# REMOTE SENSING SYSTEM FOR URBAN HEAT ISLAND STUDY

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## ABSTRACT

The studies of urban heat island 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 data. The main parts of the system are stationary microwave temperature profiler MTP-5HE and mobile microwave temperature profiler MMTP-5. For urban heat island study the stationary profiler can be installed in the center of the city and mobile profiler moving from the center to suburb with the several stops for temperature profile measurements and had been repeated for several directions during one-two weeks.

## Introduction

Urban heat island 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 structure 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. The state of the ABL determines the vertical exchange intensity. An unstable ABL is favorable 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 these processes are affected by factors different from those observed in the countryside. The main reasons for these 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, 1987, Khaikine et al, 2006].

For urban ABL thermal stratification determination traditionally in situ temperature sensors were used, raised on the radiozondes and tethering balloons, and installed in high altitude meteorological masts (Garratt, 1992). But last 10 years it is started to be possible to provide urban ABL temperature profile measurements on the basis of passive microwave remote sensing [Kadygrov and Pick, 1988; Kadygrov et al, 2002]. The advantages of microwave radiometric data include the possibility to provide measurements in practically all weather conditions, in urban area, its low operational cost, and continuity in time, which allows time series and time-height cross sections to be delivered. Passive microwave radiometers are very portable and can provide reliable automated continuous profiling from a variety of sites; these features are not available with the other techniques [Westwater et al, 1999; Ivanov and Kadygrov, 1994; Kadygrov et al, 2003]. In 1999-2006 microwave temperature profilers (MTP-5) were successfully used for study of urban heat island at several big cities in Russia (Moscow, N.Novgorod, Ufa, Orenburg, Chelyabinsk, Krasnoyarsk, Astrahan). On the basis of this experience at the Central Aerological Observatory was created a special new microwave remote sensing system for urban heat island study.

## System description

The system is based on the two MTP-5 temperature profilers: mobile (MMTP-5) and stationary (MTP-5H). MTP-5 is an angular-scanning single-channel radiometer with a central frequency of 60 GHz [Kadygrov and Pick, 1998; Ivanov and Kadygrov, 1994; Kadygrov et al, 2003]. The system include:

- stationary temperature profiler MTP-5H;
- mobile temperature profiler MMTP-5;
- GPS receiver;
- meteostation.

Fig.1 MMTP-5 version for good road conditions.


Fig. 2 – MMTP-5 version for bad road in some parts of countryside.

The receiver of MMTP-5 profiler had an additional vibroprotection system, system of automatic leveling, an additional meteoprotection system and additional channels for GPS receiver data and meteostation data. At Fig. 1 shown MMTP-5 version for good road conditions, and at Fig. 2 – for bad road in some parts of countryside.

Fig. 3 MTP-5 in Dolgoprudny, Moscow region, Russia

Fig. 4 MTP-5 in T'ai-pei, Taiwan

At Fig. 3 and Fig. 4 are shown different possibility of stationary profilers MTP-5H installation. At Fig. 5 are shown the composition of the system. The system gave possibility to measure simultaneously temperature profiles in any two point in the city center and in suburb. Altitude range is 0-600 m (possibly 0-1000 m), vertical resolution: 50÷100 m; accuracy of temperature profile measurement – 0,5oC; power requirement: 220V / 50Hz – for stationary profiler; 12V – for mobile profiler; power consumption – 20 W nominal, 60 W maximum.

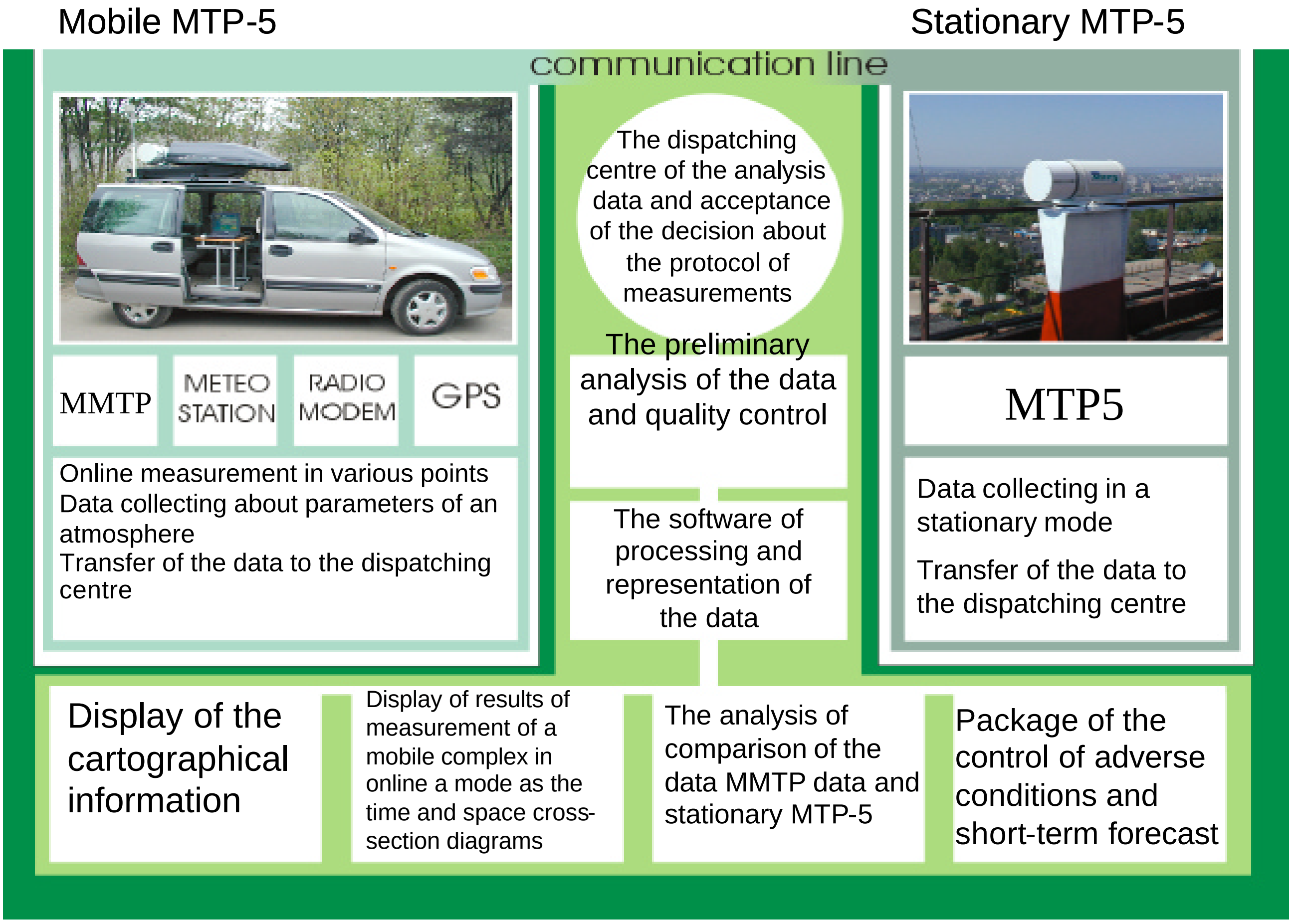


Fig. 5 The composition of the system.

## Result of testing

In 2004 – 2006 system was successfully tested for urban heat island study and study of thermal regime in urban ABL at several Russian cities: Moscow, Dolgoprudny, N. Novgorod, Orenburg, Kislovodsk. It was confirmed that in most of big industrial cities urban heat island have heterogeneous structure so-called “multicupolas” [Kadygrov et al, 2002]. Very interesting results were received in 2006 in Kislovodsk and it suburb, where stationary instrument was installed at altitude 900 m above sea level (city center), and mobile was moving from the center “down” (up to 200 m) - Fig. 6 and “up” (up to 1600 m) – Fig. 7.

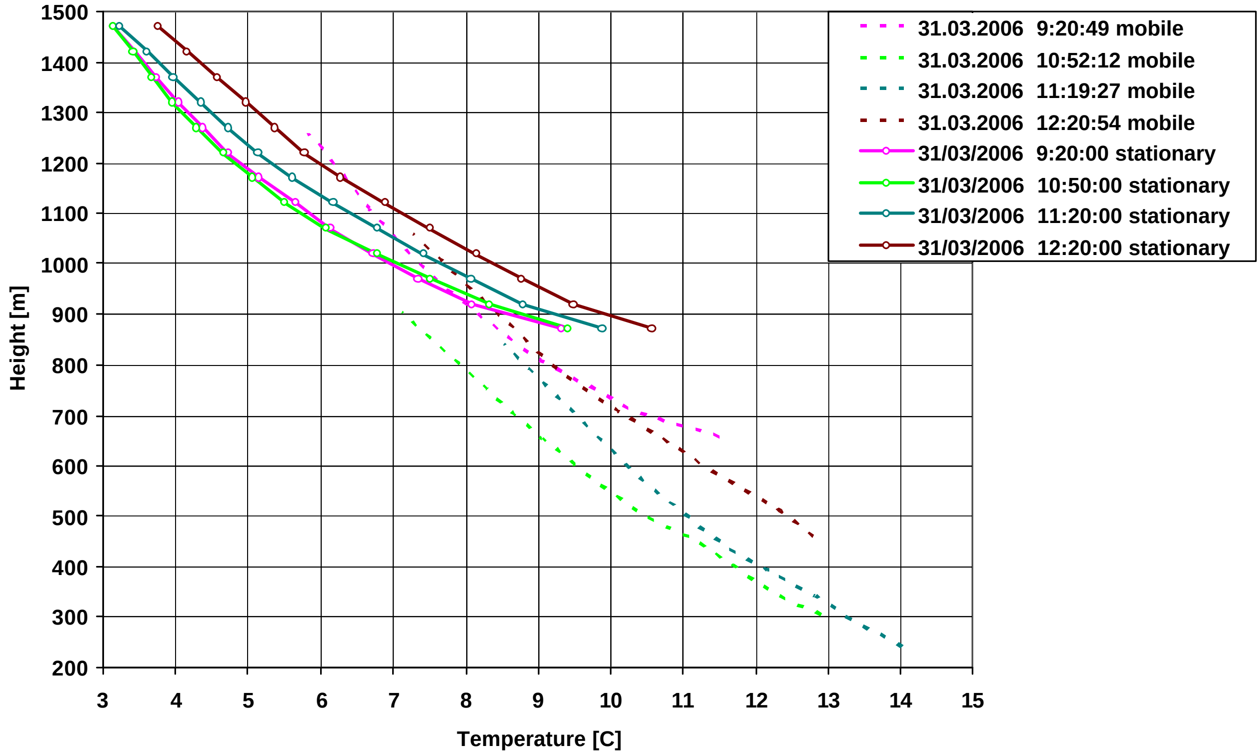


Fig.6 Mobil profiler going down.

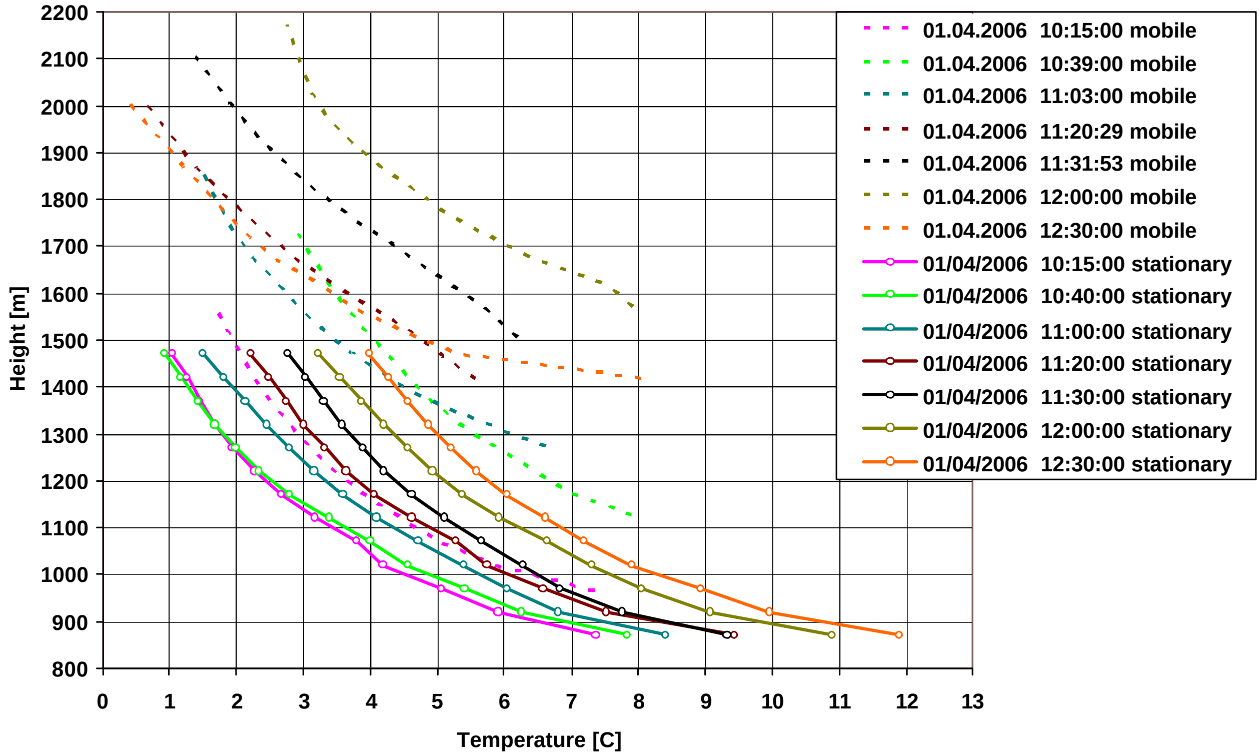


Fig.7 Mobile profiler going up.

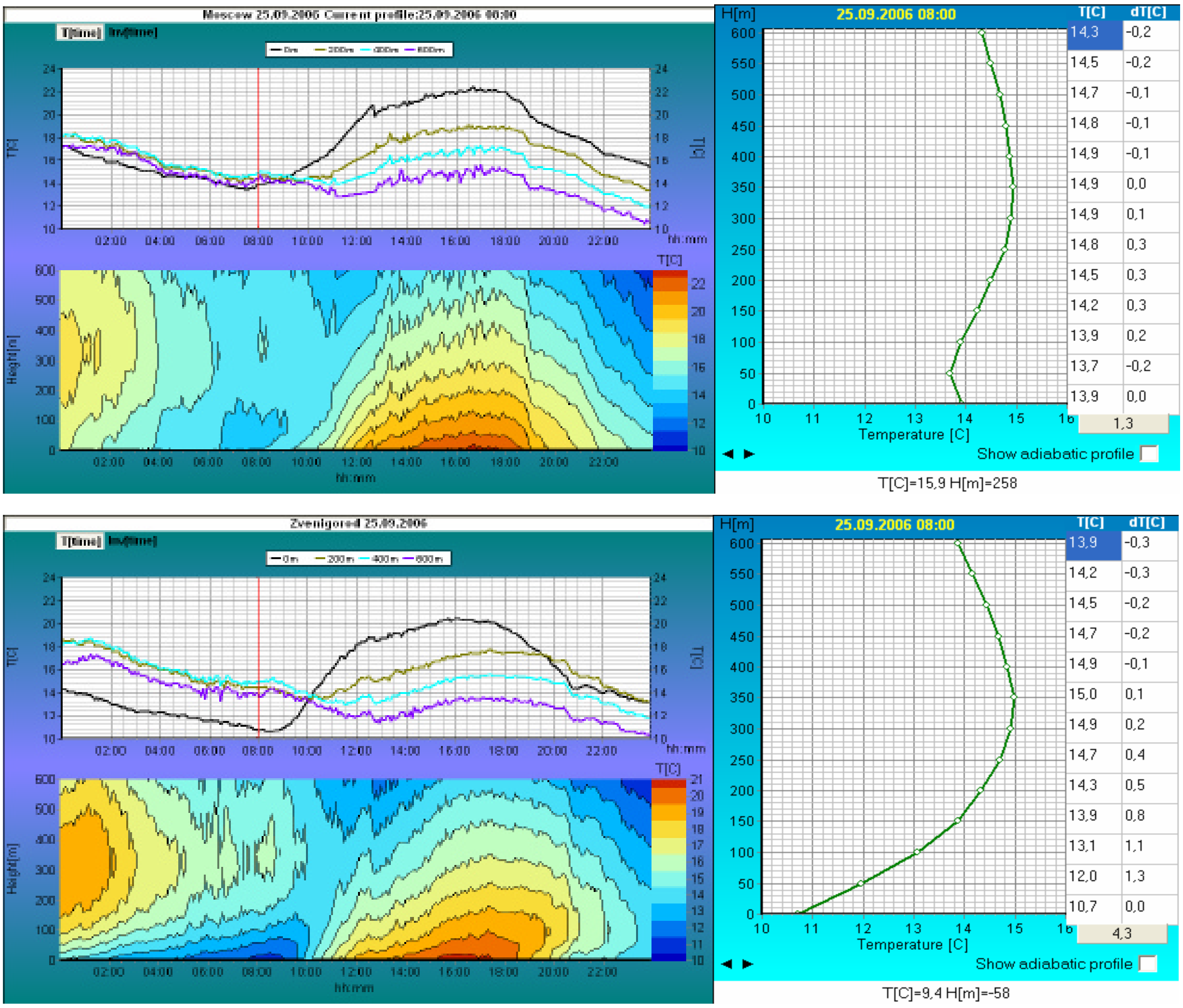


Fig. 8 Results of temperature profiles measurement at 2006/09/25.

At Fig.8 as other example are shown results of temperature profiles measurement at 2006/09/25, when stationary profiler was in Moscow city center, and mobile profiler was at about 50 km westward from the city center (Zvenigorod). At that day was cloudless, anticyclone conditions, and heat island was good indicated. At Fig.9 are shown result of temperature inversion parameters calculations.

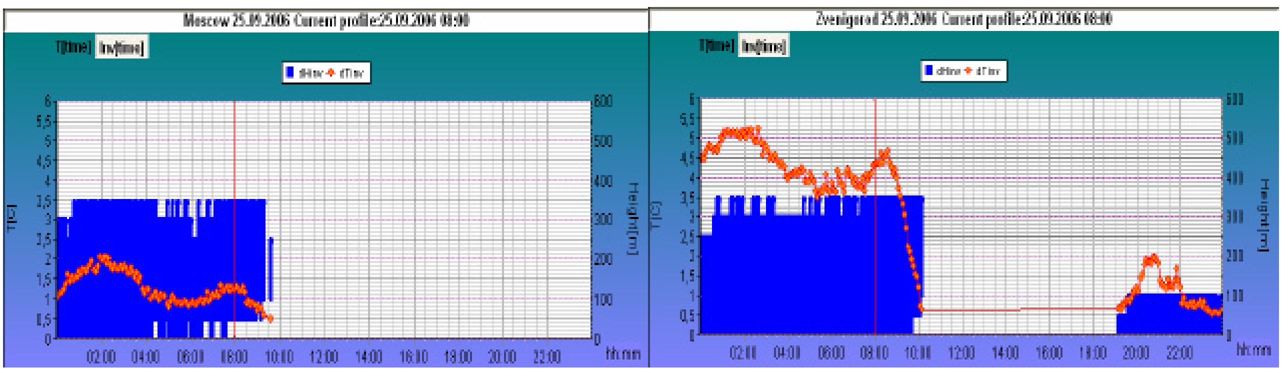


Fig.9 Result of temperature inversion parameters calculations.

## Summary

New microwave remote sensing system for urban heat island study gave new useful possibility for urban atmospheric boundary layer thermal regime investigations. It can measure heterogeneous structure of urban heat island ("multicupolas") and to measure quantities parameters of heat island of Megacity for different seasons and miscellaneous synoptical conditions. Proposed new technology can be very useful for urban research meteorology and environment.

## Acknowledgements

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