Testing the new model version COSMO 5.05_urb for Moscow megacity:

current problems and preliminary verification

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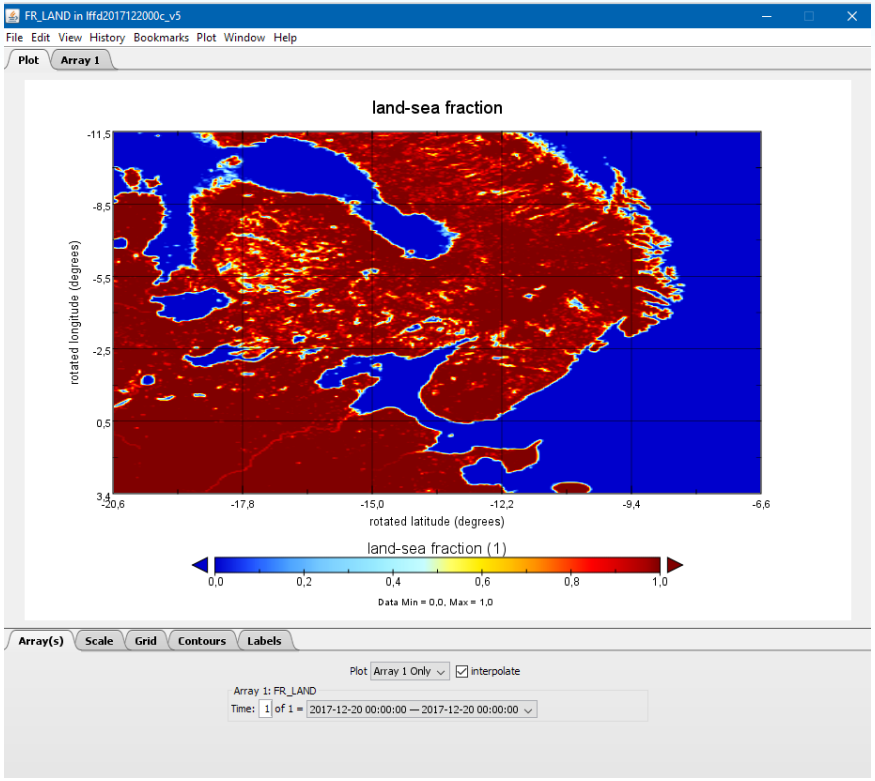
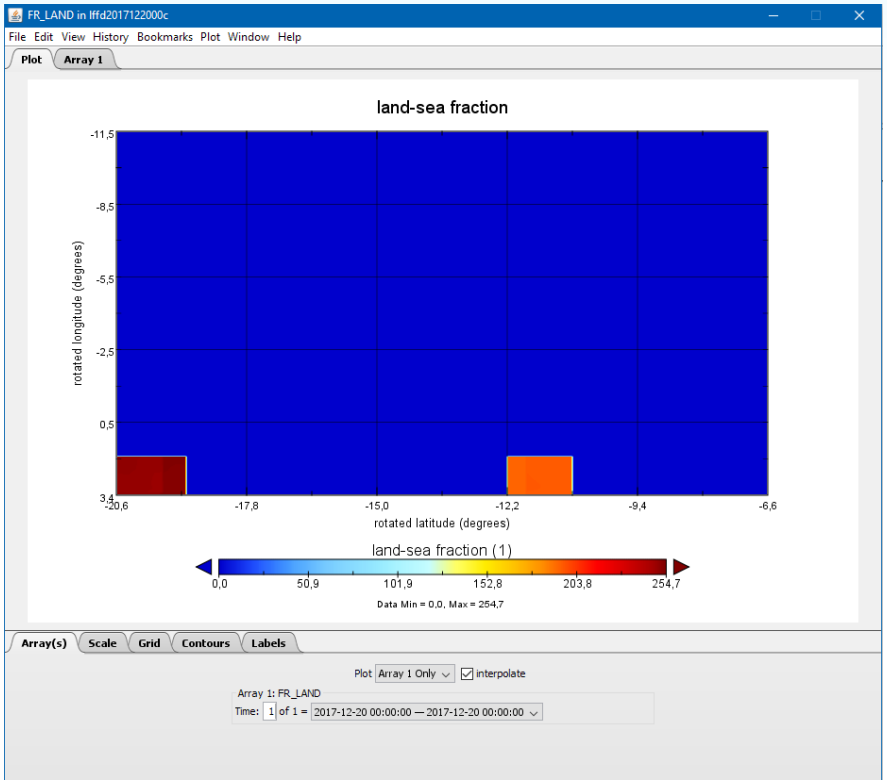
Problem 1: writing constants

lffd…c.nc file from output directory



v 5.0_clm9



v 5.05_urb1

Running nested experiments becomes annoying
due to the need of running both 5.05 and 5.0 model versions

Problem 2: model failure with significant number of CPUs

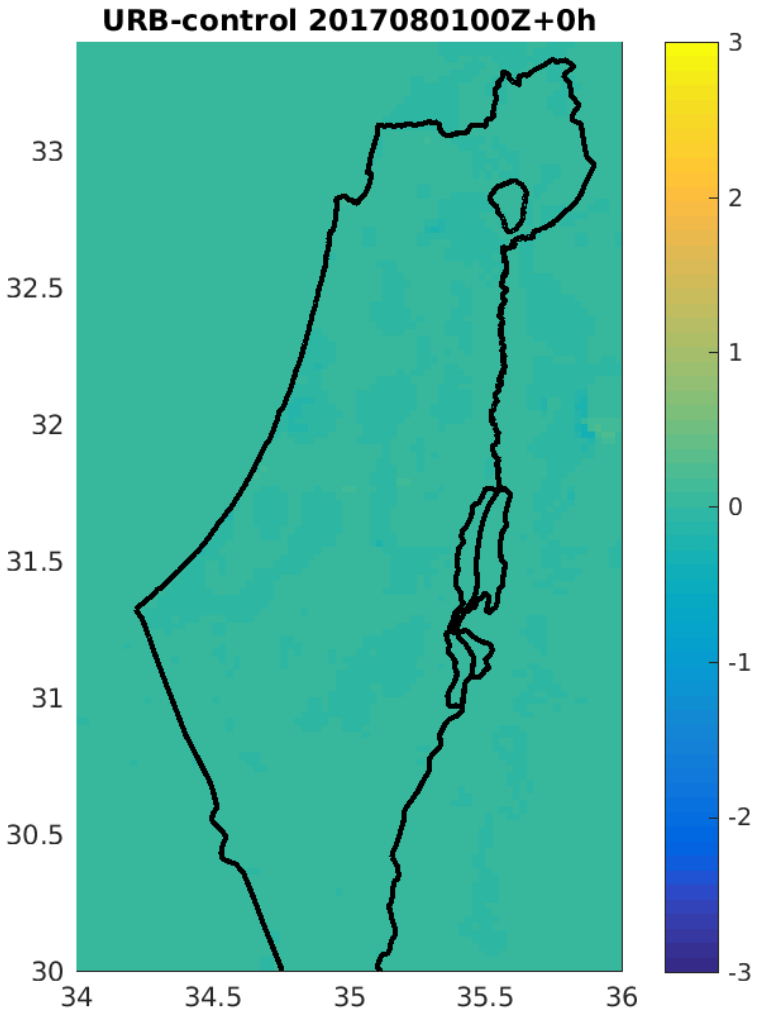
	TERRA_URB off or on	Failures observed
Arctic, K05 (300x280 grid)	**Off**	**OK with 64 CPUs**
Arctic, K02 (350x210 grid)	**off**	**OK with 100 CPUs**
Arctic, K01 (**100x100** grid	**off**	**OK with 64 CPUs**
Moscow region, D1 (140x140 grid)	**off**	**Fails with more than 12 CPUs.**
Moscow region, D3 (180x180 grid)	**off**	OK with 64 CPUs, **fails with 100 CPUs.**
	on	**Fails with more than 16 CPUs.**

New tests have shown that this problem is directly linked to a previous one.
No fails with lwrite_const = FALSE

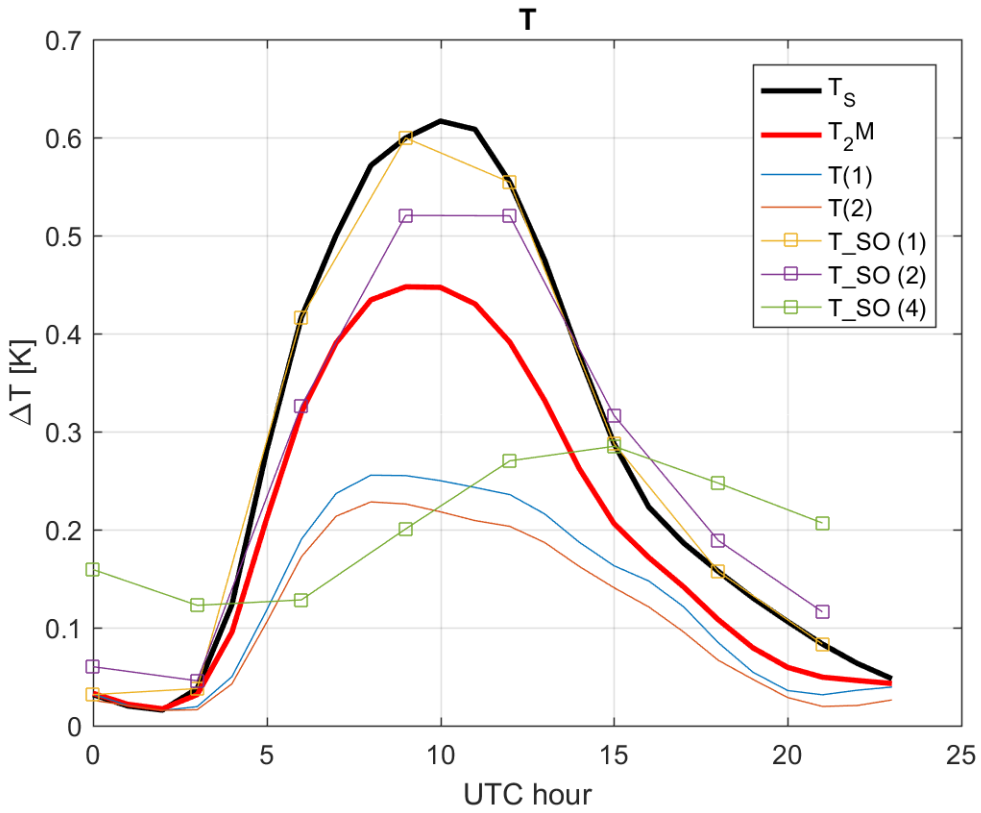
```
 OPEN: ncdf-file:
 /mnt/scratch/users/vplatonov/COSMO-CLM/experiments_misha/URBAN_REANALYSIS/2014/
 ETR_0.108_Globcover4AEVUS/OUT_default_t/out01/1ffd2014050100c.nc
forrtl: severe (174): SIGSEGV, segmentation fault occurred
Image              PC                Routine            Line        Source
cosmo_AEVUS_505_M  00000000014B9671  Unknown               Unknown  Unknown
cosmo_AEVUS_505_M  00000000014B7DC7  Unknown               Unknown  Unknown
libmpi_usempif08.  00007FFFF737C8C2  Unknown               Unknown  Unknown
libmpi_usempif08.  00007FFFF737C716  Unknown               Unknown  Unknown
libmpi_usempif08.  00007FFFF736AF6C  Unknown               Unknown  Unknown
libmpi_usempif08.  00007FFFF734C108  Unknown               Unknown  Unknown
libpthread.so.0    00007FFFF6624130  Unknown               Unknown  Unknown
cosmo_AEVUS_505_M  0000000000DA14A9  src_output_mp_out        4085  src_output.f90
cosmo_AEVUS_505_M  0000000000DD9BB6  src_output_mp_ini        1317  src_output.f90
cosmo_AEVUS_505_M  0000000000723933  organize_data_           3074  organize_data.f90
cosmo_AEVUS_505_M  00000000007E28EF  MAIN__                    886  lmorg.f90
cosmo_AEVUS_505_M  0000000000408AAE  Unknown               Unknown  Unknown
libc.so.6          00007FFFF6275AF5  Unknown               Unknown  Unknown
cosmo_AEVUS_505_M  0000000000 4089B9  Unknown               Unknown  Unknown
forrtl: severe (174): SIGSEGV, segmentation fault occurred
Image              PC                Routine            Line        Source
cosmo_AEVUS_505_M  00000000014B9671  Unknown               Unknown  Unknown
cosmo_AEVUS_505_M  00000000014B7DC7  Unknown               Unknown  Unknown
libmpi_usempif08.  00007FFFF737C8C2  Unknown               Unknown  Unknown
libmpi_usempif08.  00007FFFF737C716  Unknown               Unknown  Unknown
libmpi_usempif08.  00007FFFF736AF6C  Unknown               Unknown  Unknown
libmpi_usempif08.  00007FFFF734C108  Unknown               Unknown  Unknown
libpthread.so.0    00007FFFF6624130  Unknown               Unknown  Unknown
cosmo_AEVUS_505_M  0000000000DA1421  src_output_mp_out        4058  src_output.f90
cosmo_AEVUS_505_M  0000000000DD9BB6  src_output_mp_ini        1317  src_output.f90
cosmo_AEVUS_505_M  0000000000723933  organize_data_           3074  organize_data.f90
cosmo_AEVUS_505_M  00000000007E28EF  MAIN__                    886  lmorg.f90
cosmo_AEVUS_505_M  0000000000408AAE  Unknown               Unknown  Unknown
libc.so.6          00007FFFF6275AF5  Unknown               Unknown  Unknown
cosmo_AEVUS_505_M  0000000000 4089B9  Unknown               Unknown  Unknown
libmpi.so.1        00007FFFF6B9765A  Unknown               Unknown  Unknown
libmpi_mpifh.so.2  00007FFFF6E789ED  Unknown               Unknown  Unknown
cosmo_AEVUS_505_M  00000000004E8A26  parallel_utilitie        1505  parallel_utilities.f90
cosmo_AEVUS_505_M  0000000000DA77E2  src_output_mp_out        4199  src_output.f90
cosmo_AEVUS_505_M  0000000000DD9BB6  src_output_mp_ini        1317  src_output.f90
cosmo_AEVUS_505_M  0000000000723933  organize_data_           3074  organize_data.f90
cosmo_AEVUS_505_M  00000000007E28EF  MAIN__                    886  lmorg.f90
cosmo_AEVUS_505_M  0000000000408AAE  Unknown               Unknown  Unknown
libc.so.6          00007FFFF6275AF5  Unknown               Unknown  Unknown
cosmo_AEVUS_505_M  0000000000 4089B9  Unknown               Unknown  Unknown
```

Problem 3: additional heating in rural areas when TERRA_URB is switched on

Results from Pavel Khain



Problem 3: additional heating in rural areas when TERRA_URB is switched on



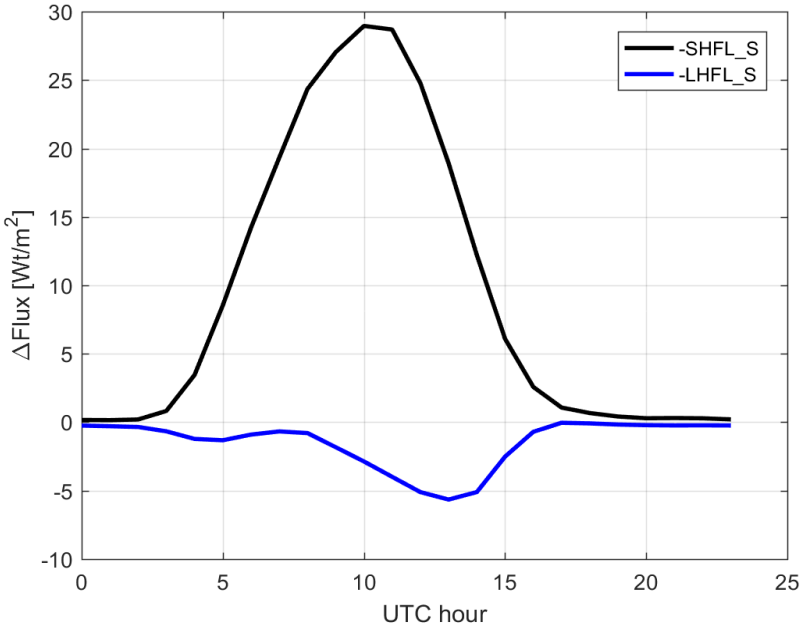
$\Delta T = T_{emptyURB} - T_{noURB}$

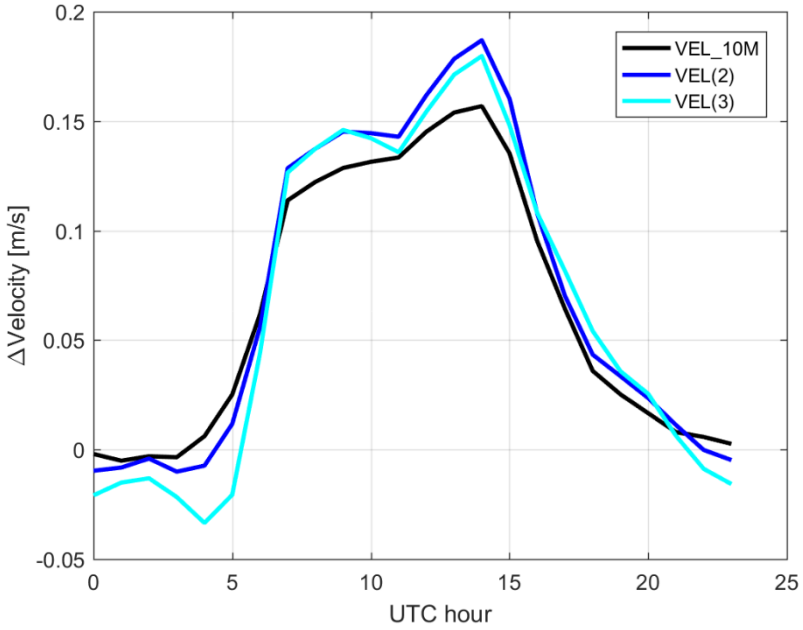
emptyURB: ISA and AHF fields are set to zero, **TERRA_URB switched on**

noURB: TERRA_URB switched off

Diurnal variation of the temperature response for switching on the TERRA_URB scheme for D3_emptyURB domain, averaged over the whole domain and over 15 days of simulation (1-15 May). Ts is surface temperature, T2m – diagnostic 2 meters temperature, T(1) and T (2) – temperature at two lowest atmospheric levels, T_SO – soil temperature (at 1st, 2nd and 4th levels from the top).

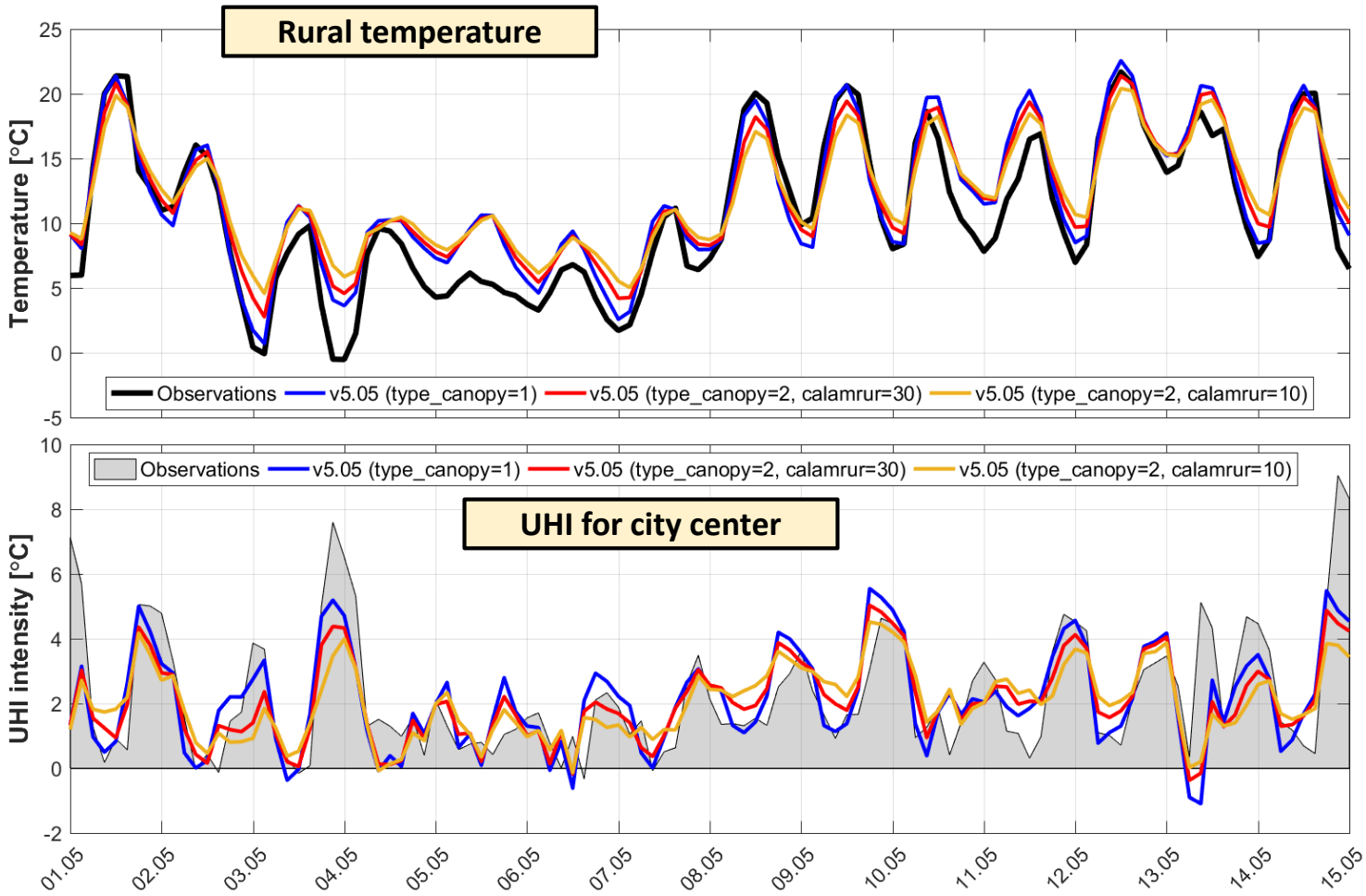
Problem 3: additional heating in rural areas when TERRA_URB is switched on





Hypothesis: something is wrong with vertical diffusion coefficients

Problem 4: something is wrong with skin-layer temperature scheme



1-15 May 2014

v5.0_clm9:	calamrur↓	→	DTR↑, UHI↑
V5.05_urb1:	calamrur↓	→	DTR↓, UHI↓

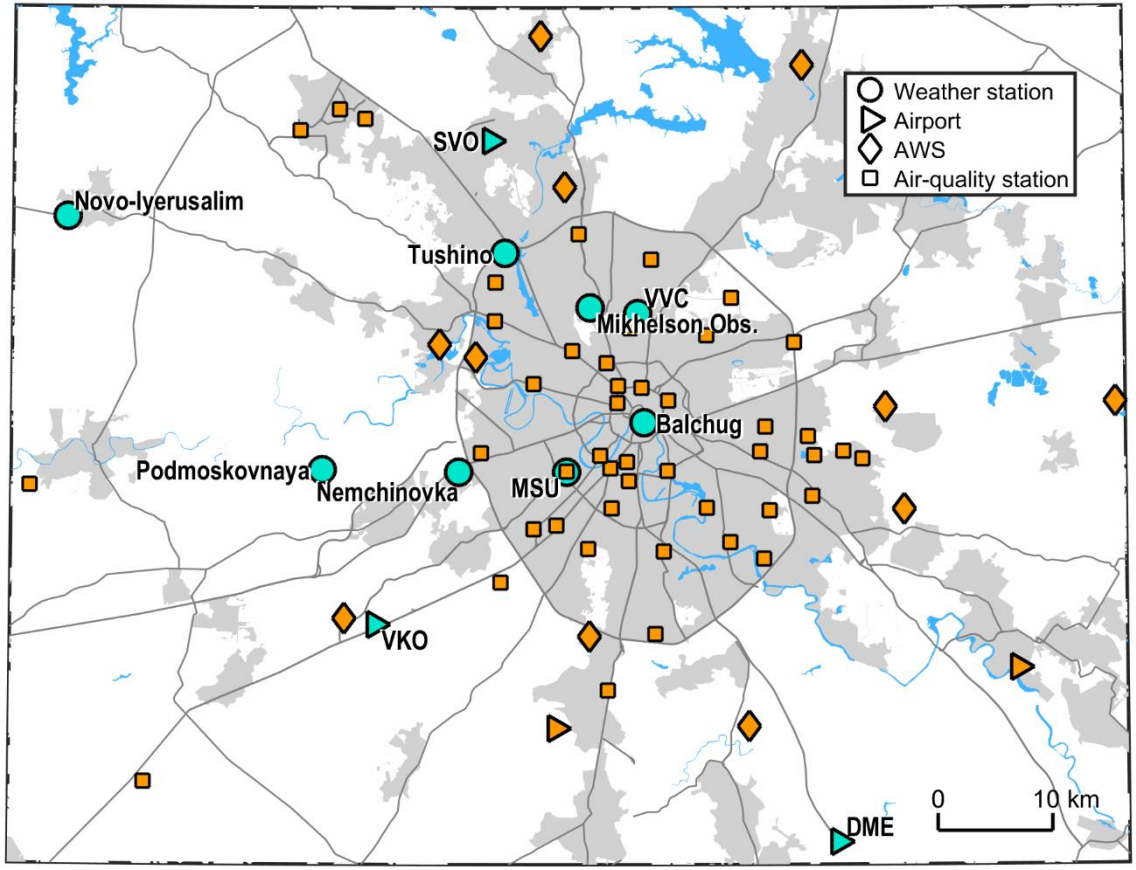
DTR – daily temperature range

Problem 5 (new):
EXTPAR names treatment

- COSMO 5.0 reads **ISA** (Impervious surface area) and **AHF** (anthropogenic heat flux) fields from the external parameter file (laf*.nc).
- In 5.05, **ISA** was renamed to **FR_PAVED**
- COSMO 5.05 try to read both **ISA** and **FR_PAVED**
- **If FR_PAVED is missing, but ISA is present:**
  - No error is thrown by the model
  - The urban fractions is set to zero everywhere

Weather observations in Moscow region

New dense meteorological networks

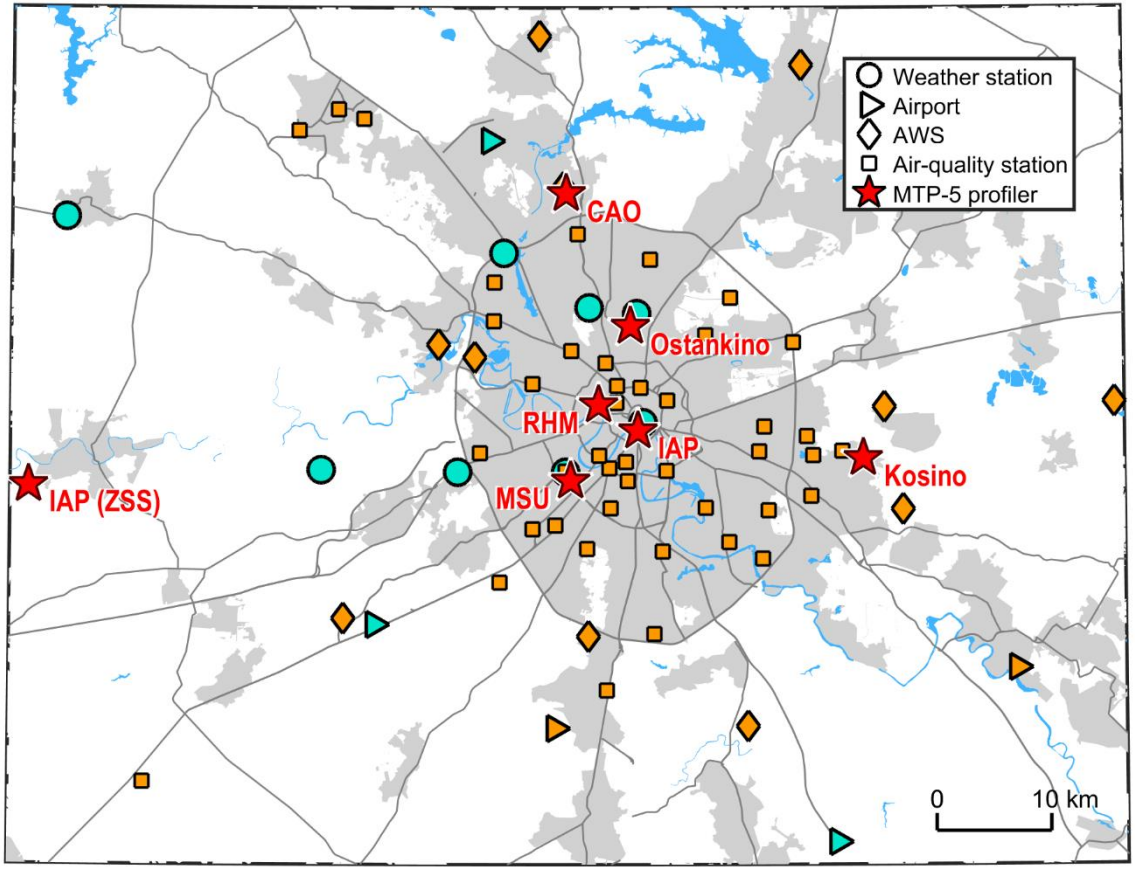


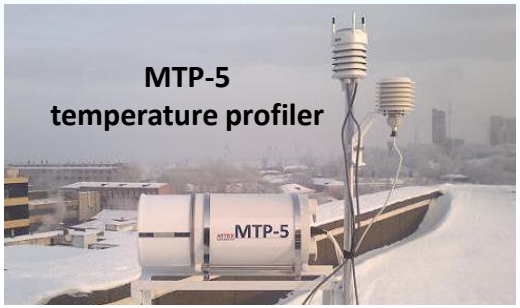
New automatic weather stations (AWSs) of Roshydromet
(since 2013)

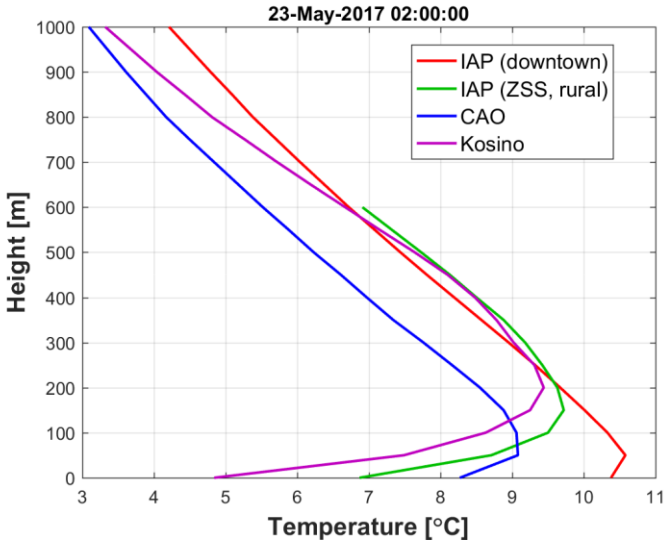
Air-quality monitoring stations of Mosecomonitring
(since 1990th)

Weather observations in Moscow region

ABL observations: microwave temperature profilers





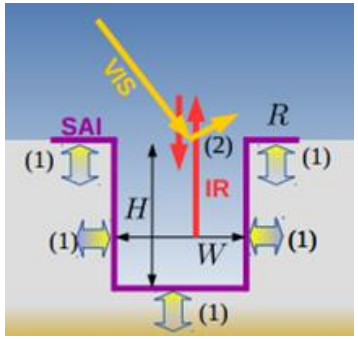


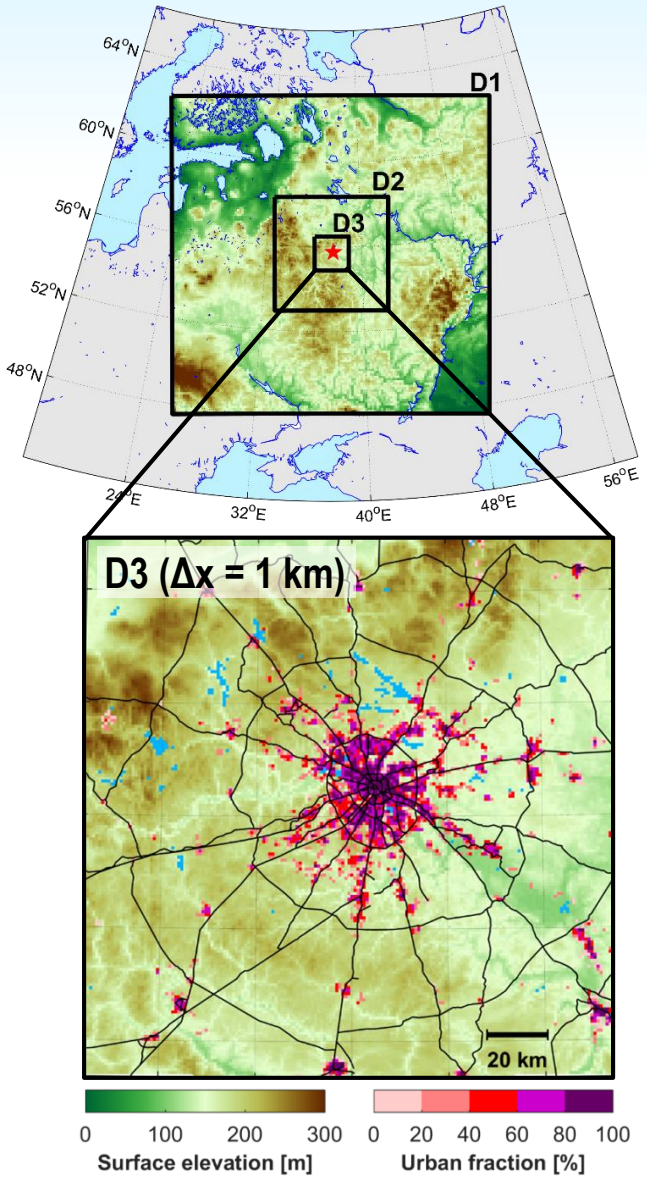
Thanks to Dr. I.A. Repina (IAP), A.Yu. Artamonov (IAP), E.A. Miller (CAO) and to Mosecomonitoring agency

Previous modelling experience

- **COSMO-CLM regional climate model** (COSMO 5.0_clm9 + TERRA_URB2.2)
- **Continuous simulations for 10 summer seasons (1 month of spin up) and a few winter seasons**
- 3 steps of dynamical downscaling

  (12 km ⟶ 3 km ⟶ **1 km**)
- Boundary conditions for the fist domain from ERA-Interim reanalysis + spectral nudging for U, V and T
- Tuned model configuration including reduced turbulent mixing in stable condition according (Cerenzia et al., 2014), new evaporation & canopy schemes (Schulz, 2016; Schulz, Vogel, 2017)
- **TERRA_URB urban scheme** (Wouters et al., 2015; 2016)



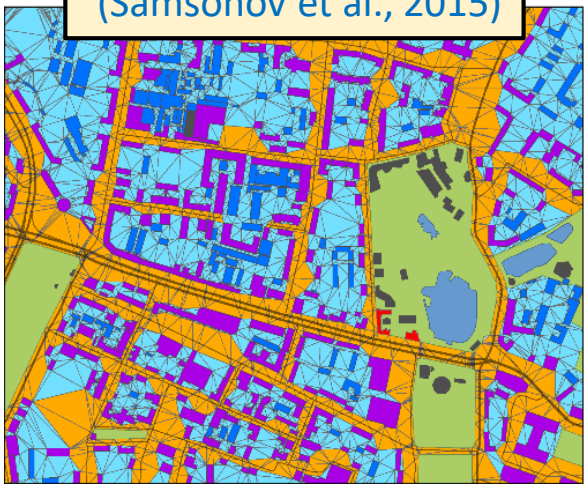


Urban canopy parameters

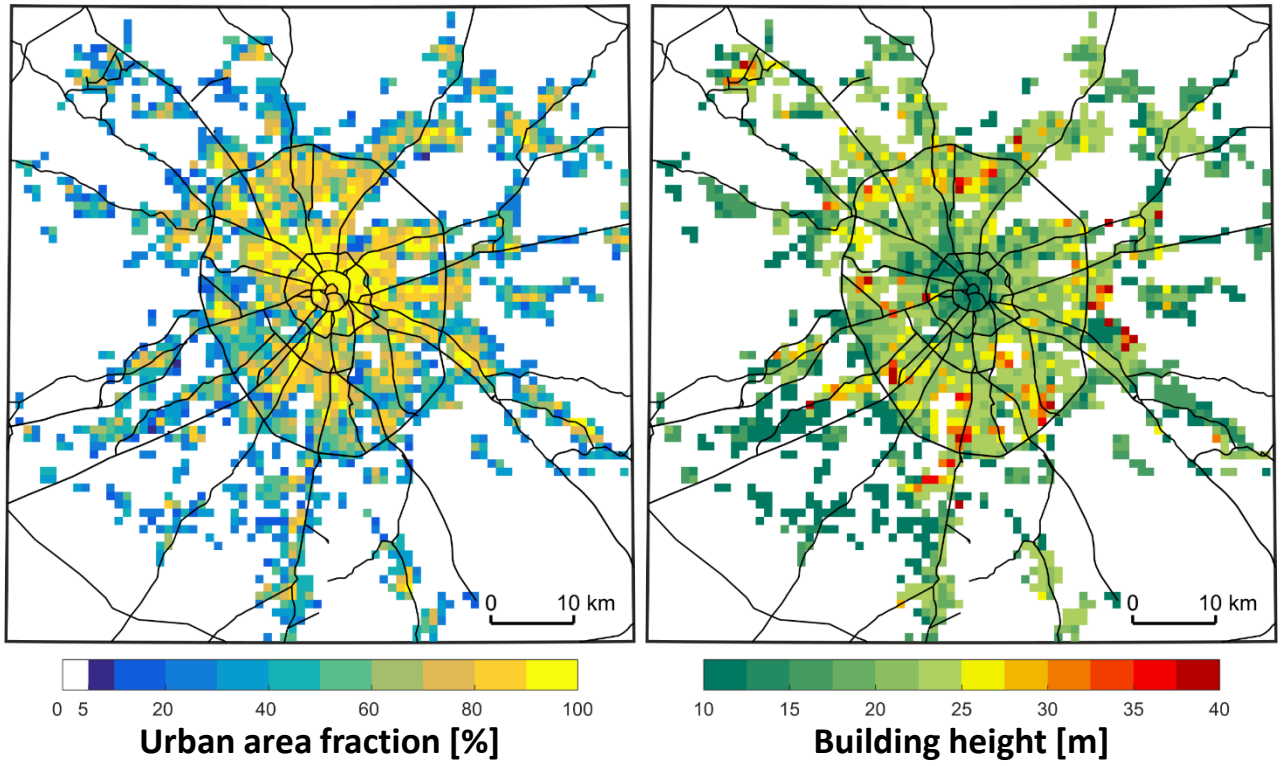
Required urban canopy parameters for TERRA_URB:

- Urban area fraction (= impervious surface fraction, ISA)
- Annual-mean anthropogenic heat flax (AHF)
- Building area fraction
- Building height H
- Street canyon aspect ration (H/W)

1) GIS-processing of OpenStreetMaps data (Samsonov et al., 2015)



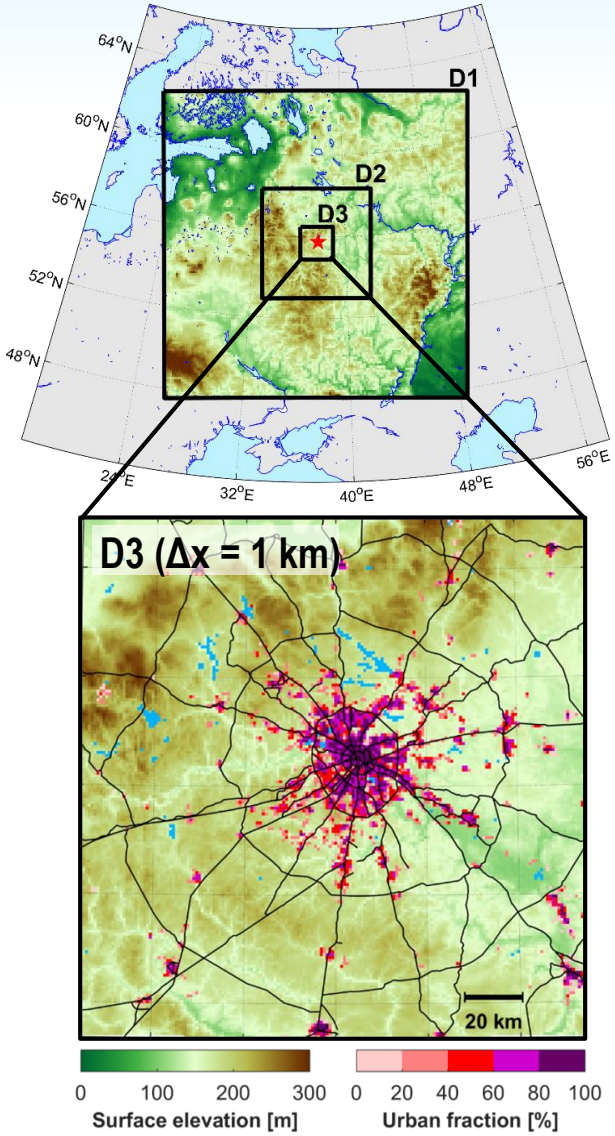
2) Averaging over given model grid cells



3) Calculation of the required parameters

Recent modelling experience

- Comparison between two model versions:
  - COSMO 5.0_clm9 TERRA_URB2.2: the original model version, developed by Wouters et al., that was used in previous modelling studies for Moscow
  - COSMO_5.05_urb1: implementation of the TERRA_URB scheme to the recent model version, developed within the framework of AEVUS PT. The key feature - new ICON physics. But some bugs are still under debugging :(
- Same forcing data, domains and model setup as before, but shorter case-focused simulations for 10-15 days.
- Main focus on the air temperature and UHI intensity for now



Namelist settings

Parameter	v5_REF	v5_MOD	v505_REF*
PHYCTL			
Itype_rootdp	1	2	2
Itype_evsl	1	4	4
Itype_heatcond	1	2	3
Itype_canopy	1	2	1*
calamrur	-	30	-**
TUNNING			
tkmmin & tkhmin	0.4	0.1 or 0.05	0.75
pat_len	500	100 or 50	100
DYNCTL			
hd_corr_(t, u, p…)	defaults	0.25 for all	defaults

/PHYCTL/	OLD	NEW
itype_evsl	2	4
itpye_heatcond	1	3
itype_root	1	2

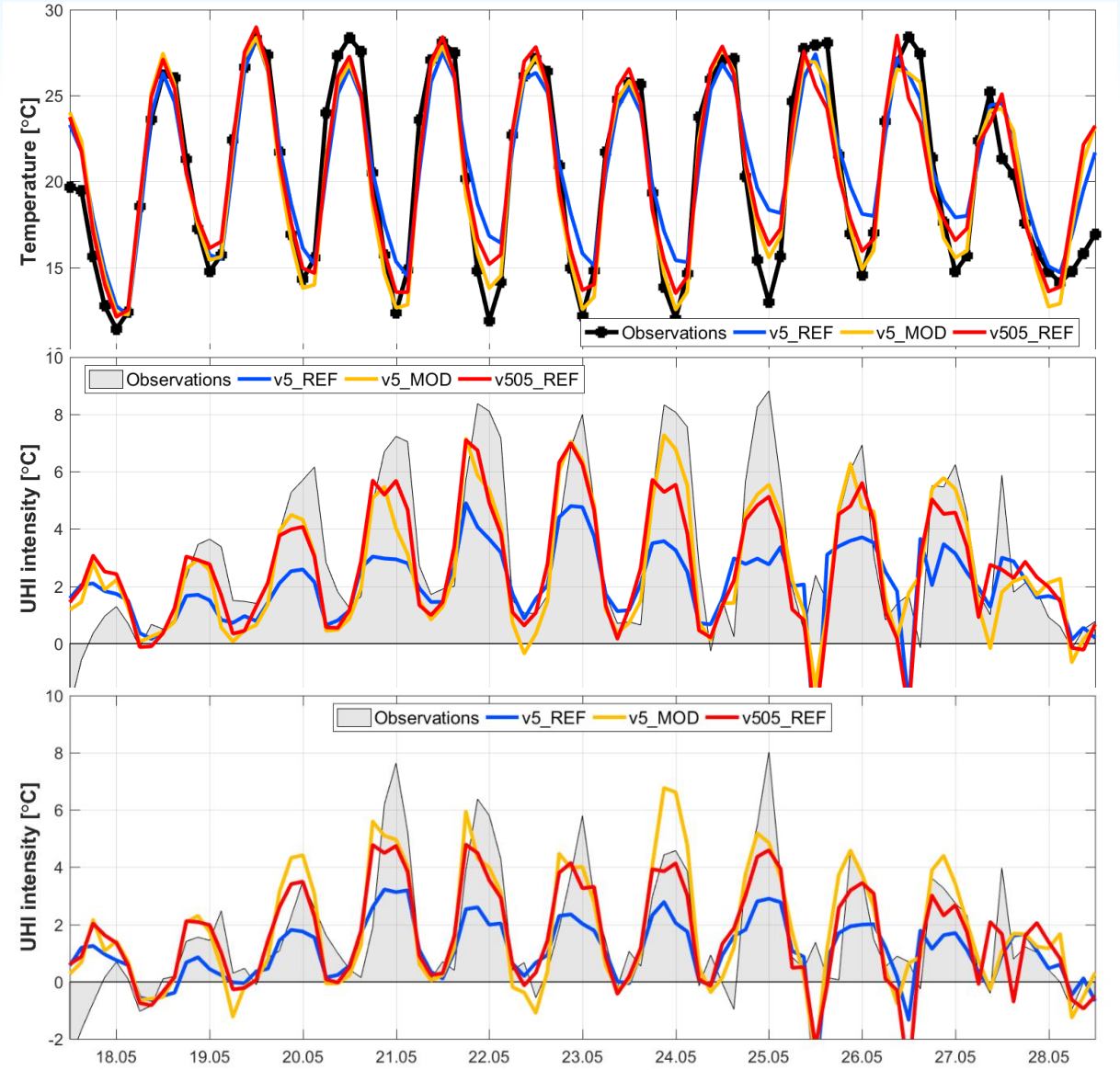
***Defaults for "new" physics**

(Different Configurations for the COSMO-ICON Physics, 2018)

**JP's skin-layer temperature scheme for 5.05_urb is still under debugging

Model verification (case 1: May 2014)

Temperature & UHI intensity dynamics



Mean rural temperature (averaged over 9 stations)

UHI intensity for the city center (Balchug)

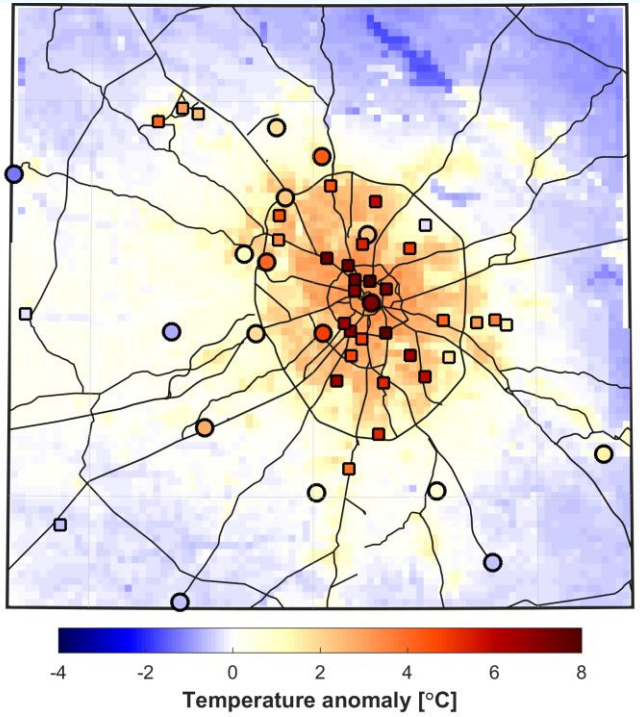
UHI intensity for the urban park (MSU)

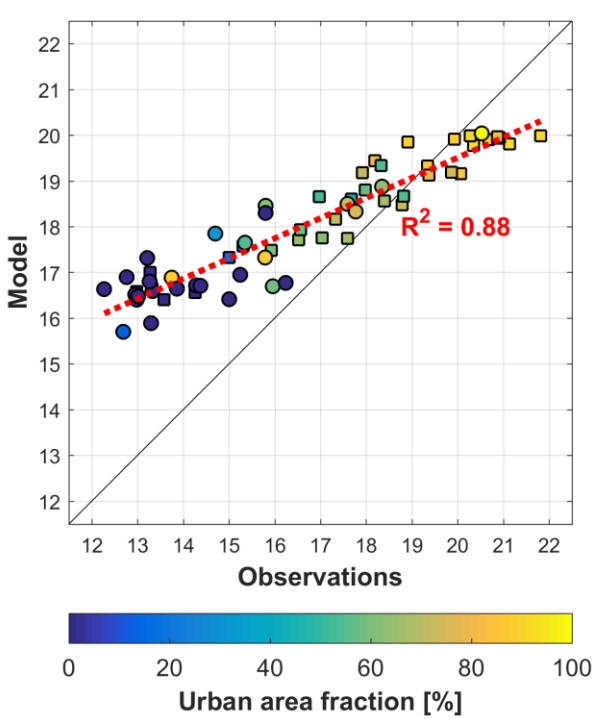
Model verification (case 1: May 2014)

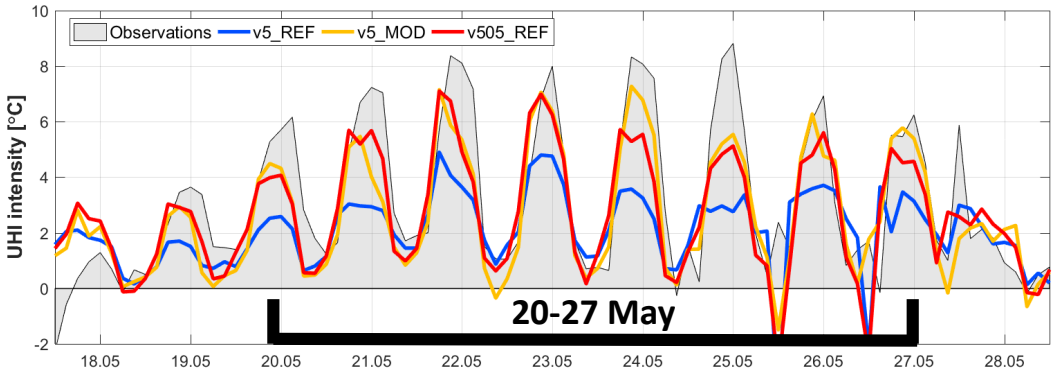
UHI spatial structure

Mean nighttime (0 UTC) temperatures over 20-27 May

v5_REF





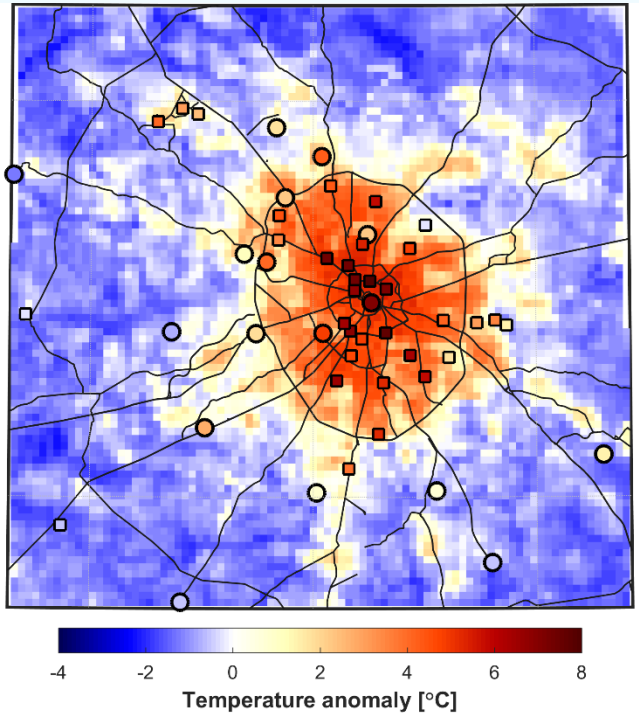


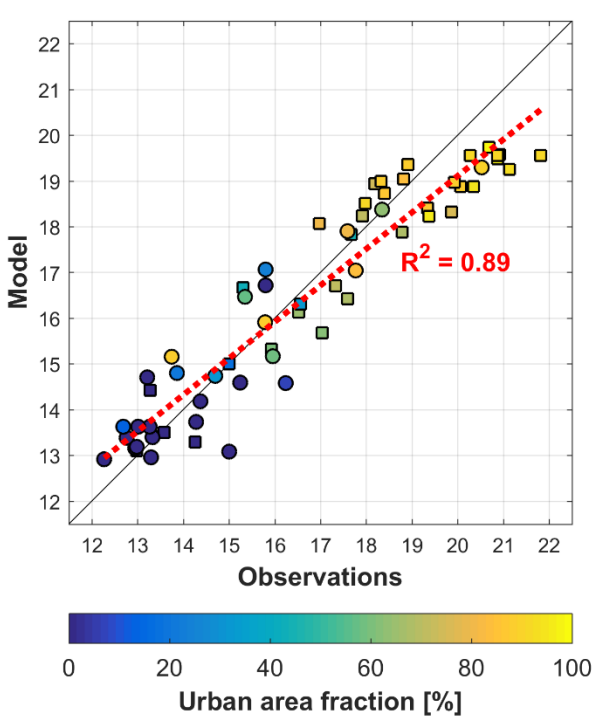
Model verification (case 1: May 2014)

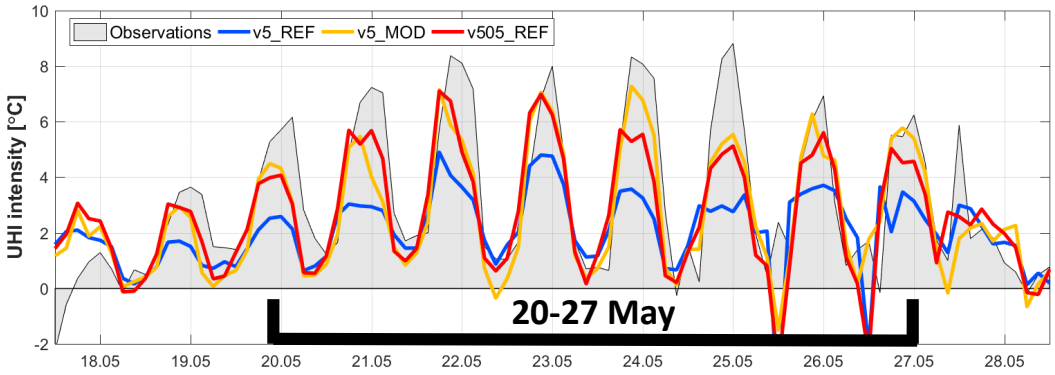
UHI spatial structure

Mean nighttime (0 UTC) temperatures over 20-27 May

v5_MOD





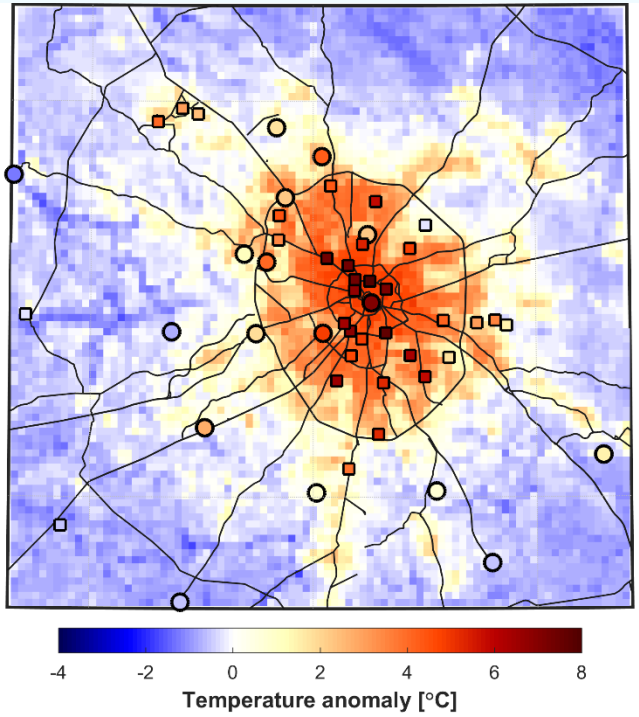


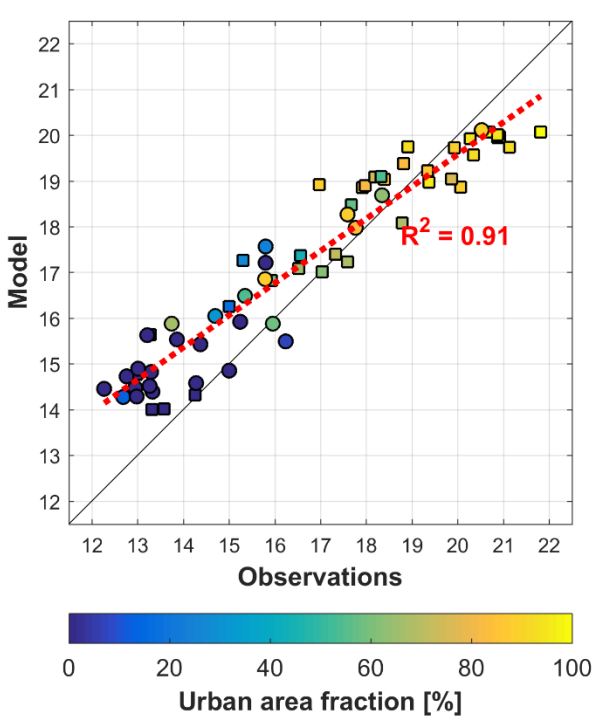
Model verification (case 1: May 2014)

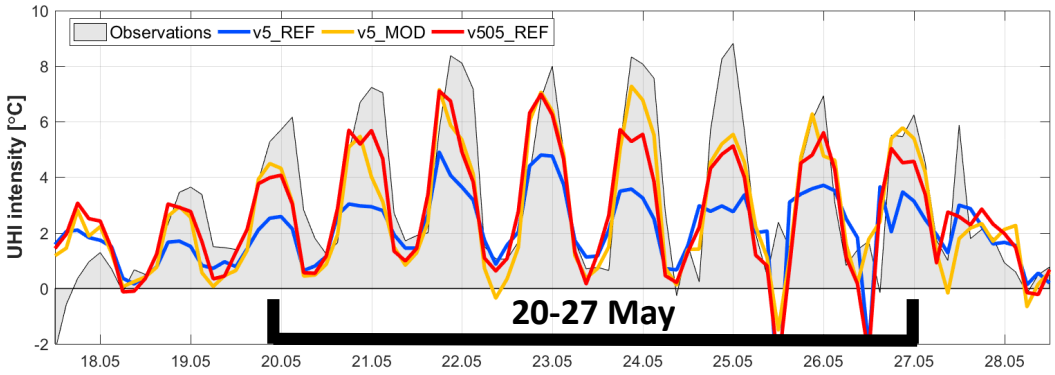
UHI spatial structure

Mean nighttime (0 UTC) temperatures over 20-27 May

v505_REF



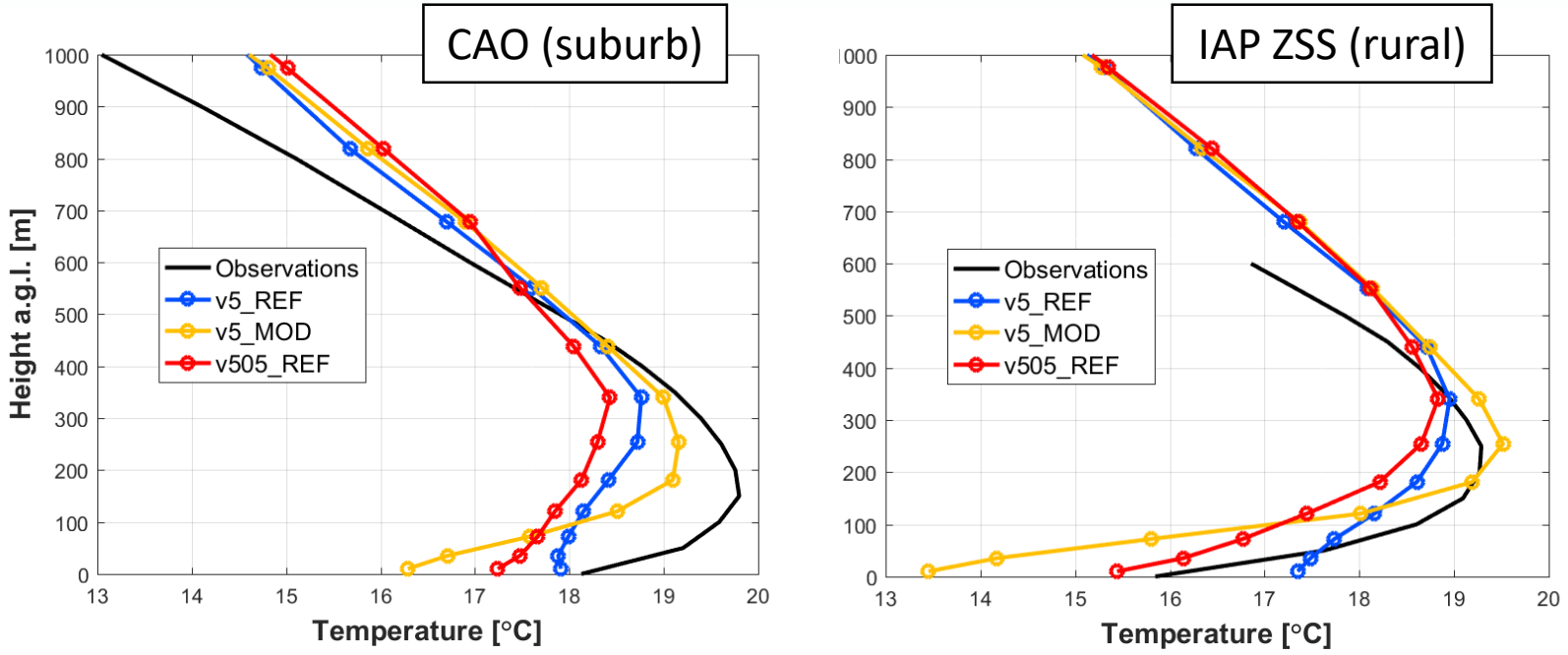


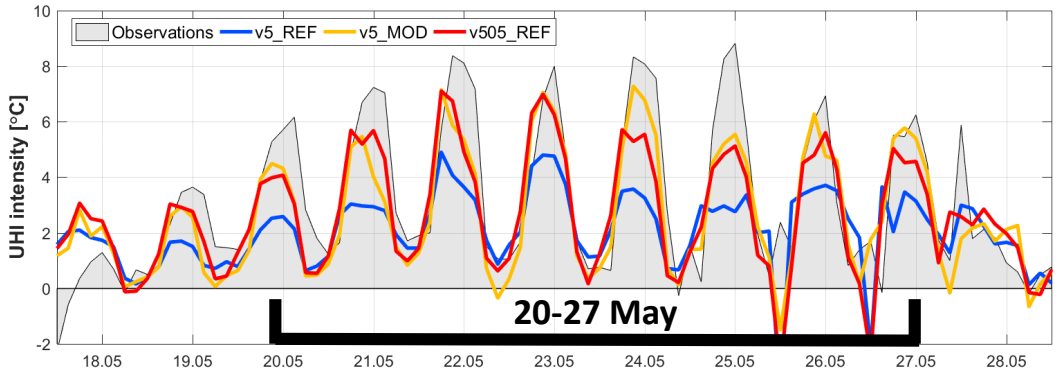


Model verification (case 1: May 2014)

ABL temperature stratification

Mean nighttime (0 UTC) temperature profiles over 20-27 May

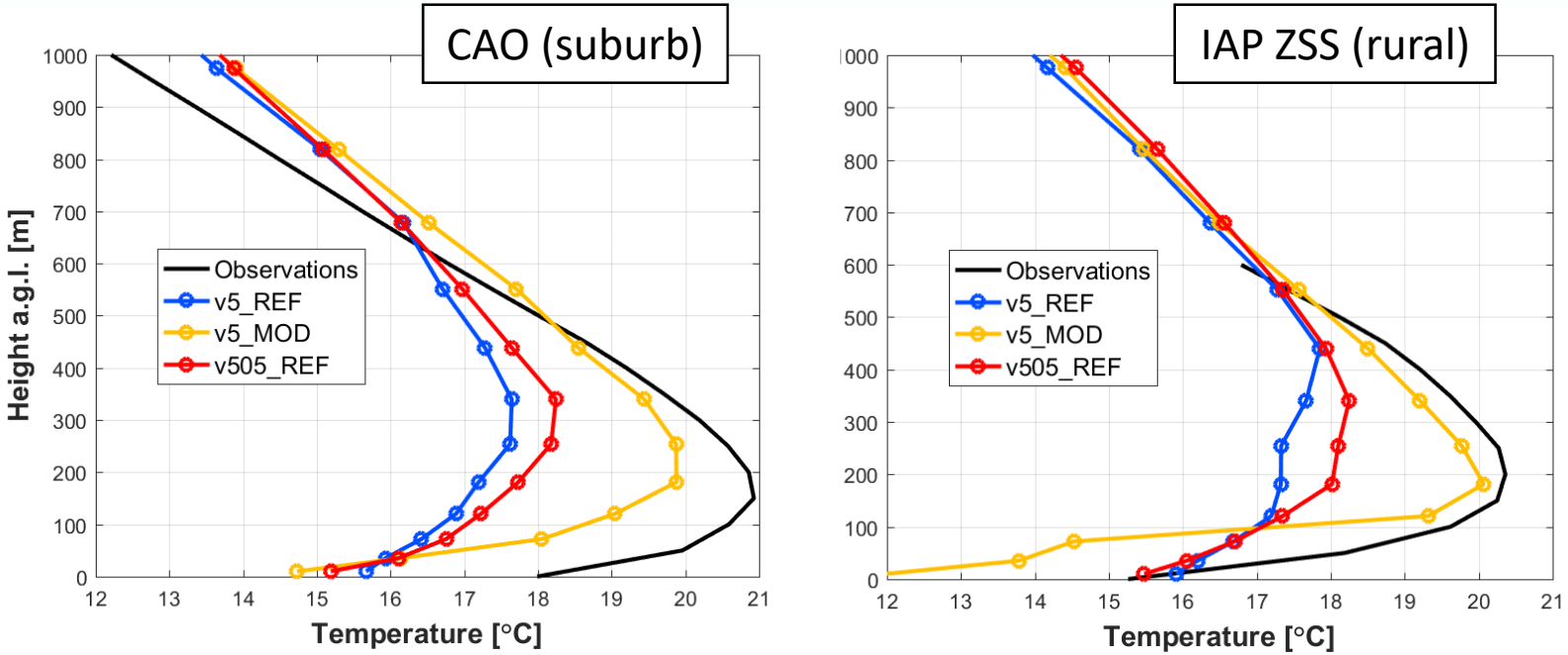


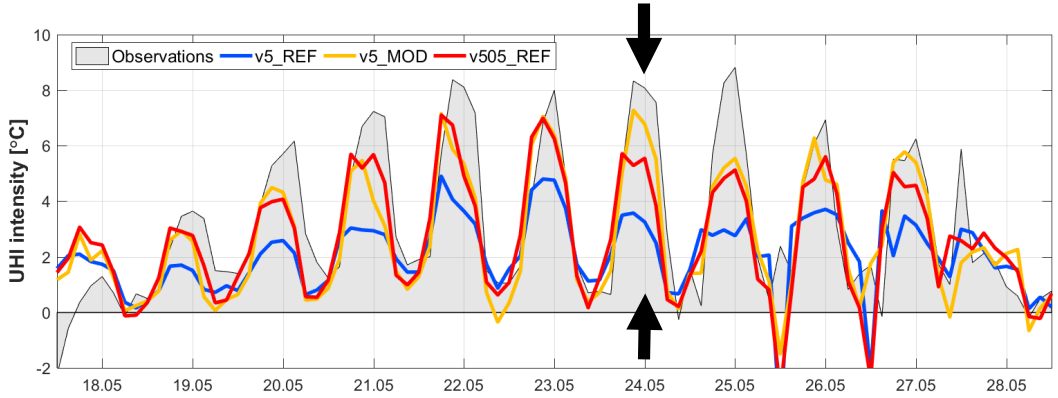


Model verification (case 1: May 2014)

ABL temperature stratification

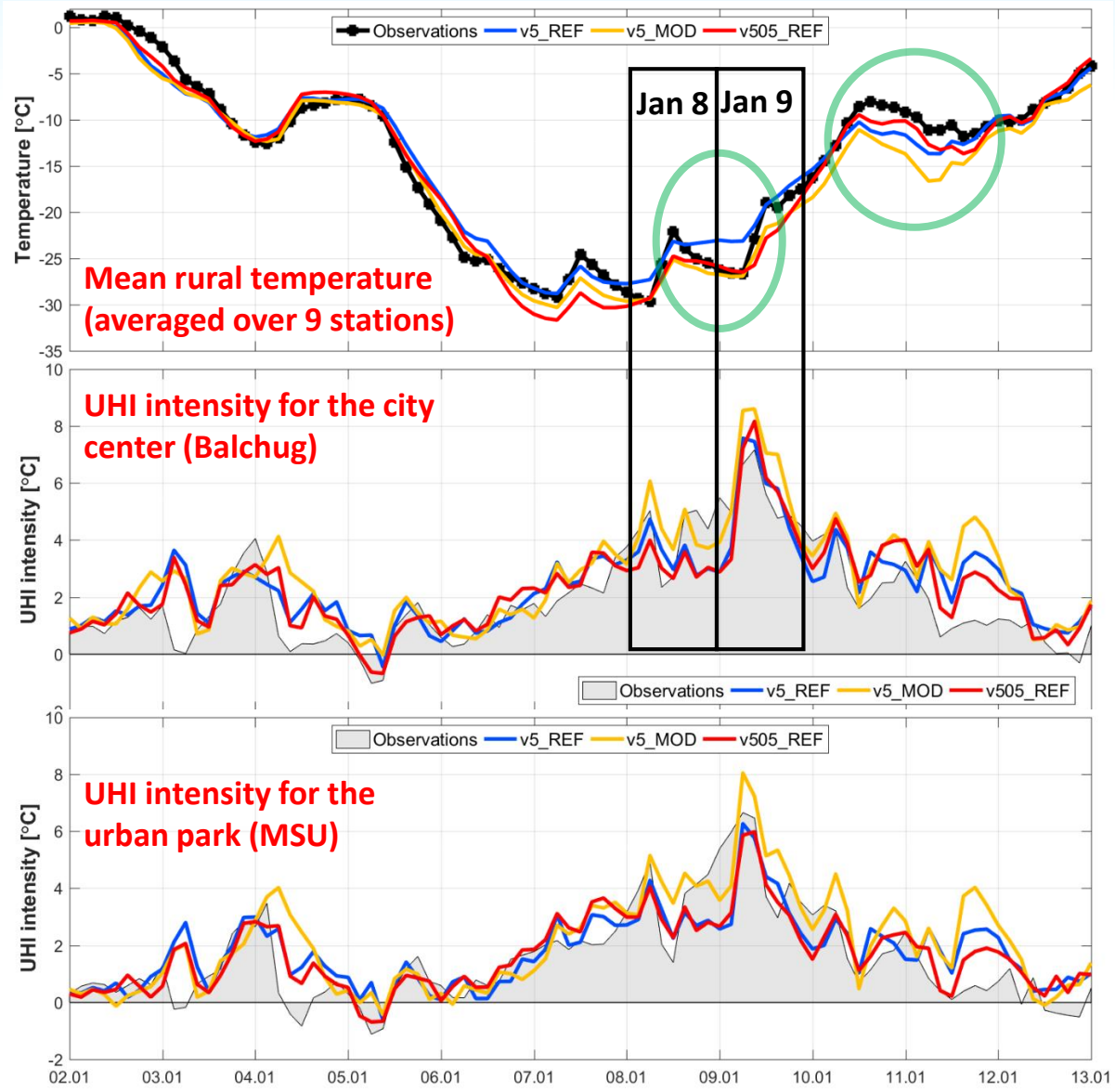
Temperature profiles at 00 UTC 24.05.2014





Model verification (case 2: Jan 2017)

Temperature & UHI intensity dynamics



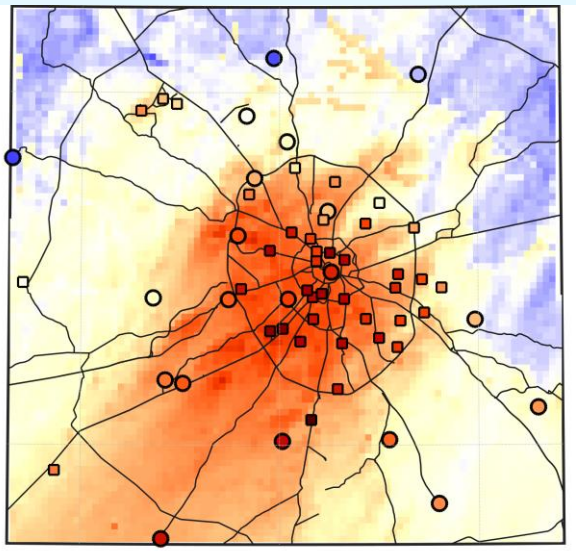
7-9 Jan 2017 – one of the coldest periods in Moscow region in XXI century

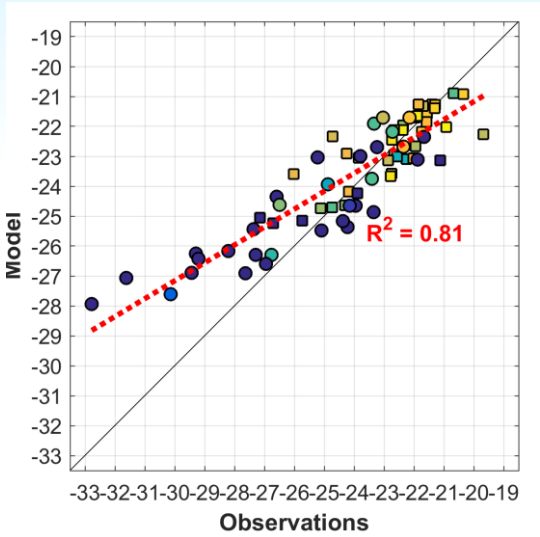
(T_{min} = -35 °C in the north of the region at 9th of January)

Model verification (case 2: Jan 2017)

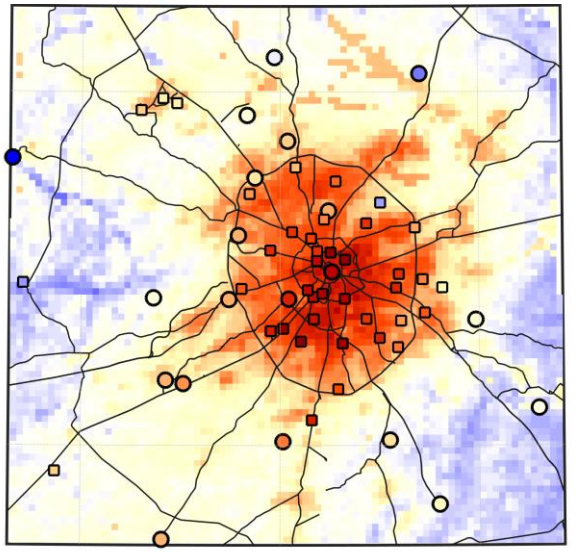
V5_REF

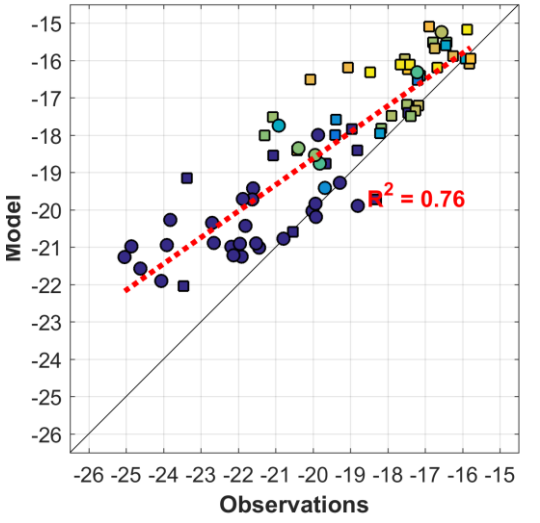
8th Jan:
UHI advection to SW

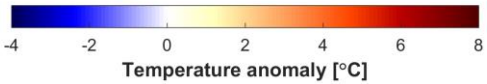


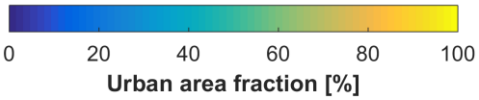


9th Jan:
Localized UHI





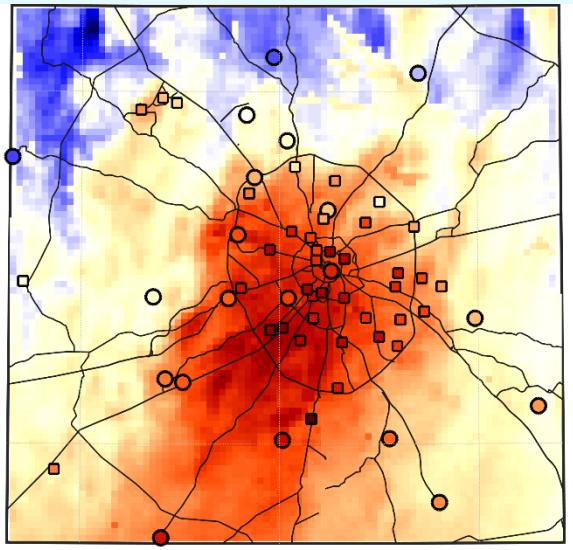


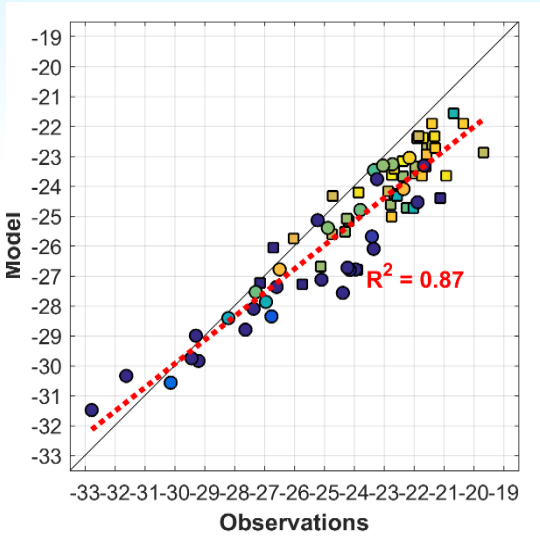


Model verification (case 2: Jan 2017)

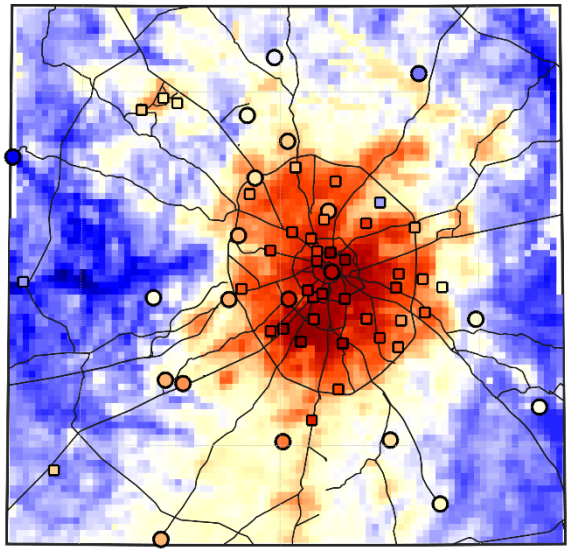
V5_MOD

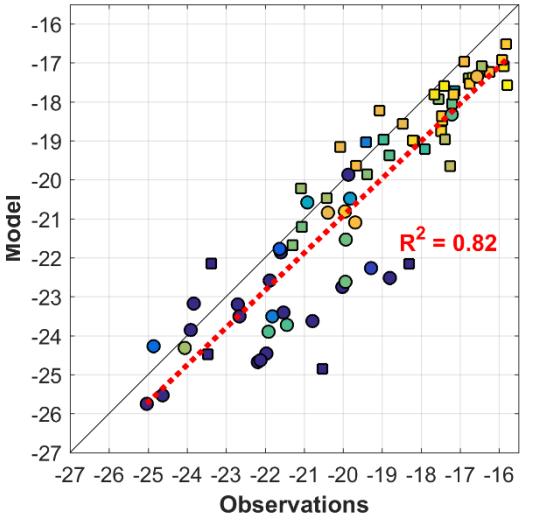
8th Jan:
UHI advection to SW

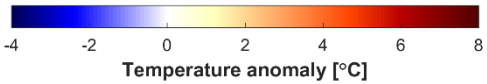


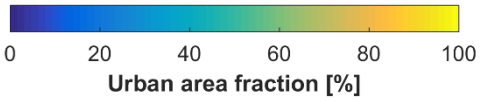


9th Jan:
Localized UHI





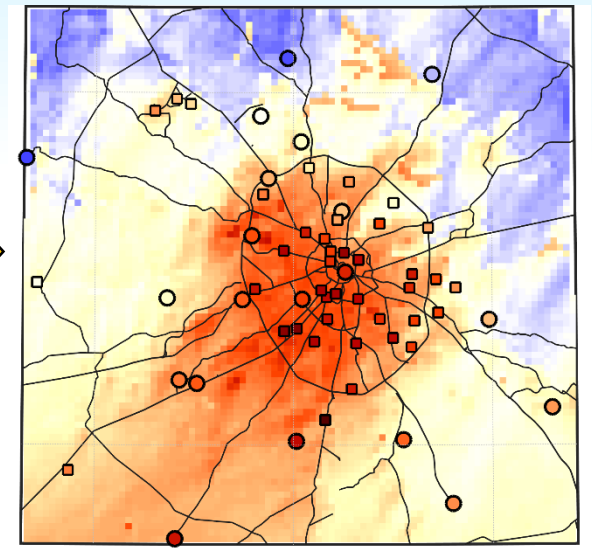


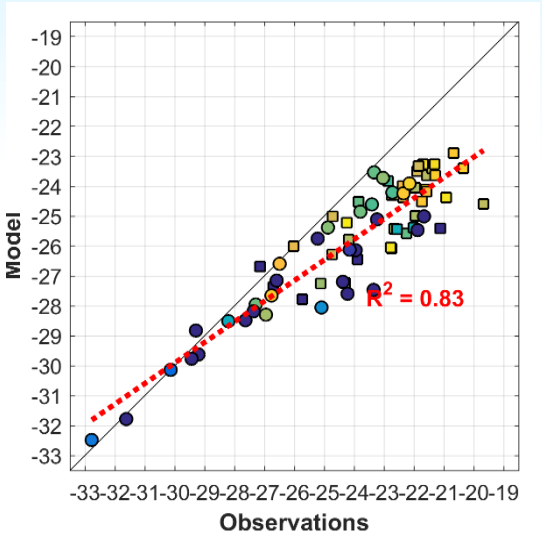


Model verification (case 2: Jan 2017)

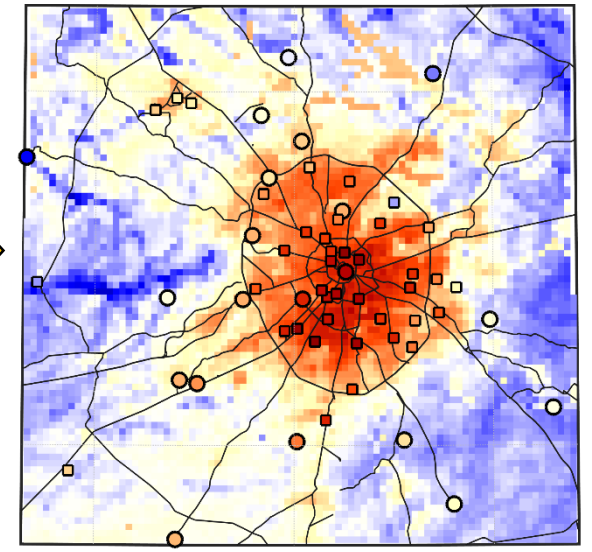
V505_REF

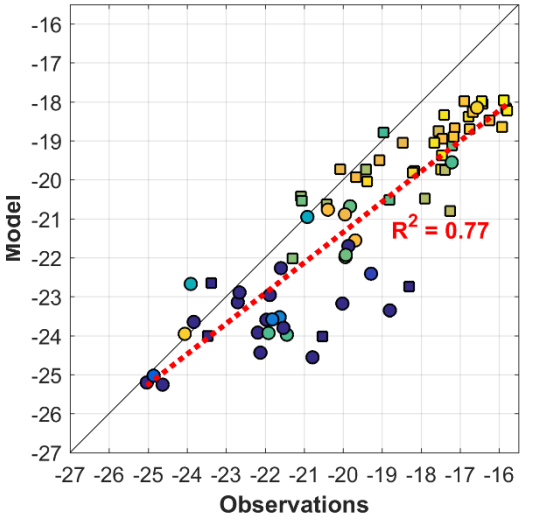
8th Jan:
UHI advection to SW

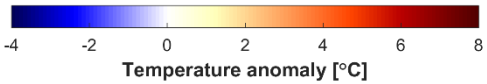


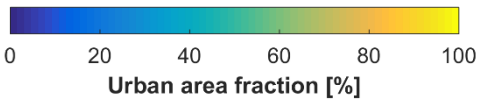


9th Jan:
Localized UHI





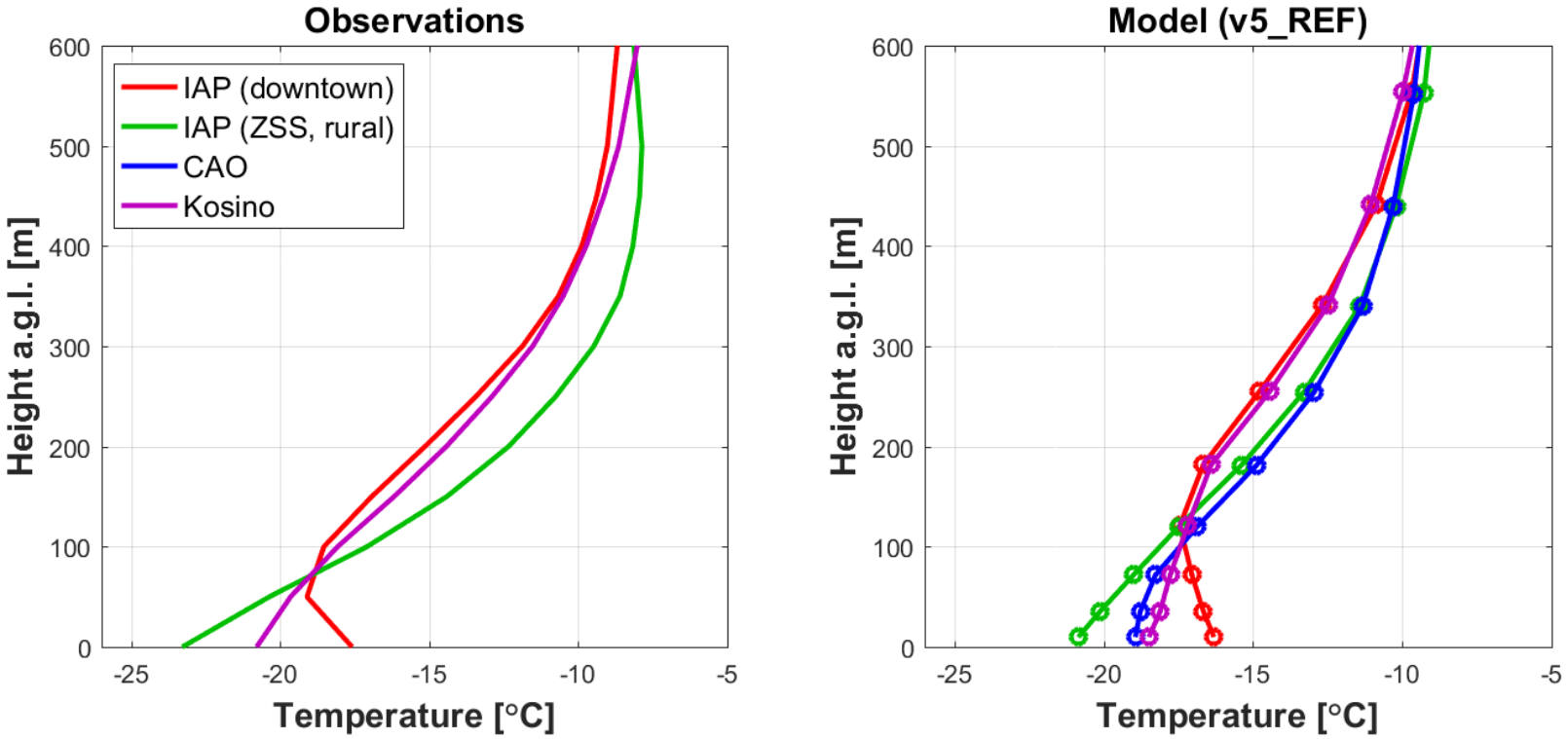




Model verification (case 2: Jan 2017)

ABL temperature stratification

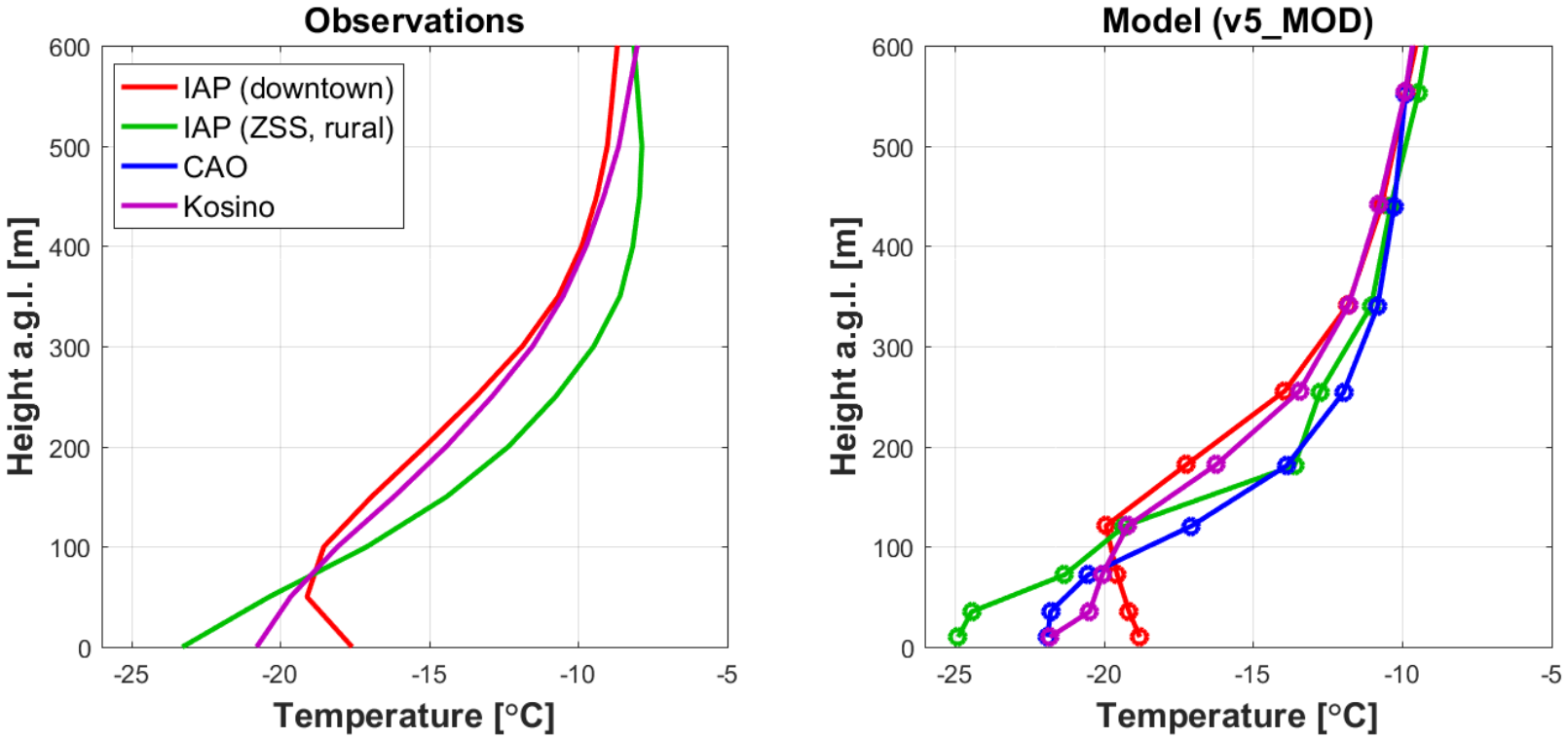
Mean profiles over 9th of January



Model verification (case 2: Jan 2017)

ABL temperature stratification

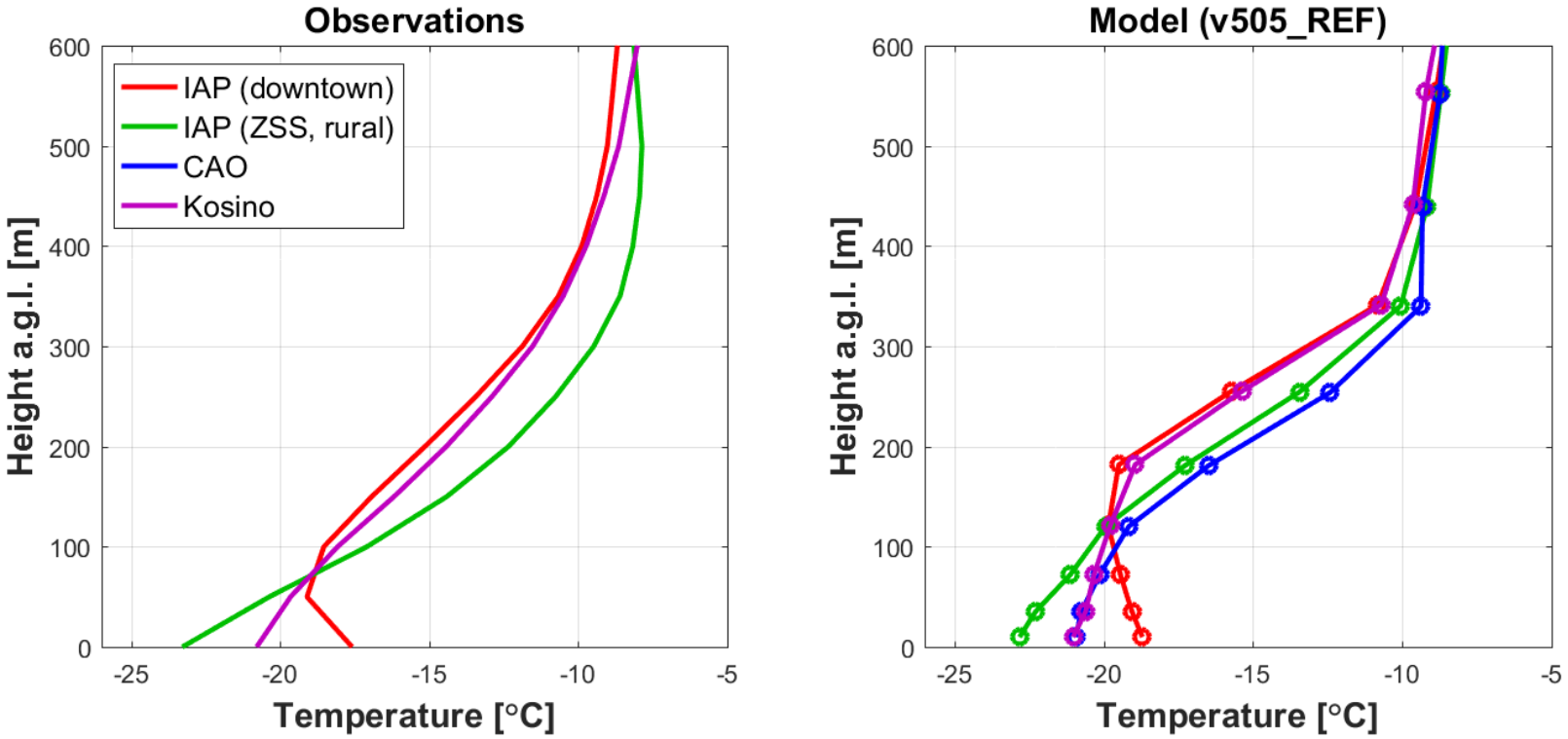
Mean profiles over 9th of January



Model verification (case 2: Jan 2017)

ABL temperature stratification

Mean profiles over 9th of January



Conclusion

- COSMO 5.0_and COSMO 5.05 model versions, coupled with TERRA_URB scheme, successfully simulate the general features of the Moscow UHI for summer and winter conditions
- Model success on the UHI intensity is densely linked with model success on T_{min} and on the ABL temperature stratification.
  - Modelling results on UHI intensity are highly sensitive to model tuning, related to surface and ABL processes (horizontal and vertical diffusion, skin-layer temperature scheme, etc.)
- COSMO 5.0 with reference settings (v5_REF) strongly underestimate the UHI intensity, but this could be fixed by tuning (v5_MOD)
- COSMO 5.05 with reference settings and new ICON-physics (v505_REF) simulates the T_{min} and UHI better than reference COSMO 5.0 run (v5_REF), but still not perfectly.
- A lot of further research is still needed…

Suggestions for further work

- We really need to find and fix the existing bugs
- I suggest to separate debugging and verification activities.
- Debugging could be done with the framework of the parallel simulations, where debugging text output is added at all places where lterra_urb switch appears:

  - a run with the city removed (ISA=0, AHF=0) and TERRA_URB on
  - a run with the city removed (ISA=0, AHF=0) and TERRA_URB off

- And the same for itype_canopy

  - a run with the recent 5.06 model where skin-temperature scheme works OK
  - a similar run with the recent 5.05_urb

- **What about a joint publication on the comparison between 5.0 and 5.05 model versions based on Moscow observational facilities, after we will find the bugs? (e.g. in GMD?)**

Outlook

Towards high resolution urban weather forecast for Moscow

- New big research project of Roshydromet **"development of a monitoring, forecasting and warning system for hazardous and adverse weather events for the city of Moscow"**, funded by Moscow city government (since 2018)
  - Aim: creation of the high-resolution NWP system for Moscow
  - Urban canopy model is needed according to a contract
  - **COSMO-RuM NWP system** is already running in a test mode (based on COSMO 5.0 + TERRA_URB, 1 km grid step)

- Further research and development
  - Developing of the COSMO-RuM: incising the resolution **(1 km → 500 m)**, migration to the recent model version **(v5.0 → v5.05)** and further to ICON-Lam
  - Acquisition and usage of the detailed **official** data on the land-use and building morphology
  - Further verification and calibration using existing and new observational systems