ALADIN Numerical Weather Prediction Project

Limited area modelling activities at the Hungarian Meteorological Service (HMS)

Gergely Bölöni, Petra Csomós, Edit Hágel, András Horányi, László Kullmann, Miklós Vörös

(boloni.g@met.hu)

Hungarian Meteorological Service

Operational configuration

Main features of the operational ALADIN/HU model

- Model version: AL30T1
- Initial conditions: 3D-VAR assimilation
- Four times productions a day: 00 UTC (54h); 06 UTC (48h); 12 UTC (48h); 18 UTC (36h)
- Boundary conditions from the ECMWF/IFS global model

Model geometry

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

Assimilation settings

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

Observation usage

- SYNOP (geopotential)
- SHIP (geopotential)
- TEMP (T, u, v, q)
- ATOVS/AMSU-A (radiances from NOAA 15, 16 and 18) with 80 km thinning distance
- ATOVS/AMSU-B (radiances from NOAA 16, 17 and 18) with 80 km thinning distance
- AMDAR (T, u, v) with 25 km thinning distance and 1 hour time-window, together with a special filter (that allows only one profile in one thinning-box)
- AMV (GEOWIND) data
- Wind Profiler data
- Web-based observation monitoring system

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

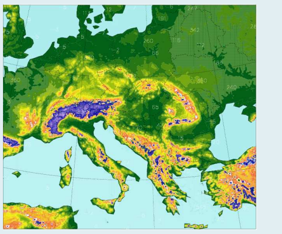
Operational suite / technical aspects

- Transfer ECMWF/IFS LBC files from ECMWF via RMDCN, 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 32 processors
- Post-processing
- Continuous monitoring supported by a web based system

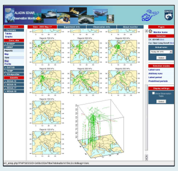
The computer system

- SGI Altix 3700
- CPU: 200 processors from which 92 are for NWP (1,5 Ghz)
- 304 Gbyte internal memory
- IBM TotalStorage 3584 Tape Library (capacity: ~ 30 Tbyte)
- PBSpro job scheduler

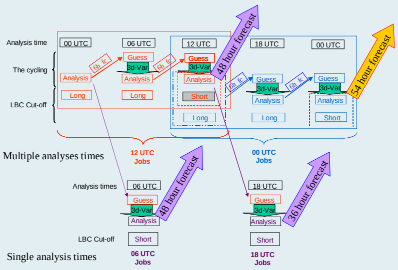
The ALADIN/HU model domain and orography



Different observations (SYNOP, TEMP, AMDAR, AMSU-A, AMSU-B) used in the operational data assimilation system



The interactive web interface of the observation monitoring system with the visualization of the spatial distribution of the status of AIREP reports



The schematic illustration of the data assimilation cycle

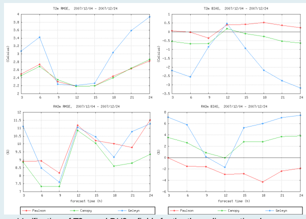
Evaluation of the PBL diagnostic schemes in SURFEX

In SURFEX (externalized surface scheme) there are currently three diagnostic schemes to calculate the screen level fields (T2m, RH2m, U10m, and V10m):

- **Paulson scheme**: The scheme diagnoses PBL values by extrapolating from the lowest atmospheric model level using the surface fluxes and stability functions
- **Geleyn scheme**: The scheme interpolates between lowest model level and surface using surface fluxes and stability functions.
- **Canopy scheme**:This scheme uses prognostic equations in the Surface Boundary Layer (SBL) to calculate the tendency of meteorological fields, taking into account large-scale forcing, turbulence and canopy drag. This scheme has also an impact on the surface temperature and water content since the forcing of surface will be the lowest level in the SBL and not that of the upper air model.

The aim of this study was twofold. Since Canopy scheme is planed to be used in SURFEX we first had to verify that the forecast with the new scheme gives as good or better results than the other ones regarding screen level fields. The second task was to find a way how Canopy scheme could be used in data assimilation. (The problem is that it is a prognostic scheme so it is difficult to define its tangent-liear and adjoint version.)

We have run AROME forecast for 24h on 2.5km horizontal resolution and 49 levels with all the 3 available diagnostic schemes and made verification against SYNOP observations for the time period: 04-24 December 2007.
We can see from the figure on the right that for this time period there is no big difference between the Canopy and Paulson scheme regarding T_{2m} and RH_{2m} but Canopy scheme gives better surface temperature scores (not shown). Geleyn scheme underestimates drastically the temperature in stable condition (during night).
On the other hand the advantage of the Geleyn scheme is that it has tangent-linear and adjoint code version and since it uses an interpolation formula it is safer to use in DA than the Paulson scheme. The idea is to modify the Geleyn scheme to give better results in stable condition.



Verification of T2m and RH2m fields for the three diagnostic schemes: Paulson (red), Canopy (green) and Geleyn (blue) for the time period: 04-24 December, 2007.

New interpolation formula for Geleyn scheme in stable condition

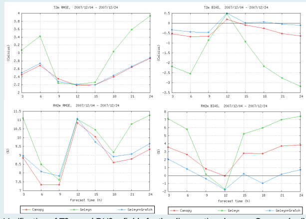
Based on the paper of Gratchev et al. 2007 we have defined a new interpolation formula for Geleyn scheme in stable condition.
In the original scheme the stability function for stable condition reads: $\phi(\xi) = 1 + \alpha\xi$
(where $\xi = z/L$, L being the Monin-Obukhov length)
while for the new formula we have used the following function:

$$\phi(\xi) = 1 + \frac{\alpha\xi}{1 + \frac{\alpha}{a_h}\xi}$$

Using the new function we can calculate the interpolation formula for dry static energy for stable condition:

$$s(Z) - s = \frac{s(Z_1) - s}{b_H}\left\{\ln\left[1 + \frac{Z}{Z_1}\left(e^{b_N} - 1\right)\right] + a_h \ln\left[1 + \frac{Z}{Z_1}\left(e^{\frac{b_H - b_N}{a_h}} - 1\right)\right]\right\}$$

where Z_1 is the forcing height, s is the dry static energy at the surface, b_H and b_n are functions of the surface exchange coefficients and a_h is a tuning parameter. We have compared the forecast using the new formula (we used a_h=5) with the other schemes. The figure on the right shows that the performance of the new formula in stable condition is much better than the original, it is close to the results of Canopy .



Verification of T2m and RH2m fields for the diagnostic schemes: Canopy (red), Geleyn (green) and modified Geleyn scheme (blue) for the time period: 04-24 December, 2007.

The tunable parameter (a_h) determines the shape of the vertical profile of s: for $a_h \rightarrow \infty$ we get back the original formula while for $a_h \rightarrow 0$ the profile is very sharp. It is hence possible to tune the profile to the Canopy diagnosed one, i.e. at every point one gets the same screen level values. Since the tangent-linear version of the new formula exists its application in data assimilation is straightforward.

Comparison of different soil schemes in SURFEX

In SURFEX over nature tile there are two methods to calculate the time evolution of soil water content and temperature.

Force-Restore scheme (Noilhan and Planton, 1989). The vertical diffusion of water and heat between the soil layers are parameterized by a force-restore method.

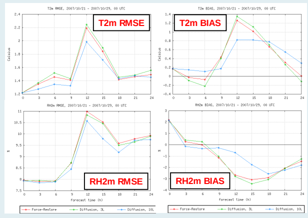
Diffusion scheme (Boone et. al. 2000). The diffusion processes are calculated explicitly. The number of layers is not restricted.

In order to be able to run the Diffusion scheme in AROME we had to modify the code since the initialization of the soil water and ice content was not consistent with the calculation of the melting/freezing processes in the Diffusion scheme. The initialized ice content was too high resulting in big temperature decrease (up to –60 Celsius!) at the beginning of integration. We recalculated the water and ice content from the total water content consistently with the melting scheme

We have made experiments to compare the two different schemes. Three different model configurations were taken into account:

- **FR3L**: Force-Restore method with 3 layers
- **DIF3**: Diffusion method with 3 layers
- **DF10**: Diffusion method with 10 layers

The 3 experiments were run for the time period: 01-14 December, 2007.
The verification of T2m and RH2m shows that the Diffusion scheme with 10 layers is better than Force-Restore. It is interesting that there is such a big difference in the 2m scores between the 3 and 10 layer version of Diffusion scheme. (We should mention here that the layer depth are not the same for the 3 layers Force-Restore and the 3 layers Diffusion scheme.)

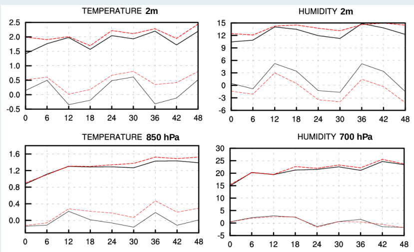


Verification of T2m and RH2m fields for the 3 different model configurations (FR3L, DIF3, DF10) Time period: 21-29 October, 2007

Recent changes in the operational system

Surface Assimilation

So far, in ALADIN-Hungary we did not perform a local data assimilation for the surface (soil) variables. Instead, we have initialized the surface variables with the actual ARPEGE analysis interpolated to our model geometry. Recently, we have implemented the ALADIN Optimum Interpolation configuration (CANARI OI) in order to perform a local surface assimilation. Similarly to the Czech implementation we do not perform SST (Sea Surface Temperature) analysis but we still take the ARPEGE analysis for the grid-points over the sea. The CANARI OI test was run for a 2 month period (May-June 2008) in a quasi-operational manner. Improvements were found mostly at 2m and to some extent also at 850-700 hPa for temperature and relative humidity. On the higher levels the impact is rather neutral. Based on these tests we have decided to implement the local CANARI OI surface assimilation operationally. Verification scores against SYNOP and TEMP observations are presented on the right, showing the joint impact of CANARI OI and the use of LBC data from the ECMWF model (see explanations below).



Joint impact of CANARI OI surface assimilation and use of LBC data from ECMWF. RMSE and BIAS scores based on 00 UTC runs are displayed in the function of forecast range.Dashed red line stands for the operational run and black solid line stands for the new experiment.

Lateral Boundary Conditions

Until now, the lateral boundary coupling information for the operational ALADIN-Hungary have been taken from ARPEGE both in the assimilation cycle and the production forecast. Several attempts to use LBC data from the ECMWF model have been made in the past 2 years in Hungary in an experimental framework, i.e. in a non-real-time manner. These investigations were done in the frame of the "SPFRCOUP" Special Project. Results suggested a potential improvement of our ALADIN forecasts when using LBC data from the ECMWF model. Recently, ECMWF provides LBC data for Hungary on a daily basis, which allowed to set up real-time parallel tests at HMS in order to compare the forecast accuracy with ARPEGE and ECMWF LBC data. Unlike with ARPEGE, the LBC data from ECMWF are available with such a time delay, that one can use only the LBC information from the previous global run, that is with a 6 hour shift. The verification figures above show the joint impact of the LBC data from the ECMWF model and of the local CANARI OI surface assimilation. These components have been tried together recently to see their interactions, as previously both of them were proven to improve the forecasts skills separately. Based on the the verification scores shown, both LBC data from ECMWF and CANARI OI surface analysis are to be implemented operationally on the 1st of October 2008.

Use of observations

Concerning the use of observations in the atmospheric 3DVAR analysis, two main changes have been done. In chronological order, first Wind Profiler data have been tested during the summer and autumn of 2007 and then introduced operationally on the 1st of October 2007. AMSU-A and MHS radiances from the NOAA-18 satellite have been introduced operationally by the end of January 2008 after parallel testing (data from the other NOAA satellites are used operationally already since May 2005). At the same time we have introduced an automatic update of satellite bias correction files by recomputing the bias correction coefficients on the first day of the given month based on obs minus guess data of the previous month.

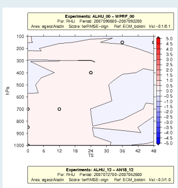
- Wind Profiler Data

The Wind Profiler data are used in a similar way as in the ARPEGE global model so far, which means that we use a blacklist file taken from Meteo-France. This implies that 4 German Wind Profiler stations are used in our setting and the data are accepted in the layer between 700 and 400 hPa only. Verification results are shown on the figure on the right (top). In the future a local blacklisting for Wind Profilers (beside other observations) is planned to define based on local observation monitoring.

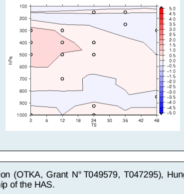
- NOAA-18 radiances (AMSU-A and MHS)

The radiances from NOAA-18 are used in the same way as radiances from the other NOAA satellites so far (80 km thinning, local bias correction based on the „Harris and Kelly method"). This means a use on a somewhat higher resolution than in ARPEGE. The bias correction is updated on a monthly basis. Verification results are shown on the right (bottom).

Vertical cross sections of RMSE differences in the function of forecast range. Reddish colors stand for improvements due to Wind Profilers



Vertical cross sections of RMSE differences in the function of forecast range. Reddish colors stand for improvements due to radiances from NOAA-18



Acknowledgement: This paper presents results of research programs supported by the Hungarian National Research Foundation (OTKA, Grant N° T049579, T047295), Hungarian National Office for Research and Technology (NKFP, Grant N°3A/051/2004, 2/007/2005) and the János Bolyai Research Scholarship of the HAS.

Application of the Flake lake parametrization scheme for the Lake Balaton

Miklós Vörös[1], Vera Istvánovics[2]
[1]Hungarian Meteorological Service (OMSZ), [2]Budapest University of Technology and Economics (BUTE)

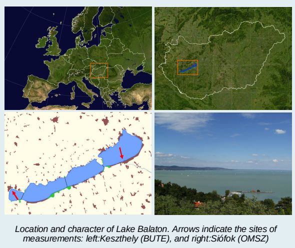
As numerical models probe ever finer horizontal spatial resolutions, the need to adequately parametrize lakes becomes greater. Presently most lakes are either subgrid sized, or shares its gridbox with other surface types. At the intended 2 km resolution of AROME, however pure lake gridpoints appear and warrant proper description. Problems with the representation of lakes are twofold. One is the initialization of its surface temperature from the driving model, the other is the fact that its temperature is kept constant throught the whole forecast. Both problems are expected to be alleviated by the recent integration of the FLake (Freshwater Lake) 1D column lake scheme into the SURFEX surface module.

The lake that is expected to have the most infuence on the Hungarian weather forecasts is the Lake Balaton.

With a surface area of 592 km^2, Lake Balaton is the largest lake in Central Europe, while its mean depth is only 3.3 m. In ice free conditions, the diurnal variation of the surface temperature is 2.5 ℃. The lake is polymictic, it has no thermal stratification in the classical sense, however at times the temperature difference between its surface and its bottom can reach 4 ℃. When this kind of micro-stratification appears, temperature tends to change progressively from the surface to the bottom, without a characteristic fully mixed layer. Most stratification occures at low windspeeds and high irradiation. Convective events rapidly mix the water, and cause a sharp drop in surface temperatures – potentially providing a negative feedback.

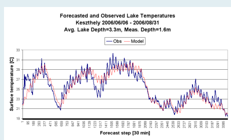
We begun the evaluation of the FLake model for the Lake Balaton to assess if FLake can provide a satisfactory description of the lake. We expect it to outperform the currently used constant temperature approximation.

Off-line simulations, initialised from observed lake temperatures, driven by observed or forecasted atmospheric forcing from the ALADIN NWP model, were used.

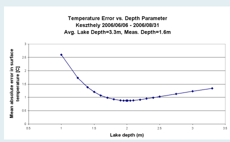


Location and character of Lake Balaton. Arrows indicate the sites of measurements: left:Keszthely (BUTE), and right:Siófok (OMSZ)

Site: Keszthely , V. Istvánovics
Measurement: water and sediment temperature profile
Water depth: 1.6 m, Mean lake depth: 3.3 m
Homogenous initial water temperature profile : observed value
Off-line Forcing : observation data
Net radiation : empirical fit (based on sample data)
Time step: 30 min, Duration: 72 days
Output variable: surface water temperature



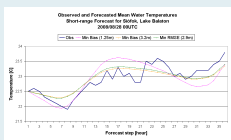
Forecasted and observed lake surface temperatures. Modelled lake depth is 2m.



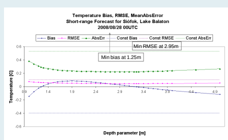
Mean absolute error of the surface temperature vs. lake depth.

In this test the lake model performed to our satisfaction, it followed the general trend of the observed values. However – maybe due to an approximation for the net radiation – its diurnal cycle has a smaller amplitude, and it is generally slower to react than the lake itself. We conclude that the lake depth parameter has great influence on the quality of the forecast. The depth that gave the smallest error is between the actual depth and the mean lake depth. The cause might be an inperfect approximation of the temperature-depth profile and the interaction between adjacent lake gridpoints.

Site: Meteorological station in Siófok
Measurement: water temperature at 1m depth
Water depth: 1.2 m, Mean lake depth: 3.3 m
Homogenous initial water temperature profile : observed value
Off-line Forcing : operative ALADIN forecast
Net radiation : empirical fit (based on sample data)
Time step: 1 hour, Duration: 36 hours
Output variable: mean water temperature



Blue line- observed mean temperature.
Magenta line – Modelled T_{mean} for 1.25m deep lake
Orange line – Modelled T_{mean} for 3.2m deep lake
Green line – Medelled T_{mean} for 2.95m deep lake



Mean tempreature bias, RMSE and abs, error values for various lake depths. Continuous line represents model results, dashed lines are values for the constant temperature approximation.

Preliminary results indicate that the model gives an acceptable approximation of the mean lake temperature on the short range of a 36 hours forecast, surpassing the currently used constant temperature approximation. The model results strongly depend on the lake depth. Further studies will also be directed towards finding the optimal choice of this depth parameter.

Acknowledgement: We would like to thank the kind help of Lajos Vörös of the Balaton Limnological Research Institute