2017 ILRS Technical Workshop

„Improving ILRS Performance to meet Future GGOS Requirements”

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How many SLR observations and how many station are needed for deriving high-quality multi-GNSS orbits?

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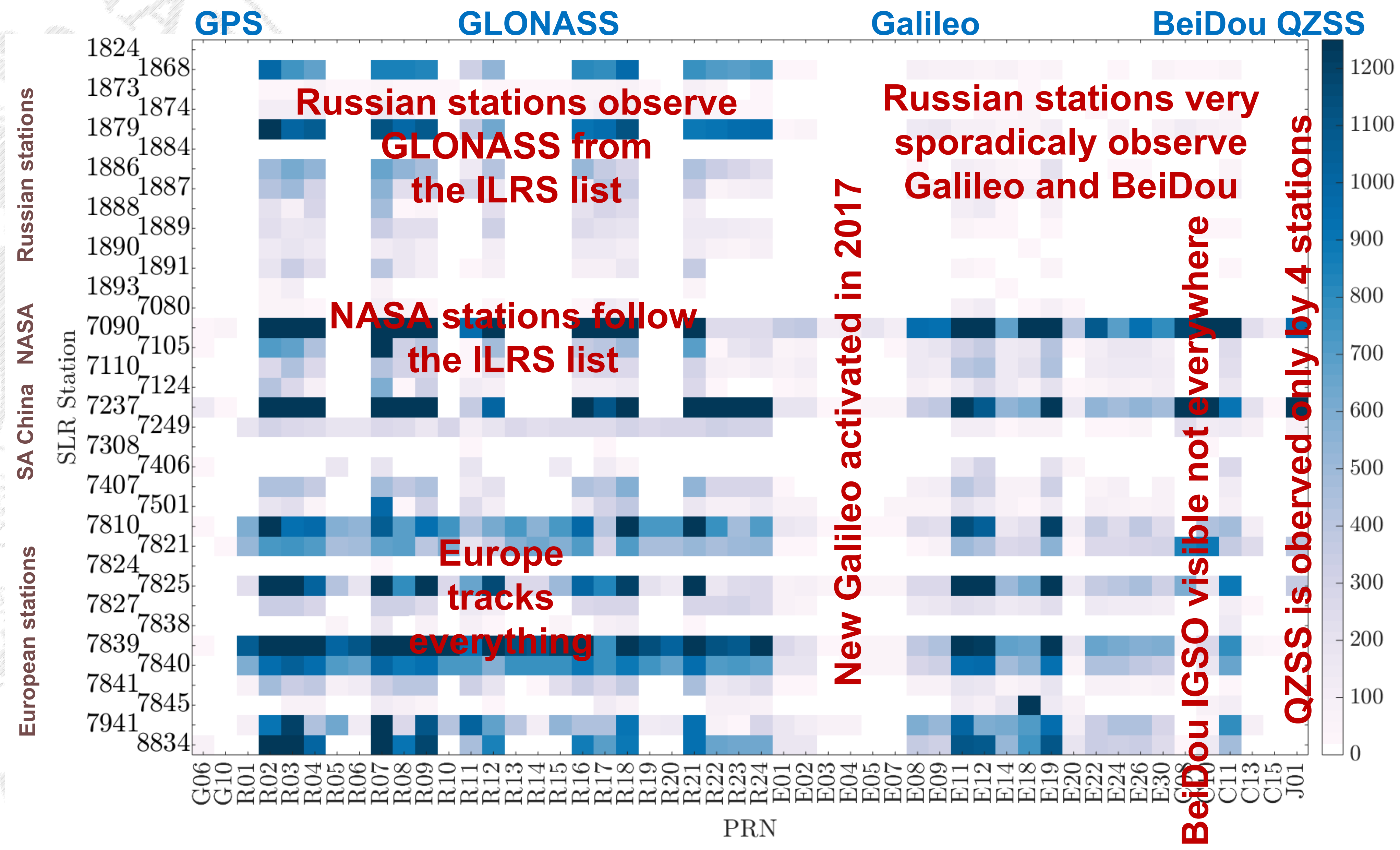
The goal of this study

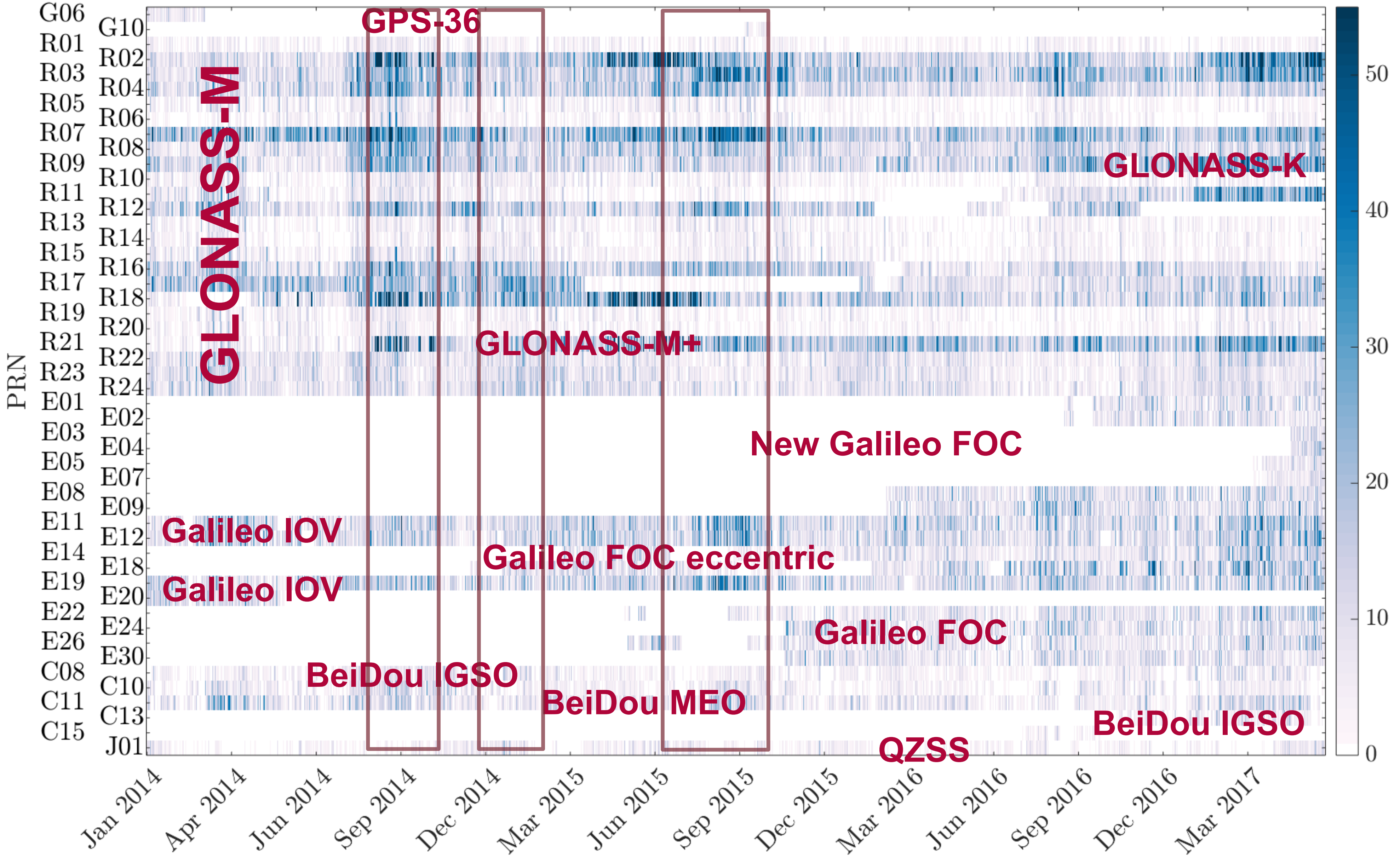
This presentation aims at addressing the following questions:

1. How does the number of SLR observations act on the multi-GNSS orbit accuracy determined using solely SLR data?
2. What is an optimal geometry of SLR observations, thus how many SLR stations are needed to determine precise multi-GNSS orbit?
3. Can we develop a common strategy for multi-GNSS orbit determination using SLR data?

Number of SLR observations to multi-GNSS (2014.0-2017.4)

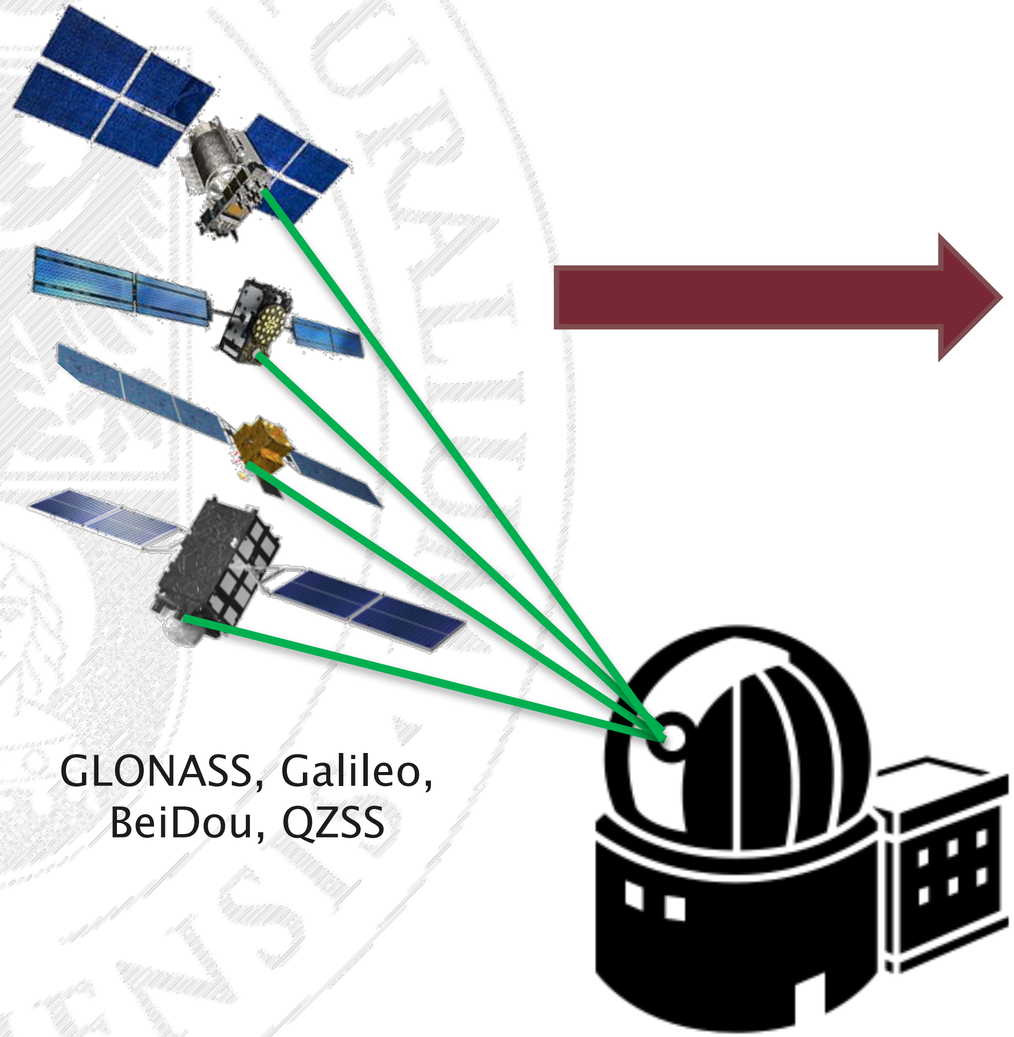


Number of SLR observations to multi-GNSS



CES

Processing scheme of parameter estimation using range measurements to multi-GNSS



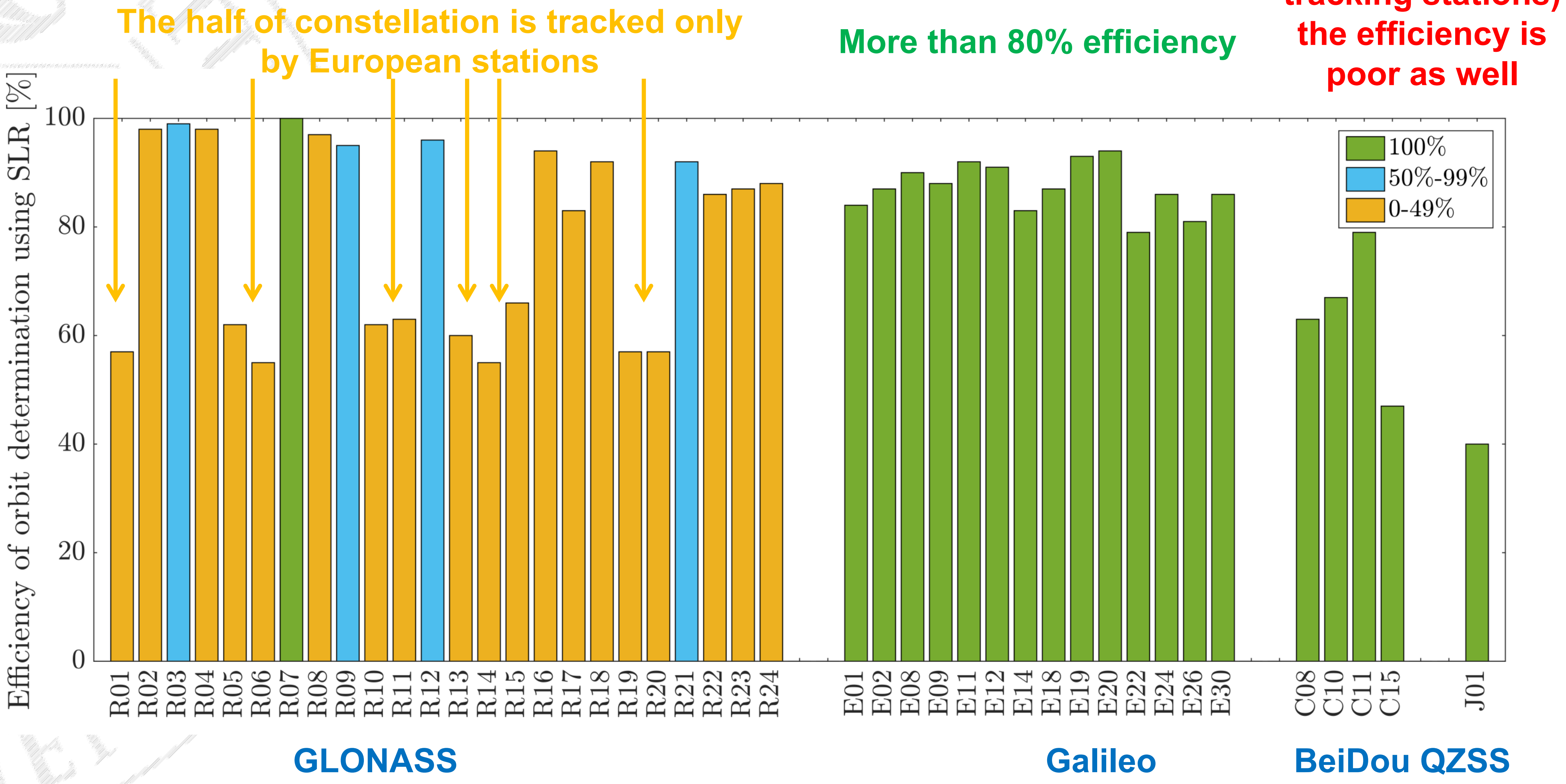
SLR & GNSS co-location

- Multi – GNSS orbits
- SLR station coordinates
- Geocenter coordinates
- Earth Rotation Parameters
- Orbit validation
- Time transfer

Multi-GNSS orbit determination using slolely SLR data and comparison with a priori CODE-MGEX products (test 3-, 5-, 7- and 9-day arcs)

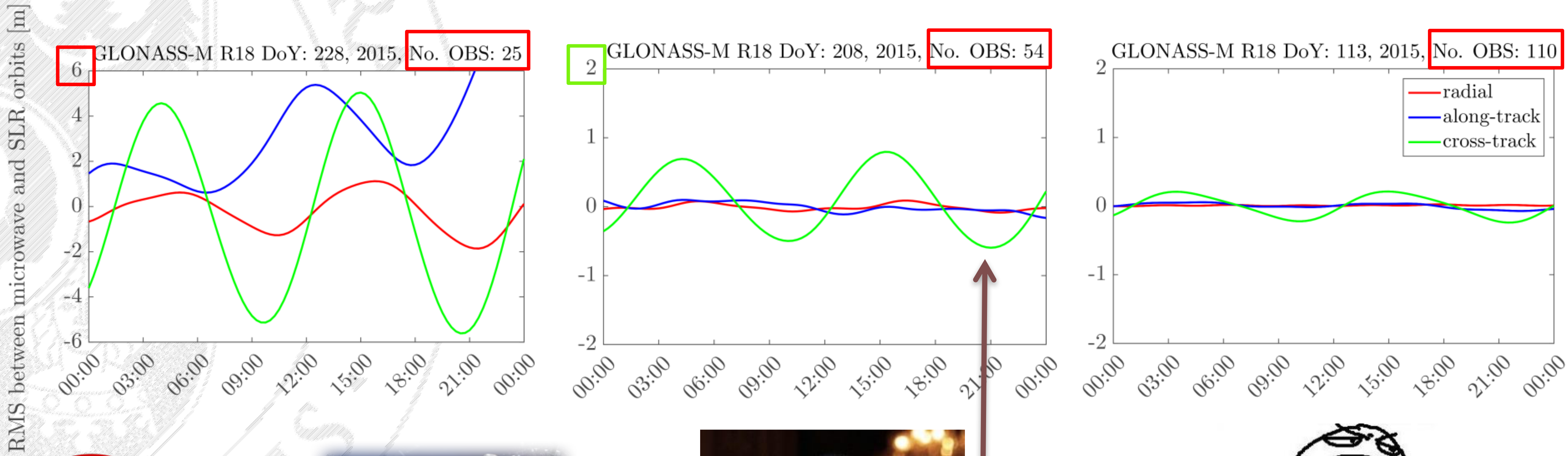
Analysis period: 2014.0 – 2016.9

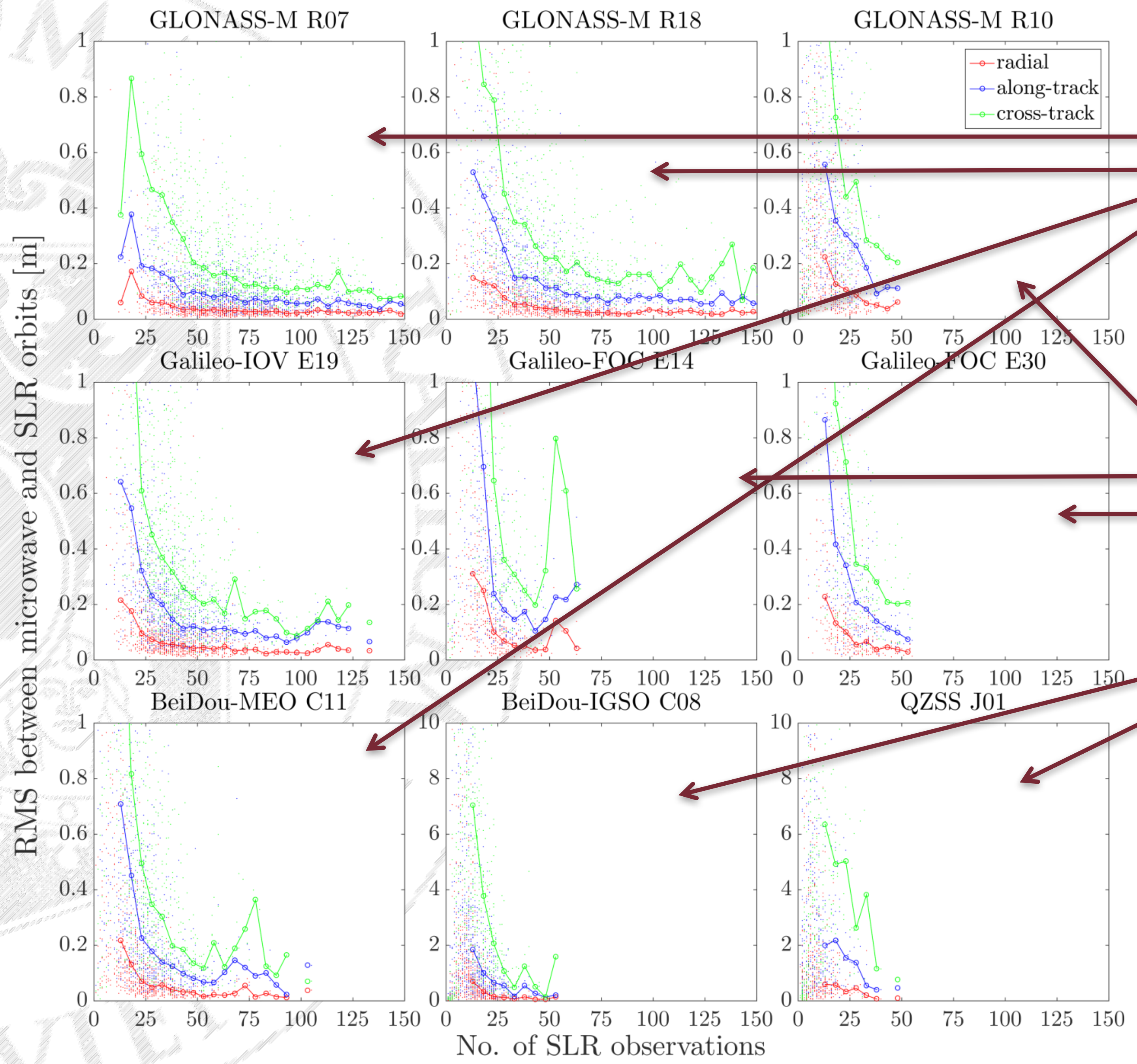
The efficiency of the 3-day solutions



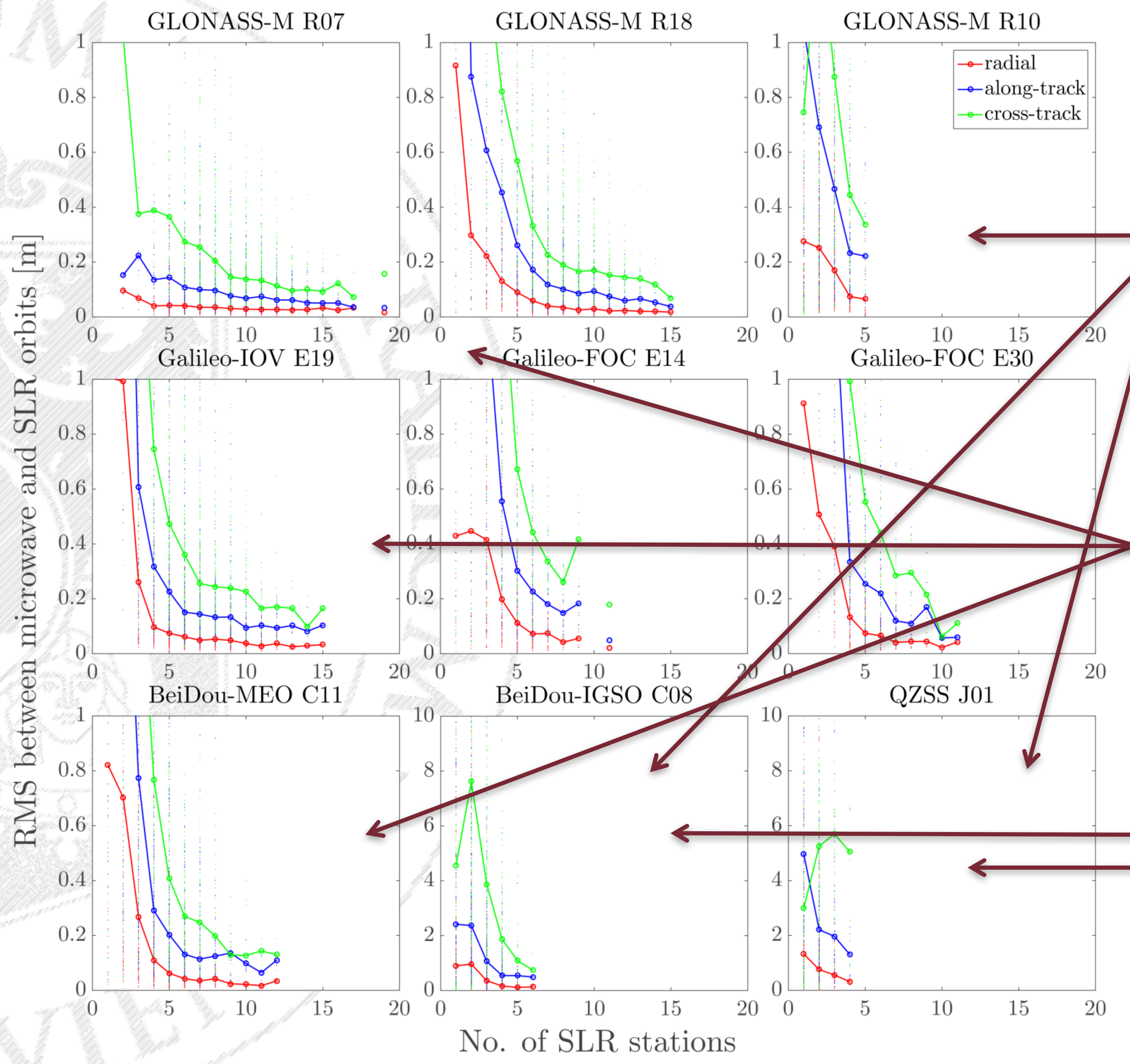
Detailed 3-day solutions

Fig. A detailed 3-day solutions provided from a high number of SLR observations: 110 (right), 54 (middle), and an insufficient number of SLR observations: 25 (left) for GLONASS R18. RMS presented for the middle day (time in UTC) of the solution.





- For intensively tracked satellites 60 SLR observations are needed to determine precise orbit at the level of 3 cm in the radial direction,
- The effort should be put on the homogenous tracking of the whole multi-GNSS constellation,
- Due to the regional attitude of BeiDou IGSO and QZSS, the number of observations is insufficient,



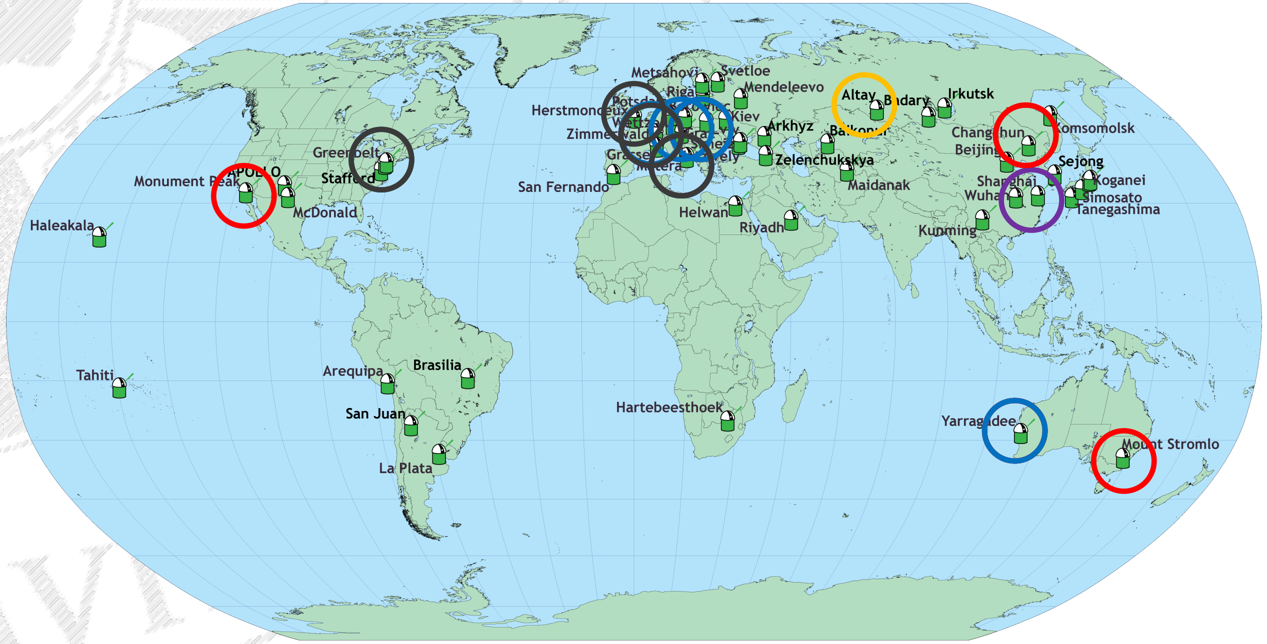
- The geometry of observations provided by 5 stations is insufficient to determine a reliable orbit,
- The increase of the number of stations from 5 to 10 reduces steadily RMS to the level of: 3, 8, and 15 cm in the radial, along-track, and cross-track direction, respectively,
- The poor geometry of BeiDou IGSO and QZSS is caused by regional attitude of those constellations,

Geometry of observations

- The best solution was obtained for GLONASS R07 at 15 July 2015 (5-day solution)

- Number of observation: **129**
- **12** evenly located SLR stations

- **RMS: 0.8, 2.4** and **1.9 cm** in the **radial, along-track** and **cross-track** direction, respectively



- 60 observations are suffcient to determine orbit of an average quality.

Median RMS of differences between SLR and microwave derived multi-GNSS orbits. All values in cm.

Component	GLONASS	Galileo		BeiDou		QZSS
		IOV	FOC	MEO	IGSO	
Radial	2.9	4.0	4.3	2.3	4.6	-
Along-track	8.8	10.4	15.7	10.2	24.5	-
Cross-track	16.7	18.1	20.3	12.3	49.8	-
3D	21.4	23.3	26.2	17.9	55.6	-

Recomendation:

At least 100 observations provided by at least 10 evenly located stations

Summary

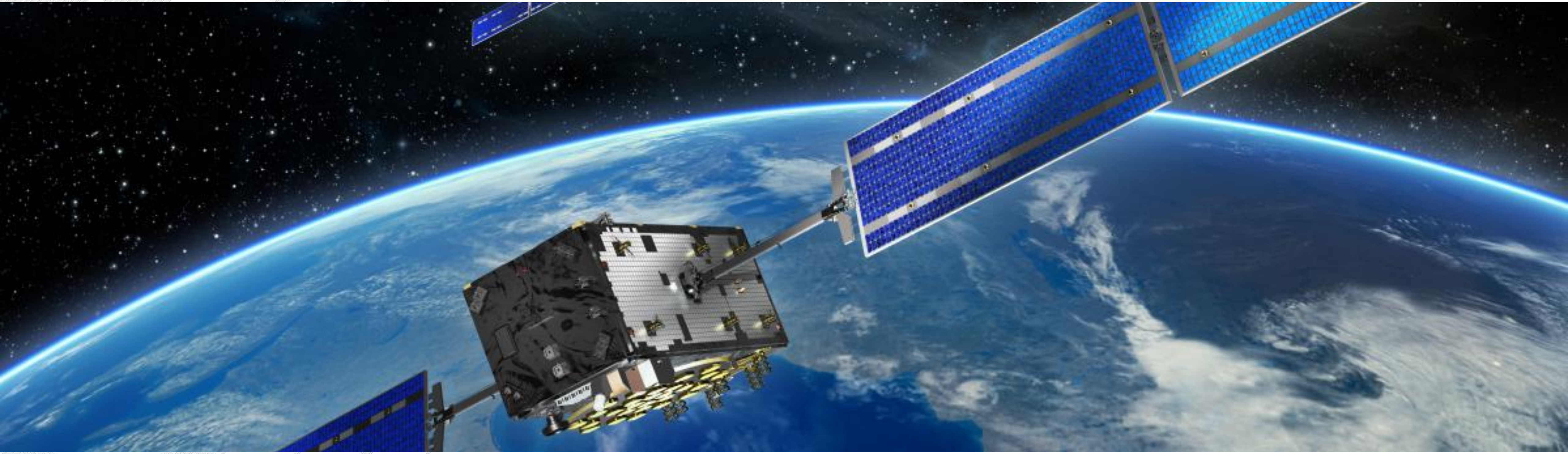
- 60 SLR observations are sufficient to determie mulit-GNSS orbit of an average quality (for inactive satellites). **Orbits calculated from ca.100 SLR observations are at the cm-level accuracy,**

- Orbits provided by more than **10 evenly distributed SLR stations are at the cm-level of accuracy,**

- However, we need observations collected by stations not only from Europe and Australia, but also from N&S America and Asia, especially if considering BeiDou IGSO and QZSS.

Thank You for Your Attention

Wrocław University of Environmental and Life Sciences



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Scheduling according to observation geometry (?)

Europe – a lot of high-performing stations:

- Station Group 1: 7810, 7941, 7824, 7811, 1874
- Station Group 2: 7839, 8834, 7841, 1884, 1886
- Station Group 3: 7840, 7827, 7845, 1837, 1888

	Day 1	Day 2	Day 3
GLONASS plane I	Group I	Group II	Group III
GLONASS plane II	Group II	Group III	Group I
GLONASS plane III	Group III	Group I	Group II

Australia:

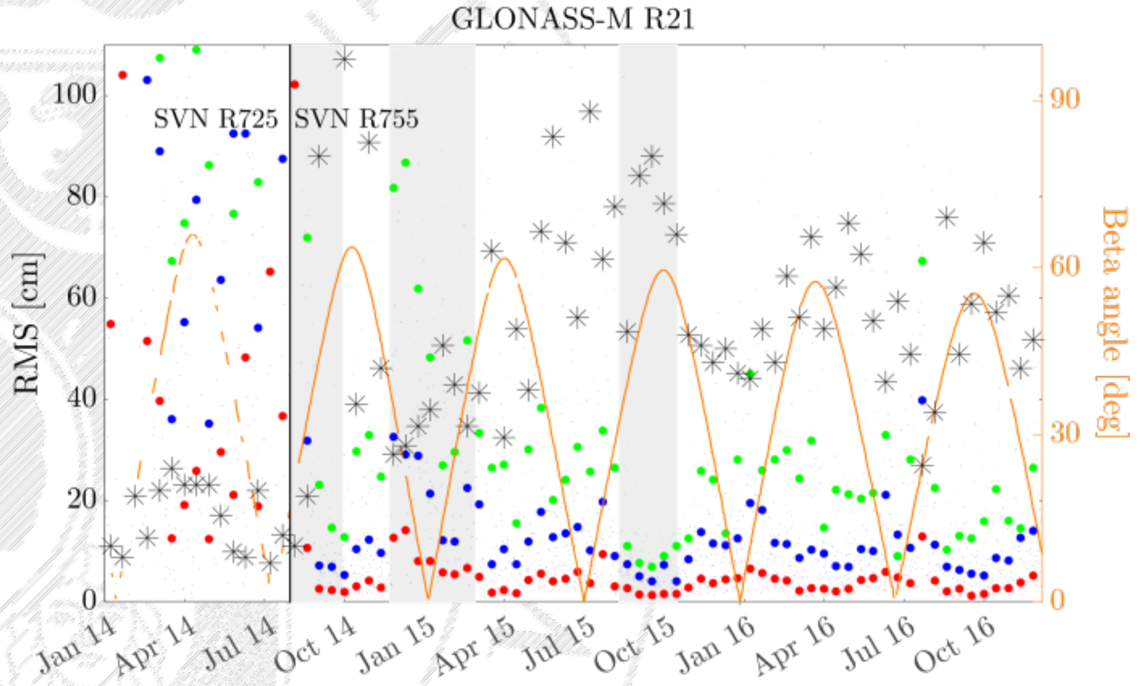
- Station Group 1: 7090
- Station Group 2: 7825

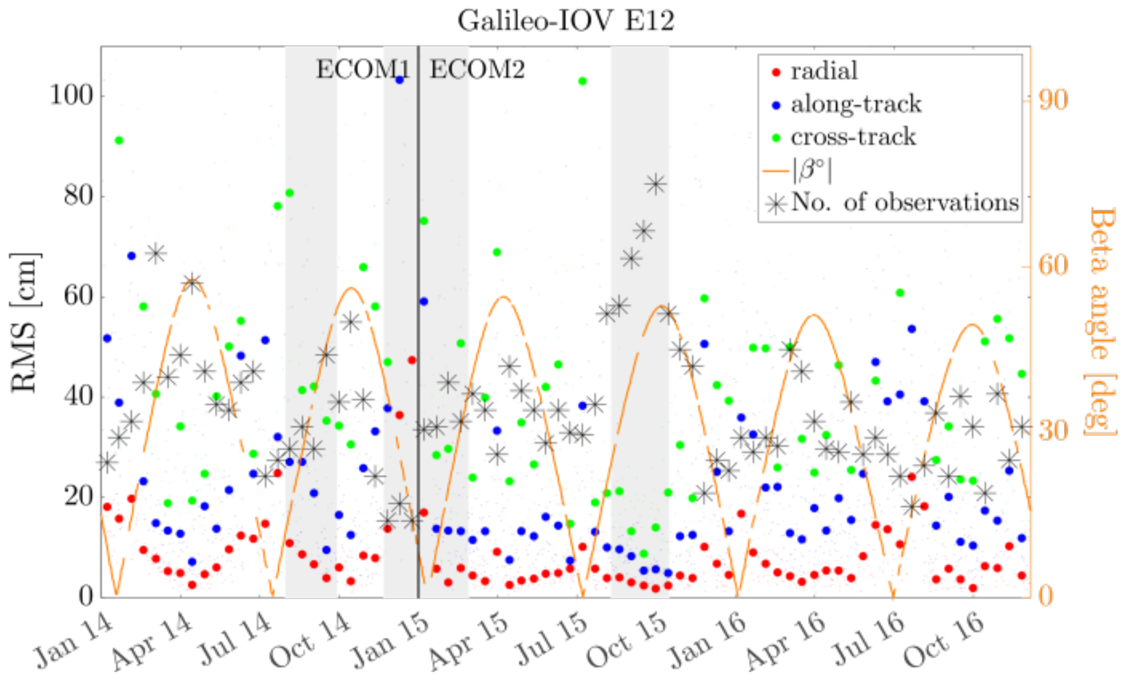
	Day 1	Day 2
GLONASS plane I	Group I	Group II
GLONASS plane II	Group II	Group I
GLONASS plane III	Group II	Group I

N&S America, Africa, Pacific

- Should track everything following the ILRS list

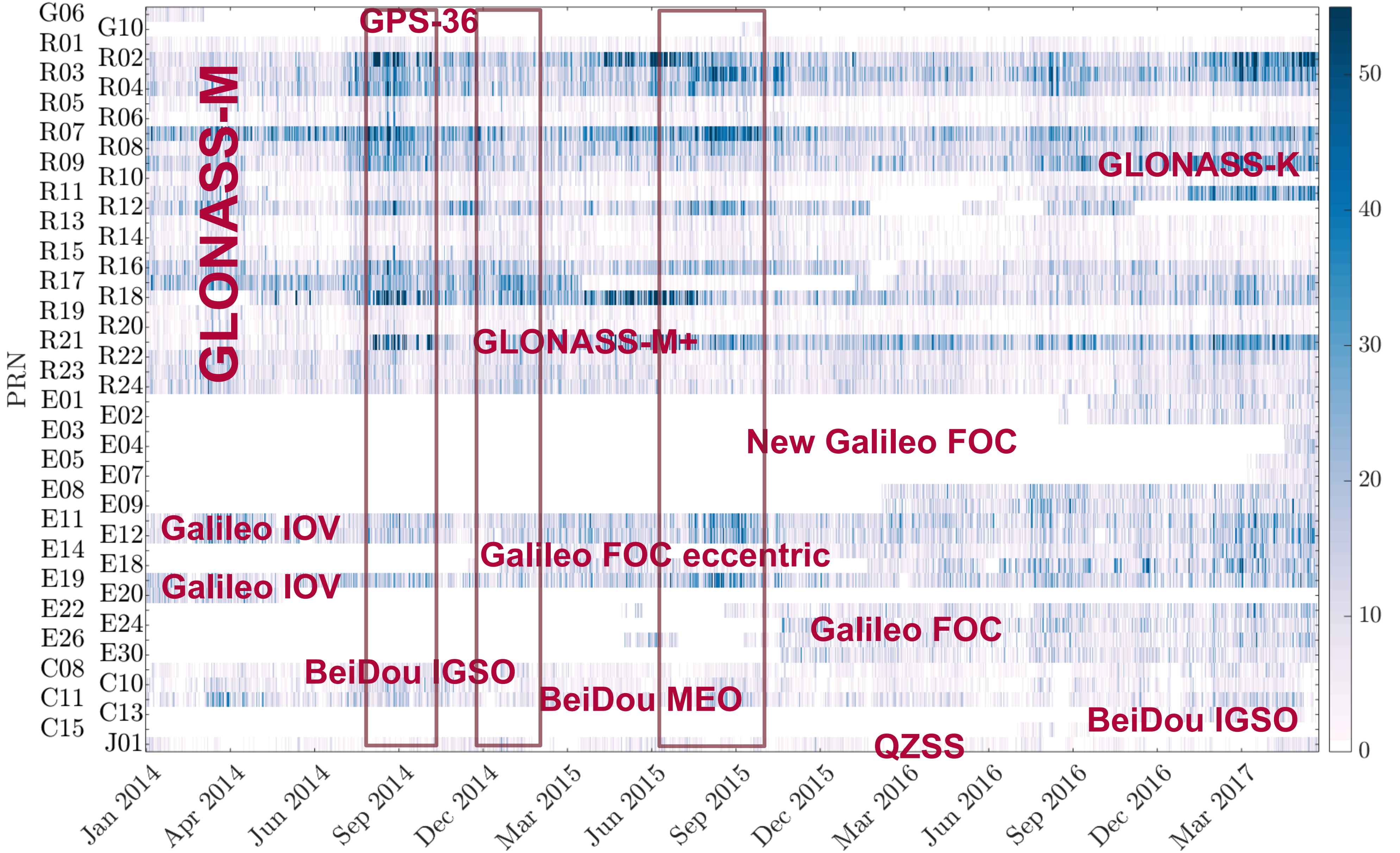
The discussion of the results

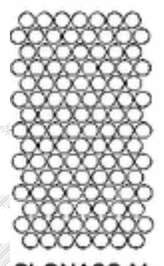


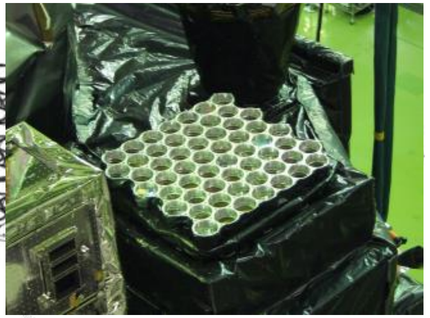


The accuracy of SLR-derived orbits depends on: (1) the number of SLR observations, (2) the number and distribution of SLR tracking stations, (3) the length of the orbital arc, (4) the generation of the satellite, (5) type of an orbital plane, (6) β angle, (7) and empirical models used in the calculation (ECOM1/ECOM2).

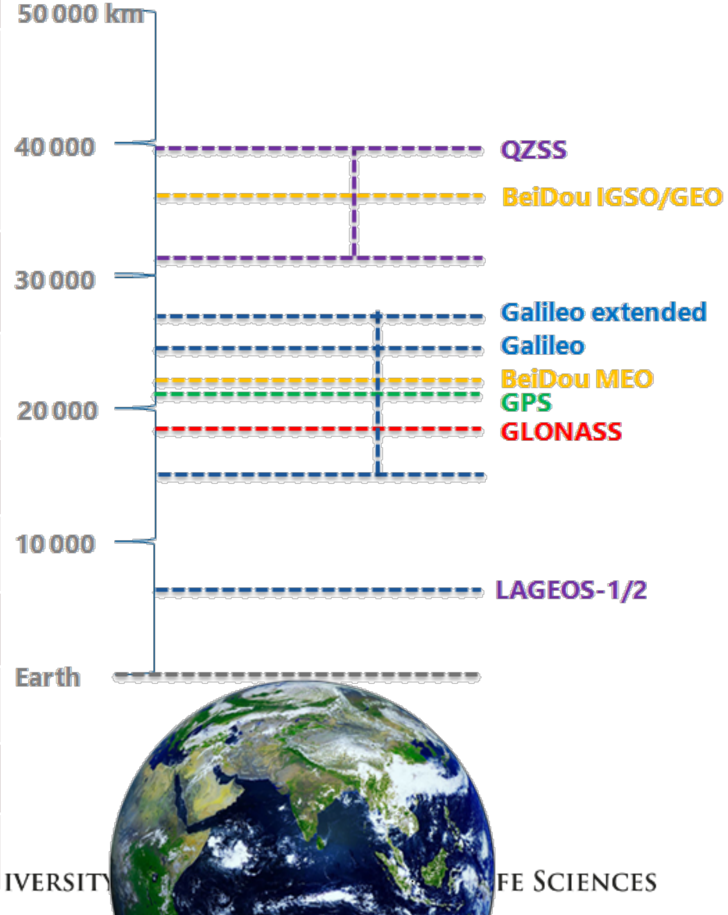
Number of observations







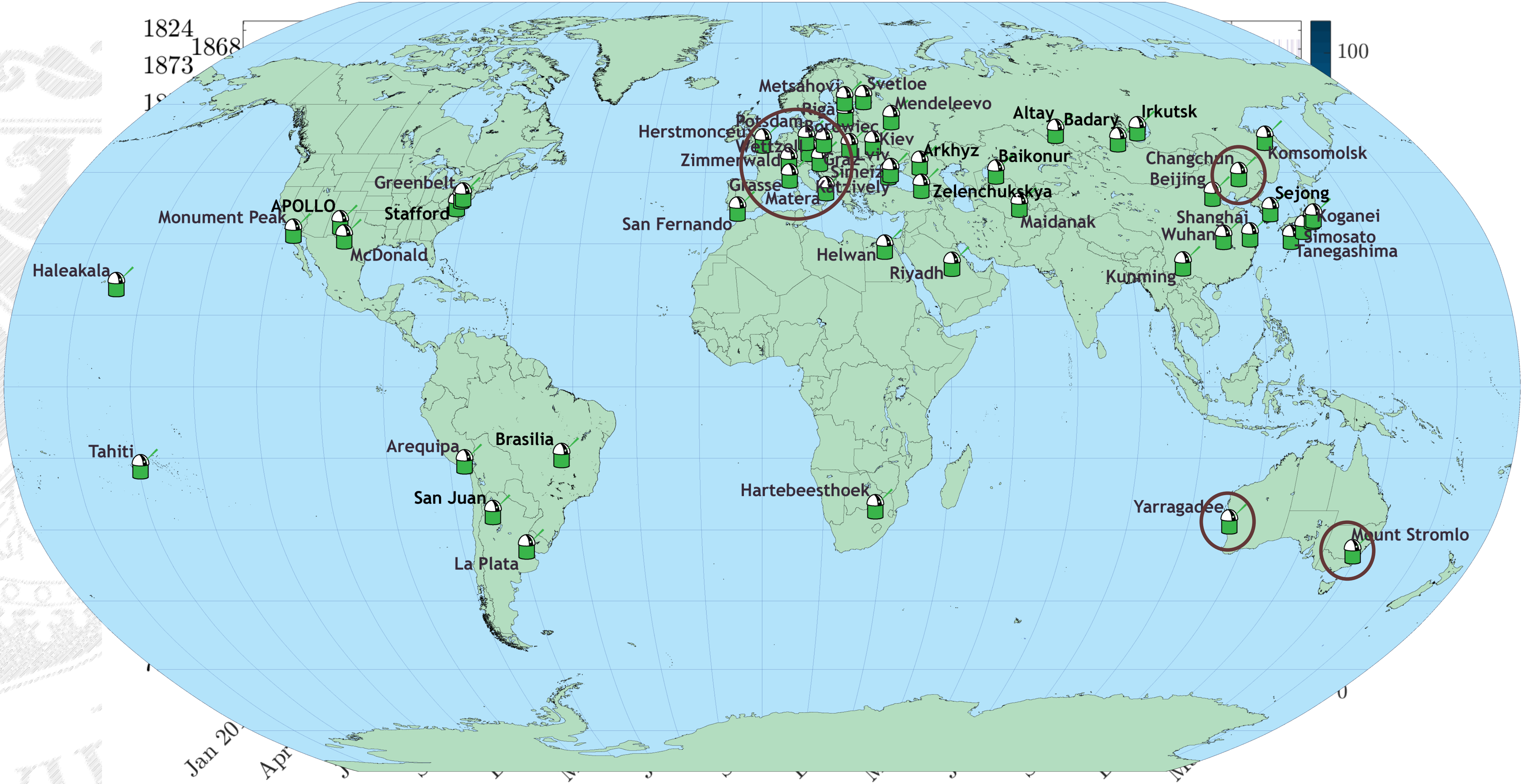
System	GLONASS		Galileo			BeiDou			QZSS	
Type	GLONASS-M	GLONASS-K	IOV	FOC (extended orbit)	FOC	MEO	IGSO	GEO	QZS-1/2 (IGSO)	QZS-3 (GEO)
PRN Number	R01-R08 R10-R19 R21-R24	R09, R20 (spare)	E11, E12, E19, E20	E14, E18	E26, E22, E24, E30, E08, E09, E01, E02, E07, E03, E04, E05	C11, C12, C14, C33, C34 , C35	C06-C10, C15, C31, C32, C13	C01-C05, C17	J01, J02	J03
CODE products	ALL	ALL	E11, E12, E19	ALL	ALL	C11-C14	C06-C10, C15	-	J01	-
ILRS tracking	ALL	ALL	ALL	ALL	ALL	C11, C33, C34	C08, C10, C15, C31, C32	C01	J01, J02	J03
Retroreflectors	112	123	84	60	60	42	42	90	56	56
Size of LRA [mm]	311.0/510.8	O: 633.7, I: 342.5	430.0/ 470.0	331.0/ 248.7	331.0/ 248.7	316.0/ 280.0	316.0/ 280.0	490.0/ 430.0	400.0/ 400.0	400.0/ 400.0
Mass [kg]	1 415	935	695-697	661/662	706-709	1 900	1 900	1 550	1 896/ 1 550	1 700
Altitude [km]	19 132	19 132	23 225	17 178 - 26 019	23 226	21 529	35 790	35 790	32 000 – 40 000	36 000
Orbit	MEO	MEO	MEO	MEO	MEO	MEO	Geosynch.	Geostat.	Geosynch.	Geostat.
Inclination [deg]	64.8	64.8	54.9-55.6	50.1	54.9-57.2	56.2	53.3-57.7	0.9-1.6	40.7	0.0

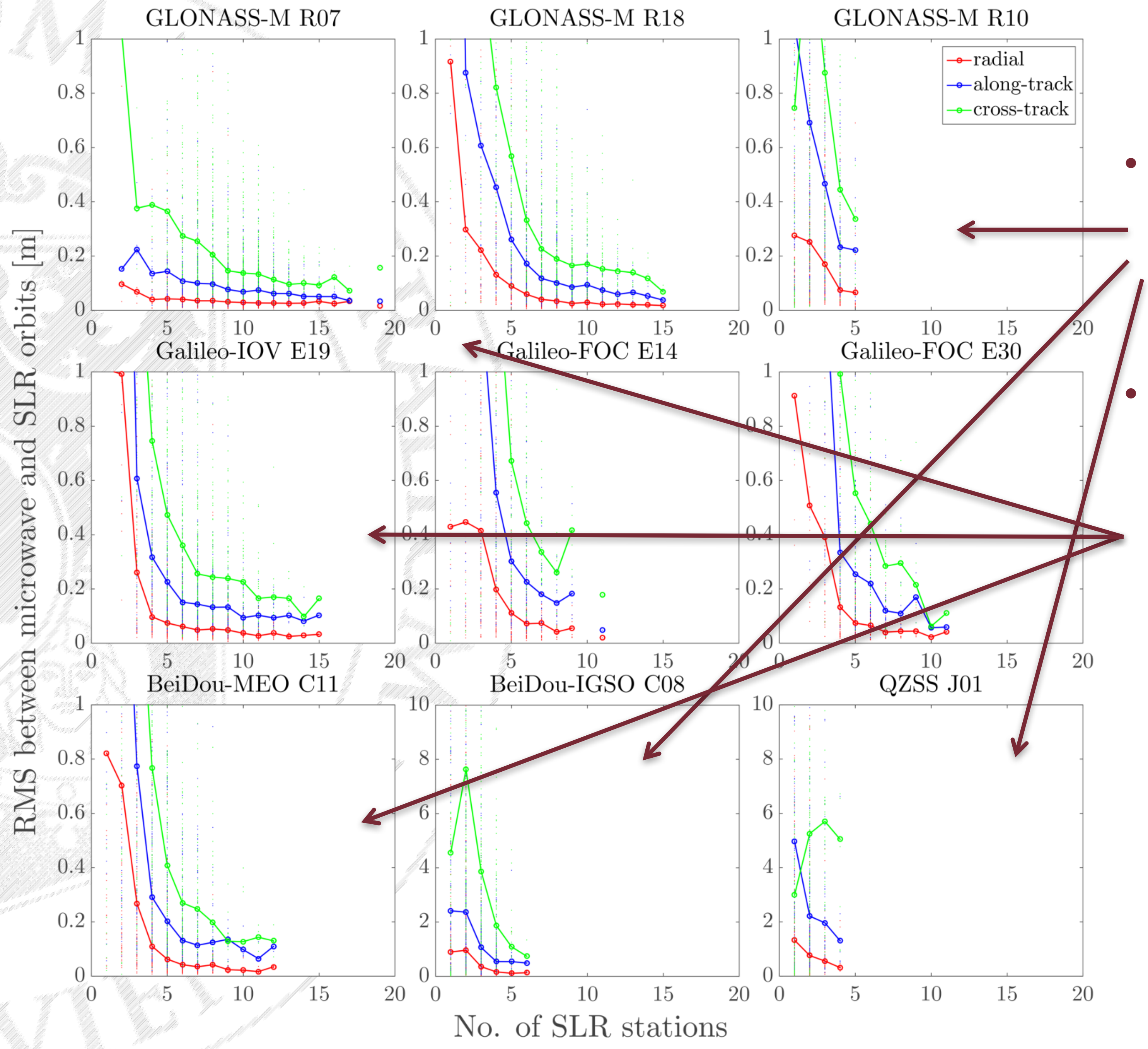


Statistics

Fig. Map of ILRS stations

Fig. The number of SLR observations to GNSS satellites during 3-year period





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Multi-GNSS EXperiment

The MGEX Tracking Network

Fig The networks of MGEX tracking stations on day: 10.01.2017
http://www.igs.org/network?network=multi-GNSS

Analysis centers:

- Centre National d'Etudes Spatiales (CNES), Collecte Localisation Satellites (CLS),
- Center for Orbit Determination in Europe (CODE)
- GeoForschungsZentrum Potsdam (GFZ)
- Technische Universität München (TUM)
- Japan Aerospace Exploration Agency (JAXA)
- Wuhan University

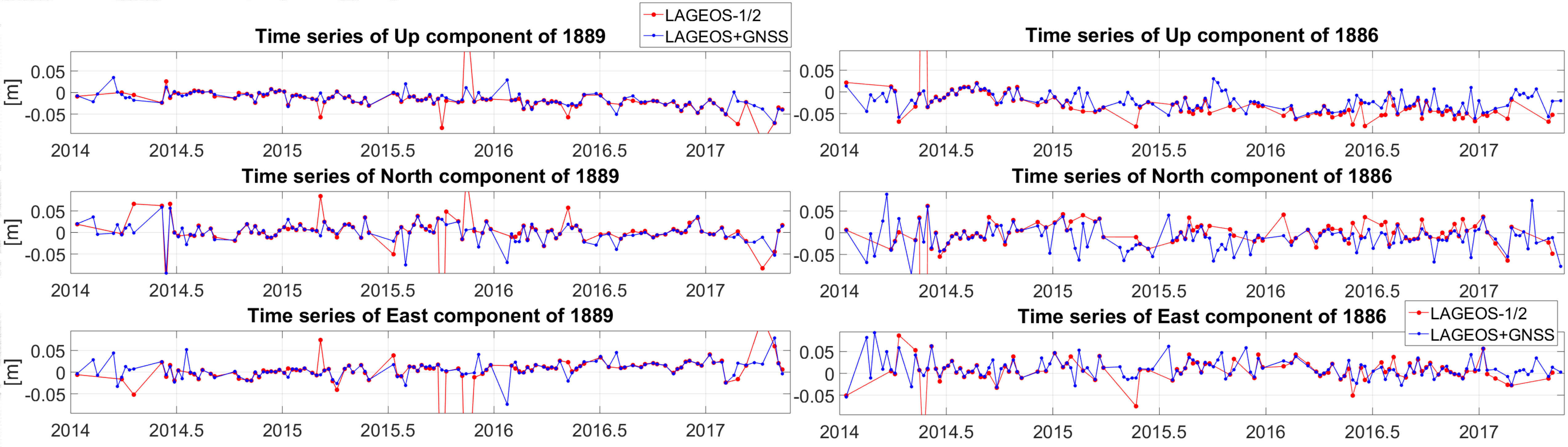
Data centers:

- Crustal Dynamics Data Information System (CDDIS)
- Institut Géographique National (IGN)
- Bundesamt für Kartographie und Geodäsie (BKG)

Products:

- Precise Orbits and Clock Products
- Broadcast Ephemerides
- Differential Code Biases
- Real-Time Products

Station coordinates – repeatability improvement when including SLR@GNSS (see poster session)



Zelenchuksakya (Russia) :

RMS: 49.6 56.3 27.9 mm for North, East, Up, resp. in LAGEOS-1/2

RMS: 21.6 18.4 15.4 mm for North, East, Up, resp. in LAGEOS+GNSS fix

108 solutions in LAGEOS-1/2

123 solutions in LAGEOS+GNSS (14% more solutions)

Arkhyz (Russia) :

RMS: 77.2 30.2 94.7 mm for North, East, Up, resp. in LAGEOS-1/2

RMS: 28.0 22.3 19.9 mm for North, East, Up, resp. in LAGEOS+GNSS fix

100 solutions in LAGEOS-1/2

139 solutions in LAGEOS+GNSS (39% more solutions)