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OPTICAL OBSERVATIONS OF THE ACOUSTIC-GRAVITY WAVES (AGW) SUPPOSEDLY INITIATED BY ROCKET LAUNCHES

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Abstract

Wave-like structures in the upper atmosphere luminosity were registered by TV SIT all-sky camera installed at 1508 UT (1808 MSK) on 10 January 1997 at the Lovozero observatory (Geographical latitude ~ 68° , longitude ~ 35°) in the Kola Peninsula. Data analysis shows that the most probable source of the pattern is a rocket launch from the rocket range in Archangelsk region. The preliminary information was announced by the Russian ITAR-TASS agency, and the trajectory of flight was observed by the Lovozero observatory TV camera since 1813 MSK. The rocket plume was marked at 1813:20, and at 1813:30 a sharp flash was recorded at the azimuth angle ~ 60E. Most probably it was accompanied by the rocket second stage separation. Two hours later several wave-like structures appeared above the Kola peninsula within the diffuse aurora. The large scale phenomena parameters were registered and documented. Calculation of the projection of registered luminosity pattern on the surface geographical grid was done at supposed fixed altitude of the object under observation by traditional formula of spherical trigonometry. Scales, velocities, wavelengths and periods of the wave-like structures calculated by the time delays after the launch and wave crest shifts are presented. The direction to source of waves was pointed out by the individual wave-crests shift and by their curvature radius. Another case connected with rocket launch was found out by retrospective analysis of TV observations at the northwest of Europe. The visible features of these acoustic-gravity waves (AGV) events are related to the auroral activity providing the highest level of the background intensity. The physical nature of the observed AGW is under consideration.

Introduction

One of consequence of the environmental rocket launch effects in the upper atmosphere and ionosphere are periodical structures known as acoustic-gravity waves (AGV). They are represented as travelling ionospheric disturbances (TID) with velocities from several tens to several hundreds m/sec. These wave shape disturbances were measured in the electron density variations and interpreted by the acoustic-gravity wave models. In general there are a lot of AGV sources as well as earthquakes, ground-based explosions, thunderstorms and other events, which can lead to sharp local density variations in the atmosphere.

First optical observations of internal gravity waves were reported by Krassovsky /1/ on the basis of observation of oscillations seen in the intensity and rotational temperature of the hydroxyl emission band showed periods and phase speeds similar to those expected from internal acoustic-gravity waves theory. In recent years images of wave-like structures in three nightglow emissions with different height profiles (the OI 555.7 nm) and Na (589.2 nm) lines and the OH bands between 715 and 810 nm have been obtained with low light TV system /2/. But never has the source of this kind of optical periodical structure been identified and interpreted as environmental rocket launch effects in the upper atmosphere.

On the other side, experiments on artificial injection of chemical components into the upper atmosphere from rocket payload demonstrate presence of the luminosity waves during development of the artificial clouds at 130 – 180 km altitudes. For example during Ba vapor injection in the middle latitudes high speed luminosity waves with quasi-spherical form were observed. They have spread at radial speed of about 3 km/s just after Ba release. Since this value exceeds the sound speed at the release altitude it gives us a plenty of questions on their nature. All above mention facts stimulated search of the AGV in the atmospheric luminosity after rocket launching and were connected with starts and maneuvers of space vehicles.

Methods and Instrumentation

Search of wave-like structures in the upper atmosphere luminosity was carried out by photo and TV cameras installed in Apatity and Lovozero in the Kola Peninsula. It was our hope to register optical signatures of rocket launches from the Plesetsk rocket range in Archangelsk region. Large scale phenomena in the upper atmosphere at the height of more than 100 km can be certainly registered by wide-angle all sky lenses used with photo and TV cameras installed at the distance of about 600 km from the rocket launch site. First experience shows that only low light level TV cameras are able to register wave-like structures because of their low intensity. Below we shall demonstrate data of video-records of AGV by TV "Aurora" camera on the basis of SIT vidicon LI-702 with the threshold sensitivity of about 10^{-5} Lk. Video-records were transformed into the digital form for further processing. The main software consists of calculation of the projection of registered luminosity pattern on surface geographical grid. There was supposed a fixed altitude of the object under observation. Calculations of the scales, velocities, wavelengths and periods were done.

Optical TV observations of AGV in the upper atmosphere

Let us look for events supposedly connected with the rocket launch from the Plesetsk range on January 10, 1997 at 1508 UT (1808 MSK). The preliminary information was announced by the Russian ITAR-TASS agency and the trajectory of flight was observed by the Lovozero observatory TV camera (Geographical latitude ~ 68° , longitude ~ 35°) at 18.13 MSK. The plume was noticed at 18.13.20, and at 18.13.30 a sharp flash was recorded at the azimuth angle ~ 60E.

Most probably it appeared in connection with the rocket second stage separation. Two hours later visible wave-like structures appeared above the Kola Peninsula in the nightglow. It is necessary to emphasize that the geophysical situation was characterized by a strong geomagnetic storm accompanied by rather an intensive aurora this time. In spite of that the analysis of the TV pictures enables us to separate both natural and artificial luminosity events.

Observations of spectacular nightglow display were started at 1730 UT. Wave structures were clearly distinguished on TV pictures (Fig.1) and continued about one hour. Camera field of view was 180°. Fig.1 demonstrates negative pictures for time intervals 1748, 1751, 1753, 1756, 1805UT. Time is running from the left to right side and from top to bottom in Fig.1. The last picture gives the camera orientation, two white lines (the straight one elongated in N-S direction and the arc in the bottom part) represent profiles used for construction of keograms (see Fig 2 below).

It is possible to see active discrete auroras in the upper part of the frames. The auroral activity was rather unstable in comparison with wave structures and it permitted to separate these different patterns. Wave structures traveled approximately from East to West during all the time of observations. It is possible to define the direction to the source of waves by the individual wave-crest shifts and by their curvature radius. The periods, wavelengths and speeds are calculated by the time delay and wave crest shifts.

To obtain more accurate calculation of those parameters an image of wave structures was projected to the ground by traditional formula of spherical trigonometry and these projections are presented in Fig. 3. It is obvious that wave-crests propagated from the source situated north-west of Archangelsk which approximately coincides with the location of the second stage of the A-2 rocket separation point. This conclusion is done on the basis of suggestion that the wave propagation is visible at altitudes of about 105 km in emission of OI 557.7 nm.

Propagation time of the wave crests from the explosion point to the southern part of the Kola peninsula is in good agreement with propagation velocities measured by positions of individual wave-crests in the fixed times. The presented data give us evidence of AGV in case under consideration. The main parameters of the event are:

Horizontal wavelength	35 -40 km
Propagation speed	180-240 km/sec
Period	3-4 min
Horizontal length about	~1500 км
Time of duration	~60 min
Wave-crests number	20

Calculated parameters are in agreement with the model speculations describing propagation of AGV in the upper atmosphere /1-3/. In addition, we would like to point out that similar optical features of AGV, which are connected with rocket launches, were also found by retrospective analysis of TV observations at north-west of Europe. For example, the event similar to the one described above was observed February 1, 1984 at the Norwegian observatory Shkiboth (Geographical latitude ~ 69°, longitude ~ 20°). The nightglow wave-like structures were observed in the OH bands by TV camera too.

This event was connected with the C-1 rocket launch from Plesetsk range at 1738 UT and was registered in the northern Norway 5 hours later. The parameters of AGV were:

Horizontal wavelength	31км
Propagation speed	15 – 25 м/sec
Period	28 min
Horizontal length more than	60 км
Time of duration about	10 min
Wave-crests number	4

Curvature radius pointed out to the source in the north of Archangelsk region, and the time of propagation from there to the northern Norway was correlated with the time measured by wave-crest shift.

The both events were related to the auroral activity, which gives highest level of background nightglow intensity level. This level permits us to visualize the AGV and observe them by the optical imagers.

References

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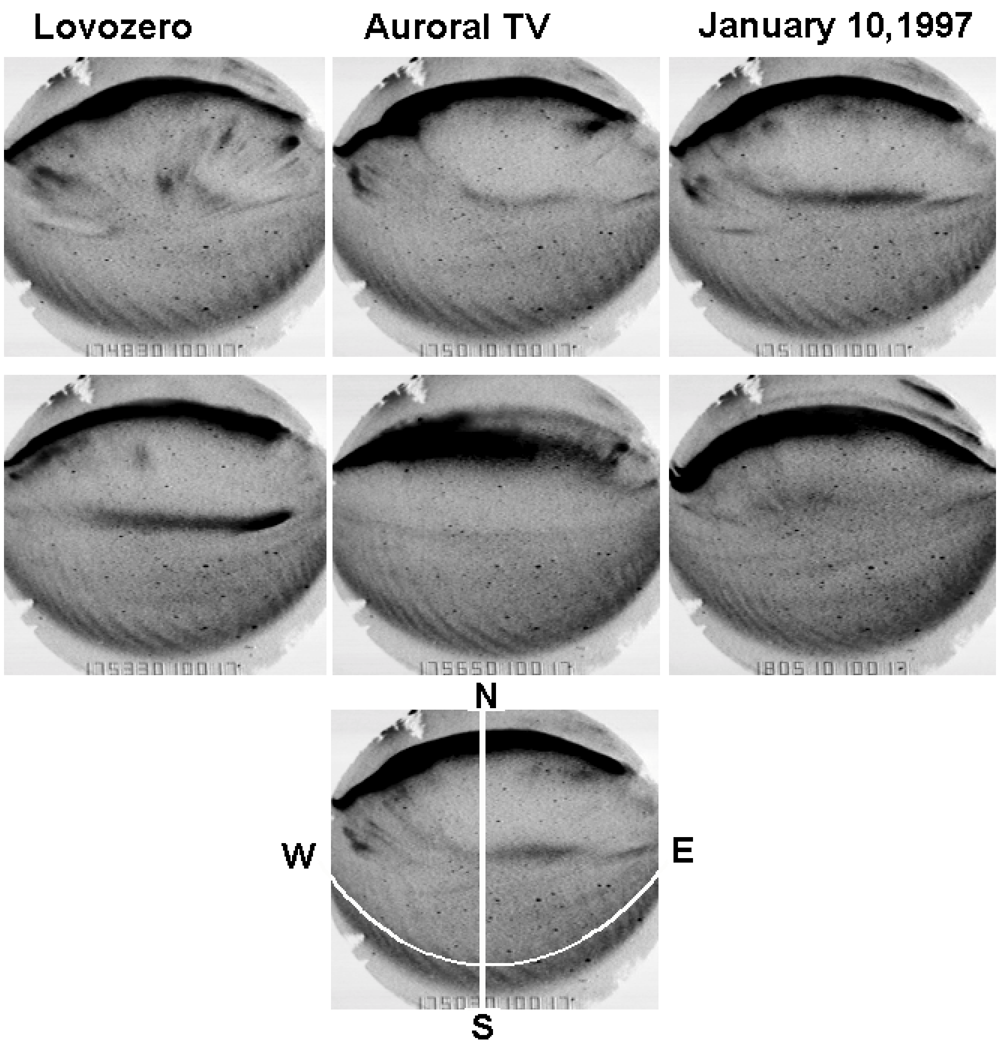

Fig. 1.
Sequence of auroral displays (negative) obtained from the auroral TV camera observations on January 10, 1997 at Lovozero, Kola Peninsula. The frame on the bottom demonstrates the orientation of the

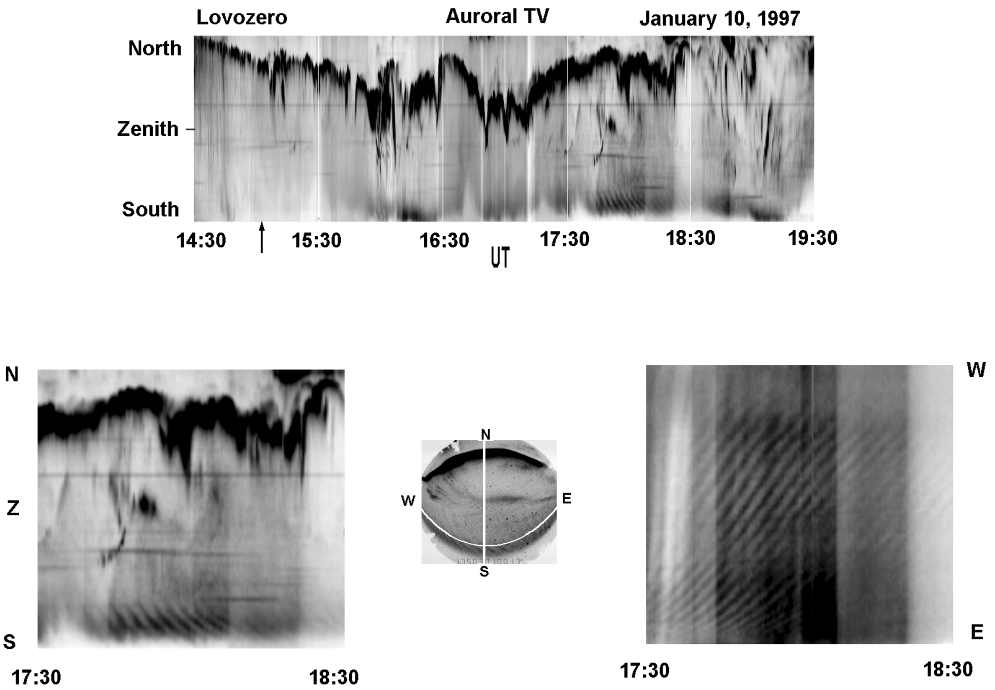

Fig. 2.

Top: Keogram made from the Lovozero TV observations from 1430 till 1930 UT along the N-S direction (vertical white line on the frame in the bottom of Fig. 1). Arrow marks the time of the rocket launch.
Bottom left: The same, but for interval 1730-1830 UT. The wave structure is seen in the diffuse aurora on the southern horizon.
Bottom right: Keogram made along the E-W direction (the white arc in the frame in the bottom of Fig. 1)

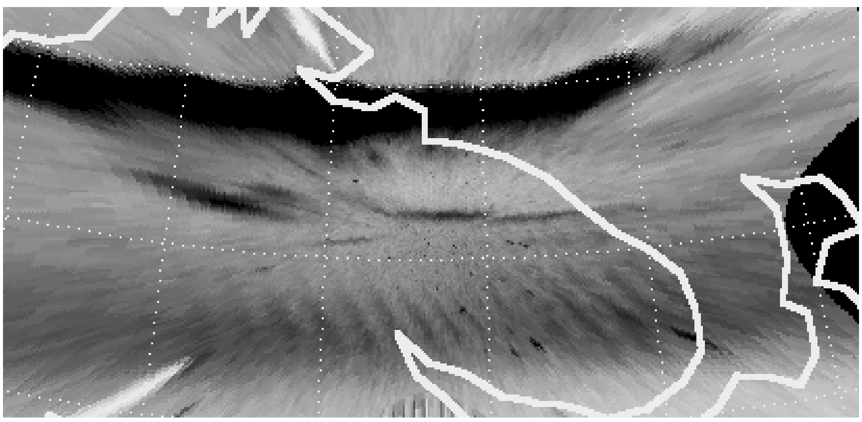

Fig. 3
Auroral display (negative) mapped onto geographic grid. White line is the coastline.