

Geodetic datum realization using SLR-GNSS co-location onboard Galileo and GLONASS

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Galileo orbit determination using GNSS and SLR-to-GNSS observations

Bury, G., Sośnica, K., Zajdel, R. *et al.* Determination of precise Galileo orbits using combined GNSS and SLR observations. *GPS Solut* **25**, 11 (2021).
<https://doi.org/10.1007/s10291-020-01045-3>

Combination of SLR and GNSS

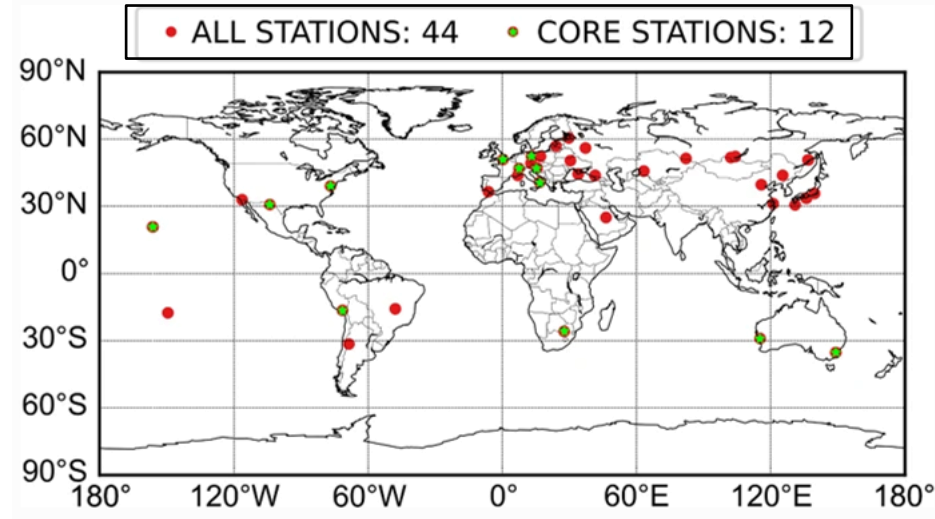
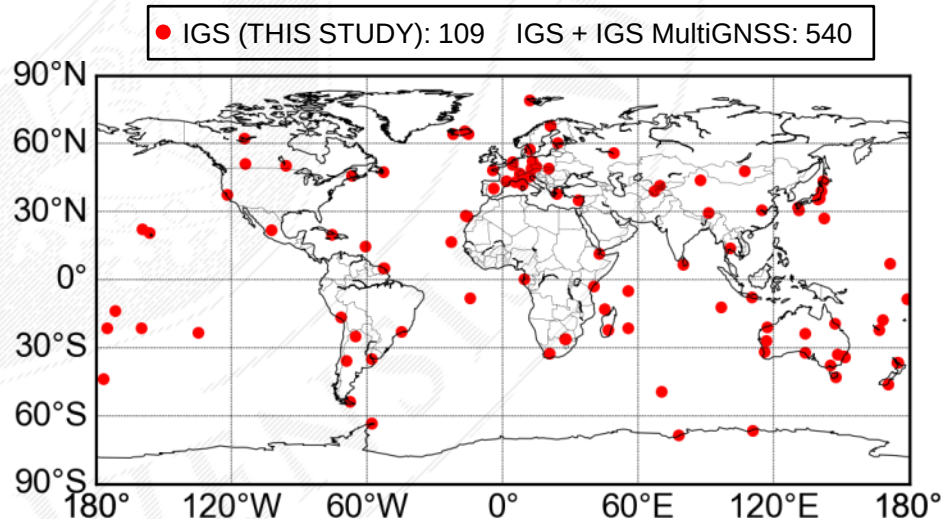
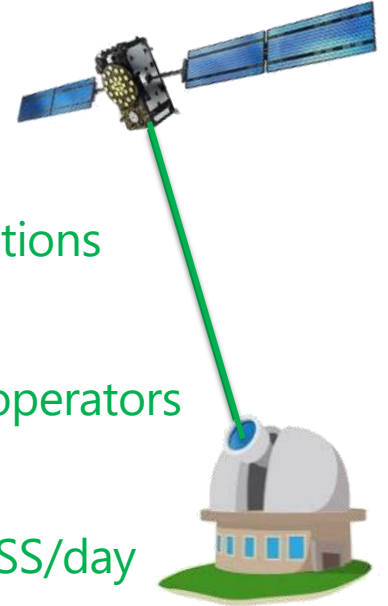
Global Navigation Satellite System

- Microwave (19-26 cm)
- Independent from weather conditions
- Sensitive to troposphere and ionosphere
- Autonomous observations
- Well distributed station network
- 12 000 observations/day



Satellite Laser Ranging

- Optical – LASER (512 – 1024 nm)
- Observations during cloudless conditions
- Sensitive to dry troposphere
- Observations conducted by station operators
- Sparse network of sites
- Around 100 SLR observations to GNSS/day

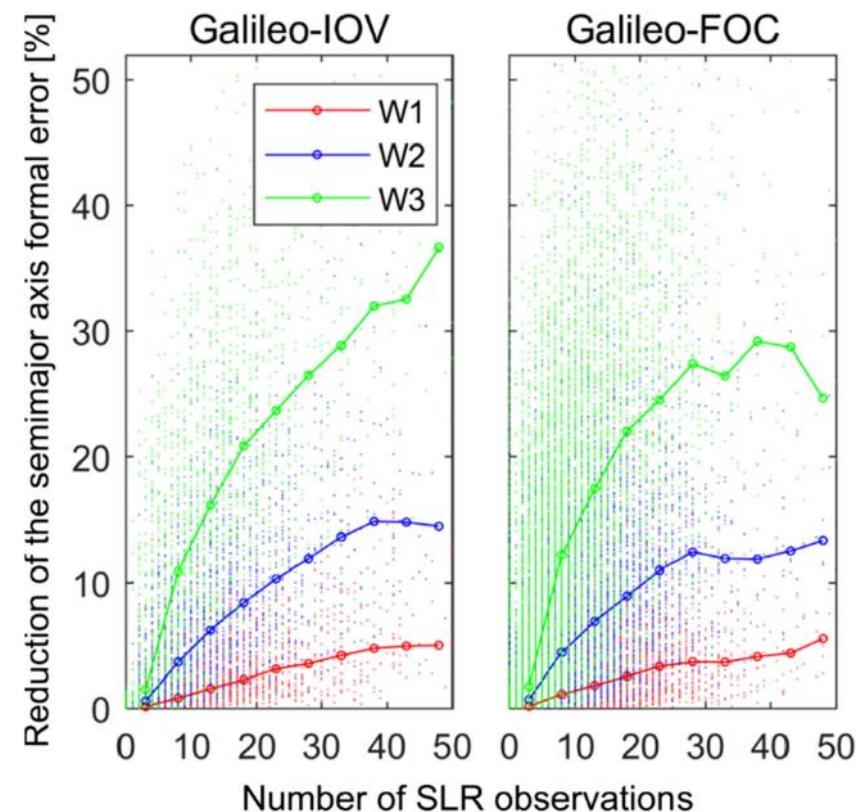


Weigthing between SLR and GNSS orbserveations

- Microwave GNSS solution (**M1**)
- **Microwave Galileo** carrier phase solutions - **1.5 mm. SLR** at the level of **15 mm (W1)**
- Intermediate case (**W2**):
Microwave: 1.5 mm, SLR: 6 mm.
- Equal weights for both types of observations (**W3**), because of the much lower number of SLR observations compared to GNSS.

	σ_{GNSS} [mm]	$\frac{\sigma_{\text{GNSS}}}{\sigma_{\text{SLR}}}$
M1	1.5	-
W1	1.5	$\frac{1}{10}$
W2	1.5	$\frac{1}{4}$
W3	1.5	$\frac{1}{1}$

Fundamental aspect:
Modeling must be fully consistent
for SLR and GNSS!



Percentile reduction of formal error of the semi-major axis for the particular weighting strategies for Galileo-IOV (left) and Galileo-FOC (right). Individual solutions are marked as faint dots, whereas median values (per bin of five SLR observations) are marked as large dots

Validation of combined SLR+GNSS orbits using SLR residuals

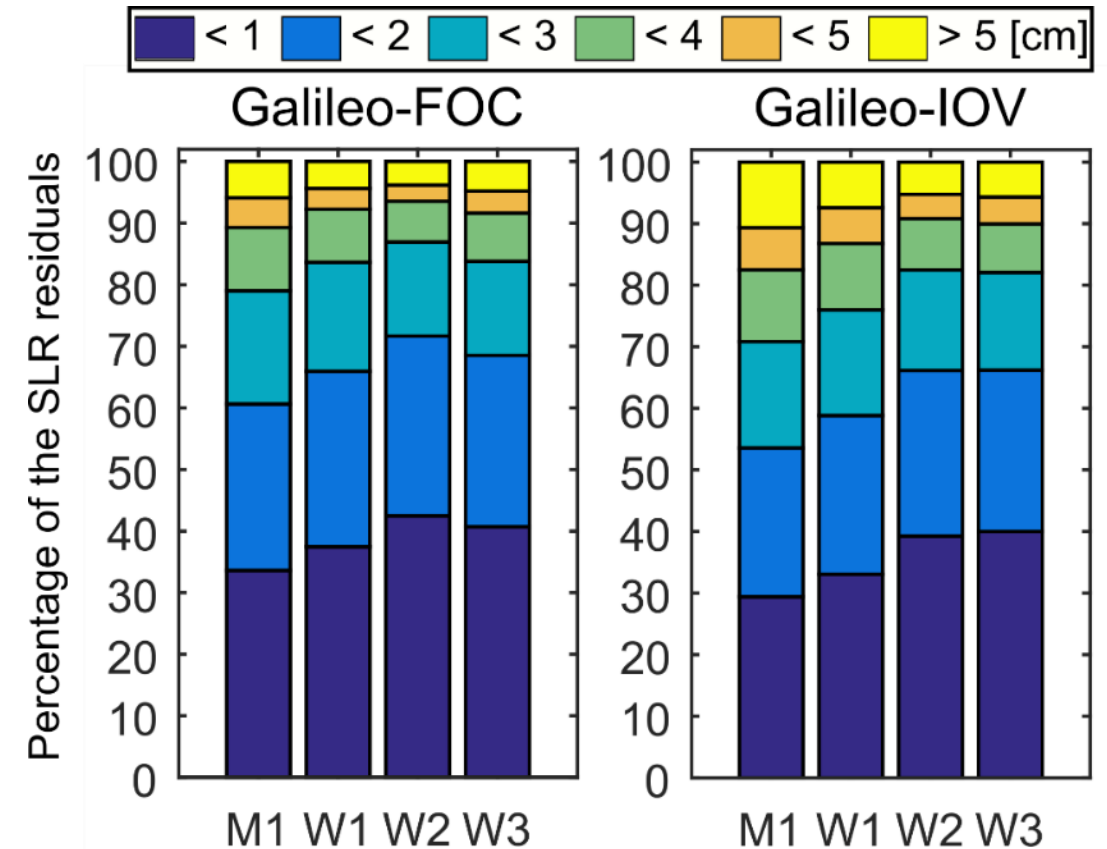
- The number of **SLR residuals smaller than 2 cm** for the solution **W3 is lower** when compared to the solution **W2**.

Thus, W2 is better than W3.

- The **number of SLR residuals lower than 5 cm is higher for the solution W1 as compared to the solution W3** for the Galileo-FOC satellites.
- As a result, the best solution is **W2**, for which the number **SLR residuals lower than 2 cm is 71.7%**.

For M1, W1, and W3 the numbers of SLR residuals below 2 cm are 60.6, 66.0, and 68.5%, respectively (FOC).

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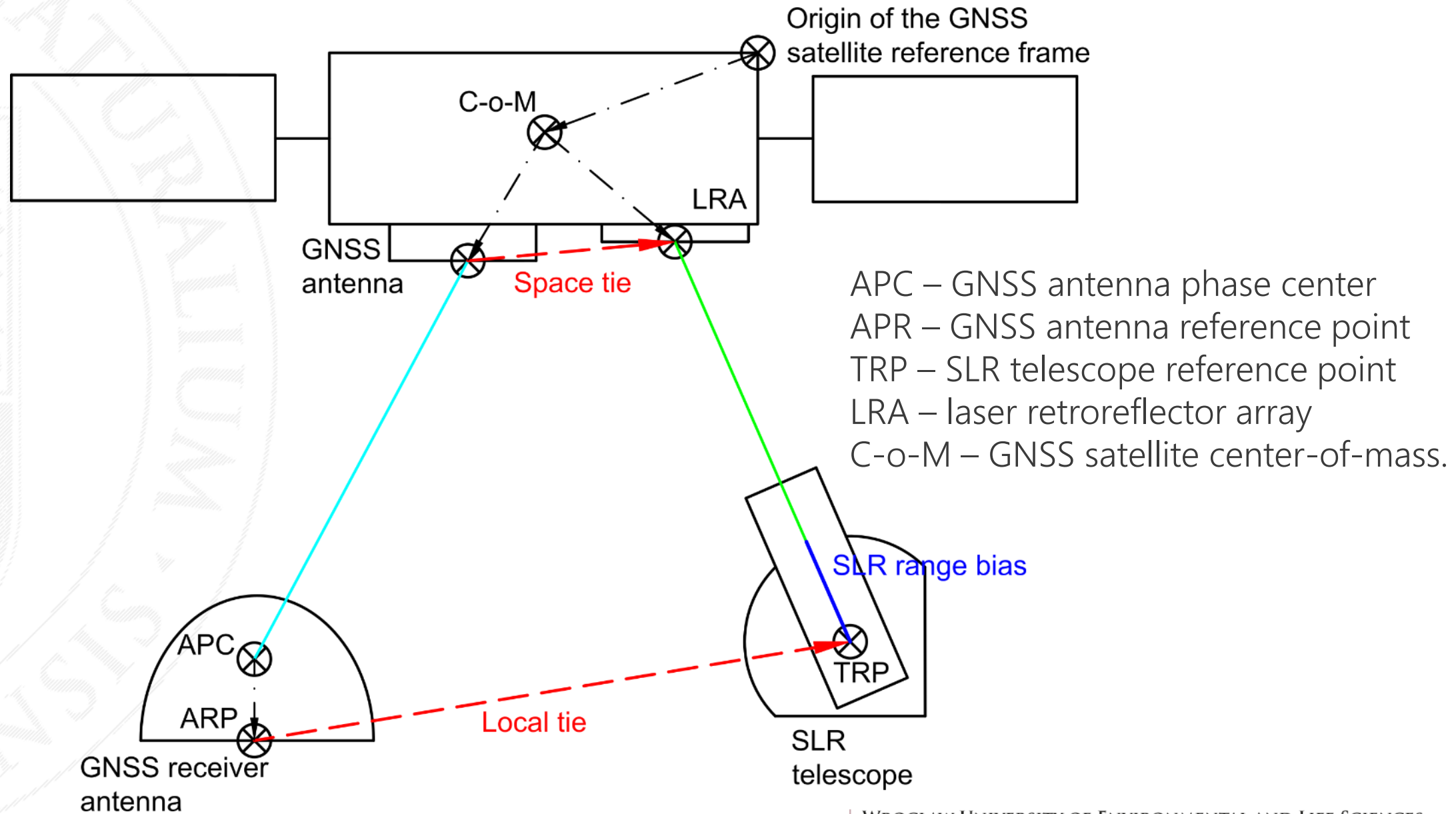
Number of SLR residuals smaller than 1, 2, 3, 4, 5 cm and above 5 cm in %.



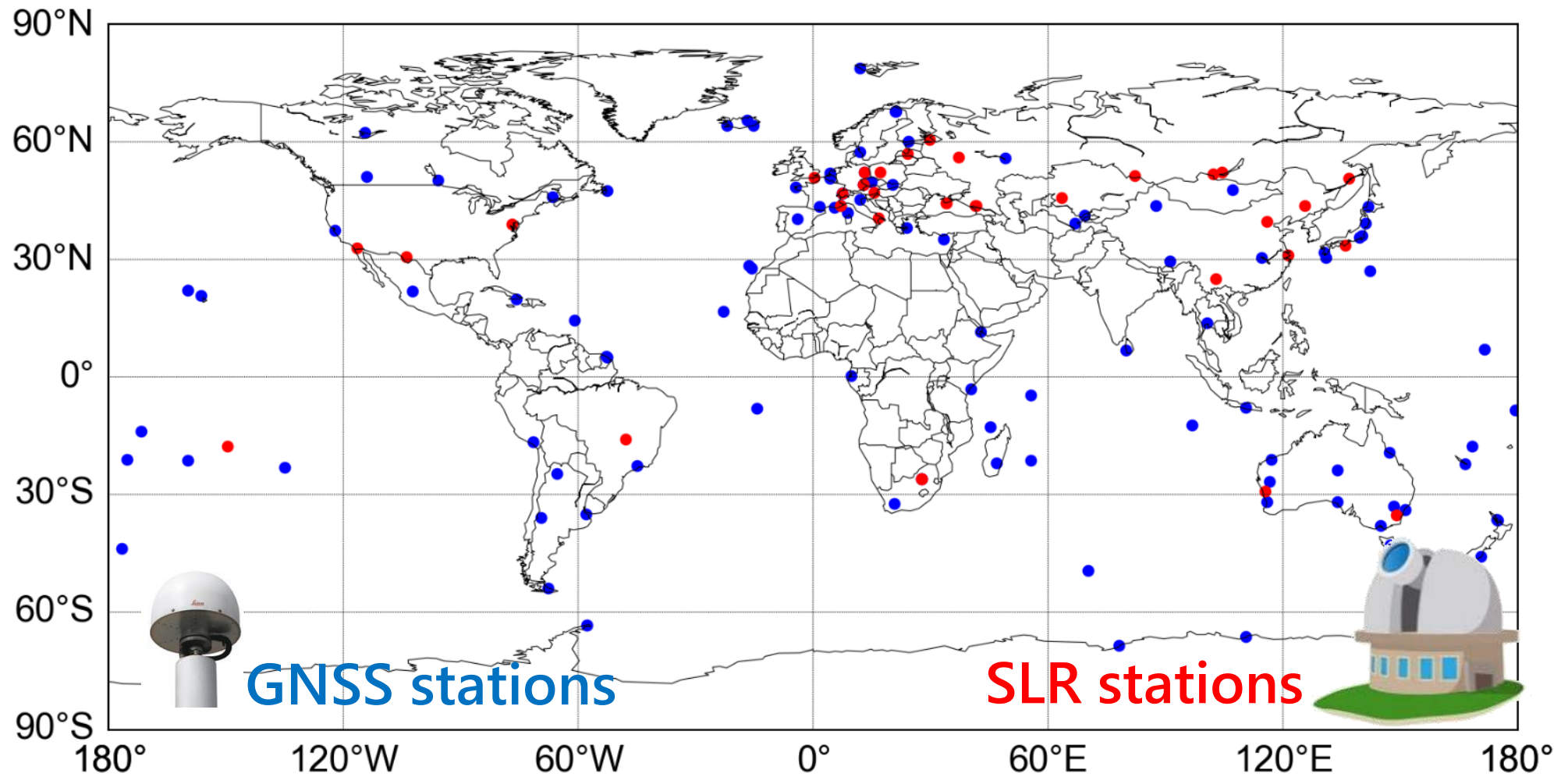
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Terrestrial reference frame realization using co-location onboard GNSS

Realization of the TRF onboard GNSS satellites

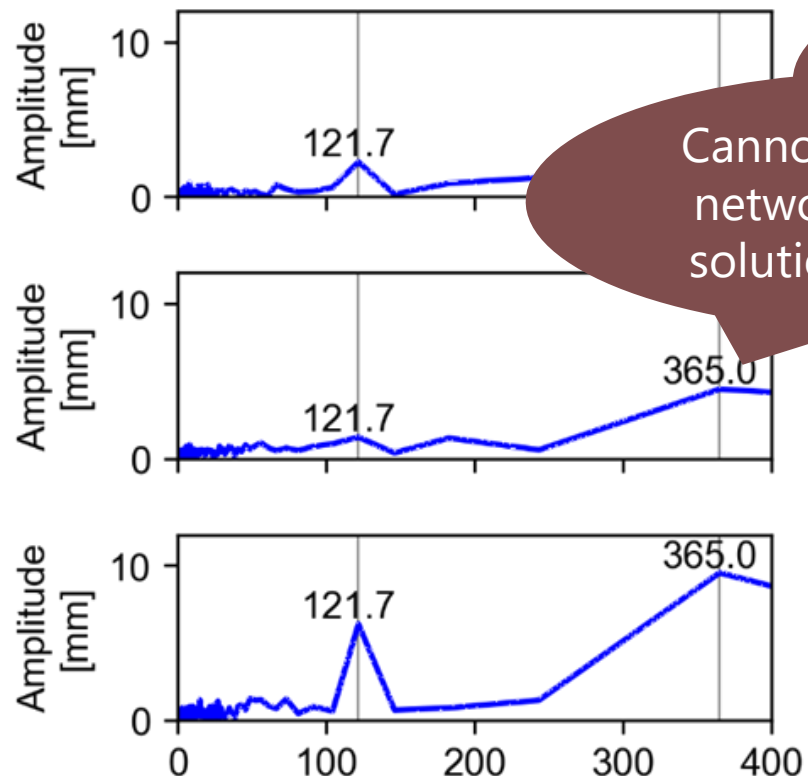
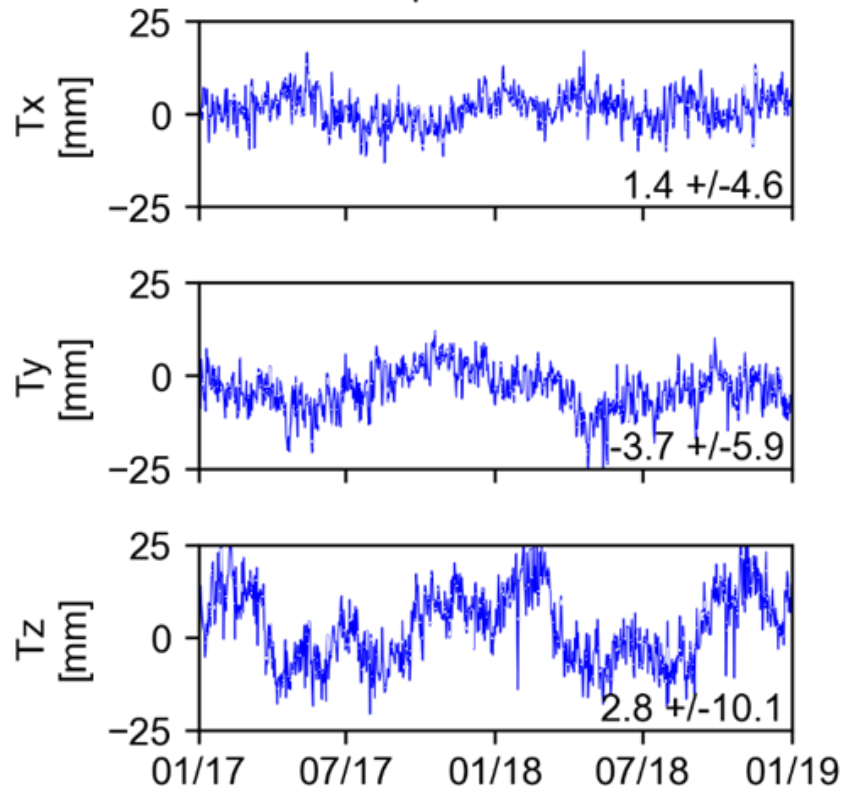


GNSS and SLR network



Different approaches to the datum realization

Translation parameters between solution W2 and I4 for the GNSS network



Reference combined solution (Burr et al)

Cannot realize SLR network (not bad for

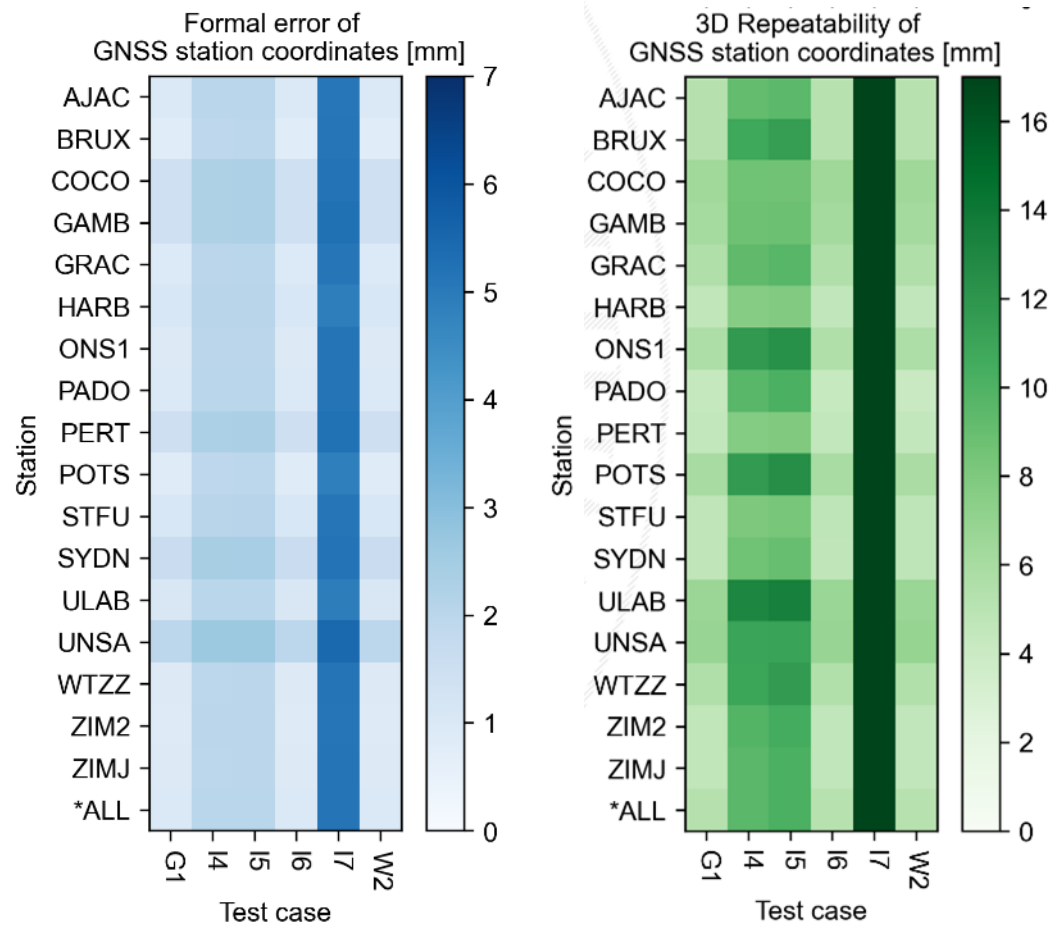
Cannot realize GNSS network (not stable solution – see

Similar to G1 – orientation for the SLR network cannot be transferred via

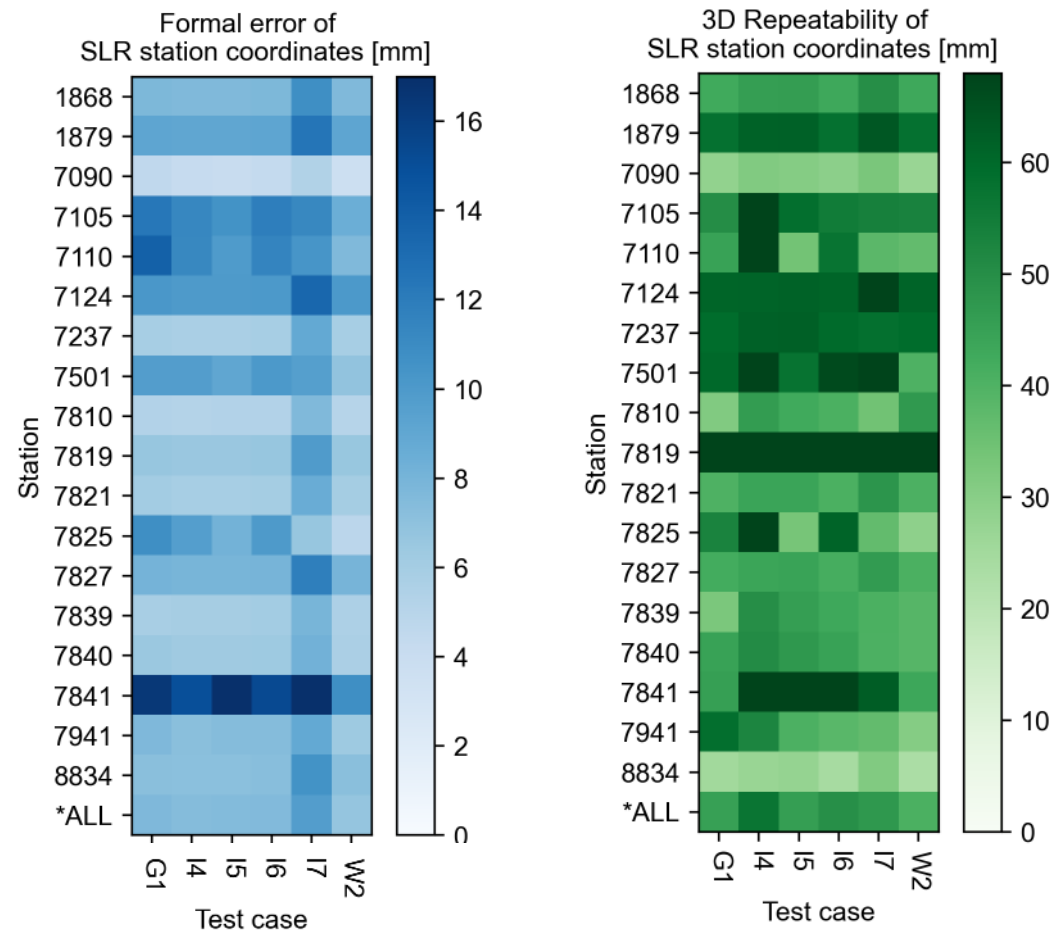
Very poor GCC...

Quality of station coordinates

GNSS

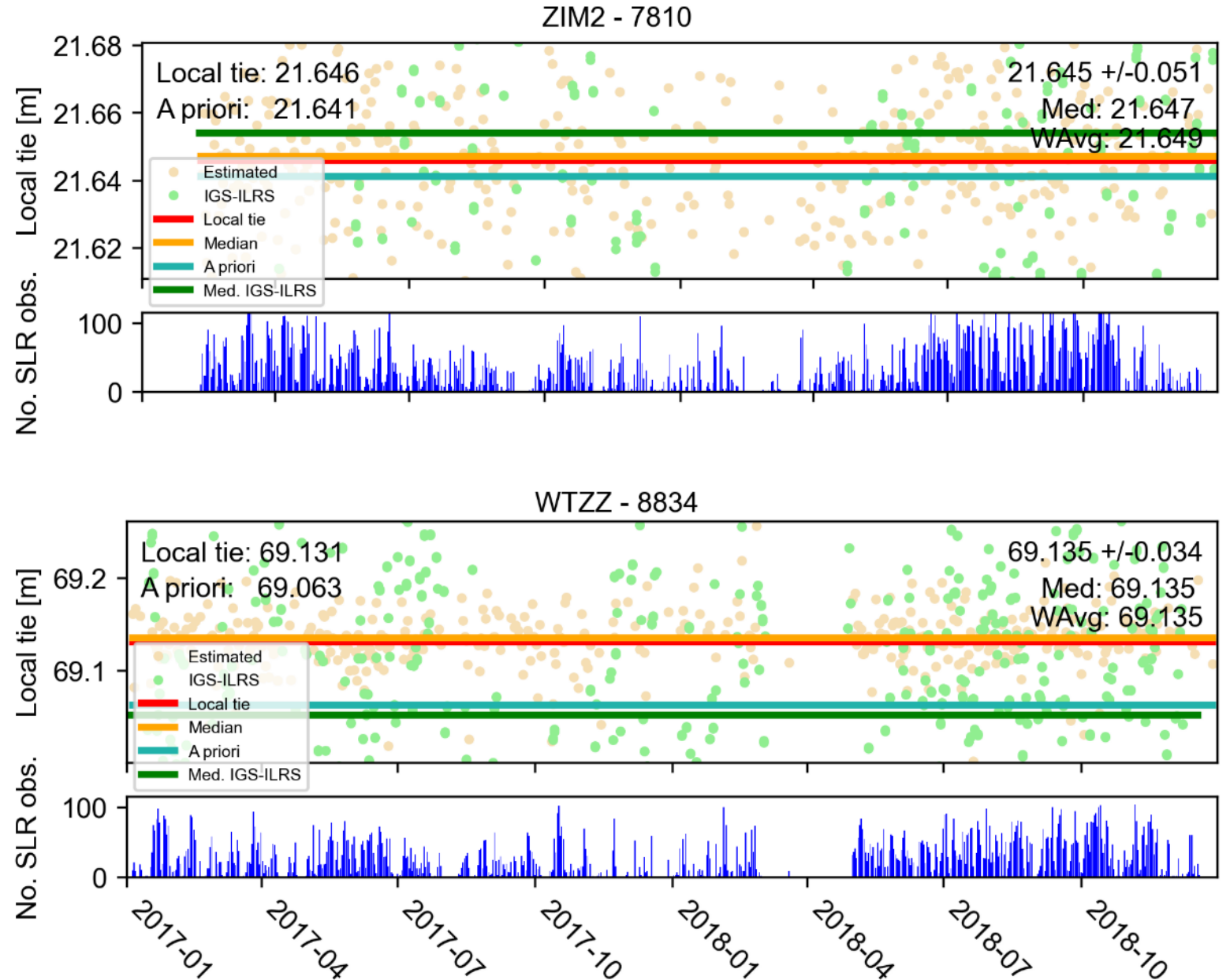


SLR

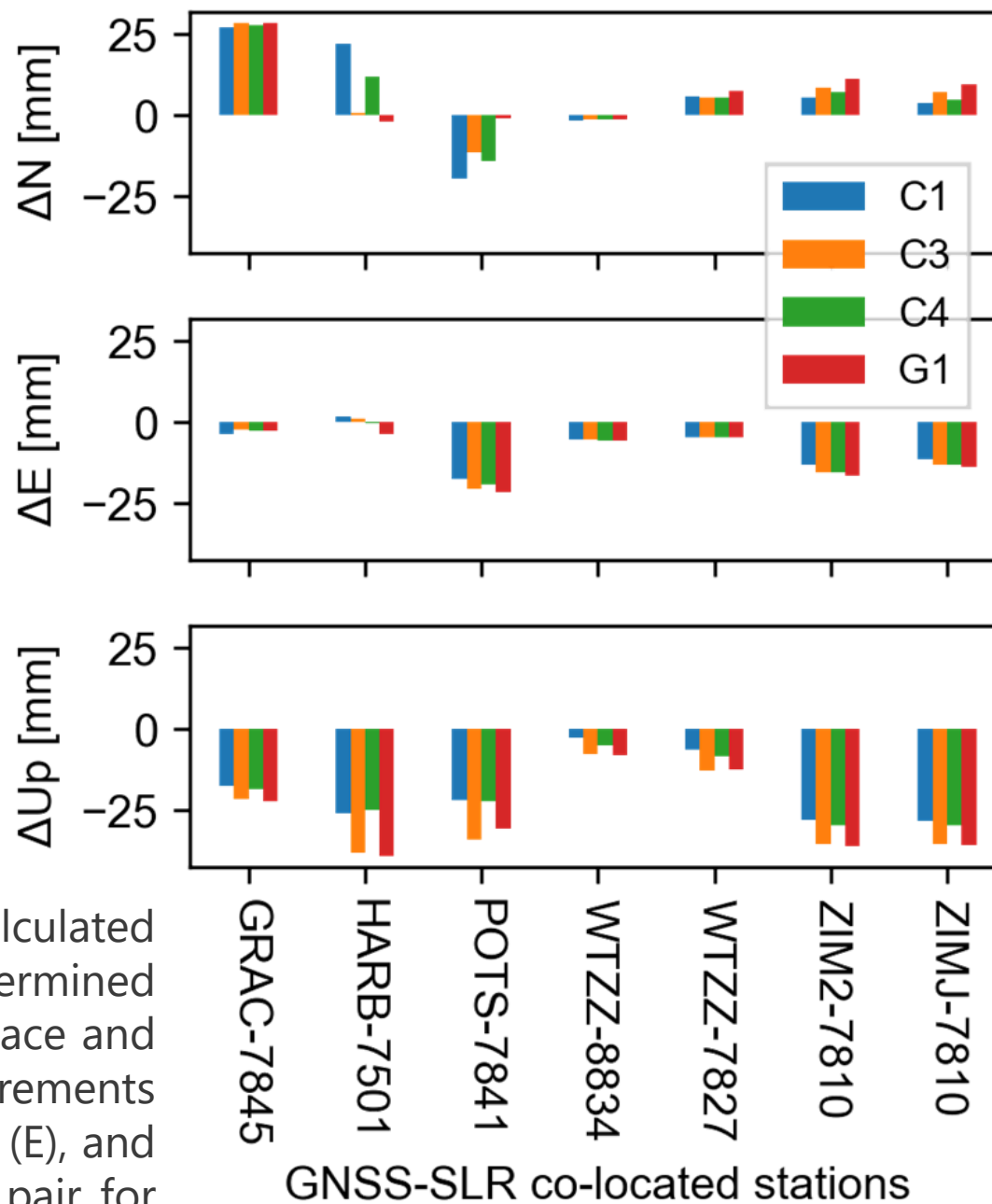


3D local tie

- **A priori** = local tie calculated based on the **a priori coordinates** of GNSS and SLR stations in ITRF2014/SLRF2014
- **Wavg** = Weighted average.
Weights = Formal error of the SLR station coordinates
- **IGS-ILRS** = distance calculated based on the operational products of IGS-ILRS for the co-located stations

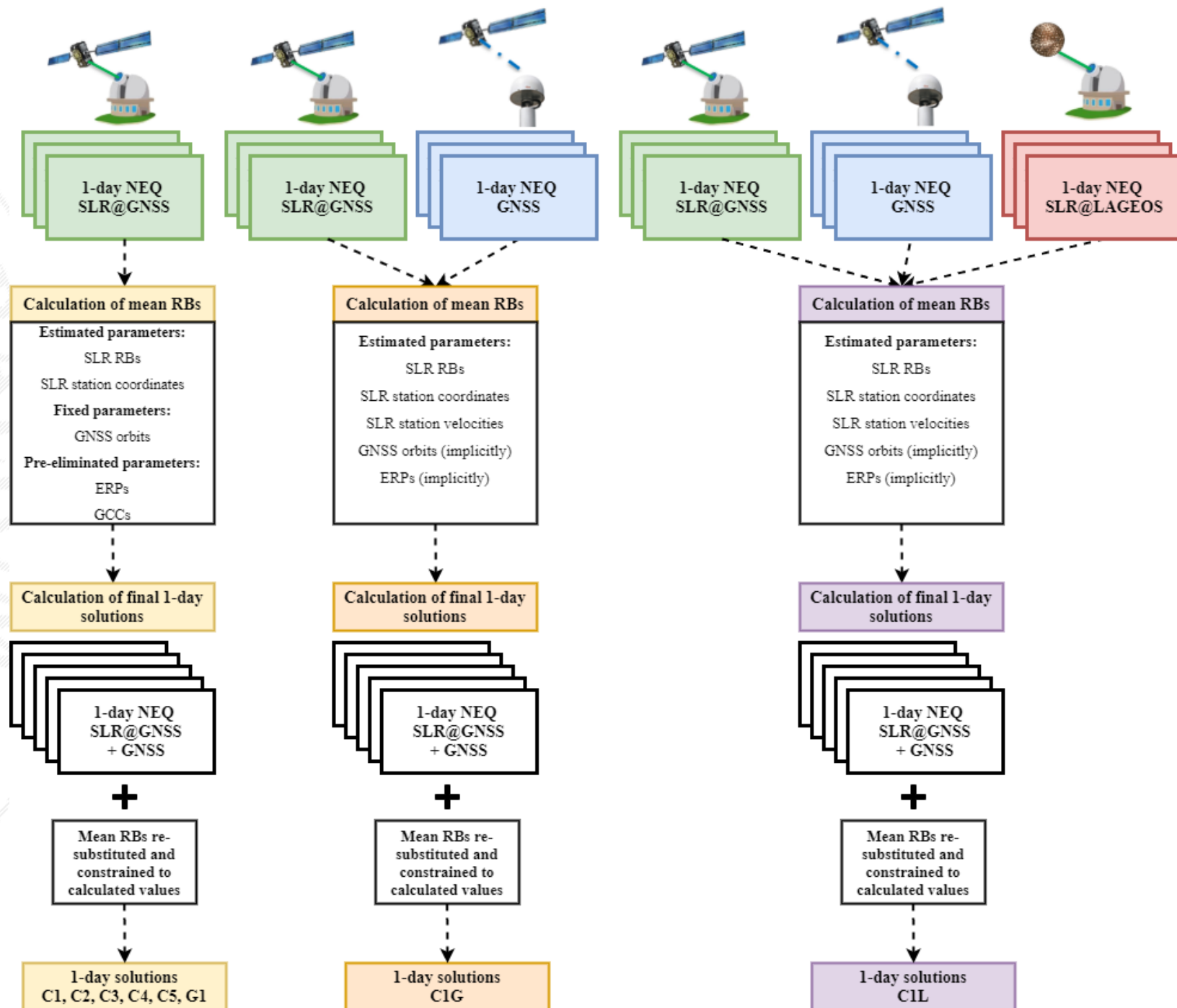


Local ties

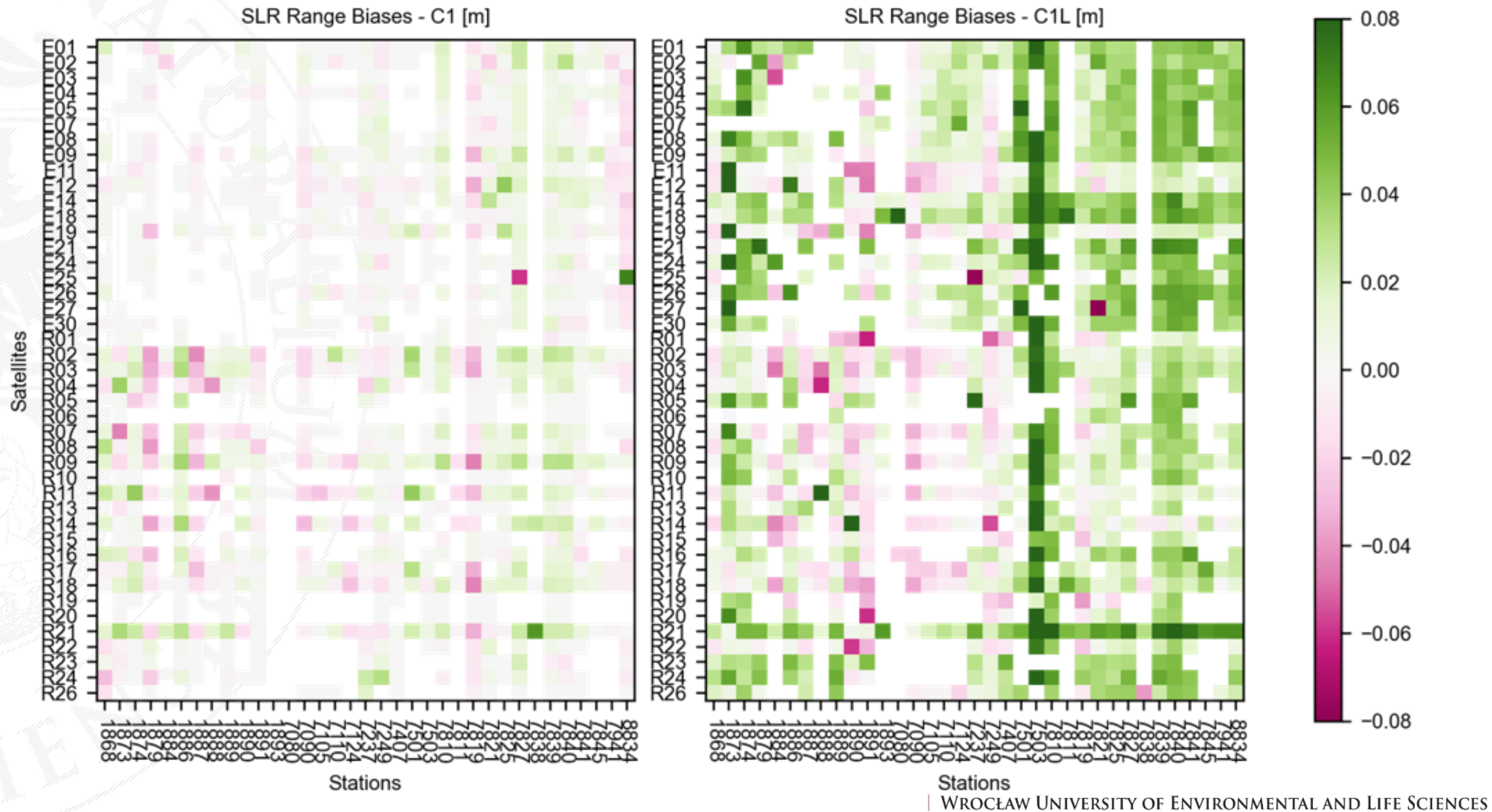


Difference between local ties calculated based on station coordinates determined from the GNSS-SLR co-location in space and using *in situ* local ties measurements decomposed into the North (N), East (E), and Up components for each GNSS-SLR pair for chosen solutions

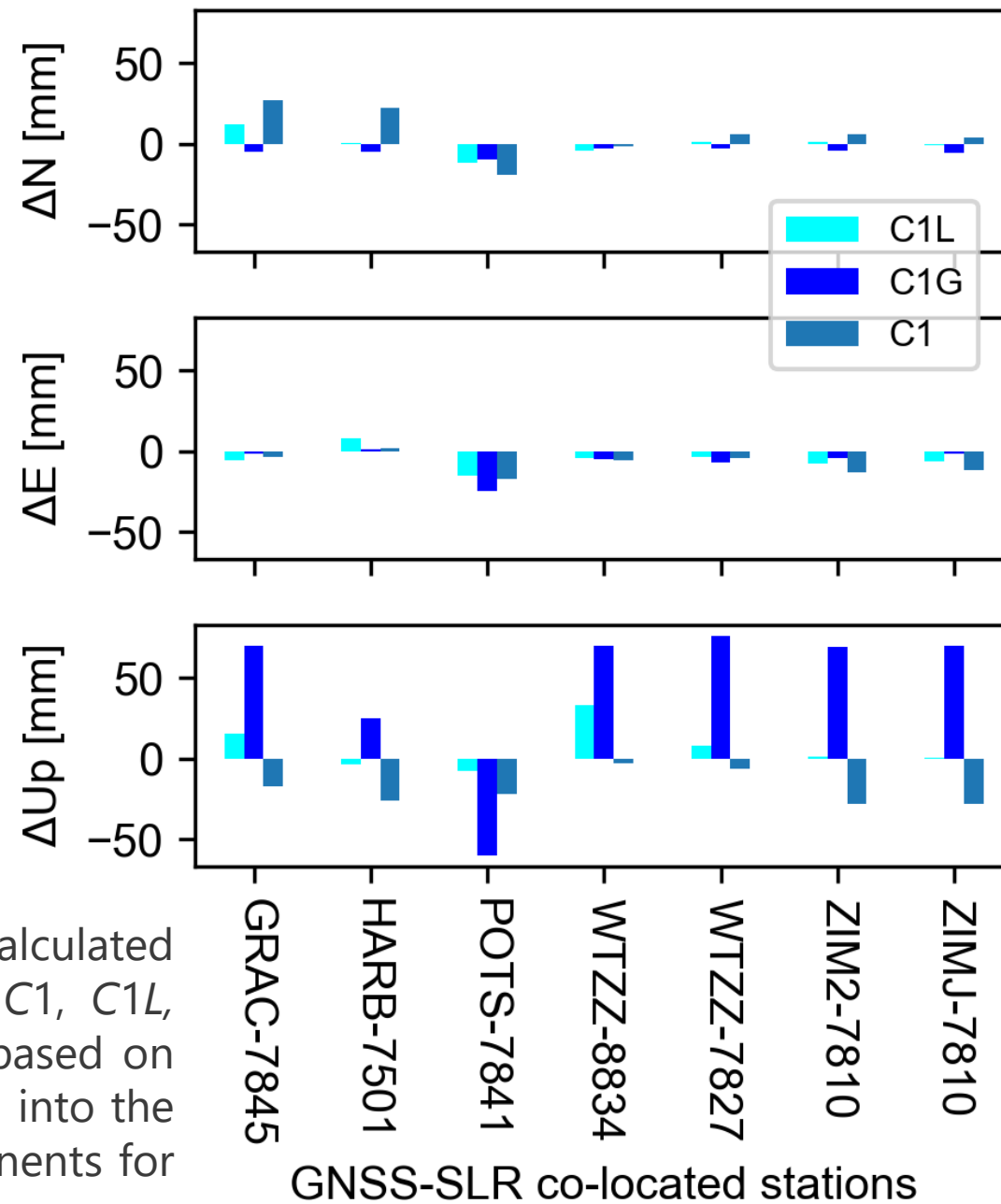
How to handle SLR range biases?



SLR range biases

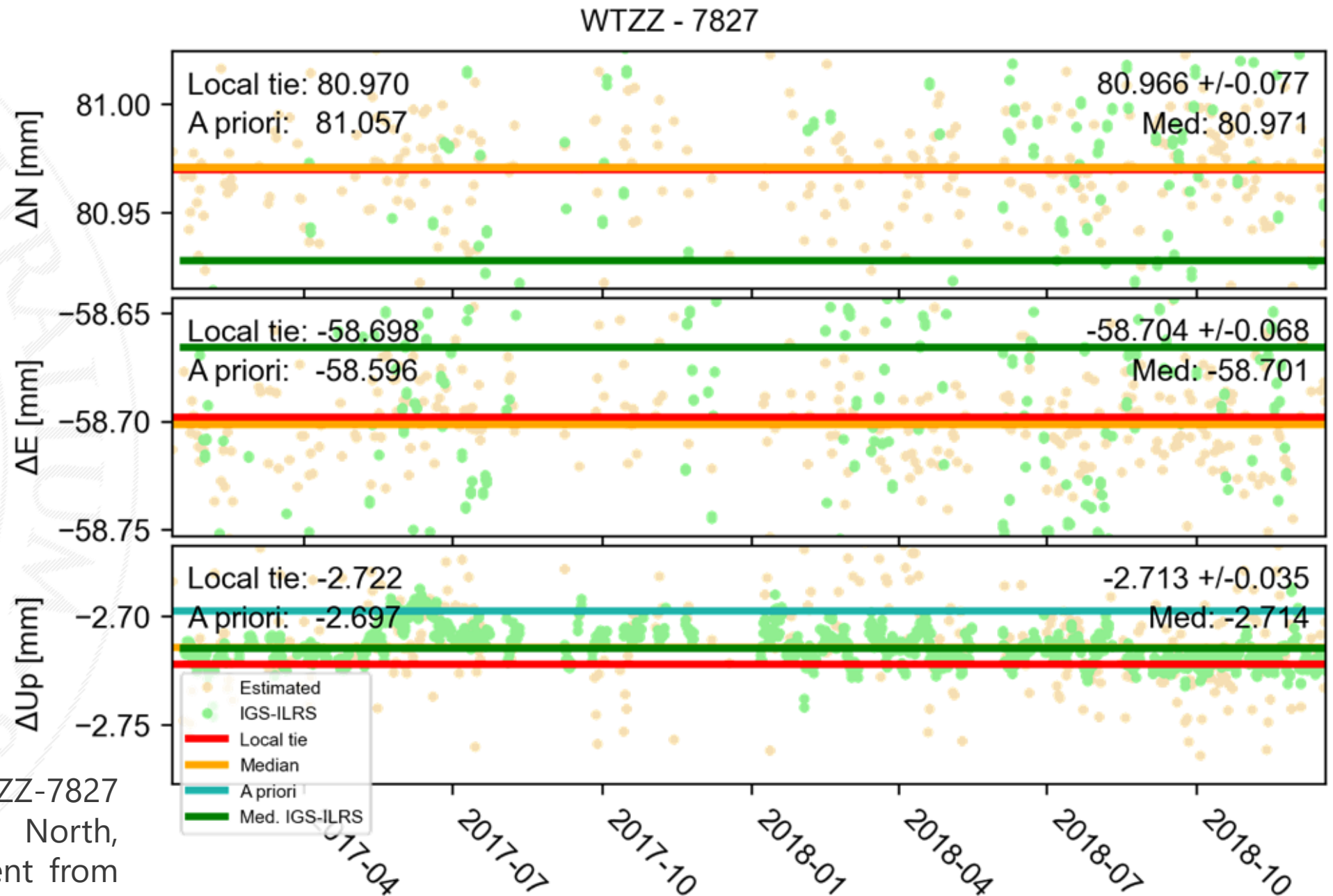


Impact of the SLR range biases



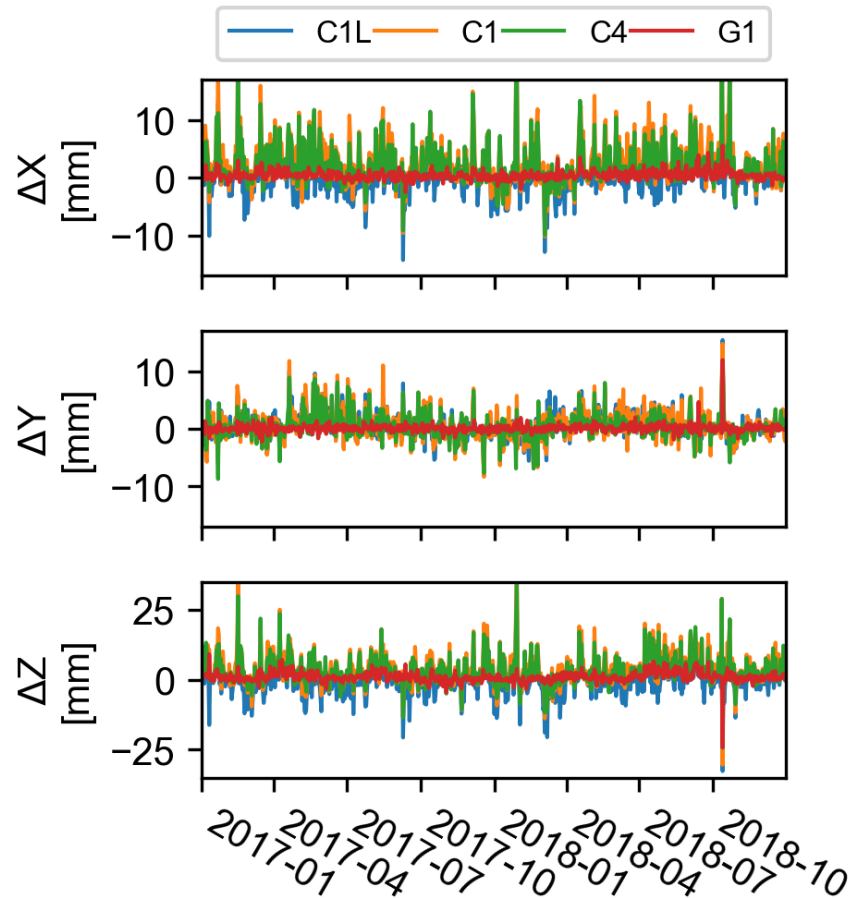
Difference between local ties calculated using co-location in space from C1, C1L, and C1G solutions and local ties based on *in situ* measurements decomposed into the North (N), East (E), and Up components for each GNSS-SLR station pair

Handling of the SLR range biases

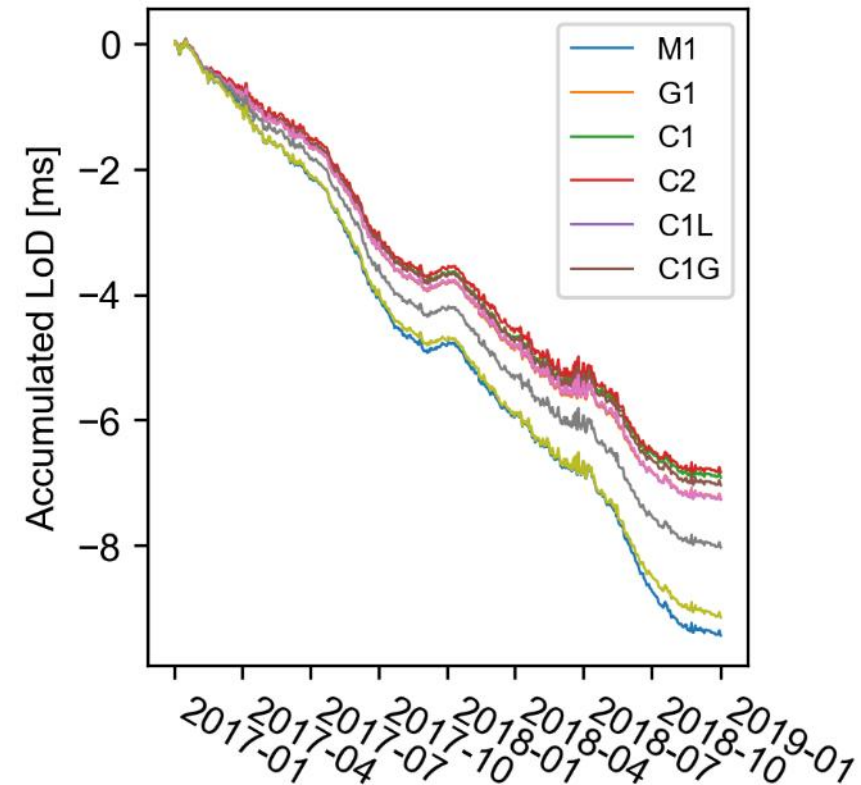


Local ties for WTZZ-7827 decomposed into the North, East, and Up, component from C1L solution.

Impact of the co-location on the global geodetic parameters



Difference between GCC calculated using solutions *M1* and solutions *C1L*, *C1*, *C4*, and *G1*.



Accumulated LoD values with respect to the IERS C04 for all the test cases

Summary

Combined GNSS and SLR-to-GNSS observations improve Galileo orbits

The best strategy for the datum realization aiming at the co-location is consistent imposing of NNT+NNR constraints on GNSS and SLR sites

The calculated local ties are more consistent with the in situ measurements than with ties calculated using a priori coordinates

SLR range biases which consider the LAGEOS-based station coordinates are the most consistent with the in situ local ties