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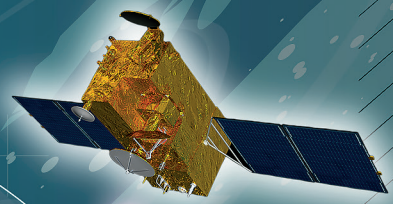
IDS

ACTIVITY REPORT 2021

International Doris Service



International DORIS Service Activity Report 2021

Edited by Laurent Soudarin and Pascale Ferrage

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International DORIS Service

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Preface

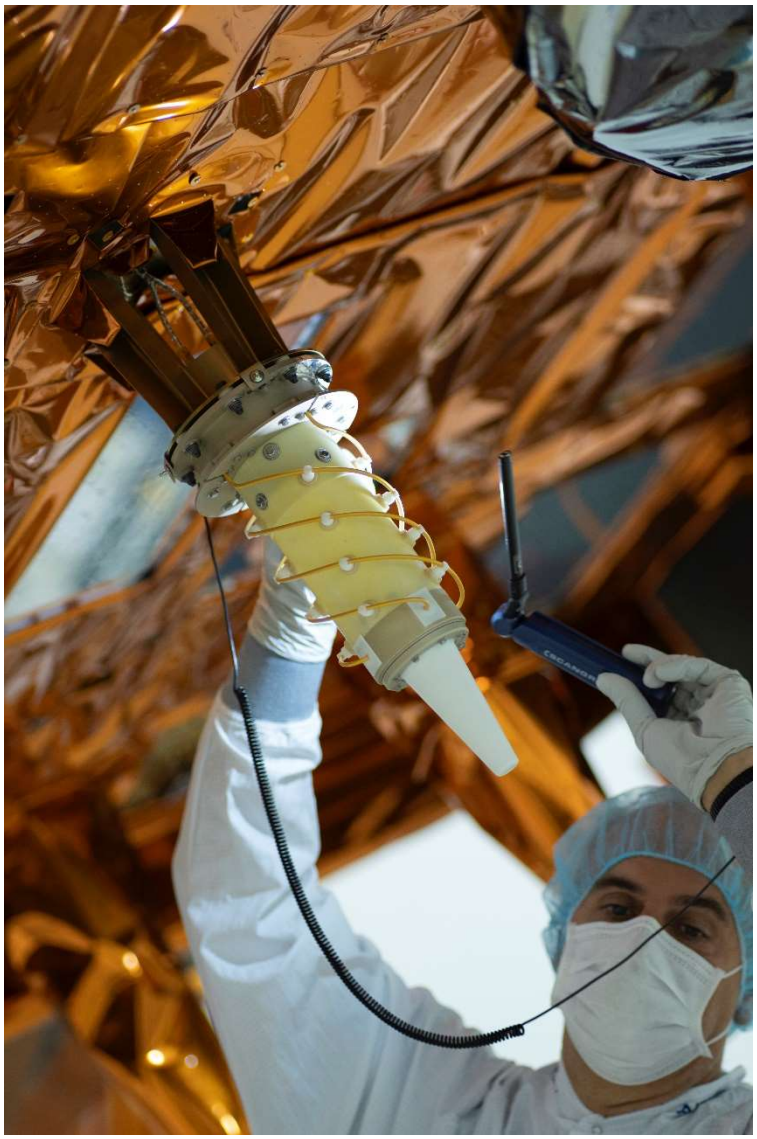
In this volume, the International DORIS Service documents the work of the IDS components between January 2021 and December 2021. The individual reports were contributed by IDS groups in the international geodetic community who make up the permanent components of IDS.

The IDS 2021 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 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_2021.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, then Sentinel-3B in 2018, 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. The years 2019 and 2020 were devoted to preparing and then carrying out the reprocessing of the DORIS data for the ITRF2020. Thanks to the efforts of the Analysis Centers whose activities were deeply affected by the COVID pandemic for two years, the Combination Centre delivered in 2021 the combined DORIS solution contributing to the ITRF2020 realization.

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 2021, a meeting of the Analysis Working Group was organized and held online.

In addition, for the first time, the IDS organized a special event called “DORIS Days" on November 16, 17 and 18, 2021. This event held online was an introductory course to give non-practitioners in DORIS the opportunity to broaden their knowledge of the DORIS technique as well as to provide information on IDS products.

Date	Event	Location
2000	DORIS Days http://ids-doris.org/ids/reports-mails/meeting-presentations/doris-days-2000.html	Toulouse France
2002	IDS workshop http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-workshop-2002.html	Biarritz France
2003	IDS Analysis Workshop http://ids-doris.org/ids/reports-mails/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/ids/reports-mails/meeting-presentations/ids-plenary-meeting-2004.html	Paris France
2006	IDS workshop http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-workshop-2006.html	Venice Italy
2008	Analysis Working Group Meeting http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-03-2008.html Analysis Working Group Meeting http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-06-2008.html IDS workshop http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-workshop-2008.html	Paris France Paris France Nice France
2009	Analysis Working Group Meeting http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-03-2009.html	Paris France
2010	Analysis Working Group Meeting http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-03-2009.html IDS workshop & 20th anniversary of the DORIS system http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-workshop-2010.html	Darmstadt Germany Lisbon Portugal
2011	Analysis Working Group Meeting http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-05-2011.html	Paris France
2012	Analysis Working Group Meeting http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-05-2012.html IDS workshop http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-workshop-2012.html	Prague Czech Republic Venice Italy

Date	Event	Location
2013	Analysis Working Group Meeting http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-04-2013.html Analysis Working Group Meeting http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-10-2013.html	Toulouse France Washington USA
2014	Analysis Working Group Meeting http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-03-2014.html IDS workshop http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-workshop-2014.html	Paris France Konstanz Germany
2015	Analysis Working Group Meeting http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-05-2015.html Analysis Working Group Meeting http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-10-2015.html	Toulouse France Greenbelt USA
2016	Analysis Working Group Meeting http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-05-2016.html IDS workshop http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-workshop-2016.html	Delft The Netherlands La Rochelle France
2017	Analysis Working Group Meeting https://ids-doris.org/ids/ids/reports-mailss-mails/meeting-presentations/ids-awg-05-2017.html	London United Kingdom
2018	Analysis Working Group Meeting http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-06-2018.html IDS workshop http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-workshop-2018.html	Toulouse France Ponta Delgada Portugal
2019	Analysis Working Group Meeting http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-04-2019.html Analysis Working Group Meeting http://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-09-2019.html	Munich Germany Paris France
2021	Analysis Working Group Meeting https://ids-doris.org/ids/reports-mails/meeting-presentations/ids-awg-04-2021.html DORIS days 2021 https://ids-doris.org/ids/reports-mails/meeting-presentations/doris-day-2021.html	online online

Table 2. List of IDS events organized between 2004 and 2021.

3 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**).

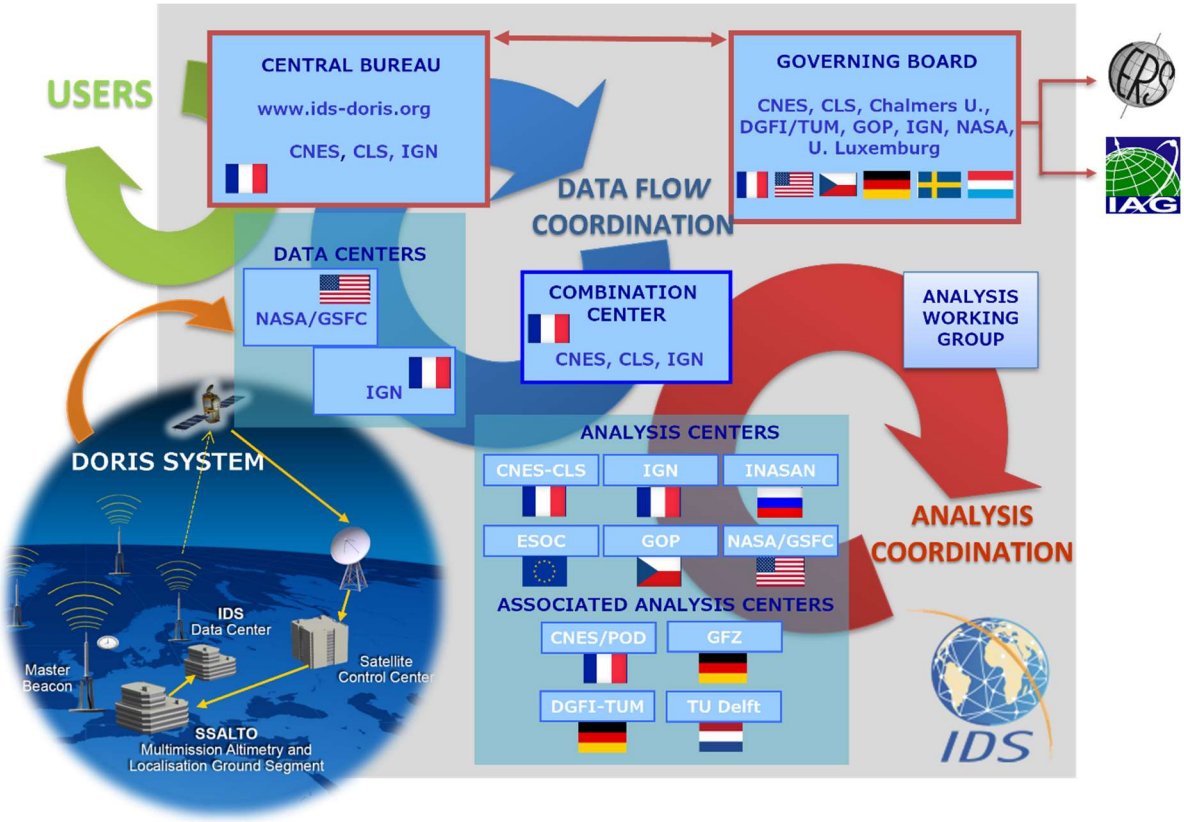


Figure 1. IDS organization.

3.1 GOVERNING BOARD

The principal role of the Governing Board (GB) is to set policy and to exercise broad oversight of all IDS functions and components. It also controls general activities of the Service, including restructuring, when appropriate, to maintain Service efficiency and reliability.

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 will be partially renewed in January 2023 and January 2025.

Table 3 gives the list of the GB's members since 2003, the members in office on January 1st, 2021, indicated in bold. Denise Dettmering is an ex officio member of the IDS GB, in the role of Chair of the IDS Working Group on Near Real Time Data.

3.2 REPRESENTATIVES AND DELEGATES

IDS representatives and delegates are:

- IDS representatives to the IERS:
  - Analysis Coordinator: Hugues Capdeville and Petr Štěpánek
  - Network representative: Jérôme Saunier
- IDS representative to GGOS Bureau of Networks and Observations: Jérôme Saunier
- IDS representatives to GGOS Bureau of Products and Standards: Petr Štěpánek

3.3 CENTRAL BUREAU

In 2021, the IDS Central Bureau is organized as follow:

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

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 Obs.*	*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*
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*

Position	Term	Status	Name	Affiliation	Country
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. Texas/CSR*	*USA*
	2009-2012	*E.b.GB*	*John Ries*	*Univ. Texas/CSR*	*USA*
	2003-2008		*John Ries*	*Univ. Texas/CSR*	*USA*
Member at large	**2021-2024**	Elected	**Karine Le Bail**	Chalmers Univ. 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 Central Bureau	Since 2003	Appointed	**Laurent Soudarin**	CLS	France
Combination Center representative	Since 2013	Appointed	**Guilhem Moreaux**	CLS	France
Network representative	**2021-2024**	Appointed	**Jérôme Saunier**	IGN	France
	2017-2020	*Appointed*	*Jérôme Saunier*	*IGN*	*France*
	2013-2016	*Appointed*	*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**	Appointed	**Pascale Ferrage**	CNES	France
	2017-2020	*Appointed*	*Pascale Ferrage*	*CNES*	*France*
	2013-2016	*Appointed*	*Pascale Ferrage*	*CNES*	*France*
IAG representative	**2019-2022**	Appointed	**Ernst Schrama**	TU Delft	The Netherlands
	2017-2018	*Appointed*	*Petr Štěpánek*	*Geodetic Obs. Pecný*	*Czech Republic*
	2013-2016	*Appointed*	*Michiel Otten*	*ESOC*	*Germany*
	2009-2012	*Appointed*	*Michiel Otten*	*ESOC*	*Germany*
	2003-2008		*Not appointed*		
IERS representative	**2021-2024**	Appointed	**Tonie van Dam**	Univ. Luxembourg	Luxembourg
	2017-2020	*Appointed*	*Brian Luzum*	*USNO*	*USA*
	2013-2016	*Appointed*	*Brian Luzum*	*USNO*	*USA*
	2009-2012	*Appointed*	*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

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. IDS GB members since 2003, with members in office on January 1st, 2021, indicated in bold.

DORIS SYSTEM

4 THE NETWORK

Jérôme Saunier / IGN, France

4.1 GENERAL STATUS AND OPERATION

During such a special year marked by the Covid-19 sanitary crisis, the main challenge was to maintain the network stations in operational condition. The maintenance teams managed it quite well and the continuation of the 4th generation beacon deployment enabled to strengthen the network robustness where equipment has been old. On the other hand, it has been more difficult to push forward projects for the network development.

The DORIS network was designed to support satellite altimetry and geodesy with a very homogeneous stations distribution. This infrastructure 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) (**Figure 2)**.

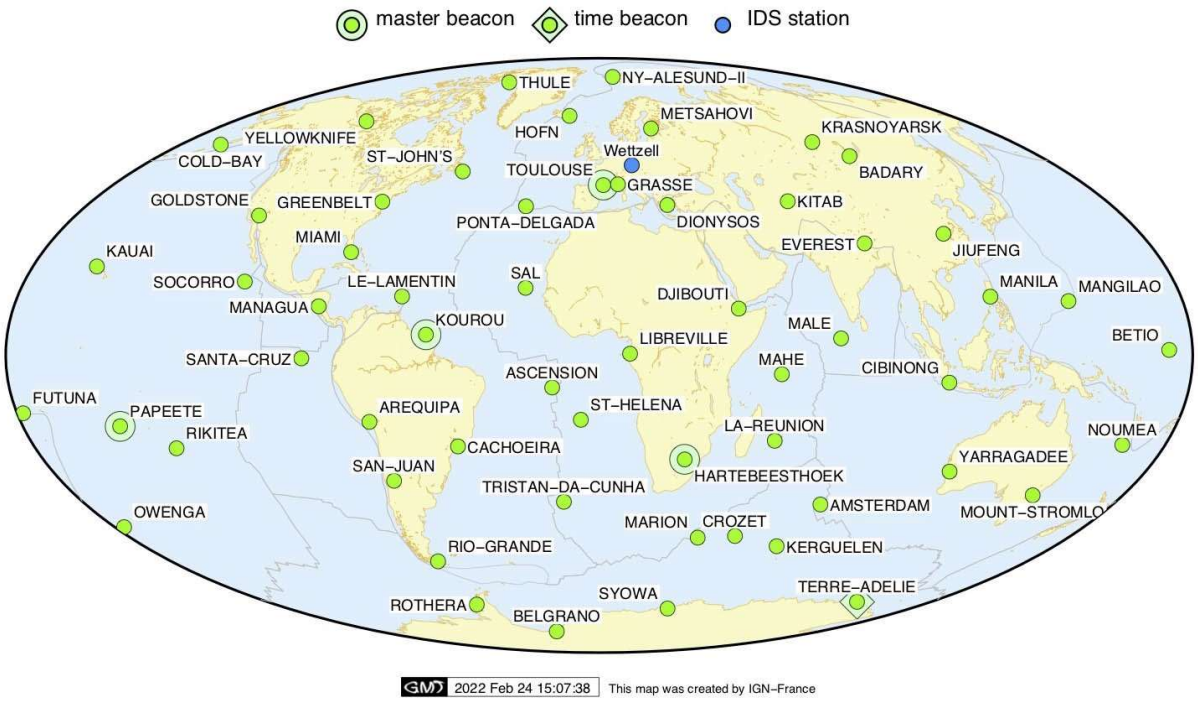


Figure 2. The DORIS permanent network.

Besides the day-to-day maintenance of the network, significant results should be highlighted following lengthy efforts needed to bring some remote stations back into operation. Returned to service in 2021 after long outage: Kerguelen (16 months), Betio (12 months), Rothera (18 months), Badary (38 months), Tristan da Cunha (27 months). 4 stations remained inactive: Futuna, Krasnoyarsk, Ny-Ålesund-II, San Juan (**Figure 3**).

During this year 2021, the DORIS network provided a reliable service with a mean of 83% of active sites over the year (**Figure 4**) through good coordination and complementarity between CNES and IGN teams with the valuable contribution of the local host agencies.

A major renovation was carried out at Malé (Maldives) in September in order to improve performance by relocating the antenna some thirty meters away from the previous location to get a better environment for transmission and by upgrading the equipment with beacon 4.0 and antenna Starec-C.

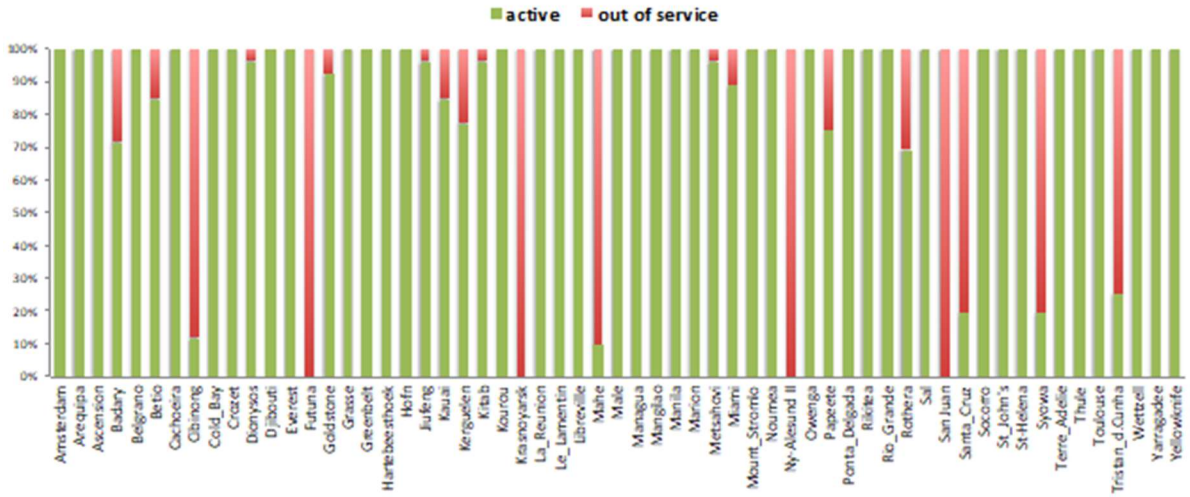


Figure 3. Network stations activity.

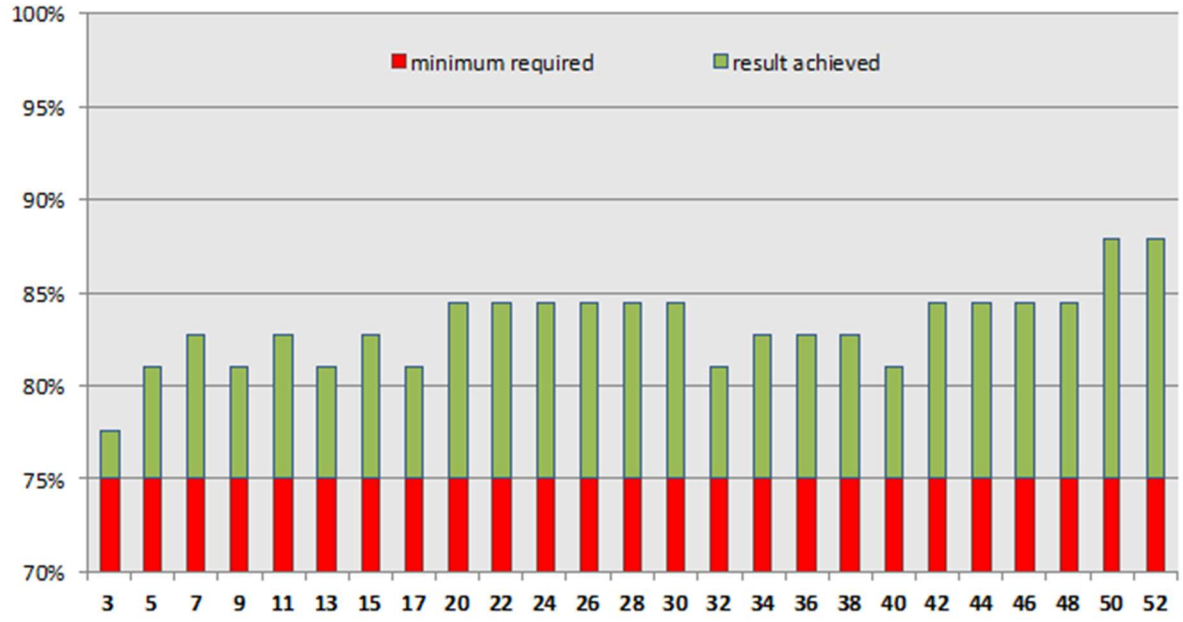


Figure 4. Network availability 2021: Rate of stations in operation (fortnightly statement).

4.2 EVOLUTION AND DEVELOPMENT

The progressive deployment of the 4th generation beacon started in 2019 continued. In addition to architecture improvements, the adding of a signal amplifier at the foot of the antenna to restore the signal to its nominal power after the signal losses during long cable transfer enables increasing the beacon-antenna distance (which was extended from 15 to 50 m) and thus, this provides better options for antenna placement in an open environment, a major criterion for obtaining good observations. Several antenna relocations in the framework of the 4th generation beacon deployment are planned in the coming years to get enhanced visibility. At the end of 2021, 35% of the network stations are equipped with the 4th generation beacon (B4G) and Starec-C antenna.

The densification of the network to have 70 stations is underway with a number of projects near completion. 5 additional sites should be operational in the next two years. The aim is to enhance the network reliability and coverage and to better contribute to geodesy.

The co-location with other space geodetic techniques is also of great interest for geodesy. 49 DORIS stations out of 59 are co-located with at least one other IERS technique: GNSS, SLR, and/or VLBI. Half of the DORIS stations are also co-located with tide gauges enabling better monitoring of the vertical land movement (**Figure 5**). IGN systematically carries out local tie surveys on the occasion of installations, renovations or dedicated visits on site to contribute to ITRF realizations. 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.

It is also worth noting the long-term life of the DORIS stations: At the end of 2021, half of the current network stations are over 27 years old with 20 of them in continuous operation since the beginning of the DORIS system (1990).

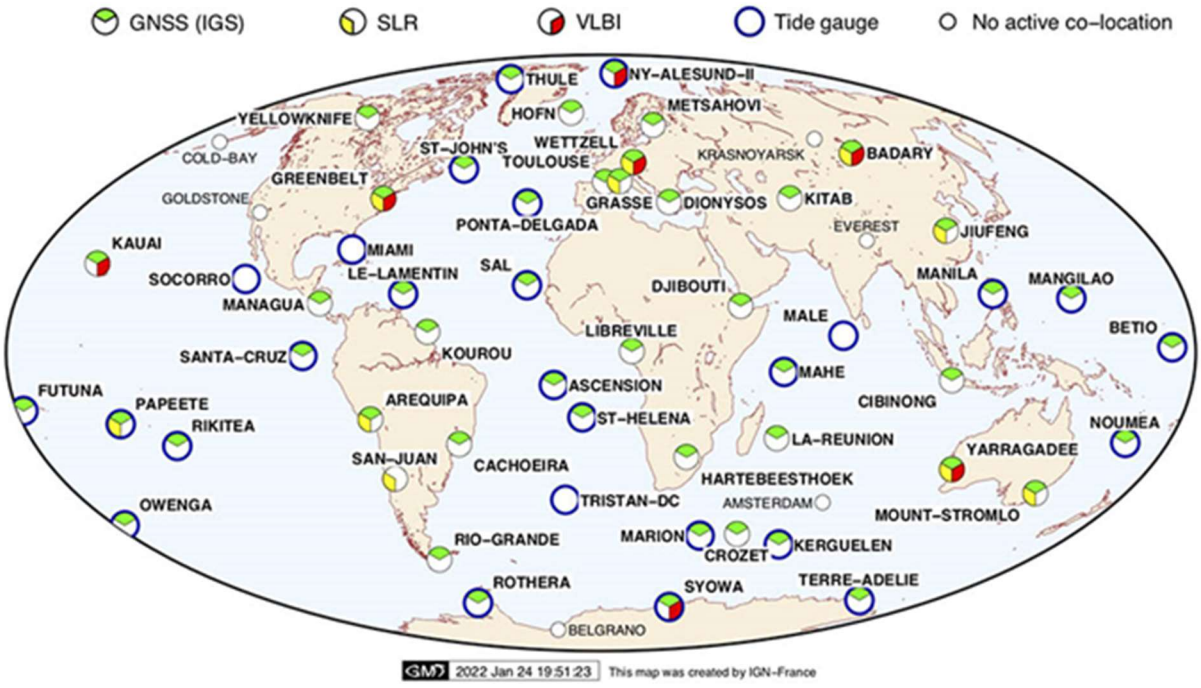


Figure 5. DORIS stations co-located with other IERS techniques and tide gauges.

In 2021 the following DORIS sites were visited:

- Maintenance at La Réunion (France, Western Indian Ocean)
- B4G installing at Metsahovi (Finland)
- Antenna relocation at Malé (Maldives)
- B4G installing at Mahé (Seychelles)

In 2022, the overall objectives are:

- Continuation of the deployment of the 4th generation beacon
- Call for interest in hosting an IDS station (with scientific objectives)
- Restarting at San Juan (Argentina), Ny-Alesund-II (Svalbard), Santa-Cruz (Galapagos)
- Installation of new DORIS site in Gavdos Island (Crete, Greece)
- Installation of new DORIS site at Katherine (Australia)
- Relocation of the DORIS station at Easter Island (Chile)
- Renovation at Rikitea (French Polynesia) or Sal (Cabo Verde)

5 THE SATELLITES WITH DORIS RECEIVERS

Pascale Ferrage / CNES, France

As described in **Table 4**, the HY-2D China's National Satellite Ocean Application Service (NSOAS) has been launched in 2022. Since then, 8 satellites have been in operation in the DORIS constellation, all equipped with 7-channel DGXX-S DORIS on-board receiver, at altitudes between 720 and 1336 km, with near-polar or TOPEX-like inclination (66 deg).

In the next few years, more DORIS satellites are planned: SWOT (Surface Water Ocean Topography), Sentinel-3C and 3D, HY-2E, Sentinel-6B, ….

Figure 6 and **Figure 7** summarize 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.

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
HY-2D	19-MAY-2021	PRESENT	CNSA, NSOAS	Altimetry

Table 4. DORIS data available at IDS data centers, as of December 2021.

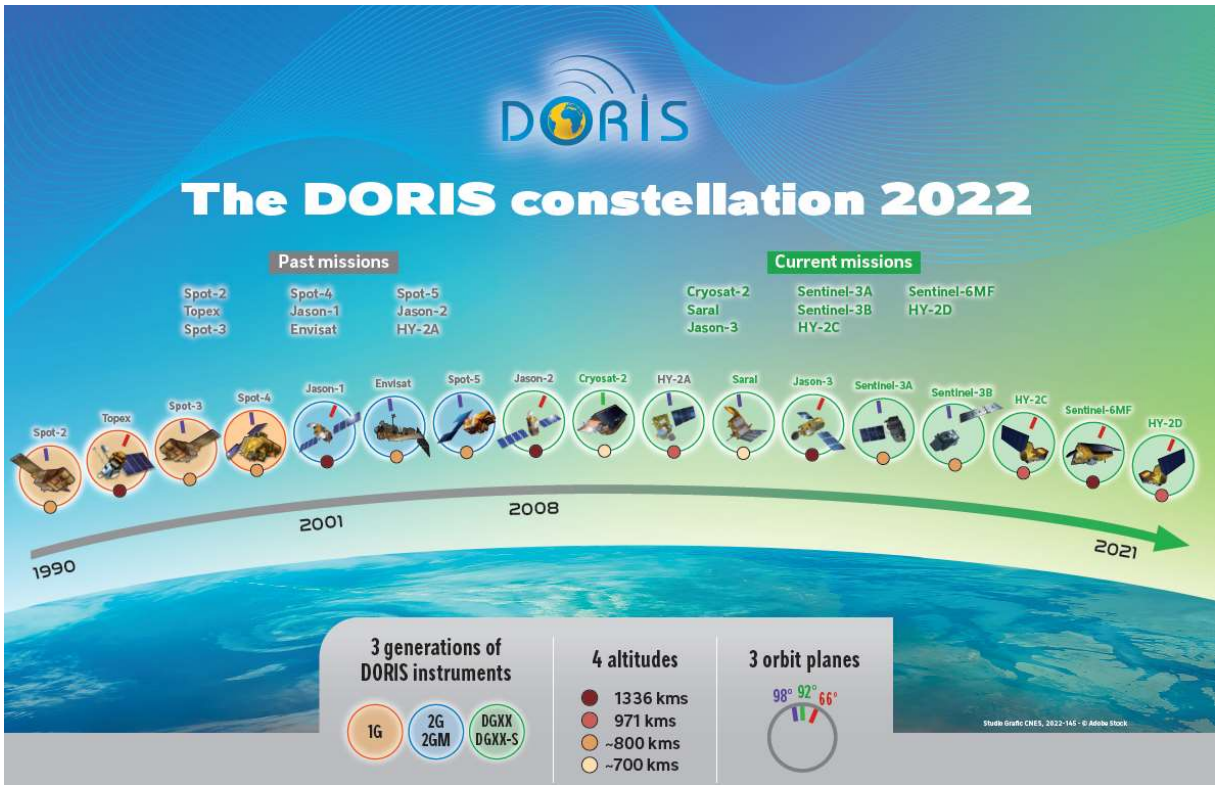


Figure 6. DORIS satellite constellation & evolution. As of December 2021.

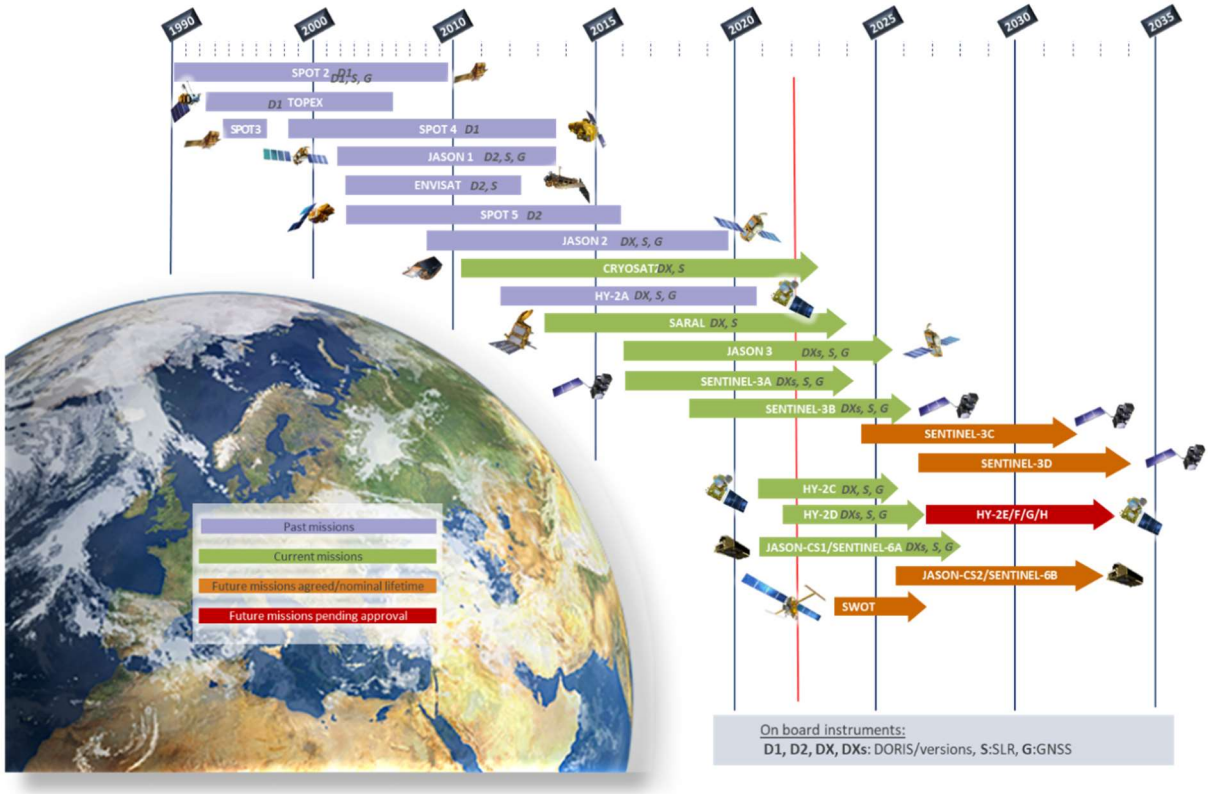


Figure 7. Past, current and future missions with DORIS. As of December 2021.

USER SERVICE

6 CENTRAL BUREAU

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

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. This report summarizes the activities of the IDS Central Bureau during the year 2021. An overview of the IDS information system is reminded in appendix.

6.1 MEETINGS

The Central Bureau participated in the organization of the AWG meeting held on April 6 and 7, 2021. It documented the Governing Board meetings held in 2021, on January 26, June 29, October 21. 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 DORIS DAYS 2021

The IDS organized online “DORIS Days" on November 16, 17 and 18, 2021. This event was an introductory course to give non-practitioners in DORIS the opportunity to broaden their knowledge of the DORIS technique as well as to provide information on IDS products.

Three sessions were given online:

- "Introduction to DORIS and the International DORIS Service" (118 participants)
- "Overview of Products Derived from DORIS" (90 participants)
- "Description DORIS Station Installation and Operations Requirements" (70 participants)

The complete program is available on the IDS website at https://ids-doris.org/ids/reports-mails/meeting-presentations/doris-day-2021.html.

This event widely mobilized the members of the Governing Board and the Central Bureau. The organization committee was composed of Pascale Ferrage, Karine Le Bail, Frank Lemoine, Guilhem Moreaux, Jérôme Saunier, Ernst Schrama, Laurent Soudarin. Several external speakers gave presentations in the form of ppt slides or pre-recorded videos.

Prior to the days, the Central Bureau and the organization committee carried out the following actions:

- Preparation of the material: logo mock-up, presentation template, final version of the wallpaper for Teams, pdf of the presentations.
- Communication about the event: dedicated page on the IDS website, announcements on DORISmails and other mailing lists, ...
- Registration management: registration form, follow-up of registrations, sending of confirmation emails.
- Management of online meetings with MS Teams: sending invitations, test sessions with speakers, technical support during sessions, retrieving attendance statistics, recording sessions.
- Forum management: setting up the https://dorisdays2021.aviso.altimetry.fr/ sub-site, configuration, creation of accounts, uploading of presentations and videos, user support.

6.3 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 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).

IDS Newsletter # 9 was published in September 2021. It is available on the website at:

https://ids-doris.org/images/documents/newsletters/IDS-Newsletter9.pdf

It contains the following articles:

- A new method for monitoring the geocenter motion using DORIS observations (A. Couhert, CNES)
- Doppler crossings on-board DORIS receiver carrier satellites (C. Jayles, CNES, J.P. Chauveau, CLS, P. Yaya, CLS)
- Major renovation at Réunion Island (J. Saunier, IGN)
- La Réunion: the host agency in short (P. Kowalski, OVPF)
- The 4th generation of DORIS beacon (J. Saunier, IGN)
- IDS life
- HY-2D, a new DORIS carrier satellite

The published newsletters and their contents are listed in **Newsletters.**

6.4 REPORTS

The CB managed the edition and publication of the IDS Activity Report 2019-2020. It also produced the IDS contributions to IAG report for the period from the middle of 2019 to the end of 2020.

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

6.5 DORIS-RELATED ARTICLES IN PEER-REVIEWED JOURNALS

A new web-based tool for the management and consultation of the DORIS bibliography has been implemented on the IDS website. All references are stored in a database. The web component of the tool deployed on the page https://ids-doris.org/ids/reports-mails/doris-bibliography/peer-reviewed-journals.html allows dynamic display of the references and offers search functionalities by filter. The administration part of the tool consists of an input interface for ingesting references and a dashboard providing statistics on the content of the database.

6.6 DOI ASSIGNATION

The Central Office has the possibility to rely on the CNES DOI service to assign DOIs to IDS documents and products. A DOI has been assigned to the IDS16 solution contributing to ITRF2020: 10.24400/312072/i01-2021.001

By resolving the DOI using https://doi.org/10.24400/312072/i01-2021.001, the users are redirected to the landing page https://ids-doris.org/analysis-coordination/combination/contributions-to-itrf/itrf2020.html where they can find information about the solution.

An IDS DOI Committee has been set up (Patrick Michael, Frank Lemoine, Guilhem Moreaux, Jérôme Saunier, Laurent Soudarin). It met online on October 22.

The Central Bureau also participates in the meetings of the GGOS DOI Working Group

6.7 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 mission HY-2D were put online the IDS data and information sites as they become available.

6.8 IDS WEBSITES

The Central Bureau maintains the web resources of the IDS. Besides the IDS website (https://ids-doris.org), dedicated sub-sites have been created on the Aviso+ Meetings portal (https://meetings.aviso.altimetry.fr):

- https://dorisdays2021.aviso.altimetry.fr/

This sub-site has been created for the needs of the DORIS 2021 days. It offers a forum space with the possibility of questions/answers for each presentation (authenticated access with user account)

Its configuration includes:

- creation of an account for all persons registered for the event
- deposit of course materials (pdf, videos, ...)

- https://idsworkshop.aviso.altimetry.fr/

It is dedicated to the IDS Workshop. It offers the following functionalities:

- registration for a user account
- abstract submission (authenticated access with user account)
- management of abstracts and organization of the program (administration part)
- organization of the forum area (administration part)
- forum area with possibility of questions/answers for each presentation (authenticated access with user account)

- https://idsawg.aviso.altimetry.fr/

This sub-site is reserved for the members of the analysis Working Group. It offers a space for discussion on topics of interest to the group. In particular, the presentations and exchanges of the AWG meeting of 6 and 7 April are accessible there.

6.9 IDS FTP SERVER

The documents and files put on the IDS ftp site in 2021 are listed hereafter.

New documents:

- « Sentinel-6A POD context »

ftp://ftp.ids-doris.org/pub/ids/satellites/Sentinel6A_PODcontext.pdf

- « HY-2C input data for Precise Orbit Determination »

ftp://ftp.ids-doris.org/pub/ids/satellites/HY2C_InputDataForPOD.pdf

Updated documents:

- «Radio-frequency characteristics of the DORIS beacon »

ftp://ftp.ids-doris.org/pub/ids/stations/DORIS_beacon_RF_characteristics.pdf

- « Modelling of the ground beacons and ground antennas »

ftp://ftp.ids-doris.org/pub/ids/stations/DORIS_System_Ground_Segment_Models.pdf

Updated files:

- Ties between DORIS and other technics

ftp://ftp.ids-doris.org/pub/ids/stations/DORIS_ext_ties.txt

- DORIS internal ties

ftp://ftp.ids-doris.org/pub/ids/stations/DORIS_int_ties.txt

7 IDS DATA FLOW COORDINATION

Patrick Michael / NASA GSFC, USA

7.1 INTRODUCTION

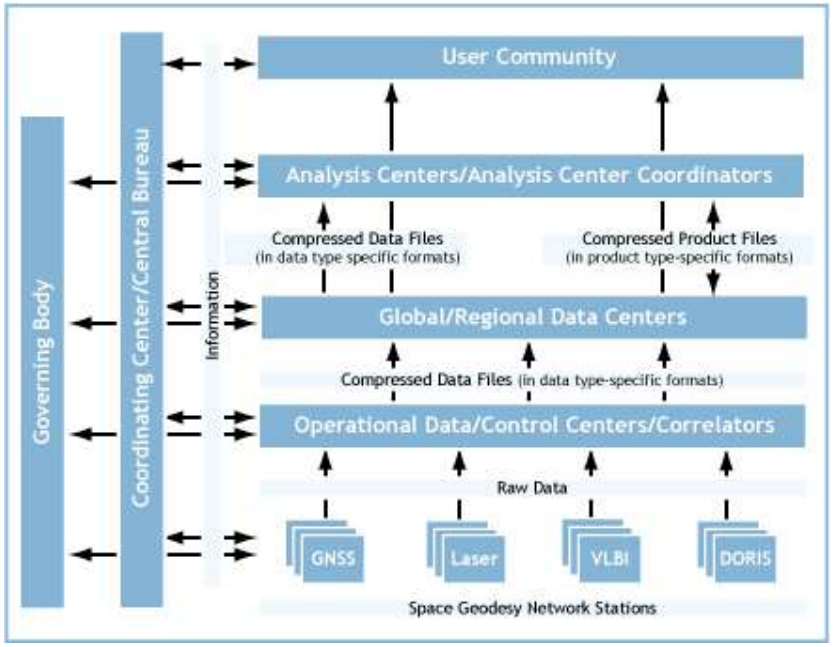
Two data centers support the archiving and access activities for the IDS:

- 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, atmospheric 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.

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*/*ccc**sss**VV.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*/*ccc**sss**VV.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*	Spacecraft body quaternions for satellite *sss*, year *yyyy*, start date/time *YYYYMMDDHHMISS*, end date/time *yyyymmddhhmiss*, and version number *LLL*
	sss/qsolp*YYYYMMDDHHMISS_yyyymmddhhmiss.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.

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/struct-dc.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 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.

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, HY-2A, Jason-2, Jason-3, SARAL, Sentinel-3A, and Sentinel-3B); data from future missions will also be archived within the IDS. Historic data from Envisat, Jason-1, SPOT-2, -3, -4, -5, and TOPEX/Poseidon, 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 2.1 (since January 15, 2002). 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.

DORIS phase data from CryoSat-2, HY-2A, Jason-2, Jason-3, SARAL, and Sentinel 3A and -3B 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 Jason-3 and Sentinel 3A and -3B 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/campdata/saacorrection/ja1
https://cddis.nasa.gov/archive/doris/campdata/saacorrection/sp5

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
HY-2D	15-May-2021 through present	RINEX
Jason-1	15-Jan-2002 through 21-Jun-2013	Multi-day
Jason-2	12-Jul-2008 through 10-0ct-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.

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 2005-2021 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

The CDDIS and IGN provide reports that list holdings of DORIS data in the DORIS format. The IDS data centers will also investigate procedures to regularly compare holdings of data and products to ensure that the archives are truly identical.

8 IDS DATA CENTERS

8.1 CRUSTAL DYNAMICS DATA INFORMATION SYSTEM (CDDIS)

Patrick Michael / 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 2021, the CDDIS has devoted nearly 140 GB of disk space (77GB or ~55% for DORIS data, 37GB or ~27% for DORIS products, and 25GB or ~18% for DORIS ancillary data and information) to the archive of DORIS data, products, and information (**Figure 9**). During the past year, users downloaded approximately 1911 Gbytes (788,000 files) of DORIS data, products, and information from the CDDIS (**Figure 10**).

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, https://cddis.nasa.gov/archive/doris/data.

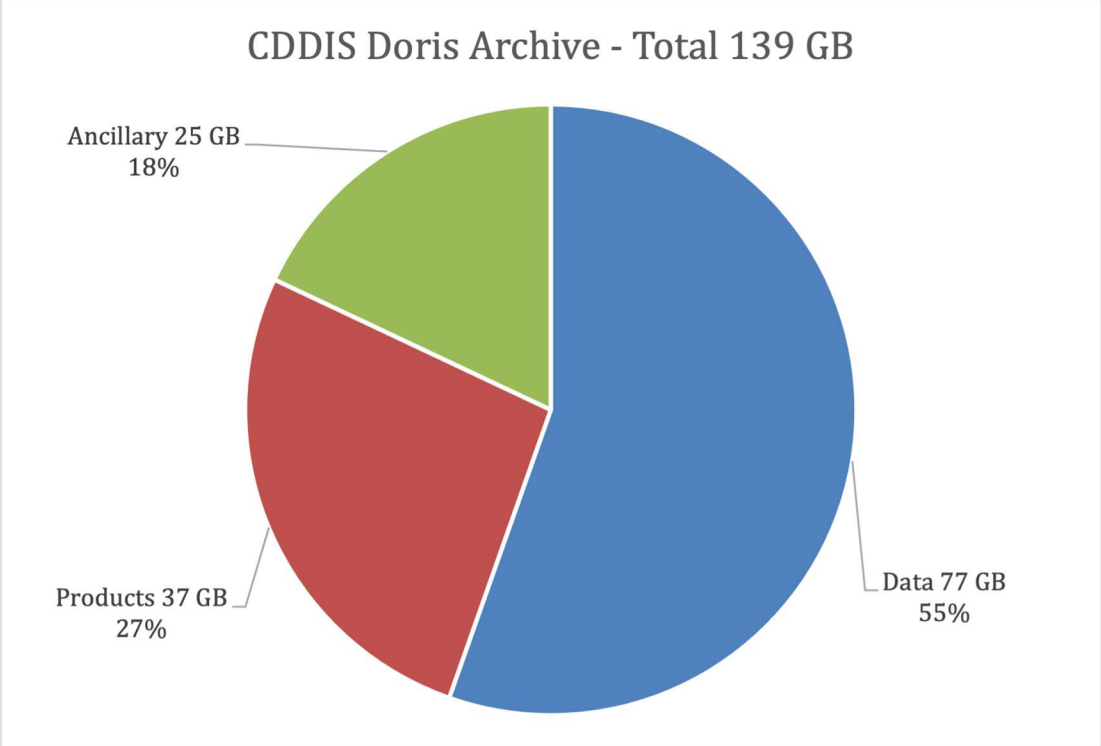


Figure 9. CDDIS DORIS archive.

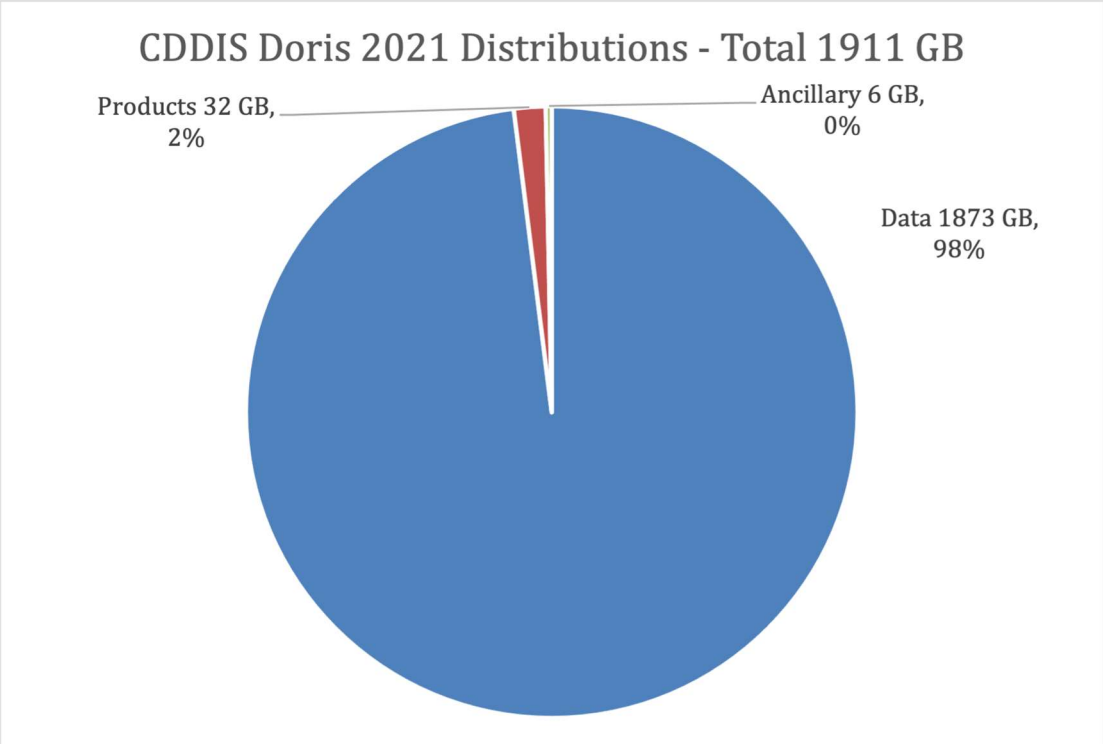


Figure 10. CDDIS DORIS 2021 distributions.

8.1.3 RECENT ACTIVITIES AND DEVELOPMENTS

No major recent activities were completed in 2021.

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 it's 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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Voice: 301-286-2887
Fax: 301-614-6015

WWW: https://cddis.nasa.gov
Archive access: 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 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
- 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 150 Go for DORIS and the IDS, including data, products, metadata and information. In 2021, regarding IDS section, the number of visits to the data center doubled compared to past years, reaching 5267 visits, with 159 Go (305 641 files) of DORIS data downloaded by the users.
A couple of hours (short outages) were devoted for maintenance activities but with continuous service thanks to the redundant IGN data center remaining available during the breakdown.
The interface with the IDS Central Bureau, Combination Center and Analysis Centers enabled reliable provision of data and products. The CNES tool scanning the whole tree structure checked the SSALTO data deliveries (orbits, RINEX, quaternions) regularly to detect missing files and anomalies, and remedial actions were carried out forthwith.
Finally, a new satellite was implemented at the end of 2021: HY-2D.

8.2.4 MAINTENANCE AND DEVELOPMENT

Following the IDS Retreat in 2019, the provision of Near-Real-Time DORIS data and products was decided. A first experience has been set up at the beginning of 2021 with the IGN Data Center: Jason-3 RINEX data and Diode orbits are distributed with a latency of about 3 hours. First feedback from the WG “NRT DORIS Data” (see Analysis Activities section) was quite positive: DORIS data latency up to 2-3 hours enables contributing to the ultra-rapid ionosphere VTEC modeling; files structure improvements were requested but all may not be taken into account because it will impact the logical organization of the directory structure.

Regarding hardware enhancement, the replacement and the virtualization of the deposit server at Saint-Mandé carried out in September 2021 will facilitate maintenance and improve the server efficiency.

As regards the prospects for 2022-2023, the IGN Data Center planned the separation of server infrastructure between GNSS data and DORIS data to have full projects independence and avoid mutual interferences. On this occasion, the IGN IDS Data Center can evolve more easily.

8.2.5 CONTACT

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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 year 2021 were deeply affected by COVID pandemic. A realization of the ITRF2020 DORIS data re-processing dominated in first half of the year. One Analysis Working Group meeting was held online in April 2021.

9.2 ANALYSIS WORKING GROUP MEETING

The only one Analysis Working Group (AWG) meeting in 2021 was held online on 6 and 7 April. The meeting program consisted of three presentation blocks: Doris system session, ITRF re-processing session and open session. Doris system session traditionally started with “IDS news” by Laurent Soudarin. Then the “Status of DORIS system” by Pascale Ferrage followed. “DORIS network status” by Jerome Saunier closed the session. We can highlight the information about confirmed future DORIS satellite missions SWOT and Sentinel-3C, -3D and -6B, and the development of new DORIS receivers: “New receiver design (T-DMS) and ongoing study of joint DORIS/GNSS receiver”.
The ITRF reprocessing session started by Zuheir Altamimi’s presentation “Status of ITRF2020 and IDS combination”. The session then continued with “IDS contribution to ITRF2020” by Guilhem Moreaux. The rest of the session was filled by Analysis centers (ACs) reports: GFZ (Patrick Schreiner), GSC (Frank G. Lemoine), GOP (Petr Štěpánek) and GRG (Hugues Capdeville). Zuheir Altamimi pointed out non-linearity of the IDS origin and scale to be investigated. Guilhem Moreaux presented a recent status of the IDS ITRF2020 combination, which was ready on time with the IERS deadline. In comparison to IDS ITRF2014 solutions, the ITRF2020 solution performs better in TX and TY series (reduction of 118 days draconitic signal) and in the station positioning WRMS.
The open session included four presentations. At the beginning, Sergei Rudenko presented "On the recent activities of the IDS Associate Analysis Center at DGFI-TUM". Then two POD presentation by Alexandre Couhert followed, "First POD Results on HY-2C" and "First POD Results on Sentinel-6A". The final presentation by Petr Štěpánek was devoted to "Sentinel-3A and Sentinel-3B SAA effects". The analysis of the Sentinel-6A clock behavior detected a very significant South Atlantic Anomaly (SAA) effect. The Ultra Stable Oscillator (USO) sensitivity of Sentinel-3A and Sentinel-3B is not mutually similar, but differs even in the sign, as well as in the basic characteristics of the memory and recovery effects.

9.3 ANALYSIS CENTERS AND ASSOCIATED ANALYSIS CENTERS

Recently, three ACs fully participate in operational solutions (GSC, GRG, GOP). In the ITRF reprocessing, the ESA AC participated in addition. ACs IGN and INA are not active. IGN center has not yet restarted after the retirement of its long- time responsible Pascal Willis. INA center has problems with a new software package development. The IDS is in contact with responsible people, but no progress was reached to get these two ACs back to the operational status.
The Associated Analysis center (AAC) GFZ contributed to ITRF2022 by testing series processing data from chosen set of satellites. DGFI-TUM AAC has been active in the satellite attitude modeling and the evaluation of reference frames. CNES AAC continues in the POD solutions, including new satellites Sentinel-6A and HY-2C. **Table 8** includes the summary of the ACs ad AACs.

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

Table 8. IDS ACs and AACs in 2021.

9.4 PLANS FOR NEXT AWG MEETING

Next AWG meeting is planned in the second or third decade of June. The meeting will be organized in online form.

10 COMBINATION CENTER

Guilhem Moreaux / CLS, France

10.1 ACTIVITY SUMMARY

In addition to the routine evaluation and combination of the IDS AC solutions, the year 2021 was mostly devoted to the realization of the IDS contribution to the ITRF2020.

10.2 IDS ROUTINE EVALUATION AND COMBINATION

At the end of 2021, the time span of the SINEX files of the IDS combined solution was 1993.0-2021.5. These files correspond to the new IDS series 17, extension of the IDS contribution to the ITRF2020 (IDS 16).

10.3 ITRF2020

On February 9th 2021, the IDS CC delivered to the IERS the IDS 15 series from 1993.0 to 2020.0. This IDS combined series was obtained from the ESA 13 (complete up to 2014.0), GOP 65, GRG 42 and GSC 48 weekly multi-satellite solutions. Due to the ESA EOP differences with respect to the IERS C04 series, the ESA EOPs did not contribute to the IDS 15 combined solution. Furthermore, in line with the station position performance of the GOP and GSC series prior to 2008 and after 2015, respectively, these two series were downweighted over the respective time periods. The comparison of the IDS 15 and 09 (IDS contribution to the ITRF2014) series with respect to the DPOD2014 version 5.0 revealed lower standard deviation of the IDS 15 Helmert parameters as well as similar station positioning performance. The analysis of the same parameters as output of the estimation of the IDS 09 and IDS 15 position and velocity cumulative solutions over the time periods 1993.0-2015.0 and 1993.0-2020.0, respectively, gave similar results. In addition, the spectral analysis of the translation parameters as output of the stacking showed a decrease of the annual and Jason's first draconitic (118 day) signals. Due to the delay of the IGS, ILRS and IVS contributions to the ITRF2020, a second IERS deadline for the delivery of the four space geodetic technique contributions was set to April 10th. Then, the IDS CC suggested to use the delay i) to extend the IDS series up to 2021.0, ii) to include the ESA contribution after 2014.0 and, iii) to define a SAA mitigation strategy for the Sentinel-3A and 3B missions. The complete IDS 15 series was delivered to the IERS by April 11th. After discussions between the IDS CC and the IDS ACs on the scales of the multi-satellite solutions, GOP discovered a small bug at the preprocessing stage which led to a new GOP series (67). Thus, the IDS CC generated a new IDS 16 series including the latest GOP (67) series as well as new series from GRG (43) and GSC (51). The new IDS 16 series was delivered to the IERS on August the 5th and is the official contribution to the ITRF2020. All the details on the realization and evaluation of the IDS 16 performance may be read soon in a dedicated paper titled "The International DORIS Service contribution to the 2020 realization of the International Terrestrial Reference Frame".

10.4 DORIS SINGLE SATELLITE SOLUTIONS

In the frame of the elaboration of the IDS contribution to the ITRF2020, the IDS AC contributors were asked to deliver single satellite solutions to better understand the behavior of the multi-satellite solutions as well as of the IDS combined solution. Then, the IDS CC received Cryosat-2, Envisat, HY-2A, Jason-1/2/3, Saral, Sentinel-3A/B, Spot-2/4/5 and TOPEX/Poseidon single satellite solutions from GOP, GRG and GSC. The IDS CC also received Jason-1/2/3 and Sentinel-3A/B solutions from GFZ as IDS Associated AC. All these series were evaluated with respect to the DPOD2015 version 5.1. The evaluation consisted in the estimation of the Helmert parameters (**Figure 11**), the spectral analysis of the Helmert parameter series and to the estimation of the ENU station position residuals. The analysis of these single satellite solutions revealed that:

- In contrary to GRG, GOP and GSC Cryosat-2 solutions depict high variations of the z-translation of the Cryosat-2 mission.
- While GRG and GSC Cryosat-2, HY-2A and Saral y-translations exhibit a linear increase since late 2015-early 2016, the GOP solutions look free of that pattern which also seems to not affect GOP, GRG and GSC Jason-2&3 solutions
- GOP, GRG and GSC Jason-3 single satellite solution scales show an increase since the starting date of that mission. So far, no explanation on such a pattern was identified.
- The GSC HY-2A scale depicts a 5mm jump while the satellite moved to the geodetic orbit mid-March 2016.

Concerning the GFZ single satellite solutions, the main conclusion concerned the station positioning since they depict worst performance on the up while all the ACs have worst results on the East. Moreover, in contrary to the AC results, while comparing the Jason-1/2/3 solutions, increasing the number of stations simultaneously received on board does not seem to improve the overall performances.

10.5 SAA SENSITIVITY OF SENTINEL-3A&B

During the analysis of the DORIS station coordinate residual time series as output of the IDS 15 stacking, the IDS CC noticed some trend changes early 2016 for the Cachoiera, Hartebeesthoek, Kourou and Libreville stations. Then, the IDS CC estimated for all the DORIS stations the RMS of the coordinate differences between the Sentinel-3A/B and Saral weekly solutions from the GOP and GRG (**Figure 12** and **Figure 13**). The Saral mission is defined as a reference since it is known as insensitive to the SAA phenomenon. As we can see from the next figures, the Arequipa, Cachoeira, Kourou and San Juan stations exhibit higher values which indicates that these missions may be sensitive to the SAA. Therefore, the IDS CC suggested to the IDS ACs to apply a SAA mitigation strategy for these two Sentinel-3 missions.

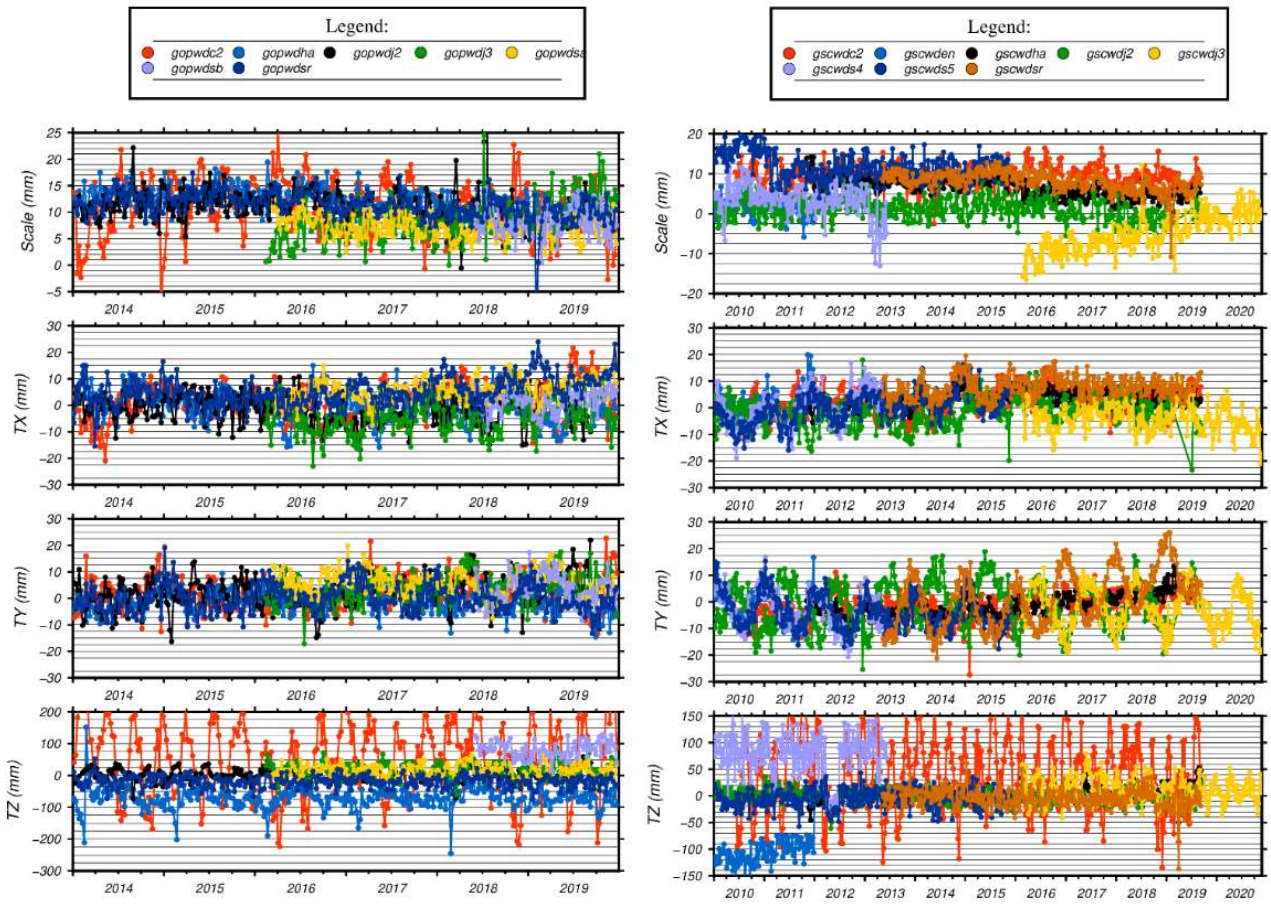

Figure 11. Helmert parameters wrt DPOD2014 v5.1 of the GOP (left) and GSC (right) single satellite solutions.

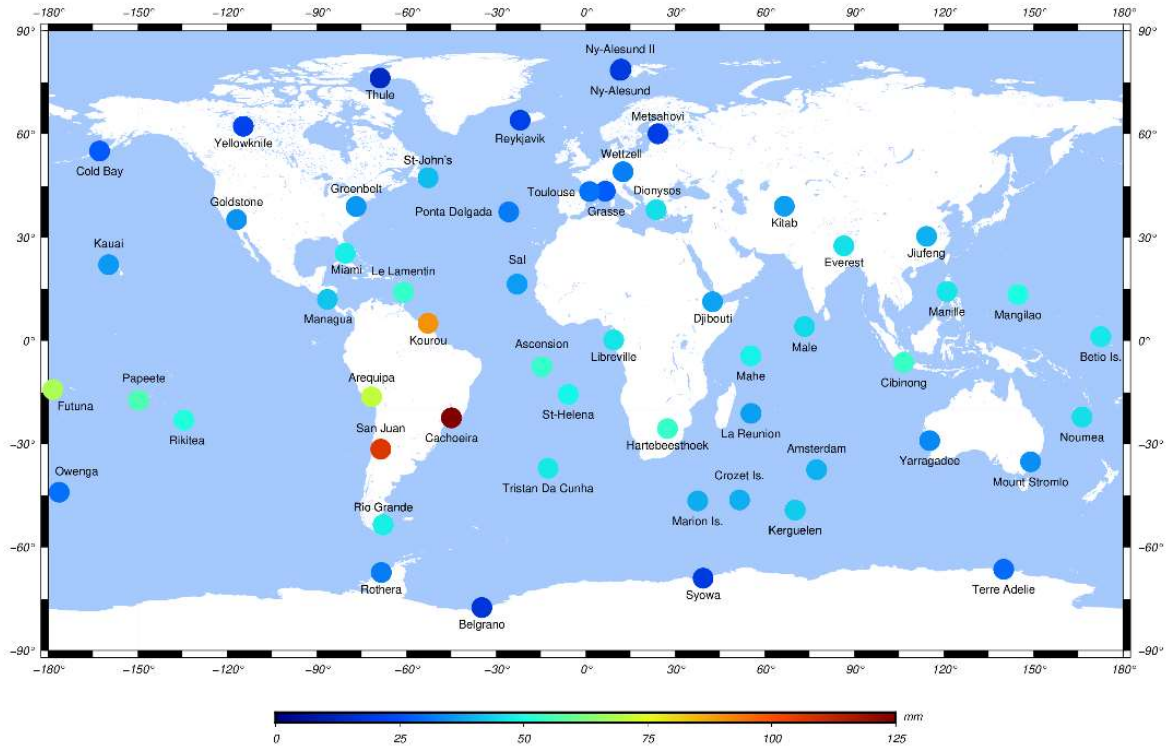

Figure 12. RMS 3D of the GOP Sentinel-3A and Saral weekly coordinate differences.

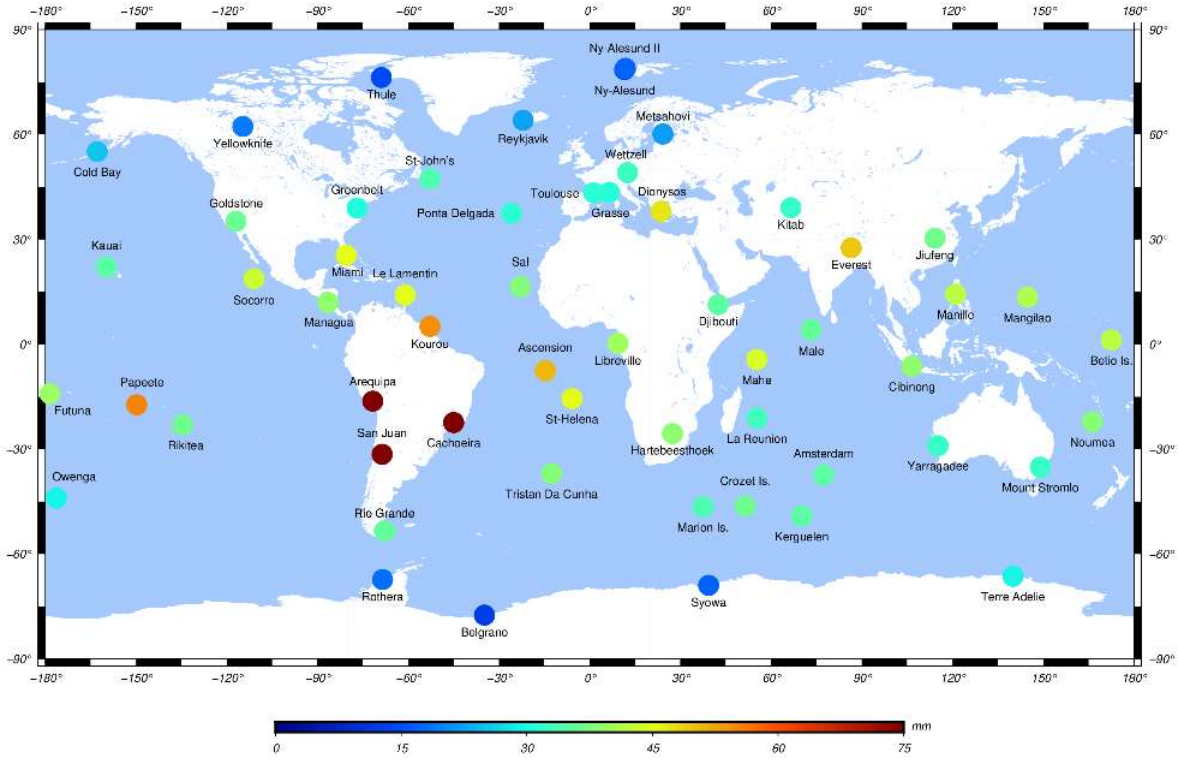

Figure 13. RMS 3D of the GRG Sentinel-3B and Saral weekly coordinate differences.

10.6 COMMUNICATIONS

In 2021, the IDS Combination Center joined the EGU and IAG meetings where it had two online presentations titled “The IDS Contribution to the ITRF2020: Realization and Evaluation” and “New Developments on the IDS Contribution to the ITRF2020”, respectively. The IDS CC also attended the AGU Fall meeting with no presentation after cancelling its poster dealing with the DORIS evaluation of the IGN, DGFI and JPL ITRF2020 realizations due to un-availability of these three solutions early December.

10.7 FUTURE PLANS

In 2022, 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 plans to work on the DORIS evaluation of the DGFI, IGN and JPL realizations of the ITRF2020 solutions as well as on the first DPOD2020 (DORIS extension of the ITRF2020). Next year may also see some papers related to the IDS contribution to the ITRF2020.

11 ANALYSIS CENTER AT EUROPEAN SPACE OPERATION CENTRE (ESOC)

Michiel Otten, Werner Enderle / ESOC, Germany

11.1 INTRODUCTION

The activities in 2021 of the European Space Operation Centre as an IDS analysis center were limited due to time constrains. As a result, the time that was available has been used to produce the ESA/ESOC contribution to ITRF2020.

11.2 MAJOR UPGRADES MADE TO THE ESA SOLUTION FOR ITRF2020

- Inclusion of all DORIS satellites in the ESA contribution (updated ESA solution ID (wd12)
- Exclusive use of the DORIS RINEX files for the newer DGXX satellites resulting in that from 2016 onwards only DORIS RINEX data is used.
- Updated NAPEOS version (4.7)
- Inclusion of all ITRF2020 recommendations in the ESA processing e.g.,
  - New mean pole
  - Up to date TVG
  - Desai & Sibois HF (diurnal-subdiurnal) tidal EOP model
  - Independent DORIS data selection, editing and pre-processing
  - Updated SSA files for Jason and SPOT-5
  - Inclusion of all data above 7 degrees with appropriate down-weighting
  - Troposphere gradient estimation

This solution covers the period from 1993 until 2021 and is foreseen to be delivered routinely again in 2022.

11.3 FUTURE ACTIVITIES

The Navigation Support Office plans for 2022 to restart the routine IDS submission. Further we are working on generating combined solution i.e., including the processing off all geodetic space techniques in a single combination (SLR, DORIS and GNSS).

12 ANALYSIS CENTER OF THE GEODETIC OBSERVATORY PECNY (GOP)

Petr Štěpánek / Geodetic Observatory Pecný, Czech Republic

12.1 MAIN ACTIVITIES

DORIS data have been routinely processed since day 270 of 2021. The new standard of wd67 has been applied, differing from the previous standards by correction of the data editing (preprocessing) strategy and eliminating some minor systematic effects. The wd67 standard was also applied for the final GOP ITRF2020 solution.
We continued in the validation of the Alcatel PCV models. When separately analyzed the residuals of the Alcatel stations with the application of both available Alcatel ground antenna models, we found a better performance of the recent IDS standard model "2.0" then the manufactured model "1.0", a standard for ITRF2014 reprocessing. Differences, significant in the specific elevations, are demonstrated in the **Figure 14**. For detailed analysis we refer Štěpánek and Filler (in press).

The complete ITRF2020 reprocessing has been finished and a complete set of the weekly SINEX files of the final solution gopwd67 have been delivered. An important improvement has been reached in comparison to the solutions gopdwd43/46 (ITRF2014 solutions). **Figure 15** shows the WRMS of station position residuals for the solutions 67 and 43/46. A significant improvement, in particular after 2002, is obvious. **Table 9** includes a percentage decrement of station position WRMS, Standard deviation of weekly transformation parameters series and Standard deviation of Pole coordinate series (with mean w.r.t. IERS C04 model removed). A negative value relates to an increment, a positive value corresponds to a decrement. A strong decrement after 2002 and in particular after 2008 is demonstrated. A detail analysis can be found in Štěpánek et al. (submitted).

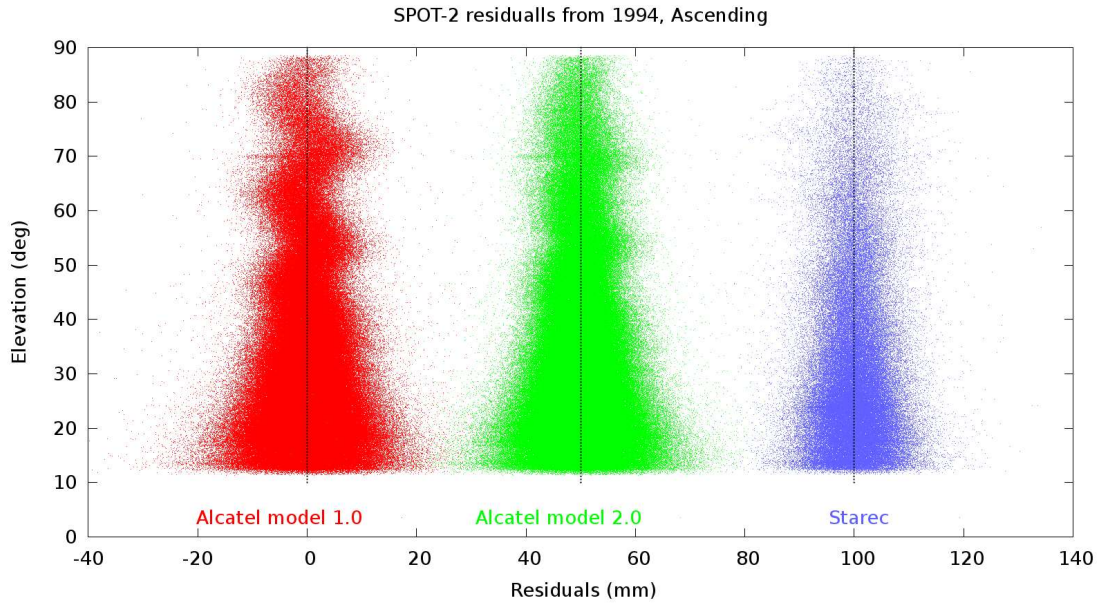

Figure 14. SPOT-2 residuals as a function of elevation, sorted by antenna model. Ascending observations only, results for years 1994. The values for the Alcatel model 2.0 are shifted by 50 mm and for the Starec by 100 mm.

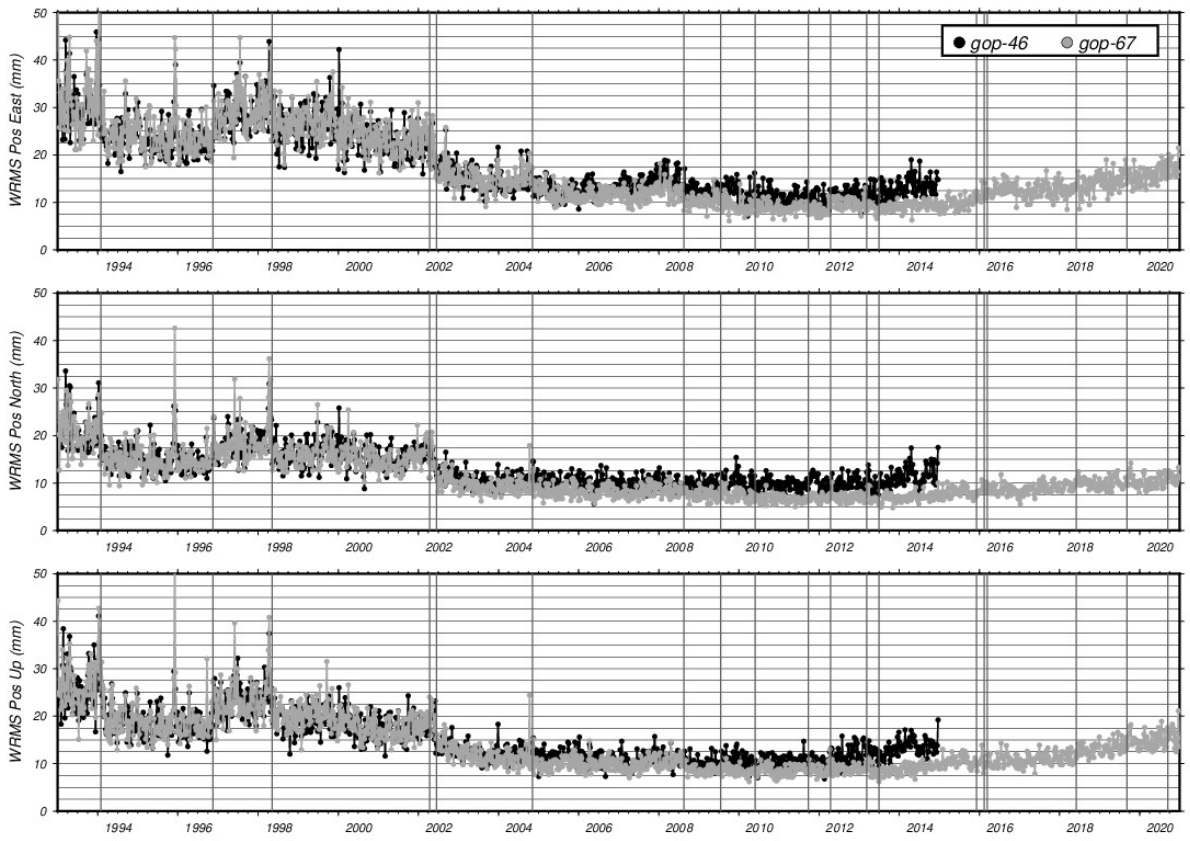

Figure 15. Weighted RMS of station position residuals of the GOP 43/46 and GOP 67 series with respect toITRF2014. *Analysis and figure by IDS combination center (Guilhem Moreaux).*

Time period	Station WRMS	Scale Std. dev.	Tx Std. dev.	Ty Std. dev.	Tz Std. dev.	Xp Std. dev.	Yp Std. dev.
001/91-167/02	-1%	10%	0%	18%	-4%	11%	15%
168/02-230/08	9%	22%	2%	12%	4%	8%	9%
231/08-001/15	26%	71%	26%	38%	19%	39%	39%

Table 9. Improvement of station WRMS, scale and translation Std. dev. and pole Std. dev. Solution GOP67 w.r.t. solution GOP43/46.

12.2 FUTURE ACTIVITIES

Plans of AC GOP for 2022 are as follows:

- Processing of Sentinel-6A data
- Processing of HY-2C and HY-2D data
- Study of new satellites USOs sensitivity to the South Atlantic Anomaly
- Detail comparison od single satellite solutions with other ACs
- Continuing contribution of routine solutions for IDS
- ITRF2020 validation/evaluation

12.3 REFERENCES

Štěpánek, P.; Filler, V., in press. DORIS Alcatel ground antenna: Evaluation of the phase center variation models, *ADVANCES IN SPACE RESEARCH*, DOI : 10.1016/j.asr.2022.02.024

Štěpánek, P.; Moreaux, G.; Hugentobler, U.; Filler, V. The GOP Analysis Center: DORIS contribution to ITRF2020, submitted to ADVANCES IN SPACE RESEARCH.

13 CNES/CLS ANALYSIS CENTER (GRG)

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

13.1 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 for the following satellites: Jason-2, Cryosat-2 and Saral. The satellites Jason-3, Sentinel-3A and Sentinel-3B are processed from RINEX data.
The main activities during 2021 were to finalize our contribution to the ITRF2020 realization and to add the satellite Sentinel-6A in our processing chain. We have implemented and evaluated the new standards and models recommended by IERS and IDS. 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 apply SAA mitigation strategy for Jason-2&3 and Sentinel-3A&B.

Theme	OLD	NEW
Attitude modelling (Spacecraft + Solar array)	Attitude model for all satellites	Quaternions for Jason-1, Jason-2 and Jason-3
Coefficient Solar Radiation pressure Cr	Satellite dependent estimated and fixed	Satellite and time dependent Adjusted per arc (Not done for ITRF2020 but planned)
Estimated measurement parameters	One frequency bias per pass	One frequency bias and drift for SAA stations per pass (for Jason-1, Jason-2 and Jason-3)
Elevation cut-off and data downweighting	Cut-off 12° downweighting: elev2/400 for elev < 20°	Cut-off 10°
Integration Step Size	60 sec	30 sec
SAA mitigation	Corrected data for Jason-1 and SPOT-5 Using SAA data from the most affected satellites only for POD (only for Jason-1)	Corrected data for Jason-1 and SPOT-5 Using SAA data from the most affected satellites only for POD (for Jason-1, Jason-2&3, Sentinel-3A&B)

Table 10. New GRG processing strategy for ITRF2020.

13.2 CONTRIBUTION TO THE ITRF2020 REALIZATION

A POD status for all DORIS missions has been done by analyzing the orbit results obtained on the time span ITRF2020 reprocessing. We took into account the standards and models recommended by IERS and IDS. We give in **Table 11** DORIS RMS of the orbit residuals, the average per arc of the amplitudes of empirical acceleration in tangential and normal and the radiation pressure coefficient for each DORIS satellite. 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&0.38 mm/s), are slightly higher than Jason-2 (0.32 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 (**Figure 16**). In the frame of our contribution to the ITRF2020 realization, we have provided 3 multi-satellite solutions to the IDS Combination Center (grgwd20, grgwd30 and grgwd42 series). These solutions have been compared to the ITRF2014 (grgwd40 series) by the IDS CC with CATREF software. In the final solution, the Jason-1 and SPOT-5 data do not contribute to the scale factor determination. We also apply the SAA mitigation strategy for Sentinel-3A and 3B. As shown in the **Figure 17**, compared to the ITRF2014 solution, the ITRF2020 solution improves the positioning in particular for East and North components. We have also provided single satellite solutions of all DORIS satellite on the reprocessing time span to IDS CC. These single satellite solutions made it possible to identify some problems on several satellites like the atypic behavior of the scale factor from Spot-5 and Jason-1. Other problems, like the drift of Ty translation from 2016 for all satellites except Jason-2&3, are still under investigations.

SATELLITE	DORIS RMS (mm/s)	OPR amplitude average (109 m/s2)		Solar radiation coefficient Cr
		Along-track	Cross-track	
SPOT-2	0.42	1.8	3.6	1.07
SPOT-3	0.44	1.1	3.4	1.07
SPOT-4	0.42	1.4	2.9	1.16
TOPEX	0.46	1.5	5.8	1.03
JASON-1	0.32	2.1	2.9	0.94
SPOT-5	0.34	1.6	1.8	1.05
ENVISAT	0.39	1.0	2.0	1.05
JASON-2	0.32	4.0	2.1	0.97
CRYOSAT-2	0.35	2.9	2.6	1.0
HY2A	0.34	0.5	3.1	0.86
SARAL	0.34	1.4	2.4	1.0
JASON-3	0.36	0.9	2.2	0.99
SENTINEL-3A	0.37	2.3	1.4	1.0
SENTINEL-3B	0.38	1.4	1.5	1.0

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

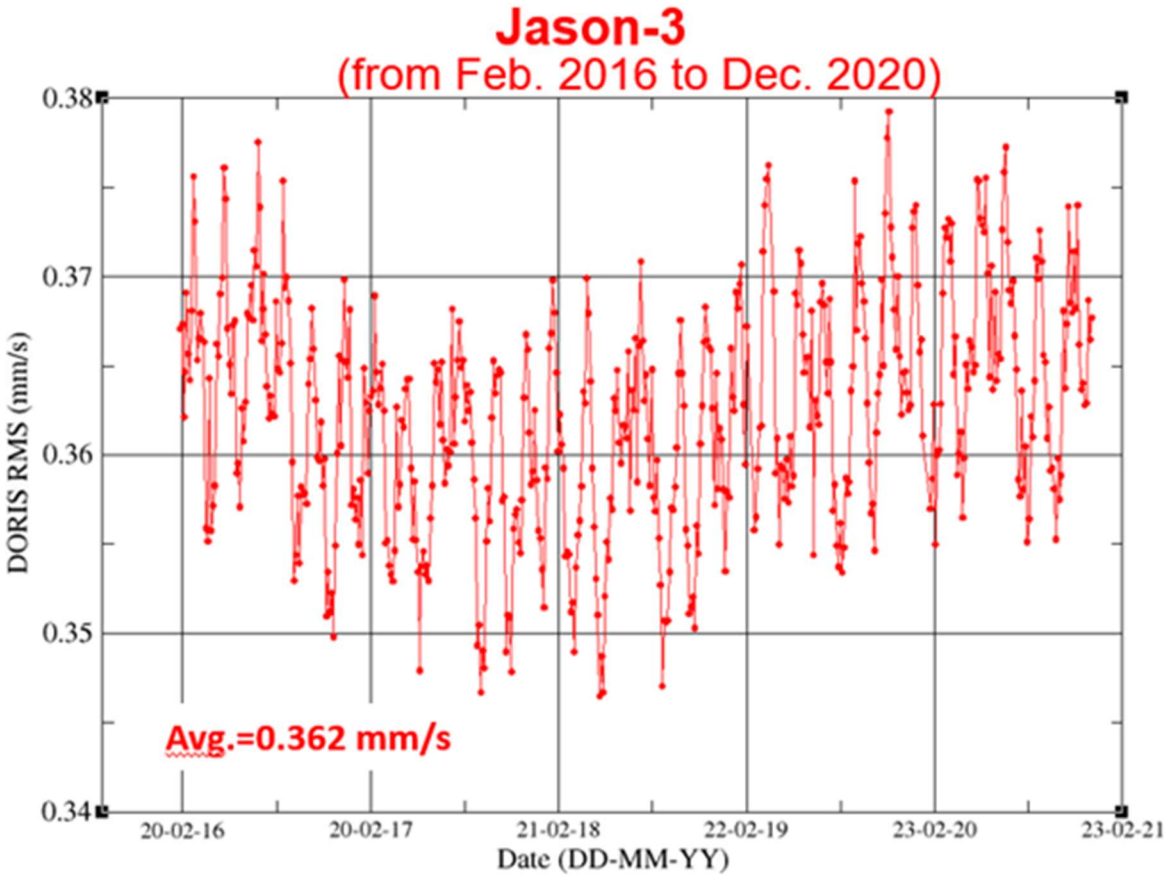

Figure 16. DORIS RMS of fit per arc.

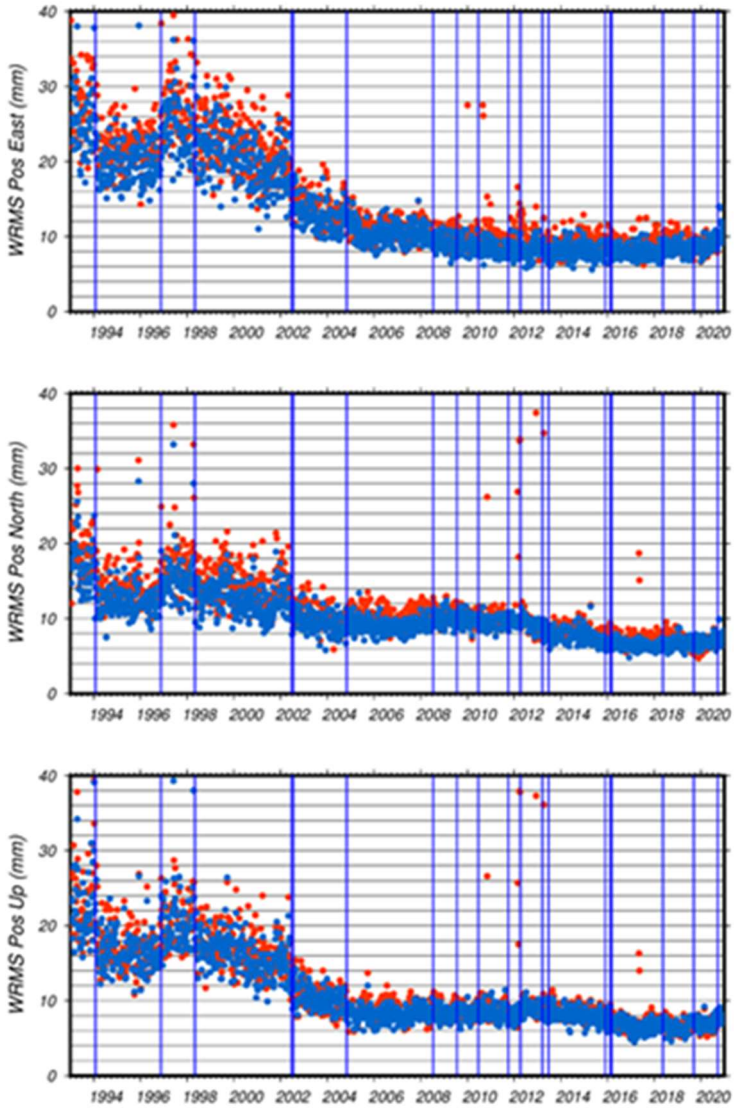

Figure 17. Positioning residuals of the ITRF2020 multi-satellite solution (in blue) and ITRF2014 solution (in red).

13.3 INTRODUCTION OF THE SENTINEL-6A IN GRG PROCESSING CHAIN

The satellite Sentinel-6A has been introduced in our processing chain in 2021. The macromodel was made from the document available on the IDS web site (https://ids-doris.org/documents/BC/satellites/DORISSatelliteModels.pdf). We also made the routine of the attitude in our GINS software.

We processed Sentinel-6A DORIS data over a sufficient time span to adjust the solar pressure coefficient. Then, we processed the DORIS data from Marth to September 2021 by fixing the solar pressure coefficient at the adjusted value (1.05). For both directions (tangential and normal), the average amplitude of the empirical accelerations is less than 6.10-9 m/s2, showing that the modeling of the macromodel and attitude laws is correct. The orbit residuals level (0.36 mm/s) is slightly lower than those obtained for Sentinel-3A&B (0.37&0.38 mm/s). We compare the GRG orbit to the one of the CNES POD team and to the one of CPOD service. There is a good agreement between the different orbits, RMS under 1 cm level for radial component.

We also provide a single satellite solution which has been compared to the Sentinel-3A solution (see **Figure 18**). The scale factor and geocenter are similar except for the Y translation Ty.

The CNES/CLS AC provides routinely the Sentinel orbit to the Sentinel Copernicus POD Quality Working Group (QWG). Since the end of year 2021, we also provide the Sentinel-6A orbit. We present here one result from the evaluation made by GMV (**Figure 19**). These results show that the DORIS-only orbit calculated with GINS is at the same level, in particular for radial component, like the other orbits which are all determined from GPS measurements.

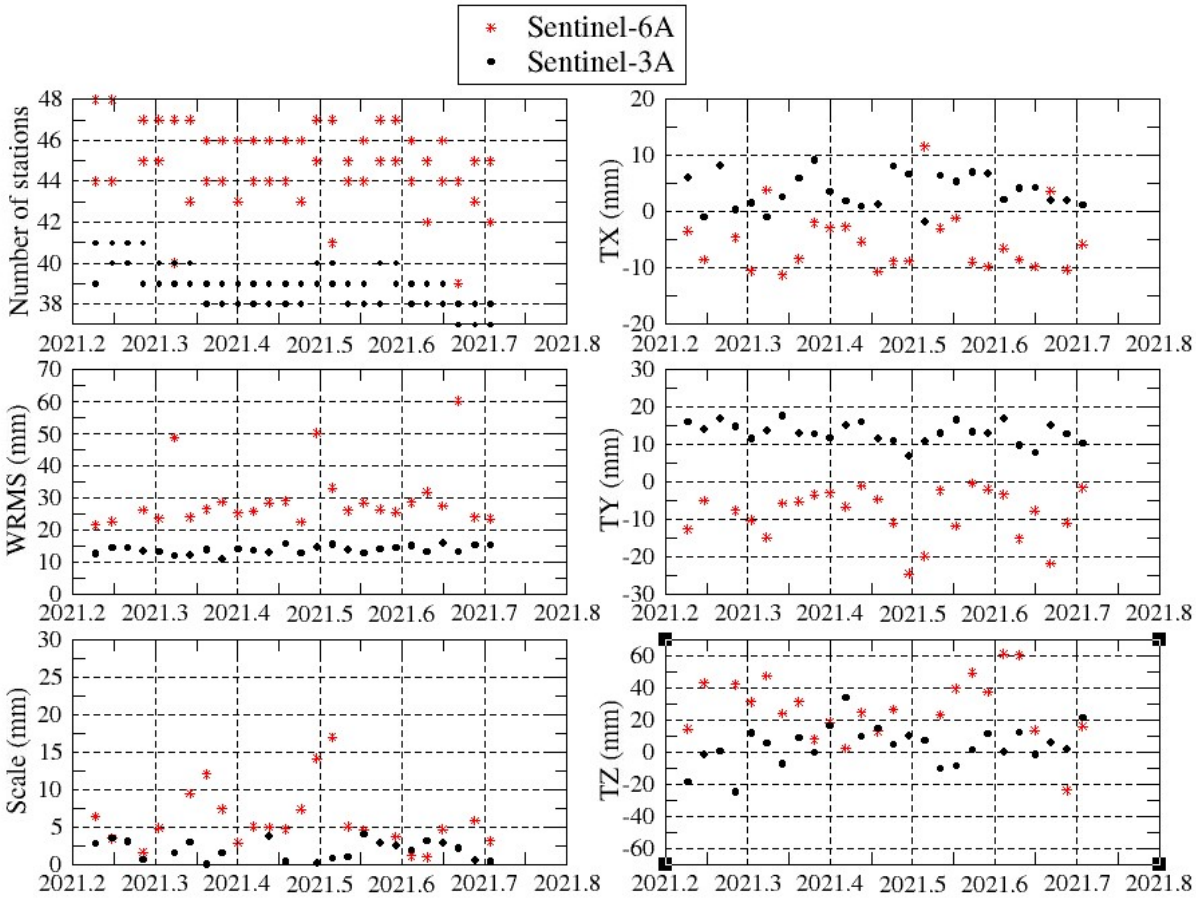

Figure 18. Geocenter and scale factor of single satellite solutions, Sentinel-3A (in black), Sentinel-6A (in red).

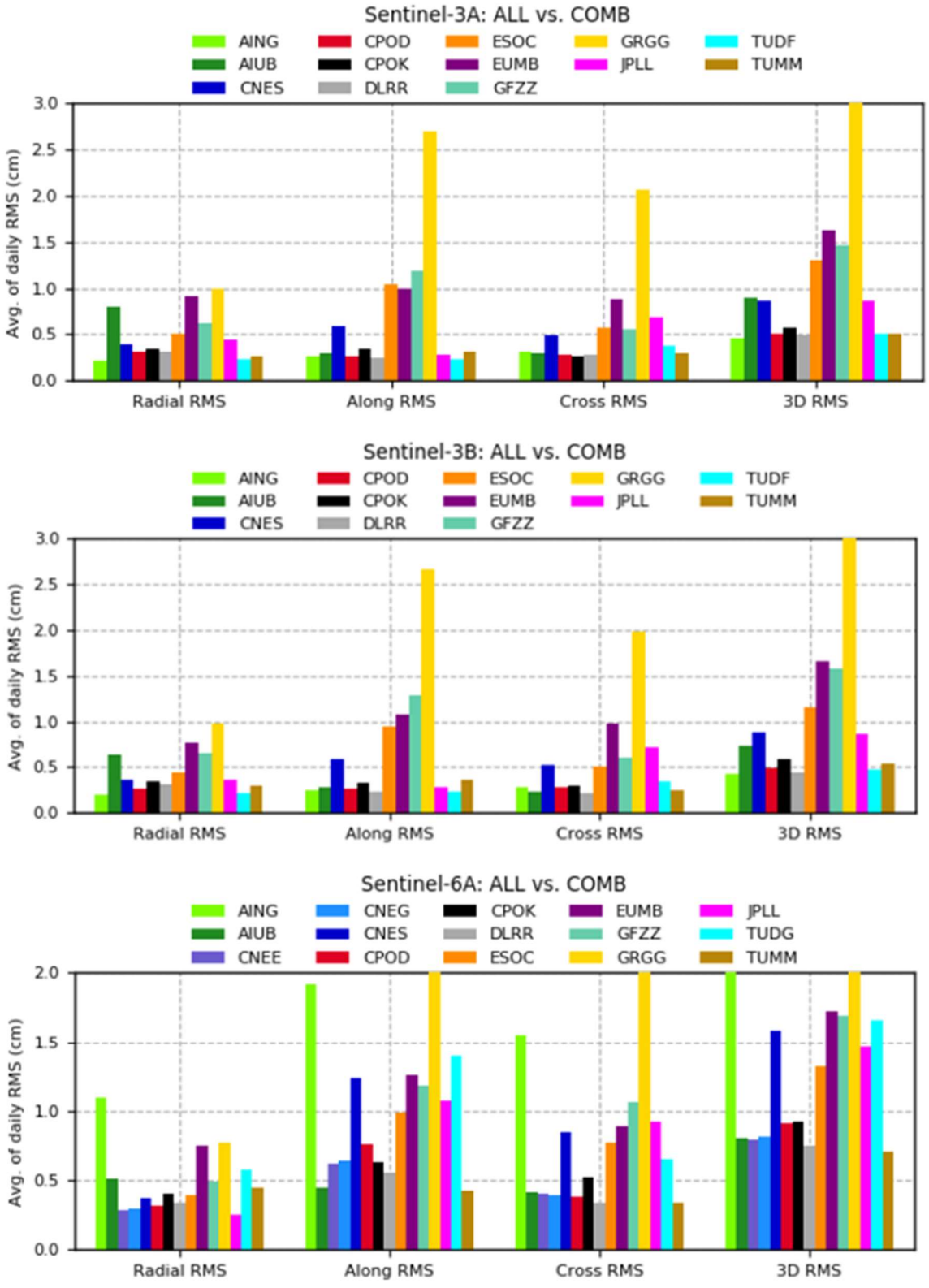

Figure 19. Sentinel-3A, B et 6 orbit comparisons per component (average of daily RMS; cm); CPOD vs. external solutions.

13.4 CONTRIBUTION TO IDS MEETINGS

The Analysis Center's representatives participated in 2021 to the AWG virtual meeting in April. We also participate to the virtual EGU in April. We presented the following works:

- AWG:

https://ids-doris.org/images/documents/report/AWG202104/IDSAWG202104-Capdeville-GRG.pdf

- EGU: "DORIS results on Precise Orbit Determination and on geocenter and scale solutions from CNES/CLS IDS Analysis Center contribution to the ITRF2020" in session « G2.4 Precise Orbit Determination for Geodesy and Earth Science».

14 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

14.1 ITRF2020

The major focus of the GSC Analysis Center in the period of 2021 was the preparation and submission of the GSC DORIS Analysis Center submission to ITRF2020. We submitted three completed series: an initial series in early 2021 (gscwd40); an updated series in April 2021 (gscwd48), and a final series in September 2021 (gscwd51), that included Sentinel-3A. Lastly in October 2021, we added Sentinel-3B, creating a new series (gscwd52). The series gscwd52 is now the operational series of the GSFC analysis center. The different series are summarized in **Table 12**.

Series	Description	Comment
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
gscwd48	gscwd40 + (1) Fix problem with Tz& Scale in 2012 by eliminating SYPB at observation level (April 4 –July 1, 2012, Bad data period not previously accounted for); (2) Fix data editing on SPOT-4, and apply modified Cr = 0.988.	Submitted April 2, 2021.
gscwd50	gscwd48 + with adj radial z-offsets for Jason-1, adj radial z offsets for SPOT-2 after 2007/11/13, no SPOT-4 after 2013-01-11, start Envisat on 2004/11/07 with Jason-1.	Implemented at request of IDSCC based on feedback from earlier submissions.
gscwd51	gscwd50 + Add Sentinel-3A + Use New Cr's for SPOT-2 & SPOT-5, + a priori macromodel for Jason-3 (per NPZ).	Final ITRF2020-related delivery to IDS Data Centers on Sept. 28, 2021.
gscwd52	gscwd51 + Sentinel-3B starting 180610	Deliveries started 2020-10-18 to the NASA CDDIS. This is the current operational series.

Table 12. DORIS SINEX solutions developed by the GSC AC in 2021.

The major modelling improvements for the ITRF2020 submission (*compared to ITRF2014*) included the following:

(1) Updated background gravity model (GOCO05s). The model is propagated to 2003.0 and no secular terms are used prior to that date.
(2) Use of the 3-hrly AOD (Atmosphere-Ocean Dealiasing) products (version RL06) provided by the GRACE FO project, for forward modelling of atmosphere and ocean mass variations.
(3) Application of the new IERS linear mean pole, and the new High Frequency EOP models recommended by the IERS.
(4) Use of shorter arcs and reduced-dynamic orbit determination (through estimation of more frequent empirical accelerations) for SPOT 2-3,4 and ENVISAT arcs (1999-2003). This helped to mitigate the mismodelling of atmospheric drag around the 1999-2002 maximum in the solar cycle.
(5) Application of elevation-dependent weighting, as well as the lowering of the elevation angle cutoff to 7.0° from the cutoff angle of 10° used for ITRF2014.
(6) Using solar array quaternions to model the orientation of the solar arrays on the Jason satellites. We had relied on the default attitude model for solar array orientation for the processing done for ITRF2014. In addition, we adjusted separated a Cr (solar radiation reflectivity coefficient) per arc for TOPEX and the Jason satellites, to further reduce the solar-radiation-pressure induced mismodelling for these satellites. The objective was to reduce the potential Jason-draconitic-related signals in the geodetic products that had been observed in ITRF2014.

For ITRF2020, we used updated versions of GEODYN that explicitly modelled all frequency and troposphere biases. Prior processing had used a "short-cut", the so-called EBIAS option in GEODYN. This option was deprecated so we had to explicitly use the "MBIAS" option to model all DORIS-related biases. The "EBIAS" option had the perverse effect of sometimes truncating data at the start and end of passes. In addition, the bookkeeping and code associated with this option made debugging extremely onerous. This was the reason for deprecation of this option. As a result, for ITRF2020, we had to completely re-edit all the DORIS data from 1993 to 2020 (*we did not retain the data deletes we had generated as part of the work on ITRF2014*). The MBIAS option resulted in the inclusion of more arc parameters in the normal matrix for batch estimation in GEODYN. This was mitigated by taking advantage of the block diagonal structure of the normal matrix with respect to the arc-related biases.

The DORIS processing for ITRF2020 also took advantage of a new option in GEODYN, the use of Huber weighting. Huber weighting is a method of data weighting that more effectively handles data outliers than a standard N-sigma RMS editing strategy, which we had previously used. The Huber weighting is particularly useful in the initial editing of DORIS RINEX data, since the raw DORIS data (*before editing*) are peppered with some extreme data outliers that sometimes can derail a normal least squares estimation.

In order to be able to process DORIS and SLR data from the Sentinel-3A & Sentinel-3B satellites in GEODYN, we had to write a separate subroutine to model the nominal attitude of these satellites. The description of the satellite attitude in the document "DORISSatelliteModels.pdf" on the IDS website, does not include the explicit roll/pitch/yaw steering angles that are implemented for these satellites. We obtained these from a memorandum provided by Flavien Mercier (CNES), "**Expressions**

des lois d'attitude en pointage géodésique". In the memorandum, the following angles of roll, pitch and yaw were provided for the Sentinel 3A/3B satellites:

- Roll: -0.0506 degrees (-0.8831366015091307D-03 radians)
- Pitch: +0.1667 degrees (+0.2909463863074547D-02 radians)
- Yaw: +3.9300 degrees (+ 0.6859143960337715D-01 radians)

In the memorandum, regarding the angle to which these roll, pitch and yaw angles are applied F. Mercier writes, "L'angle correspond a une anomalie moyenne: il a une évolution linéaire dans le temps, et est calé par rapport aux passages au noeuds ascendants. C'est donc une anomalie moyenne, mais liee a la période nodale (*The angle corresponds to a mean anomaly. It has a linear evolution in time, but is set to the ascending node, and it is linked to the nodal period*). Thus in GEODYN we defined the orbit angle argument to be $M + \varpi + \pi$, where M is the mean anomaly, ϖ is the argument of perigee. Through tests with SLR data, we found we had to add π radians to the argument in GEODYN to get the best SLR residuals and properly model the roll, pitch, yaw evolution.

In **Table 13**, we provide a summary of the POD results for Sentinel-3A & Sentinel-3B. We always complete an SLR+DORIS POD data reduction for an arc to verify the POD performance, before we do a DORIS-only POD data reduction to create the normal equations for each arc that contributes to a weekly combination. As **Table 13** shows, we obtain RMS SLR fits 0.74 – 0.75 cm. We think this validates the attitude and modelling implementation for Sentinel-3A & Sentinel-3B. The DORIS fit we report is a weighted RMS (WRMS) due to the elevation-dependent data weighting we implemented for processing the DORIS data.

Satellite	First Arc	Last Arc	No of Arcs	Avg. No. SLR obs. per arc	Avg. No. DORIS obs. per arc	Avg. SLR fit per arc (cm)	Avg. DORIS fit per arc (WRMS, mm/s)
S3A	160508	201231	282	990	76517	0.741	0.3869
S3B	180606	201227	163	849	76590	0.752	0.4015

Table 13. POD Summary for Sentinel-3A & Sentinel-3B for GSFC SLR+DORIS orbits.

14.2 SENTINEL-6A

Another important activity in 2021 was the analysis of Sentinel-6A data in GEODYN, in order to support the tandem mission activities with Jason-3.

In the first step, we had to implement a background attitude subroutine for Sentinel-6A in GEODYN. Since S6A follows a different attitude algorithm than TOPEX and the Jason satellites, we had to define and code a default attitude model for this satellite. This is necessary, even though we eventually used the mission-provided quaternions for S6A, which were made available by the Copernicus POD Service. We coded the algorithm in a similar way as for Sentinel-3A. That is, we defined the nominal axes, and then proceeded to define the roll, pitch and yaw angles, with respect to these nominal axes.

The nominal axes are given in the document “Sentinel-6A POD Context” (provided by ESA, author R. Cullen):

- +Z = nadir
- +X = flight direction
- +Y = completes the orthogonal set.

In an email message dated May 21, 2021, Alexandre Couhert (CNES) provided the roll, pitch and yaw angles computed by Flavien Mercier (CNES) that are used in the CNES/Zoom software.

- Roll: -0.1180 degrees (-0.2059488517353309D-02 radians)
- Pitch: -0.1330 degrees (-0.2321287905152459D-02 radians)
- Yaw: +4.2250 degrees (+0.7374016089676041D-01 radians)

As an illustration of the POD performance of Sentinel-6A vs. Jason-3, we show in **Figure 20** the SLR fits for the two satellites, computed in the GEODYN software. We relied on the CNES micromodel for Sentinel-6A. The modelling of nonconservative forces is more problematical for S6A than for Jason-3 because the structure of the solar arrays shadows parts of the lower surfaces around the orbit differently as the beta prime angle changes. The standard “macromodel” cannot capture these self-shadowing effects. In addition, we must reckon with radiation of energy from one part of the spacecraft to another, which also is not accounted in a standard micromodel.

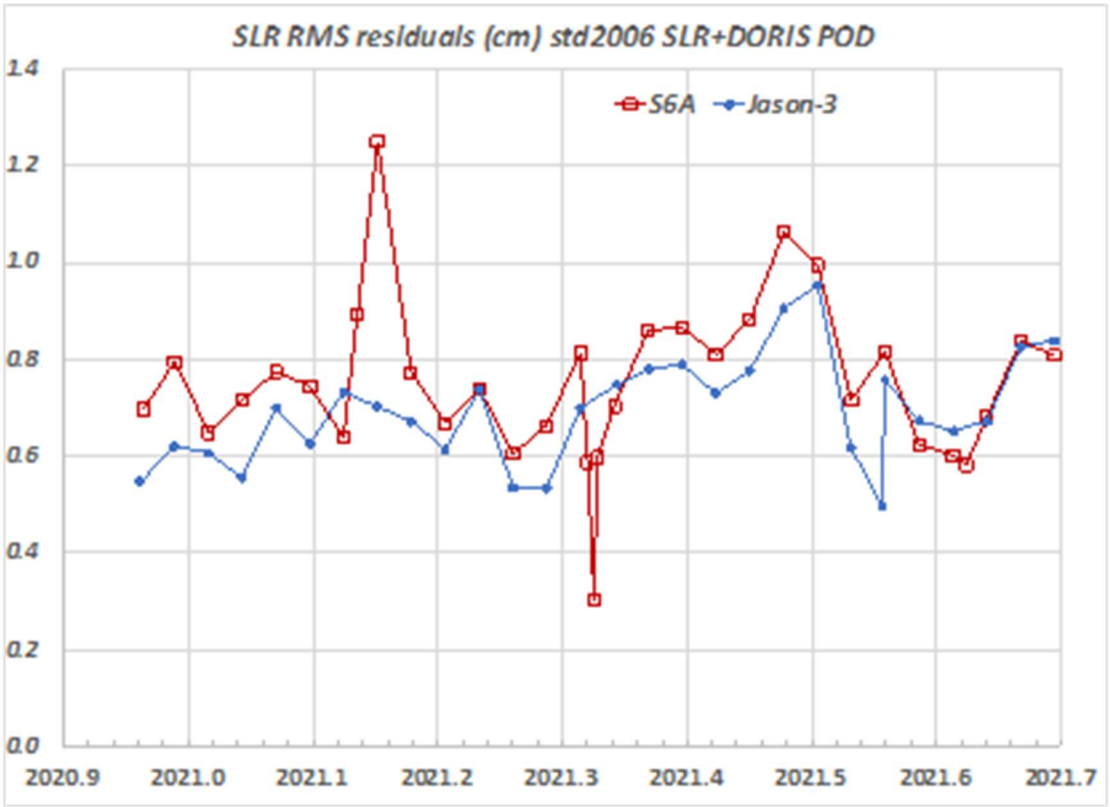

Figure 20. SLR residuals for Sentinel-6A and Jason-3 (2020-12/17– 2021-09/17) from NASA GSFC std2006 orbits.

A comparison of the DORIS residuals for Sentinel-6A vs. Jason-3 allows us to make a preliminary assessment of the sensitivity of the DORIS USO to radiation-induced perturbations, particularly from the SAA. In **Figure 21a** and **Figure 21b**, we show the weighted DORIS residuals for the DORIS stations from the two satellites. Note that throughout this period, the two spacecraft were in tandem mode, only 30 seconds apart along the orbital track. This means the space environment and solar geometry was close to identical. We observe that Sentinel-6A has a slightly lower sensitivity to the SAA, since the weighted RMS of fit (WRMS) is slightly lower. We speak of a "weighted RMS of fit" because we apply an elevation-dependent weighting function in the processing of DORIS data. We note that the WRMS is lower across the board, for both SAA, and non-SAA stations, with only one station (SCRC) behaving differently.

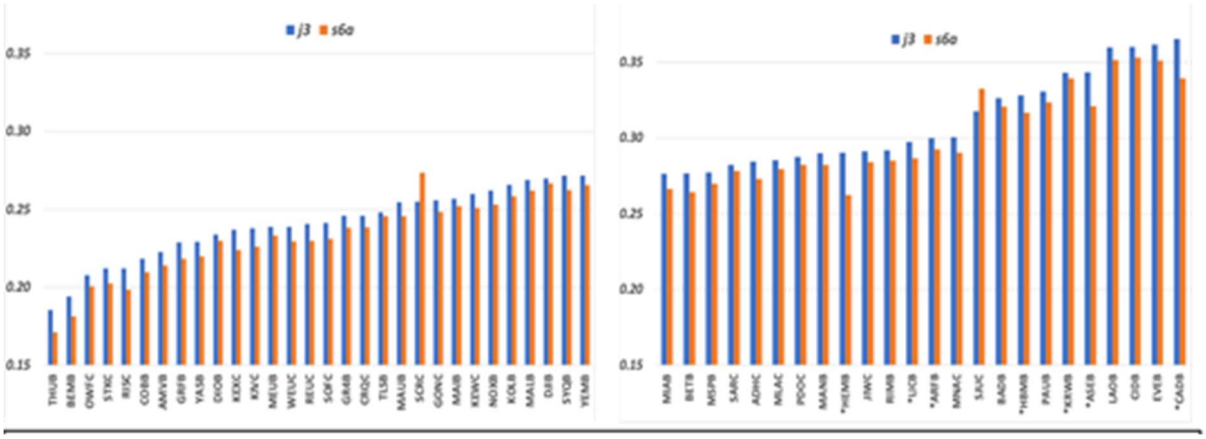

Figure 21a (left) and Figure 21b (right). Weighted DORIS residuals (mm/s) for Jason-3 and Sentinel-6A from SLR+DORIS POD with GEODYN using the std2006 standards, 2020-12/17 to 2021 09/17. The SAA stations are marked with an asterisk. The residuals are deweighted.

Another interesting comparison that we can make in the tandem phase is to examine the DORIS timing bias for the two satellites. In SLR+DORIS POD, we have always estimated a timing bias for the DORIS system. It represents the mean timing difference of the DORIS system with respect to the timing provided by the SLR network. In the early phases of the TOPEX mission, this timing bias reach tens of μsecs, but more recently these timing biases are of order 1-2 μsecs in absolute magnitude. We have computed DORIS timing biases per 10-day SLR+DORIS arc. There is a fair amount of scatter, however as we show in **Figure 2Figure** 22, the average DORIS timing bias we obtain for Sentinel-6A is close to 0 μsec, whereas for Jason-3 we can conclude the mean value is about -1 μsec. That mean value though does not necessarily mean there is a real timing bias of the amount on Jason-3. It could also reflect an along-track position error of about 7 mm in the X direction in the Jason-3 spacecraft frame for the DORIS phase center location.

Future work should concentrate on improving the nonconservative force modelling and updating the static and time-variable geopotential model used for Sentinel-6A POD.

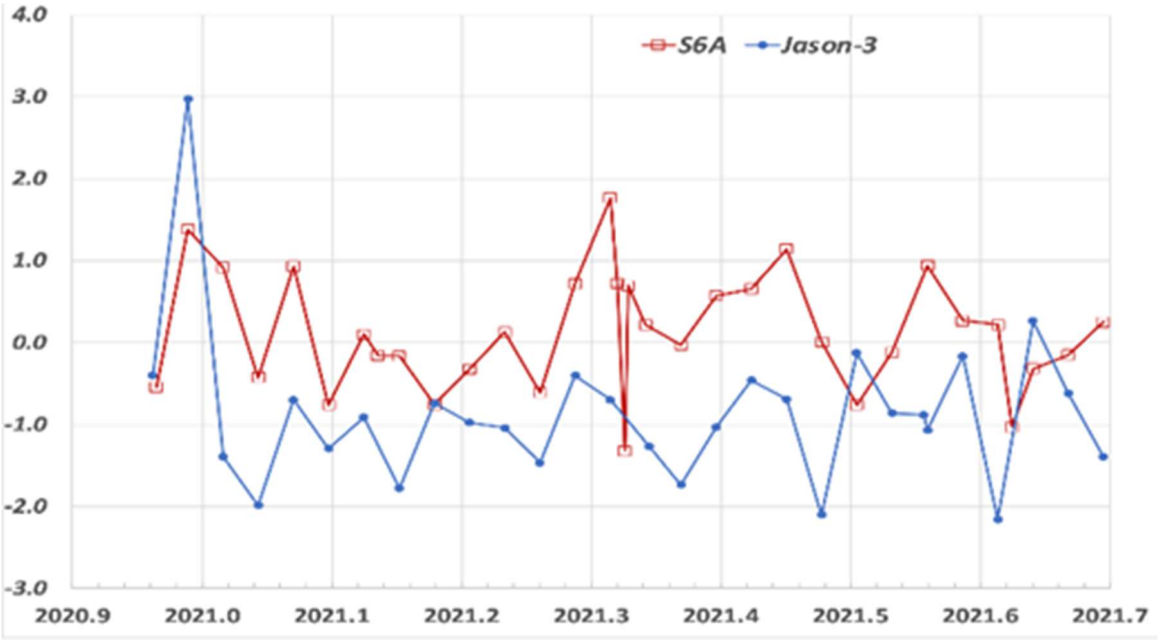

Figure 22. DORIS time biases (in µsecs) w.r.t. the ensemble time provided by the SLR stations for Jason-3 & Sentinel-6A over the tandem mission period (2020-12/17 to 2021-09/21).

15 IGN/IPGP/JPL ANALYSIS CENTER (IGN)

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15.1 1 CONTEXT

The Institut national de l'information géographique et forestière (IGN) used until 2019 the GIPSY/OASIS software package (developed by the Jet Propulsion Laboratory, Caltech, USA) to generate all DORIS products for geodetic and geophysical applications. However, this software is no longer maintained by the JPL as it has been replaced by RTGx/GipsyX software. In addition, Pascal Willis retired in 2020 and the health situation at that time (COVID-19 crisis) prevented a nominal resumption of operations of the analysis center by Samuel Nahmani and Arnaud Pollet. Indeed, upon his departure, RTGx/GipsyX was not operational for the processing of DORIS measurements. Only tests regarding the processing of RINEX measurements on the Jason-2 satellite had been provided.

15.2 2 PRODUCTS DELIVERED IN 2021

Due to the inability of the new RTGx/GipsyX software to produce DORIS products from Doppler and RINEX data at this date, no product has been deliver in 2021.

15.3 3 NEW DEVELOPMENTS

New developments concern the update of the new RTGx/GipsyX software package from JPL. The macromodels and attitude laws provided by IDS for ITF2020 have been implemented for JASON, JASON-2, JASON-3, SPOT2, SPOT4, SPOT5, Sentinel-3A, Sentinel-3B and SARAL. The use of Doppler data has also been implemented. The RTGx/GipsyX software can now use this type of measurements in addition to the RINEX data developed by P. Willis before his retirement.

To validate the new development, one year of orbit processing for Jason-2, Jason-3, Sentinel-3A and SARAL have been analysed and the results have been presented during the AGU Fall Meeting 2021. We obtain promising results for all the satellites. For example, the RMS differences between the Gipsy-X orbits and the SSA POD orbits during the test year are lower than 1cm for the radial component for all the satellites (see **Table 14**). However, there are still some points under investigation, including a bias on the along-track component of 4 mm between orbits obtained with doppler or rinex measurements for Jason-2.

	Radial (mm)	Along-track (mm)	Cross-track (mm)
Orbit difference JAS2_IGN – JAS2_SSA			
MEAN	0.1	0.2	-0.9
RMS	6.1	19.2	24.5
Orbit difference JAS2_GRG – JAS2_SSA			
RMS	7	21	19
Orbit difference JAS3_IGN – JAS3_SSA			
MEAN	-0.1	0.6	-0.1
RMS	8.3	27.7	28.7
Orbit difference SRL_IGN – SRL_SSA			
MEAN	0.3	3.7	-1.1
RMS	8.8	32.0	28.1
Orbit difference S3A_IGN – S3A_SSA			
MEAN	0.1	-6.3	0.3
RMS	8.4	33.8	21.3

Table 14. 14-year orbit differences between IGN/IPGP/JPL RTGx/GipsyX orbits, GRG orbit for JAS2 and SSA orbits.

16 GFZ ASSOCIATE ANALYSIS CENTER

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16.1 INTRODUCTION

The activities performed at GFZ in 2021 concentrated on extending the repertoire of Precise Orbit Determination (POD) of DORIS receiver carrying satellites Secondly, a substantial reprocessing of all already implemented missions was performed to deliver ITRF compatible solutions to the IDS combination center. The project on the analysis of effects of loading on orbital accuracies ended with the publication of König et al. (2021).

16.2 PRECISE ORBIT DETERMINATION

Table 15 gives an overview of the current GFZ repertoire of DORIS satellites and their DORIS and SLR RMS values.
The orbital accuracy was validated in comparison with in-house generated orbits based on GPS observations, their quality is evaluated on a regularly basis in the frame of the Copernicus POD quality working group. Compared to dynamic GPS orbits the agreement of DORIS orbits sizes near one centimeter in radial and a few centimeters in along- and cross-track direction. Systematic deviations could be minimized by handling the DORIS time bias properly. **Figure 23** shows the estimated time bias for TOPEX based on SLR observations in comparison to Lemoine et al. (2016).

	DORIS RMS [mm/s]	SLR RMS [cm]
ENVISAT	0.43	1.13
CRYOSAT-2	Under validation	
Jason-1	0.35	1.15
Jason-2	0.35	1.23
Jason-3	0.41	1.48
Sentinel-3A	0.42	1.44
Sentinel-3B	0.44	1.53
Sentinel-6A	Under validation	
TOPEX	0.48	1.82

Table 15. GFZ repertoire for DORIS satellites and corresponding RMS values.

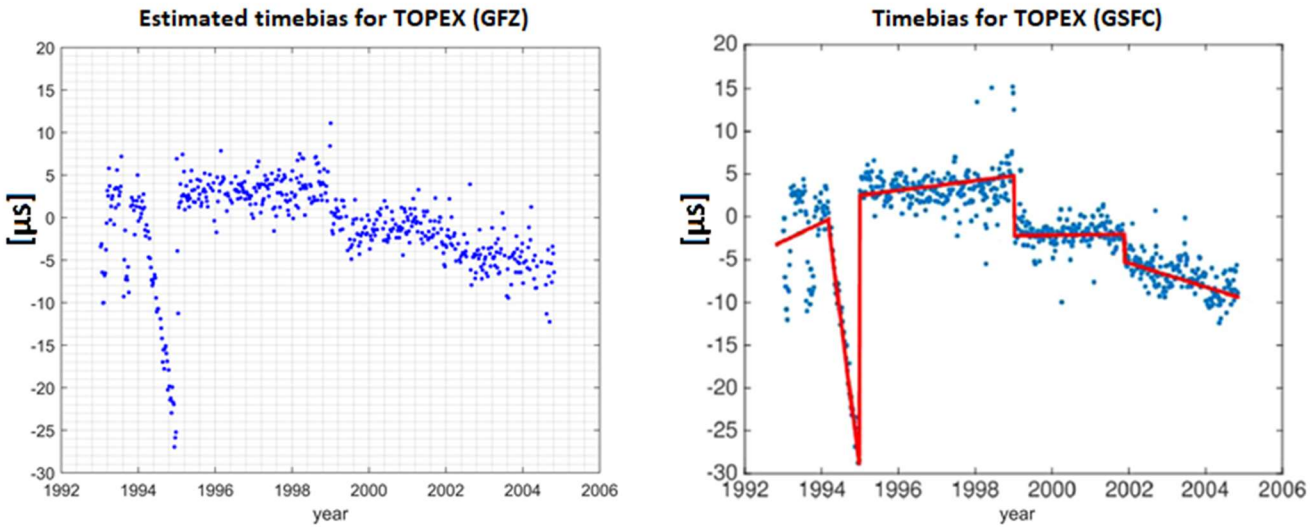

Figure 23. Validation of estimated timebias via SLR for TOPEX. The left figure shows the results for the estimated timebias for TOPEX from GFZ, the right figure the results from GSFC (Lemoine et al., 2016).

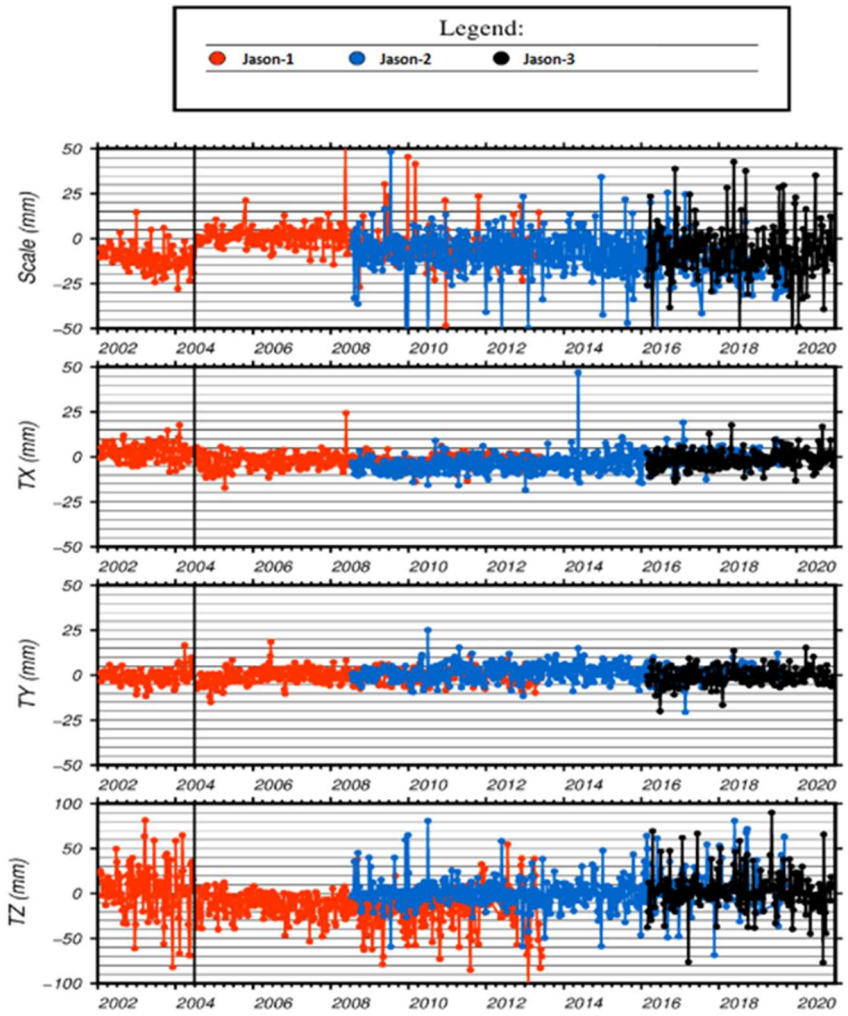

Figure 24. Evaluation of the GFZ single satellite solutions for Jason-1/2/3 by IDSCC (Moreaux, G., priv. comm.).

16.3 REPROCESSING FOR ITRF PREPARATION

The reprocessing campaign reached back to August 1992 with the start of TOPEX up to the state-of-the-art mission Sentinel-6A. The common objective of these activities was to generate and validate DORIS based solutions for reference frame determination. Therefore, weekly arcs according to GPS weeks were processed and normal equations for Earth Orientation Parameters (EOP), i.e. length of day (LOD) and pole coordinates, and station coordinates were generated.

The normal equations have been delivered to the IDS combination center for evaluation. There, detailed analyzes of GFZ's single satellite solutions have been performed (Moreaux, G., priv. comm.). These results are very valuable to proceed with improving the solutions. **Figure 24**, as an example, shows the evaluation of the single satellite solutions for Jason-1/2/3 in terms of scale and translation with reference to DPOD2014 v5.1, which shows good agreement among each solution.

16.4 PRESENTATIONS

Schreiner P, Koenig R (2021) On the processing of GFZ's DORIS contribution to ITRF2020. IDS – AWG meeting 2021

16.5 REFERENCES

König, R.; Reinhold, A.; Dobslaw, H.; Esselborn, S.; Neumayer, K.H.; Dill, R.; Michalak, A., 2021. On the effect of non-tidal atmospheric and oceanic loading on the orbits of the altimetry satellites ENVISAT, Jason-1 and Jason-2, *ADVANCES IN SPACE RESEARCH*, 68(2):1048-1058, DOI: 10.1016/j.asr.2020.05.047

Lemoine, F.G.; Chinn, D.S.; Zelensky, N.P.; Beall, J.W.; LeBail, K., 2016. The Development of the GSFC DORIS Contribution to ITRF2014, in Scientific Applications of DORIS in Space Geodesy, F. Lemoine and E.J.O. Schrama (Eds.), *ADVANCES IN SPACE RESEARCH*, 58(12):2520-2542, DOI: 10.1016/j.asr.2015.12.043 **OPEN ACCESS**

17 DGFI-TUM ASSOCIATE ANALYSIS CENTER

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

17.1 INTRODUCTION

The activities of the DGFI-TUM Associate Analysis Center (AAC) of the International DORIS Service (IDS) in 2021 included the following:

- some new background models for the precise orbit determination of altimetry satellites were implemented in DGFI-TUM DOGS-OC ("DGFI Orbit and Geodetic parameter estimation Software – Orbit Computation"),
- the algorithm for the satellite attitude modelling was optimized in DOGS-OC,
- for the validation of orbit solutions, the program was enhanced which computes the differences of satellite coordinates provided in SP3 and SP1 formats and allows the comparison of various internal and external orbit solutions,
- to derive SLR data-based orbits of TOPEX/Poseidon and to use them for the comparison with DORIS data-based orbits, station-dependent Satellite Laser Ranging measurement corrections for TOPEX/Poseidon were derived,
- new, refined orbits of TOPEX/Poseidon, Jason-1, Jason-2, and Jason-3 orbits were derived and compared with some external orbit solutions.

17.2 DEVELOPMENT OF STATION-DEPENDENT SATELLITE LASER RANGING MEASUREMENT CORRECTIONS FOR TOPEX/POSEIDON

The altimetry mission TOPEX/Poseidon was operational between 1992 and 2005 and had the main objective to monitor variations of the global and regional sea level and ocean circulation. It is one of the first major altimetry missions and the predecessor of the Jason satellites and Sentinel-6A. For precise orbit determination, the spacecraft was equipped with a DORIS and a GPS receiver as well as a laser retroreflector array (LRA) serving as a target for laser ranging measurements from ground stations. The vast dimension of the retroreflector array of over 1.6 m in diameter caused variations of the optical phase center of up to several decimeters. These variations are a significant limiting factor to derive orbit solutions on centimeter level and, thus, have to be resolved by applying a range correction to each laser ranging measurement.
We developed an analytical correction function based on an empirical analysis of normal point observation data to the TOPEX/Poseidon spacecraft. The function uses the observation's viewing angle as seen from the LRA in combination with parameters which we derived in an iterative estimation process. The obtained range correction is added to the modeled range. We estimated station-dependent correction parameters to consider the observation technology and data processing at each site.

Figure 25

shows the color-coded SLR normal point residuals of station Wettzell in the panel a. After the rejection of outliers (colored dark blue, orange, and red), revised residuals are obtained (panel b). A distinct dependency based on the angle of incidence in the retroreflector frame is visible. This dependency is compensated by the correction function which forms the cone shown in the panel c.

Applying the correction to each range measurement removes, amongst other station-systematic effects, the incidence dependency and enhanced residuals are obtained (panel d). Similar correction functions are applied to the measurements of each SLR station that tracked the TOPEX/Poseidon spacecraft. The application of these correction functions reduces the root-mean-square (RMS) fit of SLR observations over the complete duration of the mission from 33.78 cm to 1.97 cm. Further information about the parameter estimation and the correction function can be found in Zeitlhöfler et al. (2022).

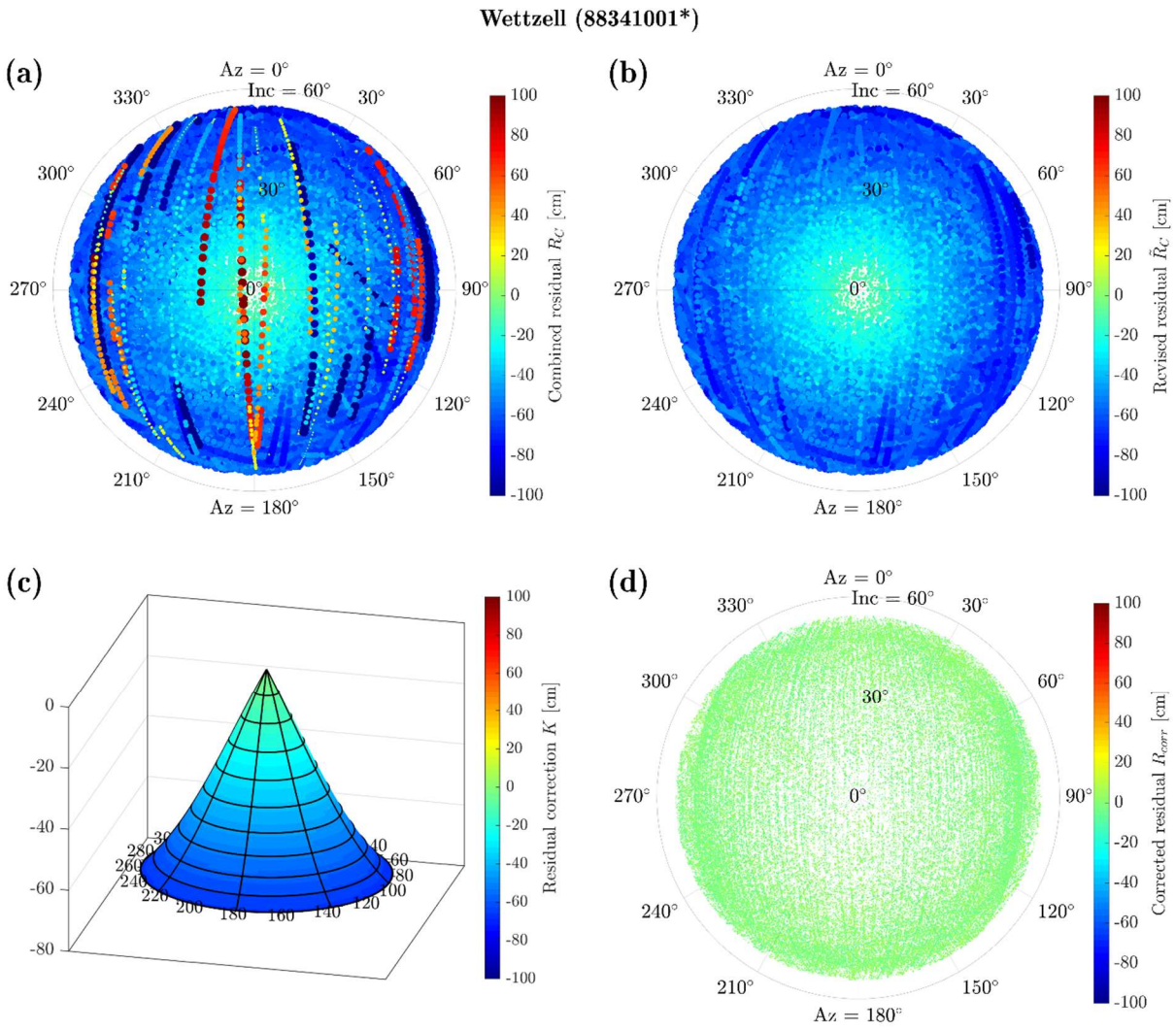

Figure 25. Measurement correction for SLR observations of the station Wettzell to TOPEX/Poseidon. (a) Normal point residuals in the retroreflector frame. (b) Revised residuals. (c) Measurement correction function based on the azimuth and incidence angles. (d) Enhanced range residuals obtained by applying the measurement correction.

17.3 IMPROVEMENTS IN THE ACCURACY OF ALTIMETRY SATELLITE ORBITS

Orbits of altimetry satellites comprise positions of satellite-fixed reference points from which the distance to the water surface is measured. To precisely derive these positions on centimeter and sub-centimeter level, accurate knowledge of both, the gravitational and non-gravitational forces acting on non-spherical altimetry satellites as well as positions of tracking stations in a precisely defined reference frame are necessary. Significant progress was made in recent years in the precise orbit determination of altimetry satellites (International Altimetry Team, 2021). However, the development and further elaboration of the models for current and past altimetry missions is still necessary and is being performed.

In 2021, the library for orbit modeling (OC) of altimetry satellites in DOGS was further elaborated. Thus, a new EIGEN-GRGS.RL04.MEAN-FIELD time-variable gravity field model (Lemoine et al., 2019) was implemented. Additionally, numerous tests on the optimal set of estimated parameters were performed. The Jason-3 orbit was extended for additional 2.8 years from 9 January 2019 to 24 October 2021. Using these improvements in the background models and parametrization, refined orbits (named DGFI-TUM SLR RUN008) were derived for the altimetry satellites TOPEX/Poseidon (27 September 1992 – 9 October 2005), Jason-1 (13 January 2002 – 30 June 2013), Jason-2 (20 July 2008 – 2 October 2019), and Jason-3 (17 February 2016 – 24 October 2021). The Jason satellites orbits were derived using the observation-based attitude realization (Bloßfeld et al., 2020). The RMS values of fits of SLR observations of these new orbits indicate a reduction (an improvement) by about 27% from 2.46 cm to 1.79 cm over the complete time span from 27 September 1992 till 24 October 2021, as compared to the DGFI-TUM SLR RUN001 orbits derived in 2019 using other background models and a less dense parametrization of empirical accelerations (cf. **Figure 26**). The mean values of RMS fits of SLR observations are 1.37 cm for Jason-1, 1.35 cm for Jason-2, and 1.38 cm for Jason-3 for DGFI-TUM SLR RUN008 orbits. These new orbits also show a reduction of the standard deviation of the orbit differences in the radial direction with respect to GFZ VER13 orbits of TOPEX/Poseidon and Jason-1 (Rudenko et al., 2019) and CNES POE-F orbits of Jason-2 and Jason-3 (https://cddis.nasa.gov/archive/doris/products/orbits/ssa/), as compared to the DGFI-TUM SLR RUN001 orbits. This improvement is from 1.69 cm to 1.57 cm over the same complete time span (**Figure 27**).

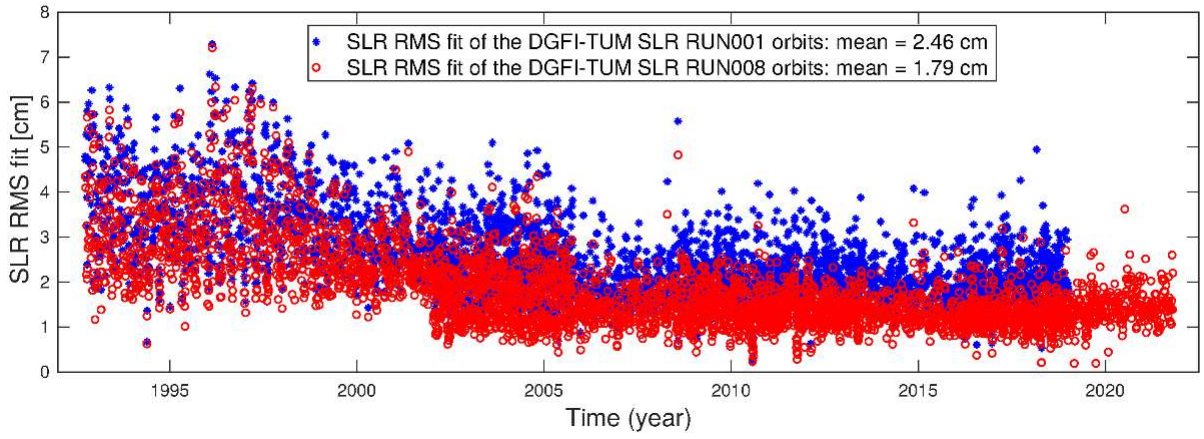

Figure 26. RMS fit of SLR observations of TOPEX/Poseidon, Jason-1, Jason-2, and Jason-3 of DGFI-TUM SLR RUN001 and RUN008 orbits.

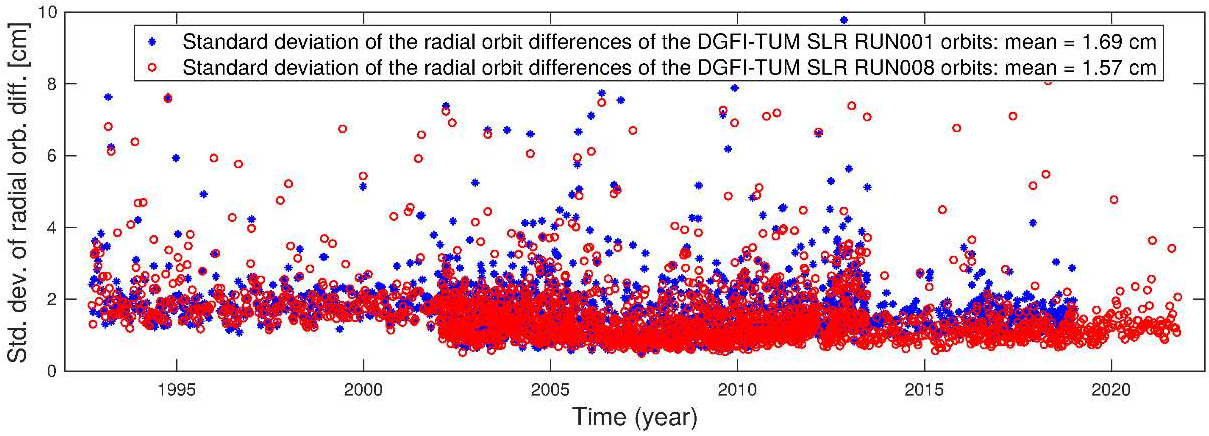

Figure 27. Standard deviation of the orbit differences in the radial directions of DGFI-TUM SLR RUN001 and RUN008 orbits with respect to GFZ VER13 orbits of TOPEX/Poseidon and Jason-1 and CNES POE-F orbits of Jason-2 and Jason-3. Outliers larger than 10 cm are neglected for the computation of mean values.

17.4 CONCLUSIONS AND OUTLOOK

Some results of the analysis of SLR and DORIS observations and orbits of TOPEX/Poseidon, Jason-1, Jason-2 and Jason-3 were presented at the DORIS Analysis Working Group online meeting of the International DORIS Service on 7 April 2021, EGU General Assembly 2021 and Frontiers of Geodetic Science (FROGS) on 23 September 2021. The IDS AAC at DGFI-TUM plans to include new altimetry satellites and further elaborate the DORIS and SLR data processing. In 2022, the DGFI-TUM AAC plans to provide some of its DORIS-related products to the IDS.

17.5 PRESENTATIONS

Rudenko S., Bloßfeld M., Zeitlhöfler J.: Recent activities of the IDS Associate Analysis Center at DGFI-TUM. DORIS Analysis Working Group meeting of the International DORIS Service, online, 07.04.2021, https://ids-doris.org/images/documents/report/AWG202104/IDSAWG202104-Rudenko-DGFI.pdf

Rudenko S., Dettmering D., Bloßfeld M., Zeitlhöfler J. and Alkahal, R.: On the current accuracy of altimetry satellite orbits, EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-12148, https://doi.org/10.5194/egusphere-egu21-12148, 2021.

Zeitlhöfler, J., Bloßfeld, M., Rudenko, S., and Seitz, F.: Estimation of station-dependent LRA correction parameters for the TOPEX/Poseidon mission, EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-12361, https://doi.org/10.5194/egusphere-egu21-12361, 2021.

Zeitlhöfler J., Bloßfeld M., Rudenko S., Seitz F.: Station-dependent laser retroreflector array correction function for TOPEX/Poseidon. Frontiers of Geodetic Science (FROGS), Online, https://mediatum.ub.tum.de/doc/1625213/1625213.pdf, 23.09.2021.

17.6 REFERENCES

Bloßfeld M., Zeitlhöfler J., Rudenko S., Dettmering D.: Observation-based attitude realization for accurate Jason satellite orbits and its impact on geodetic and altimetry results. Remote Sensing, 12(4), 682, DOI: 10.3390/rs12040682, 2020.

International Altimetry Team: Abdalla S., Abdeh Kolahchi A., Adusumilli S., ... Dettmering D., ... Passaro M., ... Rudenko S., ..., Schwatke C., ... et al.: Altimetry for the future: Building on 25 years of progress. Advances in Space Research, 68, 319-363, DOI: 10.1016/j.asr.2021.01.022, 2021.

Lemoine J.M., Bourgogne S., Biancale R., Reinquin F., and Bruinsma S.: EIGEN-GRGS.RL04.MEAN-FIELD - Mean Earth gravity field model with a time-variable part from CNES/GRGS RL04. IDS Workshop, 24-29 September 2018, Ponta Delgada, Portugal.

Rudenko S., Esselborn S., Schöne T., Dettmering D.: Impact of terrestrial reference frame realizations on altimetry satellite orbit quality and global and regional sea level trends: a switch from ITRF2008 to ITRF2014. Solid Earth, 10(1), 293-305, DOI: 10.5194/se-10-293-2019, 2019.

Zeitlhöfler J., Bloßfeld M., Rudenko S., Dettmering D., Seitz F.: Station-dependent Satellite Laser Ranging measurement corrections for TOPEX/Poseidon. Submitted to Advances in Space Research, 2022.

18 WORKING GROUP "NRT DORIS DATA"

Denise Dettmering / DGFI-TUM, Germany

18.1 WORKING GROUP "NRT DORIS DATA"

The general objective of this working group is a thorough assessment on benefits, requirements and prospects of near real-time (NRT) DORIS data with a focus on applications in ionospheric research. In 2021, the main work was focused on the usage of NRT DORIS data for the evaluation of GNSS ionospheric models as well as for ionospheric modelling in combination with GNSS data.

18.2 DORIS DATA FOR EVALUATION OF GNSS TOTAL ELECTRON CONTENT (TEC) MODELS

The performance evaluation of global ionospheric TEC models, e.g., global ionospheric maps (GIMs), is still an open question within the GNSS community. In addition to the conventional GNSS dSTEC analysis, DORIS dSTEC analysis was developed and continued to be used to validate the performance of different ionospheric TEC models. The computation of DORIS dSTEC is actually very similar to that of GNSS dSTEC, which is generated based on the dual-frequency DORIS carrier phase measurements along the individual phase continuous arc. Using NRT DORIS data from Jason-3 altimetry, the DORIS dSTEC assessment was analyzed to check the quality of RT-GIMs from different analysis centers as well as its real time (RT)-combined one.

18.3 DORIS NRT DATA ASSESSMENT

Since February 2021, the first DORIS NRT products are distributed via the IGN data center. Within the current evaluation period, observation data (RINEX) and orbit information (sp3) for the Jason-3 mission is available with a latency of about three hours. The new products are freely accessible via the following directories:

ftp://doris.ign.fr/pub/doris/data/ja3/NRT/
ftp://doris.ign.fr/pub/doris/products/orbits/ssa/ja3/NRT/

First evaluations of WG members focused on the data latency: Within the period between end of September 2021 until end of February 2022, the mean latency since file creation is a bit more than 1 hour. This leads to a mean latency of the observation between 1.656 and 3.647 hours for observations in one file (RINEX) and between 1.500 and 3.656 hours for orbits (SP3). The file length is about 2 hours for both types. The minimum latency that could be achieved is 0.7 hours, the maximal 17.4 hours (see **Figure 28**).

The NRT DORIS data are expected to significantly contribute to the ultra-rapid or NRT vertical total electron content (VTEC) modeling along with GNSS. How the few files with higher latency will affect the modelling results is subject of further studies.

The integration of the NRT products in applications, such as real time (RT) and near-real time ionospheric modelling is still under development. First results at CAS show a limited contribution of DORIS NRT data in reconstructed RT-GIM, compared to real-time multi-GNSS observation streams, including GPS, Galileo and BeiDou, which are provided by the IGS and transmitted following RTCM

conventions. This is mainly related to the fact that today, only one satellite (Jason-3) provides NRT DORIS data. The improved contribution of DORIS data in RT-GIM computation can be foreseen with more satellites providing NRT DORIS data. More and detailed results and simulations are still outstanding. This is a remaining task for the year 2022.

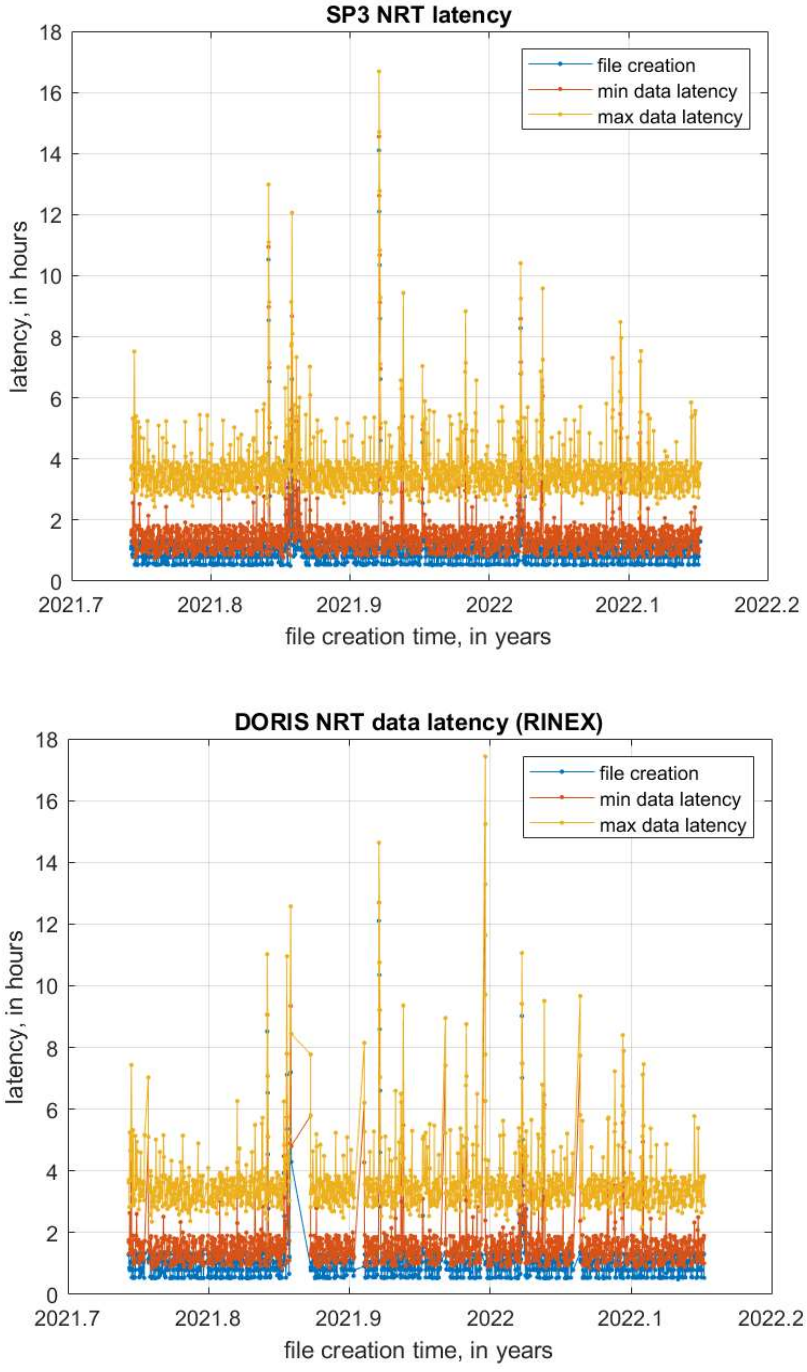

Figure 28. Latency of the NRT data: sp3 orbit files (top) and DORIS/RINX files (bottom).

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: https://cddis.nasa.gov/archive/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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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 are:

- 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

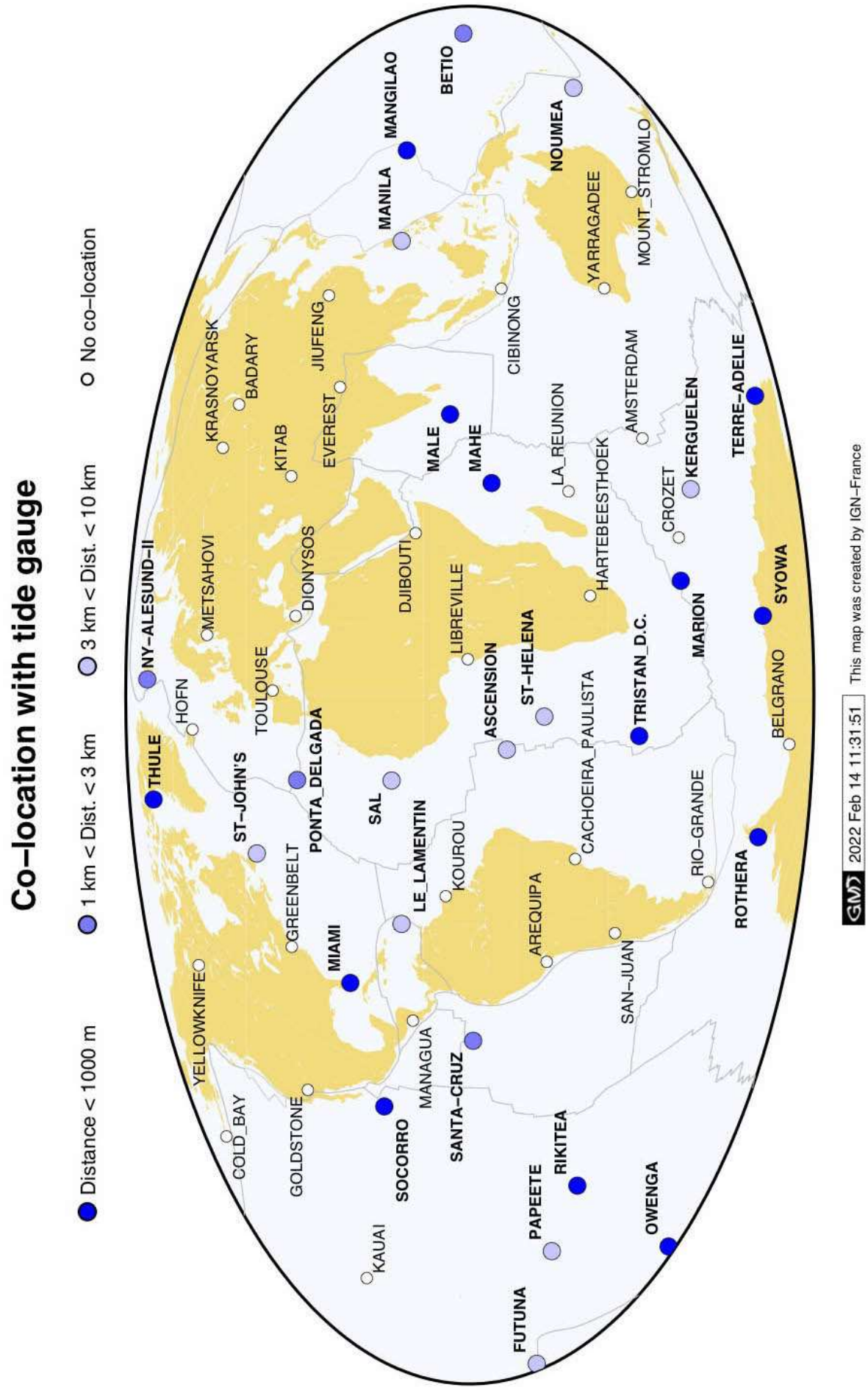
e-mail : ids.central.bureau@ids-doris.org

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)	28/02/97	6500	263	1831
BETIO	172.92	1.35	KIRIBATI	22/10/06	1600	113	1804
FUTUNA	-178.12	-14.31	FRANCE (POLYNESIA)	18/10/11	4400	353	2244
KERGUELEN	70.26	-49.35	FRANCE (TAAF)	05/04/93	3300	23	1849
LE LAMENTIN	-61.00	14.60	FRANCE (MARTINIQUE)	29/06/13	7000	338	1942
MAHE	55.53	-4.68	SEYCHELLES	20/06/01	300	339	1846
MALE	73.53	4.20	MALDIVES	15/01/05	500	28	1753
MANILA	121.03	14.53	PHILIPPINES	26/02/03	9700	73	145
MANGILAO	144.80	13.43	USA (GUAM IS.)	12/04/18	830	------	2130
MARION ISLAND	37.86	-46.88	SOUTH AFRICA	01/01/90	410	20	------
MIAMI	-80.17	25.73	USA (FLORIDA)	10/02/05	180	332	1858
NOUMEA	166.42	-22.24	FRANCE (CALEDONIA)	27/01/05	7000	123	2134
NY-ALESUND II	11.83	78.93	NORWAY (SVALBARD)	19/10/18	2500	345	1421
OWENGA	-176.37	-44.02	NEW ZEALAND (CHATHAM IS.)	20/01/14	80	------	------
PAPEETE	-149.61	-17.58	FRANCE (POLYNESIA)	27/07/95	7000	140	1397
PONTA DELGADA	-25.66	37.75	PORTUGAL (AZORES)	02/11/98	1500	245	258
RIKITEA	-134.97	-23.13	FRANCE (POLYNESIA)	23/09/06	800	138	1253
ROTHERA	-68.13	-67.57	UK (ANTARCTICA)	01/03/03	170	342	1931
SAL	-22.98	16.78	CAPE VERDE	15/12/02	5700	329	1914
SANTA CRUZ	-90.30	-0.75	ECUADOR	01/04/05	1600	------	1472
SOCORRO	-110.95	18.73	MEXICO	09/06/89	580	162	1821
ST-HELENA	-5.67	-15.94	UK (SOUTH ATLANTIC)	01/06/89	5900	264	1845
ST. JOHN'S	-52.68	47.40	CANADA (TERRE-NEUVE)	27/09/99	3600	223	393
SYOWA	39.58	-69.01	JAPAN (ANTARCTICA)	10/02/93	1000	95	1396
TERRE ADELIE	140.00	-66.67	FRANCE (ANTARCTICA)	01/02/97	500	131	2231
THULE	-68.83	76.54	DENMARK (GREENLAND)	28/09/02	450	343	------
TRISTAN DA CUNHA	-12.31	-37.07	UK (SOUTH ATLANTIC)	10/06/86	120	266	------


Co–location with tide gauge
Distance < 1000 m
1 km < Dist. < 3 km
3 km < Dist. < 10 km
No co–location
NY–ALESUND–II
THULE
HOFN
METSAHOVI
KRASNOYARSK
BADARY
JIUFENG
EVEREST
KITAB
DIONYSOS
TOULOUSE
ST–JOHN'S
PONTA_DELGADA
GREENBELT
MIAMI
SAL
DJIBOUTI
LIBREVILLE
MALE
MAHE
ASCENSION
ST–HELENA
LE_LAMENTIN
KOUROU
CACHOEIRA_PAULISTA
TRISTAN_D.C.
HARTEBEESTHOEK
LA_REUNION
CIBINONG
MANILA
MANGILAO
BETIO
NOUMEA
YARRAGADEE
MOUNT_STROMLO
AMSTERDAM
CROZET
KERGUELEN
MARION
TERRE–ADELIE
SYOWA
BELGRANO
ROTHERA
RIO–GRANDE
AREQUIPA
SAN–JUAN
YELLOWKNIFE
COLD_BAY
GOLDSTONE
SOCORRO
MANAGUA
SANTA–CRUZ
KAUAI
PAPEETE
RIKITEA
OWENGA
FUTUNA
GMD
2022 Feb 14 11:31:51
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	City, Country
Amsterdam	Institut Polaire Paul Emile Victor (IPEV)	Base Martin-de-Viviès, île Amsterdam, Sub-Antarctica, FRANCE
Arequipa	Instituto Astronómico y Aeroespacial P. Paulet Universidad Nacional de San Agustin (UNSA)	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)	Buenos Aires, 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)	Zografou, GREECE
Djibouti	Observatoire Géophysique d'Arta (CERD)	Arta, Republic of DJIBOUTI
Everest	Ev-K2-CNR Association	Bergamo, 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)	Grasse, FRANCE
Greenbelt	NASA / GSFC / GGAO	Greenbelt, Maryland, U.S.A.
Hartebeesthoek	HartRAO, South African National Space Agency (SANSA)	Hartebeesthoek, SOUTH AFRICA

Station name	Host agency	City, Country
Höfn	National Land Survey of Iceland Landmælingar Islands (LMI)	Akranes, ICELAND
Jiufeng	Innovation Academy for Precision Measurement Science and Technology (APM)	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, 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	Mount Stromlo Observatory, Geoscience Australia (GA)	Mount Stromlo, Canberra, AUSTRALIA
Nouméa	Direction des Infrastructures, de la Topographie et des Transports Terrestres	Nouméa, New Caledonia, FRANCE
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

Station name	Host agency	City, Country
Ponta Delgada	CIVISA / IVAR Universidade dos Açores	Ponta Delgada, Azores, PORTUGAL
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	National Space Institute at the Technical University of Denmark (DTU Space)	Kgs. 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	Yarragadee Geodetic Observatory, Geoscience Australia (GA)	Yarragadee, AUSTRALIA
Yellowknife	Natural Resources Canada (NRCan)	Yellowknife, 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

24 BIBLIOGRAPHY

The following list compiles articles related to DORIS published in 2021 in international peer-reviewed journals

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)

2021

Belli, A.; Zelensky, N.P.; Lemoine, F.G.; Chinn, D.S., 2021. Impact of Jason-2/T2L2 Ultra-Stable-Oscillator Frequency Model on DORIS stations coordinates and Earth Orientation Parameters, ADVANCES IN SPACE RESEARCH, 67(3):930-944, DOI: 10.1016/j.asr.2020.11.034 OPEN ACCESS

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Khelifa, S., 2021. Correlation study of the annual signal in GPS and DORIS station positions with atmospheric and hydrology loading effects, ARABIAN JOURNAL OF GEOSCIENCES, 14:370, DOI: 10.1007/s12517-021-06778-0

König, R.; Reinhold, A.; Dobslaw, H.; Esselborn, S.; Neumayer, K.H.; Dill, R.; Michalak, A., 2021. On the effect of non-tidal atmospheric and oceanic loading on the orbits of the altimetry satellites ENVISAT, Jason-1 and Jason-2, ADVANCES IN SPACE RESEARCH, 68(2):1048-1058, DOI: 10.1016/j.asr.2020.05.047

Mertikas, S.; Donlon, C.; Matsakis, D.; Mavrocordatos, C.; Altamimi, Z.; Kokolakis, C.; Tripolitsiotis, A., 2021. Fiducial reference systems for time and coordinates in satellite altimetry, ADVANCES IN SPACE RESEARCH, 68(2):1140-1160, DOI: 10.1016/j.asr.2020.05.014

Yu, H.; Sośnica, K.; Shen, Y., 2021. Separation of geophysical signals in the LAGEOS geocentre motion based on singular spectrum analysis, GEOPHYSICAL JOURNAL INTERNATIONAL, 225(3):1755–1770, DOI: 10.1093/gji/ggab063

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

To subscribe to the newsletter, please send an e-mail to ids.central.bureau@ids-doris.org, with "Subscribe Newsletter" in the subject.

The following list gives the content of the newsletters issued from #1.

Newsletter	Article title	Authors
#1 April 2016 	• Editorial • A high performing network • Two new DORIS instruments in • DORIS back in Goldstone • DORIS contributes to the International Terrestrial • IDS life: -GFZ first Associated Analysis Center -IDS Meetings 2016 -IDS component renewal	L. Soudarin (CLS) J. Saunier (IGN) P. Ferrage and C. Manfredi (CNES) J. Saunier (IGN) G. Moreaux (CLS) L. Soudarin (CLS)
#2 July. 2016 	2015 Nepal Earthquakes moved the DORIS station on Everest by a few centimeters DORIS-VLBI compatibility tests at the Geodetic Observatory Wettzell DORIS in Managua IDS life: -IDS AWG meeting at the TU Delft -IDS Workshop La Rochelle -IDS component renewal	G. Moreaux (CLS) T. Klügel (BKG) J. Saunier (IGN) L. Soudarin (CLS)
#3 Dec. 2016 	IDS held its Workshop 2016 in La Rochelle Looking back over 30 years of DORIS network development Six DORIS receivers operating in orbit and several more to come IDS life: -IDS election results -Combination Center selection	L. Soudarin (CLS) J. Saunier (IGN) P. Ferrage (CNES) L. Soudarin (CLS)

Newsletter	Article title	Authors
#4 Nov. 2017 	Station re-location at Kitab (Uzbekistan) to get better visibility	J. Saunier (IGN)
	The host agency in short: UBAI	D. Fazilova, S. Ehgamberdiev (UBAI)
	DPOD2014: a new DORIS extension of ITRF2014 for Precise Orbit Determination	G. Moreaux (CLS)
	IDS life: -Two new Associate Analysis Centers -Creation of the Working Group "NRT DORIS data" -IDS Retreat	L. Soudarin (CLS)
#5 Sep. 2018 	DORIS stations in Polar Regions, an ongoing challenge for continuous operation Focus on Rothera on the Antarctic Peninsula	J. Saunier (IGN)
	The host agency in short: BAS	D. G. Vaughan (BAS)
	DORIS on Sentinel-3B: and now seven! Jason-2, ten years after	CNES
	IDS meetings: a time to remove the nose from the grindstone - IDS retreat - IDS Analysis Working Group meeting	G. Moreaux, L. Soudarin (CLS)
	IDS life: -IDS workshop 2018 -IDS elections -IDS activity report 2017	L. Soudarin (CLS)
#6 Feb. 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)
	The host agency in short: Ponta Delgada	R. T. Fernandes Marques (CIVISA)
	Tribute to Richard Biancale (1952-2019)	F. Lemoine (NASA), L. Soudarin (CLS), J.-M. Lemoine (CNES), P. Ferrage (CNES), J.-P. Boy (EOST)
	IDS life: -IDS election results -Visit to the Ponta Delgada DORIS station -IDS Workshop 2018	L. Soudarin (CLS)

Newsletter	Article title	Authors
#7 Jan. 2020 	DORIS in Latin America: more sun, more warmth, and more rythm	J. Saunier (IGN)
	The host agencies in short: -San Juan -Santa Cruz	 R. C. Podestá (OAFA) J. Carrión (CDF)
	IDS life	L. Soudarin (CLS)
	IDS & DORIS quick reference list	
#8 Dec. 2020 	2020 celebrates 30 years of the DORIS system	J. Saunier (IGN)
	2020, two new missions have joined the DORIS constellation	P. Ferrage (CNES)
	IDS and DORIS milestones	L. Soudarin (CLS)
	IDS life Pascal Willis retires	 F. Lemoine (NASA)
#9 Sep. 2021 	A new method for monitoring the geocenter motion using DORIS observations	A. Couhert (CNES)
	Doppler crossings on-board DORIS receiver carrier satellites	C. Jayles (CNES), J.P. Chauveau (CLS), P. Yaya (CLS)
	Major renovation at Réunion Island	J. Saunier (IGN)
	The host agency in short: La Réunion	P. Kowalski (OVPF)
	The 4th generation of DORIS beacon	J. Saunier (IGN)
	IDS life	L. Soudarin (CLS)
	HY-2D, a new DORIS carrier satellite	

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