Lidar Registration of Orographic Internal Gravity Waves in the Atmosphere

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Abstract - **Local dynamics of low and medium layers in the troposphere causes diffusion on pollutants emitted from ground-based sources, typical for larger cities. Internal gravity waves (IGW) of orographic origin are a continuously operating means of action of dynamic processes in the atmosphere above Sofia city. In this paper, the results of analysis made on the periodic structure of IGW, registered through remote lidar measurements are presented.**

Keywords – **Gravity waves, Lidar, Dynamic of the atmosphere**

I. Introduction

Internal gravity waves in the atmosphere are sometimes visually observed by the cyclic shape of the clouds. They are part of the common dynamic of the atmosphere and transmit wave momentum and energy from one place to another. Most waves are of small dimensions and act on a local scale, but they do play a role in the diffusion of gaseous and aerosol pollutants in the boundary layer of the atmosphere.

IGW of orographic origin arise as a result of dragging the ground air flow when overcoming a mountainous obstacle [1]. For registration of the IGW, terrestrial or airborne installations are used. Relatively new and highly effective means of remote studying of IGW are radars and lidars [2]. The object of our research was to register IGW of orographic origin at altitudes up to 10 km, using high spatial resolution (30m) in the area above Sofia city both at day- and night-time.

II. Experiments

Lidar experiments were held on the territory of the Institute of Electronics at BAS, Sofia city. The city is situated in a field surrounded to the north by Stara Planina Mountain, to the south by Vitosha Mountain, to the east by Plana Mountain, and to the west the plain is open, as it can be observed on the satellite photograph (fig. 1). The orographic situation around Sofia fosters formation of IGW in the atmosphere. Vitosha Mountain is located 6 km southwards from the city center, the ridge reaching a height of more than 1500 m above the plain (peak Cherni Vrah – 2390 m), and having longitudinal dimensions of about 15 km. Its proximity and significant dimensions and height often result in IGW when winds are coming from the south, southwest and southeast.

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Orographic waves have been observed in the area of Sofia by the fluctuations of the atmospheric pressure [3]. The authors note that in 90% of the measuring time waves were observed, with the largest amplitude resultant from a wind coming from Vitosha and a wave period between 5 and 30 minutes in most cases.

The lidar appliances, employed for the experiments conducted in the current study was supplied with a CuBr laser (λ=510 nm) with pulse duration 10 ns and pulse repetition 13 kHz [4]. We sounded vertically upwards, and photon counts from photo detector were registered by Photon Counting Board LD_P 03_01, allowing registration of the backscattered lidar signal in altitude with spatial resolution of 30m, in 1024 strobes and cumulating time of 60s. The sounding height was 1km to 10km. The studies were conducted in 14 days in the months October 2004 – February 2005, when the sky was cloudless. The total duration of lidar profile records for this period is 48 hours, as in 39 hours or 77% of the total sounding time, presence of waves was registered. The duration of one experiment for atmosphere sounding was 1.5 hours. In two days, the records from consecutive soundings were combined into longer series, respectively 6 and 9 hours continuously. The wind speed and direction and air temperature were measured with meteorological mast. In most experiments the wind speed is below 0.5 m/s and its direction is unstable.

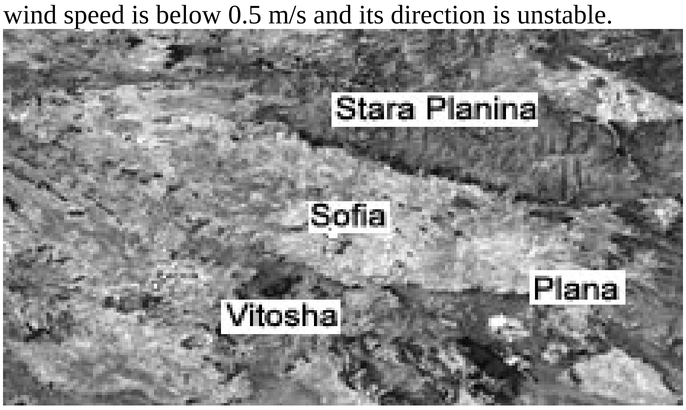

Fig.1. Map of the region of Sofia city

The lidar parameters determined registration of discrete temporal series (realizations) of 90 numerical values each, distant by time intervals of Δt=1 min. Each realization represents the time distribution of a lidar backscatter from an atmospheric layer of 30 m thickness, located at a certain height. Each lidar signal record contained 360 realizations. After filtering, the spectra of these realizations were constructed using Fourrier transformation and the respective

IGW periods were determined. Often in one spectrogram 2 or 3 significant spectral lines were observed, which shows that the waves registered represent superposition of waves with different wavelengths.

III. Results and Comments

Typical spectrograms, obtained in the analysis of temporal series of lidar data are shown on fig. 2 and fig. 3, on which summarized results from the experiments carried out on 1.12.2004 and 11.01.2005 respectively, are presented.

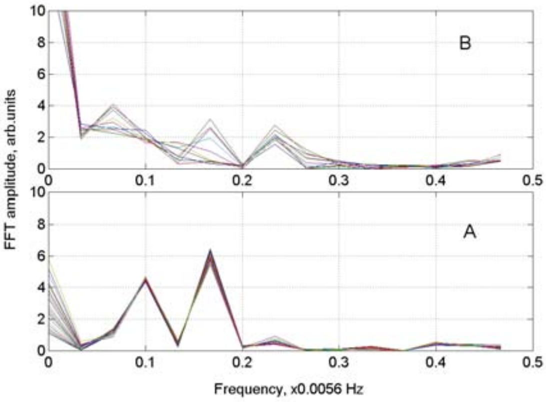

Fig.2. Spectrograms of the temporal series from a lidar sounding held on 01.Dec. 2004. For heights lower than the mountain ridge, well stressed periodic processes can be observed (A), which fade out at higher altitudes (B).

The spectrograms on fig. 2 represent the results of a lidar sounding with 1.5h duration between 15:50h and 18:20h LT. Fig. 2A presents the spectrograms of realizations of 30 sequential height intervals each of 30 m thickness, situated within a height range of 1000m-2000m above the lidar. For these heights it is typical that they are lower or of comparable height with this of the Vitosha Mountain, which causes the appearance of orographic IGW due to southern wind streams. Thus for these heights wave periods of 29 and 18 minutes respectively are registered. In contrast to these spectra, the spectrograms from higher altitudes show absence of a wave process. Fig. 2B shows the results from analysis of temporal series for 10 sequential layers of the same thickness for heights of 2500-2800m above the lidar. For these altitudes and above, until the end of the sounding range of the lidar, no cyclic processes exhibiting regularity are observed.

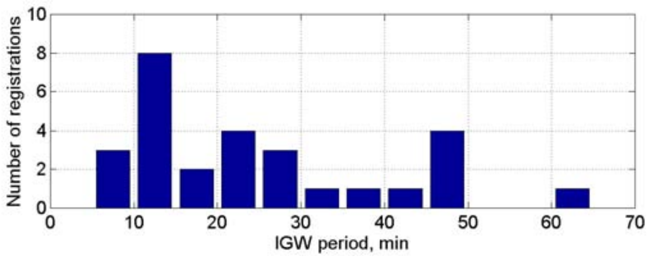

Fig.4. Histogram of registered IGW periods

The spectrograms of fig.3 are a summary of 4 consecutive lidar soundings from 11.01.2005, with a total duration of 6 h. Three spectral lines are significant for the respective heights of 1000m –2000m and they have periods of 50 min , 36 min, and 26 min respectively. From the spectrograms for heights of above 2km it is obvious that no noteworthy wave processes are observed (fig. 3b).

Fig. 4 represents the histogram of distribution of the periods of registered orographic IGW from all lidar soundings. Most often, waves with periods between 10 and 20 minuites are observed. The three local maximums for intervals 5-15min, 20-30min, and 45-50min correspond to the most frequently observed wave superpositions.

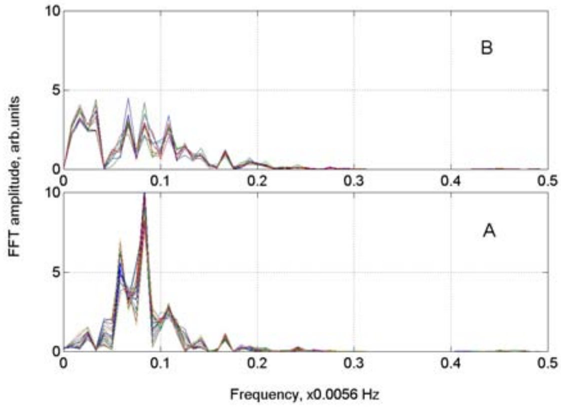

Fig.3. Spectrograms of the temporal series from a lidar sounding held on 11.Jan.2005. Superposition of 3 waves can be observed (A), which fade out at higher altitudes (B).

IV. Conclusion

The lidar system at our disposal allowed remote and simultaneous in many atmospheric layers observation of periodic structures, that represent a manifestation of internal gravity waves in the atmosphere. The lidar soundings in the area of Sofia city during the fall and winter period, with a total duration of 48 hours, confirmed the presence of such waves in 77% of the total number of experiments. At altitudes of about 2-2.5 km, fading to insignificant amplitude values was observed in the temporal series, which testified to the decomposition of the periodic structures studied. Such behaviour is characteristic for waves of orographic origin. Orographic IGW appear and depend on the wind structure and are part of the dynamics of lower and ground atmospheric layers. They are undoubtedly one of the mechanisms for distribution of gaseous and aerosol pollutants around Sofia.

References

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