Adaptation of the COSMO-CLM model to the IAP RAS computational capabilities for assessing the impact of energy consumption on the urban climate

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Abstract

Various modifications of the COSMO models are now widely used both in scientific research of mesoscale meteorological and climatic processes as well as in weather forecast operational practice.

This presentation shows the experience on the adaptation of the COSMO_CLM model with the TERRA_URB scheme for assessing the impact of energy consumption on the urban climate using limited computational capabilities.

The conducted tests show the possibility to perform calculations of the daily and seasonal meteorological characteristics of the Moscow agglomeration considering anthropogenic impacts on urban areas using computational capacities of the IAP-type cluster.

Introduction

The problem of a cities energy supply is getting more and more important due to an urbanization processes acceleration.

An energy demand for heating, ventilation and cooling depends upon the local climate conditions.

Climate of megacities is impacted not only by the global processes but also by some local interactions like “heat islands” appearing due to urban impact on the environment.

An accounting for a feedback between the climate and the energy system is still quite a challenge.

The RSF project “Analysis of an impact of the regional climate change on the residential and commercial energy consumption of Russian megacities” has goal to implement regional models of urban climate and city energy demand for better understanding applied climate parameters trends and changes influence energy consumption of megacities.

COSMO_CLM

For RSF project goals was chosen the non-hydrostatic regional model of the Consortium for Small-Scale Modelling in Climate Mode (COSMO_CLM).

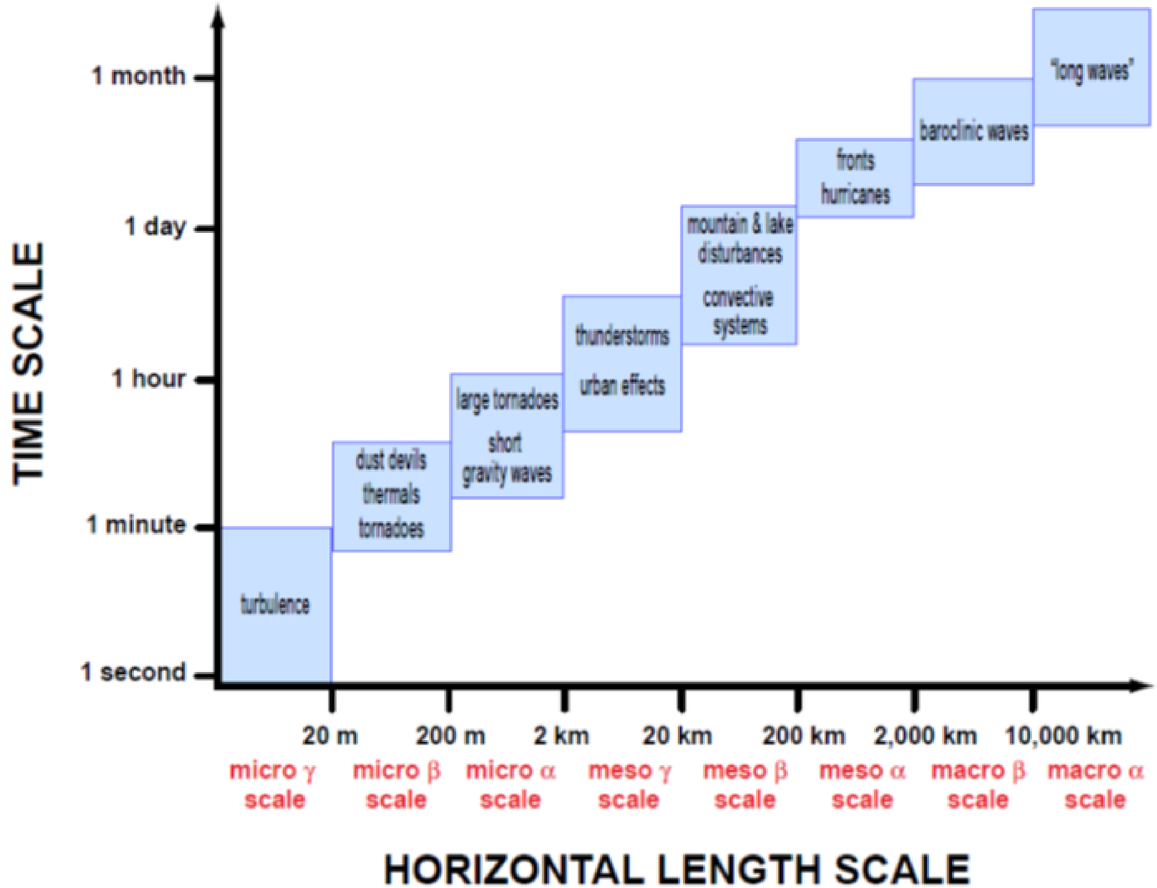
This model was chosen due to many reasons – excellent guide and documentation, possibility to became Consortium member organization, more than decade experience of usage COSMO model in Russia.

COSMO model describes the meso-β scale meteorological processes - from 20 to 200 km and meso-γ processes - from 2 to 20 km within different size domains.

COSMO has been designed for both operational numerical weather prediction and various scientific applications.

COSMO_CLM version is most useful model for studying the effects of urbanization on the regional climate.

The urban heat island in Berlin, Moscow and some other large European cities has been successfully simulated by COSMO_CLM with different surface energy balance schemes.



Urban effects are situated in the middle of the characteristic time and horizontal length scales of atmospheric processes and for better understanding energy consumption effects within large urban agglomeration is necessary to consider a wide range of atmospheric processes.

Approaches and capabilities

The IAP Laboratory of mathematical ecology passed the registration in the COSMO association in the COSMO-CLM and SOILVEG groups, which allowed to begin work on adaptation of the COSMO-CLM model and energy balance calculation schemes on the urban surface of the TERRA_URB type to the capabilities of the IAP cluster.

IAP cluster consists of two logical parts:

The first one - 8 servers SR1435VP2, each of which contains two dual-core Xeon processors with a frequency of 3 GHz. The peak performance of this part of the cluster is 3.7 Gflops.

The second part is a single Intel® S5520UR server, consisting of two quad-core Intel Xeon E5530 processors with a frequency of 2.4 GHz. The peak performance of this part of IAP cluster is 4.8 Gflops.

The cluster has a 64-bit operating system CentOS 5.2 Linux, as well as the necessary utilities and compilers.

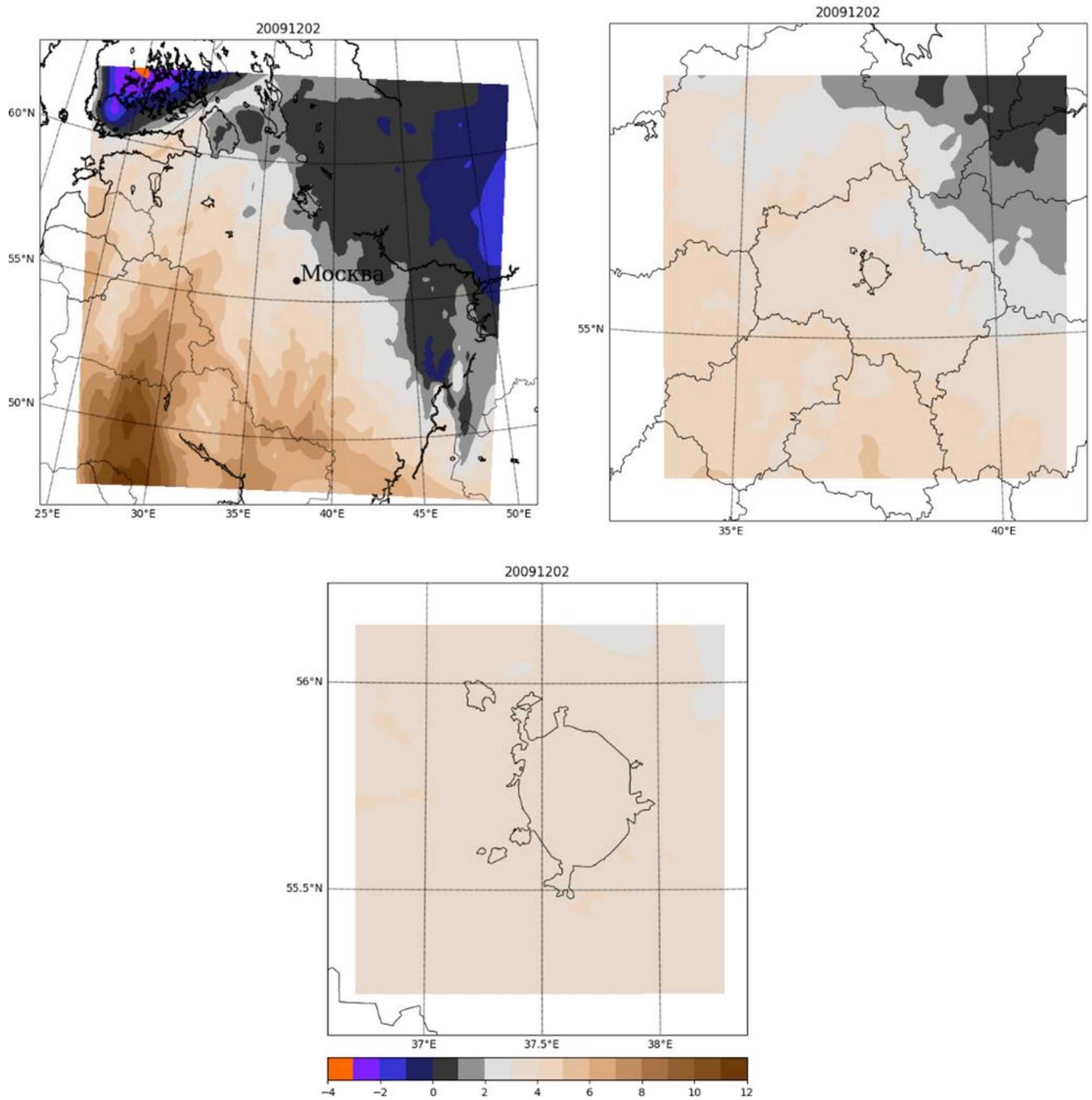
Preliminary tests

Test calculations were successfully carried out on three nested domains in the European part of Russia.

Each of these domains contains 10,000 cells of a horizontal grid, corresponding to a size of 17x17 km, 5x5 km and 1x1 km, 40 layers in the atmosphere and 9 layers in the underlying layer.

Calculating the day for these domains using two quad-core processors of the IAP cluster takes approximately 10, 30 and 180 minutes of computational time, respectively.

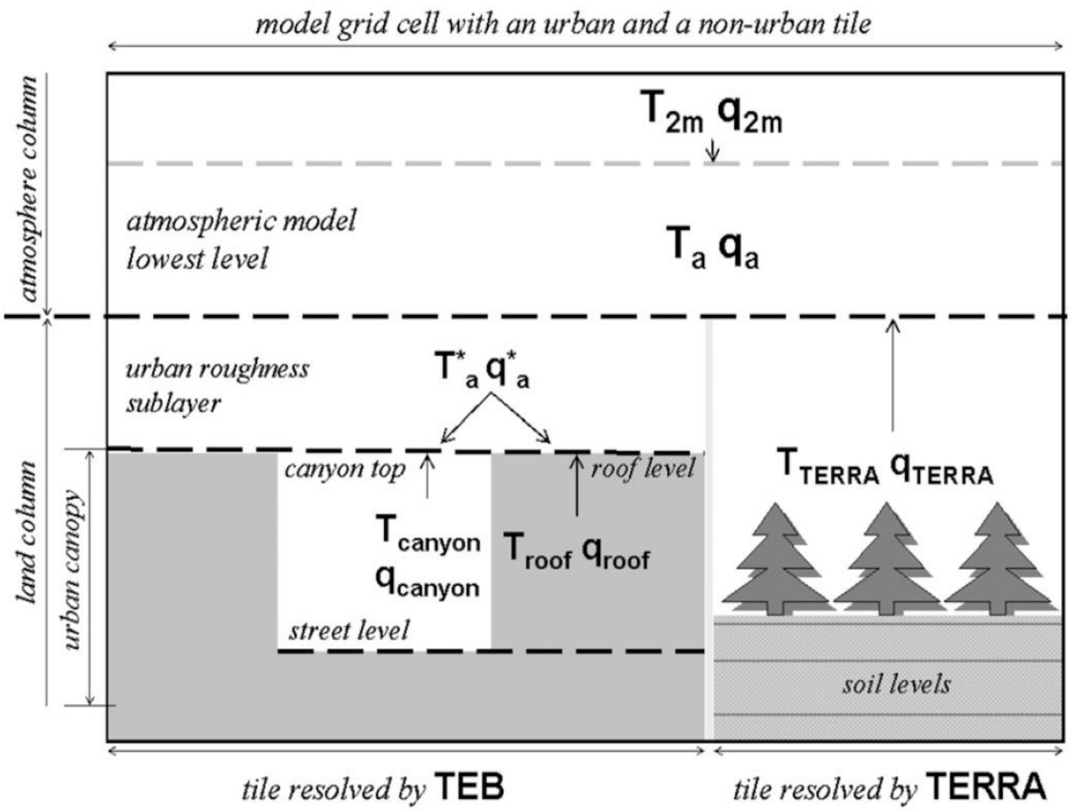
The long calculation time for the smallest domain is associated with the need to use a small-time step.



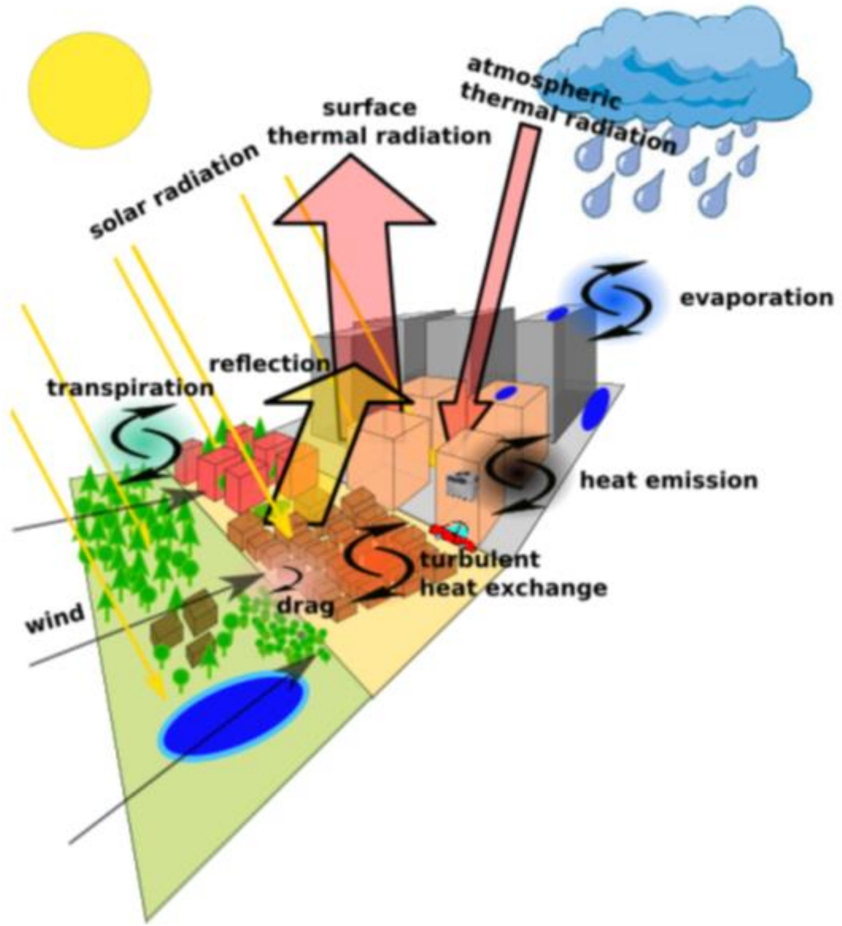
The air temperature modeling teat for three nested domains. December 2, 2009.

Surface energy balance schemes

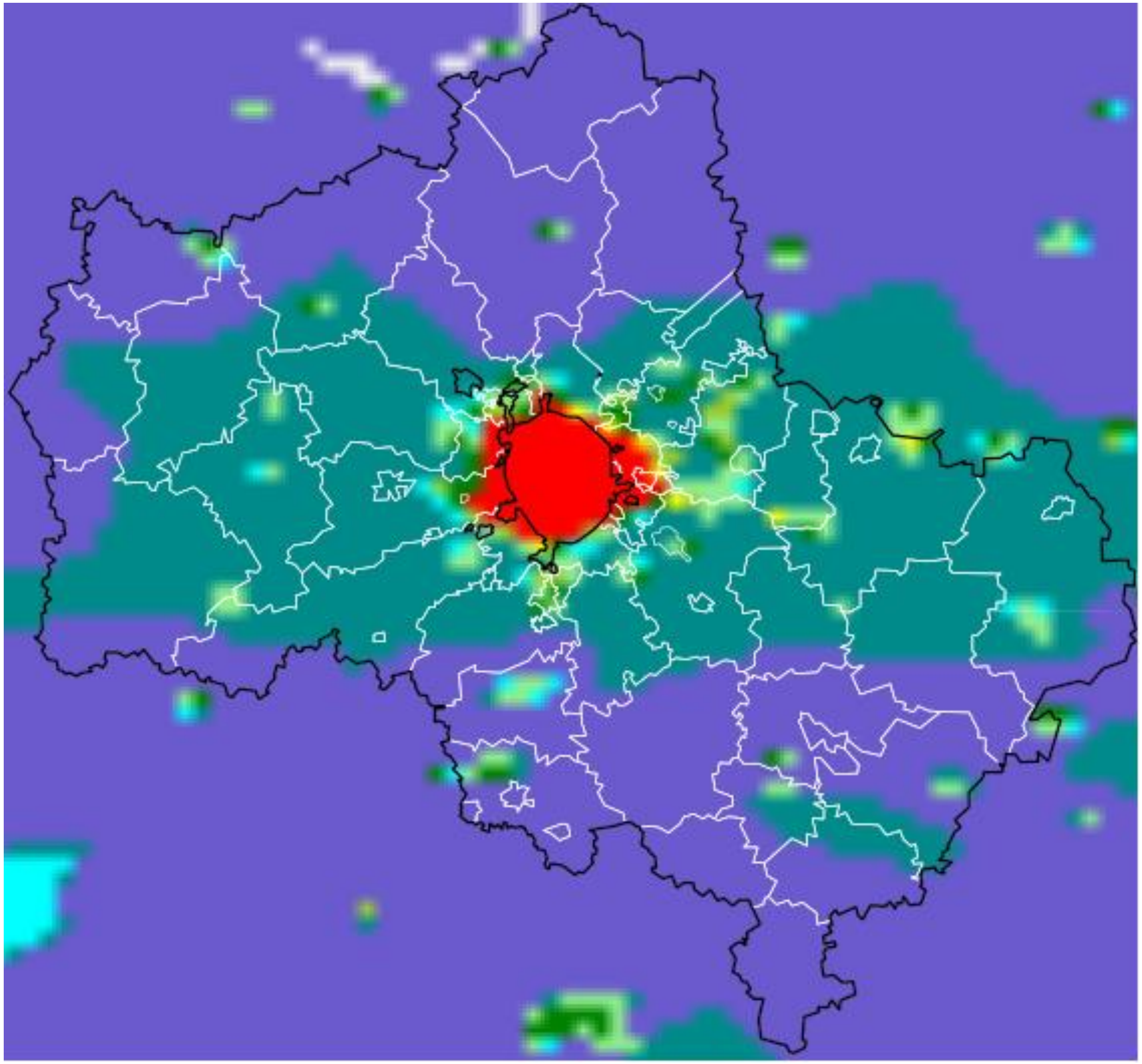
COSMO_CLM models are using some different schemes for surface energy fluxes parametrization:
SOILVEG,
TEB (Town Energy Balance),
BEP (Building Energy Parameterization),
TERRA_ML, etc.



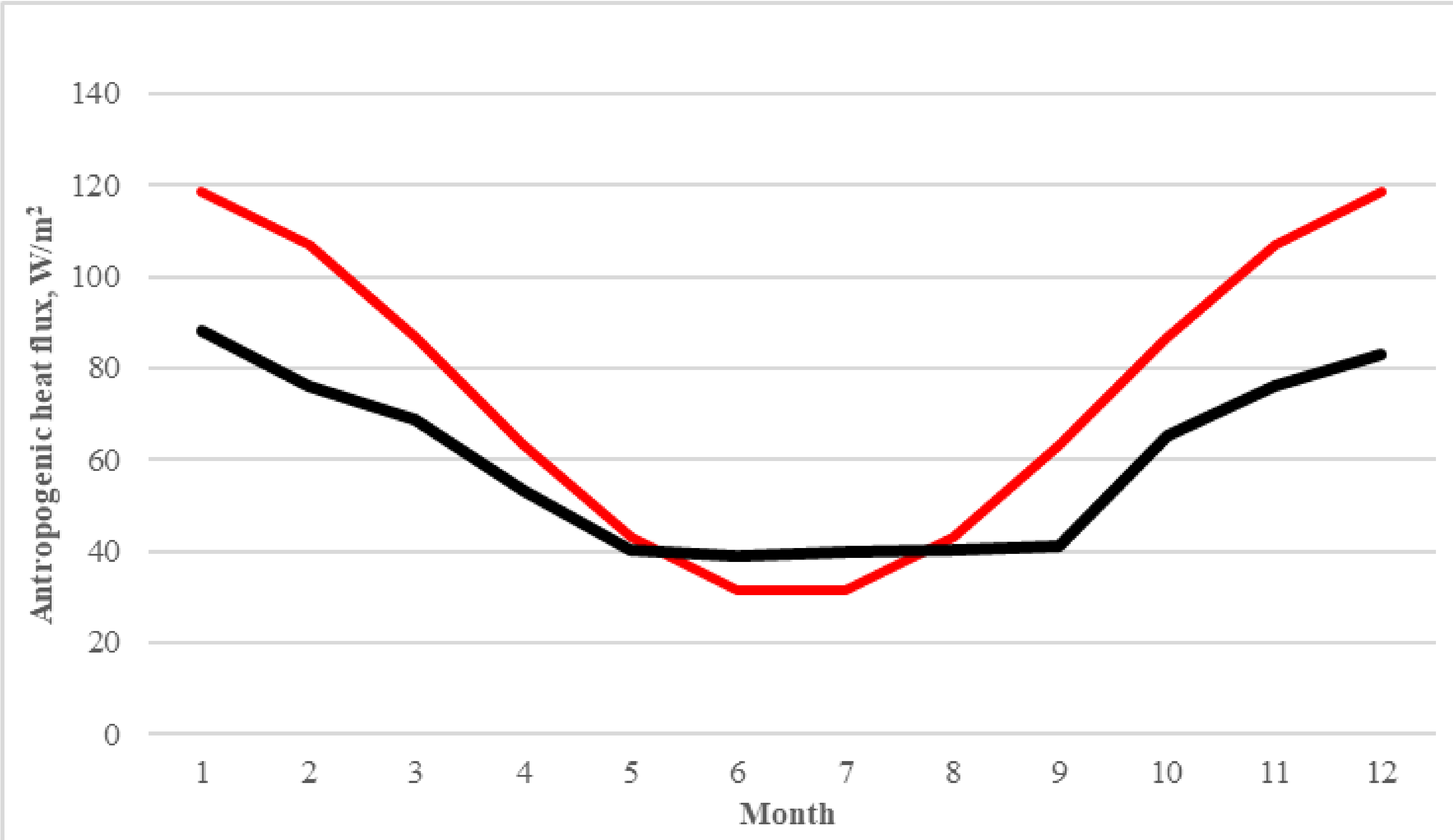
TERRA_URB



The urban-canopy land-surface scheme TERRA_URB for energy fluxes parametrization in the COSMO_CLM model made by medication the soil-vegetation module TERRA_ML.



Map of mean AHF value in Moscow region



The annual cycle of Moscow AHF

(Red line – Flanner, 2009, black – energy demand data)

Formulation of numerical modeling

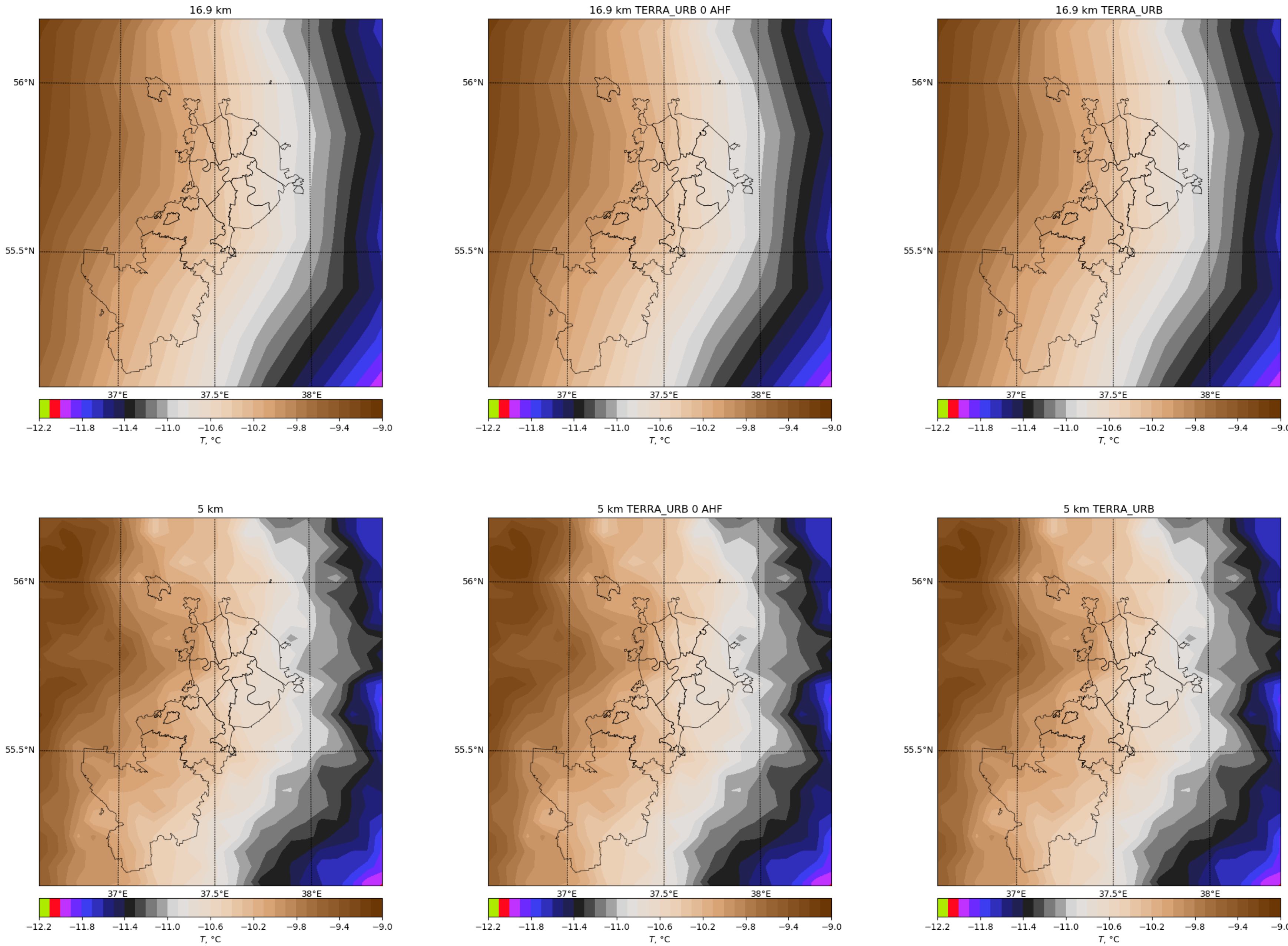
The simulation was performed in three stages: 1) without TERRA-URB module; with TERRA-URB - 2) without anthropogenic heat flux (AHF) and 3) fully functional.

Two domains were used. Each of these domains contains 10,000 cells of a horizontal grid, corresponding to a size of 17x17 km and 5x5 km, 40 layers in the atmosphere and 9 layers in the underlying layer. Center of both domains is located at the point with coordinates 37.5°N 55.7°E.

Calculating the day for these domains using two quad-core processors of the IAP cluster takes approximately 10 and 30 minutes of computational time without TERRA-URB and 11 and 35 minutes of computational time with TERRA-URB.

Numerical modeling results (next slides)

	Without TERRA	TERRA_URB without AHF	TERRA_URB with AHF
Large cells 17x17 km	1	2	3
Small cells 5x5 km	4	5	6



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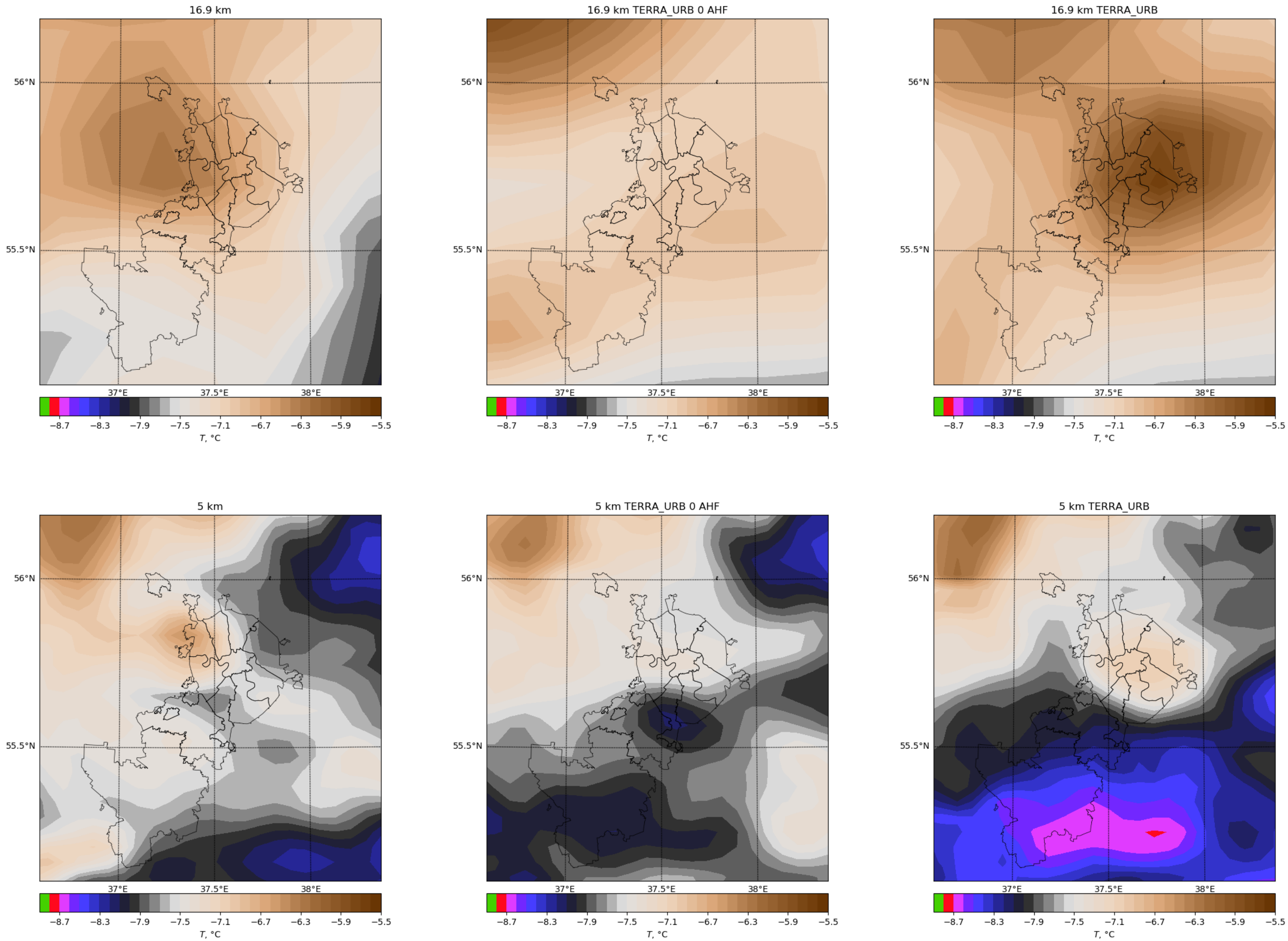

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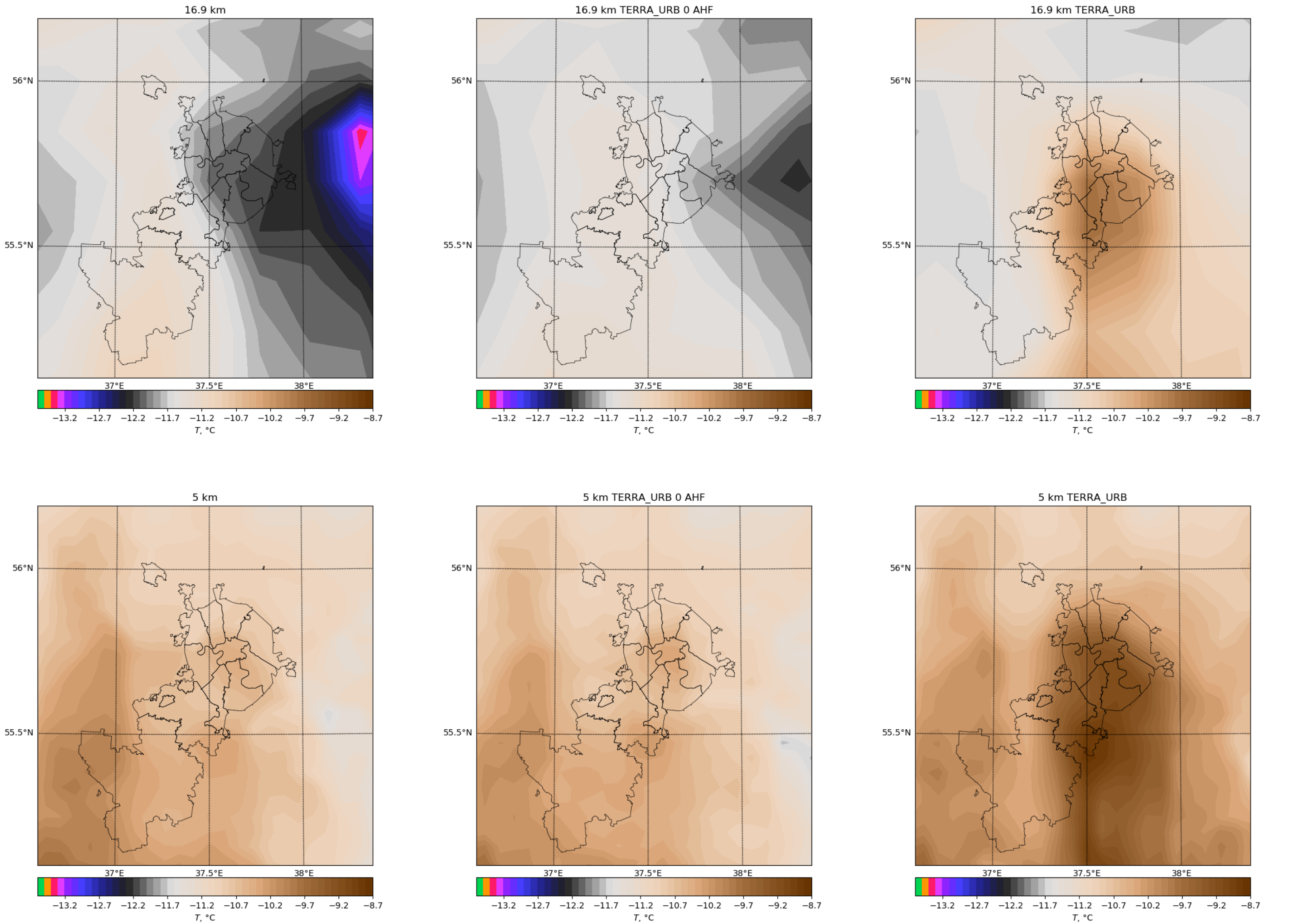

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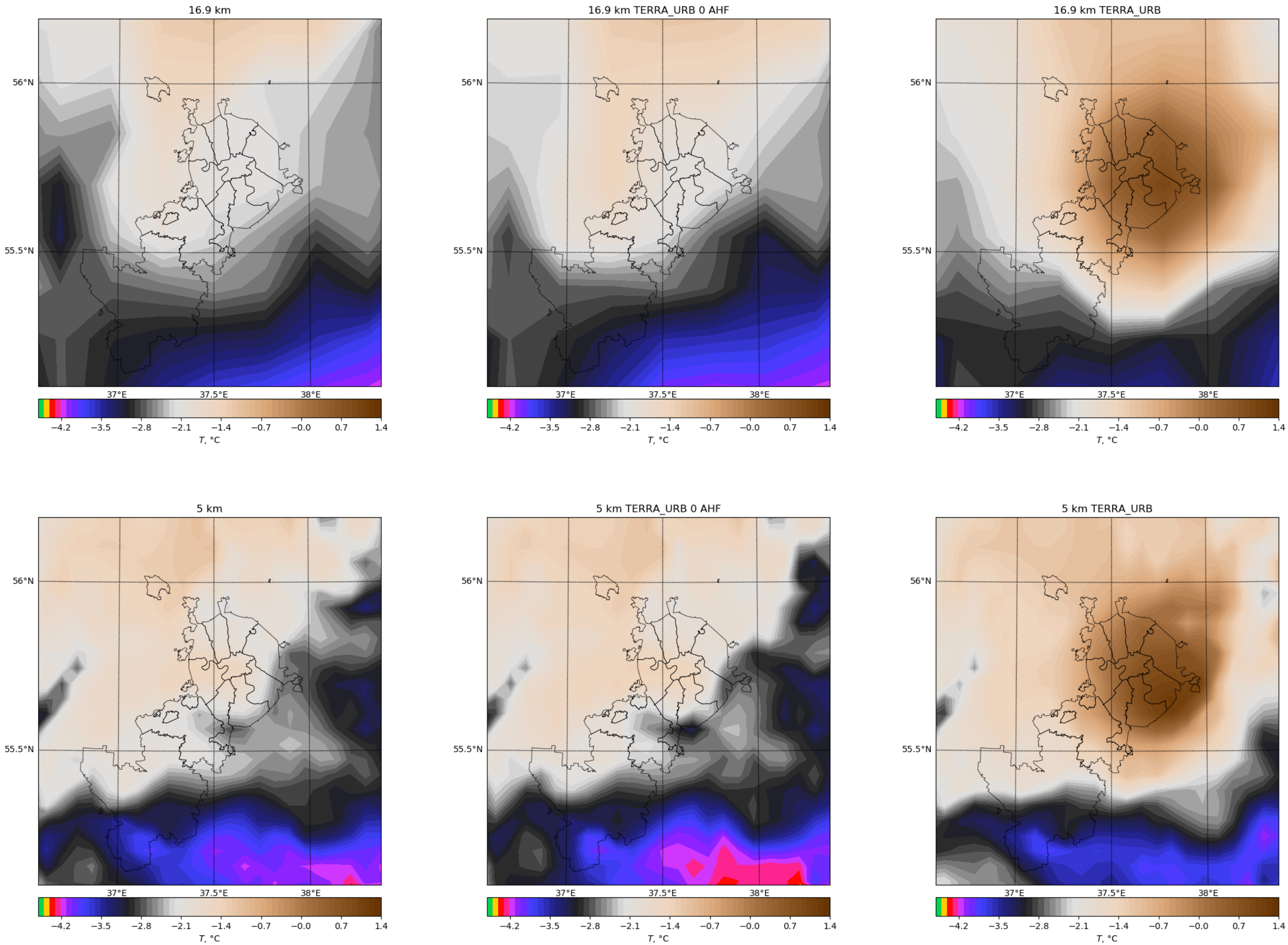

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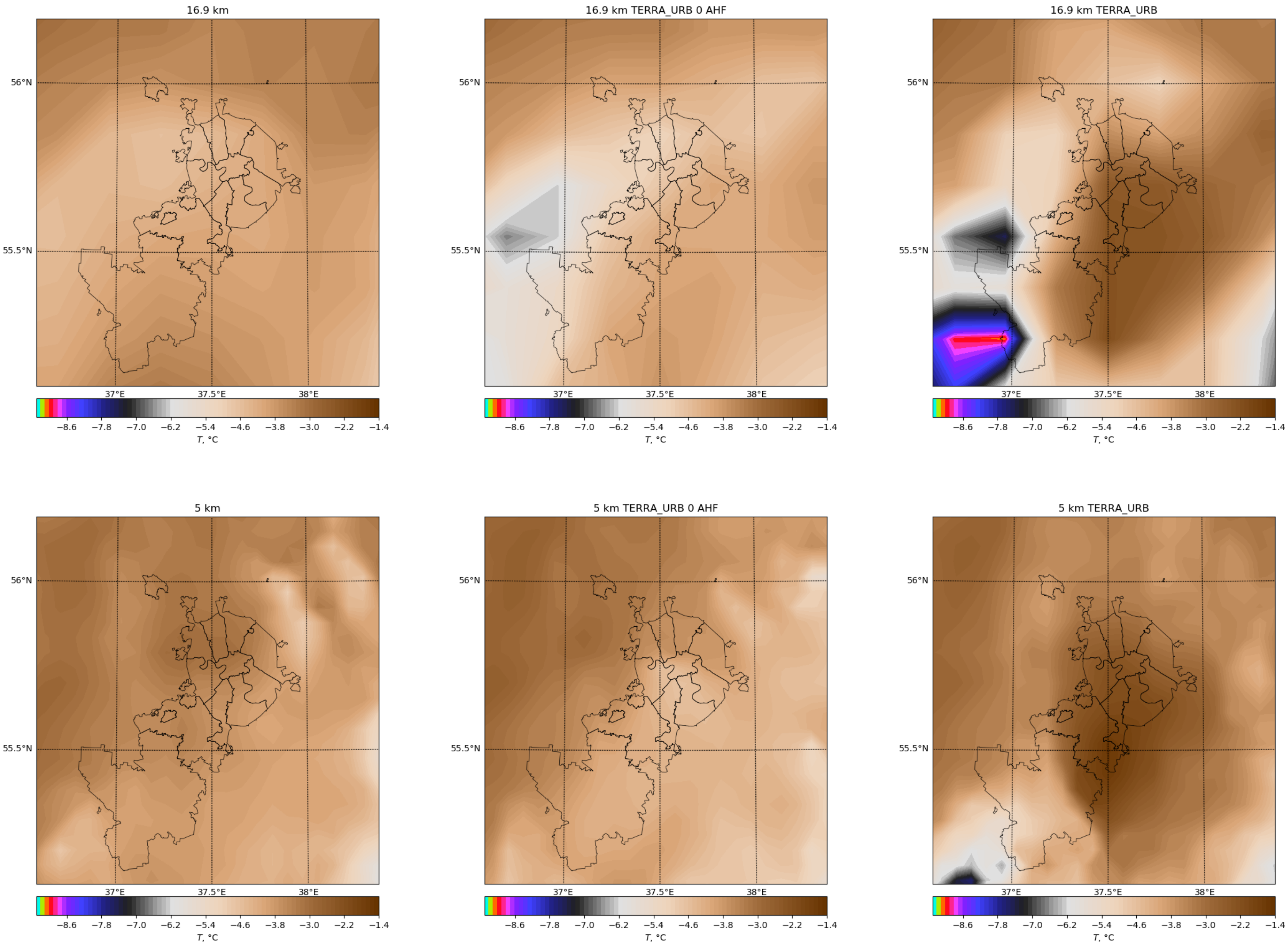

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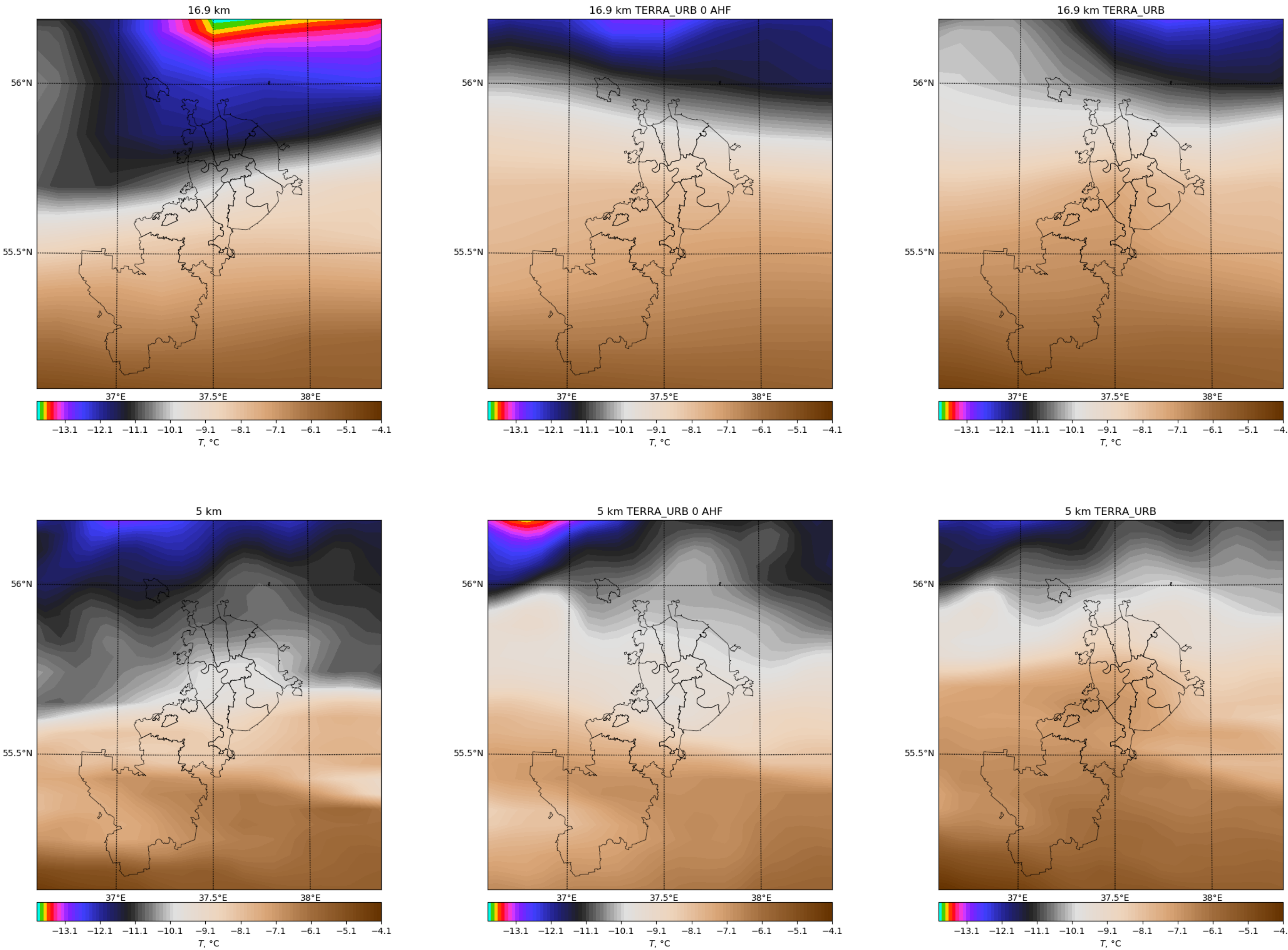

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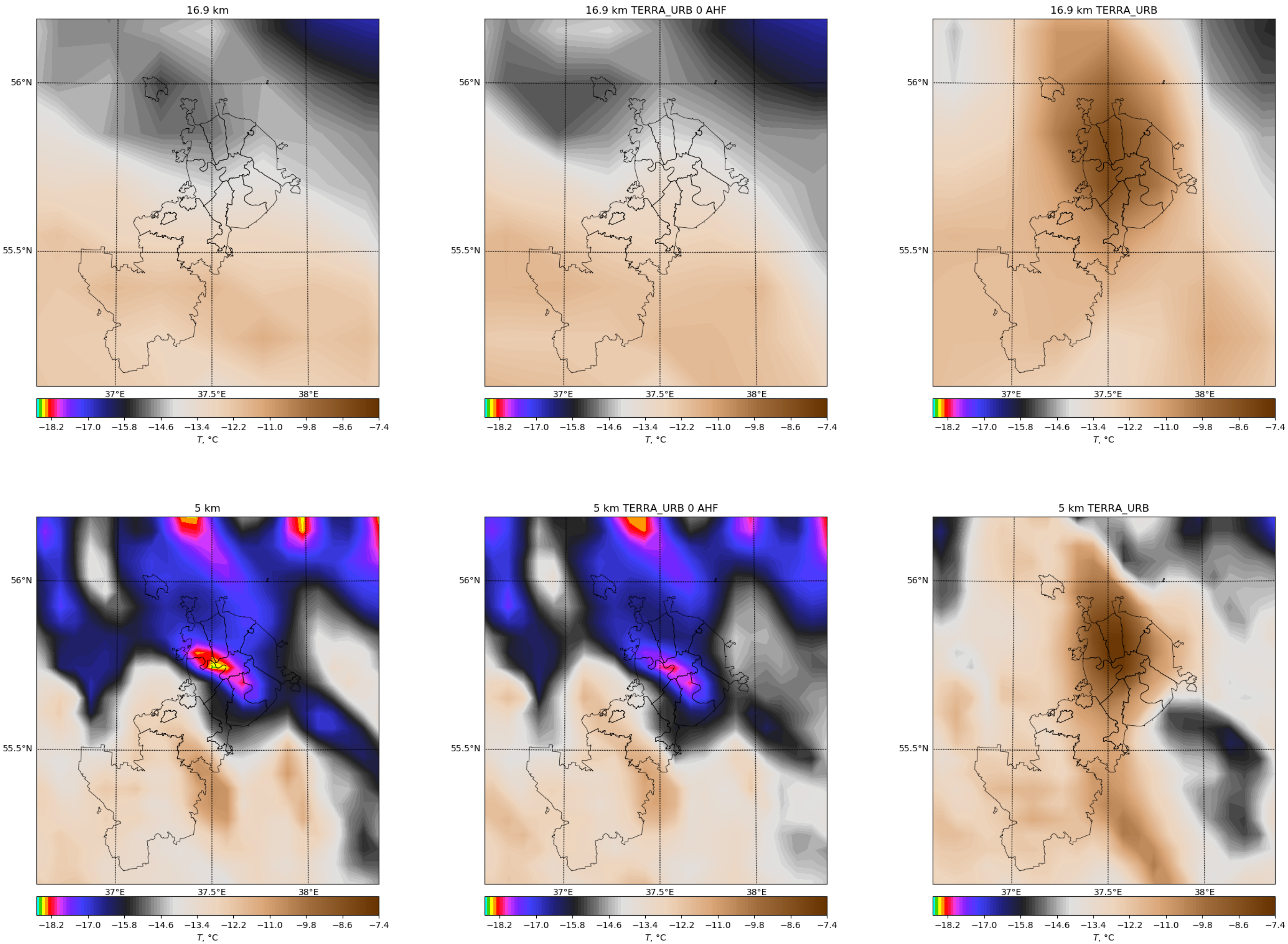

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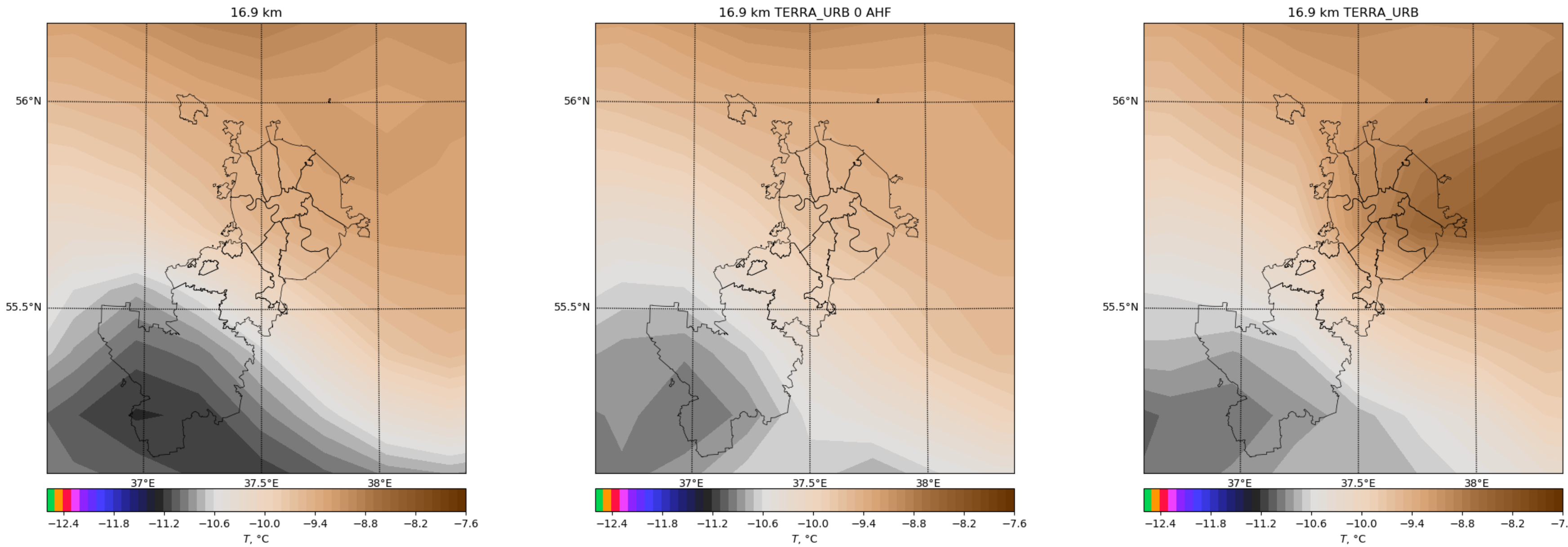

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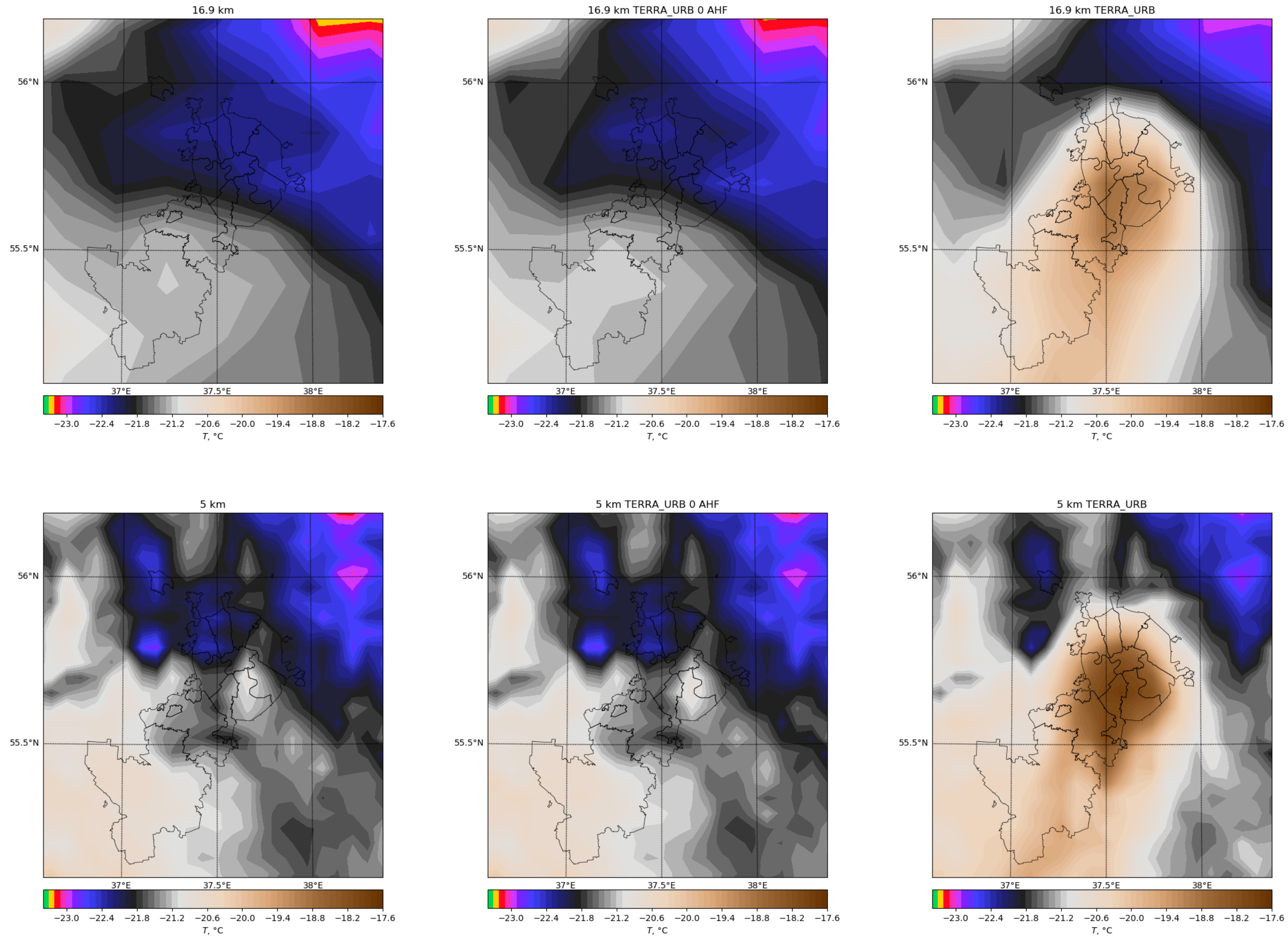

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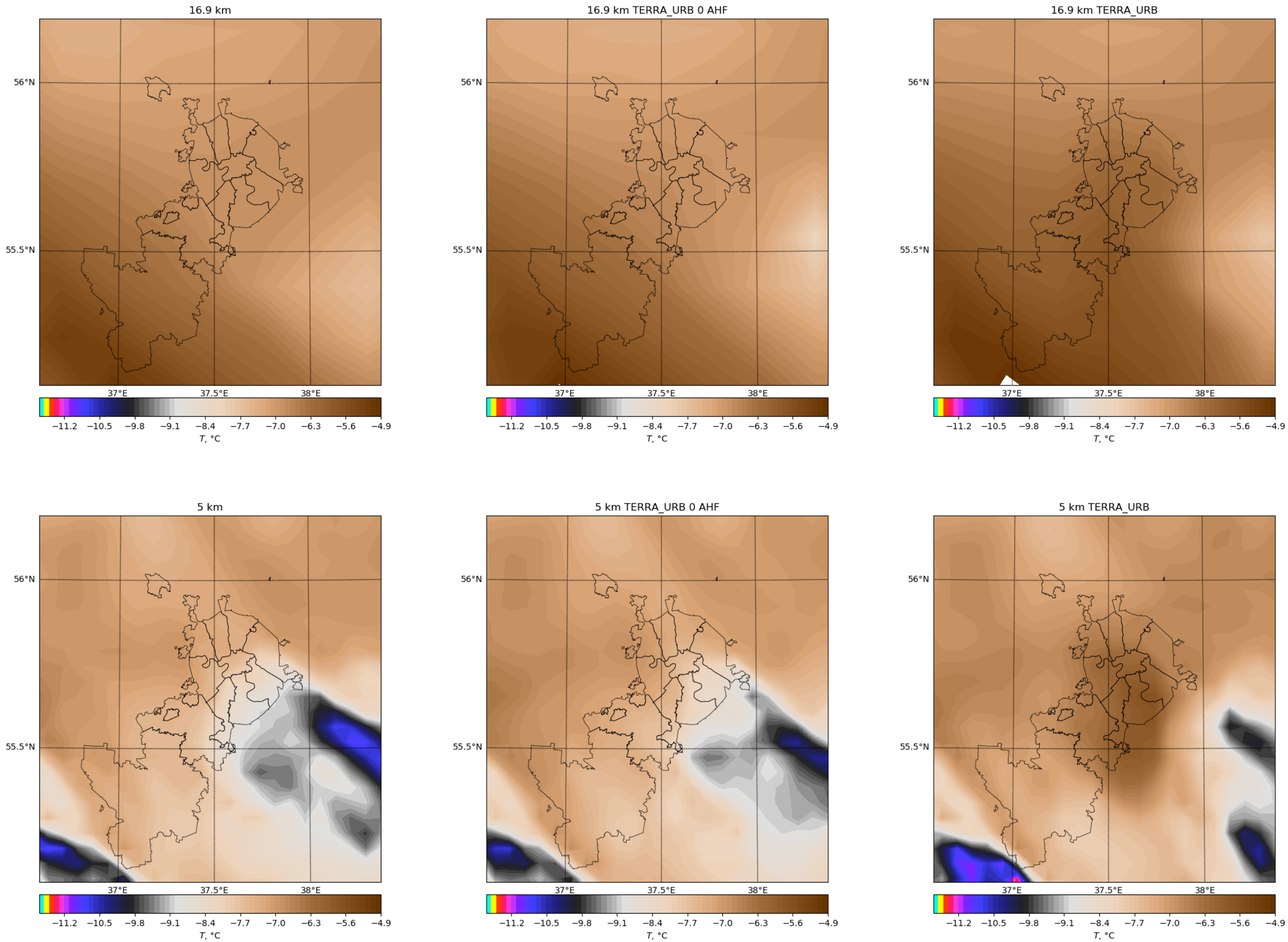

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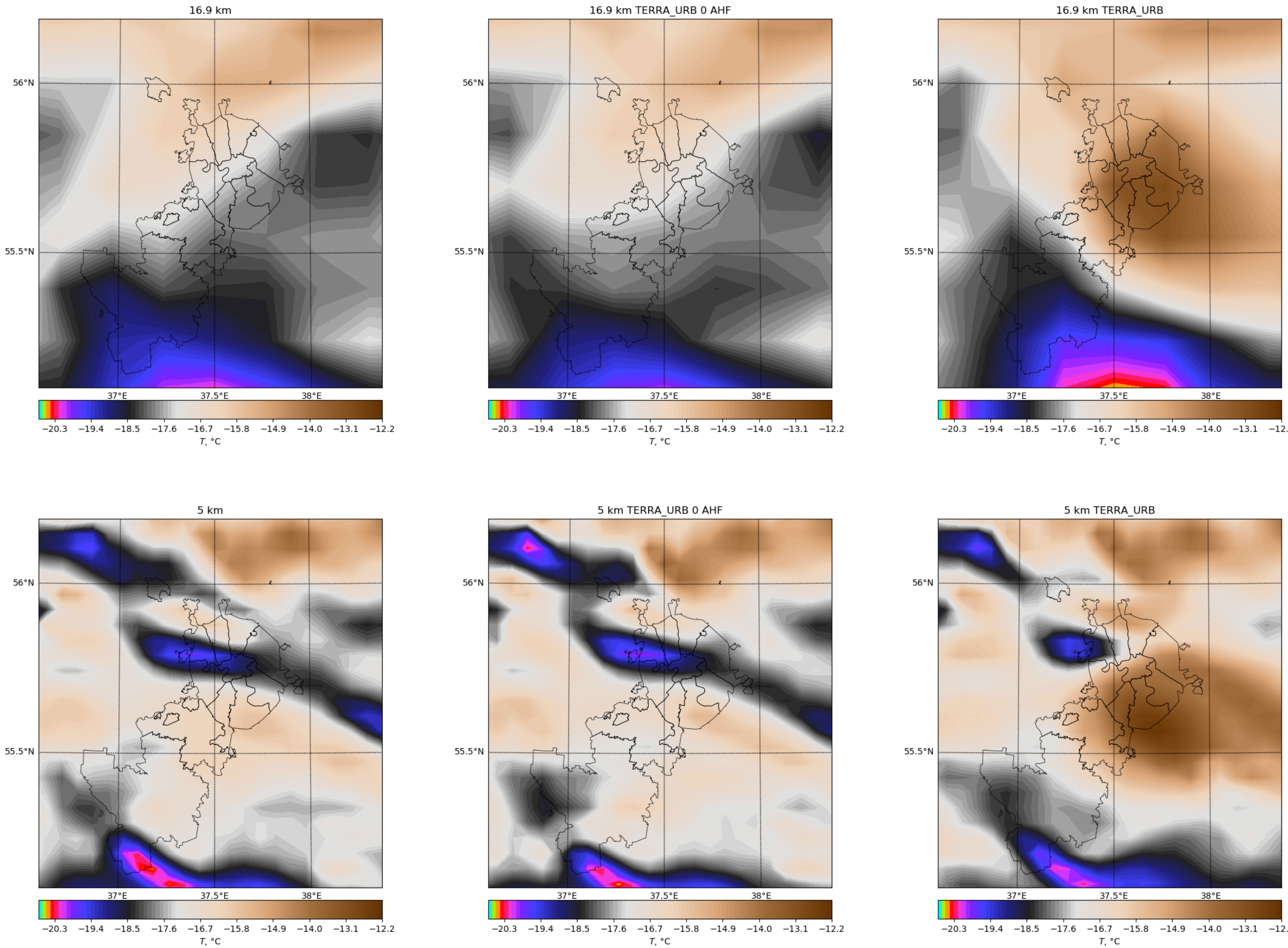

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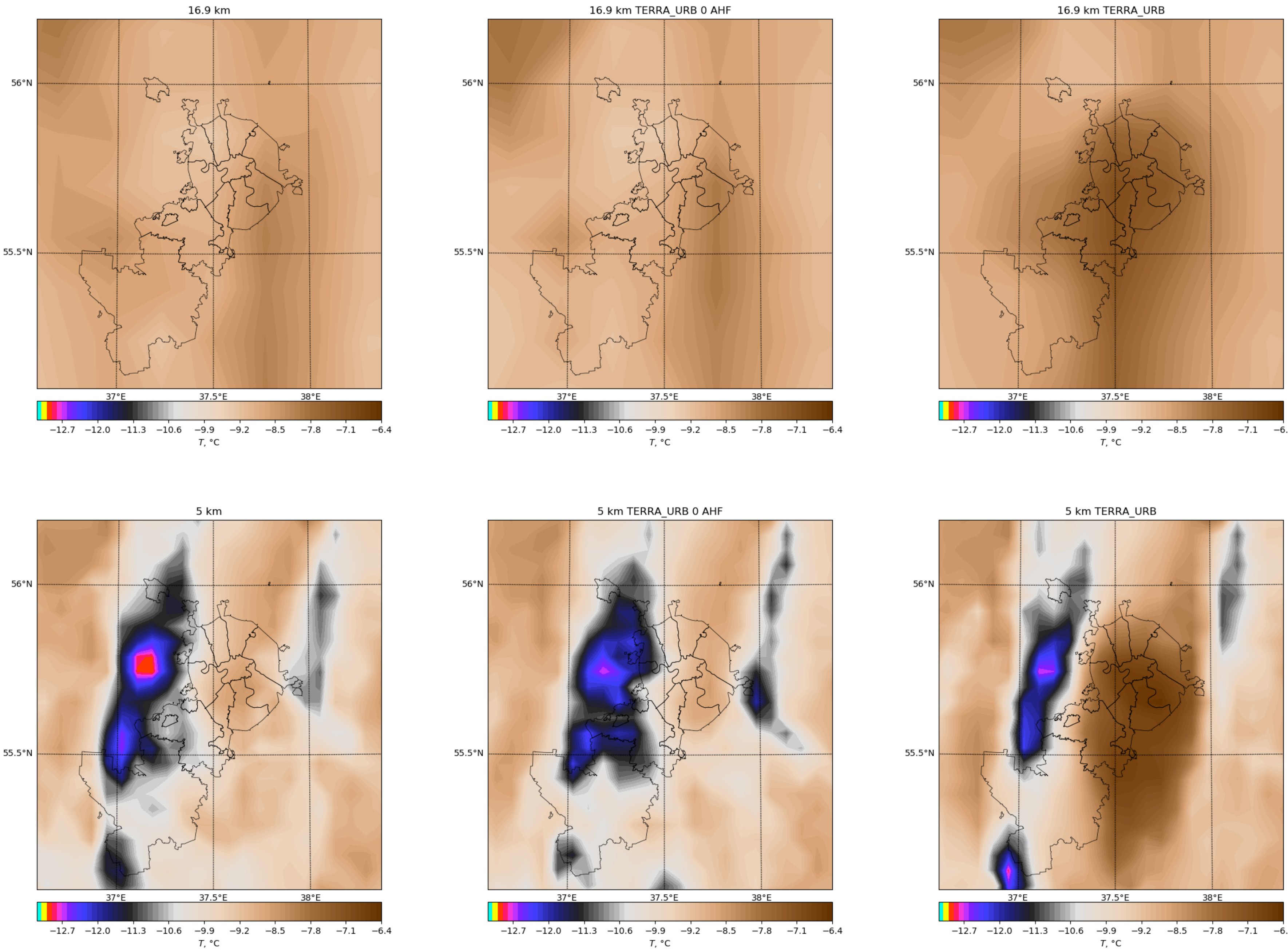

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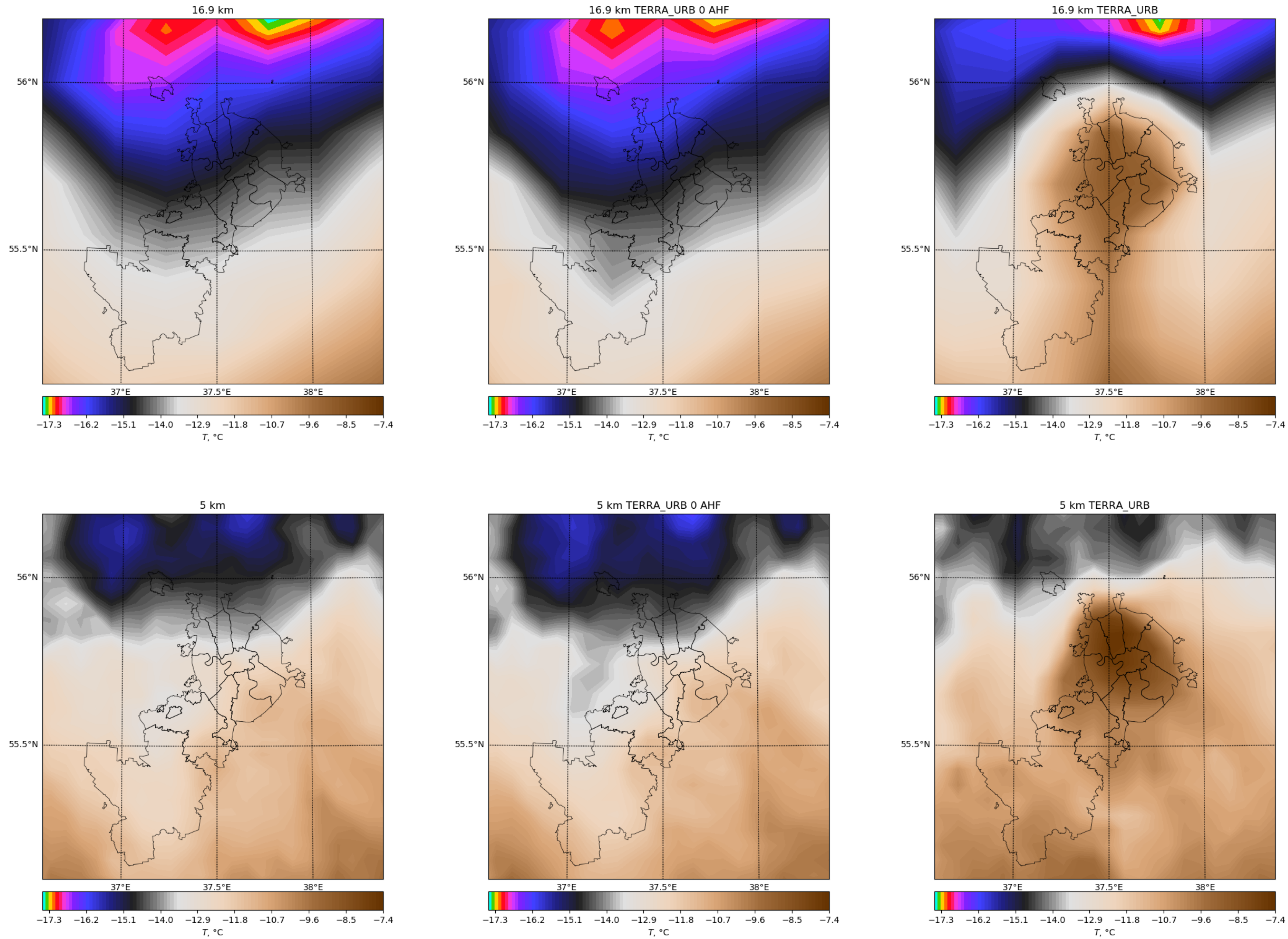

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Conclusion

It is shown the possibility to perform modelling of the meteorological characteristics of the Moscow agglomeration and other Russian large cities using COSMO-CLM model with TERRA-URB scheme and computational capacities of the IAP-type cluster.

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