DORIS DAYS 2021

November 16,17 and 18

IDS

Overview of Products for DORIS

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November 17

Session 2 – Presentation 1

Products Delivered by DORIS

- Precise orbits

(Real Time; Near Real Time (NRT); Longer latency).

→ ”**Orbitography**” in the DORIS name means “**Orbit Determination**”.

- Station coordinates and Earth Orientation Parameters (EOP).

→ This includes weekly solutions by analysis center, a combination produced by the IDS Combination Center, and IDS Contributions to the ITRF.

- DORIS Terrestrial Reference Frame for Precise Orbit Determination (DPOD).

→ Cumulative solution done ~2x/year with additional information. Latest is DPOD2014. **Dynamic reference frame for POD**.

- Geocenter

→ A derived product (estimate of CoF w.r.t. CoM).

- Time Biases for SLR network (2008-2017)

→ A derived product from the Jason-2/T2L2 experiment.

Precise Orbits from DORIS Data (1)

- **Real Time:** **DIODE (”*DORIS Immediate Orbit Determination*”).**

→ DIODE processes measurements in real-time to obtain on-board estimates of the orbital state vector.

→ Satellites: SPOT4, Jason-1, ENVISAT, SPOT5, Jason-2, Cryosat-2, SARAL/AltiKa, Jason-3, Sentinels-3A+3B, Sentinel-6A.

→ The orbit is used by the s/c for payload management (*change altimeter tracking modes by location*), and is distributed on NRT altimeter data records.

→ Only recently available as a separate product (sp3 files) to support work of IDS NRT Working Group (*probatory period with Jason-3*).

IGN Data Center (ftp://doris.ign.fr/pub/doris/products/orbits/ssa/ja3/NRT)

Example files for Friday November 5, 2021:

```
Nov 05 01:03 DJ3_DIF_AXVCNE20211105_000104_20211104_215553_20211104_233454.sp3
Nov 05 03:03 DJ3_DIF_AXVCNE20211105_020128_20211104_232523_20211105_012924.sp3
Nov 05 05:03 DJ3_DIF_AXVCNE20211105_034538_20211105_011953_20211105_032754.sp3
Nov 05 07:04 DJ3_DIF_AXVCNE20211105_054545_20211105_031823_20211105_052654.sp3
Nov 05 09:03 DJ3_DIF_AXVCNE20211105_074557_20211105_051723_20211105_072324.sp3
Nov 05 11:04 DJ3_DIF_AXVCNE20211105_094523_20211105_071353_20211105_091954.sp3
Nov 05 12:07 DJ3_DIF_AXVCNE20211105_111538_20211105_091023_20211105_105354.sp3
Nov 05 14:07 DJ3_DIF_AXVCNE20211105_131550_20211105_104423_20211105_124854.sp3
Nov 05 16:03 DJ3_DIF_AXVCNE20211105_151611_20211105_123923_20211105_144424.sp3
Nov 05 18:06 DJ3_DIF_AXVCNE20211105_170023_20211105_143453_20211105_164054.sp3
Nov 05 20:03 DJ3_DIF_AXVCNE20211105_190033_20211105_163123_20211105_183524.sp3
Nov 05 22:03 DJ3_DIF_AXVCNE20211105_210055_20211105_182553_20211105_203124.sp3
Nov 06 01:04 DJ3_DIF_AXVCNE20211106_001544_20211105_202153_20211105_235654.sp3
Nov 06 03:05 DJ3_DIF_AXVCNE20211106_021548_20211105_234723_20211106_015224.sp3
```

Contact **Dr. Denise Dettmering (DGFI/TUM)**, chair of IDS NRT WG for more information on how to use these data, & WG activities.

For general information on DIODE, contact the CNES DORIS project manager: **Cécile Manfredi @ CNES**.

Precise Orbits from DORIS Data (2)

• **Longer Latency: For Geophysical Data Records of altimeter satellites, or from routine processing for the ITRF.**

→ Orbits are in the standard sp3 format.

→ Orbits are delivered now by CNES AAC (with a few weeks latency), and GRG AC (quarterly with routine SINEX deliveries):

NB: At the IDS Data Centers, the CNES AAC has the name "SSA"; and the GRG AC has the name "LCA", for historical reasons.

→ GRG AC: Orbits are DORIS-only or DORIS+SLR, depending on the satellite.

→ CNES AAC: Orbits are DORIS-only or DORIS+GPS, depending on the satellite. Also current orbits for CNES AAC use the "POE-F" set of standards:

(ftp://ftp.ids-doris.org/pub/ids/data/POD_configuration_POEF.pdf)

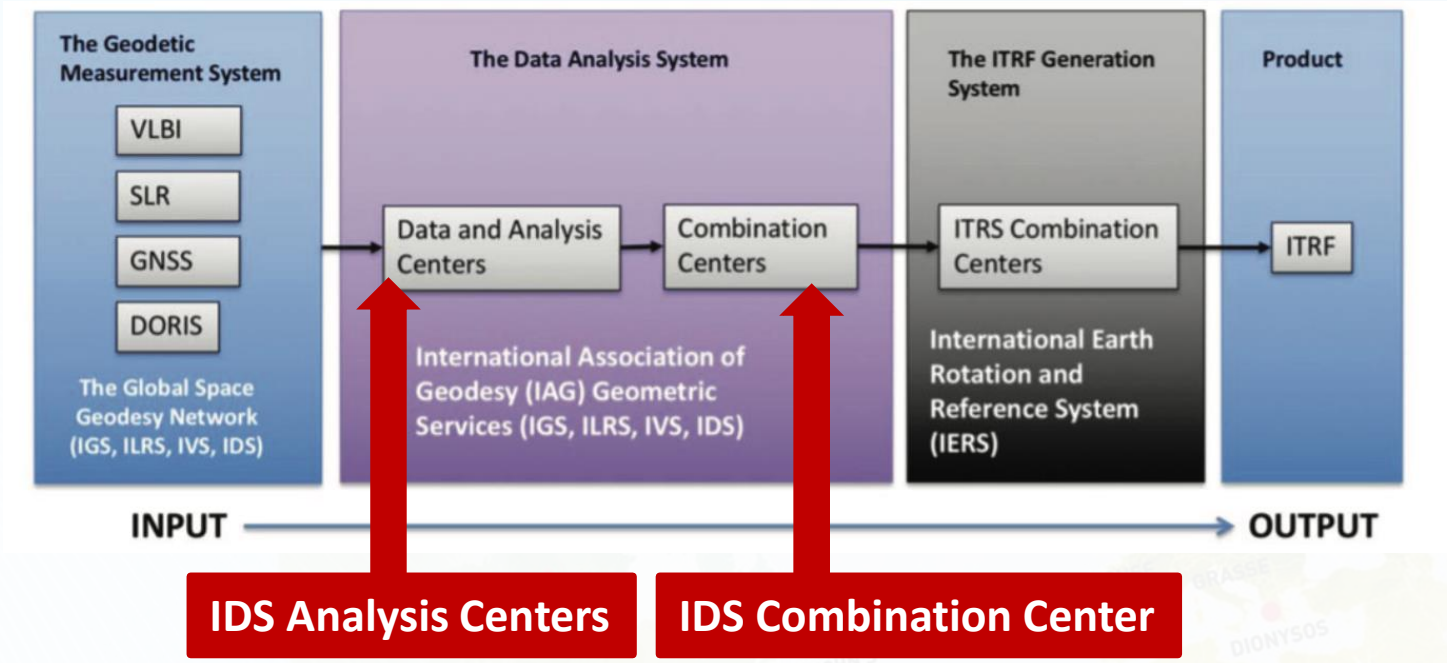
Orbits are available at IDS Data Centers (IGN & NASA CDDIS): (pub/doris/product/orbits)

Example: Recent CNES AAC POEF orbits for Sentinel-3B

```
Oct 04 22:03 ssas3b20.b21253.e21263.DG_.sp3.001.Z
Oct 12 22:04 ssas3b20.b21262.e21272.DG_.sp3.001.Z
Oct 20 22:04 ssas3b20.b21271.e21281.DG_.sp3.001.Z
Nov 02 22:04 ssas3b20.b21280.e21290.DG_.sp3.001.Z
```

For more information contact:
(1) Alexandre Couhert @ CNES (CNES AAC)
(2) Hugues Capdeville @ CLS (GRG AC)

Station Coordinates & EOP (1)



Reference:
Figure 1.5,
Evolving the Geodetic Infrastructure to Meet New Scientific Needs (2020),
National Academy of Sciences, 2020,
doi: 10.17226/25579

→ IDS Analysis Centers generate solutions weekly from processing available data, and stacking normal equations for station positions and daily EOP.

→ Four IDS Analysis centers have contributed weekly solutions to ITRF2020. The ITRF contributions span 1993.0 to 2021.0.

→ **ESA** (ESOC, Darmstadt, Germany), **GOP** (Geodetic Observatory Pecny, Czech Rep.); **GRG** (Centre National d'Etudes Spatiales/Collecte Localisation Satellites, Toulouse, France), **GSC** (NASA GSFC, Greenbelt, USA).

→ **IGN** (France): Work in progress to use new software (GipsyX); **INA** (Russia): Evaluating new software to replace legacy Gipsy Oasis, which is no longer supported.

Station Coordinates & EOP (2)

A Derivative Product

→ **IDS Combination Center (IDS CC)** *[**Guilhem Moreaux, CLS, Toulouse, France***] combines the weekly solutions to produce the ongoing operational series, and the ITRF contribution, using the **CATREF(IGN)** software. The operational combination is updated on a quarterly basis after processing the AC contributions.

→ The ITRF2021 IDS submission is available from the IDS Data Centers as "ids16" under "/pub/doris/products/sinex_series/idswd".

→ We have acquired a doi citation for the ids16 combination:

Doi: 10.24400/312072/i01-2021.001 "The IDS Data Contribution to ITRF2020 (IDS16)"

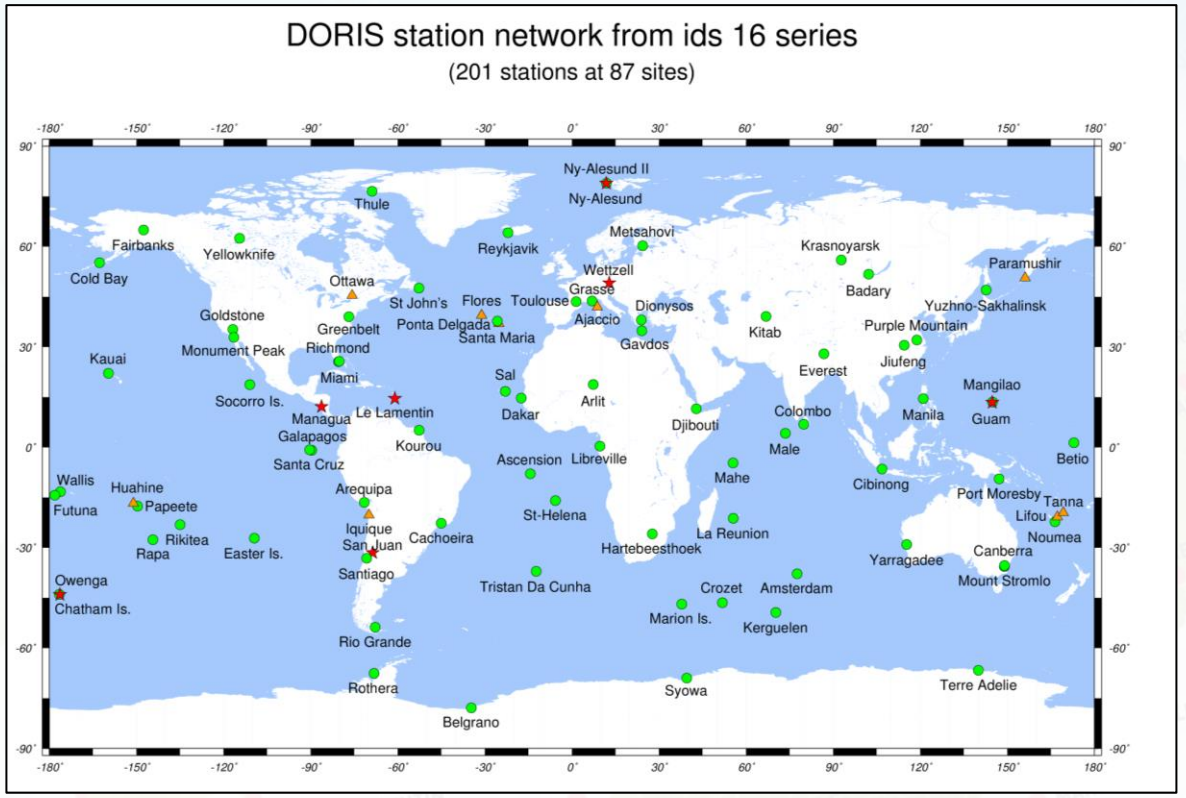
Landing Page (presently under construction):

For details on the combination process see the papers:

Moreaux et al., 2016, "The IDS contribution to the 2014 realization of the International Terrestrial Reference Frame", *Adv. Space Res., 58*, 2479-2504, doi: 10.1016/j.asr.2015.12.021.

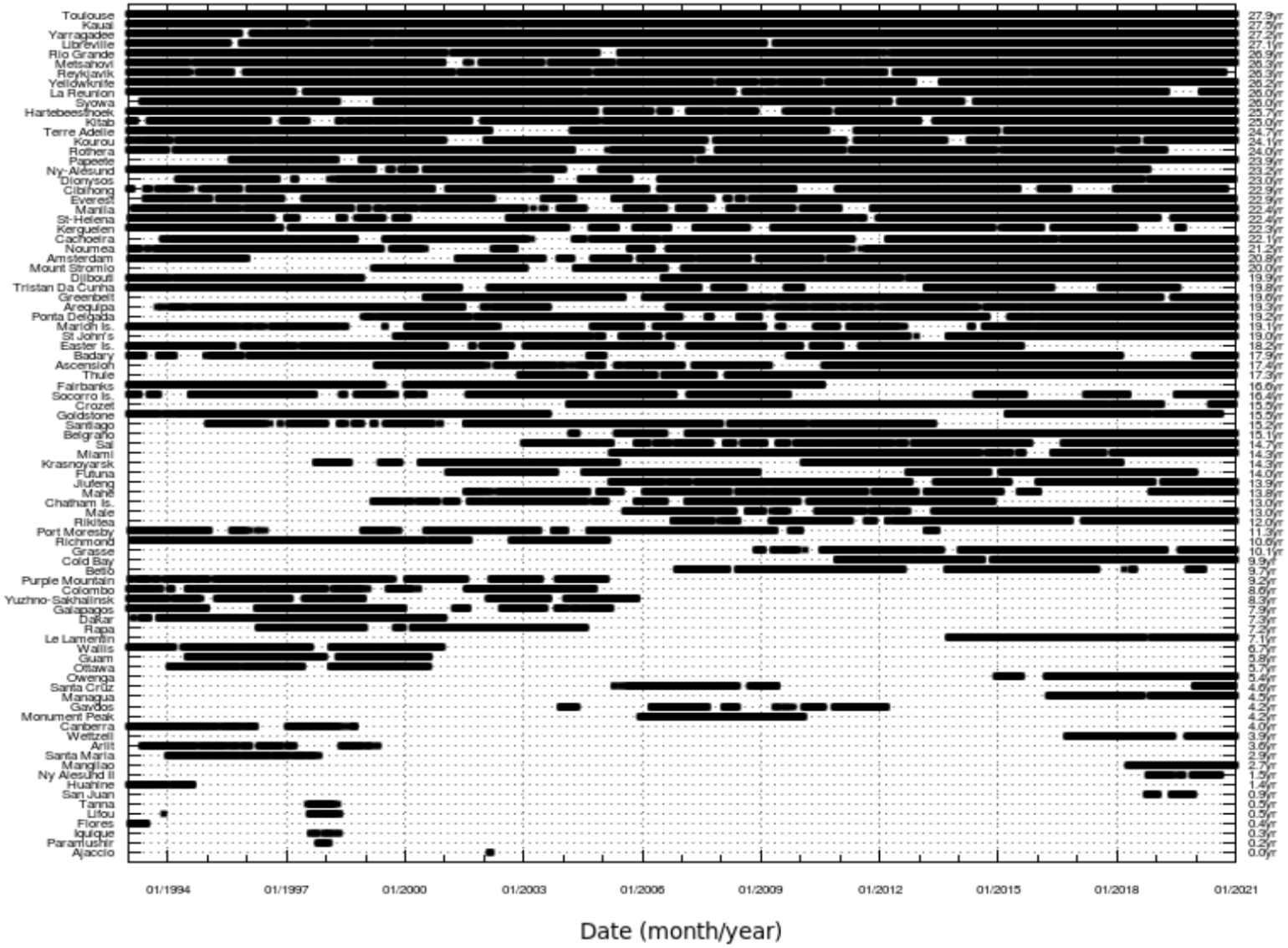
Moreaux et al., 2021-2022, "The IDS contribution to the 2020 realization of the ITRF", *Adv. Space Res*., Manuscript to be submitted to IDS Special Issue.

IDS ITRF2020 Solution Overview (1)



Geographical distribution of the DORIS stations included in the IDS contribution to ITRF2020 (**red stars indicate new sites installed since 2015.0** and **orange triangles old sites not included in ITRF2014**).
(Figure from Moreaux et al., 2021-2022, Manuscript in preparation)

IDS ITRF2020 Solution Overview (2)



Availability of DORIS data from Stations in the ITRF2020 Combination:
(Figure from Moreaux et al., 2021-2022, Manuscript in preparation)

<u>Top Sites: ≥ 25 years of data:</u>

Toulouse (France)
Kauai (Hawaii, USA)
Yarragadee (Australia)
Libreville (Gabon)
Rio Grande (Argentina)
Metsahovi (Finland)
Rekyjavik (Iceland)
Yellowknife (Canada)
La Réunion (France)
Syowa (Antarctica)
Hartebeesthoek (South Africa)
Kitab (Uzbekistan)

Station Coordinate Differences (1)

Station Coordinate Differences:

→ **A Derived Product from the weekly series.**

→ A SINEX solution (from the IDS) is either a “free-network” or “weakly-constrained” solution that is easily usable only by a small group of users.

→ The IDS developed the “STCD” format. Coordinate time series consist of residuals relative to a reference position. Each coordinate of the series is assumed to be expressed in the same reference system as at the observation epoch (Cartesian and geodetic coordinates).

Documentation: https://ids-doris.org/documents/BC/products/CB_STCD_format_v1.1.pdf

Files are at the IDS Data Centers: pub/doris/products/stcd

For the STCD files corresponding to the ITRF2020 contribution & current operational combination: go to pub/doris/products/stcd/ids21wd03/

e.g. Example file for Yarragadee (YASB) would be:

ftp://doris.ign/fr/pub/doris/products/stcd/ids21wd03/ids21wd03.stcd.yasb.Z

ftp://doris.ign.fr/pub/doris/products/stcd/ids21wd03/ids21wd03.stcd.yasb.png

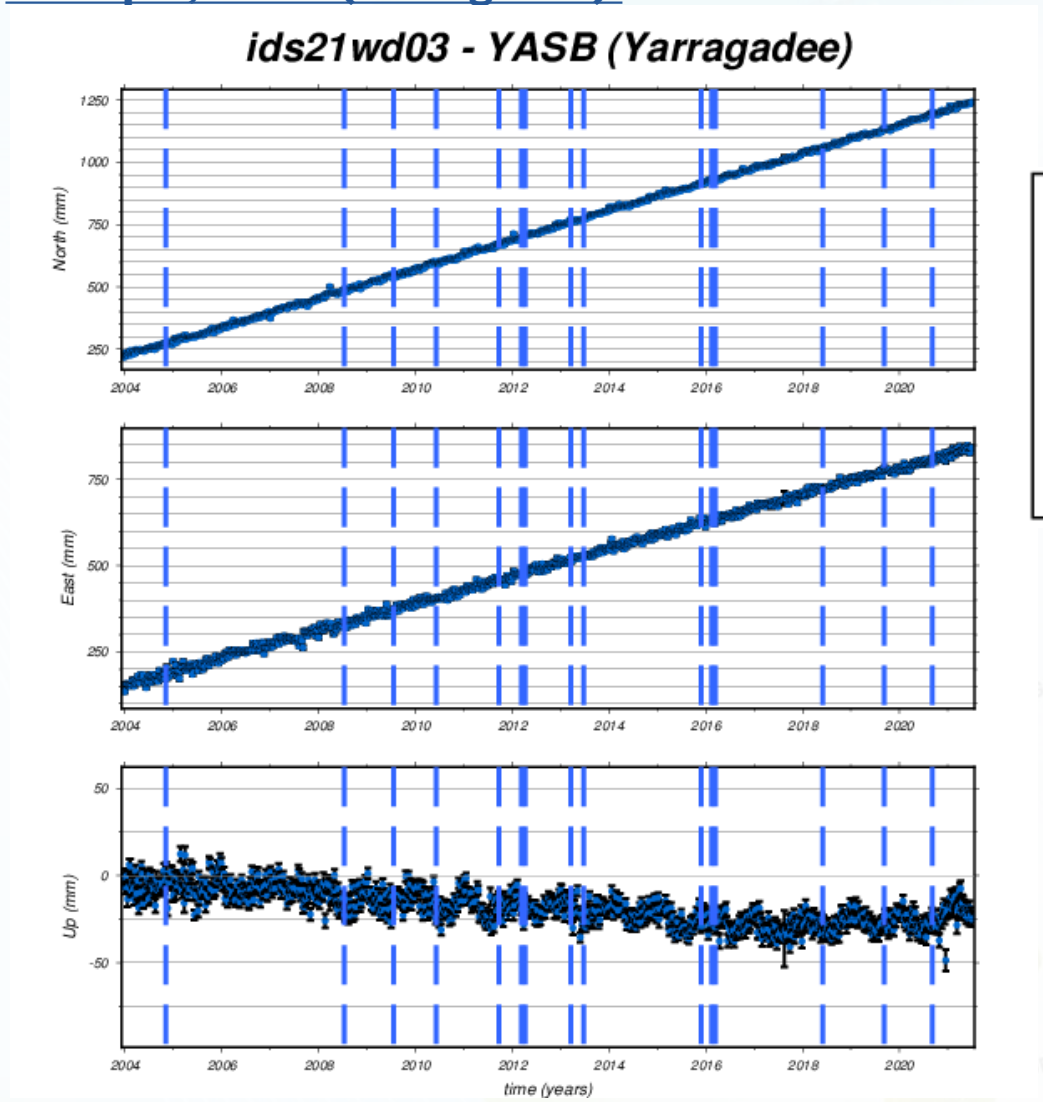
https://cddis.nasa.gov/archive/doris/products/stcd/ids21wd03/ids21wd03.stcd.yasb.Z

https://cddis.nasa.gov/archive/doris/products/stcd/ids21wd03/ids21wd03.stcd.yasb.png

For questions contact the IDS Analysis Coordinators: **Petr Stepanek & Hugues Capdeville**, or the IDS CC: **Guilhem Moreaux**

Station Coordinate Differences (2)

Example, YASB (Yarragadee):



History of Missions - Legend

- 2004/11/07 - TOPEX (end) & Jason1 (start)
- 2008/07/13 - Jason1 (end) & Jason2 (start)
- 2009/07/19 - SPOT2 (end)
- 2010/06/06 - Cryosat2 (start)
- 2011/09/25 - HY2A (start)
- 2012/03/11 - SPOT4 (end)
- 2012/04/08 - Envisat (end)
- 2013/03/17 - Saral (start)
- 2013/06/23 - SPOT4 (end)
- 2015/11/29 - SPOT5 (end)
- 2016/02/14 - Jason3 (start)
- 2016/03/13 - Sentinel3A (start)
- 2018/06/03 - Sentinel3B (start)
- 2019/09/09 - Jason2 (end)
- 2020/09/06 - HY2A (end)

Event History-Discontinuity Legend

For questions contact IDS Analysis Coordinators: **Petr Stepanek & Hugues Capdeville**, or the IDS CC: **Guilhem Moreaux.**

Earth Orientation Parameters

EOP: DORIS Supplies daily estimates (Px, Py) of the pole position:

- → Polar motion: Motion of the Earth's rotational Axis relative to its crust.
- → Like the other geodetic techniques, DORIS can measure this parameter.
- → The "free-network" weekly solutions for EOP have to be rotated or aligned to a base reference Frame.
- → The polar motion series from the IDS combination for ITRF2020 (ids16) is available at the IDS data centers:
  e.g. ftp://doris.ign.fr/pub/doris/products/eop/
  File: ids21wd01.eop.Z 139KB 11/9/21 12:56 UTC

- → DORIS can also be used to estimate LOD (Length of Day) as shown in a paper by Stepanek et al. (2018).

Stepanek P. et al. (2018). "Estimation of the Length of Day (LOD) from DORIS observations", *Adv. Space Res.,62(2),* 370-382, doi:10.1016/j.asr.2018.04.038.

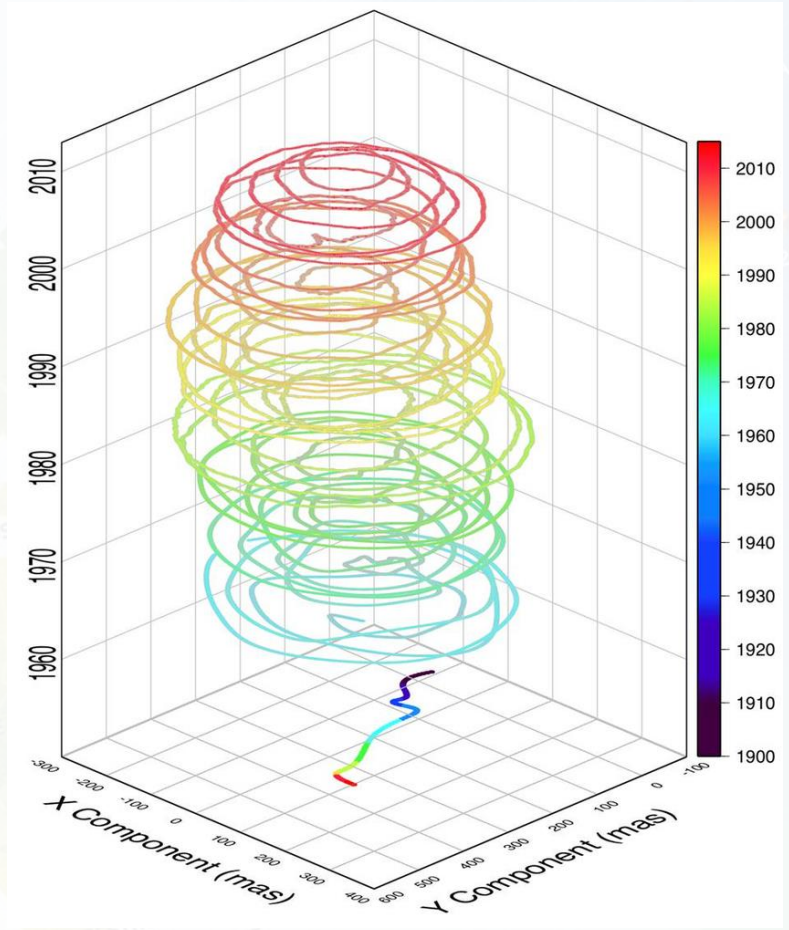


Figure from Pavlis, E.C. et al. (2015)

DORIS Terrestrial Reference Frame for Precise Orbit Determination (DPOD)

DORIS Extension of a TRF Realization:

→ DPOD2014 is the "dynamic" extension of the ITRF2014 for DORIS: **Updated ~2x/year.**

→ Unlike ITRF2014 which uses non-linear models for certain stations, DPOD2014 uses linear velocity for station modeling because a key user (DIODE) requires this type of modeling.

Steps:

(1) Create combined weekly solutions from AC contributions. ➔ ***(ITRF2014 + later data & information)***

(2) Create cumulative solution, applying velocity constraints and DORIS-DORIS tie vectors.

(3) Augment solution for newest stations or stations with too few yrs of observations with external solutions, and tie vectors if possible from other geodetic techniques (GNSS, SLR, VLBI).

(4) Validate the solution, with internal & external tests (include examination of tie vectors) and with POD analyses.

→Available at IDS data centers in a SINEX-like format: pub/doris/products/dpod/dpod2014

Latest solution is: dpod2014_054.snx.Z
2021:09:01 05:10:52, 13.81MB

Reference: Moreaux G. et al. (2019). "DPOD2014: A new DORIS extension of ITRF2014 for precise orbit determination", *Adv. Space Res., 63*, 118-128, doi:10.1016/j.asr.2018.08.043.

To participate in the evaluation group activities, contact Guilhem Moreaux @ groupcls.fr

Geocenter (1)

Concept of Geocenter

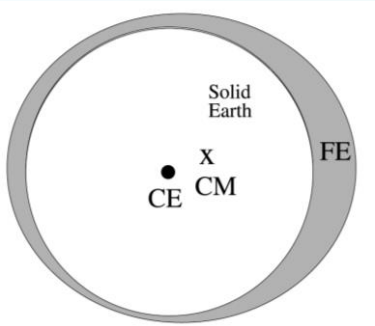


Figure from Tregoning & van Dam (2005)

CM: Center of mass of the Earth.

CE: Center of mass of the solid Earth.

FE: Fluid envelope.

CM & CE are related by a translation, known as geocenter motion.

Satellites orbit about the instantaneous CM.

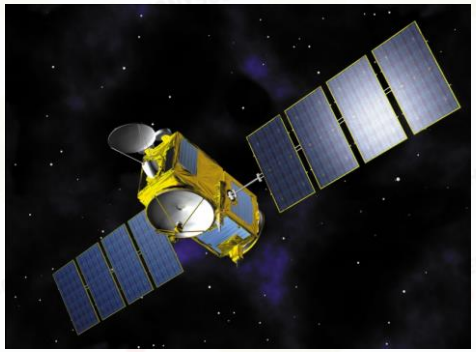
It is the mass transport of ”fluids”, e.g. in the atmosphere, hydrosphere, cryosphere that are responsible for the main signatures in geocenter motion.

Annual Amplitude: ~2-3 mm (X & Y); ~5 mm (Z)

Two types of solutions from DORIS:

1. Derived by stacking of AC or IDS combination solutions w.r.t a reference datum.

2. More recently Couhert et al. (2018) (“Systematic error mitigation in DORIS-derived geocenter motion”. *JGR, 123*, 10,142–10,161. doi:10.1029/2018JB015453) showed that DORIS data from Jason-2 only (*excluding the polar-orbiting satellites*), can be used to derive solutions for geocenter. For determination of the annual signal, the solutions are competitive with those from SLR data to the LAGEOS satellites.



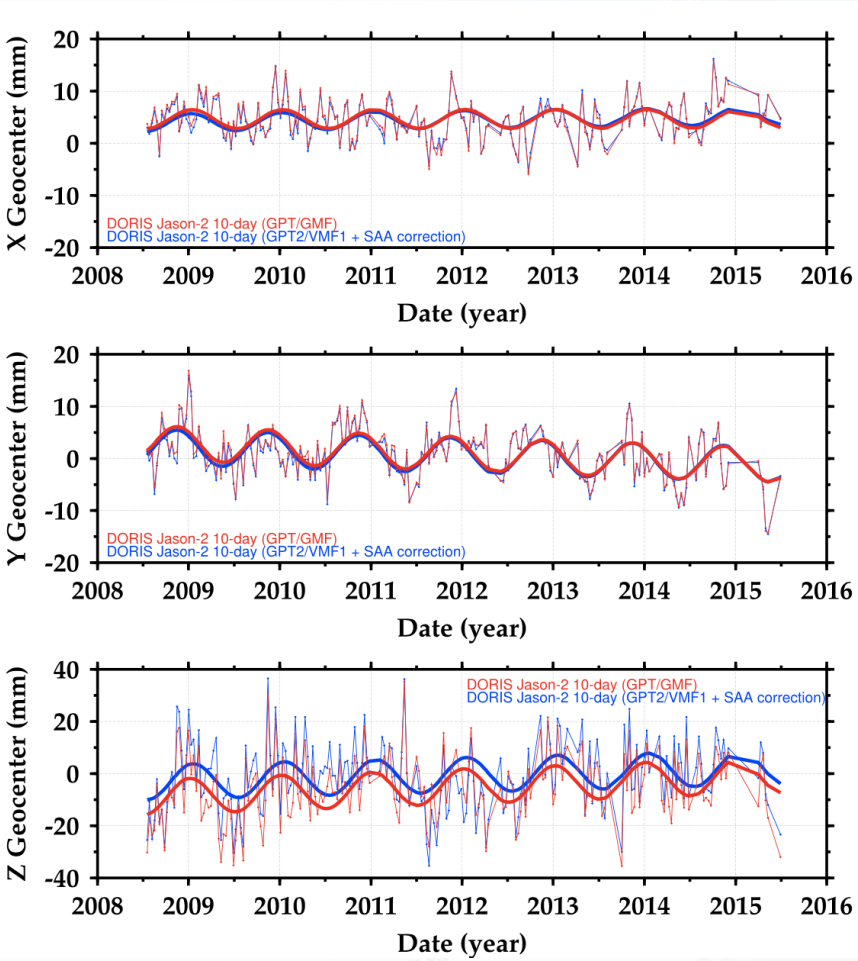
Jason-2

LAGEOS

Geocenter (2)

From IDS Combination for ITRF2020 (ids16)
(w.r.t. ITF2014)

From Couhert et al. (2018)
Ten-day estimates from Jason-2 DORIS-only



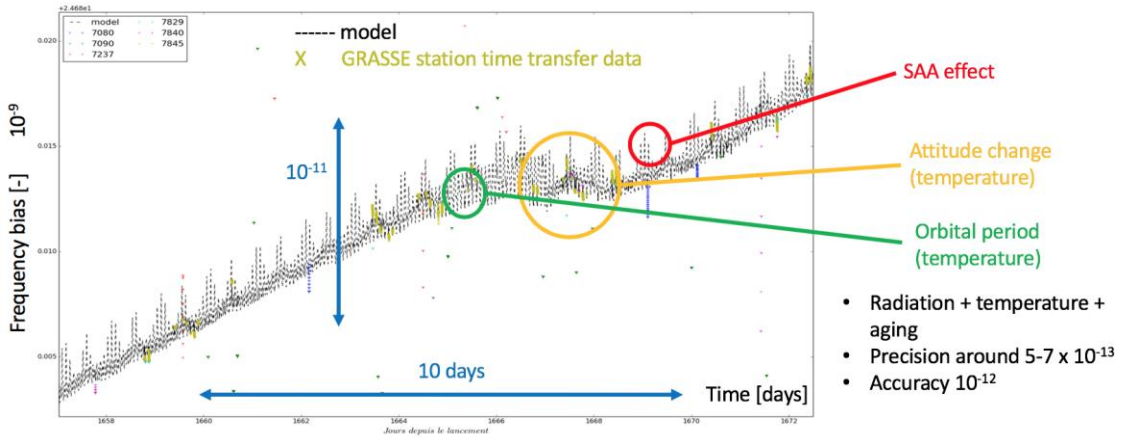
Time Biases for SLR network from Jason-2 T2L2 & DORIS

T2L2 on-board Jason-2

T2L2 + LRA

T2L2 :
- Designed for remote clocks synchronization, on-ground and on-board

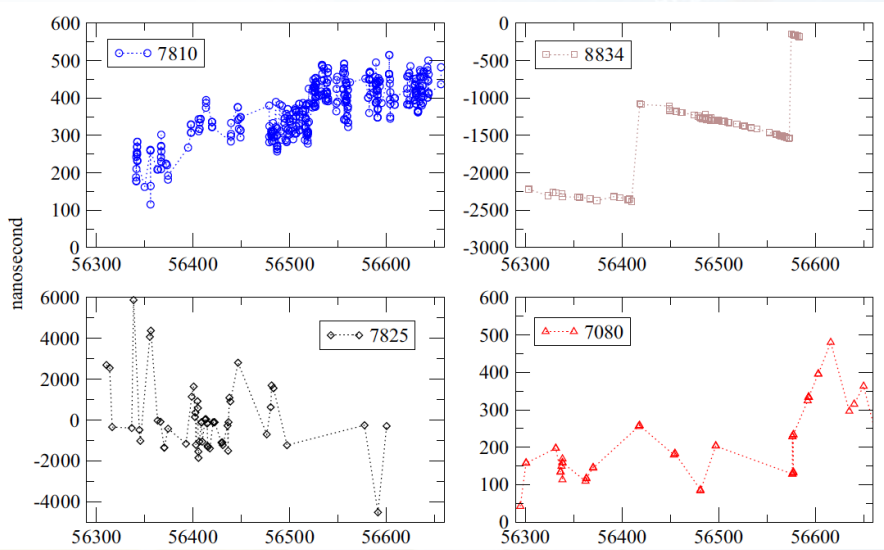
Time Transfer :
- Determine Time Bias in laser stations (ILRS)
- Read the frequency bias of the USO (Ultra Stable Oscillator)



- Radiation + temperature + aging
- Precision around 5-7 x 10^{-13}
- Accuracy 10^{-12}

Data from Jason-2/T2L2 reveal the behavior of the DORIS USO, and unmodeled effects on the DORIS/USO frequency, e.g. due to passage through the South Atlantic Anomaly (SAA), attitude changes, and USO temperature changes.
Belli, A. et al., Adv. Space Res., 58, 2589-2600, 2016, doi: 10.1016/j.asr.2015.11.025.

Time biases at SLR stations revealed by T2L2 Used in ITRF2020



Clockwise from Upper Left.
Time biases for SLR stations relative to Grasse, for Zimmerwald (7810), Wettzell (8834), Yarragadee (7090), and Mt Stromlo (7825) from Exertier et al. (2017). Units are ns.

Exertier *et al.*, "Time biases in laser ranging observations: A concerning issue of Space Geodesy", Adv. Space Res., 60, 948-968, 2017, *doi:* 10.1016/j.asr.2017.05.016.

Key points: Overview of Products for DORIS

- DORIS produces Real Time orbits for its satellites using the DIODE on-board navigator. The DIODE orbits are distributed in Near Real Time (NRT) for Jason-3 now and in near future for other satellites.
- Precise orbits are available for the DORIS Satellites (either DORIS-only or in combination, DORIS/SLR, DORIS+GNSS).
- Station Position and EOP weekly solutions are produced by IDS ACs, and made into an operational combination, and a contribution to the ITRF (ITRF2008, ITRF2014, ITRF2020).
- DORIS Extension for precise orbit determination is distributed ~2x/yr.
- Competitive solutions for geocenter are possible from the Jason-2 & 3 satellites. A WG on geocenter is proposed to start a pilot project to develop this as a routine product using approach outlined in Couhert et al. (2018).
- DORIS, through Jason-2/T2L2 supplied time offsets for the SLR network (2008-2017) which were used in the SLR analysis for ITRF2020.

Backups

Time Biases for SLR network from Jason-2 T2L2 & DORIS (2)

ILRS Data Handling File Specifies modelling for SLR stations for routine processing and the ITRF2020. The file incorporated time biases for stations that tracked Jason-2 , from 2008-2017.

Using, the Grasse SLR station hydrogen maser at the station, the time bias offsets could be determined for other ILRS stations: These time bias offsets were incorporated into the SLR reprocessing for ITRF2020.

Snapshot of ILRS Data Handling File

1873	--	us	A	15:196:00000	15:197:00000	T	-121.000	2.000	0.0000	-----
1873	--	us	A	15:197:00000	15:242:00000	T	-11.800	5.000	0.0000	-----
1873	--	us	A	15:242:00000	16:033:00000	T	-8.000	5.000	0.0000	-----
1873	--	us	A	16:033:00000	16:122:00000	T	-11.000	5.000	0.0000	-----
1889	--	us	A	16:327:55560	16:327:63480	T	10.100	0.100	0.0000	-----
7105	--	us	A	15:194:57000	15:199:00000	T	14.450	0.100	0.0000	-----
7105	--	us	A	15:199:00000	15:206:07200	T	14.600	0.100	0.0000	-----
7124	--	us	A	15:264:00000	16:021:00000	T	8.260	0.030	0.0000	-----
7124	--	us	A	16:021:00000	16:044:00000	T	16.265	0.030	0.0000	-----
7124	--	us	A	16:044:00000	16:176:00000	T	8.260	0.030	0.0000	-----
7237	--	us	A	14:353:00000	15:001:00000	T	0.080	0.030	0.0245	drift
7237	--	us	A	15:364:00000	16:002:00000	T	-0.025	0.035	0.0270	drift
7237	--	us	A	16:026:00000	16:027:01800	T	26.100	0.040	0.0000	-----
7403	--	us	A	14:167:00000	14:190:00000	T	2.185	0.040	0.0000	-----
7403	--	us	A	14:190:00000	14:225:00000	T	2.260	0.040	0.0000	-----
7403	--	us	A	14:225:00000	14:342:00000	T	2.156	0.040	0.0000	-----
7501	--	us	A	13:001:00000	13:060:00000	T	-4.125	0.045	0.0000	-----
7501	--	us	A	13:060:00000	13:100:00000	T	-4.075	0.045	0.0000	-----
7501	--	us	A	13:100:00000	13:213:00000	T	-3.990	0.045	-0.0005	drift
7501	--	us	A	13:213:00000	13:339:00000	T	-4.005	0.045	0.0000	-----
7501	--	us	A	13:339:00000	14:129:00000	T	-4.045	0.045	0.0000	-----
7501	--	us	A	14:129:00000	15:001:00000	T	-6.045	0.045	0.0000	-----
7810	--	us	B	15:187:00000	15:188:28800	T	-2.650	0.050	0.0000	-----
7838	--	us	A	13:219:00000	13:260:00000	T	-2.000	0.030	-0.0750	drift
7838	--	us	A	13:260:00000	13:292:00000	T	-4.850	0.030	0.0650	drift
7838	--	us	A	13:292:00000	13:324:00000	T	-4.100	0.030	-0.0350	drift
7838	--	us	A	13:324:00000	13:337:00000	T	-5.200	0.030	-0.0250	drift
7838	--	us	A	13:337:00000	14:001:00000	T	-8.100	0.030	-0.0150	drift
7838	--	us	A	14:001:00000	14:015:00000	T	-9.400	0.030	-0.0150	drift
7838	--	us	A	14:015:00000	14:052:00000	T	-13.900	0.030	-0.0150	drift
7838	--	us	A	14:052:00000	14:071:00000	T	-15.800	0.030	-0.0250	drift
7838	--	us	A	14:071:00000	14:090:00000	T	-16.500	0.030	-0.0450	drift
7845	--	us	A	14:317:00000	14:326:00000	T	-61.330	0.025	0.0000	-----
8834	--	us	A	13:011:00000	13:047:00000	T	-2.250	0.025	-0.0014	drift
8834	--	us	A	13:047:00000	13:125:43200	T	-2.350	0.025	-0.0014	drift
8834	--	us	A	13:125:43260	13:126:00000	T	-29.090	0.025	0.0000	-----
8834	--	us	A	14:249:00000	14:264:00000	T	-2.050	0.025	-0.0065	drift
8834	--	us	A	14:264:00000	14:279:00000	T	-2.150	0.025	-0.0065	drift
8834	--	us	A	14:279:00000	14:295:00000	T	-2.250	0.025	-0.0065	drift
8834	--	us	A	14:295:00000	14:310:00000	T	-2.350	0.025	-0.0065	drift
8834	--	us	A	14:310:00000	14:325:00000	T	-2.450	0.025	-0.0065	drift
8834	--	us	A	14:325:00000	14:338:00000	T	-2.550	0.025	-0.0065	drift

https://ilrs.dgfi.tum.de/fileadmin/data_handling/ILRS_Data_Handling_File.snx

Units are μ sec & $\mu sec/day$