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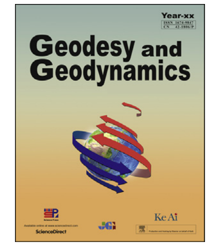

Quality analysis of the campaign GPS stations observation in Northeast and North China

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ABSTRACT

TEQC is used to check the observations quality of 173 GPS campaign stations in the Northeast and North China. Each station was observed with an occupation of 4 days. The quality of the 692 data files is analyzed by the ratio of overall observations to possible observations, *MP1*, *MP2* and the ratio of observations to slips. The reasons for multipath and cycle slips can be derived from the photos taken in the field. The results show that the coverage of trees and buildings/structures, and the interference of high-voltage power lines near the stations are the main reasons. In a small area, the horizontal velocity field in the period 2011–2013 is exemplified, where the magnitudes and directions of the 4 stations' rates are clearly different with that of other stations. It seems that the error caused by the worse environment cannot be mitigated through post processing. Therefore, these conclusions can help the establishment of GNSS stations, measurements, data processing and formulating standards in future.

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1. Introduction

The large North China is one of the most important regions with strong earthquakes in mainland China, where several $M \geq 7$ earthquakes occurred in the history. The disasters caused millions of deaths. But now, this area not only has become the most populated and developed area in China, but also it has been one of the key earthquake monitoring regions for many years. Especially, the seismic activities become more active after the 2008 Wenchuan earthquake and the 2011 Japan earthquake. A series of medium and strong earthquakes occurred frequently after these earthquakes. The co-seismic horizontal displacement is from millimeter to centimeter and the station with the maximum movement (about 35 mm) after the Japan earthquake [1]. To acquire the recent crustal horizontal movement features, the intensive GPS stations have been constructed. Most of them were built and observed since 1999. Among them, the 173 GPS stations

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located in 38.80°–53.49°N, 115.17°–134.29°E were observed and photographed in 2015 by the Second Crust Monitoring and Application Center (SCMAC), China Earthquake Administration (CEA).

There is no doubt that a good quality of the observation data can guarantee the correct analysis and explanation. The continuous stations established with high quality have been studied by some researchers [2–4]. Although the campaign stations have been established a long time, the studies about them are rare. The data quality of the repeated observation in some stations is weakened by the changing surroundings. The multipath effect and the cycle slips which always cause errors should be considered.

The GPS measurement errors come from the transmitting process of the satellite signals. The errors of ionosphere refraction and troposphere can be reduced through some models, whereas the multipath effect becomes a major error source because it is connected not only to the satellite's space structure [5], the signals direction and reflection coefficients, but also to the distance between the reflector and observation station. There is no more perfect model now. The error varies with the surface property of the reflection around antenna. The reflection could be grounds, hills, buildings and so on [6]. The experiments confirmed that the error of the pseudorange multipath could reach meter level in the general reflections, and about 4–5 m affected by the highly reflective objects. Furthermore, the lock-lose and cycle slips occur frequently. It would cause about 5 cm periodical errors in the distance by the phase deviation, and it would be ±15 cm in the elevation [7]. Therefore, the multipath effect cannot be ignored in the precise GPS navigation and measurement [8]. Some advices and methods are proposed. The location with the suitable and better surrounding should be given priority to consideration and selection [9], such as above elevating angle 10°–15°, no barrier and high-voltage line around the sites, the choke ring antenna and prolonging the observation time. In fact, the stations couldn't be selected with the ideal environments. Moreover, the environments of some stations could become worse in time and further influence the data quality.

The cycle slip is a unique and key issue in the carrier phase measurement which determine the integer ambiguity resolution. It could be caused by many reasons [10]. The common reason is that the satellite signals are interrupted by the tall buildings, hills, trees and so on. The second reason is that the low signal-noise ratio is caused by the dramatic ionosphere changes or the low satellite elevation. The third one is the low signal-noise ratio was caused by the electromagnetic interference near the station, multipath effect, and degradation of receiver performance. All the above-mentioned issues show the cycle slips are related to the observation surroundings and the performance quality of the receivers.

In this paper, the quality of 173 stations, 692 files observed in 2015 and other times are checked and analyzed. The influences are summarized from the reports of checking quality and the photos taken in the field. The conclusion will help establish GPS stations, select data files for post processing and formulate the related technical standards, and so on.

2. Quality checking and the station surrounding analysis

2.1. *TEQC introduction*

TEQC was designed and developed, and also it is maintained by the University Navstar Consortium (UNAVCO) facility in Boulder, Colorado. The program is named after its three main functions—translating, editing, and quality checking (QC). It allows the user to translate from the binary receiver format to the standard Receiver Independent Exchange (RINEX) format, to edit existing RINEX files, and to quality-check the data before post processing. Here, we check the quality using the QC portion [11], which is a process for quality checking static and kinematic dual-frequency GPS and GLONASS. The basic step is that linear combination (LC) of the pseudorange and carrier phase observations are used to compute (1) $L1$ pseudorange multipath for C/A- or Pcode-observations, (2) $L2$ pseudorange multipath for Pcode-observations, (3) ionospheric phase effects, and (4) the rate of change of the ionospheric delay. Information about the receiver clock slips, receiver cycle slips (receiver loss of tracking of $L1$ and/or $L2$), site multipath, satellite elevation and azimuth angles, receiver clock drift, receiver signal-noise ratios and other useful parameters and tracking statistics is written to a summary file. The QC report is called *.S which gives the main useful components related to the stations surroundings and data quality. $MP1$, $MP2$ and *o/slps* (complete observation/slips above 10° elevation) are always collected and studied. $MP1$ evaluates the pseudorange multipath and $MP2$ shows the pseudorange multipath and the noise intensity of the receivers. *o/slps* is always represented as CSR, which can be calculated with the formula:

$$CSR = \frac{1000}{o/slps}$$

The QC results show $MP1$, $MP2$ and CSR of two-thirds of International GNSS Service (IGS) stations were less than 0.5, 0.75 and 10 respectively [12]. In addition, the percentage of the observations (complete observation/possible observation) above 10 degrees elevation in the paper could reveal the real conditions of the stations. According to the provisions of Crustal Movement Monitor [13], the percentage of the GPS reference stations should be more than 85%, $MP1$ and $MP2$ should be less than 0.5 m. The percentage of the GPS campaign stations should be more than 80%.

2.2. *QC the GPS stations in Northeast China and some areas of North China*

The GPS stations in Northeast China and some areas of North China were observed again by SCMAC in 2015. The location of GPS stations is shown in Fig. 1. The stations were established at the end of the last century. Seven continuous stations were constructed with higher technical request based on the provisions [9]. The 2015 observations were carried out with the receiver of LEICA GX1230, TPS NET – G3A, and TPSTPSCR. G3 choke ring antenna. Each station was observed more than 23 h each day with an occupation of 4 days.