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Variations in the Horizontal Correlation Radius of the Ionosphere during a Magnetospheric Substorm

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Abstract—A change in the correlation radius of the ionosphere during the magnetospheric substorm of February 14, 2011, which is considered to be 500 km at midlatitudes, has been estimated. The vertical sounding (VS) data from the St. Petersburg and Sodankyla (Finland) observatories, as well as the data of oblique incidence sounding (OIS) at the Sodankyla–St. Petersburg path with a length of 790 km, have been analyzed. A specific feature of the experiment consisted in that the signals of a VS transmitter from Sodankyla were synchronously received at the receiving point on the OIS path in St. Petersburg. The OIS path reflection point is located at a distance of ~400 km from the VS reflection point. Ionograms typical of the VS and OIS signal reflection points in the ionosphere, the distance between which was slightly smaller than the correlation radius of the ionosphere (500 km), and the data of the Sodankyla and St. Petersburg ionosondes have been compared. It has been indicated that a horizontal correlation radius of 400 km can only be considered acceptable during three disturbance phases: the initial phase before the reconfiguration of the ionosphere; the explosion phase (the disturbance maximum), when only the sporadic *Es* layer is the reflecting ionospheric layer; and the recovery phase, when a disturbance already ceases and the ionosphere returns to its initial undisturbed state. During other disturbance phases, the correlation radius (if it exists) is much smaller than 400 km.

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1. INTRODUCTION

In spite of the fact that the ionosphere and the processes in this region have been studied well (Afraimovich and Perevalova, 2006; Davis, 1990), it is still necessary to elucidate and thoroughly study many problems, including, e.g., the following problems that were formulated by H. Rishbeth (*Special Meeting*, 2010). What are long-term variations in the ionosphere? To what altitudes are ionospheric structures transported by vertical neutral winds? Does the ionosphere have "a memory" and do geomagnetic "prerequisites" exist during ionospheric storms? What is specifically responsible for the *F*2 layer variability from day to day? Does the ionosphere have characteristic time scales? Is the correlation radius, which is considered to be ~500 km for the *F*2 and other ionospheric layers at midlatitudes, realistic? We will be interested in precisely the last question. It seems interesting to elucidate whether such a radius is really acceptable for the *F*2 and other layers in the subauroral region and, specifically, in the Sodankyla observatory (Finland) area, which is subjected to frequent magnetic disturbances of the storm and substorm types. It is natural to anticipate substantial spatial and time variations in the ionosphere during a geomagnetic substorm.

The aim of this study is to estimate the variations in the indicated radius during the geomagnetic substorm of February 14, 2011, and to determine the dynamic ionospheric processes that are responsible for these variations. It would be interesting to statistically determine similar regularities in the general form for a substorm-type disturbance. However, it is extremely difficult to perform such an analysis since all substorms have different intensities and duration.

2. MEASUREMENT METHOD

First, we analyzed VS data from the Sodankyla observatory (67.37° N, 26.63° W) (www.sgo.fi). Sounding was performed using LFM signals with a frequency variation rate of 500 kHz s^{-1}. Thus, one ionogram (0.5–16 MHz) was registered during 33 s. We analyzed successive ionograms at an interval of 5 min in order to trace the dynamics of the ionosphere in detail. Examples of these ionograms are presented below. Second, the same Sodankyla VS signals were synchronously received in St. Petersburg (60.27° N, 29.38° E) at the OIS LFM facility (Ivanov et al., 2003). The Sodankyla–St. Petersburg OIS radio path is almost oriented along the meridian. Examples of OIS ionograms are presented below. The distance between a transmitter and a receiver is 790 km. Consequently, the path reflection point is located at a distance of ~400 km from the VS reflection point at Sodankyla. We compared the data obtained at two (VS and OIS)