IDS WORKSHOP 2022
October 31 - November 2, 2022

Analyzes of the CNES/CLS IDS Analysis Center solutions for the contribution to the ITRF2020 and beyond

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Status of CNES/CLS IDS Analysis Center

❑ Contribution to the realization of the ITRF2020

Available DORIS data have been processed from 1993/01 to 2020/12 with GINS/DYNAMO software taking into account IERS conventions and IDS recommendations for ITRF2020

ITRF2020= ITRF2014 + new missions (Jason-3, Sentinel-3A, Sentinel-3B)

❑ Status of the routine DORIS data processing

We processed DORIS data until end July 2022 (Serie grgwd42**,** ITRF2020 configuration)

We provided Sentinel3-A&B and Sentinel-6MF orbits to CPOD QWG until end September 2022

Latest additions:

- Introduction of Sentinel-6MF in the GRG DORIS processing and in the multi-satellite solution
    - Macromodel available at: https://ids-doris.org/documents/BC/satellites/DORISSatelliteModels.pdf
    - Attitude: Quaternions
    - Radiation pressure coefficient strongly constrained to 1.05
- Introduction of the DORIS data from HY-2C and HY-2D satellites in our processing chain
    - Macromodel available at: https://ids-doris.org/documents/BC/satellites/DORISSatelliteModels.pdf
    - Attitude: nominal attitude law implemented

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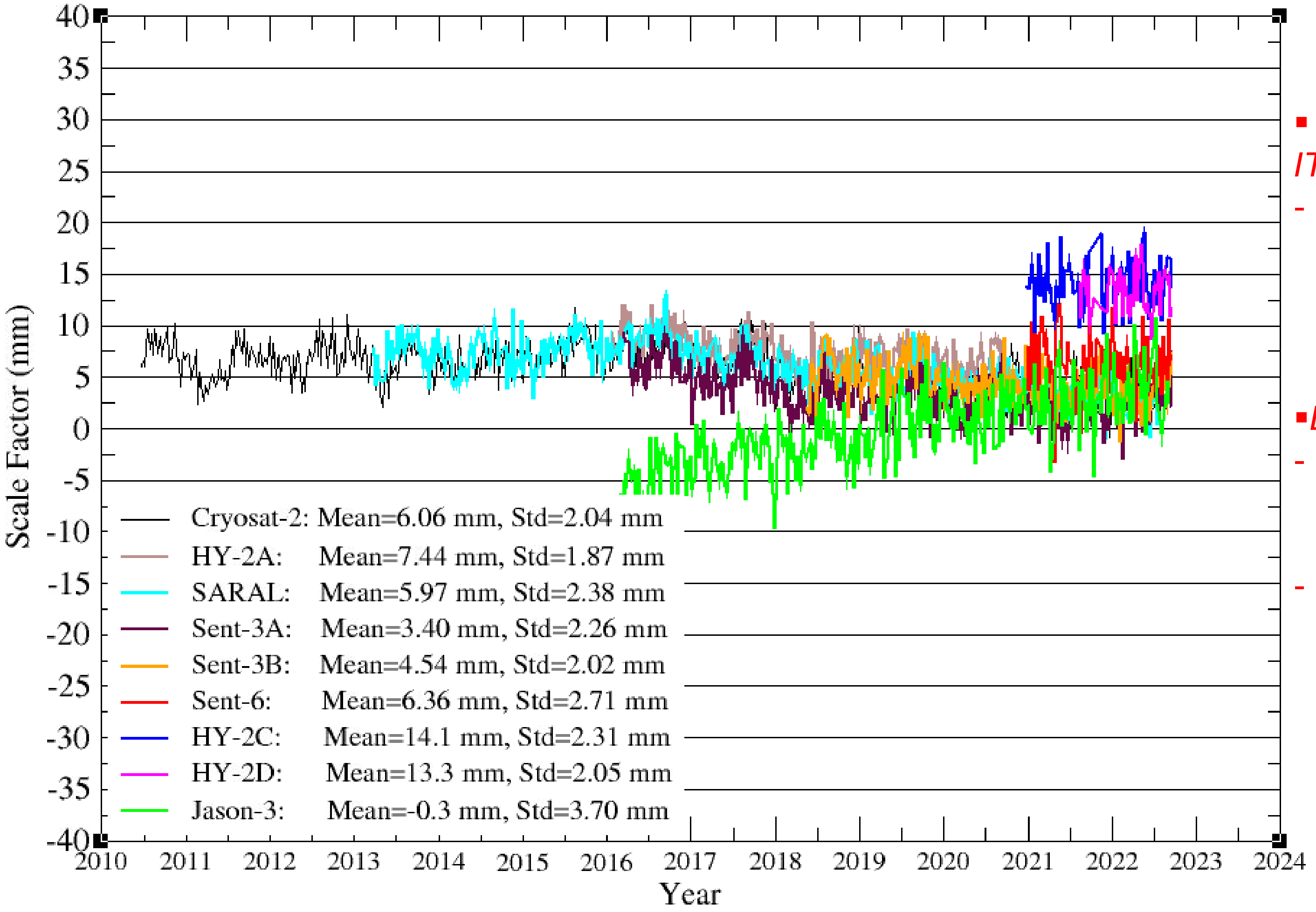
Origin and scale from single satellite solutions

❑ Comparison of each solution to DPOD2014_057 (computed by CATREF)

SATELLITE	Inclination (degree)	Altitude (km)
Cryosat-2	92	717
HY-2A	99.4	963
Saral	98.65	800
Jason-3	66.04	1336
Sentinel-3A	98.65	814
Sentinel-3B	98.65	814
Sentinel-6	66.04	1336
HY-2C	66	957
HY-2D	66	957

Scale Factor from single satellite solutions



- *Active missions contributing to ITRF2020:*
  - *Jason-3 scale: increases since the start of the mission and less since 2020.*
- *Latest satellites added:*
  - *Sentinel-6 scale is at the same level as the other satellites*
  - *HY-2C and HY-2D scales are higher.*

Origin and scale from single satellite solutions

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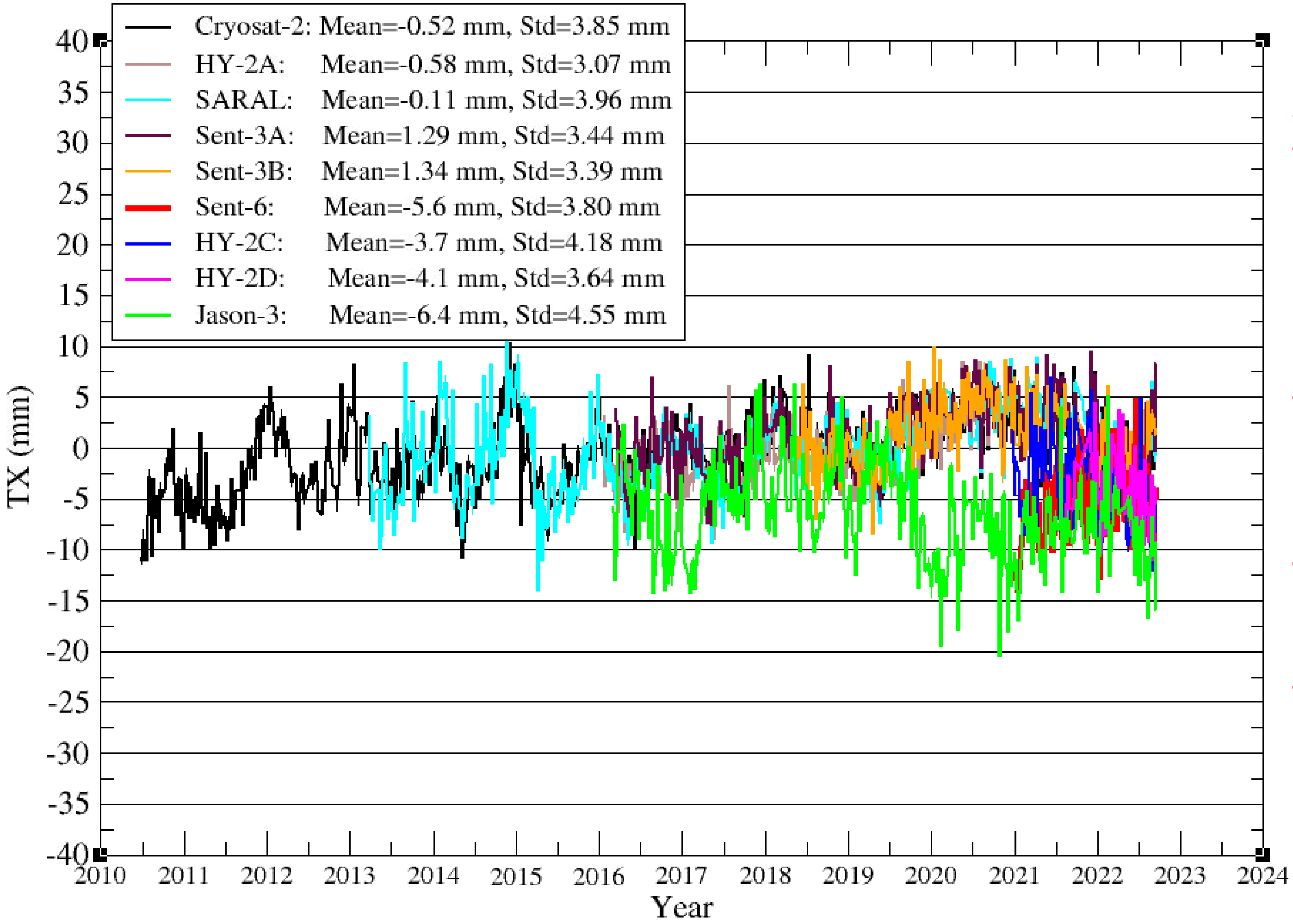
TX from single satellite solutions



- *Active missions contributing to ITRF2020:*
  - *Jason-3 TX has a behavior different compared to other satellites (different inclination).*

- *Latest satellites added:*
  - *The TX for Sentinel-6 is very close to that of Jason-3. They have the same altitude and inclination.*
  - *The TX for HY-2C and HY-2D is between that of Jason-3 and the other satellites.*
  - *They have the same inclination as Jason-3 but an altitude close to the other satellites.*

Origin and scale from single satellite solutions

❑ Comparison of each solution to DPOD2014_057 (computed by CATREF)

SATELLITE	Inclination (degree)	Altitude (km)
Cryosat-2	92	717
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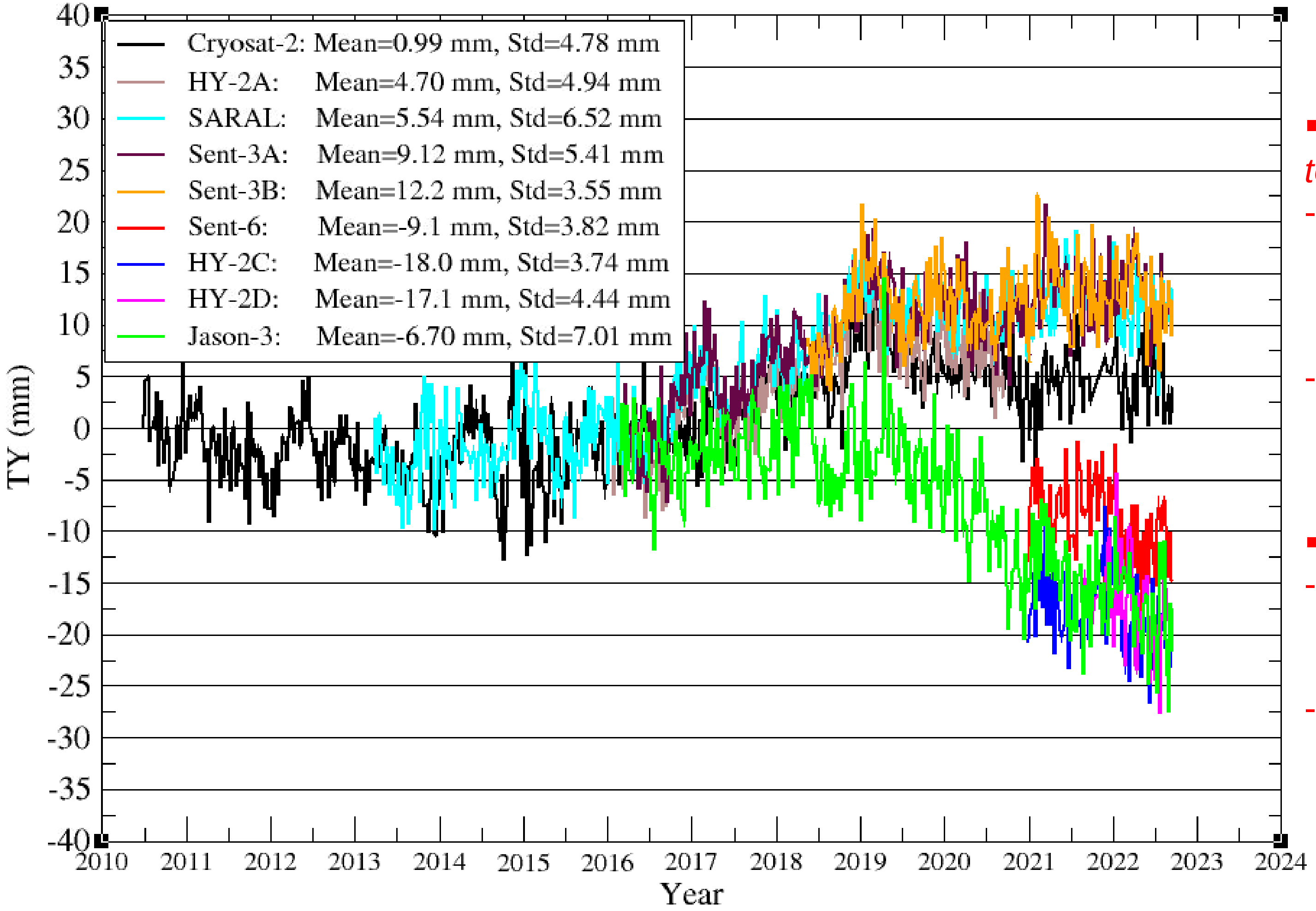
TY from single satellite solutions



- *Active missions contributing to ITRF2020:*
  - *Jason-3 TY has a behavior different compared to other satellites (different inclination and altitude).*
  - *Cryosat-2 is slightly lower from mid-2019 (inclination of 92°).*
- *Latest satellites added:*
  - *The TY for Sentinel-6A, HY-2C and HY-2D are close to that of Jason-3.*
  - *They have the same inclination, ~66°.*

Origin and scale from single satellite solutions

❑ **Comparison of each solution to DPOD2014_057 (computed by CATREF)**

SATELLITE	Inclination (degree)	Altitude (km)
Cryosat-2	92	717
HY-2A	99.4	963
Saral	98.65	800
Jason-3	66.04	1336
Sentinel-3A	98.65	814
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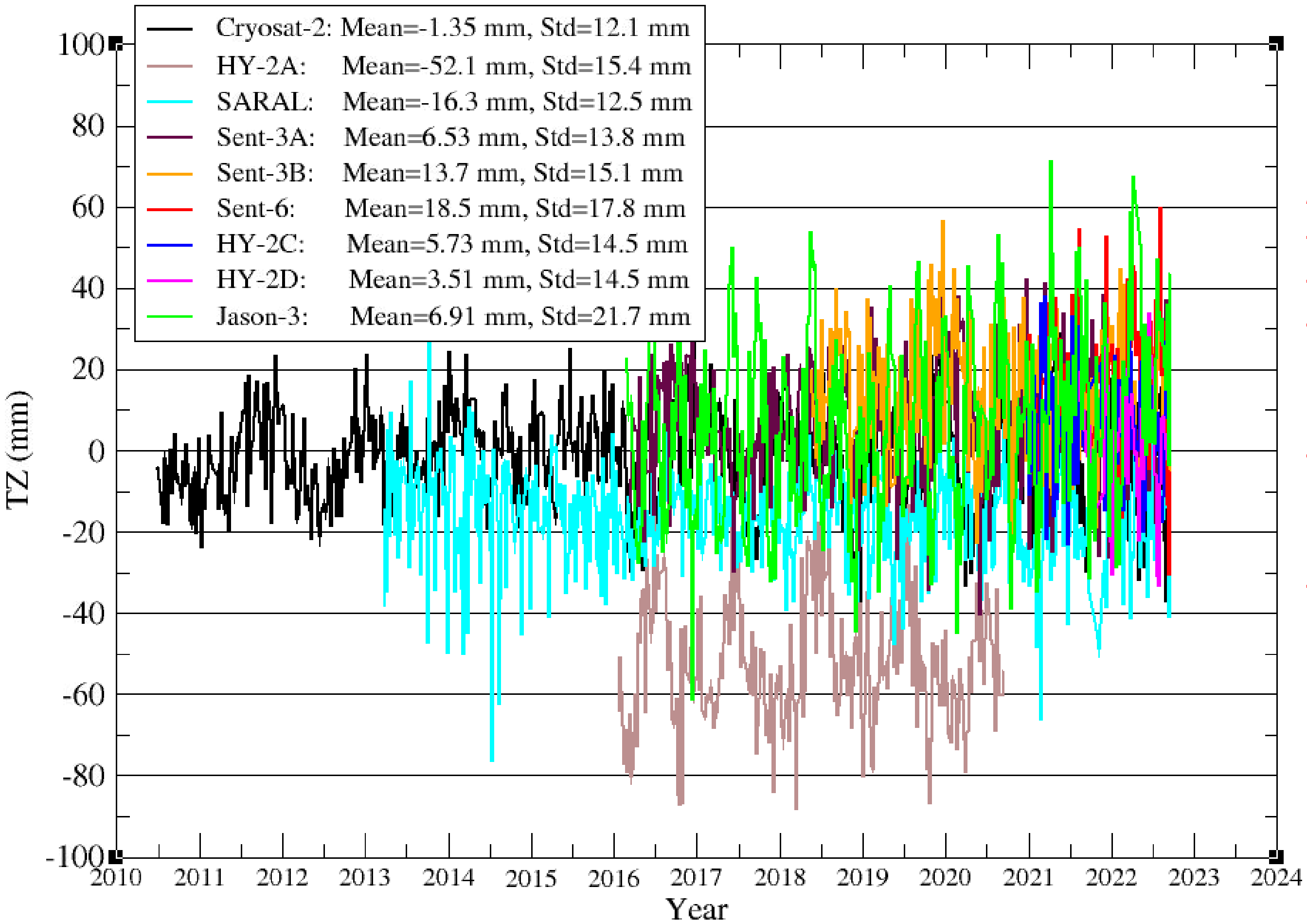
TZ from single satellite solutions



- *Active missions contributing to ITRF2020:*
  - *HY-2A has a bias.*
  - *Saral also but lower.*
  - *118 days signature for Jason-3.*
- *Latest satellites added:*
  - *TZ for Sentinel-6A, HY-2C and HY-2D is similar to other satellites.*
  - *As for Jason-3, 118 days signature for Sentinel-6.*

Origin and scale from single satellite solutions

Conclusions and future work

- **Scale factor:**

  Jason-3 drift to be understood, SAA effect?

  HY-2C and HY-2D scale higher: offset in Z direction of DORIS CoP?

- **Translation TX:**

  Jason-3 and Sentinel-6 have a behavior different compared to other satellites. They have the same inclination and altitude.

  The TX for HY-2C and HY-2D is between that of Jason-3 and the other satellites. They have the same inclination as Jason-3 but an altitude close to the other satellites.

- **Translation TY:**

  Two big families with respect to the inclination:

  66° inclination: Jason-3, Sentinel-6, HY-2C and HY-2D

  Polar inclination (~99°): other satellites except Cryosat-2 (92°)

- **Translation TZ:**

  HY-2A Bias: offset in normal direction of DORIS CoP ? use GPS to verify

  test macromodel from GSFC

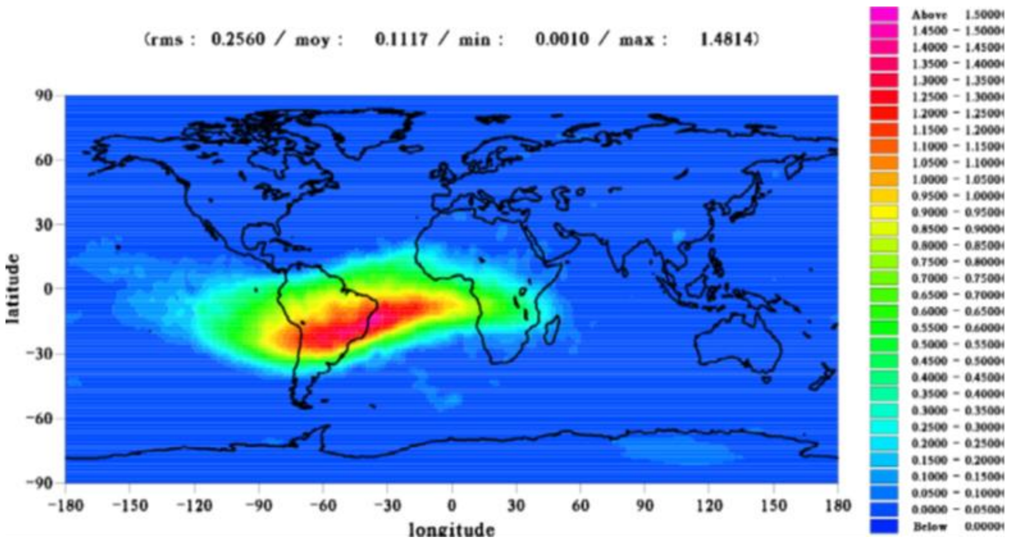
  Saral Bias to be understood

- **Continue to analyze Origin and Scale factor from single satellite solutions**

Impact of the South Atlantic Anomaly effect on the orbit and station position estimation

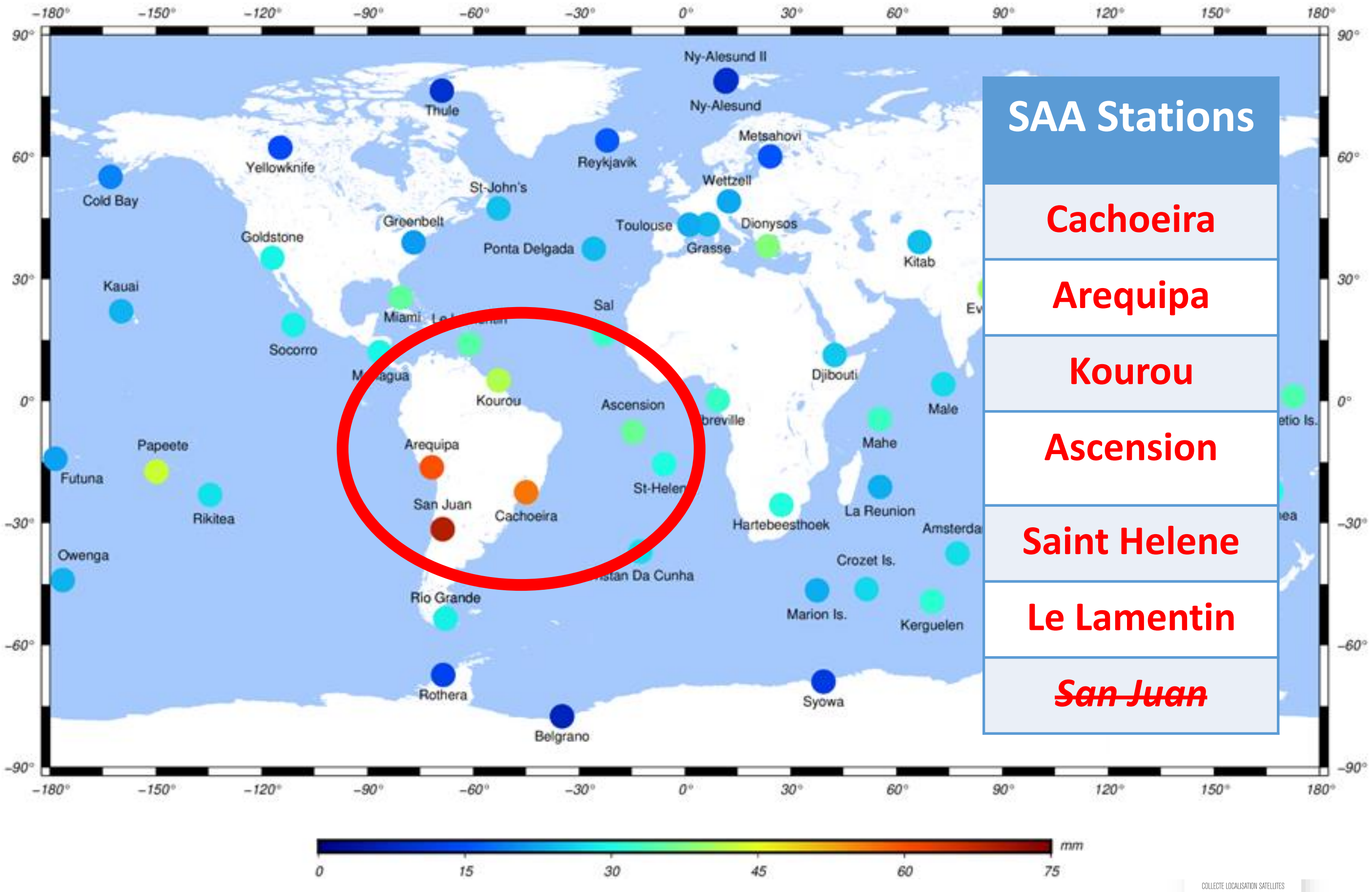
❑ South Atlantic Anomaly (SAA)

- **Plot of the DORIS derived relative dose exposure in 2002–2005 at 1300 km altitude (dimensionless units).**



- **Van Allen Belts – trapped high energy protons and electrons.**
- **Earth magnetic filed is asymmetric w.r.t. Earth surface.**
- **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 flux of energetic particles in this region can disrupt the crystal quartz oscillators that are the heart of the DORIS system, causing both short-term and long-term changes in frequency behavior.**

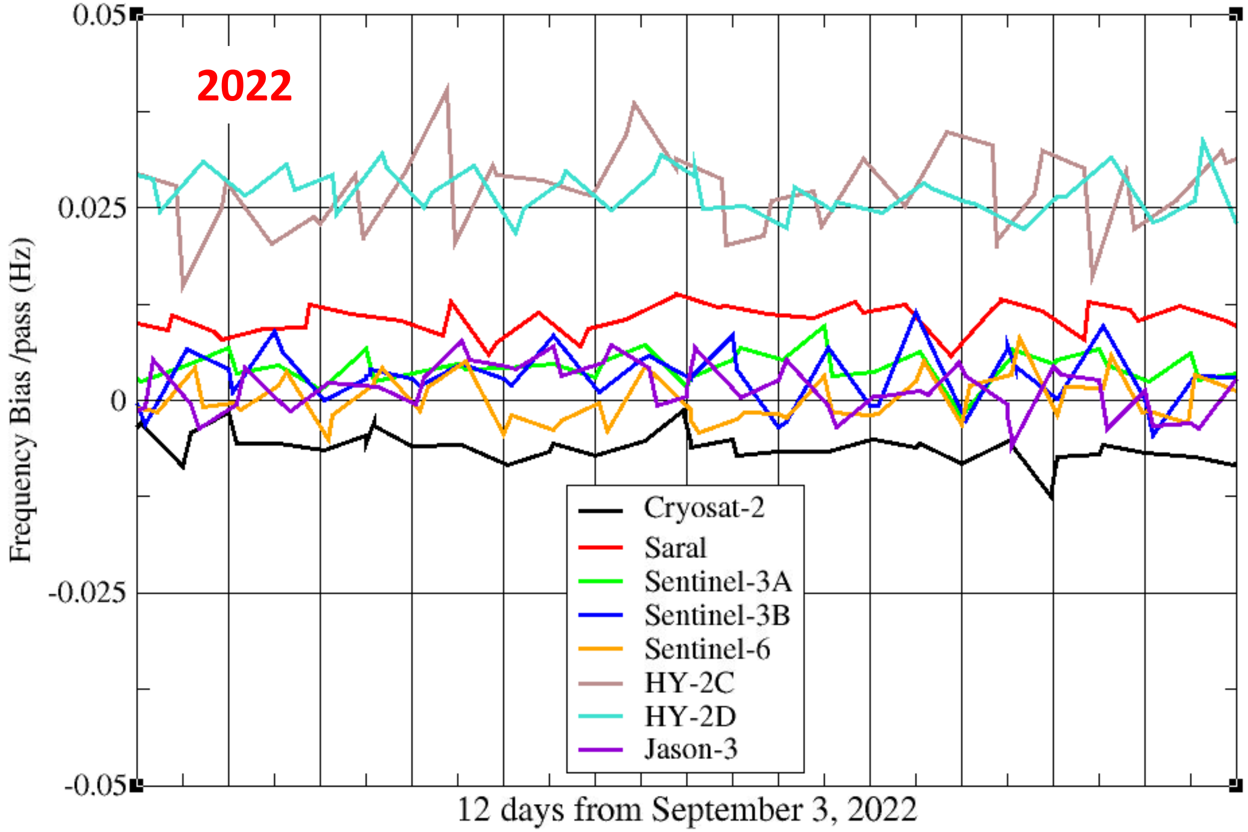
- **SAA Stations**

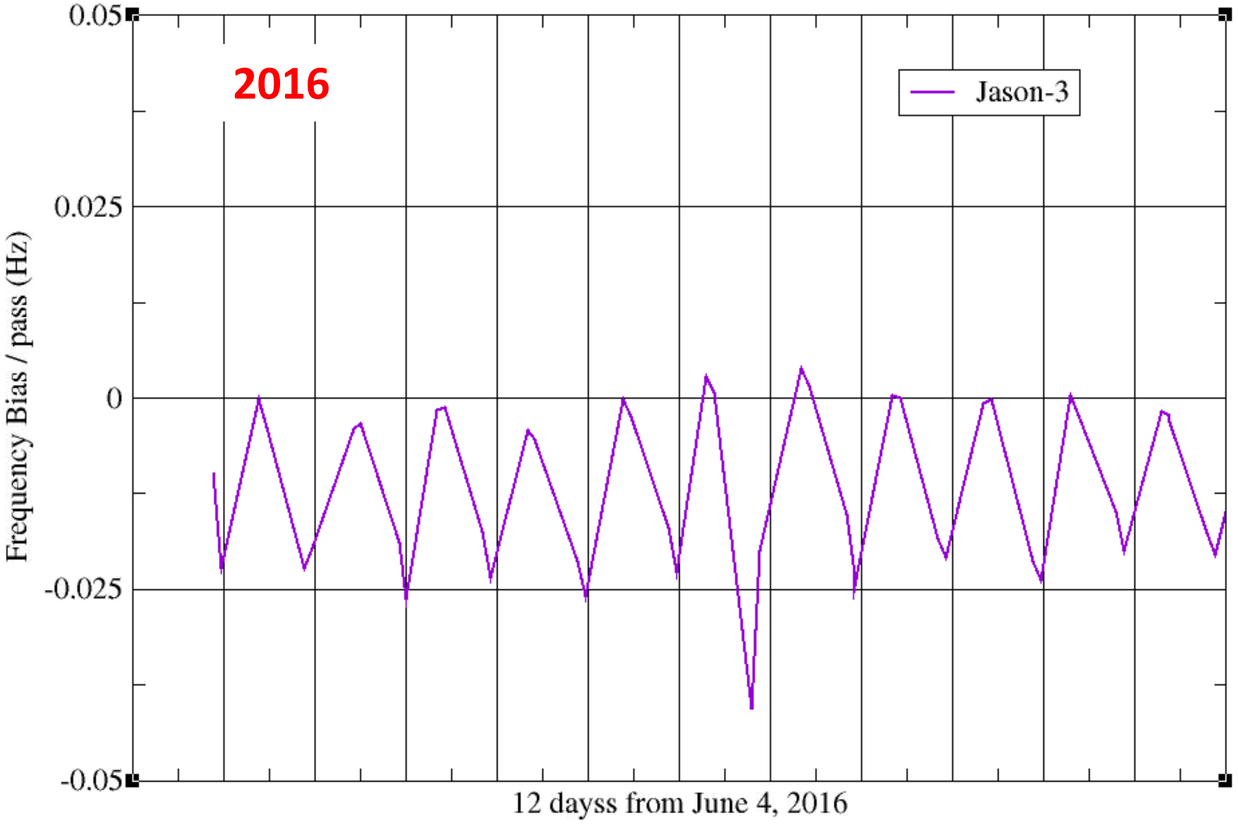


Impact of the South Atlantic Anomaly effect on the orbit

❑ Parameters adjusted per pass in GRG processing

Kourou (master beacon in SAA aera) Frequency bias/pass (measurement frequency offset)





- *Lower impact on Saral, significant impact on Jason-3,Sentinels and HY-2C.*
- *SAA impact for Jason-3 less important than in 2016*

Impact of the South Atlantic Anomaly effect on the orbit

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

Mean over 90 weeks (from December 2020 to September 2022)

Station	Cryosat-2	Saral	Jason-3	Sentinel-6MF	Sentinel-3A	Sentinel-3B	HY-2C	HY-2D
All	**0.369**	**0.346**	**0.369**	**0.364**	**0.377**	**0.390**	**0.405**	**0.370**
Cachoeira	0.453	0.432	0.454	0.451	0.495	0.486	0.593	0.475
Arequipa	0.346	0.323	0.376	0.391	0.405	0.391	0.596	0.396
Kourou	0.455	0.421	0.447	0.454	0.466	0.476	0.550	0.456
Ascension	0.398	0.374	0.421	0.422	0.413	0.420	0.531	0.418
Saint Helene	0.362	0.337	0.388	0.388	0.375	0.386	0.492	0.393
Le Lamentin	*0.477*	*0.440*	*0.474*	*0.469*	*0.478*	*0.489*	*0.516*	*0.473*
Yarragadee	0.334	0.309	0.336	0.328	0.337	0.350	0.358	0.334
Thule	0.303	0.281	0.299	0.288	0.315	0.331	0.316	0.291

- *Low altitude satellites: DORIS RMS of Saral lower, higher for Sentinel-3A and especially for Sentinel-3B.*
- *DORIS RMS of Sentinel-6 is at the same level as that of Jason-3, also for SAA stations.*
- *DORIS RMS HY-2C higher than HY-2D especially for SAA stations.*

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

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

Differences between the Jason-3/Sentinel-3A/Sentinel-3B/Sentinel-6 and Saral solutions in NEU

As the Saral USO is not affected by SAA, we use the Saral single satellite solution as a reference.

Mean over 90 weeks (from December 2020 to September 2022)

Station	Jason-3 (in cm)			Sentinel-3A (in cm)			Sentinel-3B (in cm)			Sentinel-6 (in cm)		
	North	East	Up	North	East	Up	North	East	Up	North	East	Up
Cachoeira	5.6	4.3	3.5	-5.3	-0.4	-0.9	2.0	1.2	9.3	7.1	-0.7	1.1
Arequipa	7.7	-0.7	2.2	-3.7	0.1	0.5	3.9	-1.6	1.9	3.1	0.6	-7.3
Kourou	3.5	-2.2	-4.1	3.1	0.5	0.5	-1.8	1.1	-1.4	-0.1	2.2	2.8
Ascension	10.9	-1.7	1.3	1.9	0.6	-1.0	-1.1	-0.9	-1.0	5.8	-2.4	-1.3
Saint Helene	-1.4	2.7	1.4	-2.0	0.1	-1.1	-1.8	-0.2	-2.0	-1.6	-2.3	0.6
Le Lamentin	-6.0	-0.1	-2.8	0.4	0.1	0.4	-0.5	1.1	-0.4	-4.6	2.2	-1.1
Yarragadee	-1.9	-1.1	0.3	-0.4	0.1	-0.2	-0.3	-0.1	-0.1	-1.8	-1.1	0.4
Thule	0.7	0.1	-0.9	0.4	0.1	-0.6	0.6	0.4	-0.8	-0.4	-0.1	-0.9

- *SAA impact higher for Jason-3 and Sentinel-6. Their solutions give a significant bias in at least one of the NEU components for the SAA stations.*

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

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

Differences between the Cryosat-2/HY-2C/HY-2D and Saral solutions in NEU

As the Saral USO is not affected by SAA, we use the Saral single satellite solution as a reference.
Mean over 90 weeks (from December 2020 to September 2022)

Station	Cryosat-2 (in cm)			HY-2C (in cm)			HY-2D (in cm)		
	North	East	Up	North	East	Up	North	East	Up
Cachoeira	-3.5	0.2	-0.3	5.0	-2.3	0.3	3.6	1.7	0.5
Arequipa	-0.8	0.5	-0.4	1.1	1.1	-3.6	-2.9	-0.1	-2.0
Kourou	2.5	0.1	0.1	0.2	2.7	0.4	-1.2	1.1	-2.2
Ascension	1.9	-0.4	-0.1	5.4	2.4	-1.7	2.2	-1.4	-0.7
Saint Helene	1.4	0.1	0.7	1.3	-2.3	-0.9	-0.2	-0.5	1.1
Le Lamentin	0.4	0.1	0.4	-2.6	-2.0	1.8	-1.7	0.3	-1.1
Yarragadee	-0.9	-0.1	0.2	-1.0	-1.0	0.6	2.0	-0.9	1.3
Thule	-0.2	-0.3	0.1	-0.4	1.4	-0.5	0.1	1.1	-0.4

- *HY-2C solution more impacted. The solution gives a significant bias in at least one of the NEU components for the SAA stations.*

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

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

Focus on differences between the Jason-3 and Saral solutions in NEU

As the Saral USO is not affected by SAA, we use the Saral single satellite solution as a reference.

Mean over 90 weeks (from December 2020 to September 2022)

Station	Jason-3 (in cm) 2016 Bias			Jason-3 (in cm) 2022 Bias+Drift			Jason-3 (in cm) 2022 Bias		
	North	East	Up	North	East	Up	North	East	Up
Cachoeira	7.5	3.2	21	5.6	4.3	3.5	5.5	4.1	**9.5**
Arequipa	-2.4	10.7	19.1	7.7	-0.7	2.2	**8.2**	-0.1	**4.8**
Kourou	-6.8	0.6	4.0	3.1	-2.2	-4.1	3.2	-2.1	-3.9
Ascension	1.7	-2.2	14.4	7.9	-1.7	1.3	**8.6**	0.2	**5.4**
Saint Helene	9.9	-6.5	9.7	-1.4	2.7	1.4	**-2.8**	2.5	**5.5**
Le Lamentin	-7.2	0.4	9.2	-6.0	-0.1	-2.8	-5.4	0.1	**-3.5**
Yarragadee	*-1.4*	*0.4*	*-0.3*	-1.9	-1.1	0.3	-1.7	-0.8	0.1
Thule	*2.8*	*-1.1*	*-1.2*	0.7	0.1	-0.9	0.4	0.4	-1.1

SATELLITE	DORIS RMS (mm/s)
Jason-3 (Bias)	0.372
Jason-3 (Bias+Drift)	0.369

- *SAA impact on Jason-3 seems to decrease over time.*
- *The strategy of Bias+Drift adjusting frequency per pass for SAA stations shows better results but the solution is still affected by SAA effect.*

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Impact of the South Atlantic Anomaly (SAA) effect on the orbit and station position estimation

❑ Conclusions

- **SAA impact on active missions:**

  lower impact on Saral, higher for Sentinel-3A and especially for Sentinel-3B
- **SAA impact on latest satellites:**

  Sentinel-6 and HY-2C solution more impacted than HY-2D
- **SAA impact on Jason-3 USO:**

  SAA impact on Jason-3 seems to decrease over time.

  The strategy of Bias+Drift adjusting frequency per pass for SAA stations shows better results.

❑ Future work to mitigate SAA effect

- **Awaiting a data corrective model for the active DORIS satellites we could apply SAA mitigation strategies for at least Sentinel-6MF and HY-2C**

  The strategy of Bias+Drift adjusting frequency per pass for SAA stations (already applied for Jason-3).

  Rename the SAA stations in the normal equation while estimating the station positions (already applied for Jason-3 and Sentinel-3A&B).
- **Introduction of GPS epochwise estimated onboard clocks**

  Possible with Sentinel-3A, Sentinel-3B and Sentinel-6MF.