Status of DORIS Processing at GSFC Following ITRF2020

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Summary of Current Modelling after ITRF2020

	ITRF2020
Gravity Modeling	New background gravity model: GOCO05s: (a) annual and secular terms for post 2003. (b) adapted model for pre 2003.0 (no secular terms).
AOD product	RL06 3hrly atmosphere-ocean dealiasing product (provided by GFZ for GRACE FO)
Troposphere	VMF1
Atmosphere density	MSIS86
TSI	1360.8 W/m^2 (Koop & Lean, 2011)
Satellite Attitude	Internal attitude laws (Sentinel-3A/3B, HY-2A) • Body & solar array quaternions for Jason 1,2,3 satellites. • Body quaternations for some TOPEX arcs.

	ITRF2020
GEODYN Versions	2106
Default arc length	7 days, except for data gaps or maneuvers.
Elevation cutoff	7°
Elevation-dep. weighting	Applied
Station coordinates: DORIS, SLR	DPOD2014_v05.5; SLRF2014 (v200428)
Data:	DORIS V2 for HY-2A, Cryosat-2, Saral

Updates Planned or in Progress

		Status
Station Coordinates DORIS, SLR	Switch to DPOD2020/SLRF2020.	Evaluation in progress
Gravity Modelling	Evaluate new models: GOCO06s, COSTG models + Loomis et al., values for C_{20}, C_{30}	Evaluation in progress
Data	Replace V2 processing for DGXX Satellites (Cryosat-2, HY-2A, Saral) with RINEX processing.	In progress
GEODYN	Adopt GEODYN III (old versions no longer supported).	In progress.
Jason-2	Replace solutions 2008-2016 with RINEX data & T2L2-based corrections.	After IDS WS
S3A, S3B	Introduce GPS modelling of USO following Stepanek	2023

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Summary of Recent SINEX Submissions for ITRF2020

Series	Description	Comment
gscwd50	with adj radial z-offsets for Jason-1, adj radial z offsets for SPOT-2 after 2007/11/13, no SPOT-4 after 2013-01-11, start Envisat on 2004/11/07 with Jason-1	Implemented at request of IDSCC
gscwd51	gscwd50 + Add Sentinel-3A + Use NewCr's for SPOT-2 & SPOT-5, + a priori Macromodel for Jason-3 (per NPZ)	Final Deliveries to IDS Data Centers on Sept 28, 2021

Post ITRF2020

Series	Description	Comment
gscwd52	gscwd51 + Sentinel-3B starting 180610	Deliveries Started 2021-10-18 to NASA CDDIS. Current operational series.

Summary of POD Results: RMS of fit (1)

(new satellite data for ITRF2020 and post-ITRF2020)

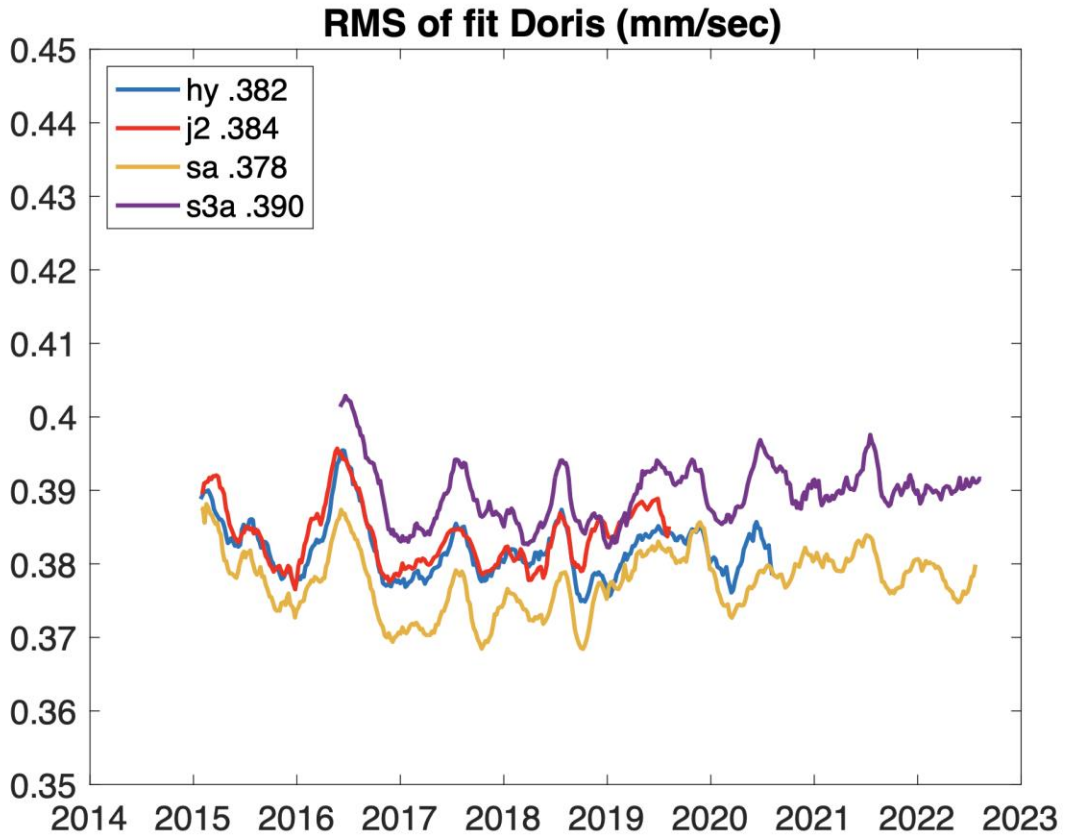
Satellite	First Arc	Last Arc	No of Arcs	Avg. No SLR obs	Avg. No DORIS obs	Avg. SLR fit (cm)	Avg DORIS fit (WRMS, mm/s)
Cryosat-2	150104	220911	492	991	62584	1.060	0.3953
HY-2A	150104	200906	336	623	83104	1.069	0.3818
Jason-2	150104	190908	227	2687	127916	0.883	0.3819
Jason-3	160223	220911	378	2560	135051	0.902	0.4075
Saral	150104	220828	415	1118	80500	0.973	0.3778
Sentinel-3A (α)	160508	220911	384	966	75533	0.760	0.3892
Sentinel-3B (β)	180606	220911	271	869	75556	0.792	0.4026

(α) No SLR data for Sentinel-3A from 2016-0306 to week of 2016-0508. Sentinel-3A still included in SINEX solution gscwd51 starting on 160302.

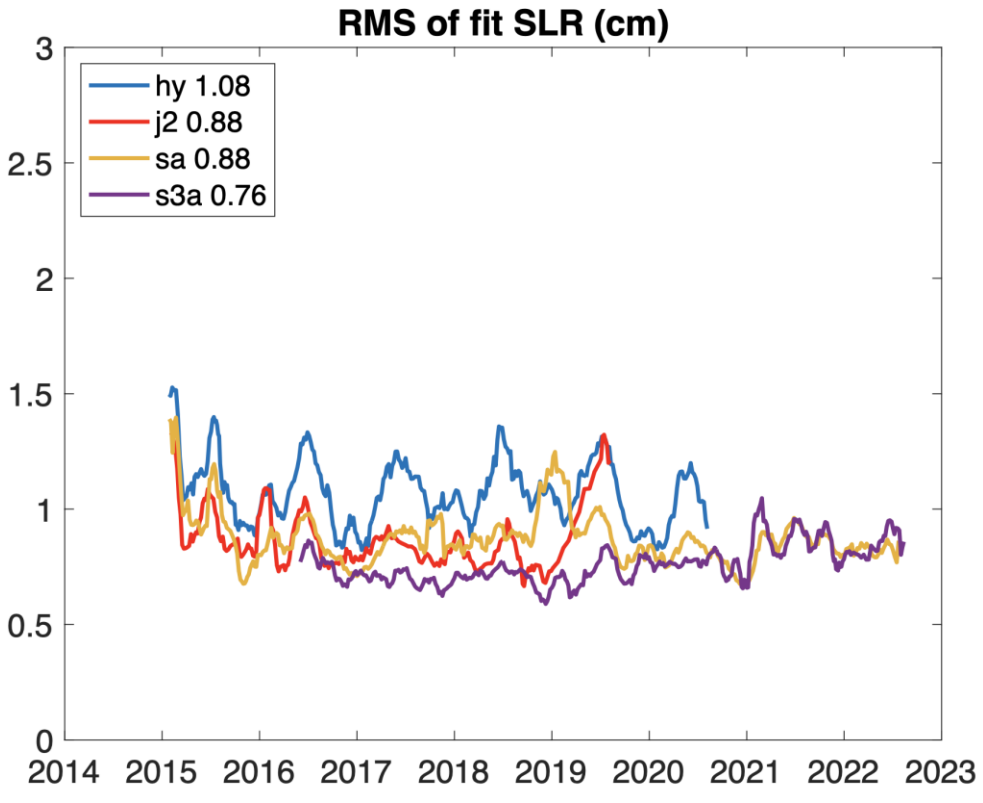
(β) Sentinel-3B not included in the ITRF2020 submission, but is now part of the operational series, gscwd52.

Summary of POD Results: RMS of fit (2)

(new satellite data for ITRF2020 and post-ITRF2020)



RMS of fit smoothed using a running ~9 week average



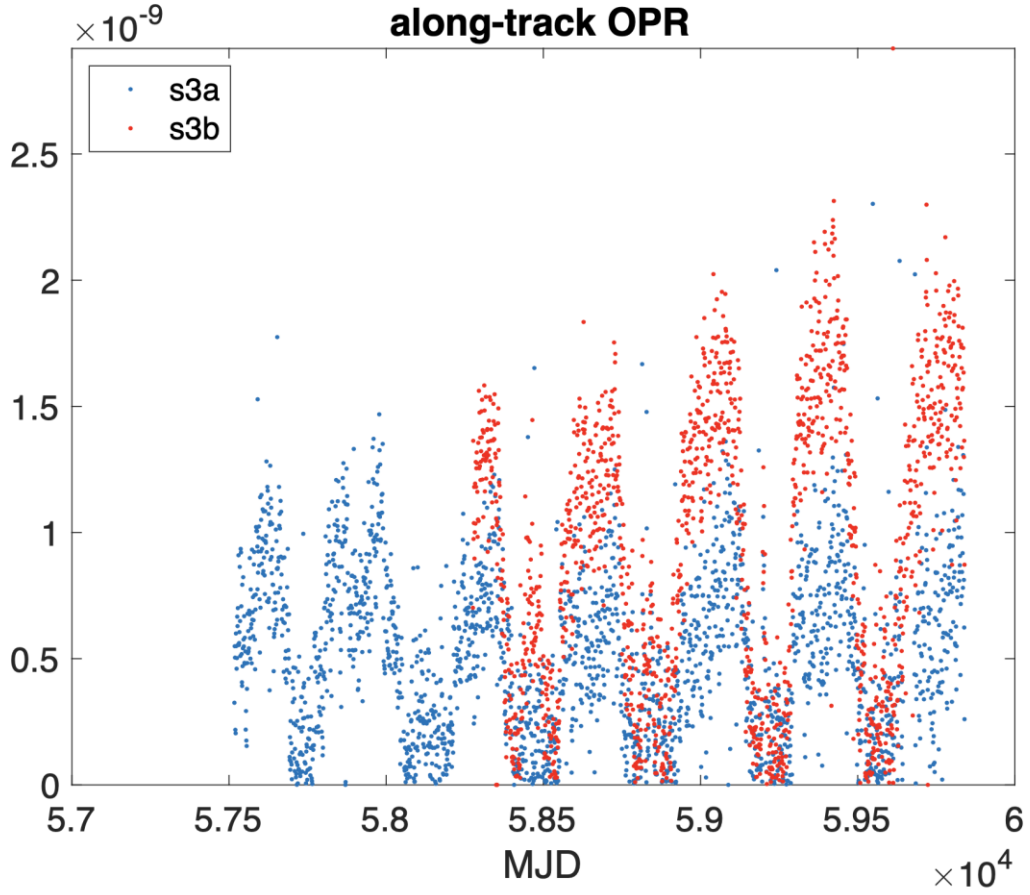
Do other ACs see
(1) the peak in 2016 (doris)?
(2) the apparent variability in Hy2A SLR RMS of fit?
(3) the runoff in Jason-2 RMS of fit in 2019?

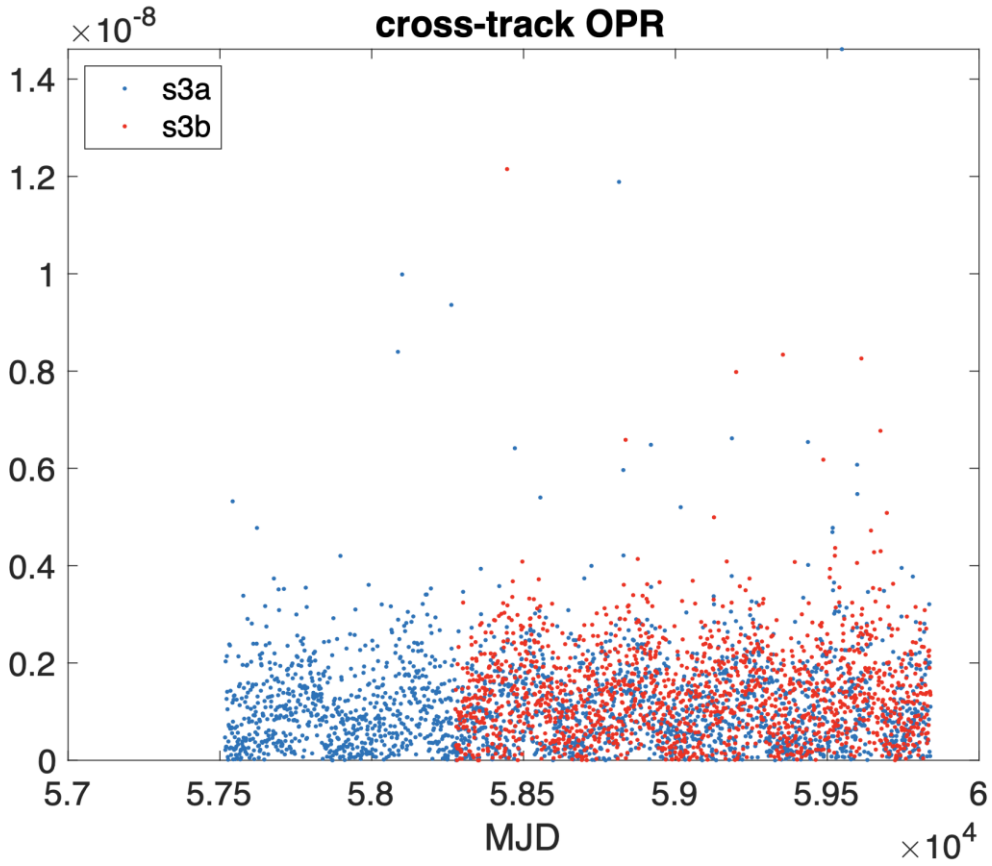
Summary of POD Results (2016 – 2020): Empirical Accelerations: (new satellite data for ITRF2020)

Satellite	First Arc	Last Arc	No of Values	Along-track Accels (nm/s^2)		Cross-track Accels (nm/s^2)	
				Average	RMS	Average	RMS
Cryosat-2	150104	220911	2838	2.351	5.346	4.371	6.290
HY-2A	150104	200906	2094	0.481	0.600	2.312	2.817
Jason-2 (α)	150104	190908	1410	0.597	0.855	2.359	2.768
Jason-3 (α)	160223	220911	2363	0.667	1.056	1.644	2.343
Saral	150104	201227	2182	1.854	2.551	0.861	1.106
Sentinel-3A	160508	220911	2316	0.525	0.622	1.126	1.490
Sentinel-3A (γ)	180603	220911	1546	0.506	0.604	1.137	1.503
Sentinel-3B (β)	180606	220911	1583	0.940	1.110	1.367	1.689
Sentinel-3A (δ)	180617	181014	128	0.654	0.714	0.961	1.196
Sentinel-3B (δ)	180617	181016	130	0.919	1.039	1.161	1.384

(α) For Jason-2 & Jason-3 Cr's were adjusted per arc in a separate POD step and then held fixed.
(β) Sentinel-3B was not included in ITRF2020, but is now part of the operational series, gscwd52.
(γ) Selecting Sentinel-3A arcs that are coincident with Sentinel-3B for comparison (180603 to 220911).
(δ) Sentinel-3A & Sentinel-3B comparison limited to S3A-S3B tandem mission period.

OPR Acceleration Amplitudes for Sentinel-3A & Sentinel-3B





DORIS/RINEX Processing for Cryosat-2, HY-2A, Saral compared to DORIS/V2

DORIS RINEX POD processing Summary (vs. V2)

Satellite	Data	No. of Arcs	Avg. No of DORIS obs	RMS (mm/s)	Avg. No of SLR obs	RMS (mm/s)	Span of Data Arcs
Cryosat-2	RINEX	800	62785	0.3931	940	1.106	2010/06/10 to 2022/09/11
	V2	800	60847	0.3914	940	1.098	
HY-2A	RINEX	535	82225	0.3820	597	1.036	2011/11/07 to 2020/09/06
	V2	535	79311	0.3801	597	1.026	
Saral	RINEX	537	79200	0.3784	1053	0.886	2013/03/17 to 2022/08/28
	V2	535	76276	0.3775	1053	0.882	

1. For the RINEX & V2 reprocessing we used dpod2014_05p5.
2. All the data (V2 & RINEX) were imported and processed from scratch (to avoid potential issues with missing stations or other anomalies).
3. With DSC, we quality controlled the arcs, and through the comparisons, cleaned up a few anomalous arc setups.

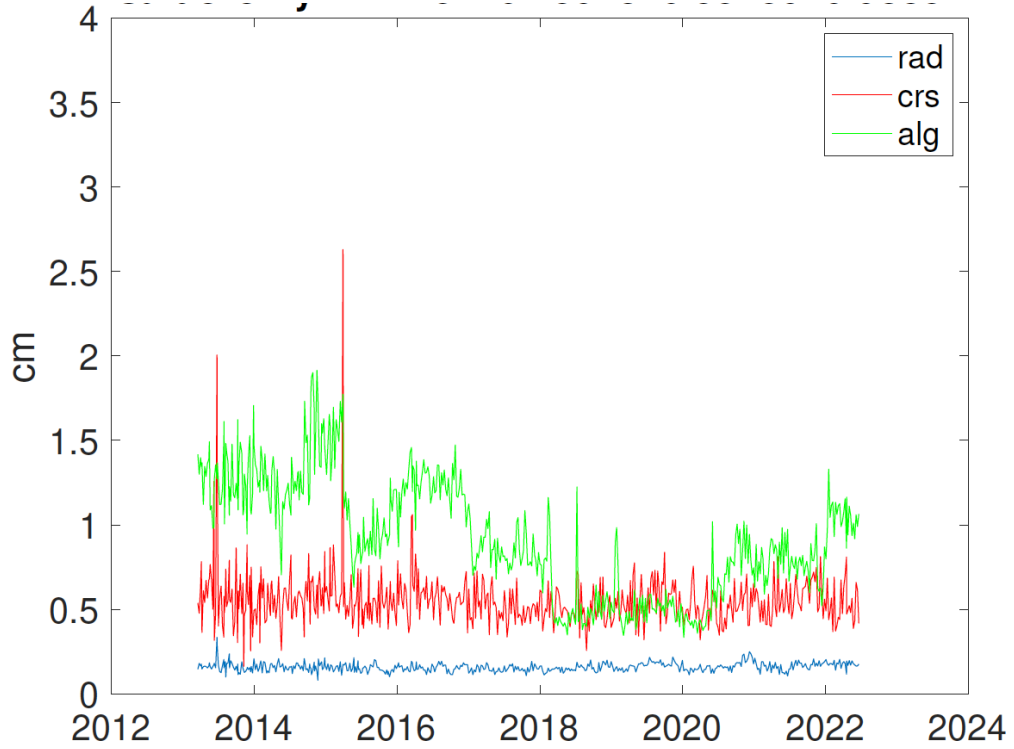
Conclusions:

(1) RINEX has 3.3 – 3.8 % more observations than the V2 data;

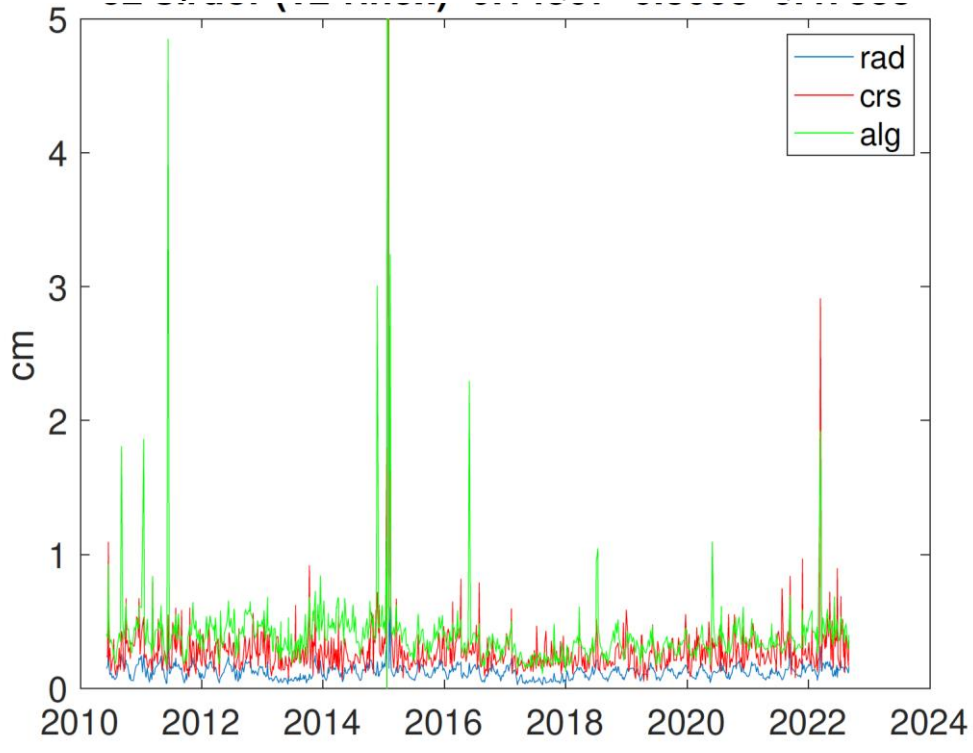
(2) DORIS RMS of fit slightly higher (0.001 to 0.002 mm/s). (*Other ACs have made this observation*)

DORIS RINEX processing Summary (vs. V2)
Orbit Differences

Saral DORIS-only (V2– RINEX)



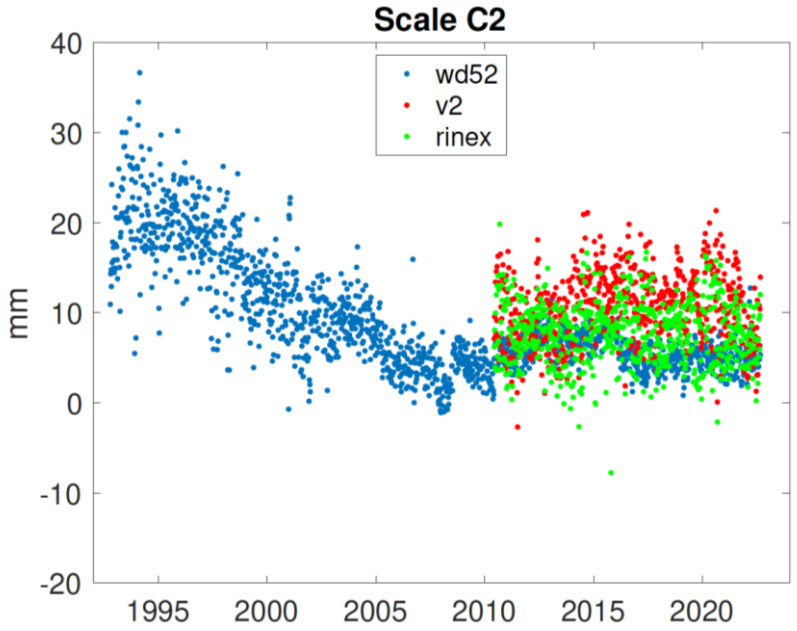
Cryosat-2 SLR+DORIS (V2 – RINEX)

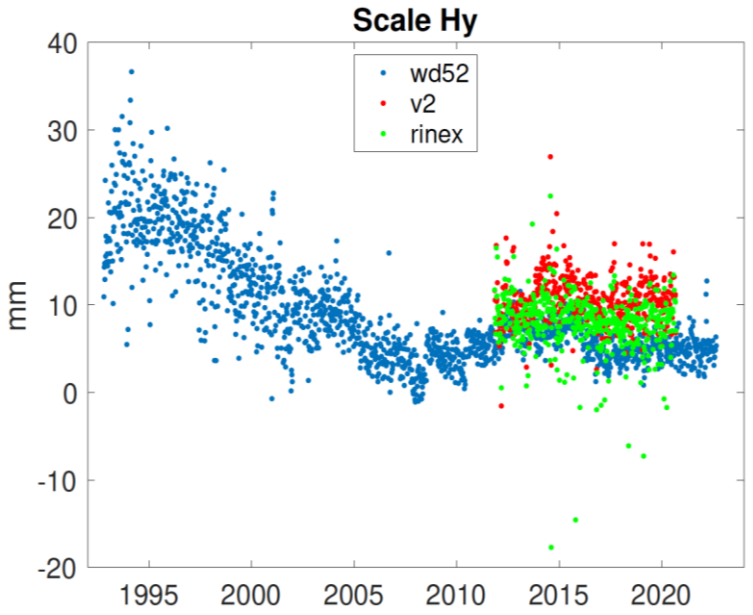


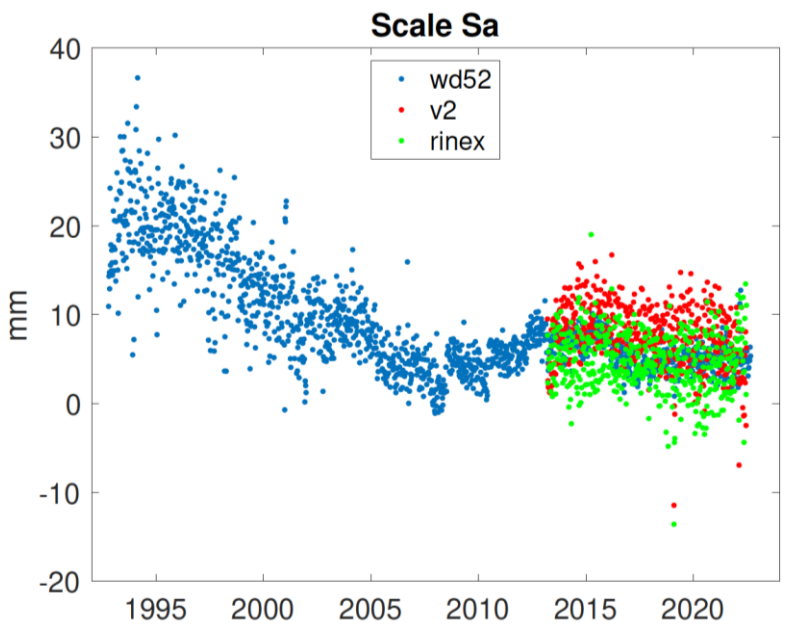
Saral Avg. RMS Differences
Radial: 1.59 mm.
Along-tr: 9.39 mm.
Cross-tr: 5.54 mm

Crysoat-2 Avg. RMS Differences
Radial: 1.45 mm.
Along-tr; 4.79 mm.
Cross-tr: 3.01 mm

DORIS RINEX processing Summary (vs. V2)
Scale w.r.t DPOD2014_v5.5







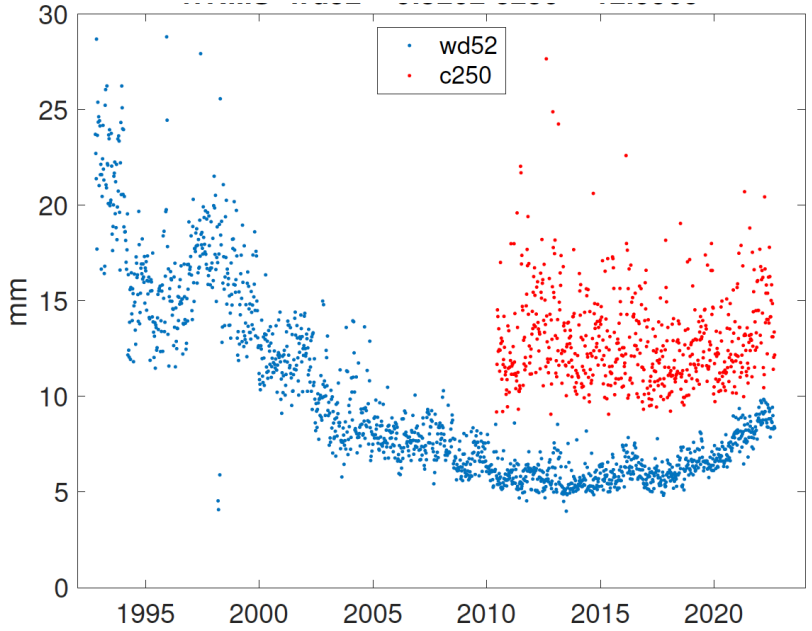
Cryosat-2 scale:
V2: 10.56 $\pm$ 3.82 mm
RINEX: 7.61 $\pm$ 3.71 mm
V2-RINEX = +3.95 mm

HY-2A scale:
V2: 10.58 $\pm$ 2.70 mm
RINEX: 7.96 $\pm$ 3.34 mm
V2-RINEX = +2.62 mm

Saral scale:
V2: 7.81 $\pm$ 3.42 mm
RINEX: 4.65 $\pm$ 3.57 mm
V2-RINEX = +3.16 mm

DORIS RINEX processing Summary (vs. V2)
WRMS Evaluation

WRMS w.r.t. DPOD2014_V5.5
Cryosat-2 DORIS/V2 single-satellite vs. GSCwd52 (combination)



DORIS V2 (Cryosat-2): 12.99 mm
wd52 (2011-2022): 6.43 mm

WRMS w.r.t. DPOD2014_V5.5 (mm)

Satellite-SINEX	DORIS/V2	DORIS/.RINEX
Cryosat-2	12.99	11.81
HY-2A	14.06	13.07
Saral	11.80	10.92
wd52	6.43 (2011-2022)	

DPOD2020/ITRF2020 Evaluations

Characterization of the DORIS & SLR Complements

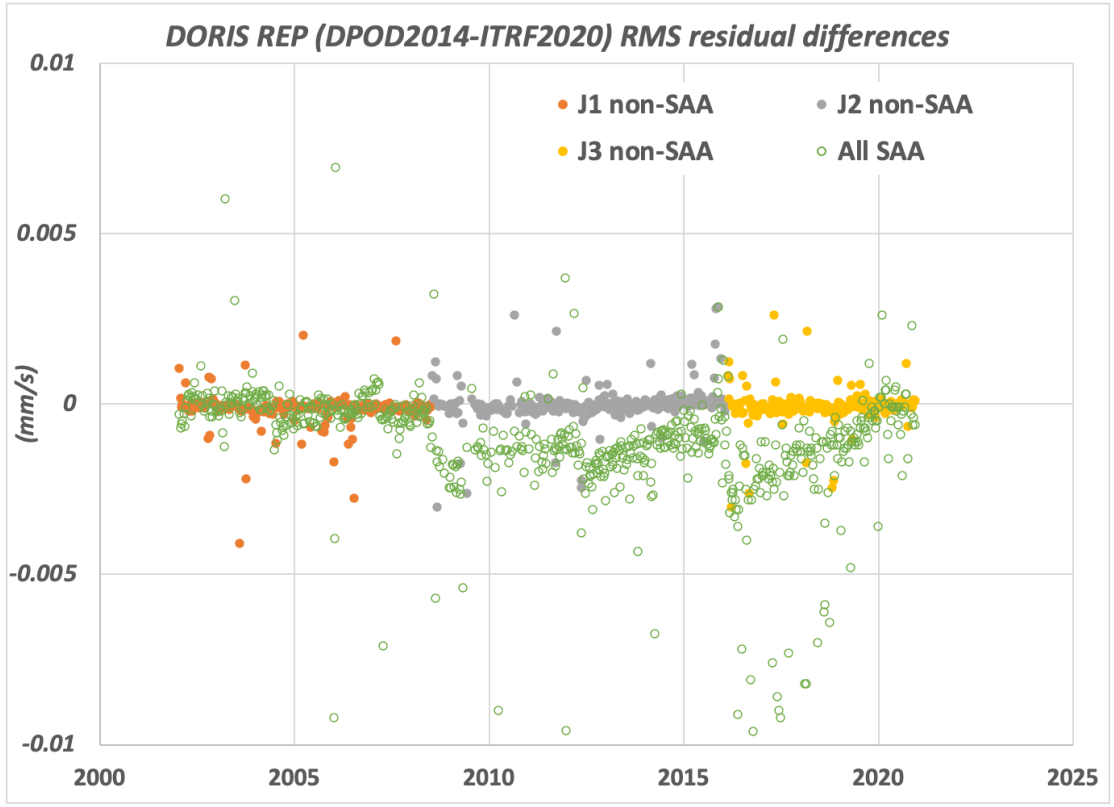
SLR Complement	No. of stations	Number of station solutions	Position Epoch	PSD applied
SLRF2014 (v200428)	469	523	2010	yes (itrf2014)
itrf2020	421	473	2015	yes

DORIS Complement	No. of stations	Number of station solutions	Position Epoch	PSD applied
DPOD2014 (v5.5)	214	342	2000	no
itrf2020	201	287	2015	yes

Summary SLR+DORIS POD Residual Statistics

Satellite	Time span	complement	DORIS Stations in POD	SLR Stations in POD	DORIS RMS (mm/s)	SLR RMS (cm)
TP	1992.9-2004.8	itrf2014	118	83	0.5131	1.595
		itrf2020	116	82	0.5131	1.632
J1	2002.1-2010.1	itrf2014	97	51	0.3885	0.810
		itrf2020	97	49	0.3887	0.896
J2 (doris:V2)	2008.5-2016.7	itrf2014	97	47	0.3927	0.729
		itrf2020	97	47	0.3929	0.742
J2 (doris:rx+t2l2)	2008.5-2016.7	itrf2014	100	47	0.3799	0.717
		itrf2020	100	47	0.3800	0.728
J3	2016.1-2022.3	itrf2014	79	41	0.3942	6.94
		itrf2020	73	40	0.3945	6.31
S6A	2020.9-2022.3	itrf2014	60	26	0.3853	7.63
		itrf2020	54	26	0.3859	7.01

DORIS Postprocessed Residual Differences



SAA stations show most scatter (degradation) in performance.

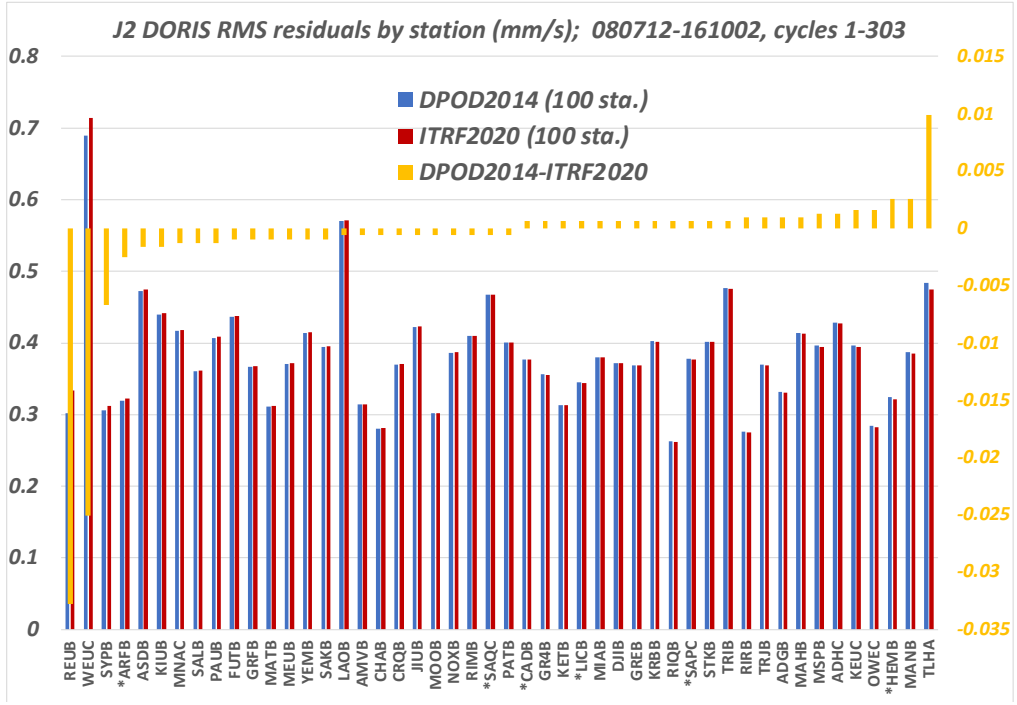
SAA Strategy for DORIS Satellites (GSC)

Satellite		SAA stations reduced (eliminated from combination)
SPOT-5	Use SAA-corrected data (2006-2015)	N
Jason-1	Use SAA-corrected data (2004-2008)	Y
Jason-2	Use DORIS V2 data	N
Jason-3	Use DORIS/RINEX data	Y
Sentinel-3A	Use DORIS/RINEX data	N
Sentinel-3B	Use DORIS/RINEX data	N

For GSC: Jason-1 & Jason-3:
SAA stations downweighted by 3X in POD.

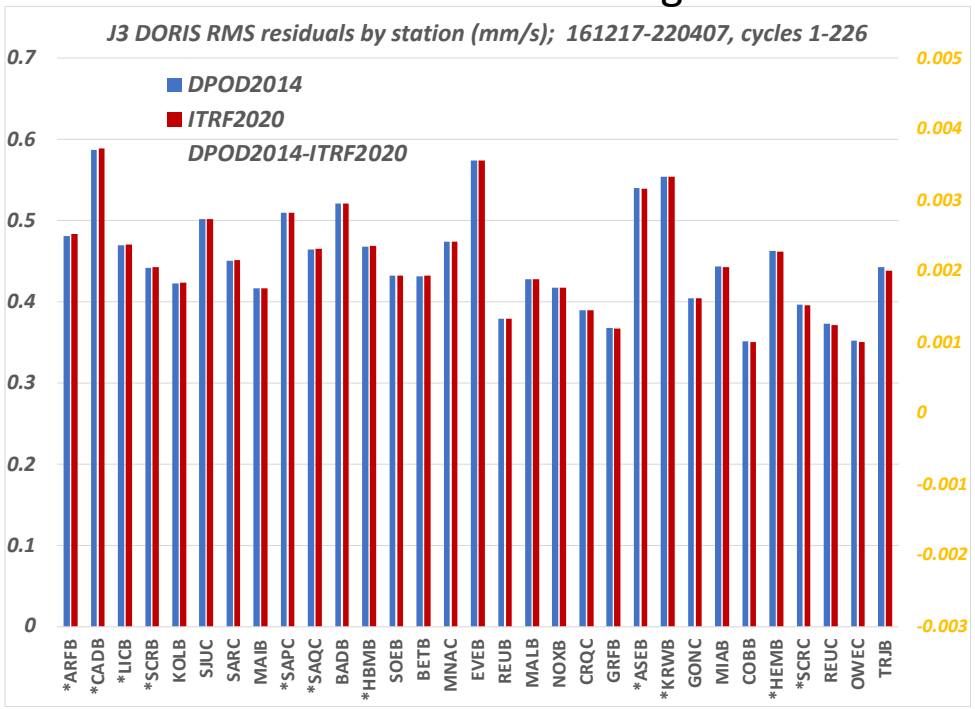
DORIS Residuals by station (Jason-2 & Jason-3)

Jason-2 DORIS residual changes



Significant improvement for ITRF2020: TLHA
Notable degradation for ITRF2020: REUB, WEUC, SYPB
*** Asterisk indicates SAA station.**

Jason-3 DORIS residual changes



Significant improvement for ITRF2020:
TRJB, OWEC, REUC, SCRC*
Notable degradation for ITRF2020:
ARFB*, CADB*
*** Asterisk indicates SAA station.**

Summary

- We have completed the RINEX processing for Cryosat-2, HY-2A and Saral, and compared the POD performance, computed orbits, and station repeatability (WRMS).
- The switch to the DORIS/RINEX in our processing introduces a delta of -3 mm in the single-satellite scale (compared to DPOD2014 v5.5). We need to investigate the reason for this unexpected result.
- We will update our operational combination to replace the V2-based normal equations with the RINEX-based normal equations, and create and an updated series.
- We have tested the ITRF2020, and the DPOD2020 using the TOPEX, Jasons 1-3, S6A satellites. The test configuration possibly favors the SLRF2014/DPOD2014. Nonetheless, for these satellites the DORIS RMS of fit shows a small degradation. The SAA stations show the most dispersion in the solution.
- It will be important to use DORIS satellites not so perturbed by the SAA to evaluate the DORIS complement in ITRF2020/DPOD2020 (Envisat, Cryosat-2, Saral).
- After the IDS workshop, we will update our Jason-2 T2L2 processing, and re-evaluate its inclusion in the weekly combination. We will be happy to share the updated frequency model with other ACs.
- Investigate Anomalous modelling (higher empirical OPR amplitudes) on Cryosat-2, compared to other satellites.
- Introduce newer DORIS satellites into the combination.