Sensitivity study of the UHI in the city of Szeged (Hungary) to different offline simulation set-up using SURFEX/TEB

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1. Introduction

SURFEX (*Le Moigne*, 2009) is an externalised land surface model describing interactions between the atmosphere and four main surface types, namely natural land surface, inland water, sea and town. Due to the specific urban parameterization scheme used in Town Energy Balance (TEB) module (*Masson*, 2000), this model is capable of simulating the modifying effect of artificial surfaces on regional climate. In our study we performed several short range simulations with SURFEX over Szeged (Hungary; Fig. 1) for a heatwave period in July 2010. SURFEX was coupled to ALARO numerical weather prediction model (Fig. 2) applied also for climate studies at the Royal Meteorological Institute of Belgium (RMI). Our aim was to investigate the effect of the different simulation set-ups (Table 1) on the performance of urban heat island (UHI) in order to adjust SURFEX for long term climate runs.

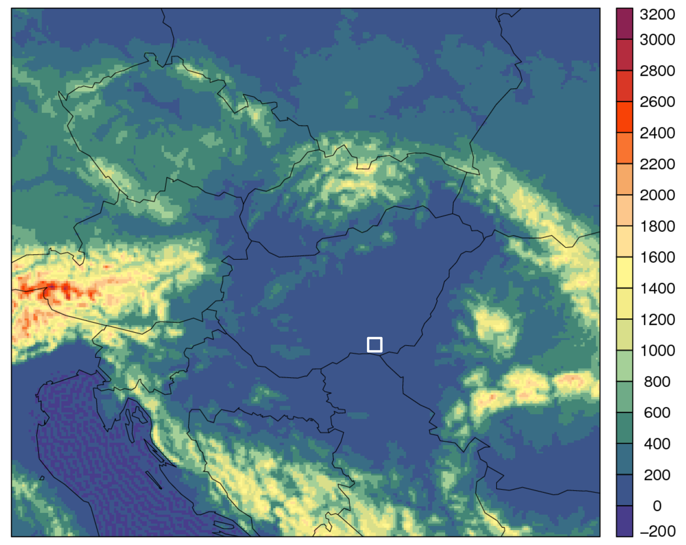


Fig.2. Integration domain of the 4 km resolution ALARO. White square indicates the domain of the 1 km resolution SURFEX offline run.

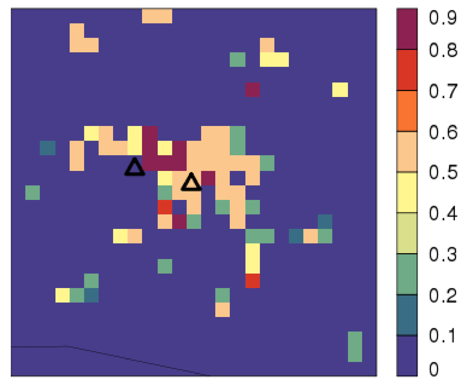


Fig. 1. Fraction of urbanised areas in grid cells according to the ECOCLIMAP (*Masson et al.*, 2003). Triangles: reference gridpoints that are the closest ones to the urban and rural observational stations.

Table 1. Main characteristics of the achieved SURFEX simulations.

Acronym	TEB_ALARO_4KM_1H | TEB_ALARO_4KM_3H | ISBA_ALARO_4KM_1H | ISBA_ALARO_4KM_3H	TEB_ALARO_10KM_1H | TEB_ALARO_10KM_3H | ISBA_ALARO_10KM_1H | ISBA_ALARO_10KM_3H
Atmospheric forcings of SURFEX	1 and 3 hourly outputs of 4 km resolution ALARO run	1 and 3 hourly outputs of 10 km resolution ALARO run
Schemes over urban tiles in ALARO	TEB / ISBA (rock)	
Lateral boundary conditions of ALARO	ERA-Interim driven 12 km resolution ALARO	
Computation methods of 2-m temperature	Diagnostic (Paulson, Geleyn, Canyon temperature) / Prognostic (CANOPY)	

References:

Le Moigne, P., 2009: *SURFEX Scientific Documentation*; Note de centre (CNRM/GMME), Météo-France, Toulouse, France. 211p.

Masson, V., 2000: A Physically-based Scheme for the Urban Energy Budget in Atmospheric Models. *Bound.-Layer Meteor.*, **94**, 357–397.

Masson V., J.-L. Champeaux, F. Chauvin, C. Meriguet and R. Lacaze, 2003: A global database of land surface parameters at 1km resolution in meteorological and climate models. *J. Climate*, **16**, 1261–1282.

3. Impact of forcing frequency: 1 h vs. 3 h

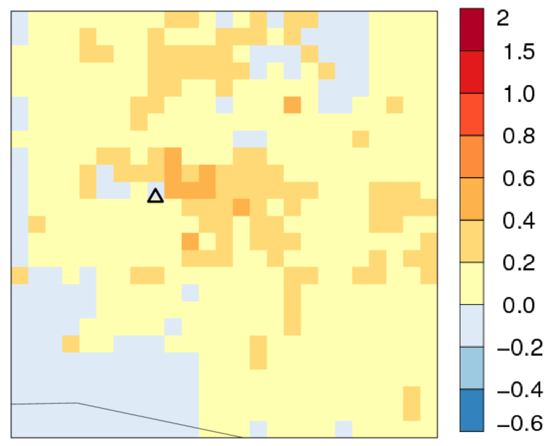


Fig. 5. Difference (in C) between UHI intensity at 21 UTC on 15 July 2010 derived from TEB_ALARO_10KM_1H and TEB_ALARO_10KM_3H. 2-m temperature from CANOPY scheme. Triangle: reference rural grid point.

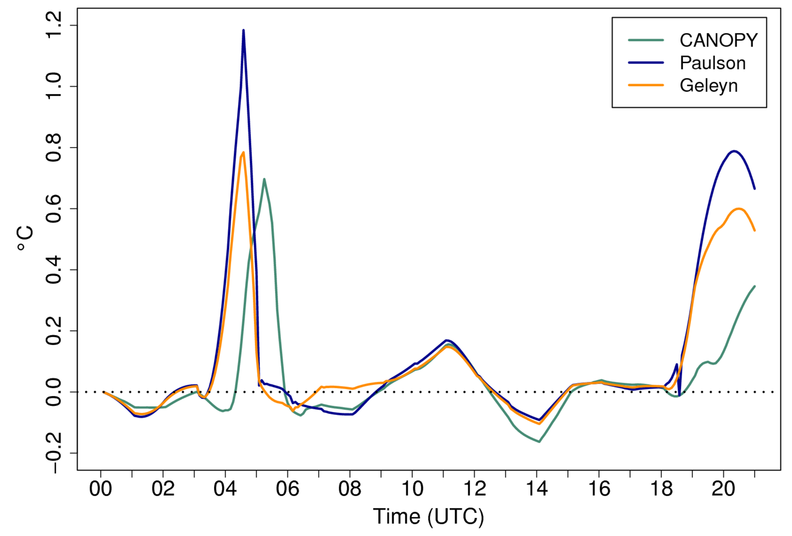


Fig. 6. Difference (in C) between UHI on 15 July 2010 derived from TEB_ALARO_10KM_1H and TEB_ALARO_10KM_3H. UHI was calculated between the two reference gridpoints.

- Stronger UHI intensity with the 1-hourly coupled forcings during sunrise and in the last hours of the day (Fig. 5 and 6). The difference is larger (above 0.5 C) with the diagnostic schemes.
- In these hours 2-m temperature is higher with the 3-hourly coupled forcings, and the difference in the rural point exceeds that in the urban point (not shown).
- Explanation: around sunrise, sunset and noon due to the linear interpolation between the steps of 3-hour forcings SURFEX cannot capture the nonlinear evolution of net radiation, thus net radiation is erroneously too high in this case, relatively most of all at sunrise and sunset (Fig. 7).

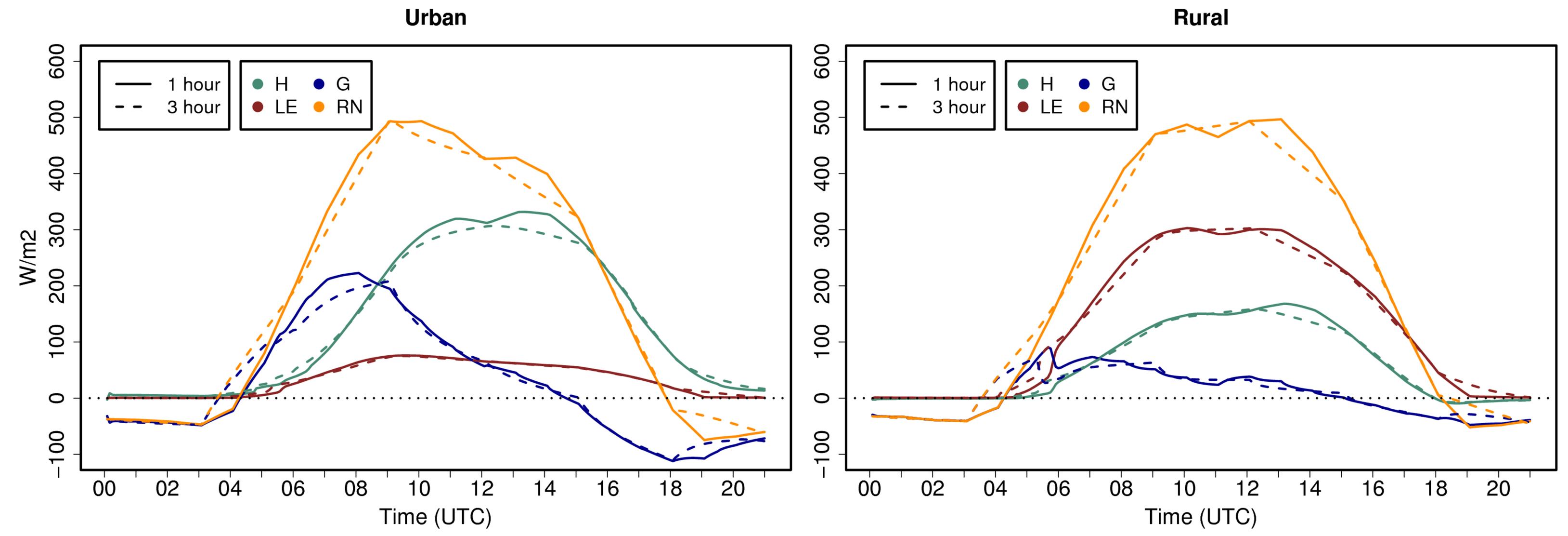


Fig. 7. Radiative fluxes (sensible (H), latent heat (LE), storage (G), and net radiation (RN) flux; in Wm-2) on 15 July 2010 in the urban (left) and rural (right) grid points according to the TEB_ALARO_10KM_1H (solid line) and TEB_ALARO_10KM_3H (dashed line). 2-m temperature from CANOPY scheme.

4. Impact of using TEB in ALARO

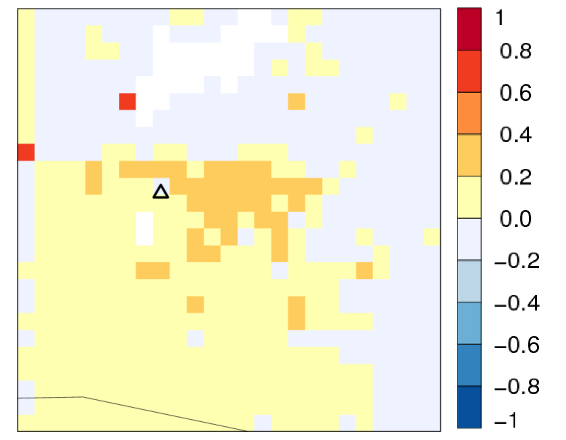


Fig. 8. Difference (in C) between UHI intensity at 21 UTC on 15 July 2010 derived from TEB_ALARO_10KM_1H and ISBA_ALARO_10KM_1H. 2-m temperature from CANOPY scheme. Triangle: reference rural grid point. White colour: grid points where the difference exceeds 1 C.

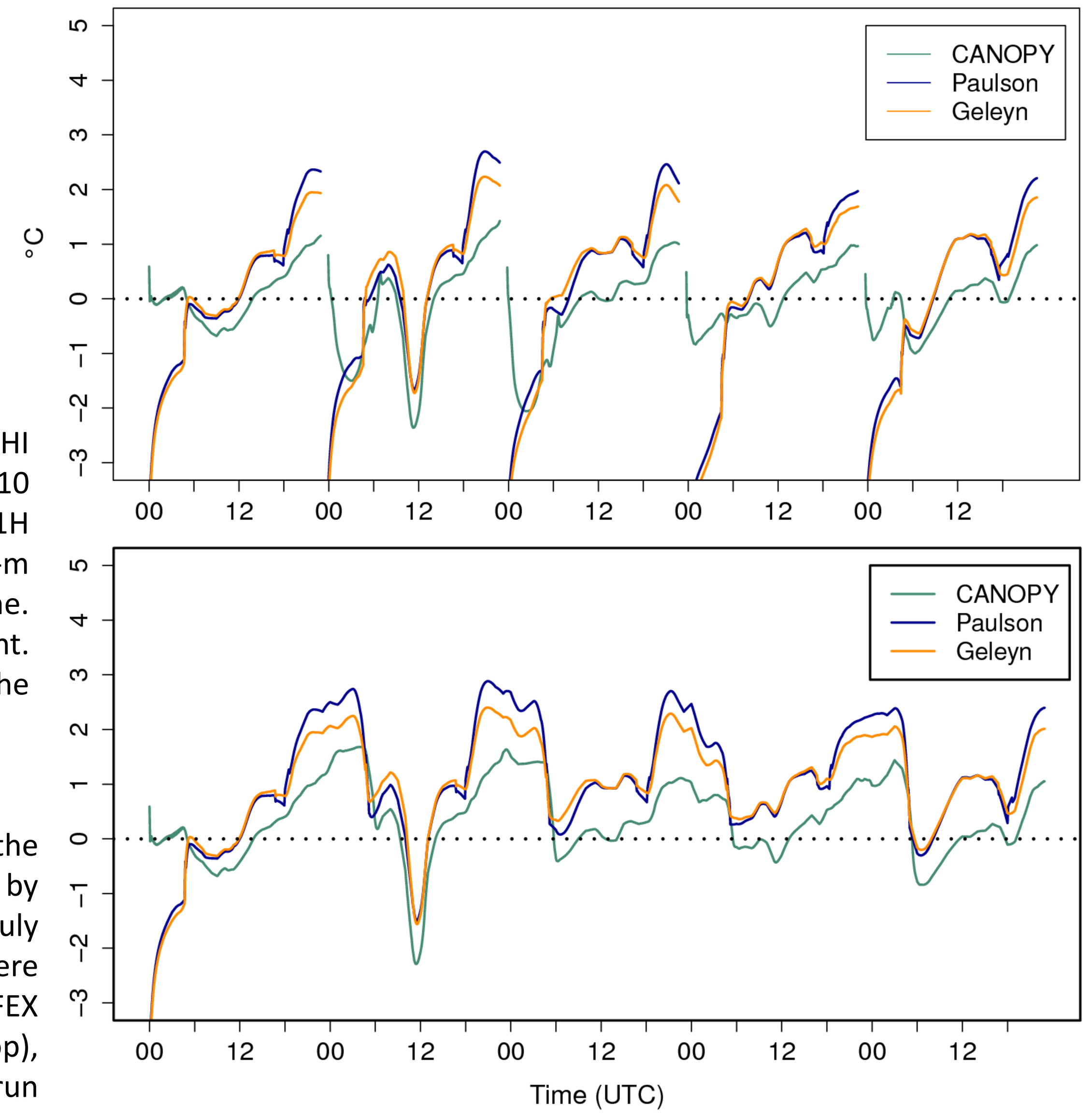


Fig. 9. UHI intensity (in C) between the two reference gridpoints simulated by ISBA_ALARO_10KM_1H for 13–17 July 2010. 36-hour ALARO runs were reinitialised each day at 12 UTC; SURFEX was initialised each day at 00 UTC (top), only on the first day and was run continuously (bottom).

- Slight enhancement (less than 0.5 C) of UHI intensity in the last hours of the day with TEB in ALARO (Fig. 8).
- If TEB is not turned on in the ALARO run, and SURFEX offline is reinitialised in each day, heavy negative, spurious UHI intensity occurred in the first 6 hours, especially if CANOPY is not used. It is an instable (equilibrium adjustment) behaviour of the model which is caused by the manually prescribed initial conditions for TEB. If SURFEX run starts at 00 UTC, approximately 6 hours are needed for TEB to reach its equilibrium (Fig. 9).
- If the forcing of SURFEX are derived from atmospheric model simulations without TEB, SURFEX should be run continuously without reinitialisation.

2. Impact of forcing resolution: 4 km vs. 10 km

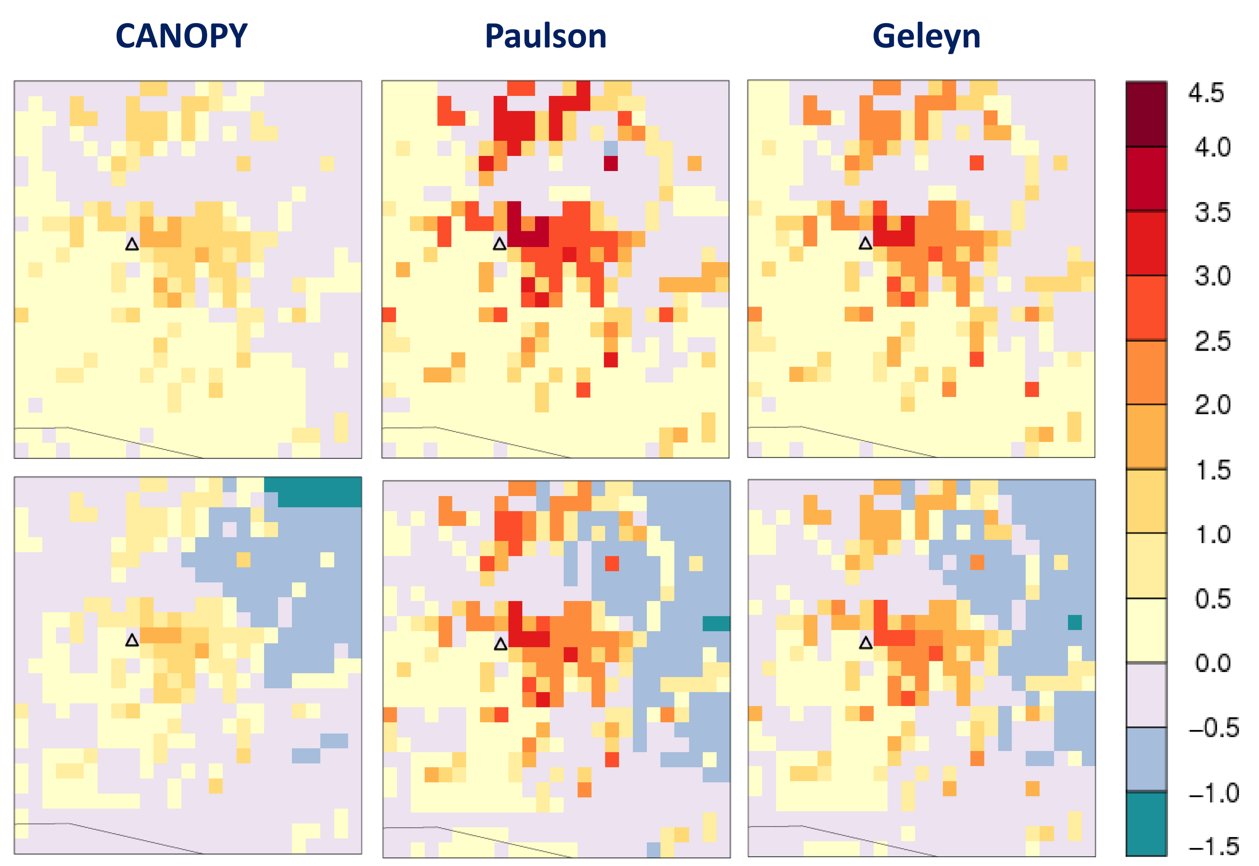
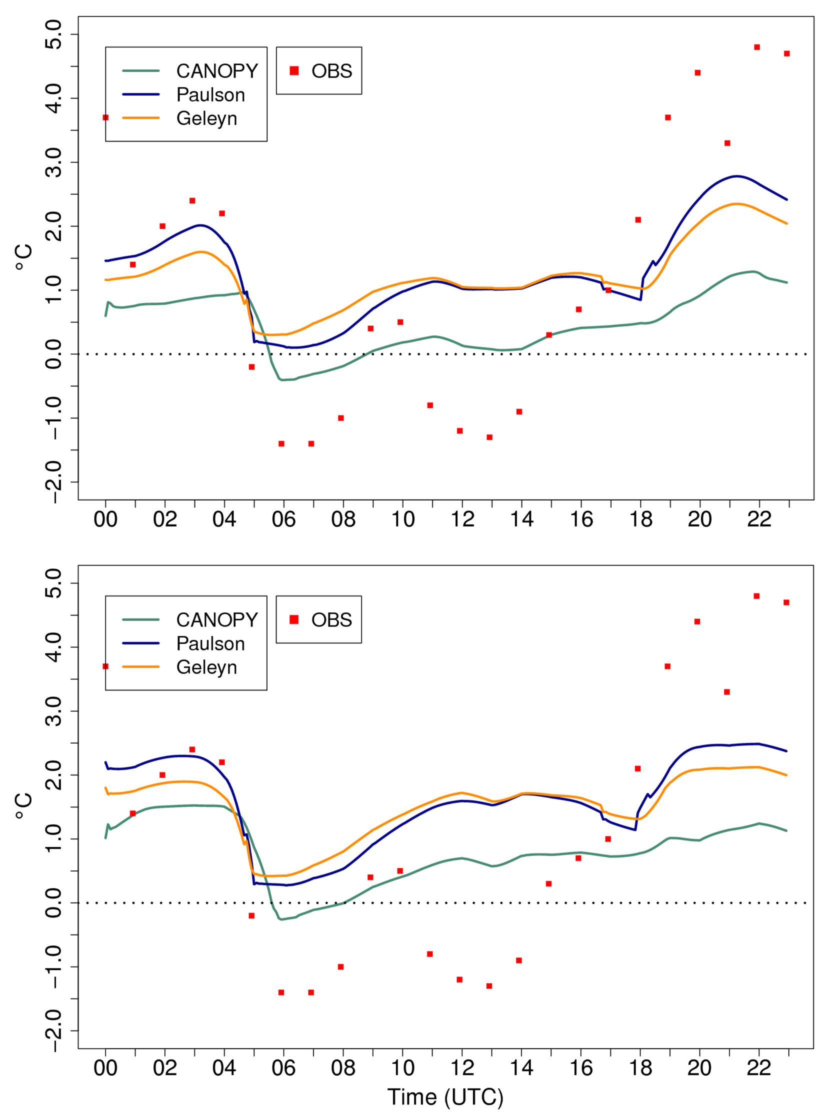


Fig. 3. UHI intensity (in C) at 21 UTC on 15 July 2010 simulated by TEB_ALARO_10KM_1H (top) and TEB_ALARO_4KM_1H (bottom). Triangles: reference rural gridpoint.



- Only small difference in UHIs between the simulations driven by the 10 km and 4 km resolution ALARO. At night slightly stronger (less than 0.5 C) UHI with 10 km resolution ALARO (Fig. 3 and 4).
- Underestimation of daily variability: under-/overestimation during the night /day.
- UHI obtained with the diagnostic schemes is higher throughout the whole day than with the CANOPY scheme.

Fig. 4. UHI intensity (in C) on 15 July 2010 between the two reference gridpoints simulated by TEB_ALARO_10KM_1H (top) and TEB_ALARO_4KM_1H (bottom). Red squares: hourly measurements.

5. Summary and outlook

- Stronger UHI intensity was obtained with the diagnostic (Geleyn, Paulson) schemes for calculating 2-m temperature compared with the CANOPY scheme.
- The more frequent forcing update caused amelioration in the strength of UHI intensity after sunset.
- Using the TEB scheme in ALARO resulted in slightly higher and more realistic UHI intensities in the end of the day.
- Considering longer SURFEX run, if TEB is not turned on in the ALARO, SURFEX should be run continuously in-stead of its daily reinitialisation to avoid spin-up time in the first couple of hours after start.

This preliminary sensitivity study is an important preceding step of long term climate simulations to achieve the most suitable model adjustments for our purpose.

Our future plan is to perform a similar study on a longer period (e.g. one month) and in different seasons to get more reasoned conclusions.

6. Acknowledgement

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