High spread and underestimation of 2m temperature over snow cover in case of the 22 February 2021 warm air advection

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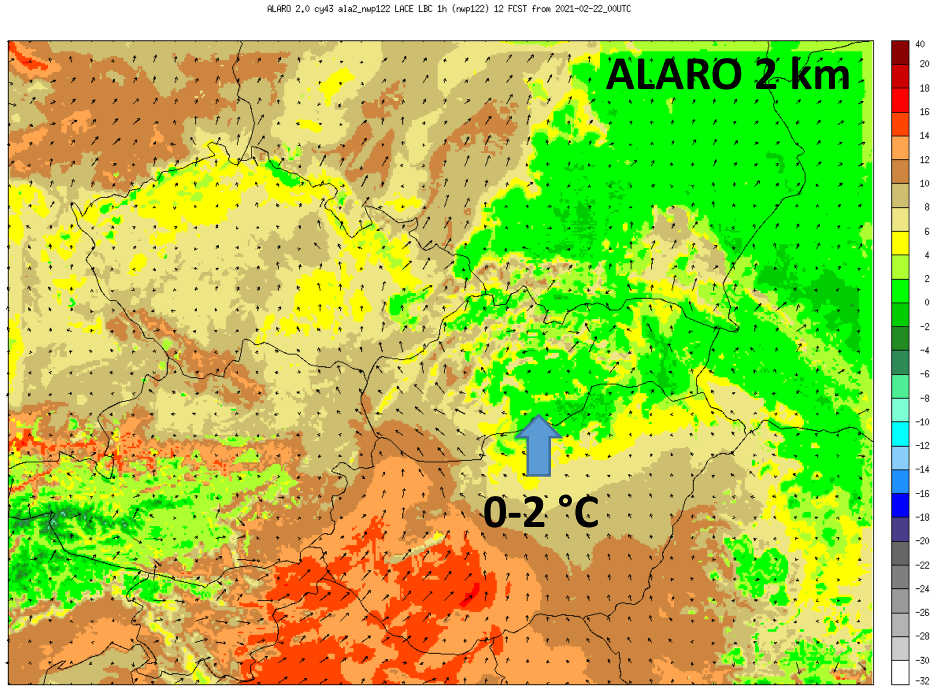
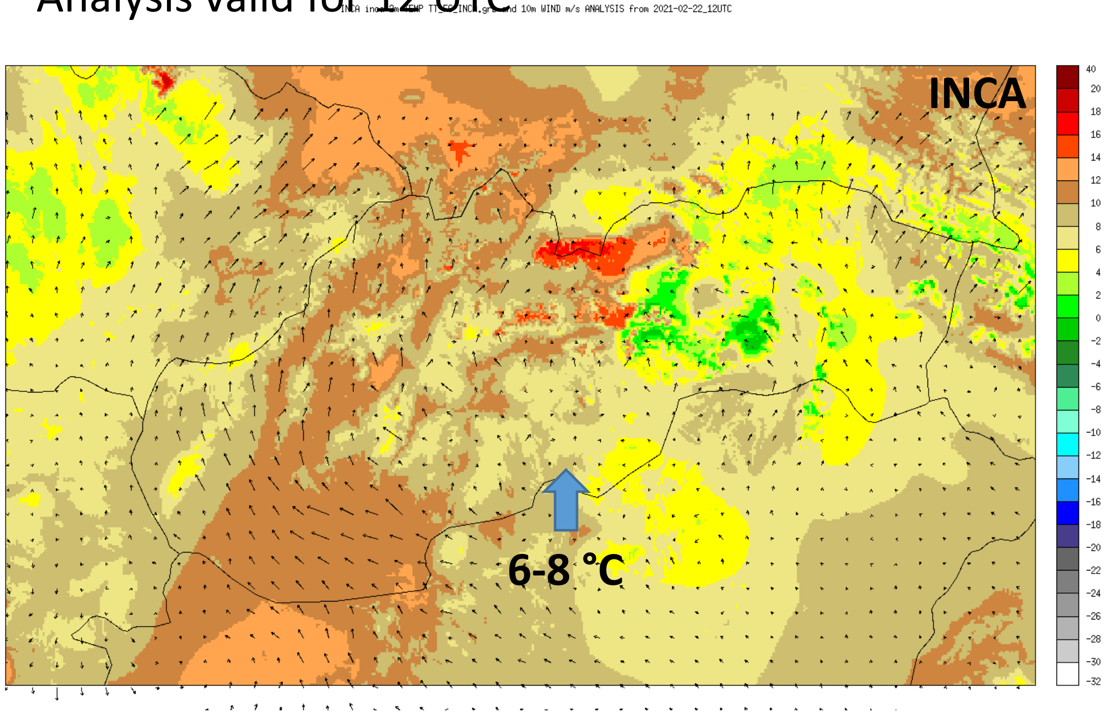
12h forecast valid for 12 UTC:



Analysis valid for 12 UTC:



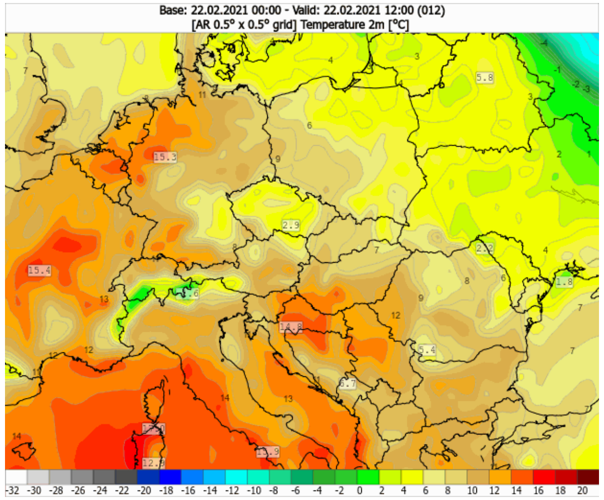
Strong warm advection over snow-covered terrain

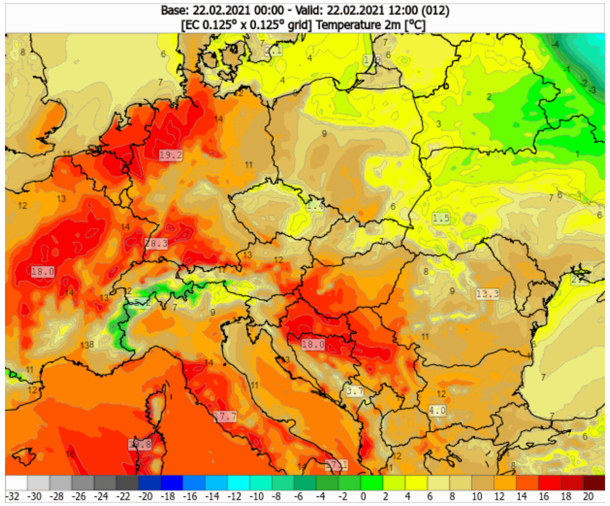
- The situation was characterised by strong southerly wind and advection of warm airmass, which caused fast rise of the 2m temperature even over snow-covered surfaces, up to 10°C
- Initially, several places had fog or low clouds, which vanished during the day
- There were large differences between the deterministic model forecasts or EPS members at some places – e.g. Northwest Slovakia (around the station Liesek), southern part of central Slovakia (station Lučenec) – even among ALARO models

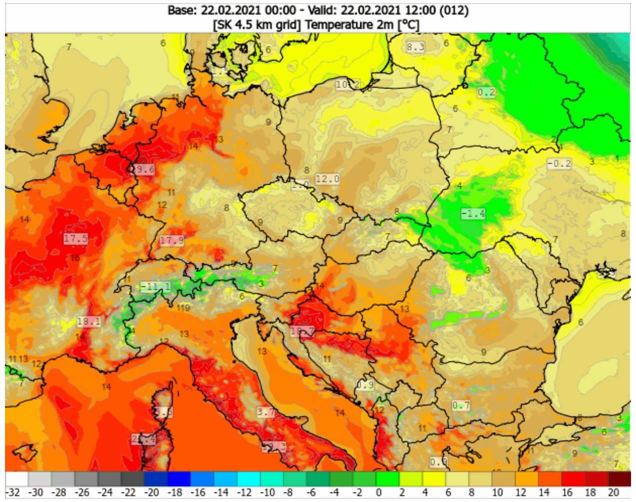
Comparison of some model forecasts (www.rclace.eu)

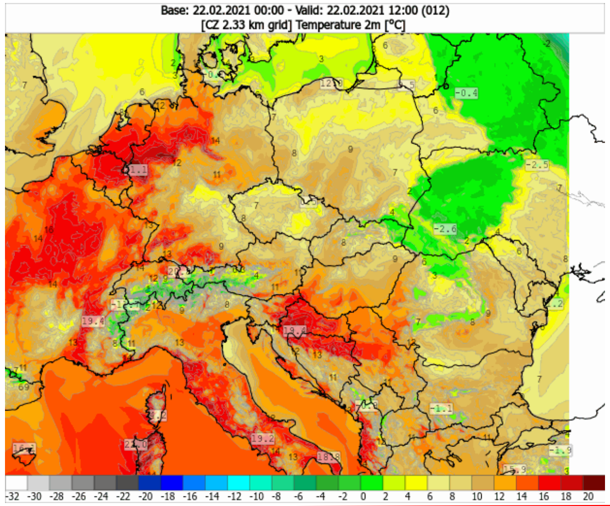
- Base: 22 February 2021 00 UTC 12h forecast

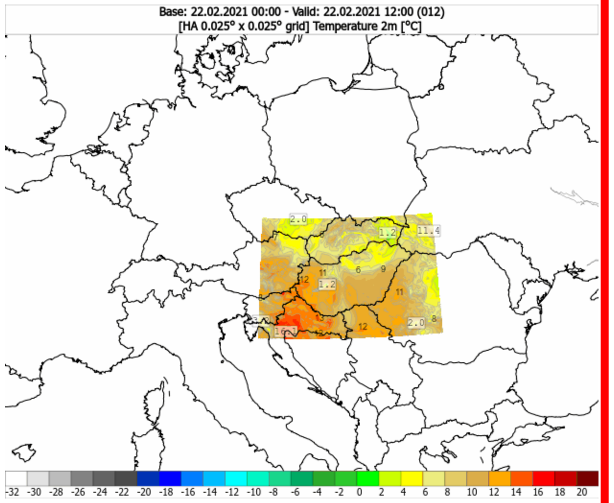
Relatively close to OBS over Slovakia

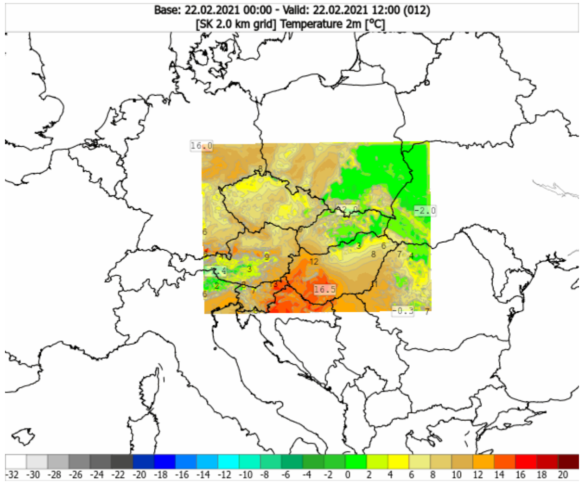


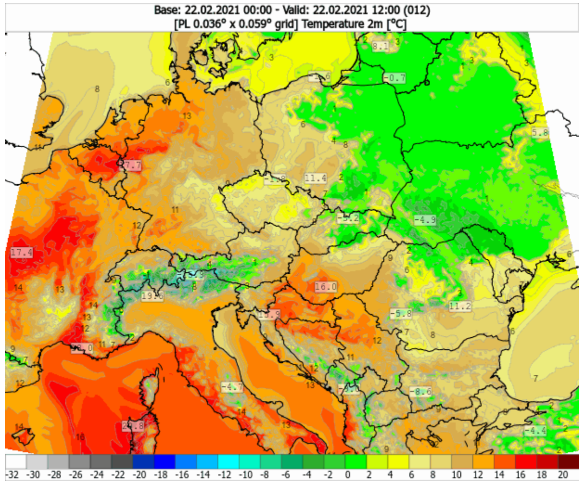


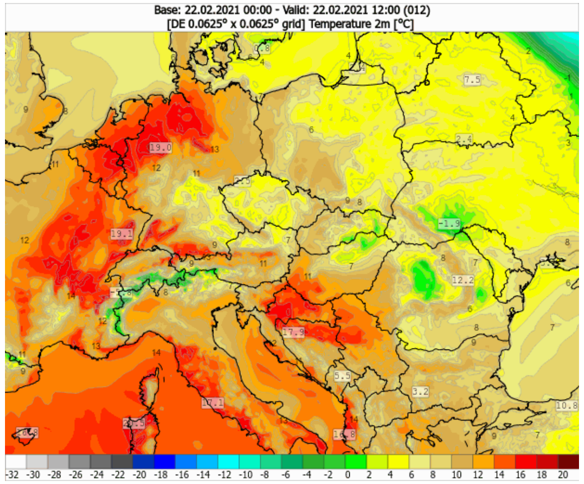










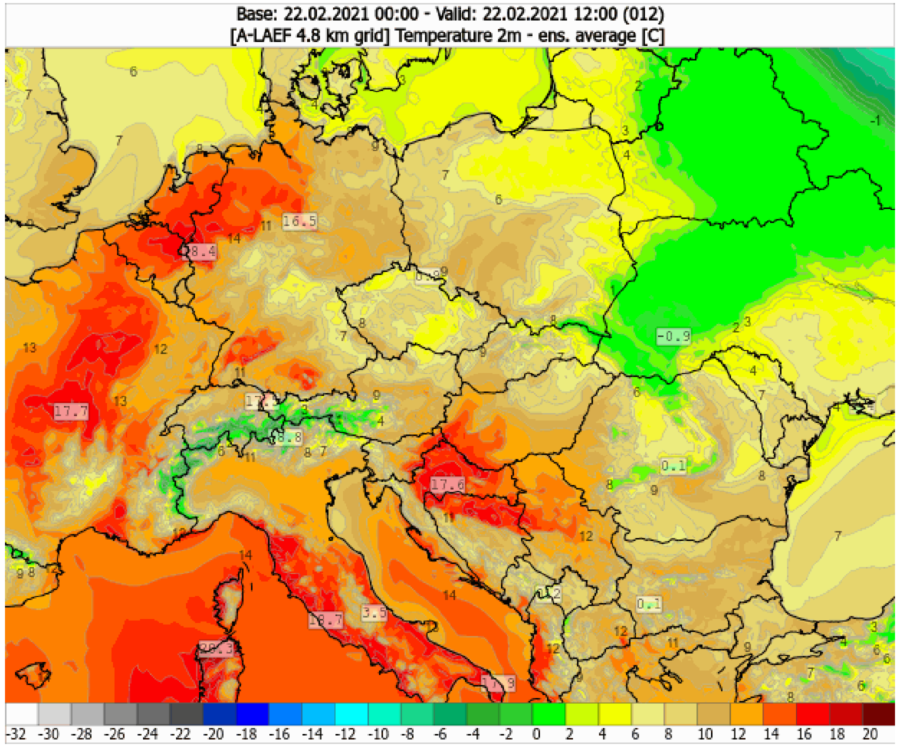


Too cold over certain regions (e.g. southern Slovakia)

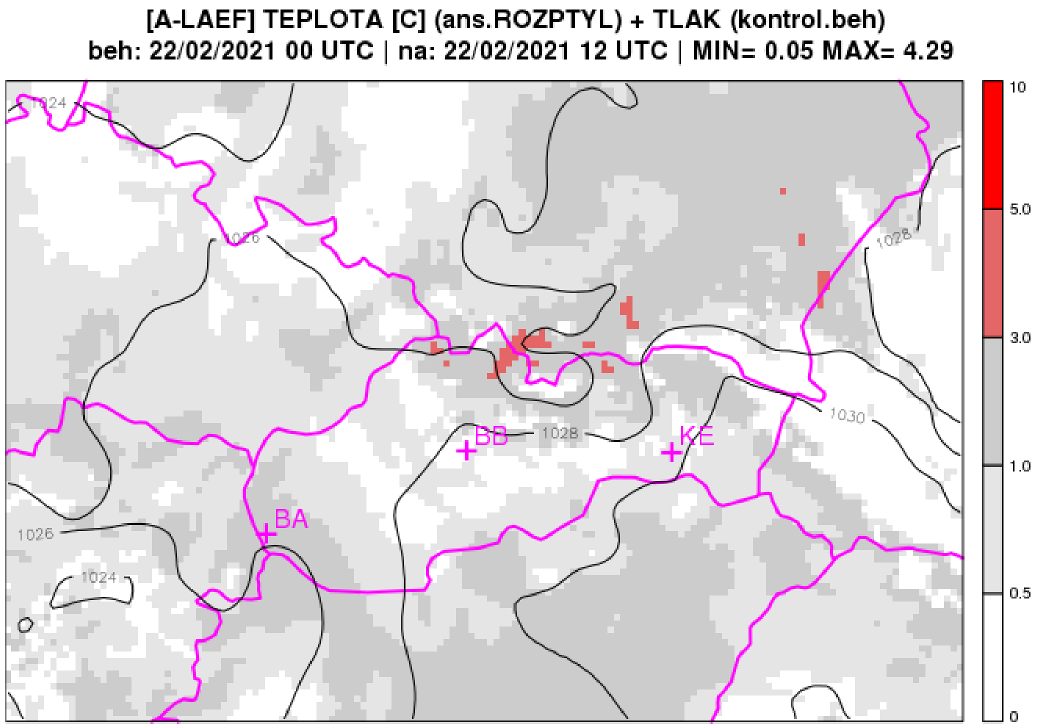
A-LAEF spread in 2m temperature

- High spread in 2m temperature appeared over the northwest Slovakia (several members showed cold temperature), although the weather was warm there in the reality. This spread was continuously present in several runs and forecast periods of various lengths
- Little spread was over the southern part of central Slovakia

A-LAEF mean



A-LAEF spread



Model statistics over 1 point

- „Top-list“ for models and EPS members on 22 February 2021
- Confirms higher spread in A-LAEF members for Liesek (mountain territory in NW) - the worst A-LAEF members are comparable to ICON or ALARO 2 km, which were the coldest models for the station Lučenec on the South

South of the central part of Slovakia

Lucenec: T2m [48.33,19.73]			
2021-02-22_00 +12h: OBS 7.0			
	model	T2m [°C]	BIAS [°C]
1	A-LAEF13	7,1	0,1
2	A-LAEF08	7,2	0,2
3	A-LAEF15	7,2	0,2
4	A-LAEF05	6,7	-0,3
5	ECMWF	7,5	0,5
6	SHMU	7,6	0,6
7	A-LAEF03	7,6	0,6
8	A-LAEF16	7,7	0,7
9	CHMU	7,8	0,8
10	A-LAEF09	7,8	0,8
11	A-LAEF00	7,9	0,9
12	A-LAEF01	8,1	1,1
13	ALAEF	8,2	1,2
14	A-LAEF06	8,4	1,4
15	A-LAEF14	8,4	1,4
16	A-LAEF11	8,7	1,7
17	A-LAEF10	9	2
18	A-LAEF12	9	2
19	A-LAEF02	9,2	2,2
20	A-LAEF04	9,2	2,2
21	A-LAEF07	9,3	2,3
22	ICON	0,8	-6,2
23	ALARO2	0,2	-6,8

Northwest of Slovakia

Liesek: T2m [49.37,19.68]			
2021-02-22_00 +12h: OBS 10.4			
	model	T2m [°C]	BIAS [°C]
1	A-LAEF05	10,6	0,2
2	CHMU	10,1	-0,3
3	A-LAEF01	10,1	-0,3
4	A-LAEF08	9,9	-0,5
5	SHMU	9,4	-1
6	ECMWF	11,8	1,4
7	A-LAEF04	9	-1,4
8	A-LAEF12	8,4	-2
9	A-LAEF00	8,3	-2,1
10	A-LAEF09	8,3	-2,1
11	A-LAEF13	7,6	-2,8
12	A-LAEF07	6,5	-3,9
13	A-LAEF16	6,1	-4,3
14	ALAEF	6,1	-4,3
15	ICON	4,8	-5,6
16	A-LAEF14	4,5	-5,9
17	A-LAEF11	4,2	-6,2
18	A-LAEF03	3,8	-6,6
19	A-LAEF06	3,8	-6,6
20	A-LAEF02	3,4	-7
21	ALARO2	2	-8,4
22	A-LAEF15	0,8	-9,6
23	A-LAEF10	0,6	-9,8

A-LAEF clusters

- The forecasts for the repective clusters are quite similar for Lučenec but highly different for Liesek (especially clusters 2,3 were very cold)
- The cluster setups are different concerning the parameterization of turbulence (different schemes, mixing lengths) or microphysics –see the presentation of Belluš(2020): http://www.umr-cnrm.fr/aladin/IMG/pdf/2020_04_ahw_online_eps_mbell.pdf

Lučenec, 7.0°C	cluster1	cluster2	cluster 3	cluster4
Forecast T2m [°C]	8,1	9,2	7,6	9,2
	6,7	8,4	9,3	7,2
	7,8	9	8,7	9
	7,1	8,4	7,2	7,7
Cluster average:	7,425	8,75	8,2	8,275
Cluster RMSE:	0,698212	1,786057	1,464582	1,530523

Liesek, 10.4 °C	cluster1	cluster2	cluster3	cluster4
Forecast T2m [°C]	10,1	3,4	3,8	9
	10,6	3,8	6,5	9,9
	8,3	0,6	4,2	8,4
	7,6	4,5	0,8	6,1
Cluster average:	9,15	3,075	3,825	8,35
Cluster RMSE:	1,759261	7,473453	6,880589	2,484955

Model statistics – next day

- „Top-list“ on the next day 23 February 2021, when the situation was similar
- There were again notable differences both within and across the clusters
- It means both physics and non-physics perturbations played a role, physics had a systematic influence on model errors

South of the central part of Slovakia

Lucenec: T2m [48.33,19.73]	
2021-02-23_00 +12h: OBS 8.5	
01. A-LAEF06	8.3 (-0.2)
02. A-LAEF02	8.8 (0.3)
03. A-LAEF01	8.2 (-0.3)
04. ECMWF	8.2 (-0.3)
05. A-LAEF12	8.2 (-0.3)
06. A-LAEF16	8.2 (-0.3)
07. A-LAEF07	8.9 (0.4)
08. A-LAEF03	8.1 (-0.4)
09. A-LAEF	8.1 (-0.4)
10. A-LAEF15	9.0 (0.5)
11. A-LAEF14	8.0 (-0.5)
12. SHMU	7.9 (-0.6)
13. A-LAEF00	7.9 (-0.6)
14. A-LAEF04	9.1 (0.6)
15. A-LAEF05	7.4 (-1.1)
16. CHMU	7.3 (-1.2)
17. A-LAEF11	9.7 (1.2)
18. A-LAEF10	7.2 (-1.3)
19. A-LAEF09	7.1 (-1.4)
20. A-LAEF13	6.7 (-1.8)
21. A-LAEF08	6.5 (-2.0)
22. ICON	4.3 (-4.2)
23. ALARO2	1.2 (-7.3)

Northwest of Slovakia

Liesek: T2m [49.37,19.68]	
2021-02-23_00 +12h: OBS 13.1	
01. ECMWF	10.8 (-2.3)
02. A-LAEF04	10.5 (-2.6)
03. CHMU	10.0 (-3.1)
04. A-LAEF12	9.9 (-3.2)
05. A-LAEF08	9.4 (-3.7)
06. A-LAEF01	9.4 (-3.7)
07. A-LAEF09	9.2 (-3.9)
08. A-LAEF16	8.9 (-4.2)
09. A-LAEF05	8.8 (-4.3)
10. A-LAEF00	8.8 (-4.3)
11. SHMU	8.3 (-4.8)
12. A-LAEF	7.9 (-5.2)
13. A-LAEF14	7.8 (-5.3)
14. A-LAEF07	7.8 (-5.3)
15. A-LAEF13	6.9 (-6.2)
16. A-LAEF11	6.6 (-6.5)
17. A-LAEF15	6.4 (-6.7)
18. A-LAEF06	6.3 (-6.8)
19. A-LAEF03	6.1 (-7.0)
20. ICON	5.9 (-7.2)
21. A-LAEF10	5.7 (-7.4)
22. A-LAEF02	5.2 (-7.9)
23. ALARO2	1.9 (-11.2)

A-LAEF clusters

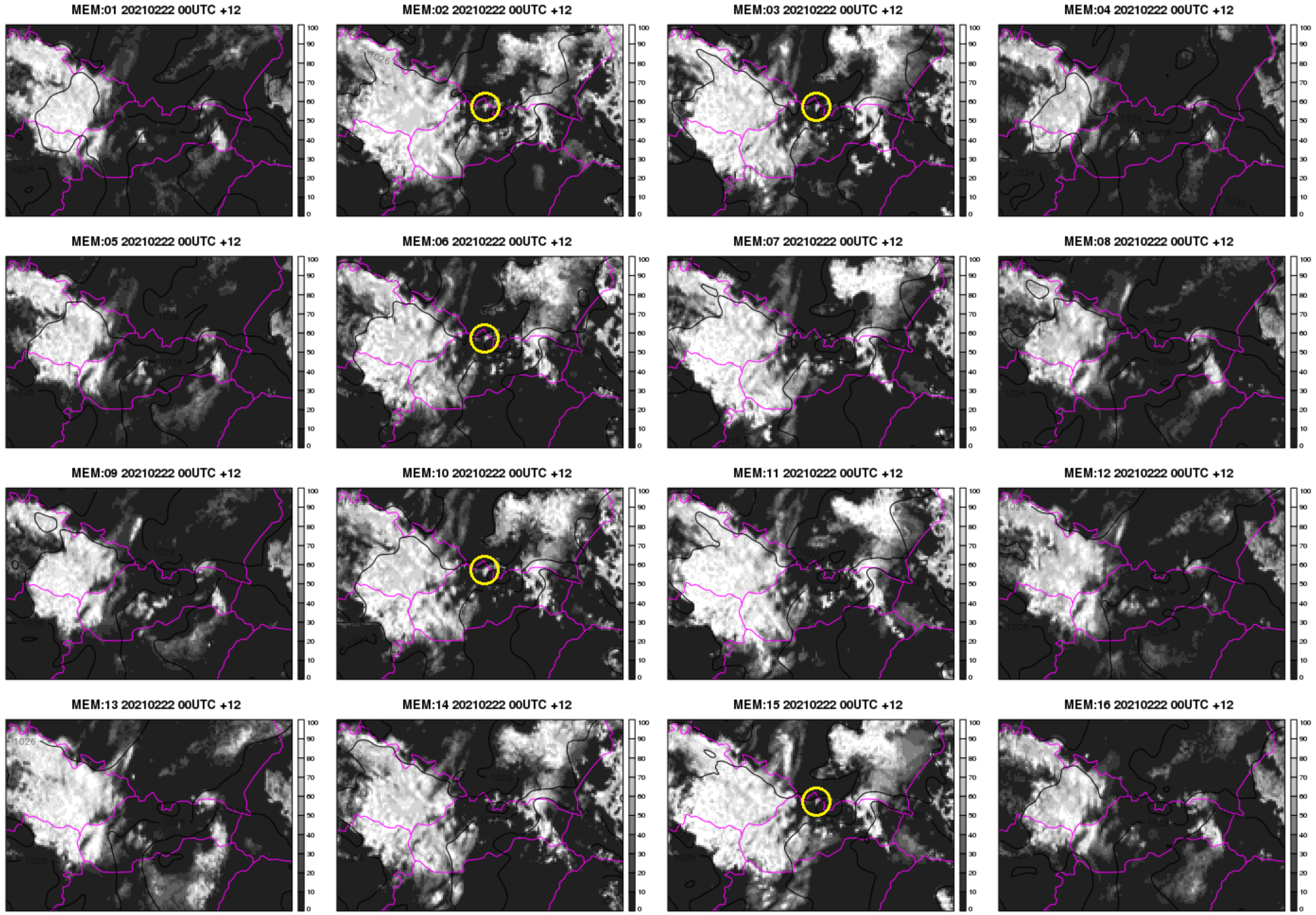
- Whereas clusters 2,3 were slightly better for Lučenec, in case of Liesek these were the worst
- The 2,3 clusters were cold in Liesek also during the previous day
- The setup with EL3 mixing length used in these clusters could support inversion or low clouds, which could damp the rise of the T2m in this region

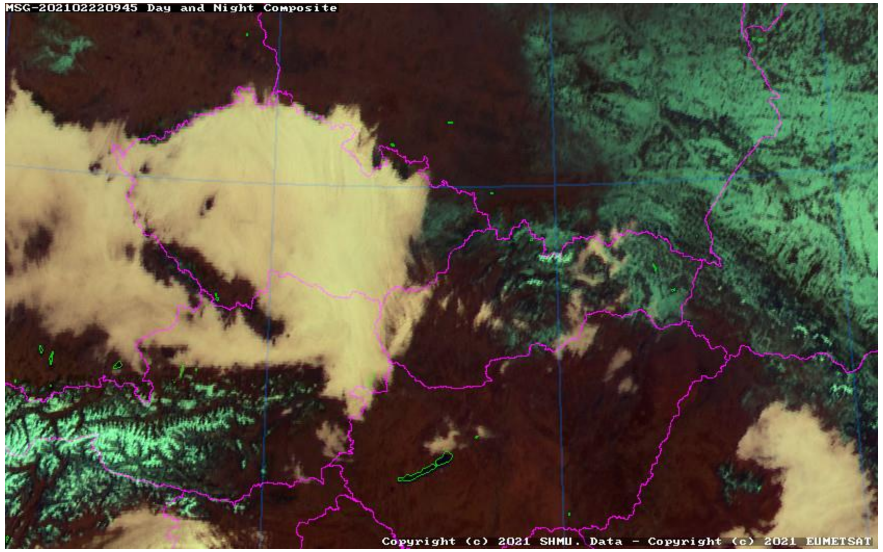
Lučenec, 8.5 °C	cluster1	cluster2	cluster 3	cluster4
Forecast T2m [°C]	8,2	8,8	8,1	9,1
	7,4	8,3	8,9	6,5
	7,1	7,2	9,7	8,2
	6,7	8	9,0	8,2
Cluster average:	7,35	8,075	8,925	8
Cluster RMSE:	1,274755	0,719375	0,708872	1,065364

Liesek, 13.1 °C	cluster1	cluster2	cluster3	cluster4
Forecast T2m [°C]	9,4	5,2	6,1	10,5
	8,8	6,3	7,8	9,4
	9,2	5,7	6,6	9,9
	6,9	7,8	6,4	8,9
Cluster average:	8,575	6,25	6,725	9,675
Cluster RMSE:	4,632224	6,919176	6,407613	3,475989

Impact of low clouds

- Also in the reality there were low clouds or fog in the morning, detectable on satellites (MSG RGB natural colors), which initially could damped the temperature rise at some places (mainly on the East).
- Similar patterns could be found in A-LAEF (mostly clusters 2,3 !) and ALARO 2km cloudiness forecasts





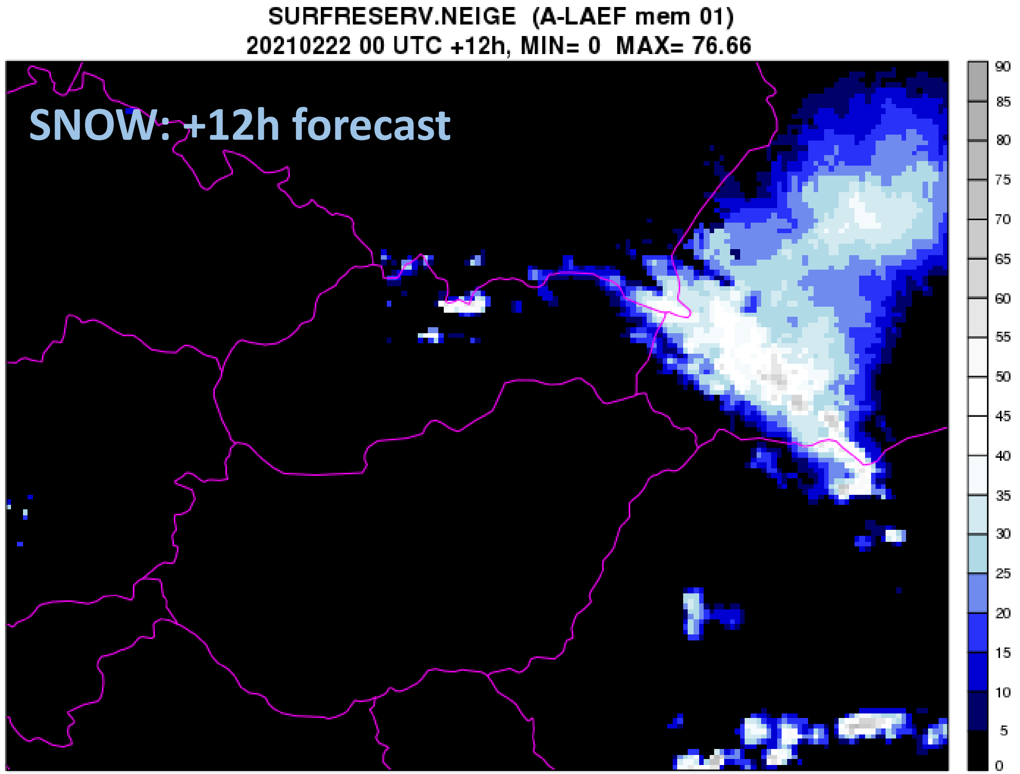
MSG: 22 February 2021 0945 UTC

A-LAEF, base: 22 February 2021 00 UTC, 12h forecast

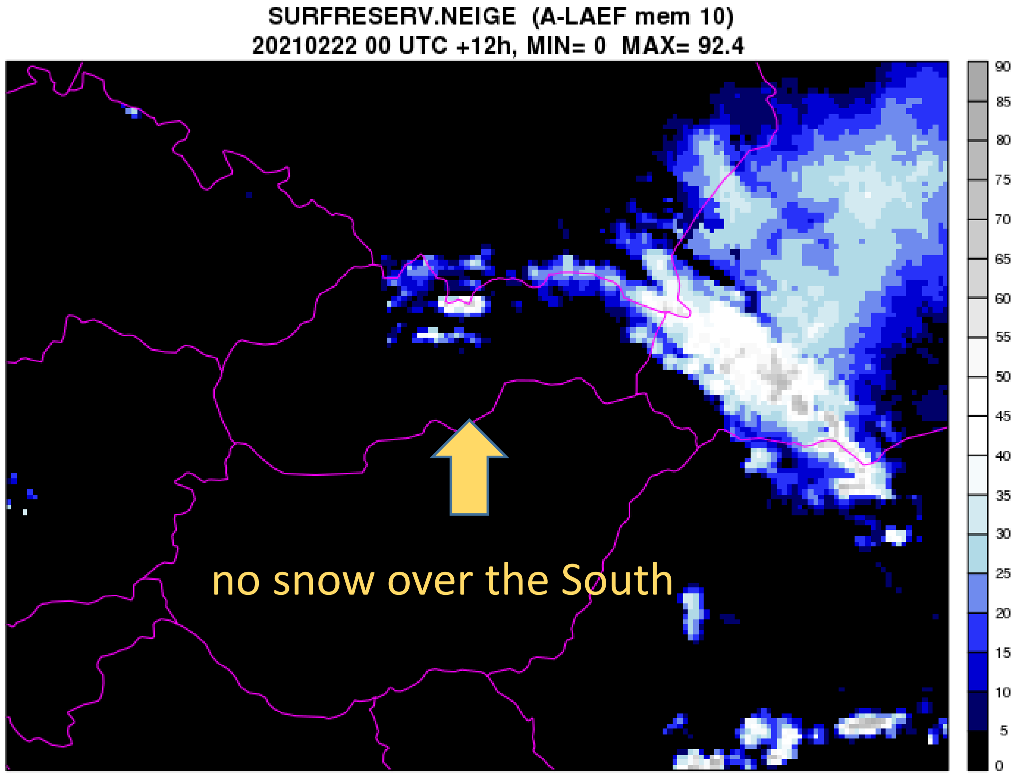
Low clouds and snow, A-LAEF

- A-LAEF members, which had cold and cloudy weather over the NW Slovakia had also snow cover in their forecasts. There was no model snow cover over the South, where the T2m spread was rather small (but there was snow in the reality).

Member 01: warmest, no clouds in NW Slovakia



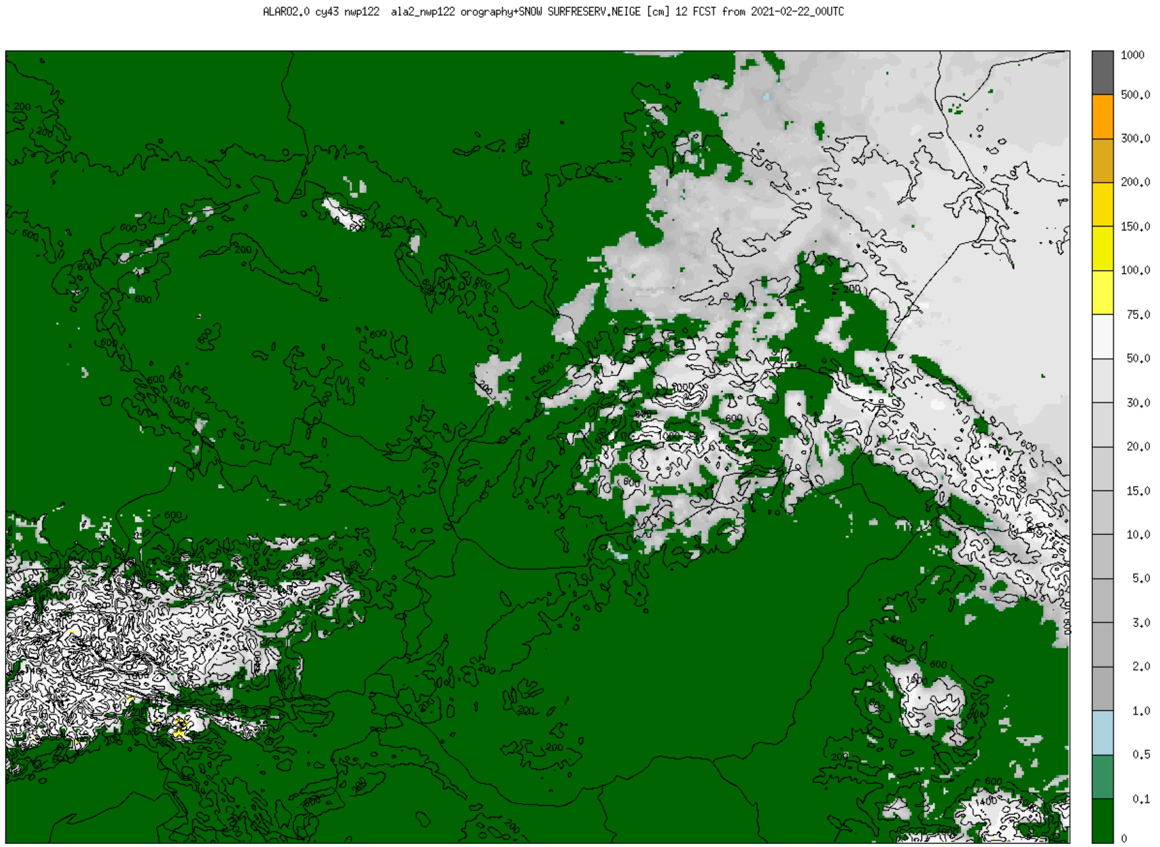
Member 10: coldest, clouds over NW Slovakia



Snow in ALARO 2km (ARPEGE 1h LBC)

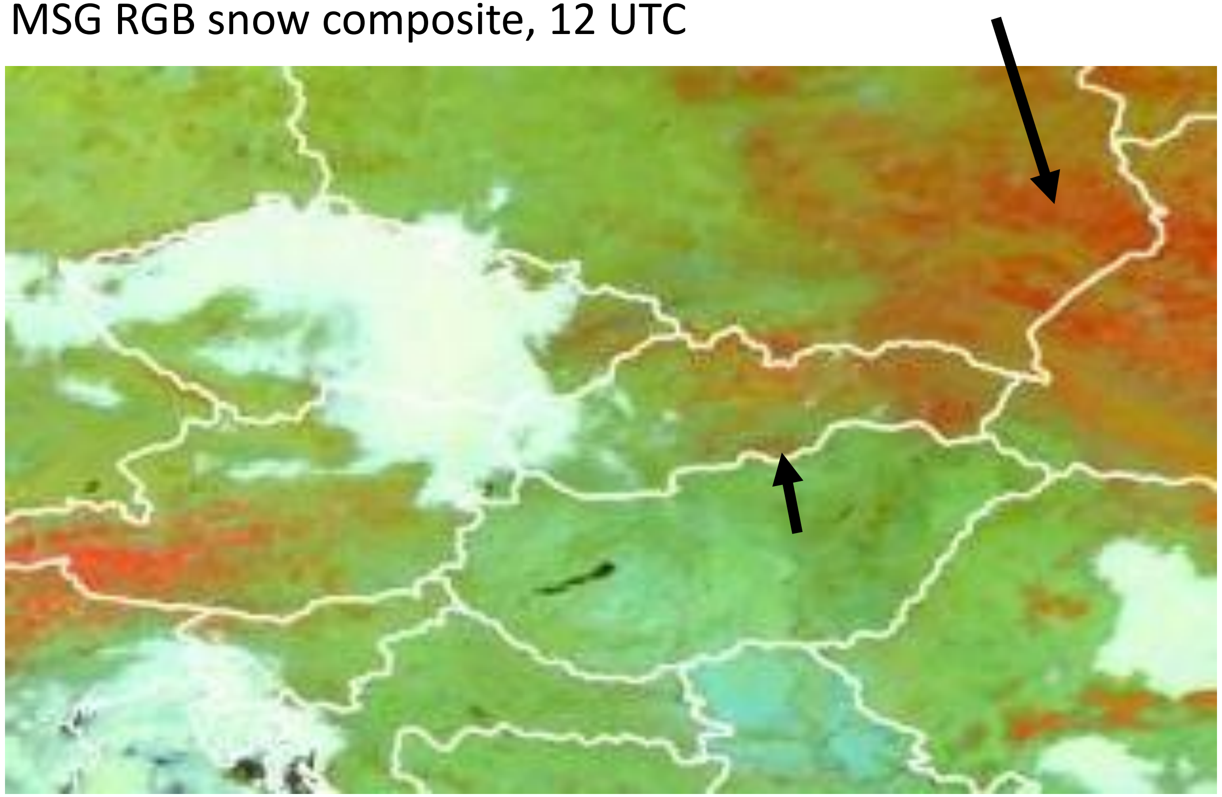
- No coupling and no cycling, snow taken from the driving model (ARPEGE) at the start of the integration, no SURFEX but ISBA scheme
- The snow forecast matches the observations (in the reality still up to 10cm snow in the South, even over lowland, mainly old snow with high water content, up to 30 cm in the Northwest)

Alaro 2km, base: 22 February 2021, 12h Forecast of snow (cm)



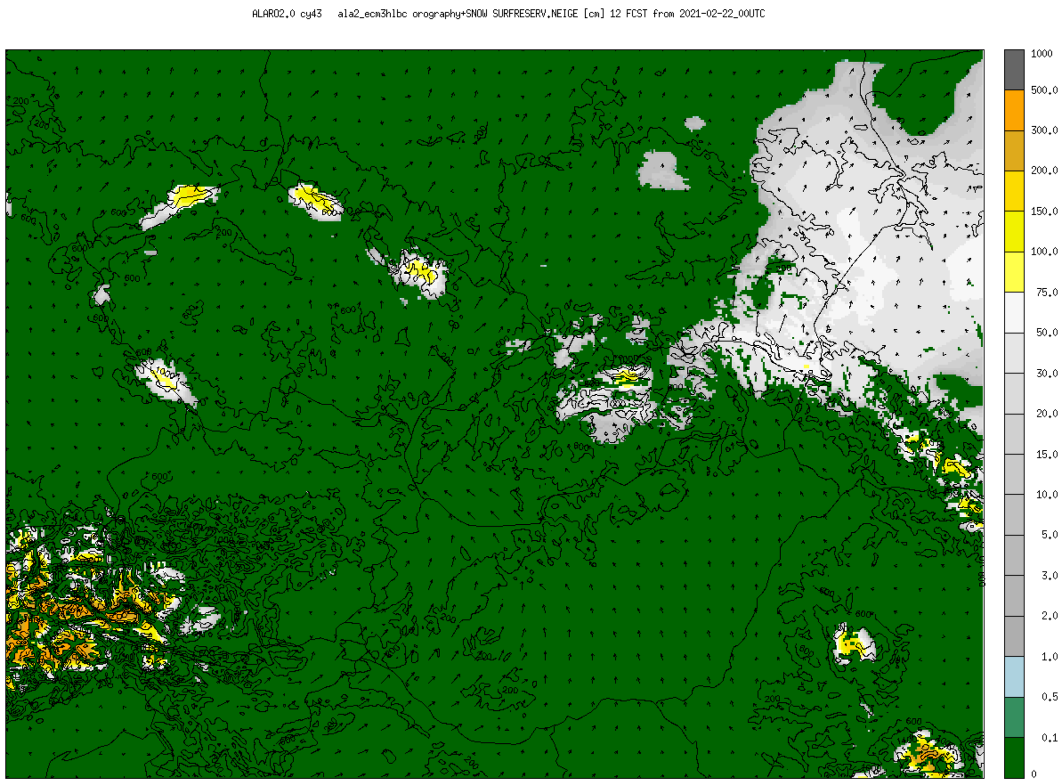
MSG RGB snow composite, 12 UTC

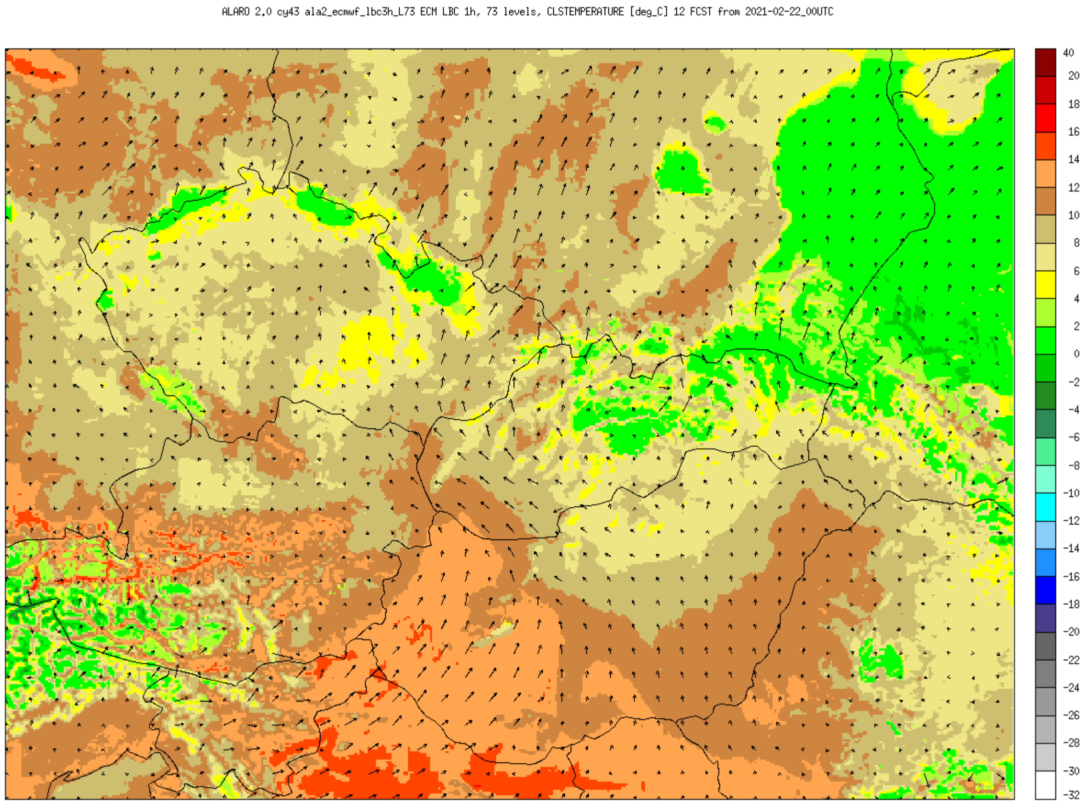
Snow cover in reddish colors



Snow in ALARO 2km (3h ECMWF LBC – ffei files)

- Less snow in the model, much warmer (by 6-8 °C against the reference) forecast for the southern part of central Slovakia, close to „warm“ deterministic and EPS runs

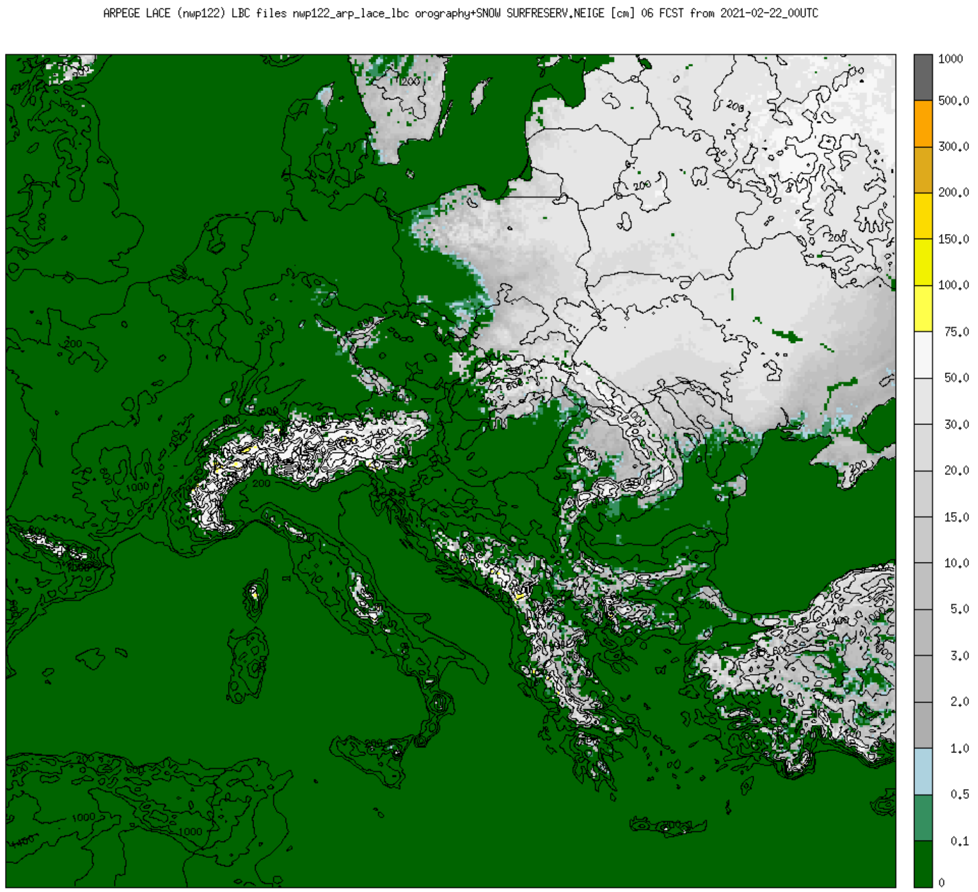




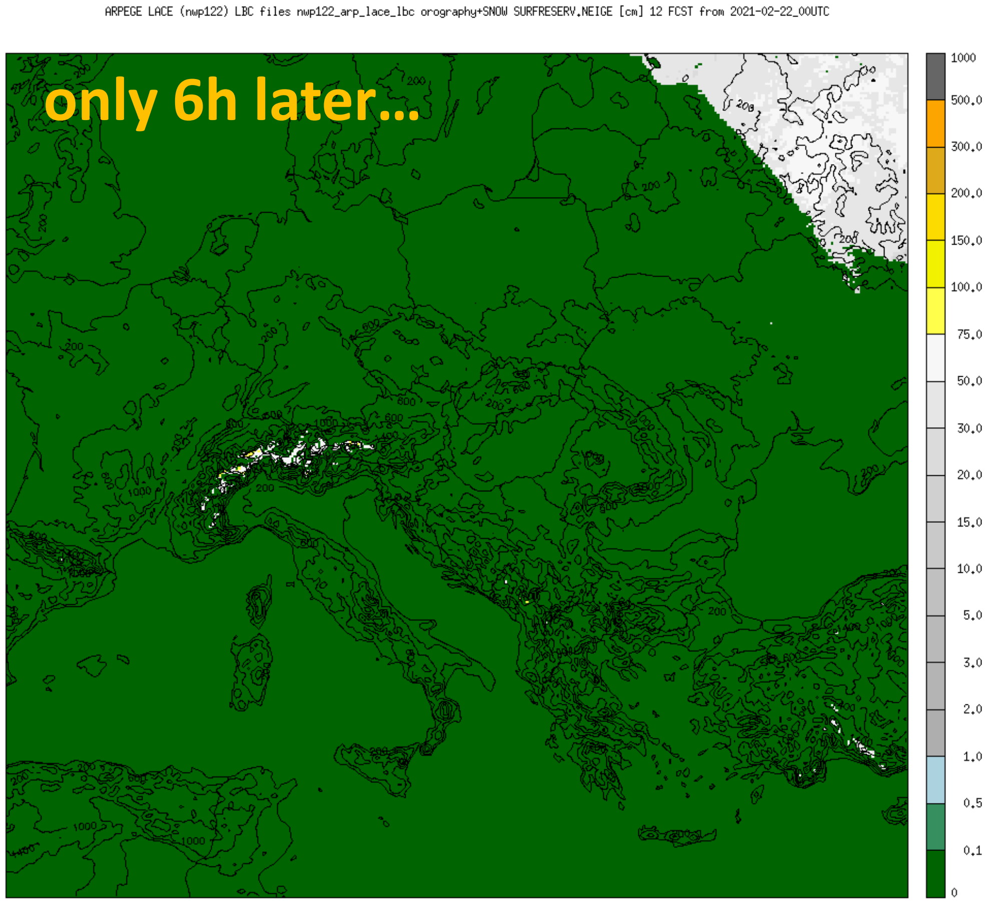
Snow melting in ARPEGE (lace LBC files)

- The snow cover disappears dramatically within 6h, which can have impact if forecasts are used as inputs (e.g. as 1st guess) to LAM models. There is no snow over Poland or Slovakia at 12 UTC, though the snow cover was present even on the next day of 23 February 2021

Base: 22 February 2021 00 UTC, 6h forecast



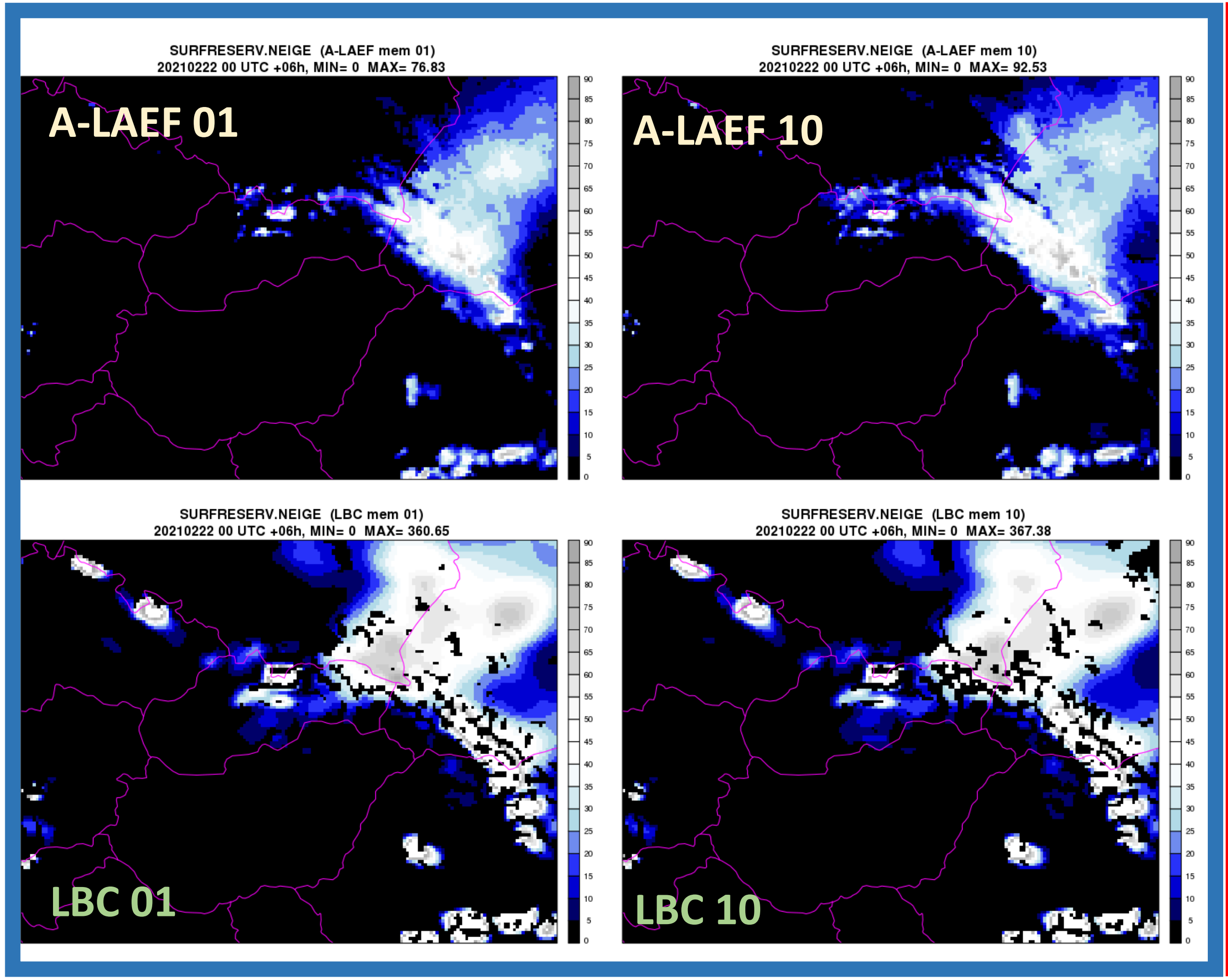
Base: 22 February 2021 00 UTC, 12h forecast



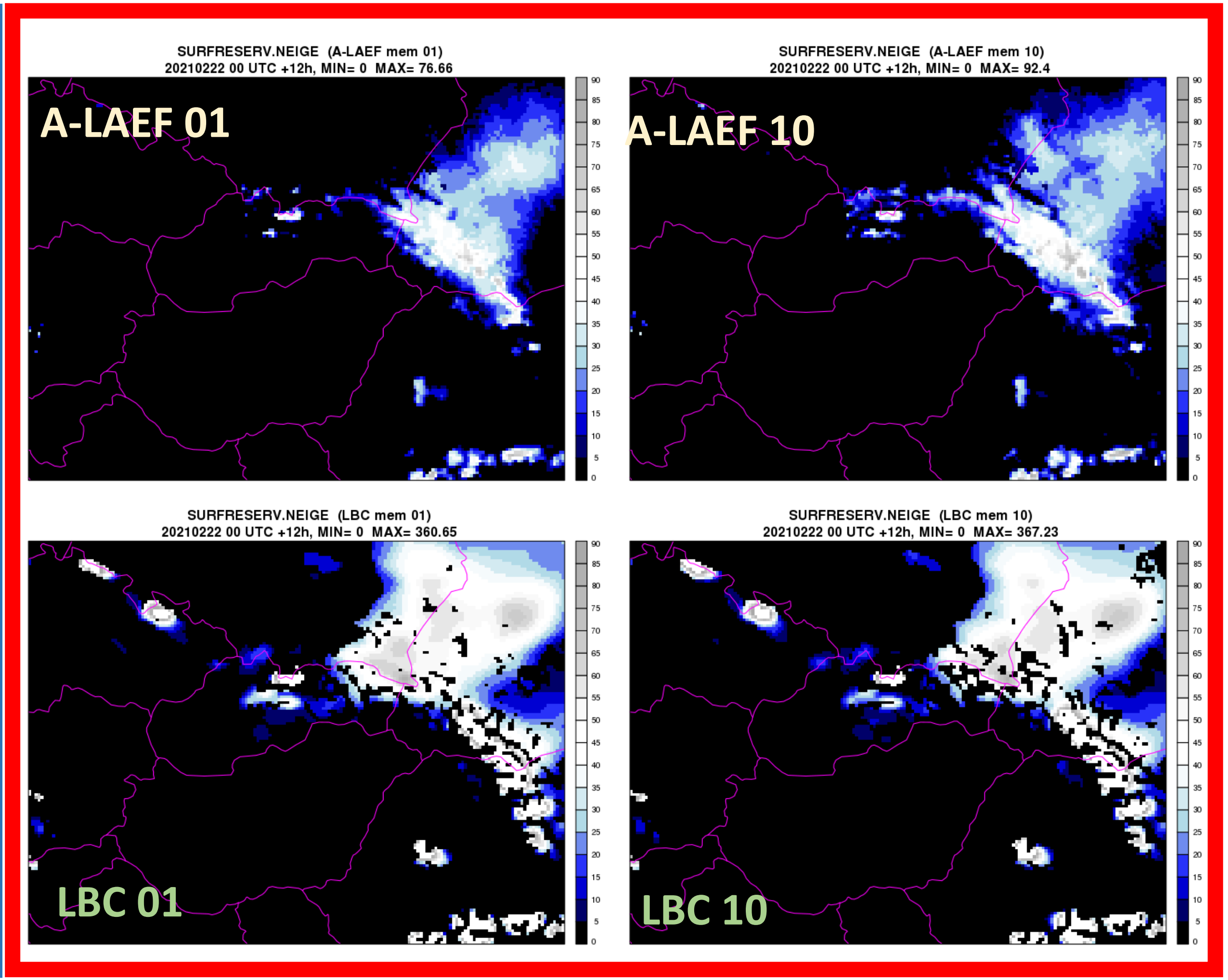
Snow cover tendencies in A-LAEF and its LBCs (ECMWF)

- Much slower melting compared to ARPEGE

06 UTC



12 UTC



MBell Atmospheric predictability 22-02-2021 00 UTC +12h (+72h...)

Liesek: T2m [49.3624,19.6746] 2021-02-20_12 **+48h**:			Liesek: T2m [49.3624,19.6746] 2021-02-21_00 **+36h**:			Liesek: T2m [49.3624,19.6746] 2021-02-21_12 **+24h**:			Liesek: T2m **OBS 10.4** [49.3624,19.6746] 2021-02-22_00 **+12h**:		
SHMU	**9.4**	d=2.38km	SHMU	**9.0**	d=2.38km	SHMU	**9.2**	d=2.38km	SHMU	**9.4**	d=2.38km
CHMU	**10.3**	d=0.51km	CHMU	**10.1**	d=0.51km	CHMU	**10.0**	d=0.51km	CHMU	**10.1**	d=0.51km
A-LAEF00	6.2	d=2.35km	A-LAEF00	6.5	d=2.35km	A-LAEF00	7.9	d=2.35km	A-LAEF00	8.3	d=2.35km
A-LAEF01	7.8	d=2.35km	A-LAEF01	8.9	d=2.35km	A-LAEF01	8.1	d=2.35km	A-LAEF01	10.1	d=2.35km
A-LAEF02	2.6	d=2.35km	A-LAEF02	0.4	d=2.35km	A-LAEF02	5.5	d=2.35km	A-LAEF02	3.4	d=2.35km
A-LAEF03	2.0	d=2.35km	A-LAEF03	0.3	d=2.35km	A-LAEF03	3.4	d=2.35km	A-LAEF03	3.8	d=2.35km
A-LAEF04	6.1	d=2.35km	A-LAEF04	7.3	d=2.35km	A-LAEF04	8.0	d=2.35km	A-LAEF04	9.0	d=2.35km
A-LAEF05	8.6	d=2.35km	A-LAEF05	10.2	d=2.35km	A-LAEF05	10.3	d=2.35km	A-LAEF05	10.6	d=2.35km
A-LAEF06	0.1	d=2.35km	A-LAEF06	0.4	d=2.35km	A-LAEF06	3.0	d=2.35km	A-LAEF06	3.8	d=2.35km
A-LAEF07	5.7	d=2.35km	A-LAEF07	6.4	d=2.35km	A-LAEF07	5.5	d=2.35km	A-LAEF07	6.5	d=2.35km
A-LAEF08	7.0	d=2.35km	A-LAEF08	6.4	d=2.35km	A-LAEF08	9.9	d=2.35km	A-LAEF08	9.9	d=2.35km
A-LAEF09	8.6	d=2.35km	A-LAEF09	9.6	d=2.35km	A-LAEF09	10.3	d=2.35km	A-LAEF09	8.3	d=2.35km
A-LAEF10	0.0	d=2.35km	A-LAEF10	0.3	d=2.35km	A-LAEF10	0.3	d=2.35km	A-LAEF10	0.6	d=2.35km
A-LAEF11	4.2	d=2.35km	A-LAEF11	4.4	d=2.35km	A-LAEF11	6.4	d=2.35km	A-LAEF11	4.2	d=2.35km
A-LAEF12	6.5	d=2.35km	A-LAEF12	9.1	d=2.35km	A-LAEF12	8.0	d=2.35km	A-LAEF12	8.4	d=2.35km
A-LAEF13	6.8	d=2.35km	A-LAEF13	8.7	d=2.35km	A-LAEF13	7.5	d=2.35km	A-LAEF13	7.6	d=2.35km
A-LAEF14	-0.1	d=2.35km	A-LAEF14	1.4	d=2.35km	A-LAEF14	3.1	d=2.35km	A-LAEF14	4.5	d=2.35km
A-LAEF15	0.2	d=2.35km	A-LAEF15	0.5	d=2.35km	A-LAEF15	1.0	d=2.35km	A-LAEF15	0.8	d=2.35km
A-LAEF16	5.7	d=2.35km	A-LAEF16	2.6	d=2.35km	A-LAEF16	7.4	d=2.35km	A-LAEF16	6.1	d=2.35km
ECMWF	12.5	d=3.85km	ECMWF	12.1	d=3.85km	ECMWF	11.8	d=3.85km	ECMWF	11.8	d=3.85km
ALARO2	**11.3**	d=1.11km	ALARO2	**1.6**	d=1.11km	ALARO2	**10.2**	d=1.11km	ALARO2	**2.1**	d=1.11km
ICON	**4.4**	d=1.68km	ICON	**4.7**	d=1.68km	ICON	**4.7**	d=1.68km	ICON	**4.8**	d=1.68km

Jumpiness in ALARO 2km – (snow taken from ARPEGE initial LBC files)
Wrong temperature forecast – snow in LBC INIT and snow in ALARO 2, which does not melt there so fast as in ARPEGE
“correct” temperature forecast – no snow in LBC INIT, thus no snow in ALARO 2
The A-LAEF clusters 2,3 are typically colder than 1,4 also in the earlier runs – this is a systematic feature

Conclusions

- The case showed large and somewhat odd influence of model snow cover on the 2m temperature forecasts. Model runs and forecasts, which correctly expected snow cover were „penalized“ and their T2m forecast went wrong. The T2m was close to OBS in the absence of model snow.
- The initial, non-physical parameterization-related differences can be even enhanced due to model physics – e.g. when supporting inversion and low cloudiness generation over the snow-covered areas as indicated by differences between A-LAEF clusters 2,3 with respect to clusters 1,4. The mechanism of this influence is probably complex – there can be feedback between the turbulence and horizontal temperature advection and then between the temperature tendencies, fluxes and melting of snow and vice-versa
- The real causes of the forecast failure can be somewhere in modeling the fluxes over the snow surface, which should be probably more dependent on the snow properties (albedo, conductivity changing in time, etc.). Here we encounter an exactly opposite situation as in the case of forecasting minimum night temperature over fresh snow, were the impact of snow on the temperature profile is insufficient (too warm forecasts)
- Another, independent problem is the fast melting of snow, characteristic for ARPEGE (SURFEX?). This can have negative impact if the snow is directly provided to LAM models or to first guesses (e.g. large variability between the runs)
- LAM EPS is still useful in showing the uncertainty, although the processes in the background are not entirely corresponding to the reality. It is important to see more scenarios with snow, because this can be a source of large differences in temperature.