Odd outflows over water surfaces in non-hydrostatic ALARO/AROME models…

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with big help of Martin Dian, Radmila Brožková & others

What happened

- The phenomenon was already recognized in 2019 in operational AROME model at OMSZ as an outflow and wave spreading very fast from the Balaton Lake shores. The model was exceptionally run as pure dynamic adaptation due to sudden technical problems, in "normal" runs with assimilation it did not occur

- Very similar traits could be recognized in outflows in high-resolution (325 m) experimental dynamic adaptation run for the domain of Slovakia (NH dynamics, cy 43). The concentrically spreading 10m wind velocity maxima indicated a problem with convection but appearing in very stable stratification on 26 January 2020 (12 UTC run). Animation follows....

10m wind velocity+orography (SW Slovakia)

After 600s

ALARO0.325 cy43v2 s32a_tuning_test1 pf orography + 10m ZVELOC [m/s] from CLSVENT.ZONAL and CLSVENT.MERIDIEN 50 FCST from 2020-01-26_18UTC
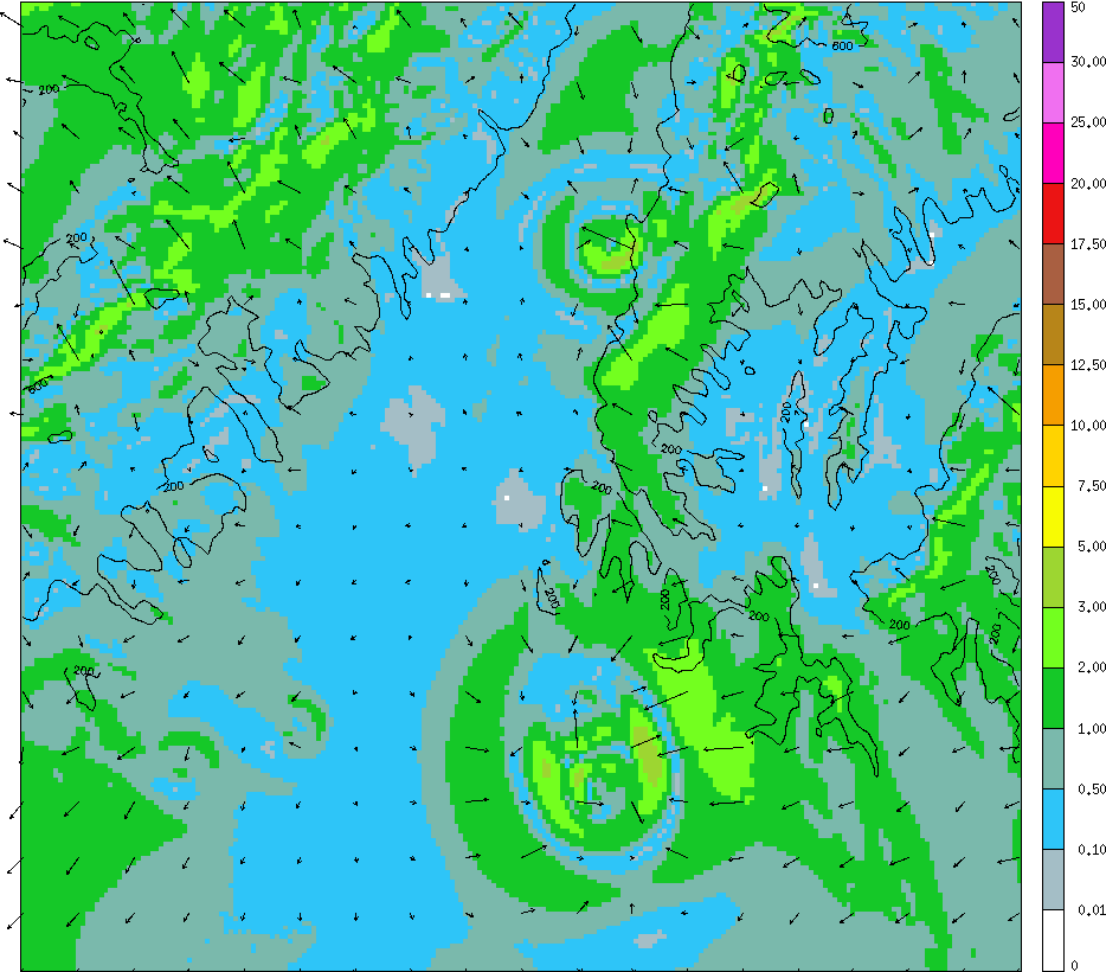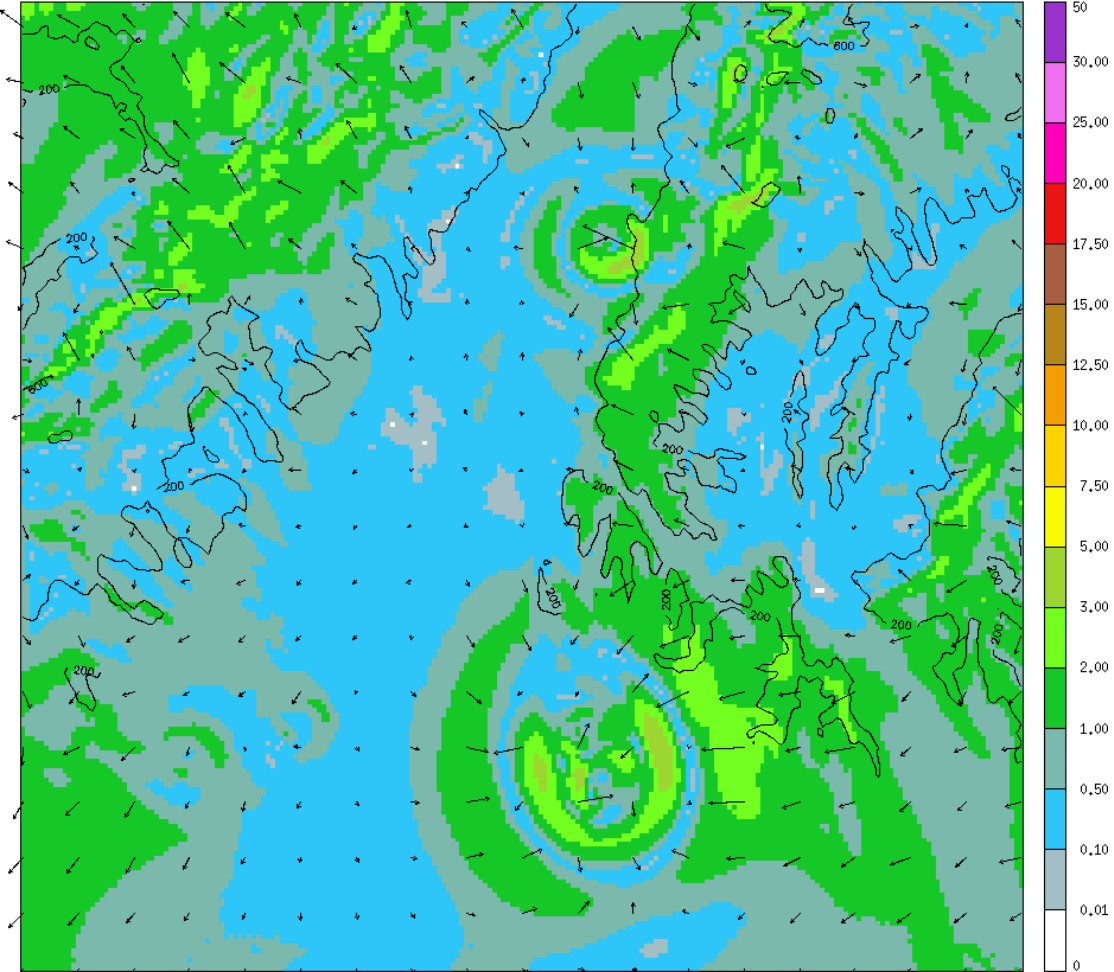
10m wind velocity+orography (SW Slovakia)

After 660s

ALARO0.325 cy43v2 s32a_tuning_test1 pf orography + 10m ZVELOC [m/s] from CLSVENT.ZONAL and CLSVENT.MERIDIEN 55 FCST from 2020-01-26_18UTC

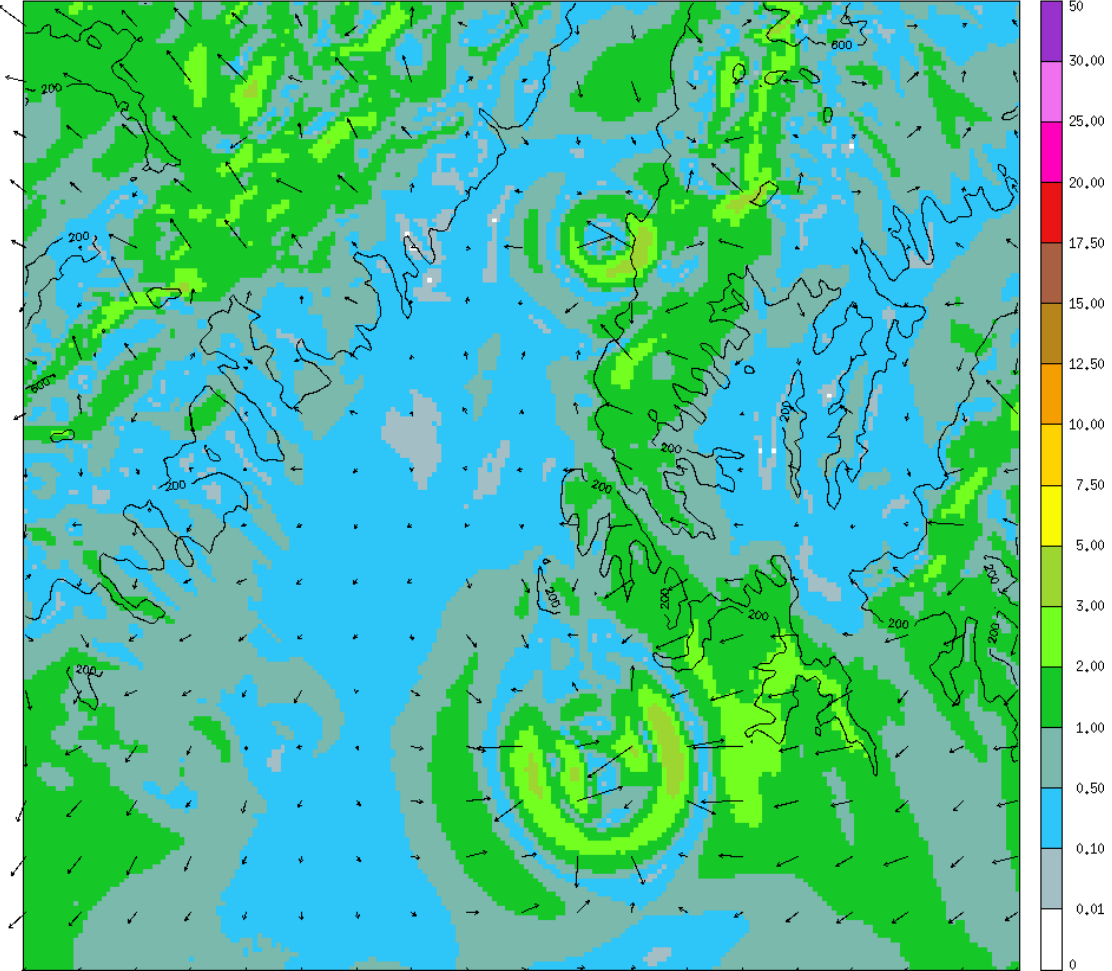# 10m wind velocity+orography (SW Slovakia)

After 720s

ALARO0.325 cy43v2 s32a_tuning_test1 pf orography + 10m ZVELOC [m/s] from CLSVENT.ZONAL and CLSVENT.MERIDIEN 60 FCST from 2020-01-26_18UTC
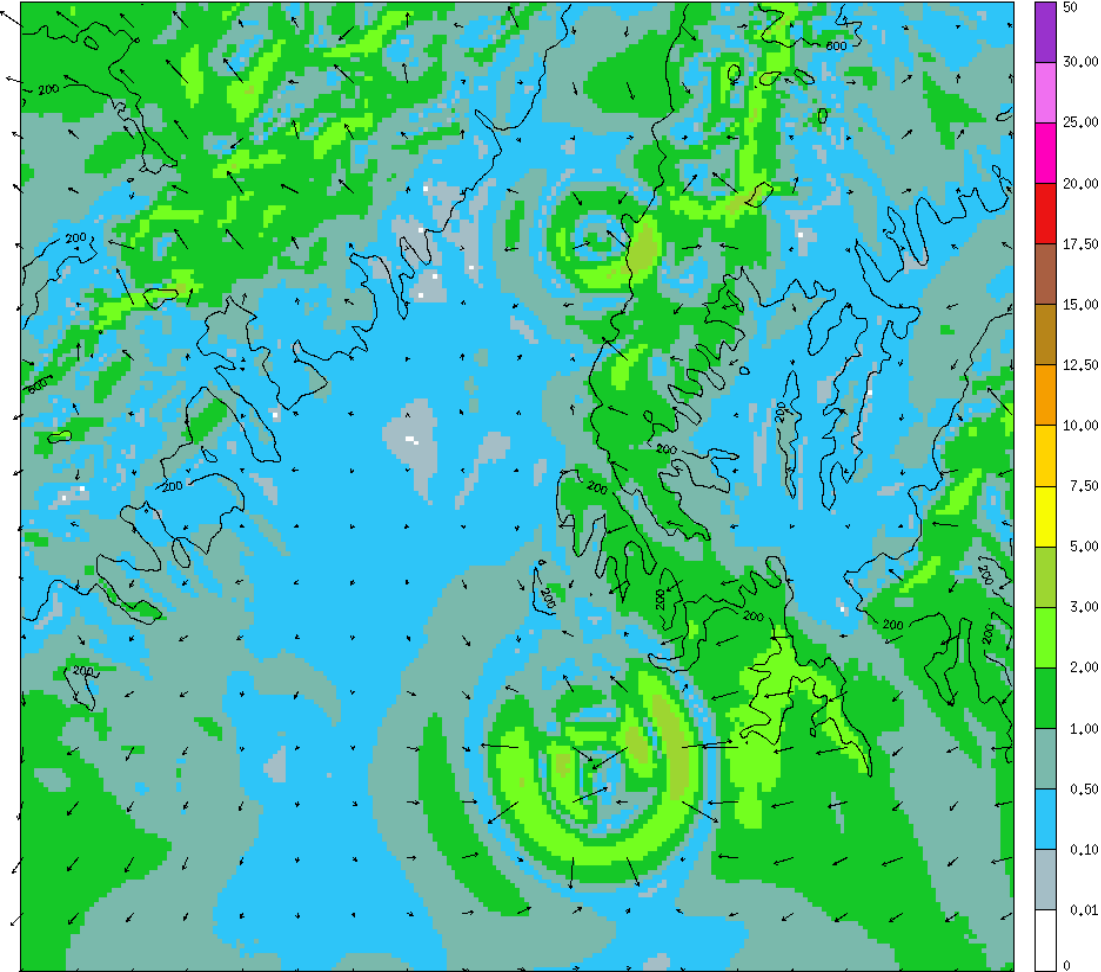
10m wind velocity+orography (SW Slovakia)

After 780s

ALARO0.325 cy43v2 s32a_tuning_test1 pf orography + 10m ZVELOC [m/s] from CLSVENT.ZONAL and CLSVENT.MERIDIEN 65 FCST from 2020-01-26_18UTC
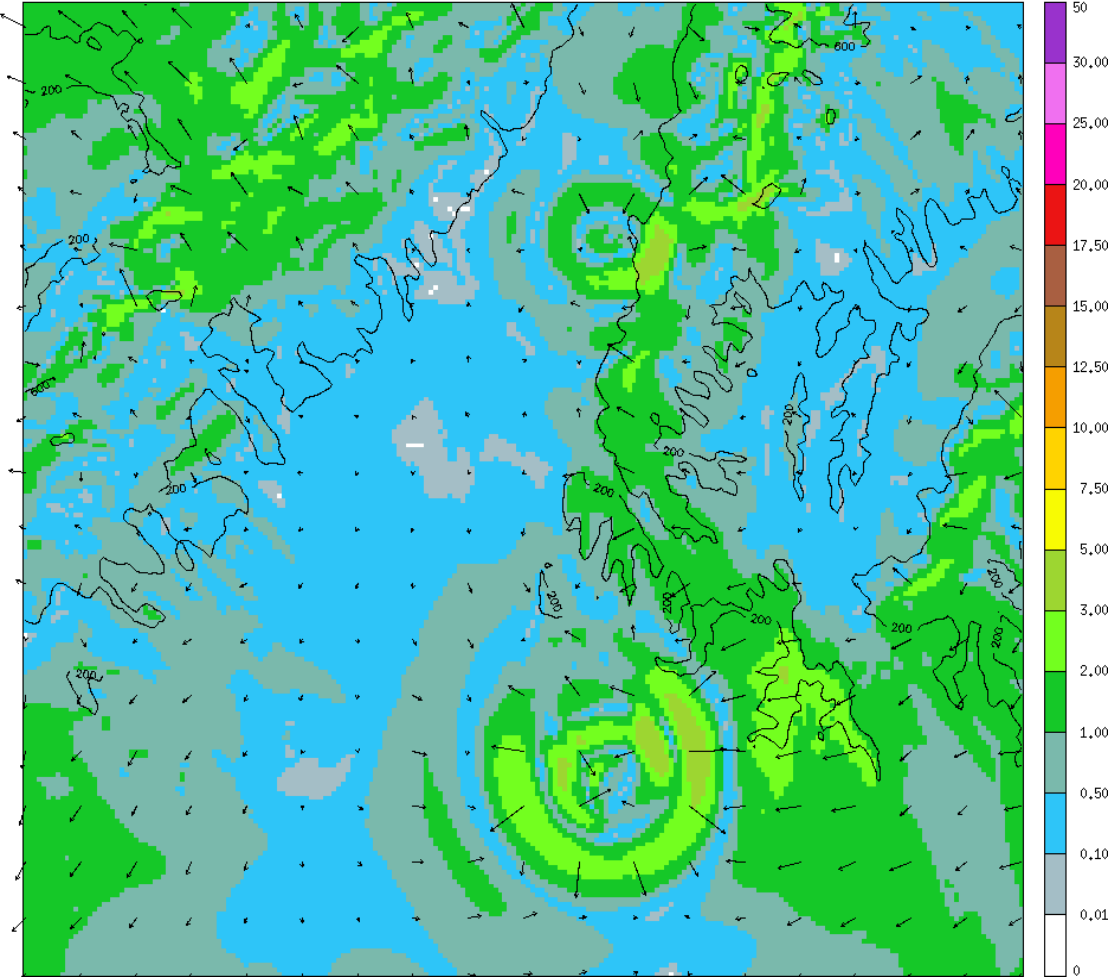
10m wind velocity+orography (SW Slovakia)

After 840s

ALARO0.325 cy43v2 s32a_tuning_test1 pf orography + 10m ZVELOC [m/s] from CLSVENT.ZONAL and CLSVENT.MERIDIEN 70 FCST from 2020-01-26_18UTC

10m wind velocity+orography (SW Slovakia)

After 900s

ALARO0.325 cy43v2 s32a_tuning_test1 pf orography + 10m ZVELOC [m/s] from CLSVENT.ZONAL and CLSVENT.MERIDIEN 75 FCST from 2020-01-26_18UTC
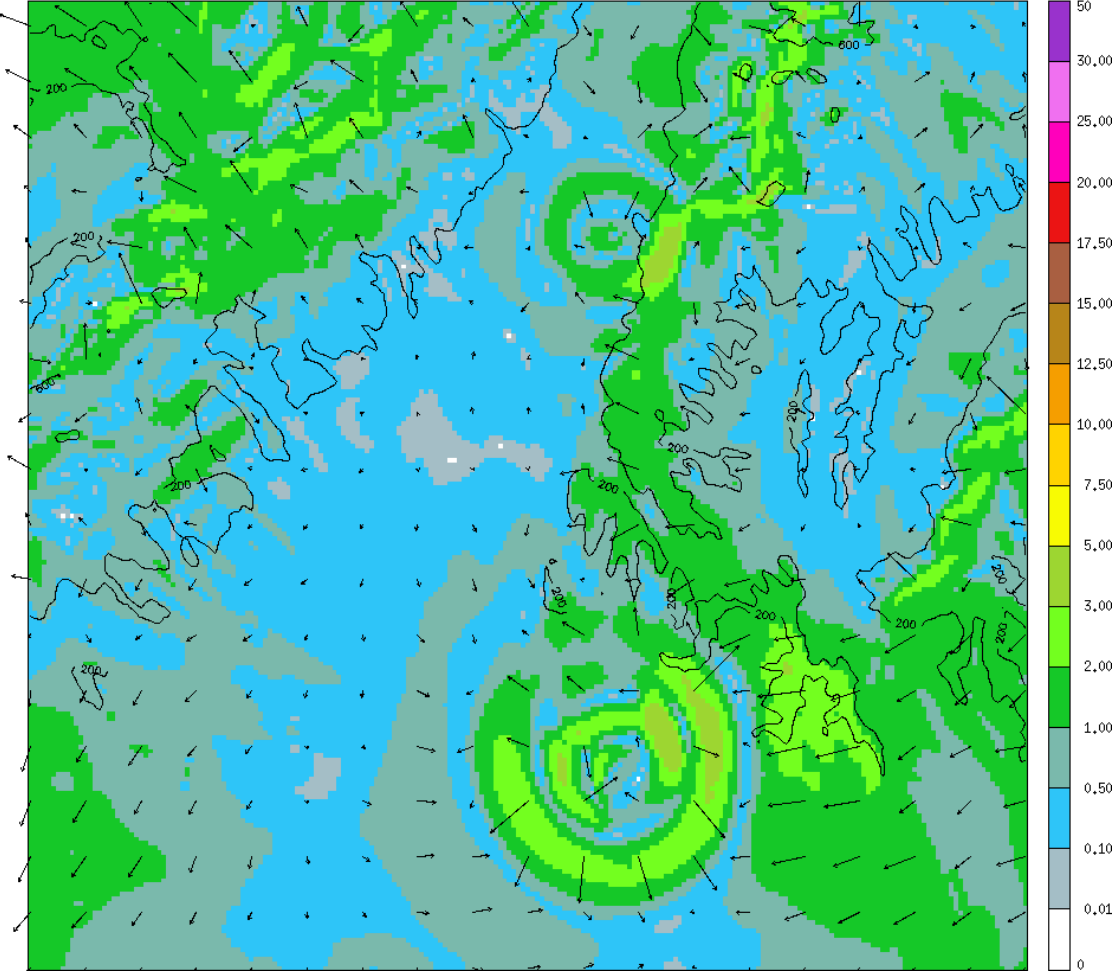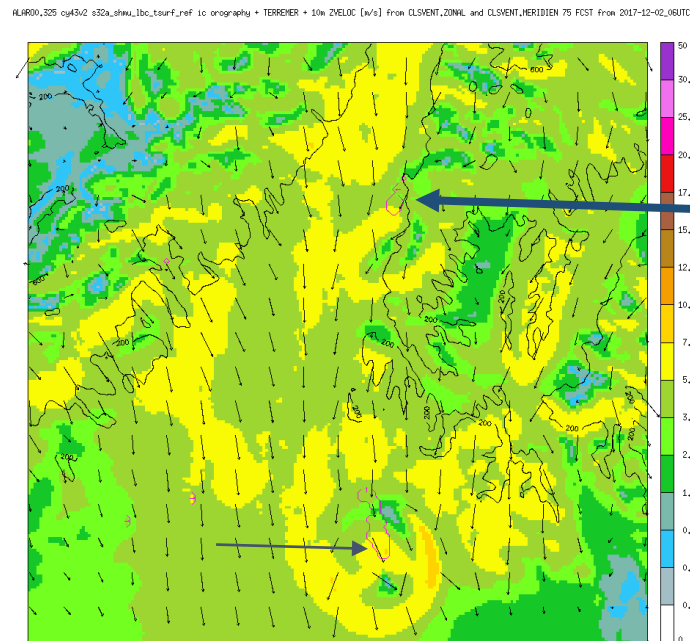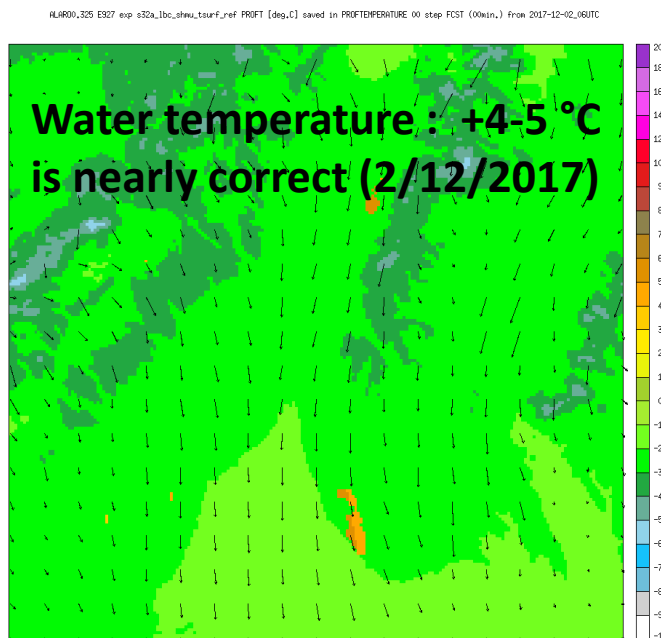
Nature of the phenomenon

- The centers of the outflows are water dams (Kráľová, Sĺňava) or fish ponds already visible at such resolution. It was revealed that the model water surface (PROFTEMPERATURE, SURFTEMPERATURE) taken from the climate files is by several °C warmer against the true lake temperature.
- The outflows exist cca in the first hour of the run, then probably become mixed
- AROME cy40 with SURFEX did not reproduce the outflows, probably because of nearly correct surface temperature
- ALARO run with artificially corrected PROFTEMPERATURE and SURFTEMPERATURE in climate files also produced realistic results
- Adding gradients to wrong lake temperature (imitating some kind of horizontal mixing) made the outflow weaker but it did not vanish

O.K., so we provide observed Lake temperature and everything will be all right?

- No, because even correct lake surface temperature can cause similar problems! Such case appeared at the dams on 2 December 2017, when a cold weather outbreak accompanied by snowfall caused large temperature differences between the lakes and the land.
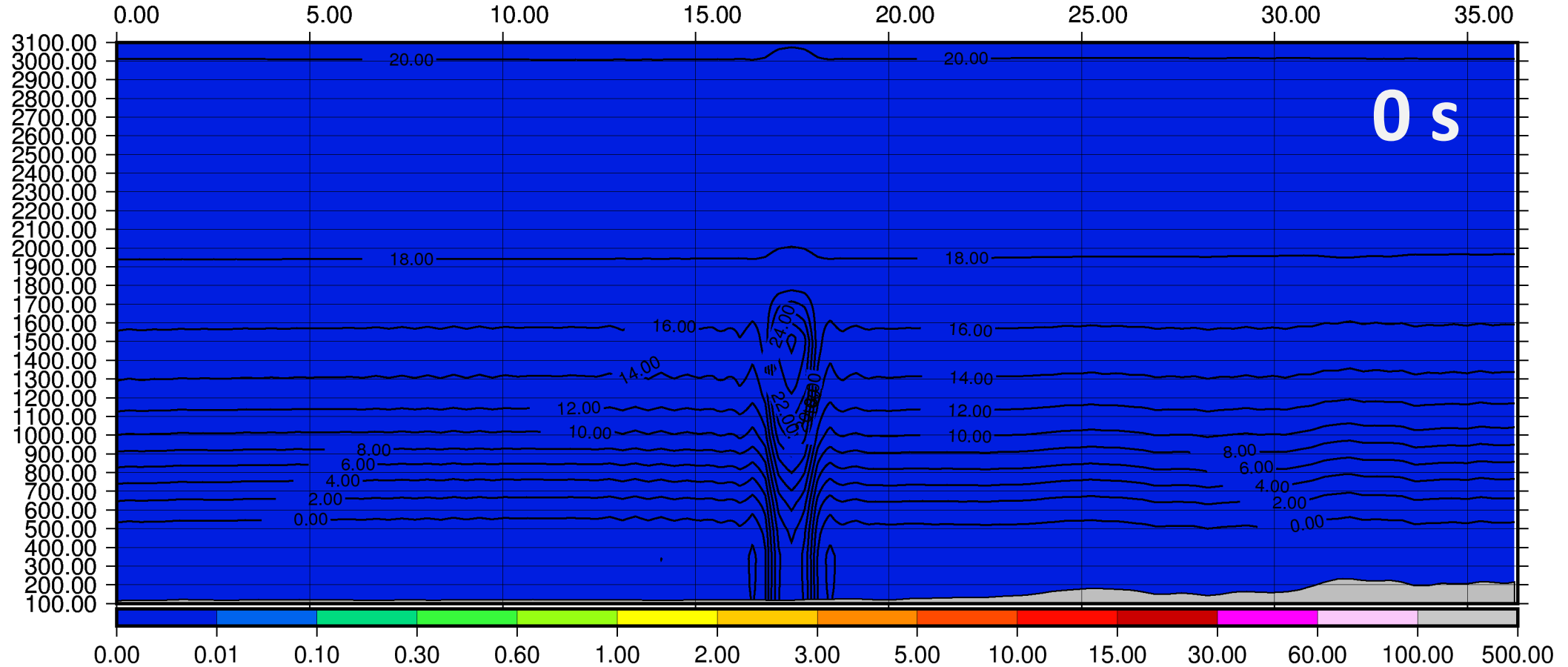

Water temperature : +4-5 °C is nearly correct (2/12/2017)

Síňava dam on that day: cold land, lake still not frozen

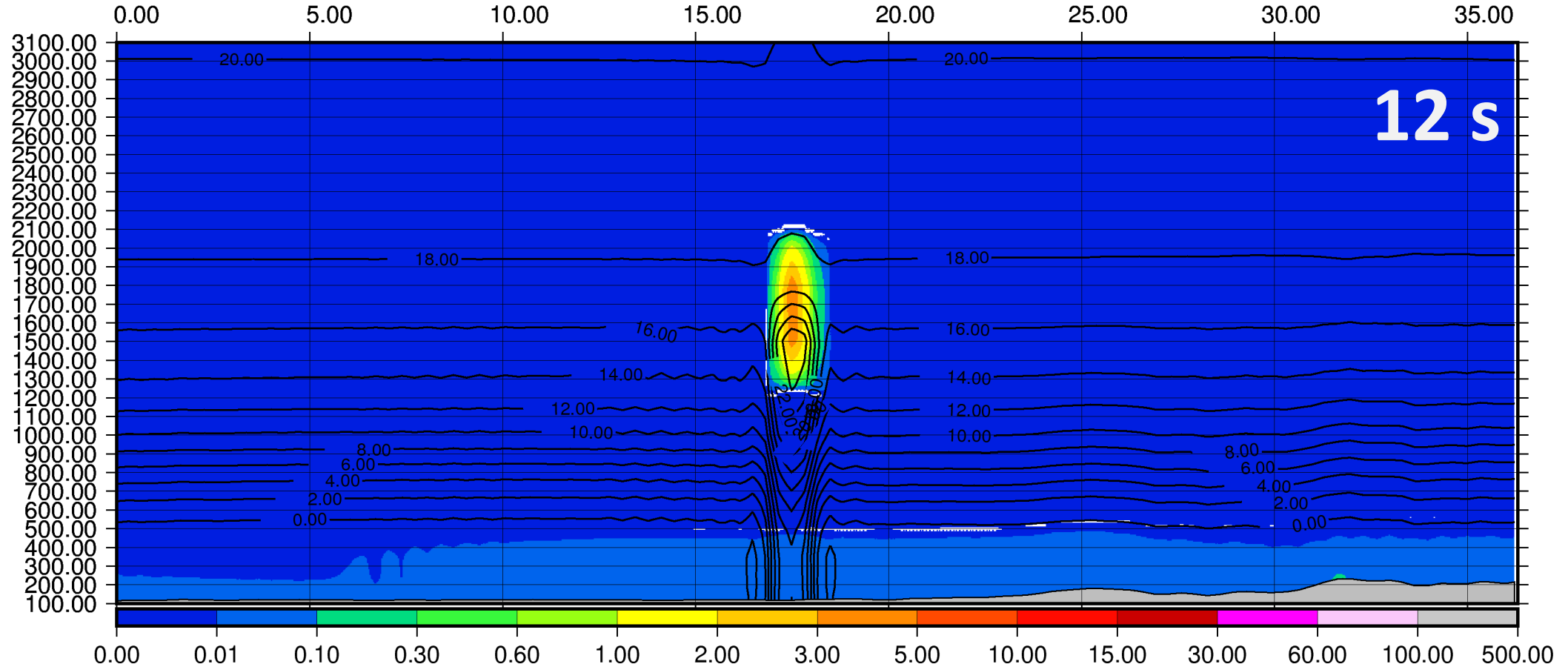Source: facebook, Yacht club at Síňava

Vertical structure and evolution of the phenomenon

- Vertical cross-sections of potential temperature and TKE

Vertical structure and evolution of the phenomenon

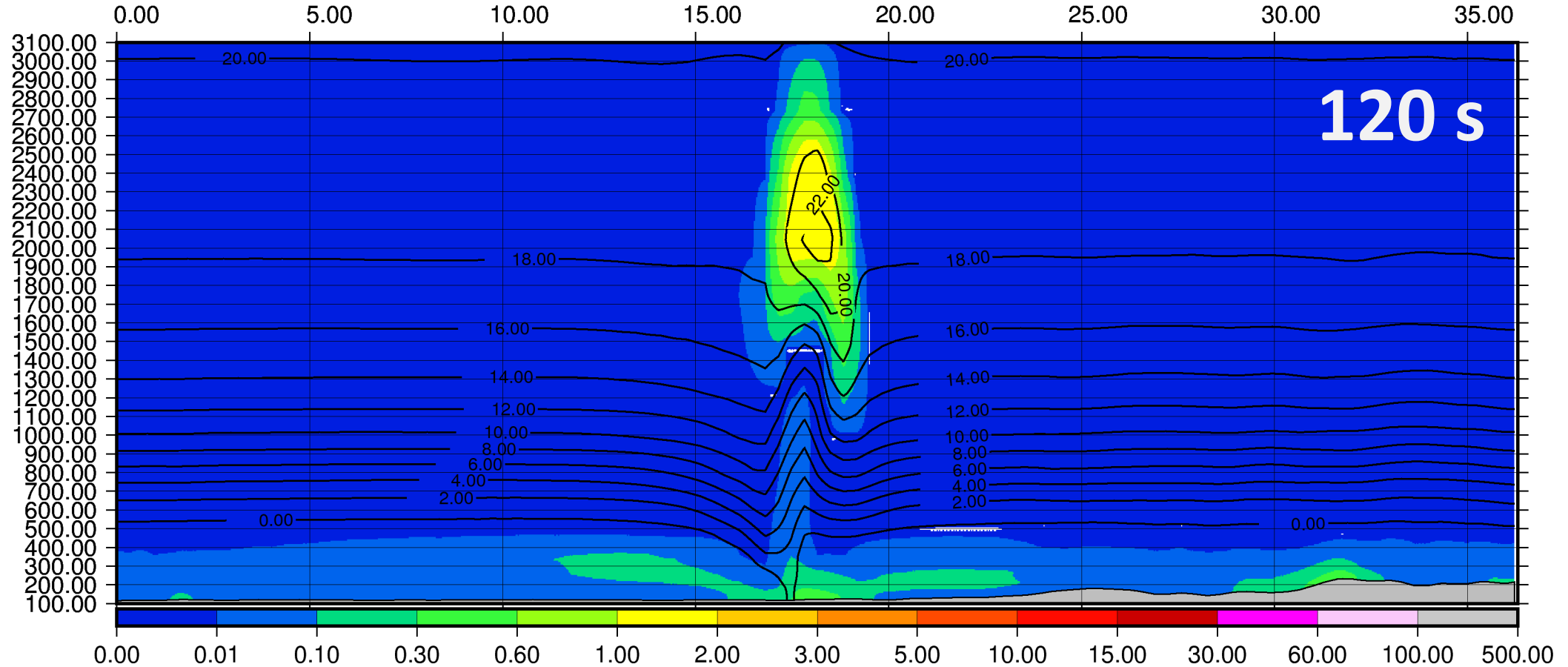- Vertical cross-sections of potential temperature and TKE

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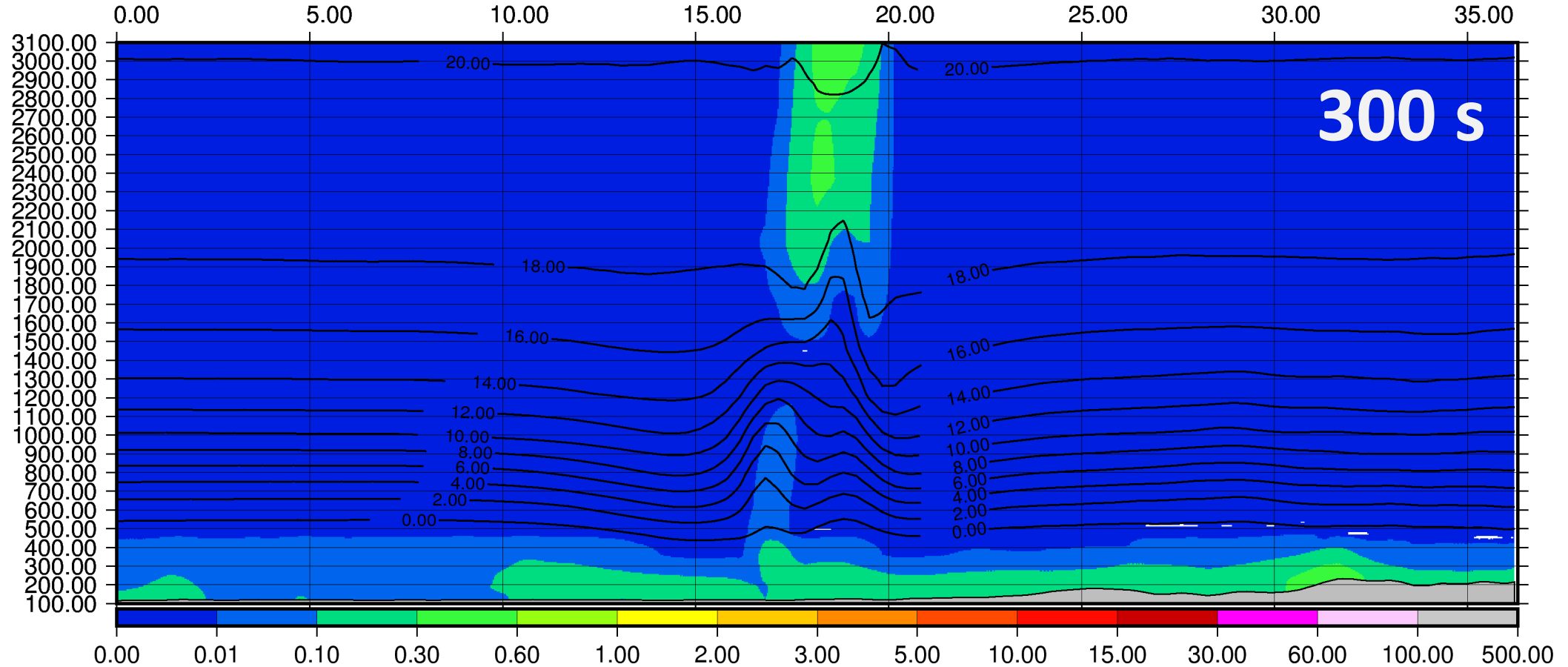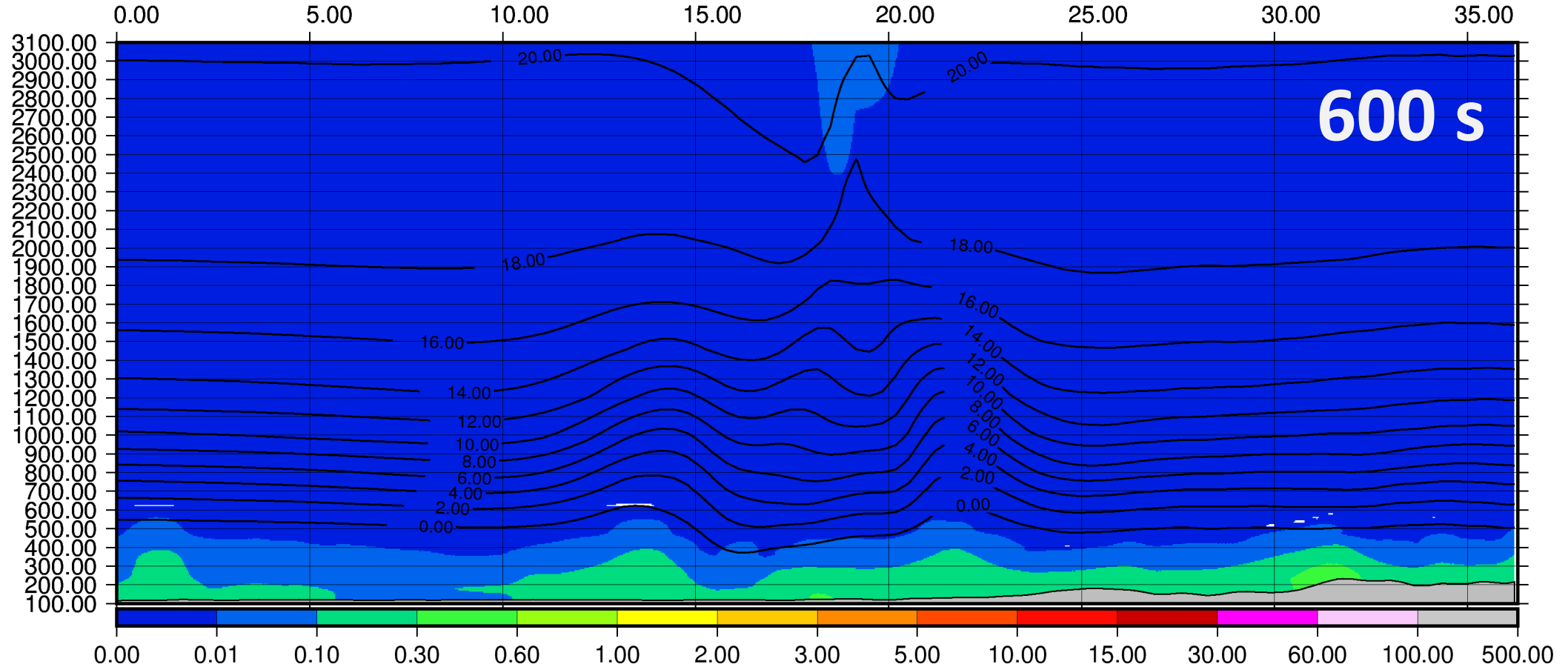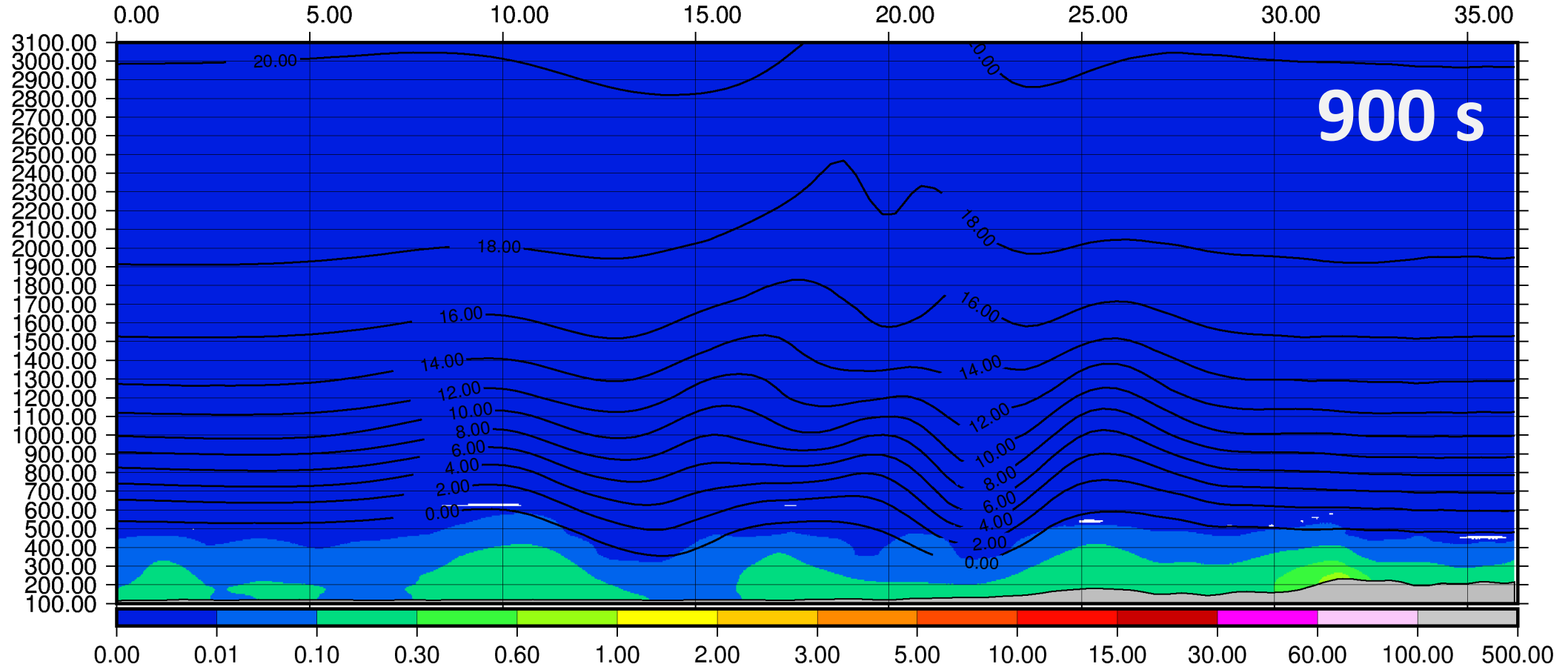- Vertical cross-sections of potential temperature and TKE

Origin of the temperature anomaly at mid-levels

- The vertical cross-sections reveal an interesting fact that the temperature anomaly over the lakes was created in the e927 configuration due to vertical interpolation. Not at surface but about 1400 m high. Switching LESCALE_T=.F. In e927 "cleaned" the anomaly, which otherwise induces deep convection immediately …

ALAR00.325 E927 exp s32a_lace_lbc_e927 T S028 [deg.C] saved in S028TEMPERATURE 00 step FCST (0 min.) from 2020-01-26_12UTC
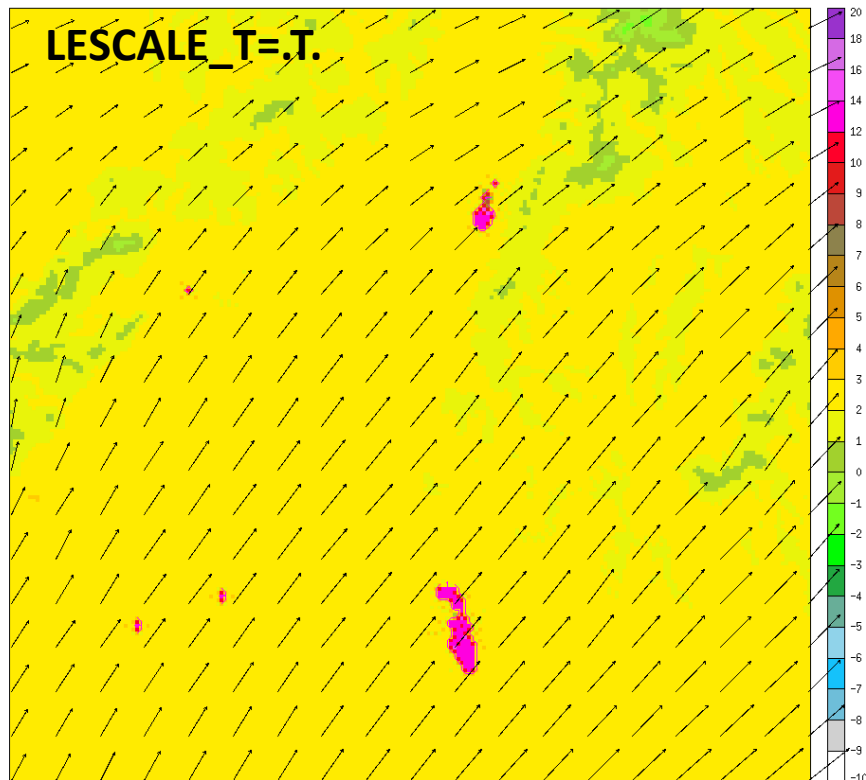
LESCALE_T=.T.

ALAR00.325 E927 exp s32a_lace_lbc_e927_temp_eq_f T S028 [deg.C] saved in S028TEMPERATURE 00 step FCST (0 min.) from 2020-01-26_12UTC
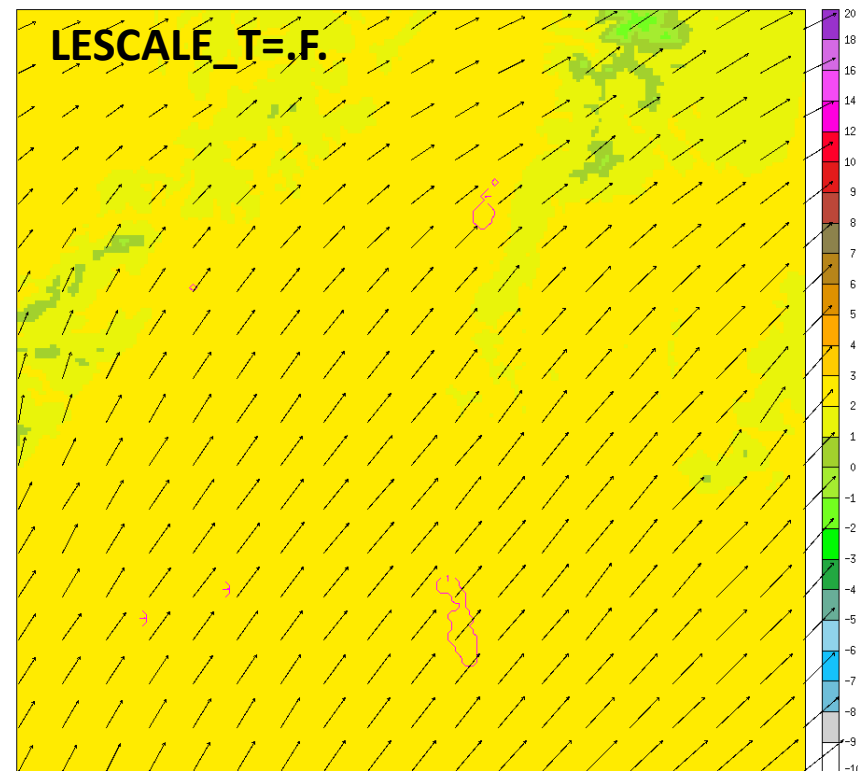
LESCALE_T=.F.

Initial LBC files: Temperature at the S028 level ~1400 m AGL

Treatment

- Besides LESCALE_T=.F. the convection is destroyed also when running the adaptation from DFI analysis. It does not appear even after longer (3h) integration time. However, DFI or assimilation do not solve the problem, only the anomalies and the convection vanish during the period, when these are activated.

ALAR00.325 cy43v2 s32a_lace_lbc_lescale_temp_eq_f ic orography + TERREMER + 10m ZVELOC [m/s] from CLSVENT.ZONAL and CLSVENT.MERIDIEN 75 FCST from 2020-01-26_12UTC
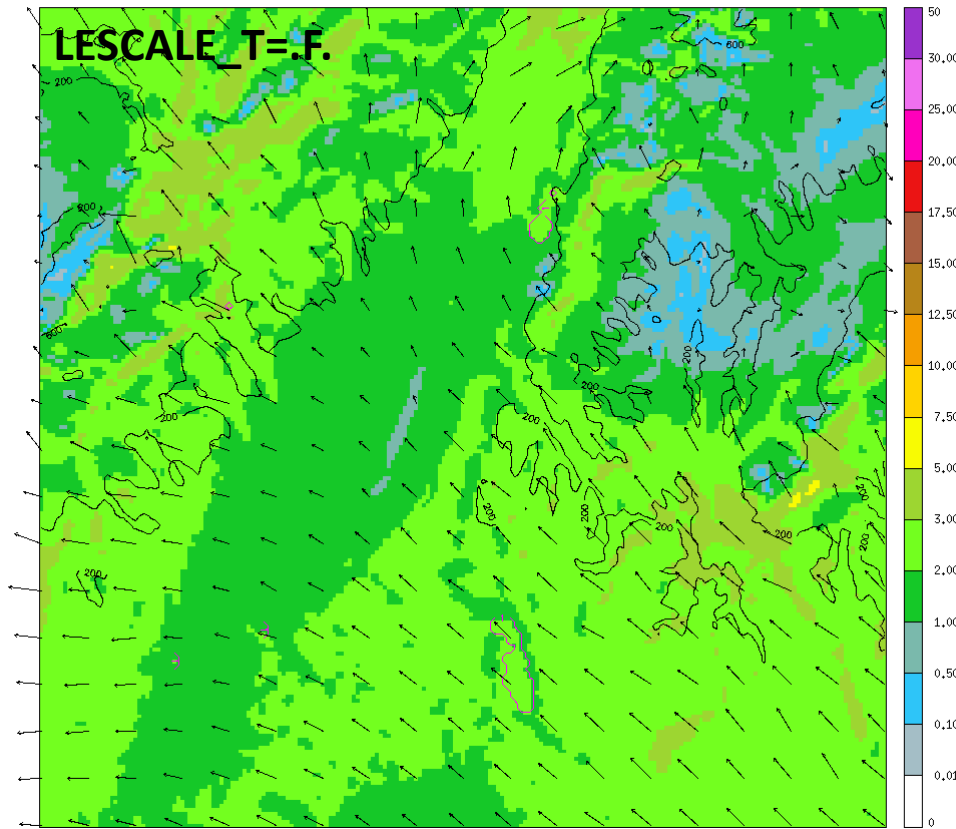
ALAR00.325 cy43v2 s32a_lace_lbc_with_dfi1 ic orography + TERREMER + 10m ZVELOC [m/s] from CLSVENT.ZONAL and CLSVENT.MERIDIEN 75 FCST from 2020-01-26_12UTC

LESCALE_T=.F.

LESCALE_T=.T. but DFI –initiated run
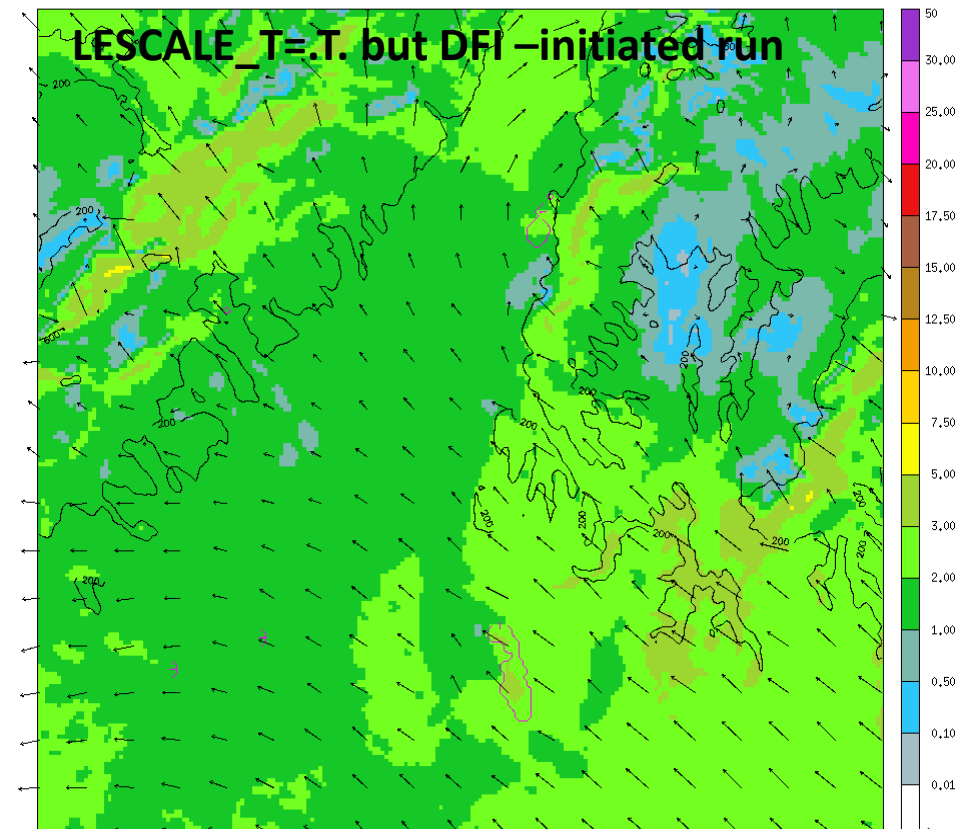
Comments

- Although the presented problem was artificial, lake-induced convection does exist. This can cause snowstorms (e.g. at large lakes as Great Lakes in the USA) and local thunderstorms - especially by warm-water shallow lakes as Balaton or in the tropics (Lake Victoria)

- At high resolution, there are already many local heat sources, not only lakes and water surfaces but also urban areas, soil/vegetation patterns, etc. However, in stable stratification, shallow heat sources should not induce deep convection as shown in the cases above

- It is probable that one would not observe such violent effects in a hydrostatic model. This problem was visualised thanks to non-hydrostatic dynamics and it is possible that it could even cause numerical instability under some circumstances (as by LESCALE_U=.T.)

- The next task would be to find how to keep positive features of the vertical interpolation, while not inserting new anomalies from too warm surfaces