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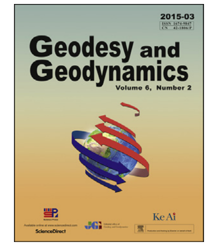

Gravity anomaly before the Leshan M5.0 earthquake?☆

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A B S T R A C T

The North–South Seismic Belt was analyzed using gravity observation data from 2011 to 2015, and the nontidal analysis results show that there was a nonlinear gravity change at both the Chengdu and Guza seismostations one month before the Leshan M5.0 earthquake.

1. Introduction

Leshan M5.0 earthquake (On Jan.14, 2015; 29.3°N, 103.2°E; focal depth 14 m) is the first earthquake at the middle of the Mabin–Yanjin fracture since 2012. The analysis of this event is useful for predicting larger earthquakes [1].

Gravity anomalies can be observed before large earthquakes occur; these are captured in regional gravity networks

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and have been analyzed and discussed in several studies [2–4]. In this study, the relationship between the epicenter of the Leshan M5.0 earthquake and the gravity field variation is discussed using data from a mobile gravity network. Furthermore, the nonlinear gravity change characteristics are determined from residual gravity from the continuous gravity observations for an area extending up to 100–200 km from the epicenter of the Leshan M5.0 earthquake.

2. Processing of gravity dataset and results

2.1. *Mobile gravity network*

To monitor earthquake activity in the eastern margin of Tibet, a mobile gravity network (Fig. 1,with 10 absolute gravity control points) has been installed by the China Earthquake Administration; this network is checked twice a year.

LCR-G and CG5 is being used in the mobile gravity network. The observation accuracy is (10–20) $\times$ 10^{-8} ms^{-2}. The data process software was LGADJ [5–7].Absolute gravity control points are used to combine different regional survey data. Based on excellent research results obtained in recent years, the dynamic images of the gravity field are developed using the Kriging method at irregular regions. Using a low-pass distance weighting matrix filter, the accidental error caused by local anomalies and the shallow crust can be eliminated and the signal caused by the deep crust and local region can be highlighted.

2.2. *Continuous gravity network*

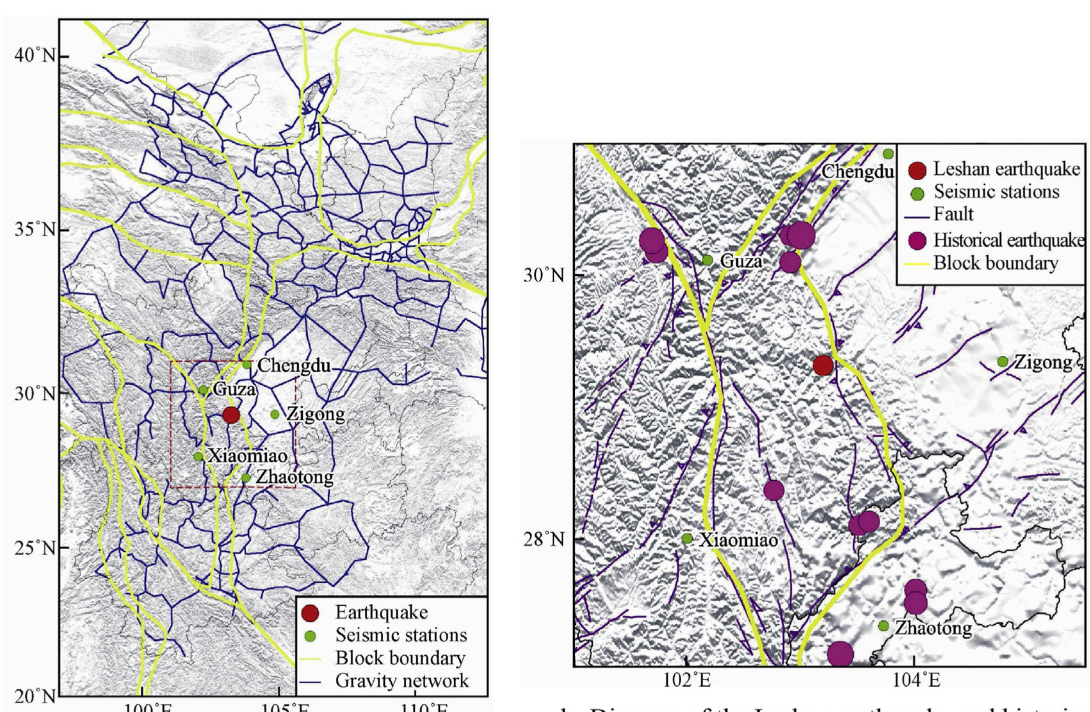
To combine with data from the mobile gravity observation network, which has a spatial resolution of about 40 km, a continuous gravity observation network was also constructed with five continuous gravimeters around about 200 km from the Leshan earthquake's epicenter. The status of the instruments and their epicentral distances are presented in Table 1. The continuous gravity network in this area has a spatial resolution of 150–200 km.

2.3. *Gravity anomalies from mobile gravity networks*

There are about 60 $\times$ 10^{-8} ms^{-2} gravity gradients(Fig. 2) at the annual scale and about 200 $\times$ 10^{-8} ms^{-2} gravity gradients from the accumulation dynamic image of the gravity field at the region between the Xianshuihe–Anninghe–Zemuhe fault and the Mabian–Yanjing fault M6.0 earthquakes have occasionally occurred in this area [8,9].

2.4. *Gravity anomaly from continuous gravity network*

Data from the five continuous gravimeters(Fig. 1b) were analyzed using the nontidal method. All the gravimeters observed a coseismic gravity change [10,11], and Chengdu and Guza, in the Sanchakou area south of the Xianshuihe and Longmenshan faults, showed a nonlinear gravity change one month before the occurrence of the earthquake (Fig. 3). The data of Zigong, located in the Sichuan basin, showed repeated increases and decreases in the noise level



a-Gravimetric network.

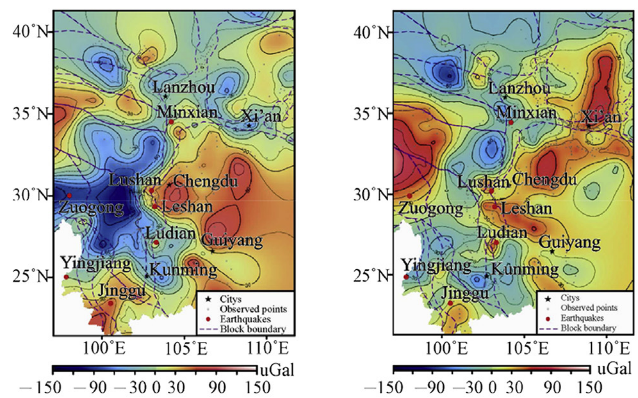
b- Diagram of the Leshan earthquake and historical earthquake in Fig. 1a's red dot line region.

Fig. 1 – Gravimetric network.

Table 1 – Continuous gravity observations around the Leshan M5.0 earthquake (see the appendices).

Stations	Equipment type	Sample rate	Epicentral distance (km)	Period of data
Chengdu	GS15	Minute	187.1	Sep. 27, 2007–Jan. 14, 2015
Guza	DZW	Second	134.1	Feb. 28, 2014–Jan. 14, 2015
Xiaomiao	DZW	Second	181.9	May 23, 2014–Jan. 14, 2015
Zigong	gPhone	Second	151.5	May 22, 2014–Jan. 14, 2015
Zhaotong	GS15	Minute	225.9	Sep. 27, 2007–Jan. 14, 2015

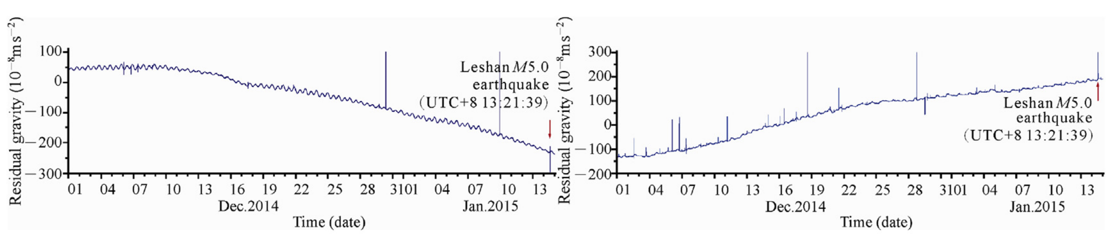
Note: Zigong, Guza, and Xichang seismic observation data are available from 2014 because the background field exploration project began operation in 2014; the observations are for less than one year. Chengdu and Zhaotong continuous gravity observation data are available since 2007.



a- Different gravity change from October 2013 to October 2014

b– Accumulated gravity changes between October 2010 and October 2014

Fig. 2 – Different and accumulated gravity change at North-South Seismic Belt's region.



a- Residual gravity time serial of Chengdu.

b- Residual gravity time serial of Guza.

Fig. 3 – Gravity residual serial of the Chengdu and Guza seismostations.

one month before the earthquake (Fig. 4). However, similar characteristics were not observed at Xiaomiao at the Anninghe–Zemuhe Fault (Fig. 5).

2.4.1. Continuous gravimeter observations for the Sanchakou area

One month before the earthquake, on Dec. 17, 2014, there was a nonlinear gravity change between the GS15 at the Chengdu seismostation and the DZW at the Guza seismostation. In addition, the nonlinear gravity change between the two gravimeters showed some difference. The nonlinear gravity change at Guza changed from -108×10^{-8} ms^{-2} to 98×10^{-8} ms^{-2} for 14 days, from Dec. 7 to Dec. 21, 2014 (Fig. 3b). However, the change at Chengdu can be split into two steps. The first step occurred on Dec. 7, 2014 after which the gravity change decreased slowly; the second step occurred on Dec. 17, 2014. After the local unknown earthquake, the gravity change decreased rapidly (Fig. 3a).

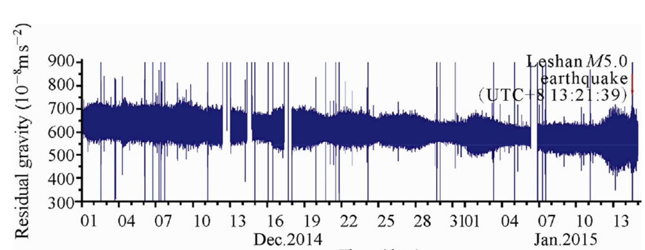
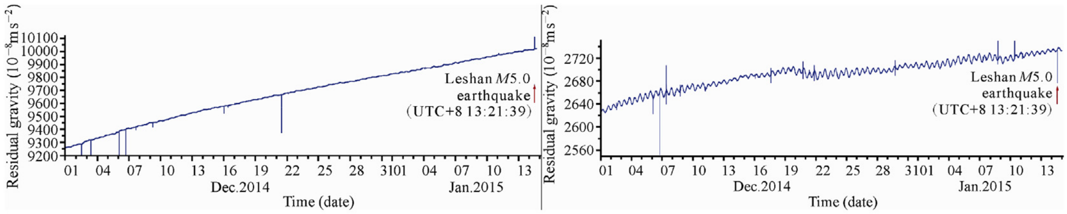


Fig. 4 – Gravity residual serial of the Zigong gPhone.



a-Xiaomiao b-Zhaotong

Fig. 5 – Gravity residual serial of the Xiaomiao and Zhaotong seismostations.

2.4.2. Continuous gravimeter observations for the Sichuan basin

The noise level of the gravity residual change is about $\pm 50 \times 10^{-8}$ ms^{-2}. Furthermore, since Dec.13,2014, the noise level of the residual gravity change increased and decreased repeatedly [12–14]. Before the Leshan *M*5.0 earthquake, the noise level became larger than before at about $\pm 150 \times 10^{-8}$ ms^{-2} (Fig. 4).

2.4.3. Continuous gravimeter observations for the Anninghe–Zemuhe fault

The residual gravity change at Xichang does not show any nonlinear processes (Fig. 5a). The residual gravity change at Zhaotong within an epicentral distance of about 225 km from the earthquake shows the same nonlinear gravity change on Dec. 20, 2014 and Jan. 9, 2015 (Fig. 5b).

The results of analysis of the mobile gravity network and the continuous gravity network show that the middle of the Mabin–Yanjin fracture where the Leshan *M*5.0 earthquake occurred was a high gravity gradient region since 2012. In addition, there were nonlinear gravity changes at the Chengdu and Guza seismostations one month prior to the occurrence of the earthquake. Data from Zigong show a noise level of more than approximately 150×10^{-8} ms^{-2} before the earthquake.

3. Discussion

Since 2012, there have been 13 earthquakes with magnitude over 5.0 in the Sanchakou area and at the Anninghe–Zemuhe Fault. The location of the Leshan *M*5.0 earthquake has not shown earthquake activity over the last two years. However, the results of analysis of the mobile gravity observation network and the continuous gravity observation network show that the Leshan *M*5.0 earthquake occurred in an approximate 160×10^{-8} ms^{-2} gravity gradient [15,16] region with a cumulative gravity change from 2010 to 2014 and in an approximate 60×10^{-8} ms^{-2} gravity gradient region with an annual scale gravity change from 2013 to 2014 [17,18]. Continuous gravity observations showed short-term nonlinear drift one month before the occurrence of the Leshan *M*5.0 earthquake. The *M*5.0 earthquake by itself cannot explain the changes in the gravity anomaly data. Therefore, to track and predict larger earthquakes in this region and its adjacent areas, all the other data also need to be processed and analyzed.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.geog.2015.02.001.

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