National Report of Great Britain 2010

M. Greaves, C. Fane & P. Cruddace[1];
R. Bingley D. Baker, N. Teferle, D. Hansen & M. Aquino [2];
G. Appleby & R. Sherwood[3];
M. A. King & P. J. Clarke[4];

1 Ordnance Survey activities

1.1 National GNSS network

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 have been built - one in the western islands of Scotland and 1 on the Isles of Scilly in the far south west of England and at the time of writing are awaiting the installation of communication lines.

The new zero order network of 12 permanent GNSS stations, mostly rock anchored and monumented to international geodetic standards, is now complete. This new network, called GeoNet, is a sub set of OS Net and the station hardware is the same with the exception that GeoNet antennas have individual robot calibrations.

In September / October 2009 a new EUREF densification campaign "EUREF IE/UK 2009" was observed. The campaign included GeoNet stations and similar stations across Great Britain, Ireland and Northern Ireland. The campaign has been submitted as the new realisation of ETRS89 in the region and is presented as a separate paper at the EUREF 2010 Symposium.

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. Current commercial partners offering RTK service in Great Britain are Leica (SmartNet), Topcon (TopNETPlus) and Trimble (VRSNow).

[1] Ordnance Survey, Romsey Road, Southampton, SO16 4GU, UK.
mark.greaves@ordnancesurvey.co.uk, colin.fane@ordnancesurvey.co.uk, paul.cruddace@ordnancesurvey.co.uk
[2] IESSG, University of Nottingham, Innovation Park, Triumph Road, Nottingham, NG7 2TU, UK.
Richard.Bingley@nottingham.ac.uk, David.Baker@nottingham.ac.uk, Norman.Teferle@nottingham.ac.uk, Dionne.Hansen@nottingham.ac.uk, Marcio.Aquino@nottingham.ac.uk
[3] NERC Space Geodesy Facility, Herstmonceux Castle, Hailsham, East Sussex, BN27 1RN, UK.
GAPP@nerc.ac.uk
[4] School of Civil Engineering & Geosciences, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK
m.a.king@ncl.ac.uk, peter.clarke@newcastle.ac.uk

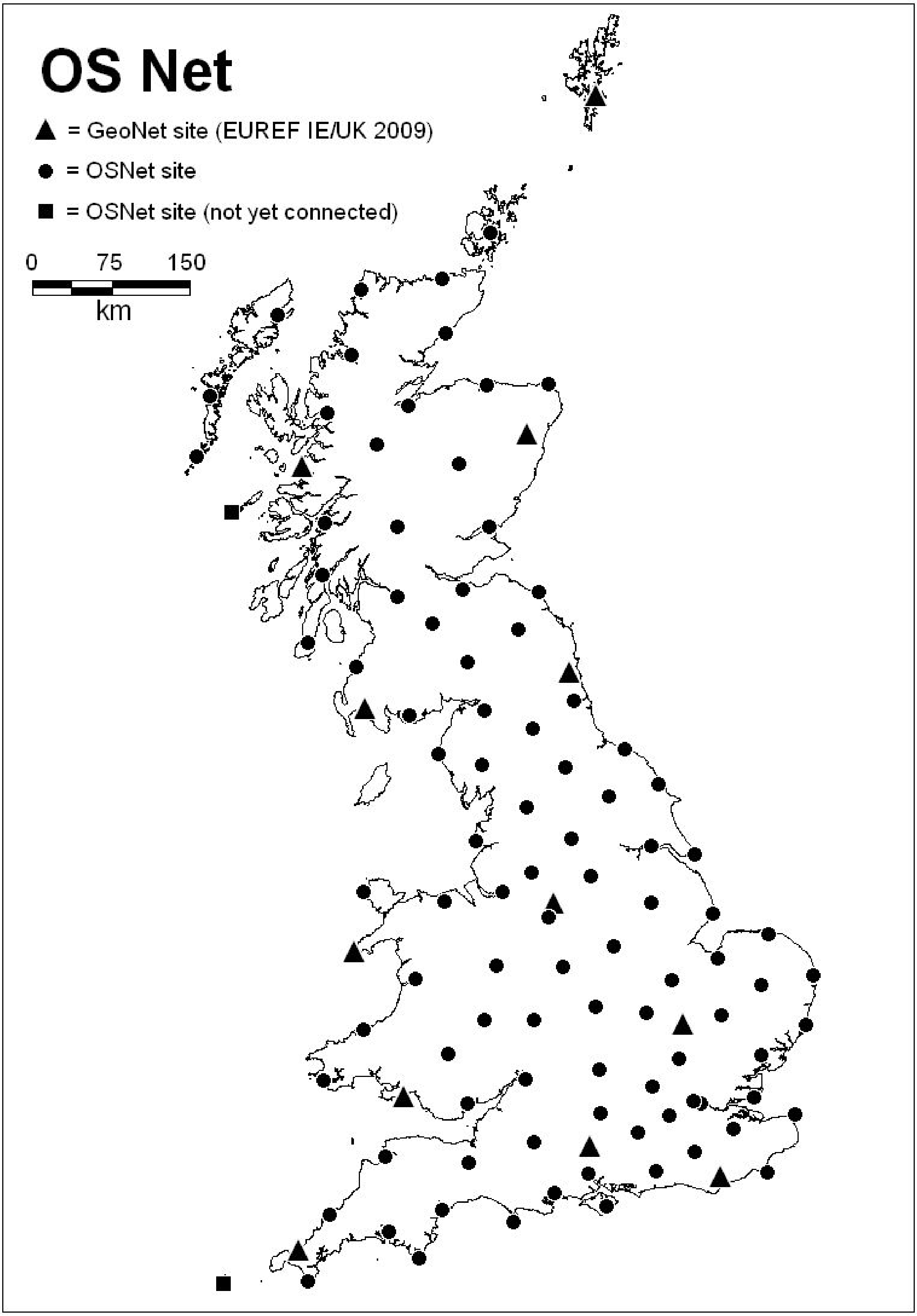

Figure 1. OS Net GNSS network.

1.2 EUREF related activities

1.2.1 EPN data submissions

Current EPN submissions from GB are hourly data from HERS, HERT and MORP plus 24 hour files from DARE, INVE, and NEWL. For a long time data integrity problems prevented us from switching DARE and INVE to hourly submissions. We now have some new hardware and intend to start hourly data submission later this year. Also we intend to submit all the GeoNet stations as EPN stations and submit hourly data from them too.

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.

1.2.2 Channel Tunnel levelling

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.

Attempts 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 have proved unsuccessful.

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. 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 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 is planned for release later this year now that the new realisation of ETRS89 in GB (EUREF IE/UK 2009) is complete.

2 BIGF British Isles GPS archive Facility

BIGF is operated from the IESSG, 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.

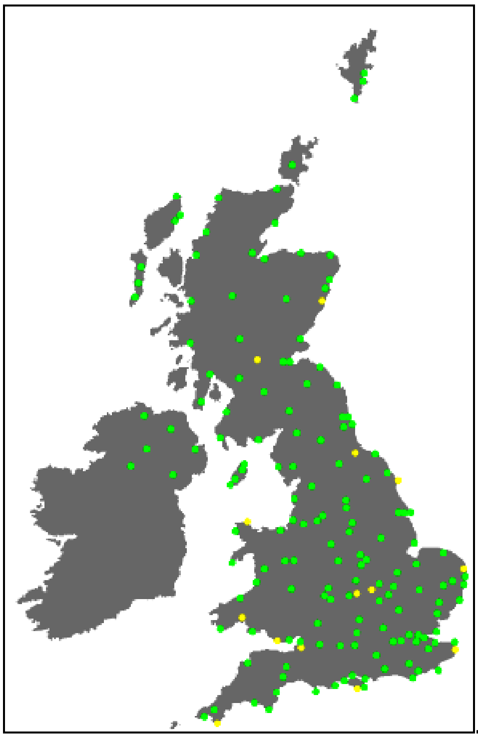

Figure 2. The current BIGF Network. Green = active, yellow = historical data available

BIGF is our long-term national archive for GNSS data, sourced from a continuously recording network of currently 155 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 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 inception in 1998 approaches 2.5m 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 downstream products derivative of the quality controlled 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 2009/10, there were 11 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 Proudman Oceanographic Laboratory.

- 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, again being carried out in collaboration with NERC 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 ‘towards unification of the vertical datum in the UK, the study of the fundamental geodetic parameter W0 from GRACE, satellite altimetry, GPS and tide gauges’.

- 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 Bath, for research into the application of the ionospheric tomographic inversion method MIDAS to radio astronomy.

- 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 2009/10 included, amongst many others:

- Archaeological landscape appraisal using geophysics.

- Boulby Geoscience Project.

- Detection of storm surge loading with GPS

- Integrated constructed wetlands.

- Soil sampling for mapping contaminated land.

- Towards centimetre level real-time kinematic GNSS single point precise positioning.

- Trophic interactions and ecosystem dynamics.

- Use of persistent scatterer interferometry for vertical land movement.

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 periodic vertical land movement.

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

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

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 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 contribute in real-time to BGS' British Isles seismic network. Frequent, on-site automated meteorological and water table depth observations augment the geodetic observations. In addition in the last year an in-house program of precise levelling for monitoring site stability has been implemented. The Facility is also 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 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 LIDAR capability, recently used for volcanic ash monitoring in collaboration with the UK Meteorological Office. The 10Hz laser is also being used regularly for one-way ranging support of the NASA Lunar Reconnaissance Orbiter [1]. 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.

The Facility is an ILRS Analysis Centre and computes daily, seven-day-arc, global station coordinates and Earth orientation solutions in support of the ILRS' contribution towards ITRF realisation and rapid Earth orientation results. A re-analysis of all 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, to be published by the IERS in mid-2010.

3.2 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 local GPS monitoring analysis using GAMIT to compute local baselines has been extended to include the Ordnance Survey GeoNet site HERO. In addition, global solutions also from GAMIT are now producing station heights of sufficient quality to allow direct comparison with those from SLR, gravimetry and our levelling results. An Active Hydrogen Maser frequency standard has recently been installed and is currently providing a stable time source for laser ranging activities. In the coming weeks a newly-acquired Septentrio timing receiver driven by the H-maser will be installed at the HERS site. This receiver has been calibrated by colleagues at the UK National Physical Laboratory. Combined with the H-maser this timing receiver represents a major upgrade to the HERS site, with the addition of dual GPS/GLONASS tracking as well as the benefits of the maser-derived time source.

3.3 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 suggest that the gravity environment is quite stable and that the effects of seasonal hydrological changes are less marked than may have been expected [2,3].

3.4 References

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4 University research work

4.1 Newcastle University

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

4.1.1 Global Navigation Satellite Systems

In 2008, 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, which has now been published [1]. 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.

More recent work [2] on kinematic positioning has focused on the use of GPS in support of airborne LIDAR measurements, and shown that advanced processing algorithms can achieve accuracies as good as 0.22 m (95th percentile) for baselines as long as ~1000 km, in contrast to commercial software which exceeds this for baselines as short as ~50 km.

The error budget due to unmodelled ocean tide loading (OTL) when using the GNSS base station network in the British Isles has been examined by [3], who make several recommendations as to possible averaging and mitigation strategies. Stability of monumentation has been addressed by [4], who concluded that this can induce time-correlated errors with significant effects at sub-daily and annual periods. Multipath errors can cause similar effects, and when coupled with changes in the GNSS constellation may induce velocity errors [5].

4.1.2 National and international networks and reference frames

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. Newcastle will host the 2010 IGS Workshop.

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 1994 have been generated by several analysis centres and combined back to year 2000 at Newcastle; work is in progress to extend this time series further back.

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 [6] 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.

4.1.3 Geophysical applications of GNSS

Work in these areas [7, 8, 9, 10, 11, 12] concentrates on the response of glaciers and ice sheets to seasonal and long-term climate change, and tidal forcing.

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4.2 University of Nottingham's IESSG

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

4.2.1 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 the NERC Proudman Oceanographic Laboratory and involves the monitoring of changes in land and sea levels at ten tide gauges around the coast of Britain. Through funding from the UK-Environment Agency, in 2009, we considered data for the period from 1997 to the end of 2009 and in our latest 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 global network of approximately 150 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 defences in the UK

4.2.2 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 2008/9, 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 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 2009 and moved to using a reference frame implementation based on a global network of approximately 150 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 defences in the UK. Following the success of the NERC grant, current and future, updated, maps are to be made available as a BIGF derivative product to facilitate collaborative research with non-GNSS specialists.

4.2.3 Mitigation of ionospheric scintillation effects

The IESSG continued with research into the effects of solar-induced ionospheric scintillation on GNSS signals and user applications. The next peak in activity is predicted to be mid-2013. The lead up to this event, its climax and decline are circumscribed by a 4-year EPSRC grant dedicated to GNSS scintillation detection, modelling and mitigation, in the UK and Europe. This is collaborative research, between the IESSG and the Universities of Bath and Newcastle.

We are also involved in CIGALA (Concept for Ionospheric Scintillation Mitigation for Professional GNSS in Latin America), which addresses a region particularly sensitive to the effect of ionospheric scintillation. This 6-partner project is led by Septentrio NV and co-funded by the GNSS Supervisory Authority. A major aim is to improve the technique described in Aquino et al (2009), to develop ionospheric scintillation mitigation countermeasures, which will be implemented in Septentrio's GNSS receivers.

Collaborative work funded by Royal Society International Joint Projects grants continued with UNESP (Brazil), and INGV (Italy). This was focused on different approaches to the improvement of the least squares stochastic model in GNSS positioning (Silva et al, 2010), and on the climatology of scintillations to support scintillation model development (Spogli et al, 2010).

4.2.4 References

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