Ionospheric disturbance statistics according to the Swarm satellite mission in 2014

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Abstract. In the present work, based on the database of magnetic field indices Kp, AE, and Dst, we consider the relationship between geomagnetic activity and ionospheric scintillation indices S4 and RODI based on in-situ satellite measurements. 37 events with quiet and disturbed geomagnetic conditions during 2014 were selected and analyzed. The correlation coefficients of the scintillation indices with high-latitude AE and low-latitude Dst are obtained. Thus, in periods of disturbed geomagnetic conditions, the RODI10s and S4 indices are, in principle, equally related to the high-latitude AE index (with a small, up to 4% in the number of realizations, the advantage of the RODI index). In periods with quiet geomagnetic conditions, the situation changes - in 17% of cases the S4 index is better reflects a relationship with mid-latitude Dst than the RODI10s index. The indicated relationship means the presence of a linear correlation of more than 0.3 between the processes.

1. Introduction

The paper deals with the description of the intensity of fluctuations of the electron density in the Earth's ionosphere under various geo-heliophysical conditions according to the data of satellite in-situ measurements in 2014 using the S4 and RODI scintillation indices.

1.1. About mission

The experimental data in the study is an array of high-frequency observations from the Swarm ESA satellite mission, designed to study the Earth's magnetic field. The mission was launched in 2013 and consists of three satellites in different polar orbits with an altitude of 460 km to 530 km. Each spacecraft, in addition to the main magnetometric equipment, is equipped with Langmuir probes, which measure electron density with a sampling frequency of 2 Hz.

1.2. Scintillation indices

The scintillation indices are related to the calculated average power of the fluctuation noise - an index similar to the amplitude index of scintillations or radio scintillations S4 at a certain time interval. The index is calculated in equation (1), where Ne is the measured in-situ electron density. Filtration
windows are selected that correspond to the required spatial resolution (so a window \( t \) of 20 samples corresponds to 10 s or 74 km).

\[
S_d = \left( \frac{\langle N_e^4 \rangle_t - \langle N_e^2 \rangle_t^2}{\langle N_e^2 \rangle_t^2} \right)^{1/2}
\]

The RODI index (Rate of Change of Density Index) [1] shows the rate of local deviation of electron density variations from the current average value, determined at a certain time interval - the filtering window. In both cases, the window is selected so as to provide the required spatial resolution. For example, a 10 sec window corresponds to a spatial latitude resolution of about 0.8 deg. The RODI10s is calculated, which is the standard deviation with a window 10s of the time derivative of the electron density ROD, calculated as in equation (2), where \( \delta t = 0.5 \) seconds.

\[
\text{ROD} \left( t \right) = \frac{N_e \left( t + \delta t \right) - N_e \left( t \right)}{\delta t}
\]

2. Data processing

Based on the database of indices Kp, AE and Dst of the magnetic field, the influence of geomagnetic activity on the fluctuations of the electron density in 2014 is considered [2]. For the study, we selected days with disturbed (Kp > 4) and quiet (Kp = 1-2) geomagnetic conditions. In each of the selected cases, the indices S4 and RODI10s were calculated. The analysis results are categorized by high, mid, and low latitudes of current Swarm flybys.

3. Results and conclusions

The correlation coefficients of the S4 and RODI10s indices with the high-latitude index AE and low-latitude Dst were calculated for 37 selected cases during 2014, based on the data from the Swarm A, B, and C satellites. Examples of the obtained and calculated data in various geophysical conditions are presented in figures 1 and 2.

\[\text{Figure 1. Indices S4, RODI10s, AE, Dst in terms of disturbed geomagnetic conditions (November 4, 2014, Kp = 4).}\]
Figure 2. Indices S4, RODI10s, AE, Dst under quiet geomagnetic conditions (September 8, 2014, Kp = 2).

Polar maps of geophysical indices were calculated, shown in figure 3, based on weekly measurements from the Swarm C satellite.

Figure 3. Polar maps of S4, RODI10s indices according to weekly measurements (from January 6 to 12, 2014) from Swarm C.

So, for 2014, in periods of disturbed geomagnetic conditions, the RODI10s and S4 indices are, in principle, equally related to the high-latitude AE index (with a small, up to 4% in the number of realizations, the advantage of the RODI index). In periods with quiet geomagnetic conditions, the situation changes - in 17% of cases the S4 index better reflects the relationship with the mid-latitude Dst than the RODI10s index. The indicated relationship means the presence of a linear correlation of more than 0.3 between the processes.
Preliminary studies have shown that the amplitude scintillation index $S_4$ is also sensitive to global variations in the AE and Dst indices, which makes it possible to use the proposed index for studying ionospheric disturbances.

References
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