Impact of the South Atlantic Anomaly effect on the station position estimation of the last DORIS satellites

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POD modeling and processing context

Processing context

- **We analyzed RINEX data with 3.5-day arcs and a cut-off angle of 12°**

ITRF2014 configuration

Time span processing: 21 February to 24 September 2016

Satellites: Jason-2, Jason-3 and Sentinel-3A

DORIS data processing results

- **DORIS RMS residuals and independent SLR RMS residuals**
- **OPR Acceleration Amplitude:** Along-track and Cross-track / Radiation pressure coefficient

Mean of 30 weeks

SATELLITE	DORIS RMS (mm/s)	SLR RMS (cm)	OPR amplitude average (10^{-9} m/s^2)		Solar radiation coefficient
			Along-track	Cross-track	
Jason-2	0.34	2.6	2.5	2.2	0.97
Jason-3	0.36	2.5	1.4	2.9	0.99
Sentinel-3A	0.37	3.3	1.8	2.3	1.00

SAA impact on the orbit

DORIS RMS of fit (in mm/s) of SAA station from GRG processing

Mean of 30 weeks (from 21 February to 24 September 2016)

Station	Jason-2 DORIS RMS (in mm/s)	Jason-3 DORIS RMS (in mm/s)	Sentinel-3A DORIS RMS (in mm/s)	Cryosat-2 DORIS RMS (in mm/s)
All	**0.336**	**0.364**	**0.371**	**0.360**
Cachoeira	*0.376*	*0.450*	*0.476*	*0.425*
Arequipa	*0.319*	*0.408*	*0.388*	*0.325*
Kourou	*0.422*	*0.461*	*0.460*	*0.449*
Ascension	*0.374*	*0.429*	*0.414*	*0.390*
Saint Helene	*0.316*	*0.389*	*0.341*	*0.335*
Le Lamentin	*0.424*	*0.460*	*0.473*	*0.459*
Libreville	*0.331*	*0.380*	*0.364*	*0.361*
Yarragadee	0.291	0.319	0.323	0.312
Thule	0.257	0.289	0.310	0.299

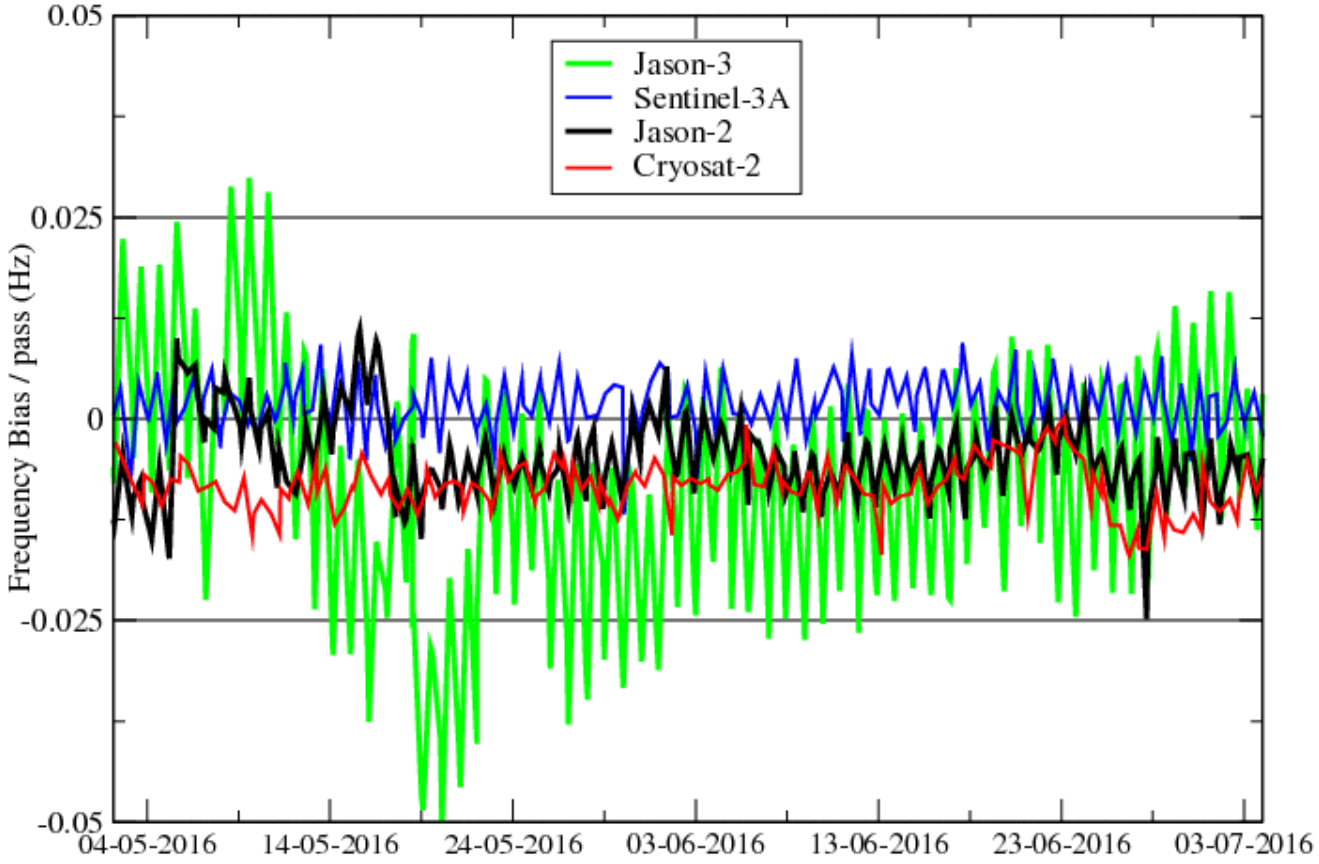
For Jason-3 all the RMS of the SAA stations are high, showing a sensitivity to the SAA.

SAA impact on the orbit

Parameters adjusted per pass in GRG processing

Kourou Frequency bias/pass

(measurement frequency offset)



If we compare to Jason-2 result, the sensitivity to SAA is ~3 times stronger for Jason-3

SAA impact on the orbit

Parameters adjusted per pass in GRG processing

ZTD bias/pass in cm

Mean of 30 weeks (from 21 February to 24 September 2016)

Station	Jason-2	Jason-3	Sentinel-3A	Cryosat-2
Cachoeira	20	27	17	18
Arequipa	11	17	8	9
Kourou	31	35	31	31
Ascension	23	28	20	21
Saint Helene	13	16	11	11
Le Lamentin	26	27	27	27
Libreville	34	36	33	33
Yarragadee	9	9	8	10
Thule	7	7	7	7

Compared to Jason-2 result, the sensitivity to SAA is stronger for Jason-3

SAA impact on the station position estimation

Single satellite Solution compared to DPOD2008 (computed by CATREF)
Differences between the Jason-2/Jason-3/Sentinel-3A and Cryosat-2 solutions in NEU
As the Cryosat-2 USO is not affected by SAA, we use the Cryosat-2 single satellite solution as a reference.
Mean of 30 weeks (from 21 February to 24 September 2016)

Station	Jason-2 (in cm)			Jason-3 (in cm)			Sentinel-3A (in cm)		
	North	East	Up	North	East	Up	North	East	Up
Cachoeira	3.9	4.5	8.2	7.2	3.2	21	1.4	-1.8	0.2
Arequipa	-1.6	4.2	8.5	-2.4	10.7	19.1	1.2	-1.1	1.4
Kourou	-2.4	-1.3	0.3	-6.8	0.6	4.0	0.8	1.1	0.1
Ascension	0.8	-6.0	5.6	1.7	-2.2	14.4	1.2	-0.6	-0.2
Saint Helene	5.1	-1.8	1.9	9.9	-6.5	9.7	0.2	-0.9	-2.2
Tristan	-2.3	0.2	-2.1	-2.9	-0.1	-5.3	-0.2	-2.0	1.3
Le Lamentin	-0.7	-0.4	-4.2	-2.8	-1.9	-6.2	1.2	0.3	-1.0
Libreville	-3.8	-1.1	2.7	-7.2	0.4	9.2	1.0	0.5	0.1
Yarragadee	*-1.5*	*-0.4*	*0.3*	*-1.4*	*0.4*	*-0.3*	*0.9*	*0.3*	*1.0*
Thule	*1.6*	*-0.5*	*-0.1*	*2.8*	*-1.1*	*-1.2*	*-0.2*	*1.2*	*-1.5*

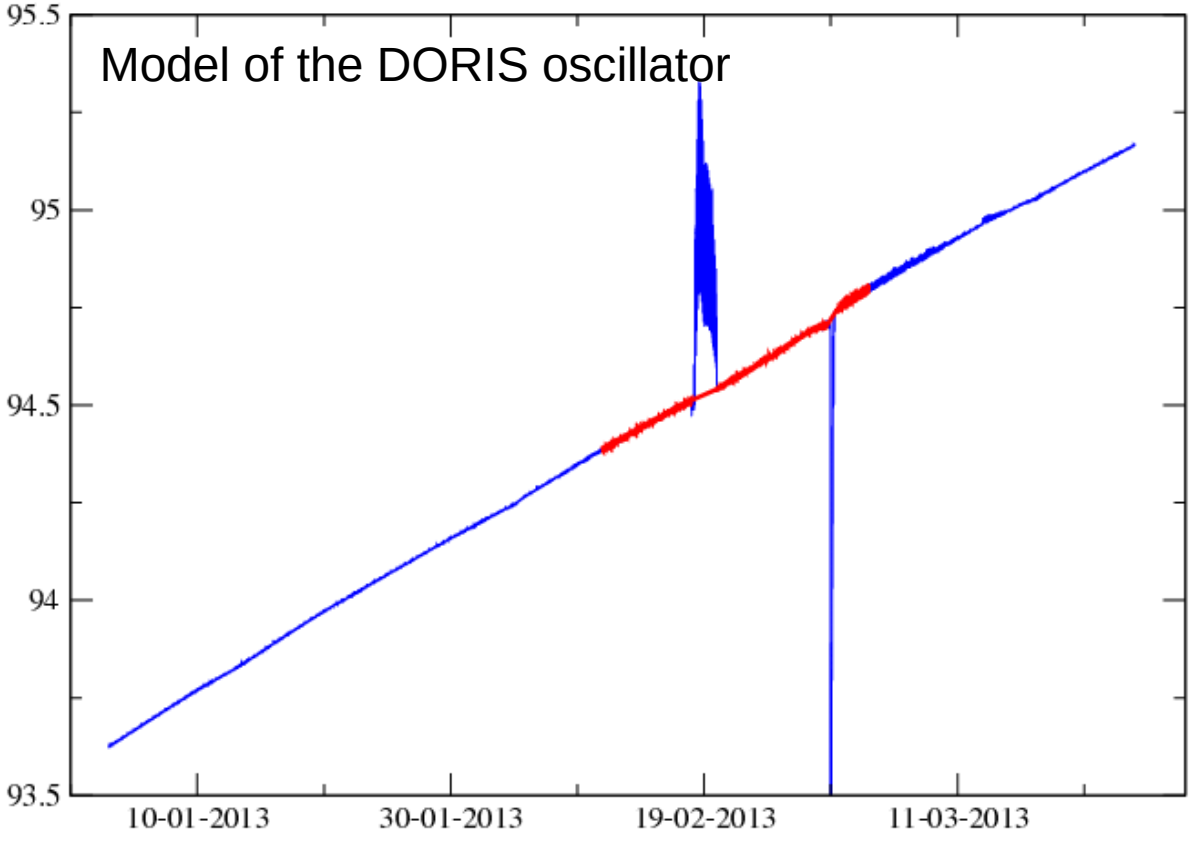
Jason-3 USO is more sensitive to the SAA than Jason-2. The Jason-3 solution gives a bias in at least one of the NEU components for the SAA stations
The sensitivity of the Sentinel-3A USO is not strong enough to affect the station position estimation.

Test of the SAA corrective model for Jason-2 DORIS data

Processing context

We corrected the DORIS data (doris2.2 format) with the corrective model for Jason-2 developed by A. Belli and P. Exertier available at: http://www.geoazur.fr/t2l2/en/data/v4/

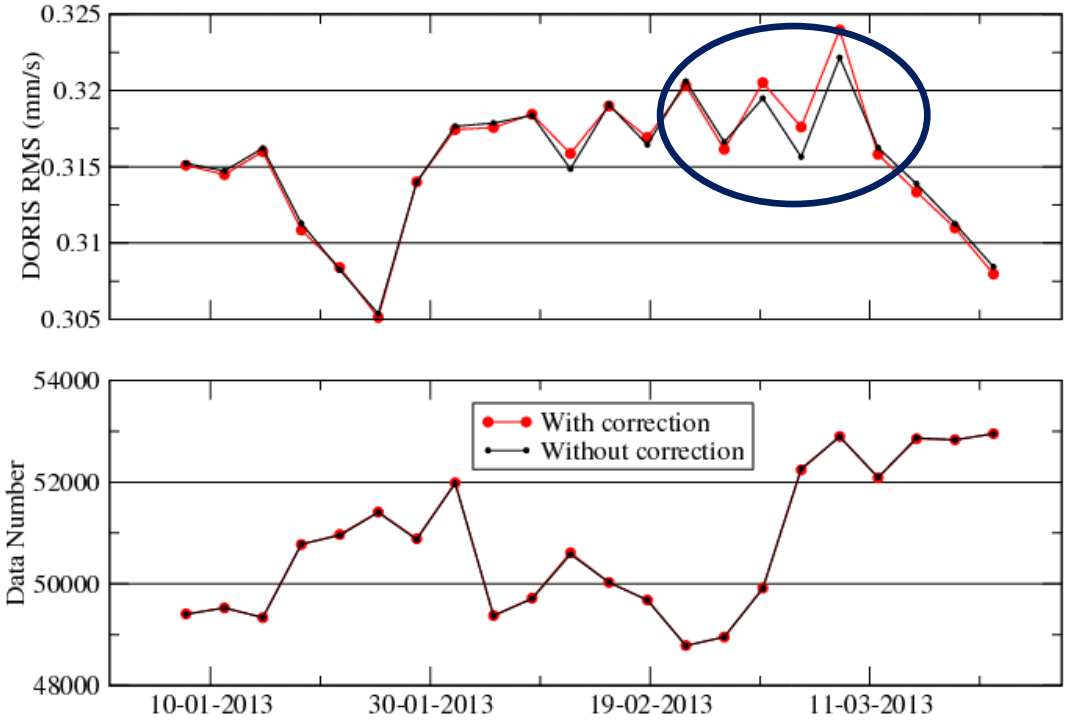
Time span processing: 6 January to 23 March 2013 (10 weeks)



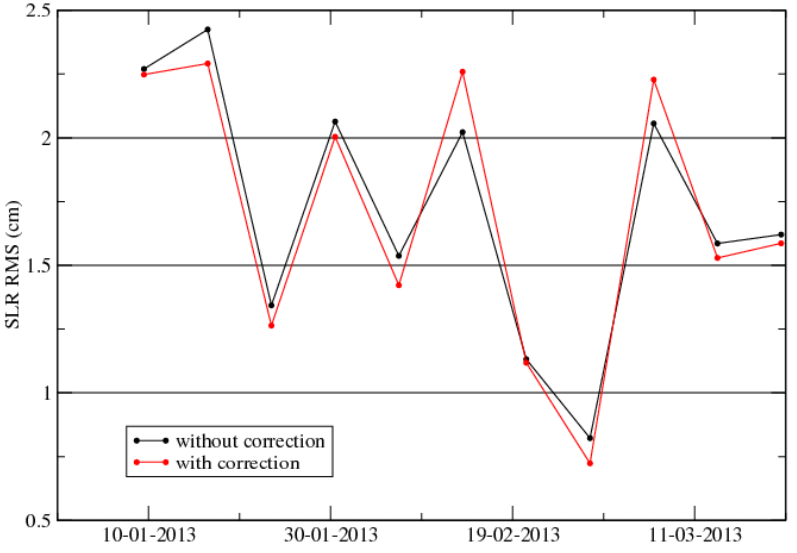
Test of the SAA corrective model for Jason-2 DORIS data

Impact on the orbit

DORIS RMS residuals and measurements number



DORIS-only orbit independent SLR RMS residuals



SLR Core Network, high elevations

DORIS and SLR residuals are slightly reduced by the use of the model but not systematically
No orbit differences significantly

Test of the SAA corrective model for Jason-2 DORIS data

Impact on the station position estimation
Single satellite Solution compared to DPOD2008 (computed by CATREF)
Differences between the Jason-2/Jason-2 corrected and Cryosat-2 solutions in NEU
As the Cryosat-2 USO is not affected by SAA, we use the Cryosat-2 single satellite solution as a reference.

Mean of 10 weeks (from 6 January to 23 March 2013)

Station	Jason-2 (in cm)			Jason-2 corrected (in cm)		
	North	East	Up	North	East	Up
Cachoeira	4.2	3.6	5.3	3.2	3.5	3.4
Arequipa	-1.8	1.9	6.8	-1.1	1.2	3.2
Santiago	8.2	-0.2	1.8	6.8	-0.8	1.0
Ascension	-0.2	-1.4	4.4	-0.1	-0.9	2.6
Saint Helene	4.2	0.5	1.3	3.3	0.5	0.2
Yarragadee	*1.2*	*-0.3*	*1.2*	*0.4*	*-0.2*	*0.2*
Thule	*-0.9*	*-0.8*	*-2.0*	*-0.8*	*-0.4*	*-1.6*

The use of the corrective model improves slightly the single satellite station position estimation

Strategy to minimize the SAA impact on the positioning

Strategy to add single satellite solution affected by the SAA in the multi-satellite solution
For Jason-1, we have developed a strategy to add the Jason-1 solution to the multi-satellite solution.
Before combining Jason-1 solution to the others single satellite solutions, we rename the SAA stations (and all their adjusted parameters). Thus, these SAA stations from Jason-1 do not contribute to the realization of the combined solution.

Multi-satellite Solution compared to DPOD2008
We computed weekly multi-satellite solutions from 21 February to 24 September 2016 (30 weeks).
Comparisons of these weekly solutions to DPOD2008 are performed with the CATREF package.

We provided 3 solutions:
•Solution of reference: combination of **Cryosat-2+HY-2A+Saral+Sentinel-3A**
- Solutions with satellites (Jason-2 and Jason-3) impacted by the SAA:
•Solution 1: combination of **Cryosat-2+HY-2A+Saral+Sentinel-3A+Jason-2+Jason-3**
•Solution 2: combination of **Cryosat-2+HY-2A+Saral+Sentinel-3A+Jason-2+Jason-3** with strategy applied

Strategy to minimize the SAA impact on the positioning

Impact on the station position estimation

Differences between the solutions with Jason-2&Jason-3 and the solution of reference in NEU

Mean of 30 weeks (from 21 February to 24 September 2016)

- *Solution of reference:* ***Cryosat-2+HY-2A+Saral+Sentinel-3A***
- *Solution 1:* ***Cryosat-2+HY-2A+Saral+Sentinel-3A+Jason-2+Jason-3***
- *Solution 2:* ***Cryosat-2+HY-2A+Saral+Sentinel-3A+Jason-2+Jason-3*** *with strategy applied*

Station	Solution 1 (in cm)			Solution 2 (in cm)		
	North	East	Up	North	East	Up
Cachoeira	4.0	-0.6	4.0	0.7	-1.0	0.8
Arequipa	-0.5	2.5	4.4	-0.1	0.7	0.9
Kourou	1.0	-0.1	0.6	-0.2	0.1	-0.2
Ascension	0.1	-1.5	3.8	0.1	-0.1	0.9
Saint Helene	2.1	-1.4	2.3	0.4	-0.2	0.7
Tristan	-0.3	0.9	-1.0	0.0	0.4	-0.1
Le Lamentin	-0.5	-0.4	-1.6	-0.1	-0.1	-0.3
Libreville	1.8	-0.3	1.8	-0.2	0.1	0.8
Yarragadee	*-0.2*	*-0.1*	*-0.2*	*-0.3*	*-0.2*	*-0.1*

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

CONCLUSIONS AND PESPECTIVES

The Jason-3 and Sentinel-3A satellites were added in the DORIS processing chain of the CNES/CLS Analysis Center.

❑ **Impact of the SAA effect**

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 Jason-3 USO is more sensitive to the SAA than Jason-2.
The SAA effect can be neglected for the POD but for the station position estimation it must be taken into account.
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.

❑ **Test of the SAA corrective model for Jason-2 DORIS data**

DORIS and SLR residuals are slightly reduced by the use of the model but not systematically
The use of the corrective model improves slightly the single satellite station position estimation

❑ **Strategy to minimize the SAA impact on the positioning**

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