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The synergy of SLR and DORIS as geodetic techniques

Frank Lemoine (NASA GSFC), Alexandre Belli (NASA Postdoctoral Program, NASA GSFC), Carey Noll (NASA GSFC)

Mount Stromlo Satellite Laser Ranging facility (left) and DORIS antenna (right)

DORIS associates, Frank Lemoine, Alexandre Belli and co-authors presented two papers to the 21st International Workshop in Laser Ranging, 5-9 November 2018 in Canberra, Australia: "The Synergy of Satellite Laser Ranging (SLR) and DORIS as Space Geodesy Techniques", and "Monitoring the Time Bias in Laser Ranging stations thanks to the T2L2 experiments". SLR sites make excellent, reliable, long-term hosts for DORIS stations. DORIS is currently hosted at ten SLR sites worldwide. Future SLR/DORIS co-locations include Changchun, China (which is awaiting approval), and Ny-Ålesund, Svalbard (where a joint NASA/Norwegian Mapping Agency SLR station will be installed by 2022). A further co-location is also planned by the CNES, NASA, and other partners at Papenoo, Tahiti, as a core site that would also include VLBI and GNSS.

DORIS data, in combination with SLR data, have been used to provide precise orbits to altimeter satellites (e.g., Jason-1, -2, and -3, Sentinel-3A and -3B) with a radial orbit accuracy of 7-10 mm, and have allowed us to measure the global rate of change and the acceleration in global mean sea level over the past 26 years. The data from the Jason-2/T2L2 experiment, enabled by DORIS, have provided a new global metrological view of the SLR station timing system stability, which previously was not available. For example, the T2L2 data showed that some SLR stations had timing biases up to several µsecs w.r.t UTC. Time bias corrections provided by Jason-2/T2L2 and the Jason-2 DORIS Ultra-stable Oscillator (2008-2017) will be used by the International Laser Ranging Service (ILRS) during the preparation of the next realization of the ITRF, ITR2020.

During the workshop, F. Lemoine, A. Belli and also former IDS Governing Board member Carey Noll met the personnel from Yarragadee and Mt. Stromlo who operate the SLR stations and host the DORIS beacons. DORIS Associate R. Govind (Space Geodesy Analysis Centre Pty Ltd) also attended the ILRS workshop. Conference participants enjoyed a visit and barbecue at the Mt. Stromlo station, on the outskirts of Canberra, at the conclusion of the meeting.

Frank Lemoine (left) and Carey Noll (right) visiting Mount Stromlo station

The Azores: a key location occupied by DORIS for three decades

Jérôme Saunier (IGN), Christian Jayles (CNES), Guilhem Moreaux (CLS), Philippe Yaya (CLS)

The archipelago of the Azores is located in the North Atlantic Ocean about 1600 km (1000 mi) west of Lisbon. These nine islands are part of Portugal (autonomous region) and they were formed through volcanic activity.

The Azores is located at the active triple junction between the North American, Eurasian and African (Nubian) tectonic plates, which is responsible for recurrent seismic and volcanic activity and gives its very high interest for geophysics.

DORIS network on Google Earth with a focus on the Azores
https://ids-doris.org/doris-system/tracking-network/network-on-google-earth.html

The DORIS ground station story

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 closure of the base at the end of 1993, the DORIS station was upgraded and moved to Santa Maria Island within another French military base, close to the airport (station acronym: SAMB). Then, subsequently the DORIS station was removed at the end of 1997.

It was in 1998 that we started a collaboration with the University of the Azores (UAC). IGN/CNES and IPCC (Instituto Português de Cartografia e Cadastro) worked together to find a location on São Miguel Island to co-locate their DORIS and GNSS stations. The Geosciences department of the UAC agreed to host both stations at Ponta Delgada. The DORIS transmissions from Ponta-Delgada started in Nov. 1998 (station acronym: PDLB) and the GNSS station (acronym: PDEL) was commissioned in Jan. 2000. Both antennas were installed on the roof terrace of a 3-story building of the university campus. Since then, the station has been operating very well with very few service interruptions. The beacon was upgraded in 2007 and 2015. Antenna changes were made in 2001 (station acronym: PDMB), 2014 (station acronym: PDNC) and 2015 (station acronym: PDOC). The station has operated smoothly for 884 weeks (i.e. 16.9 years) over the 1000 weeks since its installation in 1998.

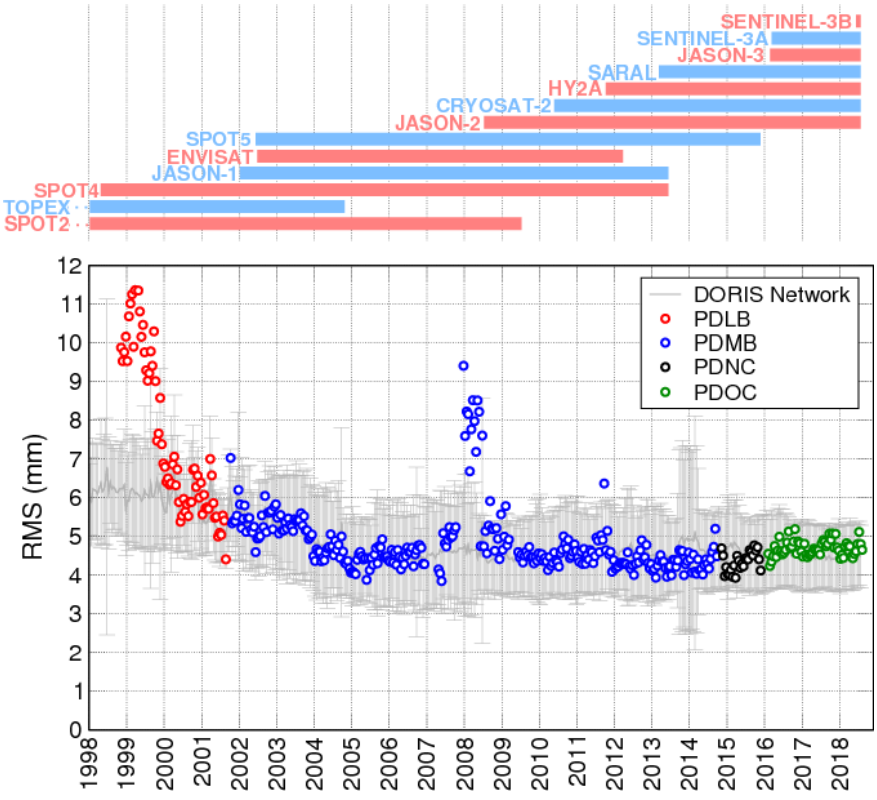
The first local tie survey was carried out in 2001, including the DORIS and the GNSS stations, a VLBI mark (portable observations in 1992) located 900 m away and the nearby tide gauge (GLOSS n°245) located in the Port 1.5 km away. The co-location of geodetic techniques as DORIS, GNSS, SLR and VLBI and local ties terrestrial measurements enable connectivity between these space techniques to contribute to the International Terrestrial Reference Frame construction. The co-location of the DORIS tracking stations with tide gauges helps to accurately calibrate sea level change.

The Centre for Information and Seismovolcanic Surveillance of the Azores (CIVISA) and the Research Institute for Volcanology and Risk Assessment (IVAR), from the UAC, are the current group that undertakes the DORIS station maintenance at the UAC (see insert about the CIVISA/IVAR on page 4).

Ponta Delgada DORIS station performance

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

Technically, 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, the DORIS station in the Azores is essential for providing tracking coverage for DORIS satellites over the Northern Atlantic, ideally located in the middle of the triangle formed by its closest nearby DORIS stations: Toulouse (France), Sal (Cape Verde) and St-John's (Canada). The station in Ponta Delgada is a good contributor to Precise Orbit Determination (POD) with mid-range POD quality performances. Its geographic situation makes it very important to provide tracking coverage in this zone at the outer boundary of the high radiation area known as South Atlantic Anomaly (SAA) to which the on-board DORIS instruments are sensitive.



Orbit RMS of Ponta-Delgada station in colored circles, averaged on all DORIS satellites, compared to the RMS from the global network in grey.
PDLB, PDMB, PDNC, PDOC are the successive acronyms of the station.

Scientifically, monitoring the DORIS station in Ponta-Delgada provides a better understanding of the relative motion between Eurasia, North America and Africa.

Visibility circle around Ponta-Delgada station for Low Earth Orbit satellite (800km) with 12° cut-off angle over the horizon

This region is in a very active seismic area. 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 with a moment magnitude M=6.0. Its epicenter was located about 16 km north-northeast from Horta (Faial Island). The main tectonic features that dominate the Azores region are:

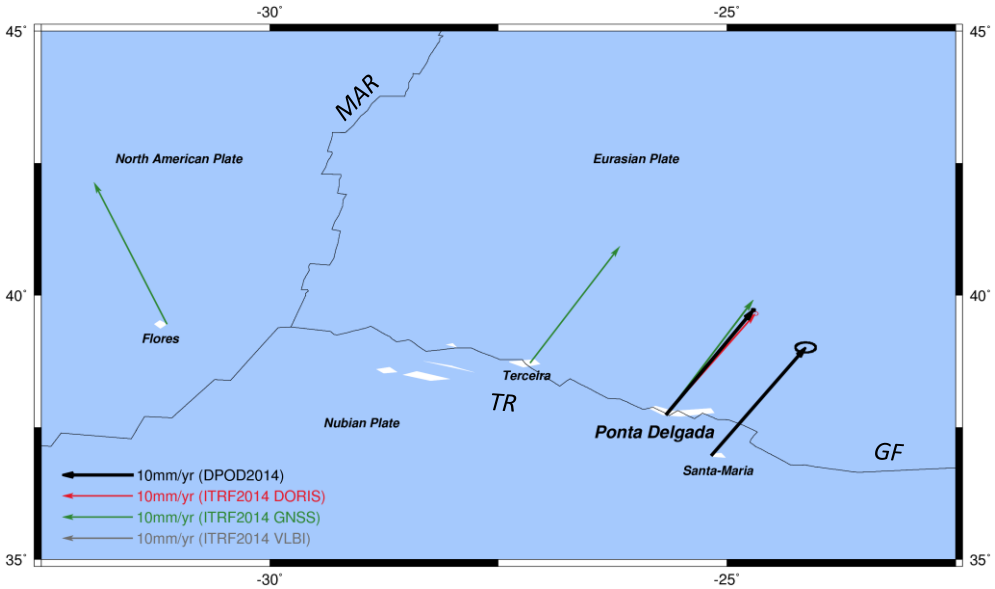
i) the Mid-Atlantic Ridge (MAR), which crosses the archipelago between the islands of Faial and Flores in a general north-south direction, and
ii) the Azores-Gibraltar Fracture Zone that constitutes the Eurasian-Nubian plate boundary and extends from the MAR to the region of Gibraltar. This boundary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

Impressive submarine and subaerial volcanic rift zones and central volcanoes extend along the MAR and the TR.

The very long temporal series of the DORIS station, starting at the end of 1998, give the following Ponta Delgada velocities (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, DORIS velocities agree with the ITRF2014 ones as well as with the local GNSS estimations.



Mean horizontal velocities in the Azores, located close to the boundary of the African, Eurasian and North American tectonic plates.

The DORIS and GNSS antennas at Ponta Delgada

Every DORIS station has a different history and local characteristics. The DORIS station at Ponta Delgada occupies a very specific point on the Earth's surface: the boundary zone where three major tectonic plates meet. DORIS has been participating for three decades now in providing geophysical observations and monitoring to better understand the structure and evolution of the Earth's crust. Its beacon in Ponta Delgada is now deeply attached to this piece of land in the middle of the Ocean!

THE HOST AGENCY IN SHORT

Rui Tiago Fernandes Marques, President of the Board of Directors
CIVISA, University of the Azores http://www.cvarg.azores.gov.pt

CIVISA is a private non-profit association that has as founding partners the Regional Government of the Azores and the University of the Azores. The main objective of the CIVISA is to ensure the monitoring and the geological hazards assessment in the Azores (through a permanent multiparametric network, including seismic, GNSS, gas geochemistry and meteorological stations), to provide technical and scientific advice to regional and local civil protection authorities, among others, in mitigating risks that may threaten the safety of people and assets.
The IVAR research activities are developed within the Earth Sciences domain, involving a multidisciplinary approach for the prevention and forecast of natural hazards. Its mission is to promote and improve Science and Technology in the area of Volcanology and related domains, in order to understand the volcanological phenomena and to assess the risk directly or indirectly associated with them, including volcanic eruptions, earthquakes, hydrothermal explosions, toxic gases release, landslides, floods and tsunamis, events that frequently occur coupled in space and in time, at different scales, as result of complex geological mechanisms.

Tribute to Richard Biancale (1952-2019)

Frank Lemoine (NASA), Laurent Soudarin (CLS), Jean-Michel Lemoine (CNES), Pascale Ferrage (CNES), Jean-Paul Boy (EOST)

It is with profound sadness that we must announce to you the passing of our colleague, Dr. Richard Biancale, geodesist, recently retired from the CNES in September 2018, and most recently working at the GFZ (Oberpfaffenhofen) with Dr. Frank Flechtner on GRACE Follow-On. We were informed of his death on Monday February 4, 2019 from a heart attack while skiing in the Alps.

Richard at the IDS AWG meeting in Toulouse in June 2018

Richard had a long and distinguished career in Space Geodesy. He received his Ph.D. in 1978 from the University Pierre and Marie Curie in Paris (France) while working under Professor Christoph Reigber at the Technical University of Munich (Germany). He worked as a research scientist at the University of Sao Paulo, at the DGFI (Deutsches Geodätisches Forschungsinstitut) in Munich (Germany), and at CERGA (Centre d'Etudes et de Recherches en Géodynamique et Astronométrie) Grasse (France), before joining the French Space Agency, the CNES (Toulouse, France) in 1982 as a scientific engineer.

Under the direction of Michel Lefebvre, one of his first jobs at the CNES was to define the DORIS tracking system for the TOPEX/Poseidon mission. Since 1984 he was very involved in the French-German cooperation on gravity field modeling, first with the GRIM models, and then with the EIGEN models after the launches of CHAMP and GRACE. He served as the scientific manager of the Stella laser geodetic satellite, launched in 1993.Under the direction of Dr. Georges Balmino, he became chief of the "Terrestrial and Planetary Geodetic Department" of the CNES in 1992. He received his “Habilitation” in 2006 and starting in 2008 served as Executive Director of the Groupe de Recherche de Géodésie Spatiale (GRGS), a French national group that gathers 120 researchers from organizations involved in Space Geodesy studies.

Over the course of his career he has supervised and inspired more than a dozen Ph.D students and served as a mentor to many colleagues and young scientists. Understanding the importance of training the next generation of scientists in satellite geodesy, he has taught geodesy for over 25 years at engineer schools (e.g. ENSG [Ecole de la Géomatique/National School of Geographic Sciences], ENSTA [Ecole Nationale Supérieure de Techniques Avancées]), at universities (e.g. Paris VI), and short training courses (e.g. GRGS Summer School).

Throughout his career he has worked assiduously to improve the quality of geodetic data, and to advance the science obtained from these data. He was a strong proponent of the need for improving the International Terrestrial Reference Frame (ITRF), supporting the contributions to the IDS, IGS, ILRS, IVS and IERS. He has participated and led national and international proposals for new innovative space missions that would continue to advance the contribution of geodesy to science and society. Most recently, before and after his retirement from CNES, he worked to advance the proposal for the Tahiti Geodetic Observatory, a fundamental station including VLBI, SLR, GNSS and DORIS whose geographic location would be of prime importance to the ITRF and to the mm-level goals of the Global Geodetic Observing System (GGOS) in the next decade.

The DORIS community is grateful for his participation in many DORIS AWG meetings, in supporting the contribution of IDS to the ITRF, serving on the IDS Governing Board, and contributing to the success of the IDS Retreat in June 2018.

As many of his colleagues noticed, Richard Biancale had a joie de vivre. He was charming, free, passionate and cheerful man who embraced life whether it was in a fine restaurant after a scientific meeting, sailing around the Mediterranean or across the Atlantic on his catamaran, "RaphyO^2", or visiting interesting cultural or natural locales. As his colleagues, we were all privileged to enjoy his friendship. We lament this tragic loss.

To his family, including wife, Irmtraud, and four children, Raphaël, Philipp, Johannes and Jocelyne, we extend our deepest sympathy and most heartfelt condolences.

IDS election results

In accordance with the Terms of Reference of the IDS, two positions in the IDS Governing Board become vacant at the end of 2018. IDS associates were invited to nominate candidates for the two open positions for the next 4-year term 2019-2022.
The elections were held from Dec. 1 to Dec.15, 2018. The members elected by the IDS Associates are the following:

- Analysis Coordinator

tandem: Hugues Capdeville (CLS, France) & Petr Štěpánek (Pecny Observatory, Czech Republic)

- Member-at-large

Claudio Abbondanza (NASA/JPL, USA)

We warmly thank Jean-Michel Lemoine (CNES, France) and Marek Ziebart (UCL, UK) for their valuable contributions to the IDS Governing Board over the past four years as Analysis Coordinator (in tandem with H. Capdeville) and Member at large respectively.

Visit to the Ponta Delgada DORIS station

During the IDS workshop in Ponta Delgada in September 2018, a group of 28 people visited the DORIS station at the UAC. The group were glad to see a DORIS ground station and to better understand the local environment and maintenance conditions. Dr. Rui Marques, President of CIVISA, led a guided tour, and described how CIVISA monitored the recurrent seismic and volcanic activity in the Azores. The visitors expressed a keen interest in the activities of CIVISA. The natural hazards monitoring by CIVISA requires significant resources and is a heavy responsibility for the host agency.

IDS Workshop 2018

The IDS workshop was held in Ponta Delgada (Azores Archipelago), Portugal, on 24 to 26 September 2018, in conjunction with the Symposium on "25 Years of Progress in Radar Altimetry" and the annual Ocean Surface Topography Science Team (OSTST) meeting.

The presentations are available for viewing or downloading on the IDS website at https://ids-doris.org/ids/reports-mails/meeting-presentations/ids-workshop-2018.html

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