On the Features of Radiative and Convective Regimes Under the Cumulus Cloudiness

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Introduction

The study of instant temperature field transformation, convective and radiative regime perturbation within the layer of 0 to 650 m was fulfilled as caused by cloud modulation of solar radiation flux. It was made within the scope of Zvenigorod Atmospheric Radiation Measurement (ARM) experiments in 2001 and 2002.

Instrumentation

The equipment used:

1. Microwave temperature profiler designed in Central Aerological Observatory (CAO) and manufactured by Russian company ATTEX (Kadygrov and Pick 1998).

2. Set of fast-response thermometers installed at the heights of 2, 5, 11, 22, and 43 m.

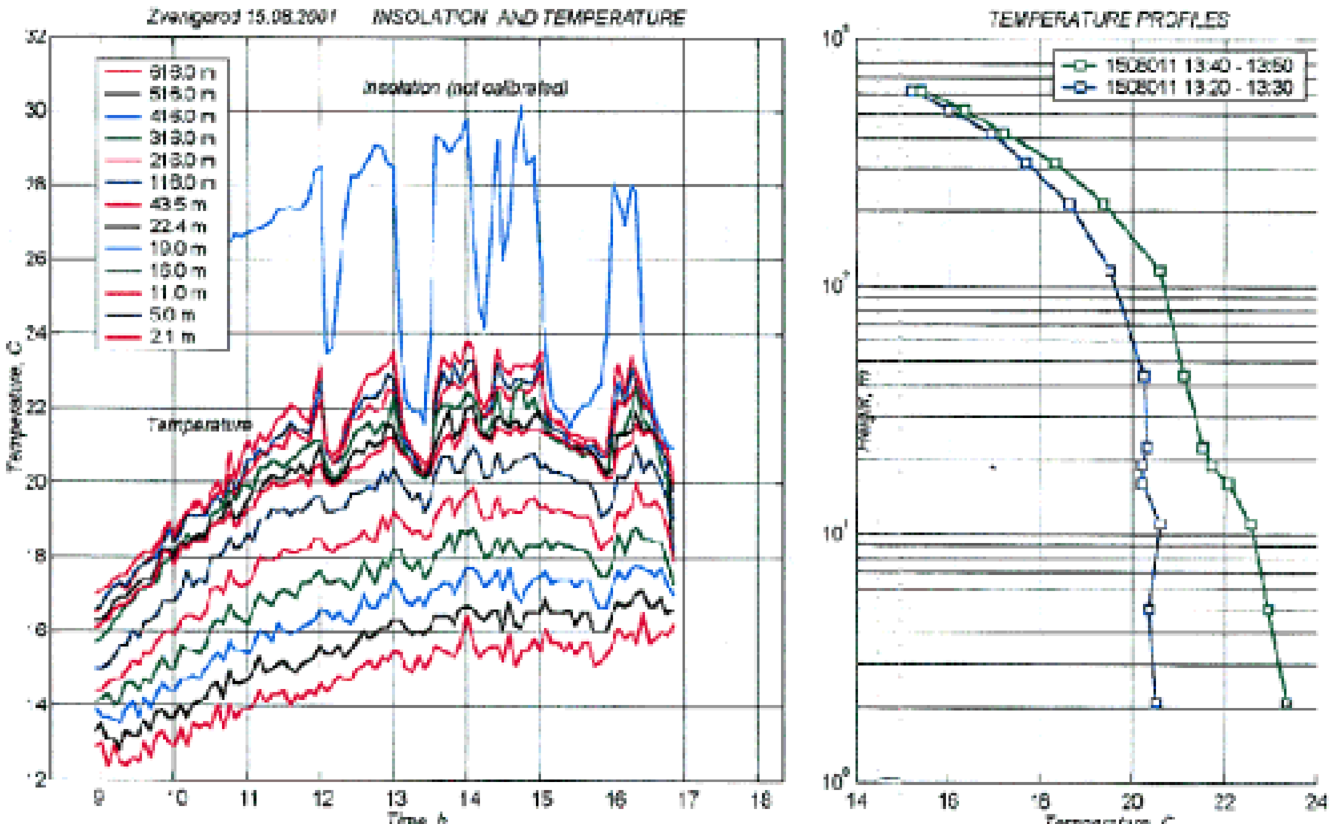
3. Sonic anemometer with joint resistance thermometer at the 17 m height.

4. Surface temperature thermometer.

5. Solar pyrgeometer.

Measurements Result

In the Figure 1, daytime trace of insolation and temperature traces at several heights are shown. Measurements are carried out under the presence of cumulus clouds. To combine the data of profiler (time resolution 5 min) and those of resistance thermometers and pyrgeometer (digitised with frequency of 2 Hz) these latter were smoothed by 5-minute filter and synchronized with profiler’s data.



(a) (b)

Figure 1. Daytime trace of insolation and temperature traces at several heights.

As seen from the Figure 1, the sharp decreases and increases of insolation (upper blue curve), caused by cumulus clouds, produce very fast and almost synchronous temperature variations at all the heights. For instance, speed fall of insolation started near 13.00 induced the drop in temperature at lower levels. The velocity of temperature decrease exceeds 20°C/hour. After the fast temperature drop the new period starts as characterizing by rather slow temperature decrease, with velocity of about 1°C/hour. The Sun appearance was followed by fast temperature rise with very high velocity of about 30°C/hour.

In the Figure 1, two temperature profiles are shown as well, related to following time intervals: 13:20–13:30 (just before the Sun appearance) and 13:40–13:50 (immediately after the Sun appearance). As one can see, the critical profile transformation may occur for only 10–20 minutes.

In Figures 2a and 2b cross-correlations are shown between smoothed insolation and temperature signals. Figure 2a relates to the mast data and Figure 2b to the profiler data. In the two upper axes in the left side of each figure the smoothed insolation and temperature traces are shown (smoothing interval is equal to 5 min) as well as their trends (time interval for trend calculation is equal to 60 min). In the two lower

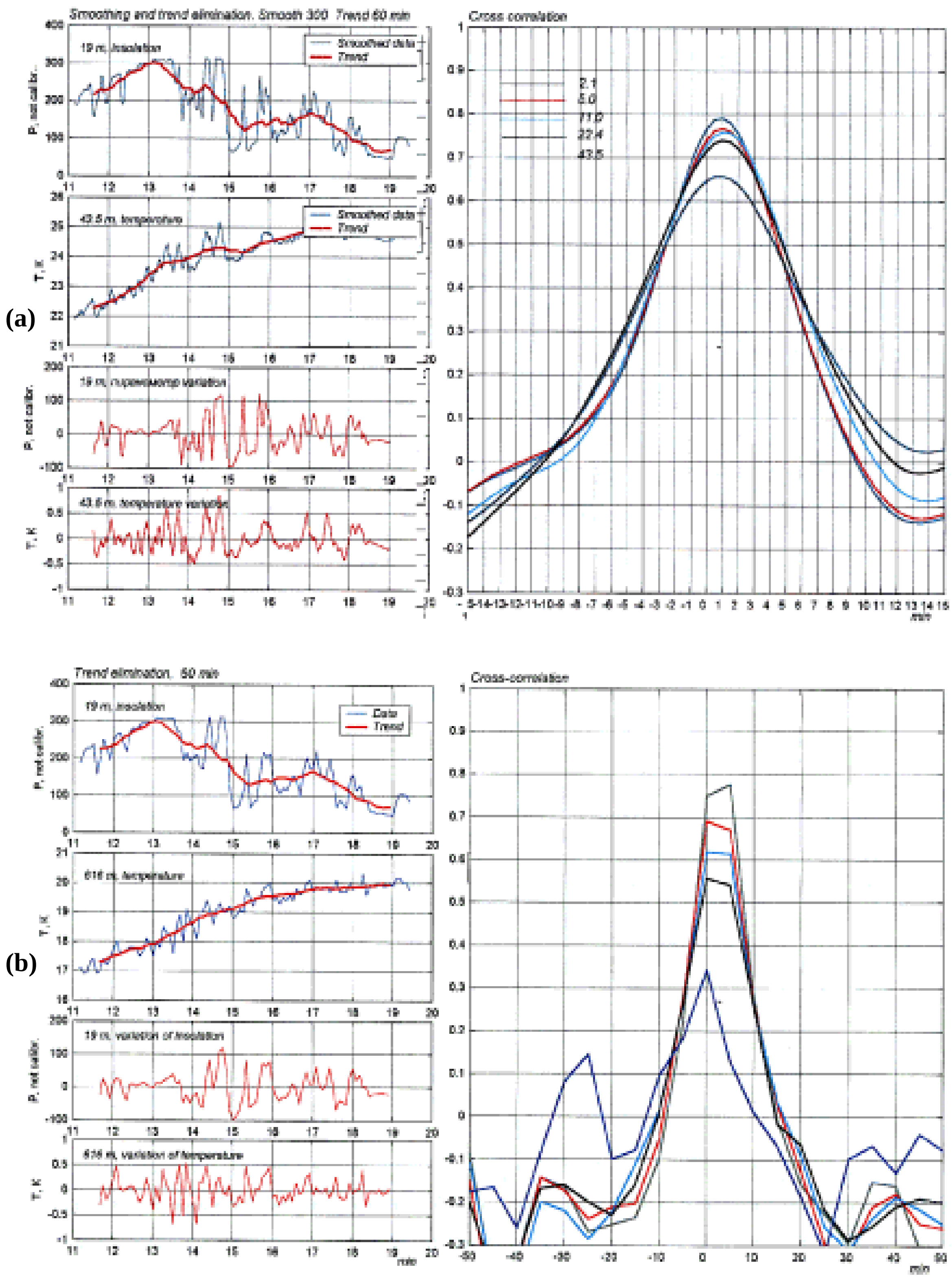


Figure 2. Cross-correlations are shown between smoothed insolation and temperature signals. (a) Relates to the mast data and (b) relates to the profiler data.

axes in the same side deviations of smoothed signals from trend are presented. Five-minute smoothing supplies almost complete elimination of turbulent variation, but as being the linear operation it remains the mean value without change.

Correlation functions achieve the maximum value at some point shifted right from zero for approximately 1 min. It means that temperature changes follow the insolation variations with some delay. It should be noted (and it seems strange) that this shift is almost independent of the height. The temporal correlation radius is equal to approximately 6 min. The maximum values of correlation functions are rather high: they exceed 0.6 for all the levels lower than 316 m.

In Figure 3, the synchronous smoothed traces are shown as related to insolation, temperature, and vertical velocity at the heights of 19, 22, and 17 m, respectively. The positive correlation between each pair of signals is obvious. The most interesting is correlation between insolation and vertical velocity (Mazin and Khrgian 1989).

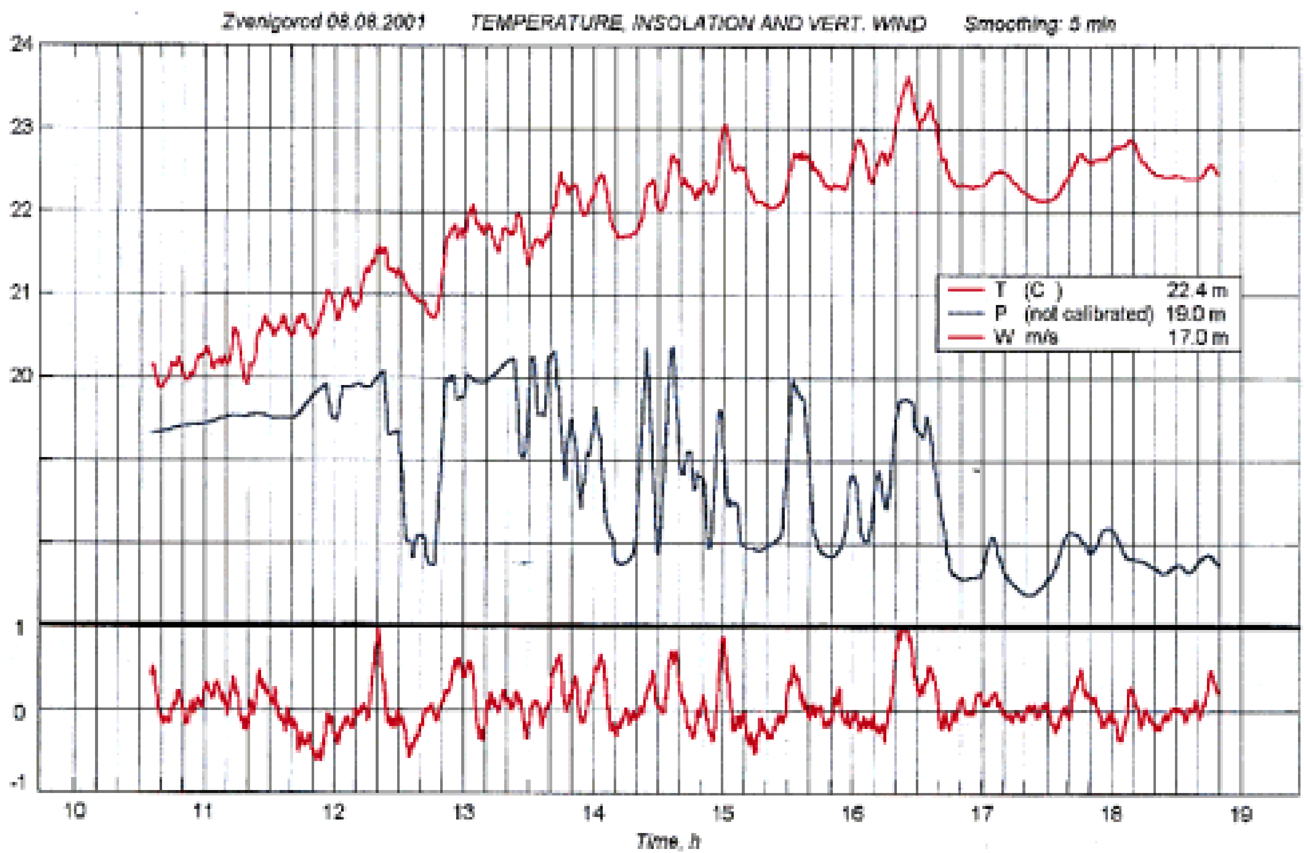


Figure 3. Synchronous smoothed traces are shown as related to insolation, temperature, and vertical velocity at the heights of 19, 22, and 17 m, respectively

As seen from the Figure 3, the cloud shade passing produces long intervals with low level of insolation. Inside these intervals one can see subintervals with steady negative vertical velocity of order of 0.3 m/s. It seems likely that organized structures may exist with descending motion near the cloud centre and updrafts around the cloud. In Figure 4, cross correlation functions are shown between each pair of values P, W, and T (insolation, vertical velocity and temperature). All the correlations are rather high near zero, especially correlation between T and W. The last one achieves the maximum value at zero value of time shift, in contrast with the others. The maximums of P-T and P-W correlations are shifted from the zero point for some two minutes. Very high level of positive one-moment W-T correlation indicates that contribution takes place from cloud-induced variations of W and T into the sensible heat flux (Li and Moreau 1996).

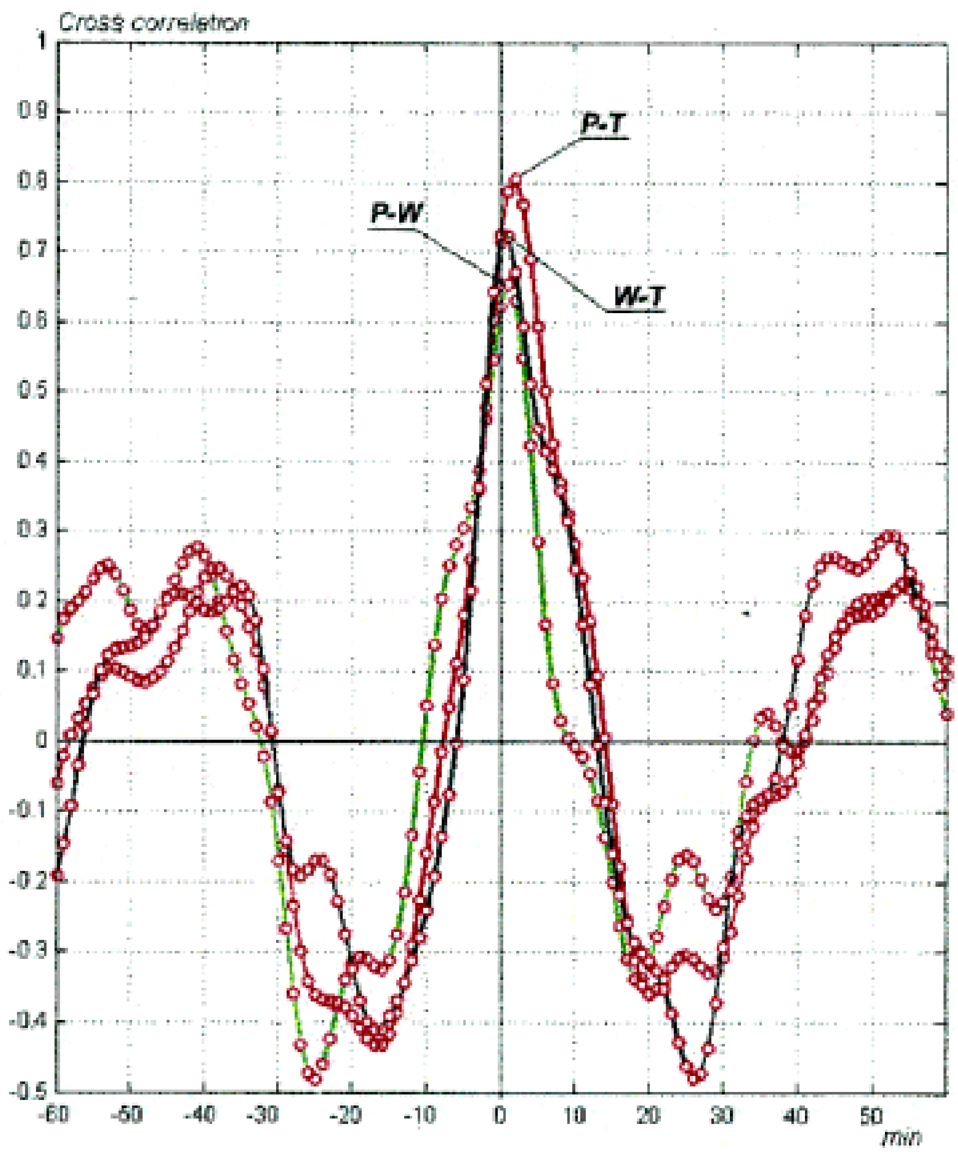


Figure 4. Cross correlation functions are shown between each pair of values P, W, and T (insolation, vertical velocity and temperature).

In the Figure 5, the co spectra W-T are shown in semi-logarithmic scale, i.e., the values of f x F_{WT} versus log f (F_{WT} is co spectrum, f–frequency in Hz). The duration of records analysed were from 8 to 10 hours, so the frequency band was from about 5 x 10^{-5} Hz up to 1 Hz. We have to note that low frequency limit of spectral analysis is determined both by records duration and parameters of trend elimination filter. The “hump” of the function takes place between 3 x 10^{-4} and 6 x 10^{-4} Hz, which undoubtedly associated with clouds. The contribution of this frequency band into the integral heat flux may be estimated as equal to approximately 20%.

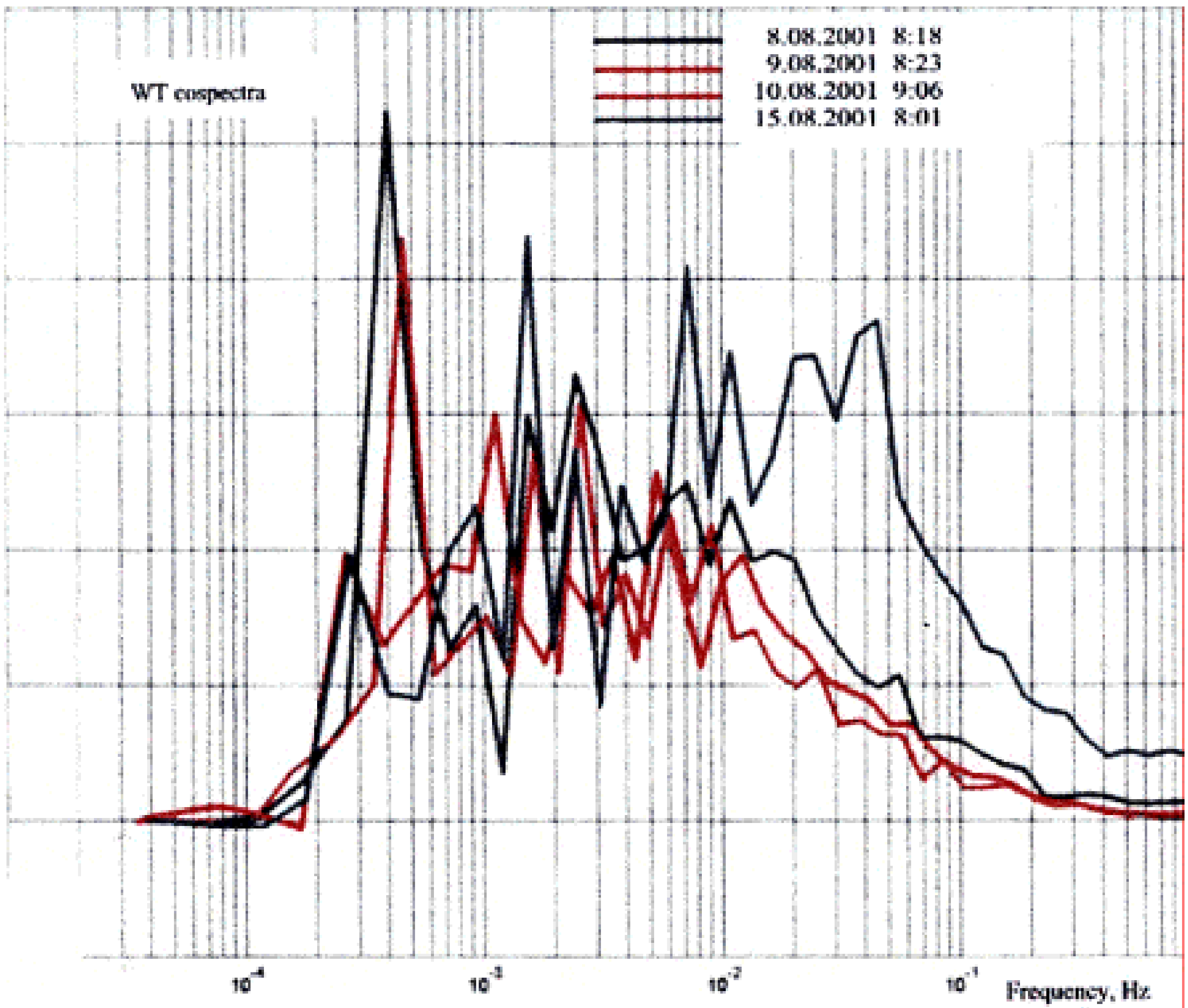


Figure 5. Co spectra W-T are shown in semi-logarithmic scale.

Conclusion

The perturbation of temperature profile within whole investigated layer as caused by Sun disappearance and appearance due to clouds passing was found to occur as fast as for few minutes. The fast transformation of surface layer (up to 6 meters) is related to fast changing of underlying surface temperature. That produces both radiative heating (cooling) due to infrared radiation absorption (emission) by greenhouse gases and temperature changing concerning with the convective structures.

In the upper layer, the other mechanism prevails. It is the presence of above-mentioned circulation pattern, which was found to advect together with cloud. It means that main factor here is the horizontal advection.

Co spectra of *W-T* have been calculated for the frequency band from 0.0003 to 1 *Hz* to estimate the cloud-induced contribution into turbulent heat flux.

The data presented demonstrate that water vapour plays not only the role of heat exchanger. The condensed vapour (i.e., cloud) appears on the other hand as a factor of negative feedback. Therefore the joint measurements of radiative and sensible turbulent heat fluxes (including the latent flux) must be continued as promising new results.

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