ACCORD flat-rate stay report
Testing ALARO model with SURFEX scheme
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1. **Introduction:**

The aim of this stay was to make sensitivity tests of ALARO model with different configurations of SURFEX scheme. For this purpose several configurations were prepared, altering number of nature patches, snow and urban schemes. The tests were conducted with SURFEX version 8.0+. The simulations of ALARO+SURFEX were done on CHMI supercomputer using local branch CY46t1mp_op3sfx which includes SURFEX-related modifications provided by Ján Mašek. The tests were done for 3-day summer and winter periods.

2. **Test of SURFEX scheme in winter period**

The study of the new model configurations was done over period between 12th and 15th January 2021. During these days snowfall occurred in Czech Republic. In Praha-Libuš, the snow water equivalent during the analyzed period increased from 9.2 to 11.5 kg/m^2. In mountain station Churáňov the snow cover was already present, during the studied period, the amount of snow water equivalent increased from 47.3 to 54.5 kg/m^2.
For winter period, the four configurations of ALARO+SURFEX scheme were prepared.
The studies included the influence of the following elements on the numerical forecast:

- Impact of heat coefficient CH taken from Building Energy Module (BEM)
- Different snow scheme (EBA and D95)
- Different number of patches (one and three).

The reference configuration was ALARO model with ISBA surface scheme (denoted ALARO+ISBA; not described in this report). Below are presented four SURFEX configurations. The first configuration is recommended one, prepared in coordination with SURFEX team. **Differences with respect to the recommended configuration** of ALARO+SURFEX (Conf 1) **are marked in bold.**

Conf 1:

Recommended configuration of ALARO with SURFEX:

- Number of patches: 3 (defined in PGD step)
- Town scheme: TEB (defined in PGD step)
- CH from Building Energy Module DOE-2 (defined in the integration namelist)
- Snow scheme: D95 (defined in fullpos PREP step)

Conf 2:

- Number of patches: 3
- Town scheme: TEB
- **CH from Building Energy Module DOE-2: NO**
- Snow scheme: D95

Conf 3:

- Number of patches: 3
- Town scheme: TEB
- CH fromBuilding Energy Module DOE-2
- **Snow scheme: EBA**

Conf 4:

- **Number of patches: 1**
- Town scheme: TEB
- CH from Building Energy Module DOE-2
- Snow scheme: D95

Figure 1 presents time course of air 2m temperature for mountain station (Churáňov) and suburban (Praha-Libuš). The tests have shown that impact of heat coefficient CH from Building Energy Module in winter period is insignificant.

The biggest differences between experiments are visible for experiments with different snow schemes (D95 and EBA). The EBA scheme, which is used in operational configuration of ALARO model, is a simple snow scheme which has some limitations (e.g. the surface temperature won't exceed 0°C until the all snow in the gridbox melts). The better results were obtained for the scheme D95, which is visible on time course of air temperature for station Praha-Libuš.

The forecast of ALARO+SURFEX with 1 and 3 patches using the same snow scheme (D95) are comparable, the biggest differences in predicted air temperature occurred between 66 and 72 hours of the forecast which can be related to the differences in the predicted cloudiness.

This single forecast aimed to verify if the ALARO model with the new surface scheme works correctly, the further step will be tuning the model and testing over longer time period.

a) b)

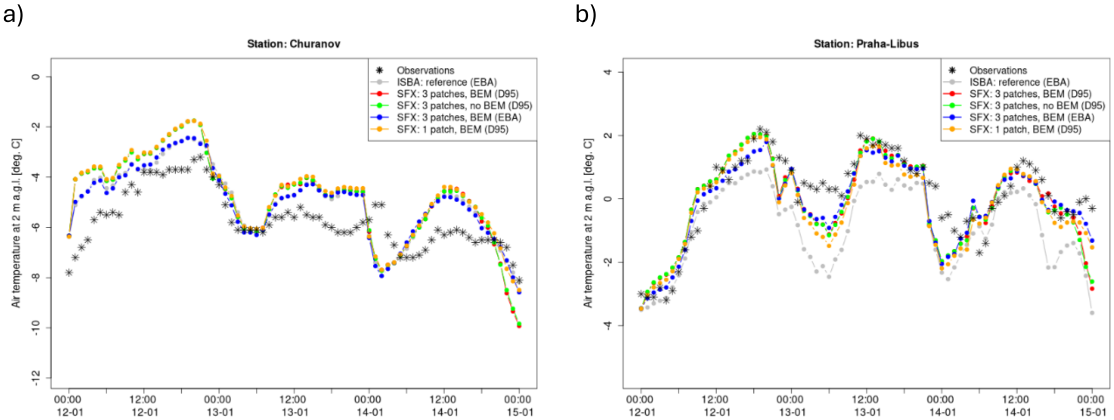


Fig. 1. Predicted air 2m temperature for a) mountain station Churáňov and b) city station Praha-Libuš during the period 12th and 15th January 2021 for model ALARO+ISBA (operational configuration) and four different configurations of ALARO+SURFEX.

3. Test of SURFEX scheme in summer

The next experiment was focused on representation of Urban Heat Island (UHI) on example of Prague. For this purpose, several configurations have been prepared.

Conf. 1:

Recommended configuration of ALARO with SURFEX:

- Number of patches: 3 (defined in PGD definition)
- Town scheme: TEB (defined in PGD definition)
- CH from Building Energy Module DOE-2 (defined in integration namelist)
- Snow scheme: D95 (defined in fullpos PREP generation)

Conf 2:

Based on the default configuration of ALARO with SURFEX (conf 1).

- Number of patches: 3
- Town scheme: TEB
- **CH from Building Energy Module DOE-2: No**
- Snow scheme: D95

Conf 4:

Based on the default configuration of ALARO with SURFEX (conf 1).

- **Number of patches: 1**
- Town scheme: TEB
- CH from Building Energy Module DOE-2
- Snow scheme: D95

Conf 4:

Based on the default configuration of ALARO with SURFEX (conf 1).

- Number of patches: 3
- Town scheme: **No**, **town fraction replaced with rock** (done in PGD step)
- **CH from Building Energy Module DOE-2: No**
- Snow scheme**:** D95

To switch off ***TEB scheme*** in SURFEX, the town fraction (field SFX.FRAC_TOWN in PGD.sxf file) must be equal to 0 in the PGD file. This requires two changes in the namelist **OPTION.nam**.

```
&NAM_PGD_ARRANGE_COVER
  LTOWN_TO_ROCK=.T., ! Replace town fraction with rock in nature tile
/
&NAM_PGD_SCHEMES
  CTOWN='NONE',
/
```

Comparison of predicted air temperature in summer season for urban and suburban station in Prague is presented in Figure 2. Comparison of ALARO+ISBA and ALARO+SURFEX without TEB scheme has shown that results are almost identical.
The time course analysis for Praha-Karlov (Figure 2b) indicates that the initial air temperature in urban areas differs between SURFEX simulations with and without the TEB model, which is given by different SURFEX initialization over nature and over town.

a) b)

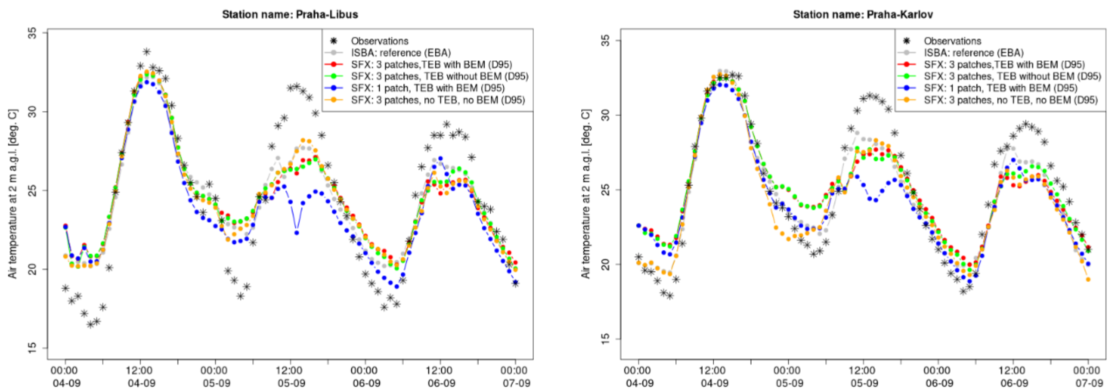
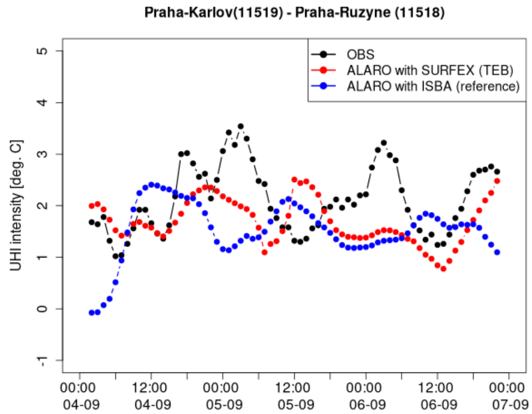


Fig. 2. Time course of air 2m temperature for the period between 4th and 7th September 2024 for station a) suburb station Praha-Libuš and b) city station Praha-Karlov. On the plot are presented results from four tested configurations of ALARO+SURFEX.

To analyze the impact of urban structures on air 2m temperature, the temperature difference between city center and suburban stations was examined. Figure 3 presents both the predicted and observed Urban Heat Island intensity, calculated for two station pairs. The operational configuration of the ALARO+ISBA scheme was used as the reference, while the tested configuration corresponds to the recommended setup of the ALARO+SURFEX (Conf 1 described in Chapter 2).
The observed UHI patterns differ significantly from the numerical predictions produced by both model configurations (ALARO+ISBA and ALARO+SURFEX). After the stay, the following findings were made:

1. It is recommended to use Praha-Karolinum as urban station and height-corrected Praha-Ruzyně (alternatively Dobřichovice) as rural station.
2. For a meaningful evaluation of UHI, it is necessary to have more days (at least one week), and to average temperature according to the time of day.
3. Model UHI intensity is contaminated by error at rural station, which can be considerable. Therefore, in addition to 2m temperature difference between urban and rural station, it is important to inspect also the temperature error at urban station alone, which gives indications about TEB weaknesses.



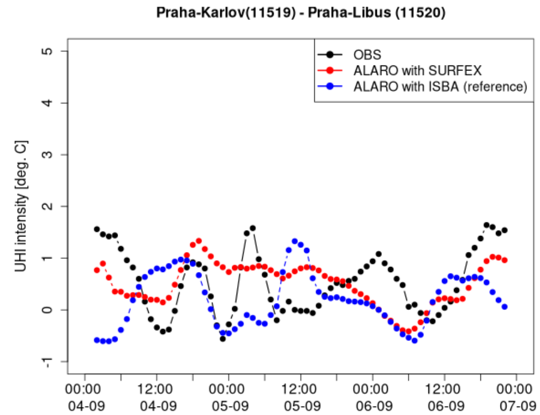


Fig.3 UHI intensity during the period between 4th and 7th September 2024 between stations a) Praha-Karlov and Praha-Ruzyně and b) Praha-Karlov and Praha-Libuš. Station Praha-Karlov is located in the city center, while Praha-Ruzyně and Praha-Libuš are located in the suburbs. Presented data are smoothed using moving average with 5 points.

4. Test of SURFEX scheme in summer – tuning of building properties

The further tests of the TEB scheme in summer period focused on thermal conductivity and heat capacity of building walls and roofs.

By default, building properties in PGD step are taken from ECOCLIMAP database. Alternatively, the user can define their own values of thermal conductivity (TC), heat capacity (HC), number of layers and their thicknesses.

In the TEB configuration, the default number of layers is equal to 5. In the routine **default_data_cover.F90** values of TC and HC are defined for three input layers, and PGD step interpolates them to target layers. If the user wants to change properties of some input layers, he must define them for a complete set of input layers in the PGD namelist block &NAM_DATA_TEB. In our experiments we have multiplied TC and/or HC of wall and roof for the first two layers by a factor of 2 (note that layers are indexed from outside to building interior). The depths of the wall and roof layers were not changed.

Below are presented default values for roofs and walls.
Those variables can be defined in the PGD namelist (file **OPTIONS.nam**).

```
&NAM_DATA_TEB
 NPAR_ROOF_LAYER = 3,
 NPAR_WALL_LAYER = 3,
 XUNIF_TC_ROOF(1:3)=1.5100,1.5100,0.05,
 XUNIF_TC_WALL(1:3)=0.9338,0.9338,0.05
 XUNIF_D_ROOF(1:3)=0.050,0.400,0.100
```

XUNIF_D_WALL(1:3)=0.020,0.125,0.050
XUNIF_HC_ROOF(1:3)= 2.11E+06,0.28E+06,0.29E+06
XUNIF_HC_WALL(1:3)= 1.55E+06,1.55E+06,0.29E+06
/

Below are presented 4 configurations:
Conf 1:
XUNIF_TC_ROOF(1:3)=**3.0,3.0**,0.05,
XUNIF_TC_WALL(1:3)=**2.0,2.0**,0.05

Conf 2:
XUNIF_HC_ROOF(1:3)= **4.22E+06**,0.28E+06,0.29E+06
XUNIF_HC_WALL(1:3)= **3.10E+06**,1.55E+06,0.29E+06

Conf 3:
XUNIF_TC_ROOF(1:3)=**3.0,3.0**,0.05,
XUNIF_TC_WALL(1:3)=**2.0,2.0**,0.05
XUNIF_HC_ROOF(1:3)= **4.22E+06**,0.28E+06,0.29E+06
XUNIF_HC_WALL(1:3)= **3.10E+06**,1.55E+06,0.29E+06

Conf 4:
XUNIF_TC_ROOF(1:3)=**3.0,3.0**,0.05,
XUNIF_TC_WALL(1:3)=**2.0,2.0**,0.05
XUNIF_HC_ROOF(1:3)= **4.22E+06**,0.28E+06,0.29E+06
XUNIF_HC_WALL(1:3)= **3.10E+06**,1.55E+06,0.29E+06

For the experiments from 1 to 3 the heat coefficient CH from Building Energy Module DOE-2 was activated, while for the fourth configuration an older default formulation was used. For this experiment the refence was recommended configuration of ALARO+SURFEX (see Chapter 2). The Figure 4 presents differences of 2m air temperature between four tested configurations and reference one.

The analysis of the results presented on figure below has shown that the biggest impact on model results was observed with increased heat capacity of the first layer for roofs and walls. During the daytime, the air 2m temperature was lower by 0.5°C, while in the nighttime it was warmer by up to 0.5°C (the first day of the simulation). The differences between tested configurations and reference model in the next two days are affected by cloudiness predicted over the Prague.

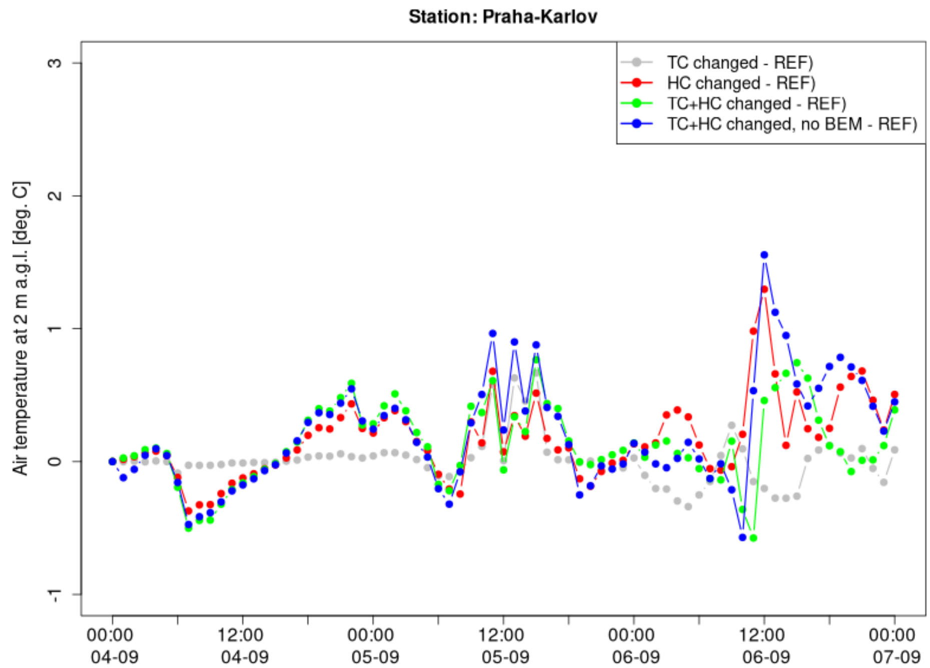


Fig.4 Air 2m temperature difference between reference ALARO+SURFEX recommended configuration and 4 tested TEB configurations for 3 day simulation covering the period between 4th and 7th September 2024 for city station Praha-Karlov.

5. Conclusions

The primary objective of this research stay was to conduct a sensitivity analysis of various configurations of the ALARO model coupled with the SURFEX scheme, which served also as a technical sanity check. To achieve this, multiple model setups—incorporating different numbers of patches, snow schemes, and the inclusion of the urban scheme—were designed and evaluated. The experiments were carried out using the SURFEX version 8.0+ on the local CY46t1mp_op3sfx branch and were performed over selected three-day periods in both summer and winter.

Building on the findings from the sensitivity tests described above, the analysis of the results indicated that the D95 snow scheme performs better than the EBA scheme under conditions of limited snow cover. Differences in forecasts between the SURFEX model using one patch and three patches were not significant; however, for a more accurate representation of winter conditions, the use of three patches is recommended—consistent with the guidance of the SURFEX development team.

The tests of the TEB scheme confirmed its positive impact on the simulation of air temperature in urban areas. Tuning of building thermal properties had smaller impact than expected. Therefore, further work is required to fully capture the thermal differences between urban and suburban environments.

Finally, we stress that our short sensitivity tests cannot serve for robust model retuning. For this purpose, tests of ALARO+SURFEX will be continued, using longer periods and including standard VERAL verification over whole model domain. The preliminary recommended configuration of ALARO+SURFEX is included in APPENDIX A-C.

APPENDIX A

Example of namelist **OPTION.nam** to generate PGD file for CHMI 2.3km domain:

```
&NAM_CONF_PROJ
 XBETA=0.,
 XLAT0=46.24470064,
 XLON0=17.,
 XRPK=0.7223,
/
&NAM_CONF_PROJ_GRID
 ILATE=11,
 ILONE=11,
 NIMAX=1069,
 NJMAX=853,
 XDX=2325.,
 XDY=2325.,
 XLATCEN=48.51629423,
 XLONCEN=15.08278899,
/
&NAM_COVER
 YCOVER='ecoclimap',
 YCOVERFILETYPE='DIRECT',
/
&NAM_DATA_ISBA
/
&NAM_DATA_TEB
 XUNIF_H_TRAFFIC=0.,   ! switch off sensible heat source from traffic
 XUNIF_LE_TRAFFIC=0.,  ! switch off latent heat source from traffic
/
&NAM_IO_OFFLINE
 CPGDFILE='PGD',
 CSURF_FILETYPE='FA',
 LFAGMAP=.T.,         ! use old convention for naming FA fields
 NHALO=20,            ! size of search halo (0 for unlimited)
/
&NAM_ISBA
 CISBA='3-L',         ! 3L force-restore soil scheme
 NPATCH=3,            ! 3 nature patches
 YCLAY='clay',
 YCLAYFILETYPE='DIRECT',
 YSAND='sand',
 YSANDFILETYPE='DIRECT',
/
&NAM_PGD_ARRANGE_COVER
 LTOWN_TO_ROCK=.F.,    ! do not convert town to rock
```

```
/
&NAM_PGD_GRID
 CGRID='CONF PROJ',
/
&NAM_PGD_SCHEMES
 CNATURE='ISBA',      ! use ISBA for nature tile
 CSEA='SEAFLX',
 CWATER='WATFLX',
 CTOWN='TEB',         ! use TEB for urban tile
 LGARDEN=.F.,         ! use 2 urban patches (roof, road)
/
&NAM_TREEDRAG
/
&NAM_ZS
 YZS='orography',
 YZSFILETYPE='DIRECT',
/
&NAM_ZS_FILTER
 NZSFILTER=0,         ! do not filter orography
/
```

APPENDIX B

Example of namelist **PRE_REAL1.nam** to generate initial SURFEX file for CHMI domain:

```
&NAM_PREP_ISBA
 LISBA_CANOPY=.F.,
/
&NAM_PREP_ISBA_SNOW
 CSNOW='D95,
/
&NAM_PREP_SEAFLUX
 LSEA_SBL=.F.,
/
&NAM_PREP_WATFLUX
 LWAT_SBL=.F.,
/
&NAM_WRITE_SURF_ATM
 LNOWRITE_TEXFILE=.T.,
/
```

APPENDIX C

Forecast namelist for SURFEX: file **EXSEG1.nam**

```
&NAM_DIAG_ISBAn
 LPGD=.T.,            ! save fields computed from ECOCLIMAP
 LSURF_MISC_BUDGET=.T.,  ! save Halstead coefficient, snow fractions, SWI
/
&NAM_DIAG_SURFn
 LCOEF=.T.,           ! save transfer coefficients and roughness lengths
 LSURF_BUDGET=.T.,      ! save fluxes for surface energy budget
 LSURF_VARS=.T.,       ! save surface specific humidity
 N2M=0,               ! no screen level interpolation in SURFEX
/
&NAM_ISBAn
 CSCOND='NP89',        ! heat conductivity after Noilhan & Planton (1989)
 CROUGH='Z01D',
/
&NAM_SEAFLUXn
 CSEA_FLUX='ECUME',     ! use ECUME for sea flux calculations
/
&NAM_SSOn
 CROUGH='NONE',        ! no orographic roughness length on gridbox level
/
&NAM_REPROD_OPER
 LREPROD_OPER=.F.,      ! do not reproduce operational defaults
/
&NAM_SURF_ATM
 LALDTHRES=.T.,       ! set minimum wind shear as in aladin
 LCPL_ARP=.F.,        ! do not use ARPEGE cp and L (q or T dependent)
 LDRAG_COEF_ARP=.T.,   ! use drag coefficients as in ARPEGE/TOUCANS
 LNOSOF=.T.,          ! no explicit subgrid orography effects on atmosphere
 LRRGUST_ARP=.T.,     ! activate moist gustiness calculation
 LVZIUSTAR0_ARP=.T.,   ! arpege formulation of z0h over sea
 LZ0_AVG_EXACT=.T.,    ! unapproximated formula of roughness length averaging
 LZ0_EFF=.T.,         ! include orographic roughness length
 LZ0SNOWH_ARP=.T.,     ! impact of snow of roughness length via snow height
 XCISMIN=5.5E-04,      ! protection of wind shear from zero
 XFACZ0=0.53,         ! scaling factor for subgrid-scale orographic roughness
 XRRGAMMA=0.8,        ! tuning of moist gustiness correction (cf. RRGAMMA)
 XRZ0_TO_HEIGHT=0.13,  ! ratio of mechanical roughness to obstacle height
 XVZIUSTAR0=12.,       ! tuning of arpege formulation of z0h over sea
 XRRSCALE=1.15E-04,    ! tuning of moist gustiness correction (cf. RRSCALE)
 XUTILGUST=0.125,      ! tuning of moist gustiness correction (cf. UTILGUST)
 XVMODMIN=0.,          ! minimum wind speed to calculate drag coefficient
 XWCRN=10.,           ! critical SWE for calculating snow fraction
/
&NAM_TEBn
 CCH_BEM='DOE-2',
```

```
/
&NAM_TREEDRAG  ! scale tree height by factor 1.5
  XSCALE_H_TREE(4)=1.5,
  XSCALE_H_TREE(5)=1.5,
  XSCALE_H_TREE(6)=1.5,
  XSCALE_H_TREE(13)=1.5,
  XSCALE_H_TREE(14)=1.5,
  XSCALE_H_TREE(15)=1.5,
  XSCALE_H_TREE(16)=1.5,
  XSCALE_H_TREE(17)=1.5,
  XSCALE_H_TREE(19)=1.5,
/
&NAM_WRITE_DIAG_SURFn
  LPROVAR_TO_DIAG=.F.,  ! do not save prognostic variables averaged over patches
/
&NAM_WRITE_SURF_ATM
  LNOWRITE_TEXFILE=.T.,  ! do not produce LaTeX output
/
```