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Pre-seismic gravity anomalies before Linkou *M*s6.4 earthquake by continuous gravity observation of Crustal Movement Observation Network of China

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ABSTRACT

A *M*s6.4 earthquake occurred at Linkou country, Heilongjiang Province (44.8°N, 129.9°E) on January 2, 2016 at a depth of 580 km. Pre-seismic gravity anomalies obtained at a 1 Hz sampling rate from Crustal Movement Observation Network of China (CMONOC) are analyzed after the earthquake. The results show that: (1) different from previous studies, both pre-seismic amplitude perturbation and co-seismic amplitude perturbation are not critical inversely proportional to epicentral distance; (2) unlike shallow earthquake, the pre-seismic and co-seismic amplitude perturbation of gravity illustrate synchronous spatial variation characters with decrease of epicentral distance for Linkou earthquake. This may because Linkou earthquake is a deep earthquake and occurred in Pacific Plate subduction zone; (3) compared to basement and semi-basement, cave can provide a better observation environment for gPhone gravimeter to detect pre-seismic gravity anomalies.

1. Introduction

Tremors with gradually increasing and decreasing amplitudes are often found in the wave form, when tide and trend signals are removed from the continuous gravity records. Some of the tremors are caused by typhoons, and the source of some tremors can be linked to earthquakes both temporally and spatially [1–7]. Neibauer et al. [8] compared the observation of Kuril islands *M*s8.2 earthquake by 5 gPhone gravimeters in Colorado. The results show that the responses of this 5 gPhone to the earthquake are almost unanimous, and gPhone can also detect earthquake ground motion like superconducting gravimeter and seismograph [8]. This demonstrates that gPhone gravimeter has good stability and can be used in the research of earthquake monitoring. Crustal Movement Observation Network of China (CMONOC) has build 30 continuous gravity observation stations in China mainland using the latest generation gPhone gravimeter produced by Micro-g LaCoste Company. For gPhone, the accuracy for long-term observation is better than 1×10^{-8} ms^{-2}, and its resolution can reach to 0.1×10^{-8} ms^{-2}. A large number of high-precision second sampling continuous gravity observation data has accumulated since 2012.

Studies have shown that the pre-seismic amplitude perturbation of gravity is inversely proportional to epicentral distance [1]. There is a *M*s6.4 earthquake happened at a depth of 580 km in Linkou country (44.8°N, 129.9°E), Heilongjiang Province on January 2, 2016. 10 days continuous gravity data of CMONOC was analyzed before the earthquake. We found that both the pre-seismic amplitude perturbation and co-seismic amplitude perturbation of gravity are not critical inversely proportional to distance between gravity stations and the epicenter. This phenomenon is different from the previous study results. Furthermore, unlike shallow earthquake, there display a good synchronization in spatial variation characters between the pre-seismic amplitude perturbation and co-seismic amplitude perturbation of gravity for Linkou earthquake. In order to strengthen the focal signals, all the units

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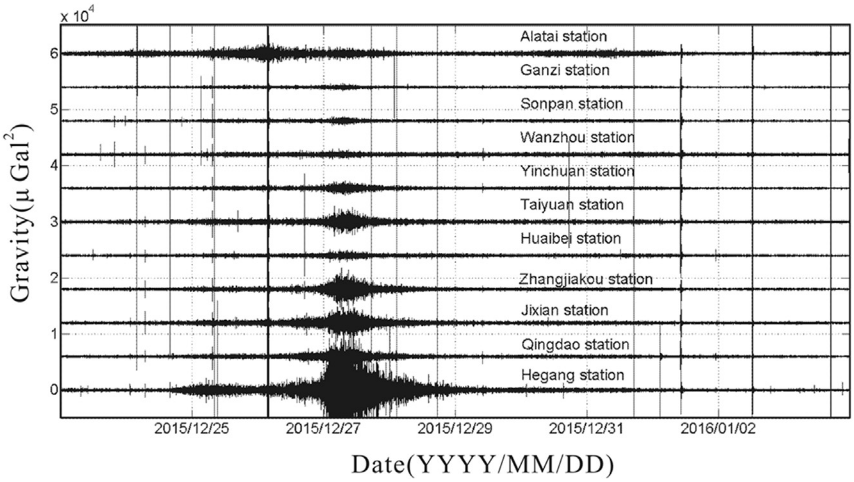

Fig. 1. The pre-seismic gravity anomaly signal before Linkou *Ms*6.4 earthquake recorded by CMONOC continuous gravity observations.

(uGal) of gravity anomalies and amplitude perturbation in this paper are replaced by uGal^2.

2. Data and results

2.1. Data

Pre-seismic gravity anomaly often happened within 10 days before strong earthquake. Their dominated frequency is between 0.125 and 0.25 Hz (4–8 s). Gravity data recorded by 25 continuous gravity stations of CMONOC from December 23, 2015 to January 3, 2016 were analyzed, which have integral data records.

2.2. Pre-seismic gravity anomalies

Gravity signal with period of 4–8 s were obtained after we adopted Butterworth band-pass filter to the original second sampling rate gravity data. In order to highlight the gravity anomaly characters, we multiplied the filtered signal amplitude by its absolute value. There were 11 out of 25 stations detected the pre-seismic gravity anomalies about six days before Linkou earthquake. The maximum amplitude happened on December 27, as shown in Fig. 1.

We squared the amplitude of pre-seismic gravity anomaly signal recorded by 11 stations, and then calculated its average value per minute. Finally, the maximum value of the minute-average value was obtained. In order to study the relationship between pre-seismic amplitude perturbation and co-seismic amplitude perturbation of gravity, same process above were used to the co-seismic gravity effects. The results are shown in Table 1.

We can see that both the pre-seismic amplitude perturbation and co-seismic amplitude perturbation of gravity are not critical inversely proportional to distance between the epicenter and stations form Table 1, different form previous study [1]. The pre-seismic amplitude perturbation and co-seismic amplitude perturbation of gravity is plotted together. As Hegang station has minimum epicentral distance, and its pre-seismic amplitude perturbation and co-seismic amplitude perturbation are far greater than others, it was not plotted in Figs. 2 and 3, in order to highlight the characters of other stations. However, this approach does not affect the analysis of spatial variation characters of amplitude. Comparing Figs. 2 and 3 we can see that, the pre-seismic amplitude perturbation and co-seismic amplitude perturbation illustrate synchronous spatial variation characters with decrease of epicentral distance except for Jixian station.

Pre-seismic gravity anomalies also were detected before Yutian *Ms*7.3 earthquake which happened on February 12, 2014 [7]. Same processes were used to the pre-seismic amplitude perturbation and co-seismic amplitude perturbation of gravity for Yutian earthquake, as used in Linkou earthquake above. The results are shown in Table 2 and Fig. 4 respectively.

Here, Ruoqiang station was not included in Fig. 4 in order to highlight the characters of others stations. It also does not affect the analysis of spatial variation characters of amplitude as Ruoqiang station has minimum epicentral distance, maximum pre-seismic amplitude perturbation and co-seismic amplitude perturbation. Meanwhile, the co-seismic amplitude perturbation of Songpan station was not plotted as its value was so large to display in Fig. 4.

It can be seen from Table 2 and Fig. 4 that both the pre-seismic amplitude perturbation and co-seismic amplitude perturbation of

Table 1
The pre-seismic amplitude perturbation and co-seismic amplitude perturbation of gravity for Linkou *Ms*6.4 earthquake.

Station numbers	Station names	Epicentral distance (Km)	Pre-seismic amplitude perturbation (uGal^2)	Co-seismic amplitude perturbation (uGal^2)
0	Alatai	4612	98.6	167.2
1	Ganzi	3598	43.2	53.9
2	Songpan	3200	57.9	85.0
3	Wanzhou	2820	60.1	129.6
4	Yinchuan	2776	101.1	182.5
5	Taiyuan	2062	191.6	280.6
6	Huaibei	1874	69.8	137.1
7	Zhangjiakou	1760	264.1	442.1
8	Jixian	1461	227.3	705.9
9	Qingdao	1402	179.9	153.2
10	Hegang	264	947.6	11,841.0

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