

## **COSMO Priority Project CITTA':**

# **City Induced Temperature change Through A'dvanced modelling**

### **Project Plan**

Final version, 16 Nov. 2020

**Project leader:** Jan-Peter Schulz (DWD)

**Project duration:** Jan. 2021 – Dec. 2023 (3 years)

### **Summary**

The aim of the COSMO Priority Project CITTA' is to transfer the achievements of the COSMO Priority Tasks AEVUS and AEVUS2 with respect to the urban surface parameterisation TERRA\_URB and its external parameters from the COSMO atmospheric model to the ICON(-LAM) model. The project will also include extensive experiments with the new package and further developments and applications of TERRA\_URB within ICON(-LAM).

### **Background and motivation**

The COSMO Priority Project CITTA' arises from the need that, due to the transition of the COSMO Consortium to the ICON model, the achievements of the COSMO Priority Tasks AEVUS and AEVUS2 with respect to the urban surface parameterisation TERRA\_URB have to be transferred as well. Within these Priority Tasks, TERRA\_URB was shown to be able to reproduce the key urban meteorological features for different European cities in the COSMO model.

Due to these positive evidences the current project is dedicated to implement TERRA\_URB in ICON-LAM, the limited-area version of the global ICON model for NWP applications. Furthermore, it is necessary to continue the activities already started in the previous Priority Tasks, such as the development and implementation of a method to avoid inconsistencies among the different data sets used to define the urban external parameters, and a sensitivity analysis regarding the parameters describing the urban geometry and the urban thermal and radiative properties. The latter are currently hard-coded in TERRA\_URB. Finally, a representation of vegetation in urban areas should be developed, and boundary layer clouds over urban areas should be studied in ICON-LAM-

ART including TERRA\_URB, both with the goal to further improve the performance of the urban surface parameterisation.

The COSMO Priority Project CITTA' will involve the entire team that has already successfully collaborated in the previous Priority Tasks and will expand on further skills. This will ensure a fast and efficient continuation of what has already been achieved. Therefore, in CITTA' we will have an experienced team which already has identified several problems related to the use of the urban surface parameterisation and its external parameters and has solved them or is working on it.

## **Description of individual tasks**

### **Task C Project coordination**

The COSMO Priority Project CITTA' coordinates activities aimed at the development of an urban module in ICON(-LAM). This includes the implementation of an urban surface parameterisation in the ICON code, the provision of improved and new urban external parameters from EXTPAR and extensive experiments with the new package. Furthermore, urban and rural in-situ observations need to be provided for an evaluation of the model. Therefore, a coordination task is activated, dealing with the organisation of virtual and physical meetings, writing of reports, and frequent e-mail exchange. A final report will be provided.

*Deliverables: Meetings, reports, Final Report.*

Involved scientists: Jan-Peter Schulz (DWD) 0.1 FTE/year, Paola Mercogliano (CMCC) 0.05 FTE/year

FTEs: 0.15 FTE/year (Jan. 2021 – Dec. 2023)

### **Task 1 Implementation of TERRA\_URB in ICON**

The urban surface parameterisation TERRA\_URB (Wouters et al. 2016, 2017) was originally implemented in COSMO-CLM (Rockel et al. 2008), the climate version of the COSMO atmospheric model (Doms et al. 2011, Baldauf et al. 2011). The purpose was to include urban effects in its land surface scheme TERRA (Schulz et al. 2016, Schulz and Vogel 2020). Within the framework of the COSMO Priority Tasks AEVUS and AEVUS2 (Bucchignani et al. 2019) during the last years, TERRA\_URB was ported to the recent COSMO NWP model version 5.05urb and successfully tested and evaluated against observations in various applications for different cities (see Bucchignani et al. 2019, Wouters et al. 2016, Varentsov et al. 2017, 2018, 2019, Rivin et al., 2020). The ability to reproduce the key urban meteorological features was shown.

In the framework of the transition of the COSMO Consortium to the ICON model TERRA\_URB needs to be implemented in ICON-LAM, the limited-area version of the global ICON model for NWP applications. The code will be implemented in the ICON NWP Development branch (icon\_nwp\_dev) in gitlab at DKRZ in Hamburg.

*Deliverables: TERRA\_URB in ICON(-LAM).*

Involved scientists: Jan-Peter Schulz (DWD) 0.4 FTE, Mikhail Varentsov (RHM) 0.1 FTE, Carmine De Lucia (CMCC) 0.1 FTE

FTEs: 0.6 FTE (Jan. 2021 – Dec. 2021)

## **Task 2 External parameters**

The land use related external parameters in the COSMO model are provided by EXTPAR as area-weighted averages over the land use classes. In the COSMO Priority Tasks AEVUS and AEVUS2 the GlobCover dataset was used for the land use classification. There are different issues concerning the external parameters when using TERRA\_URB in COSMO or ICON.

Before the TERRA\_URB parameterisation became available, a zero-order description of urban areas was used for COSMO and ICON based on land use data. Now, when the urban scheme is activated in COSMO (lterra\_urb=TRUE), a tile approach is utilized in which each cell is divided into two tiles, an urban tile and a rural (natural) tile. The urban tile is assumed to be completely paved and not vegetated, and its area fraction is defined according to the additional external parameter called Impervious Surface Area (ISA). ISA is not the same as the urban land use area fraction, and different spatial data sets are proposed as a data source for ISA. The urban scheme calculates the model variables for the urban tile, whereas the zero-order urban description provides the model variables for the natural tile. However, the current external parameters associated to the natural tile are those provided by EXTPAR and calculated by considering also the urban contribution. This is what we call the 'urban double-counting' effect, because urban is counted twice, once when adopting the urban scheme, and otherwise when referring to natural tile external parameters which take into account urban surfaces.

In order to avoid this 'urban double-counting' effect, a new dataset was constructed in which the affected external parameters (PLCOV\_MAX, PLCOV\_MIN, LAI\_MAX, LAI\_MIN, ROOTDP, Z0, FOR\_E, FOR\_D, RSMIN, EMIS\_RAD, SKC) were recalculated according to the functions implemented in EXTPAR but area-weighted excluding land use class 19 of GlobCover. This class represents urban areas (artificial surfaces). ARPAP and RUB developed R-script and Python scripts (available at <https://github.com/matthiasdemuzere/lcz-to-cclm>) which recalculate the external parameters to be associated to the natural tile for those cells in which the urban tile is greater than zero.

### **Subtask 2.1 Consistency of urban external parameters**

For TERRA\_URB in COSMO-CLM two urban external parameters were implemented in EXTPAR: The Impervious Surface Area (ISA = FR\_PAVED) and the Anthropogenic Heat Flux (AHF). Since in EXTPAR the urban area fraction (URBAN) represents the land use class 19 of GlobCover (urban areas) and the external parameters are calculated as area-weighted averages of the land use classes, some inconsistency can arise when ISA and URBAN are different. In TERRA\_URB the fraction of the urban tile is defined by ISA and it could happen, for example, that in a grid element ISA=0 and URBAN=1, which means

that the grid element in TERRA\_URB is 100% rural (ISA=0), but the associated external parameters are typically "urban" since they are calculated based on URBAN.

RUB, ARPAP and RHM will contribute to design and implement a method in order to avoid inconsistencies due to the differences between the URBAN and ISA fields. Furthermore, ARPAP and RUB will provide support in order to avoid the double-counting effect both in EXTPAR and in ICON.

*Deliverables: Consistent way to derive urban external parameters in EXTPAR.*

Involved scientists: Matthias Demuzere (RUB) 0.1 FTE, Valeria Garbero (ARPAP) 0.1 FTE, Mikhail Varentsov (RHM) 0.05 FTE, Carmela Apreda (CMCC) 0.05 FTE, Alfredo Reder (CMCC) 0.05 FTE

FTEs: 0.35 FTE (Jan. 2021 – Dec. 2021)

### **Subtask 2.2 New urban external parameters in EXTPAR for ICON-LAM**

Meanwhile, the raw EXTPAR datasets of ISA and AHF are outdated and should be replaced. RUB can contribute to update the new ISA and AHF fields into EXTPAR and make them available as options alongside the current datasets. This can be done in three ways:

- 1) Replacing the ISA and AHF global fields with more recent datasets such as those from Gong et al. (2020) and Dong et al. (2017), respectively.
- 2) Using Local Climate Zones (Stewart and Oke 2012) as a proxy for these urban canopy parameters.
- 3) Developing a unified approach to obtain the required parameters involving a GIS-based method based on vector-formatted cartographic data such as OpenStreetMap (Samsonov & Varentsov, 2020; Samsonov et al., 2015).

The Local Climate Zone approach (2) requires more work, as a global LCZ map is not yet available. Thus far, such a map is only available for Europe and the Continental United States (Demuzere et al. 2019, 2020a). Yet currently, Demuzere et al. (2020b) are developing a cloud-based LCZ generator tool, which will allow users to relatively easily create a LCZ map for their city of interest.

Furthermore, several internal parameters describing the urban geometry and the urban thermal and radiative properties, which were hardcoded in TERRA\_URB as global constants will be replaced by 2-dimensional fields from EXTPAR. A script (see github repository above) is already available that 1) converts the LCZ map into urban canopy parameters needed by TERRA\_URB (ISA, AHF, building area fraction, building height, street canyon height-to-width ratio, thermal conductivity, heat capacity, albedo and emissivity), and 2) resamples and ingests this information into the original domain file. This allows TERRA\_URB to use spatially explicit urban canopy information.

RUB will continue to 1) develop these tools, and support its integration into COSMO/ICON TERRA-URB, and 2) test its impact on the modelled thermal environment. First tests indicate that the use of Local Climate Zone information performs as good or even better for summer conditions compared to using best-available datasets sourced from OpenStreetMap, recent global land cover data and Sentinel satellite

images (Varentsov et al. 2020). ARPAP will carry out a survey using satellite data, OpenStreetMap, local cartographic data (such as shapefiles of buildings or information on building heights and street widths) and other sources (for instance ERA5-Land) to improve the characterisation of these new urban parameters for Turin.

RHM will continue the development of the unified approach (3) to obtain the input parameters for TERRA\_URB based on the vector-formatted cartographic data (e. g. from OpenStreetMap) together with other data sources, e. g. global data bases and satellite images. Due to the high labour and computational demand, this approach can not be applied to a global or even national scale, however it may provide detailed data for high-resolution limited-area studies and may be used as a reference in comparison to other approaches. Currently, this approach is proposed and tested for Moscow (Samsonov and Varentsov 2020), however it relies on data with global coverage and may be adopted for other regions.

*Deliverables: New urban external parameters in EXTPAR for ICON-LAM.*

Involved scientists: Matthias Demuzere (RUB) 0.8 FTE, Mikhail Varentsov (RHM) 0.2 FTE, Timofey Samsonov (RHM) 0.2 FTE, Valeria Garbero (ARPAP) 0.15 FTE, Massimo Milelli (ARPAP) 0.05 FTE, Francesca Bassani (PoliTo) 0.2 FTE, Jan-Peter Schulz (DWD) 0.3 FTE

FTEs: 1.9 FTE (Jan. 2021 – Dec. 2021)

### **Task 3 Numerical experiments**

The numerical experiments will be carried out in a coordinated way in the different model domains of the project partners involved.

#### **Subtask 3.1 Moscow**

Moscow, the largest Russian and European megacity, will serve as test bed for an intensive evaluation of the ICON-LAM model with the TERRA\_URB scheme, as it served for the same purpose with the COSMO model in the previous COSMO PTs AEVUS and AEVUS2 and other modelling studies with COSMO-CLM (Varentsov et al. 2017, 2018, 2019). Moscow has a population of about 17 million inhabitants (in the agglomeration) and covers an area of more than 1000 km<sup>2</sup>. The city is located within a flat and homogeneous landscape which simplifies the investigation of the urban-induced atmospheric phenomena. This turns Moscow into a prospective site for urban climate research and urban model verification. The city experiences an intense urban heat island and other urban-induced meteorological effects (Lokoshchenko 2017, Varentsov et al. 2018).

Simulations for Moscow will be conducted on the Cray-XC40 supercomputer at RHM and will include hindcast experiments for specific periods with lengths of a few weeks for different seasons as well as quasi-operational NWP runs within the framework of the COSMO-Ru system (Rivin et al. 2015, 2020). The model will be supplied by detailed city-descriptive external parameters, obtained by a comprehensive original approach that combines OpenStreetMap vector-formatted cartographic data, satellite images and

recent land cover products (Samsonov and Varentsov 2020). Such an approach is already developed for COSMO and will be adopted also to ICON. For the model evaluation and verification, a dense network of near-surface and boundary layer observations will be used, including data from dozens of urban and rural weather stations and microwave temperature profilers.

*Deliverables: Assessment of the new scheme in the Moscow mega-city domain.*

Involved scientists: Mikhail Varentsov (RHM), Denis Blinov (RHM), Vladimir Kopeykin (RHM), Gdaly Rivin (RHM)

FTEs: 1.0 FTE (Jan. 2022 – Dec. 2023)

### **Subtask 3.2 Turin**

Turin is the capital of Piedmont and its metropolitan area has a population of almost 1.5 million inhabitants, covering an area of about 600 km<sup>2</sup>. The city is located mainly over a plain (250 m a.s.l.), but it has a hilly part on the east side, and it is surrounded by the Alps on the western side. It experiences a significant urban heat island effect (see Milelli 2016) and it is very interesting to investigate and understand the role of its morphological structure in this phenomenon.

First, TERRA\_URB will be run in COSMO in order to test the urban external parameter datasets, described in the previous section and provided by different sources, and then to evaluate the optimal configuration of urban external parameters to import in ICON. Two different case studies will be selected, one in summer and the other one in autumn/winter, for a 2-week period in order to have more robust statistics. As soon as TERRA\_URB will be implemented in ICON, simulations will be conducted with ICON for the same case studies as COSMO and the evaluation of the urban scheme will be performed for both models.

The model evaluation and verification will be performed using a dense network of surface stations, three radiometers, satellite data, and possibly ERA5-Land reanalyses.

*Deliverables: Assessment of the new scheme in the Turin domain.*

Involved scientists: Valeria Garbero (ARPAP) 0.4 FTE, Massimo Milelli (ARPAP) 0.25 FTE, Francesca Bassani (PoliTo) 0.35 FTE

FTEs: 1.0 FTE (Jan. 2022 – Dec. 2023)

### **Subtask 3.3 Naples**

Naples is the capital of the Campania Region and Province of Naples. Covering an area of over 1000 km<sup>2</sup>, its densely populated metropolitan area of around 4 million people sprawls along the Mediterranean coast and up the surrounding mountains. Naples is the third largest city in Italy after Rome and Milan. The proximity of the city to the sea is a unique characteristic that deserves to be investigated specifically in this context.

Simulations adopting TERRA\_URB will be performed with the COSMO (currently operational) and ICON (currently pre-operational) models. Numerical simulations at very high resolution will be used in order to test the capabilities of the models (with TERRA\_URB) to reproduce the main features for the Naples urban heat island. The evaluation of the urban scheme will be performed for this domain taking into account the different meteorological observations available in the area, either in rural or urban context. Currently, nine in-situ stations are available, reporting different atmospheric variables at hourly resolution. Among them, three are located in the urban area. Additionally, the verification will be performed also using satellite data and Copernicus reanalysis.

*Deliverables: Assessment of the new scheme in the Naples domain.*

Involved scientists: Edoardo Bucchignani (CIRA), Paola Mercogliano (CMCC), Francesco Repola (CMCC), Alfredo Reder (CMCC), Carmela Aprea (CMCC)

FTEs: 1.0 FTE (Jan. 2022 – Dec. 2023)

### **Subtask 3.4 Bucharest**

Bucharest is proposed as a domain of interest due to the fact that it is the largest city in Romania and the sixth largest European capital city (per number of inhabitants who live in the city). The Bucharest urban area is slightly larger than the city itself and is classified as a Larger Urban Zone (LUZ), with a high population density.

Simulations for TERRA\_URB will be performed with the COSMO (currently operational) and ICON (currently pre-operational) models. Numerical simulations will be used in order to test the capabilities of the models (with TERRA\_URB) to reproduce the main features for the Bucharest urban heat island. The evaluation of the scheme will be performed for this domain taking into account meteorological observations available in the area.

For Bucharest, three meteorological stations are considered as being representative, one urban – Bucuresti Filaret (located in the city center), one peri-urban – Bucuresti Baneasa (towards the northern limit of the city) and one rural – Bucuresti Afumati (east of the city). These stations have continuous measurement datasets for the main meteorological parameters.

Selective cases of urban heat island episodes will be identified, in order to perform the numerical simulations. For these cases, apart from classical scores such as BIAS or RMSE that can generally be computed for all continuous variables, specific methods for the evaluation of simulated UHI intensity can be employed, such as an analysis of urban-periurban / urban-rural differences and temperature isotherms, percent frequencies of 1°C temperature differences and the normalization method proposed by Oke (1998).

*Deliverables: Assessment of the new scheme in the Bucharest domain.*

Involved scientists: Rodica Dumitrache (NMA), Amalia Iriza-Burca (NMA), Bogdan Maco (NMA)

FTEs: 1.0 FTE (Jan. 2022 – Dec. 2023)

## **Task 4 Further developments and applications of TERRA-URB**

Once the model is successfully implemented and tested, further scientific developments and applications of TERRA\_URB will be carried out.

### **Subtask 4.1 Improved representation of vegetated urban areas in TERRA\_URB**

The inconsistency between the parameters of the land use class for urban areas (urban fraction) and of the impervious area fraction is important not only for technical issues, but also from a physical point of view. As already noted, the urban tile in TERRA\_URB is assumed to be completely paved and not vegetated, while all vegetation is assumed to be within a natural tile. For the urban tile, semi-empirical corrections are applied for the thermal conductivity, heat capacity, albedo and emissivity in order to take into account the geometrical effects of a building-covered environment for the heat and radiation transfer. In reality, the building-covered environment includes also vegetated surfaces such as lawns, gardens, etc. Hence, there is an area fraction that should be considered as pervious and vegetated, but should still be affected by the geometrical effects of the building-covered environment. On the other hand, there are impervious surfaces outside the urban environment, such as roads and airfields.

Therefore, it is planned to modify the representation of the urban tile in TERRA\_URB allowing it to include a part of vegetated fraction, and to implement an additional tile for impervious area outside of the building-covered environment. The possibility to provide additional external parameters for a modified representation of urban/impervious areas will be investigated.

*Deliverables: Vegetated urban areas implemented in TERRA\_URB. Assessment of the impact of this new development in the Moscow domain.*

Involved scientists: Mikhail Varentsov (RHM) 1.0 FTE, Hendrik Wouters (VITO) 0.05 FTE  
FTEs: 1.05 FTE (Jan. 2022 – Dec. 2023)

### **Subtask 4.2 Boundary layer clouds over urban areas in ICON-LAM-ART**

The aim of this subtask is the spatiotemporal quantification of urban cloud patterns and properties as well as the analysis of their main influences using satellite observations and numerical modelling over European urban areas.

Clouds in the urban boundary layer are expected to interact with the urban climate by modulating and responding to the exchange of radiation, heat, and moisture within the boundary layer (Inoue and Kimura 2004, Oke et al. 2017), resulting in prominent spatial and temporal patterns of boundary layer clouds over or downwind of cities. These urban-induced cloud modifications can be identified by a contrasting spatial pattern compared to the rural area for specific cloud types, thermodynamic conditions and location as suggested by model- and satellite-based studies (Romanov 1999, Zhong et al. 2015). Depending on meteorological context, an enhancement of fair-weather cumulus clouds or a faster dissipation/delayed formation of fog, visible in so-called fog holes is encountered.



Although knowledge exists on the mechanisms of these two types of urban cloud modification, the complex interactions of large-scale dynamics, surface roughness, the urban heat island, aerosols and cloud processes in urban areas are difficult to untangle (Oke et al. 2017).

Based on measurements by the satellite sensor MODIS (MODerate Resolution Imaging Spectroradiometer) carried by the two polar-orbiting platforms Terra and Aqua, characteristics of clouds are retrieved about twice a day at a spatial resolution of 1 km (Level 2 data, Platnick et al. 2003). This spatial scale is relevant and appropriate for the analysis of patterns and interactions of urban cloud mechanisms with the urban land surface (Jin et al. 2005, Gautam and Singh 2018). The Spinning-Enhanced Visible and Infrared Imager (SEVIRI) onboard the geostationary Meteosat Second Generation (MSG) satellites complements MODIS by providing cloud properties in a 15-minutes repeat cycle at a spatial resolution of 3 km at nadir for the standard channels (1km, HRV, Schmetz et al. 2002). On the basis of this data spatial insights can be obtained into the formation of short-lived clouds over urban areas (Theeuwes et al. 2015), instantaneous changes of cloud structure and microphysics driven by mesoscale convective systems (Fuchs et al. 2017), as well as cloud dissipation processes.

In order to analyse urban effects on cloud modifications using ICON, initial boundary conditions for the formation of urban FWC and fog holes are specified (IFS and ICON data) based on meteorological conditions and locations, where changes of cloud property and cloud cover have been observed. The representation of the atmospheric state by ICON-LAM-ART (Rieger et al. 2015) and the urban-canopy land surface scheme TERRA\_URB (Wouters et al. 2017) is tested in limited urban areas of four different grid sizes (5 km, 2 km, 1 km, 500 m). Subsequently, multiple ICON-ART LAM simulations are performed by switching aerosol processes (ART module), dynamical and thermodynamic processes (ICON) and the urban canopy model TERRA\_URB on and off. In this way, the model response to each impact (relevance and spatial patterns) on cloud development can be determined by model differences of ART/noArt/Urb/noUrb simulations and sensitivity analyses.

The locations are chosen in order to cover a wide range of European climate, e. g., maritime vs. continental, and thus be representative for a wide range of situations:

Paris is one of the cities with the highest population densities (person/km<sup>2</sup>) within the first 10 km from the city centre among European cities (European Commission 2016). Paris is characterized by western European oceanic climate, surrounded by relatively flat terrain outside of the range of direct coastal influence. Here, temporal and spatial urban-induced changes in cloud cover can likely be observed using satellite data.

Istanbul is a highly populated city with maritime influence and located in a complex climate zone. Changes in cloud cover and cloud microphysics due to urban effects as the urban heat island effect and air pollution are expected (Rosenfeld 2000, Ünal et al. 2020).

The systematic quantification of patterns and drivers of urban cloud modification using MODIS and SEVIRI observations combined with ICON-ART numerical modelling is expected to improve the understanding boundary-layer cloud modifications in urban regions. Results will support the assessment of the new TERRA\_URB scheme in ICON-LAM-ART simulations.

*Deliverables: Assessment of the new scheme in ICON-LAM-ART.*

Involved scientist: Julia Fuchs (KIT)

FTEs: 1.0 FTE (Jan. 2022 – Dec. 2023)

## **Risks**

Some tasks are affected by the risk of a reduction of human resources, either because they are based on non-permanent personnel or because the research work can be delayed by operational needs. This risk may bring delays to the project, but not as serious as a cancelation of activities, because these activities are part of the plans of the respective COSMO Members.

## **Links with other projects or activities**

- COSMO WG3a: With respect to questions about the planetary boundary layer and the transfer scheme TURB\_TRAN.
- COSMO WG5: With respect to all activities concerning verification.
- COSMO PP C2I: With respect to the transition from COSMO to ICON.

## **Participants**

ARPAP: Arpa Piemonte

Valeria Garbero, Massimo Milelli

CIRA: Centro Italiano Ricerche Aerospaziali

Edoardo Bucchignani

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RUB: Ruhr University Bochum

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## Appendix 1: Task table

FTE-y 2021 (from Jan. to Dec. 2021): **3.0**

FTE-y 2022 (from Jan. to Dec. 2022): **3.17**

FTE-y 2023 (from Jan. to Dec. 2023): **3.18**

FTE-y total (from Jan. 2021 to Dec. 2023): **9.35**

Task	Sub task	Contributing scientist(s)	FTE-y Total	FTE-y 2021	FTE-y 2022	FTE-y 2023	Start	Deliverables	Date of delivery (*)	Prec eding tasks
<b>C total 0.45</b>		J.-P. Schulz P. Mercogliano	0.3 0.15	0.1 0.05	0.1 0.05	0.1 0.05	Jan. 2021	Meetings, Reports	perman ent	
<b>1 total 0.6</b>		J.-P. Schulz M. Varentsov C. De Lucia	0.4 0.1 0.1	0.4 0.1 0.1			Jan. 2021	Implementation of TERRA_URB in ICON	Dec. 2021	
<b>2 total 2.25</b>	2.1	M. Demuzere V. Garbero M. Varentsov C. Apreda A. Reder	0.1 0.1 0.05 0.05 0.05	0.1 0.1 0.05 0.05 0.05			Jan. 2021	Consistency of urban external parameters	Dec. 2021	
	2.2	M. Demuzere M. Varentsov T. Samsonov V. Garbero M. Milelli F. Bassani J.-P. Schulz	0.8 0.2 0.2 0.15 0.05 0.2 0.3	0.8 0.2 0.2 0.15 0.05 0.2 0.3			Jan. 2021	New urban external parameters in EXTPAR for ICON-LAM	Dec. 2021	
<b>3 total 4.0</b>	3.1	M. Varentsov D. Blinov V. Kopeykin G. Rivin	1.0		0.5	0.5	Jan. 2022	Moscow	Dec. 2023	1,2
	3.2	V. Garbero M. Milelli F. Bassani	0.4 0.25 0.35		0.1 0.05 0.35	0.3 0.2	Jan. 2022	Turin	Dec. 2023	1,2
	3.3	E. Bucchignani P. Mercogliano F. Repola A. Reder C. Apreda	1.0		0.5	0.5	Jan. 2022	Naples	Dec. 2023	1,2
	3.4	R. Dumitrache A. Iriza-Burca B. Maco	1.0		0.5	0.5	Jan. 2022	Bucharest	Dec. 2023	1,2
<b>4 total 2.05</b>	4.1	M. Varentsov H. Wouters	1.0 0.05		0.5 0.02	0.5 0.03	Jul. 2022	Improved representation of vegetated urban areas in TERRA_URB	Dec. 2023	1,2,3
	4.2	J. Fuchs	1.0		0.5	0.5	Jan. 2022	Boundary layer clouds over urban areas in ICON-LAM-ART	Dec. 2023	1,2,3