Activity in Interpretation and Applications in COSMO

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The 42nd EWGLAM and 27th SRNWP Meeting
Online, 2nd of October 2020

New COSMO Priority project:
MILEPOST: MachIne LEarning-based POSTprocessing

- **Project leader** Andrzej Mazur (IMGW, Poland)
- **Project Duration**: *Start 09.2020 – End 08.2022 (two COSMO years, with the possibility of extension)*

The main goal of the Project is to provide COSMO community with new and/or advanced and elaborated methods of post-processing which would allow the best possible approximation of the forecast to the actual future state of the atmosphere

New COSMO Priority project:
MILEPOST: MachIne LEarning-based POSTprocessing

CONSORTIUM FOR SMALL SCALE MODELING COSMO

- **Task 1. General survey of Machine Learning (ML) including advantages and limitations**
- **Task 2. Set-up and application of ML techniques for post-processing**
- **Task 3: Results of ML-based post-processing and verification. Comparison setup to establish common evaluation framework**

Deliverables:

Common verification dataset to be prepared and disseminated, common verification results for various elements/setups

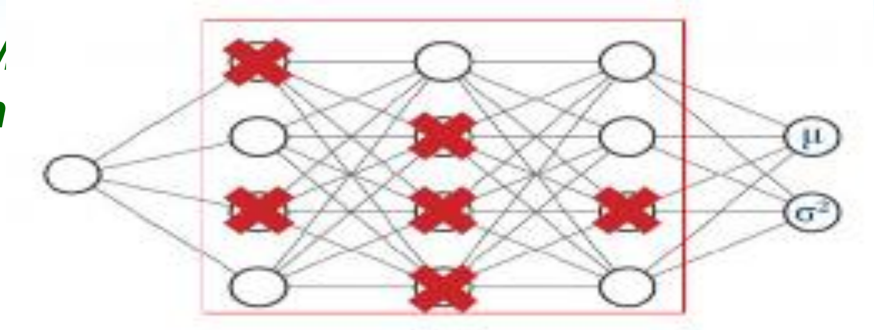
Contributors:

- **MeteoSwiss – Daniele Nerini, Daniel Cattani**
- **Roshydromet – Philipp Bykov, Gdaly Rivin**
- **IMGW – Joanna Linkowska, Grzegorz Duniec, Andrzej Mazur**
- **Long DWD COSMO-DE and observational dataset will most probably be used for testing participating methods**

Experience in ML postprocessing in COSMO

- **MCH:** Regular multilayer perceptron for wind speed and gusts

Main predictor: Swisstopo25m resolution DEM
Topographic position index (TPI) and Valley in
on different scales



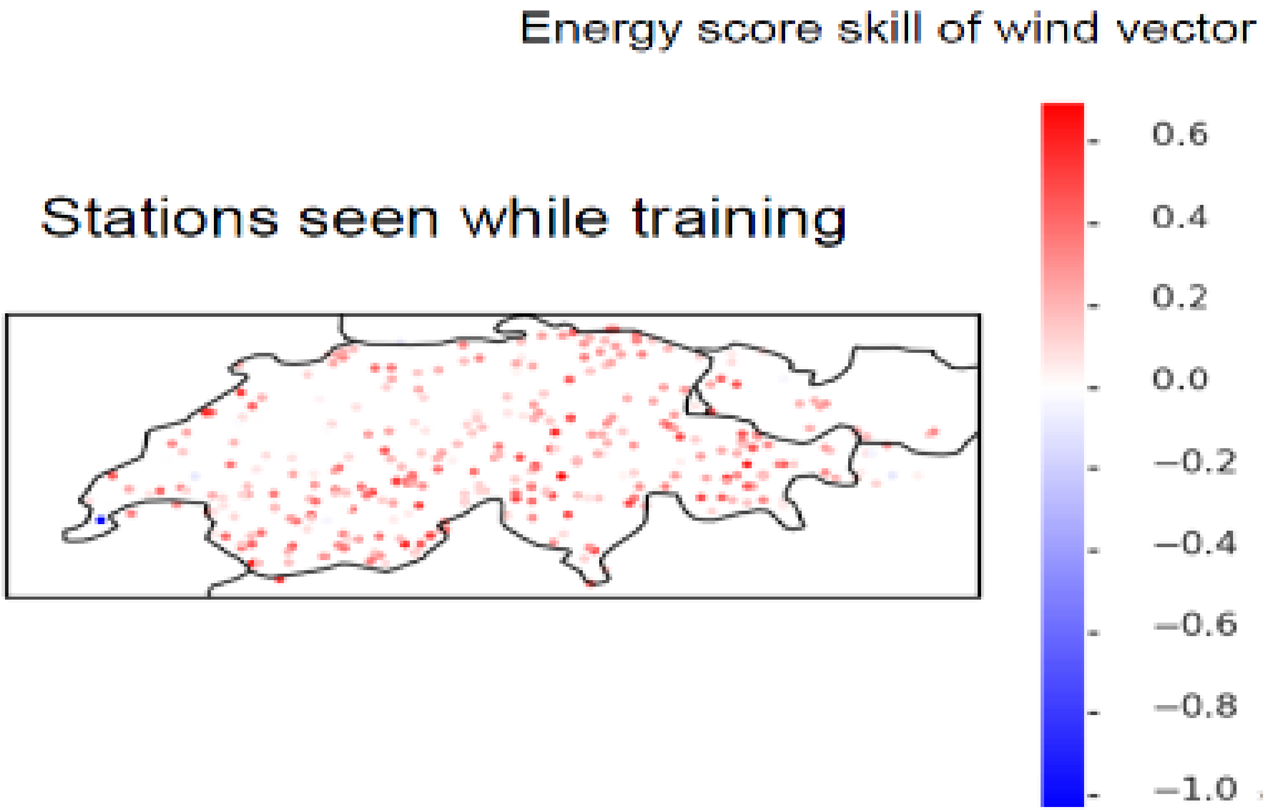
- **IMGW-PIB:** Artificial Neural Networks (ANN)
- **RHM:** Deep learning postprocessing, cross-pltaform and hardware independent (CPU-GPU)

Transition to ICON: Can be an issue due to computational costs of training!

Less demanding methods such as Multi-linear regression, Adaptive-Recursive least squares (IMGW-PIB) can be used during the transition period

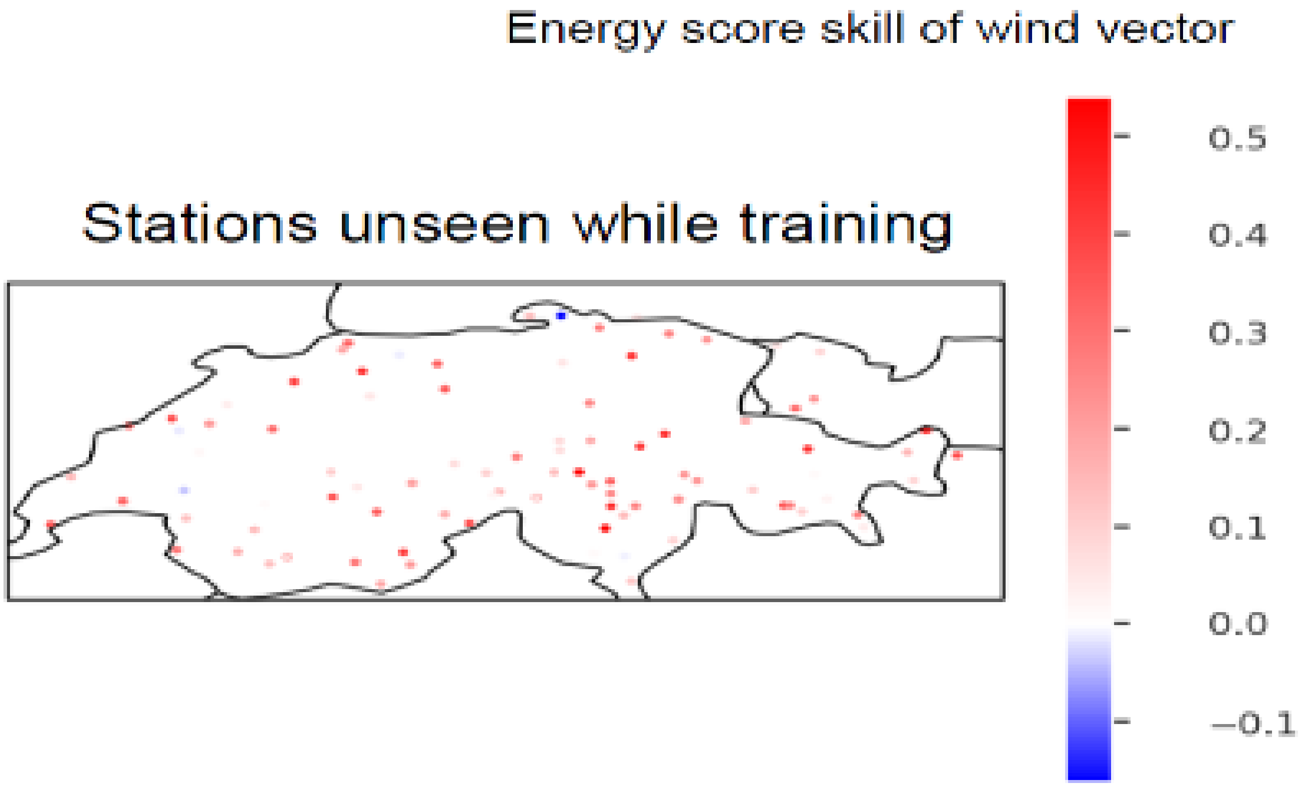
10m Wind Results: Seen Stations

- Even when regularized for better extrapolation, the forecast verifies better at unseen reference times over almost the whole grid.
- Improvement is more prevalent at locations with more complex topography.



10m Wind Results: Unseen Stations

- Forecast at unseen points also on average verify better, but not as much as on seen stations.

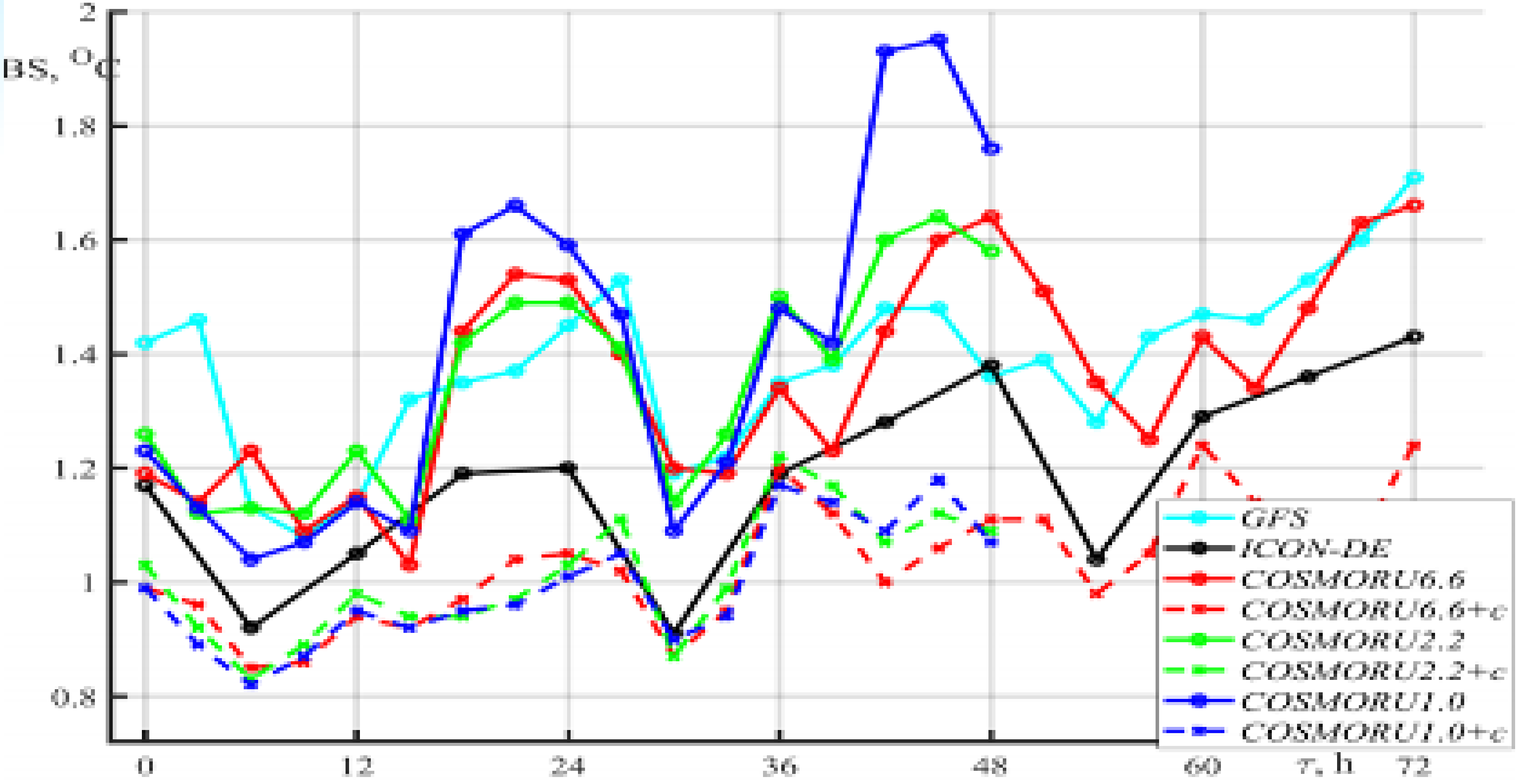


Ph. Bykov,
Hydrometeorological Research Center of the Russian Federation

Machine Learning for postprocessing at RHM

- **Deep learning postprocessing, cross-pltaform and hardware independent (CPU-GPU)**
- **Regions: European Russia, Central Russia, Asian Russia, Central Asia**
- **Weather Elements: T2m, Dew point temp, Wind speed, PMSL**
- **Training June2019-June2020, Testing August2020**
- **Verification on stations seen in the training (verification on stations unseen in the training is planned)**

Testing T_{2m} PP in Moscow region



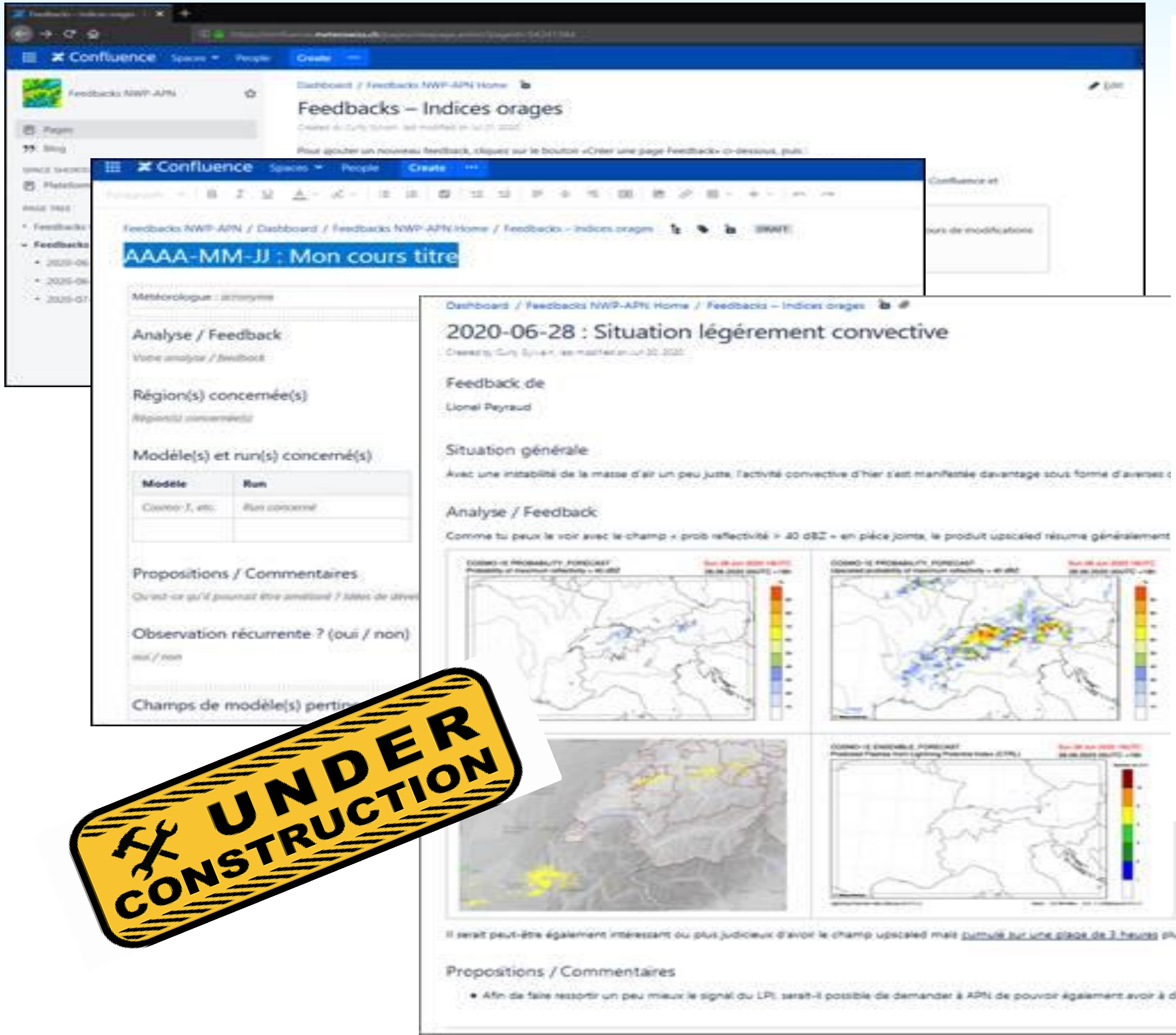
Dashed lines – ML postprocessing scores, significant improvement

Scores for CAPE-based flash rate forecasts in Poland (IMGW)

Improving existing post-processing methods: Use of MLR, A/R-LS and/or ANN techniques
Examples (3)

	ME	MAE	RMSE
ANN 4 hidden neurons	0.8406	1.6856	11.8038
ANN 3 hidden neurons	0.4088	1.8395	11.8919
RLS λ=0.95	0.1203	2.1109	12.3525
RLS λ=1.00	0.0538	2.1911	12.7302
MLR 6 predictors	0.5957	2.1503	13.0064
MLR 3 predictors	1.0369	2.2140	13.4703

Template for the analysis of particular cases (success/failure) to implement in COSMO



MeteoSwiss experience:
Online system to get forecasters feedback

The idea is **to work by event type**
For each event, the filled forms will be archived, by dates. The model type/version, run, period are integrated in each form.
It is available to other forecasters or NWP guys, who could add comments

High-resolution weather and climate simulations for Moscow megacity with TERRA_URB scheme: **the recent developments and new challenges**

Mikhail Varentsov[1-4] , Timofey Samsonov[1,2], Matthias Demuzere[5] ,

Inna Rozinkina[1,2], Gdaly Rivin[1,2], Viacheslav Vasenev[4]

1) Lomonosov Moscow State University, Russia
2) Hydrometeorologycal Research Center of Russia, Moscow
3) A.M. Obukhov Institute of Atmospheric Physics
4) RUDN University
5) Ruhr University Bochum

Many results of this study were obtained within AEVUS task of COSMO Working group WG3b (Paola's talk yesterday)

New city-descriptive external parameters

- Basic external parameters for TERRA_URB in (Wouters et al., 2016):
  - <u>Impervious area fraction (ISA)</u>
  - <u>Annual-mean anthropogenic heat flux (AHF)</u>

- Additional 2D external parameters to replace hard-coded values:

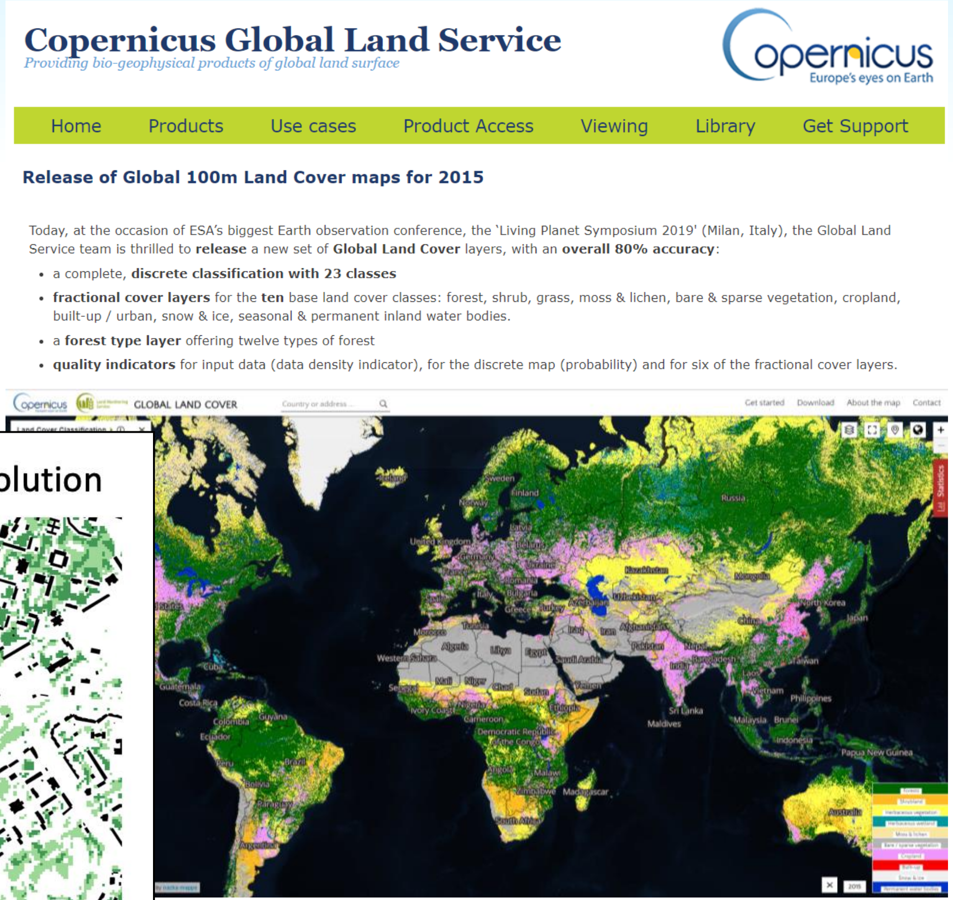
Urban canopy parameters (input of SURY)			
Parameter name	Symbol	Default values	
Surface albedo	α	0.101	Thermal and radiative parameters of urban materials
Surface emissivity	ϵ	0.86	
Surface heat conductivity	λ_s	$0.767\,\mathrm{W\,m^{-1}\,K^{-1}}$	
Surface heat capacity	$C_{v,s}$	$1.25\times10^6\,\mathrm{J\,m^{-3}\,K^{-1}}$	
Building height	H	15 m	Building morphology parameters
Canyon height-to-width ratio	$\frac{h}{w_c}$	1.5	
Roof fraction	R	0.667	

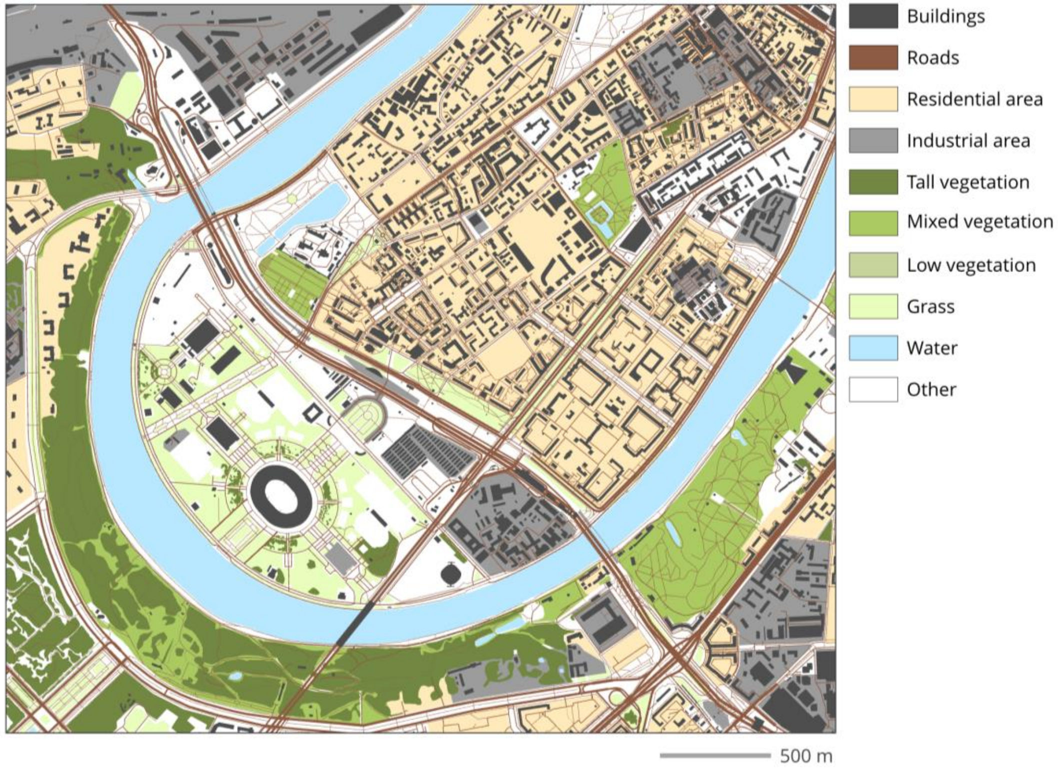
But how to define the values of new parameters?

Comprehensive GIS-based approach

Based on combined use of different global data sets

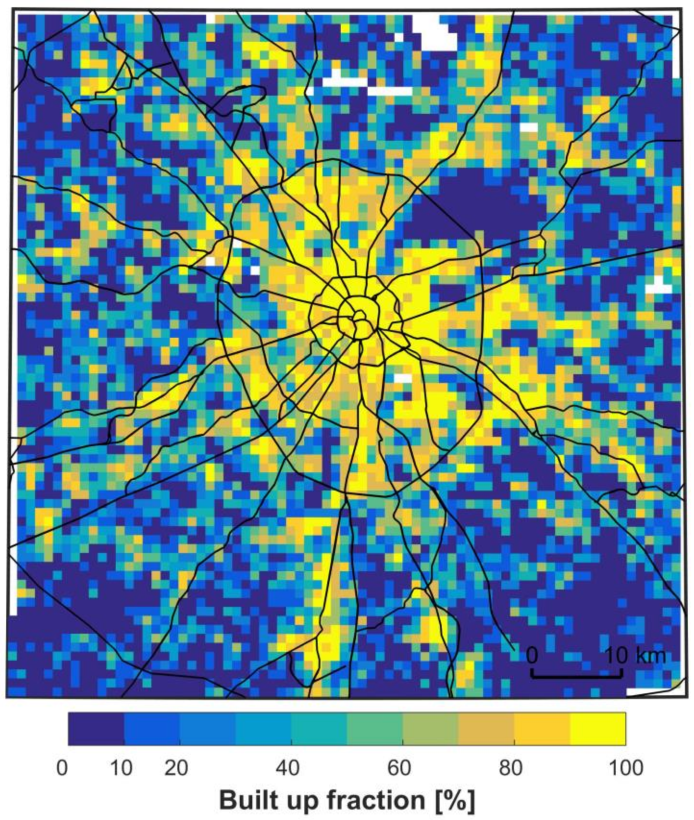
- Built up fraction area from ***Copernicus Global Land Cover*** with 100 m resolution
- Data on buildings and roads from ***OpenStreetMap***
- Data on vegetation derived from ***Sentinel-2 satellite images*** with 10 m resolution
- Literature AHF estimates (Stewart, Kennedy, 2017)





More details in (Samsonov, Varentsov, 2020)

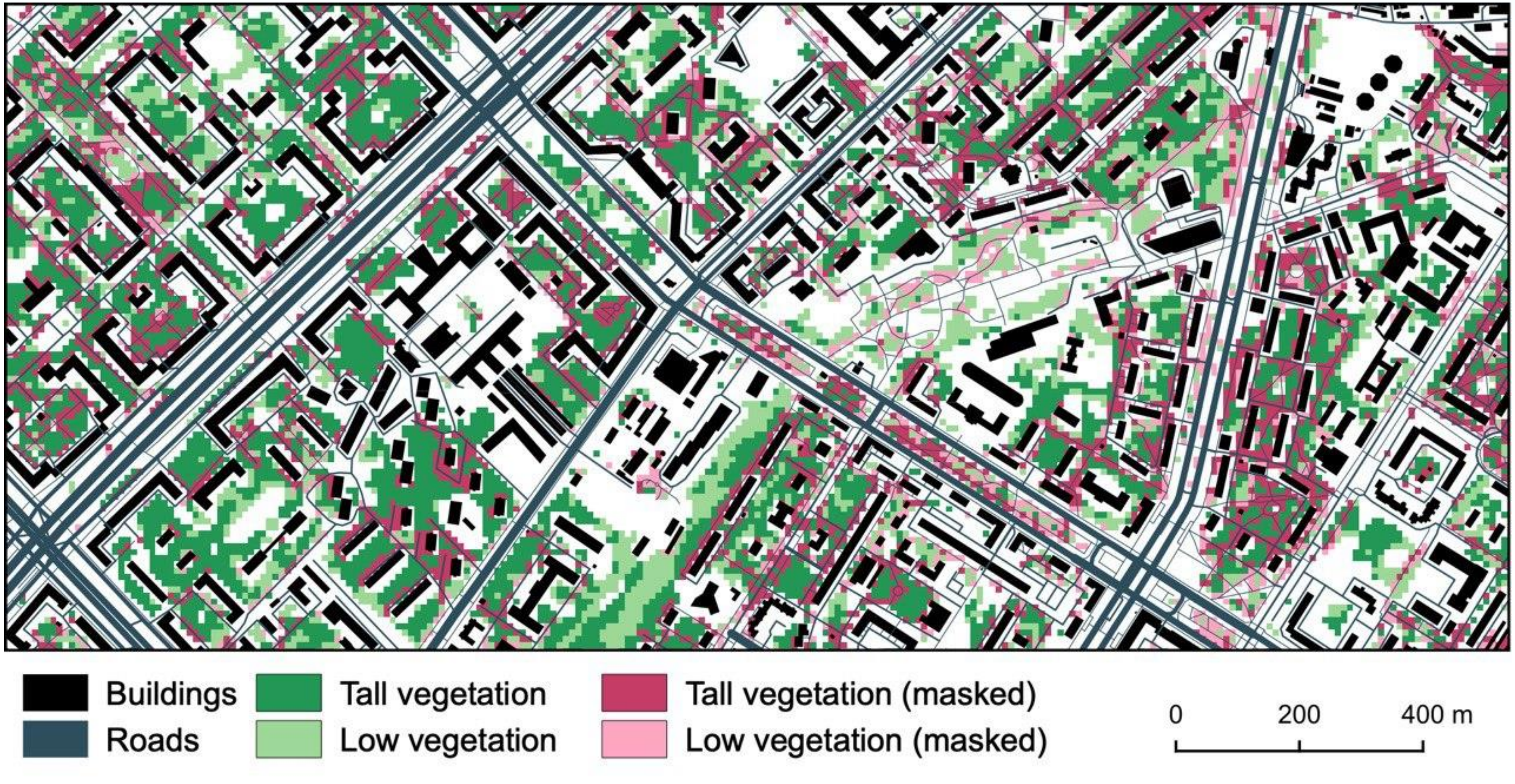
ISA in GIS-based approach



↑ Urban fraction in CGLC includes urban vegetation, but we need ISA for TERRA_URB

$$ISA = \max(\min(URBAN\_FR_{CGLC}, 1 - GREEN\_FR), BLDF\_FR_{OSM} + ROAD\_FR_{OSM})$$

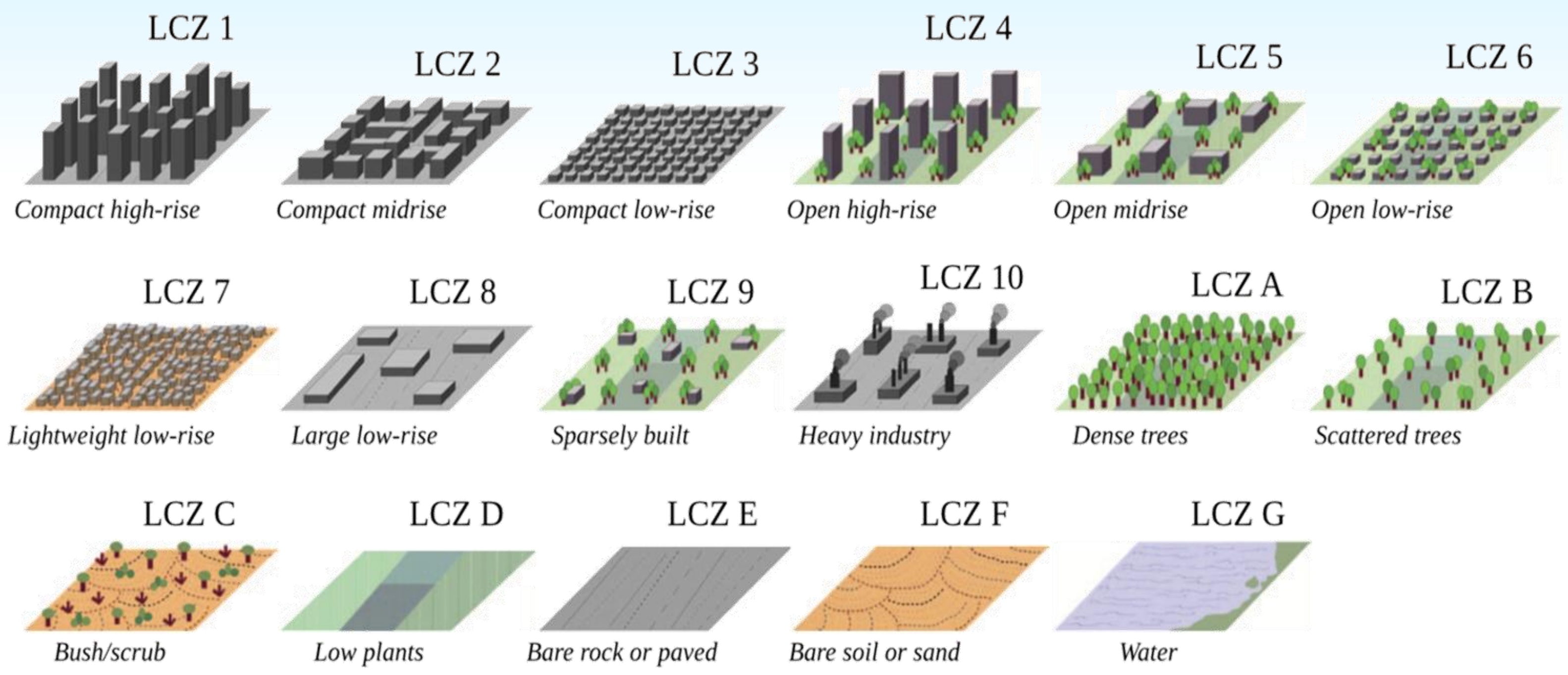
$$GREEN\_FR = \max(GREEN\_FR_{OSM}, GREEN\_FR_{SENTINEL})$$

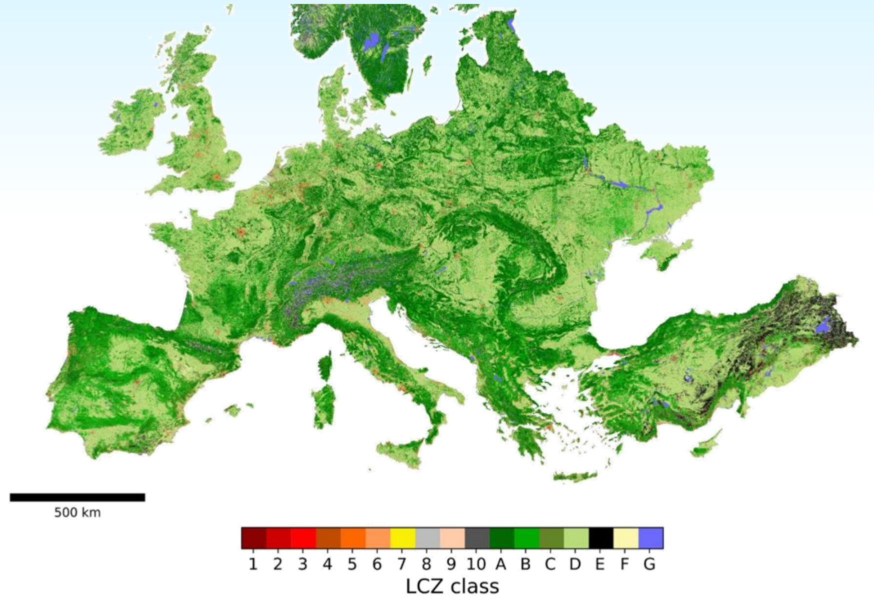


Uncertainty: what to do with vegetation, that intersects with buildings/roads?

(Samsonov, Varentsov, 2020)

LCZ-based approach





- ❑ Local climate zones (LCZs) concept by Stewart and Oke (2012)
- ❑ WUDAPT crowdsourcing initiative (Ching et al., 2018) to generate LCZ maps for the world's cities
- ❑ European and US LCZ maps is available (Demuzere et al., 2019, 2020)

WUDAPT

An Urban Weather, Climate, and Environmental Modeling Infrastructure for the Anthropocene

J. Ching, G. Mills, B. Bechtel, L. See, J. Feddema, X. Wang, C. Ren, O. Brousse, A. Martilli, M. Neophytou, P. Mouzourides, I. Stewart, A. Hanna, E. Ng, M. Foley, P. Alexander, D. Aliaga, D. Niyogi, A. Shreevastava, P. Bhalachandran, V. Masson, J. Hidalgo, J. Fung, M. Andrade, A. Baklanov, W. Dai, G. Milcinski, M. Demuzere, N. Brunsell, M. Pesaresi, S. Miao, Q. Mu, F. Chen, and N. Theeuwes

WUDAPT is an international community-generated urban canopy information and modeling infrastructure to facilitate urban-focused climate, weather, air quality, and energy-use modeling application studies

LCZ-based approach

TABLE 3. Values of geometric and surface cover properties for local climate zones. All properties are unitless except height of roughness elements (m).

Local climate zone (LCZ)	Sky view factor[a]	Aspect ratio[b]	Building surface fraction[c]	Impervious surface fraction[d]	Pervious surface fraction[e]	Height of roughness elements[f]	Terrain roughness class[g]
LCZ 1 *Compact high-rise*	0.2–0.4	> 2	40–60	40–60	< 10	> 25	8
LCZ 2 *Compact midrise*	0.3–0.6	0.75–2	40–70	30–50	< 20	10–25	6–7
LCZ 3 *Compact low-rise*	0.2–0.6	0.75–1.5	40–70	20–50	< 30	3–10	6
LCZ 4 *Open high-rise*	0.5–0.7	0.75–1.25	20–40	30–40	30–40	>25	7–8
LCZ 5 *Open midrise*	0.5–0.8	0.3–0.75	20–40	30–50	20–40	10–25	5–6
LCZ 6 *Open low-rise*	0.6–0.9	0.3–0.75	20–40	20–50	30–60	3–10	5–6
LCZ 7 *Lightweight low-rise*	0.2–0.5	1–2	60–90	< 20	<30	2–4	4–5
LCZ 8 *Large low-rise*	>0.7	0.1–0.3	30–50	40–50	<20	3–10	5
LCZ 9	> 0.8	0.1–0.25	10–20	< 20	60–80	3–10	5–6

TABLE 4. Values of thermal, radiative, and metabolic properties for local climate zones. All values are representative of the local scale.

Local climate zone (LCZ)	Surface admittance[a]	Surface albedo[b]	Anthropogenic heat output[c]
LCZ 1 *Compact high-rise*	1,500–1,800	0.10–0.20	50–300
LCZ 2 *Compact midrise*	1,500–2,200	0.10–0.20	<75
LCZ 3 *Compact low-rise*	1,200–1,800	0.10–0.20	<75
LCZ 4 *Open high-rise*	1,400–1,800	0.12–0.25	<50
LCZ 5 *Open midrise*	1,400–2,000	0.12–0.25	<25
LCZ 6 *Open low-rise*	1,200–1,800	0.12–0.25	<25
LCZ 7 *Lightweight low-rise*	800–1,500	0.15–0.35	<35
LCZ 8 *Large low-rise*	1,200–1,800	0.15–0.25	<50
LCZ 9	1,000–1,800	0.12–0.25	<10
	–2,500	0.12–0.20	>300

WUDAPT2COSMO tool developed by M. Demuzere:

LCZ map (*.tiff) → urban canopy parameters for TERRA_URB (*.nc)

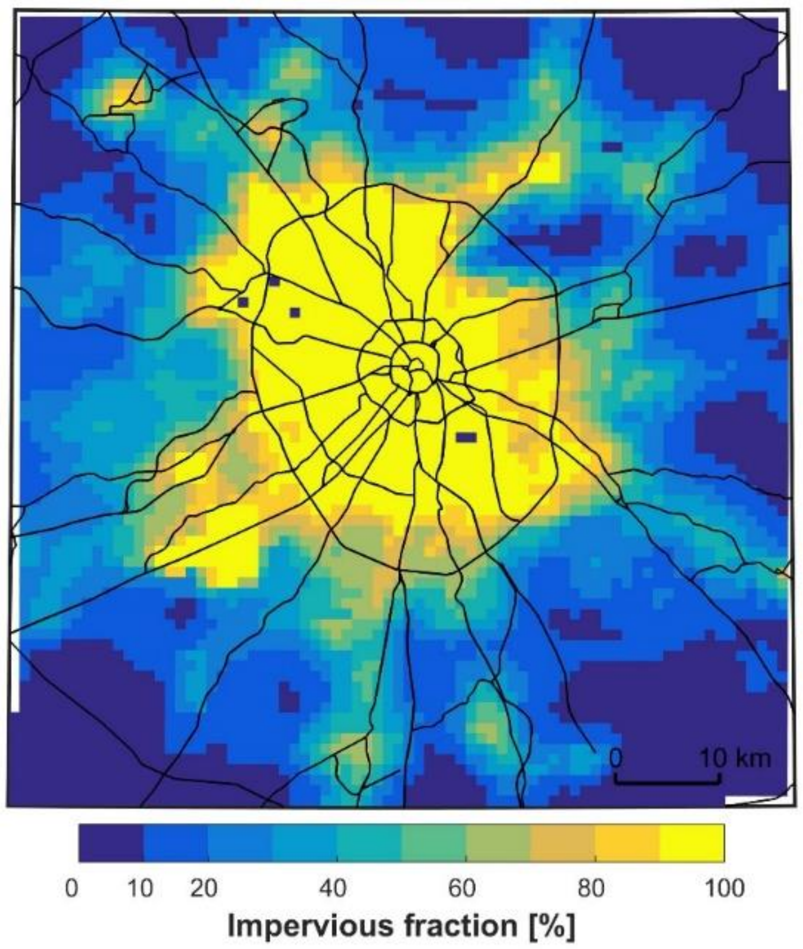
(Varentsov et al., 2020, in preparation)

Stewart & Oke (2012)

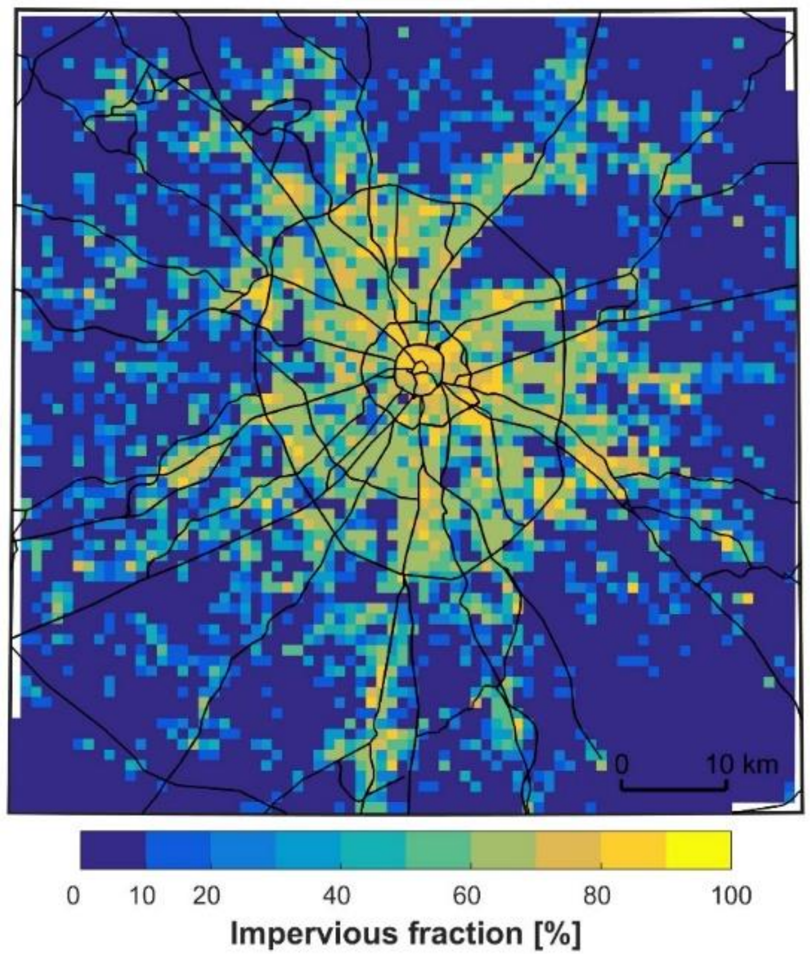
Comparison between LCZ-based and GIS-based approaches

Impervious Area Fraction (ISA)

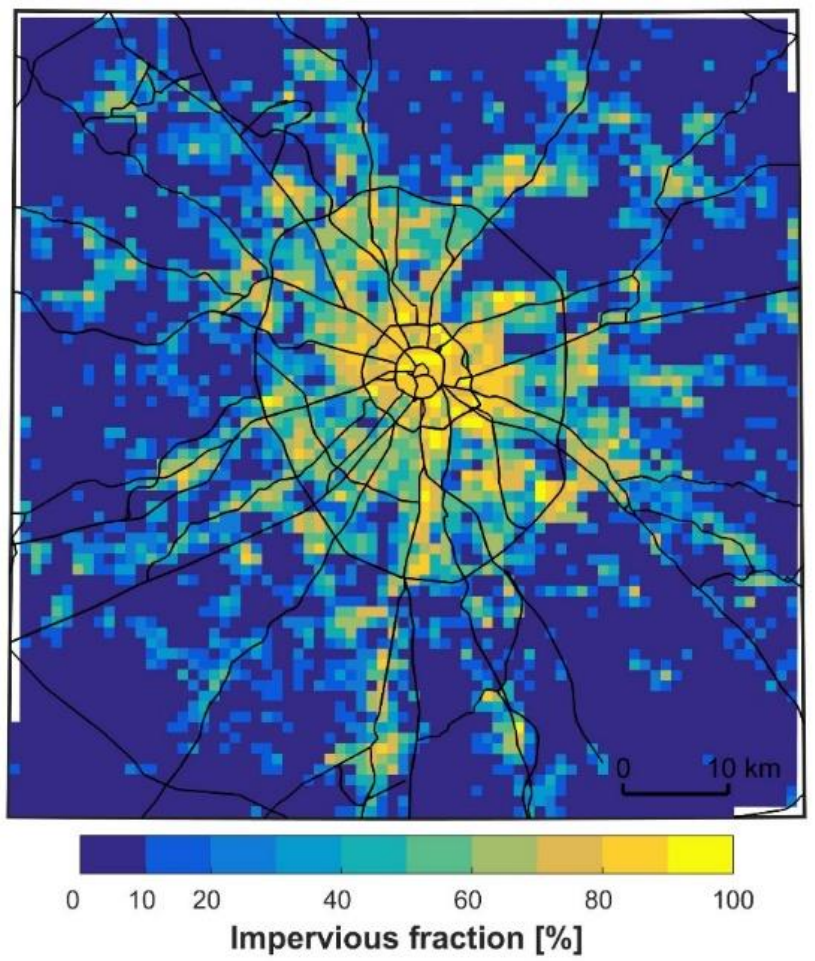
Default values from EXTPAR



LCZ-derived ISA



Reference GIS-based approach



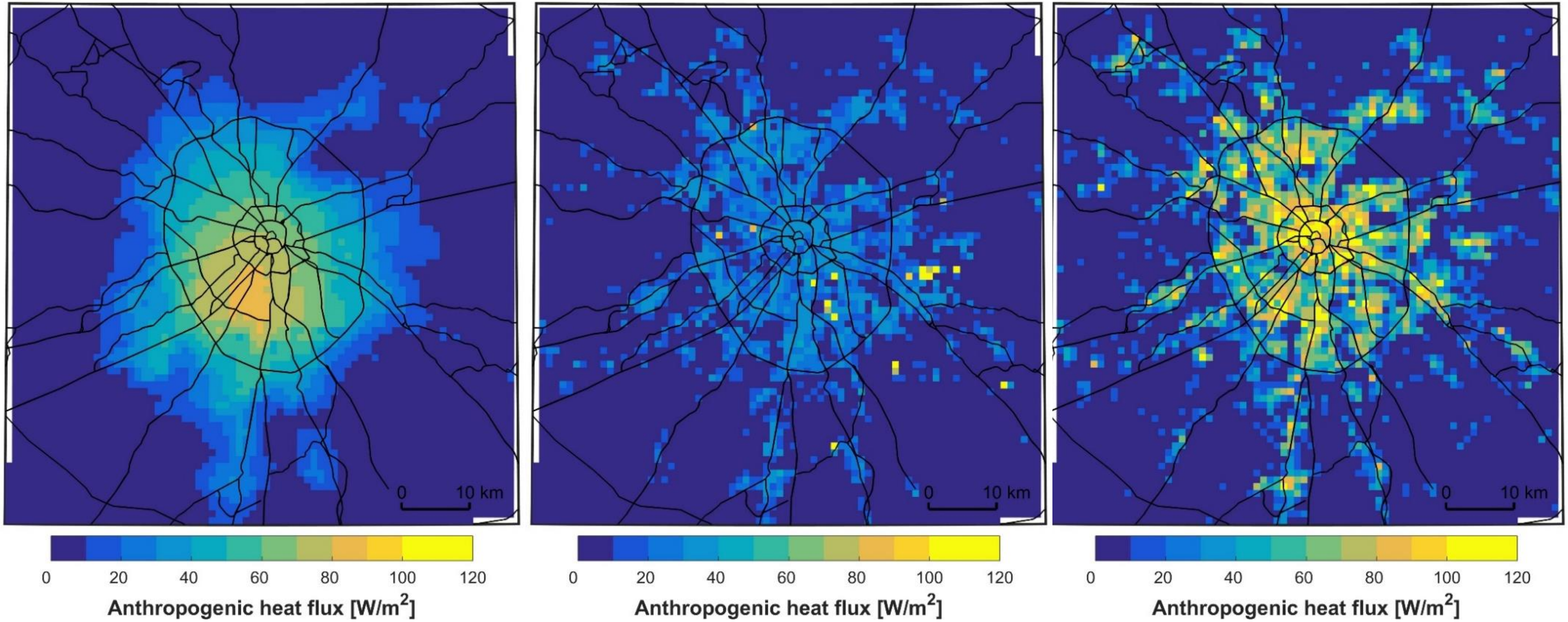
Comparison between LCZ-based and GIS-based approaches

Annual Anthropogenic heat flux (AHF)

Default values from EXTPAR (Flanner et al., 2009)

LCZ-based AHF

Reference GIS-based AHF



Winter case, January 2017

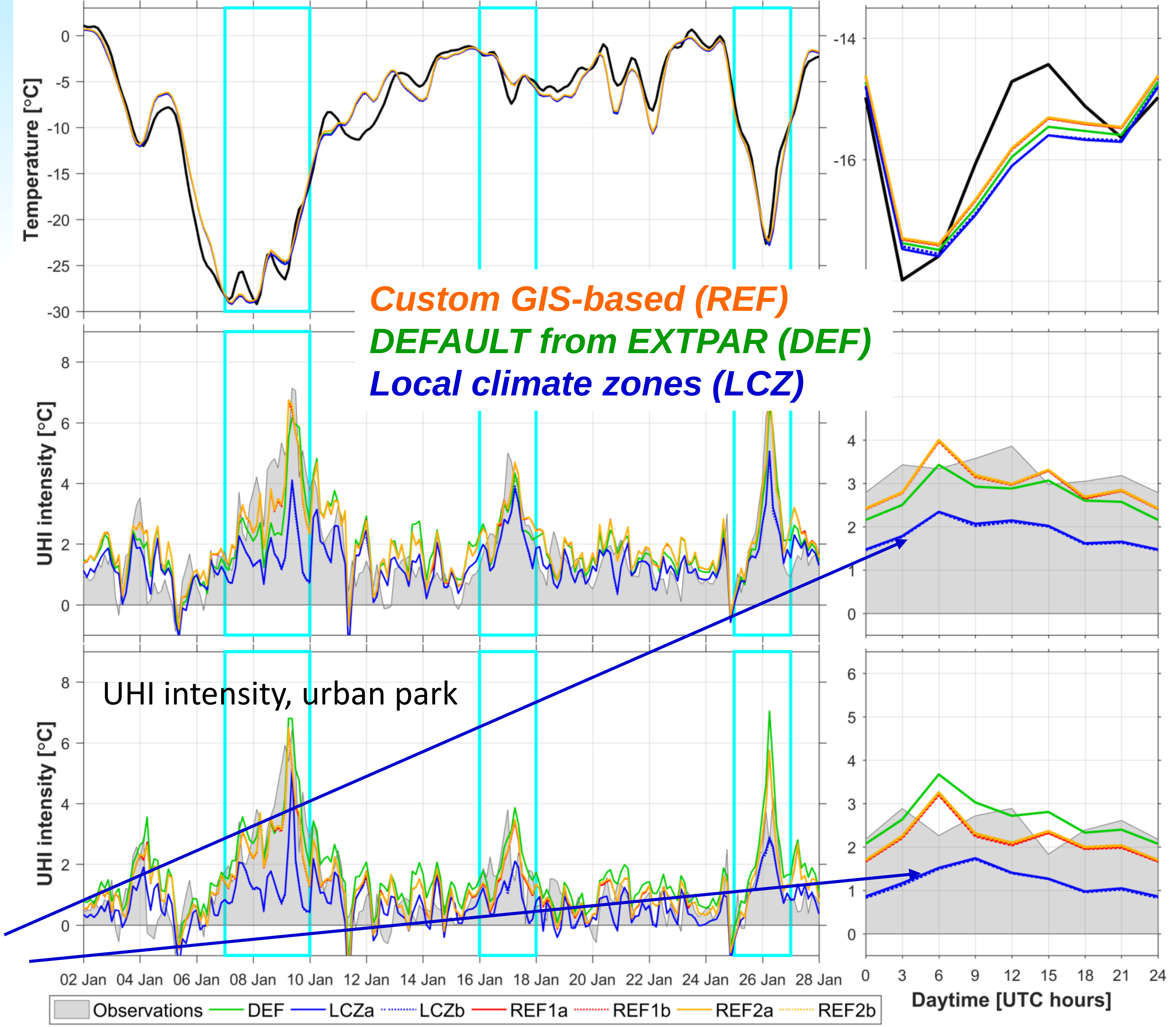
COSMO-Ru1M, 1km grid step

Mean rural temperature →

UHI intensity, city center →

UHI intensity, urban park →

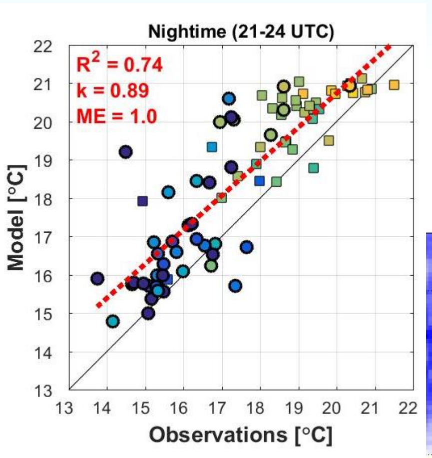
Underestimation of Urban heat island using LCZ parameters



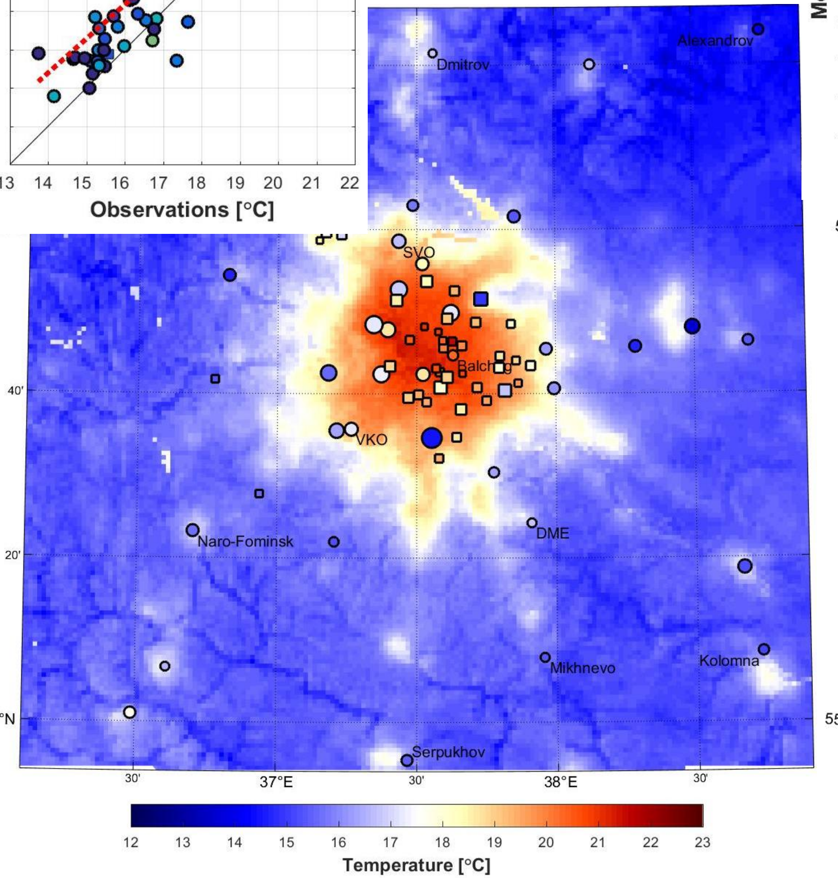
Summer case, August 2017

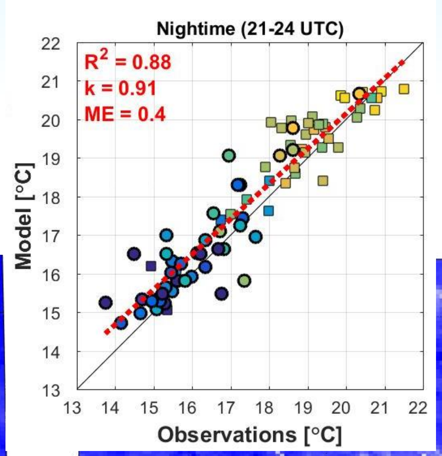
COSMO-Ru1M, 1 km grid step

Mean nocturnal temperature over the study period

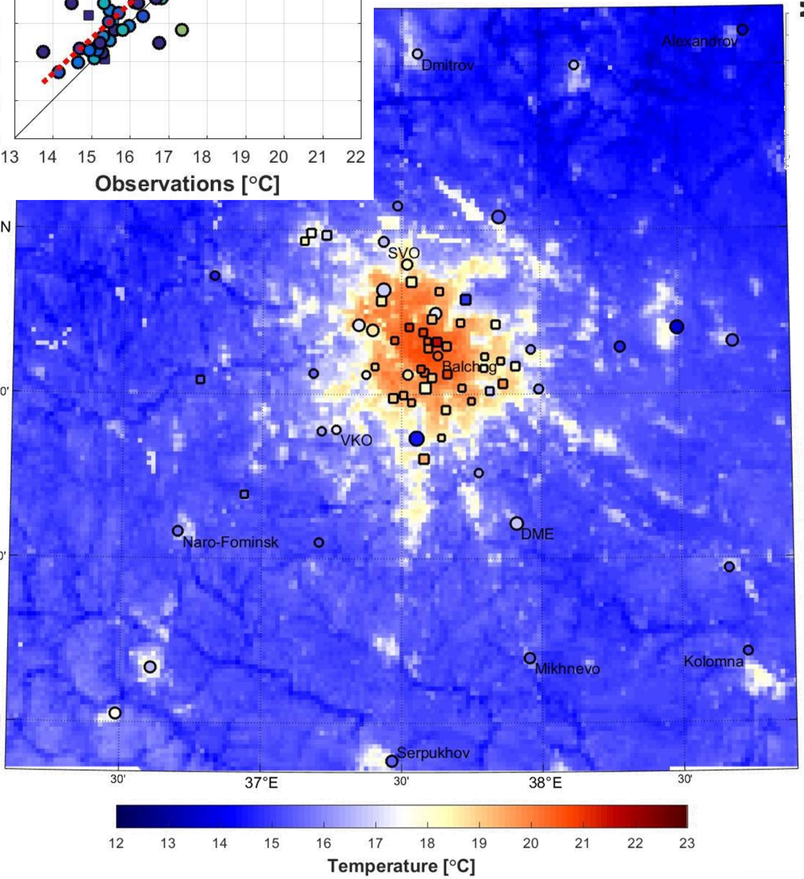


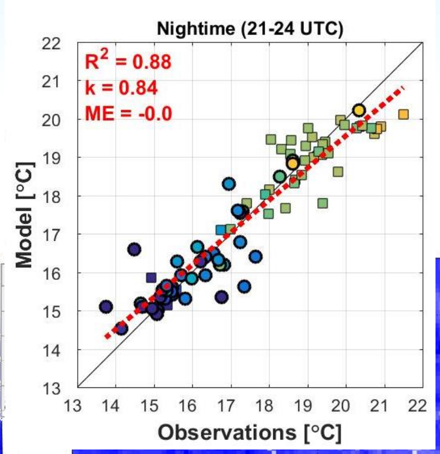
Default EXTPAR fields and constants



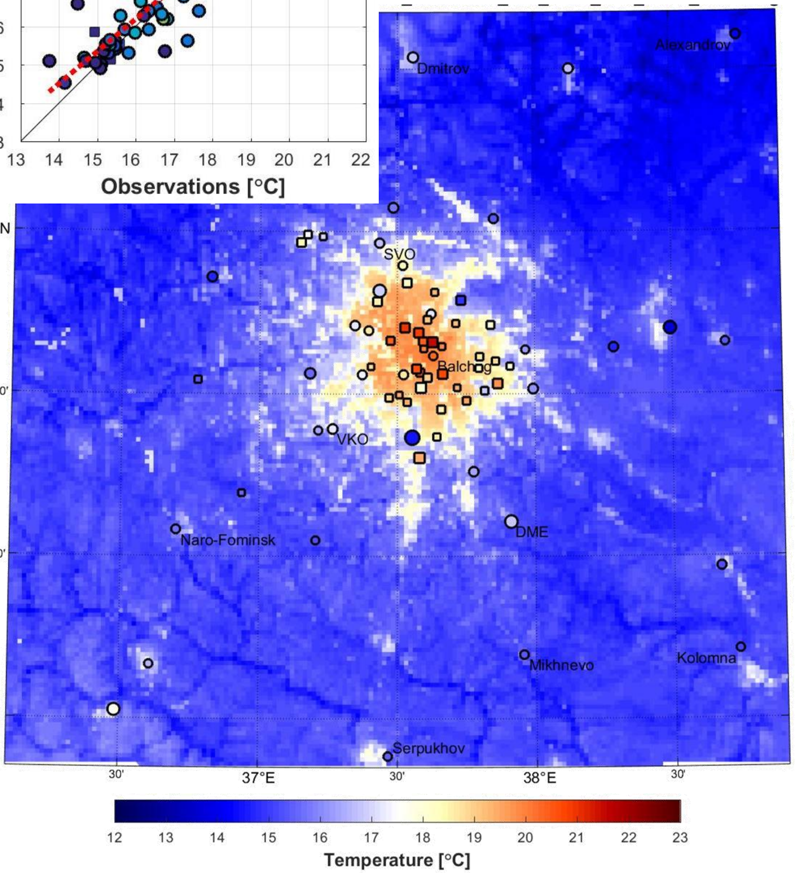


Reference GIS-based approach





LCZ-based approach

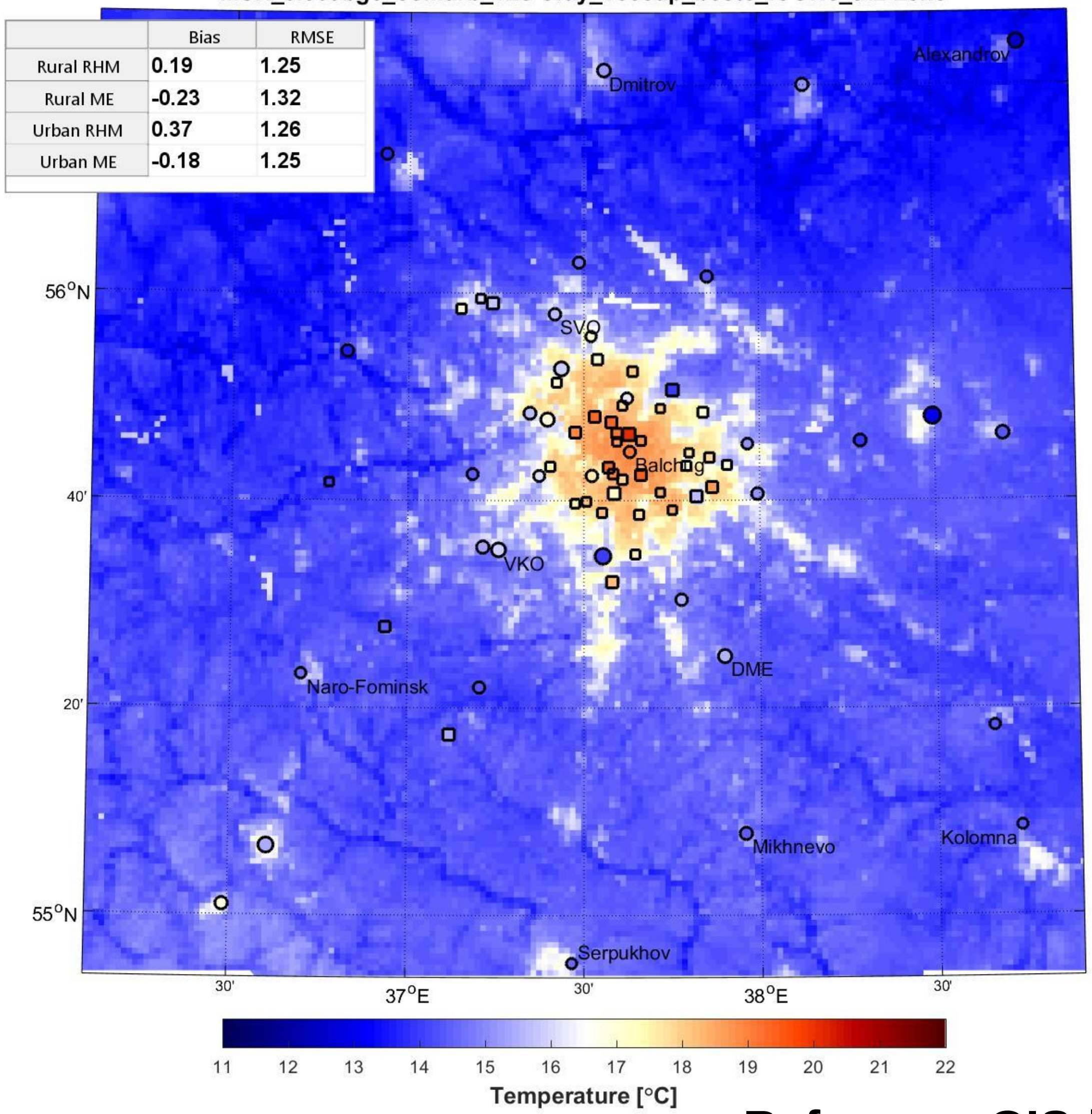


Towards the higher-resolution simulations (1 km → 500 m)

Nocturnal temperature (0 UTC), 1 km grid step

MSK_0.009bg3_osmurb_v2c Cray_v505up_best0_ICON6_th2 L3n9

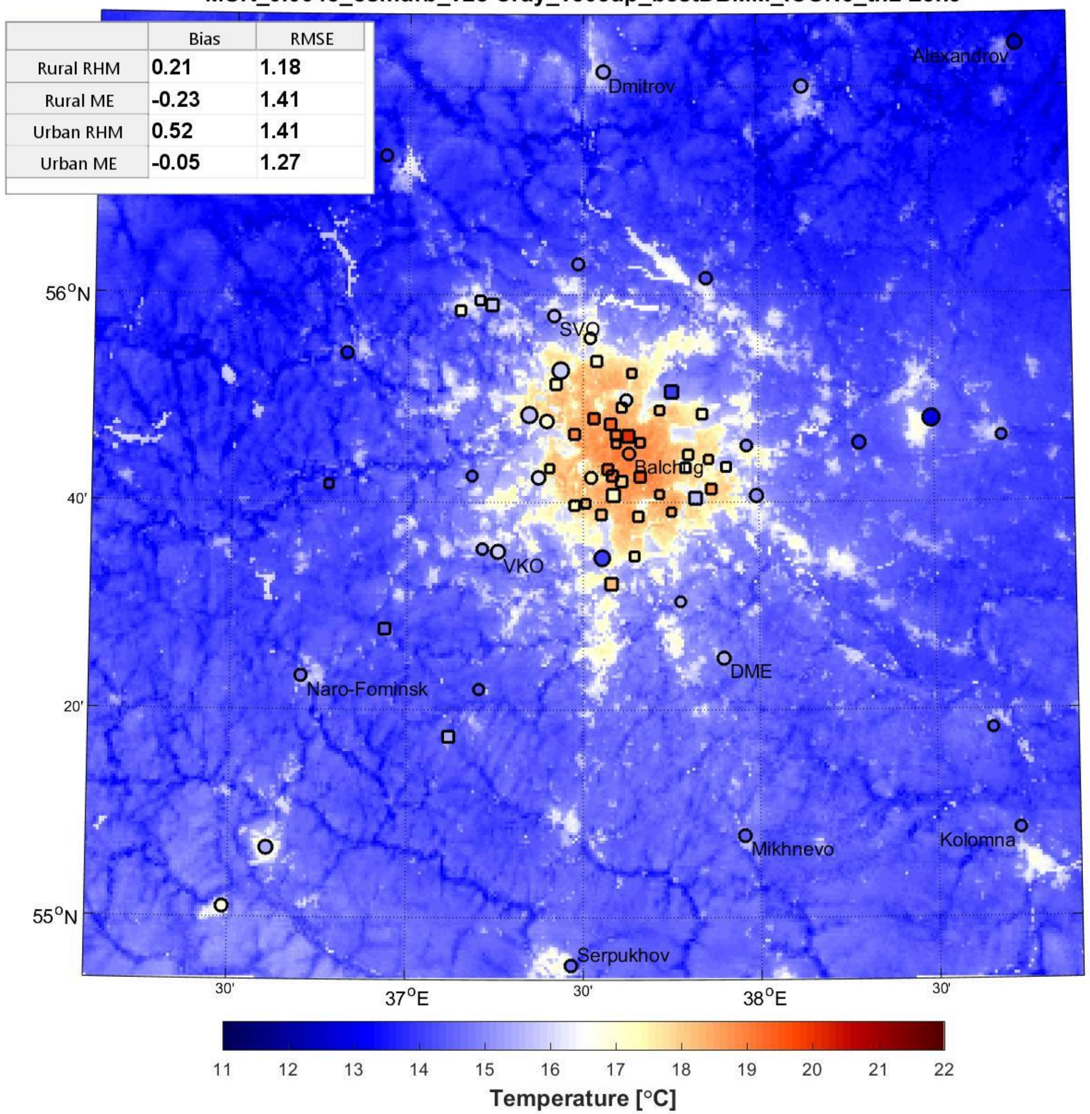
	Bias	RMSE
Rural RHM	0.19	1.25
Rural ME	-0.23	1.32
Urban RHM	0.37	1.26
Urban ME	-0.18	1.25



Nocturnal temperature (0 UTC), 500 m grid step

MSK_0.0045_osmurb_v2c Cray_v505up_bestDBMM_ICON6_th2 L3n9

	Bias	RMSE
Rural RHM	0.21	1.18
Rural ME	-0.23	1.41
Urban RHM	0.52	1.41
Urban ME	-0.05	1.27

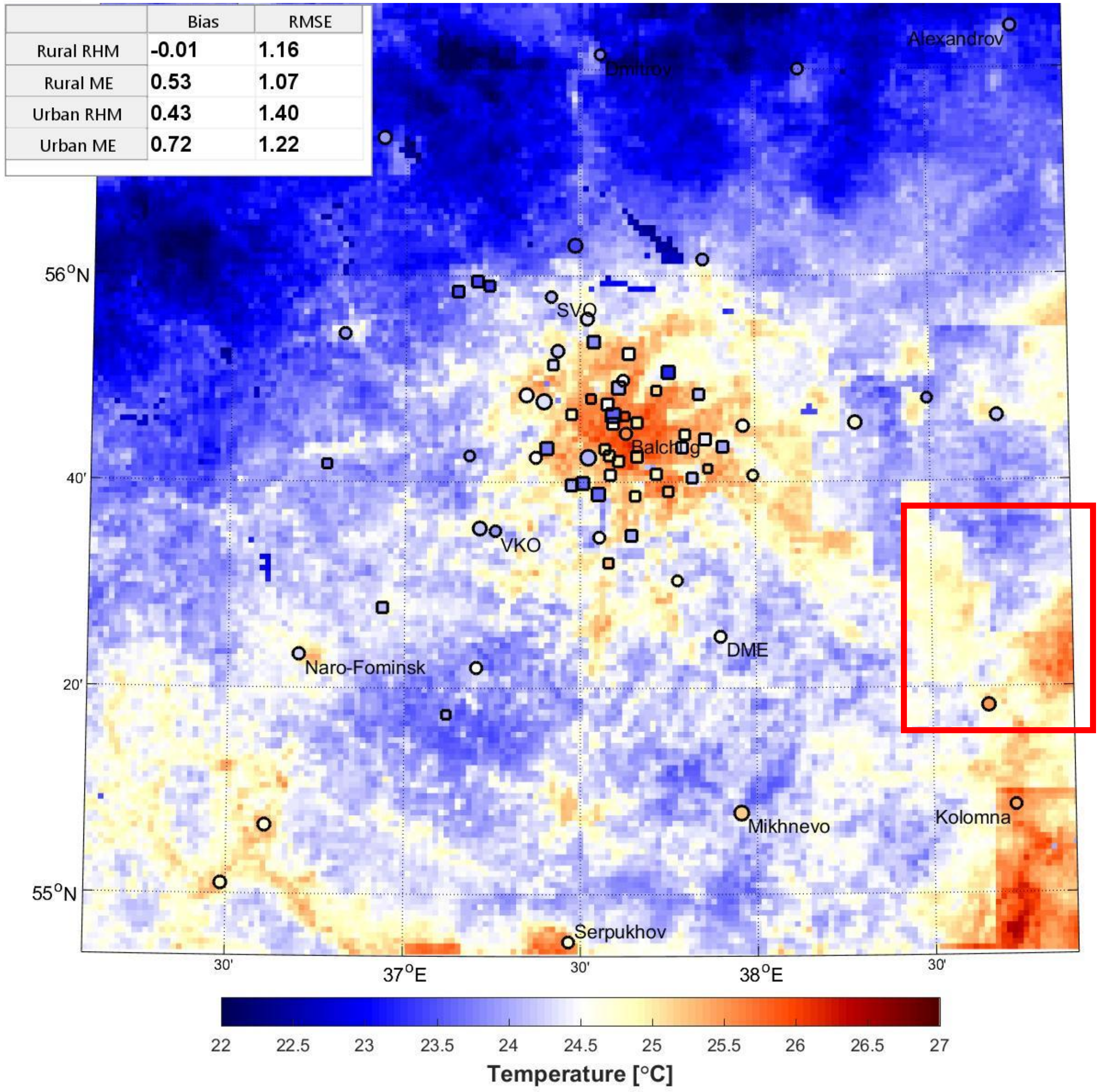


Reference GIS-based approach, August 2017

Towards the higher-resolution simulations (1 km → 500 m)

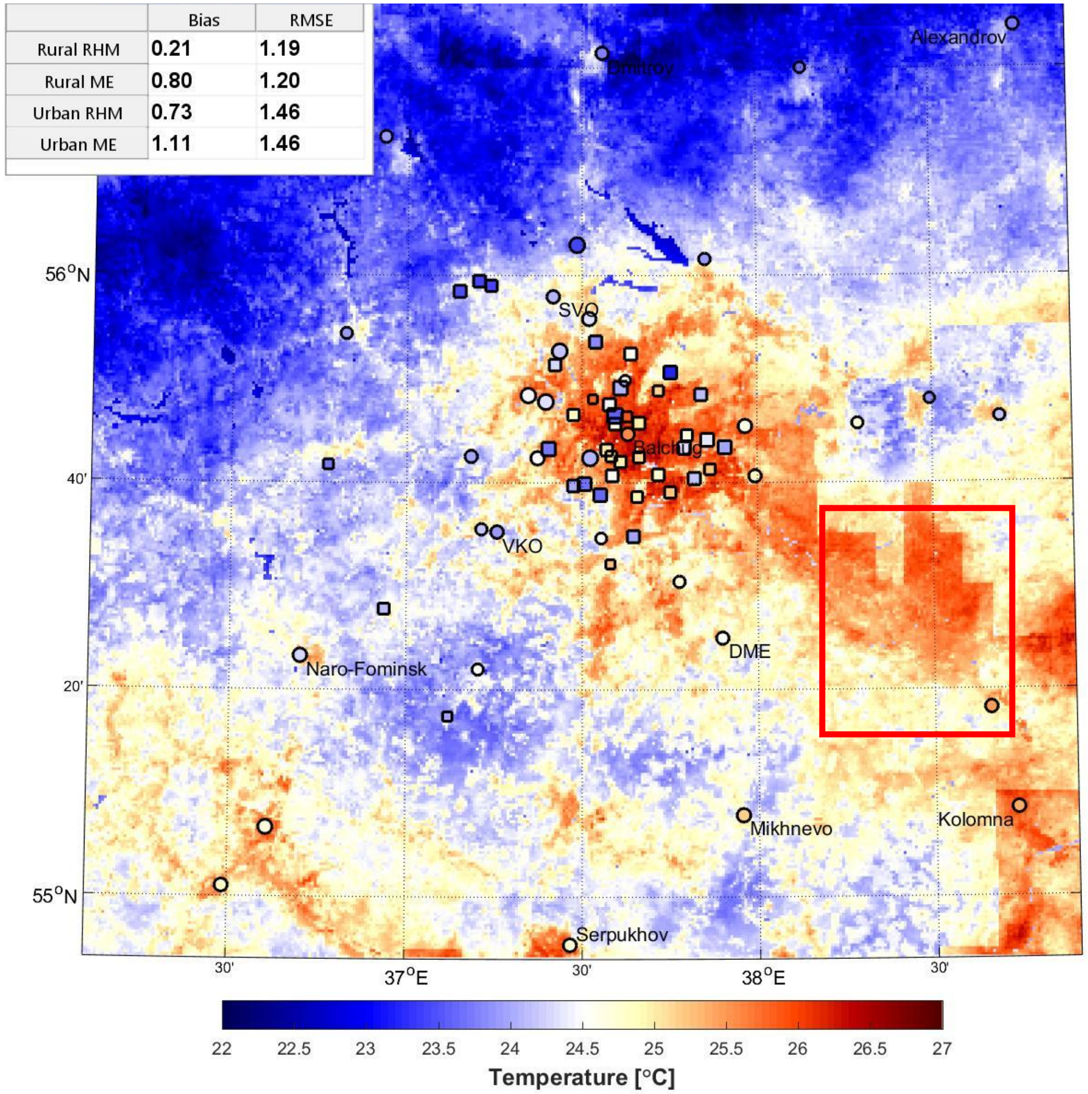
Daytime temperature (12 UTC), 1 km grid step

	Bias	RMSE
Rural RHM	-0.01	1.16
Rural ME	0.53	1.07
Urban RHM	0.43	1.40
Urban ME	0.72	1.22



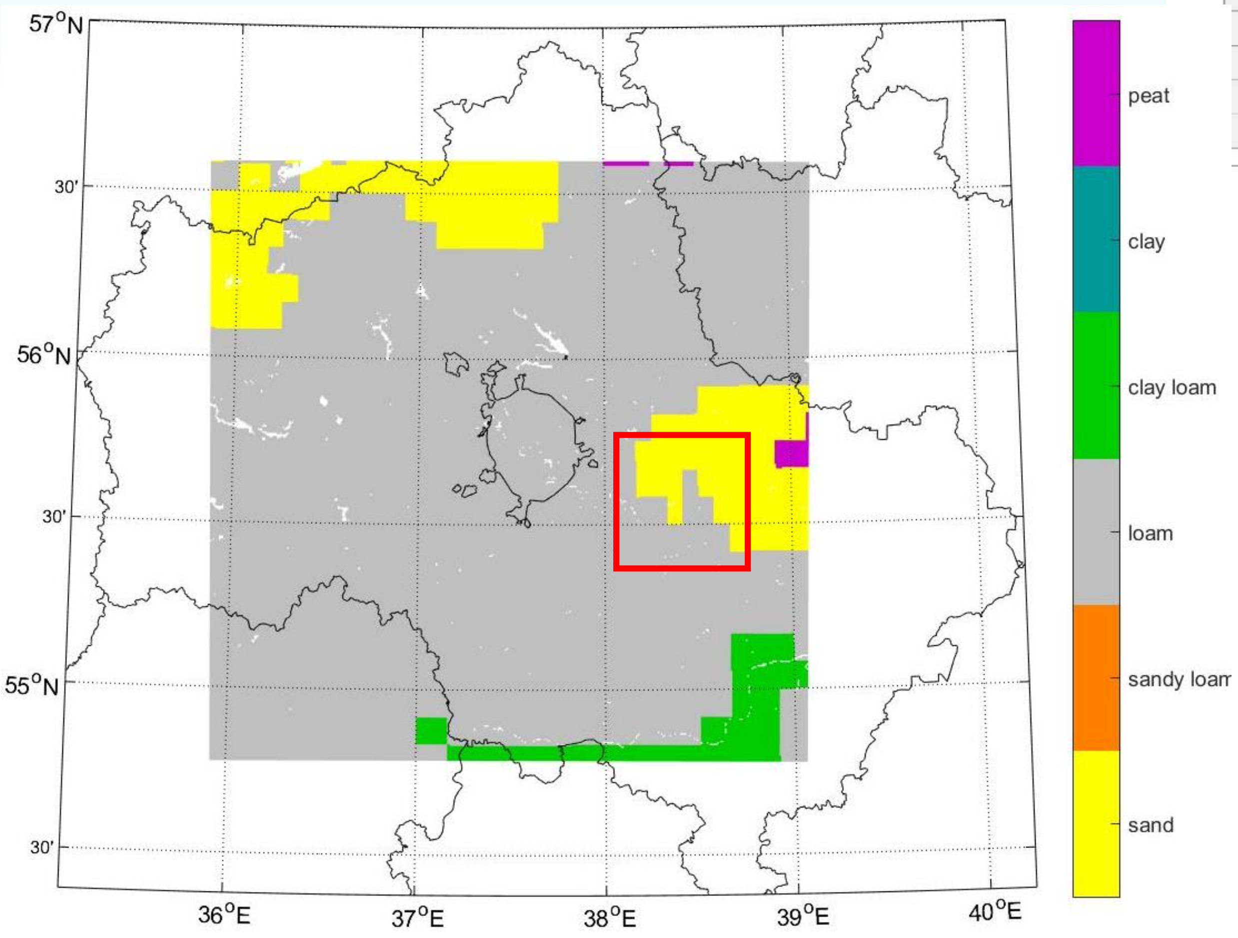
Daytime temperature (12 UTC), 500 m grid step

	Bias	RMSE
Rural RHM	0.21	1.19
Rural ME	0.80	1.20
Urban RHM	0.73	1.46
Urban ME	1.11	1.46



Reference GIS-based approach, August 2017

Need for high-resolution external parameters (non-urban)



Daytime temperature (12 UTC), 500 m grid step

	Bias	RMSE
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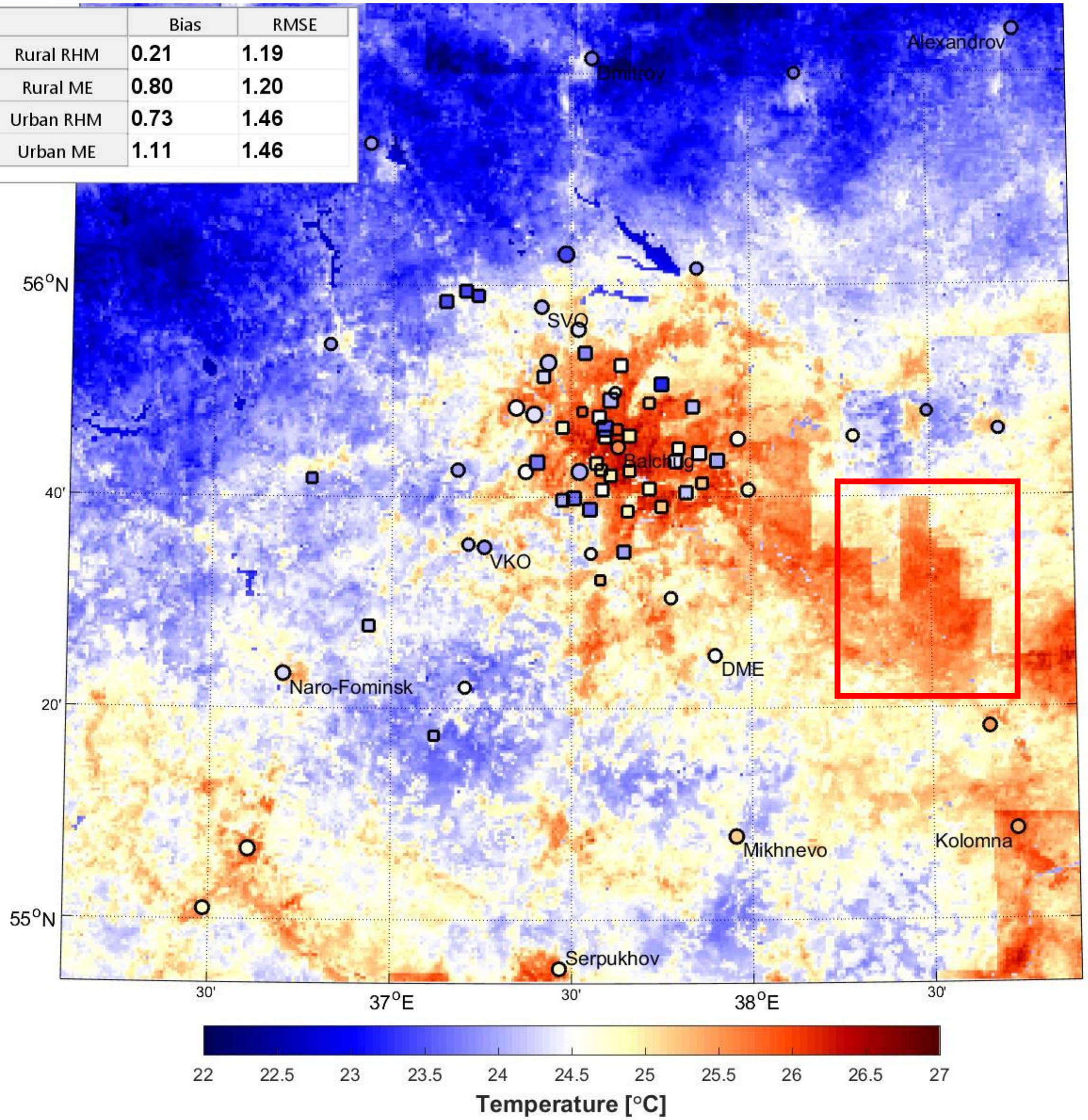
Urban RHM	0.73	1.46
Urban ME	1.11	1.46

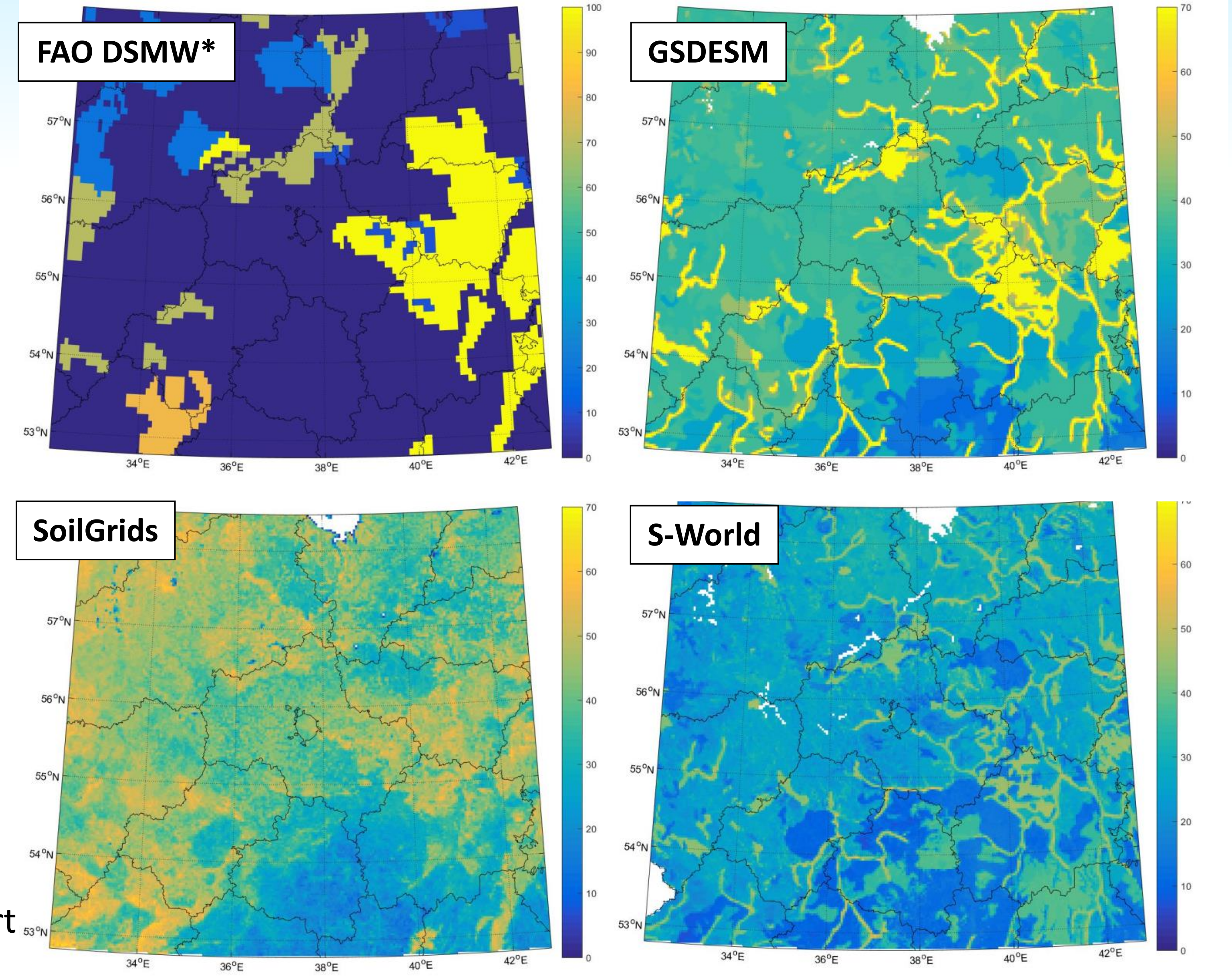


Towards improving the soil texture map

Considered data sets:

- FAO DSMW (EXTPAR default)
- GSDESM (The Global Soil Dataset for Earth System Modeling, Shangguan et al., 2014)
- Soil Grids (https://soilgrids.org/)
- S-World (Stoorvogel et al., 2017)

Uncertainties
of the input data:
sand fraction (%) →



Thanks to collaboration with Juergen Helmert

Conclusion and outlook for city-descriptive parameters

- **New developments:** COSMO 5.05urb with recent physical developments, TERRA_URB scheme and extended opportunities for setting the city-descriptive parameters
- **External city-descriptive parameters:**
  - Comprehensive GIS-based approach and faster LCZ-based approach were developed
  - For summer, both approaches provide a noticeable improvement in comparison to default configuration with urban fields from EXTPAR
  - For the winter, LCZ-based approach demonstrates worse results due to underestimation of anthropogenic heat flux
  - ***Paper under preparation:*** *Varentsov M., Samsonov T., Demuzere M. Impact of urban canopy parameters on a megacity's modelled thermal environment. Will be submitted to Atmosphere SI*

Transition to ever higher resolution models
and their proper application
requires finer external parameters and a lot of study!