Case Study 2.C

Temporal and Spatial Variability of Moscow's Urban Heat Island

Pavel Konstantinov and Eugenia Kukanova

Lomonosov Moscow State University

Mikhail Varentsov

Lomonosov Moscow State University & A. M. Obukhov Institute of Atmosphere Physics RAS

Keywords	Urban heat island, urban climatology
Population (Metropolitan Region)	16,570,000 (Demographia, 2016)
Area (Metropolitan Region)	5,310 km² (Demographia, 2016)
Income per capita	US$9,720 (World Bank, 2017)
Climate zone	Dfb – Cold, without dry season, warm summer (Peel et al., 2007)

Moscow is a very large megalopolis where, according to data from the year 2010 (Russian Federal State Statistics Service, 2010) more than 11 million people live. In July and August 2010, there was a blocking anticyclone over Moscow as well as the central part of European Russia, with anomalously hot weather conditions for a long time. This heat wave lasted from July 4 until August 18. During this period, the warmest day for Moscow in the 143-year period of direct meteorological measurements was recorded on July 29 (+39.0°C in the city center; Konstantinov et al., 2014; Kislov and Konstantinov, 2011). This heat wave led to a rise in mortality rate up to 11,000 (Shaposhnikov et al., 2015), so it was decided to investigate the urban heat island (UHI) phenomenon of Moscow and its climatology due to its propensity to amplify heat wave intensity.

We chose for the basic UHI characterization "UHI intensity." This is defined in Equation (1) as the simple difference between air temperature at an urban station and mean air temperature in a rural area.

$$UHI_{intensity} = T_{urban} - (T_{ruralNord} + T_{ruralSud} + T_{ruralEast} + T_{ruralWest})/4 \quad (1)$$

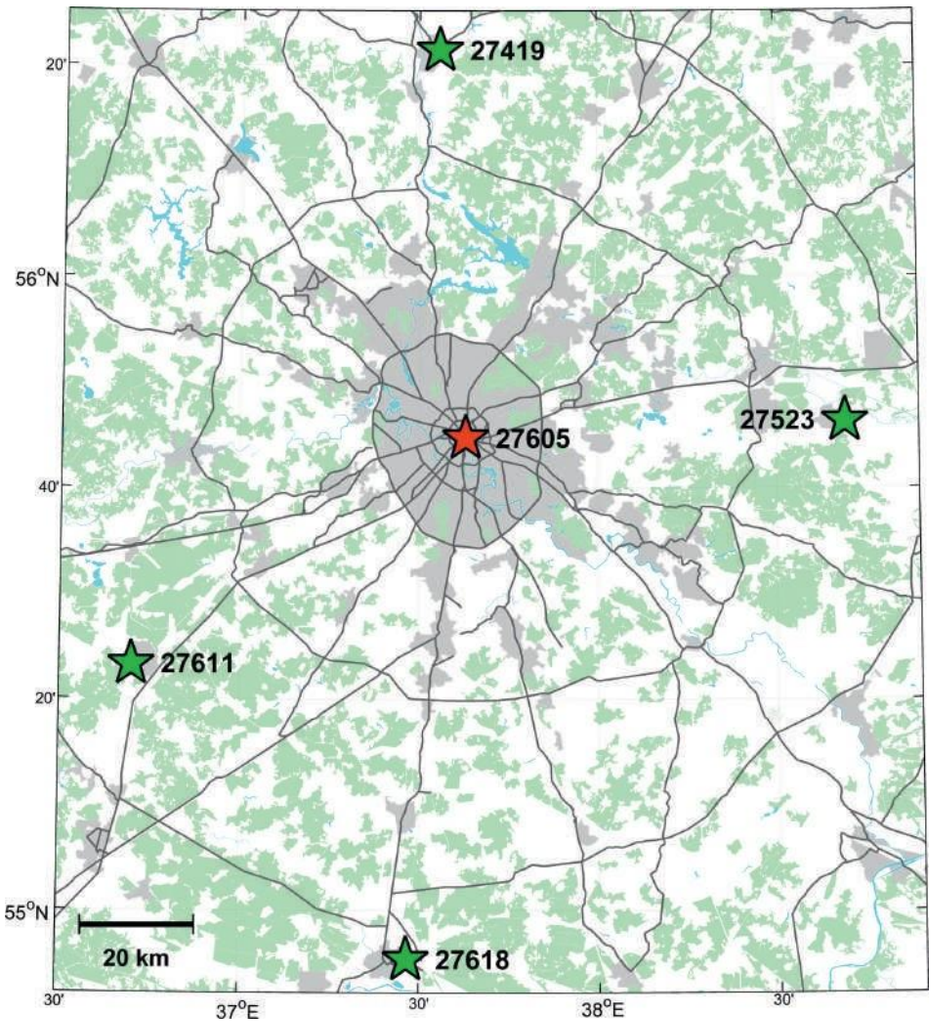
The map of the WMO meteorological stations in the Moscow region (Balchug is an classical urban station situated near the Moscow River and the Kremlin) and the elevation can be seen in Case Study 2.C Figure 1. The time period for the investigation was from January 1, 2000 to December 31, 2012. This period was chosen due to the availability of high-quality data for all stations.

Diurnal variation of UHI intensity in different seasons is shown in Case Study 2.C Figure 2. The peak intensity is during the summer and at night. In classical urban climatology (Oke, 1988), the biggest air temperature differences between a city center and its suburbs occur (in the temperate climate zones) in the autumn and at night. Apparently, this phenomenon in Moscow is caused by high-density development in the city center and warm summer conditions.

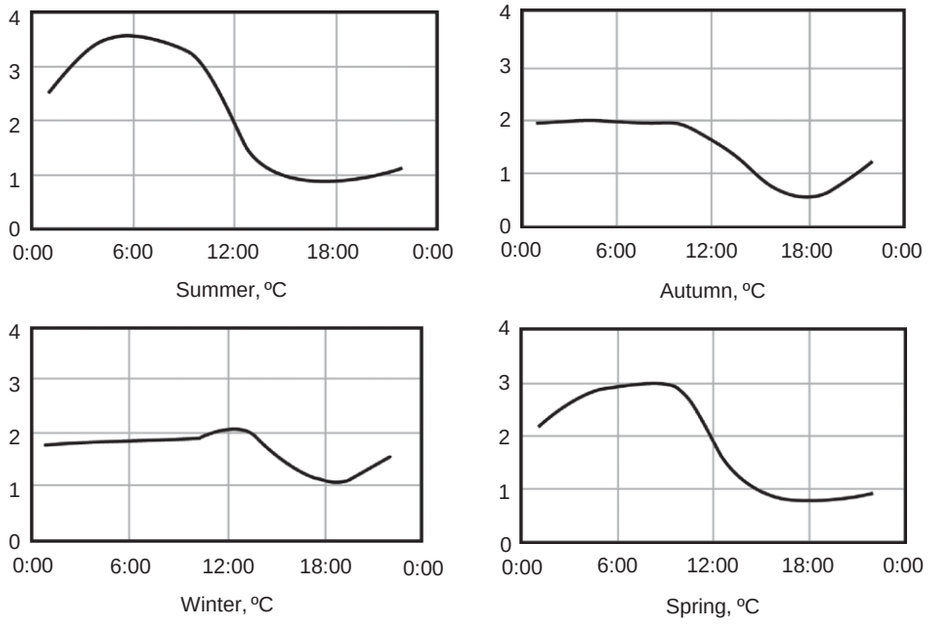
In autumn and winter, UHI intensity is lower than in the warm seasons. Cities with continental climates display higher UHI than those in environments where sea breezes may have a cooling effect.

The climatology of extreme UHI intensity values (defined as cases with air temperature differences higher than 5°C) is described in Case Study 2.C Figure 3. The frequency and total number of extreme values are higher in the morning and in winter months (especially February). This might be caused by anticyclonic conditions, the probability of which rises at the end of the winter (due to intensification of the Siberian High). The total number of cases with extreme UHI intensity values in February and in the summer months is similar. The month with the lowest UHI intensity frequency is November, which also is unusual in comparison with classical theory (Oke, 1988).

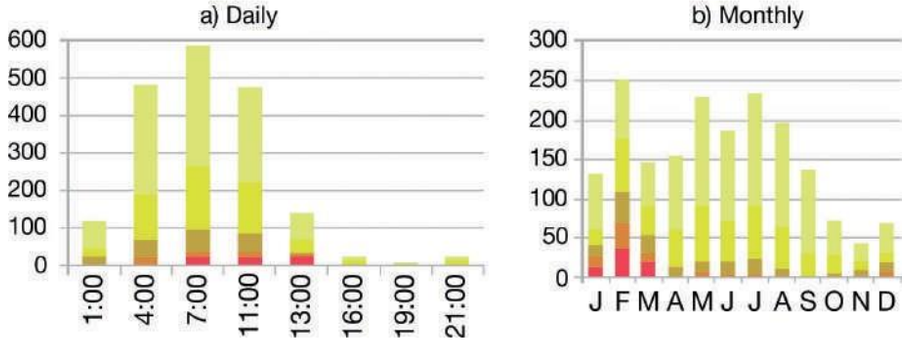
Finally, according to the physics of the UHI phenomenon, it can be slightly "blown with the wind," as shown at Case Study 2.C Figure 4. During the warm season of 2014 (May–September), averaged situations with weak (0–1.5 m/s) winds demonstrate that the displacement of the UHI zone is clearly observed, in agreement with theory (Landsberg and Maisel, 1972).



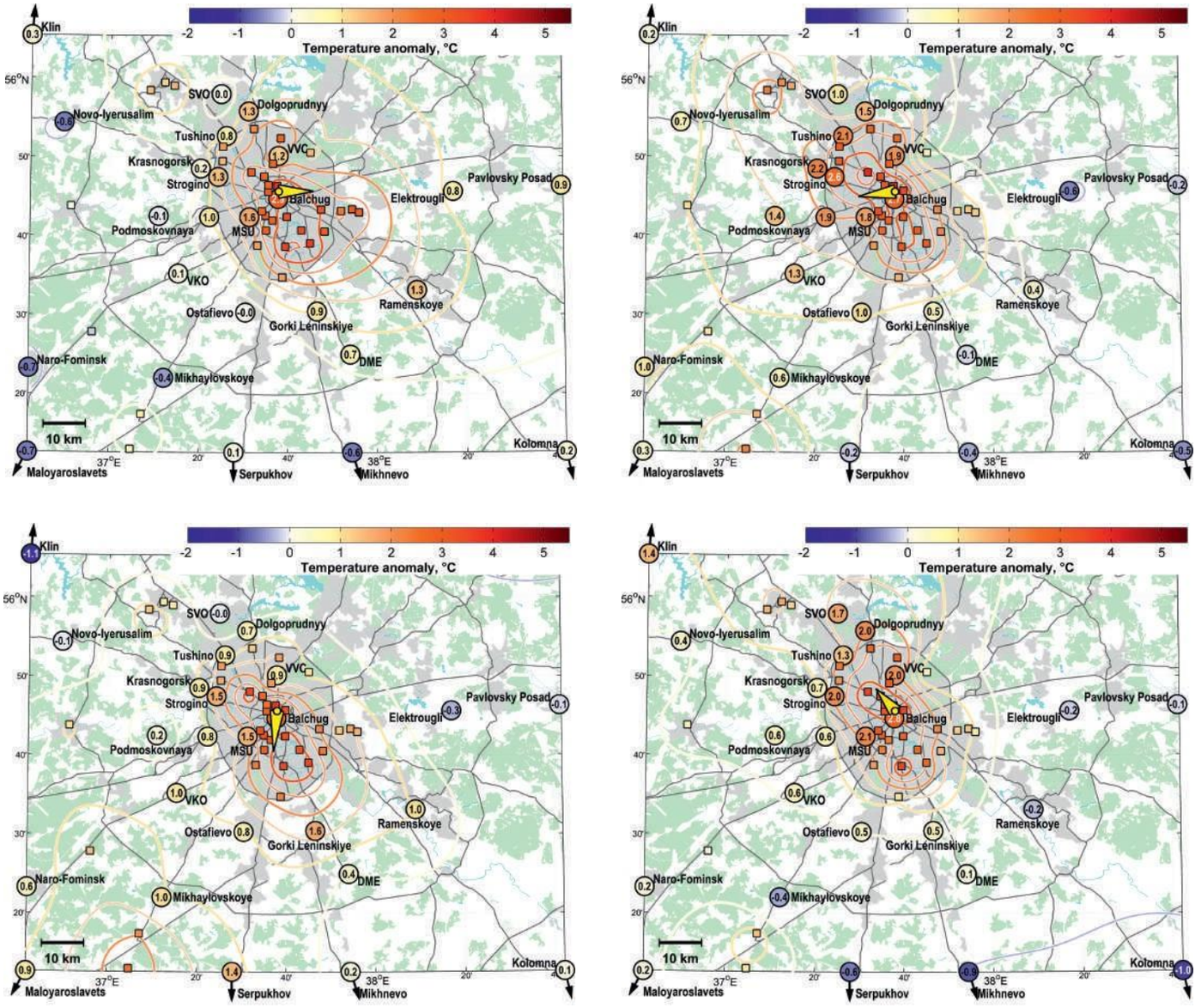
Case Study 2.C Figure 1 *Moscow region's meteorological stations map. Distance between urban and rural stations: 72 km, 92 km, 68 km, 69 km. Data available for period 2000–2012.*



Case Study 2.C Figure 2 *Diurnal urban heat island intensity variations for different seasons in Moscow (2000–2012).*



Case Study 2.C Figure 3 *Extreme urban heat island (UHI) intensity values: Number of cases with $UHI_{intensity}$ 5°C daily (a) and monthly (b). Color scale reflects five intervals with intensity increase: [5–6); [6–7); [7–8); [8–9); [9-∞) – from light yellow to red.*



Case Study 2.C Figure 4 *Spatial urban heat island zone displacement due to cases with unified wind direction averaged for the warm season of 2014: (a) western wind, (b) eastern wind, (c) northern wind, and (d) southern wind.*

Conclusion

Moscow demonstrated a strong UHI, with a mean annual intensity of 1.8°C in 2000–2012. (Kukanova and Konstantinov, 2014) The strongest UHI conditions occur in the spring and summer months, but frequency of extreme UHI intensity values (5°C) is higher in winter months (especially February). Spatial displacement of the UHI may occur in warm months due to wind influence.

Acknowledgments

This study was supported by the Russian Foundation for Basic Research grants RFBR 13-05-41306-RGO_a, RFBR 15-35-21129-mol_a_ved, RFBR 14105-31384-mol_a, and RFBR 15-55-71004 Arctica_a. The work of Dr. Konstantinov is partially supported by a President of Russia grant for young PhD scientists MK-6037.2015.5.

References

Demographia (2016) Demographia World Urban Areas (Built Up Urban Areas or World Agglomerations). 12th Annual Edition. St. Louis: Demographia. Available from: http://www.demographia.com/db-worldua.pdf.

Kislov, A. V., and Konstantinov, P. I. (2011). Detailed spatial modeling of temperature in Moscow. *Russian Meteorology and Hydrology* **36**(5), 300–306.

Konstantinov P. I., Varentsov M. I., and Malinina E. P. (2014, December). Modeling of thermal comfort conditions inside the urban boundary layer during Moscow's 2010 summer heat wave (case-study). *Urban Climate* **10**(3), 563–572.

Kukanova, E. A., and Konstantinov, P. I. (2014). An urban heat islands climatology in Russia and linkages to the climate change. In *Geophysical Research Abstracts*. EGU General Assembly Vienna, Austria, vol. **15**, p. 10833.

Landsberg, H. E., and Maisel, T. N. (1972). Micrometeorological observations in an area of urban growth. *Boundary-Layer Meteorology* **2**, 365–370.

Oke, T. R. (1988). *Boundary Layer Climates* (second ed.). Methuen.

Peel, M. C., Finlayson, B. L., and McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences Discussions* **4**(2), 462.

Shaposhnikov D., et al. (2015). Long-term impact of Moscow heat wave and wildfires on mortality. *Epidemiology* **26**(2), e21–22.

World Bank. (2017). 2016 GNI per capita, Atlas method (current US$). Accessed August 9, 2017: http://data.worldbank.org/indicator/NY.GNP.PCAP.CD