Detection of Oscillatory Motion of the Atmosphere in the Spectra of the Electric Field and Pressure Fluctuations

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ABSTRACT: The study of the spectral characteristics of the atmospheric pressure and the electric field fluctuations is produced to detect vibrations in the atmosphere caused by gravity waves. Joined analysis of microbarograph and electric field sensor data allows to determine tropospheric peak (near 600 seconds) and the stratospheric peak (near 300 seconds) The frequency of tropospheric and stratospheric peaks of gravity waves allows to estimate the thermal regime of the atmosphere, in particular, vertical temperature gradient in troposphere and temperature of stratosphere.

INTRODUCTION

Detection of oscillations of the atmosphere is important not only for research tasks, but also for weather forecasting and climate research. However, the detection of oscillations in atmosphere by using devices which are located on the Earth's surface is a difficult task. One of the possible solutions for this problem is the sharing of data of two or more independent sensors for detecting vibrations. This device is able to detect gravity waves which gives possibility for detecting temperature changes in the atmosphere.

DECRIPTION OF EXPERIMENTAL EQUIPMENT

The study of the spectral characteristics of atmospheric pressure and electric field fluctuations are produced by measurements of microbarograph and electric field sensors installed in the Central Aerological Observatory (CAO), Dolgoprudny, Moscow Region. Measurements of the electric field and pressure are produced by the electric field sensors (EFP-2/50) and microbarograph which are designed in CAO. Precipitation distort the electric field. Therefore the optical detector of precipitation (RIO) was developed to record the instantaneous intensity of precipitation. RIO operates in the infrared range and allows to record the beginning and ending of precipitation to the nearest minute and measure the intensity of solid and liquid precipitation with an accuracy of ± 50%. The using of precipitation sensor avoids misinterpretation of measurement results. Exterior view of devices and an example of recording data is shown in Figure 1.

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Figure 1.Exterior view of devices (EFS-2/50 (left) and RIO) and an example of recording data.

Specifications and description of EFS-2/50 is given in [1]. The sensors showed good metrological characteristics. The drift of zero did not exceed 5 V / m and resolution 0,1 V/m. It should be noted that the plates of the sensor during the measuring were oriented downwards, rather than upwards as usual. By simultaneous observations from the standard oriented sensor was determined reduction factor equal to the selected mode of installation 3.2 ± 20%. The selected arrangement of sensor allowed to provide long-term performance of the sensor in an unattended mode. Service of the sensor has been made only during the flowering trees and poplar fluff that caused deposits on the leading edge of the rotating grounded plate. The microbarograph has resolution 0,5 Pa.

Thus a device for detecting vibrations of the atmosphere was made. It can detect vertical atmospheric vibrations that is why it was named VAV- meter.

Data processing was carried out by calculating the cross-correlation function. Example of cross spectrum is shown in Figure 2.

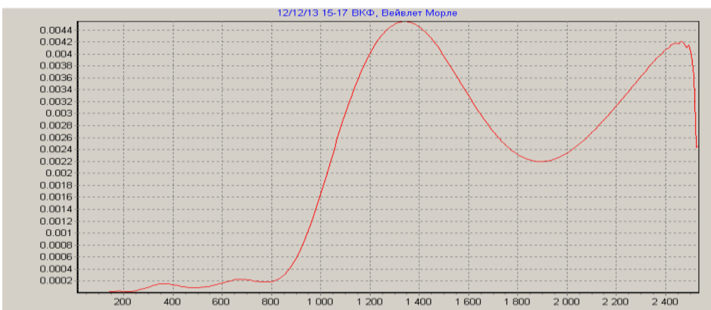


Figure 2. An example of cross spectrum of VAV-meter. The horizontal axis is the time in a seconds, the vertical axis is the relative amplitude of fluctuations

EVALUATION OF THERMAL CONDITIONS IN THE ATMOSPHERE

Thermal and kinetic energy of the atmosphere causes an oscillation in a very wide range of frequencies (wavelengths or periods). Among all vibrations gravity waves occupy a special place (2), because their period (N is a frequency of Brenta-Vaisala) depends only on two parameters: the actual temperature and the vertical temperature gradient

$$T_{BV} = \frac{1}{N} = 2\pi\sqrt{\frac{T}{g(\gamma_a - \gamma_r)}} \qquad (1)$$

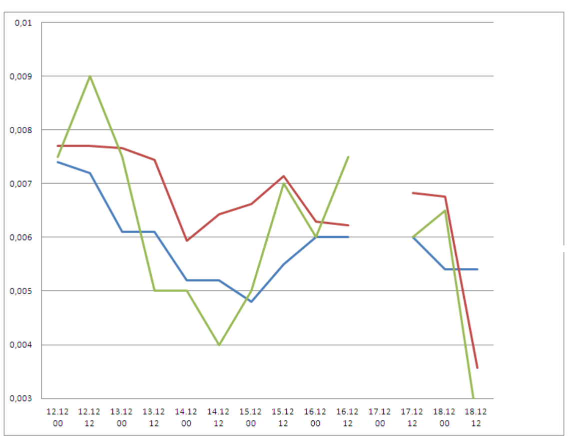
T_{BV} is the period of vibrations, γ_a is adiabatic temperature gradient 0,01 º K/m, γ_r is real vertical temperature gradient, g is acceleration of free fall. For an isothermal atmosphere (which is typical of the stratosphere), the oscillation period is about 5 minutes, for the atmosphere with a gradient of 0,006 º K/m (the average value in the troposphere), the oscillation period is about 10 minutes. From (1) the formula for vertical temperature gradient can be obtained (if we know temperature in the layer)

$$\gamma_r = \gamma_a - \frac{4\pi^2 T}{P^2 g} \qquad (2)$$

Also from (1) the formula for the temperature in the layer can be obtained (if we known vertical temperature gradient)

$$T = \frac{P^2 g(\gamma_a - \gamma_r)}{4\pi^2} \qquad (3)$$

This relations allow (under certain assumptions) to determine the vertical temperature gradient in the atmosphere and temperature in the stratosphere. If we take the temperature in the equation (2) for the period equal temperature T according to the weather station, it becomes possible to calculate the vertical temperature gradient in the troposphere by the center frequency of the peak in the range of 600 seconds. If we assume that the temperature gradient is known (for stratosphere it is close to zero), it is possible to determine the temperature of the stratosphere by the central peak frequency in the range of 300 seconds. The results of observations is on figure 3. Calculation of the vertical temperature gradient in the troposphere from VAV-meter showed that the obtained values are not only correspond to the order of the gradients determined from radiosonde data, but also have a similar tendency to change. Gradients according only microbarograph or only the electric field sensor data give only the order of measured value. Thus VAV-meter needs for measurements at least two sensors operating on different principles , and to conduct a joined analysis of the data to get the correct results .



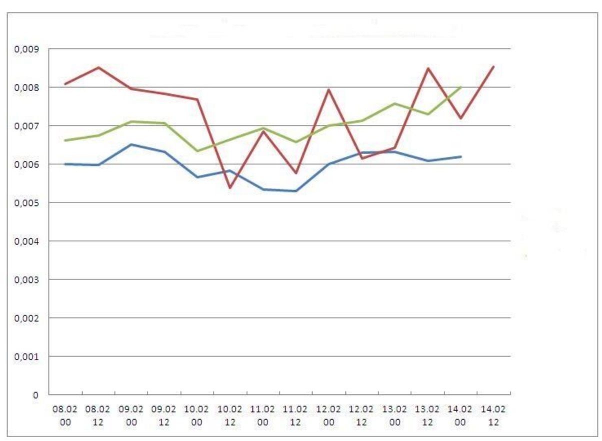


Figure 3. The vertical temperature gradient in the troposphere from VAV-meter (red line), mean value for all troposphere (blue line), and in 2 Km layer below tropopause (green line) both from aerological data. Left figure is the atmospheric front with precipitation, right is cloudless weather without precipitation.

The estimation of mean temperature in stratosphere from averaged values per day gave reasonable results, but the calculation of "instant" stratospheric temperatures on individual spectra was completely unsatisfactory. This may be due to low sensitivity of the VAV-meter to these oscillations located on the large distance (about 10 km or more), which reduces the accuracy of the measurements. Another reason is the presence of other vibrations in the atmosphere in this frequency range that distort the measurement results. It should be noted that in the spectra detected oscillations with a period of about 20 minutes, the nature of which is not currently known.

CONCLUSIONS

The results of these studies can be used to remote determination of temperature changes in the atmosphere.

REFERENCES

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