Contribution of GLONASS Observations on Precise Point Positioning

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Key words: DD, magicGNSS, PPP, RTK

SUMMARY

In recent years thanks to modernization of GLONASS, especially increasement of the satellite number, it becomes worthwhile to investigate the usability of GLONASS on global positioning in terms of accuracy and precision. Many researches have been performed for investigating the GPS and GLONASS positioning performance. These researches mostly consist of Double Difference (DD) and Real Time Kinematics (RTK) positioning studies. In the last decade the Precise Point Positioning (PPP) method has become an attractive method for researchers. In the PPP method, while at first only GPS observations can be used, lately by the help of recently popular web based GNSS softwares, GLONASS observations can also be used for positioning.

In this research, usability of GLONASS together with GPS in the PPP method has been analysed by considering different latitude regions, ionospheric conditions and also time segments. Processes have been performed by using magicGNSS software that is quite favourite web based GNSS software. Process results have been compared with Bernese 5.0(PPP) results. The results have indicated an improvement on the positioning accuracy by integrating GLONASS observations.

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1. INTRODUCTION

GPS like second global positioning system, the GLObal Navigation Satellite System(GLONASS), which is operated by Russian Federation, has reached 23 satellites in the recent days(URL1).

With recent revitalization of GLONASS, usability of these systems together may provide so many advantages. For example; geometry of observed satellites can be enhanced by increasing the number of available satellites. Minimum satellite number, which is necessary for positioning, can be derived particularly in urban areas.

Many studies have been performed to indicate the addition of GLONASS to the global positioning(Alcay (2010); Bruyninx (2007); Wang and Wang (2007); Raffaela-Marco (2000); Martin and Ladd (1997); Dodson et. al. (1999); Stewart et. al. (2000)).These studies are generally DD and RTK positioning studies. Precise point positioning (PPP) became an attractive method in the last decade(Cai and Gao (2007), Azab et. al. (2011)).

By the help of recent popular web based GNSS softwares, GLONASS observations can be used for positioning.

In order to investigate the usefulness of GLONASS together with GPS in the PPP method, 3 IGS stations have been selected in different latitude regions and processes have been performed by using magicGNSS software(URL-3). Results have been investigated.

2. POSITIONING WITH PPP

Precise point positioning is a relatively new technique, theoretical basis was first given by Zumberge et. al. (1997). PPP is a special case of zero difference processing. It is different from other precise positioning approaches like RTK or DGPS in that no base stations or reference stations are needed. The only observation data that must be processed is the user receiver data itself. Thus, the time loss is reducing.

In PPP, precise orbits and clock products are used. This is important for precise coordinate estimation. In recent years, by the help of various international centers like International GNSS Service (IGS), Center for Orbit Determination for Europe (CODE), Jet Propulsion Laboratory (JPL), which produce more precise orbits and clock product when compared to the past, accuracy and precision of PPP results have become better.

PPP is a very fast and efficient to generate good station coordinates. However, it is not possible to reach a coordinate quality as obtained from a network analysis. This mainly due to the facts, the impossibility to resolve phase ambiguities and the neglect of correlation between stations and clock corrections(Dach and Hugentobler, 2007).

PPP method is generally used in software packages and web based GNSS softwares. MagicGNSS, CSRS-PPP and GAPS can be given examples of web based GNSS softwares, Bernese and GrafNav are examples of software packages. Detailed information about software packages and web based GNSS softwares are given by Huber et. al.(2010).

3. PPP RESULTS

One of the popular web based GNSS software, magic GNSS, which can process GLONASS observations, have been selected for PPP analysis.

In this study, three stations have been chosen from different latitude regions. SOFI has been selected from mid latitude region, SVTL and WIND have been selected from high latitude and equatorial regions respectively.

Processes have been performed for 2011,DOY 100. GPS and GPS/GLONASS PDOP values for pertinent day, are given in figure 1. It can be seen in figure that, addition of GLONASS improves the PDOP values by more than %60.

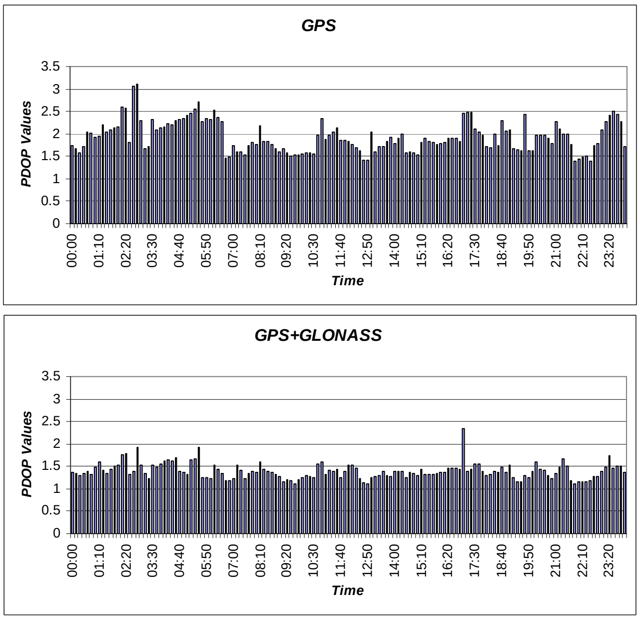


Figure 1. GPS and GPS/GLONASS PDOP values

There is s strong correlation between ionospheric variations and geomagnetic activity. This relationship is used to monitor ionospheric disturbances related with atmosphere. The geomagnetic activity is shown by using kp indices. Kp indices are estimated for 3h durations.
In order to investigate the comparison of GPS and GPS/GLONASS PPP results better, quiet time period (2011, DOY 100) has been selected. Kp index values for pertinent day are given in figure 2.

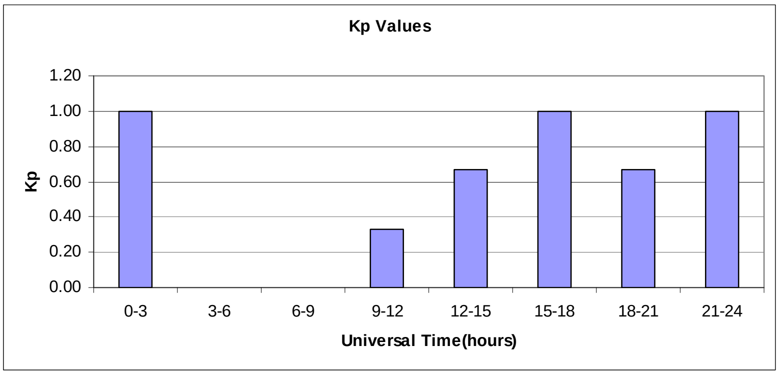


Figure 2. Kp values for 2011, DOY 100 (URL-2)

Firstly, 24 hourly GPS observations have been processed by using Bernese 5.0 PPP modul. Due to the code observations of GLONASS can not be used for PPP in Bernese GNSS software, GPS/GLONASS PPP results have not been taken into consideration. Estimated coordinates and standard deviations are given in table 1.

Table 1: Estimated station coordinates and standard deviations (GPS only)

Stations	X	Y	Z	mx	my	mz
SOFI	4319371.9850	1868687.8990	4292064.0008	0.0011	0.0008	0.0010
SVTL	2730155.2448	1562364.8232	5529989.3364	0.0006	0.0006	0.0009
WIND	5633708.7797	1732017.8363	-2433985.6580	0.0014	0.0010	0.0007

In order to investigate the influence of the time periods, 1, 2 and 4 hourly time segments have been considered.

24 hourly GPS+GLONASS and GPS observations have been processed by magic GNSS PPP modul at first. Differences between magicGNSS results and measurement epoch coordinates, which were computed from ITRF 2008 reference epoch coordinates, are given in table 2. As it is seen in the table, addition of GLONASS observations influenced the coordinate results negatively for the equatorial station, WIND.

Table 2: Differences between known and estimated coordinates (24 hourly observations)

Stations	GPS/GLONASS			GPS		
	dx	dy	dz	dx	dy	dz
SOFI	0.6	5.6	1.4	2.2	7.9	-0.4
SVTL	-0.7	2.1	9.7	0.3	-1.2	4.3
WIND	12.1	-21.8	11.9	-3.9	-5.8	5.9

When Bernese PPP results(GPS) are compared with magic GNSS GPS and GPS/GLONASS results, it can be seen in table 3 that differences are generally close for SOFI and SVTL.

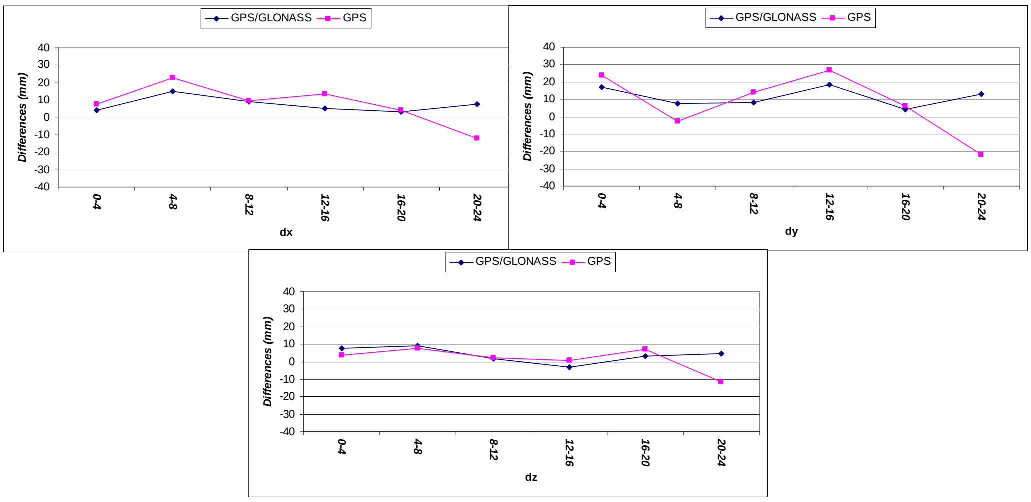
Table 3: Differences between Bernese and magicGNSS coordinate results (24 hourly observations)

Stations	GPS/GLONASS			GPS		
	dx	dy	dz	dx	dy	dz
SOFI	3.7	4.8	8.7	5.3	7.1	6.9
SVTL	5.1	5.3	19.9	6.1	2.0	14.6
WIND	11.9	-29.0	11.7	-4.1	-13.0	5.7

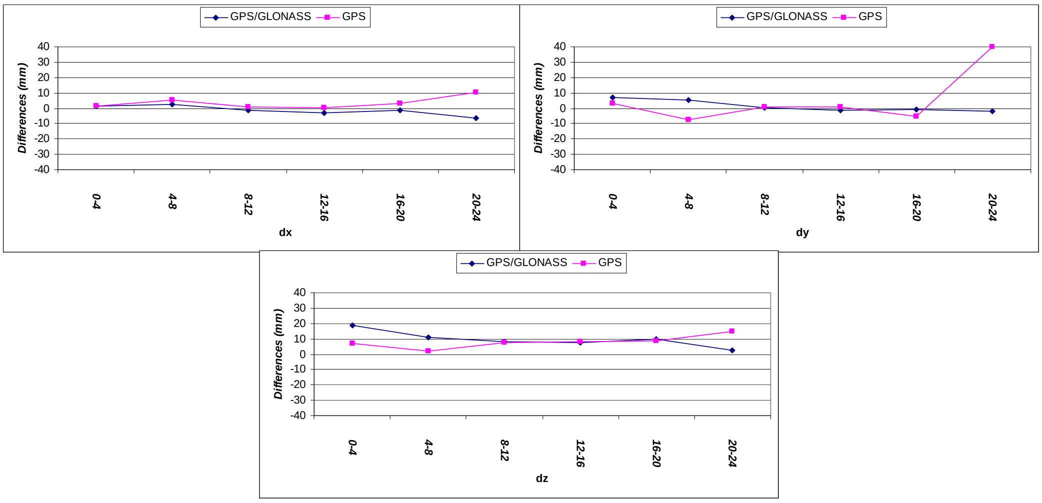
Then 4,2 and 1 hourly GPS and GPS/GLONASS observations have been processed. Differences between estimated coordinates and measurement epoch coordinates are given in figure 3 for 4 hourly, in figure 4 for 2 hourly and in figure 5 for 1 hourly data segments.

Particularly, when the 1 and 2 hourly results have been investigated, contribution of GLONASS can be seen easily for all latitude regions.

SOFI



SVTL



WIND

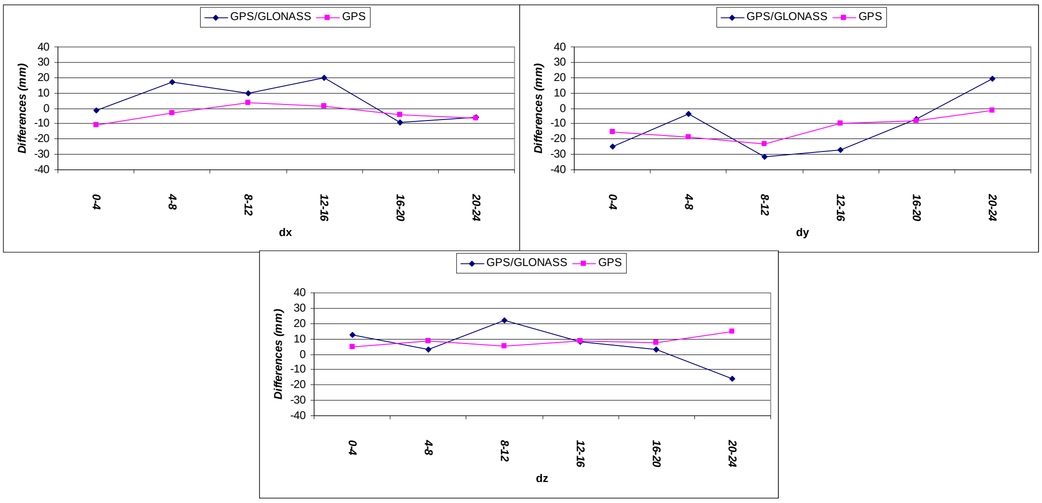
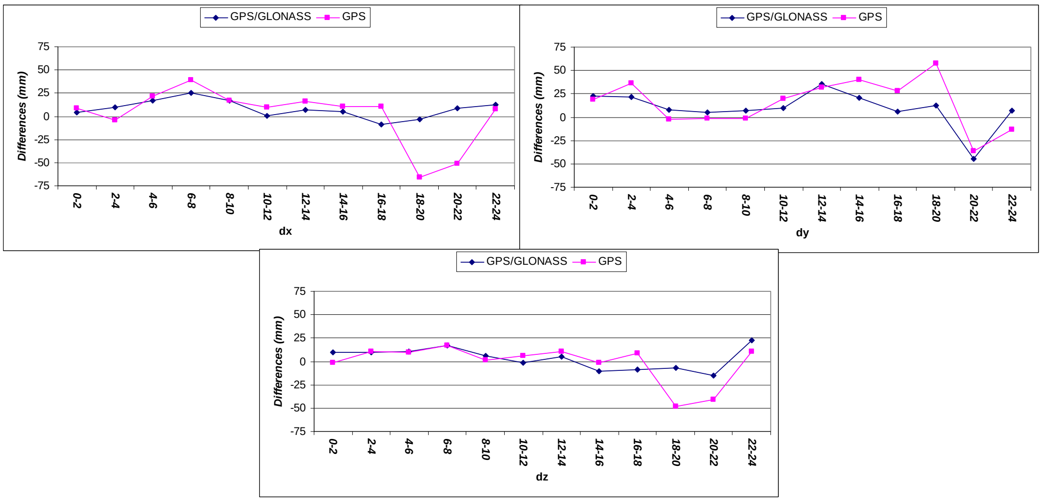
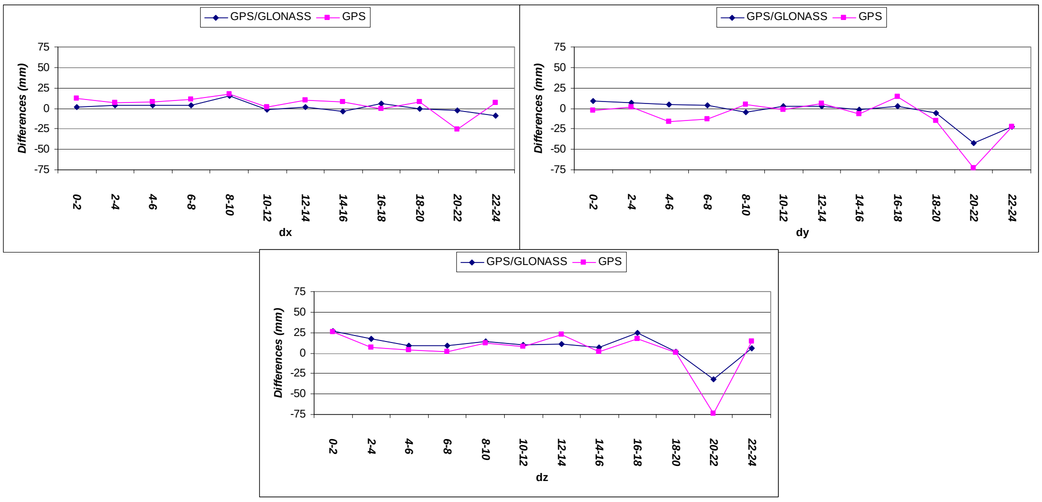


Figure 3: Differences between known and estimated coordinates (4 hourly observations)

SOFI


GPS/GLONASS
GPS
Differences (mm)
dx
dy
dz

SVTL


GPS/GLONASS
GPS
Differences (mm)
dx
dy
dz

WIND

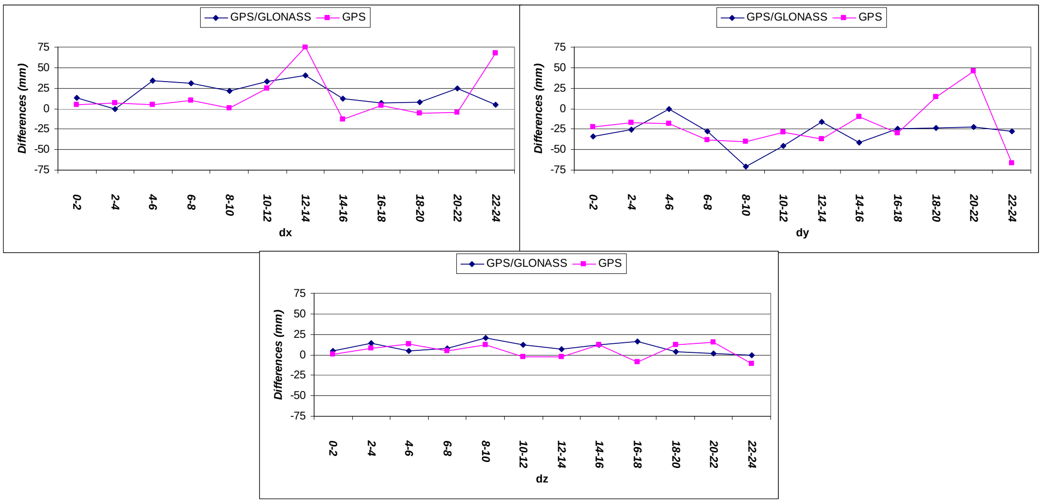
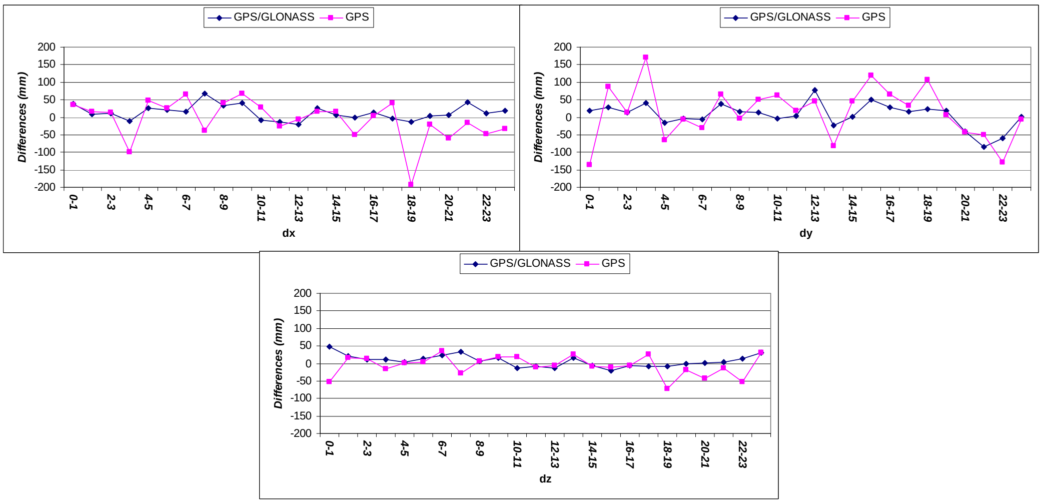
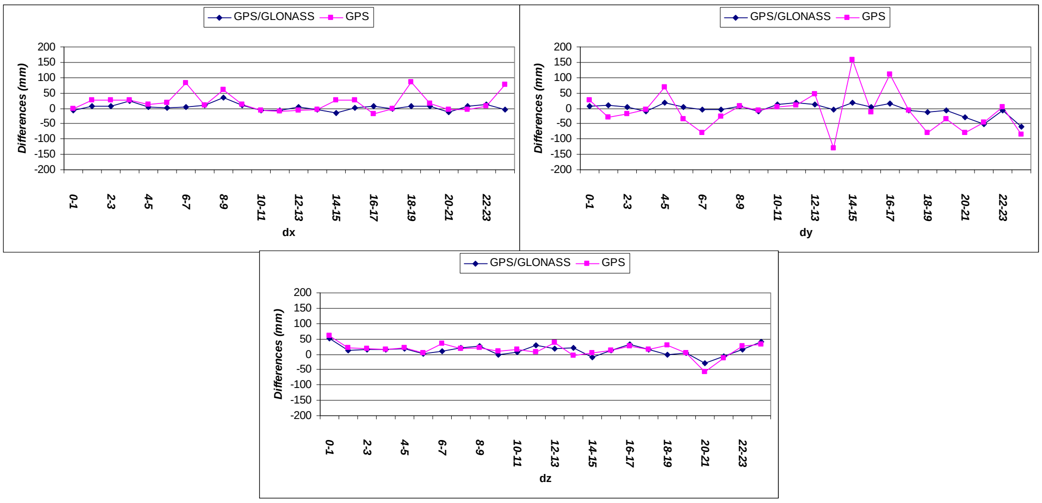


Figure 4: Differences between known and estimated coordinates (2 hourly observations)

SOFI



SVTL



WIND

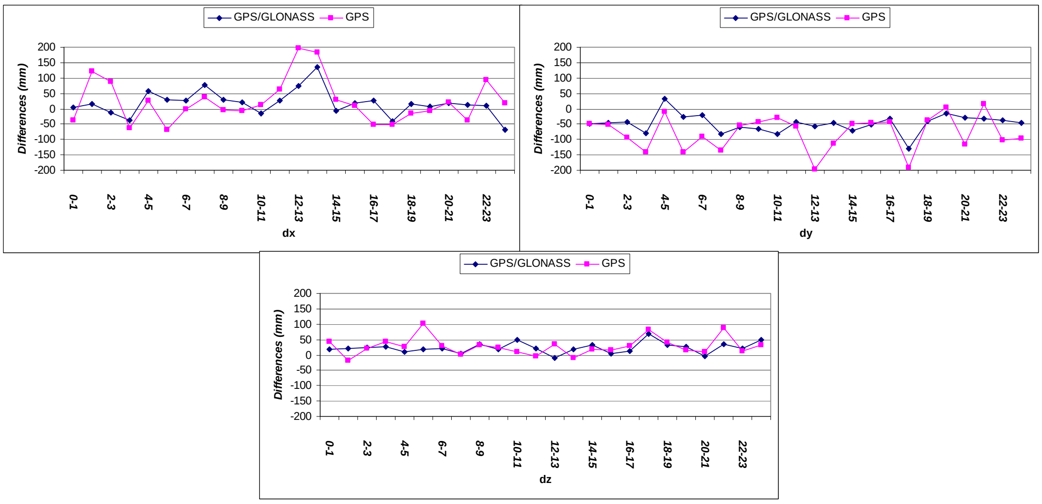


Figure 5: Differences between known and estimated coordinates (1 hourly observations)

In order to investigate the repeatabilities, standard deviations of coordinate components computed by using equation (1) and listed in table 4.

$$m = \sqrt{\frac{[vv]}{n-1}} \tag{1}$$

Where; v is the difference from the average value, n is the number of measurement.

Table 4: Standard deviations of coordinate components for all time segments

	Time Intervals	GPS/GLONASS			GPS		
		mx	*my*	*mz*	*mx*	*my*	*mz*
SOFI	1 Hourly	25.1	35.2	18.2	58.1	76.5	29.2
	2 Hourly	12.6	21.6	12.2	30.1	30.6	20.9
	4 Hourly	9.2	13.6	6.1	14.3	20.0	7.1
SVTL	1 Hourly	11.6	20.4	21.8	35.3	64.1	26.6
	2 Hourly	6.2	15.1	17.3	12.0	24.9	26.0
	4 Hourly	3.6	4.0	11.7	5.5	18.4	9.8
WIND	1 Hourly	45.2	57.8	29.1	75.1	97.4	40.7
	2 Hourly	24.0	35.6	11.2	31.9	36.0	10.2
	4 Hourly	13.3	23.6	14.0	6.3	16.1	9.6

Table 4 shows that, standard deviations, obtained from GPS+GLONASS data process, are generally smaller than GPS results. These differences can be seen better for the short time periods(1-2 hourly).

4. CONCLUSION

Contribution of GLONASS on global positioning has been investigated by considering PPP method and by using magicGNSS web based software, which allows processing GPS and GPS/GLONASS observations.

Three stations, which are located in different regions have been considered. 24 hourly and for investigating the repeatabilities; 4, 2 and 1 hourly observations have been chosen.

When the 24 hourly observations considered for SOFI and SVTL, located in mid-latitude and high latitude regions respectively, GPS/GLONASS results are better but for the station which is located in equatorial region, WIND, GPS results are generally better than GPS/GLONASS. This situation may be associated with the regional location of the stations. But more investigation is needed.

Results also confirmed that, addition of GLONASS observation has advantages on positioning especially for short time periods at all regions.

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URL-2 : http://isgi.cetp.ipsl.fr

URL-3 : http://magicgnss.gmv.com

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