Horizontal crustal movement in Chinese mainland from 1999 to 2001*

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Abstract
The paper introduces the horizontal crustal movement obtained from GPS observations in the regional networks (including the basic network and the fiducial network) of the Crustal Movement Observation Network of China (CMONOC) carried out in 1999 and 2001. This paper is characterized by the acquisition of the horizontal displacement velocities during the period from 1999 to 2001 at the observation stations in the regional networks with datum definition of a group of stable stations with small mutual displacements in east China. Based on the most detailed map of horizontal crustal movement in Chinese mainland, the division of blocks, their displacements and deformations are studied. An approach to analysis of the intensity of the horizontal crustal deformation is proposed. The general characteristics of the recent horizontal crustal movement in Chinese mainland and that before the Kunlunshan earthquake of $M=8.1$ on November 14, 2001 are analyzed.

Key words: crustal movement, GPS, displacement, block, regional network
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Introduction
In the Crustal Movement Observation Network of China (CMONOC) there are 25 fiducial stations, 56 basic stations and 1 000 regional stations. They are scattered on 10 major blocks in Chinese mainland with high density of observation stations on the blocks of high seismic activity in the regional networks. 10 major blocks or regions (they will be referred to as blocks in the paper, a letter is used as a symbol for each block) were divided during the design of the regional networks according to tectonic movement. They are north China block (A), block of the Tancheng-Luijiang fault zone (B), block of the central and southern part of north China (C), Erdos block and its surrounding areas (D), Heilongjiang block in northeastern China (E), south China block (F), Altyn-Qilianshan Alxa block (G), Sichuan-Yunnan block (H), Xinjiang block (I) and Qinghai-Xizang block (J). The first GPS observation campaign of 25 fiducial stations, 56 basic stations, 1 000 regional stations and a small number of other stations was carried out from March 10 to October 9 in 1999 and the second campaign was carried out from March 8 to September 5 in 2001. Shortly after the completion of the campaign in 2001, the great Kunlunshan earthquake of $M=8.1$ occurred on November 14, 2001. Therefore the two observation campaigns are quite important for the study on the crustal movement before the great earthquake, and some authors have

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made very interesting studies. The requirements and scenario of the GPS field surveys in both campaigns were almost the same. All the stations were occupied for 4 days and nights with sampling rate of 30 s. Besides the fiducial stations there were some stations that were common in groups of stations of simultaneous observations. The data observed at these common stations (including the fiducial stations) amount to 1/3 of all observation data. Different type of GPS receivers and antennas were used in the observations. Receivers of ASHTECH Z-XXII, TRIMBLE SSE 4000, Geotracer 3220, Geotracer 2200 and Javad Legacy, choke ring antennas and antennas of geodetic types were used. The center of CMONOC organized the GPS field observations. Institutions from the China Earthquake Administration, the Bureau of Surveying and Mapping under the General Staff and the National Bureau of Surveying and Mapping carried out the GPS field observations at the regional and basic stations and most of the fiducial stations. Technicians from the Chinese Academy of Sciences carried out observations at some fiducial stations.

The observed GPS data were processed with GAMIT/GLOBK software at the China Earthquake Administration, the Bureau of Surveying and Mapping under the General Staff and the National Bureau of Surveying and Mapping, respectively. Comparison of the results from different agencies shows the general agreement of the results. So an abundant result of crustal movement with an interval of 2 years has been obtained. Coordinates of more than 1 000 stations for 2 campaigns and velocities in the global plate motion model at 934 stations were obtained from the data processing. Because no major earthquakes that affected the displacements occurred during the period that spanned the 2 observation campaigns, the displacements and the displacement velocities for the 2 campaigns are in good agreement. In the paper the result of horizontal displacement velocities obtained at the Data Center of CMONOC is further processed and analyzed. Though the regional stations were occupied only for 4 days and nights, the accuracy of the result is close to that from the basic network because of longer occupation at the above-mentioned common stations. For example on the block of Tancheng-Lujiang fault zone, there are 70 regional stations, the RMS (Rooted mean Square) of displacement velocities is only about 1.8 mm·a⁻¹, the RMS in the east component is about 1.0 mm·a⁻¹ and the RMS in the north component is about 1.5 mm·a⁻¹. They are in agreement with characteristics of the accuracy of GPS observations. The GPS data processing and analysis on the accuracy will not be repeatedly discussed in the paper (GU, et al, 2000, 2001).

Based on the continuous GPS observational results from 25 fiducial stations and GPS results from 56 basic stations and 25 fiducial stations, pictures of horizontal crustal movement in Chinese mainland with different densities of observation stations have been obtained. They are extremely valuable for earthquake prediction. Obviously the observed result of nearly 1 000 stations has provided the most detailed information of crustal movement up to now. Based on the observed results from the regional networks, the characteristic of the block movement for the horizontal crustal movement in Chinese mainland, will be analyzed and discussed.

1 Horizontal crustal movement and deformation of block in Chinese mainland

Because of the relativity of displacements, the solutions of displacement field are numerous, some of them show clearly the internal relative movement in an area and some could be of different tectonic implications. A datum definition of a group of stable stations with small mutual displacements, in stead of the datum definition of global plate motion, is used in the paper to get a