



ESA's assessment of simulated Genesis GNSS, SLR, and DORIS data

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Overview

- This presentation provides an initial independent assessment of **DLR Genesis simulated GNSS and SLR observations** [1], and that of **CNES Genesis simulated DORIS observations** [2].
- The **main purpose of these datasets** is that they can be used to **help the development of multi-technique software to process the Genesis data**, allowing to test and validate the different software packages across analysis centres
- **GNSS simulated observations**
 - At first, an evaluation of the observation's residuals by keeping the orbit fixed to the ESA reference orbit
 - In a second step, by also estimating the orbit in a standard POD approach, we analyse the solar radiation pressure model differences, as well
- **SLR simulated observations**
 - At first, an evaluation of the observation's residuals by keeping the orbit fixed to the ESA reference orbit
 - Subsequently, an analysis of the SLR station range biases
- **DORIS simulated observations**
 - An evaluation of the observation's residuals by keeping the orbit fixed to the ESA reference orbit

[1] DLR/GSOC (2026). *Simulated GNSS observations for Genesis and ground network*, [Dataset], 14 July 2026.

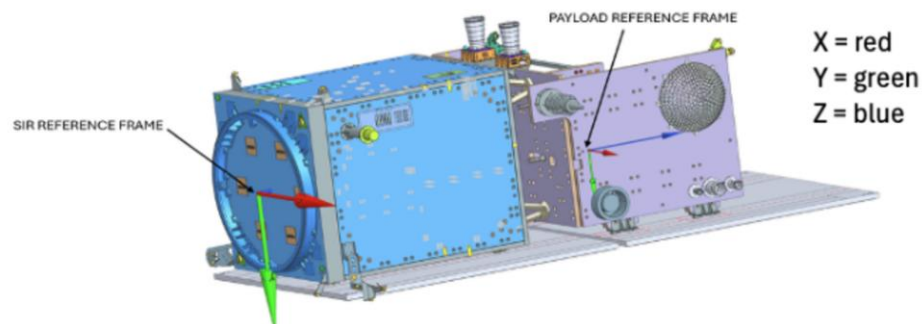
[2] CNES (2026). Context definition for DORIS/Genesis tests, [Dataset]. 24 June 2026

GNSS observations – Input Files and Processing Details

Input files

All satellite modelling follows Genesis System PDR

Type	File name
Genesis orbit (CoM)	genREF_yydd.sp3 (ESA reference orbit)
Genesis orbit (CoN)	ESA0GENFIN_yyyddd0000_01D_01M_ORB.SP3
Genesis attitude	genREF_yydd.att / Implemented Genesis Attitude Model (EPNS)
GNSS satellite orbits	COD00PSFIN_yyyddd0000_01D_05M_ORB.SP3
GNSS satellite clocks	COD00PSFIN_yyyddd0000_01D_30S_CLK.CLK_V2
GNSS satellite biases	COD00PSFIN_yyyddd0000_01D_01D_OSB.BIA
ERPs	COD00PSFIN_yyyddd0000_01D_01D_ERP.ERP
Galileo ANTEX	igs20_2408_GALext.atx1
GPS ANTEX	lmb20_30deg_260320.atx1
GPS ANTEX	gps3add_30deg_260331.atx1
Genesis nadir ANTEX	GEN_POD_NADIR_simtru.atx2
Genesis zenith ANTEX	GEN_POD_ZENITH_simtru.atx2
Genesis nadir RINEX	GENNvvINT_R_yyyddd0000_01D_30S_MO.crx.gz
Genesis zenith RINEX	GENZvvINT_R_yyyddd0000_01D_30S_MO.crx.gz



Processing

- **Software:** ESA Precise Navigation System (EPNS) 1.4.1

Models and Reference Frame

- ITRF2020-u2023 reference frame
- IERS2010 standards
- Gravity field: CNES GRGS.RL05MF (deg/or 120)
- Ocean tides: FES2022 (degree/order 50)
- Atmospheric gravity: AOD1B RL06

Observations

- Time span: 03/08/2025 – 11/08/2025
- Arc length: 24 h
- 300s sampling rate of GNSS observations

- Initially we ran a Float PPP, keeping the Genesis orbit fixed and estimating the receiver clock and phase ambiguities using both the Nadir and Zenith Antennas. CODE Final GNSS orbits, clocks, biases and extended GNSS ANTEX files have been adopted.

GPS-only solution							
SAT-ID	Antenna	Accepted Obs.	Rejected Obs.	Carrier-Phase Residuals [mm]		Code Residuals [m]	
				Mean	RMS	Mean	RMS
Genesis (GPS)	Zenith	7679	34	0.0	3.2	0.0	1.438
	Nadir	15061	78	0.0	3.9	0.0	1.549

- Considering the **overall RMS of code noise** applied in the simulation amounts to 0.6 m (GPS C1C), 0.7 m (GPS C2L), 0.2 m (GAL C1C and C5Q), our code residuals are **in good accord** as the RMS of the code noise for the ionosphere-free dual frequency combination is roughly three times higher.
- Considering the **overall RMS of phase noise** applied in the simulation ranges from about 1.3 to 1.8 mm for the individual signals, the carrier-phase residuals are also **within expectations**.
- In addition, **representative POD residuals obtained by DLR** for a nadir-only solution **align with the obtained results**.

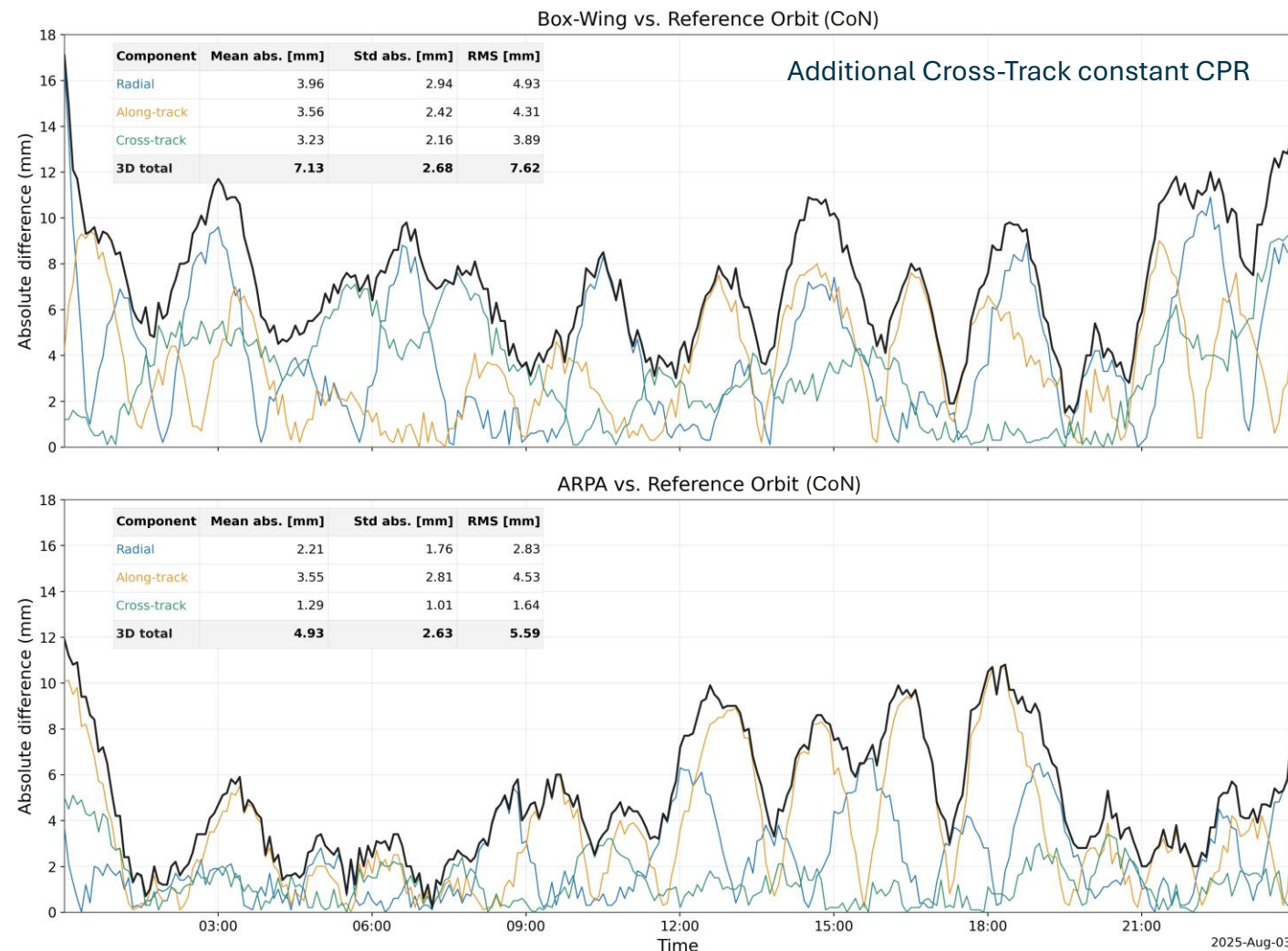
GNSS observations - Orbit estimation with Ray-Tracing and BW models

Complex geometry requires high-fidelity modelling of non-gravitational forces.

Simulations compare the commonly used box-wing (BW) Solar Radiation Pressure (SRP) model with ESA's ARPA ray-tracing approach.

While the reference orbit was created with the ARPA model, both the **Advanced Ray-Tracing modelling** and the precise Box-Wing model properly reproduce the major part of the non-gravitational effects.

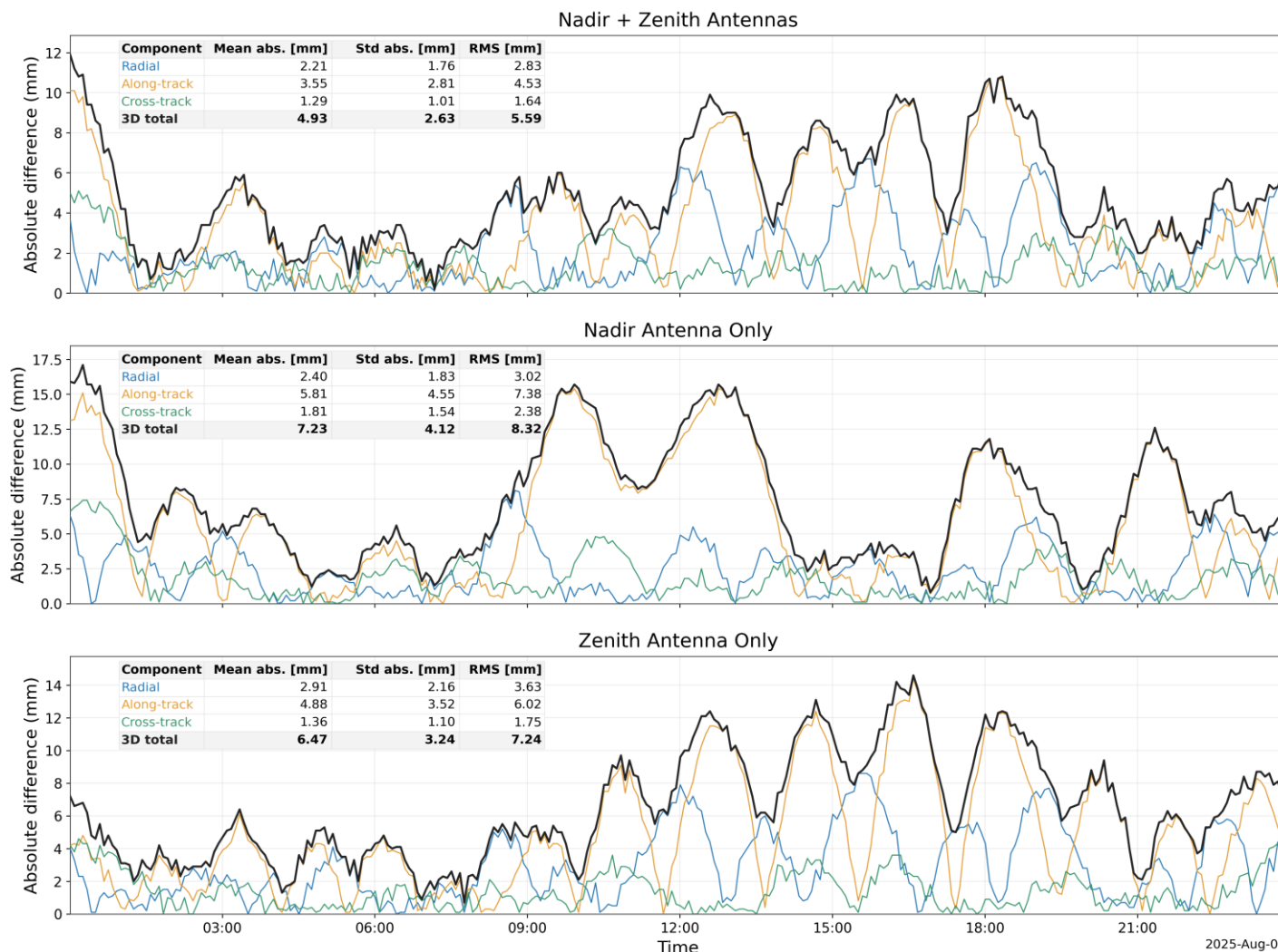
ESA plans to publish the Genesis Ray-Tracing model to support high-precision orbit determination and scientific exploitation of the Genesis data.



GNSS observations – Observations from either Nadir, Zenith or both antennas

Genesis estimated orbit solution (DoY 215, 2025)

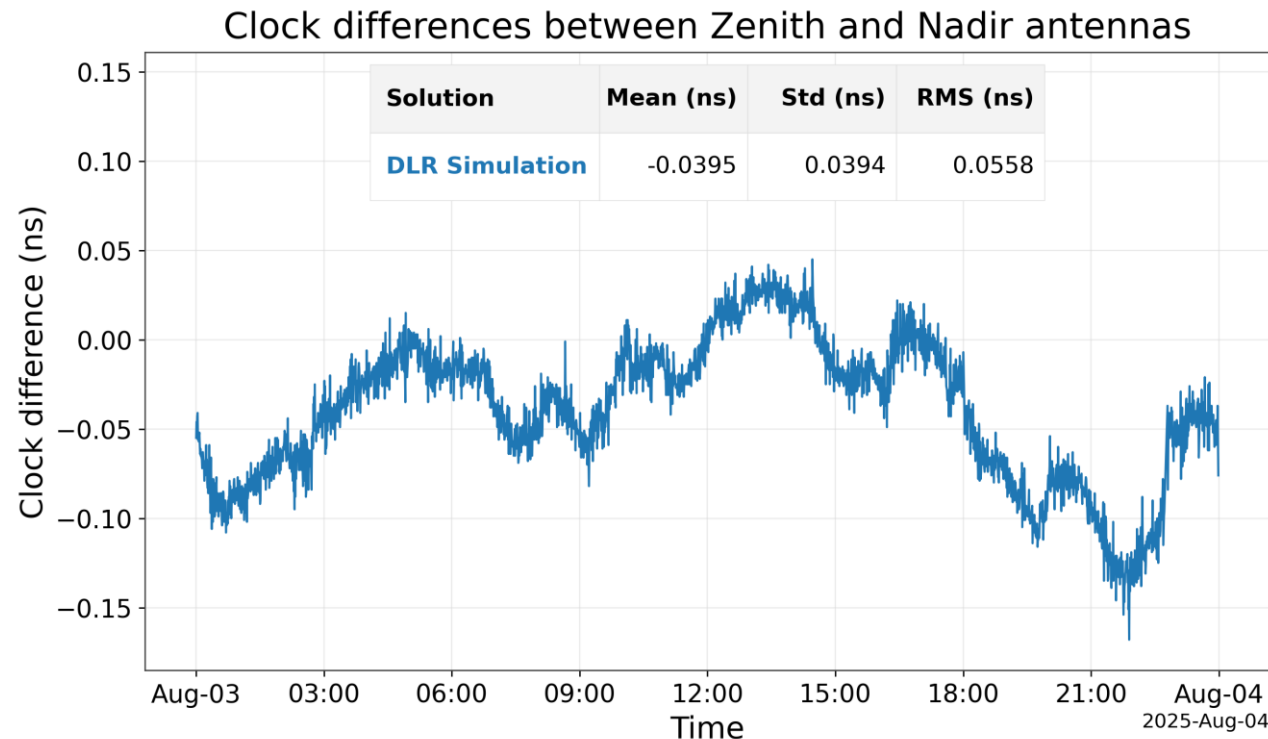
- The impact of using GPS and Galileo observations for either **only the nadir or zenith antenna**, as well as **its combination** is analysed comparing the resulting orbit against the **ESA reference orbit**.
- As expected, the combined Nadir and Zenith case leads to the best orbital agreement.
- The along-track component dominates the orbit differences in all three configurations, with the largest RMS in the nadir-only solution.



GNSS observations – GNSS Clock Bias Estimation

Genesis Float PPP solution

- In this case, our software estimates one clock per antenna per epoch, instead of a combined clock per satellite per epoch. Thus, we can compare how easy it would be to have a unique receiver clock bias by comparing how the different epoch clock biases diverge over 24h.
- The observed (~ 0.04 ns) mean value and standard deviation of the inter-antenna clock offset difference corresponds to roughly 1.7 cm position difference RMS, which should be further investigated



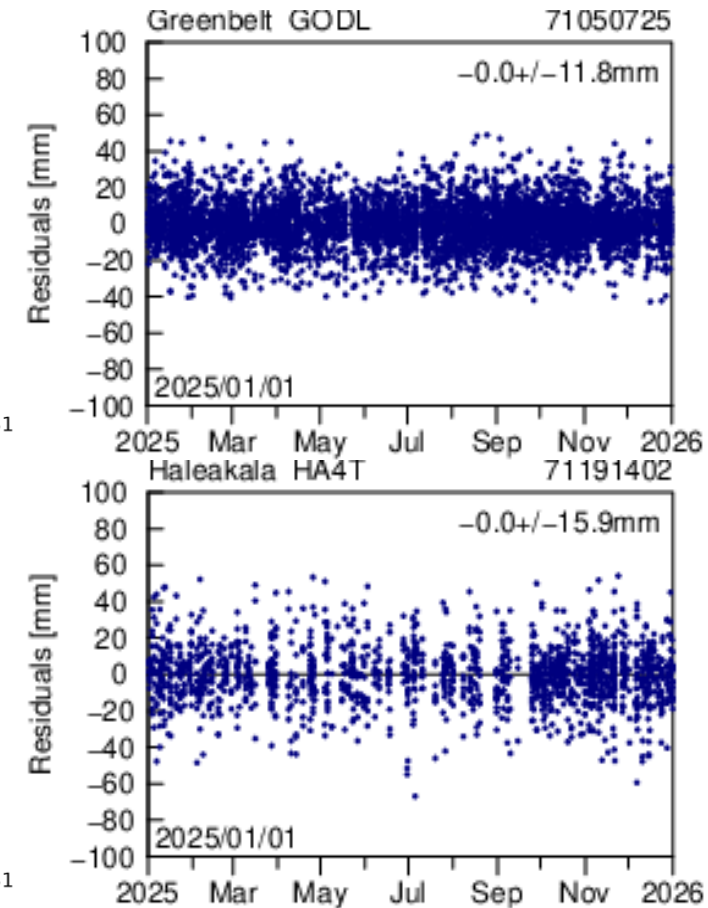
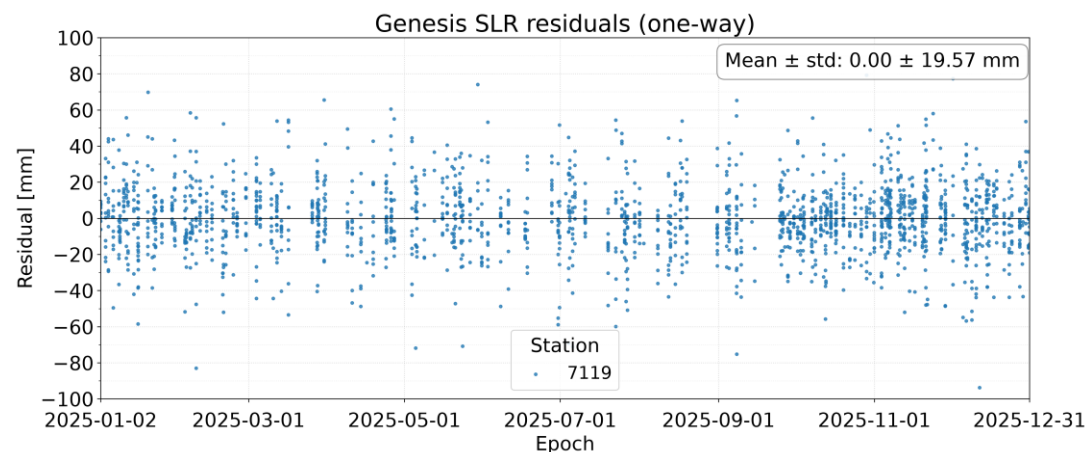
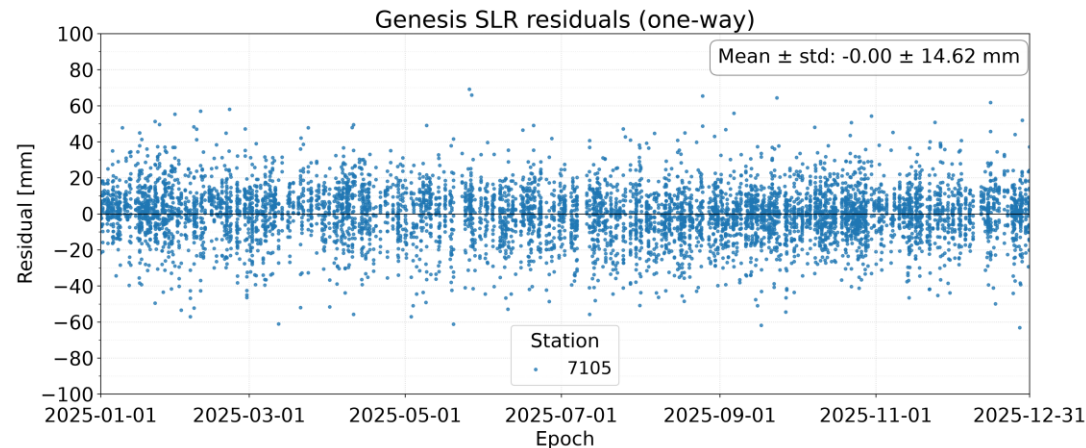
- The general standard deviation seems to be approximately 3 mm larger than the referenced DLR values, most probably due to small processing differences between ESA and DLR (e.g., ITRF Geocentre motion model handling).
- Thus, we would need to carefully compare the overall site coordinate modeling to trace down the cause of the observed differences in the residuals.



SLR observations - Genesis SLR residuals with fixed reference Genesis orbit

Comparison of one-way SLR residuals (complete 2025 dataset, Stations 7105 (GODL) and 7119 (HA4T))

- A more detailed analysis for stations 7105 (GODL) and 7119 (HA4T) shows some outliers which are not visible in DLR's reference plots



SLR observations - Genesis SLR Station Range Biases

Comparison of Station Range Biases

- Range Biases were estimated once per station, encompassing all available observations for the whole year 2025.
- The estimated range biases differ from the simulated values at a level of a few millimetres, which matches the overall consistency seen in the residuals.

Site	ID	DLR Simulated bias [mm]	ESA Estimated bias [mm]		Site	ID	DLR Simulated bias [mm]	ESA Estimated bias [mm]
1888	SVEL	7.0	5.6		7821	SHA2	-5.0	-8.1
1890	BADL	9.0	13.0		7825	STL3	4.0	9.7
7090	YARL	3.0	8.6		7839	GRZL	5.0	6.4
7105	GODL	-3.0	-0.3		7840	HERL	3.0	5.5
7110	MONL	1.0	5.1		7841	POT3	6.0	8.7
7119	HA4T	7.0	8.1		7845	GRSM	5.0	7.5
7237	CHAL	-4.0	-7.9		7941	MATM	-4.0	-2.9
7501	HARL	-8.0	-11.8		8834	WETL	1.0	2.7

GNSS/SLR observations – Orbit Transformation from Genesis CoM to CoN

Comparison of ESA and DLR orbits (DoY 215, 2025)

Input files

Type	File name
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Genesis orbit (CoM)	`genREF_yydddd.sp3`
Genesis orbit (CoN)	`ESA0GENFIN_yyyydddd0000_01D_01M_ORB.SP3`

Genesis Reference Orbit and Attitude as
of System Preliminary Design Review
available on the GSSC web portal



- ESA reconverted the reference orbits from Centre of Mass (CoM) to Centre of Network (CoN), as the reference orbit is defined in CoM.

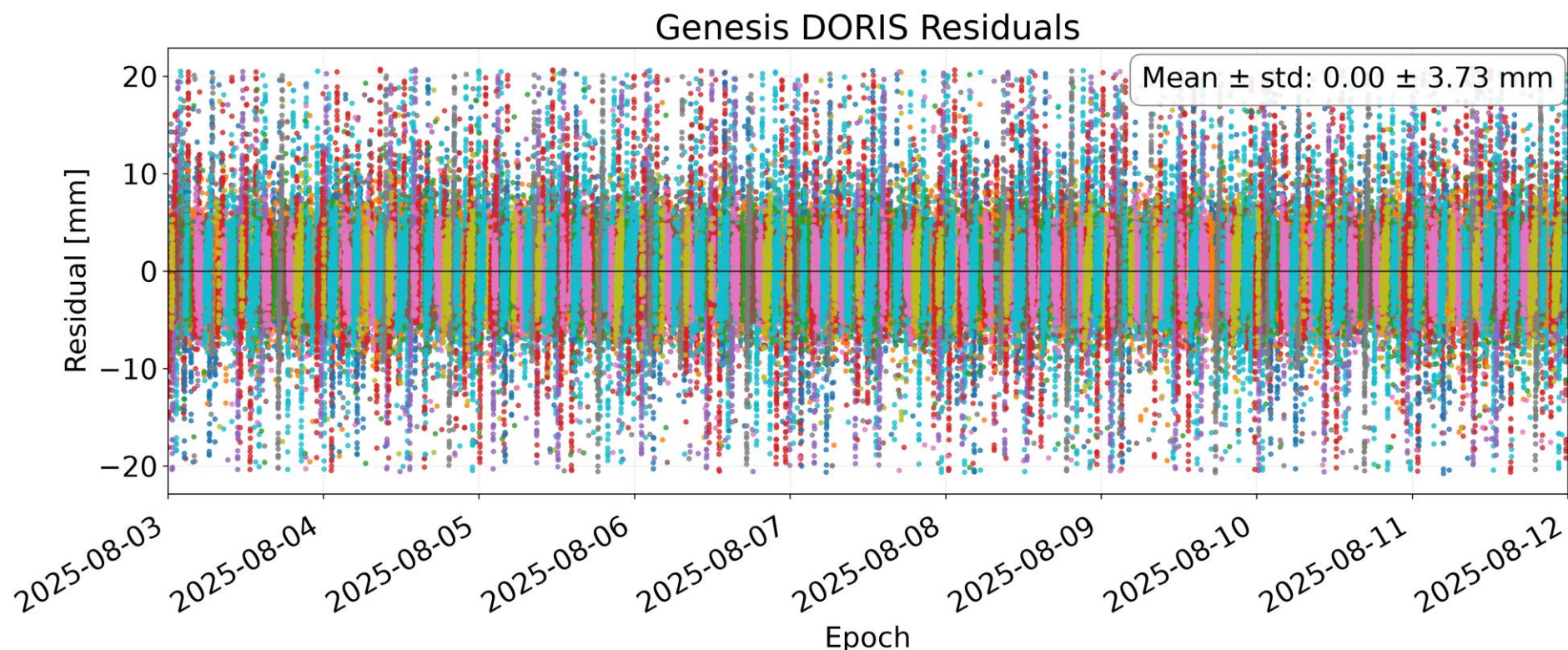
Summary of orbit comparisons for Genesis [All units in mm]

Comparison	Radial	Transverse	Cross	Total 3D RMS
ESA CoN vs. ESA CoM	3.7	3.7	2.1	5.6
DLR CoN vs. ESA CoM	5.3	5.3	3.0	8.1
ESA CoN vs. DLR CoN	3.0	3.0	1.9	4.6

- These difference between the CoN solutions suggest a need to compare, understand, and, optionally, harmonise the CoM to CoN transformation among the various analysis centers.
- We would recommend the inclusion of the DLR CoN orbits within the whole dataset for test and validation purposes.
- We expect these differences between the CoN solutions to affect in a similar magnitude the analyses where a fixed reference Genesis orbit was considered

- All analyses are based on the full period of **RUN 2**, August 3rd to 11th, 2025.
- Processing models follow Section 6 of the context definition for DORIS/Genesis Tests.
- Range Rate Biases were estimated once per station, per pass.

SAT ID	Accepted Obs.	Rejected Obs.	% Rejected Obs.
Genesis (DORIS)	262957	13285	4.8



- While the overall solution rejecting 4.8% of the initial data results in an orbital RMS below 4 mm, certain stations seem to behave differently:

STA ID	Accepted Observations	Rejected Observations	Mean [mm]	RMS [mm]
ADHC	14292	59	0.0	3.7
ASEB	6147	18	0.0	2.5
BEMB	89	1044	0.0	10.8
BETB	123	2	0.0	2.7
CADB	424	3	0.0	3.4
CIDB	8327	21	0.0	2.6
COBB	13676	38	0.0	2.4
CRRC	70	548	0.0	12.6
DIOB	95	644	0.0	10.3
DJIB	6158	108	0.0	5.9
EVEC	54	527	0.0	12.4
FUUC	6014	28	0.0	2.4
GAVC	55	392	0.0	10.1
GONC	9442	517	0.0	6.6
GRFB	88	944	0.0	11.7
HEMB	30	414	0.0	13.4
HROC	6056	22	0.0	2.5
JIWC	86	437	0.0	8.8
KEZC	12027	40	0.0	2.4
KIVC	9634	151	0.0	5.3
KOLB	3497	138	0.0	6.8
LAPB	6774	33	0.0	2.6
LICB	6749	23	0.0	2.3
MAIB	203	2	0.0	2.4
MAMC	5692	12	0.0	2.3

STA ID	Accepted Observations	Rejected Observations	Mean [mm]	RMS [mm]
MANB	415	1	0.0	2.5
MEUB	119	1175	0.0	13.0
MIAB	45	388	0.0	10.3
MLAC	4259	14	0.0	2.5
MSPB	75	1281	0.0	10.3
NOXC	3348	10	0.0	2.3
OWGC	12327	37	0.0	2.6
PAUB	6392	9	0.0	2.3
PDOC	347	4	0.0	2.9
REVC	7710	907	0.0	7.4
RIMC	355	2	0.0	2.8
RISC	12945	37	0.0	2.1
ROBC	86	667	0.0	12.3
SCSC	8126	24	0.0	2.5
SJVC	7718	87	0.0	5.1
SOFC	40	279	0.0	9.6
STKC	8184	36	0.0	2.4
SVBC	16805	65	0.0	2.6
SYQB	15498	91	0.0	4.2
THUB	87	1378	0.0	12.6
TLSB	8755	16	0.0	2.5
TRJB	9764	21	0.0	2.4
ULAC	3650	533	0.0	7.6
YASB	6164	14	0.0	2.8
YEMB	13941	44	0.0	3.1

12.3	Station being rejected
8.1	Station with degraded results

- It does not seem to be an issue with the specific station coordinate realisation between ESA and CNES based on ANNEX 3
- Issue currently under investigation

Conclusions

- The **main conclusion** obtained after working with these datasets is that **the simulated data is of excellent quality** and as such is **ideally suited to assist the different analysis centres to develop, test and validate their software towards Genesis**.
- Regarding the data results, **GNSS, SLR and DORIS analyses** (residuals-based and orbit determination) **show very good agreement with reality**, with differences at the centimetre if not millimetre level.
- The differences between the different CoN orbits suggest **a need to compare, understand, and, optionally, harmonise** the CoM to CoN transformation among the various analysis centers.
- The differences in the estimated clocks for the zenith and nadir GNSS antennas are significant.
- SLR residuals are slightly higher (~3 mm) than DLR's results, but most probably due to Geocentre motion modelling differences between the simulation and the ESA processing.
- The DORIS data still requires some further analysis to understand why certain stations are behaving differently.

So, this simulation is a great achievement for the Genesis project!



EUROPEAN SPACE AGENCY

THANK YOU!

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