Experimental urban heat island research of Norilsk city in northern Russia in the polar night

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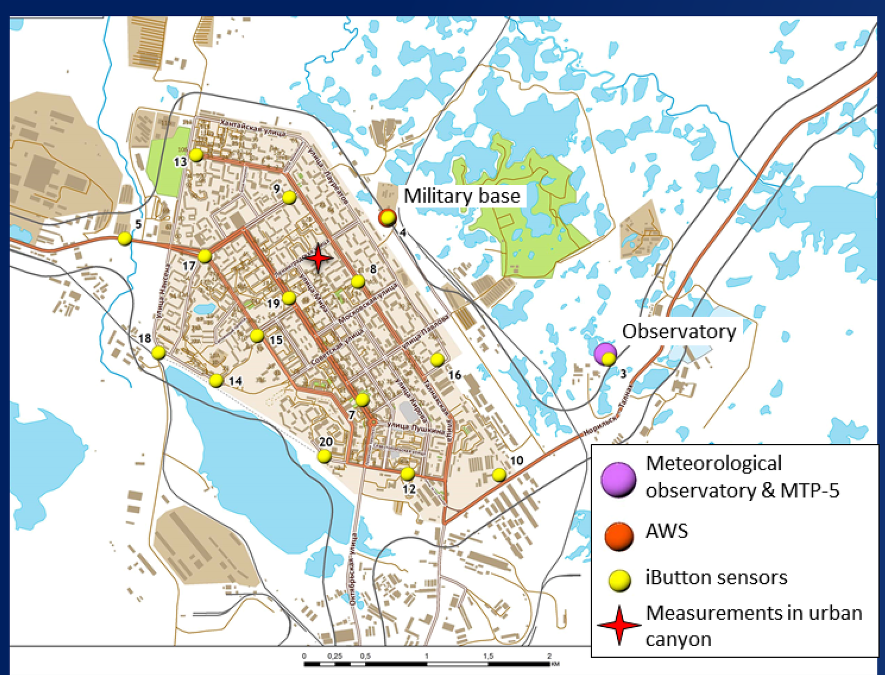
Place of research

Biggest polar cities:

1. **Murmansk** 302 000 inh.
2. **Norilsk** 177 000 inh
3. **Vorkuta** 64 000 inh.
4. **Tromsø** 61 000 inh
5. **Apatity** 59 000 inh

Measurements



Stationary weather stations

iButton temperature sensors

Mobile weather station

MTP-5 Microwave profiler

Building 2D temperature fields

Correction iButton's measurements, using difference between iButton and basic measurements in control points (AWS and meteorological observatory)

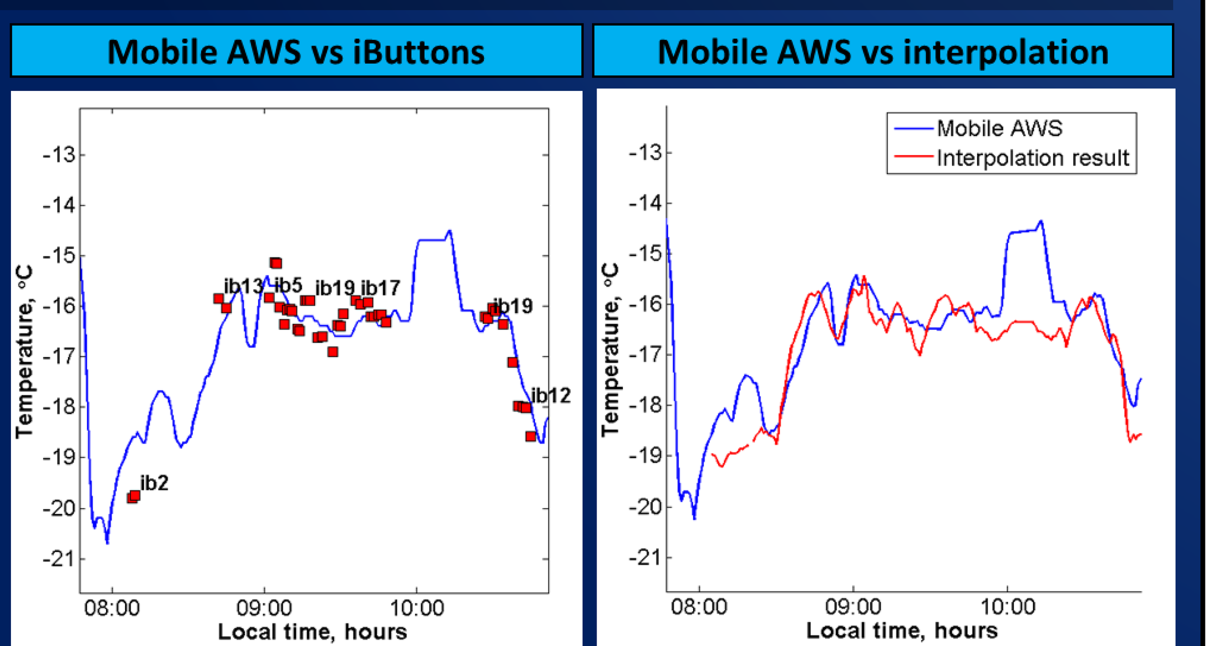
Using MTP-5 data, relief information (ASTER) and geostatistical methods for interpolation:

$$T(x,y,t) = T_0(h(x,y),t) + \overline{\Delta T(x,y)} + \Delta T'(x,y,t)$$

- $T_0(h(x,y),t)$ — *Atmosphere temperature at fixed height* ← **MTP-5 measurments**
- $\overline{\Delta T(x,y)}$ — *Time-averaged "microclimatic" correction* ← **Kriging**
- $\Delta T'(x,y,t)$ — *Correction for certain moment* ← **Kriging**

More details about method in poster (Esau, Varentsov)
Programme Group: AS4, Session: AS4.4/BG5.5/CL4.7/SSS.0.14 Display Time: Monday, 28 Apr 2014, 08:00–19:30, Yellow posters (Z178)

Comparison between stationary and mobile measurements



Abstract

Growing socioeconomic activity in Arctic zone and prospective of building new settlements in this region requires better understanding of urban-caused microclimatic features and especially of the urban heat island (UHI) effect, because in high latitudes it could mitigate severe climatic conditions and provide fuel economy for urban areas. This effect is quietly good studied for the cities in low and moderate latitudes (Oke, 1987), but there are only a few studies about cities in high latitudes (Magee et. al., 1999) and there are not any modern studies about UHI of the biggest polar cities, which are located in Russia. In this study, we consider results of experimental research in Norilsk, which is the second biggest city over the Polar Circle, obtained during the expedition in December 2013. **This study was supported by Russian Geographic Society, research projects No. 69/2013-H7 and 27/2013-H3.**

Data & methods

Field measurements continued during 21-23 of December and included measurements by automatic weather stations (AWS) and small temperature sensors called iButton (www.maximintegrated.com), installed in the city and surrounding area, and microwave temperature profiler MTP-5 (http://attex.net), installed at the roof of local meteorological observatory. Car-based temperature sounding with AWS was organized at 21 of December.

The data, obtained by stationary measurements, was used for building 2D temperature fields for mapping and further analysis. To take into account influence of relief and stratification, we used **simple kriging**, applied not for temperature values, but for the differences between temperature measurements by sensors and by MTP-5 profiler at the sensor's heights, provided by ASTER digital relief model. *For more details see poster (Esau, Varentsov, 2014).* The data, obtained by car-based sounding, was used for verification of iButton's measurements (because this type of sensors is new in such researches) and interpolation method. It showed good agreement with iButton's measurements and confirmed that chosen interpolation method is better that interpolation of the temperature values directly.

Results

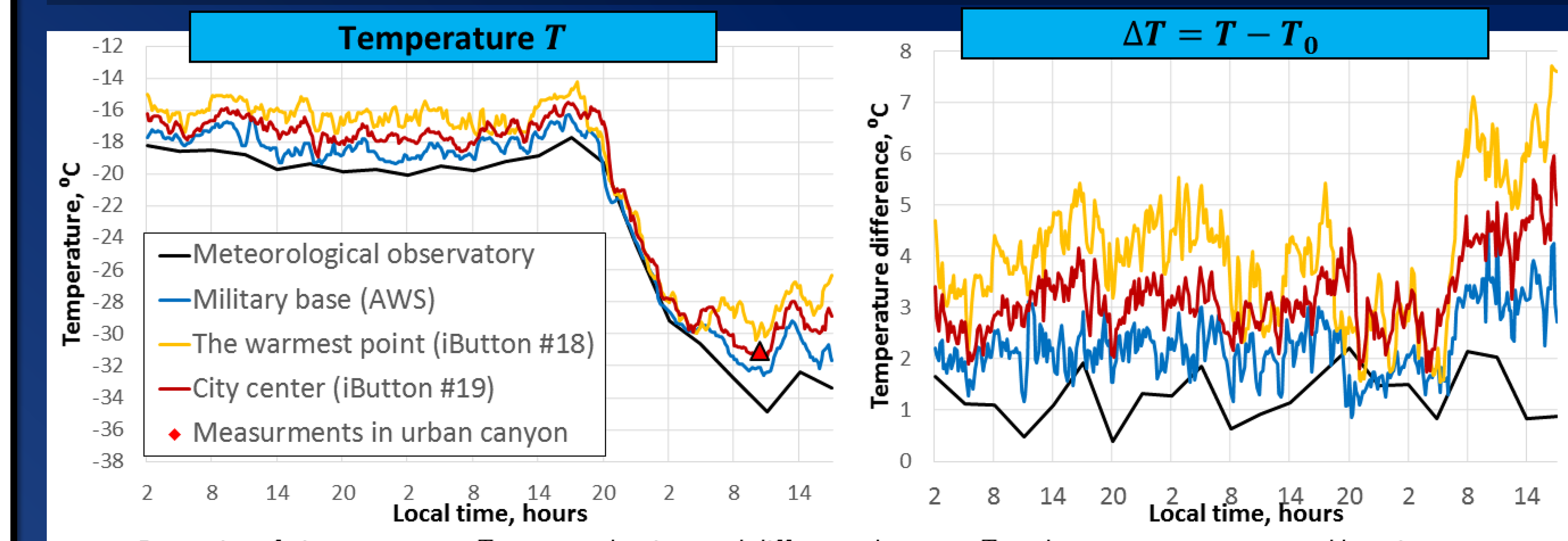
Data analysis showed the existence of permanent temperature difference between observatory and city center, with values up to 5°C and average about 2°C. The strongest contrast took place at the coldest moment of expedition, so it could be connected with increased anthropogenic heat flux. However, spatial structure of the temperature anomaly is not typical for UHI: the highest temperatures were observed not in the center, but at the western edge of the city, closely to the lake (point №18, where temperature was up to 2°C warmer than in the center). Temperature maps shows the significant temperature gradient between southwest and northeast parts of the area. It could be partly caused by relief and weakly stable stratification, observed during expedition: there are some hills at the south-west and lowlands at the northeast. However, the gradient exists even after filtering direct influence of relief and stratification, made by deduction temperatures, measured by temperature profiler at the sensor's heights. We can suggest that the gradient is also formed by influence of big and warm unfreezing (because of industry usage) lake, and by indirect influence of relief (e.g. warm downhill winds).

In attempt to estimate economical effect of the UHI, we compared temperature, averaged for all points in built areas, with temperature, measured by local thermoelectrically plant, which is used for calculation required heat production and fuel consumption. This comparison revealed that actual average temperature in the city is higher than measurements by thermoelectrically plant, with 3-days average error of 0.4 °C. However, management of thermoelectrically plant didn't provide required data, and for rough estimate we used our results for power plant in Apatity city, where 1 °C/day error could cost about 1000 €/day. *For more details, see oral presentation (Konstantinov et. al, 2014).* The power of thermoelectrically plant in Norilsk is 4 times higher than in Apatity, so mean error of 0.4 °C/day leads to economical effect of 1600 €/day and 480 000 € during heating period (300 days).

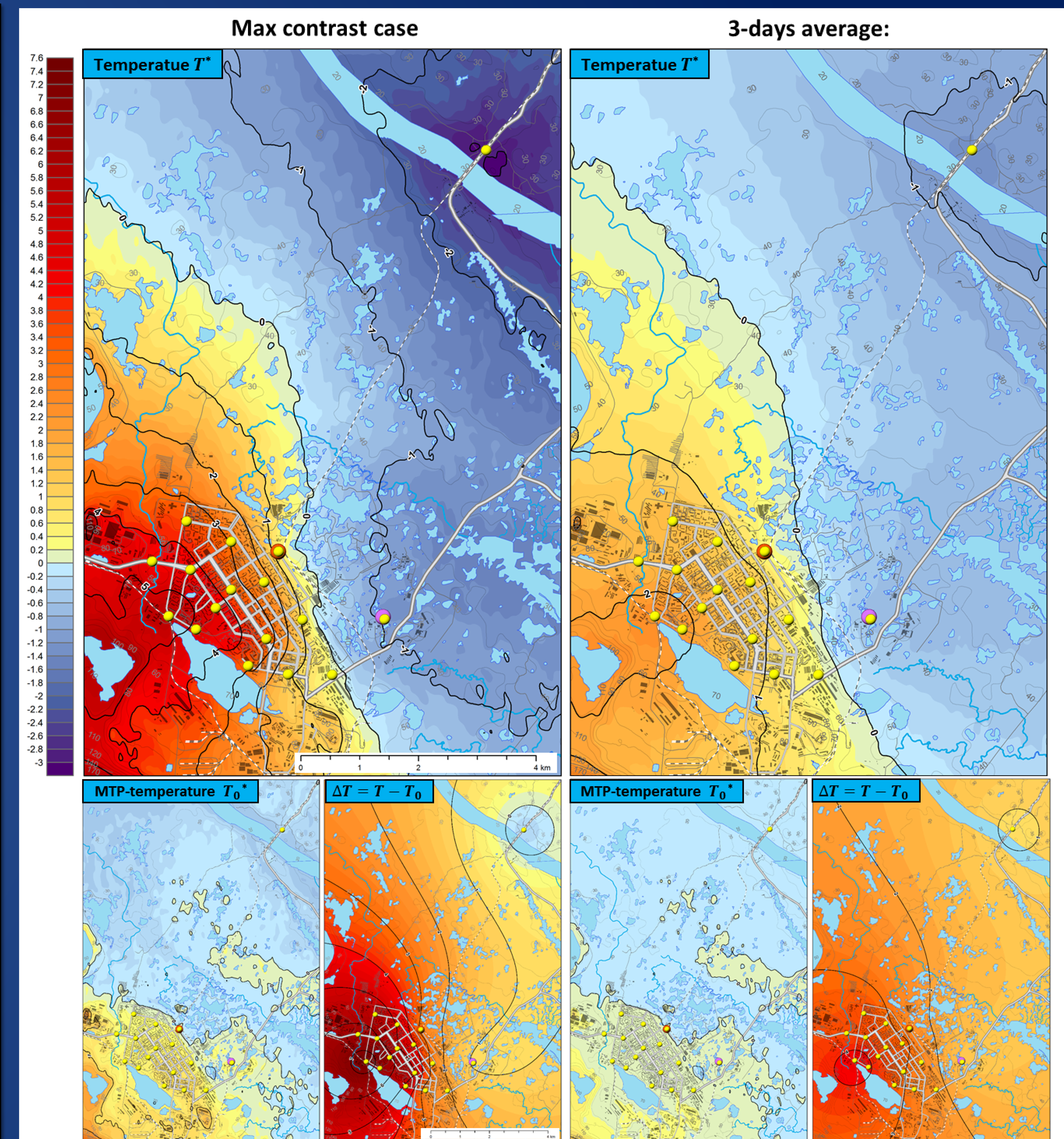
References

- Magee N., Curtis J., Wendler G., The Urban Heat Island Effect at Fairbanks, Alaska// Theor. Appl. Climatol. 1999. V. 64, pp 39-47;
- Oke, T.R. Boundary Layer Climates. 2nd edition. Routledge. 1987. 435 pp;
- Esau I., Varentsov M., Fine-resolution mapping of micro-meteorological features in regions with heterogeneous landscapes, Geophysical Research Abstracts, Vol. 16, EGU2014-1516, 2014;
- Konstantinov P., Baklanov A., Varentsov M., Kukanova E., Repina I., Shuvalov S., Samsonov T., Experimental Urban Heat Island Research of Four Biggest Polar Cities in Northern Hemisphere. Geophysical Research Abstracts, Vol. 16, EGU2014-10699-1, 2014. EGU General Assembly. 2014.

Results



Dynamics of air temperature T at several points and difference between T and temperature, measured by microwave profiler MTP-5 at the heights of these points during expedition.



Values of temperature anomalies ($T_a = T - T_{space\ average}$) are used here for mapping. Relief is shown by gray isolines.

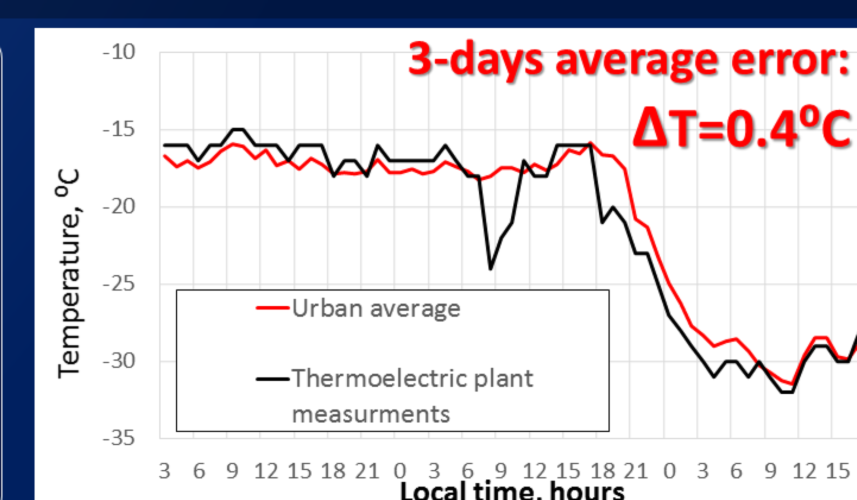
Economical effect

Statistical model of city heating system:

Outside air temperature → Hot water temperature → Heat production → Fuel (coal) consumption → Money

Cost of 1°C error:

- Apatity (686 mWt): ≈1000 €/day
- **Norilsk** (2691 mWt): **≈ 3900 €/ day**



More details about method in oral presentation (Konstantinov et. al.)
Programme Group: CL3, Session: CL3.1/AS1.18, Monday, 28 Apr 2014, 11:00–11:15, Room: Y8