Performance of GNSS-PPP in Post-Processing Mode

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Key words: Precise Point Positioning, PPP post-processing services

SUMMARY

Precise Point Positioning (PPP) is a GNSS analysis technique for cm level positioning without using observations from a reference station or a reference station network. This positioning method, however, requires precise satellite orbit and satellite clock information.
Some free PPP post-processing services enable the processing of GNSS observations stored in RINEX format and provide static and kinematic results. We tested the PPP services Automatic Precise Point Positioning (APPS) and Canadian Spatial Reference System (CSRS) Precise Point Positioning and we computed independent PPP solutions with our own software. The various PPP results were compared with precise GNSS baseline processing results. The kinematic data sets originate from hydrographic surveys on the Baltic Sea.
The APPS Service and our own PPP solution provide centimeter accurate 2D positions and a height accuracy of about 5 cm for long observation data. The standard deviations of the CSRS solution are twice as large. Additional GLONASS observations slightly improve the results.
We also tested the convergence time of the kinematic data sets. At the beginning of a PPP processing the further GLONASS observations induce large improvements. After just 30 minutes of continuous observations we achieve standard deviations in position and height smaller than one decimeter.

1. INTRODUCTION

For hydrographic surveys on the open sea the Precise Point Positioning (PPP) processing is a suitable GNSS analysis technique. No other observations from a reference station or reference station network as used by conventional differential algorithms are required (Zumberge, 1997). Using continuous GPS (and GLONASS) dual frequency phase (and code) observations, positioning with centimeter accuracy is possible for static and kinematic applications. This method requires the introduction of precise satellite orbits and clocks corrections. These information are provided by the International GNSS Service (IGS) and its analytical centers (AC). Furthermore, numerous corrections like satellite antenna offsets, tidal displacements etc. have to be considered (Kouba, 2009).
In recent years several free PPP post-processing services have been established. These services perform static and kinematic evaluation based on RINEX observation data. We have analyzed the accuracy of the PPP solutions of two such services and our own PPP software with respect to coordinate accuracy and convergence time.

2. PPP SERVICES

The two tested cost-free PPP Services are Automatic Precise Point Positioning (APPS) from Jet Propulsion Laboratory (apps.gdgps.net) and Canadian Spatial Reference System (CSRS) Precise Point Positioning (www.geod.nrcan.gc.ca) from Natural Resources Canada (NRCan). Table 1 shows the most important characteristics of these services.

Table 1: Attributes of the two PPP Services

PPP-Services	APPS	CSRS
data transfer	e-mail, web interface	web interface
Observation data	GPS, dual frequency, static and kinematic	GPS, dual frequency, static and kinematic
Data format	RINEX 2, Hatanaka	RINEX 2, Hatanaka
Satellite orbits and clocks	own products	IGS
Interval of tabular clock value	5 min, 30 sec	5 min
Antenna correction	own data	IGS
Result transfer	link via e-mail	link via e-mail
Reference system	ITRF05	ITRF05/NAD83
Coordinate format	LLH/XYZ	LLH/XYZ/UTM
Quality information	covariance matrix	standard deviations

The major difference between these two services lies in the use of different satellite clock products. CSRS uses the clock and orbit information from IGS. APPS-results, however, are based on precise orbit and satellite clocks from an own reference network.

3. PPP-ANALYSIS OF KINEMATIC OBSERVATION DATA

The sample data sets used in the following analysis originate from hydrographic surveys performed by the German Federal Maritime and Hydrographic Agency (Bundesamt für Schifffahrt und Hydrographie – BSH) on the Baltic Sea in summer of 2009. The LEICAGRX receiver recorded GPS and GLONASS observations at an interval of one second.
For our own PPP Solution we used our post-processing software modules *wapp* and *TripleP*. In contrast to the PPP Services, we are able to process GPS and GLONASS observations. Therefore we also needed GLONASS precise orbits and clock corrections. The only AC which offers these products is the European Space Operations Center (ESOC) in Darmstadt (Springer et al. 2008). The interval of these tabular clock correction values is 30 seconds.

3.1 Coordinate accuracy of long observation data

We sent four kinematic data sets to the services and also computed PPP solutions with our own software. These results were compared with the coordinates from a baseline processing to a nearby reference station. Based on the individual differences between the baseline and the PPP solutions the average standard deviation in north, east and height could be calculated (Table 2).

Table 2: Average standard deviation of kinematic data sets

Software	North [cm]	East [cm]	Height [cm]
TripleP (GPS only)	1.5	1.1	4.0
APPS (GPS only)	1.5	2.1	6.2
CSRS (GPS only)	4.7	4.0	11.2
TripleP (GPS+GLONASS)	1.2	0.9	3.1

TripleP solutions were computed for GPS only and for combined GPS and GLONASS observations. The TripleP and APPS solutions reach a high level of accuracy in position and also in height. The CSRS solution is worse by a factor 2 to 3 in all coordinate components. The addition of GLONASS observations to our processing especially improved the height results.
Figure 1 shows the height differences between the baseline solution and the three PPP solutions. The large noise in the differences and the high standard deviation (Table 2) of the CSRS solution can be explained by the satellite clock correction interval of 5 minutes. Between the tabular clock corrections an interpolation is indispensable. The short term stability of the GNSS satellite clocks causes interpolation errors depending on individual satellite clock and tabular clock correction intervals. The accuracy increases with smaller intervals of satellite clock corrections (Heßelbarth and Wanninger, 2008).

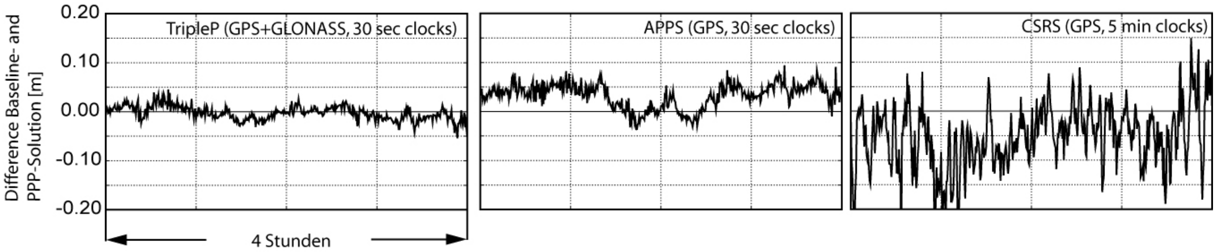

Figure 1: Height differences between baseline and PPP solutions, DOY 213/09, Baltic Sea

3.2 Convergence time

For the examination of the convergence time of kinematic GNSS data we used our software modules. The kinematic data sets were divided into intervals of different lengths of observation periods (5, 10, 15 min etc). Thus, we were able to determine the standard deviations in north, east and height for every observation block. Figure 2 shows the 2D position and height standard deviation in dependence of the observation time. It can clearly be seen that adding GLONASS observation to GPS reduces the convergence time considerably.

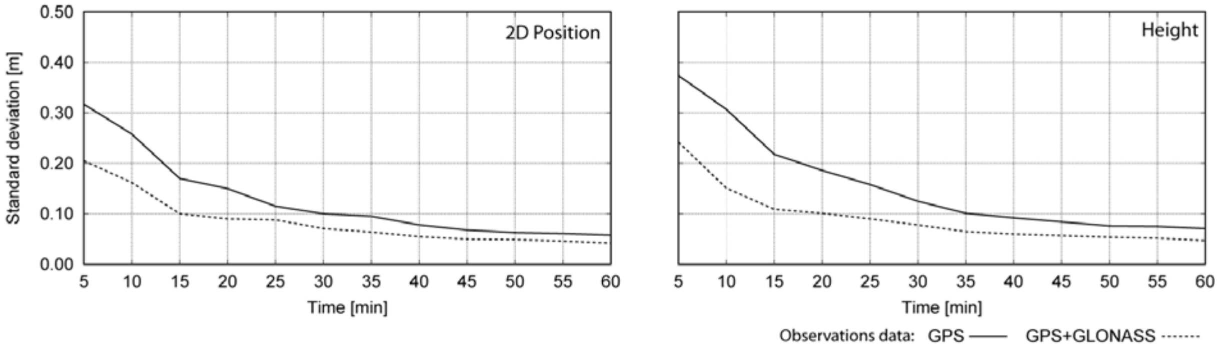

Figure 2: Standard deviations of the differences to a baseline solution as a function of observation time

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BIOGRAPHICAL NOTES

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