Prague, 08.12.2023

Report on

TESTING SOIL AND SNOW SCHEMES IN SURFEX IN ALARO

Author: Gabriel Stachura, IMGW
Supervisor: Ján Mašek, CHMI

Introduction

The report sums up the work which has been done during a research stay in Prague in November and December 2023 (4 weeks). The stay was a part of the SU3.3 task in the RWP2023. For a few years, a lot of effort has been put in the LACE community to couple ALARO with SURFEX. In general, this is nearly completed, however, SURFEX contains plenty of submodels and schemes, some of which are interesting for NWP but they have not been tested in ALARO yet. For example, within ISBA scheme (nature tile), so far only composed (single-layer) snow models have been used, together with a force-restore approach in modeling of physical processes in the soil. Therefore, the main goal of our investigations was to test the functionality of a multilayer snow scheme and the diffusive soil scheme in ALARO, and to compare them against simpler schemes.

ISBA schemes used in the experiments

In case of snow, our reference is a single-layer bulk snow scheme called EBA. The multilayer snow scheme we tested is the Explicit Snow scheme (ES) with 3 snow layers. Our experiments do not involve Crocus scheme due to its higher complexity, not suitable for NWP usage. As for soil modeling, the force-restore approach with 3 layers is the reference scheme, while the diffusion scheme with 14 layers is a subject of our tests.

Running SURFEX inline with ALARO

The process of producing forecast of ALARO coupled with SURFEX consists of three stages (Fig. 1). At first, a PGD file (PhysioGraphy Data) in the FA format needs to be produced by PGD executable. At this stage, topography, land covers and soil schemes are defined. Selection of a soil scheme is made in the namelist NAM_ISBA under the key CISBA. It is important to be reminded that besides horizontal 2D files, a complete PGD file involves also miscellaneous records of different kind and length, e.g. buffer fields (SFX_BUF*). Initially, our PGD files were missing them and we could not proceed. However, after we switched executable from 46t1_bf.06 to cy46t1_op1.18, we managed to produce the complete PGD file. Then, one more modification is required – for consistency with atmospheric model, elevation field SFX.ZS has to be copied from SURFGEOPOTENTIEL field of operational climate file and divided by gravity acceleration g=9.80665m/s.

The second stage involves interpolation of surface prognostic fields from the driving model and their writing into surface initial file (so called PREP file) in FA format. It can be performed either by PREP executable (SURFEX to SURFEX file), or by FULLPOS-PREP configuration (ISBA to SURFEX file; our case). Apart from standard FULLPOS namelist file fort.4, a separate PREP namelist file PRE_REAL1.nam is required. Here one can specify e.g. which snow scheme is used (namelist NAM_PREP_ISBA_SNOW), or to define uniform initial soil temperature and humidity for idealized tests (namelist NAM_PREP_ISBA). All namelist keys which were modified during the experiments are listed in the diagram. Apart from surface initial file, standard atmospheric initial file prepared by FULLPOS configuration E927 is needed.

In the third stage, when the initial files are ready, the forecast can be produced. Within a SURFEX integration namelist file EXSEG1.nam, it is possible to specify some physical parameters, e.g. a critical value of snow water equivalent (XWCRN in namelist NAM_SURF_ATM) needed for calculation of the snow fraction in EBA scheme. Please note that this key has been so far not available in public realeases of SURFEX and the hardcoded value of 10kg/m2 was used. A separate namelist file fort.4 for an atmospheric model is also necessary. Additional inputs include PGD file and ECOCLIMAP covers parameter files. At every output step, two historical files are produced – one with atmospherics fields and one containing surface fields (*.sfx).

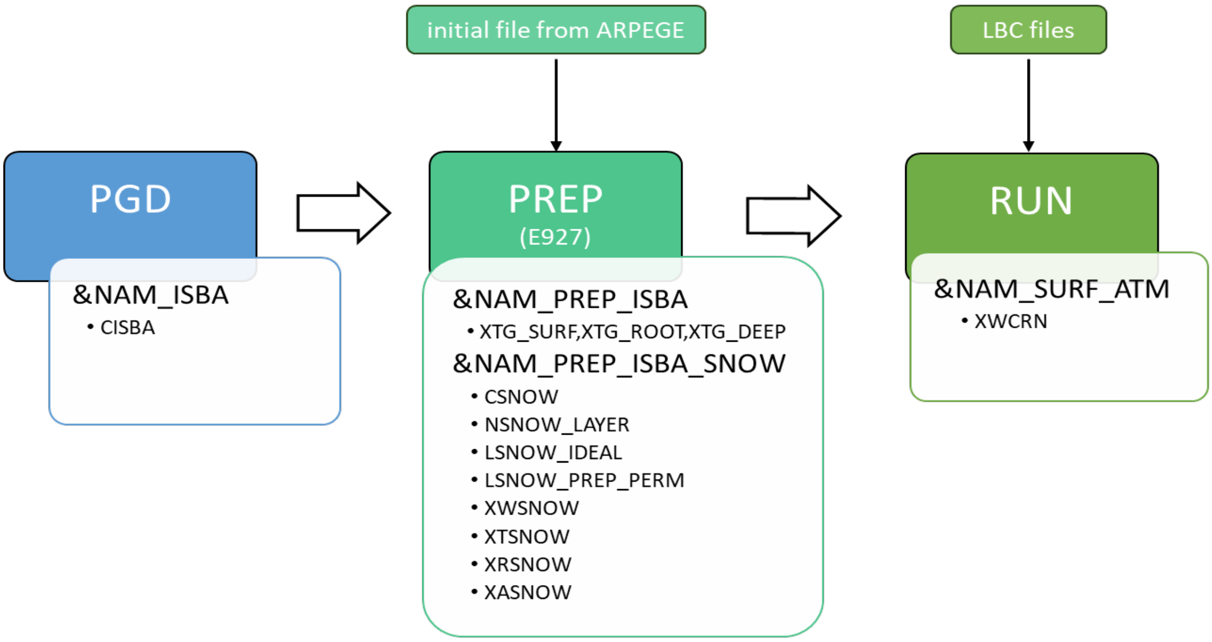


Fig. 1 Flowchart of running forecast in ALARO coupled with SURFEX. All namelists keys which were modified during the experiments are listed in frames.

Computational environment and model configurations

PGD and initial files were created in Météo-France on belenos, while forecasts were produced on local CHMI machine lada1. The baseline model cycle was cy46t1, including necessary fixes for running ALARO with SURFEX.

Experiments setup

As we expected that ES scheme should improve forecasting minimum air temperature over snow, we chose forecast timeframe that involves a winter episode of high pressure system within our domain. On 10th January 2017, there was a high with a center over Ukraine affecting most of the Central Europe (from Poland to Romania), while in western Europe, advection of warm air occurred. Therefore, we chose our initialization time to be 10th January 2017 12 UTC. The forecast length was 72h.

Initially, we aimed to carry out experiments with different combinations of snow and soil schemes with initial information about snow cover taken from the driving model ARPEGE, as it is done for other fields in a dynamical adaptation mode. Unfortunately, we were not able to initialize ES fields in this way. The problem comes from a lack of information about snow age, and from a missing algorithm for splitting integral snow cover characteristics (total snow water equivalent and average snow density) into multiple layers (there is no problem for EBA scheme, since it requires only fields available in ISBA file).In order to evaluate impact of ES scheme versus EBA scheme at least in idealized environment, we had to initialize snow cover for both schemes manually by defining horizontally uniform snow fields in the namelist NAM_PREP_ISBA_SNOW. To enable it, it is necessary to set LSNOW_IDEAL = T. We consider two different amounts of snow (XWSNOW): 10 kg/m^2 and 100 kg/m^2. Initial values of fields are given in Tab. 1. As for vertical variability (only in the ES scheme), the total snow water equivalent (SWE) is split between layers by the model, while the rest of the properties is vertically uniform. To ensure comparability, we also set ground temperature to 0°C in all soil layers. Additionally, we turned off a special initialization of snow over glaciers (LSNOW_PREP_PERM=F).

exp	CSNOW	CISBA	NSNOW_ LAYERS	XWSNOW [kg/m^2]	XRSNOW [kg/m^3]	XASNOW [1]	XTSNOW [K]	XTG_* [K]	XWCRN [kg/m^2]
1	EBA	3-L	-	10	100	0.85	273.15	273.15	4
2	3-L	3-L	3	10	100	0.85	273.15	273.15	4
3	3-L	DIF (n=14)	3	10	100	0.85	273.15	273.15	4
4	EBA	3-L	-	100	100	0.85	273.15	273.15	10
5	3-L	3-L	3	100	100	0.85	273.15	273.15	10

Tab. 1 A list of experiments and their namelist settings. Following abbreviations are used to denote meteorological fields or parameters: XWSNOW – water content, XRSNOW – snow density, XASNOW – snow albedo, XTSSNOW – snow temperature, XTG_* - temperature in a soil layer, XWCRN – critical value of the snow water content

Results

At first, we present results with initial snow depth equal to 10 cm (experiments 1-3 in Tab 1.). As we compared ES and EBA radiative temperature over nature tile (Fig. 2), we noticed some significant deviations that vary in sign and value with regard to hour of the day and the presence of snow. At night and in the morning, this temperature in ES is lower than in EBA over the areas covered with snow. This is especially significant during stable atmospheric stratification, when the radiative cooling prevails. We can see that the forecast temperature at 6:00 UTC for Poland, Czechia and Hungary is locally more than 10°C lower than in case of EBA. This can also be seen in Fig. 3 at the forecast for Prague. The drop of temperature for ES with diffusive soil scheme is by 1-2°C smaller than the basic ES, but generally the forecasts are very similar. Another deviation between ES and EBA occurs in western Europe, where a thaw started immediately. It turns out that ES melts snow faster than EBA, which is especially distinct if we look at a point forecast for Paris (Fig. 3). Moreover, it is worth to notice that in ES it is possible to have surface temperature above 0°C despite the presence of snow cover, while in EBA it cannot exceed this threshold until snow melts completely.

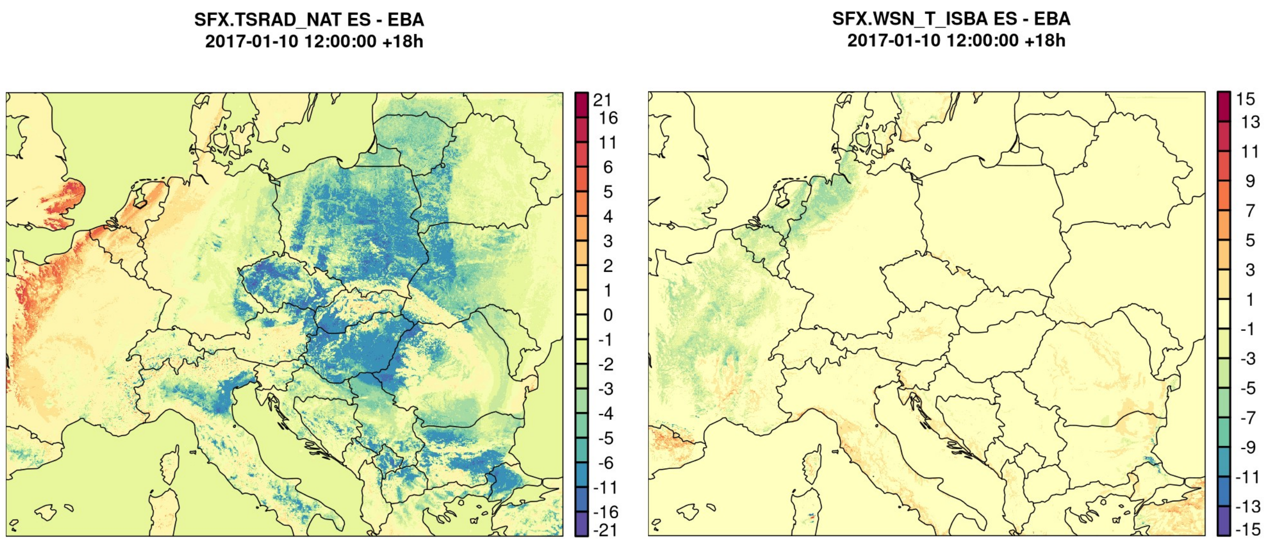


Fig. 2 Difference in radiative temperature of nature tile [in °C] and total snow water content [in kg/m^2] between ES and EBA.

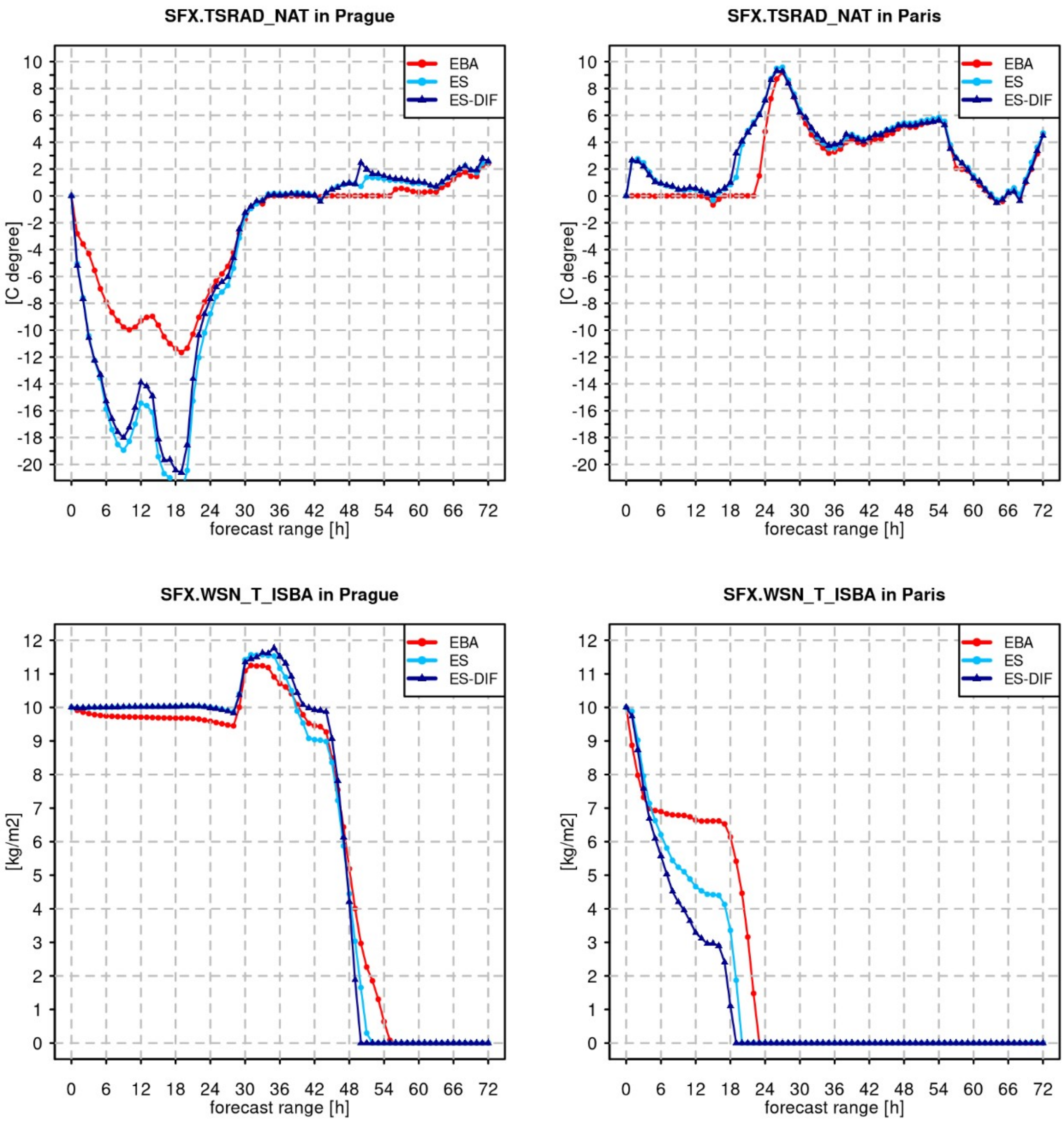
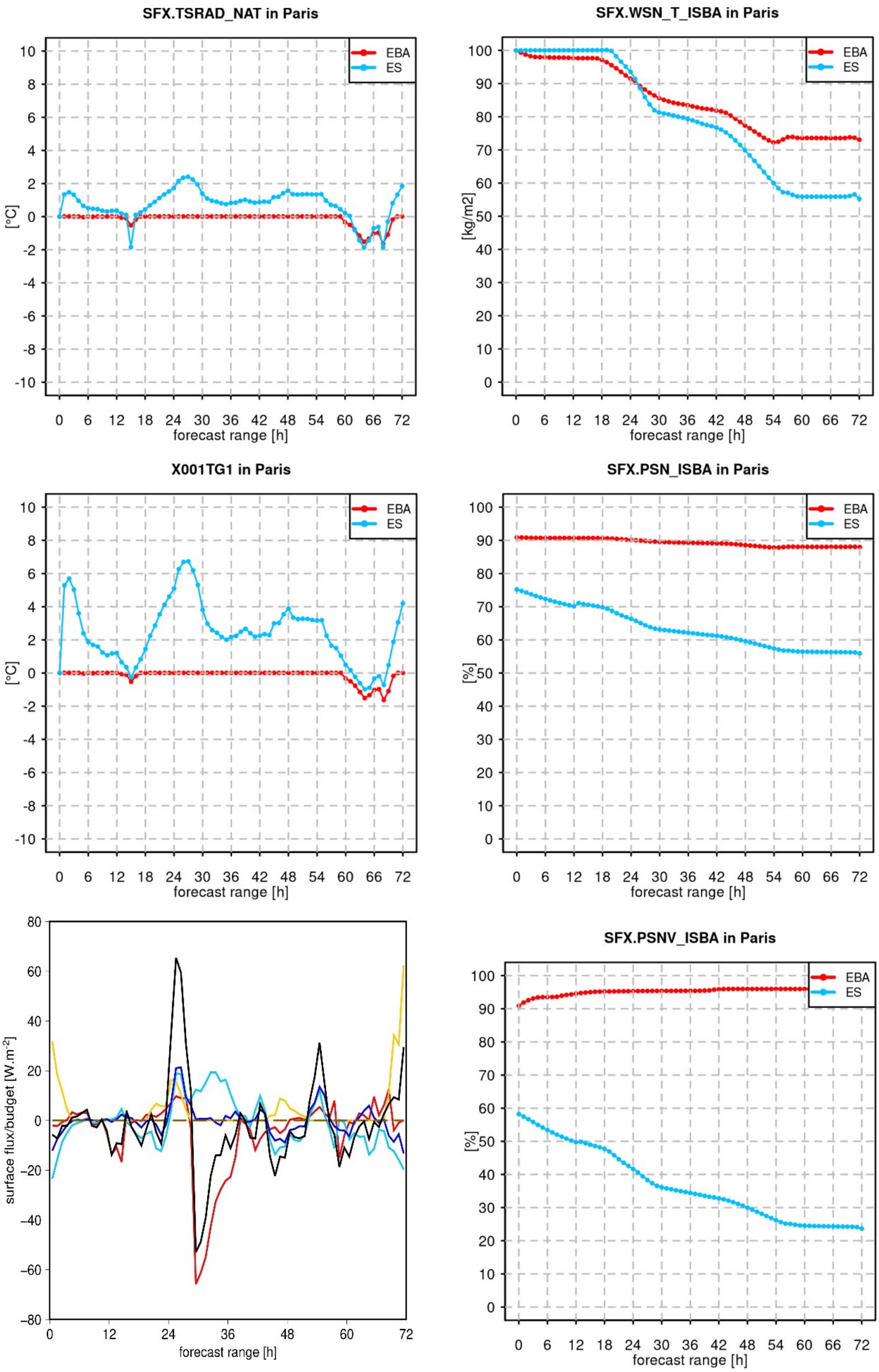


Fig. 3 Forecasted evolution of radiative temperature and total snow water content for Prague (left) and Paris (right).

In search of reasons for the above mentioned deviations, we decided to modify our experiment and increase the amount of snow to 100 cm. This time we do not consider ES with diffusive soil scheme – we compare only snow schemes combined with force-restore method (experiments 4-5 in Tab. 1). Also, in order to enhance comparability regarding snow fraction between EBA and ES, we set the critical value of SWE to 10 kg/m^2. Temporal evolution of selected meteorological fields for Paris is depicted in Fig. 4. The snow persists through the whole forecast length, however ES melts it faster than EBA. It is especially distinct in the daytime (leadtimes: 20-30,44-54 hours), while at night the melting rate is roughly similar. We can see that surface radiative temperature over nature tile in ES remains above 0°C for most of the time. It is even more pronounced for the ground temperature in the uppermost soil layer. This might be to some degree explained by lower total snow fraction in ES and than in EBA. There is 20-30% of snow-free area of a gridbox, which strongly absorbs solar radiation during the daytime . From the other side, in EBA there is also around 10% of snow-free ground, but the composed energy budget for the upper soil layer, vegetation and snow does not allow the temperature to exceed 0°C as long as there is any snow. However, not only ground can absorb solar radiation – also vegetation may play significant role here.



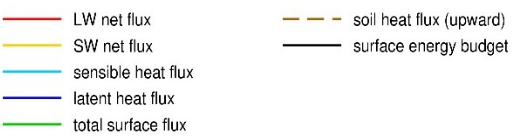


Fig. 4 From upper left: Evolution of forecast surface radiative temperature over nature tile, total snow water content, ground temperature in the uppermost layer, total snow fraction, difference of surface energy budget (ES - EBA) and snow fraction over vegetation.

While inspecting snow fraction, we also looked at snow fraction over bare ground and over vegetation. While the former decays for both snow schemes, the latter increases in case of EBA (Fig. 4 bottom right). It becomes larger than the snow fraction over the bare ground, which is not possible by construction. Therefore, we suspect a bug in diagnostics, to be investigated later.

The last thing we did to better understand the differences in surface temperature was plotting the difference of surface energy budget between ES and EBA (Fig. 4 bottom left). We are especially interested in forecast range 24-30h, when the greatest deviations occurred. We can see that during daytime surface energy budget in ES was by 70 W/m^2 greater than in EBA. This difference cannot be attributed to a single component – all sensible heat flux, latent heat flux, LW and SW heat fluxes were by 10-20 W/m^2 bigger. In the evening, the difference switched rapidly to negative values – the surface loses more heat in ES than in EBA. This was mostly caused by large discrepancy in LW net flux (by 60 W/m^2), which seems to indicate differences in cloudiness. We checked the evolution of total cloudiness (not shown here). In general, both snow schemes predict it very similar, but there was one large difference that occurred for 30h forecast. At that time, EBA was fully overcast while ES only to 20%. This matches the peak seen in LW cooling and it is a likely explanation of the observed deviation in the surface temperature.

Conclusions

Our experiments revealed some significant differences between forecasts produced with ES and EBA schemes, which concern melting rate and surface temperature evolution. Snowmelts occurs faster in ES, which is especially distinct during daytime. This may be partly caused by the fact that ES enables surface temperature to be above 0°C in the presence of snow. During clear-sky nights, the surface temperature in ES drops much more than in EBA due to radiative cooling. As ALARO often overestimates minimum temperature in such conditions, this feature is desirable. However, one should perform verification against observed values to be sure if the cooling is not too excessive. The experiments carried out in this study could not be verified because of artificial initialization of snow fields. Therefore, the primary issue to tackle is finding (or creating) a tool for transforming one-layer snow fields from an atmospheric initial file to N-layer snow fields that could be handled by ES and eventually CROCUS snow schemes. Having such tool would enable us to run the experiments in a dynamical adaptation mode. It is not so important for operational usage, where the data assimilation with the cycling of snow is supposed, Now the priority should be a better understanding of identified temperature, snowmelt and snow fraction issues, since the longer-term impact of altered snow accumulation can be very significant, affecting surface energy and water budgets.