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MICROWAVE TEMPERATURE PROFILERS – APPLICATION FOR URBAN CLIMATE INVESTIGATIONS

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ABSTRACT

The MTP-5, a microwave temperature profiler, has been widely used since 1991 for investigation of the atmospheric boundary layer (ABL). There are several MTP-5 instruments modifications: MTP-5H – with the altitude range up to 600 m and with 50÷100 vertical resolution; MTP-5HE – with the altitude range up to 1000 m and 50÷200 vertical resolution; MTP-5P – with the altitude range up to 600 m and 10 m vertical resolution at the lowest 100 m.

During 1999-2003 MTP-5 instruments were successfully used for identification of Moscow city heat island, for investigation of exchange processes between the urban surface and overlying boundary layer and for remote sensing of urban atmosphere characteristics at several big cities in Russia.
Keywords: microwave radiometer, atmospheric boundary layer temperature, urban heat island.

1. INTRODUCTION

The MTP-5 is an angular scanning single-channel instrument with a central frequency of about 60 GHz, designed to provide continuous, unattended observations (Fig. 1). It can measure the thermal emission of the atmosphere with high sensitivity (0,03 K at 1 s integration time) from different zenith angles (Troitsky et al, 1993; Kadygrov and Pick, 1998; Kadygrov et al, 2003). On the basis of this measurement, it is possible to retrieve temperature profiles at the altitude range up to 600 m (MTP-5H) or up to the 1000 m (MTP-5HE) and with accuracy $0,5^{0}$C. The advantages of microwave radiometric data include the possibility to provide measurement in practically all weather conditions, in urban area (there is no any emission from the instrument), continuity in time and in its low operation cost. Passive microwave instruments are mobile, very portable and can provide reliable automated continuous profiling from a variety of sites, these are not available with the other techniques (Kadygrov and Pick, 1998). Data from microwave temperature profiler had successful comparison with radiosonde and tethered balloon data, with radio acoustic sounding system (RASS) data, and with data from in situ temperature sensors from high altitude meteorological towers (Kadygrov and Pick, 1998; Westwater et al, 1999). The MTP-5 instruments were successfully used in 1998-2003 in a number of international projects: investigations of the dynamics of ABL temperature inversion in a mountain valley (Mesoscale Alpine program – MAP); as well as along an island coast (north part of Sakhalin Island, Russia – Japan Project); continuous measurements of the ABL temperature profile provided from a special scientific train that crossed the territory of Russia (the Transcontinental Observations of the Chemistry of the Atmosphere Project – TROICA); investigations of cloud-aerosol-gas-radiation climatology in central-continental station Zvenigorod (Atmospheric Radiation Measurement – ARM – Program), and simultaneous measurements of the ABL temperature profile provided over the central and northern part of Moscow in a continuous mode (the Global Urban Research Meteorology and Environment Project – GURME) (Kadygrov et al, 2003). In addition, the Weather Forecast Burean of Moscow and some others big cities of Russia (Ufa, Orenburg, Nigny Novgorod) successfully uses data from MTP-5 instruments for its local weather forecast, for the forecast of air pollution, and for the forecast of glaze, fog and other dangerous meteorological conditions (Kadygrov et al, 2002).

Fig. 1. Microwave temperature profiler MTP-5

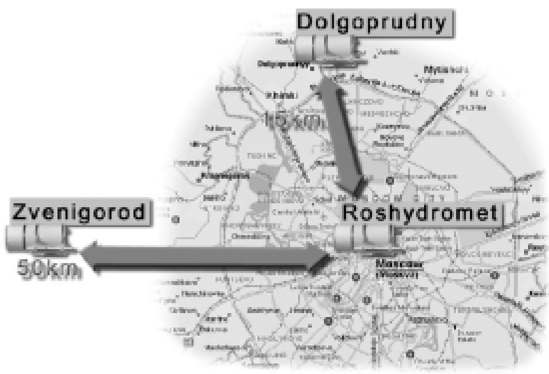

Fig. 2. Investigation of Moscow heat island on the basis of three MTP-5 instruments data

2. Investigation of the Moscow city heat island on the basis of simultaneous temperature profilers data.

For investigation of heat island above urban area ordinary were used near – surface data from meteorological stations at the city and in suburb (Kondratiev and Matveev, 1999; Oke, 1982). New technology based on consuming of microwave temperature profilers gave possibility to provide more detail investigation of heat island parameters including three dimension distribution of temperature data.

During 2000 – 2003, three microwave temperature profilers (MTP-5) were used simultaneously in the Moscow region for continuous measurements of the ABL temperature profile. One MTP-5 was installed in the center of Moscow city, the second – in the north border of Moscow (Dolgoprudny), and the third about 50 km westward from the Moscow city center (Zvenigorod) – Fig. 2. Temperature profiles measurements were provided simultaneously every 10 minutes within the altitude range 0÷600 m. The simultaneous measurements had two main scientific objectives. The first was to determine a Megacity impact to the ABL parameters, which led to creation of a so-called “heat island” (Kadygrov et al, 2002). The second objective was to investigate the ABL stability and it’s influence on a radiation balance near the ground surface. For that reason, the collection of the data (for more than 2,5 years) about ABL temperature profiles in different synoptical situations were provided. Preceding climatological data set about temperature inversion above Moscow were collected on the base of radiosonde data only (from upper air station Dolgoprudny). Three-points simultaneous remote sensing observation firstly gave detail quantitative parameters of temperature inversion, ABL stability and it’s differences in the center of urban area and in outside. It was experimentally confirmed that in some synoptic situations urban environment have influences the city microclimate which is comparable with influence from large-scale meteorological processes and sometimes the heating from antropogenic source dominates radiational cooling of the lowest atmospheric layer (Kadygrov et al, 2002; Khaikine et al, 2003).

3. **Application of temperature profilers data for forecasting of ABL parameters**

Knowledge of ABL temperature regime on the basis of MTP-5 data gave a new possibility for investigation and forecasting of different meteorological processed in ABL. (Kuznetsova et al, 2003). It’s can to improve local weather forecast, air-pollution forecast, forecast of dangerous meteorological condition. At Fig. 3 are shown as example the typical diurnal variations of thermal stratification at altitude range 0÷600 m measured by MTP-5 instrument (spring, cloudless, anticyclone), and at Fig.4 thermal stratification in overcast conditions. At Fig. 5 are shown thermal stratification on the passage of cold air front, and at Fig. 6 – passage of the warm air front. On the basis of such information it is possible to improve the ABL parameters forecasting (Khaikine et al, 2003; Kuznetsova et al, 2003).

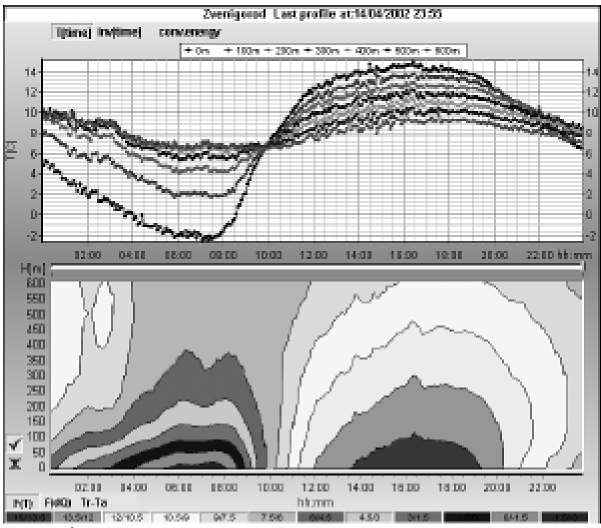

Fig. 3. Example of the typical diurnal variation of thermal Stratification at the altitude range 0 ¸600 m measured by MTP-5 (spring, cloudless, anticyclone)

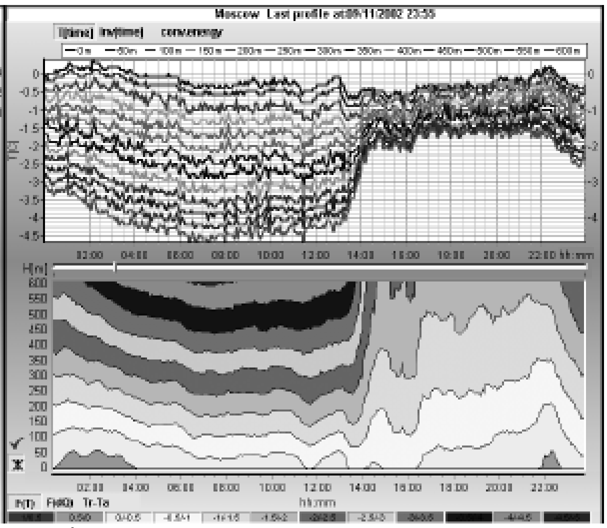

Fig. 4. Same as Fig.3 but in overcast conditions (autumn, cyclone)

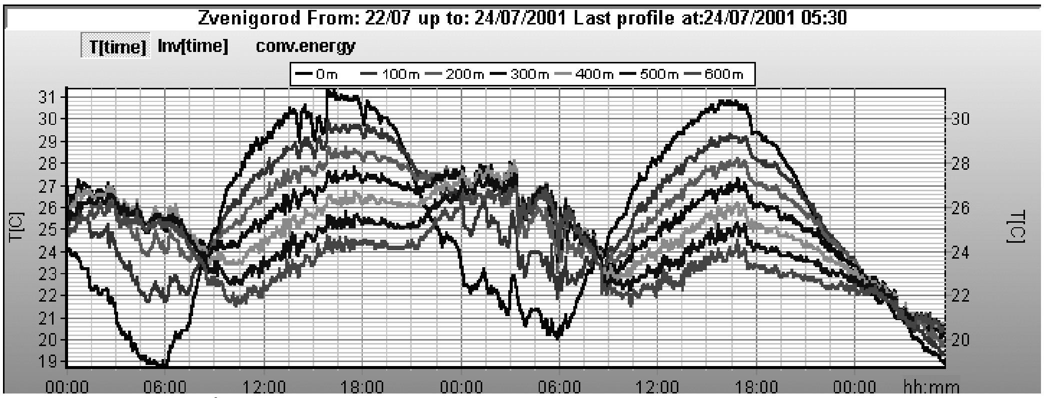

Fig. 5. Example of the thermal stratification on the passage of cold air front (altitude range 0¸600 m)

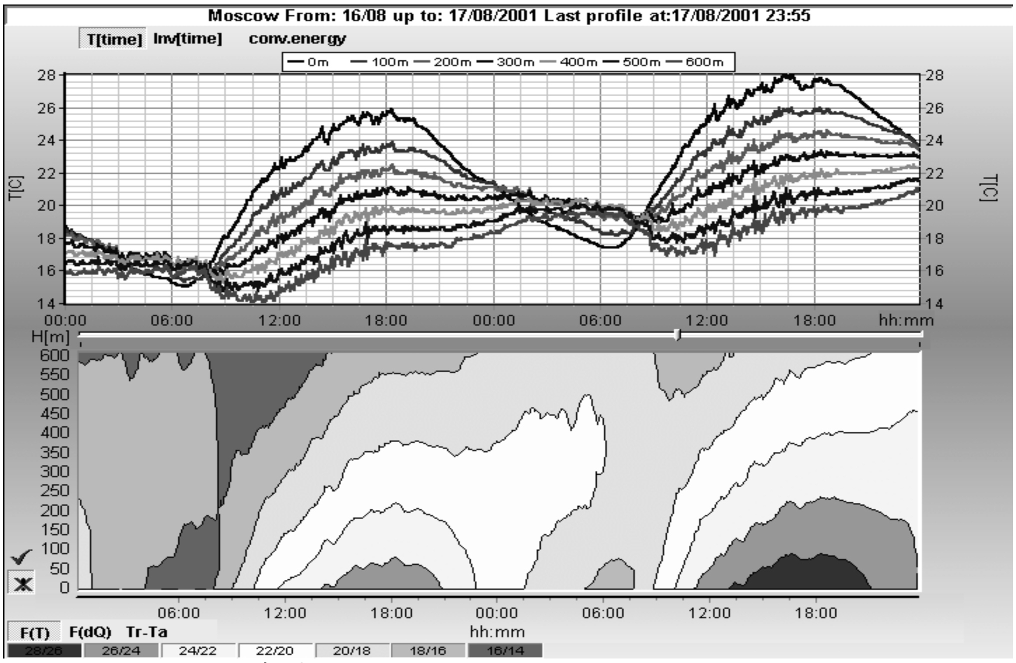

Fig. 6. Same as Fig. 5 but passage of the warm air front

4. CONCLUSION

Microwave temperature profilers are a very useful instruments for urban meteorology and can to improve our knowledge of urban heat islands and to improve accuracy of local weather forecast, air-pollution forecast, and forecast of dangerous meteorological conditions.

5. Acknowledgements

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References

1. Kadygrov, E.N., Pick, D.R., 1998, The potential for temperature retrieval from an angular – scanning single – channel microwave radiometer and some comparison with in situ observations, Meteorol. Appl., 5, 393-404.
2. Kadygrov, E.N., Shur, G.N., Viazankin, A.S., 2003, Investigation of atmospheric boundary layer temperature, turbulence, and wind parameters on the basis of passive microwave remote sensing, Radio Science, 38 (3), MAR 13-1÷13-12.
3. Kadygrov, E.N., Kuznetsova, I.N., Golitsin, G.S., 2002, Heat island above megapolicy: new results on the base of remote sensing data. Doklady Academii nauk, 385 (4), 541-548 (in Russian).
4. Khaikine, M.N., Kuznetsova, I.N., Miller, E.A., 2003. Investigation of time-spatial parameters of urban heat island on data of remote temperature measurements of atmospheric boundary layer. This proceedings.
5. Kondratiev, K.Y., and Matveev, L.T., 1999. Main factors in forming of big city heat island. Doklady Academii nauk, 367 (2), 253-256 (in Russian).
6. Kuznetsova, I.N., Kadygrov, E.N., Khaikine, M.N., 2003. Investigation of Megapolicy influence to the atmospheric boundary layer on the basis of passive microwave remote sensing data. This proceedings.
7. Oke, T.P., 1982. Boundary layer climates, Leningrad, Hydrometeoizdat, 360 (in Russian).
8. Troitsky, A., Gajkovich, K., Kadygrov, E., and Kosov, A., 1993, Thermal sounding of the atmospheric boundary layer in the oxygen absorption band center at 60 GHz., IEEE Trans. Geosci. Remote Sens., 31(1), 116-120.
9. Westwater, E.R., Han, Y., Lenskiy, V., Kadygrov, E.N., and Viazankin, S.A., 1999, Remote sensing of boundary layer temperature profiles by a scanning 5-mm microwave radiometer and RASS: Comparison experiments, J. Atmos. Oceanic Technol., 16 (7), 805-818.

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