

# Description of the Level 2 and Level 3 IGETS data produced by EOST

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## Abstract

The document presents the processing of the superconducting gravimeter data performed at EOST (Ecole et Observatoire des Sciences de la Terre) in Strasbourg, France. Starting from the raw 1-minute gravity and pressure records (level-1 products), we eliminate major perturbations, such as instrumental offsets, gaps and spikes and produce the level-2 products, ready for tidal analysis.

Finally, from these level-2 data, we produce gravity residual time series after correction for solid and oceanic tides, polar motion and length-of-day, atmospheric loading and instrumental drift (level-3 products).

## 1. Introduction

The primary objective of the International Geodynamics and Earth Tide Service (IGETS) is to provide a Service to monitor temporal variations of the Earth gravity field through long-term records from ground gravimeters and other geodynamic sensors. IGETS continues the activities of the Global Geodynamic Project to provide support to geodetic and geophysical research activities using superconducting gravimeter data within the context of an international network. 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 gravimeters, and other geodynamic sensors.

The IGETS data base, hosted by GFZ, is the main data center of worldwide high precision SG records; the different products are, according to the terms of references ([http://igets.unistra.fr/Documents/IGETS\\_ToR.pdf](http://igets.unistra.fr/Documents/IGETS_ToR.pdf)) :

- Raw gravity and local pressure records sampled at 1 or 2 seconds, in addition to the same records decimated at 1-minute samples (Level 1 products).
- Gravity and pressure data corrected for instrumental perturbations, ready for tidal analysis. This product is derived from the previous datasets, and is computed by one or several Analysis Centers (Level 2 products).
- Gravity residuals after particular geophysical corrections (including solid Earth tides, polar motion, tidal and non-tidal loading effects). This product is also derived from the previous dataset and is computed by one or several Analysis Centers (Level 3 products)

We present the processing of the superconducting gravimeter data available at the IGETS database (Voigt et al., 2016), and describe quickly the file format and content. The two next sections are devoted first to the level-2 data processing and then for the level-3 data.

## **2. EOST Level 2 data**

### **2.1 Methodology**

Raw 1-minute gravity and pressure (Level 1 data) are calibrated using the available calibration files.

We first process the pressure data, removing interpolated hourly surface pressure from MERRA2 (Gelaro et al., 2017) reanalysis model. We correct manually these residuals for eventual offsets, and fill any gaps with a linear interpolation. The de-gapped series is then corrected for the remaining perturbations (spikes) using a threshold on its derivative, following Crossley et al. (1993) procedure.

The full pressure is then restored by adding back the MERRA2 pressure.

For gravity, the methodology is similar: calibrated gravity is corrected for a local tidal model, including polar motion, and local air pressure effects. Offsets are manually corrected, gaps are filled with a linear interpolation, and remaining perturbations (spikes, earthquakes) are corrected using a threshold on the derivative of the gravity residuals.

The full gravity is then restored by adding back the modeled tidal signal and air pressure effects.

### **2.2 File format**

We provide monthly files, with the code “32”, of the corrected and filled gravity and pressure (columns 1 and 2), only valid gravity and pressure (columns 3 and 4), gaps and offsets being marked as “99999.999”, and the gravity and pressure cumulative offsets (columns 5 and 6). All data are provided in physical units, i.e.  $\text{nm s}^{-2}$  and hPa for gravity and pressure respectively. In the header, we also provide the gravity and pressure calibrations used to convert the level-1 data into physical units. An example is given on Figure 1.

```

Filename           : IGETS-SG-CORMIN-me020-19970132.ggp
Calibration        : -1107.000 &   -13.290 from 19940815 to 19970905
Calibration        : -1107.000 &   13.290 from 19970905 to 19980812
Calibration        : -1107.000 &    6.683 from 19980812 to 20010101
Calibration        : -1107.000 &    1.000 from 20010101 to 20030625
Product            : Level 2 from EOST
Author             : jeanpaul.boy@unistra.fr
Corrections        : offsets, gaps and spikes
Gravity            : filled with local tides
Pressure           : filled with hourly MERRA2
yyyymmdd hhmmss   g_fil    p_fil    g_nofil   p_nofil   g_offset  p_offset
C*****
7777777
19970101      0  1014.994  -12.136  99999.999  -12.136  99999.999  -4.247
19970101     100  1014.543  -12.166  99999.999  -12.166  99999.999  -4.247
19970101     200  1014.084  -12.191  99999.999  -12.191  99999.999  -4.247
19970101     300  1013.621  -12.213  99999.999  -12.213  99999.999  -4.247
19970101     400  1013.159  -12.233  99999.999  -12.233  99999.999  -4.247
19970101     500  1012.683  -12.246  99999.999  -12.246  99999.999  -4.247
19970101     600  1012.143  -12.237  99999.999  -12.237  99999.999  -4.247
19970101     700  1011.646  -12.239  99999.999  -12.239  99999.999  -4.247
19970101     800  1011.130  -12.234  99999.999  -12.234  99999.999  -4.247
19970101     900  1010.528  -12.197  99999.999  -12.197  99999.999  -4.247
19970101    1000  1010.001  -12.183  99999.999  -12.183  99999.999  -4.247
19970101    1100  1009.511  -12.180  99999.999  -12.180  99999.999  -4.247
19970101    1200  1009.093  -12.199  99999.999  -12.199  99999.999  -4.247
19970101    1300  1008.730  -12.234  99999.999  -12.234  99999.999  -4.247
19970101    1400  1008.238  -12.223  99999.999  -12.223  99999.999  -4.247
19970101    1500  1007.728  -12.205  99999.999  -12.205  99999.999  -4.247
19970101    1600  1007.333  -12.222  99999.999  -12.222  99999.999  -4.247
19970101    1700  1006.888  -12.221  99999.999  -12.221  99999.999  -4.247
19970101    1800  1006.402  -12.204  99999.999  -12.204  99999.999  -4.247
19970101    1900  1006.006  -12.215  99999.999  -12.215  99999.999  -4.247
19970101    2000  1005.634  -12.231  99999.999  -12.231  99999.999  -4.247
19970101    2100  1005.285  -12.253  99999.999  -12.253  99999.999  -4.247
19970101    2200  1004.975  -12.285  99999.999  -12.285  99999.999  -4.247

```

Figure 1: Example of the first lines of the EOST Level-2 products (code 32) for the GWR T020 instrument installed in Metsahovi (Finland) for the month of January 1997. The “g\_fil” and “p\_fil” columns provide corrected gravity and pressure data; “g\_nofil” and “p\_nofil” provide only the valid gravity and pressure data (no correct gravity data here). The cumulative offsets are given in the two last columns “g\_offset” and “p\_offset”.

### 3. EOST Level 3 data

#### 3.1 Geophysical Models

1-min. gravity residuals are computed after subtracting to the level 2 data:

- solid Earth tides and ocean tidal loading,
- atmospheric loading,
- polar motion and length-of-day induced gravity changes,
- an instrumental drift.

Tidal gravity variations are computed differently for the long-period tides and for the diurnal and sub-diurnal bands:

- At high frequency, a local tidal model, adjusted by least-squares, is used.
- At low frequency, we model the tidal signal using the DDW99 gravimetric factor (Dehant et al., 1999) and HW95 tidal potential (Hartmann and Wenzel, 1995) for the Solid Earth tides, and FES2014b (Carrère et al., 2016) for the ocean tidal loading.

FES2014b includes 7 different constituents: Sa, Ssa, Mm, Msf, Mf, Mtm and Msqm.

We choose the latest version of the FES model, but we also compare it to other tidal model. Figure 2 shows the differences with NAO99b (Matsumoto et al., 2000) for the Strasbourg station; in most cases, the differences are always below  $0.1 \text{ nm s}^{-2}$ .

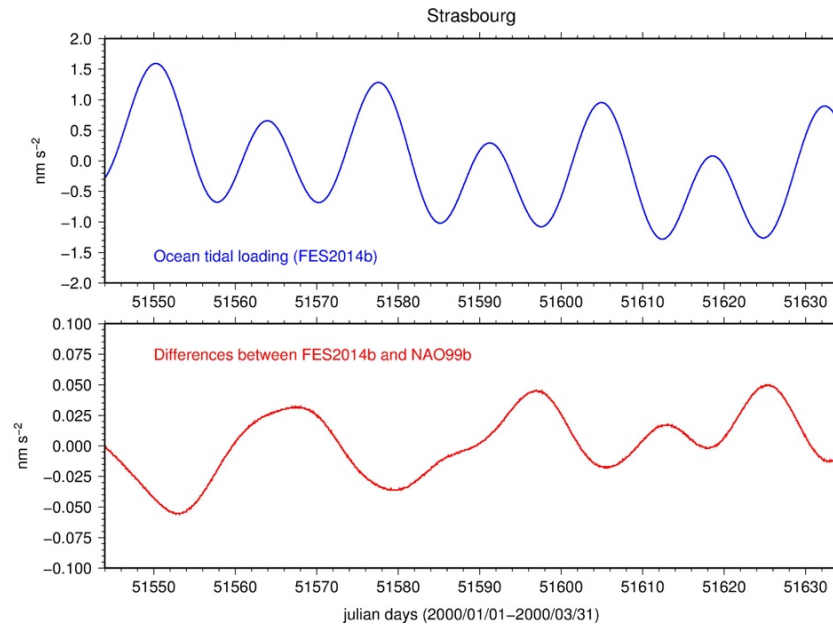


Figure 2: Long-period ocean tidal loading in Strasbourg modeled using FES2014b (Carrère et al., 2016) (7 waves: Sa, Ssa, Mm, Msf, Mf, Mtm and Msqm) (top, in blue) and differences with NAO99b (Matsumoto et al., 2000) (7 waves: Sa, Ssa, Msm, Mm, Msf, Mf and Mtm) (bottom, in red).

This hybrid methodology allows us to remove most of the short-period tides, and to keep all other long-period variations, including, for example, the seasonal hydrological contributions (Boy and Hinderer, 2006).

Atmospheric loading is computed according to Boy et al. (2002), using MERRA2 (Gelaro et al., 2017) hourly surface pressure, and assuming an inverted barometer ocean response to pressure. MERRA2 pressure is replaced by the 1-minute local pressure record for angular distance less than  $0.10^\circ$  to the station.

The polar motion and length-of-day induced gravity variations are modeled using the IERS EOPC04 daily series (<http://hpiers.obspm.fr/iers/eop/eopc04/>) (Wahr, 1985), and assuming a  $\delta_2$  factor of 1.16. We also model ocean pole tide as a self-consistent equilibrium response (Agnew and Farrell, 1978; Chen et al., 2008).

Depending on the sensor, the instrumental drift is generally modeled as a polynomial or an exponential function (Van Camp and Francis, 2007). When available (currently only for Strasbourg instruments, see Figure 3), we use time series from absolute gravimeters for the adjustment.

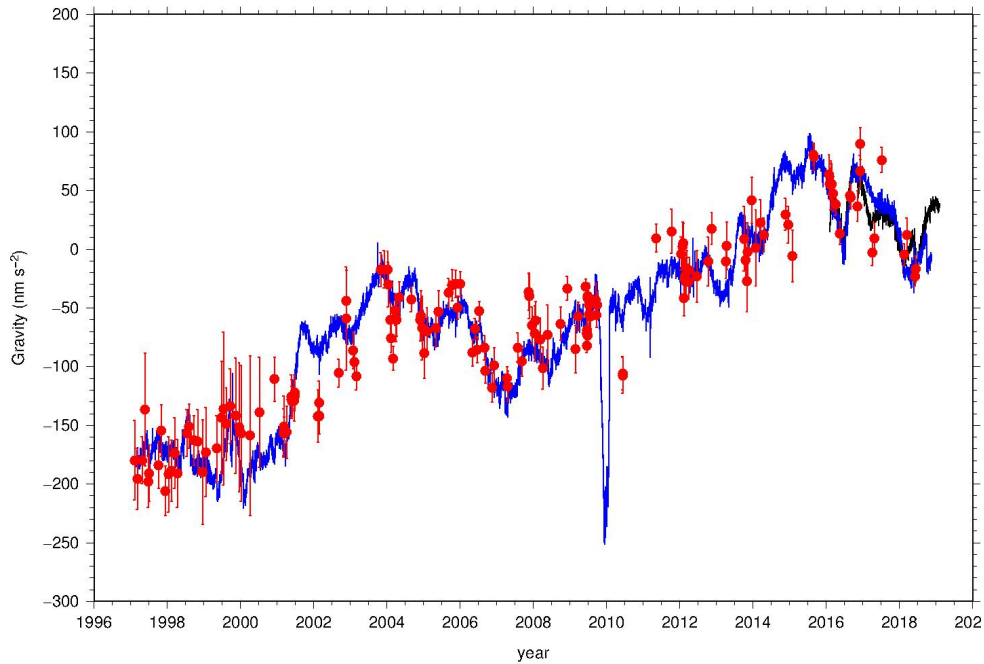


Figure 3: Gravity residuals (level 3) in Strasbourg for the CO26 (blue) and iOSG #23 (black) instruments, after correcting for geophysical models and instrumental drift, compared to FG5 #206 absolute gravity observations (red).

The large negative anomaly in late 2009 and early 2010 for the CO26 instrument is due to a malfunction of the tilt compensation system.

In addition to the residuals, each correction is provided in the monthly Level-3 data, in addition to the original gravity and pressure. Except for the solid Earth tides and ocean tidal loading, all geophysical models used to produce IGETS level 3 data are also available at the EOST loading service (<http://loading.u-strasbg.fr>)

### 3.2 File format

1-minute gravity residuals are provided as monthly files with the code "r2". In the header, we provide a reminder of the localization of the station, the different calibrations applied in our processing and the different geophysical corrections applied. The characteristics of the modeled instrumental drift (polynomial, exponential or derived using AG measurement) are also written in the header. An example of a file is given on Figure 4.

```

Filename          : IGETS-SG-RESMIN-ap046-201809r2.ggp
Station           : Apache Point, New Mexico, USA
Instrument        : GWR OSG 046
N Latitude (deg)  : 32.78036    0.0010 measured
E Longitude (deg) : -105.82042   0.0010 measured
Elevation MSL (m) : 2788.0000    5.0000 measured
Calibration      : -793.890 & 1.000 from 20130920 to 20130901
Calibration      : -945.400 & 1.000 from 20130901 to 20180916
Processing        : IGETS Central Bureau
Author           : jeanpaul.boy@unistra.fr
LP tides         : DDW99 + HW95 / FES2014b
SP tides         : local model
Rotation         : PM + LOD (del=1.16) / Self consistent ocean
Atmos. load      : MERRA2/IB + local pressure
Drift            : degree-2 polynomial
yyyyymmdd hhmmss res_fil res_nofil tides rotation atm_load drift g_fil p_fil
C*****
ap046           1.0000  1.0000  0.000  1
77777777
20180901 0 -19.089 -19.089 -82.303 -0.359 -4.130 -2800.842 -2906.724 1.907
20180901 100 -18.991 -18.991 -78.320 -0.360 -4.116 -2800.842 -2902.628 1.902
20180901 200 -18.995 -18.995 -74.320 -0.360 -4.119 -2800.842 -2898.635 1.905
20180901 300 -18.991 -18.991 -70.302 -0.360 -4.131 -2800.842 -2894.626 1.912
20180901 400 -18.920 -18.920 -66.268 -0.360 -4.145 -2800.842 -2890.535 1.920
20180901 500 -18.881 -18.881 -62.218 -0.360 -4.152 -2800.842 -2886.454 1.925
20180901 600 -18.901 -18.901 -58.151 -0.361 -4.153 -2800.842 -2882.408 1.927
20180901 700 -18.897 -18.897 -54.069 -0.361 -4.163 -2800.842 -2878.332 1.933
20180901 800 -18.921 -18.921 -49.971 -0.361 -4.175 -2800.842 -2874.271 1.940
20180901 900 -19.010 -19.010 -45.859 -0.361 -4.163 -2800.842 -2870.235 1.936
20180901 1000 -19.053 -19.053 -41.731 -0.362 -4.124 -2800.842 -2866.112 1.920
20180901 1100 -19.033 -19.033 -37.589 -0.362 -4.088 -2800.842 -2861.913 1.905
20180901 1200 -19.064 -19.064 -33.432 -0.362 -4.078 -2800.842 -2857.778 1.902

```

Figure 4: Example of the first lines of the EOST Level-3 products (code r2) for the GWR OSG #046 instrument installed in Apache Point (USA) for the month of September 2018. The “res\_fil” and “res\_nofil” columns provide the gravity residuals from the Level-2 “g\_fil” and “g\_nofil” products (see Figure 1). The “tides”, “rotation” and “atm\_load” provide the geophysical corrections applied (respectively solid and ocean tides, Polar Motion and Length-of-Day including a self-consistent ocean and global atmospheric loading using MERRA2 and assuming an IB ocean). The modeled instrumental drift is given in the “drift” column. The original “g\_fil” and “p\_fil” columns are finally given.

## References

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