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PRECISION EVALUATION FOR DIFFERENT GNSS RINEX 3 USING ONLINE SERVICES AND OPEN-SOURCE SOFTWARE PPP-MANS

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Abstract. It is critical to evaluate the reliability of using free online processing software for Global Navigation Satellite System post-processing since the advancement of GNSS gives satellite navigation customers all over the world great benefits. AUSPOS, IBGE, Magic GNSS, CSRS-PPP, and open-source software are some of the online processing solutions being evaluated for accuracy in this study. GNSS observations from IGS were used to conduct field observations using RINEX 3 data from three stations, with an observation duration of 30 seconds. After data acquisition, it was processed with online and free software that made use of GPS, GPS, and GLONASS. When compared to coordinates obtained from reference stations, the relative differences and correctness of the coordinates generated by each piece of software were then evaluated. coordinates in the ITRF14 reference for the X, Y, and Z directions. Online GNSS processing services may be used with greater accuracy for engineering and geodetic applications and are simple to use without the need for GNSS data processing expertise.

Keywords: online processing services, GNSS, AUSPOS, IBGE, Magic GNSS, CSRS-PPP, PPP-MANS.

Introduction

The creation of satellite-based global navigation systems, also known as global navigation satellite systems (GNSS), heralded the beginning of a brand-new and exciting era in location, navigation, and time. Everyone now has access to nearly instantaneous, continuous, simple, and affordable estimates of location, velocity, and time. GNSS is utilised for a variety of tasks, including surveying and navigation. As a result, using conventional techniques to build and maintain a network of permanent stations is expensive. On the other side, the International GNSS Service (IGS) provides incredibly precise satellite orbits, clock corrections, or atmospheric products (Herbert et al., 2020).

Global navigation satellite systems (GNSS), also known as satellite-based global navigation systems, heralded the beginning of a brand-new and exciting era in positioning, navigation, and timing. Today, reliable estimates of position, velocity, and time are available to everyone practically immediately, continuously, simply, and inexpensively. Navigation and surveying are only two of the numerous uses for GNSS. Because of this, it is expensive to build and maintain a network of permanent stations using conventional techniques. On the other side, the International GNSS Service (IGS) provides exceptionally precise clock corrections, atmospheric products, and satellite orbits (Öğütcü et al., 2022). Real-time based solutions like differential GPS (DGPS), real-time kinematic (RTK), and wide-area augmentation systems require satellite receiver intersystem communication to calculate a point's location. It is crucial to use this form of differential placement when prompt results are desired. The post-processing techniques perform the modifications after acquiring the GPS data (Herbert et al., 2020).

If the data was gathered using a double frequency GNSS receiver and viewed from any position on Earth, the data RINEX file can be sent to online services for post-processing. Some services also offer a wide range of data types. However, the user must take a number of factors into consideration in order to get high accuracy results for the coordinates of the submitted points, including data, the processing method, the mathematical model used in post-processing, the accuracy of the products, additional data, like reference station coordinates, satellite orbit, and clock correction, the length of the observed file, and the quality of the observed data (Wielgocka et al., 2021).

Research is necessary to evaluate the accuracy of GNSS location for different applications due to the different

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levels of accuracy. Centimetre level position is required for some purposes but not for others. Two GNSS receivers must be used in order to ensure accurate positioning because real-time kinematic techniques are susceptible to multipath, unstable data links from the reference station, and poor satellite visibility. Additionally, the data must be post-processed using specialist or commercial software due to the vulnerability of these methods to these issues. Due to their ease of use and lack of necessity for GNSS post-processing knowledge, online processing services have now supplanted research and commercial software in the processing of GNSS data (Dao et al., 2022).

1. Online post-processing services

In place of the traditional processing method, many individuals now use GNSS online processing services like in Figure 1. These processing services have grown in popularity due to their simplicity of use, absence of cost (or low cost fee), lack of requirement for a licence, and lack of GPS processing knowledge. Before being shared through email or posted to a particular website, the GNSS data that users of these services have collected must be transformed to Receiver Independent Exchange (RINEX) format. The user's registered email may be used to easily obtain the coordinates a few minutes after the data has been posted. Today, it is feasible to handle data for both static and kinematic location modes thanks to these free web-based processing engines (Alkan et al., 2016).

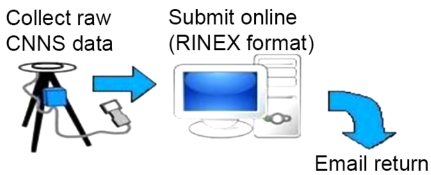


Figure 1. Online based GNSS processing method (Alkan et al., 2016)

1.1. AUSPOS

Geoscience Australia developed the free online GNSS processing facility known as AUSPOS. It makes use of the network of IGS stations, the IGS product line, and appropriate data collected from any point on Earth. The Bernese GNSS Software is used to process baselines. An easy-to-use online interface is used to enter the antenna height and type as well as an email address for the returned report set. You may use the AUSPOS service on the Geo-science Australia website at http://www.ga.gov.au (Abd-Elazeem et al., 2011).

1.2. Magic GNSS

An online programme called Magic GNSS analyses Multi GNSS data. For data processing in static and kinematic mode at two frequencies, it was developed by the firm GMV Aerospace and Defence and made accessible on the website of the company. It only supports dual-frequency observations. Using online post-processing tools has the following advantages: No matter the type of computer being used, post processing may be done whenever and wherever there is internet or email connectivity; moreover, no specialised software has to be installed, and results and reports are swiftly provided back to the sender (Oluyori et al., 2019).

1.3. CSRS-PPP

CSRS-PPP provides an online service that enables users to compute high precision positions from their initial observed data in order to post-process GNSS data. CSRS estimations are computed using carrier phase or code pseudo-range measurements of single- and dual-frequency receivers. Users can upload observed data from single- or dual-frequency receivers operating in static or kinematic mode in RINEX format over the internet for further analysis (Shehata, 2023).

2. PPP-MANS MATLAB based program

PPP-MANS was created in the MATLAB environment to aggregate multi-GNSS (GPS, GLONASS, Galileo, and BeiDou) data for PPP processing. Fundamentally, PPP-MANS aims to be a trustworthy, user-friendly, and successful software solution. PPP-MANS provides a user-friendly code to allow users to choose the navigation files, select the processing options, and examine the results. Each of the 3 main PPP-MANS components, together with any related settings, The PPP-MANS working flowchart in Figure 2 displays the essential parts and their roles. The last part is where the results are evaluated and presented. The first four elements provide multi-GNSS PPP solutions by utilising related concepts and theories (Shehata et al., 2023).

A result file including the estimated parameters for each epoch is provided by PPP-MANS when all process steps have been completed, as shown in Figure 2. Furthermore, data regarding the process, such as positioning error, root mean square error, and convergence time, may be obtained in relation to user-defined ground truth using the Analysis tab. PPP-MANS can create a number of graphs, including those for positioning error, tropospheric zenith total delay, receiver clock estimation, satellite number, and dilution of precisions, to assess the epoch-by-epoch fluctuations of estimated parameters and associated statistics. The IGS stations that are depicted in Table 1 were included in our study.

3. Experimental results

The online PPP services offer station coordinates in the ITRF frame and ZTD estimations at the user station. In order to evaluate the performance of the services in relation to many different criteria, analysis and comparisons are performed. Static positioning findings using daily observation data sets from IGS stations are compared with IGS reference values to gauge the accuracy of static PPP

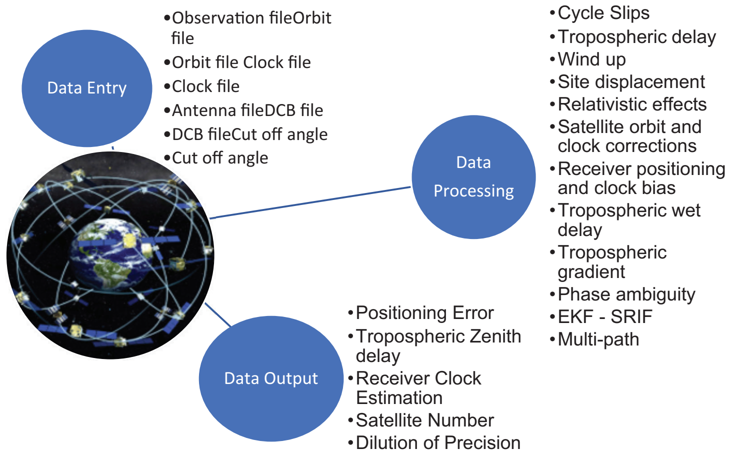
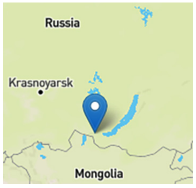
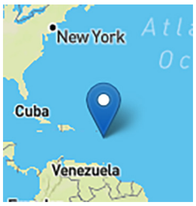


Figure 2. PPP-MANS processing steps

Table 1. IGS station information

Station	Receiver	Antenna	Location
ABMF RINEX3	SEPTPO-LARX5	TRM57971	
BADG RINEX3	JAVA-DTRE-3	JAVRIN-GANT-DM	
DAEJ RINEX3	TRIMB-LENETR9	TRM59800	

for extended observation periods. Static PPP processing results for various short observation periods are compared with reference data to examine PPP performance of accuracy and convergence for short observation periods. We compare the positioning error, zenith delay, and clock estimate for different systems (Guo, 2015).

The findings and the reference values are produced in order to show and contrast the differences between the online PPP static solutions and software using the IGS reference values. The difference and its root mean square error are displayed in the tables and graphs.

In conclusion, it can be shown from Figures 3 and 4, as well as Tables 2 and 3, that, when used with daily observation data sets, the precision of the (X, Y, Z) components may be measured to the centimetre and millimetre levels when compared to reference values. Regarding coordinate estimations, there isn't much of a difference between online PPP services and software; virtually all of them can go down to the centimetre or millimetre level.

Table 2. Difference in Cartesian coordinates between reference stations and GPS only solutions using online and PPP-MANS

Station	Coor-dinate	On line			Software
		AUSPOS	IBGE	Magic GNSS	PPP-MANS
ABMF	X	0.147	0.285	0.191	0.768
	Y	–0.001	0.087	–0.059	0.260
	Z	–0.911	–0.605	–0.894	–0.521
BADG	X	0.604	0.614	0.614	–0.138
	Y	0.050	0.012	0.010	0.824
	Z	0.114	0.072	0.086	0.001
DAEJ	X	0.405	0.381	0.299	0.187
	Y	0.038	0.022	0.009	0.846
	Z	0.249	0.176	0.278	1.179

Table 3. Difference in Cartesian coordinates between reference stations, online solutions and open-source software using Multi GNSS

Station	Coor-dinate	On line		Software	
		CSRS-PPP	Magic GNSS	GSIPOST	PPP-MANS
ABMF	X	0.18	0.199	–0.281	0.658
	Y	–0.032	–0.048	–0.756	0.21
	Z	–0.905	–0.877	–1.536	–0.299
BADG	X	0.612	0.613	–0.501	–0.13
	Y	0.018	0.016	0.156	0.034
	Z	0.074	0.088	1.183	0.004
DAEJ	X	0.325	0.422	0.327	0.180
	Y	0.048	0.049	0.014	0.785
	Z	0.388	0.249	0.988	1.219

A frequently employed metric for contrasting values received from several sets of measurements is the RMSE.

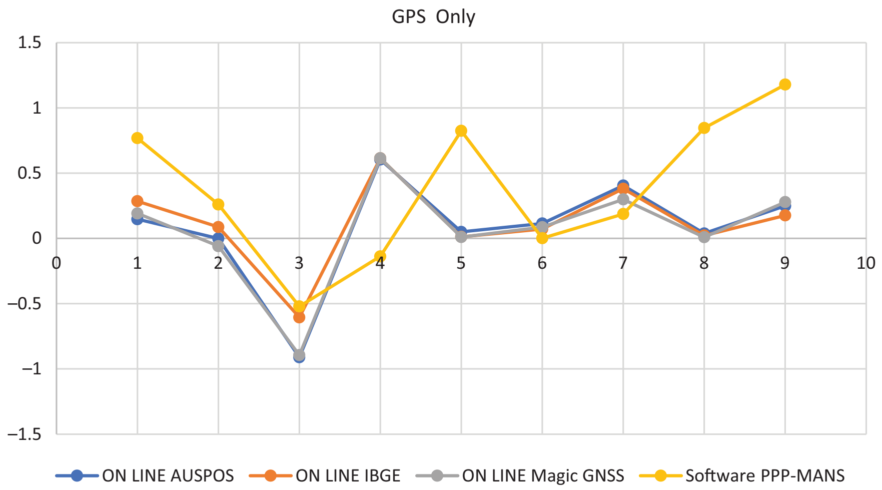


Figure 3. Difference in Cartesian coordinates between reference stations and GPS only solutions using online and PPP-MANS

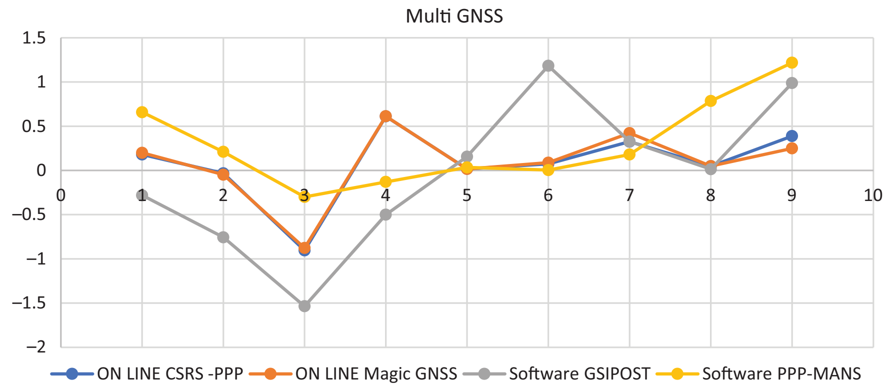


Figure 4. Difference in Cartesian coordinates between reference stations, online solutions and open-source software using Multi GNSS

The RMSE combines these distinct variations, commonly referred to as residuals, into a single extrapolative power measurement. The RMSE of the processed coordinates (obtained by GNSS software) with respect to the observed coordinates (obtained using an IGS reference station) is therefore defined as the square root of the mean squared error. With declining RMSE estimations, the 3D coordinates obtained from the GNSS processing software become more accurate. The RMSEs of the GNSS processing software are listed in the Table 4 (Charoenkalunyuta et al., 2012).

Table 4. RMSEs of the GNSS processing software

GNSS processing software	GPS only	Multi GNSS
AUSPOS (Online)	0.303	–
IBGE (Online)	0.216	–
Magic GNSS (Online)	0.273	0.300
CSRS-PPP (Online)	–	0.307
PPP-MANS	0.176	0.175
GSIPOST	–	0.499

Conclusions

All of the free online PPP services can deliver centimetre- or millimeter-level accuracy for a single station over an extended observation period when operating in static mode. In comparison to IGS solutions, online PPP services' daily horizontal component estimation precision might be millimeter-level.

Users of the free online PPP services don't need to invest in software; positioning accuracy of 1–2 cm or even millimetre level may be attained with just a single receiver.

PPP solutions can be offered by software for user multi-GNSS combinations. Within the software's GUI, users may additionally define choices, models, and parameters. also offers a variety of analysis tools and an output file with the estimated parameters for each epoch individually so that the findings may be statistically evaluated.

Additionally, it has more PPP processing functionality than online alternatives, and its capabilities may be expanded to effectively suit the needs of sophisticated users.

Online processing software outperforms PPP software in the X, Y, and Z directions with determined root mean square results.

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