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GPS and GLONASS Systems Bias Estimation and New Correction Parameters: A Case Study in Egypt

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ABSTRACT

GNSS are a combination of systems with different datum, satellite signals and orbit constellation in each system. The position solution of GLONASS in GPS datum causes biases. In this paper, the results of adjusting permanent GNSS network were used over separate 57 days in 2014. The results in case of using GPS only were compared to those in case of using GLONASS only in GPS datum. It is of great interest to use both GPS and GLONASS measurements in such a process, but it is required that any reference system discrepancies are corrected when the broadcast navigation information of each system is used. The biases of the two cases were compared to estimate new correction parameters between navigation systems. These parameters were developed to improve the performance of GLONASS results. The new model and two other classic models were assessed using permanent and local GNSS network in Egypt. The new correction parameters achieved the best performance with biases of 3mm. However, without using these parameters the biases reached to 15mm.

Keywords: GNSS, Network, Bursa, system bias, correction parameters.

1.INTRODUCTION

GPS, GOLNASS, GALILEO and BEIDOU are combined in Global navigation satellite systems (GNSS). The performance of GNSS position depends mainly on biases correction (or systematic errors) and geometric of satellite constellation [1] and [12]. All navigation systems share the same principles of data transmission and positioning methods. The reference frames of GPS, GOLNASS, GALILEO and BEIDOU are respectively the World Geodetic System (WGS84), the Parametry Zemli (PZ90), Galileo Terrestrial Reference Frame (GTRF) and China Geodetic Coordinate System (CGCS2000) [6] and [8]. The main differences among navigation systems are Kepler parameters, signals, reference systems and geometric dilution of precision (GDOP) [10], which results in different performance for every system.

The observation function of receiver (re) to GPS and GLONASS (*) satellites (i) can be written as:

$$P_{re}^{*i} = \rho_{re}^{*i} + c(dt_{re} - dt^{*i}) + I_{re}^{*i} + T_{re}^{*i} + \varepsilon 1_{re}^{*i} \quad (1)$$

$$L_{re}^{*i} = \rho_{re}^{*i} + c(dt_{re} - dt^{*i}) + \lambda^{*i} N_{re}^{*i} - I_{re}^{*i} + T_{re}^{*i} + \varepsilon 2_{re}^{*i} \quad (2)$$

Where: P_{re}^{*i} , L_{re}^{*i} are the pseudorange and carrier phase observation (in range unit) respectively; ρ_{re}^{*i} is geometrical distance; c is light speed, λ^{*i} is wavelength; dt_{re} is receiver clock offset, dt^{*i} is satellite clock offset; N_{re}^{*i} is ambiguity, I_{re}^{*i} is the ionospheric delay error; , T_{re}^{*i} is the tropospheric delay error; $\varepsilon 1_{re}^{*i}, \varepsilon 2_{re}^{*i}$ are the pseudorange and carrier phase random error respectively [9].

The GPS broadcast orbits represent the basic realization of WGS 84 for modern users. According to the present terminology, this is a reference frame. As already stated, any improvement in processing strategy may produce systematic changes that map into the similarity transformation parameters. Numerically the corresponding frame will change accordingly. The PZ-90 system is similar to WGS 84, and used as the reference system for GLONASS navigation. It was realized by positioning 26 ground stations established from observations of Russia satellite, photographing it against a star background, Doppler measurements, laser ranging, and satellite altimetry. It also included electronic and laser range measurement of GLONASS and Etalon satellites. A subset of these stations is used to generate the broadcast PZ-90 GLONASS orbits.

Many researches to transform between WGS84 and PZ90 datum, such as [2], compared WGS84 and PZ90 using 7-parameters transformations that gave zero values. Misra et al. [11] used a translation and rotation value about Z-axis to improve performance. The benefits of integrating GLONASS to the GPS were near optimal with the current GPS constellation [3]. Chen et al. [7] applying the analyse of the precise GPS and GLONASS systems bias into PPP positioning, Found that precision of GLONASS-only solution is improved by 55 %. Cai [5] used experimental data and showed that the accuracy improved by more than 50% and 30% for the horizontal and vertical components respectively after adding GLONASS to GPS. Sleem et al. [13] studied the different cases of GNSS satellite systems and indicated that the differences among GPS and GLONASS position reached to 14mm that may be due to differences in datum. The contribution of GLONAS could improve the positioning accuracy by 11% for GPS kinematic precise point position (PPP) [14].

This research aims to compare the navigation satellite systems (GPS and GLONASS) according to position biases. It also aims to develop new correction parameters to GLONASS when combined with GPS in WGS84 datum. The new developed model was evaluated with Boucher and Altamimi [2] model and Misra et al. [11] model. The methodology steps of this paper are illustrated in Fig. (1).

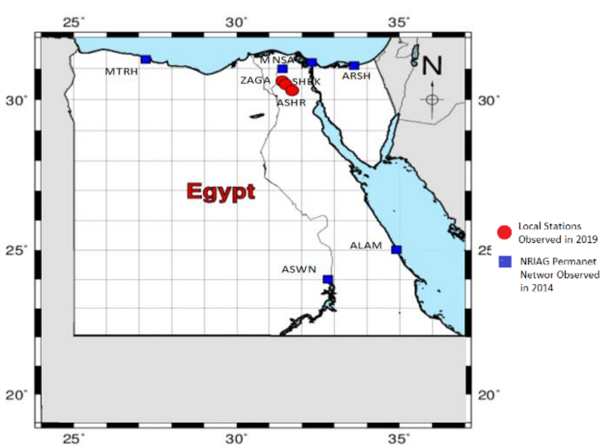
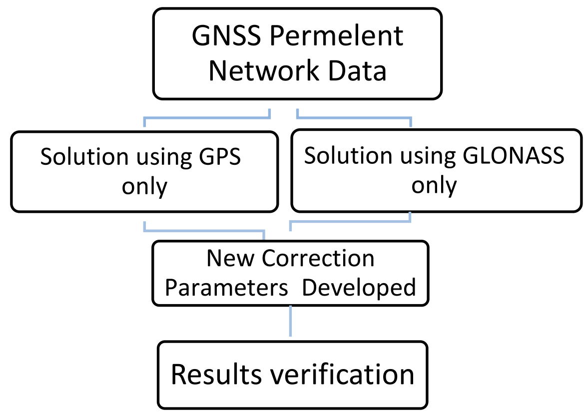


Fig. (1): Research methodology diagram of the Article.

2.GNSS NETWORK DATA COLLECTION

Three stations (ZAGA, SHBK and ASHR with circle symbol) were used over four days in 2019, together with six stations from National Research Institute of Astronomy and Geophysics (NRIAG), the permanent Network (ALAM, ARSH, ASWN, MNSA, MTRH and SAID with rectangle symbol). Bernese GPS Software Version 5.0 is used for analyzing and processing the GNSS network data. The same steps and conditions have been implemented identically for GPS and GLONASS.The coordinates were used over 57 separate days in 2014. All of these stations are equipped



with GNSS receivers that track GPS and GLONASS constellations (see Fig. 2).

Fig. (2): Distribution of GNSS Stations Used in This Study

3.METHODOLGY

Bursa [4] developed 7 transformation parameters to make a relation between two systems. This relation is the most suitable form because the reference frames of GPS and GLONASS are different; there are no significant effects of difference in relativistic values. New correction terms are proposed in this study, which use least squares to solve these parameters using seven GNSS stations (ZAGA, ASHR, ARSH, ASWN, MNSA, MTRH and SAID) and using two stations (ALAM and SHBK) for the verification of this model. This can be formulated as follows:

$$\begin{vmatrix} X' - X \\ Y' - Y \\ Z' - Z \end{vmatrix} = \begin{vmatrix} d_x \\ d_y \\ d_z \end{vmatrix} + S \begin{vmatrix} 0 & R_z & -R_y \\ -R_z & 0 & R_x \\ R_y & -R_x & 0 \end{vmatrix} \begin{vmatrix} X \\ Y \\ Z \end{vmatrix} \quad (3)$$

Where: X, Y and Z are coordinates obtained from GLONASS and X', Y' and Z' are coordinates obtained from GPS. d_x, d_y and d_z are three components of a shift vector, R_x, R_y and R_z are three rotation angles, and S is the scale factor.

For the permanent network, the results of station adjusted over 57 days are different from GPS and GOLNASS in WGS 84 datum. This means that the GLONASS falls in WGS 84 datum. The resulting seven correction parameters are:

$$\begin{vmatrix} d_x \\ d_y \\ d_z \end{vmatrix} = \begin{vmatrix} 9 \pm 0.6mm \\ -31 \pm 0.7mm \\ -92 \pm 0.4mm \end{vmatrix}, \text{ S} = 0.008 \pm 0 \text{ ppm}$$

$$\text{and } \begin{vmatrix} R_x \\ R_y \\ R_z \end{vmatrix} = \begin{vmatrix} (0.5 \pm 1.6)\ /1000\ arcseconds \\ (3.6 \pm 2.6)/1000\ arcseconds \\ (0.1 \pm 4.0)/1000\ arcseconds \end{vmatrix}$$

4.RESULTS AND DISCUSSION

The new correction parameters developed from Eq. (1) were used to convert the coordinates of GLONASS and compare it with GPS. Figs. (3) and (4) illustrate the results of the new model, Boucher and Altamin model [2], and Misra et al. Model (1996).

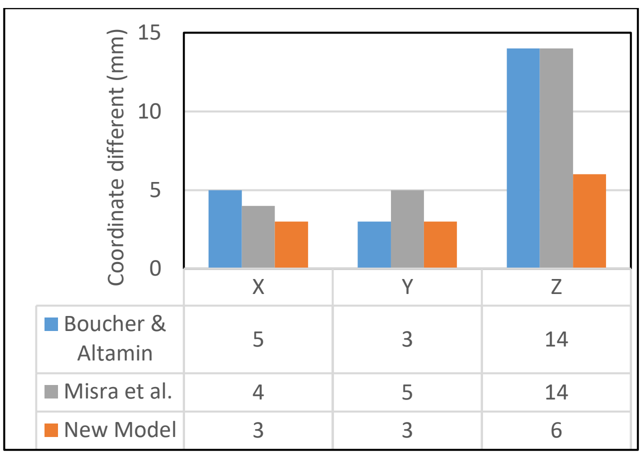


Fig. (3): Comparison between the Coordinates of GPS and GLONASS in Station ALAM Using New Correction Parameters, Boucher & Altamin model, and Misra et al. model

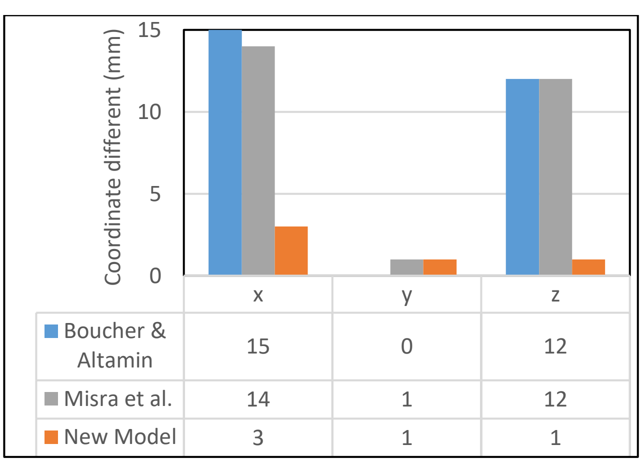


Fig. (4) Comparison between Coordinates of GPS and GLONASS in Station SHBK Using New Correction Parameters, Boucher & Altamin model, and Misra et al. model

The results using Boucher and Altamin model were 15.2mm and 19.2mm in Station ALAM and SHBK respectively. Misra et al. got the difference between GPS and GLONASS coordinates ranging from 15.4mm to 18.5mm in Station ALAM and SHBK respectively. The results of new model were 7.3mm and 3.3mm in Station ALAM and SHBK respectively. The new model get high improvement in performance with using the correction parameters.

5.CONCLUSION

GNSS navigation system use GPS datum. Currently, the position from GOLINASS has system biases in GPS datum. The GLONASS position should use new correction parameters to increase the positioning performance in the reference frame (WGS84). The analysis of two networks in Egypt was done for GPS and GLONASS separately. The biases of GLONASS and GPS were used to develop new correction parameters. The translation parameters, dx revealing the existence is a positive displacement 9mm however -31 and -92mm in dy and dz repectivly. The scale 0.008ppm and rotation parameters 0.4, 3.7 and 0 milli arc seconds Rx, Ry and Rz are very small, but they have a significant effect on the results. Applying these parameters change the difference between Cartesian coordinates of GPS and GLONASS to be very close. The precision of GLONASS solution is improved by 75 %. The new correction parameters are useful and can be incorporated in GNSS software programs.

Credit Authorship Contribution Statement

Mohamed Amin Abdelfatah: Collecting data, Methodology preparation Writing

Ashraf Mousa: Reviewing, Editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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