Signal Obstructions at GNSS Stations: Benefits From Multi-GNSS Observations

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Introduction

The high accuracy of International GNSS Service (IGS) products requires amongst other things that the location for GNSS antennas is nearly optimal for the observations. This includes a low-multipath environment and little to no signal obstructions. However, this is not guaranteed for every station, especially in urban areas and mountainous regions. As some applications such as GNSS for sea level studies or to monitor landslides, require GNSS antennas to be installed at a specific site, it is clear that the environment might not be favorable for GNSS observations. In this study, we investigate the effect of signal obstructions on station positions, specifically the up component, based on simulated obstruction scenarios using a modified Bernese GNSS Software Version 5.2 (BSW52) (Dach et al., 2007). The effects of different obstruction scenarios and the impact of multi-GNSS (GPS+GLONASS) for non-observation regions for both clear and obstructed stations are discussed.

Multi-GNSS observations provide an opportunity of diversity and redundancy through the different signal and orbital characteristics, such as orbit inclination, revolution period and repeat cycle of the different systems. As the latitude-longitude dependency and any other orbit related effects of the systems' orbital plane (Santerre, 1991). As the ground track of a satellite repeats for GPS but shifts every day for GLONASS (P18 - 73 Abraha et al., 2014), the latitude-dependency of the systems is caused by the inclination of the satellites' orbit plane (Santerre, 1991). As the ground track of a satellite repeats for GPS but shifts every day for GLONASS (Dach et al., 2009). This can be demonstrated from the skyplot in Figure 1, where the stations IRKJ and JOZ2 are separated in longitude by 83 degrees (Figure 2). The latitude-longitude dependency and any other orbit related effects of the systems will respond to specific obstruction scenarios differently. This will be discussed in this paper.

Table 1 Main orbit characteristic differences between GPS and GLONASS

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<tr>
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<th>GLONASS</th>
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<td>Inclination</td>
<td>55.0°</td>
<td>64.8°</td>
</tr>
<tr>
<td>Semi-major axis</td>
<td>6378.145</td>
<td>6378.137</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>0.000</td>
<td>0.001</td>
</tr>
<tr>
<td>Mean motion</td>
<td>10.730</td>
<td>10.700</td>
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</table>
| Sidereal day            | 1 sidereal day and half a sidereal day for GPS
| Northern  Hemisphere    | 1/3 sidereal day for GLONASS
| The combined GPS/GLONASS system has features from both systems but with reduced power.
| The features are corresponding to the repetition of the satellite geometry of the systems (Table 1).

Effects of Obstructions

Figure 4 shows the percentage of missing data and power spectra for station ONSA caused by a simulated obstruction in the east direction (the scenario in Figure 5b). The upper panel of the graphs shows the time series of the missing data from day-of-year (DOY) 019 to 092, 2014. The power spectra of the missing data time series differs considerably for the GPS, GLONASS and the combined GPS+GLONASS systems.

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Conclusions:

1. The effect of an obstruction can be of site specific and latitude dependent nature.
2. Obstructing objects cause varying satellite geometry and missing data features corresponding to the orbit characteristics. They cause bias and noise in GNSS time series and as a consequence bias in the up rate estimations.
3. The combined GPS+GLONASS solution clearly benefits both un- and obstructed sites and the positive impact being larger for the latter.
4. More work is needed to better quantify the current results and to include observations from Galileo and BeiDou.

References:


Results: Long term effects

The obstruction profile from the severity obstructed UNAVCO/PBO site P123, Figure 6a, is extracted and used as a scenario for the IGS sites. Figures 6b and 6c show the skyplot for ONSA before and after the P123 obstruction scenario is applied, respectively. A PPP solution (Figure 3) is created from 2011-2015 to investigate the long term effects of the scenario.

Main Results:

- The North and South (Figures 5a and 5c) obstruction scenarios show a clear latitude-dependency – Stations near the equator are more affected than others from all North-South scenarios.
- The obstruction on the Northern Hemisphere - GNSS observations are more affected than those of GPS by the North-South obstruction scenarios.
- The misssing data time series and the power spectra show for stations IRKJ and JOZ2 are separated in longitude by 83 degrees (Figure 2). The latitude-longitude dependency and any other orbit related effects of the systems will respond to specific obstruction scenarios differently. This will be discussed in this paper.

Figure 5 RMS of daily coordinate differences versus station latitude for the up component (top panel) and percentage of missing data (bottom panel) for all stations in Figure 2. The grey shaded area of the obstruction profile inset is the simulated obstruction scenario and represents a severe case: a) for North, b) for East c) for South and d) for West scenarios. Blue and red dots are for GPS-only and GPS+GLONASS solutions.

Main Results: Up Component

- Obstruction scenarios in the North, East, South and West directions are simulated (Figure 5).
- PPP solutions for all scenarios and a reference solution without obstructions are generated using the processing strategy in Figure 3.
- All solutions are created using the same European Space Agency (ESA) satellite orbit and clock, and Earth Orientation parameter (EOP) products. Idemical models were employed except for the application of the obstruction scenario, which enables the differences to reflect the effects of the obstructions.
- EOPs, satellite orbits and clocks are fixed while site coordinates, tropospheric parameters and receiver clocks are estimated for each solution.
- The applied obstruction scenarios affect all the aforementioned parameters. However, only the effects on the up component are presented here.

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Daily coordinate differences are computed for all solutions (with obstruction scenario) with respect to the reference solution.

Acknowledgements:

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