OSTST Meeting, POD Splinter
Chicago, October 2019

Precise Orbit Determination of DORIS satellites by CNES/CLS IDS Analysis Center in the frame of the next ITRF

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Outline

- ❑ Models and Standards Update

- ❑ Processing Strategy update

- ❑ POD results
  - OPR and DORIS RMS of fit

- ❑ Status of POD for Jason-2/3 and Sentinel-3A/3B satellites
  - DORIS RMS of fit
  - Independent SLR RMS of fit
  - Comparison to external orbits

- ❑ Impact on the multi-satellite solution

- ❑ Summary

Models/Standards update

❑ Models and standards recommended by IERS

Models/Standards		OLD	NEW
Earth rotation	Mean pole	IERS2010	Linear mean pole from updated IERS conventions
	Subdaily pole model	Previous IERS convention	Desai & Sibois from updated IERS conventions
Gravity model	Time variable gravity field	EIGEN-GRGS.RL03	EIGEN-GRGS.RL04
	Oceanic/Atmospheric gravity Dealiasing Products	No	AOD 1B RL06 (GFZ)
Ocean tides	Station displacements (ocean loading)	FES2012	To be implemented FES2014b
	Gravitational attraction	FES2012	FES2014b

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Processing strategy update

❑ Processing strategy (GINS/DYNAMO software)

Theme	OLD	NEW
Attitude modelling (Spacecraft + Solar array)	Attitude model for all satellites	Quaternions for Jason-2 and Jason-3 Quaternions for s3a, s3b and cs2 (planned)
Coefficient Solar Radiation pressure Cr	Satellite dependent estimated and fixed	Satellite and time dependent Adjusted per arc planned
Estimated measurement parameters	One frequency bias per pass	One frequency bias **and drift for SAA stations per pass (for Jason-2 and Jason-3)**
Elevation cut-off and data downweighting	Cut-off 12° downweighting: $elev^2/400$ for elev < 20°	Cut-off 10° CNES downweighting law (planned)
Integration Step Size	60 sec	30 sec
Estimation of the DORIS Center Of Phase locations	NO	Sentinel-3A/3B, Envisat Others?

Status of POD for the currently flying DORIS satellites

❑ POD Summary

DORIS RMS of fit and OPR Acceleration Amplitude / Radiation pressure coefficient

SATELLITE	DORIS RMS (mm/s)	OPR amplitude average (10^{-9} m/s^2)		Solar radiation coefficient Cr
		Along-track	Cross-track	
Cryosat-2	0.348	2.8	2.6	1.00
HY-2A	0.346	0.46	3.3	0.86
SARAL	0.340	1.3	2.7	1.00
Jason-2	0.338	3.8	2.6	0.97
Jason-3	0.360	0.9	2.3	0.99
Sentinel-3A	0.371	2.3	1.6	1.00
Sentinel-3B	0.389	1.4	1.8	1.00

Average (128 weeks)
(from January 2017 to June 2019)
54 weeks for Sentinel-3B

- *For the two directions, Along-track and Cross-track, the mean amplitudes are lower than 4x10^{-9} m/s^2, reflecting a satisfying level in the modeling of the satellite macromodels and the attitude law*

But could be improved by adjusting a Cr/arc in particular for Jasons satellites

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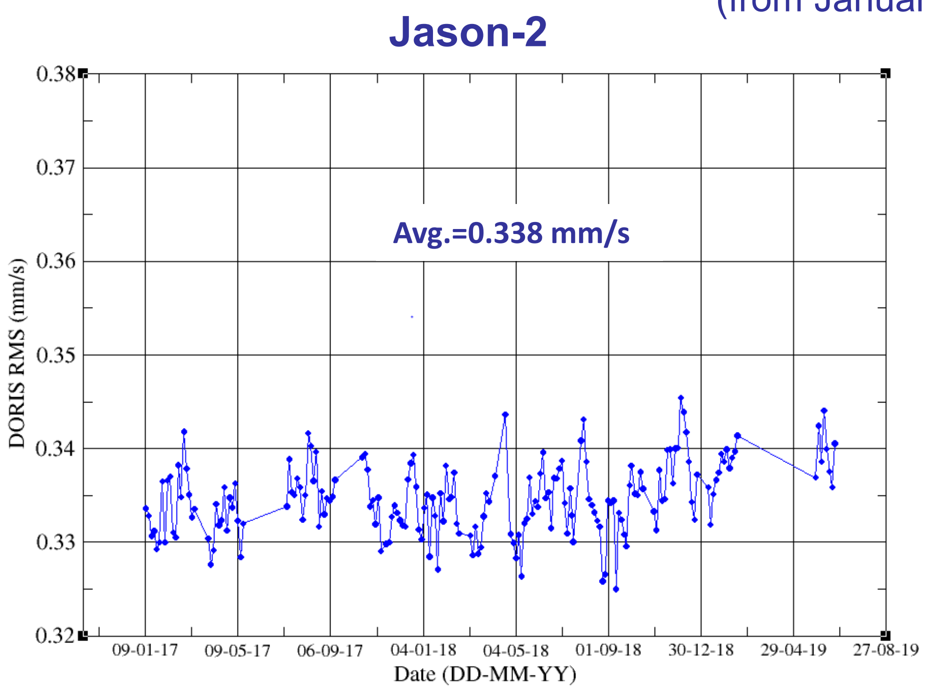
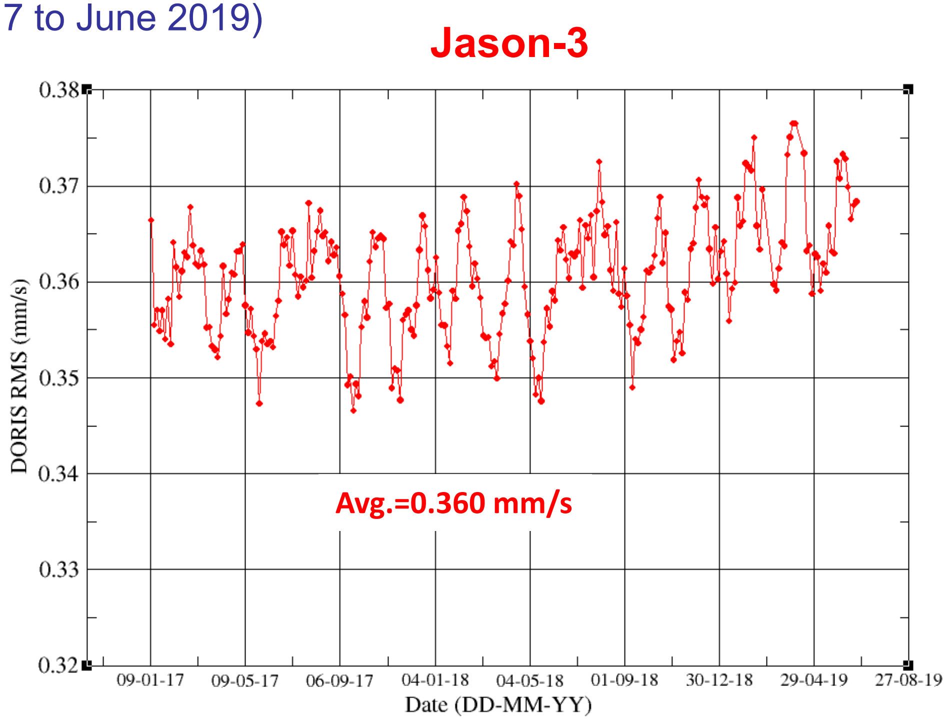
COLLECTE LOCALISATION SATELLITES

Status of POD for Jason-2/3 and Sentinel-3A/3B satellites

❑ DORIS RMS of fit

(from January 2017 to June 2019)





- *For Jason-3,the level of DORIS RMS residuals is slightly higher compared to Jason-2, explained by its higher sensitivity to the South Atlantic Anomaly (SAA).*
- *There is a ~59 days periodic signal for both satellites (draconitic period).*

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Status of POD for Jason-2/3 and Sentinel-3A/3B satellites

❑ Estimation of the beacon frequency Bias+Drift on SAA station per pass

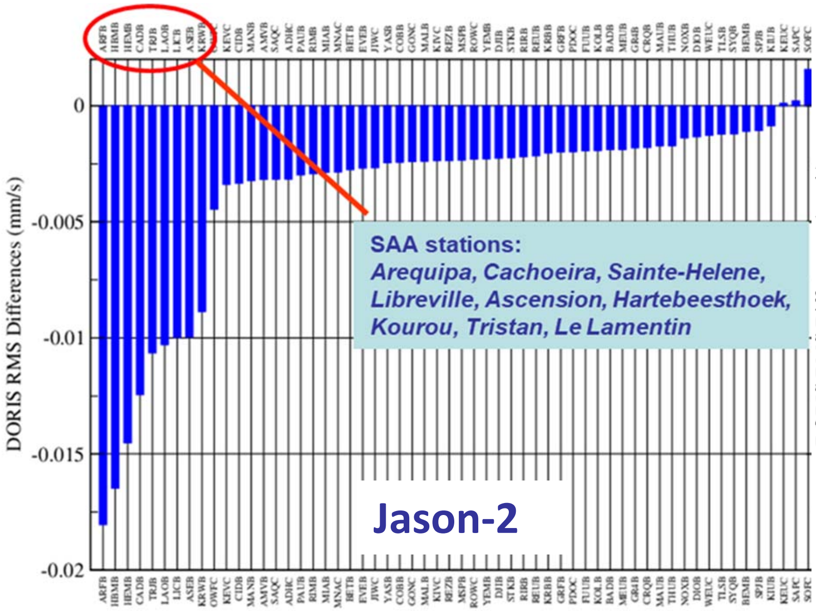
- **Impact on the precise orbit**

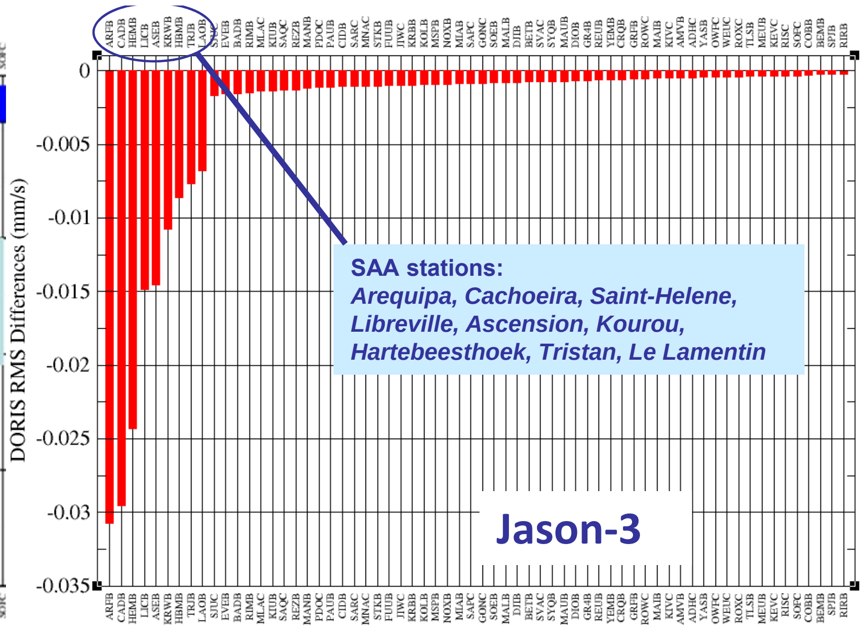
Classical processing: one Frequency Bias adjusted per pass for all stations

With strategy: Frequency Bias+Drift adjusted per pass.

Average (128 weeks)
(from January 2017 to June 2019)

DORIS RMS of fit differences per station
(with strategy – without strategy)





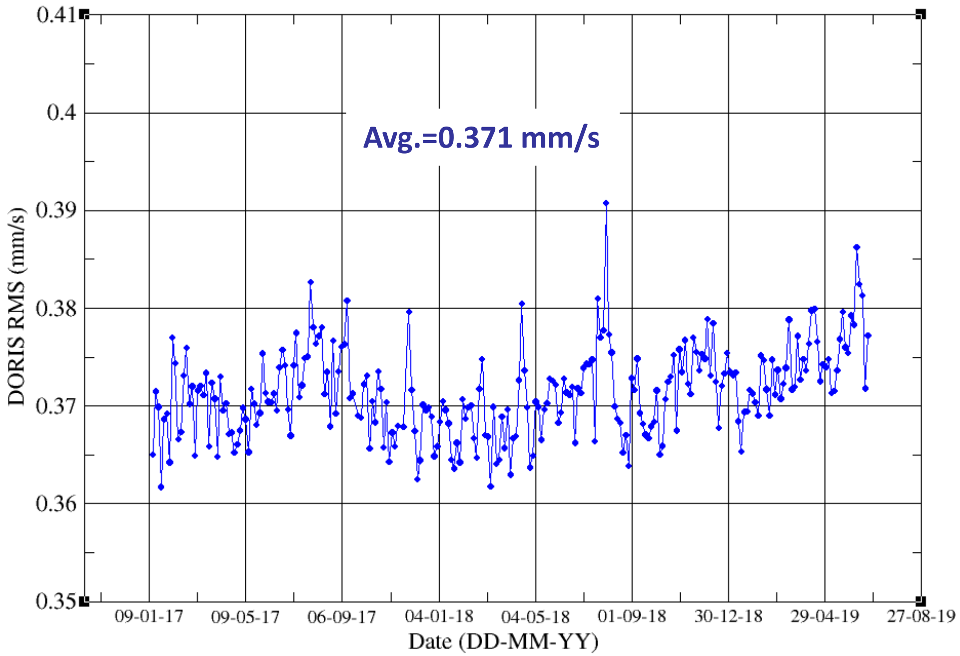
- *The DORIS residuals are lower when we apply the strategy of Bias+Drift adjusting frequency per pass for SAA stations.*
- *The impact is significant for SAA stations and the number of measurements is higher.*
- *For Jason-3, the level of DORIS RMS residuals is slightly higher compared to Jason-2, explained by its higher sensitivity to the SAA.*

Status of POD for Jason-2/3 and Sentinel-3A/3B satellites

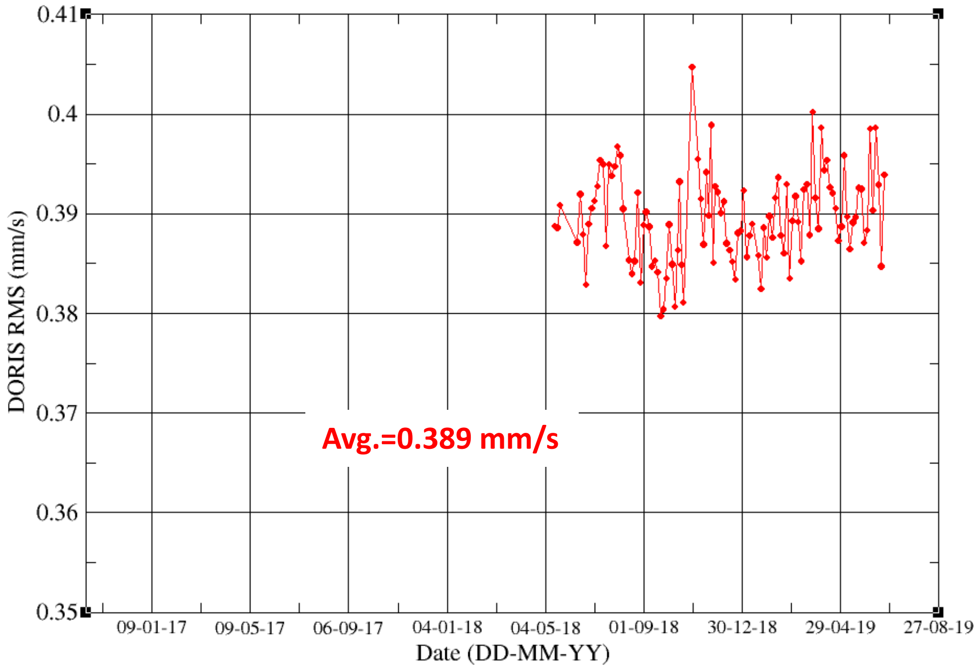
❑ DORIS RMS of fit

128 weeks (from January 2017 to June 2019)
54 weeks for Sentinel-3B

Sentinel-3A



Sentinel-3B



- *The level of DORIS RMS residuals is slightly higher for Sentinel-3B.*

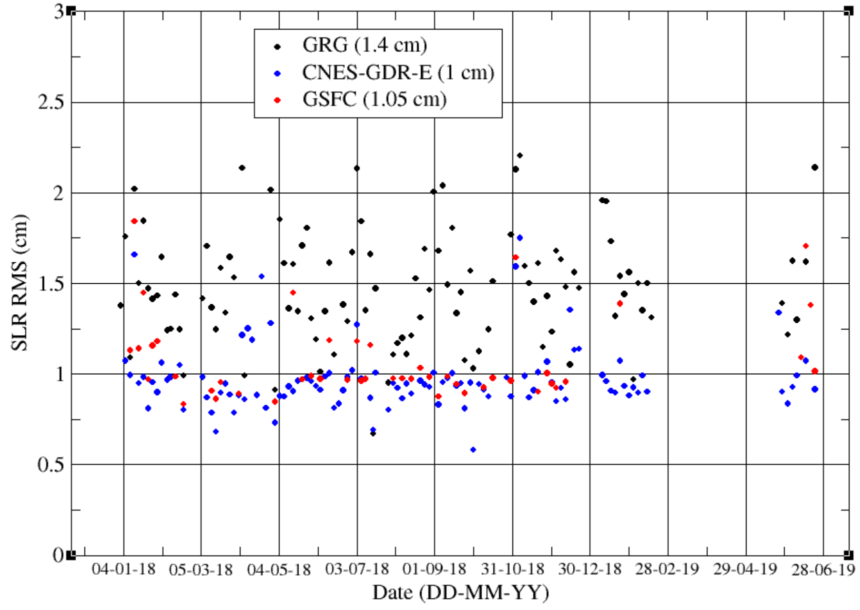
Status of POD for Jason-2/3 and Sentinel-3A/3B satellites

❑ Comparison to CNES (POE-E/F), GSFC (1808a+DPOD2014) and JPL (jplgpspoe) orbits

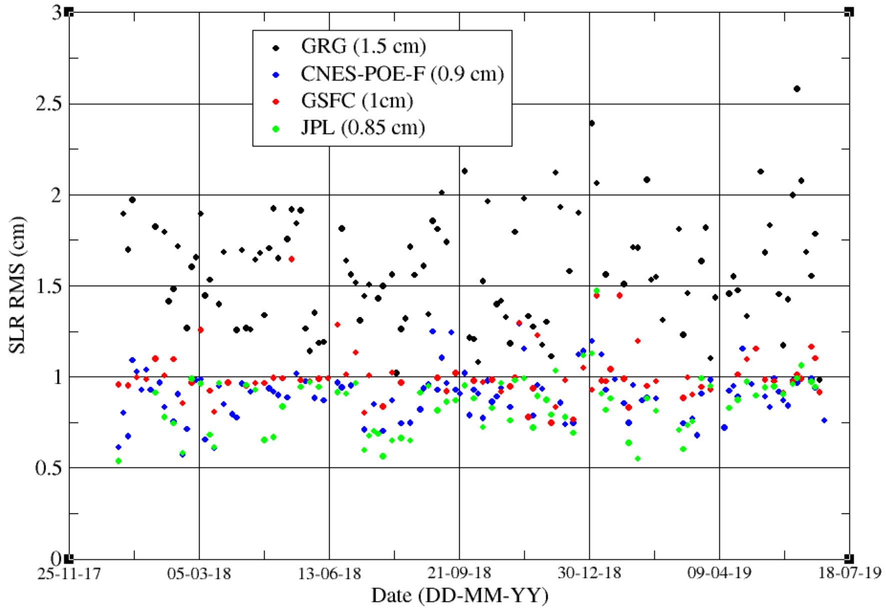
Independent SLR RMS of fit

(from January 2017 to June 2019)

Jason-2



Jason-3

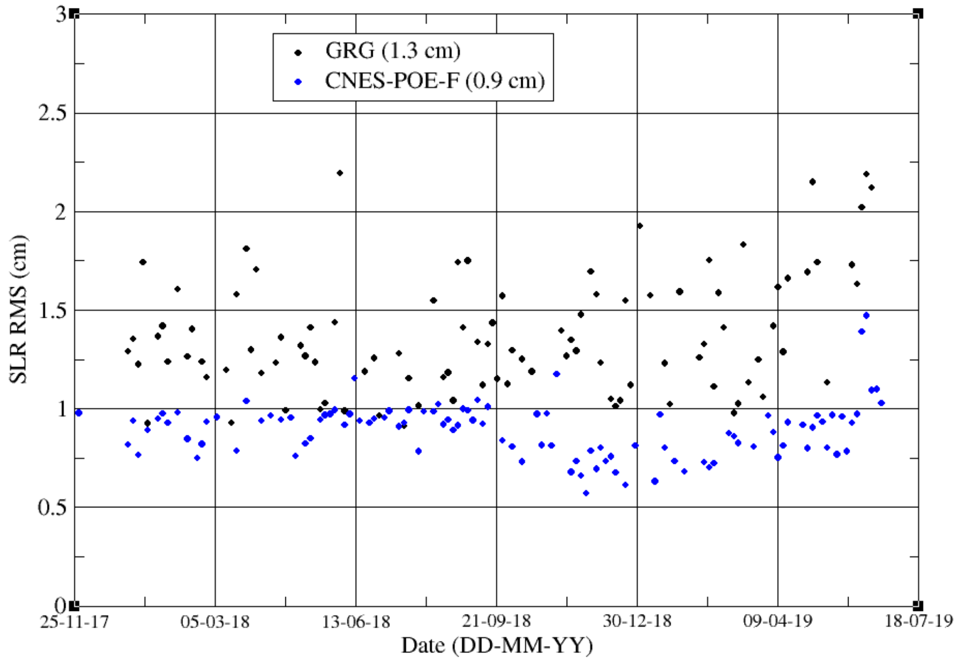


- *The SLR RMS residuals on Jason-2 and Jason-3 orbits are higher (few mm) to the other orbits evaluated (GPS+DORIS, DORIS+SLR and GPS-only orbits)*

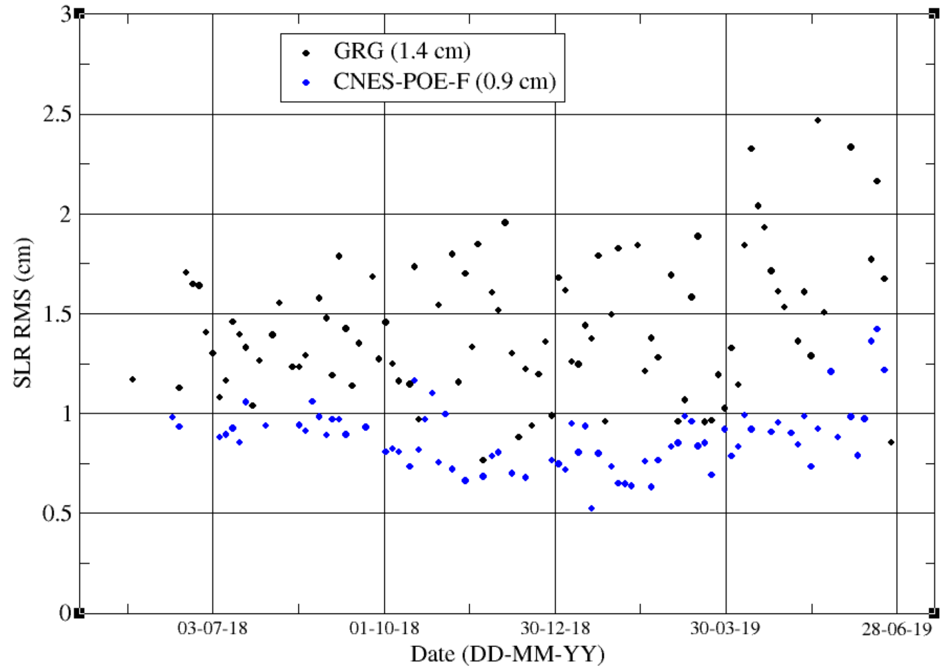
Status of POD for Jason-2/3 and Sentinel-3A/3B satellites

❑ Comparison to CNES (POE-F) orbits
Independent SLR RMS of fit

Sentinel-3A (from Jan. 2017 to Jun. 2019)



Sentinel-3B (from Jun. 2018 to Jun. 2019)



- *The SLR RMS residuals on Sentinel-3A and Sentinel-3B orbits are also higher compared to the CNES-POE-F orbit (GPS+DORIS)*

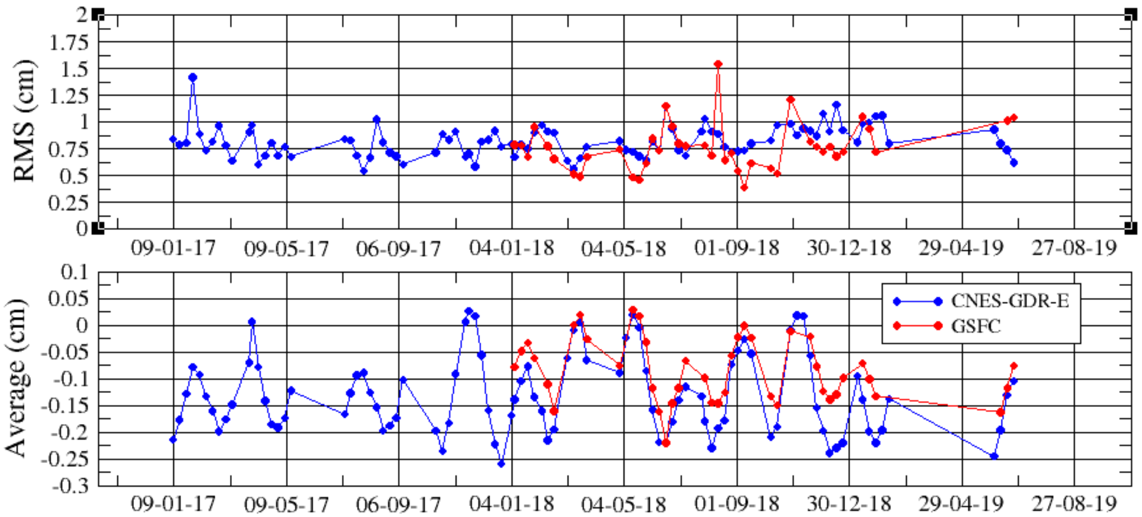
Status of POD for Jason-2/3 and Sentinel-3A/3B satellites

❑ Comparison to CNES (GDR-E) and GSFC orbits

Jason-2 orbit differences

(from January 2017 to June 2019)

RMS and Avg. Radial orbit differences (in cm)



Reference orbit = GRG orbit

Jason-2 orbit differences (cm)			
Difference	Radial RMS | AVG	Cross-track RMS | AVG	along-track RMS | AVG
CNES-GDR-E	0.80 | -0.13	1.9 | 0.12	2.3 | 0.21
GSFC	0.76 | -0.08	2.4 | 0.24	2.6 | 0.34

- *There is a good agreement between GRG orbit and external orbits CNES-GDR-E and GSC (~0.8 cm RMS)*
- *There is a 59 days periodic signal in the radial component and small bias*

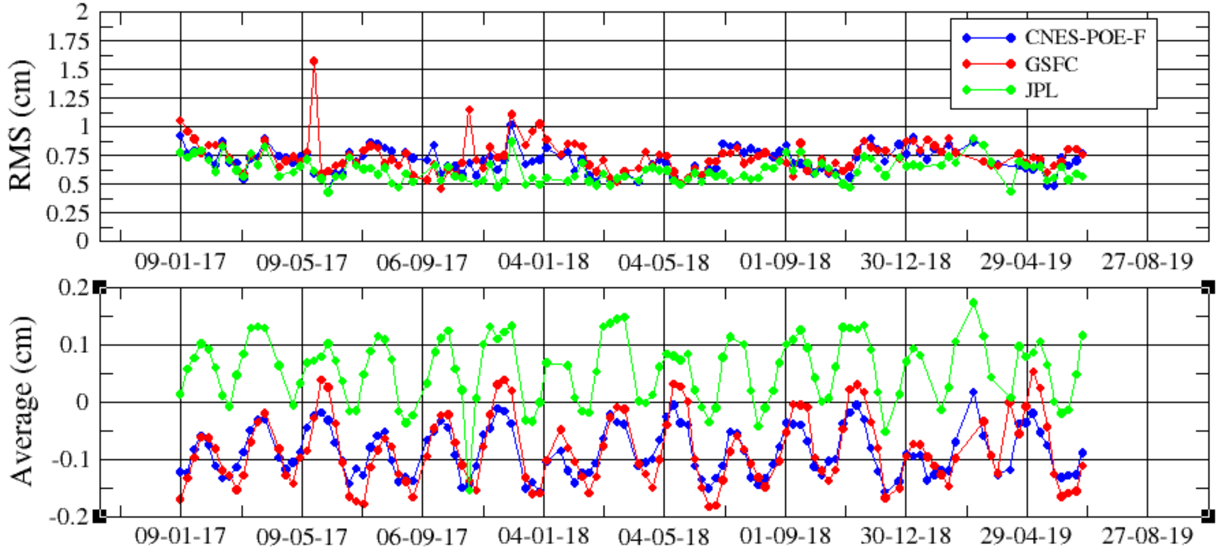
Status of POD for Jason-2/3 and Sentinel-3A/3B satellites

❑ Comparison to CNES (POE-F), GSFC and JPL orbits

Jason-3 orbit differences

(from January 2017 to June 2019)

RMS and Avg. Radial orbit differences (in cm)



Reference orbit = GRG orbit

Jason-3 orbit differences (cm)			
Difference	Radial RMS | AVG	Cross-track RMS | AVG	along-track RMS | AVG
CNES-POE-F	0.70 | -0.08	2.5 | 0.18	2.3 | 0.60
GSFC	0.74 | -0.08	2.8 | 0.21	2.6 | -0.30
JPL	0.62 | 0.05	2.4 | 0.17	2.2 | 0.70

- *There is a good agreement between GRG orbit and external orbits (~0.7 cm RMS)*
- *There is a 59 days periodic signal (low amplitude) in the radial component and a small bias (< 1mm) (draconitic period)*
- *There is also an along-track bias higher with GPS orbits*

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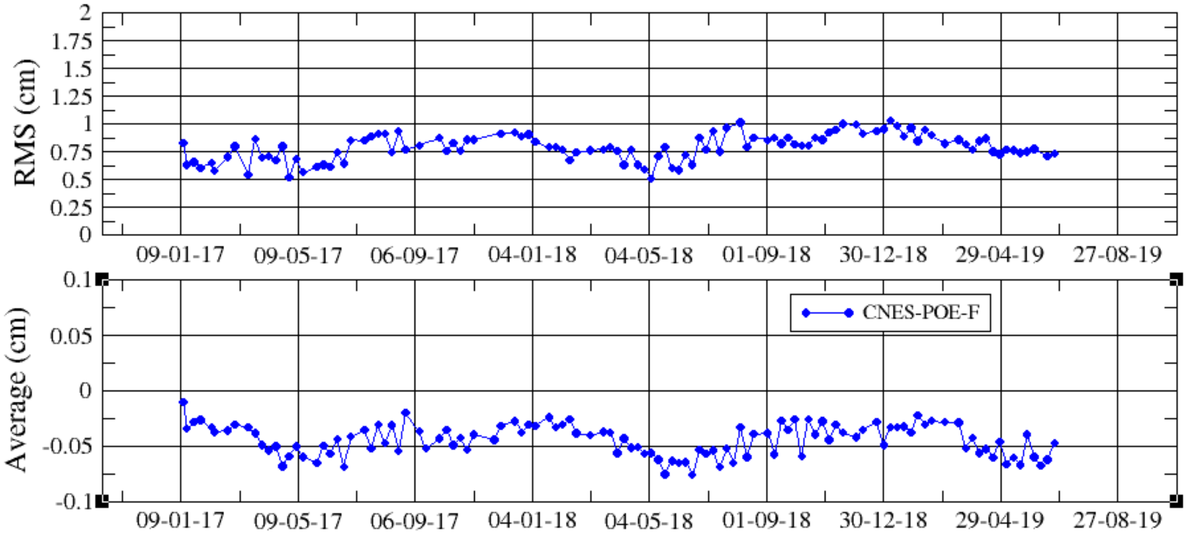
Status of POD for Jason-2/3 and Sentinel-3A/3B satellites

❑ Comparison to CNES (POE-F) orbits

Sentinel-3A orbit differences

(from January 2017 to June 2019)

RMS and Avg. Radial orbit differences (in cm)



Reference orbit = GRG orbit

Sentinel-3A orbit differences (cm)			
Difference	Radial RMS | AVG	Cross-track RMS | AVG	along-track RMS | AVG
CNES-POE-F	0.79 | -0.04	1.7 | 0.11	2.1 | -0.29

- *There is a good agreement between GRG orbit and CNES-GDR-E (~0.7 cm RMS)*

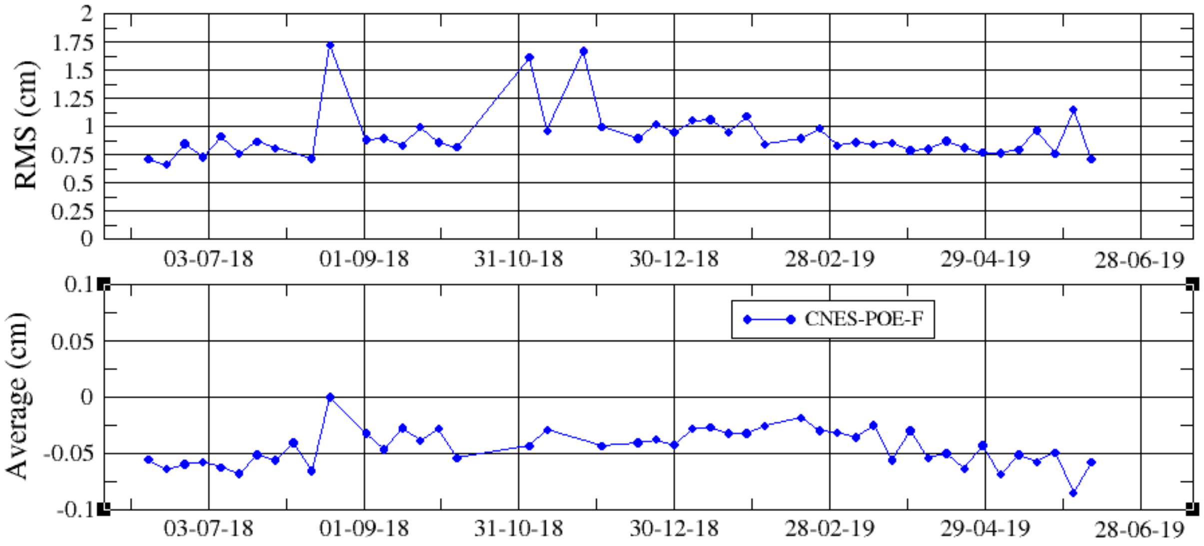
Status of POD for Jason-2/3 and Sentinel-3A/3B satellites

❑ Comparison to CNES (POE-F) orbits

Sentinel-3B orbit differences

(from July 2018 to June 2019)

RMS and Avg. Radial orbit differences (in cm)



Reference orbit = GRG orbit

Sentinel-3B orbit differences (cm)			
Difference	Radial RMS | AVG	Cross-trk RMS | AVG	along-trk RMS | AVG
CNES-POE-F	0.92 | -0.04	1.9 | -0.13	2.5 | 0.10

- *There is a good agreement between GRG orbit and CNES-GDR-E (< 1 cm RMS)*

Status of POD for Jason-2/3 and Sentinel-3A/3B satellites

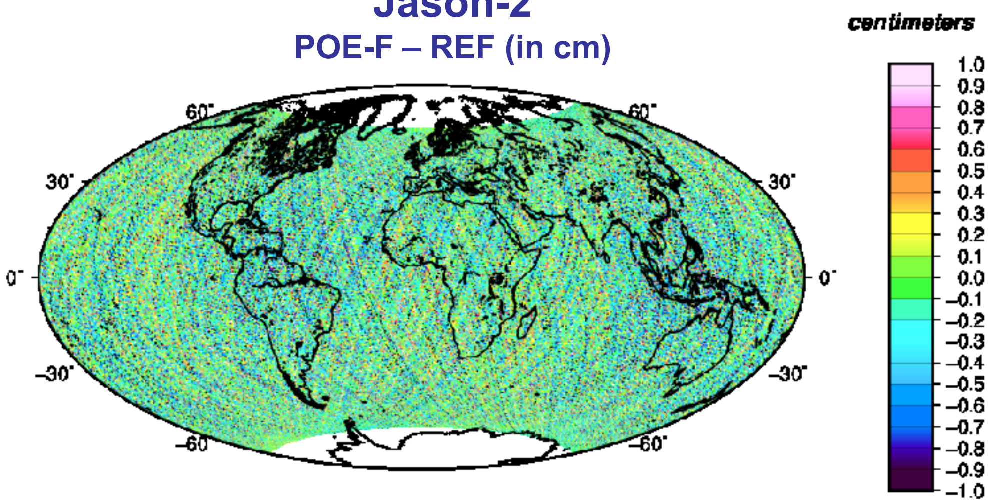
❑ Comparison to CNES (GDR-E) and GSFC orbits

Mapping radial orbit differences

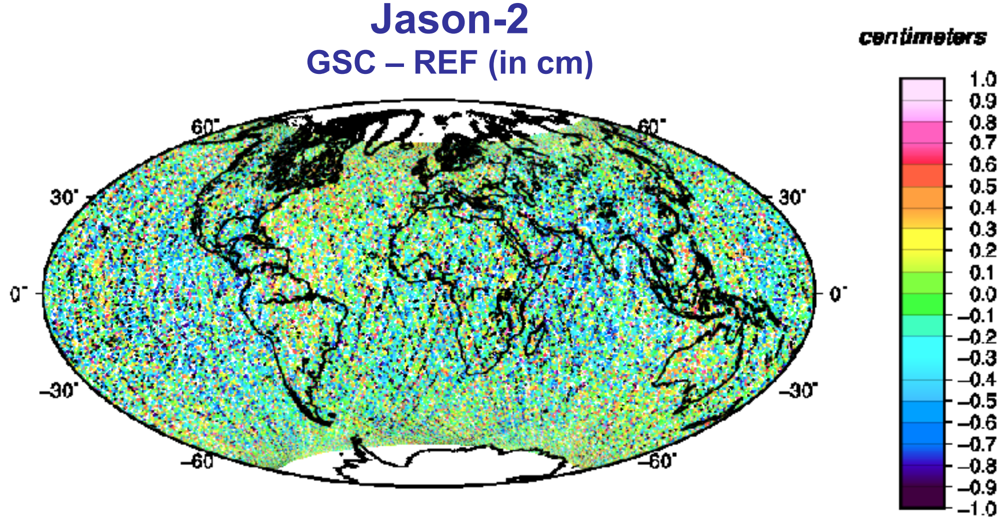
Average (128 weeks)
(from January 2017 to June 2019)

REF = GRG orbit

Jason-2
POE-F – REF (in cm)



Jason-2
GSC – REF (in cm)



- *There is a good agreement between GRG orbit and external orbits*
- *No patch but small bias*

Status of POD for Jason-2/3 and Sentinel-3A/3B satellites

❑ Comparison to CNES-POE-F, GSFC and JPL orbits

Mapping radial orbit differences

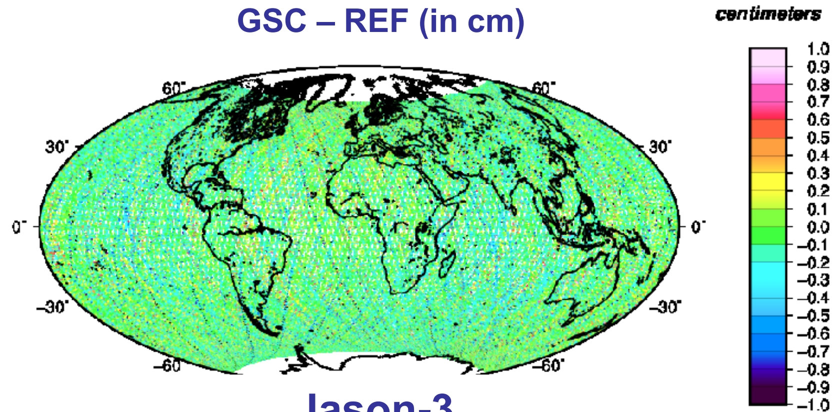
Average (128 weeks)

(from January 2017 to June 2019)

REF = GRG orbit

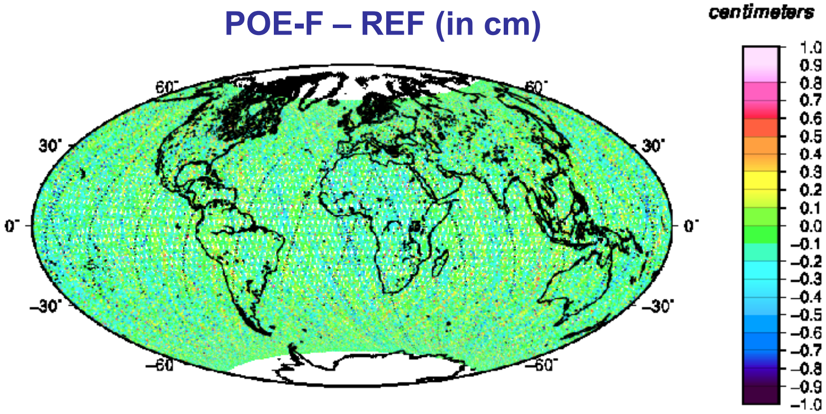
Jason-3

GSC – REF (in cm)



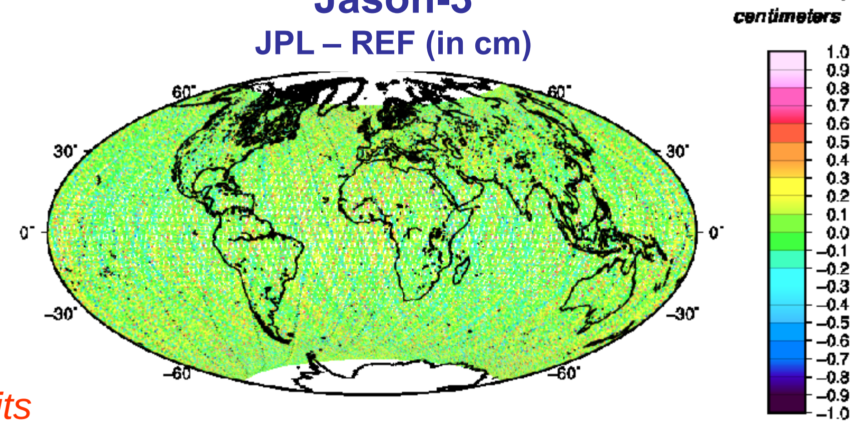
Jason-3

POE-F – REF (in cm)



Jason-3

JPL – REF (in cm)



- *There is a good agreement between GRG orbit and external orbits*
- *No patch but small bias, opposite for JPL comparison*

Status of POD for Jason-2/3 and Sentinel-3A/3B satellites

❑ Comparison to CNES (POE-F) orbits

Mapping radial orbit differences

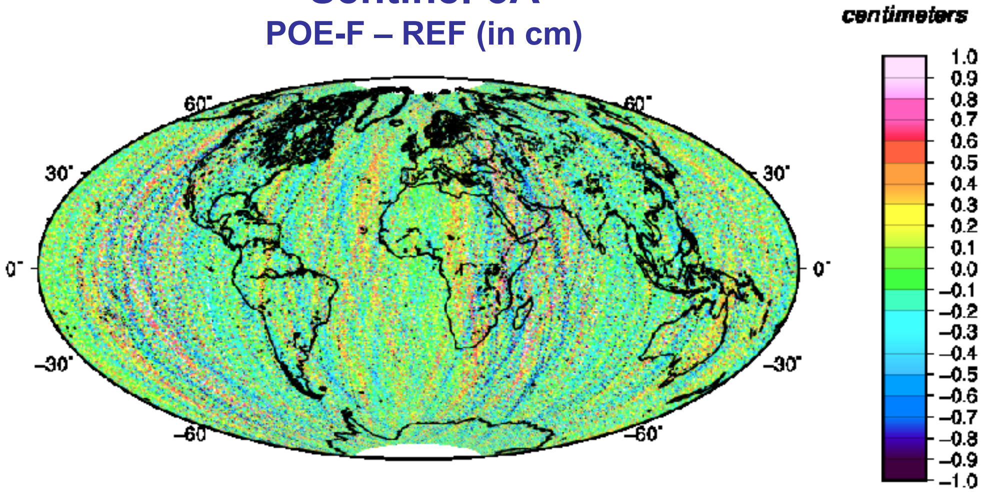
Average (128 weeks)

(from January 2017 to June 2019)

REF = GRG orbit

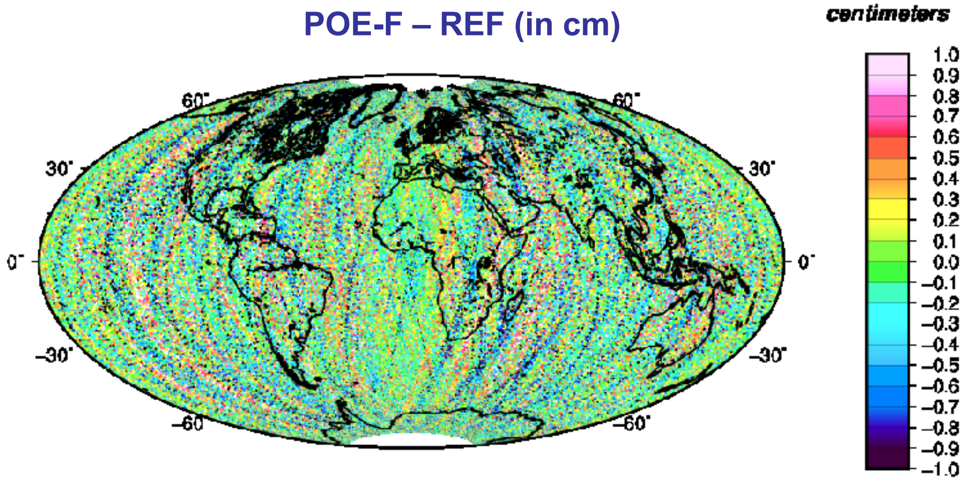
Sentinel-3A

POE-F – REF (in cm)



Sentinel-3B

POE-F – REF (in cm)



- *There is a good agreement between GRG orbit and external orbits*
- *No patch but small bias*

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Status of POD for Jason-2/3 and Sentinel-3A/3B satellites

❑ Comparison to CNES (POE-E/F), GSFC and JPL orbits

Altimeter crossover Cycles

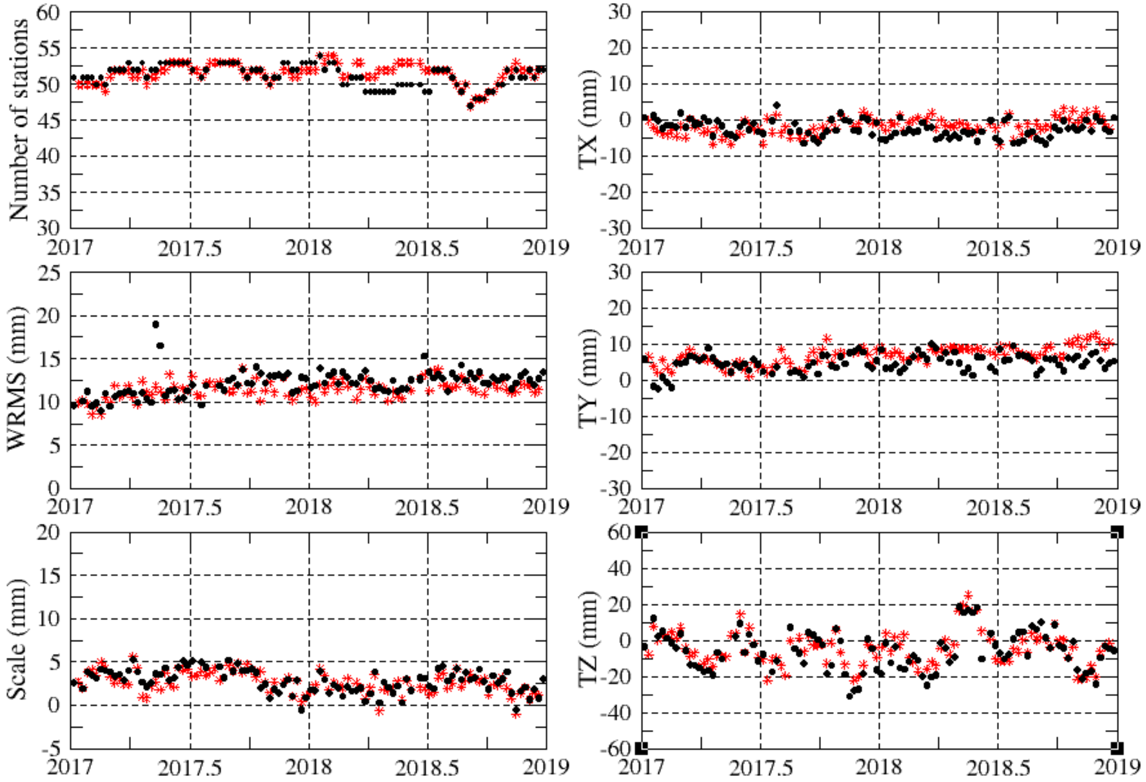
Altimeter Xover (in cm)			
Orbit	Jason-2	Jason-3	Sentinel-3A
GRG	5.70	5.58	5.48
CNES	5.66	5.56	5.44
GSC	X	5.57	X
JPL	X	5.55	X

- *The altimeter xover obtained with GRG orbit are at a good level*
- *The level is comparable but slightly higher to the others orbits evaluated*

Impact on the new multi-satellite solution

❑ **Multi-satellite Solution (weekly) compared to DPOD2014 (from Jan. 2017 to Dec. 2018)**

GRG OLD serie /NEW serie



Summary

❑ Preparation for the next ITRF

- *Models and Standards recommended by IERS and Processing strategy update*

❑ Status of POD for Jason-2/3 and Sentinel-3A/3B satellites

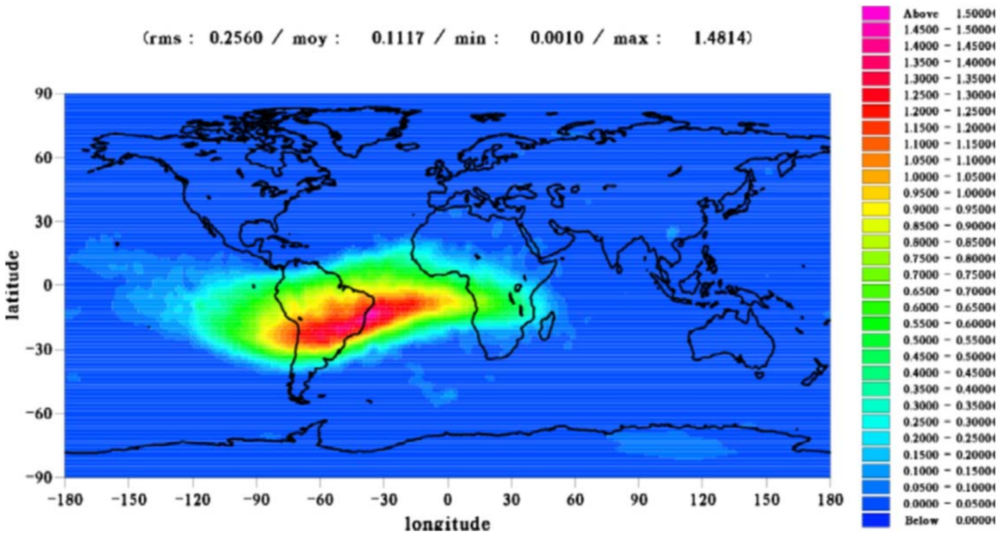
- *The POD results are of good quality but the DORIS RMS for Jason-3 and Sentinel-3 satellites are still higher than the other DORIS satellites. It can be due from the RINEX format. For Jason-3, it can also be explained by the SAA effect.*
- *For the GRG DORIS-only orbit, the SLR residuals are still higher than those of the external orbits (CNES, GSFC and JPL)*
- *There is good agreement between GRG orbit and external orbits but there is still room for improvement*

❑ Future work

- *Finalize the Preparation to the next ITRF:*
  - *Implement the CNES downweighting data*
  - *Analyze Geocenter and Scale factor from single satellite solutions*
  - *Use quaternions for Sentinels and Cryosat-2 satellites*
  - *Mitigate the ~118-day draconitic signal identified in the DORIS geodetic products*
  - *Apply a strategy recommended by IDS to mitigate the SAA effect on the multi-satellite solution*
- *Comparison to GRG GPS-only orbit and external DORIS-only orbits*

Backup: South Atlantic Anomaly

- The South Atlantic Anomaly (SAA) is an area where the Earth's inner Van Allen radiation belt comes closest to the Earth's surface, dipping down to an altitude of 200 kilometres. This leads to an increased flux of energetic particles in this region and exposes orbiting satellites to higher-than-usual levels of radiation. The SAA is the near-Earth region where the Earth's magnetic field is weakest relative to an idealized Earth-centered dipole field. The increased radiation perturbs the crystal quartz oscillators that are the heart of the DORIS system, causing short-term and long-term changes in the frequency behavior



Plot of the DORIS derived relative dose exposure in 2002–2005 at 1300 km altitude (dimensionless units).
Lemoine et Capdeville 2006.