ALARO-1 with SURFEX - current status and plan

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1. Motivation

MAIN motivation is scientifically consistent transition from ISBA to SURFEX in ALARO-1. Code checks on ISBA side were performed, revealing several bugs and inconsistencies to be corrected. The issue of roughnesses was investigated.

Following terminology is introduced:

ISBA - ISBA scheme called directly from APLPAR
SURFEX - ISBA scheme called via SURFEX

The new roughness treatment in ISBA is:

LZ0THER – .F. excludes subgrid orography in thermal roughness (configuration e923; array SURFGZ0.THERM) .

LZ0HSREL – .T. assumes that subgrid orography is excluded in thermal roughness in array SURFGZ0.THERM; configuration 001.

It means that in:

thermal roughness: array SURFGZ0.THERM contains **micrometeorological** roughness - without subgrid orography

mechanical roughness: array SURFZ0.FOIS.G contains **effective** values - with subgrid orography:

$$z_0^{\mathrm{eff}} = \sqrt{(z_0)^2 + (z_0^{\mathrm{orog}})^2} \qquad (1)$$

The new treatment should correspond to SURFEX aproach, but it has to be checked.

2. Inspection of SURFEX roughnesses comparing with ISBA (LZ0THER = .F.)

On the fig. 1 (left column) ISBA roughness lengths 10*SURFGZ0.THERM/G (top left) and SURFZ0.FOIS.G/G (bottom left) are plotted. Maximum of multiplied thermal roughness is approx 2 metres so it is micrometeorological value. Maximum of mechanical roughness is aprrox 100 metres in the hilly areas so it is effective value.

On the right column on the fig. 1 SURFEX roughness lengths from ICMSH SURFFEX (SFX) file: field X001Z0VEG - micrometeorological mechanical roughness (top right) and expression $\sqrt{X001Z0VEG^2 + SFX.Z0REL^2}$ - effective mechanical roughness (bottom right) are plotted. Comparing with ISBA roughnesses are in the same scale but are more horizontally detailed.

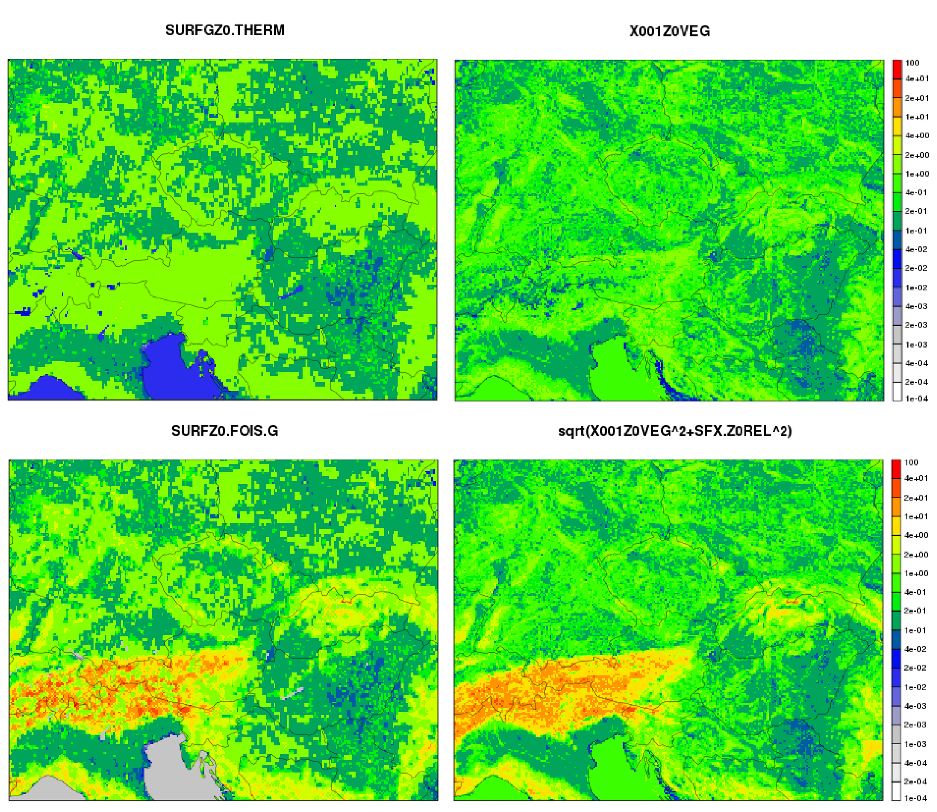

Figure 1: *Comparison of roughness lengths in clim files. Left column: ISBA side. Right column: SURFEX side. Top row: thermal roughness. Bottom row: mechanical roughness. Figure shows that thermal roughness is without subgrid orography while mechanical roughness includes subgrid orography. ISBA used old GTOPO30 database while SURFEX used new GMTED2010 database.*

3. Transfering of roughnesses from SURFEX to atmospheric part

Surface roughnesses are transferred to atmosperic model:
1) indirectly via exchange coefficients C_{D} and C_{H},
2) directly as the gridbox averages $z_{0\mathrm{D}}$ and $z_{0\mathrm{H}}$.

Both of them are evaluated by SURFEX in SURFACE_CDCH_1DARP as arrays PCD and PCH for drag and heat exchange coefficients and PZ0EFF and PZ0H for drag and heat roughnesses respectively.

For default SURFEX namelist default snow scheme 'D95'[2] is used and array PZ0EFF contains micrometeorological value, see fig. 2 (top left).

The next investigation was thus dedicated to the origin of roughness values entering subroutine SURFACE_CDCH_1DARP via argument PZ0EFF. Their calculation is performed in SURFEX subroutine Z0EFF. In order to enter desired code branch TSNOW%SCHEME='EBA'[1] and HROUGH='Z01D' (isotropic roughness), it is necessary to take two steps:

1) Specify 'EBA' snow scheme in configuration EE927 when preparing initial sfx file. This is done via namelist PRE_REAL1.nam:

```
&NAM_PREP_ISBA_SNOW
  CSNOW='EBA',
/
```

2) Ensure that argument HROUGH='Z01D' enters subroutine Z0EFF. This is achieved by following setting in integration namelist EXSEG1.nam:

```
&NAM_ISBAn
  CROUGH='Z01D',
/
&NAM_SSOn
  CROUGH='NONE',
/
```

Setting CROUGH='Z01D' in both &NAM_ISBAn and &NAM_SSOn would result in subroutine Z0EFF receiving argument HROUGH='NONE'.

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 ARO_GROUND_DIAG are corrupted, see fig. 2 (bottom left). The reason is in gridbox averaging roughnesses.

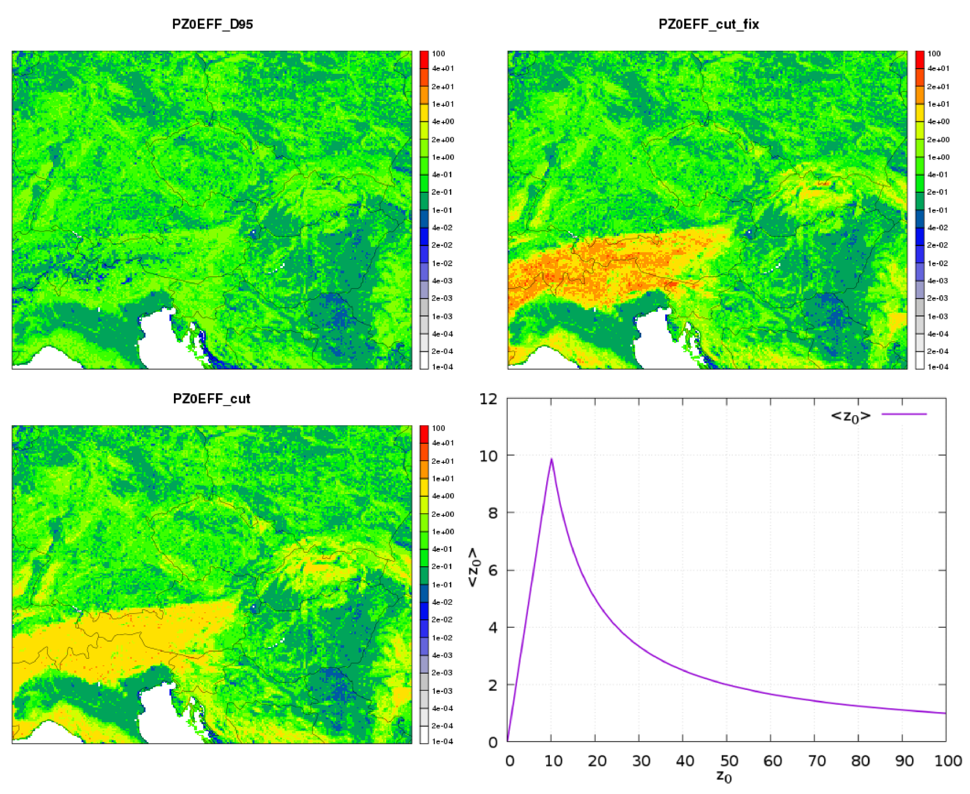

Figure 2: *Comparison of array PZ0EFF entering SURFEX subroutine SURFACE_CDCH_1ARP. Top left: default snow scheme 'D95' and HROUGH='NONE'. Bottom left: snow scheme 'EBA' and HROUGH='Z01D' (isotropic roughness) Top right: snow scheme 'EBA', HROUGH='Z01D' and fix of approximation in logarithmic expressions in eq.* (2)*. Bottom right: averaged roughness for single patch or tile, eq.* (4)*.*

4. Gridbox averaged roughness

Gridbox averaging formula in SURFEX routiness is :

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

and follows linear averaging of drag coefficient in neutrality:

$$C_{\mathrm{DN}} = \frac{\kappa^2}{\ln^2(1 + H/z_{0\mathrm{D}})}, \qquad (3)$$

provided that $H \gg z_{0\mathrm{D}}$. Reference height H is set to height of the lowest model full level. Typical value in ALARO is ~10 m. Therefore, $H \gg z_{0\mathrm{D}}$ holds for micrometeorological value of mechanical roughness $z_{0\mathrm{D}}$ which does not exceed ~2 m, but not for effective value which can easily exceed 10 m in high mountains like the Alps.

For gridbox averaging for single patch or tile eq. (2) should be reduced to identity:

$$z_0 = \begin{cases} (z_0)_1 & (z_0)_1 < H, \\ \dfrac{H^2}{(z_0)_1} & (z_0)_1 > H. \end{cases} \qquad (4)$$

It means that identity is ensured only for $(z_0)_1 < H$, but for $(z_0)_1$ growing beyond this limit z_0 starts to decrease, fig. 2 (bottom right).

After replacing approximation $\ln[H/(z_0)_i]$ by $\ln[1 + H/(z_0)_i]$ in all ~ 17 averaging SURFEX routines PZ0EFF is array of effective values of mechanical roughness also over Alps, see fig. 2 (top right).

5. Other problems with averaging roughnesses

Issues with snow-nosnow averaging in routine Z0EFF were found.

Roughnesses with snow are calculated as follows:

$$\begin{aligned} z_{0D} &= f_{D\mathrm{snow}} a_1 + (1 - f_{D\mathrm{snow}})(z_{0D}^{\mathrm{nosnow}}), \\ z_{0H} &= f_{H\mathrm{snow}} a_1 + (1 - f_{H\mathrm{snow}})(z_{0H}^{\mathrm{nosnow}}), \\ z_{0EFF} &= Z_{0D} + Z_{0REL}, . \end{aligned} \qquad (5)$$

where linear formulas and more snow fractions $f_{D\mathrm{snow}}$, $f_{H\mathrm{snow}}$ were used. Repairing eq. (5) by:

$$\begin{aligned} z_{0D} &= \sqrt{f_{\mathrm{snow}}(a_1)^2 + (1 - f_{\mathrm{snow}})(z_{0D}^{\mathrm{nosnow}})^2}, \\ z_{0H} &= z_{0D}/10, \\ z_{0EFF} &= \sqrt{Z_{0D}^2 + Z_{0REL}^2}, \end{aligned} \qquad (6)$$

we get averaged roughnesses by fixed quadratic formulas with single snow fraction f_{snow} according to ISBA.

6. Lowest model level temperature difference

Comparison of the lowest model level temperature between SURFEX after fixing logarithmic expressions in gridbox averagaging in section 4. and ISBA was tested. After one hour of integration there are large areas with difference $\sim 2K$, fig. 3 (left). After 24 hours the difference is much bigger $\sim 5K$, fig. 3 (right).

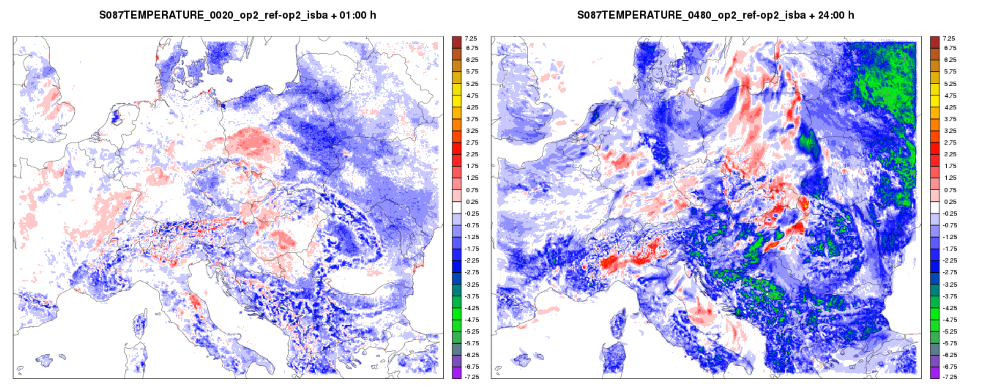

Figure 3: *Comparison of the lowest model level temperature between SURFEX after fixing logarithmic expressions in gridbox averagaging and ISBA. Base time 2017-07-10 00. Left: forecast +01h. Right: forecast +24h.*

Summary of listed issues:

Mechanical roughness is without subgrid orography with default 'D95' snow scheme and 'Z01D' isotropy.

Serious problem with roughness averaging in SURFEX was found.

Experiments with constant emissivity and albedo on ISBA and SURFEX was performed with negligible difference in lowest model temperature (not shown).

Different RCTVEG (vegetation thermal coefficient) values were corrected in SURFEX and ISBA leading to only slight difference in lowest model temperature (also not shown).

Other differences in some fields between ISBA and SURFEX remain unclear.

References

[1] E. Bazile, et al., HIRLAM 5 Project, 14–19 (2002).
[2] H. Douville et al., Clim. Dyn., 12, 21–35 (1995).

THIS work was done on NEC machine in Prague, using locally ported ARPEGE/IFS cycle 43t2 bf.08 with SURFEX version 8.1 within RC LACE stays.