Summary of Results from ILRS GNSS Tracking Campaigns (2014-2015)

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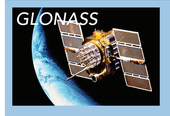
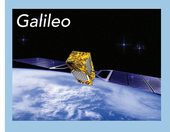
Abstract: The ILRS has organized three campaigns to provide intensive tracking of GNSS satellites by stations in its network. This work has been organized within the ILRS study group, LAser Ranging to GNSS s/c Experiment (LARGE). The campaigns primarily focused on intensive tracking of GLONASS, Galileo, and Beidou (Compass) satellites. The ILRS wants to use the experience gained from these experiments to help define an operational GNSS tracking strategy for the service that will address all proposed requirements for tracking from the GNSS missions. Furthermore, it is hoped that the results from these tracking campaigns can clarify any outstanding ILRS and IGS issues with the GNSS satellites and ground stations. The results of the three campaigns will be shown.

LARGE Study Group (SG): LAser Ranging to GNSS s/c Experiment – Expanded SLR Tracking of GNSS Satellites *(http://ilrs.gsfc.nasa.gov/science/ILRS_LARGE_sg/index.html)*





Objectives:

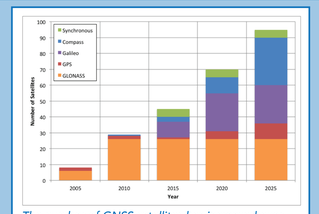
- Define an operational GNSS tracking strategy for the ILRS that addresses all proposed requirements and then tests its realization with a tracking campaign to be run as a Pilot Project
- Clarify outstanding ILRS and IGS issues with the GNSS satellites and ground stations

The satellite constellations of interest with retroreflector arrays include GLONASS, BeiDou (Compass), Galileo, and GPS. The GLONASS constellation is fully populated. BeiDou and Galileo (including GIOVE) constellations are being populated. The GPS constellation will begin being populated in the 2018 time frame. When completed, the full GNSS complex should reach about 70 – 80 satellites.

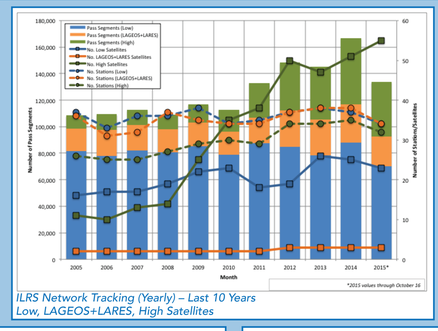
Tasks:

1. Collect the quantitative requirements with supporting documentation from each interested group (SG)
2. Perform any simulations necessary to justify the separate requirements (SG)
3. Recommend a unified tracking strategy for the network (SG)
4. Implement the strategy with 8 – 10 test stations and assess results (ILRS Central Bureau/SG)
5. Adjust the strategy as necessary (SG)
6. Clarify outstanding SLR issues with GNSS satellites and ground stations (ILRS CB)
7. Clarify outstanding radio issues with GNSS satellites and ground stations (IGS CB)

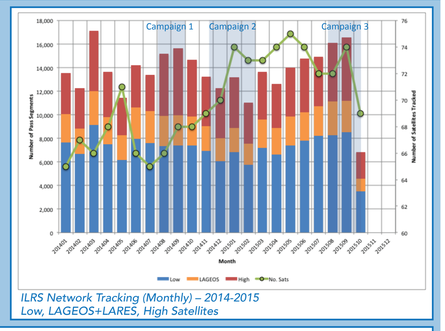
Thus far, the LARGE SG has organized three SLR intensive tracking campaigns on GNSS targets.



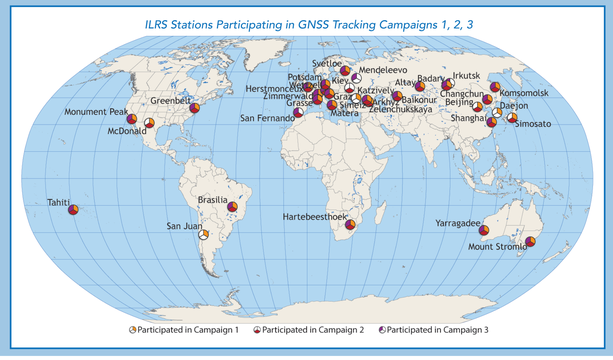
The number of GNSS satellites has increased over the last 10 years and will continue to increase through the next 10.

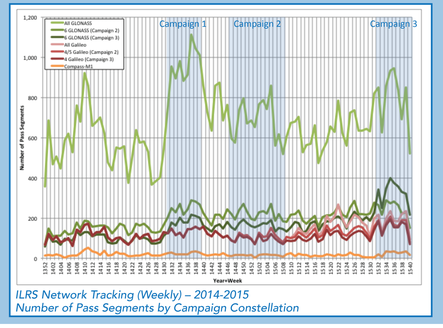


ILRS Network Tracking (Yearly) – Last 10 Years
Low, LAGEOS+LARES, High Satellites

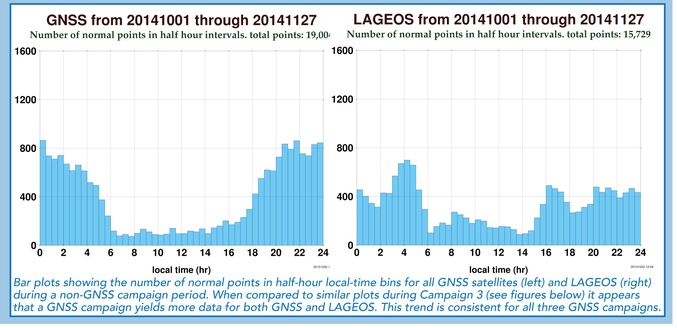


ILRS Network Tracking (Monthly) – 2014-2015
Low, LAGEOS+LARES, High Satellites





ILRS Network Tracking (Weekly) – 2014-2015
Number of Pass Segments by Campaign Constellation



Bar plots showing the number of normal points in half-hour local-time bins for all GNSS satellites (left) and LAGEOS (right) during a non-GNSS campaign period. When compared to similar plots during Campaign 3 (see figures below) it appears that a GNSS campaign yields more data for both GNSS and LAGEOS. This trend is consistent for all three GNSS campaigns.

Campaign 1

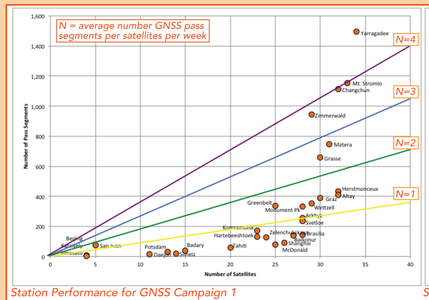
August 01 – September 30, 2014 (2 months/8 weeks/61 days)

Instructions:

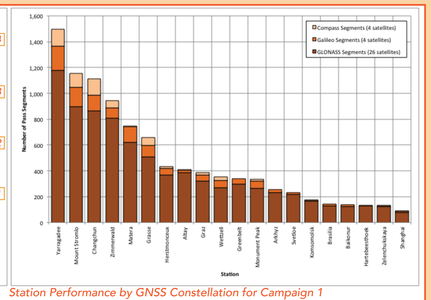
- Track all GNSS satellites on current ILRS priority list (18 satellites); can track more if able (total of 33 satellites available, 24 GLONASS/5 Galileo/4 Beidou)
- Acquire three sets of two normal points distributed over that transit of each satellite; normal point includes 1000 FR points or last 5 minutes, whichever is shorter; no need to obtain more than 1000 FR points
- Cycle through all of the GNSS satellites (GLONASS, Galileo, and Beidou); and track the full cycle at least three times per week
- Attempt some daytime passes if conditions are favorable

Conclusions:

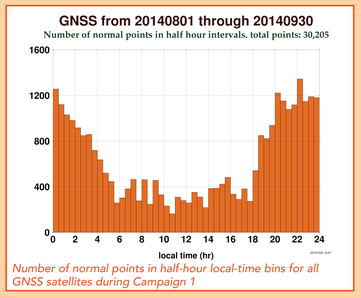
- Number of stations tracked all of the satellites
- Few stations tracked a thousand or more pass segments and a few thousand normal pts
- Several stations averaged 2 – 4 passes a week on all of the satellites
- Largest data yield was achieved by the Yarragadee site
- Increased GNSS tracking did not appear to noticeably reduce LAGEOS & LEO data yield
- Few stations got more than one segment per pass
- Small amount of data in daylight



Station Performance for GNSS Campaign 1
Number of Pass Segments vs. Number of Satellites



Station Performance by GNSS Constellation for Campaign 1
Number of Pass Segments for Top 20 Stations



Number of normal points in half-hour local-time bins for all GNSS satellites during Campaign 1

Campaign 2

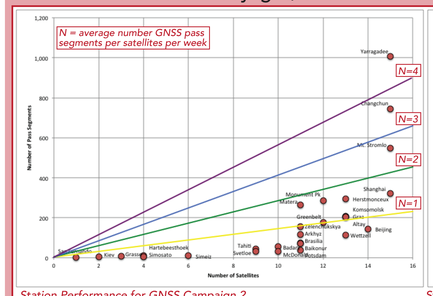
November 22, 2014 – February 28, 2015 (3 months/14 weeks/99 days)

Instructions:

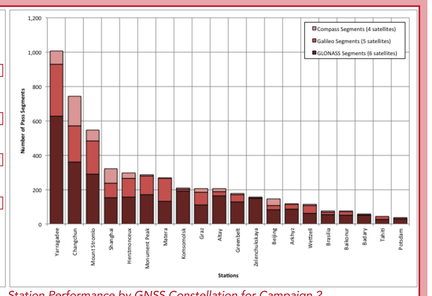
- Track six GLONASS only: GLONASS-123, -125, -129, -130, -131, and -132 (first priority)
- Track Beidou and Galileo as second priority
- Tracking remaining GLONASS satellites as third priority
- At minimum, stations obtain three segments along each pass, with three NPTs in each segment
- Include daylight data, even if it is just a couple of hours after sunrise and a couple of hours before sunset

Conclusions:

- Some stations obtained 2 and 3 segments and daylight data on some passes
- Need more sectors covered for the six higher priority GLONASS satellites and Galileo and Compass-M satellites; more important to get 2 and 3 sectors of data in the higher priority GLONASS satellites than to track the lower priority GLONASS satellites
- Need more data in daylight, or at least around sunrise and sunset

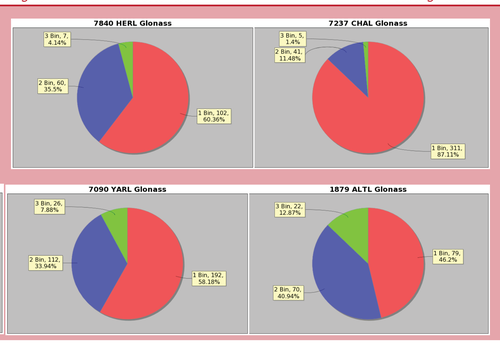


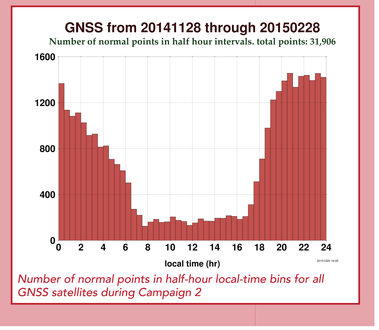
Station Performance for GNSS Campaign 2
Number of Pass Segments vs. Number of Satellites



Station Performance by GNSS Constellation for Campaign 2
Number of Pass Segments for Top 20 Stations

Figures found in Campaign 2 summary report (http://ilrs.gsfc.nasa.gov/docs/2015/GNSScampaign2_statisticreport_20150630.pdf) show the percentage of the passes tracked that included one, two, and three segments for GLONASS. Some stations were able to track 2 and 3 segments in some passes. The charts could also show that some stations may be tracking with their own tracking preferences.





Number of normal points in half-hour local-time bins for all GNSS satellites during Campaign 2

Campaign 3

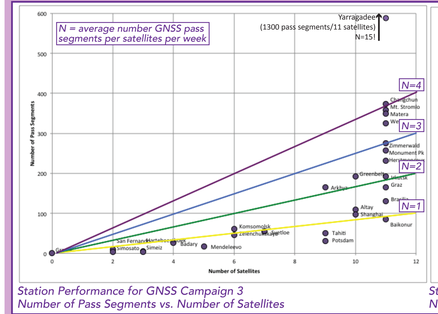
August 20 – October 16, 2015 (2 months/8 weeks/58 days)

Instructions:

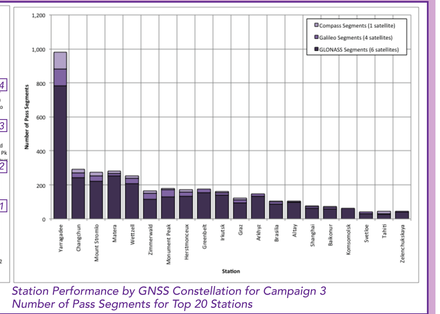
- Track six GLONASS only: GLONASS-123, -125, -128, -129, -133, and -134 (first priority)
- Track Compass-M3 and Galileo-101, -102, -103, and -104 (second priority)
- Tracking remaining GLONASS satellites as third priority but less important
- Obtain nine NPTs over the pass
  3 during the ascending or early region of the pass;
  3 in the central region of the pass
  3 in the descending or late region of the pass
- NPTs in each region may be taken together of separately whichever is better for your operation
- Obtain more daylight ranging even if it is around sunrise and sunset

Conclusions:

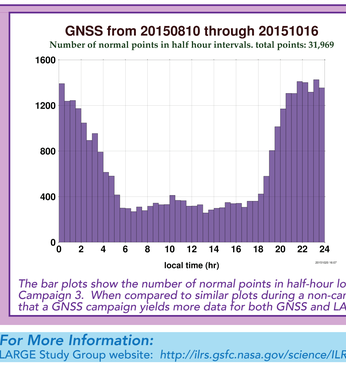
- High data yields can be expected when conditions are very good
- Need more data in daylight, or at least around sunrise and sunset
- May have same issues as with previous campaigns



Station Performance for GNSS Campaign 3
Number of Pass Segments vs. Number of Satellites



Station Performance by GNSS Constellation for Campaign 3
Number of Pass Segments for Top 20 Stations



The bar plots show the number of normal points in half-hour local-time bins for all GNSS satellites (left) and LAGEOS (right) during Campaign 3. When compared to similar plots during a non-campaign period (20141001–20141127, see figures above) it appears that a GNSS campaign yields more data for both GNSS and LAGEOS. This trend is consistent for all three GNSS campaigns.

For More Information:
LARGE Study Group website: *http://ilrs.gsfc.nasa.gov/science/ILRS_LARGE_sg/index.html*

10/21/2015