National Report of Great Britain 2012

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Abstract. Activities of Ordnance Survey the national mapping agency of Great Britain. Also an overview of activities of - 2 BIGF – NERC British Isles continuous GNSS Facility at the University of Nottingham; NERC Space Geodesy Facility, Herstmonceux; Newcastle University.

Keywords. Ordnance Survey, BIGF, University of Nottingham, NERC Space Geodesy Facility, Newcastle University.

1 Ordnance Survey activities

1.1 National GNSS network

Work is still progressing on a complete readjustment of the OS Net network (see Fig. 1) station coordinates using the EUREF ratified EUREF IE/UK 2009 results as control. This will be the first homogeneous computation of the network since its completion. The work has been delayed due to problems with the servers hosting the Ordnance Survey's Bernese Software.

The OS Net network is managed using the GPSNet™ software from Trimble and delivers RTK corrections via GSM and GPRS to approximately 230 Ordnance Survey surveyors. All surveyors RTK equipment was recently upgraded to GNSS capable including an upgrade path for Galileo signals. A server and software upgrade to OS Net is planned for later this year.

Public RTK services are also available via Ordnance Survey commercial partners. 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 services 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/commercial-partners.html*

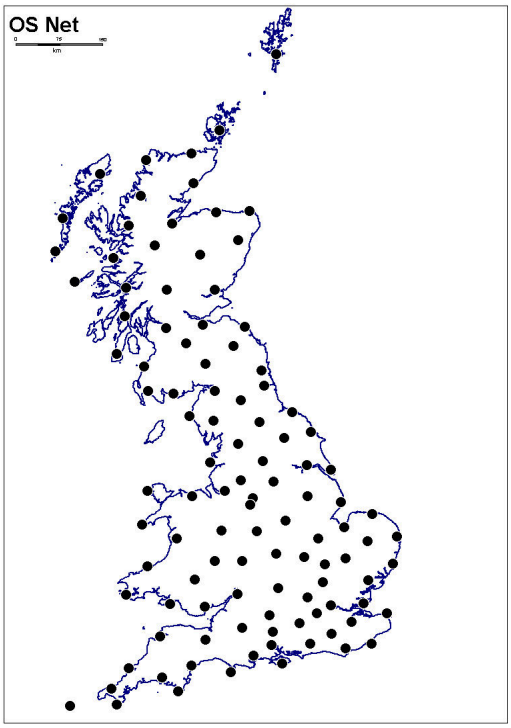

Fig. 1 OS Net GNSS Network

1.2 EUREF related activities

1.2.1 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 University of Nottingham). The planned hourly data submission from DARE and INVR is delayed until server and software updates have taken place later this year. At the same time we also intend to submit all the GeoNet stations as EPN stations and submit hourly data from them as well. New software should also enable us to comply with EUREF 2011 resolution 2 and submit L5 data.

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.

1.2.2 Channel Tunnel levelling

Progress on the final connection of the British Tunnel portal bench mark to Ordnance Datum Newlyn (ODN) has been held back by a delay in the computation of a new British geoid model (see 1.3 below). UELN point G4868, Dover Tide Gauge Bench Mark (DVTG) was included in the EUREF IE/UK 2009 campaign. The levelled height from G4868 to the Tunnel portal BM is 52.9352m and when the new geoid model is complete the computed ODN height of DVTG can be linked to the Tunnel portal bench mark to give a final ODN height for the mark.

1.3 Geoid model improvement

Geodetic GPS observations were taken at 30+ levelling points in the northwest of Scotland and on the Scottish islands in order to improve the OSGM02 geoid model. These build upon existing observations at the fundamental height bench marks around Great Britain.

It was hoped to complete the new geoid model in 2010 but initial analysis showed some inconsistencies remained. Further test observations at bench marks are being taken to test the preliminary post-fit model surface. Depending on the outcome of these tests more GNSS observations may be required to improve the fit of the geoid model to Ordnance Datum Newlyn (ODN).

2 BIGF – NERC British Isles continuous GNSS Facility

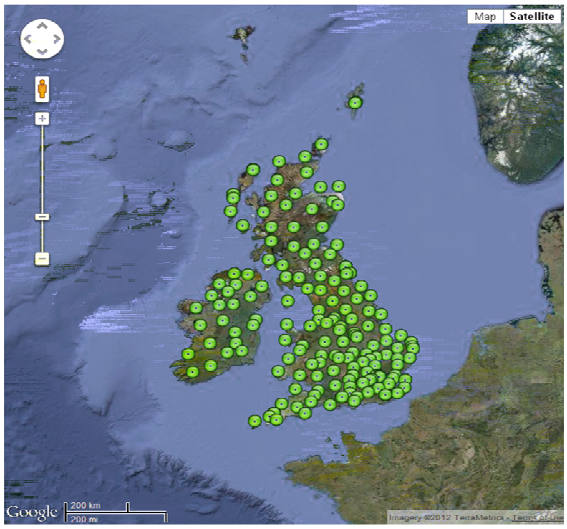

Fig. 2 The BIGF Network 2012

BIGF is operated from the Nottingham Geospatial Institute (NGI, formerly IESSG, the Institute of Engineering Surveying and Space Geodesy) at The University of Nottingham, and is funded by the UK Natural Environment Research Council (NERC), until at least 2014. Fig. 2 shows the current network of 160 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, NSTG/NSLG, PMTG, SHEE and SWTG).

BIGF is our long-term national archive for quality-assured raw data, sourced from the continuously recording network of GNSS stations, sited throughout the British Isles. This mature network, comprises: Ordnance Survey of Great Britain active stations and their GeoNet sub-network of 12 connected to solid rock; active stations of Leica Geosystems, Ordnance Survey Ireland and Land and Property Services Northern Ireland; and 26 scientific stations. The scientific stations were established by Defra, the UK Environment Agency, NGI, the UK Met Office, NERC National Oceanography Centre, Liverpool, NERC Space Geodesy Facility, and Newcastle University. Data are provided and transmitted free-of-charge to the archive by all collaborators, with whom long-term agreements to supply are in place.

Cumulative demand on the archive since inception in 1998 approaches 4.3m station-days, but

more importantly, the number of scientists annually making use of the archive has risen steadily since then. There are new scientific user-disciplines, with emphases on the estimation of environmental signatures from necessarily long tracts of historic data and access to spatially extensive ongoing daily data sets, for tectonics, sea level study and atmospheric work in both the ionosphere and troposphere. The density of observations required can only be supplied by a dense national network, which together with the temporal extent of the archive, means that BIGF is not only an essential national capability, but also one of international importance and demonstrable utility. BIGF does not stand still but is advancing, using expertise at NGI in the development of a range of derived products from the quality assured raw data, with the aim of facilitating the academic research of non-GNSS specialists.

The development of derived products has focussed initially on long term trend station coordinates and velocities, based on time series computed from a re-processing and re-analysis of data from 1997-2010 with an in-house modified version of Bernese Software version 5.0, using IGS repro1 (CO1) re-analysed satellite orbit and Earth orientation products, a global network, ITRF2008, 1st order ionosphere corrections, and I05.ATX for antenna phase centre variations; with the first products using GPT for a-priori ZHD and GMF mapping functions for the troposphere, while the second products used VMF1G mapping functions. These derived products build on previous NGI research on the use of CGPS and absolute gravity (AG), which was carried out in collaboration with the NERC National Oceanography Centre, Liverpool (formerly Proudman Oceanographic Laboratory), 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 latest BIGF derived products include an improved map of current vertical land movements. This research also involved a rigorous assessment of the suitability of all 161 CGPS stations that were processed and analysed, based on excluding any stations with unacceptably large (greater than 0.8mm/yr) vertical station velocity uncertainties, mainly related to their time series being less than 5 years in length, and by giving each CGPS station a 'site suitability rating' from a detailed consideration of local environment, monument type and foundation, and local site geology. The result was a final total of 104 CGPS stations considered, at this stage, to provide reliable estimates. As in (Teferle et al. 2009), an optimal combination of AG and CGPS was then considered to be achieved by aligning the CGPS to the AG vertical station velocities, using two co-located sites (Lerwick and Newlyn).

The BIGF map of current vertical land movements, based on the AG-aligned CGPS vertical station velocities for the 104 CGPS stations, is presented in Fig. 3 This 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, 2002; 2012), which are of the order of 1 to 2 mm/yr, with Scotland rising and the South of England subsiding, so that Great Britain is effectively 'tilting', with the highest uplift centred around the area of Scotland with maximum ice loading at the last glacial maximum, and a zero line running roughly between Liverpool and Newcastle.

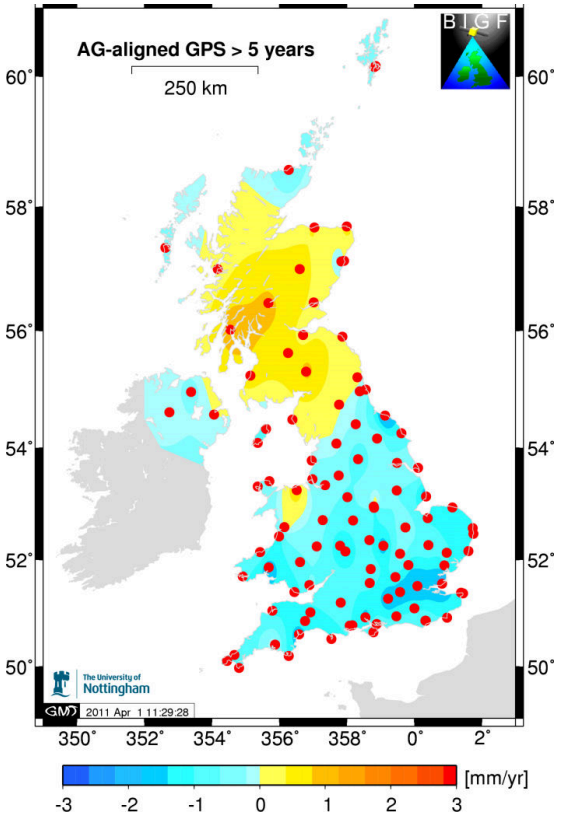

Fig. 3 Map of current vertical land movements at 104 CGPS stations in the UK, based on CGPS measurements for the period from 1997 to 2010 and AG measurements for the period from 1995/6 to 2009.

Examples of major projects using BIGF quality-assured raw data in 2011/12:

- EUMETNET (Network of European Meteorological Services) funded E-GVAP Project, for research into near real-time tropospheric water vapour estimation.
- German Federal Institute of Hydrology, for research into the impacts of climate change on navigation and waterways.
- Japanese National Institute of Information and Communications, for ionospheric research using total electron content over Europe.
- NGI for research into vertical land movements at tide gauges, as part of UK-Environment Agency funded work being carried out in collaboration with NERC National Oceanography Centre, Liverpool.
- Royal Observatory of Belgium, for research into the densification of the European Permanent GNSS Network for ionospheric studies.
- UK Met Office for research into near real-time estimation of atmospheric water vapour content.
- University of Leeds for research into British Isles motion and rotation pole.
- University of Luxembourg for research into the potential of precipitable water vapour measurements from GNSS.
- University of Luxembourg for their reprocessing of the TIGA GPS data set.
- University of Nevada, for research towards a global ambiguity resolved precise point solution and time series, for studies of plate tectonics and global strain rate analysis.

Examples of major projects that used BIGF derived products in 2011/12:

- University of Luxembourg for research into change detection analysis in geodetic time series.
- University of Nottingham for research into Innovative Navigation using new GNSS Signals with Hybridised Technologies (iNsight).

Examples of other research supported with BIGF quality-assured raw data in 2011/12:

- A comparison of PPP and double difference processing strategies using an episodically collected GPS time series.
- Archaeological assessment of Dartmoor peat.
- Bathymetric survey for marine renewable energy equipment installation.
- Detection of storm surge loading with GPS.
- Evaluating the potential use of natural flood management techniques in the Middleburn, Scottish Borders.
- GPS Signal in Space (SiS) monitoring to support aircraft navigation activities of the UK Civil Aviation Authority.
- Gradiometry Survey of the Knowe of Swandro.
- Mitigation of ionospheric scintillation effects on GPS.
- Multi-sensor fusion for driverless car technologies.
- Sensor integration and indoor positioning.
- Science, participation, and a new approach to river restoration.
- Thames Barrier automated monitoring system: a study of diurnal movements at Barking Barrier during Spring tides.
- The accuracy of LiDAR data in urban environments.

See http://www.bigf.ac.uk for details of the services offered and how to make a request for data or derived products.

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3 NERC Space Geodesy Facility

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 ILRS station, making daytime and night- time range measurements to geodetic, gravity-field, altimeter and GNSS satellites at heights of from 300 to 23,000km. 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 system is unique in the ILRS worldwide network. One laser is a modern short-pulse, high repetition-rate (2kHz) instrument, which, in combination with the high-precision event timer, delivers single-shot ranging precision at the 3mm level. During the year, for several months the 2 kHz laser was out of operation following serious energy-stability issues. The laser was returned to the manufacturer for repair, and resumed operations in Spring 2012. 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 when the 2kHz laser was out of action, 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 as the first two Galileo vehicles were launched in October 2011. New satellites of the Chinese COMPASS GNSS are also to be tracked by the network, including SGF [1].

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. Pilot projects organised by the ILRS Analysis Working Group and undertaken by SGF as well as the other ACs include testing of the new SGF-derived tables of centre of mass corrections for LAGEOS and Etalon for all the ILRS stations from 1983 onwards [2] and a new evaluation of atmospheric loading models.

G Appleby was elected in June 2011 for a second two-year term as Chair of the ILRS Governing Board.

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. When processed by sufficient IGS analysis centres to be considered in the IGS combination, the HERS data continues to be amongst the highest weighted clocks in the IGS final clock product. There was a frustrating period between November 2011 and mid-February 2012 when one analysis centre (AC) was rejecting the HERS data in error. Following correspondence with that AC, the situation was rectified, but the problem meant that over this period only one IGS AC was routinely using HERS data, which therefore did not contribute to the IGS timescale. The results from the one AC were however sufficient as a check on the SGF in-house maser vs GPS-derived UTC calculations, a vital step in using the maser to time-tag SLR observations

A study into local site stability using daily GAMIT-based solutions for HERS and HERT coordinates and precise HERS-HERT and HERS- and HERT-SOLA baselines has revealed near-annual periodic baseline variations of amplitude close to 1mm. This study has been extended to include baselines to additional nearby systems and other UK and worldwide short-baselines, all of which exhibit periodic variations in length. [3].

3.3 Absolute Gravity

Regular weekly operations of the FG5 absolute gravimeter have continued since operations began in October 2006, with a strong contribution to the data set during 2011. The baseline observational programme is a 24-hour session centred on mid-GPS week, resulting in hourly average gravity values of precision about 1-2 μgal, equivalent to a daily vertical precision of around 1mm. Analysis of the results, in combination with SGF-derived space geodetic station-height solutions and local groundwater measurements, are underway in collaboration with the Proudman Oceanographic Laboratory and UCL. Particular focus is being placed this year on modeling the effects on gravity of variation in level of the water table and of daily rainfall amounts.

3.4 Site Levelling

The in-house survey programme is leading to the conclusion that the site is internally stable at the sub-mm level, but that the tower that supports the HERS GNSS antenna is affected by solar-driven vertical expansion of up to 2mm at the top. Part of the expansion derives from the exposed concrete base and consideration is being given to enclosing it under topsoil and grass. [4]

3.5 GGOS

SGF this year responded, through NERC, to a GGOS Call for Participation: The Global Geodetic Core Network: Foundation for Monitoring the Earth System. The response, in which SGF applied to be recognized as a GGOS New Technology SLR Site, detailed the multi-technique aspects of the site, its development of kHz-rate laser ranging and installation of an active hydrogen maser time and frequency source, its involvement in data analysis as an ILRS Analysis Centre, and its aspirations for adding VLBI to its observational capability [5]. A positive acceptance letter granting Herstmonceux New Technology site status was received from the GGOS Coordinating Board, in which was emphasized the need for regular monitoring of inter-technique tie-vectors. Also strongly supported is the proposal to add a VLBI2010 component, it being stated by the Coordinating Board that 'A Core Site at Herstmonceux would greatly strengthen both the European and global networks.'

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4 Newcastle University

Contact Matt King [m.a.king@newcastle.ac.uk] or Peter Clarke [peter.clarke@newcastle.ac.uk] for more information.

4.1 Global Navigation Satellite Systems

4.1.1 Real time and kinematic positioning

Newcastle University have produced a revised set of Best Practice Guidelines for using Network RTK in Great Britain, through a study commissioned by The Survey Association, Ordnance Survey, Leica Geosystems, Topcon and Trimble [1,2]. These guidelines expand the previous edition to include further comparison of GPS-only and GPS+GLONASS positioning, and extensive testing in RTK detailing mode in a variety of real urban and semi-urban environments.

4.1.2 Systematic errors

Our GPS signal modelling studies have focused on the propagation of unmodelled subdaily signals into spurious long period signal, including multipath and monument-antenna effects [3,4].

4.2 Atmosphere studies

At Newcastle, [5] examined tropospheric delay models for use in kinematic positioning over wide ranges in altitude, by comparing their effect on positioning accuracy over a repeated trajectory on board a train traversing 1 km of relief on the Snowdon Mountain Railway.

4.3 National and international networks

Newcastle University continues to contribute to the International GNSS Service as an Associate Analysis Centre, providing weekly global coordinate combinations in parallel with the official IGS product.

4.4 Geoid Determination

[6,7] estimated the Gauss-Listing parameter W0 and its rate of change, using tide gauge, GPS and GRACE data around the UK, the Baltic Sea and globally. Results were used to show how vertical datums could be unified across a range of spatial scales.

4.5 Mean Sea Level Studies

[8] have investigated effects of seafloor and coastline topography on local sea level rise. Work described in section 13.2 has also contributed to this overall topic.

4.6 Geophysical, Glaciological, and Oceanographic Applications of GNSS

At Newcastle, applications of GPS in particular have been made to a wide range of global geophysical and glaciological problems.

4.6.1 Ocean tides and their consequences

[9] investigated the effects of tides on the Ronne Ice Shelf, Antarctica. [10-12] examined more generally the response of glaciers and ice shelves to tidal forcing in their grounding line.

4.6.2 Cryospheric geodesy

A review of the uses of GPS positioning in glaciology was provided by [13].

4.6.3 Glacio-isostatic adjustment

[14] reviewed the state of the art in modelling and observations of GIA. New results for Antarctic GIA based on a state-of-the-art GPS global reprocessing were provided by [15].

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