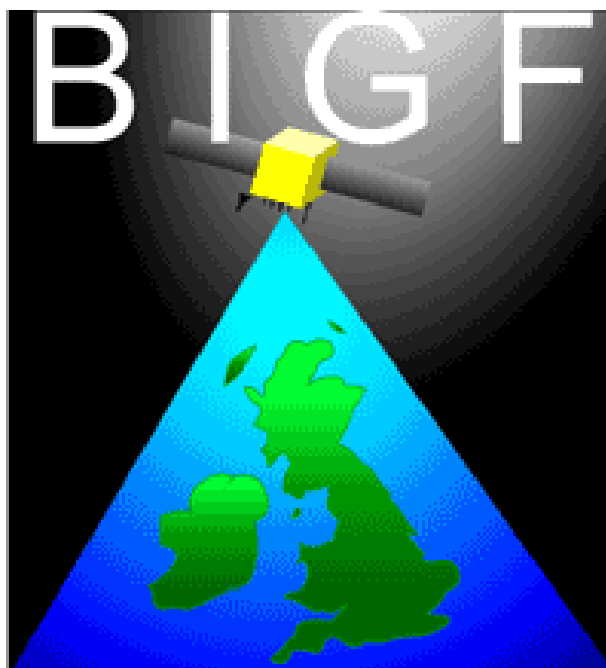


The British Isles continuous GNSS Facility (BIGF) and BGS

MHR Programme

Open Report OR/22/002



BRITISH GEOLOGICAL SURVEY

MHR PROGRAMME

OPEN REPORT OR/22/002

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The British Isles continuous GNSS Facility (BIGF) and BGS

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BRITISH GEOLOGICAL SURVEY

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The London Information Office also maintains a reference collection of BGS publications, including maps, for consultation.

We publish an annual catalogue of our maps and other publications; this catalogue is available online or from any of the BGS shops.

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Foreword

This report is the published product of a study by the British Geological Survey (**BGS**) and concerns the British Isles continuous GNSS Facility (**BIGF**) and the hand-over of the management and running of the facility from the University of Nottingham (**UoN**) to the BGS from April 2023.

The report firstly introduces BIGF and goes on to explain what it is and what it does. It then discusses what expertise the current (UoN) staff have and what expertise the staff at BGS will therefore need to have. It then goes on to discuss the plans that need to be put in place at the BGS in order to take on the facility, before finally setting out the steps in this process.

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Mr Luke Bateson – Head of Remote Sensing (BGS)

Dr David Baker – BIGF Manager (UoN)

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1 Introduction

The British Isles continuous GNSS Facility (BIGF) supports research scientists with archived RINEX format GNSS (Global Navigation Satellite System) data, metadata and derivative products.

The archive comprises RINEX data from GPS and GLONASS satellites, from a high-density network of around 160 continuously recording stations, sited throughout mainland Britain, Northern Ireland and Ireland. The data are provided to BIGF free-of-charge by a number of collaborators. We automatically receive, quality control and archive these data, which we then process into derivative products. Galileo data will be archived as they become available.

After quality control and archival, these data can be supplied, on request and free-of-charge, for approved usage. They have utility in relative positioning accuracy improvement, as a source for mining environmental variables, and in the generation of derivative products.

2 What is BIGF

2.1 WHAT IS BIG-F

BIGF provides these services:

- **Data centralisation and archival**

BIGF receives RINEX format GNSS observation data directly from a large number of continuously recording GNSS stations, operated by collaborating organisations. These data are automatically quality controlled on receipt, then archived along with IGS (International GNSS Service) format station log files.

- **Data dissemination**

All quality assured GNSS data and associated metadata are available, on request, subject to approval. Delivery is via the web or ftp, at 30-second (unrestricted access), and 1Hz (restricted access) data rates. Final broadcast ephemerides are also supplied, as provided by the IGS.

- **Scientific product generation**

BIGF processes its archived GNSS data along with data from the global network of IGS stations to generate derivative products. Current products are related to 3D land movement, and signal delays owing to tropospheric effects.

- **Scientific product dissemination**

Products are available to scientific users, on request, subject to approval. Not only do we welcome applications to use these products, but also the collaborative development of alternative products.

- **Guidance and advice**

BIGF can provide guidance and advice on all aspects of GNSS data and product usage.

Data are sourced from a network of around 160 continuously recording GNSS (CGNSS) stations, sited throughout the British Isles (164 currently active plus 163 ceased)

Such data have always been, and continue to be, provided to BIGF free-of-charge by a number of collaborators that own, operate and manage the CGNSS stations in the British Isles (at an approx. cost to them of £4m over a 5 year period), but who do not archive their data beyond 45 days of age.

These collaborators currently include:

- Three National Ordnance Surveys (Ordnance Survey of Great Britain (OSGB) Ordnance Survey Ireland (OSi) and Ordnance Survey of Northern Ireland (OSNI))
- University of Nottingham
- Environment Agency Thames region
- Herstmonceux Observatory
- Met Office
- Newcastle University

- University of Hertfordshire
Giving a total number of current stations of 134 – 164

2.2 WHERE HOSTED

This unique Facility in the UK, is hosted at the Nottingham Geospatial Institute - a centre for related postgraduate teaching and research, at The University of Nottingham.

2.3 FUNDED BY (BUDGET)

BIGF was funded by the Natural Environment Research Council (NERC) from 2002 to 2018, and is now funded by United Kingdom Research and Innovation (UKRI) since 2018.

2.4 STAFF

- Dr Richard Bingley – Head of Facility
- Dr David Baker – Manager

2.5 HISTORY

- 1998 – 2002 – Feasibility funding through NERC EOSI
- 2002 – 2004 – Initial funding through NERC Services & Facilities (S&F). British Isles GPS archive Facility, i.e. Level 0 – GPS RINEX observation data and related data only
- 2004 – 2009 – Renewed funding through NERC S&F. University of Nottingham parallel R&D on long term trend station coordinates (Defra and the Environment Agency) and near real time tropospheric parameters (Met Office)
- 2009 – 2014 – Renewed funding through NERC S&F. British Isles continuous GNSS Facility, i.e. Level 0 – GNSS RINEX observation data and related data plus creation of Level 1, 2 and 3 – GNSS derived products
- 2014 – 2018 – Extended funding through NERC S&F via BGS
- 2018 – 2023 – New funding through UKRI via BGS

2.6 USERS

BIGF supplies continuous data sets, directly or indirectly, to many regional and global scale projects and organisations:

- E-GVAP (EUMETNET EIG GNSS water vapour programme) for atmospheric water vapour research.
- EPN (European Permanent Network) for wide ranging applications in regional earth science.
- EPOS (European Plate Observing System) a research infrastructure for solid earth science.
- EuroSea, a Horizon 2020 project, for proof of concept use of GPS reflection measurements for tide gauge levelling.
- IGS (International GNSS Service) for wide ranging applications in global earth science.
- Met Office for near-real-time integrated water vapour estimation as input to weather forecasting, and in space weather forecasting.
- NICT (National Institute of Information and Communications Technology, Japan) for the construction of 2D maps of total electron content over Europe.
- Royal Observatory of Belgium for densification of European permanent GNSS network for ionospheric studies.
- SONEL (Système d'Observation du Niveau des Eaux Littorales) for global absolute sea level trends.

Here are recent examples of other BIGF-supported research projects:

- Assessment of the calcareous fen habitat of Crymlyn Bog, and many other SACs (Special Areas of Conservation).
- Cirrus climatology from ground-based remote sensing.
- Densification of the European Permanent GNSS Network for ionospheric studies.

- European scale velocity field from permanent GNSS data.
- MarRINAV (Maritime Resilience and Integrity of Navigation) to consider the navigation and integrity provision of EGNOS (existing and incoming v2 and v3) in comparison with DGPS beacons deployed by GLA.
- Metrology for Earth Observation and Climate (MetEOC).
- North Atlantic Waveguide and Downstream Impact Experiment (NAWDEX).
- PROtection of European Cultural HERitage from GeO-hazards (PROTHEGO) - Derwent Valley site.
- The creation of a map of current vertical land movements in the UK, based on absolute gravity and CGPS.
- The application of drones to detect and monitor invasive plant species.

3 What does BIGF do

3.1 HIGH LEVEL DESCRIPTION OF THE PROCESS:

BIGF provides a unique source of quality assured RINEX format GNSS data and derivative products for the British Isles. There is also the opportunity to design and create new products, to facilitate downstream research, where for example scientists are unfamiliar with GNSS data or do not have the necessary data processing capability. Data sets are divided into 4 levels - from raw data (level 0) to products (levels 1-3), described below:

- **Description LEVEL 0 – GNSS RINEX observation and related data**
 - RINEX observation data at a 30-second data rate, sample.
 - RINEX observation metadata, based on 30-second data, as monthly updated text time series, sample, and as graphic time series, samples.
 - RINEX observation data at a 1Hz data rate.
 - RINEX navigation data (broadcast ephemeris), sample.
 - RINEX observation data file header record change catalogue, with explanatory notes at the end of file.
 - Station log files.
- **Description LEVEL 1 – Raw product**
 - http://www.bigf.ac.uk/data_access.html - level%201 Long term trend station coordinates (raw estimates). A set of daily, network-specific SINEX files containing station-specific coordinate estimates from each daily processing solution, as text, sample.
 - Long term trend tropospheric parameters (raw estimates). A set of daily, network-specific SINEX TRO files containing station-specific 1 hourly troposphere zenith total delay estimates from each daily processing solution, as text, sample.
- **Description LEVEL 2 – Product time series**
 - Long term trend station coordinates (QA'd time series). A set of station-specific files containing station-specific daily coordinate estimates and time, based on the estimates in the daily SINEX files, as text: Cartesian X,Y,Z sample; Cartesian dX,dY,dZ sample; or North,East,Up (dN,dE,dU) sample; and as graphics: dN,dE,dU sample.
- **Description LEVEL 3 – Product trend**
 - Long term trend station velocities. One network-specific file containing station-specific velocities and their uncertainties based on a time series analysis of the coordinates in the daily SINEX files, as text, sample, and as graphics (e.g. a map of vertical motions

showing spatial variations, with some consideration of the station's geological setting, sample).

3.2 FLOW CHART:

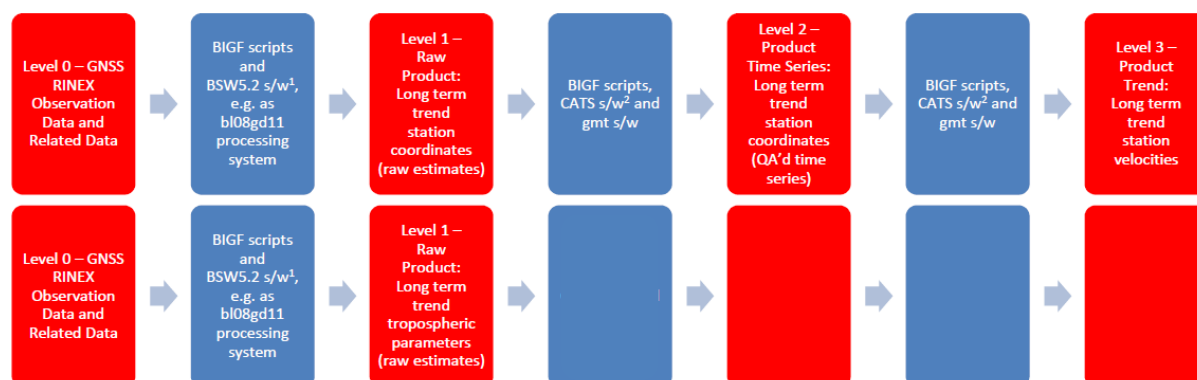


Figure 1 – Flow Chart of BIGF Processes

- **Access LEVEL 0 - GNSS RINEX observation and related data**
 - Accessibility (30s data, including broadcast ephemeris): UNRESTRICTED, with a minimum data age of 30 days
 - Accessibility (1Hz data): RESTRICTED, to academic users and collaborators only, with a minimum data age of 45 days
 - Apply, for 30s and 1Hz data using the request data form
 - Lead time: Same day approval is normal, although for reasons of workload or complexity/size of a request, this may take up to 5 working days. On approval, you will receive emailed access instructions
 - Access mode: For small volumes, by emailed link to a zipfile; for large volumes, via named ftp account
- **Access LEVEL 1 - Raw product; LEVEL 2 - Product time series; LEVEL 3 – Product Trend**
 - Accessibility: RESTRICTED, to academic users and collaborators only
 - Apply using the request data form
 - Lead time: Up to 5 working days. On approval, you will receive emailed access instructions
 - Access mode: For small volumes, by emailed link to a zipfile; for large volumes, via named ftp account

4 How do they do it

4.1 WHAT ARE THE (HIGH-LEVEL) PROCESSES?

Richard Bingley is responsible for the incoming RINEX 2/3 data files (including checks on the RINEX headers) and IGS-style log files on pezbifdata1 and pezbifdata2, the maintenance of the station information database on bigfarch1 (updated manually when new stations are introduced), and the maintenance of the archive of data and metadata on bigfarch1 and bigfarch3.

David Baker is responsible for the provision of files and information for the maintenance of the BIGF website and for servicing outgoing data requests using bigfarch1 and pezbifdata2.

4.2 HARDWARE OWNED

- pezbifdata1 – a Linux workstation using Ubuntu 18.04.5 LTS that was purchased in 2013/14.
- pezbifdata2 – a Linux workstation using Ubuntu 18.04.5 LTS that was purchased in 2013/14 (which is accessible through the University firewall).
- bigfarch1 - a Linux workstation using CentOS 5.6 that was purchased in 2007/08.
- bigfarch3 - a Linux workstation using CentOS 5.6 that was purchased in 2007/08.

4.3 SOFTWARE OWNED

- Linux shell scripts, Perl scripts and mySQL databases that were developed in-house;
- RINEX GNSS Data Conversion and Manipulation Toolbox (GFZRNXTtoolbox) that is available FOC from <https://dataservices.gfz-potsdam.de/panmetaworks/showshort.php?id=escidoc:1577894> and widely used within the IGS community;
- Software for compression/restoration of RINEX observation files (RNXCMP) that is available FOC from <https://terras.gsi.go.jp/ja/crx2rnx.html> and widely used within the IGS community;
- Translation, Editing and Quality Check software (TEQC) that is available FOC from <https://www.unavco.org/software/data-processing/teqc/teqc.html> and widely used within the IGS community - noting that this is now end-of-life following the 2019-02-25 final release, but we continue to use it for its Quality Check aspect only.

4.4 SOFTWARE TOOLS (E.G. XXX PROCESS DOES YY TO CREATE ZZ)

The current BIGF data flow at the University of Nottingham is based on the use of multiple in-house developed Linux shell scripts (mostly run on a cron), some in-house developed Perl scripts, and some mySQL databases, along with the GFZRNXTtoolbox, RNXCMP and TEQC softwares, that facilitate:

- datman5@pezbifdata2 receiving the daily 30 second RINEX 2 data files that are sent from Newcastle University, NOCL and NSGF once per day.
- datman5@pezbifdata2 receiving the hourly 1Hz RINEX 2 data files that are sent from the CGNSS at the Tide Gauges of Newlyn, Aberdeen, Stornoway and Lerwick every hour.
- datman1@pezbifdata1 downloading the hourly 1Hz RINEX 3 data files from OSGB every hour, then creating hourly 1Hz RINEX 2 data files, hourly 30s RINEX 3 data files and hourly 30s RINEX 2 data files every hour, and then creating daily 30s RINEX 3 data files and daily 30s RINEX 2 data files once per day.
- datman2@pezbifdata1 copying the daily 30 second RINEX 2 data files that are sent from Newcastle University, NOCL and NSGF from pezbifdata2 once per day.
- datman2@pezbifdata1 copying the hourly 1Hz RINEX 2 data files that are sent from the CGNSS at the Tide Gauges of Newlyn, Aberdeen, Stornoway and Lerwick from pezbifdata2 every hour, then creating hourly 30s RINEX 2 data files every hour, and then creating daily 30s RINEX 2 data files once per day.
- datman2@pezbifdata1 downloading hourly 05s RINEX 2 data files from OSI and OSNI once per week (as 28x6 hourly zip files of all stations manually downloaded from their website once per week), then creating hourly 30s RINEX 2 data files once per week, and then creating daily 30s RINEX 2 data files once per week.
- datman@bigfarch1 (and datman@bigfarch3 as a mirror) copying the data files from datman1@pezbifdata1 and datman2@pezbifdata2 once per day to update the archive of data, and carrying out quality control on the data once per day to update the archive of metadata and provide files for the BIGF website.
- reqman@bigfarch1 packaging up zip files, in response to requests from ad-hoc users, which are then made available to those ad-hoc users (who are not allowed access through the University firewall) via DropBox.
- datman5@pezbifdata2 making the archive of daily 30s RINEX 2 data files available to continuous users (who are allowed access through the University firewall).

5 What expertise do the staff have

5.1 GNSS SKILLS

Richard Bingley is a Professor of Geodetic Surveying at the University of Nottingham, and has been responsible for BIGF since its inception in 2002. For BIGF the GNSS skills that are called upon are his knowledge of satellite-based positioning, CGNSS station operation, RINEX 2/3 data files and IGS-style log files, in order to maintain the incoming data flow and ensure that the archive of data and metadata is as complete and correct as possible.

5.2 PROGRAMMING SKILLS

Richard Bingley has programming skills related to the development of Linux shell scripts and Perl scripts, and the use of mySQL databases, and is responsible for writing and maintaining those that are used in BIGF.

David Baker has programming skills related to website development and maintenance, and the use of databases, and is responsible for the development of the original BIGF website, providing files and information for the maintenance of the current BIGF website, and creating and maintaining an MS-Access database related to user requests.

5.3 DELIVERY SKILLS

David Baker is the BIGF Manager, and has been since 2004. For BIGF he has used delivery skills (including e-mail, ftp and DropBox) to facilitate the delivery of data and products to about 1,400 scientific projects over an 18-year period.

6 Initial plan to move this into BGS

6.1 TIME SCALES

If funding is continued to provide the BIGF service, the fully working system should be in place at the BGS by April 2023.

6.2 EXPERTISE NEEDED

BGS will require certain expertise and staff who are able to continue the work of the existing BIGF staff, currently employed by UoN. These will be a BIGF Manager, BIGF Processer, BIGF Deliverer.

- **Is this already in house?**

- BGS currently has staff who are capable of creating the database and storage facility, but possibly not the processing side of the facility.
- BGS has staff with Linux capabilities, Web Delivery skills and Database capabilities.
- BGS also has Security knowledge for passing the data 'In' and 'Out' of our Firewall and web systems.

- **Do we need to recruit?**

- BGS will need to recruit a member of staff with the capacity to understand and process GNSS/RINEX data using Linux, and be able to programme data in order to create the existing outputs, plus potential new ones.

6.3 HARDWARE AND SOFTWARE NEEDED

- High specification Linux PC with large storage size (~50 TB) and good processing capability (~256GB RAM)
- Linux shell scripts, UoN in-house developed Perl scripts, and some mySQL databases, along with the GFZRNStoolbox, RNXCMP and TEQC softwares,

6.4 WHERE WILL IT BE RUN FROM?

- This needs to be run on a networked server in Keyworth

7 Next steps

7.1 RESEARCH IDEAS

- Long-term UK ground motion
- Others?

7.2 IMPROVED SERVICES

- Automated distribution service
- Web delivery
- Other?

7.3 QUESTIONS

- Who are the collaborators?
 - People who contribute data to the network
 - Others
- How much time each year does it take to deal with these, and to maintain the relationship?

