

Assets and strengths of the DORIS station at Ponta Delgada

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Abstract

In late 1998, with the cooperation of the University of the Azores, the DORIS project installed a DORIS station in Ponta Delgada, São Miguel island, Portugal. The location of this DORIS site is very interesting as it is close to the boundary of the African, Eurasian and North American tectonic plates and is co-located with a GNSS station and a tide gauge. This paper first presents the history and the status of the DORIS station in Ponta Delgada. Then, taking account of the successive configurations of the DORIS station, both the orbit and positioning performance are assessed from the IDS official products.

Interest for a DORIS station in Ponta Delgada

Having a DORIS station in Ponta Delgada is interesting for both technical and scientific reasons.

To support the navigation of the DORIS-equipped satellites, the DORIS ground beacons have to be located at sites distributed homogeneously across our planet, so that a DORIS receiver on a LEO satellite can receive signals from at least one beacon. Thus, as located on the São Miguel Island, in the Azores, the DORIS Ponta Delgada station is essential for providing tracking coverage for DORIS satellites over the Northern Atlantic.

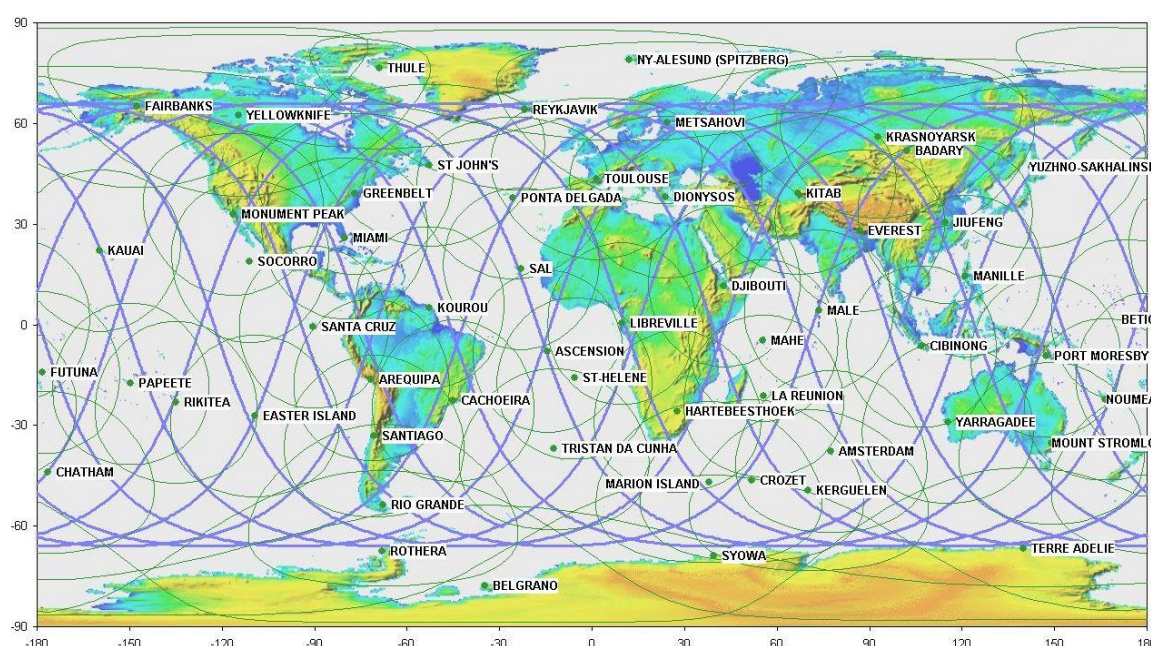


Figure 1 – Jason-1 DORIS stations visibilities.

The Azores archipelago is a seismically active region composed of nine islands and is located at the triple junction of the American, Nubian, and Eurasian plates. The last volcanic eruption, lasting from late 1998 till the beginning 2000, took place in the sea, west of Terceira island, and the last important earthquake occurred on July 9, 1998, at 05:19 am with a moment magnitude $M=6.0$. Its epicentre was located about 16 km N-NE from Horta (Faial Island). The main tectonic features that dominate the Azores region are:

- the Mid-Atlantic Ridge (MAR), which crosses the archipelago between the islands of Faial and Flores in a general N-S direction, and
- the Azores-Gibraltar Fracture Zone that constitutes the Eurasian-Nubian plate boundary and extends from the MAR to the region of Gibraltar. This boundary includes the Terceira Rift (TR) and the Gloria Fault (GF).

The Terceira Rift is a complex structure trending NW-SE extending from the MAR to the Gloria Fault along a line defined by Graciosa, Terceira and São Miguel islands. The Gloria Fault is an E-W dextral strike-slip fault which extends from the vicinity of Santa Maria Island to the east. Impressive submarine and subaerial volcanic rift zones and central volcanoes extend along the MAR and the TR. Therefore, monitoring the DORIS station in Ponta Delgada enhances a better understanding of the relative motion between Eurasia, North America and Africa.

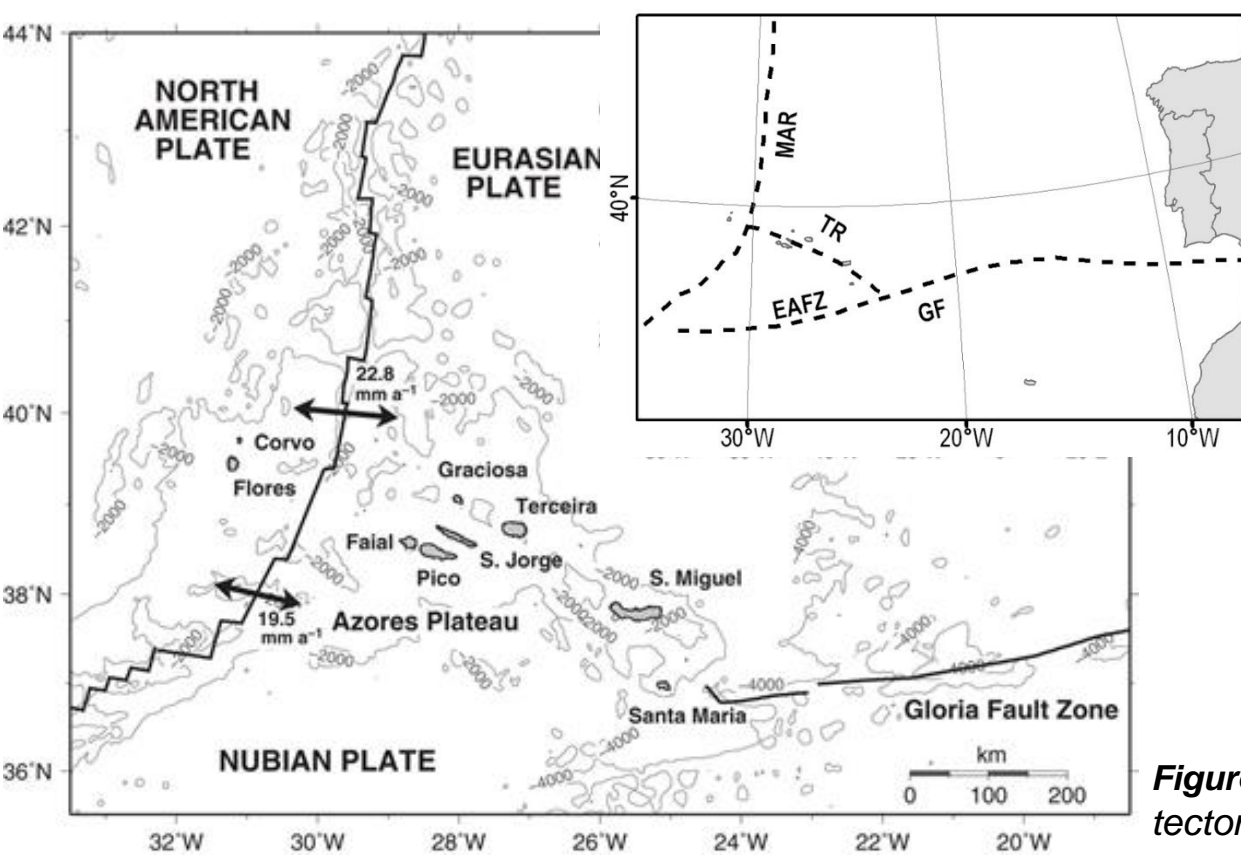


Figure 2 – Azores region main tectonic structures.

History of the DORIS station

DORIS has been present in the Azores Islands since 1987. The station was first located in Flores, the most western island, within the French military base (station acronym: FLOA). Following the base closure at the end of 1993, the DORIS station was upgraded and moved in Santa Maria Island within another French military base, close to the airport (station acronym: SAMB). Then, further to the cessation of French military activities in the Azores, the DORIS station was removed at the end of 1997.

It was in 1998 that DORIS started a DORIS station at Ponta-Delgada, in São Miguel Island in cooperation with the University of the Azores (UAC). IGN and IPCC (Instituto Português de Cartografia e Cadastro) worked together to find a location in São Miguel Island to co-locate their DORIS and GNSS stations. The Geosciences department of the UAC was prepared to host both stations. The DORIS transmissions from Ponta Delgada started in November 1998 (station acronym: PDLB) and the GNSS station (acronym: PDEL) was commissioned in January 2000. Both antennas were installed on the terrace roof of a 3-story building located to the north of the university campus.

Then, in August 2001, the DORIS antenna monument – a guyed 2 m tower – was replaced with a 2 m high very rigid steel tower in order to improving stability (station acronym: PDMB). The first local tie survey was carried out on this occasion, including a VLBI mark (portable observations in 1992) located 900 m away and the nearby tide gauge (GLOSS n° 245) located in the Port 1.5 km away.

Since then, the station has been operating very well with very few service interruptions: beacon upgrading in 2007 and 2015; antenna change in 2001, 2014 and 2015. The main maintenance events are summed up in the table below.

Table 1 – Logbook of the DORIS station at Ponta Delgada

Acronym	Event	Settled	Removed
PDLB	Antenna (B type) installed on guyed 2 m tower	02/11/1998	21/08/2001
PDMB	Antenna monument change: 2 m high rigid metal tower	22/08/2001	10/10/2001
PDMB	Antenna replacement	10/10/2001	24/09/2014
PDMB	Beacon upgrading: 1.0 > 3.0	03/04/2007	02/12/2015
PDNC	Antenna change: B type > C type	25/09/2014	01/12/2015
PDOC	Antenna replacement + Beacon upgrading: 3.0 > 3.1	02/12/2015	

The Seismological Monitoring and Information Center of the Azores (CIVISA), part of the Institute for Research in Volcanology and Risk Assessment (IVAR), is the current group that undertakes the DORIS station maintenance at the University of Azores.



Figure 3 – The DORIS antenna "PDOC" with the GNSS "PDEL" in the background, part of the IGS network

Orbit Performances

The station in Ponta Delgada is a good contributor to Precise Orbit Determination (POD). Each year, a statistical study is performed, which compares the residuals of different stations contributing to the DORIS system. An averaged RMS per station is obtained, considering all available DORIS satellites.

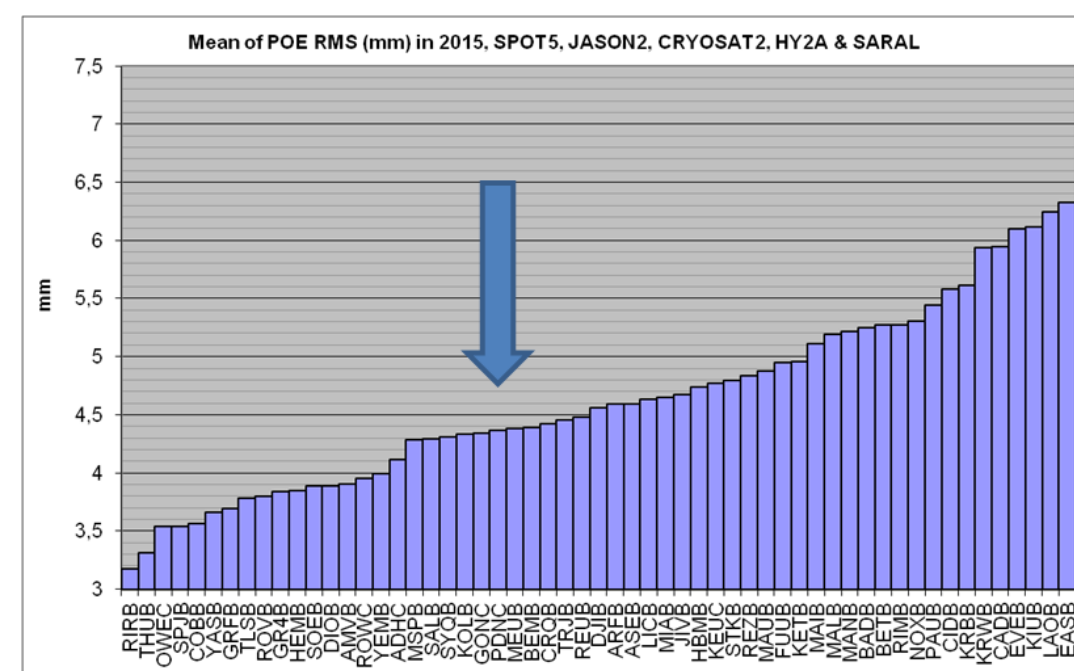


Figure 4 – POE orbit RMS of each DORIS stations in 2015, computed with Spot5, Jason-2, Cryosat2, Hy2a and Saral.

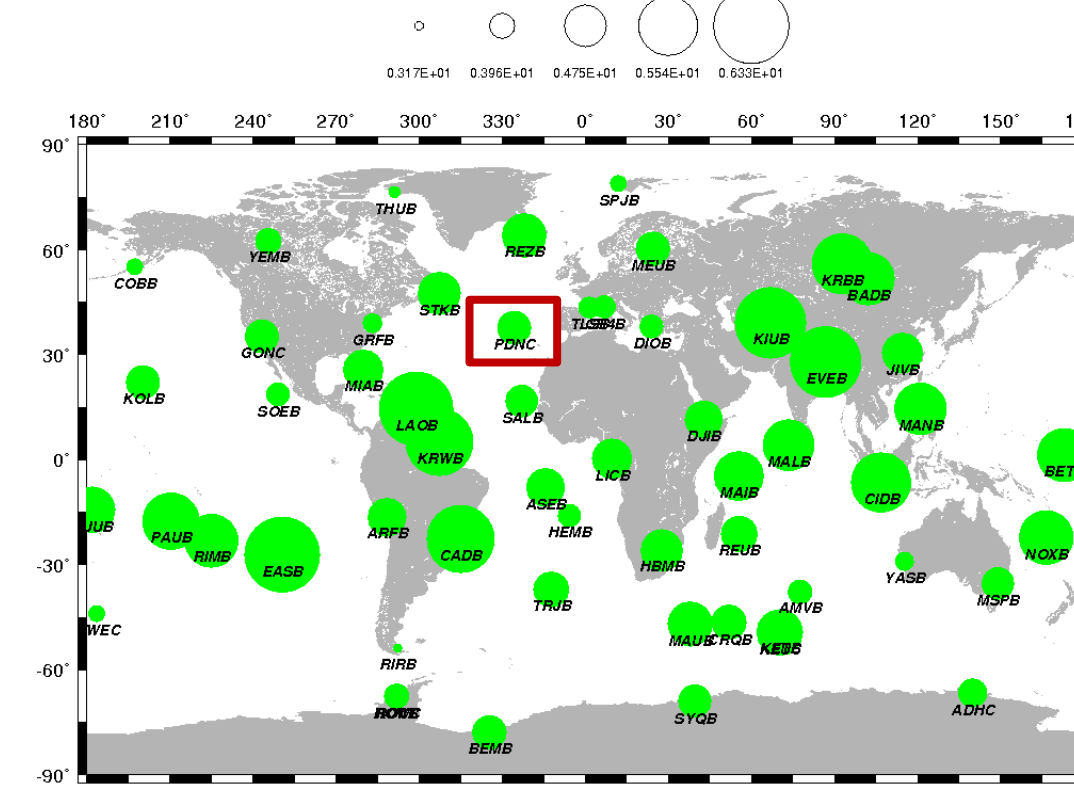


Figure 5 – POE orbit RMS in 2015 (same satellites as Fig. 4). The disk diameters are proportional to the RMS.

Its temporal series is very long, starting at the end of 1998. Figure 6 shows the orbit RMS of Ponta Delgada station, averaged on all DORIS satellites, and compared to the RMS of the whole network. The first beacon (PDLB) had problems during the first year (probably due to an initial cable screwing issue) but reached a good level for the next two years. The second beacon had a stable level of RMS during its 13 years of activity, roughly following the mean of the DORIS network and even slowly improving toward the best stations at the end. An exception occurred at the beginning of 2008 where the RMS reached 8 mm due to a malfunctioning of the antenna, which has been replaced. The next beacon (PDNC) was in the continuity of its predecessor, with a very good level of RMS during the year 2015 (less than 4.5 mm). The current beacon (PDOC), for its two and a half years of activity has a slightly worse level of RMS after all the on-site material has been changed in December 2015.

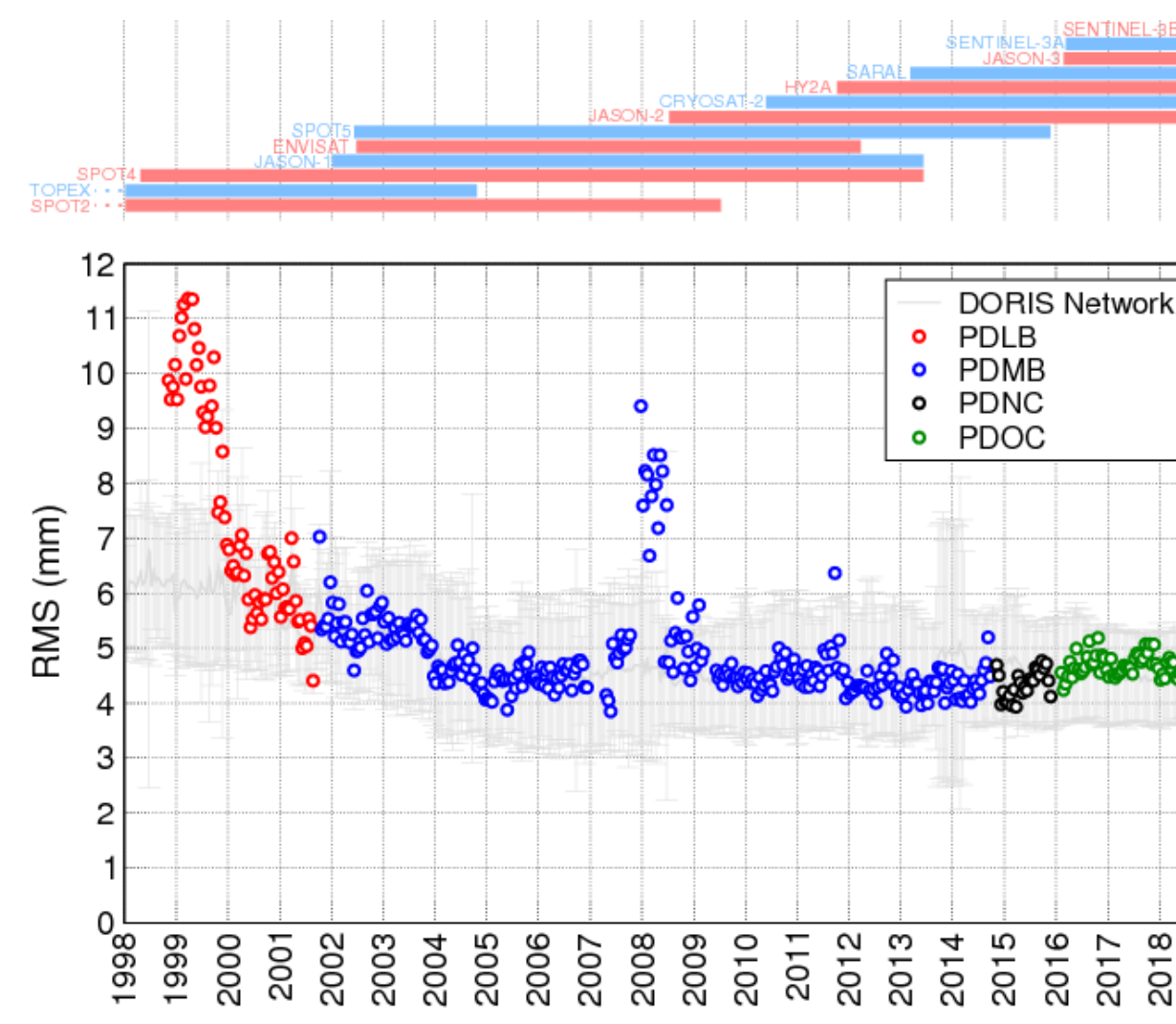


Figure 6 – POE RMS at Ponta Delgada, all DORIS satellites considered.

For instance in 2015 (Fig. 4 and 5), PDNC was at the 23rd rank, among the very good contributors. Its POE RMS had a good 4.37 mm, below the whole network value (4.62 mm).

Its geographic situation in the middle of Atlantic Ocean makes it very important to fill the zone and to counterbalance the SAA effect (quartz sensitivity to South Atlantic radiations)

One should note that the time series of Ponta Delgada's orbit RMS shows a 1-year period, especially visible after 2010. Maybe the origin of such a variation comes from the difficulty to modelize the tropospheric correction, which varies a lot in the vicinity of the sea.

Positioning Performance

Between 1993.0-2018.0, as depicted by the next two plots, the Ponta Delgada DORIS site has been part of the IDS weekly combined solutions for 884 weeks, (i.e. 16.9 years), over the 1000 weeks since its installation on 1998/11/02.

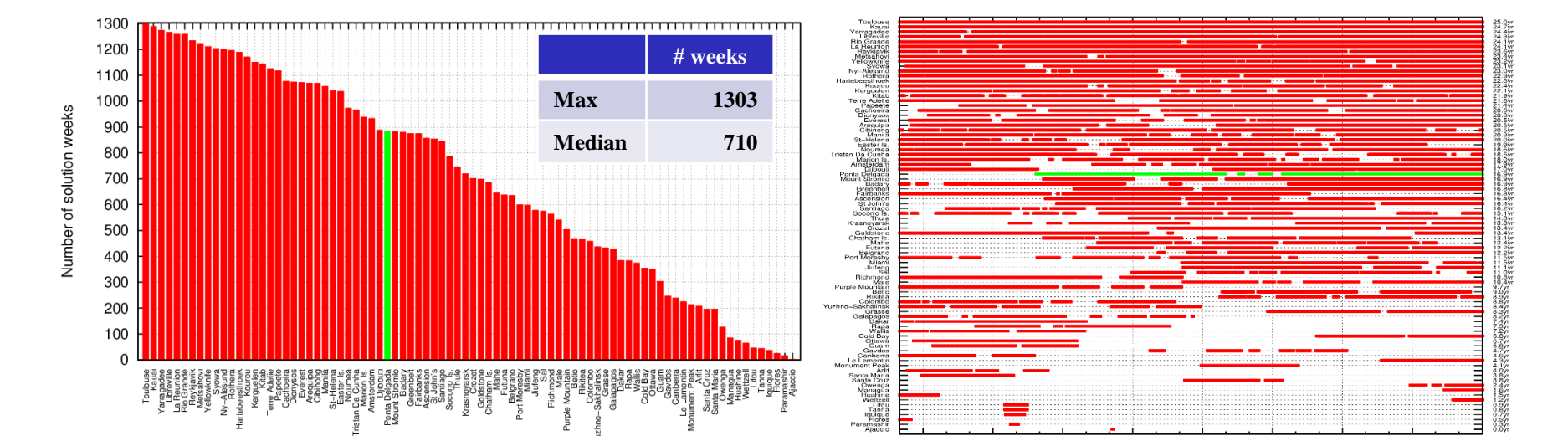


Figure 7 – History of the Ponta Delgada site in the IDS weekly combined solution.

As part of the routine updating of the DPOD2014 (DORIS terrestrial reference frame for Precise Orbit Determination; Moreaux et al., 2018) solution, the IDS Combination Center estimates the mean positions and velocities of all the DORIS stations from the IDS weekly combined solution assuming a linear motion model. Then, the quality/precision of the mean positions and velocities depend on the dispersion of the weekly estimates with respect to a linear model.

Figure 8 – Residuals of the PDLB, PDMB, PDNC and PDOC DORIS stations wrt mean linear model deduced for Ponta Delgada.

Reduction of the dispersion over time thanks to expansion of the DORIS satellite constellation and technical evolution of the DORIS system and the stability improving of the antenna monument.

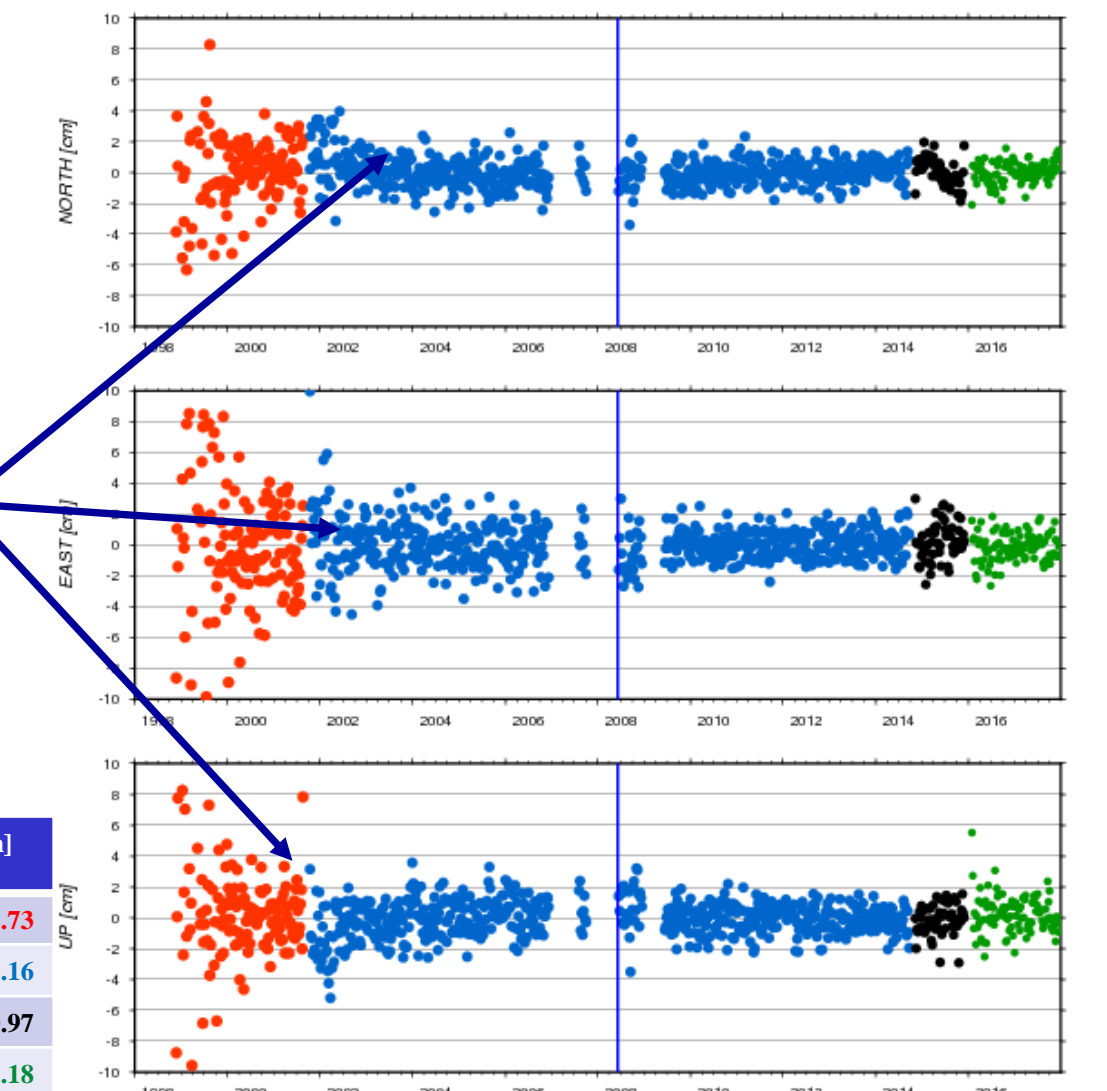


Table 2 – Main statistics of the residuals.

	# weeks	North [cm]	East [cm]	Up [cm]
PDLB	125	0.07 ± 2.21	0.00 ± 3.73	0.16 ± 2.73
PDMB	582	0.03 ± 0.94	0.06 ± 1.34	-0.06 ± 1.16
PDNC	56	0.05 ± 0.86	0.21 ± 1.20	-0.13 ± 0.97
PDOC	100	0.04 ± 6.85	-0.13 ± 0.91	0.22 ± 1.18

Ponta Delgada mean velocities from DORIS only (1998.8 to 2018.):

North: 14.79 ± 0.17 mm/yr / East: 12.35 ± 0.28 mm/yr / Up: -1.14 ± 0.21 mm/yr

Within their respective standard deviations, our velocities agree with the ITRF2014 (Altamimi et al. 2016) ones as well as with the GPS estimations from Trota et al. (2006) (who also inferred that the east and the west parts of the São Miguel island were moving apart).

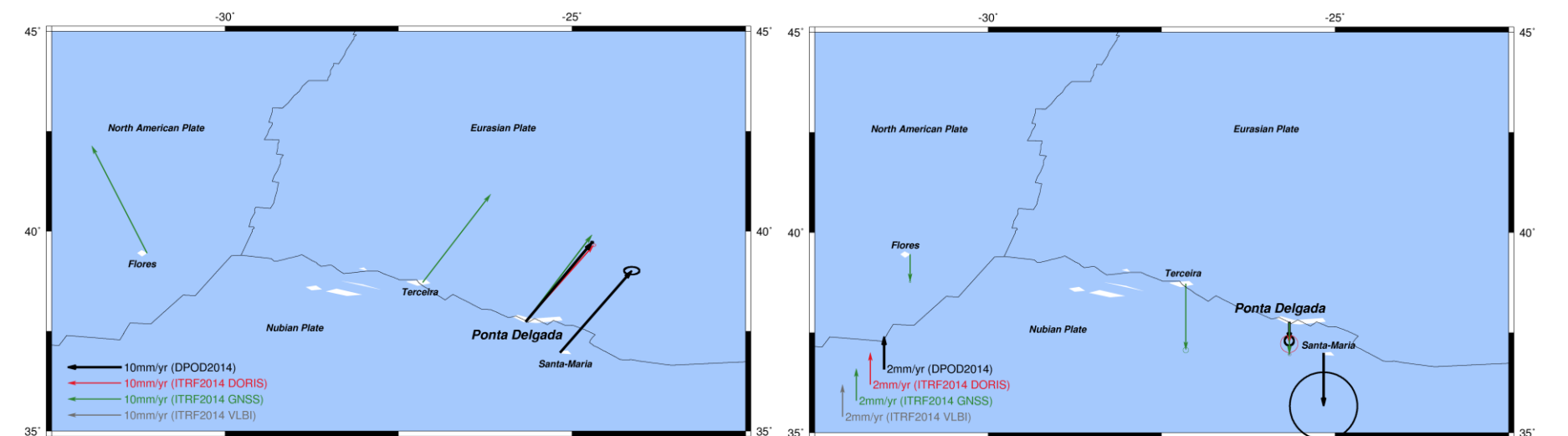


Figure 9 – DORIS, GNSS and VLBI mean horizontal (left) and vertical (right) vertical velocities for Ponta Delgada.

References

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