

Overview

The current report presents the different activities held in 2015 by the components of the International DORIS Service (IDS). In a first step, we give the current status of the DORIS system (satellites and tracking network). In a second step, we provide the latest news of the IDS (Governing Board, Central Bureau, Data Centers). Then we focus on the most recent activities conducted by the Analysis Centers and the Analysis Coordination. The report ends with information about the meetings and the publications.

1 DORIS system

1.1 DORIS satellites

During this report period (2015), the number of DORIS satellites has decreased to four (see Table 1).

Satellite	Start	End	Type
SPOT-2	31-MAR-90 04-NOV-92	04-JUL-90 15-JUL-09	Remote sensing
TOPEX/Poseidon	25-SEP-92	01-NOV-04	Altimetry
SPOT-3	01-FEB-94	09-NOV-96	Remote sensing
SPOT-4	01-MAY-98	24-JUN-13	Remote sensing
SPOT-5	11-JUN-02	11-DEC-15	Remote sensing
Jason-1	15-JAN-02	21-JUN-13	Altimetry
ENVISAT	13-JUN-02	08-APR-12	Altimetry, Environment
Jason-2	12-JUL-08	–	Altimetry
Cryosat-2	30-MAY-10	–	Altimetry
HY-2A	1-OCT-11	–	Altimetry
SARAL	14-MAR-13	–	Altimetry

Table 1: DORIS data available at IDS Data Centers. As of December 2015

In December 2015, SPOT-5 was decommissioned after 13.5 years of a successful mission. It was launched in 2002 with the last DORIS instrument of the 2nd generation. The constellation is now only composed of DGXX receivers which include the following features:

- The simultaneous tracking capability was increased to seven beacons (from only two in the previous generation of receivers)

- The new generation Ultra Stable Oscillator (USO) design provides better frequency stability while crossing the South Atlantic Anomaly (SAA), and a better quality of Medium Orbit Ephemeris (MOE) useful for beacon location determination.
- New DIODE navigation software (improved accuracy)

Two missions with DORIS onboard will be launched early 2016: Jason-3 (EUMETSAT/NOAA/CNES) and Sentinel-3A (GMES/ESA).

Some other DORIS missions are under development and should guarantee a constellation with at least 4 DORIS contributor satellites through 2032:

- Sentinel 3B is planned for 2018, Sentinel 3C and 3D are foreseen for 2020 and 2025.
- HY-2D & 2E (China Academy of Space) are foreseen for 2020, 2021
- Jason CS1/Sentinel6A (Eumetsat/ESA/CNES) is expected from 2020, and Jason CS2/Sentinel6B from 2025,
- SWOT is foreseen for late 2020.

1.2 DORIS network

The DORIS permanent network is made up of 56 stations achieving 90% coverage (for satellites orbiting at 800 km altitude) (Figure 1). An additional station is dedicated to experimentation: Grasse (France).

A new DORIS station, "GONC", was installed this year at the Goldstone Deep Space Communications Complex (GDSCC) in California. DORIS actually occupied this site at Goldstone between 1988 and 2004 but the station was moved 300 km south to Monument Peak (east of San Diego, California) for co-location with the SLR tracking station "7110" and the GNSS station "MONP". Unfortunately, following insoluble conflict at the 2 GHz frequency with a nearby TV microwave relay system, which manifested itself after the US switched to digital television transmissions in 2009, the DORIS station of Monument Peak had to be decommissioned in 2010 after only 4 1/2 years of service. After discussion with NASA, it was determined that the remote location of the GDSCC in the heart of the Mojave Desert was then the best-suited option to ensuring a peaceful and safe environment for the DORIS station. The return to service of DORIS in California is of great importance for the development of altimetry data products. A gap in coverage leads to degradation in orbit determination, which affects both the real-time orbits computed by the DIODE instrument on-board

the DORIS satellites, as well as for the precise orbits that are computed later. This much-awaited station fills a hole in the DORIS data coverage over the northern Pacific Ocean.

Other sites out of order for a long time making gaps in coverage are awaiting solutions: Yuzhno-Sakhalinsk (Russia), Santa Cruz (Galapagos, Ecuador), Port-Moresby (Papua New-Guinea) and Santiago (Chili). For most of them, a relocation or/and a host agency change is required.

However, the DORIS network still provided a high level of performance and a reliable service with a network availability maintained over 85% of operating stations since 2012 thanks to the responsiveness and the joint effort of CNES, IGN and all agencies hosting the stations

The number of maintenance operations is greater since the network equipment is ageing: 9 beacons and 5 antennas required replacements in 2015. The 4th DORIS beacon generation currently under development is the eagerly awaited evolution with the delivery of a prototype in 2017 and the start of the deployment in 2019.

When choosing a new site, co-location with other space geodetic techniques remains a priority goal. We use all opportunities to increase the number of co-located sites with over three-quarters of the DORIS network stations (see Figure 1).

In 2015 the following sites were visited:

- Goldstone, CA, USA: new site replacing Monument Peak (Figure 5).
- Arequipa, Peru: visit
- Kourou, French Guyana: tracking oscillator replacement
- Northern Australia: reconnaissance with a view to installing a new station
- Ny-Ålesund, Spitsbergen, Norway: reconnaissance with a view to move
- Sal, Cape Verde: renovation with a shift of 5 m.
- Ponta Delgada, Portuguese island: antenna change

Finally, the overall objectives for the next year are:

- New stations at Managua (Nicaragua), Wettzell (Germany) and San Juan (Argentina)
- Re-location in Kitab (Uzbekistan)
- Restarting at Santa-Cruz (Galapagos, Ecuador)
- Reconnaissance in Mariana Islands (USA), Manchuria (China) and Reykjavik (Iceland)

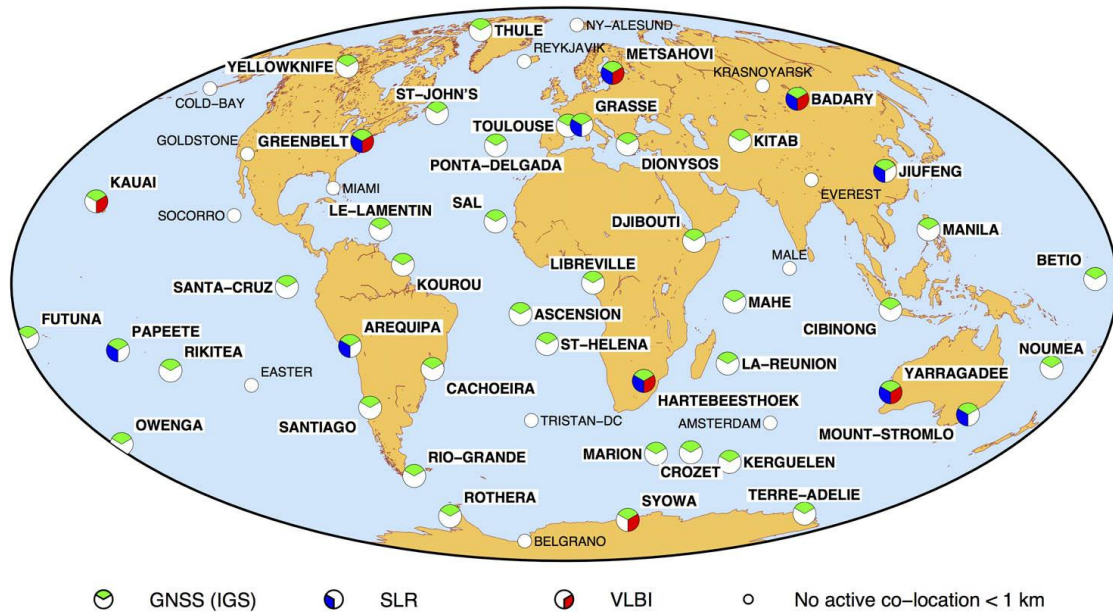


Fig. 1: The permanent DORIS network – 56 stations – and co-location with other IERS techniques (as of Aug. 2015).

2 IDS Governing Board

On January 1st, 2015, new members took up their duties within the Governing Board (GB) to serve for the period 2015-2018:

- Hugues Capdeville (CLS) and Jean-Michel Lemoine (CNES) as Analysis Coordinators,
- Marek Ziebart (UCL) as a Member at Large.

For the first time, a tandem will share together the responsibility and the work of the Analysis Coordination. Hugues and Jean-Michel can be contact at <ids.analysis.coordination@ids-doris.org>

The composition of the new Governing Board is given in Table 2.

The IDS Terms of Reference (ToR) have been revised by the GB in May 2015, to include the definition of Associate Analysis Center, clarifications of the definition of Analysis Center, amendments to the definition of IDS Associates. The revised version was approved by the IAG Executive Committee at its meeting on June 26, 2015, in Prague, Czech Republic.

At its meeting in October 2015, the GB has decided to accept GFZ (German Research Center for Geosciences) as an Associated Center, following the recommendation of the Analysis Coordination, on the basis of the GFZ's DORIS analysis activities.

Name	Institution	Country	Mandate
Richard Biancale	CNES	France	Member at large
Hugues Capdeville Jean-Michel Lemoine	CLS CNES	France	Analysis Coordination
Pascale Ferrage	CNES	France	System representative
Brian Luzum	GSFC	USA	IERS representative
Guilhem Moreaux	CLS	France	Combination Center representative
Carey Noll	GSFC	USA	Data flow Coordinator
Michiel Otten	ESOC	Germany	IAG representative
Jérôme Saunier	IGN	France	Network representative
Laurent Soudarin	CLS	France	Director of Central Bureau
Pascal Willis (chair)	IGN/IPGP	France	Analysis Center representative
Marek Ziebart	UCL	UK	Member at large

Table 2: Composition of the IDS Governing Board (January 2015 – December 2016)

3 IDS Central Bureau

In 2015, the Central Bureau (CB) participated in the organization of the AWG meetings held at CLS in Toulouse on May 28 and 29, and at NASA/Goddard Space Flight Center in Greenbelt, Maryland, on October 15 and 16. It documented the GB meetings held on these occasions. Between the meetings, the CB coordinates the work of the GB.

The CB managed the edition and publication of the IDS Activity Report 2014. In addition, it provided the IDS contributions to IERS Annual report 2014, IAG Travaux 2011-2015, and ICSU World Data System (ICSU-WDS) Biennial Report 2013-2014.

A report of the IDS Workshop 2014 has been written for publication in IAG Newsletter, January 2015 issue.

In January, the Central Bureau launched a new survey to hear from the IDS users about the services and ask them to give their feedback by filling a form

on the web site. Questions from users concerning IDS data and products were answered or forwarded to other specialists.

3.1 IDS Web and ftp sites

The IDS Central Bureau (CB) maintains the IDS web (<<http://ids-doris.org>>) and ftp (<<ftp://ftp.ids-doris.org/pub/ids>>) sites.

Besides the regular updates of pages and additions of documents, the website was enriched with new pages and received some slight modifications.

In order to help the access to an ever-increasing number of documents on the website, a new page “Documentation” was created in the section “Reports & Mails”. 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.

<http://ids-doris.org/report/documentation.html>

With the aim of giving a broader visibility and making the search easier, the full list of presentations given at DORIS or IDS meetings with the corresponding access links is now available on a unique page “Meeting presentations” in the section “Reports & Mails”. From October 2015, the new pages dedicated to each meeting do no longer contain the list of presentations but a link to this page.

<http://ids-doris.org/report/meeting-presentations.html>

To give an overview of the DORIS and IDS data and products, a new page “Tables of Data & Products” was created in the section “Data & Products”. It shows in tables the data and product provided by IDS with their main characteristics: latency, sample interval, archive locations, format, missions, content, provider.

<http://ids-doris.org/data-products/tables-of-data-products.html>

The section “Combination” in the part “Analysis coordination” was restructured. It contains now the two pages: “Contribution ITRF2008” (<http://ids-doris.org/combination/contribution-itrf2008.html>) and “Contribution ITRF2014” (<http://ids-doris.org/combination/contribution-itrf2014.html>)

The page with the composition of the Governing Board was revised. A table gives the list of the current and former members with position, term, status, affiliation:

<http://ids-doris.org/organization/governing-board.html>

A new section « Satellites » in the part “DORIS system” has been open since early 2016: <http://ids-doris.org/satellites.html>

The main updates of the website as well as the list of the new documents and files put on the ftp site can be found in the IDS Activity report 2015 (<http://ids-doris.org/report/governing-board.html#activity>).

3.2 DOR-O-T, the IDS Webservice

The IDS web service (<<http://ids-doris.org/webservice>>) named DOR-O-T for DORIS Online Tools (pronounced like the French given name Dorothee) has been upgraded with a new plot tool to visualize the time series of Earth Orientation Parameters from the IDS Combination Center analysis (Xp, Yp, LOD) (<http://apps.ids-doris.org/apps/eoptool.html>).

3.3 IDS Mail system

Several types of emails are distributed by the IDS Central Bureau:

- DORISMail: general DORIS interest
- DORISReports: reports related to DORIS data and products
- AWG mailing list: technical discussion between analysis centers, combination and coordination
- DORISstations: information about station events (data gap, positioning discontinuities)

Everyone is welcome to subscribe to any of these emails. See more details on <<http://ids-doris.org/report/emails.html>>.

4 IDS Data Centers

The IDS data flow organization remains the same. It is based on two data centers: one on the East Coast of the U.S. (CDDIS at NASA GSFC) and one in Europe (IGN in France). They are both exact mirrors of each other, and so, are able to continue on an operational basis, even if one of them is inaccessible due to a temporary failure.

These two data centers archive the DORIS data as well as the IDS products (station coordinates and velocity, geocenter motion, earth orientation parameters, ionosphere data, etc.).

The main events of the year are listed hereafter:

- In January 2015, SSALTO developed improvements in the time tagging of DORIS measurements in the RINEX format (missions Jason-2, Cryosat-2, HY-2A, and SARAL). Updates were applied to RINEX data starting on January 20, 2015. Older RINEX data were reprocessed and submitted to the data centers in May 2015; these updated data files were named with a new version number to indicate a revised data set.
- Precise satellite orbits provided by SSALTO were updated to new Geophysical Data Record (GDR) standards (GDR-E) starting in April 2015. Orbit files for Jason-1, Jason-2, Cryosat-2, and SARAL were submitted using these standards with new version numbers; older files were archived to subdirectories by GDR designation. Other satellites (e.g., Envisat, HY-2A) will be updated to the GDR-E standards in the future and upcoming missions (e.g., Jason-3) will also utilize the GDR-E standards.

5 IDS Analysis Centers and IDS Analysis Coordination

The activities of the DORIS analysts in 2015 have been dominated by the IDS contribution to ITRF2014 and its evaluation, and the implementation of the DORIS RINEX data processing. Analysis working group meetings were held in Toulouse (France), May 28-29, 2015 at CLS, and in Greenbelt (Maryland, USA), October 15-16, 2015 at NASA/GSFC.

The first period of 2015 was devoted to the processing of the second half of 2014 and to the delivery of that time period to IDS Combination Center (CC) after the extension of ITRF2013 into ITRF2014. An evaluation of the preliminary version of ITRF2014 provided by IERS (Z. Altamimi) has been done by IDS CC, some Analysis Centers (ACs) and one Associated Analysis Center (AAC).

For the participation of the IDS to the realization of ITRF2014, the six active ACs agreed to submit new SINEX solutions. The CNES POD (Precise Orbit Determination) team has greatly contributed to this activity as the source of technical information about the spacecrafts and the measurements, and as the provider of DORIS data and orbit products. Two other institutions performing DORIS data processing participate in the analysis work: GeoForschung Zentrum (GFZ) and TU/Delft. GFZ is involved in the POD analysis of altimeter satellites

and brought valuable contributions to the evaluation of the models and standards. TU/Delft routinely performs orbits of Cryosat-2 for calibration and validation, and made available the spacecraft quaternions to the community.

The list of the participating groups is given in Table 3. Some of the centers perform POD processing of DORIS satellites using other geodetic techniques (SLR, GNSS). The multi-technique analyses are useful since they can provide an independent assessment of DORIS system performance, and help validating model changes and implementations of attitude laws when spacecraft quaternions are not available.

We may mention that Marek Ziebart from University College/London and Geir Arne Hjelle from the Norwegian Mapping Authority (NMA) regularly attend the meetings of the Analysis Working Group. UCL is interested in working with individual DORIS ACs on the refinement of non-conservative force modeling for DORIS satellites. NMA plans to include DORIS in a geodetic multi-technique software (Where) under development. The participation of the NMA is, of course, strongly encouraged.

The second major work for the IDS ACs was to implement the RINEX/DORIS data processing in their software. Starting with Jason-2 in 2008, the satellites equipped with a DORIS receiver carry the new generation of receiver called DGXX which is able to track up to seven beacons simultaneously and provides phase and pseudo-range measurements. They are distributed in a dedicated format, called RINEX/DORIS 3.0, derived from the RINEX/GPS format. One major advantage of these new measurements is that they are available with a very short latency. They also allow analysis centers to be less dependent on the CNES since the new data format provides the raw information that is necessary for computing the ionospheric delays and the precise time-tagging of the measurements. This was not the case for the former data format where this information was only given in a pre-processed form, following a pre-processing done by the CNES. While CNES supplies data files in doris2.2 and RINEX/DORIS 3.0 formats for the missions equipped with DGXX (Jason-2, Cryosat-2, HY-2A and Saral), only the latter format will be made available for the future missions, starting with Sentinel-3A and Jason-3.

Processing this new data format requires software upgrades for the Analysis Centers. Some groups have started this work and two ACs have completed. GRG AC has implemented the processing of RINEX/DORIS data files in the GINS software. GSC showed in Washington DC (October 2015) that they obtain encouraging results. Work is underway for GOP in cooperation with the Technical University of Munich (TUM), and for IGN.

This activity will prevail in 2016. The objective is to be ready to process the data of the new coming missions Jason-3 and Sentinel 3A.

Group	AC	AAC	Other	Country	Software package	Multi-technique: DORIS +
ESA/ESOC	✓			Germany	NAPEOS	SLR, GNSS
Geodetic Observatory Pecny	✓			Czech Rep.	Bernese	-
CNES-CLS	✓			France	GINS/DYNAMO	SLR, GNSS
NASA/GSFC	✓			USA	GEODYN	SLR
IGN-JPL	✓			France	GIPSY/OASIS	-
INASAN	✓			Russia	GIPSY/OASIS	-
GFZ		✓		Germany	EPOS-OC	SLR, GNSS
CNES			✓	France	ZOOM	SLR, GNSS
TU Delft			✓	The Netherlands	GEODYN	SLR

Table 3: List of IDS Analysis Centers and Associated Analysis Centers participating in the analysis activities in 2015.

6 IDS Combination

The IDS Combination Center started 2015 by extending the IDS contribution to ITRF2014. Thus, the IDS contribution to ITRF2014 consists in a set of 1140 weekly solution files (including station coordinates and earth orientation parameters) from 1993.0 to 2015.0. All the details on the processing as well as the on evaluation of the IDS contribution to ITRF2014 can be found in Moreaux et al. (2016). Then, the IDS Combination Center developed a new chain to compute a DORIS position/velocity cumulative solution. The first objective of that new chain was to validate the IDS 09 series which is the IDS contribution to ITRF2014. The second objective was for the IDS Combination Center to succeed to P. Willis in the realization of ITRF extensions for precise orbit determination (the so-called DPOD cumulative position/velocity solutions). To validate its first cumulative solution from the 1140 SINEX files of the IDS 09 series, we compared the horizontal velocities with two global plate models. The validation of the DORIS vertical velocities were obtained by comparison with the ULR6 GNSS solution from La Rochelle University at 31 DORIS-GNSS co-localized sites. Late 2015, the IDS combined solution was updated by the addition of the first six months of 2015. In addition, the IDS Combination Center participated in the evaluation of the preliminary version of the IGN ITRF2014 realization. Last but not least, in 2015, the IDS Combination Center joined both EGU and AGU fall

meetings where it presented one oral presentation and one poster respectively titled “IDS Combined Solution improvements between ITRF2008 and ITRF2014” and “Horizontal and vertical velocities derived from the IDS contribution to ITRF2014, and comparisons with external models”.

Moreaux, G., Lemoine, F.G., Capdeville, H., et al., 2016. The International DORIS Service contribution to the 2014 realization of the International Terrestrial Reference Frame. *Adv. Space Res.*, doi: 10.1016/j.asr.2015.12.021.

7 Meetings

In 2015, the IDS organized two DORIS Analysis Working Group (AWG) meeting, first in Toulouse, France, on May 28 and 29, then in Greenbelt, Maryland, USA, on October 15 and 16.

All the presentations from these meetings are made available by the Central Bureau on the IDS website at:

<<http://ids-doris.org/report/meeting-presentations/ids-awg-05-2015.html>>

<<http://ids-doris.org/report/meeting-presentations/ids-awg-10-2015.html>>

8 Publications

IDS published a 2015 activity report that was broadly distributed to all DORIS participants and relevant services (see <<http://ids-doris.org/report/governing-board.html#activity>>).

All DORIS related articles published in international peer-reviewed journals are available on the IDS Web site <<http://ids-doris.org/report/publications/peer-reviewed-journals.html>>.

Conclusions

Again, the DORIS community had a productive year in 2015. The activities of the DORIS analysts have been dominated by the IDS contribution to ITRF2014 and its evaluation, and the implementation of the DORIS RINEX data processing. The effort will continue in 2016. On one hand, several issues raised during the ITRF processing remain to be addressed. On the other hand, the Analysis Centers must prepare for the new missions Jason-3 and Sentinel-3A launched early 2016.

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