# Early Results from New Initiatives on SLR Tracking of GNSS and Synchronous Satellites
## (Abstract 3114)

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On November 16, 2013, at the 18th International Workshop on Laser Ranging in Fujiyoshida, Japan, the attendees adopted a resolution endorsing expanded ILRS tracking on Global Navigation Satellite System—GNSS satellites with retroreflector arrays of sufficient quality, highlighting the example of the fully populated GLONASS constellation.

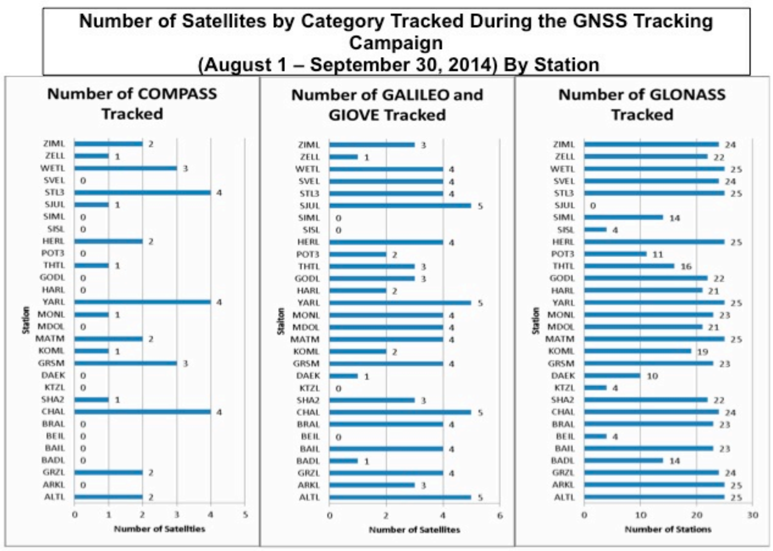
As a result, a Global Geodetic Observing System—GGOS Study Group "LAser Ranging to GNSS s/c Experiment (LARGE)" was organized to improve the global network performance of high precision Satellite Laser Ranging (SLR) on the GNSS constellations and to expand co-location of space geodetic techniques in support of the ILRS, GNSS, and GGOS. The Study Group includes members who are specialists on laser ranging, data processing and analysis and representatives from International GNSS Service—IGS and other interested parties. The Study Group had its first meeting at the Technical University of Vienna on April 28, 2014 with a follow-on meeting on May 1. Participants included members of GGOS, the ILRS, the IGS, ROSCOSMOS, the Russian Academy of Science, and a number of other agencies. Dr. Erricos Pavlis, the LARGE WG Chairperson, chaired the meetings.

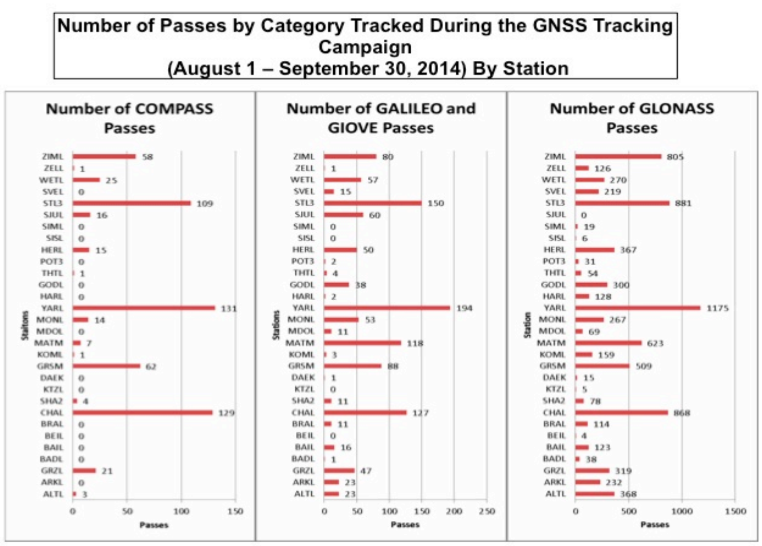
The participants at the meeting agreed that we should develop an operational strategy for expanded SLR tracking of the GNSS constellations taking into account the GLONASS, GGOS, and ILRS requirements and constraints, and that as a first step in that direction, we should organize, through the ILRS Central Bureau, a tracking campaign to test the capability limits of the ILRS network, using an expanded set of GNSS satellite targets (perhaps all of the GNSS satellites), inviting all stations to participate.

## First GNSS Campaign

The first campaign was organized over the period August 1 through September 30, 2014 to test the capability of the ILRS network, using the full constellation of GNSS satellites with retroreflectors, inviting all stations to participate with each (1) making its best effort to acquire three sets of 3 normal points (termed a pass segment) distributed over the transit of the satellite, (2) trying to cycle through all of the GNSS satellites on the updated roster, and (3) the stations with high-repetition rate lasers try to use the 1000 FR/NP recipe to improve their yield and lessen the impact on other missions.

The Campaign covered 25 GLONASS satellites, five Galileo satellites, and four BeiDou/Compass (including the synchronous satellites). Twenty of the stations tracked all or nearly all of the satellites at one time or another (see Figure 1). Figure 2 shows the number of pass segments tracked per constellation by station during the nine-week campaign. Three stations tracked over 1000 pass segments; another three tracked over 600. Figure 3 shows these data from a little different perspective. Here we looked at the performance of each station in terms of number of satellites tracked and number of total pass segments taken. Although we did not display coverage on individual satellites, we plotted colored lines denoting the average number of pass segments per satellite tracked per week to get a sense of satellite coverage. Four stations averaged greater than three segments per week per satellite. Interestingly enough, the legacy station at Yarragadee demonstrated the best performance. This of course illustrates the value of a good-weather site with full-schedule operations.




Figures 1 and 2

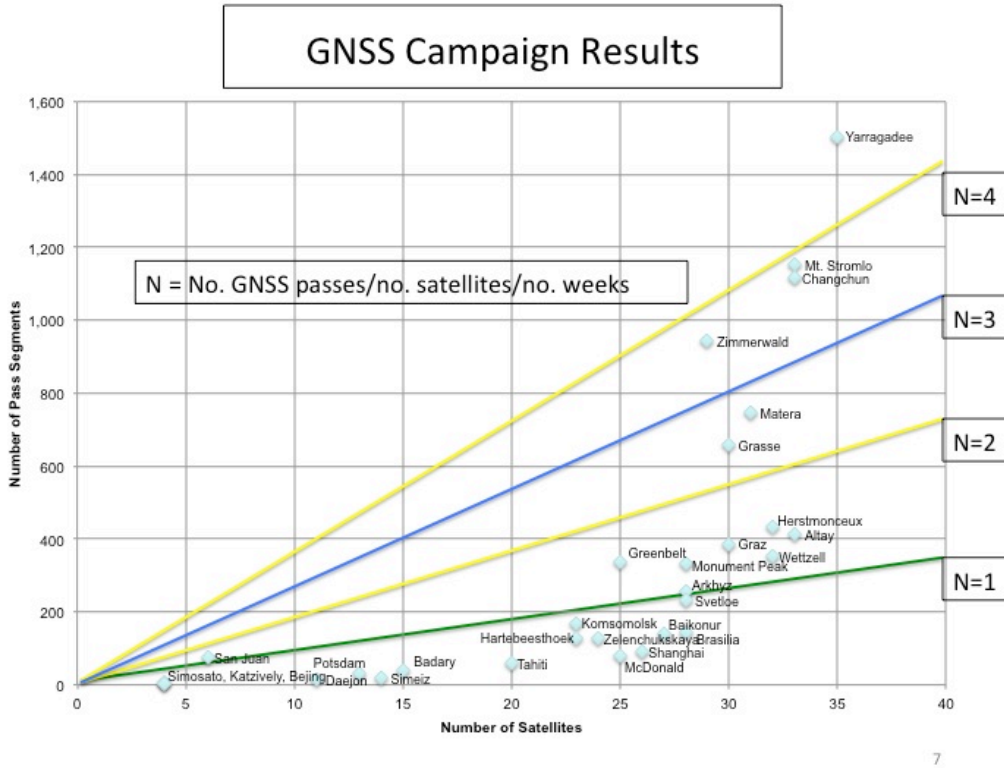
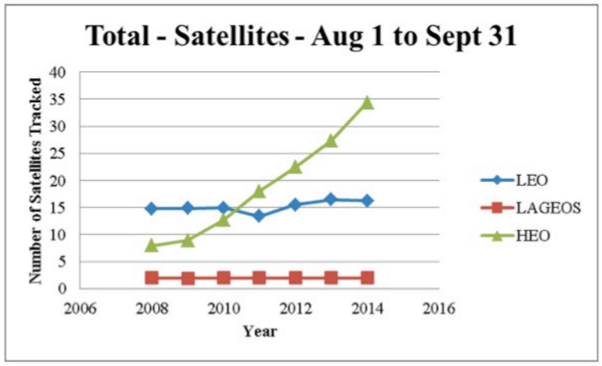



Figure 3

We made a rough estimation of the potentially-negative impact of the enhanced GNSS tracking on the data yield from the LAGEOS and LEO satellites. We looked at the number of passes in each category for the same nine week period each year going back to 2008. The number of LAGEOS and LEO satellites remained essentially the same over the period (see Figure 4). We recognize that conditions change from year to year, but the results indicated that there is no loss in the number of LAGEOS and LEO passes due to the increased GNSS tracking (see Figure 5), and the number of normal points remained about the same (See Figure 6).

Although the number of GNSS satellites and passes tracked increased significantly, the network tracked essentially no daylight or multiple segment passes. Figures 7 and 8 show the lack of data during daylight hours. A second GNSS campaign will run from November 22, 2014 through February 28, 2015, reducing the number of GLONASS satellites to six and stressing three segments per pass and daylight ranging, particularly around sunrise and sunset as an aid to acquisition.

Number of Satellites Tracking During the August – September Period

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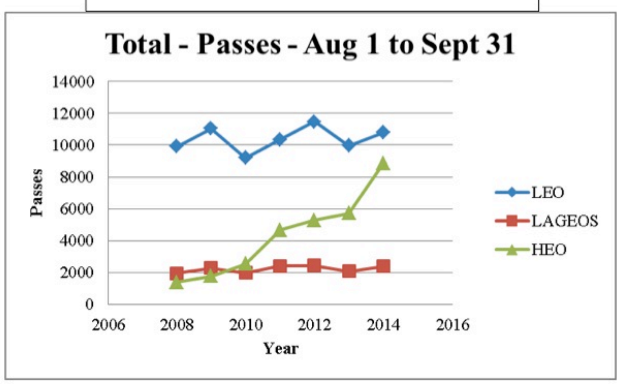
Number of Passes Acquired During the August – September Period

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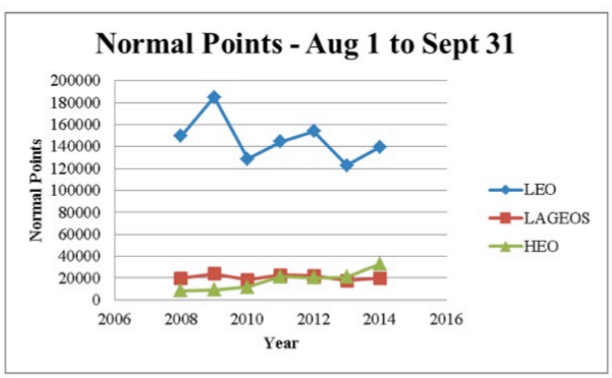
Number of NP's Acquired During the August – September Period

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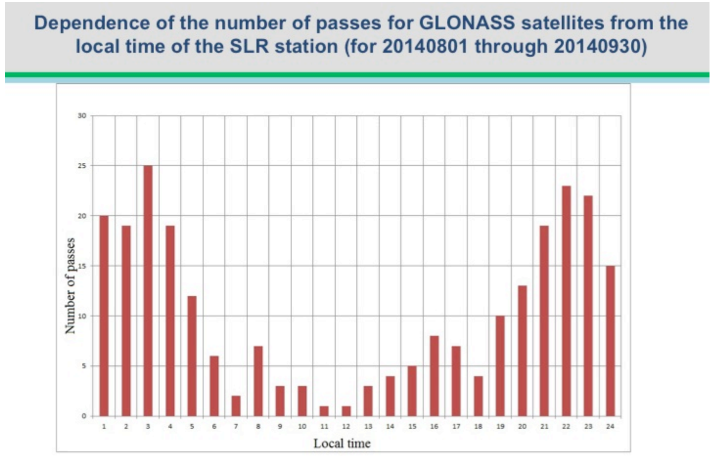
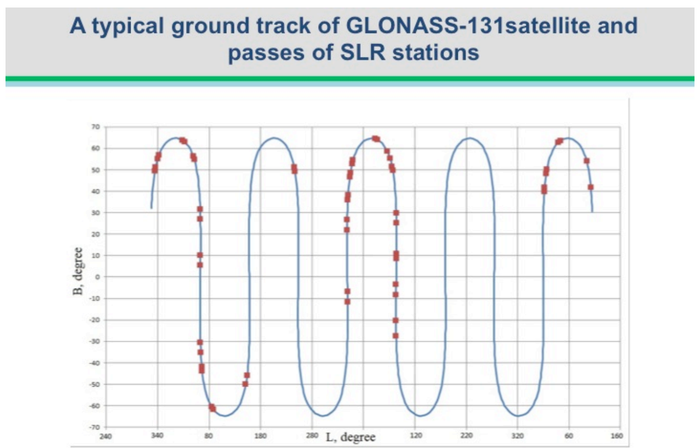
Figures 4, 5, and 6



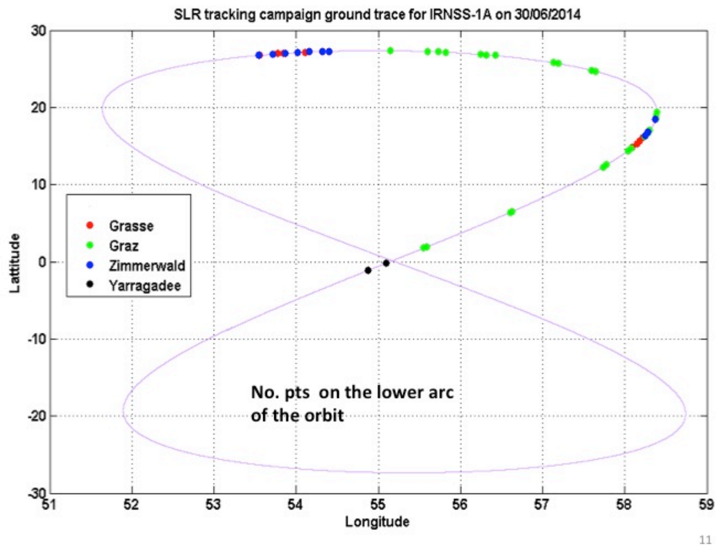

Figures 7 and 8

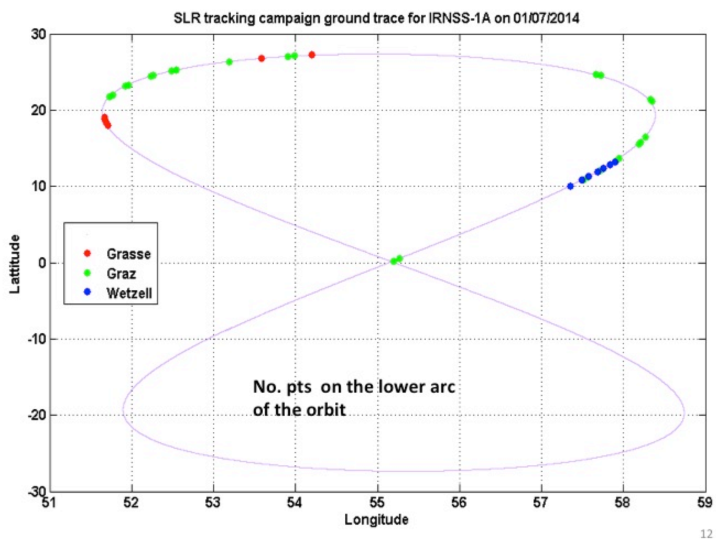
**IRNSS Campaign**

The Indian Space Research Organization (ISRO) requested that the ILRS undertake one-week tracking campaigns on the geosynchronous IRNSS-1A and IRNSS-1B satellites to improve the orbit determination accuracy for evaluation of time synchronization between IRNSS Network time (IRNWT) and onboard clocks as well as to calibrate the CDMA ranging systems on the ground.. Six stations took part in the campaigns (see Figures 9, 10,and 11 in some cases with overlapping data.

**Conclusions**

Tracking of GNSS satellite targets with the ILRS network is possible and does not impact adversely the data yield on the rest of the tracked targets. However, a 24/7 tracking schedule is demanding, mainly due to local operational scheduling at each participating station, local weather and system capabilities (day/night tracking performance). This aspect needs some more work on the network side and until stations are upgraded with GGOS-era hardware, it is unlikely that we will have much daylight data from the majority of the stations. Through planned tracking campaigns using lessons learned to upgrade tracking procedures, we will develop a better understanding of network capabilities and limitations, and improve performance




Figures 9 and 10

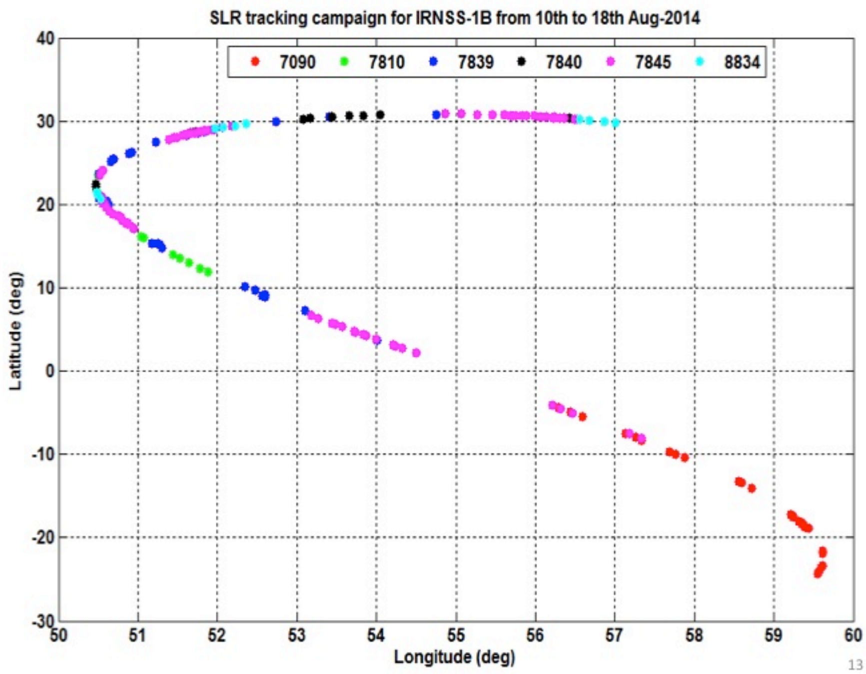

SLR tracking campaign for IRNSS-1B from 10th to 18th Aug-2014
7090
7810
7839
7840
7845
8834
Latitude (deg)
Longitude (deg)
40
30
20
10
0
-10
-20
-30
50
51
52
53
54
55
56
57
58
59
60
13

Figure 11