IDS REPORT 2018

IERS Directing Board Meeting

Washington DC, U.S.A.

December 8, 2018

Frank Lemoine (NASA GSFC)
Hugues Capdeville (CLS)
Jean-Michel Lemoine (CNES)
Jérôme Saunier (IGN)
Guilhem Moreaux (CLS)
Pascale Ferrage (CNES)
Alexandre Couhert (CNES)
Flavien Mercier (CNES)
- Current IDS Representatives to IERS.

DORIS Constellation Status - Current Missions (7)

Satellite	Sponsors	Alt. (km)	Inc. (º)	Dates	SLR,,GNSS
Sentinel-3B	ESA/Copernicus	814	98.65	4/25/18 – 2025+	S, G
Sentinel-3A	ESA/Copernicus	814	98.65	02/2016 – 2023+	S, G
Jason-3	NASA/CNES/NOAA/EUMETSAT	1336	66.0	1/17/16–2021+	S, G
SARAL	CNES/ISRO	800	98.5	03/2013 – 2018+	S
HY-2A	CNSA/NSOAS	960	99.0	11/2011 – 2018+	S, (G)
Cryosat2	ESA	717	92.0	06/2010 – 2019	S
Jason-2	NASA/CNES/NOAA/EUMETSAT	1336	66.0	07/2008 – 2019 +	S, G

DORIS Constellation Status - Future Missions (7 confirmed)

Satellite	Sponsors	Alt. (km)	Inc. (º)	Dates	SLR,GNSS
Sentinel-3C, 3D	ESA/Copernicus	814	98.65	2020, 2025 + 5 yrs	S, G
HY-2C, 2D	CNSA/NSOAS	960	66	2019, 2020 + 3 yrs	S, (G)
Jason-CS1+ CSB	ESA/Copernicus/EUMETSAT/ NOAA/NASA/CNES	1336	66.0	2020, 2025 + 7 yrs	S, G
SWOT	NASA/CNES	970	78	After 2021 + 3 yrs	S, G
MOBIL	Proposal to ESA, gravimetry, geodesy	LEO-HEO	TBD	After 2028	S,G, + VLBI

DORIS CONSTELLATION

Currently 7 satellites contribute to IDS (13 since the beginning), more than 7 future missions ➔ 2030++.

1990 2000 2010 11 12 13 14 2015 16 17 18 19 2020 21 22 23 24 2025 26 27 28 29 2030 31 32 33 34 2035

SPOT 2 *D1*

TOPEX *D1, S, G*

SPOT 3

SPOT 4 *D1*

JASON 1 *D2, S, G*

ENVISAT *D2, S*

SPOT 5 *D2*

JASON 2 *DX, S, G*

CRYOSAT2 *DX, S*

HY-2A *DX, S, G*

HY-2C/D

SARAL *DX, S*

JASON 3 *DXs, S, G*

SENTINEL3A *DXs, S, G*

SENTINEL3B *DXs, S, G*

SENTINEL 3C

SENTINEL 3D

JASON-CS1 DXs,S,G

JASON-CS2 DXs,S,G

SWOT DXs,S,G

MOBIL

Past missions

Current missions

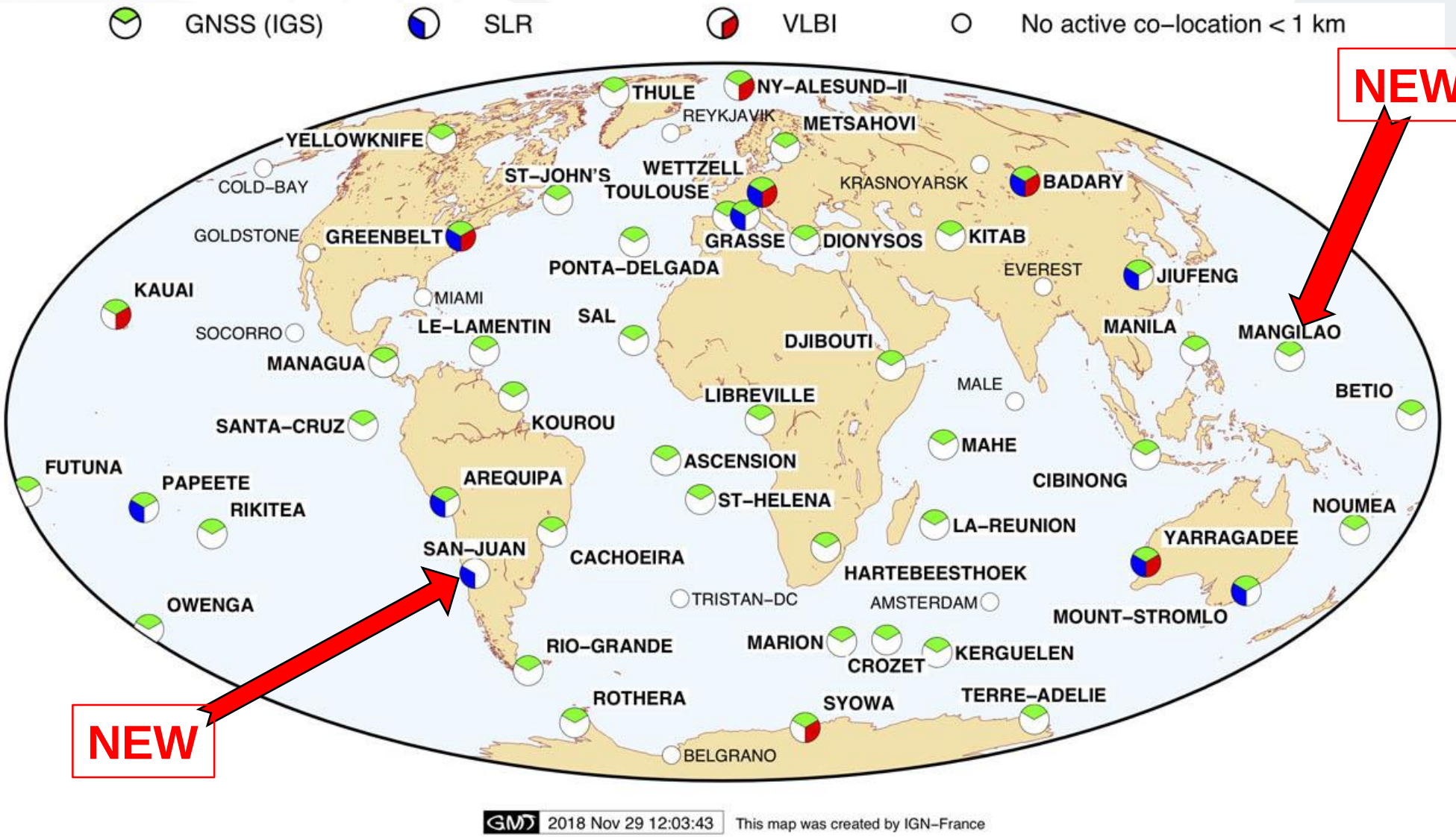
Future missions agreed/nominal lifetime

Future missions pending approval

On board instruments:

D1, D2, DX, DXs: DORIS/versions, **S**:SLR, **G**:GNSS

Current DORIS tracking network



48 co-locations out of 59 DORIS sites

DORIS Network Evolution (1)

➔ 3 generations of beacons have been developed

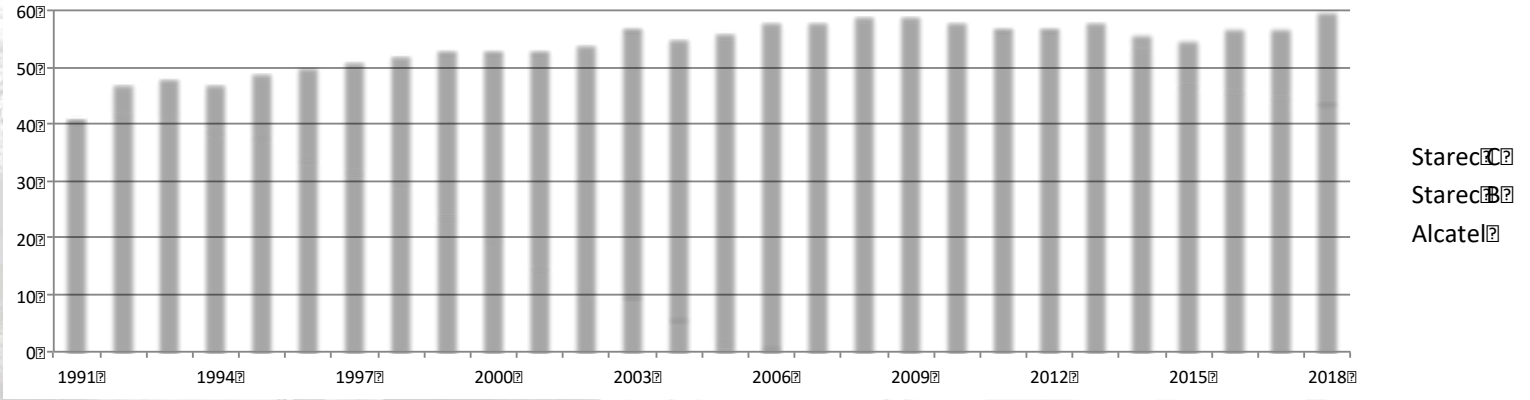
- Improving reliability, robustness and performance (Auriol & Tourain, 2010)

➔ The third-generation beacon is implemented everywhere since 2010

- With the capacity to shift the frequencies to eliminate the risk of jamming between neighboring stations

➔ Development of antennae to improve measurements accuracy

- Gradual replacement of Alcatel antennae with Starec antennae from 1992 to 2006 (Fagard, 2006)
- Continual improvement in manufacturing processes of the Starec antennae to improve the repeatability
- Key development: Starec C type from Sept. 2014: standard uncertainty of the 2GHz phase center in the vertical direction was reduced to 1 mm from 5 mm (Saunier & Tourain, 2016)



Today, about 25% of the network has Starec C antennae

DORIS Network Evolution (2)

➔ Planned network maintenance (2019)

- ☞ Restarting at Santa-Cruz, Ecuador
- ☞ Reconnaissance in Iceland with the view to relocate the station
- ☞ Relocation at Easter Island, Chile
- ☞ 4th generation beacon deployment from mid-2019

➔ 4th generation beacon

- ☞ Up-to-date electronic components: to be operational up to 2033
- ☞ Signal amplifier at the foot of the antenna: longer distance between beacon and antenna (up to 50 m vs. 15 m before)
- ☞ Deployment will start in mid-2019

Foot of the antenna

4th generation beacon

Antenna cables: 50 m long
=> finding better environment for the signal transmission

DORIS Network Events (Highlights, 2018)

Rothera (*ROXC, Antarctica*). relocation completed: **Feb. 27, 2018**.

Guam (*MLAC, Mangilao*). New station installation: **April 12, 2018**.

Badary, Krasnoyarsk, Russia (*BADB, KRBB*), shut down for indefinite period from Feb. 2018. Discussions are underway with the Russian authorities.

Rio Grande, Argentina (*RISC*). Restarted after 2-yr outage: **Aug. 28, 2018.**

San Juan, Argentina (*SJUC*). New station starts transmissions: **Oct. 2, 2018.**

Ny-Ålesund II, Svalbard (*SVAC*) DORIS station relocated: **Oct. 19, 2018.**

Mahé, Seychelles (*MAIB*). Restarted after 3-yr outage: **Nov. 14, 2018.**

Analysis Update

❑ Routine Processing

- *Six DORIS Analysis Centers (**ESA, GOP, GSC, IGN, INA, GRG**) routinely process data.*
- *The processing of the 3rd quarter of 2018 is underway by the IDS Combination Center.*
- ***IDS Combination through the end of 2nd quarter 2018 is available**:*
  - → ***https://cddis.gsfc.nasa.gov/pub/doris/products/sinex_series/idswd***
  - → ***https://doris.ensg.eu/pub/doris/products/sinex_series/idswd***
- ***DPOD2014 v3 is available**. (DORIS extension to ITRF2014 for Precise Orbit Determination).*
  - → ***https://cddis.gsfc.nasa.gov/pub/doris/products/dpod/***
  - → ***https://doris.ensg.eu/pub/doris/products/dpod/***

Moreaux, G., Willis, P., Lemoine, F.G., Zelensky, N.P., Couhert, A., Ait Lakbir, H., Ferrage, P., 2018. "DPOD2014: a new DORIS extension of ITRF2014 for Precise Orbit Determination", *Adv. Space Res.*, in press, doi:10.1016/j.asr.2018.08.043.

❑ Work in progress

- **Implement DORIS/RINEX data processing by all ACs.**
- **Introduce Jason-3 and Sentinel-3A in the IDS combined solution for All ACs.**
- **Verify that all ACs can reprocess 2012 data to eliminate scale anomaly.**
  - → *ACs must do their own preprocessing (ignore data-provided flags).*
  - → *Apply updated position of HY-2A Center of Mass (CoM).*
- ***Mitigate the SAA effect on Jason-2 and Jason-3 USOs.***
  - → *SAA strategy for SAA stations, or*
  - → *Use better (corrected frequency model for USO, e.g. as in Belli et al. (2017, 2018)*

❑ Continuing work.

- ***Implement and validate the new standards/models recommended by the IDS/IERS***

IDS Retreat: June 13-14, 2018

IDS Retreat, Château de Mons, France

Topics Discussed

1. Review of POD for space missions.
2. Atmosphere/New Products
3. Technology Evolution.
4. Reference Frame.
5. IDS Science & organization
6. Breakout sessions:
   (i) Community perception of DORIS.
   (ii) How to grow the IDS.
   (iii) Barriers to entry.
   (iv) SWOT Analysis.
   (v) Stop, Start, Carry-On.

Participants

- IDS Governing Board
- Invited DORIS experts.
  (i) Richard Biancale (GRGS)
  (ii) Alexandre Couhert (CNES)
  (iii) Pierre Exertier (Géoazur)
  (iv) Christian Jayles (CNES)
  (v) Cécile Manfredi (CNES)
  (vi) Flavien Mercier (CNES)
  (vii) Pascal Willis (IPGP/IGN)
- Invited outside experts:
  (i) Christian Bizouard (Obs. De Paris)
  (ii) Klaus Börger (Univ. of Bonn)
  (iii) Oliver Montenbruck (DLR)
  (iv) Paul Poli (SHOM)

Facilitators (IDS GB members):
Marek Ziebart (UCL), Guilhem Moreaux (CLS)

Actions & Next Steps

1. IDS GB Meeting Paris, Sept 18, 2018.
2. Preparation of Retreat Report (*for IDS GB*).
3. Drafting of Strategic Plan (*In Progress*).
4. Consultation with Stakeholders
5. Finalize Strategic Plan.

How DORIS can Contribute to Future Realizations of the ITRF Origin

AGU100 ADVANCING EARTH AND SPACE SCIENCE

JGR

Journal of Geophysical Research: Solid Earth

RESEARCH ARTICLE
10.1029/2018JB015453

Systematic Error Mitigation in DORIS-Derived Geocenter Motion

Alexandre Couhert[1], Flavien Mercier[1], John Moyard[1], and Richard Biancale[2,3]

[1]Centre National d'Etudes Spatiales, Toulouse, France, [2]Deutsche GeoForschungsZentrum, Oberpfaffenhofen, Germany, [3]Groupe de Recherche de Géodésie Spatiale, Toulouse, France

Key Points:
- Independent geocenter coordinates were derived using DORIS data and the OSTM/Jason-2 satellite
- Sources of correlations and modeling issues were identified and mitigated
- Uncertainties in the realization of the ITRF origin are addressed

Couhert, A., Mercier, F., Moyard, J., Biancale, R., 2018.
"Systematic error mitigation in DORIS-derived geocenter motion",
***J. Geophysical Research -Solid Earth*, in press, doi: 10.1029/2018JB015453.**

Motivation

- **Why is DORIS observation of the geocenter motion still so challenging?**

  (I) Complex modeling of the nongravitational forces of the tracked satellites.

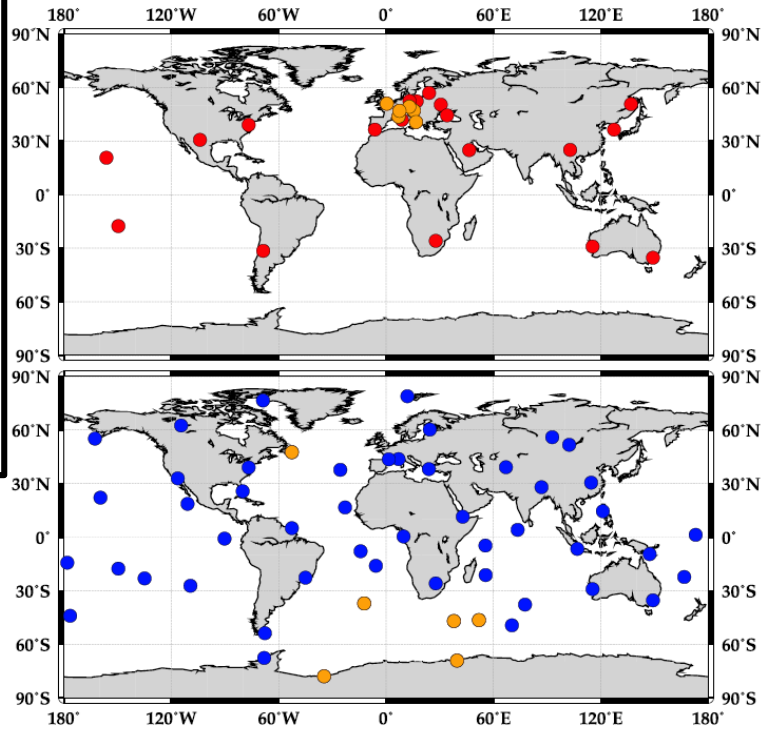
  (II) Requirement to systematically estimate nuisance parameters for microwave techniques (e.g. Doppler).

  - Zenith Tropospheric Delays (ZTD) also need to be estimated.

- **Why should DORIS play a role?**

  (I) Stable and well-distributed tracking network (reduces network effects).

  (II) Need for an independent time series.



SLR network distribution (top) and DORIS network distribution (bottom) for stations used in this study.

"Cookbook" for obtaining independent DORIS-based geocenter time series (I)

- **Sun-synchronous satellites should be disregarded (β'≈365 days)**
  - **Solar Radiation Pressure (SRP) modeling deficiencies primarily affects the Z geocenter (T_Z) derived from non-spherical satellites**
    - **(I) A lower orbital inclination reduces this sensitivity**
    - **(II) The collinearity of T_Z with residual SRP modeling errors can be mitigated well for Jason-like satellites since their 118-day draconitic period is not close to one solar year**

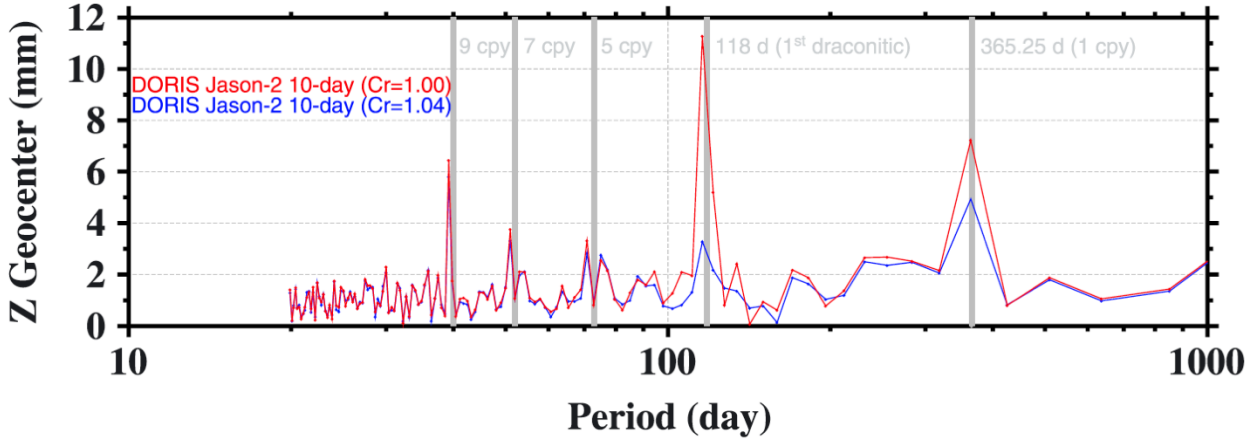


Fig.8 from Couhert et al. (2018). Amplitude spectra of the Z geocenter using Lomb-Scargle method for time series from July 2008 – June 2015, with a SRP coefficient of 1.00 (red), and **1.04 (blue)**.

“Cookbook” for obtaining independent DORIS-based geocenter time series (II)

- **Vertical site displacement should be estimated**

  (I) It is a sensible way to take into account the various error sources reducing the quality of station height estimates => better sense the motion of CF w.r.t. CM:

  (a) Nontidal (atmospheric, hydrological) loading corrections are currently mismodeled

  (b) Multipath and troposphere delay parameters, …

  (II) An exclusive cross-track observability of the T_Z coordinate should be secured.

  - Necessary for not compromising the observability of the Z geocenter coordinate with residual Once-Per Revolution (OPR) modeling error perturbations

$$\delta_R(t) = -\frac{\dot{\delta}_S(0)}{2\omega_0}\cos\omega_0 t + \frac{\dot{\delta}_R(0)}{\omega_0}\sin\omega_0 t$$

$$\delta_S(t) = \left(\frac{1}{{\omega_0}^2}\left[\frac{R_{S_0}}{2} - T_Z\frac{GM}{r^3}\sin i\right] + 2\frac{\dot{\delta}_R(0)}{\omega_0}\right)\cos\omega_0 t + \left(-\frac{R_{C_0}}{2{\omega_0}^2} + \frac{\dot{\delta}_S(0)}{\omega_0}\right)\sin\omega_0 t - 2\frac{\dot{\delta}_R(0)}{\omega_0} + \delta_S(0)$$

$$\delta_W(t) = \delta_W(0)\cos\omega_0 t + \frac{\dot{\delta}_W(0)}{\omega_0}\sin\omega_0 t + \frac{1}{{\omega_0}^2}\left(C_{N_0} + T_Z\frac{GM}{r^3}\cos i\right)$$

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Observation of T_Z via the cross-track equation

Synthesis

- The Jason-2/3 satellites are appealing for geodetic DORIS-based geocenter motion determination and should allow a better realization for CF.

- Upcoming launches of future DORIS satellites HY-2C (inclination of 66°), Jason-CS/Sentinel-6 (66°), and SWOT (inclination of 78°), should also permit the same type of geocenter solutions.

Table 9
Estimates of Geocenter Annual Variations From This Study and Independent Results

	X		Y		Z	
Solution	*A* (mm)	ϕ (day)	*A* (mm)	ϕ (day)	*A* (mm)	ϕ (day)
GPS+GRACE	0.9	105	3.5	334	—	—
SLR L1+L2 (CN)	2.3	61	2.3	317	6.1	41
SLR L1+L2 (CF)	1.7	59	2.7	322	3.6	39
DORIS Jason-2	1.6	13	3.2	322	6.4	18
SLR Jason-2	1.5	21	3.1	302	5.9	21

Note. *A* ratio = Amplitude ratio; $\delta\phi$ = Phase shift; GPS = Global Positioning System; DORIS = Doppler Orbitography and Radiopositioning Integrated by Satellite; SLR = Satellite Laser Ranging; CN = center-of-network; CF = center-of-figure.

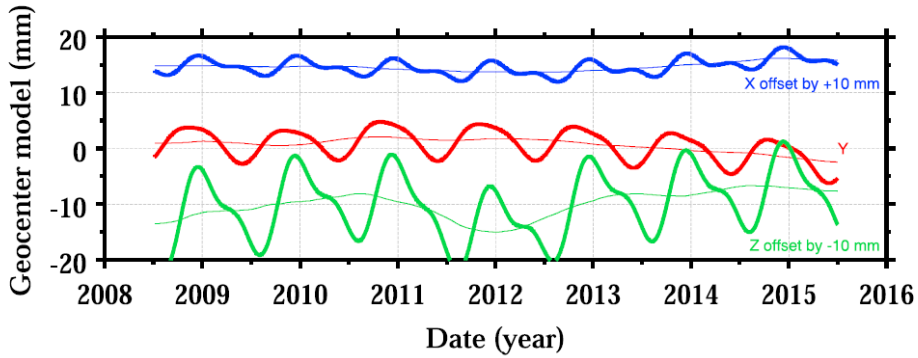

Figure 11. Smoothed DORIS-only Jason-2 geocenter motion time series using a Kalman filter. The bold lines represent the adjusted seasonal (semiannual and annual) and bias parameters, while the thin lines indicate the long-term component. Fictitious +10 and −10 mm offsets were introduced along the X and Z axes, respectively. DORIS = Doppler Orbitography and Radiopositioning Integrated by Satellite.

IDS News

IDS Meetings in 2018:

- **IDS AWG: 11-12 June, 2018** *(@ CNES, Toulouse, France*).
- **IDS Workshop (***in conjunction with altimetry meeting "25 years of Progess in Radar Altimetry***"), Ponta Delgada, Portugal, 24-29 September 2018.**

IDS Working Groups:

- **WG "Near-real time data", Chair is Denise Dettmering (DGFI/TUM). Delivery of NRT for use in Ionosphere models (***NB: This is not the only possible application.***)**
- **IDS GB is evaluating formation of another WG, on the Geocenter where non-IDS participation would be encouraged.**

IDS Newsletter:

- **Published ~3X/yr.**
- **Latest issue is Issue #5 (September 2018)**

Issues available at:

https://ids-doris.org/ids/reports-mails/newsletter.html

IDS Elections:

- **Two positions to be renewed within the Governing Board for the term, 2019-2022:**
- **Candidates solicited and encouraged by an IDS Election Committee.**
- **List of IDS Associates updated this Summer.**

Analysis Coordinator:

(1 candidate team):

***Member-at-large*:**

(4 candidates):

***Election dates*:**

December 1 to December 15:

vote by the IDS Associates

- **January 2019: start of 4-yr term for the two new elected members**

https://ids-doris.org