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IDS

ACTIVITY REPORT 2019-2020

International Doris Service

International DORIS Service Activity Report 2019-2020

Edited by Laurent Soudarin and Pascale Ferrage

International DORIS Service

Central Bureau

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Preface

In this volume, the International DORIS Service documents the work of the IDS components between January 2019 and December 2020. The individual reports were contributed by IDS groups in the international geodetic community who make up the permanent components of IDS.

The IDS 2019-2020 Report describes the history, changes, activities and the progress of the IDS. The Governing Board and Central Bureau kindly thank all IDS team members who contributed to this report.

The IDS takes advantage of this publication to relay the thanks of the CNES and the IGN to all of the host agencies for their essential contribution to the operation of the DORIS system. The list of the host agencies is given in the appendix of this Report.

The entire contents of this Report also appear on the IDS website at

https://ids-doris.org/documents/report/IDS_Report_2019-2020.pdf

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ABOUT IDS

1. INTRODUCTION

As other space-techniques had already organized into services - the International GNSS Service (IGS) for GPS, GLONASS and, in the future, Galileo (*Beutler et al. 1999*), the International Laser Ranging Service (ILRS) for both satellite laser ranging and lunar laser ranging (*Pearlman et al. 2002*) and the International VLBI Service for Geodesy and Astrometry (IVS) for geodetic radio-interferometry (*Schlueter et al. 2002*) -, the IDS was created in 2003 as an IAG service to federate the research and developments related to the DORIS technique, to organize the expected DORIS contribution to IERS and GGOS (*Rummel et al. 2005*; *Willis et al. 2005*), and to foster a larger international cooperation on this topic.

At present, more than 60 groups from 38 different countries participate in the IDS at various levels, including 50 groups hosting DORIS stations in 35 countries all around the globe.

Two analysis centers contributed as individual DORIS solutions to ITRF2005 and in 2006 four analysis centers provided results for IDS. Since 2008, eight analysis groups have provided results, such as orbit solutions, weekly or monthly station coordinates, geocenter variations or Earth polar motion, that are used to generate IDS combined products for geodesy or geodynamics. All these centers have provided SINEX solutions for inclusion in the IDS combined solution that was submitted in 2009 to the IERS for ITRF2008. In 2009, a first IDS combined solution (*Valette et al., 2010*) was realized using DORIS solutions from 7 Analysis Groups for weekly station positions and daily Earth orientation parameters. In 2012, 6 analysis centers (ACs) provided operational products, which were combined in a routine DORIS combination by the IDS Combination Center in Toulouse. In 2013, several inter-comparisons between ACs were performed (orbit comparisons, single-satellite SINEX solutions for station coordinates). In 2013 and 2014, the Analysis Centers and the Combination Center hardly worked on preparing the DORIS contribution for the new realization of the ITRF. All the DORIS data (since 1993) were processed by the six Analysis Centers. They submitted sets of weekly SINEX solutions to the Combination Center to generate the combined products. Thanks to the numerous exchanges between the groups to address the issues identified, several iterations were performed. The final version of the IDS contribution was submitted to the IERS in 2015. It was then included in the solutions produced by the IERS Production Centers at IGN, DGFI and JPL. The activities of the DORIS analysts in 2016 and 2017 were dominated by the evaluation of these three independent realizations (ITRF2014, DTRF2014, and JTRF2014), and the DPOD2014, which is the DORIS extension of the ITRF for Precise Orbit Determination. They also focused on analyzing the data of the last DORIS satellites Jason-3 and Sentinel-3A, defining a strategy to minimize the impact of the sensitivity to the South Atlantic Anomaly effect of their Ultra Stable Oscillator and resolving the scale factor jump of the IDS solution.

This report summarizes the current structure of the IDS, the activities of the Central Bureau, provides an overview of the DORIS network, describes the IDS data centers, summarizes the DORIS satellite constellation, and includes reports from the individual DORIS ACs.

2. HISTORY

The DORIS system was designed and developed by CNES, the French space agency, jointly with IGN, the French mapping and survey agency, and GRGS the space geodesy research group, for precise orbit determination of altimeter missions and consequently also for geodetic ground station positioning (*Tavernier et al. 2003*).

DORIS joined the GPS, SLR and VLBI techniques as a contributor to the IERS for ITRF94. In order to collect, merge, analyze, archive and distribute observation data sets and products, the IGS was established and recognized as a scientific service of the IAG in 1994, followed by the ILRS in 1998 and the IVS in 1999. It is clear that DORIS has benefited from the experience gained by these earlier services. There was an increasing demand in the late nineties among the international scientific community, particularly the IAG and the IERS, for a similar service dedicated to the DORIS technique.

On the occasion of the CSTG (Coordination of Space Technique in Geodesy) and IERS Directing Board meetings, held during the IUGG General Assembly in Birmingham in July 1999, it was decided to initiate a DORIS Pilot Experiment (*Tavernier et al. 2002*) that could lead on the long-term to the establishment of such an International DORIS Service. A joint CSTG/IERS Call for Participation in the DORIS Pilot Experiment was issued on 10 September 1999. An international network of 54 tracking stations was then contributing to the system and 11 proposals for new DORIS stations were submitted. Ten proposals were submitted for Analysis Centers (ACs). Two Global Data Centers (NASA/CDDIS in USA and IGN/LAREG in France) already archived DORIS measurements and were ready to archive IDS products. The Central Bureau was established at the CNES Toulouse Center, as a joint initiative between CNES, CLS and IGN. The IDS Central Bureau and the Analysis Coordinator initiated several Analysis Campaigns. Several meetings were organized as part of the DORIS Pilot Experiment (**Table 1**).

The IDS was officially inaugurated on July 1, 2003, as an IAG Service after the approval of the IAG Executive Committee at the IUGG General Assembly in Sapporo. The first IDS Governing Board meeting was held on November 18, 2003, in Arles, France. Since then, each year, several IDS meetings were held (**Table 2**).

In 2019, two meetings of the Analysis Working Group are organized: first, in Munich (Germany) on April 4, then in Paris (France) on September 30 and October 1st.

Due to the global Covid-19 pandemic, no event was organized in 2020

Date	Event	Location
2000	DORIS Days http://ids-doris.org/report/meeting-presentations/doris-days-2000.html	Toulouse France
2002	IDS workshop http://ids-doris.org/report/meeting-presentations/ids-workshop-2002.html	Biarritz France
2003	IDS Analysis Workshop http://ids-doris.org/report/meeting-presentations/ids-workshop-2003.html	Marne La Vallée France

Table 1. List of meetings organized as part of the DORIS Pilot Experiment

Date	Event	Location
2004	Plenary meeting http://ids-doris.org/report/meeting-presentations/ids-plenary-meeting-2004.html	Paris France
2006	IDS workshop http://ids-doris.org/report/meeting-presentations/ids-workshop-2006.html	Venice Italy
2008	Analysis Working Group Meeting http://ids-doris.org/report/meeting-presentations/ids-awg-03-2008.html Analysis Working Group Meeting http://ids-doris.org/report/meeting-presentations/ids-awg-06-2008.html IDS workshop http://ids-doris.org/report/meeting-presentations/ids-workshop-2008.html	Paris France Paris France Nice France
2009	Analysis Working Group Meeting http://ids-doris.org/report/meeting-presentations/ids-awg-03-2009.html	Paris France
2010	Analysis Working Group Meeting http://ids-doris.org/report/meeting-presentations/ids-awg-03-2009.html IDS workshop & 20th anniversary of the DORIS system http://ids-doris.org/report/meeting-presentations/ids-workshop-2010.html	Darmstadt Germany Lisbon Portugal
2011	Analysis Working Group Meeting http://ids-doris.org/report/meeting-presentations/ids-awg-05-2011.html	Paris France
2012	Analysis Working Group Meeting http://ids-doris.org/report/meeting-presentations/ids-awg-05-2012.html IDS workshop http://ids-doris.org/report/meeting-presentations/ids-workshop-2012.html	Prague Czech Republic Venice Italy
2013	Analysis Working Group Meeting http://ids-doris.org/report/meeting-presentations/ids-awg-04-2013.html Analysis Working Group Meeting http://ids-doris.org/report/meeting-presentations/ids-awg-10-2013.html	Toulouse France Washington USA

Date	Event	Location
2014	Analysis Working Group Meeting http://ids-doris.org/report/meeting-presentations/ids-awg-03-2014.html IDS workshop http://ids-doris.org/report/meeting-presentations/ids-workshop-2014.html	Paris France Konstanz Germany
2015	Analysis Working Group Meeting http://ids-doris.org/report/meeting-presentations/ids-awg-05-2015.html Analysis Working Group Meeting http://ids-doris.org/report/meeting-presentations/ids-awg-10-2015.html	Toulouse France Greenbelt USA
2016	Analysis Working Group Meeting http://ids-doris.org/report/meeting-presentations/ids-awg-05-2016.html IDS workshop http://ids-doris.org/report/meeting-presentations/ids-workshop-2016.html	Delft The Netherlands La Rochelle France
2017	Analysis Working Group Meeting https://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-05-2017.html	London United Kingdom
2018	Analysis Working Group Meeting http://ids-doris.org/report/meeting-presentations/ids-awg-06-2018.html IDS workshop http://ids-doris.org/report/meeting-presentations/ids-workshop-2018.html	Toulouse France Ponta Delgada Portugal
2019	Analysis Working Group Meeting http://ids-doris.org/report/meeting-presentations/ids-awg-04-2019.html Analysis Working Group Meeting http://ids-doris.org/report/meeting-presentations/ids-awg-09-2019.html	Munich Germany Paris France
2020	-	

Table 2. List of IDS events organized between 2004 and 2020

3. ORGANIZATION

3.1. IDS ORGANIZATION

Like the other IAG Services, an IDS Governing Board (GB), helped by a Central Bureau (CB), organizes the activities done by the Analysis Centers (AC), the Data Centers (DC), and the Combination Center (CC) (**Figure 1**).

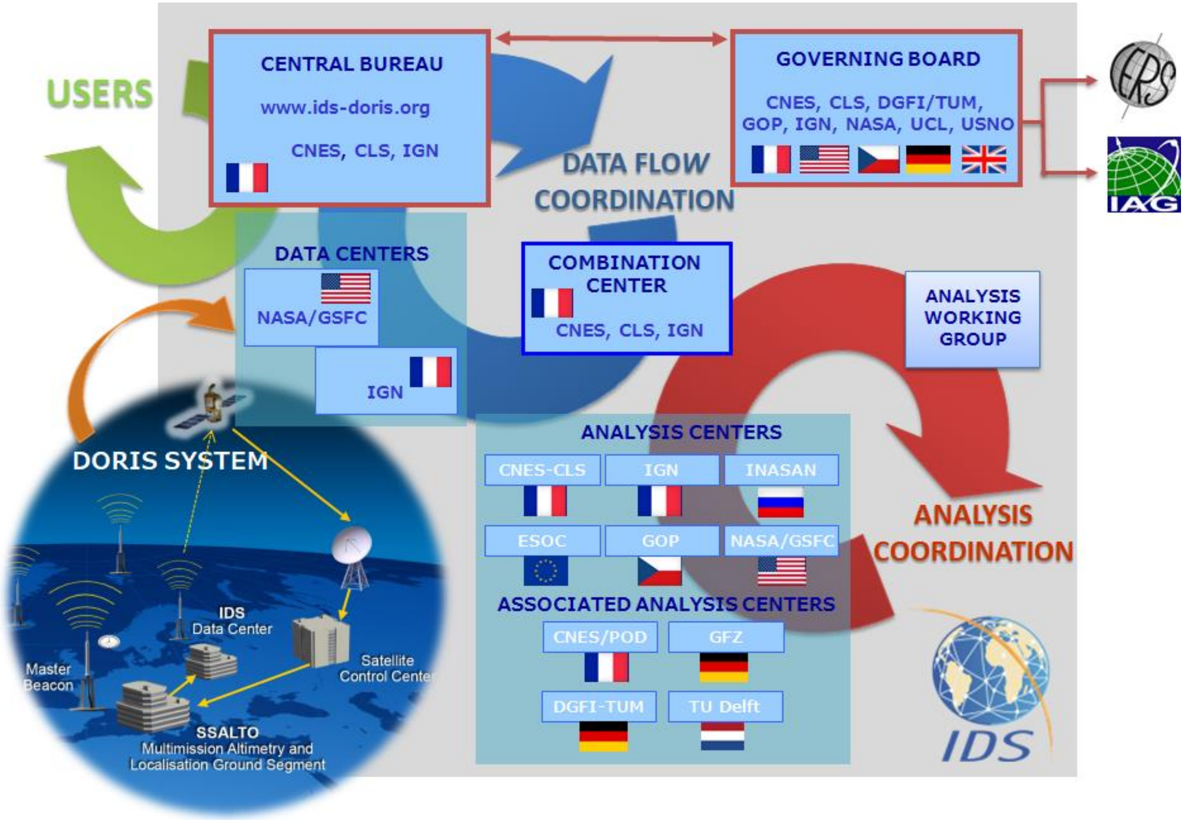


Figure 1. IDS organization

3.2. GOVERNING BOARD

The GB consists of eleven voting members and several nonvoting members. The voting membership of the GB is composed of 5 members elected by the IDS Associates, and 6 appointed members. The elected members have staggered four-year terms, with elections every two years. The Analysis Centers' representative, the Data Centers' representative, and one Member-at-Large are elected during the first two-year election. The Analysis Coordinator and the other Member-at-Large are elected in the second two-year election. In accordance with the Terms of Reference of the IDS, the GB was then partially renewed in January 2017 and January 2019 (see **Table 3**).

Normally scheduled for late 2020, the last elections were held in early January 2021. The purpose of the elections was to renew the position of the Analysis Centers' representative, the Data Centers' representative, and one Member-at-Large. In addition, IDS proceeded to the renewal of three representatives appointed respectively by CNES (DORIS system), IGN (network), and IERS. First, the CB contacted the relevant organizations to appoint their representatives; second, the CB organized the elections for the three vacant positions. In a final step the GB elected its new chairman.

The members who were elected or appointed for the term 2021-2024 are:

- Frank Lemoine (NASA/ GSFC, USA) as Analysis Center Representative,
- Patrick Michael (NASA/GSFC, USA) as Data Center Representative,
- Karine Le Bail (Chalmers University of Technology, Sweden) as Member-at-Large,
- Pascale Ferrage (CNES, France), reappointed by CNES as the DORIS system representative,
- Jérôme Saunier (IGN, France), reappointed by IGN as the Network representative.
- Tonie van Dam (University of Luxembourg, Luxembourg), appointed by IERS as the IERS representative.

Note that Ernst Schrama (TU Delft, The Netherlands) was designated by IAG as its representative within the Governing Board for 2019-2022, to replace Petr Štěpánek (Geodetic Observatory Pecny, Czech Republic), who resigned from this position after he was elected with Hugues Capdeville (CLS, France) to form the Analysis Coordination team for the term 2019-2022.

The new Governing Board has re-elected Frank Lemoine as the Chairperson of the IDS Governing Board for 2021-2024.

Denise Dettmering remains an ex officio member of the IDS GB, in the role of Chair of the IDS Working Group on Near Real Time Data.

Table 3 give the list of GB's members since 2003, the members in office on January 1st, 2021, indicated in bold.

3.3. REPRESENTATIVES AND DELEGATES

IDS representatives and delegates are :

- IDS representatives to the IERS :
  - Analysis Coordinator: Hugues Capdeville (+Petr Štěpánek)
  - Network representative: Jérôme Saunier
- IDS representatives to GGOS consortium : Frank Lemoine, Laurent Soudarin
- IDS representative to GGOS Bureau of Networks and Observations : Jérôme Saunier
- IDS representative to GGOS Bureau of Products and Standards : Petr Štěpánek

3.4. CENTRAL BUREAU

In 2020, the IDS Central Bureau is organized as follow :

- Laurent Soudarin CLS (Director)
- Pascale Ferrage CNES
- Jérôme Saunier IGN
- Guilhem Moreaux CLS

3.5. IDS STRATEGIC PLAN

After the IDS Retreat held in June 2018, the IDS GB worked on the development of a strategic plan for the IDS. In the coming years, IDS will focus on growing the community, extending the DORIS applications, and improving the technology, the infrastructure, and the processing.

3.6. IDS LIFE

The period 2019-2020 started sadly because on February 4, 2019, we lost our colleague and friend Richard Biancale recently retired from the CNES in September 2018, and newly installed at the GFZ (Oberpfaffenhofen) to work with Dr. Frank Flechtner on GRACE Follow-On. A tribute was paid to him in the IDS Newsletter #6:

https://ids-doris.org/images/documents/newsletters/IDS-Newsletter6.pdf#page=5.

IDS also experienced a more joyful departure as in April 2020 Pascal Willis retired from the Institut Géographique National (IGN) after a long and active career promoting analysis and use of DORIS data in geodesy, an article was dedicated to him in the IDS Newsletter #8:

https://ids-doris.org/images/documents/newsletters/IDS-Newsletter8.pdf#page=8.

Arnaud Pollet and Samuel Nahmani will lead the IGN/DORIS Analysis Center activities following the retirement of Pascal Willis.

The application of the DGFI-TUM (Munich, Germany) to become an Associate Analysis Center was approved by the IDS Governing Board at its meeting on October 1st, 2019. In addition to the six regular Analysis Centers, four Associate Analysis Centers now contribute to the IDS analysis activities.

Frank Lemoine and Laurent Soudarin attended the International Workshop for the Implementation of the Global Geodetic Reference Frame in Latin America held in Buenos Aires, Argentina, from September 16 to 20, 2019. It was the opportunity to meet the friendly colleagues from the agencies hosting DORIS stations in this part of the world.

Position	Term	Status	Name	Affiliation	Country
Analysis coordinator	**2019-2022**	Elected	**Hugues Capdeville** **Petr Štěpánek**	CLS Geodetic Obs. Pecný	France Czech Republic
	2015-2018	*Elected*	*Hugues Capdeville* *Jean-Michel Lemoine*	CLS *CNES/GRGS*	*France*
	2013-2014	*Ext'd*	*Frank Lemoine*	*NASA/GSFC*	*USA*
	2009-2012	*E.b.GB*	*Frank Lemoine*	*NASA/GSFC*	*USA*
	2005-2008		*Frank Lemoine (subst.)*	*NASA/GSFC*	*USA*
	2003-2005		*Martine Feissel-Vernier*	*IGN/Paris Observatory*	*France*
Data Centers' representative	**2021-2024**	Elected	**Patrick Michael**	NASA/GSFC	USA
	2017-2020	*Elected*	*Patrick Michael*	*NASA/GSFC*	*USA*
	2013-2016	*Elected*	*Carey Noll*	*NASA/GSFC*	*USA*
	2009-2012	*Elected*	*Carey Noll*	*NASA/GSFC*	*USA*
	2003-2008		*Carey Noll*	*NASA/GSFC*	*USA*

Position	Term	Status	Name	Affiliation	Country
Analysis Centers' representative	**2021-2024**	Elected	**Frank Lemoine (chair)**	NASA/GSFC	USA
	2017-2020	*Elected*	*Frank Lemoine (chair)*	*NASA/GSFC*	*USA*
	2013-2016	*Elected*	*Pascal Willis (chair)*	*IGN+IPGP*	*France*
	2009-2012	*Elected*	*Pascal Willis (chair)*	*IGN+IPGP*	*France*
	2003-2008		*Pascal Willis*	*IGN+IPGP*	*France*
Member at large	**2019-2022**	Elected	**Claudio Abbondanza**	NASA/JPL	USA
	2015-2018	*Elected*	*Marek Ziebart*	*UCL*	*UK*
	2013-2014	*Ext'd*	*John Ries*	*Univ. of Texas/CSR*	*USA*
	2009-2012	*E.b.GB*	*John Ries*	*Univ. of Texas/CSR*	*USA*
	2003-2008		*John Ries*	*Univ. of Texas/CSR*	*USA*
Member at large	**2021-2024**	Elected	**Karine Le Bail**	Chalmers Univ. Of Tech.	Sweden
	2017-2020	*Elected*	*Denise Dettmering*	*DGFI/TUM*	*Germany*
	2013-2016	*Elected*	*Richard Biancale*	*CNES/GRGS*	*France*
	2009-2012	*E.b.GB*	*Pascale Ferrage*	*CNES*	*France*
	2003-2008		*Gilles Tavernier (chair)*	*CNES*	*France*
Director of the CB Bureau	Since 2003	App.	**Laurent Soudarin**	CLS	France
Combination Center representative	Since 2013	App.	**Guilhem Moreaux**	CLS	France
Network representative	**2021-2024**	App.	**Jérôme Saunier**	IGN	France
	2017-2020	*App.*	*Jérôme Saunier*	*IGN*	*France*
	2013-2016	*App.*	*Jérôme Saunier*	*IGN*	*France*
	2010-2012		*Bruno Garayt (subst.)*	*IGN*	*France*
	2009	*E.b.GB*	*Hervé Fagard*	*IGN*	*France*
	2003-2008		*Hervé Fagard*	*IGN*	*France*
DORIS system representative	**2021-2024**	App.	**Pascale Ferrage**	CNES	France
	2017-2020	*App.*	*Pascale Ferrage*	*CNES*	*France*
	2013-2016	*App.*	*Pascale Ferrage*	*CNES*	*France*
IAG representative	**2019-2022**	App.	**Ernst Schrama**	TU Delft	The Netherlands
	2017-2018	*App.*	*Petr Štěpánek*	*Geodetic Obs. Pecný*	*Czech Republic*
	2013-2016	*App.*	*Michiel Otten*	*ESOC*	*Germany*
	2009-2012	*App.*	*Michiel Otten*	*ESOC*	*Germany*
	2003-2008		*Not appointed*		
IERS representative	**2021-2024**	App.	**Tonie van Dam**	Univ. of Luxembourg	Luxembourg
	2017-2020	*App.*	*Brian Luzum*	*USNO*	*USA*
	2013-2016	*App.*	*Brian Luzum*	*USNO*	*USA*
	2009-2012	*App.*	*Chopo Ma*	*NASA/GSFC*	*USA*
	2003-2008		*Ron Noomen*	*TU Delft*	*The Netherlands*
Chair of WG "NRT DORIS data"	**Nov. 2016-**	Ex-officio	**Denise Dettmering**	DGFI/TUM	Germany

App. = Appointed; Elected = Elected by IDS Associates; E.b.GB = Elected by the previous Governing Board;
Ext'd = Extended term for two years linked to the set-up of the partial renewal process

Table 3. Composition of the IDS Governing Board since 2003

DORIS SYSTEM

4. THE NETWORK

Jérôme Saunier / IGN, France

4.1. GENERAL STATUS AND OPERATION

Built to meet the precise orbit determination requirements for satellite altimetry, the network also greatly contributes to geodesy and geophysics applications thanks to its very homogeneous geographical distribution and the reliability and availability of the ground stations data.

The current DORIS network consists of 59 stations including 4 master beacons (Toulouse, Greenbelt, Hartebeesthoek, Kourou), 1 time beacon (Terre-Adelie) and 1 experimental beacon dedicated to IDS for scientific purposes (Wettzell). Mangilao (Guam Island, USA), initially dedicated to IDS, joined the permanent DORIS network in September 2019. (**Figure 2**)

As regards maintenance, the good news is that after very long outage the DORIS station at Santa-Cruz, Galapagos Islands, Ecuador, has been back in operation since December 2019. The station was completely reinstalled, and a new relationship was initiated with the new local staff. In 2020, two stations were fully renovated to enhance performance by changing the antenna environment and upgrading the equipment: antenna relocation at Réunion Island (France, Indian Ocean) and new DORIS site in Höfn (Iceland) in place of Reykjavik. On the other hand, the extensive power outage at Betio has not yet been solved and the two Russian stations (Badary and Krasnoyarsk) are still awaiting authorization from the government authorities for transmitting the DORIS signal. (**Figure 3**)

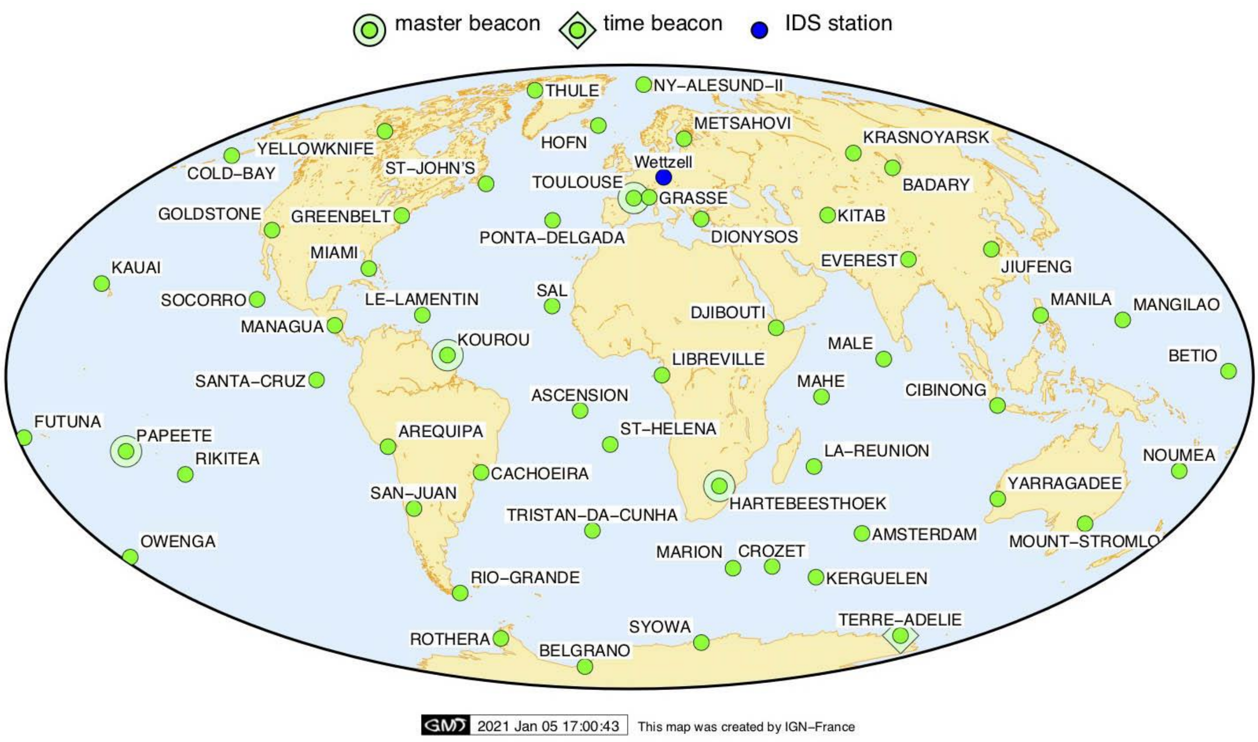


Figure 2. The DORIS permanent network

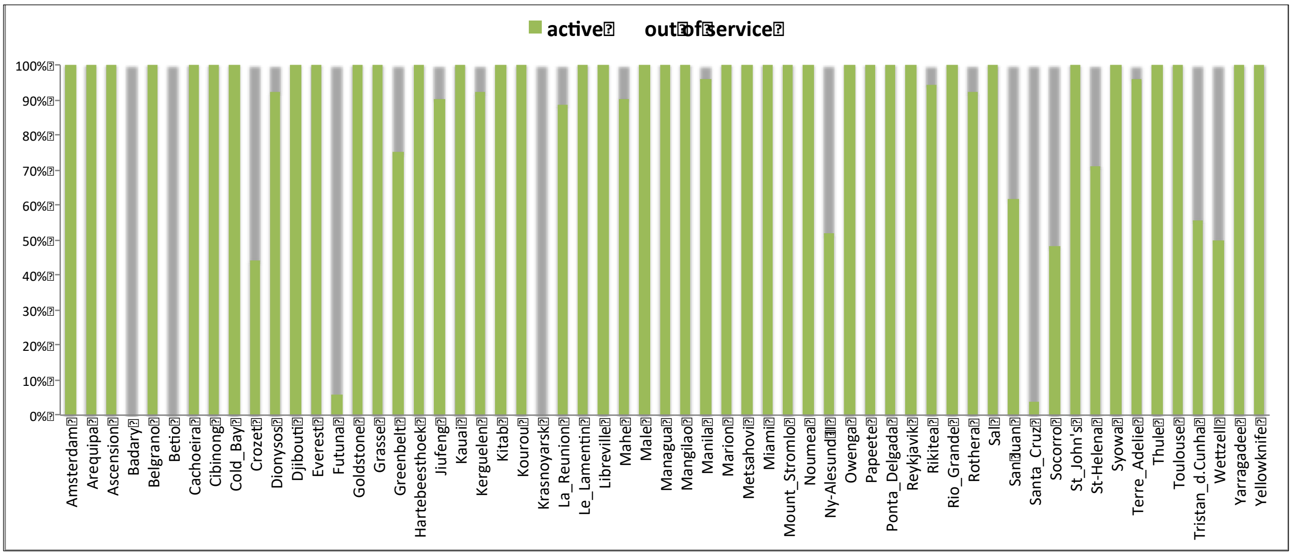


Figure 3. Network activity 2019

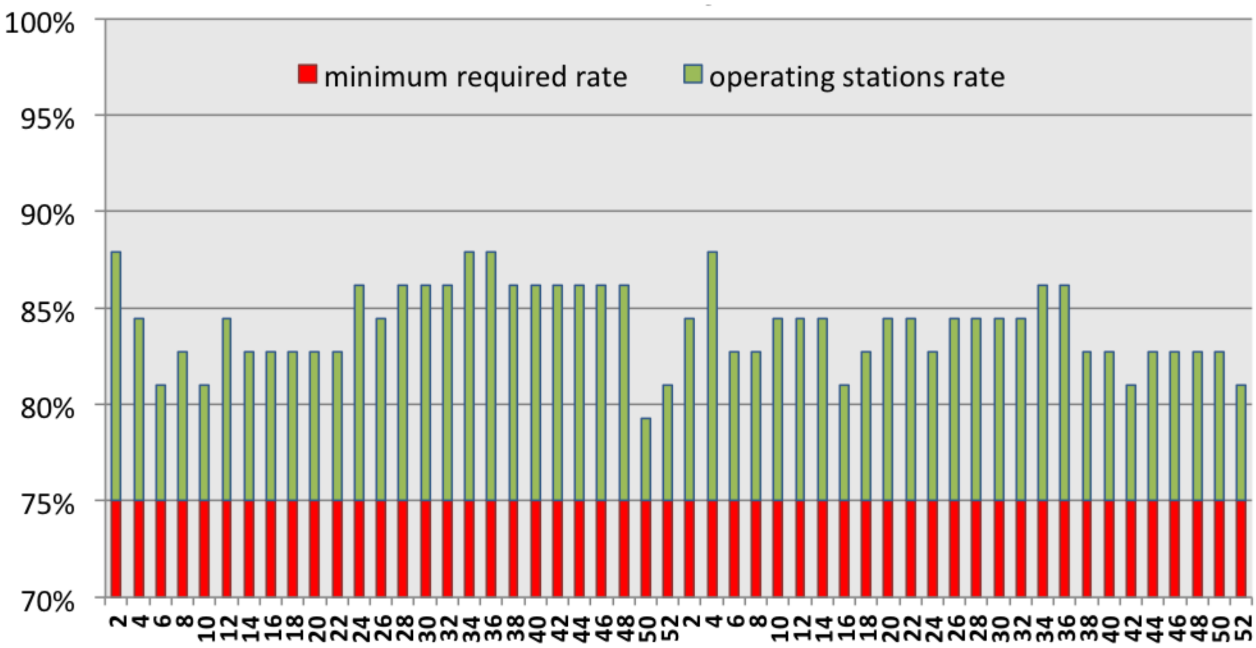


Figure 4. Network availability 2019-2020

Notwithstanding those local difficulties and the global sanitary crisis complicating maintenance operations in 2020, DORIS network provided a reliable service with a mean of 84% of active sites over the two-year period 2019-2020 (**Figure 4**) thanks to the reactivity of the agencies hosting the stations and an efficient and effective overall management and coordination steered by CNES and IGN: 13 failed beacons and 5 failed antennas were replaced.

4.2. EVOLUTION AND DEVELOPMENT

2019 was a year marked by the start of the deployment of **4th generation DORIS beacon** (B4G), a much-awaited development. Indeed, a new architecture built with up-to-date electronic technology and advanced components will allow reliable operation through 2030+ and the addition of a signal amplifier at the foot of the antenna will allow a larger distance between beacon and antenna (50m instead of only 15 m) providing better options to satisfy the sky-clearance criterion for new or renovated DORIS sites.

The B4G deployment started from mid-2019 at St-John's, Canada. The deployment strategy consists in replacing gradually the aging equipment and renovating sites for which the relocation of the antenna will enhance the station performance. 12 sites were equipped with B4G over the past two years: Grasse, St-John's, Ponta-Delgada, and Saint Helena in 2019, then Crozet, La Réunion, Mount-Stromlo, Toulouse, Höfn, Amsterdam and Yarragadee in 2020.

Furthermore, we continued deploying the new generation of **ground antennae (Starec C type)** for which standard uncertainty of the 2GHz phase center in the vertical direction was significantly reduced to improve measurements accuracy. We achieved the antenna replacement of 35% of the network (21 sites) at the end of 2020.

Throughout the network development there has been a continuing effort to co-locate DORIS with other space geodetic techniques and with tide gauges. 49 DORIS stations out of 59 are co-located with at least one other IERS technique: GNSS, SLR, and/or VLBI and 27 with tide gauges (**Figure 5**). All tie vectors at co-located sites with DORIS are available in a maintained file "DORIS_ext_ties.txt" on IDS web and data centers.

In 2019-2020 the following DORIS sites were visited:

- 2019-03: B4G testing and site survey at Grasse (France)
- 2019-06: Reconnaissance in Reykjavik and Höfn (Iceland)
- 2019-06: Renovation and site survey at St-John's (Canada)
- 2019-07: B4G installing at Ponta-Delgada (Azores, Portugal)
- 2019-09: Re-installation at Santa-Cruz (Galapagos, Ecuador)
- 2019-11: B4G installing at Saint-Helena (South Atlantic, UK)
- 2020-01: Reconnaissance at Male' (Maldives)
- 2020-02: Renovation of the DORIS station at La Réunion (France)
- 2020-03: B4G installing at Miami (USA)
- 2020-09: Relocation of the Icelandic DORIS station in Höfn
- 2020-09: Reconnaissance in Athens and Crete (Greece)

In 2021, the overall objectives are:

- Continuation of the deployment of the 4th generation beacon
- Antenna relocation at Malé (Maldives)
- Restarting at Badary (Russia)
- Reconnaissance in Russia with a view to find another DORIS site
- Installation of new DORIS site in Gavdos Island (Crete, Greece)
- Installation of new DORIS site at Katherine (Australia)
- Installation of new DORIS site at Changchun (China)
- Relocation of the DORIS station at Easter Island (Chile)

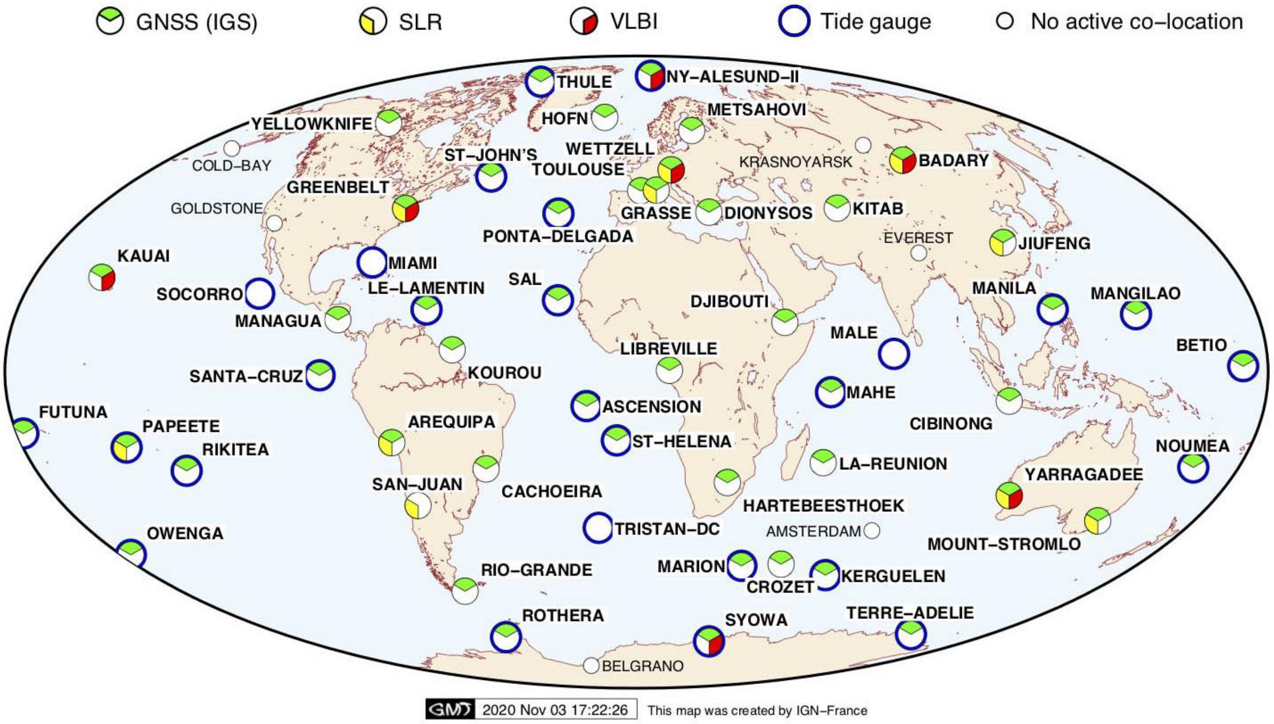


Figure 5. DORIS stations co-located with other IERS techniques and tide gauges

5. THE SATELLITES WITH DORIS RECEIVERS

Pascale Ferrage / CNES, France

As described in **Table 4**, two new satellites were launched over the report period: HY-2C and Sentinel-6A Michael Freilich in 2020. Both use the new 7-channel DGXX-S DORIS on-board receiver. During the same period, two missions were decommissioned: Jason-2 and HY-2A.

The number of satellites in the DORIS constellation remains stable with 7 spacecraft in operation, at altitudes between 720 and 1336 km, with near-polar or TOPEX-like inclination (66 deg).

Note that an eighth satellite joined the DORIS constellation in May 2021. It is the HY-2D mission of China's National Satellite Ocean Application Service (NSOAS), which also carries a DGXX-S DORIS receiver.
In the next few years, more DORIS satellites are planned: Sentinel-3C and 3D, HY-2E, Sentinel-6B, SWOT (Surface Water Ocean Topography). In addition, other missions are under consideration.

Satellite	Start	End	Space Agency	Type
SPOT-2	31-MAR-1990 04-NOV-1992	04-JUL-1990 15-JUL-2009	CNES	Remote sensing
TOPEX/Poseidon	25-SEP-1992	01-NOV-2004	NASA/CNES	Altimetry
SPOT-3	01-FEB-1994	09-NOV-1996	CNES	Remote sensing
SPOT-4	01-MAY-1998	24-JUN-2013	CNES	Remote sensing
JASON -1	15-JAN-2002	21-JUN-2013	NASA/CNES	Altimetry
SPOT-5	11-JUN-2002	1-DEC-2015	CNES	Remote sensing
ENVISAT	13-JUN-2002	08-APR-2012	ESA	Altimetry, Environment
JASON -2	12-JUL-2008	10-OCT-2019	NASA/CNES	Altimetry
CRYOSAT-2	30-MAY-2010	PRESENT	ESA	Altimetry, ice caps
HY-2A	1-OCT-2011	14-SEP-2020	CNSA, NSOAS	Altimetry
SARAL/ALTIKA	14-MAR-2013	PRESENT	CNES/ISRO	Altimetry
JASON-3	19-JAN-2016	PRESENT	NASA/CNES/NOAA/ Eumetsat	Altimetry
SENTINEL-3A	23-FEB-2016	PRESENT	GMES/ESA	Altimetry
SENTINEL-3B	25-APR-2018	PRESENT	GMES/ESA	Altimetry
HY-2C	21-SEP-2020	PRESENT	CNSA, NSOAS	Altimetry
SENTINEL-6A	21-NOV-2020	PRESENT	NASA/CNES/NOAA/ Eumetsat/ESA	Altimetry

Table 4. DORIS data available at IDS data centers, as of December 2020

Figure 6 summarizes the evolution of the DORIS constellation since the launch of the SPOT-2 satellite in 1990 and includes satellites that are currently planned. It must be noted that since 2002, five or more DORIS satellites have been available to IDS users, which is a key requirement for the precision of the geodetic products.

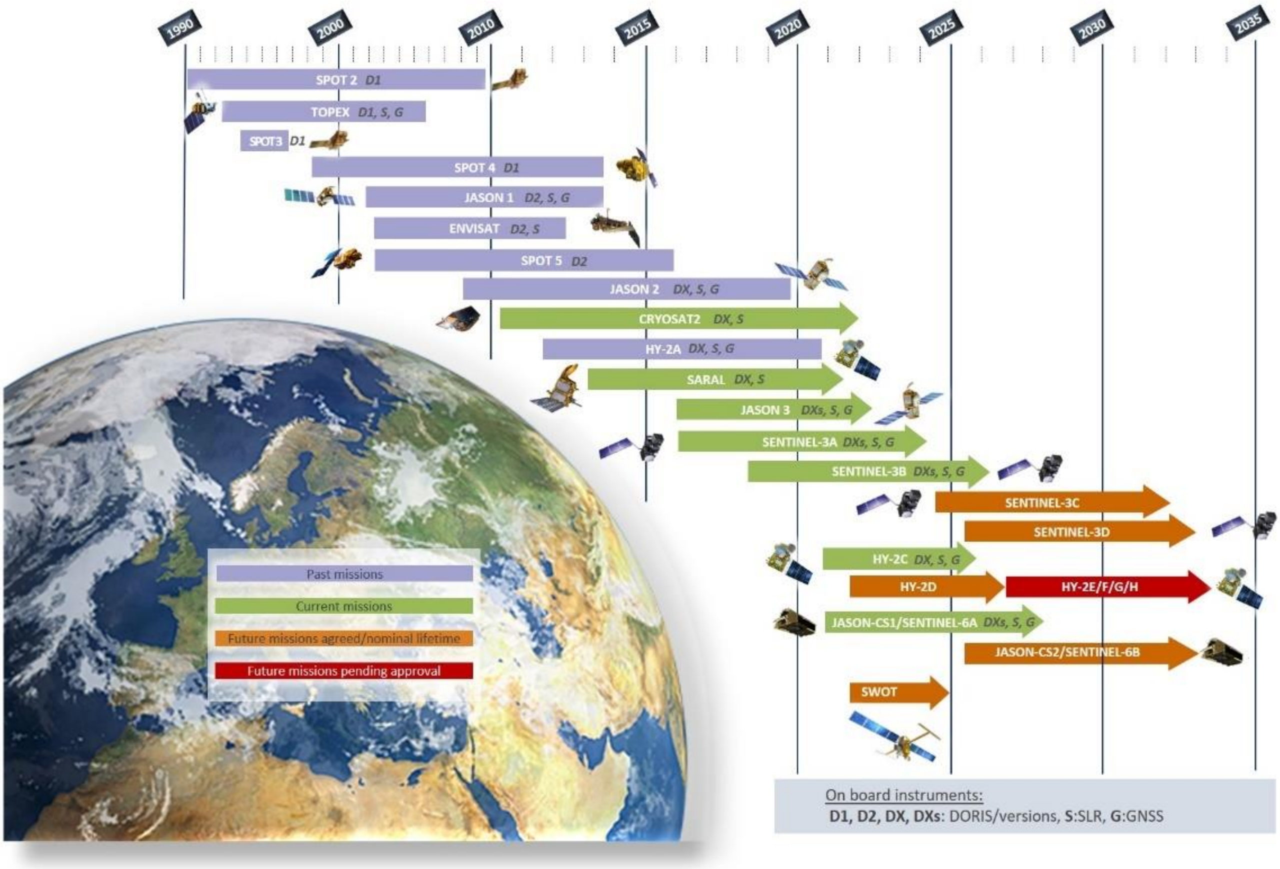


Figure 6. DORIS satellite constellation. As of December 2020

USER SERVICE

6. CENTRAL BUREAU

Laurent Soudarin [1], Pascale Ferrage [2]
[1] CLS, France / [2] CNES, France

6.1. INTRODUCTION

The Central Bureau, funded by CNES and hosted at CLS, is the executive arm of the Governing Board and as such is responsible for the general management of the IDS consistent with the directives, policies and priorities set by the Governing Board. It brings its support to the IDS components and operates the information system.
The Central Bureau participated in the organization of the AWG meetings held in 2019 (see **Table 2**). It documented the Governing Board meetings held on these occasions. The Minutes of the GB meetings are available on the website at https://ids-doris.org/ids/reports-mails/governing-board.html#minutes.

6.2. WEBSITE

The Central Bureau maintains the web resources of the IDS. Besides the regular updates of pages and additions of documents, the website has been upgraded and was enriched with new information. New features were added to the network viewer (https://apps.ids-doris.org/apps/map.html). IVS and ILRS co-located stations with DORIS sites can now be displayed in addition to the IGS stations (see **Figure 7**). The list of the colocations is based on the file of ties between DORIS and GNSS, VLBI and SLR stations provided by IGN. This item completes the list already in place: boundaries of the tectonic plates (Bird, 2003), large Earthquakes (magnitude greater or equal to 6) within a 500 km radius of the DORIS stations (source USGS), horizontal and vertical velocity vectors of the DPOD2014 solution, as well as rates (North, East and Up; in mm/yr) and local events, i.e., the events of the station (dates of installation, change of beacon equipment, Earthquakes in the vicinity).

6.3. NEWSLETTER

Launched in April 2016, the IDS Newsletter aims to provide regular information on the DORIS system and the life of IDS to a wide audience, from the host agencies to the other sister services.

The issues are distributed via email to the subscribers to the DORISmail and several identified managers and decision-makers. They are also available from the IDS website (https://ids-doris.org/ids/reports-mails/newsletter.html).

Three issues were published in 2019 (#6 in February) and 2020 (#7 in January, #8 in December) (see **Appendix 25**). A new more dynamic presentation has been adopted since issue #7.

6.4. DATA DISSEMINATION

The Central Bureau works with the SSALTO multi-mission ground segment and the Data centers to coordinate the data and products archiving and the dissemination of the related information. Data, metadata, and documentation of the two missions HY-2C and Sentinel-6A, were put online the IDS data and information sites as they become available.

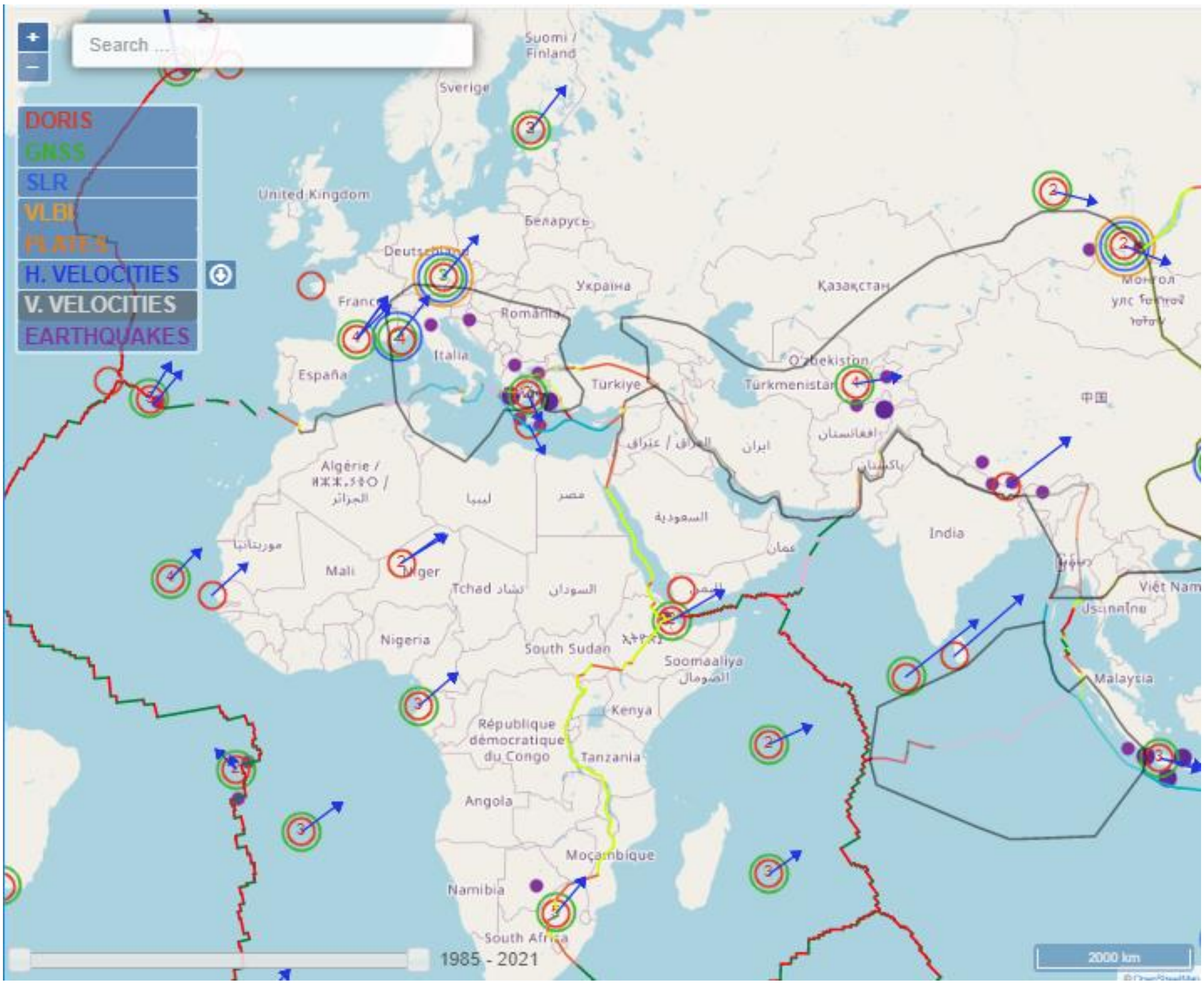


Figure 7. Screenshot of the network viewer on the IDS web (https://apps.ids-doris.org/apps/map.html).

7. DATA FLOW COORDINATION

Patrick Michael / NASA GSFC, USA

7.1. INTRODUCTION

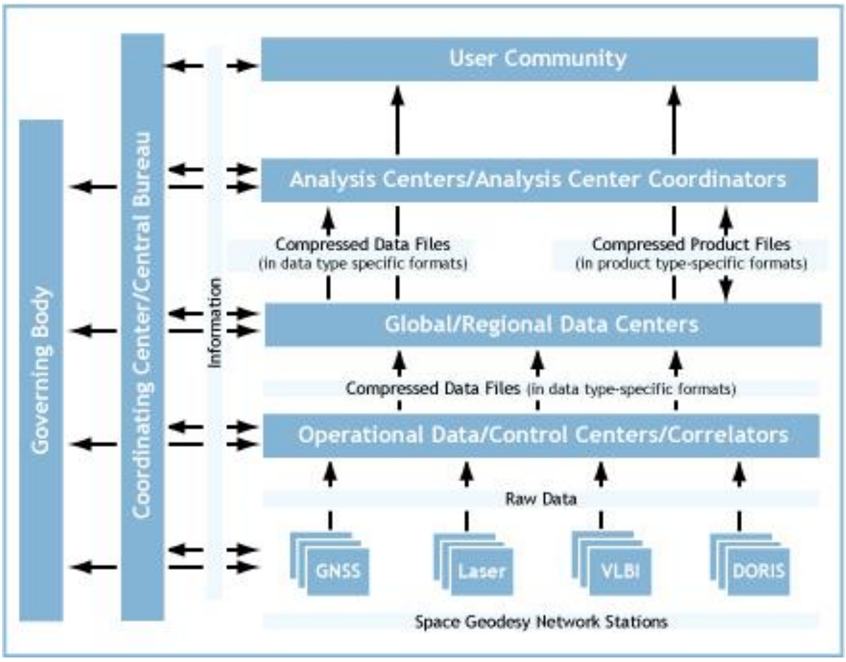
Two data centers support the archiving and access activities for the IDS:

- Crustal Dynamics Data Information System (CDDIS), NASA GSFC, Greenbelt, MD USA
- l'Institut National de l'Information Géographique et Forestière (IGN), Marne la Vallée France

These institutions have archived DORIS data since the launch of TOPEX/Poseidon in 1992.

7.2. FLOW OF IDS DATA AND PRODUCTS

The flow of data, products, and information within the IDS is similar to what is utilized in the other IAG geometric services (IGS, ILRS, IVS) and is shown in **Figure 8**. IDS data and products are transmitted from their sources to the IDS data centers. DORIS data are downloaded from the satellite at the DORIS control and processing center, SSALTO (Segment Sol multi-missions d'ALTimétrie, d'Orbitographie et de localisation précise) in Toulouse, France. After validation, SSALTO transmits the data to the IDS data centers. IDS analysis centers, as well as other users, retrieve these data files from the data centers and produce products, which in turn are transmitted to the IDS data centers.



Network Stations
Continuously operational
Timely flow of data

Data Centers
Interface to network stations
Perform QC and data conversion activities
Archive data for access to analysis centers and users

Analysis Centers
Provide products to users (e.g., station coordinates, precise satellite orbits, Earth orientation parameters, atmos. products, etc.)

Central Bureau/Coordinating Center
Management of service
Facilitate communications
Coordinate activities

Governing Body
General oversight of service
Future direction

Figure 8. Routine flow of data and information for the IAG Geodetic Services

The IDS data centers use a common structure for directories and filenames that was implemented in January 2003. This structure is shown in **Table 5** and fully described on the IDS website at:

https://ids-doris.org/ids/data-products/data-structure-and-formats.html

The main directories are:

- */doris/data* (for all data) with subdirectories by satellite code
- */doris/products* (for all products) with subdirectories by product type and analysis center
- */doris/ancillary* (for supplemental information) with subdirectories by information type
- */doris/campdata* (for SAA-corrected data) with subdirectories by campaign and satellite code
- */doris/cb_mirror* (duplicate of the IDS Central Bureau ftp site) with general information and data and product documentation (maintained by the IDS Central Bureau)
- */doris/general* (for miscellaneous information and summary files)

The DORIS mission support ground segment group, SSALTO, and the analysis centers deliver data and products to both IDS data centers (CDDIS and IGN) to ensure redundancy in data delivery in the event one data center is unavailable. The general information available through the IDS Central Bureau ftp site are mirrored by the IDS data centers thus providing users secondary locations for these files as well.

From mid-2019, CNES developed a new tool to control the SSALTO deliveries of DORIS data and products at both IDS Data Centers (CDDIS and IGN). Missing files and anomalies were identified and fixed for the whole sub-tree of both data centers through detailed joint work between the IDS Central Bureau, SSALTO team and the Data Centers teams. This routine maintenance is now regularly carried out to ensure the integrity of SSALTO data and products (orbits, RINEX, quaternions…).

Directory	File Name	Description
Data Directories		
/doris/data/*sss*	*sss*data*MMM*.*LLL*.Z *sss*.files	DORIS data for satellite *sss*, cycle number *MMM*, and version *LLL* File containing multi-day cycle filenames versus time span for satellite *sss*
/doris/data/*sss*/sum	*sss*data*MMM*.*LLL*.sum.Z	Summary of contents of DORIS data file for satellite *sss*, cycle number *MMM*, and file version number *LLL*
/doris/data/*sss*/yyyy	*sss*rx*YYDDD*.*LLL*.Z	DORIS data (RINEX format) for satellite sss, date YYDDD, version number *LLL*
/doris/data/*sss*/yyyy/sum	*sss*rx*YYDDD*.*LLL*.sum.Z	Summary of contents of DORIS data file for satellite *sss*, cycle number *MMM*, and file version number *LLL*
/doris/data/yyyy	*yyddd*.status	Summary file of all RINEX data holdings for year *yy* and day of year *ddd*
Product Directories		
/doris/products/2010campaign/	*ccc*/*cccYYDDDtuVV*.*sss*.Z	Time series SINEX solutions for analysis center *ccc*, starting on year *YY* and day of year *DDD*, type *t* (m=monthly, w=weekly, d=daily) solution, content *u* (d=DORIS, c=multi-technique), and solution version *VV* for satellite *sss*
/doris/products/dpod/	*dpodYYYY/dpodYYYY_VV.snx.Z* *dpodYYYY/dpodYYYY_ VV.txt.Z*	DPOD solutions (DORIS extension of the ITRF for Precise Orbit Determination) for year *YYYY (2000, 2005, 2008, 2014)* and solution version *VV* in sinex (*snx*) or text (*txt*) format.
/doris/products/eop/	*cccWWtuVV*.eop.Z	Earth orientation parameter solutions for analysis center *ccc*, for year *WW*, type *t* (m=monthly, w=weekly, d=daily), content *u* (d=DORIS, c=multi-technique), and solution version *VV*
/doris/products/geoc/	*cccWWtuVV*.geoc.Z	TRF origin (geocenter) solutions for analysis center *ccc*, for year *WW*, type *t* (m=monthly, w=weekly, d=daily), content *u* (d=DORIS, c=multi-technique), and solution version *VV*
/doris/products/iono/	*sss*/*cccsssVV*.*YYDDD*.iono.Z	Ionosphere products for analysis center *ccc*, satellite *sss*, solution version *VV*, and starting on year *YY* and day of year *DDD*
/doris/products/orbits/	*ccc*/*cccsssVV*.*bXXDDD*.*eYYEEE*.sp1.*LLL*.Z	Satellite orbits in SP1 format from analysis center *ccc*, satellite *sss*, solution version *VV*, start date year *XX* and day *DDD*, end date year *YY* and day *EEE*, and file version number *LLL*
/doris/products/sinex_global/	*cccWWuVV*.snx.Z	Global SINEX solutions of station coordinates for analysis center *ccc*, year *WW*, content *u* (d=DORIS, c=multi-technique), and solution version *VV*
/doris/products/sinex_series/	*ccc*/*cccYYDDDtuVV*.snx.Z	Time series SINEX solutions for analysis center *ccc*, starting on year *YY* and day of year *DDD*, type *t* (m=monthly, w=weekly, d=daily) solution, content *u* (d=DORIS, c=multi-technique), and solution version *VV*
/doris/products/stcd/	*cccWWtu*/*cccWWtuVV*.stcd.*aaaa*.Z	Station coordinate time series SINEX solutions for analysis center *ccc*, for year *WW*, type *t* (m=monthly, w=weekly, d=daily), content *u* (d=DORIS, c=multi-technique), solution version *VV*, for station *aaaa*
Information Directories		
/doris/ancillary/quaternions	*sss/yyyy/*qbody*YYYYMMDDHHMISS_yyyymmddhhmiss.LLL* *sss/*qsolp*YYYYMMDDHHMISS_yyyymmddhhmiss.LLL*	Spacecraft body quaternions for satellite *sss*, year *yyyy*, start date/time *YYYYMMDDHHMISS*, end date/time *yyyymmddhhmiss*, and version number *LLL* Spacecraft solar panel angular positions for satellite *sss*, year *yyyy*, start date/time *YYYYMMDDHHMISS*, end date/time *yyyymmddhhmiss*, and version number *LLL*
/doris/cb_mirror		Mirror of IDS central bureau files

Table 5. Main Directories for IDS Data, Products, and General Information

7.3. DORIS DATA

SSALTO deposits DORIS data to the CDDIS and IGN servers. Software at the data centers scans these incoming data areas for new files and automatically archives the files to public disk areas using the directory structure and filenames specified by the IDS. Today, the IDS data centers archive DORIS data from seven operational satellites (CryoSat-2, Saral, Jason-3, Sentinel-3A, Sentinel-3B, HY-2C (from September 2020), Sentinel-6A (from December 2020)); data from future missions will also be archived within the IDS. Historic data from Envisat, Jason-1, SPOT-2, -3, -4, -5, TOPEX/Poseidon, Jason-2 (last data in October 2019), and HY-2A (last data in September 2020) are also available at the data centers. A summary of DORIS data holdings at the IDS data centers is shown in **Table 6.** The DORIS data from select satellites are archived in multi-day (satellite dependent) files using the DORIS data format 1.0 (before January 2002), 2.1 (from 2002 to 2008), or 2.2 (since June 2008). This format for DORIS data files is on average two Mbytes in size (using UNIX compression). SSALTO issues an email notification through DORISReport once data are delivered to the IDS data centers.

Satellite	Time Span	Data Type
CryoSat-2	30-May-2010 through present	Multi-day, RINEX
Envisat	13-Jun-2002 through 08-Apr-2012	Multi-day
HY-2A	01-Oct-2011 through 11-Sep-2020	Multi-day, RINEX
HY-2C	11-Sep-2020 through present	RINEX
Jason-1	15-Jan-2002 through 21-Jun-2013	Multi-day
Jason-2	12-Jul-2008 through 10-Oct-2019	Multi-day, RINEX
Jason-3	17-Feb-2016 through present	RINEX
SARAL	14-Mar-2013 through present	Multi-day, RINEX
Sentinel-3A	23-Feb-2016 through present	RINEX
Sentinel-3B	01-May-2018 through present	RINEX
Sentinel-6A	17-Dec-2020 through present	RINEX
SPOT-2	31-Mar through 04-Jul-1990 04-Nov-1992 through 14-Jul-2009	Multi-day
SPOT-3	01-Feb-1994 through 09-Nov-1996	Multi-day
SPOT-4	01-May-1998 through 24-Jun-2013	Multi-day
SPOT-5	11-Jun-2002 through 30-Nov-2015	Multi-day
TOPEX/Poseidon	25-Sep-1992 through 01-Nov-2004	Multi-day

Table 6. DORIS Data Holdings Summary

DORIS phase data from CryoSat-2, HY-2A, HY-2C, Jason-2, Jason-3, SARAL, Sentinel-3A, Sentinel-3B, and Sentinel-6A are also available in the format developed for GNSS data, RINEX (Receiver Independent Exchange Format), version 3.0. These satellites have the newer, next generation DORIS instrumentation on board, which is capable of generating DORIS data compatible with the RINEX format; future satellites will also utilize this type of DORIS receiver. These data are forwarded to the IDS data centers in daily files prior to orbit processing within one-two days (typically) following the end of the observation day. Data from HY-2C, Jason-3, Sentinel-3A, Sentinel-3B, and Sentinel-6A are only available in the RINEX format.

In the fall of 2012, the IDS Analysis Working Group requested a test data set where data from stations in the South Atlantic Anomaly (SAA) were reprocessed by applying corrective models. Data in DORIS V2.2 format from the Jason-1 satellite (cycles 104 through 536, Jan. 2002 through Jun. 2013) have been submitted to the IDS data centers; a set of SPOT-5 data (cycles 138 through 501, Dec. 2005 through Nov. 2015) have also been submitted and archived. These files are archived at the IDS data centers in campaign directories, e.g., at CDDIS:

https://cddis.nasa.gov/archive/doris/data/ja1/saacorrection
https://cddis.nasa.gov/archive/doris/data/sp5/saacorrection

7.4. DORIS PRODUCTS

IDS analysis centers utilize similar procedures by putting products to the CDDIS and IGN servers. Automated software detects any incoming product files and archives them to the appropriate product-specific directory. The following analysis centers (ACs) have submitted products on an operational basis to the IDS; their AC code is listed in ():

- European Space Agency (esa), Germany
- Geoscience Australia (gau) (historic AC)
- Geodetic Observatory Pecny (gop), Czech Republic
- NASA Goddard Space Flight Center (gsc) USA
- Institut Géographique National/JPL (ign) France
- INASAN (ina) Russia
- CNES/CLS (lca historically, grg starting in 2014) France
- CNES/SOD (sod) France (historic AC)
- SSALTO (ssa) France

A solution (designated “ids”) produced by the IDS combination center from the individual IDS AC solutions started production in 2012. IDS products are archived by type of solution and analysis center. The types and sources of products available through the IDS data centers in 2005-2018 are shown in **Table 7**. This table also includes a list of products under evaluation from several DORIS analysis centers.

Type of Product	ACs/Products										
	ESA	GAU *	GOP	GRG **	GSC	IDS	IGN	INA	LCA **	SOD *	SSA
Time series of SINEX solutions (*sinex_series*)	X	X	X	X	X	X	X	X	X	X	X
Global SINEX solutions (*sinex_global*)				X			X		X		
Geocenter time series (*geoc*)							X	X	X		
Orbits/satellite (orbits)				X	X				X		X
Ionosphere products/satellite (*iono*)											X
Time series of EOP (*eop*)							X	X			
Time series of station coordinates (*stcd*)	X		X	X	X	X	X	X	X		X
Time series of SINEX solutions (*2010campaign*)		X	X		X		X	X	X		

*Note: GAU and SOD historic solutions

**Note: CNES/CLS transitioned their AC acronym from LCA to GRG in 2014.

Table 7. IDS Product Types and Contributing Analysis Centers

7.5. SUPPLEMENTARY DORIS INFORMATION

In 2009 an additional directory structure was installed at the IDS data centers containing ancillary information for DORIS data and product usage. Files of Jason-1, -2, and -3 satellite attitude information were made available through the IDS data centers. Two types of files are available for each satellite: attitude quaternions for the body of the spacecraft and solar panel angular positions. The files are delivered daily and contain 28 hours of data, with 2 hours overlapping between consecutive files. Analysts can use these files in processing DORIS data to determine satellite orientation and attitude information.

7.6. FUTURE PLANS

Following the IDS Retreat in 2019, the provision of Near-Real-Time DORIS data and products was decided. A first experience is planned at the beginning of 2021 with the IGN Data Center: Jason-3 RINEX data and Diode orbits will be distributed with a latency of about 3 hours.

8. DATA CENTERS

8.1. CRUSTAL DYNAMICS DATA INFORMATION SYSTEM (CDDIS)

Patrick Michael, Carey Noll / NASA GSFC, USA

8.1.1 INTRODUCTION

The CDDIS is a dedicated data center supporting the international space geodesy community since 1982. The CDDIS serves as one of the primary data centers for the following IAG services, projects and international groups:

- International DORIS Service (IDS)
- International GNSS Service (IGS)
- International Laser Ranging Service (ILRS)
- International VLBI Service for Geodesy and Astrometry (IVS)
- International Earth Rotation and Reference Frame Service (IERS)
- Global Geodetic Observing System (GGOS)

The CDDIS is one of NASA's Earth Observing System Data and Information System (EOSDIS) Distributed Active Archive Centers (DAACs); EOSDIS data centers serve a diverse user community and are tasked to provide facilities to search and access science data and products. The CDDIS is also a regular member of the International Council for Science (ICSU) World Data System (WDS).

8.1.2 OPERATIONAL ACTIVITIES

At the end of 2020, the CDDIS has devoted nearly 135 GB of disk space (74GB or ~55% for DORIS data, 36GB or ~27% for DORIS products, and 23GB or ~17% for DORIS ancillary data and information) to the archive of DORIS data, products, and information. During the past year, users downloaded approximately 9400 Gbytes (4.2M files) of DORIS data, products, and information from the CDDIS.

The CDDIS provides a file that summarizes the RINEX-formatted data holdings each day. Information provided in the status file includes satellite, start and end date/time, receiver/satellite configuration information, number of stations tracking, and observation types. These files are accessible in yearly sub-directories within the DORIS data subdirectory on CDDIS, ftps://gdc.cddis.eosdis.nasa.gov/doris/data or https://cddis.nasa.gov/archive/doris/data .

8.1.3 RECENT ACTIVITIES AND DEVELOPMENTS

No major recent activities were completed in 2019-2020 time period.

8.1.4 FUTURE PLANS

The CDDIS staff will continue to interface with the IDS Central Bureau (CB), SSALTO, and the IDS analysis centers to ensure reliable flow of DORIS data, products, and information. Enhancements and modifications to the data center will be made in coordination with the IDS CB.

The CDDIS has established Digital Object Identifiers (DOIs) for several of its GNSS data sets; website “landing” pages have been established for these published DOIs. DOIs for additional items, including DORIS data and products, are under development and review prior to registering and implementation.

The CDDIS continues to review and update its ingest procedures to both decrease latency of file delivery to the public archive and to continually improve quality control checks to all incoming data and products. In addition, CDDIS has made its archive fully available through https and will soon add ftp-ssl access as well.

In response to increased Information Technology (IT) security requirements from both the U.S. Government and NASA, CDDIS was forced to remove unencrypted anonymous ftp access to its archive in the fall of 2020 and in its place put in encrypted ftp or what is commonly called ftp over SSL/TLS. The entire archive with the same directory structure is available using ftp-ssl at gdc.cddis.eosdis.nasa.gov.

8.1.5 CONTACT

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Sandra Blevins, Deputy CDDIS Manager	Email:	Sandra.Blevins@nasa.gov
NASA GSFC	Voice:	301-286-2887
Code 61A	Fax:	301-614-6015
Greenbelt, MD 20771		
USA		

WWW:	https://cddis.nasa.gov
Archive access:	ftps://gdc.cddis.eosdis.nasa.gov/doris
	https://cddis.nasa.gov/archive/doris
Technical support:	support-cddis@earthdata.nasa.gov

8.2. IGN DORIS DATA CENTER

Jérôme Saunier / IGN, France

8.2.1 INTRODUCTION

The IGN Data Center was set up in order to archive and distribute data from French national and international services and projects such as Réseau GNSS Permanent (RGP), EUREF, IGS, and IDS. The IGN Data Center has been operational since 2006. Today the IGN Data Center serves as IGS Global Data Center, EPN Local Data Center, IDS Data Center, RGP Data Center, REGINA Data Center and SONEL Data Center.

8.2.2 ARCHITECTURE AND DATA ACCESS

To ensure a more reliable data flow and a better availability of the service, two identical infrastructures and configurations have been setup in two different locations at IGN: (1) Saint-Mandé and (2) Marne-la-Vallée.

Each site offers:

- FTP deposit server for data and analysis centers uploads, requiring special authentication
- Free FTP anonymous access to observations data and products
- Independent Internet links

All the DORIS data and products archived and available at IGN GDC may be access through:

- ftp://doris.ign.fr (Saint-Mandé)
- ftp://doris.ensg.eu (Marne-la-Vallée)

8.2.3 OPERATIONAL ACTIVITIES

The IGN Data Center stores about 125 Go for DORIS and IDS including data, products, metadata, and information. In 2019, we had 2146 visits and users downloaded 20 Go (27 852 files) of DORIS data. While for the following year 2020: 3162 visits, 77 Go (167 110 files) downloaded data.

A couple of hours (short outage) were devoted for maintenance activities each year but with continuous service thanks to the alternate IGN data center remaining available during the break.

From mid-2019, CNES developed a new tool to control the SSALTO deliveries of DORIS data and products at both IDS Data Centers (CDDIS and IGN). Missing files and anomalies were identified and fixed for the whole sub-tree of both data centers through detailed joint work between the IDS Central Bureau, SSALTO team and the Data Centers teams. This routine maintenance is now regularly carried out in order to ensure the integrity of SSALTO data and products (orbits, RINEX, quaternions…).

Lastly, two new satellites were implemented at the end of 2020: HY-2C and Sentinel-6A.

8.2.4 FUTURE DEVELOPMENT

Following the IDS Retreat in 2019, the provision of Near-Real-Time DORIS data and products was decided. A first experience is planned at the beginning of 2021 with the IGN Data Center: Jason-3 RINEX data and Diode orbits will be distributed with a latency of about 3 hours.

The mirroring applied between both IGN DORIS Data Centers will be consolidated in order to have exact identical contents.

Finally, IGN Data Center is thinking about possible evolution regarding file access and transfer by implementing the Secure File Transfer Protocol (SFTP).

8.2.5 CONTACT

After more than 12 years of service for the IGN DORIS Data Center, Bruno Garayt handed over to Jérôme Saunier from January 2019. Thank you, Bruno!

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ANALYSIS ACTIVITIES

9. ANALYSIS COORDINATION

Hugues Capdeville / CLS, France
Petr Štěpánek / Geodetic Observatory Pecný, VÚGTK, Czech Republic

9.1. INTRODUCTION

The activities of all the DORIS analysts of the past years 2019-2020 have been dominated by preparation (2019) and realization (2020) of ITRF2020 DORIS data re-processing. The two Analysis Working Group meetings were realized in 2019, in April (Munich, Germany) and in September/October (Paris, France). As the major topics we can highlight ITRF reprocessing schedule and standards, South Atlantic Anomaly mitigation, Satellite attitude/orbit modeling and stability of the scale. Also, the Geocenter working group was established. In 2020, all AWG meetings as well as IDS workshop were cancelled due to COVID pandemic.

9.2. AWG MEETINGS

The first International DORIS Service Analysis Working Group (IDS-AWG) in 2019 was hosted in Munich on April 4, 2019 thanks to our hosts Denise Dettmering and Mathis Bloßfeld. As usual, IDS ACs and CC gave their processing status. The new DORIS groups as DGFI-TUM and Copernicus POD service presented results of their DORIS satellite data processing. The CNES POD team presented studies on the update of the HY-2A SRP model, on the progress on CNES mascon solutions and on the preprocessing of DORIS phase data for Doppler solutions. The main objective of this meeting was the IDS contribution to the ITRF2020. Zuheir Altamimi introduced the subject by giving the roadmap for ITRF2020. In the following part, we discussed the main DORIS items for the preparation for the next ITRF as the South Atlantic Anomaly compensation, the attempt to mitigate the non-conservative force model errors on satellites, the implementation of DORIS RINEX processing and the implementation of the new standards/models recommended by IERS for the next ITRF. After, an IDS processing schedule proposal for the next ITRF was given. The formation of a working group on the observation of geocenter motion was proposed by Alexandre Couhert.

The second International DORIS Service Analysis Working Group (IDS-AWG) in 2019 was hosted in Paris @CNES on September 30 – October 1, 2019, thanks to our host Pascale Ferrage. The first part of the meeting was devoted to the general IDS presentations, while the second part focused on the most important topics relevant for ITRF 2020 reprocessing. As usual, we started with IDS News (L. Soudarin) and DORIS system status (P. Ferrage), followed by DORIS Network status (J. Saunier). The general IDS part of the presentation was closed by Status of the combination, presented by G. Moreaux. The ITRF-2020 reprocessing part of the meeting was divided into four general presentations. J.M. Lemoine presented new models and standards recommended by IERS and IDS, focused on time-variable gravity field modeling, ocean tides and de-aliasing products. F. Lemoine presented Attempt to mitigate the non-conservative force model error on satellites, including mitigation of TOPEX/Jason 117 days draconitic signal, Solar radiation pressure Cr estimation strategy, Earth radiation modelling and discussion on thermosphere models. G. Moreaux presented South Atlantic mitigation, including several methods how to deal with SAA. The last presentation by P. Štěpánek was devoted to the DORIS scale and its dependence on elevation cut off and data downweighting, as well as to comparison of GOP and GRG single- and multi- satellite solutions in context of the scale.

9.3. ANALYSIS CENTERS AND COMBINATION CENTERS

All the IDS Analysis Centers (AC) continue the standard routinely processing by taking into account the last DORIS data available. The IDS includes six ACs and four “associate analysis centers” who use eight different software packages, as summarized in **Table 8**. We also note which analysis centers on a routine basis perform POD analyses of DORIS satellites using other geodetic techniques (c.f. Satellite Laser Ranging (SLR and GNSS). For ITRF 2020 reprocessing, the analysis centers ESA, GOP, GRG and GSC promised full participation, while INA plans a limited contribution processing pure DORIS RINEX data. Also, a Geocenter working group was established including ACs CNES, GOP, GRG and DGFI-TUM.

Name	AC	AAC	Location	Contact	Software	Multi-technique
ESA	✔		EU/Germany	Michiel Otten	NAPEOS	SLR, GNSS
GOP	✔		Czech Republic	Petr Stepanek	Bernese	
GRG	✔		France	Hugues Capdeville	GINS	SLR, GNSS
GSC	✔		USA	Frank Lemoine	GEODYN	SLR
IGN	✔		France	Arnaud Pollet, Samuel Nahmani	GIPSY	
INA	✔		Russia	Sergei Kuzin	GIPSY/own development	
CNES		✔	France	Alexandre Couhert	Zoom	SLR, GNSS
GFZ		✔	Germany	Rolf Koenig	EPOS-OC	SLR, GNSS
TU Delft		✔	The Netherlands	Ernst Schrama	GEODYN	SLR
DGFI-TUM		✔	Germany	Mathis Bloßfeld, Sergei Rudenko	DOGS	SLR

Table 8. Summary of IDS Analysis Centers

9.4. ITRF 2020 REPROCESSING STANDARDS AND SCHEDULE

The ITRF 2020 reprocessing standards and the processing schedule were defined, as follows.

9.4.1. ORBITS AND FORCE MODELING

- Quaternions (strongly recommended for Jasons, and if possible, for Cryosat-2 and Sentinels if available),
- Introduce precise SPOT-5 solar panel angle values,
- Use last version of macromodel from IDS documentation (ftp://ftp.ids-doris.org/pub/ids/satellites/DORISSatelliteModels.pdf) or/and own improvements
- Adjust Cr/arc determined from POD with separate arc empirical accelerations on TOPEX, and Jason satellites,
- For sun-synchronous, polar-orbiting satellites: adjust mean. Cr over entire time series (suggestion),

- Apply more complex Earth radiation modeling than Knocke (e.g. from CERES) (suggestion),
- New mean pole model (secular model),
- Up to date TVG (e.g. last EIGEN proposed by Jean Michel Lemoine). Be careful about consistency with new mean pole model,
- Desai & Sibois HF (diurnal-subdiurnal) tidal EOP model recommended by IERS
- Ocean tides model (e.g. FES2014b, be careful to use the version with all recent corrections),
- De-aliasing model must be applied since gravity models were determined using this model. It can be CNES-provided or GFZ-RL06 (provided for GRACE Follow-On project). Air Tides need to be separately applied e.g. as described by Dobslaw et al. (2017), in the case of GFZ RL06.

9.4.2. DATA USING, EDITING/WEIGHTING

- Do not use validity indicators from Doppler observation files (Doris2.2 format),
- ACs have to do their own preprocessing,
- Use elevation dependent downweighting, no strong recommendations of which applied function to be used by ACs (CNES weighting function suggested),
- Reasonable elevation cut off (7-10 deg),
- One RINEX/Doppler data format per mission,
- Adjust tropospheric gradients if possible.

9.4.3. SOUTH ATLANTIC ANOMALY

The following mix of strategies is proposed:

- Corrected data for Jason-1 and SPOT-5,
- Data corrective model from A. Belli for Jason-2 can be used, if available (Free decision for ACs),
- Suggestion of removing or downweighting of data from SAA stations (Free decision for ACs)
- Using SAA data from the most affected satellites only for POD,
- Linear or quadratic frequency adjustment per pass – ACs can apply if they can demonstrate that it is beneficial.

9.4.4. OTHERS

- Alcatel, STAREC-B/C + associated phase laws

9.4.5. IDS REPROCESSING SCHEDULE

- 2020, March 30: AC delivery of 1993.0 2002.3 (Until start of Envisat First DORIS 2G receiver)
- 2020, June 30: AC delivery of 2002.3 2011.8 (Until start of HY-2A).
- 2020, September 30: AC delivery of 2011.8 2020.0.
- 2021, February 10: First delivery of the IDS combined solution to the IERS (1993.0 2020.0).
- 2021, Feb. 14: AC delivery of 2020
- 2021, March 15: Complete delivery to the IERS of the IDS combined solution (1993.0-2021.0)

9.5. STATUS OF ITRF 2020 REPROCESSING

4 analysis centers participated in ITRF 2020 reprocessing: GSC, GRG, GOP and ESA. GSC, GRG and GOP processed data 1993.0-2020.0. GSC did not include Sentinel-3A and Sentinel-3B data but plans its inclusion in final solution. GOP completely excluded Jason-1 data. ESA data processing is delayed but with anticipation of full contribution. IGN and INA were not able fully contribute. Not, that the official end of the ITRF reprocessing was postponed to April 2021. During the ITRF data re-processing following new issues raised

- New Alcatel phase law model has impact on station estimated height (scale of the solution). However, AC tests confirmed improvement in post-fit observation residuals and also better agreement between DORIS-estimated station height differences and vertical components of DORIS/DORIS local ties for pairs of Alcatel/Starec stations
- SPOT-5 scale sawtooth pattern – GSC and GRG removed SPOT-5 from the scale contribution
- Hy-2A Tz offset (eliminated by GSC-tuned satellite micromodel)
- Cryosat-2 Tz variations (present in GOP and GSC solutions but not for GRG)
- Higher Scale for GOP w.r.t. GRG and GSC for Jason-2 and Jason-3 (about 10 mm)
- Sentinel-3A and Sentinel-3B South Atlantic anomaly effects
- Scale increment in 2018-2019
- Draconitic signal 118 days in Tz related to Jason-3

9.6. PLANS FOR NEXT AWG GROUP MEETING

An AWG meeting is plan in first half of April 2021. The form of the meeting will be completely online. The format will consist of 3 sessions: DORIS system session, ITRF 2020 re-processing session and open session.

10.COMBINATION CENTER

Guilhem Moreaux / CLS, France

10.1. ACTIVITY SUMMARY

In addition to the routine evaluation and combination of the IDS AC solutions, in 2019 and 2020, the IDS Combination Center released the two versions of the IDS cumulative position and velocity and DPOD2014 solutions. The IDS CC also performed some analysis mostly related to the forthcoming realization of the IDS contribution to the ITRF2020 and initialized the analysis and construction of the IDS series for the ITRF2020.

10.2. IDS ROUTINE EVALUATION AND COMBINATION

At the end of 2020, the time span of the SINEX files of the IDS combined solution was 1993.0-2020.5. These files correspond to the new IDS series 14 which differs from the previous one (ids 13) by a new preprocessing of the IDS AC weekly SINEX files as input.

Late 2019, the IDS CC released a new version of the coordinate time series plots which are routinely delivered to the IDS Data Centers. That new version (see **Figure 9**) displays as vertical lines dates of events which may have an impact of the positions and/or velocities. Depending on their origin, three types of events are displayed: seismic, technical (beacon or USO change, antenna displacement…) and unknown.

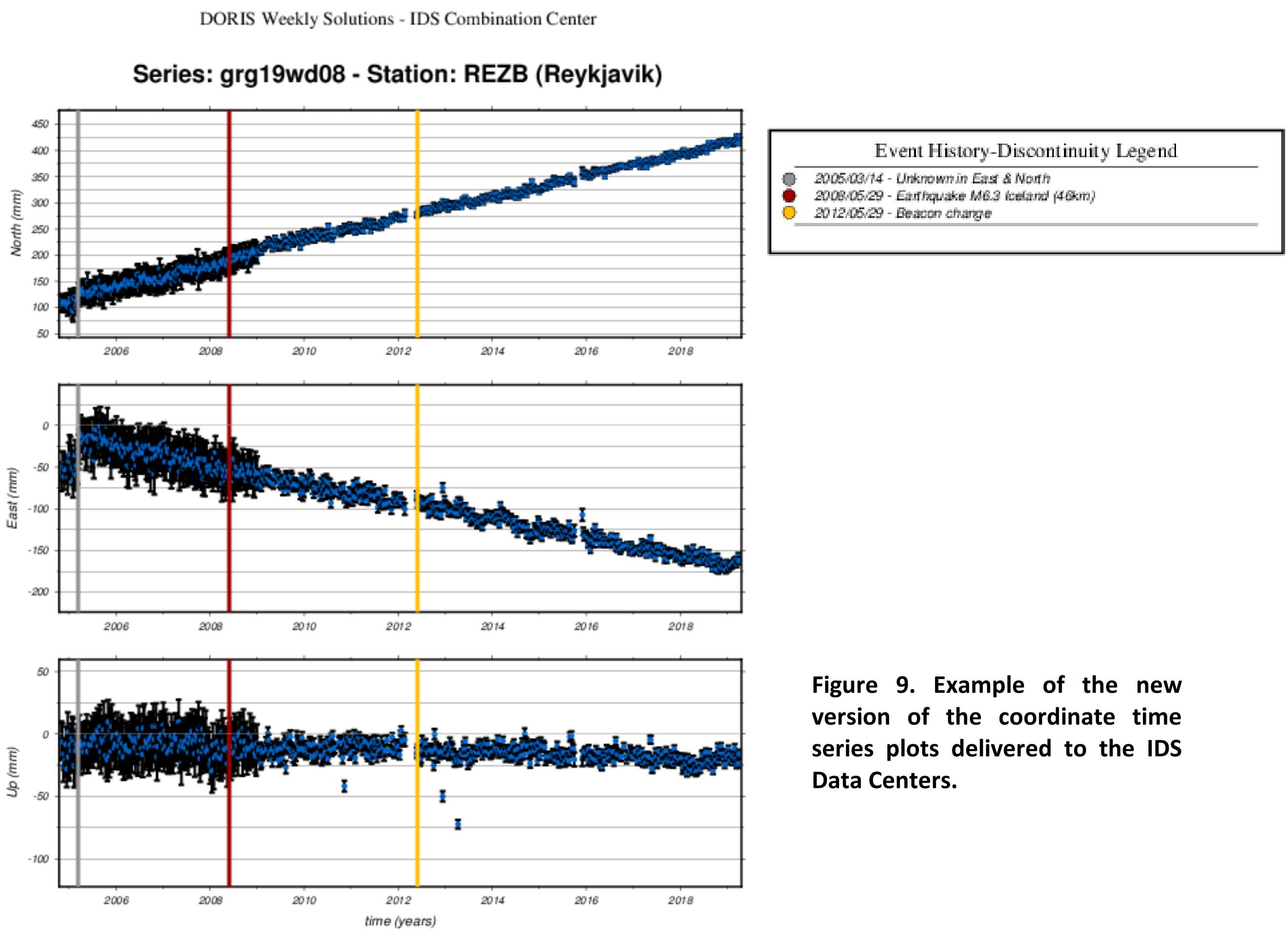
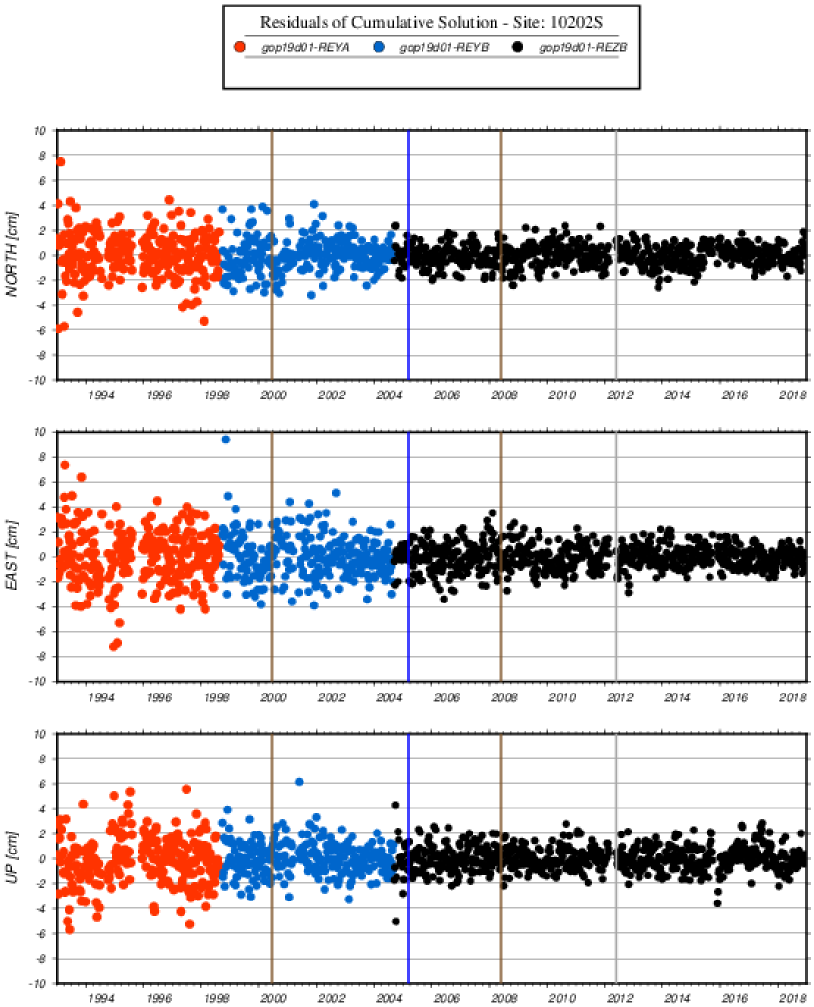


Figure 9. Example of the new version of the coordinate time series plots delivered to the IDS Data Centers.

10.3. IDS CUMULATIVE SOLUTION

In 2019, the IDS Combination Center realized and made available (through the IDS Data Centers) the fourth version of the DORIS cumulative position and velocity solution (ids19d04). That solution is obtained by the stacking of the ids 13 weekly combined solution from 1993.0 to 2019.0. As a consequence, the cumulative solution contains only the mean positions and velocities of the DORIS stations included in the IDS combined solution. We remind that all the IDS cumulative solutions are available in SINEX format and can be freely downloaded from the subdirectory "products/sinex_global/ids/" from the IDS Data Centers (CDDIS and IGN). From the dedicated corner of the IDS web site, you can also have access to the internal validation report as well as to the plots of the station position residuals (difference between the weekly positions as input and the positions deduced from the mean positions and velocities). In line with the new version of the coordinate time series plots, a new version of the station position residual plots (see **Figure 10**) has been developed with vertical lines of three colors (brown: seismic origin; grey: technical origin; blue: origin unknown) reporting discontinuities used in the stacking.



AC	# weeks	North [cm] mean	North [cm] std	East [cm] mean	East [cm] std	Up [cm] mean	Up [cm] std	Serie nb	Beacon
gop	257	0.074	1.727	0.059	2.110	-0.112	1.878	19d01	REYA
gop	286	-0.007	1.268	0.034	1.711	0.021	1.265	19d01	REYB
gop	714	-0.024	0.832	-0.008	0.985	0.005	0.967	19d01	REZB

Figure 10. Example of a new version of the station position residual plots.

Mid-2020, due to both the evolution of the beacon ground network and of new geophysical events, the IDS CC realized a new cumulative solution from 1993.0 to 2020.0 based on the ids 13 and 14 weekly combined solutions. In order to better understand the differences between the IDS AC solutions and their impact on the estimation of the mean positions and velocities, the IDS CC adapted the cumulative chain to get position and velocity cumulative solutions for each operational IDS AC. As the IDS cumulative solution, these solutions are also aligned to the ITRF2014 and make use of the same discontinuities. As depicted by the **Figure 11**, an overall good agreement is obtained for the horizontal velocities.

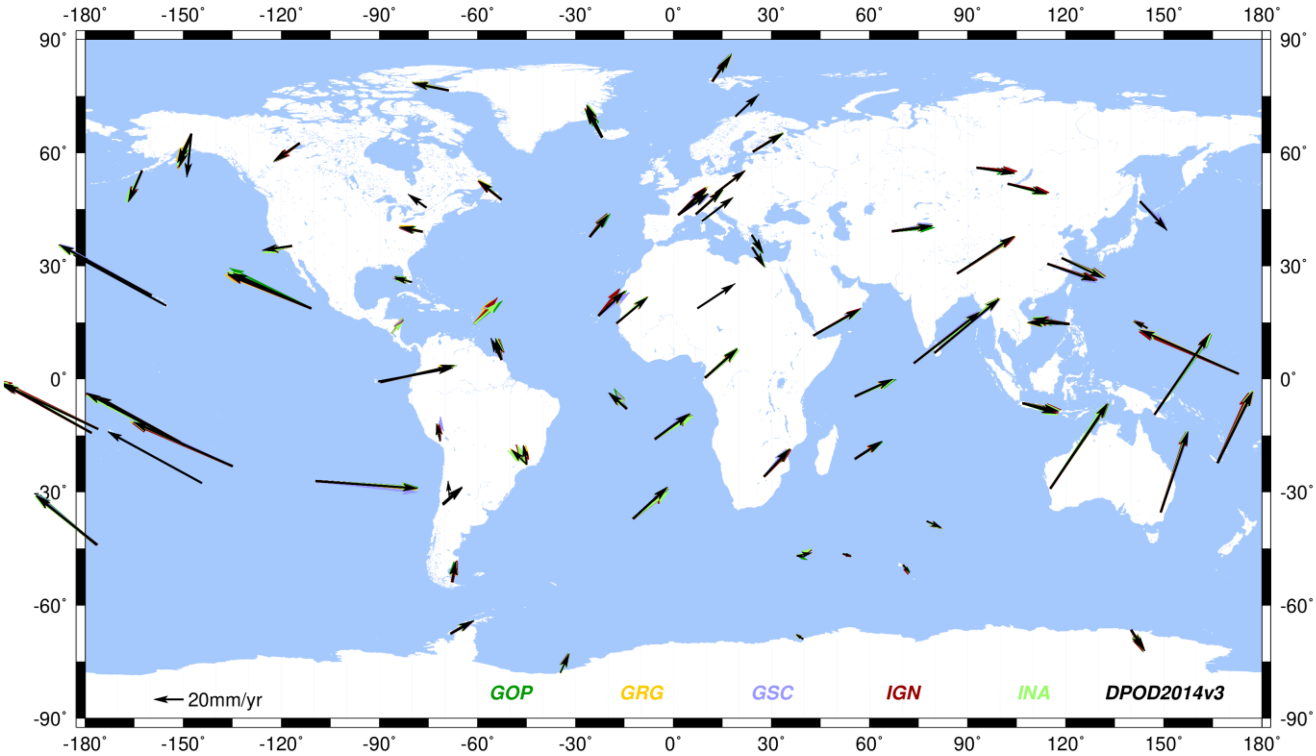


Figure 11. Horizontal velocities from the IDS AC cumulative solutions from 1993.0 to 2018.0.

10.4. DPOD2014

In line with the realization of the fourth version of the DORIS cumulative solution, the IDS CC also delivered to the IDS community the fourth and fifth versions of the DORIS extension of the ITRF2014: DPOD2014. Compared to the cumulative solution, the DPOD2014 contains the stations observed before 1993 as well as the stations turned on after the ending date of the stacking (see **Figure 12**). The DPOD2014 solution is available for download from the IDS Data Centers through the subdirectory "products/dpod/dpod2014/" in both SINEX and text formats. From the DPOD2014, the IDS CC generates a so-called IDS SINEX Master file containing the names and locations of all the DORIS stations since the start of DORIS. The SINEX Master file is freely available for download from the IDS Central Bureau ftp site.

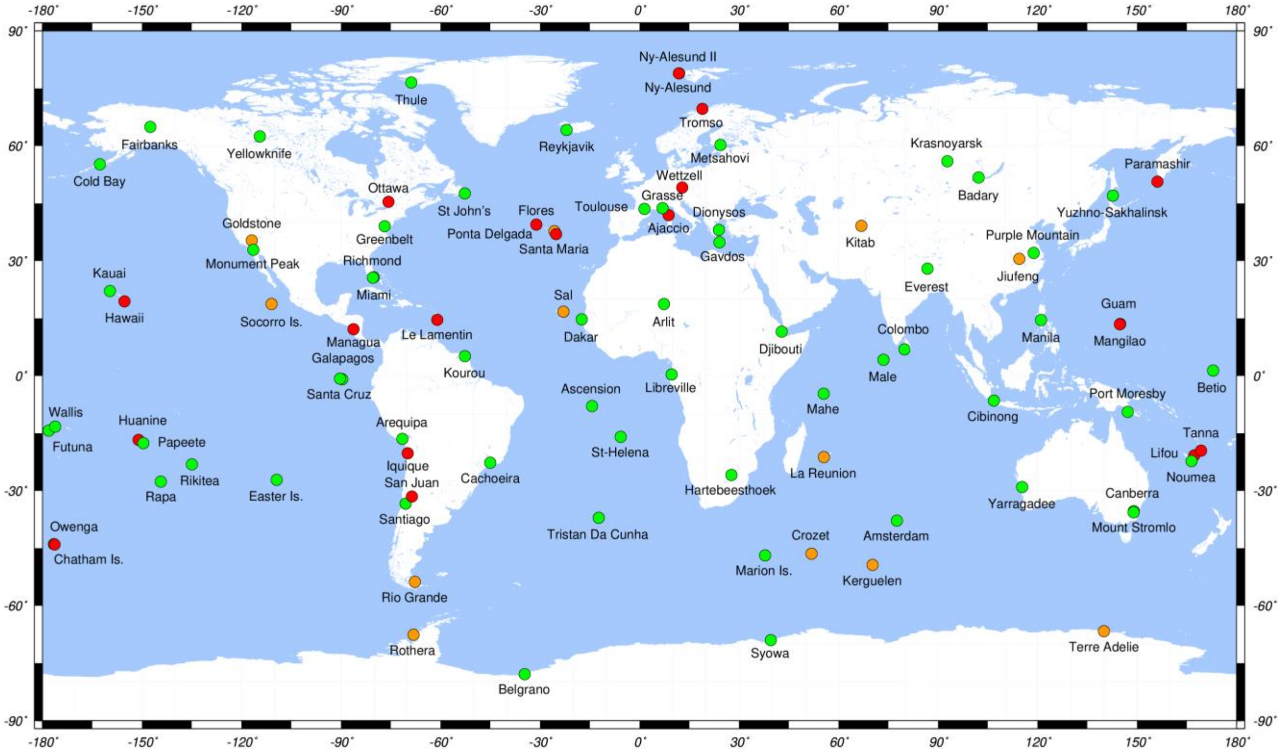


Figure 12. DORIS sites included in the version 5 of the DPOD2014 (i.e. DORIS extension of the ITRF2014). Green: ITRF2014 sites. Orange: ITRF2014 sites with new station(s) since ITRF2014. Red: sites not included in the ITRF2014.

10.5. IDS CC STUDIES

The first study we performed in 2019 concerns the analysis of the ITRF2014 DORIS-to-DORIS tie vector residuals. The tie vector residuals are the difference between the measured and the deduced tie vectors. While the measured tie vectors belong to some physical measurements on land, the deduced ones are estimated by the differences of the coordinates from an estimated solution, such as the ITRF2014. These tie vector residuals are made available by the IGS as part of the ITRF2014 solution package (see http://itrf.ensg.ign.fr/ITRF_solutions/2014/doc/ITRF2014-Tie-Residuals.dat).

We started by plotting the 59 DORIS-to-DORIS tie residuals at the 42 DORIS sites (see **Figure 13**). For 27 over the 59 tie residuals, one component represents more than 75% of the 3D tie residual. No correlation between the tie residual and neither the distance nor the time interval nor the observation duration was found.

According to **Figure 13**, we observe that the largest residuals are located:

- Mostly in the tropical region of the southern hemisphere (0°S-30°S).
- On islands (Futuna, Easter Island, Tristan, St-Helena, Mahé, Nouméa, Kerguelen).
- In the South Atlantic Anomaly region (Cachoeira, Kourou, St-Helena, Tristan).
- Surprisingly in the Antarctic (Syowa, Rothera).

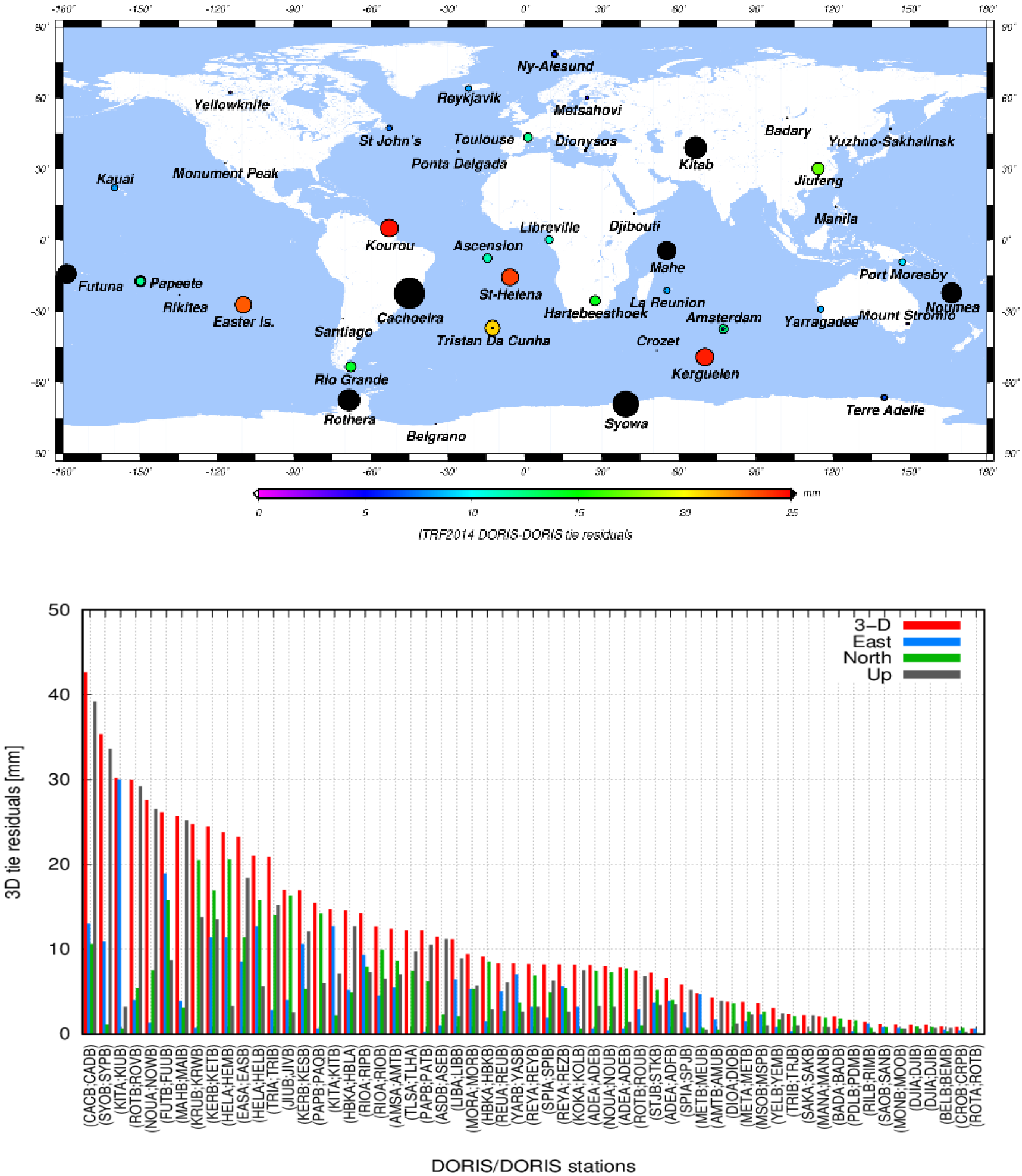


Figure 13. DORIS-to-DORIS tie residuals from the ITRF2014 solution.

Analyzing the tie residuals at Syowa and Tristan, we found that the values were smaller than the station position errors. So, for at least these two sites, the tie residuals are not relevant. Thus, we decided to concentrate on the 21 tie residuals larger than the positioning errors (see **Figure 14**). For 12 over these 21 tie residuals (associated with 18 DORIS sites), one component represents more than 75% of the 3D tie residual. Then, we went into the details of the some of the tie residuals with the highest values.

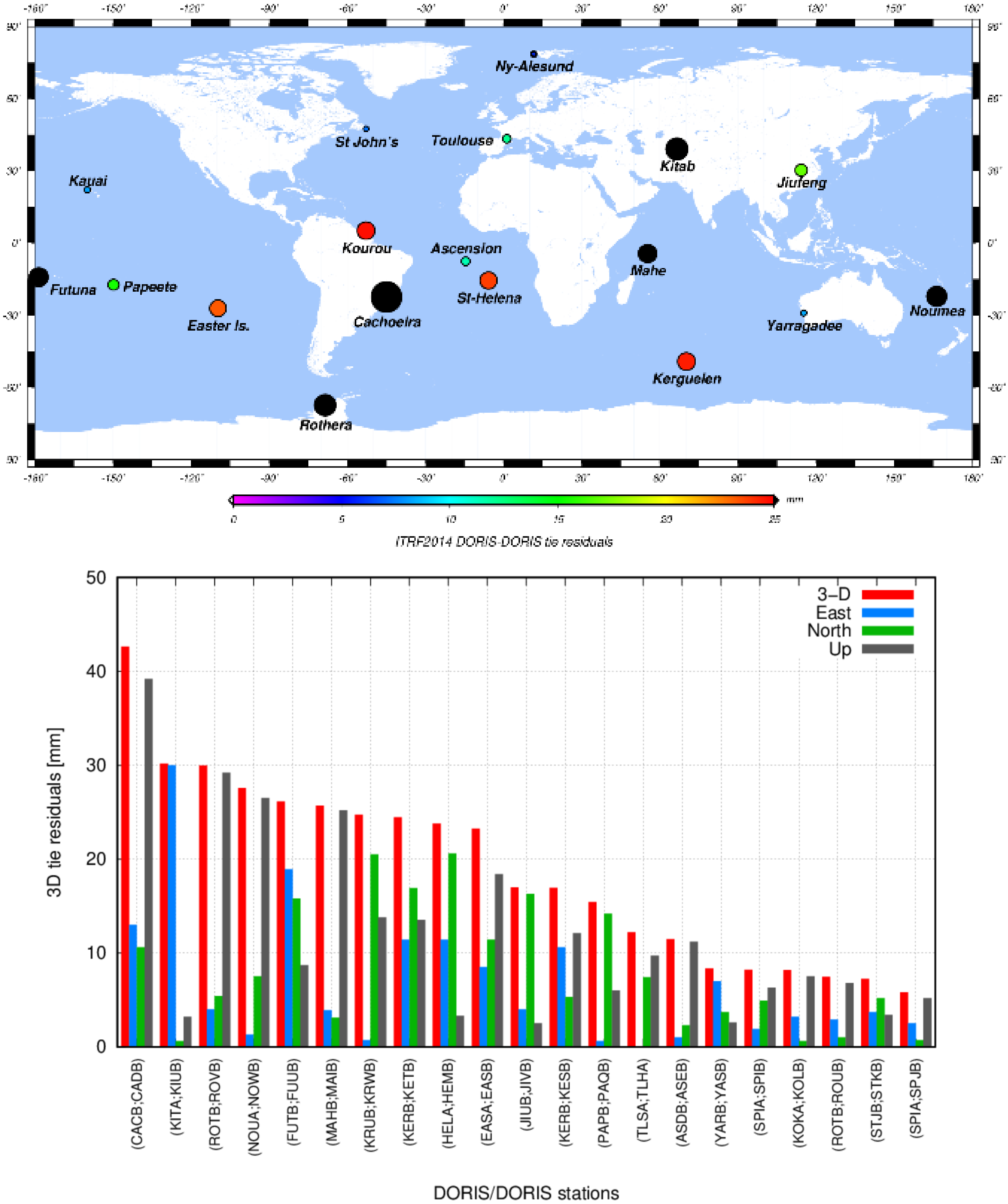


Figure 14. DORIS-to-DORIS tie residuals larger than the positioning errors.

At Cachoeira, the 3D tie residual (42.6mm) is mostly fully due to the up component (39.2mm). That site is well known to be one of the most SAA affected. In addition, the antenna is on a sheet metal roof. At Rothera, we have 3 tie vector residuals with 3 pairs of antennas. While the first two residuals are below 10mm, only the last one between ROTB and ROVB is suspicious. For Nouméa, whereas the first tie residuals associating NOUA and NOUB is ok (8mm 3D), the second one involving NOUA and NOWB is questionable. However, the distance between these two stations reaches nearly 9km. At Mahé, the tie residual of 25.7mm 3D is mostly due to the vertical with a discrepancy of 25.2mm. Looking at the time periods used in the estimation process by the ITRF2014, we found that it is more appropriated to use the second instead of the first time period of the former beacon. Then, if we use that second time period, the tie residual decreases to 4.2mm.

That study emphasized the need to analyze the tie vector residuals with respect to the station position errors as well as to use the most appropriated time intervals while estimating the coordinate differences. However, some of the largest tie residuals may be associated to the impact of the South Atlantic Anomaly on the DORIS positioning.

10.6. ITRF2020

So far, nearly fifteen series were delivered by the four IDS ACs (ESA, GOP, GRG and GSC) which agreed to participate to the realization of the DORIS contribution to the ITRF2020. All these series are fully compliant with the latest IERS standards and recommendation to the ITRF2020 call of participation. The delivery of the ACs were scheduled over time periods linked with the time evolution of the DORIS satellite constellation: 1993.0-2002.5, 2002.5-2011.7 and 2011.7-2020.0. Due the DORIS data and model latencies, the final year will be delivered around February 2021.

All the series were first evaluated with respect to both the ITRF2014 and the latest version of the DPOD2014 as well as with the IERS C04 series for the EOPs. The very first analyze revealed that the adoption of the new ALCATEL antenna phase law introduces a scale drift from 1993.0 to 2002. The reason of the negative slope depicted on **Figure 15** is due to the decrease of the number of ALCATEL antennas which were time after time replaced by Starec ones.

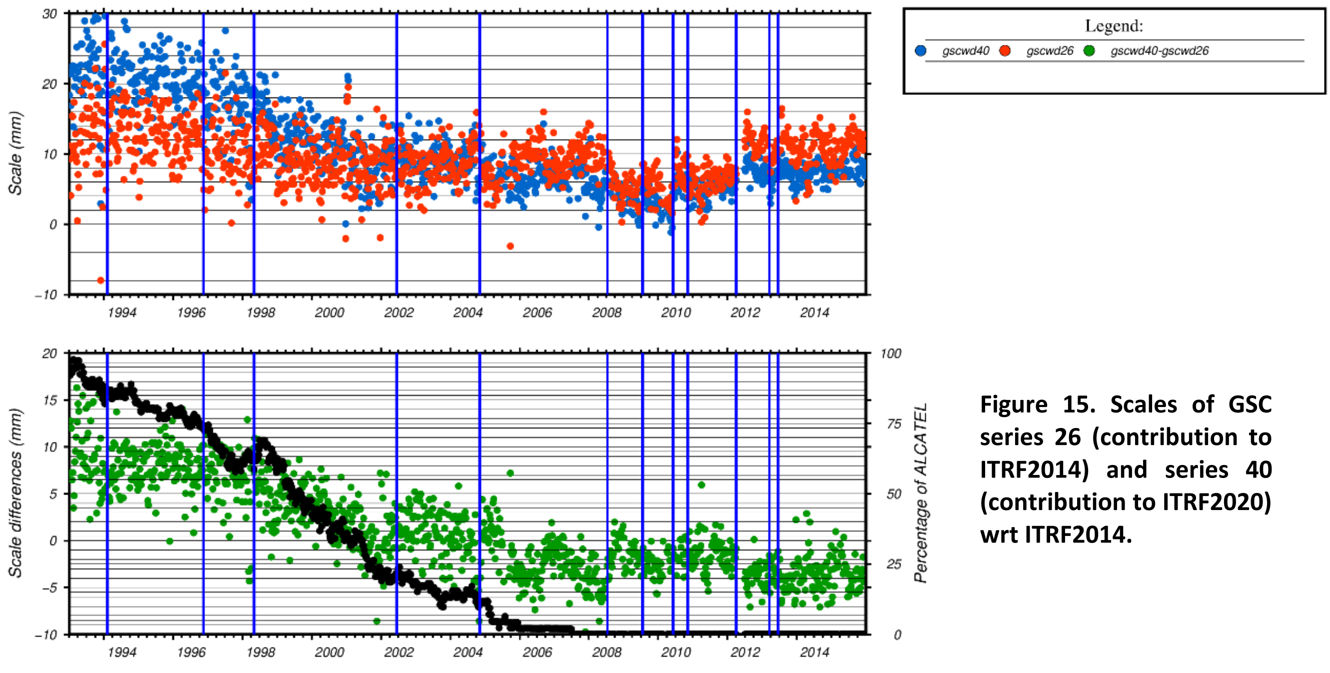


Figure 15. Scales of GSC series 26 (contribution to ITRF2014) and series 40 (contribution to ITRF2020) wrt ITRF2014.

The IDS CC also compared the weeks of presence of all the stations in the weekly SINEX files to the presence of the stations in the daily observation files from the DORIS satellites in order to get the most complete set of stations in the ITRF2020. The IDS CC also identified some weeks for which at least one AC estimated less than 7 days of EOPs.

In order to mitigate the effect of the SPOT-5 scale saw tooth pattern of the multi-satellite solutions, some AC performed some test on the contribution of the SPOT-5 mission. For some ACs, adjusting the SPOT-5 scale may also result in a higher sensitivity of the global scale to the time evolution of the DORIS constellation. Therefore, the contribution of the SPOT-5 scale to the multi-satellite solutions is not already definitively fixed.

As a consequence of the first IDS telecon organized on the DORIS contribution to the ITRF2020, the GRG IDS AC was able to improve the station positioning of the DORIS beacons prior to 2002.5 by not estimating the tropospheric gradients (see **Figure 16**) as the consequence of less measurements with only receivers of the first generation onboard of the satellite before that date. The GSC AC also succeeded to reduce the higher values of the station position WRMS during the period of high solar activity by going from 7day to 3.5day arcs (see **Figure 17**).

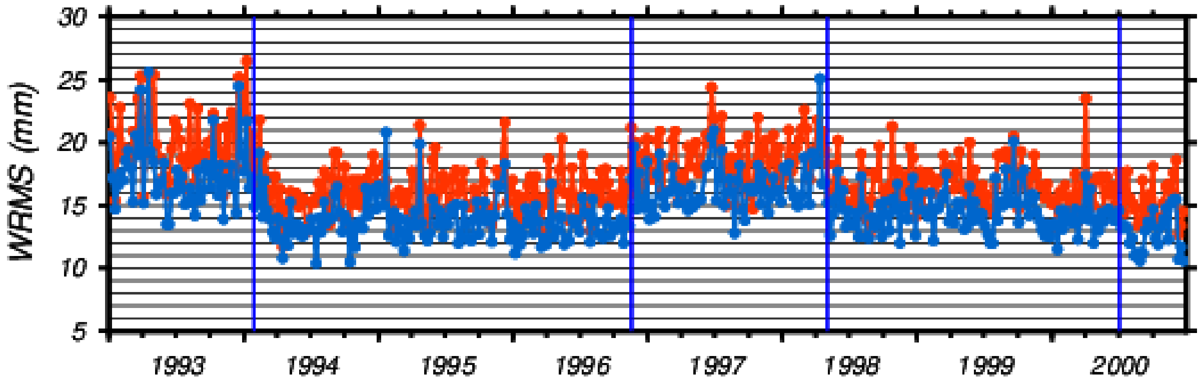


Figure 16. Station position WRMS wrt ITRF2014 before (red) and after (blue) not estimating tropospheric gradients in GRG solution.

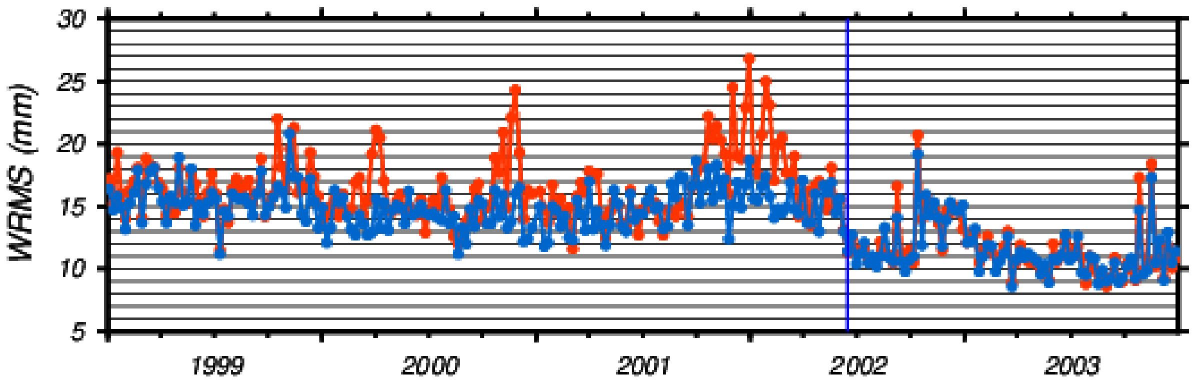


Figure 17. Impact of going from 7day (red) to 3.5day (blue) arcs by GSC.

In order to evaluate the intrinsic performances of the AC and CC solutions, the IDS CC started to estimate position and velocity cumulative solutions without any alignment to an external reference frame such as ITRF. That exercise emphasized the need to better understand the large weekly deviation of the rotation, mainly in Z, of the GRG solutions. After reviewing their rotation constraints, GRG delivered a new solution which seems to solve that problem and may allow the IDS CC to fully include the GRG contribution to the determination of the IDS combined solution.

To better understand some geocenter patterns post-2016, the IDS ACs were asked to deliver single satellite solutions. These solutions are still under investigation.
In parallel to these investigations on the AC and CC solutions, the IDS CC tested several new versions of the combination chain. Note that these new versions are based on the CATREF software from IGN received in February 2020. New combined test solutions were also performed depending on the weighting and contribution of all the AC solutions to the IDS weekly combined solution. Prior to AGU 2020 Fall meeting, the IDS CC made available for evaluation to the IERS combination centers (DGFI, IGN and JPL) a preliminary IDS solution from 1993.0 to 2020.0.

10.7. COMMUNICATIONS

In 2019, the IDS Combination Center joined the EGU and AGU fall meetings where it had, respectively, one poster titled “Analysis of the ITRF2014 tie vector discrepancies at the DORIS sites” and one oral presentation “IDS first improvements for the next ITRF2020”. The IDS CC also attended the IERS UAW held in Paris where it presented some results on the different South Atlantic Anomaly mitigation strategies developed by the IDS. In addition, the IDS CC actively participated to the IDS AWG held in Munich and Paris and contributed to the IERS Technical Note 40 devoted to the ITRF2014 with the paper titled “A comparison of the DTRF2014, ITRF2014 and JTRF2014 solutions using DORIS”.
In 2020, the IDS also actively took part of both the EGU and AGU Fall meeting with “oral” presentations focusing on the status of the realization of the IDS contribution to the ITRF2020. In between, with the help of the IDS ACs contributing the ITRF2020, the IDS CC organized two telecons devoted to the realization of the DORIS contribution to the ITRF2020.

10.8. FUTURE PLANS

In 2021, in parallel to the routine delivery of the IDS weekly combined solution and its associated products (coordinate time series of the DORIS stations, EOP time series), the IDS Combination Center will mainly work on the finalization of the DORIS contribution to the ITRF2020. The IDS CC will also release two versions of the DORIS cumulative position and velocity solution as well as the last version of the DPOD2014 and the first one of the DPOD2020 (DORIS extension of the ITRF20XX).

11.ANALYSIS CENTER OF THE GEODETIC OBSERVATORY PECNY (GOP)

Petr Štěpánek / Geodetic Observatory Pecný, Czech Republic

11.1. ROUTINE DATA PROCESSING

The standards of GOP routine data processing were updated. In 2019, the old version wd53 was substituted by wd60 with following changes:

- RINEX/DORIS data are processed, if available. Sentinel-3A and Sentinel-3B are included.
- SAA mitigation strategy is applied for Jason-2 and Jason-3, including “renaming“ of the SAA stations and linear modeling of beacon frequency for SAA station passes.
- EIGEN-GRGS.RL04 time-variable gravity field is used instead of EIGEN-GRGS.RL03 (v2)
- Secular pole as defined in the recent version of IERS 2010 convention is applied instead of older definition of Mean pole.
- Desai and Sibois model for sub-daily ERP instead of IERS 2010 standards.

Figure 18 display the comparison of the GOP solutions wd53 and wd60, performed by the IDS CombinationCcenter. The main differences between series 52 and 60 over the 40 weeks in common are on the mean scale (10.2 vs 8.1 mm), Ty (-4.4 vs 1.6 mm) and Tz (-23.4 vs 0.0 mm).

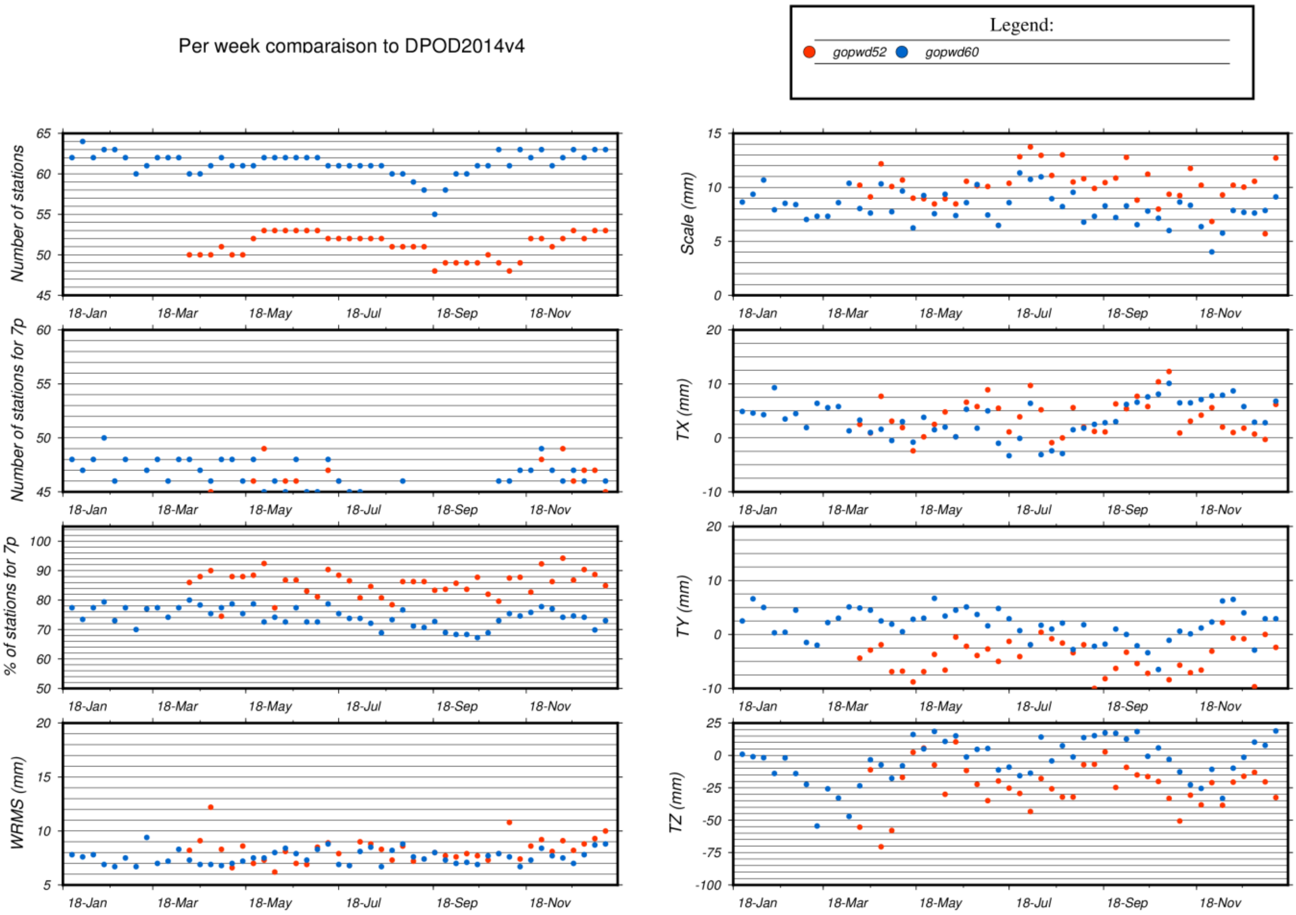


Figure 18. Comparison of gopwd53 and gopwd60 performed by IDS combination center.

In 2020, another upgrade wd60 -> wd65 was realized to use ITRF 2020 reprocessing standards also in new operational solutions. Additional update to standard wd61 included only one additional change – correction of the re-radiation term in radiation pressure modeling. The GOP SINEX series were delivered for data time span until day 270/2019.

11.2. PREPARATION FOR ITRF 2020 REPROCESSING

Our activities in 2019 focused on preparation of the ITRF reprocessing to run in 2020. To optimize our solutions, we performed the following improvements:

- Technical optimization of our DORIS data processing, decreasing the machine time to process a year of all DORIS data in 1-2 days.
- Optimization of interval for onboard clock polynomial modeling, when RINEX data processed – we chose 4th degree polynomial and 3 days sliding average.
- Usage of FES2014 Ocean Tides model
- Usage of de-aliasing product based on ECMWF-operational solutions
- Usage of TOPEX/Poseidon event file including yaw ramps and solar panel angle changes.

11.3. STATUS ITRF 2020 DATA REPROCESSING

Data 1993 – 2020 were re-processed, including all available satellites with exception of Jason-1. During the processing we optimized following settings:

- SPOT-5 was not excluded from scale contribution, even if sawtooth pattern was detected
- Jason-1 was completely excluded
- We used special SAA strategy for Jason-3, but not for Jason-2
- For HY-2A we used GSC-tuned macromodel
- New antenna offset for Sentinel-3B

11.4. RESIDUAL ANALYSIS

For a better understanding of the DORIS scale dependence on the data down-weighting and the elevation cut off, we analyzed the observation residuals separately for 2 degrees elevation intervals. We also divided ascending and descending residuals (i.e., before and after maximal elevation of the satellite pass), since the relation between observation residuals and the estimated station height has different sign for ascending and descending part of the satellite pass in the case of DORIS Doppler measurement. **Figure 19** shows mean of differences between ascending and descending residuals divided by 2, for each of 2 degrees elevation intervals. Values are displayed for satellites Jason-2 -3, Hy-2A, Cryosat-2, Saral and Sentinel-3A. The behavior under elevation of 18 degrees is similar for all the satellites, when values are negative with decreasing trend in relation with decreasing elevation. We have not yet an explanation for this effect, but this plot demonstrates the impact of low elevation observations on the estimated station height. A similar analysis of the post-fit observation residuals from other analysis centers can specify this issue as GOP-individual problem or confirm general origin of the issue.

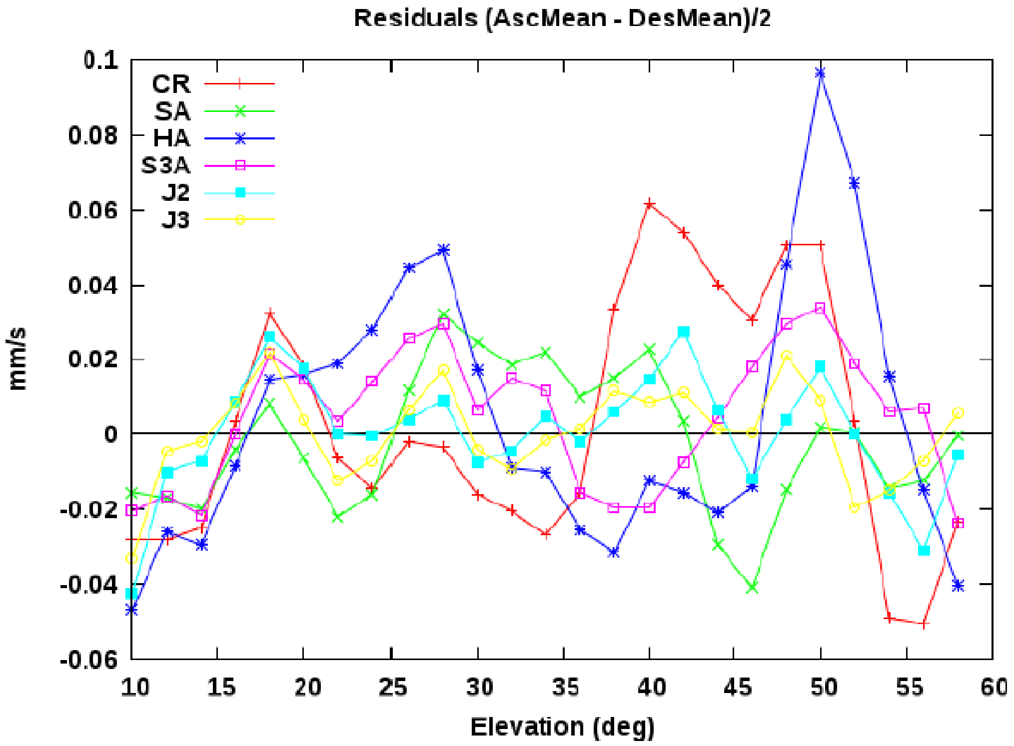


Figure 19. Differences between ascending and descending residuals divided by 2 for elevation 2 degrees interval.

11.5. ALCATEL ANTENNA PCV MODELS TESTING

We performed a comparison of the recent Alcatel antenna phase center model (PCV) and older version of the model used in ITRF reprocessing 2014. We compared the impact on residuals and the height differences with DORIS-DORIS ties for pairs of Alcatel-Starec stations as a reference. The experiment reached following conclusions:

- A bias between height differences from DORIS-DORIS ties and from global DORIS GOP solution is -2.7 mm with standard error 3.0 mm. Values are calculated for pairs of Alcatel and Starec stations at the same place (new Alcatel PCV model)
- A height bias between applying an old and new Alcatel model in GOP DORIS solutions is about 15.4 mm (average from campaigns 1994 and 2003). When applying this bias together with above mentioned bias (local ties-estimated) height of -2.7 mm, we get an (ties-estimated) height bias of about 12.7 mm when old Alcatel phase law applied. Then old Alcatel model application result is in worse agreement with height component of DORIS-DORIS ties than application of new Alcatel
- Observation residuals are reduced applying new Alcatel law v.s. old Alcatel law. Improvement is small, but present for all the satellites observed in campaigns 1994 and 2003.
- Differences in the observation residuals between application of both models are present in particular for higher elevations. Residuals related to the new Alcatel models performs better, in higher elevations.

- When difference between residual std. dev. between old and new Alcatel is plotted, we get a curve looking like a signal with amplitude increasing by elevation.
- Residuals of Starec stations performs better in low elevations and residuals of Alcatel stations perform better in higher elevations. The same finding for campaigns 1994 and 2003, where ratio between number of Alcatel and Starec stations is the opposite.
- Since new-old Alcatel impact on the observation residuals is observed mainly for the higher elevation observations, the station coordinate bias would relate to the application of elevation- dependent observation downweighting.

11.6. EXPERIMENT WITH GPS ESTIMATED ONBOARD SENTINEL CLOCKS, INTRODUCED IN DORIS DATA REPROCESSING

A unique architecture of Sentinel-3A and Sentinel-3B satellites includes the shared ultra-stable oscillator (USO) by the DORIS and GPS receivers. This concept enables to apply onboard GPS clock estimates in the DORIS processing substituting the DORIS polynomial clock model by the GPS epoch-wise model, together with a DORIS-specific clock offset. Such an approach is particularly profitable for the mitigation of the South Atlantic Anomaly effect (SAA) affecting the short-term frequency stability of the USO oscillator in the South America and South Atlantic region. The GPS clock behavior precisely maps the SAA effect and enables us to demonstrate a difference of the USO sensitivity to the SAA for Sentinel-3A and Sentinel-3B. A similar concept was firstly presented in Jalabert and Mercier (2018) for Sentinel-3A.

Together with group of Professor Urs Hugentobler from TU Munich, we performed and experiment using a full year of data (mid 2018 - mid 2019) of both Sentinels, studying the impact on station positioning and ERP estimation. Using GPS estimates of onboard clocks, we created world grid maps of clock time derivatives for both Sentinels, displaying a different sign of the direct effect and other differences in the USO memory/recovery effect. As an example, we add **Figure 20**, displaying clock time derivative for Sentinel-3B, related to the North-South satellite paths. Moreover, we found the impact of SAA on 3D positioning where the largest SAA-related bias reaches several centimeters. In addition to these improvements the elimination of the SAA effect gives us an opportunity to get an almost SAA-free DORIS solution from Sentinel-3A and Sentinel-3B satellites. Using the combined solution of both Sentinels as a reference, we estimated the SAA effect on the DORIS beacon positions also for satellites Jason-2, Jason-3, Saral, Cryosat-2 and Hy-2A and find significant positioning biases for all the recent satellites except Saral. Detailed results are summarized in Štěpánek et al. (2020).

11.7. REFERENCES

Jalabert, E.; Mercier, F., 2018. Analysis of South Atlantic Anomaly perturbations on Sentinel-3A Ultra Stable Oscillator. Impact on DORIS phase measurement and DORIS station positioning, *ADVANCES IN SPACE RESEARCH*, 62(1):174-190, DOI: 10.1016/j.asr.2018.04.005

Štěpánek, P.; Bingbing, D.; Filler, V.; Hugentobler, U., 2020. Inclusion of GPS clock estimates for satellites Sentinel-3A/3B in DORIS geodetic solutions, *JOURNAL OF GEODESY*, 94(116), DOI: 10.1007/s00190-020-01428-x

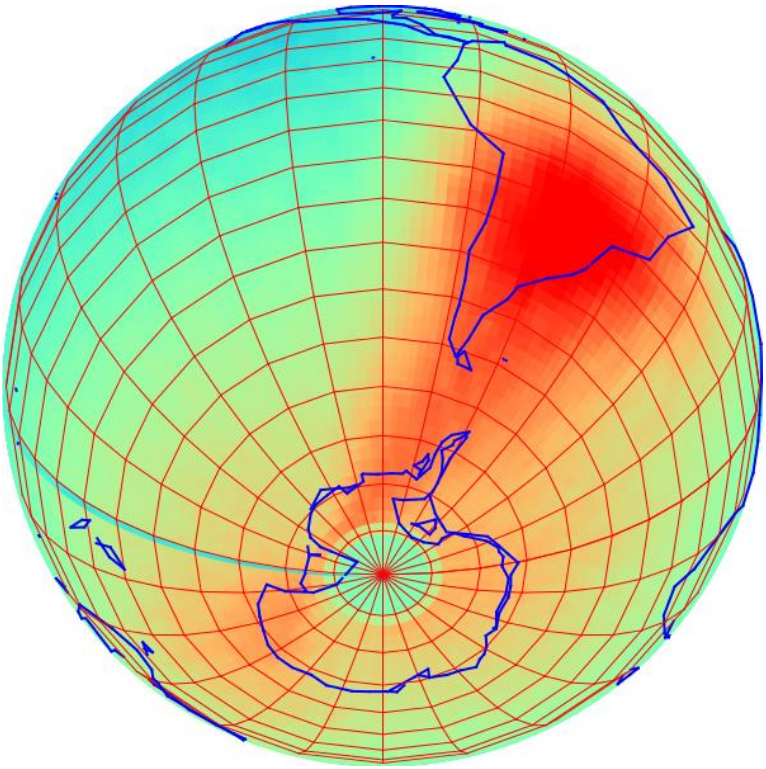


Figure 20. Onboard clock time derivative for Sentinel-3B, North-South satellite passes.

12.CNES/CLS ANALYSIS CENTER (GRG)

Hugues Capdeville [1], Adrien Mezerette [1], Jean-Michel Lemoine [2]
[1] CLS, France / [2] CNES/GRGS, France

12.1. INTRODUCTION

The CNES and CLS participate jointly to the IDS as an Analysis Center. The processing of the DORIS data is performed using the GINS/DYNAMO software package developed by the GRGS.

We continued the standard routinely processing. We analyzed the DORIS2.2 data with 3.5-day arcs and a cut-off angle of 12° by using the ITRF2014 configuration for the following satellites: Jason-2, Cryosat-2, HY-2A and Saral. The satellites Jason-3, Sentinel-3A and Sentinel-3B are processed from RINEX data.

The main activity during 2019 was to prepare our contribution to the ITRF2020 realization. We have implemented and evaluated the new standards and models recommended by IERS and IDS. The models given in **Table 9**, linear mean pole, new gravity field compatible EIGEN-GRGS.RL04, new ocean tide FES2014b and dealiasing products (AOD1B) from GFZ have been implemented and tested. It stays to implement the loading oceanic based on ocean tide model FES2014 for DORIS stations. The **Table 10** gives the new GRG processing strategy for ITRF2020. We reduced the elevation cutoff to 10°, we use quaternions for Jason satellites, and we plan to implement the CNES downweighting law.

Models/Standards		OLD	NEW
Earth rotation	**Mean pole**	IERS2010	Linear mean pole from updated IERS conventions
	Subdaily pole model	Previous IERS convention	Desai & Sibois from updated IERS conventions
Gravity model	**Time variable gravity field**	EIGEN-GRGS.RL03	EIGEN-GRGS.RL04
	Oceanic/Atmospheric gravity Dealiasing Products	No	AOD 1B RL06 (GFZ)
Ocean tides	**Station displacements (ocean loading)**	FES2012	To be implemented FES2014b
	Gravitational attraction	FES2012	FES2014b

Table 9. Models recommended by IERS and IDS for ITRF2020.

Theme	OLD	NEW
Attitude modelling (Spacecraft + Solar array)	Attitude model for all satellites	Quaternions for Jason-2 and Jason-3 Quaternions for s3a, s3b and cs2 (planned)
Coefficient Solar Radiation pressure Cr	Satellite dependent estimated and fixed	Satellite and time dependent Adjusted per arc planned
Estimated measurement parameters	One frequency bias per pass	One frequency bias **and drift for SAA stations per pass (for Jason-2 and Jason-3)**
Elevation cut-off and data downweighting	Cut-off 12° downweighting: elev²/400 for elev < 20°	Cut-off 10° CNES downweighting law (planned)
Integration Step Size	60 sec	30 sec
Estimation of the DORIS Center Of Phase locations	NO	Sentinel-3A/3B, Envisat Others?

Table 10. New GRG processing strategy for ITRF2020.

12.2. POD STATUS

A POD status for the active DORIS missions has been done by analyzing the orbit results obtained on the time span processing of 130 weeks (from January 2017 to June 2019). We took into account the standards and models used for our next contribution to the realization of the ITRF2020, the IERS conventions and the IDS recommendations. We give in **Table 11** the average per arc of the amplitudes of empirical acceleration in tangential and normal, DORIS RMS of the orbit residuals. For both directions (tangential and normal), the average amplitude of the empirical accelerations is less than 4.10-9 m/s2, showing that the modeling of the macromodel and attitude laws is correct.

We use now quaternions for BUS and solar panels for Jason satellites. The orbit residuals level of the Jason-3 (0.36 mm/s on average) and Sentinel-3A&B (0.37&0.39 mm/s), are slightly higher than Jason-2 (0.34 mm/s) (see **Table 11**). For Jason-3, it can be explained by a higher sensitivity to SAA than other satellites. For Jason-2&3, there is also a ~59-day signal in the DORIS residuals despite that we use quaternions.

SATELLITE	DORIS RMS (mm/s)	OPR amplitude average (10^{-9} m/s^2)		Solar radiation coefficient Cr
		Along-track	Cross-track	
Cryosat-2	0.348	2.8	2.6	1.00
HY-2A	0.346	0.46	3.3	0.86
SARAL	0.340	1.3	2.7	1.00
Jason-2	0.338	3.8	2.6	0.97
Jason-3	0.360	0.9	2.3	0.99
Sentinel-3A	0.371	2.3	1.6	1.00
Sentinel-3B	0.389	1.4	1.8	1.00

Table 11. Average of DORIS RMS of fit per arc, OPR amplitude average and Solar radiation coefficient on the entire processing period data processing

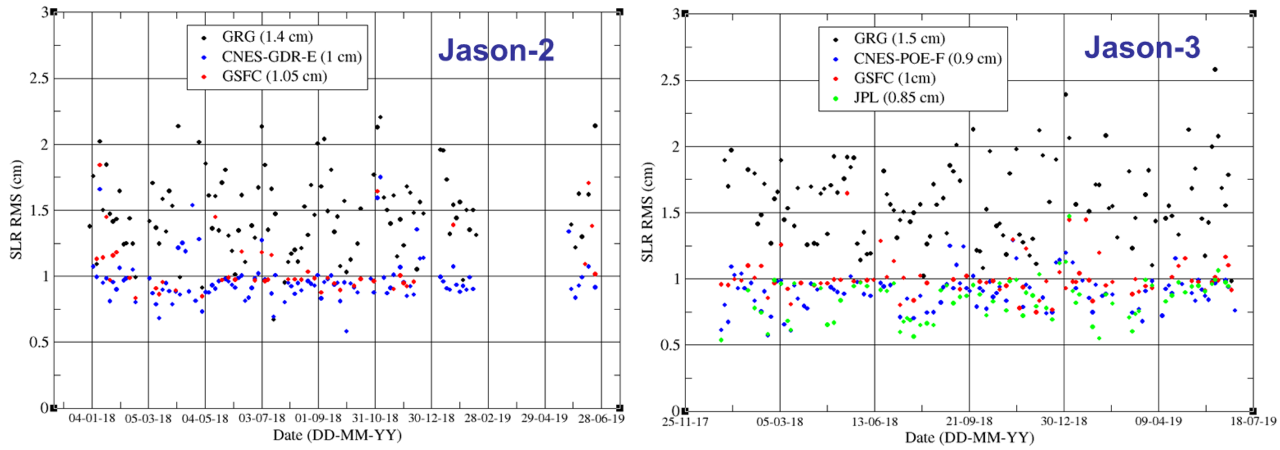


Figure 21. Independent SLR RMS of fit on Jason-2 and Jason-3 orbits, DORIS-only orbit for CNES/CLS AC (in black), (GPS+DORIS) orbit for POD CNES team (GDR-E and POE-F) (in blue), GSFC AC (in red) and GPS-only for JPL (in green).

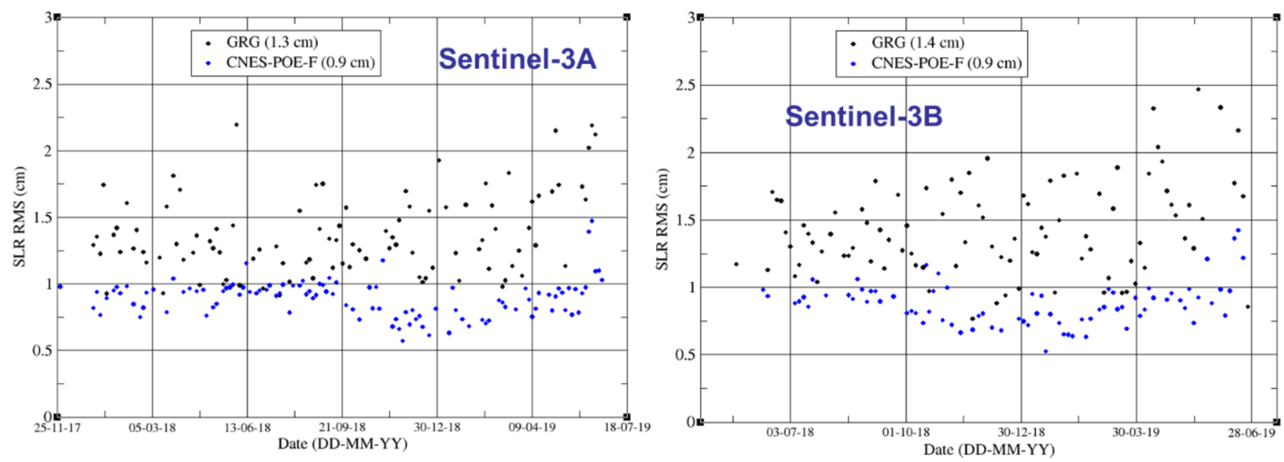
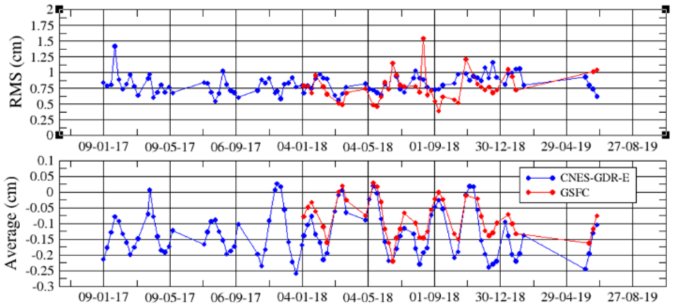


Figure 22. Independent SLR RMS of fit on Sentinel-3A et Sentinel-3B orbits, DORIS-only orbit for CNES/CLS AC (in black) and (GPS+DORIS) orbit for POD CNES team (POE-F) (in blue).

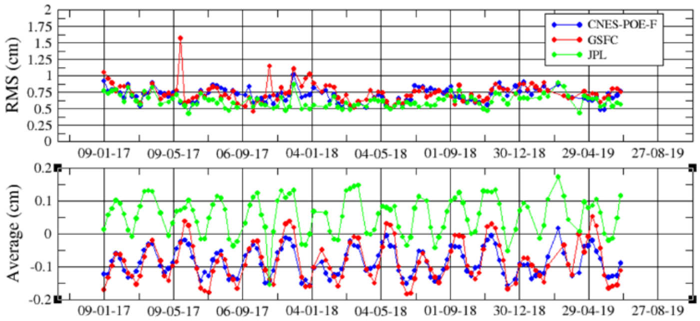
The DORIS-only orbits have also been evaluated by an independent SLR measurements processing. As shown in **Figure 21** and in **Figure 22**, SLR residuals on DORIS-only orbits are slightly higher compared to the others orbits evaluated, precise orbit DORIS+GPS of CNES POD team, precise orbit DORIS+SLR of GSFC and GPS-only orbit of JPL. We have to look at the results for radial component by taking into account only high elevation SLR measurements from one core network.

We compared our Jason and Sentinel orbits with those of the CNES POD team, of GSFC and of JPL. We give on the **Figure 23**, **Figure 24**, **Figure 25**, **Figure 26**, the average and STD of the orbit differences by week overall 130 weeks (January 2017 to June 2019) for the 3 components (radial, normal and tangential) for Jason-2, Jason-3, Sentinel-3A and Sentinel-3B respectively. For Jason-3, there is a good agreement between our orbits and the others (RMS 0.7 cm) but there is a tangential bias of ~ 1.3 cm which could be explained by a difference in the time tagging of the DORIS and GPS measurements. There is also a signal at ~59 days in the average of the radial component but the amplitude is low. For Sentinel-3A, the agreement between the orbits is at the same level.



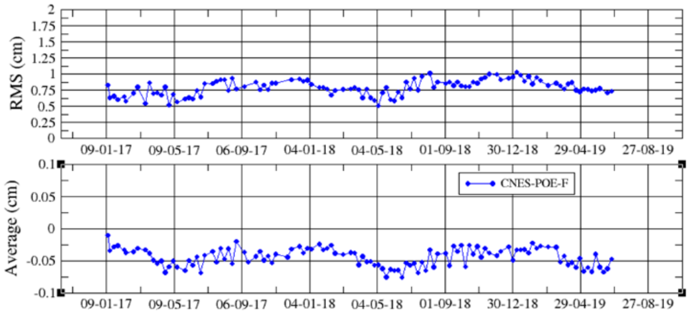
Jason-2 orbit differences (cm)			
Difference	Radial RMS | AVG	Cross-track RMS | AVG	along-track RMS | AVG
CNES-GDR-E	0.80 | -0.13	1.9 | 0.12	2.3 | 0.21
GSFC	0.76 | -0.08	2.4 | 0.24	2.6 | 0.34

Figure 23. Jason-2 orbit differences between CNES/CLS AC and CNES POD team (in blue), and GSFC (in red).



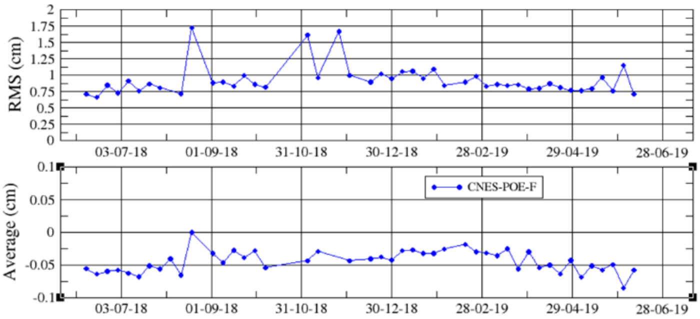
Jason-3 orbit differences (cm)			
Difference	Radial RMS | AVG	Cross-track RMS | AVG	along-track RMS | AVG
CNES-POE-F	0.70 | -0.08	2.5 | 0.18	2.3 | 0.60
GSFC	0.74 | -0.08	2.8 | 0.21	2.6 | -0.30
JPL	0.62 | 0.05	2.4 | 0.17	2.2 | 0.70

Figure 24. Jason-3 orbit differences between CNES/CLS AC and CNES POD team (in blue), and GSFC (in red), and our JPL orbit (in green).



Sentinel-3A orbit differences (cm)			
Difference	Radial RMS | AVG	Cross-track RMS | AVG	along-track RMS | AVG
CNES-POE-F	0.79 | -0.04	1.7 | 0.11	2.1 | -0.29

Figure 25. Sentinel-3A orbit differences between CNES/CLS AC and CNES POD team.



Sentinel-3B orbit differences (cm)			
Difference	Radial RMS | AVG	Cross-trk RMS | AVG	along-trk RMS | AVG
CNES-POE-F	0.92 | -0.04	1.9 | -0.13	2.5 | 0.10

Figure 26. Sentinel-3B orbit differences between CNES/CLS AC and CNES POD team.

The GRG orbits were also evaluated by the calculation of Sea Surface Height (SSH) difference at crossover per cycle for Jason missions and Sentienel-3A. As shown in **Table 12**, the STD of the SSH differences calculated from GRG orbit are at the same level than other orbits.

The CNES/CLS AC provides routinely the Sentinel orbit to the Sentinel-3 Copernicus POD Quality Working Group (QWG). We present here one result from the evaluation made by GMV (**Figure 27**). These results show that the DORIS-only orbit calculated with GINS is at the same level, in particular for radial component, as the other orbits which are all determined from GPS measurements.

Altimeter Xover (in cm)			
Orbit	**Jason-2**	**Jason-3**	**Sentinel-3A**
GRG	**5.70**	**5.58**	**5.48**
CNES	**5.66**	**5.56**	**5.44**
GSC	**X**	**5.57**	**X**
JPL	**X**	**5.55**	**X**

Table 12. STD of the SSH differences at crossover per cycle calculated from GRG, CNES-GDRE, GSFC and JPL orbits.

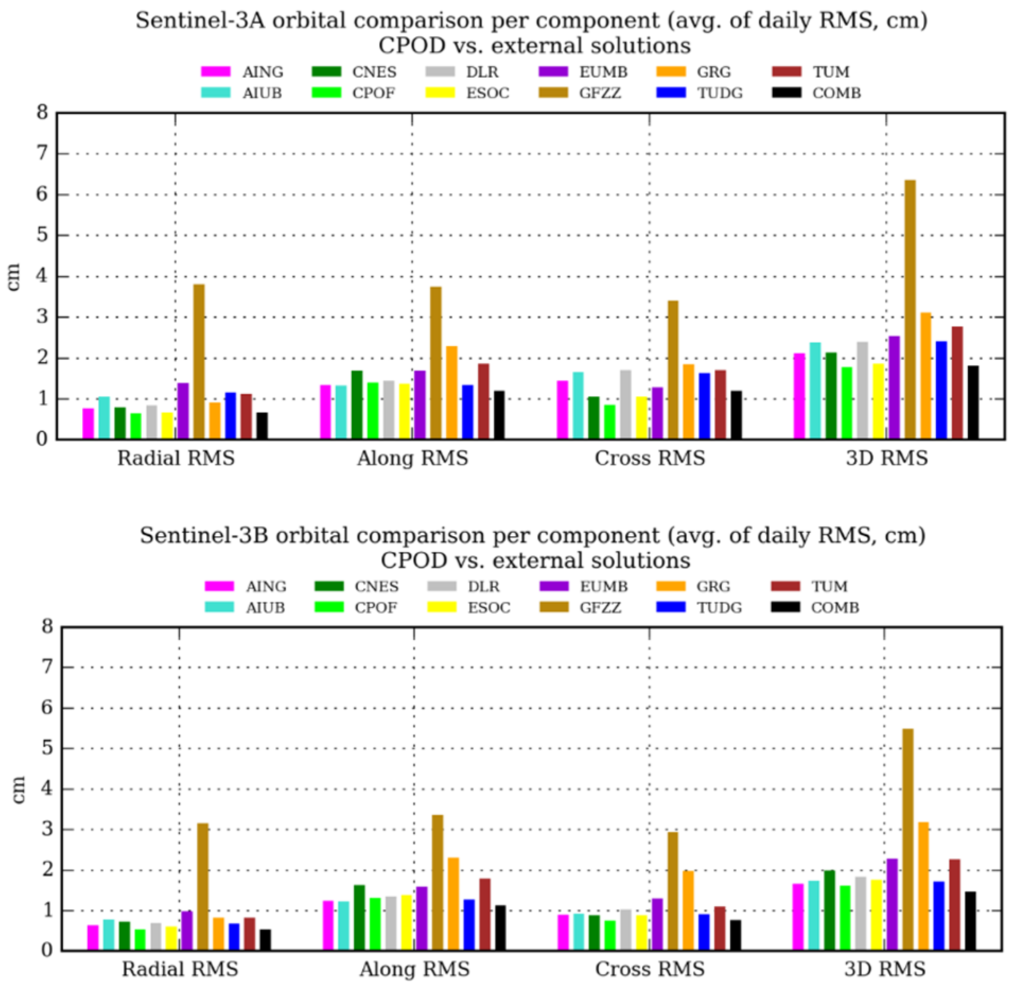


Figure 27. Sentinel-3A&B orbit comparisons per component (average of daily RMS; cm); CPOD vs. external solutions.

12.3. IMPACT ON THE POSITIONNING

We have also calculated a multi-satellite solution from our preliminary ITRF20 configuration. This solution is compared to the operational solution with CATREF software. As shown on **Figure 28**, the new configuration has not significantly impact on the DORIS geocenter and scale.

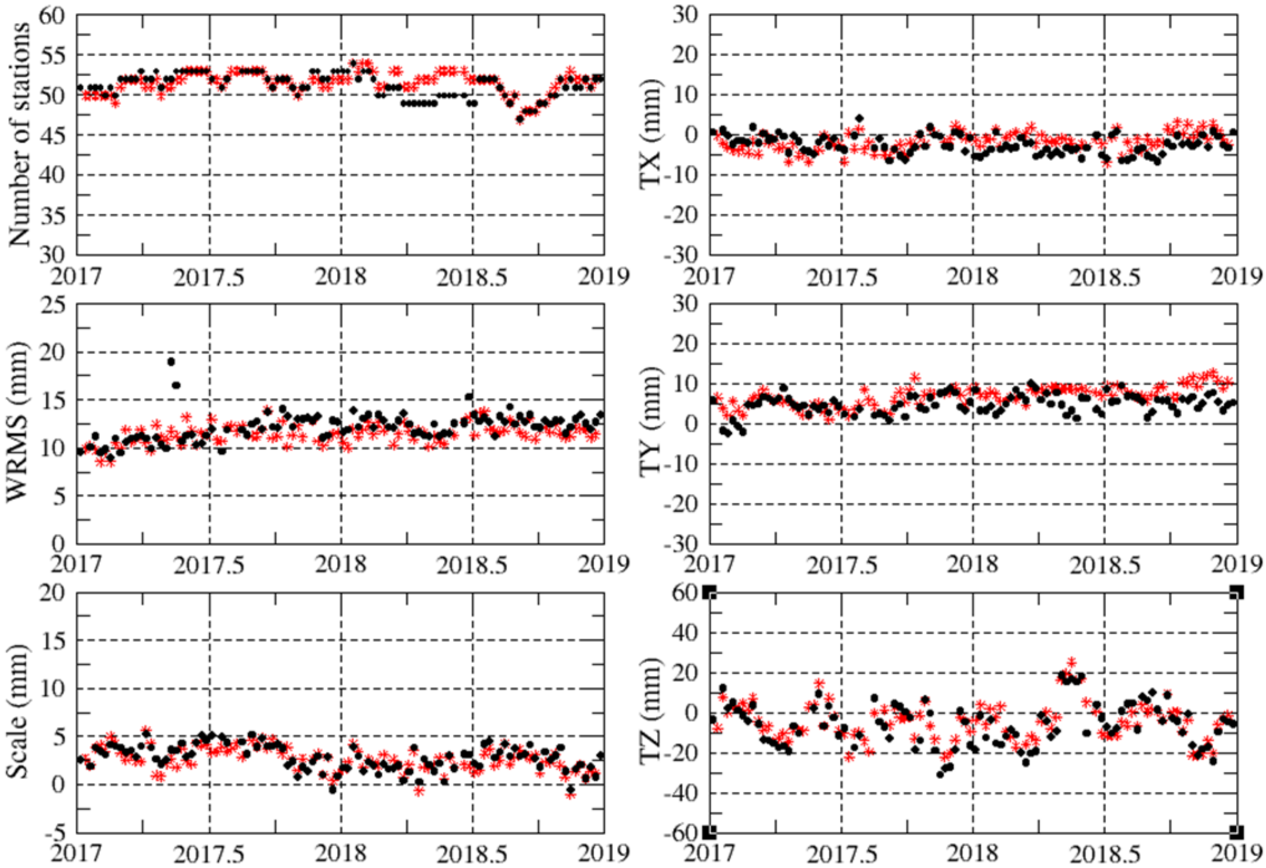


Figure 28. Geocenter and scale factor of GRG multi-satellite solutions, operational configuration (in black) /ITRF2020 configuration (in red).

12.4. CONTRIBUTION TO IDS MEETINGS

The Analysis Center's representatives participated in 2019 to the AWG meetings in Munich in April and in Paris in October. They also participate to the EGU in Vienna and OSTST in Chicago. They presented the following works:

AWG (Munich):

- https://ids-doris.org/documents/report/AWG201904/IDSAWG201904-Capdeville-GRG_StatusReport.pdf

EGU (Vienna):

- "Precise Orbit Determination of DORIS satellites by CNES/CLS IDS Analysis Center in the frame of the next ITRF"

OSTST (Chicago):

- "Precise Orbit Determination of DORIS satellites by CNES/CLS IDS Analysis Center in the frame of the next ITRF"

AWG (Paris): (contribution to the IDS presentations)

- "South Atlantic Anomaly Compensation"
- "Scale in DORIS Solutions"
- "Mitigation of Non-conservative Force Model Error for DORIS Satellites"

13.GSFC/NASA ANALYSIS CENTER (GSC)

F.G. Lemoine [(1)], D.S. Chinn [(2)], N.P. Zelensky [(2)], Alexandre Belli [(3)], Karine Le Bail [(4)]
[(1)] NASA GSFC, USA / [(2)] SGT Inc. @ NASA GSFC, USA / [(3)] USRA, NASA Postdoctoral Program @ NASA, USA / [(4)] NVI Inc. @ NASA GSFC, USA

The major focus of the GSC Analysis Center in the period of 2019-2020 was the preparation of the GSC DORIS Analysis Center submission to ITRF2020. A major portion of this work was carried out while working remotely due to the COVID-19 pandemic. We summarize below some of the most significant updates implemented for ITRF2020.

13.1. ITRF2020

13.1.1. GEODYN UPDATES

The first step was to update the version of the NASA GSFC precise orbit determination and geodetic parameter estimation software, GEODYN. Whereas, we used GEODYN version 1410 for ITRF2014, we eventually settled on version 2002 for ITRF2020. The major change to the software involved the handling of the pass-by-pass parameters (troposphere and range-rate). For earlier versions the bias estimation was done by a shortcut method that worked operationally, but that made operational debugging of ongoing problems exceedingly difficult. As a result, bias estimation was made to be explicit by including the biases in the batch least squares normal matrix at each iteration. While this would result in a much larger normal matrix (with the attendant penalties for processing time) this was mitigated by taking advantage of the block-diagonal structure of normal matrix (w.r.t. to biases) to speed up inversions. In addition, inadvertent data clipping at the start and the end of passes was also eliminated. These changes required a complete reprocessing of all the DORIS data from 1993 to the present time, and completely re-editting all the data using the new a priori models.

13.1.2. ARC LENGTH

For ITRF2014, the default was to use 7-day arcs whenever possible. We noted, along with the IDS Combination Center (CC), the increase in WRMS around the time of the Solar Maximum (1999-2003) in both GSC SINEX solutions and in the IDS combination. We found that reducing the arc length by default to 3.5 days for this time period for the 800 km satellites improved the Precise Orbit Determination (POD), and improved the WRMS. This included SPOT-2, SPOT-4 (1998-2003), SPOT-5 and ENVISAT (2002-2003).

13.1.3. ELEVATION DEPENDENT WEIGHTING

Since other DORIS analysis centers had demonstrated the benefits of processing the lower elevation data, while using an elevation-dependent weighting function, we requested that this feature be added to GEODYN. One of us (NPZ) carried out tests of different functions, including (a) the Mercier-Moyard function, (b) 1/sin(elevation), and (c) 1/sqrt(sin(elevation)). We chose option (c), while lowering the minimum elevation for data processing to 7 degrees, instead of 10 degrees used in ITRF2014. For

Cryosat-2, HY-2A, Jason-2 and Saral, this increased the amount of data by 10-14%. There is very little data below 10 degrees elevation for the satellites using the first-generation of DORIS receivers. While introducing the lower elevation data, we were careful to edit out passes with too few observations, or passes whose maximum elevation was no greater than 13 degrees. The introduction of elevation-dependent weighting effectively downweights the data across the board. To compensate, for the period 2003-2020, we changed the a priori data sigma in GEODYN from 0.2 cm/s to 0.125 cm/s.

13.1.4. GRAVITY FIELD

For ITRF2014, we used GOCO02s, augmented by a 5x5 weekly gravity field determined from SLR & DORIS data. For ITRF2020, we adopted GOCO05s. This is a later model based on GRACE, GOCE, SLR and other data developed by the GOCO consortium. It consists of a static background model, where the time-variable terms include secular rates and annual terms. The model required special adaption for the early DORIS data. Since the epoch of the GOCO05s solution was 2008.0, we propagated the coefficients to 2003.0 (near the start of the GRACE mission), and then used only the annual terms prior to 2003.0. After 2003.0, the gravity model we applied included both the static and the time-variable terms. For background modelling of the atmospheric and ocean gravity variations, we adopted the GFZ Atmosphere-ocean product (RL06) developed for the GRACE and the GRACE FO mission (Dobslaw et al., 2017). These operational AOD products are available in a timely manner with very short latency.

13.1.5. OTHER MODELLING

As requested by the IERS, we adopted the IERS2017 linear mean pole, and the new High-Frequency prior model for Earth Orientation (IERS, 2017). We adopted the Vienna Mapping Function-1 model for ITRF2020 (Boehm and Schuh, 2004), replacing the GMF/GPT model used for ITRF2014. We initialized our processing with Koop and Lean (2011) value of 1360.8 W/m^2 for the Total Solar Irradiance (TSI), replacing the previous standard value of 1367.2 W/m^2. The macromodels for TOPEX, the Jason satellites, HY-2A and SPOT-4 were also retuned. We leveraged our separate work on TOPEX, Jason1-3 POD to improve nonconservative force modelling of these satellites for ITRF2020. To mitigate the nonconservative force model error at the 117-day period, in addition to systematically applying the solar array quaternions (when available) for the Jason 1-2-3 satellites, we adjusted a solar radiation reflectivity coefficient on an arc-by-arc basis. This approach helps to absorb radiation model error not accounted for in the macromodel. It necessitates a separate orbit determination run to estimate Cr, without adjusting empirical accelerations, and then applying that value of Cr in the final solution that is converged to create the normal equations.

13.1.6. DORIS SATELLITE OFFSET MODELLING & DORIS SCALE

The radial component of the DORIS tracking point offset on the DORIS satellite has a direct impact on the scale these DORIS data produce for the reference frame. We followed closely the recommendations of the IDS to apply the offsets specified in the document DORISSatelliteModels.pdf. We applied the updates in the modeling for HY-2A as recommended by the CNES and the Analysis Coordinators. We noticed already in ITRF2014, that in single-satellite solutions SPOT-5 produced anomalous sawtooth-like patterns in the reference frame scale. No specific cause could be determined by the SPOT-5 satellite team. As a result, when we included SPOT-5, we systematically estimated a radial (Z) offset, in order to mitigate this effect.

13.1.7. JASON-2 T2L2-DERIVED USO MODEL

Belli et al. (2021) used the Jason-2 T2L2 data to derive an improved frequency model for the behavior of the USO from 2008 to 2016. In applying the model, they showed that the pass-by-pass biases for the atomic clock stations were reduced compared to the standard approach of modeling the USO frequency in RINEX data processing. For ADHC (Terre Adélie) data from 2015/03/23 to 2016/08/05 the average bias was reduced from 0.411 mm/s to 0.280 mm/s using the T2L2-derived model. For GR4B (Grasse) data from 2013/08/01 to 2016/08/05 the average bias was also reduced from 0.466 mm/s to 0.219 mm/s. Belli et al. (2021) showed reductions in the Tz parameter at the draconitic period, and an improvement of about 10% in the Earth Orientation Parameters (EOP), as measured by the differences with IERS C04. Nonetheless, a challenge in using the Jason-2 T2L2-derived USO model is that it is only available to 2016, and not until the end of the Jason-2 DORIS mission in 2019.

We summarize in **Table 13** the various SINEX series, internal and those delivered to the IDS Combination Center, as we systematically tested different changes to the processing in preparation for developing the final solution. We are grateful to the IDSCC for individually testing some of these individual solutions.

Series	Description	Comment
gscwd35	First test series produced for ITRF2020.	DORISREPORT 4992 (23-Mar-2020); DORISREPORT 5069 (30-Jun-2020)
gscwd36	gscwd35 + apply HFEOP model.	internal
gscwd37	gscwd35 + adjust radial offset offset on SPOT-5.	IDSCC Email April 15, 2020
gscwd38	gscwd35 + adjust radial offset on all SPOT satellites.	internal
gscwd39	gscwd35 + apply 3.5 day arcs for SPOT-2, -4, -5, & Envisat (instead of 7-day arcs), 1999-2003.	internal
gscwd40	gscwd35 + apply radial offset on SPOT-5, HFEOP, 3.5 day arcs (cf. gscwd39) + elevation-dependent weighting on all satellites.	DORISREPORT 5096 (04-Aug-2020)
gscwd41	gscwd40 + use DORIS/RINEX data for Jason-2 with Jason- 2-T2L2-derived USO correction	IDSCC Email Dec. 8, 2020

Table 13. DORIS SINEX solutions developed by the GSC Analysis Center for ITRF2020.

13.2. NEW ORBITS FOR TOPEX & THE JASON 1-2-3 SATELLITES

As part of our responsibilities to the Ocean Surface Topography Science Team (OSTST), and to support the development of an improved orbit series for the Integrated Multi-Mission Ocean Altimeters TOPEX/Poseidon, Jason-1, OSTM/Jason-2, and Jason-3 Version 5.0 Product, for the NASA MEaSUREs Program (Making Earth System Data Records for Use in Research Environments), we have developed improved orbits for TOPEX and the Jason satellites.

The orbits incorporated the following improvements:

- ITRF2014, including latest updates supplied by the ILRS with the SLR-internal realization SLRF2014.
- Recommended corrections from the ILRS SLR Data Handling File dated 2020-06-16. The ILRS Data Handling File includes time biases for the SLR network derived from the Jason-2 T2L2 experiment from 2008-2016.
- The GOT4.10c ocean tide model for both dynamic ocean tide computations, and for ocean loading corrections at the tracking stations.
- The new linear IERS mean pole (2017) and associated pole tide.
- The GOCO05S gravity model augmented by internal gsfc model of 5x5 solutions developed from 21 SLR+DORIS satellites.
- The atmosphere-ocean dealiasing model to 90x90 from the GFZ (developed for GRACE & GRACE FO) to handle atmospheric and oceanic gravity variations (Dobslaw et al., 2017).
- Improved macromodels for TOPEX, Jasons-1,3, where a solar radiation reflectivity coefficient was adjusted per arc in a separate orbit determination run.
- An annual model of the Earth's geocenter (Ries, 2013) in the data reduction.

We illustrate the improvements in the orbits in **Figure 29** by showing the difference in the altimeter crossover variances for the new orbits (designated std2006, and the older generation of orbits, dpod2014). A positive value of the variance difference indicates an improvement in orbit quality. We see a notable improvement after about 2005, and especially after 2016, with the new Jason-3 orbits.

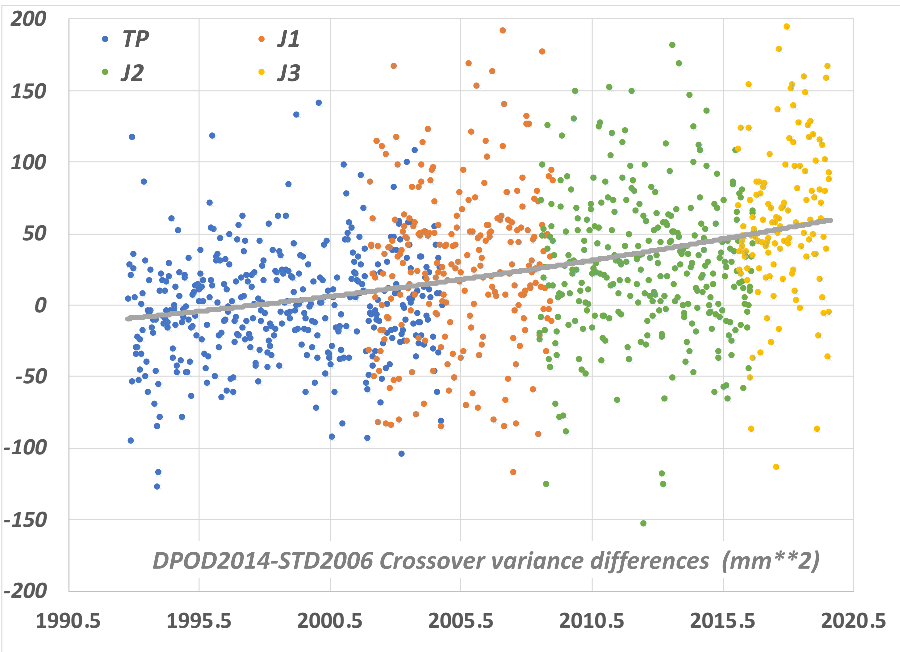


Figure 29. Radial orbit accuracy for the std2006 orbits relative to the previous generation of orbits (designated dpod2014) using independent Crossover data. Positive values indicate improvement derived from std2006.

13.3. ACKNOWLEDGEMENTS

Despina E. Pavlis (University of Maryland, Earth System Science Interdisciplinary Center) who worked closely with GEODYN for over 30 years for NASA, retired on September 25, 2020. We are grateful for her contributions to making DORIS data processing and analysis with GEODYN operational. Despina Pavlis has been a key member of our team as we have assembled the NASA GSFC DORIS contributions to ITRF2008, ITRF2014 and ITRF2020. We wish her well in her future endeavors and adventures.

As of January 2021, Alexandre Belli, a NASA Postdoctoral Fellow in our Space Geodesy group, has moved to a new position at the U.S. National Geodetic Survey (NGS). We wish him good luck in his future career.

13.4. REFERENCES

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14.INASAN ANALYSIS CENTER (INA)

Sergey Kuzin / INASAN, Russia

14.1. INTRODUCTION

In 2019-2020, INASAN (ina) DORIS Analysis Center (AC) continued routine processing DORIS data using GIPSY-OASIS II software package (v. 6.4, developed by JPL). The processing strategy and the used models stayed the same as for the ITRF2014 preparation. There were no done any strategy, software package and models modifications for the period under consideration. Currently INA AC processes DORIS data in doris2.2 format for CRYOSAT2, HY2A (the end of the HY2A mission is 12 September 2020), JASON2 (the end of the JASON2 mission is 1 October 2019) and SARAL satellites. **Table 14** shows current products delivered by INASAN to the IDS.

Product	Latest version	Span
Sinex weekly Free-network solutions	Inawd10	1993.0 – 2020.5

Table 14. INASAN SINEX series delivered to the IDS (February 2021)

14.2. ANALYSIS RESULTS DESCRIPTION: THE MAIN SCIENTIFIC RESULTS OBTAINED IN 2019-2020

Table 15 gives statistical information of the current INASAN (inawd10) and combined (idswd14) contribution to IDS. The epoch for the comparison is the mean value over the whole time period. From the Analysis Coordinator graphs (https://apps.ids-doris.org/apps/7ptool.html) we can see that there are no considerable features for the transformation parameters except those which have been already noticed in the previous IDS 2018 activity report. A priori the errors of the transformation parameters of the idswd14 combined solution should be better by comparison to errors of any analysis center. The values of these errors in the **Table 15** confirm that fact.

AC series (time interval)	WRMS (mm)	Scale (mm)	Tx (mm)	Ty (mm)	Tz (mm)	Scale rate (mm/yr)	Tx rate (mm/yr)	Ty rate (mm/yr)	Tz rate (mm/yr)
idswd14 (1993.0-2020.5)	9.17 ±2.22	10.15 ±4.19	-1.01 ±4.35	-1.77 ±5.38	-10.40 ±17.98	-0.10	0.23	-0.35	-0.20
inawd10 (1993.0-2019.9)	14.04 ±3.72	11.56 ±5.05	-1.25 ±6.69	-6.54 ±8.47	-12.02 ±24.59	0.09	0.28	-0.63	-0.10

Table 15. Comparative statistical characteristics (mean values) of the INA analysis center (inawd10) and IDS combined solution (idswd14) contribution to IDS wrt ITRF2014

Table 16 displays the statistical information about inawd10 and idswd14 EOP time series. The standard deviation (std) for the X-pole and Y-pole components of the current INA eop series has about the same values (0.53 mas and 0.52 mas, correspondently). These values are a little worse compared to the same ones obtained by IDS (0.46 mas and 0.42 mas, correspondently).
It should be mentioned that numbers in the **Table 16** and **Table 17** were obtained by G. Moreaux using CATREF software package (http://apps.ids-doris.org/apps).

Solution	Span	X-pole			X-pole			LOD		
		mean (mas)	std (mas)	trend (mas/y)	mean (mas)	std (mas)	trend (mas/y)	mean (mas)	std (mas)	trend (mas/y)
idswd14	1993.0-2020.5	0.02	0.46	0.00	0.02	0.42	0.01	-	-	-
inawd10	1993.0-2019.9	-0.03	0.53	0.01	0.03	0.52	-0.00	-0.02	0.34	-0.00

Table 16. INA AC and combined idswd14 Earth Orientation Parameters Residuals wrt IERS C04

Table 17 represents amplitudes and phases for the annual components of the geocenter motion for the 1993.0 - 2019.9 time period obtained from the transformation free-network inawd10 series to DPOD2008. In order to estimate amplitudes, periods and phases of geocenter variations with a least square estimation procedure we used CNES software package FAMOUS (Frequency Analysis Mapping On Unusual Sampling) developed by F. Mignard, OCA/CNRS (Obs. de la Cote dAzur Cassiop/Centre National de la Recherche Scientifique, ftp://ftp.obs-nice.fr/pub/mignard/Famous). The amplitudes A and phases φ are modeled by $A\cos(\omega t + \varphi)$, ω – angular frequency. The evaluated amplitudes of the annual oscillations are 3.2±0.3 mm and 4.2±0.3 mm for X and Y components, respectively, and 2.7±1.0 mm for Z component. The phase estimates of the annual signal relative to January 1 for ina10wd geocenter time series are 136±5 and 343±5 degrees for X and Y components, respectively, and 134±29 degrees for Z component.

Solution	X-component		Y-component		Z-component		Span
	A, mm	φ, deg.	A, mm	φ, deg.	A, mm	φ, deg.	
inawd10	3.2±0.3	136±5	4.2±0.3	343±5	2.7±1.0	134±29	1993.0 - 2019.9

Table 17. Annual geocenter motion estimations from weekly inawd10 time series wrt DPOD2008

14.3. PROGRESS IN DEVELOPMENT OF GEOIS INASAN'S SOFTWARE PACKAGE FOR DORIS RINEX DATA PROCESSING

The primary concept of DORIS data processing has been implemented in 2018-2019. The INASAN software package for SLR and DORIS data processing was named GeoIS (Geodetic Investigation). During 2020 we were working on implementation of several major features which are mandatory for producing results into ITRF combination campaigns. The most important features are described below. Let's split this list into several parts: satellite-specific models and data, orbit modeling, Earth rotation data processing, general processing features.

14.3.1. SATELLITE-SPECIFIC MODELS AND DATA

Support of Sentinel-3B has been added since measurements of this satellite have not been allowed before. After that the following list of satellites could be processed: CRYOSAT-2, JASON-2, JASON-3, Sentinel-3A, Sentinel-3B, HY2A, SARAL.
To be fully aligned with IDS recommendations we implemented processing of quaternions for following satellites: CRYOSAT-2, both Sentinel-3 (previously only JASON quaternions were processed).
In addition, a very serious bug related to phase center offset compensation has been fixed. Thanks to this fix final residuals of measurements decreased by approximately 30% (to the level of 0.5mm/s).

14.3.2. ORBIT MODELING

The full support of different variants of ICGEM (International Centre for Global Earth Models) format has been implemented. Currently all available models in ICGEM format could be processed.
We also supported FES2014b ocean tide model and AOD1B RL06 de-aliasing model (Dobslaw et all, 2017) to be aligned with other processing centers.

14.3.3. EARTH ROTATION DATA PROCESSING

IERS currently recommends (https://iers-conventions.obspm.fr/content/chapter7/icc7.pdf) a new mean pole motion model (secular pole) which has been implemented in GeoIS software.
Another thing related to Earth rotation parameters is a new tidal model for accounting of diurnal and semi-diurnal effects from ocean Desai and Sibois (2016).

14.3.4. GENERAL PROCESSING ROUTINES

DORIS processing in GeoIS software has been implemented for daily intervals. To have weekly solutions we need to have combining on normal equations level be implemented. Currently we store daily results (including normal equations system) using certain format. We started implementation of a routing for combination process. This is our goal for next months to produce weekly SINEX files.
There are three major items which have not been implemented.
Initially GeoIS software was intended to process SLR data from spherical satellite. So, albedo models have been applied very easy. To apply these models to DORIS data processing some tuning need to be done.
Some additional parameters need to be estimated along with others: solar radiation pressure coefficients and horizontal gradients of troposphere. This is a task for 2021.

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15. GFZ ASSOCIATE ANALYSIS CENTER

Rolf König, Anna Michalak, Patrick Schreiner / Helmholtz Centre Potsdam – GFZ German Research Centre for Geosciences, Oberpfaffenhofen, Germany

15.1. INTRODUCTION

The activities performed at GFZ in 2019 concentrated on Precise Orbit Determination (POD) of altimeter carrying satellites. In particular, the analyses of DORIS and SLR observations to ENVISAT, Jason-1 and -2 were used to infer the impact of non-tidal atmospheric and oceanic loading on the orbits. New in our portfolio is POD of the Sentinel-3A and -3B satellites based on DORIS, SLR and GPS observations. Also we are moving towards POD of Jason-3 based on DORIS, SLR and GPS observations, and we are revisiting TOPEX/Poseidon POD based on DORIS and SLR observations. The common objective of these activities is to contribute the DORIS based part of these missions to the development of the upcoming ITRF2020 reference frame.

15.2. NON-TIDAL LOADING EFFECTS ON ENVISAT, JASON-1 AND -2 DORIS AND SLR ORBITS

The effect of deformations of station locations by non-tidal mass variations in atmosphere and oceans has been analyzed in POD of ENVISAT, Jason-1 and -2 from DORIS and SLR observations (König et al., 2019). The loading model of GFZ being compatible with GRACE AOD1B short-term gravitational mass variations was compared to the IMLS model intended for use in VLBI applications. These loading models encounter for coordinate variations of a few millimeters in terms of standard deviation and a few centimeters in terms of extreme values (see **Figure 30**) mainly in radial direction. Their effect on the orbits, particular in the radial direction important for altimetry, is much smaller, i.e. at the sub-millimeter level. The effects can hardly be detected by altimeter cross-over analyses. It however can be noticed that the orbital fits benefit at that same low level so that it is justified to apply the loading correction.

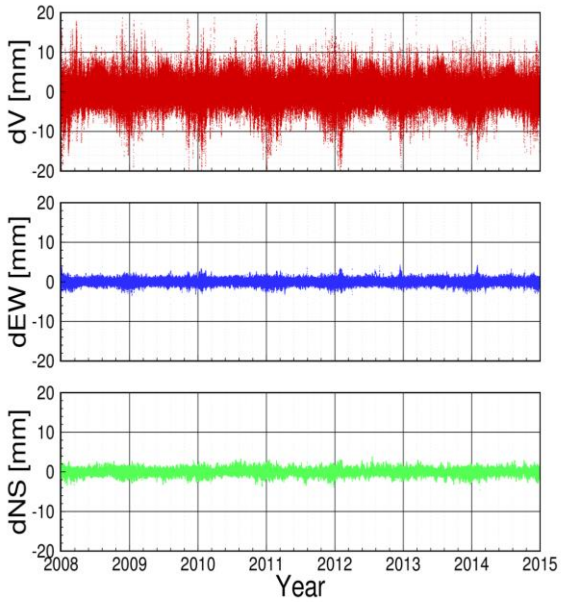

Figure 30. All GFZ loading model displacements of all stations used in the analysis

15.3. POD OF SENTINEL-3A AND -3B

The Copernicus satellites Sentinel-3A and -3B are equipped each with a DORIS and a GPS receiver, as well as with a SLR retro-reflector. The SLR retro-reflectors of both satellites exhibit a particular azimuth and elevation dependent behavior concerning the center of mass corrections. This, and the DORIS specific phase law for the center of mass corrections, are currently being implemented in our POD software EPOSOC, both migrations of the software are under testing and validation. The center of mass corrections for the GPS observations have been validated already. Therefore, we compare the GPS based orbits to the combined orbit product of the Copernicus POD service being an external, high quality orbit product. As can be seen in **Figure 31**, the mean differences are in the order of millimeters to sub-millimeters, the variations of the differences in terms of Root Mean Squared (RMS) values are in the range of sub-centimeters in all three directions. The GPS orbits can now be used to validate the SLR and DORIS based orbits.

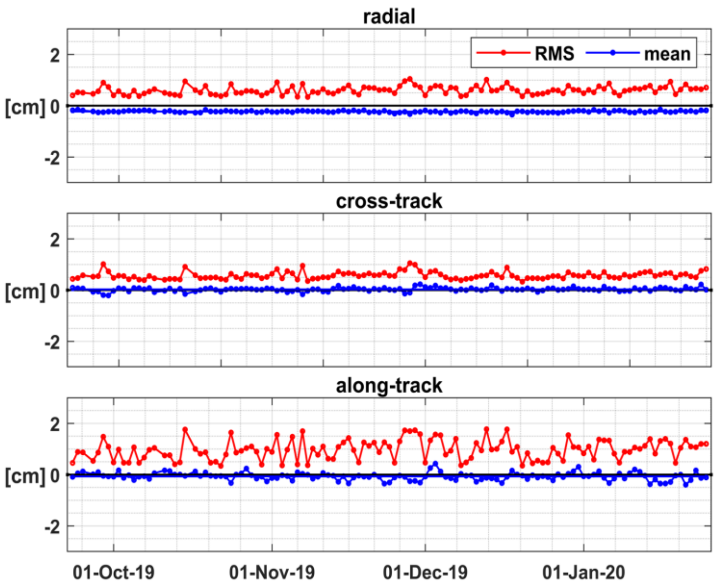

Figure 31. Sentinel-3B orbits based on GPS observations only vs. the Copernicus COMB solution

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16.DGFI-TUM ASSOCIATE ANALYSIS CENTER

Sergei Rudenko, Mathis Bloßfeld and Julian Zeitlhöfler / Deutsches Geodätisches Forschungsinstitut der Technischen Universität München (DGFI-TUM)

16.1. DORIS DATA ANALYSIS

Precise orbits of altimetry satellites are a prerequisite for the investigation of global, regional and coastal sea levels together with their changes since an accurate orbit information is required for the reliable determination of the water surface height (distance between the altimeter position in space and the water surface). In 2018, the Deutsches Geodätisches Forschungsinstitut der Technischen Universität München (DGFI-TUM) started to extend its Satellite Laser Ranging (SLR) analysis software DOGS-OC ("DGFI Orbit and Geodetic parameter estimation Software – Orbit Computation") to also analyse DORIS data in the IDS 2.2 format. In particular, satellite-specific information such as the satellite mass and its center of mass, the macro-models of the non-spherical satellites Jason-1, Jason-2, Jason-3, and TOPEX/Poseidon were implemented according to Cerri et al. (2019). The implementation was done within a collaboration of DGFI-TUM with the NASA Goddard Space Flight Center, Greenbelt, USA. Moreover, the ability to estimate corrections for the wet part of the tropospheric zenith delay, the estimation of pass-wise frequency biases, and the modelling of station-dependent phase center offsets in the measurement direction were implemented in DOGS-OC. To reach better orbit quality, processing of observation-based attitude data in the quaternion form for satellite main body and solar panel angles was implemented and tested in 2019 (see **Section 2** and Bloßfeld et al., 2020).

The following DORIS-specific measurement corrections have been implemented in DOGS-OC:

- center of mass correction of the instrument at the satellite,
- phase center correction of the receiver (satellite),
- phase center correction of the emitter (beacon),
- tropospheric refraction (different models available),
- relativistic correction (according to model of Moyer),
- frequency bias and frequency drift,
- IDS phase law (at the beacon).

As it is realized for SLR, DOGS-OC also allows for DORIS to compute partial derivatives of the theoretical observation with respect to the included free parameters, i.e. dynamic parameters (such as initial state vector, gravity field coefficients, empirical accelerations), center of mass correction, pole coordinates, time parameter UT1, station parameters (coordinates and velocities), station frequency biases, tropospheric (wet) scaling factors, etc.

In 2020, macro-models and other satellite-specific information for Jason-1 and Jason-2 were updated within the DOGS-OC software. In addition, the metadata of TOPEX/Poseidon was implemented and initial state vectors for this satellite were computed. Within the software, the modelling of the satellite attitude and its solar arrays was updated and homogenized among all satellites.

Orbits of altimetry satellites are derived at DGFI-TUM using SLR and DORIS measurements. Up to now, both techniques are analysed separately at DGFI-TUM although in future a combined orbit product is envisaged. In 2019-2020, in the framework of an extensive DORIS reprocessing of all implemented altimetry missions, precise orbits for TOPEX/Poseidon, Jason-1, Jason-2 were computed at the time intervals from 28 January 1996 to 31 October 2004 for TOPEX/Poseidon, from 13 January 2002 to 30 June 2013 for Jason-1 and from 20 July 2008 to 11 September 2019 for Jason-2. Orbits were computed based on DORIS 2 GHz measurements in the IDS 2.2 format available from IDS. The orbit length is 3.5-days except arcs which are affected by orbit manoeuvres, safe hold mode effects and measurement gaps. The force models and the background models used for the computation of station coordinates are described in Bloßfeld et al. (2020). The information about the DORIS phase center coordinates and the satellite macro-model is used according to Cerri et al. (2019). For the DORIS solutions, the list of estimated parameters includes:

- Keplerian elements (once per arc),
- solar radiation scaling factor (once per arc),
- Earth albedo and infrared radiation scaling factor (once per arc),
- atmospheric drag scaling factor (every 12 hours),
- empirical acceleration in the cross-track and along-track directions (every 12 hours),
- and DORIS station beacon frequency bias (once per station path).

In order to assess the reliability of the estimated parameters, several tests using different a-priori standard deviations of dynamical parameters were performed. Since dynamical parameters like, e.g., solar and Earth albedo/infrared scaling factors, thermospheric drag scaling factors or empirical accelerations directly affect the satellite orbit, they are highly correlated and need to be constrained. By increasing these constraints, the scatter of all dynamical parameters was reduced, but, at the same time, a small increase of RMS fits of DORIS measurements of the new (RUN004) Jason-1/-2 orbits with respect to solutions computed in 2019 was observed.

Figure 32 provides RMS fits of DORIS measurements for TOPEX/Poseidon, Jason-1 and Jason-2 at the time spans used for each satellite. The mean values of the RMS fits of these measurements are 0.752 mm/s for TOPEX/Poseidon, 0.515 mm/s for Jason-1 and 0.497 mm/s for Jason-2. A drop in the RMS fits of DORIS measurements for Jason-1 in 2008 is due to a change in the procedure of generating of DORIS measurements in the IDS 2.2 format.

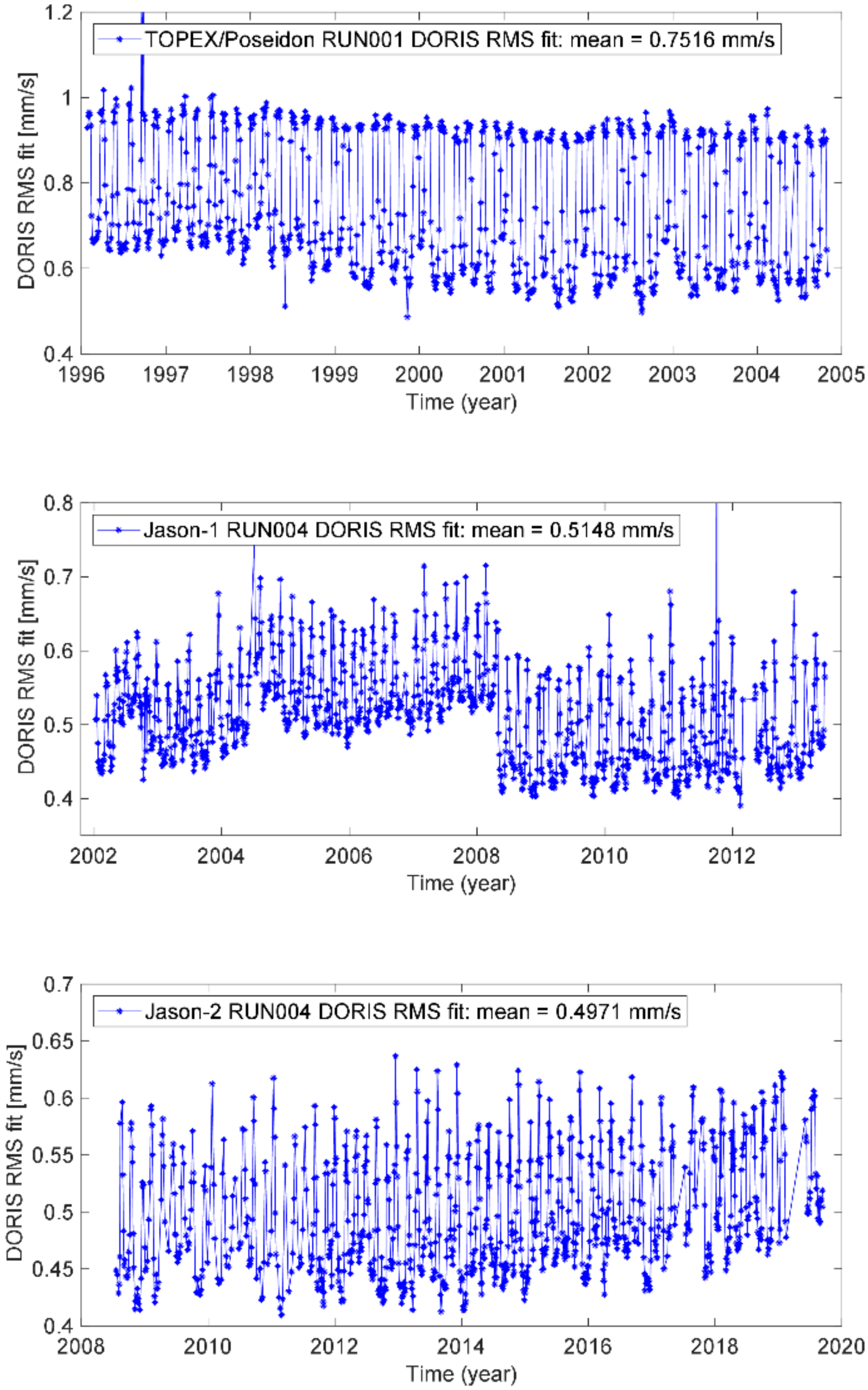

Figure 32. RMS values of the DORIS observation fits obtained for TOPEX/Poseidon, Jason-1 and Jason-2.

16.2. OBSERVATION-BASED ATTITUDE REALIZATION FOR JASON SATELLITES

The altimetry satellites Jason-1, Jason-2 and Jason-3 have been providing continuous, precise measurements of the global and regional sea level since December 2001. These satellites have a non-spherical, complex shape comprising two solar panel arrays and the main satellite body on which numerous measurement and positioning instruments are mounted. Precise investigation of the sea level and its trend requires computation of satellite positions at cm and even sub-cm level. Therefore, both gravitational and non-gravitational perturbations should be computed with high accuracy. Since the non-gravitational forces such as atmospheric drag, solar radiation pressure and Earth albedo depend on the satellite's effective cross-sectional area and the incidence angle of the perturbing force, satellite precise orientation in space is important. Additionally, the correct vector between the reference point of the tracking station and the spacecraft's center of mass (the resulting orbit) is required. This vector depends on the position of the reference point of the tracking system mounted on the spacecraft which continuously changes its orientation towards the tracking station. Both conditions require an accurate modelling of the satellite-body attitude and the solar panel orientation that is important during the precise orbit determination (POD).

For these satellites, attitude information is available in two forms: the satellite attitude can be modelled by a nominal yaw steering algorithm or be represented by measured attitude information (derived from star tracking camera observations), for example, in the quaternion form, and rotations angles of the solar arrays. The nominal yaw steering model consists of four regimes: sinusoidal and fixed yaw and the events ramp-up/ramp-down and yaw flip (see **Figure 33**).

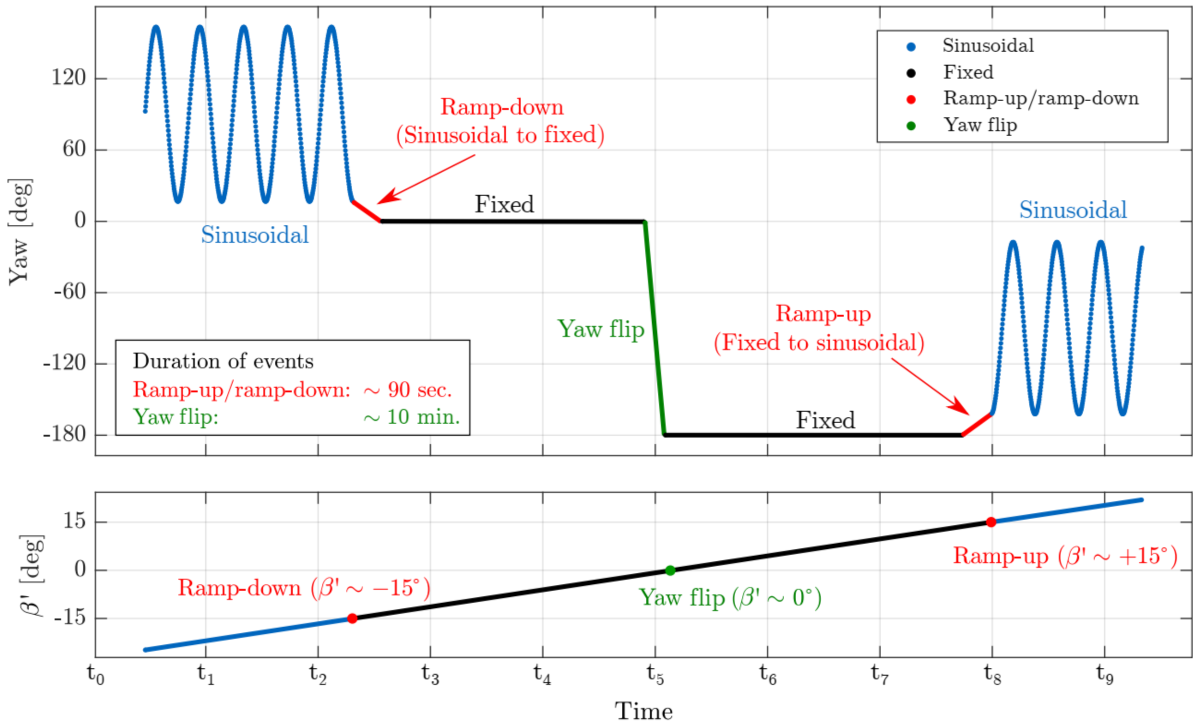

Figure 33. Principle of the nominal yaw steering model of Jason satellites (top) depending on the angle β' (bottom).

We have developed a preprocessing algorithm for publicly available satellite attitude information (attitude quaternions and solar panel rotation angles). This algorithm comprises a detailed analysis of the data, the detection and elimination of outliers, a temporal resampling of the data and the optimal interpolation of missing data. To accurately model the satellite attitude, a set of six parameters – four quaternion elements and two rotations angles – has to be given at each epoch. This requirement is not automatically given at each epoch of the original data. Thus, missing rotation angles are obtained by linear interpolation and the optimal spherical linear interpolation is used to calculate missing quaternions. Further information about the attitude preprocessing is available in Zeitlhöfler (2019).
Based on the analysis of SLR-only orbits of Jason satellites at an overall time interval of approximately 25 years, the influence of using preprocessed observation-based attitude in contrast to a nominal yaw steering model for the POD of these satellites has been investigated by Bloßfeld et al. (2020). It has been found that using preprocessed observation-based attitude reduces (improves) RMS of SLR observation residuals by 5.9%, 8.3% and 4.5% for Jason-1, Jason-2 and Jason-3, respectively. Parameters, which are estimated within the orbit computation, e.g. the solar radiation scaling coefficient and empirical accelerations, are closer to the intended values at orbits with the observed attitude. Furthermore, the station coordinate repeatability clearly improves at the draconitic period. The altimetry analysis indicates a clear improvement of the single-satellite crossover differences (6%, 15% and 16% reduction of the mean of absolute differences and 1.2%, 2.7% and 1.3% of their standard deviations for Jason-1, Jason-2, and Jason-3 (see **Figure 34**), respectively, when using observation-based satellite attitude). The observation-based preprocessed attitude data of Jason satellites can be made available by DGFI-TUM on request.

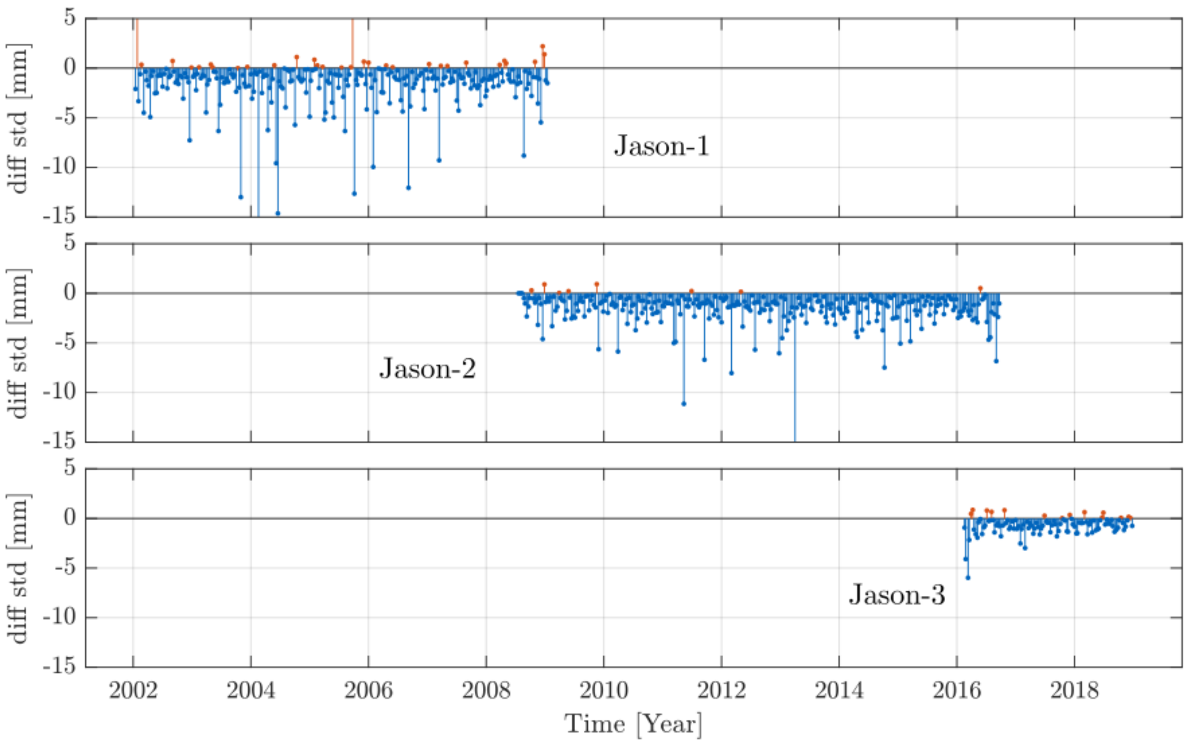

Figure 34. Single-satellite crossover differences (standard deviations per 10-day cycle) for the nominal orbit phases of the three Jason missions. Differences between the solutions using quaternion-based orbits and nominal orbits are shown. Negative differences mean improvements due to the observation-based attitude modelling (from Bloßfeld et al., 2020).

16.3. CONCLUSIONS AND OUTLOOK

Some results on the analysis of SLR and DORIS observations of Jason-1, Jason-2 and Jason-3 were presented at the IDS Analysis Working Group Meeting in Munich, Germany on 4 April 2019 and Ocean Surface Topography Science Team (OSTST) Meeting 2019 in Chicago, Illinois (USA) on 22 October 2019. DGFI-TUM was a host of the IDS Analysis Working Group Meeting held on 4 April 2019. In October 2019, the Governing Board of the IDS accepted DGFI-TUM as an Associate Analysis Centre (AAS) of the IDS. The IDS AAS at DGFI-TUM plans to include new DORIS satellites, further elaborate DORIS data processing and provide some of its products to IDS.

16.4. PRESENTATIONS

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17.TU DELFT ASSOCIATE ANALYSIS CENTER

Ernst J.O. Schrama, Section of Astrodynamics and Space missions, Faculty of Aerospace Engineering at the Delft University of Technology

17.1. INTRODUCTION

In the reporting period we focused on CryoSat-2 precision orbit determination based on the method described in our paper published in Advances in Space Research [1]. Currently we look at the transition of GRACE to GRACE follow-on and the strategy for optimally handling temporal gravity modelling in the transition phase between both space gravimetry missions. A second aspect is the infrastructure, the covid pandemic has affected all progress but there are running contracts for instance with ESA and on education that simply have priority. It turns out that some activities like education are more difficult to manage when you can only work from home, or in a limited way from the university.

17.2. TEMPORAL GRAVITY

A significant update that we applied during the POD of CryoSat-2 concerns an extension of the a-priori temporal gravity model (TVG model). Monthly gravity field variations as obtained from the GRACE mission have been used in Schrama (2017) before the GRACE mission came to the end of its lifetime in Oct 2017. Since GRACE there is approximately a 1,5 year transition gap to GRACE follow-on which was launched in late 2018 while the first monthly solutions became available in 2019.

GRACE-FO is somewhat noisier than GRACE due to an accelerometer failure on one of the spacecrafts and temporal gravity that is seen by CS2 is modelled partially by the AOD1B model which contains the atmospheric and oceanic signals. The interruption between both gravity missions means that you need an approximation method which only concerns temporal gravity signal caused by the cryosphere and terrestrial water storage. The objective is to study the consequences of the GRACE to GRACE-FO transition which left an approximately 1,5 year gap in the monthly gravity field set, so this is a period where we could not directly observe mass changes in the cryosphere and terrestrial hydrology and have chosen to rely on model based approximations.

The TVG model maximum degree and order is 60 and its source comes from the Center of Space Research (CSR) release 6 GSM solutions. In order to be able to apply the information contained in the GSM coefficients from GRACE and GRACE-FO during POD we approximate the spherical harmonics contained in the GSM coefficients of GRACE and GRACE-FO and we evaluate criteria to find an optimal approximation that can be used for precision orbit determination of the CryoSat-2 mission.

We have re-processed all CryoSat-2 orbits between June-2010 and April-2021 where several versions of the orbits are based on different TVG models. Without going into details we looked at the consequences for SLR and DORIS residuals, and the magnitude of the empirical accelerations that are solved. Our conclusions are that well chosen TVG patch models based on a sliding window approach over the GRACE and GRACE-follow-on data can be successful during POD. The evaluation criteria are based on empirical accelerations, but also the laser and the Doppler residuals that we obtain from the POD procedure. Preliminary results were presented at the AGU fall meeting in San Francisco in 2019, and currently we are working on a paper to document the results in more detail.

17.3. MAINTENANCE OF INFRASTRUCTURE

Retrieval procedures for EOP and flux data that we need for POD requires access to public archives maintained for instance by the CDDIS, the IGN and the GFZ. Since the start of 2020 FTP access has stopped to several services and this required us to review data retrieval procedures and protocols. Our own quaternion archive of CS2 is has been operational during the pandemic, albeit that we had to switch from server within the campus due to hardware failure. We are currently involved in a discussion with ESA ESRIN to investigate the consistency between a new ESA quaternion product for CS2 and our quaternion archive. In the future the user may expect improvements in the accuracy of the satellite quaternions which is mostly relevant for precision applications of CS2 interferometric SAR data.

17.4. REFERENCES

Ernst Schrama (2017) Precision orbit determination performance for CryoSat-2, Advances in Space Research, Volume 61, Issue 1, 1 Jan 2018, pp. 235-247 doi: 10.1016/j.asr.2017.11.001

18.WORKING GROUP "NRT DORIS DATA"

Denise Dettmering / DGFI-TUM, Germany

Following user requests for rapid dissemination of DORIS data for assimilation in ionospheric models, the IDS Governing Board created a Working Group (WG) dealing with near real-time (NRT) DORIS data, on November 1st, 2017, and appointed Denise Dettmering (DGFI-TUM) as chair.

The general objective of this working group is a thorough assessment on benefits, requirements, and prospects of DORIS data with improved data latency with a focus on applications in ionospheric research.

The main topics addressed by the WG are:

- Development of a DORIS ionospheric product (STEC/VTEC or dSTEC/dVTEC),
- Using DORIS data for global real-time ionospheric modeling,
- Using DORIS data to validate the performance of global ionospheric TEC models,
- Improving ionospheric modelling with focus on the combination of different space-based observation datasets,
- Networking with other IAG working groups: GGOS JWG 3 “Improved understanding of space weather events and their monitoring by satellite missions” and IAG JWG 4.3.1 “Real-time ionosphere monitoring and modelling”.

At the end of 2020, the ongoing activities are:

- Simulated DORIS NRT test data set (RINEX and sp3) currently under investigation,
- Software preparation to use the data.

The WG did not meet in 2020.

APPENDIX

19.IDS AND DORIS QUICK REFERENCE LIST

1. **IDS website**
   https://ids-doris.org/

2. **Contacts**
   Central Bureau ids.central.bureau@ids-doris.org
   Governing Board ids.governing.board@ids-doris.org

3. **Data Centers**
   CDDIS: ftp://cddis.gsfc.nasa.gov/doris/
   IGN: ftp://doris.ensg.eu and ftp://doris.ign.fr

4. **Tables of Data and Products**
   https://ids-doris.org/ids/data-products/tables-of-data-products.html

5. **IDS web service**
   https://ids-doris.org/webservice
   DOR-O-T for DORis Online Tools (pronounced in French like the given name Dorothée) is the IDS web service developed to promote the use of the DORIS products. The current version of the service provides tools to browse time series in an interactive and intuitive way, and a network viewer.

6. **Citation**
   The following article is suggested for citation in papers and presentations that rely on DORIS data and results:

   Willis, P.; Lemoine, F.G.; Moreaux, G.; Soudarin, L.; Ferrage, P.; Ries, J.; Otten, M.; Saunier, J.; Noll, C.; Biancale, R.; Luzum, B., 2016. The International DORIS Service (IDS), recent developments in preparation for ITRF2013, IAG SYMPOSIA SERIES, 143, 631-639, DOI: 10.1007/1345_2015_164

7. **DORISmail**
   The DORIS mail service is used to send information of general interest to the DORIS community. To send a DORISMail, use the following address: dorismail@ids-doris.org

8. **List of the documentation**
   It gives a table compiling links to the various pages providing documents, grouped in four categories: DORIS system components; IDS information system; Publications, presentations; Documents
   https://ids-doris.org/ids/reports-mails/documentation.html

9. **List of presentations given at DORIS or IDS meetings**
   Full list of presentations given at DORIS or IDS meetings with the corresponding access links
   https://ids-doris.org/ids/reports-mails/meeting-presentations.html

10. **List of documents and links to discover the DORIS system**
    https://ids-doris.org/analysis-coordination/documents-related-to-data-analysis.html

11. **List of DORIS publications in international peer-reviewed journals**
    https://ids-doris.org/ids/reports-mails/doris-bibliography/peer-reviewed-journals.html

12. **Overview of the DORIS system**
    https://www.aviso.altimetry.fr/en/techniques/doris.html

13. **Overview of the DORIS satellite constellation**
    https://ids-doris.org/doris-system/satellites.html

14. **Site logs**
    DORIS stations description forms and pictures from the DORIS installation and maintenance department: https://ids-doris.org/doris-system/tracking-network/site-logs.html

15. **Virtual tour of the DORIS network with Google Earth**
    Download the file at https://ids-doris.org/doris-system/tracking-network/network-on-google-earth.html and visit the DORIS sites all around the world.

16. **IDS video channel**
    Videos of the DORIS-equipped satellites in orbit
    https://www.youtube.com/channel/UCiz6QkabRioCP6uEjkKtMKg

17. **IDS Newsletters**
    Find all the issues published in color with live links on the IDS website
    https://ids-doris.org/ids/reports-mails/newsletter.html

18. **Photo Gallery**
    https://ids-doris.org/ids/gallery.html

19. **More contacts**
    For particular requests, you may also contact the following persons:

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E-mail: jerome.saunier@ign.fr

20.IDS INFORMATION SYSTEM

20.1. WHAT AND WHERE

IDS has three data/information centers:

- CB: the Central Bureau web and ftp sites at CLS
- DC: the Data Center(s): * CDDIS: web and ftp sites * IGN: ftp sites
- AC: the Analysis Coordination webpages on the CB web site

The baseline storage rules are as follows:

- CB produces/stores/maintains basic information on the DORIS system, including various standard models (satellites, receivers, signal, reference frames, etc).
- DC store observational data, products, and ancillary information required for the use of these data and products + formats and analysis descriptions.
- AC refers to CB and DC information on the data and modeling, and generates/stores analyses of the products.

Two criteria are considered for deciding where files are stored/maintained:

1. the responsibility for their content and update,
2. the ease of user access.

To avoid information inconsistencies, duplication is minimized. Logical links and cross referencing between the three types of information centers are systematically used.
Products are deposited in ad hoc DCs areas. The analysis centers need to have an account at both DCs.

A description of the data structure and formats is available at:
https://ids-doris.org/ids/data-products/data-structure-and-formats.html

20.2. WEB AND FTP SITES

20.2.1. IDS WEB SITE

address: https://ids-doris.org (or https://www.ids-doris.org)

The IDS web site gives general information on the Service, provides access to the DORIS system pages on the AVISO web site, and hosts the Analysis Coordination pages.

It is composed of four parts:

- “IDS” describes the organization of the service and includes documents, access to the data and products, event announcements, contacts and links.
- “DORIS System” allows to access general description of the system, and gives information about the system monitoring and the tracking network.
- “Analysis Coordination” provides information and discussion areas about the analysis strategies and models used in the IDS products. It is maintained by the Analysis Coordinator with the support of the Central Bureau.

- "Web service" gives access to DOR-O-T, the IDS Web service that proposes a family of plot tools to visualize time series of DORIS-related products and a network viewer to select sites.

It is supplemented by a site map, a glossary, FAQs, a history of site updates, news on the IDS and news on DORIS.

The main headings of the “IDS” parts are:

- Organization: structure of the service, terms of reference, components
- Data & Products: tables of data and products, information and data center organization, data structure and formats, access information to the IDS Data Centers and to the Central Bureau ftp site.
- Documentation: synthetic table of the documentation available, newsletters, documents of the IDS components, DORIS bibliography including DORIS-related peer-reviewed publications and citation rules, meeting presentations, mail system messages, etc.
- Meetings: calendars of the meetings organized by IDS or relevant for IDS, as well as links to calendars of other international services and organizations.
- Contacts and links: IDS contacts, directory, list of websites related to IDS activities
- Gallery: photo albums for the DORIS stations (local teams, equipment, obstruction views) and IDS meetings.

The headings of the “DORIS system” part re:

- The DORIS technique (a link to the official DORIS website): a description of the DORIS system on the AVISO web site.
- Tracking network: Site logs, station coordinate time series, maps, network on Google Earth, station management.
- Satellites: information on the DORIS missions.
- System monitoring: table of events that occurred on the DORIS space segment and ground segment, classified into 4 categories ("Station", "System", "Earthquake", "Data"), station performance plots from the CNES MOE and POE processings.

The headings of the “Analysis Coordination” part are:

- Presentation: a brief description of this section
- Combination Center: information about the activity and products, cumulative solution, DPOD, contributions to ITRF2008, ITRF2014 (list of standards used by IDS Analysis Centers) and next ITRF2020
- Documents for the data analysis: about the DORIS system’s components (space segment, ground segment, stations, observations), the models used for the analysis, the products and their availability.
- About DORIS/RINEX format: all the material related to the DORIS/RINEX gathered on one page.
- DORIS related events: history of the workshops, meetings, analysis campaigns...
- Discussion: archive of the discussions before the opening of the forum.

DORIS and IDS news as well as site updates are accessible from the Home page. Important news is displayed in the box “Highlights”. The lists of news about the DORIS system and IDS activities (also widely distributed through the DORISmails) are resumed respectively in the two headings “What’s new on DORIS” (https://ids-doris.org/doris-news.html) and “What’s new on IDS” (https://ids-doris.org/ids-news.html). The history of the updates of the website is given in “Site updates” (https://ids-doris.org/site-updates.html).

The IDS web site is maintained by the Central Bureau.

20.2.2. IDS WEB SERVICE

address: https://ids-doris.org/webservice (or https://apps.ids-doris.org/apps/)

DOR-O-T for DORis Online Tools (pronounced in French like the given name Dorothée) is the IDS web service developed to promote the use of DORIS products. The current version of the service provides tools to browse time series in an interactive and intuitive way. Besides products provided by the CNES Orbitography Team and the IDS components (Analysis Centers and Combination Center), this service allows comparing time evolutions of coordinates for DORIS and GNSS stations in co-location, thanks to a collaboration with the IGS Terrestrial Frame Combination Center.

The tools proposed by this web service are:

- a NETWORK VIEWER to select sites
- a family of PLOT TOOLS to visualize the following time series:
    - **Station position** differences at observation epochs relative to a reference position: North, East and Up trended time series.
    - **Orbit residuals** and amount of station measurements from CNES Precise Orbit Ephemeris processing: RMS of post-fit orbit residuals, total and validated number of DORIS measurements per arc.
    - **Combination parameters** i.e. outputs of the IDS Combination Center analysis: WRMS of station position residuals, scale and translation parameters, number of stations used in the analysis.
    - **Earth Orientation Parameters** from the IDS Combination Center analysis (Xp, Yp, LOD).
    - **Position residuals** of the cumulative solution from the IDS Combination Center analysis (North, East, Up)

20.2.3. IDS FTP SERVER

address: ftp://ftp.ids-doris.org/pub/ids

The IDS ftp server gives information on the DORIS system, and provides analysis results from the Analysis Coordination's combination center.

The main directories are :

- ancillary: documents about the DORIS ancillary data *(such as bus quaternions and solar panel angles of Jason-1 and Jason-2)*
- centers: documents for the analysis centers
- combination_center: products and reports of the combination center
- combinations: working directory of the combination center
- data: documents about the DORIS data *(format description 1.0, 2.1, 2.2, and RINEX, POE configurations for GDRB, GDRC, …)*
- dorismail: archive of the mails of DORISmail mailing list
- dorisreport: archive of the mails of DORISreport mailing list
- dorisstations: archive of the mails of DORISstations mailing list
- events: lists of events occurring on the DORIS system

- ids.analysis.forum: archive of the mails of ids.analysis.forum mailing list
- products: format descriptions of the products *(eop, geoc, iono, snx, sp1, sp3, stcd)*
- satellites: documents and data related to the satellites *(macromodels, nominal attitude model, center of mass and center of gravity history, maneuver history, instrument modelling, corrective model of DORIS/Jason-1 USO frequency, …)*
- stations: documents and data related to the stations *(sitelogs, ties, antennas phase laws, …)*

The contain is described in the document "IDS data structure and formats" (https://ids-doris.org/ids/data-products/data-structure-and-formats.html).

The IDS ftp site is maintained by the Central Bureau. There is a mirror site at CDDIS: ftp://cddis.gsfc.nasa.gov/pub/doris/cb_mirror/ and at IGN: ftp://doris.ensg.eu/pub/doris/cb_mirror/

20.2.4. DORIS WEB SITE

Address: https://www.aviso.altimetry.fr/en/techniques/doris.html

The official DORIS web site is hosted by the Aviso website which is dedicated to altimetry, orbitography and precise location missions. The DORIS pages present the principle of the system, its description (instruments onboard, ground beacons, control and processing center, system evolutions, Diode navigator), the applications and the missions. The site is maintained by the Aviso webmaster with the support of the IDS Central Bureau.

20.2.5. DATA CENTERS' FTP AND WEB SITES

Data and products, formats and analysis descriptions are stored at the CDDIS and IGN Data Centers. A detailed description is given in the report of the Data flow Coordinator.

The contain stored on the ftp sites is also described in the document "IDS data structure and formats" (https://ids-doris.org/ids/data-products/data-structure-and-formats.html).

Address of the CDDIS web site:
https://cddis.nasa.gov/Data_and_Derived_Products/DORIS/DORIS_data_and_product_archive.html
Address of the CDDIS ftp site: ftp://cddis.gsfc.nasa.gov/pub/doris/
Address of the IGN ftp site: ftp://doris.ensg.eu/pub/doris/ (or ftp://doris.ign.fr/pub/doris/)

20.3. THE MAIL SYSTEM

The mail system of the IDS is one of its main communication tools. Depending on the kind of the information, mails are distributed through the DORISmail, DORISreport or DORISstations. The mails of these four lists are all archived on the mailing list server of CLS. Back-up archives of the text files are also available on the Central Bureau ftp server for the DORISmails and the DORISreports.

A description of the mailing lists can be found on the IDS web site on the page: http://ids-doris.org/report/mails.html

Dedicated mailing lists were also created for the Central Bureau, the Governing Board and the Analysis Working Group, but without archive system.

20.3.1. DORISMAIL

e-mail: dorismail@ids-doris.org

The DORISmails are used to distribute messages of general interest to the users' community (subscribers). The messages concern:

- Network evolution: installation, renovation…
- Data delivery: lack of data, maneuver files
- Satellite status
- Status of the Data Centers
- Meeting announcements
- Calls for participation
- Delivery by Analysis Centers
- etc…

The messages are moderated by the Central Bureau.

They are all archived on the mailing list server of CLS at the following address:
http://lists.ids-doris.org/sympa/arc/dorismail

They are also available in text format on the IDS ftp site: ftp://ftp.ids-doris.org/pub/ids/dorismail/

20.3.2. DORISREPORT

e-mail : dorisreport@ids-doris.org

This list is used for regular reports from Analysis Centers, from the Analysis coordination and from the CNES POD team. The DORISReport distribution list is composed by Analysis Centers, Data Centers, IDS Governing Board and Central Bureau, CNES POD people delivering data to the Data Centers (subscribers).

They are all archived on the mailing list server of CLS at the following address:
http://lists.ids-doris.org/sympa/arc/dorisreport

They are also available in text format on the IDS ftp site: ftp://ftp.ids-doris.org/pub/ids/dorisreport/

The list is moderated by the Central Bureau and the CNES POD staff.

20.3.3. DORISSTATIONS

e-mail : dorisstations@ids-doris.org

This mailing list has been opened to distribute information about station events (data gap, positioning discontinuities).

The messages are archived on the mailing list server of CLS at the following address:

http://lists.ids-doris.org/sympa/arc/dorisstations.

They are also available in text format on the IDS ftp site: ftp://ftp.ids-doris.org/pub/ids/dorisstations/

The archive contains also the mails distributed on the analysis forum before the creation of the dedicated list.

20.3.4. OTHER MAILING LISTS

ids.central.bureau@ids-doris.org: list of the Central Bureau

ids.governing.board@ids-doris.org: list of the Governing Board

ids.cbgb@ids-doris.org: private common list for the Central Bureau and the Governing Board.

ids.awg@ids-doris.org: list of people who attend the AWG, and/or analysis center representatives.

ids.analysis.coordination@ids-doris.org: list of the Analysis Coordination

20.4. HELP TO THE USERS

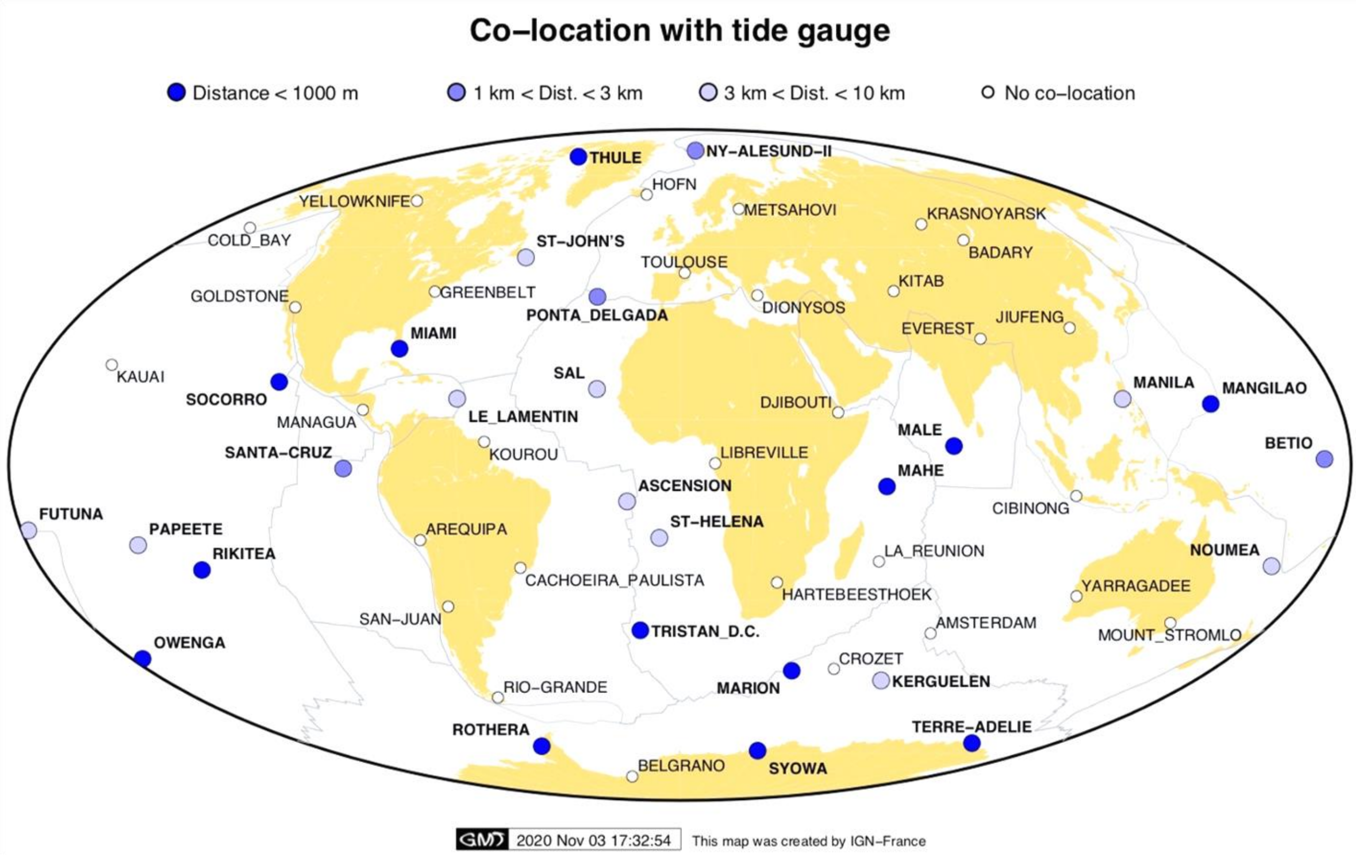
e-mail : ids.central.bureau@ids-doris.org

The contact point for every information requirement is the Central Bureau. It will find a solution to respond to user’s need. A list of contact points has been defined for internal use depending on the kind of questions.

21.DORIS STATIONS / CO-LOCATION WITH TIDE GAUGES

The table and the figure below are managed by IGN and the University of La Rochelle within the framework of their collaboration on « Système d'Observation du Niveau des Eaux Littorales » (SONEL, http://www.sonel.org).

DORIS Name	Long	Lat	Country	Start date	Distance (m)	GLOSS Id	PSMSL Id
ASCENSION	-14.33	-7.92	UK (SOUTH ATLANTIC)	28/02/1997	6500	263	1831
BETIO	172.92	1.35	KIRIBATI	22/10/2006	1600	113	1804
FUTUNA	-178.12	-14.31	FRANCE (POLYNESIA)	18/10/2011	4400	353	2244
KERGUELEN	70.26	-49.35	FRANCE (TAAF)	05/04/1993	3300	23	1849
LE LAMENTIN	-61.00	14.60	FRANCE (MARTINIQUE)	29/06/2013	7000	338	1942
MAHE	55.53	-4.68	SEYCHELLES	20/06/2001	300	339	1846
MALE	73.53	4.20	MALDIVES	15/01/2005	500	28	1753
MANILA	121.03	14.53	PHILIPPINES	26/02/2003	9700	73	145
MANGILAO	144.80	13.43	USA (GUAM IS.)	12/04/2018	830	------	2130
MARION ISLAND	37.86	-46.88	SOUTH AFRICA	01/01/1990	410	20	------
MIAMI	-80.17	25.73	USA (FLORIDA)	10/02/2005	180	332	1858
NOUMEA	166.42	-22.24	FRANCE (CALEDONIA)	27/01/2005	7000	123	2134
NY-ALESUND II	11.83	78.93	NORWAY (SVALBARD)	19/10/2018	2500	345	1421
OWENGA	-176.37	-44.02	NEW ZEALAND (CHATHAM IS.)	20/01/2014	80	------	------
PAPEETE	-149.61	-17.58	FRANCE (POLYNESIA)	27/07/1995	7000	140	1397
PONTA DELGADA	-25.66	37.75	PORTUGAL (AZORES)	02/11/1998	1500	245	258
REYKJAVIK	-21.99	64.15	ICELAND	04/07/1990	1570	229	638
RIKITEA	-134.97	-23.13	FRANCE (POLYNESIA)	23/09/2006	800	138	1253
ROTHERA	-68.13	-67.57	UK (ANTARCTICA)	01/03/2003	170	342	1931
SAL	-22.98	16.78	CAPE VERDE	15/12/2002	5700	329	1914
SANTA CRUZ	-90.30	-0.75	ECUADOR	01/04/2005	1600	------	1472
SOCORRO	-110.95	18.73	MEXICO	09/06/1989	400	162	1821
ST-HELENA	-5.67	-15.94	UK (SOUTH ATLANTIC)	01/06/1989	5900	264	1845
ST. JOHN'S	-52.68	47.40	CANADA (TERRE-NEUVE)	27/09/1999	3600	223	393
SYOWA	39.58	-69.01	JAPAN (ANTARCTICA)	10/02/1993	1000	95	1396
TERRE ADELIE	140.00	-66.67	FRANCE (ANTARCTICA)	01/02/1997	500	131	2231
THULE	-68.83	76.54	DENMARK (GREENLAND)	28/09/2002	450	------	------
TRISTAN DA CUNHA	-12.31	-37.07	UK (SOUTH ATLANTIC)	10/06/1986	120	266	------


Co–location with tide gauge
Distance < 1000 m
1 km < Dist. < 3 km
3 km < Dist. < 10 km
No co–location
THULE
NY–ALESUND–II
HOFN
YELLOWKNIFE
METSAHOVI
KRASNOYARSK
COLD_BAY
ST–JOHN'S
BADARY
TOULOUSE
GOLDSTONE
GREENBELT
KITAB
PONTA_DELGADA
DIONYSOS
JIUFENG
MIAMI
EVEREST
KAUAI
SAL
MANILA
MANGILAO
SOCORRO
DJIBOUTI
LE_LAMENTIN
MANAGUA
MALE
BETIO
SANTA–CRUZ
KOUROU
LIBREVILLE
MAHE
ASCENSION
CIBINONG
FUTUNA
PAPEETE
AREQUIPA
ST–HELENA
RIKITEA
LA_REUNION
NOUMEA
CACHOEIRA_PAULISTA
HARTEBEESTHOEK
YARRAGADEE
SAN–JUAN
AMSTERDAM
OWENGA
TRISTAN_D.C.
MOUNT_STROMLO
CROZET
MARION
RIO–GRANDE
KERGUELEN
ROTHERA
TERRE–ADELIE
BELGRANO
SYOWA
2020 Nov 03 17:32:54
This map was created by IGN–France

22.DORIS STATIONS / HOST AGENCIES

The local teams that take care of the DORIS stations contribute in large part with skill and efficiency to the high quality of the DORIS network improving continuously its robustness and reliability.

The following table gives the list of the organizations involved as host agencies of the DORIS stations.

Station name	Host agency	Location, Country
Amsterdam	Institut Polaire Paul Emile Victor (IPEV)	Base Martin-de-Viviès, île Amsterdam, Sub-Antarctica, FRANCE
Arequipa	Instituto Astronómico y Aeroespacial P. Paulet	Observatorio de Characato, Arequipa, PERU
Ascension	ESA Telemetry & Tracking Station	Ascension Island, South Atlantic Ocean, UK
Badary	Badary Radio Astronomical Observatory (BdRAO, Institute of Applied Astronomy)	Republic of Buryatia, RUSSIA
Belgrano	Instituto Antártico Argentino (DNA)	Base Antártica Belgrano, ARGENTINA
Betio	Kiribati Meteorological Service	Tarawa Island, Republic of KIRIBATI
Cachoeira Paulista	Instituto Nacional de Pesquisas Espaciais (INPE)	Cachoeira Paulista, BRAZIL
Cibinong	Badan Informasi Geospatial (BIG)	Cibinong, INDONESIA
Cold Bay	National Weather Service (NOAA)	Cold Bay, Alaska, U.S.A.
Crozet	Institut Polaire Paul Emile Victor (IPEV)	Base Alfred Faure, archipel de Crozet, Sub-Antarctica, FRANCE
Dionysos	National Technical University Of Athens (NTUA)	Dionysos Satellite Observatory, GREECE
Djibouti	Observatoire Géophysique d'Arta (CERD)	Arta, Republic of DJIBOUTI
Everest	Ev-K2-CNR Association	Pyramid International Laboratory-Observatory, Mount Everest, ITALY
Futuna	Météo-France	Malae, Wallis-et-Futuna, FRANCE
Goldstone	NASA / GDSCC	Fort Irwin, California, U.S.A.
Grasse	Observatoire de la Côte d'Azur (OCA)	Plateau de Calern, FRANCE
Greenbelt	NASA / GSFC / GGAO	Greenbelt, Maryland, U.S.A.
Hartebeesthoek	HartRAO, South African National Space Agency (SANSA)	Hartebeesthoek, SOUTH AFRICA
Höfn	National Land Survey of Iceland Landmælingar Islands (LMI)	Höfn, ICELAND

Station name	Host agency	Location, Country
Jiufeng	Innovation Academy for Precision Measurement Science and Technology	Jiufeng Mountain, Wuhan, CHINA
Kauai	Kokee Park Geophysical Observatory (KPGO)	Kauai Island, Hawaï, U.S.A.
Kerguelen	Institut Polaire Paul Emile Victor (IPEV)	Base de Port-aux-Français, archipel de Kerguelen, Sub-Antarctica, FRANCE
Kitab	Ulugh Beg Astronomical Institute (UBAI)	Kitab Observatory, UZBEKISTAN
Kourou	Centre Spatial Guyanais (CSG)	Kourou, FRENCH GUYANA
Krasnoyarsk	Siberian Federal University (SibFU)	Krasnoyarsk, RUSSIA
La Réunion	Observatoire Volcanologique du Piton de La Fournaise (IPGP)	Ile de la Réunion, FRANCE
Le Lamentin	Météo-France	Martinique, French West Indies, FRANCE
Libreville	ESA Tracking Station	N'Koltang, GABON
Mahé	Seychelles Meteorological Authority	Mahé Island, Republic of SEYCHELLES
Male'	Maldives Meteorological Service (MMS)	Male', Republic of MALDIVES
Managua	Instituto Nicaragüense de Estudios Territoriales (INETER)	Managua, NICARAGUA
Mangilao	University of Guam (UoG)	Guam Island, USA
Manila	National Mapping and Ressource Information Authority (NAMRIA)	Taguig, Republic of the PHILIPPINES
Marion	Antartica & Islands Department of Environmental Affairs (DEA)	Marion Island Base, SOUTH AFRICA
Metsähovi	Finnish Geospatial Research Institute National Land Survey (NLS)	Masala, FINLAND
Miami	Rosenstiel School of Marine and Atmospheric Science (RSMAS)	Miami, Florida, U.S.A.
Mount Stromlo	Geoscience Australia (GA)	Mount Stromlo Observatory, Canberra, AUSTRALIA
Nouméa	Direction des Infrastructures, de la Topographie et des Transports Terrestres	Nouméa, NEW CALEDONIA
Ny-Ålesund II	Institut Polaire Paul Emile Victor (IPEV) Kartverket (Norwegian Mapping Authority)	Ny-Ålesund, Svalbard, NORWAY
Owenga	Land Information New Zealand (LINZ)	Chatham Island, NEW ZEALAND
Papeete	Observatoire Géodésique de Tahiti, Université de la Polynésie Française (UPF)	Fa'a, Tahiti, Polynésie Française, FRANCE
Ponta Delgada	CIVISA / IVAR Universidade dos Açores	Ponta Delgada, Azores, PORTUGAL

Station name	Host agency	Location, Country
Rikitea	Météo-France	Archipel des Gambier, Polynésie Française, FRANCE
Rio Grande	Estación Astronómica de Rio Grande (EARG), Universidad Nacional de la Plata (UNLP)	Rio Grande, ARGENTINA
Rothera	British Antarctic Survey (BAS)	Rothera Research Station, Adelaide Island, Antarctica, UK
Sal	Instituto Nacional de Meteorologia e Geofisica (INMG)	Sal Island, CAPE VERDE
San Juan	Observatorio Astronómico Félix Aguilar Universidad Nacional de San Juan (UNSJ)	San Juan, ARGENTINA
Santa Cruz	Fundación Charles Darwin (FCD)	Santa Cruz Island, Galápagos, ECUADOR
Socorro	Instituto Nacional de Estadística y Geografía (INEGI) Secretaría de Marina Armada (SEMAR)	Aguascalientes, MEXICO Socorro Island, MEXICO
St John's	Geomagnetic Observatory, Natural Resources Canada (NRCan)	St. John's, CANADA
St-Helena	Met Office Saint-Helena Government	Longwood, St Helena Island, South Atlantic, UK
Syowa	National Institute of Polar Research (NIPR)	Syowa Base, Antarctica, JAPAN
Terre Adélie	Institut Polaire Paul Emile Victor (IPEV)	Base de Dumont d'Urville, Terre-Adélie, Antarctica, FRANCE
Thule	US Air Force Base Technical University of Denmark (DTU)	Pituffik, Greenland, DENMARK Lyngby, DENMARK
Toulouse	Collecte Localisation Satellites (CLS)	Ramonville, FRANCE
Tristan da Cunha	Communications Department of TDC	Tristan da Cunha Island, South Atlantic, UK
Wettzell	Geodetic Observatory Wettzell (BKG)	Bad Kötzting, GERMANY
Yarragadee	Geoscience Australia (GA)	Yarragadee Geodetic Observatory, AUSTRALIA
Yellowknife	Natural Resources Canada (NRCan)	Yellowknife Geophysical Observatory, CANADA

23.GLOSSARY

AC

Analysis Center

AGU

American Geophysical Union.

AVISO

Archiving, Validation and Interpretation of Satellite Oceanographic data. AVISO distributes satellite altimetry data from TOPEX/Poseidon, Jason-1, Jason-2, ERS-1 and ERS-2, and Envisat, and DORIS precise orbit determination and positioning products.

AWG

Analysis Working Group

CB

Central Bureau

CDDIS

Crustal Dynamics Data Information System

CLS

Collecte Localisation Satellites. Founded in 1986, CLS is a subsidiary of CNES and Ifremer, specializes in satellite-based data collection, location and ocean observations by satellite.

CNES

Centre National d'Etudes Spatiales. The Centre National d'Etudes Spatiales is the French national space agency, founded in 1961.

CNRS

Centre National de la Recherche Scientifique. The Centre National de la Recherche Scientifique is the leading research organization in France covering all the scientific, technological and societal fields

CryoSat-2

Altimetry satellite built by the European Space Agency launched on April 8 2010. The mission will determine the variations in the thickness of the Earth's continental ice sheets and marine ice cover.

CSR

Center for Space Research, the University of Texas

CSTG

Coordination of Space Technique in Geodesy

DC

Data Center

DGXX

DORIS receiver name (3rd Generation)

DIODE

Détermination Immédiate d'Orbite par DORIS Embarqué. Real-time onboard DORIS system used for orbit determination.

DORIS

Doppler Orbitography and Radiopositioning Integrated by Satellite. Precise orbit determination and location system using Doppler shift measurement techniques. A global network of orbitography beacons has been deployed. DORIS was developed by CNES, the French space agency, and is operated by CLS.

DPOD

DORIS extension of the ITRF for Precise Orbit Determination. The so-called DPOD product is a set of coordinates and velocities of all the DORIS tracking stations for Precise Orbit Determination (POD) applications.

ECMWF

European Centre for Medium-range Weather Forecasting

EGU

European Geosciences Union

EOP

Earth Orientation Parameters

Envisat

ENVIronmental SATellite Earth-observing satellite (ESA)

ESA

European Space Agency. The European Space Agency is a space agency founded in 1975. It is responsible of space projects for 17 European countries.

ESA, esa

acronyms for *ESA/ESOC* Analysis Center, Germany

ESOC

European Space Operations Centre (ESA, Germany)

EUMETSAT

EUropean organisation for the exploitation of METeorological SATellites

GAU, gau

acronyms for the *Geoscience Australia* Analysis Center, Australia

GB

Governing Board

GDR-B, GDR-C, GDR-D, GDR-E

Versions B, C, D, and E of **Geophysical Data Record**

geoc

Specific format for geodetic product: time series files of coordinates of the terrestrial reference frame origin (geocenter)

eop

Specific format for geodetic product: time series files of Earth orientation parameters (EOP)

GFZ

GeoForschungsZentrum, German Research Centre for Geosciences

GGOS

Global Geodetic Observing System

GNSS

Global Navigation Satellite System

GLONASS

Global Navigation Satellite System (Russian system)

GOP, gop

acronyms for the *Geodetic Observatory of Pecný* Analysis Center, Czech Republic

GRG, grg

Acronyms for the CNES/CLS Analysis Center, France (see also LCA))

GRGS

Groupe de Recherche de Géodésie Spatiale

GSC, gsc

acronyms for the *NASA/GSFC* Analysis Center, USA

GSFC

Goddard Space Flight Center (NASA).

HY-2

HY (for **HaiYang** that means 'ocean' in Chinese) is a marine remote sensing satellite series planned by China (HY-2A (2011), HY-2B (2012), HY-2C (2015), HY-2D (2019))

IAG

International Association of Geodesy

IDS

International DORIS Service

IERS

International Earth rotation and Reference systems Service

IGN

Institut national de l'information géographique et forestière, French National Geographical Institute (formerly Institut Géographique National)

IGN, ign

acronyms for *IGN/IPGP* Analysis Center, France

IGS

International GNSS Service

ILRS

International Laser Ranging Service

INA, ina

acronyms for the *INASAN* Analysis Center, Russia

INASAN

Institute of Astronomy, Russian Academy of Sciences

IPGP

Institut de Physique du Globe de Paris

ISRO

Indian Space Research Organization

ITRF

International Terrestrial Reference Frame

IUGG

International Union of Geodesy and Geophysics

IVS

International VLBI Service for Geodesy and Astrometry

Jason

Altimetric missions (CNES/NASA), follow-on of TOPEX/Poseidon. Jason-1 was launched on December 7, 2001, Jason-2 on June 20, 2008, and Jason-3 on January 17, 2016.

JOG

Journal Of Geodesy

JASR

Journal of Advances in Space Research

LCA, lca

Former acronyms for the CNES/CLS Analysis Center, France (previously LEGOS/CLS Analysis Center)

LEGOS

Laboratoire d’Etudes en Géodésie et Océanographie Spatiales, France

LRA

Laser Retroreflector Array. One of three positioning systems on TOPEX/Poseidon and Jason. The LRA uses a laser beam to determine the satellite's position by measuring the round-trip time between the satellite and Earth to calculate the range.

MOE

Medium Orbit Ephemeris.

NASA

National Aeronautics and Space Administration. The National Aeronautics and Space Administration is the space agency of the United States, established in 1958.

NCEP

National Center for Environmental Prediction (NOAA).

NLC, ncl

acronyms for *University of Newcastle* Analysis Center, UK

NOAA

National Oceanic and Atmospheric Administration. The National Oceanic and Atmospheric Administration (NOAA) is a scientific agency of the United States Department of Commerce focused on the studies of the oceans and the atmosphere.

OSTST

Ocean Surface Topography Science Team

POD

Precise Orbit Determination

POE

Precise Orbit Ephemeris

Poseidon

One of the two altimeters onboard TOPEX/Poseidon (CNES); Poseidon-2 is the Jason-1 altimeter.

RINEX/DORIS

Receiver INdependent EXchange. Specific format for DORIS raw data files, based on the GPS-dedicated format

SAA

South Atlantic Anomaly

SARAL

Satellite with ARgos and Altika

Sentinel-3

The Sentinel-3 satellites fit into the Copernicus program, a joint project between Esa and European Union. They are dedicated to Earth monitoring and operational oceanography. Sentinel-3A was launched on February 16, 2016, and Sentinel -3B on April 25, 2018.

SINEX

Solution (software/technique) Independent Exchange. Specific format for files of geodetic products

SIRS

Service d'Installation et de Renovation des Balises (IGN). This service is in charge of all the relevant geodetic activities for the maintenance of the DORIS network.

SLR

Satellite Laser Ranging

SMOS

Service de Maintenance Opérationnelle des Stations (CNES). This service is responsible for the operational issues of the DORIS stations

snx see SINEX

SOD

Service d'Orbitographie DORIS, CNES DORIS orbitography service

SPOT

Système Pour l'Observation de la Terre. Series of photographic remote-sensing satellites launched by CNES.

sp1, sp3

Specific format for orbit ephemeris files

SSALTO

Segment Sol multimissions d'ALTimétrie, d'Orbitographie et de localisation precise. The SSALTO multi-mission ground segment encompasses ground support facilities for controlling the DORIS and Poseidon instruments, for processing data from DORIS and the TOPEX/Poseidon, Jason-1, Jason-2 and Envisat-1 altimeters, and for providing user services and expert altimetry support.

STCD

STation Coordinates Difference. Specific format for time series files of station coordinates (geodetic product)

STPSAT

US Air Force **Space Test Program SATellite.** The first satellite **STPSAT1** was launched in 2007 with a new DORIS receiver called CITRIS. This experiment is dedicated to global ionospheric measurements.

SWOT

Surface Water Ocean Topography. Name of a future CNES/NASA satellite mission.

TOPEX/Poseidon

Altimetric satellite (NASA/CNES).

USO

Ultra-Stable Oscillator

UTC

Coordinated Universal Time. Timekeeping system that relies on atomic clocks to provide accurate measurements of the second, while remaining coordinated with the Earth's rotation, which is much more irregular. To stay synchronized, UTC has to be adjusted every so often by adding one second to the day, called a leap second, usually between June 30 and July 1, or between December 31 and January 1. This is achieved by counting 23h59'59", 23h59'60" then 00h00'00". This correction means that the Sun is always at its zenith at noon exactly (accurate to the second).

VLBI

Very Long Baseline Interferometry.

ZTD

Zenith Tropospheric Delay

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The full list since 1985 is available on the IDS website at http://ids-doris.org/ids/reports-mails/doris-bibliography/peer-reviewed-journals.html (follow IDS > Reports & Mails > DORIS bibliography > Peer-reviewed journals)

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25.NEWSLETTERS

Launched in April 2016, the IDS Newsletter aims to provide regular information on the DORIS system and the life of IDS to a wide audience, from the host agencies to the other sister services. The issues are distributed electronically (to subscribe to the newsletter, please send an e-mail to ids.central.bureau@ids-doris.org, with "Subscribe Newsletter" in the subject).

They can also be downloaded from the IDS website at https://ids-doris.org/ids/reports-mails/newsletter.html (follow IDS > Documentation > Newsletter)

The following list gives the content of the newsletters issued in 2019 and 2020.

IDS Newsletter #6 (February 2019)

- The synergy of SLR and DORIS as geodetic techniques (F. Lemoine, A. Belli, C. Noll, NASA GSFC)
- The Azores: a key location occupied by DORIS for three decades (J. Saunier, IGN, C. Jayles, CNES, G. Moreaux, CLS, P. Yaya, CLS)
- Ponta Delgada: the host agency in short (R. TF. Marques, CIVISA)
- Tribute to Richard Biancale (F. Lemoine, NASA, L. Soudarin, CLS, JM. Lemoine, CNES, P. Ferrage, CNES, JP. Boy, EOST)
- IDS life

IDS Newsletter #7 (January 2020)

- DORIS in Latin America: more sun, more warmth, and more rythm (J. Saunier, IGN)
- The host agencies in short: San Juan (R. C. Podestá, OAFA) and Santa Cruz (J. Carrión, CDF)
- IDS life
- IDS & DORIS quick reference list

IDS Newsletter #8 (December 2020)

- 2020 celebrates 30 years of the DORIS system
- 2020, two new missions have joined the DORIS constellation
- IDS and DORIS milestones
- IDS life
- Pascal Willis retires

Newsletter of the International DORIS Service #6 February 2019

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.

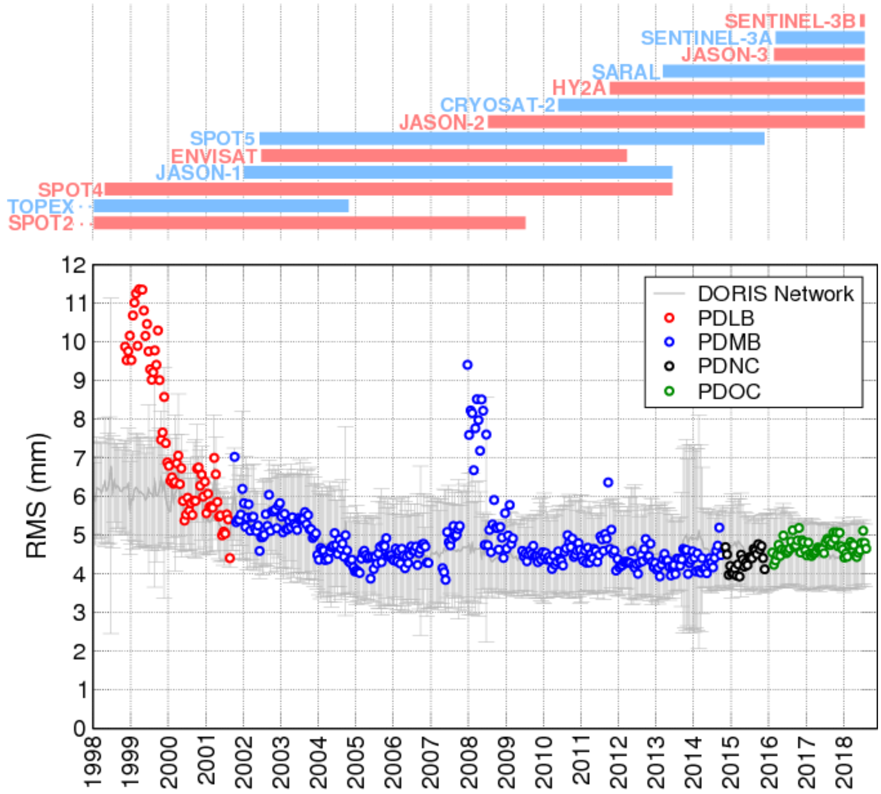
The first local tie survey was carried out in 2001, including the DORIS and the GNSS stations, a VLBI mark (portable observations in 1992) located 900 m away and the nearby tide gauge (GLOSS n°245) located in the Port 1.5 km away. The co-location of geodetic techniques as DORIS, GNSS, SLR and VLBI and 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.

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).

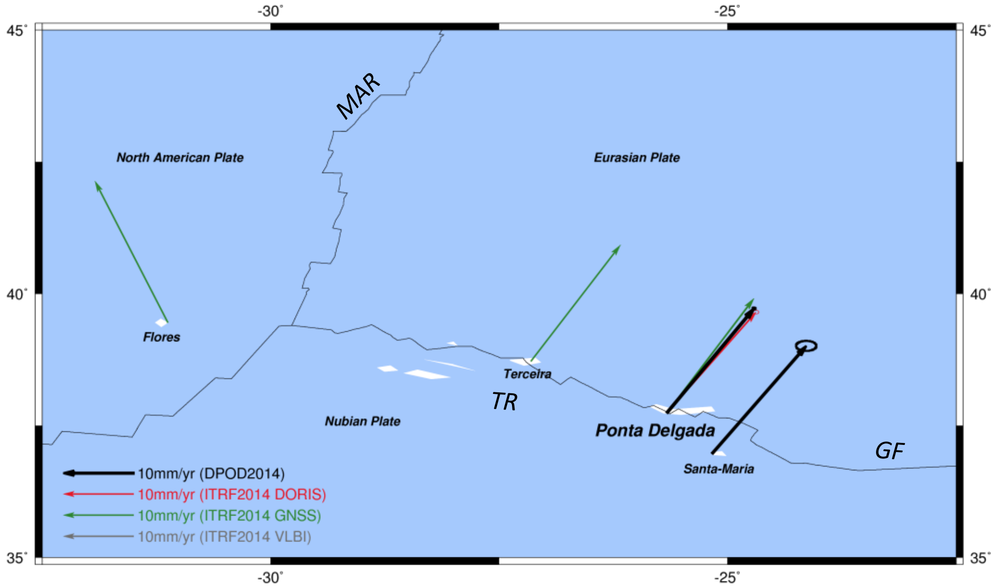
Impressive submarine and subaerial volcanic rift zones and central volcanoes extend along the MAR and the TR.

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

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 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.

Richard at the IDS AWG meeting in Toulouse in June 2018

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

IDS Newsletter

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Newsletter of the International DORIS Service

January 2020

DORIS in Latin America: more sun, more warmth, and more rhythm

By Jérôme Saunier (IGN),

France and the French people have always had a very close and special relationship with Latina America where Romance (Latin) languages are spoken because of their similar culture, history and language.

Thus, DORIS as French system forged strong links with its Latin partners who host nine stations of the current ground network: at Socorro (Mexico) with INEGI and the help of the Secretariat of the Navy (SEMAR), Managua (Nicaragua) with INETER, Le Lamentin (West Indies) with Météo-France, Kourou (French Guyana) with CSG, Santa Cruz (Ecuador) with FCD, Arequipa (Peru) with UNSA, Cachoeira-Paulista (Brazil) with INPE, San Juan (Argentina) with UNSJ, and Rio Grande (Argentina) with UNLP.

DORIS STATIONS HOSTED BY COUNTRIES OF LATIN AMERICA.

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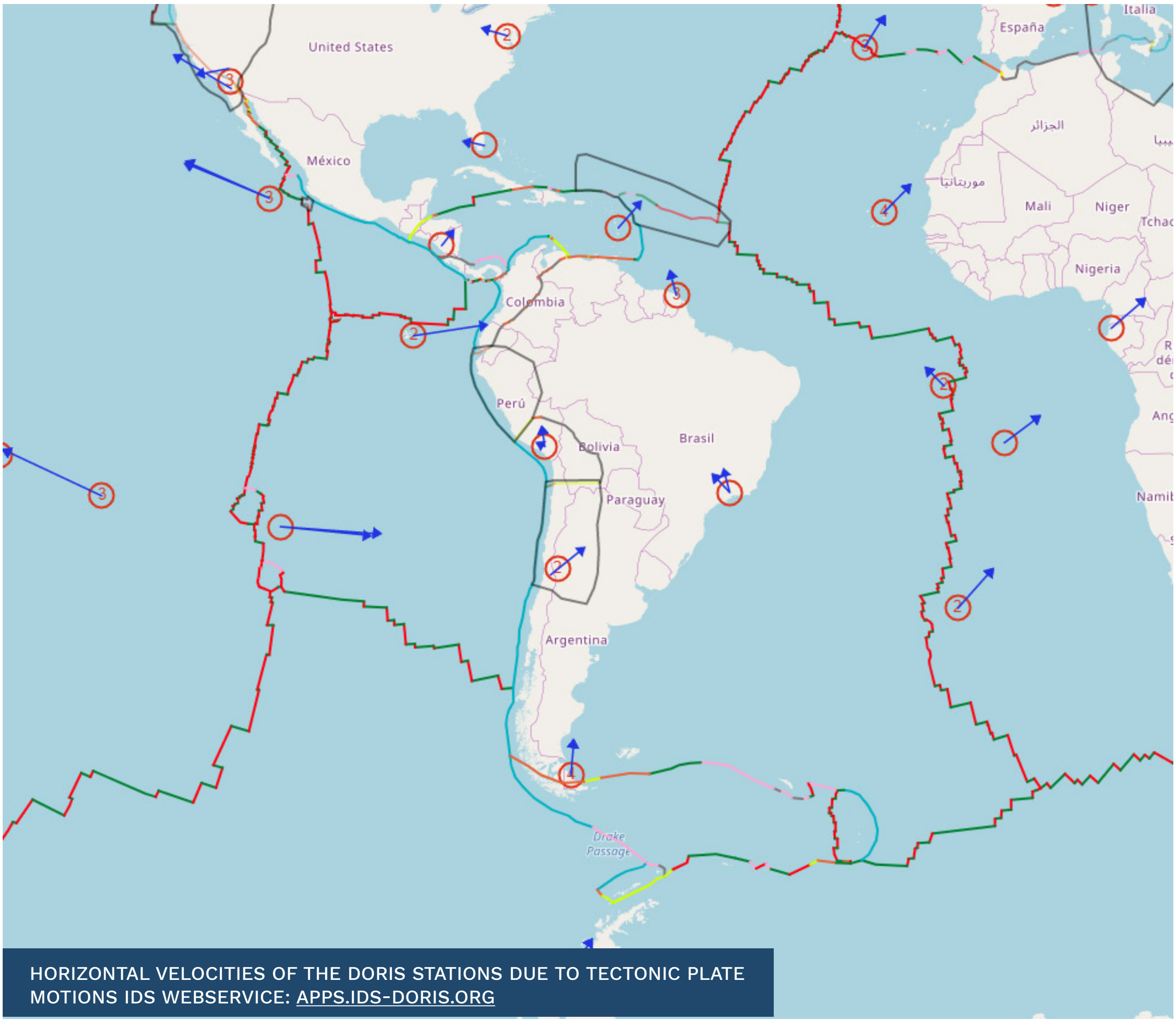


HORIZONTAL VELOCITIES OF THE DORIS STATIONS DUE TO TECTONIC PLATE MOTIONS IDS WEBSERVICE: APPS.IDS-DORIS.ORG

LAS ESTACIONES DORIS EN LATINA AMÉRICA

The Latin American DORIS stations are located on coastal regions and islands so as to provide a good coverage of the oceans. Some have been part of the permanent network since the start of DORIS in the early 90's years (Socorro, Arequipa, Cachoeira-Paulista, Rio Grande, Kourou), while the others were established more recently (Santa Cruz, 2005, Le Lamentin, 2013, Managua, 2016, San Juan, 2018). The long-standing stations contributed to the study of crustal deformations and plates motion especially in active deformation zones such as the south-western America coast, and also to the modeling of the South Atlantic Anomaly (SAA) for Low Earth Orbit (LEO) satellites.
The best example of DORIS contribution to geophysics in this area is the observation and measurement of local deformation from the time series analysis of the DORIS station, following submarine eruption close to Socorro Island. Socorro DORIS station, co-located with tide gauge, allowed observing displacements due to the subsidence of the volcano after eruption and, at another time, the arrival of lava in a secondary duct (Briole et al., 2009).
The old-established stations located further to the south (Kourou, Arequipa, Cachoeira-Paulista) have been extensively studied to explain from the 2000s satellite-specific problems and errors in the stations positioning. Actually, the magnetic field that is much weaker over this region affects the behavior of satellites equipment, in particular on-board clocks, causing erroneous results in the stations position/velocity estimation. Since then, the modeling of the SAA effecthas been continuously improved and evaluated through the DORIS data of these South American stations. In addition, the DORIS station at Kourou plays an important role as one of the four master beacons of the network that are connected to atomic clocks and to the control center in order to send essential information to satellites, like the time reference for the system. More recent DORIS stations in Latin America are also very interesting for geodesy and geophysics. Le Lamentin in Martinique Island (French West Indies) and Managua in Nicaragua are both located on the Caribbean plate and thus will provide valuable

information on the plate motion in this geologically complex area. In addition, these DORIS stations are both co-located with GNSS stations, which will allow comparisons to enhance geodynamical models.
Finally, stations in Chile and Argentina are essential for the coverage of the southern part of Latin America. If we count the DORIS station at Belgrano, the scientific base of the Instituto Antártico Argentino, Argentina currently hosts three DORIS stations: Belgrano, Rio Grande and the latest San Juan replacing the Chilean former station at Peldehue, Santiago. In Chile, Easter Island is a key location for the Pacific coverage and there is an ongoing project with the University of Chile for a new DORIS site on the island.

The recent workshop "Implementation of the Global Geodetic Reference Frame in Latin America" held in Buenos Aires last September was an opportunity to strengthen the links with these countries and reinforce how the DORIS presence is important in Latin America for the terrestrial reference frame realization.

DORIS site	Host agency
Arequipa PERU *since Dec 1988*	Instituto Astronómico y Aeroespacial P. Paulet Universidad Nacional de San Agustin (UNSA)
Cachoeira Paulista BRAZIL *since Aug 1992*	Instituto Nacional de Pesquisas Espaciais (INPE)
Kourou French Guyana, FRANCE *since Dec 1986*	Centre Spatial Guyanais (CSG)
Le Lamentin Martinique, FRANCE since June 2013	Météo-France
Managua NICARAGUA since *April 2016*	Instituto Nicaragüense de Estudios Territoriales (INETER)
Rio Grande ARGENTINA *since Dec 1987*	Estación Astronómica de Rio Grande (EARG), Universidad Nacional de la Plata (UNLP)
San Juan ARGENTINA *since Oct 2018*	Observatorio Astronómico Félix Aguilar Universidad Nacional de San Juan (UNSJ)
Santa Cruz Galápagos, ECUADOR *since April 2005*	Fundación Charles Darwin (FCD)
Socorro MEXICO *since Feb 1991*	Instituto Nacional de Estadística y Geografía (INEGI) Secretaría de Marina (SEMAR)
Belgrano ARGENTINA base *since Feb 2004*	Instituto Antártico Argentino (IAA)

We will now focus on the two main recent DORIS ground network events: installations in San Juan, Argentina, and Santa Cruz, Galapagos Islands.

DORIS EN EL OBSERVATORIO ASTRONÓMICO FÉLIX AGUILAR, SAN JUAN, ARGENTINA

The DORIS station in San Juan was installed on October 21th, 2018 at the astronomical observatory Felix Aguilar (OAFA) that is managed by the National University of San Juan (UNSJ) (see insert on page 6). San Juan is located 300 km northeast of Santiago, Chile on the other side of the border formed by the Andean Mountains. Settled in the Tulúm Valley, the astronomical observatory benefits from an exceptional climate (the sunniest place of South America) and one of the purest skies in the world for astronomical observation. After the reconnaissance

THE DORIS ANTENNA "SJUC" OF SAN JUAN, CO-LOCATED WITH SLR AND GNSS

AERIAL VIEW OF OAFA OBSERVATORY WITH THE PART OF THE LAND DEDICATED TO GEODESY (CIRCLE)

in 2014 for a new DORIS site in the area, including several options in Chile, the choice was made for the San Juan observatory. This site offers good environment for the DORIS antenna broadcasting and co-location with other space geodetic techniques: the Satellite Laser Ranging (SLR) station set up by the Chinese Academy of Sciences in 2005 and the permanent GNSS station of the national network RAMSAC (Red Argentina de Monitoreo Satelital Continuo) in operation since 2012. This instrument co-location is of high interest for geodesy and geophysics. With three of the four geodetic techniques contributing to the International Terrestrial Reference Frame (ITRF) realization, San Juan observatory is a core site for the combination of the reference frames of the different techniques into a unique reference frame by introducing terrestrial measurements (tie vectors between co-located instruments). In addition, using the measured station velocities from three different techniques, this co-location will provide essential information for the study of this deformation zone where global plate models are not applicable.

The three geodetic instruments are gathered together in the middle of the observatory in a 50 m radius area that offers a clear view of the sky. After the installation, IGN carried out a local tie survey to determine with high precision the relative position of the reference points of the three instruments: DORIS, GNSS and SLR. As the GNSS data observations from the OAFA station should be included in the IGS data reprocessing that will be used as input data for the next ITRF realization, these tie vectors will be very useful.

The commissioning of the DORIS station has come as a great relief after lot of paperwork and lengthy delays for shipping and customs clearance of the equipment. Patience and perseverance are needed with such obscure administrative processes.

We hope long and continuous operation for this major station of the DORIS network that will play an essential role in the Global Geodetic Observing System (GGOS).

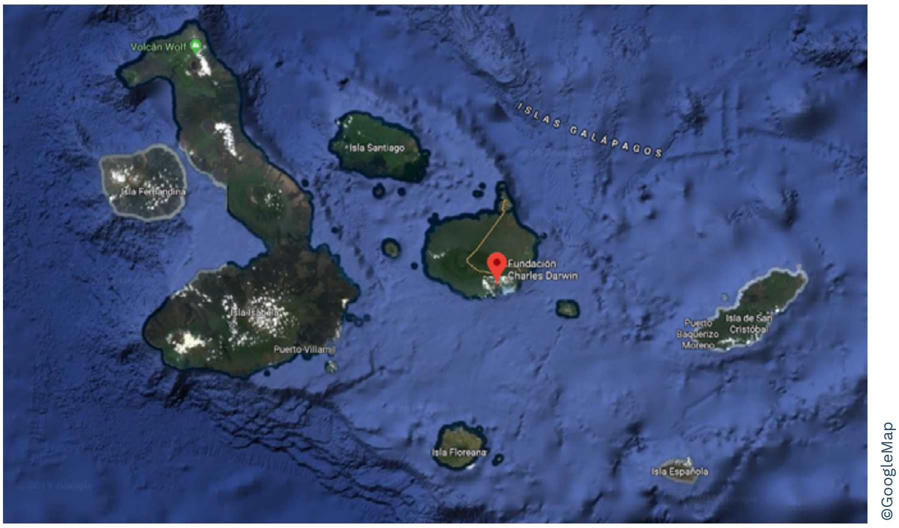
DORIS EN LA ESTACIÓN CIENTÍFICA CHARLES DARWIN, ISLA SANTA CRUZ, GALÁPAGOS, ECUADOR

DORIS has been present in the Galapagos Islands since 1991. The station was first located in San Cristobal Island at the Instituto Oceanográfico de la Armada (INOCAR). The station was then moved in 2005 in Santa Cruz Island in order to improve its operating conditions and environment. After very good results in the four early years, the equipment unfortunately broke down. And all that went with it got worse: loss of the spare equipment, a fruitless search, and loss of time, loss of motivation, loss of contact...

We had to start all over again from scratch: new people, new agreement, new equipment and new confidence in the future!

The DORIS station were reinstalled in September 2019 thanks to the efficient cooperation of the local staff of the Fundación Charles Darwin (FCD) that hosts the equipment. The

FCD scientific station is located in a quiet place south of Puerto Ayora where iguanas and tortoises are living peacefully for millions of years. A permanent GNSS from the IGS network took up residence in the parcel in 2003 and must fight against the hardy vegetation on ground. The DORIS antenna was set-up on the terrace roof of the one-story building of the directing staff assuring an undisturbed environment. Galapagos archipelago is located 1000 km away from the West coast of South America. Thus, the DORIS station in Santa Cruz is essential for providing tracking coverage for DORIS satellites over the Pacific Ocean. It is also a key location for the Nazca plate motion monitoring, one of the fastest moving plates.



LOCATION AND VISIBILITY CIRCLE OF THE DORIS STATION IN SANTA CRUZ, GALÁPAGOS, ECUADOR

THE DORIS ANTENNA « SCRC » OF SANTA CRUZ

FCD activities (see insert on p. 6) are far away from geodesy or geophysics but the FCD found a common cause to work together because the DORIS system contributes through Earth observation satellites to the study of climate change and they are particularly interested in satellite imagery that constitute essential material for their work of research. With the Santa Cruz DORIS station back to operation, the orbit determination and thus the height measurements from the altimetry satellites will be improved in this area and the co-location with the GNSS station will provide meaningful data to contribute toward the understanding of the complex structure of this area known as hot spot in geological terms. We wish a long and successful life to this station!

LOS COLORES DE LAS ESTACIONES DORIS LATINOAMERICANAS

When you look at a Latin America DORIS station, there is no apparent difference compared to the others. But yet you see more sun in the picture, you feel the heat. If you think about the people taking care of the equipment, you remember their warm welcome the first time you met them. You notice their unique generous support to deal with difficulties greater than elsewhere. The station history has a different flavor imbued with the local situation and hampered by administrative barriers.
But your friends there make it fun and always look on the bright side. Don't you hear the Latin sounds in the South American DORIS stations transmissions? /

THE HOST AGENCIES **IN SHORT**

SAN JUAN

By **Dr. Ricardo C. Podestá,**
OAFA Director, San Juan National University, Argentina

The Observatorio Astronómico Félix Aguilar (OAFA) was founded on September 28, 1953 and belongs to the National University of San Juan. The OAFA was firstly dedicated to astrometric observations through scientific projects that led to outstanding discoveries of asteroids, comets, other celestial bodies and contributions to stellar catalogs. It is now playing an important role in space geodesy, in the maintenance of the International Terrestrial Reference Frame and Solar Physics. OAFA research areas are Dynamic Astronomy, Astrophysics, Astronomy of Position and Geodesy, Technological Development, Divulgation and Astronomical Tourism. Historically, the institute's research projects have been conducted with the help of other countries. The first international agreement concluded with a foreign entity was with the Universities of Yale and Columbia for the operation of the Double Astrograph telescope. Then, over the years, more agreements were added with countries such as China through the National Astronomical Observatories of China (NAOC) of the Chinese Academy of Sciences (CAS), the Royal Institute and Observatory of the Spanish Navy, the Max Planck MPS and MPE institutes in Germany, the Mackenzie Presbyterian University of Brazil, the Moscow State University in Russia and the National Centre for Space Studies (CNES) and the National Geographic Institute of France (IGN). The OAFA has two astronomical observatories. One hand, the OAFA Headquarters, located 15 km west of the city of San Juan. It includes the offices of the researchers and the administration. SLR and GNSS space geodetic techniques were installed on this site through an agreement with the Chinese Academy of Sciences, and recently, a DORIS station was added through an agreement with CNES and IGN. On the other hand, Carlos U. Cesco Station, located 250 km away from San Juan in the location of Calingasta in the Andes mountain range, was founded on March 31, 1965 through an agreement between San Juan National University and the Universities of Yale and Columbia, where mainly astrometric, solar physics and astrophysical observational activities are developed.

Observatorio Astronómico Félix Aguilar (OAFA) Website
www.cielodesanjuan.com

SANTA CRUZ

By **Johanna Carrión,**
Executive Coordinator and Interinstitutional Affairs,
Charles Darwin Foundation, Galápagos Ecuador

The Charles Darwin Foundation for the Galapagos Islands (CDF) is an international non-profit organization dedicated to scientific research. CDF has carried out its mission in the Galapagos since 1959, thanks to an agreement with the Government of Ecuador and with the mandate to pursue and maintain collaborations with government agencies by providing scientific knowledge and technical assistance to promote and secure conservation of Galapagos. The Charles Darwin Foundation puts a high priority on collaborative conservation. In addition to working with individual researchers through our Visiting and Adjunct Scientist program, the Foundation also enters into inter institutional agreements with other organizations. These Agreements promote the causes of joint research projects, knowledge transfer, data management, volunteer support and training, facilitation of research, and many others. Our current collaborators include governmental institutes, national and international universities, and private organizations. For the CDF it is important to be part of the DORIS project since this contributes to generating knowledge and sharing information for science purposes around the world.

IDS LIFE

DORIS will turn 30 in 2020.

The first DORIS measurement was received by the first DORIS receiver embarked on SPOT-2 on Feb. 3rd 1990.

Bye bye Jason-2

After more than 11 years in orbit, the ocean-observing altimetry satellite Jason-2 ended its mission on October 10th, 2019.

DGFI-TUM is the 4th Associated Analysis Center

The application of the DGFITUM (Munich, Germany) to become an Associate Analysis Center was approved by the IDS Governing Board at its meeting on October 1st, 2019.
In addition to the six regular Analysis Centers, four Associate Analysis Centers now contribute to the IDS analysis activities.

IDS Strategic Plan

After the IDS Retreat held in June 2018, the IDS GB worked on the development of a strategic plan for the IDS. In the coming years, IDS will focus on growing the community, extending the DORIS applications, and improving the technology, the infrastructure and the processing.

DORIS RINEX and DIODE orbit soon available in NRT

Following a request from the Working Group "NRT DORIS data" chaired by D. Dettmering, Jason-2/3: DORIS RINEX and DIODE orbit may be soon available in NRT.

Creation of an IDS Working Group on Geocenter

A new IDS Working Group on the observation of geocen-ter motion was proposed. DORIS can play a role because the tracking network is stable and well distributed.

IDS AT GGRF WORKSHOP

VIRGINIA MACKERN (UNIVERSIDAD NACIONAL DE CUYO AND UNIVERSIDAD JUAN AGUSTÍN MAZA, MENDOZA, ARGENTINA; VICE-PRESIDENT OF SIRGAS) AND FRANK LEMOINE (NASA/GSFC; CHAIRMAN OF THE IDS GB)

Frank Lemoine and Laurent Soudarin attended the International Workshop for the Implementation of the Global Geodetic Reference Frame in Latin America held in Buenos Aires, Argentina, from Sep 16 to 20, 2019.
It was the opportunity to meet the friendly colleagues from the agencies hosting DORIS stations in this part of the world.

www.sirgas.org

EVENTS

DORIS day 2020

A « DORIS day » will be organized on May 2 at the Vienna University of Technology prior to EGU 2020 to promote the use of the IDS products. More information soon on the IDS website.

IDS Analysis Working Group, Spring 2020

Date and location are still to be defined.

IDS Workshop 2020

The next IDS Workshop will be held on October 19-21, 2020, in Venice, Italy, in conjunction with the Ocean Surface Topography Science Team meeting.

IDS & DORIS
QUICK REFERENCE LIST

1. IDS website
https://ids-doris.org/

2. Contacts
Central Bureau
ids.central.bureau@ids-doris.org
Governing Board
ids.governing.board@ids-doris.org

3. Data Centers
CDDIS: ftp://cddis.gsfc.nasa.gov/doris/
IGN: ftp://doris.ign.fr
and ftp://doris.ensg.eu

4. Tables of Data and Products
https://ids-doris.org/ids/data-products/tables-of-data-products.html

5. IDS web service
https://ids-doris.org/webservice
DOR-O-T for DORis Online Tools (pronounced in French like the given name Dorothée) is the IDS web service developed to promote the use of the DORIS products. The current version of the service provides tools to browse time series in an interactive and intuitive way, and a network viewer.

6. Citation
The following article is suggested for citation in papers and presentations that rely on DORIS data and results:
Willis, P.; Lemoine, F.G.; Moreaux, G.; Soudarin, L.; Ferrage, P.; Ries, J.; Otten, M.; Saunier, J.; Noll, C.; Biancale, R.; Luzum, B., 2016. The International DORIS Service (IDS), recent develop-ments in preparation for ITRF2013, IAG SYMPOSIA SERIES, 143, 631-639, DOI: 10.1007/1345_2015_164

7. DORISmail
The DORIS mail service is used to send information of general interest to the DORIS community. To send a DORISMail, use the following address: dorismail@ids-doris.org

8. List of the documentation
It gives a table compiling links to the various pages providing documents, grouped in four categories: DORIS system components; IDS information system; Publications, presentations; Documents
https://ids-doris.org/ids/reports-mails/documentation.html

9. List of presentations given at DORIS or IDS meetings
Full list of presentations given at DORIS or IDS meetings with the corresponding access links
https://ids-doris.org/ids/reports-mails/meeting-presentations.html

10. List of documents and links to discover the DORIS system
https://ids-doris.org/analysis-coordination/documents-related-to-data-analysis.html

11. List of DORIS publications in international peerreviewed journals
https://ids-doris.org/ids/reports-mails/doris-bibliography/peer-reviewed-journals.html

12. Overview of the DORIS system
https://www.aviso.altimetry.fr/en/techniques/doris.html

13. Overview of the DORIS satellite constellation
https://ids-doris.org/doris-system/satellites.html

14. Site logs
DORIS stations description forms and pictures from the DORIS installation and maintenance department:
https://ids-doris.org/doris-system/tracking-network/site-logs.html

15. Virtual tour of the DORIS network with Google Earth
Download the file and visit the DORIS sites all around the world.
https://ids-doris.org/doris-system/tracking-network/network-on-google-earth.html

16. IDS video channel
Videos of the DORIS-equipped satellites in orbit
https://www.youtube.com/channel/UCiz6QkabRioCP6uEjkKtMKg

17. IDS Newsletters
Find all the issues published in color with live links on the IDS website
https://ids-doris.org/ids/reports-mails/newsletter.html

18. Photo Gallery
https://ids-doris.org/ids/gallery.html

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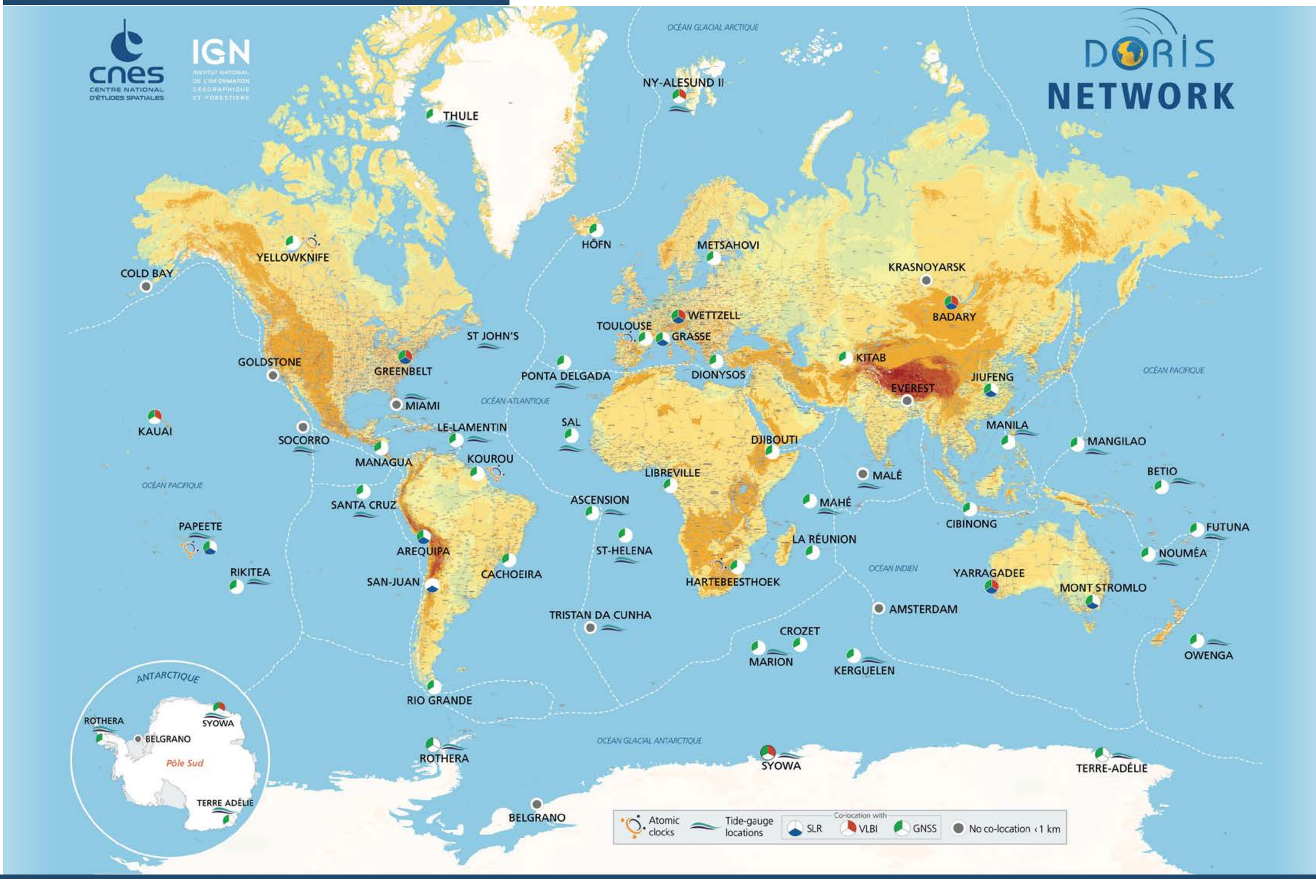
Newsletter of the International DORIS Service December 2020

2020 celebrates 30 years of the DORIS system

30 years of continuous operations at the heart of altimetry mission performance for oceanography and geodetic applications.

DORIS was first carried on the SPOT-2 satellite, which recorded the first DORIS measurements on 3 February 1990. Since then, the system has operated continuously on 18 satellites, including the space imaging satellites SPOT-2/3/4/5, Pleiades1A-1B, altimetry missions for ocean observations such as TOPEX-Poseidon, ENVISAT, Jason-1/2/3, HY-2A, Saral/AltiKa, Sentinel3-A/B, and also for hydrological monitoring and ice measurements with Envisat, Cryosat-2, Saral/AltiKa and Sentinel3-A/B. On the latest missions such as Sentinel-3A/3B, the DORIS system can achieve radial orbit accuracies of 8-10 mm RMS (Root mean square). The DORIS data are used for both real-time orbit determination onboard the satellite, and precise orbits developed with a latency of two days to a few weeks for use with altimeter data provided by these different missions.

MOST OF THE DORIS STATIONS ARE CO-LOCATED WITH OTHER SPACE GEODETIC TECHNIQUES AND TIDE-GAUGES



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The editors reserve the right to edit all contributions.

THULE, ON THE NORTHWEST COAST OF GREENLAND

The DORIS system (Doppler Orbitography and Radio positioning Integrated by Satellite) was designed and developed in the early 1980s by CNES (the French Space Agency), IGN (Institut Géographique National, the French Mapping and Survey Agency) and the GRGS (Groupe de Recherche de Géodésie Spatiale) to determine satellite positions with high accuracy for support altimetry missions dedicated to ocean monitoring.

This system is based on Doppler shift measurements of radio-frequency signals (400 MHz and 2 GHz) transmitted by a network of ground stations, used as reference points on the Earth's surface. There are about 60 DORIS stations uniformly distributed around the world, and these stations are hosted by 48 various international host agencies.

In addition to precise orbit determination, the DORIS system can also locate ground positions with the same intrinsic accuracy. The data are also used for determination of Earth Orientation Parameters (EOP), and can be used to determine the geocenter of the Earth. DORIS is one of the four space geodetic techniques that contribute to the International Terrestrial Reference Frame (ITRF).

Over the past 30 years, DORIS has enlarged the scope of its scientific applications:

1. DORIS has contributed to monitoring changes in mean sea level, both regionally and globally, using data from the TOPEX/Poseidon and Jason 1, 2, & 3 missions.

2. Through the precise orbits provided for the Envisat, CryoSat-2, Saral/AltiKa and Sentinel3-A/B missions, the DORIS system has participated in monitoring the change in height of the Antarctic ice sheet over 25 years.

3. DORIS contributes to the International Terrestrial Reference Frame (ITRF) realization and maintenance with increased performance each time,

4. The co-location of DORIS with tide gauges allows monitoring on the same site the vertical ground movements measured by the DORIS technique and the variations in sea level relative to the ground recorded by the tide gauge in order to deduce the absolute variations in sea level and compare them to the values obtained by satellite altimetry.

5. DORIS observes and analyses geophysical phenomena such as earthquakes or periodic inflation and deflation events of volcanoes, tectonic plate movements, local ground uplift or subsidence, etc.

The DORIS instruments (both on board the satellites and on the ground), as well as the DORIS

THE GREEK DORIS STATION OF DIONYSOS FACING THE AEGEAN SEA

DORIS STATION AT CROZET ISLANDS, FRENCH SOUTHERN AND ANTARCTIC LANDS

monitoring and control system have undergone continual improvement over the years. The centralized CNES/IGN management has made it possible to control the development of the network and more easily achieve its objectives: the DORIS network is today the most homogeneous, stable and durable geodetic network in the world. Most of the DORIS stations are co-located with other space geodetic techniques (Satellite Laser Ranging, Very Long Baseline Interferometry and Global Navigation Satellite Systems) and tide-gauges, thus promoting technological inter-comparisons and scientific advances.

In 30 years, the position in orbit has been reduced from 13 cm to less than 1 cm. The DORIS-DIODE navigator on board the satellites calculates the satellite's trajectory in real time with a radial accuracy of 2 to 3 cm. The DORIS contribution to the ITRF has progressed in the same way with new possible applications.

Further progress is expected in the next decade with the 4th generation beacon and the 3rd generation antenna, whose deployments started in 2019. The 3rd generation antenna (the Starec "C" antennae) defines the 2 GHz phase center location with a precision of ± 2 mm. Studies are underway for the development of a future miniaturized on-board receiver coupling GNSS and DORIS signals.

THE DORIS STATION OF FUTUNA IN THE PACIFIC OCEAN

In addition, following the IDS retreat organized in 2018, the IDS has drawn up a strategic plan for the years to come. About twenty recommendations were presented to stakeholders during the DORIS steering committee (CNES/IGN) at the end of 2019. These recommendations focus on three main themes:

→ expand the DORIS community;
→ evolve the technology;
→ improve infrastructure and treatment of data.

Some recommendations are already being implemented; others are in preparation.

The DORIS system really has a bright future ahead of it and will contribute to the success of many future missions.

IDS AND DORIS MILESTONES

early 1980s
Decision of the realisation of the DORIS system, jointly by the French space agency (CNES, Centre National d'Etude Spatial), the French national mapping agency (IGN, previously for Institut Géographique National), and the French research group in the field of space geodesy (GRGS, Groupe de Recherche de Géodésie Spatiale)

1986
Start of the deployment of the DORIS ground network. 32 stations with ALCATEL antenna (type "A") installed before Spot-2

1990
Spot-2 (Cnes) embarkes the first DORIS instrument, 1st generation with 1-channel receiver (6–month trial experiment, in use for more than 19 years). Goal of the mission: Earth observation. Objective for DORIS: decimeter level orbit accuracy. **First DORIS measurement on February 3rd.**

1990
DORIS Day meeting (December 1990, Paris)

1992-1999
Densification of the network, expanded to 54 stations. Massive Alcatel antennas are progressively replaced by the light and narrow Starec model (type "B").

1992
Topex/Poseidon (Nasa/Cnes) Goal: measure sea surface height. Objective reached by DORIS: 5-cm orbits quality in the radial component

1993
Spot-3 (Cnes)
Goal: Earth observation

1994
First DORIS contribution to the International Terrestrial Reference Frame (ITRF); 2 groups: IGN and LEGOS/GRGS)

1995
2nd generation of ground beacon

1998
Spot-4 (Cnes) with the first version of Diode software for real-time on-board orbit determination.
Goal: Earth observation

1999
DORIS Pilot Experiment to assess the need and feasibility of an International DORIS Service

2000-2009
Major renovation effort of the network. Objective: 1 cm over 10 years in terms of stability of the DORIS antenna reference point. Deployment of the 3rd generation ground beacons with the ability to emit on shifted frequency

2001
Jason-1 (Cnes/Nasa) with the first DORIS receiver of the 2nd generation with 2 channels. Goal: measure sea surface height

2002
Envisat (Esa). Goal: observe Earth's atmosphere and surface

2002
Spot-5 (Cnes).
Goal: Earth observation

2003
Official start of IDS as an IAG Service, on July 1st. Objective: to provide a service to support geodetic and geophysical research activities through DORIS data and derived products

2003
First IDS Governing Board meeting (November 2003, Arles, France)

2004
3rd Master Beacon at Hartebeesthoek (South Africa)

2005
DORIS Integrity Team set up to monitor permanently the DORIS signal transmitted in space, control its characteristics, investigate non nominal situations, take corrective actions if needed.

2005
Contribution to ITRF2005 (4 groups: IGN/JPL, LEGOS/CLS, INASAN, NASA/GSFC)

2007
STPSat-1: Citris (Scintillation and Tomography receiver in space) developped by the NRL (Naval Research Laboratory) uses the transmissions of the DORIS beacons.

2008
Jason-2 (Cnes/Nasa/Eumetsat/Noaa) with the first DORIS receiver of the 3rd generation (DGXX) with 7 channels. Goal: measure sea surface height

2008
First Analysis Working Group meeting

2009
Start of the Combination Centre

2009
Contribution to ITRF2008 (7 groups: IGN/JPL, CNES/CLS, INASAN, NASA/GSFC, ESOC, GOP, Geosciences Australia)

2009
4th Master Beacon at Papeete

2010-today
Modernization of the network. The DORIS network achieves 90% coverage (for satellites orbiting at 800 km altitude) and provides a reliable service with a network availability maintained over 85% of operating stations since 2012 thanks to the joint effort of CNES, IGN and all agencies hosting the stations.

2010
3 cm orbit accuracy achieved in real time on board Jason-2

2010
Cryosat-2 (ESA); DORIS enters the Spacecraft Attitude & Orbit Control System. Goal: polar observation

2011
HY-2A (China Academy of Space Technology) Goal: observe the ocean dynamics

2013
Saral/Altika (Isro/CNES) Goal: observe the oceans

2014
Deployment of Starec ground antennae with consolidated manufacturing process (type "C")

2014-2015
Contribution to ITRF2014 (6 groups: IGN/JPL, CNES/CLS, INASAN, NASA/GSFC, ESOC, GOP)

2016
Jason-3 (Cnes/Nasa/Eumetsat/Noaa) with the 1st DGXX-S instrument. Goal: measure sea surface height

2016
Sentinel-3A (ESA - Copernicus program) Goal: deliver routine operational services to policy-makers and marine and land service users

2018
Sentinel-3B (ESA - Copernicus program) Goal: deliver routine operational services to policy-makers and marine and land service users

2018
First IDS retreat

2019
Start of the 4th generation ground beacon deployment

2020
30 years of DORIS measurements

2020
HY-2C (China Academy of Space Technology) Goal: observe the ocean dynamics

2020
Sentinel-6A/ Michael Freilich (ESA - Copernicus program) Goal: measure sea surface height

2020
Contribution to ITRF2020 in progress

satellites
network

2020, **TWO NEW MISSIONS** HAVE JOINED THE DORIS CONSTELLATION

HY-2-C WAS LAUNCHED ON 21 SEPTEMBER 2020 FROM THE CHINESE LAUNCH BASE OF TAIYUAN.

HY-2 (HaiYang means "ocean") belongs to a series of Chinese oceanographic satellites started in 2011 with HY-2A, HY-2B (2018), HY-2C (September 21, 2020) and HY-2D planned in 2021. All these satellites except model "B" carry a DORIS receiver onboard. The objective of HY-2 is to monitor ocean dynamics using microwave sensors to detect wind fields at the ocean surface, sea surface height and surface temperature. CNES provides the precise orbit and retrieves the altimetry measurements which then contribute to the multi-mission maps of AVISO+ and the Copernicus Marine Service. After the commissioning phase, CNES will also distribute, the raw DORIS data (DORIS RINEX format) and the precise orbits (SP3 format) to the IDS data centers.

© CNES Sentinel-6A

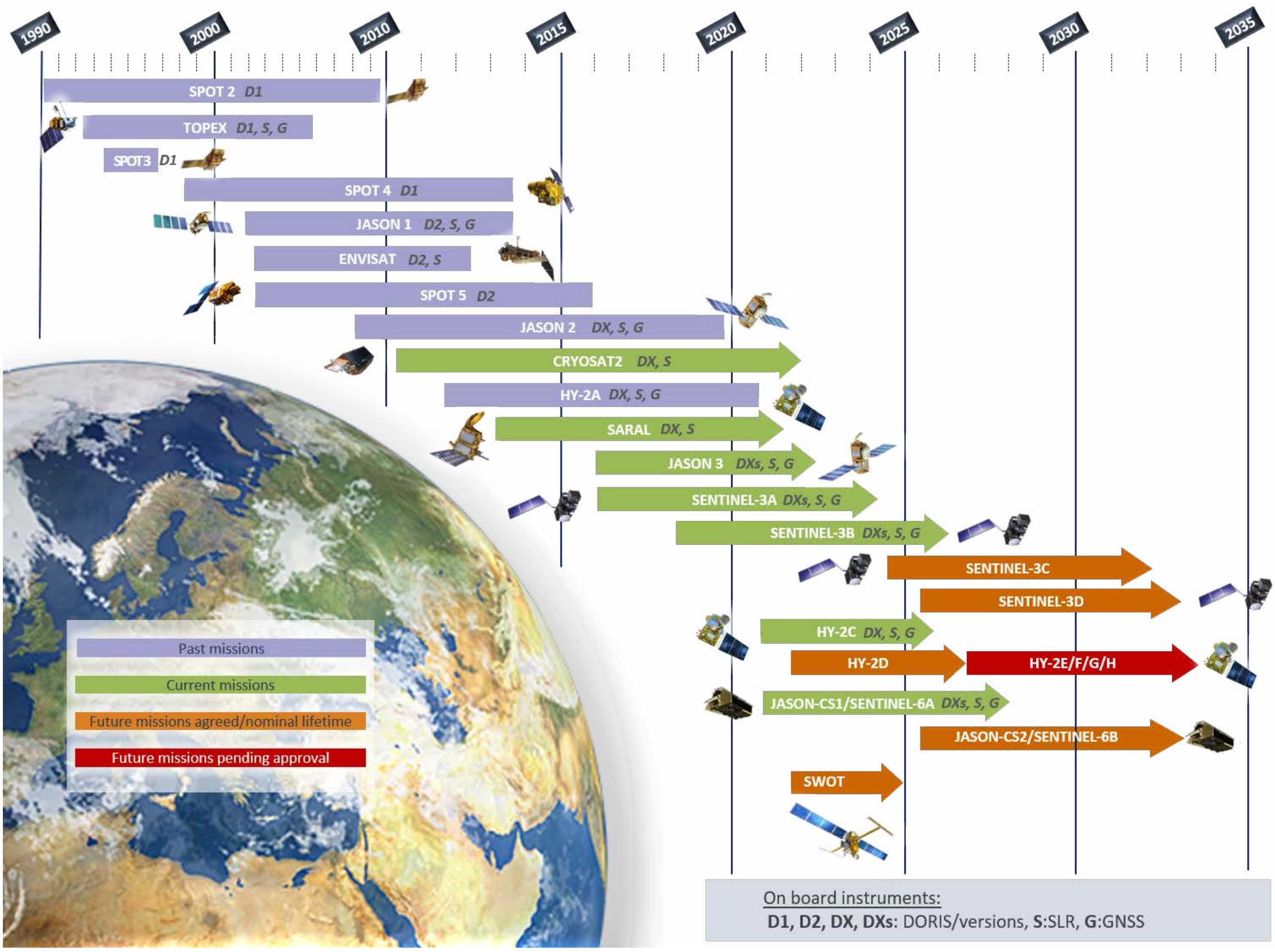
THE SENTINEL-6/JASON-CS IS A RESULT OF INTERNATIONAL COOPERATION BETWEEN ESA, EUMETSAT, THE EUROPEAN UNION, NOAA, CNES AND NASA.

SENTINEL-6A MICHAEL FREILICH (COPERNICUS- ESA/ EUMETSAT/CNES/NOAA/ NASA), THE FIRST OF A TWO-SATELLITE SENTINEL-6 SERIES, WAS LAUNCHED BY A FALCON-9 ROCKET FROM VANDENBERG AIR FORCE BASE, CALIFORNIA, ON 21 NOVEMBER 2020.

Also known as Jason Continuity of Service (Jason-CS), the Sentinel-6 satellites will replace the Jason-3 satellite, thus ensuring the continuity of sea level measurements and operational oceanographic services on the Topex and Jason reference orbit beyond 2030.

The Sentinel-6 mission is part of the European Copernicus program and the MyOcean operational oceanography project supported by the European Commission. This mission is a cooperation between ESA, the European Commission and EUMETSAT. The United States is also a key partner in the mission, with NASA and NOAA playing a role in the launch, US-side operations and the provision of a radiometer, GNSS-RO receiver and Laser Retroreflector.
CNES, another key partner of the mission, is in charge of providing the precise orbit of the satellite (via its DORIS instrument and ground station network, and the GNSS-POD receiver), as well as the sea surface height and wave height products that will be used by the Copernicus Marine Service. CNES is also responsible for the expertise and evaluation of the performance of the instruments and the mission. Sentinel-6 uses a new satellite bus based on CryoSat, with a capability to minimize the accumulation of orbital debris (the de-orbiting of the satellite within 25 years is now required by law). The Poseidon-4 altimeter will operate in the so-called ‘interleaved mode’ that provides simultaneously pulse-limited waveforms (computed on-board and in line with previous reference missions) and Full Rate RAW waveforms that allow SAR processing on-ground.

2020, **TWO NEW MISSIONS** HAVE JOINED THE DORIS CONSTELLATION



Today there are seven DORIS satellites that contribute to IDS: CryoSat-2, SARAL/Altika, Jason-3, Sentinel-3A, Sentinel-3B, HY-2C, Sentinel-6A/Mike Freilich.

In the future, many news missions are scheduled with the following launches to come:

- **HY-2D** (CNSA/NSOAS) with DORIS DGXX-S + LRA + GPS is planned for May 2021, and HY2 E-F-G-H are waiting for approval.
- **SWOT** (Surface Water Ocean Topography) is planned for the end of 2021 (DGXX-S + GPS + LRA). Further information on Swot website or on Aviso website.
- **Sentinel-3C** (Copernicus- ESA/ EUMETSAT/CNES) is planned for 2024 (DORIS DGXX-S with mini USO + LRA + GPS) (nominal lifetime of 7 years). Then Sentinel-3D is planned for 2025. Further information is available on the ESA website
- **Sentinel-6B/Jason-CS2** is planned in 2025

More information on the International DORIS Service website (https://ids-doris.org)

IDS LIFE

HY-2A satellite decommissioned

With the end of the mission, the last DORIS data were delivered in September 2020. HY-2A has been part of the DORIS constellation since its launch (2011-08-15). The satellite carried a DGXX receiver, and provided nine years of data from its orbit at an altitude of 963 km and at an inclination of 99.4 deg.

DORIS network projects continue notwithstanding Covid-19

Notwithstanding the difficulties in maintaining the stations during the global Covid-19 pandemic, the ground network showed good operating results thanks to the 4th generation beacon deployment started last year to firstly replace old equipment with signs of weakness. Most of the development projects are at a standstill but, fortunately, some advances were made in Europe this summer: new DORIS site in Höfn, Iceland in place of Reykjavik (commissioned September 24th); reconnaissance in Crete, Greece for an additional station. We thank all the host agencies for their ongoing efforts to keep the DORIS station operating!

Access to DORIS data and products

The NASA CDDIS Data Center stopped providing anonymous ftp services as of 1 November 2020. All users are now requested to use https, and an NASA Earthdata login as a method of access to the CDDIS archive. Instructions and example links are available here: **https://cddis.nasa.gov/Data_and_Derived_Products/CDDIS_Archive_Access.html**
Unencrypted anonymous ftp services are still available at IGN Data Center for the time being: **ftp://doris.ign.fr/**

Coming soon: Near-real-time DORIS data and DIODE orbits

The near-real-time (NRT) distribution of DORIS/RINEX data and DIODE orbits from Jason-3 satellite will be available in the near future. These NRT products will be delivered initially to the IGN Data Center; a test and evaluation period will follow before the availability of NRT products is extended to other missions. Interested persons should contact Pascale Ferrage (CNES) or Denise Dettmering (DGFI/TUM) for more information.

IGN DORIS Analysis Center

Arnaud Pollet and Samuel Nahmani will lead the IGN/DORIS Analysis Center activities following the retirement of Pascal Willis.

DORIS Meetings planned for 2021:

- **February.** (Virtual) Meeting of Analysis Centers and Associate Analysis Centers. Subject: update on ITRF2020.
- **Late March to early April 2021.** (Virtual) Analysis Working Group meeting.
- **Late May, early June 2021.** (Virtual) IDS School on DORIS data and products (postponed from May 2020).
- **October 18-20,** Venice, Italy. IDS Workshop associated with Ocean Surface Topography Science Team (OSTST) meeting: **https://ostst-altimetry-2021.com/**

Some noteworthy DORIS-related publications in 2020

1. Bertiger, W., Bar-Sever, Y., Dorsey, A., et al. (2020). “GipsyX/RTGx, a new tool set for space geodetic operations and research”, *Adv. Space Res.*, 66(3), 469-489, doi:10.1016/j.asr.2020.04.015.

2. Zhou, C.C., Zhong, S.M., and Peng, B.B., et al. (2020). “Real-time orbit determination of Low Earth orbit satellite based on RINEX/DORIS 3.0 phase data and spaceborne GPS data”, *Adv. Space Res., 66(7),* 1700-1712, doi:10.1016/j.asr.2020.06.027.

3. Hernandez-Pajeres, M., Lyu, H.X., Garcia-Fernandez, M. and R. Orus-Perez (2020). “A new way of improving global ionospheric maps by ionospheric tomography: consistent combination of multi-GNSS and multi-space geodetic dual-frequency measurements gathered from vessel-, LEO- and ground-based receivers”, *J. Geodesy, 94(8),* 73, doi:10.1007/s00190-020-01397-1

4. Stepanek, P., Bingbing, D., Filler, V. and U. Hugentobler, (2020). “Inclusion of GPS clock estimates for satellites Sentinel-3A/3B in DORIS geodetic solutions”, *J. Geodesy, 94:116,* doi:10.1007/s00190-020-01428-x.

5. Beutler, G., Villager, A., Dach, R., Verdun, A., and A. Jäggi (2020). “Long polar motion series: Facts and insights”, *Adv. Space Res., 66(11),* 2487-2515, doi: 10.1016/j.asr.2020.08.033.

A full list of articles related to DORIS published since 1985 is available on the IDS website at https://ids-doris.org/ids/reports-mails/doris-bibliography/peer-reviewed-journals.html

PASCAL WILLIS RETIRES

After a long and active career promoting analysis and use of DORIS data in geodesy, Dr. Pascal Willis retired from the Institut Géographique National (IGN) in April 2020. Pascal and his wife, Michèle have retired to their new domicile, near La Rochelle, France. Pascal remains active as Editor-in-Chief of the journal, Advances in Space Research. In this capacity, people in the DORIS community can continue to take advantage of his advice and suggestions regarding the research they would like to publish.

Pascal received degrees as engineer from the École Polytechnique (1983) and the École Nationale des Sciences Géographiques (1986). In 1989, he received his Ph.D from the Paris Observatory with a thesis focused on "The Static and Kinematic Applications of GPS for Geodesy". He received his "Habilitation à Diriger des Recherches (HDR)" in 2003 from the Université Pierre et Marie Curie (Paris VI)[1]. His initial professional work was with GPS, but he became more focused on the analysis of DORIS data starting with the TOPEX/Poseidon mission. His work concentrated on how to apply methodological improvements to the analysis of DORIS data and the development of better DORIS-derived geophysical products. He worked to improve precise orbit determination with DORIS data throughout his career. Pascal directed an analysis center for DORIS at the IGN that regularly submitted geophysical products and contributed to ITRF realizations. He worked to interpret the time series of coordinates for science and geophysics. He also worked to promote new products from DORIS data, collaborating with researchers to promote DORIS as a tool for to use troposphere delays for climate studies. As part of his research activities he co-directed or directed the Ph.D work of Jean-François Crétaux (Ph.D, 1993), Laurent Morel (Ph.D, 2001), Stéphane Durand (Ph.D, 2003) and Marie-Line Gobinddass (Ph.D, 2010).

A career devoted to geodesy

Pascal Willis forged a tight collaboration with the Jet Propulsion Laboratory (JPL) from the early days of the TOPEX/Poseidon mission. He used the JPL GIPSY/OASIS II software to process DORIS data, working closely with JPL to maintain and continually improve this capability. He worked at JPL as a visiting scientist from 2001-2006, and in recent years collaborated with Dr. William Bertiger and other scientists at JPL to validate the processing of DORIS/RINEX data in the new JPL GipsyX software.

Pascal Willis was one of the co-founders of the International DORIS Service (IDS) in 2003, and served on the Governing Board as Analysis Centers' Representative. In this capacity, he was elected and served as Chairperson from 2009 to 2016. Throughout his career, Pascal worked tirelessly to promote and improve the contribution of DORIS as one of the four techniques of space geodesy.

Pascal's non-DORIS professional contributions also included being an early advocate of the scientific contributions of other GNSS constellations (GLONASS & Galileo). He led the IGEX-98 campaign for GLONASS as part of his responsibilities being a member, at the time, of the Governing Board of the (then) International GPS Service (IGS). As a guest editor for GLONASS and Galileo special issues in the Journal of Geodesy (2000-2001) and Advances in Space Research (2009-2010) he helped to elevate the contributions of these navigation systems in the scientific community. Since 1995 Pascal has served continuously as an Associate Editor or Guest Editor for different scientific journals and International Association Geodesy (IAG) proceedings volumes. Many readers will be familiar with this pointed and detailed reviews of their papers, always aimed to improving the quality of science communication.

We will miss Pascal as a regular participant in the IDS. We congratulate Pascal on his retirement and wish both him and his wife Michèle enjoyable and exciting explorations in the coming years.

1. In some countries (such as France) a "Habilitation" is required to conduct university teaching, direct research or become a university professor.

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