National Report of Great Britain 2014

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Abstract. Activities of Ordnance Survey, the national mapping agency of Great Britain. Also activities from NERC British Isles continuous GNSS Facility (BIGF), NERC Space Geodesy Facility Herstmonceux, Newcastle University and University College London.

Keywords. Ordnance Survey, NERC British Isles continuous GNSS Facility (BIGF), NERC Space Geodesy Facility Herstmonceux, Newcastle University, University College London.

1 Ordnance Survey activities

1.1 National GNSS network

The OS Net network is now managed using the Trimble Pivot Platform (TPP)™ software from Trimble and delivers RTK corrections via GSM and GPRS to approximately 250 Ordnance Survey surveyors. Public services are also available via Ordnance Survey commercial partners.

Fig. 1 OS Net GNSS Network

Partners take the raw GNSS data streams from OS Net servers via NTRIP and use them to generate their own correction services.

Current commercial partners offering RTK service in Great Britain are AXIO-NET, Leica, Soil Essentials, Topcon and Trimble. Current partner details can be found at :
http://www.ordnancesurvey.co.uk/oswebsite/products/os-net/index.html.

A server and software upgrade was recently completed. The new software is Trimble Pivot Platform and is run off duplicated virtual server clusters – one at Ordnance Survey HQ and the other at an offsite facility. This provides complete redundancy of all aspects of the service and also allows for quick resource scaling and testing of upgrades and changes.

1.2 EPN data submissions

Current EPN submissions from GB are hourly data from HERS, HERT (run by the Natural Environment Research Council, NERC) and MORP (run by Newcastle University) plus 24 hour files from DARE, INVR (OS Net stations), and NEWL (run by University of Nottingham). It is still intended to ultimately submit all the OS Net stations that were part of EUREF GB/IE 2009 stations as EPN stations and submit hourly data from them as well. However this is currently on hold waiting for resources to work on the changes.

RTCM 3.0 data from EPN stations DARE, INVR and from OS Net station SHOE are streamed in real time via NTRIP. This is in addition to RTK data from HERT.

1.3 Geoid model improvement

Work to improve the geoid model is almost complete. It was hoped to complete the new geoid model in 2010 but initial analysis showed some inconsistencies remained. Further test observations at bench marks were taken to test the preliminary post-fit model surface. Further post computational testing of the fit to Ordnance Datum Newlyn (ODN) is now being planned. The introduction of the new model will then be tied to an update of the transformation model and also the coordinates of the OS net statons.

The geoid model work is in collaboration with University College London. See section 5.

2 BIGF – NERC British Isles continuous GNSS Facility

BIGF is operated from the Nottingham Geospatial Institute (NGI, formerly IESSG) at The University of Nottingham, and is funded by the UK Natural Environment Research Council (NERC). Figure 2 shows the current network of 163 stations, which includes six stations that are part of the IGS and EPN (DARE, HERS, HERT, INVR, MORP, NEWL) and ten CGPS@TG stations that contribute to the IGS TIGA Project (ABER, DVTG, LWTG, LIVE, LOWE, NEWL, NSLG, PMTG, SHEE, SWTG).

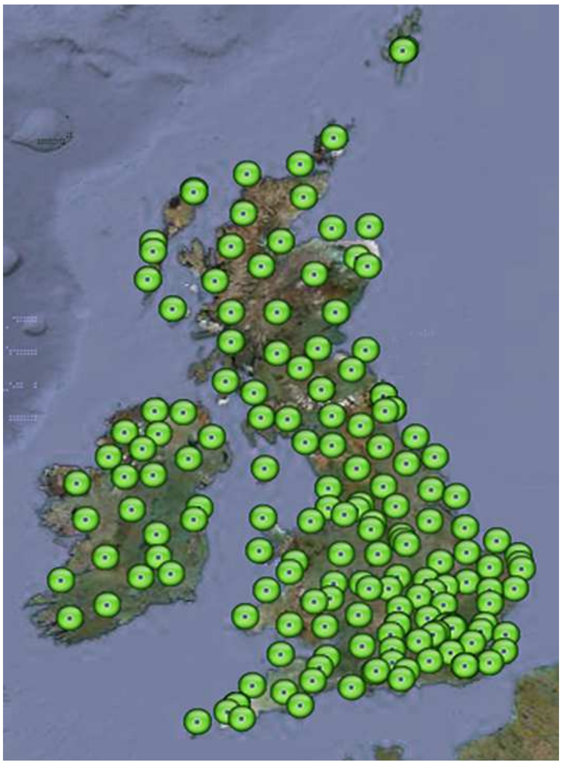

Fig. 2 The BIGF Network 2014

BIGF archives quality-assured RINEX data and generates derived products, based on a network of continuous GNSS stations sited throughout the British Isles. This network includes the active stations of OSGB plus those of Leica Geosystems, Ordnance Survey Ireland and Land and Property Services Northern Ireland. It also includes a number of ‘scientific’ stations established by: Defra; the UK Environment Agency; the UK Met Office; NERC National Oceanography Centre, Liverpool; NERC Space Geodesy Facility; Newcastle University, the University of Hertfordshire and the University of Nottingham.

Quality assured RINEX data can be requested from www.bigf.ac.uk. Cumulative demand on the archive, since inception in 1998, amounts to 4,855k stations-days (13,300 station-years) of 30 second data, 9k station-days (25 station-years) of 1Hz data and 1,605k product-days (4,400 station-years) of derived products, with the 1Hz data and the derived products having been available for 3 years now and with a broadening of the science annually making use of the archive, such as ongoing studies of land movement and sea level and atmospheric work in both the ionosphere and troposphere, facilitated by both historic data and ongoing hourly and daily data from this dense network.

BIGF's derived products are aimed at facilitating the scientific research of non-GNSS specialists. The initial derived products are station coordinates and velocities, building on previous University of Nottingham research on the use of CGPS and absolute gravity (AG), which was carried out in collaboration with the NERC National Oceanography Centre, Liverpool to provide: maps of current horizontal and vertical land movements based on about 30 CGPS stations for the period from 1997 to 2005 (Teferle et al. 2009); estimates of changes in land and sea levels at ten tide gauges (Woodworth et al. 2009); and constraints for models of crustal motion due to glacio-isostatic adjustment (Bradley et al. 2009).

The most recent BIGF map of current vertical land movements is shown in Figure 3. This map is based on a re-processing of data from 1997 to present with Bernese Software version 5.2, connecting the BIGF network to the IGB08 via a global network of reference stations, and using C11 (CODE repro2/repro_2011) re-analysed satellite orbit and earth orientation parameter products; mitigation of 1st and higher order (2nd and 3rd order and ray bending) ionospheric effects; a-priori modelling of troposphere effects using VMF1G and mitigation using zenith path delay and gradient parameters; I08.ATX models for antenna phase centre variations; and models for Solid Earth tides, ocean tidal loading and atmospheric tidal loading.

The resultant map is generally consistent with maps of relative land level changes in the UK over the last ~1,000 years based on geological studies (Shennan and Horton, 2012). In addition to station coordinates and velocities, other derived products that can be requested from www.bigf.ac.uk include near real-time tropospheric parameters (15 minute estimates of zenith total delay, zenith wet delay and integrated water vapour) and re-processed tropospheric parameters (as time series from 1997 to present).

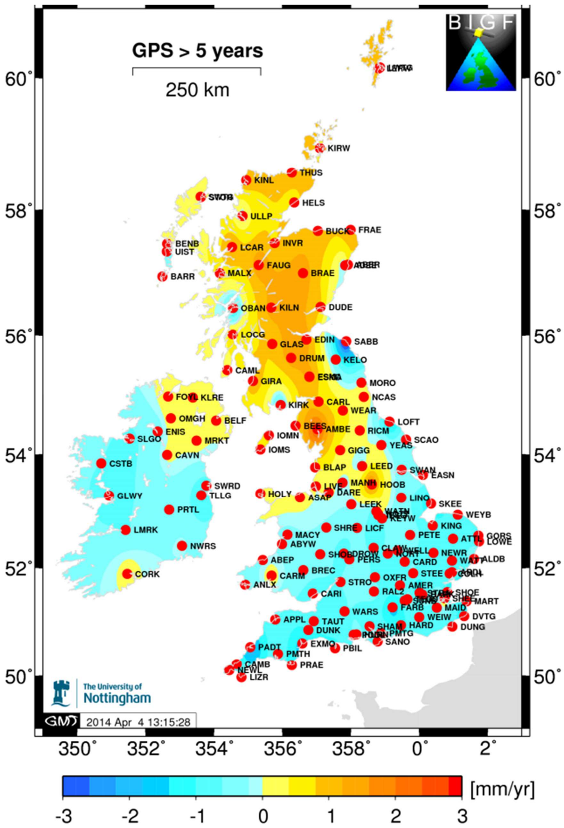

Fig. 3 Map of current vertical land movements at 104 CGPS stations in the UK, based on CGPS measurements for the period from 1997 to 2010 and AG measurements for the period from 1995/6 to 2009

Examples of major research projects using BIGF quality-assured data in 2013/14:

- CNES (French Space agency) - Study on the effects of solar activity on ECAC (European Civil Aviation Conference) zone.
- European Space Agency - ISSWIND - supporting services for the wind power industry based on space technologies.
- Geodetic Observatory Pecny, Czech Republic - E-GVAP near real-time atmospheric water vapour project.
- National Institute of Information and Communications Technology, Japan - Ionospheric research using total electron content over Europe.
- Newcastle University - GNSS Wave Glider: A new tool for sea level and sea state measurement.

- Newcastle University - Near-field GNSS for real-time tsunami early warning systems.
- Newcastle University - Towards airborne GNSS estimation of atmospheric water vapour.
- Royal Observatory of Belgium - Densification of European Permanent GNSS Network for ionospheric studies.
- University of la Rochelle, France - International GNSS Service GPS tide gauge benchmark monitoring.
- University of Luxembourg - The potential of precipitable water vapour measurements from GNSS in Luxembourg.
- University of Nevada, USA - Towards a global ambiguity resolved precise point solution and time series.
- University of Nottingham - Evaluation of IMU/GNSS sensor fusion.
- University of Plymouth - Managing the retreat: understanding the transition to salt marsh in coastal realignment projects.
- University of Ulster - Forcing factors impacting Oransay shoreline.

Examples of major projects using BIGF derived products in 2013/14:

- University of Hertfordshire - Aerosol and Clouds Consortium - cirrus climatology from ground-based remote sensing.
- University of Nottingham - Modelling tropospheric delay for the UK area with estimated ZTD values from GNSS using independent component analysis.
- University of Nottingham – Land deformation studies.

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3 Space Geodesy Facility at Herstmonceux

The Space Geodesy Facility is located at Herstmonceux, UK, with funding from the Natural Environment Research Council and the UK Ministry of Defence. It is an observational and analytical facility with a highly productive and precise Satellite Laser Ranging (SLR) system, two continuously operating IGS GNSS receivers, one of the UK Ordnance Survey GeoNet GNSS receivers, a permanent FG5 absolute gravimeter and one of BGS' broadband seismometers that automatically contributes in realtime to BGS' British Isles seismic network. A very stable active hydrogen maser frequency source drives the timing systems of both the SLR and the long-running HERS GPS/GLONASS receiver. On-site automated meteorological and water table depth observations augment the geodetic observations. The Facility is an International Laser Ranging Service (ILRS) Analysis Centre.

3.1 Satellite Laser Ranging

The system is a core ‘new technology’ ILRS station, making daytime and night- time range measurements to geodetic, gravity-field, altimeter and GNSS satellites at heights of from 500 to 30,000km. The precision of the range normal points is about 1mm, and the station is ranked among the top ten in the ILRS global network in terms of data productivity and close to the top on accuracy. The two-laser (2kHz and 10Hz) system is unique in the ILRS worldwide network. Towards the end of the year the 2kHz laser was returned to the manufacturer for an upgrade to provide greater energy, and will resume operations in Spring 2014. The original 10Hz laser remains in operation when required for specific applications such as the LiDAR capability, and is also being used regularly for one-way ranging support of the NASA Lunar Reconnaissance Orbiter. During the period following the temporary removal of the 2kHz laser, the 10Hz laser was used for all operations, such that there was little impact on overall numbers of passes tracked.

Laser tracking of the GNSS satellites continues to increase in importance for the ILRS community. A full constellation of GLONASS, the first four Galileo vehicles and new satellites of the Chinese COMPASS GNSS are regularly tracked by the most capable stations in the network, including SGF. GGOS-level discussions with the GNSS agencies, with SGF involvement, are focusing on the value of laser tracking for orbit QC and more importantly, ultimately for linking the GNSS orbits and navigational signals directly to the ITRF, with origin defined by SLR and scale by SLR and VLBI. Laser ranging and analysis to the now-debris Envisat has resulted in a laser-only solution of the spin axis dynamics [1].

3.1.1 SLR Analysis

The Facility is an ILRS Analysis Centre (AC) and daily computes seven-day-arc, global station coordinates and Earth orientation solutions in support of the ILRS' contribution towards ITRF realisation work and rapid Earth orientation results for the IERS [2]. The activities of the Analysis Centre during the last year have been focused around two main issues: the preparations for the submission of the ITRF2013 - the latest iteration of the International Terrestrial Reference Frame - and the research into systematic errors present in the data from the global network and their potential mitigation.

Several updates were carried out in the analysis software to implement the models agreed and required by the ILRS Analysis Working Group for the ITRF, such as the implementation of new geopotential models and the adoption of updated algorithms for Earth rotation through the use of standard subroutines sanctioned by the International Astronomical Union. The tables of centre-of-mass corrections developed by SGF [3] are also incorporated in all ACs' processing schemes. A few operational updates have also been performed, with the objective of reducing the runtime required for a complete multi-satellite solution. The software is now considered ready to compute a new 30-year solution that will form part of the new ILRS official combined product.

Continuing previous efforts at the Analysis Centre aimed at uncovering the presence of possible biases in the data produced by the SLR network, a novel analysis of range biases was performed, encompassing all contributing stations for a 10-year period. It was found that very few tracking stations are genuinely free of at least significant sub-centimetre biases (Herstmonceux among those few), and that these biases can be dealt with successfully by including them in the observational equations as additional parameters that need solving for. While the variance of the resulting coordinates is increased, the accuracy of the longer-term solution is arguably improved by eliminating systematic effects that corrupt the scale of the computed frame if left untreated. Preliminary results of the analysis were presented at the EGU2014 conference, and there is scope for a future full publication on this topic [4].

3.1.2 Time transfer by SLR

SGF team members attended a workshop in March 2014 on the subject of laser time transfer and joined SLR colleagues from Austria, Germany, France and Switzerland in Wettzell, Germany. This work has gained interest from NPL and UKSA, and it is possible but not confirmed that a dedicated fibre link may be leased for a period to bring UTC(NPL) to SGF for the purpose of comparing time between European Time labs using initially T2L2 on Jason-2 and ultimately the ACES system on the ISS.

3.2 GNSS

The two IGS stations HERS and HERT remain in continuous operation, with HERT, a Leica GRX GG Pro system, also streaming GPS and GLONASS navigation data into the Internet in support of the EUREF-IP and IGS Real-time Projects. The Ordnance Survey GeoNet system HERO, installed by the OS close to the SOLA trig pillar, continues to be fully operational and has become useful as a fourth site for local stability monitoring work. The active hydrogen maser with its highly stable frequency source and one-second-tick pulse are driving both the HERS Septentrio receiver and the SLR event timer. As a result of the maser, the HERS data continues to be amongst the highest weighted clocks in the IGS final clock product.

3.3 Site Stability

The on going study into local site stability using daily GAMIT-based solutions for HERS, HERT and HERO coordinates as well as high-precision optical levelling confirm the high degree of stability of the site. Sub-mm-level seasonal changes to the height of the HERT tower are however present, and are almost certainly temperature-driven. Plans are underway to make regular, automated measurements of the tie vectors between the GNSS and SLR monuments, as per recommendations from GGOS.

3.4 Absolute Gravimetry

Regular weekly operations of the FG5-X absolute gravimeter have continued since operations began in October 2006, with the baseline observational programme being a 24-hour session centred on mid-GPS week. Work continues to separate hydrological signals from station vertical motion, and intriguing tidal signals are also clearly present. Following discussions between BGS, SGF and NOC Liverpool, the two FG5 absolute gravimeters from NOC (FG5#103 & FG5#222) are now at Herstmonceux having been delivered in September 2013. An operational assessment on both instruments has been carried out, which included options and recommendations for servicing and possible upgrade. The presence of all three AGs at SGF is seen as a major resource, and a recent short-term loan of one of them to NPL is seen as a precursor to potential future campaign work in support of a variety of geophysical applications, with SGF as the UK calibration base.

3.5 VLBI

The case will continue to be made, and options explored, to add VLBI to the SGF's capability. With its existing high-quality SLR and GNSS systems, there is growing interest among the international geodetic community to see the station become a core GGOS site.

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4 Newcastle University

4.1 Global Navigation Satellite Systems positioning

[1] Demonstrated that a local ionospheric zenith delay correction, generated from code pseudorange measurements at a receiver, could improve single-epoch relative position solutions obtained via an ambiguity search algorithm over long (60-120 km) baselines, from 30-50 cm in the uncorrected case to 10 20 cm median absolute deviation.

[2] Performed a community experiment to investigate the detectability of offsets in synthetic GPS coordinate time series with realistic noise properties, using both manual and automated time series analysis. Manual analysis continues to outperform automatic, although neither approach can be considered robust to within 0.5 mm/yr.

4.2 Synthetic Aperture Radar Interferometry

[3] and [4] demonstrated improvements in InSAR deformation monitoring using tropospheric delay and geoid models respectively.

4.3 National and international geodetic networks

Newcastle University has continued to contribute to the International GNSS Service as an Associate Analysis Centre, providing weekly global coordinate combinations in parallel with the official IGS product. [5] used combination solutions from the first IGS reprocessing experiment, in tandem with forward models of glacial isostatic adjustment, to derive secular trends in surface mass loading and Euler poles for the major tectonic plates. Since week 1769 (December 2013), operational combination of individual Analysis Centre solutions is performed and submitted on a daily basis, followed by a 7-day combination.

We continue to operate IGS site 'MORP' (Morpeth) and TIGA site 'NSLG' (North Shields Tide Gauge), both of which contribute to the NERC BIGF.

4.4 Geodynamics and Glacial Isostatic Adjustment

As the British Geophysical Association's 2012 Bullerwell Lecturer, [6] provided a review of recent progress in the modelling of glacial isostatic adjustment in Antarctica and its implications for the measurement of present-day sea level change. [7] investigated the sensitivity of present-day surface uplift in the Antarctic Peninsula to changes in surface mass balance over the last 1½ centuries, and found that significant viscoelastic deformation over this timescale could partially explain discrepancies between modelled and observed glacial isostatic adjustment rates in this region.

4.5 Glaciological and Cryospheric Geodetic Applications

At large spatial scales, [8] reconsidered the detectability of recent ice mass changes in Antarctica using GRACE gravity field data, once realistic temporal correlations within the time series had been considered. [9-10] used GNSS data at local scales to investigate seasonal changes in ice flow in Greenland.

4.6 Geodetic Measurement of Tectonic Strain

[11-16] used InSAR to observe co-seismic and inter-seismic strain associated with fault movements at a variety of locations in the Alpine-Himalayan belt and south-east Asia.

4.7 Landslide Monitoring with Geodesy

[17] used SAR image co-registration to observe episodic landslide displacements in vegetated terrain, whereas [18-19] used a combination of InSAR techniques.

4.8 Other Geodetic Applications

[20] used retracked radar altimetry data to observe inland water level changes at a number of ungauged river sites. [21] reconsidered the apparent British sea slope, using levelling-based Ordnance Datum Newlyn heights of benchmarks, EGM2008 quasi-geoid data and GNSS observations at selected tide gauges and benchmarks, and concluded that the apparent slope is caused by the vertical geodetic datum.

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5 University College London

5.1 Height Corrector Surfaces

New height corrector surfaces to enable conversion between ellipsoidal and orthometric heights for the UK and the Republic of Ireland have now been finalised. The work was undertaken by Prof Marek Ziebart from University College London in consultation with Ordnance Survey (UK), OSI (Ordnance Survey Ireland) and the LPS (Land and Property Services, Northern Ireland). The principal driver for the updated model was the availability of the new UK gravity field model, OSGM10. Details of analysis and testing of the new model are in Ziebart et al, 2008.

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