Analysis and Comparison of GPS/Beidou GNSS Signal Performance

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Key words: GNSS, GPS, BeiDou,

SUMMARY

The University of Nottingham Ningbo China (UNNC) has full access to the Beidou system, QZSS, GLONASS, Galileo and GPS on its campus. Currently UNNC has a number of GNSS receivers that can access the multi-GNSS constellation, these being a ComNav K508 triple frequency GPS/BeiDou/GLONASS system, Unicore UR240-CORS-II and UR240-RTK GPS/BeiDou receivers, Javad SIGMA and TIUMPH-VS multi GNSS receivers, Leica GR25, GR10, GS10 GPS/GLONASS receivers, Septentrio AsteRx2eL multi-GNSS receivers, as well as U-Blox NEO-7P GPS receivers. In addition to this, UNNC owns a Spirent GSS8000 GPS, GLONASS, Galileo and BeiDou hardware simulator.

Currently, it is typical to observe 30 or more GNSS satellites at any time at UNNC, allowing the campus to be an excellent test bed for such work.

This paper brings together some initial results, processed with in-house software, to illustrate the performance of the BeiDou solution, compared to the GPS solution, and a combined BeiDou/GPS solution. These tests include the results of zero baseline tests using 24 hours of GPS/BeiDou data. The results illustrate that the GPS solution has RMS values of 1.03mm, 1.22mm and 3.7mm in the East, North and Height components respectively, GPS has RMS values of 0.67mm, 0.81mm and 1.94mm in the East, North and Height components respectively, and a combined GPS+BeiDou solution has RMS values of 0.62mm, 0.69mm and 1.71mm in the East, North and Height components respectively.

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1. INTRODUCTION

The integration of multiple GNSS has many advantages. These include an increase in the number of satellites seen at any one time, as well as the positional distribution of these GNSS satellites, which improves the precision due to a better geometrical solution.

A study in 2003 stated that research into the availability of GPS signals for positioning in urban areas in Leeds and London found that GPS positions were only possible on 60% of the points surveyed to the required accuracies in order to position utility cables and pipes [Parker, 2003]. Previous work [Cruddace *et al.*, 2009], [Hancock, *et al.*, 2009], highlighted the upcoming advancements in GNSS, and the use of simulation to predict the scenarios with ore GNSS satellites, as well as using pseudolites to augment the GPS signals. This paper illustrates, using real data, the potential accuracies and availability of a combined GPS+BeiDou approach over GPS alone.

2. MULTI GNSS ADVANTAGES

An instantaneous snapshot of the location and number of satellites is important when using kinematic GNSS. Figure 1 illustrates a 5-minute snapshot of the 6 GPS satellites available during this period, and Figure 2 the 25 GNSS satellites available (right) during the same 5-minute period. These data were recorded in Ningbo, China, at the University of Nottingham's campus. The GNSS satellites consist of 6 GPS, 7 GLONASS, 1 Galileo, 6 BeiDou, 1 Japanese Quazi Zenith Satellite System (QZSS) SBAS satellite and a further 4 SBAS from India and Japan. An elevation angle cut off of 15° was used, which is typical when using GNSS for engineering surveying.

Figure 1, a 5-minute sky-plot of GPS on the 1 July 2014, between 21:00 to 21:05 at Ningbo, China.

Figure 2, a 5-minute sky-plot of GNSS on the 1 July 2014, between 21:00 to 21:05 at Ningbo, China.

Figure 3 illustrates the total number of GPS satellites available over a 20-minute period. The number can be seen to fluctuate between five and four satellites. It can also be seen that the various Dilution of Precision (DOP) values fluctuate. The DOP values are an indication of the precision expected as a result of the location and geometry of the satellite constellation - the lower the number, the better the expected precision. These DOP values are calculated in the various components, such as the overall Geometry (GDOP), Position (PDOP), Vertical (VDOP) and Horizontal (HDOP). Figure 4 illustrates the number of GNSS satellites available over the same time period. Here it can be seen that the number of satellites fluctuates from 21 to 24, and more importantly the DOP values are constantly low. There are satellites that go in and out of view in both plots in Figures 3 and 4, but this has less of an effect on the GNSS solution compared to that obtained using GPS alone. This shows that a multi-GNSS solution is far more stable.

Figure 3, The total number of GPS satellites seen on the 1 July 2014, between 18:30 to 18:45 at Ningbo, China, with a satellite elevation mask of 15°, in an open sky environment without any obstructions.

Figure 4, The total number of GNSS satellites seen on the 1 July 2014, between 18:30 to 18:45 at Ningbo, China, with a satellite elevation mask of 15°, in an open sky environment without any obstructions.

3. ZERO BASELINE TESTS

Figure 5 illustrates the configuration of a zero baseline experiment, carried out at UNNC. The GNSS receivers used are ComNav K508 GPS/GLONASS/BeiDou receivers, connected to a GEMS signal splitter (PN:GS18) using two 3-metre long antenna cables. The splitter, in turn, is connected to a Leica AR25 choke ring antenna using a 50-metre long antenna cable. Previous work by the authors has shown that there was an improvement in similar results when comparing a Leica SR530 dual frequency GPS receiver with a Leica GX1230 dual frequency GNSS receiver. The standard deviations of the SR530 receiver were found to be 0.9mm, 1.3mm and 2.1mm in the east, north and height component. The standard deviations for the GX1230 receiver were found to be 0.4mm, 0.7mm, and 1.2mm in the east, north and height components respectively when processing the GPS data [Roberts, *et al.*, 2012]. Both datasets used 45 minutes of GPS data.

Figure 5, The Zero baseline field experiment; a Leica AR25 choke ring antenna, connected to the two ComNav K508 GNSS receivers via the GEMS signal splitter.

Figure 6 illustrates the results in the east-west component of a zero-baseline experiment, using the two ComNav GNSS receivers. By comparing the GPS and BeiDou solutions; using the

BeiDou solution alone gives the least precise results with an RMS positional error of 1.03mm, 1.22mm and 3.70mm in the east, north and height components respectively. This is due to the BeiDou constellation not yet being complete. The GPS solution is more precise than the BeiDou with a positional RMS error of 0.67mm, 0.81mm and 1.94mm in the east, north and height components respectively. The combined solution is the most precise with a positional RMS error of 0.62mm, 0.69mm and 1.71mm in the east, north and height components respectively. This is due to the overall satellite constellation giving a better distribution of signals.

Figure 6, Position Error in the East-West component for GPS-only BeiDou-only and Integrated GPS+BeiDou.

Figure 7 illustrates the distribution of the positional error time series for the GPS-only, BeiDou-only and integrated GPS+BeiDou results using the same 24-hours of data. Again, these results illustrate the improvements in combining the two systems.

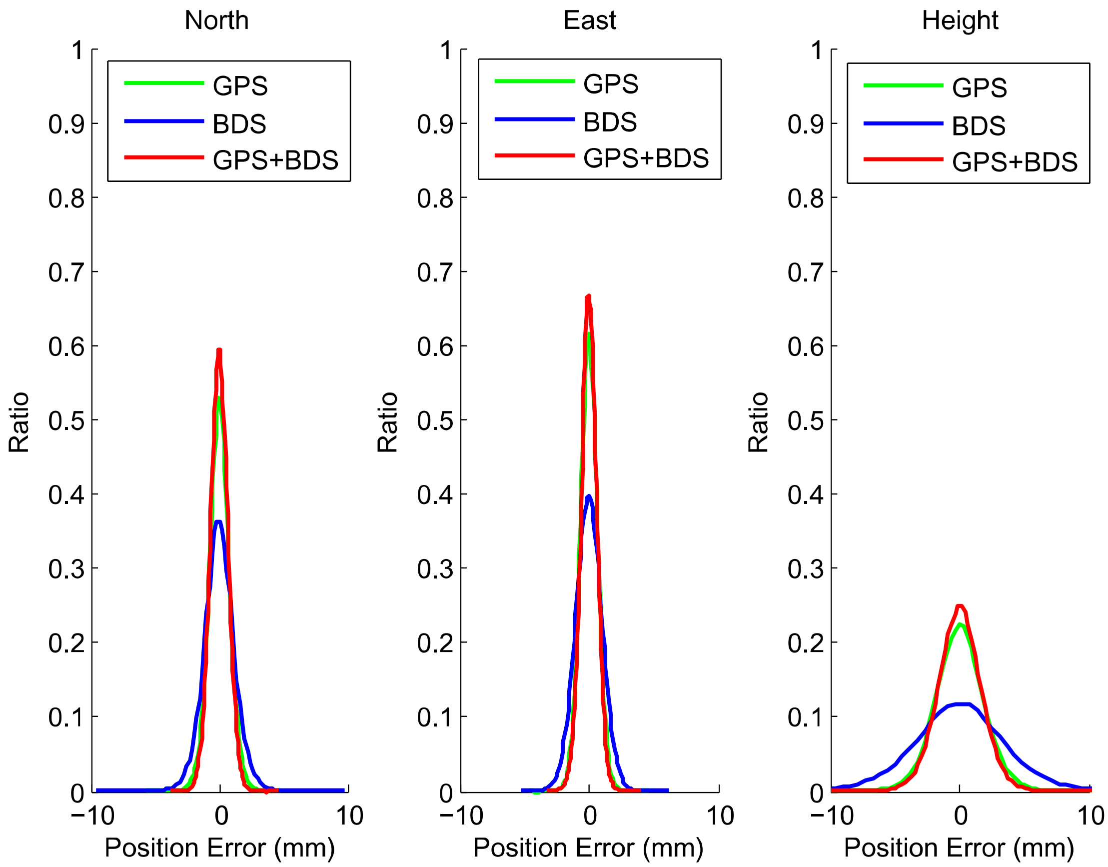

Figure 7, Error distribution graphs of GPS only, BeiDou only and combined GPS+BeiDou results in the north, east and vertical components.

4. CONCLUSIONS

The paper illustrates that by using both GPS and BeiDou signals, it is possible to improve the precision of the GPS-alone and the BeiDou-alone solutions. Currently GPS-alone gives a more precise result than the BeiDou-alone, as the BeiDou constellation is not yet complete. However, the integrated solution of GPS+BeiDou gives the most precise solution, as the geometrical spread of the satellites is improved.

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BIOGRAPHICAL NOTES

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