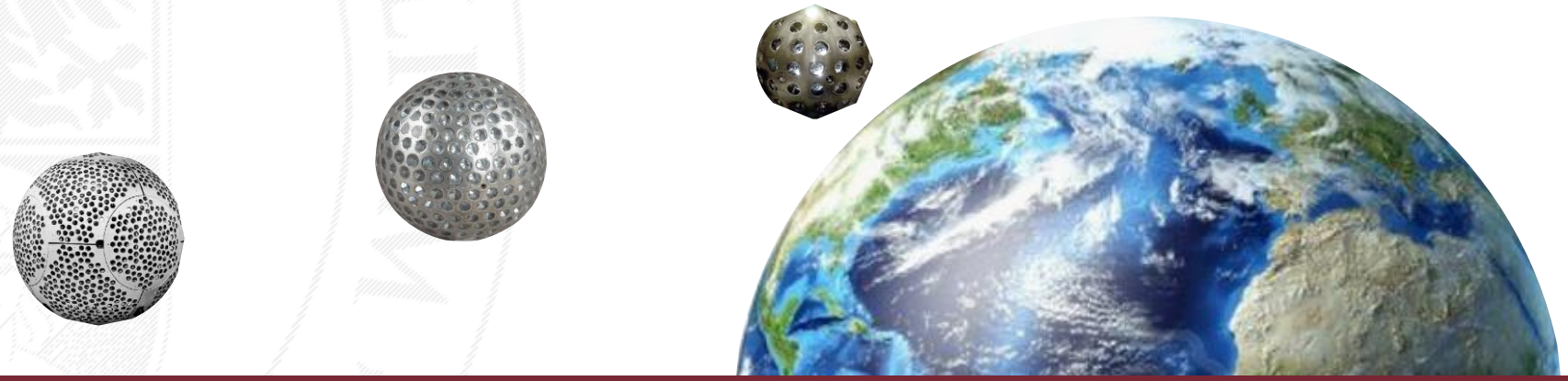
22ND INTERNATIONAL WORKSHOP ON LASER RANGING
7-11 November 2022
Yebes, Spain
RECONNECTING THE ILRS COMMUNITY

WROCŁAW UNIVERSITY OF ENVIRONMENTAL AND LIFE SCIENCES

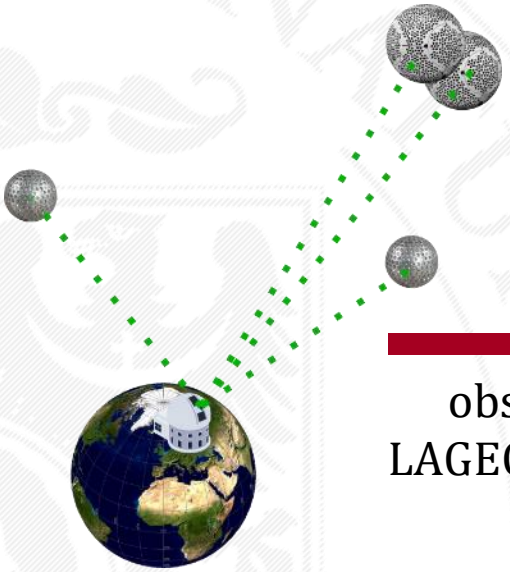
A SIMULATION STUDY FOR FUTURE GEODETIC SATELLITE CONSTELLATIONS



Joanna Najder, Krzysztof Sośnica,
Dariusz Strugarek, Radosław Zajdel

Institute of Geodesy and Geoinformatics

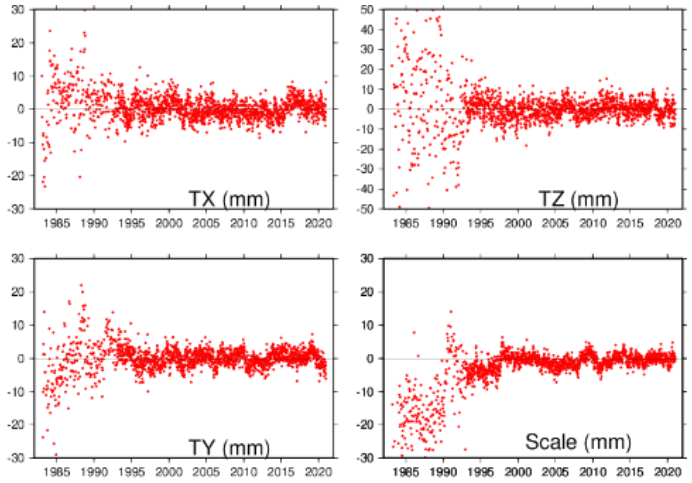
SATELLITE LASER RANGING



observations to the LAGEOS-1/-2, Etalon 1/2

Geocenter coordinates

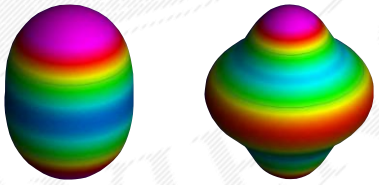
Orgin and scale - ITRF



Earth's rotation parameters

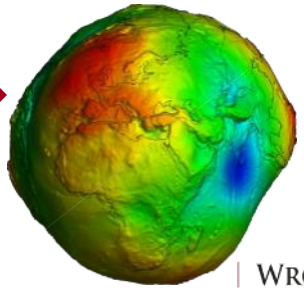
SLR station coordinates

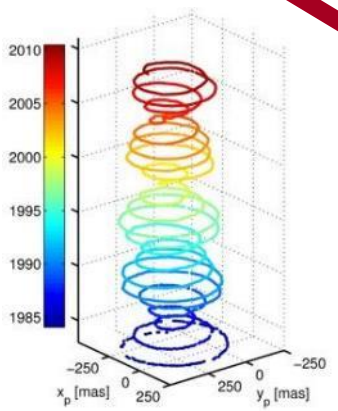
Low-degree harmonics of the Earth's gravity potential

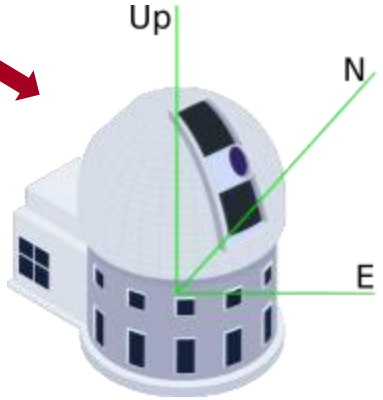


C_{20} C_{30}

coefficients C_{20} and C_{30} are replaced by SLR-based estimates



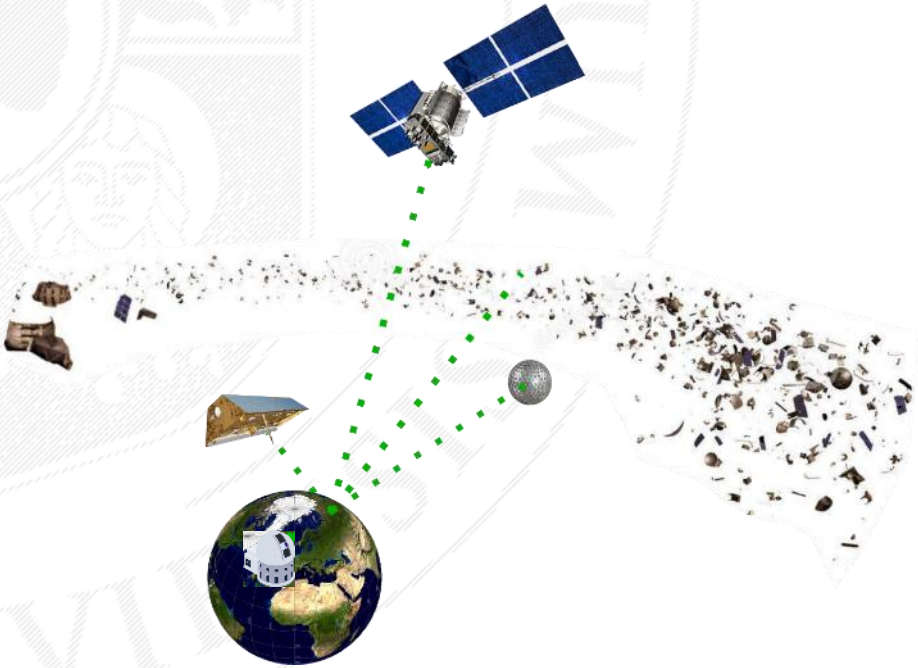


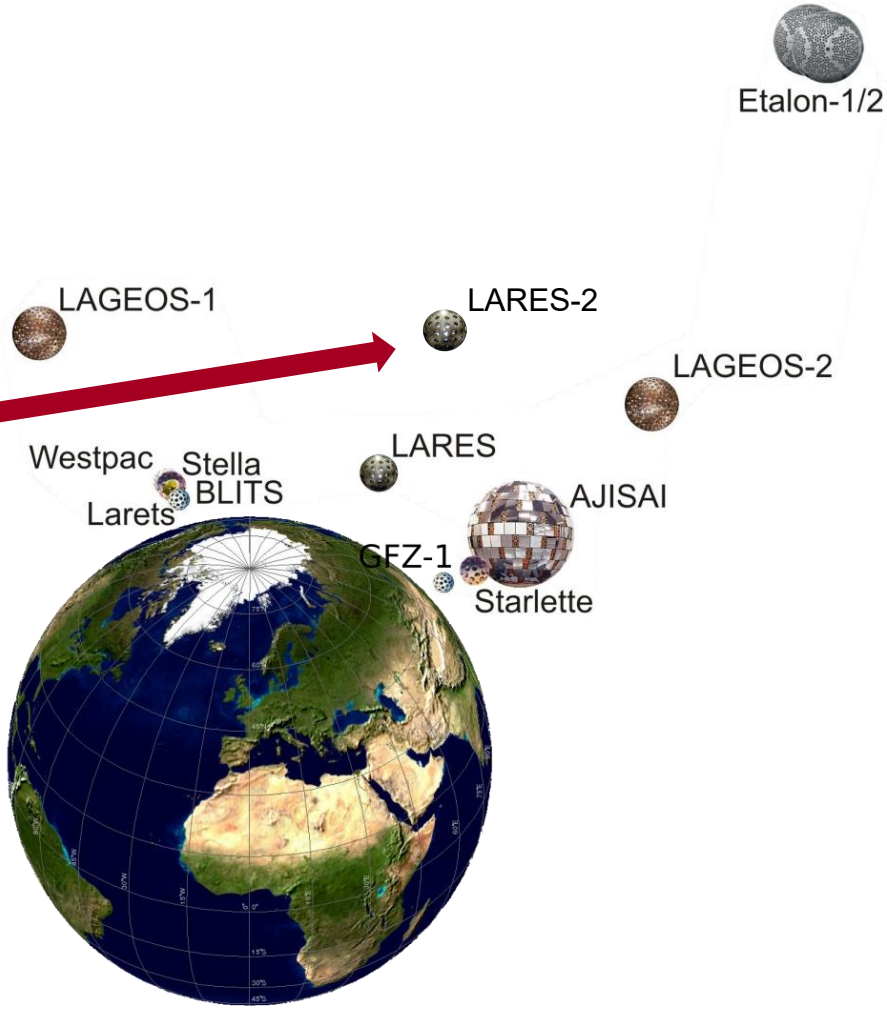


MOTIVATION

New geodetic satellite – LARES 2 was launched on 13 July 2022.

The main task of the LARES 2 is to study general relativity measurements, particularly the Lense-Thirring effect.



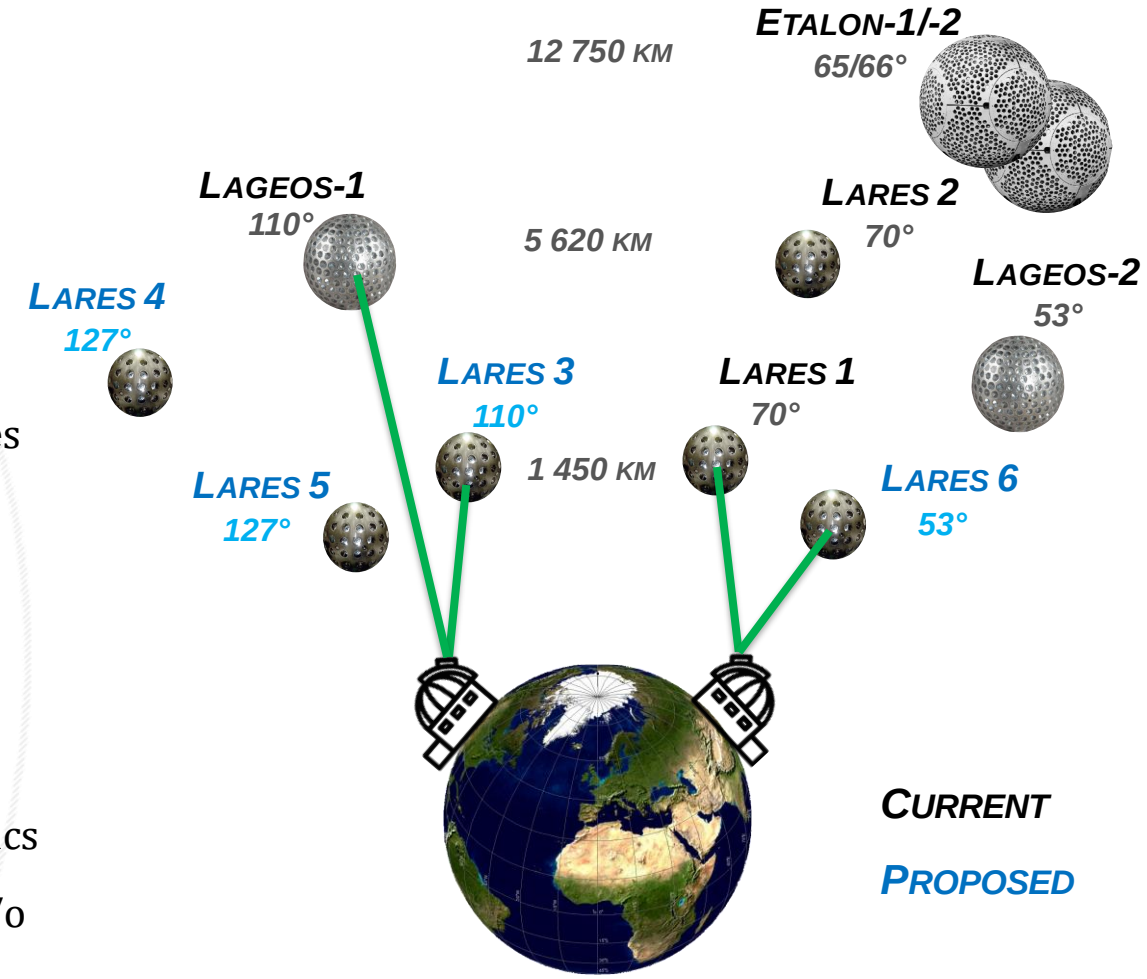


The increasing number of observation targets for SLR stations, e. g., space debris, or next navigation satellites.

MOTIVATION

Investigate the impact of adding observations of the proposed satellites on the determination of geodetic parameters:

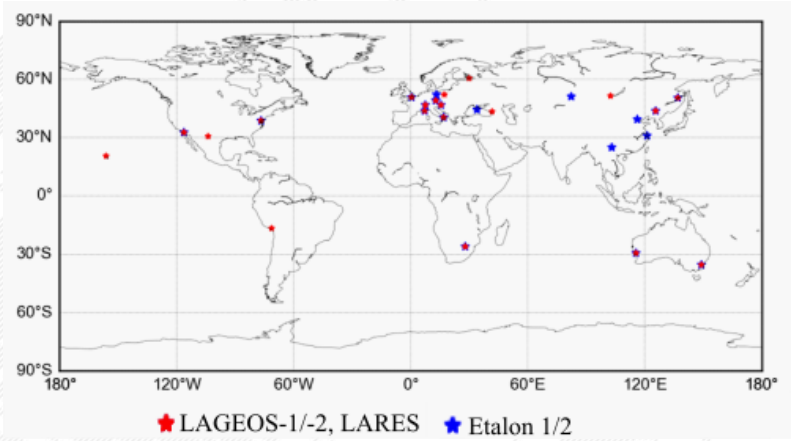
- ERPs,
- Geocenter (GCC),
- SLR station coordinates,
- The low-degree spherical harmonics of the Earth's gravity field up to d/o 6/6.

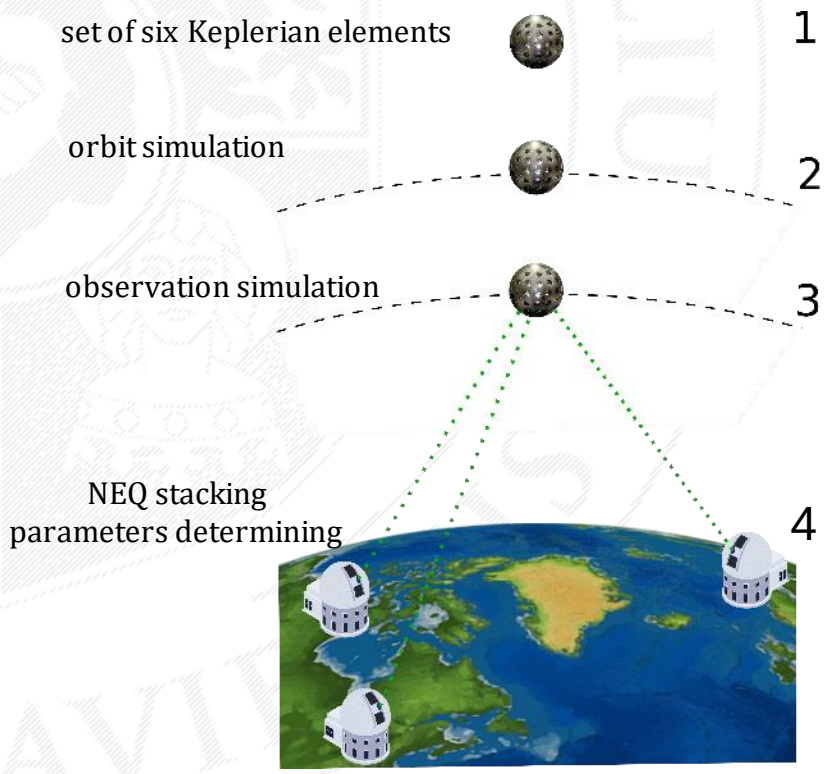


GOALS:

- What will be the influence on global geodetic parameters when taking the observations of LARES 2 into account?
- What shall be the orbit parameters for future satellites that will bring the greatest improvement in determining geodetic parameters?

DATA PROCESSING





- LAGEOS-1/-2, Etalon-1/-2, LARES 1/2/3/4/5/6
- 20 of the best-performing SLR stations
- Year of simulated orbits and SLR observations (2013)
- 7-day solutions
- The number of simulated observations corresponds with the number of real observations

  LAGEOS-1/-2 ~ 2600
  Etalon 1/2 ~ 400
  LARES ~ 1600

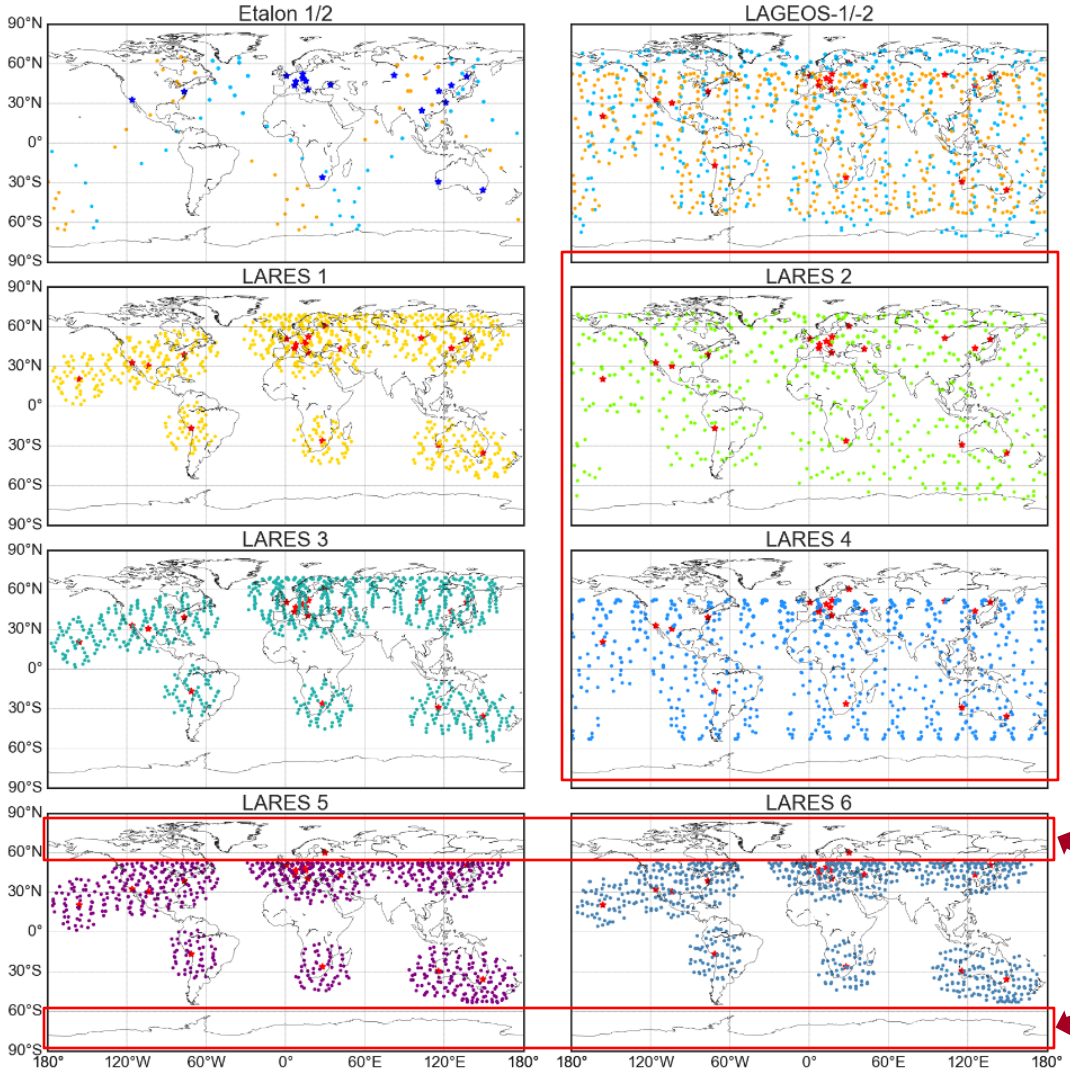
- Different observation noises for satellites:

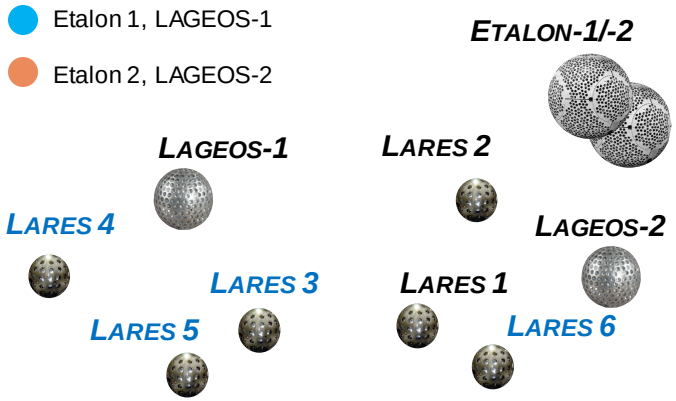
  LAGEOS-1/-2, LARES 2/4: 6 mm
  LARES 1/3/5/6 : 9 mm
  Etalon 1/2: 15 mm

- Relative weighting on individual satellites in the combined solutions:

  LAGEOS-1/-2, LARES 2/4: $\sigma^2 = 1.0$
  LARES 1/3/5/6 : $\sigma^2 = 0.44$
  Etalon 1/2: $\sigma^2 = 0.25$

DISTRIBUTION OF SIMULATED OBSERVATIONS



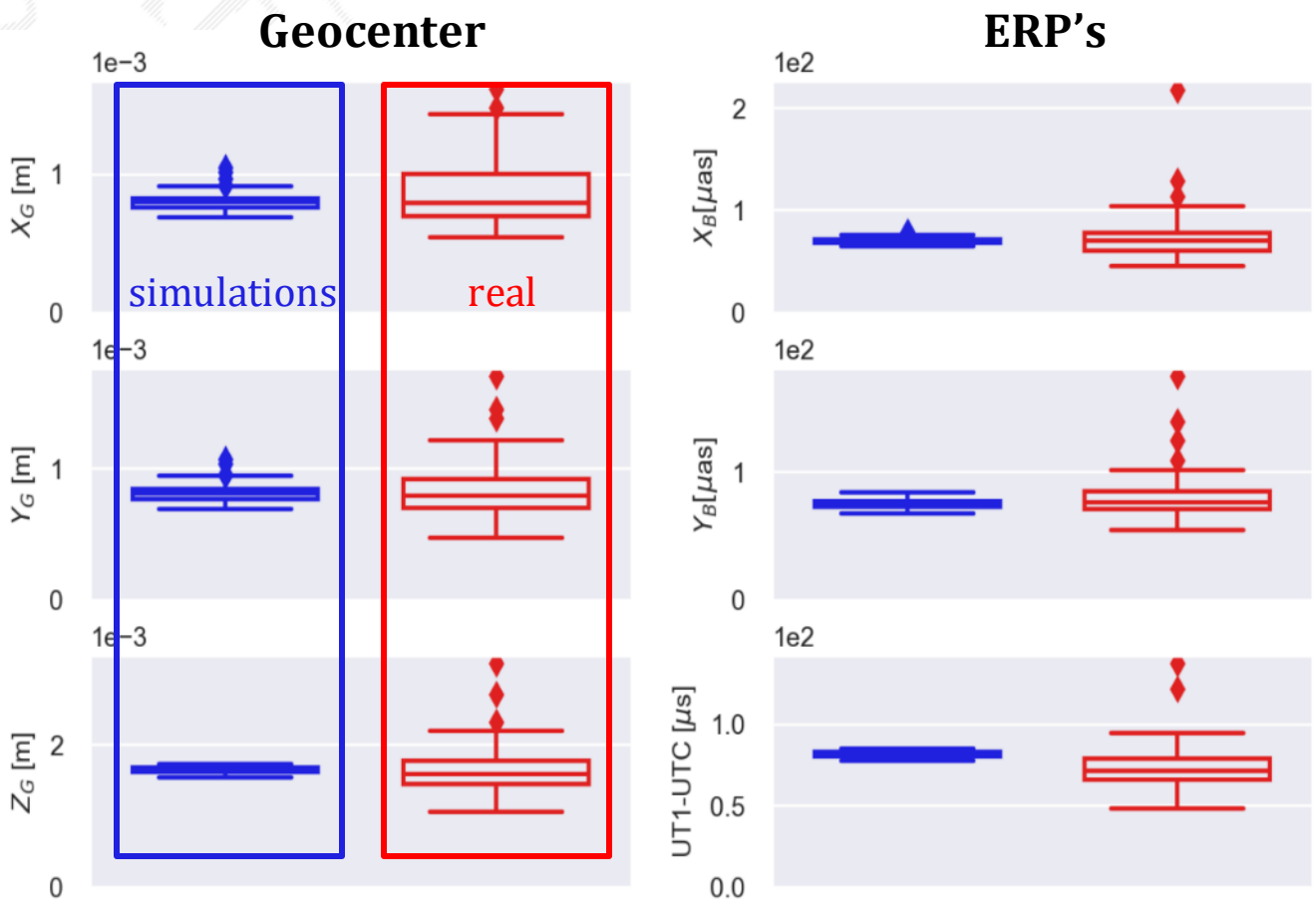


For satellites on MEO the distribution of observations is more dispersed

For satellites on LEO – LARES 5 and LARES 6 no normal points are collected for heights over/below 50° lattitude

Presented distribution of simulated observations corresponds the distribution of real observations

COMPARING THE SOLUTIONS BASED ON REAL OBSERVATIONS TO SIMULATION RESULTS



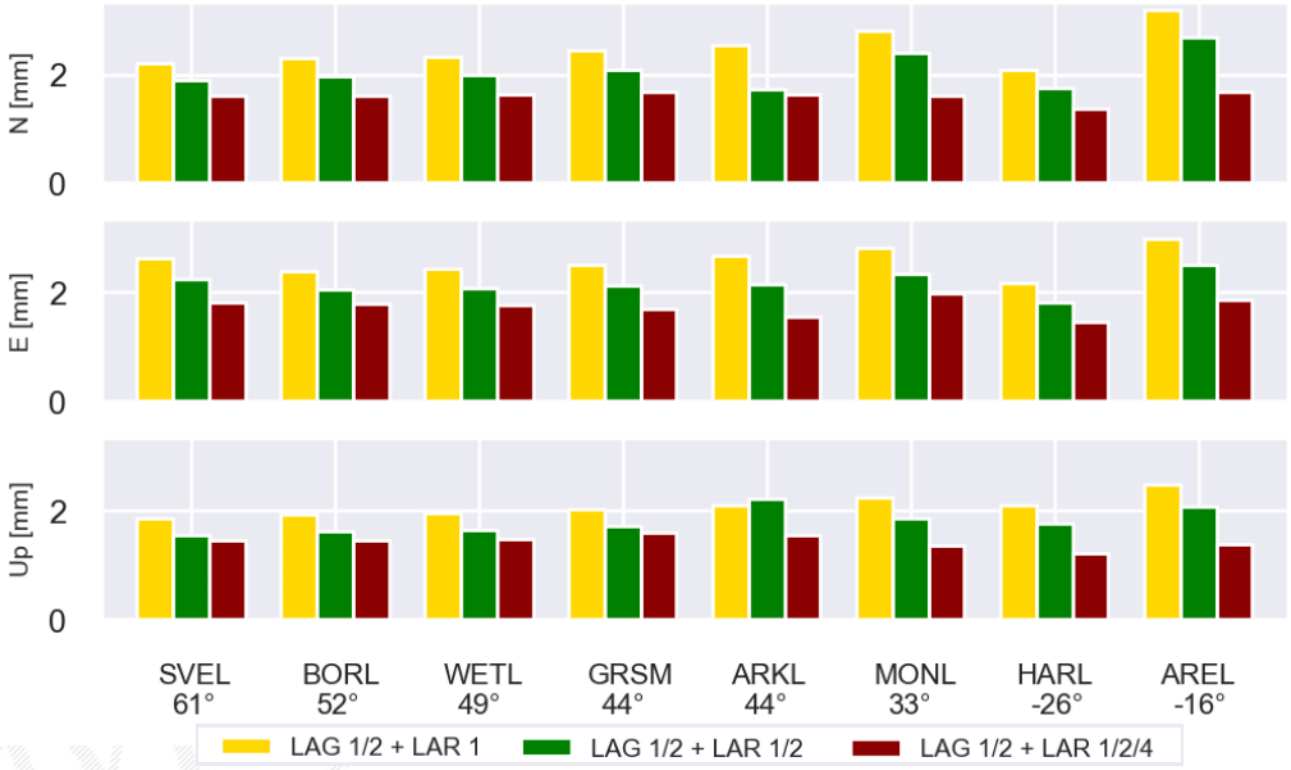
We also compare the results achieved for simulated data with the solution obtained for the real observations of LAGEOS-1/-2 satellites. These solutions agree well in terms of the consistency of the formal error values of the obtained parameters of the ERP and the geocenter.

RESULTS

STATION COORDINATES

The current constellation of geodetic satellites based on LAGEOS-1/-2 and LARES 1/2 satellites in weekly solutions allows to determin station coordinates with formal errors below 2 mm

Solution	E [mm]	N [mm]	Up [mm]
LAGEOS-1/-2 + LARES 1	2.2	2.3	2.0
LAGEOS-1/-2 + LARES 1/2	**1.9**	**1.9**	**1.7**
LAGEOS-1/-2 + LARES 1/2/4	1.7	1.8	1.5



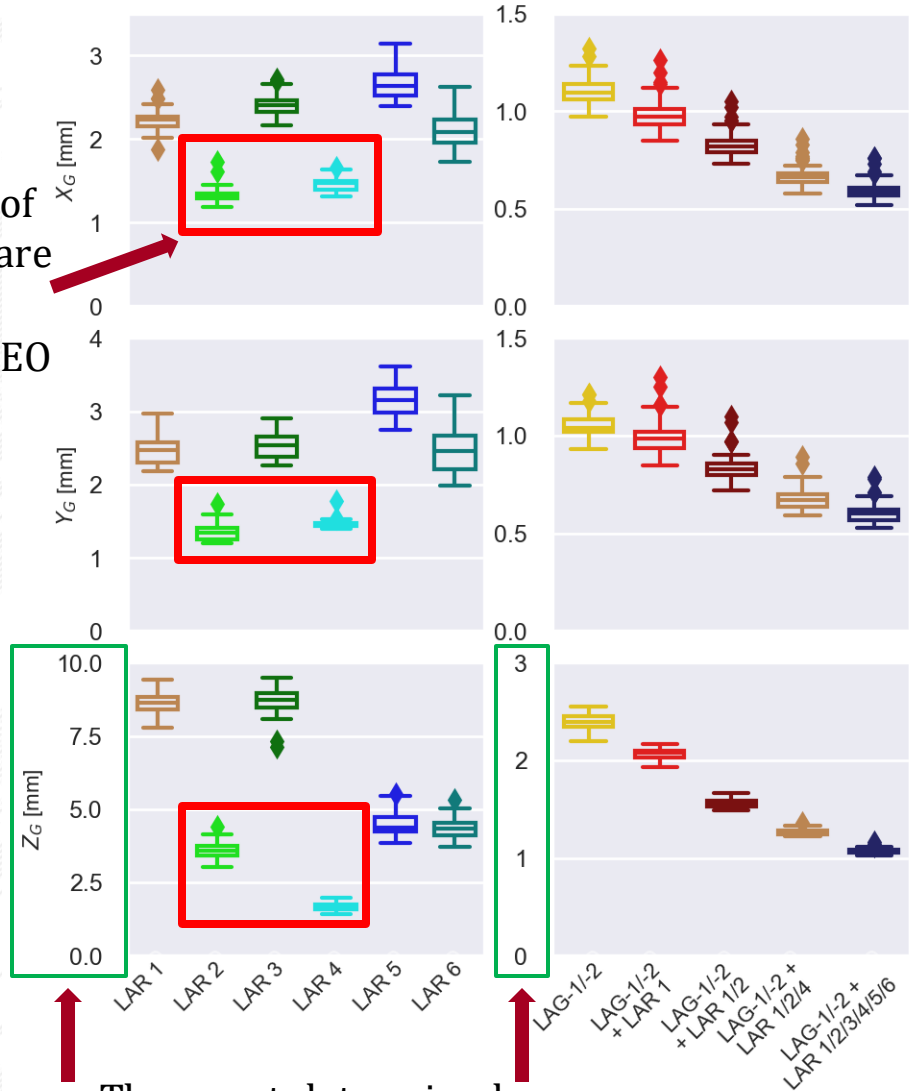
By adding observations of LARES 2 – reducing formal errors for stations, especially located at higher lattitudes

By adding observations of LARES 4 – reducing formal errors for stations, especially located at lower lattitudes

RESULTS

GEOCENTER COORDINATES

The medians of formal errors are smaller for satellites on MEO



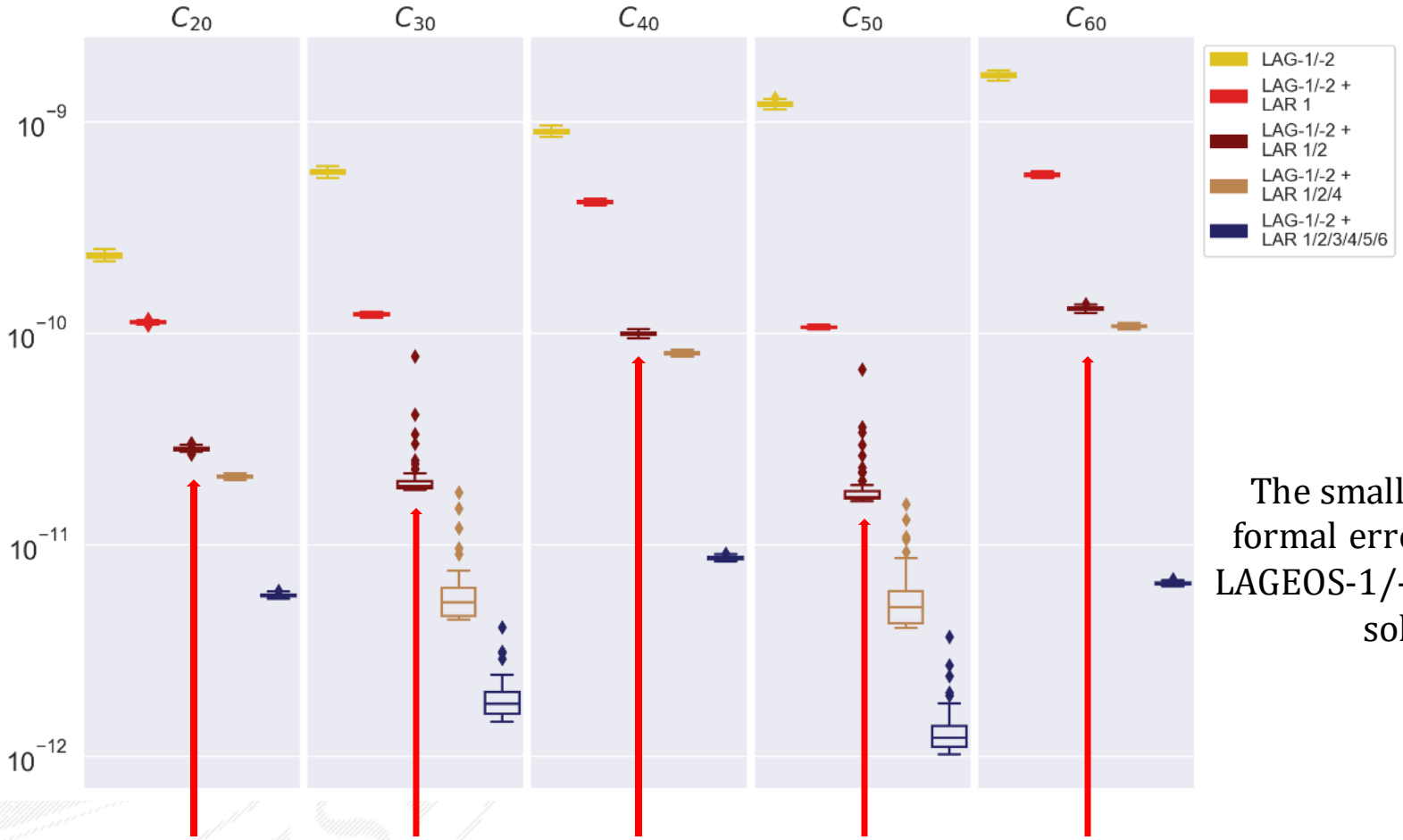
The worst determined component is Z geocenter

Solution LAGEOS-1/-2 + LARES 1/2 decreases formal errors by 20, 20, and 33% for X, Y, and Z, respectively with reference to LAGEOS-1/-2 + LARES 1 solution

Satellites	X [mm]	Y [mm]	Z [mm]
LAGEOS-1/-2	1.1	1.0	2.4
LAGEOS-1/-2 + LARES 1	1.0	1.0	2.1
LAGEOS-1/-2 + LARES 1/2	**0.8**	**0.8**	**1.6**
LAGEOS-1/-2 + LARES 1/2/4	0.7	0.7	1.3
LAGEOS-1/-2 + LARES 1-6	0.6	0.6	1.1

RESULTS

EARTH'S GRAVITY POTENTIAL – ZONAL HARMONICS

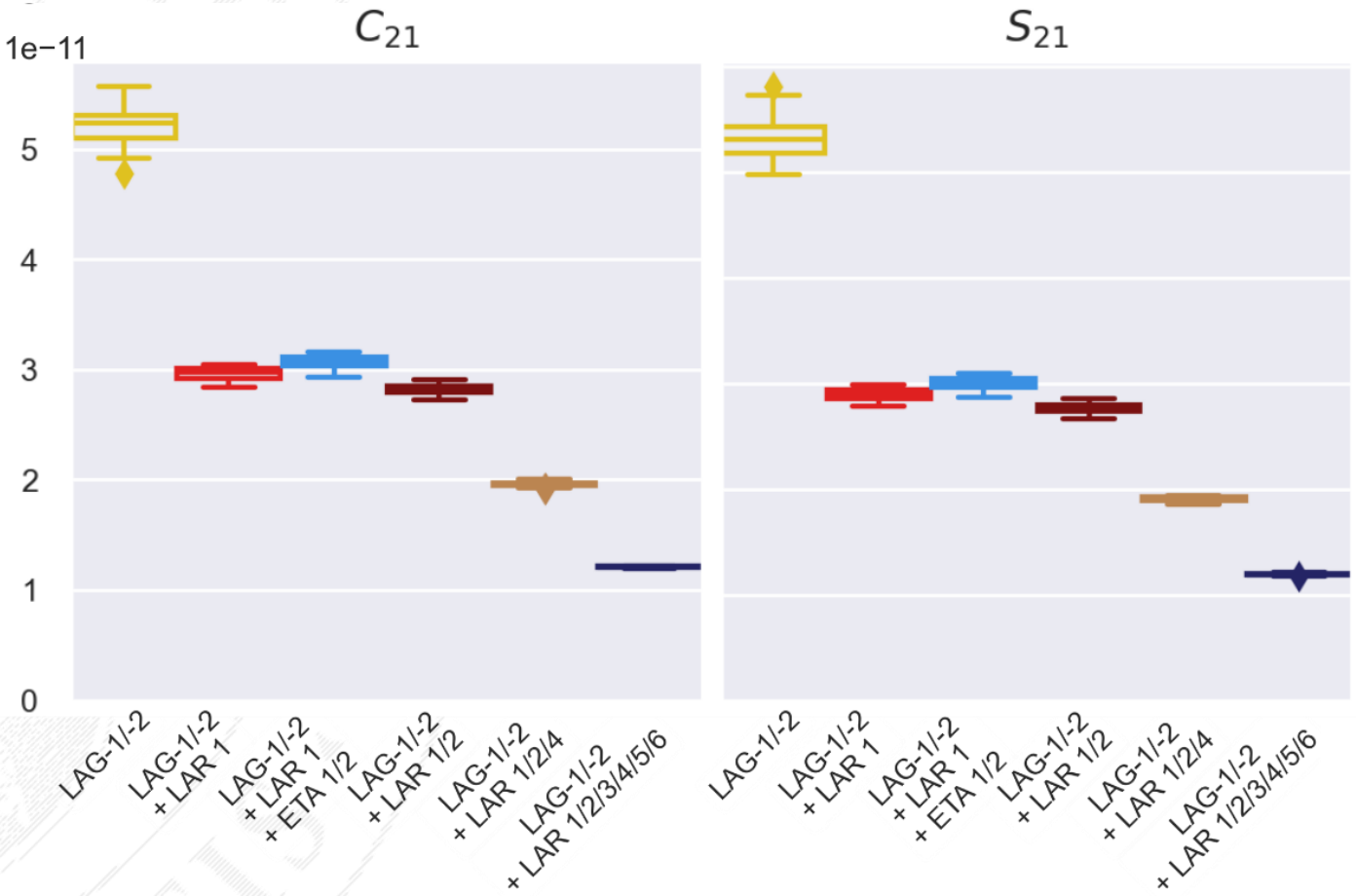


The smallest values of formal errors are for the LAGEOS-1/-2 + LARES 1-6 solution

Adding observations to LARES 2 to solutions LAGEOS-1/-2 + LARES 1 could decrease formal errors for zonal terms by one order of magnitude

RESULTS

EARTH'S GRAVITY POTENTIAL – C_{21} AND S_{21}



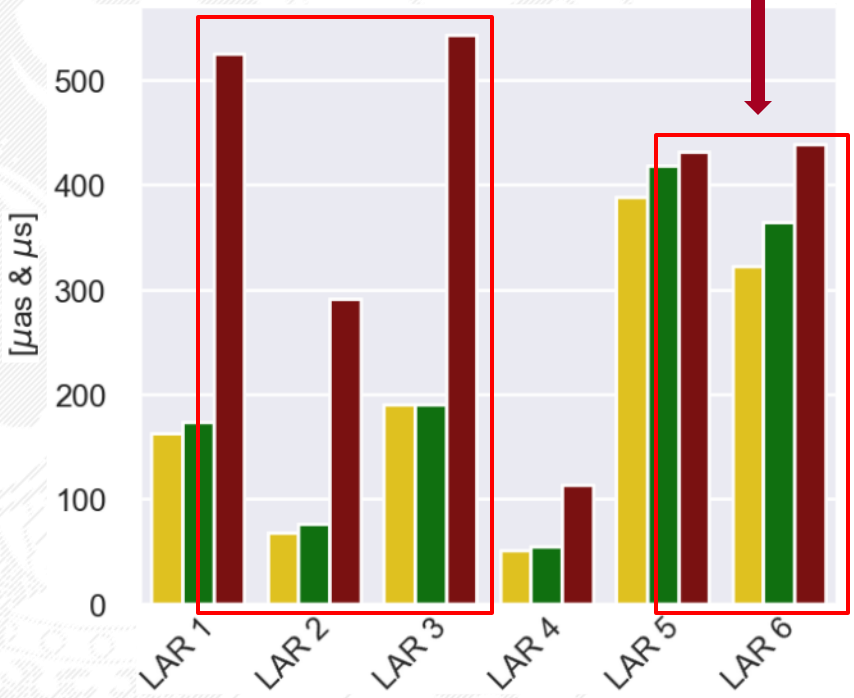
The observations of LARES 1 satellite could significantly improve the quality of determined C_{21} and S_{21} coefficients compared to observations of LARES 2 satellite.

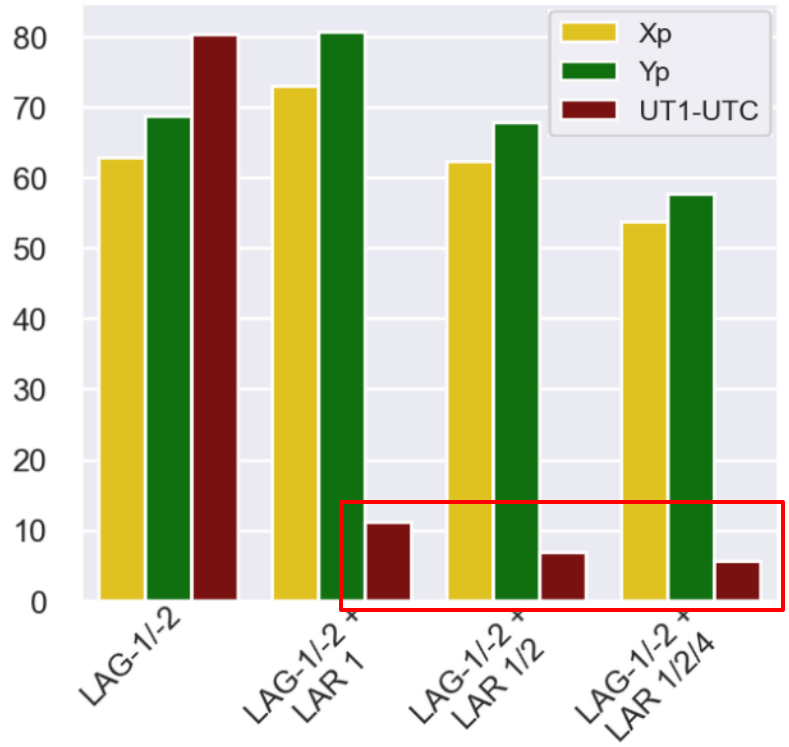
RESULTS

EARTH'S ROTATION PARAMETERES

The satellites in almost polar orbits increase the formal errors for UT1-UTC

The satellites orbiting close to the equatorial plane increase the formal errors for the pole coordinates





	X_P [μas]	Y_P [μas]	UT1-UTC [μs]
LEO satellites	0.26	0.28	0.48
MEO satellites	0.06	0.07	0.20

LARES

LARES 1/3/5/6

2/4

Adding observations to LARES 1/2/4 satellites decreases the formal errors for UT1-UTC

CONCLUSION

ANSWER TO THE QUESTIONS:

- What will be the influence on global geodetic parameters when taking the observations of LARES 2 into account?

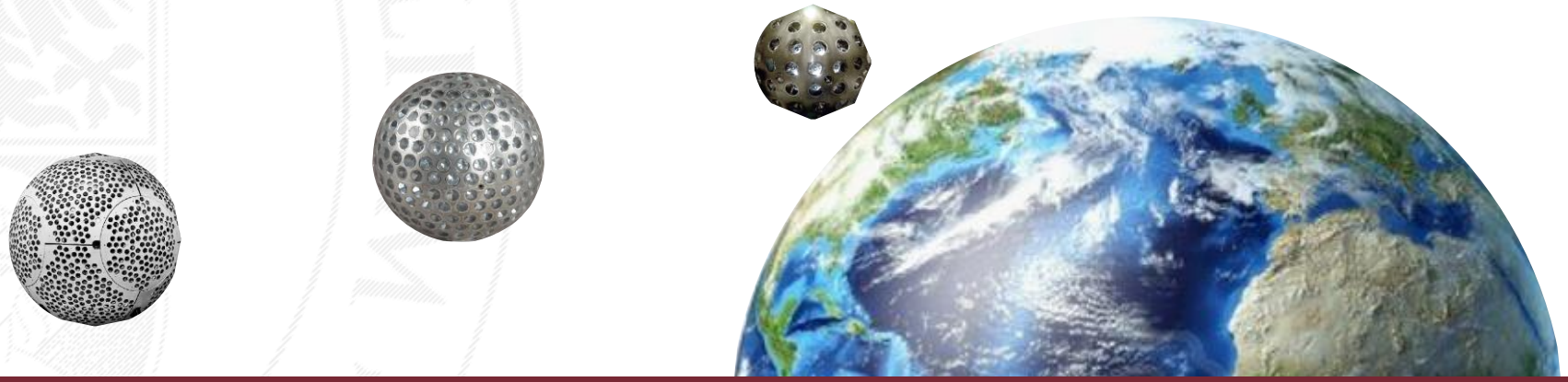
  Adding observations will improve the quality of the parameters determined not only by a greater number of observations, but also by adding observations to satellites with different altitudes and orbit inclinations, causing the correlations between estimated parameters are reduced. The greatest reduction in formal errors should occur for the coordinates of the SLR stations, as well as for the geocenter coordinates - in particular for the Z component.

- What shall be the orbit parameters for future satellites that will bring the greatest improvement in determining geodetic parameters?

  The biggest improvement would be for the LARES 4 satellite, which would supplement the current constellation – LARES 4 satellite will be the **retrograde satellite, orbiting symmetrical to the LAGEOS-2.**

WROCŁAW UNIVERSITY OF ENVIRONMENTAL AND LIFE SCIENCES

THANK YOU FOR YOUR ATTENTION!



Joanna Najder, Krzysztof Sośnica,

Dariusz Strugarek, Radosław Zajdel

Institute of Geodesy and Geoinformatics