Overview of Satellite Altimetry

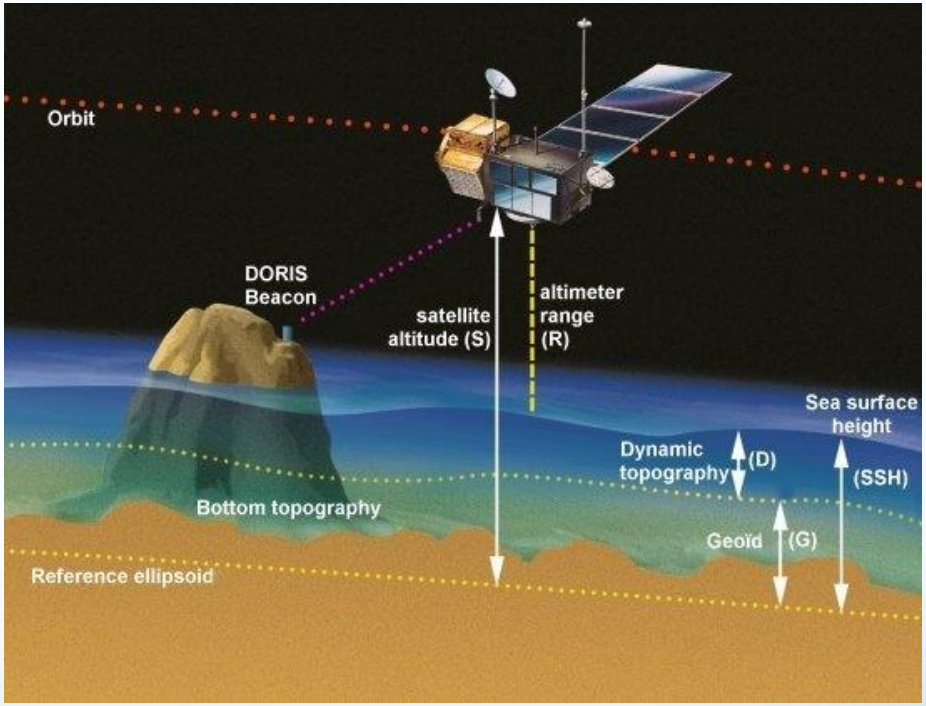
Jose Barcenas

Overview

- Basics of satellite altimetry
  - Geoid
  - Beam footprints
  - Ionosphere delay
- Scatterometry
- TOPEX/Poseidon Satellite
  - Altimetry data used for El Niño comparisons
- Jason-2

Principle of satellite altimetry

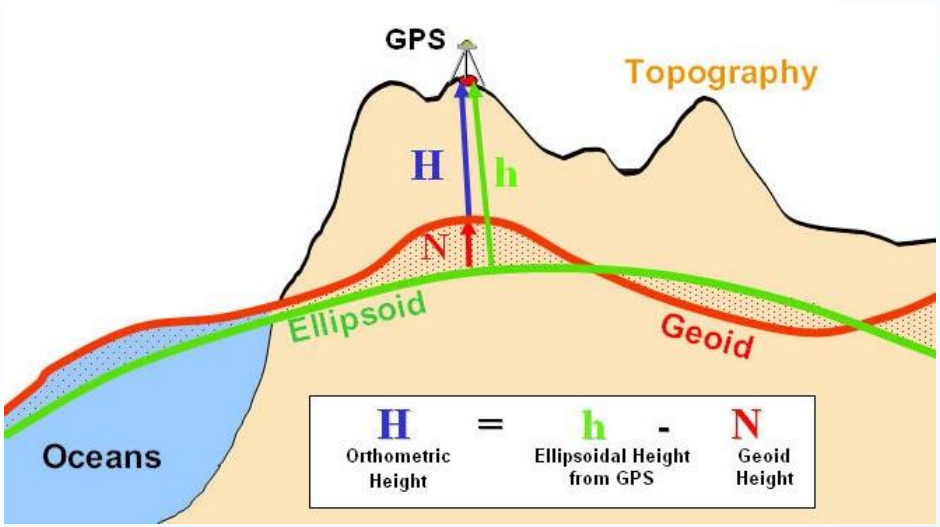
- Using the Geoid, measurements can be taken for:
  - Wave height
  - Wind speed
- Measurements calculated by microwave electromagnetic pulses
- Accuracy affected by ionosphere, water vapor, Orbit error



Source: http://aviso.altimetry.fr/gallery/entry_21_altimetry_principle_topex_poseidon_satellite_.html

Geoid

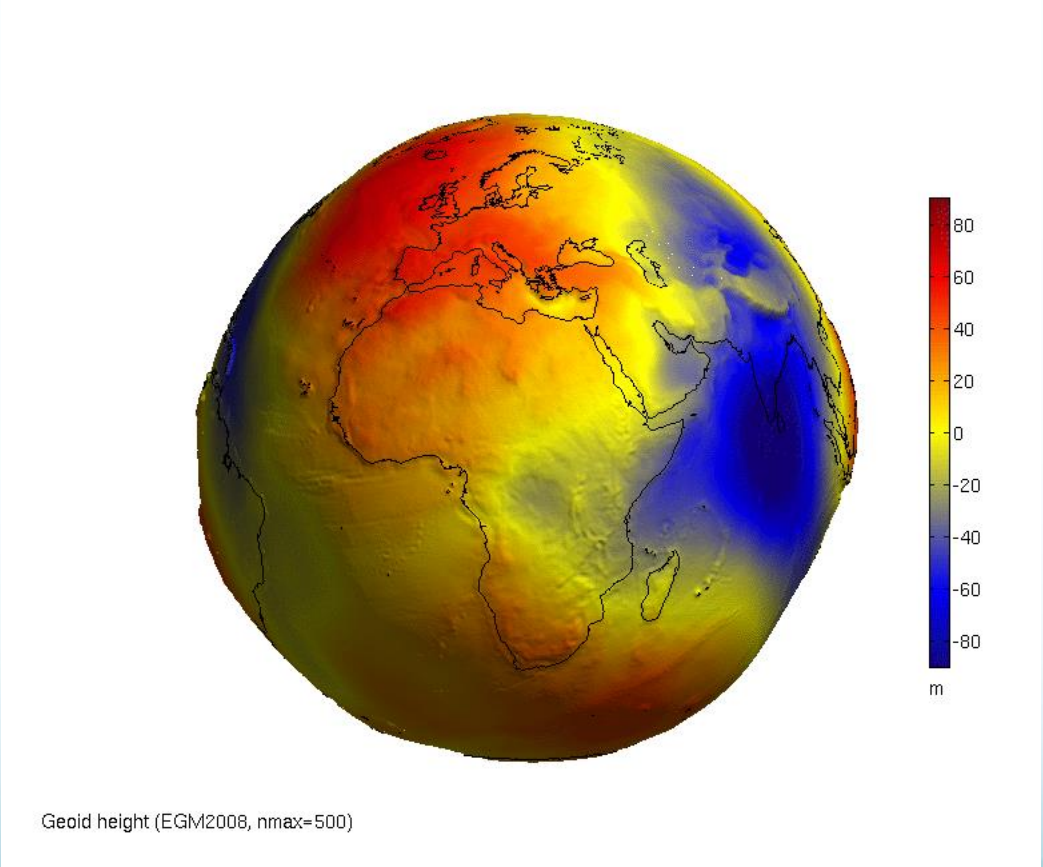
- Sea surface height measured relative to a reference height, the geoid.
- Geoid is the average global sea level
  - Shape determined by gravity effects, earth's rotation, and ellipsoid



Source:
http://principles.ou.edu/earth_figure_gravity/geoid/

Geoid

- Egm2008 model



Geoid height (EGM2008, nmax=500)

Source http://www.asu.cas.cz/~bezdek/vyzkum/rotating_3d_globe/

Radar Altimetry

- Scientific applications of radar altimetry

Feature	Typical Amplitudes	Horizontal Scale	Timescale
Geoid	30m	10,000km	∞
Dynamic topography	1m	10,000km	∞
Climate Changes	.01m	10,000km	10-100,000 yr
Tides	.2-3m	100-100,000km	Lunar and solar frequency
El Niño	.1m	6,000km	~5 yr
Fronts and eddies	.3m	100-1000km	~1 mo
Seamounts	1m	50km	∞
Ridge axes	.02m	10km	∞

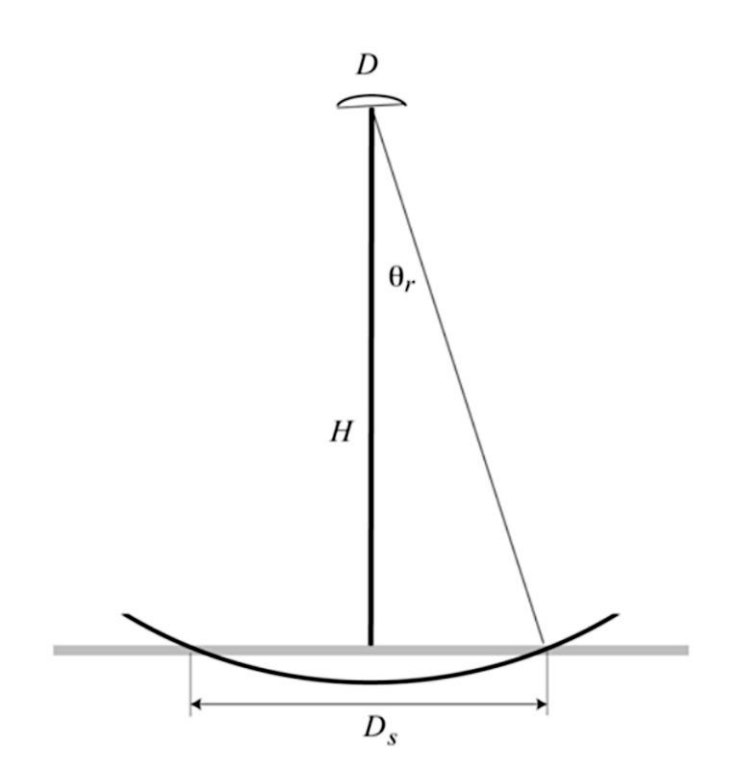
Source: http://topex.ucsd.edu/rs/altimetry.pdf

Beam Footprint

- Illumination pattern on ocean surface can be determined by the following equation

$$D_s = 2H\sin(\theta_r) = 2.44H\frac{\lambda}{D}$$

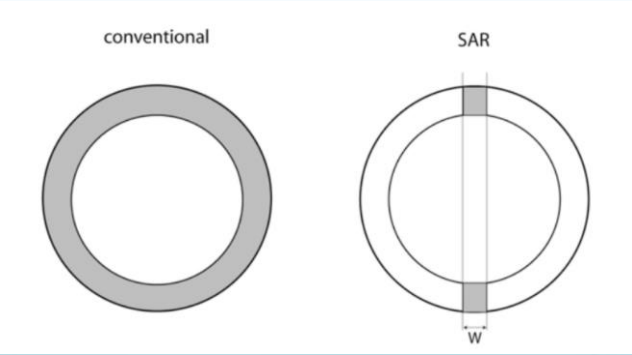
- Example: 1m diameter radar operating in the Ku band(22nm), orbiting at an altitude of 800km, yields a beam width of 43km



Source: http://topex.ucsd.edu/rs/altimetry.pdf

Pulse-limited Footprint and Synthetic Aperture Radar(SAR)

- Pulse-limited Footprint
  - Similar operation to that of the Beam Footprint, however it uses filtering techniques to reduce the footprint
  - Matched filter used to regenerate pulse
    - Commonly used in radar systems, improves signal to noise ratio in the presence of additive stochastic noise
- SAR
  - To further reduce footprint, pulses are sent at a high rate(18,000 per second)
    - Pulses summed to form a synthetic(moving antenna) aperture
  - Radar designed to consume less power per pulse



Source: http://topex.ucsd.edu/rs/altimetry.pdf

Resolution calculation

- To achieve resolution needed for an application, the travel time of the radar echo can be determined by:

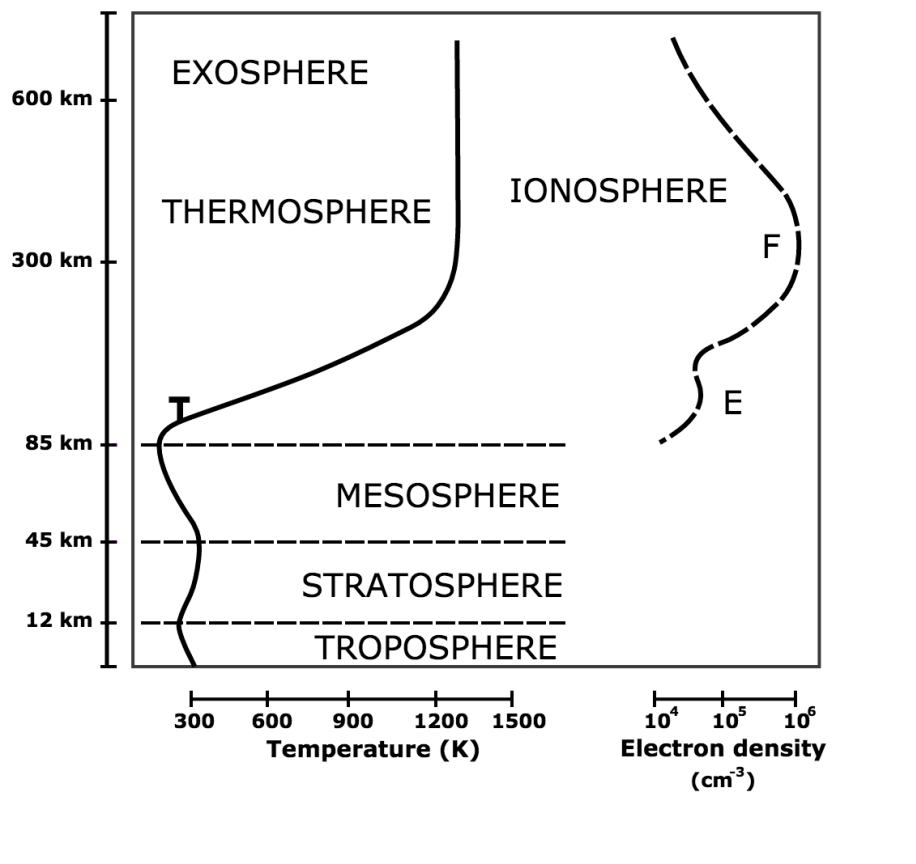
$$\Delta t = \frac{2\Delta h}{c}$$

- Example: if .02m range resolution needed, travel time needs to be accurate within .13ns(8Hz bandwidth needed)
- However, due to ocean waves limiting travel time measurement due to diffraction and scattering, a smaller bandwidth of .3GHz will suffice

Source: http://topex.ucsd.edu/rs/altimetry.pdf

Ionosphere effect on satellite altimetry

- Microwave pulses experience a delay in the ionosphere
  - Free electrons alter dielectric properties of the medium, resulting in frequency dispersion
- Effect strongest between 250km and 400km altitudes
- Free electron content changes diurnally



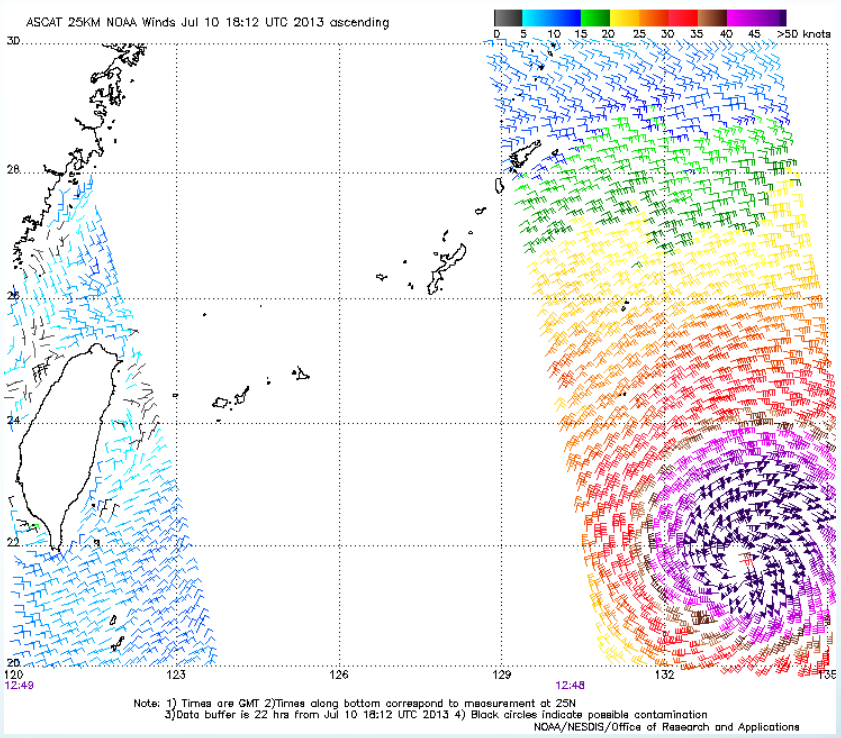
Source:
https://en.wikipedia.org/wiki/Ionosphere

Scatterometry

- Wind velocity can be determined by satellite sensors using similar techniques to altimetry
  - Fraction of energy returned to satellite(backscatter) is used to determine wind speed and wind direction

$$Backscatter = f(U, X, \theta, f, p)$$

  - U= wind speed
  - X=relative azimuth angle(angle between instrument azimuth and wind direction
  - Θ= incidence angle
  - f = instrument frequency
  - p = instrument polarization

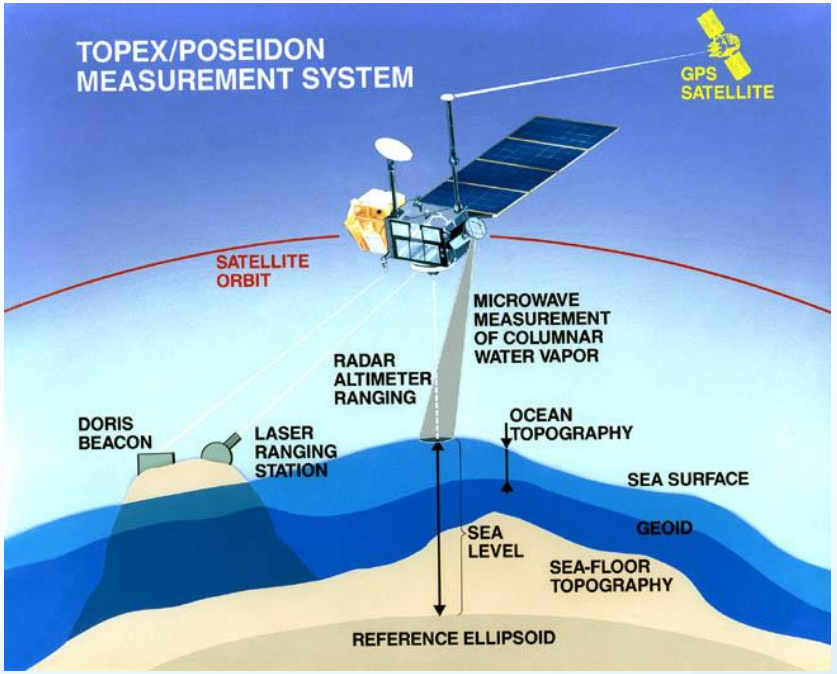


Typhoon Soulik- Category 4
Data collected using MetOp

Source: https://coaps.fsu.edu/scatterometry/about/overview.php

TOPEX/Poseidon

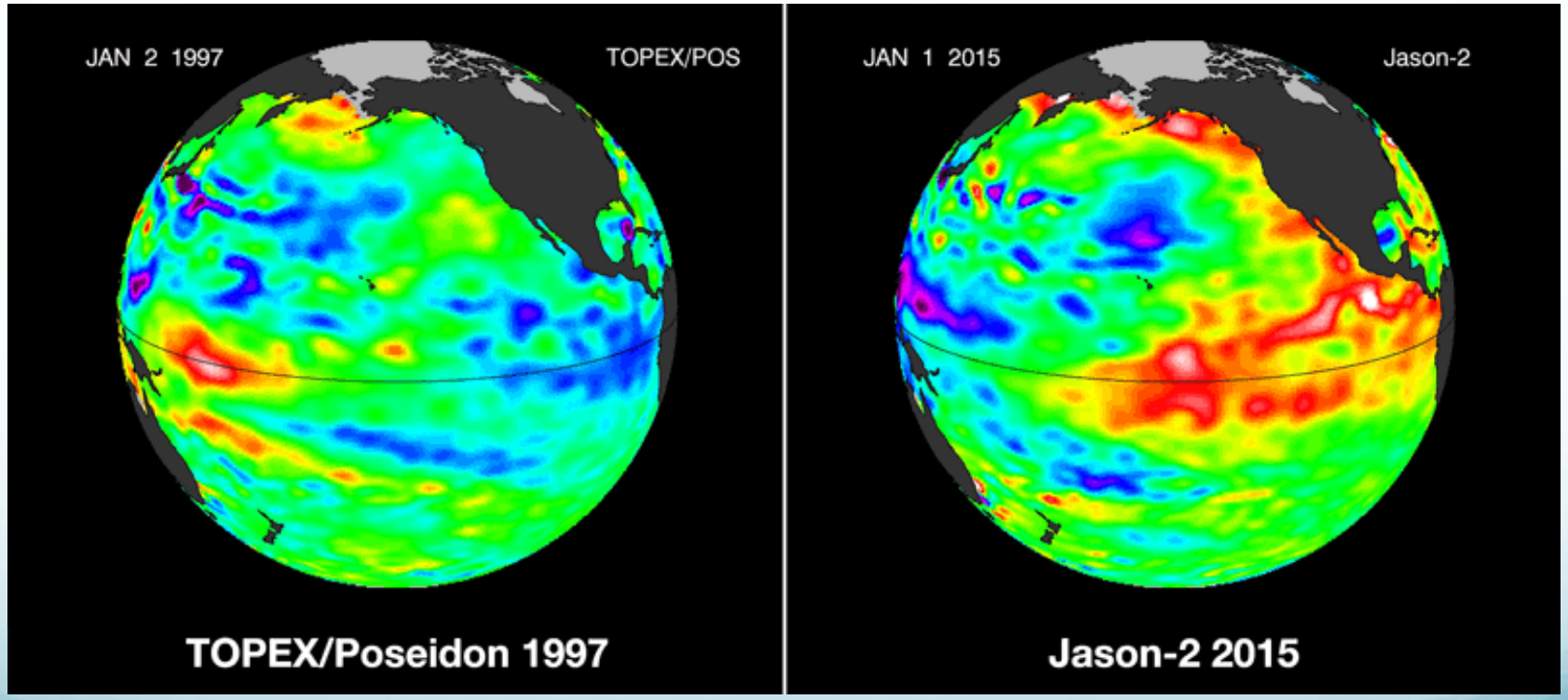
- First major oceanographic research vessel in space
  - Joint satellite mission between NASA and CNES
  - Malfunction ended normal satellite operations in 2006
- Provided continuous global coverage of surface topography of oceans
- Provided 10 years of data
  - Mapped global tides for the first time
  - Determine patterns of ocean circulation
  - Produced first global views of seasonal changes of currents



Source: https://en.wikipedia.org/wiki/TOPEX/Poseidon

TOPEX/Poseidon data

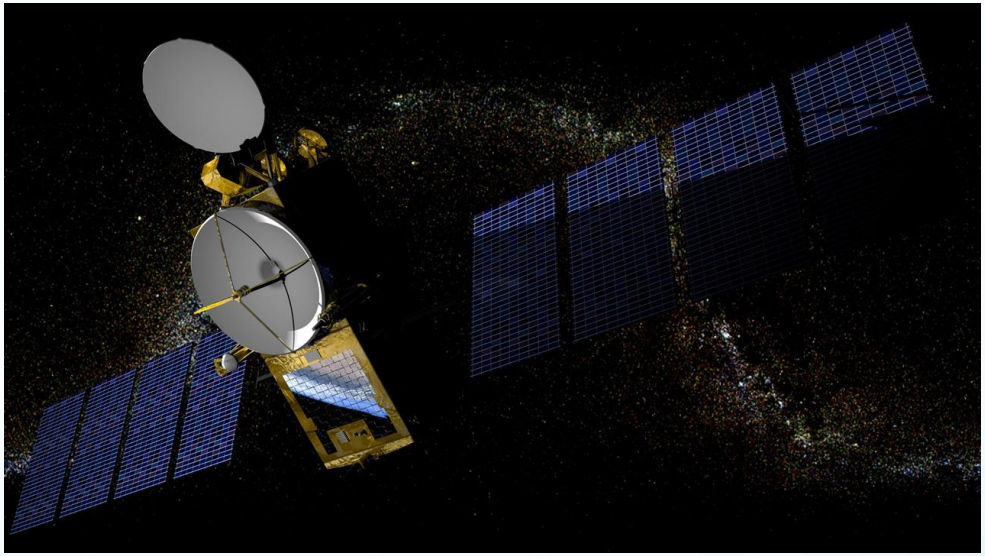
- 1997 vs 2015 El Niño



Source: https://sealevel.jpl.nasa.gov/elnino2015/index.html

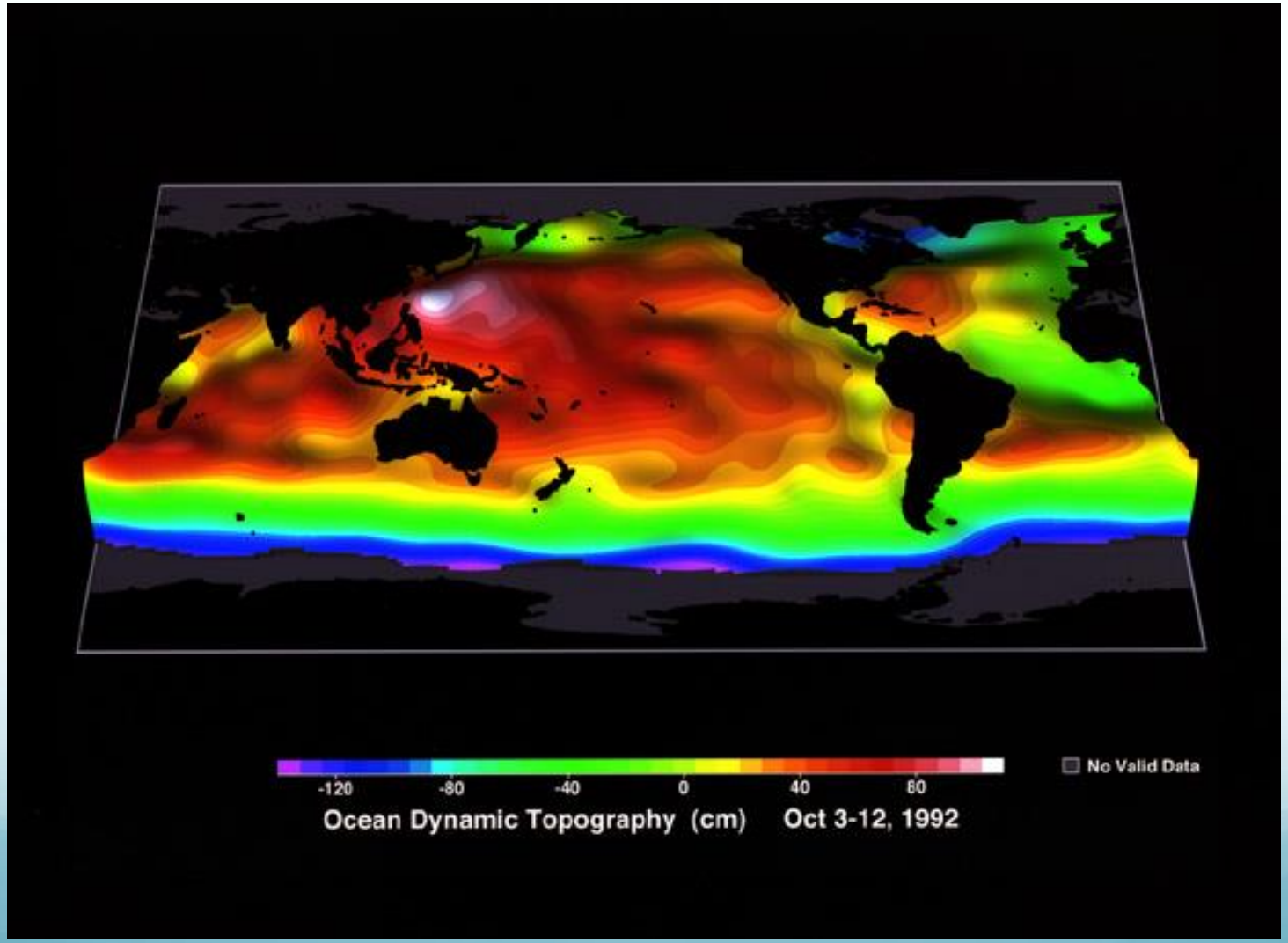
Ocean Surface Topography Mission(OSTM)

- Jason-2 satellite launched on 2008
- Uses similar instrumentation that the TOPEX/Poseidon used.
- Frequency altimeter combines scatterometer with radar altimeter.



Source: https://sealevel.jpl.nasa.gov/missions/ostmjason2/spacecraftandinstruments/

Questions?


-120
-80
-40
0
40
80
Ocean Dynamic Topography (cm)
Oct 3-12, 1992
No Valid Data