Working Group proposal on the "observation of geocenter motion"

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WHY ?

- The space-geodetic observation of geocenter motion is still in its infancy
  - Independent solutions have systematic differences as large as the signal level
- The ITRF origin is only sensed by SLR observations of the LAGEOS-1 and 2 satellites
  - There are other techniques than SLR (DORIS, GPS-LEO satellites)
    - The DORIS and GNSS tracking networks are stable and uniquely well distributed geographically
  - AND other missions than the LAGEOS satellites (other spherical satellites, Jason-2/3) which can observe geocenter motion, in both competitive and independent manner
    - The number of laser range normal point data for Jason-2/3 is two to three times higher than for the LAGEOS satellites

SCOPE

- Two options
  1. Pilot project to develop a new IDS product
     - ⇒ Too soon to contribute to the next ITRF realization ?
  2. Campaign handled at the IERS level (as in the late 90s) ?
- One should probably favor the first option

FRANK ARGUED THE CASE AT THE IERS DB

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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

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

Systematic Error Mitigation in DORIS-Derived Geocenter Motion

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

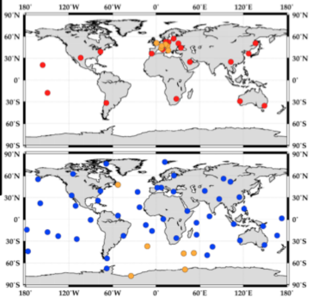
  (II) Requirement to systematically estimate nuisance parameters for microwave techniques (e.g. Doppler).

  - 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

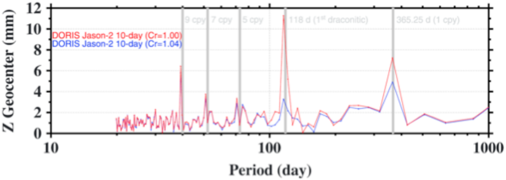


Fig.8 from Couhert et al. (2018). Amplitude spectra of the Z geocenter using Lomb-Scargle method for time series from July 2008 – June 2015, with a SRP coefficient of 1.00 (red), and 1.04 (blue).

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“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

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

$$\delta_S(t) = \left(\frac{1}{\omega_0{}^2}\left[\frac{R_{s_0}}{2} - T_Z\frac{GM}{r^3}\sin i\right] + 2\frac{\dot{\delta}_R(0)}{\omega_0}\right)\cos\omega_0 t + \left(-\frac{R_{c_0}}{2\omega_0{}^2} + \frac{\dot{\delta}_S(0)}{\omega_0}\right)\sin\omega_0 t - 2\frac{\dot{\delta}_R(0)}{\omega_0} + \delta_S(0)$$

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

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 66º), Jason-CS/ Sentinel-6 (66º), and SWOT (inclination of 78º), should also permit the same type of geocenter solutions.**

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

Solution	X A (mm)	X ϕ (day)	Y A (mm)	Y ϕ (day)	Z A (mm)	Z 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.

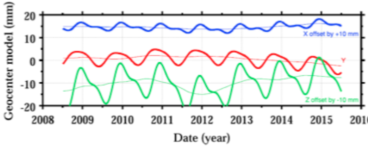

Figure 11. Smoothed DORIS-only Jason-2 geocenter motion time series using a Kalman filter. The bold lines represent the adjusted seasonal (semiannual and annual) and bias parameters, while the thin lines indicate the long-term component. Fictitious +10 and −10 mm offsets were introduced along the X and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

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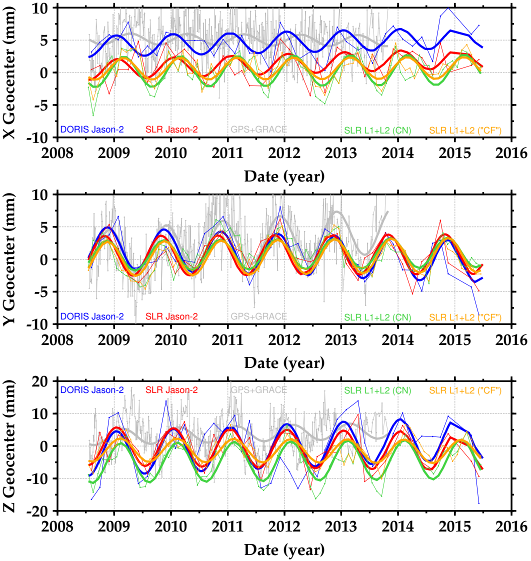
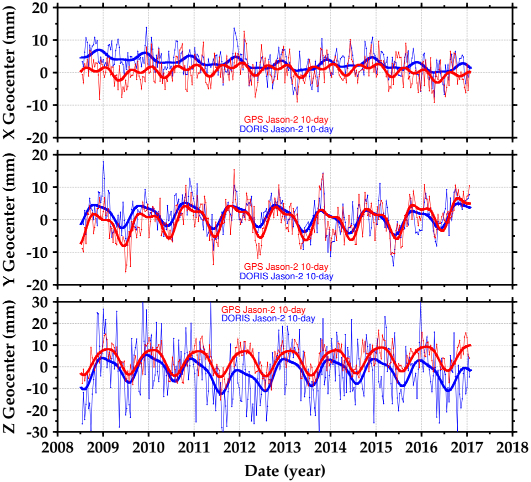
SLR/DORIS AGREEMENT (PREVIOUS PAPER)



GPS/DORIS AGREEMENT (ARTICLE IN PREP.)

Table 1. Estimates of geocenter annual variations for two independent GPS-based and DORIS-derived solutions.

Solution	*X*		*Y*		*Z*	
	A (mm)	ϕ (day)	*A* (mm)	ϕ (day)	*A* (mm)	ϕ (day)
GPS+Jason-2	1.1	0	4.1	337	5.7	27
DORIS Jason-2	1.3	15	3.3	323	5.8	17



PRELIMINARY WG'S OBJECTIVES

- Identify a list of IDS members
  - At least two to three groups should be able to produce similar results so that a combination could be performed
    - CAVEAT : Spacecraft attitude data (quaternions) have to be processed
- Solicit participation from non-IDS members
  - Jason-like altimetry missions are all equipped with three independent geodetic techniques (DORIS, GPS, and SLR)
    - Individual IGS and ILRS members could at least contribute on this basis and/or provide external geocenter motion estimates
  - Can geophysicists independently validate the derived time series based on geophysical interpretations ?
  - Benefit from the interactions with institutes interested in this topic
    - 2017–2020 : "GEODESIE" research project aiming at the improvement of the quality of the space-geodetic references (IGN, CNES, Paris' Observatory, and ULR)
    - 2020–2021 : CNES/IGN TOSCA research contract on underpinning geocenter motion estimation approach differences
- From those who volunteers to process a DORIS Jason-2/3 geocenter motion time series in the frame of the ITRF2020 reprocessing, a combined DORIS solution could thus be available by that time