Moscow megacity forecasting based on COSMO1 modelling

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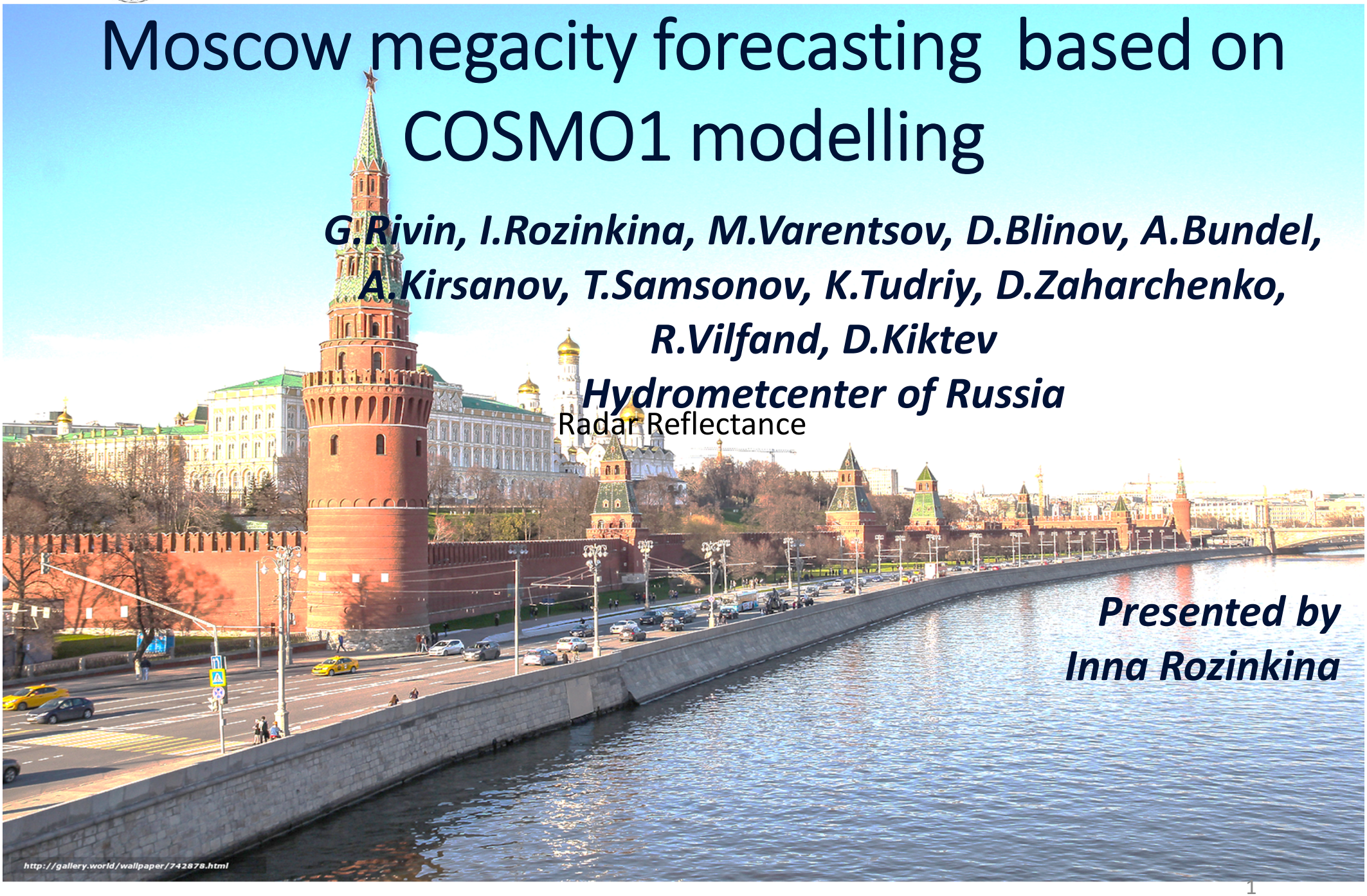
Hydrometcenter of Russia

Radar Reflectance



Presented by Inna Rozinkina

Moscow Megacity:

- The largest megacity in Europe
- About 17 million people
- Enormous number of institutions, factories, objects of infrastructure…
- Diameters: from ~35 to ~100 km
- The Moscow government Program "Safe City" (to create a quality urban environment) started in 2011

- Severe weather events: Storm winds, heavy precipitations, extreme cold and heat, fogs, thunderstorms, ….

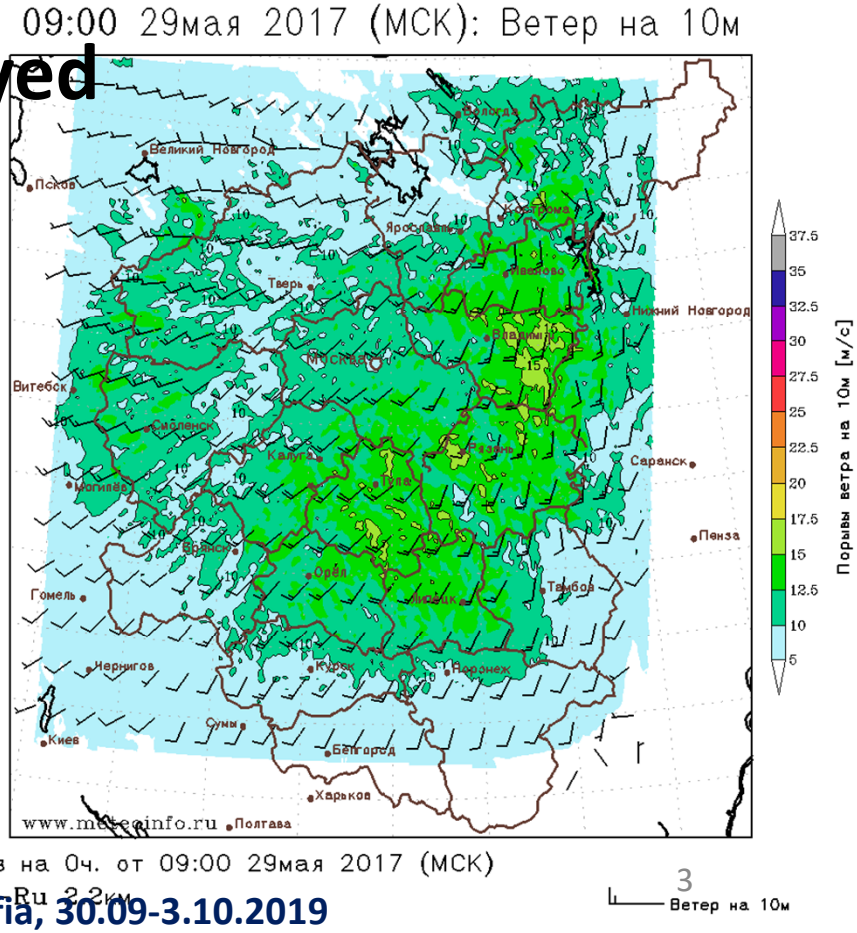
The 29-h May 2017

Squally stormy wind (15 - 30 m/s)

18 persons were killed, about 170 people were injured,

27 000 (!) of trees were broken, some of them broke cars

Some small buildings were destroyed



COSMO-Ru have predicted:

Lead Time (LT) ***72 hours (COSMO_Ru7):*** strong winds reaching 20 m/s

LT ***18 and 12 hours (COSMO_Ru2): :*** storm winds (max 25 m/s)

LT ***6 hours (COSMO_Ru7)***: **localized** storm winds (max.27 m/s)

FORECASTERS DIDN'T BELIEVE IT

- This wind was ***not be directly connected with strong convective cloudiness, radar data didn't see the coming storm***.
- Forecasters didn't have ***advanced statistics*** about skill of COSMO-Ru2 forecasting of storm winds.

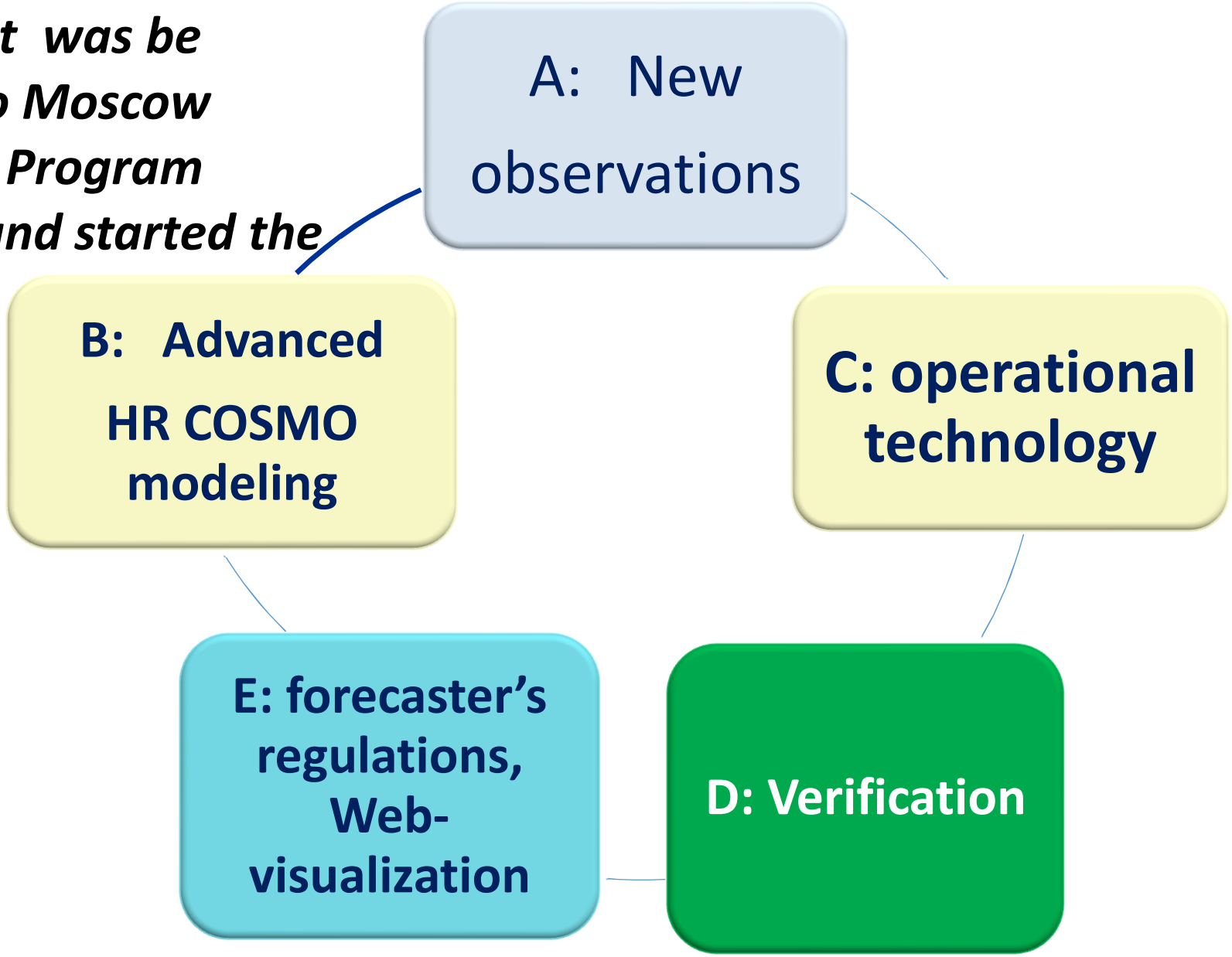
The citizens messages and SYNOP in-situ data from north-western Moscow suburb confirmed before 3 hour the arrival of danger

THE MAIN LESSON:

The ***COMPLEX PROGRAM*** of new Moscow meteosupport is necessary

Moscow Advanced Meteosupport (MAM) Project components:

MAM project was be included into Moscow government Program "Safe City" and started the 23 Oct 2018



	NDJ	FMA	MJJ	ASO	NDJ	FMA	MJJ	ASO	NDj	FMA	MJJ	ASO
A	First stage, formalities, 10 new AMSs				30 new AMSs, regular data flow				35 new AMS, Operational data flow			
B	Prototype COSMO-RuM1+ Terra Urb Terra-Urb testing		Terra-Urb + COSMO 5.06 - HR Terra Urb External parameters, - Tests of COSMO-RuM1 - New: COSMO-RuM0.5		- Terra-Urb Coupling with ICON; - Updating of urban external parameters calculating system with flexible resolution (≤ 500m) - Start of HR EPS - Start of HR DAS - Start of COSMO/ICON ART				- Terra_URB+ICON tests Preparing COSMO/Icon RuM05 for operational runs Experiments Δx 300 m - Downscaling postprocessing - HR EPS - HR DAS - ICON-ART			
C	Technology Configuration Regular Runs		COSMO-RuM1 pre-operational runs		COSMO-RuM1 operational ICON_RuM1 experimental				ICON_RuM0.05 pre- operational HR EPS Pre- operational			
D	verification, case studies											
E	Improved forecasting for Severe Weather, feedback											

The Road-Map for MAM project

2018 2019 2020 2021

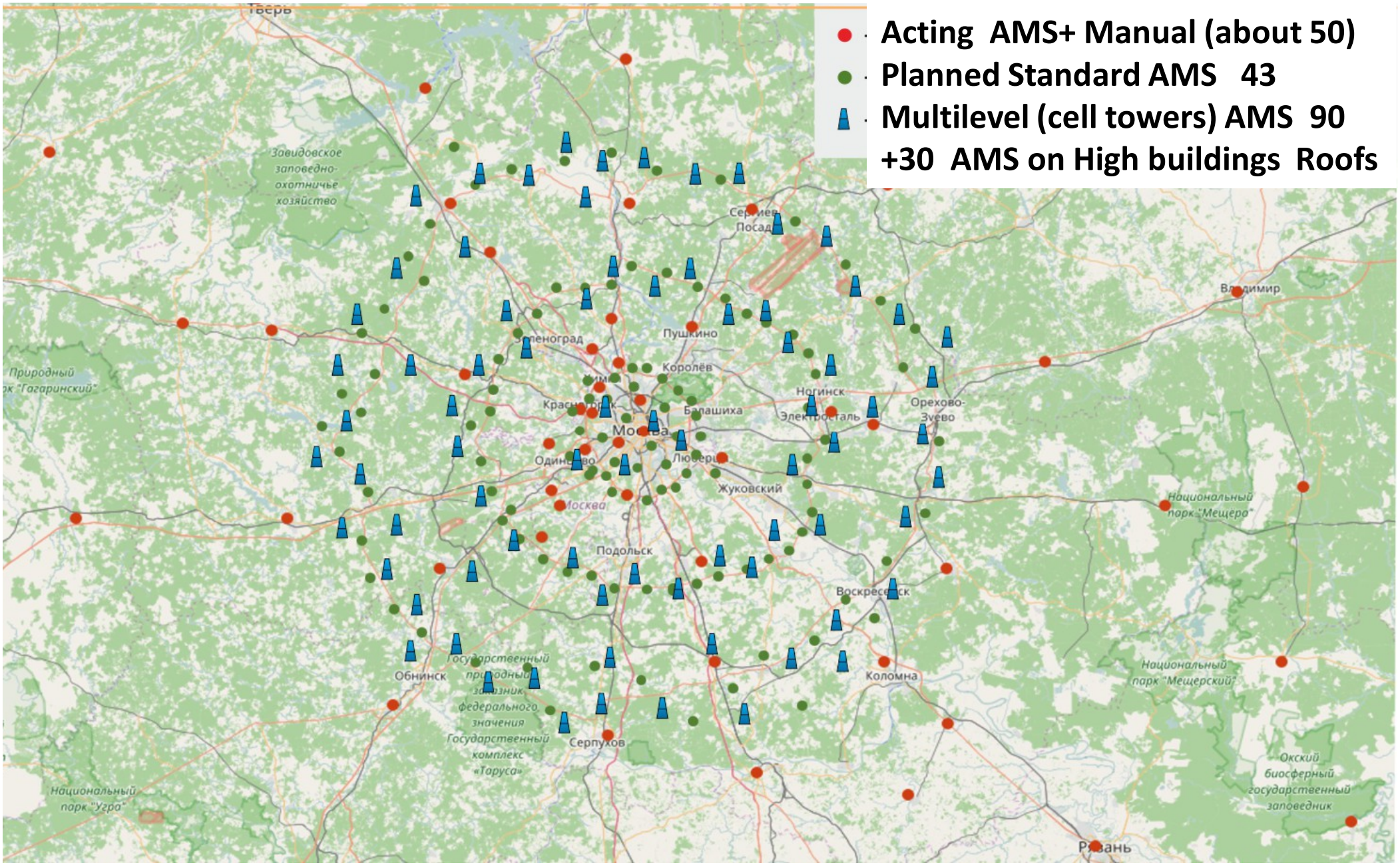
FMA	MJJ	ASO	NDJ	FMA	MJJ	ASO	NDj	FMA	MJJ	ASO	NDJ
First stage, formalities, 10 new AMSs			30 new AMSs, regular data flow				35 new AMS, Operational data flow				

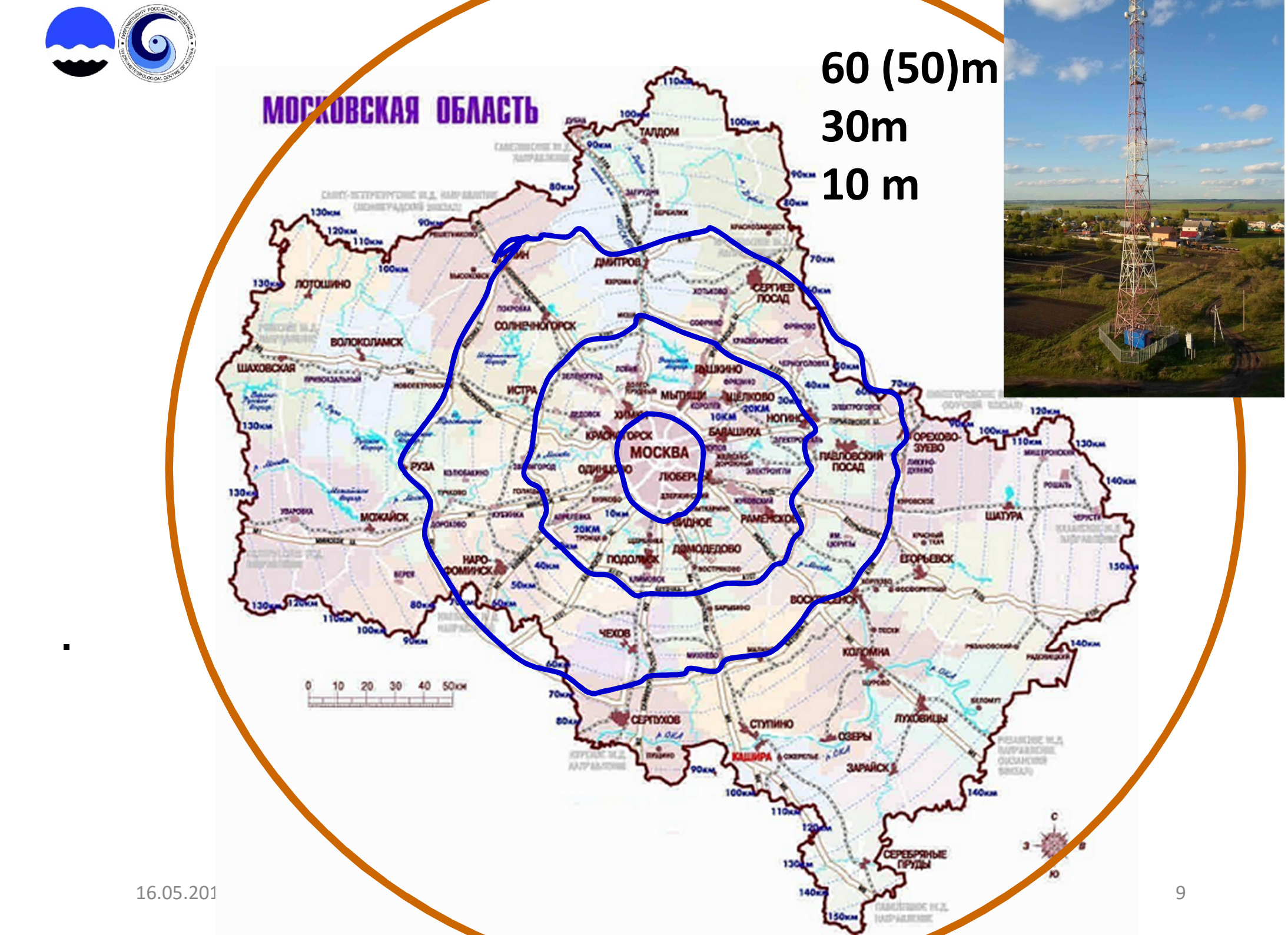
Component A:
AMS Observations network development

Working MAM project Plan based the Road-Map

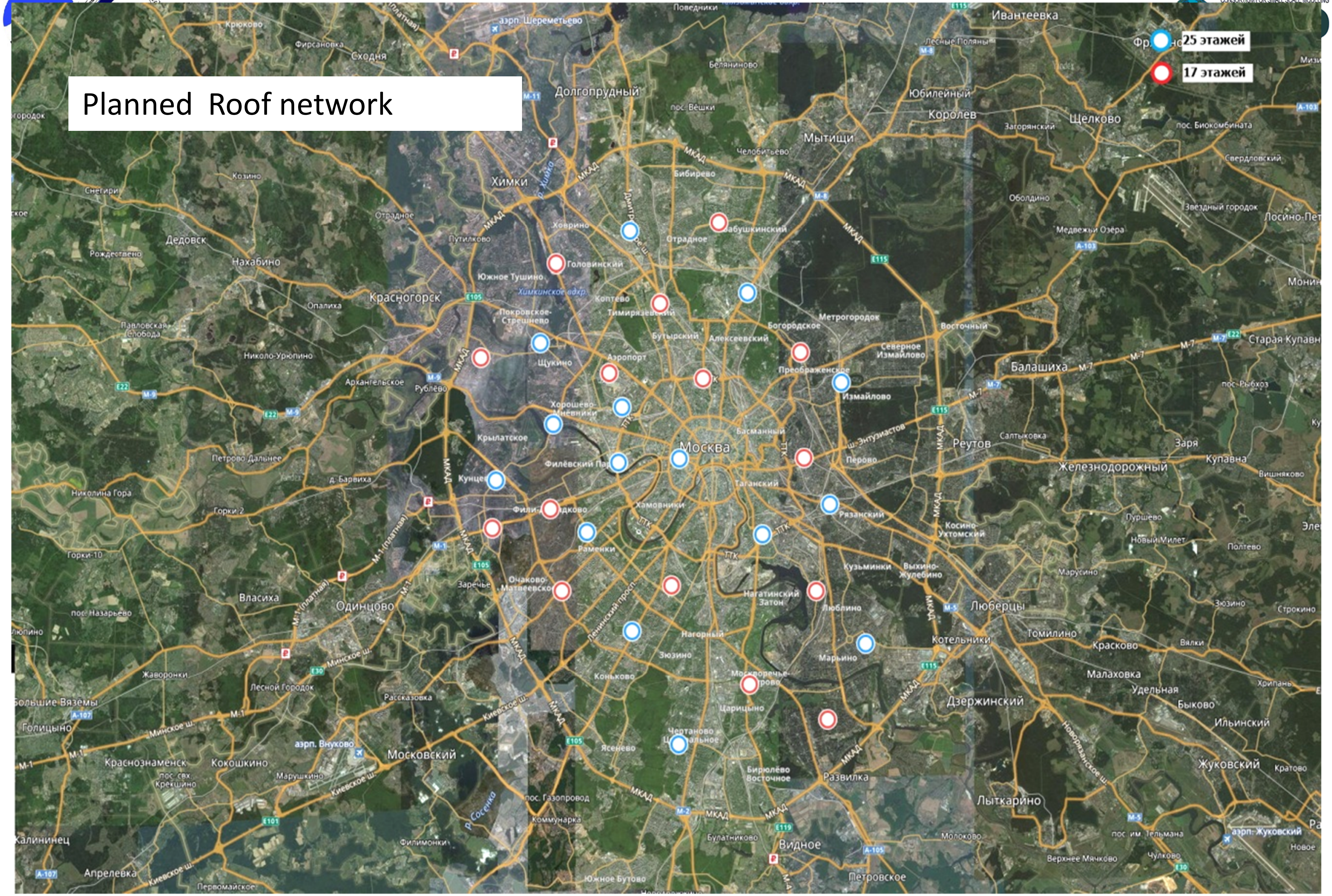
2018 2019 2020 2021

Component A: Planned Network: Standard + multilevel (cell towers +HB Roofs) AMS




МОСКОВСКАЯ ОБЛАСТЬ
60 (50)m
30m
10 m
МОСКВА
ТАЛДОМ
ДМИТРОВ
СЕРГИЕВ ПОСАД
ЛОТОШИНО
СОЛНЕЧНОГОРСК
ВОЛОКОЛАМСК
ШАХОВСКАЯ
ИСТРА
МЫТИЩИ
ЩЕЛКОВО
НОГИНСК
БАЛАШИХА
ОРЕХОВО-ЗУЕВО
ПАВЛОВСКИЙ ПОСАД
РУЗА
МОЖАЙСК
ОДИНЦОВО
ЛЮБЕРЦЫ
ВИДНОЕ
РАМЕНСКОЕ
ШАТУРА
НАРО-ФОМИНСК
ПОДОЛЬСК
ДОМОДЕДОВО
ЕГОРЬЕВСК
ЧЕХОВ
КОЛОМНА
СЕРПУХОВ
СТУПИНО
ЛУХОВИЦЫ
ОЗЕРЫ
КАШИРА
ЗАРАЙСК
СЕРЕБРЯНЫЕ ПРУДЫ
0 10 20 30 40 50км

Planned Roof network



	NDJ	FMA	MJJ	ASO	NDJ	FMA	MJJ	ASO	NDj	FMA	MJJ	ASO	NDJ
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Component B:
Development of modelling, preparing new versions

2018 2019 2020 2021

Component B:
Development of modelling

Focal point:

COSMO PT AEVUS

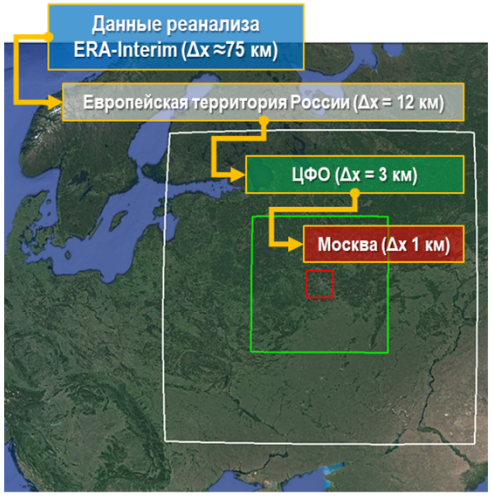
COSMO-Ru modeling based on TERRA- Urb

grid-steps 1 km (in testing, pre-operational runs)
500 m (experimental runs, in study)
300 m (in progress)

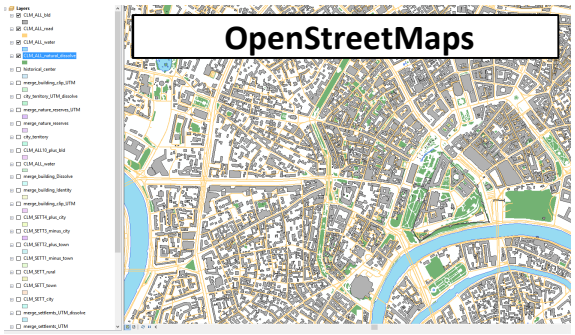
Background for experiments

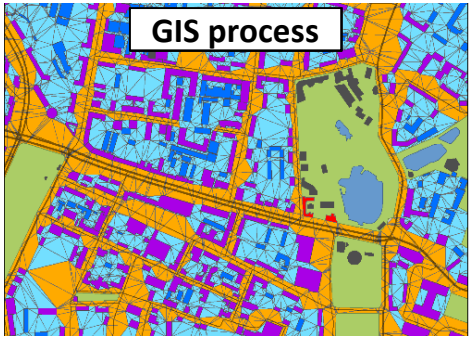
TERRA_URB (Wouters, 2016) **allows you via economical approach to describe the main factors of forming of urban forcing in weather and climatic scales, first – on temperature and as result – to precipitation and wind fields**

"Translation of urban canopy parameters into bulk parameters"

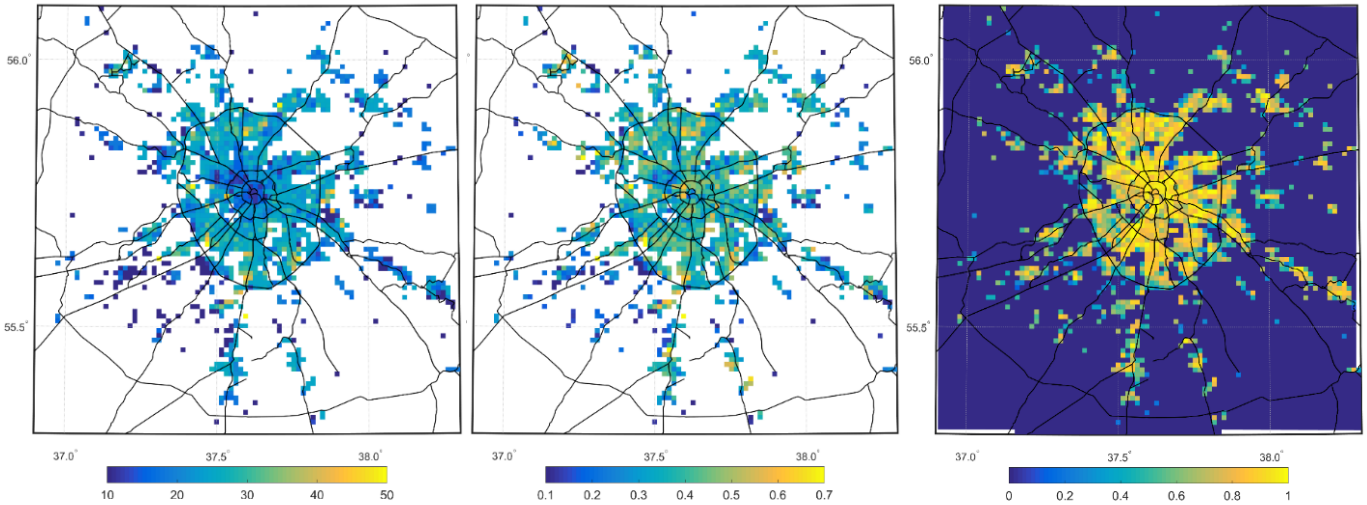


Experimental nesting for Long-term COSMO-Terra_urb runs





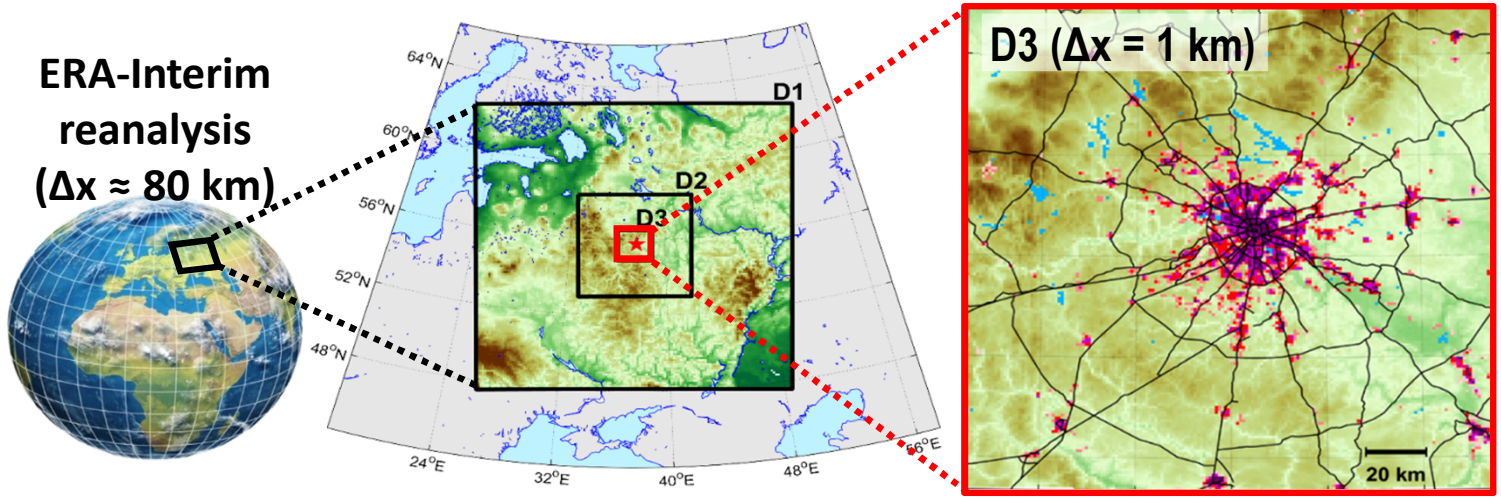
Parameters for modeling



High of buildings | **Parameter of urban canions** | **urban index**

Previous studies (MSU)

- Downscaling of the ERA-Interim in continuous simulations for selected case studies (10-15 days) using three nested domains D1-D3
- TERRA_URB is used for the finest domain D3 with 1-km horizontal grid step
- Urban canopy parameters (FR_PAVED/ISA & AHF) are clarified using OpenStreetMap data according to the original GIS-based technology



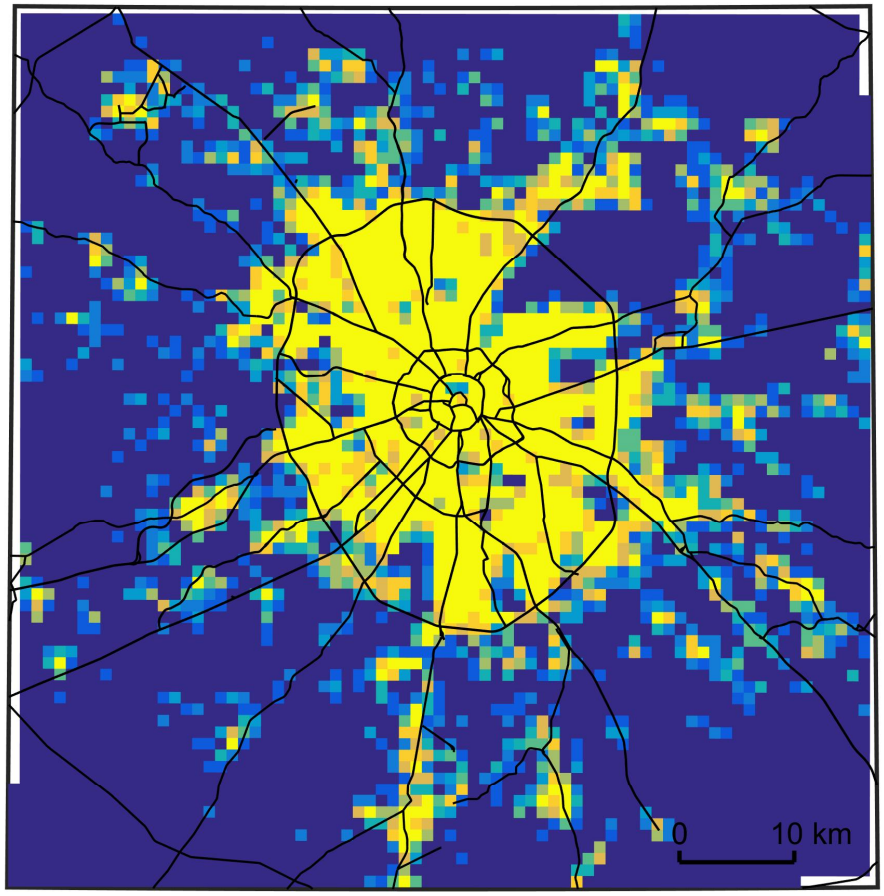
- **COSMO 5.0_clm9_urb**
- **MSU Lomonosov, Department of meteorology and climatology, Department of cartography**
- **Simulations at supercomputers Lomonosov-2 of Moscow State University and Cray-XC40 of RHM**

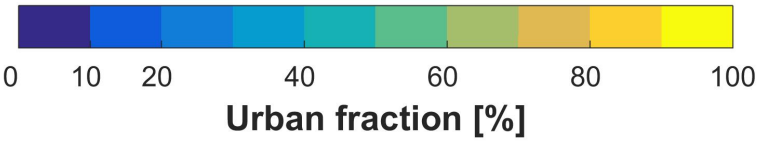
Moscow is an ideal polygon for testing tiled urban parametrizations

Towards higher-resolution simulations

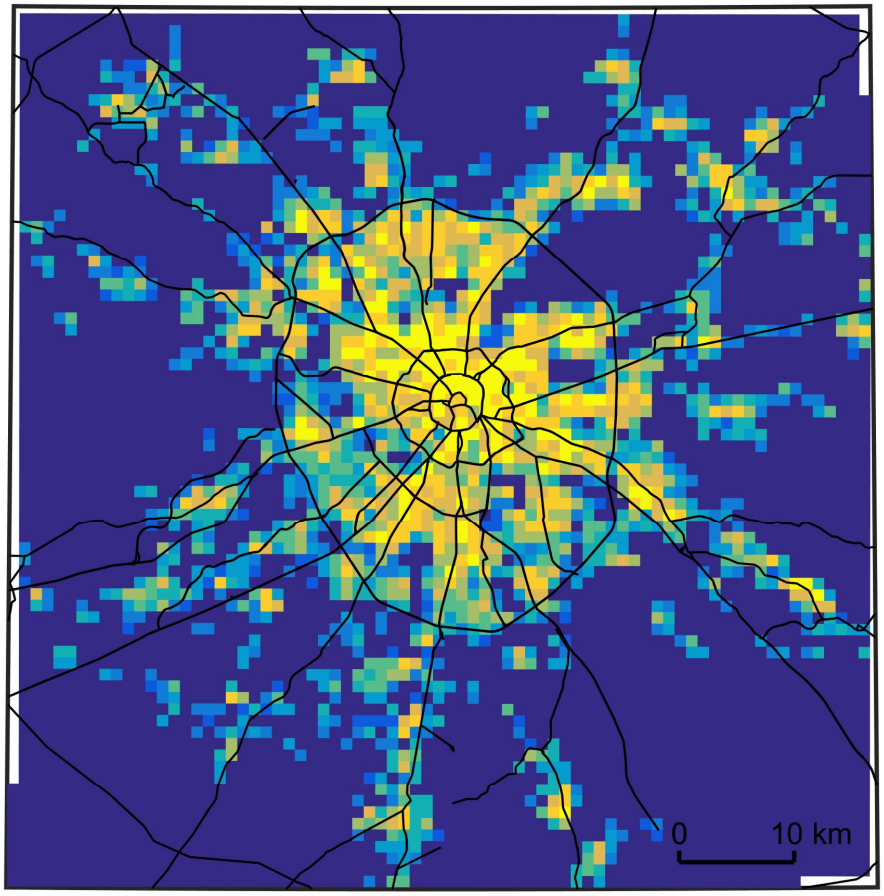
External parameters for TERRA_URB: urban fraction **(Δx = 1 km)**

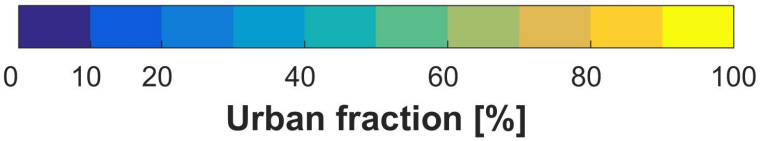
EXTPAR/WebPEP output
(Globcover data, URBAN field)



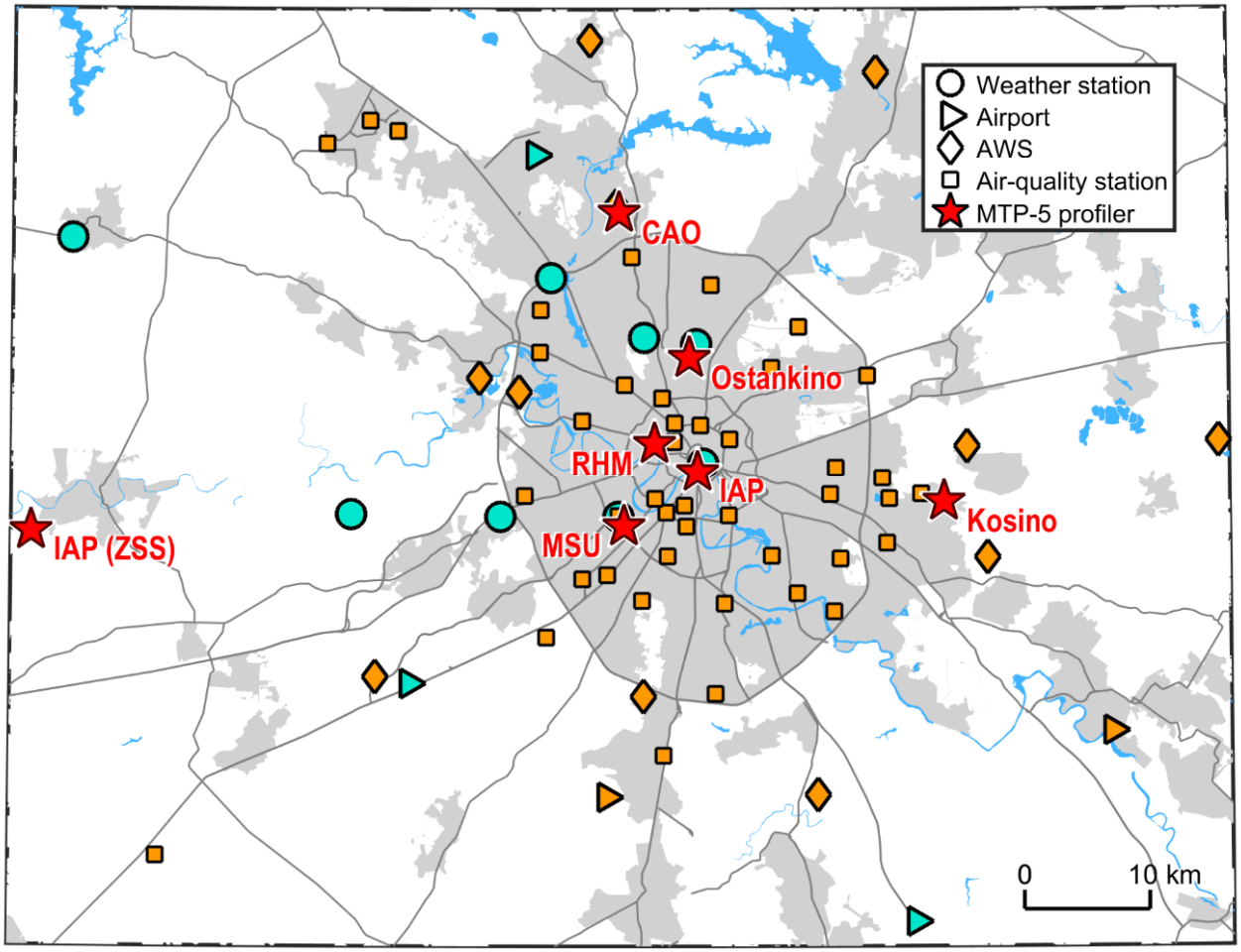


Data based on OpenStreetMaps data
and empiric estimates





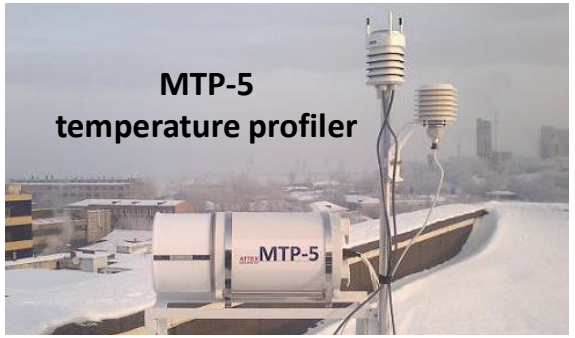
Data used for model verification and tuning



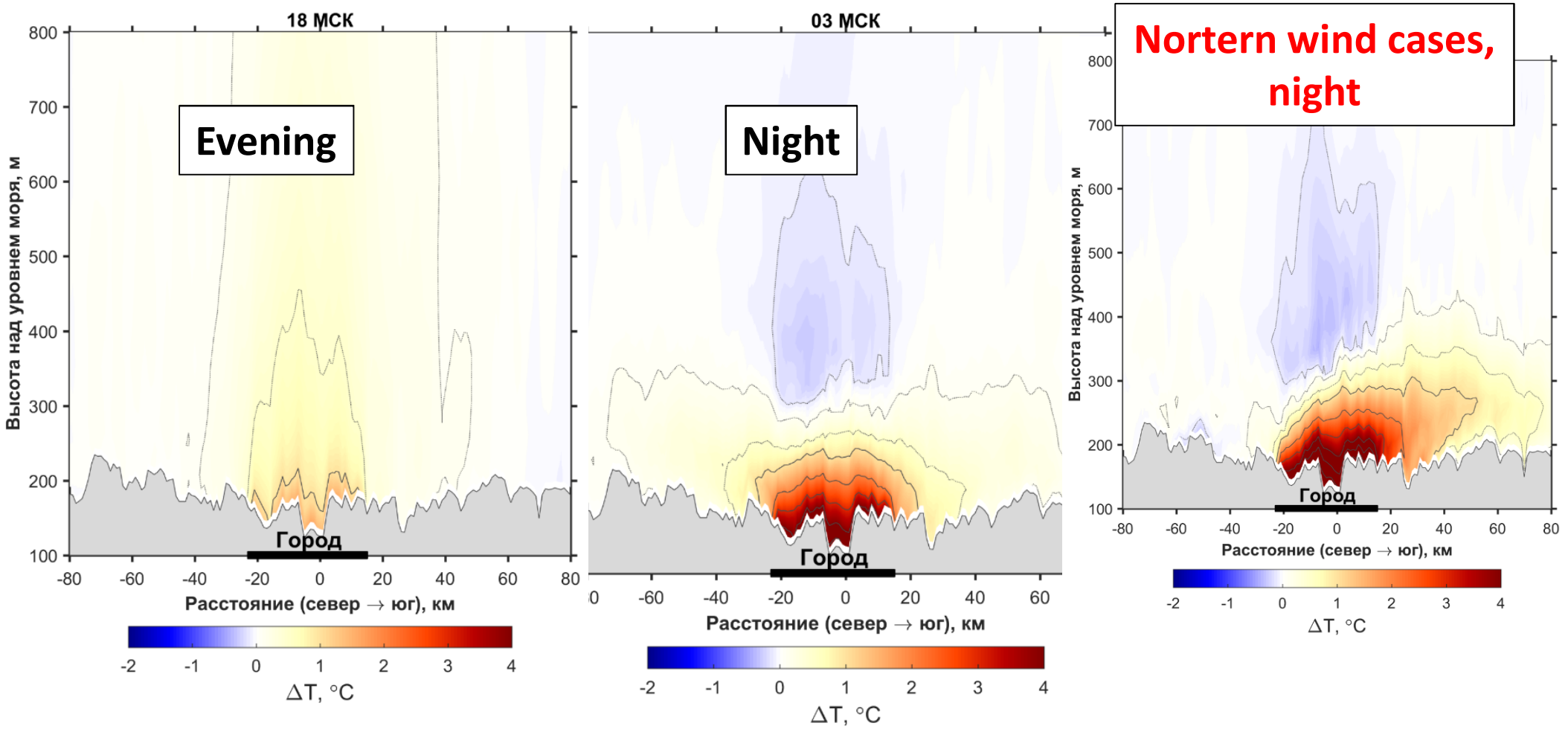
Data provided by RHM, A.M. Obukhov Institute of Atmospheric Physics, Moscow State University, Central Aerological Observatoty Mosecomonitoring agency

Observations used:

- Weather stations, including new AWSs
- Air-quality monitoring stations of Mosecomonitoring agency
- **A unique network of microwave temperature profiles MTP-5** (vertical profiles up to 1000 m)



The heat island over Moscow

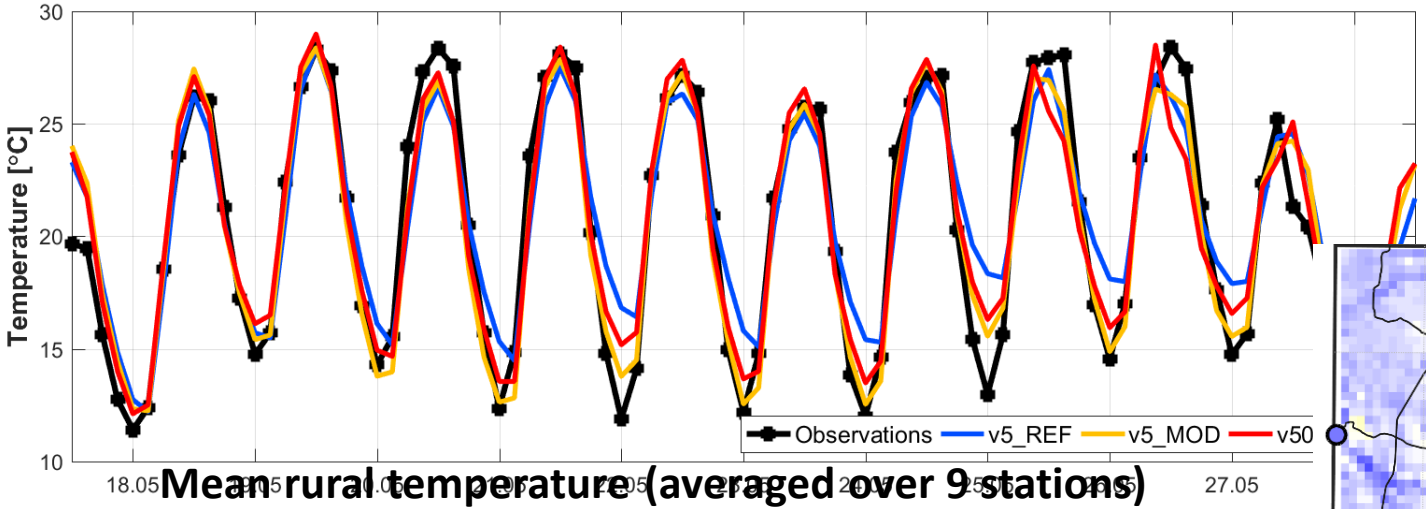


N to S crossections of Model reply (Δ Terra_urb -- no Terra Urb)

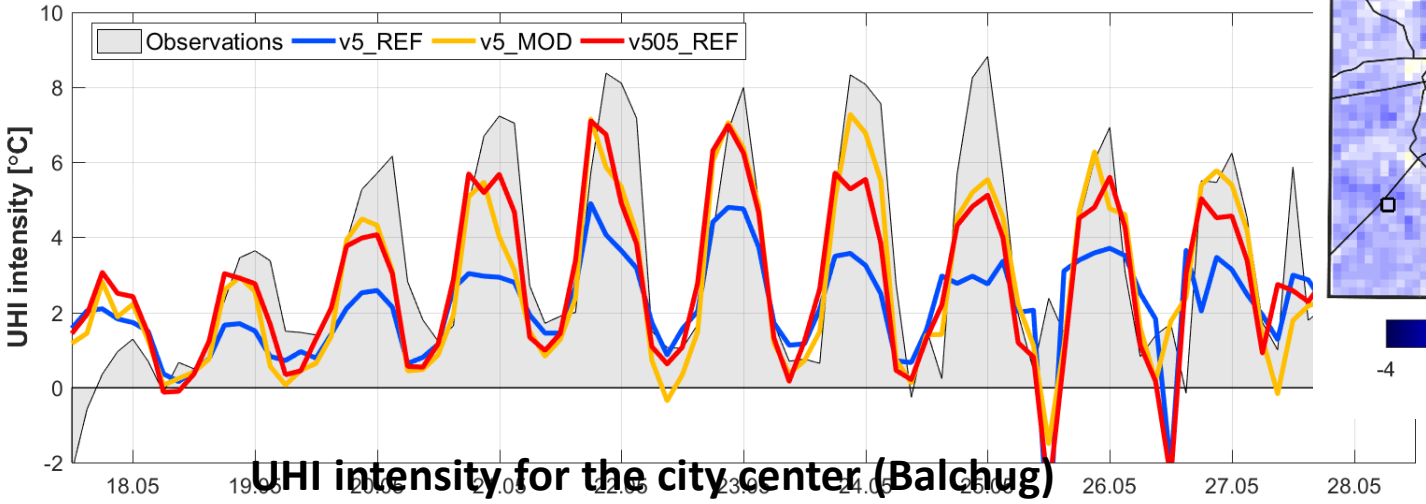
Testing of COSMO 5.05urb

COSMO PT AEVUS

Model verification for a summer case (17-28 May

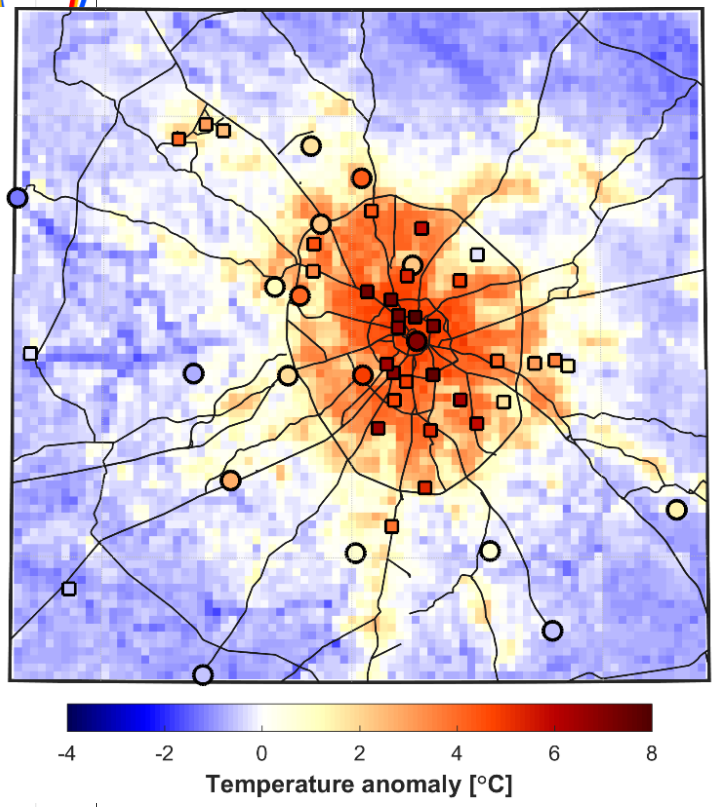


Mean rural temperature (averaged over 9 stations)



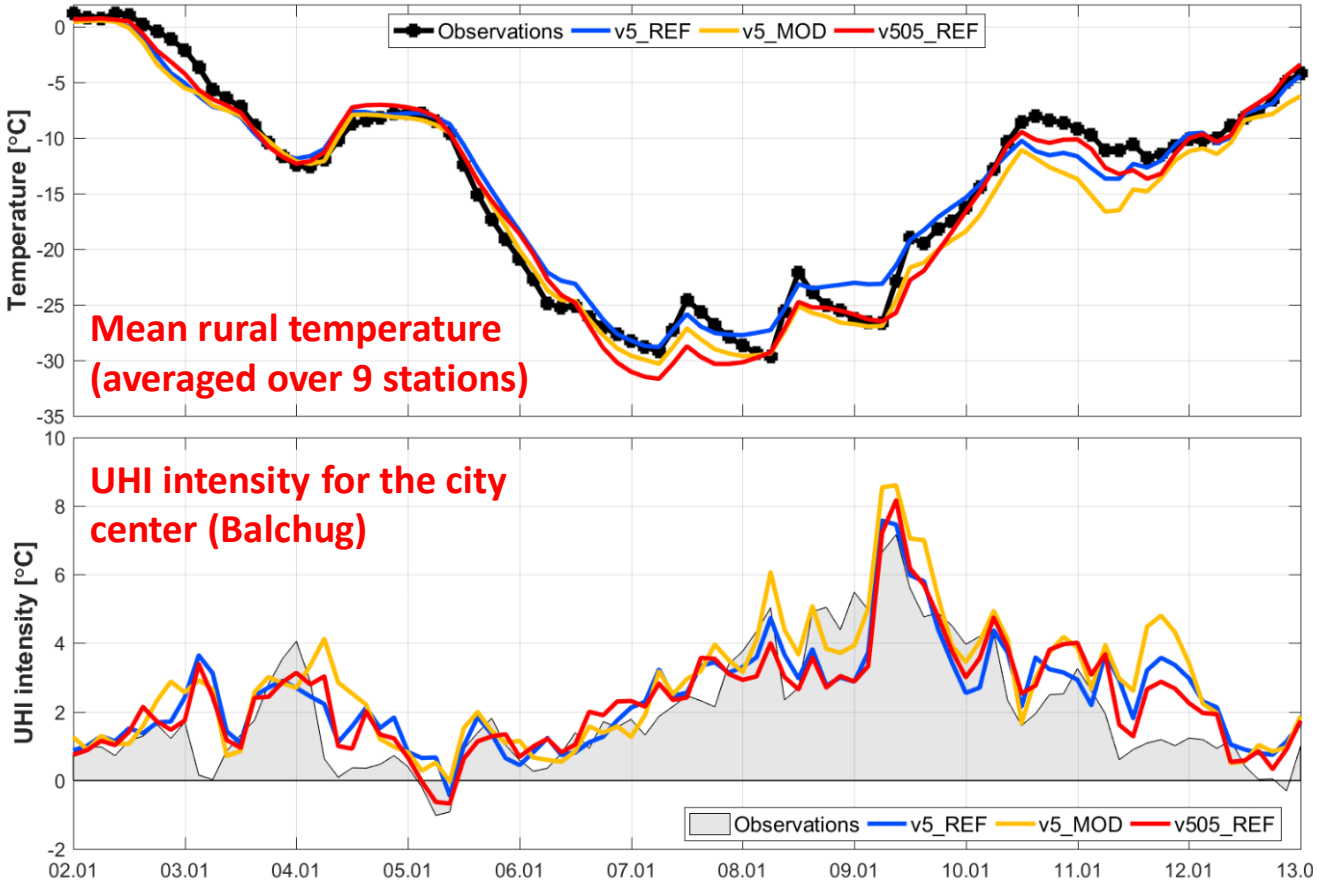
UHI intensity for the city center (Balchug)

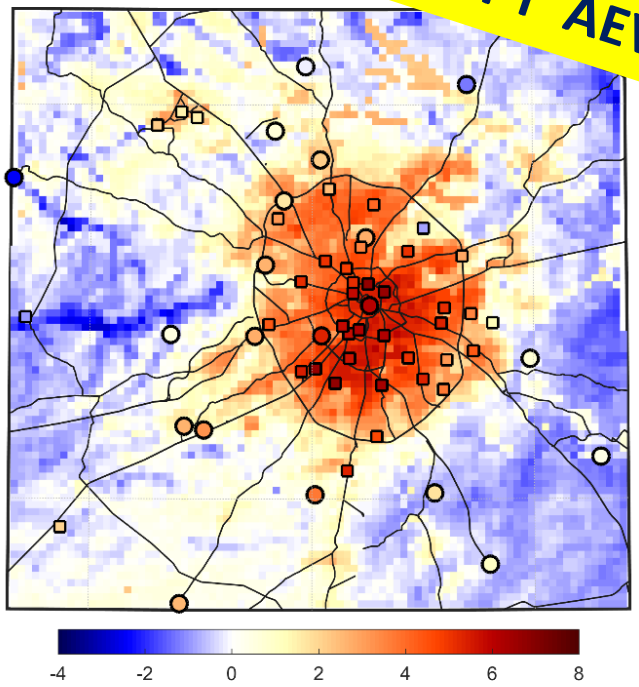
Mean nighttime (0 UTC) temperature anomaly



Model verification for a winter case with extreme frosts (1-15 Jan 2017)

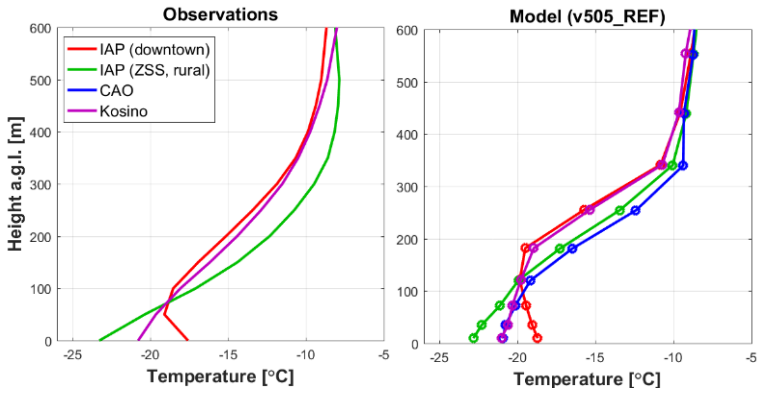
COSMO PT AEVUS





Mean temperature anomaly over 9th of January [°C]

One of the coldest periods in Moscow region in XXI century with T_{min} = -35 °C in the north of the region



Mean temperature profiles over 9th of January [°C]

Key results from RHM in PT AEVUS

- The results obtained with the new model version 5.05urb are consistent with results obtained with 5.0_clm9_urb

- The new model version based on ICON ID/BC shows almost good results as a carefully-tuned old version

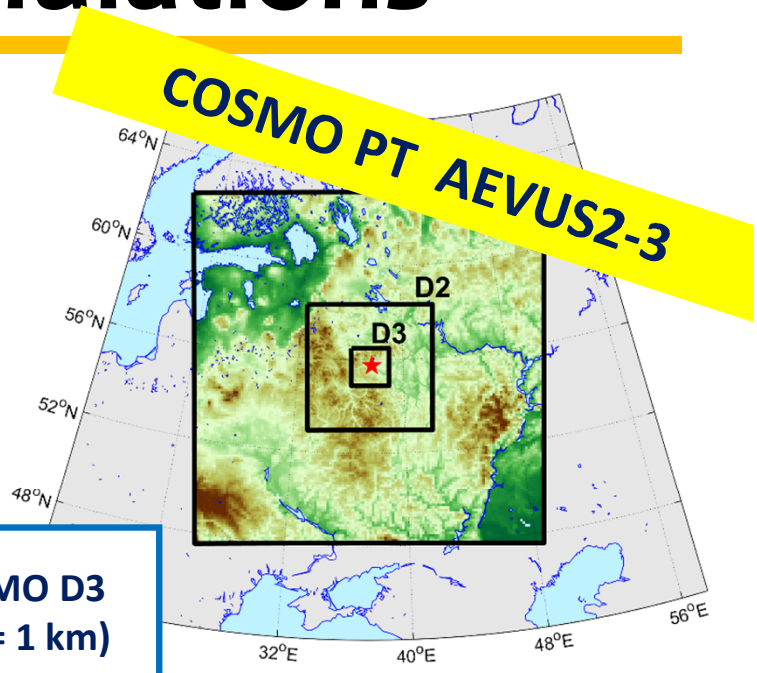
New ICON-driven simulations

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 | … |



Old downscaling chain:

ERAI (Δx ≈ 80 km) → COSMO D1 (Δx = 12 km) → COSMO D2 (Δx = 3 km) → COSMO D3 (Δx = 1 km)

New downscaling chain:

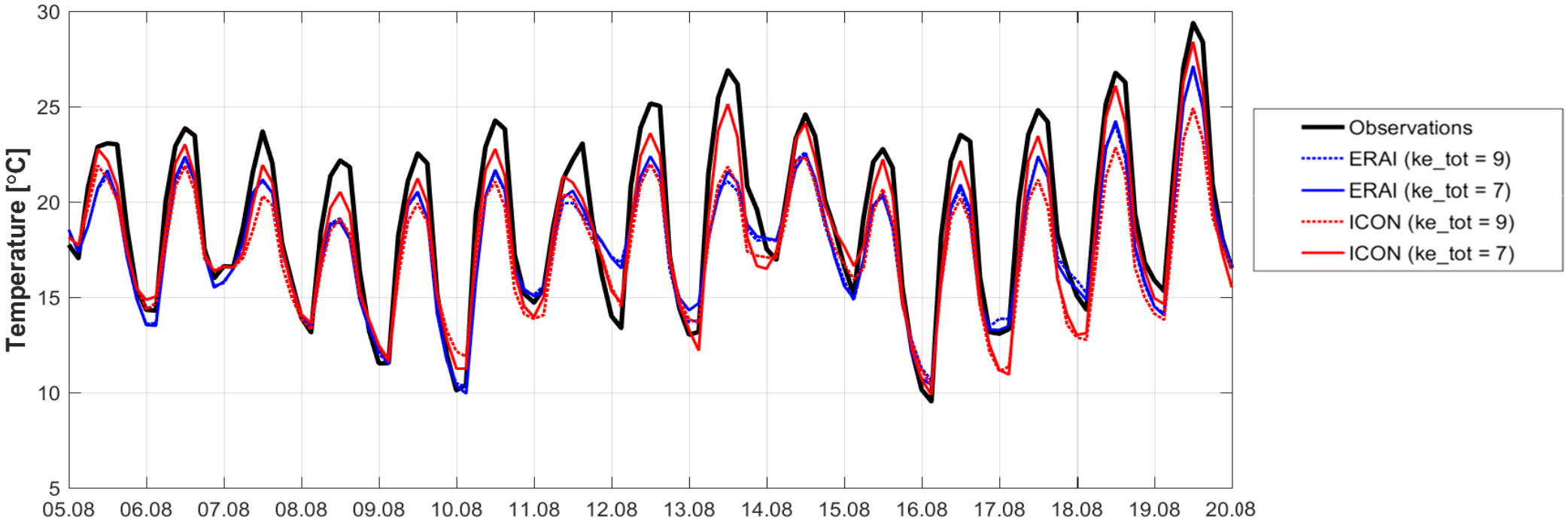
ICON (Δx ≈ 13 km) → COSMO D2 (Δx = 3 km) → COSMO D3 (Δx = 1 km)

ICON (Δx ≈ 13 km) → COSMO D1 (Δx = 12 km), only for testing

COSMO D2 (Δx = 3 km) → COSMO $D3_{hr}$ (Δx = 500 m)

Motivation for new downscaling chain: we want to eliminate the errors which comes from the initial conditions on soil temperature and humidity, and from the imperfect model physics on the rough resolution of the basic domain (D1)

New ICON-Terra_URB simulations



Difference are due to the in initial conditions for soil moisture

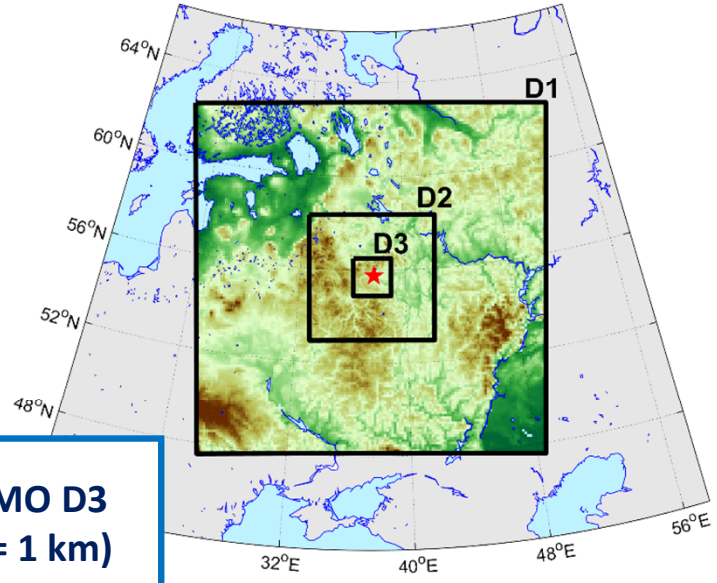
New ICON-driven simulations

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 | … |



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ICON (Δx ≈ 13 km) → **COSMO D1** (Δx = 12 km), only for testing

COSMO D2 (Δx = 3 km) → **COSMO $D3_{hr}$** (Δx = 500 m)

Motivation for new downscaling chain: we want to eliminate the errors which comes from the initial conditions on soil temperature and humidity, and from the imperfect model physics on the rough resolution of the basic domain (D1)

Towards the higher-resolution simulations

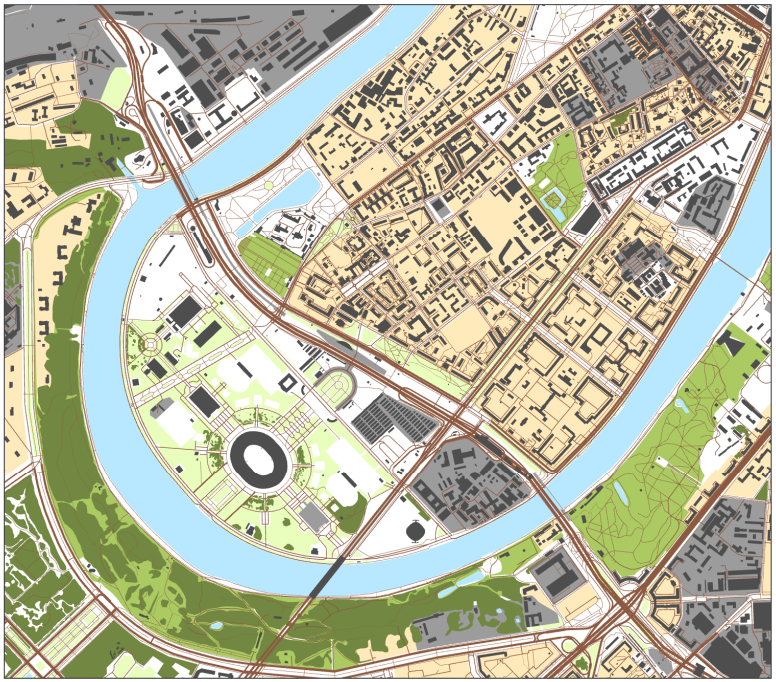
External parameters for TERRA_URB

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

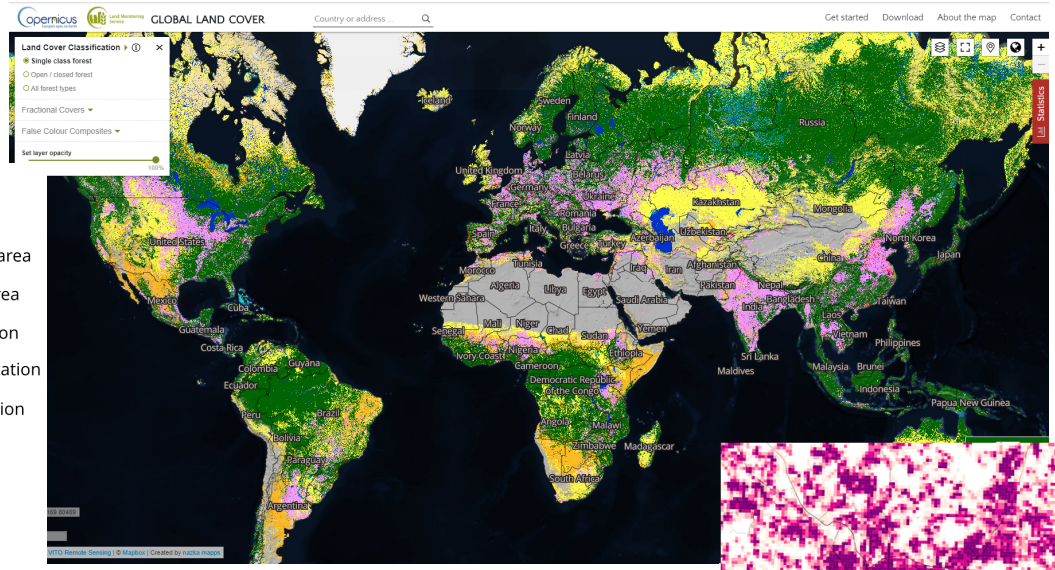
Providing bio-geophysical products of global land surface

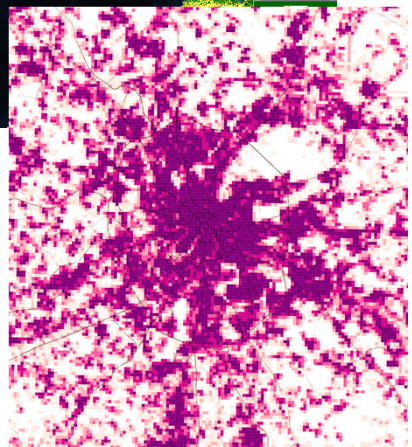
Home | Products | Use cases | Product Access | Viewing | Library | Get Support

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.



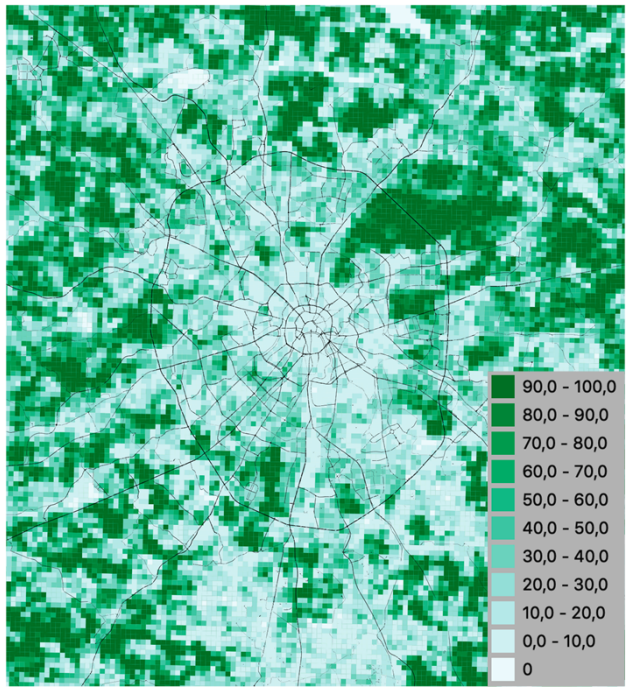


Green spaces from Sentinel-2 data

Trees and grass in 10 m resolution

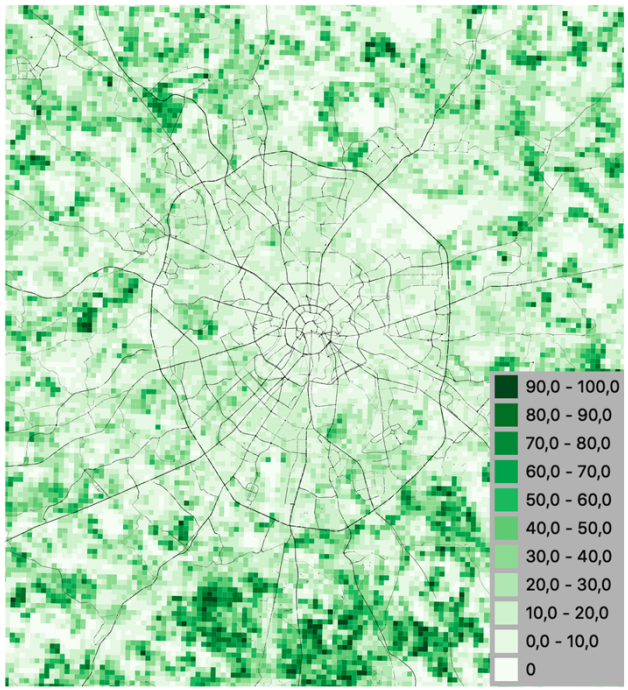
Деревья и трава, разрешение 10 м

Trees ratio, %



Доля деревьев, %

Grass ratio, %

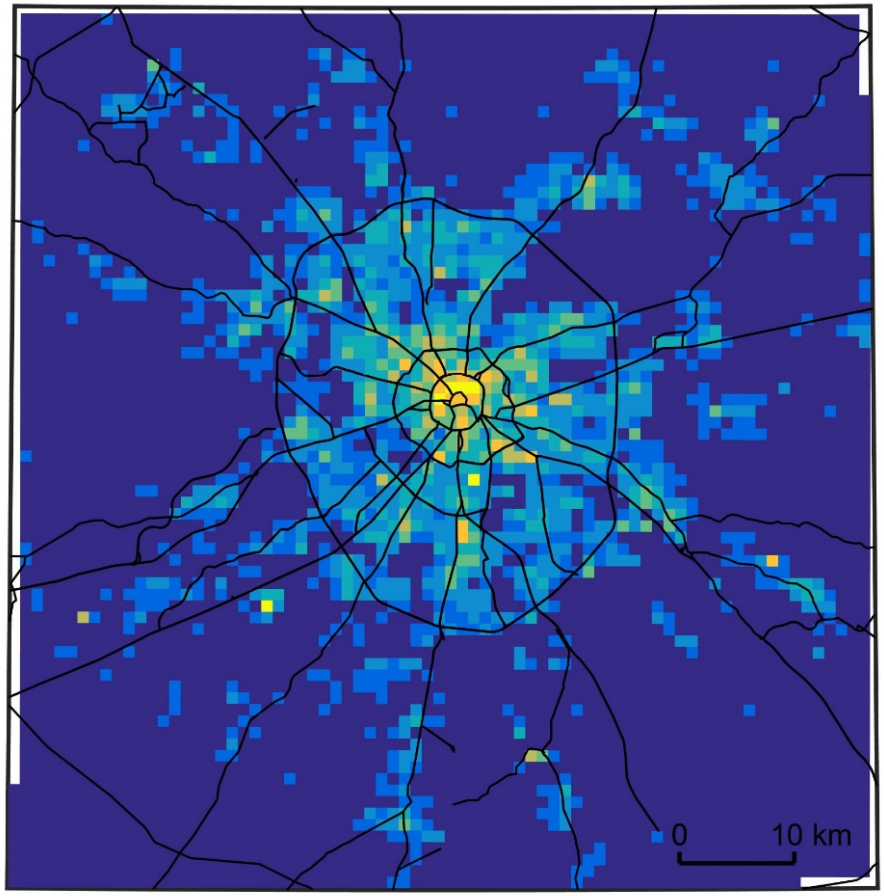


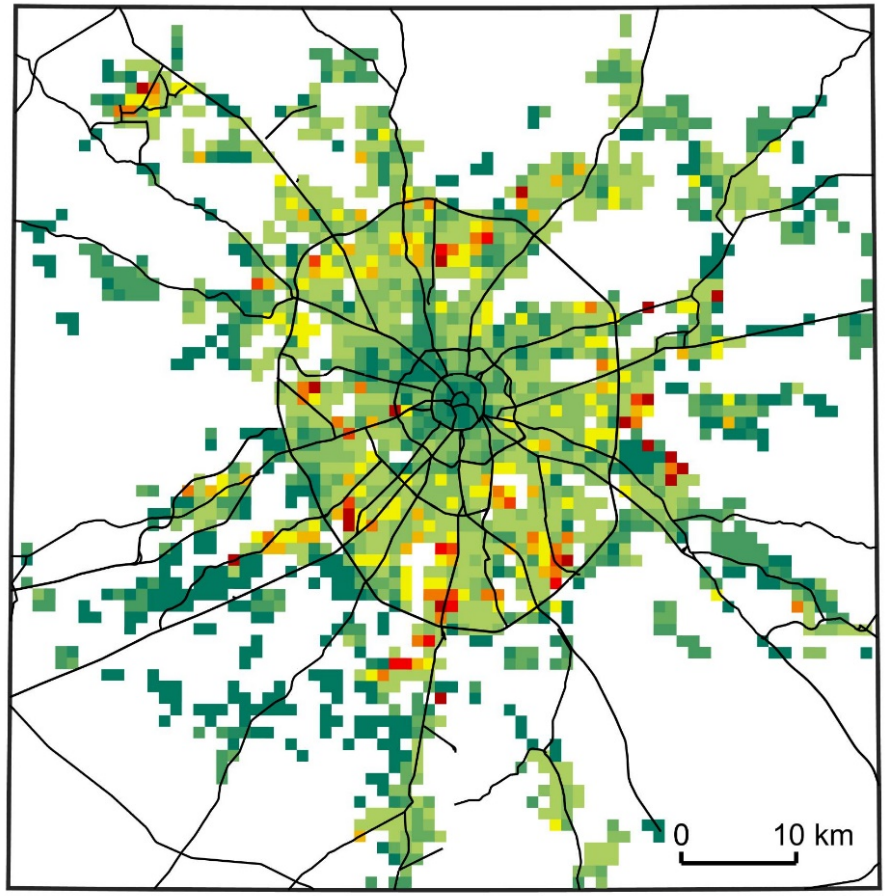
Доля травы, %

Towards higher-resolution simulations

New 2D external parameters **(Δx = 1 km)**

Parameters, used in previous 1-km simulations with 5.0_clm9_urb model version (based on OpenStreetMap data)

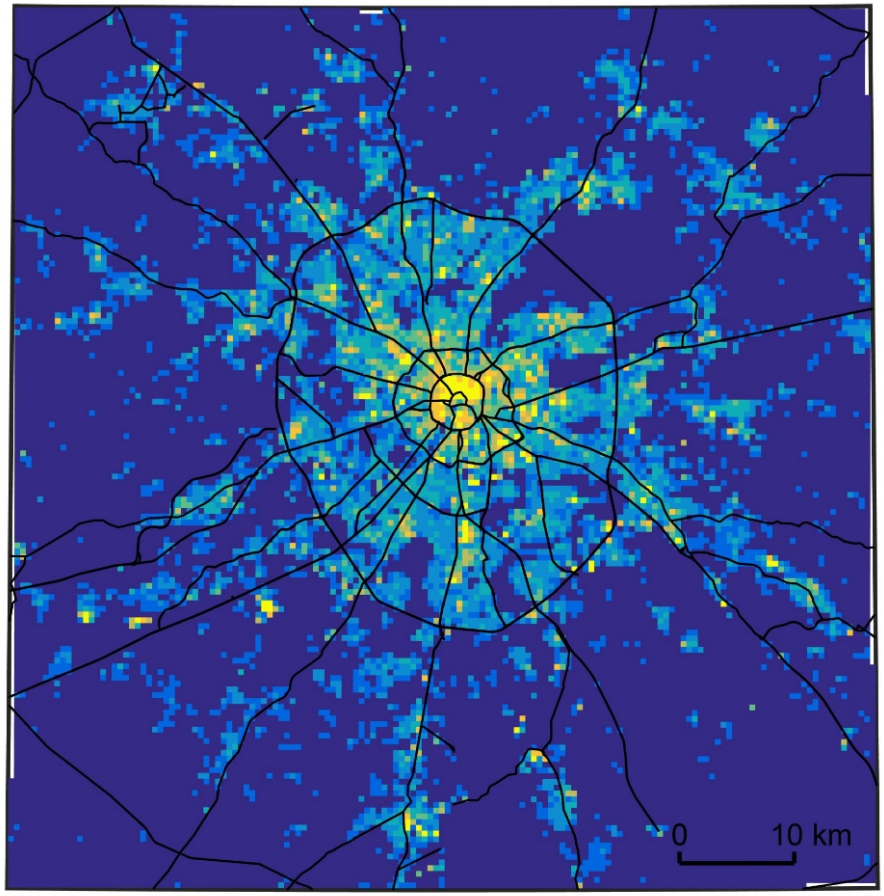


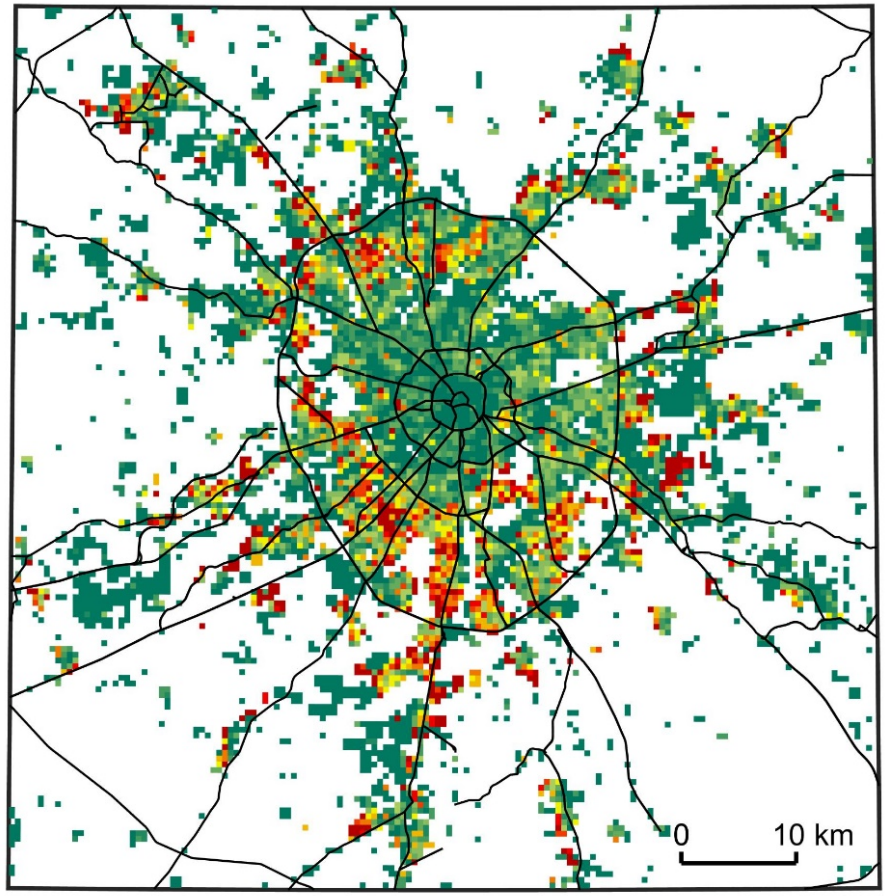


Towards the higher-resolution simulations

New 2D external parameters **(Δx = 0.5 km)**

Parameters, prepared for new 500-m simulations, not used yet
(based on OpenStreetMap data)

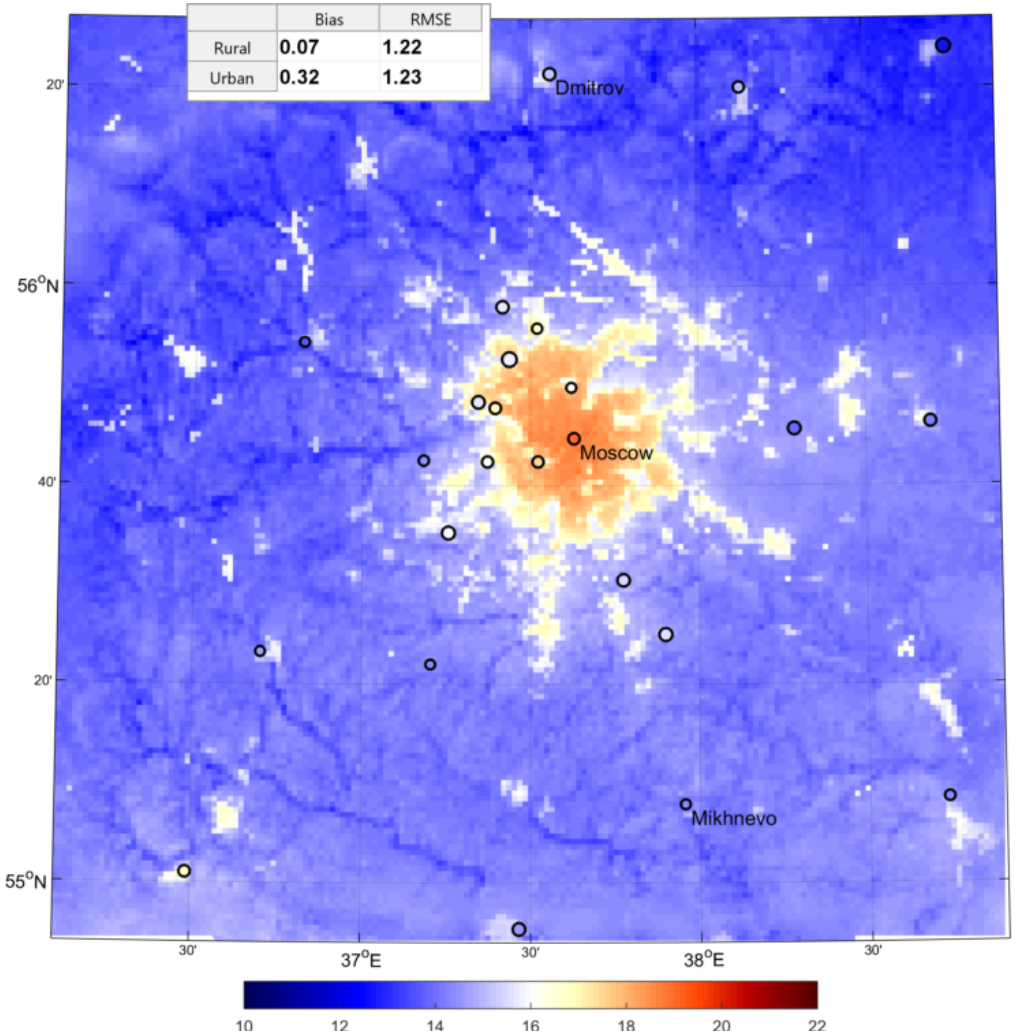




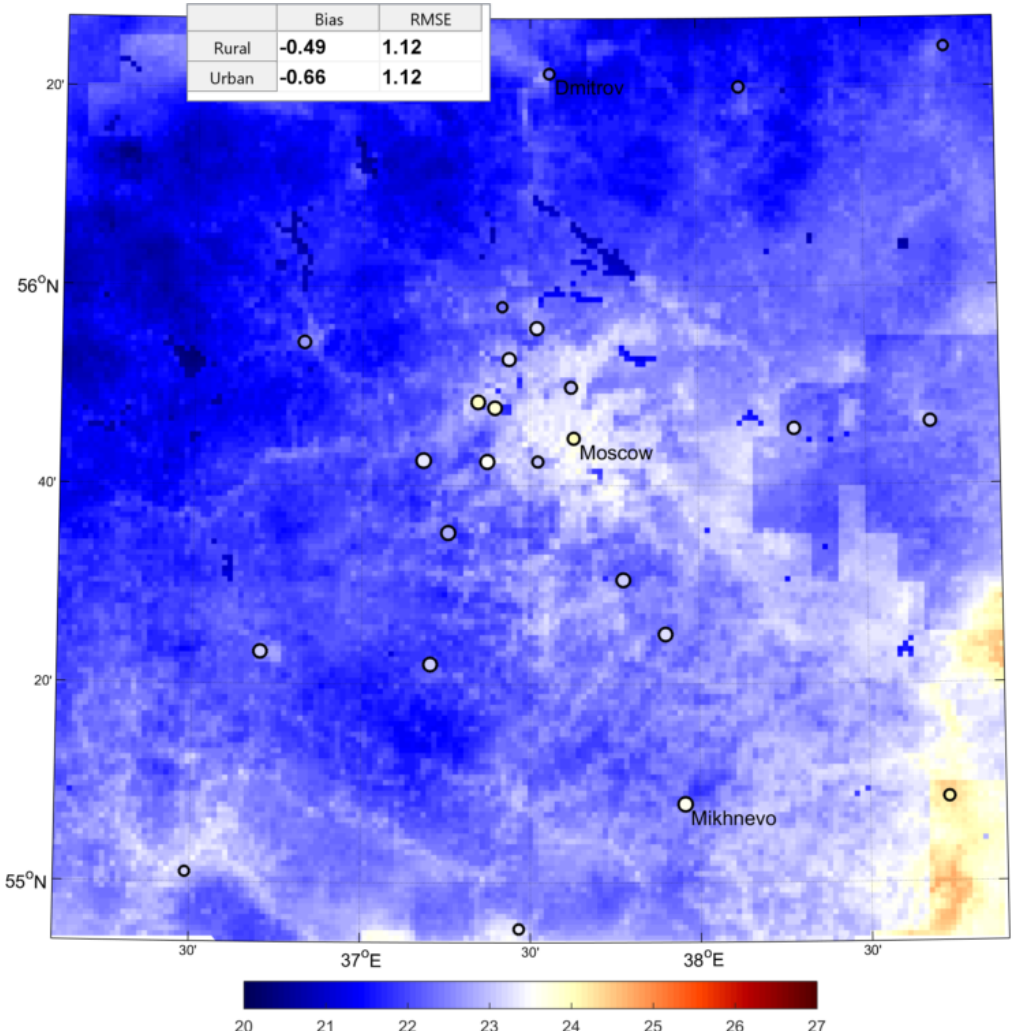
Towards higher-resolution simulations

Model verification for a summer case (5-20 August 2017)

Δx = 1 km (0.009°), 180x180 grid cells, dt = 10 sec



Mean nocturnal temperature (0 UTC)

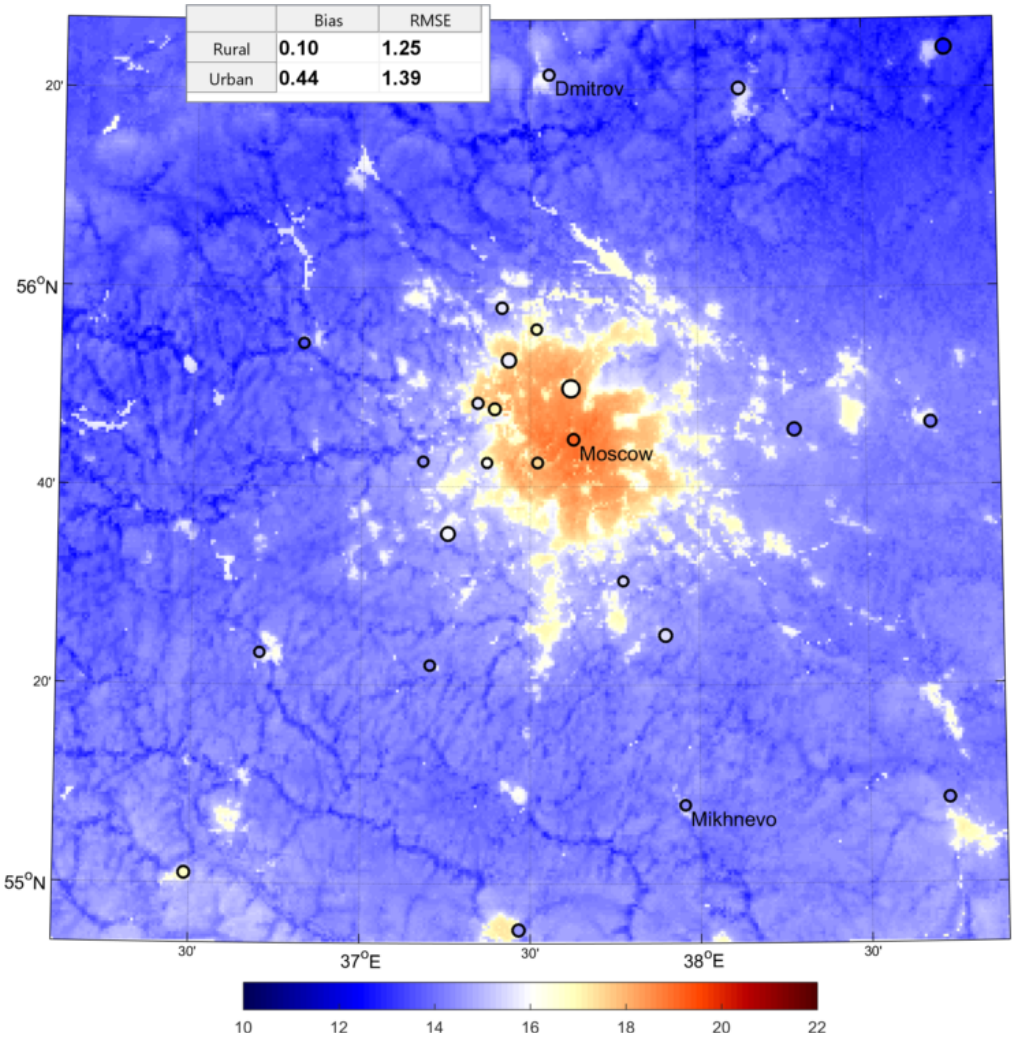


Mean daytime temperature (12 UTC)

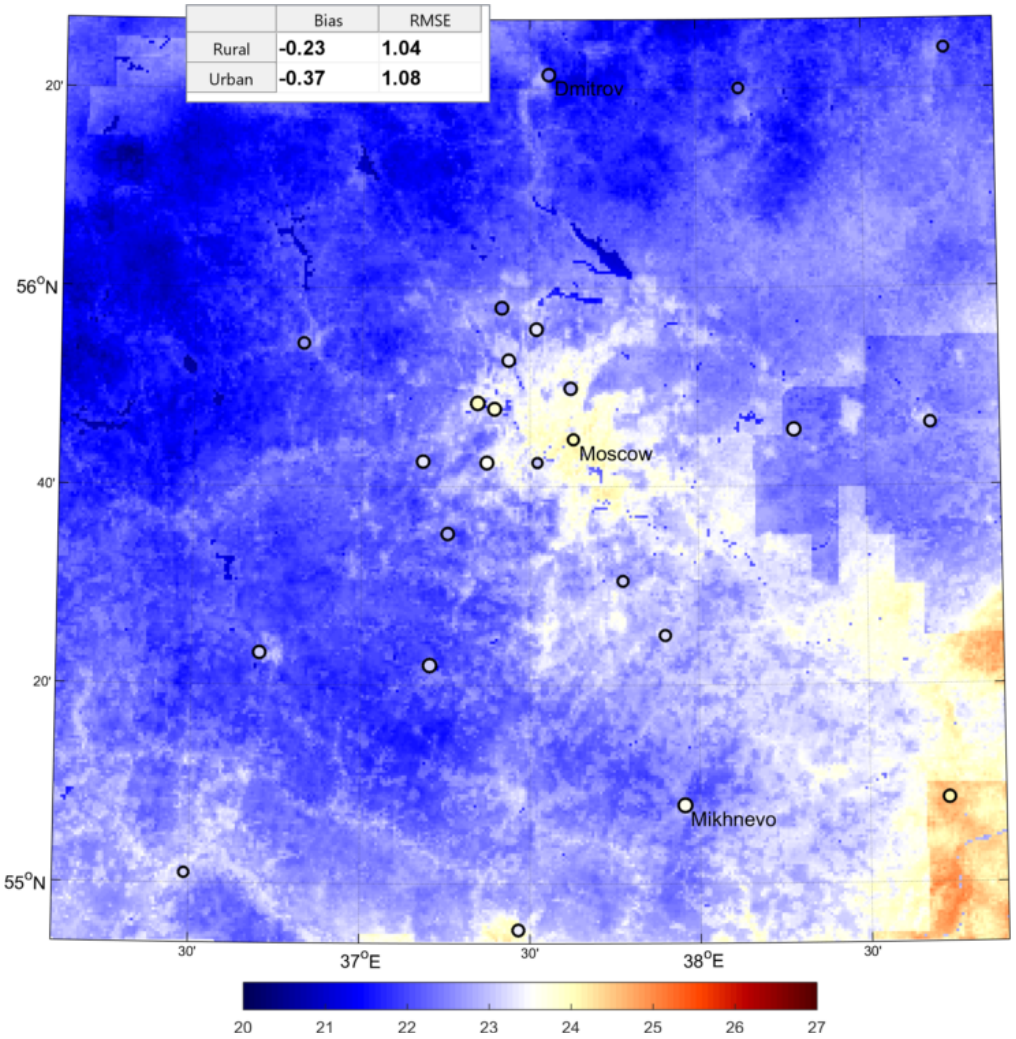
Towards the higher-resolution simulations

Model verification for a summer case (5-20 August 2017)

Δx = 500 m (0.0045°), 400x400 grid cells, dt = 5 sec



Mean nocturnal temperature (0 UTC)



Mean daytime temperature (12 UTC)

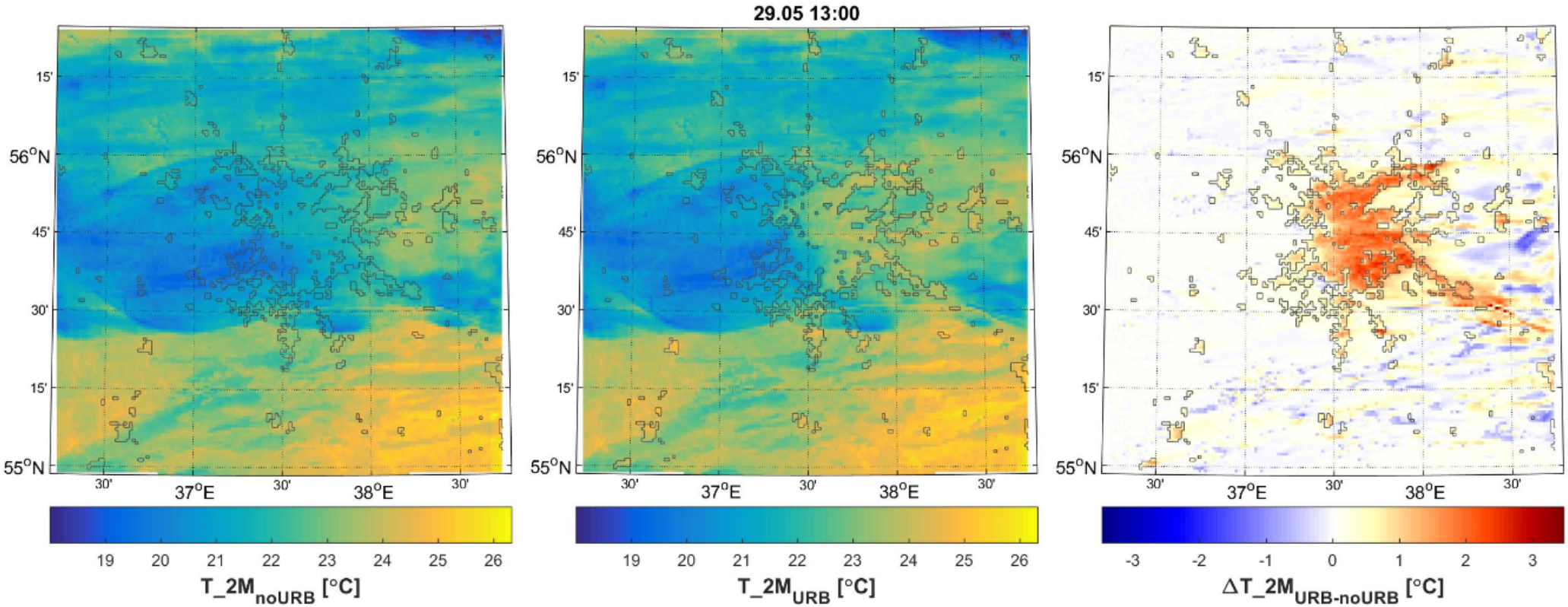
Any suggestions on the namelist settings for "gray-zone" simulations?

29.05.2017: simulations

Δx= 1 km

Δx= 500 km

ΔT2m



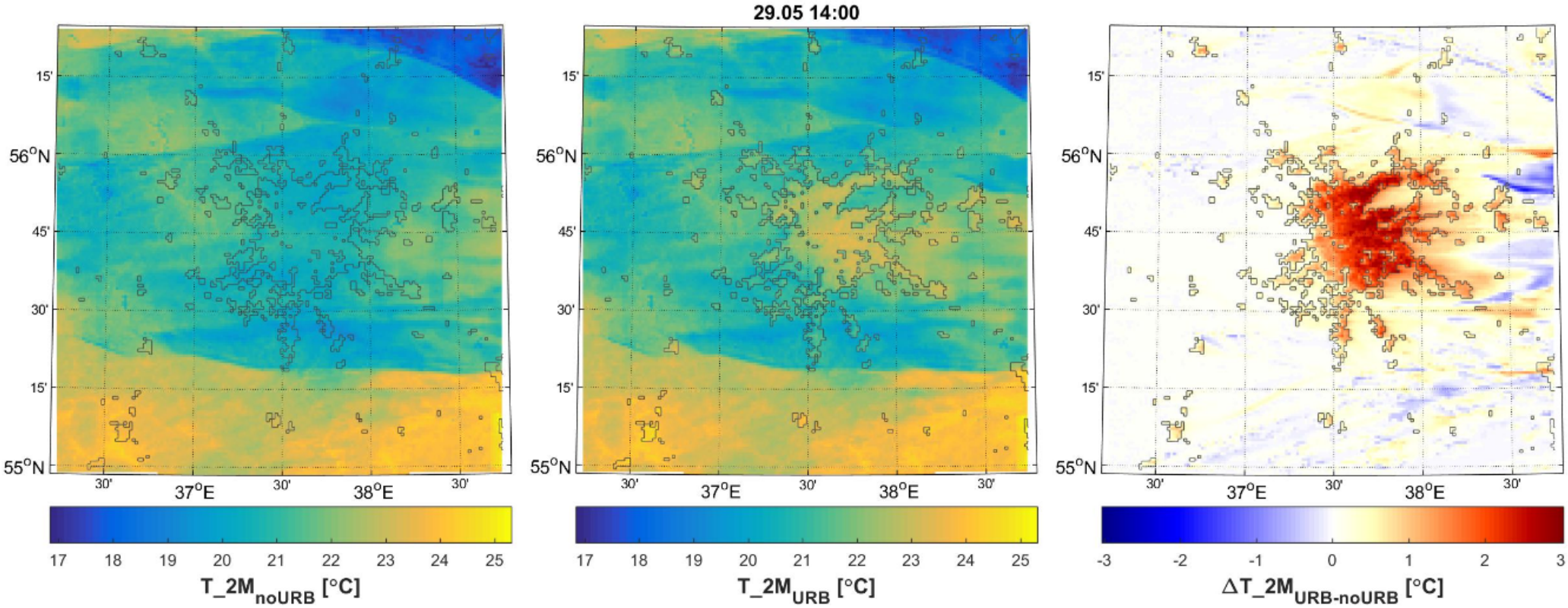
13 MSK

29.05.2017: simulations

Δx= 1 km

Δx= 500 km

ΔT2m



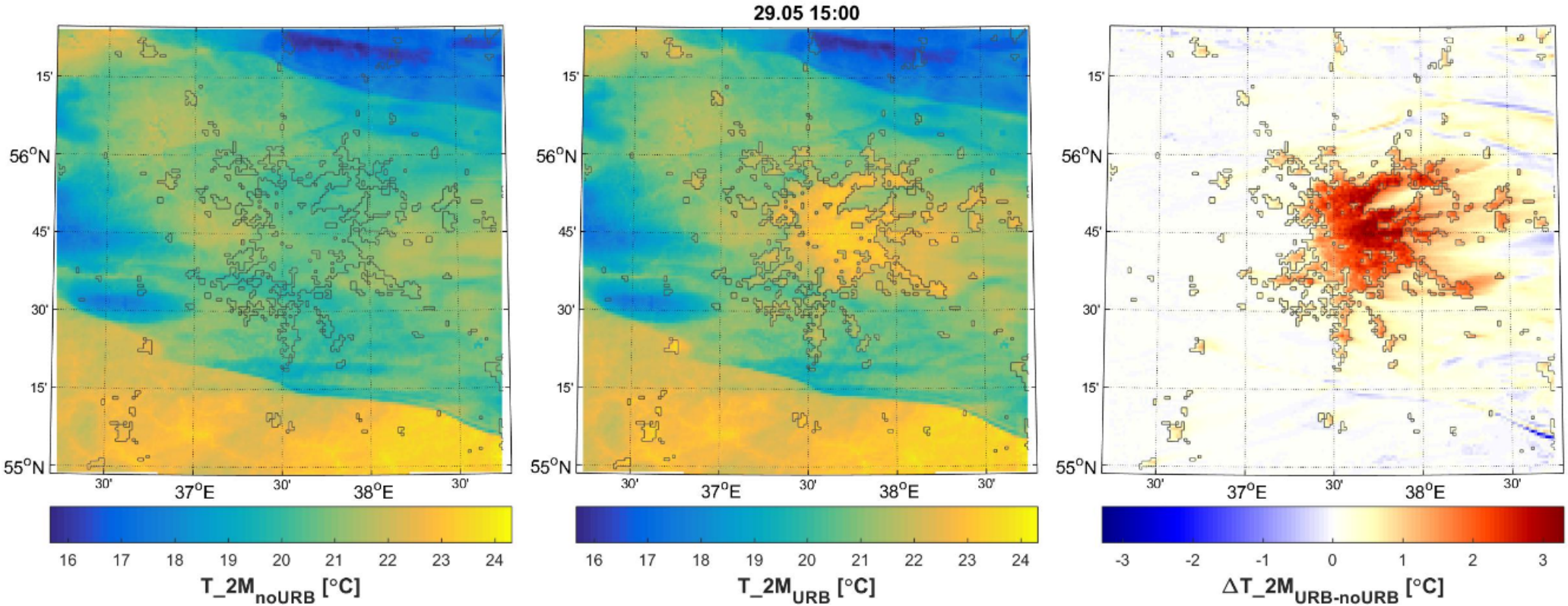
14 MSK

29.05.2017: simulations

Δx= 1 km

Δx= 500 km

ΔT2m



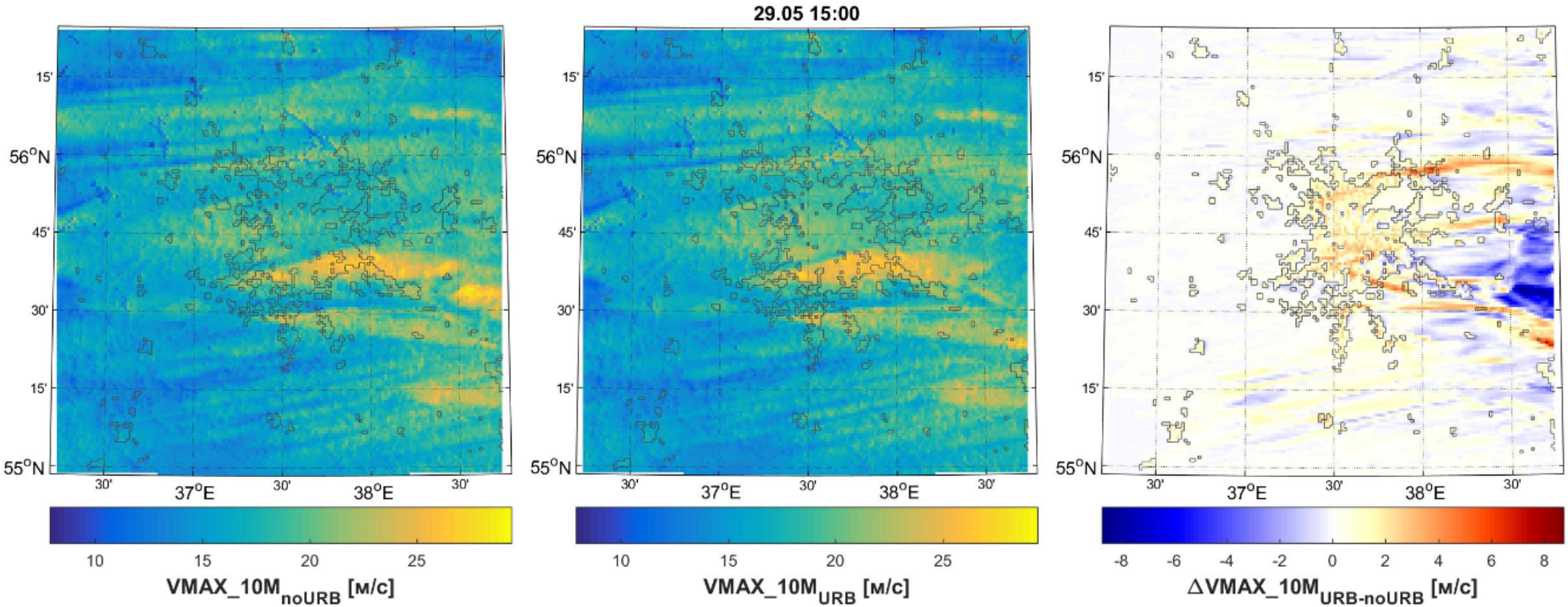
15 MSK

29.05.2017: simulations

Δx= 1 km

Δx= 500 km

ΔU2m



15 MSK

Component B – Lessons:

- There is the significant overestimation of urban fraction in Glob Cover (EXPAR) as well in Copernicus Global Land Cover.
- These data can be used as global first guess fields.
- These data could be efficiently improved using OpenStreet data for $\Delta X \equiv$ 1 km - 500 m and for future $\Delta X \leq$500 m using Sentinel-2 data.

- The reliable Land surface modelling tests can be obtained via long-term runs. The first variant for 1Year period database very short-term forecasts of ICON was obtained

		FMA	MJJ	ASO	NDJ	FMA	MJJ	ASO	NDj	FMA	MJJ	ASO	NDJ
C	technology		COSMO-RuM1 Regular runs		COSMO-RuM1: operational runs ICON_RuM1 experimental runs				ICON_RuM0.05: pre- operational runs Convective-scale EPS Pre- operational runs				
D	verification, case studies												

The Road-Map of MAM project

2018 2019 2020 2021

Component C:
Technological aspects

Component D:
Verification and Case studies

Focal point:

COSMO-Ru_ Urb operational runs

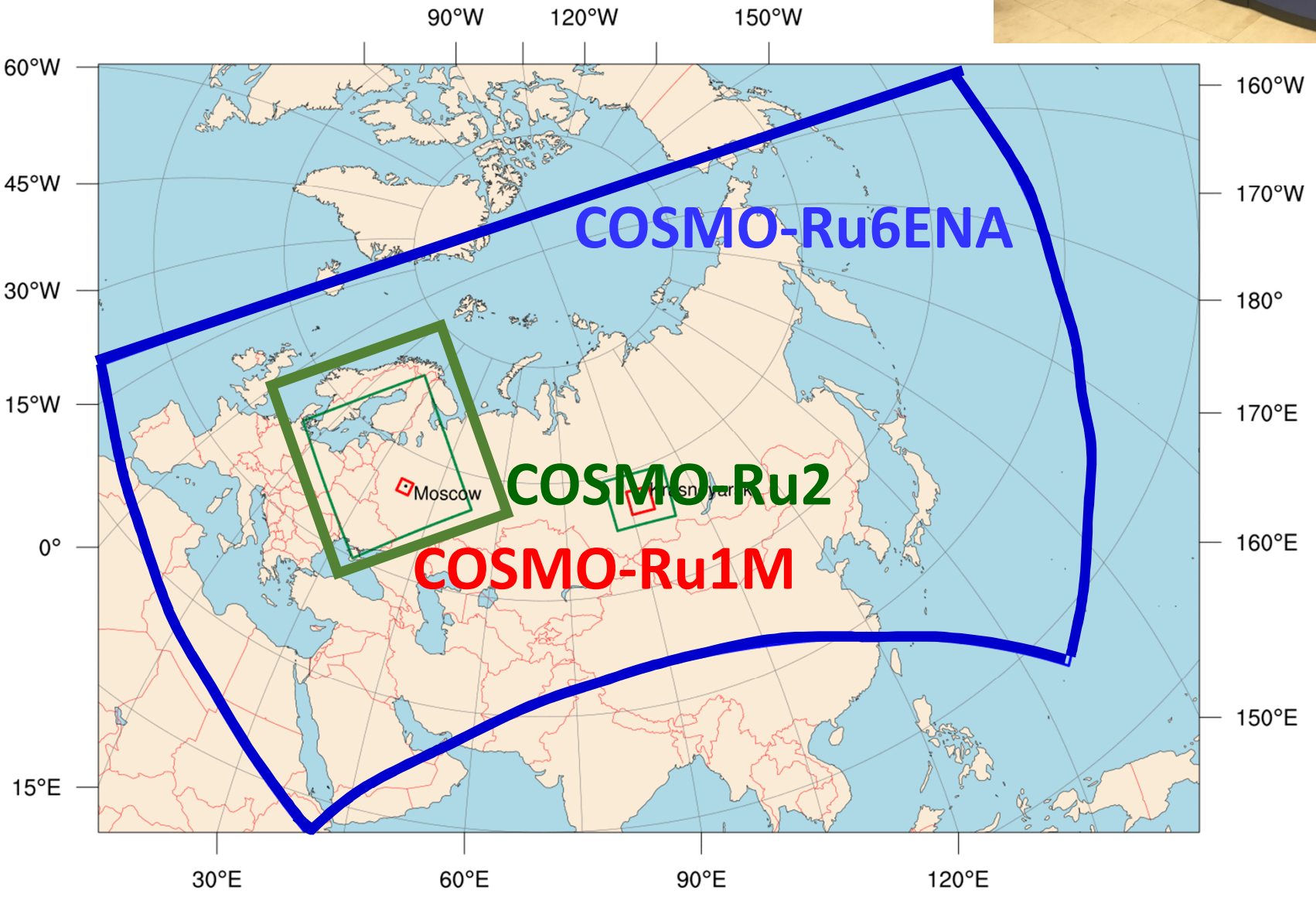
Planned beginning of operational runs:

grid-steps 1 km: 2020

500 m: 2021

300 m: 2022 (in progress)

Cray XC40:
NWP domains

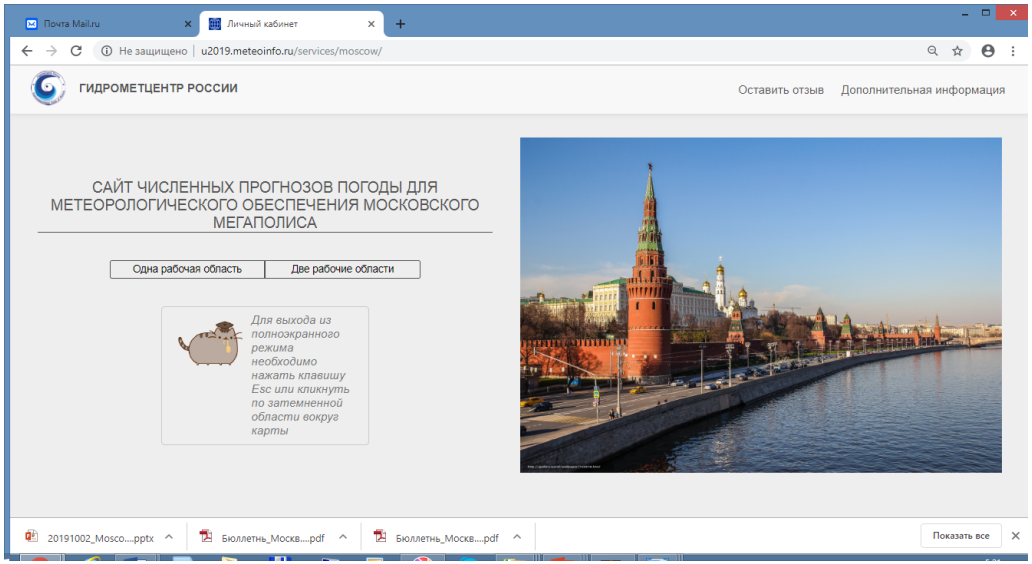


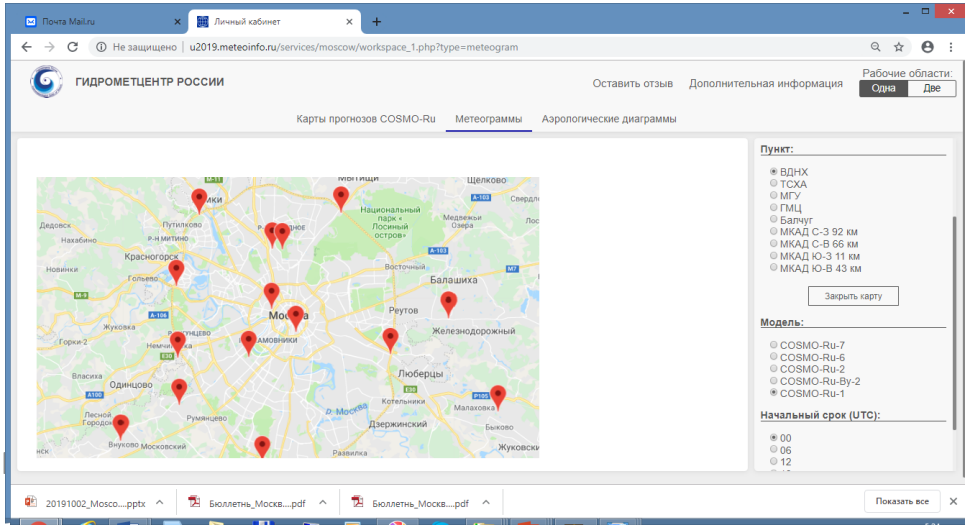
Operational activities

- Since 03.2019 COSMO-RuM1 runs daily,

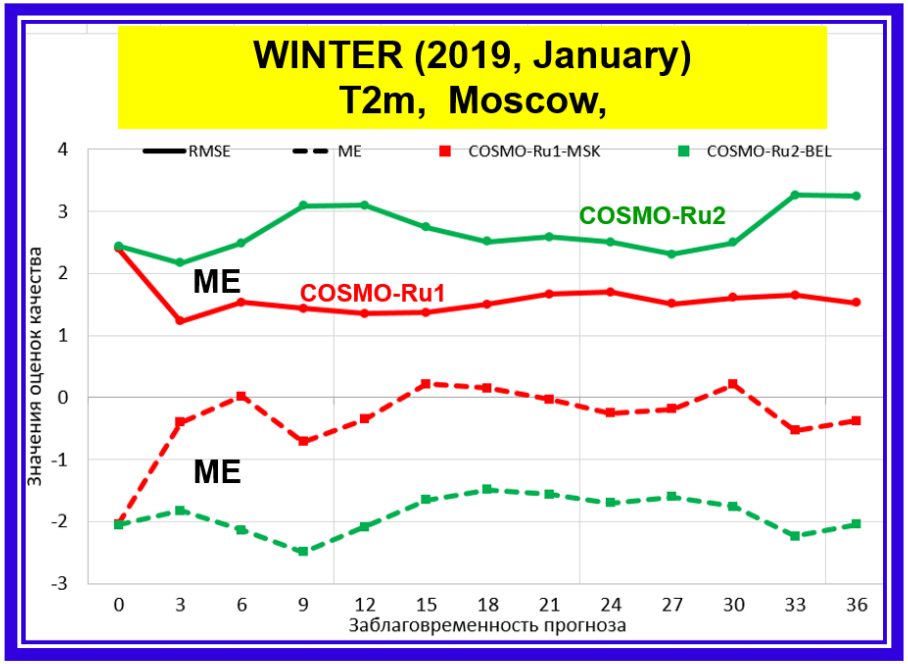
4 times a day, close to operational

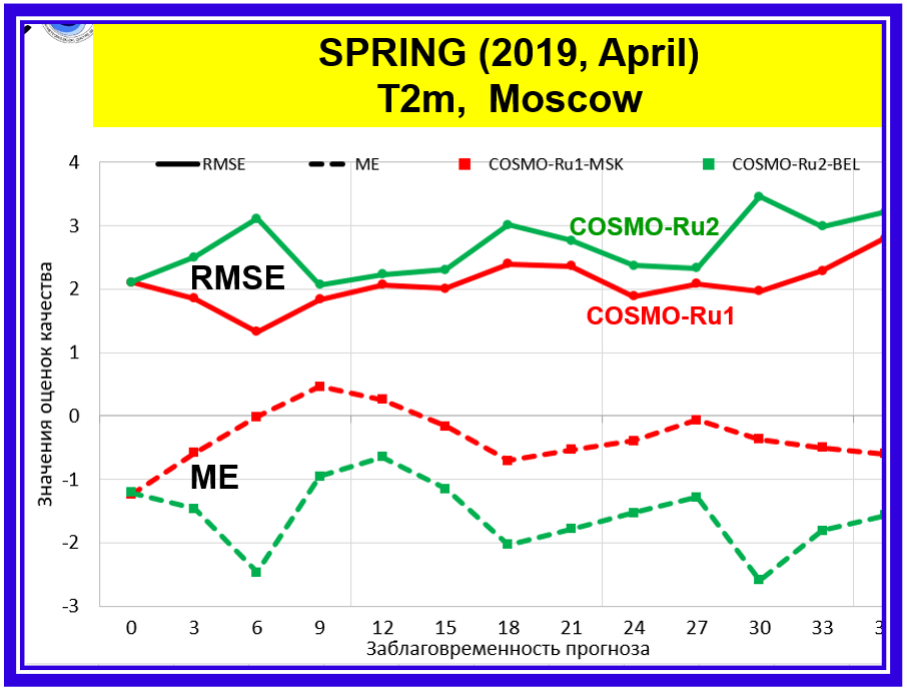
- Grafic products (meteograms, maps, aerological diagrams) are available via Web-site in combination with
- COSMO-Ru versions





Verification results





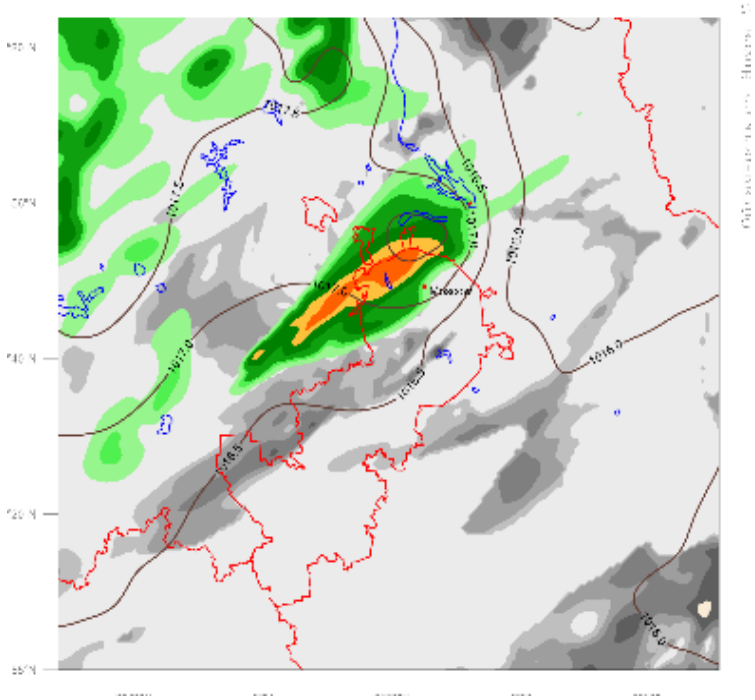
COSMO-Ru2 VS COSMO-Ru1M, T2m

- **The more efficient improving of T2m in the cold period**
- **Overestimation of wind speed.**

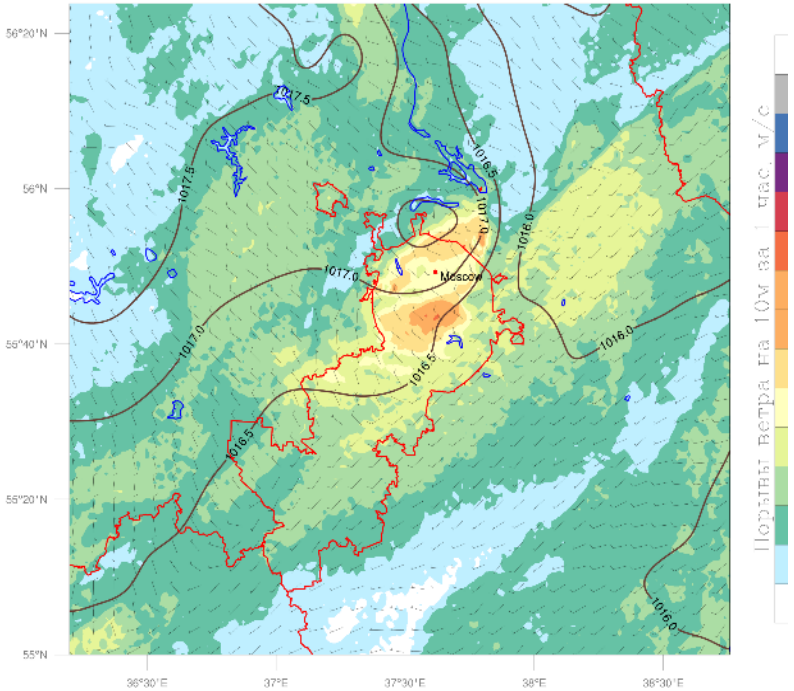
Case studies

Thunderstorms and heavy rains in Moscow 30 May 2019/ Simulations of COSMO-RuM1

Precipitation (Forecast, +27)



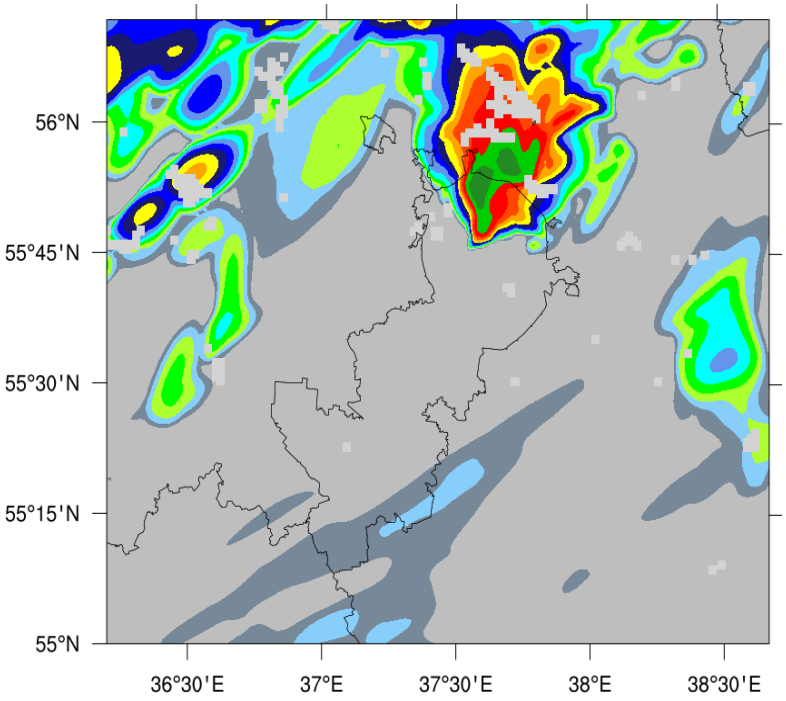
Wind 10 m (Forecast, +27)



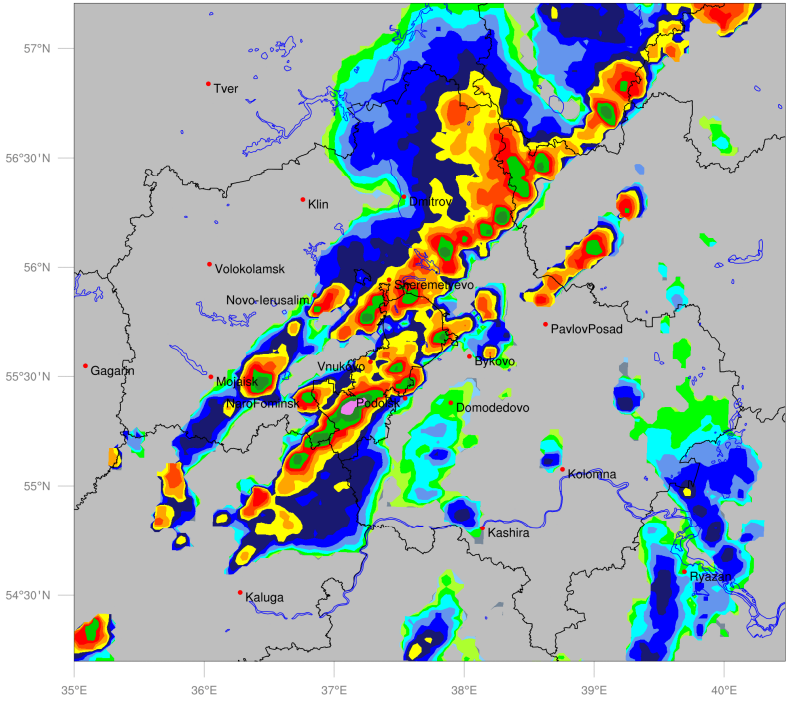
Case studies

Thunderstorms and heavy rains in Moscow 30 May 2019/ Simulations of COSMO-RuM1

Radar Reflectance (Forecast, +27)



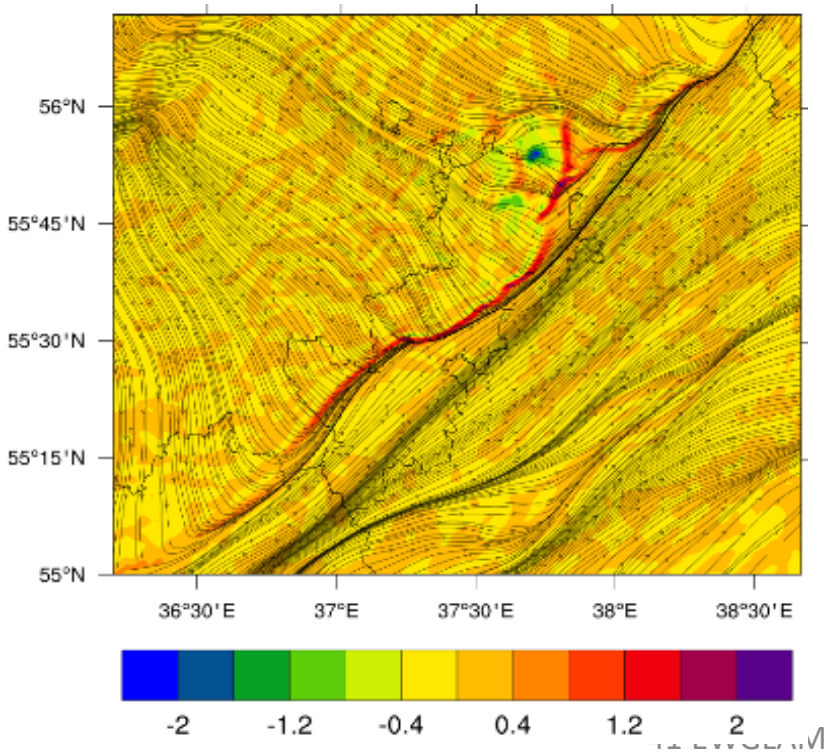
Radar Reflectance, fact



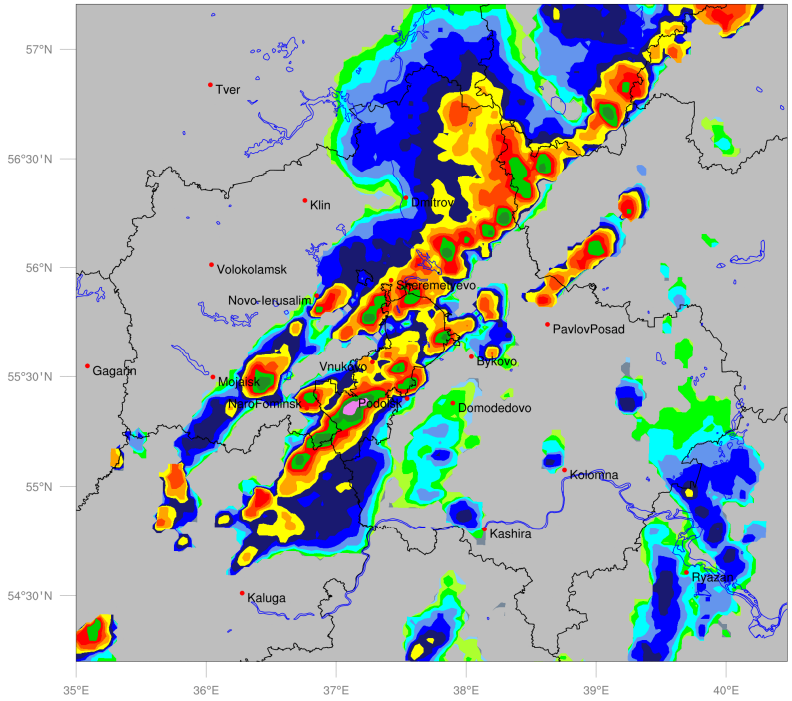
Case studies

Thunderstorms and heavy rains in Moscow 30 May 2019/ Simulations of COSMO-RuM1

Stream Lines (10m) (Forecast, +27)



Radar Reflectance, fact



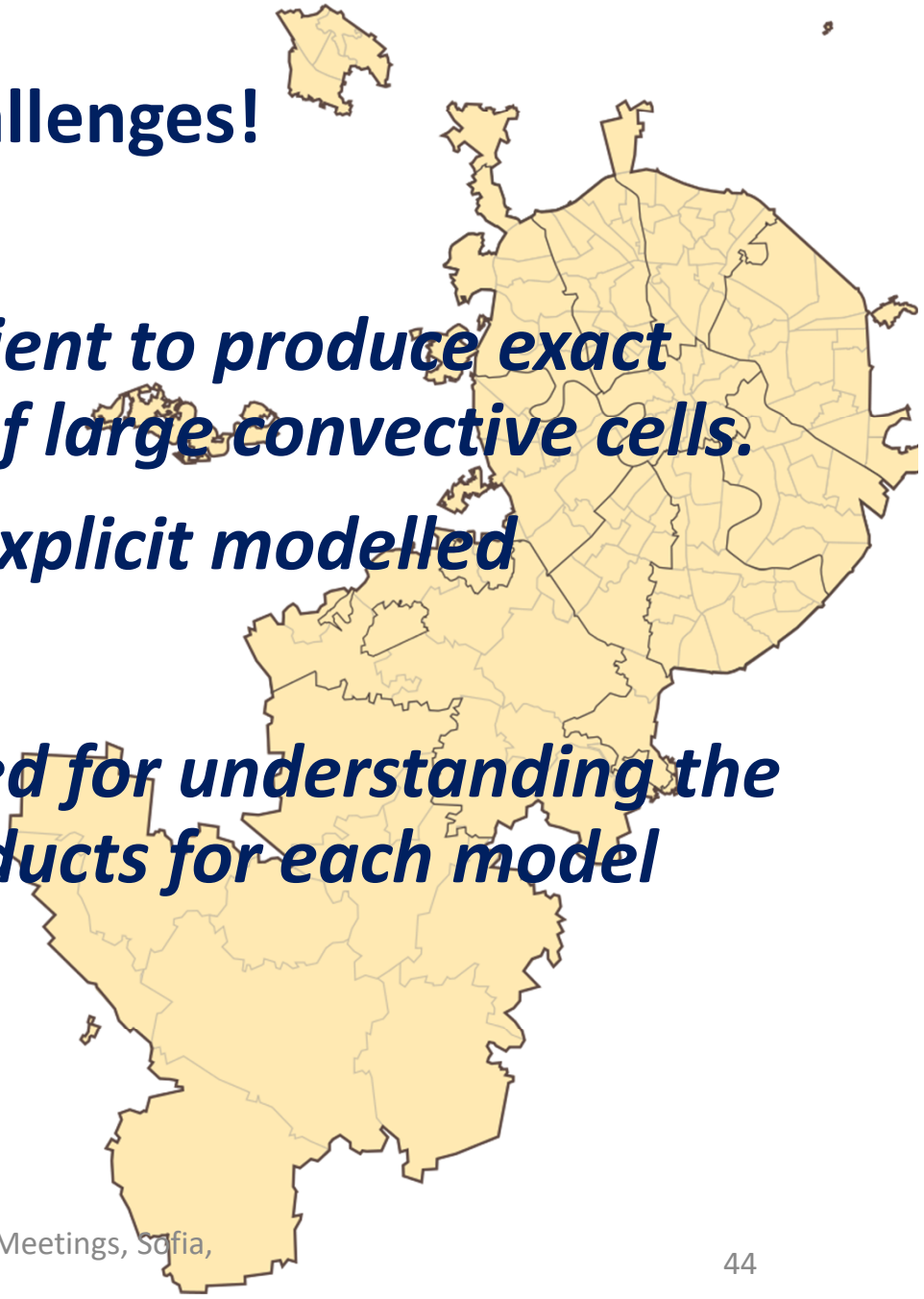
Component C & D – Lessons:

The success produces new challenges!

Grid step 1 km is not fully sufficient to produce exact dimensions, time and position of large convective cells.

Small convective cells can't be explicit modelled

The forecasters should be trained for understanding the limitations and features of products for each model resolution



Moscow megacity forecasting based on COSMO modelling

Thank you!