Comparison of Data Sets Recorded with the Dual Sphere Superconducting Gravimeter CD 034 at the Geodynamic Observatory Moxa

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Abstract

Since April 1999 the dual sphere superconducting gravimeter CD 034 is operating at the Geodynamic Observatory Moxa (Germany). A comparison of the period range between 20 s and 2 days shows a high similarity of the two data sets. As expected the upper sensor produces a slightly noisier signal than the lower one. Up to now the difference signal of the two sensors gives no indication for the small arbitrary steps older instruments are susceptible to. Regarding the long-period range we find, after eliminating the barometric pressure influence, a long-term trend in both data sets that can be traced back to hydrological effects. The difference of the time series yields a small linear drift signal of presently unknown physical origin.

1. Introduction

Since April 1999 a dual sphere superconducting gravimeter (Richter and Warburton, 1998) is operating at the Geodynamic Observatory Moxa (Germany; coordinates: 50.645°N, 11.616°E, elevation: 455 above msl). One sensor is placed approximately 20 cm above the other. The main reason for a two sensor system lays in the detection of small instrumental steps as only one of the two sensors produces a jump at a certain time. The use of two sensors thus allows the correction of these steps and ensures a control of the instrumental drift. The signals of the two sensors were first recorded with a sampling rate of 10 s, later the rate was changed to 1 s. A preliminary calibration was done by a parallel recording with the LaCoste & Romberg Earth Tide gravimeter ET-18. The first year of recording was used to familiarize with the instrument, to compare the two data sets, and to study local influences on the gravity observations. Local disturbing influences should be restricted to environmental effects due to e.g. barometric pressure variations or changes in the hydrological situation as there are no major industrial plants, towns or major roads in the vicinity of 10 km of the observatory. In the following the signal contents of the gravity data sets of upper and lower sensor is compared according to different frequency bands. The noise studies are of special interest as a lot of experience and information exist for seismic fre-
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Quencies due to the 36 year-long history of seismological observations at Moxa, but almost no informations are available for frequencies below the seismic range.

2. Frequencies > 0.05 mHz

In the frequency range above 0.05 mHz the interest is focussed on the general noise level of the gravity data to get first informations how well instrument and station perform for this part of the frequency spectrum. Figure 1 gives an example of the power spectral density of the two data sets averaged over 5 quiet days. The spectra were calculated according to Banka and Crossley (1999). The spectra show a high similarity although the one of the upper sensor data has a slightly higher noise level. From the spectrum of the difference of the gravity data it emerges that this noise level has an instrumental origin probably due to the fact that the upper sensor is artificially kept in the tilt insensitive position of the lower sensor by additional superconducting side coils. At frequencies below 0.8 mHz it is lower than the ‘New Low Noise Model ’ (NLNM) by Peterson (1993) because the model considers tides as noise. Between 0.8 and 10 mHz the

Fig. 1. Power spectral density of 5 quiet days at Moxa.
spectra are fairly close to the noise model. At frequencies higher than 10 mHz a rising noise level exists. The maxima at about 27 and 30 mHz resp. are probably caused by the so-called parasitic mode, a horizontal oscillation of the sensor spheres.

Up to now only barometric pressure variations and wind could be identified as major noise sources in the frequency range above 0.05 mHz. An increase in amplitude and variation rate in one of them or in both will lead to a higher noise level than the one in Figure 1. This holds true although a barometric pressure reduction is applied.

The difference between the residuals of upper and lower sensor as shown in Figure 2 is of uniform character without any striking features. This means the difference time series is characterized by arbitrary variations in the instrumental noise and no geophysical signal contents can be found.

3. Tidal Bands

In Table 1 some preliminary tidal parameters are summarized for the two gravity data sets as well as regression coefficients for the barometric pressure reduction. They were calculated with the tidal analysis program ETERNA 3.40 (comp. e.g. Wenzel, 1996). No significant deviations in the parameters can be found but indications exist that there might be a slightly different response of the sensors to barometric pressure variations. The data sets are still too short to have real evidence for this observation. In accordance with the results found in the previous section the standard deviations for the tidal parameters of the upper sensor are somewhat higher than those of the lower sensor.

Up to now no small offsets could be detected, a problem of older superconducting gravimeters hampering studies of long-periodic and long-term signals. By calculating the
difference between the 1 min decimated residuals of both sensors it is possible to detect steps in the order of magnitude of 0.3 nm/s².

Table 1. Tidal parameters and regression coefficient for barometric pressure and standard deviations, 1999/06/10-2000/10/31.

<table>
<thead>
<tr>
<th>wave group</th>
<th>lower sensor</th>
<th>upper sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>δ</td>
<td>Δ [°]</td>
</tr>
<tr>
<td>O1</td>
<td>1.15040</td>
<td>±0.00009</td>
</tr>
<tr>
<td>K1</td>
<td>1.13795</td>
<td>±0.00007</td>
</tr>
<tr>
<td>M2</td>
<td>1.18765</td>
<td>±0.00006</td>
</tr>
<tr>
<td>S2</td>
<td>1.18590</td>
<td>±0.00015</td>
</tr>
<tr>
<td>barometric pressure [nm/s²/hPa]</td>
<td>-3.32267</td>
<td>±0.00971</td>
</tr>
</tbody>
</table>

4. Long-term Variations

The hourly gravity residuals obtained from the recordings of the two sensors after subtracting model tides, polar motion (amplitude factor 1.16) and applying a frequency-dependent barometric pressure correction (Figure 3) show a clear non-linear long-term trend of about 80 nm/s² for one year (calculated with Tschebyscheff polynomials within the tidal analysis). The difference between the residuals yields the deviation in the instrumental drift behaviour of the sensors. The resulting difference curve can be approximated by a linear curve with a gradient of 1.5 nm/s²/month. A physical explanation of this sensor divergence cannot be given yet. It must be mentioned that some intervention on the instrument was necessary during the first year resulting in gaps and several offsets in the gravity data that might explain at least part of the observed difference. It remains to be seen if the divergent behaviour continues when the instrument is undisturbed for a longer time span.

The common drift behaviour observed in the residuals can be traced back mainly to soil moisture and water table variations in the observatory area. Due to the location of the observatory in a valley a major part of the hydrological variations takes place above the gravimeter level leading to an apparent anticorrelation between gravity residuals and groundwater table changes (Figure 4) for periods below 3 months. For longer periods indications exist for a change into a correlation. The increase in the long-term trend around July 1999 e.g. is a result of hydrological effects. More details on the hydrological influence and its correction are reported in Kroner (2001).
5. Conclusions

From the first year of observation with a dual sphere superconducting gravimeter at Moxa observatory some relevant conclusions can already be drawn. A good correspondence between gravity residuals and Peterson’s ‘New Low Noise Model’ can be shown. The expected slightly higher noise contents of the upper sensor data is confirmed. There are indications for a somewhat different instrumental response of the two sensors to barometric pressure variations. In the long-term range a significant influence of hydrological variations on gravity can be detected. The removal of this influence from the gravity data will be one main task for the near future. The observed divergence in the drift behaviour of the sensors should be studied further. For this absolute gravity measurements would be helpful in order to determine what the real long-term gravity change at the observatory looks like.

Fig. 3. Gravity residuals and their difference.
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References