ALADIN Numerical Weather Prediction Project

NWP at the Hungarian Meteorological Service

Hungarian Meteorological Service

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Operational ALADIN configuration

Main features of the operational ALADIN/HU model

- Model version: CY36T1 (ALARO-0 baseline physics)
- Initial conditions: local analysis (atmospheric: 3dVar, surface: OI)
- Four production runs a day: 00 UTC (54h); 06 UTC (48h); 12 UTC (48h); 18 UTC (36h)
- Lateral Boundary conditions from the ECMWF/IFS global model

Assimilation settings

- 6 hour assimilation cycle
- Short cut-off analysis for the production runs
- Downscaled Ensemble background error covariances
- Digital filter initialisation
- LBC coupling at every 3 hours

Model geometry

- 8 km horizontal resolution (349*309 points)
- 49 vertical model levels
- Linear spectral truncation
- Lambert projection

Forecast settings

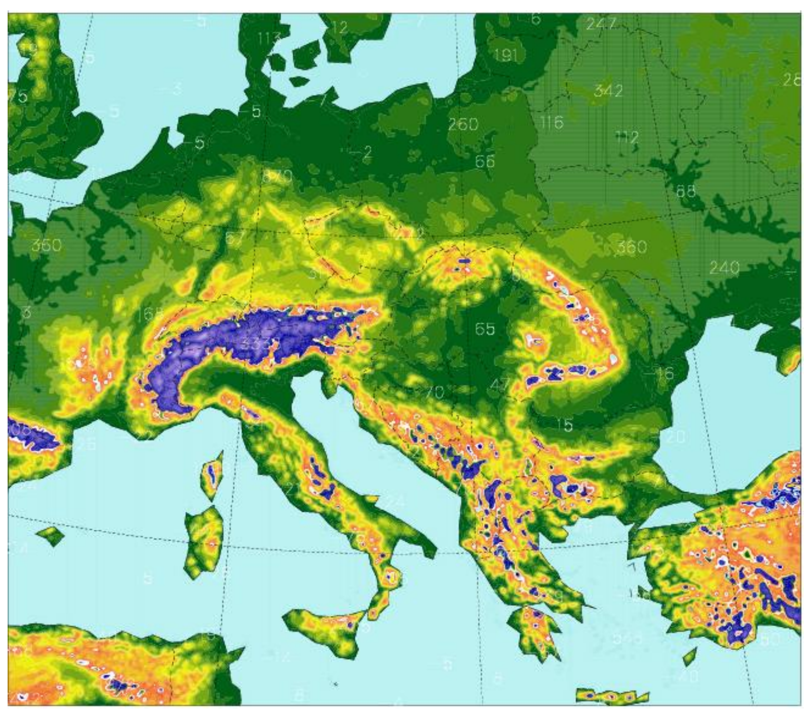
- Digital filter initialisation
- 300 s time-step (two-time level SISL advection scheme)
- LBC coupling at every 3 hours
- Output and post-processing every 15 minutes

Operational suite / technical aspects

- Transfer ECMWF/IFS LBC files from ECMWF via Internet, ARPEGE LBC files (as backup) from Météo France (Toulouse) via Internet and ECMWF re-routing.
- Model integration on 32 processors
- 3D-VAR and Canari/OI on 48 processors
- Post-processing
- Continuous monitoring supported by a web based system

The computer system

- IBM iDATAPLEX Linux cluster
- CPU: 500 Intel Xeon processors (2,6 Ghz)
- 1.5 Tbyte internal memory
- Torque job scheduler



The ALADIN/HU model domain and orography

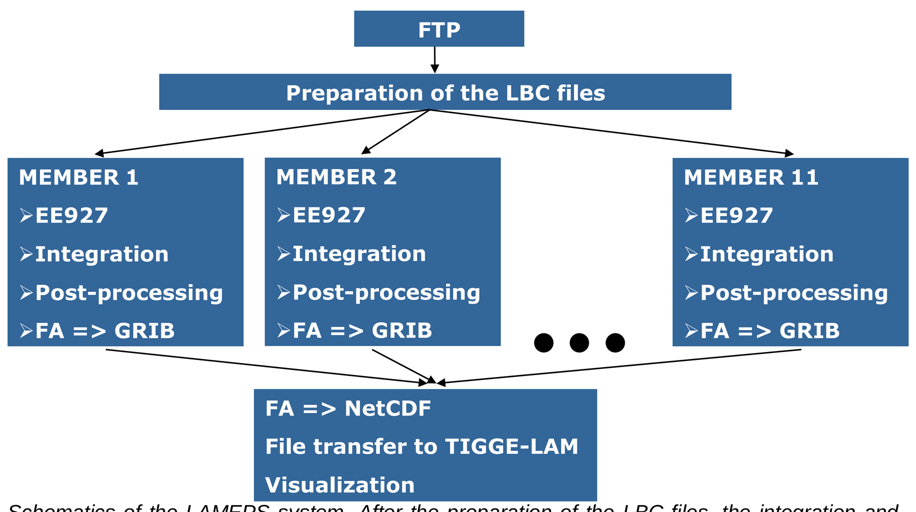
Observation usage

- Maintenance and use of the OPLACE system (Operational Preprocessing for LACE)
- SYNOP (T, Rh, Z)
- SHIP (T, Rh, Z, u, v)
- TEMP (T, u, v, q)
- ATOVS/AMSU-A (radiances from NOAA 16, 18) with 80 km thinning distance
- ATOVS/AMSU-B (radiances from NOAA 16, 17 and 18) with 80 km thinning distance
- METEOSAT-9/SEVIRI radiances (Water Vapor channels only)
- AMDAR (T, u, v) with 25 km thinning distance and 3 hour time-window,
- Variational Bias Correction for radiances
- AMV (GEOWIND) data (u, v)
- Wind Profiler data (u, v)
- Web-based observation monitoring system

Operational ALADIN ensemble system

The main characteristics of the operational short-range limited area ensemble prediction system of HMS is listed below.

- The system is based on the ALADIN limited area model and has 11 members.
- For the time being we perform a simple downscaling, no local perturbations are generated.
- The initial and lateral boundary conditions are provided by the global ARPEGE ensemble system (PEARP3.0).
- LBCs are coupled in every 6 hours
- The LAMEPS is running once a day, starting from the 18 UTC analysis, up to 60 hours.
- The integration of the single members is similar than in 'deterministic' ALADIN/HU case (see above): same resolution, same physics, etc.
- The forecast process starts every day from cron at 23:50 UTC and finishes around 02:00 UTC.

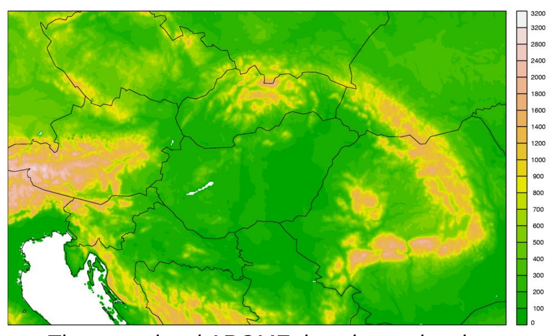


Schematics of the LAMEPS system. After the preparation of the LBC files, the integration and the post-processing are running in parallel for all the members. The preparation of the NetCDF files is done in one go for all members.

Operational AROME configuration

Main features of the AROME/HU model

- Model version: CY36T1
- 2.5 km horizontal resolution (500*320 points)
- 60 vertical model levels
- Four production runs a day: 00 UTC (48h); 06 UTC (39h); 12 UTC (48h); 18 UTC (39h)
- Initial conditions: 3DVAR (upper air), interpolated ALADIN surface analysis (see details in the block below)
- Lateral Boundary conditions from ALADIN/HU with 1h coupling frequency
- To calculate the screen level fields we use the SBL scheme over nature and sea



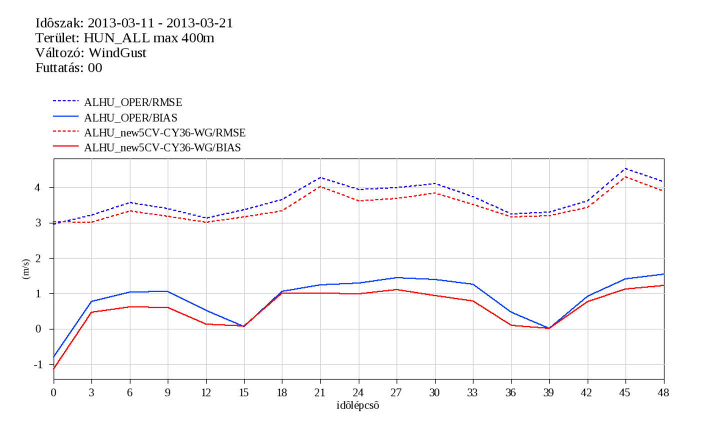
The operational AROME domain used at the Hungarian Meteorological Service.

We are running the AROME model over Hungary on daily basis since November 2009 (since December 2010 operationally and since March 2013 with local 3DVAR data assimilation). The model performance is evaluated regularly by our NWP group and the forecasters group. Moreover it is compared with other available models (ALADIN, ECMWF).

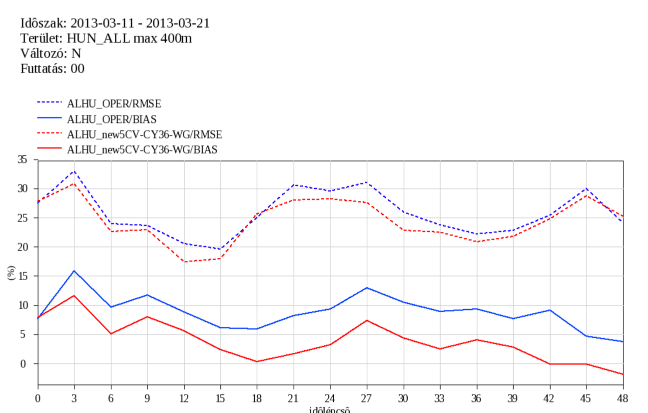
As a general conclusion, our experience is that the AROME model gives the best temperature and cloudiness forecasts. Based on the SAL verification (not shown here) it also captures the size of the precipitation objects very well. However, it tends to overestimate precipitation maximum and wind gusts in strong convective cells (see also the SLHD tuning on right panel)

Operational upgrade of ALARO

A new version of the ALARO physics based on CY36T1 (ALARO-0 baseline) was introduced operationally in September 2013 both in the deterministic and EPS ALADIN systems at 8 km resolution. The evaluation of this new physics package (developed by LACE) was based on parallel suites over more then a one month period. Verification scores against observations have been computed and feedbacks were obtained from the duty forecasters. The upper air performance remained similar to the previous model version (CY35T1, ALARO-0) but there has been an improvement found in the forecasts of 10m wind, cloudiness and precipitation in terms of scores. The feedbacks from the forecasters supported the findings from the scores: cloudiness and precipitation patterns have been found more structured and realistic in the new model version.



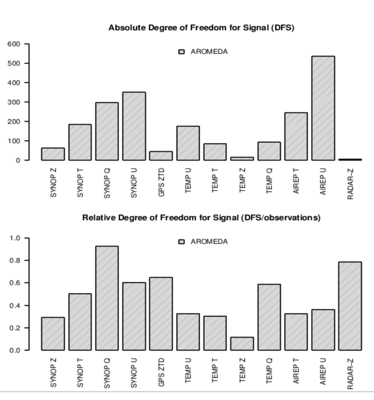
10m wind speed RMSE and BIAS scores showing an improvement by the new model version (red) over the old one (blue)



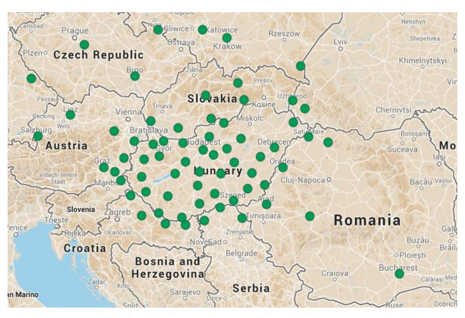
Cloudiness RMSE and BIAS scores showing an improvement by the new model version (red) over the old one (blue)

Assimilation of GNSS ZTD data in AROME

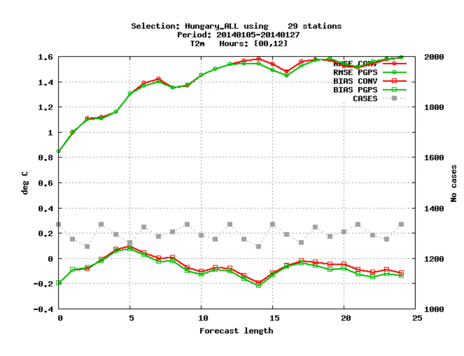
The operational data assimilation system of our AROME model is using only SYNOP, TEMP and AMDAR reports which limited number of conventional sources are not efficiently cover our assimilation system. Hence this and the importance of humidity observations shown by relative DFS the assimilation of Zentih Total Delay observations were tested.



Absolute and Relative DFS values of 3DVAR AROME data assimilation with additional ZTD and RADAR observations



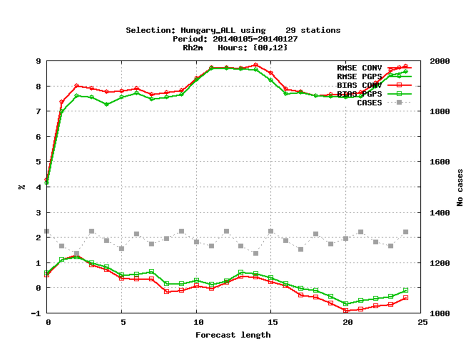
Assimilated ground-based GPS stations from EGVAP network SGOB



RMSE and BIAS of 2m temperature forecasts for January 2014.

The ZTD observations from EVGAP SGOB network were employed which can bring good data coverage over Hungary. The assimilation of ZTD data is made by whitelisting method to select reliable and proper ground-based GPS stations. During a 15 days selection procedure bias parameters for static bias correction is also computed which can be activated at real assimilation study. The methodology of whitelisting and static bias correction is developed by Meteo-France colleagues especially by Paul Poli and Patrik Moll.

The impact of GPS ZTD observations added to conventional observations were verified and compared with the operational system. The importance of ZTD observations is visible on (relative) DFS diagnostics figure above this paragraph. The overall impact regarding ZTD assimilation was mainly neutral in the upper-air, but a positive impact was observed near the surface, especially on relative humidity and dew point temperature forecasts (RMSE and BIAS score for surface temperature and relative humidity on the left). The impact on preciptiation was neutral for experimental period of January 2014.



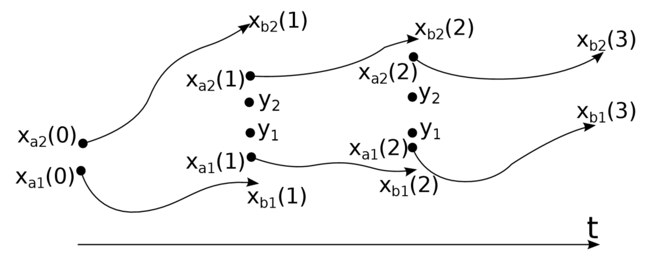
RMSE and BIAS of 2m relative humidity forecasts for January 2014

Test of Ensemble Data Assimilation (EDA) with AROME-EPS

Since 2012 Hungarian Meteorological Service (HMS) is a participant of an ECMWF special project called 'Continental winter weather prediction with the AROME ensemble prediction system'. Our long-term goal in this project is to develop a high-resolution EPS which can correctly estimate the uncertainty of the forecasts especially in such weather situations which are frequently problematic for forecasters in Hungary. Low clouds and fog are typically from these weather types in the Carpathian Basin but heavy snowfall and strong wind events are also in the focus of our interest.
In the first year of this project (2012) SPPT scheme was tested to simulate model error in this ensemble system and some coupling strategies were tried out (presented on HMS national poster last year). In the second year of the project (2013) there were additional lateral boundary condition tests, mainly with IFS LBC sets produced on different resolution. However the development of an EDA system was in the focus of our interest, which can produce ICs to the AROME-EPS with good quality and correct representation of IC uncertainty.

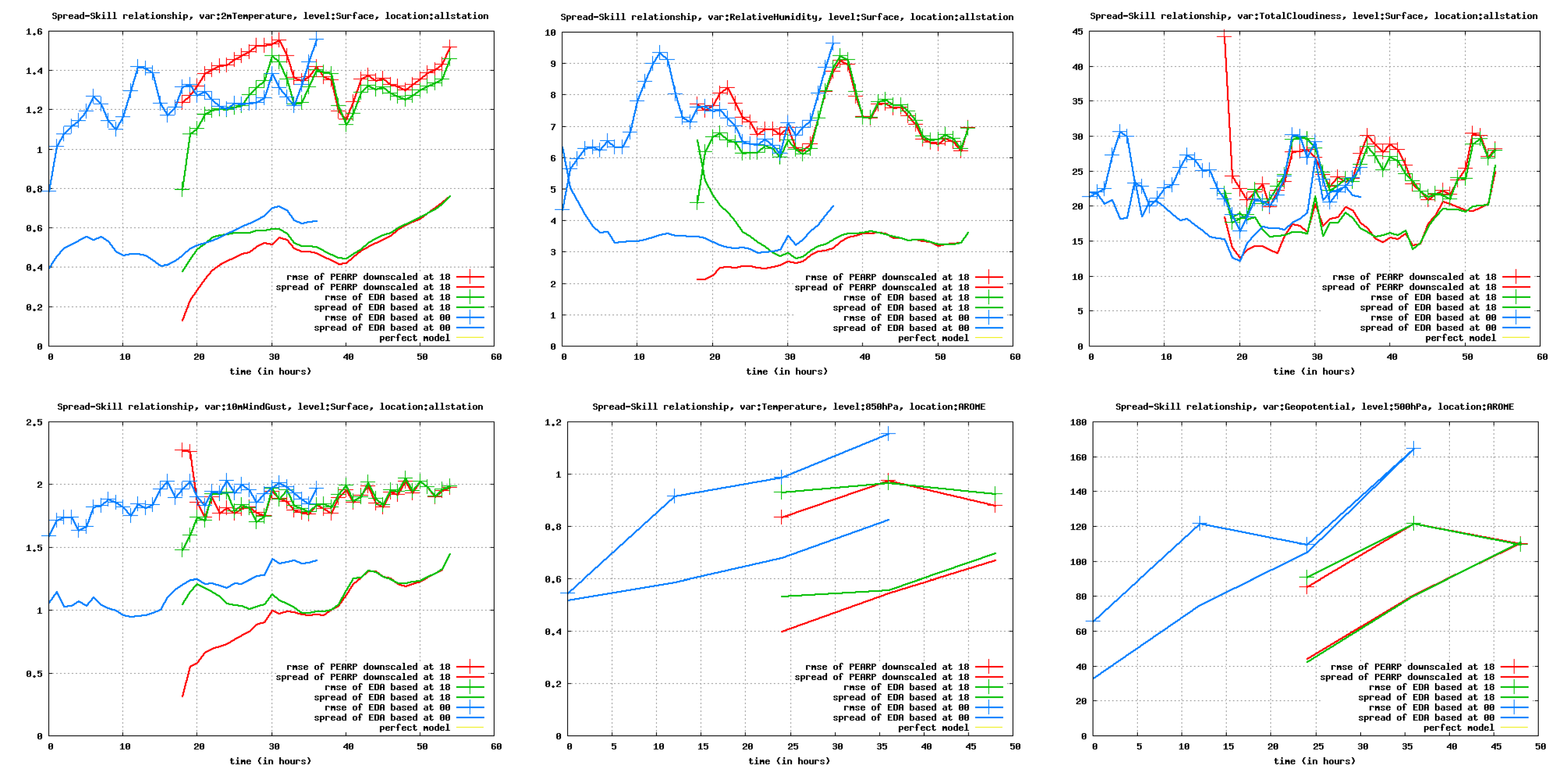
The first version of our AROME-EDA system was designed on the simplest possible way. It meant in the practice, that:

- For 10+1 AROME members belonged 10+1 data assimilation cycle (IC perturbations were evolved independently),
- Only high-atmospheric 3DVAR was used in assimilation cycles (no surface assimilation yet),
- Surface lfi files were interpolated from ALADIN/HU system, where CANARI is operating,
- Only conventional data was used (as in 'deterministic' AROME-DA at HMS),
- Assimilation frequency was 3 hours (as in 'deterministic' AROME-DA at HMS),
- Cycle 36 was used (as in 'deterministic' AROME-DA at HMS),
- The whole system was coupled to 18UTC run of PEARP (as operational ALADIN-EPS at HMS).



Simple, schematic 1D figure of a 2-members-EDA. 'x' reprsents the model states and 'y' the observations. y_1 and y_2 are the perturbed versions of the same observation.

It can be summarized, that in single cycles we tried to assimilate observations on the same way than in the operational 'deterministic' system, while designation of the EPS (used global system, number of members) followed the way how operational ALADIN-EPS works.
In this EDA all the observations are perturbed to represent the uncertainty of the analysis. Technically perturbations are added after screening by an external program written by Andrea Storto (met.no). This program reads observations and their error. For all the observations it generates a random number which is from a Gaussian distribution with 0 mean and 1 variance. Then observation error is multiplied by this random number and the result is added to the observation itself.
It is important to underline, that only one PEARP run was used, so forecasts and guesses were integrated usually with a massive time lag, which can cause a negative impact on results. It plays role especially in case of 18UTC runs in the high-atmosphere (see right bottom figures). It can be noted that hydrometeor initialization from the actual guesses made also a big impact (see the scores of cloudiness in the first 3 hours).



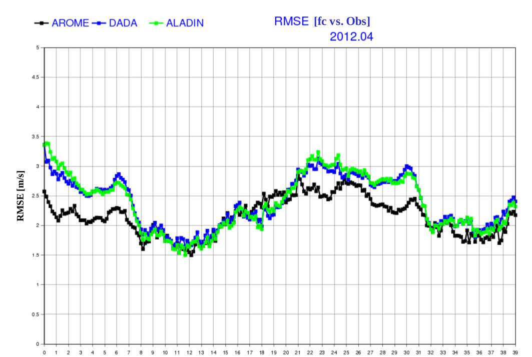
Spread-Skill relationship of AROME-EPS. On every figure red line shows simple PEARP downscaling, green and blue line represents EDA based system started at 18 and 00 UTC. In upper line 2meter temperature, relative humidity and cloudiness can be seen. In bottom line 10 meter wind gust is followed by high atmospheric scores: 850 hPa temperature and 500 hPa geopotential. Verification period was: 26th of December 2011 – 08th of January 2012.

The above-mentioned results suggest that AROME-EDA can be a useful tool to improve the ICs in an AROME-EPS. Obviously there is still room for improvement and the following challenges are in the focus:

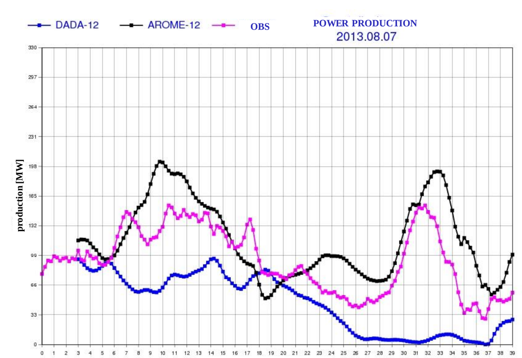
- More frequently updated LBC from a global system,
- More observation used in DA cycles (satellites, radar, GPS),
- Surface assimilation (possibly with similarly perturbed observations).

Wind and wind energy estimation based on the AROME model

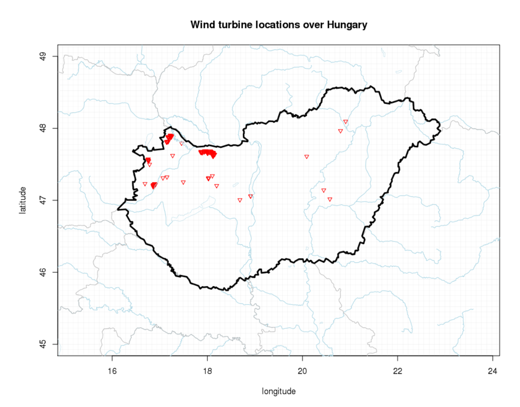
The Hungarian Meteorological Service provides the Hungarian energy transmission system operator, MAVIR Zrt. with the forecast of several meteorological parameters, such as temperature, precipitation, etc. Something that is quite different from those is the power production estimation for the whole country, because it is a derived and spatially integrated parameter. We use AROME model's wind speed for that purpose, vertically interpolated to hub height, and horizontally to turbine position. To some of the individual power-plants HMS is responsible for sending 48 hours ahead wind speed forecasts. All of these forecasts were previously based on the dynamical adaptation (DADA) of ALADIN, specifically used for wind prediction, but after a preliminary test period, from August 2013, HMS produces these forecasts based on AROME operationally. The reason behind changing model is that DADA was run only for wind energy prediction purposes, and that the analysis of the results showed that on the average AROME is more accurate than DADA (*shown in the figure on the left*). Examining specific cases proved also that AROME is able to model those features in the atmosphere – in terms of changes in wind speed – that DADA can not (*see the figure below in the middle*). The position of individual turbines might be seen in the plot below on the right.



The RMSE of wind speed as a function of leadtime for the previously used DADA (blue) which is dynamically downscaled from ALADIN (green), and the currently operatively used AROME (black) in April 2012 (spatial average over five points).

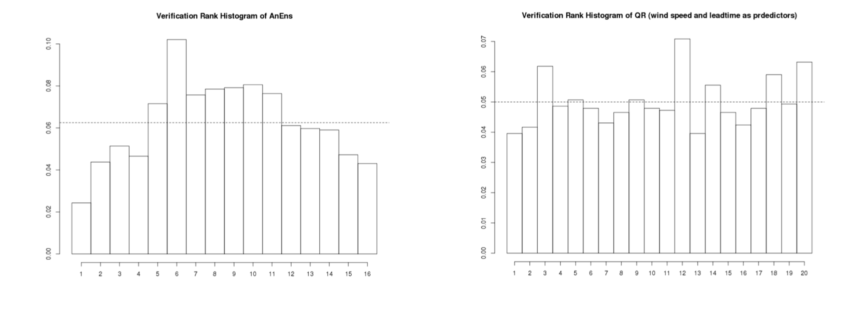


A specific case was examined: for 07/08/2013 the forecasts of DADA (blue), AROME (black) and the measurement (magenta) of power production are plotted as a function of time in hours.



The location of wind turbines over Hungary.

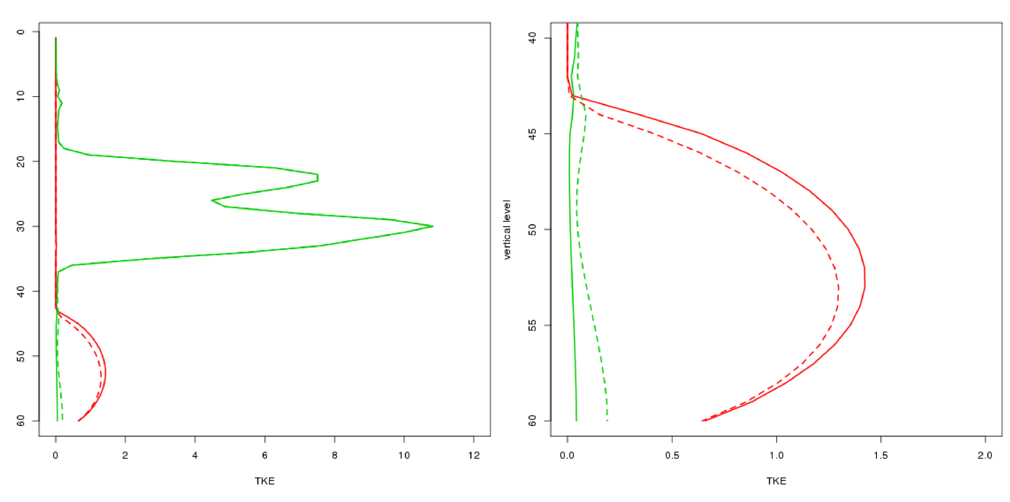
HMS is desperate about statistical correction of the energy estimation, but is facing with several problems. First of all, power measurements are available only for the whole country, wind speed measurements for each locations are not sent. It makes any kind of statistical correction work less accurate. A lot of methods have been tested, such as Short Term Rolling Trend Correction, linear regression, Kalman Filter, that aimed to gain forecasts closer to measurements, with no real success. Two methods that have been learnt in a Short Term Scientific Mission sponsored by COST, have been tested. Preliminary results of Quantile Regression (that has an ensemble member for each chosen quantile) and the Analog Ensemble technique from the control run of the Hungarian ALADIN LAM EPS are shown on the right.



The rank histograms of the Analog Ensemble (on the left) and Quantile Regression using wind speed and leadtime as predictors (on the right).

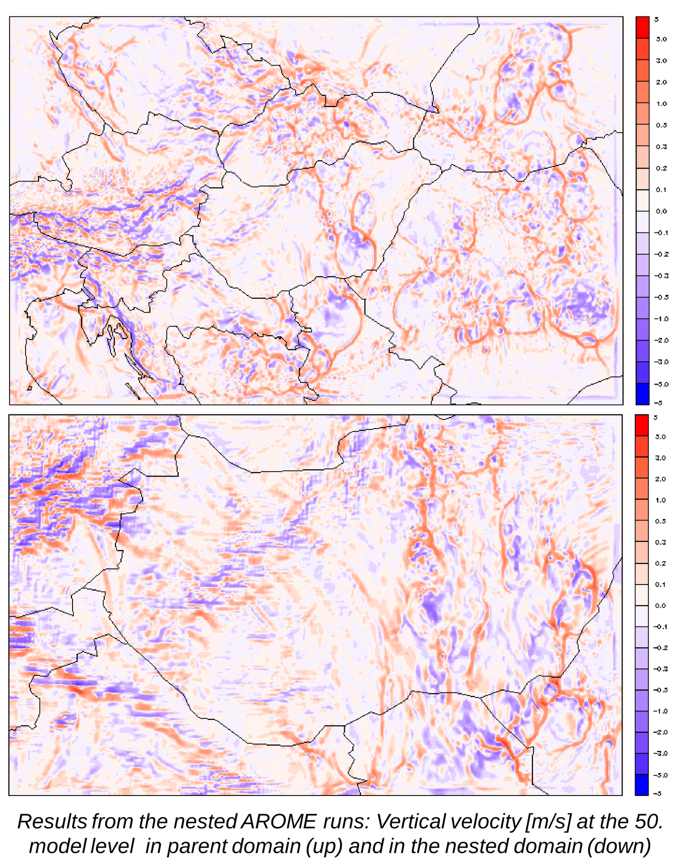
AROME Very Fine Resolution experiments

At the Hungarian Meteorological Service the grid size of the operational AROME domain is 2.5 km. Recently, experiments are run with smaller grid sizes, with a motivation to allow the non-hydrostatic dynamics to resolve deep convection with a higher probability than in the current system. With other words, a way out of the gray zone of deep convection is explored. However, by increasing the resolution to 1 km or below we expect to arrive to another problematic range of scales, the gray zone of turbulence, where the shallow convection should partly be resolved by the dynamics of the model. In order to find out more about the turbulence gray zone, we are performing idealized AROME runs at different resolutions (IHOP dry convective case). These experiments are based on the work of Honnert et al. (2011) about the representation of turbulence in atmospheric models. The evaluation of the results is still in progress and we plan to continue and extend the research. The actual parameterization of the turbulence in the AROME is the EDKF (Eddy Diffusion and mass-flux parameterization with Kain and Fritsch approach). Our goal is to properly modify the effect of the EDKF as a function of the resolution, to avoid possible problems connected to the gray zone of turbulence.



Results from the idealised AROME runs: The vertical cross section of the average subgrid (red) and resolved (green) turbulent kinetic energy [m2/s2] at the end of the simulations. The grid size is 1000 m and the mass-flux parameterization is turned on (solid line) or turned off (dashed line).

In one of the very fine resolution experiments we compared the results of a parent domain's run (top) and the nested domain's run (bottom). The parent domain's grid size was 2.5 km while the nested domain's grid size was 1 km. The examined case was rainy with a cold front and Cb-s (Jun 24, 2013). The comparison showed that at the higher resolution some unrealistic pattern appeared in the verical velocity field, which can be caused in our opinion by the too coarse topography or by the inadequate parametrization of the turbulence in the gray zone of the shallow convection.



Results from the nested AROME runs: Vertical velocity [m/s] at the 50. model level in parent domain (up) and in the nested domain (down)

Rachel Honnert, Valéry Masson, and Fleur Couvreux (2011): A Diagnostic for Evaluating the Representation of Turbulence in Atmospheric Models at the Kilometric Scale. (2011) J. Atmos. Sci., **68**, 3112-3131

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