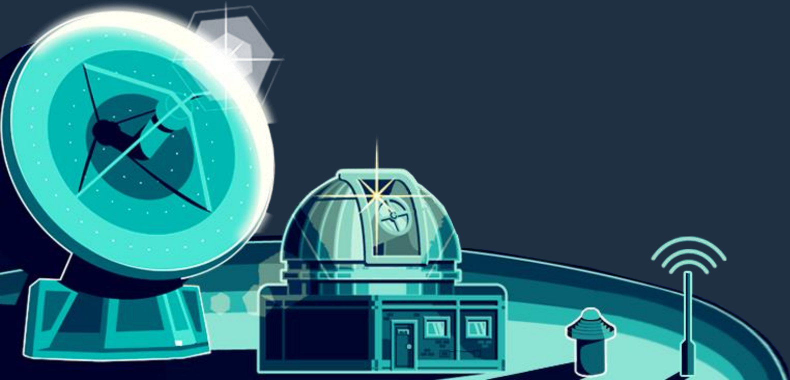
Introduction to the Space-Geodetic Technique DORIS

Karine Le Bail

Chalmers University of Technology / Onsala Space Observatory



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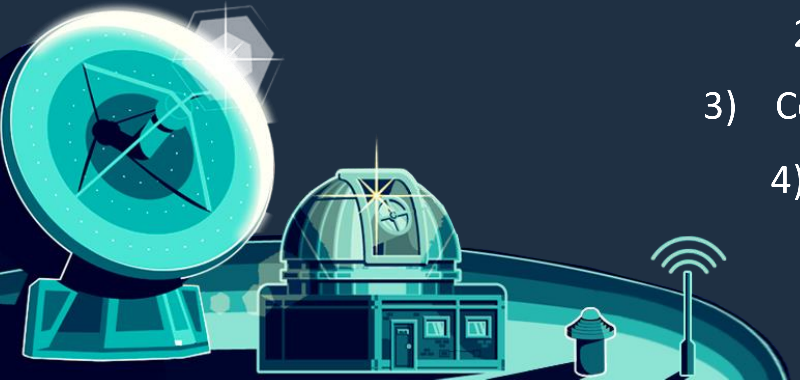
2) Institut Géographique National, St-Mandé, FRANCE
3) Collect Localisation Satellites, Ramonville Saint-Agne, FRANCE
4) Centre National d’Etudes Spatiales, Toulouse, FRANCE

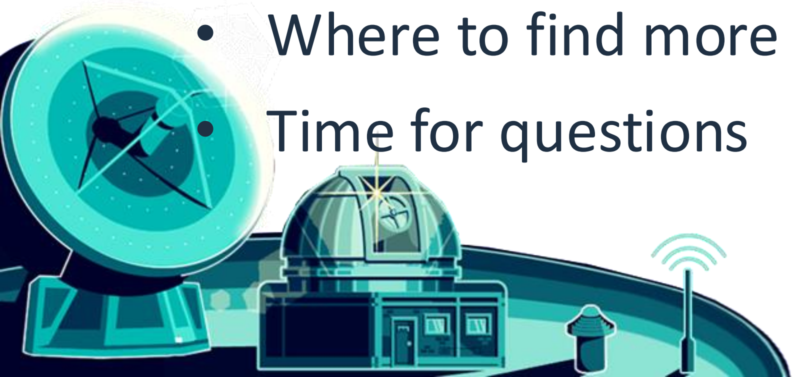


What we will cover:

- Short introduction to the lecturer
- What is DORIS?
- Space and ground segments?
- What does DORIS measure and how?
- Applications in geodesy and beyond.
- The DORIS/IDS community: how to get involved
- Where to find more information?
- Time for questions

Pay attention… there is a

BINGO GAME!



Who am I?

- Background in Mathematics, Astronomy, and Space Geodesy
- 2000-2004: PhD. DORIS, implementation
- 1 July 2003: Launch of the International DORIS Service (IDS)
- 2005-2008: Postdoctoral researcher. Assistant to IDS analysis coordinator
- 2021-2024: Member-at-large, IDS Governing Board
- 2023-2027: IDS representative to the GGOS Governing Board

The International DORIS Service

The IDS is an IAG service created in 2003 to:

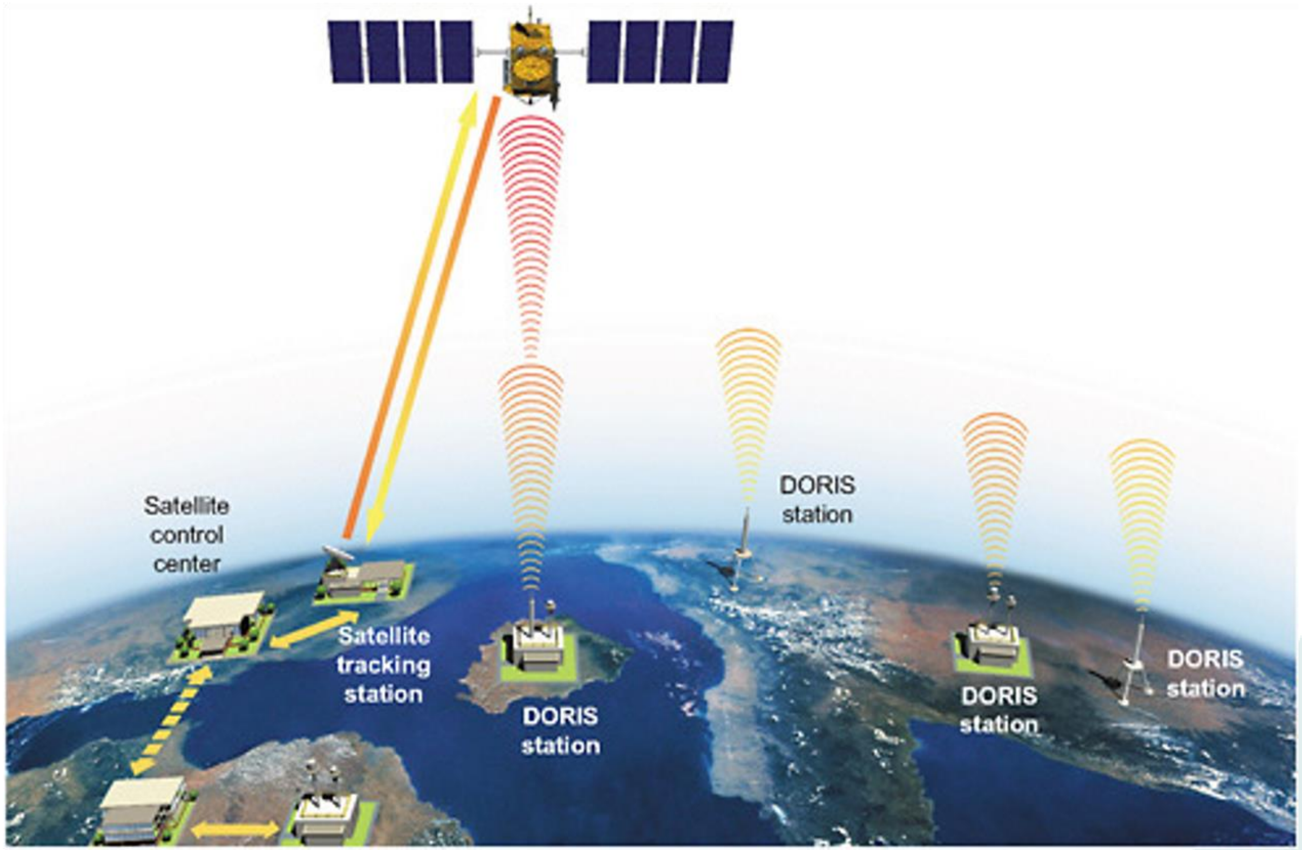
- Develop and support DORIS scientific applications,
- Provide access to DORIS data, products and documents,
- Contribute to the IERS realizations (ITRF),
- Support GGOS objectives.

https://ids-doris.org

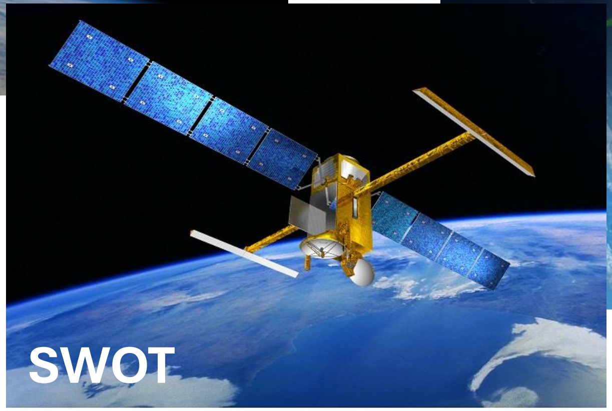
Doppler **O**rbitography by **R**adiopositioning **I**ntegrated on **S**atellite

The DORIS system

- A global network of transmitting stations,
- The DORIS signal,
- On-board satellite receivers,
- Control center to receive the DORIS satellite observations.



The space segment



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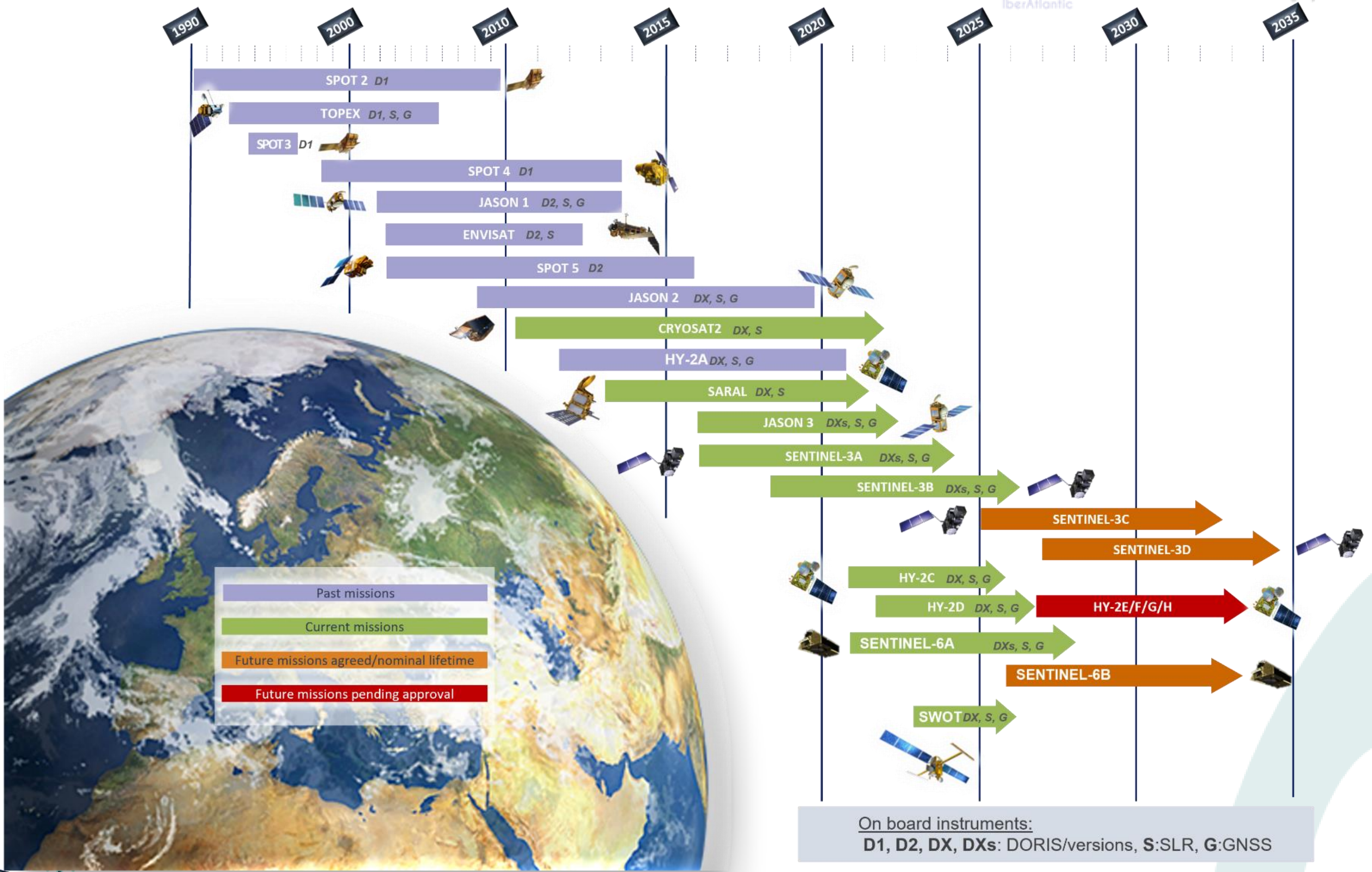
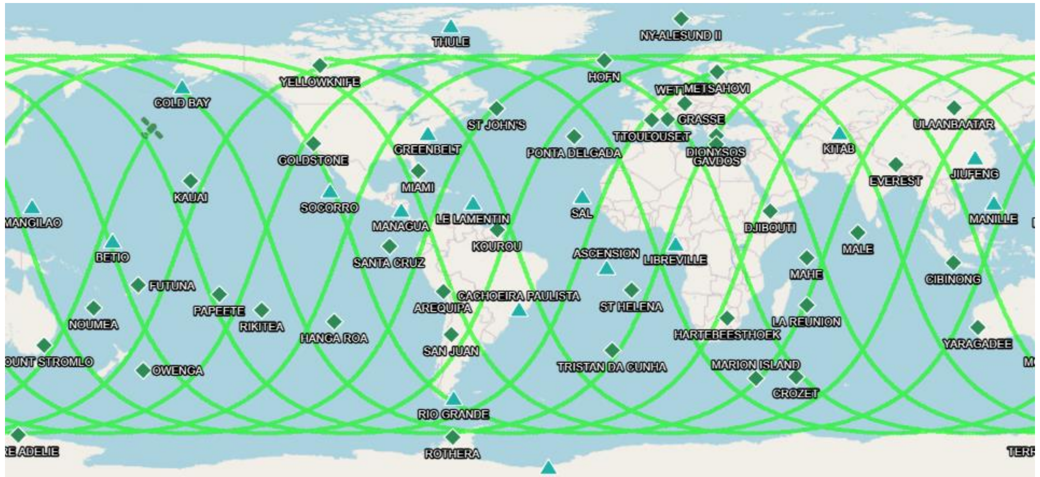
The DORIS constellation



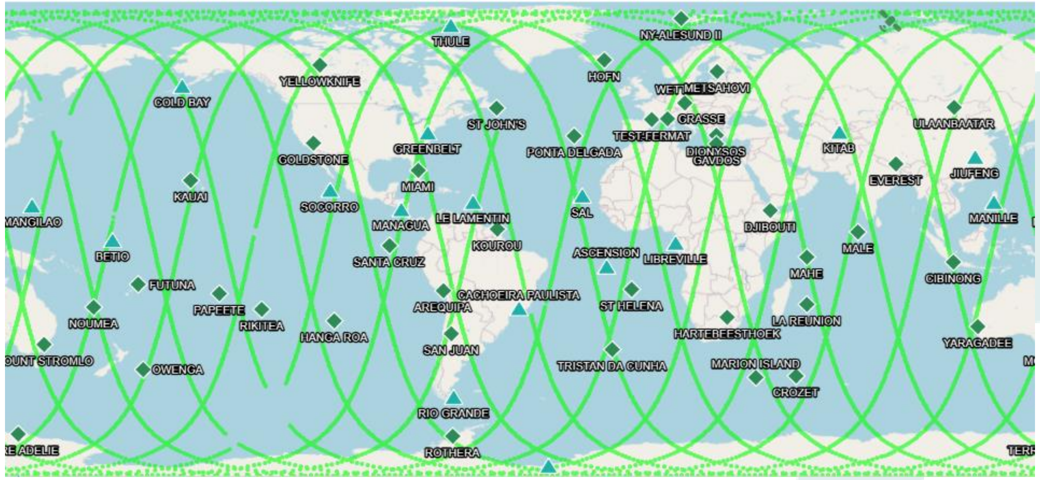
Orbits of the satellites

- Inclination:
  - 66º (near circular) e.g. Sentinel-6A,
  - 77º e.g. SWOT,
  - 92º e.g. Cryosat-2,
  - 98º (near polar) Sentinel-3B.
- Altitude: 700 km to 1400 km (LEO)
- Affected by:
  - Atmospheric drag (Low Earth Orbit),
  - Solar Radiation Pressure (shape of the satellite).

Satellite tracks Sentinel-6A



Satellite tracks Sentinel-3B



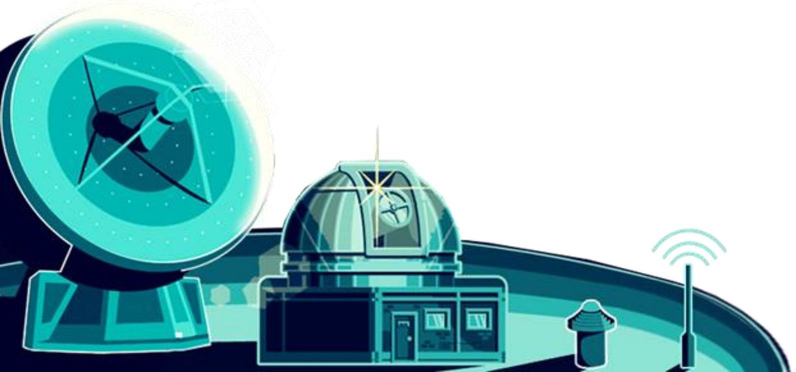
How to calculate the velocity of a satellite?

Kepler's 3rd law: $v = \sqrt{\frac{GM}{R}}$, satellite altitude: $r_a = 800$ km

with $G = 6.67 \times 10^{-11}$ m^3 kg^{-1} s^{-2}, $M = 5.97 \times 10^{24}$ kg , $r_E = 6.38 \times 10^6$ m

$$v = \sqrt{\frac{(6.67 \times 10^{-11})(5.97 \times 10^{24})}{(6.38 + 0.8) \times 10^6}} \approx 7\,447\ m/s = 7{,}447\ km/s$$

$$v \approx 7{,}5\ km/s$$

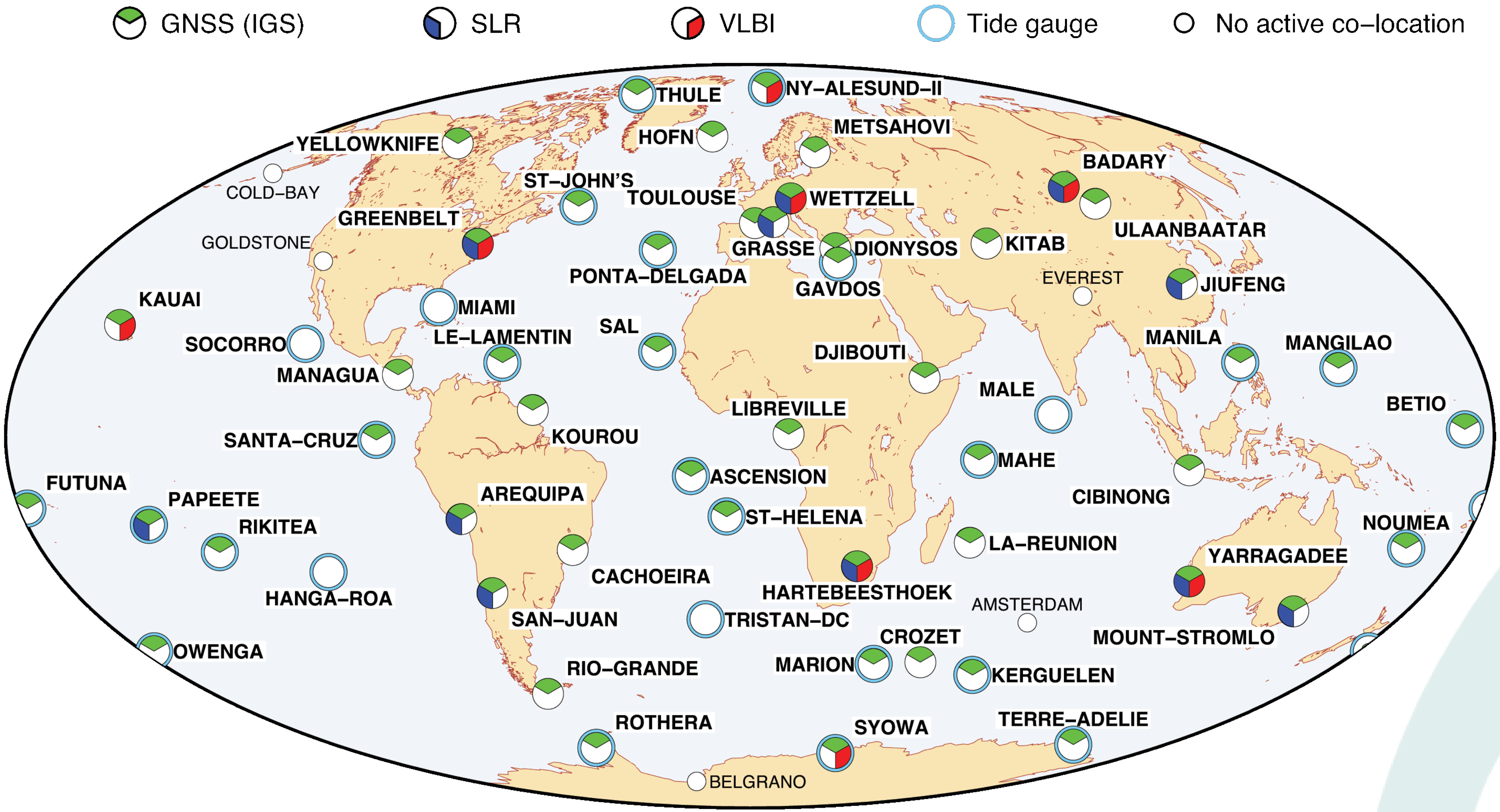


The DORIS On-Board Instrument

- Includes:
  - an dual-frequency omnidirectional antenna,
  - a receiver with two receiving chains (nominal + redundant),
  - two Ultra Stable Oscillators (one per chain - kind of ultra stable clock),
  - + DIODE software for on-board real-time orbit determination.
- 5th generation DORIS receiver under development (CNES).

The ground segment

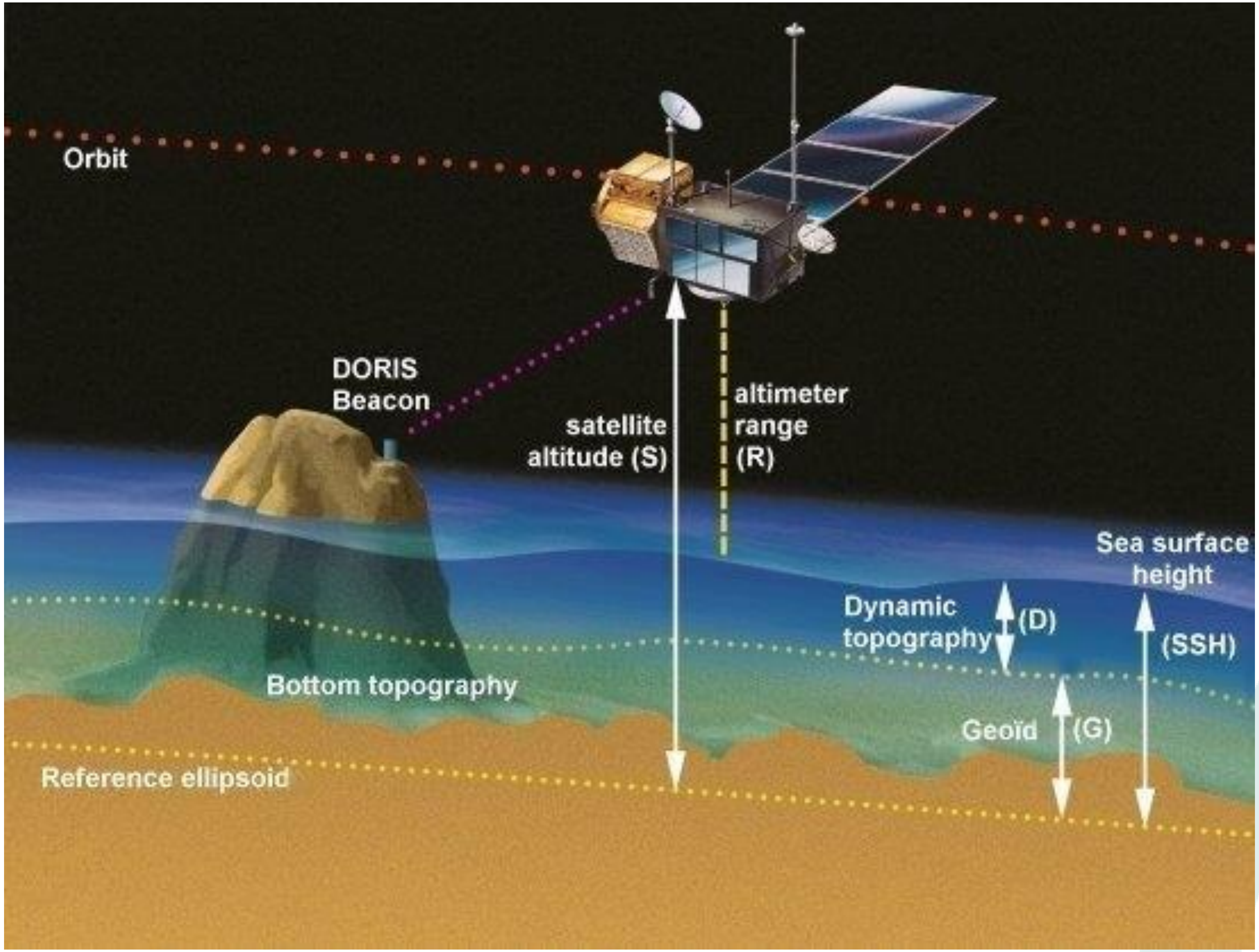
The DORIS Network



The DORIS Ground Station Components

- Beacon (4.0) - *indoor equipment*
  - generates two modulated signals: 401.25 MHz / 2.03625 GHz.
  - contains the reference oscillator, the frequency synthesizer, the management board, the power pack and the battery.
- Omnidirectional Antenna (Starec C): transmits the signal generated by the beacon.
- External MGM box contains a remote-control system, an Iridium modem, a GPS sensor, meteorological sensors.
- External Amplifier box contains the amplification and the remote-control systems.
- Main requirements: continuous service 24/7 365 days operation, clear view of the sky: visibility from LEO satellites, stability of the antenna monument.

The DORIS measurement



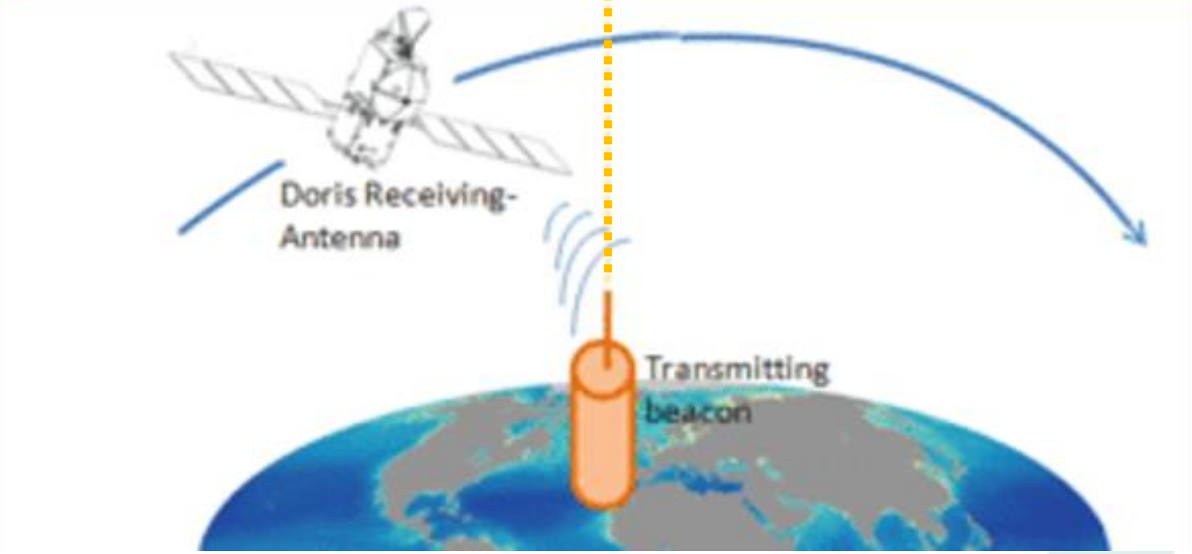
How DORIS Measures Doppler Shift

- Radial velocity: $f_r = f_e\left(1 - \frac{v}{c}\right)$
  - f_e: beacon frequency,
  - f_r: received frequency,
  - *c:* speed of light,
  - *v:* relative velocity between the beacon and the satellite.
- DOPPLER effect

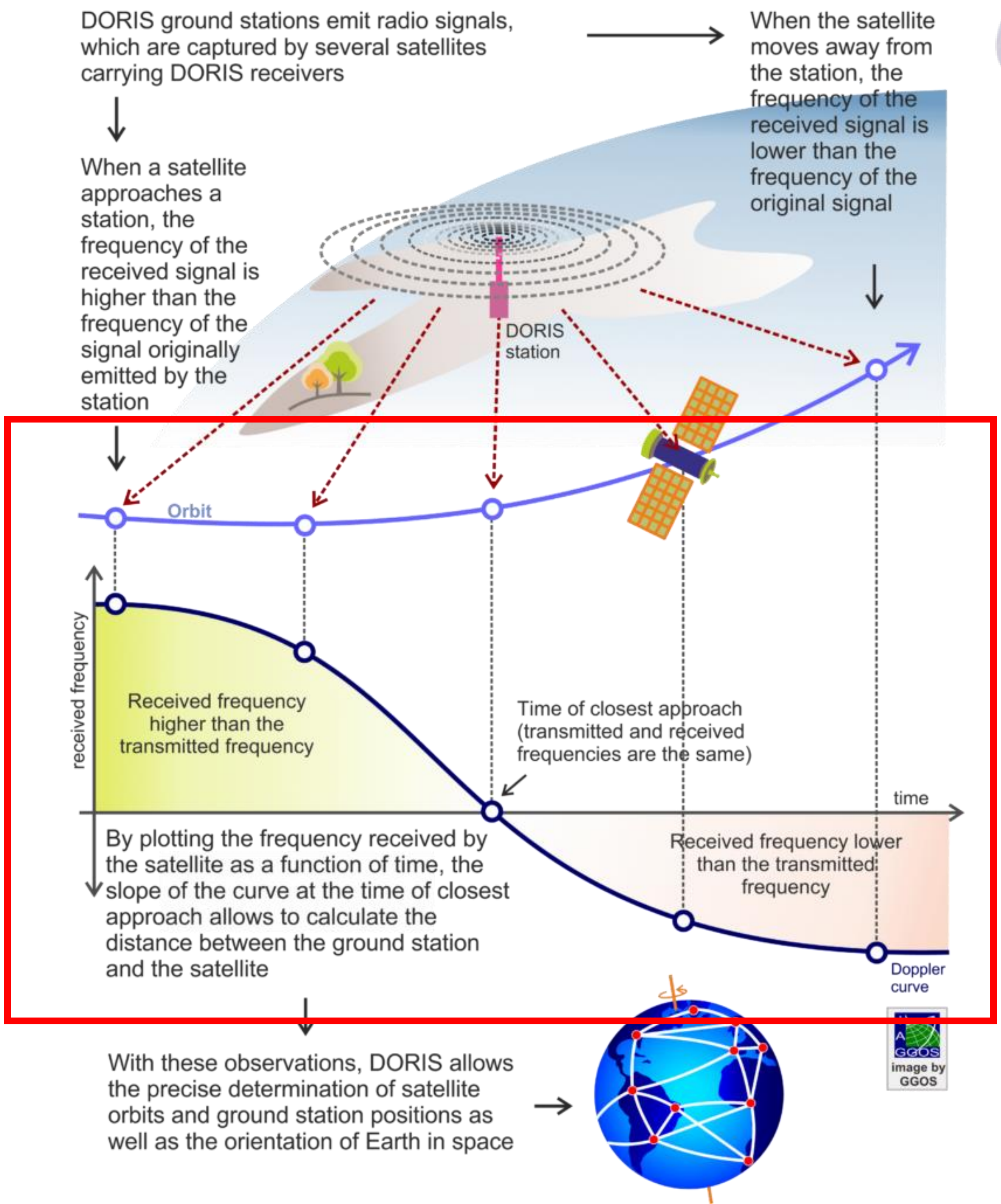
The satellite is **upright** the beacon, it's the TCA point (Time of Closest Approach).
The frequency of the received signal is **equal** to the frequency of the transmitted signal.

The satellite is **approaching** the beacon:
The frequency of the received signal is **greater** than the frequency of the transmitted signal.

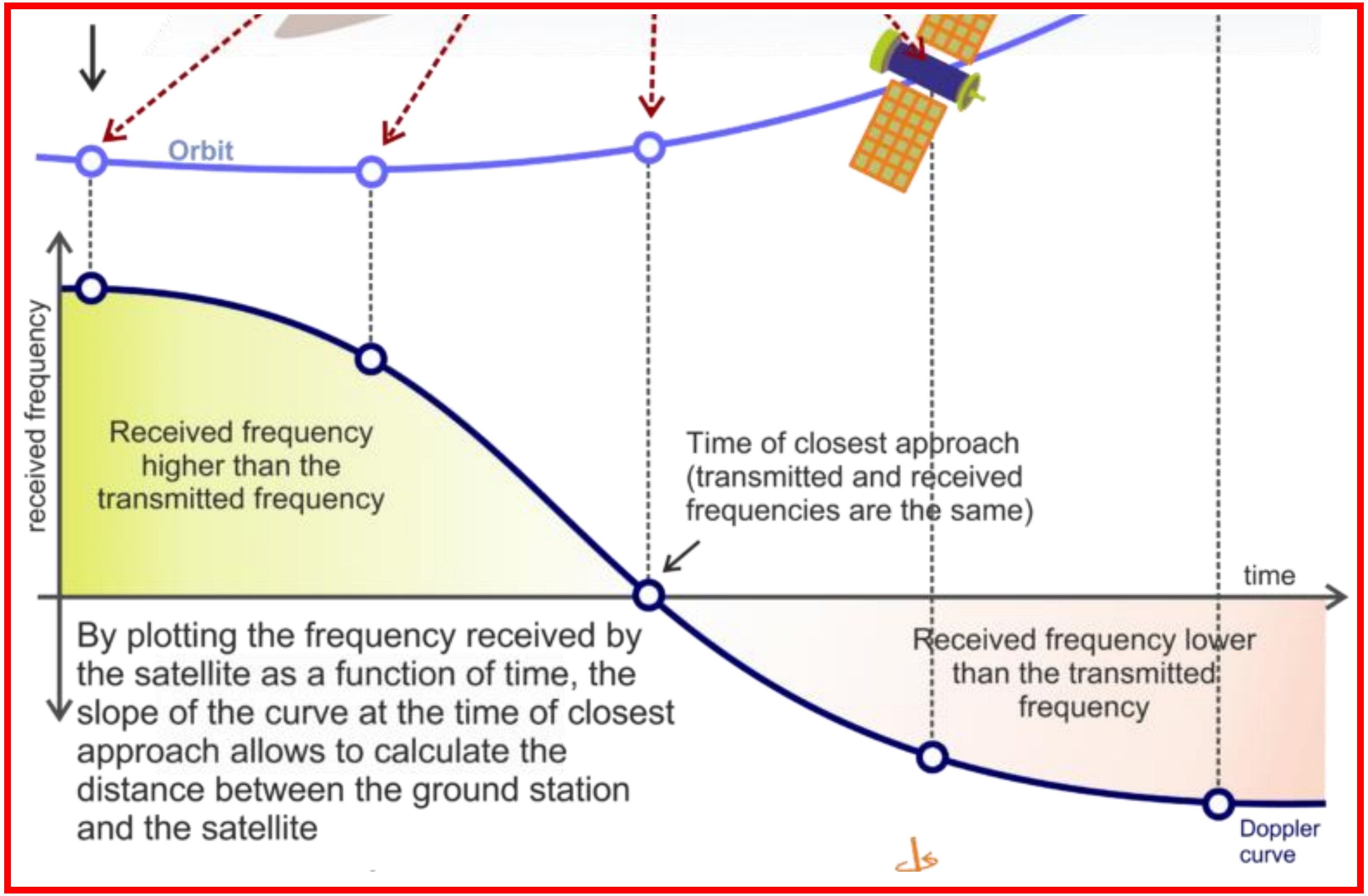
The satellite is **moving away** the beacon:
The frequency of the received signal is **lower** than the frequency of the transmitted signal.



How DORIS Measures Doppler Shift



How DORIS Measures Doppler Shift



How DORIS Measures Doppler Shift

- Measurement every 10 seconds
- Radiofrequencies:
  - 2.03625 GHz
    precise measurements,
  - 401.25 MHz
    ionospheric correction.
- Up to 7 beacons

The satellite is **upright** the beacon, it's the TCA point (Time of Closest Approach).
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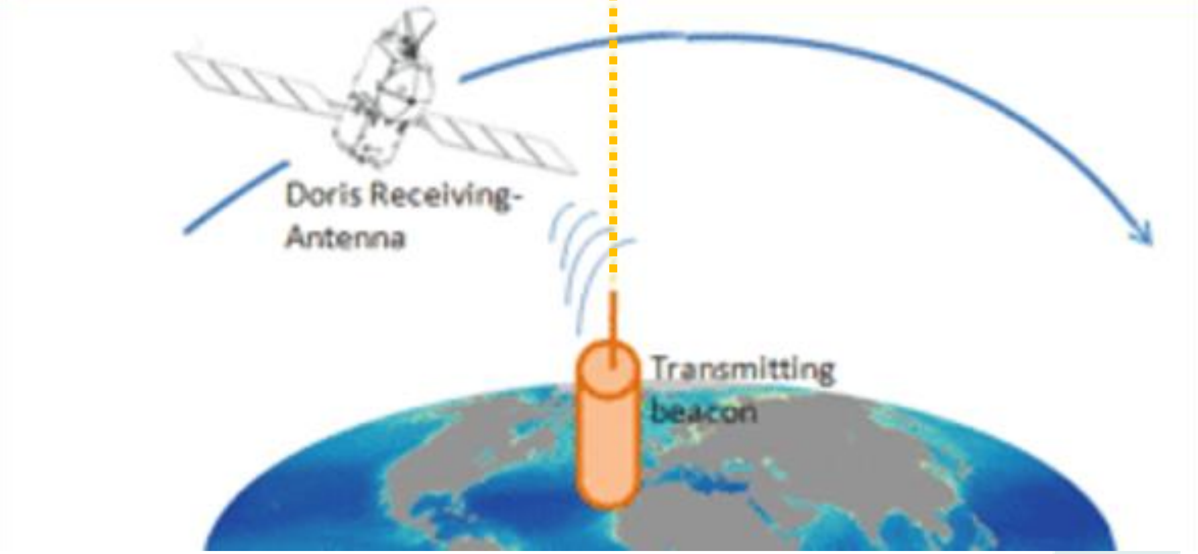

How DORIS Measures Doppler Shift

Products:

Precise Orbit Ephemerides

→ accurate location of satellites in the International Terrestrial Reference Frame (ITRF)

The satellite is **upright** the beacon, it’s the TCA point (Time of Closest Approach).
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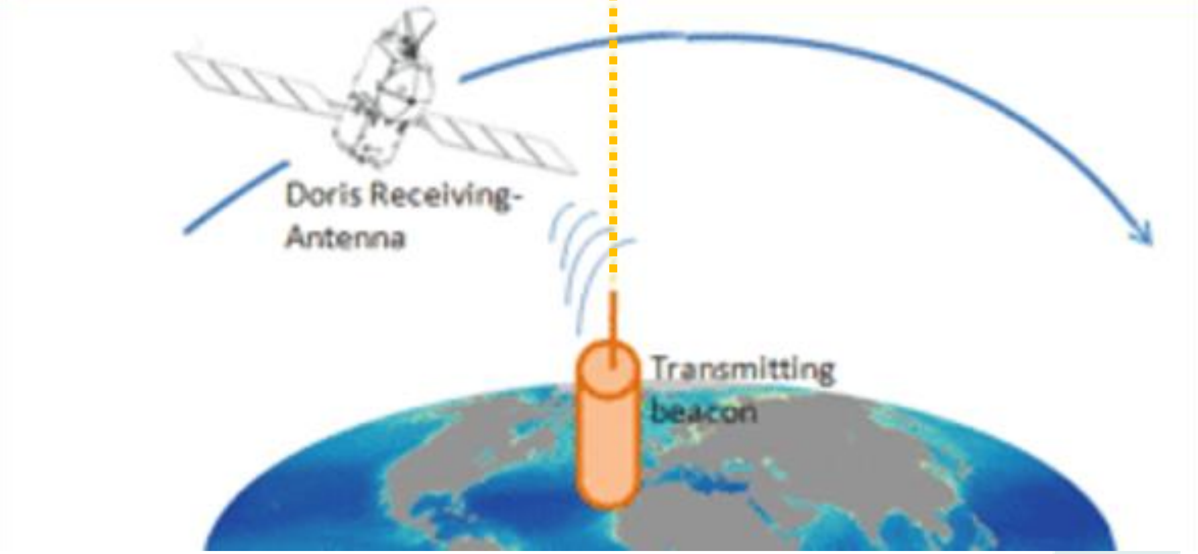


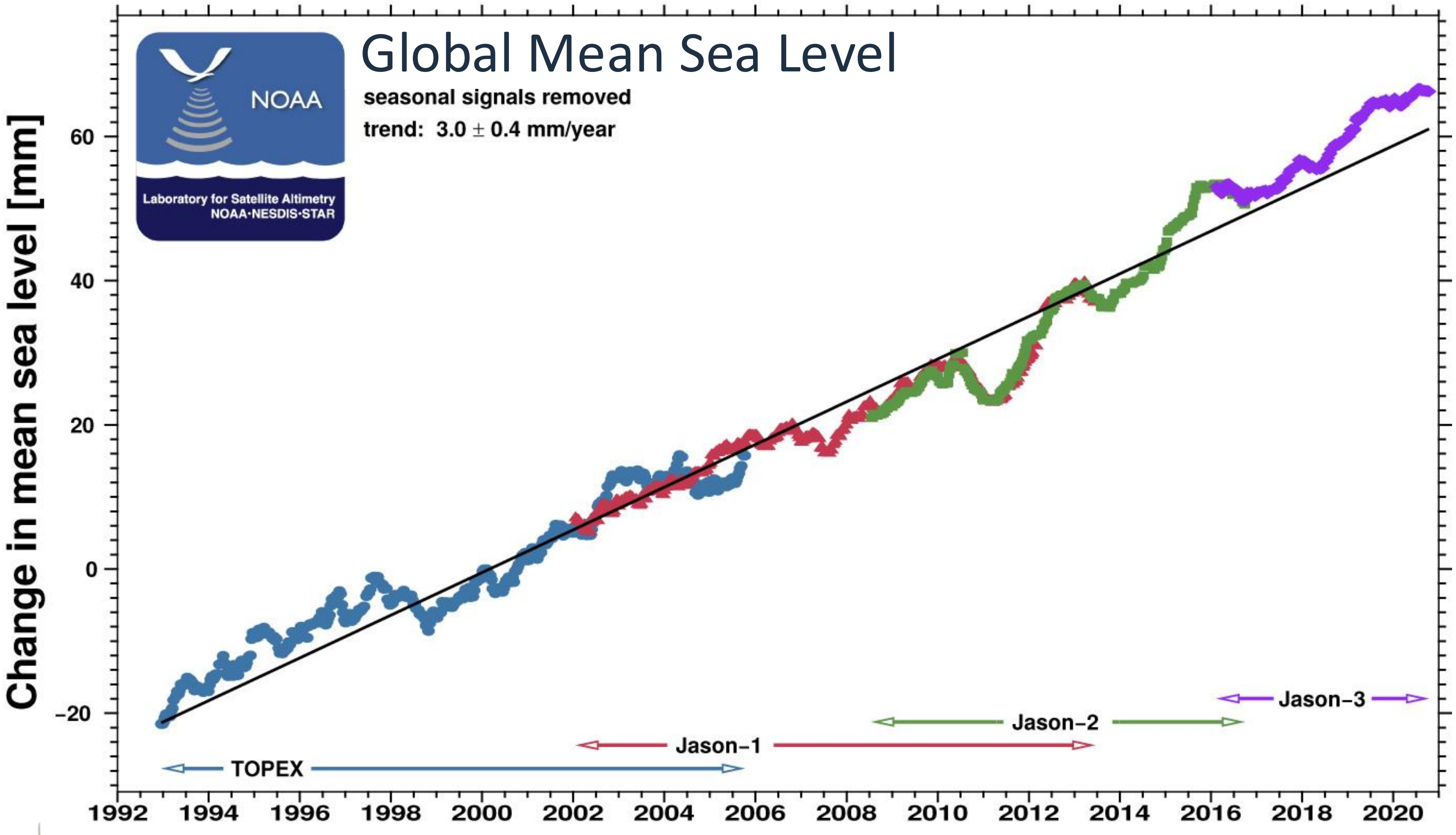
Scientific applications of DORIS

- Monitoring sea level rise and ocean circulation,
- Studying tides, currents and ENSO,
- Contributions to ITRF,
- Submarine volcanic eruption detection.

Altimetry missions

Accurate estimate of the satellite position → oceanic height

- Average sea level and how much it rises every year (climate change),
- Tides and water currents,
- El Niño Southern Oscillation (ENSO) phenomenon,
- Mean surface of the ocean.

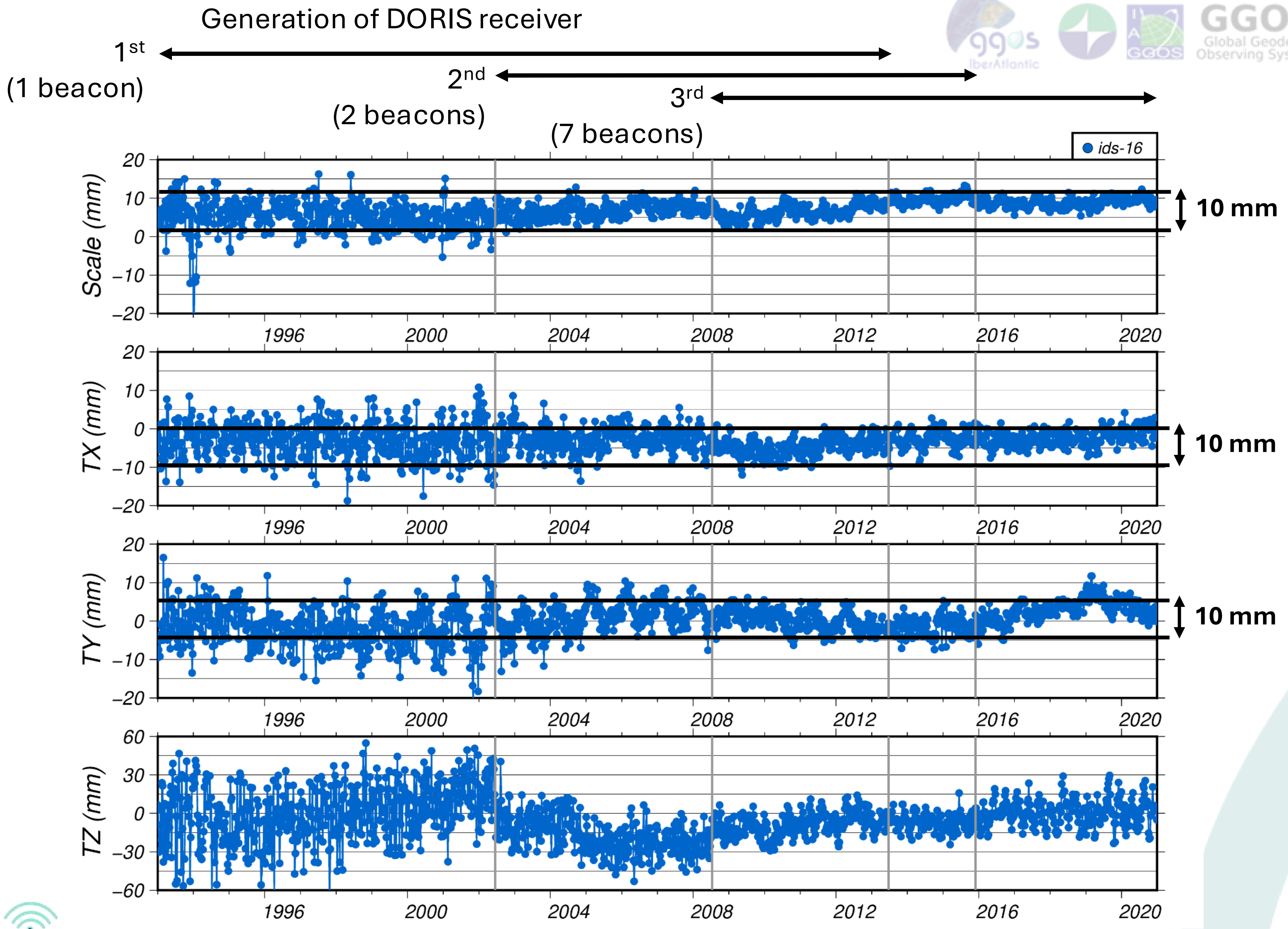

Global Mean Sea Level
seasonal signals removed
trend: 3.0 ± 0.4 mm/year
NOAA
Laboratory for Satellite Altimetry
NOAA·NESDIS·STAR
Change in mean sea level [mm]
60
40
20
0
−20
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
TOPEX
Jason−1
Jason−2
Jason−3

DORIS and the International Terrestrial Reference Frame (ITRF)

- One of the four techniques contributing to the ITRF (GNSS, VLBI, SLR),
- Provides weekly station coordinates + Earth Orientation Parameters,
- Current realization: ITRF2020-u2023,
- Scale and translation parameters,
- Station position residuals,
- Earth Orientation Parameters comparisons with IERS C04,
- Precise Orbit Determination.

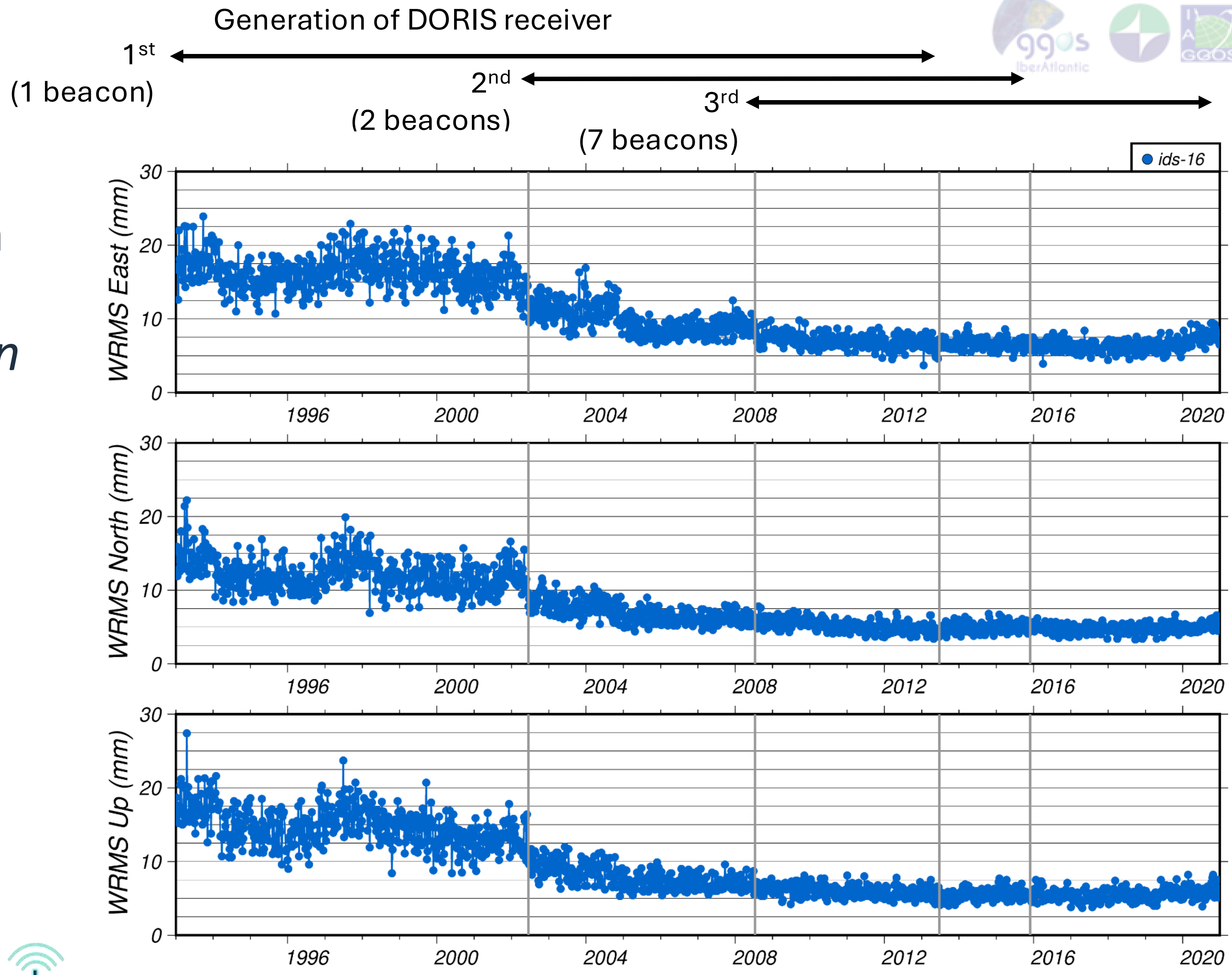
ITRF2020 DORIS solution

Scale and translations



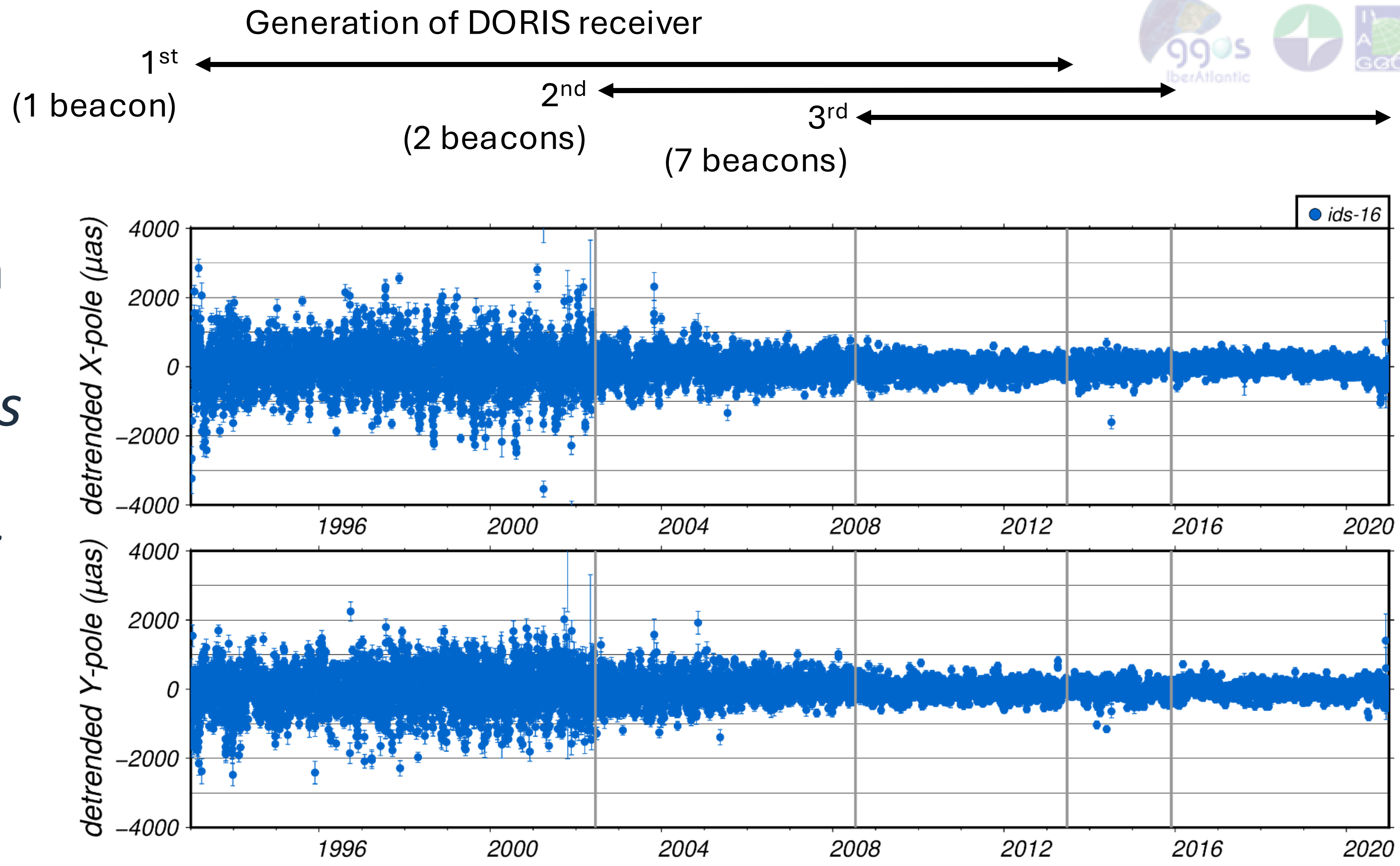
ITRF2020 DORIS solution

Station position residuals

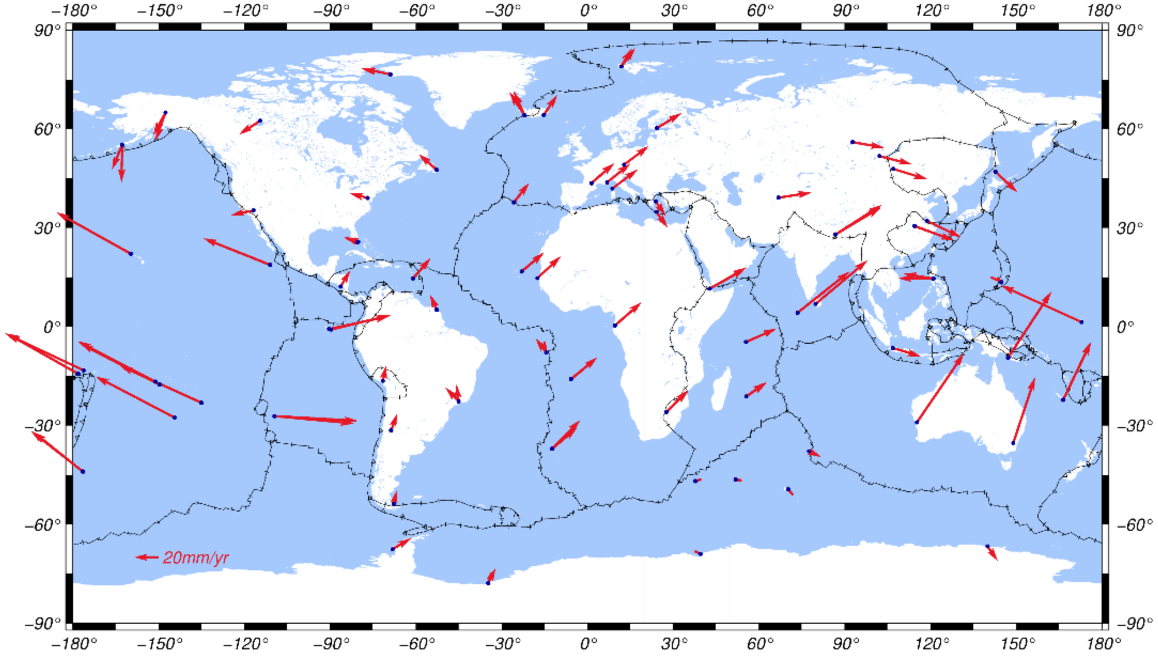


ITRF2020 DORIS solution

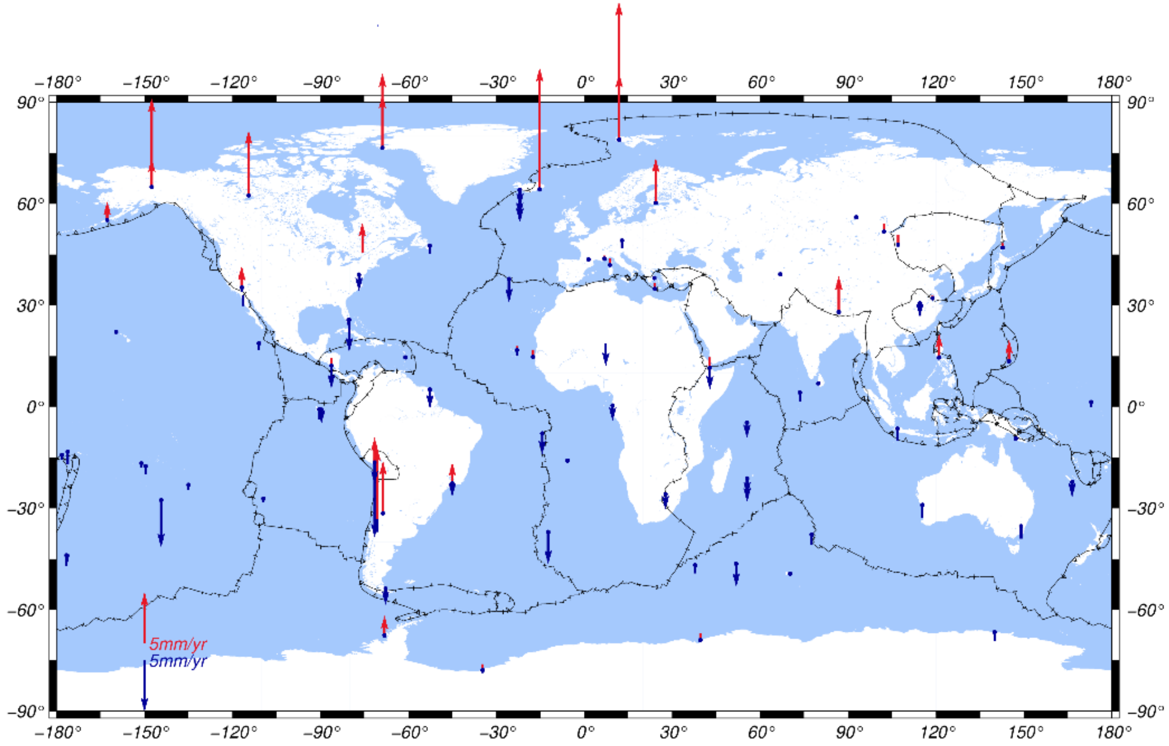
EOP differences w.r.t. IERS C04 series



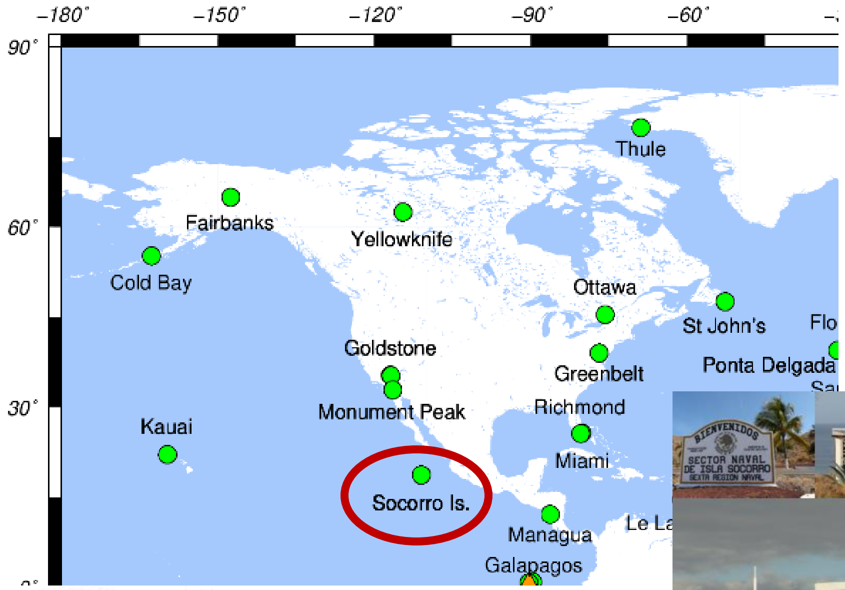
DORIS extension of the ITRF for Precise Orbit Determination

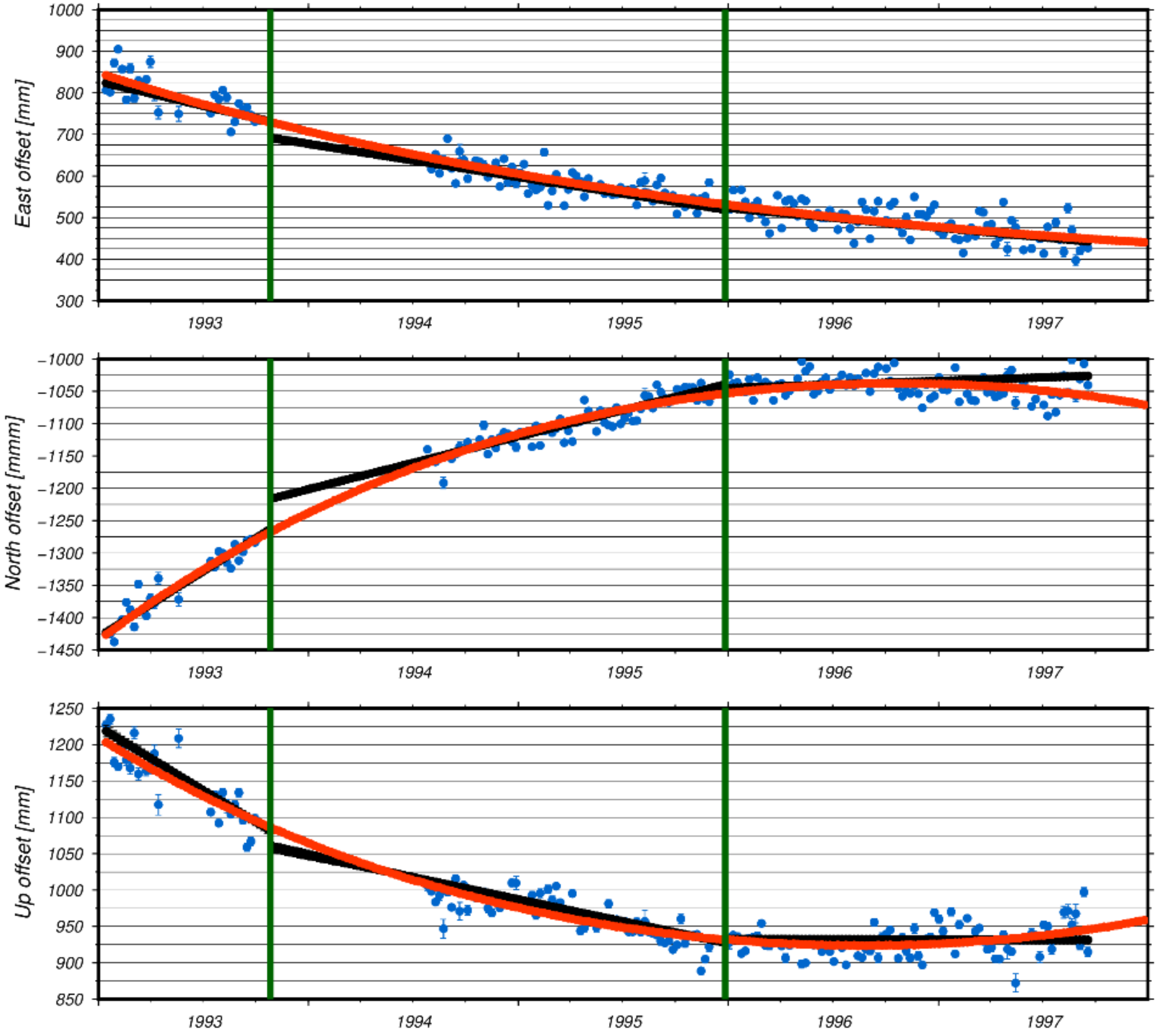


Example: DPOD2020 version 4.0



Uncovering a submarine volcanic eruption





Exciting future…
The genesis mission

Do you want to learn more?

- **DORIS days**

Nov 3-5, 2025 - hybrid event. Advanced courses on the DORIS system + hands-on sessions to discover DORIS data analysis.

https://ids-doris.org/ids/meetings/ids-meetings.html

Meet IDS members and DORIS experts at AGU, EGU, IAG assemblies.

Come and Join the IDS Community

https://ids-doris.org

- **Meetings**

DORIS Analysis Working Group (twice a year)

IDS Workshop (every two years)

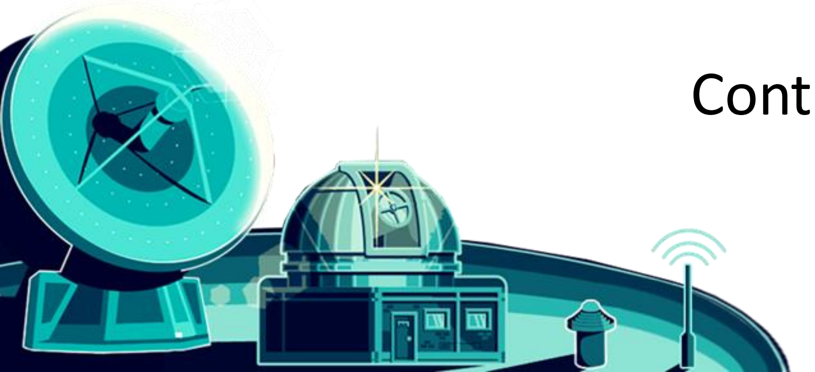
- **Publications**
- **Newsletters**

Regular information on the DORIS system and the life of IDS

- **Annual activity reports**

Progress reports about IDS, DORIS system, user service, analysis activities.

Contact: ids-central.bureau@ids-doris.org



DORIS is one of the four geodetic space techniques based on Doppler measurements at 401.25 MHz and 2.03625 GHz.

The signal is transmitted by the ground stations and received on board the satellites.

DORIS missions until 2035 and beyond, including the ESA genesis mission dedicated to the ITRF.

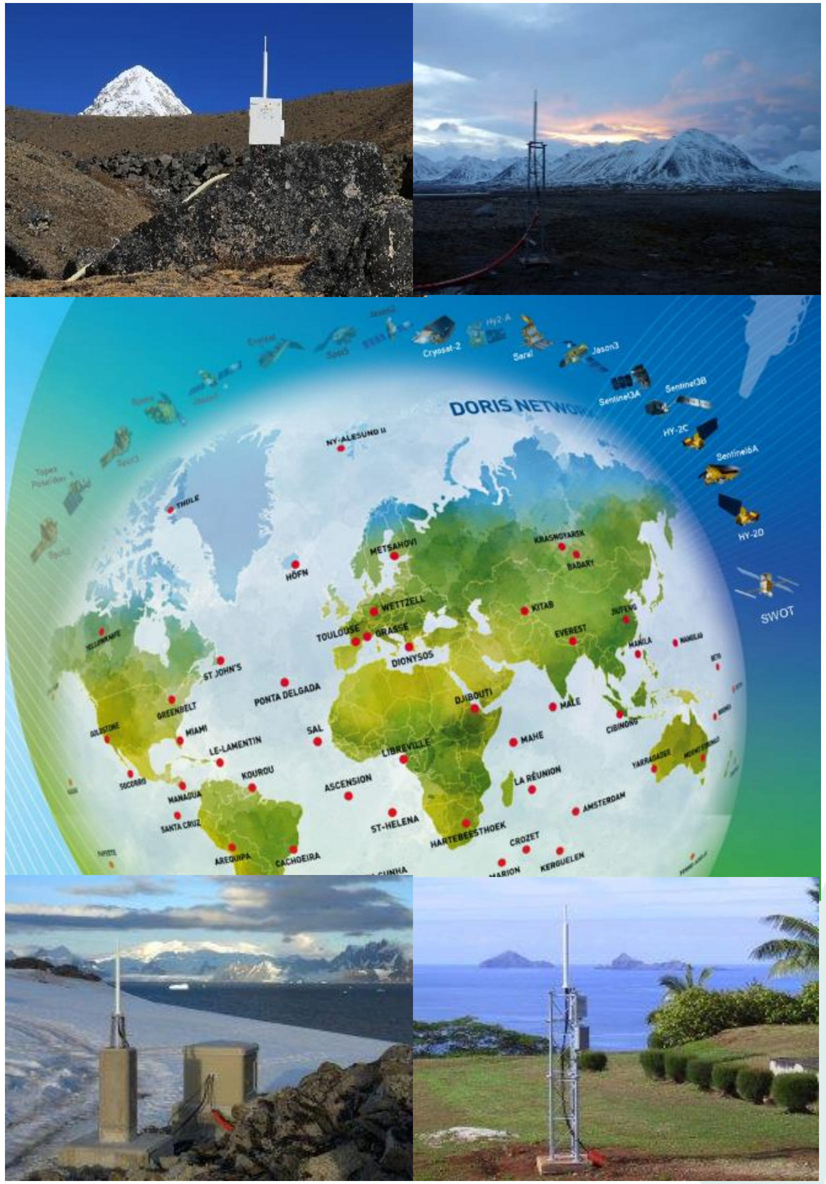
The DORIS ground beacon network includes 60 sites with a very even distribution.

New DORIS sites to come.

DORIS scientific applications are promoted by the IDS.

DORIS through the IDS contributes to the ITRF realizations since 2005.

More information on DORIS
https://ids-doris.org



Thank you very much!

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Contact IDS Central bureau: ids-central.bureau@ids-doris.org

BINGO GAME!