Preliminary results of measuring the crustal deformation in Qinghai-Xizang area using GPS technique

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Abstract GPS repetition measurement data in Qinghai-Xizang (Tibetan) area in 1992 and 1994 have been used to determine the change rates of seven baseline vectors of Lhasa-Wenquan, etc. It is the first time to obtain the direct observation results of the large-scale crustal horizontal motions in this area. These preliminary results also for the first time provide the direct observation evidence for some important geophysical and geological viewpoints, such as the northward gradual reduce of the effect of the northward push-pressing to Eurasian continent by Indian Plate in the Qinghai-Xizang area, having a southward strike slip movement of the Chuan-Dian diamond block, etc.

Keywords: GPS, Qinghai-Xizang Plateau, crustal horizontal motion.

The Qinghai-Xizang Plateau, called the world ridge, is the youngest plateau in the world at present, and the present-day crustal horizontal displacement reaches 1—3 cm/a. It is the region where the crustal motion is the strongest in the global continents. Therefore, the Qinghai-Xizang Plateau is the most ideal object to study interplate deformation and dynamics. But the quantitative survey of the present-day crustal motion in this area is basically limited to its vertical movement, and the observed results of the large-scale horizontal motion are not available till now. Hence, there is no evidence about horizontal displacement to study the dynamic mechanism of the crustal motion in the Qinghai-Xizang Plateau area.

Now the development of GPS technique guarantees the direct surveying of large-scale crustal movement of the Qinghai-Xizang Plateau[1]. Investigation on Present Crustal Motion and Geodynamics in China, as one of nationally important basis research programs in China, has set up a GPS network for measuring and monitoring the crustal motion in China. The first test was operated in the Qinghai-Xizang Plateau in 1992, and the second was extended to the whole continent of China in 1994. In the two tests seven baselines in the Qinghai-Xizang area were repeatedly measured. Using SHAGAP software system, which stands for Shanghai Observatory GPS Analysis Program, these seven baseline vectors and their change rates have been preliminarily determined. The results show that the estimation of the baseline change rates is reliable, and are available to study the crustal horizontal motion in this area.

1 SHAGAP software system

As one of the analysis centers of new spatial techniques in IERS, Shanghai Observatory has been developing the GPS analysis program system[1,2], named SHAGAP, to process the GPS data, and to estimate satellite orbit, geodetic and geodynamic parameters. The SHAGAP software system is based on the GAMIT program from MIT and SHORDE program which is used to process SLR data estimating satellite orbit and dynamic and geodetic parameters at Shanghai Observatory[3].

Possible solution parameters in SHAGAP process are: initial states of all satellites (solar radiation pressure scaling factors, scaling factors in x, z directions in the satellite body fixed frame can be either the same or different); additional y bias value; a set of station clock parameters including epoch, rate and acceleration parameters; Zenith delay parameters for each station and each session for selected interval; ambiguities (for L_1 and L_2-L_1) for each station and each session; station coordinates; polar motion and length of day; geocentric coordinates.

For all cases, dual frequency double difference phase measurements are used in the estimation, and pseudo-range measurements are used to correct the respective station clocks and to fix the ambiguities.

2 Campaigns and data processing

The first observation campaign was only performed in the part area of the Qinghai-Xizang Plateau with 4 sets of WILD 200 dual frequency GPS receiver during Oct. 8—12, and Oct. 21—23, 1992. The second campaign was extended to whole network operated in Aug. 1994 with 15 sets of WILD 200 GPS receivers. The campaign of 1994 was divided into eastern section from Aug. 15 to Aug. 20 and western section from Aug. 28 to Sept. 2. Two sections, in which the Urumqi, Golmud and Xiaguan stations were three common points, consist of 15 and 10 stations respectively. In both campaigns of 1992 and 1994 seven common baselines in the Qinghai-Xizang area were repeatedly measured. They were Lhasa-Wenquan, Golmud-Wenquan, Golmud-Xining, Lhasa-Xiaguan, Golmud-Xialatuo, Wenquan-Xiaguan and Xining-Xialatuo.

Baseline processing for both campaigns of 1992 and 1994, was performed on the basis of daily solution using SHAGAP software and precise ephemerides and earth orientation parameters derived from Scripps Institute of Oceanography (SIO)[4]. Tropospheric delay was estimated at each station in every 2 or 3 h period. In the processing of 1994 campaign, two additional IGS core stations Taiwan and Usuda were used as fixed points (fiducial points) and their data were processed simultaneously with the network data. In the processing of 1992 campaign, the coordinates of Wenquan station were fixed which derived from the results of 1994 campaign.

The repeatability of daily solution is an important criterion of judging solution accuracy. It can be written as

$$R = \left[\frac{\dfrac{n}{n-1} \sum_{i=1}^{n} \dfrac{(C_i - \bar{C})}{\sigma_i^2}}{\sum_{i=1}^{n} \dfrac{1}{\sigma_i^2}} \right]^{1/2}$$

where n is the number of daily solution; C_i is the daily solution of three components and length of each baseline; $\bar{C}$ is the weighted mean value of C_i; σ_i is the variance of C_i.

Figure 1 shows the daily repeatability in North-South (NS), East-West (EW) and Up-Down (UD) component, and lengths of 7 baselines for both of 1992 and 1994 solutions. Because the SIO ephemerides and the data observed for campaign of 1994 are much better than the ones for campaign of 1992, the accuracy of the front solutions is obviously higher than the back solutions.

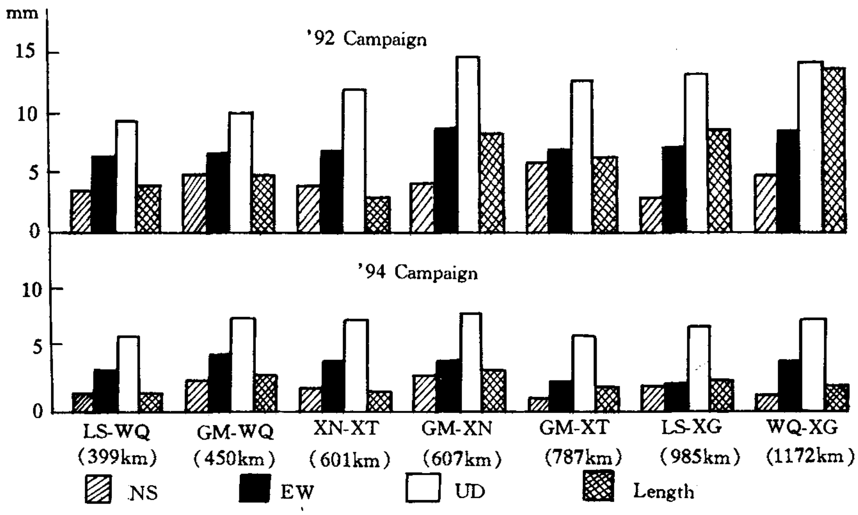

Fig. 1. Daily repeatability of coordinates difference and lengths for 7 baselines.

3 Results and analysis

The change rates of lengths and horizontal components of seven baselines are listed in the third column of tables 1 and 2, respectively. As a comparison, the fourth column in table 1 shows the results without fiducial points in data processing, and the fifth column is the results of performing a network adjustment using solved baseline vectors and relevant covariances as observational values. Tables 1 and 2 show that estimations of baseline vectors and their change rates are reliable. These results are used to make some preliminary analysis of the crustal horizontal motion in this area.

Table 1 Change rates of 7 baseline lengths monitored by GPS

		Length (I)/cm	Length (II)/cm	Length (III)/cm
Golmud-Wenquan	(1992)	44 966 617.62 ± 0.48	44 966 615.32 ± 0.51	44 966 617.41 ± 1.51
	(1994)	44 966 616.25 ± 0.30	44 966 613.92 ± 0.34	44 966 616.27 ± 0.83
	change rate	− 0.72 cm/a	− 0.74 cm/a	− 0.62 cm/a
Golmud-Xining	(1992)	60 747 270.36 ± 0.81	60 747 266.53 ± 0.85	60 747 269.73 ± 0.95
	(1994)	60 747 271.54 ± 0.35	60 747 267.57 ± 0.28	60 747 271.51 ± 0.94
	change rate	0.66 cm/a	0.56 cm/a	0.97 cm/a
Golmud-Xialatuo	(1992)	78 699 398.81 ± 0.63	78 699 393.65 ± 0.71	78 699 398.58 ± 0.99
	(1994)	78 699 400.67 ± 0.20	78 699 395.86 ± 0.24	78 699 400.64 ± 0.65
	change rate	0.97 cm/a	1.19 cm/a	1.11 cm/a
Lhasa-Wenquan	(1992)	39 882 771.29 ± 0.38	39 882 769.22 ± 0.40	39 882 771.40 ± 1.21
	(1994)	39 882 768.73 ± 0.16	39 882 766.70 ± 0.18	39 882 768.72 ± 0.22
	change rate	− 1.38 cm/a	− 1.35 cm/a	− 1.45 cm/a
Lhasa-Xiaguan	(1992)	98 486 127.41 ± 0.86	98 486 120.82 ± 0.92	98 486 127.91 ± 1.06
	(1994)	98 486 128.66 ± 0.26	98 486 121.97 ± 0.30	98 486 128.57 ± 1.10
	change rate	0.66 cm/a	0.62 cm/a	0.36 cm/a
Wenquan-Xiaguan	(1992)	117 211 393.18 ± 1.36	117 211 384.60 ± 1.38	117 211 393.52 ± 1.03
	(1994)	117 211 395.49 ± 0.22	117 211 386.99 ± 0.25	117 211 395.40 ± 0.93
	change rate	1.21 cm/a	1.28 cm/a	1.02 cm/a
Xining-Xialatuo	(1992)	60 081 467.47 ± 0.29	60 081 463.43 ± 0.48	60 081 467.50 ± 1.16
	(1994)	60 081 468.81 ± 0.17	60 081 465.42 ± 0.19	60 081 468.76 ± 0.20
	change rate	0.72 cm/a	1.07 cm/a	0.68 cm/a

Table 2 Change rates of horizontal component of 7 baselines

	North-South component/cm			East-West component/cm		
	1992	1994	change rate/ $cm \cdot a^{-1}$	1992	1994	change rate/ $cm \cdot a^{-1}$
Golmud-Wenquan	−35 059 968.71±0.49	−35 059 967.76±0.26	−0.51	−2 812 072.23±0.67	−2 812 071.25±0.48	−0.53
Golmud-Xining	4 644 560.28±0.41	4 644 557.64±0.30	−1.43	60497481.78±0.87	60 497 483.17±0.43	0.63
Golmud-Xialatuo	−55 234 271.18±0.59	−55 234 274.55±0.11	1.82	−55 867 525.63±0.68	−55 867 524.87±0.25	−0.41
Lhasa-Wenquan	39 595 733.21±0.34	39 595 730.72±0.16	−1.35	4 608 907.45±0.64	4 608 906.93±0.34	−0.28
Lhasa-Xiaguan	−41 516 383.46±0.30	−41 516 390.00±0.23	3.55	88 979 284.48±0.71	88 979 282.77±0.24	−0.92
Wenquan-Xiaguan	−80 954 478.42±0.48	−80 954 482.35±0.14	2.12	84 070 848.47±0.84	84 070 847.72±0.42	−0.41
Xining-Xialatuo	−59 405 180.84±0.38	−59 405 181.83±0.20	0.54	−8 616 200.01±0.68	−8 616 198.36±0.42	1.27

Figure 2 shows the locations of these 6 stations in the Qinghai-Xizang area. The big arrows represent the motion direction and rate (mm/a) of the Indian Plate and various blocks with respect to the Siberia from the geological and geophysical data. The Lhasa and Wenquan stations are located in the Gangdise (II_1) and Qiangtang (II_2) subblocks of the Xizang block (II) respectively, and the Xialatuo and Xiaguan stations both are in the Chuan-Dian diamond block (II_3), the Golmud and Xining stations are situated in the Qaidam subblock (III_2) and the Qilianshan tectonic belt (III_4) of the Gan-qing block (III) respectively.

From these preliminary results measured from GPS technique, it can be see that in general, the change rates in North-South direction are larger than those in East-West direction; the shortening rate (−1.35 cm/a) of N-S component of the Lhasa-Wenquan baseline is obviously larger than that of Golmud-Wenquan baseline; there is a marked stretch for the N-S components of all baseline vectors of the Lhasa, Wenquan, Golmud and Xining to the Xialatuo or Xiaguan situated in the Chuan-Dian diamond block. These motion features indicate that all Lhasa, Wenquan and Golmud stations have a northward motion under the effect of the strong northward propulsion of the Indian Plate. The motion rates decreased from south to north as the effect of the propulsion on various blocks in the Qinghai-Xizang Plateau reduced from south to north. The Chuan-Dian diamond block situated in southeastern part of the Qinghai-Xizang Plateau has an obvious southward strike slip movement at the rate of about 5 mm/a.

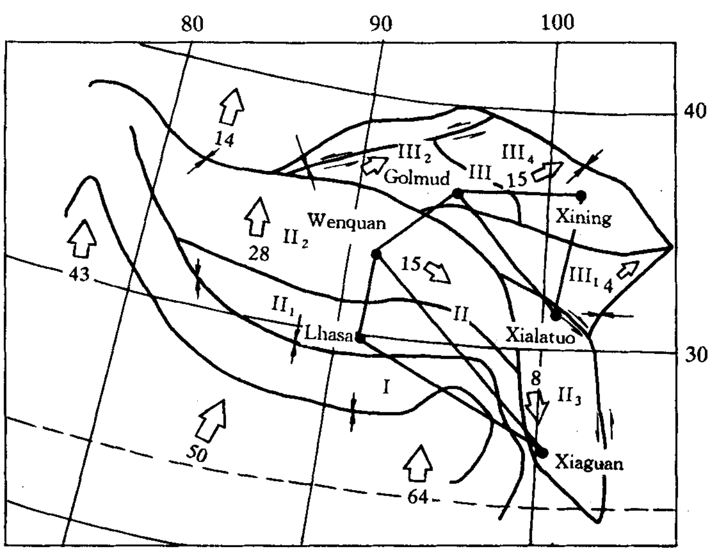

Fig. 2. The locations of Lhasa, Wenquan and other stations in the Qinghai-Xizang Plateau.

4 Conclusions

1) At present, the relative accuracy of measuring baseline is better than 10^{-8}, and near 10^{-9} using GPS technique. It is possible to obtain a reliable information about large-scale crustal horizontal motion from the periodic repetitious measurements for a short time.

2) These preliminary results for the first time give the direct observed evidence for supporting the opinion that the main force source to affect the motion of Chinese continental crust is from the northward propulsion of Indian Plate. The results also give the evidence that the effect of the propulsion on crustal motion of the Qinghai-Xizang area is gradually reduced from south to north.

3) The result shows that the Chuan-Dian diamond block, surrounded by the fracture from Jinsha River to Honghe River and other fractures from south to north in southwest China, has a southward strike slip movement at the rate of about 5 mm/a, which coincides with the motion model from the geological or geophysical data.

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