Preparations to high resolution run of ALARO+SURFEX

Gabriel Stachura (IMGW), Ján Mašek (CHMI)

1 Introduction

The report summarizes work which has been done during a 3-week stay in Prague in March 2026. The stay was a part of the SU3.9 task in the RWP 2026. Its main goal was to examine the potential added value of kilometric ALARO+SURFEX forecast (in terms of verification scores), and to evaluate its computational efficiency. Apart from that, some testing was also performed considering heat fluxes from industry and traffic sources. Additionally, some technical work has been done to port a new method for calculating surface direct albedo implemented by P. Sekuła (IMGW) in CY46T1, as well as to make the ORORAD parameterisation (according to Senkova et al., 2007) work with ACRANEB2 radiation scheme in CY48T3. The version of the ALARO+SURFEX model we worked on was based on CY48T3 (SURFEX 8.1+) and included latest developments and fixes provided by CHMI (e.g., Dian screen level interpolation inside SURFEX).

Following points are concerned in this report:

- sensitivity tests regarding impact of anthropogenic heat source from traffic and industry;
- necessary fixes to make ORORAD working in CY48T3;
- forecast accuracy assessment in increased horizontal resolution (1.25 km);

2 SURFEX configuration

Unless specified otherwise, Table 1 includes the basic namelist settings of SURFEX that were used during the experiments.

Table 1: SURFEX namelist settings used in the experiments

Parameter	value
CISBA	3-L
NPATCH	3
CTOWN	TEB
CSNOW	D95
LGARDEN	F
XTAU_SMELT	0
N2M	5
CALBEDO	CM13
XUNIF_H_TRAFFIC	0

3 Results

Sensitivity tests regarding anthropogenic heat sources

Anthropogenic heat sources include two contributions: traffic and industry. In SURFEX they are confined to certain land cover types. In the case of ECOCLIMAP first generation, these are land cover types number 151-158 (traffic), as well as 151-153 and 155 (industry). The default values of sensible heat flux are from 10 to 30 W/m^2 for traffic and from 5 to 20 W/m^2 for industry, depending on the cover type. The values can be changed at the stage of creating a PGD file via namelist keys XUNIF_H_TRAFFIC and XUNIF_H_INDUSTRIES under NAM_DATA_TEB. Although it is also possible to modify anthropogenic latent heat fluxes, we did not touch them as they are set to 0 W/m^2

by default, i.e. the anthropogenic sources do not add water vapor into the atmosphere (this setting may be disputable when the dominant heat source is combustion). The initial date of forecast start was set to 3rd September 2024 as there was a heat wave in Central Europe. Since anthropogenic sources add heat to the street canyon (traffic) or directly to the lowest model level (industry), we depict air temperature at the lowest model level in Fig. 1. We can see that at 6:00 UTC (one hour after traffic starts in SURFEX), the impact on the temperature is relatively low (up to around +1°C) and limited to large urban areas. However, as integration advances (e.g., +36h), the differences spread out further from the urban areas, particularly in areas where more dynamic meteorological conditions occur (e.g., frontal zone from the Balearic Islands to Denmark). Differences can increase locally up to 6°C there.

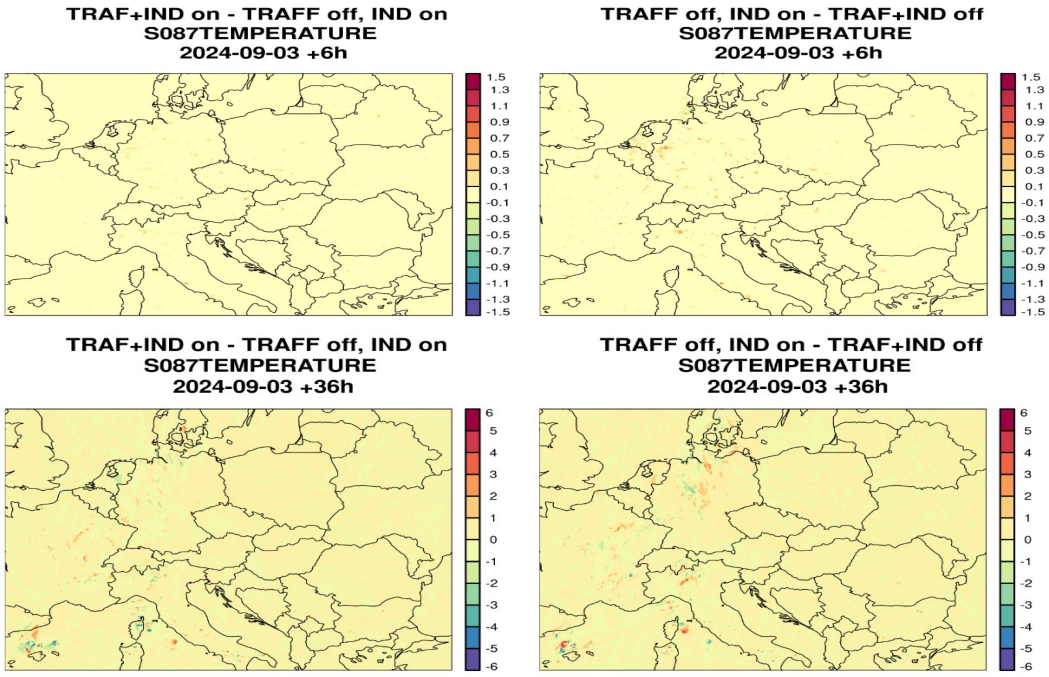


Figure 1: Spatial distribution of air temperature differences between specific experiments at the lowest model level at leadtime +6h (top) and +36h (bottom) as an impact of traffic heat sources (left) and of industry heat sources (right).

Essential fixes for ORORAD in CY48T3

ORORAD has become a desirable option in NWP as it makes spatial patterns of radiation fluxes more realistic in complex terrain. It was proposed and used by colleagues from HIRLAM several years ago. When tested with ALARO, the model crashed after sunrise due to unphysical values of shortwave radiation flux. Tracing the error eventually led us to problems with the azimuth angle during calculation of the slope contribution to ORORAD, particularly during sunrise. The problem disappeared after turning off ACRANEB2 shortwave intermittency (NSORAYFR=1). The source of the problem was a mismatch between the cosine of the zenith angle passed to ORORAD and the one used in the radiation scheme. What was passed to ORORAD was the actual value of the cosine of the solar zenith angle, while shortwave gaseous transmissions within ACRANEB2 intermittency window were calculated with slightly different approximate value. Since the two values were not vanishing exactly at the same time, their ratio at sunrise and sunset could become huge, resulting in unphysical value of direct normal irradiance in ORORAD. The fix is straightforward: put the cosine of solar zenith angle used in the radiation scheme to an array ZRDG_MU0R in APLPAR, and pass it to SURFEX.

Having fixed it, we were able to run the integration successfully. However, when examining the output fields we found out that the atmospheric radiation fluxes for shortwave radiation do not get updated after ORORAD. Impact of ORORAD is visible only in SURFEX radiation fields. Interestingly, the issue concerns only shortwave radiation. After careful investigation of the source code, we found out that right after calculating the surface physics, there is a correction of longwave radiation net flux

(YDMF_PHYS%OUT%FRTH) with respect to the values from ORORAD to close the radiation budget. The value of compensation is calculated in the ARO_GROUND_DIAG subroutine. While it is calculated for both longwave and shortwave fluxes (variables PBUDTH and PBUDSO), apparently it is applied only to the net longwave flux. Hence, our second modification of the APLPAR subroutine involved applying it to the net shortwave flux as well. After this fix, the radiation output fields became consistent. The impact of ORORAD on global radiation flux over complex terrain (the Alps) is depicted in Fig. 2. Impact on forecast accuracy will be evaluated in high resolution runs.
For the time being, the implemented fix is available only for the ACRANEB radiation scheme (LRAY=T). For radiation schemes with multiple shortwave bands (NSW > 1), the fix must address split of the broadband offset PBUDSO to target spectral bands.

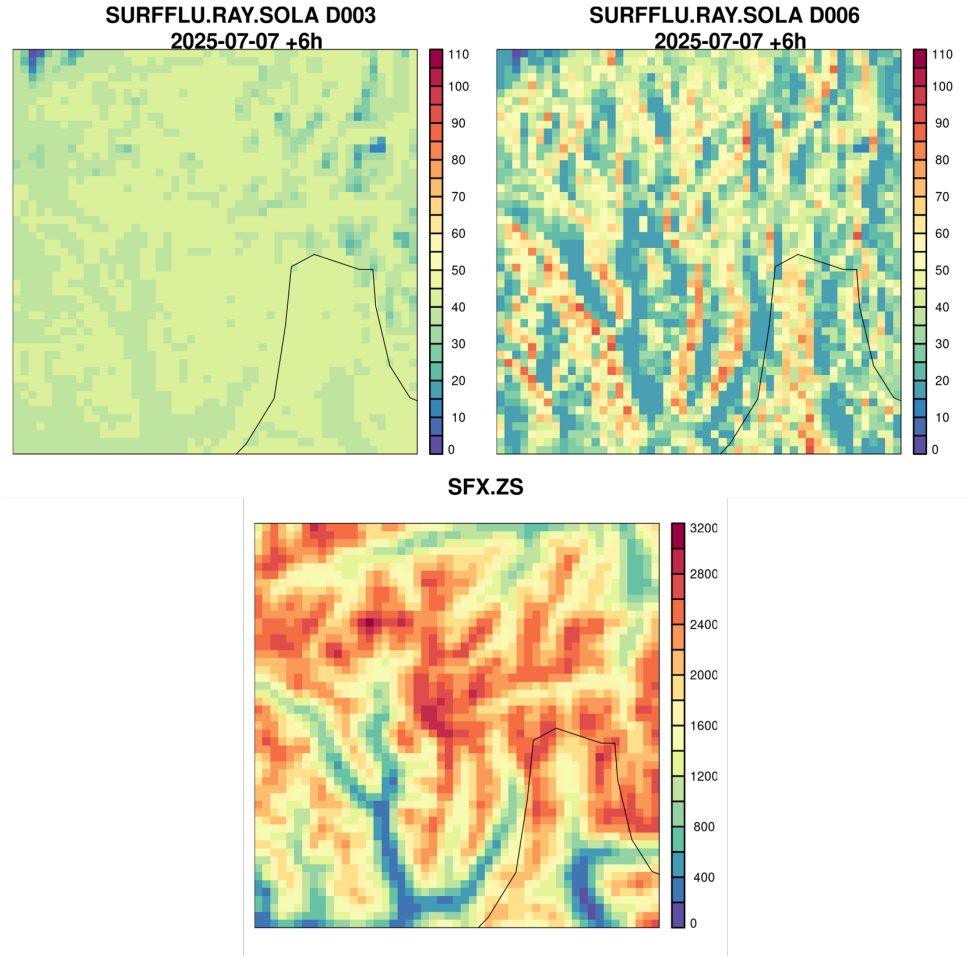


Figure 2: Top row: Global solar radiation flux (W/m2) at 6:00 UTC (+6 lead time) in the Alps without (left) and with ORORAD (right). Bottom row: model surface orography (meters a.s.l.).

Accuracy assessment of high resolution forecast of ALARO+SURFEX

Due to recent progress in the NWP community and increased availability of computational resources, CHMI started preparing a higher resolution ALARO configuration. The new geometry is defined as follows: NDGL=1536, NDLON=2000, EDELX=EDELY=1250m. The increase in horizontal resolution is roughly double compared to the current operational settings. The spatial extent of the domain is more or less the same. The size of the coupling and extension zones in points and the number of vertical levels remain unchanged. While all the setup regarding geometry and atmospheric physics has been already designed, our task was to investigate added value of SURFEX (especially ORORAD) and focus on technical features in order to achieve acceptable performance regarding both file size and computational time.

Regarding reduction of output file size, we identified a few namelist switches that allows to limit the number of output fields. These are: LPROVAR_TO_DIAG in &NAM_WRITE_DIAG_SURFn and LPGD in NAM_DIAG_ISBAn. LPROVAR_TO_DIAG is a logical switch that enables saving prognostic variables to an output file in a tile-averaged form (as is done for diagnostics). The default value is false, which saves prognostic fields separately for every patch. The more patches in ISBA configuration, the bigger is the file size reduction due to this switch. As for the LPGD switch, setting it to true adds to the output file fields regarding ECOCLIMAP land covers (e.g., fraction of each of 19 vegetation types within the desired number of patches). Finally, it was decided to explicitly specify the list of output fields by setting LSELECT=T and filling the array CSELECT with desired record names (namelist NAM_WRITE_DIAG_SURFn). This made a single output surfex file with default 16-bit packing around 3 times smaller (from 2.8 GB to 844 MB). In addition, we decreased the frequency of saving atmospheric ICMSH files from 1h to 3h, adjusting resets of min/max temperature, maximum wind gusts and precipitation type accordingly Frequency of surface ICMSH.sfx files was kept 1h, so that screen level quantities are available hourly.

Verification was performed in order to assess added value of SURFEX and ORORAD in high resolution. As initial verification scores featured considerable and systematic overestimation of wind speed, it was decided to tune tree height scaling factor (array XSCALE_H_TREE_ECOFG). Eventually, following forecasts were compared:

- D000: high resolution ALARO+ISBA (reference)
- D004: high resolution ALARO+SURFEX without ORORAD + H_TREE×2
- D005: high resolution ALARO+SURFEX with ORORAD + H_TREE×2

In Fig. 3, one can find selected verification scores from 5 consecutive forecast runs initialized at 00 UTC (each run was 54h long) from 11th to 15th September 2024 (a flood event in Poland and Czech Republic). Initial conditions were produced using FULLPOS-PREP from cycled ALARO+ISBA run. TEB initial prognostic variables were cycled every 24h (by mistake we did not cycle canyon temperature and humidity which are pseudo-prognostic). Although cold temperature bias in the reference run appears to be mitigated, the RMSE score indicates that the accuracy deteriorated slightly, particularly right after the initialisation. More distinct and systematic bias occurs when it comes to relative humidity. SURFEX clearly underestimates this parameter. This is reflected also in precipitation sums – in this case the scores are improved since the reference predicts too much rain. There is also considerable increase in mean bias of wind speed for experiments D004 and D005, which is reflected also in RMSE. It suggests that we may need to increase also the height of low vegetation, not only of trees. It is also evident that ORORAD has barely any impact on verification scores. The only difference we can see is in T2M – ORORAD causes nights to be a little cooler. However, one has to be aware of the fact that the scores are averaged over the whole domain, while we do not expect any impact of ORORAD outside areas with complex orography. Therefore, to thoroughly assess ORORAD contribution, one would need to select a couple of stations in complex terrain (preferably varying regarding slope aspect and sky view factor). Then the differences are expected to be more pronounced.

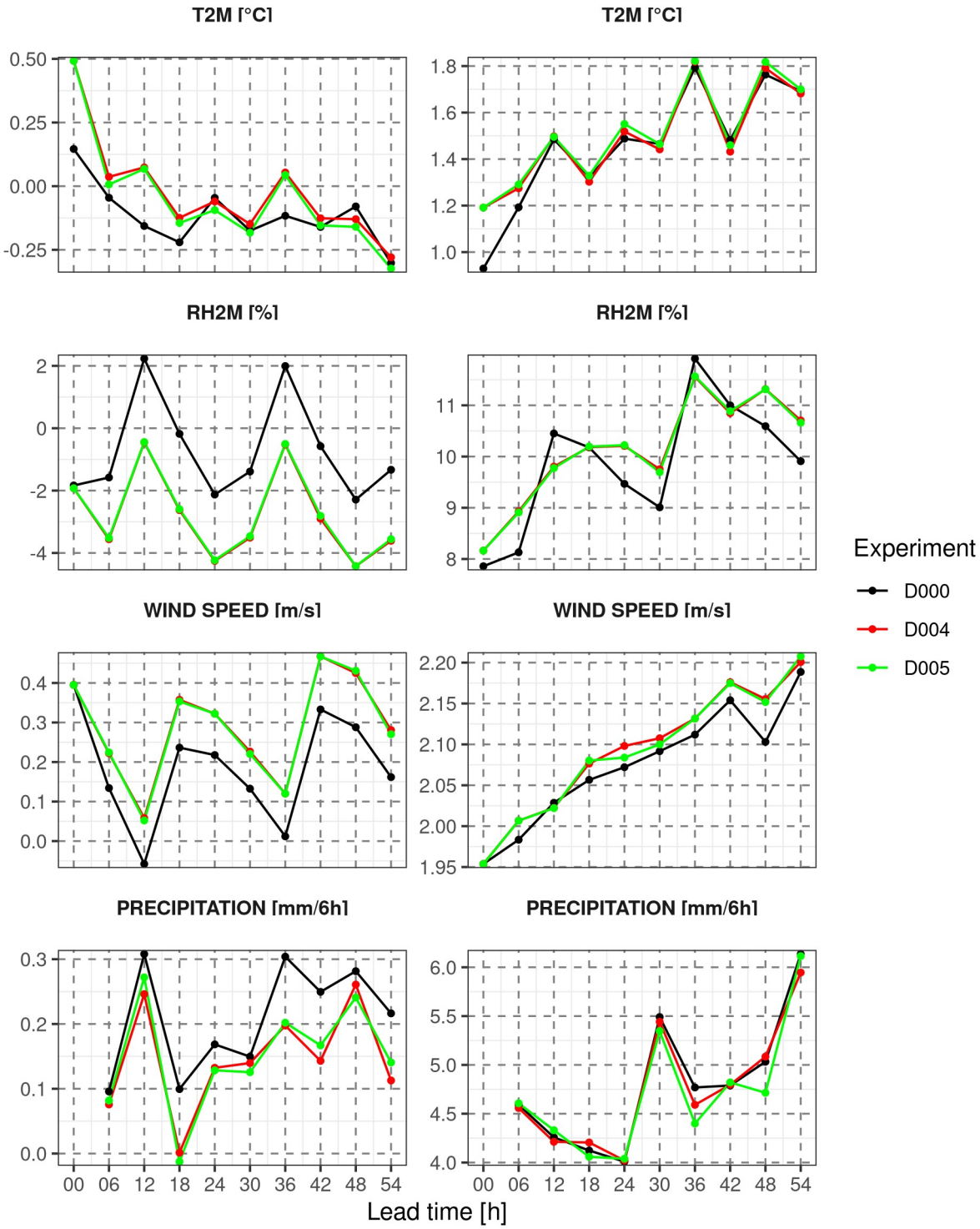


Figure 3: Temporal evolution of 5-day mean bias (left) and RMSE (right) for selected near-surface meteorological fields. Black – ISBA reference; red – SURFEX without ORORAD; and green – SURFEX with ORORAD.

4 Conclusions

In the first few hours of the forecast, the impact of traffic and industry sources on the lowest model level temperature is limited to large urban zones. However, in dynamic weather conditions, major differences (up to several ^{o}C) may arise locally as the forecast advances. Given the unrealistic switch-

on/switch-off behaviour of SURFEX traffic heat sources, we decided to deactivate them in further experiments, keeping only the industry sources. Here it must be remembered that industry sources may need to be revised when switching to ECOCLIMAP SG, where they are generally larger.
ORORAD scheme is now working with ACRANEB2 radiation in CY48T3, where two issues had to be addressed: passing solar zenith angle consistent with shortwave intermittency to SURFEX, and making shortwave fluxes consistent with surface reflection diagnosed by ORORAD. The latter fix has not yet been made working for radiation schemes with multiple shortwave bands. ORORAD added value cannot be seen much in classical scores over the model domain. To show it, point verification should be performed for some sites in complex terrain with variable conditions in terms of shadowing, slope aspect and sky view factor.

5 References

Senkova, A. V., Rontu, L., & Savijärvi, H. (2007). Parametrization of orographic effects on surface radiation in HIRLAM. *Tellus A: Dynamic Meteorology and Oceanography*, *59*(3), 279–291. https://doi.org/10.1111/j.1600-0870.2007.00235.x