GSC Analysis Center Update

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Virtual IDS AWG Meeting via M.S. Teams

April 6-7, 2021

Summary of Modelling updates for ITRF2020 (1)

	ITRF2014	ITRF2020
Gravity Modeling	GOCO2s + SLR+DORIS solutions to 5x5	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	ECMWF-derived 6hr (Univ. of Strasbourg, JP Boy)	RL06 3hrly atmosphere-ocean dealiasing product (provided by GFZ for GRACE FO)
Troposphere	Saastamoinen. GMF. GPT for a priori met. data	VMF1
Atmosphere density	MSIS86	no change
TSI	1367.2 W/m^2	1360.8 W/m^2 (Koop & Lean, 2011)
Nonconservative Force Models	**Updated by satellite. See next slides.**	
Satellite Attitude	Internal attitude law; • Body quaternions for Jason-1 & Jason-2 & some TOPEX arcs.	Internal attitude laws; • Body & solar array quaternions for Jason 1,2,3 satellites. • Body quaternations for some TOPEX arcs.

Summary of Modelling updates for ITRF2020 (2)

	ITRF2014	ITRF2020
Ground Antenna Phase Law	Applied.	Updated for Alcatel antennae (2017).
HF EOP	IERS 2010	IERS 2017
Pole model	IERS 2010	Linear mean pole (IERS, 2017)
Hy2A offset	--	Updated per IDS AWG recommendations.
SPOT-5 radial offset	Not adjusted.	Adjusted per week (reduced from weekly NEQ) to resolve SPOT-5 induced perturbations in DORIS scale.
Geocenter	--	Annual model. (Ries, 2013)
Station coordinates	DPOD2008	DPOD2014 (latest version Nov. 2020).

Summary of Processing updates for ITRF2020

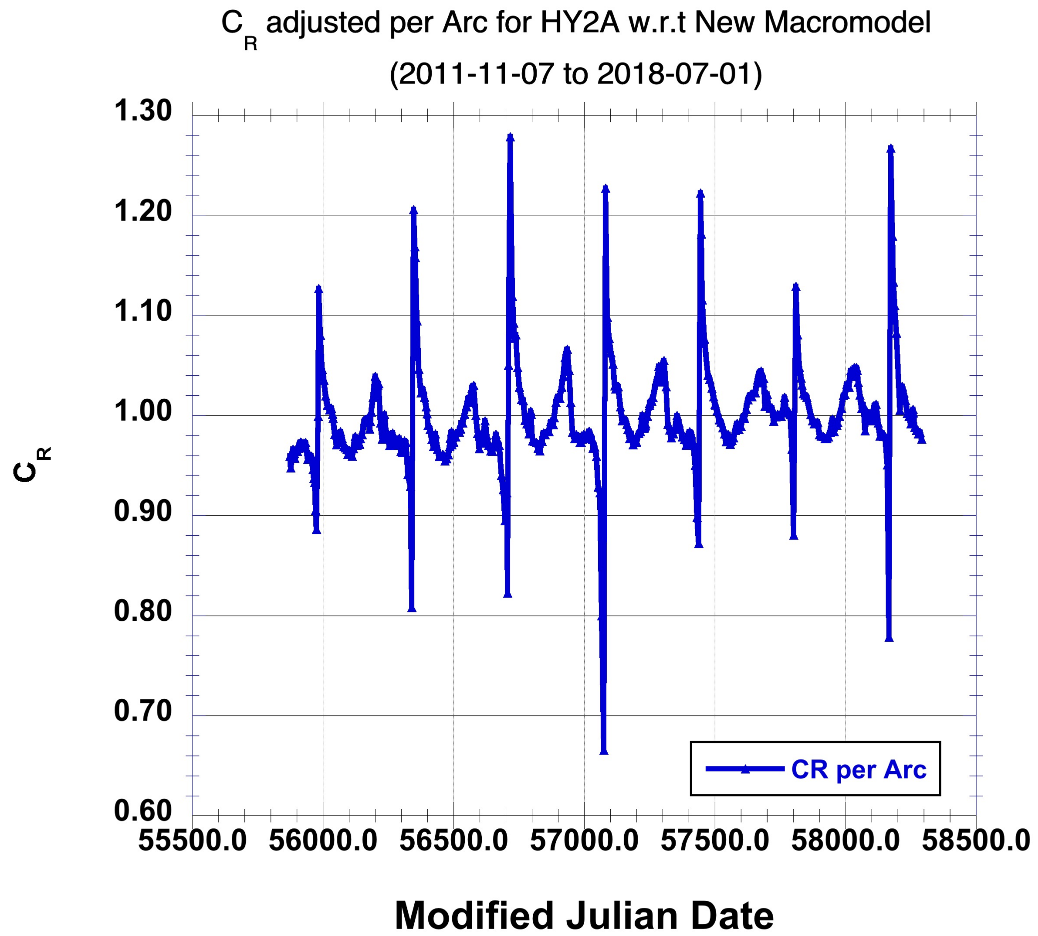
	ITRF2014	ITRF2020
GEODYN Versions	1410. (2014 version)	1906 & 2002 (2019 & 2020 versions)
pass-by-pass bias estimation	shortcut. akin to arc reduction by iteration.	Explicitly part of normal matrix for batch solution (1)
Editing of Data	--	All data completely re-editted.
Data arc length, 1999 – 2003 for 800 km satellites	Default of 7 days, except for maneuvers or data gaps	Default of 3.5 days, except of maneuvers or data gaps; Arc lengths as short as 1-2 days in very high solar flux periods.
Elevation cutoff	10°	7°
Elevation-dep. weighting	none.	Applied for all elevation angles.
A priori Data sigma (GEODYN)	0.2 mm/s	0.125 mm/s ($\geq$ 2003.0).
Data Editing	3.5 – 4.0 x RMS	Use Huber weighting; Edit data whose max elevation is $\leq 13°$.

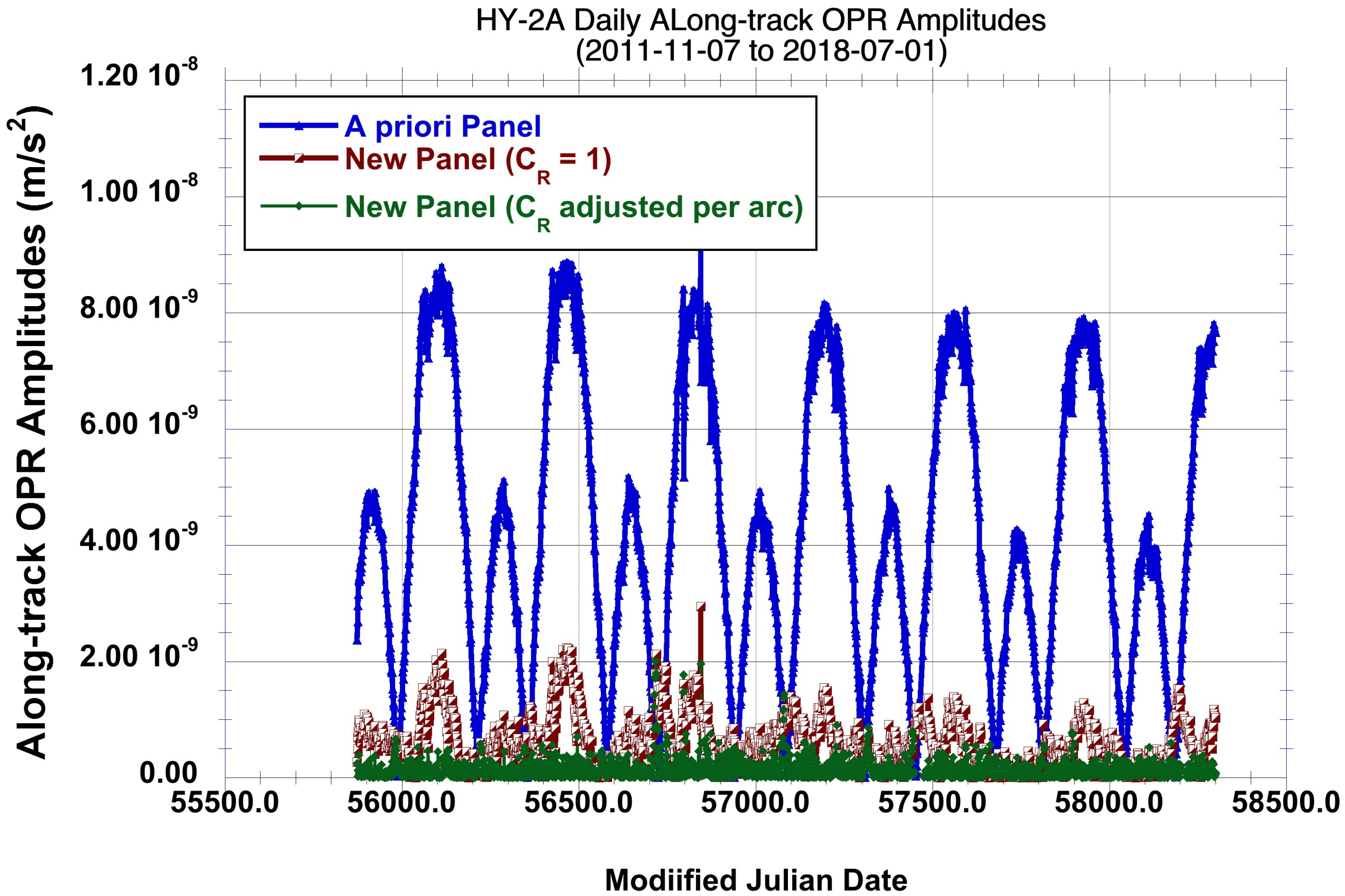
(1) The specification of biases is now explicit (MBIAS), rather than "implicit". In the previous "implicit" processing (EBIAS) it was possible that data at the start & end of passes were deleted because the implicit definition of the time span of the biases did not always include all the data. In addition, badly determined troposphere and range-rate parameters (*e.g. < 5 observations*) were included when they should have been deleted.
This would have been invisible to us in most instances, but probably means that a small percentage of data was systematically deleted for every satellite, or conversely in the second case, data were included that weakened the satellite solution.

Summary of Macromodel updates for ITRF2020

Satellite	ITRF2014	ITRF2020
TOPEX	Derived from Marshall et al. (1995); Cr=1.0	Retuned by year; Cr, adjusted per arc.
Jason-1	10-plate model; Cr=1.000	Retuned. Cr, adjusted per arc.
Jason-2	10-plate model (pre-launch); Cr=0.945	Retuned. Cr, adjusted per arc.
Jason-3	--	Retuned. Cr, adjusted per arc.
SPOT-2	derived from Gitton & Kneib (1990); modified by Le Bail et al. (2010)	unchanged.
SPOT-3	Tuned for ITRF2014 (Lemoine et al., 2016)	unchanged.
SPOT-4	Le Bail et al. (2010). Cr = 1.000	Le Bail et al. (2010). Cr=0.988
SPOT-5	Le Bail et al. (2010). Cr = 1.000	unchanged.
Envisat	SRP: Sibthorpe (2006). Cr = 1.0041747. Drag & Albedo/TE: Ten-plate macromodel.	unchanged.
Cryosat-2	CNES 7-plate model (trapezoidal prism)	unchanged.
HY-2A	Tuned macromodel (Lemoine et al., 2016)	Retuned. Cr=0.998
Saral	---	Zelensky et al. (2016). (unchanged).

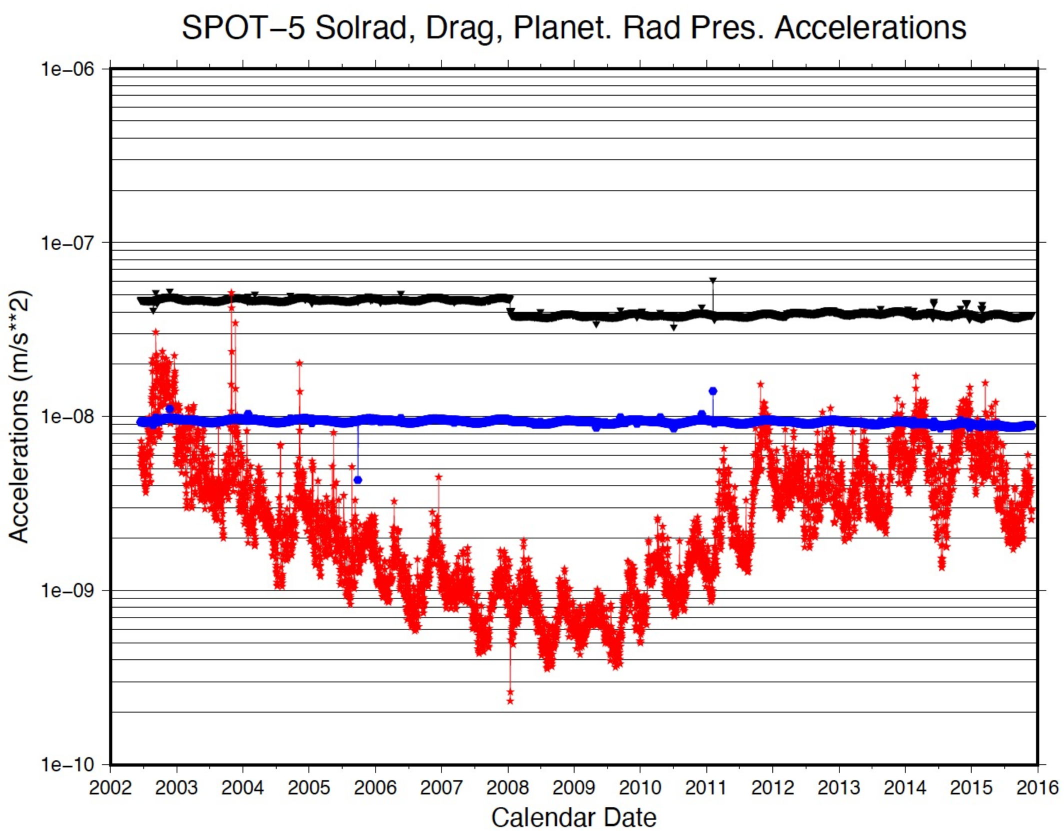
Macromodel Improvement for HY-2A



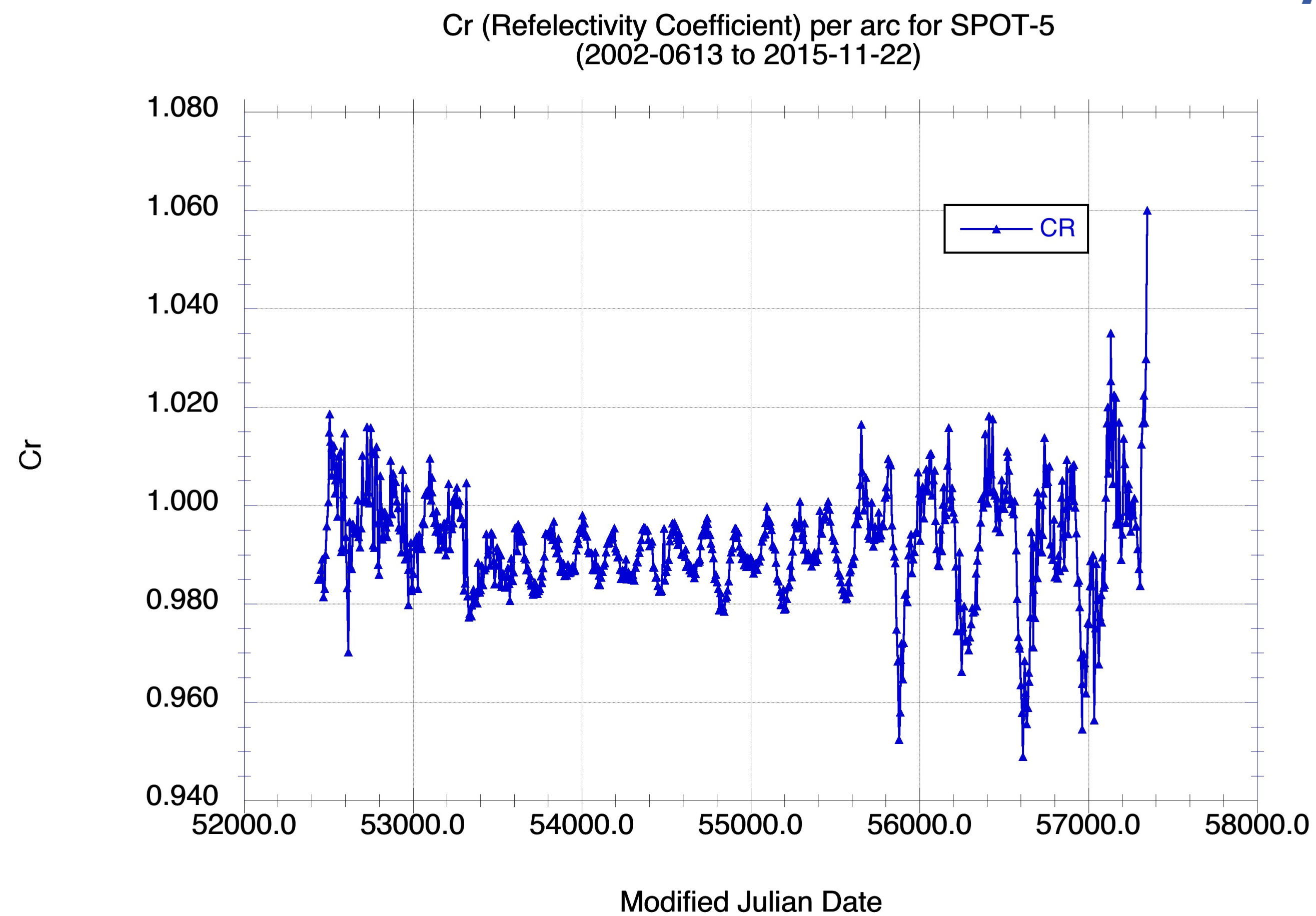


Cr. is with respect to the macromodel and HY-2A attitude law implemented in GEODYN. HY-2A in a full-Sun orbit (near-face-on), undergoing a short period of eclipse in May-June of each year (no more than 13% in shadow). For ITRF2020, we elected to apply a mean Cr = 0.988.

Macromodel Improvement for SPOT-5?

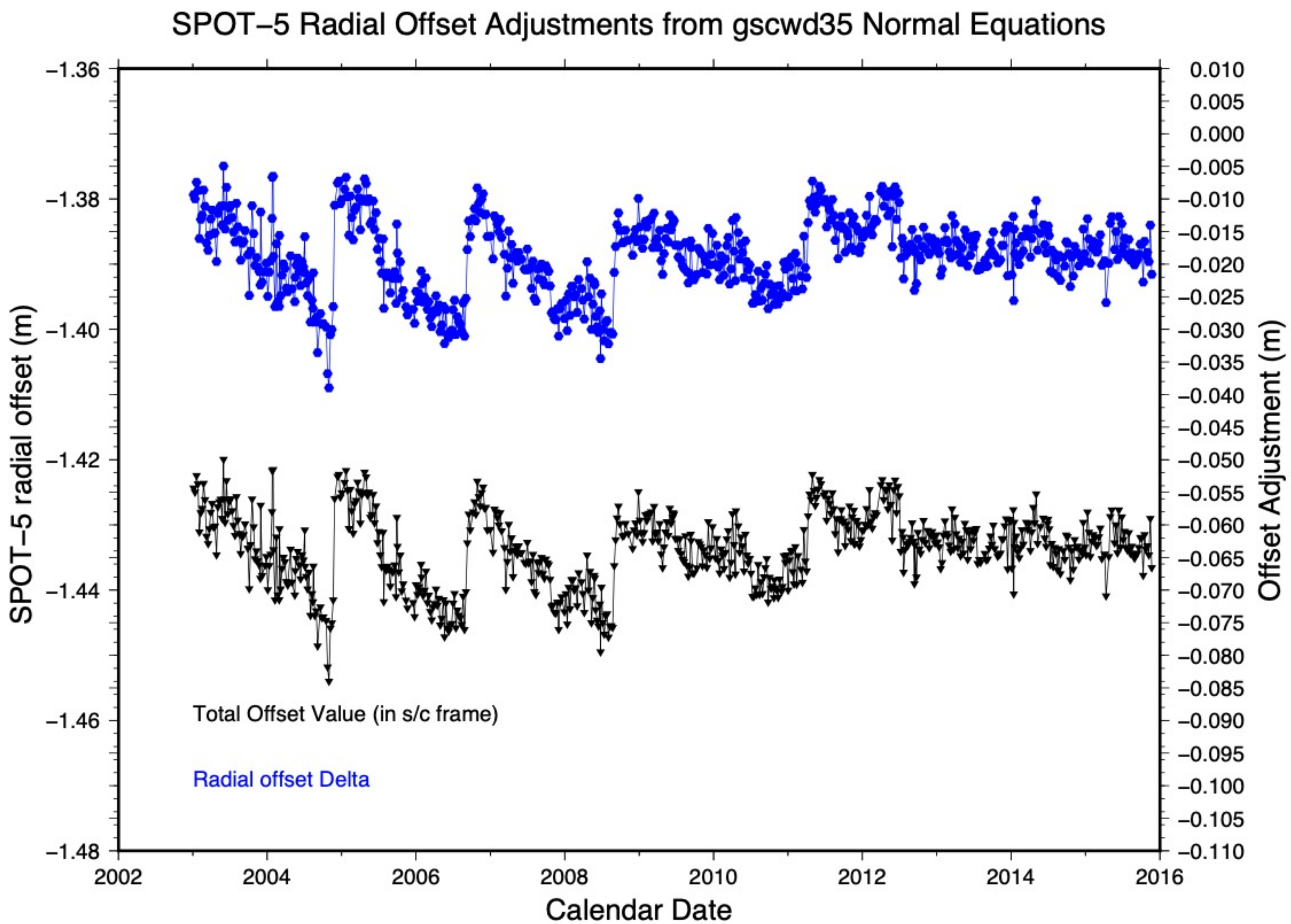


SOLRAD (Black); Albedo/TE (Blue); Drag (Red)



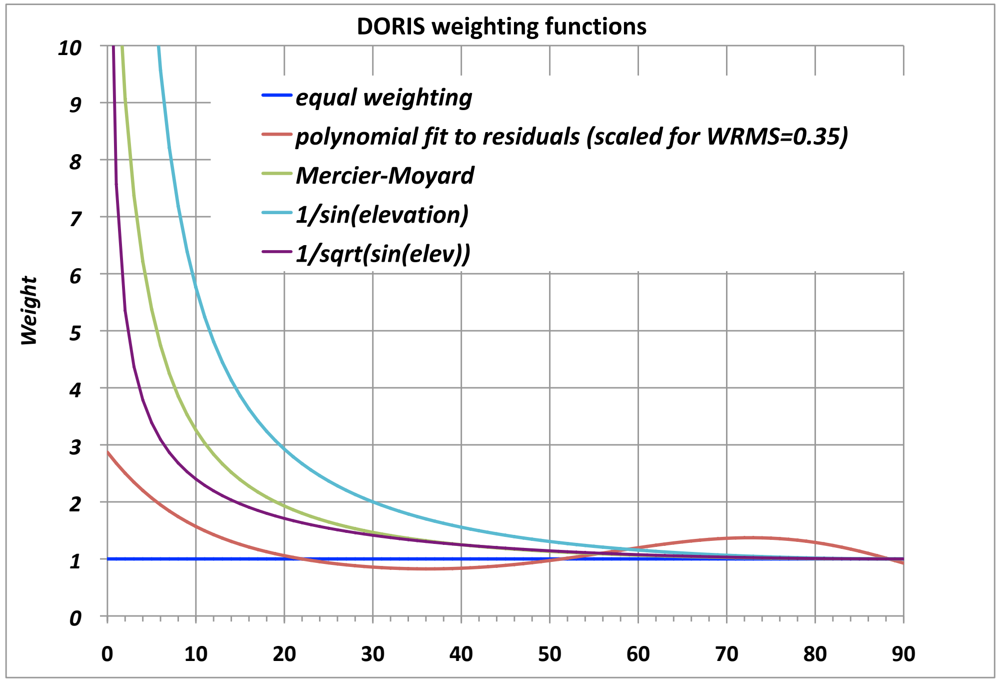
Cr estimates for SPOT-5 are hard to interpret. They are noisier, near the solar maximums. There may be three distinct phases: 2002-2005; 2005 to about 2011; About 2011 to 2015, which might represent three distinct behaviors of the spacecraft AND/OR conflation of solar radiation pressure & drag when OPRS are not estimated.

SPOT-5 Radial (Z) Offset Adjustments



We adjust the SPOT-5 radial or Z offset, because of the perturbations on the DORIS (combined) scale.

DORIS data elevation weighting functions.



We applied data sigma = 1 /sqrt (sin(elev)).

1. Not so much low-elevation data for first generation receiver DORIS satellites.
2. Weighting function effectively reduces "average" data sigma
3. Hence for ≥ 2003, we apply an *a priori* data sigma of 0.125 mm/s vs 0.200 mm/s.

Average Data for DORIS Data Arcs in 2015 (example)

Satellite	Narcs	Avg. Obs. Per arc		Percent change
		elcut=10°	elcut=7°	
Cryosat-2	68	52225	59636	+14.1%
HY-2A	64	80069	88729	+10.8%
Jason-2	55	122971	138068	+12.3%
SPOT-5	53	53148	53130	no change
Saral	61	63069	71563	+13.5%

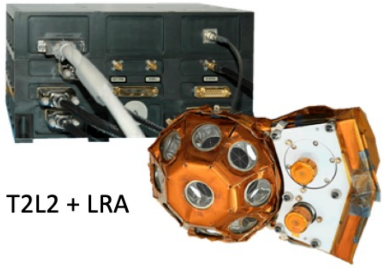
SAA Strategy for DORIS Satellites.

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

<u>SAA Stations for Jason-1:</u>
ASDB, ASEB; HELA, HELB; CACB, CADB; SANA, SANB SAOB; AREA, AREB, ARFB; KRUA, KRUB, KRVB, KRWB; LIBA, LIBB, LICB; GALA; EASA, EASB; SALB; TRIA, TRIB, TRJB.
Stations are down-weighted by 3x in orbit determination from 0.125 mm/s to 0.400 mm/s.

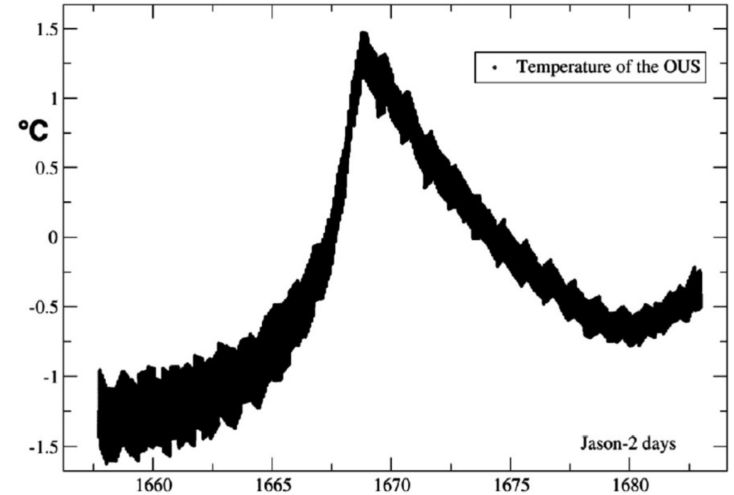
<u>SAA Stations for Jason-3:</u>
RIPB; ASEB; ARFB; CADB; KRWB, KRVB; LICB; LAOB; TRIB, TRJB; HELB, HEMB; SCRB, SCRC; SAPC, SAQC, SARC, SJUC.

Jason-2 DORIS USO Modelling from T2L2 (1)

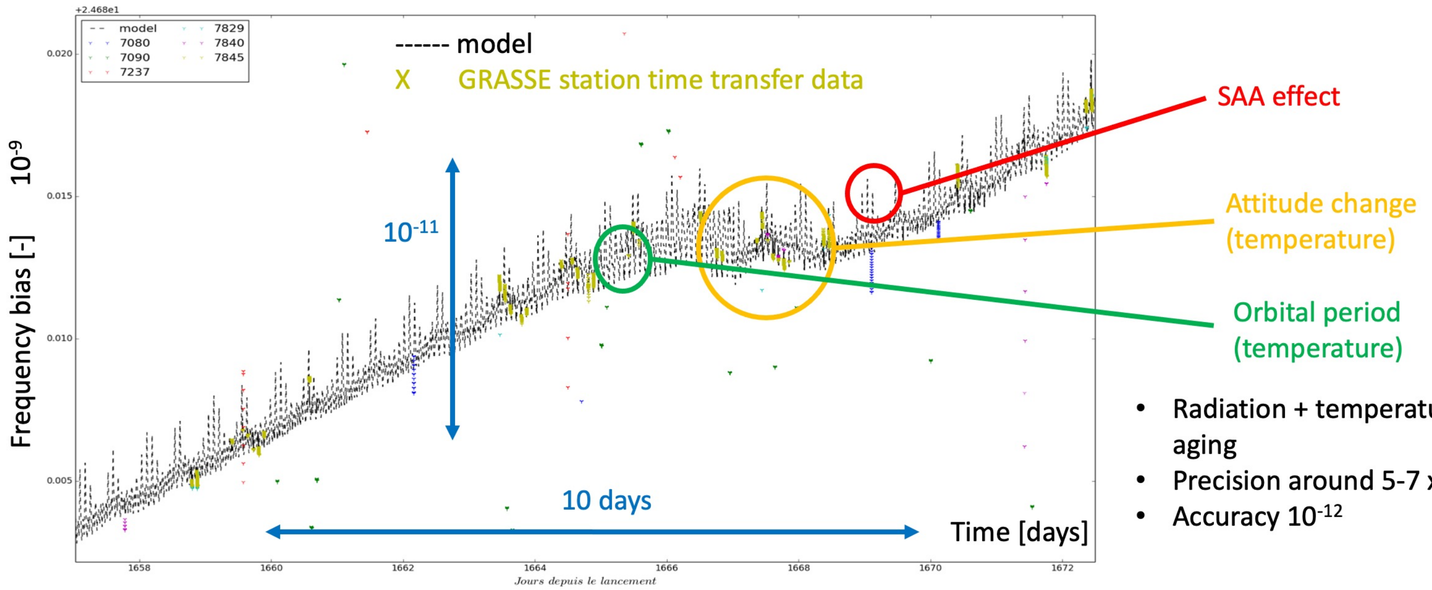


T2L2 :
- Designed for remote clocks synchronization, on-ground and on-board

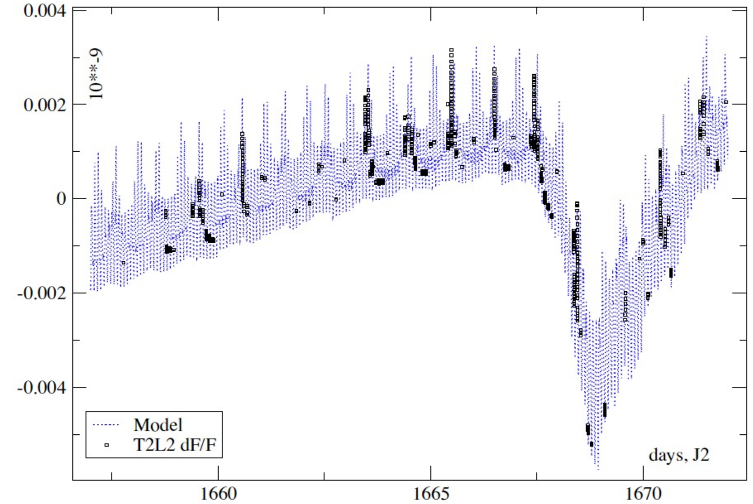
Time Transfer :
- Determine Time Bias in laser stations (ILRS)
- Read the frequency bias of the USO (Ultra Stable Oscillator)



Jason-2 USO Temperature variations in Jan. 2013.



- Radiation + temperature + aging
- Precision around 5-7 x 10^{-13}
- Accuracy 10^{-12}



Jason-2 USO Model variations in Jan. 2013.

Belli et al., (2016), Adv. Space Res. "Temperature, radiation and aging analysis of the DORIS Ultra Stable Oscillator by means of the Time Transfer by Laser Link experiment on Jason-2", ***Adv. Space Res., 58(12),*** **2589-2600, doi: 10.1016/j.asr.2015.11.025**

Jason-2 DORIS USO Modelling from T2L2 (2)

Summary:

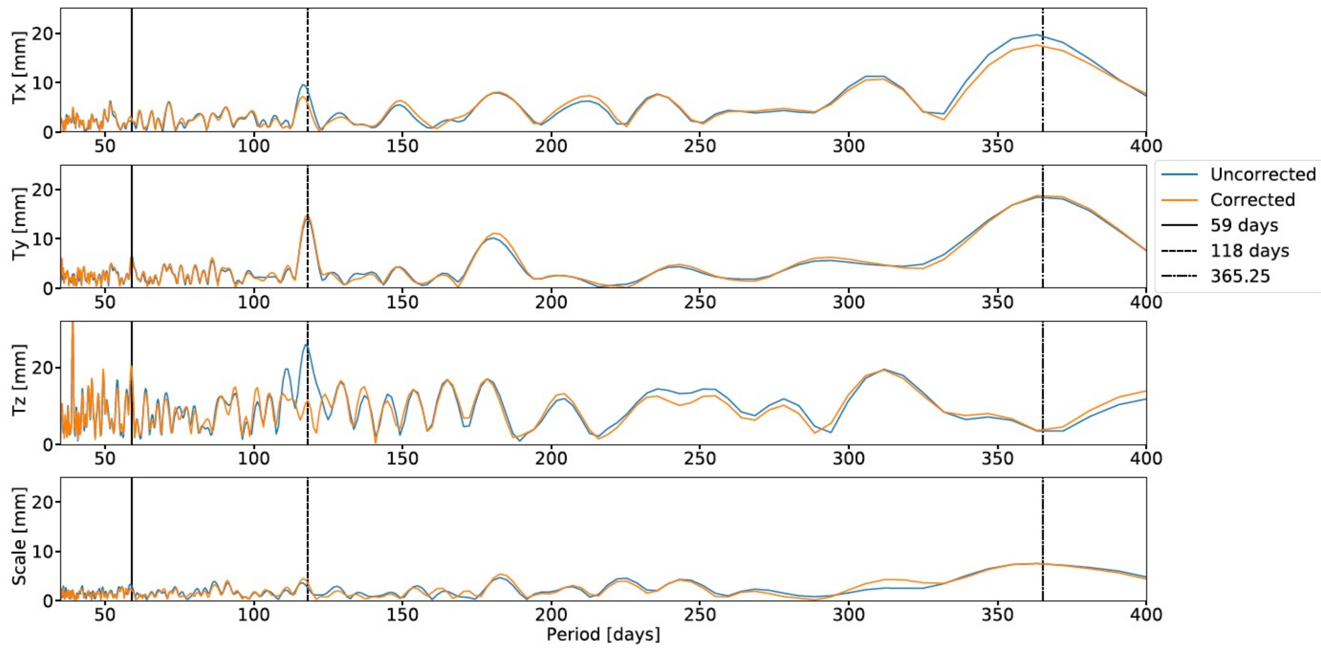
1. Belli et al. (2021) applied the T2L2-derived Jason-2 USO Model to DORIS station + EOP solutions (2008-2016).
2. They showed reductions in avg. biases for atomic-clock stations; Reductions in the Amplitude of the Tz at the draconitic period (~117 days), and a slight improvement (up to 10% in EOP, as measured by differences with IERS C04).

Table 2
Range-rate (frequency) bias statistics for the DORIS stations equipped with atomic clocks.

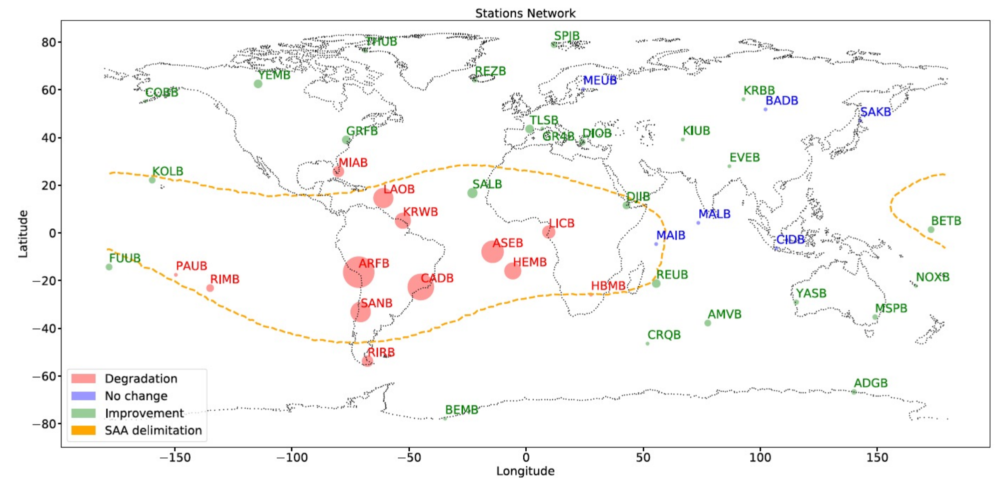
ID	Name	Dates	RINEX		T2L2-corrected	
		yy/mm/dd	n	RMS (mm/s)	n	RMS (mm/s)
ADHC	Terre Adélie	15/03/23–16/08/05	3104	0.411	3103	0.280
TLSB	Toulouse	10/02/17–16/08/05	14192	1.817	14183	0.699
GR4B	Grasse	13/08/01–16/08/05	6702	0.466	6691	0.219
HBMB	Hartebeesthoek	08/07/13–16/08/04	9564	1.735	9557	0.495
KRUB	Kourou	08/07/13–11/03/03	2955	3.321	2931	0.542
KRWB	Kourou	11/03/04–16/08/05	5438	0.904	5435	0.607

Belli et al., (2021), Adv. Space Res. “Impact of Jason-2/T2L2 Ultra-Stable-Oscillator Frequency Model on DORIS stations coordinates and Earth Orientation Parameters”, ***Adv. Space Res., 67(3),* 2589-2600, doi: 10.1016/j.asr.2020.11.034.**

Jason-2 DORIS USO Modelling from T2L2 (3)



Periodogram of Helmert parameters between "T2L2-corrected" and uncorrected coordinate solutions (Fig 6 from Belli et al., 2021)



Change in DORIS Residuals (w.r.t. DPOD2014) when using Jason-2-T2L2-derived USO model for 2008-2016. (Fig. 7 from Belli et al., 2021).

Belli et al., (2021), Adv. Space Res. "Impact of Jason-2/T2L2 Ultra-Stable-Oscillator Frequency Model on DORIS stations coordinates and Earth Orientation Parameters", ***Adv. Space Res., 67(3),*** **2589-2600, doi: 10.1016/j.asr.2020.11.034.**

Jason-2 DORIS USO Test with gscwd41 (vs. gscwd40)

1. So we created a SINEX series (gscwd41) that switched in the Jason-2-corrected data (2008-2016) and tried two different ways to handle the Jason-2 data for 2017-2019: (a) no correction for SAA stations; (b) with correction (reduction) for SAA stations.

2. From Evaluation by IDS CC (email Dec 08, 2020).
(a) Better centering of Tx, Ty, Tz; Slight degradation of std. dev;
(b) Similar performance in positioning as measured by WRMS (E-N-U).
(c) DORIS-GNSS Tie Discrepancies at SAA sites: Improvement with gscwd41 by 5 mm in mean and std. dev.
(d) Problems: discontinuities in station height in 2008, ARFB, ASEB, CADB HEMB (both solutions); for ARFB, ASEB, CADB, and possibly LAOB for gscwd41 in 2017.

Conclusion: We have a dilemma. The Jason-2 USO model is an improvement over not applying any corrective model. It shows potentially a profound impact on coordinates from the USO mismodelling. This discontinuities might have some other origin (we don't know yet).

Yet if they are related to Jason-2, how do we interpret and handle the discontinuities when the model ceases to be valid (after January 2017)?

Unit: mm	GSC 40	GSC 41
RMS	49.97	45.07
Median	50.72	39.69
Mean	46.92	42.00
STD	18.12	17.24

DORIS-GNSS Tie Discrepancies at SAA sites
(from IDS CC, Dec. 08, 2020)

Summary of Recent SINEX Submissions for ITRF2020

Series	Description	Comment
gscwd35	First test series produced for ITRF2020. Included many of the improvements included in the + first slides.	DORISREPORT 4992 (23-Mar-2020); DORISREPORT 5069 (30-Jun-2020)
gscwd36	gscwd35 + apply HFEOP model.	
gscwd37	gscwd35 + adjust radial offset on SPOT-5	IDSCC Email April 15, 2020.
gscwd38	gscwd35 + adjust radial offset on all SPOT satellites.	internal
gscwd39	gscwd35 + apply 3.5 day arcs for SPOT-2,-4,-5, & Envisat (instead of 7-day arcs), 1999-2003.	internal
gscwd40	gscwd35 + apply radial offset on SPOT-5, HFEOP, 3.5 day arcs (cf. gscwd39) + elevation-dependent weighting on all satellites.	DORISREPORT 5096 (04-Aug-2020)
gscwd41	gscwd40 + use DORIS/RINEX data for Jason-2 with Jason-2-T2L2-derived USO correction	IDSCC Email Dec. 8, 2020.
gscwd48	gscwd40 + (1)Fix problem with Tz & Scale in 2012 by eliminating SYPB at observation level (April 4 – July 1, 2012, Bad data period not previously accounted for); (2) Fix data editing on SPOT-4, and apply modified Cr = 0.988.	Submitted April 2, 2021.

Summary

- The GSC Analysis Center has submitted a solution for ITRF2020. The preferred solution at present is gscwd48 (1993 to 2020).

- Some outstanding questions remain on the proper handling of the SAA perturbations, especially in view of the fact nearly all the DORIS satellites are affected by this phenomenon to different degrees.

- Sentinel-3A processed through the end of 2020, but a problem in the GEODYN attitude model for Sentinel-3 prevented its inclusion in ITRF2020.

- We congratulate our colleague Despina Pavlis on her retirement and wish her good luck in her further journeys; We wish Alexandre Belli good luck in his new postdoc at NOAA (as of Jan 2021).