MONITORING FOR LONG-TERM AND SHORT-TERM SITE INSTABILITIES AT THE SGF, HERSTMONCEUX.

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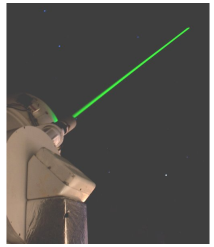
ABSTRACT. New technical challenges placed on ground-based geodetic observatories by the scientific goals of IAG's GGOS initiative led the Space Geodesy Facility (SGF) in Herstmonceux UK to carry out a programme of hardware upgrade and capability expansion. In recent years the SGF Satellite Laser Ranger has been upgraded to operate at kHz rates, and both IGS GNSS sites have had new receivers installed. In 2006 the SGF commissioned and permanently installed an FG-5 absolute gravimeter. Co-location of these independent geodetic techniques brings to the facility an added significance and responsibility in the formation of the International Terrestrial Reference Frame. Consequently, inter-technique site-ties, which are made every few years by site survey to a precision of a few mm, are crucially important. If, however, the site itself is to some degree 'unstable' this would not only impact on the measurements from each technique but also introduce errors in to the published site-ties.

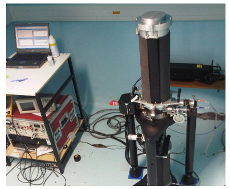
In order to monitor potential instability at the site, two independent measurement programmes are carried out. A campaign of digital leveling began in 2010 to measure at intervals of a few weeks the relative heights of each technique monument. From the two years of data accumulated to date, well-defined annual height variations of magnitude ±0.5mm have been discovered between certain monuments. Of particular interest is the steel tower holding the HERS GNSS site which has a lower and an upper leveling monument. Additional short campaigns of digital levelling at hourly intervals were carried out to investigate potential sub-daily motions in association with measurements of tower temperatures at different points on the structure. Daily GPS solutions using the GAMIT software for the short baseline between the HERS and HERT GNSS sites reveal an annual variation at the few mm level. To investigate further any short-term variations of this baseline, high rate GPS analysis was carried out using the TRACK software.

Monitoring the SGF site has so far shown that the monumentation are reasonably stable at the few mm level. An annual variation of ±0.5mm was easily detected and the larger 1cm scale height variations observed in SLR co-ordinates have not been attributed to any local aspect of the site.

SGF, HERSTMONCEUX.



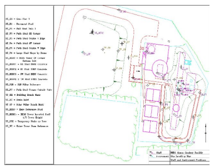
The co-located techniques in operation at the SGF, satellite laser ranging, GNSS and absolute gravimetry, are in very close proximity, within approximately 10 to 135 metres. The SLR station has a historical data set of over 25 years of tracking the Lageos satellites and presently supports over 50 geodetic, Earth observation and GNSS satellites. By analysis of SLR data from geodetic Lageos and Etalon satellites, station heights are well determined on a weekly basis. SLR station co-ordinate time series are sensitive to change in station height, which transfers directly in to a range error. Absolute gravimetry is also very sensitive to height change and a campaign of weekly 24-hour AG runs began at the SGF in 2006. A programme of research is underway to compare the gravity signals to the geodetic results from analyses of the SLR and GNSS observations



Any instabilities in the technique monuments would impact on this comparison and so a site stable in the short and long term is essential. A campaign to determine the stability of the SGF local site is reported here.

DIGITAL LEVELING.

Any height changes due to the local site will introduce errors in the time series of each geodetic technique. Such variations need to be closely observed if present with the end goal to be modelling and removal. The SGF has 2 years of repeated digital leveling runs using a Lecia DNA03, with instrumental accuracy of 0.3mm, at intervals of 2-3 weeks. A leveling run begins in the site basement on an absolute gravimetry pier and in steps of a few metres to several 10s of metres it then includes the SLR pillar (which is estimated to reach more than 10 metres deep in to the ground), several points on the HERS monument, and points on the HERO, HERQ and HERT GNSS sites. In total 22 site heights are measured within approximately two hours.



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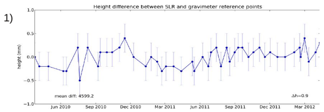

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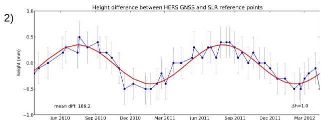

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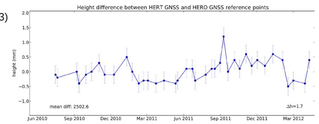

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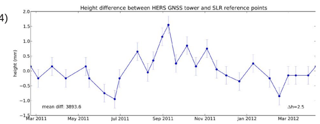

Figure 1 shows the height difference between a gravimetry pier and the SLR pillar does not exhibit any longterm signals of amplitude greater than the instrument error. This is a good result for the inter-technique comparisons at the SGF. However in **figure 2** the height difference between the SLR pillar and a stud near the base of the steel HERS tower (pictured right) shows a very clearly annual signal with an amplitude of 0.5mm. This annual signal could be driven by temperature changes in the steel tower or the concrete base or instead this may be caused by the soaking and drying of the ground clay soil.

Figure 3 shows the measurements from the HERO GNSS monument (pictured left) to the bottom of the brick tower that hosts HERT. These monuments do not have much relative movement. Finally in **figure 4** the upper HERS tower leveling mark is plotted relative to the SLR pillar. When this is compared to figure 2, larger movement is observed higher up the tower, however it is unclear if this is due to the leveling technique as this is a more difficult mark that requires the staff to be held up high and up-side-down.

The HERS tower is a 7m tall latticed mast made from hot rolled mark steel. The digital leveling program detected a height signal at the bottom of this tower relative to the SLR pillar and so further investigation into this tower began. This included adding a second levelling point approximately half-way up the tower. As this tower is outside it expected to undergo thermal expansion. The height difference between the upper and lower points on the tower are plotted in **figure 5**.

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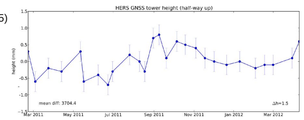

A short campaign of digital levelling at hourly intervals was carried out on 29th September 2011 to investigate potential sub-daily motions at these two levelled points, plotted in **figure 6**. Temperature gradually increased over this levelling period from 15 degrees to over 21 degrees centigrade. In addition, temperatures at different points on the structure were recorded and a large variation is seen due to sunlight, see **figure 7**. This suggests that thermal expansion of the tower is complex due to the dual effect of ambient temperature and heating from direct sunlight.

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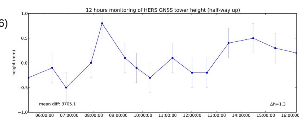

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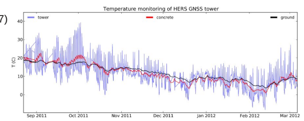
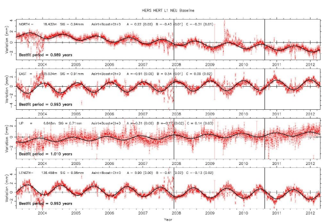
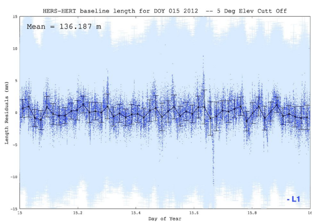
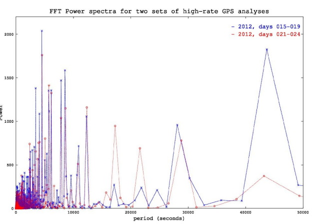


GPS BASELINES.

Short baselines between GNSS sites are determined very precisely at the SGF, near to the 1 mm level, on a daily basis using the GAMIT analysis software. The SGF has four GNSS sites, two of which (HERS and HERT) are IGS sites. Near-annual signals of amplitude 1-2 mm are present in a GPS baseline between any pair of chosen sites, for example the HERS-HERT baseline calculated using only the L1 GPS frequency is plotted here in red and signals are clearly visible in each baseline component. Jumps in the time series, due to hardware changes are corrected for and marked with vertical black lines. It has not yet been possible to attribute the near-annual signal to the real motion or multipath environment of one site because similar signals are present in each baseline pair analysed. Furthermore, analysis of short baselines away from the SGF, in the UK and internationally, found similar near-annual signals in at least one component for every short baseline analysed.







To further investigate the variation of the HERS tower, daily GPS baseline analysis was carried out using the TRACK analysis package and the HERT site. Both GNSS receivers can collect data at 1 Hz rates allowing for detailed sub-daily analysis. If the HERS tower is moving and driven by annual temperature change then a similar effect should also occur due to the day-night temperature differences. Daily RINEX files were analysed at 2 second rates, ambiguities were fixed using the LC frequency combination but only the L1 frequency results were used for analysis and an example baseline length for 15th January 2012 is plotted here in blue. The precision for 30 minute averages is close to that reached for the daily baseline calculations, however no clear variations have yet been seen which may partly be due to subdaily signals present in the data as indicated by the plotted FFT analyses of a 4 and a 5 day data series of complete 1s data. The signals present in these independent datasets match up well together, other datasets contained similar signals and also larger cm level excursions, which was problematic for analysis.

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