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New configuration of the climate model ALARO-CLIM/CZ

(Nová klimatická konfigurácia modelu ALARO-CLIM/CZ)

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Abstract: Once the integration of the regional climate model ALARO-CLIM/CZ covering the four main climate scenarios CMIP6 (Coupled Model Intercomparison Project, phase 6) for the period 2015–2100 gets completed, an improved version of this model shall be used to re-calculate them. The model domain and resolution remain the same. Innovations are about improvements in the model dynamics, microphysics and new surface scheme SURFEX. Key enhancements consist in the use of physiography database ECOCLIMAP II, 14-layer diffuse soil scheme describing transport of heat and moisture, 6-layer snow scheme, sub-grid description of bare, low and high vegetation patches, prognostic urban model and lake model. To improve consistency with global radiation calculations, prognostic aerosols and ozone will be imported from the global climate driving system, besides the use of prescribed greenhouse gases. Present work demonstrates added value of some of the new components of the ALARO-CLIM/CZ model.

Keywords: Regional climate model – surface scheme components – physiography – aerosols – numerical simulations

Abstrakt: Po dopočítaní štyroch hlavných klimatických scenárov CMIP6 (Coupled Model Intercomparison Project, fáza 6) pre obdobie rokov 2015–2100 regionálnym klimatickým modelom ALARO-CLIM/CZ bude nasledovať ich prepočet s vylepšenou verziou modelu. Doména a rozlíšenie ostávajú zachované, inovácie sa týkajú modelovej dynamiky, mikrofyziky a novej schémy povrchu SURFEX. Zásadným vylepšením je prechod na fyzicko-geografickú databázu ECOCLIMAP II, 14hladinová difúzna schéma pre šírenie tepla a vlhkosti v pôde, 6-hladinová schéma snehovej pokrývky, diferencovaný popis nízkej vegetácie, vysokej vegetácie a povrchov bez vegetácie v rámci výpočtovej bunky, použitie prognostického modelu mesta a jazier. Kvôli lepšej konzistencii s riadiacim globálnym systémom z neho budú okrem skleníkových plynov prevzaté aj prognostické aerosóly a ozón, vstupujúce do radiačnej schémy. Prezentácia demonštruje pridanú hodnotu niektorých nových elementov modelu ALARO-CLIM/CZ.

Kľúčová slova: Regionálny klimatický model – komponenty povrchovej schémy – fyzicko-geografický popis, aerosóly – numerické simulácie

Introduction

Back in 2021, we faced an urgent demand to have at disposal a high-resolution regional climate model covering the Central Europe and Czech Republic in particular. Therefore, we have based its first version on at that time the operational configuration of the ALADIN Numerical Weather Prediction (NWP) model in the Czech Hydrometeorological Institute. It was still rather close to the ALARO Canonical Model Configuration described in Termonia et al. 2018 and to the choices of Brožková et al. 2019.

We have adapted the NWP version to its climate counterpart with some minor changes, such as adding third and fourth layer to the soil scheme in order to better capture annual soil temperature cycle. On the other hand, starting from a well proven operational NWP model had also its advantages regarding skills to be expected. In addition, with the horizontal resolution of 2.3 km and non-hydrostatic dynamical kernel, we were ready to start numerical simulations of present and future climate at convection-permitting scales. Here we denote this first climate version of the model as ALARO-CLIM/CZ2.3-1.

A set of experiments was performed with this first climate version of the model, including priority scenarios treated by the CMIP6 (Coupled Model Intercomparison Project, Phase 6, https://wcrp-cmip.org/cmip-phases/cmip6/). These were the following Shared Socio-economic Pathways: SSP5-8.5, SSP2-4.5, SSP1-2.6 and currently computed SSP3-7.0, where the number after dash denotes associated Representative Concentration Pathway.

In parallel to the experimental works, we have designed an enhanced version of the model by incorporating novelties in atmospheric physics, in the surface model and by introducing better description of atmospheric aerosols and physiography descriptions. This new version is denoted as ALARO-CLIM/CZ2.3-2. We describe here briefly its innovative content regarding used data and methods.

Data

As said above, the new version of the climate model will use better and more detailed databases of physiography characteristics, namely over Europe. These have much higher resolution compared to those we used before (1 km versus 1 degree) and so they yield qualitatively improved conditions for modelling atmosphere and important surface processes. Soil and land cover data sources are summarised below in Tab. 1.

Table 1. New physical geography databases.

Soil type	HWSD version 2.01 (https://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/harmonized-world-soil-database-v20/en)
Land cover	ECOCLIMAP II (https://opensource.umr-cnrm.fr/projects/ecoclimap/wiki)

As an example of improved soil description, Fig. 1 shows percentage of sand over the computational domain according to older soil dataset (Giard and Bazile 2000), and according to newer HWSD (Harmonized World Soil Dataset) dataset version 2.01.

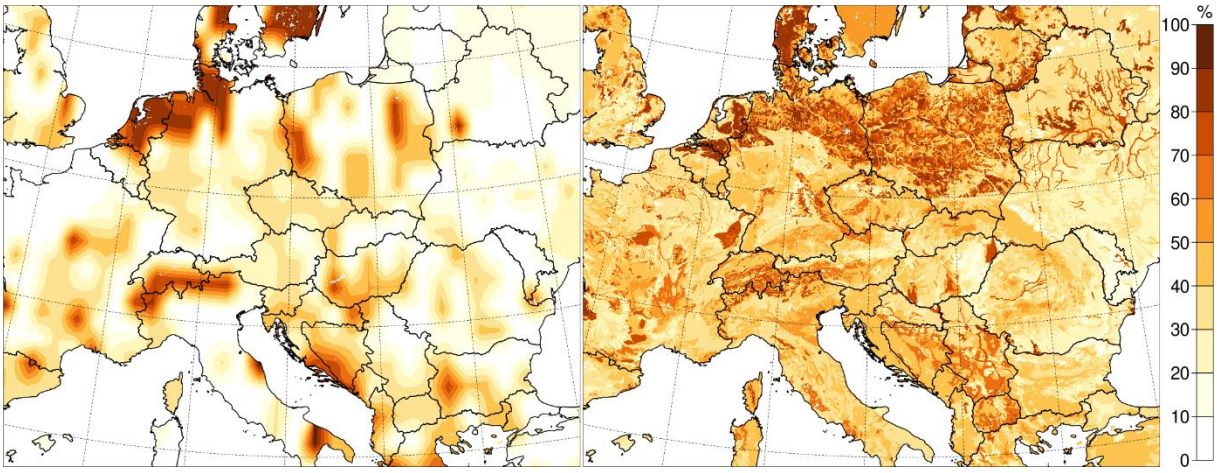


Fig. 1. Percentage of sand over the computational domain. Left: the previously used dataset; right: the higher resolution and more recent HWSD dataset.

Another improvement concerns atmospheric aerosols. For the present climate we shall replace previously used Tegen et al. 1997 aerosol climatology by the CAMS (Copernicus Atmosphere Monitoring Service) aerosols climatology. While Tegen data contain four basic tropospheric aerosols, CAMS provides eleven types, and in near real time (n.r.t.) three additional ones. In the stratosphere, Tegen has two types of aerosols of a volcanic origin, while in CAMS case stratospheric aerosols are represented by background values. Tab. 2 shows aerosol types of the Tegen and CAMS sources.

Table 2. Overview of aerosol types.

Aerosol type			Default scale height (km)	
Tegen	CAMS	abbreviation	Tegen	CAMS
1 land	ammonium sulfate	SU	1	4
	hydrophilic organic matter hydrophobic organic matter	OM1 OM2		2
2 sea	sea salt, three size bins	SS1, SS2, SS3	1	1
3 desert	desert dust, three size bins	DD1, DD2, DD3	3	3
4 soot (urban)	hydrophilic black carbon hydrophobic black carbon	BC1 BC2	1	1
	fine mode nitrate Coarse mode nitrate Fine mode ammonium sulfate	NI1 NI2 AM		3D n.r.t.
5 stratospheric sulfate ashes		optical properties of OM2	N/A	N/A
6 stratospheric volcanic sulfates		optical properties of SU	N/A	N/A

In case of future scenarios, we intend to take over aerosols and ozone concentration from the driving global Earth System Model.

Method

The new version of the climate model ALARO-CLIM/CZ2.3-2 deploys improved schemes of atmospheric physics and a new complex surface model.

Besides use of new aerosol CAMS dataset in the radiation scheme, there is an enhanced microphysics having graupel as another prognostic hydrometeor. This three-ice one-momentum type of scheme is described in detail by Němec et al., 2024. In addition, the evaporation/sublimation process of falling precipitation species is now parameterized following Lopez 2002.

The most important change represents the implementation of the surface model SURFEX. It enables to use more recent physiography datasets. At the same time, it offers more advanced and/or additional parameterizations of surface processes. For the new version of the climate model, we have made the following choices:

- Soil: for climate simulations we will use diffuse version of ISBA soil scheme (Boone et al. 2000) with 14 layers compared to the force-restore one with 4 layers. Heat and moisture transport in the soil will be better physically described;
- Surface radiation fluxes: there will be 2D parameterization of radiative effects of orography (Senkova et al. 2007) modifying surface radiative fluxes in presence of resolved and subgrid orographic slopes due to modified sky-view factor, self-shadowing, and inter-gridbox shadowing;
- Snowpack: we shall use snow scheme named ISBA-ES (Boone and Etchevers 2001) with 6 layers and with parameterization of glaciers;

- Sea: ECUME version 6 scheme (Roehrig et al. 2020) will be used to handle interactions of atmosphere with sea surface;
- Lakes and possibly rivers: prognostic lake model FLAKE (Mironov et al. 2010);
- Urban areas: we shall use TEB (Town Energy Balance; Masson 2000) model to capture exchanges of heat and moisture between atmosphere and street canyons, building walls and roofs. Fig. 2 shows the scheme of considered heat fluxes and prognostic temperatures of TEB;
- Non homogeneity of the grid-box surface: SURFEX allows to have up to four tiles within one grid-box: sea, nature, inner land water (lake or river), and town. Moreover, in case of the nature tile we intend to use three patches (bare soil, low vegetation, high vegetation) and in case of the town tile two patches (buildings, street canyons). Urban vegetation will be treated within the nature tile.

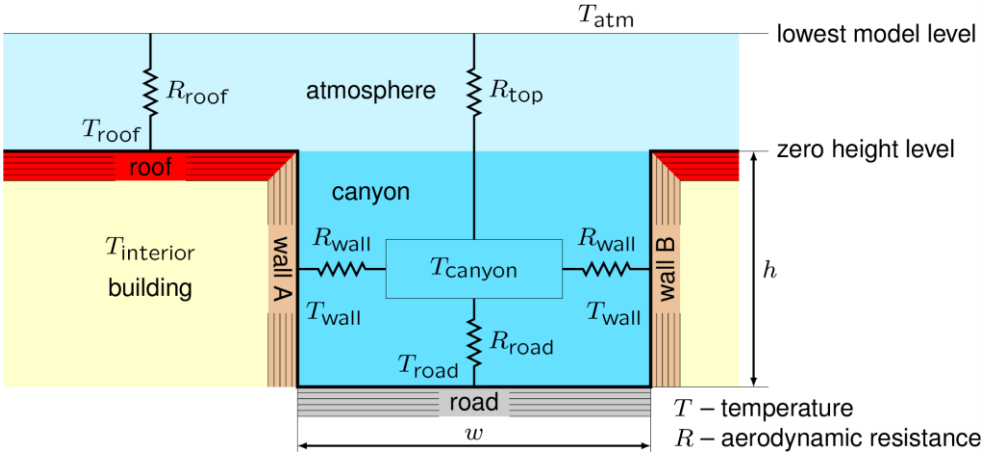


Fig. 2. Scheme of prognostic temperatures and heat exchanges considered in the urban model TEB, and its interface with the atmospheric model. Aspect ratio of street canyon, affecting the radiative fluxes, is h/w.

So far, we have tested individual SURFEX schemes in the mode of simple forecasts compared to the observations and/or compared at the level of individual processes via fluxes of momentum, heat and moisture. It is the preliminary validation step which allows to assess the basic functionality of individual schemes and their options, the potential added value of sophistications, to relieve possible shortcomings, e.g. in the numerical treatment, in the interface to the atmospheric model, and so on.

Fig. 3 shows an example of such a validation regarding the urban model TEB. Temperature forecasts are compared with respect to the observations of urban stations situated in the centre of Prague and of Vienna. Experiments using the urban model TEB capture better the warmer nights as registered by observations.

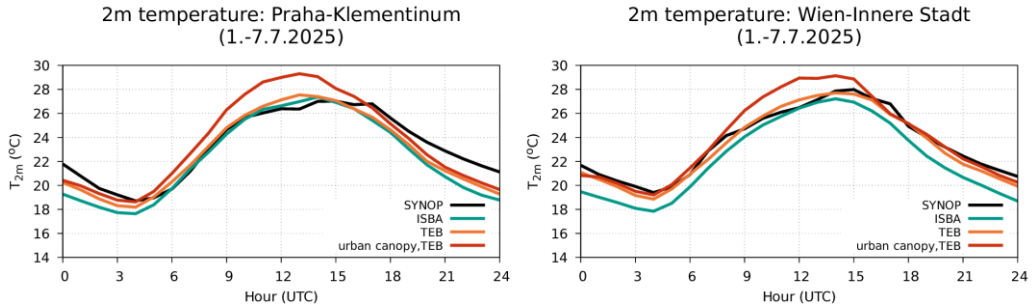


Fig. 3. Diurnal temperature evolution of forecasts using different settings of the model compared to SYNOP observations (black curve) of two urban stations: Prague-Klementinum (left), and Wien-Innere Stadt (right). The 72-hour forecasts started always at 00 UTC in the period from 1 to 7 July 2025. For each model settings the corresponding curve represents an average of individual days: ISBA with no use of TEB (green); TEB in a basic setup (orange); TEB in a more sophisticated setup with the urban canopy parameterization on top (red).

Discussion

We have presented here a selection of improved methods and data to create a new version of the regional climate model from ALADIN family. This selection was at first based on the overall NWP model improvement, like is the example of microphysics moving to the three ice prognostic species. One could argue that the implementation of the surface model SURFEX falls in the same spirit, which is true. On the other hand, SURFEX offers quite some sub-schemes and options inside them, going up to maybe too fine details. Therefore, we must be careful to stay with reasonable, robust choices of schemes to be deployed.

The example shown above is the use of the urban model TEB. General experiments show success of TEB to describe better the diurnal cycle of temperature. However, adding the urban canopy option leads to somewhat exaggerated heating during the daytime. Here we are not going to speculate about plausible causes which could be either in the canopy data or method. It is to demonstrate that a use of unverified sophistications might deteriorate the results.

Careful preliminary validations, such as skills in the numerical weather prediction mode, assessment of contribution of individual processes, or other parameterization targeted validations are important prior to long climate experiments. These experiments are expensive in both computational and storage resources and will follow only as another validation step.

Conclusion

A new version of convection-permitting regional climate model has been prepared by importing the improvements from its NWP counterpart in the model dynamics, atmospheric and surface physics, including a more recent, high-resolution physiography. Another set of improvements, specific for climate simulations, covers usage of prognostic aerosols and ozone from the driving Earth system model to ensure consistency between global and regional scenarios. Although the new model version ALARO-CLIM/CZ2.3-2 was not yet tested in the climate mode, results obtained so far show a good potential for improvement.

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