LIDAR STUDIES OF GRAVITY MOUNTAIN WAVES OVER VITOSHA MOUNTAIN

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ABSTRACT

In a joint lidar-meteorological radiosonde experiment, lee wave were detected originating from Vitosha Mountain located near the city of Sofia. The Vitosha Mountain's orographic parameters were calculated. The wave period in each atmospheric layer with $\Delta z = 30$ m was estimated for the entire sounding range (1 – 5 km). A correlation was established between the heights of the layers with best expressed wave structure and the profile of the Scorer parameter. Lee waves with periods ranging from 8 to 25 minutes were observed.

1. INTRODUCTION

When the ground airflow overcomes a mountainous obstacle in a stratified atmosphere, internal gravity waves are formed on the lee side, which are called mountain waves due to their origin. The process of mountain waves formation depends both on the airflow dynamic characteristics and on the height, shape and orientation of the mountainous obstacle. Four parameters are used to characterize the orography, namely, slope, standard deviation of the height from the basic grid, asymmetry coefficient and mountain crest orientation [1]. Trapped lee waves are formed by the superposition of two non-hydrostatic waves moving upward and downward in a waveguide. During the Mesoscale Apline Program, performed in 1999, an airborne aerosol lidar was employed [2].

Using a stationary aerosol lidar, located near the Vitosha Mountain, we detected trapped lee waves; by spectral statistical signal processing, we obtained the waves periods. Combining the lidar data with simultaneous meteorological radiosonde measurements, we were able to estimate the influence of the mountainous obstacle on the wave content and height distribution.

2. EXPERIMENT AND RESULTS

Sofia plain is located at 580 m above sea level and is surrounded by three mountains. Vitosha Mountain is located at about 6 km to the south-west from the lidar location. Cherni Vrah Peak has altitude of 2290 m asl, while the crest below is at 2000 m. We have counted the topographic characteristics of mountain by the grid-point 10/11 performed with an interval 0f 1850 m.

On 29.11.2005 meteorological radiosounding was carried out at 14:30 hours LST at the National Institute of Hydrology and Meteorology, Bulgarian Academy of Sciences, located near the Institute of Electronics. On the same day, between 14:45 – 17:51 hours LST, a vertical lidar sounding experiment was performed using the aerosol lidar at the Institute of Electronics, Bulgarian Academy of Sciences (23.4E, 42.6N)

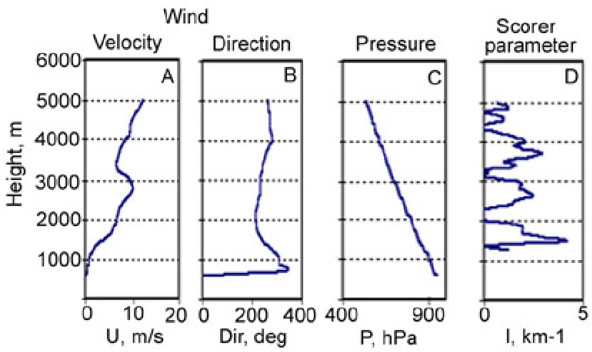

Fig.1. Data from meteorological radiosounding

The wind velocity rises with the height up to 10 m/s and peaks at about 3000 m, while the direction remains constant from the southwest (Fig. 1A, 1B). The atmospheric pressure plot (Fig. 1C) indicated a stratified atmosphere. Fig. 2 presents a Vitosha

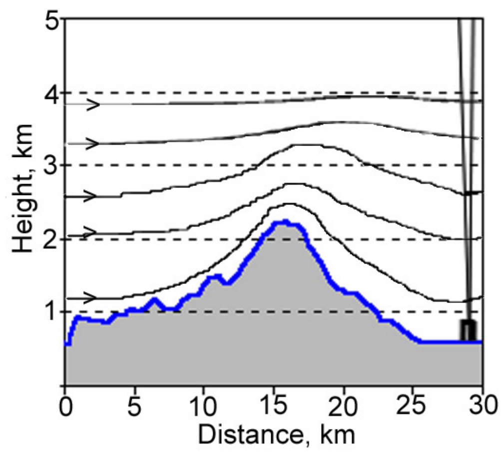

Fig.2. Vitosha Mountain profile

Mountain profile along the wind direction. The lidar location is indicated, too. The orographic parameters on a sub-grid scale are: half-length $b = 7250$ m, halfwidth $a = 5100$ m, anisotropy $\gamma = 0.7$, standard deviation of $h(x, y)$ is $\mu = 500$ m, slope $\sigma = 0.146$.

The Scorer parameter is $l^2(z) = \frac{N^2}{U} - \frac{1}{U}\frac{\partial^2 U}{\partial z^2}$, where U is the wind velocity and N (the Brunt-Vassala frequency) is calculated using the meteorological data. It decreases at heights of 2300 m, 3300 m, and 4400 m, which points to trapped waves (Fig. 1D). The Scorer parameter is an important quantity, as it participates in the gravity waves equation $\frac{d^2 w}{dz^2} + (l^2 - k^2) = 0$, where w is the vertical velocity and k is the horizontal wavenumber.

Using the lidar system described in [3], we acquired the vertical profile of the lidar response at equal 1-minute intervals with spatial resolution of $\Delta z = 30$ m. From each layer of height z, we obtained a series of discrete signals (realizations), which are proportional to the molecular density and the aerosol concentration. Between 120 – 240 discrete values are sufficient for statistical interpretation. This corresponds to continuous sounding for two to four hours; a power spectrum for each realization is constructed *a posteriori*, which is used to determine significant values of cyclic processes frequencies in a given layer, together with their relative values [4]. As is demonstrated by the plot of the Scorer parameter l^2, its maximal values occur at 1500 m, 2700 m and 3700 m.

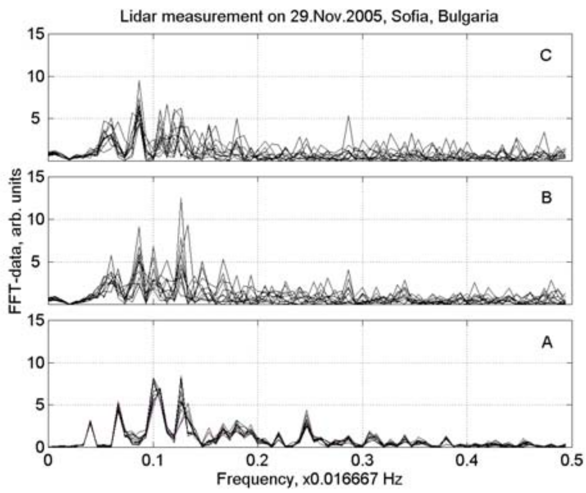

Fig.3. Power spectrums of lidar realizations from three layers of heights 1350-1650 m (A), 2550-2850 m (B) and 3550-3850 m (C).

The best power-spectra were obtained approximately at the same heights (Fig. 3). Using the spectrograms for the respective heights, we established the following periods: 8 min, 10 min, 14 min and 25 min; 8 min, 11 min and 17 min; 11 min and 17 min. The spectra are shown for ten consecutive layers with overall thickness of 300 m, in order to demonstrate the frequency dispersion.

3. CONCLUSION

Using a stationary aerosol lidar based at the Institute of Electronics of the Bulgarian Academy of Sciences, in the city of Sofia, we observed mountain lee waves with periods ranging from 8 to 25 minutes. The lidar realizations registered from different atmospheric layers and the periods calculated using the spectrograms indicated a correlation between the heights with the least dispersion of the waves temporal frequencies and the heights where the Scorer parameter profiles have maxima. The meteorological radiosounding performed simultaneously demonstrated that the gravity waves are the result of the air flowing above the Vitosha Mountain. The Vitosha Mountain's orographic parameters were also calculated. Due to the limitations of our lidar system we were not able to obtain data on the waves length and velocity. This could be performed by using a scanning lidar or a lidar sounding in several directions simultaneously.

4. REFERENCES

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