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Using Un-diffrenced Technique by Combining Triple-Constellations GNSS (GPS, Galileo, and BeiDou) For Enhancing Level of Accuracy

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ملخص البحث

هذا البحث يتضمن استخدام القمر الامريكى و القمر الصينى والقمر الفرنسي ويتم عمل دمج من الأرصاد الناتجة من هذه الأقمار للحصول على نتائج افضل من استخدام كل قمر صناعى على حدة. فيتم عمل مقارنة بين الأرصاد الناتجة من كل قمر على حدة وبين عدة أقمار مدمجة على نقاط مختلفة في الشبكة العالمية وذلك باستخدام عدد من النقاط المختلفة وفى أماكن متعددة . وكانت نتيجة البحث ان الاحداثيات الناتجة تزيد دقتها بشكل كبير عند دمج الأرصاد عن استخدام كل قمر منفصل و كذا تستغرق وقت اقل في القياس و تثبت الأرصاد بعد حوالى ساعة من بداية القياس

ABSTRACT

Precise Point Positioning (PPP) are traditionally based on dual-frequency observations of GPS satellite navigation systems. Recently, new GNSS constellations, such as the European Galileo and the Chinese BeiDou are developing rapidly .The new IGS project known as IGS MGEX will produce highly accurate GNSS orbital and clock products. Multi-constellations PPP becomes feasible. On the other hand, the un-differenced ionosphere-free is commonly used as standard precise point positioning technique. New GNSS constellations enhance the results . The contribution of the new GNSS observations is assessed and compared with the existing GPS . PPP will use three-hours GNSS static data positioning results for several GNSS stations and three consecutive days. Inter-system biases between GPS and other GNSS systems are obtained as additional unknowns in the developed PPP filter. The new IGS project known as IGS MGEX will produce high accurate GNSS orbital and clock corrections.

Key words: GNSS, IGS MGEX, Un-differenced Technique ,ISB

1- Introduction

PPP solution accuracy and convergence time are influenced by the ability to mitigate all potential error sources in the system. PPP essentially relies on the availability of precise satellite products, namely orbital and clock corrections. At present, the IGS-MGEX provides precise satellite orbital and clock corrections and the satellite hardware delays for all GNSS constellations (Montenbruck ; Steigenberger; Khachikyan, Weber; Langley; Mervart; Hugentobler, 2014). Precise Point Positioning has been investigated by a number of research groups in the last two decades (Zumberge et al 1997, Kouba . and Héroux 2001, Gao Y, Chen 2004) .PPP has used some applications, including precise surveying, disaster monitoring, offshore exploration, and others (Xu et al 2013 and Geng et al 2013).

2-GNSS Observations Equations

Typically, the International Global Navigation Satellite System (GNSS) Service (IGS) estimates its precise clock corrections using the ionosphere-free linear combination of P1 and P2 pseudoranges. By convention, hardware delays are ignored during the estimation process of the precise clock corrections. As such, an additional term to account for hardware delay should be applied when using IGS precise clocks. This additional term results from the combination of the neglected P1 and P2 hardware delays. As satellite hardware delay is different for each observable, this means that its absolute value cannot be determined. The general ionosphere-free equations for pseudorange and carrier-phase can be written as (Shi, & Gao, 2013, Leick, 2004 and Hofmann-Wellenhof, Lichtenegger, and Walse 2008).

$$P_3 = \frac{f_1^2 P_1 - f_2^2 P_2}{f_1^2 - f_2^2} = \rho + c\,dt_r - c\,dt^s + T - c\,(A\,d_{r1} - B\,d_{r2}) + c\,(A\,d^{s1} - B\,d^{s2}) + e \qquad (1)$$

$$\Phi_3 = \frac{f_1^2 \Phi_1 - f_2^2 \Phi_2}{f_1^2 - f_2^2} = \rho + c\,dt_r - c\,dt^s + T + c\,(A\delta_{r1} - B\delta_{r2}) - c\,(A\delta^{s1} - B\delta^{s2}) + (\overline{\lambda N}) + \varepsilon \qquad (2)$$

Where

$$\overline{\lambda N} = \frac{f_1^2 \lambda_1 N_1 - f_2^2 \lambda_2 N_2}{f_1^2 - f_2^2}$$

$$A = \frac{f_1^2}{f_1^2 - f_2^2} \qquad B = \frac{f_2^2}{f_1^2 - f_2^2}$$

- P_1 and P_2 are GNSS pseudorange measurements on L_1 and L_2, respectively;
- Φ_1 , Φ_2 are the GNSS carrier phase measurements on L_1 and L_2 respectively
- d_r and d^s are frequency-dependent code
- hardware delay for receiver and satellite
- δ_r and δ^s are frequency-dependent carrier phase hardware delay for receiver and satellite, respectively;
- e, ε are relevant system noise and un-modeled residual errors; and $\overline{\lambda N}$ is the ambiguity term for phase measurements

3-Standard Un-differenced GNSS PPP Technique

Traditionally, PPP has been carried out using dual-frequency ionosphere-free linear combinations of carrier-phase and pseudorange GPS measurements In this section we will illustrate the ionosphere-free linear combinations of GPS, Galileo, and BeiDou observations (Li, Doua, Wickert,2014) ,then consider GPS time as a reference time system, the un-differenced ionosphere-free linear combinations of GPS, , Galileo and BeiDou observations (El-Sobeiey and El-Rabbany 2014, Wickert,2014).

$$P_{G_{IF}} = \rho_G + c[dt_{rG} - dt^s] + c[\alpha d_{P1} - \beta d_{P2}]_r + c[\alpha d_{P1} - \beta d_{P2}]^s + T_G + \varepsilon_{PG_{IF}} \quad (3)$$

$$P_{E_{IF}} = \rho_E + c[dt_{rG} - GGTO - dt^s] + c[\alpha d_{E1} - \beta d_{E5a}]_r + c[\alpha d_{E1} - \beta d_{E5a2}]^s + T_E + \varepsilon_{E_{IF}} \quad (4)$$

$$P_{B_{IF}} = \rho_B + c[dt_{rG} - GB - dt^s] + c[\alpha d_{B1} - \beta d_{B2}]_r + c[\alpha d_{B1} - \beta d_{B2}]^s + T_B + \varepsilon_{B_{IF}} \quad (5)$$

$$\Phi_{G_{IF}} = \rho_G + c[dt_{rG} - dt^s] + c[\alpha\delta_{L1} - \beta\delta_{L2}]_r + c[\alpha\delta_{L1} - \beta\delta_{L2}]^s + T_G + N_{G_{IF}} + \phi_{r0_{G_{IF}}} + \phi^s_{0_{G_{IF}}} + \varepsilon_{\Phi G_{IF}} \quad (6)$$

$$\Phi_{E_{IF}} = \rho_E + c[dt_{rG} - GGTO - dt^s] + c[\alpha\delta_{E1} - \beta\delta_{E5a}]_r + c[\alpha\delta_{E1} - \beta\delta_{E5a}]^s + T_E + N_{E_{IF}} + \phi_{r0_{E_{IF}}} + \phi^s_{0_{E_{IF}}} + \varepsilon_{\Phi E_{IF}} \quad (7)$$

$$\Phi_{B_{IF}} = \rho_B + c[dt_{rG} - GB - dt^s] + c[\alpha\delta_{B1} - \beta\delta_{B2}]_r + c[\alpha\delta_{B1} - \beta\delta_{B2}]^s + T_B + N_{B_{IF}} + \phi_{r0_{B_{IF}}} + \phi^s_{0_{B_{IF}}} + \varepsilon_{\Phi B_{IF}} \quad (8)$$

Where:-

- G, E and B : - refer to GPS, Galileo and BeiDou systems observations, respectively are the ionosphere-free pseudoranges in meters for GPS, Galileo, and BeiDou systems, respectively

- $P_{G_{IF}}$, $P_{E_{IF}}$ and PBIF are the ionosphere-free pseudoranges in meters for GPS , Galileo, and BeiDou systems, respectively;

- $\Phi_{G_{IF}}$, $\Phi_{E_{IF}}$ and $\Phi_{C_{IF}}$ are the ionosphere-free carrier phase measurements in meters for GPS, Galileo, and BeiDou systems, respectively :

- GGTO is the GPS to Galileo time offset

- GB:n is the GPS to BeiDou time offset

- ρ : is the true geometric range from receiver at reception time to satellite at transmission time in meter

- dtr, dts are the clock errors in seconds for the receiver at signal

reception time and the satellite at signal transmission time, respectively

- dp1r, dp2r, dE1r ,dE5ar,dB1r, dB2r are frequency-dependent code hardware delays for the receiver at reception time in seconds

- dp1 S, dp2S, dE1S ,dE5aS,dB1S, dB2aS are frequency-dependent code hardware delays for the satellite at transmission time in seconds

- δL1r, δL2r, , δE1r, , δE5r, , δB1r, , δB2r are frequency-dependent carrier-phase hardware delays for the receiver at reception time in seconds

- δL1 S , δL2 S, δE1 S, δE5, S , δB1 S, δB2 S are frequency-dependent carrier-phase hardware delays for the satellite at transmission time in seconds;

- T: is the tropospheric delay in meter;

- NGIF , NEIF , NBIF are the ionosphere-free linear combinations of the ambiguity parameters for both GPS, Galileo, and BeiDou carrier phase measurements in meters, respectively;

- $\phi r0_{G_{IF}}, \phi_{0_{G_{IF}}}^{S}, \phi r0_{E_{IF}}, \phi_{0_{E_{IF}}}^{S}, \phi r0_{B_{IF}}, \phi_{0_{B_{IF}}}^{S}$ are ionosphere-free linear combinations of frequency-dependent initial fractional phase biases in the receiver and satellite channels for both GPS, Galileo, and BeiDou in meters, respectively;

- C: is the speed of light in vacuum in meter per second

- α G , β G, αE , β E ,αB , βB are the ionosphere-free linear combination coefficients for GPS, Galileo, and BeiDou which are given, respectively

$$\alpha_G = \frac{f_1^2}{f_1^2 - f_2^2} \qquad \beta_G = \frac{f_2^2}{f_1^2 - f_2^2}, \qquad \alpha_E = \frac{f_{E1}^2}{f_{E1}^2 - f_{E5a}^2}, \beta_E = \frac{f_{E5a}^2}{f_{E1}^2 - f_{E5a}^2}, \qquad \alpha_B = \frac{f_{B1}^2}{f_{B1}^2 - f_{B2}^2}, \quad \beta_B = \frac{f_{B2}^2}{f_{B1}^2 - f_{B2}^2}.$$

Where :

f^1 and f^2: are GPS L1 and L2 singles frequency

;

fE1 and fe5 are Galileo E1 and E5a signals frequencies

fB1 and fB2 are BeiDou B1 and B2 signals frequencies

All remaining errors and biases are accounted for using existing models as shown in (Kouba, 2009. accessed on 15 April 2016). The developed PPP model employs GPS L1/L2, Galileo E1/E5a, and BeiDou B1/B2 signals in dual-frequency ionosphere-free linear combinations fE1 and fE5a are Galileo E1 and E5a signals frequencies; fB1 and fB2 are BeiDou B1 and B2 signals frequencies.

$$N_{G_{IF}} = \alpha_G \lambda_1 N_1 - \beta_G \lambda_2 N_2 \qquad (9)$$

$$N_{E_{IF}} = \alpha_E \lambda_{E1} N_{E1} - \beta_E \lambda_{E5a} N_{E5a} \qquad (10)$$

$$N_{B_{IF}} = \alpha_B \lambda_{B1} N_{B1} - \beta_B \lambda_{B2} N_{B2} \qquad (11)$$

where

λ_1 and λ_2 are the GPS L1 and L2 signals wavelengths in meters

λ_{E1} and λ_{E5a} are the Galileo E1 and E5a signals wavelengths in meters

λ_{B1} and λ_{B2} are the BeiDou B1 and B2 signals wavelengths in meters

N1, N2: are the integer ambiguity parameters of GPS signals L1 and L2

NE1,NE5a: are the integer ambiguity parameters of Galileo signals E1 and E5a

NB1,NB2: are the integer ambiguity parameters of BeiDou signals B1 and B2

Precise orbit and satellite clock corrections of IGS-MGEX networks are formed for GPS, Galileo and BeiDou observations and are indicated to GPS time. IGS precise GPS satellite clock correction contains the effect of the ionosphere-free linear combination of the satellite hardware delays of L1/L2 P(Y) code, while the Galileo counterpart includes the effect of the ionosphere-free linear combination of the satellite hardware delays of the Galileo E1/E5a pilot code. In addition, BeiDou satellite clock correction includes the effect of the ionosphere-free linear combination of the satellite hardware delays of B1/B2 code (Fritsche, Wickert,2015). By using GNSS" GPS, Galileo and BeiDou" un-differenced post-processed PPP solution, the GPS receiver clock error is joined to the GPS receiver differential code biases. To keep steadiness in the calculating the common receiver clock offset, this happened by using the ionosphere-free linear combination of GPS L1/L2, Galileo E1/E5a, and BeiDou B1/B2 observations in the post-processed PPP solution. However, additional bias in the Galileo ionosphere-free PPP mathematical model, which represents the difference in the receiver differential code biases of both systems. Such an additional bias is commonly known as the inter-system bias, which is referred to as ISB. In our PPP model, the Hopfield tropospheric correction were applied and other correction too .

3-Analysis and Results

A new PPP model, which combines the observations of current GNSS constellations, only positioning accuracy that the convergence time for the combined GNSS PPP was enhanced by 27% compared with the standard GPS/BeiDou PPP convergence time, while the additional Galileo satellite was found to be insignificant when its observations were added to the GPS observations. Compared with GPS PPP, the GNSS PPP enhanced the positioning accuracy by 10 cm, 6 cm and 11 cm in East, West and H , respectively.figure (1,2,3)

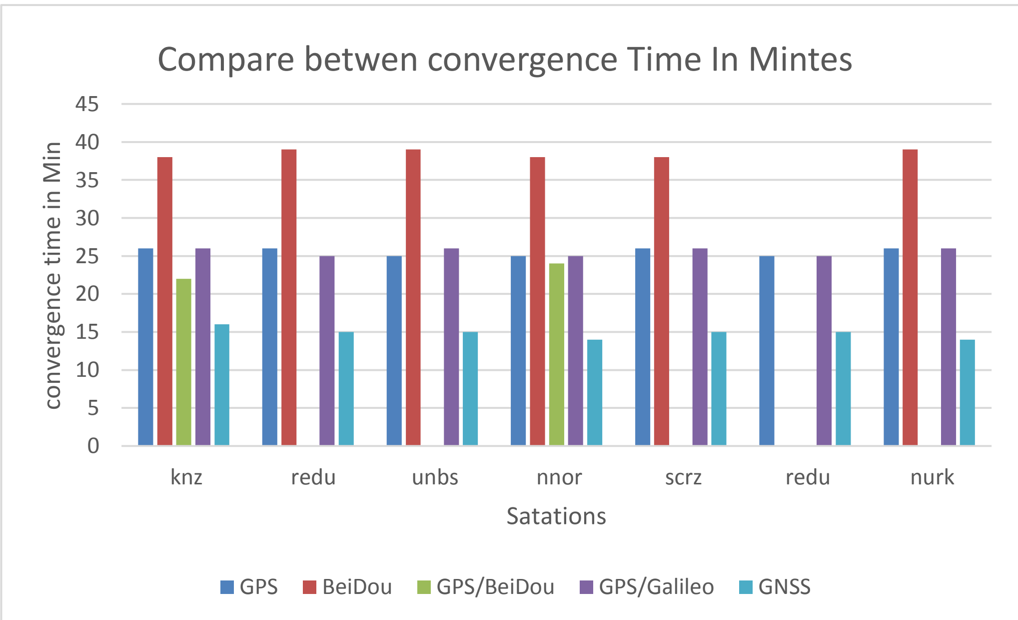


Figure (1): Convergence time for used stations by using un-differenced technique

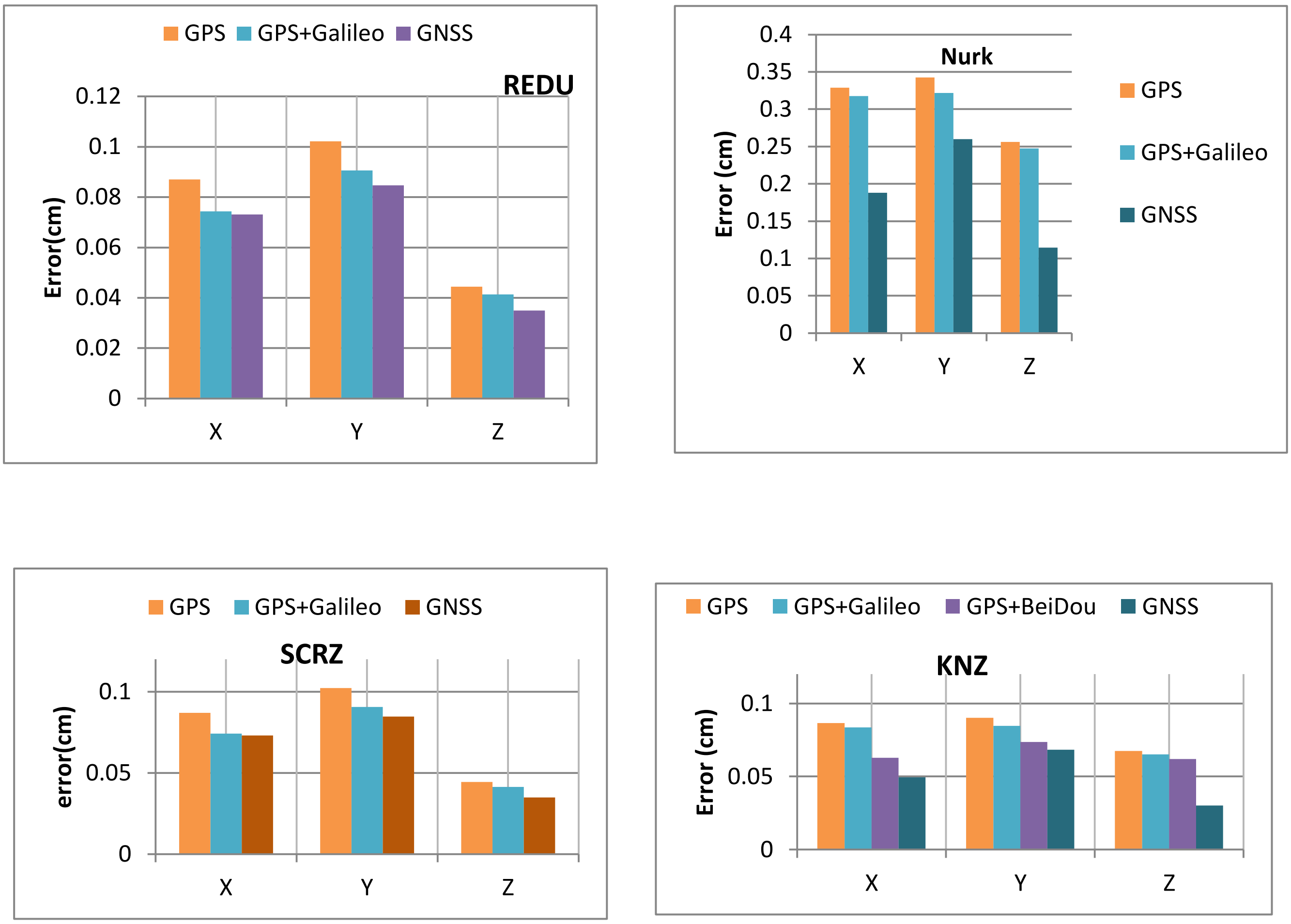
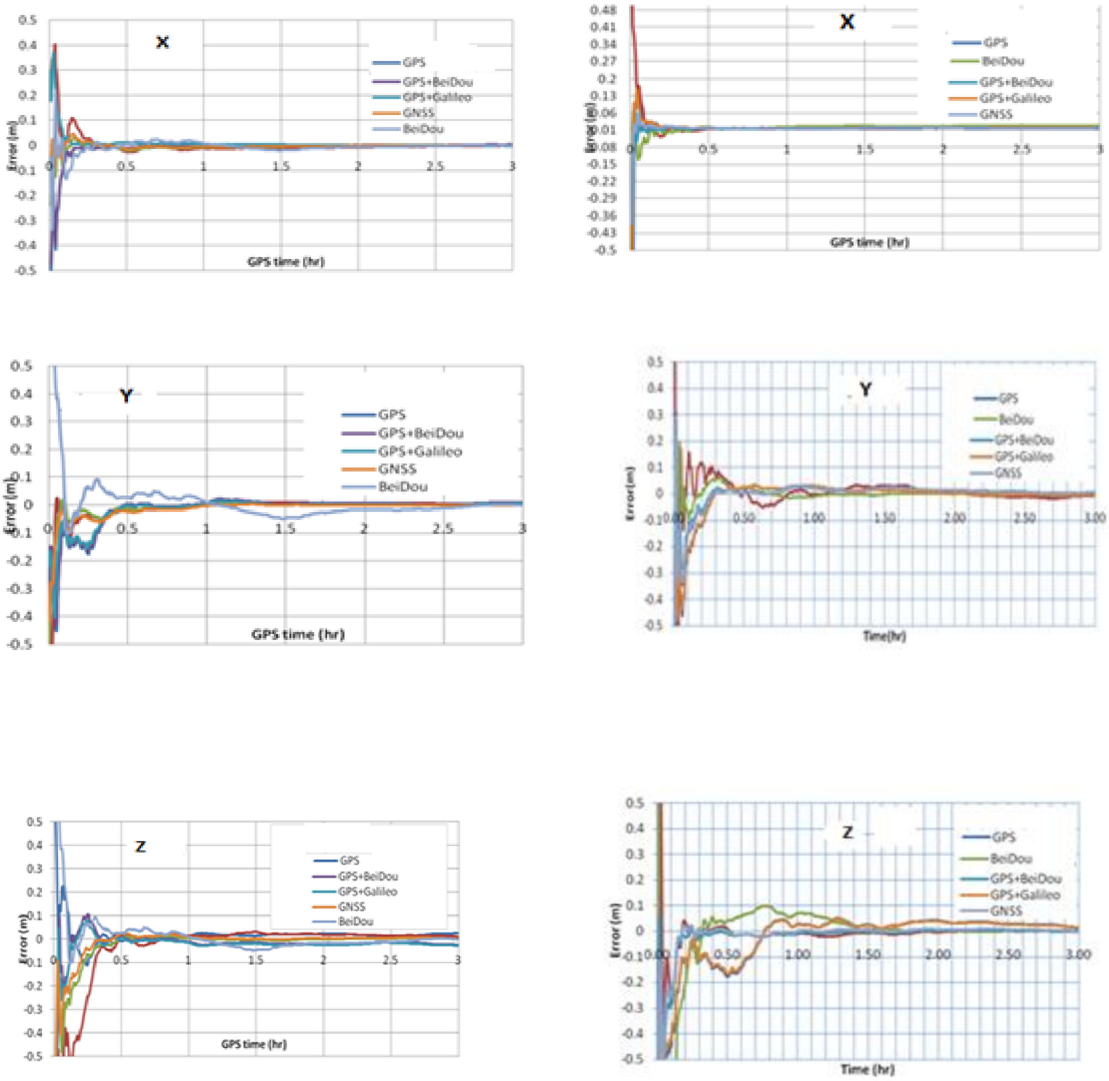


Figure (2): Positioning accuracy summary for different GNSS combinations for multiple point



Station KNZ at DOY 1/4, 2016

Station: REDU at DOY 1/4 2016

Figure (3): _ Summary of positioning standard deviations in East, North, and Up directions of all un-differenced post-processed PPP solutions combinations for stations KNZ and REDU at DOY 1/4 ,2016

4-Conclusion

A new PPP model has been introduced in this paper, which combines GPS, Galileo and BeiDou system observations. Triple-constellation GNSS (GPS, Galileo, and BeiDou) PPP model, which rigorously accounts for all errors and biases, including the additional biases introduced as a result of combining the observations of different GNSS constellations. These additional biases will collect together into a new unknown parameter, which is referred to the inter-system bias in our PPP model . At present, the IGS-MGEX provides precise satellite orbital and clock corrections and the satellite hardware delays for all GNSS constellations . PPP essentially relies on the availability and using of precise satellite products, namely orbital and clock corrections . A dual frequency PPP model, which combines GPS /Galileo,GPS /BeiDou observables has been developed. The developed PPP model employs GPS L1/L2, Galileo E1/E5a, and BeiDou B1/B2 signals in dual-frequency ionosphere-free linear combinations. Sequential least-squares estimation technique is used to obtain the best estimation, in the least-squares sense, for the unknown parameters. Global navigation satellite systems (GNSS) precise point positioning (PPP) has been proven the capable of providing positioning accuracy with sub-decimeter and decimeter levels in static modes . It has been shown that the un-differenced PPP positioning gives better results than using GPS-only and can reach sub-decimeter level of accuracy.

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