DORIS contribution to GGOS project

IUGG 2019 Symposia

Montreal, 16 July 2019

St-John's, Terre-Neuve

© IGN

Jérôme Saunier, IGN

Frank G. Lemoine, NASA

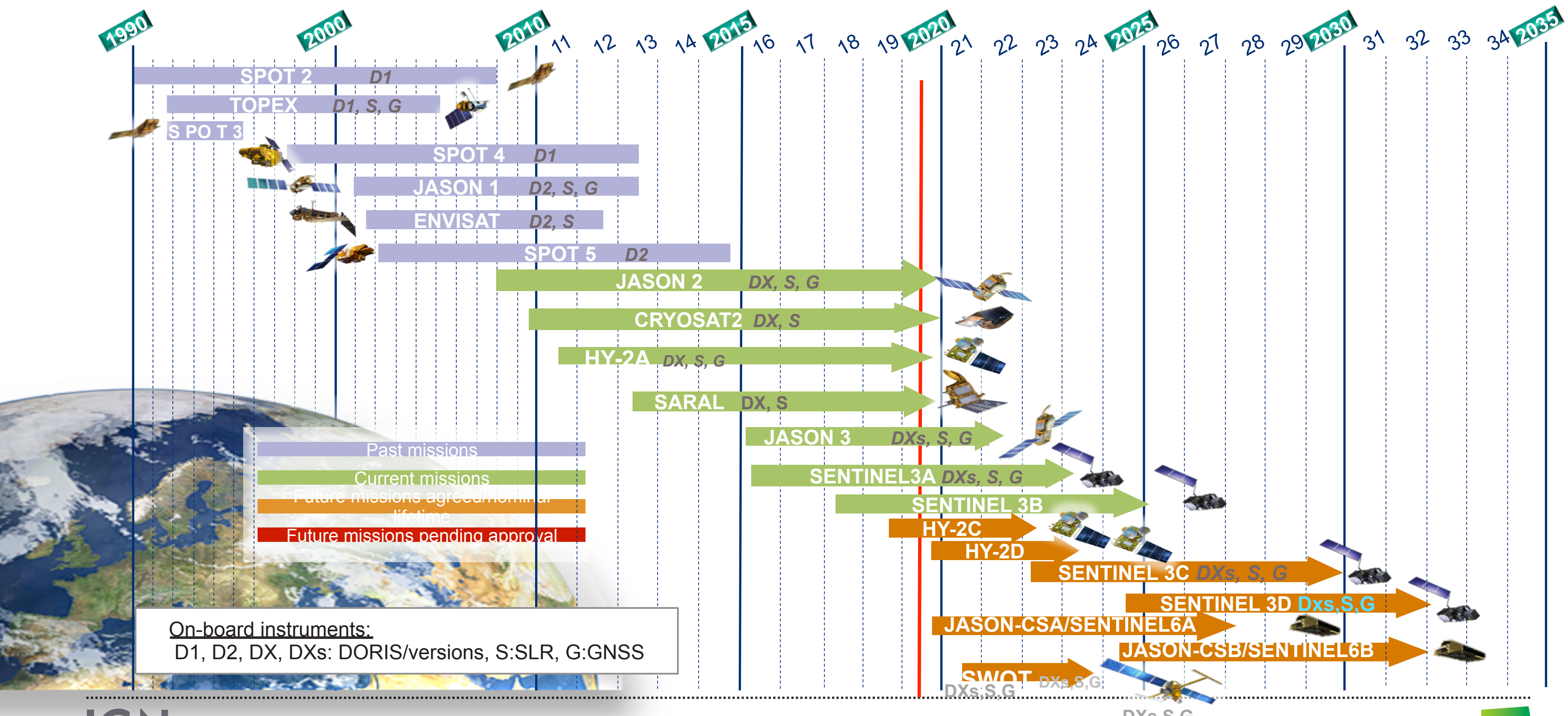
Guilhem Moreaux, CLS

REMINDER

The DORIS system has been operated for 3 decades

Accurate orbitography and positioning service: leading system for altimetry

7 DORIS-equipped satellites currently in flight



REMINDER

DORIS contributes to the realization of the ITRF since 1995:

most recently, ITRF2005, ITRF2008, ITRF2014, and now for the next realization, ITRF2020

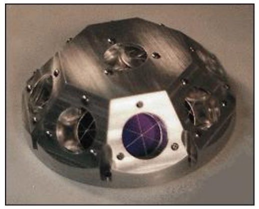
The IDS was created in 2003 as an IAG service

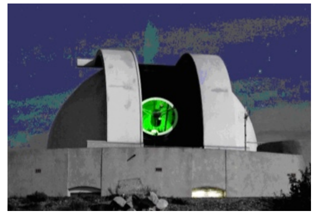
The IDS includes 6 analysis centers, 3 associate analysis centers, a combination center and an analysis coordination team

Continuing improvement of the DORIS contribution to ITRF:

- **Geocenter motion time series**
- **Earth Orientation Parameters**
- **Position and velocity of DORIS tracking stations**

JASON-2/T2L2 TO BE USED FOR THE NEXT ITRF





T2L2:

- Designed for remote clocks synchronization, on-ground and on-board

Time Transfer:

- Determine Time Bias in laser stations (ILRS)
- Read the frequency bias of the USO (Ultra Stable Oscillator)

Time Bias history for almost 10 yrs (e.g. Yarragadee)

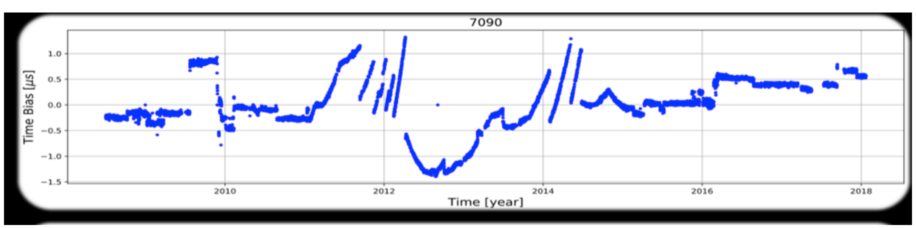


Figure from A. Belli (postdoc @ NASA/GSFC)

- T2L2 on board Jason-2 was operational from June 2008 to April 2018
- With the DORIS Ultra Stable Oscillator, time can be propagated from a reference SLR station with a stable H2 Maser (time colocation in space)
- Time biases determined for SLR stations and shown to be up to several *µ*secs
- Time biases evolve rapidly and are correlated with events at the SLR station or drifting of the local clocks

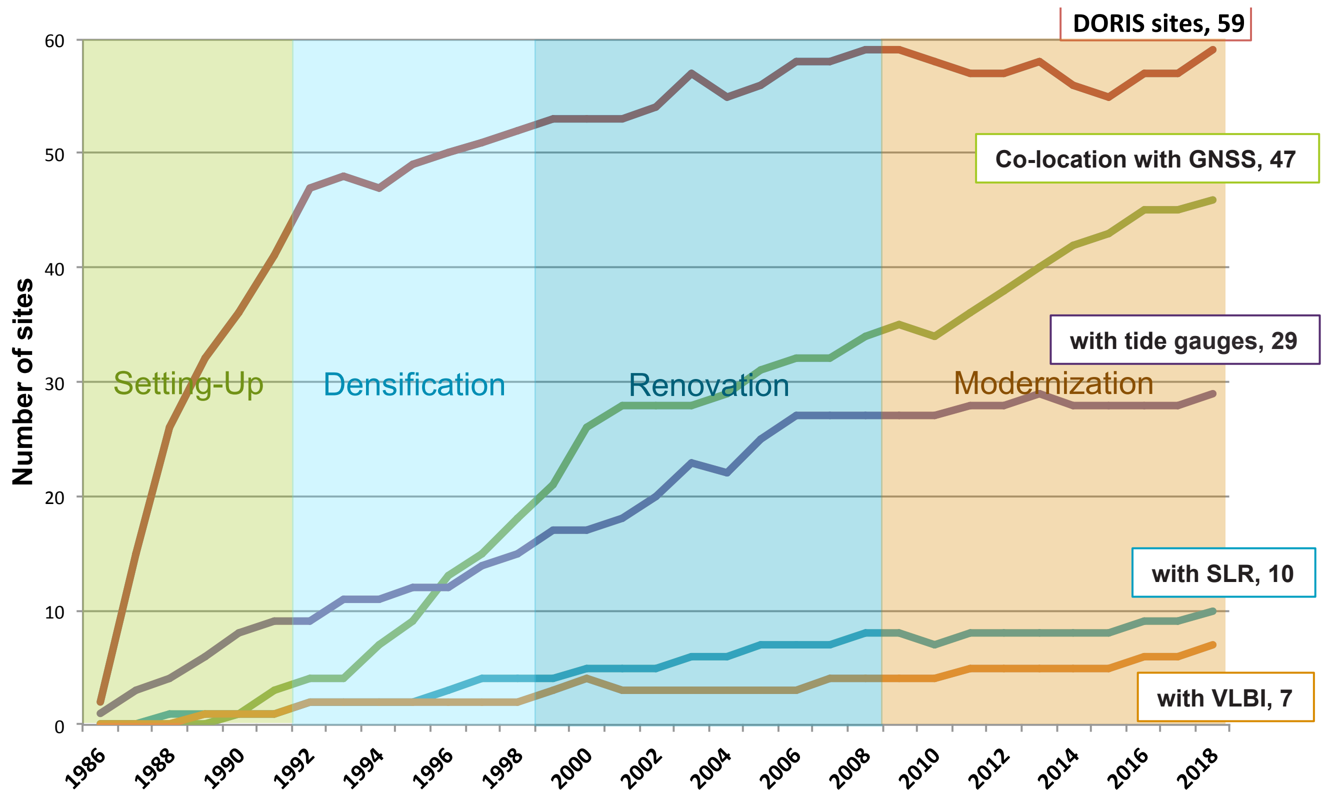
These T2L2_DORIS-derived time biases will be incorporated into the reprocessing of SLR data for ITRF2020

NETWORK DEPLOYMENT AND EVOLUTION

4 major phases of evolution : Setting-Up; Densification; Renovation; Modernization

Number of stations around 60

Continuing effort to co-locate DORIS with others techniques



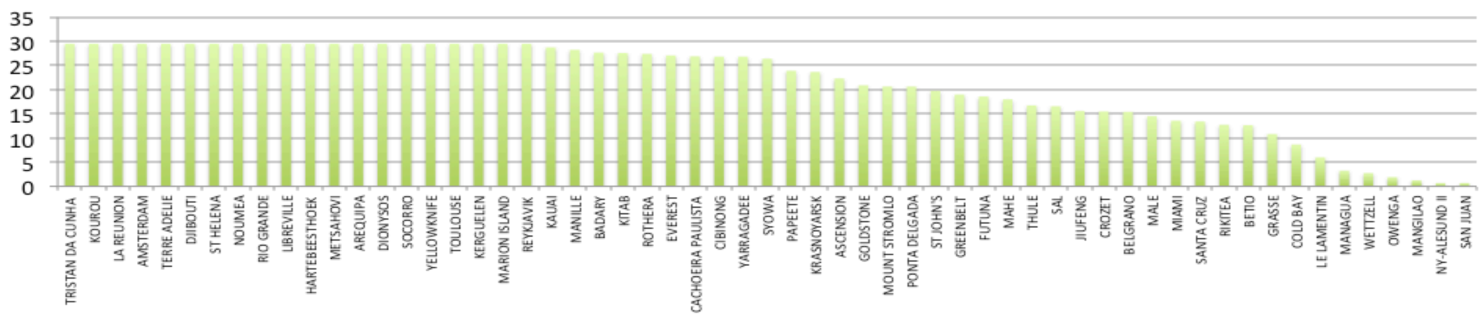
STRENGTHS OF THE DORIS NETWORK

Managed by a single entity (CNES/IGN)

- **Centralized control of the network deployment and evolution**

Long time series

- **Operating time of the current stations: 21 y (average) / 26.4 y (median)**



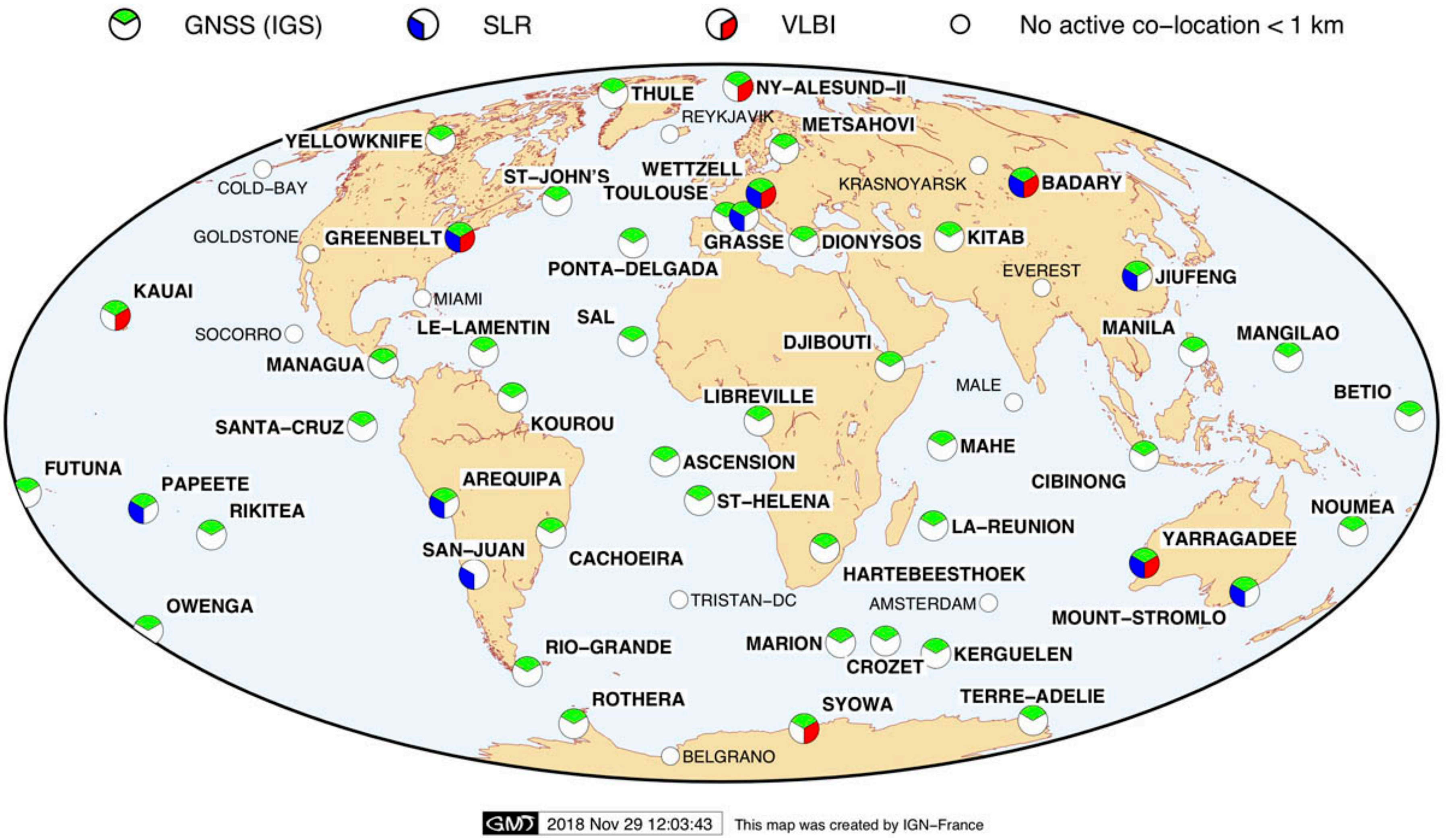
The much more homogeneous station distribution

- **Half of stations located on islands or coastal areas**
- **Good North-South distribution**

Co-location with other space geodetic techniques and tide-gauges

- **48 stations out of 59 co-located with other techniques: <u>47 with GNSS; 10 with SLR; 7 with VLBI</u>**
- **28 stations out of 59 co-located with tide gauges**

CO-LOCATIONS



Very homogeneous geographical distribution - 48 co-located sites (/59)

THE POSITIVE IMPACT OF THE GGOS PROJECT

Opportunities to move to new geodetic observatories

- **Many countries followed the GGOS call to build the core network infrastructure**
- **DORIS moved to Wettzell (2016), San-Juan (2018), Ny-Alesund II (2018), Papenoo (2020?)**

Synergy between the different techniques

- **DORIS-VLBI RF compatibility studies**
- **Increase in surveying co-located sites and improving the accuracy of the site surveys**
- **Fruitful discussions and cooperative investigations**

Instrument and infrastructure performance improvement

- **New goals according to the GGOS objectives:** 1 mm position and 0.1 mm/yr velocity accuracy
- **DORIS ground antenna characterization to draw up an error budget (2014)**
- **Assessment of the DORIS network monumentation (2016)**
- **Deployment of the 4th generation beacon (as of mid-2019):** with the aim of securing the future of DORIS and improving the stations performance

=> These points are expanded on below

DORIS / VLBI RF COMPATIBILITY

Successive RF compatibility campaigns:

- **Greenbelt, MD USA (2014) / Wettzell, Germany (2015-2016) / Papenoo, French Polynesia (2017)**

Subsequent requirements for the installation at co-located sites:

- **Minimum distance between DORIS and VLBI antennas shall be 300 m**
- **RF barrier (natural or artificial) between both antennas is highly recommended**
- **Strive for having DORIS above VLBI because DORIS signal is lower at low elevation**
- **RF compatibility tests in real conditions are in any case required (reflection/environment…)**

Recent DORIS installation at Ny-Alesund II:

- **Fully complies with the above requirements**
- **First RF compatibility tests were conclusive (end of 2018)**
- **Twin telescopes are not yet fully operational: tests under real conditions are planned**

EQUIPMENT IMPROVEMENT

Ground antenna C type

- Improvement in manufacturing processes of the ground antenna to improve the repeatability
- Consolidated specifications: standard uncertainty of the 2GHz phase center position in the vertical direction was reduced to 1 mm from 5 mm
- Deployment started from Sept. 2014: today 17 stations equipped

4th generation beacon

- Up-to-date electronic components: to be operational up to 2033
- Signal amplifier at the foot of the antenna: longer distance between beacon and antenna (up to 50 m vs. 15 m before)
- Deployment started from June 2019

Foot of the antenna

4th generation beacon

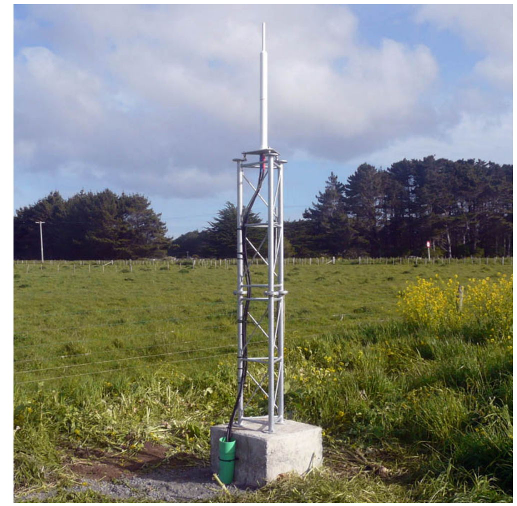
Antenna cables: 50 m long
=> Finding better environment for the signal transmission

STABILITY OF DORIS MONUMENTS

Standardizing installations: 3 standard monuments (2009)

Type I (29%): steel tower on load-bearing wall of building

Type II (22%): custom-made tripod on concrete pillar



Type III (29%): very rigid steel tower on concrete block

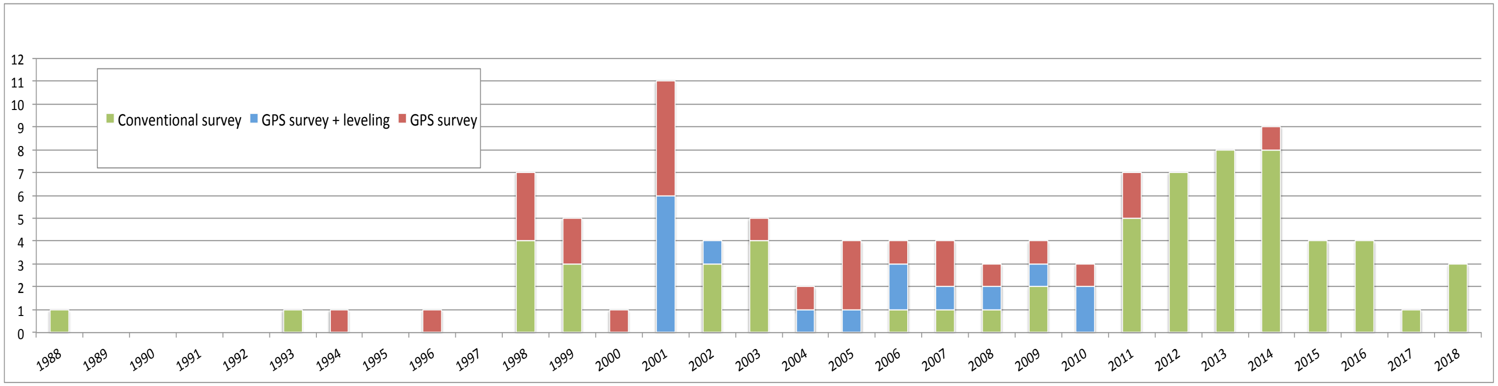
Assessment of the DORIS network monumentation (2016)

- **Elastic deformations < 1 mm when undergoing extreme climatic conditions**
- **50 verticality checks in the last 15 y. : 80% of the monuments are stable (within a mm)**
- **2/3 of the network monuments are compliant with standards**
- **Further details: : 10.1016/j.asr.2016.02.026**

DORIS LOCAL TIE SURVEYS

Gradual improvement in the DORIS tie vectors determination

- **59% of the tie vectors (since 1988) have been determined with mm accuracy**
- **84% of the tie vectors in the 10 last years have been determined with mm accuracy**



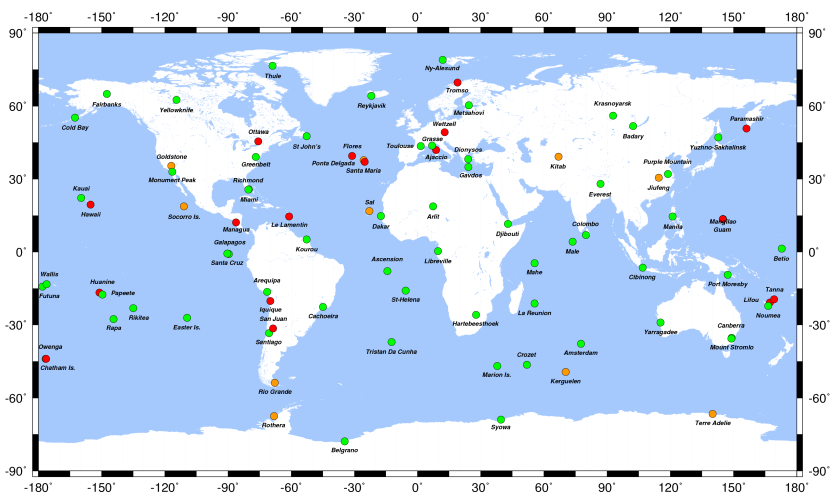
DORIS ties vectors at co-located sites

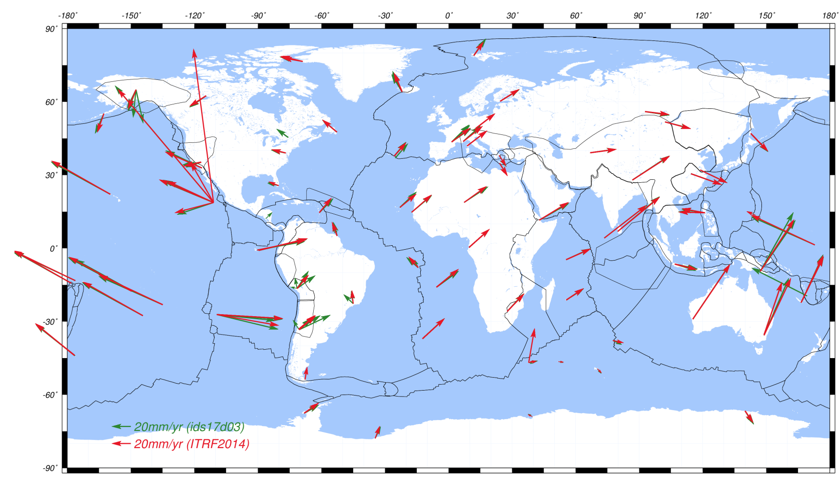
- **All available DORIS tie vectors with instruments identification, co-location dates, site survey date and estimated uncertainties**
- **File available on** ftp://doris.ign.fr/pub/doris/cb_mirror/stations/DORIS_ext_ties.txt **or CDDIS server**
- **IERS technical note N°39 (2017):** “IGN best practice for surveying instrument reference points at ITRF co-location sites” J.C. Poyard, with contributions by X. Collilieux, JM. Muller, B. Garayt and J. Saunier

DPOD: DORIS EXTENSION OF THE ITRF

DPOD2014

- **DORIS extension of the ITRF for Precise Orbit Determination**
- **Based on the latest DORIS position and velocity cumulative solution (from 1993)**
- **Updated twice a year**
- **Last available release: dpod2014_03 (SINEX and text format):** CDDIS and IGN data centers
- **More detailed information:** Moreaux, G.; Willis, P.; Lemoine, F.G.; Zelensky, N.P.; Couhert, A.; Ait Lakbir, H.; Ferrage, P., 2018. DPOD2014: a new DORIS extension of ITRF2014 for Precise Orbit Determination, ADVANCES IN SPACE RESEARCH, DOI: 10.1016/j.asr.2018.08.043 – **Open access**





OUTLOOK FOR THE FUTURE

Network

- **Additional co-locations** (in Changchun, Katherine, Reykjavik, Papenoo) **and additional stations in critical areas to make the network more robust**
- **Monument stability monitoring**
- **Continuous effort to perform high precision local tie surveys at co-located sites**

System

- **Additional missions:** HY-2C, HY-2D, Jason-CS, Sentinel 3C, Sentinel 3D…
- **Assessing the contribution of the new equipment** (antenna + beacon) **to the system performance**
- **Using highly stable atomic clocks at:** Greenbelt, Mount-Stromlo, Ny-Alesund II, Wettzell, Yellowknife
- **Linking DORIS to GNSS on ground via co-located GNSS receivers:** about 30 DORIS/REGINA sites
- **Developing combined DORIS-GNSS on-board receiver**

Contribution to ITRF

- **Improving the processing methods**
- **Using the new mean gravity field model** EIGEN-GRGS.RL04
- **Systematic Error Mitigation in DORIS-Derived Geocenter Motion**

THANK YOU FOR YOUR ATTENTION

Sentinel-3