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

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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: 30 weeks (from February 21 to September 24, 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 over 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 over 30 weeks (from February 21 to September 24, 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

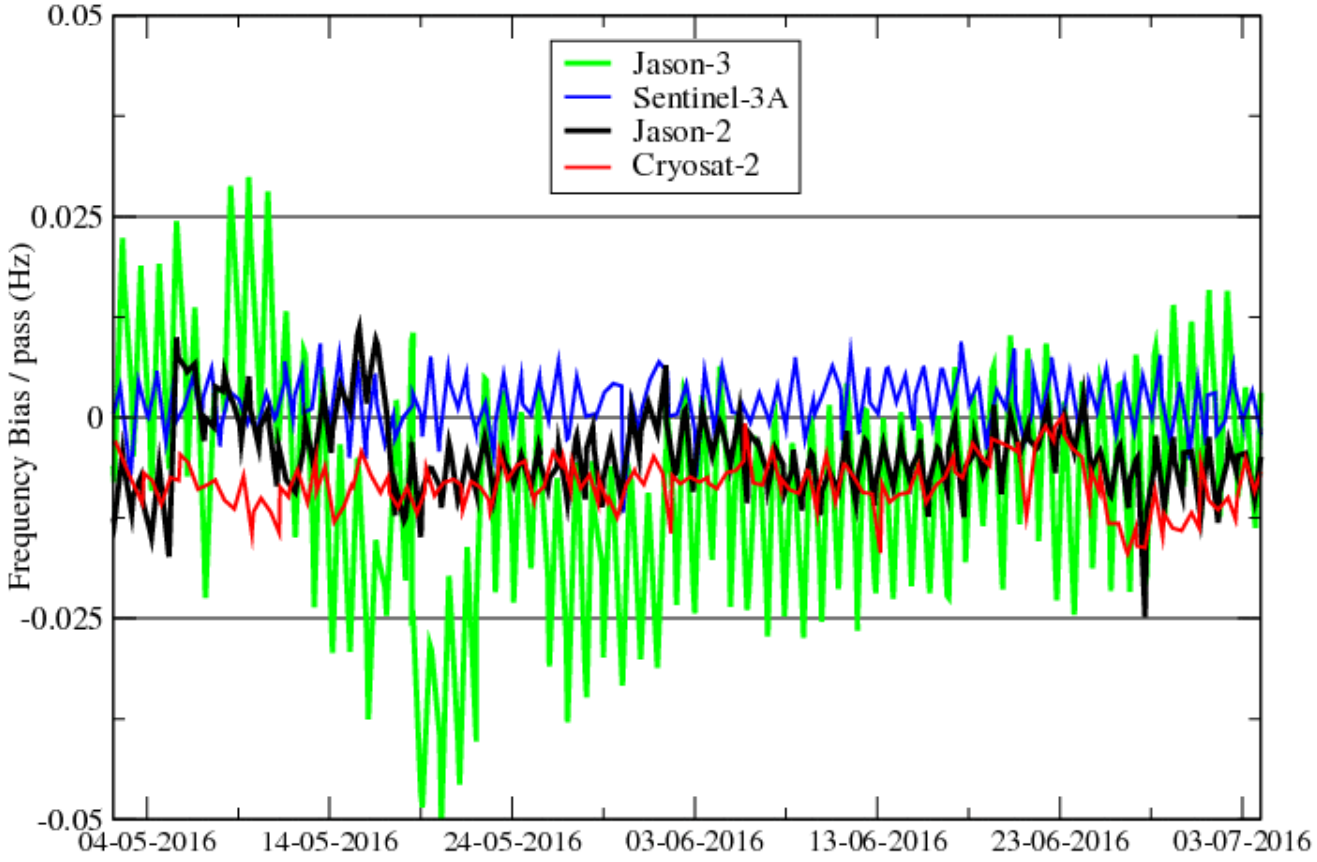
For Jason-3, all the RMS of the SAA stations are higher, showing a sensitivity to the SAA.

SAA impact on the orbit

Parameters adjusted per pass in GRG processing

Kourou Frequency bias/pass

(measurement frequency offset)



Compared to Jason-2, Jason-3 is ~3 times more sensitive to SAA.

SAA impact on the orbit

Parameters adjusted per pass in GRG processing
ZTD bias/pass in cm
Mean over 30 weeks (from February 21 to September 24, 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, Jason-3 is ~3 times more sensitive to SAA.

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 over 30 weeks (from February 21 to September 24, 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*

Compared to Jason-2, the Jason-3 USO is more sensitive to the SAA.

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.

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, the method we implemented, tested and adopted for ITRF2014 is:
before combining Jason-1 solution to the other single satellite solutions, we rename the SAA stations (and all their adjusted parameters) so 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 February to 24 September 24 2016 (30 weeks).
Comparisons of these weekly solutions to DPOD2008 are performed with the CATREF package.

We provided 3 solutions:
- Solution of reference (Ref): **Cryosat-2 + HY-2A + Saral + Sentinel-3A**
- Solution 1: **Ref + Jason-2 + Jason-3**
- Solution 2: **Ref +Jason-2 SMS + Jason-3 SMS (SMS = SAA Mitigation Strategy)**

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

- Solution 1: **Ref + Jason-2 + Jason-3**
- Solution 2: **Ref +Jason-2 SMS + Jason-3 SMS (SMS = SAA Mitigation Strategy)**

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

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

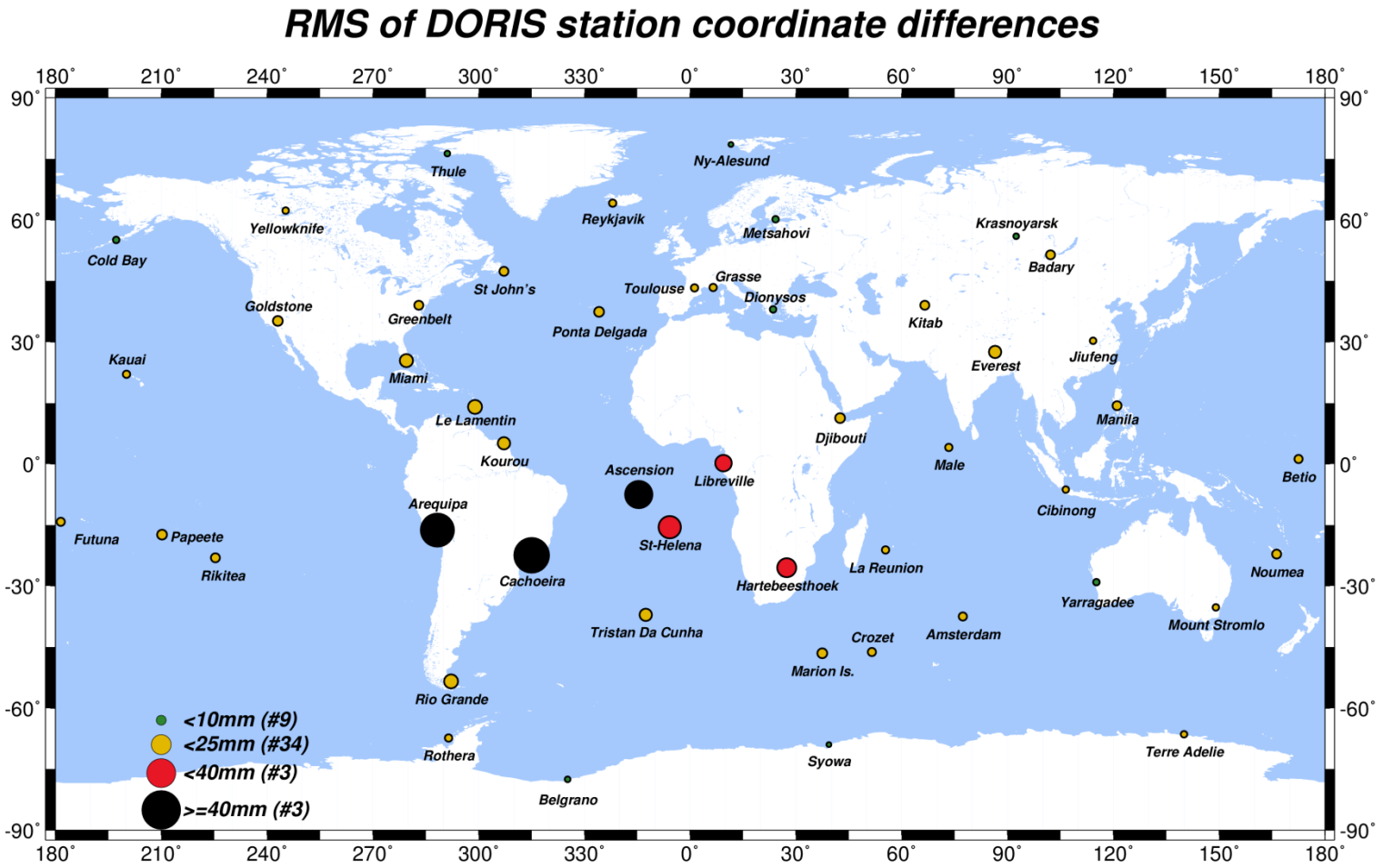
Strategy to minimize the SAA impact on the positioning

Impact on the station position estimation

Differences between the solutions 1 (with Jason-2&Jason-3) and the solution of reference

Solution 1: **Ref + Jason-2 + Jason-3**

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



The Jason-2 & Jason-3 solutions damage the station position estimation for the SAA stations

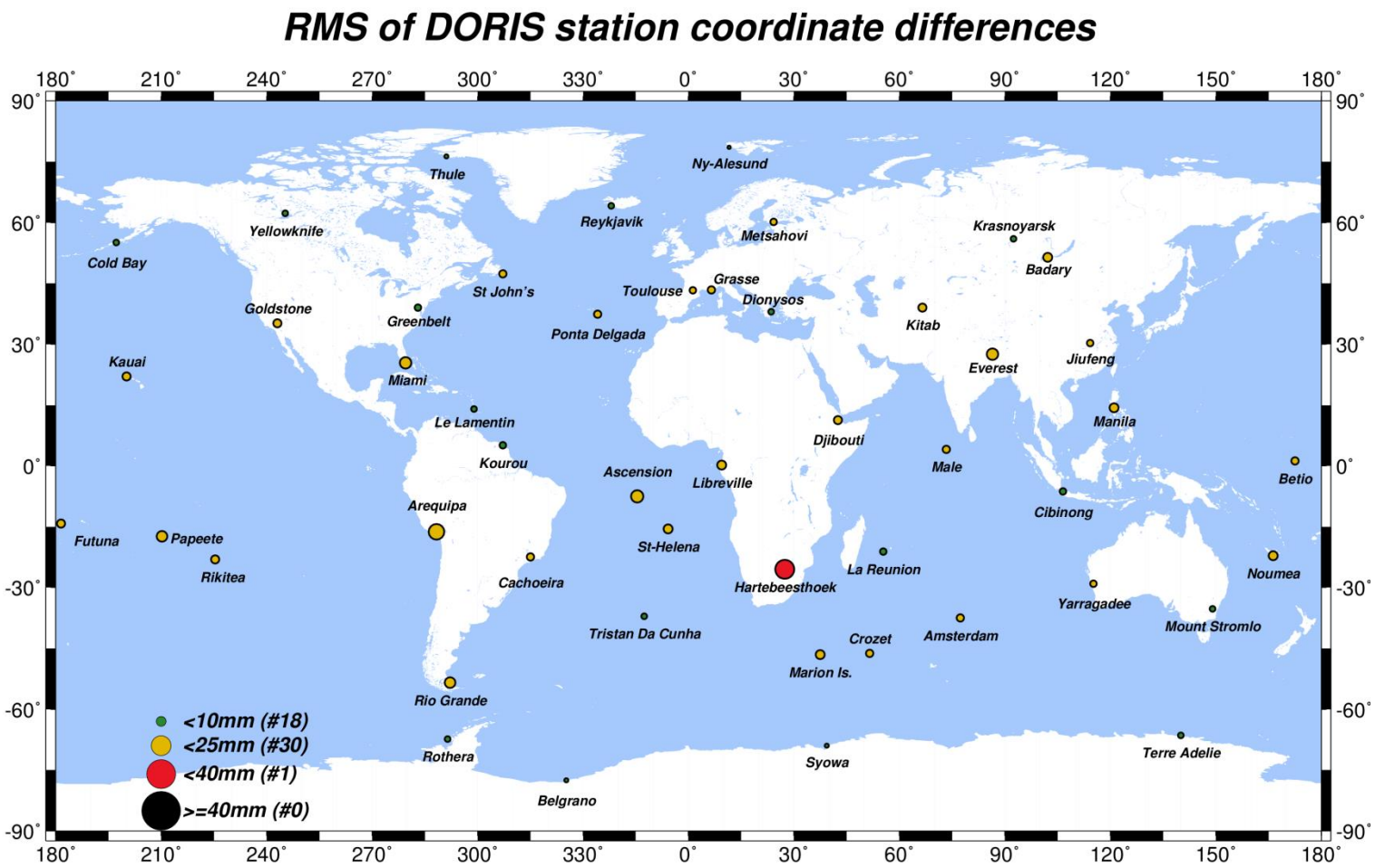
Strategy to minimize the SAA impact on the positioning

Impact on the station position estimation

Differences between the solutions 2 (with Jason-2&Jason-3) and the solution of reference

Solution 2: **Ref +Jason-2 SMS + Jason-3 SMS (SMS = SAA Mitigation Strategy)**

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



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

CONCLUSIONS AND PESPECTIVES

❑ Impact of the SAA effect

- *In overall, the POD results are of good quality.*
- *Jason-2 and Jason-3 exhibit higher DORIS RMS for the DORIS stations in the SAA region.*

- *Compared to Jason-2, the Jason-3 USO is more sensitive to the SAA.*

- *The SAA effect can be neglected for the POD but not for the station positioning.*
- *Without any correction, Jason-3 and Jason-2 induce coordinate differences larger than 10 cm.*
- *A data corrective model for Jason-3 could be useful for the station positioning.*

- *The sensitivity of the Sentinel-3A USO is not strong enough to affect the station positioning.*

❑ Strategy to minimize the SAA impact on the positioning

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

IDS developed tools to both identify and mitigate the impact of the SAA on the positioning. But, there are still rooms of improvement.

Strategy to minimize the SAA impact on the positioning

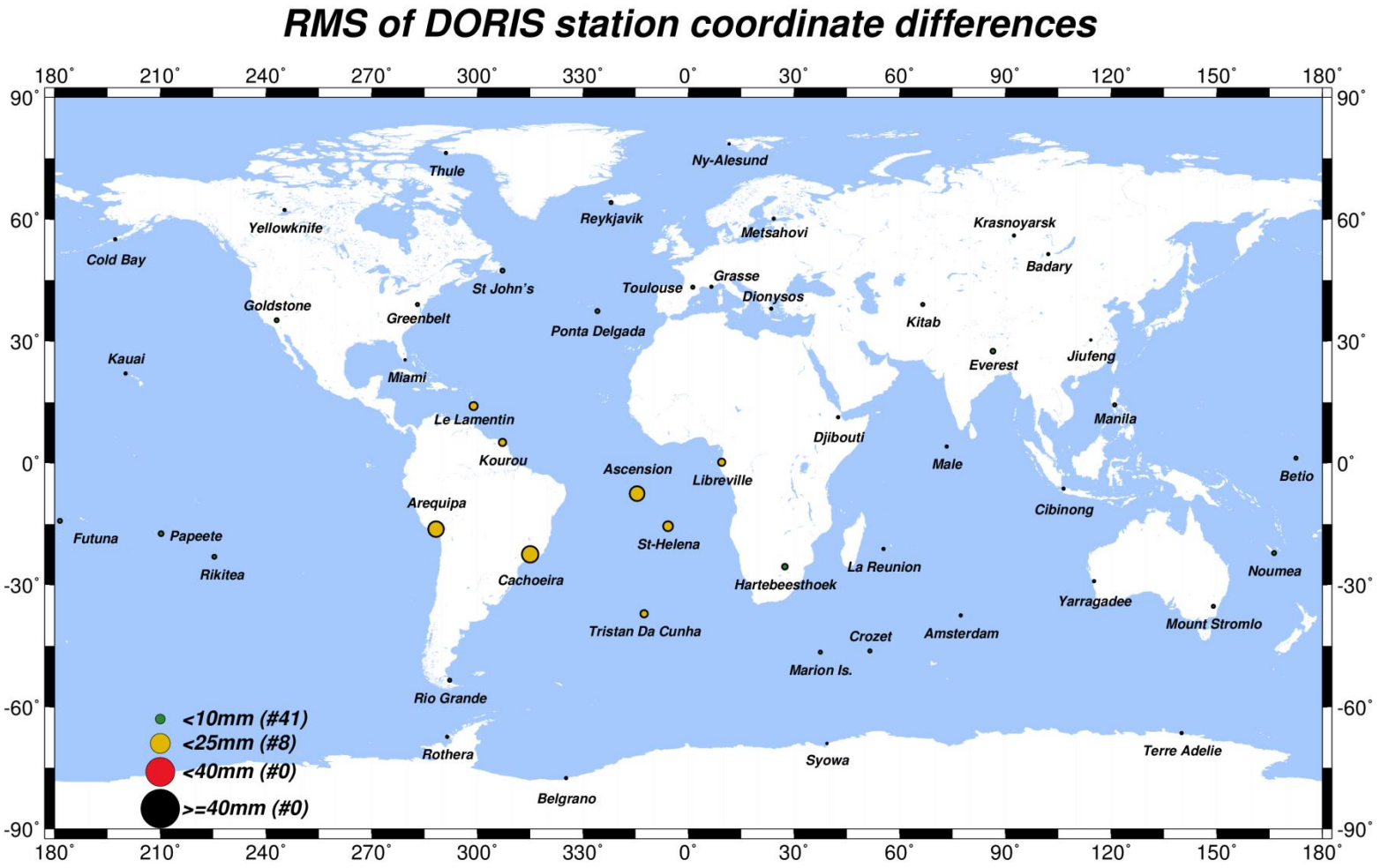
Impact on the station position estimation (+Jason-2)

Differences between the solutions 1 and 2

- Solution 1: **Ref + Jason-2**
- Solution 2: **Ref + Jason-2 SMS (SMS = SAA Mitigation Strategy)**

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

Backup



Strategy to minimize the SAA impact on the positioning

Impact on the station position estimation (+Jason-3)

Differences between the solutions 1 and 2

- Solution 1: **Ref + Jason-3**
- Solution 2: **Ref + Jason-3 SMS (SMS = SAA Mitigation Strategy)**

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

Backup