

## PRELIMINARY RESULTS OF A STUDY OF AIR TEMPERATURE DISTRIBUTION IN TBILISI INTO SUMMER SEASON

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**Abstract.** Microclimate is understood as a local climate emerging under the influence of relief differences, vegetation, soil state, and the presence of water, buildings and other characteristics of underlying surface of land. The characteristics of the microclimate manifest themselves in the upper soil layers and in the lower atmospheric boundary layer up to a height of several meters or ten of meters, often to a height of 100-150 m and a horizontal scale up to some tens meters to 10 km. Most part of a city represents a plateau of warm air with the temperature increasing toward the center. The thermal uniformity of the plateau is broken by the influence of parks, rivers and densely built-up industrial zones and buildings. A variety of microclimatic characteristics of the city form the so-called "Urban Climate" significantly differing from the rural. In the work some results of research on distribution of air temperature in Tbilisi are presented.

Measurements of air temperature in both regimes of stationary measurements on two fixed bases of observation (territory of the Institute of Geophysics - basic meteorological station and Tortoise Lake – standard automatic meteorological station) and irregular mobile route regime measurements on 20-30 points in different districts of the city in the summer 2010 are carried out. Points of measurement settled down at the heights from 397 to 648 m above sea level. The distance from these points to a base station varies from 0.7 to 17.2 km.

The maps of the spatial distribution of air temperature are represented. In particular, it is received that the temperature difference between a base station and points of measurements in various districts of the city reaches 5°C.

**Key words:** Urban climate, air temperature.

### Introduction

The microclimatic and mesoclimatic features which distinguish cities with their environment are caused by a number of factors. They include the conversion of the natural ground surface into a three-dimensional space consisting largely of artificial materials, the resulting reduction in the proportion of the surface covered by vegetation and the impact of industrial processes, causing waste of heat, gases, dust and soot.

The climatic and air hygiene features characterizing conurbations are normally referred to as "urban climate". They can be observed both in small towns and in large cities. The factors mentioned above affect the radiation and energy balance of near-surface layers of the atmosphere, the possibilities of evaporation and the wind field to such degree that urban areas are generally characterized by higher air temperatures, lower relative humidity's, poorer ventilation and accumulations of particulate and gaseous contaminants. These features of urban climate can be modified both by small scale factors such as relief and the location of cities at different latitudes [1, 2].

Microclimate is understood as a local climate emerging under the influence of relief differences, vegetation, soil state, presence of water, buildings and other characteristics of the underlying surface of land. The characteristics of the microclimate manifest themselves in the upper soil layers and in the lower atmospheric boundary layer up to a height of several meters or tens of meters, often to a height of 100-150 m. There is also a notion of mesoclimate. A boundary between the microclimate and mesoclimate can be drawn based on the extent of irregularities of the underlying surface, including urban development. The mesoclimate can be characterized by a horizontal scale of up to 100 km and a vertical scale of up to 1000 m, while the microclimate by a horizontal scale of up to 10 km and vertical scale of up to 100-200 m respectively [3].

Most part of a city represents a plateau of warm air with the temperature increasing toward the center. The thermal uniformity of the plateau is broken by the influence of parks, rivers and densely built-up industrial zones and buildings. Wind speed fields behind buildings of different shape and orientation relative to the direction of the flow have a large perturbation. The mean wind speed between buildings is decreased, but the flow is more turbulent than on an open area at the same height. So basically the wind speed decreases in a city. At the same time in some parts of the city wind tunnels can emerge with strongly increased wind speeds [4].

The presence of heat islands in big cities is confirmed by a number of biological, environmental and meteorological consequences. Urban heat promotes earlier, swelling of buds, flowering of trees, increasing the growing season. From an economic point of view a heat island is favorable in the winter due to reduced heating costs and conversely is unfavorable in the summer because of an increased need in air conditioning. From an environmental point of view in the summer heat islands with low wind speeds are extremely unfavorable to human health due to effective temperatures (a biological indicator of complex meteorological effects on the human body) rising higher than the comfort value. In the winter on the contrary heat islands with little wind contribute to comfortable, effective temperatures, although in parts with high wind speeds the opposite may be the case - excessive cooling [3, 5, 6].

For example, the works [5,7] presents the data of the influence of air Equivalent Effective Temperature (EET - one of the complex bioclimatic indices, calculated on the data about the temperature, relative humidity of air and speed of the wind) on the mortality of the inhabitants of Tbilisi city for reasons with cardiovascular diseases. In particular, the deviation of the

values of EET both to the side of the cold and to the side’s hot range increases mortalities. However, this is the common picture, which does not describe the bioclimatic situation of the separate locations of Tbilisi city.

A change in values of EET in two locations of Tbilisi city (territory of thermobarochamber of the institute of geophysics and Tortoise Lake) during July 2011 in 16 hours is shown in the work [7]. The difference between the values of EET for these points, it frequently reaches high values. In seven cases in the territory of tortoise lake values of EET corresponded to range "Hotly" (unfavorable for human health), whereas on the territory of thermobarochamber - "Warmly"(favorably for human health).

The difference of EET in some locations of the Tbilisi Botanic Garden and the territory of the Institute of Geophysics 30.07.2011 varies from -3.1° to 0°. Let us note that for the usual temperature of air this difference changes from -5.5°C to 1.5°C [8].

Thus, in mega cities a very inhomogeneous spatial distribution of the fields of basic meteorological elements and correspondingly of the fields of biological indicators of microclimate can be the case. In other words, in cities there could be formed comfortable or uncomfortable meteorological conditions for human health as well as safe or dangerous wind speeds for the buildings, etc.

Georgia in general has great traditions of climate research. In particular, the general trends of climate change in Tbilisi of the past century have been studied and extrapolated for several future decades [9-15]. As regards microclimatic research in 1989-1990, at specially selected 19 weather stations in Tbilisi simultaneous wind speed and air temperature observations were carried out at 10 and 13 o’clock in January, April, July and October. The data of these studies revealed the presence of a significant contrast of temperature (several degrees) and wind in various parts of Tbilisi and confirmed the need for more detailed investigation of the climate of the city. However, as a result of known events these quite scale researches of the microclimate of Tbilisi city instead of the evolution were stopped [16].

The infrastructure of Tbilisi is developing rapidly, the city expands the boundaries and the meteorological data for the past years only partly reflect the real picture. Therefore the need to conduct studies of microclimatic characteristics in Tbilisi, similar to other countries, arises. We note that the Institute of Geophysics has experience in conducting such research (personnel, equipment, stationary and mobile monitoring laboratories, etc. [6]).

In the work some results of research on distribution of air temperature in Tbilisi in the summer season are presented.

### Study Area and Methods

Tbilisi is located in the South Caucasus (41°43' N and 44°47' E). The city lies in East Georgia on both banks of the Mtkvari (Kura) River. The elevation of the city ranges from 380-770 meters above sea level and has the shape of an amphitheatre surrounded by mountains on three sides. To the north, Tbilisi is bounded by the Saguramo Range, to the east and south-east by the Iori Plain, to the south and west by various endings (sub-ranges) of the Trialeti Range. The city stretches 33 km along the Mtkvari River and covers an area of 372 square km. The densely populated district of Tbilisi covers an area of 100 square km. The population of Georgia’s capital currently stands at 1.15 million inhabitants. Average population density is around 3090 persons per square km, with a peak value in the Didube-Chugureti district with 7855 persons per square km [17].

Measurements of air temperature both in the regime of stationary measurements on two fixed bases of observation (territory of the Institute of Geophysics –1 basic meteorological station (1BMS), valley of the Mtkvari river, 41.75°N, 44.93°E, the height – 450 m above sea level and Tortoise Lake (2BMS), 41.7°N, 44.75°E , the height 425 m above sea level – standard automatic meteorological station [18]) and in the of irregular mobile regime route measurements on 20-30 points in different districts of city in the summer 2010 are carried out [6, 18]. Points of measurement settled down at the heights from 397 to 648 m above sea level. The distance of these points from a base station made from 0.7 to 17.2 km (table 1). The measurements of the air temperature in the mobile regime by use of the portable meteorological station PCE-FWS 20 were carried.

Table 1. Coordinates of the Points of Measurement with Relation to the 1 Base Meteorological Station on the Territory of the Institute of Geophysics. H - height above sea level, L - distance from 1BMS

Location	X (km)	Y (km)	H (m)	L (km)	Location	X (km)	Y (km)	H (m)	L (km)
Heroes Square	-0.12	-0.71	416	0.7	Makhata Mount	4.6	-0.1	635	4.6
Beijing Street	-1.05	0.60	492	1.2	Saburtalo	-5.48	0.48	537	5.5
T. Shevchenko Monument	-0.34	-1.33	456	1.4	Vazisubani	5.67	-1.74	562	5.9
Vere River	-1.41	-0.70	441	1.6	Underground Varketili	7.29	-3.27	471	8.0
Underground Marjanishvili	1.2	-1.1	400	1.6	Varketili (buildings)	7.8	-2.4	508	8.2
Radisson Blu Iveria Hotel	0.8	-1.9	420	2.0	Varketili (shadow)	8.36	-1.5	546	8.5

Abashidze Street	-2.19	-1.30	490	2.5	Varketili (asphalt road)	8.4	-1.5	546	8.5
Saarbrucken Square	1.8	-1.9	397	2.6	Tbilisi Sea	9.81	-0.54	581	9.8
Underground Delisi	-3.07	0.61	479	3.1	Gldani	4.13	9.59	533	10.4
Pushkin Square	1.6	-2.8	410	3.3	Moscow Avenue	8.92	-5.59	404	10.5
Hydrological Station	-3.21	-0.64	470	3.3	Avjala	1.15	10.64	465	10.7
2BMS	-3.36	-1.96	425	3.9	Chichinadze Street	10.83	-5.07	441	12.0
Underground Avlabari	2.55	-3.11	429	4.0	Zemo Ponichala	9.16	-8.51	455	12.5
Lisi Lake	-3.91	2.22	648	4.5	Lilo Settlement	16.68	-4.34	526	17.2

The route measurements in the clear, windless weather in the second half of day were conducted. In the work the data of the air temperature in 15 hours of local time from 11 to 14 August 2010 are represented (maximum air temperature).

**Results and discussion**

The main results of the works are given in fig. 1-3. In fig. 1 daily max of air temperature motion (15 hour) on the 1 and 2 basic meteorological stations are given. The distance between these stations is 3.9 km, altitude difference – 25 m. Analysis of data showed that between the air temperatures at both stations high linear correlation is observed (near 1).

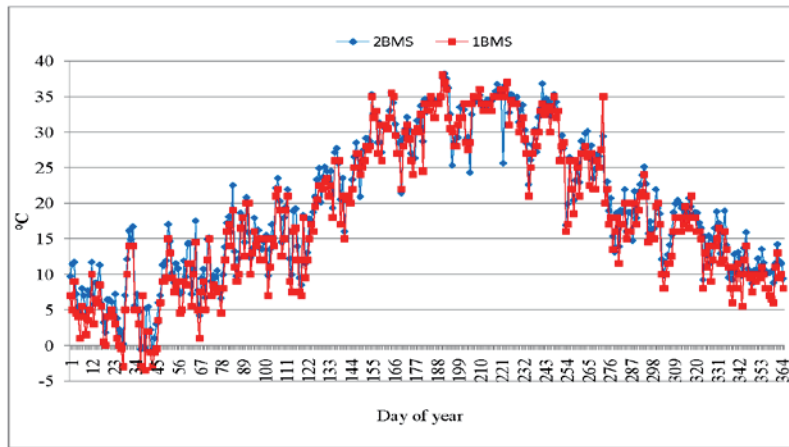


Fig. 1. Daily max of Air temperature Motion on the 1BMS and 2BMS in 2010

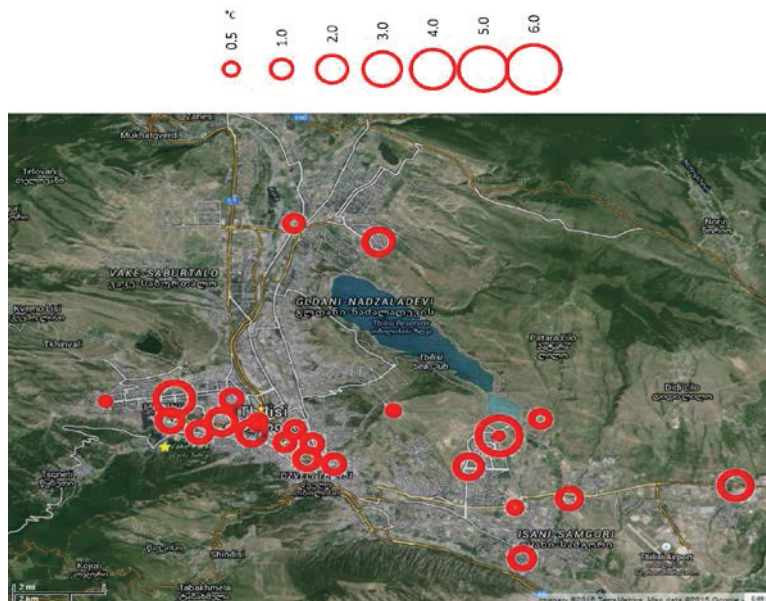


Fig. 2 Distribution of Difference of Air Temperature in Different Measurement Point of Tbilisi City and 1BMS (Upper and Lower Asterisk - 1BMS and 2BMS Respectively)

The average annual value of air temperature on 2BMS is 19.6°C and on 1BMS – 18.3°C (difference – 1.3°C). In winter, spring, summer and autumn the mean value of air temperature on 2BMS and 1BMS respectively equal: 8.7°C and 6.6°C (difference – 2.1°C), 16.7°C and 15.3°C (difference – 1.4°C), 32.0°C and 31.5°C (difference – 0.5°C), 20.9°C and 19.5°C (difference – 1.4°C).

Thus, for all seasons of year air temperature in the territory of the second base meteorological station is higher than on the first. The greatest difference is in winter, smallest – in summer, in spring and autumn this difference is identical. Lower air temperature on the territory of the first base meteorological station, apparently, is connected with the fact that it is located on the cliff in the valley of the Mtkvari River where is the more intensive exchange of air masses, in comparison with the first station. In addition to this, the influence of the spreading surface on the air temperature at the first station (its location near the precipice) it is lower than on the second.

It is important to note that despite the fact that the first base meteorological station is located on the nonstandard place for the typical meteorological stations, its data are completely representative, about which the analysis fig. 1 is testifies. Subsequently the comparison of the air temperature in different points of measurement with this station will be carried out. In fig. 2 for the clarity distribution of difference of air temperature at different measurement point of Tbilisi city and the first base meteorological station  $\Delta T$  is presented. As it follows from this figure, in the majority measurement points the value of  $\Delta T$  exceeds 1.0°C. Let us note that the mean air temperature at the second base meteorological station in the days of measurements was 35.3°C and to 0.7°C it exceeded its values at the first station.

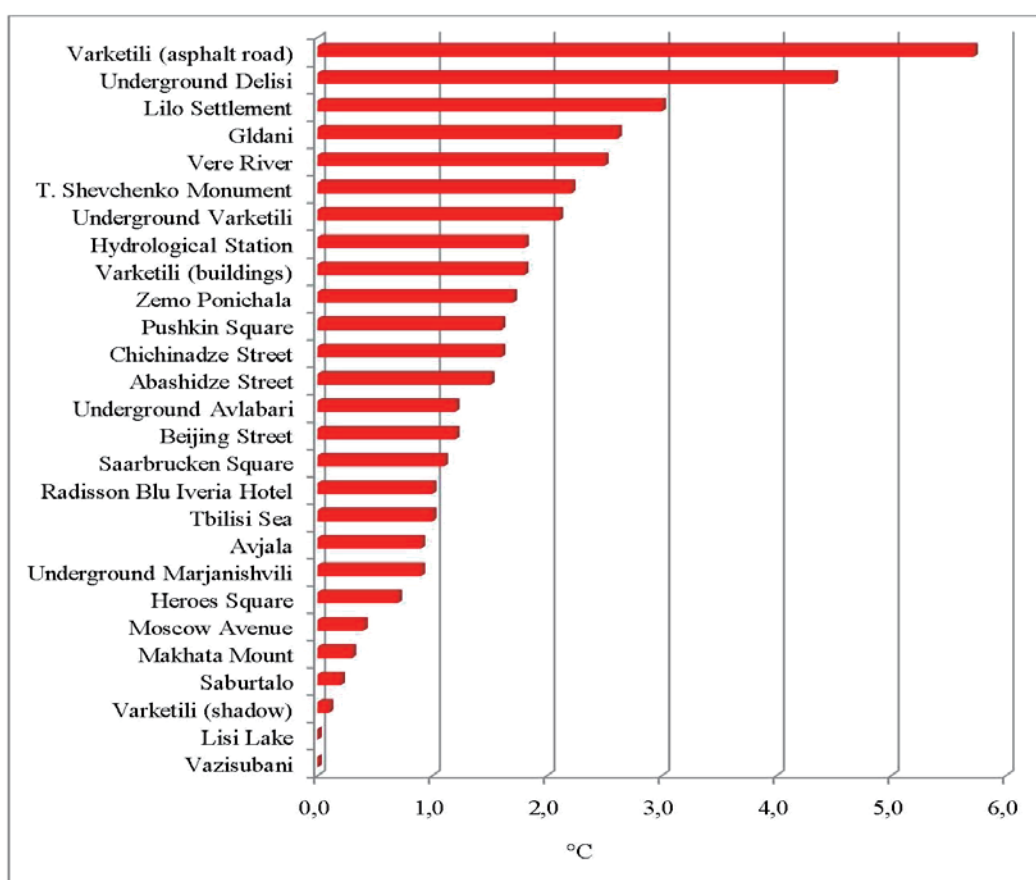


Figure 3. Values of difference of air temperature in different measurement point of Tbilisi city and 1BMS

More detailed information about the values of  $\Delta T$  is presented in fig. 3. Minimum values of  $\Delta T$  in the points Vazisubani and Lisi Lake were observed (-0.3°C and -0.1°C respectively). Maximum values of  $\Delta T$  (5.7°C) were observed in the points Varketili (asphalt road). Let us note that only in 40 meters from this point of measurement in the shadow of trees (Varketili (shadow)) the value of  $\Delta T$  is only 0.1°C, which is compared with the air temperature at the 1BMS.

As one expects the high values of  $\Delta T$  (2.0°C) in the solar places above the asphalt were observed (Underground Delisi, Lilo Settlement, Gldani, Vere River, T. Shevchenko Monument, Underground Varketili). Lower values of  $\Delta T$  (<2.0°C) - in the shadow of trees or buildings were observed (all the remaining points of measurement). These data compared with those of the air temperature at the first base meteorological station ( $\Delta T \approx 0.5^\circ\text{C}$ ) in the points Saburtalo, Makhata Mount, Moscow Avenue were observed also.

Thus, the distribution of air temperature on the territory of Tbilisi city, as in other metabolizes, extremely heterogeneous nature has. Data from standard meteorological stations give the information only about the general values of air



temperature for the city, which significantly differs from its values in different places of the city. It comes to ridiculous situations. For example, in the summer of 2010 some non-governmental organizations and political parties accused Georgian Hydrometeorological Service of concealing information on the air temperature claiming that it was much higher than the officially announced 39-40 degrees. Interestingly, both sides were actually right. The former referred to the data at their offices the latter to the data of the weather stations located far from buildings and roads.

Let us note for an example that in the days of measurements the air temperature in different places of city varied from 32.4°C to 40.7°C (difference 8.3°C), whereas on the 1BMS and 2BMS these variations composed 31.0-37.0°C (difference 6.0°C) and 32.7-36.7°C (difference 4.0°C) respectively.

### Conclusions

The temperature of air is the essential bioclimatic factor, which specifies the human physiological state. Even during the overall favorable weather situation in the metabolism there can be more locations with the harmful thermal regime for the human health. The data of the standard meteorological stations only partly reflect the real picture of the air temperature distribution in Tbilisi city. Therefore the need to conduct detailed studies of microclimatic characteristics in Tbilisi, similar to other countries, arises. Subsequently, we plan conducting these studies.

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