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GRAVITY WAVES AND INFRASOUND IN THE POLAR MESOSPHERE AND LOWER THERMOSPHERE

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Abstract. Interaction of the gravity and infrasonic waves with the polar lower ionosphere observed by vertical MF radar sounding at a fixed frequency is described in terms of characteristic changes in the waves with ordinary and extraordinary polarization partially reflected from D-region irregularities. Observations of this interaction are presented for the atmospheric waves generated during the undersea explosion of 12.08.2000, magnetic substorm of 30-31.03.2001, and Siberian meteorite explosion (near Bodaibo, Irkutsk region) of 24.09.2002.

Introduction

Ionospheric effects caused by disturbances of different origin have been considered in numerous studies [Alperovitch et. al., 1985; Blanc, 1985; Hunsucker et. al., 1982], mostly concentrating on the processes proceeding in the midlatitude ionosphere at altitudes greater than 100 km. At the same time, there are only few researches for the D-region of the polar ionosphere, where it is difficult to clear up either the nature of disturbance source or mechanisms of perturbation generation and transport, so that more detail observations are often required.

In this paper we present the radar observations of the polar lower ionosphere perturbations associated with the atmospheric waves. The partial reflection (PR) radar of the Polar Geophysical Institute (PGI) located in Tumanny (69.0°N, 35.7°E) is operating with a peak power of ~100 kW at the frequencies of 2.6-2.75 MHz. The pulse duration is 15 µs, the repetition rate is a pair of pulses (i.e. an ordinary and extraordinary waves) per second. The PR technique as well as PR facility of the PGI has been described in detail in the paper [Tereshchenko et. al., 2003] and will not be discussed here.

Undersea explosion

In Fig. 1 a, b the time-altitude picture of the O-mode echo amplitude and electron density are shown for 12 August, 2000. A magnetogram for this date is given in Fig. 1 c. An explosion of the magnitude ML=2.8 occurred at 7:31 UT at distance of 70 km to the north - east from the radar. The depth of the explosion was 100 m. From Fig. 1a,b some types of undular perturbations are seen, which are displayed in the lower ionosphere within the coverage of the PGI radar.

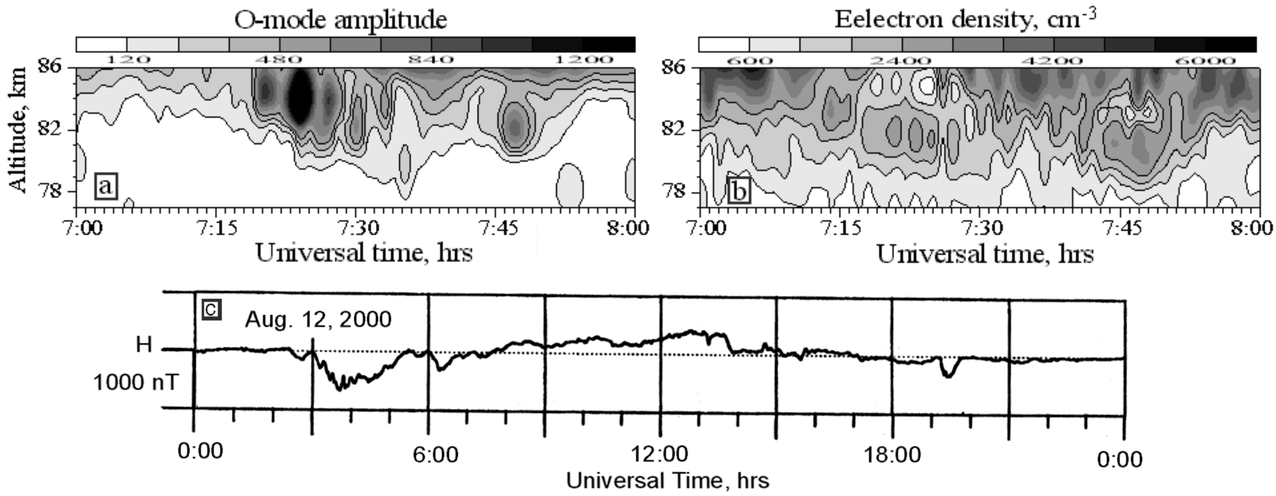

Fig. 1. Time-altitude distribution of the echo amplitude of the ordinary mode and electron density, as well as the horizontal H component of the magnetic field on 12.08.2000

We note, that intensive reflections of the ordinary wave (see Fig. 1a), which are observed at 7:19-7:31 UT and at 7:45-7:48 UT are related to the regions of lowered electron density (Fig. 1b). Spectrum analysis of the fluctuations of radar echo amplitudes reveals oscillations of different periods (Fig. 2 and 3) and intensities varying both with height and in time. The power spectra of the ordinary wave were calculated by the data in the 12 minute time period from 07:18 UT to 07:30 UT.

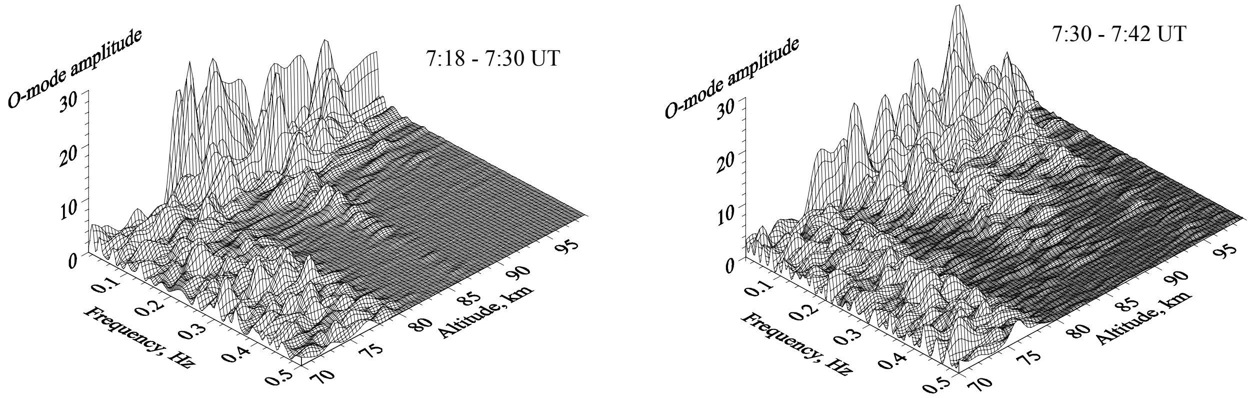

Fig. 2. Spectra of twelve-minute data as a function of height obtained during an undersea explosion

From Fig. 2 and 3 it is seen that the typical wave periods are 3-4 minutes and 9-10 minutes. The vertical wave structures on the scale of a few kilometres are displayed. The amplitude of the wave with a period of 10 minutes grows with height increasing, suggesting this wave to be of the IGW type. The amplitude of the perturbations with a period of 3 minutes reaches maximum at heights of 80-85 km. Thus, the mesosphere is a filter for the infra-acoustic waves.

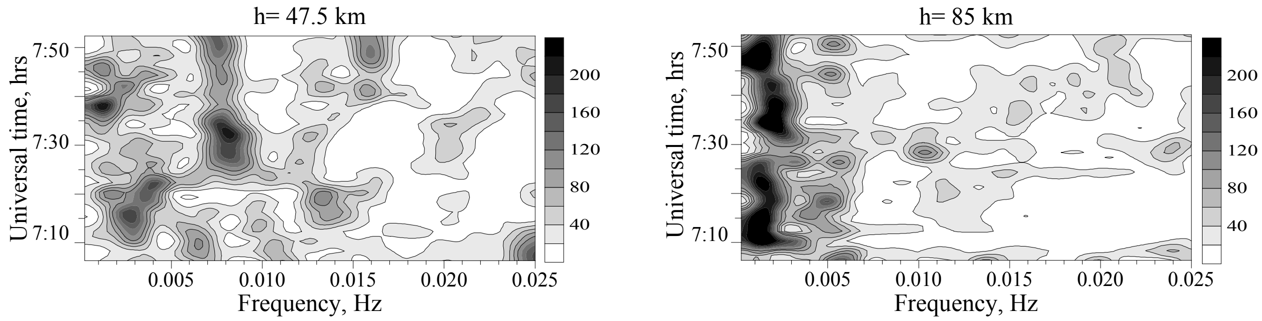

Fig. 3. Spectra of twelve-minute data as a function of time at the heights of 47.5 and 85 km

Polar magnetic substorm

The partial-reflection data and magnetogram of the H-component taken during a magnetic substorm on March 30-31, 2001 in Tumanny are shown in Fig. 4.

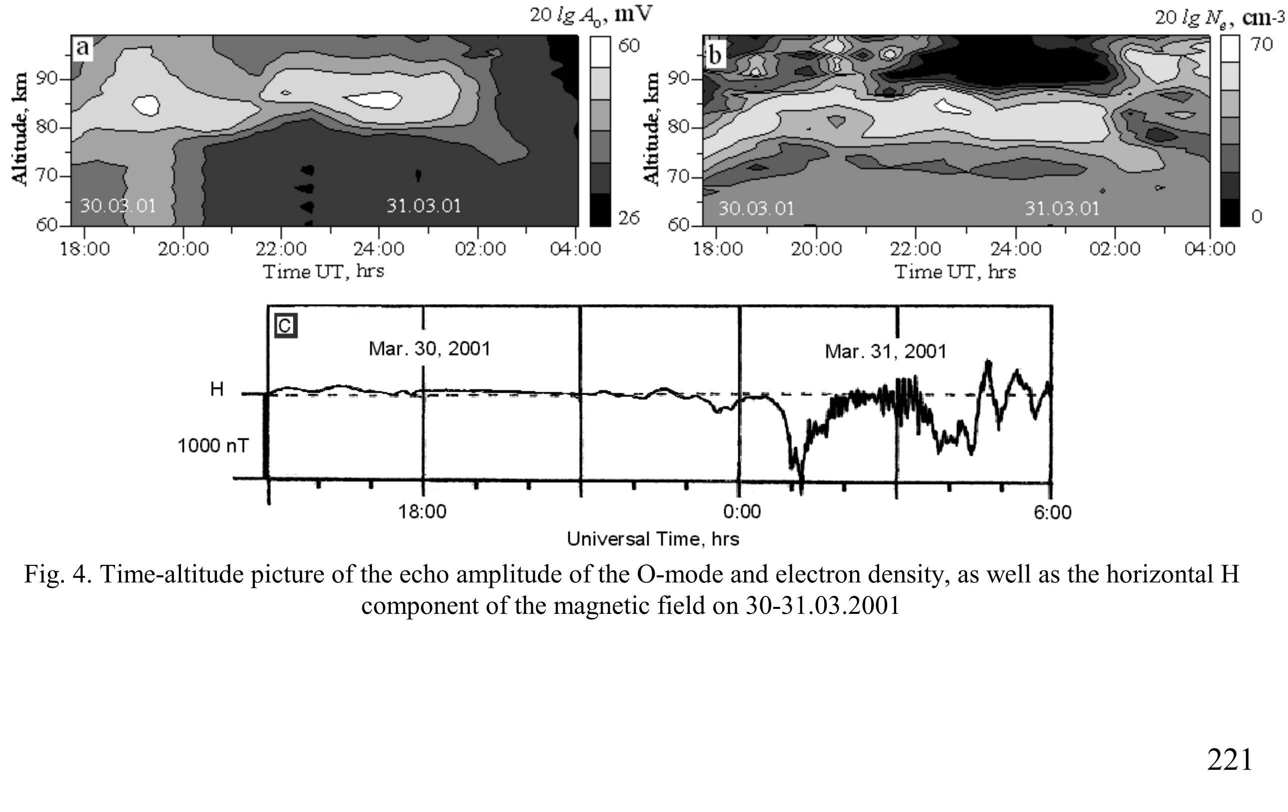

Fig. 4. Time-altitude picture of the echo amplitude of the O-mode and electron density, as well as the horizontal H component of the magnetic field on 30-31.03.2001

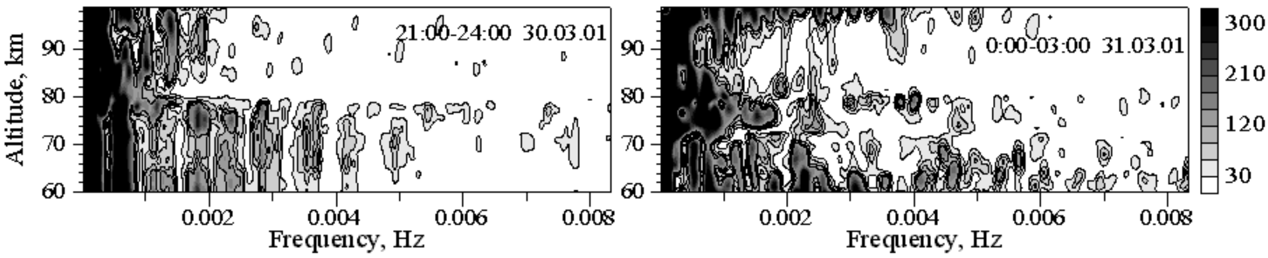

Fig. 5. Spectra of three-hour data as a function of height obtained during a magnetic substorm

In Fig. 4a one can see an intensive radiowave backscattering at the heights of the D-region in the night hours. This backscattering proceeds in a rather narrow altitude range around 85 km. The maximum amplitude of the scattered signals is observed at about 24:00 UT. Then it starts decreasing at heights ~ 85 km and increasing around ~ 75 km, the nighttime electron concentration being considerable and exhibiting similar variations (Fig. 4b). From the Figure it is seen that about 02:00 UT there appears stratification in the electron concentration, with a “valley”, i.e. a region of low density, being formed in the altitude range of 75 to 85 km. Simultaneously, the riometer records at frequency 32 MHz indicate an additional absorption of 1 to 3 dB. In Fig. 4c the development of a polar magnetic substorm is shown. The negative perturbation in the H-component at Tumanny lasts about one hour.

Fig. 5 shows the power spectra of the amplitude fluctuations of the backscattered waves at different heights.From comparing the above spectra, two features of the explosion event can be revealed: strengthening of atmospheric wave intensity and infrasonic wave dissipation at the heights of 80-85 km. Thus, filtering properties of the polar mesosphere for the infrasound are evident.

Siberian meteorite explosion

One more event of undular perturbation is associated with the Siberian meteorite explosion of 24.09.2002 at 16:49 UT. In Fig. 6 the data of radio noise amplitude measurements by the PGI radar as well as a magnetogram from Tumanny are presented. From Fig. 6a it follows that, despite of the absence of any magnetic disturbances in the period considered, an increase of the radio noise, as compared to the subsequent day, is registered. The amplitude of the signal exhibits quasi-harmonic oscillations. The first splash of the radio noise intensity in Tumanny is indicated at 17:40 through 17:50, the second one – at 21:00 through 21:45, the third one - at 25:35 through 22:55 (see. Fig. 6b).

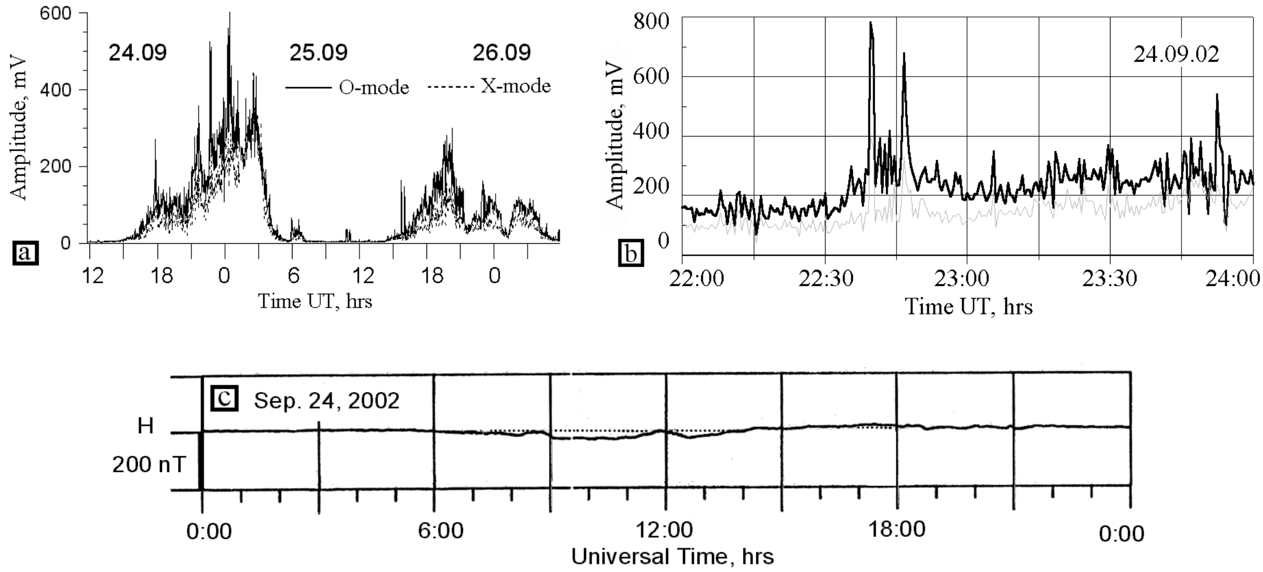

Fig. 6. Time variation of the radio noise intensity at the frequency of 2.7 MHz and the magnetogram obtained during the meteorite explosion

Under the assumption that these perturbations have originated from the explosion site in the ionosphere, the propagation velocities can be estimated as ~ 1.2 km/s, ~ 300 m/s and ~ 200 m/s, respectively. Such values are consistent with the propagation velocities of the IGW and infrasound. Similar effects were detected at the explosion of the orbital station "Skylab" in July, 1979 [Sorokin et. al., 1982]. It is interesting to note, that in Apatity the PGI microbarographs detected a pressure impulse on September 24, 2002 at 22:20 UT [Shumilov et. al., 2003]. The above estimations suggest that the perturbation considered can be related to the explosion of the Siberian meteorite.

Spectrum analysis of the radio noise amplitudes (Fig. 7) reveals oscillations with the periods of 3-4, 6 and > 9 minutes. From comparing spectra for the data of 23-24 September and for those of 24-25 September, it follows that the inclination of the spectrum obtained during the meteorite explosion is steeper than that on the previous day. This can be associated with an increase in the background temperature after the meteorite explosion.

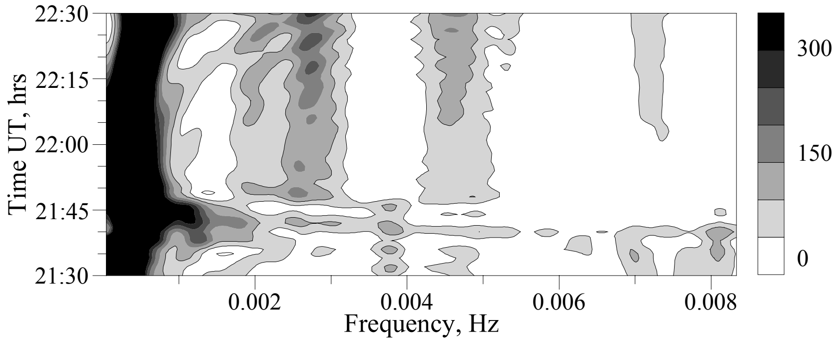

Fig. 7. Spectrum of one-hour data as a function of time obtained during the meteorite explosion

Conclusions

Undular perturbations in the polar lower ionosphere associated with the undersea explosion, polar substorm and Siberian meteorite explosion have been detected. It is established that during these events in the polar lower ionosphere two types of atmospheric waves can propagate: (1) the internal gravity waves with the periods greater than 9-10 minutes and (2) infrasonic waves with the periods of 3-4 minutes. At the heights of the polar mesosphere the effect of infrasonic wave filtration is revealed. A possible reason for this effect can be a reverse of the sign of ionospheric irregularities horizontal velocity. To verify the results obtained, further studying of atmospheric waves originating from different sources in the lower ionosphere is required.

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