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

Jean-Paul Boy

(1) EOST/IPGS, 5 rue René Descartes, 67084 Strasbourg Cedex, France.
    jeanpaul.boy@unistra.fr

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) :

- 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 “999999.999”, and the gravity and pressure cumulative offsets (columns 5 and 6). All data are provided in physical units, i.e. 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.
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 models. 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 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 0.1° 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.
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.

<table>
<thead>
<tr>
<th>yyyyddd</th>
<th>hhmmss</th>
<th>res_fil</th>
<th>res_nofil</th>
<th>tides</th>
<th>rotation</th>
<th>atm_load</th>
<th>drift</th>
<th>g_fil</th>
<th>p_fil</th>
</tr>
</thead>
<tbody>
<tr>
<td>20180901</td>
<td>0</td>
<td>-19.089</td>
<td>-19.089</td>
<td>-82.303</td>
<td>-0.359</td>
<td>-4.130</td>
<td>-2800.842</td>
<td>-2906.724</td>
<td>1.907</td>
</tr>
<tr>
<td>20180901</td>
<td>100</td>
<td>-18.991</td>
<td>-18.991</td>
<td>-78.320</td>
<td>-0.360</td>
<td>-4.116</td>
<td>-2800.842</td>
<td>-2902.628</td>
<td>1.902</td>
</tr>
<tr>
<td>20180901</td>
<td>200</td>
<td>-18.996</td>
<td>-18.995</td>
<td>-74.329</td>
<td>-0.360</td>
<td>-4.119</td>
<td>-2800.842</td>
<td>-2898.635</td>
<td>1.905</td>
</tr>
<tr>
<td>20180901</td>
<td>300</td>
<td>-18.991</td>
<td>-18.991</td>
<td>-70.302</td>
<td>-0.360</td>
<td>-4.131</td>
<td>-2800.842</td>
<td>-2894.626</td>
<td>1.912</td>
</tr>
<tr>
<td>20180901</td>
<td>400</td>
<td>-18.920</td>
<td>-18.920</td>
<td>-66.268</td>
<td>-0.360</td>
<td>-4.145</td>
<td>-2800.842</td>
<td>-2889.532</td>
<td>1.928</td>
</tr>
<tr>
<td>20180901</td>
<td>500</td>
<td>-18.881</td>
<td>-18.881</td>
<td>-62.218</td>
<td>-0.360</td>
<td>-4.152</td>
<td>-2800.842</td>
<td>-2884.436</td>
<td>1.925</td>
</tr>
<tr>
<td>20180901</td>
<td>600</td>
<td>-18.901</td>
<td>-18.901</td>
<td>-59.151</td>
<td>-0.361</td>
<td>-4.153</td>
<td>-2800.842</td>
<td>-2882.408</td>
<td>1.927</td>
</tr>
<tr>
<td>20180901</td>
<td>700</td>
<td>-18.897</td>
<td>-18.897</td>
<td>-56.169</td>
<td>-0.361</td>
<td>-4.163</td>
<td>-2800.842</td>
<td>-2878.332</td>
<td>1.933</td>
</tr>
<tr>
<td>20180901</td>
<td>800</td>
<td>-18.921</td>
<td>-18.921</td>
<td>-49.971</td>
<td>-0.361</td>
<td>-4.175</td>
<td>-2800.842</td>
<td>-2874.271</td>
<td>1.948</td>
</tr>
<tr>
<td>20180901</td>
<td>900</td>
<td>-19.018</td>
<td>-19.010</td>
<td>-46.059</td>
<td>-0.361</td>
<td>-4.163</td>
<td>-2800.842</td>
<td>-2878.235</td>
<td>1.936</td>
</tr>
<tr>
<td>20180901</td>
<td>1000</td>
<td>-19.053</td>
<td>-19.063</td>
<td>-41.731</td>
<td>-0.362</td>
<td>-4.124</td>
<td>-2800.842</td>
<td>-2866.112</td>
<td>1.928</td>
</tr>
<tr>
<td>20180901</td>
<td>1100</td>
<td>-19.033</td>
<td>-19.033</td>
<td>-37.589</td>
<td>-0.362</td>
<td>-4.088</td>
<td>-2800.842</td>
<td>-2861.913</td>
<td>1.906</td>
</tr>
</tbody>
</table>

References


