Report of RC LACE stay at CHMI Prague
26.11.2018–07.12.2018

INVESTIGATING SURFEX IN ALARO-1
(correct averaging enabling use of effective roughness)

Supervisor:
Ján Mašek
jan.masek@chmi.cz

Author:
Martin Dian
martin.dian@shmu.sk

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1. Introduction

During the previous stay [1], serious problem with averaging of surface roughness in SURFEX was identified, corrupting effective roughness passed to atmospheric model. Aim of this stay was to implement unapproximated averaging formula that can correctly deal with roughness values exceeding height of the lowest model level, and to evaluate its impact. During the work another issue with setting vegetation thermic coefficient was addressed. Finally the impact of differing surface albedo and emissivity was eliminated. Unfortunately, deviation of ALARO-1 run with SURFEX from the reference run calling 2-level ISBA scheme directly remains too big to be explained solely by different physiogeographic datasets.

2. Corrected roughness averaging in SURFEX

Even if subroutine SURFACE_CDCH_1DARP is supplied with effective value of mechanical roughness PZ0EFF, gridbox averaged values delivered to subroutine APLPAR via call to interface subroutine ARO_GROUND_DIAG are corrupted (see left panel on figure 2.1). Roughness in SURFEX is averaged as follows:

$$z_0 = \frac{H}{\exp\left\{\left[\sum_{i=1}^{N} \frac{w_i}{\ln^2[H/(z_0)_i]}\right]^{-\frac{1}{2}}\right\}}, \tag{2.1}$$

where w_i is areal fraction of surface type with roughness $(z_0)_i$, N is number of patches or tiles, and H is reference height alias height of the lowest model level. Formula (2.1) follows from linear averaging of drag coefficient in neutrality:

$$C_{\mathrm{DN}} = \frac{\kappa^2}{\ln^2(1 + H/z_{0\mathrm{D}})} \approx \frac{\kappa^2}{\ln^2(H/z_{0\mathrm{D}})}, \tag{2.2}$$

provided that $H \gg z_{0\mathrm{D}}$, where κ is von Kármán constant. However, effective value of mechanical roughness $z_{0\mathrm{D}}$ can be comparable to or even greater than H, so it is not possible to make an approximation:

$$\ln(1 + H/z_{0\mathrm{D}}) \approx \ln(H/z_{0\mathrm{D}}). \tag{2.3}$$

More detailed explanation is given in previous report [1]. Correct averaging formula for mechanical roughness follows from linear averaging of non-approximated drag coefficient (2.2):

$$z_{0\mathrm{D}} = \frac{H}{\exp\left\{\left[\sum_{i=1}^{N} \frac{w_i}{\ln^2[1 + H/(z_{0\mathrm{D}})_i]}\right]^{-\frac{1}{2}}\right\} - 1}. \tag{2.4}$$

When effective value of mechanical roughness $z_{0\mathrm{D}}$ is used, thermal roughness $z_{0\mathrm{H}}$ is no longer proportional to it, requiring separate averaging formula. According to the Monin-Obukhov theory, the heat coefficient in neutrality reads:

$$C_{\mathrm{HN}} = \frac{\kappa^2}{\ln(1 + H/z_{0\mathrm{H}}) \ln(1 + H/z_{0\mathrm{D}})}. \tag{2.5}$$

Correct averaging formula for thermal rougness is obtained from linear averaging of heat coefficient (2.5), with average mechanical roughness substituted from formula (2.4):

$$z_{0\mathrm{H}} = \frac{H}{\exp\left\{ \left[\sum_{i=1}^{N} \frac{w_i}{\ln[1 + H/(z_{0\mathrm{H}})_i] \ln[1 + H/(z_{0\mathrm{D}})_i]} \right]^{-1} \left[\sum_{i=1}^{N} \frac{w_i}{\ln^2[1 + H/(z_{0\mathrm{D}})_i]} \right]^{\frac{1}{2}} \right\} - 1}. \tag{2.6}$$

The next step was thus finding all approximate expressions $\ln[H/(z_0)_i]$ in the SURFEX code and replacing them by $\ln[1 + H/(z_0)_i]$, in order to remove restriction $H \gg z_{0\mathrm{D}}$. Averaging formulas (2.1) were consistently replaced by either (2.4) or (2.6). After fixing all concerned SURFEX subroutines, roughness entering subroutine APLPAR is correct (see right panel on figure 2.1). List of fixed SURFEX subroutines is given in the Appendix.

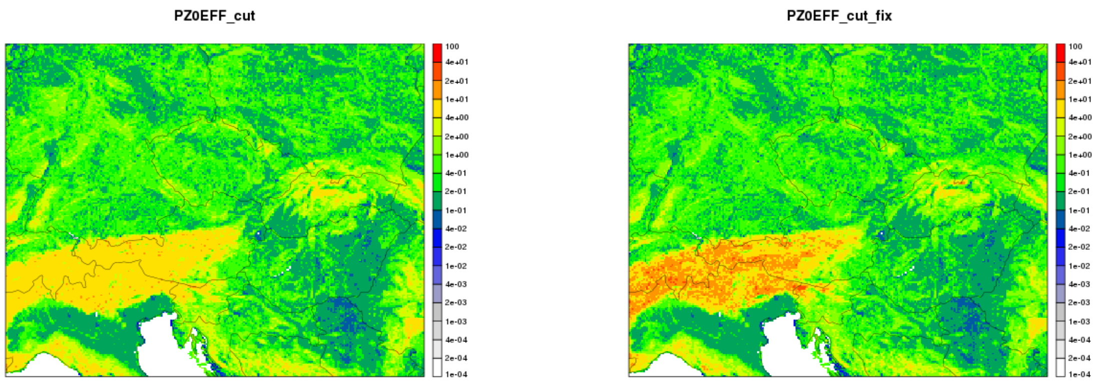

Figure 2.1: Gridbox averaged roughness PGZ0 delivered to subroutine APLPAR by interface subroutine ARO_GROUND_DIAG. Snow scheme 'EBA' and isotropic roughness HROUGH='Z01D' were used. **Left:** before fix; **right:** after fix.

3. Impact on the lowest model level temperature

All experiments were performed using ALARO-1 on ALADIN/CHMI domain (horizontal mesh size 4.7 km, 87 vertical levels). For consistency with PGD procedure, e923 climate files used in ISBA runs were prepared with setting FACZ0=1.0 (scaling factor for orographic roughness) and NLISSZ=1 (number of Laplacian smoothings applied on orographic roughness). In order to bypass screen level interpolation which is different in SURFEX and ISBA, comparisons were done using temperature on the lowest model level. To avoid snow related issues, summer case from July 2017 was used. Figure 3.1 shows the difference between SURFEX run with old roughness averaging (2.1) and reference ISBA run. After one hour integration there are large areas with difference ∼2 K (left panel). After 24 hours the difference is much bigger, reaching ∼5 K (right panel).

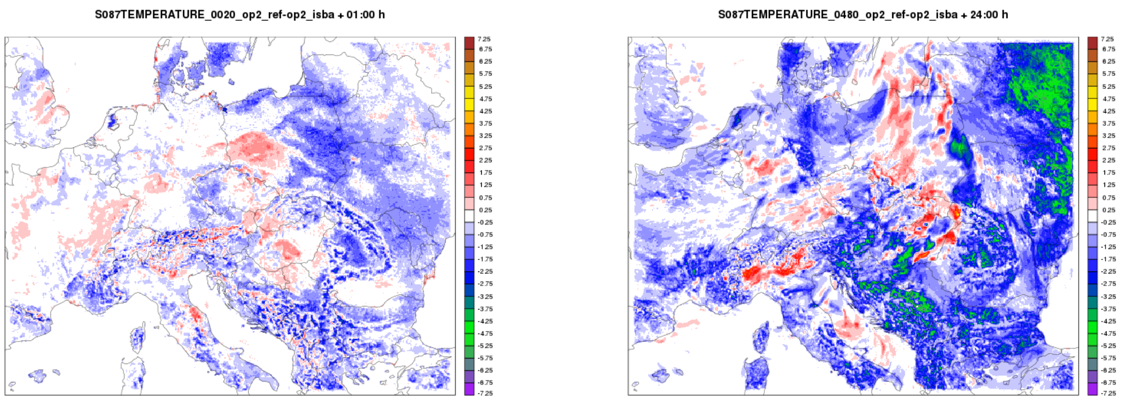

Figure 3.1: Difference in the lowest model level temperature: SURFEX run without fixed roughness averaging minus ISBA run. Base time 10-Jul-2017 00 UTC. **Left:** 1h forecast; **right:** 24h forecast.

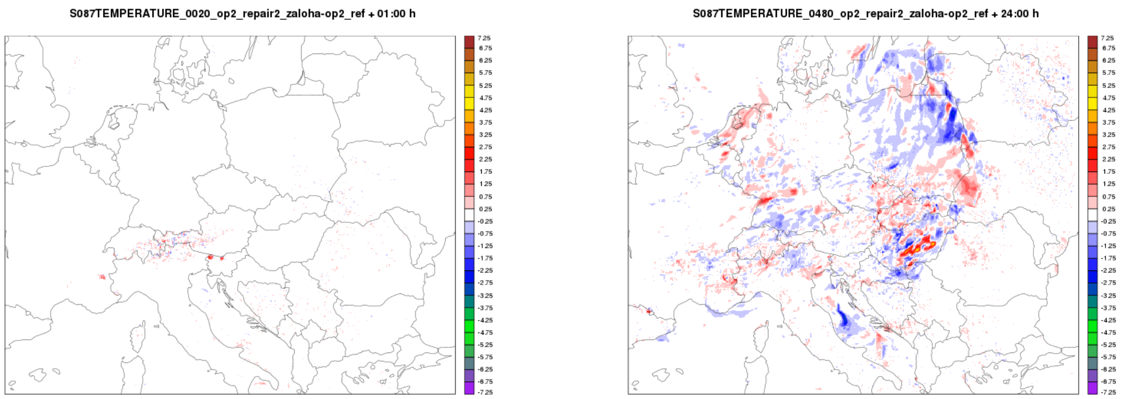

Figure 3.2: Impact of fixed roughness averaging on the lowest model level temperature in SURFEX run. Base time 10-Jul-2017 00 UTC. **Left:** 1h forecast; **right:** 24h forecast.

When averaging formulas (2.4) and (2.6) were used in the SURFEX run, temperature at the lowest model level changed only slightly, see figure 3.2. Therefore, roughness averaging cannot explain differences seen on figure 3.1. This is not so surprising, since the old averaging was corrupting mechanical roughness z_{0D} entering the calculation of mixing length via expression $\kappa(z - z_{0D})$, but not drag and heat coefficients used in the boundary condition for turbulent fluxes. Therefore, turbulent fluxes in the surface layer were correct, and the influence on the mixing length for momentum was felt mostly for the low model levels over the mountains, where the effective mechanical roughness z_{0D} is negligible neither with respect to the reference height $H \approx 10\,\mathrm{m}$, nor with respect to height z.

4. Vegetation thermic coefficients and surface optical properties

Further inspection of the code revealed inconsistency in vegetation thermic coefficients. In ISBA they can be set individually via namelist NAMPHY1 array RCTVEG(1:18). Common default value is 0.8×10^{-5}, but in ALARO-1 setup thermic coefficient of low vegetation RCTVEG(3) was increased to 1.1×10^{-5}. In SURFEX, however, vegetation thermic coefficients do not react to RCTVEG setting and they cannot be changed individually. Prescribed value in ARPEGE is 0.8×10^{-5} (same as ISBA default), while in AROME it is 2.0×10^{-5}. The choice is done by the logical key LARP_PN in EXSEG1.nam namelist MODD_SURF_ATM. Default value is LARP_PN=F (AROME setting), that is why all previous comparisons were contaminated by much bigger vegetation thermic coefficients on SURFEX side. In order to get the same values on both sides, RCTVEG was kept at default value in ISBA, and corresponding ARPEGE setting LARP_PN=T was used in SURFEX. Figure 4.1 shows how the consistent setting of vegetation thermic coefficients affected the difference between SURFEX and ISBA runs. Difference on the right panel is generally smaller than on the left panel (see e.g. Great Britain, Italy, Romania and Bulgaria, or NE part of Belarus), but it is still too big.

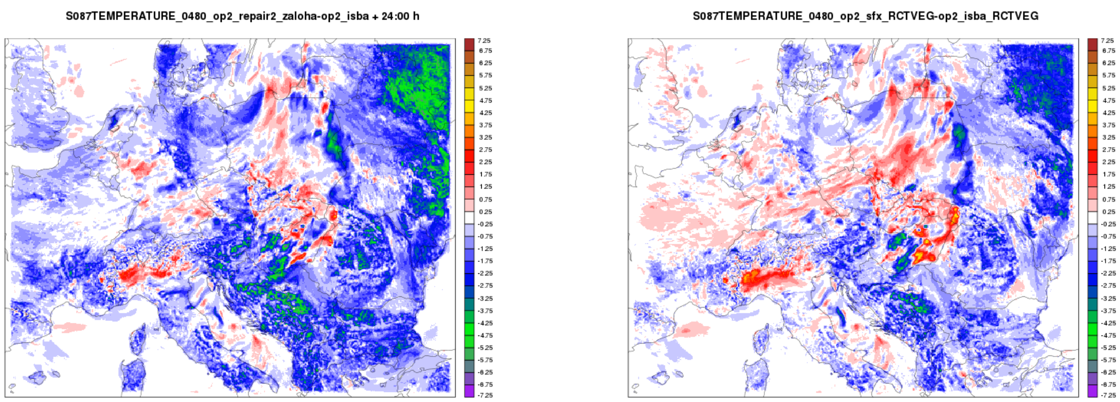

Figure 4.1: Difference in the lowest model level temperature: SURFEX run with fixed roughness averaging minus ISBA run. **Left:** LARP_PN=F, RCTVEG(3)=1.1E-05; **right:** LARP_PN=T, RCTVEG(:)=0.8E-05. Base time 10-Jul-2017 00 UTC, 24 hour forecast.

Another possible reason for the big difference between SURFEX and ISBA runs could be caused by radiation, since the surface optical properties in the two runs are not identical. To ensure the same surface radiative forcing, constant albedo and emissivity were hardcoded in subroutine APLPAR. Results are ploted on figure 4.2. Roughness averaging and vegetation thermic coefficients being the same, unified surface optical properties (right panel) do not bring SURFEX and ISBA runs closer.

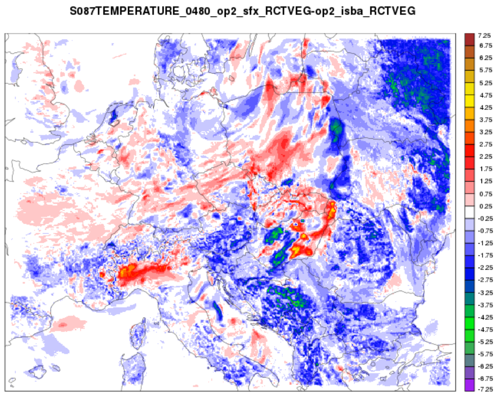

Figure 4.2: Difference in the lowest model level temperature: SURFEX run with fixed roughness averaging minus ISBA run. Vegetation thermic coefficients in both runs were 0.8×10^{-5}. **Left:** albedo and emissivity from ECOCLIMAP dataset in SURFEX, and from e923 dataset in ISBA; **right:** constant albedo 0.2 and emissivity 1.0 in both SURFEX and ISBA. Base time 10-Jul-2017 00 UTC, 24 hour forecast.

5. Conclusions

Systematic use of effective mechanical roughness and correct roughness averaging were implemented locally in cy43t2_bf.09 with SURFEX version 8.1. However, they did not remove substantial differences between SURFEX and ISBA runs, seen in the lowest model level temperature. Differences were slightly reduced by unified setting of vegetation thermic coefficients. They are assumed still too big to be explained by different physiogeographic datasets used in SURFEX and ISBA. Test with identical surface optical properties did not help as well. There is still a major difference between ALARO-1 runs with SURFEX and with directly called 2-level ISBA scheme, that should be subject to further investigation.

6. Appendix

List of SURFEX subroutines containing approximate logarithmic expressions for drag and heat coefficients:

AVERAGE1_MESH	... `Sfx/SURFEX/average1_mesh.F90`
MAKE_AVERAGE_Z0	... `Sfx/SURFEX/average_diag.F90`
AVERAGE_DIAG_ISBA_n	... `Sfx/SURFEX/average_diag_isban.F90`
AVERAGE_PHY	... `Sfx/SURFEX/average_phy.F90`
AV_PGD_1D, AV_PATCH_PGD_1D	... `Sfx/SURFEX/av_pgd.F90`
AV_PGD_2D, AV_PATCH_PGD	... `Sfx/SURFEX/av_pgd.F90`
AV_PGD_PARAM	... `Sfx/SURFEX/av_pgd_param.F90`
COARE30_FLUX	... `Sfx/SURFEX/coare30_flux.F90`
COUPLING_FLAKE_n	... `Sfx/SURFEX/coupling_flaken.F90`
COUPLING_ISBA_SVAT_n	... `Sfx/SURFEX/coupling_isba_svatn.F90`
COUPLING_SEAFLUX_n	... `Sfx/SURFEX/coupling_seafluxn.F90`
COUPLING_TEB_n	... `Sfx/SURFEX/coupling_tebn.F90`
DIAG_INLINE_ISBA_n	... `Sfx/SURFEX/diag_inline_seafluxn.F90`
SSO_Z0_FRICTION_n	... `Sfx/SURFEX/sso_z0_frictionn.F90`
SURFACE_CD	... `Sfx/SURFEX/surface_cd.F90`
URBAN_EXCH_COEF	... `Sfx/SURFEX/urban_exch_coef.F90`
Z0EFF	... `Sfx/SURFEX/z0eff.F90`
Z0V_FROM_LAI_0D,1D,2D	... `Sfx/SURFEX/z0v_from_lai.F90`

Bibliography

[1] Dian, M., and Mašek, J., 2018: Investigating SURFEX in ALARO-1 (roughness flow from SURFEX to atmospheric model). *RC LACE stay report*, 12pp.