Processing Improvements for the GSC AC

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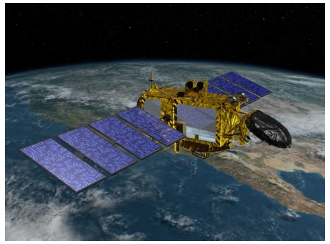

2026 IDS Workshop

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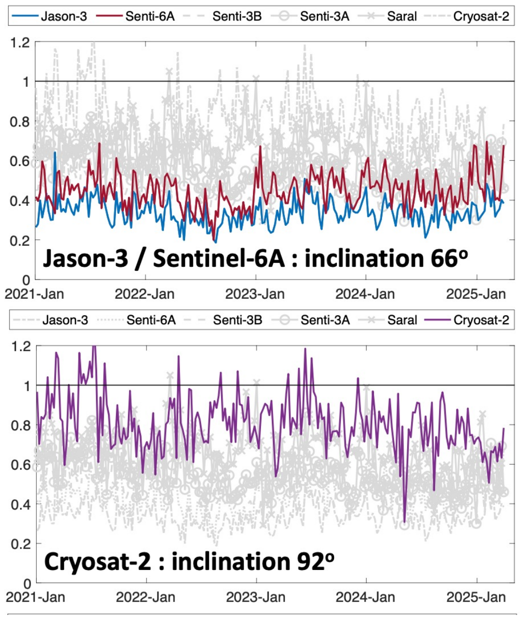
Summary of Recent SINEX Submissions Post ITRF2020

Series	Description	Comment
gscwd60	SINEX series for the contribution to ITRF2020-u2024. Use COSTG-FSM + the low degree terms (C_{20}, C_{21}, C_{22}, S_{21}, S_{22}, & C_{30}) from SLR.	Delivered 2021-2024 2025-02-25 for ITRF2020-u2024.
gscwd61	GOT5.5/GOT5.6 ocean tide model (Ray, 2025), replacing the prior model, GOT4.10c.	First Delivery 2025-08-16.
gscwd62	Same as the gscwd61 SINEX series, but the satellite weights in the weekly combinations are replaced with those determined by Le Bail et al. (2025), based on VCE.	First Delivery 2025-12-03. (2021-2025). Used for contribution to ITRF2020-u2025.
gscwd63	Same as the gscwd62 SINEX series, but adopt DPOD2020_052 as a priori, + minor OLOAD fixes. (*Two versions with & without pole-rate parameters*)	First Delivery 2026-05-29. (2021-2026.0)
gscwd64	Same as gscwd63, but adjust LOD. No pole-rate parameters.	First Delivery 2026-06-11 (2021-2026.0)

Sinex series gscwd62

"Strategies for combining mono-satellite DORIS solutions"
Le Bail, K., Lemoine F., Moreaux G., Chinn, D.
IAG Assembly Rimini, Italy (2025).
K. Le Bail (Chalmers Univ) used CATREF to combine single-satellite solutions with VCE.
Thus we obtain a more optimum set of weights, replacing the weights determined from an ad-hoc method.

Weights	Prior weights (gscwd60, gscwd61)	CATREF	CATREF w./out SAA stations
Cryosat-2	12.755	0.810	0.861
Jason-3	13.500	0.340	0.372
Saral	17.000	0.669	0.690
Sentinel-3A	13.600	0.545	0.637
Sentinel-3B	13.700	0.500	0.616
Sentinel-6A	17.400	0.446	0.469

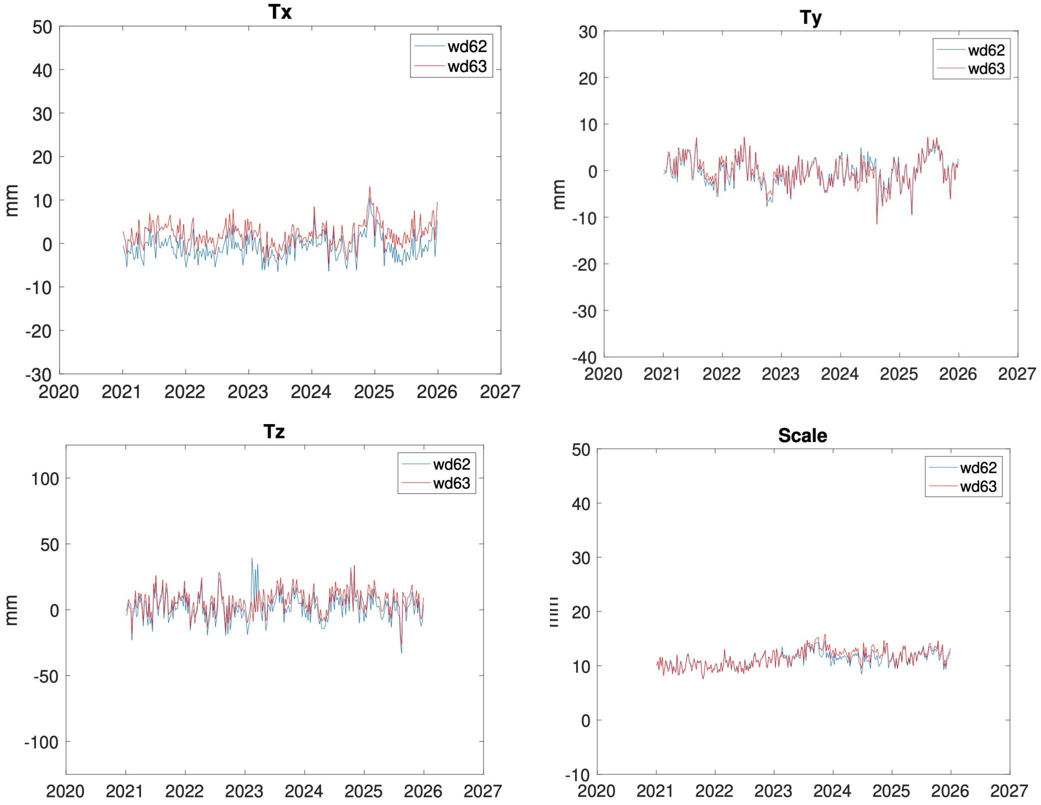


→ The big surprise of the study was that the highest relative weights were assigned to Cryosat-2 & Saral. The lowest weight was assigned to Jason-3 by (2– 2.5 X). Sentinel-6A was down weighted also. The results suggest a systematic source of error renders the Jason-3 contribution less compatible with that of the other satellites. *SAA effect or other modelling error*?

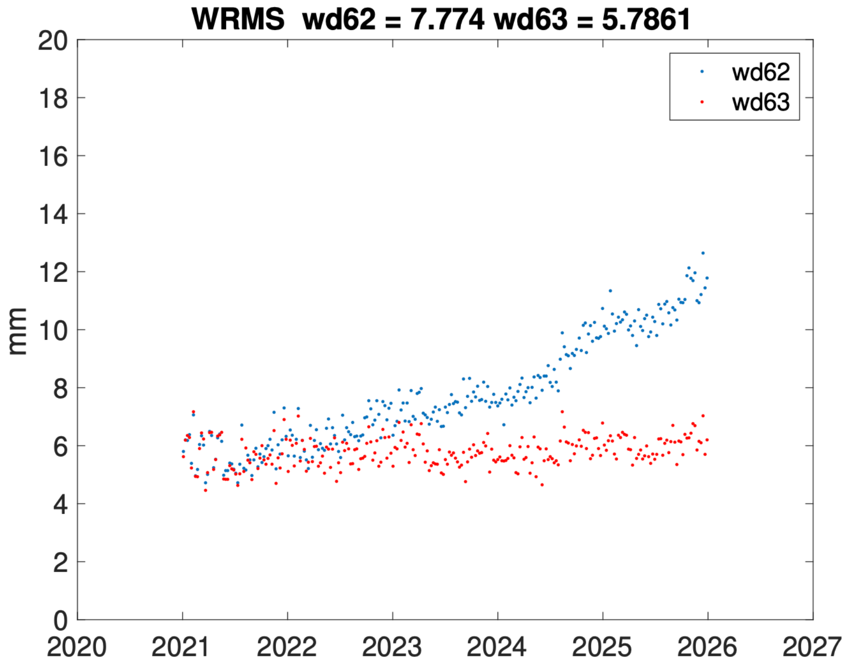
→ Only minor improvements in WRMS due to the new weights.(Wd61 vs. wd62), but this might be due to using an older DPOD2020 solution as reference.

Sinex series gscwd63 (1)

The primary difference with this series was the adoption of the new DPOD2020 a priori (dpod2020_052).



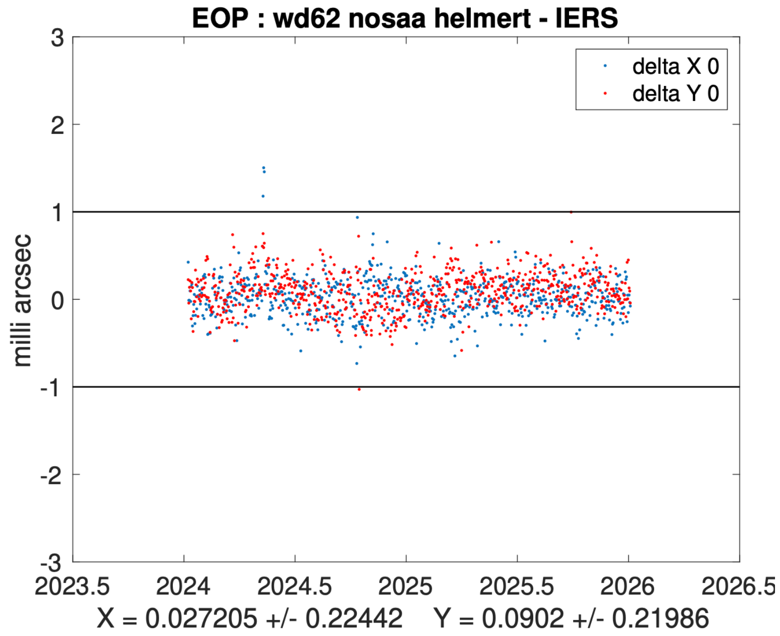
No significant change in Helmert parameters;
Some Tz outliers removed in wd63.



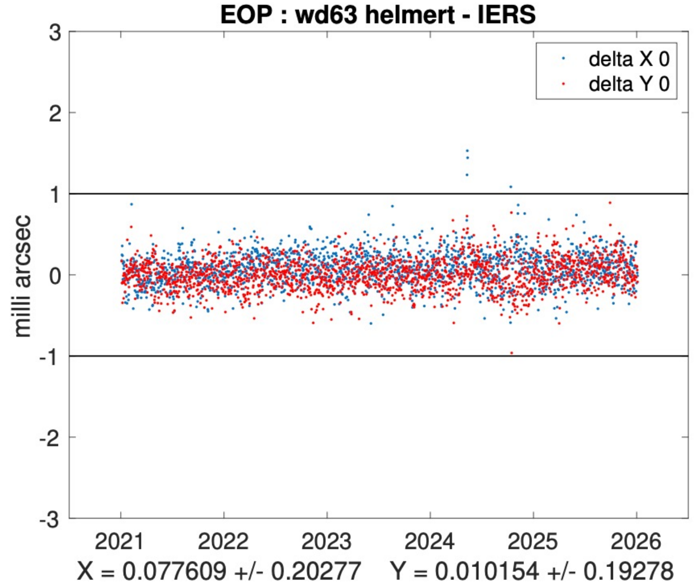
WRMS computation excludes SAA stations.
The 3-D repeatability for gscwd63 is ~5.79 mm for 2021.0-2026.0

EOP (Px, Py): wd62 vs wd63

wd62 series



wd63 series

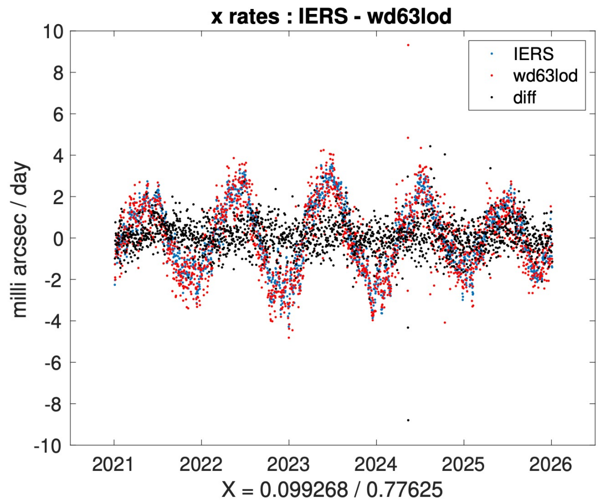


<u>Wd62</u>: Std. Dev of the Differences with IERS C04 are 224 μas for Xp and 220 μas for Yp.

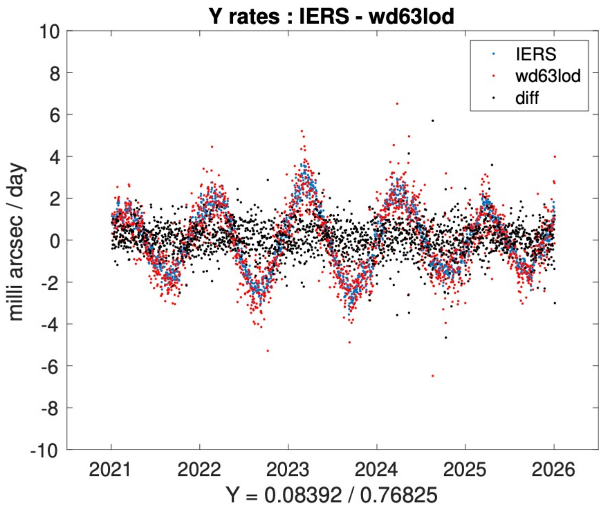
<u>Wd63</u>: Std. Dev of the Differences with IERS C04 are 203 μas for Xp and 193 μas for Yp.
→ Improvement of 10% in quality of EOP due to improved station coordinate a priori.

EOP (Pole-rate & Px, Py): test solution, wd63lod

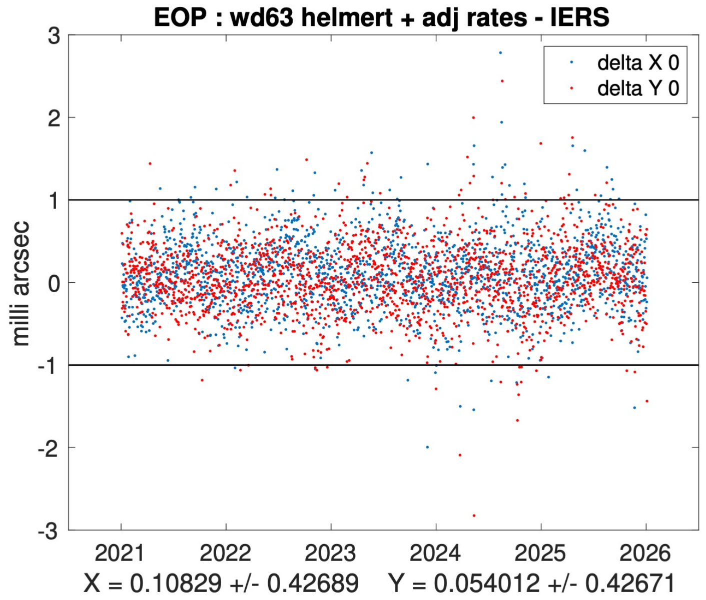
dPx/dt (wd63lod)



dPy/dt (wd63lod)



wd63lod Px, Py diff w. IERSC04



- In theory it is possible to solve for pole rates with DORIS data, …. However….

Wd63: Std. Dev of the Differences with IERS C04 are 426 μas for Xp and 427 μas for Yp.

→ **Adjustment of pole-rate parameters degrades Xp, Yp, by a factor of ~2X.**

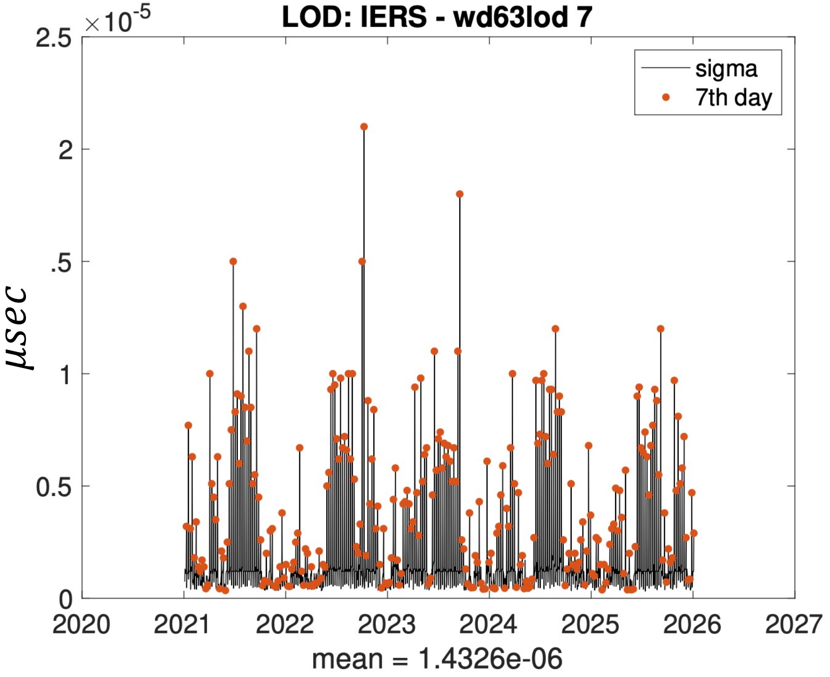
(as mentioned previously by Pascal Willis, and by Erricos Pavlis w.r.t. adjusting pole-rates with SLR data).

EOP (Adjust LOD) (1)

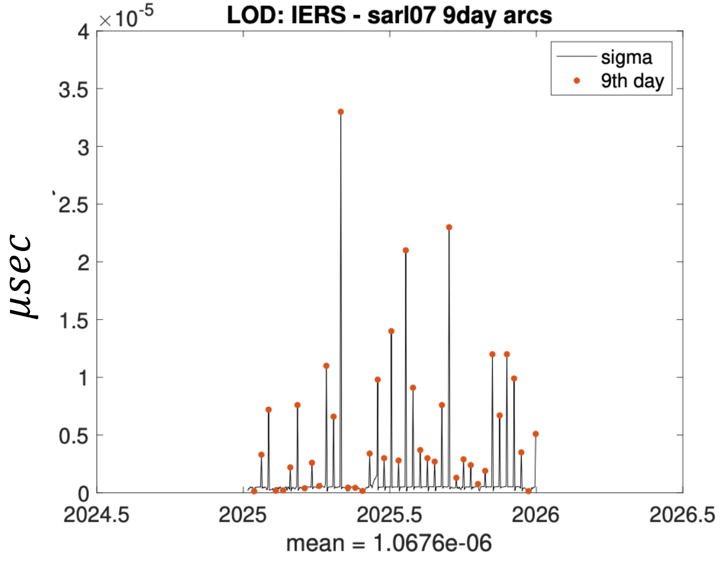
<u>Procedures for Adjusting LOD</u>:

1. Partial derivatives present in normal equations, but have not been rewritten into SINEX.
2. Modified “sinex_write” program to accommodate Pole-rate and LOD parameters.
3. GEODYN a-priori is modified by removal of zonal_tides perturbations in LOD, following IERS conventions (*we use same subroutine as is used by the UMBC/JCET ILRS analysis center, conv_lod.f)*
4. The SINEX (NEQ format) now include the LOD parameter per day.

<u>Bad news</u>: LOD Sigmas, anomalous on last day of the week (day 7).



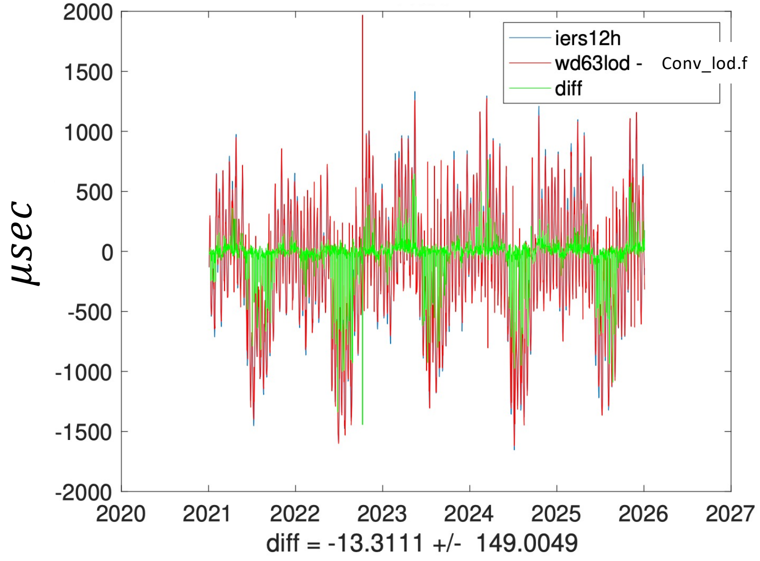
Test with 9-day arcs (Saral) instead of nominal 7-day arcs.



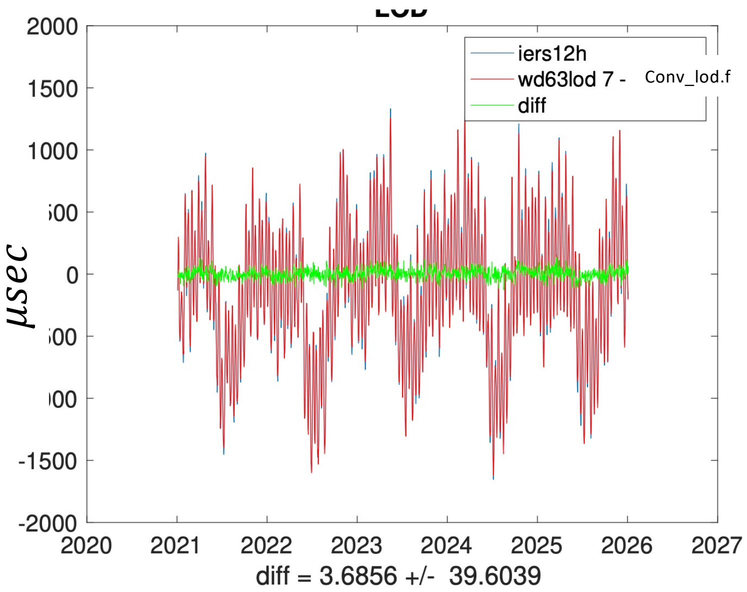
Anomalous sigmas occur on the 9th day (last day of the 9-day arcs). This suggests a problem in the GEODYN code – but we have not identified the root cause (yet).

EOP (Adjust LOD) (2)

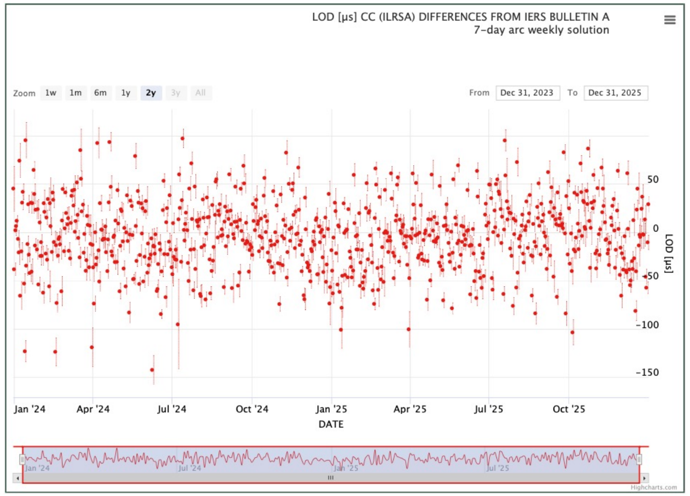
LOD Solution gscwd63lod (all)



LOD Solution gscwd63lod (edit 7th d)



ILRSA LOD Solution (2023-2025)
(differences with IERS C04)



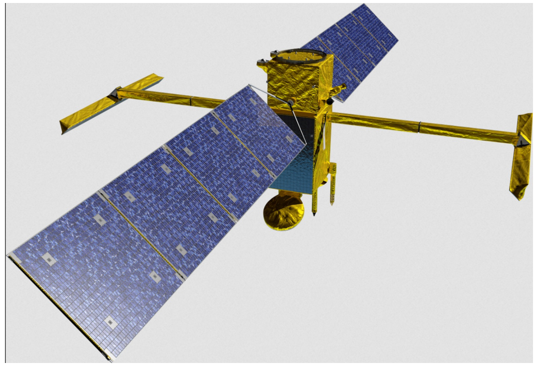
Considering all the data, the differences with the IERS C04 have a std. deviation of 149.0 μsec.

Eliminating day 7 of each week, the differences with the IERS C04 have a std. deviation of 39.6 μsec !

We compare with the v80 ILRSA solution for LOD (2023.0– 2026.0) which has a std. dev. of 35.9 μ sec.

→Therefore, if we can solve this “end-of-arc” problem in LOD, gsc will be able to supply a DORIS-based LOD solution, that is comparable to that supplied by the ILRS.

SWOT: Setup & Processing with GEODYN (1)



<u>Steps</u>:

1. Verify Implementation of SWOT attitude model in GEODYN, including orientation of solar arrays, and specification of yaw flips.
2. Obtain (body) quaternion data and integrate them into processing.
3. Compare analytical vs. external attitude to verify performance.
4. Analyze POD performance & computed empirical accelerations.

Examples of Gaps in Body Quaternions

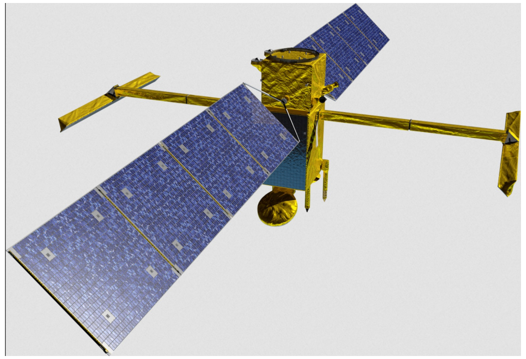
```
Gap =  (min)    11.4999999955762
    60334       0.924956608796    240125   221156.251
    60334       0.932942719907    240125   222326.251

Gap =  (min)    2.71666666259989
    60346       0.765917256944    240206   182255.251
    60346       0.767803831019    240206   182538.251

Gap =  (min)    160.466666668653
    60371       0.571021423611    240302   134216.251
    60371       0.682456608796    240302   162244.251

Gap =  (min)    21.9999999983702
    60395       0.290280682870    240326    65800.251
    60395       0.305558460648    240326    72000.251

Gap =  (min)    93.8833333400544
    60408       0.025604756944    240408     3652.251
    60408       0.090801516204    240408    21045.251

Gap =  (min)    25.4499999980908
    60416       0.780014479167    240416   184313.251
    60416       0.797688090278    240416   190840.251

Gap =  (min)    195.683333332418
    60428       0.209759849537    240428    50203.251
    60428       0.345651053241    240428    81744.251

Gap =  (min)    61.6000000038184
    60441       0.454864016204    240511   105500.251
    60441       0.497641793981    240511   115636.251
```

- Since there can be long gaps in the quaternion data, it is essential that the implementation of the analytical (GEODYN) attitude subroutine for SWOT be robust.
- We implemented the subroutine to use information derived from the "swoatt.txt" which specifies solar panel rotation times, and the timing of yaw-flips.

Examples of GEODYN inputs for SWOT POD runs

```
TATBIA          2217301      330.2
TATBTM          2217301    231124230545.00240119090957.00
TATBIA          2217301      348.2
TATBTM          2217301    240119090957.00240127174753.00
TATBIA          2217301      360.2
TATBTM          2217301    240127174753.00240130072740.00
TATBIA          2217301        0.2
TATBTM          2217301    240130072740.00240130075026.00
TATBIA          2217301        0.2
TATBTM          2217301    240130075026.00240202004225.00
TATBIA          2217301      -11.8
TATBTM          2217301    240202004225.00240210110553.00
TATBIA          2217301      -29.8
TATBTM          2217301    240210110553.00240405085355.00
TATBIA          2217301      -11.8
TATBTM          2217301    240405085355.00240414053359.00
TATBIA          2217301        0.2
TATBTM          2217301    240414053359.00240417020541.00
```

SWOT: Setup & Processing with GEODYN (2)



Additional Considerations

- Due to large & complicated shape, → Arclengths = 1 – 3.5 d.
- We explicitly delete data around the time of the solar panel transitions, since the CoM changes rapidly.
- We use CNES-specified macromodel (DORISSatelliteModels.pdf) and offset parameters.
- We adjust along-track, cross-track OPRs, and like on S6A, an along-track constant accel (several per arc , per 18-24 hrs); Therefore cd's are adjusted less frequently (per 6 hrs).
- No specific handling of possible SAA effect in SWOT data, for first analyses.

POD Results for 2024:
(elcut: 7 deg with elev. Dep weighting).

Average RMS (123 useful arcs)

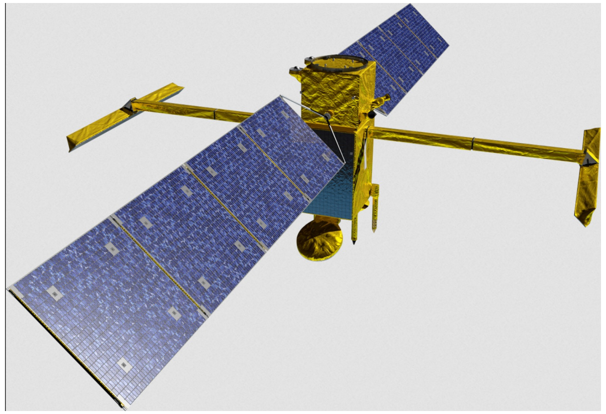
- With-exat: 0.704 cm (SLR); 0.3917 mm/s (DORIS).
- No-exat: 0.775 cm (SLR); 0.3919 mm/s (DORIS).

Anomalous arcs:

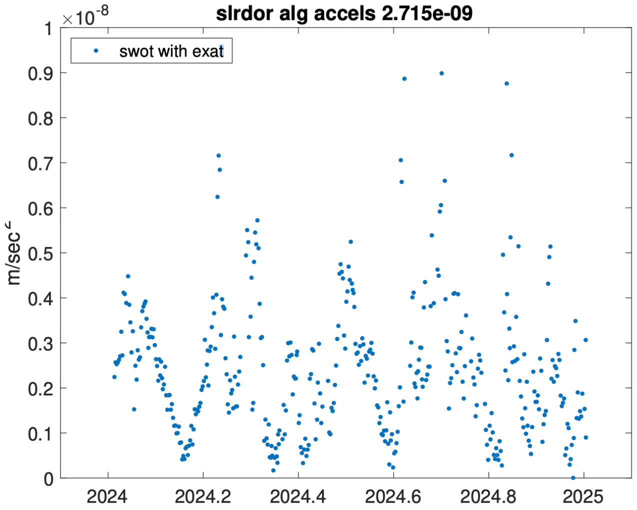
- 240510 12:00 -> 240512 00:00.
- 241009 12:00 -> 241011 13:30. (inexplicably high DORIS RMS).

Cr	Use Ext. Attitude	Along-track OPR Daily Amp (nm/s^2)		Along-track Constant (nm/s^2)		Cross-track OPR Daily Amp (nm/s^2)	
		Avg.	RMS	Avg.	RMS	Avg.	RMS
Cr=1	Yes	2.79	5.21	-2.23	3.73	3.16	7.19
Adjust	Yes	2.94	5.31	-2.24	3.74	2.86	7.03
Cr=0.98212	Yes	2.72	5.18	-2.24	3.74	2.71	6.95
Cr=0.98212	No	2.77	5.19	-2.31	4.26	2.70	7.00

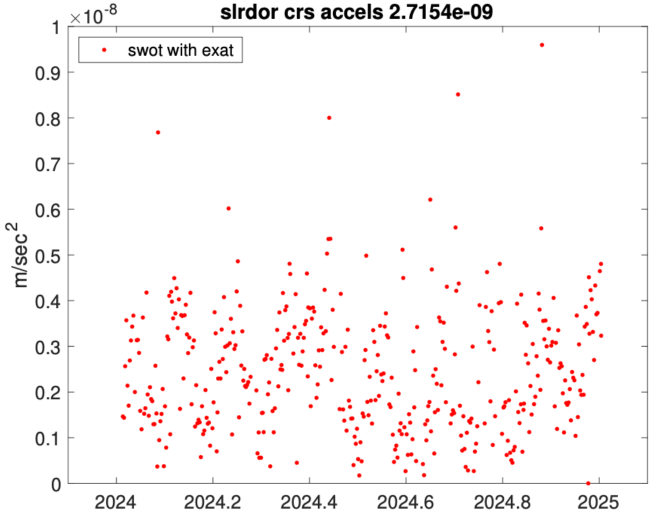
SWOT: Setup & Processing with GEODYN (3)



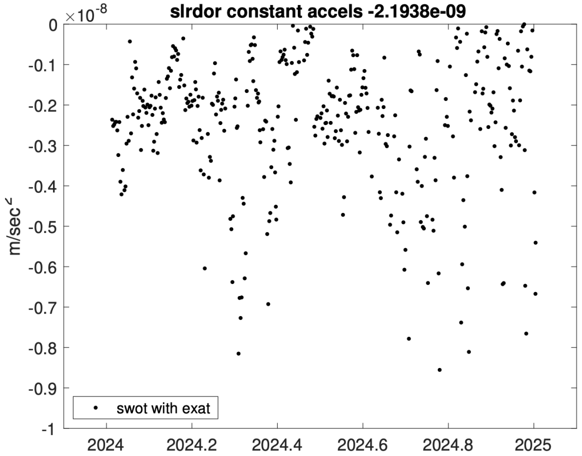
Along-track OPR Amplitudes



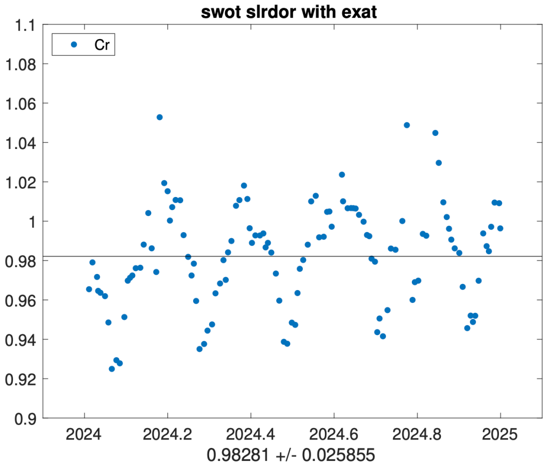
Cross-track OPR Amplitudes



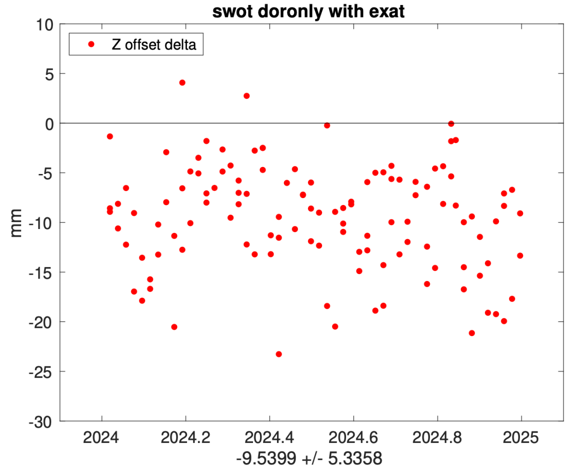
Along-track Constant Accel



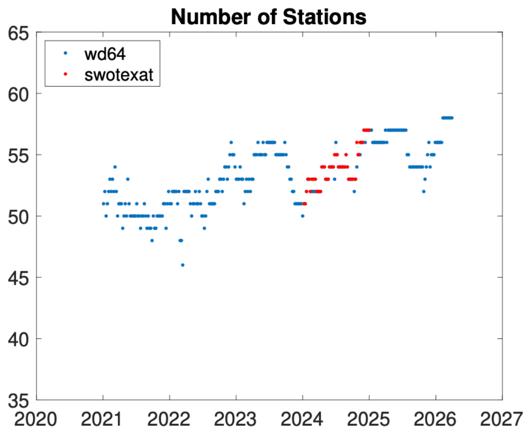
Cr Adjustment Per Arc

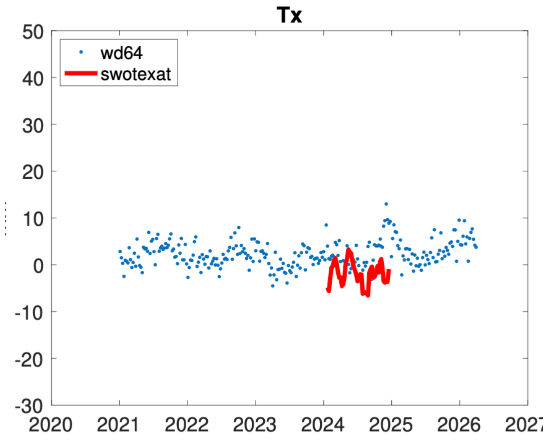


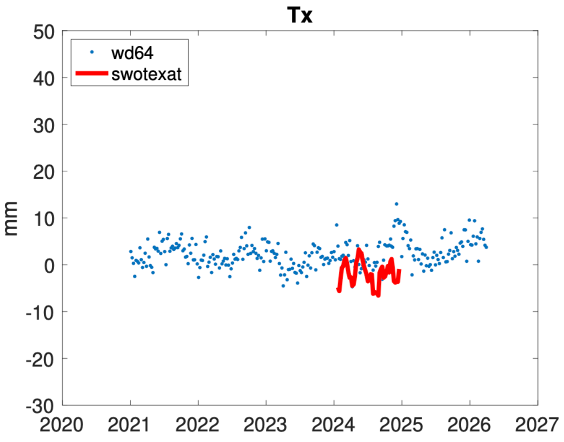
Z (Radial) offset adjustment

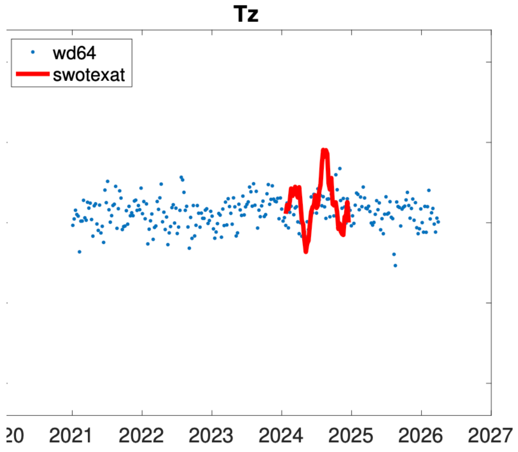


SWOT: Single-SINEX Results (2024-only)

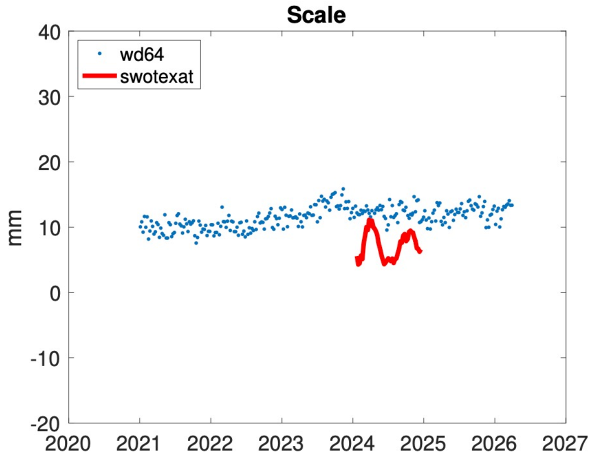


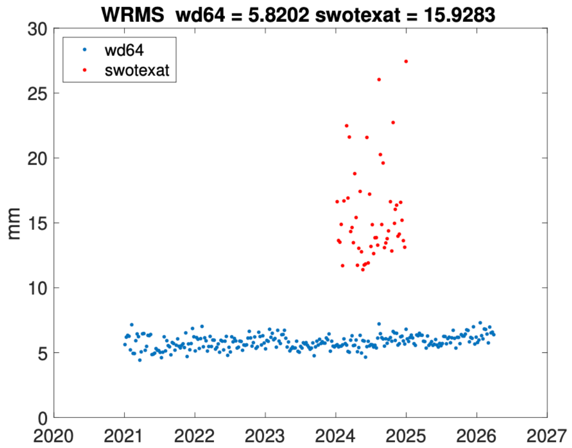






SWOT Helmert parameters shown as a five week running average.





Conclusions

- We have re-processed the DORIS data from 2021.0-2025.0 in support of the latest update of the ITRF2020 (ITRF2020-u2025), by submitting the gscwd62 SINEX series.

- We have updated our DORIS station coordinate a priori to DPOD2020_v052. With this a priori, we obtain solutions for Xp & Yp that have a std. deviation of the difference with IERS C04 of 203 & 193 μas.
- **The latest solutions (gscwd63 and later) have a 3D WRMS repeatability of 5.79 mm.**
- We have experimented with providing a solution for LOD. The results looking promising, but we still need to resolve a GEODYN problem in the calculation of the LOD partial derivatives for the last day of the 7-day data arcs.
- We have begun to process SWOT DORIS data with GEODYN. The initial POD results look good, but additional work is required:
  - → Use the solar array quaternions.
  - → Perform additional verifications on the quality of the POD.
  - → Understand why some arcs have inexplicably high RMS or anomalous Cr estimation.
  - → Complete the assessment of the SAA impact on SWOT DORIS data, and then update the POD modelling.

Acknowledgements: *D.D. Rowlands (NASA GSFC emeritus), for the implementation of the SWOT attitude model in GEODYN; K. Le Bail (Chalmers Univ.) for the CATREF/VCE results; J.B. Nicholas (NASA GSFC) for aid with GEODYN; G. Moreaux, IDSCC (CLS) for testing the different interim series and providing useful comments.*