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SIMULTANEOUS OBSERVATIONS OF GRAVITY WAVES IN AURORA AND BY PARTIAL REFLECTION RADAR

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Abstract. During aurora observations at the observatory Lovozero in certain cases the luminescence of the night sky had a wavy structure with the wavelengths of several tens kilometers and with the temporary periods about 15-30 minutes. It allows assuming that they are caused by acoustic-gravity waves. For two cases comparisons with data of the radar of partial reflections in the observatory Tumanny have been carried out. Maxima of reflection amplitudes of the radar took place at the heights of 80-90 km and amplitudes at these heights had the periods similar to the periods of fluctuations of luminous intensity of the sky.

1. Introduction

In 1960 Hines had shown that gravity waves were the important atmospheric phenomenon [*Hines*, 1960] and intensive researches of this phenomenon including the use of optical methods have begun [*Armstrong*, 1982]. Optical registration of the waves in the ionosphere was carried out during the campaign ALOHA-93 on low latitudes by several researchers. So, in works of *Taylor et al.* [1995a, b] were presented results of photography of all-sky cameras in the OI emissions (557.7 nanometers), the doublet of sodium (589.2 nanometers) and the near infrared range of the OH hydroxyl emissions. These emissions have different mechanisms of excitement and emit at little different heights that allows to judge about dynamics of waves. The auroral origin of waves in these and similar works, of course, is excluded because of the near equatorial location of points of their observations.

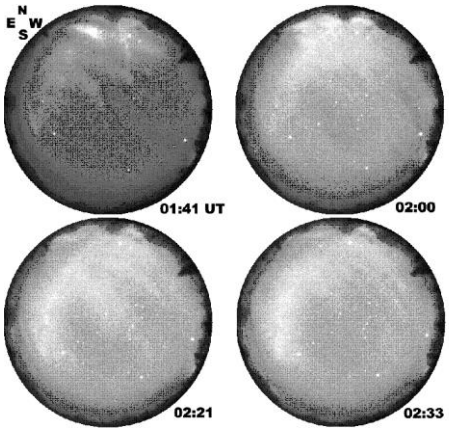

Figure 1. Pictures of the all sky over Lovozero, 26.02.2012.

There are many data, which show that the certain class of the traveling ionospheric disturbances caused by the acoustic-gravity waves (AGW) has the origin in the auroral zone during its hyperactivity. The problem of generation of AGW by the auroral electrojet and the relative role of Joule heating and Lorentz force were theoretically considered in works [*Chimonas, Hines*, 1970; *Francis*, 1974, 1975].

In the article by *Chimonas and Hines* the authors have received an expression, which described the relative contribution of Joule heating and Lorentz force to generation of AGW from the auroral electrojet.

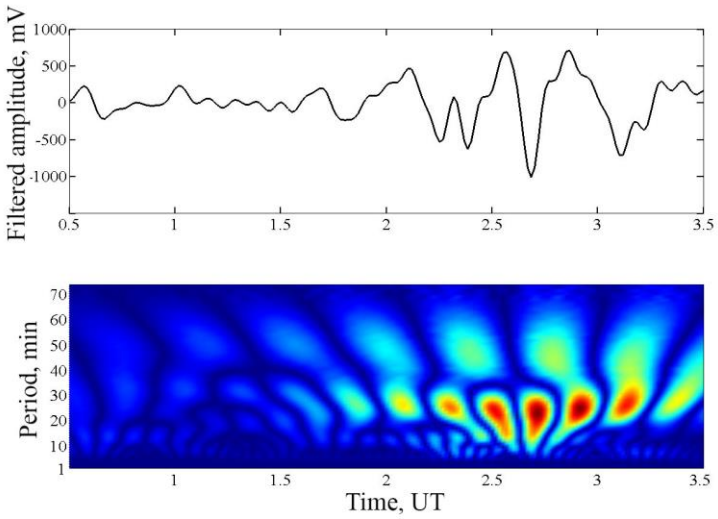

Figure 2. Temporary behavior of the filtered amplitude of the reflected ordinary wave (up) and its wavelet spectrum (down) for 26.02.2012

Hunsucker [1977, 1982] has estimated the AGW parameters, using experimental data. In the series of experiments *Wilson* [1969a, 1969b, 1969c] has shown that the auroral arc at its supersonic movement was followed by a pressure wave, which could be recorded by experimental means. *Chernouss et al.* [2002] reported about a wave-like structure in aurora luminosity over Lovozero after a rocket launch in the Arkhangelsk region. It had the horizontal wavelength about of 35 – 40 km, the period about 3-4 min and propagation speed 180-240 km/s.

For consideration of manifestation of gravity waves we have compared observations of independent measurements: the luminescence of the night sky and data of the radar. The luminescence intensity data were obtained by the all-sky camera of the observatory Lovozero of the Polar Geophysical Institute (67.97º N, 35.02º E).

The received pictures of the luminescence intensity have been compared with measurements of amplitudes of reflections of ordinary and extraordinary waves of the partial reflections radar in the observatory Tumanny of the Polar Geophysical Institute (69.0º N, 35.7º E) [*Tereshchenko et al*, 2003].

2. Results of observations

On the ascafilms of the all-sky camera of the Lovozero observatory which was used for record of the aurora it was found out that sometimes the sky luminescence had wave pictures with the spatial periods of several tens kilometers which were slowly changing with the temporal periods of 15–30 minutes. This luminescence can not be identified with auroras and morphologically corresponds to acoustic-gravity waves. Such waves were registered also on similar cameras, but with the filters which were specially picked up for photography of luminescence at the heights about 80-90 km, for example, of Na, OH, OI, O2(0, 1).

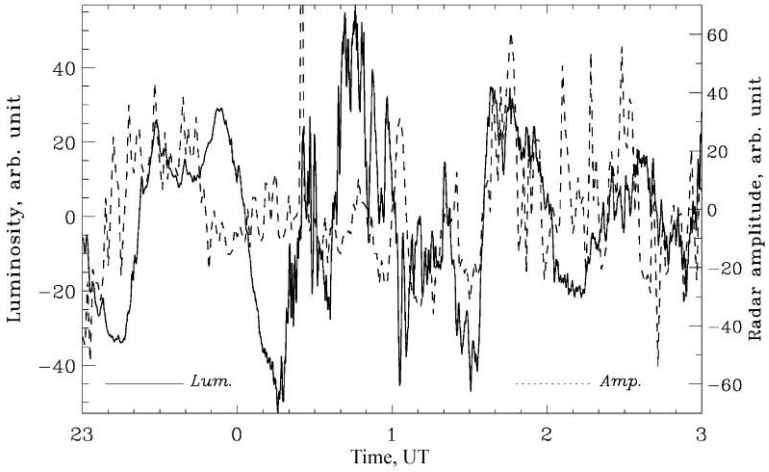

Figure 3. Variations of luminosity intensity of the night sky above the northerner sector over Lovozero, 25-26 February 2012 (solid curve), and reflected ordinary wave amplitude from 90 km (dashed curve). Slowly changing variations are removed from both curves

The sample of the wavy luminescence registered by us is given in Fig. 1. The camera worked without an optical filter and its maximum sensitivity is in the green range where there is the OI emission of 557.7 nanometers, the exposition was 0.05 second. In the pictures the orientation of the camera and universal time of shots are specified. The wavy structure of the strips extended from the northeast to the southwest with wavelength about 100 km is well visible.

AGW are registered and studied as well in PGI on the radar of partial reflections at the observatory Tumanny. In view of the big spatial extent of considered waves it makes sense to compare the optical observations with the radar ones. The reflected amplitudes of the ordinary and extraordinary waves of the radar were analyzed and filtered by the digital bandpass elliptic filter with the periods from 10 to 90 minutes. In Fig. 2 filtered amplitude variations of the reflected ordinary wave of the radar and the wavelet spectrum of this amplitude for time of the case in Fig. 1 are shown. The wave structure of reflection amplitude with the periods about 20-30 minutes is well visible.

The ascafilms of the night sky were received with the frequency of one picture per second, the dynamic range of the camera was 2 bytes, i.e. 65536, that allowed to build figures of intensity behavior in the chosen segments of the sky. Such variations have been constructed for eleven circles of the sky. Slowly changing components have been removed and it was revealed that there were variable components with the period of 15-30 minutes at some sites of the sky. For the northern site of the sky located over Tumanny the curve of intensity is shown in Fig. 3 by the solid line. One can see in the figure the period about 30 minutes. The dashed curve is the amplitude reflected from the 90 km altitude after detrending by a cubic polynomial. Both the curves are similar. Such similarity can be considered as good one if to remember that the photometric curve integrates intensity of luminescence in the circle of the diameter of 60º near the horizon and so reflects, in the basic, change of integrated intensity, but the radar curve shows spatial movements in the region of reflection over the radar.

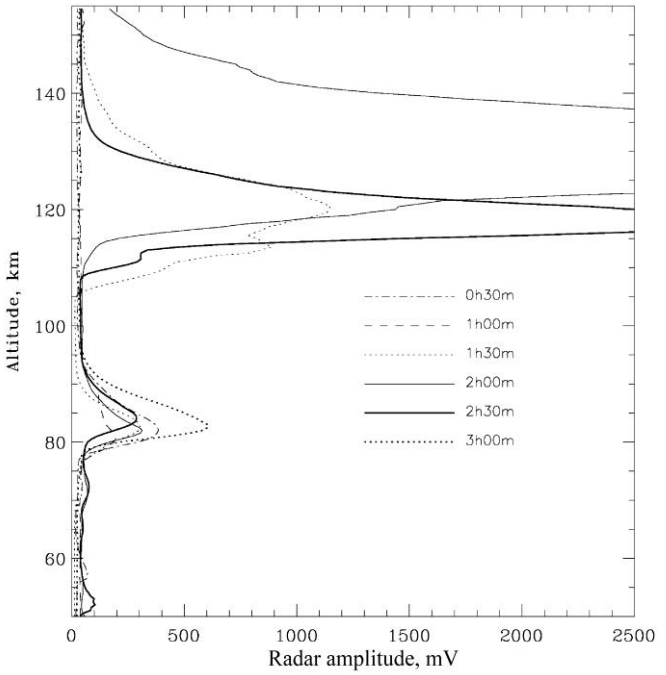

Figure 4. Altitude profiles of the reflected ordinary wave amplitude for the case of 28 January 2012

Other case of simultaneous observations of AGW by the optical way and the radar took place in the local morning on 28 January 2012. It was the

case with small auroral activity. The altitude profiles of the reflected ordinary wave amplitude from 00:30 UT till 03:00 UT are shown in Fig. 4. It is seen that from 01:30 UT at the radar data appear reflections from heights of 120-140 km which are obviously connected with auroral activity, however both to and after this moment there are reflections from heights of the mesopause of 80-90 km. Temporary variations of the reflections have periodic character with the characteristic time of 15-20 minutes, similar to changes of intensity of luminescence according to the all-sky camera data. The luminescence is generally caused by forbidden OI emission of oxygen at 557.7 nanometers which is extinguished lower the height of the mesopause because of collisions of the excited atoms with neutrals.

The interesting feature of this case is good correlation of changes of luminescence intensity with reflections at the height of 47.5 km where the luminescence is obviously impossible, and spreading of AGW takes place. The considered comparison is presented in Fig. 5: the signal of the radar is shown by dotted line in the logarithmic scale, the luminescence is shown by solid line. After 03:00 UT luminescence variations are a little late concerning the radar signal that most likely is connected with change of speed and a form of a wave.

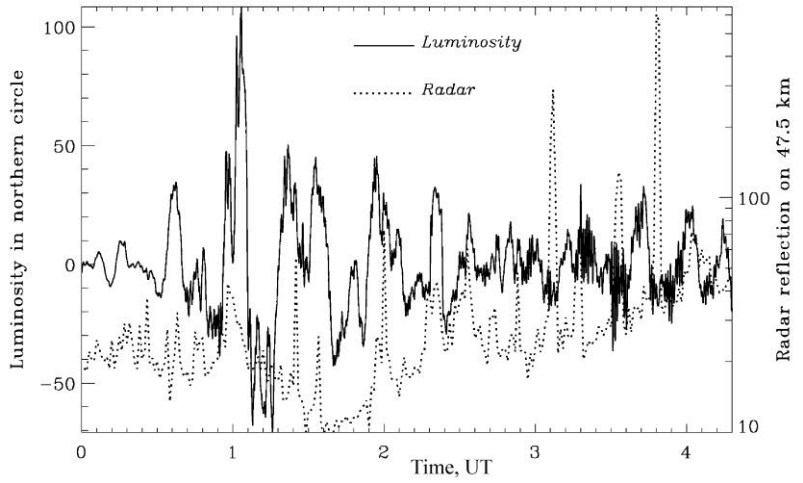

Figure 5. Behavior of luminosity intensity of the night sky above the northern part of the sky over Lovozero (solid line) and the reflected ordinary wave amplitude over Tumanny from the height of 47.5 km (dotted line).

3. Conclusion

From comparison of data of the radar of partial reflections with optical observations of waves it is possible to assume that wavy changes in a structure of luminescence intensity are connected with passing of gravity waves. The joint analysis of data will allow to interpret more fully data of reflected ordinary and extraordinary waves amplitudes, and also to clear physics of luminescence of the ionosphere when passing waves.

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