Ocean Altimetry and Sea Level

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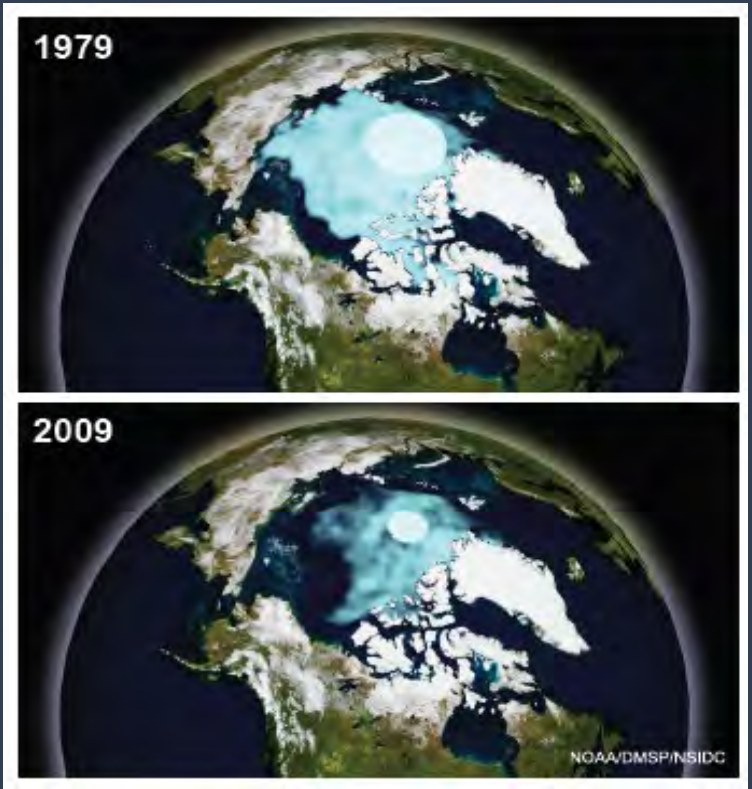
Contents

- What is Satellite altimetry?
- Why need it for monitoring climate & sea level change?
- How do satellites measure ranges?
- What technology is available?
- How do we calibrate satellite measurements?
- Future of altimetry.

Why Altimetry for Climate Change



Earth Warms, Ice caps melt

- Ice melts at rates -5m/yr as measured over 1000km sections;
- Greenland looses about -250Gtons/yr.

Sea measurements & satellite altimetry

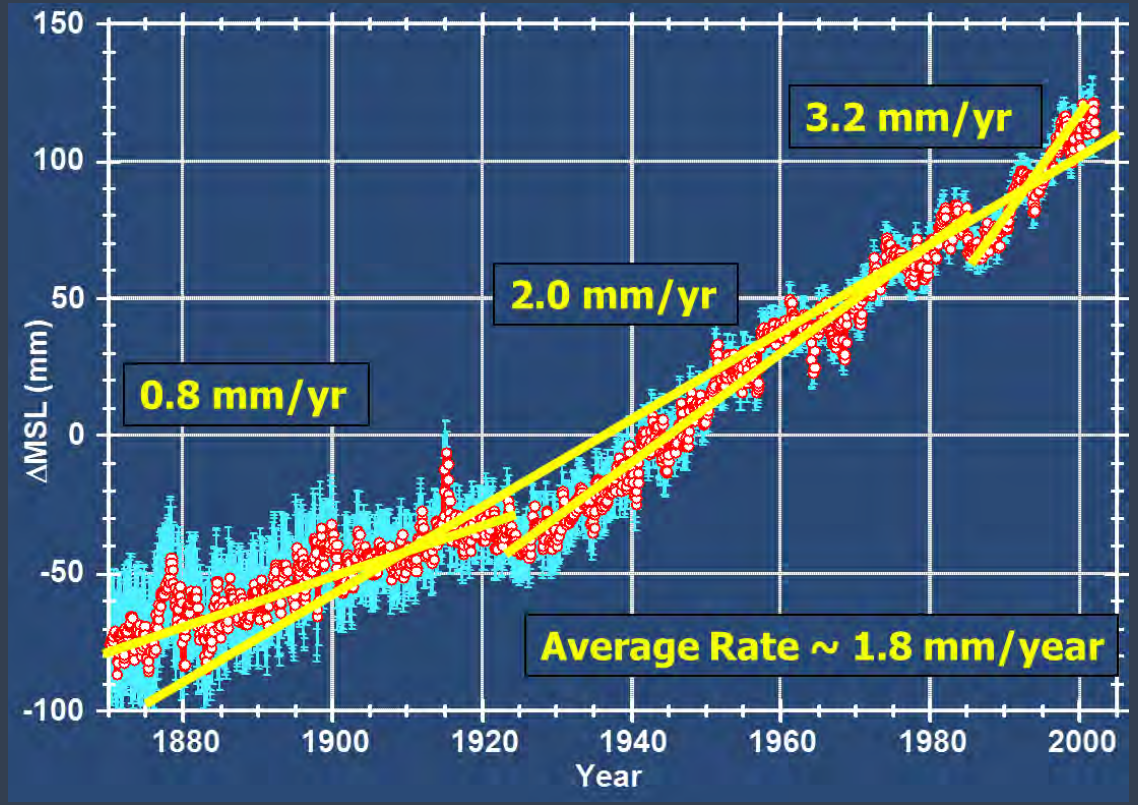
Earth warms today.

- 90% of this energy goes to ocean.
- Ocean warms mostly in the upper 75m,

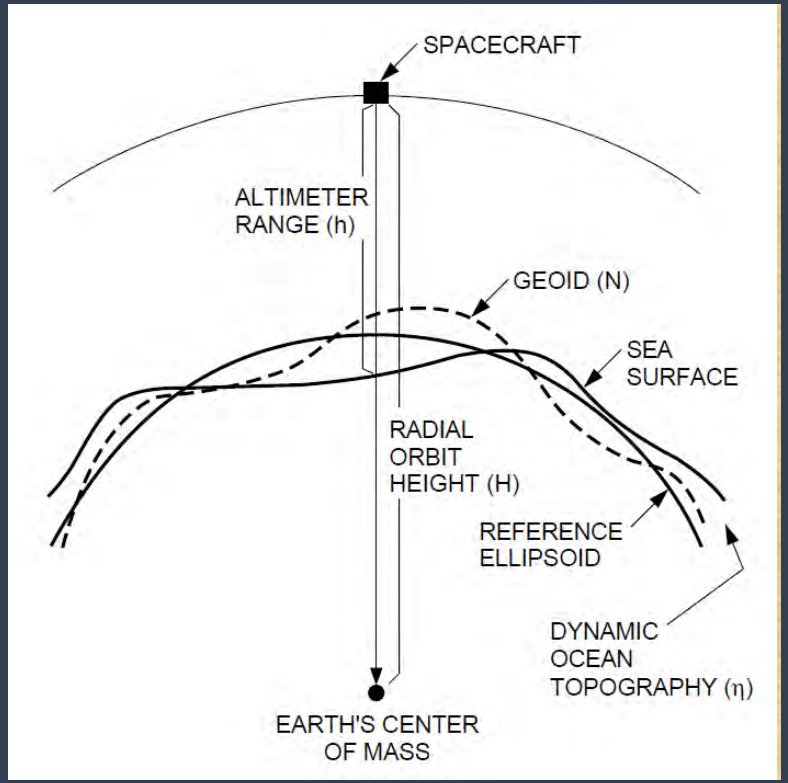
Up to 2100:

- 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.

Sea level rises at +3.2mm/yr

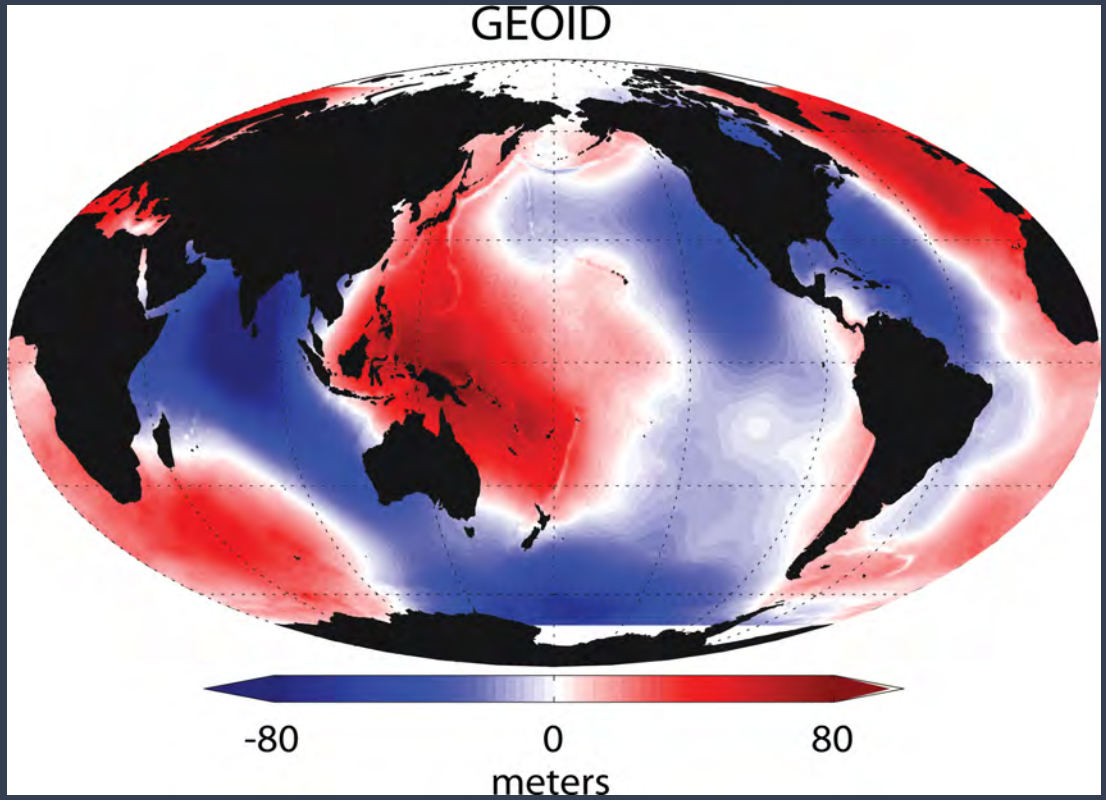


Principle of Satellite Altimetry



Determination of Mean Sea Surface

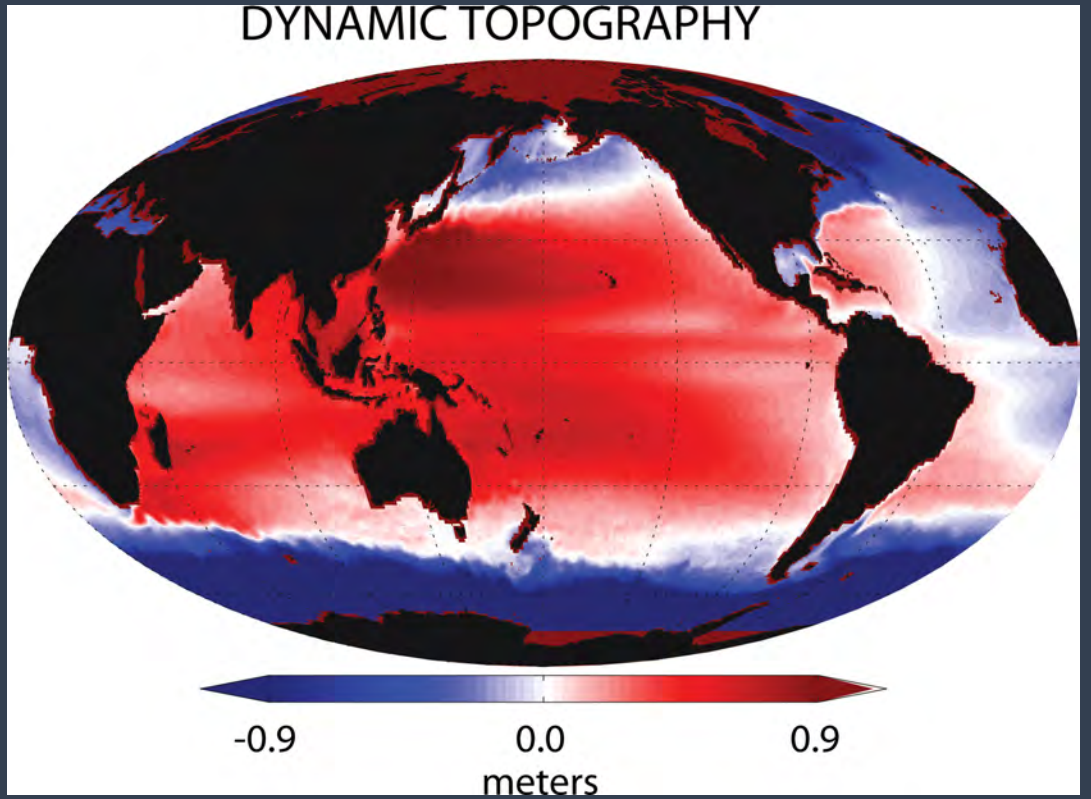
MSS= Geoid-MDT



Mean Dynamic Topography

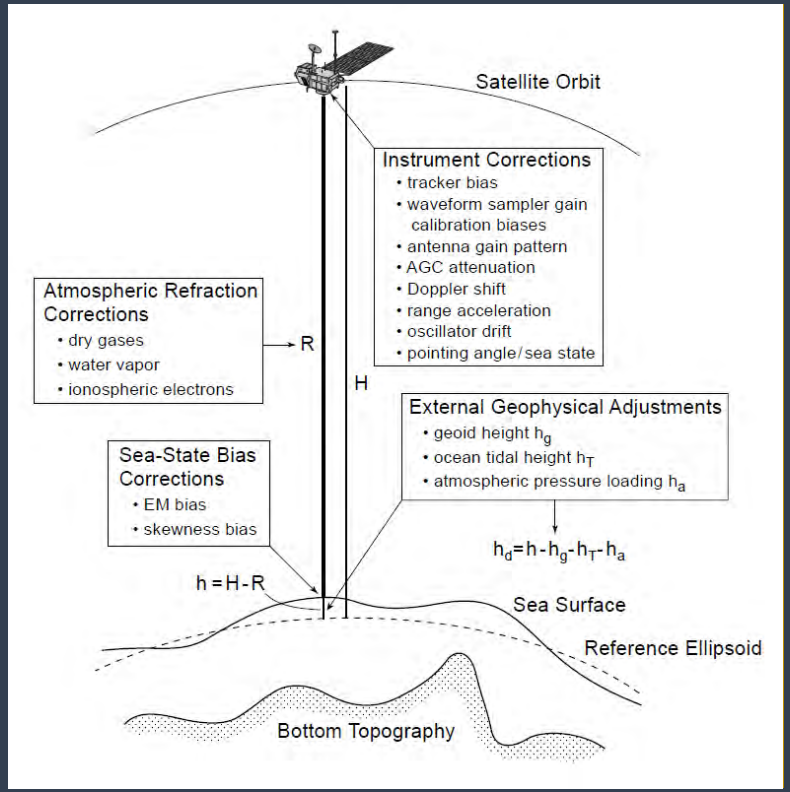
Caused by:

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

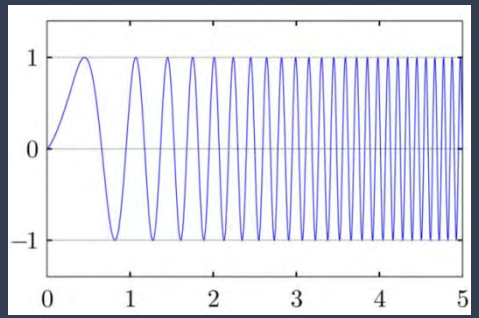


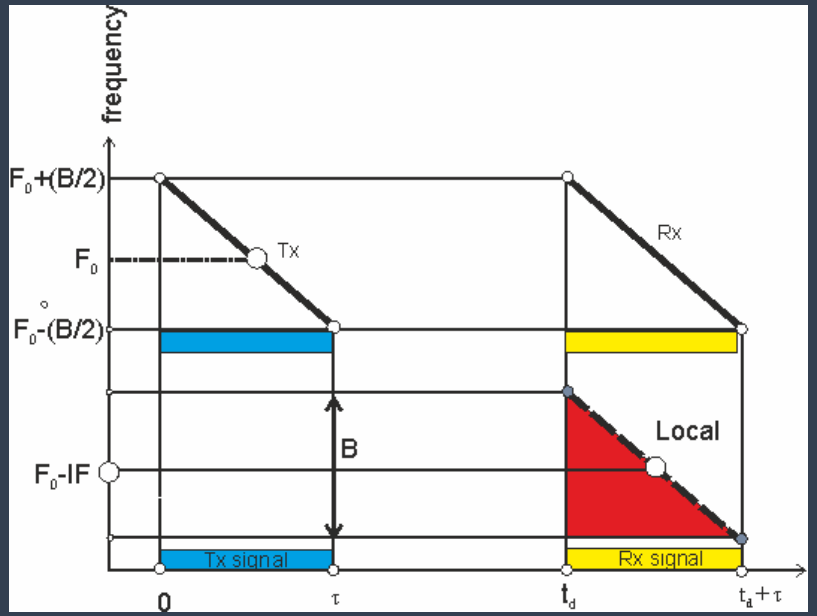
Sea surface and its riddles

What altimetry measures

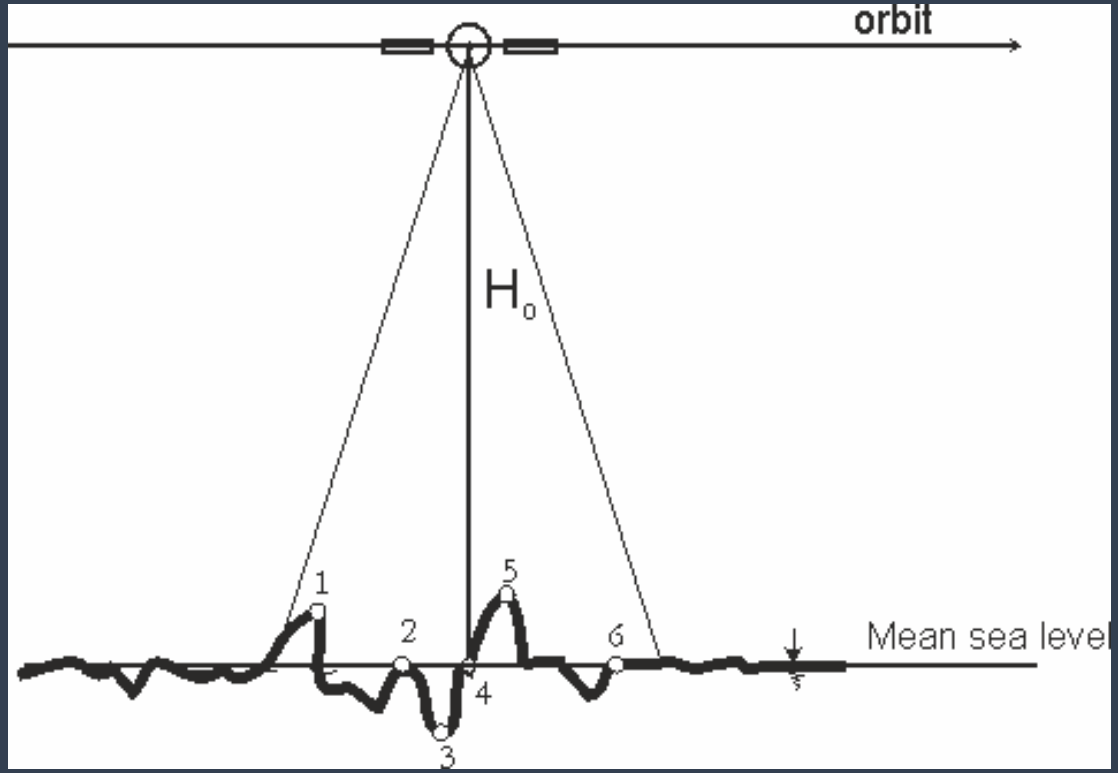


Chirp transmission and reception

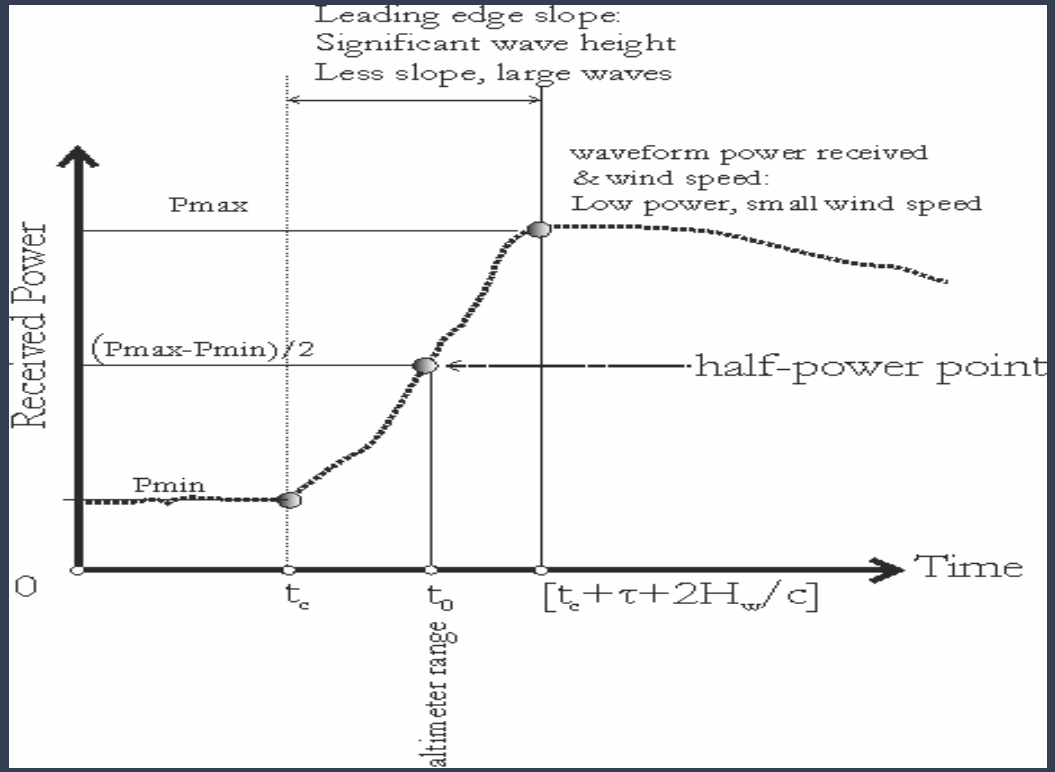




Reflecting wave facets



Return waveform at altimeter

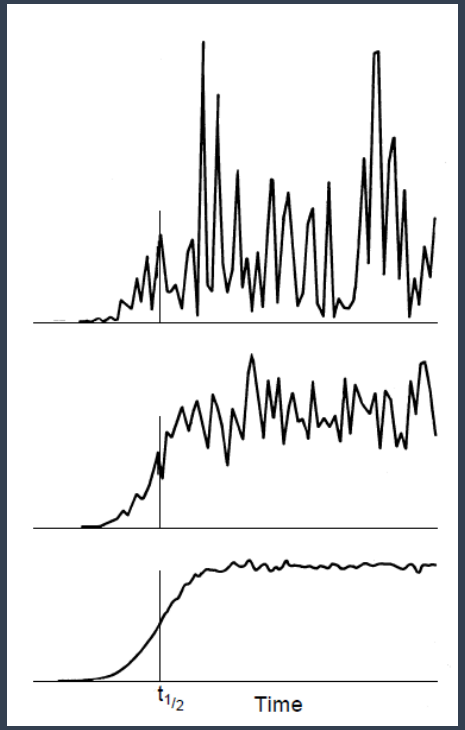


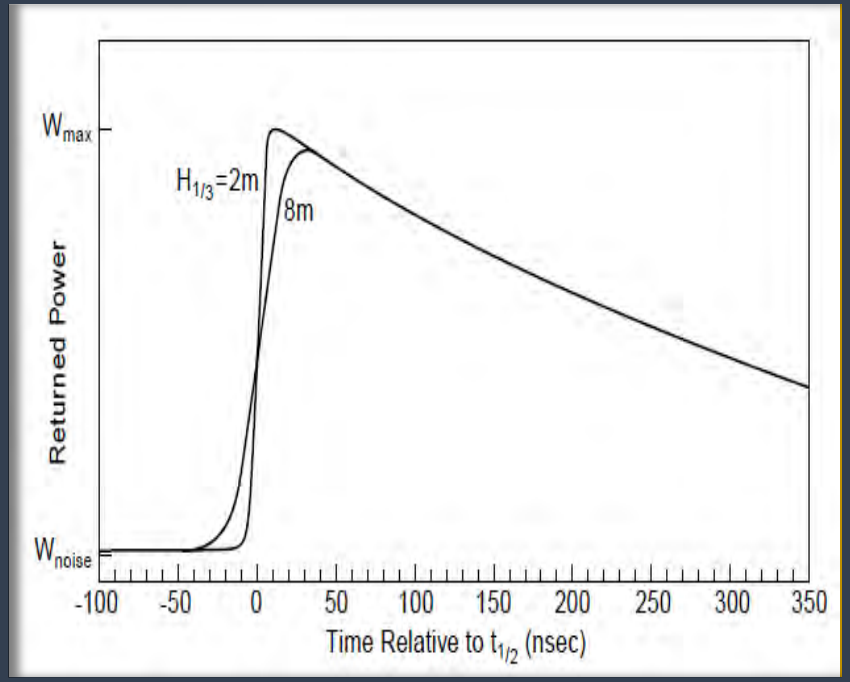
Altimeter Wave forms

Individual wave form

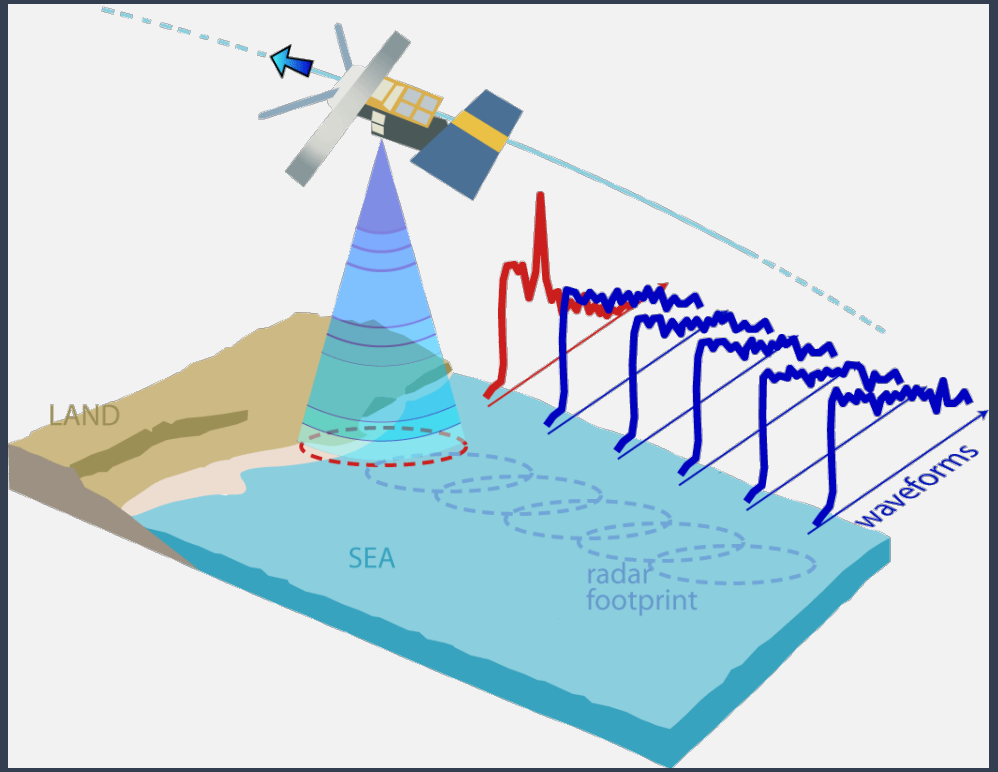
Average of 25

Average of 1000

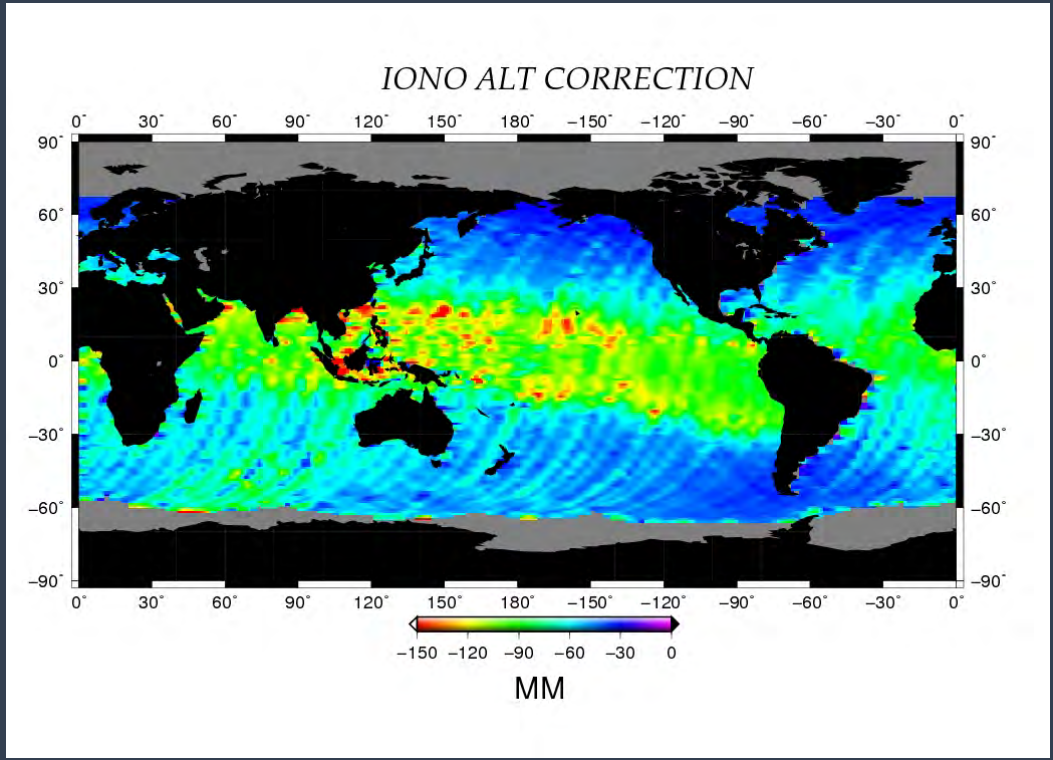




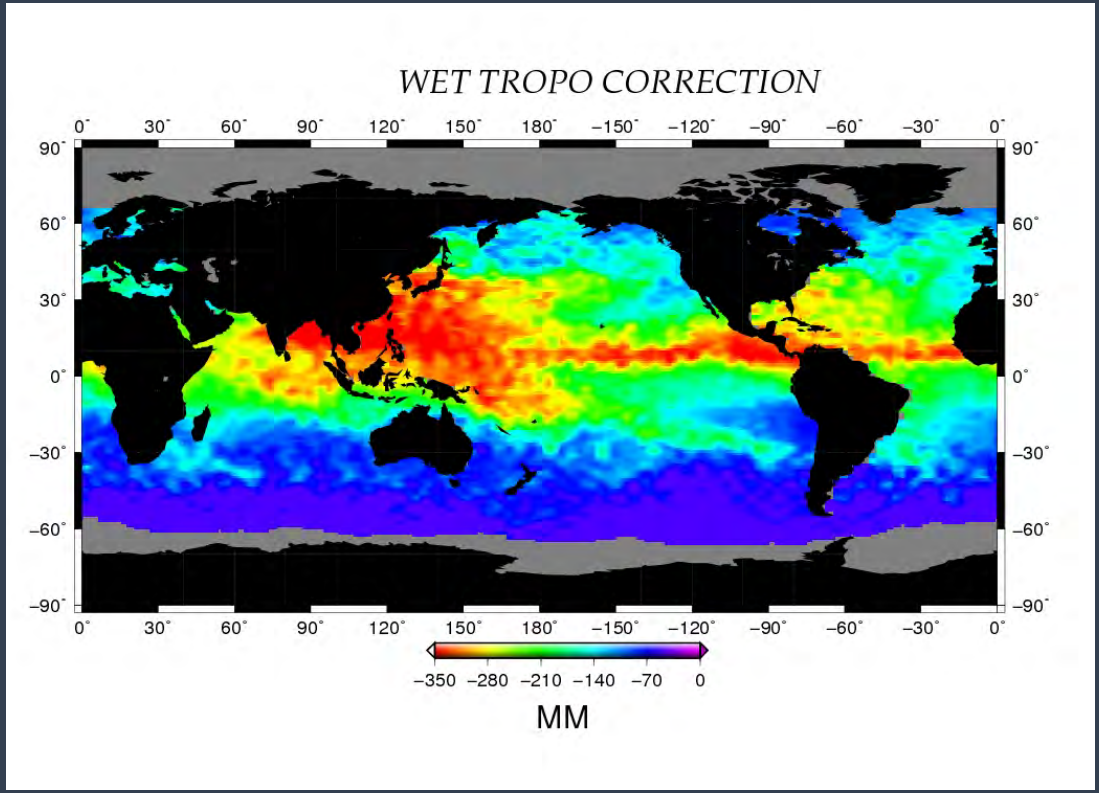
Satellite Altimeter in Operation



Ionosphere range Corrections



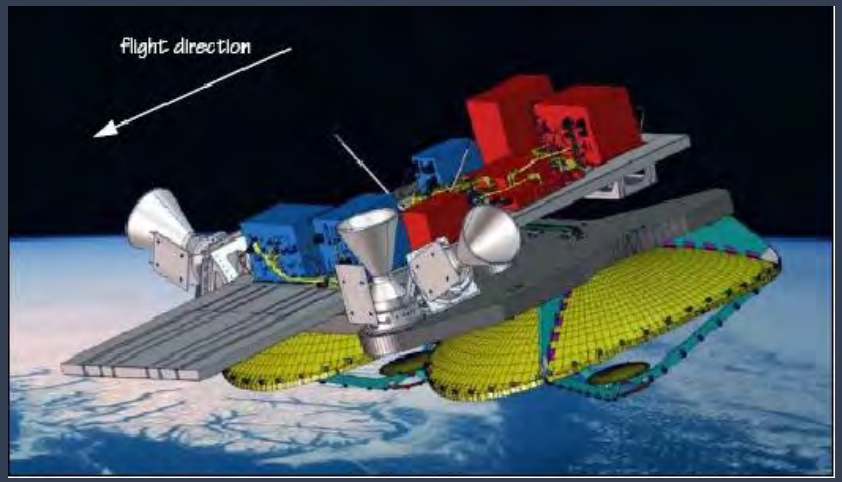
Wet Troposphere Corrections



Satellite altimeters

ESA Altimetric satellites

- Cryosat-2: 2008

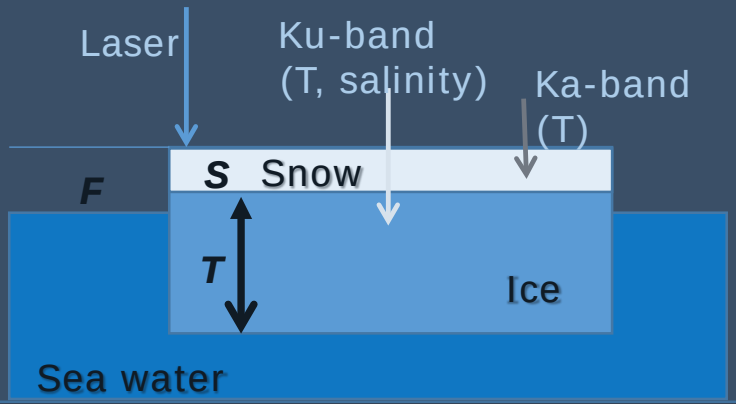


- Sentinel-3A: 2016, Sentinel-3B: 2018

ESA new missions

CRISTAL (Launch 2025)

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

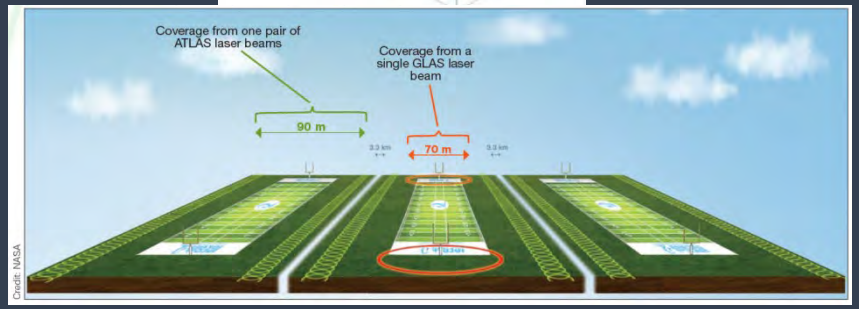


Sentinel-6/Jason-CS (15-Nov-2020 Launch),

ICESat-2 Mission (USA)

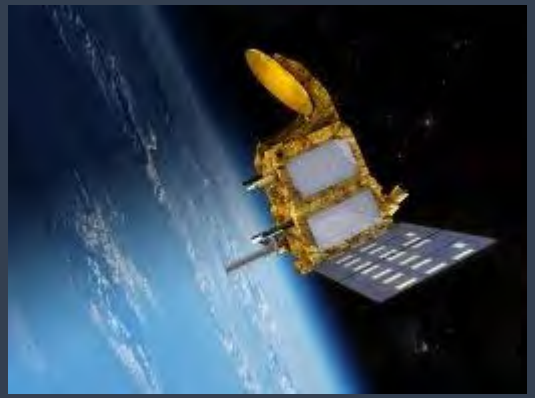
Advanced Topographic Laser Altimeter System (ATLAS)

- 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.



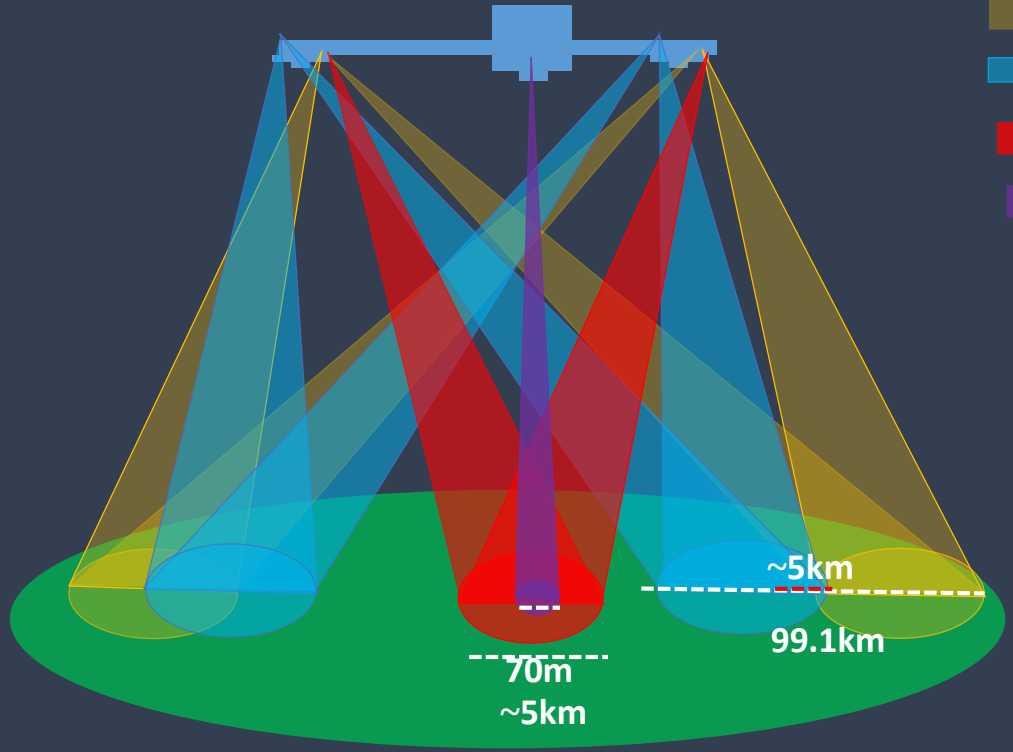
France-India, China satellites

- SARAL/AltiKa:
  - 25-Feb-2013 (France/India),
  - **Ka-Band**: 35.75 GHz,
  - **2-3 km close** to coast,
  - Less impact from rain (**2.6% loss**),
  - Icebergs and ships are monitored.



- HY-2A and HY-2B: China:
  - 15-Aug-2011 (HY-2A),
  - 24-Oct- 2018 (HY-2B)
  - **Ku-Band**, 13.58 GHz,

China “Quanlan” satellite

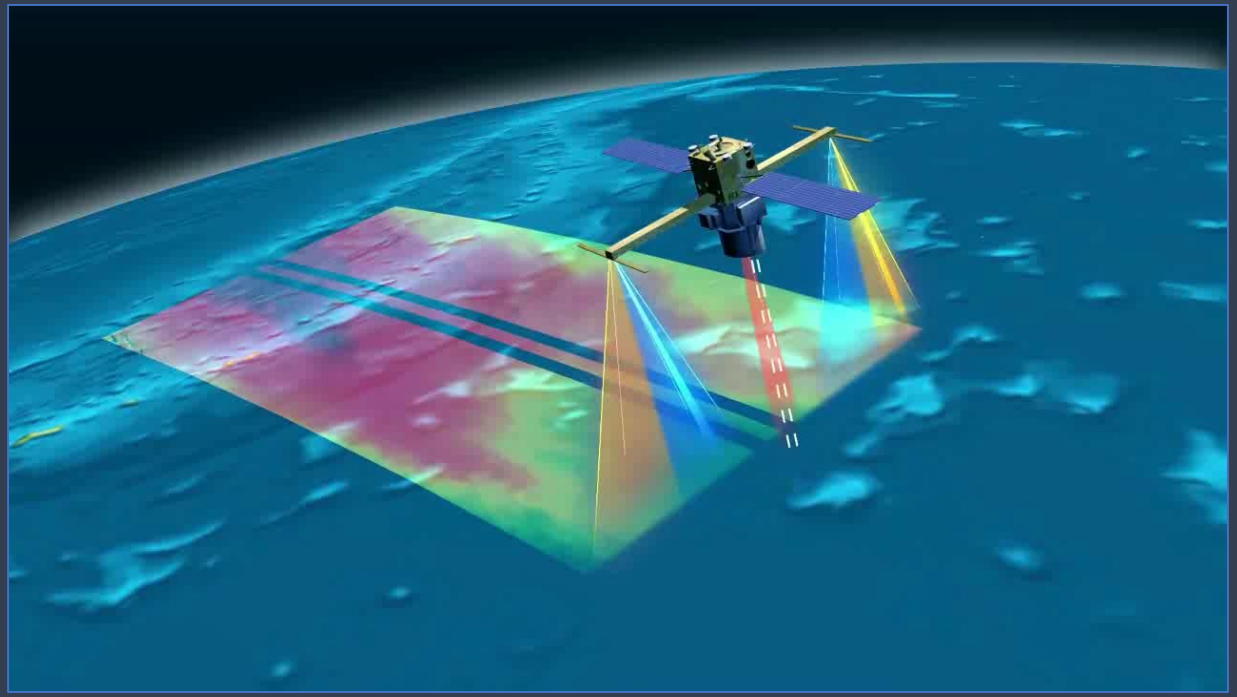


China “Quanlan” Altimeter

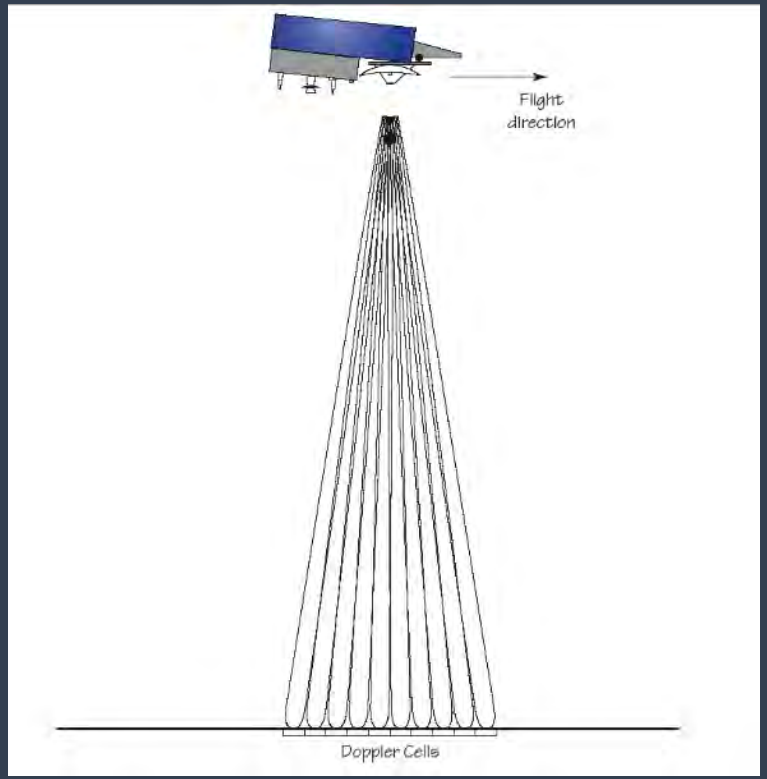
Dual-frequency altimeter

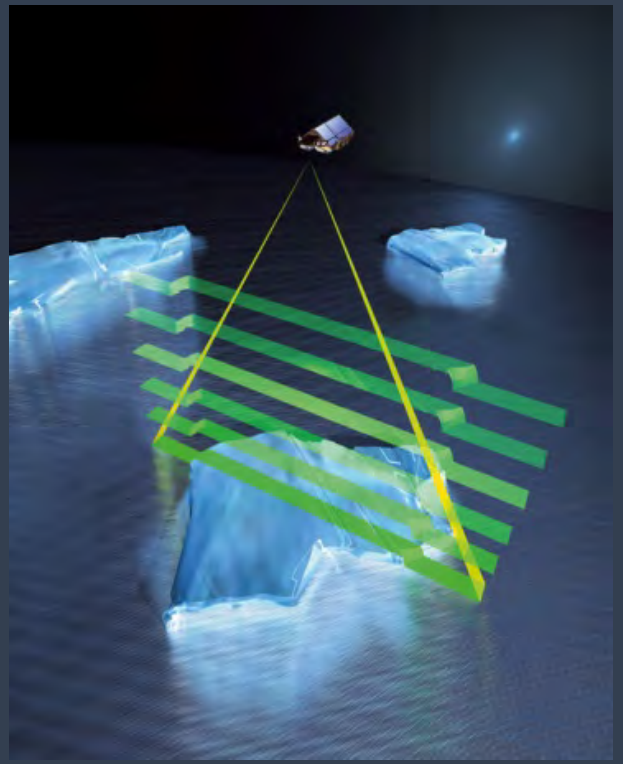
Interferometer:
- wide swath of ~100 km,
- overlap of ~5 km (Ka- & Ku-band),
- nadir swath of ~5 km (Ka-Band).

Ocean Lidar
- (Blue + Green)
- Nadir footprint of ~70 m.

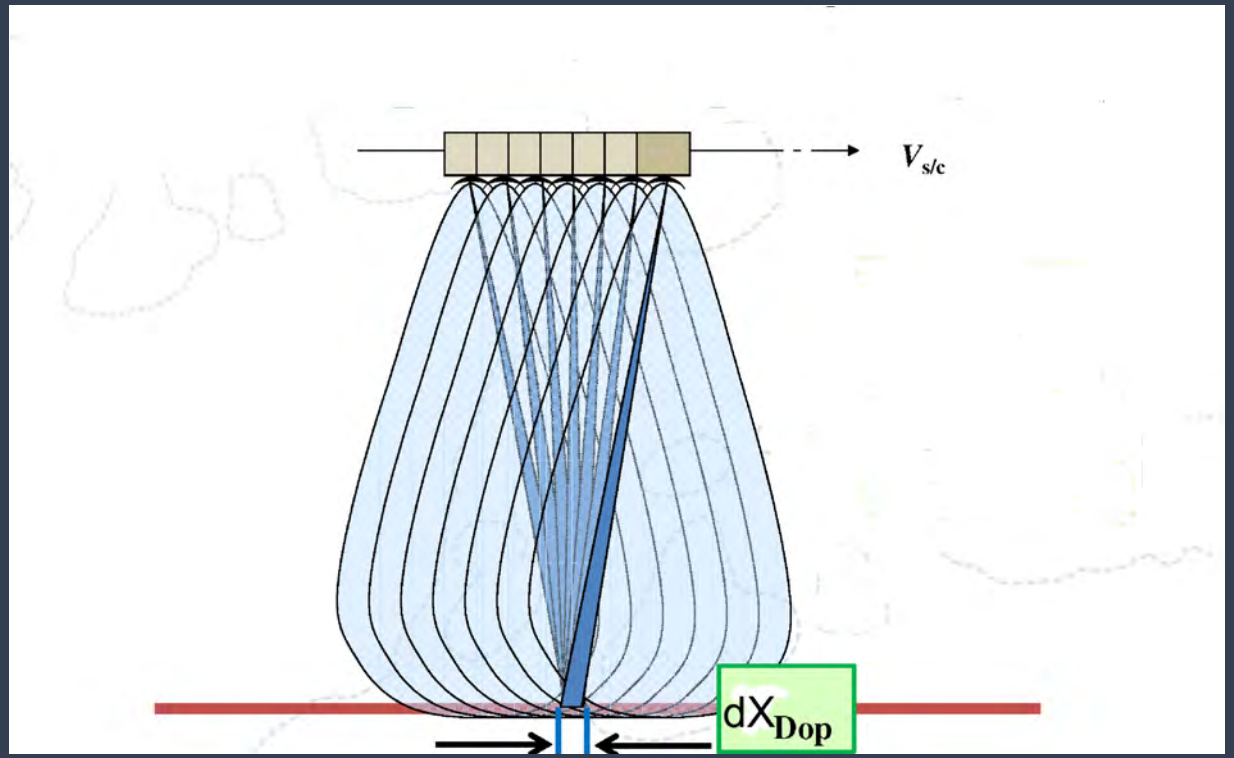


SAR Altimetry today (ESA)

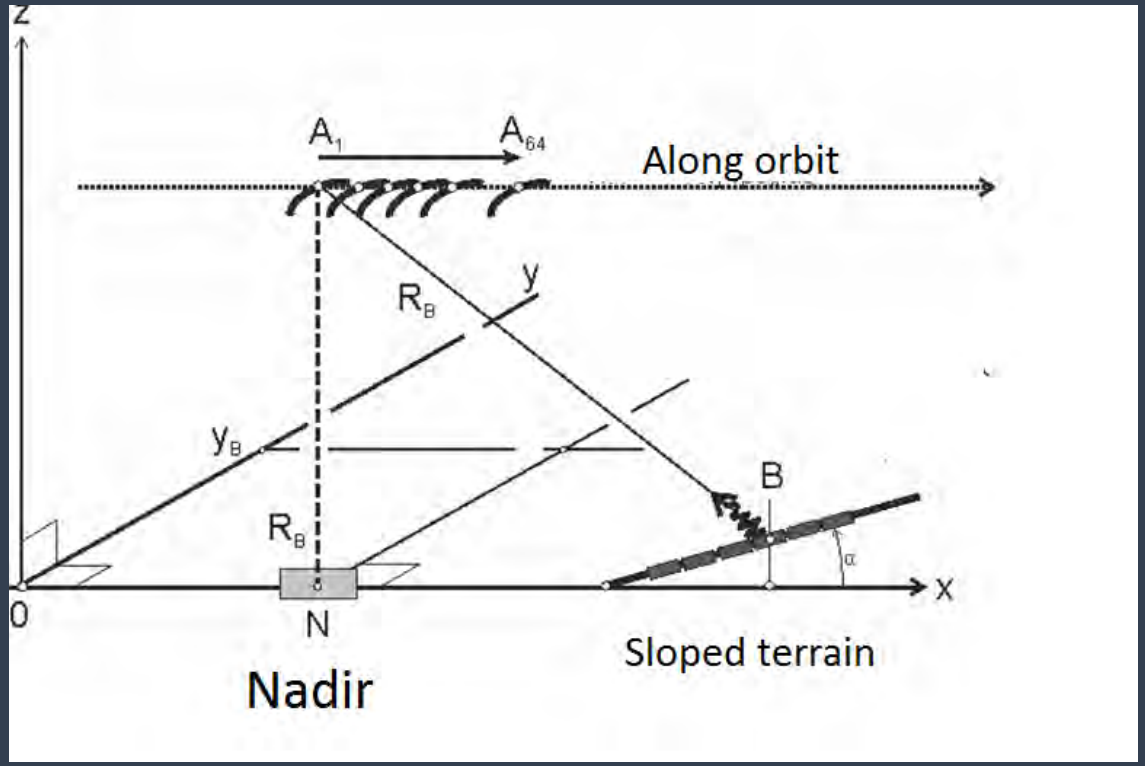




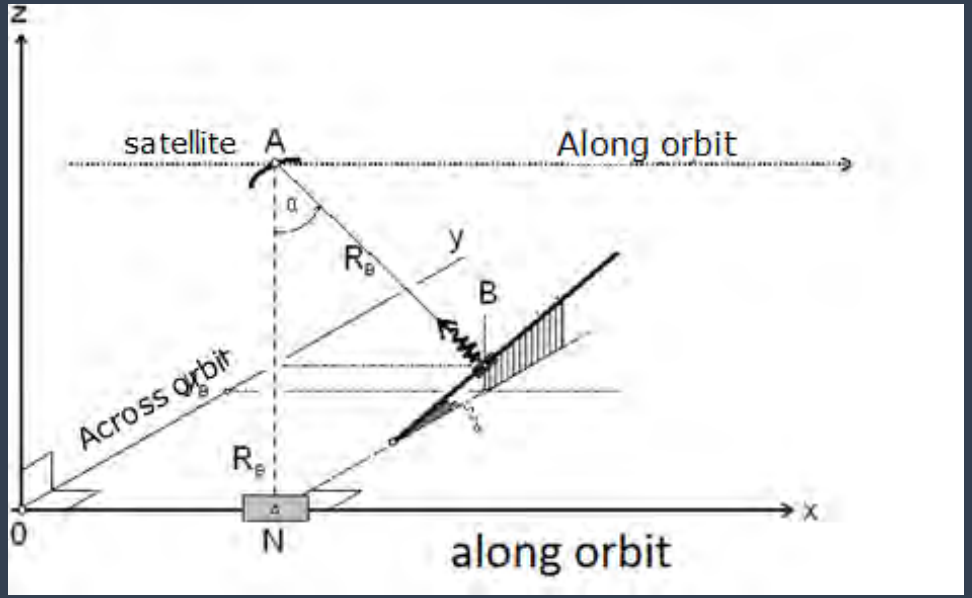
Along track: Delay-Doppler Altimetry

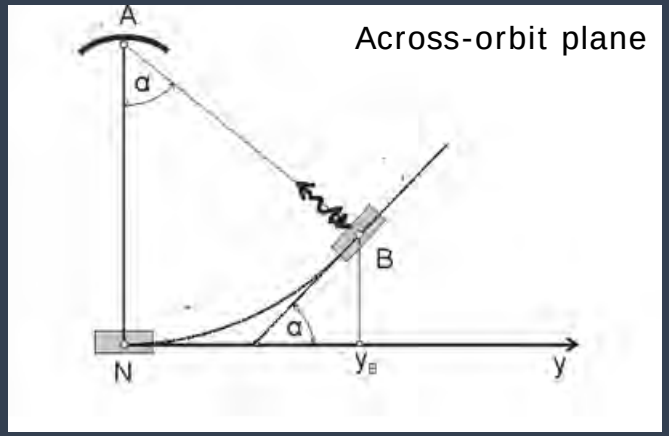


Along-track resolution



Across-track error in sloped terrain

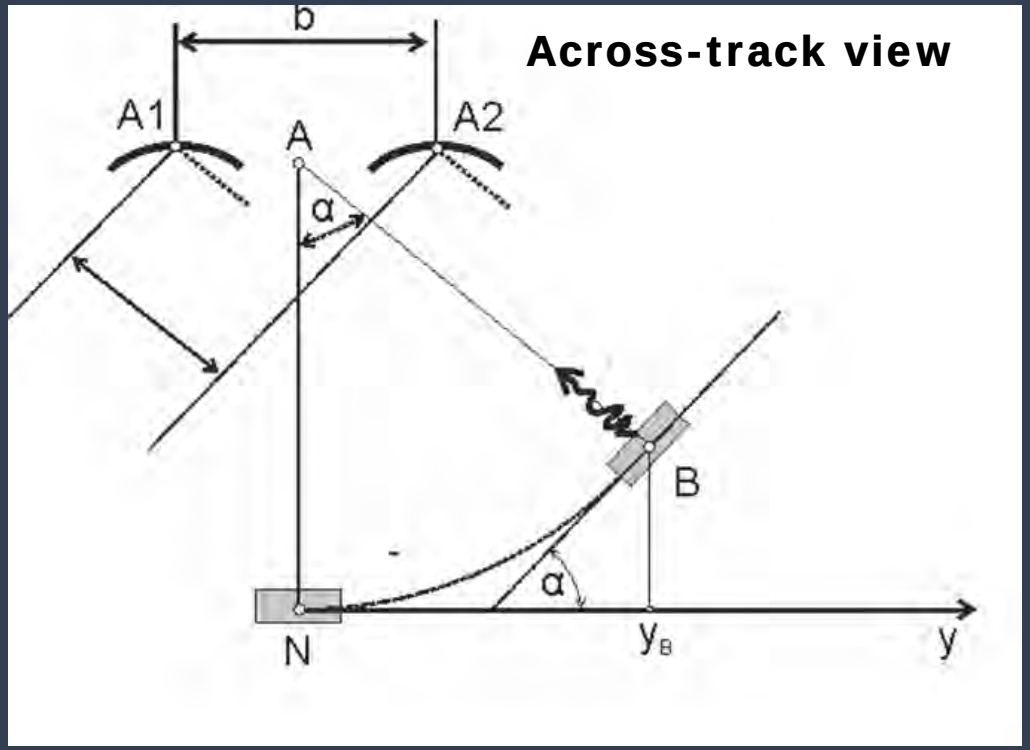




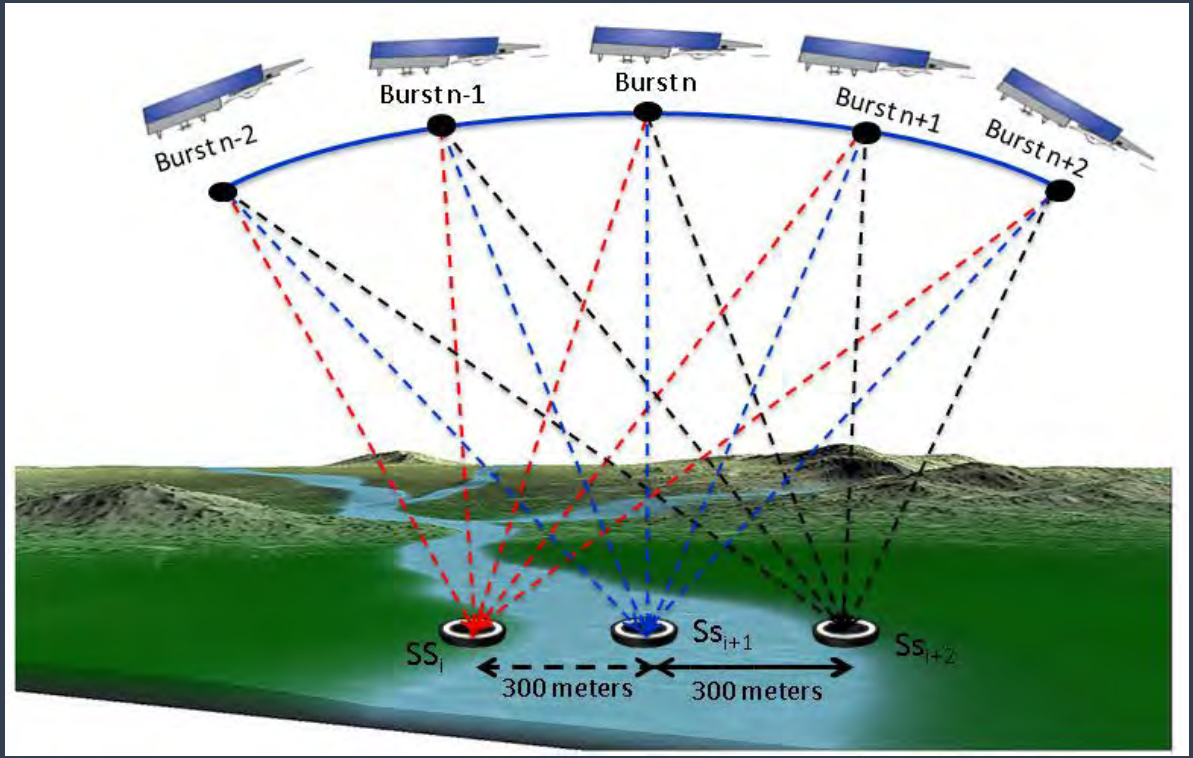
When earth surface has slope:

- Range is assumed at nadir,
- Altimetry height incorrect;
- Slope determined by 2 antennas.

Across-track ranges: Interferometry

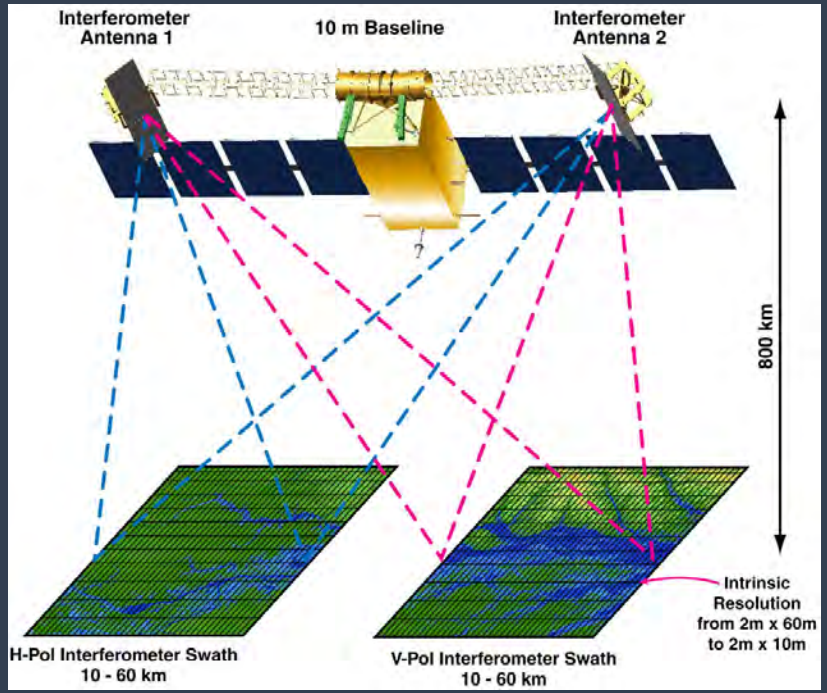


SAR altimetry over rivers



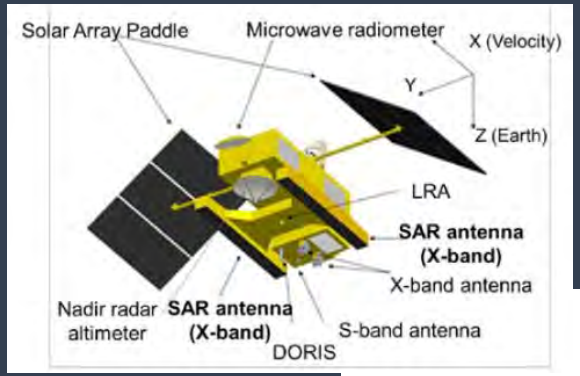
SWOT Mission in 2020 (US/France)

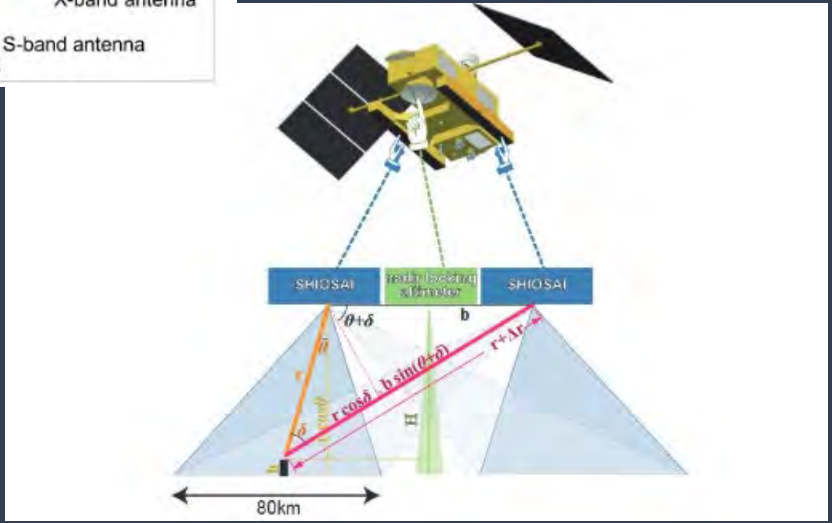
- Orbit height= 970 km,
- 22-day repeat,
- Frequency= Ka-band, Interferometer,
- Height precision= ~1 cm @ 1 km resolution,
- Swath= **120 km**,
- Spatial resolution <**100 m**.

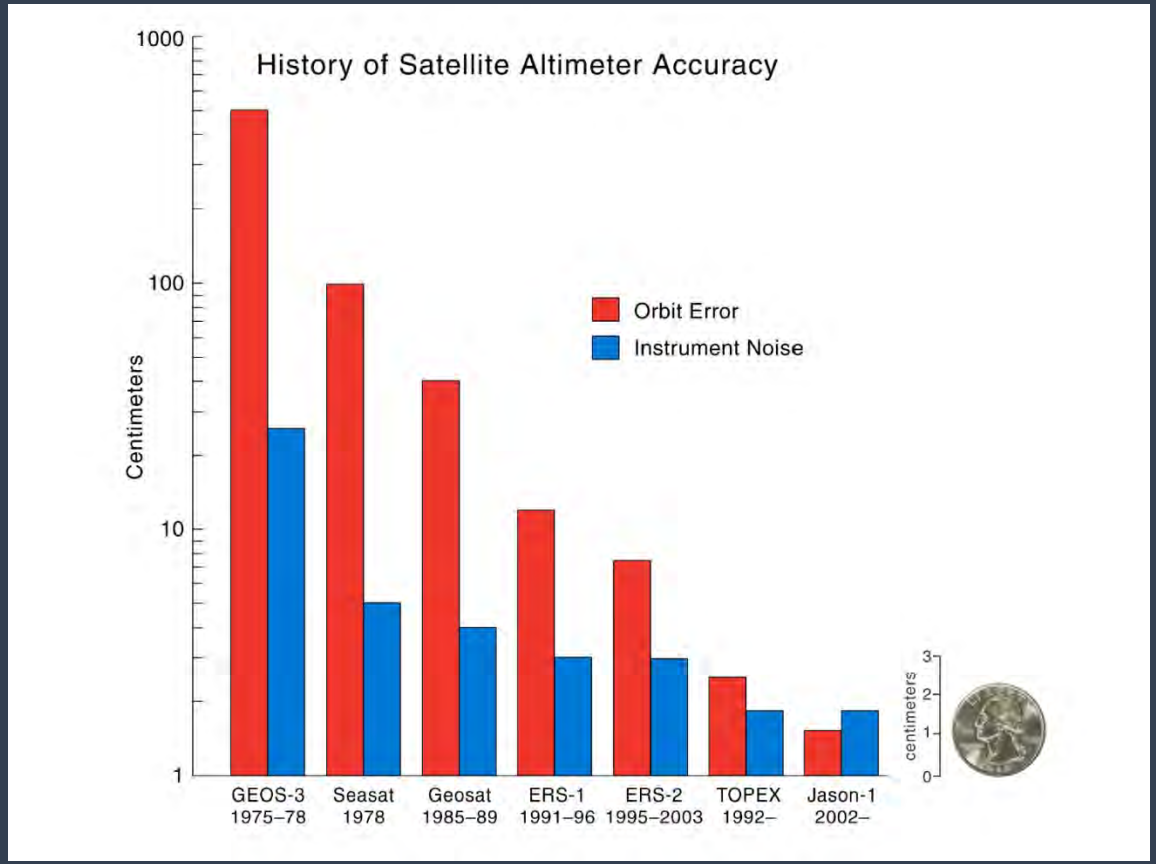


COMPIRA satellite altimeter (Japan)

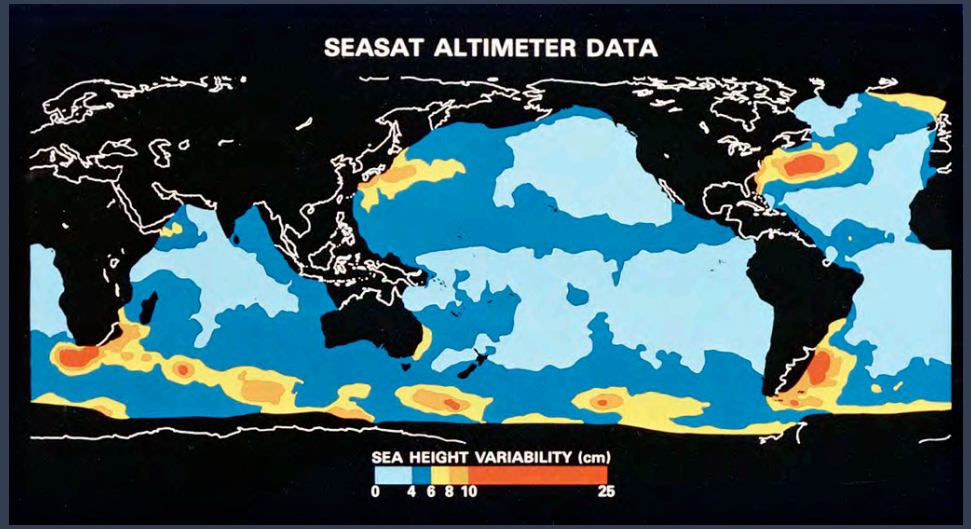
- Built by **Japan**,
- To be launched 2020 (?),
- Altitude= 937 km,
- Repeat orbit 10 days,
- 2 **X-band SAR** antennas,
- **3m** SAR baseline (X-Band),
- **80 km SAR swath**, with a 20 km separation,
- 1 nadir altimeter: **4km** footprint.



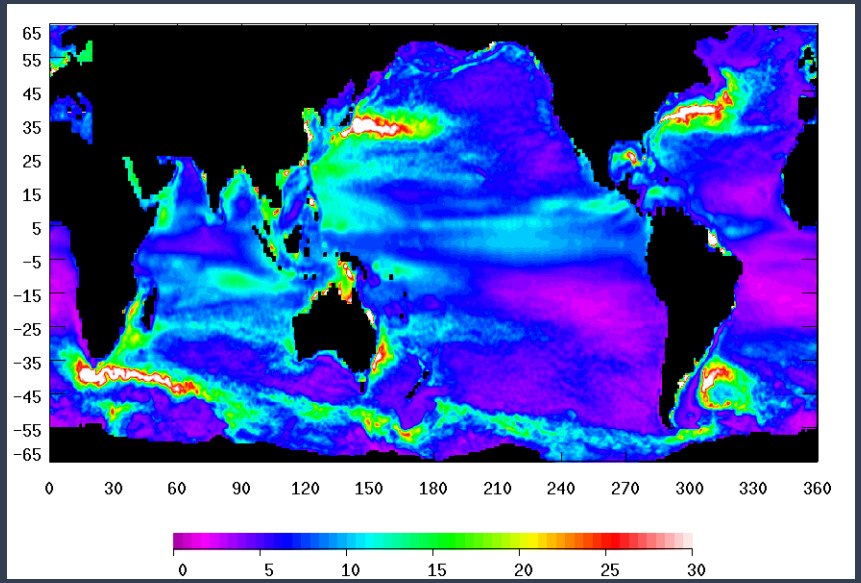



History of Satellite Altimeter Accuracy
1000
100
10
1
Centimeters
Orbit Error
Instrument Noise
GEOS-3 1975–78
Seasat 1978
Geosat 1985–89
ERS-1 1991–96
ERS-2 1995–2003
TOPEX 1992–
Jason-1 2002–
centimeters
3
2
1
0

Sea-surface height monitoring

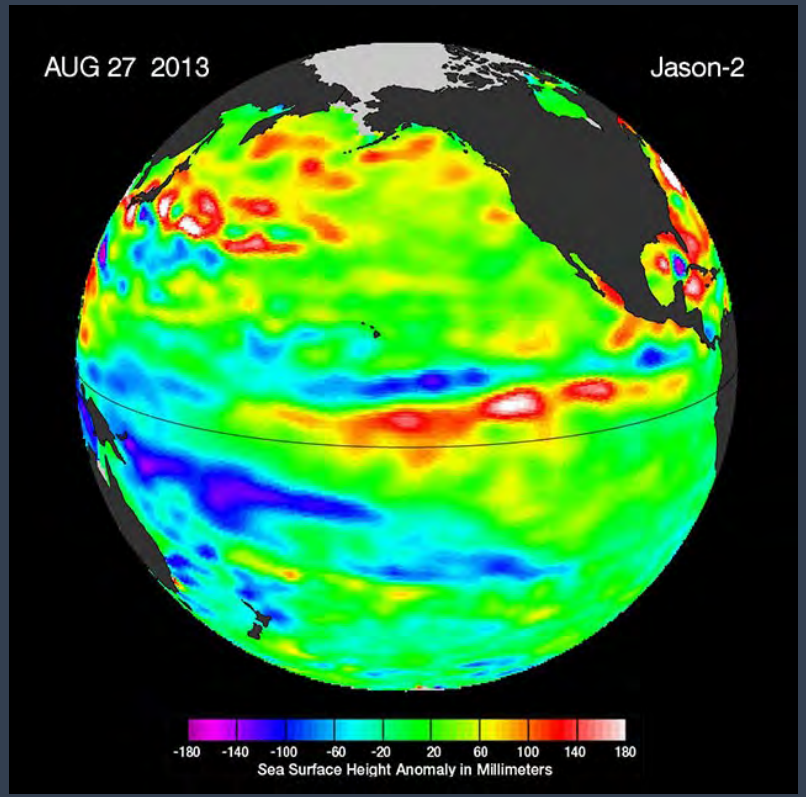


1978

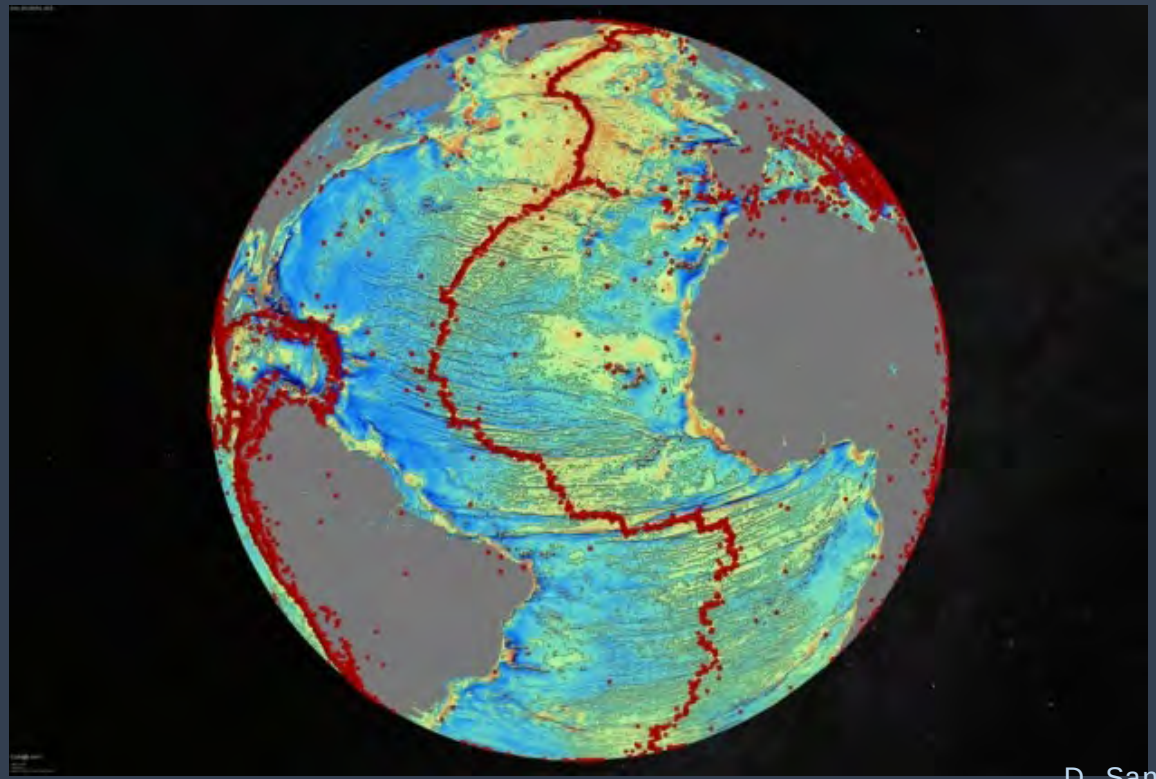


TOPEX/Poseidon & ERS Data 1992

Sea Surface heights from Jason-2

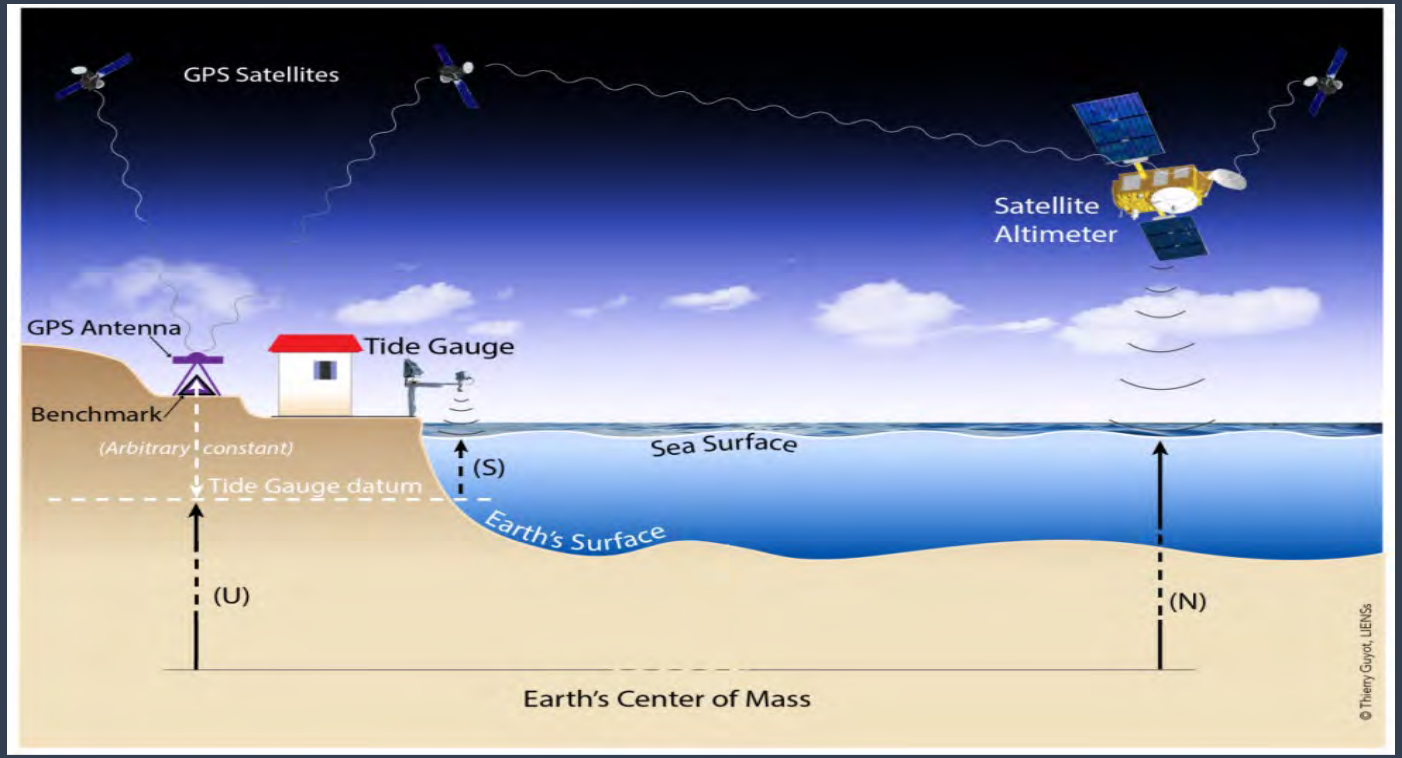


Uncharted sea-mountains by Altimetry



D. Sandwell,et al., Science, 2014

Calibration and Validation



Satellite calibration history

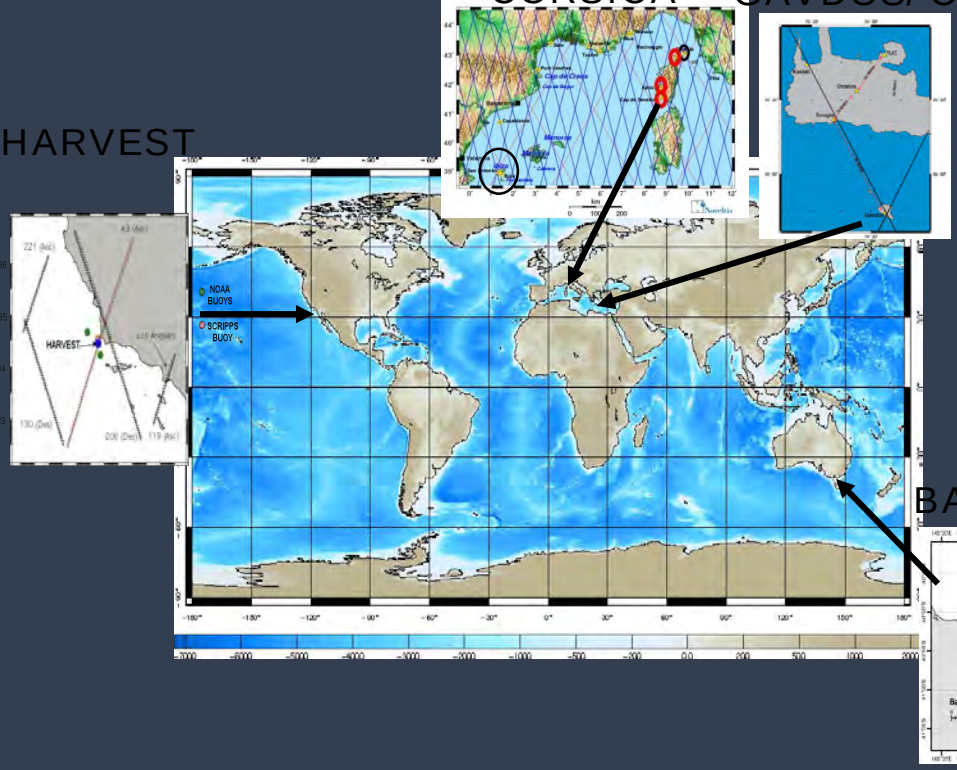
- Acqua Alta Tower, Venice, Italy
- Platform in Adriatic Sea, Italy,
- Installed 1970 for CNR,
- 16 km off Venice, 16m depth.
- Absolute calibration site for ERS-1 (Francis, 1992)
- Satellite flew directly overhead
- Tide gauges & sensors on platform
- GPS campaigns (1990, 1991) to link tide gauge to regional SLR network.
- Designed for limited campaign
- “Calibration” based on instrument.

World Distributed calibration sites

CORSICA

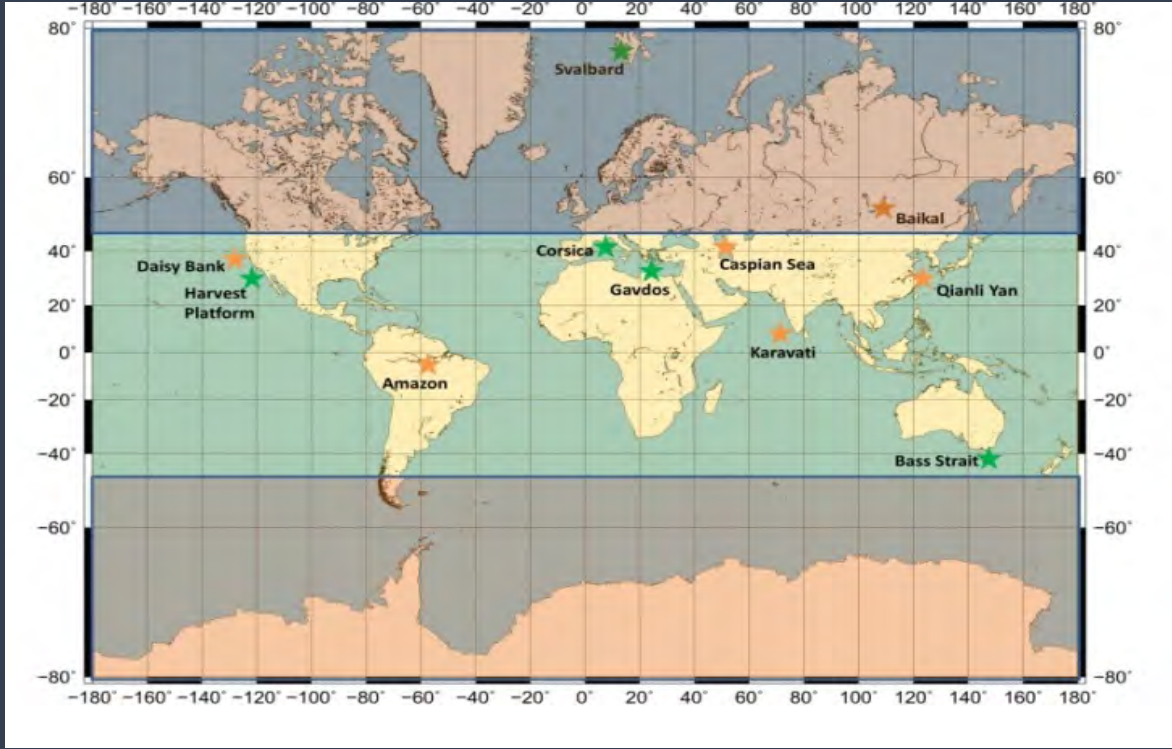
GAVDOS/ Crete

HARVEST

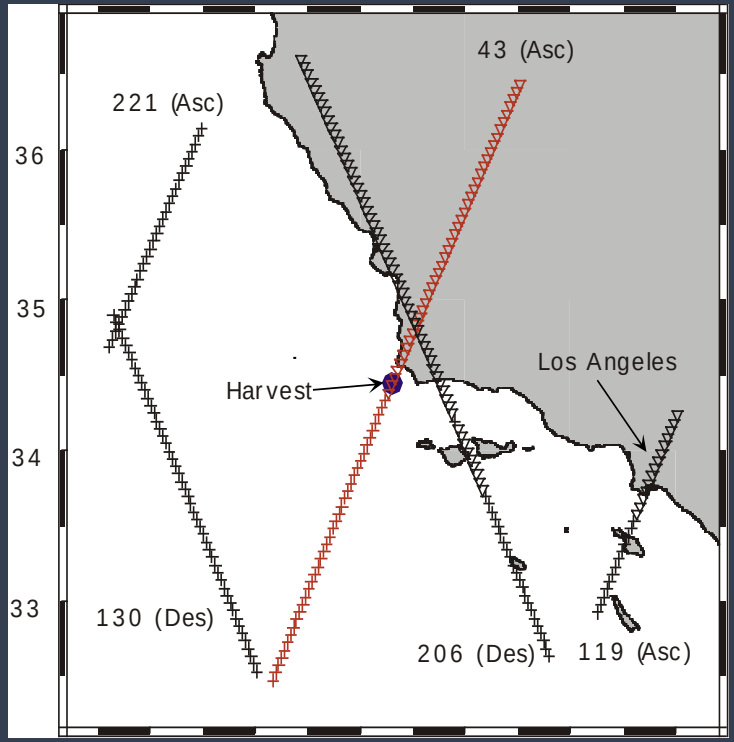


BASS STRAIT

World Cal/Val sites for altimetry

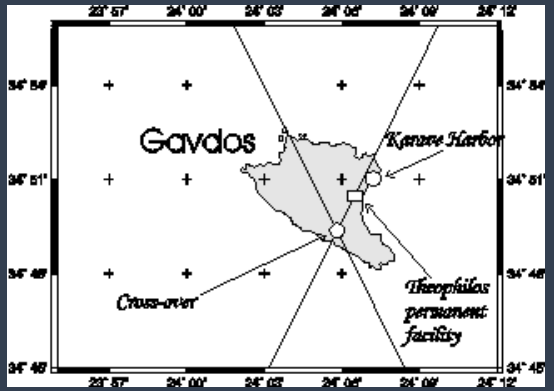


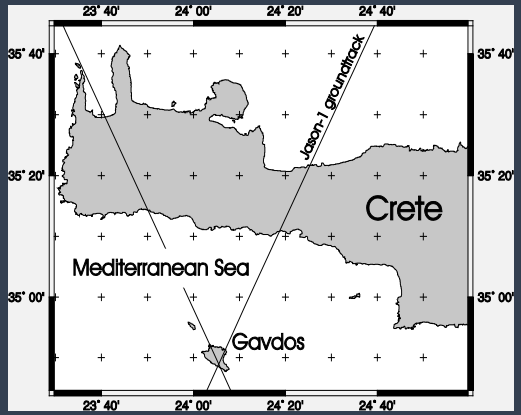
Harvest Platform (NASA), USA



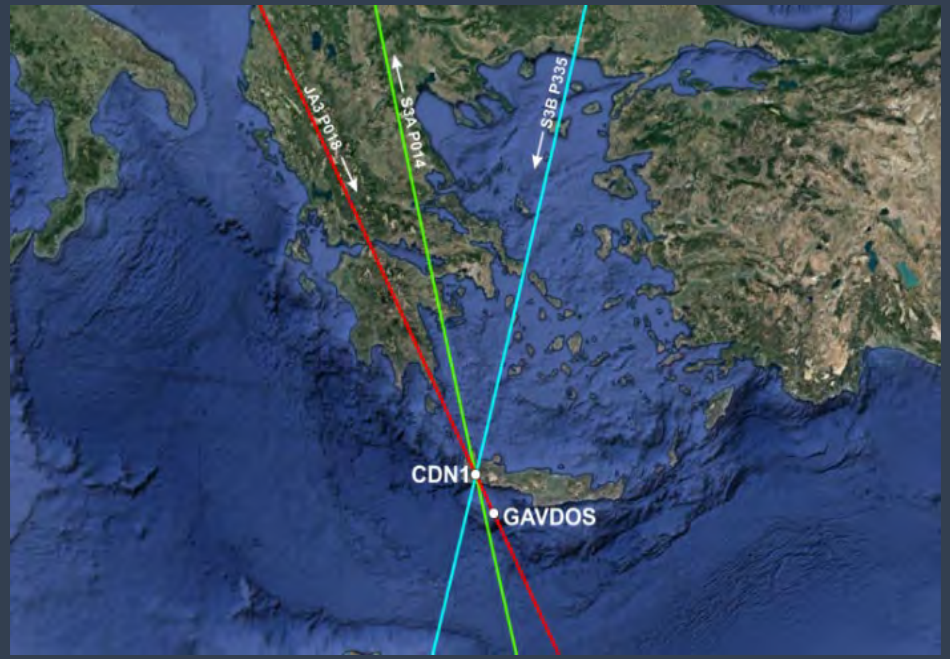
- To be abandoned soon,
- Operated about 30 years

Gavdos/Crete Permanent Cal/Val Facility





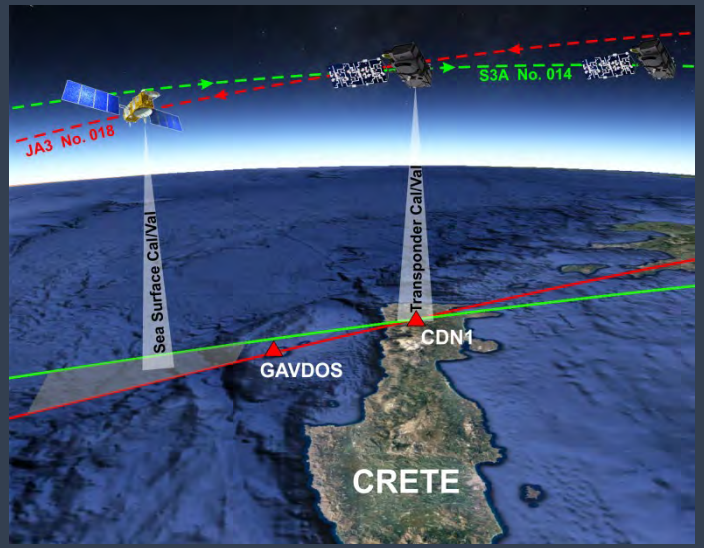
Land & Sea Calibrating Regions



Transponder at CDN1 Cal/Val

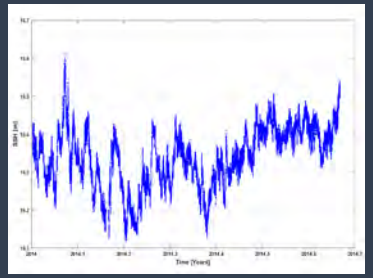
Gavdos sea-surface Cal/Val

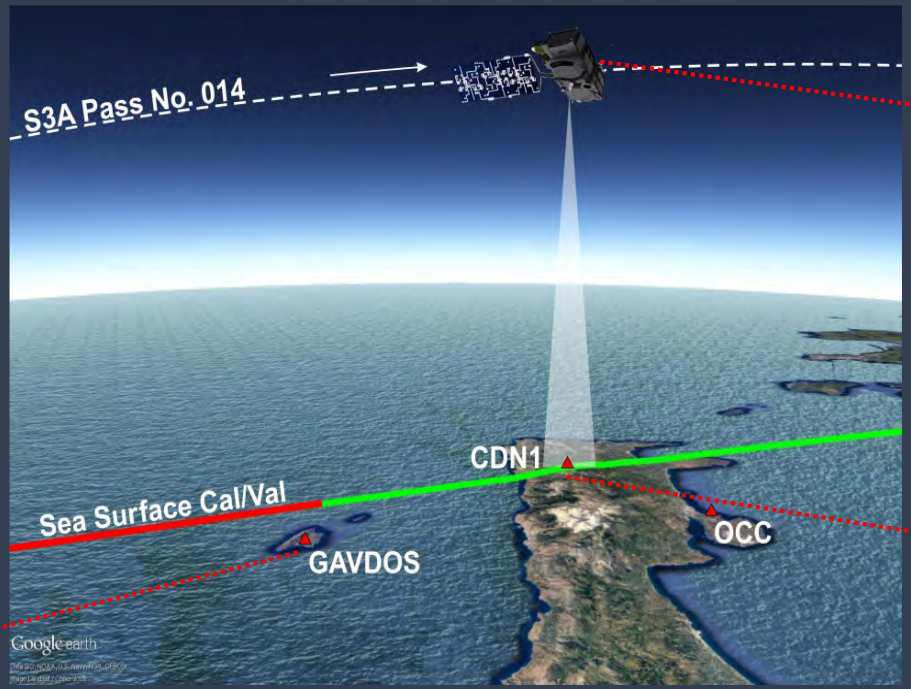
Groundtracks around Crete & Gavdos

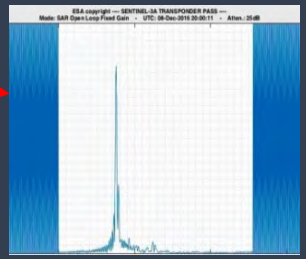


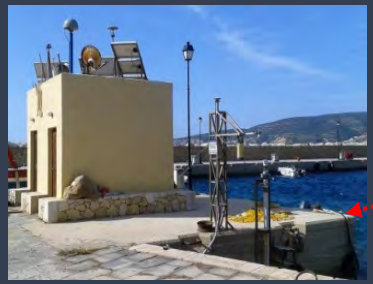
Transponder & Sea-Surface simultaneous

Simultaneous Transponder & Sea Cal/Val

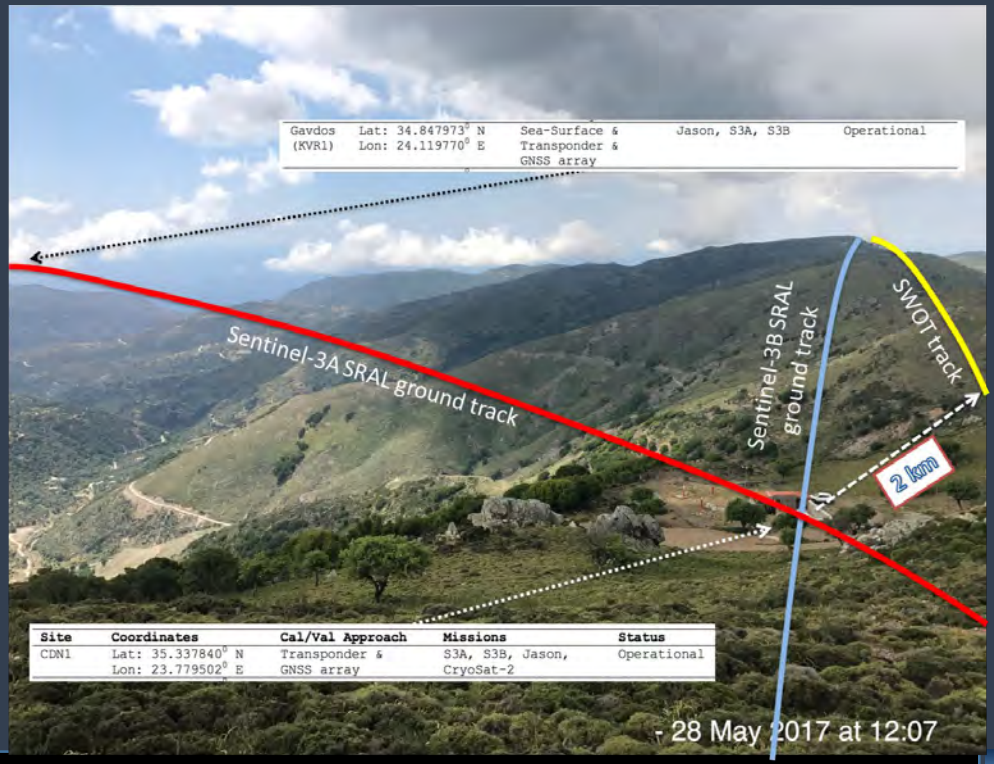




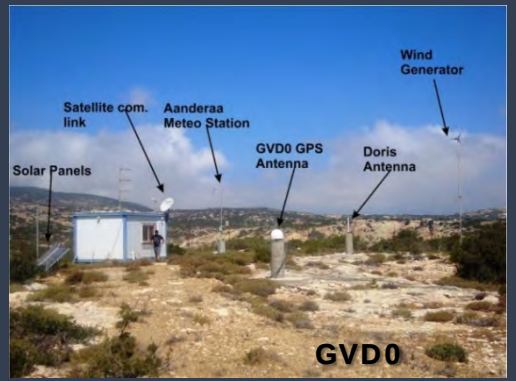




Transponder CDN1 Cal/Val Facility



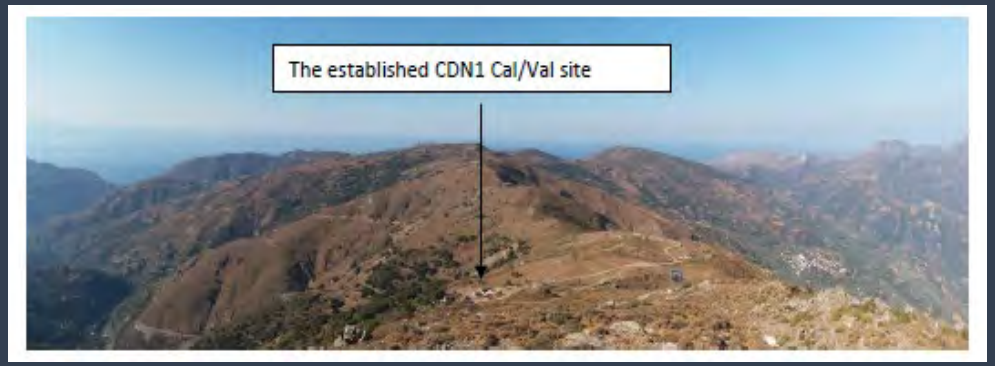
Sea-surface Cal/Val Facilities



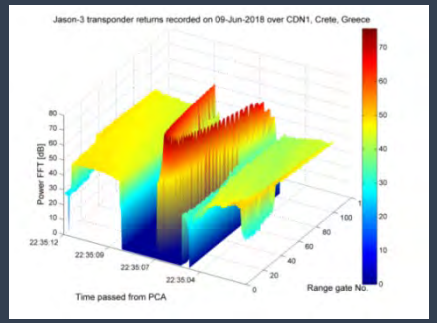
RDK1 in southcentral Crete

SUG1 south Crete

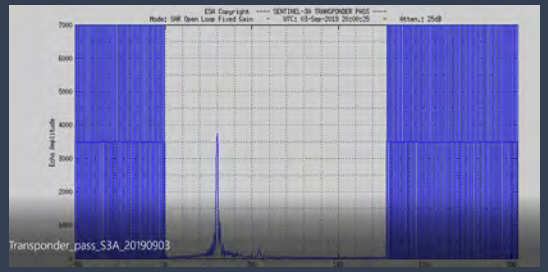
CDN1: ESA S-3 Altimeter Calibration

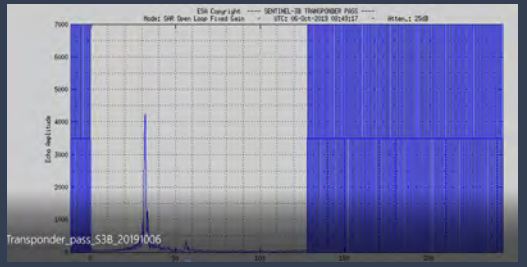


Transponder Calibrations

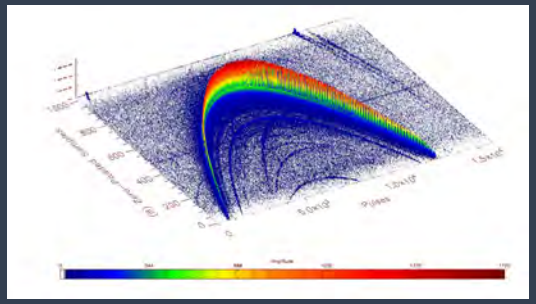


Jason-3, 9-June-2018



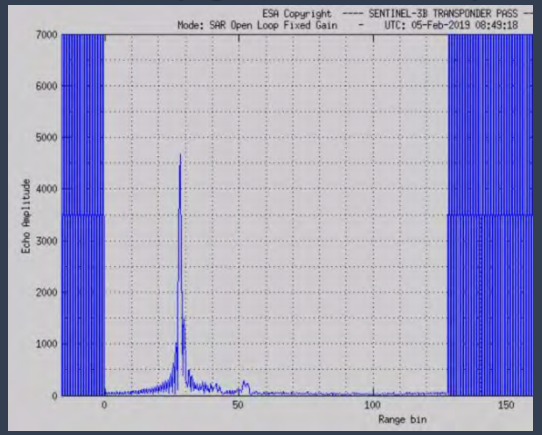


Sentinel-3A (3-Sept-2019) & **Sentinel-3B** (right, 6-Oct-2019)

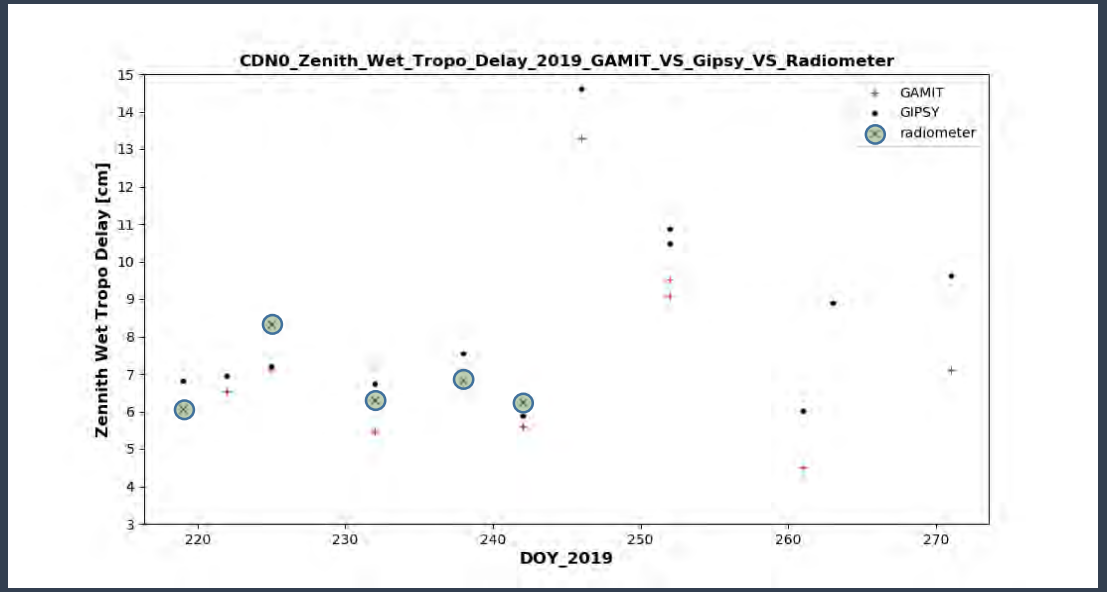


CryoSat-2, 20-Sept-2019

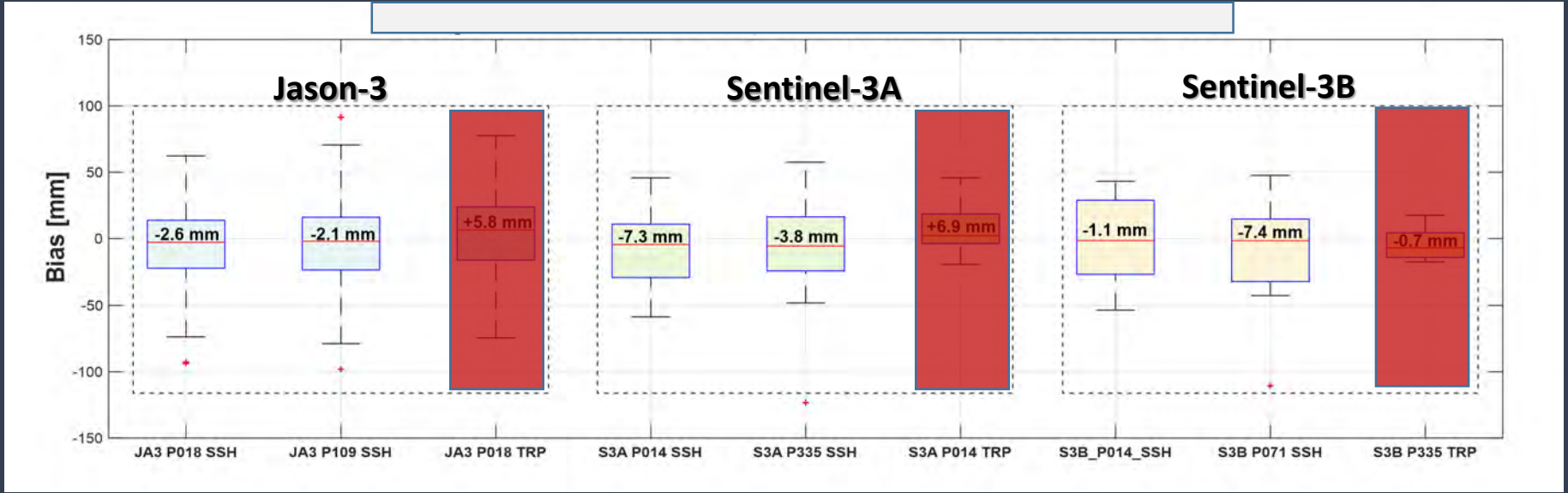
Sentinel-3B (nominal orbit), 5-Feb-2019



Radiometer Operational at CDN1 Cal/Val



Cal/Val Summary in Boxplots



Laws of Monitoring Sea Level & Climate Change

Accuracy	In scientific and monitoring data we produce and evaluate.	Science
Accuracy	Information presented to the Public for understanding effects of sea level rise to their lives.	People
Accuracy	In helping make the **right** Decisions, and put into action the **right** Policies.	Future

Long-term, Consistent, Continuous Sea Level record only when:

- **Monitoring of data quality we produce,**
- **Proper Archiving (data bases),**
- **Seamless Distribution of Retained Data,**
- **Monitor Performance of Observing Systems.**

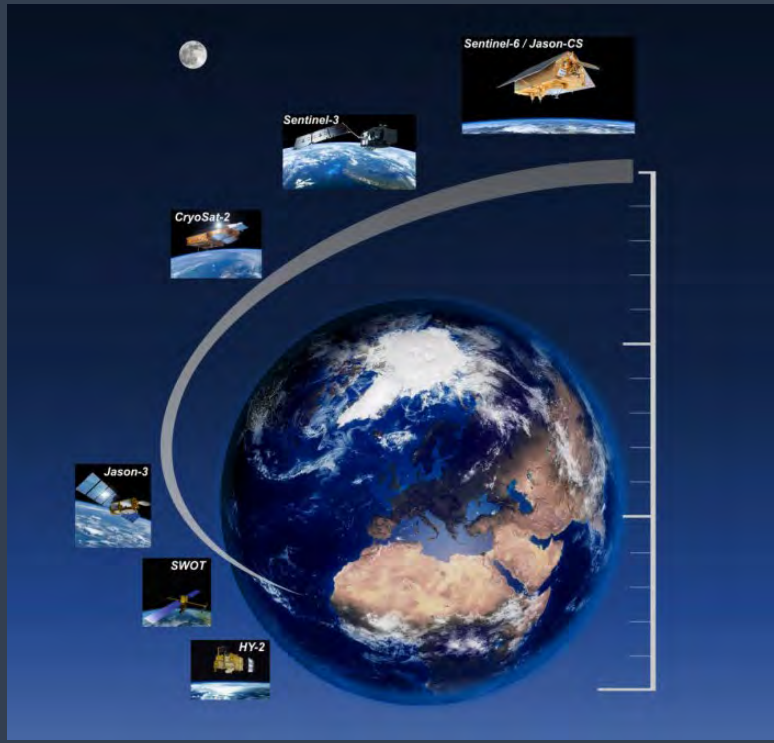
Fiducial Reference Measurements for Altimetry

New Strategy to achieve:

- Reliable,
- Long-term,
- Consistent, Redundant,
- Undisputable altimetry products.

ESA Effort to reach:

- Uniform and Absolute,
- Standardization of Earth observation,
- Uncertainty on Metrology Standards,
- Trust on data we produce,
- Correct information to Pubic,
- Right decisions for Policies.



FRM4ALT Video