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"Double low-points" anomaly in daily variation of vertical component of geomagnetic field before the M_S8.0 Wenchuan earthquake*

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Abstract The "double low-points" anomaly in daily variation of vertical geomagnetic component was observed on May 9, 2008 at 13 geomagnetic observatories belonging to the geomagnetic observatory network center of China Earthquake Administration. These observatories distribute roughly on three belts with the intersection in western Sichuan. On May 12, three days after the anomaly appearance, the great M_S8.0 Wenchuan earthquake occurred. The "double low-points" anomaly in daily variation of vertical geomagnetic component is an anomalous phenomenon of regional geomagnetism, which does exist objectively. The possible cause is the change of extrinsic eddy current system resulting in geomagnetic daily quiet variation (S_q), or the delay of several hours between the intrinsic and the extrinsic eddy current systems. The relationship between the "double low-points" anomaly of daily geomagnetic variation and the earthquake reveals that the former possibly reflects the accelerative alteration of earthquake gestation in the deep Earth.

Key words: Wenchuan earthquake; geomagnetism; vertical component; double low-points

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1 Introduction

As early as the 1980s, Ding et al (1989) summarized the method for predicting earthquake by using "low-point displacement" and "double low-points" anomaly in daily variation of vertical geomagnetic component, which was considered as a better method for the short-term and imminent earthquake prediction. After the great M_S8.0 Wenchuan earthquake occurred in Sichuan on May 12 in 2008, the authors examined the daily variation shapes of vertical geomagnetic component obtained several months before the earthquake at the geomagnetic observatories in China. They have discovered that on May 9, three days before the great earthquake, "double low-points" anomaly appeared in the daily variation of vertical geomagnetic component at 13 geomagnetic observatories located in Sichuan, Gansu, Shaanxi, Guizhou, Hunan, Jiangxi and Fujian provinces and Guangxi autonomous region. These observatories distribute roughly on three belts intersected just at the epicenter and the adjacent regions of the great M_S8.0 Wenchuan earthquake in Sichuan, which indicates further that "double low-points" anomaly in daily variation of vertical geomagnetic component is possibly one kind of short-term and imminent precursors.

2 "Double low-points" anomaly in daily variation of vertical geomagnetic component

In the regions of medium and low latitudes in the Northern Hemisphere, the daily variation shape of vertical geomagnetic component has a minimal value around 12 at noon in local time, which is called "daily- variation low point". This kind of daily variation is calculated in the period of a solar day and it varies with the geographical longitude. The appearance of "daily-variation low point" has a delay of one hour every 15 longitudinal degrees from the east to the west. The geographical distribution of the existing geomagnetic observatories in China spans as long as four time zones. Therefore, the "daily-variation low point" of vertical geomagnetic component in Beijing time is about 11 o'clock in the utmost east to nearly 15 o'clock in the utmost west with a mean time of 13 o'clock. Chengdu observatory is

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located in the middle of the geographical longitude of China and its time of "daily-variation low point" is around 13 o'clock (Li and Liang, 1989). Figure 1 shows an example of general daily variation shape of vertical geomagnetic component observed at some geomagnetic observatories in China on March 7 in 2007, which indicates that the appearance time of "daily-variation low point" lags gradually from the east to the west.

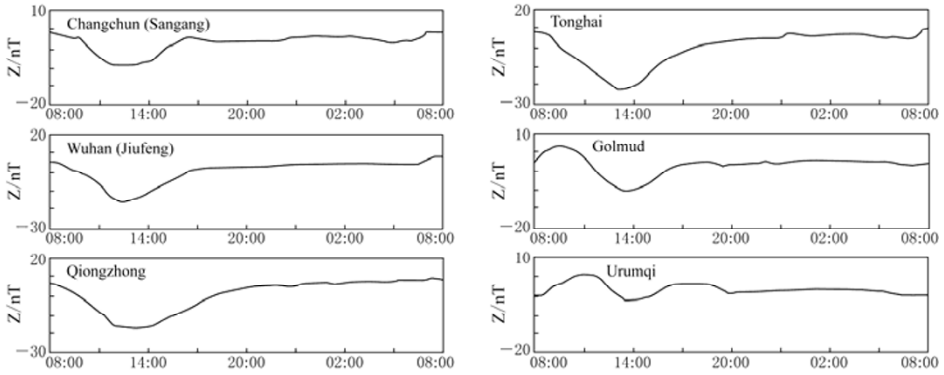

Figure 1 Schematic diagram of general daily variation shape of vertical geomagnetic component (Z).

It has been discovered by observations and analyses in a long time that sometimes a kind of "double low-points" anomaly would appear in the daily variation shape of vertical geomagnetic component, and the interval between the two low points could be as long as more than three hours. The observatories with "double low-points" anomaly are usually characterized by a belt distribution. Chen and Xie (1989) and Hu (1994) proposed that this kind of "double low-points" anomaly in daily variation of vertical geomagnetic component has a better time-space correlation to the regional seismic activity.

On May 9 in 2008, the "double low-points" anomaly appeared in the daily variation shape of vertical geomagnetic component at 13 observatories located in Nan'an and Longyan (Fujian), Huichang (Jiangxi), Shaoyang (Hunan), Yongning and Hechi (Guangxi), Guiyang (Guizhou), Xichang, Daofu and Chengdu (Sichuan), Golmud (Qinghai), Tianshui (Gansu), and Qianling (Shaanxi) (see Figure 2). The former low point appeared at (11±1) o'clock and the latter at (16±1) o'clock. The difference of interval between the two low points is 3–7 hours and that of intensity extreme value is no more than 3 nT.

The observatories with "double low-points" anomaly in daily variation of vertical geomagnetic component does not distribute on a single belt, but on three belts intersected in the western Sichuan as shown in Figure 3. On May 12, three days after the appearance of "double low-points" anomaly, a M_S8.0 great earthquake occurred in Wenchuan in the western Sichuan. It is just the intersection of the three belts where the observatories with "double low-points" anomaly are located.

3 Discussion

Daily geomagnetic variation is a kind of short-period varying magnetic field superimposed on the stable field of the Earth, which is mainly composed of solar quiet daily variation (S_q) with a period of about 24 hours. It is apparent from the geomagnetic map that generally a sensible maximum and minimum values appear respectively in the variations of horizontal geomagnetic component $S_q(H)$ and vertical geomagnetic component $S_q(Z)$ around noon in local time, while the variation of magnetic declination $S_q(D)$ has an extreme value with opposite symbol in the morning and afternoon, respectively. The "double low-points" anomaly in daily variation of vertical geomagnetic component in this paper refers to the two low points with an interval of 3–7 hours appeared in daily variation shape of vertical geomagnetic component around noon in local time, while at the same time, the magnetic declination and the horizontal component still remain the normal shape of quiet daily variation.

The geomagnetic disturbance variation from the external space of the Earth will affect the daily variation shapes of magnetic declination, horizontal and vertical components simultaneously. However, the magnetic declination and the horizontal component still remain the normal shape of quiet daily variation, we thus can infer that the "double low-points" anomaly in daily

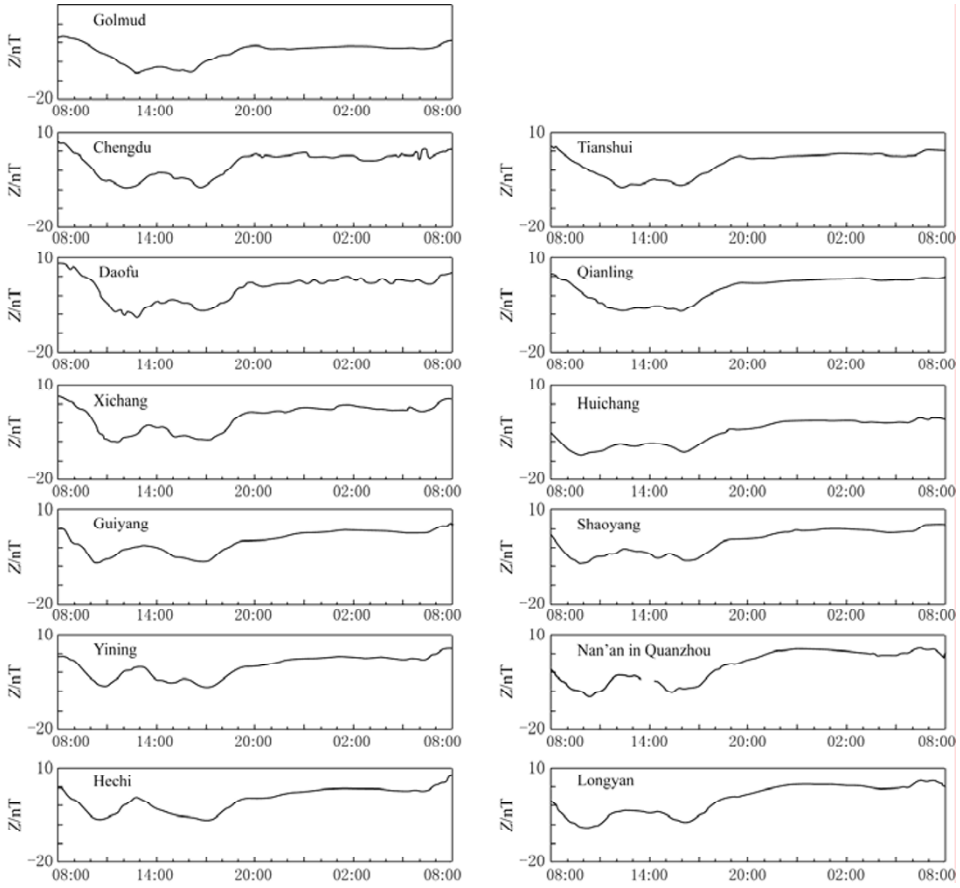

Figure 2 "Double low-points" anomaly in daily variation of vertical geomagnetic component (*Z*) on May 9 in 2008.

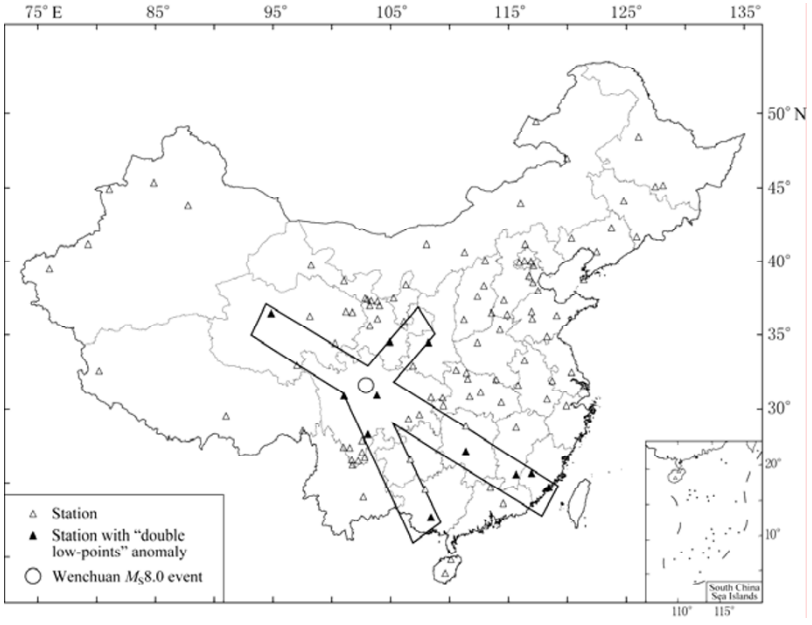

Figure 3 Belt distribution of observatories with "double low-points" anomaly in daily variation of vertical geomagnetic component on May 9, 2008.

variation of vertical geomagnetic component is not caused by the geomagnetic disturbance variation, but the change of eddy current system itself resulting in geomagnetic daily quiet variation (S_q) that is composed of two parts of extrinsic and intrinsic varying fields. The extrinsic varying field originates from the eddy current system in the external atmosphere (ionosphere) of the Earth, while the intrinsic varying field is an induction magnetic field resulted from a back eddy current system induced by the extrinsic varying field in the deep crust. On the basis of the spherical harmonic analysis on the solar quiet daily variation S_q of vertical geomagnetic component (Peking University and University of Science and Technology of China, 1986), the extrinsic varying field accounts for about 2/3 of the total field in amplitude and the intrinsic varying field amounts to only about 1/3, while in phase, the intrinsic varying field lags behind the extrinsic varying field for no more than 15°, i.e., no more than one hour (Peking University and University of Science and Technology of China, 1986), which reflects the long-term stability of electric conductivity in the deep crust.

By analyzing the spatial-temporal characteristics of daily variation shape of vertical geomagnetic component, we have found that the "double low-points" anomaly in daily variation of vertical geomagnetic component consists of two types. The first type shows the following evolution characteristics of "double low-points" anomaly in daily variation shape of vertical component in spatial distribution. The daily variation shape of vertical component takes the former low point as the lowest one for the observatories on the side of the belt where the observatories with "double low-points" anomaly in daily variation of vertical geomagnetic component are distributed, while the daily variation shape of vertical component uses the latter low point as the lowest one for the observatories on the other side. With the increase of distance to the belt where the observatories with "double low-points" anomaly of daily variation are distributed, the daily variation shape of vertical component recorded at the observatories changes gradually to single low-point shape. The low-point time of daily variation shape recorded at the observatories on one side of the belt where the observatories with "double low-points" anomaly in daily variation of vertical geomagnetic component are distributed is taken as the low-point time of normal quiet daily variation (around 12 o'clock in local time), while the low-point time of daily variation shape recorded at the observatories on the other side has a delay of three hours and more from the normal time (see Figure 4). The second type displays the following feature of "double low-points" anomaly in daily variation shape of vertical component in spatial distribution. The daily variation shape of vertical component recorded at the observatories on both sides of distribution belt of "double low-points" anomaly is considered as the normal quiet daily variation, and both low-point times of daily variation are around 12 o'clock in local time.

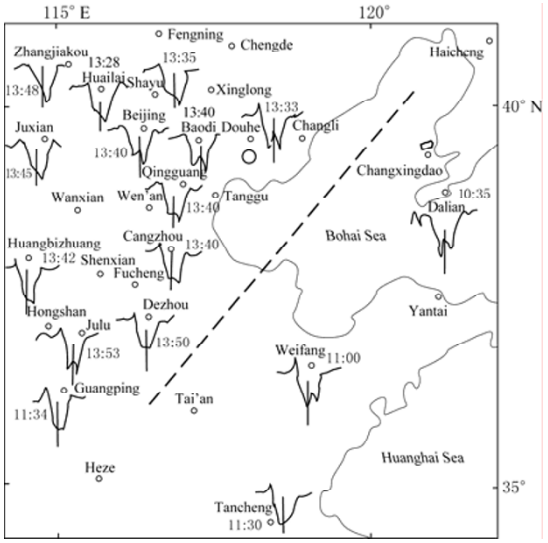

Figure 4 Distribution of low-point displacement in daily variation of vertical geomagnetic component on July 7, 1976 before Tangshan earthquake.

By analyzing the origin of geomagnetic quiet daily variation and the evolution characteristics of "double low-points" anomaly in daily variation of vertical geomagnetic component in spatial distribution, we propose that the first type of "double low-points" anomaly in daily variation of vertical geomagnetic component is induced by the reason that the extrinsic eddy current system evolves from single eddy current system to double eddy current system, and then to single eddy current system again. The vertical bisector of the connection line to both centers of the two eddy current systems is roughly correspondent to the distribution belt of observatories with the observed "double low-points" anomaly in daily variation of vertical geomagnetic component; The strengths of both eddy current systems are characterized by a variation of down here and up there, but they are roughly consistent over the observatories with "double low-points" anomaly in daily variation of verti-

cal geomagnetic component. This result is rather close to the analysis of Chen et al (2009) by studying the relationship between the geomagnetic low-point displacement and the equivalent current system of geomagnetic field. The second type of "double low-points" anomaly in daily variation of vertical geomagnetic component is resulted from the delay of several hours between the intrinsic and extrinsic eddy current systems. In brief, both types of "double low-points" anomalies in daily variation of vertical geomagnetic component originate from the variations in intrinsic and extrinsic eddy current systems of the Earth. And it is just this kind of variation, especially the variation of intrinsic eddy current systems of the Earth, possibly reflects the accelerative alteration of earthquake gestation in the deep Earth.

The "double low-points" anomaly in daily variation of vertical geomagnetic component appeared in China on May 9, 2008 includes the above-mentioned two types of "double low-points" anomalies, which is the main cause for the three-belt spatial distribution of geomagnetic observatories with the appearance of anomaly.

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