Temperature forecasts in very cold weather of 12-13 February 2021

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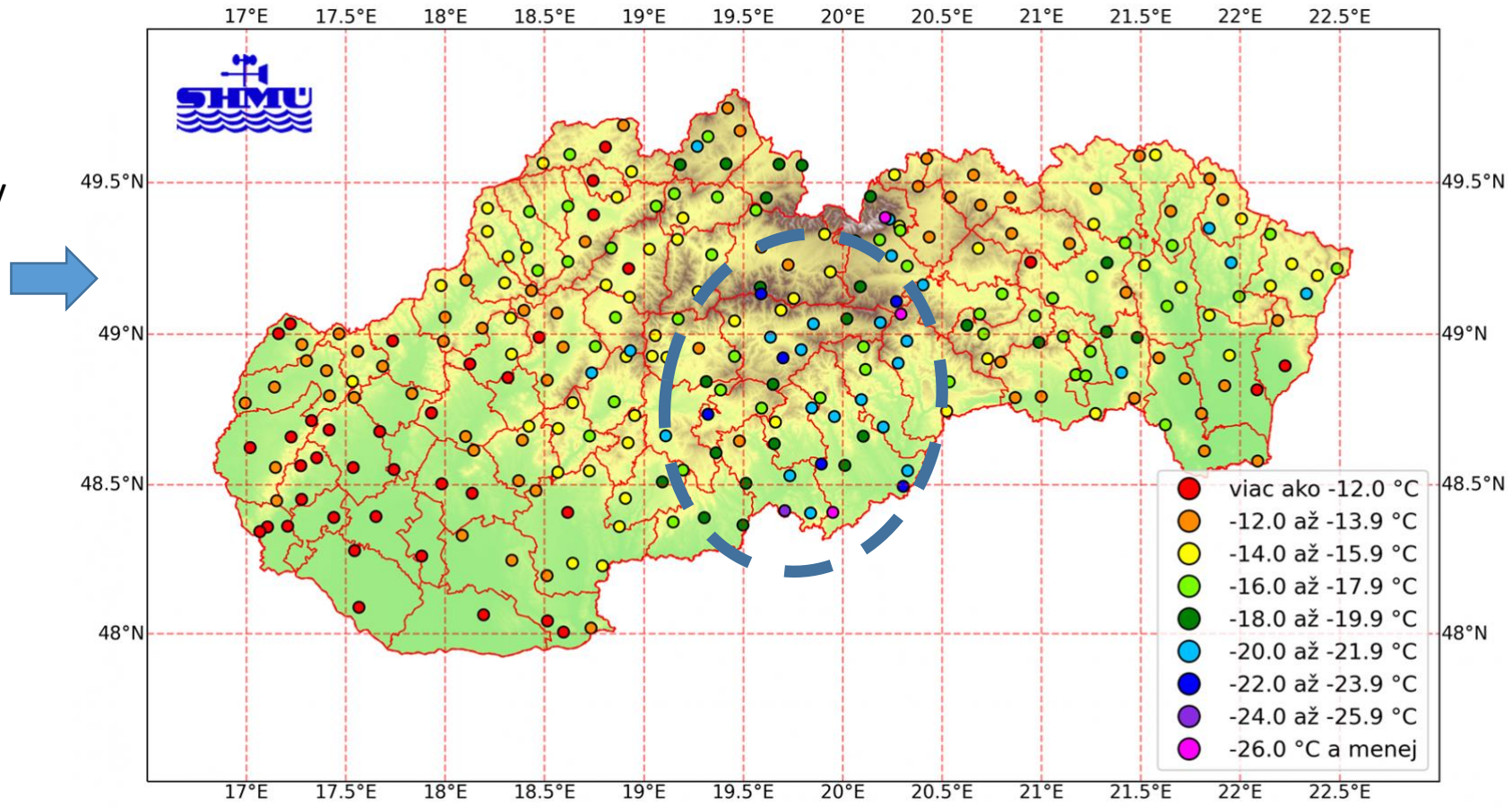
Temperature minima on 13 February 2021 with depiction of the coldest area (minima below -20 °C).

Source:
http://www.shmu.sk/sk/?page=2049&id=1116



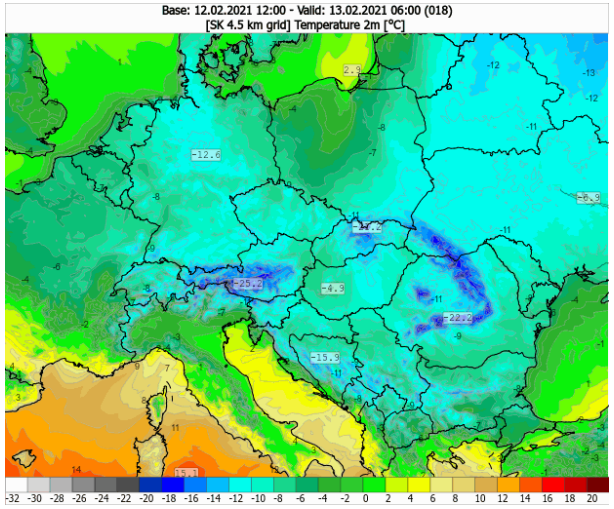
Problem with forecasting 2m temperature over snow cover in very cold situations

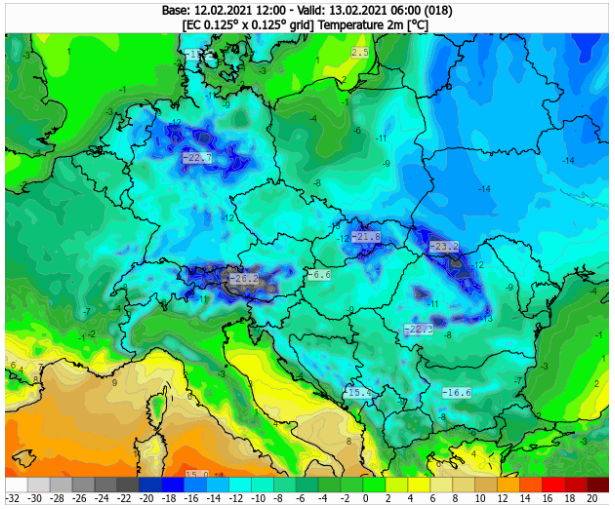
- This problem regularly appears in the ALARO/AROME models in cases, there is deep snow cover of (relativly) new snow, clear sky and weak wind. During the 12-13 February 2021 night such conditions were present over Slovakia (an upper-air temperature minimum of -19 °C in 850 hPa). The minimum temeratures were underestimated by 10 °C or even more by regular model runs at SHMÚ, especially in the southern part of central Slovakia, where the most extreme observed temperature was -26 °C.
- Nevertheless, there were numerical models (e.g. ECMWF, ALARO-PL, ICON) performing somewhat better over the cold weather regions.

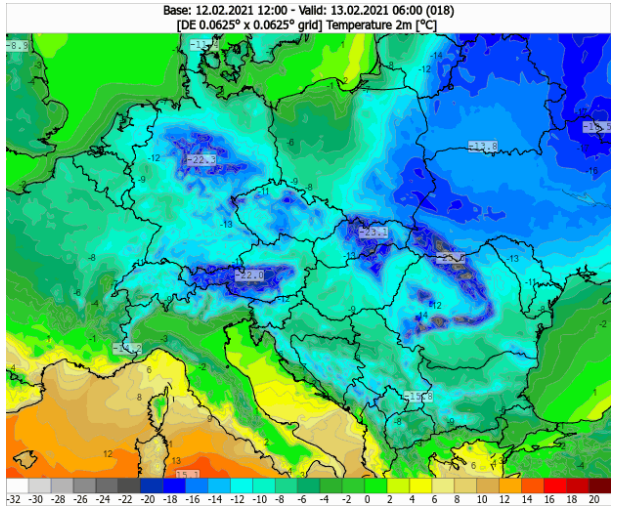
Comparison of 2m temperature forecasts (RCLACE)

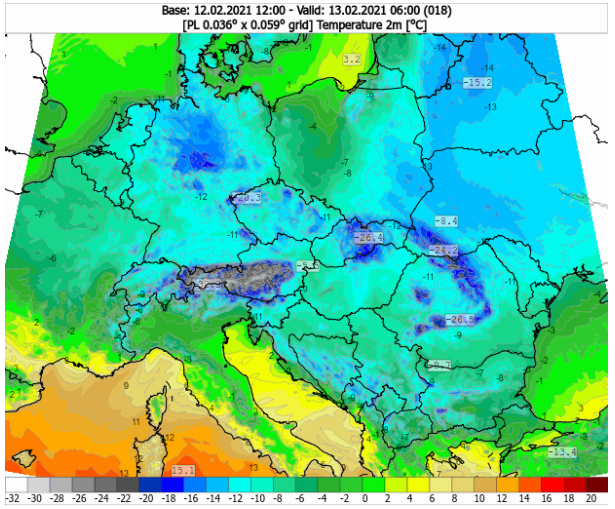
Base: 12 February 2021 12 UTC, 18h forecasts

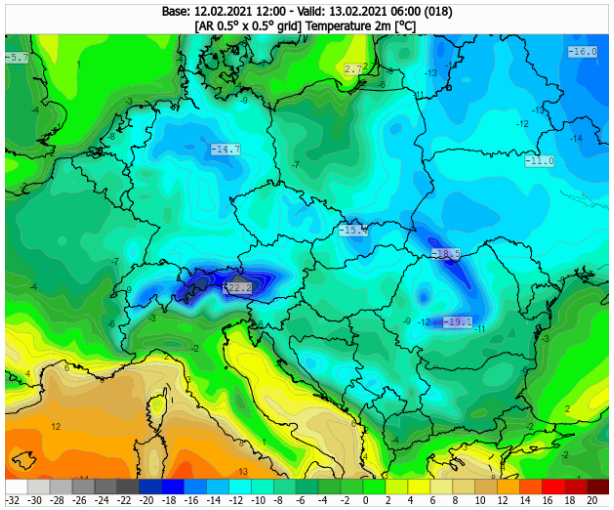
There are differences by 5,6 °C between the models for the region in question

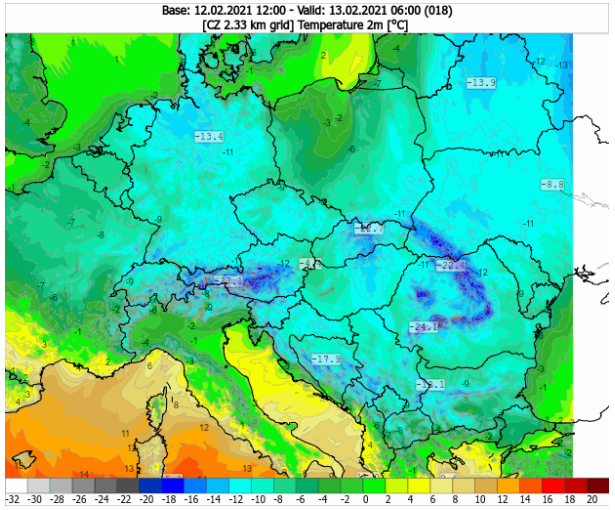


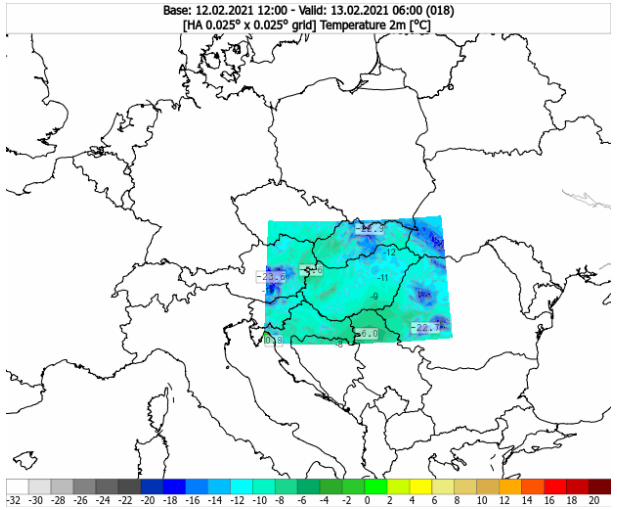


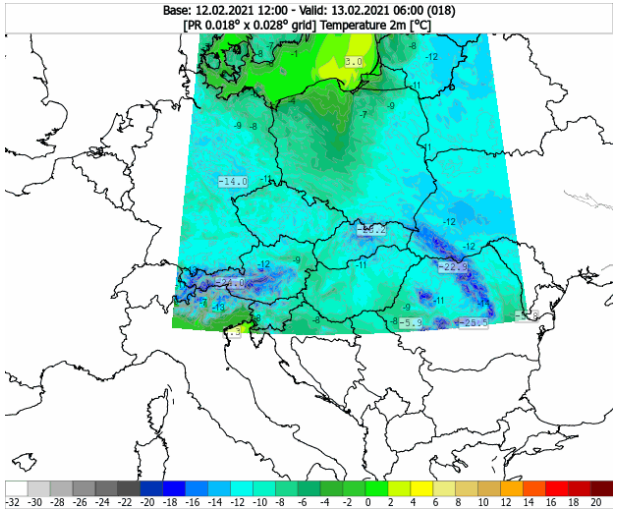






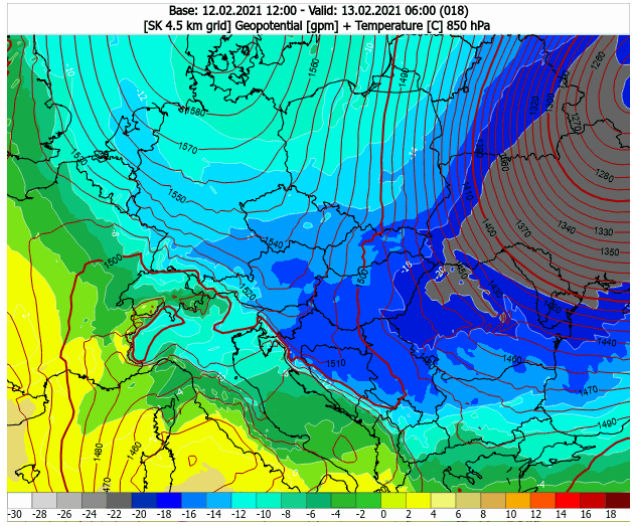


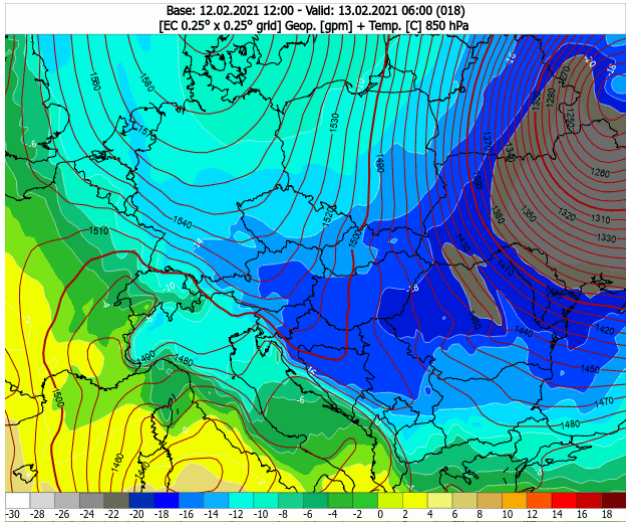


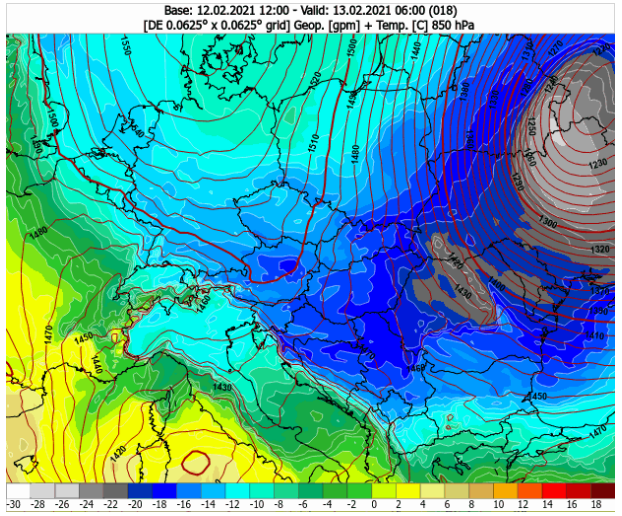


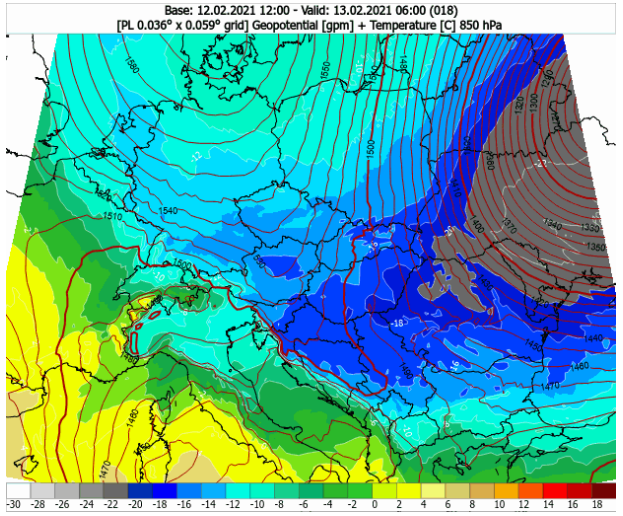
850 hPa temperature forecasts

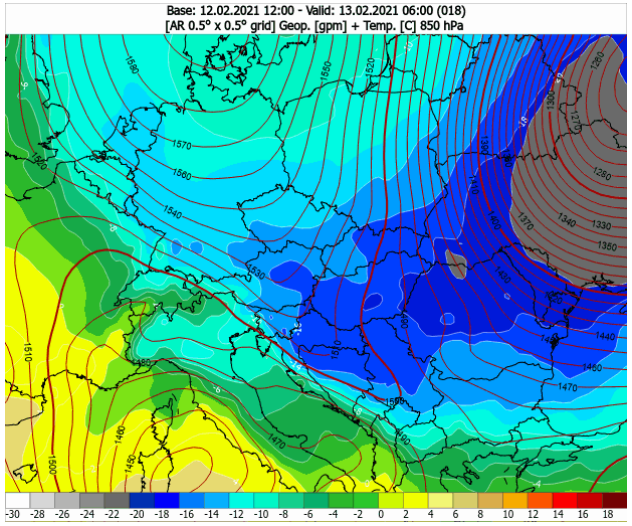
Not as big differences between model forecasts

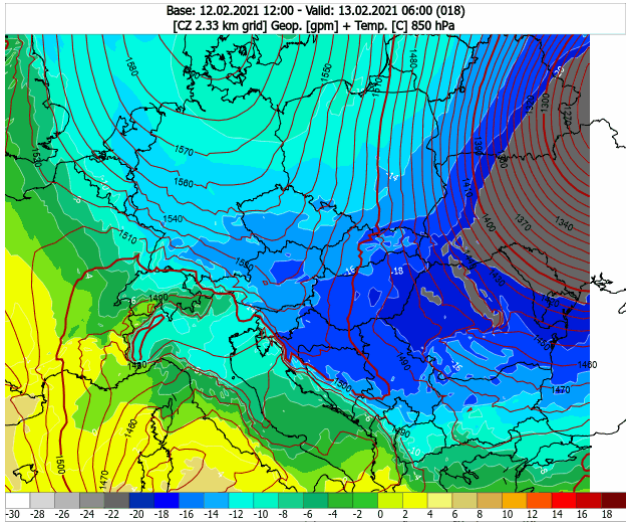


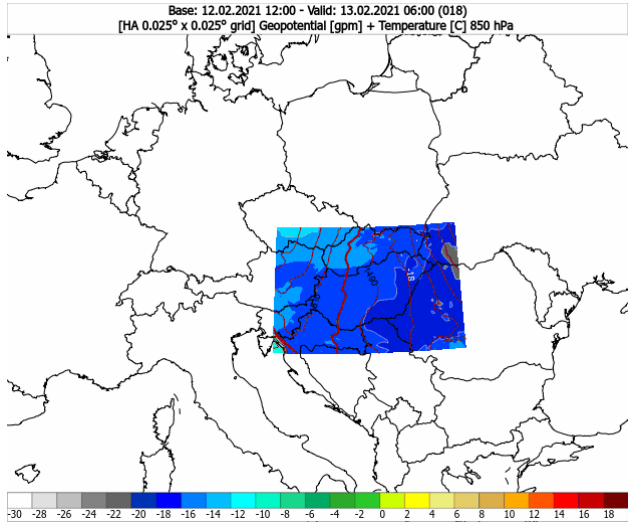


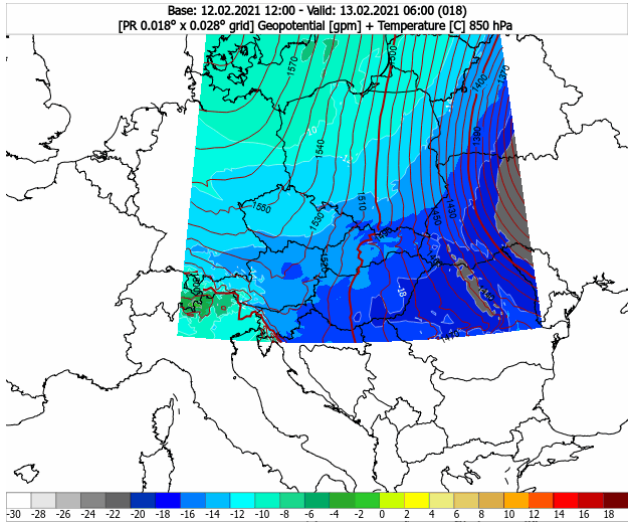






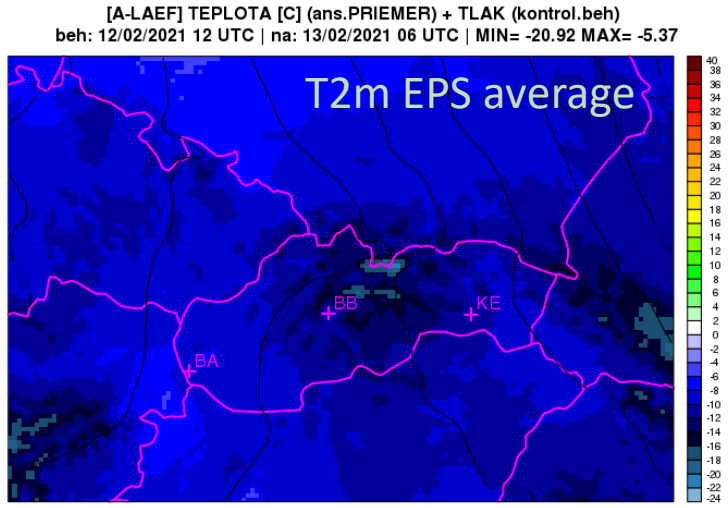


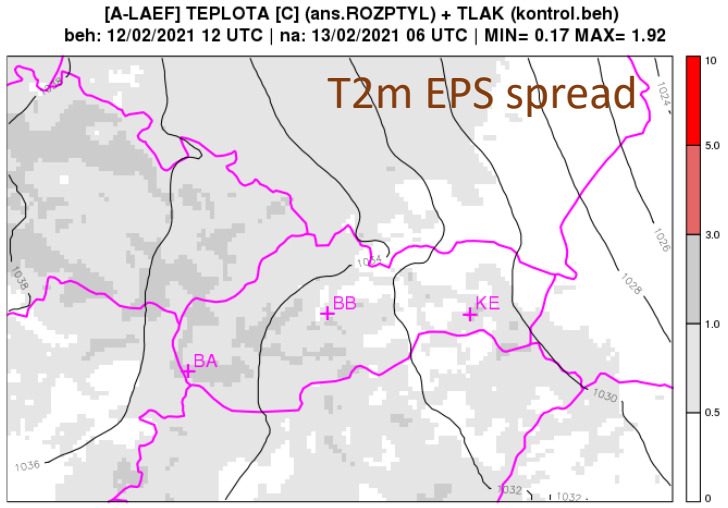


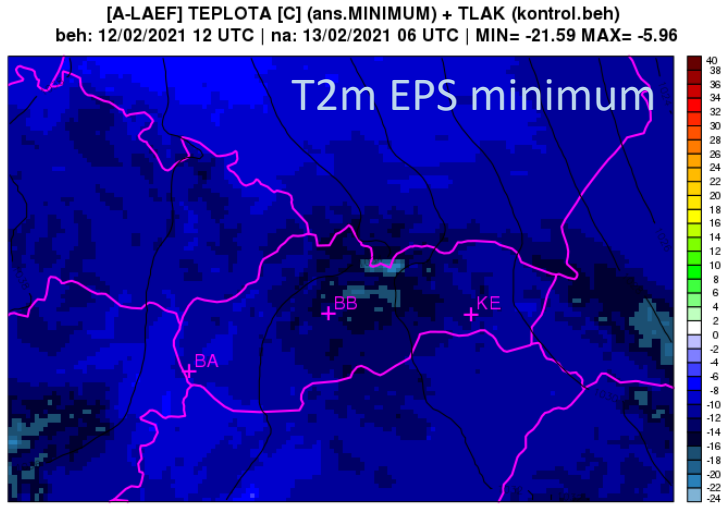


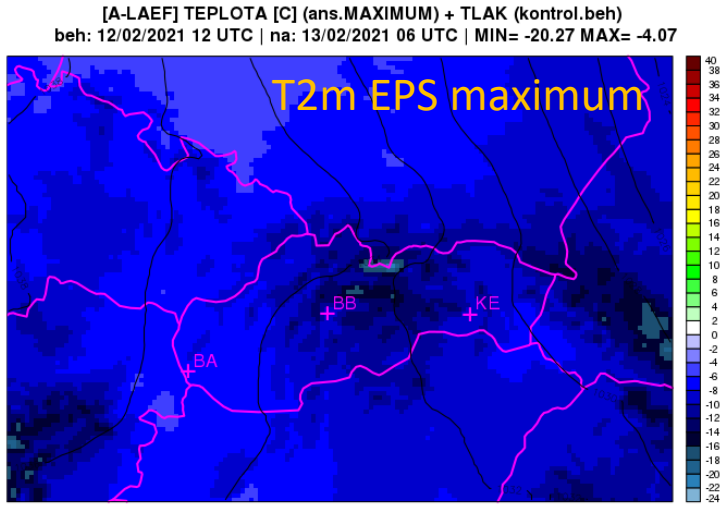
A-LAEF

- Little spread, temperature in valleys ~ -15°C in coldest runs, little sensitivity on turbulence parameterization or mixing length (experiments with ala2, not shown)







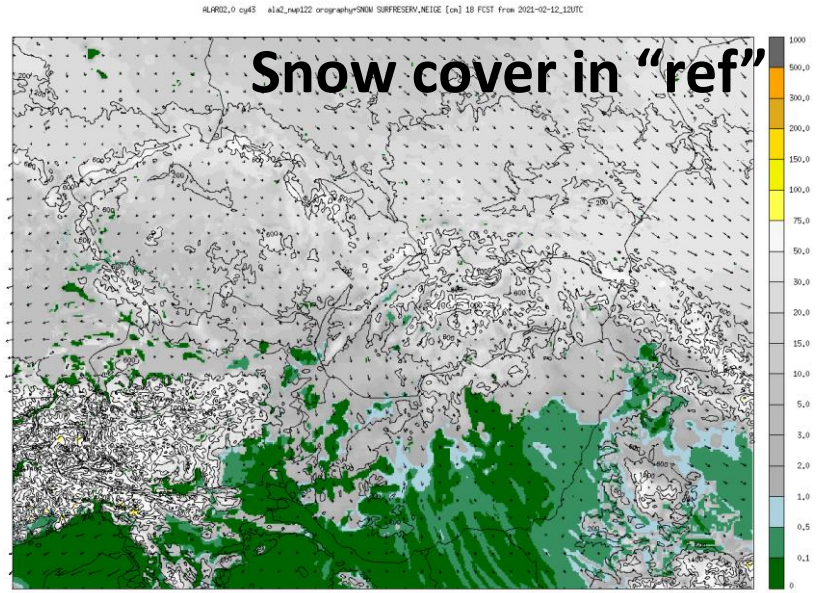


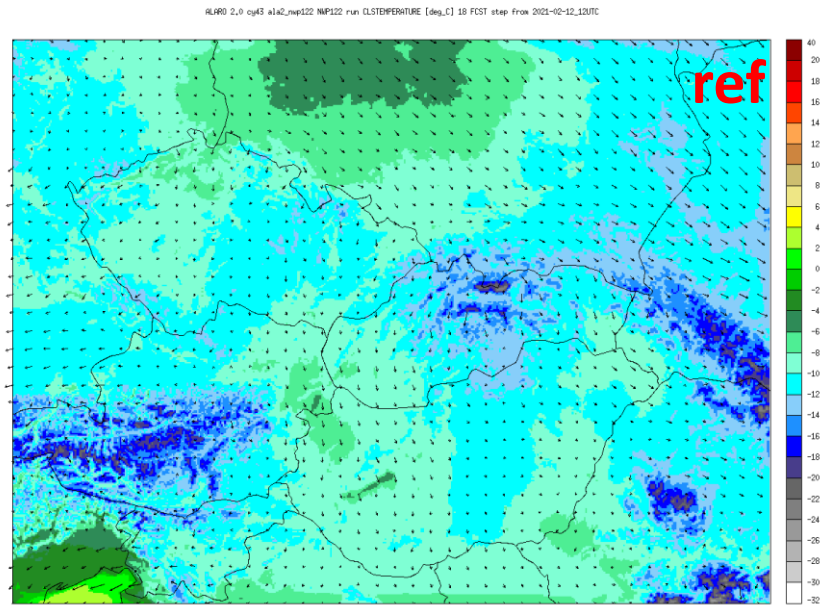
ALARO 2 km dynamic adaptation experiments

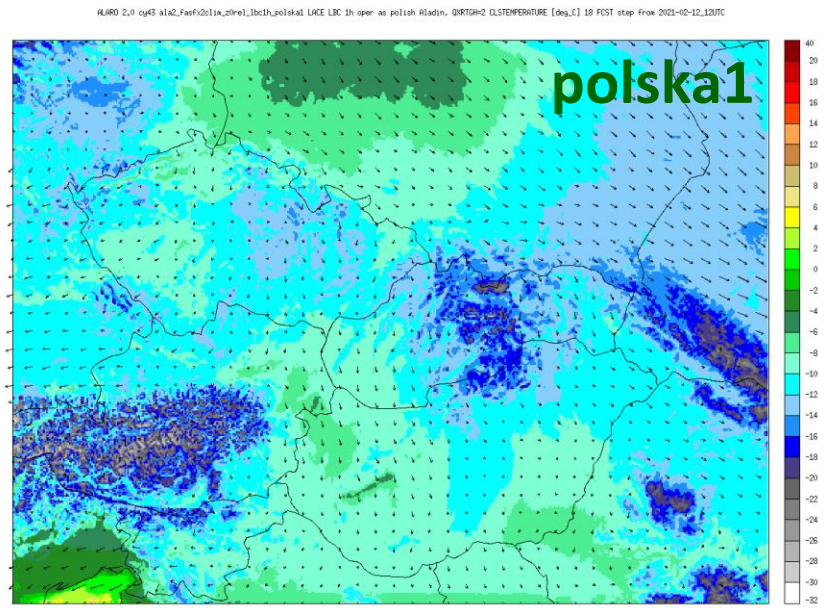
- ARPEGE (LACE) 1h LBC, NH run, 73 vertical levels
- The goal was to find, which setting makes the biggest differences between the coldest ALARO run (PL) and the reference. We concentrated later on the NCHSP and WCRIN parameters, which have direct influence on the snow fraction and heat flux over the snow cover (see Mašek, 2017): http://www.rclace.eu/File/Physics/2017/masek_isba_snow2_Mar2017.pdf
- **"ref"** reference setting: LQXRTGH=.T., QSSC=400., RMULACVG=5.5, RPHI0=1500., NCHSP=0, RCTVEG(3)=1.4E-05, RCTVEG(4)=1.1E-05, WCRIN=4.,
- **„polska1"** experimental setting: LQXRTGH=.F., HUCREDRA=0.33, QSSC=800., RMULACVG=-25.0, RPHI0=400., NCHSP=2, RCTVEG(3)=1.1E-05, WCRIN=5.,
- **"nchsp_eq_2"** experimental setting: "ref"+ NCHSP=2
- Other experiments: e.g. "ref"+NCHSP=1, "ref"+WCRIN=1,"nchsp_eq_2"+WCRIN=10, "nchsp_eq_2"+WCRIN=1, "ref"+87 vertical levels starting at ~0.9m AGL

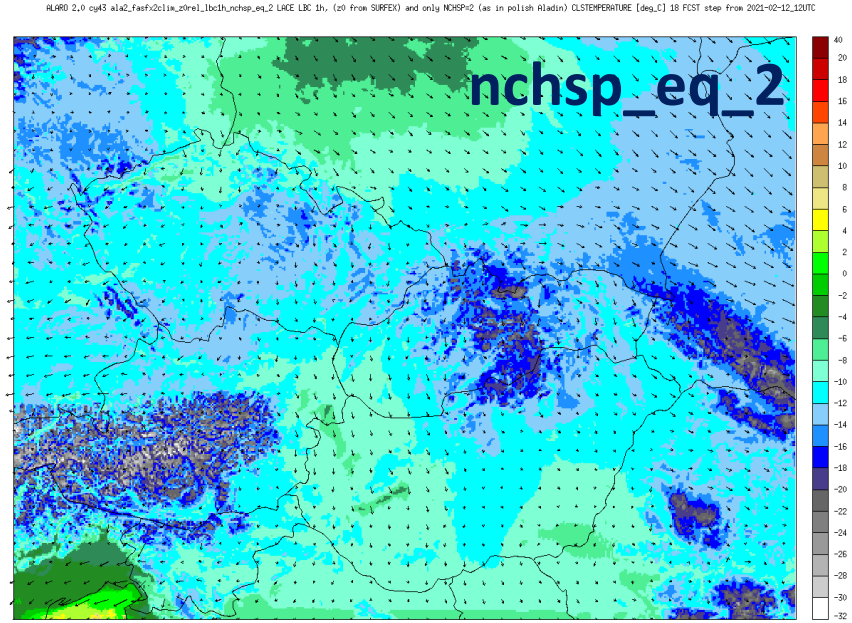
T2m forecasts in experimental ALARO

- The “polska1” setting nearly reproduced the ALARO-PL forecast. With “nchsp_eq_2” the predicted minima are even colder, close to -20°C as observed over the southern Slovakia



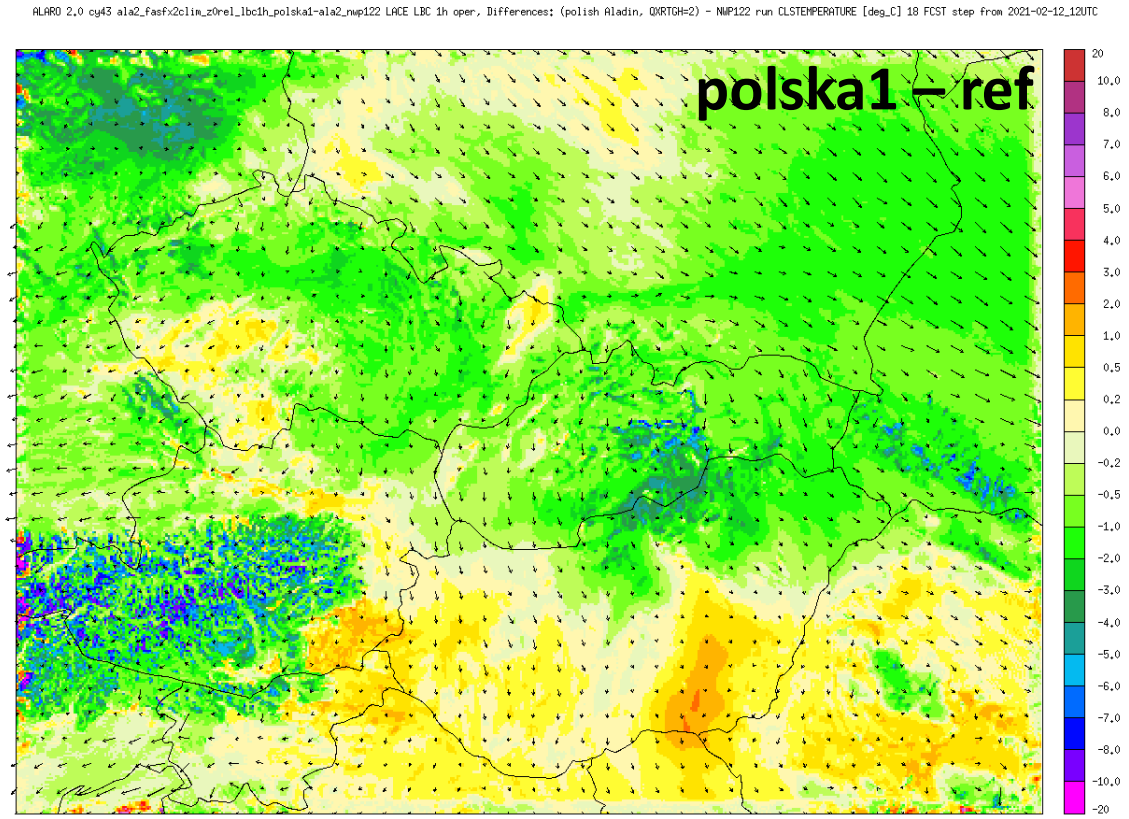


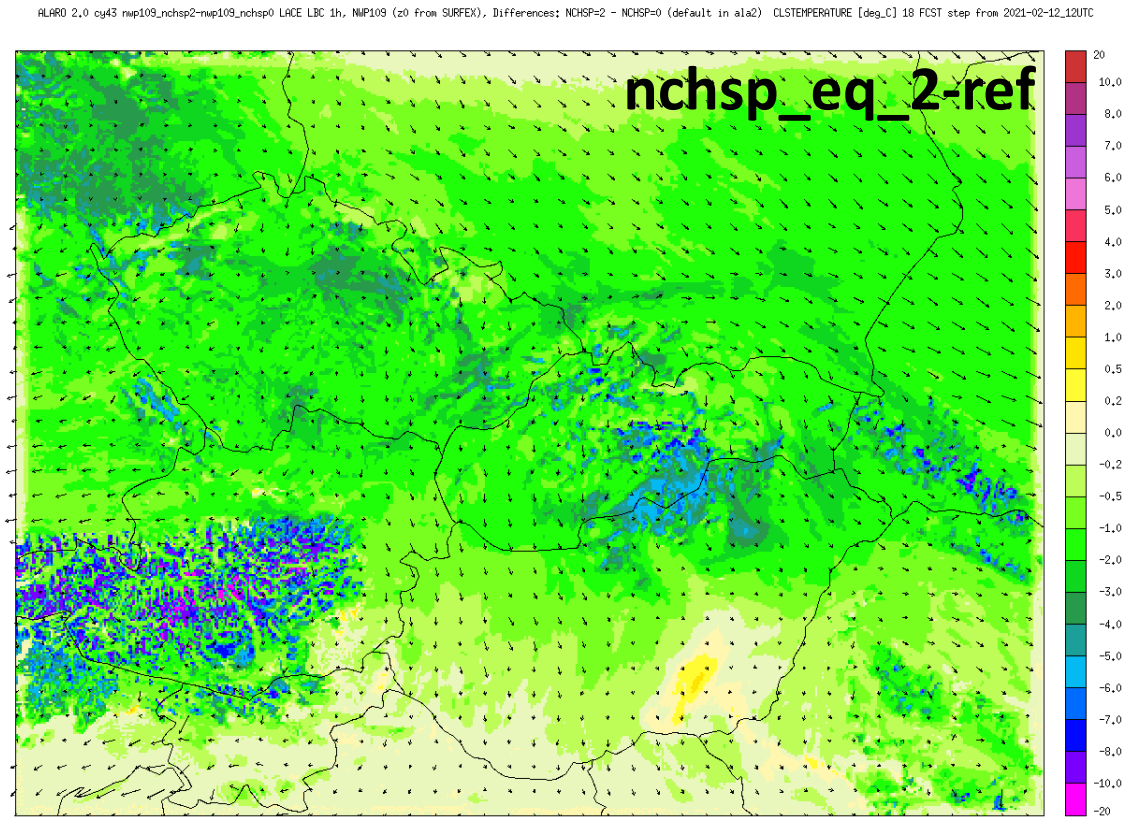




T2m differences with respect to the reference

- With „polska1“ setting there is also a positive T2m tendency (maybe also due to higher WCRIN). With “nchsp_eq_2“ the tendencies are mainly negative and much larger, mainly over the mountains

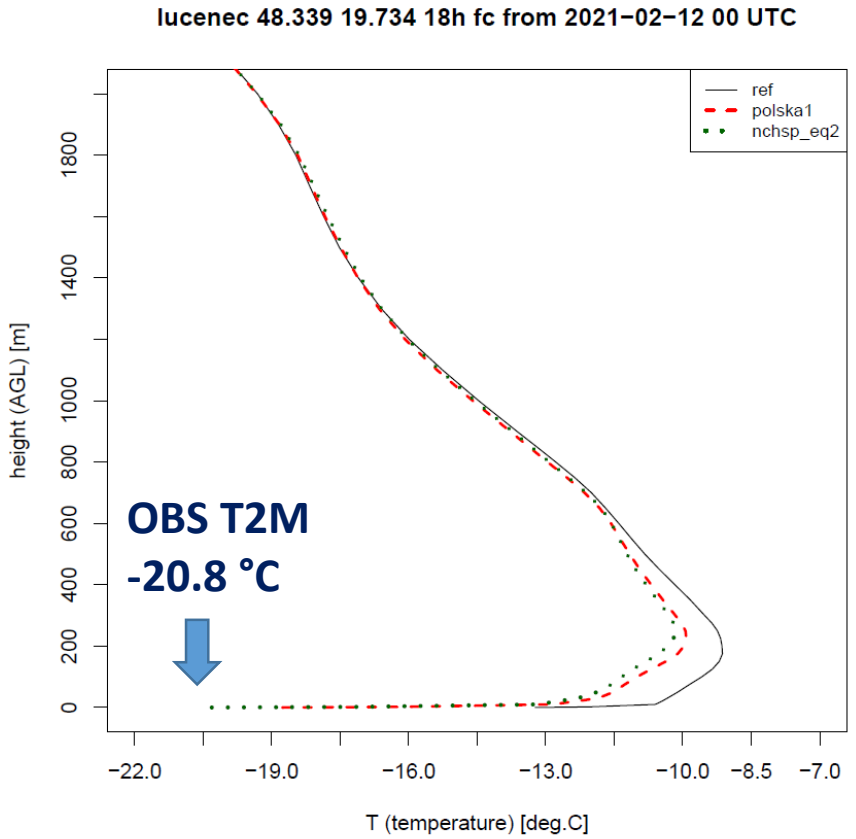


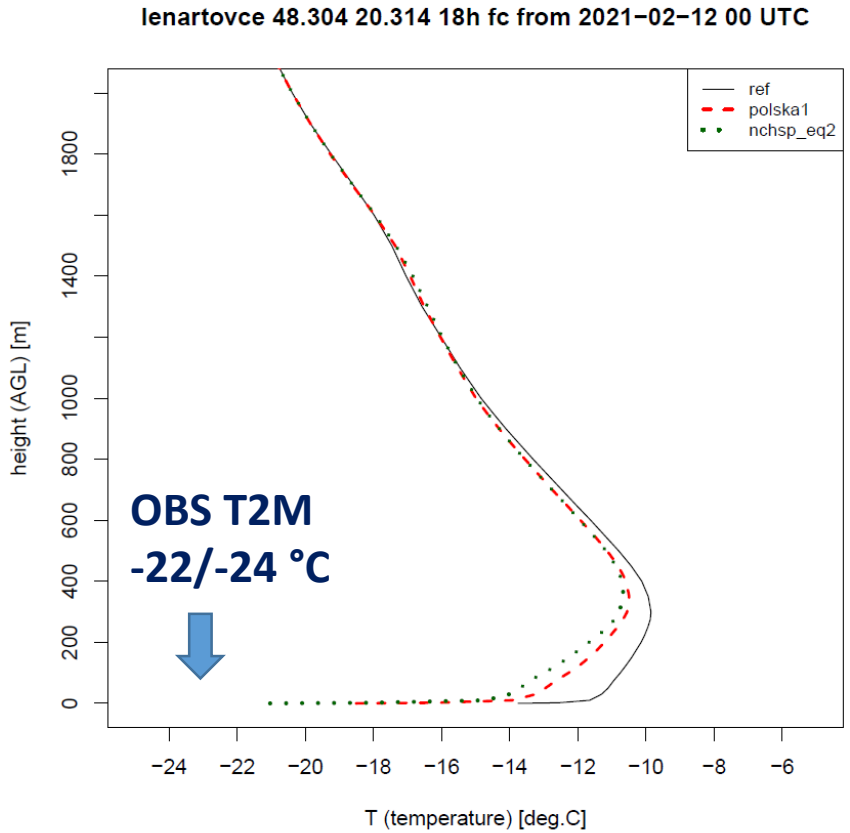


Vertical temperature profiles over southern Slovakia

- Valid for 13 February 2021 06 UTC
- Influence is visible up to ~700 m AGL
- The near-surface values were underestimated even for NCHSP=2

Lučenec 06 UTC	ref	polska1	nchsp_eq_2	OBS
T surface	-13.2	-18.8	-20.3	min. -25
T2m [°C]	-12.1	-16.2	-17.2	-20.8

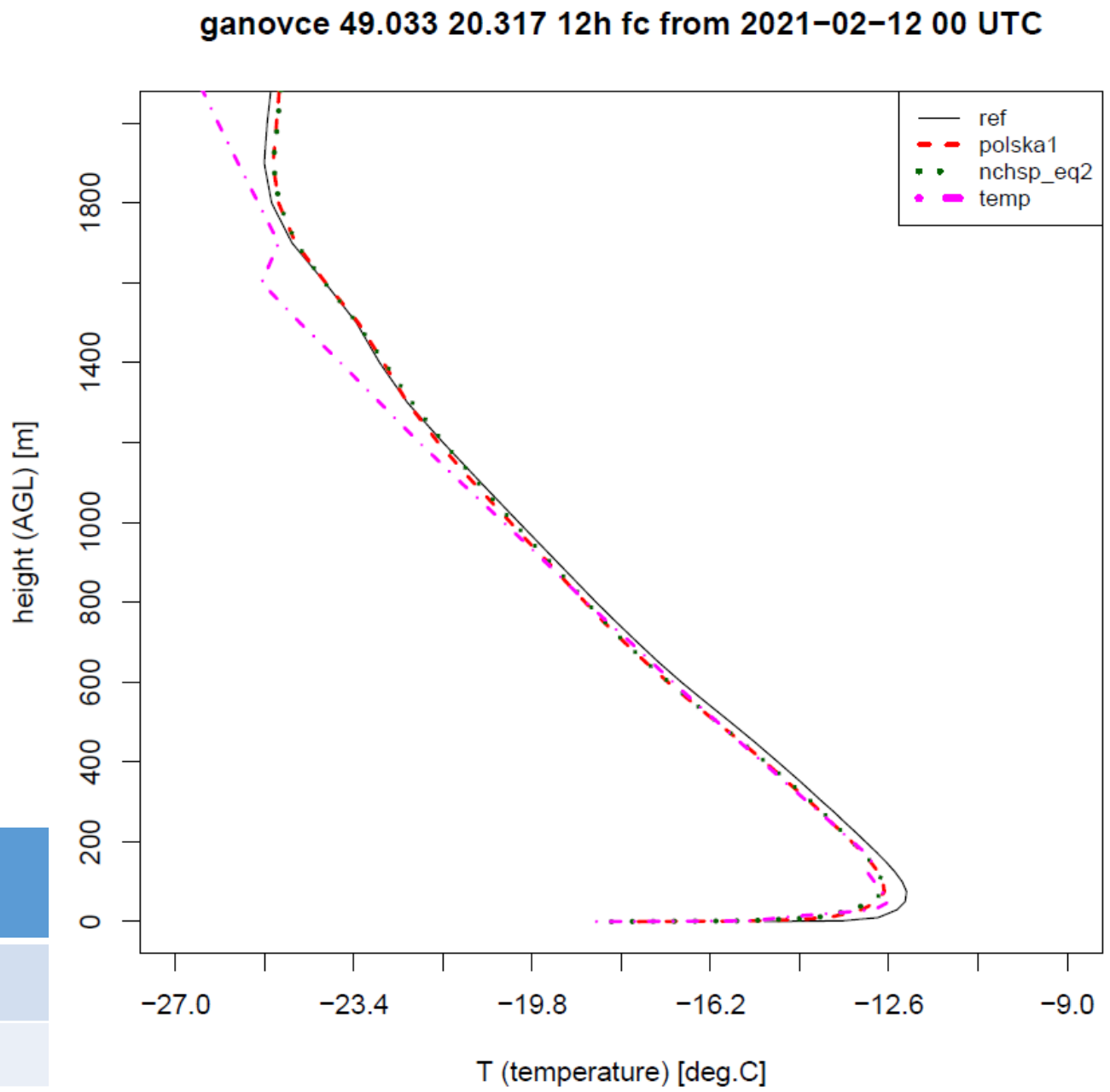




TEMP vs. PSTEMP

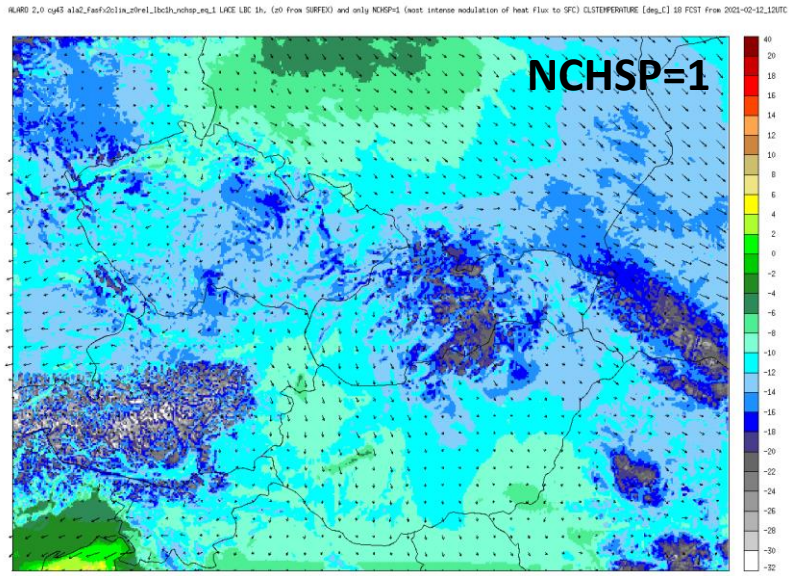
- Valid for 13 February 2021 00 UTC
- Not as big differences between the reference and experiments
- nchsp_eq_2 is close to OBS, also the difference between surface (5 cm) and 2m temperature is more realistic, in ref it is one half of it

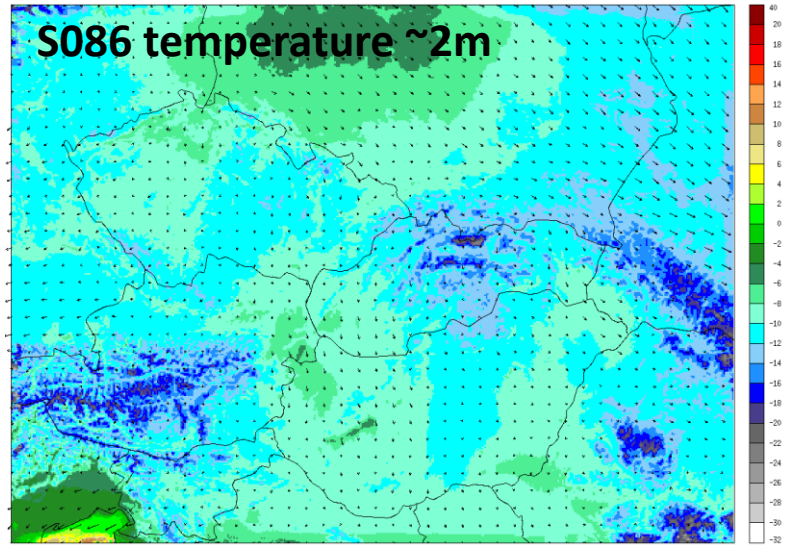
Gánovce 00 UTC	ref	polska1	nchsp_eq_2	OBS
T surface	-15.1	-17.7	-18.2	-18.5
T2m [°C]	-13.5	-15.1	-15.5	-15.3



Other experiments

- Solely decreasing of WCRIN (critical snow reservoir) from 4 to 1 kgm-2 had little effect on the 2m temperature (mostly negative, below 1 °C)
- Setting NCHSP=1 (strongest damping of the soil heat flux) had the largest effect, which is quite strong in all regions with snow cover
- Other assumption was that we perhaps miss model levels close to the ground in order to realistically simulate the temperature gradients. We prepared an experimental run with 87 levels but with the lowest level at around 0.9m and second lowest level at ~2m. A correct experiment would need also retuning of some parts of the namelist, which was not done but even so, the results show very little sensitivity on such increase of model vertical levels.





Some conclusions

- As stated in Mašek (2017), one of the biggest problems with forecasting low temperature over snow cover is the two-layer approximation of the soil and surface in the ISBA-scheme. Surface ISBA layer with snow has a single constant temperature. Thus, the heat exchange between the soil and atmosphere is too high.
- The heat exchange can be artificially damped with the NCHSP parameter (see the ACDIFUS routine), which has a strong impact on both surface and 2m temperature and improves the temperature gradient over the snow cover. NCHSP=2 is sufficient in such cases.
- However, at other places or in other types of situations (e.g. by warm advection and melting of snow as on 22 February 2021) this damping can have an exactly opposite effect and can result in underestimated temperature. One of the reasons can be that the snow properties (its water content and density) have also impact on the heat conductivity and transfer, which effects are not simulated by the model. Other factor can be the interaction between the surface layer and the upper atmosphere. It seems that in daytime, the presence of snow causes that the heat flux from atmosphere toward surface is damped too much, leading to artificial inversions, stratus clouds, etc.
- The previous assumptions can be tested using soil- and surface schemes with more layers, more realistic snow cover, etc. The experiment with more atmospheric layers near surface indicated that changes in the atmospheric part of the model alone do not improve the temperature profile without treating the surface in these situations.