Static Precise Point Positioning Accuracy in GrafNav 8.10

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Executive Summary

Four days of data from five permanent GPS stations are used in this report to evaluate static Precise Point Positioning (PPP) performance in GrafNav 8.10.

Results show that horizontal accuracies of 1 cm and vertical accuracies of 2.5 cm are achievable provided 24 hours of open sky, low multipath dual frequency GPS data

RMS and 95% results are summarized for 1, 2, 3, 6, 12 and 24 hours of data collection in order to give an overall impression of static PPP performance as a function of observation length.

Background

GrafNav is a popular Windows based GNSS post-processing package used for high precision applications such as airborne mapping, trajectory reconstruction and surveying. For more information on GrafNav please see: http://www.novatel.ca/products/waypoint_grafnav.htm

In order to achieve moderate to high levels of accuracy, one or more base stations can be used within a GrafNav project (for kinematic processing) or a static network can be processed and adjusted in GrafNet. Base station(s) provide differential corrections that eliminate correlated GPS error sources. Any error in base station coordinates will directly bias a differentially processed trajectory. Static PPP processing is one way to verify or even compute base station coordinates. GrafNav includes a PPP processor that requires dual frequency GPS data and precise clock and orbit files.

Precise clock and orbit files can be downloaded through GrafNav's interface provided an internet connection is available. Final precise clock and orbit files have a latency of approximately two weeks, whereas rapid products have a latency of approximately one GMT day. Testing has shown a negligible difference (within 0.2 cm) between static PPP results obtained using either the rapid or final precise products supported by GrafNav.

The accuracy to which base station coordinates can be checked or surveyed depends both on the GPS data quality and the length of data collection. It is the goal of this report to provide a guide for obtainable static PPP accuracy in GrafNav 8.10 as a function of time for high quality data (open sky, low multipath).

Although this report focuses on static PPP accuracy, two reports regarding kinematic PPP accuracy can be found on NovAtel's website here: http://www.novatel.ca/products/waypoint_techreports.htm

Static PPP Testing

In order to quantify static PPP results, data and station coordinates from the Scripps Orbit and Permanent Array Center (SOPAC) GPS network were used. SOPAC freely provides GPS data for download via their GARNER archive (see http://sopac.ucsd.edu/other/services.html).

Five stations were chosen from different countries in order to provide independent satellite geometry at each location for a given test period. The five stations were also selected as they provide un-interrupted 24 hour GPS data coverage for the chosen dates of January 01, April 01, July 01, and August 01 2007. The four digit designations of the stations used are:

- BRUS (Brussels, Belgium)
- CHPI (Sao Paulo, Brazil)
- DDSN (Oregon, USA)
- KUNM (Yunnan, China)
- PRDS (Alberta, Canada)

The receivers used at each station respectively are Ashtech Z-XII3T, Ashtech UZ-12, Trimble NetRS, ROGUE SNR 8000 and AOA Benchmark ACT. This combination of stations and dates produces a total of twenty 24 hour data sets. By evenly splitting this into 12 and 6 hour data sets, forty 12 hour sessions and eighty 6 hour sessions are formed. By extension it can be seen that many more sessions can be formed with 1, 2 and 3 hour files. In order to practically limit the number of processing runs for these shorter observation periods, a limit of eighty processing runs was used for any processing interval.

Final precise clock and ephemerides were downloaded through GrafNav's interface from the Crustal Dynamics Data Information System (CDDIS) FTP site. For more information on the CDDIS please see http://cddisa.gsfc.nasa.gov/.

The CDDIS FTP site stores several final precise orbit and clock files produced by various analysis centers. GrafNav's download utility assigns the highest priority to the precise files produced by the Massachusetts Institute of Technology (MIT) analysis center at Cambridge, MA. The MIT precise correction files were used for all data processing in this report.

All results to follow were generated from a combined forward and reverse static PPP solution in GrafNav 8.10. Computed coordinates for each session were differenced with the published coordinates provided by SOPAC. Care was made to request published positions at each station for each day of data processing (day of year numbered 001, 091, 182 and 213 of 2007). This was done as ITRF station coordinates can change by up to a centimeter or more throughout the year depending on location.

Results from all five permanent GPS stations were combined for each processing interval (1, 2, 3, 6, 12 and 24 hours) in order to report globally representative values for each interval.

RMS and 95% error values are calculated for each data processing interval for North, East, horizontal and height. North and East are presented separately in order to show the different levels of convergence between the horizontal axes.

Results

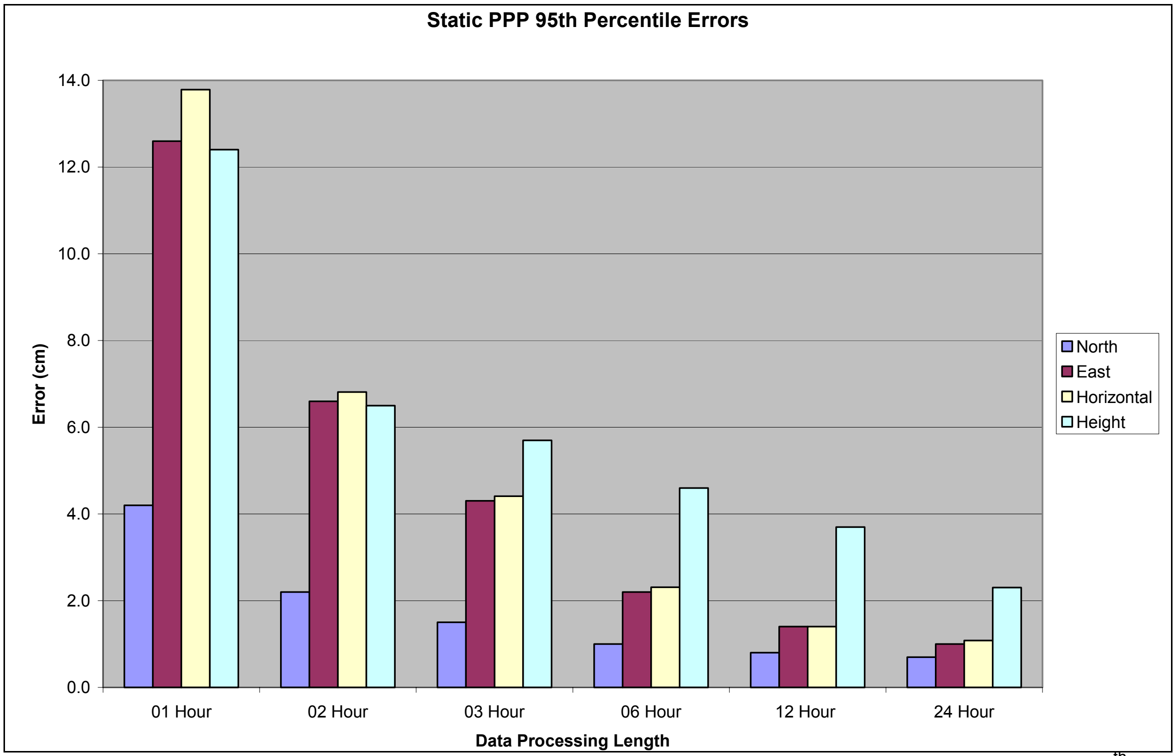

Figure 01: GrafNav 8.10 Static Precise Point Positioning North, East, Horizontal and Height Errors (95th percentile) using five SOPAC sites over four Dates in 2007

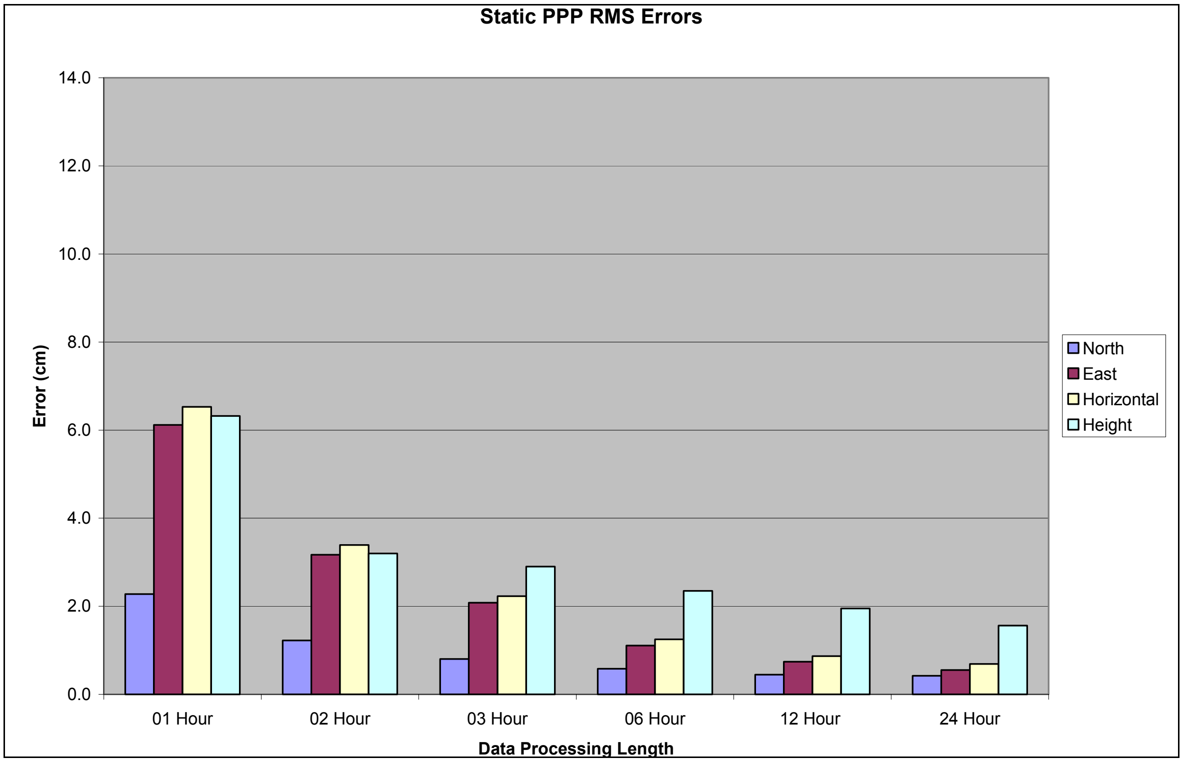

Figure 02: GrafNav 8.10 Static Precise Point Positioning North, East, Horizontal and Height Errors (RMS) using five SOPAC sites over four Dates in 2007

Table 1: GrafNav 8.10 Static Precise Point Positioning North, East, Horizontal and Height Errors (95th percentile) using five SOPAC sites over four Dates in 2007

Data Processing Length	Error (cm)			
	North	East	Horizontal	Height
01 Hour	4.2	12.6	13.8	12.4
02 Hour	2.2	6.6	6.8	6.5
03 Hour	1.5	4.3	4.4	5.7
06 Hour	1.0	2.2	2.3	4.6
12 Hour	0.8	1.4	1.4	3.7
24 Hour	0.7	1.0	1.1	2.3

Table 2: GrafNav 8.10 Static Precise Point Positioning North, East, Horizontal and Height Errors (RMS) using five SOPAC sites over four Dates in 2007

Data Processing Length	Error (cm)			
	North	East	Horizontal	Height
01 Hour	2.3	6.1	6.5	6.3
02 Hour	1.2	3.2	3.4	3.2
03 Hour	0.8	2.1	2.2	2.9
06 Hour	0.6	1.1	1.3	2.4
12 Hour	0.5	0.7	0.9	2.0
24 Hour	0.4	0.6	0.7	1.6

Remarks

Given the above results, static PPP can viably be used to verify or even survey base station positions. Table 1 can be used to conservatively gauge static PPP accuracy as a function of data processing length provided high quality GPS data.

It should be remembered that Tables 1 and 2 were generated using data from a permanent GPS network. All stations used operate in a low multipath environment and have a completely open view of the sky. The correct antenna model was also applied which is critical for high accuracy PPP results.

Further, all results were generated using final orbit and clock files produced by the MIT analysis center. These files are currently given the highest priority in GrafNav's download program and have a latency of approximately two weeks.

A rapid high data rate clock and precise ephemeris is available through the Center for Orbit Determination in Europe (CODE). These precise correction files have a latency of approximately one GMT day. Due to the removal of the rapid CODE products after approximately two weeks (replaced with final orbits and clocks), a direct comparison to results using rapid products was not possible. A further test was performed to evaluate the difference in PPP static accuracy when using rapid products as apposed to the final products in the next section.

Further Questions

Two questions arise from this report. Firstly, how much variation was observed in static PPP accuracy from all five sites included in this report? Secondly, is there any (and if so how much) degradation when using the rapid

CODE products as apposed to the final MIT products?

Figure 03 shows the 3D RMS and 95% error values at each site for all 3 hour tests. Note that this represents results from 80 processing runs for each station over four widely separated dates. The best results were obtained at the stations BRUS and CHPI which had an average RMS accuracy between them of 3.0 cm. Stations DDSN and PRDS were not far off, both showing results approximately 20% (0.6 cm) larger than this average value. The largest errors were seen from station KUNM which had a 3D RMS 53% (1.7 cm) larger than the benchmark value from BRUS and CHPI. KUNM consistently showed the highest errors for each processing interval tested (1, 2, 3, 6, 12 and 24 hours).

Two factors that influence accuracy on a site by site basis include satellite geometry and receiver noise characteristics. While PDOP was not output for any of the processing runs, the receiver used at KUNM is a Turbo-Rogue SNR8000. This is an old receiver and in the opinion of the author is not in the same class as more modern receivers such as the others used in this test. Therefore results summarized in table 1 and 2 are pessimistic due to the inclusion of the results from KUNM.

The question of accuracy when using rapid products as apposed to final products is important as a quick turnaround is essential to many industries. In order to illustrate the impact of using rapid CODE products as apposed to final MIT products, three days of data from PRDS was processed (Dec 30 and 31 2007 and Jan 01 2008). Results using final CODE products are also included to show the difference when using rapid and final products from the same analysis center.

The same methodology was used in this test as was used previously in splitting the data into 1, 2, 3, 6, 12 and 24 hour sessions. This resulted in twelve 1, 2, 3 and 6 hour sessions, six 12 hour sessions and three 24 hour sessions. This test is meant only to give a general impression regarding PPP static accuracy when using rapid and final products.

Figure 04 shows results are very similar for three hours of processing or more regardless of which precise products are used. Further, the difference when using rapid or final products from the same source (in this case CODE) are very similar – differing by less than 0.2 cm on average.

For one and two hours of data processing, static PPP results were actually better using rapid CODE products as apposed to final MIT products for this test. Similar tests using other stations and dates have not shown this to be a consistent trend and therefore these should not be interpreted as typical results. Further, not enough samples were used in this test to fairly compare the products. What is important to note in figure 04 is that no appreciable degradation is seen when using rapid products as compared to final products.

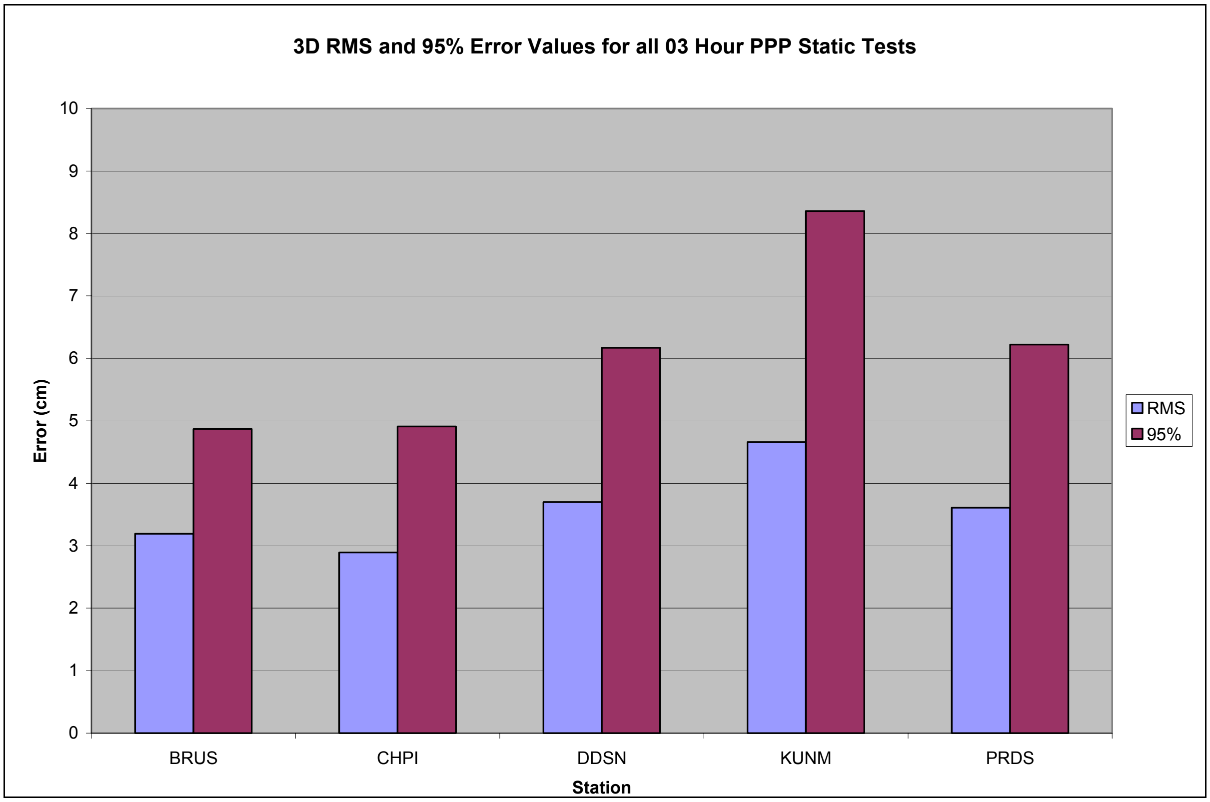

Figure 03: 3D and 95th percentile errors for 80 total 3 hour PPP Static processing sessions

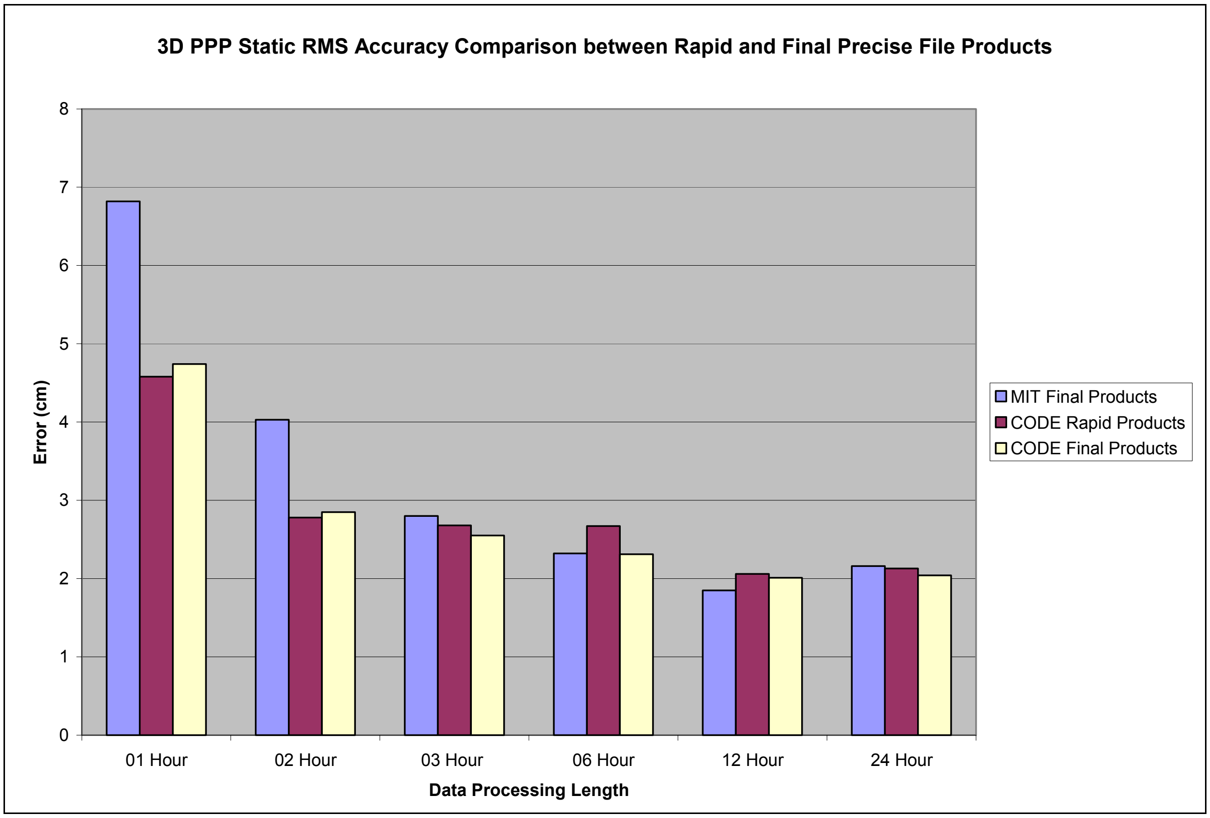

Figure 04: 3D PPP Static Accuracy Comparison (RMS) at PRDS using three days of data - Final MIT and CODE products as well as rapid CODE products are compared