



Tracking strategy and Experiments of Laser Ranging to GNSS satellites

Zhou Shanshi¹, Zhang Haifeng¹, Zhang Zhongping¹, Liu Li²

1. Shanghai Astronomical Observatory, Chinese Academy of Sciences
2. Beijing Satellite Navigation Center

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Outline:

1. **The Role of SLR in GNSS**
2. **Processing of ILRS tracking application**
3. **LARGE tracking campaign organized by ILRS**
4. **Some suggestions for tracking strategy of laser ranging to GNSS satellites**



1. The Role of SLR in GNSS

- SLR is used to evaluate the accuracy of GNSS orbit determined by L-band observations.
- The accuracy of geodetic products are improved by combining the data from co-located GNSS and SLR sites.
- SLR to GNSS targets can also be applied to improve dynamics and measurement models, such as:
 - Solar radiation pressure models (SRP);
 - Antennae phase center offsets (PCO) and their variations (PCV);
 - Clock behavior and monitoring their aging;
 - Orbital attitude models;
 - Other non-conservative force effects on the dynamics of the GNSS satellites

Both GNSS providers and geodetic studies are benefits from SLR tracking data!



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2. Processing of ILRS tracking application

- **Firstly, the applications should be reviewed by the Missions Standing Committee (MSC) in ILRS, including the information of target satellite and laser retro-reflector (LRA), tracking requirements, etc.**
- **Secondly, MSC will make recommendation to the ILRS Governing Board (GB) and determine the priority with respect to other approved tracking missions.**
- **Finally, when the applications are approved by GB, SLR stations will be informed to start tracking.**

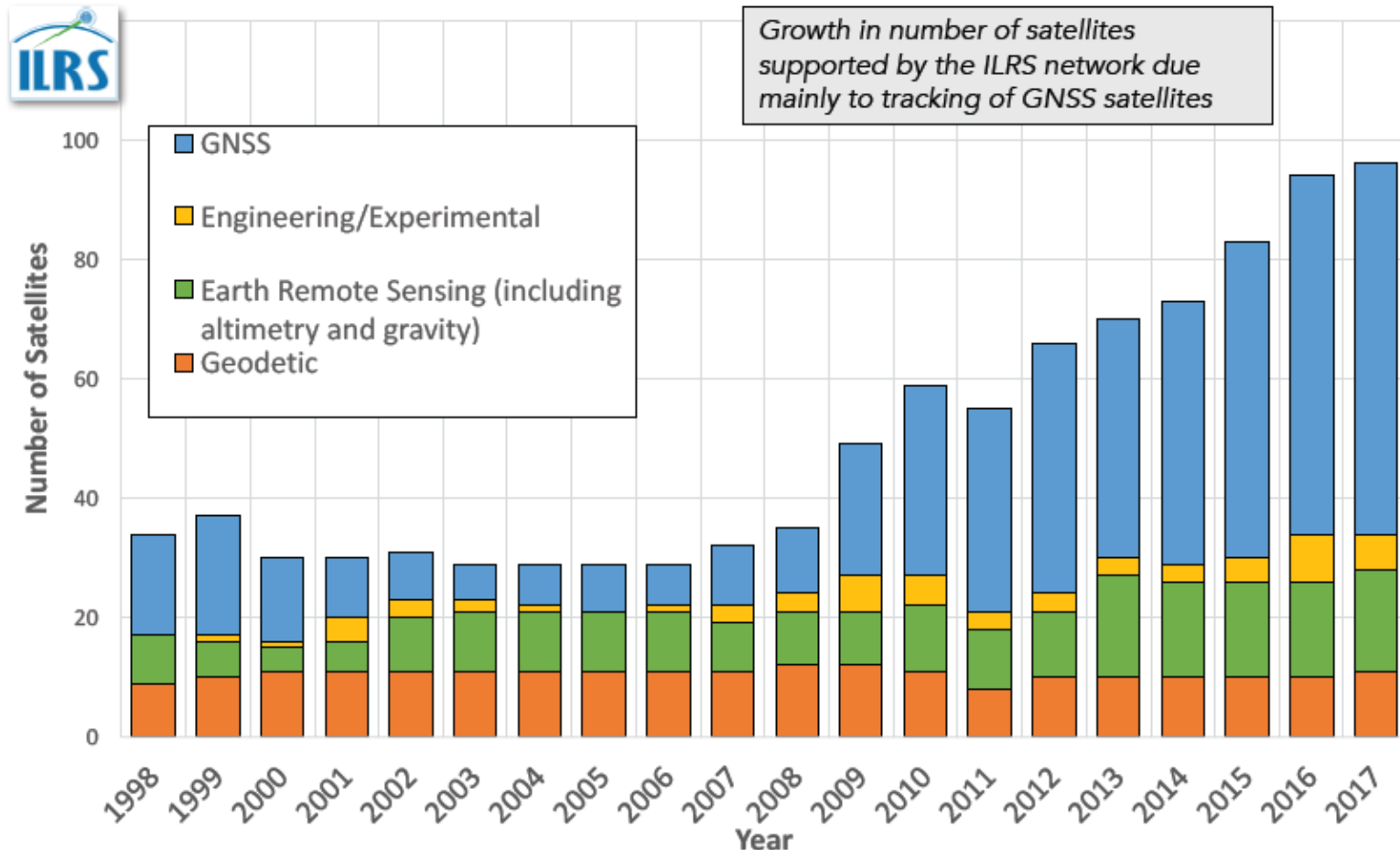


Current list of global tracking GNSS satellites by ILRS

Constellation	Satellites
GLONASS	26 (8 on priority list)
Galileo	22 (18FOC, 4 IOV)
BDS	9 (4 GEO/IGSO, 5MEO)
QZSS	4
IRNSS	6
GPS	2



The number of ILRS tracking GNSS satellites are increased yearly with the developments of GNSS constellations





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LARGE (LAser Ranging to GNSS Experiment) Campaign

- Current situations:

1. The increasing number of GNSS satellites brings problems to SLR stations
2. Tracking all of GNSS satellites is impossible for all stations

It's important to make an agreement on tracking strategy within the ILRS.

- For this purpose, ILRS established a new work group in 2014 in order to research on GNSS satellites tracking strategy: **LARGE (LAser Ranging to GNSS Experiment).**



LARGE (LAser Ranging to GNSS Experiment) Campaign

- **The objectives of this group are:**
 - **Defining an operational GNSS tracking strategy that addresses all proposed requirements from all interested parties.**
 - **Clarifying outstanding ILRS and IGS issues with the GNSS satellites and ground stations.**
- **In the frame of LARGE, each GNSS constellation recommends few satellites which will be joined into LARGE tracking campaign.**
- **Three special GNSS-tracking campaigns had been carried out during 2014 to 2017.**

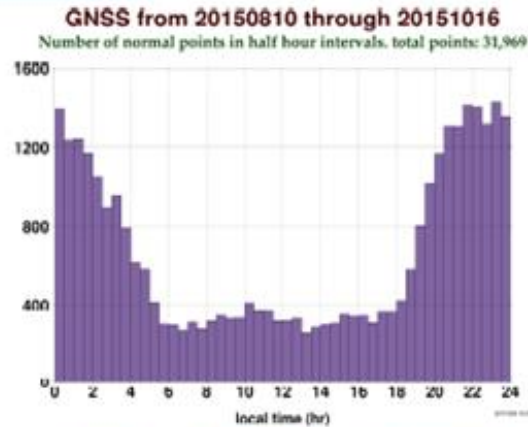


ILRS GNSS-Tracking Campaigns in 2015

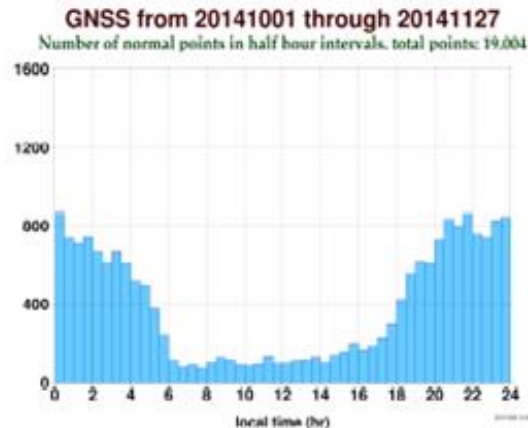
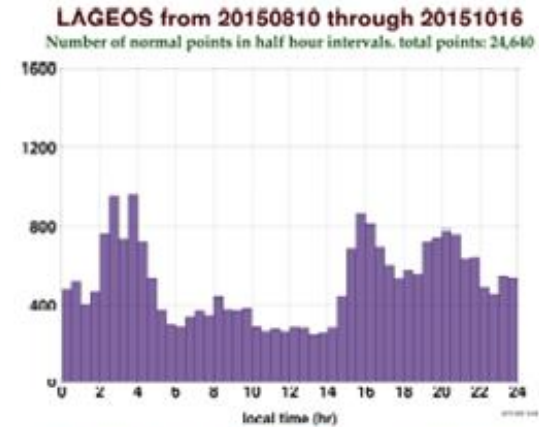


Tracking: Campaign vs. No Campaign

- It appears that GNSS campaign may provide more measurements.
- This trend is the same for three campaigns.

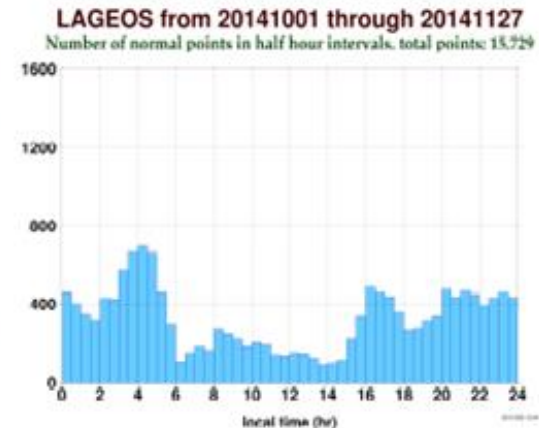


GNSS Campaign 3



Non GNSS Campaign period

It appears that a GNSS campaign yields more data for both GNSS and LAGEOS. This trend is consistent for all three GNSS campaigns.





The first LARGE Campaign in 2018 (February 15-May 15, 2018)

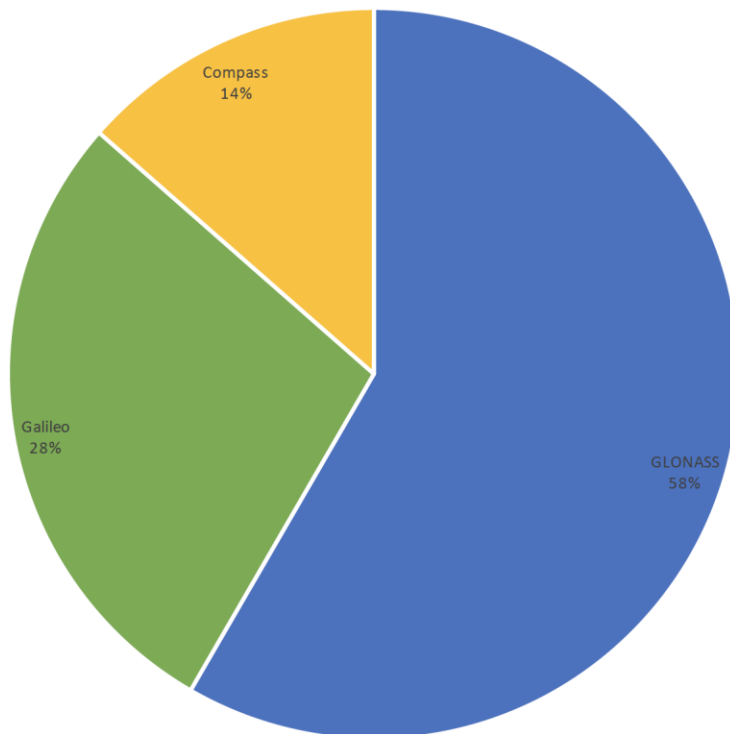
- The objective of this campaign is to obtain an improvement of time and space coverage for GNSS constellations.
- Four primary and four secondary satellites of each GNSS are chosen for this campaign:

System	Primary	Secondary	Comments
GLONASS	-131, -134, -136, -137	-128, -132, -133, -135	
Galileo	-102, -202, -209, -210	-103, -203, -211, -213	March 15-April 15
		-103, -203, -215, -216	April 15-May 15
BDS	-G1, -I3, -M3, -MS1	-I5, -IS2, -I6B, -MS2	



The tracking results of BDS satellites in the first LARGE

Station Tracking Totals by Constellation
(passes)



- The total tracking passes of BDS are much less than GLONASS and Galileo.

- Some possible reasons:

1. Most satellites in tracking list are GEO/IGSO which are located in the regional area.

2. The distance between BDS GEO satellites and ground stations is more than 36000km, which bring difficult to SLR tracking.



The summary of the first campaign in 2018 (~30sites)

- This mission lasted about 90 days. An average of one pass per constellation per day would amount to a total of 270 passes.
 - 9 stations met or nearly met this number, while 15 stations obtained 100 passes or more. More than half the stations take little data.
- About 60% of the tracking passes were GLONASS data.
 - SLR tracking passes to other GNSS satellites (Galileo, Beidou satellites) are recommended.
- Some stations tracking more satellites outside the campaign list than inside the list.
 - If these stations focus on tracking the satellites in the campaign list, the coverage of these satellites will be increased and then the results of SLR processing will be more reliable and stable.



The second LARGE Campaign in 2018 (August 1-October 31, 2018)

- The second LARGE Campaign has been carried out according to the different requirements of each system.
- SLR stations are asked to track the designated GNSS satellites with two, if possible three, segments spread out over the pass.

Constellation	Satellites tracked for the second LARGE campaign
GLONASS	Glomass-131, -134, -136, -137
Galileo	Galileo-102, -202, -209, -210,-103,-203,-211,-213
Compass/Beidou	Compas-I3, -M3,-I5, -I6B Beidou-3M2,-3M3,-3M9,-3M10

2018 ILRS workshop is being held on Nov. 4-9 in Australia and the subject of LARGE campaign will be discussed in detail.



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Suggestion #1

The number of GNSS satellites selected for global SLR tracking should be limited.

- Due to the comparability of GNSS satellites, it is not necessary to track all satellites of each system.
- Each GNSS provider recommend satellite list to join SLR global tracking campaign.
- The tracking list of GNSS satellites can be replaced if some changes happen.



Suggestion #2

LARGE campaign should be carried out continually to obtain enhanced tracking of GNSS satellites in a given period.

- **LARGE campaign can not be limited to the global stations, some regional stations can also be selected to take more robust sampling of the designated GNSS satellites.**
- **LARGE campaigns are implemented by turns among the arranged stations to lighten the tracking burden.**



Suggestion #3

GNSS providers recommend the satellite priority in tracking mission, and meanwhile, SLR core stations should be selected for tracking satellite with higher priority.

- Specify the number of GNSS satellites to be tracked in order to achieve the expected goal.
- Establish the coordination of GNSS providers to propose the priority GNSS satellites to be tracked.



Suggestion #4

Encourage international and space agency support for stations in the ILRS network.

- **The resource issue: operation and technology upgrading are required in order to deliver more data to GNSS users;**
- **Upgrading current stations or building new SLR stations to expand the capacity of tracking GNSS satellites.**



Conclusions

- 1. SLR tracking data is very important in GNSS operation and precise applications.**
- 2. With the development of GNSS, tracking strategy should be made more reasonably.**
- 3. LARGE campaign have made some efforts on these issues.**
- 4. GNSS providers and international organizations should coordinate with each other to get more efficient tracking.**



Shanghai Astronomical Observatory
Chinese Academy of Sciences

Thanks for your attention!