43th EWGLAM and 28th SRNWP Meeting, 27/09/2021 – 1/10/2021, online

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NWP in Poland

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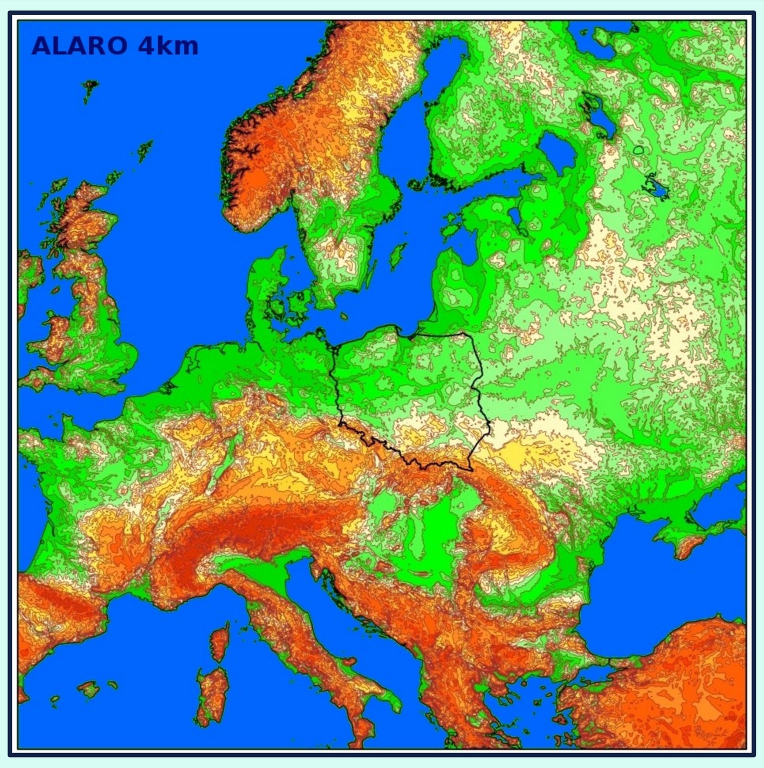
Operational

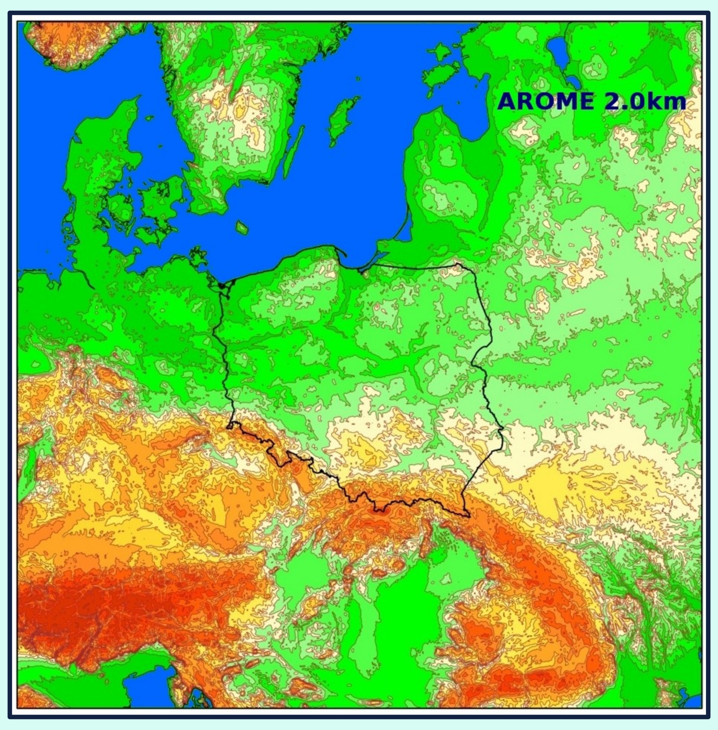
ALARO-v1B NH (CY43T2)

Operational Domain:

E040 domain:

4.0 km horizontal resolution, 789x789 grid points, 70 vertical model levels on a Lambert projection with 3h coupling frequency and 1h output, coupling zone with 16 points; Runs 4 times per day (00,06,12 and 18) with 72 hours forecast range; LBC from ARPEGE with 9.4km horizontal resolution; Time step ~160s.





AROME (CY43T2) Operational Domain:

P020 domain:

2.0km horizontal resolution, 799x799 grid points, 70 vertical model levels on a Lambert projection with 3h coupling frequency and 1 hour output 4 runs per day (00, 06, 12 and 18UTC) with 30 hours forecast range; LBC from ALARO-1 4.0km; GRIB format, every 1h – for LEADS system; 10min output for INCA Nowcasting System.

Operational machine characteristics

Cluster of HP BL460c_GEN8 servers connected with Infiniband network, OS Scientific Linux 6, Intel Xeon E5-2690 processors – with maximum 1552 cores (97 nodes with 16 cores each), each core RAM 128 GB, disc array – 64 TB.

Multi-model machine learning

A machine learning-based tool for post-processing of 2m air-temperature numerical forecast has been tested. It is based on a concept of a multi-model since it uses forecasts from 3 limited-area models operating at the Institute of Meteorology and Water Management: ALARO, AROME and COSMO.

Predictors include forecasts of elementary weather elements produced by the NWP models for 35 selected synoptic stations in Poland as well as station-embedded data on ambient orography. They were then compared to real values of 2m air temperature according to observations at the stations.

A training set contains data from two years: 2018 and 2019.

A Random Forest algorithm (RF) has been used to produce bias-corrected forecasts on a test set spanning a whole one year (2020).

Results were verified against forecast from single NWP models as well as the mean of the models. The improvement of forecast accuracy was noted at every station and for every lead time, with the average reduction of RMSE equal to 20.4% with respect to the mean (26.6% with respect to the best NWP model, Figure 1). The biggest training error occurred for stations located in mountain basins (12500 and 12625), while for mountain-top stations (12510 and 12650) it was significantly smaller (Figure 1).

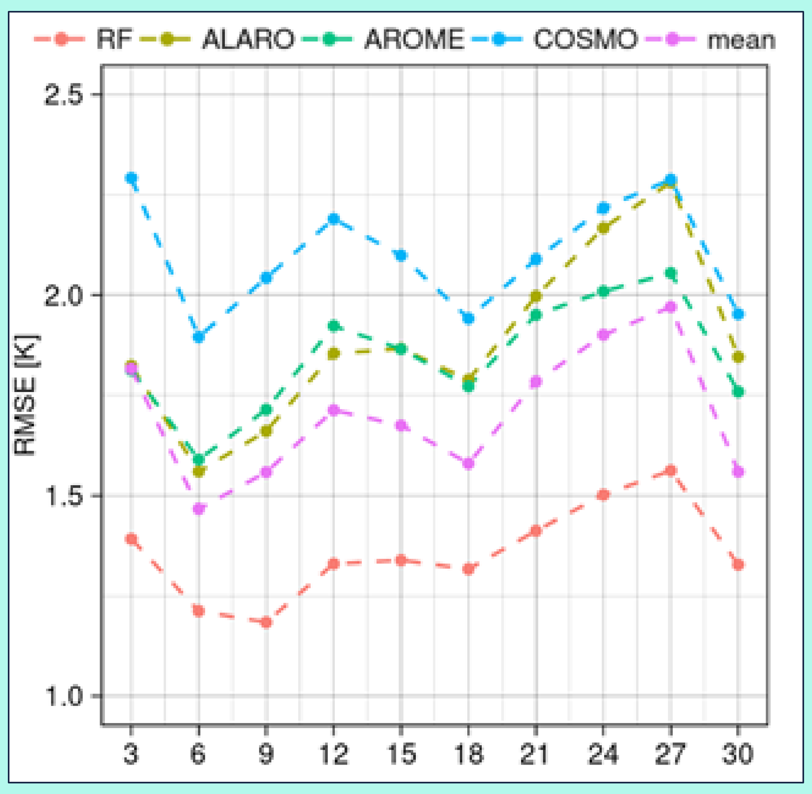


Fig.1 Comparison of RMSE errors. RF corresponds to the lowest error.

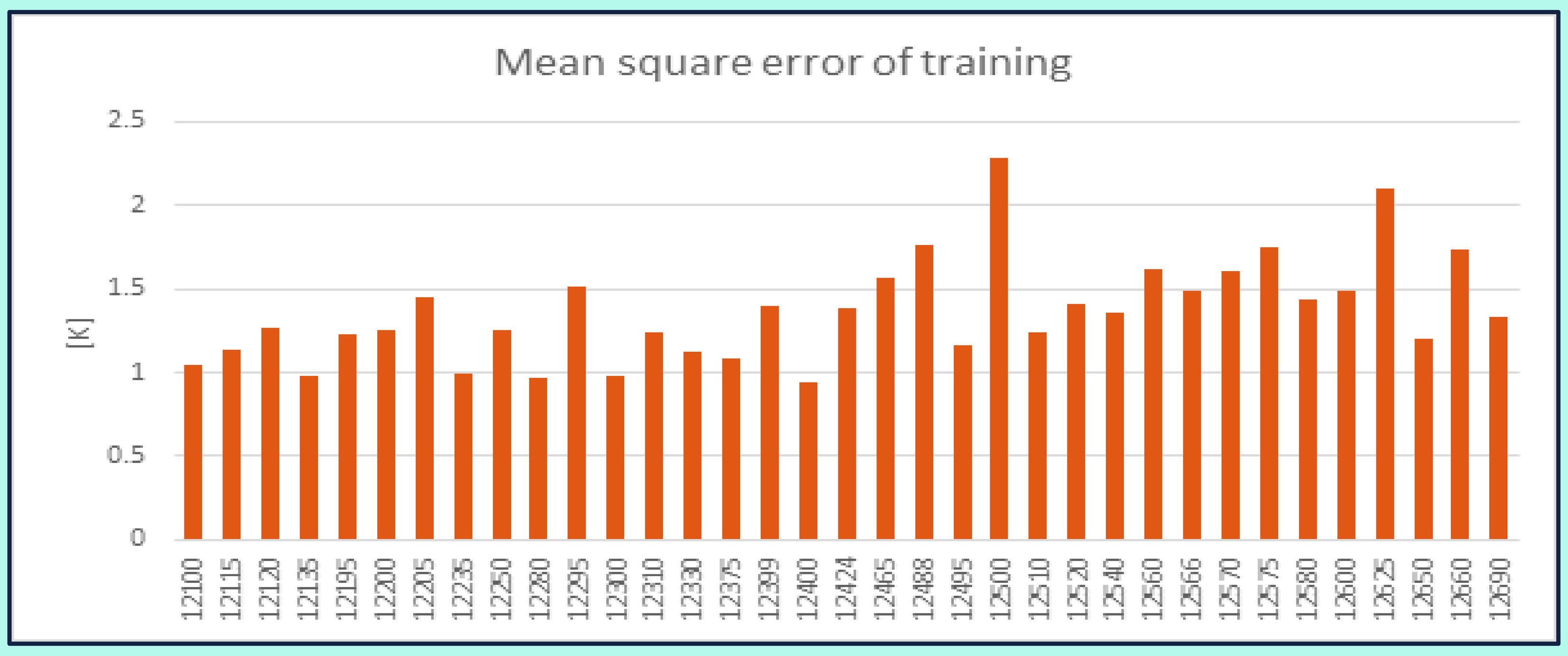


Fig.2 Mean square error of RF training for various Polish synoptic stations.

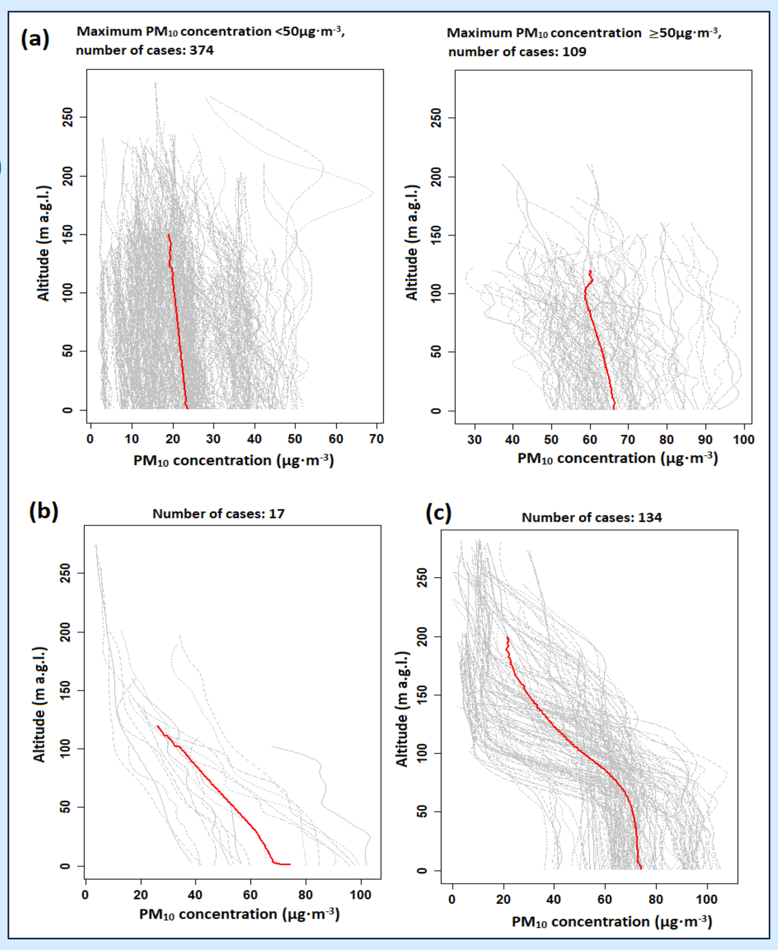
PM10 concentration above Kraków

Wind shear impact on PM_{10} vertical profiles, in Kraków, southern Poland.

The data (Sep. 2018 to Apr. 2019, and Sep. 2019 to Apr. 2020) is composed of PM_{10} measurements, model data, and wind speed and direction data. The background model data come from operational forecast results of AROME model. PM_{10} concentration in the vertical profile was measured with a sightseeing balloon.

Significant spatial variability of wind field was found. The case studies represent the conditions with much lower wind speed and a much higher PM_{10} levels than the seasonal average. The analysis of PM_{10} profiles allows to distinguish three vertical zones of potential air pollution hazard within the valley (about 100 m deep) and the city of Kraków:

1. up to about 60 m a.g.l. – the zone where during periods of low wind speed, air pollution is potentially the highest and the duration of such high levels is the longest, i.e. the zone with the worst aerosanitary conditions;
2. about 60-100 m a.g.l. – transitional zone where the large decrease of PM_{10} levels with height is observed;
3. above 100-120 m a.g.l. – the zone where air quality is significantly better than in the zone 1, either due to the increase of the wind speed, or due to the wind direction change and advection of different, clean air masses.



Classification of PM_{10} vertical profiles into the three main types: a. type I (it is presented in two plots due to a wide range of PM_{10} concentration values); b. type II; c. type III. Explanations: gray lines – individual vertical profiles of PM_{10} concentration, red lines - mean profiles of a certain type.

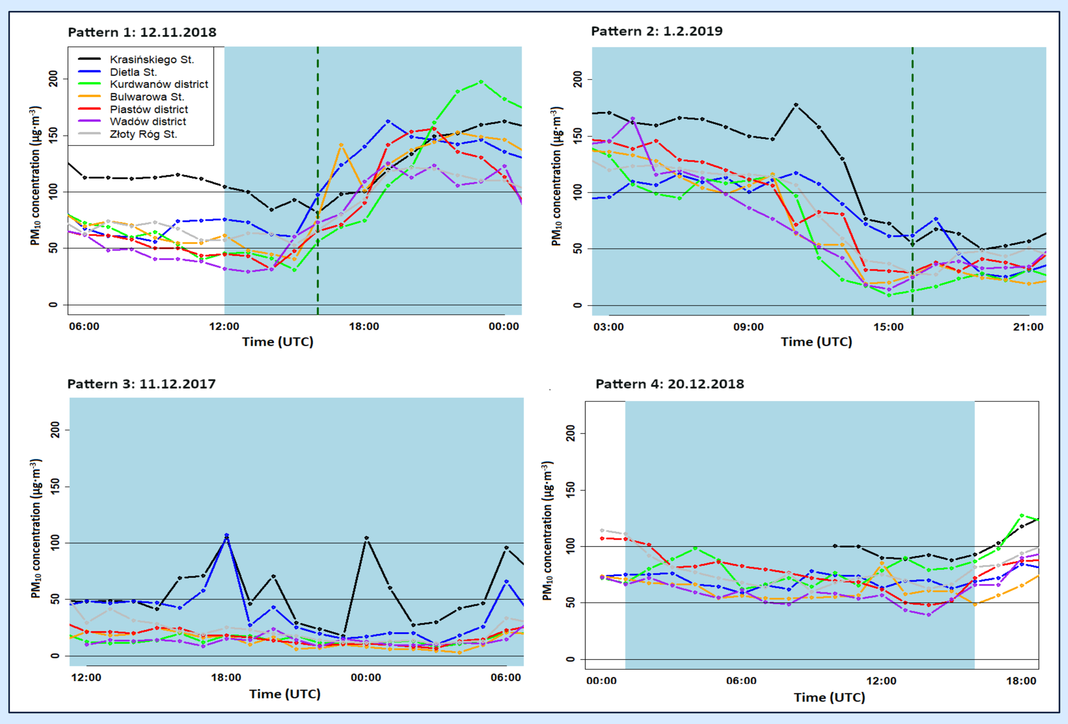
Impact of Foehn Wind on PM10 Concentrations.

Kraków, southern Poland, is a city with poor air quality (abundant PM_{10} concentrations). It is located in the large Wisła valley, and affected by a foehn wind, the '*halny*', from the Tatra Mountains in the Carpathians. 14 long episodes of the foehn analyzed from the periods Sep 2017 - Apr 2018 and Sep 2018 - Apr 2019. Data used included measurements of PM_{10} concentrations, air temperature and relative humidity, wind speed and direction from ground stations and tower measurements up to 100m a.g.l., along with model analysis results.

Non-operational configuration of the AROME CMC 1km x 1km (AROME CMC 1km) was applied. A conceptual model concerning the impact of a foehn on urban air pollution was developed.

The occurrence of a particular effect of a foehn on the PM_{10} spatial-temporal pattern depends on its mode of transfer through the city and nearby:

a. a foehn flows above the valley where a strong cold air pool and a return flow can be found;
b. a foehn enters the valley from the eastern, wider part or from the valley top and destroys the cold air pool;
c. gravity waves generated by a foehn are strong enough to enter the western narrower part of the valley and cause large spatial differences in turbulence parameters within the city.



Examples of the four spatial-temporal patterns of PM_{10} concentration.
Key: blue background: foehn period; vertical green dashed line: occurrence of altocumulus lenticularis cloud.

Derecho case in Poland, 2017, seen by ALARO NH CY43T2

Developing storms in a warm air mass before a waving front transformed from single cells and chaotic multi-cell systems to the supercells and gathered into the large MCS (Mesoscale Convective System). In that developed a squall line which turned into a strong bow echo (Figure 1) and MCV (Mesoscale Convective Vortex). The evolving convective system, supported by the jet stream, fulfilled criterion of derecho occurrence and the observed maximal values of wind gusts exceeded 42 m/s (150km/h).

The weather forecast by the means of the presently operational model ALARO CY43T2 a non-hydrostatic one with 4km horizontal resolution (unavailable in 2017), forecasted enhanced convective system (MCS), bow echo structure as well as MCV – mesoscale convective vortex also mapped well the possible severe wind gusts. The highest precision in position of the MCV were achieved by the ALARO NH 00UTC model forecasts and strength by 12UTC forecast (Figure 2), and can be seen on relative vorticity map. Other severe weather phenomena, such as cold pool and rear inflow jet (RIJ) (Figure 3, Figure 4), are clearly seen on forecasts on the maps of the wind velocity at 850 and 925hPa pressure levels and on temperature at 2m.

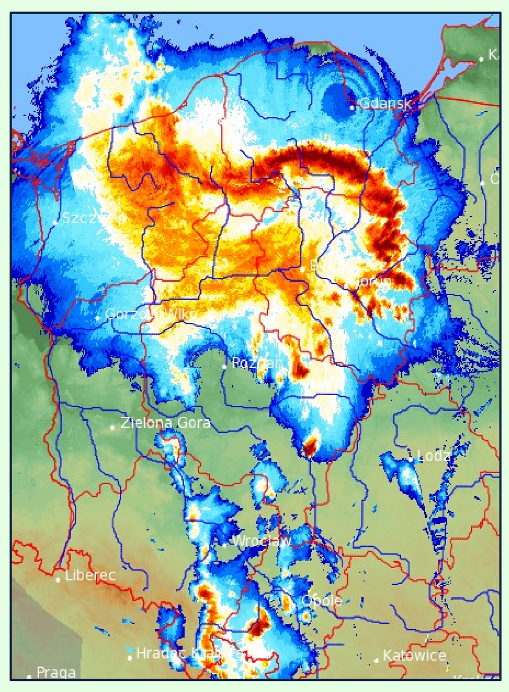


Fig.1 .Radar reflectivity, CMAX, observed for a couple of radar stations. 21UTC of 11.08.2017.

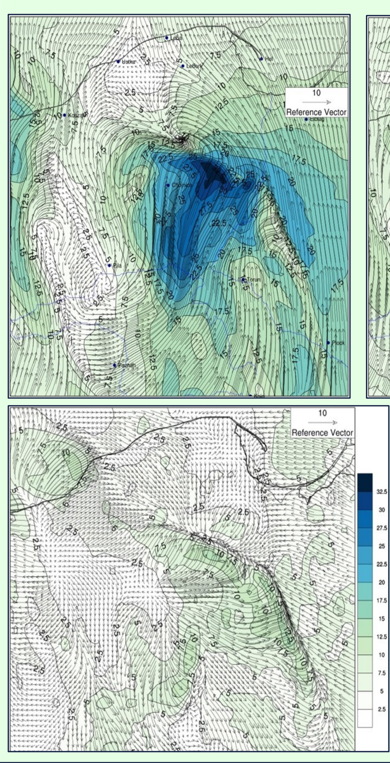


*Fig.4 .**a**) and **b**) wind and the module of velocity (colour) at pressure levels of 850 and 925hPa; **c**) wind and the module of velocity (colour) at 10m AGL. ALARO r12 forecast for 22UTC, 11 August 2017.*

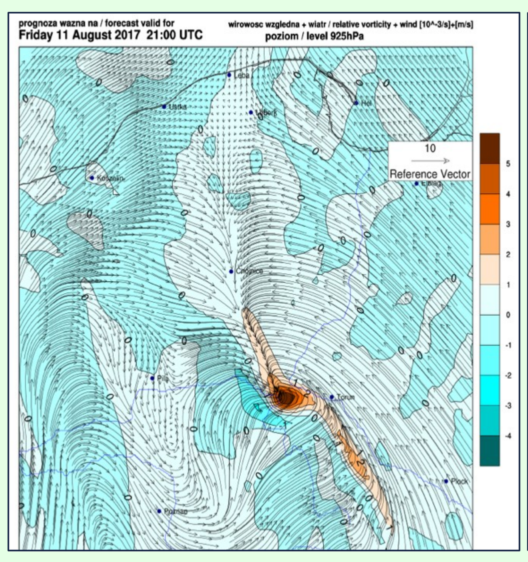


Fig.2 The forecast of MCV. Wind ($m \cdot s^{-1}$, vectors) and relative vorticity (s^{-1}, colour) at 925hPa. ALARO r12 on 21UTC 11 August 2017.

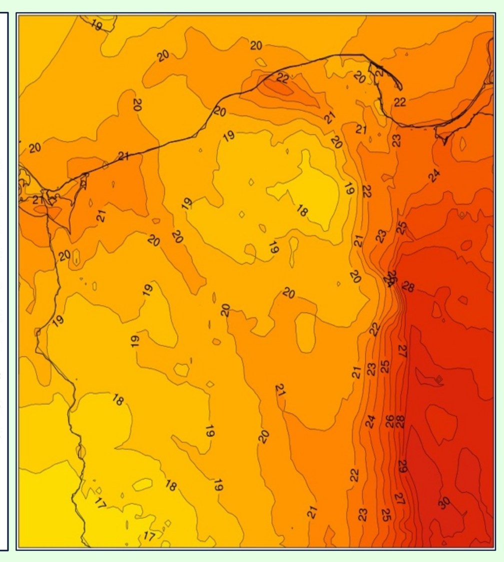


Fig.3 Cold pool from ALARO T2m. The forecast for 21UTC 11 August 2017, r00.