AEVUS-2 PT Web Meeting, 18.03.2020

Contribution to AEVUS-2 PT by RHM & Moscow State University: Key results and recent updates

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and all other contributing colleagues

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Outline

1. Recent developments on the model code: new options and parameters for TERRA_URB
2. Model sensitivity to the new parameters
3. On the namelist settings and tuning parameters
4. On the consistency of EXTPAR data
5. On the uncertainty of the data on urban/impervious area fraction

Current model versions

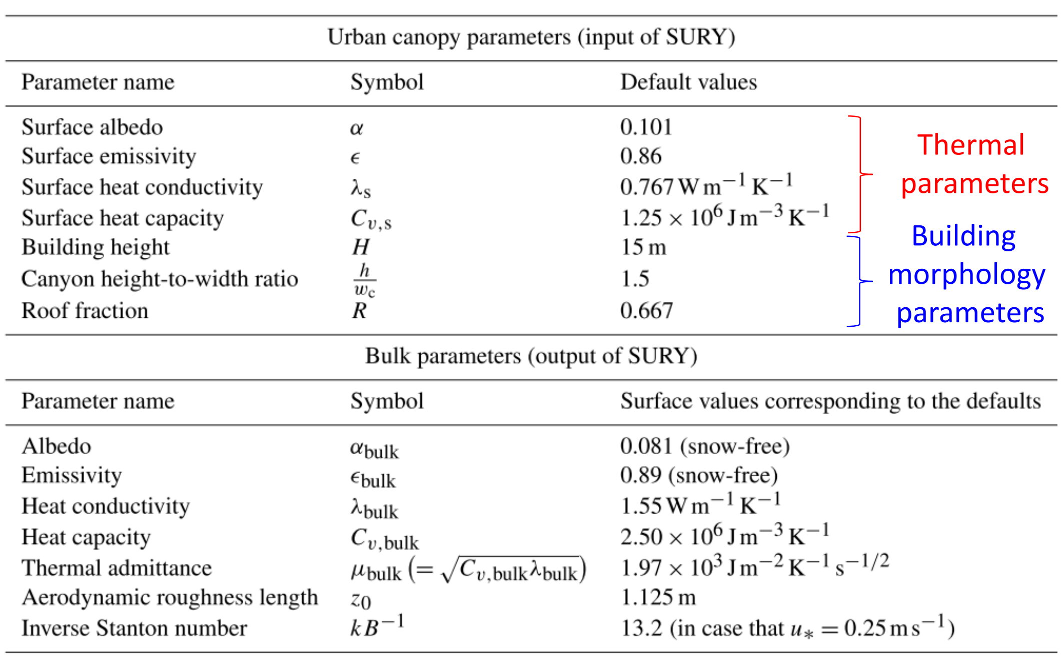
1. **cosmo_191107_5.05_urb5**: a basic stable version with TERRA_URB which we have as an outcome from AEVUS PT (fixed bugs with artificial heating and skin-layer temperature scheme)
2. **cosmo_191107_5.05_urb5 + update from Ulrich Schättler:**
   - Fixed bug with writing constants (indeed it works!)
   - Option for writing tiled variables to Netcdf output (not tested yet)
3. **cosmo_191107_5.05_urb5up* with my new developments:**
   - New external parameters and namelist parameters instead of some of the hard-coded constants (building morphology and thermophysical properties)
   - Skin-layer temperature scheme is controlled in the same way as in v5.06a using cskinc namelist parameter
   - **Distributed in November 2019 before meeting in Naples.**
4. **cosmo_191213_5.05_urb6**
   - Resent updates for 5.05urb5 from Ulrich Schättler + support of new external parameters from 5.05urb5up
   - **Bug found:** model crashes when new urban canopy parameters are not defined for grid cells wit FR_PAVED = 0.
5. **cosmo_191213_5.05_urb6up3:**
   - Fixed bug for COSMO 5.05urb6
   - Some other developments on the new external parameters
   - Send to Ulrich Schättler in the end of February as a candidate for GitHub version

1. **int2lm_190524_2.06:** a basic INT2LM version which supports TERRA_URB
2. **int2lm_190524_2.06up*** which supports my recent developments

*up means urban parameters

Motivation for new parameters

Table 1 from (Wouters et al., 2016)



Urban canopy parameters (input of SURY)		
Parameter name	Symbol	Default values
Surface albedo	α	0.101
Surface emissivity	ϵ	0.86
Surface heat conductivity	λ_s	$0.767\,\mathrm{W\,m^{-1}\,K^{-1}}$
Surface heat capacity	$C_{v,s}$	$1.25 \times 10^6\,\mathrm{J\,m^{-3}\,K^{-1}}$
Building height	H	15 m
Canyon height-to-width ratio	$\frac{h}{w_c}$	1.5
Roof fraction	R	0.667
Bulk parameters (output of SURY)		
Parameter name	Symbol	Surface values corresponding to the defaults
Albedo	α_{bulk}	0.081 (snow-free)
Emissivity	ϵ_{bulk}	0.89 (snow-free)
Heat conductivity	λ_{bulk}	$1.55\,\mathrm{W\,m^{-1}\,K^{-1}}$
Heat capacity	$C_{v,\mathrm{bulk}}$	$2.50 \times 10^6\,\mathrm{J\,m^{-3}\,K^{-1}}$
Thermal admittance	$\mu_{\mathrm{bulk}}\ (=\sqrt{C_{v,\mathrm{bulk}}\lambda_{\mathrm{bulk}}})$	$1.97 \times 10^3\,\mathrm{J\,m^{-2}\,K^{-1}\,s^{-1/2}}$
Aerodynamic roughness length	z_0	1.125 m
Inverse Stanton number	kB^{-1}	13.2 (in case that $u_* = 0.25\,\mathrm{m\,s^{-1}}$)

Thermal parameters

Building morphology parameters

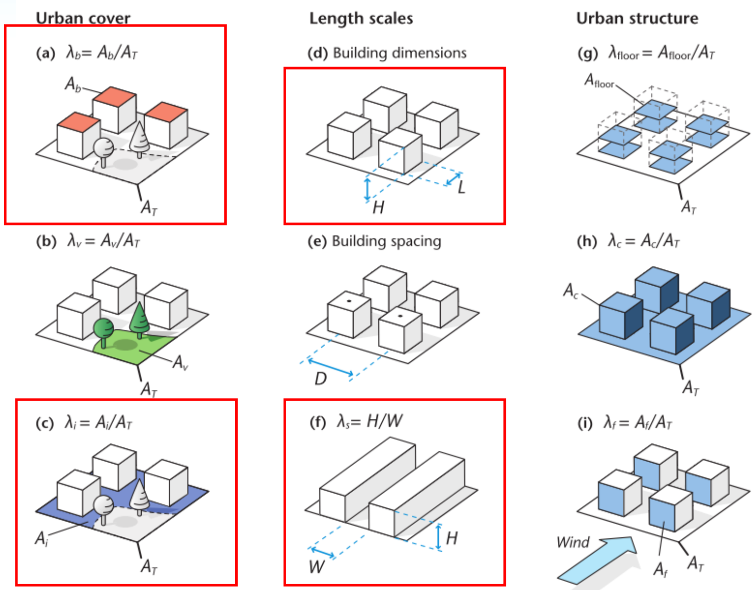
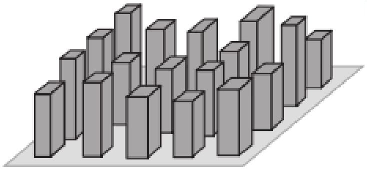


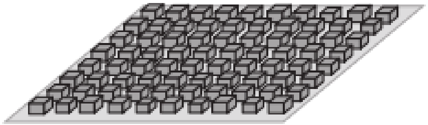
Figure 2.4 Parameters used to describe urban cover, length scales and urban structure.

Motivation for new parameters

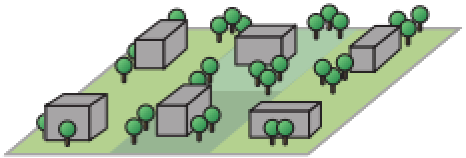
Cities and their parts are very different!



LCZ 1
Compact
highrise



LCZ 3
Compact
lowrise



LCZ 5
Open
midrise

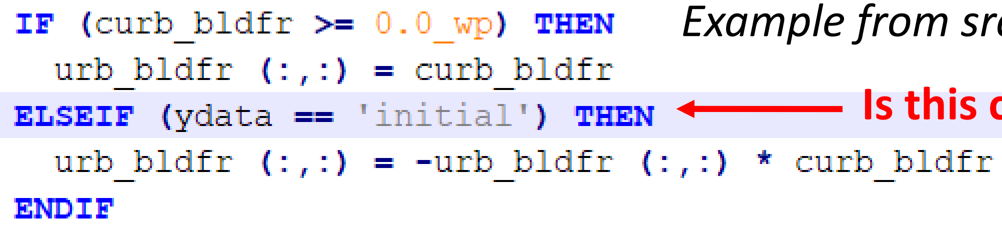
White roofs in Capri

Black roofs in Moscow

<u>SubTask1 of AEVUS2 PT:</u>
Code developments and tests, related to new urban canopy parameters

Implementation of new parameters

- **General idea is inspired by Jan-Peters' implementation of the skin-layer temperature scheme in a newer COSMO version 5.06a:**



```
IF (curb_bldfr >= 0.0_wp) THEN
  urb_bldfr (:,:) = curb_bldfr
ELSEIF (ydata == 'initial') THEN
  urb_bldfr (:,:) = -urb_bldfr (:,:) * curb_bldfr
ENDIF
```

Example from src_input.f90

Is this condition important?

- **New parameters works as following :**
  - If **curb_*** is positive, it is used as a constant. **For AHF, curb_ahf is multiplied by urban fraction.**
  - If **curb_*** is negative, external parameter **URB_*** is used, with a scaling factor equal to **–curb_*** (e.g. curb_* = -2 means that value from URB_* are doubled)
  - If **curb_*** is not specified in the namelist, a default values is used (**curb_*_d** variables in code)
  - **lurb_*** swithch controls the processing of URB_* in INT2LM.

- **Affected source files:**

COSMO: data_fields.f90, data_block_fields.f90, src_allocation.f90, src_block_fields_org.f90, sfc_interface.f90, sfc_tile_approach.f90, src_input.f90, radiation_utilities.f90, sfc_terra.f90, src_setup_vartab.f90, organize_data.f90, sfc_terra_data.f90, organize_physics.f90, radiation_interface.f90

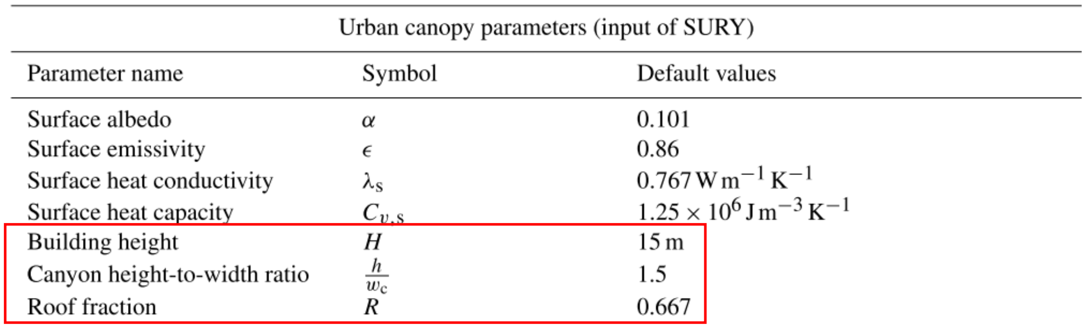
INT2LM: src_read_ext.f90, src_namelists.f90, src_memory.f90, src_gribtabs.f90, src_cleanup.f90, data_fields_lm.f90, external_data.f90, data_int2lm_control.f90

Implementation of new parameters

Description and units	Default value	Old variable in COSMO code	New variables in COSMO code	COSMO namelist parameters	INT2LM namelist parameters	External parameter name
Building area fraction with respect to an urban tile [1]	0.67	c_roof	curb_bldfr, curb_bldfr_d, curb_bldfr(:,:)	curb_bldfr	lurb_bldfr	URB_BLDFR
Building height [m]	15	c_uf_h	curb_bldh, curb_bldh_d, urb_bldh (:,:)	curb_bldh	lurb_bldh	URB_BLDH
Street canyon aspect ration (H/W) [unitless]	1.5	c_htw	curb_h2w, curb_h2w_d, urb_h2w(:,:)	curb_h2w	lurb_h2w	URB_H2W
Anthropogenic heat flux [W/m2]	**-1 (to use external parameter)**	ahf_an	curb_ahf, curb_ahf_d, ahf_an (:,:)	curb_ahf		**AHF**
Urban material thermal albedo [1]	0.14	ctalb_bm	curb_talb, urb_talb_d, urb_talb (:, :)	curb_talb		**URB_TALB**
Urban material shortwave albedo [1]	0.1	csalb_bm	curb_salb,curb_salb_d, urb_salb (:, :)	curb_salb		**URB_SALB**
Volumetric heat capacity of urban material (capacity * density) [J · m^{-3} · K^{-1}]	1.25E6	c_rhoc_bm	curb_hcap, curb_hcap _d, urb_hcap (:, :)	curb_hcap		**URB_HCAP**
Heat conductivity of urban material [W · m^{-1} · K^{-1}]	0.777	c_ala_bm	curb_hcon, curb_hcon_d, urb_hcon (:, :)	curb_hcon		**URB_HCON**
Skin-layer conductivity for rural areas [???]	10 or 30 (now 30)	calamrur	cskinc, cskinc_d, skinc (:,:)	cskinc	lskinc	SKC
Skin-layer conductivity for urban areas [???]	1000	calamurb	cskinc_urb	cskinc_urb		

Suggestion for new defaults

- Defaults from TERRA_URB seems to be misrepresentative for the most of the cities
- According to Matthias's global LCZ map, the most frequent LCZ is LCZ6.
- Most frequent LCZ in Moscow is LCZ5.



Urban canopy parameters (input of SURY)

Parameter name	Symbol	Default values
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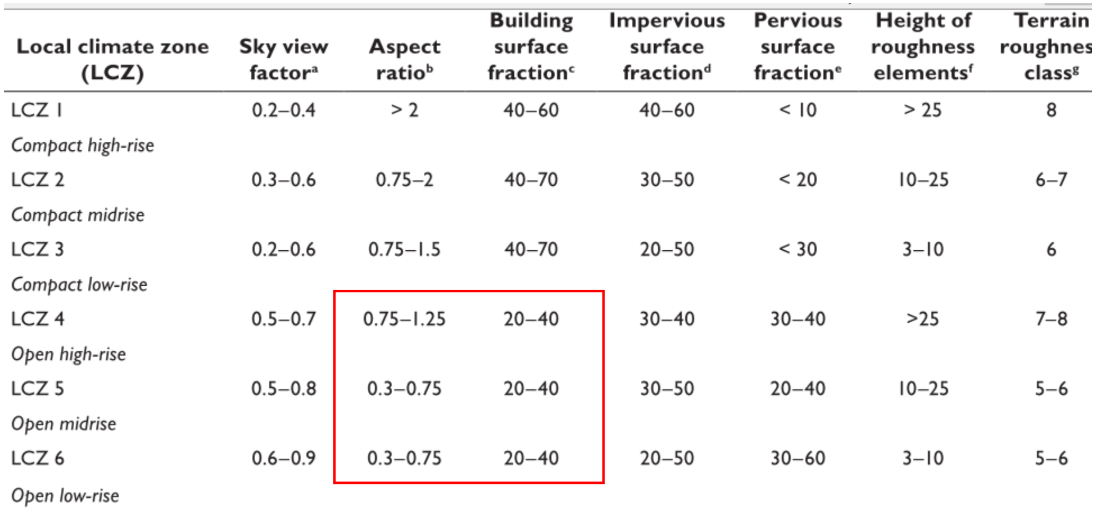
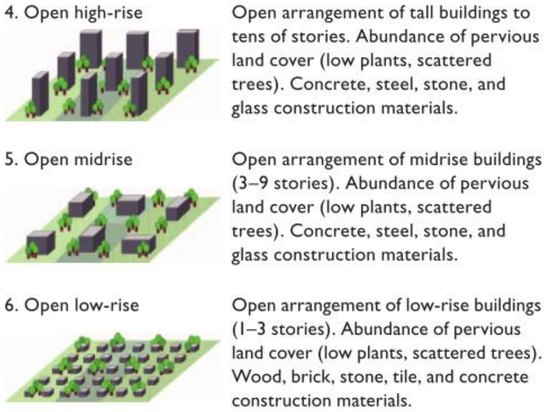
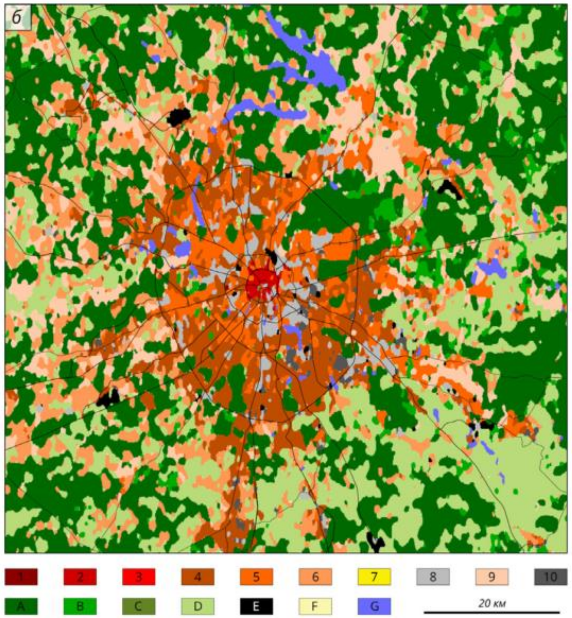
Building height	H	15 m
Canyon height-to-width ratio	$\frac{h}{w_c}$	1.5
Roof fraction	R	0.667



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 roughnes 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



4. Open high-rise	Open arrangement of tall buildings to tens of stories. Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials.
5. Open midrise	Open arrangement of midrise buildings (3–9 stories). Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials.
6. Open low-rise	Open arrangement of low-rise buildings (1–3 stories). Abundance of pervious land cover (low plants, scattered trees). Wood, brick, stone, tile, and concrete construction materials.



Outline

1. Recent developments on the model code: new options and parameters for TERRA_URB
2. Model sensitivity to the new parameters
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Design of the sensitivity tests

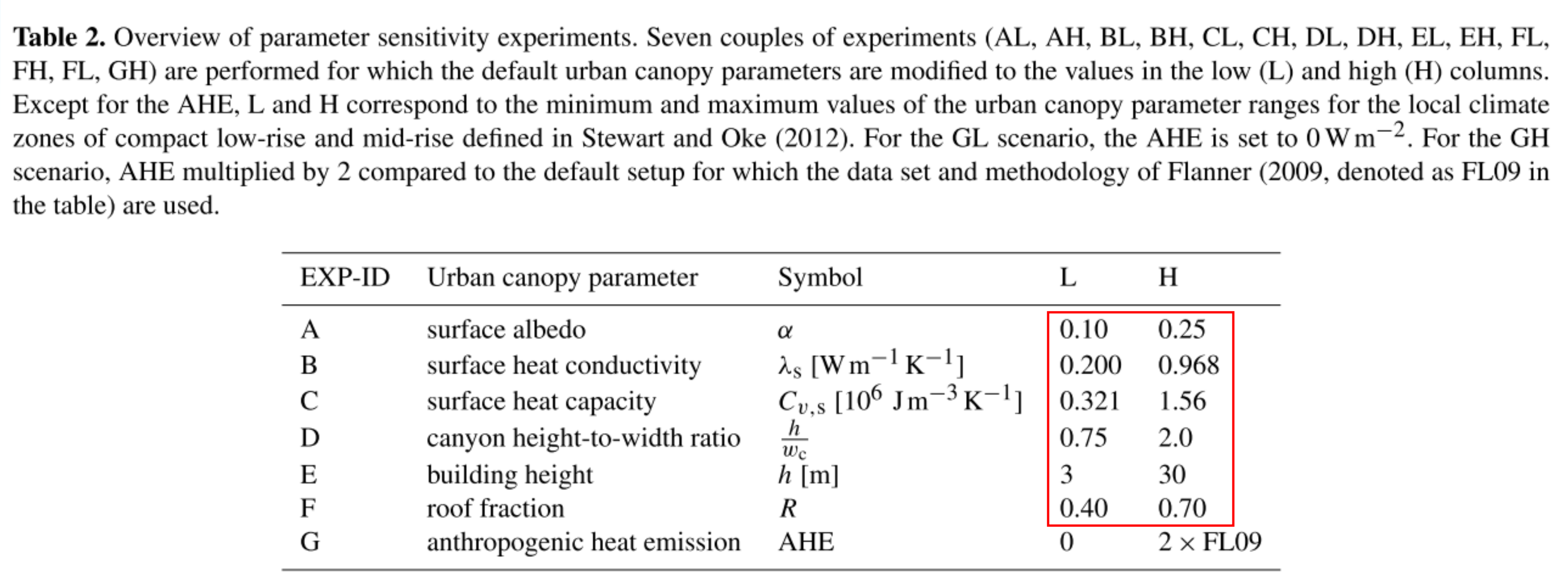


Table 2. Overview of parameter sensitivity experiments. Seven couples of experiments (AL, AH, BL, BH, CL, CH, DL, DH, EL, EH, FL, FH, FL, GH) are performed for which the default urban canopy parameters are modified to the values in the low (L) and high (H) columns. Except for the AHE, L and H correspond to the minimum and maximum values of the urban canopy parameter ranges for the local climate zones of compact low-rise and mid-rise defined in Stewart and Oke (2012). For the GL scenario, the AHE is set to $0\,\mathrm{W\,m^{-2}}$. For the GH scenario, AHE multiplied by 2 compared to the default setup for which the data set and methodology of Flanner (2009, denoted as FL09 in the table) are used.

EXP-ID	Urban canopy parameter	Symbol	L	H
A	surface albedo	α	0.10	0.25
B	surface heat conductivity	λ_s $[\mathrm{W\,m^{-1}\,K^{-1}}]$	0.200	0.968
C	surface heat capacity	$C_{v,\mathrm{s}}$ $[10^6\ \mathrm{J\,m^{-3}\,K^{-1}}]$	0.321	1.56
D	canyon height-to-width ratio	$\frac{h}{w_\mathrm{c}}$	0.75	2.0
E	building height	h [m]	3	30
F	roof fraction	R	0.40	0.70
G	anthropogenic heat emission	AHE	0	2 × FL09

Should we further use the same H & L values for the unified tests?
Maybe let's increase the H-values?

Design of the sensitivity tests

❑ **New downscaling chain:**

ICON
(Δx ≈ 13 km)

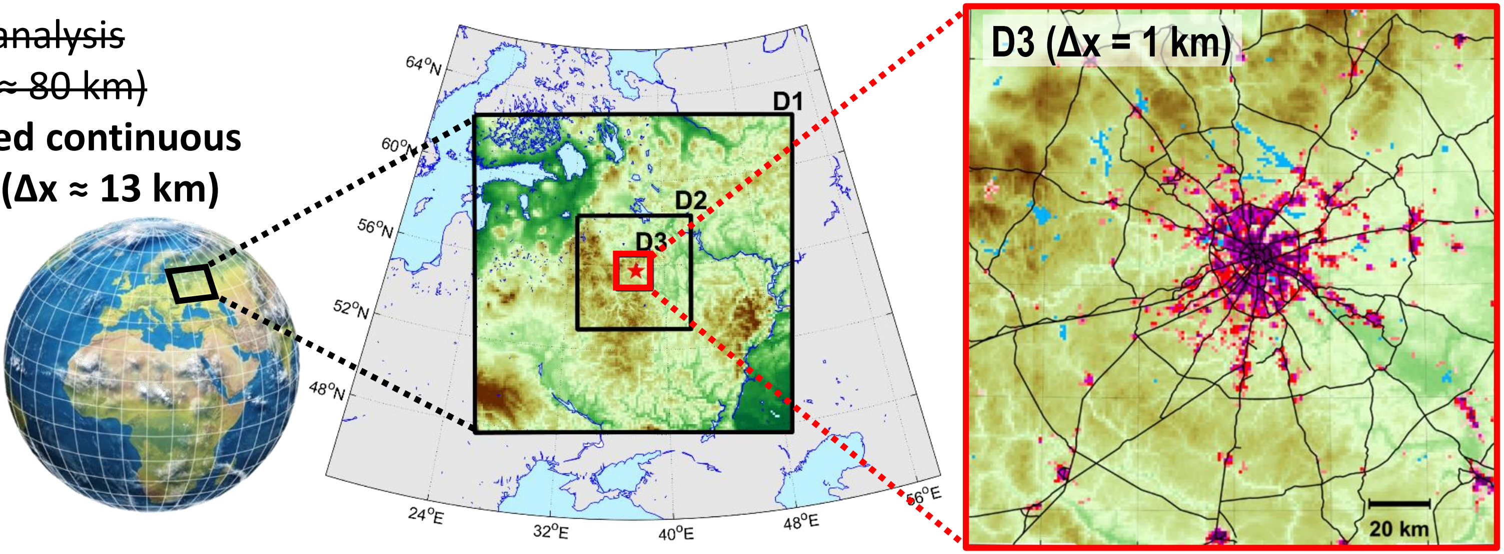
COSMO D2
(Δx = 3 km)

COSMO D3
(Δx = 1 km)

COSMO D3h
(Δx = 500 m)

~~ERA-Interim reanalysis (Δx ≈ 80 km)~~

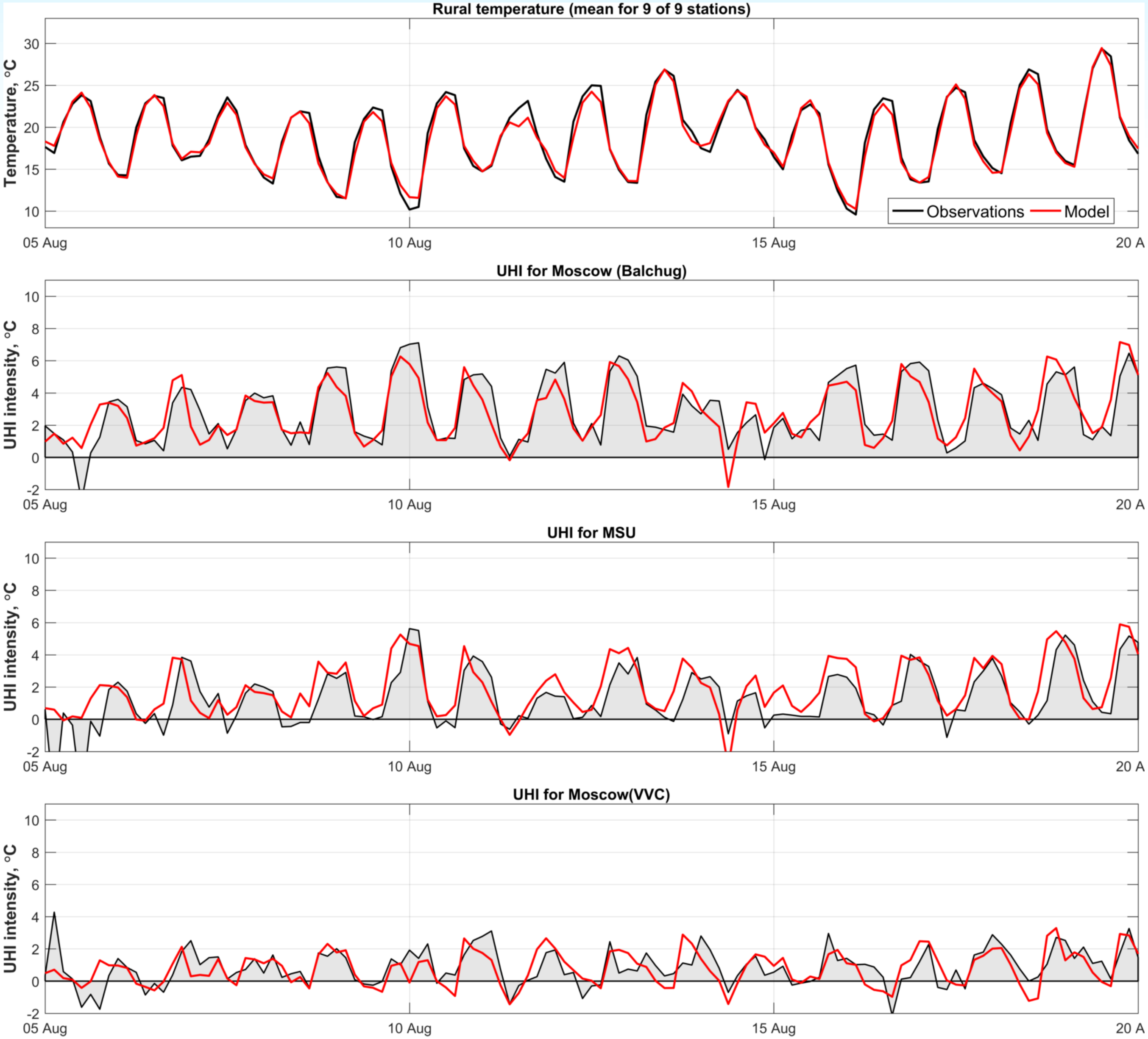
ICON-based continuous dataset (Δx ≈ 13 km)



❑ **ICON forecasts to "reanalysis:**

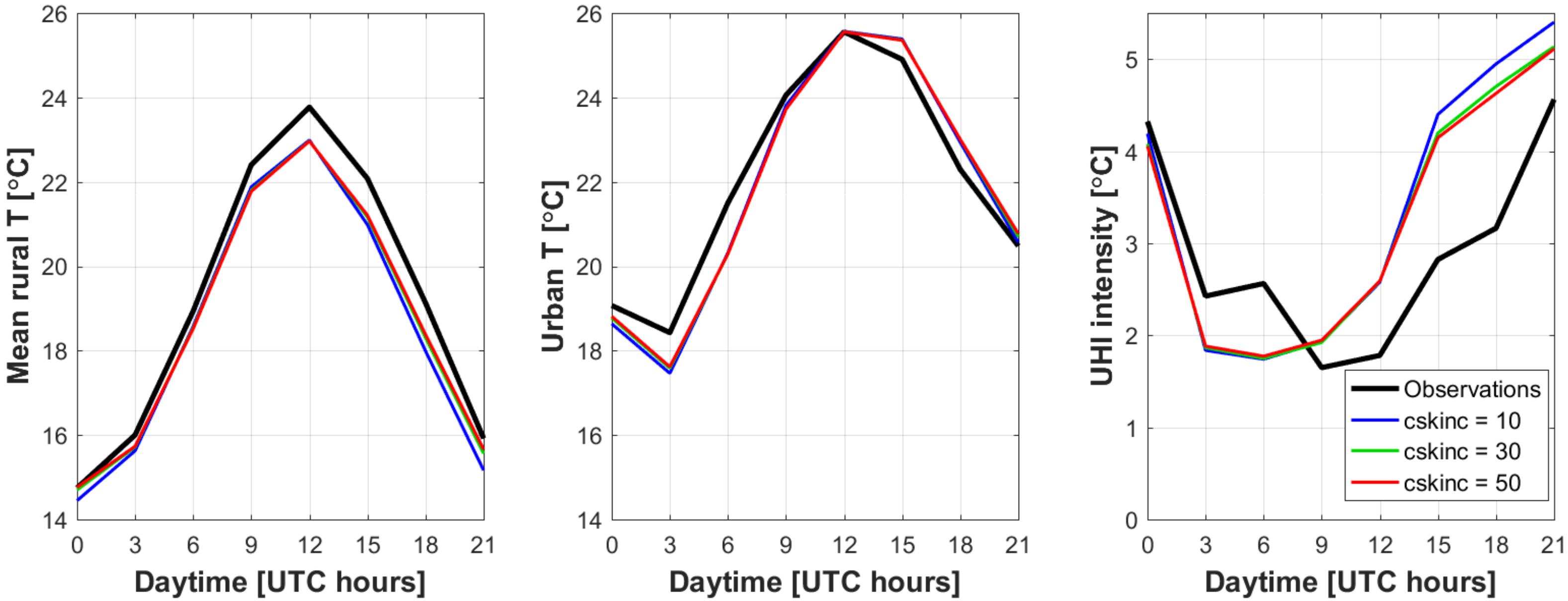
Forecast from 0 UTC	0	3	6	9	12	…				
Forecast from 6 UTC			0	3	6	9	12	…		
Forecast from 12 UTC					0	3	6	9	12	…

New case study: 5-20 August 2017



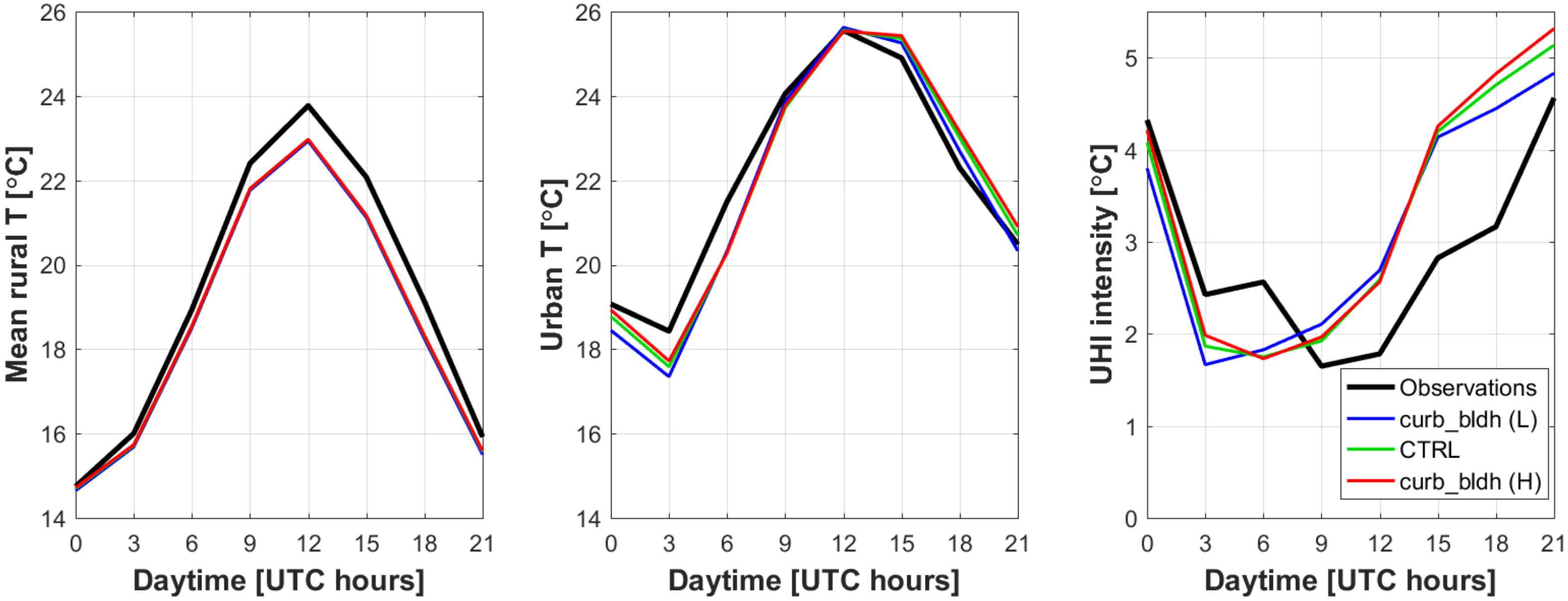
First results of sensitivity test

Sensitivity to skin conductivity (cskinc)



First results of sensitivity test

Sensitivity to building height (curb_bldh)



$\Delta T_{H\text{-}L}$

all / night

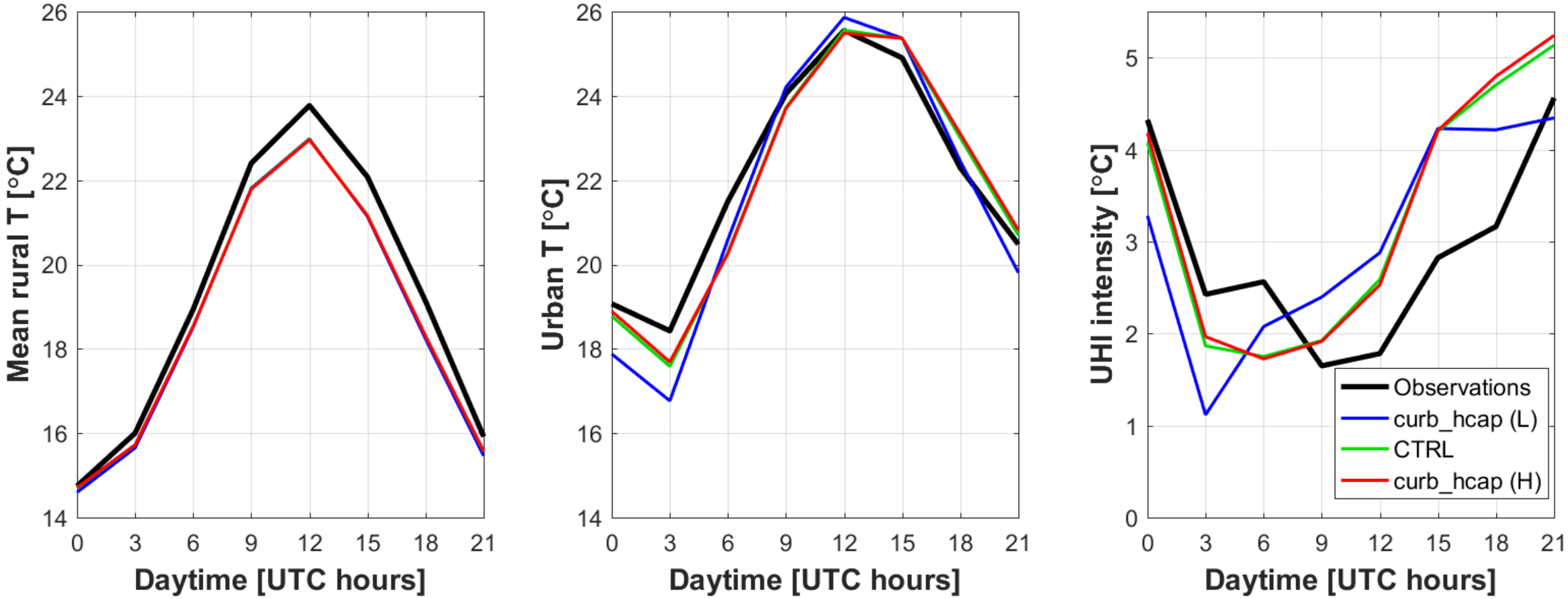
$\Delta T_{H\text{-}L}$ (mean over city): 0.21 K / 0.45 K

$\Delta T_{H\text{-}L}$ (city center): 0.23 K / 0.48 K

$\Delta T_{H\text{-}L}$ (Wouters et al., 2016): 0.16 K / 0.24 K

First results of sensitivity test

Sensitivity to urban heat capacity (curb_hcap)



ΔT_{H-L}

all / night

ΔT_{H-L} (mean over city): 0.21 K / 0.81 K

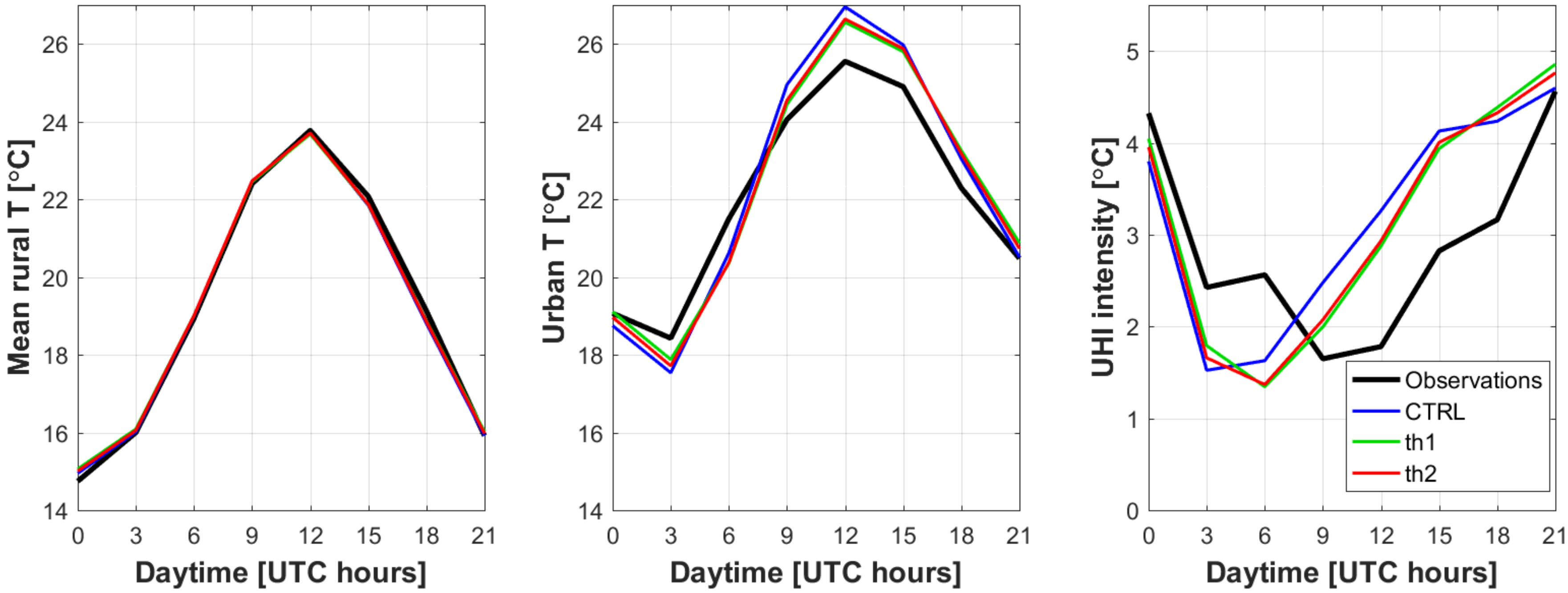
ΔT_{H-L} (city center): 0.29 K / 1.00 K

ΔT_{H-L} (Wouters et al., 2016): 0.19 K / 0.57 K

Sensitivity to thermal parameters

Attempt to solve the problem with diurnal turn of UHI intensity

Parameter	CTRL	Th1	Th2
curb_salb	0.1	0.2	0.2
curb_talb	0.14	0.14	0.1
curb_hcap	1.25E6	1.8E6	1.8E6
curb hcon	0.777	1.0	0.777



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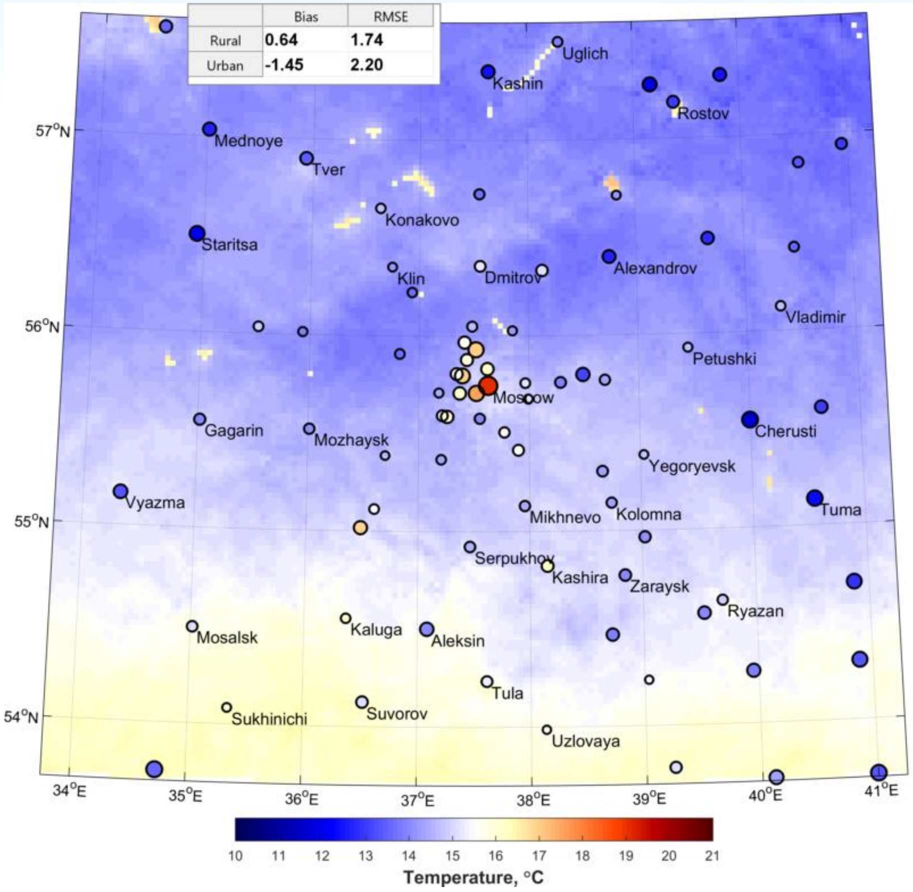
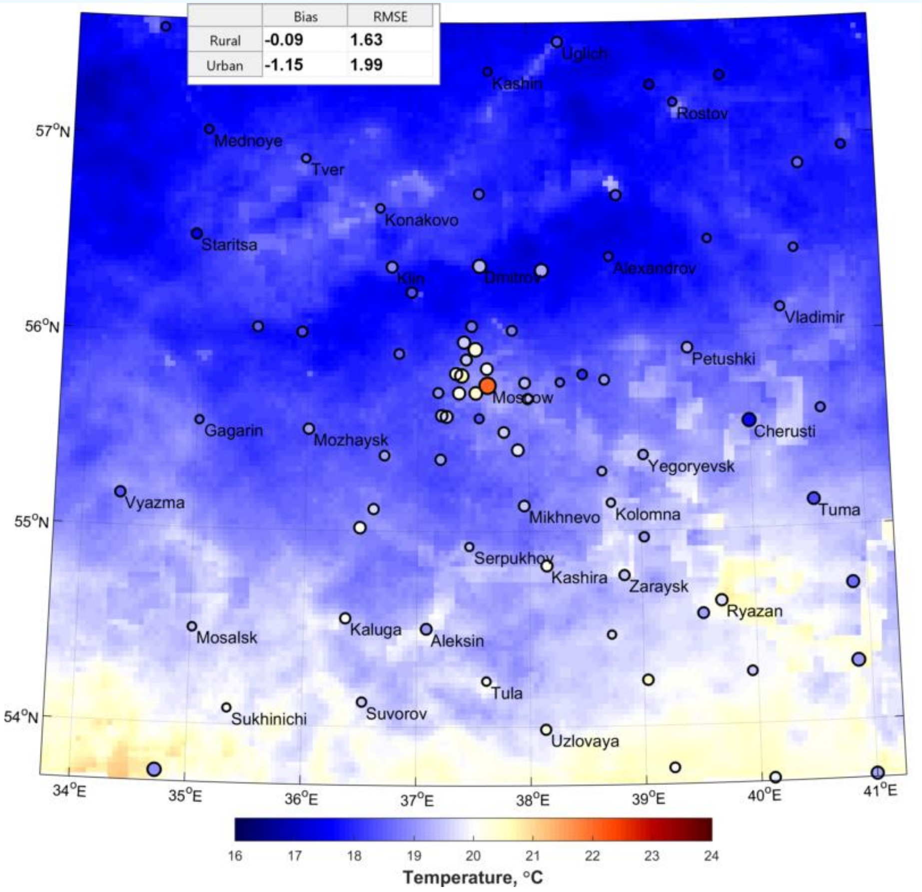
What is the "best" configuration?

Parameter	bestJP	bestMM	bestMV
itype_canopy	2	2	2
itype_evsl	4	4	4
itype_heatcond	3	3	3
Itype_root	2	2	2
itype_albedo	3	3	2
Itype_aerosol	1	1	2
lstomata	True	True	True
lemiss	True	True	True
c_soil	1.25	1.25	1
pat_len	**100 (def)**	**750**	**100 (def)**
tkmmin	0.75	0.75	0.75
tkhmin	0.75	0.75	0.75



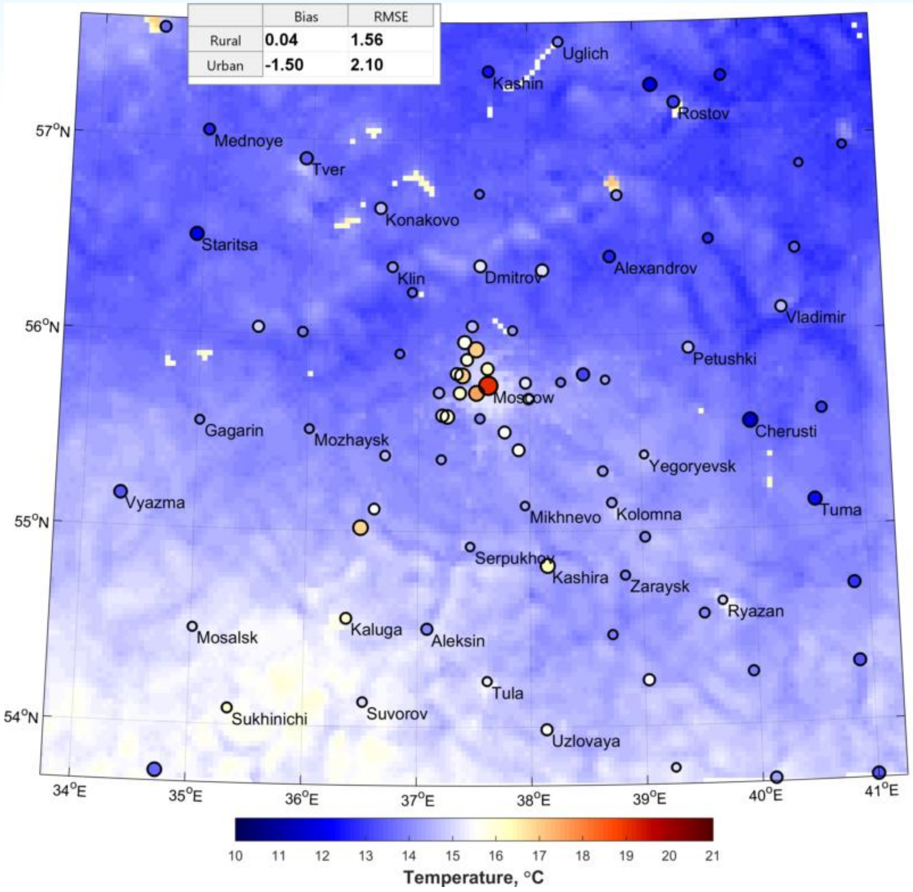
	Bias	RMSE
Rural	0.64	1.74
Urban	-1.45	2.20

Nocturnal temperature for the test case.
BestMM configuration.



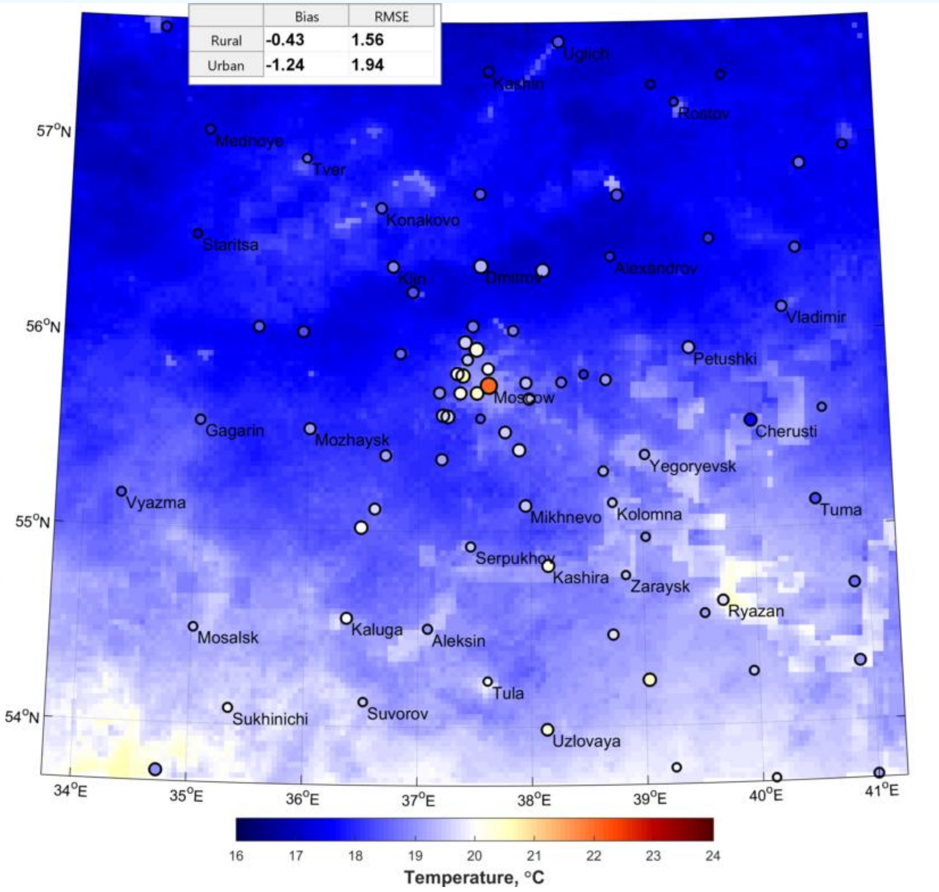
	Bias	RMSE
Rural	-0.09	1.63
Urban	-1.15	1.99

Daily mean temperature for the test case.
BestMM configuration.



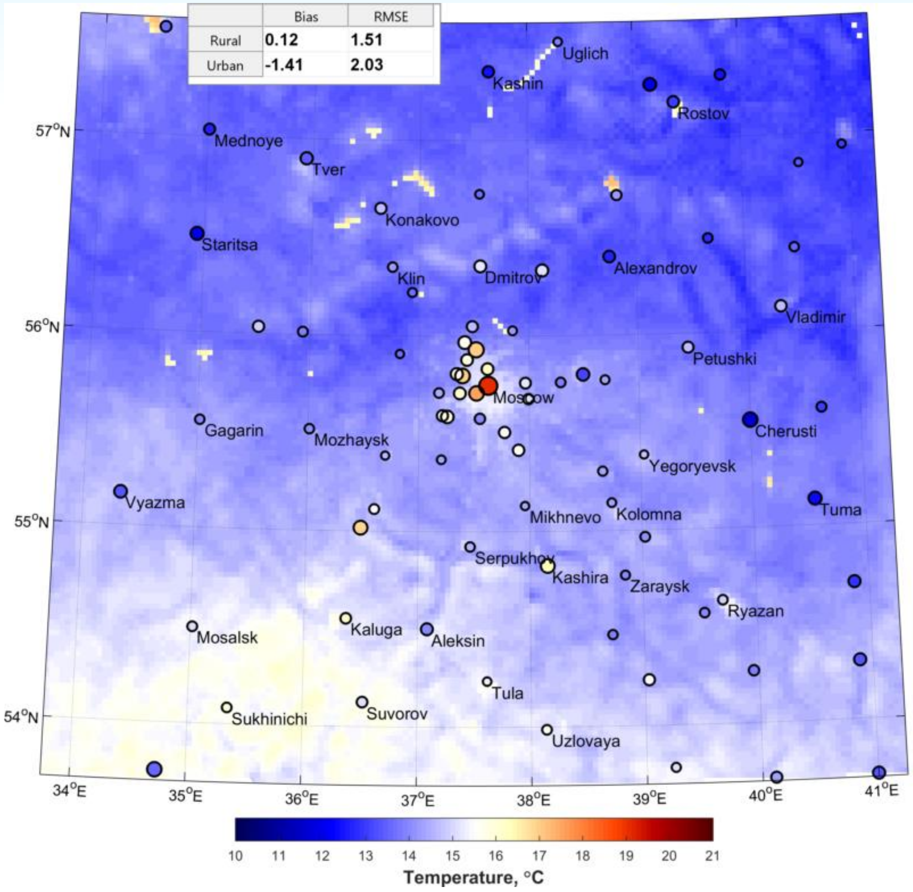
	Bias	RMSE
Rural	0.04	1.56
Urban	-1.50	2.10

Nocturnal temperature for the test case.
BestJP configuration.



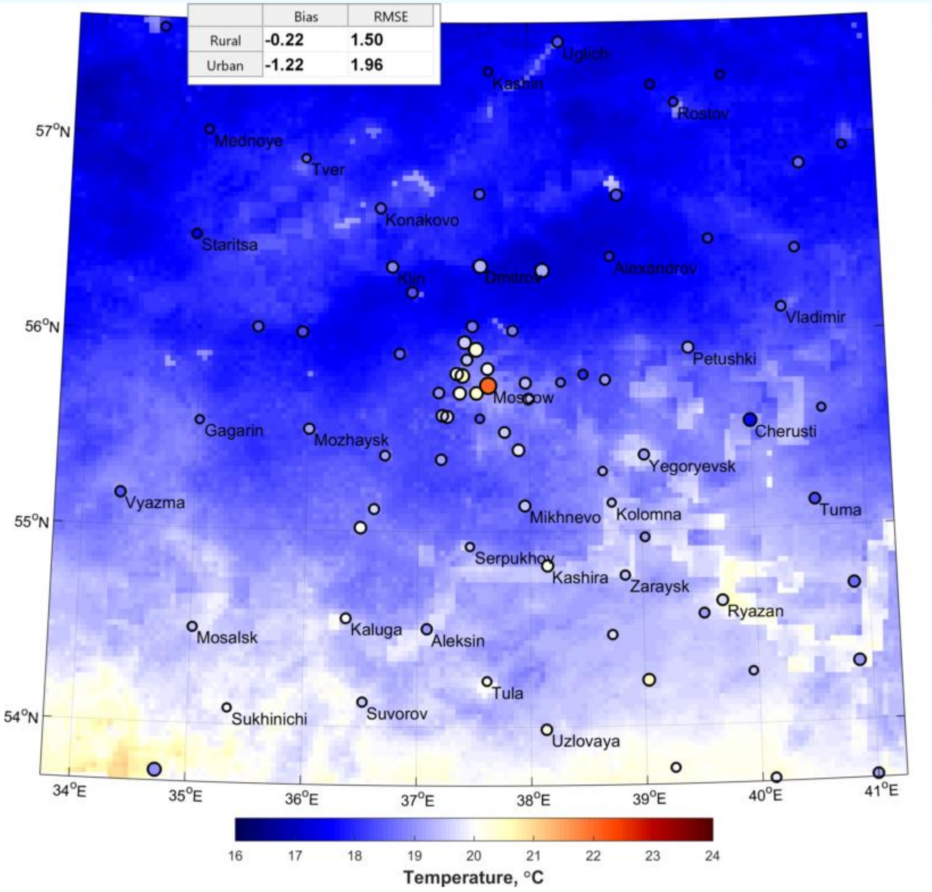
	Bias	RMSE
Rural	-0.43	1.56
Urban	-1.24	1.94

Daily mean temperature for the test case.
BestJP configuration.



	Bias	RMSE
Rural	0.12	1.51
Urban	-1.41	2.03

Nocturnal temperature for the test case. BestMV configuration.



	Bias	RMSE
Rural	-0.22	1.50
Urban	-1.22	1.96

Daily mean temperature for the test case. BestMV configuration.

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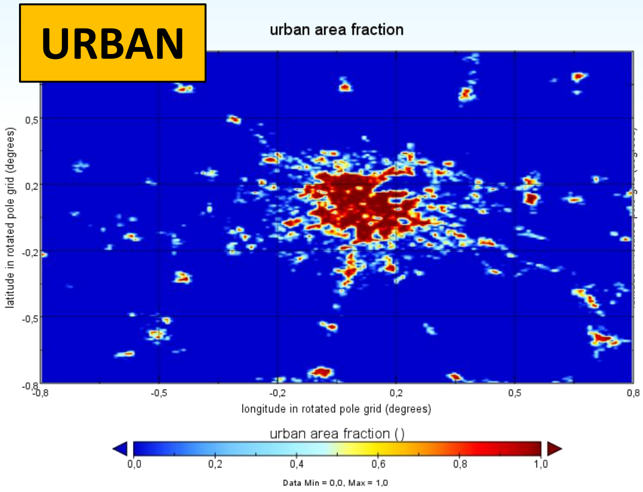
SubTask2:
Testing of new external parameters

"Finally, ***in order to avoid a double counting*** *of the different urban-induced effects, we will further investigate* ***the consistency between the different urban related external parameters*** *(i.e. impervious surface area fraction, anthropogenic heat flux QF, vegetation skin-layer conductivity SKC, roughness length z0, etc.)."*

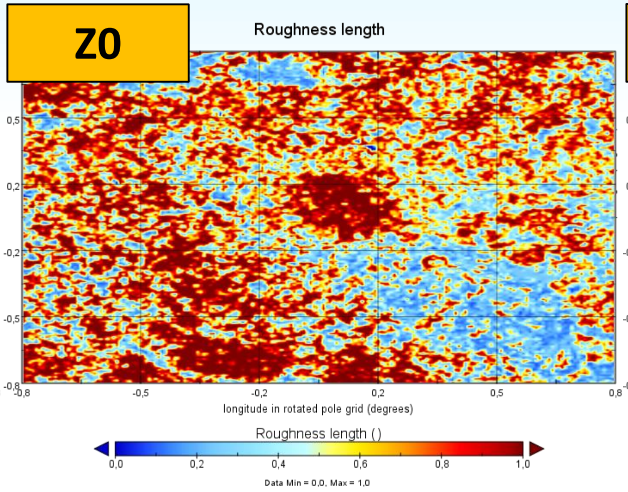
Zero-order urban description in the EXTPAR data

URBAN



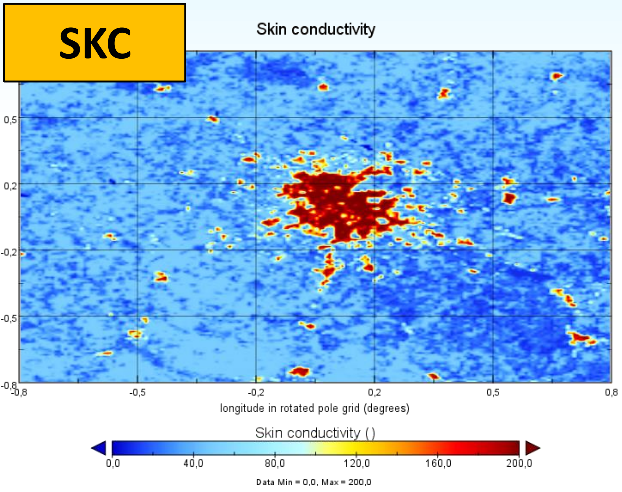
urban area fraction

Z0



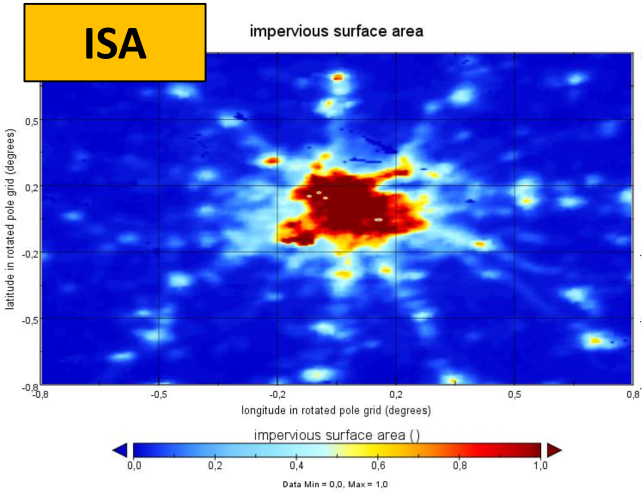
Roughness length

SKC



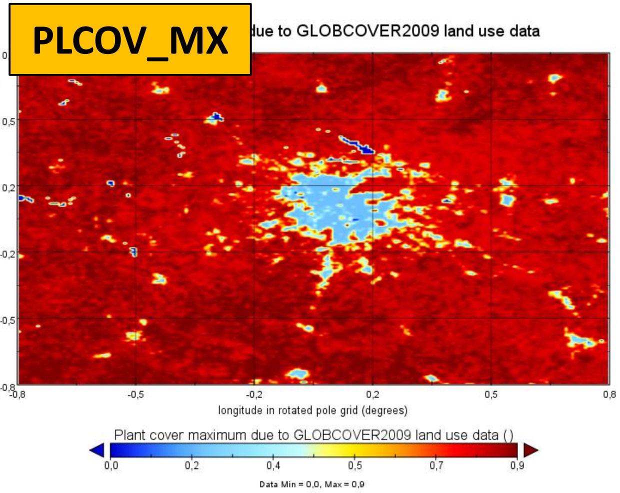
Skin conductivity

ISA



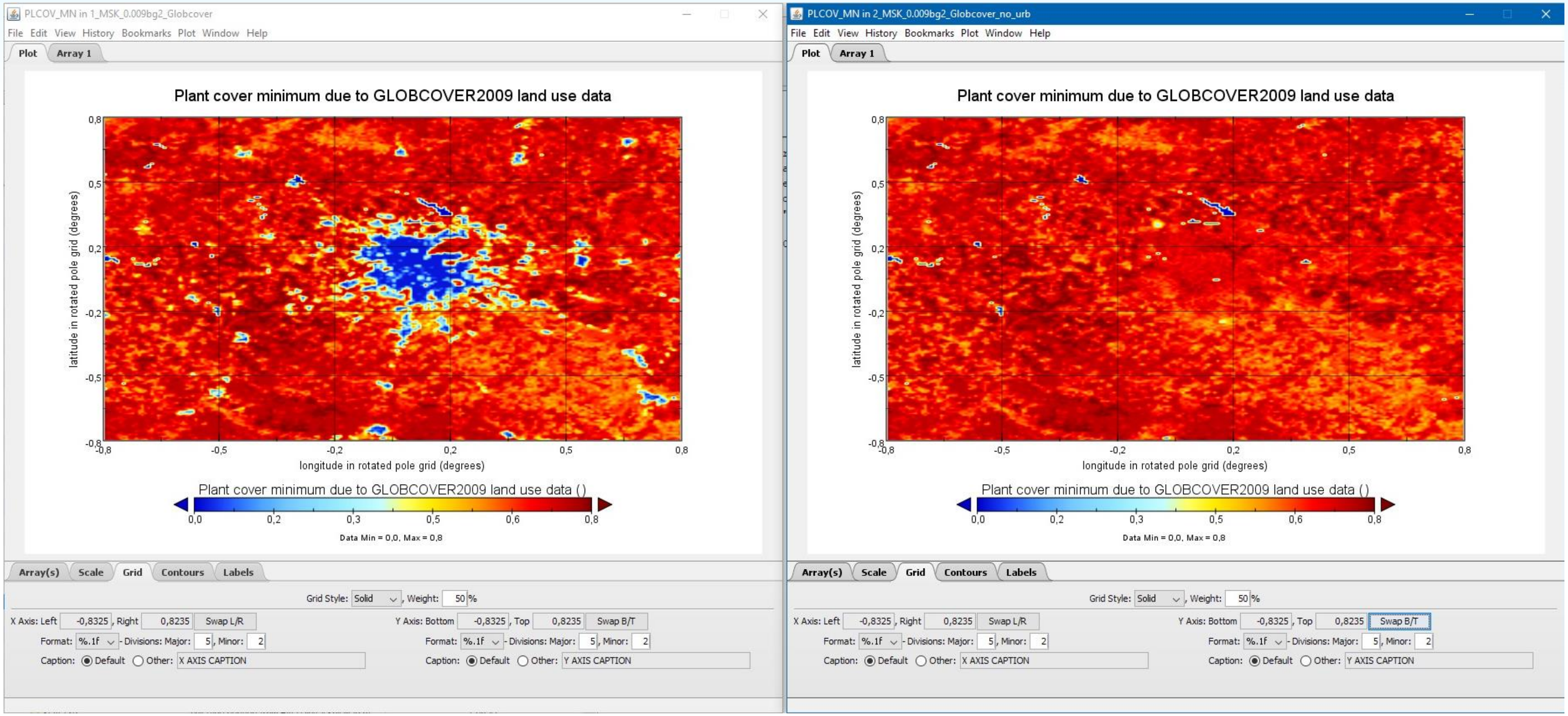
impervious surface area

PLCOV_MX



due to GLOBCOVER2009 land use data

Zero-order urban description in the EXTPAR data



Grid Style: Solid, Weight: 50 %

X Axis: Left -0,8325, Right 0,8235

Format: %.1f - Divisions: Major: 5, Minor: 2

Caption: ● Default ○ Other: X AXIS CAPTION

Y Axis: Bottom -0,8325, Top 0,8235

Format: %.1f - Divisions: Major: 5, Minor: 2

Caption: ● Default ○ Other: Y AXIS CAPTION

Grid Style: Solid, Weight: 50 %

X Axis: Left -0,8325, Right 0,8235

Format: %.1f - Divisions: Major: 5, Minor: 2

Caption: ● Default ○ Other: X AXIS CAPTION

Y Axis: Bottom -0,8325, Top 0,8235

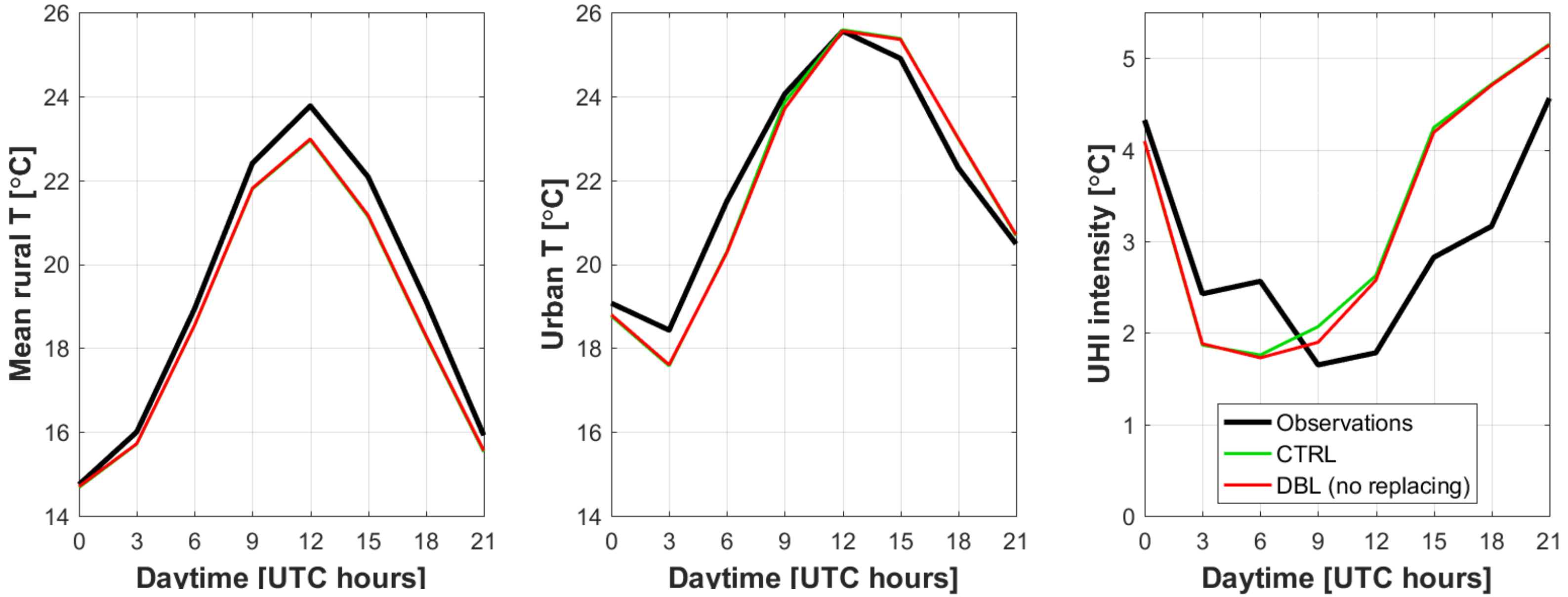
Format: %.1f - Divisions: Major: 5, Minor: 2

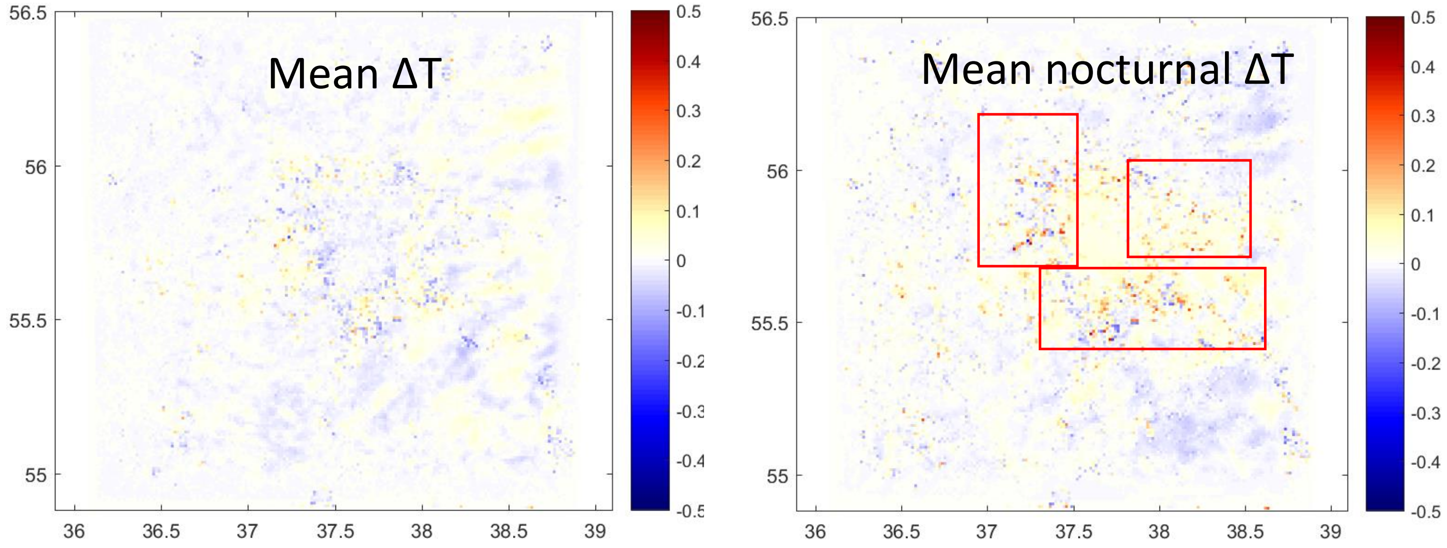
Caption: ● Default ○ Other: Y AXIS CAPTION

Solution: replacing the values for urban areas for those ones from the nearest non-urban areas.

How significant is these effect?

Sensitivity test for “double accounting”

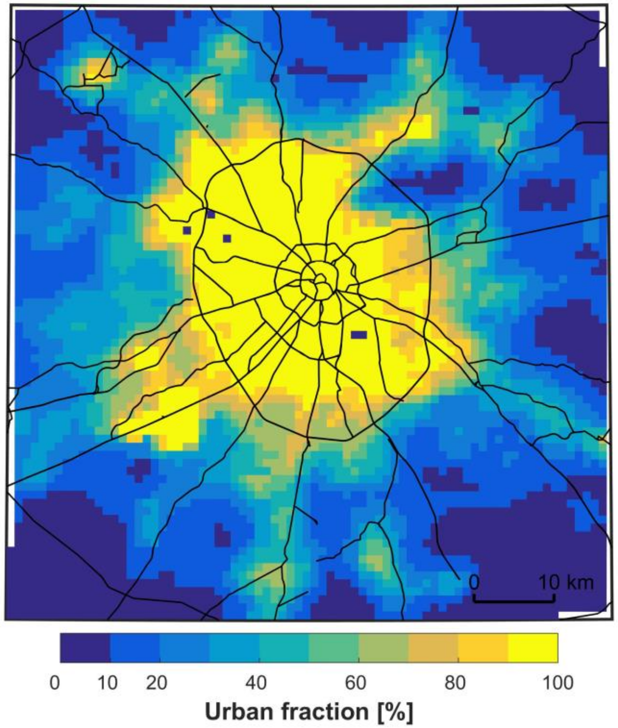




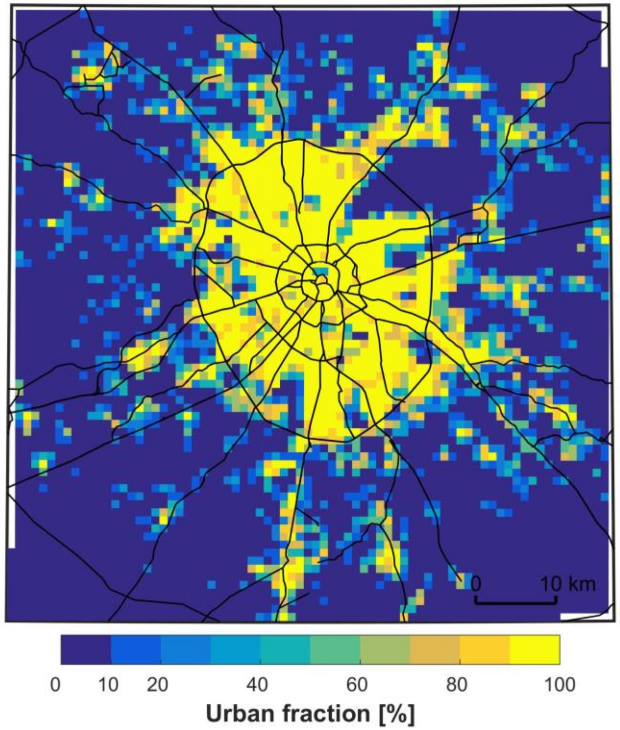
In contrast to previous runs, the spatially-varied SKC field is used here.

Other issues on EXTPAR data consistency

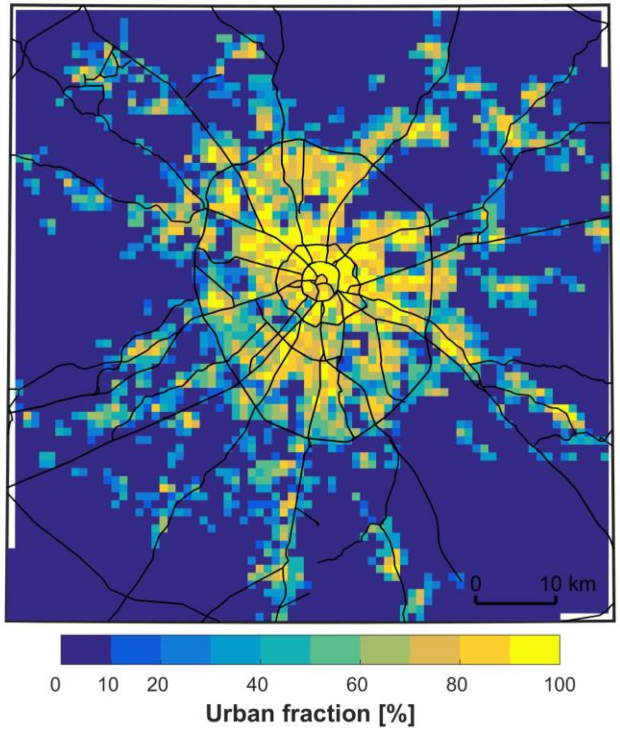
ISA/FR_PAVED field from EXTPAR



URBAN field from EXTPAR (based on Globcover LU classes, linked with other fields as SKC)

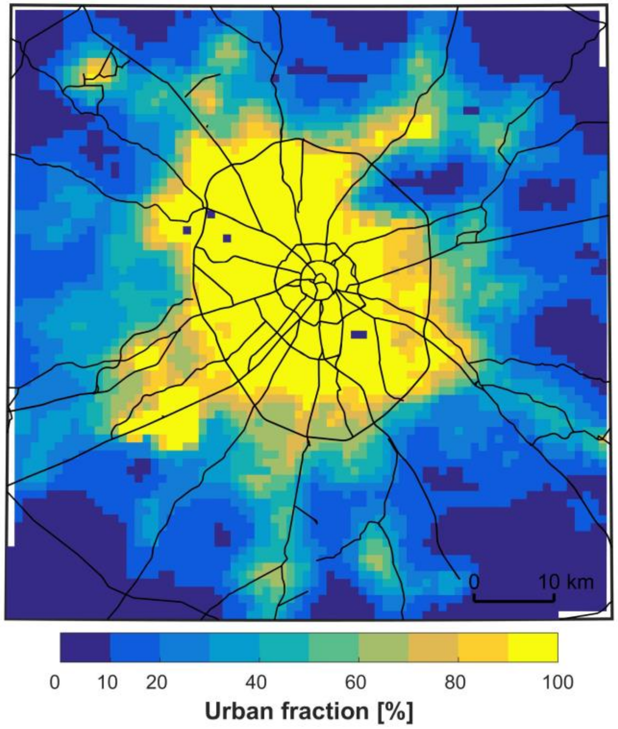


What we used for 1-km runs (based on OpenStreetMaps data and empiric estimates)

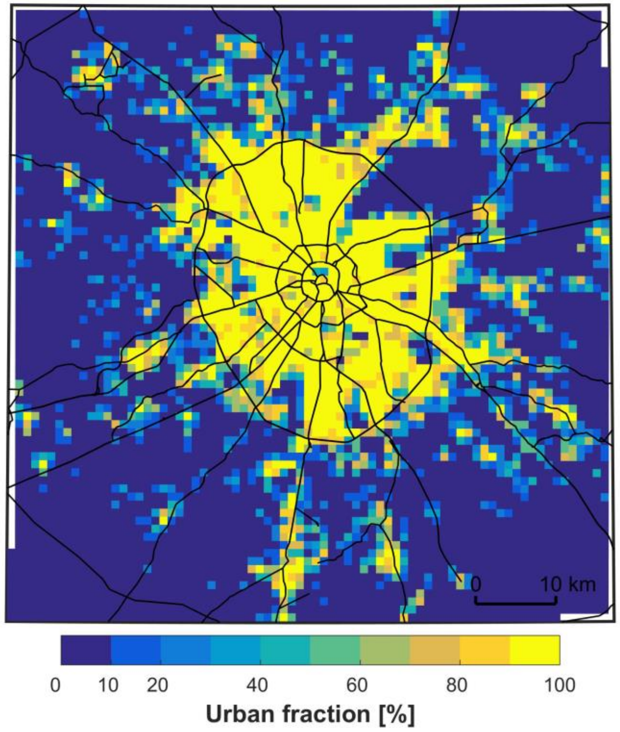


What is a benefit to use ISA/FR_PAVED field from EXTPAR?
For Moscow it looks completely unrealistic.
URBAN field from GLOBCOVER looks much more realistic.

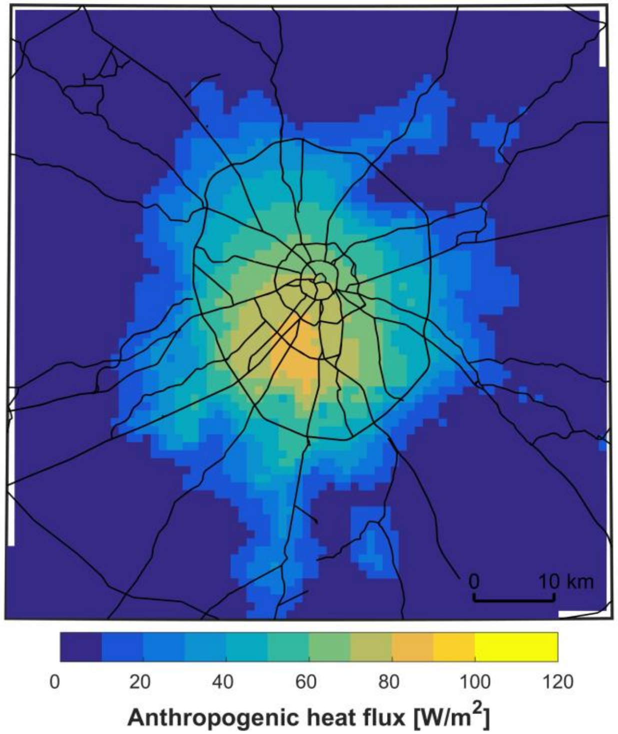
Other issues on EXTPAR data consistency



ISA/FR_PAVED field from EXTPAR



URBAN field from EXTPAR (based on Globcover LU classes, linked with other fields as SKC)



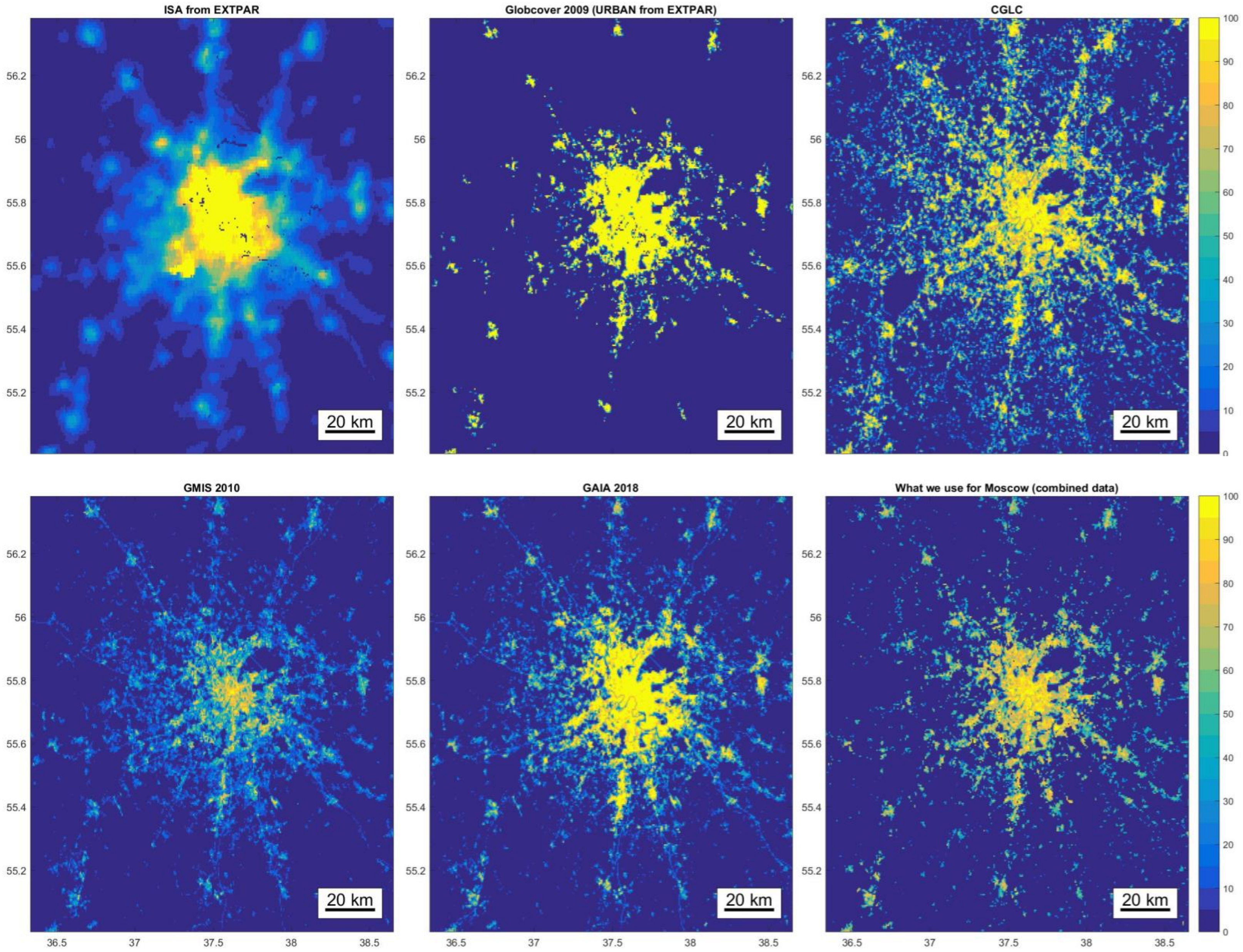
AHF from EXTPAR

Now the external data sets which affects the model behavior for urban areas are inconsistent with each other!

Outline

1. Recent developments on the model code:
   new options and parameters for TERRA_URB
2. Model sensitivity to the new parameters
3. On the namelist settings and tuning parameters
4. On the consistency of EXTPAR data
5. On the uncertainty of the data on
   urban/impervious area fraction

Different sources of data: so high uncertainty!



Our approach for Moscow

Old approach (for Δx = 1 km):

1) OpenStreetMap data
2) Empiric estimates

New approach (for Δx = 500 m):

1) New Copernicus Global Land Cover data
2) OpenStreetMap data
3) High-resolution (10 m) vegetation data from Sentinel images

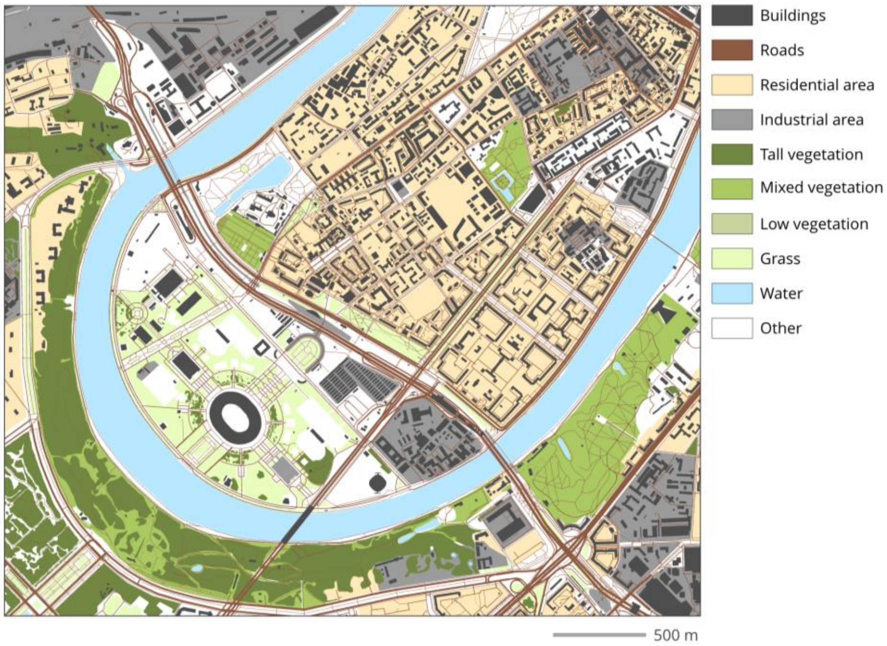
Copernicus Global Land Service

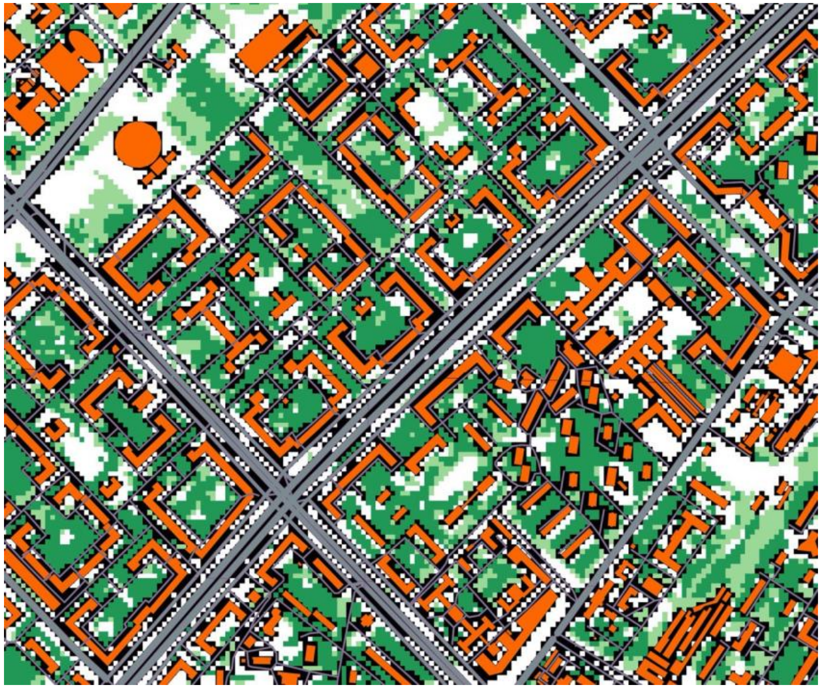
Providing bio-geophysical products of global land surface

Release of Global 100m Land Cover maps for 2015

Today, at the occasion of ESA's biggest Earth observation conference, the 'Living Planet Symposium 2019' (Milan, Italy), the Global Land Service team is thrilled to **release** a new set of **Global Land Cover** layers, with an **overall 80% accuracy**:

- a complete, **discrete classification with 23 classes**
- **fractional cover layers** for the **ten** base land cover classes: forest, shrub, grass, moss & lichen, bare & sparse vegetation, cropland, built-up / urban, snow & ice, seasonal & permanent inland water bodies.
- a **forest type layer** offering twelve types of forest
- **quality indicators** for input data (data density indicator), for the discrete map (probability) and for six of the fractional cover layers.



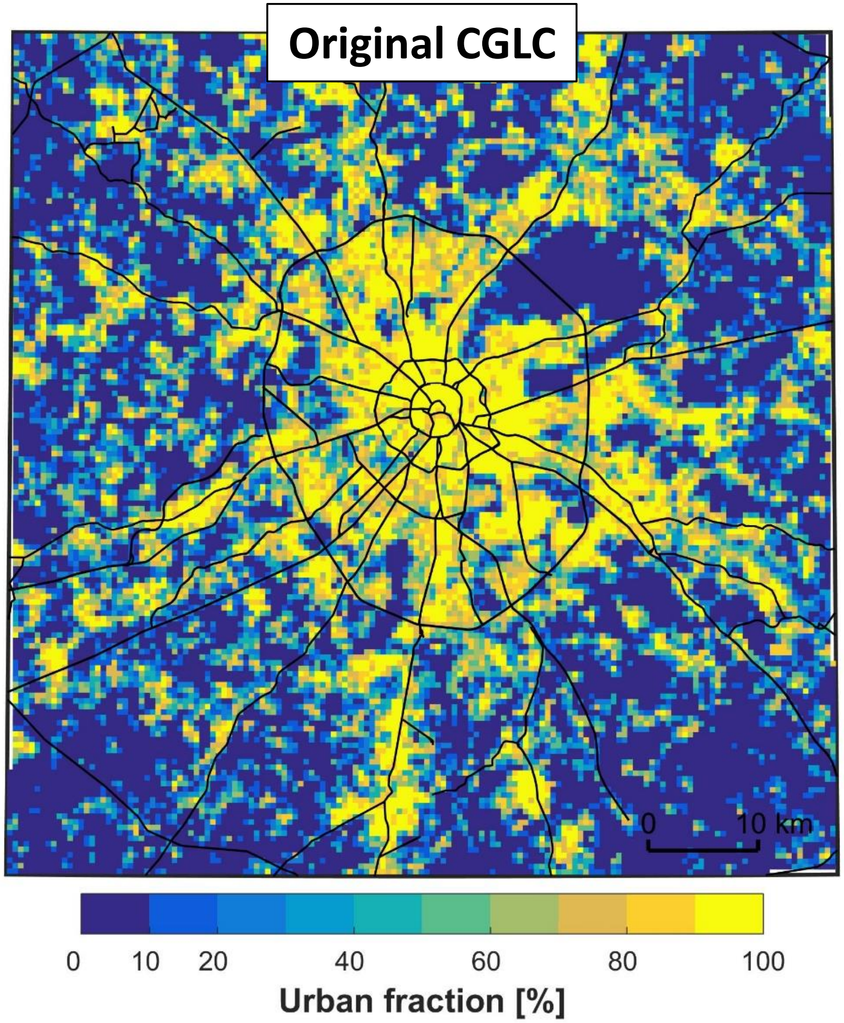


Our approach for Moscow

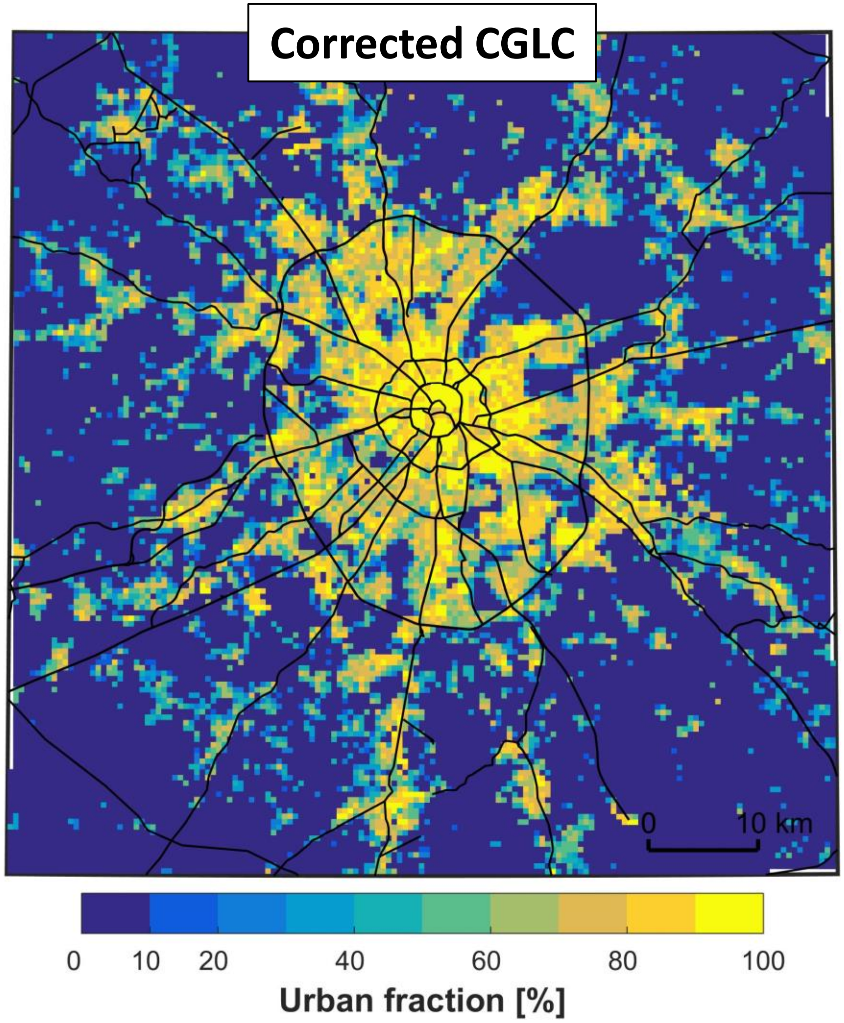
$\text{URBAN\_FR} = \max(\min(\text{URBAN\_FR}_{GLC}, 1 - \text{GREEN\_FR}), \text{URBAN\_FR}_{OSM})$

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

$\text{URBAN\_FR}_{OSM} = \text{BLDF\_FR}_{OSM} + \text{ROAD\_FR}_{OSM}$



Original CGLC



Corrected CGLC

Thank you for attention!

Any questions?