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Application of HF Doppler measurements for the investigation of internal atmospheric waves in the ionosphere

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Abstract

We present results of the spectral analysis of data series of Doppler frequency shifted signals reflected from the ionosphere, using experimental data received at Kazan University, Russia. Spectra of variations with periods from 1 min to 60 days have been calculated and analyzed for different scales of periods. The power spectral density for spring and winter differs by a factor of 3–4. Local maxima of variation amplitude are detected, which are statistically significant. The periods of these amplitude increases range from 6 to 12 min for winter, and from 24 to 48 min for autumn. Properties of spectra for variations with the periods of 1–72 h have been analyzed. The maximum of variation intensity for all seasons and frequencies corresponds to the period of 24 h. Spectra of variations with periods from 3 to 60 days have been calculated. The maxima periods of power spectral density have been detected by the MUSIC method for the high spectral resolution. The detected periods correspond to planetary wave periods. Analysis of spectra for days with different level of geomagnetic activity shows that the intensity of variations for days with a high level of geomagnetic activity is higher.

Keywords: HF Doppler; Ionosphere; Gravity waves; Planetary waves

1. Introduction

Internal atmospheric waves (planetary waves, tides, and gravity waves) propagating to the upper atmosphere with the ionosphere as a part of it are an important factor in the system of the global atmospheric circulation. It is impossible to solve the problems of dynamics of the upper atmosphere without taking into account these processes. It has become apparent that the ionosphere cannot be studied properly without considering the general properties of the neutral atmosphere. Many works based on experimental results have confirmed the existence of correlations between the parameters of the lower neutral atmosphere and the ionosphere (e.g., Lastovicka and De La Morena, 1987; Lastovicka et al., 1990; Kazimirovsky and Kokourov, 1991; De La Morena and Kazimirovsky, 1996; Pietrella et al., 2002; Lastovicka, 2006). The upward propagation of planetary waves, tides, and acoustic-gravity waves from the troposphere and stratosphere is an essential source for the transport of energy to ionospheric heights. These wave-motions can affect the behavior of the ionosphere generating ionospheric irregularities. For example, from several experimental and theoretical studies emerged the conclusion that traveling ionospheric disturbances (TIDs) are the ionospheric effect of the internal gravity waves in the neutral atmosphere (e.g., Jordan, 1972; Bertin et al., 1975; Hung and Smith, 1979; Pietrella et al., 1997; Belashova et al., 2007). At present there is a growing interest to study ionosphere irregularities. This study has not only fundamental, but also practical importance for questions connected with the radio wave propagation.

Time and spatial spectra are the basic characteristics of wave processes. The spectral analysis gives information about typical periods of wave processes and allows detecting ionospheric irregularities of different scales. The analysis of spectral characteristics for ionospheric disturbances allows

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