Experiments with the explicit blending and the 3D-Var scheme for the ALADIN/HU model.
Part I: General evaluation

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Contents

1 Introduction

Data assimilation can be defined as the method through which all the available information (the observations, the background) is used in order to describe, as accurately as possible, the state of the atmosphere on a regular grid. In the NWP field, data assimilation uses the information from the observations and from the background weighted according to their accuracy, combined with a numerical model, in order to provide the initial model state.

In the 3D-Var system of the ALADIN model the background information is provided by the 6h forecast from the previous model run, which contains small scales features. In order to bring more large scale information in the initial condition for the limited area model, it was proposed to use the explicit blending. This method represents a simple procedure to merge the large scale information from the ARPEGE analysis together with the small scale features of the ALADIN forecast, which is performed in the spectral space. The weight given to the ARPEGE features is decreasing following a simple linear function, until an established wave number. Afterwards the information is taken only from the ALADIN forecast. Symbolic equation of the explicit blending procedure:

$$BLEND = (\alpha - 1) * ARPEGE + \alpha * ALADIN$$

where $\alpha \in (0, 1)$ till the wave number equal to 31. After it, α becomes equal to 1. One can see that the explicit blending was designed in such a way to take as much as possible from the small scale information. (Tóth, 2003)

This method can be used in two different ways: either to merge the "classical" first guess (i.e. the 6h forecast from the previous integration of the limited area model) with the analysis of the global model, and further the result to be used as a first guess for the data assimilation process, or either to perform the data assimilation step, to obtain an analysis of the limited area model, and afterwards to combine it with the global model analysis, the result being the initial condition for the model integration.

In order to establish the framework of the optimal combination between the 3D-Var scheme and the blending procedure, different experiments have been performed. First of all some preliminary tests about the blending procedure were carried out. It was investigated whether or not is needed to use initialization after the blending, if some spin-up effect appears in the 6h forecast. Based on these preliminary results it was decided to perform three different combinations of the blending procedure, 3D-Var scheme, with/without digital filter initialization. A period of 15 days has been selected in order to carry out some general experiments, to check the verification scores against the real measurements. And also case studies, for some interesting meteorological situations, were investigated.

The paper is organized thus: section 2 presents the preliminary tests, which helped to establish the basic framework for the further experiments. In section 3, the results of the verification scores from the general experiments are discussed. The concluding remarks are gathered at the end.

2 The description of the experiments

The first three sets of experiments have been performed for a case study from the 18th of July 2003 in order to compare the results of the model running in dynamical adaptation (as the reference), and using the blended state as initial condition, with digital filter initialization (DFI) and without any initialization. Therefore the names of the experiments: "*dyn adap DFI*", "*blend DFI*" and "*blend no DFI*". It was investigated whether or not is need to use initialization after the blending, if the fields look realistic, if some spin-up effect appears in the 6h forecast.

All the experiments were carried out with the ALADIN/Hungary model, whose characteristics are summarized in **Table 1**. We can see that the actual domain of the ALADIN/HU model is covering the former LACE one. The global model ARPEGE provided the lateral boundary conditions.

Table 1: Basic characteristics of the ALADIN/HU model

Number of gridpoints (including the extension zone)	240x216
Spectral truncations	79x71
Horizontal resolution	12.2 km
Number of vertical levels	37
NE corner	55.62 °N; 39.08 °E
SW corner	33.99 °S; 2.17 °W

The analyses of different fields from these experiments have been plotted. One can see in the Figures 1 - 4 that the fields starting with the initial condition, obtained by blending, do not look noisier, than in the reference experiment, either when no initialization has been used. The 6h cumulated precipitation forecast presents realistic features. The same pattern of the area where precipitation occurred can be seen in all three experiments (Figure 4).

But the aim of our experiments was to establish the best possible combination between the 3D-Var scheme and the blending procedure. So, beside the experiments described above, also other experiments were carried out, as preliminary tests, with the 3D-Var scheme using as first guess, the 6h forecast from the previous integration of the ALADIN/HU model (as reference) and the blended state between the ARPEGE analysis and the ALADIN/HU 6h forecast, with and without digital filter initialization after the blending and in cycling. The background error statistics were computed by the lagged NMC method (Široká *et al.*, 2003). The observation term takes into account surface and upper-air (radiosonde) observations. Thus the surface pressure measurements are assimilated from the surface data, and geopotential, wind, temperature and specific humidity observed variables from the radiosondes.

2.1 Ectoplasm plots

Ectoplasm program permits to compute the spectral energy distribution on the different wavenumbers. The spectrum of different fields was computed on the ARPEGE analysis, on the first guess from the ALADIN model and on the blended state, valid at the 18th of July 2003, 00 UTC. The aim of these plots was to check whether or not the blending procedure is working correctly (i.e. if the scales are really taken from the appropriate fields on the suitable scales).

In the Figure 5, the spectral energy is shown for divergence at the model levels 18 ($\sim$ 500 mb) and 31 ($\sim$ 925 mb). For the large scales (with the wave numbers between 1 and 10) the spectrum of the all three states is very similar, because the large scale information from the first guess was partly influenced by the coupling with the ARPEGE forecast. Then for the wave numbers between 10 and 31, it can be easily observed that the blended state took information both from the analysis and from the first guess. After the wave number 31, the blended state curve is identical with the one of the first guess.

2.2 Echkevo plots

In order to check the balance properties of the fields, the echkevo scores have been plotted for the same day as the ectoplasm plots. These scores show the time evolution of the fields at different levels for some selected points on the domain. For our preliminary tests, the following points in (x, y) coordinates were chosen (Figure 6):

◇ [57, 104] - a point over the mountains (one of the highest point in the orography of the model),

◇ [119, 111] - a point in the middle of the domain,

◇ [135, 105] - a point over the plain of Hungary,

◇ [150, 126] - a point of medium height.

In the Figure 7, the time evolution of the surface pressure, during the first 6h integration, is represented for the selected points. One can see that for some points all three curves are almost similar, but for the point in the middle of the domain [119, 111], some unbalanced features are shown, especially when no initialization has been applied on the blended state.

The surface pressure tendency diagnostic reveals similar curves for the blending with DFI and dynamical adaptation with DFI (the maximum value in the first hour is around 15 Pa). The experiment "*blending no DFI*" presents a more unbalanced field. But till the end of the 6 hours integration, the three curves are getting the same shape (Figure 8).

For the same day and for the same points, the time evolution of the surface pressure has been plotted, for the experiments where the 3D-Var scheme and the blending procedure were used. Four different combinations to obtain the initial condition for the model have been performed: using the 3D-Var scheme with and without DFI in cycling, starting from a first guess produced by the blending between the ARPEGE analysis and ALADIN 6h forecast, with and without digital filter initialization. One can see in the Figure 9 that the most balanced fields are when initialization has been used in cycling. The biggest difference between experiments appeared again for the point in the middle of the domain. It is interesting to remark that the curves are getting similar at the end of the 6h integration, depending if DFI has been applied or not, in cycling.

Because the explicit blending is performed rather in a "rough way", and also in order to have a balanced first guess, it was decided to use DFI, before the variational step. It was difficult to conclude from the echkevo plots whether or not is need of initialization in cycling too. So it remains to perform more experiments with and without DFI in cycling and to compare the results.

2.3 The evaluation of the spin-up effect

The spin-up can be defined as a process occuring at the initial period of integration of a numerical model, while the dynamical and physical processes succeed to establish their internal equilibrium. In order to check whether or not some spin-up effect in the precipitation fields appeared, the time evolution of the spatial average of the precipitation over the domain during the 6 hours was plotted for four experiments: in dynamical adaptation and when the initial condition was obtained by blending, with/without initialization. The precipitation amount was computed between two consecutive time-steps.

It can be seen in the Figure 10, that for all the experiments the spin-up exists in the first two hours of integration. Then the equilibrium is established, and the rain rate value remains at around 0.6 mm/6h. It was interesting to see that when no initialization has been used the quantity of precipitation was higher (the rain rate was starting from 1 mm/6h, comparing to 0.4 mm/6h, as for the other experiments), but after two hours the curves reach almost the same value. Therefore the precipitation forecast at each hour, during the first 6 hours interval has been plotted, and revealed that the experiments without initialization predicted more precipitation at the beginning. The radar images were checked (Figure 11), and according to them, it seems that indeed between 00 UTC - 03 UTC, precipitation fell in the central part of Hungary. But we cannot say whether the forecast of the non-initialized model was good by chance, or the digital filter initialization removed some important features from the analysis.

2.4 Maps with increments

As another evaluation tool, maps with increments for different fields have been drawn. Here mainly the plots for the mean sea level pressure and temperature at 500 hPa are presented.

First of all, the differences between the blended state and the ARPEGE analysis, respectively the ALADIN forecast, have been plotted in the Figures 12 and 13. The difference between the blended state and the global model analysis (the top rows of the figures) emphasizes the small scales differences between the ALADIN forecast (that might have a more physical meaning on the small scales) and the analysis of the ARPEGE model (which is mainly noise at these scales). Therefore the resulting field for both the mean sea level pressure and the temperature is quite noisy. The large scales are fully zeroed in this difference.

The small scale differences are presented in the regions with high orography (as example: over the Alps, in the southern part of Italy, over the Corsica Island). The reason is that the orography in the limited area model is better represented than in the global model, because of the higher resolution (12 km, compared to 20 km of the ARPEGE over the ALADIN/HU domain).

One can see in the bottom rows of the figures, the difference between the blended state and the limited area model forecast, that points out the large scales difference between the ALADIN guess and ARPEGE analysis. Here the small scales are fully zeroed through the difference.

As a concluding remark, we may say that it is not very clear which field (from the global or from the limited area model) brought more information into the blended state on each scale. The ALADIN model counterpart is important in the blending procedure, because the global model analysis has no physical meaning on the small scales. At the same time the ARPEGE model has a great impact, because the contribution to the blended state on the large scale from the limited area model guess is quite different.

In the Figure 14, the observation impact from the reference experiment (i.e. using the 3D-Var scheme with the 6h forecast from the previous integration of the model, as first guess) is presented, with and without DFI after the variational and optimal interpolation steps. Thus the differences between the initialized/non-initialized analyses of the model and the first guess show a higher influence of the observations over the Czech Republic and Germany, and also over the Alps and Turkey.

For the experiments with the blended state as first guess, one can recognize the same area of influence of the observations over the central part of Europe, but the increments are slightly smaller, mainly when the DFI has been applied after the blending step (Figures 15 and 16). One explanation of these small increments might be that the blended state already contains the observation information, through the ARPEGE analysis. Because the blended state is closer to the observations and in the data assimilation process for the limited area model approximately the same observations are used as for the global model, it results smaller 3D-Var analysis increments.

In order to see the impact of the blending, the differences between the temperature analyses of the model using the 3D-Var scheme with the blended state as first guess (with/without initialization) and the reference 3D-Var experiment are plotted in the Figures 17 and 18. Comparing to the Figure 13 (bottom row) we can recognize mainly the influence of the large scale information from the global model.

3 General evaluation

Based on these preliminary results it was decided to perform three different combinations of the blending procedure, 3D-Var scheme, with/without digital filter initialization. The generic names of the combinations are: ***blendvar***, when the blending step was performed first, followed by the variational step, and ***varblend***, when the order is the reverse, i.e. the variational step first, and then the blending procedure.

The description of the experiments is presented below:

a) "*blendvar DFI*": the blending between the ARPEGE analysis and the 6h forecast of the ALADIN/HU model is performed first, and then the digital filter initialization is applied on the blended state. This initialized analysis is used as first guess for the 3D-Var scheme. After the variational step, the surface analysis is performed using the Optimal Interpolation method. In cycling (i.e. the integration of the model in order to obtain the first guess for the next cycle), digital filter initialization was used and the lateral boundary conditions are provided by the ARPEGE analyses from the assimilation cycle. In this way we are using as much as possible the information from the observations.

b) "*blendvar no DFI*": as the name already suggested, this experiment was carried out in a similar way as the previous one, except that no initialization has been used in cycling.

c) "*varblend DFI*": the variational and the optimal interpolation steps were performed first, followed by the blending between the analysis of the ALADIN/HU model and the ARPEGE analysis. The blended state has been used as initial condition in cycling, where DFI has been applied, and the lateral boundary conditions were provided by the ARPEGE analyses.

As reference for all the experiments performed with the blending and the 3D-Var scheme, the ALADIN/HU model was running in dynamical adaptation and using the 3D-Var scheme with 6h forecast from the previous run, as first guess.

A period of 15 days, between 24.05.2004 and 07.06.2004, has been selected to perform some general experiments, in order to check the verification scores against the real measurements. These verification scores have been computed only for the forecasts from the 00 UTC model run. The model was integrated for 48h, with lateral boundary conditions (LBCs) from the ARPEGE model (from production) and using digital filter initialization. The refreshment of the LBCs was done every 3 hours.

For the computation of the verification scores, the VERAL procedure has been used. This procedure works in two steps. First, a quality control of the observations against the ARPEGE analysis is performed based on the Optimal Interpolation method for the ALADIN model (called CANARI). Different criteria are applied for it like the first guess departure check, horizontal cross-check with other observations, etc. Then the departures of the model forecast from each observation are computed at the observation point, followed by a spatial average over the domain, which represent the quality of the given meteorological field for the entire domain. In order to have a reference for all five experiments, the departures were computed between the ARPEGE analysis and the observations. Further these departures have been used for the evaluation of the BIAS and RMSE for different meteorological parameters on the selected pressure levels. An average RMSE and BIAS was computed for each experiment, for each forecasting range. (Janousek, 1999).

The names of the experiments on the figures with the verification scores means: BLVD - "*blendvar DFI*", BLVn - "*blendvar no DFI*", VBLD - "*varblend DFI*", 3DVA - the reference experiment using the 3D-Var scheme, and finally DYAD - the experiment with the model running in dynamical adaptation.

First of all the verification scores for the two ***blendvar*** experiments are presented. Figure 19 shows the evolution of scores with the forecast range over the entire period, at 500 mb. One can see that the differences between the two experiments are very small. Also for the other levels (surface, 850 mb, 700 mb) the scores are the same (not shown). Figures 20 and 21 present the RMSE scores for individual runs, for the 500 mb level, at the analysis time and after 48h integration. Again we can see similar verification scores, with small differences mainly for the relative humidity, and for almost all the fields at the analysis time, except for the first day of the verification period.

These similar scores of the ***blendvar*** experiments can be explained by the fact that also without digital filter initialization, after 6h integration, the forecast in cycling is getting balanced. And this forecast is blended with the ARPEGE analysis, followed by the DFI and the 3D-Var and OI steps. Then the resulted analysis is used as initial condition in production, where DFI is applied. Further we won't show anymore the verification scores for the "*blendvar no DFI*" experiment, considering that is following the scores for the "*blendvar DFI*".

Figures 22 and 23 present the evolution of the RMSE and BIAS scores with forecast range for the four experiments, at the levels 500 mb and 700 mb. There is a slight advantage for the "*blendvar DFI*" experiment for all the fields in the first 6h of integration. Also very small differences between experiments can be seen for the relative humidity and wind, when the "*3dvar*" experiment has worse RMSE scores. Otherwise the verification scores are almost neutral.

Also the RMSE scores for individual runs have been checked. Further only the scores from the surface and 700 mb levels are presented, at the analysis time, respectively after 6h and 48h integration. For the analysis at the 700 mb, the "*blendvar DFI*" experiment shows better scores for all the fields. We have to remark the big difference, which appeared between the "*blendvar DFI*"/"*varblend DFI*" and the "*dynamical adaptation*" for wind and relative humidity. For the temperature and mean sea level pressure analyses the difference between all four experiments is not very big, but still the "*blendvar DFI*" shows a small improvement (Figure 24). Similar behavior we have seen for the analysis at the 850 mb, only that the difference for the temperature between the "*dynamical adaptation*" and the "*blendvar DFI*"/"*varblend DFI*" experiments slightly increased (not shown).

Figure 25 illustrates for the 6h forecast of the temperature, at the 700 mb level, a positive impact in the "*blendvar DFI*"/"*varblend DFI*" experiments, mainly in the first part of the verification period. For geopotential the scores are rather neutral, and for the wind and relative humidity, sometimes the reference experiment with the 3D-Var scheme ("*3dvar*") is better, and sometimes it is the reverse. Also we could remark the same evolution of the scores for the fields at the 850 mb from all the experiments (not shown).

After 48h integration there is no impact from one experiment or another for the geopotential. Also for the temperature the scores are neutral, except that for some runs we can see an improvement for "*blendvar DFI*"/"*varblend DFI*" experiments. For the wind and relative humidity forecast we can say that "*blendvar DFI*" and "*varblend DFI*" are slightly better (Figure 26).

The biggest difference in the verification scores between the "*blendvar DFI*"/"*varblend DFI*" and "*dynamical adaptation*" experiments can be seen in the Figure 27, at the surface, for temperature and relative humidity, at the analysis time. For the temperature, all the experiments using the 3D-Var scheme have similar RMSE scores. A better analysis for mean sea level pressure and relative humidity is obtained with "*blendvar DFI*". Relatively neutral impact for the surface wind can be seen.

The improvement for the relative humidity in the "*blendvar DFI*"/"*varblend DFI*" experiments is kept also after 6h integration, compared to the "*3dvar*" experiment. Only that the forecast of the "*dynamical adaptation*" experiment has been improved. The scores for temperature are slightly better for the "*blendvar DFI*"/"*varblend DFI*" than in the "*3dvar*". Also for some days, the "*blendvar DFI*" improved the forecast for the mean sea level pressure. For the wind the scores show a neutral impact (Figure 28).

The verification of the 48 forecast for the surface fields illustrates that the "*blendvar DFI*"/"*varblend DFI*" experiments still have improved the relative humidity. For wind speed and temperature, the scores are similar, and just some small differences for the mean sea level pressure and wind direction, when sometimes the "*3dvar*" is better, or the other experiments. The difference between the "*blendvar DFI*"/"*varblend DFI*" and the "*dynamical adaptation*" becomes smaller and smaller (Figure 29).

After these experiments have been performed and investigated, it arose the idea that the improvement of the ***blendvar*** experiments can be related to the fact that the humidity has been treated multivariate, while in the "*3dvar*" set, was univariate. So in some extent the differences between the two experiments were due also to this inconsistency in the way of treatment of the humidity. Further a new set of experiments was carried out by Gergely Bölöni, using the 3D-Var scheme, with the first guess as 6h forecast from the previous integration of the model and with multivariate humidity. Figures 30 - 33 present the verification scores for the "*blendvar DFI*", "*3dvar*" sets of experiments and the newest one, called "*3dvm*", (from multivariate treatment), for the analysis and 6h forecast, at the surface and 700 mb levels. We remark that generally the verification scores of the experiments when the blending procedure has been used, kept the slight improvement as before.

4 Discussion and conclusions

As concluding remarks from the pre-tests, we can say that the fields obtained with the model when the blending procedure was used present realistic features and do not look noisier than those from the reference experiments (the model running in dynamical adaptation and using the 3D-Var scheme, with 6h forecast from the previous integration, as first guess).

The echkevo plots showed that the fields are balanced, less for one point in the middle of domain. But because we wish to have a balanced first guess, in the experiments when the blending step is preceding the variational one, it was decided to apply DFI on the blended state. For cycling, it was not evident if we have to use initialization, so it remains to be concluded after the general evaluation and some case studies.

The spin-up effect has been checked for the precipitation field. It seems that for all experiments, with and without initialization, the spin-up exists at the beginning of the integration, for two hours; afterwards the curves are normalized at almost the same value of rain rate.

The maps of increments revealed that it is not obvious which field (from the ARPEGE or from ALADIN models) brought more information into the blended state on each scale. The ALADIN model counterpart is important in the blending procedure, because the global model analysis has no physical meaning on the small scales. At the same time the ARPEGE model has a great impact, because the contribution to the blended state on the large scale from the limited area model guess is quite different. The small scale contribution is present mainly in the regions with a higher orography. This can be partly due to a better representation of the orography at the finer resolution of the limited area model. The observation impact in the ***blendvar*** experiments can be seen over the central part of Europe, as in the reference experiment, only that their values are slightly smaller, especially when DFI has been applied after the blending step.

The preliminary tests helped us to establish the basic framework for the general evaluation of the optimal combination of the blending procedure and the 3D-Var scheme, and for the investigation of some case studies. The general evaluation consists in running for a period of 15 days, three different experiments: the first one, when the 3D-Var analysis was merged with the ARPEGE analysis, and the initialized blended state was used as initial condition in cycling (so called "*varblend DFI*" experiment), and the other two, when the initialized blended state was the first guess for the 3D-Var scheme, and further the obtained analysis was used as initial condition for the model integration, with and without digital filter initialization (hereafter the names "*blendvar DFI*" and "*blendvar no DFI*"). The verification scores have been compared with those of the reference experiments. They were computed using the VERAL procedure, based on the 48h forecasts of the model, from production, for the 00 UTC run.

First of all, the verification scores from the two ***blendvar*** experiments have been checked and they revealed very small differences between them, mainly for the RMSE scores for each model run, at different levels. For the evolution of the scores with the forecast range over the entire period, the curves for RMSE and BIAS are similar. This leads us to the conclusion that when the blending step is performed before the variational one, it is not necessary to use initialization in cycling, because after 6 hours of integration the fields are balanced. And also in the 3D-Var scheme the background information is already balanced due to the DFI applied after the blending step.

Comparing now the evolution of RMSE and BIAS scores for each forecast range over the verification period, for the new experiments, "*blendvar DFI*", "*varblend DFI*" and the references, "*dynamical adaptation*", "*3dvar*", we can say that there is a small positive impact for the first 6h forecast for all the fields, at almost all the levels, for the "*blendvar DFI*". Along the 48h integration of the model, some differences appeared between the "*3dvar*" and the other experiments, when the relative humidity and wind have been better predicted in the latter ones than in "*3dvar*". But otherwise the curves of the verification scores are similar.

The RMSE scores of individual runs have been checked at different forecasting range, and at different levels. For the analysis time, generally the "*blendvar DFI*" have better scores. There are some model runs and some fields, for which the scores are similar between all four experiments. Between the "*blendvar DFI*", "*varblend DFI*" experiments, it seems that the first one improved better the analysis. After 6h integration, the difference between scores starts to decrease. At the surface, "*blendvar DFI*" succeeded for the relative humidity to keep from the initial improvement till the end of the integration period, and only a slight positive impact for the wind and the mean sea level pressure, while for the temperature the scores become neutral.

For the upper-levels, at the analysis time, the verification scores for the "*blendvar DFI*" show an improvement for relative humidity and a small positive impact also for temperature and geopotential. For the wind the "*3dvar*" is very close to the "*blendvar DFI*". The model running in dynamical adaptation seems to have the worst scores for all the fields, followed by the "*varblend DFI*" experiment. This improvement from "*3dvar*" and "*blendvar DFI*", at the analysis time, is due to the assimilation of the observations. In the "*varblend DFI*", the blending being performed after the variational steps, it looks that the analysis is loosing some information gained from the observations. The scores of the 6h forecast illustrate a smaller difference between all the experiments. For the geopotential the scores are rather neutral. Some improvements for other fields can be seen for "*blendvar DFI*". But there are some model runs, when "*3dvar*" has better scores. Also the differences between "*blendvar DFI*" and "*varblend DFI*" decreased, but still "*blendvar DFI*" looks slightly better. At the end of the integration period, no impact from one experiment or another can be seen for the geopotential field. For temperature, wind and relative humidity, the verification scores reveal very small improvements with "*blendvar DFI*" and "*varblend DFI*". The "*3dvar*" experiment obtained good results few times.

The comparison of the verification scores between the "*blendvar DFI*", "*3dvar*" and "*3dvar multivariate*" experiments revealed that the improvement of the first one is due mainly to the blending procedure together with the assimilation of the observations, and only in some extent to the multivariate treatment of the relative humidity.

The main conclusion from this general evaluation would be that using the blen-ding procedure with the 3D-Var scheme, the forecast of the ALADIN/HU model can be improved. The best framework can be described thus: first, the first guess of the ALADIN/HU model (i.e. the 6h forecast from the previous integration) to be merged with the ARPEGE analysis, then the initialized blended state (i.e. after the DFI was applied) will be used as first guess for the 3D-Var scheme and the Optimal Interpolation method. In cycling, there is no need to apply digital filter initialization. The general evaluation showed that the DFI does not change too much the verification scores. The second part of the report describes the case studies, which have been performed.

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List of Figures

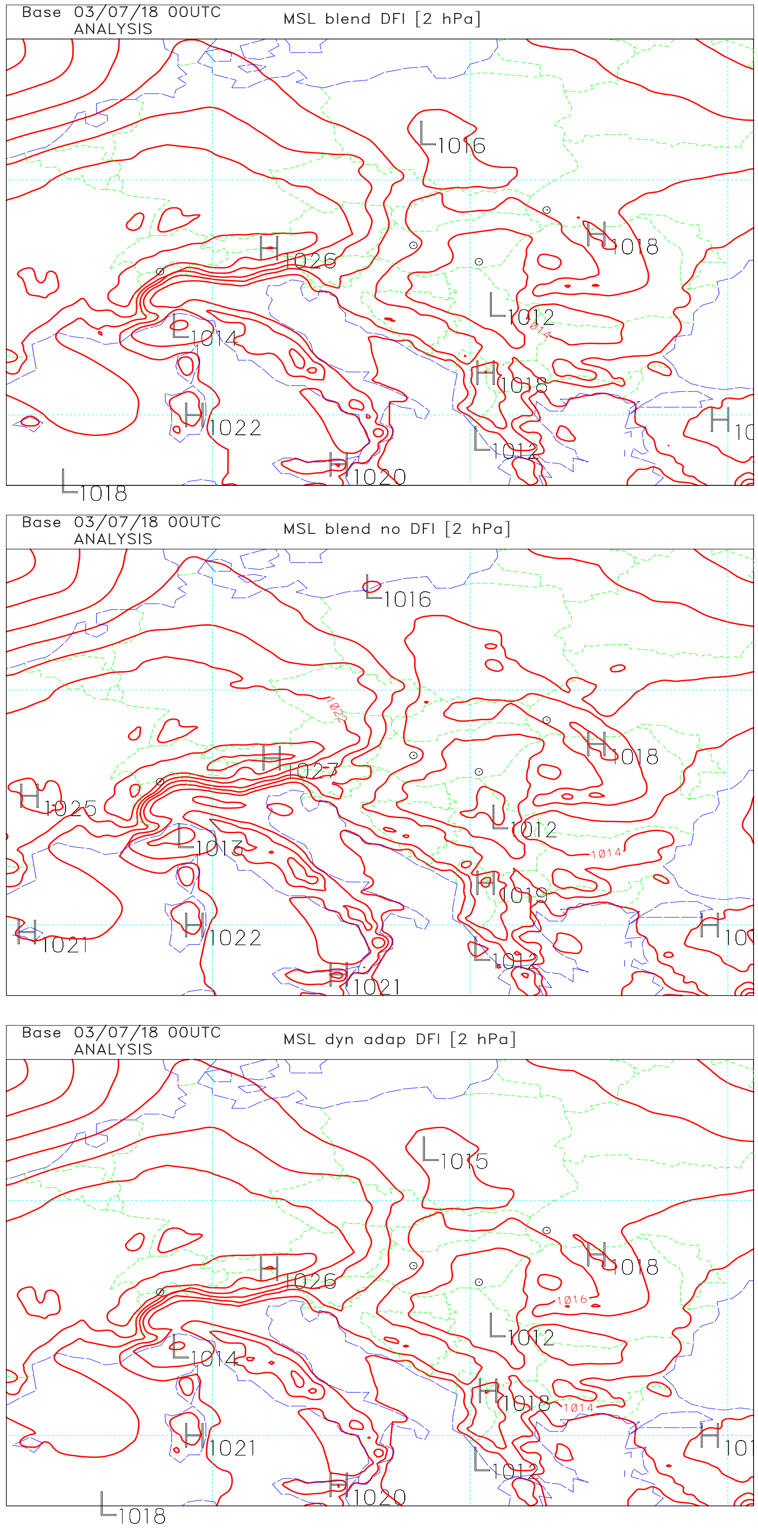

Figure 1: The mean sea level pressure analyses from the "*blending DFI*" (top), "*blending no DFI*" (middle) and "*dynamical adaptation DFI*" (bottom) experiments, from 18.07.2003 00 UTC model run

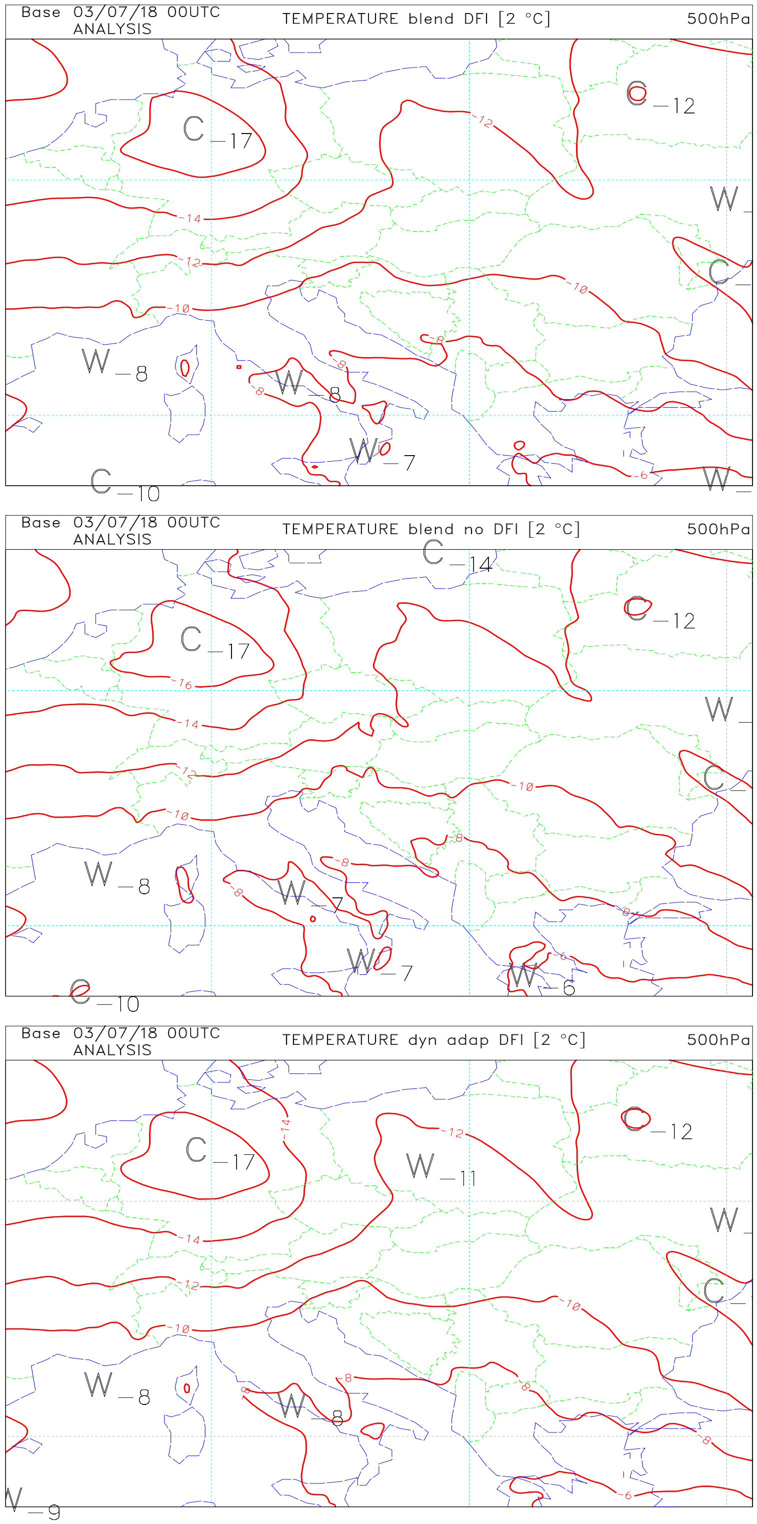

Figure 2: The temperature analyses at 500 hPa from the "*blending DFI*" (top), "*blending no DFI*" (middle) and "*dynamical adaptation DFI*" (bottom) experiments, from 18.07.2003 00 UTC model run

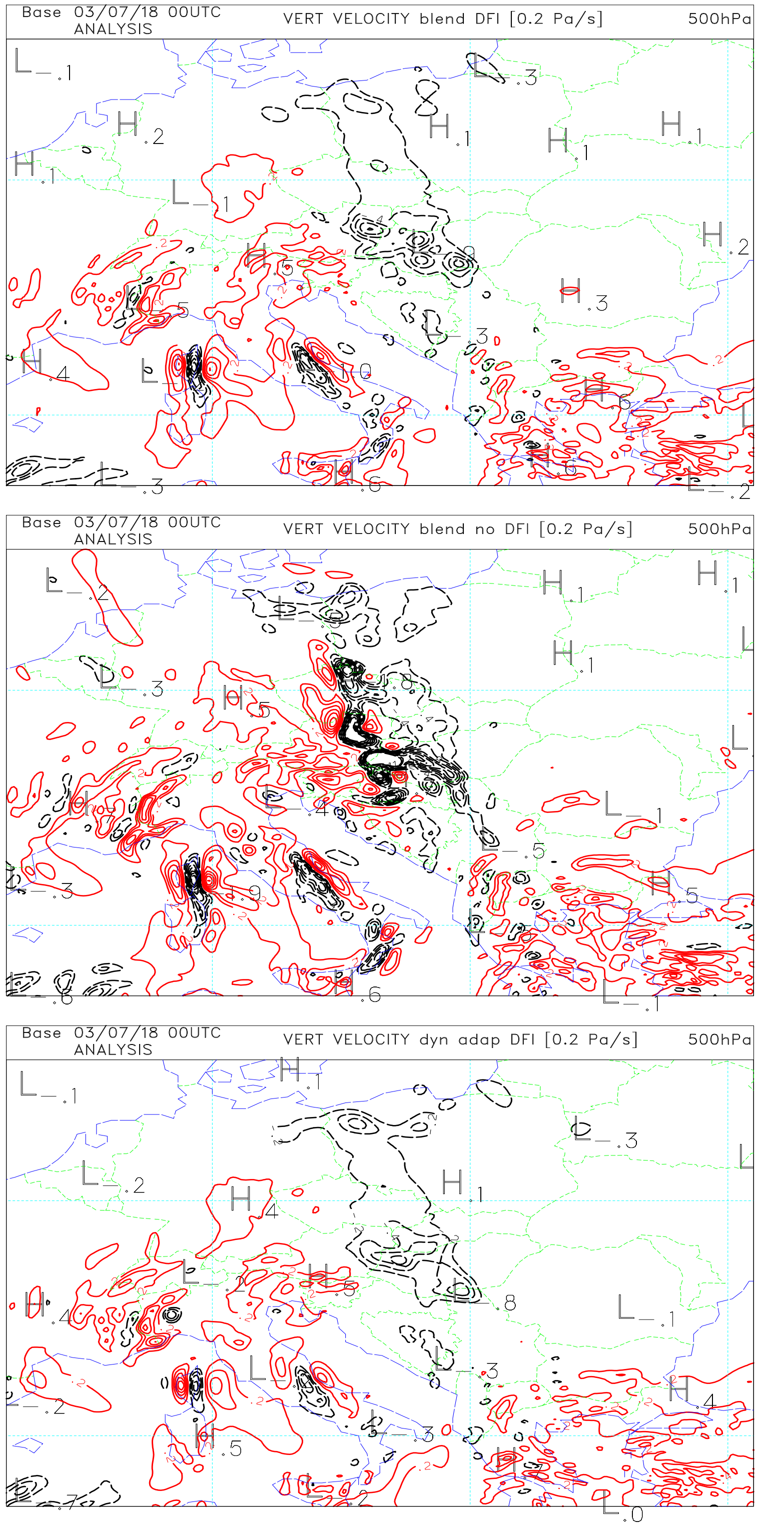

Figure 3: The vertical velocity analyses at 500 hPa from the "*blending DFI*" (top), "*blending no DFI*" (middle) and "*dynamical adaptation DFI*" (bottom) experiments, from 18.07.2003 00 UTC model run

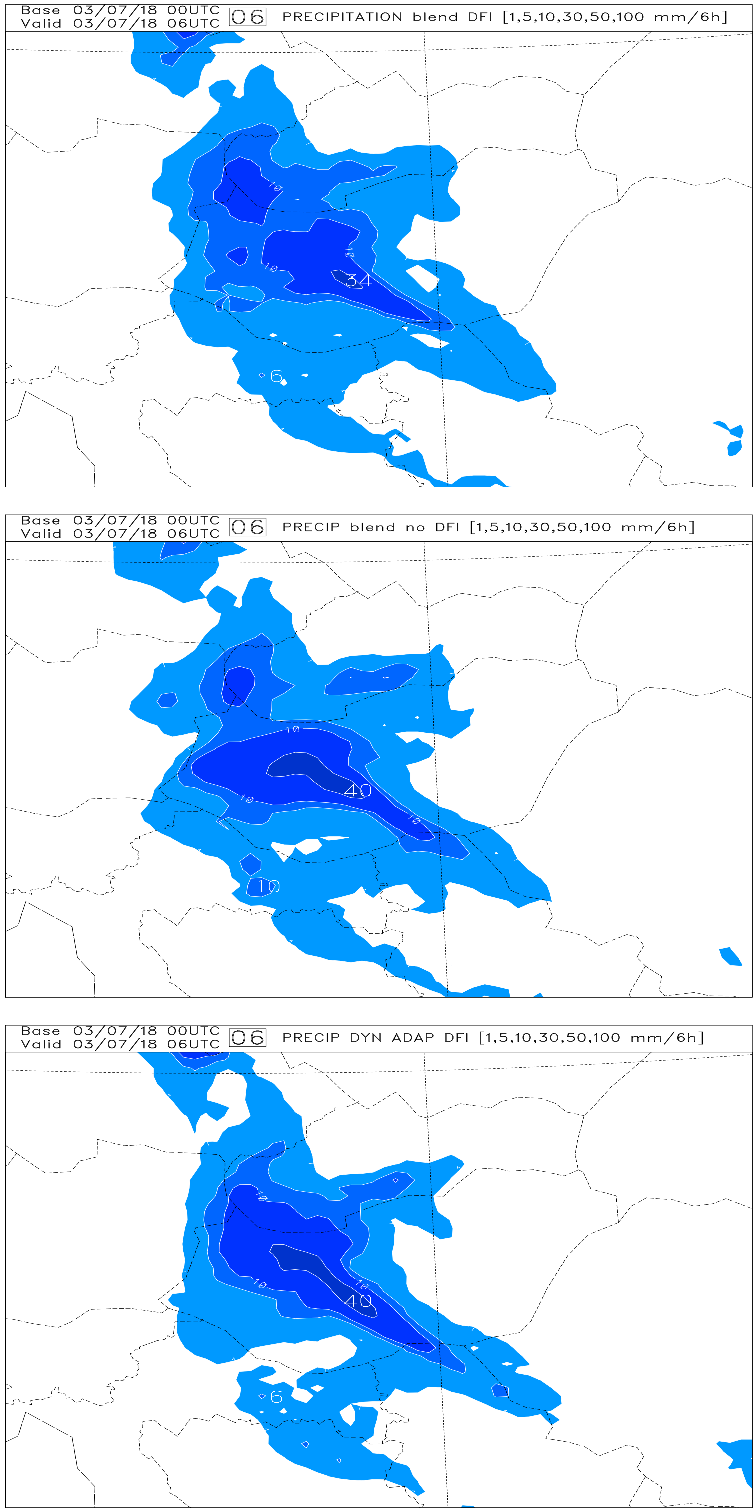

Figure 4: The quantity of precipitation (mm/6h) forecasted from the "*blending DFI*" (top), "*blending no DFI*" (middle) and "*dynamical adaptation DFI*" (bottom) experiments, between 18.07.2003 00 UTC - 06 UTC, from 18.07.2003 00 UTC model run

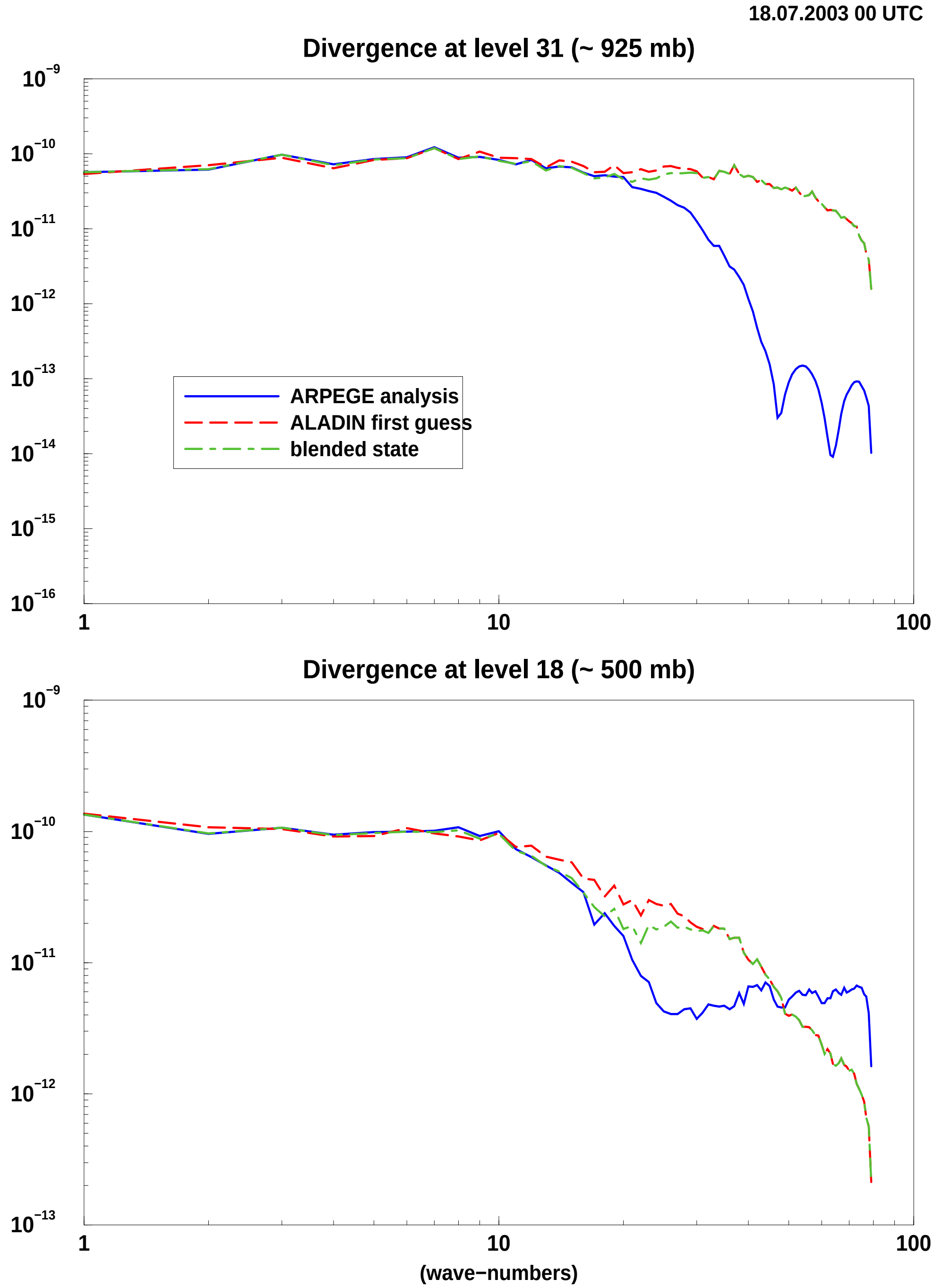

Figure 5: The spectral energy for divergence of the analysis from ARPEGE, of the first guess from ALADIN/HU model and of the blended state between the previous two, for the model levels 31 (top) and 18 (bottom), from 18.07.2003 00 UTC model run

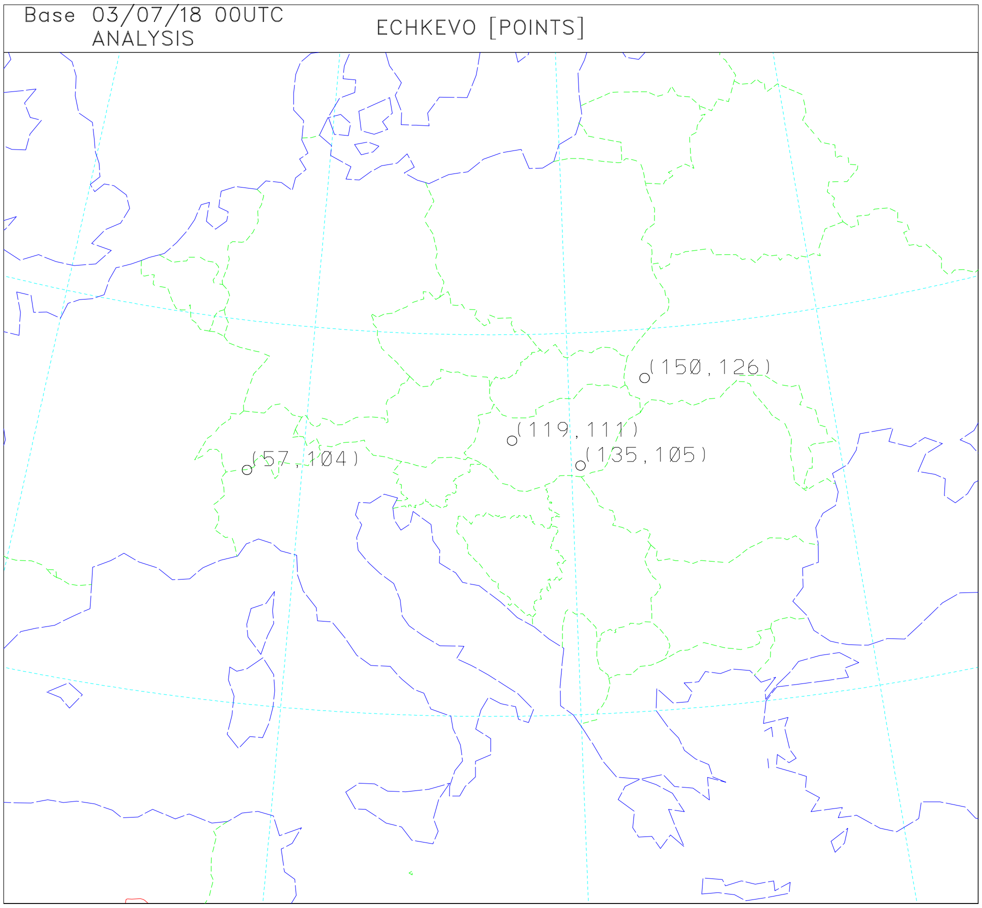

Figure 6: The points over the ALADIN/HU domain, for which the echkevo scores have been computed

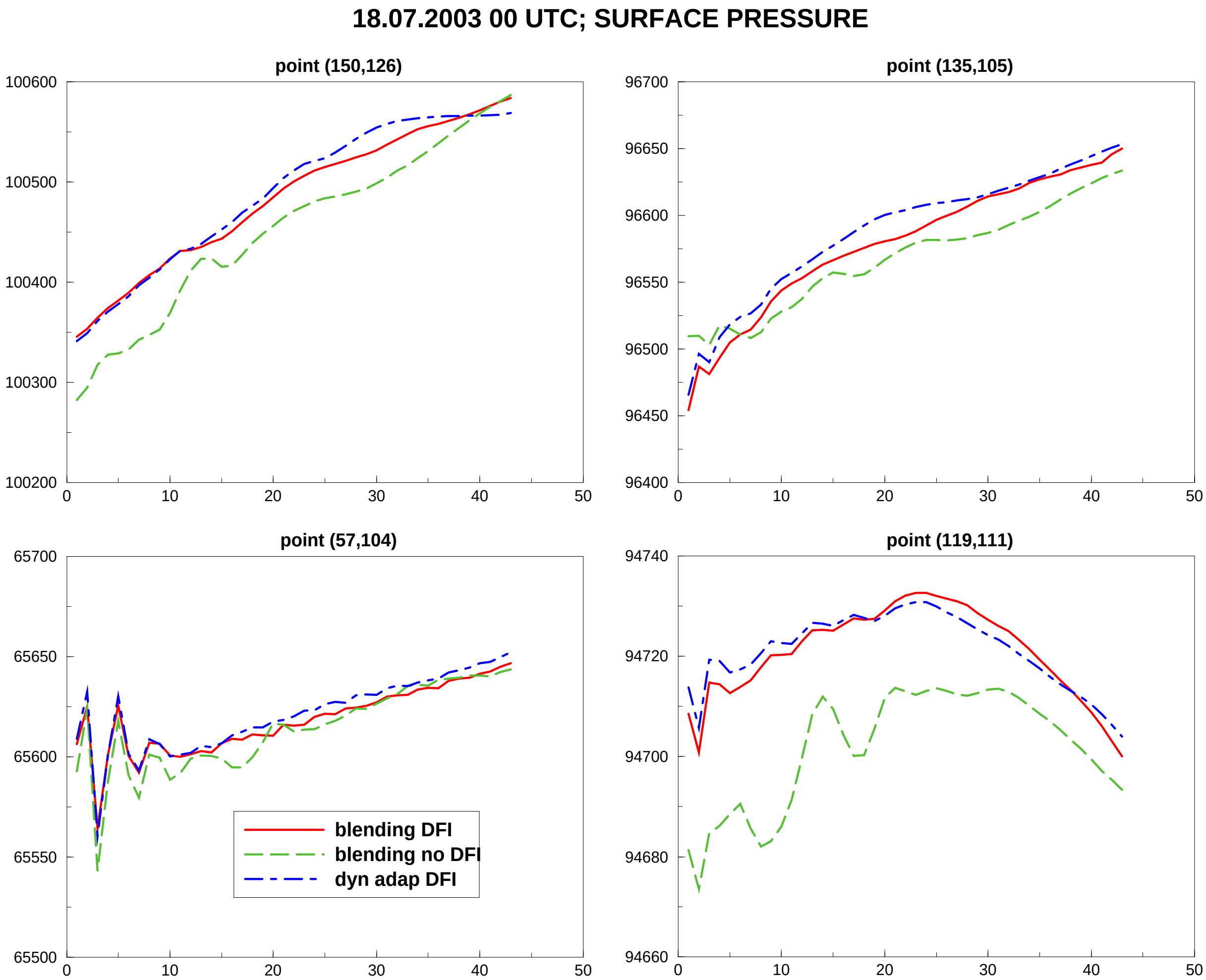

Figure 7: The echkevo scores for the surface pressure, from the "*blending DFI*", "*blending no DFI*" and "*dynamical adaptation DFI*" experiments, from 18.07.2003 00 UTC model run

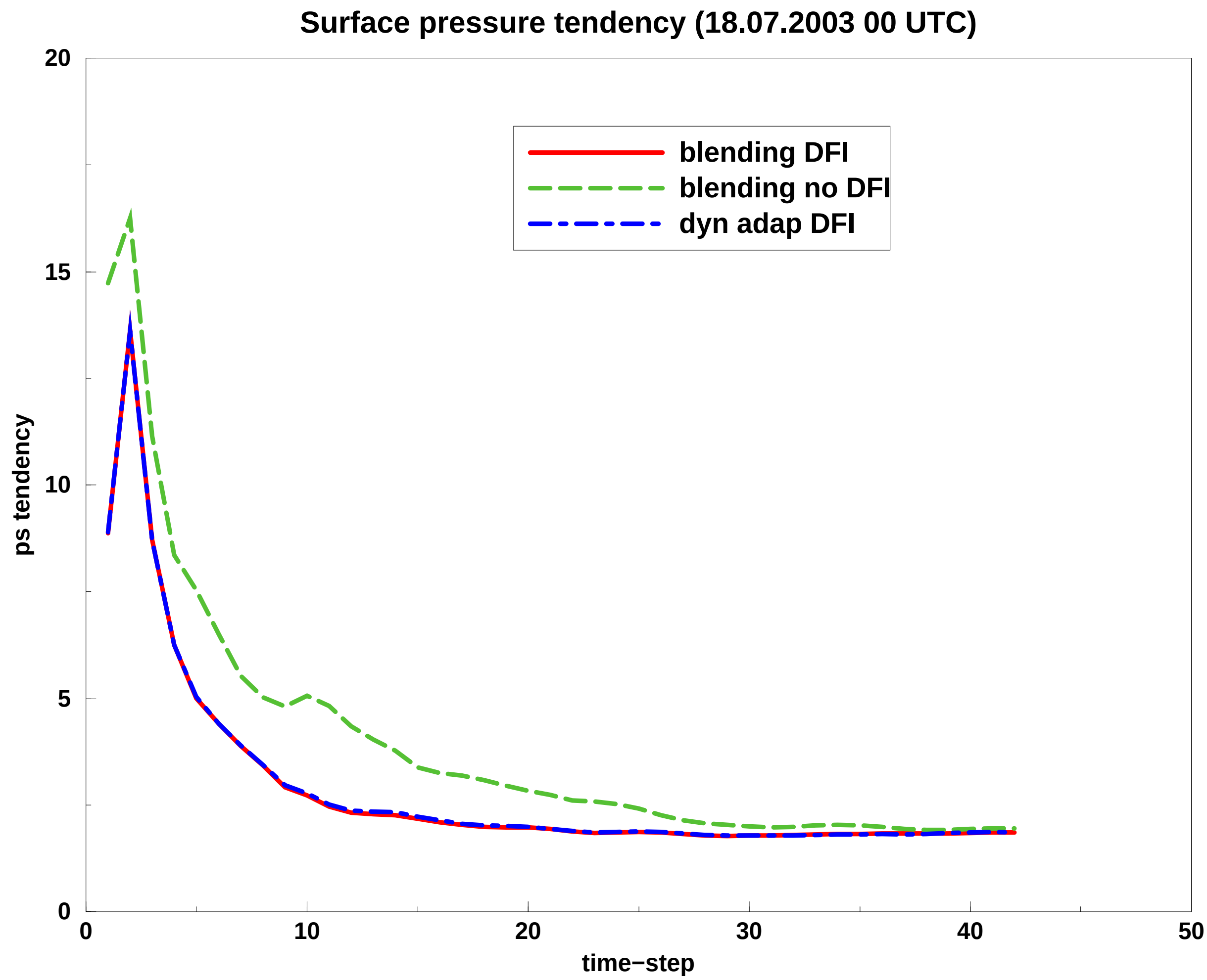

Figure 8: The surface pressure tendency, from the "*blending DFI*", "*blending no DFI*" and "*dynamical adaptation DFI*" experiments, from 18.07.2003 00 UTC model run

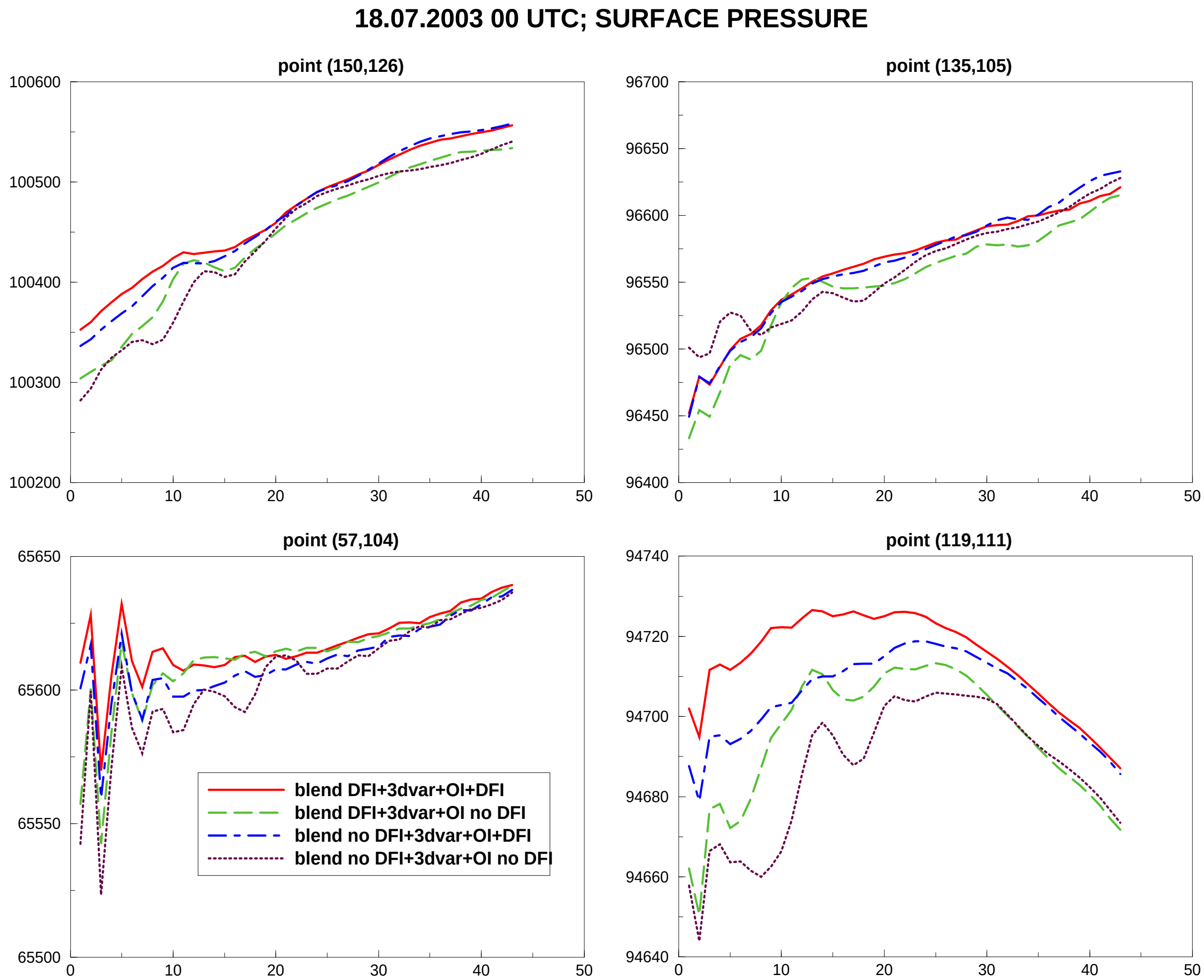

Figure 9: The echkevo scores for the surface pressure, from the experiments with different combinations of the blending procedure, the 3D-Var scheme, Optimal Interpolation and digital filter initialization methods, from 18.07.2003 00 UTC model run

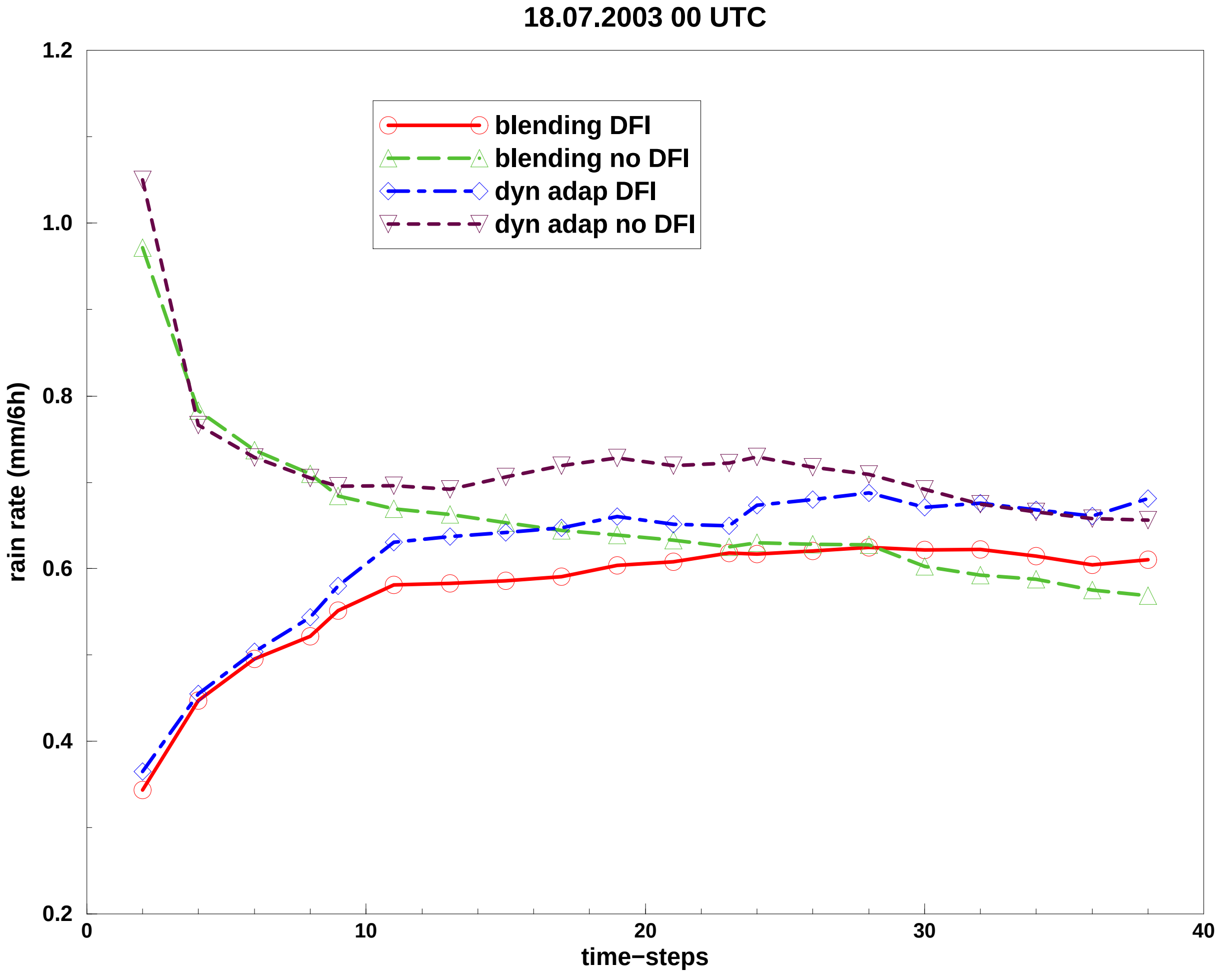

Figure 10: The rain rate (mm/6h) during the first 6h integration of the model running in dynamical adaptation (with and without initialization), and using the blending procedure (with and without initialization), from 18.07.2003 00 UTC model run

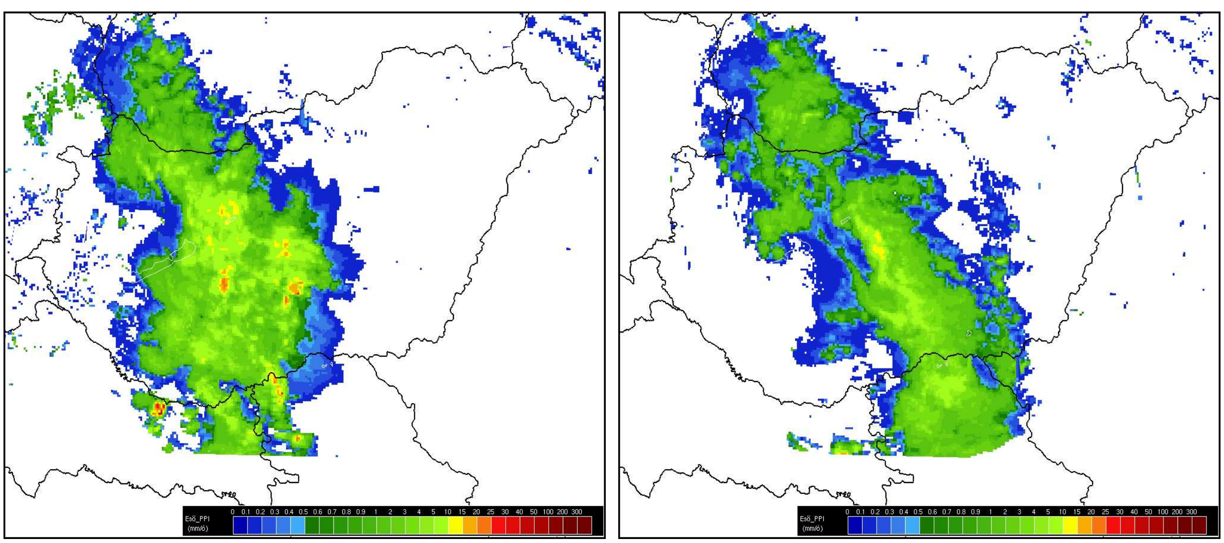

Figure 11: Radar images over Hungary, valid at 18.07.2003 00 UTC and 18.07.2003 02 UTC

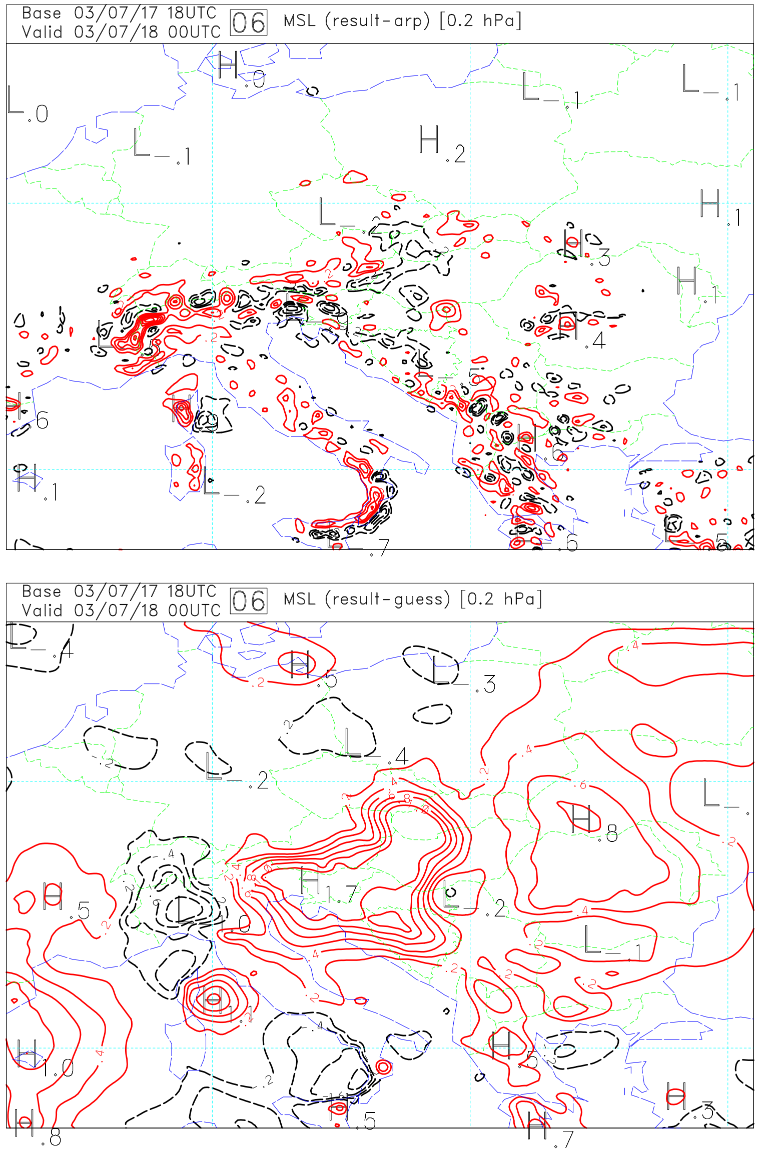

Figure 12: The mean sea level pressure increments (the difference between the blended state and the analysis of the ARPEGE model - top, the difference between the blended state and the first guess of the ALADIN/Hungary model - bottom), from 18.07.2003 00 UTC model run

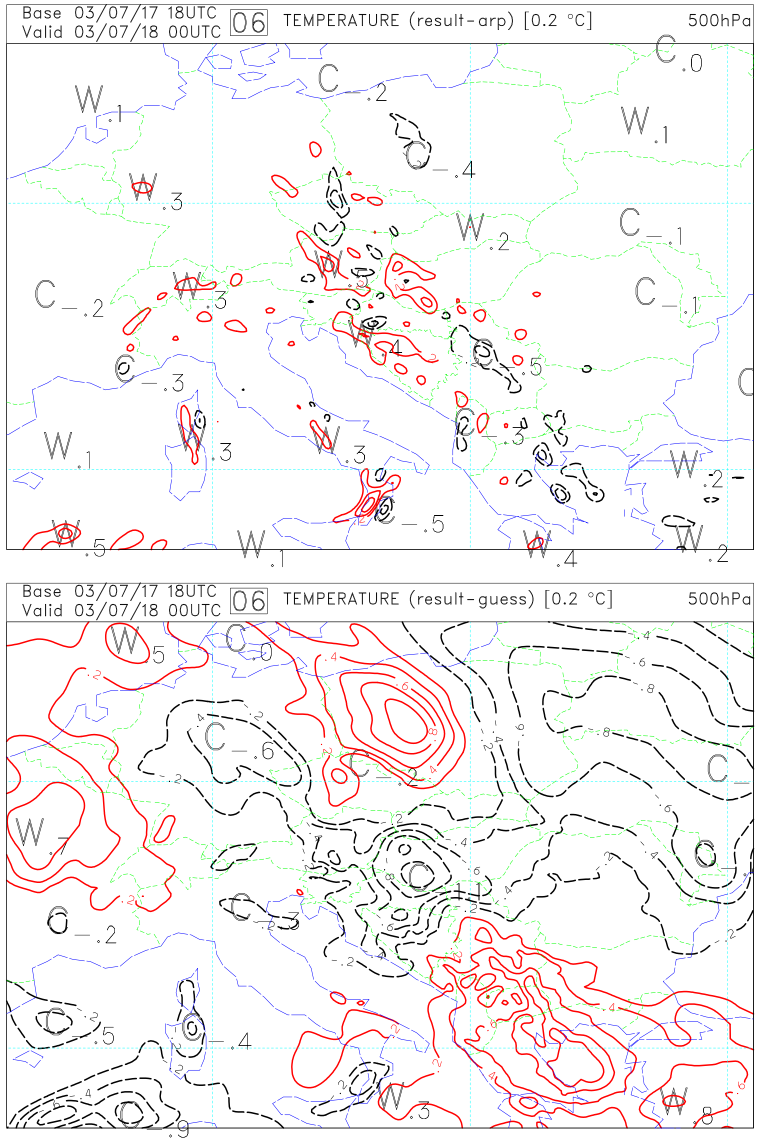

Figure 13: The temperature increments at 500 hPa (the difference between the blended state and the analysis of the ARPEGE model - top, the difference between the blended state and the first guess of the ALADIN/Hungary model - bottom), from 18.07.2003 00 UTC model run

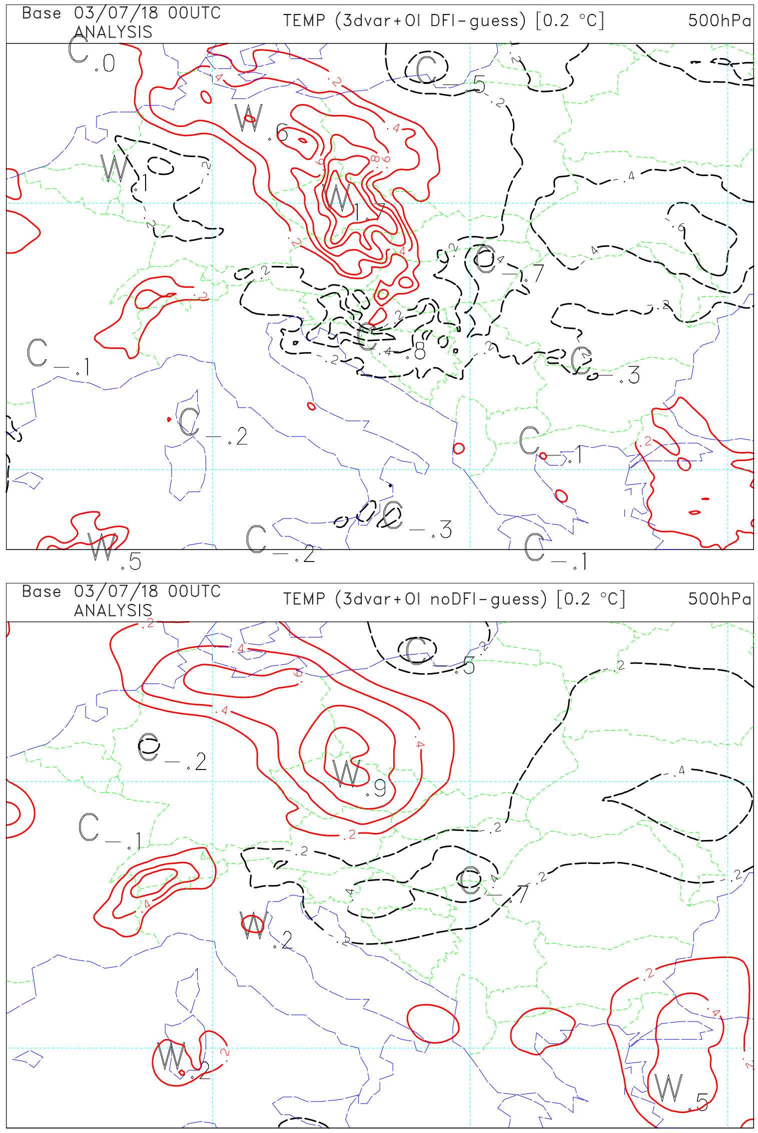

Figure 14: The temperature increments at 500 hPa (the difference between the analysis after the 3D-Var and OI schemes (with/without DFI) and the first guess of the ALADIN/Hungary model), from 18.07.2003 00 UTC model run

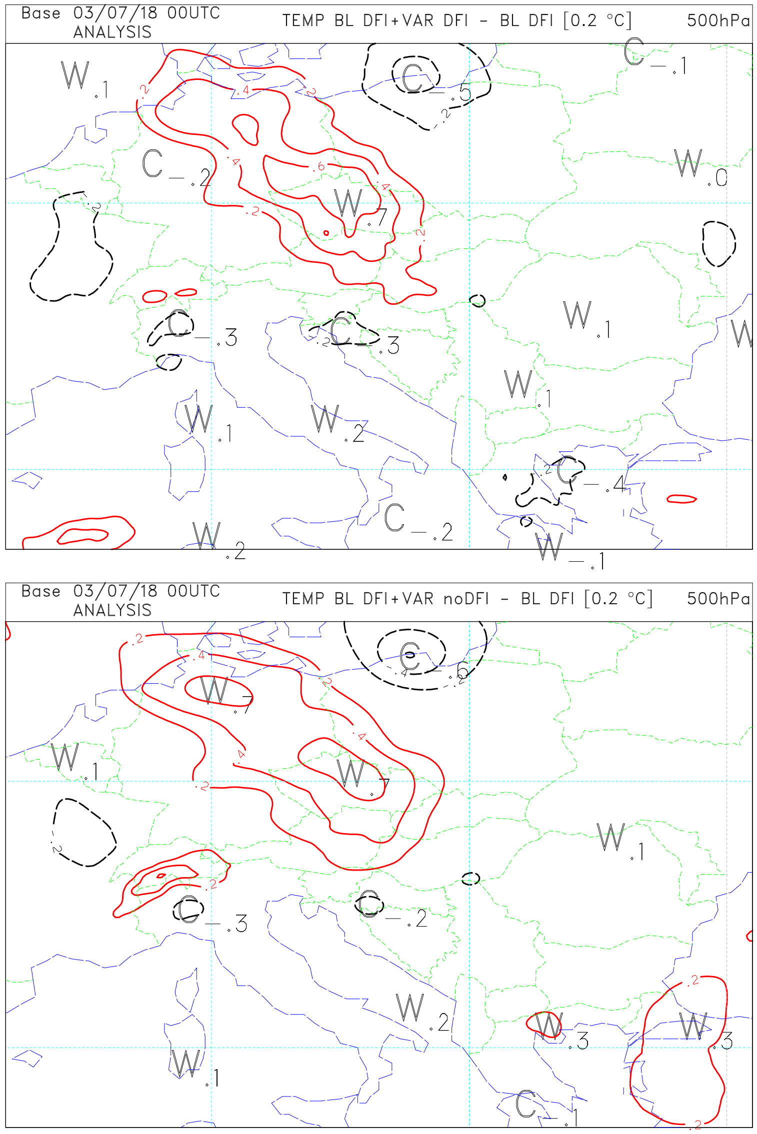

Figure 15: The temperature increments at 500 hPa (the difference between the analysis, using the initialized blended state as first guess, after the 3D-Var and OI schemes (with/without DFI), and the initialized blended state), from 18.07.2003 00 UTC model run

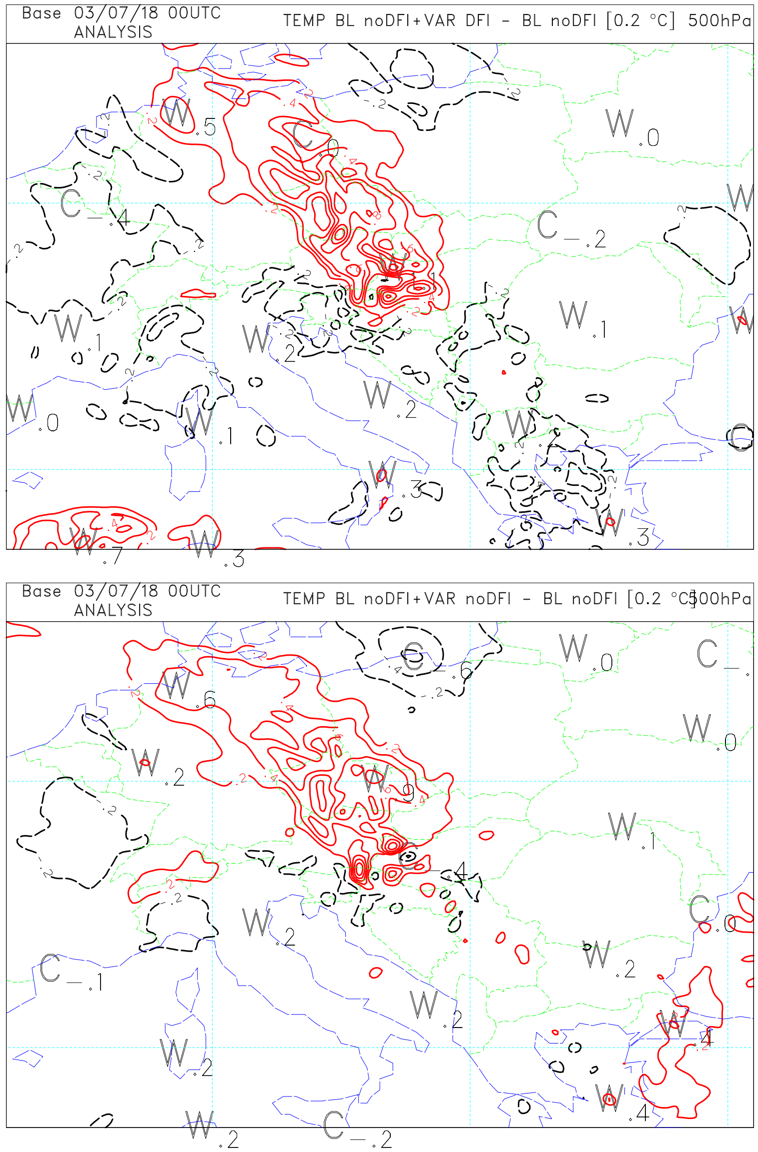

Figure 16: The temperature increments at 500 hPa (the difference between the analysis, using the non-initialized blended state as first guess, after the 3D-Var and OI schemes (with/without DFI), and the non-initialized blended state), from 18.07.2003 00 UTC model run

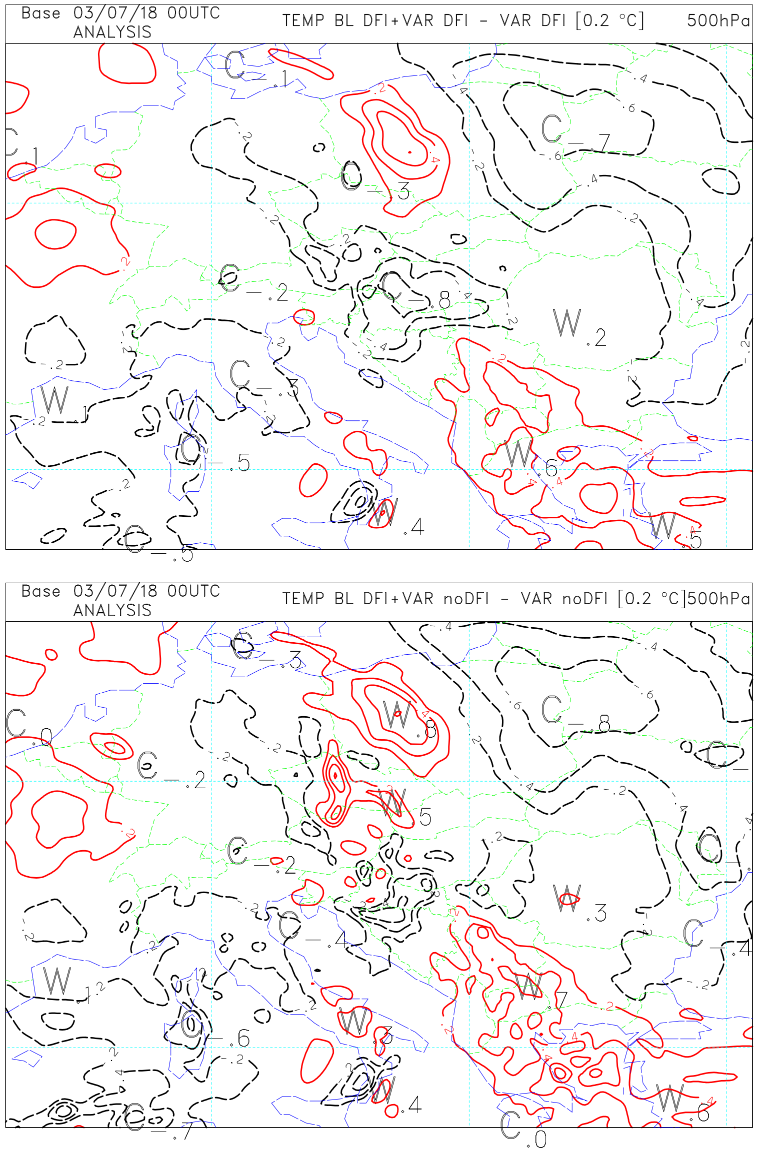

Figure 17: The temperature increments at 500 hPa (the difference between the analysis, using the initialized blended state as first guess, after the 3D-Var and OI schemes (with/without DFI), and the analysis, using the 6h forecast as first guess, after the 3D-Var and OI schemes (with/without DFI)), from 18.07.2003 00 UTC model run

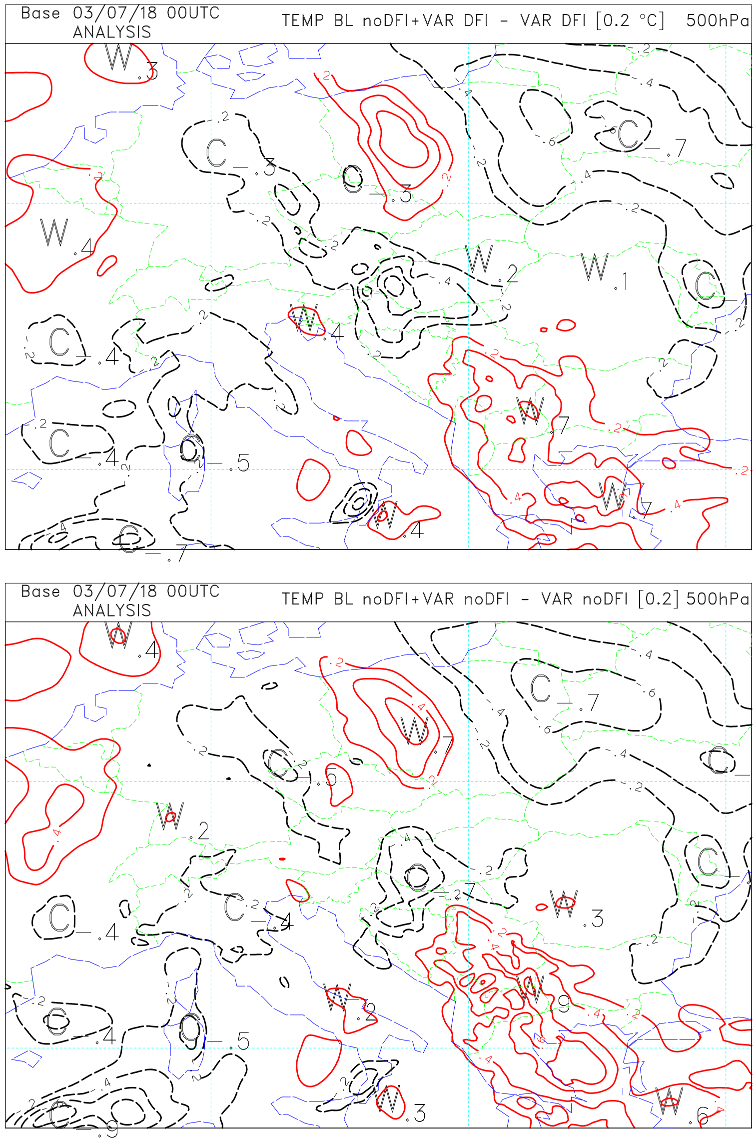

Figure 18: The temperature increments at 500 hPa (the difference between the analysis, using the non-initialized blended state as first guess, after the 3D-Var and OI schemes (with/without DFI), and the analysis, using the 6h forecast as first guess, after the 3D-Var and OI schemes (with/without DFI)), from 18.07.2003 00 UTC model run

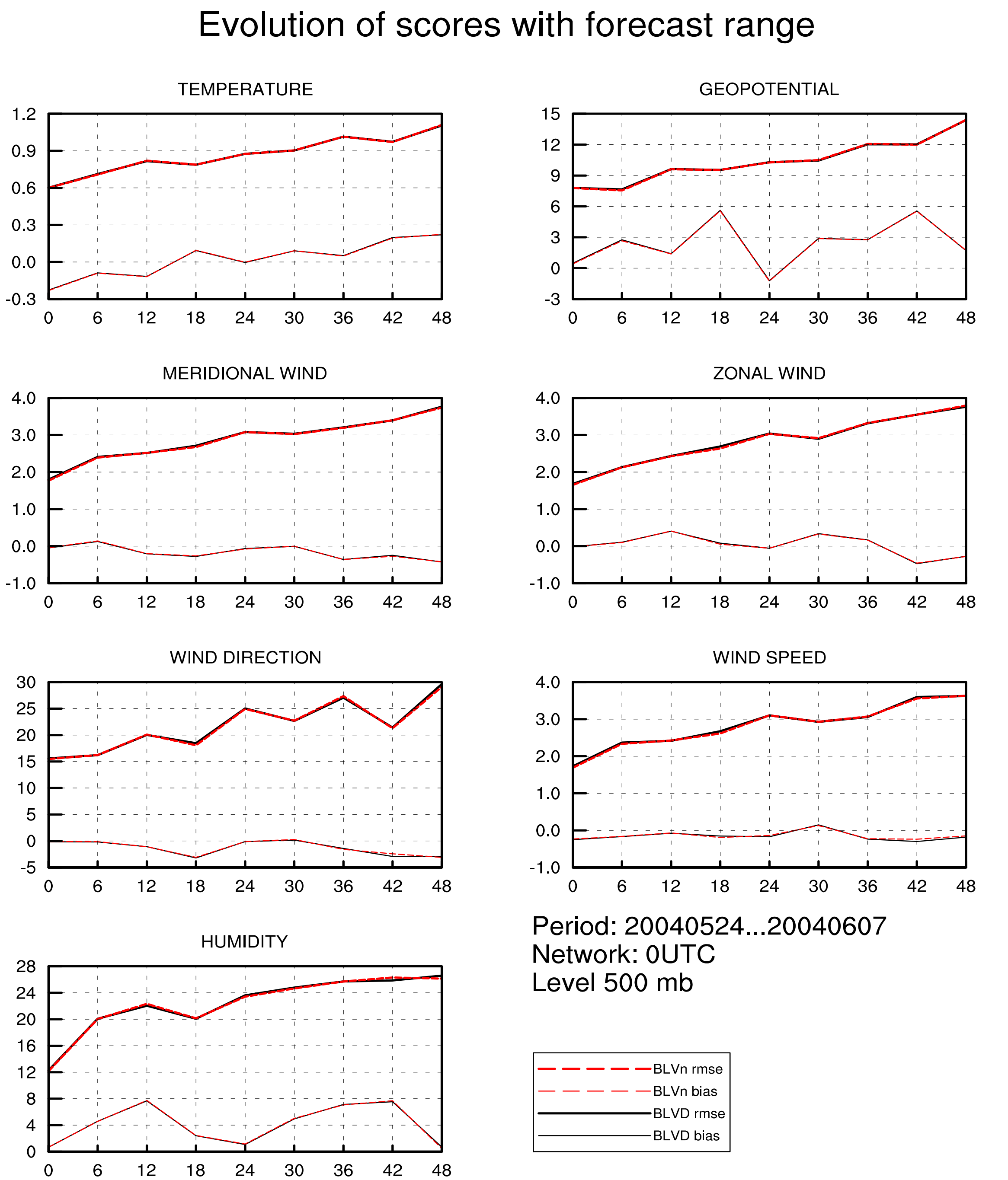

Figure 19: Evolution of the scores (BIAS and RMSE) with the forecast range, for different fields, at the level 500 mb, from the "*blendvar DFI*" (BLVD) and "*blendvar no DFI*" (BLVn) experiments, between 24.05.2004 - 07.06.2004, at 00 UTC model runs

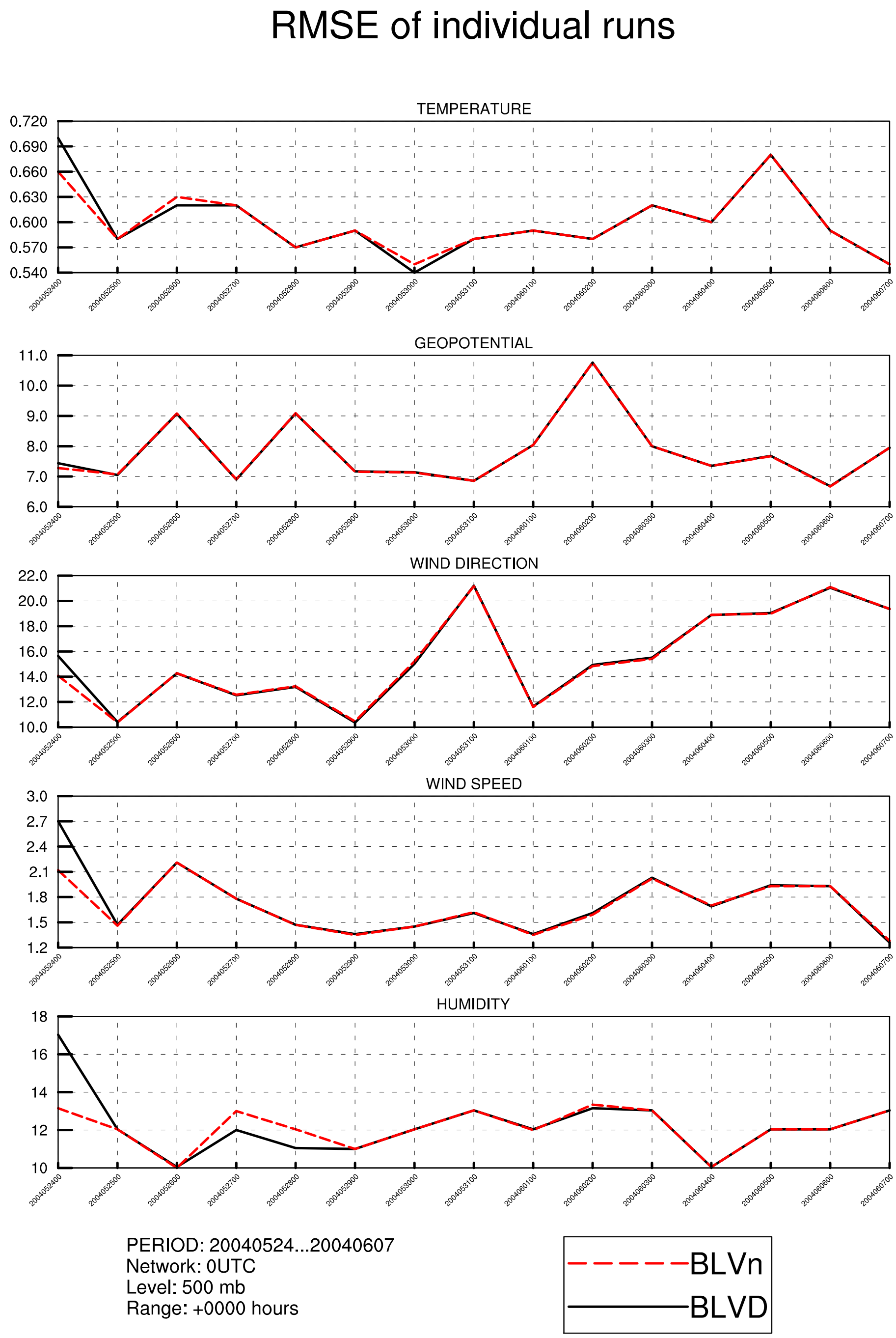

Figure 20: The RMSE scores of the analyses from individual runs, at the level 500 mb, from the "*blendvar DFI*" (BLVD) and "*blendvar no DFI*" (BLVn) experiments, between 24.05.2004 - 07.06.2004, at 00 UTC model runs

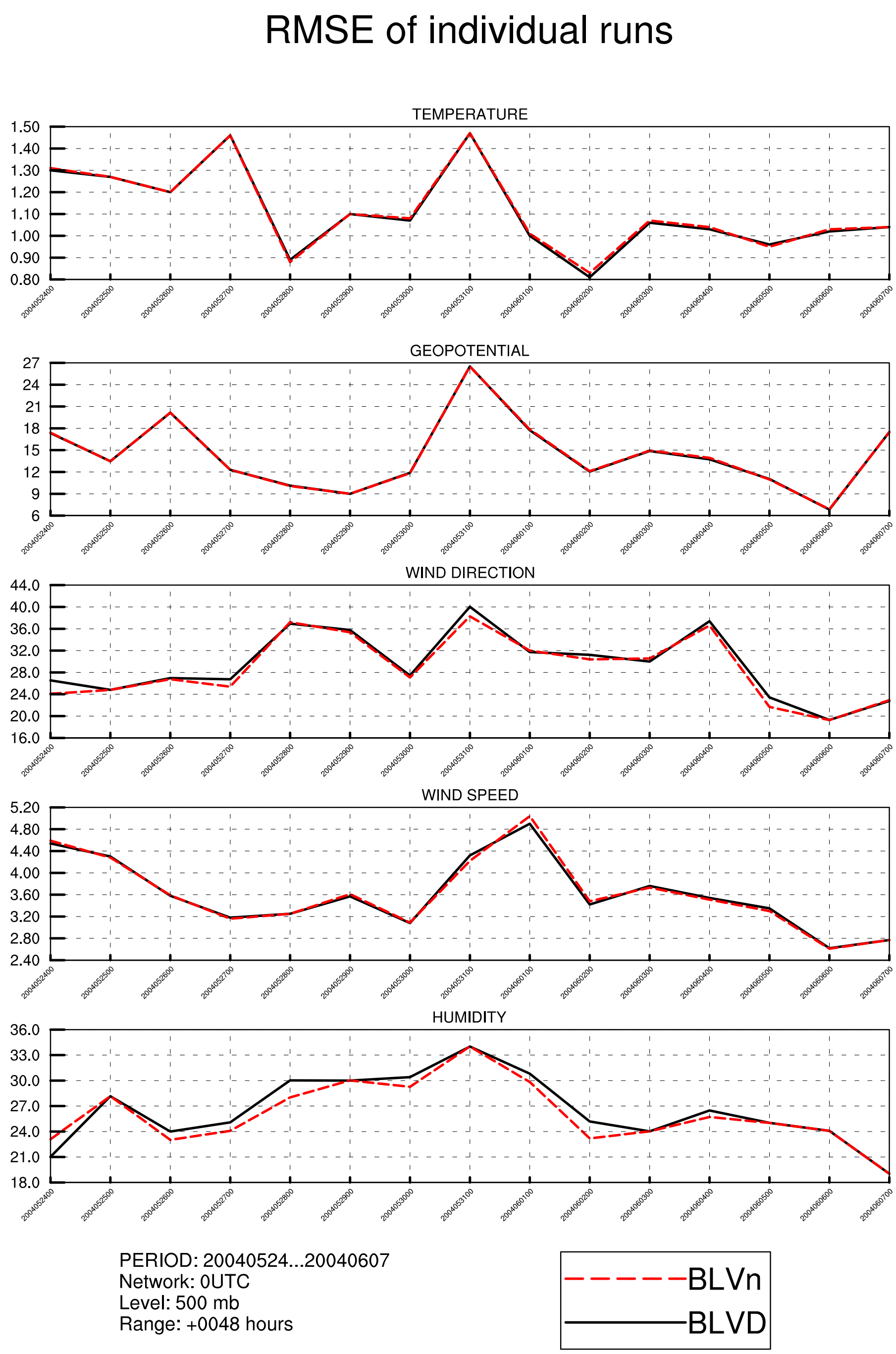

Figure 21: The RMSE scores of the 48h forecasts from individual runs, at the level 500 mb, from the "*blendvar DFI*" (BLVD) and "*blendvar no DFI*" (BLVn) experiments, between 24.05.2004 - 07.06.2004, at 00 UTC model runs

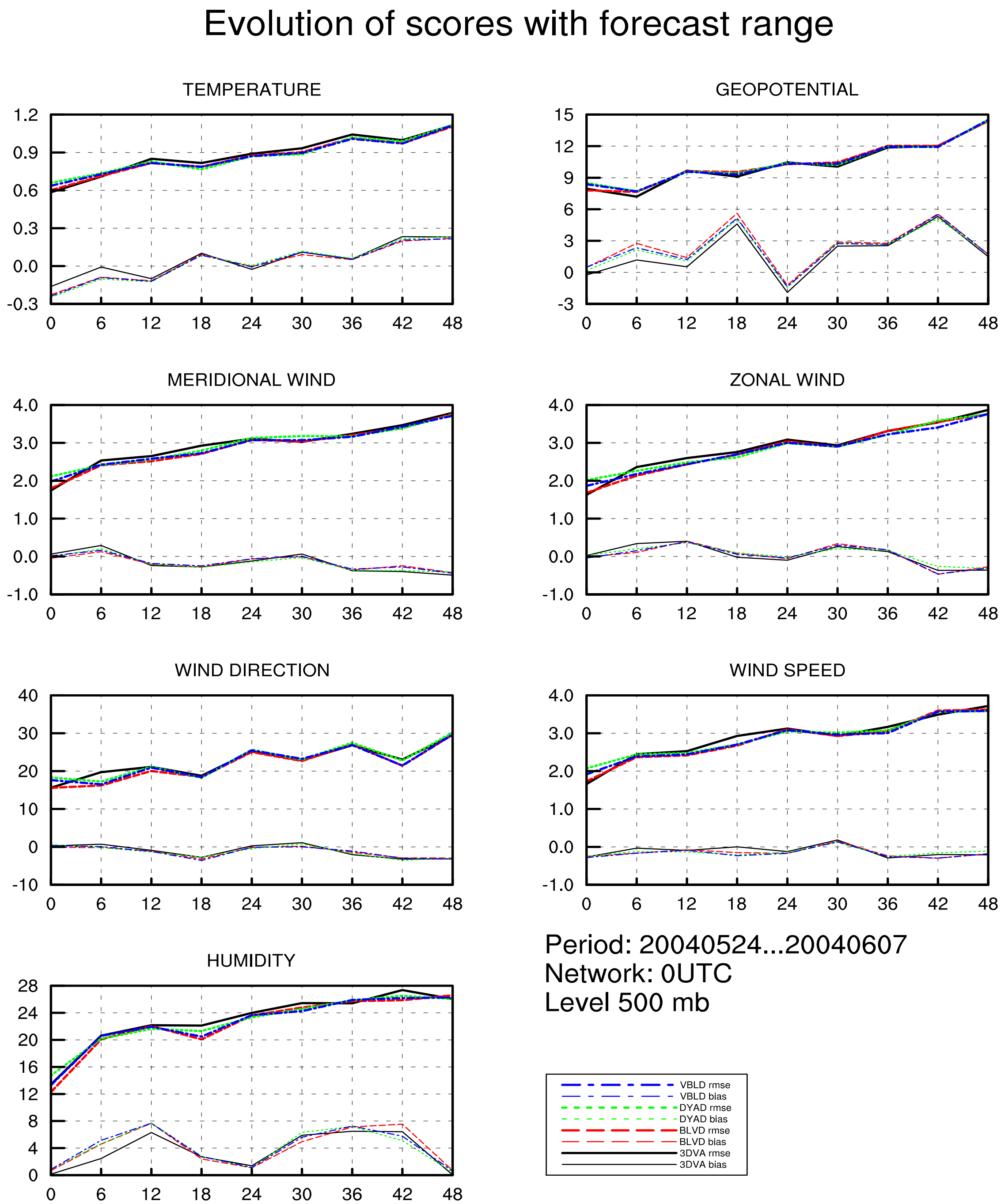

Figure 22: Evolution of the scores (BIAS and RMSE) with the forecast range, for different fields, at the level 500 mb, from the "*varblend DFI*" (VBLD), "*dynamical adaptation*" (DYAD), "*blendvar DFI*" (BLVD) and "*3dvar*" (3DVA) experiments, between 24.05.2004 - 07.06.2004, at 00 UTC model runs

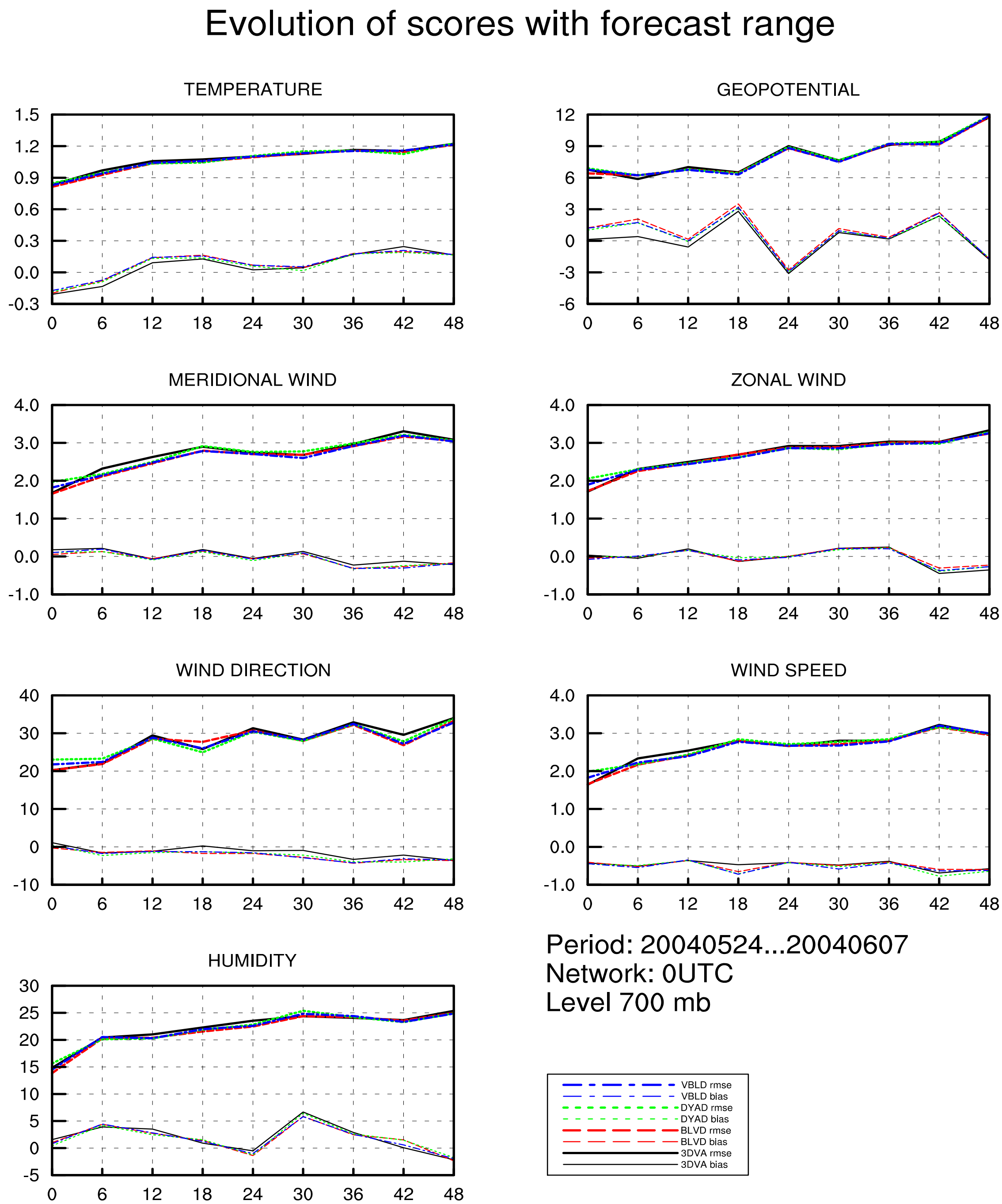

Figure 23: Evolution of the scores (BIAS and RMSE) with the forecast range, for different fields, at the level 700 mb, from the "*varblend DFI*" (VBLD), "*dynamical adaptation*" (DYAD), "*blendvar DFI*" (BLVD) and "*3dvar*" (3DVA) experiments, between 24.05.2004 - 07.06.2004, at 00 UTC model runs

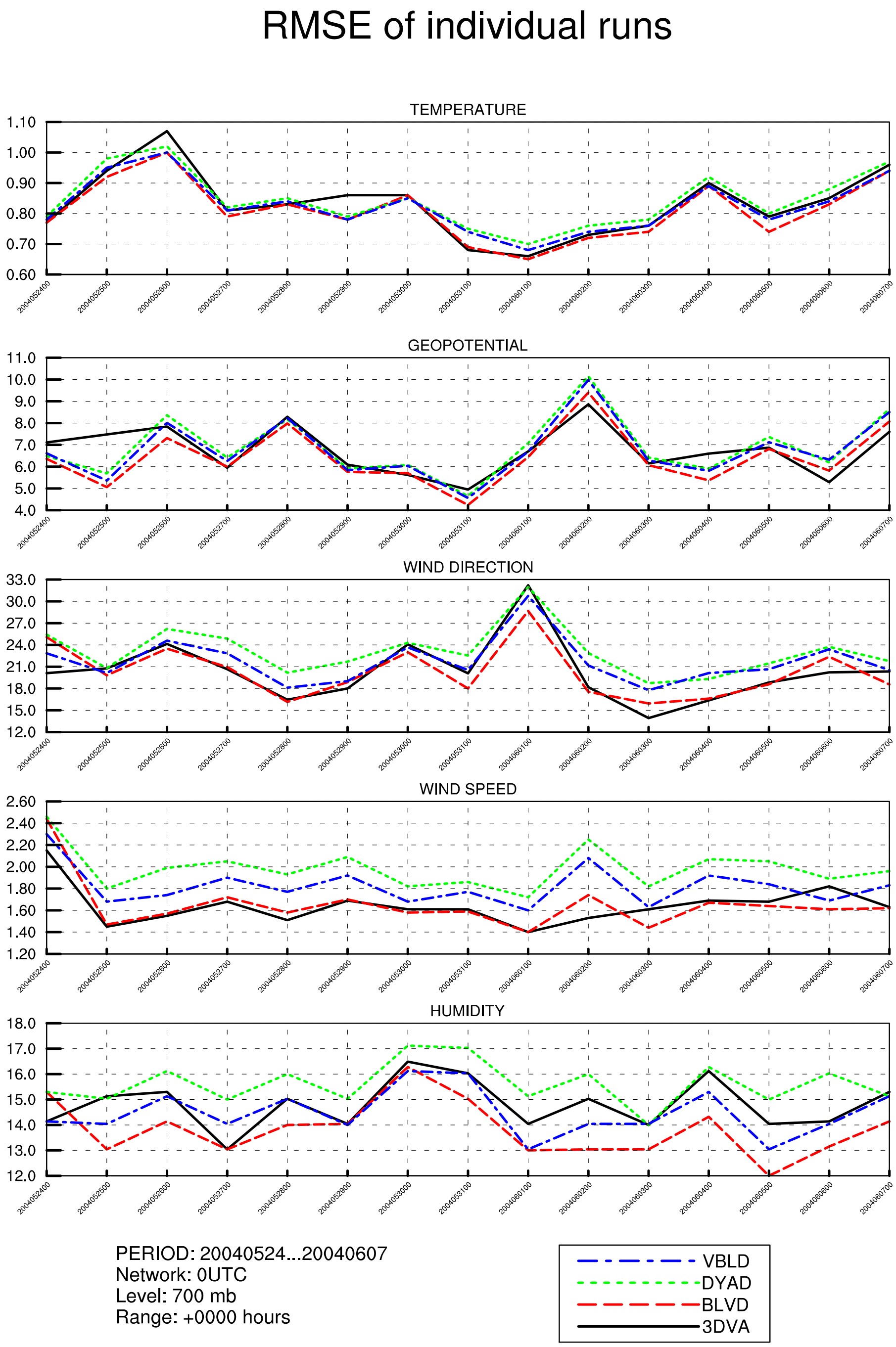

Figure 24: The RMSE scores of the analyses from individual runs, at the level 700 mb, from the "*varblend DFI*" (VBLD), "*dynamical adaptation*" (DYAD), "*blendvar DFI*" (BLVD) and "*3dvar*" (3DVA) experiments, between 24.05.2004 - 07.06.2004, at 00 UTC model runs

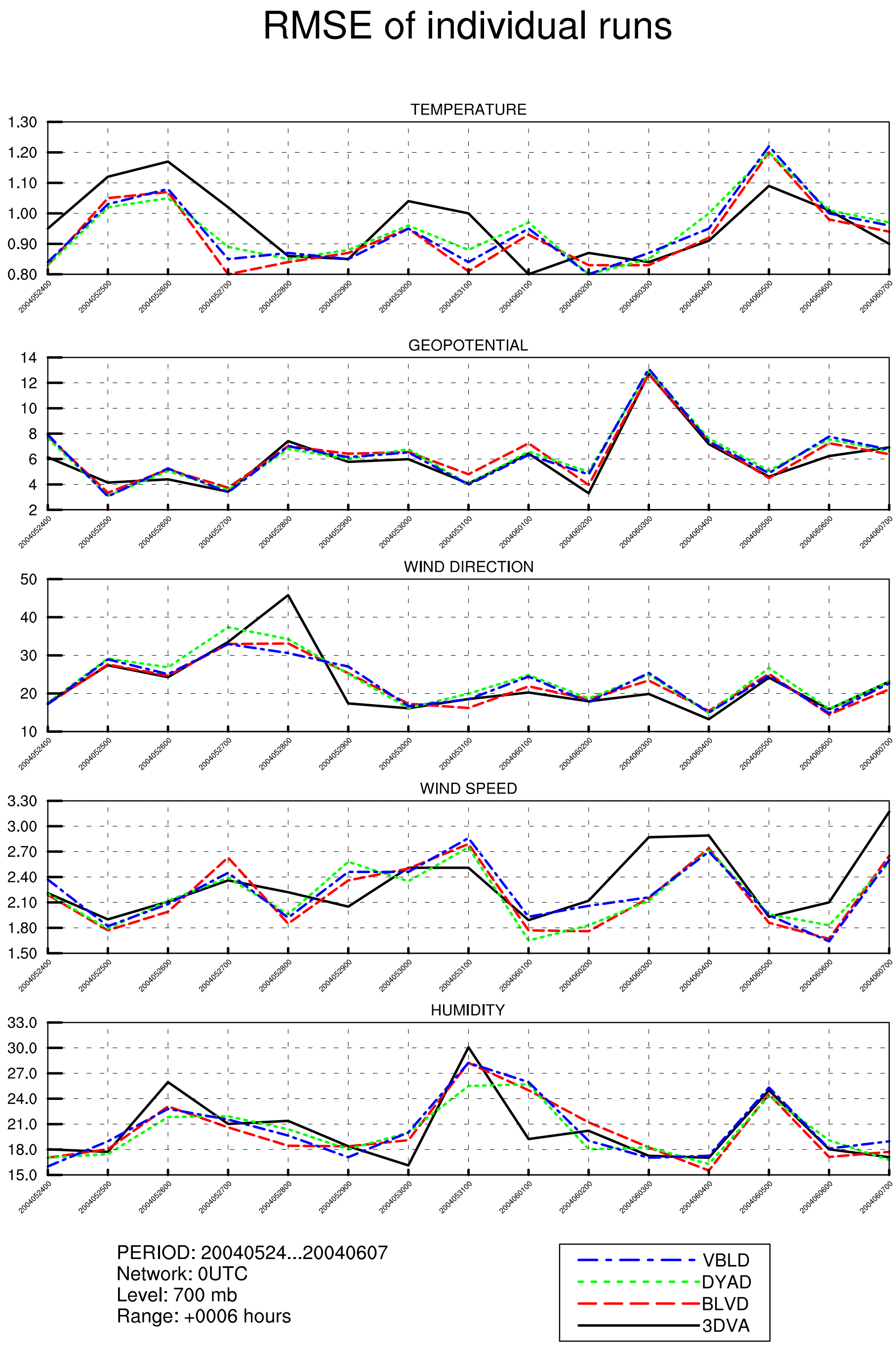

Figure 25: The RMSE scores of the 6h forecasts from individual runs, at the level 700 mb, from the "*varblend DFI*" (VBLD), "*dynamical adaptation*" (DYAD), "*blendvar DFI*" (BLVD) and "*3dvar*" (3DVA) experiments, between 24.05.2004 - 07.06.2004, at 00 UTC model runs

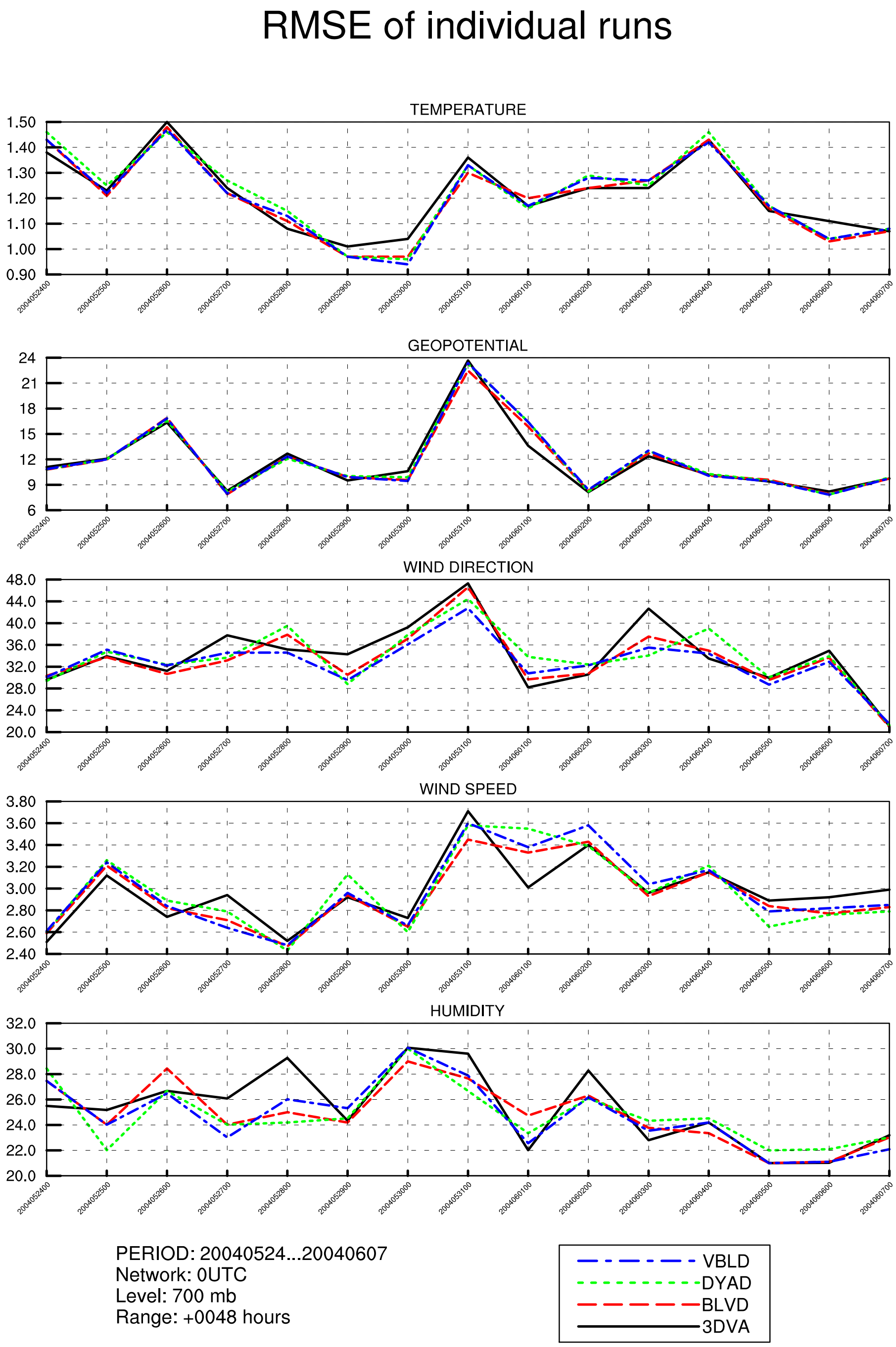

Figure 26: The RMSE scores of the 48h forecasts from individual runs, at the level 700 mb, from the "*varblend DFI*" (VBLD), "*dynamical adaptation*" (DYAD), "*blendvar DFI*" (BLVD) and "*3dvar*" (3DVA) experiments, between 24.05.2004 - 07.06.2004, at 00 UTC model runs

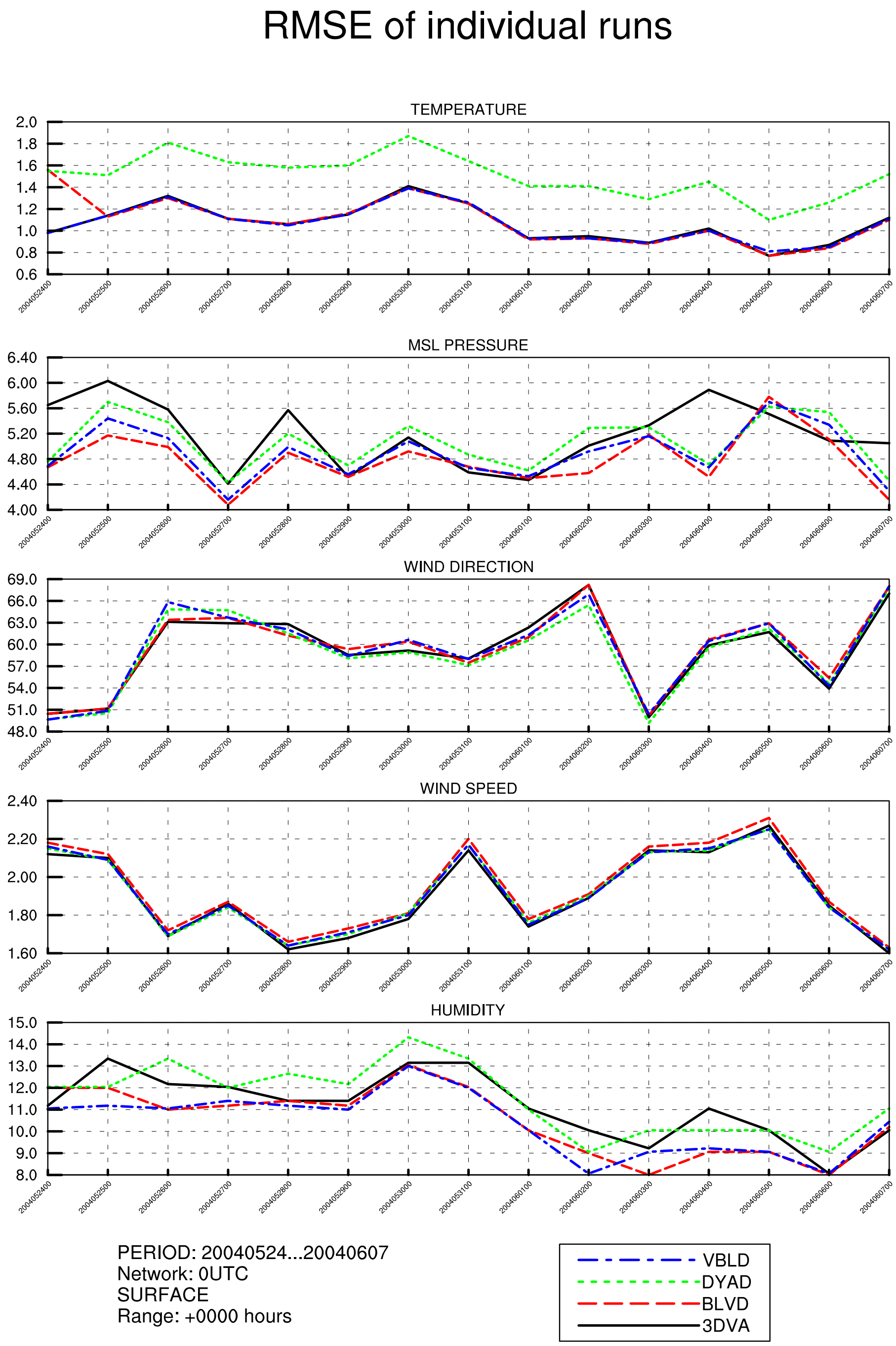

Figure 27: The RMSE scores of the analyses from individual runs, at the surface level, from the "*varblend DFI*" (VBLD), "*dynamical adaptation*" (DYAD), "*blendvar DFI*" (BLVD) and "*3dvar*" (3DVA) experiments, between 24.05.2004 - 07.06.2004, at 00 UTC model runs

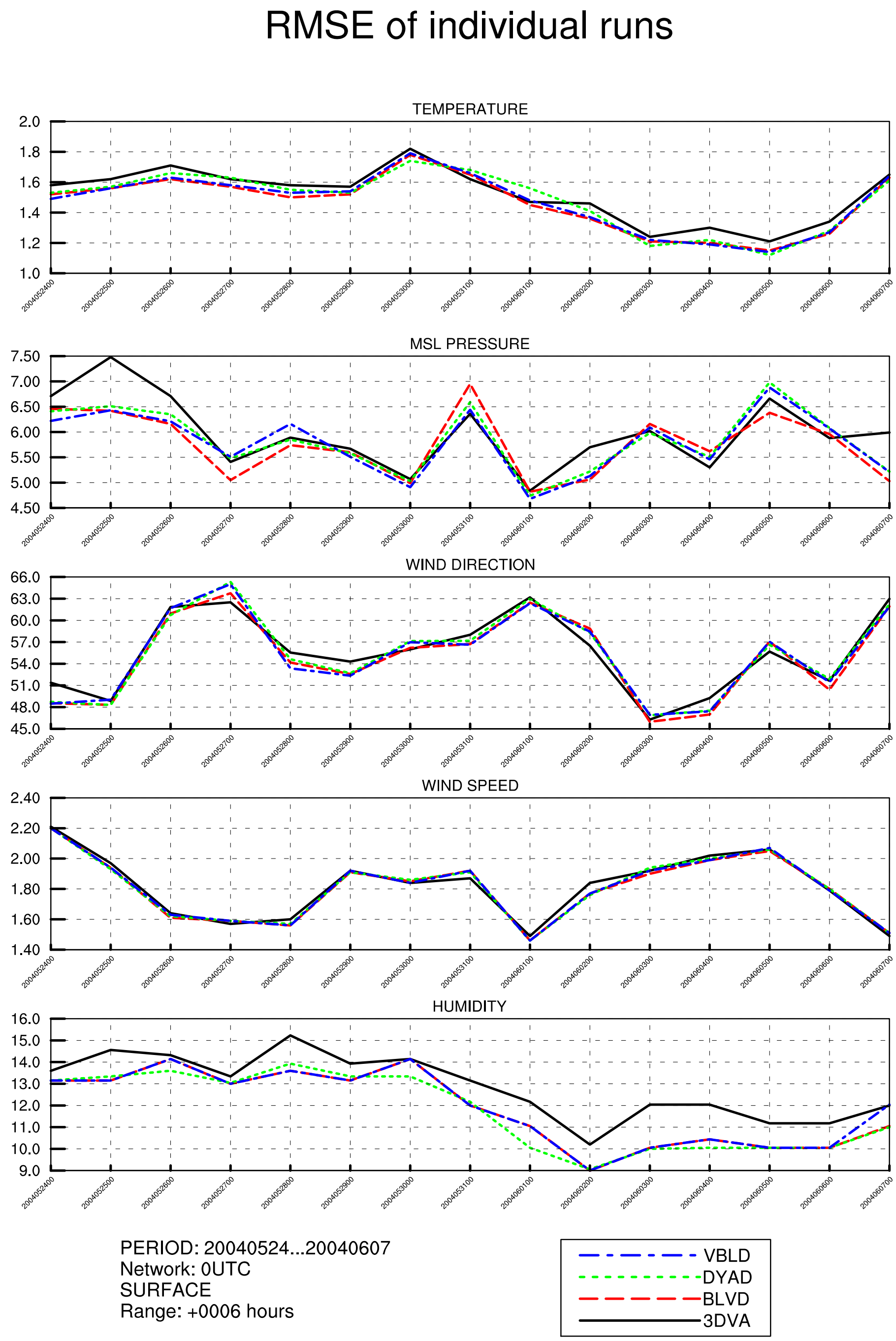

Figure 28: The RMSE scores of the 6h forecasts from individual runs, at the surface level, from the "*varblend DFI*" (VBLD), "*dynamical adaptation*" (DYAD), "*blendvar DFI*" (BLVD) and "*3dvar*" (3DVA) experiments, between 24.05.2004 - 07.06.2004, at 00 UTC model runs

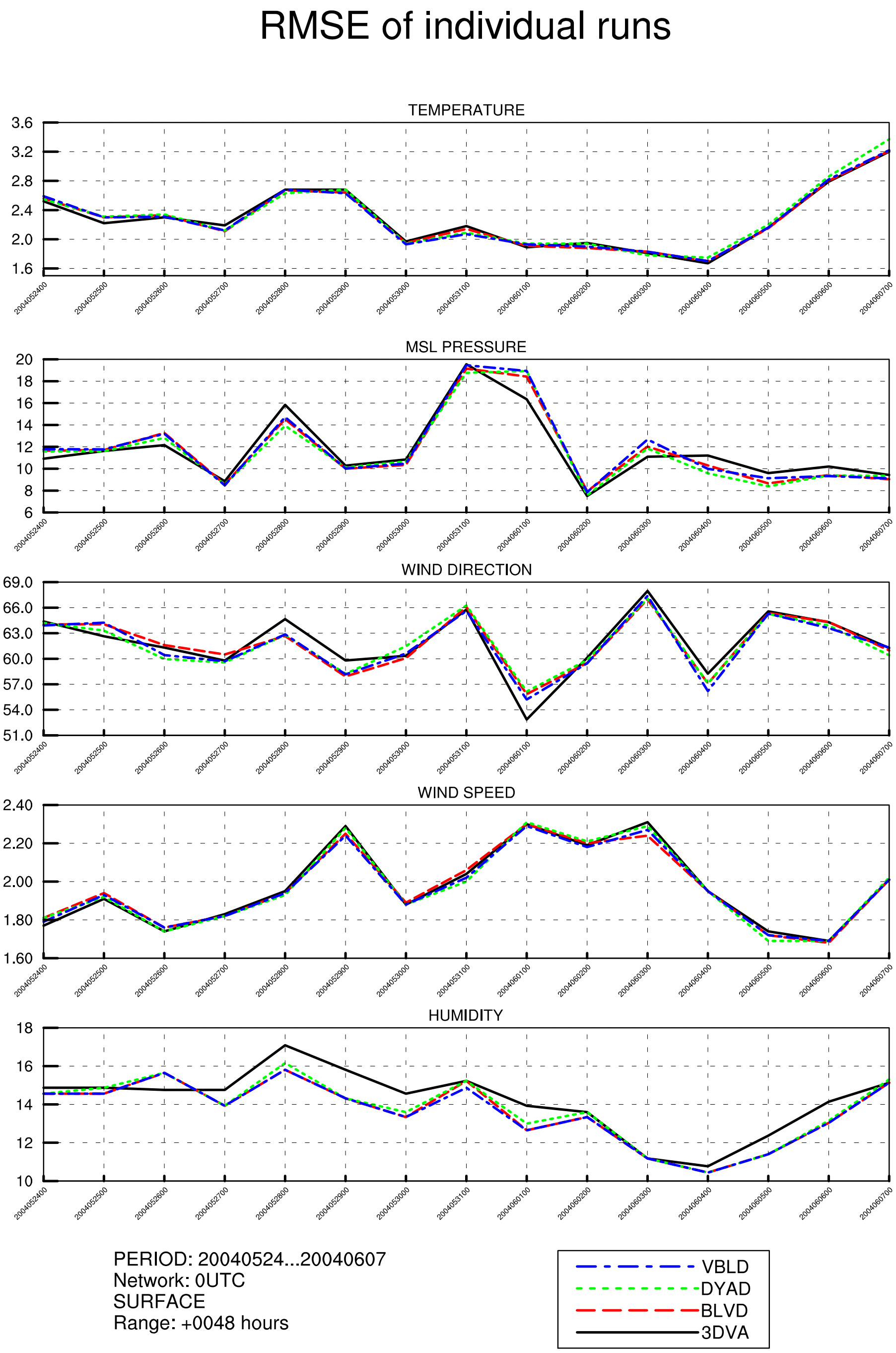

Figure 29: The RMSE scores of the 48h forecasts from individual runs, at the surface level, from the "*varblend DFI*" (VBLD), "*dynamical adaptation*" (DYAD), "*blendvar DFI*" (BLVD) and "*3dvar*" (3DVA) experiments, between 24.05.2004 - 07.06.2004, at 00 UTC model runs

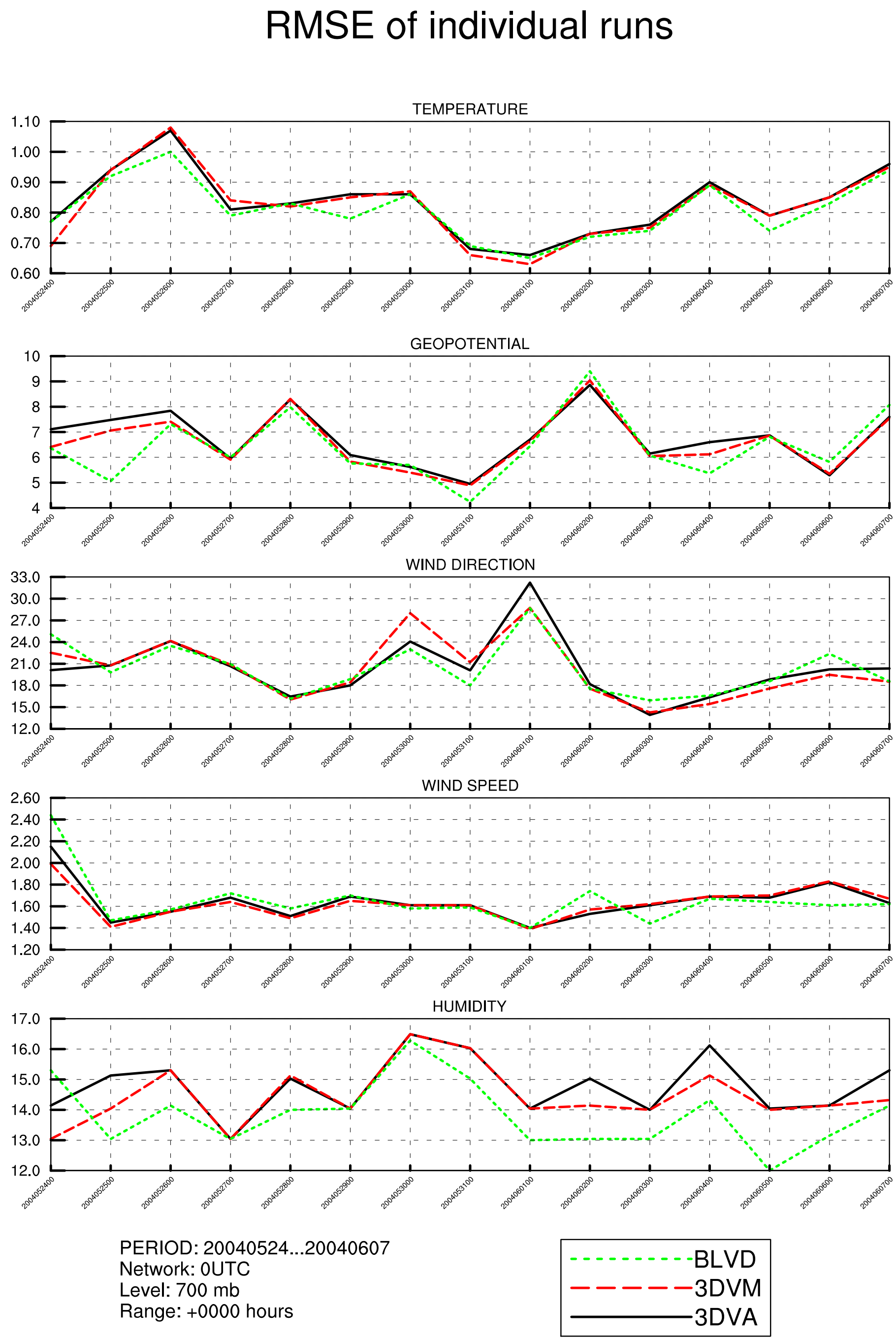

Figure 30: The RMSE scores of the analyses from individual runs, at the level 700 mb, from the "*blendvar DFI*" (BLVD), "*3dvar multivariate*" (3DVM) and "*3dvar*" (3DVA) experiments, between 24.05.2004 - 07.06.2004, at 00 UTC model runs

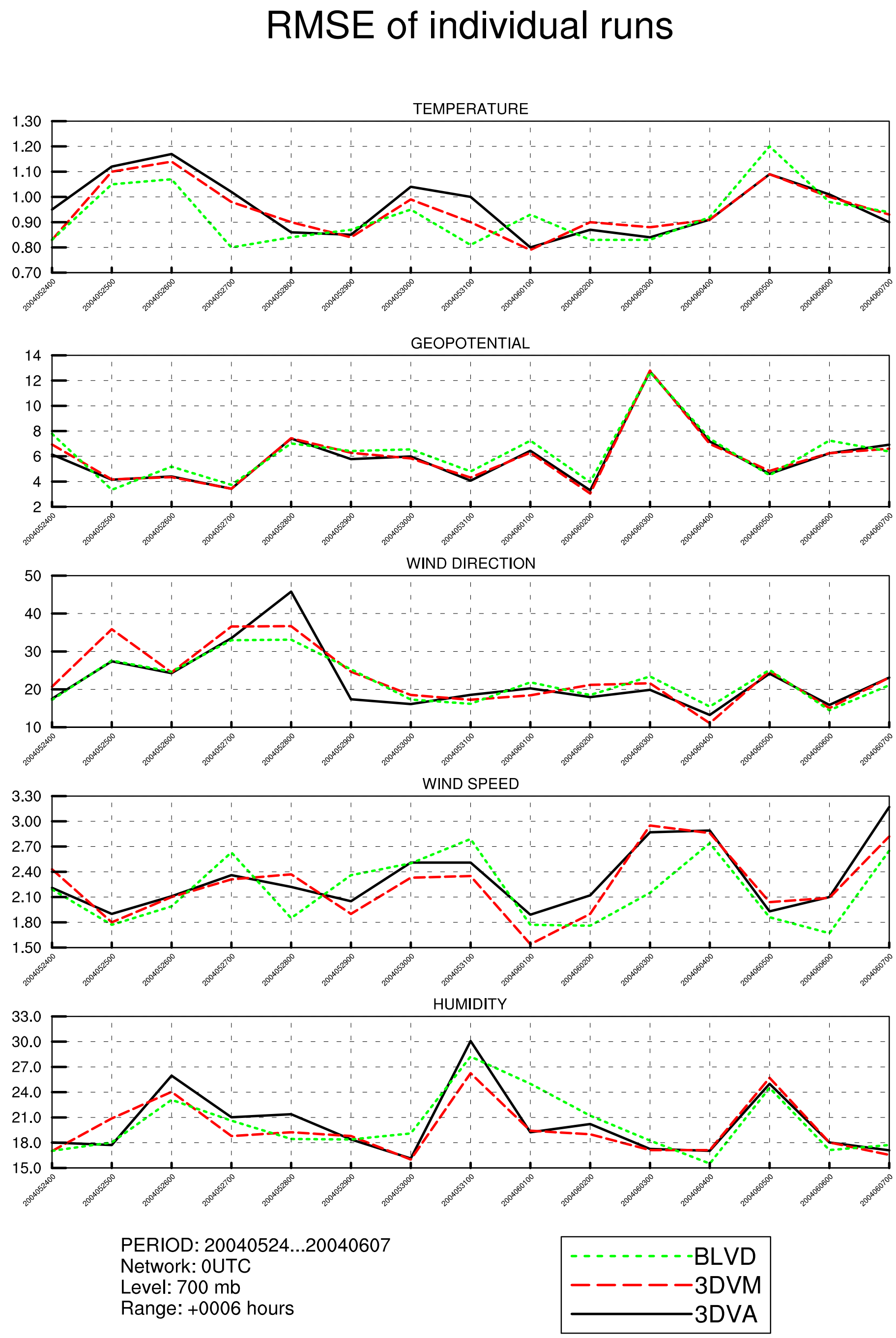

Figure 31: The RMSE scores of the 6h forecasts from individual runs, at the level 700 mb, from the "*blendvar DFI*" (BLVD), "*3dvar multivariate*" (3DVM) and "*3dvar*" (3DVA) experiments, between 24.05.2004 - 07.06.2004, at 00 UTC model runs

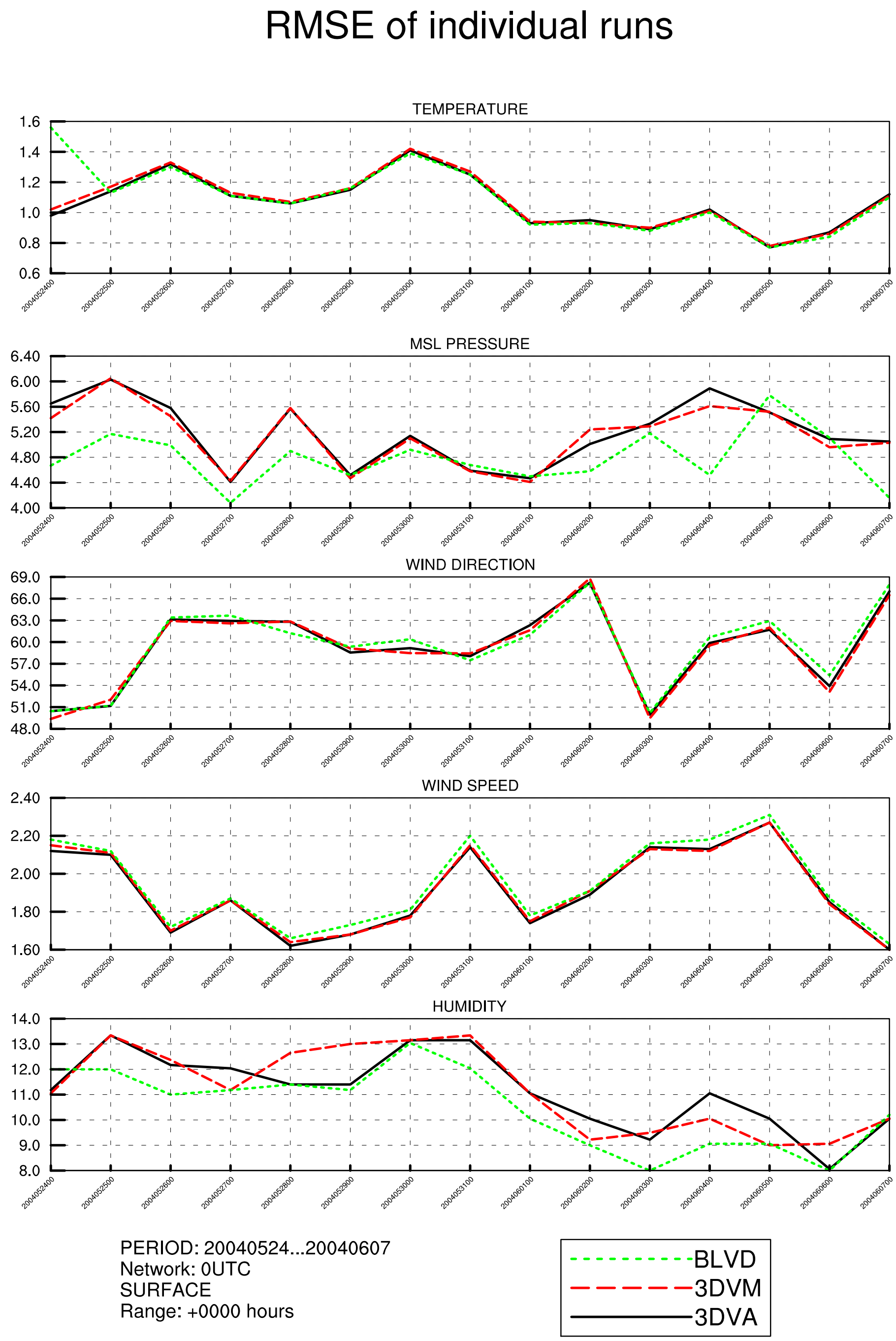

Figure 32: The RMSE scores of the analyses from individual runs, at the surface level, from the "*blendvar DFI*" (BLVD), "*3dvar multivariate*" (3DVM) and "*3dvar*" (3DVA) experiments, between 24.05.2004 - 07.06.2004, at 00 UTC model runs

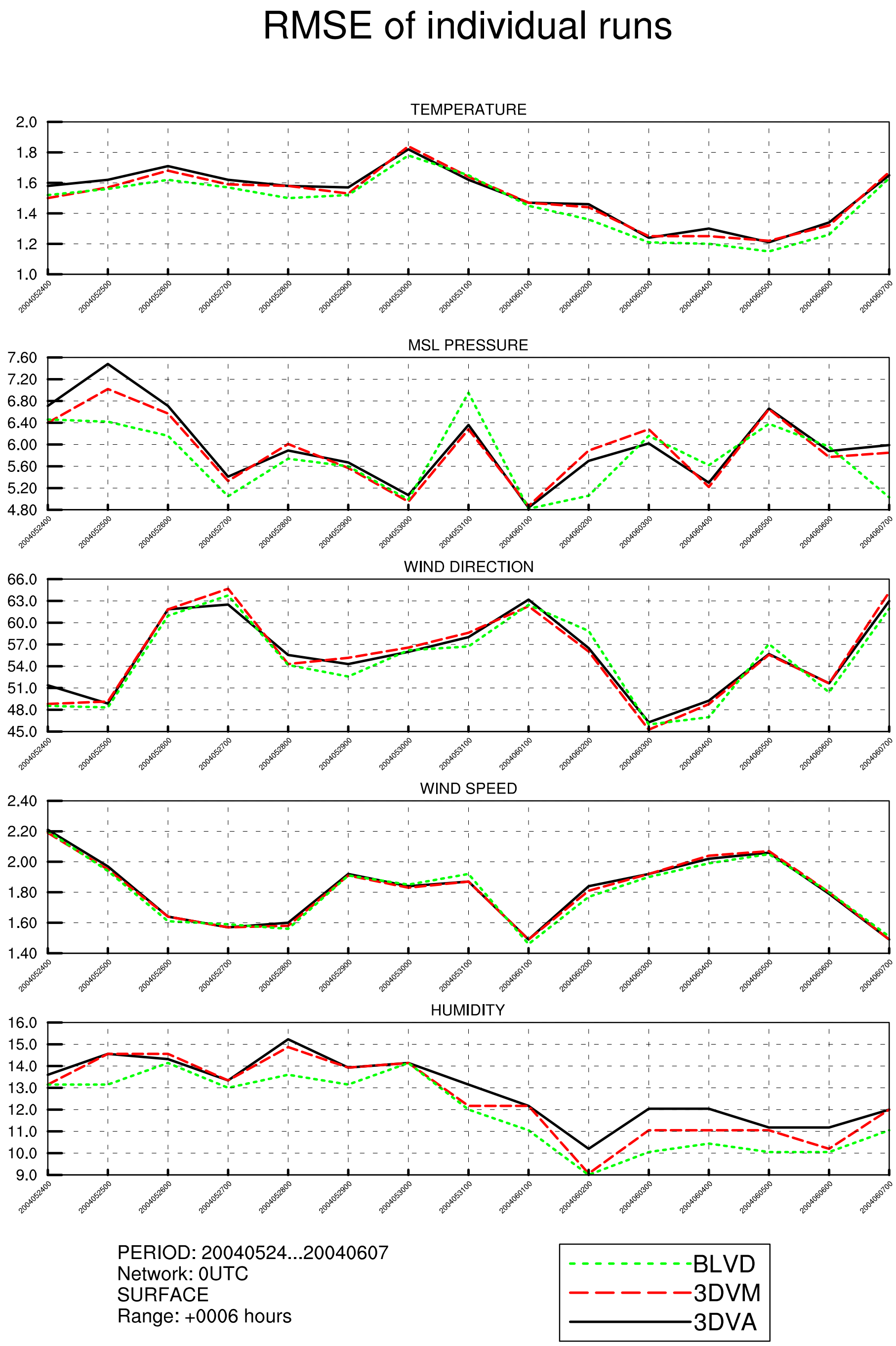

Figure 33: The RMSE scores of the 6h forecasts from individual runs, at the surface level, from the "*blendvar DFI*" (BLVD), "*3dvar multivariate*" (3DVM) and "*3dvar*" (3DVA) experiments, between 24.05.2004 - 07.06.2004, at 00 UTC model runs