Urban Heat Island of Arctic cities

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ICUC-9, 19-24 July 2015 , Toulouse, France

World's biggest polar cities (top-5):

1. **MURMANSK (RUSSIA)** 302 000 people 
2. **NORILSK (RUSSIA)** 177 000 people 
3. **VORKUTA (RUSSIA)** 64 000 people 
4. **TROMSO (NORWAY)** 61 000 people 
5. **APATITY (RUSSIA)** 59 000 people 

Research area (5 expeditions)

Norilsk (December 2013)

Murmansk (Jan-Feb 2014)

Apatity (Jan-Feb 2014; 2015)

Vorkuta (March 2014)

Main features of the case-stydy:

1. First complex experimental study of temporal and spatial characteristics of Urban Heat Island in 4 biggest polar cities in the world (in Russia).
2. For obtaining good data quality, we used 3 different measurements techniques
3. Evaluation of possible economical effect of UHI at polar city heating system

Measurements techniques:

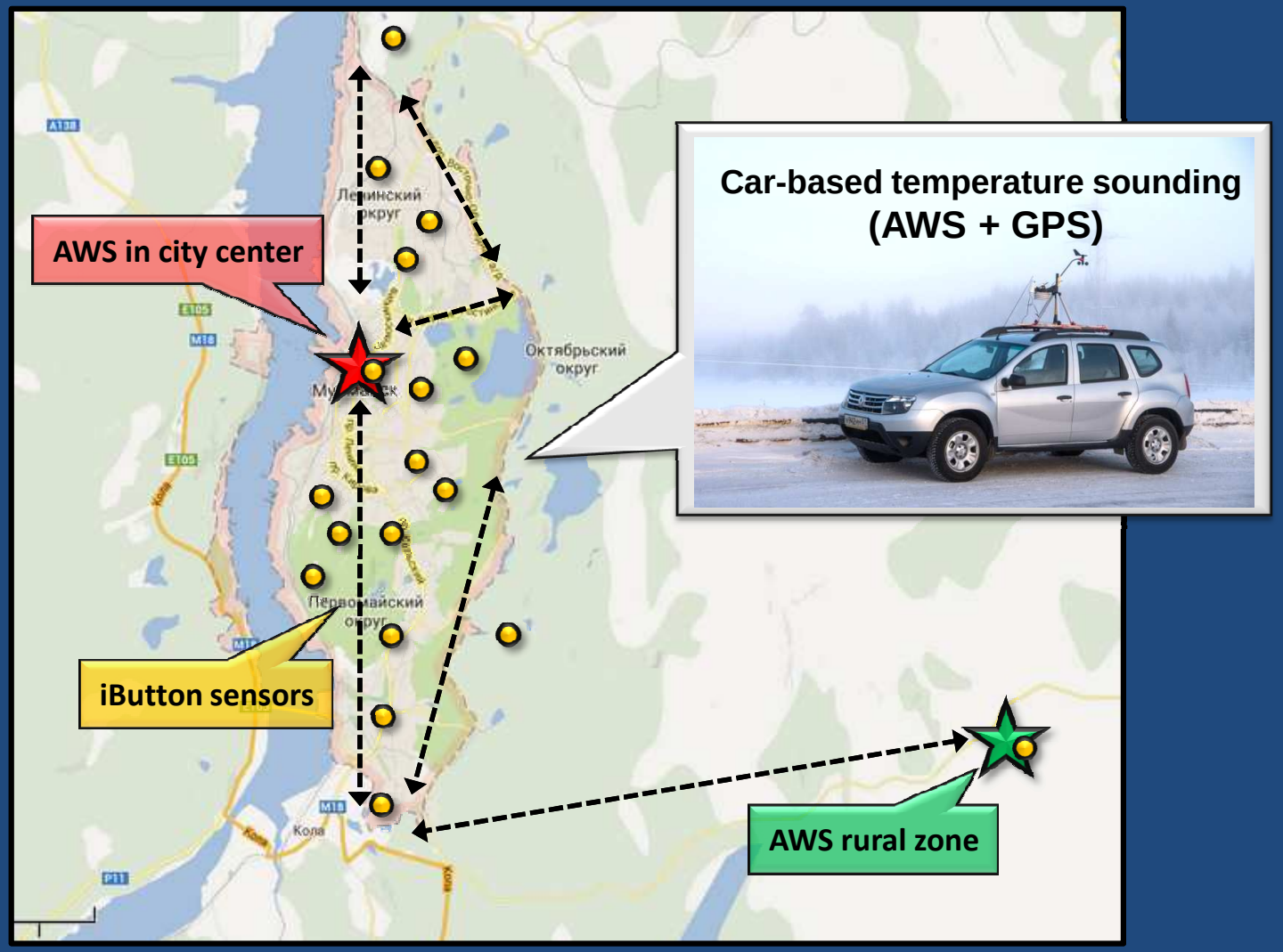
Stationary automatic weather stations (AWS)	Mobile weather station	Low-cost compact temperature sensors (iButton)	MTP-5 microwave temperature profiler (Norilsk only)
			

In situ measurements

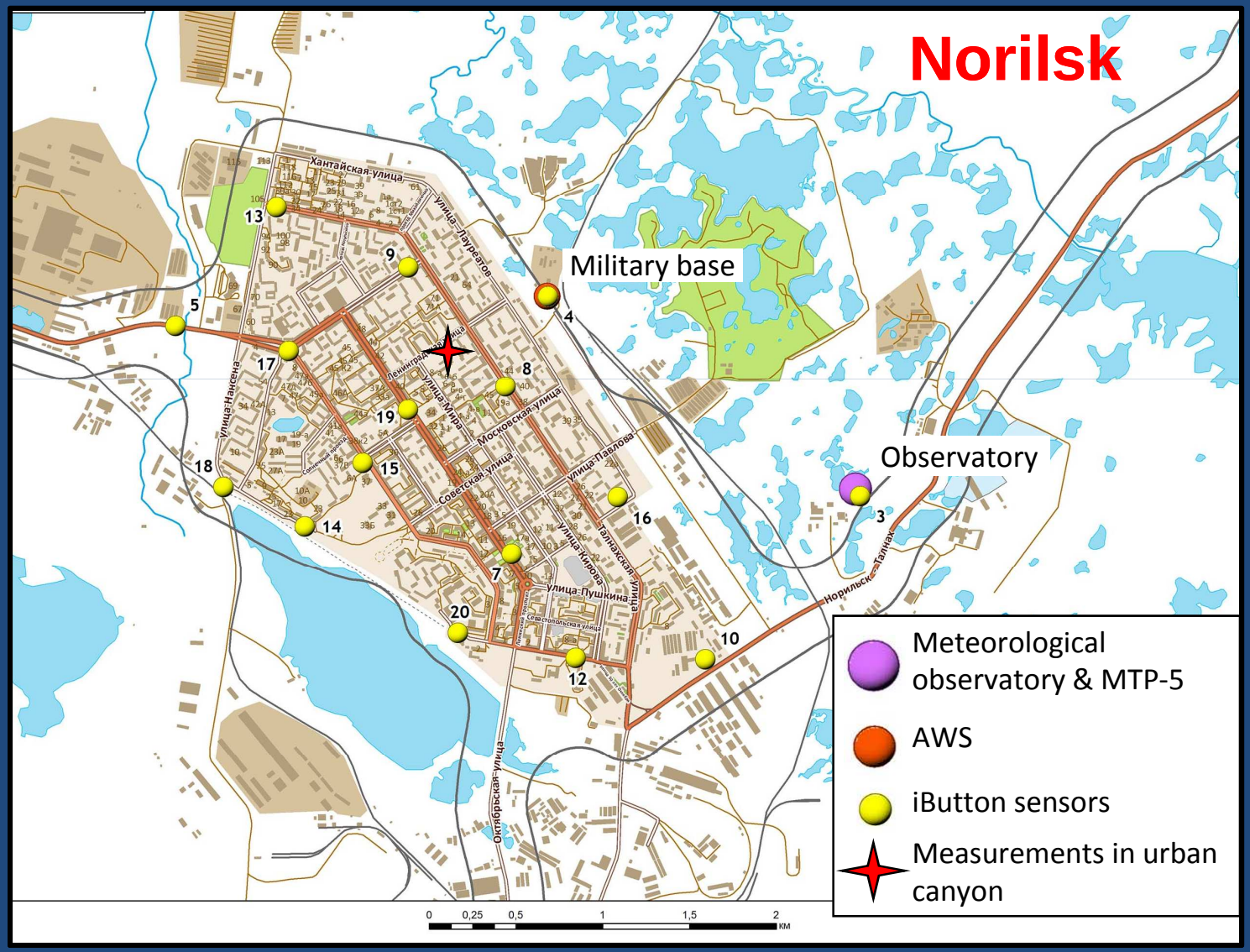
Post-processing of the raw data (synchronization, quality-control, correction)

Building 2D temperature fields (geostatistical modelling)

Measurement techniques:



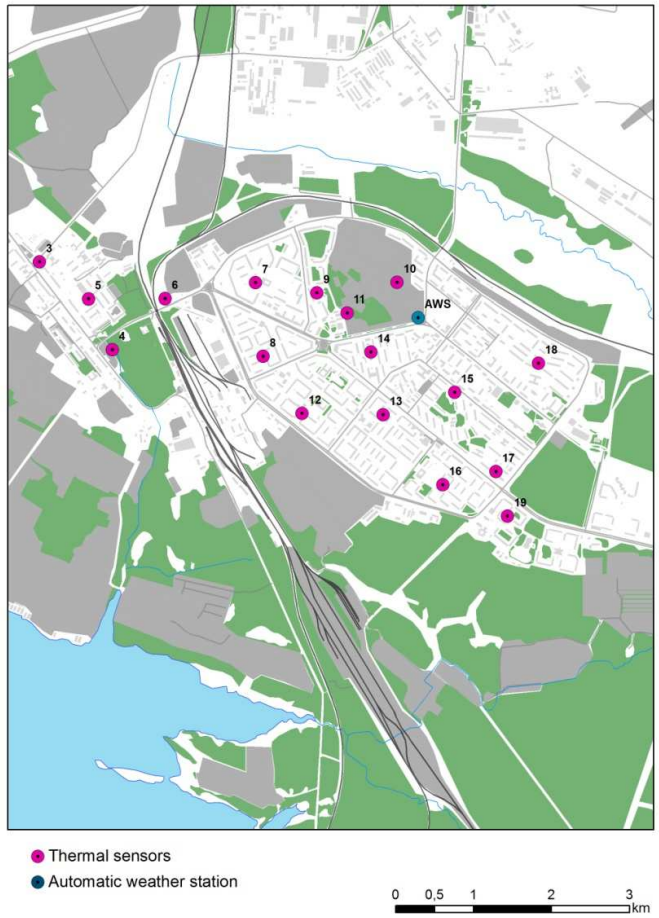
Measurements network:



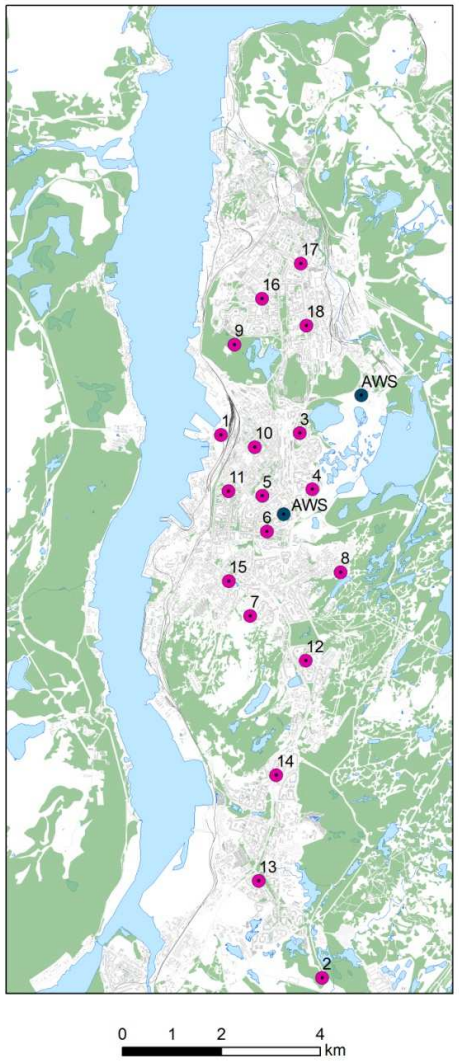
Measurements network:

Apatity (2014)

Apatity, thermal sensors and automatic weather station



Murmansk, thermal sensors and automatic weather stations

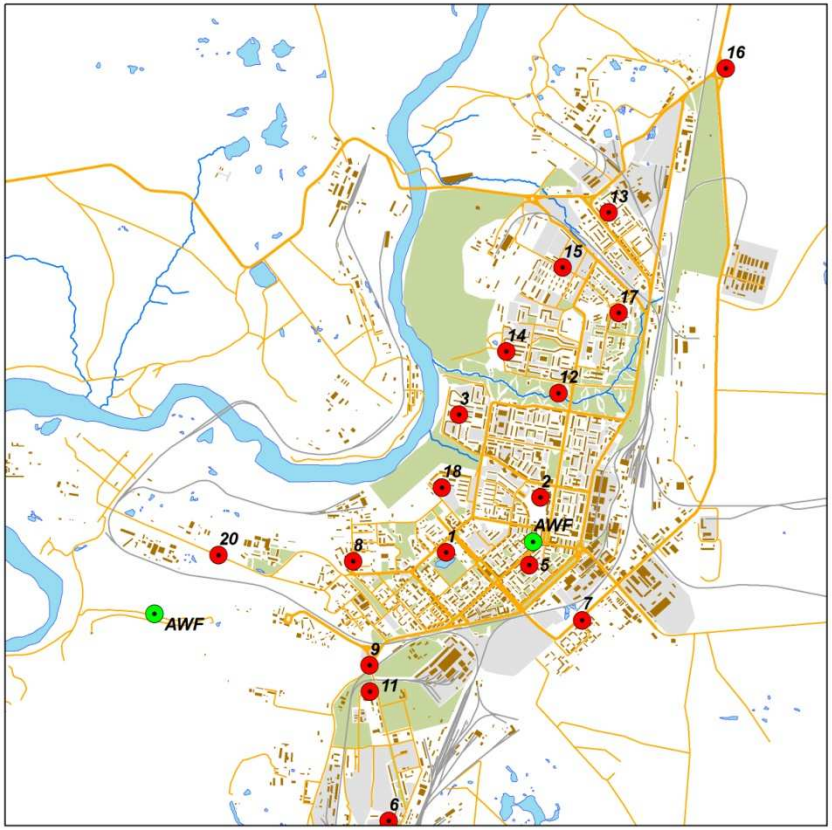


Murmansk

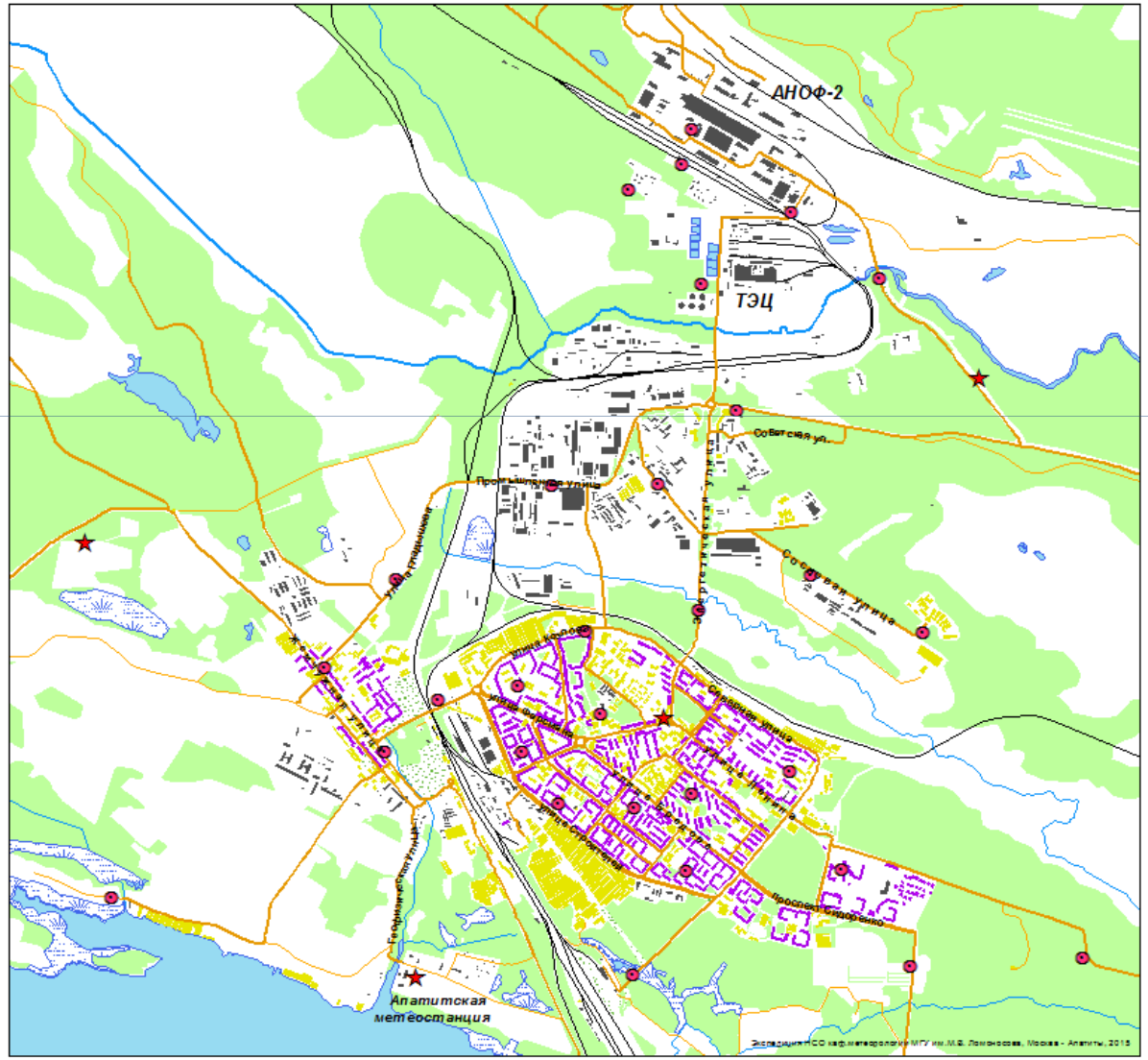
Measurements network:

Vorkuta

Vorkuta, thermal sensors and automatic weather stations



Measurements network:



Apatity (2015)

Точки метеорологических наблюдений

- **iButton sensor**
- **AWS**

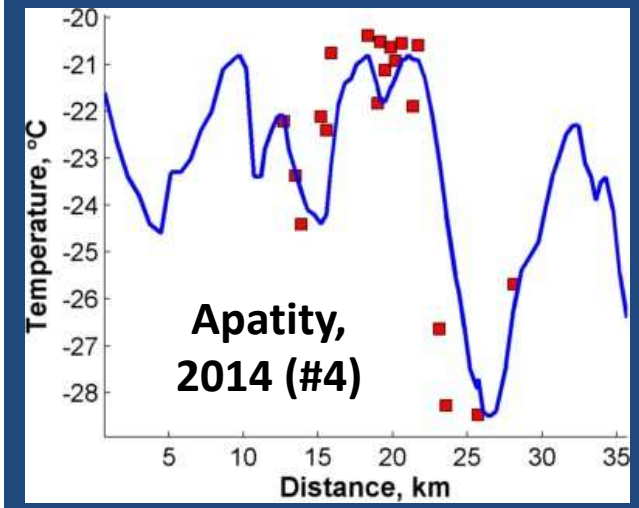
Строения

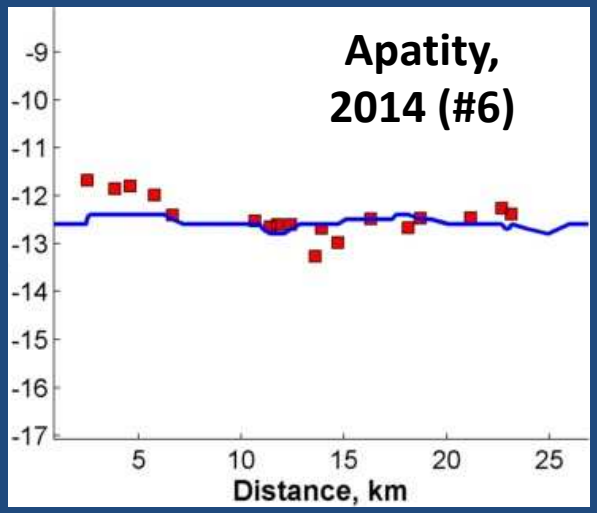
- промышленные
- жилые
- инфраструктуры

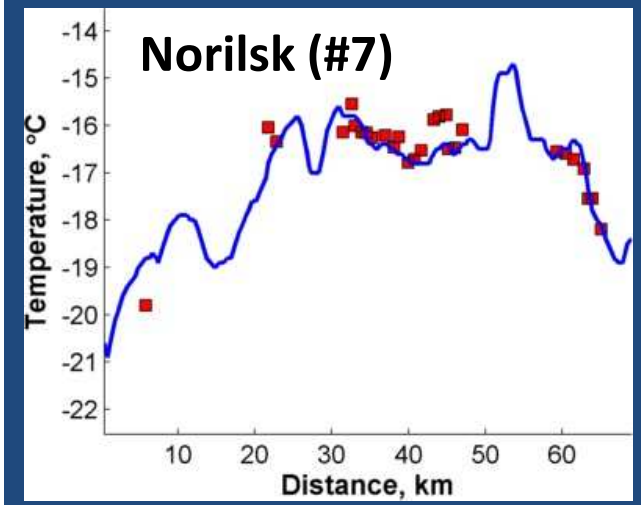
Preliminary results

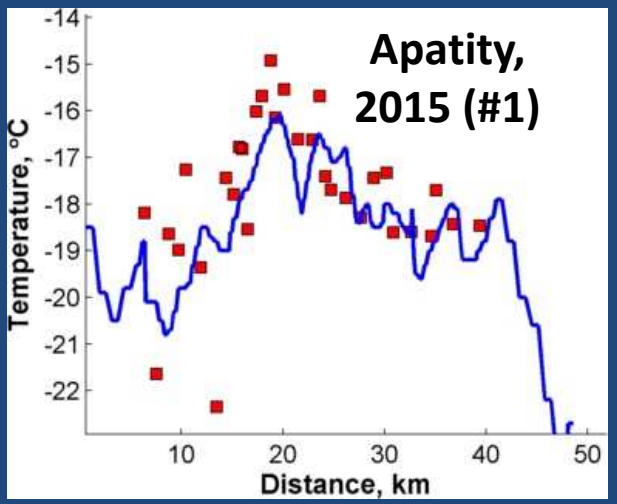
Mobile measurements
vs
stationary sensors

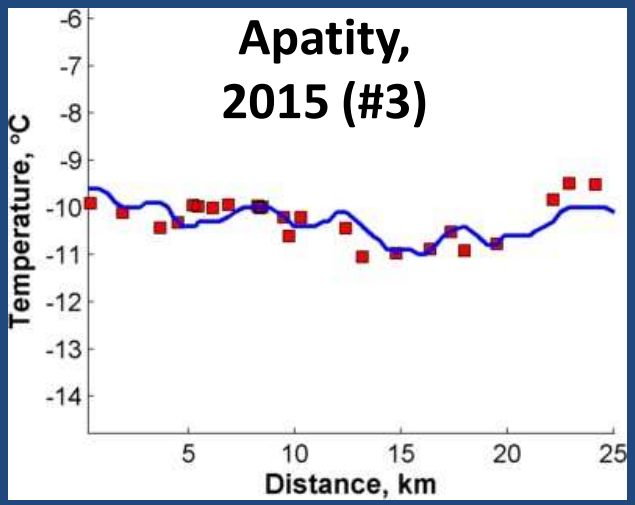
Mean square error		
# of sounding	Dyn. corr	No corr
1. Apatity 31.01.2015	1.19	1.4
2. Apatity 31.01.2015	0.36	0.31
3. Apatity 30.01.2015	0.32	0.67
4. Apatity 29.01.2014	1.64	1.69
5. Apatity 30.01.2014	0.9	1.14
6. Apatity 02.02.2014	0.45	1
7. Norilsk 21.12.2013	0.37	0.48



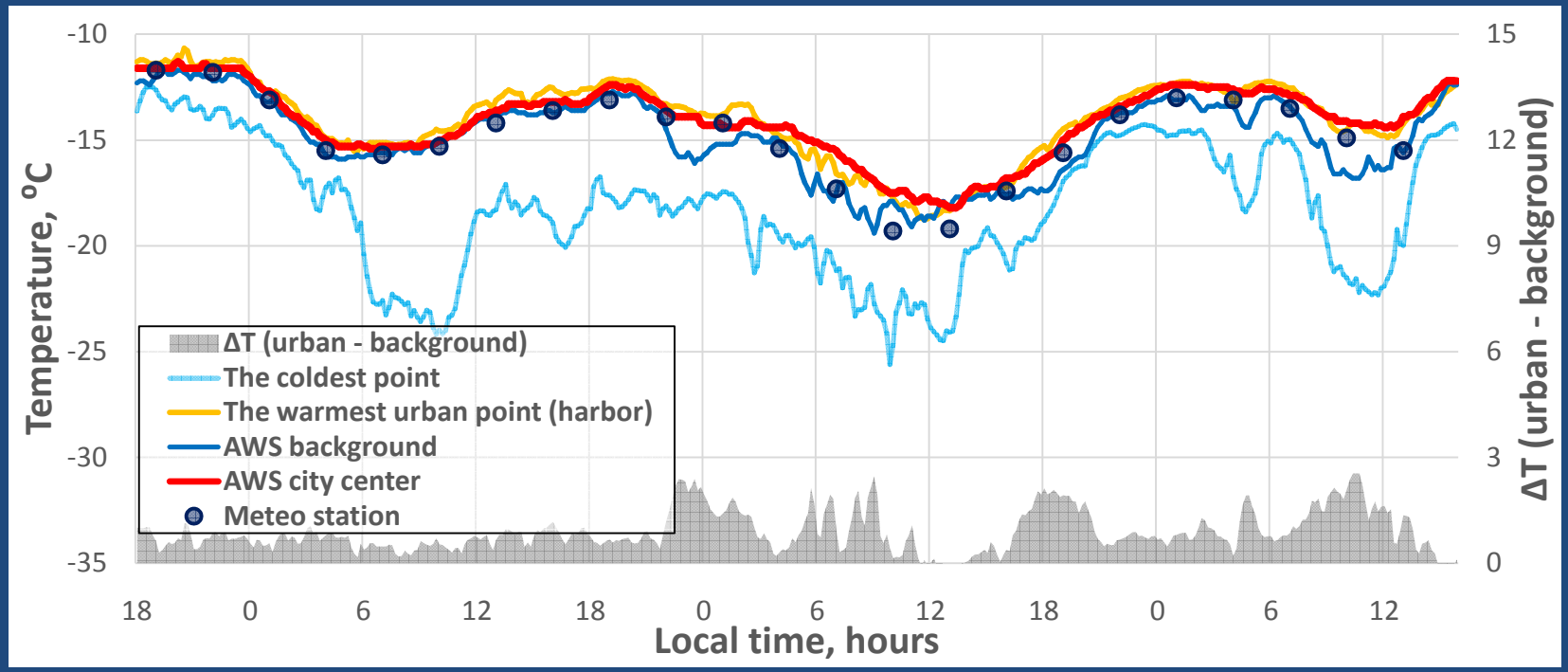




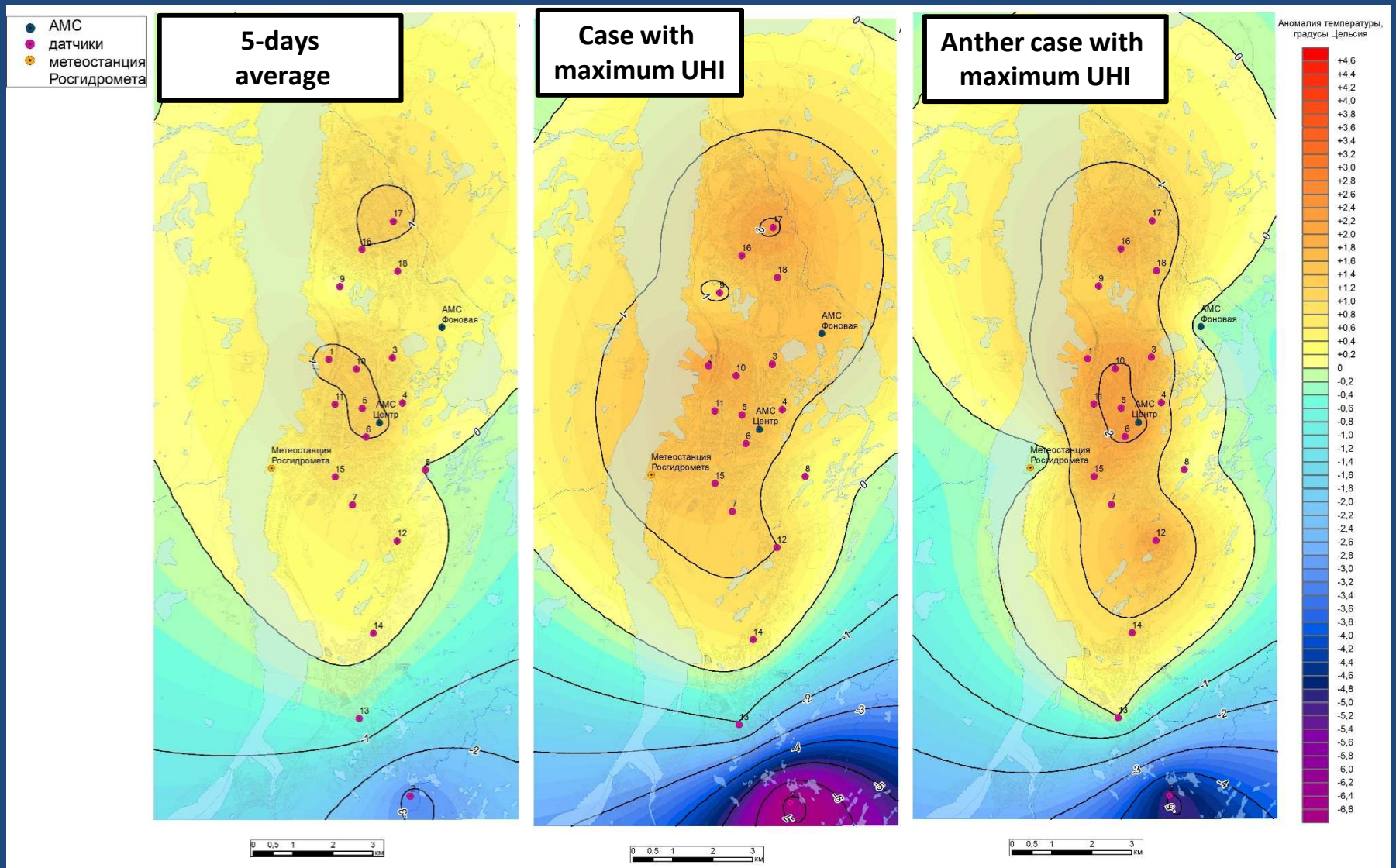




Preliminary results: Murmansk

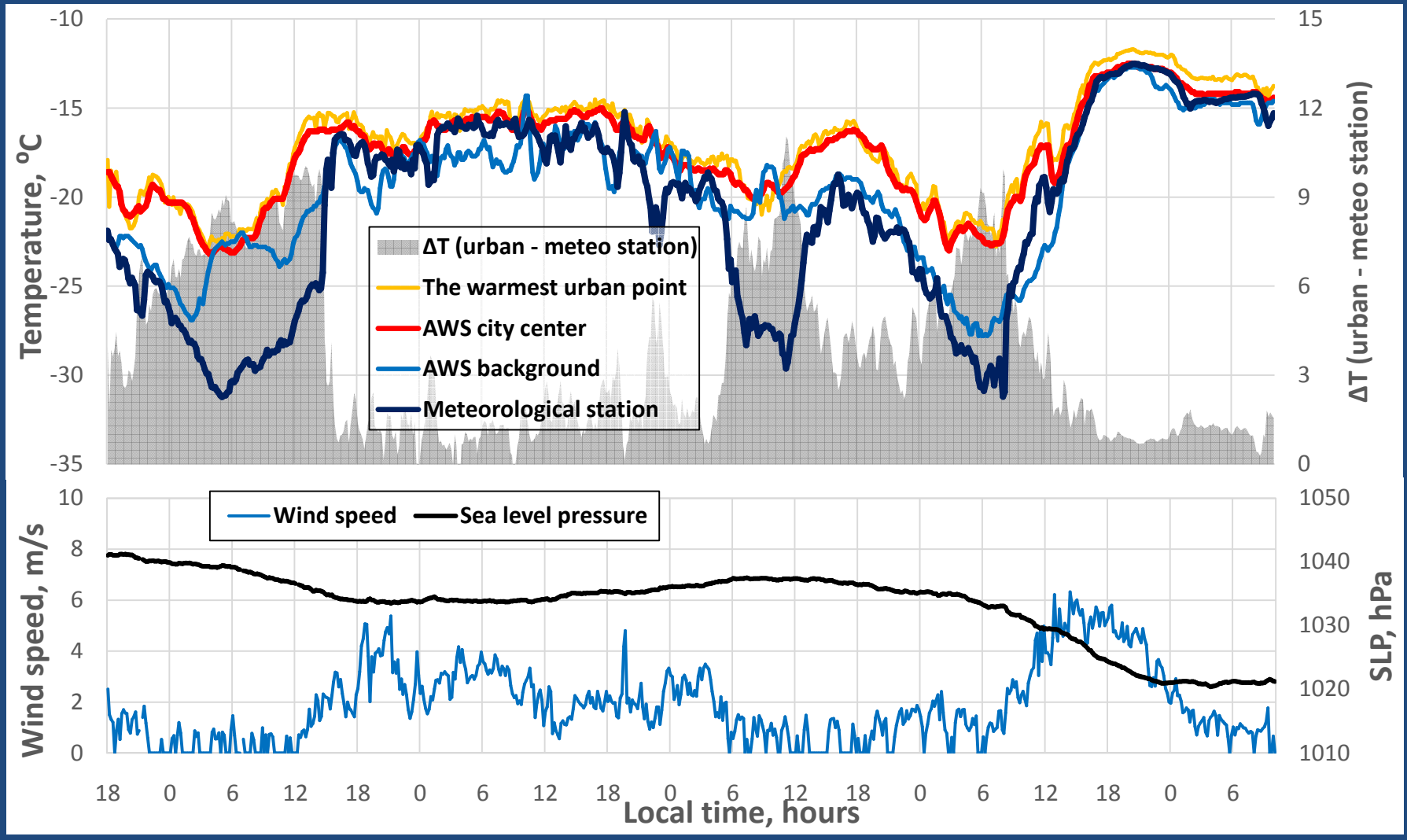


Preliminary results: Murmansk



*Spatial distribution of **temperature anomaly** (deviation from area mean) is shown*

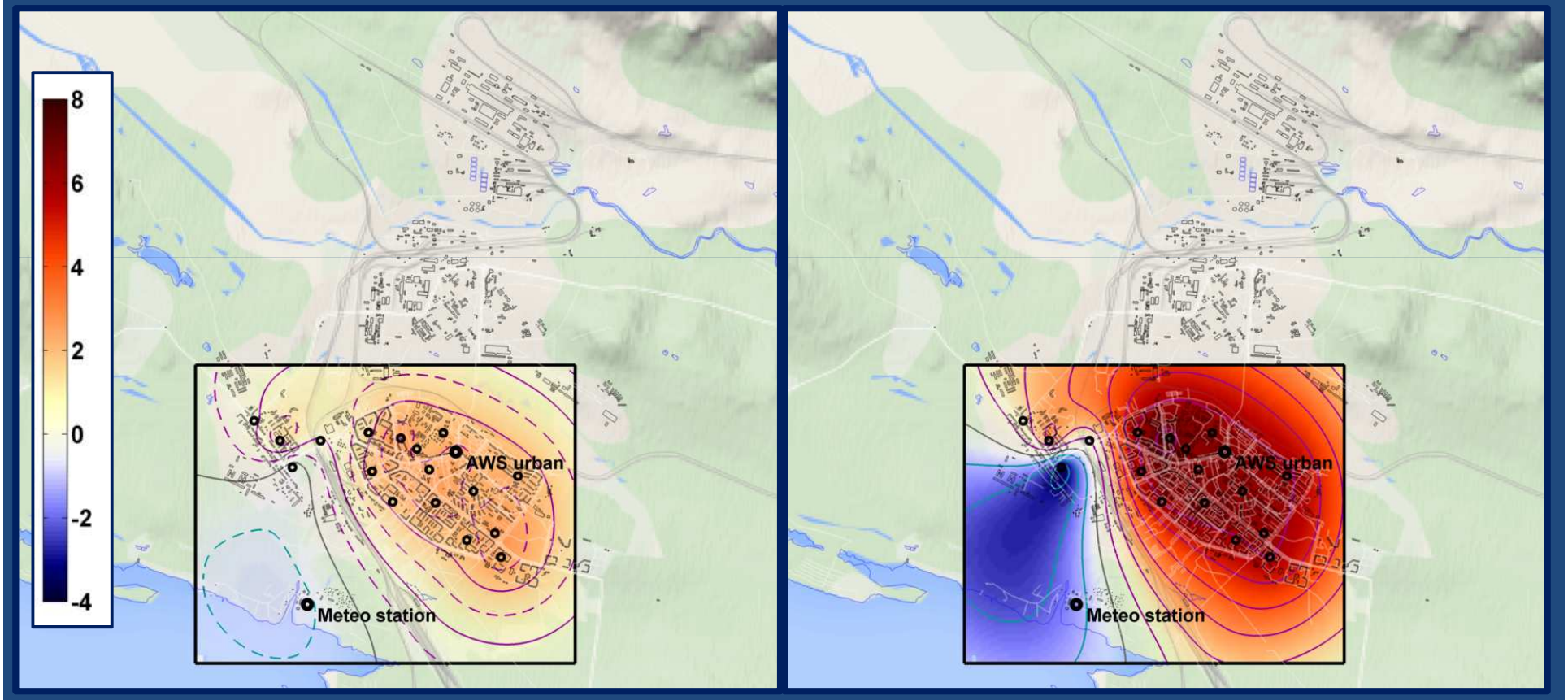
Preliminary results: Apatity (2014)



Preliminary results: Apatity (2014)

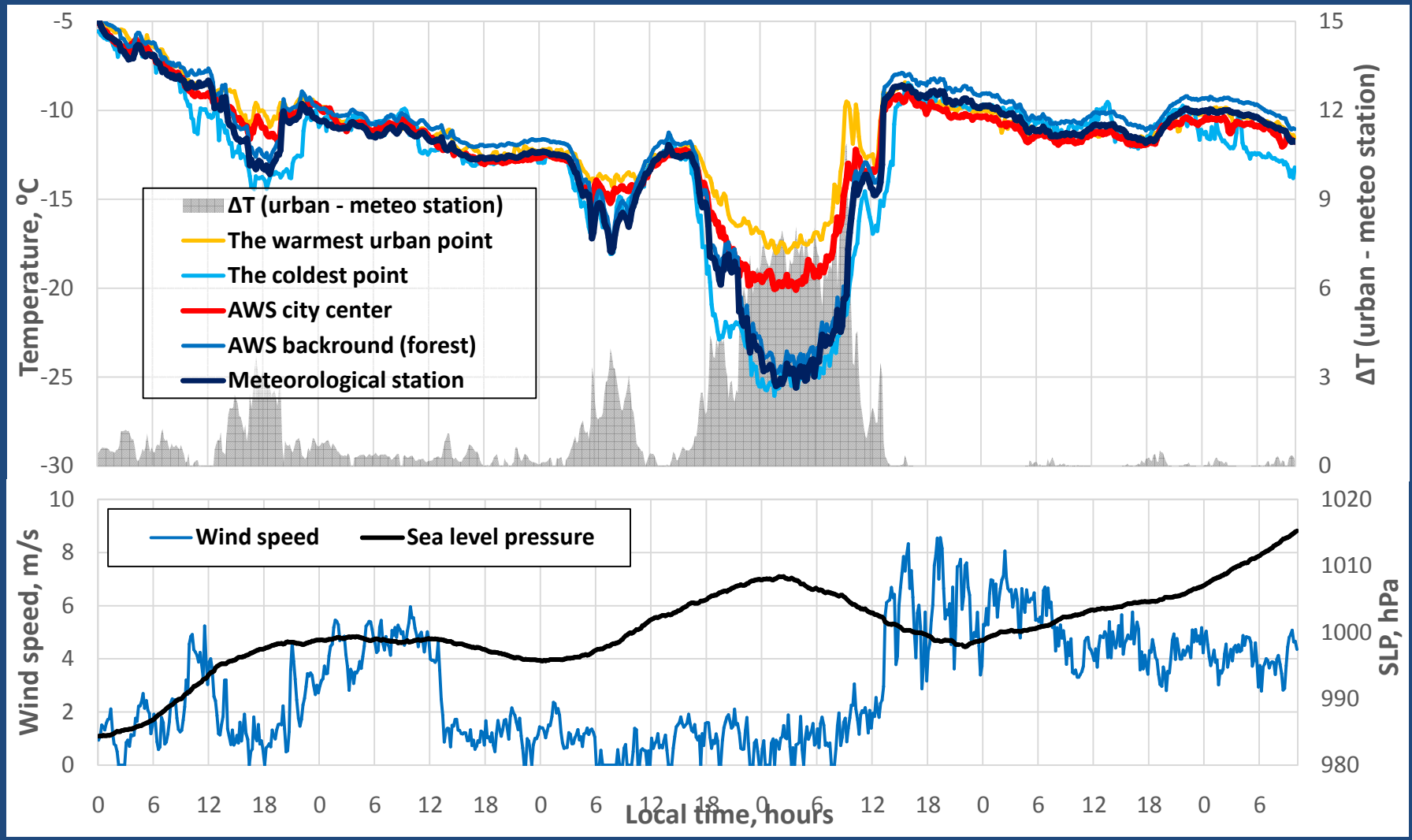
5-days average

Case with max. UHI
(1-hour average)



*Spatial distribution of **the temperature anomaly** - deviation from mean value at background points (Meteo station and AWS located outside of the map border). Solid isotherms go every 1 ºC*

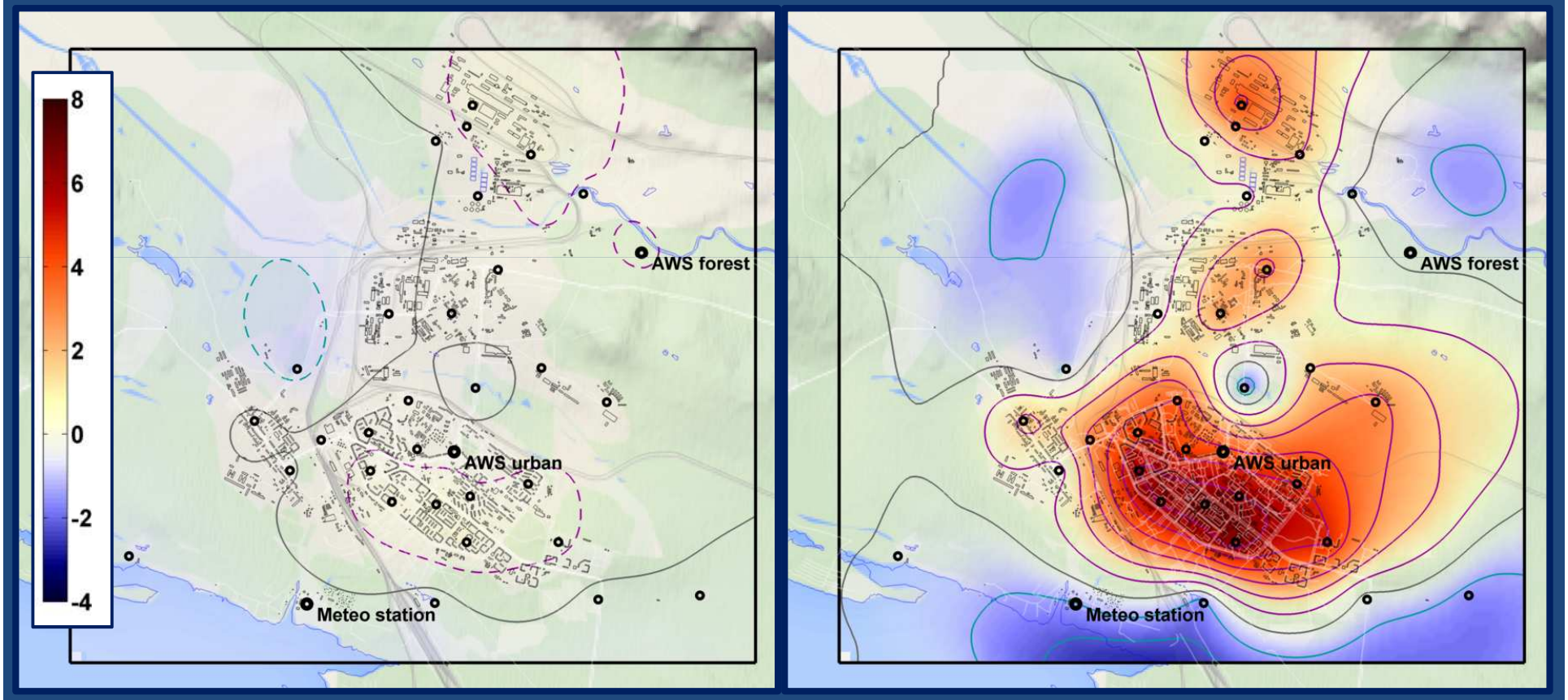
Preliminary results: Apatity (2015)



Preliminary results: Apatity (2015)

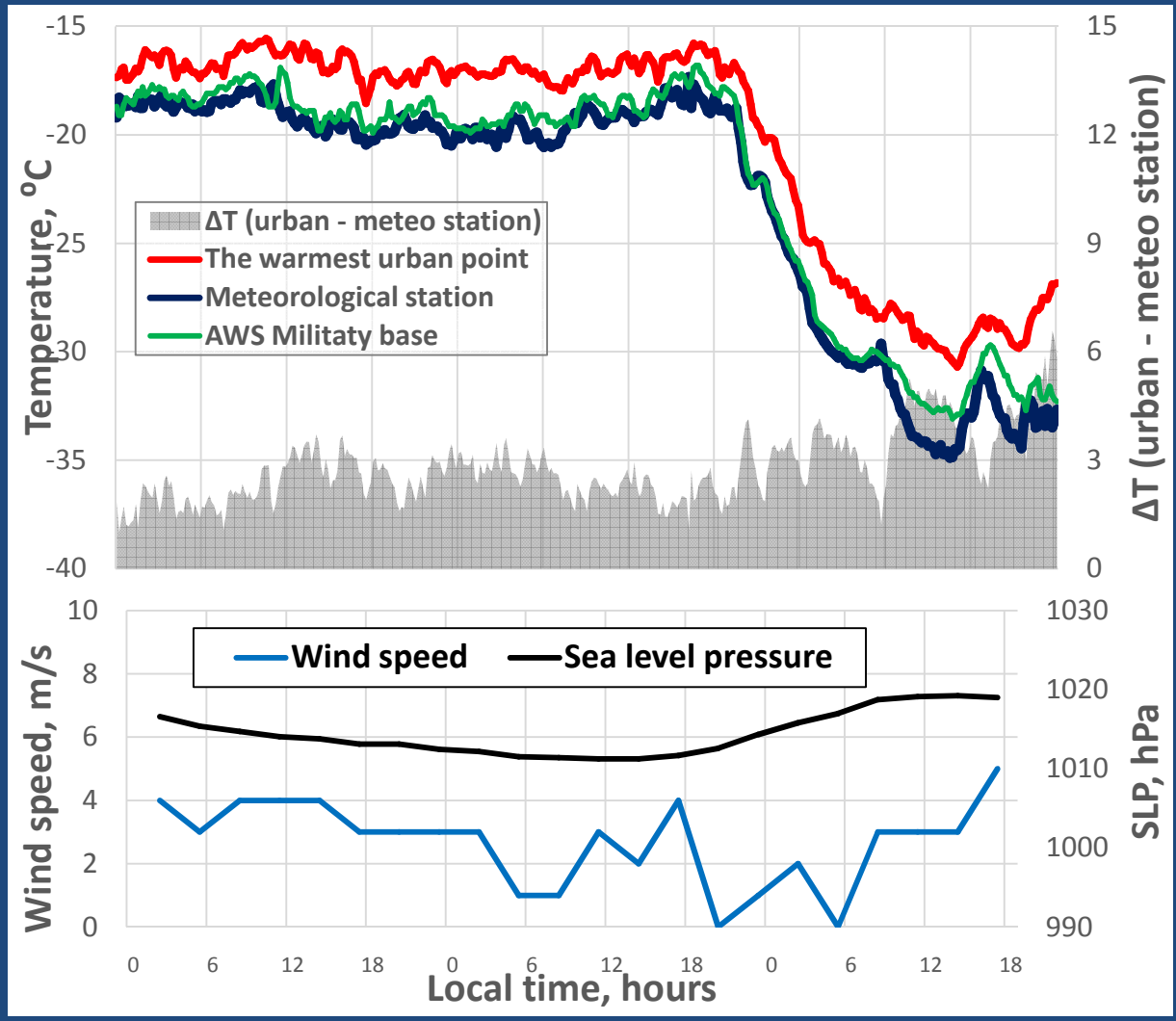
6-days average

Case with max. UHI
(1-hour average)

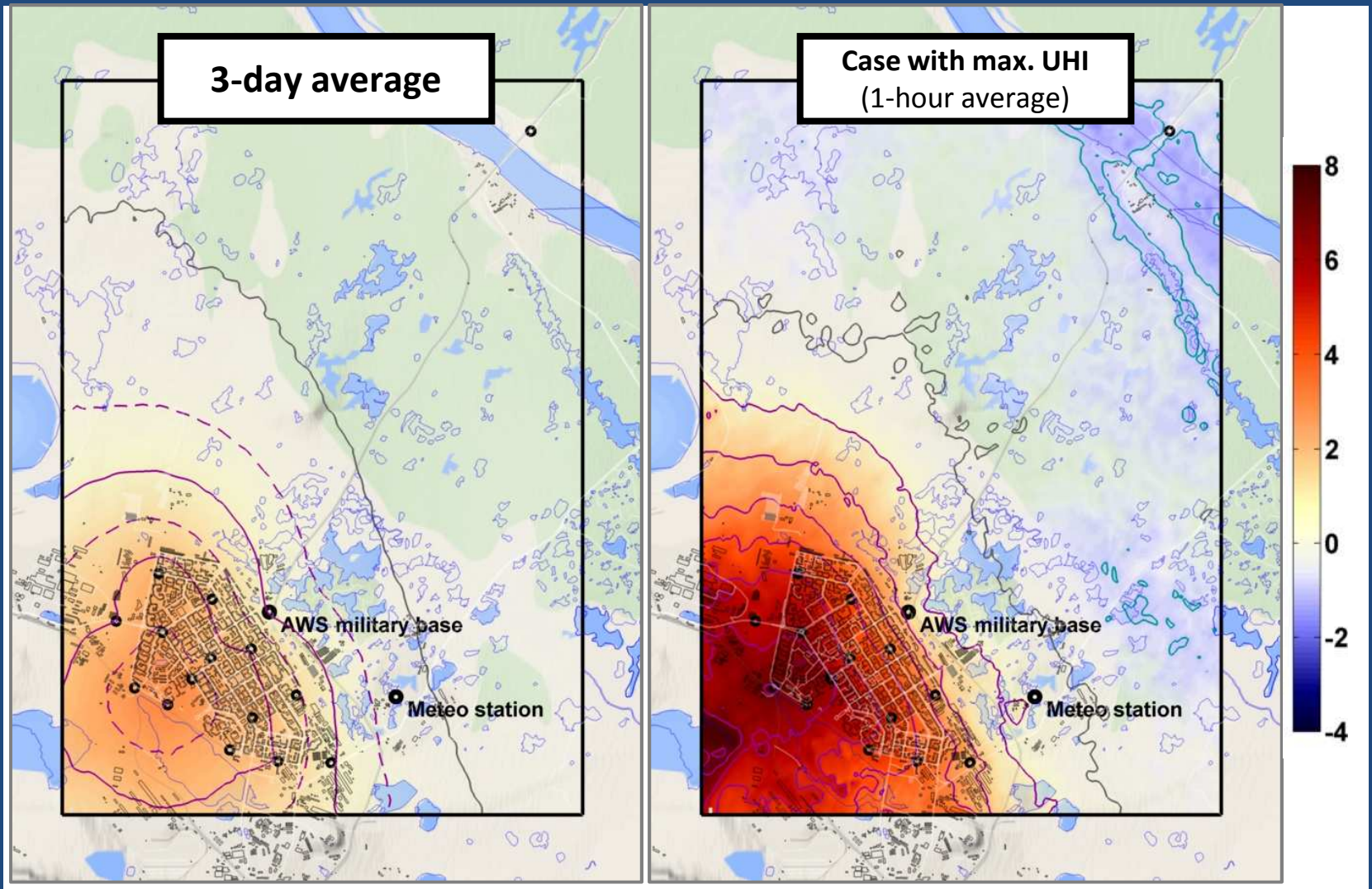


*Spatial distribution of **the temperature anomaly** - deviation from mean value at background points (Meteo station, AWS in forest and several iButtons). Solid isotherms go every 1 ºC*

Preliminary results: Norilsk



Preliminary results: Norilsk

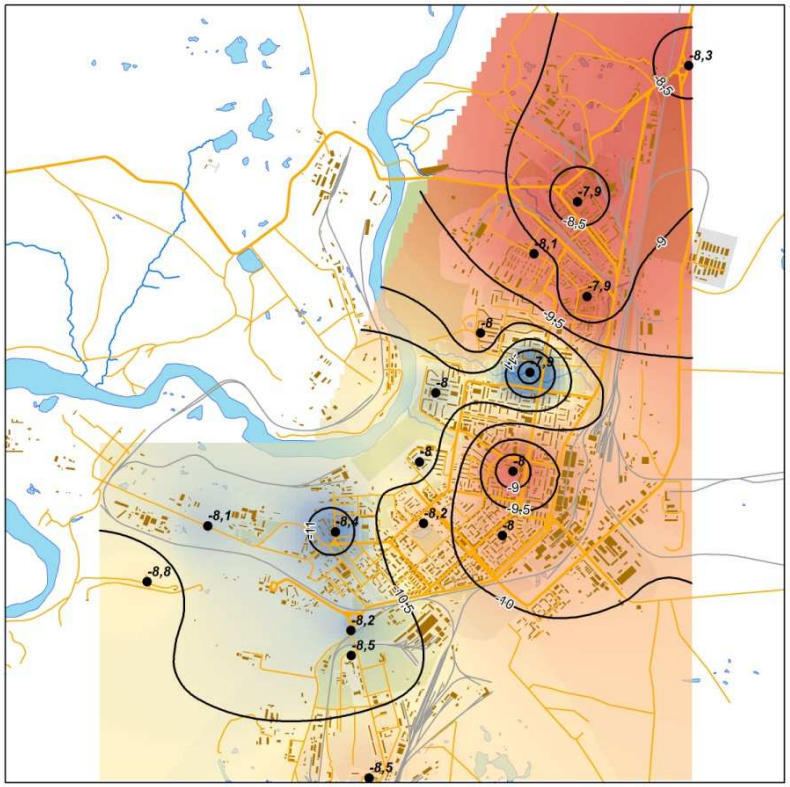


Spatial distribution of temperature anomaly - deviation from mean value at background points (Meteo station and iButton sensor at the north-east of the area) is shown. Solid isotherms goes every 1 °C.

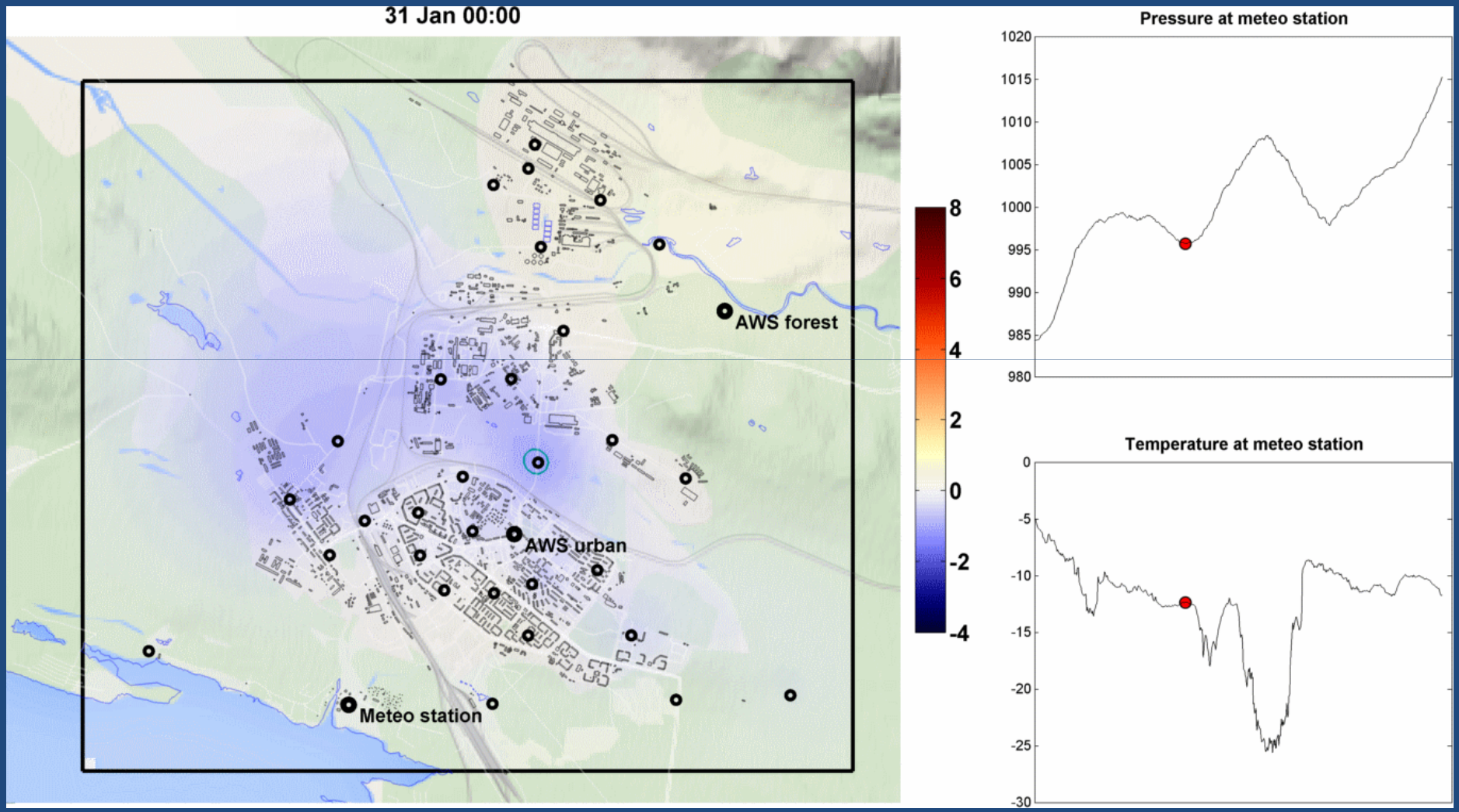
Preliminary results: Vorkuta

Air temperature, Vorkuta, 04.03.14 - 08.03.14,
average heat island

Air temperature, Vorkuta, 04.03.14 - 08.03.14,
maximum heat island

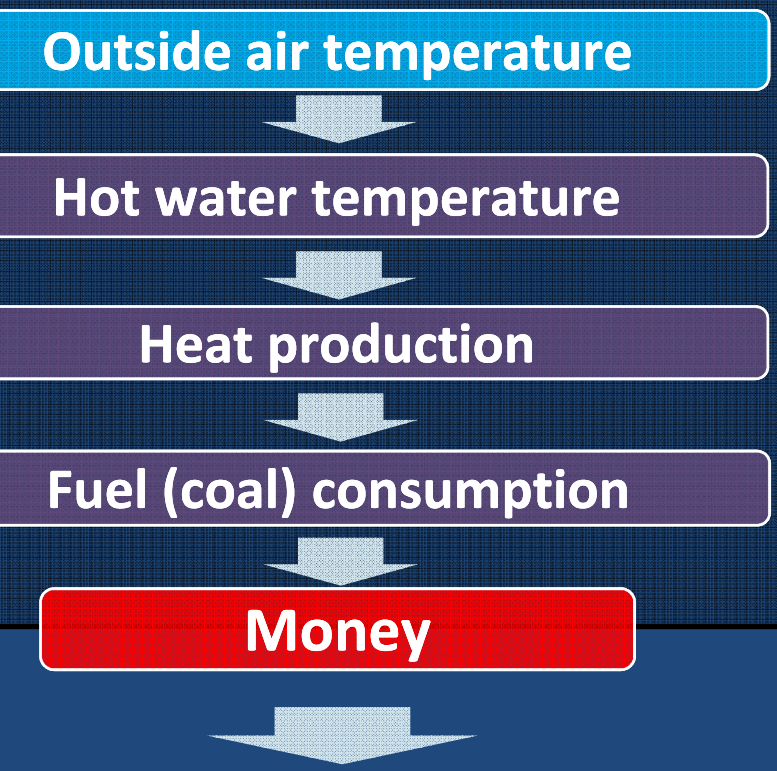


UHI of Apatity: animation



Potential economical effect

Statistical model of city heating system:



Cost of 1°C error:

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

Summary

1. First temporal and spatial characteristics of Urban Heat Island in 4 polar cities (Murmansk, Norilsk, Vorkuta and Apatity) were obtained.
2. The different measurements techniques showed the similar results for every city.
3. Preliminary analysis showed that the nature of Urban Heat Island in every polar city is different and depends of geographical features of the city.
4. Economical effect of UHI in polar regions could be significant: and the cost of 1^0C error can exceed 3900 €/ day.

Thank you for your attention

More details in out poster:

POSTER 1: UCP - UHI characteristics and micro-scale variability · 21/Jul/2015: 3:00pm-4:00pm

Investigation of urban heat island of Norilsk and Apatity cities in Russian Arctic with usage experimental measurements and remote sensing

Mikhail Varentsov[1,2], Pavel Konstantinov[1], Irina Repina[2], Timofey Samsonov[3]

Data & methods

Stationary automatic weather stations (AWS)	Mobile weather station	Low-cost compact temperature sensors (iButton)	MTP-5 microwave temperature profiler (Norilsk only)
			

In situ measurements

Post-processing of the raw data

The problem: joining the data from local meteorological station (reliable), AWS (relatively reliable) and iButtons (less reliable)

Solution:

- Calibration of the sensors before the experiment – static correction for each sensor
- In points with AWS we also install iButtons – dynamic correction for control sensors
- Spatial interpolation of the dynamic correction for other sensors

$$T(t) = T_{src}(t) + \Delta T + \Delta T_{dyn}(t, x, y)$$

Building 2D temperature fields

For Apatity: $T(x, y) = SK\ (\{T_1, \dots, T_n\}, \overline{T_{no\ urb}})$

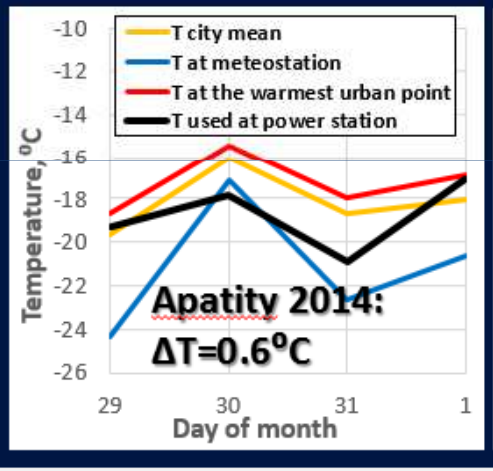
For Norilsk: $T(x, y) = T_0(z(x, y),) + SK\ (\{\Delta T_1, \dots, \Delta T_n\}, \overline{\Delta T_{no\ urb}})$

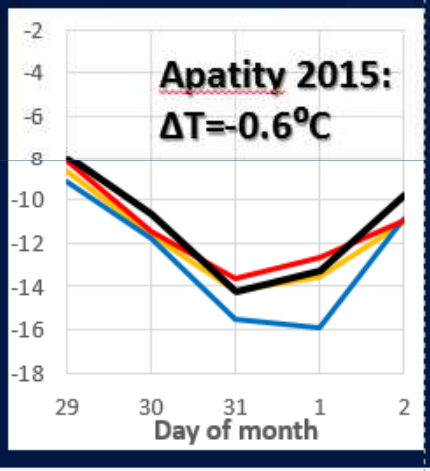
$$\overline{T_{no\ urb}} = \frac{1}{k}\sum_{i=1}^{k} T_i \qquad \overline{\Delta T_{no\ urb}} = \frac{1}{k}\sum_{i=1}^{k} \Delta T_i \qquad \Delta T_i = T_i - T_0(Z_i)$$

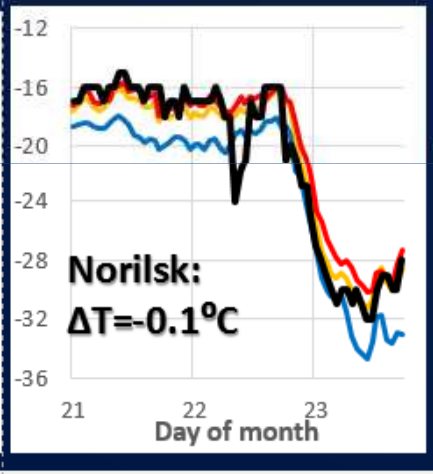
where T_i - temperate measurements by AWS and iButton sensors,
n – total number of measurement points, k – number of points outside built territory
z_i - height of measurement point (according ASTER DEM)
$T_0(z)$ – vertical temperature profile according MTP-5 measurements
$SK\ (\{X_1, \dots, X_n\}, \overline{X})$ – simple kriging interpolation operator with prescribed mean $\overline{X}$

Effect on the house heating

The question: is the UHI of the polar cities taken into consideration at power station, providing the house heating?
Answer: generally yes, except the moments with strong frosts and the most significant UHI, when power station use lower temperature that it is really observed, and spent more fuel that is necessary







According to the analysis of the work parameters of Apatity power station (Jan-Feb 2014):

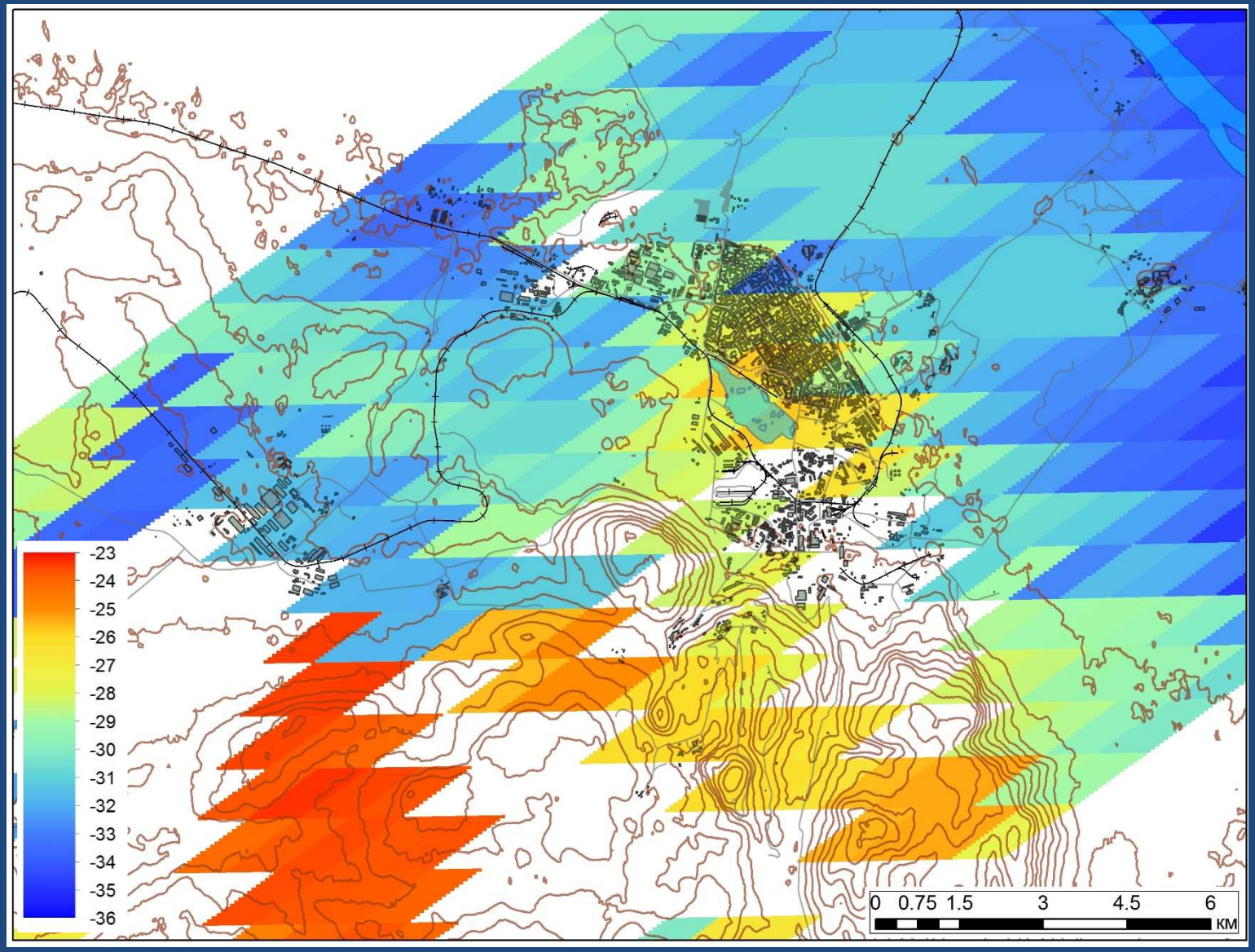
Cost of 1°C error:

Apatity (686 mWt):
≈ 1000 €/day

Norilsk (2691 mWt):
≈ 3900 €/ day

MODIS for Norilsk

TERRA 17 January 2014



MODIS for Norilsk

Mean data (TERRA) for November 2013 – January 2014