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Effects of the differences between the ITRF2000 and ITRF2005 models in GNSS data processing

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Abstract: In comparison with the ITRF2000 model, the ITRF2005 model represents a significant improvement in solution generation, datum definition and realization. However, these improvements cause a frame difference between the ITRF2000 and ITRF2005 models, which may impact GNSS data processing. To quantify this impact, the differences of the GNSS results obtained using the two models, including station coordinates, baseline length and horizontal velocity field, were analyzed. After transformation, the differences in position were at the millimeter level, and the differences in baseline length were less than 1 mm. The differences in the horizontal velocity fields decreased with as the study area was reduced. For a large region, the differences in these value were less than 1 mm/a, with a systematic difference of approximately 2 degrees in direction, while for a medium-sized region, the differences in value and direction were not significant.

Key words: ITRF2000; ITRF2005; GNSS data processing; difference; effect

1 Introduction

The use of a reference frame is the basis of Global Navigation Satellite System (GNSS) data processing, and an appropriate coordinate frame for this purpose must be globally unified, continuously self-consistent, and maintain elaboration. Presently, the only reference frame that satisfies these conditions is the International Terrestrial Reference System (ITRS), or the ITRF reference frame. ITRF2000, released in 2001, and ITRF2005, released in 2006, are the most commonly used models[1,2]. Most GNSS data processing results are unified into the ITRF2000 model[3,4]. However, it is considered more accurate to adopt the latest ITRF reference frame and to align old GNSS results into the latest ITRF reference frame.

In comparison with the ITRF2000 model, the ITRF2005 model represents a significant improvement in solution generation, datum definition and realization[2,5,6]. Therefore, due to its high precision and high resolution, ITRF2005 will gradually replace ITRF2000 and become the most widely used frame for GNSS data processing.

In high precision GNSS data processing, it is necessary to determine whether there are differences in the results of the ITRF2000 and ITRF2005 models, as well as the magnitude of these differences and the influence they may have on deformation analysis. Therefore, the present study analyzes the differences of the results, including station coordinates, baseline length and horizontal velocity field, obtained using the ITRF2000 and ITRF2005 models based on continuous observation and flow observation of GNSS data. This analysis provides a reference for differences in high-precision GNSS data processing and results transformation between different

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reference frames.

2 Differences in station coordinates

2.1 Processing of the time series

A collection of 30 fiducial stations of the Crustal Movement Observation Network of China (CMONC)[7] and 16 IGS stations around China were used as a regional network (Fig. 1), designated as the Ji Zhun Wang (JZW). Data were collected from the JZW stations from 2008 to 2009 and processed using GAMIT/GLOBK software 10.34 to obtain the time series of each station's coordinates, and the parameter settings used for the calculations were as follows: the data sampling interval was 30 seconds; the baseline processing mode was relaxation; the Earth's gravitational field, earth tide and pole tide model adhered to the latest specification of IERS2003; the global ocean tide model was the latest version of the FES2004 (otl_FES2004. Grid); the Linear Combinations (LC) observation was used to eliminate the ionosphere first-order refraction effect; the Vienna Mapping Function 1 (VMF1) model was used as the troposphere mapping function; and the zenith delay parameters were estimated every 2 hours.

2.2 Differences in station coordinates

The time series of the station coordinates (*XYZ*) calculated under the ITRF2000 and ITRF2005 models were designated as *X*2000 and *X*2005, respectively. According to the 14 Helmert transformation parameters between ITRF2000 and ITRF2005[1], *X*2005 was converted into the ITRF2000 model and designated as *X*0005. Because the NEU coordinate system is most often used to analyze station movement, *X*2000, *X*2005, *X*0005 were converted into *N*2000, *N*2005 and *N*0005 according to previous methods[8]. The coordinate differences were then calculated as *N*2000−*N*0005, and the standard deviation of the coordinate differences in the three directions (N, E, U) were analyzed (Fig. 2). Figure 2 indicates that the standard deviations of the N, E, U coordinate differences in the two different frames for each station were at the millimeter level. Therefore, the differences of the station coordinate time series between ITRF2000 and ITRF2005 are at the millimeter level: the maximum value is 3.67 mm, and the minimum value is 1.26 mm.

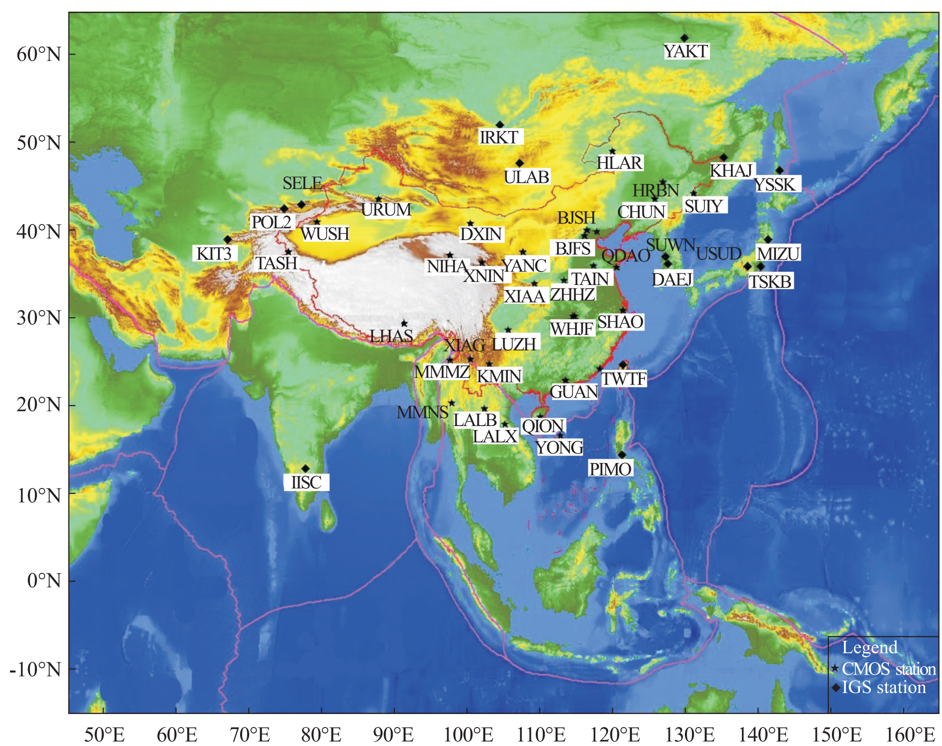

Figure 1 Distribution of IGS stations and the GNSS fiducial stations of the CMONC

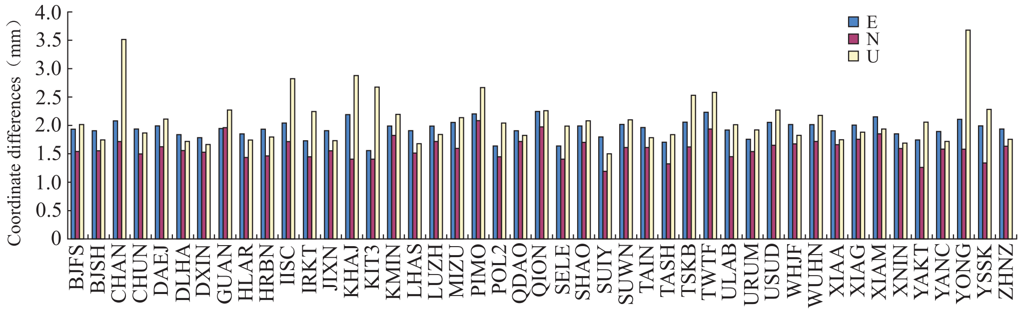

Figure 2 Residuals of the difference in position between ITRF2000 and ITRF2005 after transformation

3 Differences in baseline length

The baseline lengths *S*2000 and *S*0005 were calculated according to the time series *X*2000 and *X*0005, respectively, and the differences between them were compared. Due to the limited space of this study, table 1 only shows the differences between five representative baselines.

Table 1 Residuals of the difference in baseline length between ITRF2000 and ITRF2005 after transformation

Baseline	Length (km)	Residuals (mm)			
		Min	Max	Mean	Rms
BJSH-BJFS	76.7	−1	0.6	0	0.1
DLHA-XNIN	400.8	−0.6	1.6	0	0.1
BJSH-TAIN	454.9	−1.2	0.5	0	0.1
JIXN-DLHA	1773.8	−1.5	2.1	0.3	0.3
CHUN-LUZH	2432.1	−2	2	0.1	0.4

Table 1 shows that the differences in baseline length between ITRF2000 and ITRF2005 slowly increased as baseline length increased, but these differences are generally very small (maximum is 1−2.1 mm, and the standard deviation is within 1 mm). The differences in the JIXN-DLHA baseline, for example, are within 0.5 −1 mm (Fig.3).

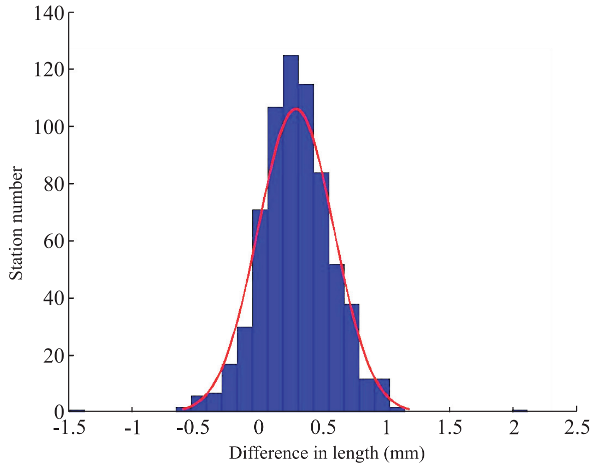

Figure 3 Histogram of the differences in JIXN-DLHA baseline lengths

4 Differences in horizontal velocity field

4.1 Large range regional network

A total of 27 stations were selected based on the completeness of their *N*2000 and *N*0005 and the linearity of their time series for the N and E components.

The 2008−2009 horizontal velocity fields were obtained by the linear fitting of each time series and designated as *V*2000 and *V*0005. According to equation 1, the horizontal velocity *V* and azimuth *A* of each station were calculated from *V*2000 and *V*0005 (rotated clockwise from the north):

$$\begin{cases} V = \sqrt{(|Vn|^2 + |Ve|^2)} \\ A = a\sin\left(\dfrac{Ve}{V}\right) \end{cases} \tag{1}$$

where *V*n and *V*e are the velocities in the N and E directions, respectively.

The differences between *V* and *A* from *V*0005 to *V*2000 were calculated and designated as D_V and D_A, respectively, and are presented in table 2.

Table 1 shows that the differences in the horizontal velocity field of JZW between ITRF2000 and ITRF2005 are small, within 1 mm/a, and the system error in direction is approximately 2°.

Table 2 Differences in the horizontal velocity field of the JZW between ITRF2000 and ITRF2005

Station	D_V (mm/a)	D_A (°)
BJFS	0.39	−1.05
BJSH	0.30	−1.08
CHUN	0.35	−1.12
DAEJ	0.36	−1.01
DXIN	0.66	−1.70
HLAR	0.39	−1.20
HRBN	0.39	−1.21
IRKT	0.55	−1.78
JIXN	0.67	−1.57
KHAJ	0.42	−1.01
KIT3	0.37	−1.58
LUZH	0.23	−1.42
POL2	0.50	−1.84
QION	−0.13	−1.17
SELE	0.42	−1.33
SHAO	0.30	−0.82
SUIY	0.64	−1.64
SUWN	0.42	−1.02
TAIN	0.31	−1.12
TWTF	0.38	−1.24
ULAB	0.26	−1.65
WHJF	−0.22	−0.86
WUHN	0.40	−1.07
XIAA	0.45	−1.62
XIAM	0.36	−1.20
YANC	0.33	−1.19
ZHNZ	0.63	−1.52

4.2 Middle range regional network

The GNSS monitoring network in Shanxi Province is a system of high-precision GNSS monitoring stations along the Shanxi fault zone built by the Earthquake Administration of Shanxi Province in 1996. They initially constructed 40 stations, and most of them remain in operation, except for 5 stations that have been rendered inoperable due to damage or other factors. Surveys were conducted every year from 1996–2009, usually 3 to 4 times per year both during the day and at night at every station. The regional network used in this study, designated as the Shan Xi Wang (SXW), was composed of 35 stations in Shanxi and the surrounding 17 domestic base stations and international IGS stations. The methods previously described were used to process the observational data of the SXW from 2008 and 2009, and the horizontal velocity field of the SXW for 2008 to 2009 was obtained using the ITRF2000 and ITRF2005 models (Fig. 4). Figure 4 shows that the value and directional differences of the horizontal velocity field between the ITRF2000 and ITRF2005 models are not significant (numerical differences within 0.7 mm/a, azimuth differences within 0.5°), and these differences should not affect the deformation analysis of this region.

5 Conclusions

The differences in station coordinates (NEU), baseline length and horizontal velocity field between ITRF2000 and ITRF2005 were analyzed, leading to the following conclusions:

(1) The differences in station coordinates between ITRF2000 and ITRF2005 are at the millimeter level (1.26 mm – 3.67 mm), which is an acceptable range for high precision GNSS observations.

(2) The baseline length is less affected by the differences between ITRF2000 and ITRF2005 (within 1 mm). Because changes of baseline length can reflect

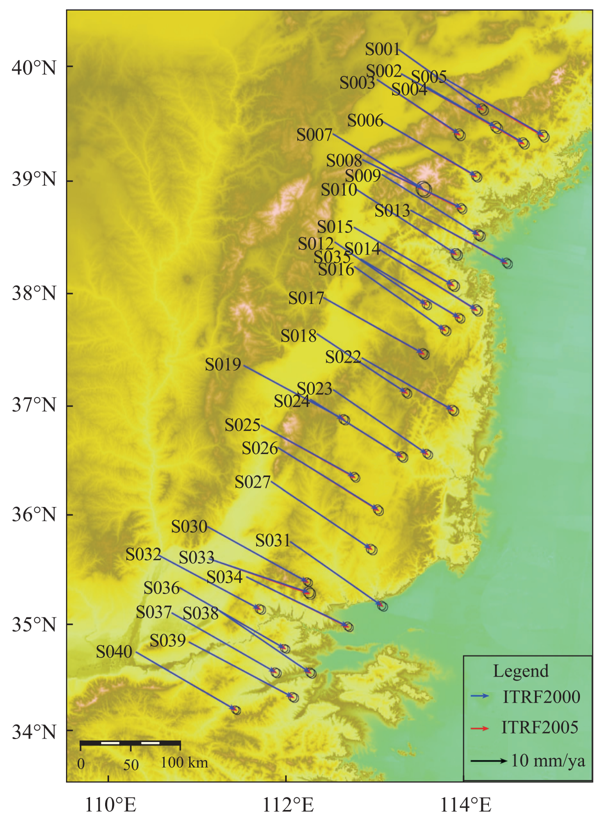

Figure 4 Difference of the SXW's horizontal velocity field between ITRF2000 and ITRF2005

the characteristics of deformation between stations, differences less than 1 mm indicate that the deformation information is not affected by the reference frame.

(3) The differences in the horizontal velocity field between ITRF2000 and ITRF2005 decrease as the research scope narrows. The differences of the horizontal velocity field in the large area are within 1 mm/a, with approximately 2° of system error in direction; for the medium area, the differences are not significant in either values or direction.

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