2nd URSI AT-RASC, Gran Canaria, 28 May – 1 June 2018

GNSS scintillations in Siberia during 2014-2017

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Abstract

The paper presents the results on appearance of phase and amplitude scintillations in Siberia regions (Irkutsk, 52° N, 104° E). We recorded S4 and σφ during 2014-2017. Both GPS and GLONASS data at L1 and L2 were analyzed. We found unexpected differences in GPS and GLONASS data as well differences in L1 and L2 data. Not much intense scintillations were recorded at mid-latitudes.

1. Introduction

Changes in the ionosphere have a significant impact on radio propagation [1]. Small-scale irregularities with size of the first Fresnel zone result in signal scattering and amplitude scintillations [2]. Phase scintillations are caused by irregular refraction on larger irregularities. For the global navigation satellite systems such irregularities can result in losses-of-phase lock [3] and deterioration of positioning quality [4].

Usually, S4 index [5] is used to study amplitude scintillations and σφ index [6] - to study phase scintillations. Current paper is devoted to statistical analysis of phase and amplitude GPS/GLONASS scintillations at mid-latitude station in Irkutsk (52° N, 104° E).

2. Data and facilities

We used NovAtel GPStation-6 to record the scintillation data. The receiver is installed at the Institute of solar-terrestrial physics SB RAS (Irkutsk, 52N, 104 E).

S4 index is the signal intensity I standard deviation normalized to the average signal intensity:

$$S4 = \frac{\sqrt{\langle I^2 \rangle - \langle I \rangle^2}}{\langle I \rangle}$$

σφ index is simply the standard deviation of signal phase φ:

$$\sigma\varphi = \sqrt{\langle \varphi^2 \rangle - \langle \varphi \rangle^2}$$

The GNSS receiver records S4 and σφ (1-sec, 3-sec, 30-sec, 60-sec) with 1-min time resolution. For analysis we used S4 and 3-sec σφ data obtained between August 2014 and November 2017.

We used normalization of S4 and σφ to reduce influence of elevation changing [7]. Thus quasivertical indexes were obtained.

3. Results and discussion.

Figures 1 and 2 shows the distribution of amplitude scintillation (S4) by GPS (Fig. 1) and GLONASS (Fig. 2) signals. The statistics for GPS and GLONASS at L1 frequency are not very different ($7.7 \cdot 10^6$ vs $6.3 \cdot 10^6$ records). The difference is due to different numbers of satellites. Bin of "1" contains all measurements when S4 >=1. Ignoring S4 <=1 the amount of records with corresponding S4 decrease exponentially with increasing S4. But The factor of decreasing is different for GPS and GLONASS. The total amount of recorded GPS samples with S4>= 0.7 was 825 while there were only 11 such cases for GLONASS. It is rather unexpected because both GPS and GLONASS use almost the same frequency (~1.2 GHz).

Statistics at L2 is lower: ~ 4.2 and 3.6 million records for GPS and GLONASS respectively. We suppose that exponential decreasing at L2 corresponds to S4>0.2. For GPS there is sharp decrease in scintillation amount with increase of S4. There were only 114 cases of S4 >=0.2 for GPS and 1223 of such cases - for GLONASS.

The significant difference in S4 at L1 and S4 at L2 is also unexpected. The size of irregularities which cause amplitude scintillation at L1 and at L2 differ less than 10%.

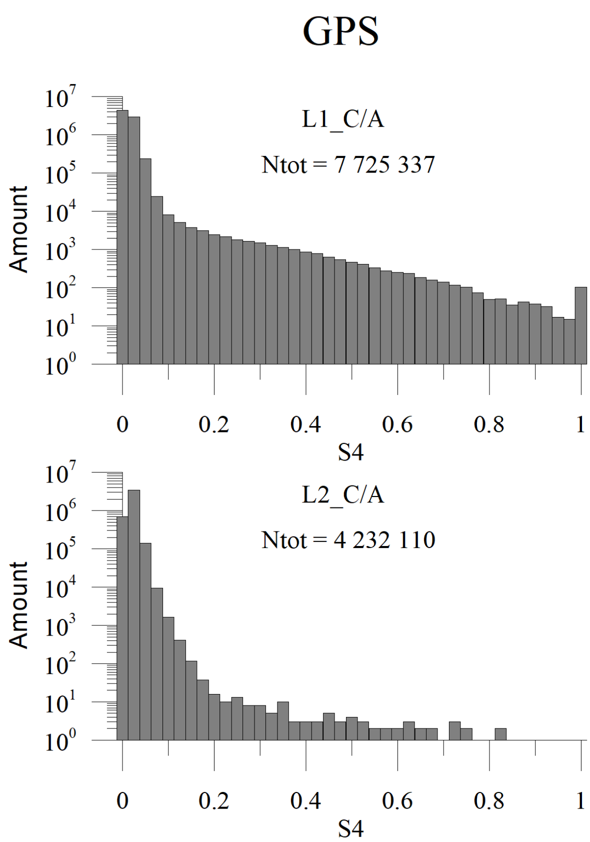

Figure 1. Distribution of GPS amplitude scintillation intensity (S4 index). Upper panels show distribution of S4 at the main frequency L1, bottom panels show those at L2. Ntot is the total number of measurements.

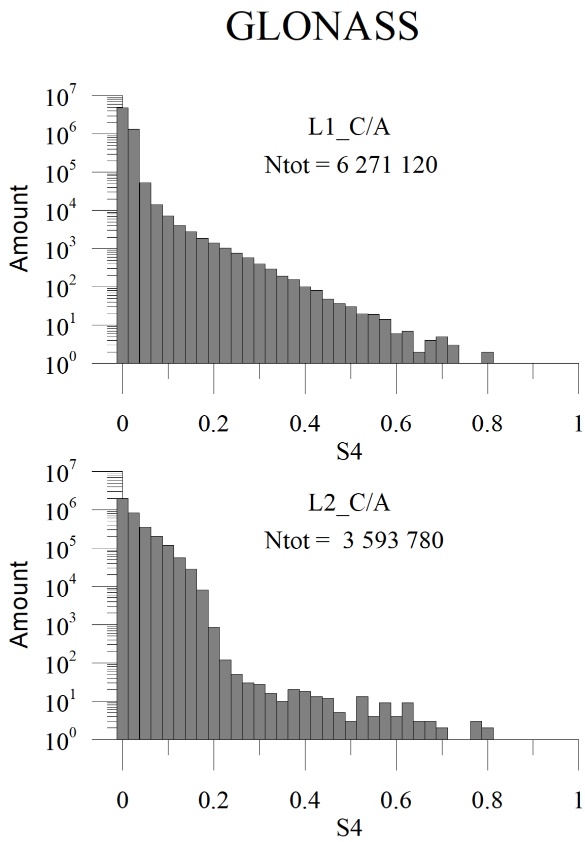

Figure 2. Distribution of GLONASS amplitude scintillation intensity (S4 index). Upper panels show distribution of S4 at the main frequency L1, bottom panels show those at L2. Ntot is the total number of measurements.

Figures 3 and 4 shows distribution of the GPS and GLONASS phase scintillation intensity $\sigma\varphi$. Bin "1.5" contains all the records with $\sigma\varphi$>=1.5 rad. It worth noting a large number of such records: 16571 - at L1 GPS, 23377 - at L2 GPS, 11251 - at L1 GLONASS and 23963 - at L2 GLONASS. Such records correspond to loss-of-phase lock. There are more losses-of-phase locks at L2-frequency due to less signal intensity.

In the majority of cases the phase scintillation had the intensity less than 0.1 rad. There were almost no scintillations with $\sigma\varphi$>=0.6 rad. Probably, it is connected with peculiarities of signal treatment in the receiver. The standard phase recording model suggests that $\sigma\varphi<15°$ (0.26 rad.) [8]. However, more intense scintillations can be measured with the receiver.

The data obtained from GLONASS is characterized by higher level of phase scintillations (Fig. 3 and 4). Though the power of transmitter of GPS and GLONASS are similar, there can be differences due to the frequency division multiplexing.

The difference in GPS and GLONASS data at close frequencies indicates that the data from different systems should not be mixed. Usually, strong amplitude and phase scintillations do not occur together at mid-latitudes. The low scintillation level allows using GPS and GLONASS data as an reliable source of data on iono-sphere state. Unexpected difference in GPS and GLONASS amplitude scintillations requires additional studying with modeling of radio signal propagation through random media.

3. Acknowledgements

This work was performed under the Russian Science Foundation Grant No. 17-77-20005. Experimental data were recorded by the Angara Multiaccess Center facilities at ISTP SB RAS under program of the fundamental research of the state academies of Russia for 2013-2020 years (project No. II.16.1.1).

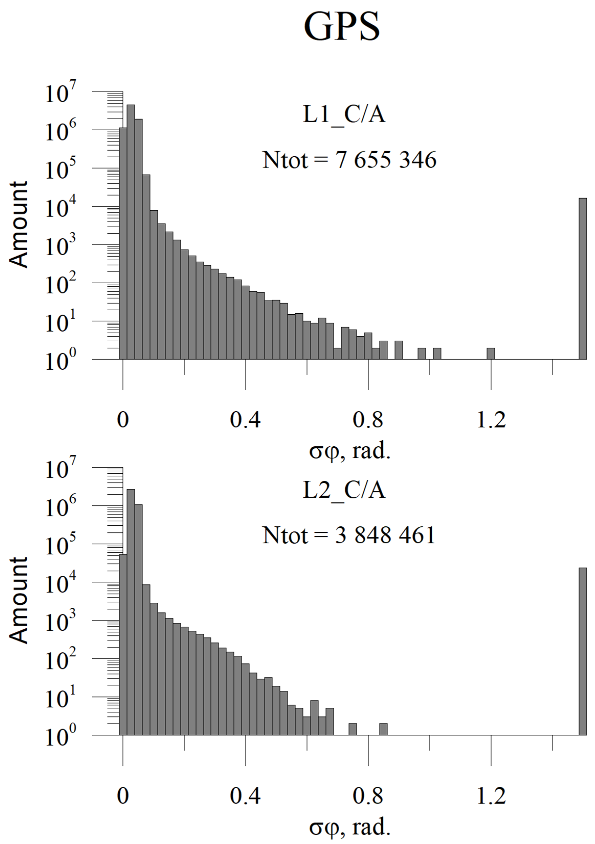

Figure 3. Distribution of the GPS 3sec phase scintillation intensity (σφ index). Upper panels show distribution of σφ at main frequency L1, bottom panels show those at L2. Ntot is the total number of measurements.

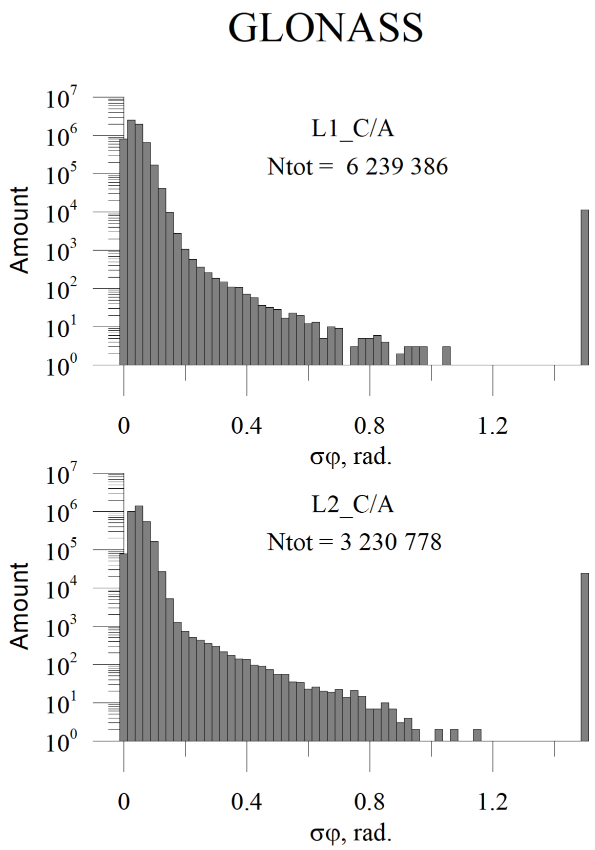

Figure 4. Distribution of the GLONASS 3sec phase scintillation intensity (σφ index). Upper panels show distribution of σφ at main frequency L1, bottom panels show those at L2. Ntot is the total number of measurements.

4. References

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