RC LACE Stay Report

Testing ALARO model with SURFEX scheme

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1. Introduction

This stay focused on testing and extending selected SURFEX scheme options to identify the optimal configuration for coupling with the ALARO model. The first task was to analyze the impact of traffic and industry heat sources in the TEB scheme by using ALARO+SURFEX. The second task was to implement a new method to calculate the direct albedo of the surface based on the formula presented in the article Mašek et. al (2016). The work was done using CY46T1 with local modifications done at CHMI.

2. Studies of heat sources in the SURFEX scheme

2.1. Description of the experiments (impact of heat sources)

The starting configuration of the SURFEX scheme employed three nature patches, 3-L force-restore soil scheme, TEB scheme with garden option, heat sources from industry and no traffic sources. ECOCLIMAP II physiography was used.

To analyze the impact of the two anthropogenic sources, three PGD files were prepared:

Conf 0 (exp. name: **P610**): includes only heat sources from industry.
Conf 1 (exp. name: **P611**): does not include heat sources from industry and traffic.
Conf 2 (exp. name: **P612**): includes heat sources from industry and traffic.

To switch off sensible heat sources from traffic and industry, in the PGD step the user must set those variables to 0:

```
&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
 XUNIF_H_INDUSTRY=0.,   ! switch off sensible heat source from industry
 XUNIF_LE_INDUSTRY=0.,  ! switch off latent heat source from industry
/
```

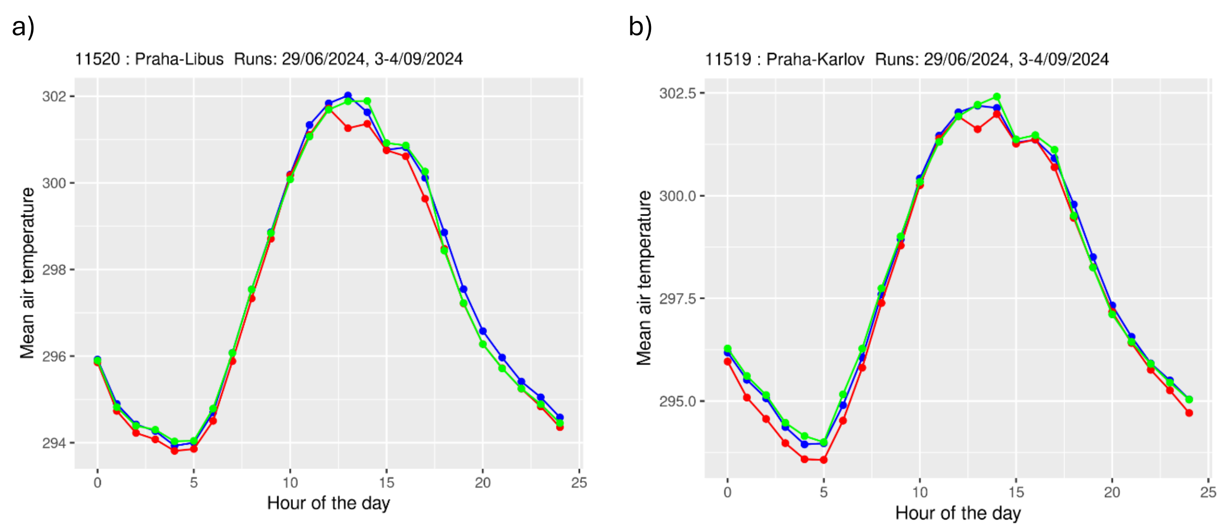
When the user defines their own values of traffic or industry sources in the namelist, in PGD file are included four additional fields:

```
SFX.D_H_TRAF
SFX.D_LE_TRAF
```

SFX.D_H_IND
SFX.D_LE_IND

2.2. Forecast verification

To analyze the impact of two anthropogenic sources, three periods were selected: two in summer where temperature exceeded 30 °C and one in winter. Analysis of the winter period (12-15 Jan. 2021) has shown that the impact of traffic sources is insignificant (not shown in this report). In order to analyze the impact of these sources on the diurnal cycle during the summer period, the average temperature for individual hours from 0 to 23 UTC was calculated based on the three-day periods of 29 June–1 July 2024 and 3–7 September 2024. The models forecast with a +72 h leadtime was divided into three 24-hour intervals, which were averaged for the individual urban stations. The Figure 1 present the mean diurnal cycle for two urban stations Praha-Libuš and Praha-Karlov, and one mountain station Churáňov. The analysis has shown that for the station Praha-Karlov, experiment without industrial sources (red line) during the nighttime is colder on average by 0.3 °C compared to the reference (blue line), while the maximum difference occurs at 2 UTC, equal to 0.5 °C. The forecasts for mountain station for three configurations are similar, the maximum difference is lower than 0.1°C.



c)

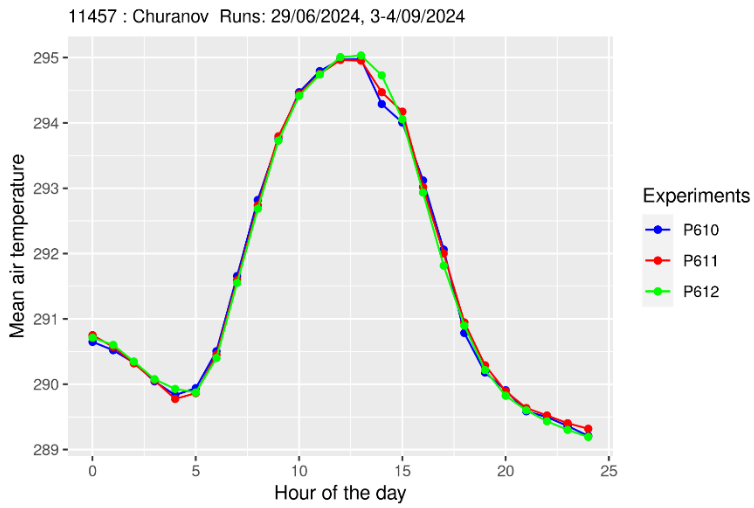


Figure 1. Predicted mean 2 m air temperature over the period 29/06-01/07/2024 and 03-07/09/2024 for station a) Praha-Libuš, b) Praha-Karlov and c) Churáňov.

For selected periods, the verification against stations in the model domain was calculated. The verification has shown that differences between the three configurations are small; they would be larger if only urban stations were used. Figure 2 present BIAS and RMSE of 2 m air temperature for a set of runs starting at three different summer days.

a) BIAS of 2 m air temperature　　b) RMSE of 2 m air temperature

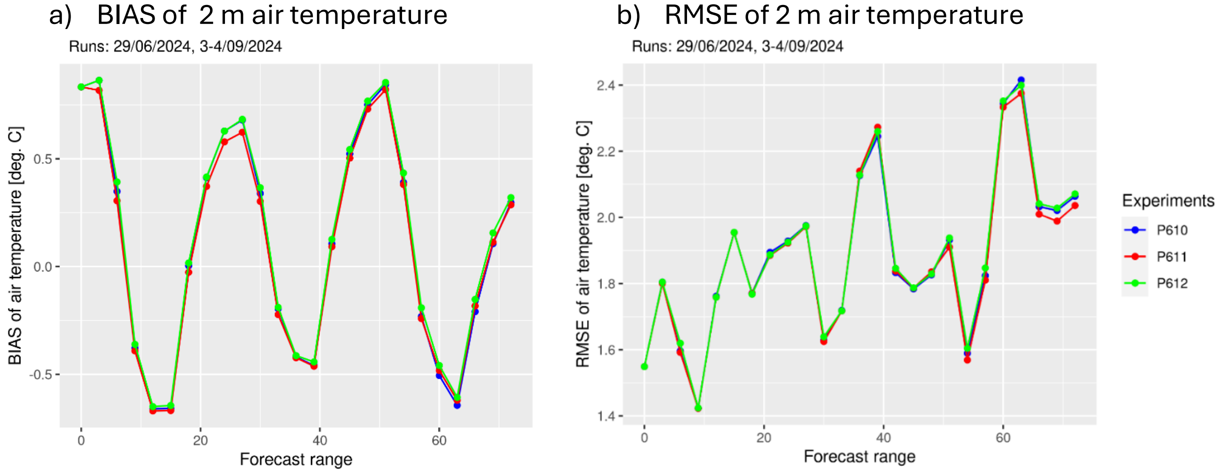


Figure 2. Verification of air temperature at 2 m for three different configurations for runs starting on 29/06, 03/09 and 04/09/2024.

2.3. Modification of traffic sources

In the TEB scheme, the temperature change in the urban canyon takes into account the influence of anthropogenic heat flux from transport. This is described by the equation 1 (reference equation 3.25 from Moigne, P. Le (2018))

$$\Delta T_{traff} = \frac{H_{traff}}{\left(C_{pd}\rho_a(1-f_{bld})\right)\left(\delta_r(1-\delta_{snowr})\frac{1}{RES_r}+\frac{2h}{\omega}(1-f_{win})\frac{1}{RES_\omega}+\frac{1}{RES_{top}}\right)} \quad (1)$$

where:

H_{traff} - sensible heat flux from traffic

ΔT_{traff} – change of canyon air temperature due to traffic contribution

C_{pd} - heat capacity of dry air

ρ_a – air density

f_{bld} – fraction of buildings

δ_r – fraction of the roads

δ_{snowr} – snow fraction on the roads

f_{win} – fraction of windows

h/ω - the ratio between building's height h and (idealized) modelled canyon width w

RES_r – aerodynamical resistance of roads

RES_ω – aerodynamical resistances of walls

RES_{top} – aerodynamical canyon resistance

The traffic source is active between 6:00 and 18:00 solar time (routine: **coupling_tebn.F90**). The heat source coming from traffic is defined in routine: **default_data_cover.F90.** For most of urban covers, this source is set to 10 in ECOCLIMAP FG. For specific urban covers the value may be bigger (maximum value is equal to 30), or equal to 0 (e.g. for urban parks, and sport facilities). Below is included part of the code describing traffic sources for specific covers.

```
WHERE(XDATA_TOWN>0.) XDATA_H_TRAFFIC(:) = 10.
XDATA_H_TRAFFIC(151) = 20.  ! COVER 151 : Dense urban
XDATA_H_TRAFFIC(156) = 30.  ! COVER 156 : Road and rail networks
XDATA_H_TRAFFIC(159) = 0.   ! COVER 159 : Mineral extraction, construction sites
XDATA_H_TRAFFIC(160) = 0.   ! COVER 160 : Urban parks
XDATA_H_TRAFFIC(161) = 0.   ! COVER 161 : Sport facilities
XDATA_H_TRAFFIC(254) = 0.
XDATA_H_TRAFFIC(255) = 0.
```

Previous tests of ALARO model with SURFEX scheme have shown that for very stable conditions, the contribution from traffic sources to canyon temperature may be dominant and yield unrealistic air temperature in the canyon. For the three cases described above, the ALARO model with SURFEX scheme was stable, but for different case and/or SURFEX configuration, the model blow up can occur eventually. To prevent this issue, the formula for canyon air temperature was modified. The maximum change of air temperature in the street canyon coming from the traffic sources in one timestep was limited through the namelist variable, e.g. 5°C.

```
&NAM_SURF_ATM
  XCAN_TEMP_LIMIT = 5.0,
/
```

To keep reproducibility of the results, the default value of this parameter was set to **HUGE(1.0)**. Below is presented new variable:

List of modified routines:

sfx/SURFEX/avg_urban_fluxes.F90 ! calculation of canyon temperature
sfx/SURFEX/default_surf_atm.F90 ! Definition of the new variable XCAN_TEMP_LIMIT
sfx/SURFEX/modd_surf_atm.F90
sfx/SURFEX/modn_surf_atm.F90
sfx/SURFEX/read_namelists_surf.F90
sfx/SURFEX/read_surf_atm_conf.F90

To check if the new solution keeps the model stable, during the PGD preparation the traffic sources were set to 250W/m^2. The test was done on 12 Jan. 2021. The formula for canyon air temperature without safety threshold caused that air temperature was too high in the lowest model level in few timesteps after activation of traffic sources. The test of the ALARO model with modified formula included has confirmed that the model was stable.
Aiming to check impact of new approach compared to the original solution below is presented difference between reference (ALARO model without traffic sources) and two experiments which includes traffic sources (**P612** – unchanged formula; **P613** – formula with threshold) for two urban stations Praha-Karlov (city center) and Praha-Ruzyne (suburban). At 6 UTC there is a visible sudden peak which is related to activation of traffic sources in the model. For the first 24 hours of the forecast, both experiments P612 and P613 give almost identical results for both locations. Substantial differences of predicted 2 m air temperature during the second day are caused by the cloud fields differences between experiments (not shown in the report).

a) b)

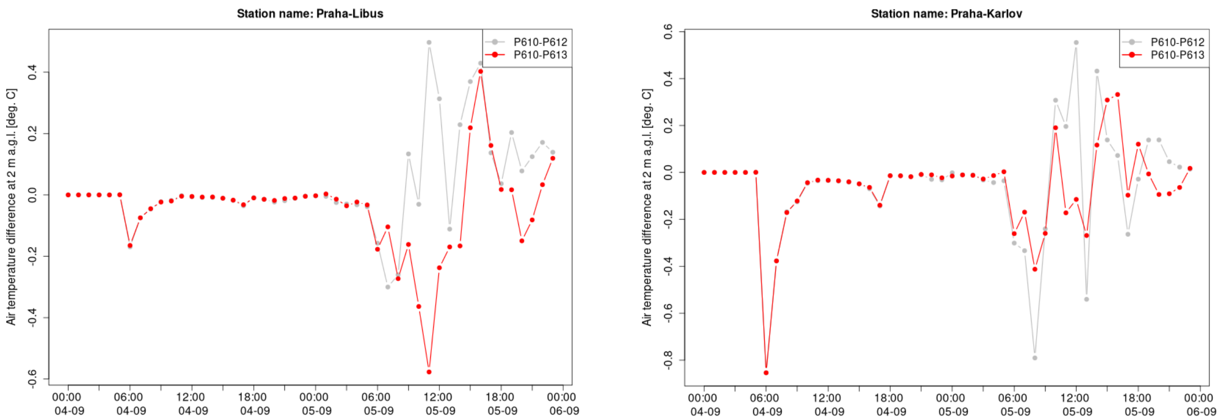


Figure 3. Difference of 2 m air temperature between reference configuration P610 (without traffic sources) and two configurations with traffic sources: P612 – unmodified formula and P613 – formula with threshold for suburban station a) Praha-Libuš and b) Praha-Karlov.

3. Introduction of a new scheme for albedo calculation.

The second task was to implement a new method of albedo calculation in SURFEX, so called generalized Geleyn formula. It is based on the studies presented in article Mašek et al. (2016). The formula has one parameter r_{lamb} which can be modified through the namelist. The parameter defines the proportion of Lambertian reflection.

$$\alpha(\mu_0) = (1 - r_{lamb}) \cdot \frac{1 + \frac{\mu_0}{2}\left(\frac{1}{\overline{\alpha}} - 1\right)}{\left(1 + \mu_0\left(\frac{1}{\overline{\alpha}} - 1\right)\right)^2} + r_{lamb} \cdot \overline{\alpha} \tag{2}$$

$$0 \leq r_{lamb} \leq 1$$

where:

r_{lamb} – parameter of Lambertian reflection proportion

μ_0 – cosine of solar zenith angle

$\overline{\alpha}$ – diffuse albedo

For solid surfaces, variation of direct albedo with sun elevation is significantly smaller than for water bodies. This effect can be accounted for by incorporating an appropriate level of Lambertian reflection. The default value of Lambertian reflection for water bodies is equal to 0, while for land, snow or ice it is set to 0.6.

The Lambertian coefficients for water and solid surfaces are included in the namelist block.

&NAM_SURF_ATM

```
    XLAMB_SOLID=0.6,
     XLAMB_WATER=0.0,
/
```

Adding new variables required modifications in the following routines:

sfx/SURFEX/modd_surf_atm.F90
sfx/SURFEX/modn_surf_atm.F90
sfx/SURFEX/read_surf_atm_conf.F90
sfx/SURFEX/read_namelists_surf.F90
sfx/SURFEX/default_surf_atm.F90
sfx/interfaces/modi_default_surf_atm.F90

This new approach was applied for three tiles:

- Open water - sea
- Inland water – rivers and lakes
- Nature - ISBA and for nature in the city (TEB with garden option).

The calculation of direct albedo in the urban areas wasn't modified, since it would be complicated to accommodate generalized Geleyn formula in canyon geometry. We do not see it as a problem, as the town albedo is dominated by shadowing effect in the canyon anyway. Direct radiation for flooded area wasn't also changed; the calculation is done using **albedo_ta96.F90**. During the test one bug in **flake scheme** was found. Some lake points which are frozen or covered by snow have a diffuse albedo set to 0. This issue requires further investigation. To solve this issue, in routine **albedo_mg16.F90** was included a check of diffuse albedo equal to 0.

The albedo calculation is selected in the integration namelist. The new formula of direct albedo is implemented in the routine **albedo_mg16.F90**. The new option is available under the key **MG16** in several places (separately for sea, inland water, and nature, including nature in the town).

It's important to switch on this key 'MG16' at all places to have direct albedo calculation consistent across the tiles.

By default, for the water bodies (sea, river and lake) there are available several options of albedo definition ('UNIF', 'TA96', 'MK10', 'RS14').

Below are presented new options included in the **EXSEG1.nam** (integration namelist):

```
&NAM_SEAFLUXn
  CSEA_FLUX='ECUME',     ! use ECUME for sea flux calculations
  CSEA_ALB='MG16',       ! Other possibilities: 'UNIF', 'TA96', 'MK10', 'RS14'; default:   'TA96',
/
```

```
&NAM_WATFLUXn
  CWAT_ALB='MG16',       ! Other possibilities: 'UNIF', 'TA96'; default 'UNIF'
/

&NAM_FLAKEn
 CFLK_ALB= 'MG16',       ! Other possibilities: 'UNIF', 'TA96'
/

&NAM_ISBAn
CNAT_ALB='MG16',! NEW KEY; Other possibilities: 'UNIF' - default option
/
```

Generalized Geleyn formula was first applied to water bodies. The new option was added to the list of possibles schemes. This task didn't require many modifications. The list of modified is as follows:

sfx/SURFEX/read_default_seafluxn.F90
sfx/SURFEX/read_default_watfluxn.F90
sfx/SURFEX/read_flake_confn.F90
sfx/SURFEX/read_seaflux_confn.F90
sfx/SURFEX/read_watflux_confn.F90
sfx/SURFEX/update_rad_flake.F90
sfx/SURFEX/update_rad_sea.F90
sfx/SURFEX/update_rad_water.F90

Below is presented calling tree for 3 water schemes:

update_rad_water.F90
  → albedo_mg16.F90

update_rad_sea.F90
  → albedo_mg16.F90

update_rad_flake.F90
  → albedo_mg16.F90

At the next step, the new formula was applied to nature patch. The calculation of direct albedo is done by the same routine **ALBEDO_MG16**, which is called in the routine ALBEDO_FROM_NIR_VIS. The default formula assumes that direct albedo is mean value of near infra-red and visible scattered albedos. The code development required adding two arguments **PZENITH** (solar zenith angle) and **CNAT_ALB** (selection of albedo formula) in calling tree of function ALBEDO_FROM_NIR_VIS. To keep the reproducibility, the default formula for calculating direct albedo is unchanged (**CNAT_ALB=**

'UNIF '). Figure 4 presents calling tree of function albedo_from_nir_vis.F90. Due to many possible configurations, the calling tree for nature is more complex than for water bodies. Below are included calling trees which were modified.

read_namelists_tebn.F90
→ default_teb_veg.F90

init_isban.F90
→ default_isba.F90

read_namelists_isban.F90
→ default_isba.F90

init_teb_veg_optionsn.F90
→ default_isba.F90

garden_properties.F90 **OR** greenroof_properties.F90
→ isba_properties.F90
→ isba_albedo.F90
→ albedo_from_nir_vis.F90
→ albedo_mg16.F90

init_teb_gardenn.F90
→ avg_albedo_emis_garden.F90
→ albedo_from_nir_vis.F90
→ albedo_mg16.F90

init_teb_greenroofn.F90
→ avg_albedo_emis_greenroof.F90
→ albedo_from_nir_vis.F90
→ albedo_mg16.F90

prep_isba.F90 **OR** compute_isba_parameters.F90
→ averaged_albedo_emis_isba.F90
→ update_rad_isban.F90
→ albedo_from_nir_vis.F90
→ albedo_mg16.F90

coupling_isban.F90 **OR** update_esm_isban.F90
→ update_rad_isban.F90
→ albedo_from_nir_vis.F90

→ albedo_mg16.F90

coupling_isban.F90
→ treat_patch.F90
→ isba_albedo.F90
→ albedo_from_nir_vis.F90
→ albedo_mg16.F90

To assess the impact of albedo calculation on the model forecast, two model configurations were prepared (Table 1). The first configuration employed the generalized Geleyn formulation, while the second used the default albedo parameterizations available within the SURFEX scheme. The SURFEX scheme employed three nature patches, 3-L force-restore soil scheme, WATFLX inland water scheme, TEB scheme with garden option, heat sources from industry and no traffic sources.

Table 1. Description albedo calculation in two experiments using ALARO with SURFEX scheme.

New configuration (experiment M611)	Default configuration
&NAM_SEAFLUXn CSEA_FLUX='ECUME', CSEA_ALB=**'MG16'**, / &NAM_WATFLUXn CWAT_ALB='**MG16**', / &NAM_ISBAn CNAT_ALB='**MG16**', /	&NAM_SEAFLUXn CSEA_FLUX='ECUME', CSEA_ALB= 'TA96', / &NAM_WATFLUXn CWAT_ALB='UNIF', / &NAM_ISBAn CNAT_ALB= 'UNIF', /

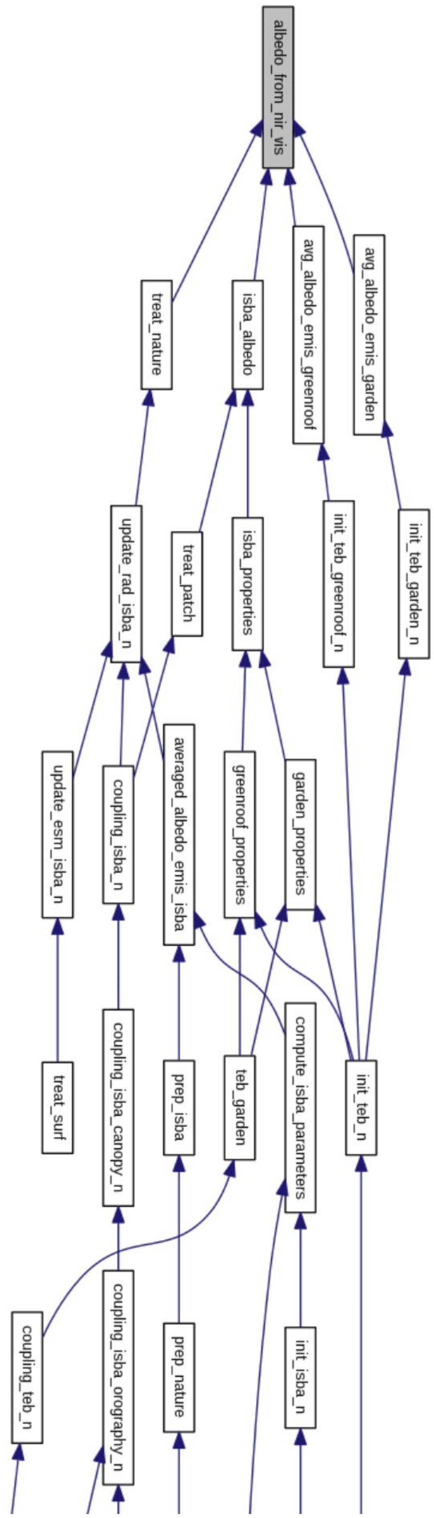


Figure 4. The calling tree of routine albedo_from_nir_vis.F90 in SURFEX v8.0. Access online: https://www.umr-cnrm.fr/surfex/data/BROWSER/out_doc80/albedo__from__nir__vis_8F90.html#a9fa39477f6d37e3eab38da504e8b9217

According to our expectations, the test confirmed that differences in direct albedo are dominant during the sunrise and sunset. During the daytime, the differences are negligible. Figure 5 presents predicted direct albedo at 12 UTC and 17 UTC 4th September 2024 from two experiments described in Table 1.

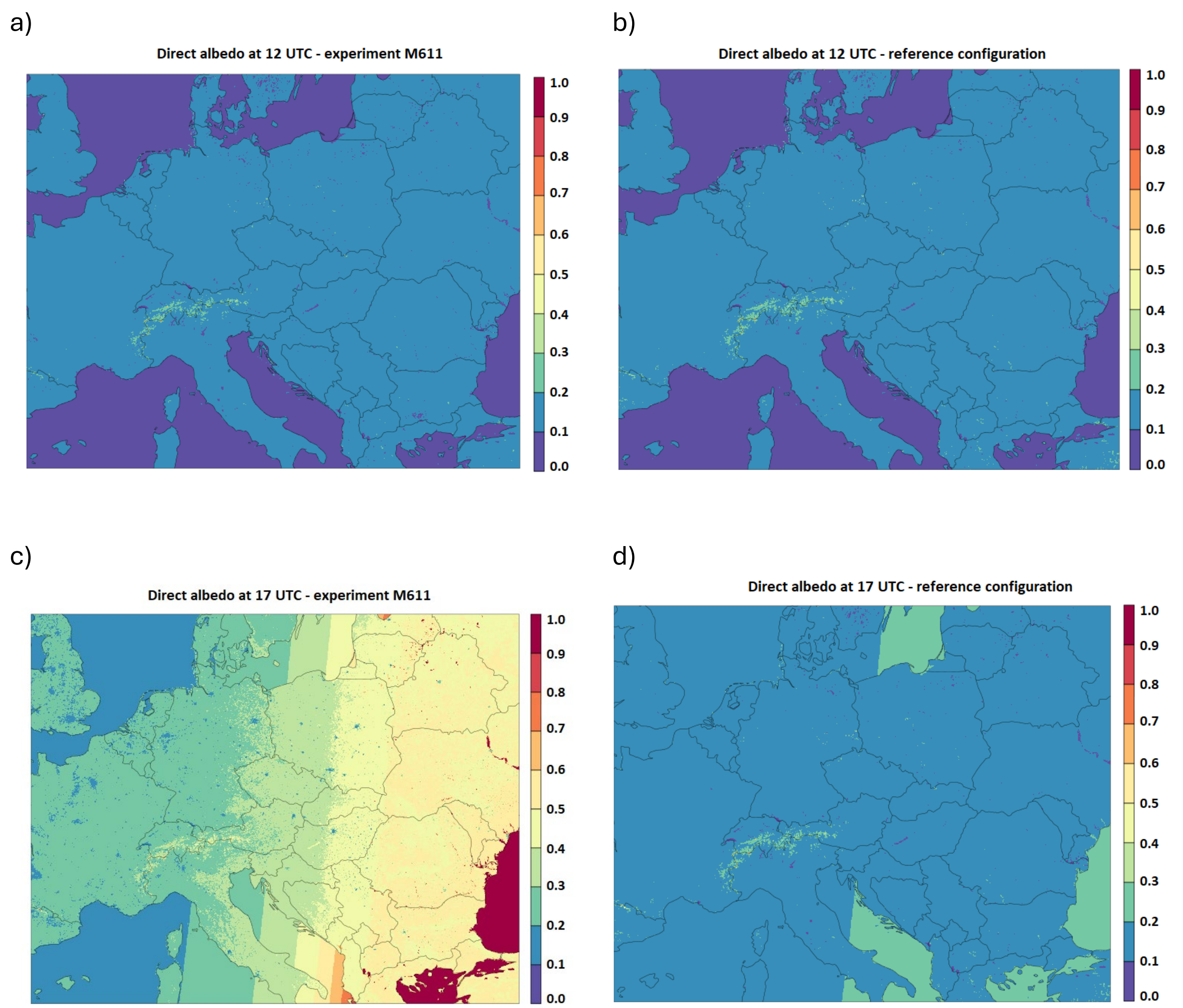


Figure 5. Direct albedo on 4th September 2024 at 12 and 17 UTC for b), d) reference model; and a), c) using the generalized Geleyn formula.

Impact of generalized Geleyn formula for direct albedo on surface temperature is minor. As an example, the difference of surface temperature at 6 UTC between the two configurations is presented on Figure 6. The surface temperature over Eastern and Central part of the Europe is colder up to 0.25°C compared to the reference forecast.

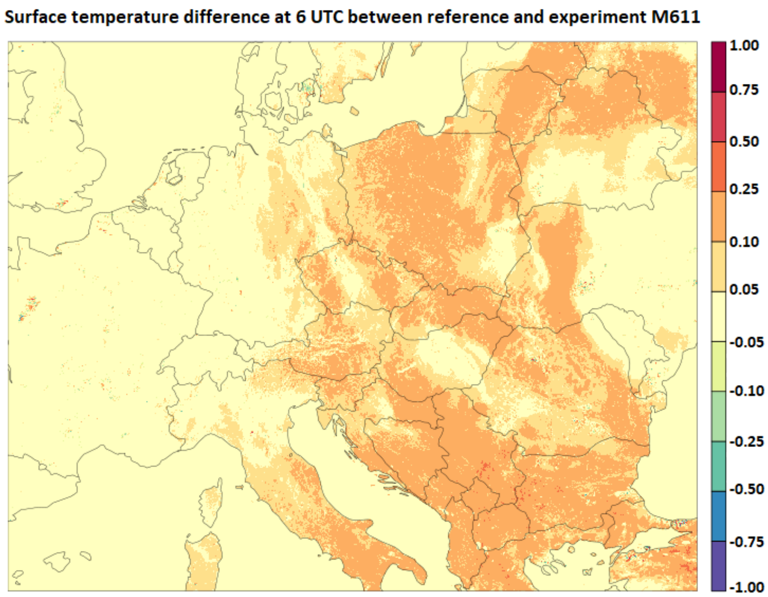


Figure 6. Surface temperature difference at 6 UTC 4th September 2024 between reference configuration and new configuration with modified direct albedo calculation for nature and water bodies.

To better understand the impact of the new albedo calculation, the analysis was extended to include the average surface and air temperatures across the entire domain (Figure 7). The results showed that, during morning and evening hours, the surface temperature is up to 0.06°C lower compared to the reference simulation. This reduction results from higher albedo values than in the reference simulation when the sun is low on the horizon, the albedo computed using Equation (2) is higher than in the reference case.

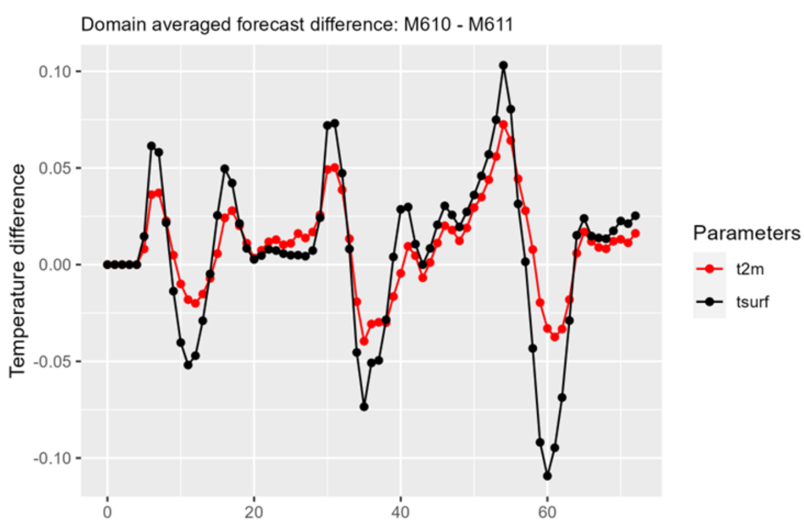


Figure 7. Domain average 2 m air and surface temperature difference between reference and new configuration for period between 4th and 7th September 2024.

To verify the correctness of the modifications, four ALARO configurations employing the generalized Geleyn formulation were tested: two using the ISBA scheme and two using the SURFEX scheme. Within each pair of experiments, the only difference concerned the Lambertian parameters prescribed for water bodies and solid surfaces. In the default configuration, these parameters were set to 0 for water bodies and 0.6 for solid surfaces, while in the second configuration they were set to 1 for both surface types. Figure 8 presents DDH plots of air temperature for pair of the experiments (new-reference). Near the surface, there is visible negative gradient related to the thermal radiation (black line) and turbulence (light blue) compared to the reference forecast. On the other side, there is visible heating of the air which is related to solar radiation (dark green). The both pair of the experiments have similar patterns, which confirms correctness of new albedo implementation.

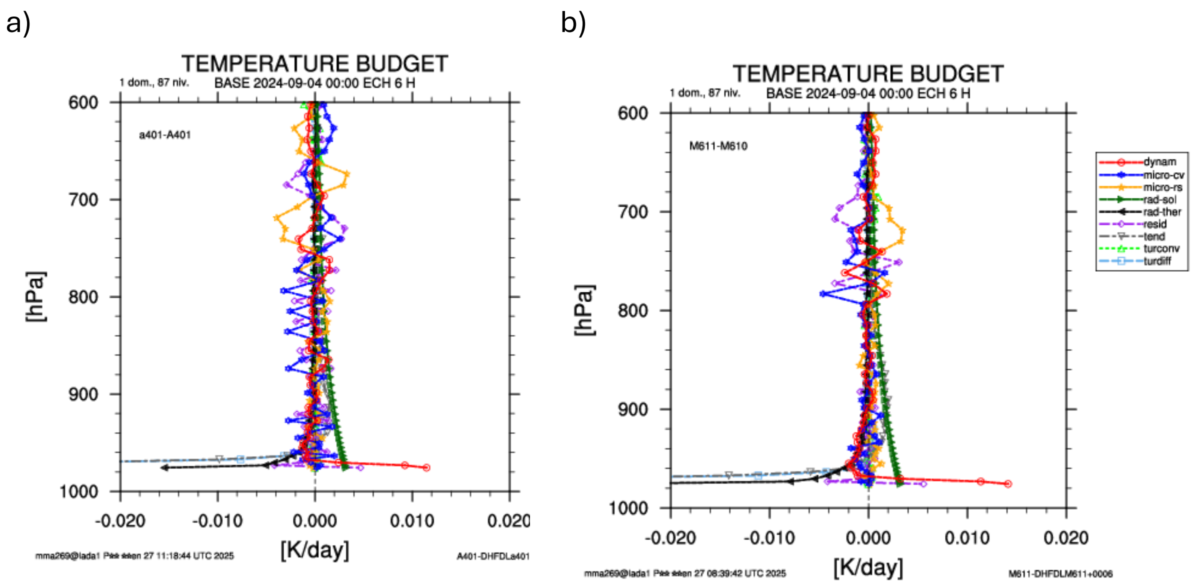


Figure 8. DDH budgets difference between experiments with Lambertian parameters equal to 0 and 0.6 and both equal to 1, for water and solid surface respectively for ALARO with (a) ISBA and with (b) SURFEX scheme.

4. Conclusion

The studies performed during the stay focused on sensitivity tests of several options available in the SURFEX scheme. The tests have shown that impact of industrial sources in the urbanized areas is not negligible. The case studies have shown that in diurnal cycle of 2 m air temperature, this source warms the air temperature by 0.3 °C. The second anthropogenic effect included in the TEB scheme are traffic sources. Previous studies of traffic sources have shown that for very stable conditions, the contribution from this source may be dominant and lead to unrealistic air temperature in the canyon. To prevent this discretization issue, the formula for canyon air temperature was protected. The maximum increment of air temperature in the street canyon coming from the traffic sources is limited though the namelist variable XCAN_TEMP_LIMIT. These tests have shown that this modification avoids instability during jump evolution of the traffic term, while it has almost no impact on forecast results.

The last modification was related to calculation of direct albedo based on the generalized Geleyn formula presented in the article Mašek et. al (2016). This formula was applied to the nature, open water and inland water tiles (option MG16). These tests have shown that this modification has slight impact on the forecast results.

The final list of modified routines:

sfx/interfaces/modi_albedo_from_nir_vis.F90
sfx/interfaces/modi_albedo_mg16.F90
sfx/interfaces/modi_averaged_albedo_emis_isba.F90
sfx/interfaces/modi_avg_albedo_emis_garden.F90
sfx/interfaces/modi_avg_albedo_emis_greenroof.F90
sfx/interfaces/modi_default_isba.F90
sfx/interfaces/modi_default_surf_atm.F90
sfx/interfaces/modi_default_teb_veg.F90
sfx/interfaces/modi_garden_properties.F90
sfx/interfaces/modi_greenroof_properties.F90
sfx/interfaces/modi_init_teb_gardenn.F90
sfx/interfaces/modi_init_teb_greenroofn.F90
sfx/interfaces/modi_isba_albedo.F90
sfx/interfaces/modi_isba_properties.F90
sfx/interfaces/modi_update_rad_isban.F90

sfx/SURFEX/albedo_from_nir_vis.F90
sfx/SURFEX/albedo_mg16.F90
sfx/SURFEX/averaged_albedo_emis_isba.F90
sfx/SURFEX/avg_albedo_emis_garden.F90
sfx/SURFEX/avg_albedo_emis_greenroof.F90
sfx/SURFEX/avg_urban_fluxes.F90
sfx/SURFEX/compute_isba_parameters.F90
sfx/SURFEX/coupling_isban.F90
sfx/SURFEX/default_isba.F90
sfx/SURFEX/default_surf_atm.F90
sfx/SURFEX/default_teb_veg.F90
sfx/SURFEX/garden_properties.F90
sfx/SURFEX/greenroof_properties.F90
sfx/SURFEX/init_isban.F90
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sfx/SURFEX/init_teb_greenroofn.F90
sfx/SURFEX/init_tebn.F90
sfx/SURFEX/init_teb_veg_optionsn.F90
sfx/SURFEX/isba_albedo.F90

sfx/SURFEX/isba_properties.F90
sfx/SURFEX/modd_isban.F90
sfx/SURFEX/modd_surf_atm.F90
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sfx/SURFEX/modn_surf_atm.F90
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sfx/SURFEX/read_default_seafluxn.F90
sfx/SURFEX/read_default_watfluxn.F90
sfx/SURFEX/read_flake_confn.F90
sfx/SURFEX/read_isba_confn.F90
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sfx/SURFEX/update_esm_isban.F90
sfx/SURFEX/update_rad_flake.F90
sfx/SURFEX/update_rad_isban.F90
sfx/SURFEX/update_rad_sea.F90
sfx/SURFEX/update_rad_water.F90

References:

Mašek, J., Geleyn, J.-.-F., Brožková, R., Giot, O., Achom, H.O. and Kuma, P. (2016), Single interval shortwave radiation scheme with parameterized optical saturation and spectral overlaps. Q.J.R. Meteorol. Soc., 142: 304-326.
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https://www.umr-cnrm.fr/surfex/IMG/pdf/surfex_scidoc_v8.1.pdf