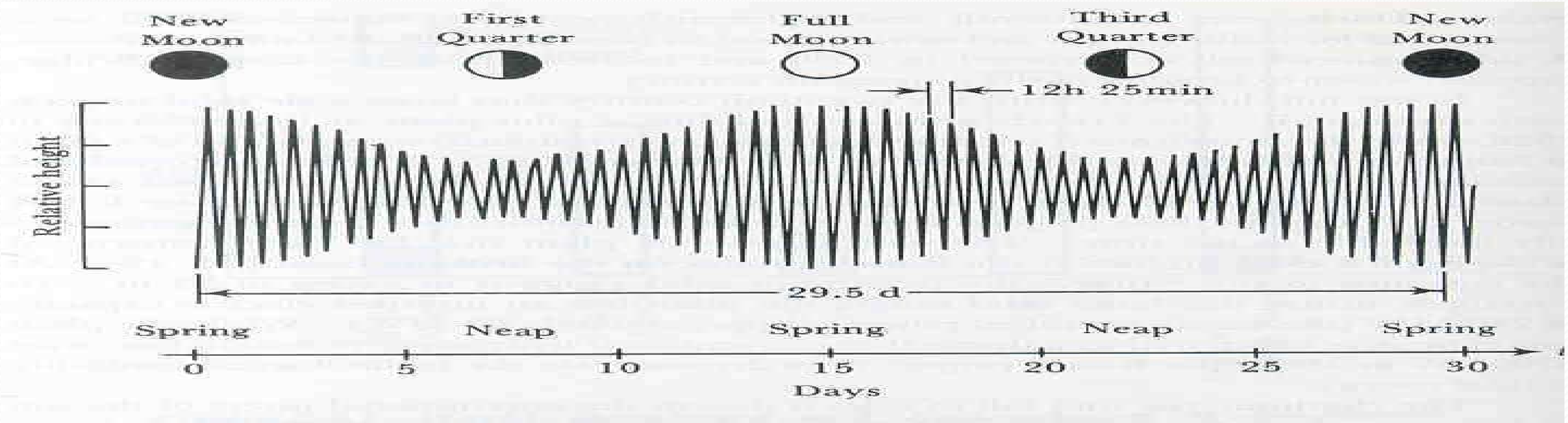


- **Tides are periodic short-term changes in the height of the ocean** surface caused by a combination of the gravitational force of the moon and the sun and the motion of the Earth.

- When the **directions of the moon and sun gravitation coincide** (full moon or new moon), **the tidal range is maximum** (spring tide, above).

- When the **direction of the sun gravitation is perpendicular to the moon gravitation** (first quarter of third quarter), **the tidal range is minimum** (neap tide, below).

Sea Surface Height: Ocean Tides



- **Maximum tidal range is up to 15 m** (the Bay of Fundy near Moncton, New Brunswick, Canada.
- **Tides** can be **estimated from mathematical models** and **removed from the altimetric measurements**.
- **Altimetric measurements provided a comprehensive information on tidal cycles**.

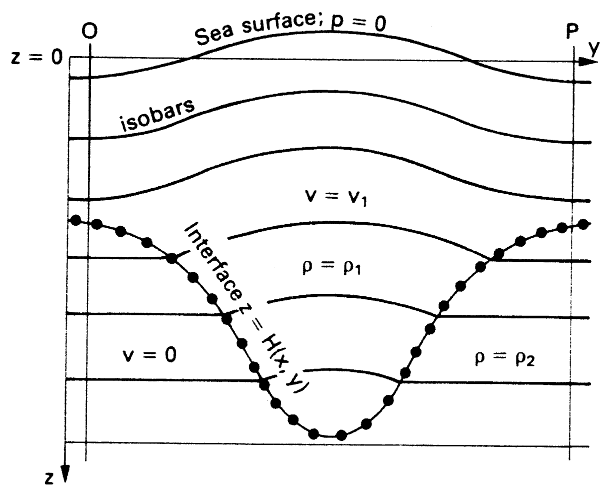
Sea Surface Height: Geostrophic Circulation

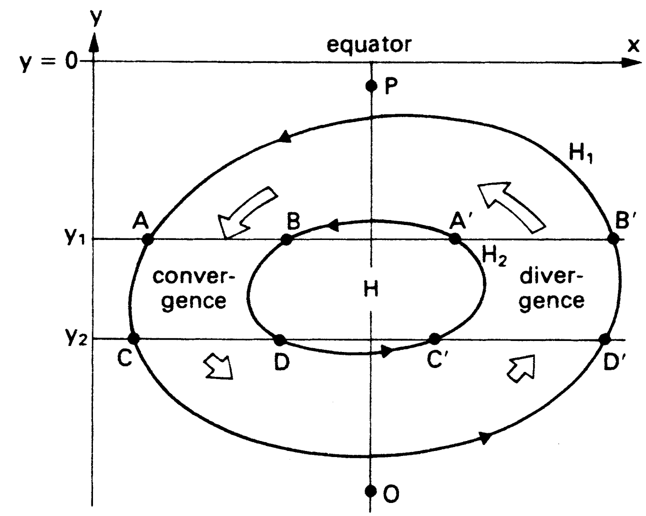
- **Sea Surface Height** estimated **after removal of tidal variability** is attributed to **steric height** resulting from the differences in the ocean column density (refers to global changes in sea level due to **thermal expansion** and **salinity variations**).

- From the horizontal gradients of steric height we can estimate **geostrophic circulation**.

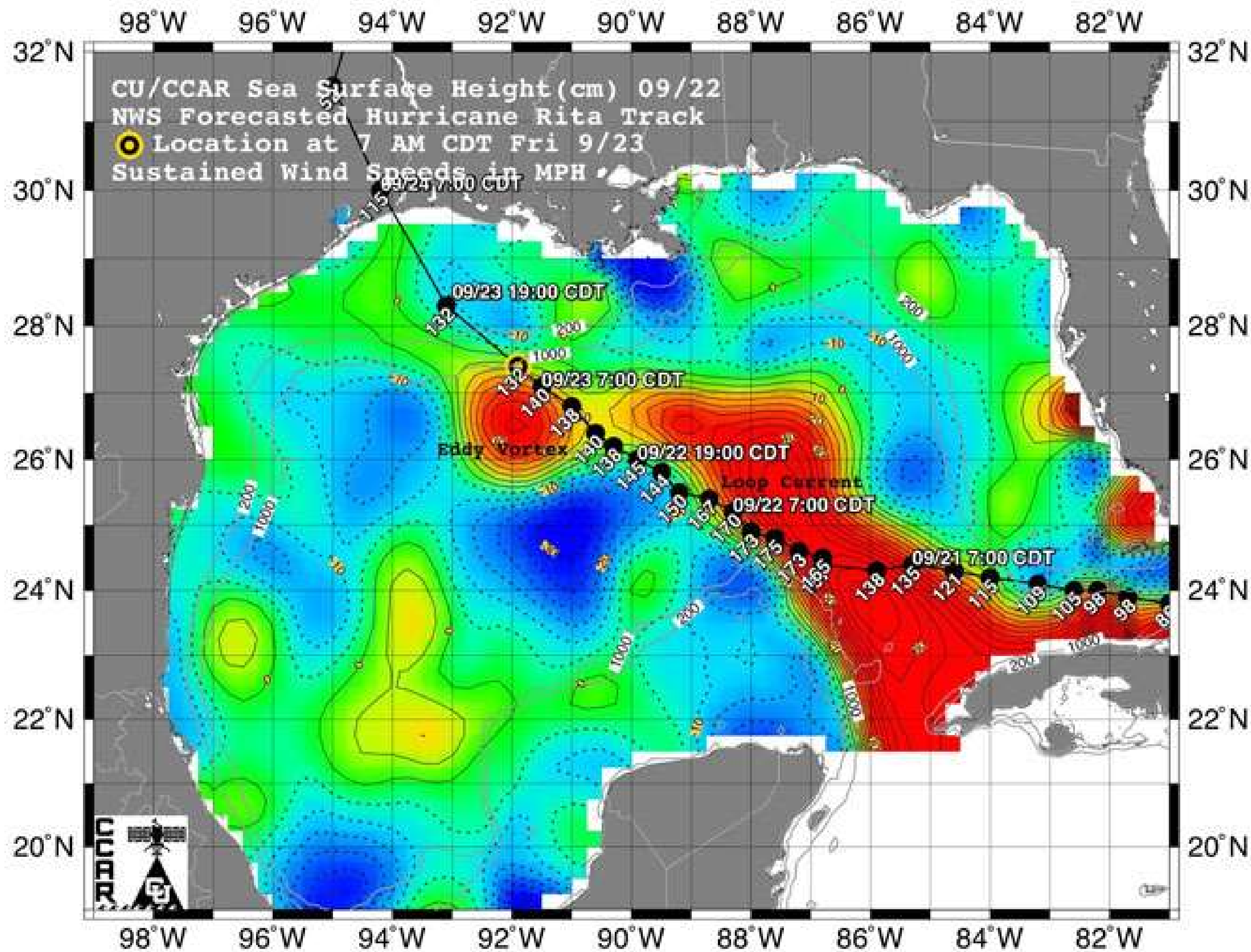
- In practice we cannot obtain from altimetry the estimations of steric height because instead of geoid mean ocean surface which includes both geoid and the elements of steady ocean circulation is used.

- The most productive way of analysis of sea surface topography is mathematical modeling with data assimilation.



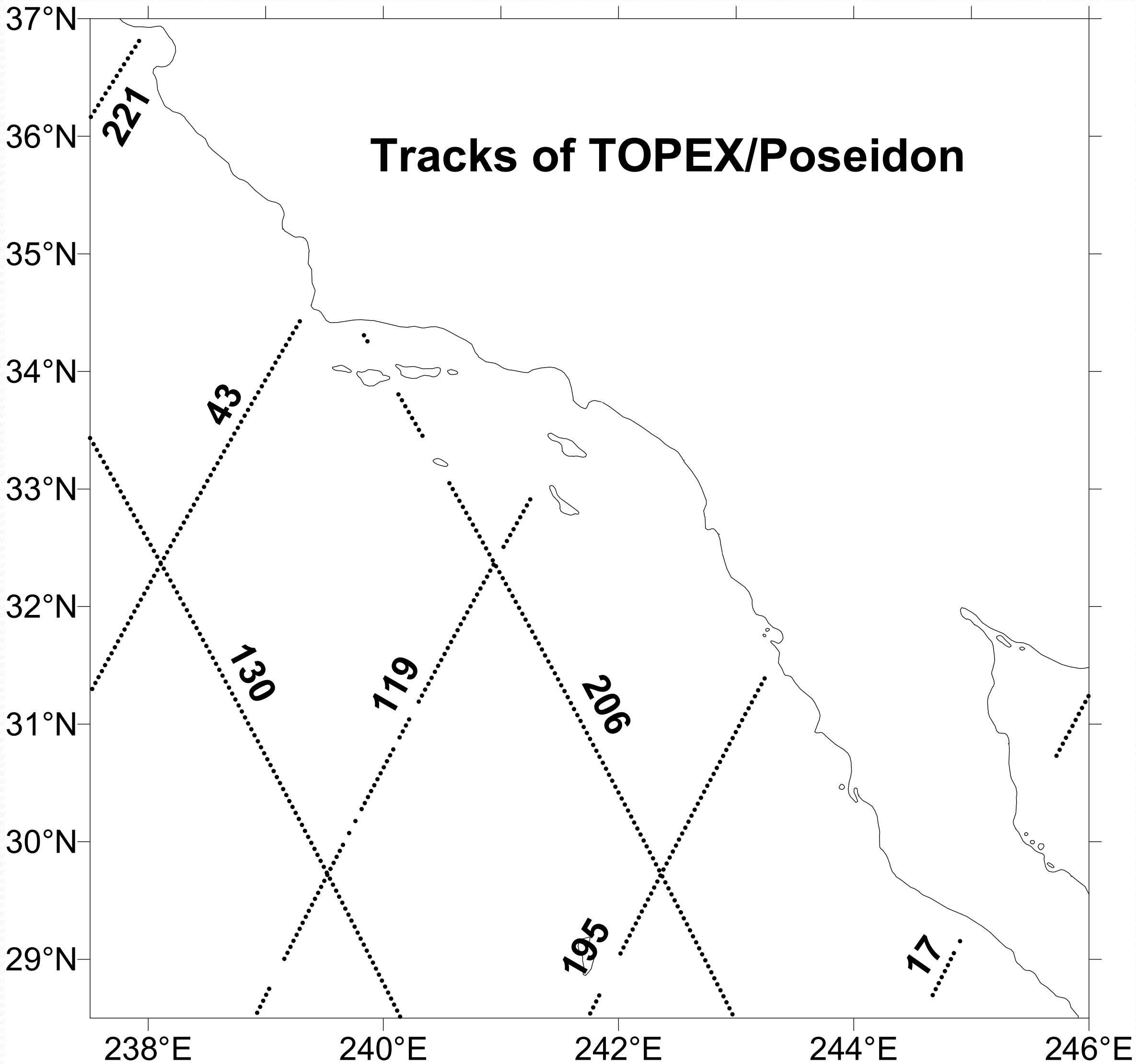


Sea Surface Height- Hurricane



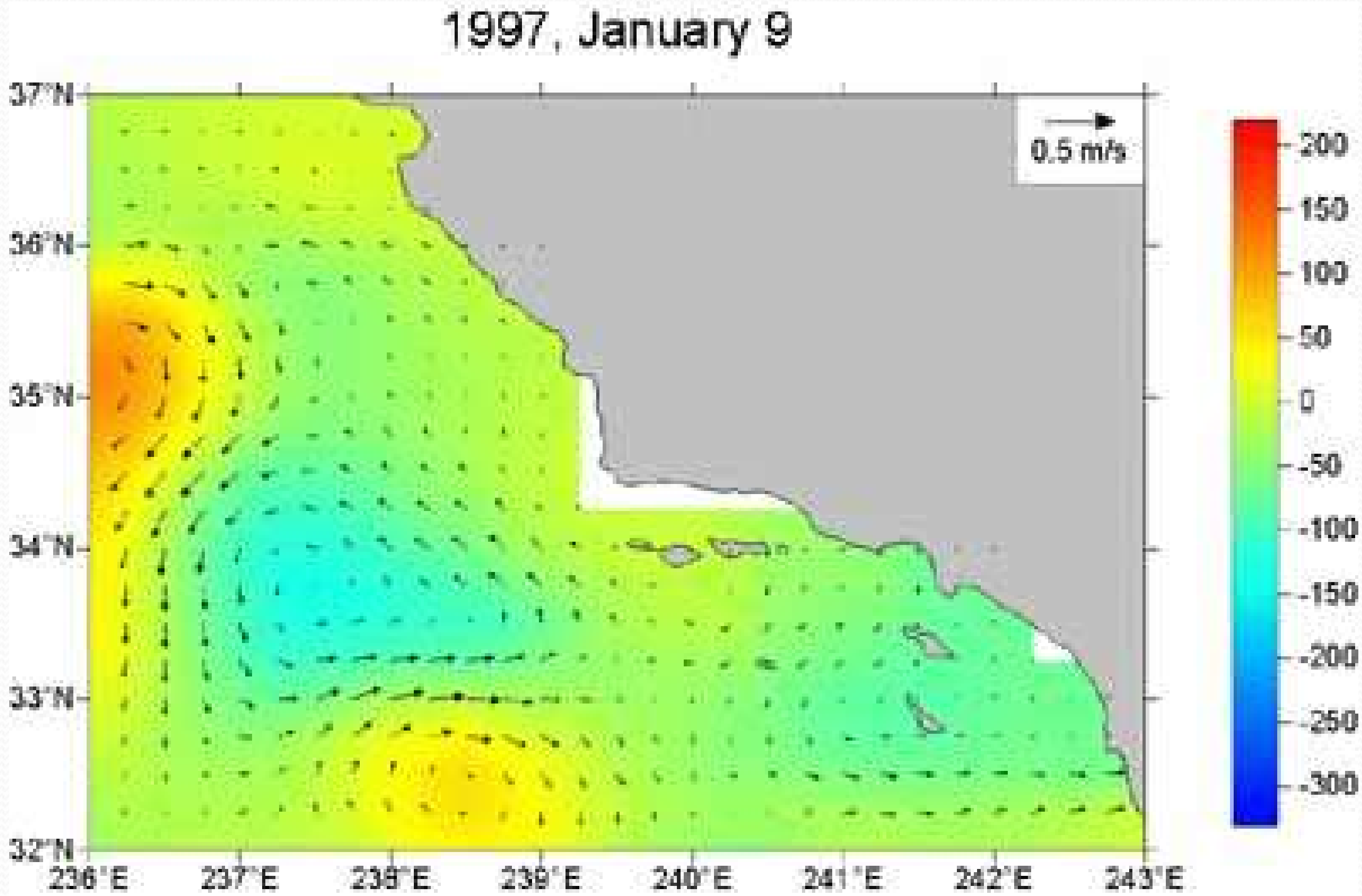
Hurricane Rita in the Gulf of Mexico.

Sea Surface Height



The TOPEX/Poseidon truck numbers off southern California

Sea Surface Height



Example of sea surface topography dynamics off California.

Data Access

Orbits and Auxilary Data

Semi-major axis	7,714.43 km
Eccentricity	0.000095
Inclination	66.04°
Argument of periapsis	90.0°
Inertial longitude of the ascending node	116.56°
Mean anomaly	253.13°
Reference altitude	1,336 km
Nodal period	6,745.72 sec
Repeat period	9.9156 days
Number of revolutions within a cycle	127
Number of passes within a cycle	254
Equatorial cross track separation	315 km
Ground track control band	+1 km
Acute angle at Equator crossings	39.5°
Longitude of Equator crossing of pass 1, cycles 1-365	99.9249°
Longitude of Equator crossing of pass 1, cycles 369-onward	98.5°
Inertial nodal rate	-2.08°/day
Orbital speed	7.2 km/s
Ground track speed	5.8 km/s

Additional information about instruments, orbit or other properties of TOPEX/Poseidon can be found in the

- The data collected by TOPEX/Poseidon and Jason-1 can be obtained from various sites but the "PODAAC" site is the best:

http://podaac.jpl.nasa.gov/datasetlist?ids=Measurement&values=Sea+Surface+Topography#

- There are many ways to access the data and different formats.
- https://podaac.jpl.nasa.gov/TOPEX-POSEIDON

All Products › Parameter: Sea Surface Topography

TOPEX/POSEIDON ALTIMETER MERGED GEOPHYSICAL DATA RECORD GENERATION B

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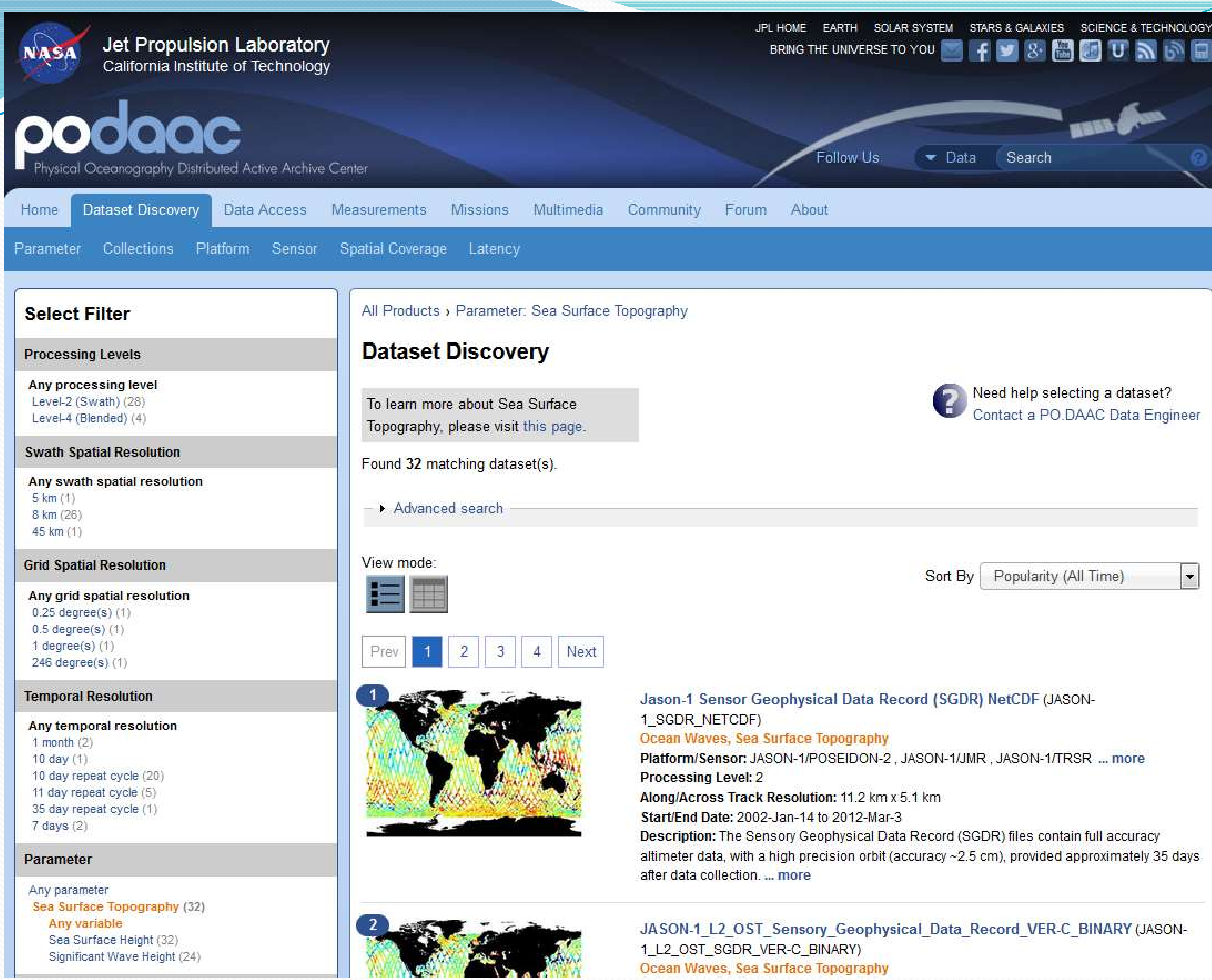
http://podaac.jpl.nasa.gov/dataset/PODAAC_MGDR

Please contact us if there are any discrepancies or inaccuracies found below.

Information | Data Access | Documentation | Granule (File) Listing | Citation

DOI	10.5067/TPMGD-BIN0B
Short Name	PODAAC_MGDR
Description	The TOPEX/POSEIDON MGDR (Merged Geophysical Data Record) contains global coverage altimeter data. This data set (MGDR-B) contains generation B data which replaces the generation A data set. The objective of the TOPEX/POSEIDON mission, launched in August 1992 and currently operating, is to determine ocean topography with a sea surface height measurement precision of 3 cm and a sea level measurement accuracy of 13 cm. The data product combines measurements from two altimeters, a NASA dual frequency (Ku and C band) instrument similar to the Geosat altimeter, and a French (CNES) instrument which is a proof-of-concept solid-state altimeter (Ku band). This data set contains mean sea surface, ionospheric corrections, sigma0 and all parameters needed to calculate sea surface height anomalies and total electron content. The data are in binary format.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Spatial Coverage
Latency
Select Filter
Processing Levels
Any processing level
Level-2 (Swath) (28)
Level-4 (Blended) (4)
Swath Spatial Resolution
Any swath spatial resolution
5 km (1)
8 km (26)
45 km (1)
Grid Spatial Resolution
Any grid spatial resolution
0.25 degree(s) (1)
0.5 degree(s) (1)
1 degree(s) (1)
246 degree(s) (1)
Temporal Resolution
Any temporal resolution
1 month (2)
10 day (1)
10 day repeat cycle (20)
11 day repeat cycle (5)
35 day repeat cycle (1)
7 days (2)
Parameter
Any parameter
Sea Surface Topography (32)
Any variable
Sea Surface Height (32)
Significant Wave Height (24)
All Products › Parameter: Sea Surface Topography
Dataset Discovery
To learn more about Sea Surface Topography, please visit this page.
Need help selecting a dataset?
Contact a PO.DAAC Data Engineer
Found 32 matching dataset(s).
Advanced search
View mode:
Sort By
Popularity (All Time)
Prev
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1
Jason-1 Sensor Geophysical Data Record (SGDR) NetCDF (JASON-1_SGDR_NETCDF)
Ocean Waves, Sea Surface Topography
Platform/Sensor: JASON-1/POSEIDON-2 , JASON-1/JMR , JASON-1/TRSR ... more
Processing Level: 2
Along/Across Track Resolution: 11.2 km x 5.1 km
Start/End Date: 2002-Jan-14 to 2012-Mar-3
Description: The Sensory Geophysical Data Record (SGDR) files contain full accuracy altimeter data, with a high precision orbit (accuracy ~2.5 cm), provided approximately 35 days after data collection. ... more
2
JASON-1_L2_OST_Sensory_Geophysical_Data_Record_VER-C_BINARY (JASON-1_L2_OST_SGDR_VER-C_BINARY)
Ocean Waves, Sea Surface Topography

Data Access

Index of ftp://podaac-ftp.jpl.nasa.gov/allData/topex/L2/mgdrb/

Up to higher level directory

Name	Size	Last Modified
MGB_001		9/6/2012 12:00:00 AM
MGB_002		9/6/2012 12:00:00 AM
MGB_003		9/6/2012 12:00:00 AM

Information | Data Access | Documentation | Granule (File) Listing | Citation

Information | Data Access | Documentation | Granule (File) Listing | Citation

- 1992 (2475)
- 1993 (9099)
- 1994 (9249)
- 1995 (9051)
- 1996 (9207)
- 1997 (9269)
- 1998 (8493)
- 1999 (8897)
- 2000 (8729)
- 2001 (8104)
- 2002 (5943)
- 2003 (8666)
- 2004 (4704)
- 2005 (491)

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