A joint SLR processing between Sentinel-6 and spherical geodetic satellites

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Motivation

Our group (CNES/CLS):

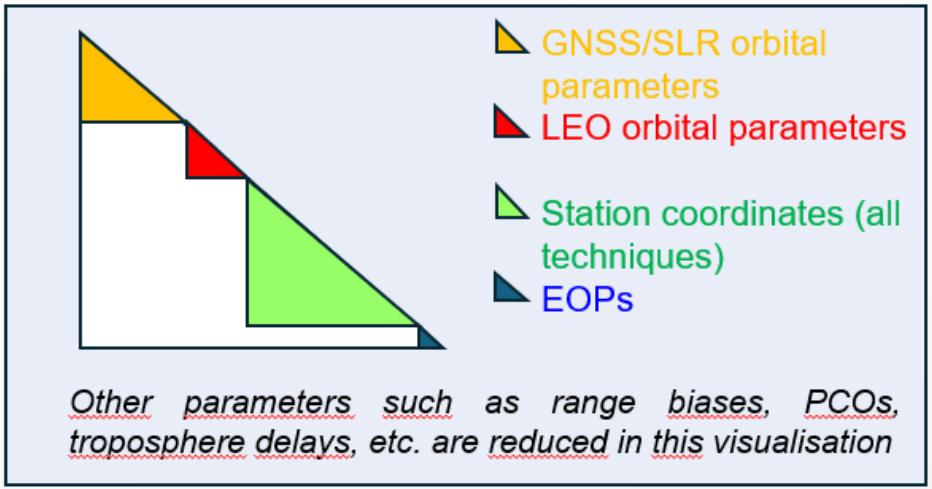
- Holds IDS (DORIS), IGS (GNSS) and ILRS (SLR) Analysis Centers
- Uses a single POD software (GINS from CNES)
- Contributes to the POD of altimetric satellites and is involved in the Copernicus Precise Orbit Determination (CPOD) WG

In view of the forthcoming ESA GENESIS mission with the four space geodetic techniques onboard, we began a multi-technique project by processing Sentinel-6 data, since its platform is equipped with three (DORIS, GNSS, SLR) out of the four techniques. The idea is to:

1) Be prepared for the processing of future GENESIS observations.
2) Assess the benefits of a multi-technique space mission (space tie) to TRF realizations.
3) Asses the benefits of the inclusion of LEO satellites into the classical IGS/ILRS solutions.

Joint processing of Sentinel-6 observations

1) We do either a single multi-technique processing…
2) …or a technique-specific processing with the same models, initial state vector, arc length, software, etc. and perform a combination of the resulting NEQs.



Advantages:

- Real « space tie »
- Correlations between station coordinates of different techniques available thanks to LEO observations → No need for constraints
- All techniques will benefit from each other's strengths

Possible experiments

	Experiment	Classical / No LEO	Classical + LEO
1 technique	GNSS (ground-only)	**IGS contribution**	
	SLR (spherical satellites)	**ILRS contribution**	
	DORIS		**IDS contribution**
	GNSS + LEO		**(*)**
	SLR + LEO		**THIS PRESENTATION**
2 techniques	SLR + GNSS + LEO		In progress
	DORIS + GNSS + LEO		In progress
3 techniques	GNSS + SLR + DORIS + LEO		In progress

What is the impact of LEO observations on the individual technique solutions? And in particular, on the SLR solution for the ILRS? (station coordinates, EOPs, geocenter motion, scale, range biases, etc.)

(*) Work presented by Sylvain Loyer during the IGS Workshop, July 2024

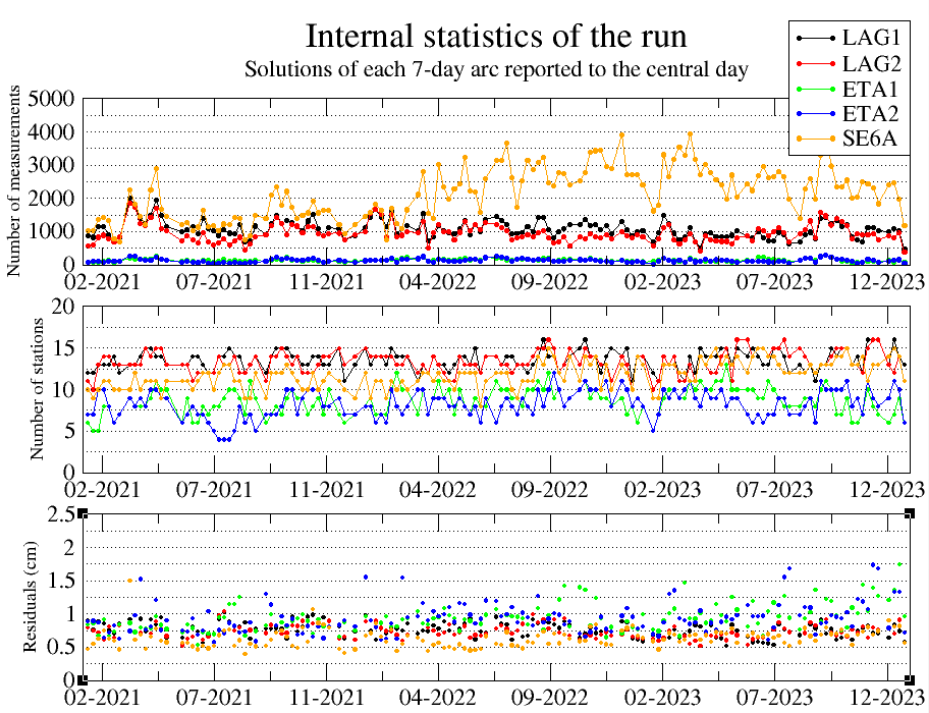
How to evaluate the impact of Sentinel-6 on the ILRS solution

	CNES solution for the ILRS	CNES solution for the ILRS + Sentinel-6
Satellite(s)	Spherical satellites (Lageos and Etalon)	Spherical satellites + Sentinel-6
Type of solution	Weekly	
Arc length	7 days	
Network	Core sites	
Time span	3 years (2021, 2022 and 2023)	
Measurements	All SLR Normal Points available	
Elevation angle cutoff	12 degrees	
Weighting	Station-dependent Same weighting for LAG1, LAG2 and S6 ETA1 and ETA2 are down-weighted	
Estimates *(loosely constrained)*	Station coordinates (apriori SLRF2020) ERPs (apriori IERS C04) Range biases for some stations (according to DHF)	Station coordinates (apriori SLRF2020) ERPs (apriori IERS C04) Range biases for all stations for S6 (apriori Lageos biases)
NNR/NNT	No	

Parametrisation of spherical satellites vs. Sentinel-6

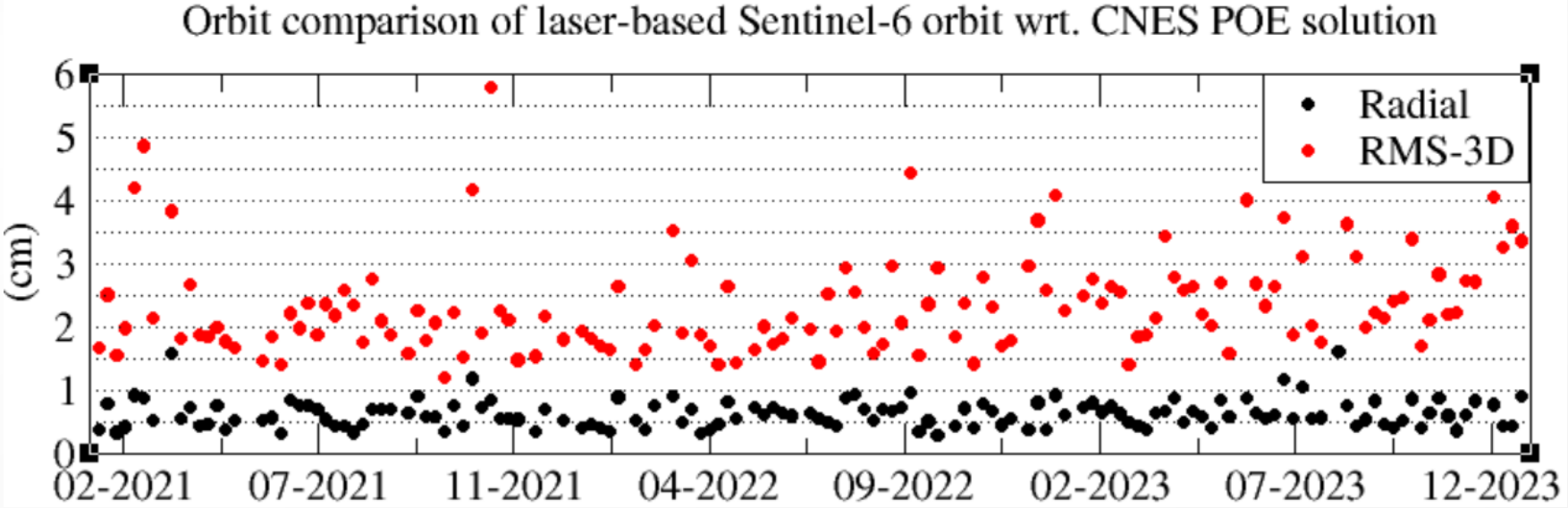
	Spherical satellites	Sentinel-6
Geopotential	CNES_GRGS.RL05MF (no degree 1)	
Tidal forces	Solid Earth tides: IERS 2010 convention Ocean tides: FES2014 Ocean pole tides: Desai 2002 Atmospheric tides: Ray Ponte	
Troposphere	Mendes-Pavlis	
Atmospheric pressure	-	RLO6_GLOBAL
Orbital parameters	Initial state vector (6 satellite elements for each arc)	
SRP	Direct and albedo radiation Macromodel (apriori) and empirical parameters	
Empirical parameters	Constant and OPR along & cross-track (one set per arc)	Constant and OPR along & cross-track Atmospheric drag (one set per day)
Measurement corrections	Center of mass/phase, range and time biases (according to DHF)	Center of mass/phase
Attitude	-	Quaternions

Internal statistics



- Sentinel-6 has more measurements available than Lageos-1 & -2 and Etalon-1 & -2.
- Still, less stations emit pulses towards Sentinel-6 than Lageos-1 & -2.
- The Sentinel-6 RMS fit of the residuals is the lowest (~5 mm) due to its good parametrization and because we estimate a range bias for every station.

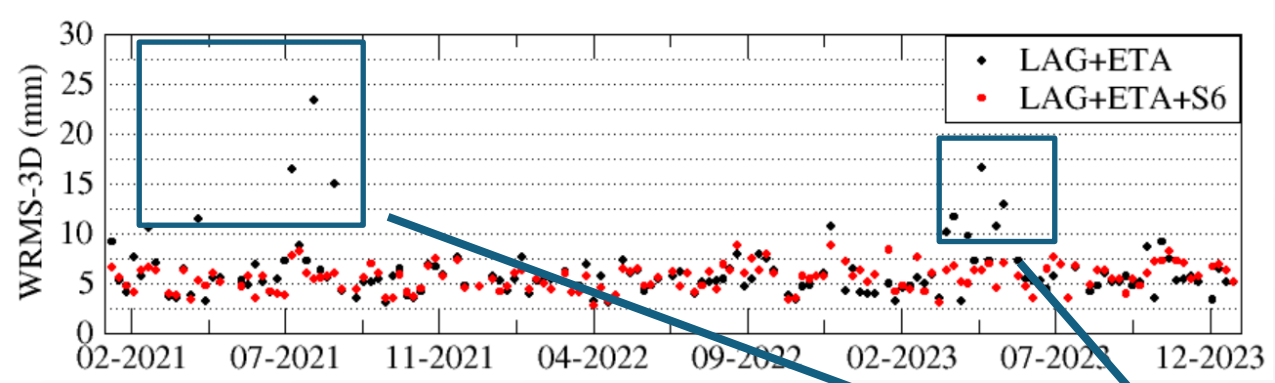
Orbit quality



Radial (cm)	**0.64 +/- 0.22**
3D-RMS (cm)	**2.38 +/- 0.81**

Could perfectly qualify for the CPOD combination

Station coordinates wrt. ITRF2020



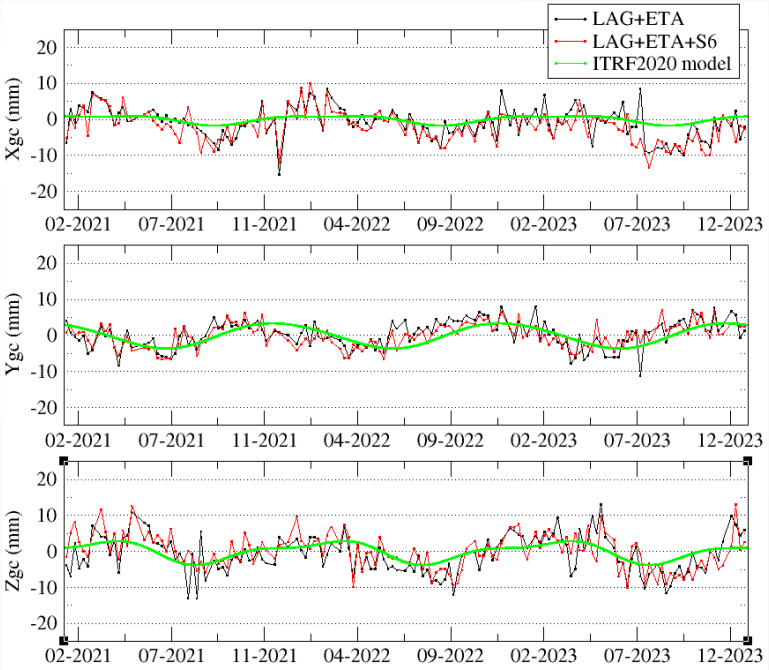
The inclusion of Sentinel-6 does not significantly affect the station network geometry (relatively to ITRF2020) for most of the time.

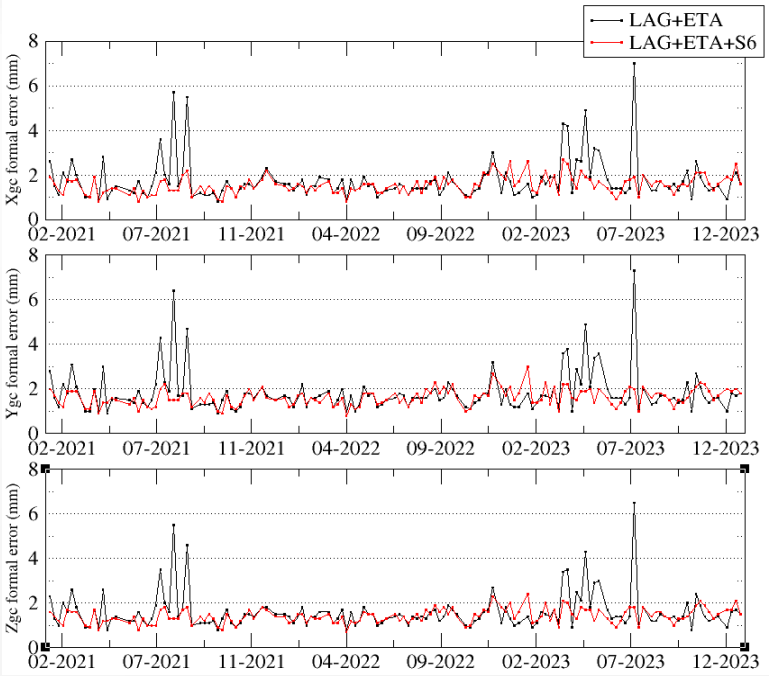
	LAG+ETA	LAG+ETA+S6
WRMS-E (mm)	5.47 +/- 3.69	4.60 +/- 1.51
WRMS-N (mm)	5.70 +/- 3.65	5.15 +/- 1.73
WRMS-U (mm)	5.51 +/- 1.77	5.38 +/- 1.53
WRMS-3D (mm)	6.22 +/- 3.21	5.57 +/- 1.29

However, it improves significantly the outliers of the Lageos and Etalon-only solution due to a better observability.

This translates into better WRMS and STD in general.

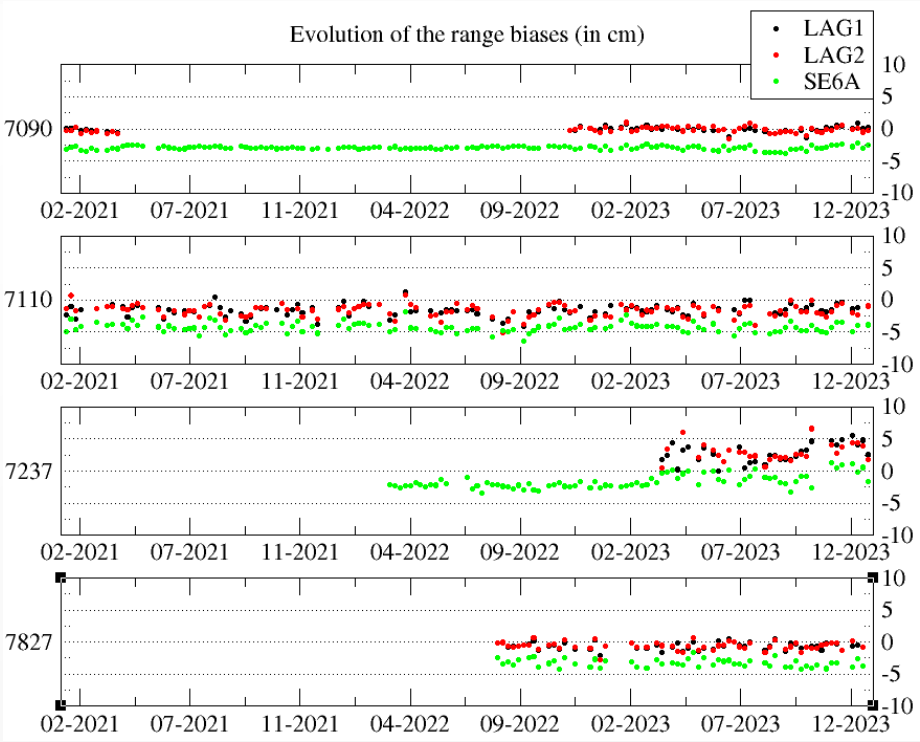
Geocenter motion





The inclusion of Sentinel-6 doesn't degrade the observation of the geocenter. If anything, it helps getting rid of outliers by improving the general observability, as it happened with the station coordinates residuals.

Range biases



For Sentinel-6, a range bias is estimated for every station if measurements are available, whereas for the spherical satellites, a bias is estimated only if it's not to be found in the DHF for the given period.

With this in mind, a simple comparison of the range biases observed for 4 stations (7090, 7110, 7237, 7827) between both Lageos and Sentinel-6 has been done.

An offset of ~2.5 cm can be found in the estimation of all these biases between the Lageos and Sentinel-6, which is a bit concerning, specially knowing than the formal errors are slightly lower for Sentinel-6 biases.

To be investigated…

Conclusions & Perspectives

We started to investigate space ties using unique software for all techniques:
- Our processing allows the computation of single & multi-technique solutions.
- Solutions can be provided in SINEX format to allow collaboration with other teams.

First results show that the inclusion of Sentinel-6A in typical SLR solutions for the ILRS:
- Doesn’t significantly affect the geometry of the ILRS ground network. In fact, it helps when the observability of Lageos and Etalon satellites is poor, ending up with a neater solution in general.
- Sentinel-6 measurement residuals and orbit (SLR pure) are of very good quality.

Future ILRS/ITRF products should benefit from the use of LEO SLR observations.

Future work will consist of:
- Combining two and three techniques. For example, perform a NEQ combination of GNSS + SLR + LEO, where the LEO orbit and pole will be strongly constraint by GNSS and assess the impact on the SLR network solution.
- Investigate the range biases difference between Lageos and Sentinel-6.
- Include more LEO satellites and be prepared for GEODESIS.