CONSORTIUM FOR SMALL SCALE MODELING

COSMO

COSMO Priority Task: Analysis and Evaluation of TERRA_URB Scheme (ÆVUS)

Version 1.57, 29/06/2017

Task Leader: Paola Mercogliano (CIRA)

Goal

Testing the implementation of the TERRA_URB scheme.

Motivation

The increase of built surfaces (with consequent reduction of natural surfaces) constitutes the main reason for the formation of Urban Heat Islands (UHIs). While natural soil with vegetation uses most of the absorbed radiation in evapotranspiration processes with release of water vapor cooling the surrounding air, paved terrains and buildings tend to absorb a lot of the incident radiation which is then released as heat. The presence of parks in the city has a beneficial effect because of horizontal air circulation due to the formation of temperature gradients. Instead, urban canyons block the release of the reflected radiation. The main contribution to the formation of UHIs is therefore the missing night-cooling of horizontal surfaces, together with cloudless sky and light winds. Of course, there is also a contribution from indoor heating (during winter), vehicles presence, waste heat from air conditioning and refrigeration systems (anthropogenic effects) but it has been found that they have a minor impact (Taha, 1997). For a more comprehensive analysis of the UHIs it is possible to read (among many others) the EPA report (2008) or Shahmohamadi et al., 2011.

The COSMO model, even at high resolution, is not able to cope with this effect (see Milelli, 2016), but when increasing the resolution, any NWP application needs to account for urban features. **In fact, it is crucial to better forecast temperature, moisture and precipitation in urban environments where many people live.** The modelling of urban environments and of the urban land surface has gained much attention in the last years, as multiple parameterizations for this land use type became available (Trusilova et al., 2015). The importance of the deployment of an urban module in COSMO model has been already recognized in the frame of the COLOBOC Priority Projects (Bettems, 2015); in fact the parameterization BEP (Building Effects Parametrization) was implemented in COSMO and tested over the city of Basel within the COSMO-2 configuration.

Recently, three urban parameterizations have been incorporated in COSMO for the standard land-surface module TERRA-ML: a DCEP - multilayer urban canopy model, TEB - single layer urban canopy model, and TERRA_URB - bulk parameterisation scheme with a prescribed anthropogenic heat flux. Anthropogenic heat emissions are included as an additional heat source to the first above-ground model layer. The urban canopy scheme DCEP coupled with COSMO-CLM has been evaluated extensively against data over Basel (Schubert and Grossman-Clarke, 2014), while TEB has been evaluated over Berlin (Trusilova et al. 2013). TERRA_URB offers an intrinsic representation of the urban physics with modifications of the input data, soil module and land atmospheric interactions (the details can be found in Wouters et al. (2015, 2016)). **TERRA_URB is computationally fast and is recommended for studies with spatial and temporal scales where the interactions between the urban canyon air and the atmosphere do not need to be resolved in detail**.

TERRA_URB (in the following named as TU) is currently implemented in a test-version of COSMO v5.1, which has been used in order to carry out the first preliminary tests. However, TU will be soon available in the official COSMO v5.6 version and so it will be possible to perform additional tests to confirm the promising results obtained up to now. **The aim of this PT is an evaluation and a deep verification of the performances of the code using more case studies, in order to decide if (and how) to improve the calibration of the namelist parameters, or the parameterisation itself.** Since the goal of the urban scheme is to catch small-scale features, only very-high resolution runs will be considered.

Being not possible to find an optimal configuration, able to provide good results for all the cities present in the model domain, the disposable parameters of the TU parameterization should be specified as 2D external-parameter fields. However, this is a significant task which cannot be accomplished in the frame of the present PT; **a follow-up PT will be defined later on, having the goal to provide better and additional worldwide urban datasets**. Simulations performed inside AEVUS will assume constant values for the disposable parameters.

Expected results

It is expected to include a stable, efficient and reliable urban scheme in the official COSMO model code, with well tested and documented impact of the scheme. This has a great importance in view of the expected increase of horizontal resolution in the operational configuration of the COSMO members; the improvement of the screen level parameters will have beneficial effects in the operational forecast where the heat island effect is present (usually large and populated cities).

A comprehensive and clear documentation will also be prepared for the whole community.

Description of Individual Sub-Tasks

SubTask0: debugging of the COSMO climate version

Currently, the only version of COSMO model that includes TERRA_URB is the climate one (COSMO5.0-CLM9), which is affected by some minor bugs. Considering that the release of the COSMO version to be used in this PT is not scheduled before September 2017, a debugging of COSMO-CLM+TERRA_URB will be performed in the frame of this sub-task, in order to speed up the release of the COSMO version and the startup of the activities of this PT. This version (COSMO5.0-CLM9+TERRA_URB2.2) has been evaluated thoroughly in former studies for different cities and urban meteorological parameters (Demuzere et al., 2017; Wouters et al., 2016; Wouters et al., 2015). Hence, this version can be used as a benchmark for the upcoming COSMO+TERRA_URB releases.

Deliverables

Short communication on the debugging activity performed

Participating scientists

E. Bucchignani (CIRA) 0.01 FTE, V. Garbero (ARPA Piemonte) 0.01, H-Wouters (KU Leuven) 0.03 FTE

SubTask1: selection of case studies

Concerning Italy, different regions will be considered: the urban area of Torino and of other cities where observations in urban and rural context will be available. The days will be selected in recent summer and winter periods (2015 and 2016).

Moscow (about 35 km diameter of urban landscapes) with 50-80 km surrounding rural region will be chosen as test domain for Russia. The test periods (1-2 weeks) will be selected for summer, winter and spring in 2016 and/or 2017. The days with big differences of observed T2m values between urban and rural observations and the days with poor quality of T2m operational COSMO-Ru forecasts for Moscow region will be included into analysis. The most important results are expected for this domain for different winter conditions (effects of anthropogenic heating in dependence on different air temperature) and for snow melting at spring (snow-free city with snow-covered surroundings).

Urban areas of Belgium, selecting summer and winter periods (from 2012 onwards) will also be considered, performing an extensive evaluation using “standard” scores, with urban climate observations (in terms of air temperature at 2 m and UHI for Antwerp and Ghent, and boundary-layer temperatures and UHI observed from 100m high mast towers), boundary-layer profiles and satellite imagery.

Deliverables

A document with a set of test cases whose length varies up to a week, with characteristics, which should be suitable to test the summer/winter urban effects for selected regions. Description of features of weather for selected test periods; datasets including observations. Evidences about estimates of control runs for selected test regions/periods.

Participating scientists

E. Bucchignani (CIRA) 0.005 FTE, P. Mercogliano (CIRA) 0.005 FTE, E. Oberto (ARPA Piemonte) 0.01 FTE, I. Rozinkina (RHM) 0.04 FTE, D. Blinov (RHM) 0.02 FTE, H. Wouters (KU Leuven) 0.01 FTE.

SubTask2: simulation setup and runs

After the installation of COSMO v5.6, a simulation setup must be provided. In particular, the reference configuration (ctrl) has to be decided, so the first comparison will be between ctrl (with TU scheme off) and ctrl-TU (with TU scheme on). Initial and boundary conditions are provided by the ECMWF IFS global model, at resolution of about 10 km. Then, it should be investigated the structure of the chain in case of very high-resolution runs (IFS→ COSMO1 or IFS→ COSMO2→ COSMO1), the use of data assimilation cycle (yes or not), the domain of COSMO-1 (compromise between CPU needs and lack of interference at the borders), tuning parameters, etc.

An alternative chain ICON → COSMO-Ru6.6→ COSMO2→ COSMO1 or ICON → COSMO-Ru6.6→ COSMO1 will be realized with use or not of assimilation cycle.

Deliverables

A complete set of namelists required for the simulations and the simulation output.

Participating scientists

E. Bucchignani (CIRA) 0.05 FTE, P. Mercogliano (CIRA) 0.05 FTE, V. Garbero (ARPA Piemonte) 0.1 FTE, G. Rivin (RHM) 0.05 FTE, D. Blinov (RHM) 0.02 FTE, H. Wouters (KU Leuven) 0.05 FTE.

SubTask3: calibration of the TERRA_URB scheme

The TERRA_URB scheme has two mandatory input fields, namely the Impervious Surface Area (ISA) and the annual-mean Anthropogenic Heat Flux (AHF), varying throughout the domain. The TERRA_URB scheme also uses the Semi-Empirical Urban Canopy parametrization (SURY) (Wouters et al, 2016) in order to calculate the additional bulk parameters needed. Therefore, SURY requires supplementary input urban parameter fields, which are currently set to default values and hard-coded. These parameters are:

- Surface albedo
- Surface heat conductivity
- Surface heat capacity
- Canyon height to width ratio
- Building height
- Roof fraction

Default values could not be suitable for the area under study, depending on the urban canopy properties. For this reason, it is necessary to investigate the model sensitivity performing a series of experiments, under the limitations described at the end of the motivation section.

Starting from the reference configuration (including all the default values), the parameter values for the urban canopy are changed according to the minimum (L) and maximum (H) values of their ranges, derived from the Local Climate Zones of compact "low-rise and mid-rise" (Stewart and Oke, 2012). A further sensitivity study can be performed on the Anthropogenic Heat Flux distribution. The reference distribution takes into account latitude-dependent seasonal and diurnal distribution functions (Flanner, 2009) that are superimposed on the annual-mean value. This last one is obtained from a global dataset (Flanner, 2009), which is generated from country-specific data of energy consumption from non-renewable sources. A possible sensitivity study can be performed by setting the Anthropogenic Heat Flux equal to 0 W/m2 (low scenario) or multiplying by 2 the reference values (high scenario).

Scenarios of experiments will be corrected depending on achieved results. A sensitivity for prescribed anthropogenic heat flux needs to be investigated, together with some proposals for algorithms for improving the dependence from thermal winter conditions (the cases of hard frost or thaw for same calendar period and same region must be different).

Moreover, other COSMO model parameters – not specifically related to TERRA_URB – seem to affect urban climate (UHI) modelling as well, and this seems to relate mostly to the stratification of the nocturnal boundary layer. So, these parameters need to be considered as well for finding the optimal model setup; they are listed in the TERRA_URB manual (Wouters et al., 2017 a) and some of their effects are reported in (Wouters et al., 2017 b).

Deliverables

A document with users' guidelines on the optimal setup of the parameters inside the scheme, the description of effects of sensitivity for different parameters, and some proposals for development of proposed algorithms.

Participating scientists

E. Bucchignani (CIRA) 0.2 FTE, V. Garbero (ARPA Piemonte) 0.01 FTE, M. Varentsov (RHM) 0.1 FTE, H. Wouters (KU Leuven) 0.06 FTE.

SubTask4: evaluation and verification of the case studies

The verification is the key point of the work. It is necessary to have a dense network of weather stations, to determine the performance of the model in its various flavours, both at the surface and in the atmosphere. The correct approach should be specified (which statistical index on which variable...). It would be also important to evaluate the behaviour of the heat fluxes, depending on the availability of the data. Moreover, some tests based profile measurements could be performed.

Deliverables

A reliable statistic on the behaviour of the model in its ctrl and TU configuration.

Participating scientists

E. Bucchignani (CIRA) 0.04 FTE, E. Oberto (ARPA Piemonte) 0.1 FTE, M. Varentsov (RHM) 0.05 FTE, A. Kirsanov (RHM) 0.05 FTE, H. Wouters (KU Leuven) 0.05 FTE.

SubTask5: writing of the final report

The results must be summarized in a document useful for all the scientists of the Consortium.

Deliverables

Results of the project in the form of a COSMO Technical Report, and/or paper, and/or COSMO Newsletter. Full documentation of TERRA_URB scheme in the COSMO web.

Participating scientists

P. Mercogliano (CIRA) 0.03 FTE, E. Oberto (ARPA Piemonte) 0.02 FTE, I. Rozinkina (RHM) 0.02 FTE, H. Wouters (KU Leuven) 0.01 FTE.

Advising and collaborations

J.M. Bettems (MeteoSwiss), U. Blahak (DWD), M. Milelli (ARPA Piemonte), P. Khain (IMS).

Gantt chart

	Time	**09/17**	**10/17**	**11/17**	**12/17**	**01/18**	**02/18**	**03/18**	**04/18**	**05/18**	**06/18**	**07/18**	**08/18**
Task													
0													
1													
2													
3													
4													
5													

FTE summary

	Institution	CIRA	ARPA Piemonte	RHM	KU Leuven
Task					
0		0.01	0,01	xxx	0,03
1		0.01	0.01	0.06	0.01
2		0.1	0.1	0.07	0.04
3		0.2	0.01	0.1	0.05
4		0.05	0.1	0.1	0.04
5		0.03	0.02	0.02	0.01
Total FTEs		0.4	0.25	0.35	0.18

Total of 1.00 FTE (COSMO) + 0.18 FTE (KU Leuven)

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