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GPS positioning accuracy during the 2016 September and 2010 August campaigns at the SURA heater

Yu.V. Yasyukevich*(1), S.V. Syrovatskii(1,2), A.M. Padokhin(2), V.L. Frolov(3,4), A.M. Vesnin(1), D.A. Zatolokin(1), G.A. Kurbatov(2), R.V. Zagretdinov(4), A.V. Pershin(3), A.S. Yasyukevich(1)
(1) Institute of Solar-Terrestrial Physics of the Siberian Branch of the Russian Academy of Sciences, Irkutsk, Russia, 664033, P/O Box 291, http://en.iszf.irk.ru/
(2) Lomonosov Moscow State University, Faculty of Physics, Moscow, Russia
(3) Radiophysical Research Institute at Lobachevsky State University of Nizhni Novgorod, Nizhny Novgorod, Russia
(4) Kazan Federal University, Kazan, Russia

Abstract

We have conducted ionosphere heating experiments using HF radiation of SURA facility in August of 2010 and in September of 2016. We analyzed GPS positioning accuracy during the experiments. Positioning errors were estimated for 14 GPS receivers located at various distance, from just at the facility up to more than 1000 km from the facility. Data show that there were no noticeable positioning errors for both precise point positioning (PPP) and standard single-frequency modes.

1 Introduction

Global navigation satellite systems (GNSS) are tightly integrated in human activity in past two decades. The GNSS application extent far from its primary use. GNSS are employed the geodynamics process studies [1], monitoring the ionosphere [2] and the troposphere [3]. Besides near Earth space can be studied using GNSS, the GNSS signals are affected and can be disturbed by this media. The media dynamics can arise naturally or be induced by active experiments.

For example, the experiments on the Earth's ionosphere heating have been conducted since 1960-70th [4]. There are four heating facilities currently. They are high latitude HAARP and EISCAT/Heating, low latitude Arecibo and middle latitude SURA. Powerful HF radiation can induces wide band of ionospheric disturbances include large, middle and small scale ones. Middle and large scale disturbances are observed not only at the location of the facility by can travel far from it and registered at considerable distance from the facility. In particular Kunitsyn et al. [5] observed wave-like structures arose from heating region. GNSS (GPS, GLONASS, Galileo, BeiDou) positioning accuracy may be affected by such structures and hence may be suffer from ionospheric heating experiments.

In the current study we consider GPS positioning accuracy during heating experiments on September 19-20, 2016 (264-265 Day Of Year) and August 23, 2010 (235 DOY). During the experiments, the ionosphere was modified by SURA facility with powerful HF radiation.

2 Experimental Facilities and Data

SURA facility of NIRFI, Lobachevsky State University of Nizhny Novgorod is located at 56.15°N, 46.1°E [6]. The location of the facility is shown by the star in Fig. 1. The heating is conducted for daytime and nighttime ionosphere using O- and X- polarization pump waves (PW) with frequency close to the F2 critical frequency, foF2. This approach grants resonant interaction of PW and ionospheric plasma for O-mode heating.

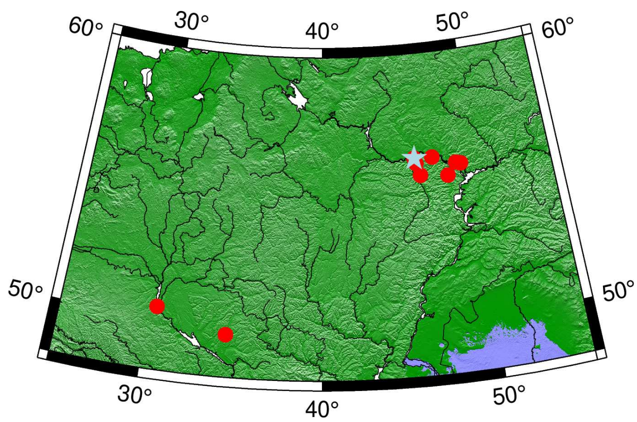

Figure 1. Experiment geometry. Star marks SURA facility, red circles – GPS stations.

GPS positioning accuracy was estimated given 10 receivers located near the facility (red dots on Fig. 1). There were data from 8 receivers available on September 20 and from 7 receivers available on September 21 Receivers coordinates and distance from SURA facility are listed in Table 1.

Positioning accuracy was estimated for two modes:
- Precise point positioning. This is post processing routine and relays of precise ephemerids, satellite clock corrections and inter-channel delays information. There

are different realizations for PPP. We used GAMP software to perform it [7].
- Single-frequency mode with Klobuchar ionosphere correction [8].

Table 1. GPS stations used for study.

Receiver name	Latitude, °	Longitude, °	Distance from SURA, km
SURA	56.2	46.1	-
PREG	56.2	46.1	-
ZASU	56.0	46.3	16
VORO	56.1	45.9	18
YADR	55.9	46.2	23
CHEB	56.1	47.3	73
CHEA	56.1	47.3	74
SHUM	55.5	46.4	75
KAYB	55.4	48.2	155
EAOZ	55.8	48.8	172
KZN2	55.8	49.1	192
ULIA	54.3	48.3	253
POLV	49.6	34.5	1061
GLSV	50.36	30.5	1217

3 Experimental Results

Fig. 2. shows time series of 3D-positioning error in PPP mode for two days under investigation. Gray regions marks time intervals when heating was performed. The receivers are arranged in growing distance order: top is receiver which is the closest to SURA, bottom — the farthest. The error is calculated as current position deviation from 1 day median position.

PPP coordinates for GPS on September 19 are not affected by the heating (see Fig. 2a). GPS-PPP accuracy stays at almost the same level. Amplitude of error fluctuations was even smaller than before heating had started. Higher error variability on September 20 is linked to longer analyzed time interval. The satellite constellation is changing over time and radio-navigation parameters measurements accuracy is different for different visible satellite constellation configuration.

GPS positioning errors in single-frequency mode are shown in Fig. 3. Spatial scale of heating region in the ionosphere is 70 km across, hence the largest response is expected on the receivers that are close to the facility namely SURA, PREG, YADR, CHEB, SHUM. Time series of 5 hour long on September 19 show no enhancement of positioning error fluctuations. The positioning error for SURA and PREG receivers increases a little just in the beginning of heating cycle at 11:32-12:32 UT on September 20, 2016. The error for SURA receiver increase even in heating pause after first pulse was emitted and decreases during the second pulse.

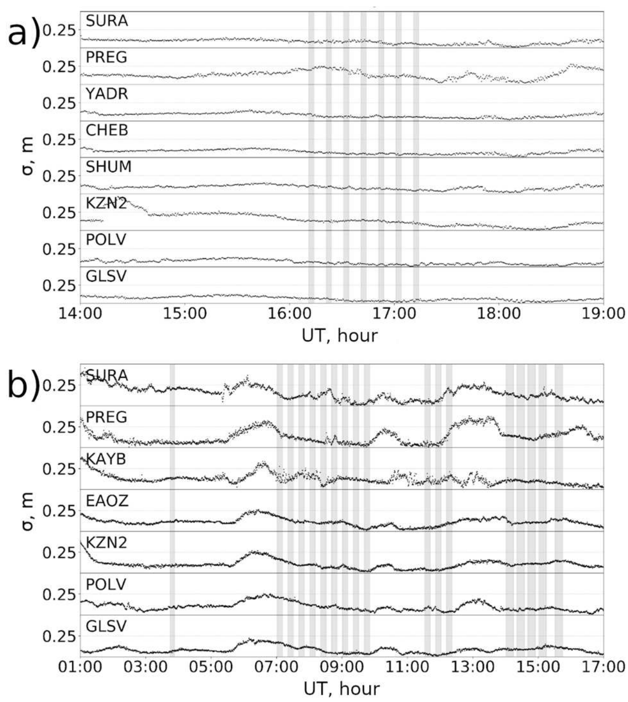

Figure 2. PPP GPS error during September 19 (a) and 20 (b), 2016. Gray regions mark heating. Station names are shown on the panels.

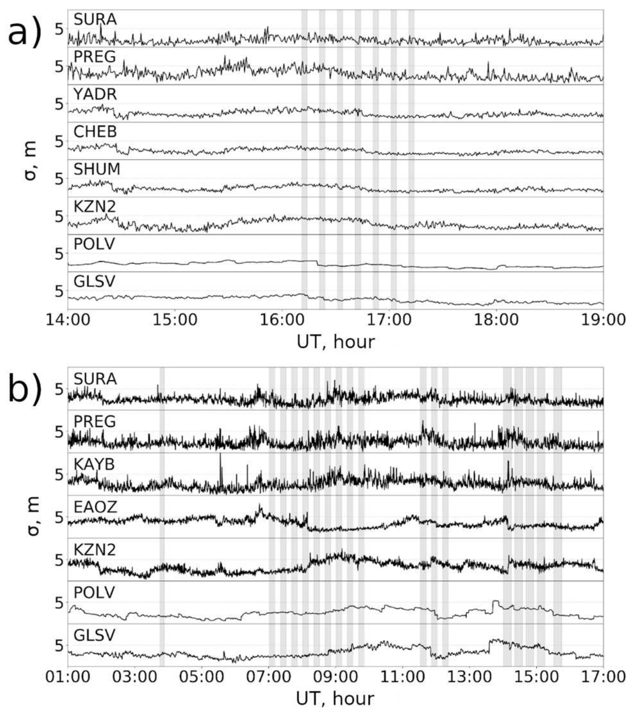

Figure 3. Single-frequency GPS error during September 19 (a) and 20 (b), 2016. Gray regions mark heating. Station names are shown on the panels.

During 14:01–14:54 UT on September 20 heating cycle distant receivers KAYB and KZN2 show the jump error increase. However this jump is absent for close to the facility receivers and position accuracy for EAOZ receiver is even improved.

The 2010 August campaign also does not reveal effects on GPS positioning. More details on experiments could be found in [9].

4 Conclusions

We have conducted two ionosphere heating experiments using HF radiation of SURA facility. We used 14 GPS receivers located at various distances from the facility (just next to it and up to more than 1000 km from the facility). During both campaigns, we have not observed any significant positioning distortions associated with HF heating for both precise point positioning and typical iterative single-frequency positioning.

Direct effect of refraction caused by the ionospheric irregularities are rather small to be seen. 0.5 TECU variations (observed by Kunitsyn et al. [5]) lead to range change at about 10 cm. To see it over standard single-frequency positioning error, which is several meters, is hard even not counting that the range varies not for the every satellite. We assumed that such a localized variation of range can affect accuracy in PPP mode. However for the performed experiments this did not happen.

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