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Strategy to minimize the impact of the South Atlantic Anomaly effect on the Jason-3 and Sentinel-3A POD and on the station position estimation

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Outline

❑ Status of POD for Sentinel-3A and Jason-3 satellites
- Processing strategy
- DORIS RMS of fit and SLR external validation
- Comparison to CNES (GDR-E) and ESOC orbits

❑ SAA impact on satellites
- Impact on the orbit
- Impact on the station position estimation

❑ Strategy to minimize the SAA effect
- Impact on the orbit
- Impact on the station position estimation

❑ Conclusions and perspectives

Status of POD for Sentinel-3A and Jason-3 satellites (1/8)

❑ Processing strategy

(we took the IERS conventions and the IDS recommendations)

Software	GINS/DYNAMO
DORIS data	RINEX 3.0 phase measurement converted to DOPPLER
Station Coordinates	ITRF2014 (DPOD2014)
Gravity Field	EIGEN-GRGS.RL03-v2.MEAN-FIELD with mean slope extrapolation
DORIS Troposphere	VMF1 + one gradient per station in North & East directions
Attitude Model	for Jason-3: nominal law likeTopex for Sentinel-3A: nominal law like Envisat
Surfaces Forces **&** **Estimated Parameters**	Box-wing model for solar radiation,drag, Albedo and IR Macromodel available at : *ftp://ftp.ids-doris.org/pub/ids/satellites/DORISSatelliteModels.pdf* Radiation pressure scale coefficient : 1 coef/day but strongly constrained to: 0.99 for Jason-3 and 1.0 for Sentinel-3A OPR empiricals: 2 coeff cos-sin /orbital period in normal direction and 2 coeff cos-sin /orbital period in tangential direction (per arc) Drag coefficients adjusted: 1 coef/4 hours for Sentinel-3A and 1 coef/half day for Jason-3
Time span processing	From April 2016 to August 2017 3.5-day arcs with a cut-off angle of 12°

Status of POD for Sentinel-3A and Jason-3 satellites (2/8)

❑ POD Summary

DORIS RMS of fit and SLR external validation

OPR Acceleration Amplitude:

Along-track and Cross-track / Radiation pressure coefficient

Mean of 72 weeks *(from April 2016 to August 2017)*

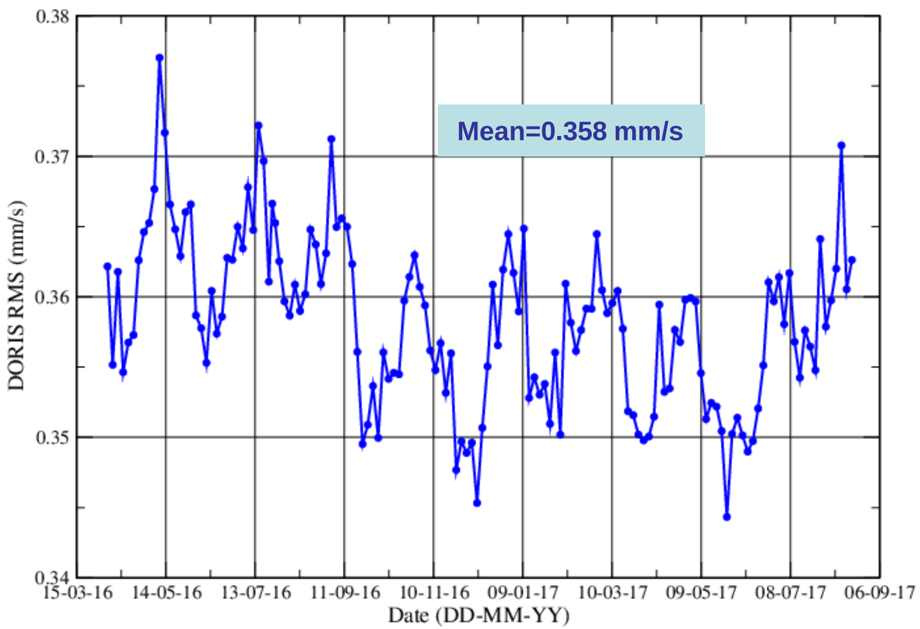
SATELLITE	DORIS RMS (mm/s)	SLR RMS (cm)	OPR amplitude average (10^{-9} m/s^2)		Solar radiation coefficient
			Along-track	Cross-track	
Jason-3	0.358	1.8	1.3	2.5	0.99
Sentinel-3A	0.365	1.3	2.2	1.9	1.00

- *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.*

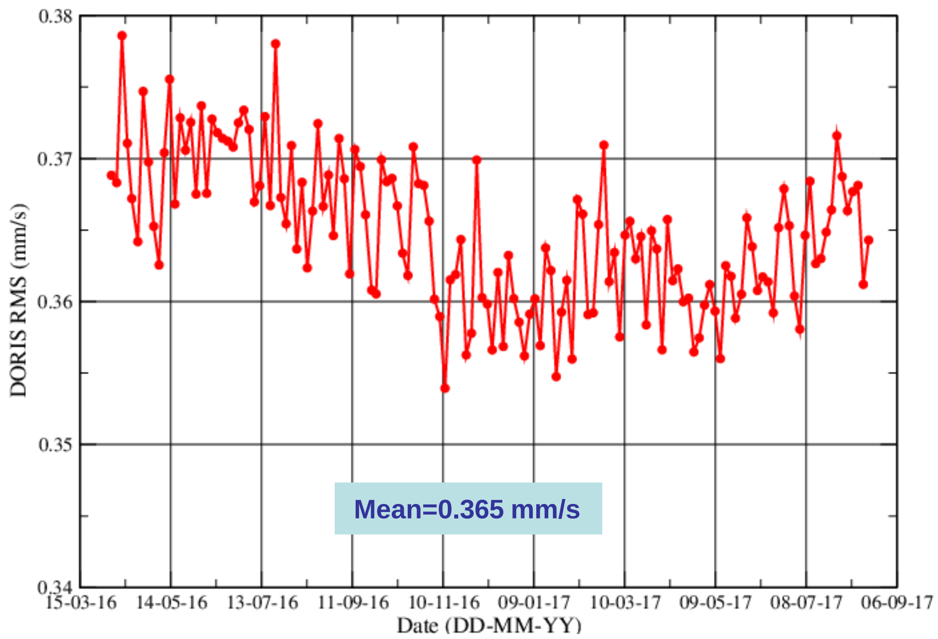
Status of POD for Sentinel-3A and Jason-3 satellites (3/8)

❑ DORIS RMS of fit

Jason-3



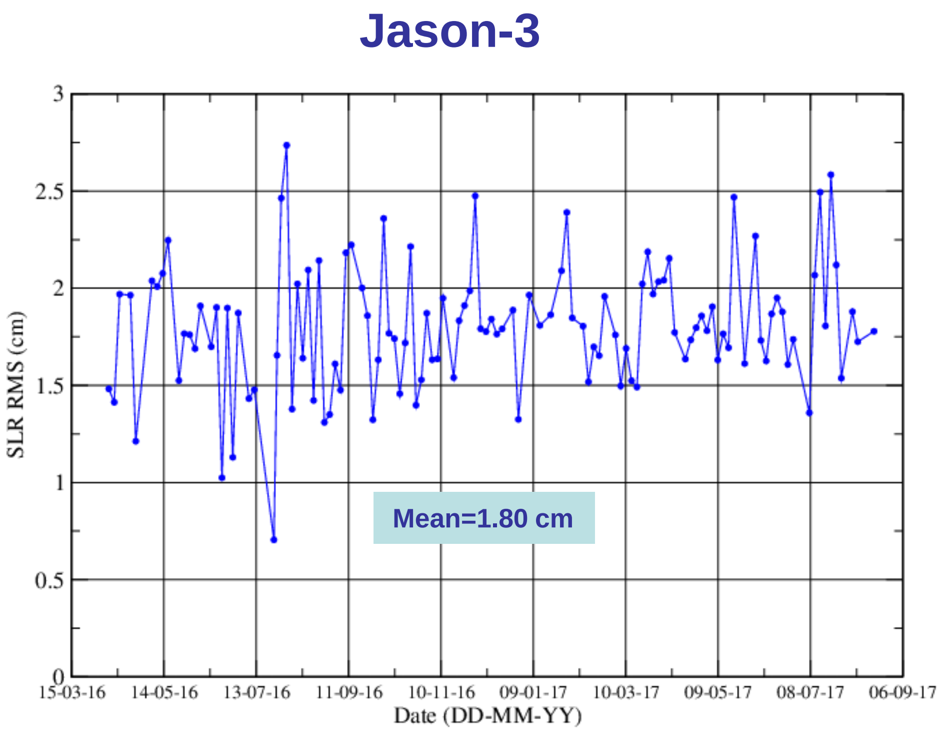
Sentinel-3A

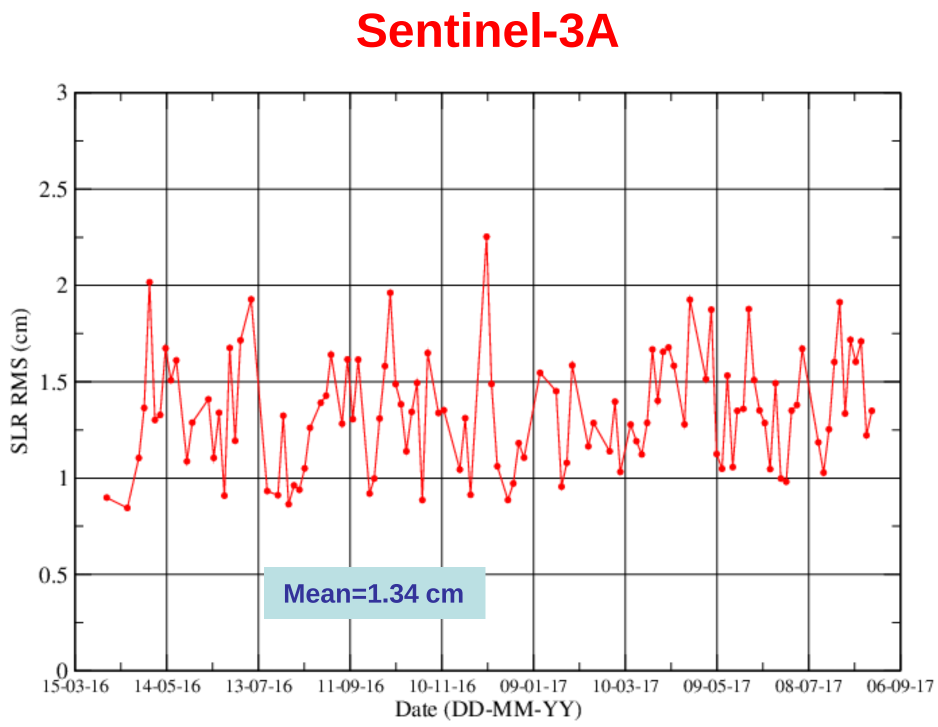


- *The level of DORIS RMS residuals is slightly higher compared to Jason-2.*
- *For Jason-3, that could be explained by its sensitivity to the SAA. There is also a 60 days periodic signal.*

Status of POD for Sentinel-3A and Jason-3 satellites (4/8)

❑ Independent SLR RMS of fit





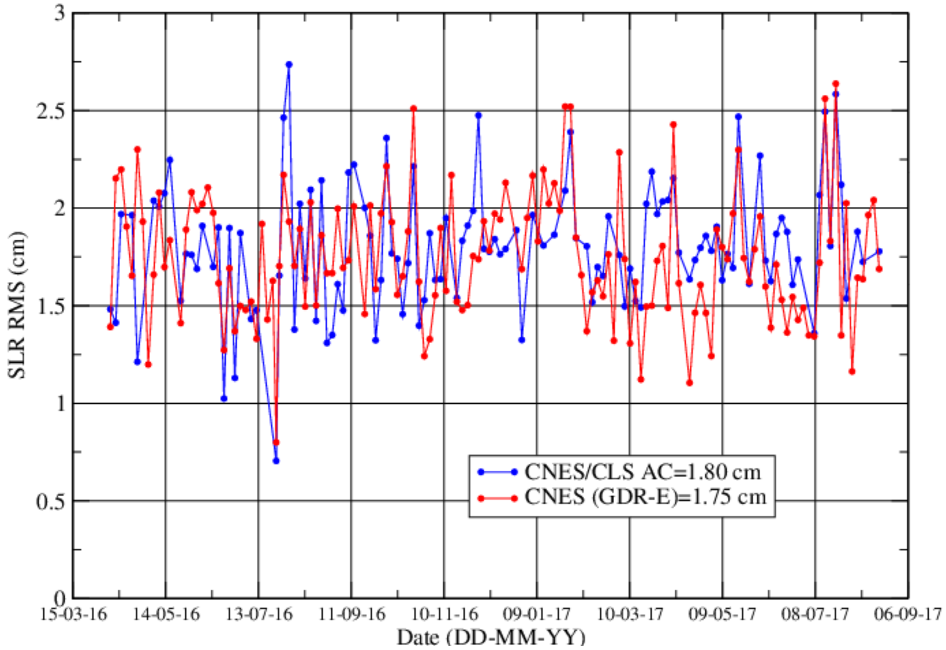
- *The SLR RMS residuals on Jason-3 and Sentinel-3A orbits are at a good level.*

Status of POD for Sentinel-3A and Jason-3 satellites (5/8)

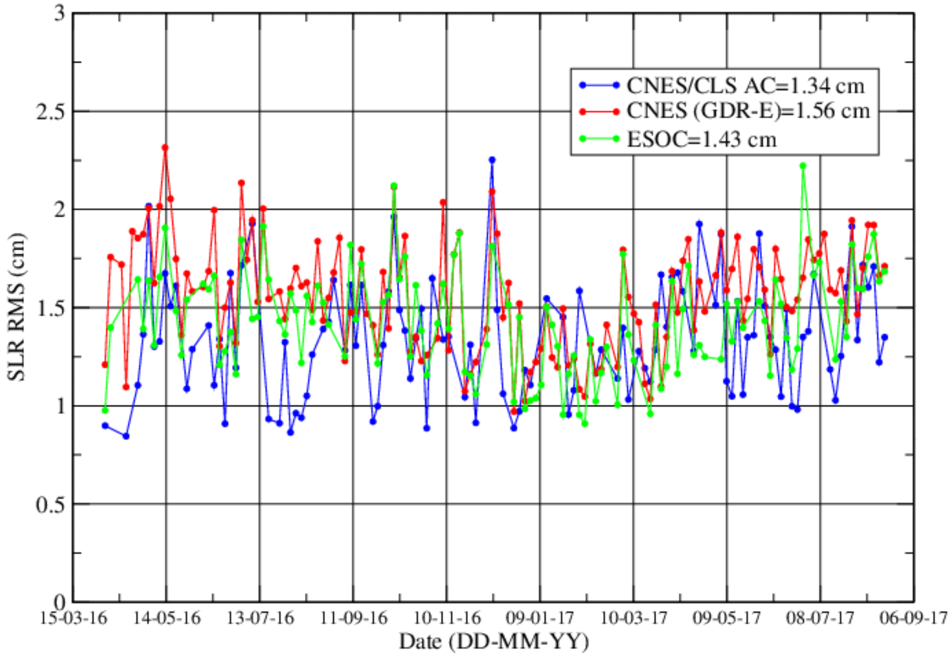
❑ Comparison to CNES (GDR-E) / ESOC orbits

Independent SLR RMS of fit

Jason-3



Sentinel-3A

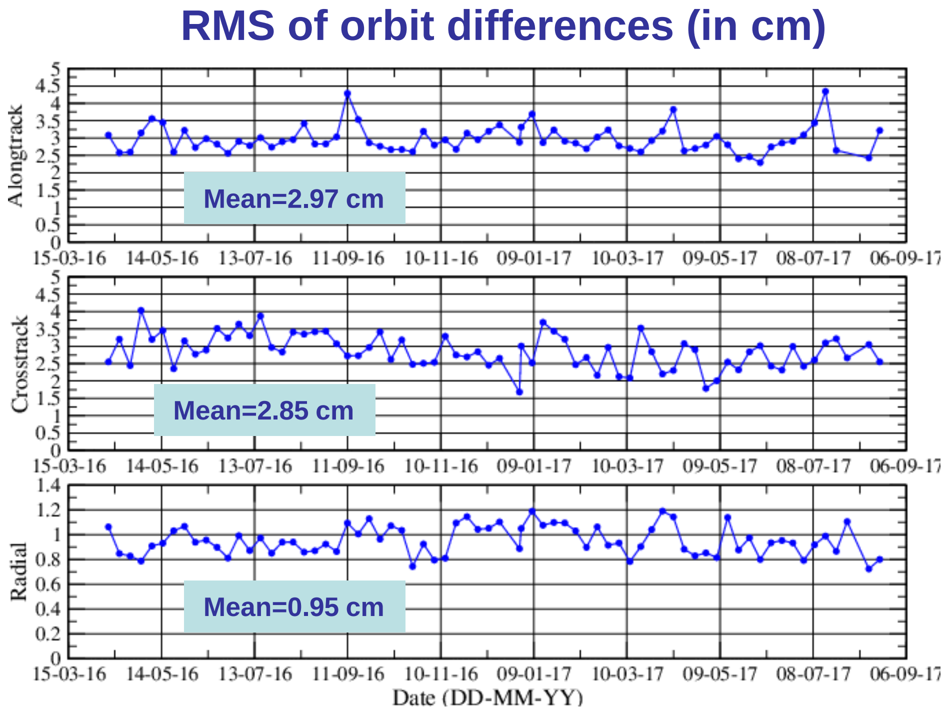


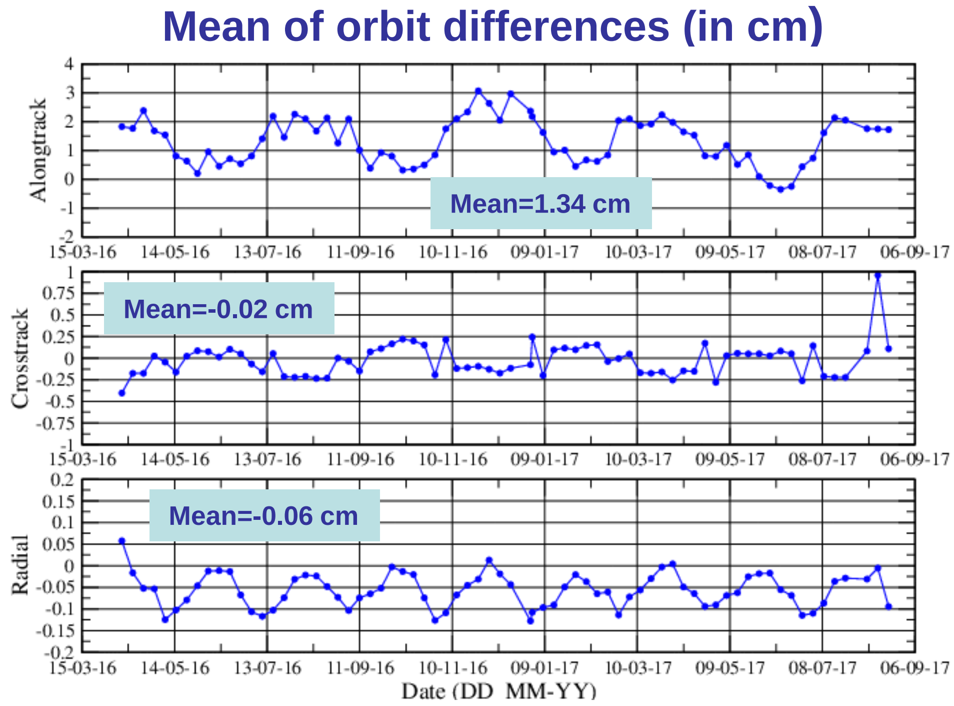
- *The SLR RMS residuals on Jason-3 and Sentinel-3A orbits are at a good level.*
- *The level is comparable to the others orbits evaluated, CNES-GDR-E and ESOC.*

Status of POD for Sentinel-3A and Jason-3 satellites (6/8)

❑ Comparison to CNES (GDR) orbits

Jason-3 orbit differences





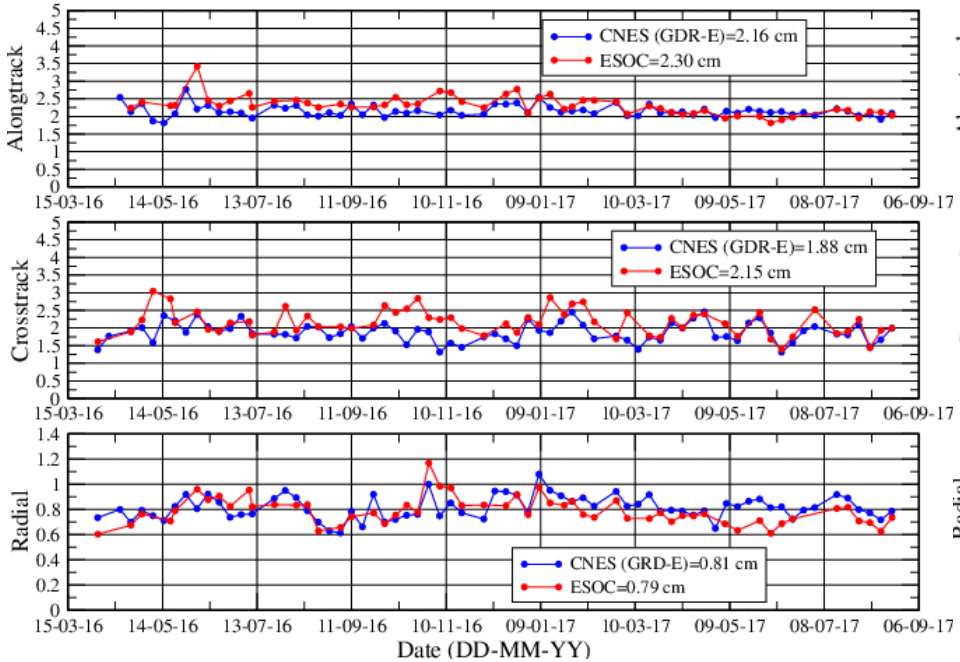
- *There is a good agreement between the orbits calculated with GINS and ZOOM (GDR-E) but there is an along-track bias (~ 1.34 cm) which can be explained by the difference in time tagging.*
- *For Jason-3, there is also a 60 days periodic signal in the radial component.*

Status of POD for Sentinel-3A and Jason-3 satellites (7/8)

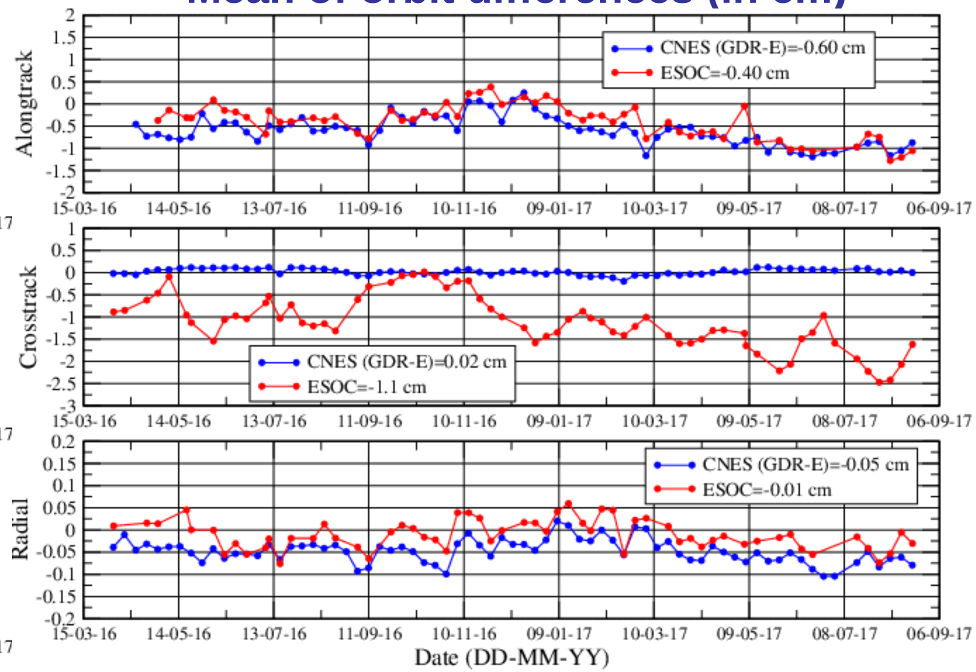
❑ Comparison to CNES (GDR) / ESOC orbits

Sentinel-3A orbit differences

RMS of orbit differences (in cm)



Mean of orbit differences (in cm)



- *For Sentinel-3A, the agreement is better but there is also an along-track bias (~ 6 mm).*
- *The comparison to ESOC orbit gives better results except for crosstrack component with a bias of 1.1 cm.*

Status of POD for Sentinel-3A and Jason-3 satellites (8/8)

❑ Comparison to CNES (GDR) / ESOC orbits

Radial geographically correlated errors

Mean of 72 weeks

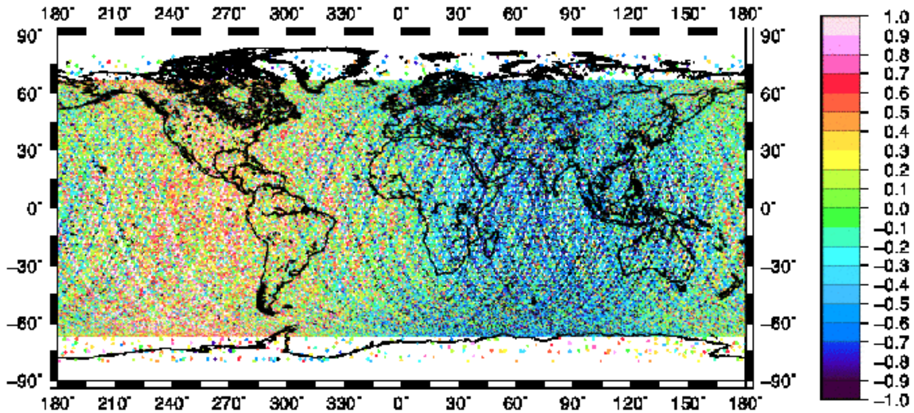
(from April 2016 to August 2017)

(2° by 2° grids)

REF=CNES/CLS orbit

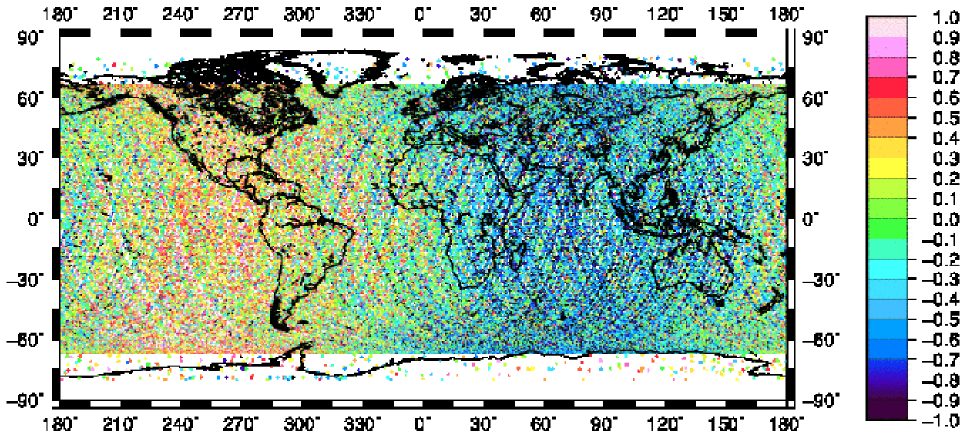
Sentinel-3A

GDR-E – REF (in cm)



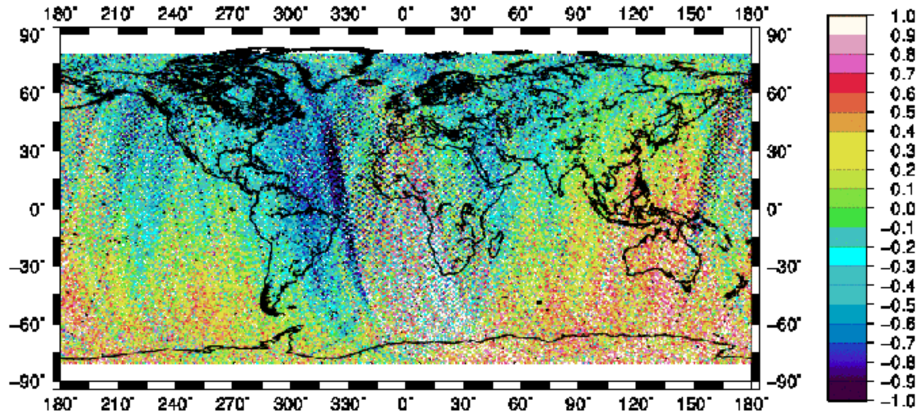
Jason-3

GDR-E – REF (in cm)



Sentinel-3A

ESOC – REF (in cm)



- *There is a good agreement between CNES/CLS orbits and CNES GDR-E and ESOC POE.*
- *An East/West patches for radial geographical systematic differences with CNES/GDR-E orbits.*

Outline

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  - **Processing strategy**
  - **DORIS RMS of fit and SLR external validation**
  - **Comparison to CNES (GDR-E) and ESOC orbits**

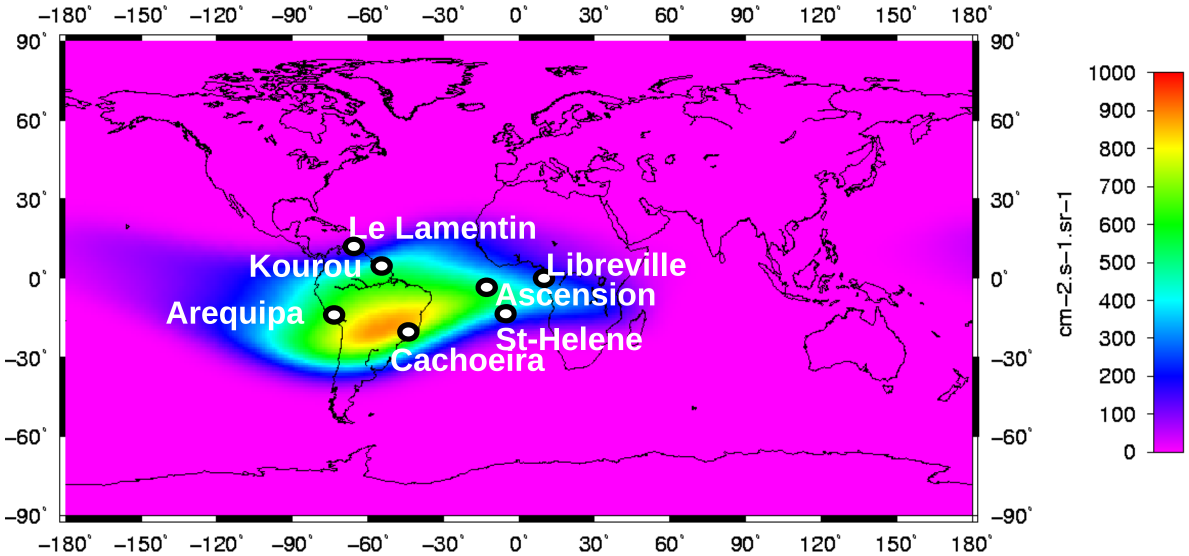
- ❑ **SAA impact on satellites**
  - **Impact on the orbit**
  - **Impact on the station position estimation**

- ❑ **Strategy to minimize the SAA effect**
  - **Impact on the orbit**
  - **Impact on the station position estimation**

- ❑ **Conclusions and perspectives**

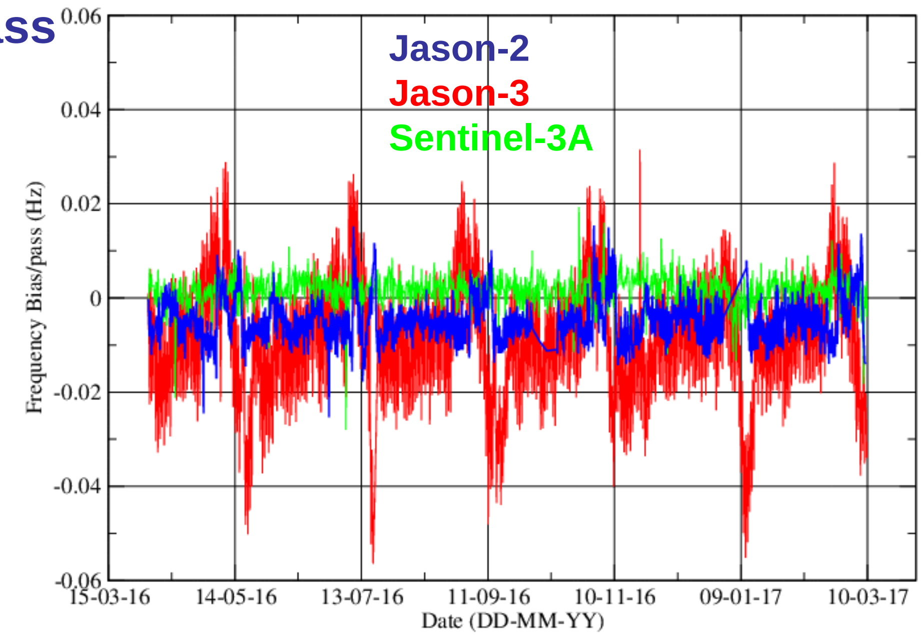
SAA impact on the orbit

❑ SAA area at the altitude of Jason-3



- ***SAA map from Jason-2 CARMEN data and the SAA stations***
  (>87 MeV integrated proton flux map (2009-2011 average))
- ***Stations in the heart of the SAA area:***
  Arequipa, Ascension, Cachoeira, Kourou, Le Lamentin, Libreville, Sainte-Helene

❑ Kourou Frequency bias adjusted per pass



(Measurement frequency offset)

- The Frequency bias of Kourou (master beacon) for Jason-3 is larger than those obtained for Jason-2 and Sentinel-3A.
- The DORIS residuals for Jason-3 (0.36 mm/s) are also larger than those obtained for Jason-2 (0.33 mm/s) certainly due to the SAA effect.

- *Jason-3 USO is more sensitive to the SAA than Jason-2: ~3 times stronger.*

SAA impact on the station position estimation

❑ Single satellite Solution compared to DPOD2014 (computed by CATREF)

As the Cryosat-2 USO is not affected by SAA, we use the Cryosat-2 single satellite solution as a reference

Differences between the Jason-2/Jason-3/Sentinel-3A and Cryosat-2 solutions in NEU

Mean of 72 weeks *(from April 2016 to August 2017)*

Station	Jason-2 (in cm)			Jason-3 (in cm)			Sentinel-3A (in cm)		
	North	East	Up	North	East	Up	North	East	Up
Cachoeira	4.4	4.5	**8.9**	**6.8**	2.6	**20.0**	0.3	-0.6	0.1
Arequipa	-1.6	4.2	**8.8**	-1.7	**10.8**	**20.1**	0.4	-0.7	1.9
Kourou	-2.0	-1.1	0.8	**-6.0**	1.3	3.5	0.8	1.3	0.4
Ascension	1.4	-3.9	**6.1**	2.1	-0.2	**14.8**	1.5	-0.5	-0.2
Saint Helene	**5.0**	-1.6	2.4	**9.5**	-3.2	**9.3**	0.3	-0.7	-1.5
Le Lamentin	-0.6	-0.2	-3.6	-1.8	-2.1	**-5.6**	1.2	0.4	-0.8
Libreville	-3.9	-0.4	2.9	**-6.1**	1.1	**8.3**	1.1	0.3	0.4
Yarragadee	*-1.1*	*-0.1*	*0.2*	*-0.2*	*0.9*	*-0.4*	*0.8*	*0.2*	*0.5*
Thule	*0.2*	*-0.6*	*-0.4*	*1.2*	*-0.7*	*-1.1*	*-0.4*	*0.9*	*-1.6*

- *Jason-3 USO is more sensitive to the SAA than Jason-2.*
- *The Jason-3 solution gives a bias in at least one of the NEU components for the SAA stations.*
- *The sensitivity of the Sentinel-3A USO is not strong enough to affect the station position estimation.*

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Strategy to minimize the SAA effect

❑ Strategy description

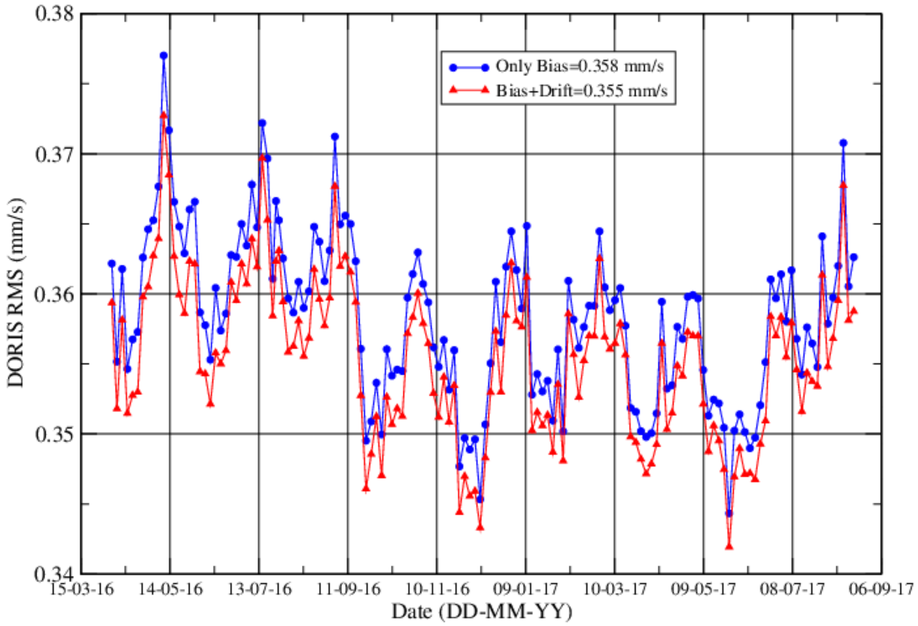
Estimation of the beacon frequency Bias**+Drift** on SAA station per pass

❑ Impact on the orbit

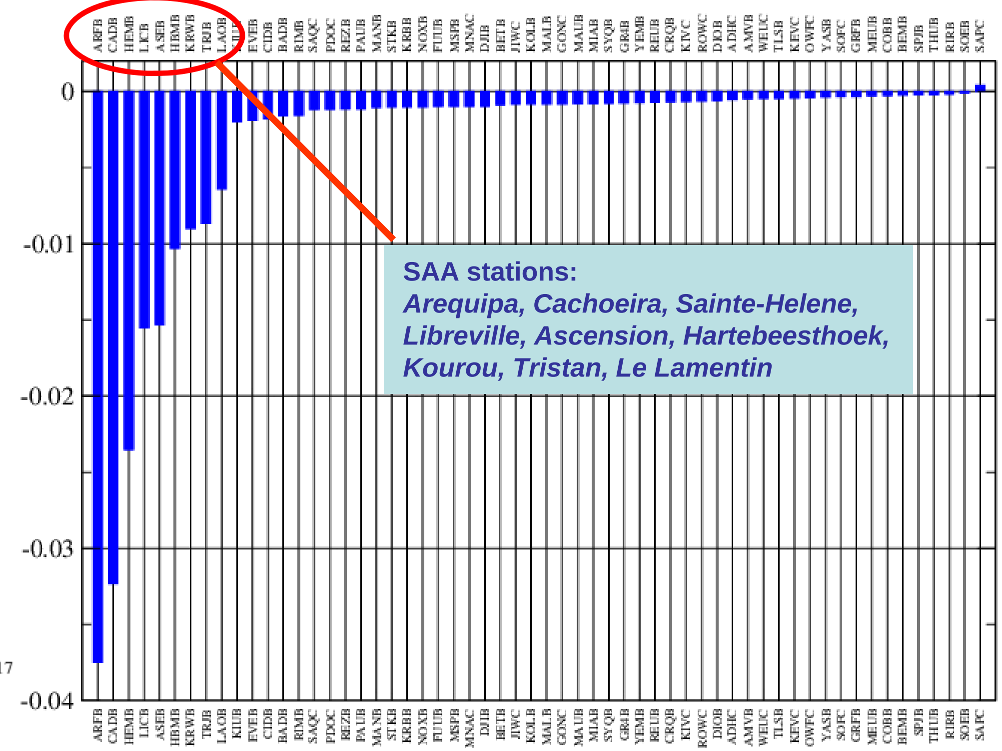
Classical processing: only a Frequency Bias adjusted per pass

With strategy: Frequency Bias**+Drift** adjusted per pass

DORIS RMS of fit



DORIS RMS of fit differences by station



- *The DORIS residuals are lower when we apply the strategy of adjusting a frequency drift per pass for SAA stations.*
- *The impact is significant for SAA stations and the number of measurements is higher.*

Strategy to minimize the SAA effect

❑ Impact on the station position estimation

Differences between the Jason-3 and Cryosat-2 solutions in NEU

Solution with strategy: Frequency Bias**+Drift** adjusted per pass

Mean of 72 weeks *(from April 2016 to August 2017)*

Station	Jason-3 (in cm) North	East	Up	Jason-3 with strategy (in cm) North	East	Up
Cachoeira	**6.8**	2.6	**20.0**	**5.8**	3.4	**5.6**
Arequipa	-1.7	**10.8**	**20.1**	-1.2	7.6	3.5
Kourou	**-6.0**	1.3	3.5	-4.6	0.8	0.7
Ascension	2.1	-0.2	**14.8**	-2.2	2.9	**5.5**
Saint Helene	**9.5**	-3.2	**9.3**	**9.5**	-3.6	1.9
Le Lamentin	-1.8	-2.1	**-5.6**	-1.9	-3.6	-0.6
Libreville	**-6.1**	1.1	**8.3**	**-5.3**	2.5	2.2
Yarragadee	*-0.2*	*0.9*	*-0.4*	*-1.8*	*0.2*	*0.1*
Thule	*1.2*	*-0.7*	*-1.1*	*0.3*	*-0.3*	*-1.9*

- *The strategy brings an improvement in the station position estimation for the SAA stations, especially for the vertical component.*

Strategy to minimize the SAA effect

❑ Impact on the station position estimation

Differences between the Jason-3 and Cryosat-2 solutions in NEU

Solution with strategy: Frequency Bias**+Drift** adjusted per pass

Mean of 72 weeks *(from April 2016 to August 2017)*

Station	Jason-3 (in cm)			Jason-3 with strategy (in cm)		
	North	East	Up	North	East	Up
Cachoeira	**6.8**	2.6	**20.0**	**5.8**	3.4	**5.6**
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Saint Helene	**9.5**	-3.2	**9.3**	**9.5**	-3.6	1.9
Le Lamentin	-1.8	-2.1	**-5.6**	-1.9	-3.6	-0.6
Libreville	**-6.1**	1.1	**8.3**	**-5.3**	2.5	2.2
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- *The strategy brings an improvement in the station position estimation for the SAA stations, especially for the vertical component.*

Strategy to minimize the SAA effect

❑ Impact on the station position estimation

Differences between the Jason-3 and Cryosat-2 solutions in NEU

Solution with strategy: Frequency Bias**+Drift** adjusted per pass

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Kourou	**-6.0**	1.3	3.5	-4.6	0.8	0.7
Ascension	2.1	-0.2	**14.8**	-2.2	2.9	**5.5**
Saint Helene	**9.5**	-3.2	**9.3**	**9.5**	-3.6	1.9
Le Lamentin	-1.8	-2.1	**-5.6**	-1.9	-3.6	-0.6
Libreville	**-6.1**	1.1	**8.3**	**-5.3**	2.5	2.2
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Thule	*1.2*	*-0.7*	*-1.1*	*0.3*	*-0.3*	*-1.9*

- *The strategy brings an improvement in the station position estimation for the SAA stations, especially for the vertical component.*

Conclusions and perspectives

❑Status of POD for Sentinel-3A and Jason-3 satellite

The Jason-3 and Sentinel-3A satellites were added in the DORIS processing chain of the CNES/CLS Analysis Center.
The POD results are of good quality but the DORIS RMS are still higher than the other DORIS satellites. For Jason-3, that could be explained by the SAA effect.
The orbit comparisons give good agreement with CNES GDR-E and ESOC orbits.

❑ Impact of the SAA effect

The Jason-3 USO is more sensitive to the SAA than Jason-2 and it is visible in the POD and in the the station position estimation.
The Jason-3 and Jason-2 solutions give a bias in at least one of the NEU components for the SAA stations (can be ~20 cm for Jason-3 et ~10 cm for Jason-2).
A data corrective model for Jason-3 could be useful for the station position estimation.
The sensitivity of the Sentinel-3A USO is not strong enough to affect the station position estimation.

❑ Strategy to minimize the SAA effect

The strategy brings an improvement in the POD and in the station position estimation for the SAA stations.