Comparison of noise levels of the new *i*Grav-007 superconducting gravimeter and the SG-065 superconducting gravimeter in Wuhan (China)

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Abstract

The new GWR *i*Grav® superconducting gravity meter is designed with the characteristics of an ultra-low drift, a virtually constant scale factor, and being less expensive, more portable and simpler to use than the traditional Observatory Superconducting Gravimeter. This paper aims to test the performance of the new *i*Grav-007 in Wuhan in terms of noise levels in the seismic band (2 min – 1 h), sub-seismic band (1 h to 6 h) and tidal band (above 6 h) with respect to the collocated SG-065 superconducting gravimeter. In the seismic band, based on the Seismic Noise Magnitude (SNM), 0.97 and 0.37 respectively, we see that the *i*Grav-007 is noisier than the SG-065; what's more, the Power Spectral Densities (PSD) curve of the *i*Grav-007 is slightly higher than that of the SG-065, with the maximum difference of 10 dB. Similar to the comparison in the seismic band, the *i*Grav-007 is also noisier than the SG-065 in the sub-seismic band in terms of the Sub-Seismic Noise Magnitude (SSNM), 1.96 and 1.86 respectively, and the slightly higher PSD curve of the *i*Grav-007, with the maximum difference of no more than 10 dB. Nevertheless, because of the small SNMs (below 1.0) and SSNMs (below 2.0), we can infer that both instrument-site combinations in Wuhan have low noise and a good quality in the seismic and sub-seismic bands. Furthermore, the above results in the seismic and sub-seismic bands have been confirmed by the comparison of the amplitude spectra between 0.2 and 1.7 mHz obtained from the residuals of the *i*Grav-007 and the SG-065 after the 2013/11/17 Mw=7.8 Scotia Sea earthquake and the background free oscillations of the Earth observed in both SGs records. In the tidal band, however, by using the ETERNA 3.4 Earth Tide Analysis program we find that the *i*Grav-007 performs slightly better due to the lower average noise amplitudes, especially in the 1 circle/day frequency band where the *i*Grav-007 is 3 times quieter than the SG-065. Nonetheless, the tidal parameters obtained from the two SGs are almost same, with the maximum discrepancies of 0.4‰ for amplitude factors and -0.03° for phase lags respectively, and match well with those given in the theoretical models; besides, the unfiltered residuals of both SGs are highly correlated. Given the above discussion in the tidal band, we imply that both SGs perform well and similar in this band, even though the noise levels are different. Additionally, the mechanical instability of the SG-065 revealed by the signal difference has been improved recently. Compared with the noise levels of the old C032, the two new SGs perform much better in all the above bands and even Wuhan can be regarded as one of the quietest sites in the GGP network for seismic and sub-seismic study at present. Knowledge of the noise levels of the new *i*Grav-007 and the SG-065 in Wuhan in the different frequency bands provides us with a necessary precondition and reference to make full use of these two SGs for the global and regional research.

Keywords: *i*Grav-007 superconducting gravimeter; SG-065 superconducting gravimeter; noise levels; Wuhan tidal station

1. Introduction

With an extremely high sensitivity, an extremely long-term stability, an extremely wide dynamic linearity measuring range and an extremely low noise level (Heping Sun et al., 1999; H. P. Sun et al., 2001), superconducting gravimeters (SGs) have been known to be the most precise and stable relative gravity meter in existence (Goodkind, 1991) and regarded as an important tool in the research fields of geophysics, geodynamics and geodesy. As one of the earliest SG stations in the world and the sole international tidal gravity fundamental station in China (Hsu & Sun, 1998), Wuhan SG station has accumulated a great many of tidal gravity observations since 1985. It is playing a very important role in both global and regional research projects, such as the Global Geodynamics Project (GGP), the Asia-Pacific Space Geodynamics Project (APSG) and the Crustal Movement Observation Network of China (CMONOC), which can contribute to the study of Earth tides, the nearly diurnal-free wobble and modes of the Earth's core, Earth's rotation and polar motion, interaction of the Earth with atmosphere and oceans, gravity changes due to tectonic motions, regional seasonal effect and seismic effect, seismic modes, and so on (Courtier et al., 2000; Crossley et al., 1999; Heping Sun & Xu, 1997). Until now a series of research successes have been achieved at Wuhan SG station, including the accurate determination of the Earth tidal parameters, the establishment of international tidal gravity references, the construction of synthetic tidal gravity signals, the retrieval of atmospheric and oceanic gravity signals and the determination of free core nutation parameters and so on (Heping Sun et al., 2002).

On 5 March 2013, the new GWR *i*Grav-007 superconducting gravity meter and the SG-065 superconducting gravimeter were installed at Wuhan SG station by Wuhan University and the Institute of Geodesy and Geophysics, Chinese Academy of Sciences, to replace the GWR C032 superconducting gravimeter (stopped on 29 July 2012). Both SGs operate under almost the same environmental conditions and the same processing procedure, about 20 m apart from each other. Designed to replace mechanical spring-type gravity meters with SGs for geophysical applications that require much higher stability and precision, the new GWR *i*Grav® superconducting gravity meter not only maintains the same operating features as the traditional Observatory Superconducting Gravimeter, but also has such superiorities as an ultra-low drift of less than 0.5 microgal / month and a virtually constant scale factor; it is also much less expensive, portable and much simpler to use (Warburton et al., 2010) (cf. Fig. 1). Till now we have few studies of the performances of the new *i*Grav meters, and this paper aims to test the performance of the *i*Grav-007 in terms of noise levels in the seismic (2 min to 1 h), sub-seismic (1 h to 6 h) and tidal bands compared with the SG-065, by using one-minute and one-hour decimated data spanning from 30 March 2013 till 31 December 2013.

Figure 1.Comparison between *i*Grav® and OSG. *i*Grav® system is much less complex than the Observatory SG shown on the right side.(Warburton et al., 2010)

2. Noise levels in the seismic (2 min to 1 h) and sub-seismic (1 h to 6 h) bands

Here we first compare the noise levels of the *i*Grav-007 and the SG-065 in the seismic band with the processing procedure proposed by Banka and Crossley (Banka, 1997; Banka & Crossley, 1999) and recommended by GGP (http://www.eas.slu.edu/GGP/ggphome.html). The concept of Seismic Noise Magnitude (SNM) similar to earthquake magnitude is introduced in this procedure to quantify and quickly compare the noise levels at seismic frequencies. Then, following almost the same procedure, the noise levels of both SGs in the sub-seismic band are also compared with respect to the term Sub-Seismic Noise Magnitude (SSNM) (Rosat & Hinderer, 2011; Rosat et al., 2004; Rosat et al., 2003) generalized from SNM. Based on this method, Rosat *et al* (Rosat et al., 2004; Rosat et al., 2003) have enabled the quantitative comparison of noise levels of GGP stations in these two bands. Knowledge of the noise levels at each station in the seismic and sub-seismic bands is significant for site selection, instrumental modifications, evaluation of the recent potential of SGs to contribute to seismic normal mode studies and the search for the Slichter mode, and combination of the SGs to determine global Earth parameters (Banka, 1997; Rosat et al., 2004; Rosat et al., 2003). We describe briefly the processing procedure for studying the noise levels in the seismic band as follows.

The one-minute interval raw gravity and pressure daily files of the *i*Grav-007 and the SG-065, spanning from 30 March 2013 till 31 December 2013, are assembled and calibrated in amplitude from volts to microgal and to mbar respectively. The pressure files should be fixed for spikes, gaps, and offsets to avoid transferring problems in the pressure into the gravity data. A synthetic elastic tide, based on a modern tidal potential (Tamura, 1987; Xi, 1989) or later with recent values for the elastic tidal Love numbers, is subtracted and the influence of the air pressure is reduced with an admittance factor of -3 nm/s^2 hPa^{-1}. In order to eliminate the instrument drift and any residual tidal signal, a best-fitting 9th degree polynomial is subtracted. Then we compute the RMS of the reduced gravity data for each of the days, and select the 5 quietest days with the lowest RMS. We take a FFT for the data in each of the 5 quietest days through windowing with the Hann window and padding the data with zeros to the (next+1) power of 2, and then compute the average of the 5 unnormalized amplitude spectra. According to the average FFT spectrum, we can plot the Power Spectral Densities (PSD) and compute the mean PSD in the period range 200-600 sec to acquire the SNM through the relation(Banka, 1997):

$$\mathrm{SNM}=\log_{10}\left(\text{mean PSD} / (\mathrm{nm/s^2})^2/\mathrm{Hz}\right)+0.5 \qquad (1)$$

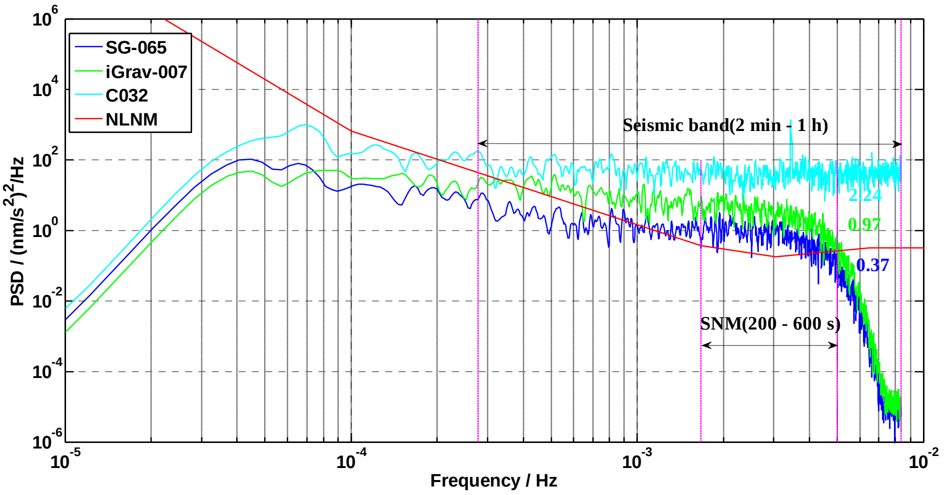

Figure 2.PSD noise levels in the seismic band for the *i*Grav-007, the SG-065 and the C032.

The SNMs for *i*Grav-007 and SG-065 are 0.97 and 0.37 respectively. Additionally, the SNM for the old C032 computed based on the one-min interval data spanning from 30 March 2011 till 31 December 2011, equals to 2.24, which is far beyond those for the *i*Grav-007 and the SG-065 indicating that these two new instrument-site combinations have much lower noise than the old one in the seismic band. The PSDs of them are shown in Figure 2**,** referring to the New Low Noise Model (NLNM) (Peterson, 1993) which is a reference noise model in seismology and represents the lower bound for the best seismometers. As a matter of fact, removing a 9th degree polynomial artificially decreases the PSDs at low frequencies, resulting in the lower PSD curve of the SG with respect to that of the seismometer; but in the period range 200-600 sec, the PSD curve of the SG is always higher than that of the seismometer. Based on the SNMs and Figure 2, we can conclude that *i*Grav-007 is slightly noisier than SG-065 in the seismic band with the maximum PSD difference of 10 dB, corresponding to a factor of 10 in power and a factor of about 3 in amplitude. Nonetheless, the SNMs for *i*Grav-007 and SG-065 are small (below 1.0) enough, indicating that both instrument-site combinations in Wuhan SG station have low noise and a good quality in the seismic band, and even now Wuhan is one of the quietest sites in the GGP network (cf. Fig. 3).

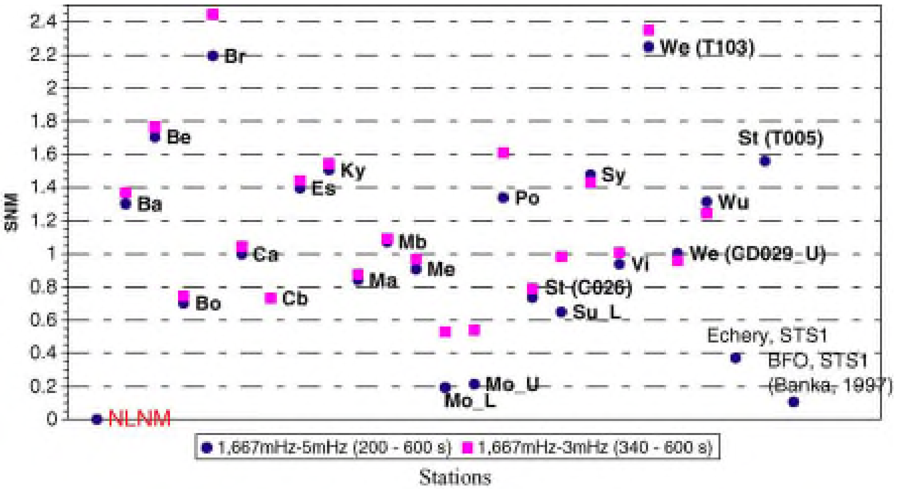

Figure 3.Seismic noise magnitudes in the frequency bands 200–600 s and 340–600 s for the 19 GGP stations. (Rosat et al., 2004).

Slightly different from the above mentioned processing procedure, we replace subtracting a 9th degree polynomial by high-pass filtering with a corner period of 8h; instead of computing the RMS for each day and selecting the 5 quietest days with the lowest RMS, we compute the RMS with a moving window of 15 days shifted by 1 day and then choose the quietest 15 continuous days with the lowest RMS (Rosat et al., 2004). In addition, the PSD is smoothed in the frequency domain with a 101-point Parzen window.

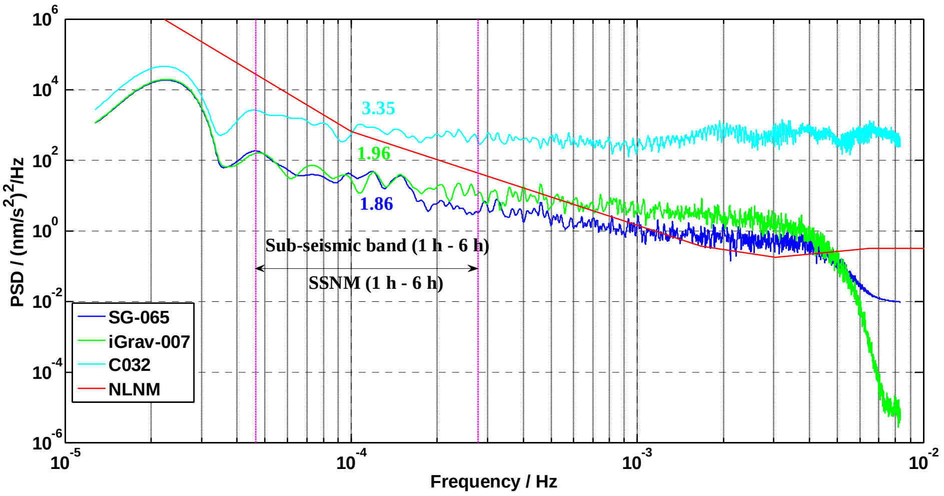

Figure 4.PSD noise levels in the sub-seismic band for the *i*Grav-007, the SG-065 and the C032.

The SSNMs for *i*Grav-007 and SG-065 are 1.96 and 1.86 respectively. We also give the SSNM (3.35) for the old C032 by using the one-min interval data spanning from 30 March 2011 till 31 December 2011; with respect to it, we imply that the performances of these two new SGs have been quite improved in the sub-seismic band. From Figure 4, the maximum difference between the PSDs of the *i*Grav-007 and the SG-065 in the sub-seismic band is no more than 10 dB, i.e., a factor of 10 in power and a factor of about 3 in amplitude. Similar to the comparison of noise levels of both SGs in the seismic band, the *i*Grav-007 is slightly noisier than the SG-065 in the sub-seismic band while both instrument-site combinations are not noisy in terms of the small

SSNMs (below 2.0) and even now Wuhan is one of the quietest sites in the GGP network (cf. Fig. 5). In fact, the results in this study are consistent with the conclusion that there exists high linear correlation between the noise levels in the seismic and sub-seismic frequency bands, and thus estimating the noise level in only the seismic frequency band would be sufficient(Rosat & Hinderer, 2011; Rosat et al., 2004). However, no conclusions can be drawn for other *i*Grav superconducting gravimeters, considering the slightly lower noise level of *i*Grav 001 in the seismic band compared to the OSG 061 operating at GWR (Warburton et al., 2010). In addition, due to almost the same environmental conditions and the same processing procedure for the two SGs in Wuhan, there is the possibility that the slightly higher noise levels of the *i*Grav-007 in the seismic and sub-seismic bands are due to instrumental effects. After reviewing the dewar operating conditions, the higher noise levels of the *i*Grav-007 in the seismic and sub-seismic bands can be to a large extent attributed to the operating conditions with only a simple damper inserted in the neck and could probably be reduced by inserting a 2 inch spacer below the coldhead (Richard Warburton 2014, private communication).

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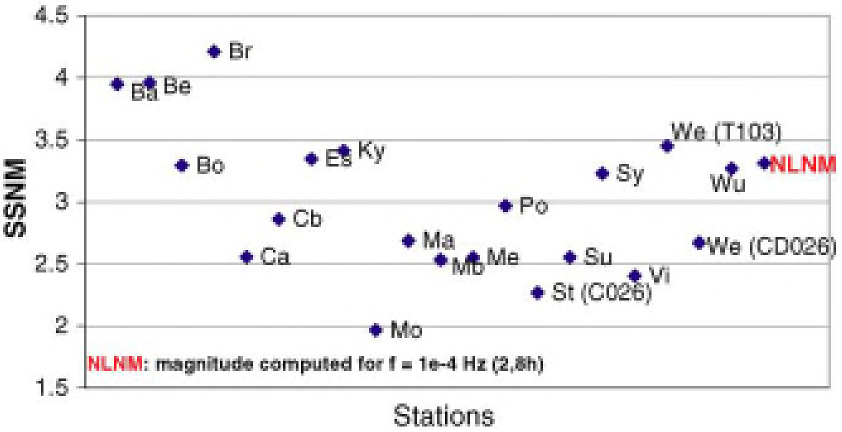

Figure 5.Sub-seismic noise magnitudes in the frequency band 1–6 h for the 19 GGP stations.(Rosat et al., 2004).

Furthermore, on the one hand, we have confirmed the above results by comparing the SNRs of the *i*Grav-007 and the SG-065 in the frequency band between 0.2 and 1.7 mHz (i.e. 83 and 10 min in period), where the ultra-low-frequency free modes of the Earth have their eigenfrequencies and are not excited to large amplitudes even by very large earthquakes (Freybourger et al., 1997; Richter et al., 1995). Figure 6 shows the amplitude spectra of the residuals (with the local tides and the barometric pressure effect subtracted by using tidal parameters and the barometric pressure admittance derived from tidal analysis) for time window from 5 to 85 h after the 2013/11/17 Mw=7.8 Scotia Sea earthquake. Obtained by parallel registration with AG measurements, the scale factors of the *i*Grav-007 and the SG-065 are -91.6402 +/- 0.0852 μGal/V and -92.3533 +/- 0.0854 μGal/V, equivalent to a precision of 0.093% and 0.092% respectively, which have been proved to be correct within the error bars considering the closeness of the analyzed tidal amplitudes of both SGs and the theoretical ones discussed in the section 3. Cleary, the SG-065 performs better in general and has slightly larger SNRs for most peaks ($_0S_4$, $_0S_5$, $_3S_1$, $_0S_6$, $_1S_4$, $_0S_7$, $_2S_4$, $_0S_8$, $_1S_6$, $_0S_9$, $_1S_7$, $_2S_6$) in this band. In addition, between 0.6 and 1.7 mHz, the strong similarities and the large SNRs of the two spectra imply that both SGs perform well and similarly for the study of the modes of the Earth in the seismic and even sub-seismic bands.

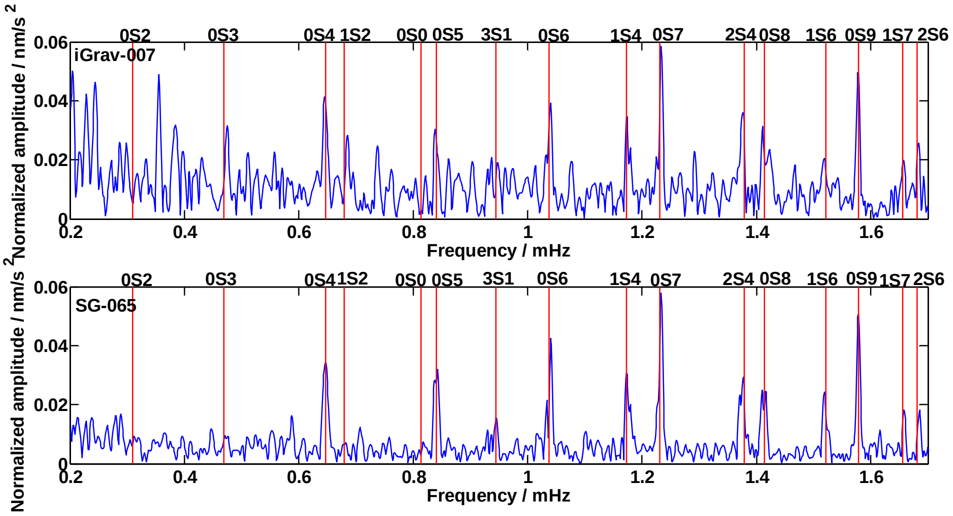

Figure 6.Amplitude spectra for time window from 5 to 85 h after the 2013/11/17 Mw=7.8 Scotia Sea earthquake obtained from the residuals of the *i*Grav-007 and the SG-065. Vertical red lines indicate theoretical eigenfrequencies for some modes from Earth Model PREM (Dziewonski & Anderson, 1981).

On the other hand, the background free oscillations of the Earth, which are commonly called ‘hum’ and provide a good reference for the evaluation of the noise level in the milliHertz band(Nawa et al., 2000), are observed in both SGs records and thus indicate they have low noise in the seismic and even sub-seismic bands. Following the method recommended in Nava et al. (2000), we removed the local synthetic tides and the pressure effect with an admittance of -3 nm/s^2 hPa^{-1} from the one-min interval data and computed power spectra for every seismically quiet period, which is defined as a 3-day-long interval not containing the day of or day immediately after any earthquakes with moment magnitude greater than 5.7 listed in the Harvard CMT catalogs; then, we stacked these power spectra to obtain the averaged power spectrum and smoothed it with an 11-point rolling average. Figure 7 shows the averaged power spectrum between 1 and 5 mHz for almost the same period in 2013 for the *i*Grav-007, the SG-065, for MO (Moxa, Germany) which is the quietest SG station in GGP and for ME (Metsähovi, Finland) where the background free oscillations were detected in 1995(Nawa et al., 2000). We can see the spectral peaks of the background free oscillations for both the *i*Grav-007 and the SG-065 data especially at frequencies between 3 and 5 mHz, though these peaks are slightly less clear for the *i*Grav-007. In contrast, the peaks are clearly visible at MO while less clear at ME. In addition, our results are consistent with the critical noise level, 10^{-17} m^2 s^{-3} or 10 (nm/s^2)^2 Hz^{-1}(Nawa et al., 2000), below which the background free oscillations can be identified easily.

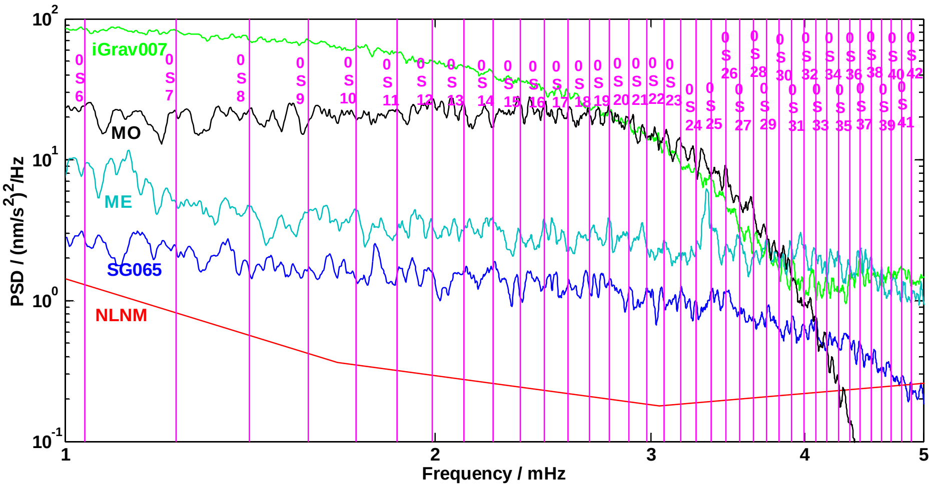

Figure 7.Averaged power spectra between 1 and 5 mHz (with logarithmic scale for both axes) for seismically quiet periods with a cutoff magnitude of 5.7 in 2013 for the *i*Grav-007, the SG-065, MO, and ME. Vertical magenta lines indicate theoretical eigenfrequencies for some modes from Earth Model PREM (Dziewonski & Anderson, 1981).

3. Noise levels in the tidal band (above 6 h)

In this part, the comparison of noise levels of the *i*Grav-007 and the SG-065 in the tidal band is also carried out by using the ETERNA 3.4 Earth Tide Analysis program (Wenzel, 1996). After numerical filtering and decimation from 1 s to 1 min, the data are preprocessed for gaps, spikes, steps and other disturbances with the TSoft software (Van Camp & Vauterin, 2005), and then decimated to the hourly data spanning from 31 March 2013 till 31 December 2013. By applying high-pass filtering, the tidal potential development of Tamura (1987) and a linear regression with air pressure, ETERNA 3.4 performs the tidal analysis on the hourly data of both SGs. Here it is worth to note that there is a gap between 2013/05/25 09:00:00 and 2013/05/27 17:00:00 in the data of the *i*Grav-007 and thus the whole data of the *i*Grav-007 have been separated into two sets, spanning from 2013/03/31 00:00:00 till 2013/05/25 08:00:00 and from 2013/05/27 18:00:00 till 2013/12/31 23:00:00 respectively.

The noise levels estimated from the Fourier spectral analysis of the *i*Grav-007 and the SG-065 residual records after tidal analysis with ETERNA are normalized by the number of samples and then listed in table 1. We can find that in all the tidal frequency bands the average noise amplitudes of the *i*Grav-007 are always lower than those of the SG-065, especially in the 1 cycle/day frequency band where a factor of 3 is obtained. In addition, we also list the average noise amplitudes of the old C032 hourly data spanning from 31 March 2011 till 31 December 2011, which are always much higher than those of the *i*Grav-007 and in general slightly higher than those of the SG-065 except for the 1 cycle/day frequency band. Table 2 shows the tidal parameters (amplitude factors δ and phase lags Δφ) and their Root-Mean-Square (RMS) errors for the four main tidal waves (O_1, K_1, M_2, S_2). For these tidal waves, the RMS errors of the amplitude factors and phase lags for the *i*Grav-007 are always smaller than those for the SG-065, with a ratio of nearly 3 for O_1, 4 for K_1, 1.5 for M_2 and nearly 2 for S_2. To be exact, the internal precision of the tidal analysis results obtained by the *i*Grav-007 is higher, at 0.12‰, 0.1‰, 0.04‰, 0.12‰ for the O_1, K_1, M_2 and S_2 waves, respectively; the determined average internal precision of the phase lags is also superior with ±0.0051°. In fact, the higher internal precision of the tidal parameters for the *i*Grav-007 is a consequence of smaller residual noise levels in table 1 (Freybourger et al., 1997).

Table 1.Estimates of noise levels in different tidal frequency bands normalized by the number of samples

Frequency band (cycles/day)	Noise level of *i*Grav-007 record (nm s^{-2})	Noise level of SG-065 record (nm s^{-2})	Noise level of C032 record (nm s^{-2})
1	0.031945	0.095074	0.068411
2	0.025210	0.038842	0.063672
3	0.012210	0.025697	0.024384
4	0.007420	0.014807	0.018439

Table 2.Results obtained by tidal analysis of the *i*Grav-007 hourly data and the SG-065 hourly data for main tidal waves

Wave group	*i*Grav-007		SG-065		Difference (*i*Grav- SG)	
	δ & RMS error	Δφ(°) & RMS error	δ	Δφ(°)	Δδ(x1000)	ΔΔφ(°)
O_1	1.17436 ±0.00012	-0.5009 ±0.0059	1.17416 ±0.00033	-0.5016 ±0.0162	+0.20	+0.0007
K_1	1.14842 ±0.00010	-0.5626 ±0.0052	1.14802 ±0.00040	-0.5529 ±0.0202	+0.40	-0.0097
M_2	1.17094 ±0.00004	-0.4724 ±0.0017	1.17092 ±0.00006	-0.4456 ±0.0027	+0.02	-0.0268
S_2	1.16509 ±0.00012	-0.6857 ±0.0077	1.16487 ±0.00020	-0.6549 ±0.0126	+0.22	-0.0308

From the last two columns in table 2, we can conclude that the calibrations of both instruments agree within 0.4‰ in amplitude and 0.03° in phase. Meanwhile, the tidal parameters of the *i*Grav-007 and the SG-065 match well with those given in the theoretical model □ (Dehant (1997) model (Dehant et al., 1997)+ TOPEX/POSEIDON satellite altimetry ocean data) and in the theoretical model □ (Dehant (1997) model (Dehant et al., 1997)+ Schwiderski global ocean data + local Chinese data) mentioned by Xu *et al* (Xu et al., 2000); the averaged discrepancies between observed tidal amplitude factors and those given in the theoretical models □ and □ are 3.8‰ and 3.0‰ (*i*Grav-007), 3.9‰ and 3.2‰ (SG-065) respectively; the mean differences between observed phase lags and those given in the theoretical models □ and □ are 0.104° and 0.223° (*i*Grav-007), 0.093° and 0.207°(SG-065) respectively.

Furthermore, a correlation analysis of the unfiltered residuals of both SGs is carried out for the two periods (2013/03/31 00:00:00 – 2013/05/25 08:00:00 and 2013/05/27 18:00:00 – 2013/12/31 23:00:00) respectively. The unfiltered residuals are obtained by subtracting synthetic tides, air pressure effect (using adjusted tidal parameters and air pressure regression parameters derived from the above mentioned tidal analysis) and polar motion effect from the hourly data (Figure 8). It is worth to note that, in order to observe the correlation between the two data sets more easily, this figure is obtained by offsetting both records (so that they start close to zero and are close to overlapping-but not quite) and then expanding the scale. The correlation coefficients for the two periods are very high, with 0.9871 and 0.9106 respectively. It reflects the fact that there are still common signals such as an installation drift during the 100 first registration days, unmodelled gravity signals from the Earth(especially the long period wave Mf), atmosphere and hydrosphere in both SGs observations (Richter et al., 1995). Given to the small discrepancies for tidal parameters and the high correlation coefficients between both SGs residuals, we can infer that both SGs perform well and similar in the tidal band, even though the noise levels are different.

However, the individual residuals are not matching well at certain areas and many of the problems with SG-065 can be seen either on its residual or more easily on the signal difference between SG-065 and *i*Grav-007 (cf. Figure 8 and 9). The signal difference shows that apart from the relative drift between these two SGs and concrete identified events in the auxiliary data, there are some other disturbances which appear mainly on SG-065, such as the offset marked by the red circle in Figure 9. Recently, further experiments and analysis conducted by the GWR team (including closing compressor, tilt desensitizing, purging coldhead, cleaning neck, interchanging the electronics between the X and Y axis, field servicing of X and Y axis thrusters, greasing all three post slides and so on) have revealed that we could associate many of these disturbances to the mechanical instability of Tilt X and Y thermal levelers of the SG-065 caused by small temperature changes. Meanwhile, the mechanical instability of SG-065 has been improved, which will be useful for lowering its noise level in the tidal band.

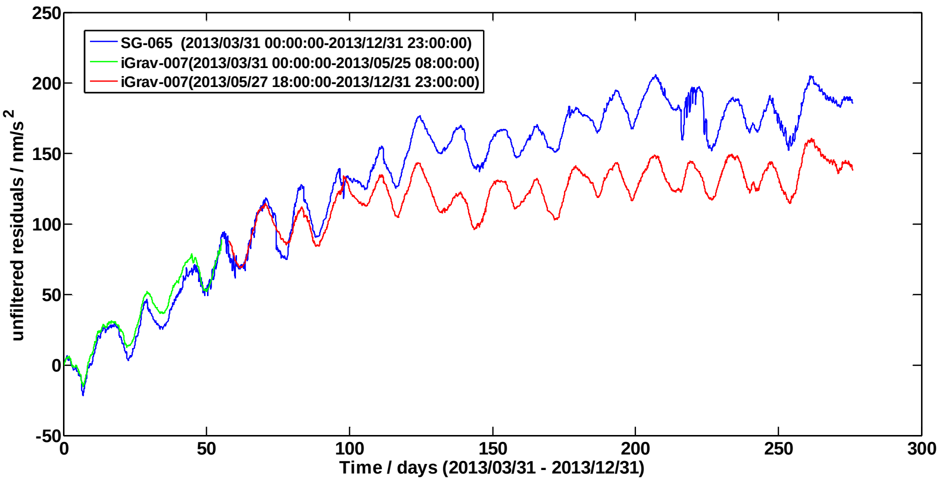

Figure 8.Residual curves of tidal records from the *i*Grav-007 and the SG-065 with tides, air pressure effect and polar motion effect subtracted

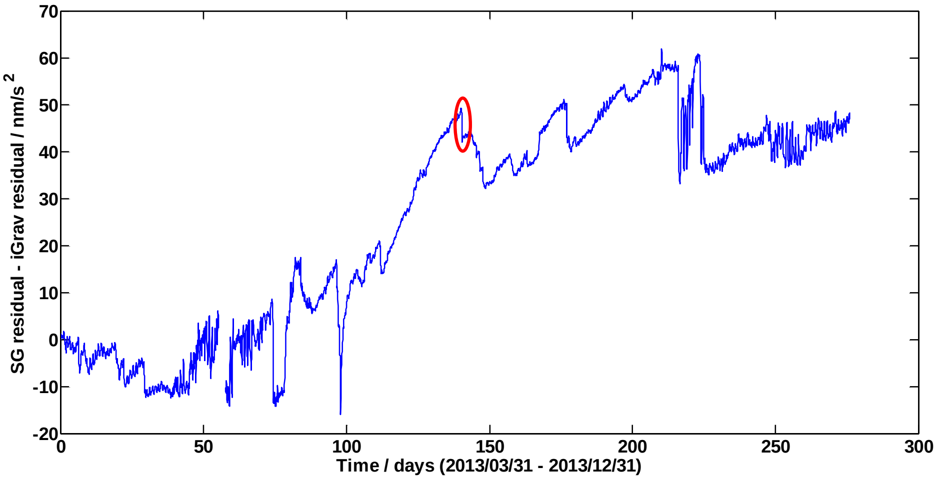

Figure 9.The difference between the SG-065 and the *i*Grav-007 residuals (i.e. SG-065 residual – *i*Grav-007 residual). An offset is marked by the red circle.

4. Conclusions

We have investigated the performance of the new *i*Grav-007 superconducting gravimeter in Wuhan in terms of noise levels in the seismic band (2 min – 1 h), sub-seismic band (1 h to 6 h) and tidal band (above 6 h) by comparing with the SG-065 superconducting gravimeter.

In the seismic and sub-seismic bands, the *i*Grav-007 is noisier than the SG-065, with the maximum PSD difference of 10 dB, corresponding to a factor of 10 in power and a factor of 3 in amplitude. Given the small SNMs (0.966 and 0.366) and SSNMs (1.9604 and 1.8631), we can infer that both instrument-site combinations in Wuhan have low noise and a good quality in these two bands. Moreover, we confirm the conclusion in these two bands by comparing the amplitude spectra between 0.2 and 1.7 mHz obtained from the residuals of the *i*Grav-007 and the SG-065 after the 2013/11/17 Mw=7.8 Scotia Sea earthquake, and by the background free oscillations of the Earth observed in both SGs records especially at frequencies above 3 mHz. Thus both SGs are suitable for the geophysical research such as seismic normal mode and Slichter mode. Additionally, the higher noise levels of the *i*Grav-007 in the seismic and sub-seismic bands are to a large extent attributed to the operating conditions only with a damper inserted in the neck and are probably to be lowered by inserting a 2 inch spacer below the coldhead.

In the tidal band, the *i*Grav-007 performs slightly better with respect to the lower average noise amplitudes, especially in the 1 circle/day frequency band where the *i*Grav-007 is 3 times quieter than the SG-065, which contributes to the higher accuracy of the tidal parameters. However, the tidal parameters obtained by tidal analysis of the *i*Grav-007 record are to a large extent in good agreement with those of the SG-065 record, and match well with those given in the theoretical models. In addition, the unfiltered residuals of both SGs are highly correlated, which reflects that there are still common signals such as unmodelled gravity signals from the Earth, atmosphere and hydrosphere in both SGs observations. As a result, we imply that both SGs perform well and similarly in the tidal band, and thus can collaborate with or refer to each other for the studies of

Earth tides, the validation of solid Earth and ocean tidal models (Baker & Bos, 2003; Boy et al., 2003) and so on. In addition, further investigation of the individual residuals and the signal difference revealed the mechanical instability of the SG-065 and hopefully the recent improvement of the operation of the SG-065 will contribute to lowering its noise level in the tidal band.

Here, it is worthy to note that, due to almost the same environmental conditions and the same processing procedure, the differences between the noise levels in each band for the two SGs should be of instrumental origin mainly.

In addition, compared with the noise levels of the old C032, we can conclude that the two new SGs in Wuhan perform much better in all the above bands; specially, in both the seismic and sub-seismic bands, Wuhan can be regarded as one of the quietest sites in the GGP network at present. Knowledge of the noise levels of the new *i*Grav-007 and the SG-065 in Wuhan in the different frequency bands provides us with a necessary precondition and reference to make full use of these two SGs for the global and regional research, such as the Global Geodynamics Project (GGP), the Asia-Pacific Space Geodynamics Project (APSG) and the Crustal Movement Observation Network of China (CMONOC).

Acknowledgments

The authors are grateful to the GWR team (Mr Richard Warburton, Mr Richard Reineman and Mr Harish Pillai) for helping analyze some of data sets. This work was jointly supported by the National Basic Research Program of China (Grant No. 2014CB845902）, and the National Natural Science Foundation of China (Grant Nos. 41274085, 41374084, 41321063).

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