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Temporal gravity changes before the 2008 Yutian *Ms*7.3 earthquake

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Abstract: Based on the data of the repeated gravity observation network in Chinese mainland since 1998, we analyzed the temporal changes of regional gravity field before the 2008 Yutian *Ms*7.3 earthquake. The result shows some mid-to-long term (two to ten years) changes during the earthquake's preparation. Notable features are a gravity increase lasting several years and a relatively large-scaled gradient zone of gravity change, the former indicating a continuous energy accumulation and the latter a possible location of seismic rupture. These gravity changes showed a trend of increase-accelerated increase-decelerated increase, similar to that of the Tangshan *Ms*7.8 earthquake in 1976. The maximum accumulated gravity change related to the earthquake reached 200×10^{-8} ms^{-2}.

Key words: Yutian earthquake; gravimetry; dynamic change; seismogeny

1 Introduction

Temporal changes of gravity field, whether measured on ground surface or in space, are mainly caused by position change of observation points, overall surface deformation (mainly vertical-displacement), and density and deformation changes caused by tectonic movement in earth's interior[1]. Since seismogenic process is part of crustal-movement process, which may involve gravity changes, it may be possible to catch some precursor information by carefully analyzing gravity changes. This is our motive focusing gravity method to study earthquake mechanism and prediction.

Since the 1920s, certain credible data of earthquake-related gravity changes have been obtained for such earthquakes, as Niigata, Japan, 1964[2]; the Alaska, 1964[3]; Matsushiro swarm, Japan, 1965 - 1967[4]; Inangahua, New Zealand, 1968[5]; San Fernando, USA, 1971[6]; Haicheng in 1975 and Tangshan in 1976[7-9]; Lijiang, Yunnan, 1996[10]; and Wenchuan, 2008[11]. In the case of Tangshan, Li[9] used 34 repeated survey data and found an obvious pattern of increase-decrease-earthquake-recovery in gravity change before and after the earthquake. He also gave an explanation of this pattern based on earthquake mechanism.

Other useful models for earthquake-related gravity changes have been proposed, including migration of deformation and mass[7], dilatancy[12], dislocation[13] and coupled movement[1,14,15].

The Yutian *Ms*7.3 earthquake occurred in Xinjiang China on March 21, 2008 with epicenter located at 35.60°N, 81.6°E and a focal depth of 19 km. It occurred in the west about 1000 km away from the Kunlun Mountain Pass *Ms*8.1 earthquake on November

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14, 2001, which was very influential on strong-earthquake occurrence in China's continent. The success of mid-term prediction of this earthquake based on gravity changes[16] showed the potential of using gravity means in large-earthquake prediction. In this paper, we report on the characteristics of gravity changes during the preparation process of the Yutian earthquake, in order to examine possible use of gravity signals for earthquake prediction.

2 Regional gravity-field changes before the Yutian earthquake

2.1 The earthquake

The epicentral region of this earthquake is a plateau over 4700 m high in the West Kunlun Mountains, about 110 km away from the town of Yutian and about 215 km from Hetian city. It is the main shock of an earthquake series that included a *M*s6.1 aftershock, 18 aftershocks between 5.0 and 5.9, and many more smaller ones. It shook the Yutian and Cele areas strongly and was felt in a wider area of Hetian.

The earthquake was located at the intersection of the West Kunlun seismic zone and the Altun seismic zone, which is the southern margin of Tarim Basin, near the southwestern end of the Altun NE trending fracture zone and adjoining edge of the West Kunlun Mountains. Developed near the epicenter are thrust faults to the south in nearly EW-strike direction and left-slip faults to the east. This area is transitional between the Qinghai-Tibetan block and the western region block, including three secondary blocks of Bayan Har, Eastern Kunlun and Tarim, two active boundary zones of the front of West Kunlun and Altun mountains. Shallow earthquakes occurred basically along the active faults, mainly strike-slip, developed in the active boundary zones[17].

This was the largest earthquake since the *M*s8.1 West of Kunlun Mountain Pass earthquake in 2001, and it broke a 6-year seismic quiescence of no earthquake larger than *M*s7.0. It may be an signaling earthquake of the Wenchuan *M*s8.0 earthquake on May 12, 2008 that followed less than two months later in Sichuan province and away from about 2000 km. The occurrence of these three earthquakes may indicate that a seismically active period has arrived in Chinese continent.

2.2 Data and data-process results

We used data from the gravity networks in Chinese continent[18], including four surveys (1998, 2000, 2002, 2005) of the Crustal Movement Network of China and one survey (2007) of the Digital Earthquake Observation Network of China. Absolute gravity was measured with an FG5 absolute gravimeter produced by Micro-g with an precision exceeding $5 \times 10^{-8}\ ms^{-2}$, and relative gravity was measured generally with a LCR-G relative gravimeter and partly with a CG5 relative gravimeter produced by SINTRIX, with a precision exceeding $15 \times 10^{-8}\ ms^{-2}$. By synthesizing both sets of data, we obtained pre-earthquake gravity field changes at an interval of 2 – 3 years since 1998. The precision of point value was found to be between 11×10^{-8} and $16 \times 10^{-8} ms^{-2}$ in each survey, and about $20 \times 10^{-8}\ ms^{-2}$ for gravity change between surveys. Previous research had shown that such gravity data could reflect basic characteristics of gravity evolution on a relatively large spatial scale[18].

To study this earthquake, we used only data west of 90°E. Figure 1 shows the distribution of observation lines, epicenters of *M*s≥7.0 earthquakes (solid dots) from 1998 to 2008, and fault structures based on data of MapSIS.

We plotted the data in two different ways, differential changes between two consecutive surveys (Fig. 2) and cumulative changes since 1998 (Fig. 3). The former may highlight information of differential changes and the latter the cumulative changes.

2.3 Gravity changes between consecutive surveys

From 1998 to 2000, a small positive change of less than $20 \times 10^{-8}\ ms^{-2}$ appeared in the northern epicenter region, and some small negative changes of generally less than $40 \times 10^{-8}\ ms^{-2}$ but locally as much as $60 \times 10^{-8}\ ms^{-2}$ appeared in the southern and eastern region (Fig. 2). Yutian was located in a gravity-change gradient zone developed near the southward contour-bending area. The *M*s8.1 West of Kunlun Mountain Pass