Tracking Many GNSS: Introduction

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ABSTRACT

The Global Navigation Satellite Systems (GNSS) technique has evolved to become the most widely available positioning tool used by both civilians and scientists. The Global Positioning System (GPS) has been fully operational since 1994 and the Global Navigation Satellite System (GLONASS) continues to take shape and is on track to having a full constellation in the coming year. SLR has supported both GPS and GLONASS since 1993. However a significant change is about to take place with a large increase in the number of retro-reflector target carrying GNSS satellites orbiting the Earth, potentially placing an increased demand on SLR tracking. This paper provides an overview of SLR tracking of GNSS as an introduction to the session “Improving support for GNSS and other challenging missions”. It also draws upon the experience and describes the GNSS tracking activities of the Space Geodesy Facility (SGF), Herstmonceux SLR station in the UK.

1. ILRS support of GNSS constellations

SLR provides useful tracking support to GNSS missions and acts as a valuable, independent check on microwave orbits through a technique that is insensitive to the ionosphere and has only a small refraction delay due to tropospheric water vapour (Pavlis et al, 2009). SLR aids the modelling of on-board clocks, the alignment of the GNSS reference frames to the ITRF and helps to improve and validate spacecraft dynamics.

In 2009 the ILRS held a workshop in Metsovo, Greece, entitled “SLR tracking of GNSS Constellations” during which position papers from each of the GNSS projects described SLR as a valuable tool for verification of orbital parameters and models. SLR was described as particularly useful in the initial phases of satellite deployment and also provides a common, independent measurement technique for each GNSS constellation.

Combination of GNSS observations and SLR measurements with accurate space ties could strengthen the determination of the ITRF (Thaller, *et al.*, 2011) and daytime SLR observation are desirable for the modelling of solar and terrestrial radiation forces acting on satellites (Flohrer, 2008).

At present, the ILRS supports one GPS satellite (GPS-36, PRN-06) that carries a retro-reflector target, two GIOVE satellites for validation of the upcoming Galileo mission, one COMPASS satellite at GNSS height and six GLONASS satellites. In addition the first Quasi-Zenith Satellite System (QZSS) satellite is tracked by those stations under its geo-synchronous orbit footprint. Each of these missions will launch additional retro-reflector target carrying satellites in the coming years with each GNSS mission evenually reaching full constellations, with QZSS having a total of three satellites.

This increases significantly the number of satellites available for SLR tracking at GNSS heights and, since a SLR station can only track one satellite at a time, will place increased demands on the ILRS network. Best practice support from the ILRS and tracking priority at individual stations should be driven by the scientific benefit of tracking multiple GNSS satellites in a given constelation.

2. GNSS tracking at Herstmonceux

Herstmonceux, like many ILRS stations, has over many years gained a significant amount of experience of tracking high orbiting satellites, at altitudes of 20 000km. These remain the most challenging targets that need high quality telescope pointing, minimal beam divergence and clear and cloud-free skies. At night the targets are easily tracked using a camera to display the telescope iris, which allows the beam and possibly the sunlight satellite to be positioned at the centre of the field of view. Searching for the best relative alignment between the satellite image and the laser beam or for invisible satellites in shadow may also require small azimuth and elevation offset searches. In the clearest skies, GNSS satellites can also be tracked at Herstmonceux during daylight hours. This requires a small iris, a very narrow daylight spectral filter (~0.2nm, centred on 532nm), close gating of the SPAD detector and a daytime camera system to see and align the laser beam to the centre of the iris. Daylight tracking of GNSS satellites is not always successful at Herstmonceux as the sunlit telescope is open to non-uniform heating which introduces error into the telescope pointing model. The most difficult GNSS satellites, GPS and GIOVE, are not attempted during the day because of the low return rates, respectively due to the small on-board retro-reflector array and greater radial distance.

The Herstmonceux SLR station tracks all ILRS GNSS and Etalon satellites and in addition now tracks all of the remaining operational GLONASS satellites. As there are 24 operational GLONASS this increases the number of GNSS altitude satellites being tracked by 2.5 times. This scenario could be similar to that requested of the ILRS from GNSS missions in the future. Taking on this additional burden should be fully considered in terms of any impact on other SLR tracking priorities. Figure 1 contains the results from an investigation that used the predicted SGF schedule for 2011. Firstly the left hand plot was for all satellites at LAGEOS altitudes and below, finding the total time each day that the telescope is required for SLR. This is then repeated including the Etalon, GIOVE, COMPASS-M1 and GPS satellites, which gave the right hand plot. On an average day the SLR facility is only required for approximately 35% of the time for LAGEOS or lower altitude satellites. Considering only those satellites appearing in night-time hours shows greater variation in the demand for SLR with the system requirement varying from less than 20% to more than 50% of the night over the course of a year. The right hand plot shows this demand increase to 80% of the day with the addition of the high altitude satellites.

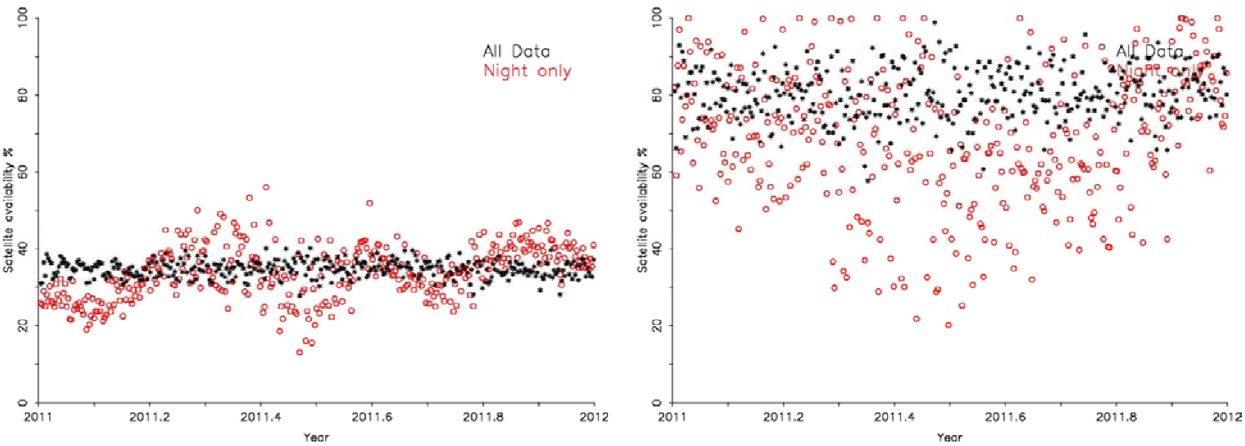

Figure 1. The left had plot shows the percentage during which LAGEOS or LEO satellites can be tracked for the whole day (in black) and for night hours only (in red). The right plot shows the percentages for the LAGEOS, LEO, Etalon, GIOVE, COMPASS-M1 and GPS. This work was in collaboration with P. Gibbs.

Figure 1 shows that there is a large amount of spare capacity in the LAGEOS and LEO schedule. Adding the high orbiting satellites significantly reduces the spare capacity, but this is only the case because it includes the entire high altitude satellite passes. A GNSS satellite takes about 5-6 hours to pass from horizon to horizon and does not need to be tracked for the whole duration. Reducing the tracking of a high altitude satellite to 5-10 minutes when it is ascending, overhead and descending reduces this demand considerably.

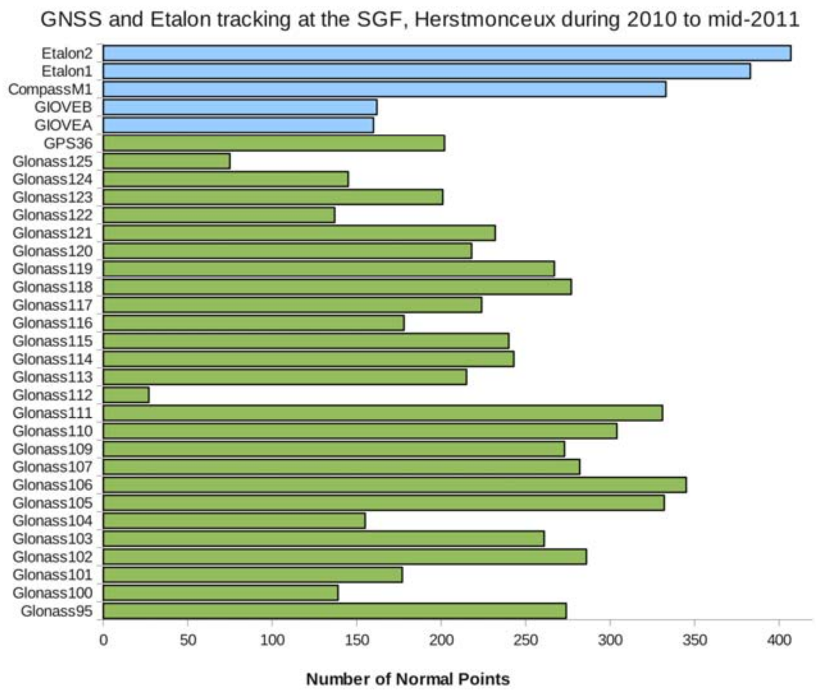

Figure 2. The number of normal points collected at the Herstmonceux station for all the GLONASS and Etalon satellites tracked from the beginning of 2010 to mid-2011.

Figure 2 shows the total number of GNSS and Etalon normal points acquired by the SGF from the beginning of 2010 to mid-2011. At the top of the plot are the higher priority Etalon targets with subsequently higher yield. The next satellite normal point total is Compass-M1 and then follows the GIOVE and GPS totals, which are comparatively fewer due to these being more difficult targets. Then in green are the GLONASS satellites which show a reasonably even distribution of normal point for each satellites, with fewer normal points recoded if a satellite is newly launched or has reached the end of its operational lifetime. This plot shows the successful tracking of all GLONASS by SGF, Herstmonceux, over this period.

2.1. Real time precision

If the SLR observer has multiple satellite passes at one time he or she will decide what is the best use of the SLR system taking satellite priority into account but to also aiming to support each satellite for at least a proportion of its pass. This means that the observer needs to be able to decide when the data collection on one pass is sufficient and it is time to move from one pass to another. For the high altitude satellites which use longer normal point bin intervals this maybe before the end of a normal point, particularly at stations such as Herstmonceux with the high-rate 2kHz system. The SGF has implemented a real-time estimation of normal point precision for display and when the precision reaches 1mm the observer is advised to move to another satellite. This is particularly useful when the observer has, for example, 5 or 6 GNSS satellites to be tracked and only a short gap between observing higher priority satellites.

The real time normal point precision estimation relies on the satellite residuals having near to zero along track time bias and so being flat in the range window. This is regularly the case for LAGEOS and GNSS altitude satellites. In addition, reliable track detection software is also required.

2.2. Efficient satellite switching

Using a high repetition rate laser allows 1mm normal point precision to be reached in a short time within the time duration of the normal point. After reaching this precision the observer is then free to consider the other satellites in the schedule and switch, with the option of returning to the previous satellite later in its pass. This leads to a novel approach to SLR observing where only minimal time is spent on one satellite before switching to the next. Figure 3 shows an attempt to track a high number of coinciding satellite passes and to minimise the time spent on one satellite with efficient satellite switching. Working in this manner requires the observer to be closely aware of which satellites have recently been tracked and which satellites should be the next priority for SLR.

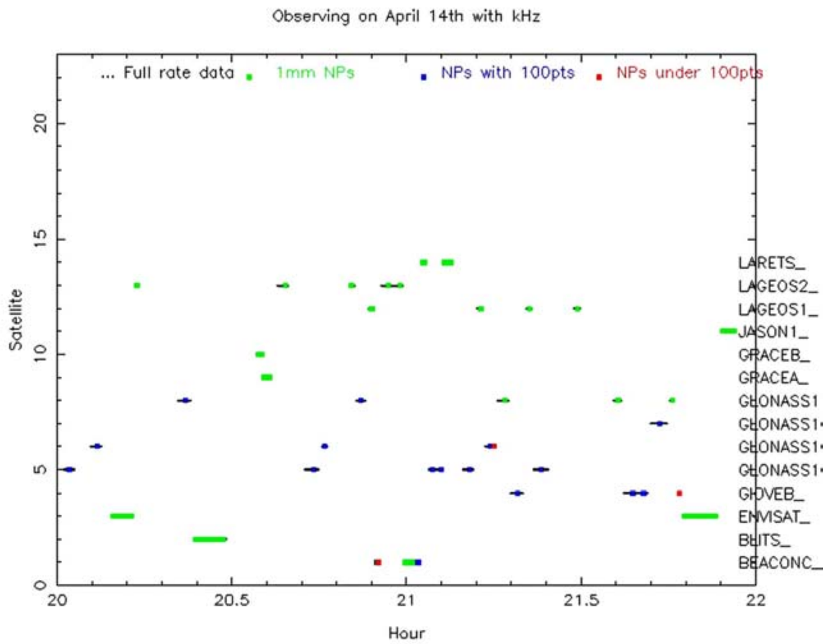

Figure 3. Supporting many satellites with efficient satellite switching using the 2kHz system. This work was carried out by P Gibbs.

3. Conclusion

Should the ILRS decide to support all future GNSS satellites this will mean a significant jump in the number of satellites tracked. The experience of the Herstmonceux station shows that there is sufficient capacity in the SLR station schedule to observe many GNSS, and at present all GNSS, without impacting on the priority LAGEOS and LEO tracking. It should be demonstrated whether SLR support for full GNSS constellations is beneficial or support limited to only certain selected satellites is sufficient.

References

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