Addressing the Warm Bias of the Nocturnal Near-Surface Air Temperature Forecasts of C-LAEF 1k in Alpine Valleys

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C-LAEF 1k is a pre-operational, convection-permitting limited-area ensemble forecasting system developed by GeoSphere Austria. It employs the AROME model with a refined grid spacing of 1 km, compared to the 2.5-km grid spacing of the current operational system (Wastl et al., 2021). Another important change in this system is the deactivation of the surface boundary layer (canopy) scheme. Despite these modifications and adjustments to some parameters for the new model version and resolution, a nocturnal warm bias persists in the near-surface air temperature forecasts. This report focuses on several candidate changes to C-LAEF 1k aimed at reducing this bias, particularly the one observed in winter forecasts within Alpine valleys. The 2-m temperature correction from Meier et al. (2021), which was applied in the pre-operational C-LAEF 1k, has been deactivated in all the experiments presented herein.

1. Effect of reducing the maximum Richardson number

Reducing the maximum value of the Richardson number used in the calculation of the surface turbulent fluxes has a substantial impact in stable conditions. This is controlled by the XRIMAX parameter in the model. In the current configuration of C-LAEF 1k, XRIMAX is set to 0.2, whereas many AROME-based forecasting systems have used XRIMAX = 0. The highest positive impact on near-surface air temperature was obtained with XRIMAX set to 0 in our experiments. The resulting larger transfer coefficients led to increased surface turbulent fluxes, which positively affected the simulation of the stable boundary layer in the Inn Valley (Austria), as indicated by comparisons with observational data. The larger surface fluxes may not be more realistic, but this approach could help compensate for processes that are missing or inadequately represented at the grid scale.

Figure 1 presents the hourly air temperatures at 2 m and the two lowest model levels for two 33-hour forecast experiments initialized at 00 UTC 5 February 2024: NOCAN and NRIMAX0. The NOCAN experiment used the control member of C-LAEF 1k with XRIMAX set to 0.2, while XRIMAX was set to 0 in the NRIMAX0 experiment. The simulated temperatures were extracted at the grid point nearest to the i-Box Kolsass observation station (Rotach et al., 2017), located in the Inn Valley, approximately 20 km east of Innsbruck. Observed air temperatures at 2, 4, and 17 meters at the i-Box Kolsass station are also shown in Fig. 1.

While the 2-m air temperatures simulated in both experiments are comparable, the temperatures simulated in NRIMAX0 at the two lowest model levels are much closer to the observed temperatures at 4 and 17 m than those simulated in NOCAN. Similar results were observed in the 3-hour temperature forecasts generated during the continuous data assimilation cycles that provided the initial conditions.

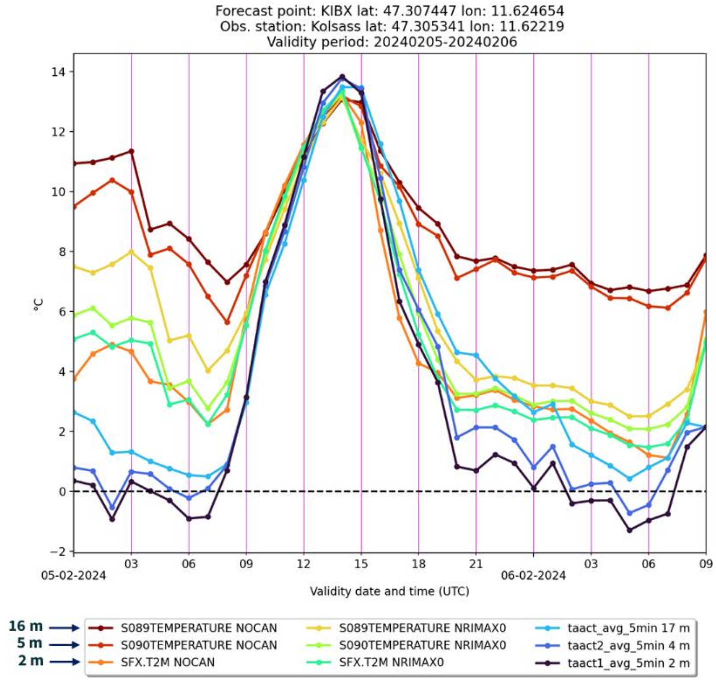

Figure 1. Hourly air temperatures observed at the i-Box Kolsass station and simulated at the nearest grid point at different heights. The observation heights are 2, 4, and 17 m and the hourly observed temperatures are averages of 1-min observed temperatures over the preceding 5 min. Simulated temperatures at 2 m, the lowest model level (approximately 5 m), and the second-lowest model level (approximately 16 m) are shown for two forecast experiments, NOCAN and NRIMAX0.

2. Effect of a modified version of the soil freezing scheme

Daily soil freeze-thaw cycles linked to seemingly unrealistic deep-soil temperature (TG2 variable) variations have been noticed in C-LAEF 1k simulations, particularly in grid cells covered by grass. Figure 2 provides an example by showing TG2 simulations from four experiments: NOCANWGI0, FRZDP, FRZDPLWT and FRZDPKVEG1P5. The NOCANWGI0 experiment used the configuration of the control member of C-LAEF 1k, while the FRZDP experiment tested a modified version of the soil freezing scheme used in ISBA's force-restore mode. In the modified version, the soil water freezing and ice melting rates are calculated for the entire deep layer rather than just the subsurface layer. In addition to this modification, the soil freezing characteristic curve, which links the sub-zero temperature of soil to its unfrozen water content, is activated in the FRZDPLWT experiment by setting the CSOILFRZ option to LWT. Compared to the FRZDP experiment, the K_2 coefficient in the vegetation insulation coefficient K_s is reduced from 5 to 1.5 in the FRZDPKVEG1P5 experiment, to enhance the insulation effect of vegetation. All experiments were initialized with ice-free soil.

In the NOCANWGI0 experiment, a relatively large TG2 increase of approximately 4 °C was simulated within the first 7 hours, followed by a drop of similar magnitude in just 3 hours during the morning. Another large TG2 increase is observed after 18 UTC (Fig. 2). These variations are primarily driven by the freezing and thawing of soil ice in the surface soil layer. What is particularly unusual is the high sensitivity of TG2 to these processes occurring in the just 1-cm thick surface layer, while the subsurface layer remained ice-free throughout the integration.

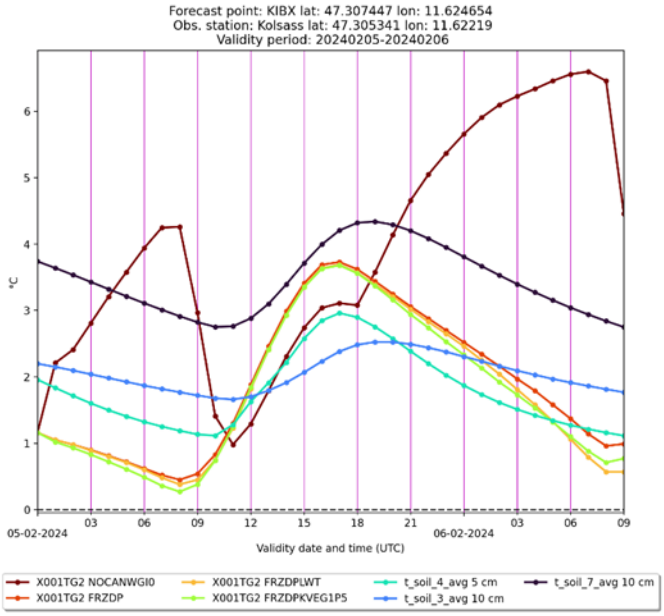

Figure 2. Hourly soil temperatures observed at the i-Box Kolsass station and simulated at the nearest grid point. The deep-soil temperature (TG2) is shown for the NOCANWGI0, FRZDP, FRZDPLWT and FRZDPKVEG1P5 experiments. Soil temperatures were measured at two sites located 5 m apart: t_soil_3 and t_soil_4 were measured at one site at depths of 10 cm and 5 cm, respectively, while t_soil_7 was measured at the second site at a depth of 10 cm.

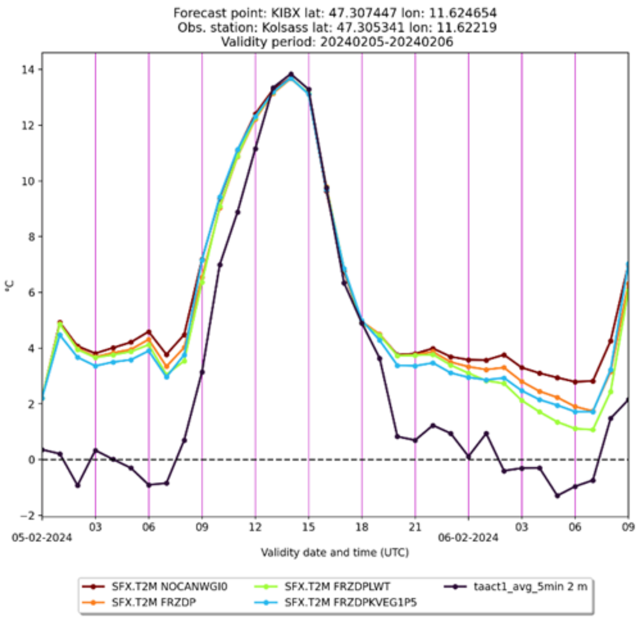

Figure 3. Hourly 2-m temperatures observed at the i-Box Kolsass station and simulated at the nearest grid point in the NOCANWGI0, FRZDP, FRZDPLWT and FRZDPKVEG1P5 experiments. The hourly observed temperature is the average of 1-min observed temperatures over the preceding 5 min.

The FRZDP experiment simulated a more realistic variation in TG2, despite increased production and melting of soil ice in the surface soil layer compared to the NOCANWGI0 experiment. Additionally, the continuous nighttime decrease in surface temperature (TG1) observed in FRZDP (not shown) is also more realistic. Consequently, the 2-m temperature also decreased (Fig. 3), under the high-pressure, clear-sky, and weak-wind conditions of the experiments. In the FRZDPLWT and FRZDPKVEG1P5 experiments, the nocturnal soil temperatures TG2 and TG1, and consequently T2M, are further reduced due to the simulation of decreased soil ice content compared to the FRZDP experiment.

References

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