National Report of Great Britain 2009

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1 Introduction

National geodetic activity in the past year has included:

- the upgrade of station hardware at almost all the 110 stations in the Ordnance Survey OS Net® GNSS network. The network is now fully GNSS compatible;
- work on a geodetic, zero order sub network (GeoNet) has started;
- distribution of national RTK corrections from OS Net data via licensed Ordnance Survey partners;
- the ongoing submission of data to the EPN;
- the continued development of the NERC BIGF (British Isles GPS archive Facility), housed at the Institute of Engineering Surveying & Space Geodesy (IESSG),University of Nottingham;
- continued space geodesy and gravity observations at Herstmonceux;
- research at GB universities, of interest to EUREF.

2 National GNSS network

The Ordnance Survey's National GNSS network –OS Net® (www.ordnancesurvey.co.uk/gps), is now almost complete with 107 stations in place (see Figure 1). Only 3 stations remain to be built to complete national coverage – 2 in the western islands of Scotland and 1 on the Isles of Scilly in the far south west of England.

A complete refresh of the station hardware has recently been carried out. All stations have been upgraded to GPS/GLONASS receivers and antennas. The majority of stations are now equipped with Leica GRX1200+GNSS or GRX1200GGPRO receivers and LEIAR25 antennas (with LEIT radome). The antennas are Galileo ready and the receivers can be upgraded to Galileo when required.

Whilst all the current GNSS stations are firmly mounted on solid structures/ground, not many could be classed as being of zero order, geodetic quality monumentation. Also over half of the EUREF GB 2001 stations that realise the ETRF in GB have been destroyed. To address these issues, a new zero order network of 13 permanent GNSS stations, mostly rock anchored and monumented to international geodetic standards, is currently being built. Consultation on the monumentation and site location was held with Geomatics, Geology and Geophysics experts from academia, the

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British Geological Survey, the Environment Agency and Proudman Oceanographic Laboratory. This new network, called GeoNet, is expected to be complete later in 2009. GeoNet will be a sub set of OS Net and the station hardware will be the same. Where possible, GeoNet stations will be collocated with other sensors. Following GeoNet's completion a new EUREF quality campaign will take place to realise an updated ETRF in GB.

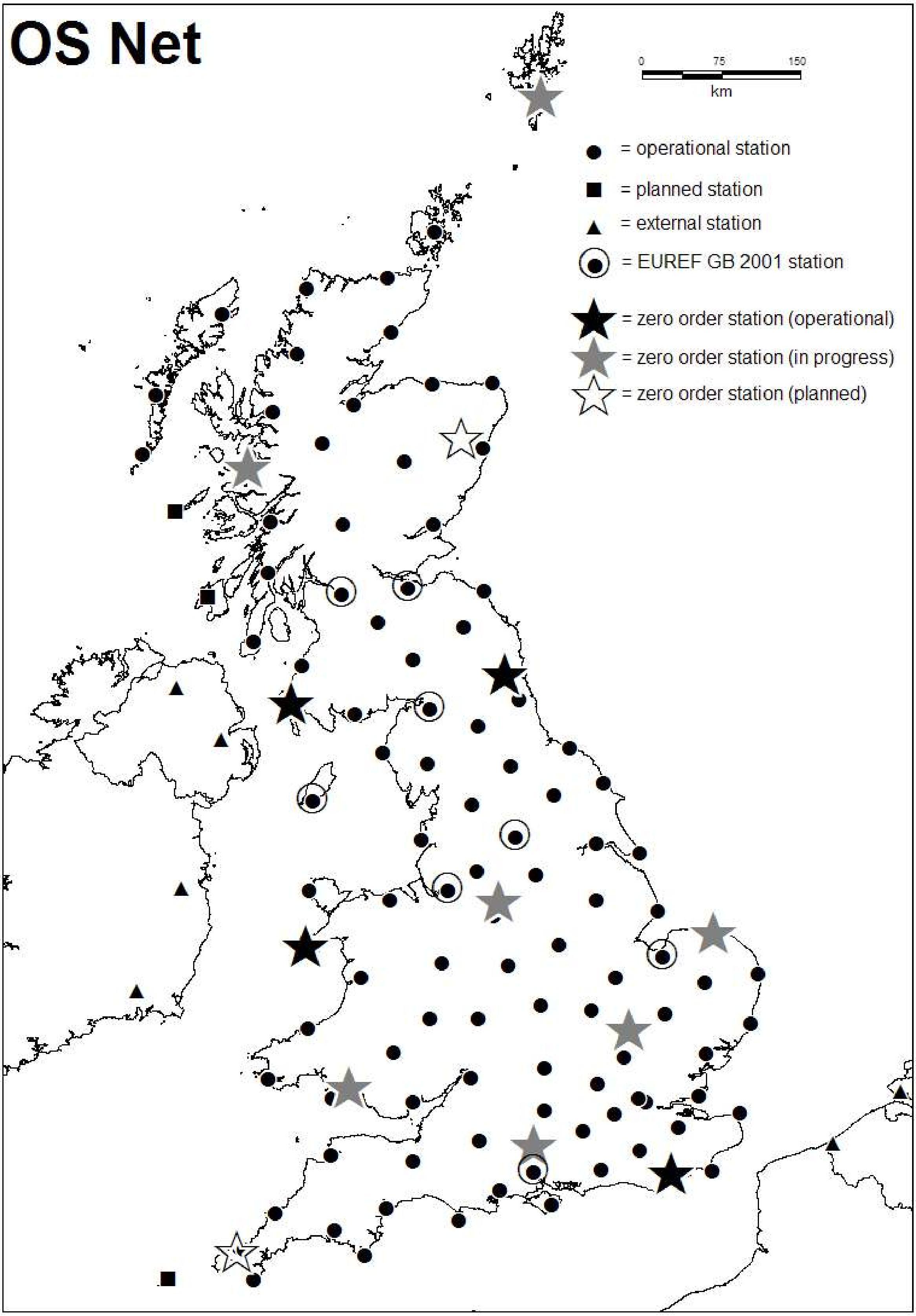

Figure 1. OS Net GNSS network.

The whole OS Net network is managed using the GPSNet™ software from Trimble and delivers RTK corrections via GSM and GPRS to approximately 130 Ordnance Survey surveyors. Public 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. Topcon have recently been announced as the 3rd partner to offer an RTK correction service (TopNETPlus) based on data streams from OS Net. They join Leica (SmartNet) and Trimble (VRSNow).

3 EUREF related activities

3.1 Maintenance of national ETRF coordinates

As requested by the TWG (EUREFMail 4365) information is given on how the national ETRF coordinates of the permanent stations are maintained.

The ETRF is currently realised in Great Britain by the stations of the EUREF GB 2001 campaign. These stations are included in the OS Net GNSS network and are monitored on a continuous basis by the GPSNet software. The ETRF realised by EUREF GB 2001 is tied to ITRF97 at epoch 2001.55. Two stations – DARE and INVE were in EUREF GB 2001 and are also EPN stations. Table 1 shows the difference between EUREF GB 2001 coordinates and ETRF2000 coordinates at these two stations.

EUREF ETRF2000 ETRS89 (e2000.00) coordinates			
Station	**X (m)**	**Y (m)**	**Z (m)**
DARE	3811965.5890	-175800.0490	5093615.4940
INVE	3427172.3810	-252834.3160	5355255.5100
EUREF GB 2001 ETRS89 (e2001.55) coordinates			
DARE	3811965.5996	-175800.0542	5093615.4759
INVE	3427172.3922	-252834.3342	5355255.4901
ENU differences from ETRF2000 to EUREF GB 2001			
	East (m)	**North (m)**	**Up (m)**
DARE	-0.0047	-0.0195	-0.0081
INVE	-0.0173	-0.0212	-0.0101

Table 1. Comparison of EUREF GB 2001 and EUREF ETRF2000 coordinates.

Since the EUREF GB 2001 campaign took place over half of the stations have been destroyed. Out of the original 20 CORS stations in EUREF GB 2001 just 9 remain and 8 of these are part of OS Net (the 9th is IESG belonging to the University of Nottingham). The distribution of the remaining EUREF GB 2001 stations is no longer evenly spread across GB – see Figure 1.

As stated in 2 above, the GeoNet zero order GNSS network to replace EUREF GB 2001 is currently being built. When complete it will form a new ETRF realisation for GB, expected in late 2009. The GeoNet stations will be part of OS Net and will be monitored in the same way but it is also planned to introduce high accuracy monitoring of the GeoNet coordinates with Bernese GPS Software.

3.2 EPN data submissions

Current EPN submissions from GB are hourly data from HERS, HERT and MORP plus 24 hour files from DARE, INVE, NEWL and NPLD. Data integrity problems currently prevent us from switching DARE and INVE to hourly submissions but some planned new hardware should enable us to do this.

Raw GPS data from DARE, INVE and RTCM 3.0 data from SHOE are also streamed in real time via NTRIP. This is in addition to RTK data from HERT.

3.3 Channel Tunnel levelling

Work started last year with colleagues of the French Institut Geographique National to finally come to a common answer for the levelling through the Channel Tunnel carried out in 1994. This will enable a better connection of the GB levelling network to UELN.

Progress on the final connection of the British Tunnel portal bench mark to Ordnance Datum Newlyn has been held back by a delay in the computation of a new British geoid model (see 4 below).

Attempts are being made to recover some of Ordnance Survey's original Tunnel levelling data from printouts and archived files in order to further investigate the discrepancy between the British and the French levelling.

4 Geoid model improvement

Geodetic GPS observations have been 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.

A new geoid model was planned for release last year but is now on hold until the new realisation of ETRS89 in GB (EUREFGB2009) is computed.

5 BIGF British Isles GPS archive Facility

BIGF is operated from the IESSG, at The University of Nottingham, with funding from the UK Natural Environment Research Council (NERC), until at least 2014. Figure 2 shows the current network.

BIGF is the long-term national archive for GNSS data, from a continuously recording network of currently 155 stations sited throughout the UK. This network comprises all Ordnance Survey of Great Britain active stations, all Leica Geosystems active stations, all Land and Property Services Northern Ireland active stations and 26 scientific stations. The scientific stations have been established by various agencies and organisations, who are: Defra, Environment Agency, IESSG, Met Office, NERC Proudman Oceanographic Laboratory, NERC Space Geodesy Facility, and Newcastle University. Data are provided and transmitted free-of-charge to the archive by these collaborators, with whom long-term agreements to supply are in place.

Cumulative demand on the archive since its inception in 1998 is approaching 5,000 site years. More importantly the number of scientists annually making use of the archive increased from 4 to over 100 annually over the same period. This growing user base has elevated BIGF's profile in the scientific community, increasing the possibilities for infiltration of new scientific fields, the enabling of new applications, and cross-fertilisation and collaboration between experts in satellite positioning technology and experts in other disciplines.

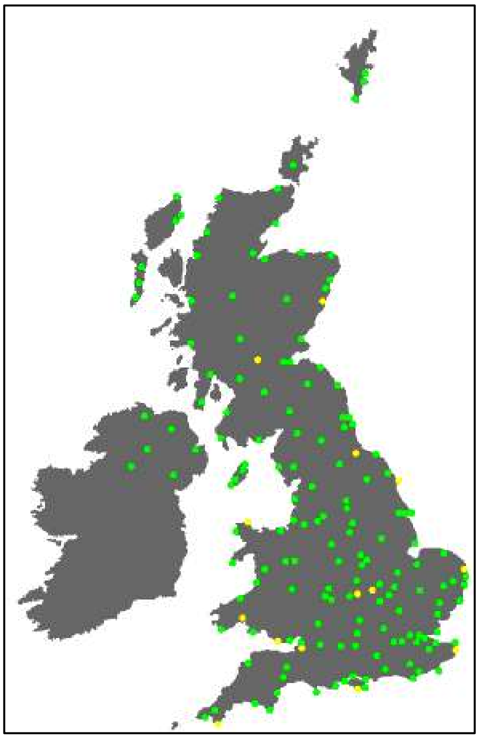

Figure 2. The current BIGF Network. Green = active, yellow = historical data available

During the period from 1998 to present, there has been a steady net growth in the BIGF network to the current live complement of 155 stations (a further 43 have ceased operation but data are preserved in the archive). The current status of the network is shown on the map in Figure 2.

In 2008/9, there were 7 major projects using BIGF data:

- EUMETNET (Network of European Meteorological Services) funded E-GVAP Project, for research on near real-time tropospheric water vapour estimation.
- IESSG for research on vertical land movements at tide gauges, as part of UK-funded work being carried out in collaboration with NERC Proudman Oceanographic Laboratory, and EC-funded work being carried out as part of the European Sea Level Service (ESEAS).
- IESSG for NERC-funded creation of a map of current vertical land movements in the UK based on an optimal combination of absolute gravity and continuous GPS.
- Japanese National Institute of Information and Communications, for ionospheric research using total electron content over Europe.
- UK Met Office for research into near real-time estimation of atmospheric water vapour content.
- 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.
- University of Nice, France, for research into the European scale velocity field from permanent GNSS data.

Other research supported by archive data in 2008/9 included, amongst many others:

- Collection and analysis of coastal data for coastal management.
- Creek and cliff dynamics of salt marshes.
- Design of low-cost remote sensing equipment for agricultural use.
- Evaluating the role of grass buffer strips in arable catchments.
- Visualising integrated information on buried assets to reduce street works.
- Mechanisms of coastal erosion in Devensian tills on the East Yorkshire coast.
- Mitigation of ionospheric effects on GPS.
- Post-project monitoring of river rehabilitation projects in the UK and Japan.

The long-term nature and increasing spatial density of the BIGF network lends itself to take on a facilitative role as an environmental laboratory, enabling the more incisive determination of spatially dependent environmental variables, and isolation of lower frequency components of parameters such as ocean tide loading and vertical land movement.

Six of the stations are part of the IGS and EPN (DARE, HERS, HERT, INVE, MORP, NEWL) and four CGPS@TG stations contribute to the IGS TIGA Pilot Project (ABER, NEWL, NSTG and SHEE).

See http://www.bigf.ac.uk for details of the service and how to request data.

6 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 system, two continuously operating IGS GNSS receivers, one of the UK Ordnance Survey GeoNet GNSS receivers and a permanent FG5 absolute gravimeter. Frequent, on-site automated meteorological and water table depth observations augment the geodetic observations. The Facility is also an International Laser Ranging Service (ILRS) Analysis Centre.

6.1 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 accuracy. The upgrade to include a short-pulse, high repetition-rate (2 kHz) laser and a very high-accuracy event timer is complete and this combination is now delivering single-shot ranging precision at the 3mm level. The original 10Hz laser remains in operation when required for specific applications such as a promising LIDAR capability in collaboration with the Chemistry Department at Cambridge University. Modelling work done by SGF has improved to the mm-level the corrections required to relate the Herstmonceux 2kHz laser measurements to the centres of mass of the geodetic spherical satellites. A measurement campaign to resolve non-linearity effects that can reach 10mm in range as a result of some stations' counter hardware has been terminated with limited success. It has proved very difficult to re-create the electronic circumstances pertaining in the past at the stations, and empirical range-correction estimation is likely to be more fruitful.

The Facility as an ILRS Analysis Centre computes daily, 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. In common with the other Analysis Centres, a re-analysis of all laser data taken since 1983 to the geodetic (two LAGEOS and two ETALON) satellites is underway, taking account of historical range corrections and other modelling issues, which may have a bearing on the scale differences relative to the VLBI solutions that were evident in the ITRF2005.

6.2 GNSS

The two IGS stations HERS and HERT remain in continuous operation, with HERT also streaming GPS and GLONASS navigation data into the Internet in support of the EUREF-IP and IGS Real-time Projects. The new GPS/GLONASS 'all in view' Leica GRX GG Pro system at HERT has performed well throughout. The old HERT Z18 system has continued to supply data from the OS trig point (informally 'SOLA') close to the Facility and adds a third station to the ongoing local network study into subtle baseline variations. Daily GAMIT-based solutions for HERS and HERT coordinates and precise HERS-HERT and HERS- and HERT-SOLA baselines are showing near-annual periodic baseline variations of amplitude close to 1mm, which are under investigation. The purchase process is well-advanced for an active H-maser frequency source to drive at least one of the receivers and thus contribute to IGS GNSS observations that are independent of time derived from the GPS system itself, as well as improving the quality of the frequency source used in the laser ranging operations.

One of the Ordnance Survey GeoNet systems has been installed by the OS and is fully operational close to the SOLA trig pillar.

6.3 Absolute Gravity

Regular weekly operations of the FG5 absolute gravimeter have continued since operations began in October 2006. 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. Results to date, in press, suggest that the gravity environment is quite stable and that the effects of seasonal hydrological changes are less marked than may have been expected.

7 University research work

7.1 Newcastle University

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

7.1.1 Global Navigation Satellite Systems

Real time positioning

Newcastle led a study under the auspices of The Survey Association, supported by Ordnance Survey, the Royal Institution of Chartered Surveyors, and major commercial RTK service providers, to benchmark the available Network RTK GPS services in Great Britain [1, 2]. The study concluded that these services were capable of providing positioning at the level of 10 – 20 mm in plan and 15 - 35 mm in height (one sigma), but recommended a number of window averaging strategies which could be used if accuracy was critical, in the locations furthest in plan or vertically from active base stations or where ocean tide loading effects were suspected to be significant.

Systematic errors

"Sidereal filtering" methods to remove multipath-related errors were shown to be effective [3, 4] in improving precision in short-baseline kinematic processing at quasi-static sites (not moving, or undergoing small controlled displacements). An improvement in 3-D precision from 7.4 - 9.6 mm (one sigma) in the unfiltered case to 5.4 - 6.6 mm was demonstrated using coordinate residual based filtering. Carrier phase residual based filtering is marginally less effective in terms of final coordinate precision, but significantly improves ambiguity resolution time when using a single-epoch processing strategy.

7.1.2 National and international networks and reference frames

IGS routine analysis and reprocessing

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. The current IGS reprocessing effort aims to reanalyse prior data back to 1994 using the same processing strategy and models as the present-day operational solutions. To date, solutions back to year 2000 have been generated by several analysis centres and combined at Newcastle; work is in progress to extend this time series further back and to incorporate newer iterations of these solutions. Newcastle will host the 2010 IGS Workshop.

7.1.3 Geophysical applications of GNSS

Cryospheric applications

Two linked studies [5, 6] using GPS in kinematic precise point positioning mode demonstrated localised acceleration of ice sheet flow during the drainage of a supra-glacial lake, implying that meltwater lubrication has at least a localised effect on flow speed. However, it appears that the influence of meltwater on outlet glacier speed is more limited.

Tidal and surface mass loading

Estimates of harmonic motion at the principal sub-daily tidal periods within precise point positioning GPS solutions were used to validate ocean tide models around the coast of Antarctica [7]. Of the global tidal models, TPXO6.0 and TPXO7.0 were found to perform best; regional model CADA00.10 performed at a similar level.

GPS and GRACE estimates of the degree-2 surface mass load were compared with Earth rotation data corrected for atmospheric and oceanic angular momentum and with climatological surface mass load models [8]. The GPS estimates best explain the degree 2, order 1 model data, whereas the GRACE estimates best explain the order 0 and order 2 data.

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7.2 University of Nottingham's IESSG

Contact Richard Bingley [richard.bingley@nottingham.ac.uk] in the first instance for further details of these projects.

7.2.1 Monitoring changes in land and sea levels at tide gauges

The IESSG's research on using CGPS and absolute gravity at tide gauges continued in 2008 with funding from the Environment Agency. This research is being carried out in collaboration with Proudman Oceanographic Laboratory and involves the monitoring of changes in land and sea levels at ten tide gauges around the coast of Britain. The results of the project and its implications for future flood and coastal risk management were published in Bingley et al 2008, and used in Woodworth et al 2009, to compute new trends in UK mean sea level.

7.2.2 Maps of UK land movement

Maps of UK horizontal and vertical land movement for the period from 1997 to 2005, based on more than 30 CGPS stations, were published in Teferle et al 2009. These were then used to provide new constraints for models of crustal motion due to glacio-isostatic adjustment of the British Isles (Bradley et al 2009). Through funding from NERC, in 2008, the IESSG and POL started a short project to create an updated map of vertical land movement from a re-processing that included data for the period from 1997 to 2008, from more than 100 CGPS stations and 2 absolute gravity stations, in this region. Not only was the CGPS network dramatically expanded from previous investigations by the authors, it now also includes, for the first time, stations in Northern Ireland, which will be interesting for defining the westerly extent of uplift associated with the glacio-isostatic processes active in the region. In our processing strategy we apply a combination of re-analysed satellite orbit and Earth rotation products together with updated models for absolute satellite and receiver antenna phase centres and for the computation of atmospheric delays, and a reference frame implementation using a semi-global network of approximately 50 IGS stations. The aim is to produce a geodetic map of vertical land movements over the last decade and compare this to the geological map currently used in assessments of future changes in relative sea level for the planning of flood and coastal defences in the UK.

7.2.3 Mitigation of ionospheric scintillation effects

The IESSG has been involved in studies of the mitigation of polar and auroral scintillation effects on GNSS positioning (Aquino et al. 2009). Incorporating satellite-specific phase and amplitude scintillation effects into the variance of tracking errors allows the assignment of different weights to measurements from different satellites. This technique gives the least squares stochastic model a more realistic representation, in particular in a scintillation scenario, where it is likely that the satellites in view are affected differently. Ongoing collaboration involving IESSG, UNESP (Sao Paulo State University, Brazil) and INGV (National Institute for Geophysics and Volcanology, Italy), through two Royal Society International Joint Projects, has exploited this approach. Improvement of 17% to 38% in the height error was achieved when the technique was applied to relative positioning based on GPS C1 and P2 pseudoranges for baselines ranging from 1km to 750km, at mid to high latitudes in Northern Europe (50N to 79N), under different geomagnetic conditions ($4 \leq Kp \leq 6$). During a period of high phase scintillation, problems related to carrier phase ambiguity resolution were also reduced using this approach. It is envisaged that such a technique could be embedded into a future scintillation robust receiver.

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7.3 University College London

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7.3.1 Geoid modelling

A team consisting of Marek Ziebart and Jonathan Iliffe at UCL, and Rene Forsberg and Gabriel Strykowski at DNSC (national Danish space centre) computed a new geoid model for the UK and assessed the improvements over the existing OSGM02 model, comparing both to the UK fundamental benchmark network.

The results of this study suggest that a traditional height network based on fundamental benchmarks can be used meaningfully to assess the quality of a satellite-derived geoid model. We compared the pre- Gravity Recovery and Climate Experiment (GRACE) OSGM02 and the recent OSGM05 geoid models with the datum surface inferred by the UK fundamental benchmark network combined with network monument ellipsoidal heights derived from GPS data.

OSGM05 incorporates long-wavelength gravity field data from GRACE to degree/order 90. Switching from OSGM02 to OSGM05, the mean difference between the leveling datum and the geoid model reduces from 0.129 m to 0.004 m, and RMS differences reduce from 0.110 m to 0.048 m. The mean tilt between the height datum and the geoid model in the north-south direction reduces from 34 mm to 12 mm per degree of latitude. This demonstrates a systematic convergence between the geoid models and the leveling datum surface in terms of mean offset, RMS scatter and tilt without any fitting of one surface to the other. The implication is that the leveling datum surface represented a more accurate model of the geoidal geometry compared to OSGM02 in terms of form (in both short- and long-wavelength features) and surprisingly also in terms of its offset from the GRS80 ellipsoid. While the latter point can be no more than a coincidence, the former indicates that the UK leveling network, based on its fundamental benchmark network, can be used to test the accuracy of geoid model improvements derived from missions such as GRACE, with implications for the forthcoming Gravity Field and Steady State Ocean Circulation Explorer (GOCE) mission.

7.3.2 Vertical Offshore Reference Frames

Jonathan Iliffe, Marek Ziebart and James Turner of UCL carried out further work in 2008 to deliver an operational solution for the United Kingdom Hydrographic Office's vertical offshore reference frame (VORF). This is a mathematical model of all the major offshore reference surfaces used in charting and navigation in UK home waters. The surfaces model LAT, HAT, MSL, MHWS and MLWS above the GRS80 ellipsoid, positioned in ETRF89. The models were developed by a combination of tide gauge data, GPS data, satellite altimetry and gravity field data.

The principal advantage of the models is that they enable offshore surveying without recourse to tide gauge data to reduce soundings to chart datum.

The UKHO have started to licence the model to offshore survey companies.

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