Investigation of the climate change within Moscow metropolitan area

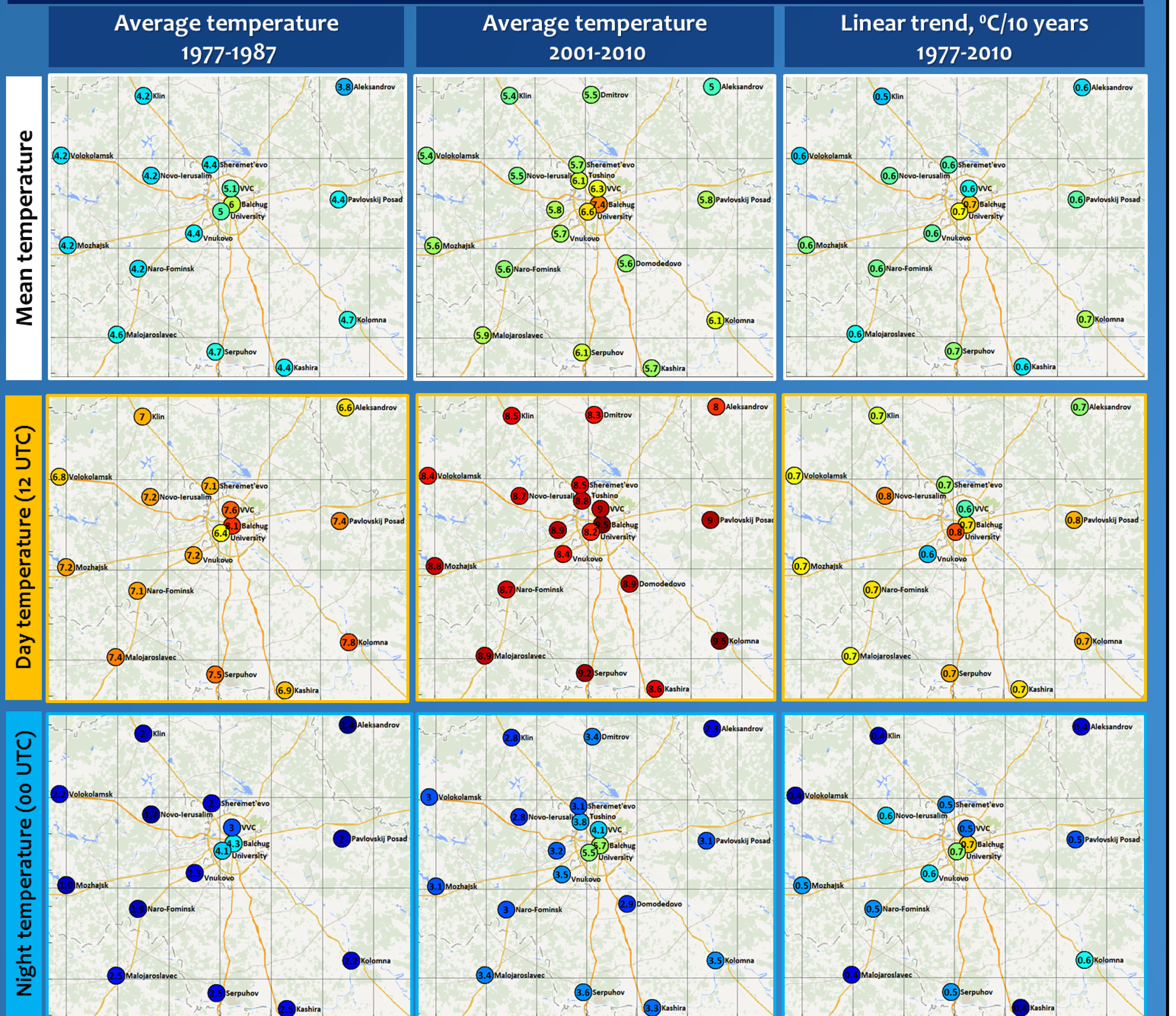
Mikhail Varentsov[(1)], Kristina Trusilova[(2)], Pavel Konstantinov[(1)], Timofey Samsonov[(3)]

[(1)] Lomonosov Moscow State University, Faculty of Geography, Department of Meteorology and Climatology, **mvar91@gmail.com**
[(2)] Deutscher Wetterdienst, Department of Climate and Environment Consultancy
[(3)] Lomonosov Moscow State University, Faculty of Geography, Department of Cartography and Geoinformatics

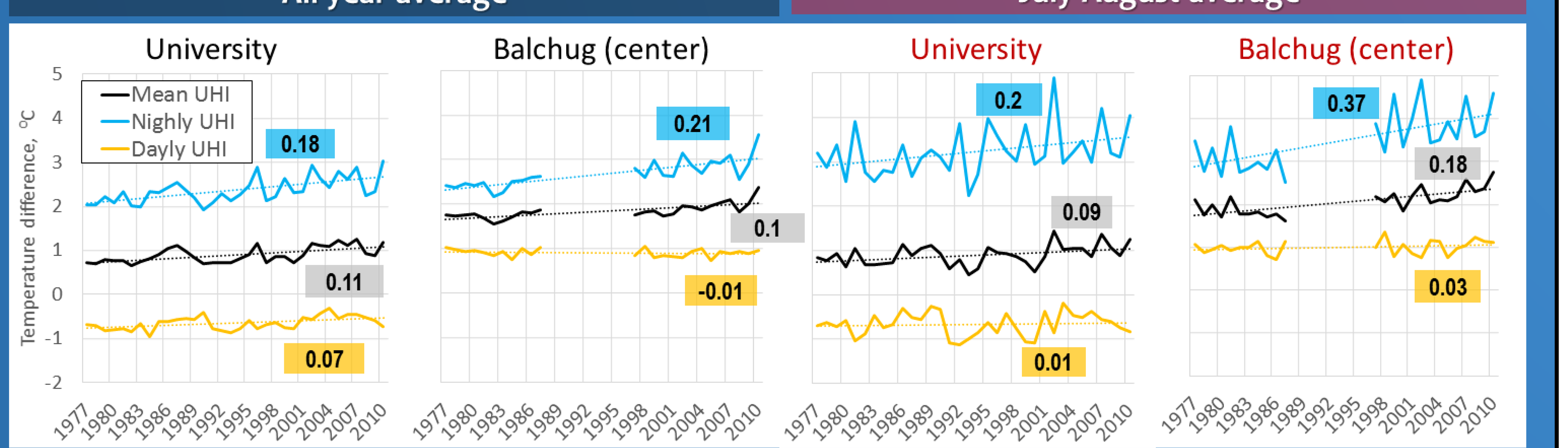
Observation data sources

Climate database for Moscow and Saint-Petersburg
63 stations in total, 49 st. for 2001-2010 , 41 st. for 1977-2010

Climate change in Moscow metropolitan area

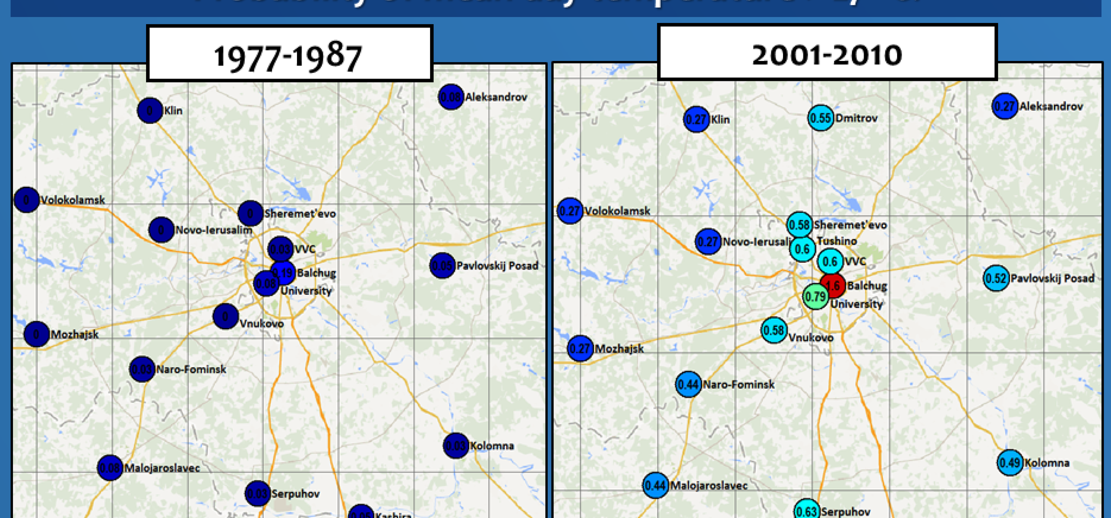


Changes of the UHI intensity, °C/10 years

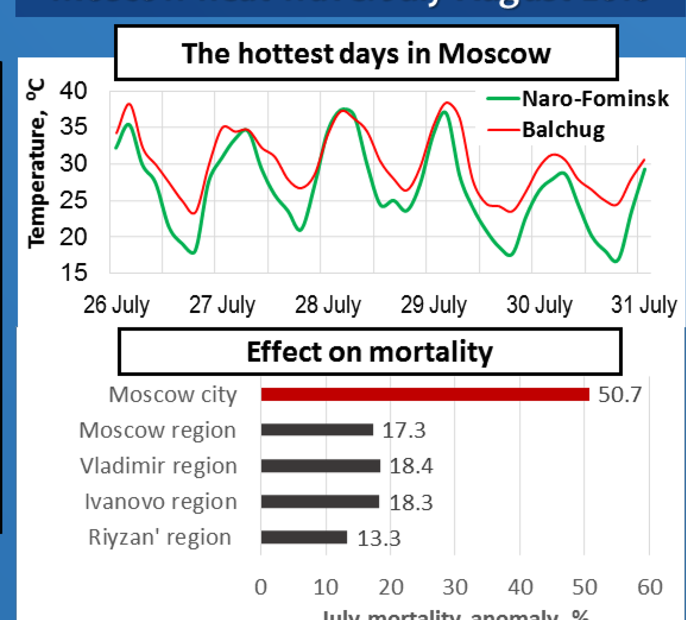


Extreme heat events

Probability of mean day temperature > 27 °C:



Moscow heat wave: July-August 2010



Abstract

As the urbanization continues worldwide more than half of the Earth's population live in the cities (U.N., 2010). Therefore the vulnerability of the urban environment – the living space for millions of people - to the climate change has to be investigated. It is well known that urban features strongly influence the atmospheric boundary layer and determine the microclimatic features of the local environment, such as urban heat island (UHI). Available temperature observations in cities are, however, influenced by the natural climate variations, human-induced climate warming (IPCC, 2007) and in the same time by the growth and structural modification of the urban areas. The relationship between these three factors and their roles in climate changes in the cities are very important for the climatic forecast and requires better understanding.

In this study, we made analysis of the air temperature change and urban heat island evolution within Moscow urban area during decades 1977-2010, while this urban area had undergone intensive growth and building modification allowing the population of Moscow to increase from 7 to 12 million people. Analisis was based on the data from several meteorological stations in Moscow city and surrounding territory. It shown that climate in Moscow region is rapidly warming, and warming rates, especially for night temperatures (00 UTC), are higher for urban stations – Balchug in city center and University in the south-west. Average warming rates for rural site are about 0.6 ⁰/10 years and for urban – about 0.7 ⁰/10 years. This allows to separate 'urban warming' trend as 0.1⁰/10 years. It should be noted that rates of urban warming are maximum for night temperature (up to 0.2 ⁰C) and especially – for night summer temperatures (up to 0.37 ⁰/10 years). The most dangerous effect of such warming is increasing of the number of days with extreme heat during the summer. For example, during the Moscow Heat wave (2010) the effect of the heat on mortality in Moscow was much higher than in nearby regions, probably because of heat island, which keeps temperature above the comfortable level not only during the day, but also at night. Our analysis shown, that during considered time period the probability of day-averaged temperature higher than 27 ⁰C in the city center has reached from 0.2 to 1.6%.

Because of the need for better understanding processed of observed climate change and prediction of probable climate changes and its consequences, we investigated the ability of climatic model COSMO-CLM to simulate extreme heat waves. Numerical experiments shown high sensitivity of the model to initial volumetric soil water content and also to surface parameters database: deferent combinations of this models leads to different sighs of average errors for daily-mean, day and night temperatures. Also it was shown that even for the best combinations of these parameters square error is higher than for reanalysis, which is used for boundary and initial conditions.

Several numerical experiments was launched version of model with urban parameterization, based on the urban canyon scheme (Masson, 2000, Trusilova, 2013). They shown that this parameterization is possible to reproduce average UHI intensity, but could't correctly simulate its diurnal variation with daily minimum and nightly maximum, which could be caused by the fact, that this parameterization resistances for heat and momentum don't depend on stratification conditions.

References:

- U.N. (2010), World Urbanization Prospects. The 2009 Revision.Rep., 1-47 pp, United Nations. Department of Economic and Social Affairs. Population Division., New York.
- IPCC (2007), IPCC Fourth Assessment Report: Climate Change 2007 (AR4) Rep.,Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- Masson V. A Physically-Based Scheme for the Urban Energy Budget in Atmospheric models// Bound. Layer Meteor. 2000. V. 94 (3). P. 357-397.
- Trusilova K., Früh B., Brienen S., Walter A., Masson V., Pigeon G., Becker P. Implementation of an Urban Parameterization Scheme into the Regional Climate Model COSMO-CLM. J. Appl. Meteor. Climatol., 52, 2296–2311.

Acknowledgment

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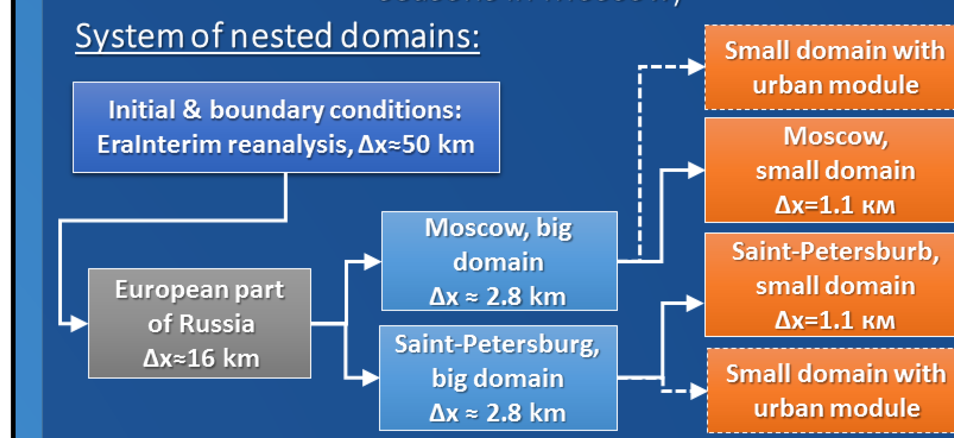
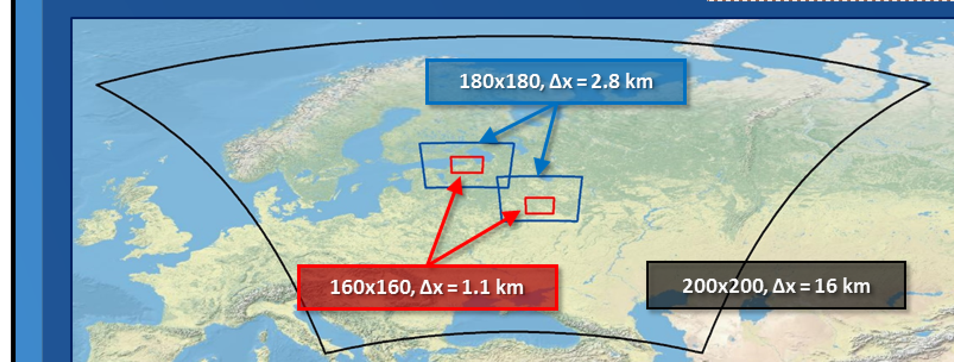
Numerical experiment with COSMO-CLM model

Integration periods: May – August of 2002 and 2010 (years with the warmest summer seasons in Moscow)

System of nested domains:





Some statistics for rural stations:

Model vs observations, statistics for absolute values

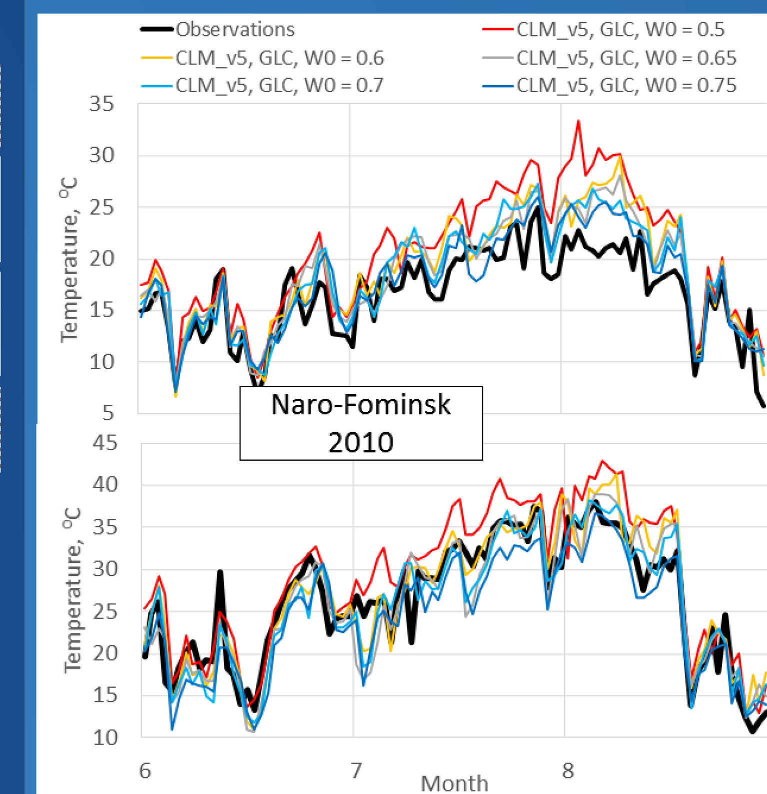
Year		ERA Interim Reanalysis	COSMO-CLM: GLC, optimat W0, 16 км	GLC, optimat W0, 2.8 км	GLC, optimat W0, 1.1 км	Ecoclimap, 16 км	Ecoclimap, 2.8 км	Ecoclimap, 1.1 км
2002	ΔT	0.36	-1.19	-0.12		-1.00	-0.04	0.12
	ΔT night	0.96	1.39	1.96		1.54	2.02	2.03
	ΔT day	0.01	-2.99	-1.32		-2.74	-1.27	-1.01
	RMSE	1.37	3.44	3.07		3.12	2.83	2.79
2010	ΔT	0.47	-0.02	0.91	0.96	-0.48	0.46	0.45
	ΔT night	0.89	1.65	2.04	2.00	1.23	1.73	1.67
	ΔT day	0.35	-1.04	0.51	0.54	-1.55	-0.06	-0.08
	RMSE	1.51	3.01	3.05	3.02	3.07	3.02	3.03

Model vs observations, statistics for relative values
('microclimatic' difference $\Delta T=T-T_{base}$, base station is Naro-Fominsk)

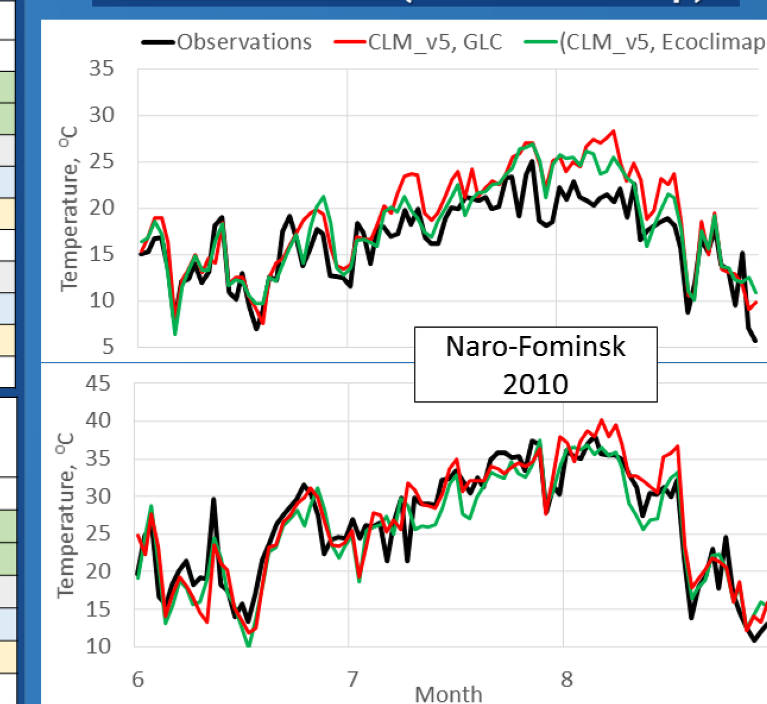
Year		ERA Interim Reanalysis	COSMO-CLM: GLC, optimat W0, 16 км	GLC, optimat W0, 2.8 км	GLC, optimat W0, 1.1 км	Ecoclimap, 16 км	Ecoclimap, 2.8 км	Ecoclimap, 1.1 км
2002	ΔT	0.28	-0.35	-0.18		-0.19	-0.14	-0.23
	ΔT night	1.48	1.88	1.87		1.84	1.83	1.80
	ΔT day	0.74	-0.32	-0.19		-0.34	-0.24	-0.32
	RMSE	-0.07	-0.52	-0.17		-0.17	-0.05	-0.11
2010	ΔT	0.14	-0.42	-0.38	-0.40	-0.60	-0.49	-0.52
	ΔT night	1.42	1.85	1.87	1.83	1.92	1.93	1.95
	ΔT day	0.45	-0.12	-0.11	-0.12	-0.23	-0.19	-0.24
	RMSE	-0.25	-0.68	-0.56	-0.57	-0.80	-0.65	-0.67

The search for the optimal model parameters

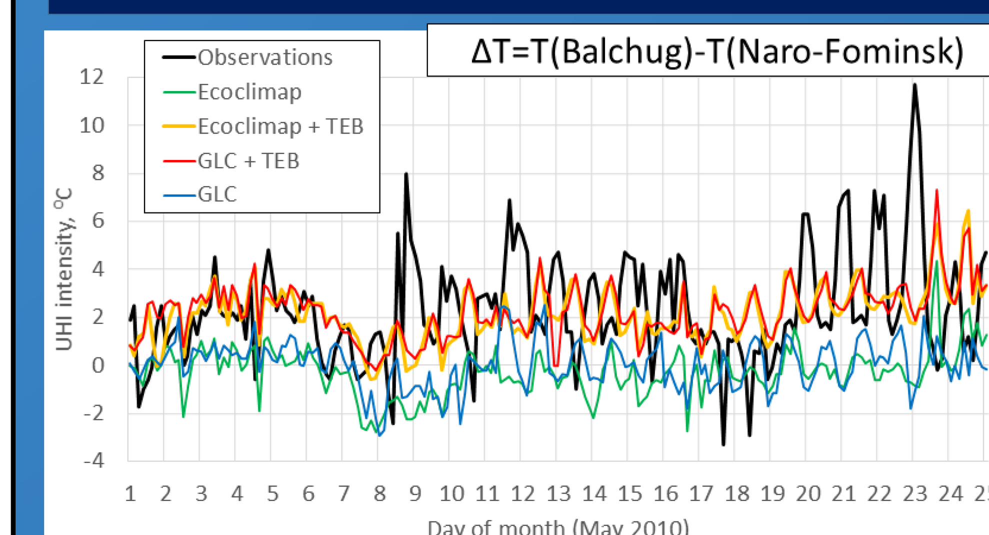
Sensivity to the initial soil volumetric moisture content:



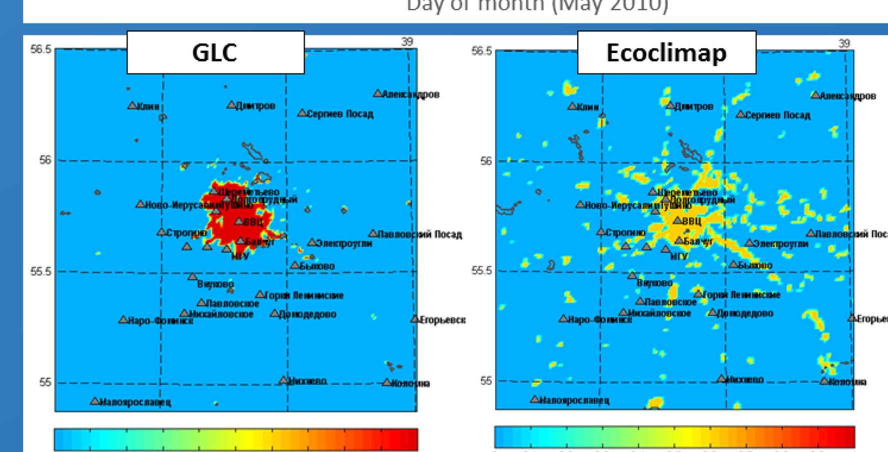
Sensivity to the choice of surface database (GLC vs Ecoclimap):

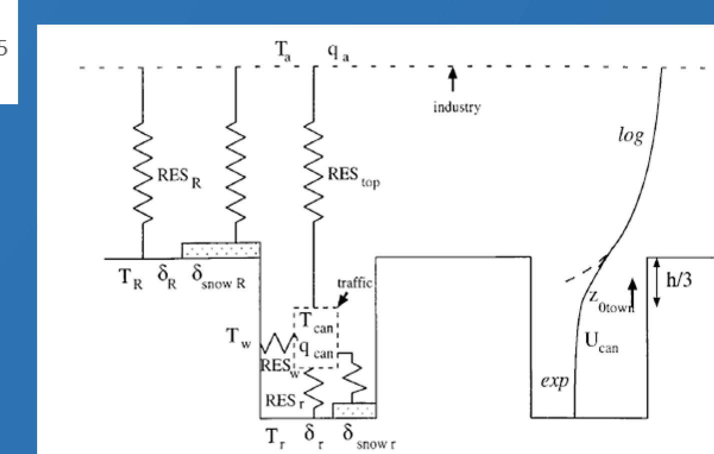


Simple tests with urban module



- TEB-scheme (Masson, 2000), implemented into the model code (Trusolova, 2013)
- Urban fraction from Ecoclimap/GLC
- Building fraction: 0.5
- Building height: 25 m
- H/W ratio: 1.0
- Typical for Moscow thermophysical parameters





Fluxes in urban canyon in TEB parameterization (Masson, 2000)