STUDY OF URBAN ATMOSPHERIC BOUNDARY LAYER TERMODYNAMIC PARAMETERS SPATIAL DISTRIBUTION IN MOSCOW

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Abstract

One of the important problems in urban heat island (UHI) study is proper evaluation of its intensity and spatial structure at different altitudes in time and in different weather conditions. This report presents results of UHI study that was conducted in the city of Moscow on the basis of data from stationary and Mobil microwave system. Stationary microwave remote sensing system can continuously measure temperature profile at the 3 stations inside Moscow and two stations at suburb (Dolgoprudny and Zvenigorod). New mobile microwave remote sensing system can measure temperature profiles at any part of the city and in all weather conditions and can simultaneously measure total water content at the atmosphere. Temperature and water vapour determines many physical processes at atmospheric boundary layer and its spatial structure are essential for various modeling processes.

Key words : urban heat island, microwave radiometer, temperature profiles

1. INTRODUCTION

Urban heat island (UHI) is one the atmospheric phenomena which requires further study. The main lack of information is connected to the absence of representative data on the three dimensional temperature structures over cities. Thermal stratification controls both the turbulence intensity and the thickness of the mixing layer and hence the replacement of polluted air by purer air from upper layers. The atmospheric boundary layer (ABL) plays the role of a buffer zone accumulating heat, moisture, and pollutants [Garrat, 1992]. The state of the ABL determines the vertical exchange intensity. An unstable ABL is favourable for the removal of pollutants from the lowest atmospheric layer whilst when the ABL is stable exchange is suppressed creating the conditions for the growth of pollutant concentrations. In large industrial cities and megapolises this processes are affected by factors different from those observed in the countryside. The main reasons for this differences are the higher water vapour content, greater concentrations of anthropogenic gases and aerosols as well as strong variations of the underlying surface parameters in the city [Oke, 1973, Khaikin et al, 2006]. The studies of UHI based mainly on in situ measurements of temperature and humidity on the surface layer. New remote sensing system based on consuming of stationary and mobile microwave temperature profilers gave possibility to provide more detail study of urban heat island parameters including of the three dimension distribution of temperature and water vapour data. The main parts of the system are stationary microwave temperature profiler MTP-5HE and mobile microwave temperature profiler MMTP-5 with the dual channel microwave radiometer for measurement of total water vapour content[Kadygrov and Pick,1998]. . For urban heat island study the stationary profiler can be installed in the centre of the city and mobile profiler moving from the centre to suburb with the several stops for temperature profile measurements and had been repeated for several directions during one-two weeks. At the report will be presented comparison of temperature profile data from 5 stationary stations in Moscow and suburb and some data from mobile system which will be use in Moscow during April-September 2009. Moscow is a capital of Russia placed on Moskva river in between of two lagers rivers in the Eastern European plain: Volga River and Oka River. The population of Moscow is about 9 million people with the density of population 318,1 people / m^2.

2. NEW MOBILE MICROWAVE SYSTEM

New mobile microwave remote sensing system can measure temperature profiles at any part of the city and in all weather conditions and can simultaneously measure total water content at the atmosphere(Fig.1). The mobile system MMTP-5 was created for studying the special features of urban boundary layer structure on the different scales . It consist of MTP-5 temperature profiler installed on the roof of car, ultra-sonic anemometer for measurement of near surface meteorological parameters (temperature, humidity, wind speed and direction), system for remote control of measurements, the dual channel microwave radiometer for measurement of total water vapour content and GPS-system.

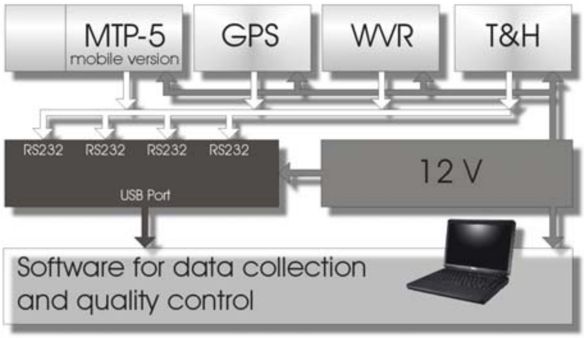

Fig.1 The schema of the mobile system where MTP-5 - meteorological temperature profiler, WVR - water vapor radiometer, T&H - temperature and humidity sensor.

Fig.2 Old and new modification of the mobile measurements system.

3. RESULTS OF MEASUREMENTS

Some results of temperature profiles measurements in the city center (Moscow) and in suburb(Dolgopruprudny) are presented in Fig.3 :

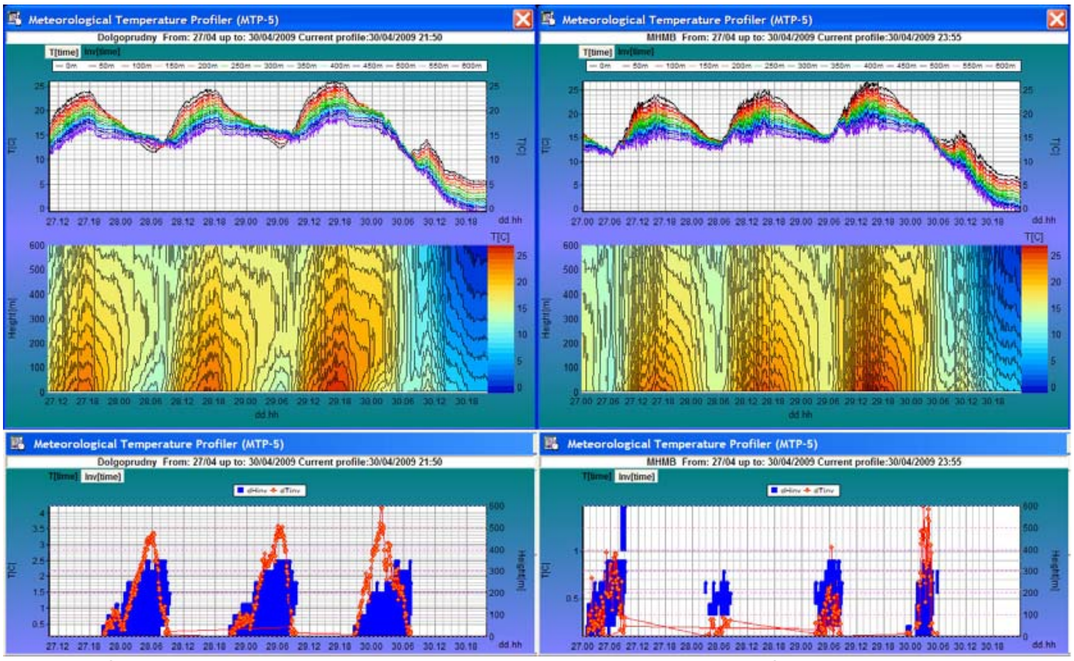

Fig.3 Example of the measurement in Dolgoprudny and Moscow during period from 27/04-30/04 2009

It was also provided some study of the influence of aerosol concentration to the thermal stratification in the city and in suburb.At Table 2 are presented results of measurement of thermal stratification in the city center (Moscow) and in suburb (Zvenigorod) when aerosol concentration was very different (“polluted”-during forest fair around Moscow, “clear”-in ordinary situations)[Khaikin et al,2006]

Table 1

Temperature change rate dT_h [deg/hr] for clear and polluted air in Moscow and Zvenigorod for morning(M), day (D) and evening(E) time

	0 m			300 m			600 m		
	M	D	E	M	D	E	M	D	E
Moscow. “clear” air	-0.8	1.5	-1.1	-0.6	0.8	-0.6	-0.5	0.2	-0.4
Moscow “polluted” air	-0.6	1.5	-0.6	-0.3	0.6	-0.3	-0.1	0.0	-0.2
Zvenigorod “clear” air	-0.6	1.9	-1.8	-0.5	0.7	-0.6	-0.3	0.0	-0.2
Zvenigorod “polluted” air	-0.7	3.2	-1.2	-0.4	1.3	-0.5	-0.2	0.0	-0.2

The investigations showed the additional aerosol particles injected into atmosphere of Moscow by combustion products had not caused the strong changes of temperature rate change in the layer 0-600 m in average in the morning time. An increase of aerosol concentration produced substantial changes of the profile of temperature change rate in the lower 400 m layer in Zvenigorod. Especially strong changes were observed during the maximum solar radiation in the daytime[Khaikin et al,2006].
At Fig.4 are presented some results of total water vapour content measurements around a big lake not far from Moscow:

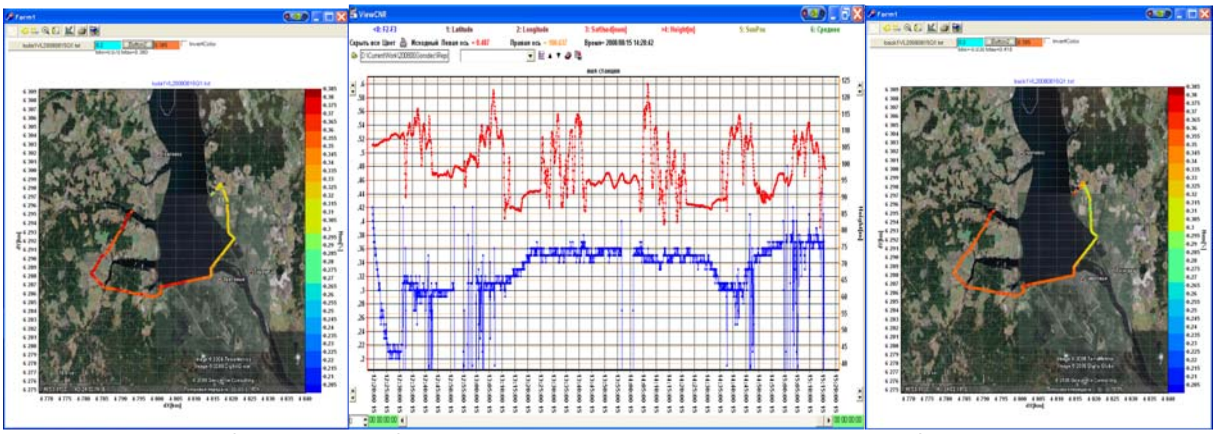

Fig.4. The example of the variation of water vapor around big lake in the central part of the Russia are shown. Two direction of trace are presented.

4. MODEL FOR DATA ANALYSIS

For analisis of data about UHI vertical structure was developed special model[Kadygrov N. et al, 2007]. It is evident that periodic components of ABL temperature are determined by its seasonal and diurnal variations. Therefore, a model of temperature variations was constructed for each of three stations(Moscow-center, Dolgoprudny and Zvenigorod) and 13 height levels in the form [Kadygrov N. et al,2007]:

$$T(t) = S(t)Q(t) + rest(t) \qquad (1)$$

where T - is the absolute temperature at the station (St); t is time, $S(t)$ -is the function describing seasonal variations in absolute temperature at a given height and station, $Q(t)$ - is the dimensionless function (animator) describing diurnal variations in absolute temperature at a given height and station, $rest(t)$ is remainder of the model.The function S(t) describing seasonal ("slow") variations was obtained from the regression decomposition of daily averaged reading in terms of harmonics of the annual cycle:

$$<T(<t>)> = \sum_{k=0}^{N} A_k \cos[k\Omega(<t> - \tau_k)\} + rest(<t>) \qquad (2)$$

$$S(t) = \sum_{k=0}^{N} A_k \cos[k\Omega(t - \tau_k)] \qquad (2a)$$

where $\Omega = \frac{2\pi}{365.25}$ is the angular frequency of the first harmonic of the annual cycle; τ_k is the time (in Julian days) of occurrence of the maximum of the k- th harmonic at a given height, which is often not quite strictly called its phase (below, the term "phase"is used exactly in this common sense); and $rest(<t>)$ is decomposition remainder. Among the amplitudes A_k , only those are retained in the sum whose significance is no less than 95% according to the Stiudent's test. [Kadygrov N. et al, 2007]].The dimensionless function $Q(t)$ describing diurnal (fast) variations was obtained from an interdiurnal averaging of the ratio:

$$q(t - \{t\}) = \frac{T(t)}{S(\{t\} + 0.5)} \qquad (3)$$

$$Q(t - \{t\}) = < q(t - \{t\}) >_{\{t\}} \qquad (3a)$$

The interdiurnal averaging was performed for each of 144 possible values of $t-\{t\}$, where $\{t\}$ is the integral part of t and the angle brackets with the subscript $\{t\}$ denote interdiurnal averaging[Kadygrov N. et al]]. In addition, the function Q was expanded into the Fourier series in terms of daily-cycle harmonics :

$$Q(t-\{t\})=\sum_{k=0}^{N} B_k \cos[k\omega(t-\{t\}-\upsilon_k)]+rest(t-\{t\}) \qquad (4)$$

$$D(t-\{t\})=\sum_{k=0}^{N} B_k \cos[k\omega(t-\{t\}-\upsilon_k)] \qquad (4a)$$

где: $\omega=\frac{2\pi}{1}$ is the angular frequency of the first daily-cycle harmonic, υ_k is the phase of the k-th daily-cycle harmonic at the height h, and $rest_D(t-\{t\})$ is the remainder of the expansion. It is clear that the animator and the other fast functions depend only on the intradiurnal time $t-\{t\}$. A model of seasonal and diurnal variations in the ABL –temperature gradients was constructed in a similar way. Results of calculations by this model for different years will be presented at the report.

4. SUMMARY

Continuous measurements of urban ABL temperature profiles and total water vapour on the basis of stationary and a new mobile microwave remote sensing systems allow to obtain unique data about vertical structure of UHI and its spatial distribution.

Acknowledgments

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