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# Report on the Data Base of the International Geodynamics and Earth Tide Service (IGETS)

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# Abstract

***The International Geodynamics and Earth Tide Service (IGETS) was established in 2015 by the International Association of Geodesy (IAG). IGETS continues the activities of the Global Geodynamics Project (GGP, 1997-2015) to provide support to geodetic and geophysical research activities using superconducting gravimeter data within the context of an international network. The primary objective of IGETS is to provide a service to monitor temporal variations of the Earth's gravity field through long-term records from ground gravimeters, tiltmeters, strainmeters and other geodynamic sensors. IGETS also continues the activities of the International Center for Earth Tides, in particular, in collecting, archiving and distributing Earth tide records from long series of the various geodynamic sensors. This report is a compilation of data descriptions originating to a large part from GGP but including updates and extensions for IGETS.***


# 1. Introduction

IGETS is the International Geodynamics and Earth Tide Service of the International Association of Geodesy (IAG) and was established in July 2015. The main objective of IGETS is to monitor temporal variations of the Earth's gravity field through long-term records from ground gravimeters, tiltmeters, strainmeters and other geodynamic sensors. IGETS continues the activities of the Global Geodynamics Project (GGP) to provide support to geodetic and geophysical research activities using superconducting gravimeter (SG) data within the context of an international network.

GGP was a long-term initiative in order to establish a world-wide network of superconducting gravimeter (SG) stations by the voluntary consolidation of unique observatories using such devices. The initial 6-year-period of the project ran from July 1997 to July 2003 with three following 4-year-periods until 2015. The high-accuracy gravity data were used for study of global motions of the entire Earth as well as for the estimation of local gravity effects caused by atmospheric pressure and groundwater. By the start of high accurate satellite gravity missions CHAMP and GRACE, the SG data got a new impact for the validation and calibration of these missions. An introduction to the scientific objectives of GGP can be found, e.g., in Crossley et al. (1999), while the status report by Crossley and Hinderer (1995) provides more technical and administrative information. A review of the GGP network and scientific challenges is provided by Crossley and Hinderer (2009). Thorough information including recent activities, software and tools can be found on the GGP website (http://www.eas.slu.edu/GGP/ggphome.html), which is continued by the IGETS website (http://igets.u-strasbg.fr/).

The IGETS data base of worldwide high precision SG records is hosted by GFZ. Available products are

- Raw gravity and local atmospheric pressure records sampled at 1 or 2 seconds and the same records decimated at 1-minute samples (Level 1 products). These data sets are provided by the individual station operators of the IGETS network.



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- Gravity and atmospheric pressure data corrected for instrumental perturbations and ready for tidal analysis (Level 2 products). These products are derived from Level 1 products, and are computed by one or several analysis centers, e.g., by the University of French Polynesia, which is in charge of producing corrected gravity time series, or by the station operators themselves.
- Gravity residuals after particular geophysical corrections (including tidal and atmospheric effects as well as possibly non-tidal loading effects). These products are derived from Level 1 and 2 products and are computed by one or several analysis centers, e.g., by EOST, which produces the final gravity residuals with the help of loading models by BKG and EOST (Level 3 products).

In addition, IGETS continues the activities of the International Center for Earth Tides (ICET), in particular, in collecting, archiving and distributing Earth tide records ground gravimeters, tiltmeters, strainmeters and other geodynamic sensors. This report compiles the information on the GGP network provided by the GGP website and the former website of ISDC (Information Systems and Data Center) hosted by GFZ and gives some updates and extensions regarding the stations and sensors as well as additional data products involved in the IGETS network. The IGETS data base was launched in July 2016. However, up to this date, solely SG data from the GGP network are included in the data base. Therefore, this report focuses on the description of SG data.

# 2. Stations and Sensors

Present (active) and past (passive) SG stations are depicted in figure 1 along with the data sets provided in the IGETS data base and available at the launch in July 2016 in table 1. The largest number of stations delivered data at the start of the initial period of GGP in 1997. Since 2009, a number of stations have stopped contributing to the GGP network. Moreover, some present stations, particularly in Asia, unfortunately have not provided any data to the international network yet. The data sets of the sensors at stations operated by EOST can be accessed via http://cdg.u-strasbg.fr/PortailEOST/Gravi/gravimetrie-data.html, i.e. Strasbourg, Djougou and Rustrel. The IGETS data base was initially expanded to time series of a GWR transportable superconducting gravimeter iGrav and a LaCoste & Romberg spring gravimeter data at station Borowa Gora (BG), Poland, as the first non-former GGP station.

At this point, we would like to ask the operators of present SG stations to start, continue or resume with providing data to the IGETS data base. As IGETS is seeking for providing all kinds of long-term geodynamic time series, operators of other ground gravimeters, tiltmeters and strainmeters are cordially invited to provide their data sets to the IGETS data base as well. In return, the operators will benefit from the long-term storage of their data, their increased visibility to and usage by a large number of IGETS users as well as a proper data citation by assigning digital object identifiers (DOI) to the individual data sets by the research repository of GFZ Data Services (see chapter 10).

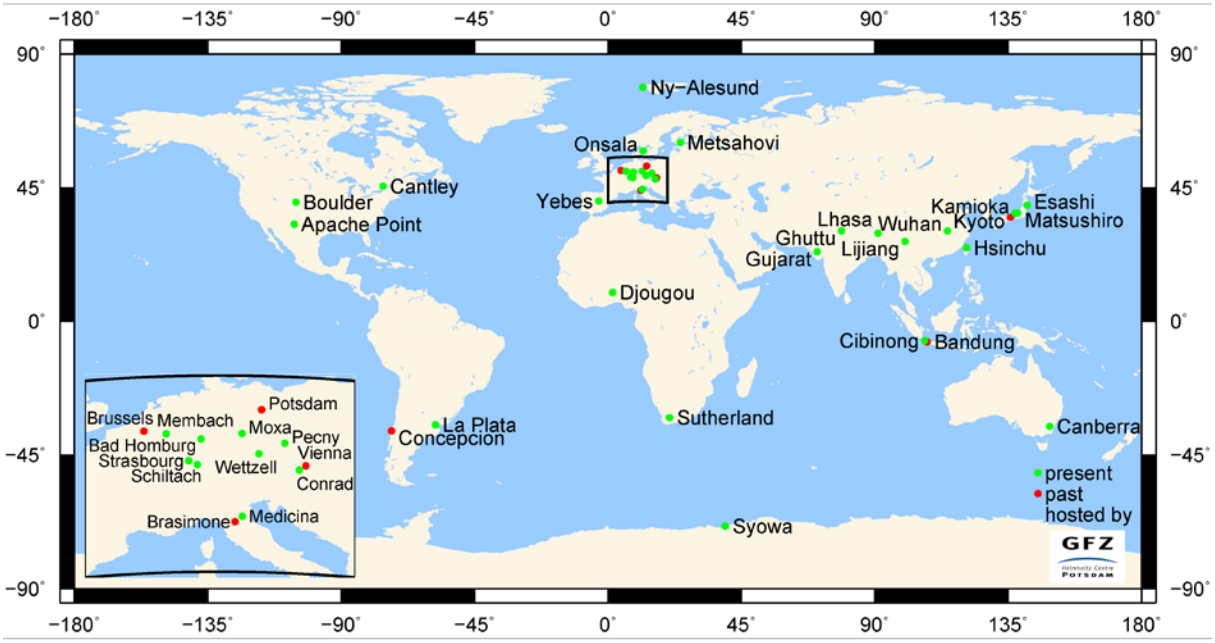


*Figure 1: Present (green) and past (red) SG stations*

# 3. Instrument Properties and Data Processing

The primary objective of IGETS is to provide a service to monitor temporal variations of the Earth's gravity field through long-term records of various geodynamic sensors. However, the data sets from GGP come exclusively from SGs by GWR Instruments as the only commercial producer. Thorough information on SGs is provided, e.g., by Hinderer et al. (2007) or Neumeyer (2010). A description of The Observatory Superconducting Gravimeter (OSG) by GWR Instruments is provided in http://catalog.gwrinstruments.com/Asset/OSG_Dual_Brochure_Rev_1.0.pdf. The SGs involved in GGP are either single or dual sensor instruments (Richter and Warburton 1998, Kroner et al. 2005). A list of published papers utilizing SGs from GWR can be found at http://www.gwrinstruments.com/published-papers.html.

The performance of a SG gravity sensor is characterized by the qualitative parameters drift, stability and precision and can be quantified as follows from Hinderer et al. (2007). Usually, the drift is characterized by a small initial exponential term (typically a few months) followed by a linear behaviour of a few µGal/a (1 µGal = 10nm/s²). For a discussion concerning long-term records exceeding 10 years see Van Camp and Francis (2007). Calibration values are typically determined by parallel observations with an absolute gravimeter over several days at regular intervals. The relative stability of the calibration is estimated to be at the level of $10^{-3}$ to $10^{-4}$. The nominal precision or sensitivity of a SG gravity sensor is estimated to be 1 nGal and better (1 nGal = 0.01 nm/s²). Barometric pressure sensors delivered with the SG have a resolution of better than 0.1 Pa with a total accuracy of better than 0.1 hPa. The data sampling time is referenced to UTC through a GPS or DCF receiver with an accuracy of a few milliseconds of UTC (OSG Brochure by GWR Instruments, see above).

*Table 1: SG stations and sensors (2 digit station code + 3 digit SG serial number) with available data sets in black years in the IGETS data base at the launch in July 2016*

| Station | Sensor | 1989 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 2000 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Apache Point | ap046 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bad Homburg | bh030-1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bad Homburg | bh030-2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bad Homburg | bh044 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bandung | ba009 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Boulder | bo024 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Brasimone | br015 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Brussels | be003 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Canberra | cb031 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cantley | ca012 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cibinong | ci022 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Concepcion | tc038 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Conrad | co025 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Djougou | dj060 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Esashi | es007 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ghuttu | wg051 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Gujarat | gu055-1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Gujarat | gu055-2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hsinchu | hs048 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Kamioka | ka016 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Kyoto | ky009 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| La Plata | lp038 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lhasa | lh057 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lijiang | li066 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Matsushiro | ma011 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Medicina | mc023 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Membach | mb021 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Metsahovi | me020 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Metsahovi | me073-1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Metsahovi | me073-2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Moxa | mo034-1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Moxa | mo034-2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ny-Alesund | ny039 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Onsala | os054 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pecny | pe050 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Potsdam | po018 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Schiltach | bf056-1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Schiltach | bf056-2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Strasbourg | st026 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sutherland | su037-1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sutherland | su037-2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sutherland | su052 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Syowa | sy016 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vienna | vi025 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Wettzell | we029-1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Wettzell | we029-2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Wettzell | we030-1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Wettzell | we030-2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Wettzell | we103 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Wuhan | wu004 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Yebes | ys064 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Raw gravity and atmospheric pressure data, usually with a time sampling of 1 s, are the essential results of the observation process. In general, these are raw data as recorded by the SGs without pre-processing. The provision of raw data on the 1 s basis is one of the major benefits of IGETS compared to GGP. The 1 s raw data sets are decimated to 1 min. In this context, the term raw data by definition still applies to 1 min data after filling very short gaps or spikes shorter than 10 seconds by linear interpolation between good data points on the raw data (full data). These are the essential data sets of Level 1 provided by the station operators.

The Level 2 data can be characterized by a certain processing, i.e. the elimination of gaps, spikes, steps and earthquakes. These data sets are ready for tidal analyses. For the processing, usually the software packages ETERNA (Wenzel 1996) or TSOFT (Van Camp and Vauterin 2005) are used. Corresponding download links can be found on the IGETS website (http://igets.u-strasbg.fr/soft_and_tool.php). The provision of these data sets is either done by the station operators themselves or by the University of French Polynesia or by both. For a study on the influence of different processing methods see Hinderer et al. (2002).

Residual gravity data of Level 3 are the results of reducing Level 2 gravity data for tidal and non-tidal gravity variations. Tidal effects comprise the summed effect of solid Earth tides, ocean tides, polar motion, angular velocity and atmosphere. Respective tidal parameters for the IGETS stations are obtained from harmonic analysis of the records. In addition, non-tidal loading effects due to atmospheric, oceanic and hydrological mass-redistributions are reduced according to the products provided by the EOST Loading Service (http://loading.u-strasbg.fr/) and the Atmospheric Attraction Computation Service ATMACS by BKG (http://atmacs.bkg.bund.de/). In order to separate various pre-processing strategies inherent in the data sets, the GGP community introduced repair codes, which are part of the file names and adopted by IGETS; see chapter 8.

# 4. Data Availability and Access

The IGETS members decided in July 2015 at the IUGG General Assembly in Prague to setup a new IGETS data base according to the proposal by GFZ. The new user access for browsing and downloading the IGETS data is realized by a FTP server, which can be accessed by

**ftp://igetsftp.gfz-potsdam.de.**

The access to the FTP server requires a username and a password, obtained by a registration procedure presupposing a valid e-mail address. The registration form can be found on the IGETS data base website (http://igets.gfz-potsdam.de). The applicant gets a first e-mail to validate the registration process, followed by a second one containing the specific username and a FTP-URL. The IGETS data base website provides some fundamental information on the data products including an interactive map with station markers, names and codes as well as links to the landing pages of the data sets (if any exists). The website provides also this report,

gives access to the registration as new user and the login to the data base for existing users. It should be noted that every former GGP user has to register again due to technical reasons.

# 5. Instructions for Data Producers

The login details (account + password) of all former GGP data producers were transferred from the old ISDC to the new IGETS FTP server at GFZ in order to ensure that the data upload for former GGP data producers has not changed. Each producer gets a new specific directory for the upload of the data sets. The data base operators at GFZ transfer the uploaded data sets into the corresponding directories of the IGETS FTP server. The producers are obliged to follow the new IGETS file name convention (see chapter 7). However, the old GGP file names will also be accepted within a period of transition.

We invite all operators of present SGs and other geodynamic sensors such as ground gravimeters, tiltmeters, strainmeters and other geodynamic sensors to contribute to the IGETS data base as data producer. In case of interest please send initially an e-mail to

**igets-support@gfz-potsdam.de**

including an introductory description of the data set and the station. The admissions procedure will then be individually launched by the representative of the IGETS data base.

# 6. Directory Structure of the IGETS FTP Server

The directory structure for all SG products on the FTP server ftp://igetsftp.gfz-potsdam.de for all SG data products is

***/<station>/<sensor>/<level>/<year>/***

with the general structure

<*station*> full name of the station with two words separated by a hyphen, e.g., *Sutherland*, *Wettzell, Bad-Homburg*

<*sensor*> 2 digit station code according to GGP convention (see table 1) and 3 digit instrument serial number (for single sphere SGs) and serial number-sensor (for dual sphere SGs), respectively, e.g., *su052*, *su037-1*, *su037-2*

<*level*> indication of the three specified levels, i.e. *Level1*, *Level2* and *Level3*

<*year*> 4 digit indication of the year, e.g., *2016*.

Specific examples are

*/Sutherland/su037-1/Level1/2016/*

for the directory containing the raw data from 2016 observed by the lower sensor of dual SG 037 at Sutherland and

*/Wettzell/we030-2/Level2/2015/*

for the corrected data from 2015 observed by the upper sensor of dual SG 030 at Wettzell. The directory structure is exemplarily shown for Level1 data of SG 052 at Sutherland in figure 2.

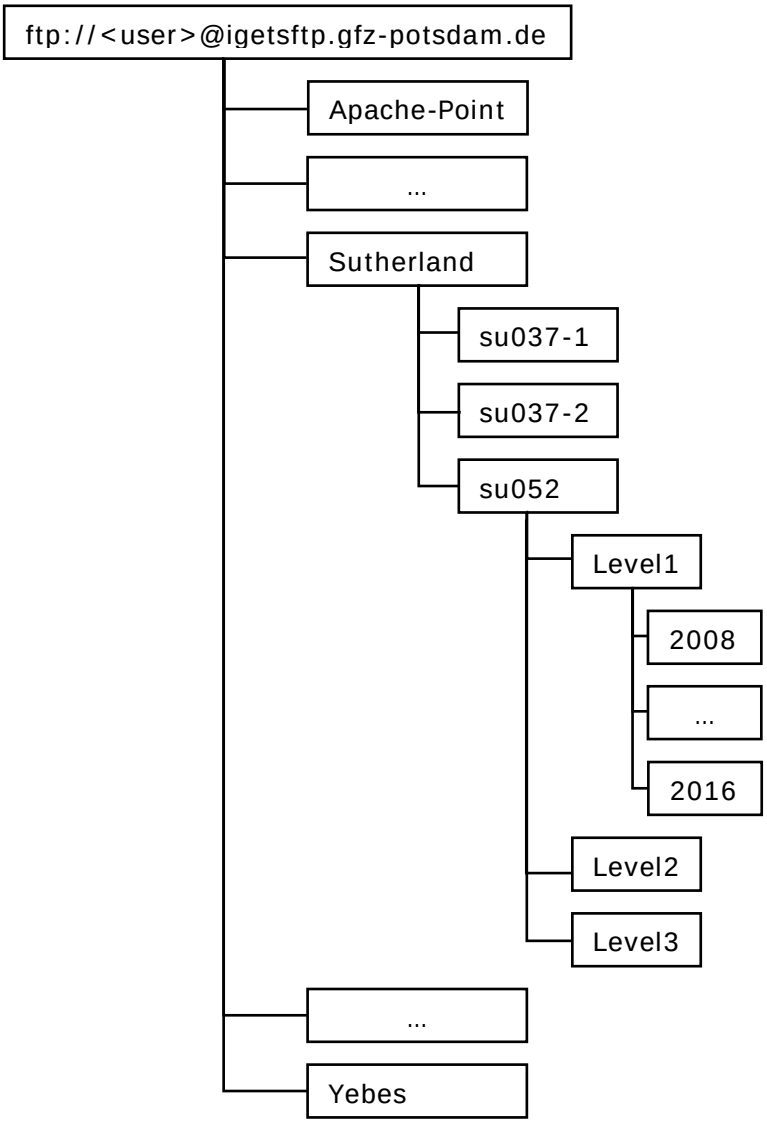


*Figure 2: Directory structure of the IGETS data base FTP server exemplarily for station Sutherland, sensor su052 and Level1 data*

# 7. File Name Convention (Data Product Types)

All files are stored as monthly files with the exception of the calibration files (CAL; see section 9.4). The IGETS file name convention provides unique file identifiers as follows

*IGETS-<instrument>-<type>-<sensor>-<year><month><code>.<extension>*

with

| | | |
|---|---|---|
| | *IGETS-* | constant prefix |
| *<instrument>* | *SG* | Observatory superconducting gravimeter |
| | *IOSG* | New generation observatory superconducting gravimeter |
| | *IGRAV* | Transportable superconducting gravimeter iGrav |
| | *LCR* | Spring gravimeter LaCoste & Romberg |
| | … | Additional instruments to be added. |
| *<type>* | *SEC* | Level 1 second files with raw gravity and pressure data |
| | *MIN* | Level 1 minute files with raw gravity and pressure data |
| | *AUX* | Level 1 auxiliary data files content |
| | *STATLOG* | Level 1 station log files content |
| | *CAL* | Level 1 calibration files with a history of calibration values |
| | *CORMIN* | Level 2 minute files with corrected gravity and pressure data |
| | *HOUR* | Level 2 hour files with corrected gravity and pressure data |
| | *RESHOUR* | Level 3 hour files with residual gravity data after geophysical corrections |

*<sensor>* 2 digit station code and 3 digit instrument serial number (for single sphere SGs) and serial number-sensor (for dual sphere SGs), respectively, e.g., su052, *su037-1*, *su037-2*

*<year>* 4 digit indication of the year, e.g., *2016*

*<month>* 2 digit indication of the month from *01* to *12*

*<code>* 2 digit indication of the GGP Repair Codes (see next section)

*<extension>* 3 digit file extension

| | |
|---|---|
| *.ggp* | for all kinds of gravity and pressure files |

*.aux* for auxiliary files

*.log* for station log files

*.cal* for calibration files

*.zip* compressed version of all files.

Specific examples are

*IGETS-SG-SEC-su052-20160100.ggp*

for Level 1 second file with repair code “00” from January 2016 observed with SG 052 at Sutherland and

*IGETS-SG-CORMIN-we030-1-20160122.ggp*

for Level 2 minute file with repair code “22” from January 2016 observed with the lower sensor of dual SG 030 at Wettzell. The format of the IGETS files follows the GGP File Format V5 from 2010. CAL files represent a special case as there is only one file per station stored in the individual <station> directory given the name IGETS-SG-CAL-<sensor>-<*year*><*month*><*code*>.cal (see section 9.4). The already existing earthquake files GGP-SG-EARTHQ with different second samplings are not stored separately anymore. Instead these moved to the corresponding yearly directories.

# 8. Repair Codes

The repair codes originating from GGP documented in the GGP Newsletters 5 (1997) and 19a (2009) are part of the IGETS file names as well. They are used to indicate the processing steps of the data sets. The repair codes of GGP are taken over by IGETS with extensions concerning the residual gravity data as Level 3 products. Table 2 lists and explains the various repair codes.

*Table 2: IGETS repair codes*

| Repair Code | Significance | Explanation |
|---|---|---|
| 00 | Raw gravity and pressure data (as recorded), 1 s or decimated to 1 min | No pre-processing prior to decimation (IGETS standard) with the exception that very short gaps or spikes shorter than about 10 s can be filled by linear interpolation between good data points on the raw data, i.e. the full signal, prior to decimation. This will avoid unnecessary spreading of minor problems through the filtering and decimation procedure to 1 min data. Data (gravity and pressure) processed in this way can still be given the '00' code. |
| 01 | Gaps and disturbances filled with synthetic signal, 1 s or decimated to 1 min | Gaps and other disturbances are linearly interpolated after removal of synthetic data for tidal and atmospheric effects. All models are restored before decimation to 1 min. |

| | | |
|---|---|---|
| 02 | As 01 + offsets adjusted, 1 s or decimated to 1 min | As above including the removal of offsets in the residual signal, generally when there is a clear jump of non-geophysical origin (such as power surge due to lightening). |
| 11 | Gaps and disturbances filled with synthetic signal, 1 min data | Pre-processing done by station operator on data after decimation to 1 min. |
| 12 | As 11 + offsets adjusted, 1 min data | As above. |
| 21 | Gaps and disturbances filled with synthetic signal, 1 min data | Pre-processing done by the University of French Polynesia, prior to tidal analysis. |
| 22 | As 21 + offsets adjusted, 1min data | As above. |
| h1 | Data processed by station operator,<br>1 h data | Decimated from 1 min. |
| h2 | Data processed by University of French Polynesia, 1 h data | Decimated from 1 min. |
| r1 | Residual data provided by station operator, 1 h data | Reductions of tidal and atmospheric effects by station operator on Level 2 data. Treatment of non-tidal effects to be discussed by the IGETS directing board. |
| r2 | Residual data provided by EOST | Reductions of tidal and atmospheric effects by EOST on Level 2 data. Treatment of non-tidal effects to be discussed by the IGETS directing board. |

# 9. File Formats

The IGETS data base continues to provide different types of data, which can be distinguished by <*type*> in the file name, by extension and file format. All files are formatted text files. Observed gravity and barometric pressure data are stored in GGP files with the extension *.*ggp.* Major events at a station are documented in STATLOG files (*.*log*), whereas AUX files (*.*aux*) give some additional hydrological and/or meteorological data for further interpretation of the gravity signal. As a new data type in IGETS, CAL files (*.*cal*) provide a compilation of the amplitude and phase calibrations of the sensors.

## 9.1 GGP Files

The IGETS GGP files follow the GGP File Format V5 from 2010 acknowledging Bernhard Ducarme, Vojtech Pálinkáš, Jacques Liard and others for useful comments. This format applies to the one second and one minute *.*ggp* files uploaded by the station operators. It is intended for files coded “00”, “01”, or “02” as specified in the repair codes (see previous section). The

corrected one minute and one hour files and other files produced by the University of French Polynesia are different in that the gravity data are calibrated in units of nm/s² to be used directly for tidal analysis (e.g., in ETERNA). SG station operators providing data to IGETS should modify their data preparation programs (if necessary) to conform to the following specifications.

An IGETS 1 s or 1 min *.*ggp* file is made up of a header section and a data section. Each section is divided into three parts:

**1. Header**

***1.1 First 7 required lines***

Former lines 4 (Time Delay), 8 (Gravity Cal) and 9 (Pressure Cal) of the GGP files should be removed by the producers and ignored by the users due to the introduction of CAL files (see section 9.4). Each line permits one or more text strings or numerical values to be read by a program:

Line 1: text string "`Filename :`" (a21) + filename (a30)
Line 2: text string "`Station :`" (a21) + station (a30)
Line 3: text string "`Instrument :`" (a21) + instrument (a30)
Line 4: text string "`N. Latitude (deg) :`" (a21) + latitude (f10.4) + uncertainty (f10.4) + *method**
Line 5: text string "`E. Longitude (deg) :`" (a21) + longitude (f10.4) + uncertainty (f10.4) + *method**
Line 6: text string "`Elevation MSL (m) :`" (a21) + sensor height (f10.4) + uncertainty (f10.4) + *method**
Line 7: text string "`Author :`" (a21) + author e-mail (a40)

**method* denotes the means of specifying the uncertainty in the quantity and should be replaced by
"nominal" (if provided by manufacturer, and not checked),
"measured" (if actually measured) , or
"unknown" (if neither of the first two options. If no value is found this field, the University of French Polynesia will enter 0.).

*Table 3: The header section of *.ggp files*

| Line | Text (a21) | Parameter 1<br><br>Text (a30) or value (f10.4) | Parameter 2<br><br>Uncertainty (f10.4) | Text<br><br>(a10) |
|---|---|---|---|---|
| 1 | `Filename :` | (a30) | | |
| 2 | `Station :` | (a30) | | |
| 3 | `Instrument :` | (a30) | | |
| 4 | `N. Latitude (deg) :` | (f10.4) | (f10.4) | **method* |
| 5 | `E. Longitude (deg) :` | (f10.4) | (f10.4) | **method* |
| 6 | `Elevation MSL (m) :` | (f10.4) | (f10.4) | **method* |
| 7 | `Author :` | [e-mail address of author] (a40) | | |

Please note that line 7 (geoid height) is given only as f10.2 because higher precision is not required.

### *1.2 Optional comment lines inserted by SG station operator*

text line (a60)
text line (a60)
...
text line (a60)
Please note that this is the only place in the header, where additional lines of information about the station are permitted.

### *1.3 Two required text lines*

Line 1: fixed text string "`yyyymmdd hhmmss gravity(V) pressure(V)`" (a60)
Line 2: fixed text string "`C**********`" (a60)
These header lines appear as in table 4.

*Table 4: Additional lines of the header section of *.ggp files*

| Line | Text (a60) |
|---|---|
| 1 | Optional text line |
| 2 | Optional text line |
| 3 | … |
| 4 | Optional text line |
| 5 | `yyyymmdd hhmmss gravity(V) pressure(V)` |
| 6 | `C*******************************************************` |

## 2. Data

### *2.1 One required introductory line*

Line "`77777777 0.0 0.0`" denotes the start of record or data block. The values "0.0 0.0" are placed in the columns defined for the data values (see next entry below) to denote the initial offsets of all columns in the data. This is not useful for IGETS data, but is required for PRETERNA.

### *2.2 Lines of gravity and pressure data*

Lines containing year month day hour min sec gravity_value pressure_value (i4,2i2,1x,3i2,2f10.6)

### *2.3 Last required termination line*

Line "99999999" (a8) denotes the end of the data file.

Please note that

a. Timing samples are given in UTC.
b. Additional individual lines beginning with "77777777" were allowed in the original PRETERNA format to allow step corrections to be added to the channel values. This is not part of the IGETS conventions.
c. As part of the PRETERNA format, it is permitted to specify multiple data blocks within the file, in which case each data block should be terminated with a line containing a string of eight "8"s, and the next block restarted with a line containing eight "7"s, followed by the indication of a jump value for each channel (normally 0.0), e.g.,

```
...
20050320 042800 -1.141063 1001.19516
20050320 042900 -1.141547 1001.19009
20050320 043000 -1.142061 1001.18142
88888888
77777777          0.0         0.0
```

```
20050320 161100 -0.151548  998.28556
20050320 161200 -0.146616  998.29147
20050320 161300 -0.141674  998.30143
…
```

This device is best suited to long data gaps. Moreover, it is always possible to replace a few missing values by 999999.999. Please note that TSOFT accepts both "8's" and "9's" to end a block.

d. PRETERNA and ETERNA are slightly different. The ETERNA format specifies that the end of a block is denoted by "99999999" and the end of data is denoted by an additional "88888888". IGETS data follows the PRETERNA format.
e. The gravity and pressure values must both fit within the two f10.6 fields allowed. It is up to the station operator to format the values so that overflow in writing or reading does not occur. Usually, the gravity values will be limited to ±10 volt from the digital voltmeter (DVM), thus up to 6 decimal places in gravity is normal; further decimal digits are not meaningful[1]. For the barometer, some are calibrated directly in hPa (calibration 1.0), thus a maximum of 5 decimal places can be allowed, as in the sample above.

## 3. Example

An example GGP file "IGETS-SG-MIN-su052-20160100.ggp" from Sutherland should appear as follows:

```
Filename            : IGETS-SG-MIN-su052-20160100.ggp
Station             : Sutherland, South Africa
Instrument          : GWR SG052
N. Latitude (deg)   :  -32.3814    0.0003  measured
E. Longitude (deg)  :   20.8109    0.0003  measured
Elevation MSL (m)   : 1755.0000    5.0000  measured
Author              : C. Voigt (cvoigt@gfz-potsdam.de)
Approximate position from IGS/ITRF station SUTM.
Orthometric height from approximate WGS84 height
of SG pillar (1791 m) subtracted by geoid height
from SAGEOID10 (36 m).
yyyymmdd hhmmss  gravity(V)  pressure(V)
C********************************************
77777777         0.000000    0.0000
20160101 000000  4.694506 829.06000
20160101 000100  4.699112 829.05000
20160101 000200  4.703689 829.05000
20160101 000300  4.708038 829.04000
20160101 000400  4.712238 829.01000
```

[1] Some data acquisition systems produce 8 digits (7 decimals) of apparent precision from the DVM, but the 7th decimal is noise if it derives from a 7.5 digitizing voltmeter. For example, using a calibration factor of -700 nm/s² / V, a voltage of $10^{-7}$ V = only 0.007 nGal.

```
…
20160131 235500  4.680835 827.14000
20160131 235600  4.685236 827.13000
20160131 235700  4.689883 827.10000
20160131 235800  4.694478 827.11000
20160131 235900  4.698875 827.10000
99999999
```

## 9.2 STATLOG Files

The STATLOG files note the major problems and changes regarding instrument and station. These are important for identifying and assessing problems in the data such as helium refills, icing of the coldhead, service or failure of the cooling system or power supply and other disturbances as well as strong, major and great earthquakes. An example LOG file "IGETS-SG-STATLOG-su037-1-20160100.log" from Sutherland appears as follows:

```
Filename            : IGETS-SG-STATLOG-su037-1-20160100.log
Station             : Sutherland, South Africa
Instrument          : GWR D037_L
Author              : C. Voigt (cvoigt@gfz-potsdam.de)
yyyymmdd hhmmss  comments
C*********************************************
77777777
20160101 000000  start of recording
20160122 093000  coldhead exchange (step of approx. -159.9 nm/s²)
20160131 235959  end of recording
99999999
88888888
```

## 9.3 AUX Files

AUX data files contain additional hydrological and meteorological data for scientific investigations, such as groundwater, rainfall or soil moisture. However, these are frequently missing for a large number of stations involved in IGETS. However, it is recommended to directly contact the station operators, as these are usually observed. An example for the station of Medicina is shown providing rainfall and groundwater data in "IGETS-SG-AUX-mc023-201501h2.aux":

```
Filename            :  IGETS-SG-AUX-mc023-201501h2.aux
Station             :  Medicina, Italy
Instrument          :  GWR C023
Author              :  P. Wolf (peter.wolf@bkg.bund.de)
Ground water interpolated from 1 daily value at 12h
Rain only one value per day at 12h
yyyymmdd hhmmss  ground water(m)  rain(mm).
C*********************************************
77777777
20150101 000000     0.002     0.000
20150101 010000     0.000     0.000
```

```
20150101 020000    -0.002     0.000
20150101 030000    -0.004     0.000
20150101 040000    -0.006     0.000
…
20150131 190000    -0.147     0.000
20150131 200000    -0.145     0.000
20150131 210000    -0.142     0.000
20150131 220000    -0.139     0.000
20150131 230000    -0.137     0.000
99999999
```

## 9.4 CAL Files

Information on the history of amplitude calibrations (scale factors) and phase calibrations (time delays) of the SG sensors were not provided in GGP. Instead, the current values appear in the header of respective monthly GGP files. IGETS establishes individual calibration files for the stations providing a systematic review of the calibration changes in the file headers. The calibration values (Time Delay, Gravity Cal, Pressure Cal) given in the former GGP file headers can thus be removed by the producers and ignored by the users in order to avoid any confusion; for a discussion see Crossley and Hinderer (2009). The format of the IGETS calibration files follows the proposal by David Crossley, Bruno Meurers, Vojtech Pálinkáš, Jacques Hinderer and Jean-Paul Boy from January 2016, which is provided in the following.

The only information about the calibration (scale factor) of the SG and the local pressure sensor was contained in the headers of the GGP 1 min data. This is inconvenient for extracting and using for purposes such as tidal analysis. Moreover there is no indication in the header as to the reason for changes in the calibration factors. Are they updates, improvements, or new sensor measurements, and for what time period should they be applied? To correct this situation, all SG stations participating in IGETS should upload a CAL files (*.*cal*) containing the necessary information. This file should fulfil the following requirements:

- Being retroactive,
- following the style and format indicated in the sample below,
- being uploaded to the IGETS data base as soon as possible and
- being updated with a new entry every time there is a new determination of the scale factor for the instrument (or sensor), indicating the date, rounded to midnight UT of the day of the change
- with the pressure sensor calibration and determination of the instrument time delay being reported similarly.

In many cases, new scale factors are routinely determined for an instrument at a site, especially using absolute gravity (AG) measurements. The manner of doing the SG-AG regression is not discussed here, but the assumption is (and must be) that when the sensor remains the same, so must the calibration factor. The calibration factor is quoted as a mean value gcal and the standard deviation $\sigma$ providing the uncertainty of the measurements

involved. The weight of the determination is given by the usual formula $w = 1/\sigma^2$. Therefore measurements on the same sensor spaced in time are taken to be repeat measurements of the same quantity, without any allowance for a time dependency. In this case the updated calibration may be expected to improve the accuracy of gcal, and invariably reduce the new standard deviation by the process of conflation with previous results. The updated calibration factor is the accumulated mean of all relevant determinations, and the new standard deviation should be obtained from weighting the individual standard deviations. Assuming each calibration is gcal(i) with standard deviation $\sigma$(i) and weight $w(i) = 1/\sigma^2$(i), the mean values for the calibration and the squared standard deviation (variance) are

$$\text{gcal} = \frac{\sum_{i=1}^{n} \text{gcal(i)}\cdot\text{w(i)}}{\sum_{i=1}^{n} \text{w(i)}} \text{ and } \sigma^2 = \frac{1}{\sum_{i=1}^{n} \text{w(i)}}$$

over all n calibration determinations for which the scale factor should be considered constant. An initial example for a CAL file should appear as follows for the sensor ap046 at Apache Point and should be given the name “IGETS-SG-CAL-ap046-20160900.cal”. The continuous updates of a CAL file have to be distinguished by date due to uniqueness requirements (see chapter 10). Thus, a new CAL file should be generated whenever a new calibration is carried out. This replaces the former CAL file, but provides the complete history of calibrations.

There are three parameters that can be reported along with their uncertainty estimations (standard deviations std), i.e. the gravity amplitude calibration gcal (former Gravity Cal) in units of nm/s²/V, the barometric pressure amplitude calibration pcal (former Pressure Cal) in units of hPa/V and the phase calibration in terms of time lag (former Time Delay) in units of s. These values are determined by the specific hardware of the instrument and electronics. A new entry is necessary in two cases:

- If a new value is determined as the result of a hardware change, three lines are required:
    1. A “99999999” line to indicate a change in hardware (except for the first entry),
    2. a date and the new value in the appropriate column and
    3. a line showing the date and all current values ending with an ‘applied since’ date.
- If a parameter is re-measured and to be considered as an update to the existing value (e.g., gcal), the new value is to be reported, as well as the result of merging this with previous values. Then there should be two lines:
    1. A date and the new value in the appropriate column and
    2. a line showing the date and all merged values with an ‘applied since’ date.

In addition, it may be necessary to modify previous lines to accommodate new measurements (see the sample file below). In this manner, the CAL file contains single parameter determinations on lines that do not have an ‘applied since’ date at the end. This may be useful

to the station operator to show results of single experiments. The CAL file also has lines with an 'applied since' date at the end, and these lines are the most useful for other users to show the current values that should be used, e.g., for tidal analysis. The CAL file could be subsequently edited to show one or other of these alternatives.

```
Filename            : IGETS-SG-CAL-ap046-20160900.cal
Station             : Apache Point, New Mexico, USA
Instrument          : GWR OSG 046
Author              : Tom Murphy (tmurphy@physics.ucsd.edu)
each line gives the date and any updated value such as gcal, pcal, the time lag,
their standard deviations and 'applied since' date. the format is (a8,6f10.3,5x,a8)
yyyymmdd gcal(nm/s^2/V); std; pcal(hPa/V); std;   time lag(s); std;   applied since
C*******************************************************************************
20110801  -793.28      0.041     1.000     0.001     1.540     0.010     20110801
99999999
20131120  -940.18      0.121
20140910  -939.97      0.084
20140910  -940.04      0.069     1.000     0.001     1.540     0.010     20131120
20141205                                             1.320     0.015
20141205  -940.04      0.069     1.000     0.001     1.320     0.015     20141205
.....
99999999
```

# 10. Data Publication and Citation

A major benefit of IGETS is the provision of digital object identifiers (DOI) for the data sets of every station. DOIs are unique and persistent identifiers used to reference and link the individual data sets. The advantages are that DOIs

- make it simple to clearly reference objects, e.g., data sets,
- enable the scientific results to be linked with associated publications,
- are a standard feature in science when publishing scientific articles,
- improve access to scientific data, avoiding duplication enhances the visibility of research data, encourage new research to be conducted, and foster scientific cooperation.

The DOIs of the IGETS Level 1 data sets are assigned for each station, i.e. one for all sensors of a station referencing the station operators. The DOIs consist of the prefix *10.5880*, which means that the DOIs are published by the GFZ Data Services, the research repository of GFZ. An individual suffix is given for each station following the convention *igets.<2 digit station code>.<l1>.<3 digit DOI version number>*, e.g., for the Level 1 data sets from Sutherland in the original DOI version 001:

> Förste, C., Voigt, C., Abe, M., Kroner, C., Neumeyer, J., Pflug, H., Fourie, P. (2016). Superconducting Gravimeter Data from Sutherland – Level 1. GFZ Data Services. DOI: http://doi.org/10.5880/igets.su.l1.001

The Level 2 data sets computed by the University of French Polynesia are assigned for all IGETS stations in total, i.e. one DOI for all data sets, with the suffix *igets.l2.001* indicating the original DOI version 001 and referenced by:

Barriot, J.-P. (2016). Superconducting Gravimeter Data – Level 2. GFZ Data Services. DOI: http://doi.org/10.5880/igets.l2.001

If a station operator computed Level 2 data and provided them to IGETS, then the assignment should be done according to the Level 1 data, i.e. *igets.<2 digit station code>.<l2>.<3 digit. version number>* with the respective reference. As this is not the standard case, a message to the representative of the IGETS data base is required.

The Level 3 data sets computed by EOST are also assigned for all IGETS stations in total, i.e. one DOI for all data sets, with the suffix *igets.l3.001* indicating the original DOI version 001 and referenced by:

Boy, J.-P. (2016). Superconducting Gravimeter Data – Level 3. GFZ Data Services. DOI: http://doi.org/10.5880/igets.l3.001

The citation rules and copyright information for the usage of the IGETS files is added at the beginning of the IGETS files in front of the header automatically by the representative of the IGETS data base. The IGETS data sets are freely available under a Creative Commons - Attribution 4.0 (CC-BY) Licence.

As DOIs provide persistent access to the specific data sets, it is not allowed to make modifications to a published data set. This is ensured by the transferring process of the uploaded data that prevents the overwriting of an existing data set. In case of later corrections or changes of published data sets, a new DOI version has to be assigned. However, new data sets can naturally be added without assigning a new version. The reference year is the year of the first DOI version.

The DOIs of the Level 1 data sets resolve to DOI landing pages with an overview of the station and the data following the given example of Sutherland (Förste et al. 2016). For support please contact igets-support@gfz-potsdam.de. The landing pages in turn refer to the IGETS data base FTP server. The DOIs of all stations are distributed, e.g., in the map on the IGETS data base website http://igets.gfz-potsdam.de. Finally, this report should be indicated on the landing pages and referenced by:

Voigt, C., Förste, C., Wziontek, H., Crossley, D., Meurers, B., Pálinkáš, V., Hinderer, J., Boy, J.-P., Barriot, J.-P., Sun, H. (2016): Report on the Data Base of the International Geodynamics and Earth Tide Service (IGETS), (Scientific Technical Report STR – Data; 16/08), Potsdam: GFZ German Research Centre for Geosciences. DOI: http://doi.org/10.2312/GFZ.b103-16087

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