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The Ordnance Survey's National GNSS network –OS Net® (www.ordnancesurvey.co.uk/gps), is now complete with 110 stations in place (see Figure 1). The final 2 stations - one in the western islands of Scotland and 1 on the Isles of Scilly in the far south west of England were connected to the network in late summer 2010. OS Net also contains a network of zero order geodetic stations – "GeoNet".

The EUREF densification campaign "EUREF IE/UK 2009" was ratified in resolution 1 from the EUREF 2010 Symposium. The campaign included the "GeoNet" stations and similar stations across Great Britain, Ireland and Northern Ireland.

Work is now progressing on a complete readjustment of the OS Net station coordinates using the EUREF IE/UK 2009 GeoNet results as control. This will be the first homogeneous computation of the network since its completion.

The 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. Current commercial partners offering RTK service in Great Britain are AXIO-NET, Leica, Topcon and Trimble.

In early 2011 the resiliency of the partner data streams, and the bandwidth available for them, was increased through the implementation of a dedicated, offsite, dynamically clustered pair of NTRIP servers. The whole of the OS Net server hardware was also replaced (with some parts being virtualised) as part of the Ordnance Survey headquarters move to a brand new building.

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Figure 1. OS Net GNSS network.

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). Now that the Ordnance Survey headquarters move is complete and new hardware is in place hourly data submission from DARE and INVR should be able to start later this year. We also intend to submit all the GeoNet stations as EPN stations and submit hourly data from them as well.

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.

Some work took place in recent years 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. A mean answer for the height difference through the tunnel (+44.8272m from France to GB) was agreed and presented at EUREF2007.

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. Following the successful EUREF IE/UK 2009 campaign this work should now be able to proceed (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.

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).

BIGF is operated from the IESSG (Institute of Engineering Surveying & Space Geodesy), at The University of Nottingham. It is funded by the UK Natural Environment Research Council (NERC), until at least 2014. Figure 2 shows the current network.

BIGF is our long-term national archive for GNSS data, sourced from a continuously recording network of currently 160 stations, sited throughout the UK. This now mature network, comprises the Ordnance Survey of Great Britain active stations, including their GeoNet sub-network of 12 connected to 'solid rock', and active stations of Leica Geosystems and Land and Property Services Northern Ireland, plus 26 scientific stations. The scientific stations have been established by various agencies and organisations, namely: Defra, Environment Agency, IESSG, Met Office, NERC National Oceanography Centre, Liverpool (formerly 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.

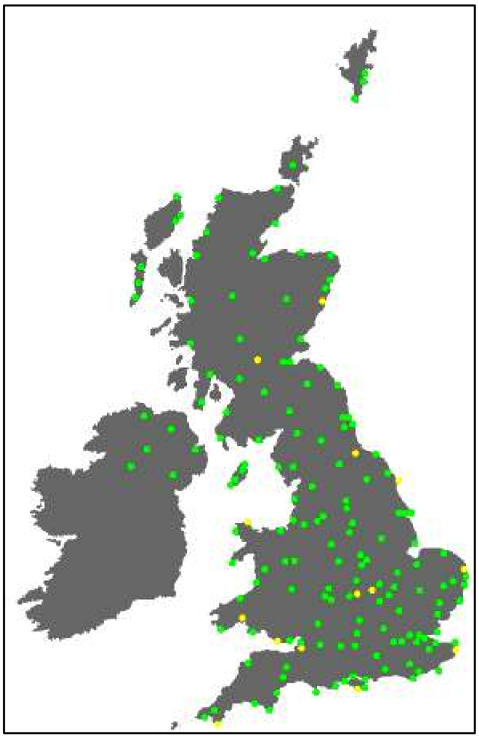

Figure 2. The current BIGF Network. Green = active, yellow = historical data available.

Cumulative demand on the archive since inception in 1998 approaches 2.75m station-days, but more importantly, the number of scientists annually making use of the archive has increased by an order of magnitude 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 dense national networks, which together with the temporal extent of the archive, means that BIGF is not only an essential national capability, but also one of great international importance and demonstrable utility. BIGF does not stand still, but is advancing using expertise at the IESSG, in the development of a range of derived products using the quality assured raw data. The aim of this is to facilitate collaborative research with non-GNSS specialists. These products currently comprise various temporal realisations of tropospheric delay and reference station coordinate dynamics.

In 2010/11, there were 8 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-Environment Agency funded work being carried out in collaboration with NERC National Oceanography Centre, Liverpool (formerly Proudman Oceanographic Laboratory).
- 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.
- Newcastle University, for research on global loading and deformation at tidal timescales.
- Royal Observatory of Belgium, for research into the densification of European Permanent GNSS Network for ionospheric studies.
- 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.

Other research supported by archive data in 2010/11 included, amongst many others:

- Archaeological excavation at Peacehaven.
- Boulby Geoscience Project.
- Channel-Scale Discrete Particle Modelling of River Channel Junctions.
- Cold air pooling over complex terrain.
- Determination of urban flood routes.
- Imaging coastal archaeological sites in Uist.
- Mitigation of ionospheric scintillation effects.
- Outfall chamber flood risk management improvement project.
- Physical properties and behaviour of UK rocks and soils.
- Predicting salmonid population ecology from individual fish responses to environmental change; bridging behaviour, conservation and fishery management.
- Rectifying aerial photography related to field trials for monitoring agriculture by remote sensing.
- Re-levelling or levelling in new flood warning gauging station benchmarks.

- River channel survey and creation of 3D topographic model, for flood risk assessment.
- Sustainable drainage system for flooding events.
- Talla Earth Observatory.
- Testing the accuracy of internet-based PPP services, related to integrated flood management strategy in an un-gauged river basin.
- Thames Barrier GPS monitoring, and datum point establishment.
- THESEUS project - coastal flooding risk and options for mitigation in Europe.
- Watercourse flood modelling survey.
- Woodland bird habitat modelling with integrated remotely sensed data.

Six of the stations are part of the IGS and EPN (DARE, HERS, HERT, INVR, MORP, NEWL) and ten CGPS@TG stations contribute to the IGS TIGA Pilot Project (ABER, DVTG, LWTG, LIVE, LOWE, NEWL, NSTG/NSLG, PMTG, SHEE and SWTG).

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

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 real time to BGS' British Isles seismic network. A new and 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.

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 (2 kHz) instrument, which, in combination with the high-precision event timer, delivers single-shot ranging precision at the 3mm level. 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. 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, and this work has been extended to ranges made by the primary ILRS systems [1].

Laser tracking of the GNSS satellites is set to increase in importance for the ILRS community as new constellations are developed that include laser retro-reflectors on each vehicle for independent orbit determination and quality control. As part of the ILRS discussions about how best to meet this need, a study has been carried out by SGF to test the relative efficiencies of the laser retro-reflector corner-cubes on the orbiting GNSS satellites from the GPS, GLONASS, Galileo (GIOVE) and COMPASS constellations. The results show that the uncoated cubes on the COMPASS-M1 satellite perform better than any of the other, mostly-uncoated cubes in current operational use [2]. This result confirms and supports results from the only other study, which used a ground-based test facility, and is likely to inform best practice standards for future high-orbiting missions.

The Facility is an ILRS Analysis Centre 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. A re-analysis of all global laser data taken since 1983 to the geodetic (two LAGEOS and two ETALON) satellites has been completed, taking account of historical range corrections and other modelling issues, and combined with all the AC's solutions by the ILRS Combination Centres to form the laser ranging contribution to the ITRF2008, published by the IERS in late-2010.

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. A modern GPS/GLONASS Septentrio Timing receiver has replaced this year the HERS Ashtech Z12 receiver. 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 the local stability monitoring work. A newly purchased active hydrogen maser has been installed in an air-conditioned room in the Facility basement, and its highly-stable frequency source and one-second tick pulse are driving both the HERS Septentrio receiver and the SLR event timer. The timescale derived from the H-maser, unofficially named UTC(SGF), is continuously compared with UTC(GPS), and in this way the SLR observations continue to be time-tagged with respect to UTC(GPS), but greatly benefit from the high-precision and stability of the frequency source. 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].

Regular weekly operations of the FG5 absolute gravimeter have continued since operations began in October 2006, but with some several months' loss of observing time during 2010 due to problems with the laser. 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 suggest that the gravity environment is quite stable and that the effects of seasonal hydrological changes are less marked than may have been expected [4,5]. A study is underway to use the observations to compare and assess different ocean-loading models.

[1] Current Trends in Satellite laser Ranging. G. Appleby, G. Kirchner, J. McGarry, T. Murphy, C. Noll, E. Pavlis, M. Pearlman, F. Pierron (2010). EOS AGU, December 2010 (abstract)

[2] In-Orbit Assessment of Laser Retro-Reflector Efficiency Onboard High Orbiting Satellites, M. Wilkinson, G. Appleby (2011, available online 15 April 2011). Advances in Space Research, http://dx.doi.org/10.1016/j.asr.2011.04.008

[3] Monitoring site stability at SGF Herstmonceux. M. Wilkinson, R. Sherwood and G. Appleby (2011, accepted). Commission 1 Symposium 2010 Reference Frames for Applications in Geosciences (REFAG2010)

[4] Appleby, G.M., V. Smith, M. Wilkinson, M. Ziebart and S. Williams (2010). Comparison of height anomalies determined from SLR, absolute gravimetry and GPS with high frequency borehole data at Herstmonceux. Gravity, Geoid and Earth Observation, International Association of Geodesy Symposia, 135(1):107-113, DOI:10.1007/978-3-642-10634-7_15.

[5] Attempts to separate apparent observational range bias from true geodetic signals. G . Appleby, M. Wilkinson, V. Luceri, P. Gibbs, V. Smith (2010). In 'Schilliak, S (Ed), Proceedings of the 16th International Workshop on Laser Ranging, Poznan, Poland.

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Real time and kinematic positioning

Newcastle University have produced Best Practice Guidelines for using Network RTK in Great Britain, through a study commissioned by The Survey Association, Leica Geosystems, Trimble, Ordnance Survey and the Royal Institution of Chartered Surveyors, the scientific findings of which are detailed in [1] and [2]. A follow-up theoretical study has been undertaken, predicting the likely impact of ocean tide loading on Network RTK in Great Britain, which they estimated could exceed the centimetre level. See also sections 4.2.4, and 4.2.6.

Systematic errors

GPS signal modelling studies have focused on the propagation of unmodelled subdaily signals into spurious long period signal, including mean bias, offsets, periodic signal, velocity bias and high frequency noise [3].

Troposphere

At Newcastle, [4] produced precipitable water vapour (PWV) estimates from a global GPS reanalysis and compared them to estimates from independent radiosonde and satellite based techniques. They showed a reduced bias in the GPS PWV compared to those from radiosonde data, and concluded that much of the bias in previous GPS-radiosonde studies could be attributed to deficiencies in the GPS observation modelling.

Ionosphere

Several Newcastle outputs [5, 6, 7, 8] considered the effects of higher order ionospheric terms on GPS coordinate time series, velocities, reference frame parameters and tropospheric zenith delay terms, again within the context of a global GPS reanalysis.

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 new IGS08 reference frame is now being used to align the weekly solutions.

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. Solutions back to year 1994 have been generated by several analysis centres and combined at Newcastle.

A reprocessing effort is under way at Newcastle to produce a time series of site coordinates incorporating newer analysis models not included in ITRF2008, for example the second-order ionospheric effect. A recent study of this [7, 8] indicated small but significant effects on the geocentre, and, depending on the time period of analysis in relation to the solar cycle, possible effects on site velocities.

Newcastle hosted the 2010 IGS Workshop with over 200 delegates from 29 countries, followed by a one-day COST Action ES0701 symposium on vertical rates of land motion relating to improved estimates of glacio-isostatic adjustment and sea level.

At Newcastle, [9] considered the potential for GOCE to be used to determine secular mass change over polar regions. They found that with the pre-launch GOCE noise levels and mission duration that reasonable mass changes would not be detected by GOCE.

A recent Newcastle PhD thesis [10] 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.

Research at Newcastle by [11] has shown that local deformation monitoring networks using a switched antenna system with a single receiver can achieve coordinate precisions of better than 5 mm in plan and 8 mm vertically, with a recommended antenna switching interval of 119 s or a multiple thereof.

Work described in section 4.2.6 has also contributed to this topic.

Outputs arising from Newcastle contributions to the GOCE User Toolbox [12, 13] have used new high-resolution geoids derived from GOCE satellite data to obtain significantly improved estimated of mean dynamic ocean topography both globally and with a focus on the North Atlantic circulation. [14] have investigated optimal filtering strategies for use with these and similar datasets.

Work described in section 4.2.6 has also contributed to this overall topic.

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

Ocean tides and their consequences

[15, 16, 17] examined the response of glaciers and ice shelves to tidal forcing in their grounding line and identified a nonlinear velocity response allowing insights into sub-glacial processes. [18] report on a new GPS data set of ocean tides in the Weddell Sea - namely on the floating Filchner-Ronne and Larsen C ice shelves. Accuracy of several ocean tide models was tested against the data and errors remain at the 5-20 cm level in the most energetic constituents, although with spatial variation.

Non-tidal surface mass loading

[19] reported on new estimates of the non-secular variation in J2 from a global GPS reprocessing, GRACE, load models and SLR and found that previously reported SLR-derived J2 anomalies may be SLR analysis artefacts. A keynote presentation at the 3rd IGCP565 Workshop in Reno, NV [20] addressed the issues of estimating hydrological surface mass loading in the presence of other, confounding, geophysical deformations.

By considering sites around the southern North Sea, [21] showed that reprocessed GPS height time series exhibit non-tidal ocean loading effects of comparable size to atmospheric pressure loading, and hence should be modelled. Correcting for the effect using a high-resolution numerical ocean model achieved an 11% better GPS height variance reduction than when using a lower-resolution global ocean model

Glacio-isostatic adjustment

As part of COST Action ES0701, led by Dr Matt King at Newcastle, [22] undertook a benchmark study of GIA codes for the first time. Immediately following the 2010 IGS Workshop, Newcastle hosted a one-day ES0701 symposium on vertical rates of land motion relating to improved estimates of glacio-isostatic adjustment and sea level. [23] reviewed the state-of-the-art in modelling and GPS observations of GIA, particularly for Greenland and Antarctica and with a focus on GPS vertical velocities.

[1] Edwards SJ; Clarke PJ; Penna NT; Goebell S. Assessment of network RTK GPS accuracy in Great Britain. Survey Review, 42(316), 107-121, 2010.

[2] Clarke PJ; Penna NT. Ocean tide loading and relative GNSS in the British Isles. Survey Review, 42(317), 212-228, 2010.

[3] King MA; Watson CS. Long GPS coordinate time series: multipath and geometry effects. Journal of Geophysical Research – Solid Earth, 115, B04403, doi:10.1029/2009JB006543, 2010.

[4] Thomas I; King MA; Clarke PJ; Penna NT. Precipitable water vapor estimates from homogeneously reprocessed GPS data: An intertechnique comparison in Antarctica. Journal of Geophysical Research – Atmospheres, 116, D04107, doi:10.1029/2010JD013889, 2011.

[5] Petrie EJ; Hernández-Pajares M; Spalla P; Moore P; King MA. A review of higher order ionospheric refraction effects on dual frequency GPS. Surveys in Geophysics, 32(3), 197-253, doi: 110.1007/s10712-10010-19105-z, 2011.

[6] Petrie EJ; King MA; Moore P; Lavallée DA. A first look at the effects of ionospheric signal bending on a globally processed GPS network. Journal of Geodesy, 84(8), 491-499, doi:10.1007/s00190-010-0386-2, 2010

[7] Petrie EJ; King MA; Moore P; Lavallée DA. Higher order ionospheric effects on the GPS reference frame and velocities, Journal of Geophysical Research – Solid Earth, 115, B03417, doi:10.1029/2009JB006677, 2010.

[8] Petrie EJ. Modelling higher-order ionospheric effects on global GPS solutions. PhD thesis, Newcastle University, 2010.

[9] Moore P; King MA. Satellite gravity gradiometry: Secular gravity field change over polar regions. Journal of Geodynamics, 49, 247–253, doi:10.1016/j.jog.2010.01.007, 2010.

[10] Dayoub N. The Gauss-Listing gravitational parameter, W0, and its time variation from analysis of sea levels and GRACE. PhD thesis, Newcastle University, 2010.

[11] Ragheb AE; Edwards SJ; Clarke PJ. Using filtered and semi-continuous high rate GPS for monitoring deformations. Journal of Surveying Engineering, 136(2), 72-79, doi:10.1061/(ASCE)SU.1943-5428.0000016, 2010.

[12] Knudsen P; Bingham RJ; Andersen OB; Marie-Hélène R. A global Mean Dynamic Topography and ocean circulation estimation using a preliminary GOCE gravity model. Journal of Geodesy, in press, 2011.

[13] Bingham RJ; Knudsen P; Andersen O; Pail R. An initial estimate of the North Atlantic steady-state geostrophic circulation from GOCE. Geophysical Research Letters, 38, L01606, doi:10.1029/2010GL045633, 2011.

[14] Bingham RJ. Nonlinear anisotropic diffusive filtering applied to the ocean's mean dynamic topography. Remote Sensing Letters, 1(4), 205-212, 2010.

[15] King MA; Makinson K; Gudmundsson GH. Nonlinear interaction between ocean tides and the Larsen C Ice Shelf system. Geophysical Research Letters, 38, L08501, doi:10.1029/2011GL046680, 2011.

[16] King MA; Murray T; Smith AM. Non-linear responses of Rutford Ice Stream to semi-diurnal and diurnal tidal forcing. Journal of Glaciology, 56(195), 167-176, doi:10.3189/002214310791190848, 2010.

[17] Brunt KM; King MA; Fricker HA; MacAyeal DR. Flow of the Ross Ice Shelf, Antarctica, is modulated by the ocean tide. Journal of Glaciology, 56(195), 157-161, 2010.

[18] King MA; Padman L; Nicholls K; Clarke PJ; Gudmundsson GH; Kulessa B; Shepherd A. Ocean tides in the Weddell Sea: new observations on the Filchner-Ronne and Larsen C ice shelves and model validation. Journal of Geophysical Research - Oceans, in press, doi:10.1029/2011JC006949, 2011.

[19] Lavallée DA; Moore P; Clarke PJ; Petrie EJ; van Dam T; King MA. J2: an evaluation of new estimates from GPS, GRACE and load models compared to SLR. Geophysical Research Letters, 37, L22403, doi:10.1029/2010GL045229, 2010.

[20] Clarke P. Between a rocky planet and a watery place: the problem of observing the solid Earth and hydrosphere together. IGCP 565 Workshop 3, University of Nevada, Reno, 2010.

[21] Williams SDP; Penna NT. Non-tidal ocean loading effects on geodetic GPS heights. Geophysical Research Letters, 38, L09314, doi:10.1029/2011GL046940, 2011.

[22] Spada G; Barletta VR; Klemann V; Riva REM; Martinec Z; Gasperini P; Lund B; Wolf D; Vermeersen LLA; King MA. A benchmark study for glacial isostatic adjustment codes. Geophysical Journal International, doi:10.1111/j.1365-246X.2011.04952.x, 2011.

[23] King MA; Altamimi Z; Boehm J; Bos M; Dach R; Elosegui P; Fund F; Hernández-Pajares M; Lavallée D; Mendes Cerveira PJ; Penna N; Riva REM; Steigenberger P; van Dam T; Vittuari L; Williams S; Willis P. Improved constraints to models of glacial isostatic adjustment: a review of the contribution of ground-based geodetic observations. Surveys in Geophysics, 31(5), 465-507, doi:10.1007/s10712-010-9100-4, 2010.

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The IESSG's research on using CGPS and absolute gravity at tide gauges has continued, in collaboration with the NERC National Oceanography Centre, Liverpool (formerly Proudman Oceanographic Laboratory), and involves the monitoring of changes in land and sea levels at ten tide gauges around the coast of Britain (Teferle et al. 2009; Woodworth et al. 2009). In our latest processing strategy, we considered data for the period from 1997 to the end of 2010 and we applied a combination of re-analysed satellite orbit and Earth orientation 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 based on a global network of approximately 170 IGS stations. The aims are to produce estimates of the changes in mean sea level (decoupled from changes in land level) over the last decade and into the future, for the planning of flood and coastal risk management in the UK, which will be made available as a BIGF derived product to facilitate collaborative research with non-GNSS specialists.

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 2008/9, the IESSG and NERC National Oceanography Centre, Liverpool (formerly Proudman Oceanographic Laboratory) carried out 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 also included, 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 initial processing strategy we applied a combination of re-analysed satellite orbit and Earth orientation 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 based on a semi-global network of approximately 50 IGS stations. In our latest processing we have extended the time series to the end of 2010 and moved to using a reference frame implementation based on a global network of approximately 170 IGS stations. The aims are 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 risk management in the UK. Following the success of the NERC grant, updated maps are to be made available as a BIGF derived product to facilitate collaborative research with non-GNSS specialists.

Bradley, S L, Milne, G A, Teferle, F N, Bingley, R M, and Orliac, E J. (2009). Glacial Isostatic Adjustment of the British Isles: New Constraints from GPS Measurements of Crustal Motion. Geophysical Journal International, Volume 178, Number 1, May 2009, ISSN 0956-540X pp 14-22, available online May 2009, DOI 10.1111/j.1365-246X.2008.04033.x.

P L Woodworth, F N Teferle, R M Bingley, I Shennan and S D P Williams. (2009). Trends in UK Mean Sea Level Revisited. Geophysical Journal International, Volume 176, Number 1, January 2009, pp 19-30, available online December 2008, DOI 10.1111/j.1365-246X.2008.03942.x.

Teferle, F N, Bingley, R M, Orliac, E J, Williams, S D P, Woodworth, P L, McLaughlin, D, Baker, T F, Shennan, I, Milne, G A, Bradley, S L, and Hansen, D N. (2009). Crustal Motions in Great Britain: Evidence from Continuous GPS, Absolute Gravity and Holocene Sea-Level Data. Geophysical Journal International, Volume 178, Number 1, May 2009, ISSN 0956-540X pp 23-46, available online May 2009, DOI 10.1111/j.1365-246X.2009.04185.x.