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Ocean Altimetry and Sea Level

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- Future of altimetry.

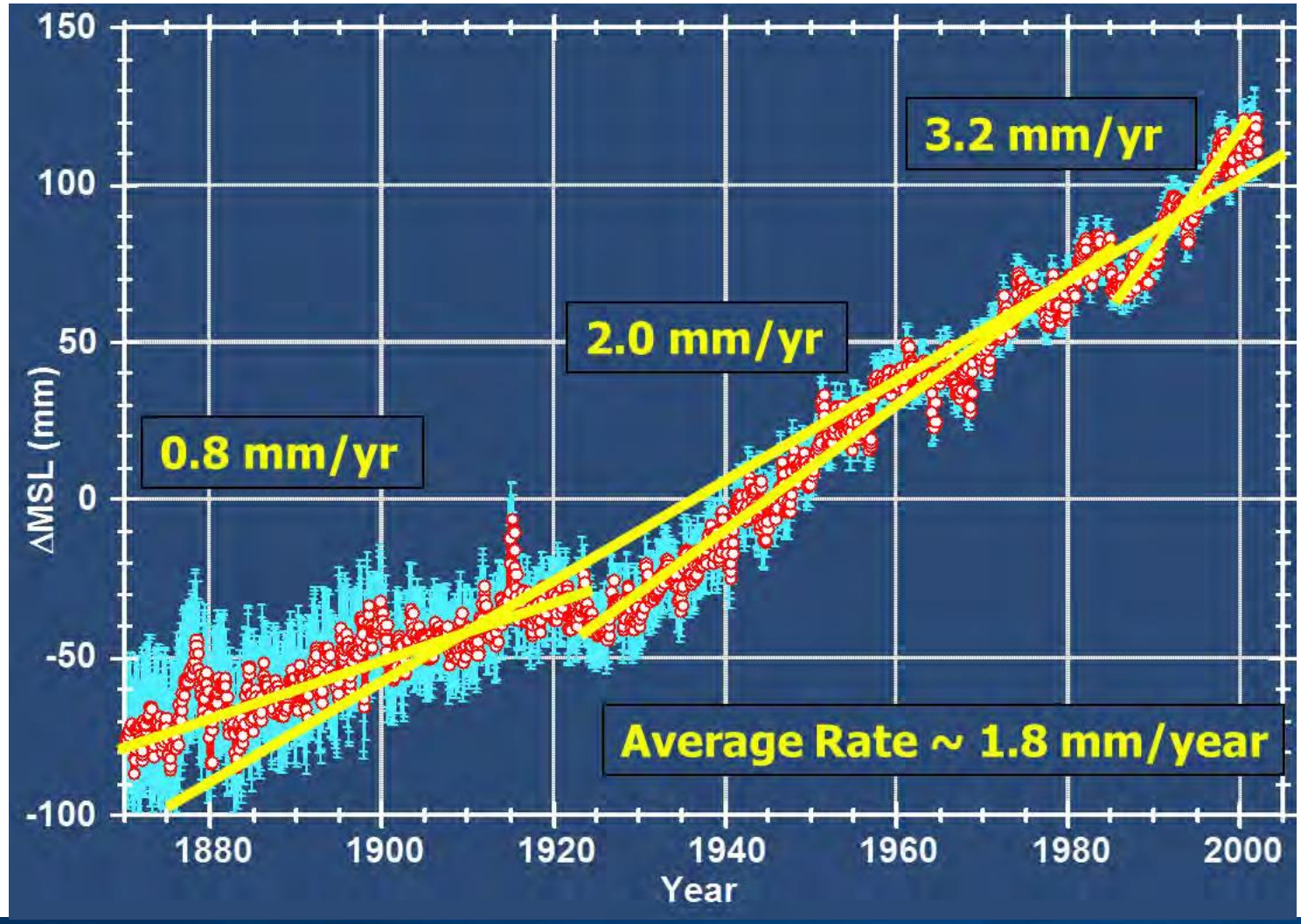
Why Satellite Altimetry?

Sea measurements & satellite altimetry

- Earth warms today.
- -90% of this energy goes to ocean.
- Ocean warms mostly in the upper 75m,
- Up to 2100:
  - Sea level rise +1 m due to thermal expansion,
  - only +0.2 m from glacier melting,
  - Sea level rise mainly by thermal expansion of the ocean.

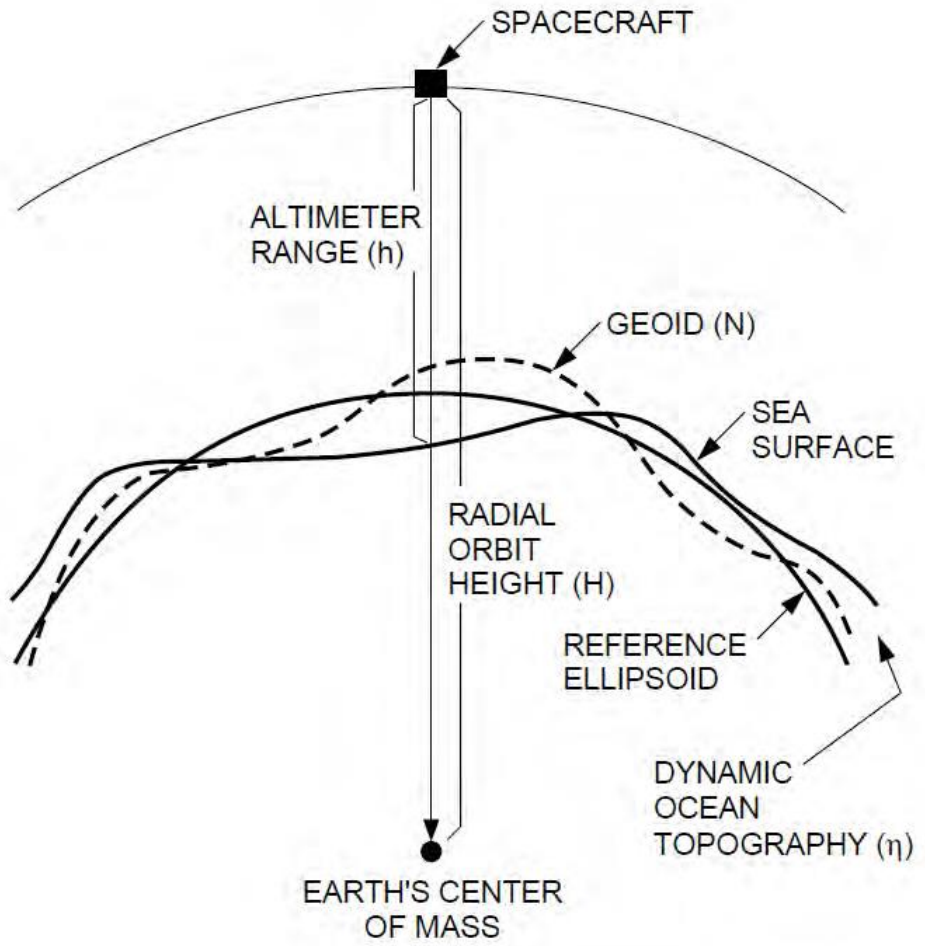
Why Satellite Altimetry?

Sea level rises at +3.2mm/yr



What is Satellite Altimetry?

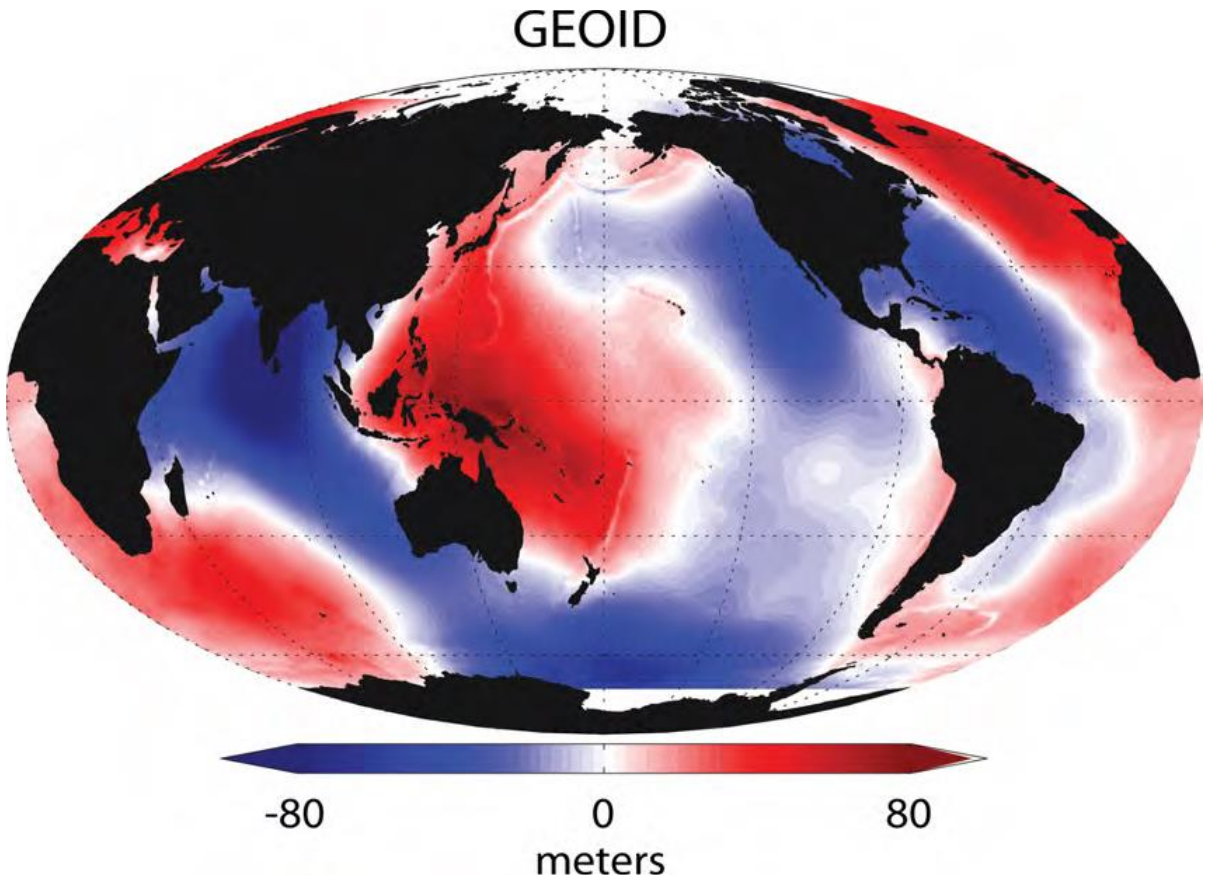
Principle of Satellite Altimetry



What is Satellite Altimetry?

Mean Sea Surface

The sea surface is not smooth and flat, it is a surface that is in constant movement. This moving surface is what we call a dynamic topography.



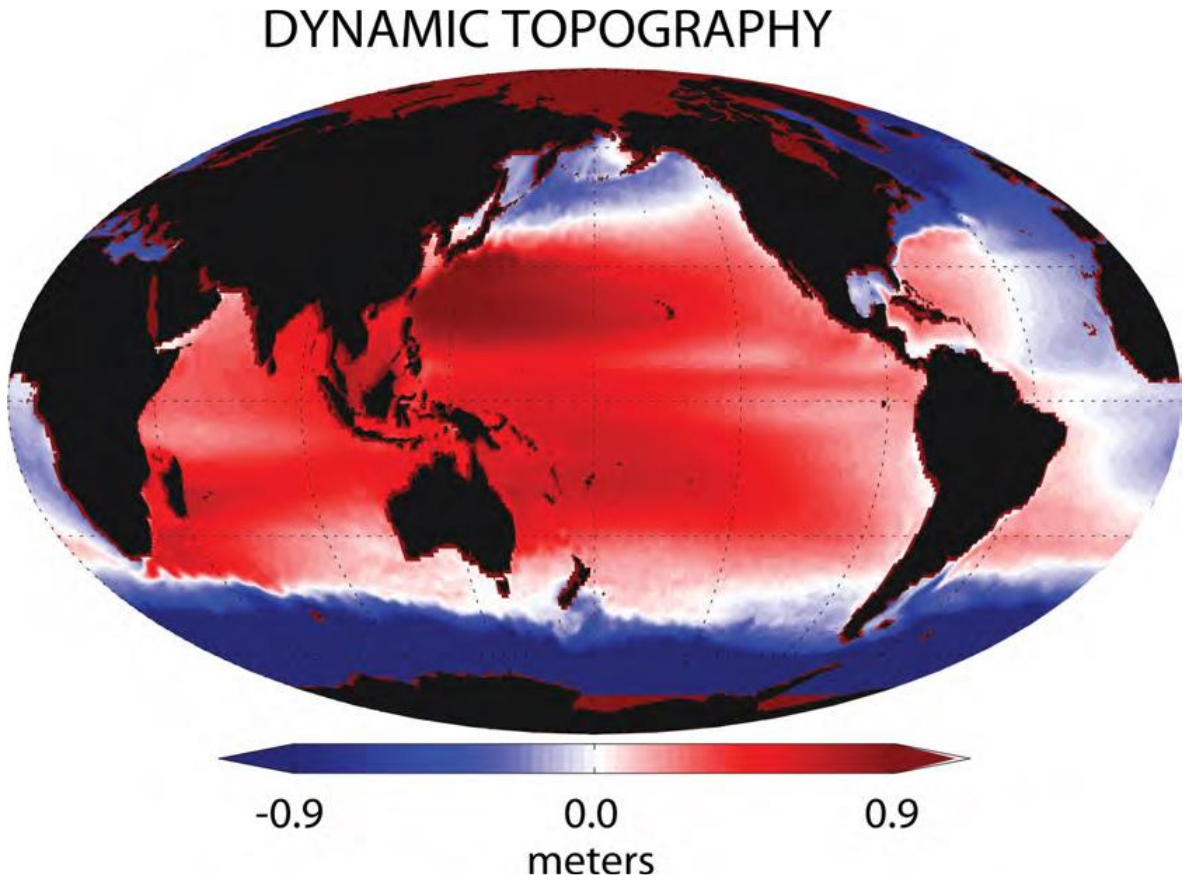
MSS = Geoid - MDT

MDT = Mean Dynamic Topography

What is Satellite Altimetry?

Mean Dynamic Topography

- Caused by:
- Temperature, salinity variations in the ocean
- permanent currents (Gulf Stream, Kuroshio, etc.)

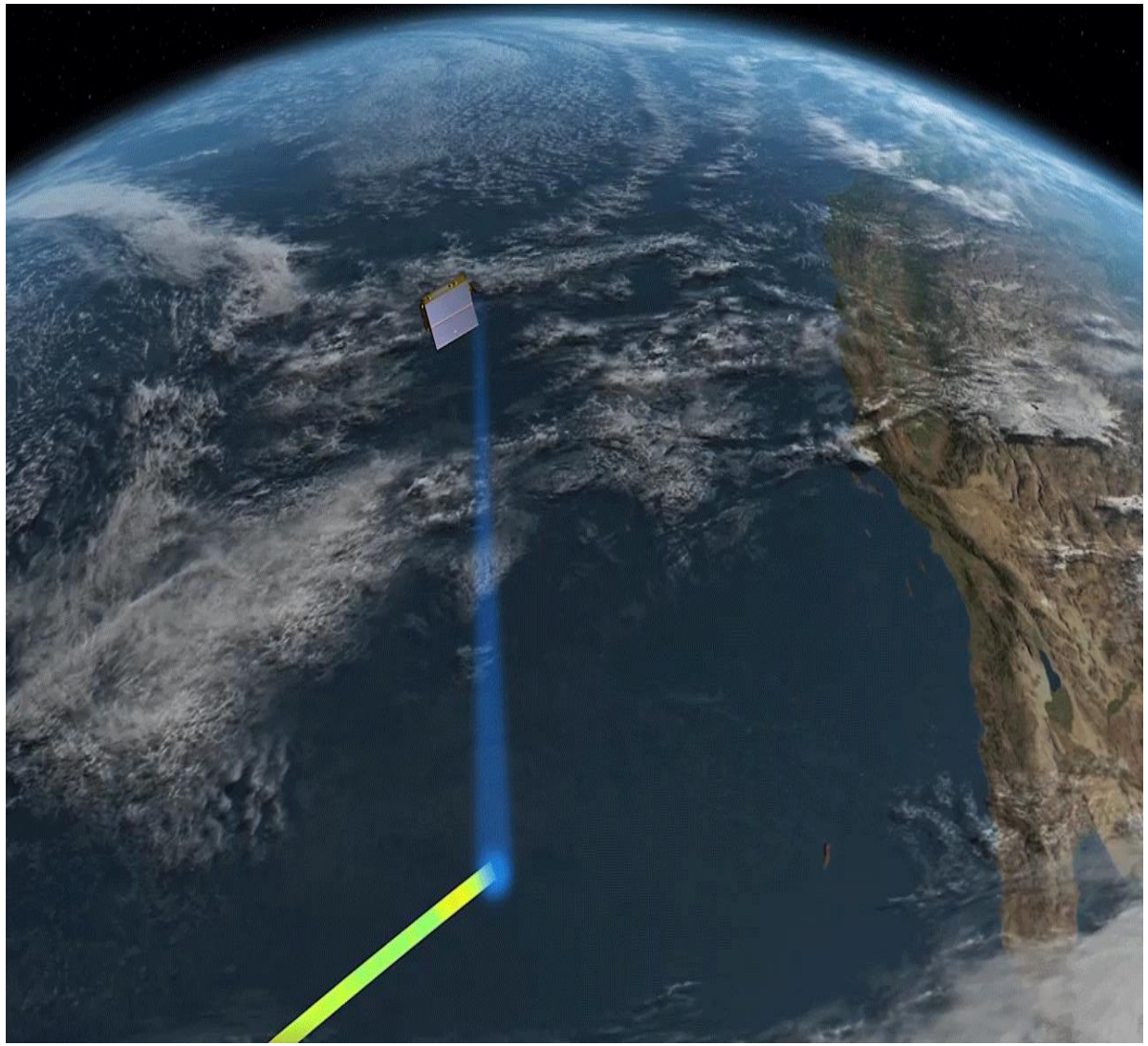


What is Satellite Altimetry?

What altimetry measures?

- Satellite flies in an orbit at a certain altitude (**S**) from the *theoretical reference ellipsoid*.
- The altimeter on board the satellite emits a radar wave and analyses the return signal that bounces off the surface.
- The time it takes to the surface and back again, satellite-to-surface range (**R**).
- The sea surface height (**SSH**) at any location or point in time is a deviation from the stable reference ellipsoid.
- The sea surface height is defined as the difference between the satellite's position with respect to the reference ellipsoid, and the satellite-to-surface range.

SSH = S – R.

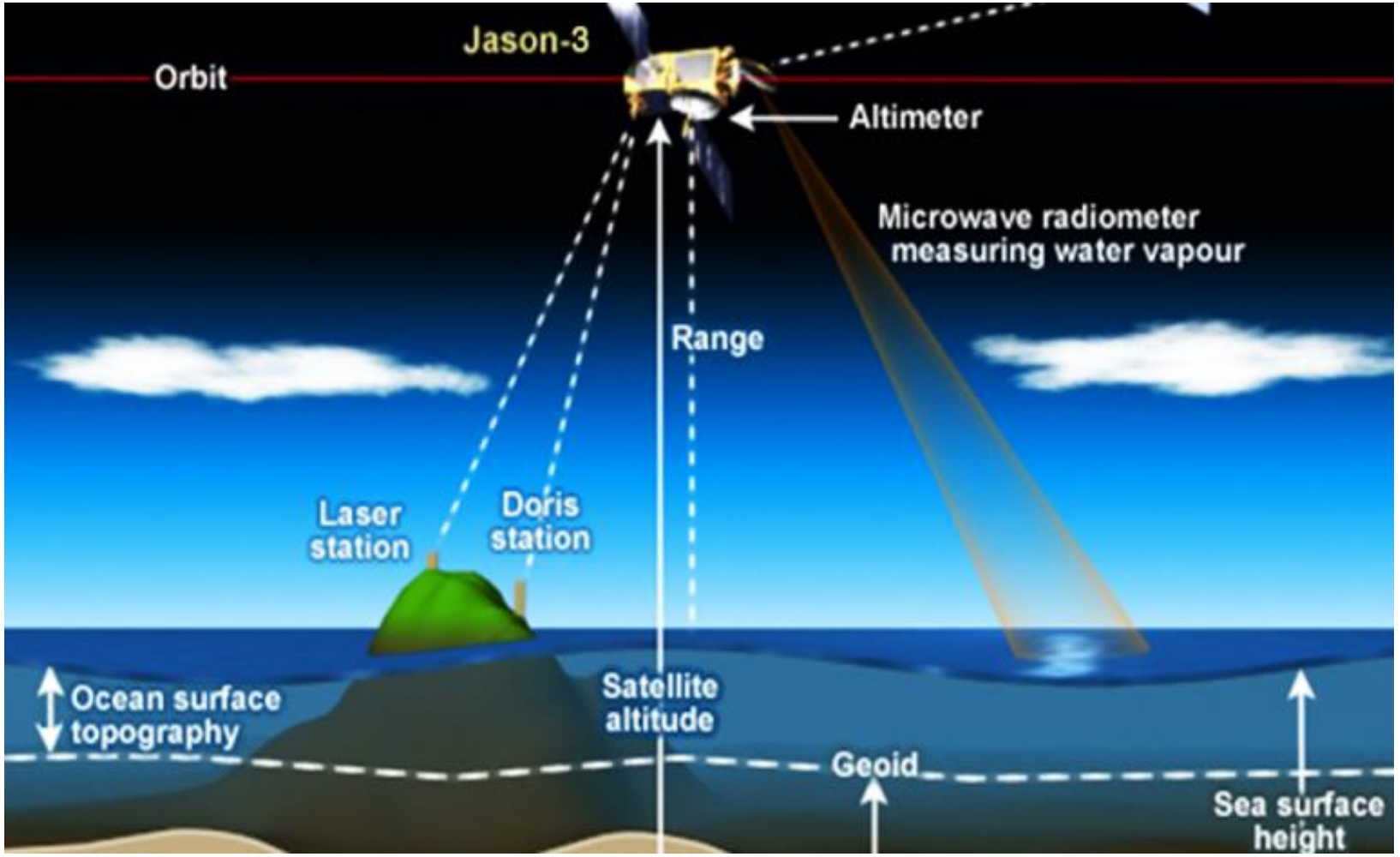


What is Satellite Altimetry?

What altimetry measures?

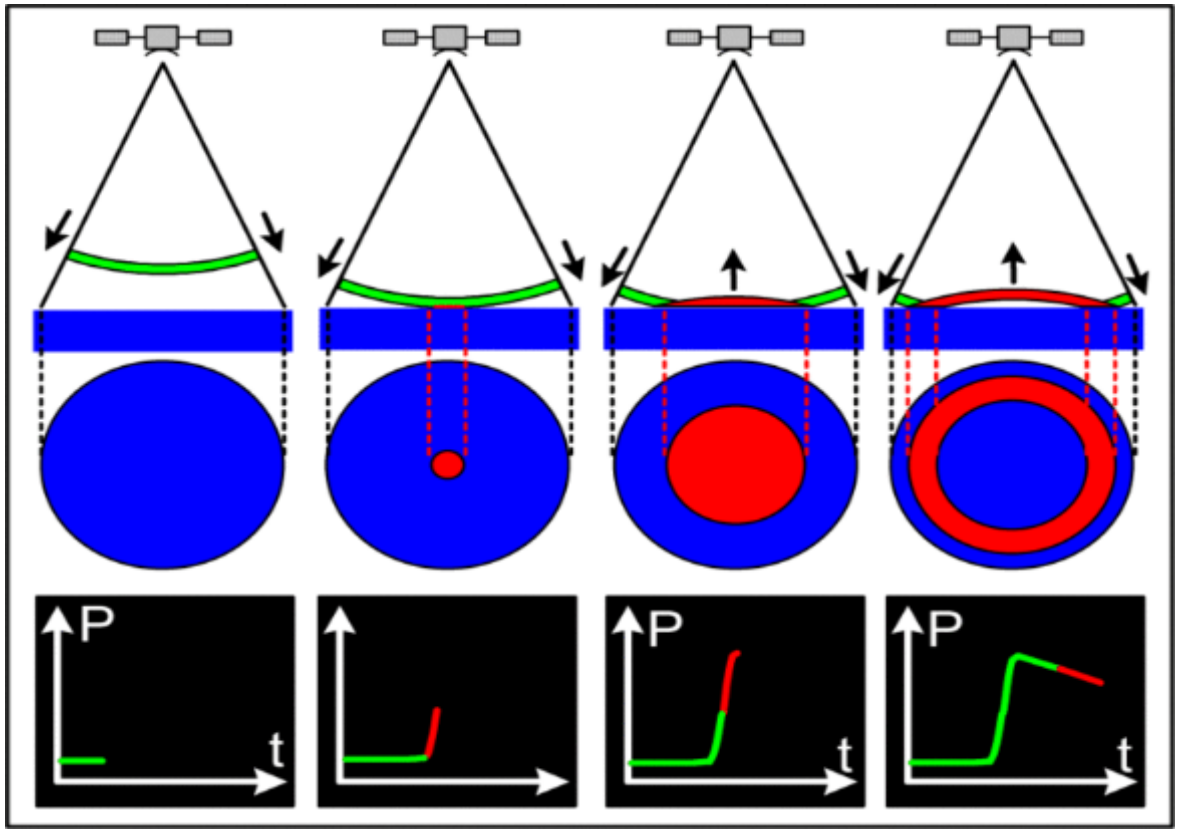
This method requires precise knowledge of;

- Satellite altitude
- Terrestrial reference frame

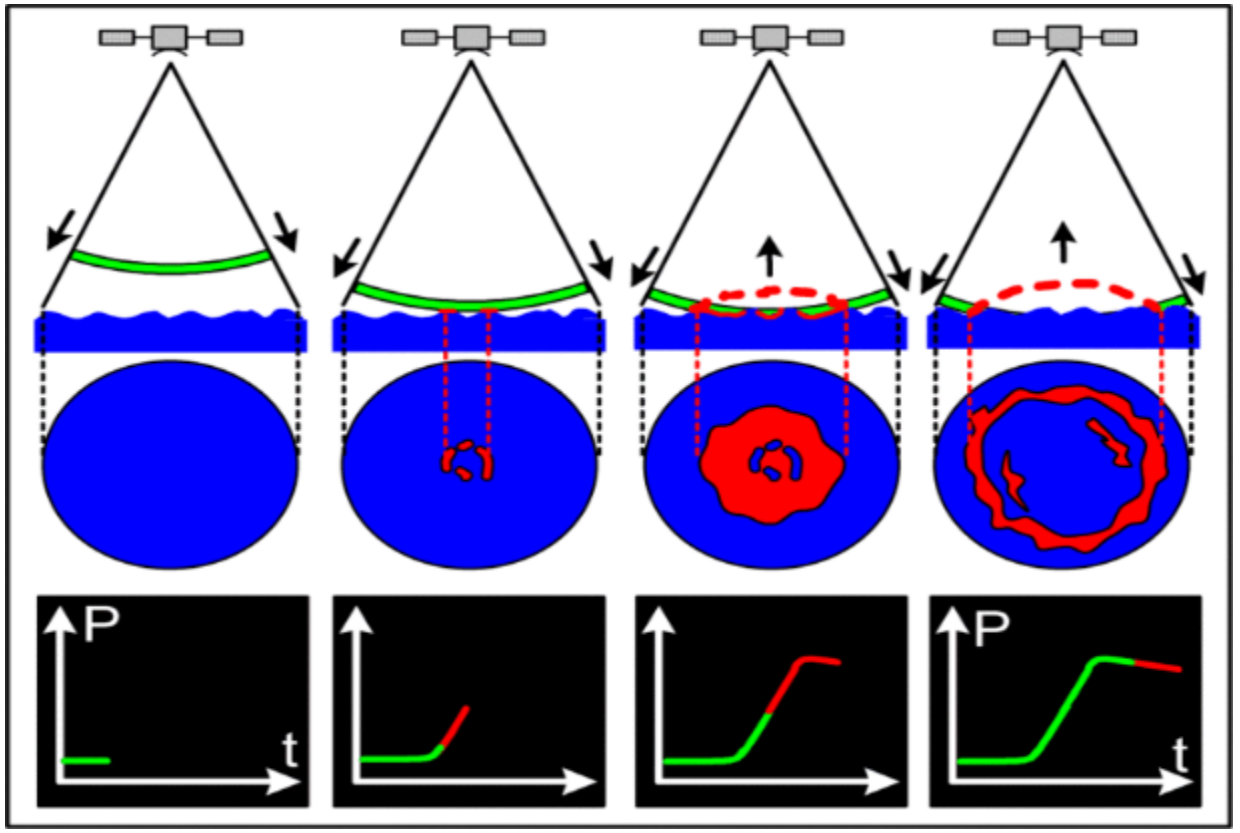


What is Satellite Altimetry?

Waveforms



The radar altimeter receives the reflected wave (or echo), which varies in intensity over time. Where the sea surface is flat, the reflected wave's amplitude increases sharply from the moment the leading edge of the radar signal strikes the surface.



The crest of one wave which cause the reflected wave's amplitude to increase more gradually. We can derive ocean wave height from the information in this reflected wave, since the slope of the curve representing its amplitude over time is proportional to wave height.

What is Satellite Altimetry?

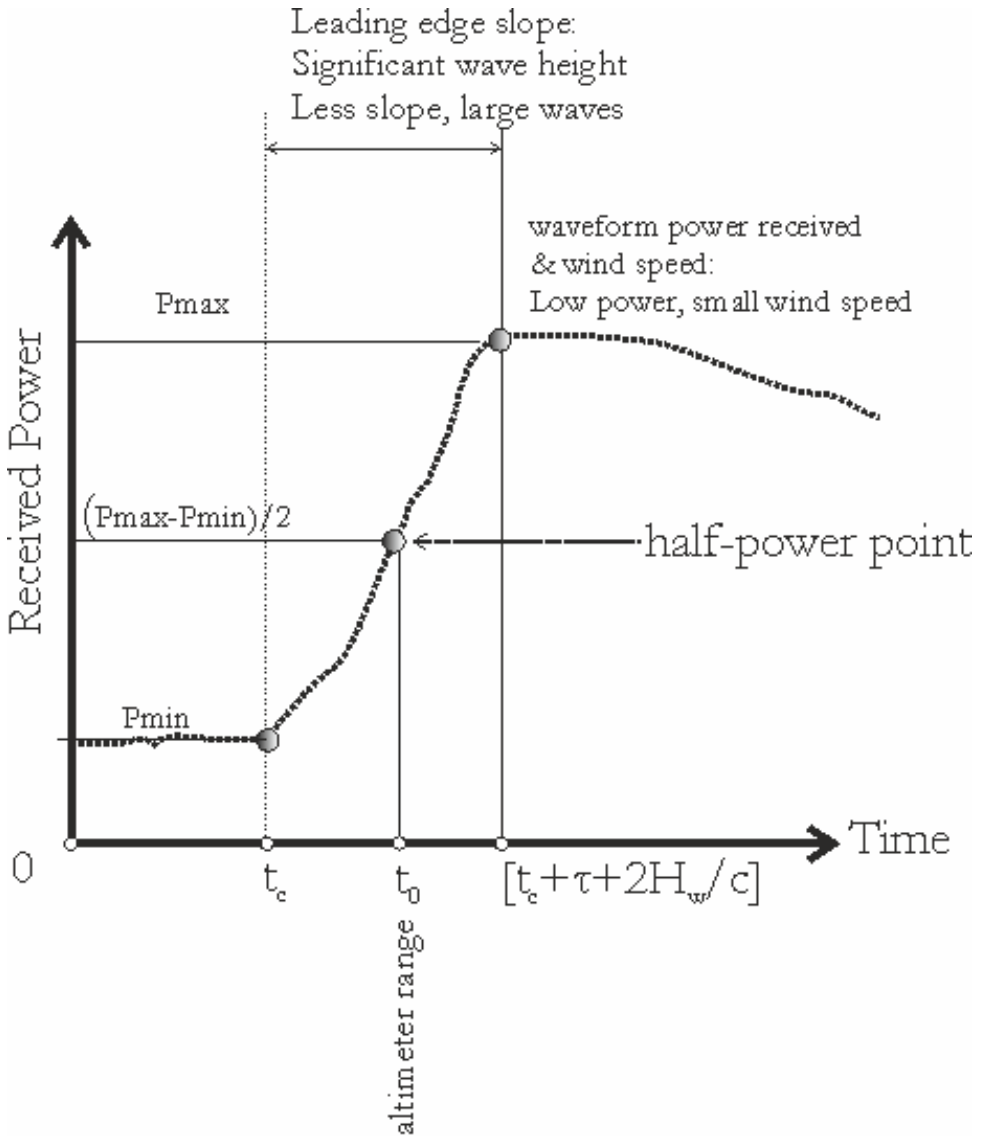
Waveforms

As well as sea surface height,

by looking at the return signal's amplitude, waveform and backscatter coefficient and surface roughness :

Wave height and wind speed over the oceans are measured

The Poseidon-3 altimeter on board Jason-3 emits in two frequencies, and by comparing the signals with respect to the frequencies used, interesting information can be extracted, e.g. rain rate over the oceans and detection of ice shelves.



What is Satellite Altimetry?

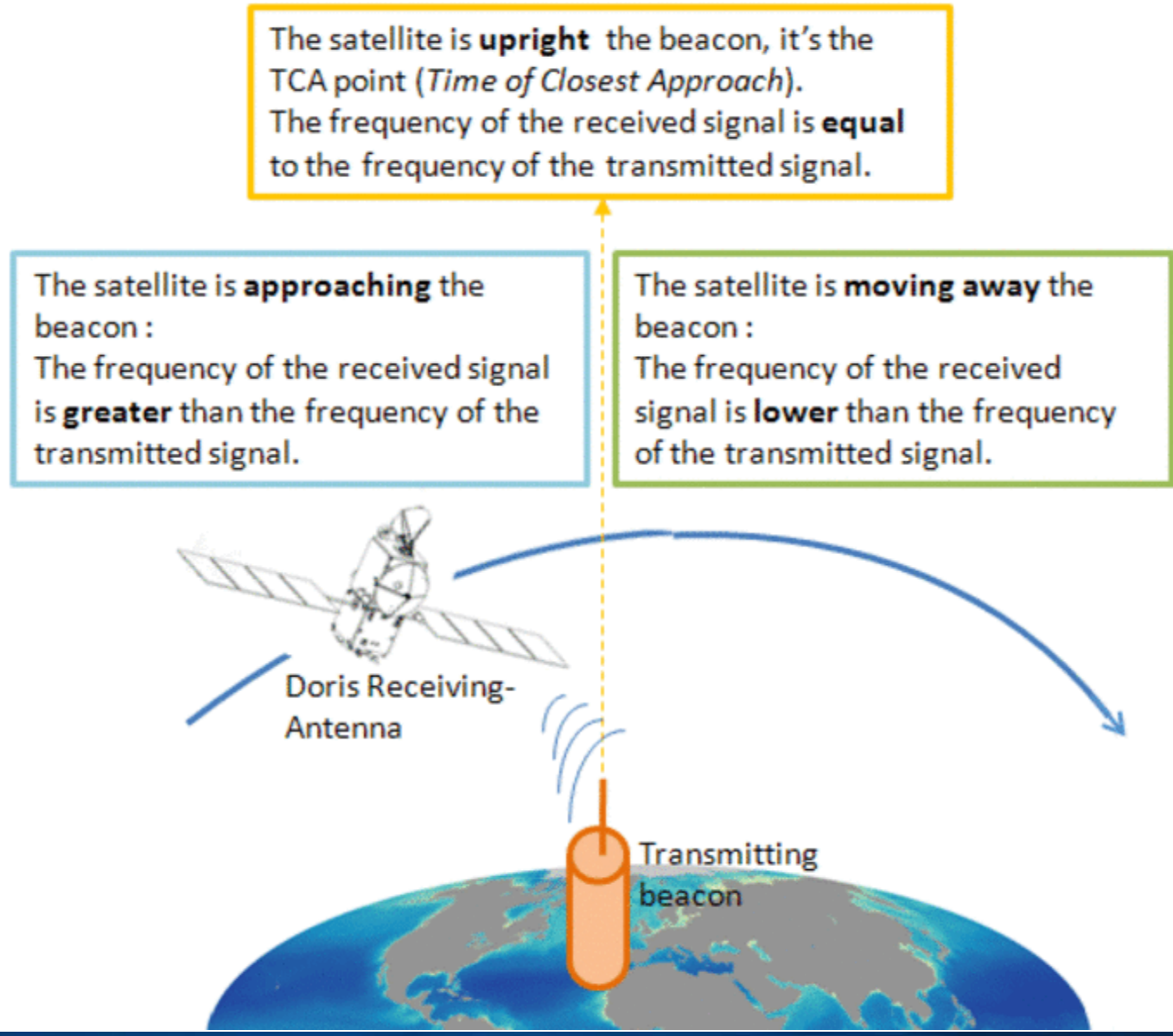
POSITIONING PRINCIPLE

The ability to precisely determine a satellite's position on orbit is a key factor in the quality of altimetry data.
The Doris system, based on the Doppler effect, contributes to this delicate orbitography exercise .

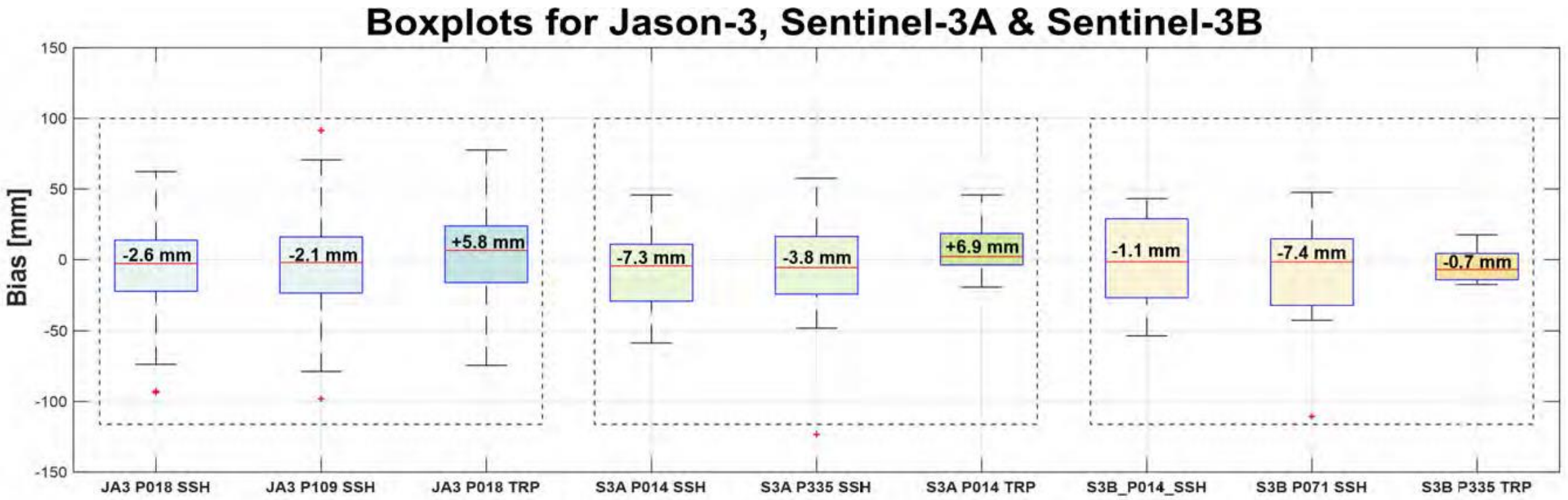
The Doris antenna onboard satellites receives signals emitted by the terrestrial stations network. When the receiver and the source are moving each other, the receiving wavelength differs from the emitting wavelength : it is the Doppler effect.

How does Doris work, VIDEO Pesentation

view on the network of Doris, VIDEO Presentation



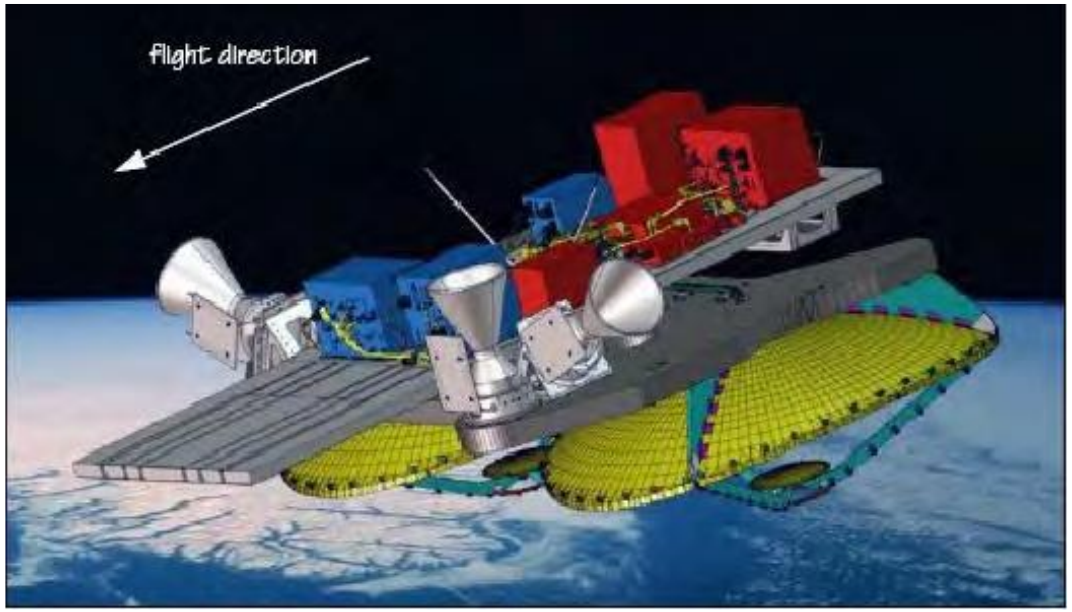
Cal/Val Summary



Altimeter Satellites

ESA Altimetric satellites

Cryosat-2: 2008



Sentinel-3A: 2016, Sentinel-3B: 2018

Altimeter Satellites

ESA new missions

CRISTAL (Launch 2025)

- Ka-band and Ku-band altimeter
- Interferometer
- Polar regions monitoring
- Sea-surface, freeboard

Sentinel-6/Jason-CS (15-Nov-2020 Launch),

Altimeter Satellites

ICESat-2 Mission (NASA)

- Advanced Topographic Laser Altimeter System (ATLAS) 10,000 laser pulses a second
- λ= 532 nanometers, Green,
- splits the single laser into six beams,
- 6 beams in 3 pairs,
- Measurements every 70 cm, along orbit,
- Footprint 17 m diameter,
- Range ±3cm,
- Monitor Land Ice Elevation.

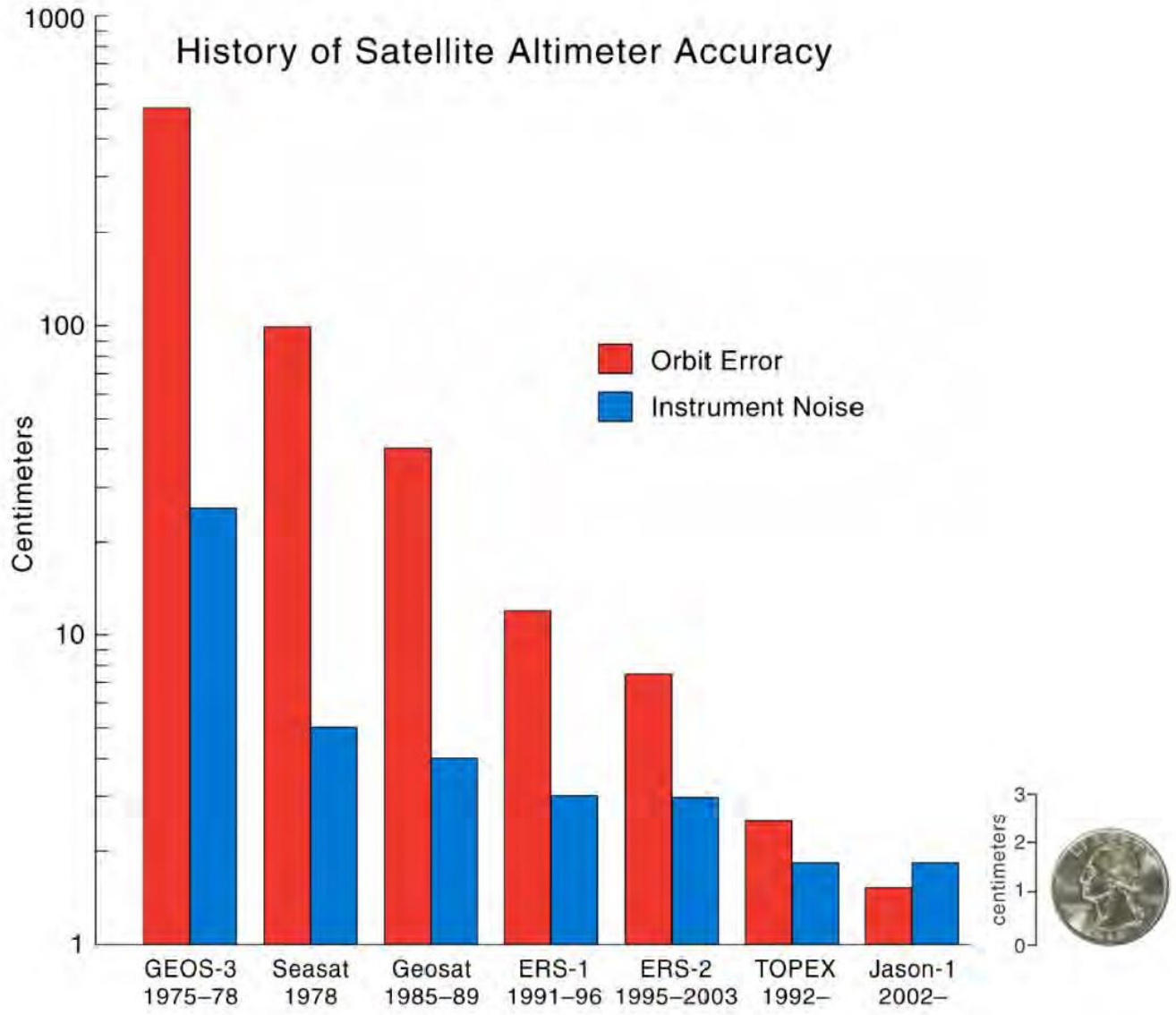
Altimeter Satellites

Past missions

- Geosat
- ERS-1
- Topex/Poseidon
- ERS-2
- GFO
- Jason-1
- Envisat
- Jason-2
- HY-2A
- Spot

Current missions

- Cryosat
- Saral
- Jason-3
- Sentinel-3A
- Sentinel-3B
- CFOSAT
- HY-2B
- HY-2C
- HY-2D
- Sentinel-6MF
- Swot



Applications

Oceanography:
sea level height , ocean currents, ocean circulation.

Geodesy:
shape and size of the Earth, position and motion of continents and tectonic plates

Hydrology:
height and volume of lakes, rivers, and reservoirs

Land use and land cover: deforestation, urbanization, agricultural practices

Cryosphere: thickness and movement of ice sheets and glaciers

Atmospheric science: atmospheric pressure, temperature, humidity

Coastal zone management: erosion, sedimentation, sea level rise

Navigation: improve the accuracy of GPS

Climate Research

Applications

Ocean

- **Sub-mesoscale circulation:** A number of processes, especially concerning vertical exchanges in the upper-ocean occurs at "sub-mesoscale" (i.e. features less than 25 km in size)
- **Large-scale circulation:**

- **Mesoscale circulation:**
  several hundred kilometers and time scales ranging from a few days to several months

- **Operational oceanography:**
  Describe and forecast the global ocean in real time and at any moment from satellites and in situ observations.

- **Tides Ocean:**
  tides represent more than 80% of the variability of the surface in the open ocean.

- **Mean Sea Level:**
  As global temperatures rise, mean sea level is rising with them.

Source of Data

Altimetry products/contacts in Europe

- **CMEMS** (https://marine.copernicus.eu)
- **AVISO** (https://www.aviso.altimetry.fr)
- **ESA** (http://altimetry.esa.int)
- **Radar Altimeter Database** (RADS): (http://rads.tudelft.nl/rads/rads.shtml)

Data Access

Aviso FTP (ftp-access.aviso.altimetry.fr) is an authenticated FTP

AVISO - CNES DATA CENTER, For registered users (https://aviso-data-center.cnes.fr/)

LIVE ACCESS SERVER (LAS) (https://ferret.pmel.noaa.gov/LAS/**)**

- visualize data with on-the-fly graphics;
- request custom subsets of variables in a choice of file formats;
- access background reference material about the data (metadata);
- compare (difference) variables from distributed locations.

The OPeNDAP service (https://www.aviso.altimetry.fr/en/data/data-access/thredds-data-server.html)

allows you to access remote data over the internet

GRIDDED DATA EXTRACTION TOOL (https://www.aviso.altimetry.fr/en/data/data-access/gridded-data-extraction-tool.html)

enables to extract a data sub-set from the Aviso gridded datasets.

Software & Tools

Aviso'VIZ (https://aviso.oceandatalab.com/)

Visualization portal

Ocean Data Lab (https://ovl.oceandatalab.com/)

PASS LOCATOR (https://www.aviso.altimetry.fr/en/data/tools/pass-locator.html**)**

Google Earth KMZ

Software

Basic Radar Altimetry Toolbox (BRAT) (https://www.altimetry.info/)

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Thank You