Experiments with the explicit blending and the 3D-Var scheme for the ALADIN/HU model.
Part II: Case studies

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1 Introduction

In the frame of the numerical weather prediction (NWP), to produce an accurate weather forecast, precise knowledge of the current state of the atmosphere (the initial condition) is needed. This is achieved by using observations and assimilating them into the model. The data assimilation procedure is described as the method in which observed values of meteorological variables and short-range forecasts from a previous model integration (called background or first guess) are combined to produce grid point estimates of the initial conditions used to begin a new forecast. Because the background field is so important to the analysis, this forecast should be as close as possible to reality.

For the ALADIN limited area model, the 6h forecast from the previous integration as first guess has been considered a natural choice, because the forecast of the model contains already the small-scale information of the atmosphere. Another option for the first guess consists in merging the small-scale features from the limited area model together with the large-scale information from the global model (ARPEGE). The method is called the ***explicit blending***, and it is performed in the spectral space, according to the equation:

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

where α is following a simple linear function for the values between 0 and 1, till the wave number reaches 31. After it, α becomes equal to 1, which means that only the limited area model will provide the information.

In the frame of the 3D-Var system for the ALADIN model, the explicit blending method can be used in two different ways: the first one, to combine the information from the 6h forecast of the limited area model from the previous integration (the "classical" first guess) with the analysis of the global model, and the blended state to be used as first guess for the data assimilation procedure, and the second one, to perform first the assimilation step (as it is now), then the analysis of the limited area model is merging with the global model analysis, and the result is the initial condition for the model integration.

The general evaluation of these combinations is described in the first part of this report (Alexandru, 2004). The conclusions were that the use of the explicit blending with the 3D-Var scheme can improve the forecast of the ALADIN model. According to the verification scores, the best combination would be that the blending between the "classical" first guess of the ALADIN and the ARPEGE analysis, to be performed first, and then the initialized blended state (i.e. after the digital filter initialization was applied) is used further as first guess for the 3D-Var scheme. In cycling, there is no need to apply digital filter initialization.

In this report, some case studies have been selected in order to investigate whether or not the choices, which have been made from the general evaluation, can be found also in forecasts for these cases. The description of the experiments is performed in section 2. Then the results are explained in section 3. The conclusions are summarized at the end.

2 The description of the experiments

All the experiments were carried out with the limited area model, ALADIN/Hungary. The operational version of the model is running in dynamical adaptation, which means that the initial and lateral boundary conditions are obtained through the interpolation of the ARPEGE analyses and forecasts onto the high-resolution grid of the limited area model. Digital filter initialization (DFI) has been applied in order to remove the fast propagating inertia-gravity waves from the initial conditions.

The 3D-Var data assimilation scheme consists in minimization of a cost function, in order to get the best fit to the available information sources, providing the best analysis for the model integration. The cost function in ALADIN model sums the observation term (which measures the distance between the observations and the analysis) and the background term (which measures the distance between the first guess and the analysis). In our experiments with the 3D-Var scheme (and no blending), the standard NMC statistics (Parrish and Derber, 1992; Berre, 2000) have been used for the background term, while for the sets with the blending procedure, the lagged NMC statistics (Široká *et al.*, 2003) have been chosen. 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.

Three sets of experiments have been performed with the blending procedure for different case studies in order to compare the results of the model running in dynamical adaptation and using the 3D-Var scheme, with the first guess as 6h forecast from the previous integration of the model (as the references). The names of the experiments are the same as in the first part of the report, namely: "*dyn adap DFI*" (when the model is running in dynamical adaptation with digital filter initialization), "*3dvar DFI*" (the model is using the 3D-Var scheme) "*blendvar DFI*" and "*blendvar no DFI*" (for the experiments when the model was using as a first guess for the 3D-Var scheme, the result of the blending between the ARPEGE analysis and the 6h forecast of the ALADIN/HU model, with/without digital filter initialization in cycling) and finally "*varblend DFI*" (when the assimilation of the observations from the altitude and from the surface have been performed first, followed by the blending procedure, between the analyses of the ALADIN/HU and ARPEGE models; the DFI has been applied as well in cycling). We have to mention that for the lateral boundary conditions in the assimilation cycle the ARPEGE analyses have been used, while for the production, they were provided by the ARPEGE forecasts interpolated to the ALADIN/HU domain (the same LBCs as the operational ALADIN/HU model is using). The horizontal resolution was of 12 km for all sets of experiments.

3 Case studies

In this chapter the results of the case studies are presented in detail. The forecasts of different fields have been plotted, in order to compare the prediction of the "reference" experiments with the new ones. The maps with the forecasts for the relative humidity, vertical velocity and precipitation have a zoom between 45.5 °C - 49 °C latitude and 15.5 °C - 23.5 °C longitude, in order to point out the location of the events.

3.1 The summer case (the $17^{\mathbf{th}}$ - $18^{\mathbf{th}}$ of July 2003)

A short synoptic description is presented below. In the days previous to this event, the air, over Hungary, was very warm, with temperatures till 35 °C near to the surface. A low pressure system was located over the Great Britain and its through was extended over Europe till the western part of Austria. On the 18^{th} of July 2003, the cold front was located west to Hungary. As the front advanced, the colder air lifted the warmer air ahead of it. The moisture condenses producing precipitation ahead of and along the cold front. The quantity of precipitation over Hungary, measured between 17.07 18 UTC - 18.07 18 UTC, reached values as 35 - 40 mm/24h (Figure 1).

The forecasts of different fields from these experiments have been plotted. One can see in the Figures 2 and 3, that all the experiments, both the "references" and using the blending procedure, predicted a low pressure system located over the north-western part of Hungary. The location was similar, and also the values of it were close. The shape of the area with very high humidity is corresponding to the location where the rainfall happened. The forecasts obtained by the new experiments are very similar. As we can see in Figure 4, the "*3dvar DFI*" experiment, predicted also a larger place where moisture is available south to Hungary. The real measurements of the rainfall confirm this forecast. Comparing the forecasts of the vertical velocity field at 700 hPa, from the Figure 5, we can see an intensive vertical motion of the air masses (with values till 5 hPa/s) mainly in the experiments with the blending procedure.

The same pattern of the area where rainfall occurred, covering the northern part of Austria, the south of Czech Republic, and the north-western part of Hungary, was predicted by all the experiments, from the 17.07 00 UTC model run (Figure 6). The difference between them appeared for the maximum amount forecasted, and for the location of it. The ***blendvar*** experiments predicted the biggest quantity of precipitation (around 100 mm/24h). The "*varblend DFI*" is following more or less the forecast of the reference model "*dyn adap DFI*", with more reasonable values for the maximum (as 67 mm/24h), but located mainly over Austria and Czech Republic. We have to mention that forecasts from all the experiments show an area with precipitation in the southern part of Hungary, that in reality has been located more to south, but with values of the maximum close to those measured. Comparing with the real measurements, one can see that no experiment could predict the rainfall from the eastern part of Austria.

The forecasts from the 17.07 12UTC model run brought a change in the location of the rainfall. The ***blendvar/varblend*** experiments have been closer to reality. From the point of view of the predicted amount, the models using the blending procedure overestimated the quantity of precipitation, reaching a maximum as 100 mm/24h, but still they were the closest ones that gave the indication of the right area of the rainfall (Figure 7). The reference experiments forecasted a more reasonable amount, only that the location was further than reality. The "*3dvar DFI*" experiment was the only one who predicted again the precipitation south to Hungary.

For this case the use of the blending procedure for obtaining the first guess helped mainly to improve the forecast of the location of the rainfall, and less the quantity of precipitation (which has been overestimated).

3.2 The inversion case (the 27$^{\text{th}}$ of December 2002)

This case study has been investigated also in another report, comparing only the results of the model running in dynamical adaptation and using the 3D-Var scheme with the first guess, as 6h forecast from the previous integration of the ALADIN/HU model (Alexandru, 2003). A short description of the synoptic situation is presented here. An anticyclone was extended over Hungary in the days before this temperature inversion occurred. The air was dry and very cold, with the temperature between -10 °C and -6 °C at the surface. On the 26$^{\text{th}}$ of December, a warm advection was moving over the country, replacing the cold air in the altitude, causing a strong temperature contrast on the 27$^{\text{th}}$ of December, at 12 UTC (around 8 °C between the 850 hPa and 980 hPa layers).

As for the previous case, also here the results of the three set of experiments, when the blending and data assimilation procedures are combined, were compared to the references (the models running in dynamical adaptation and using the 3D-Var scheme).

First the forecasts from the 27.12 2002 00 UTC model run have been checked. One can see that all the experiments failed to predict the inversion (Figures 8 and 9). The advection of the warm air is shown, mainly near to the surface. The "*dyn adap DFI*" and the ***blendvar/varblend*** experiments present similar vertical cross-sections through the temperature field over Hungary. We can say that the reference experiment with the model using the 3D-Var scheme, misforecasted completely the inversion, with more than 12 hours before the event.

Starting with the 27.12 2002 06 UTC model run, the temperature inversion was predicted by the "*dyn adap DFI*" and the ***blendvar/varblend*** experiments. The temperature contrast is not too big, only around 4 °C (Figures 10 and 11). The forecast from the "*3dvar DFI*" experiment has been slightly improved compared to the forecast from the previous run, valid at the 12 UTC, but still is far from reality. This difference between the experiments is due to the information provided through the ARPEGE analysis. The global model, using the 4D-Var scheme, is able to take a better advantage of the observations. Usually for the 06 UTC and 18 UTC model runs, only the cycling for the data assimilation is performed, and not the production. So for the daily forecasting, this run is not available, which means that only the next run would provide information about the inversion, but it is too late.

The temperature analyses from the 27.12 2002 12 UTC model run have been improved for the "*dyn adap DFI*" and the ***blendvar/varblend*** experiments, revealing that the information from the large scale was very close to reality (Figures 12 and 13). Between them it seems that "*varblend DFI*" performed better. The "*3dvar DFI*" experiment predicted an inversion, but the temperature contrast was very small.

We remark the similar cross-sections of the temperature field from the two ***blendvar*** experiments. Further the temperature fields from the first guess and from the analysis of the model after the variational and optimal interpolation steps were compared (Figure 14), and again the differences are very small, which confirm the conclusion from the general evaluation, that the use of digital filter initialization in cycling for the ***blendvar*** experiments is not really necessary.

The main conclusion from this case investigation was that the blending procedure is able to improve the analysis of the model, taking information both from the observations and from the large scale provided by the global model. The annoying part is that here the improvement came only at the analysis time, which means too late for the forecasters.

3.3 The spring case (the $26^{\mathbf{th}}$ of May 2003)

The case has been selected because an important quantity of precipitation fell in the north-western part of Hungary, with a maximum of 45 mm/24h (Figure 15). In the days previous to the 26^{th} of May 2003, a cyclone has been developed over the Mediterranean Sea, bringing warm and wet air over the ground. North to Hungary an anticyclonic belt was extended from the Atlantic Ocean to Russia. In this region the air was stable, blocking the northerly motion of the warm air. Therefore the warmer air rose, the moisture was available, which led to the rainfall over Hungary.

The forecasts for the geopotential field revealed a well defined low pressure system located over the Mediterranean Sea (as it was in reality) (Figures 16 and 17). The experiments had a very close prediction for it. The area where the moisture is available forecasted by the model in dynamical adaptation and using the blending procedure (from the 26.05 00 UTC model run), is located in the western part of Hungary (Figure 18). The earlier forecasts of all experiments have shown the sky partly cloudy. The vertical velocity field had relatively small values over Hungary, so no intensive motion of the air masses is expected (not shown).

The results from the 25.05 12 UTC model run, showed very restricted areas where precipitation may occur for all the experiments, but neither of them predicted the correct location of the rainfall (Figure 19). The 26.05 00 UTC model run seems to have a better forecast for the ***blendvar/varblend*** experiments mainly regarding the area of rainfall, but still the quantity of precipitation was underestimated. The "*varblend DFI*" predicted correctly the area with high precipitation, but it appeared also a spot of rainfall in the southern part of Hungary. The "*3dvar DFI*" experiment looks the worst between them, no improvement either in location, either in amount. Comparing to the real measurements, in the case of the other reference set ("*dyn adap DFI*"), the rainfall was predicted more in the central part of Hungary, than in the western part, and the maximum was located over the border between Slovakia and Hungary (Figure 20).

From this case study we may conclude that generally the models underestimated the amount of precipitation, and between them the "*blendvar DFI*" experiment was the closest one to reality, because of a better prediction of the location.

3.4 The second summer case (the $11^{\mathbf{th}}$ - $12^{\mathbf{th}}$ of June 2004)

The last case has been distinguished by the significant amount of precipitation felt over Hungary and Austria. The synoptic situation can be described by a low pressure system located over the Baltic Sea with the cold front west to Hungary. In altitude the geopotential height decreased. Thus the cold air mass advanced and replaced the warm air. Advancing the cold front forced the warm moist air to rise sharply, producing showers and thunderstorms. The strong jet stream amplified the through, which determined the fast moving of the cold front. At the beginning of the rainy period (11.06 18 UTC - 12.06 18 UTC), the area affected was located in the eastern part of Austria and the western part of Hungary. The real measurements have shown values as 45 mm/24h. Then, the front moved, and the precipitation had a maximum around of 33 mm/24h, north-east to Hungary (Figure 21).

The results of all the experiments are presented further. The forecasts of the geopotential and temperature at 500 hPa and 850 hPa levels revealed the location of the low pressure system over the Baltic Sea (Figures 22 and 23). At 500 hPa level, in the eastern part of Austria, one can see a decreasing of the geopotential height, due to the cold advection. The forecasts of relative humidity at 700 hPa show that the moisture is available in some parts of Hungary, Austria and Slovakia (Figure 24). One can see in the Figure 25, in the eastern part of Austria, an intensive vertical motion of the air masses, with values around -5.5 Pa/s (except for the "*3dvar DFI*" experiment, where the velocity is smaller, -3.7 Pa/s). All these fields gave an indication of the heavy rainfall to occur over the border between Austria and Hungary (Figure 26 and 27). According to reality in that area, the measurements reached values as 45 mm/24h. The cold front was moving very fast, thus 6 hours later (i.e. at 12.06 06 UTC), the forecasts of the relative humidity and vertical velocity fields at 700 hPa, from all five experiments, indicate the new location of the expected rainfall over the border between Hungary, Slovakia and Ukraine (not shown). Here the quantity of precipitation measured 33 mm/24h.

Generally all the experiments from the 11.06 00 UTC model run had a reasonable prediction, i.e. they pointed out the two areas of rainfall, but with overestimated quantities. Moreover the ***blendvar*** and "*3dvar DFI*" sets forecasted like a band of precipitation through Hungary, from west to east, which has not been in reality. The "*varblend DFI*" was closer to the "*dyn adap DFI*". The next model run (11.06 12 UTC) brought a decreasing of the amount of precipitation, which was more realistic. A good prediction of the rainfall from the border between Hungary, Ukraine and Slovakia, has been obtained by all the experiments. Regarding the other area of interest, between Hungary and Austria, one can see a slight improvement in the location for the "*3dvar DFI*" and "*varblend DFI*" sets. Also the other experiments ("*dyn adap DFI*"/***blendvar***) forecasted a significant amount of precipitation there, only that on a small area located near to the border between Hungary, Austria and Slovenia, the quantity is less than 5 mm/24h, and in reality here the maximum has been reached.

Even it is not easy to draw a conclusion for this case, which experiment had a better prediction of the event, we can say that comparing to the measurements, the model using the blending procedure after the variational step ("*varblend DFI*") pointed out better in its forecast both the location and the maximum.

4 Discussion and conclusions

In this report, four case studies have been investigated. The new experiments were performed using the blending procedure (in order to combine the large scale features from the global model with the small scale information of the first guess or analysis of the limited area model) together with the data assimilation scheme. As reference, we have considered the experiments with the model running in dynamical adaptation and using the 3D-Var scheme, with the first guess, as 6h forecast from the previous integration of the model. The aim of the new experiments was to show whether or not the blending procedure applied together with the 3D-Var scheme can help to improve the forecast of the ALADIN/HU model.

The first case study (the 17^{th}-18^{th} of July 2003) has been chosen because a cold front was passing through Hungary, associated with precipitation, which fell in some parts of Austria, Slovakia, Czech Republic and Hungary. The reference experiments ("*dyn adap DFI*" and "*3dvar DFI*") predicted a smaller amount of precipitation, which was more realistic. The first one predicted a good location of the rainfall in the central part of Hungary, but it missed the area of the precipitation in the eastern part of Austria and the western part of Hungary. The forecasts of the model using the 3D-Var scheme show the location of the rainfall mainly over the central and southern parts of Hungary. The other experiments, using the blending procedure showed a bigger amount of precipitation, but the location was well forecasted. So we can say that the ***blendvar/varblend*** experiments succeeded to have a better prediction of the rainfall, compared to the references, regarding the location, because otherwise the quantity of precipitation was overestimated.

The inversion case (the 27$^{\text{th}}$ of December 2002) was selected in order to see if the blending of the first guess provided by the ALADIN/HU model with the ARPEGE analysis, could improve the temperature forecast. The "*3dvar DFI*" experiment did not predict the inversion with 12 hours before the event, and either at the analysis time (the temperature contrast was very small). One can see how the warm air was moving nearer to the surface than in altitude. The main difference between the "*3dvar DFI*" and the other experiments appeared since the 27.12 06 UTC model run, when the latter ones succeeded to predict an inversion, but not as strong as it was in reality. We have to mention that this model run is not used for production (i.e. to obtain the 48h forecast). A better prediction of the temperature inversion has been realized at the analysis time. It seems that the "*varblend DFI*" was slightly better than the ***blendvar*** and "*dyn adap DFI*" experiments. The analysis from the "*3dvar DFI*" experiment has not been improved compared to the forecast from the previous run, so it remains far from reality. From this case study we can say that the information from the ARPEGE model helped to improve the 6h forecast and mainly the analysis of the limited area model. The problem is that for the forecasters, this improvement came too late in order to help them.

The third case study (the 26$^{\text{th}}$ of May 2003) has been interesting because of an important quantity of precipitation that fell in the north-western part of Hungary, reaching a maximum of 45 mm/24h. The earliest forecasts of all five experiments revealed that neither of them predicted the right location of the rainfall. The amount of precipitation is very small (just some spots over Hungary). Later, with only 12 hours before the event, the ***blendvar/varblend*** experiments improved their forecast, mainly regarding the location where the precipitation will occur. But the predicted quantity is still underestimated. The "*varblend DFI*" predicted correctly the area with high precipitation, but it appeared also a spot of rainfall in the southern part of Hungary. The "*3dvar DFI*" experiment has shown the location of the rainfall in the southern part of the country. Regarding the results from the other reference experiment, "*dyn adap DFI*", we can say that the rainfall was predicted more in the central part of Hungary, than in the western part, and the maximum is located over the border between Slovakia and Hungary. As a conclusion for this case study, all the experiments have been underestimated the amount of precipitation, and the "*blendvar DFI*" was the closest one to reality, because of a better prediction of the location.

The last investigated case (the 11$^{\text{th}}$-12$^{\text{th}}$ of June 2004) was distinguished by the quantity of precipitation. At the beginning of the rainy period (11.06 18 UTC - 12.06 18 UTC), the affected area was located in the eastern part of Austria and the western part of Hungary. The quantity of precipitation reached values as 45 mm/24h. Then, the system moved over the border between Hungary, Slovakia and Ukraine, when the maximum was around of 33 mm/24h. Generally all the experiments from the 11.06 00 UTC model run had a reasonable prediction, i.e. they pointed out the two areas of rainfall, but with overestimated quantities. The forecasts from the next model run (11.06 12 UTC) show a decreasing of the amount of precipitation, which was closer to reality. Here some differences appeared between the experiments, namely a slightly better location for the rainfall at the border between Austria and Hungary, obtained by the "*3dvar DFI*" and "*varblend DFI*" sets. It is difficult to conclude for this case, which experiment had performed better, but comparing to the real measurements, we may say that the "*varblend DFI*" succeeded to emphasize in its forecast from both model runs, the main features of the event (good location and maximum).

The main conclusion, both from the general evaluation and from the investigation of the case studies, is that the use of blending procedure brings some improvements in the forecasts of the limited area model, but the differences are not very big, compared to the references. Generally the "*blendvar DFI*" experiment seems to be the best choice. Thus the steps would be like that: first, the "classical" first guess of the ALADIN/HU model (i.e. the 6h forecast obtained from the previous integration of the model), to be combined with the analysis provided by the global model ARPEGE, then the digital filter initialization is applied to this blended state, and further, the result will be used as first guess for the 3D-Var scheme. After the variational step, the CANARI surface analysis is performed. The experiments established that the DFI is not needed in cycling.

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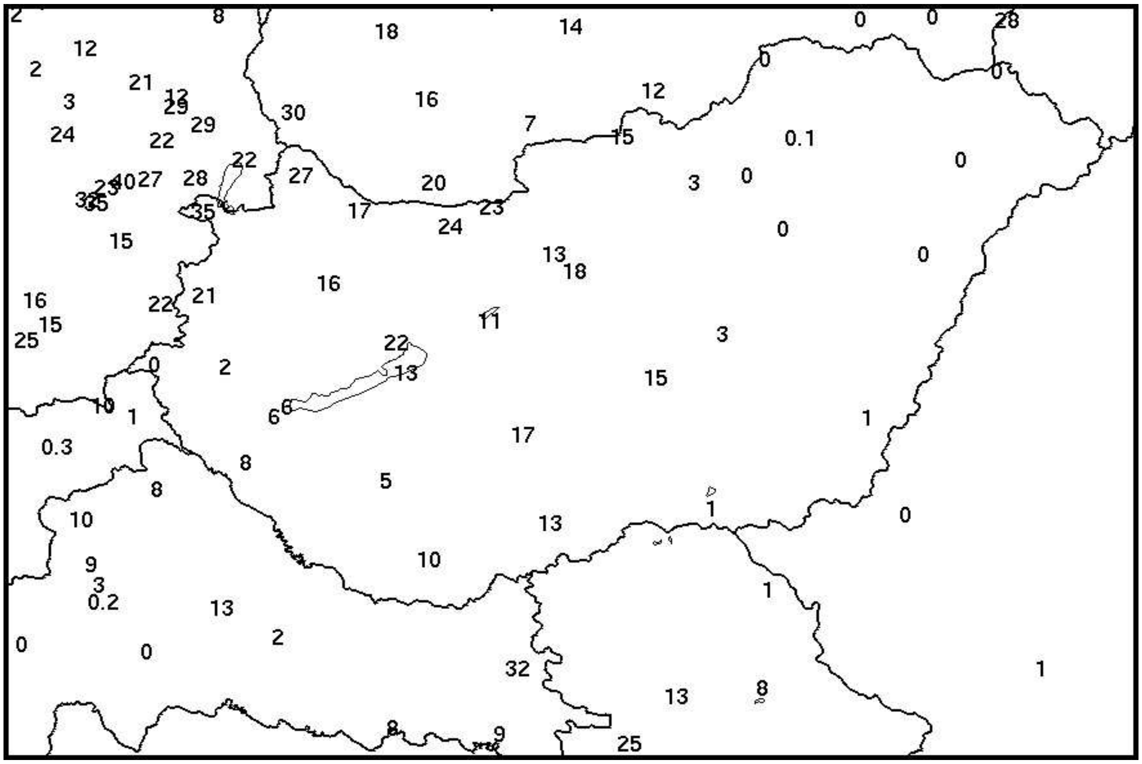
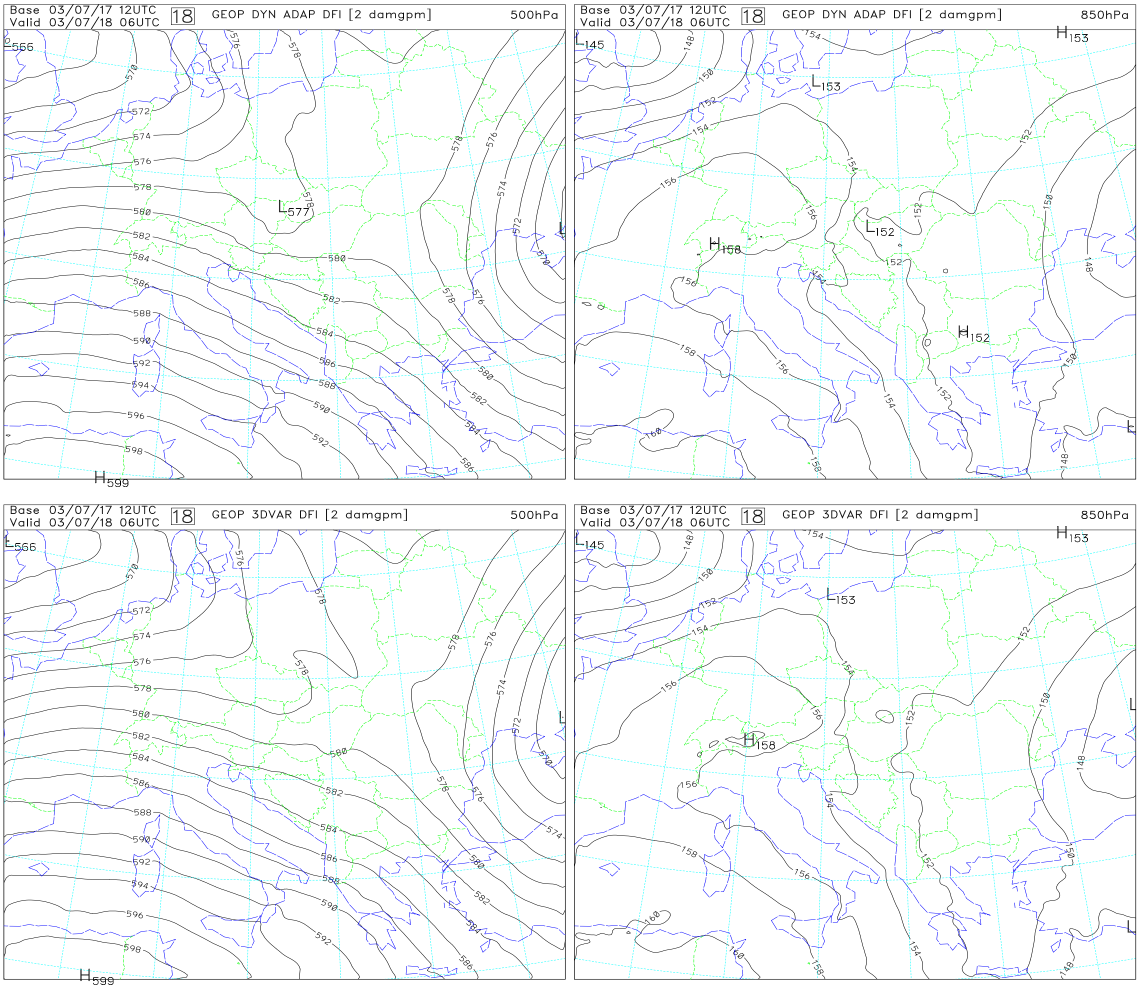


Figure 1: The quantity of precipitation (mm/24h) measured over Hungary between 17.07.2003 18 UTC - 18.07.2003 18 UTC



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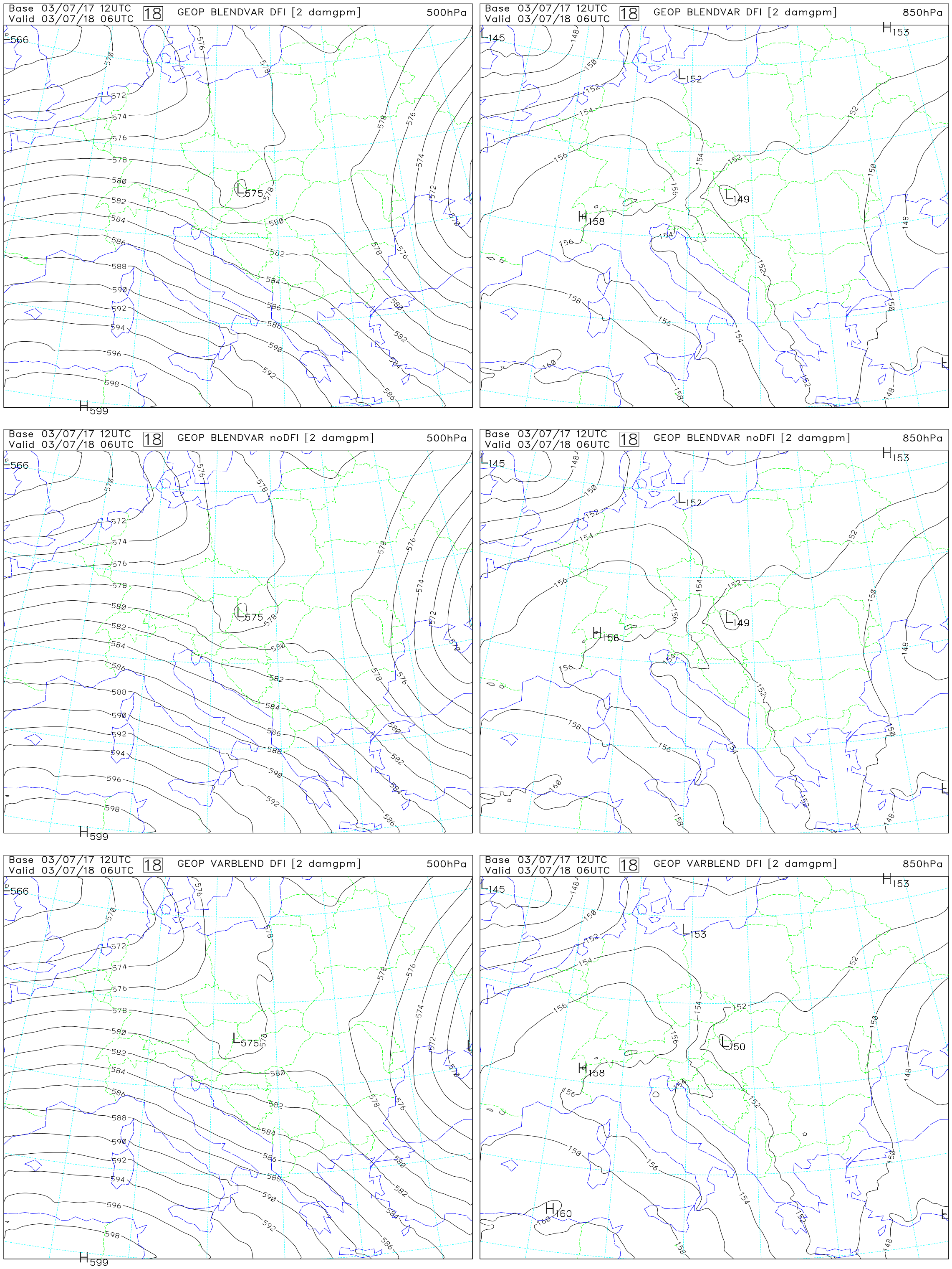

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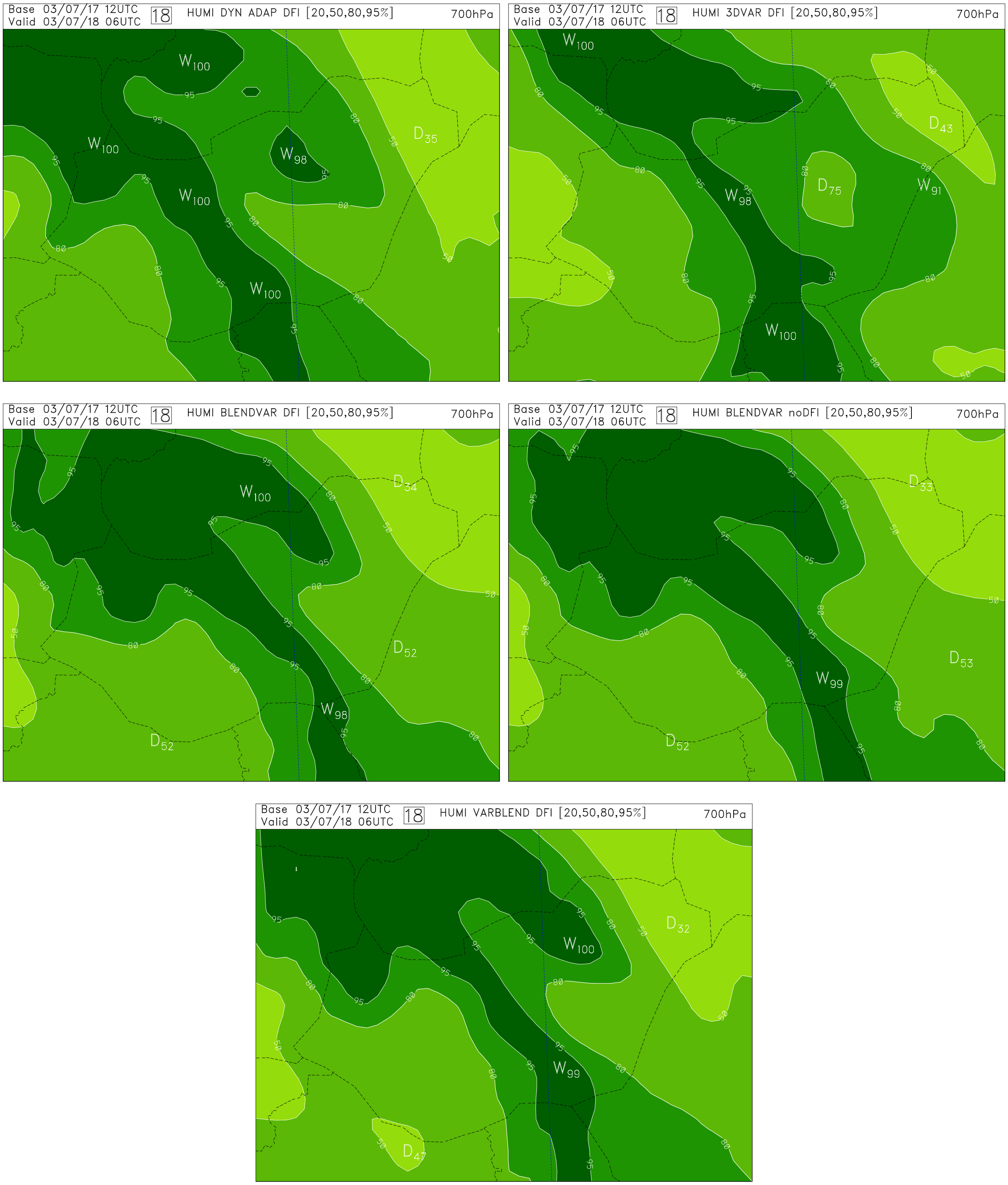

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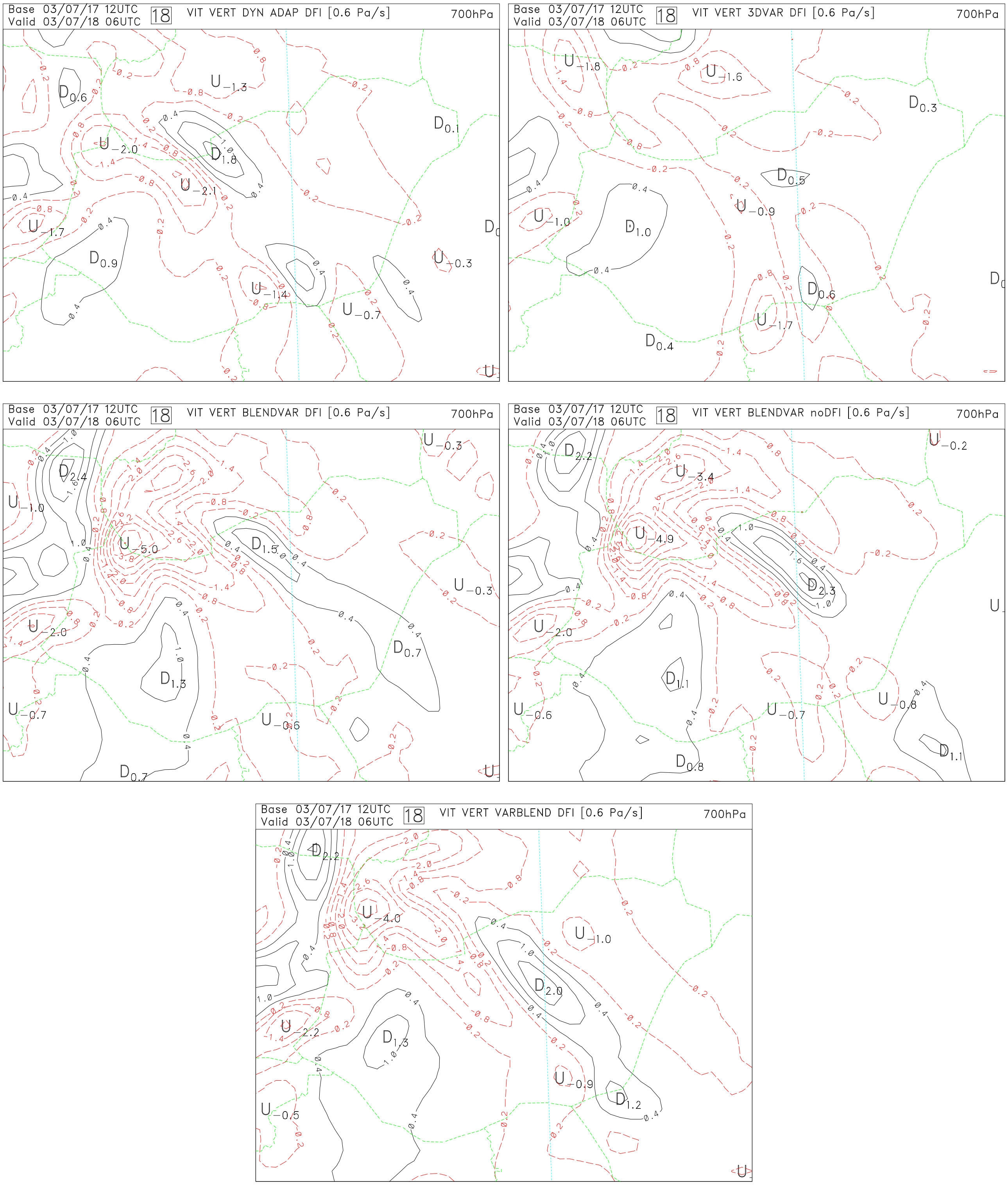

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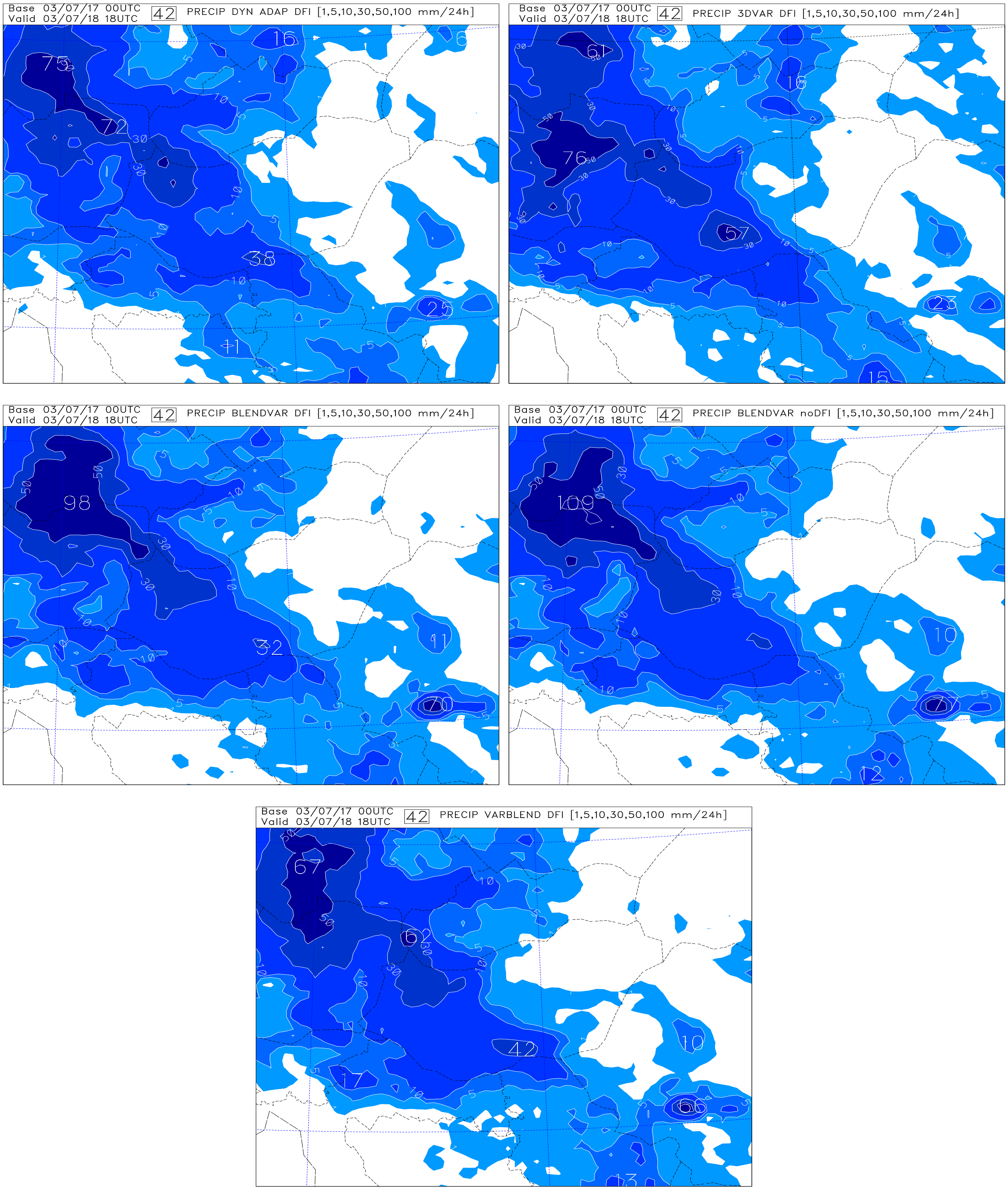

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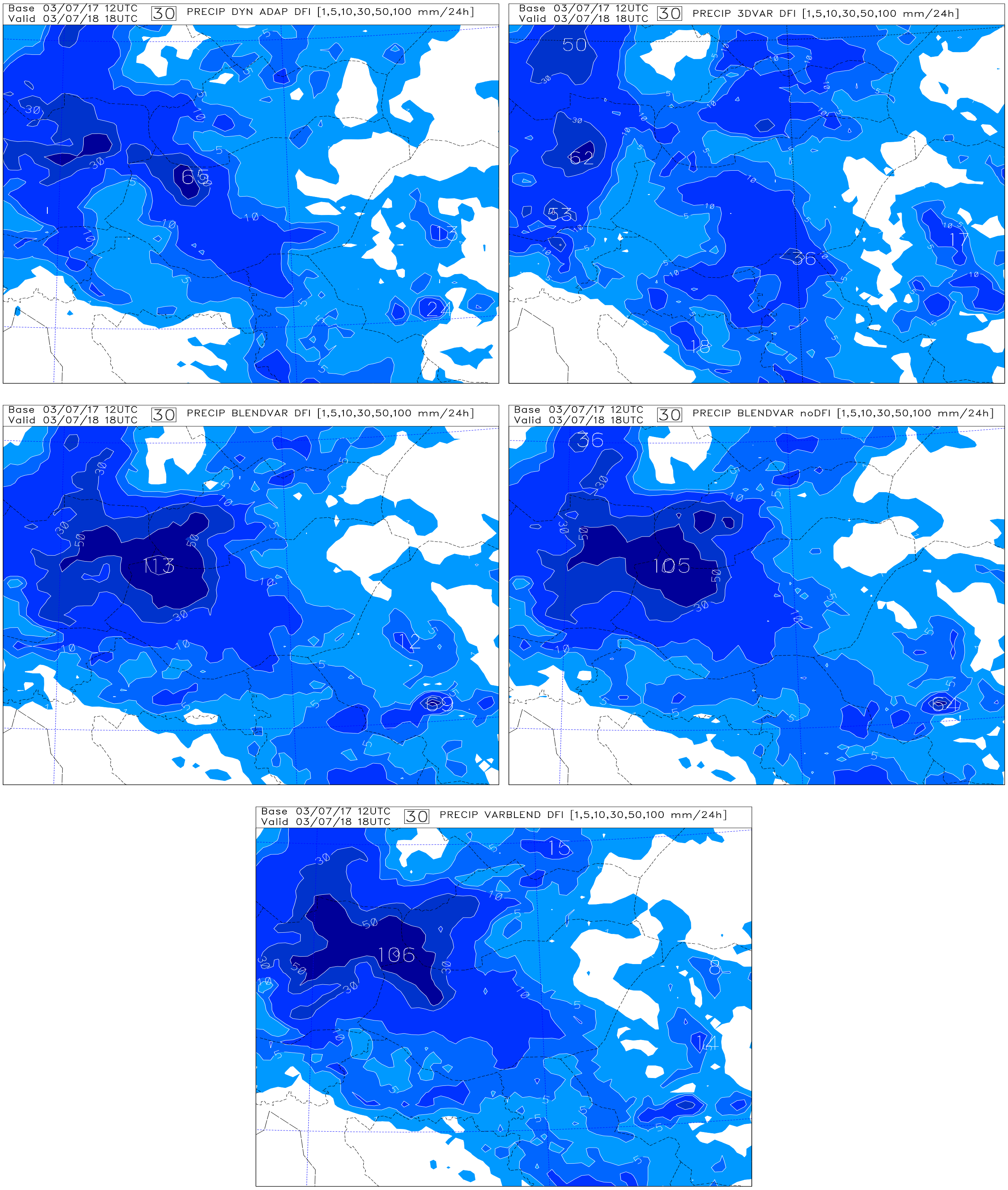

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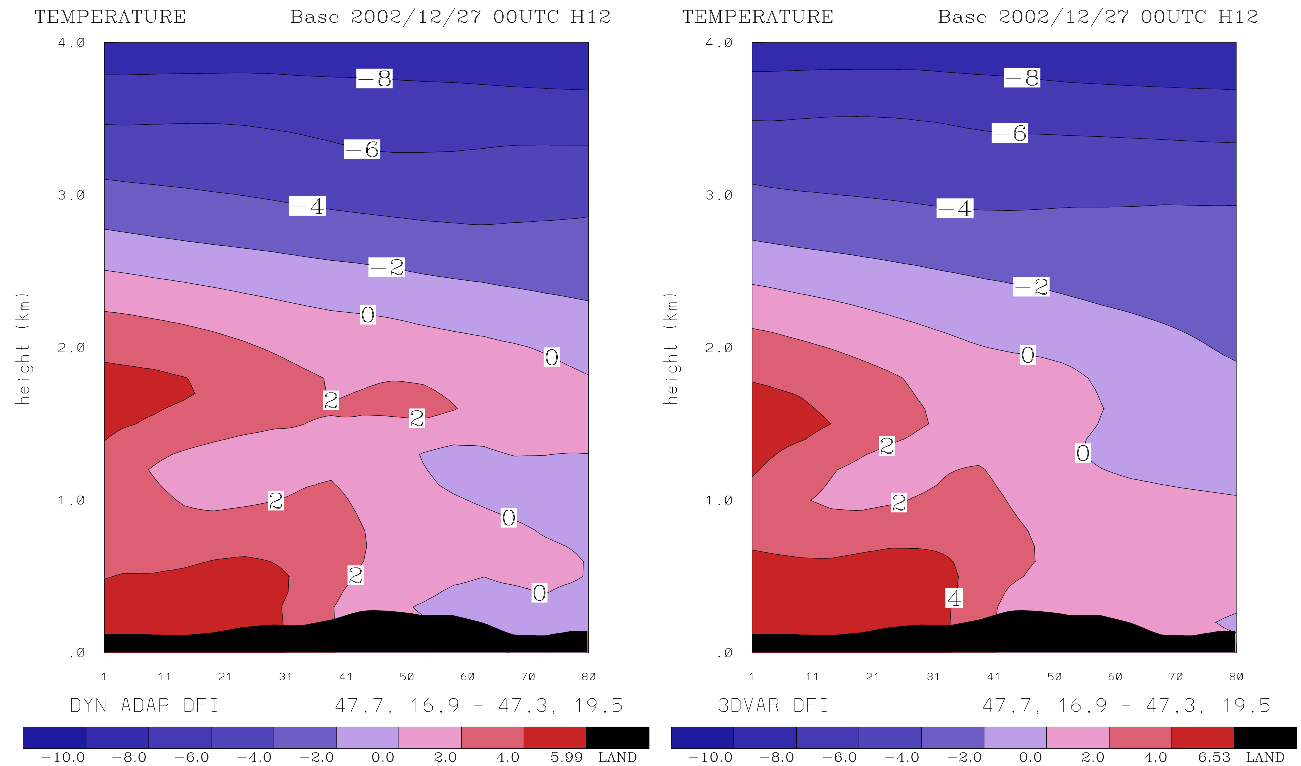

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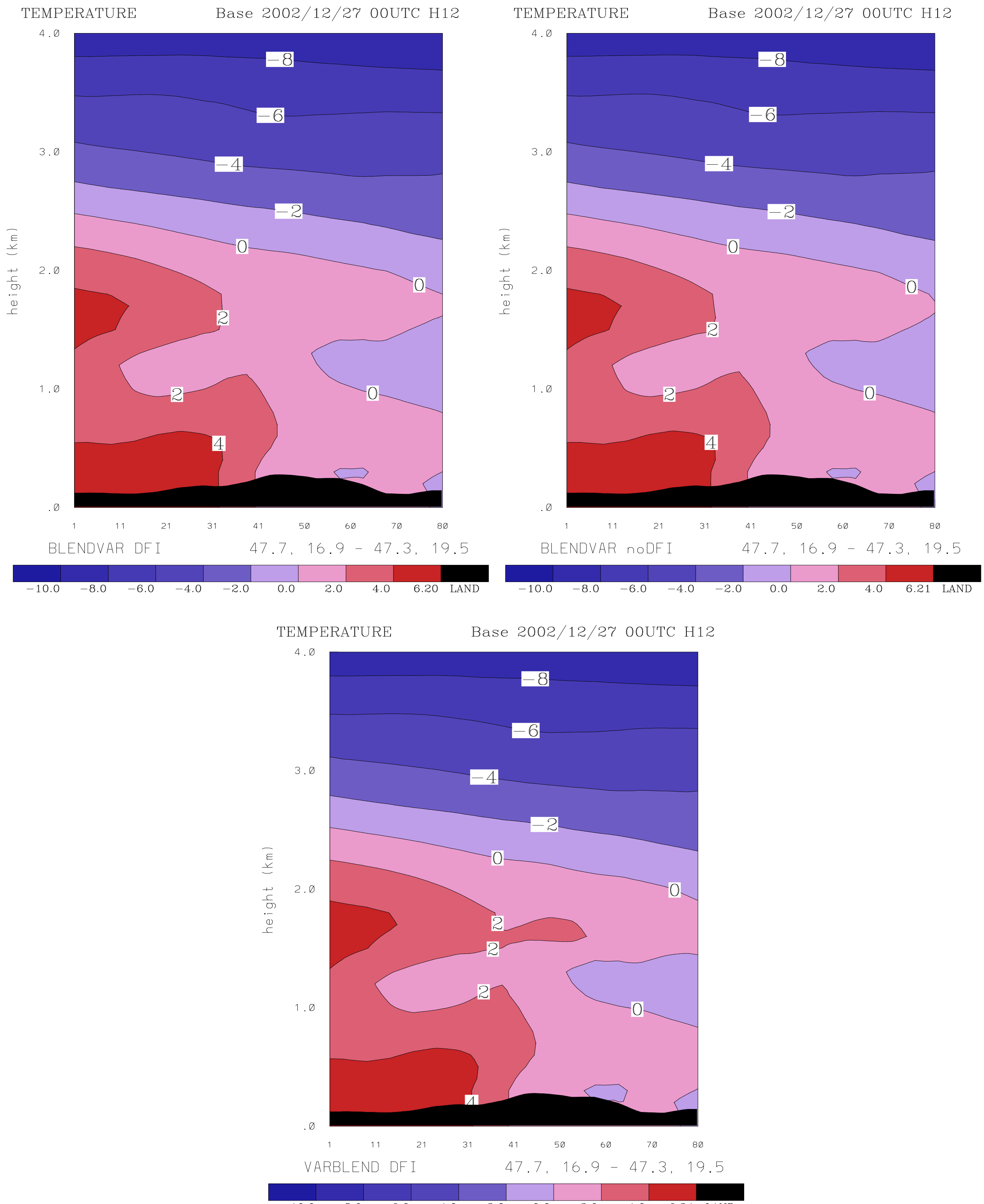

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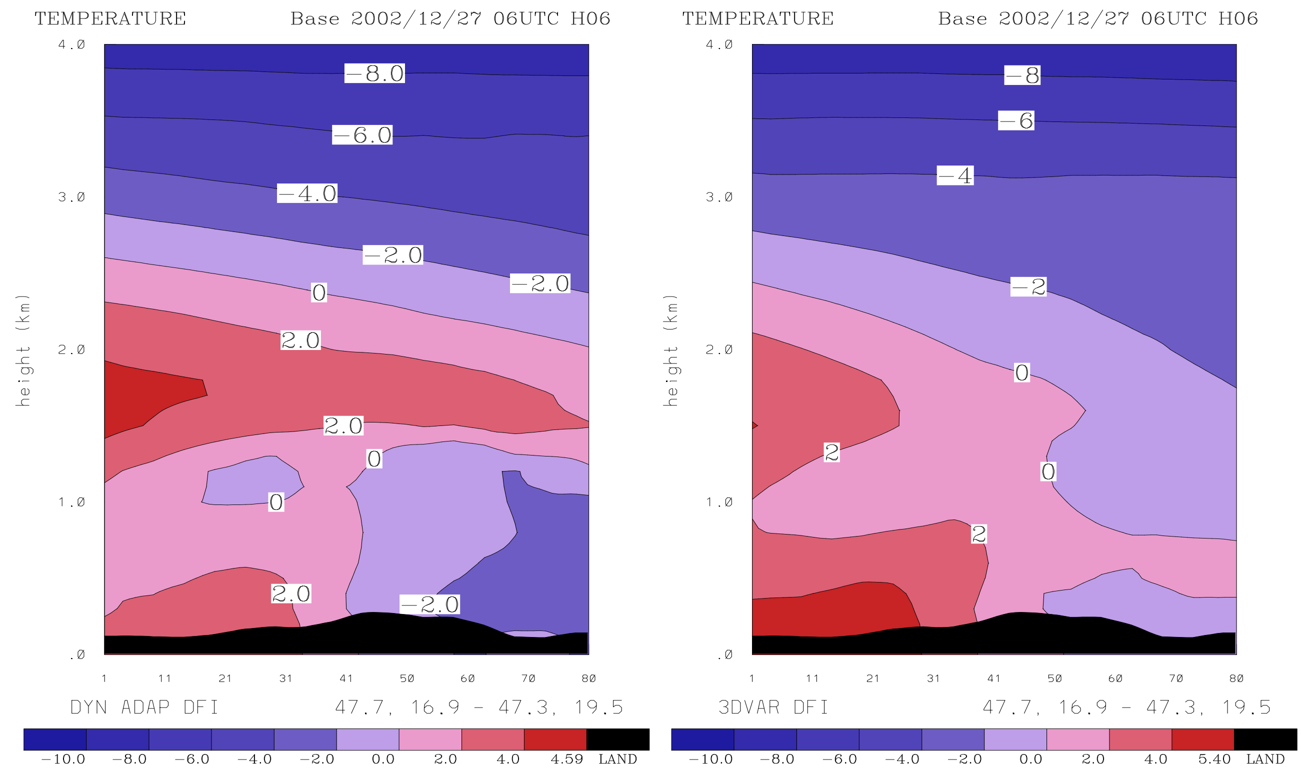

Figure 10: The vertical cross-sections of the temperature field, through Hungary, from the operational model ("*dyn adap DFI*") (left) and using the 3D-Var scheme ("*3dvar DFI*") (right), from the 27.12.2002 06 UTC model run, valid at 27.12.2002 12 UTC

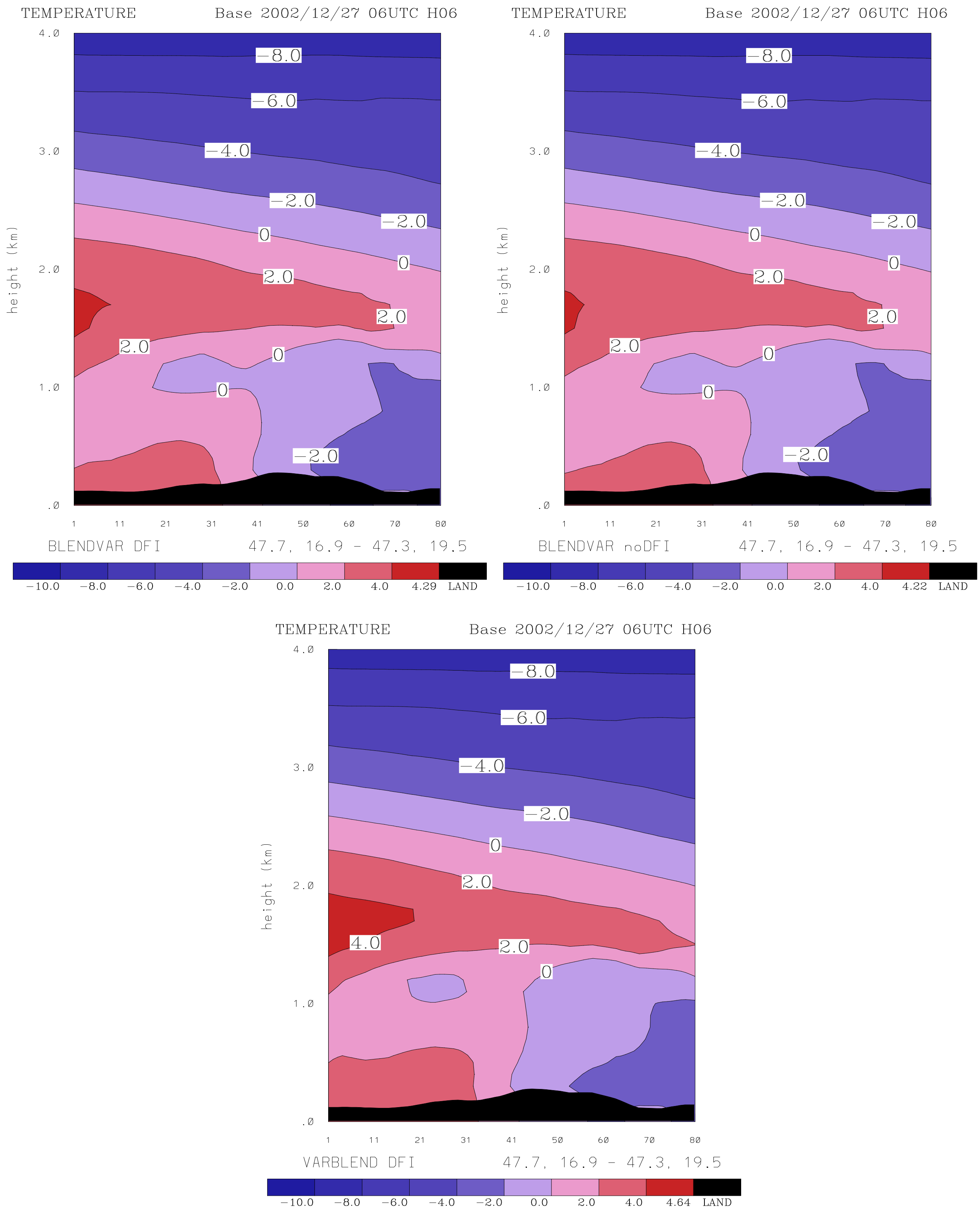

Figure 11: The vertical cross-sections of the temperature field, through Hungary, from different experiments ("*blendvar DFI*" and "*blendvar no DFI*" (top) and "*varblend DFI*" (bottom)), from the 27.12.2002 06 UTC model run, valid at 27.12.2002 12 UTC

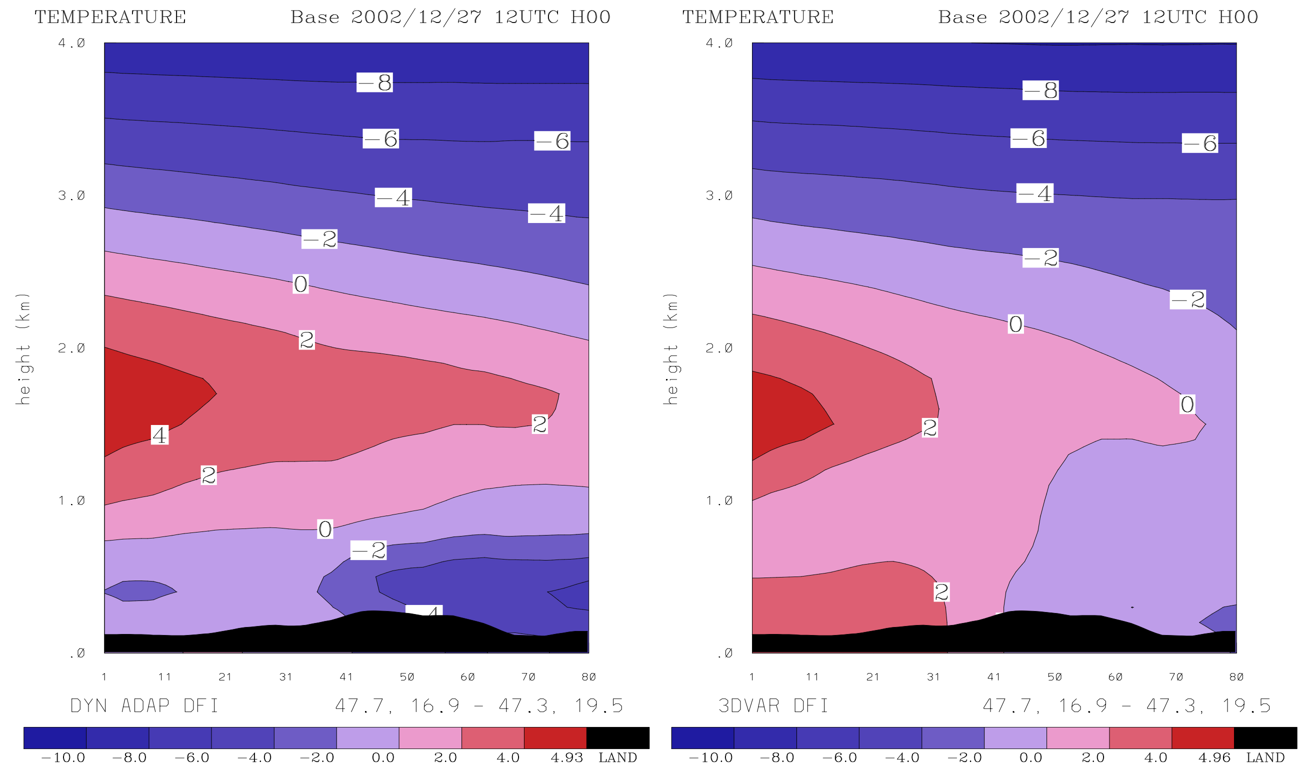

Figure 12: The vertical cross-sections of the temperature field, through Hungary, from the analyses of the operational model (”*dyn adap DFI*”) (left) and using the 3D-Var scheme (”*3dvar DFI*”) (right), from the 27.12.2002 12 UTC model run

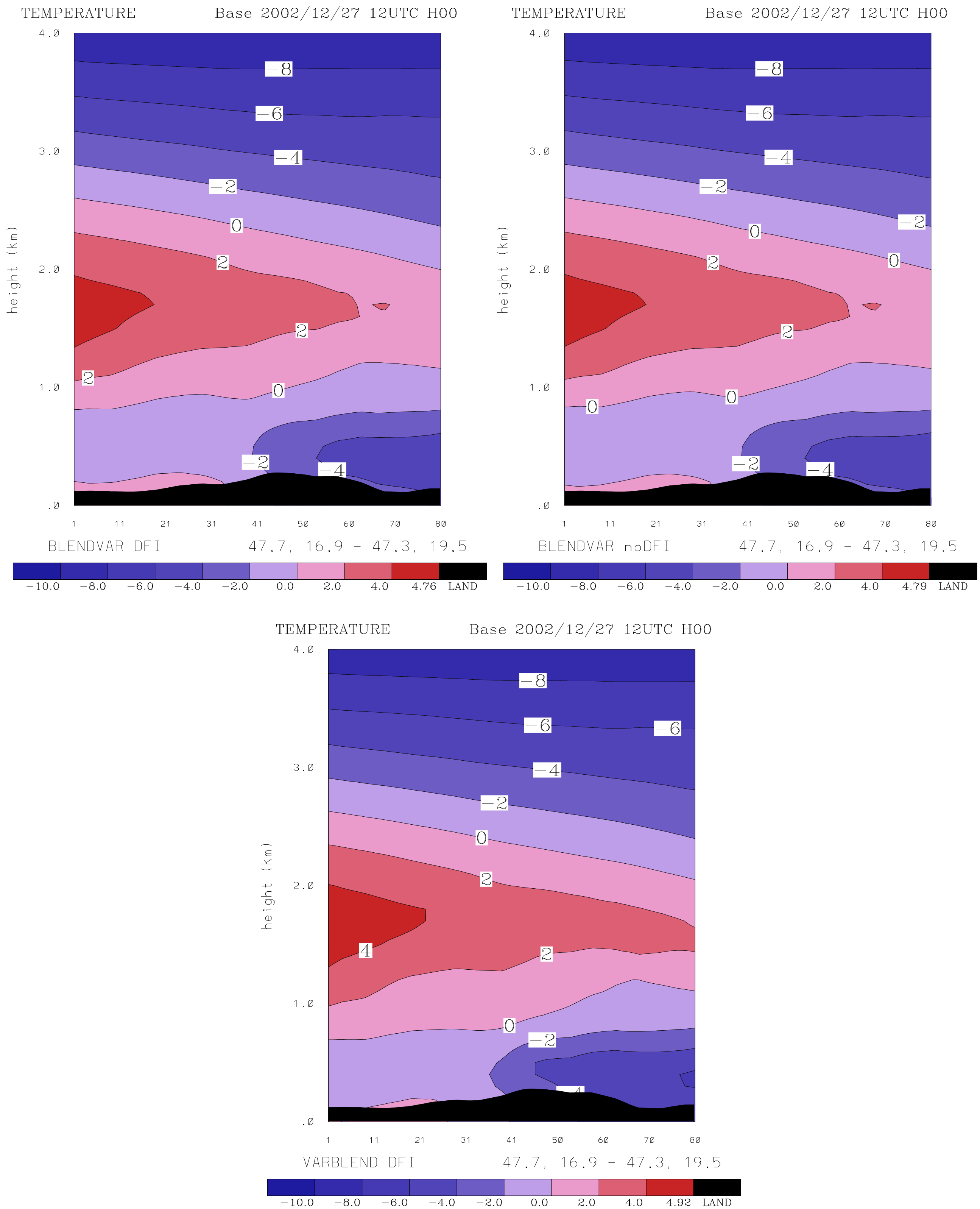

Figure 13: The vertical cross-sections of the temperature field, through Hungary, from the analyses of different experiments (”*blendvar DFI*” and ”*blendvar no DFI*” (top) and ”*varblend DFI*” (bottom)), from the 27.12.2002 12 UTC model run

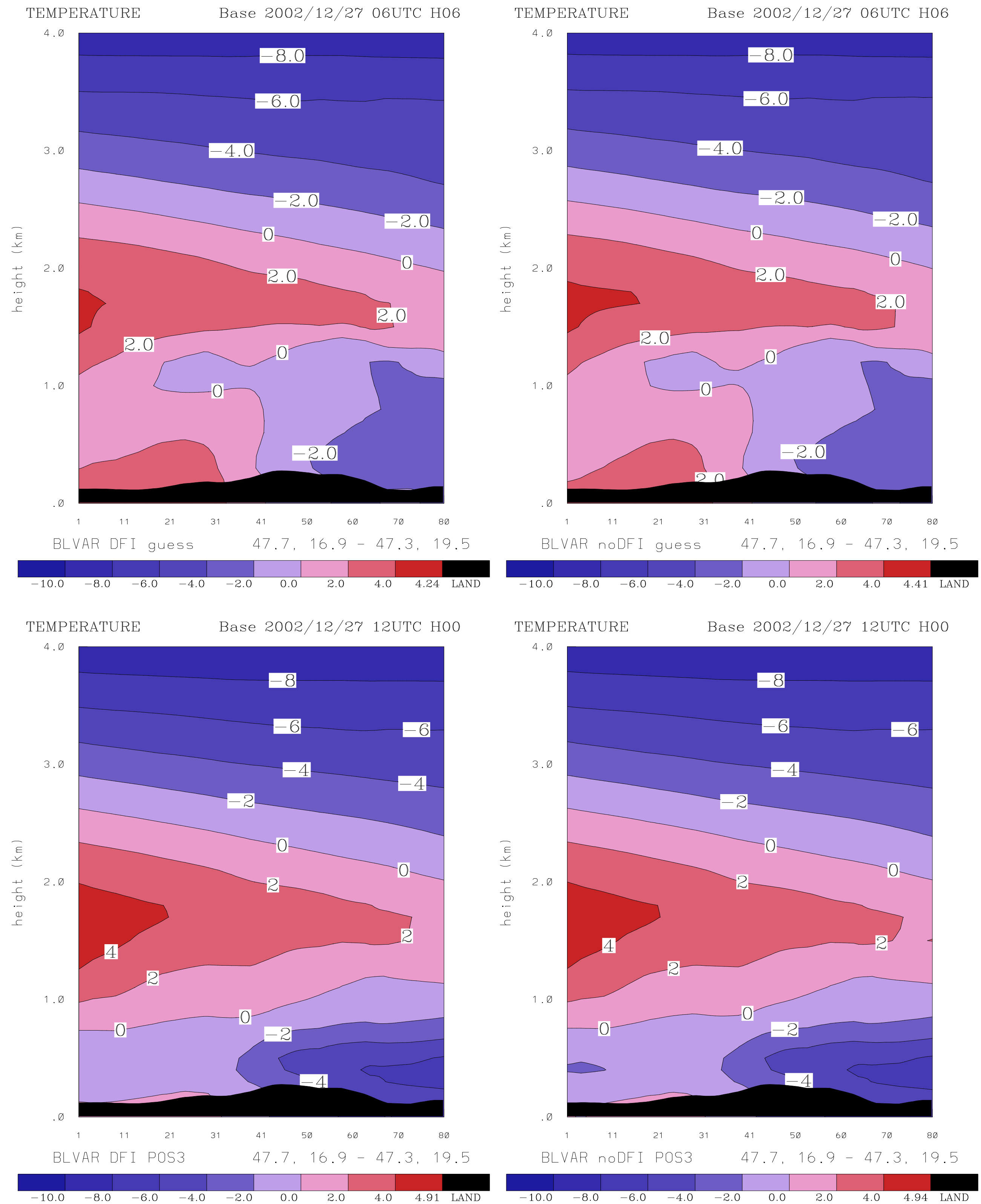

Figure 14: The vertical cross-sections of the temperature field, through Hungary, from different experiments ("*blendvar DFI*" (left column) and "*blendvar no DFI*" (right column)), from the first guess (top) and the 3D-Var analysis (bottom), from the 27.12.2002 12 UTC model run

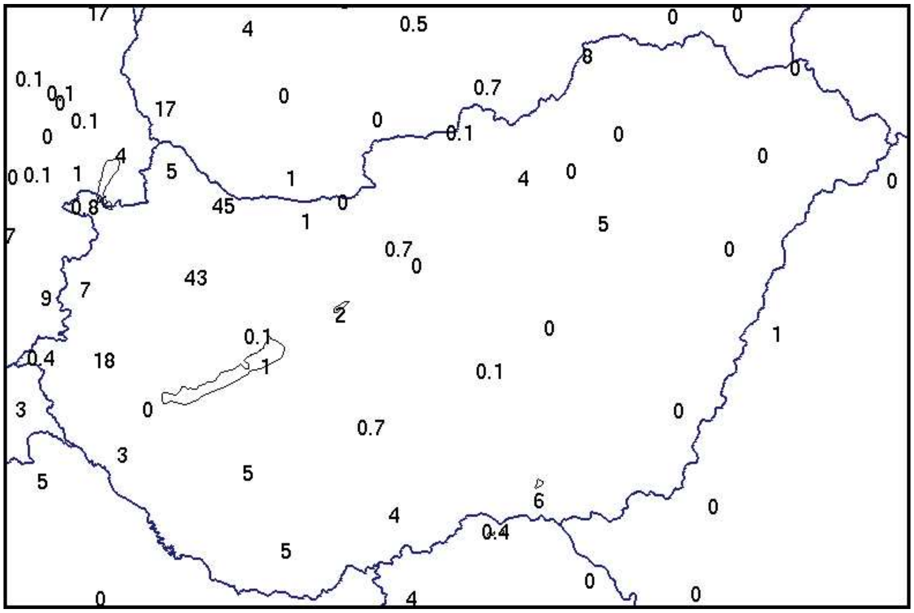

Figure 15: The quantity of precipitation (mm/24h) measured over Hungary between 26.05.2003 06 UTC - 27.05.2003 06 UTC

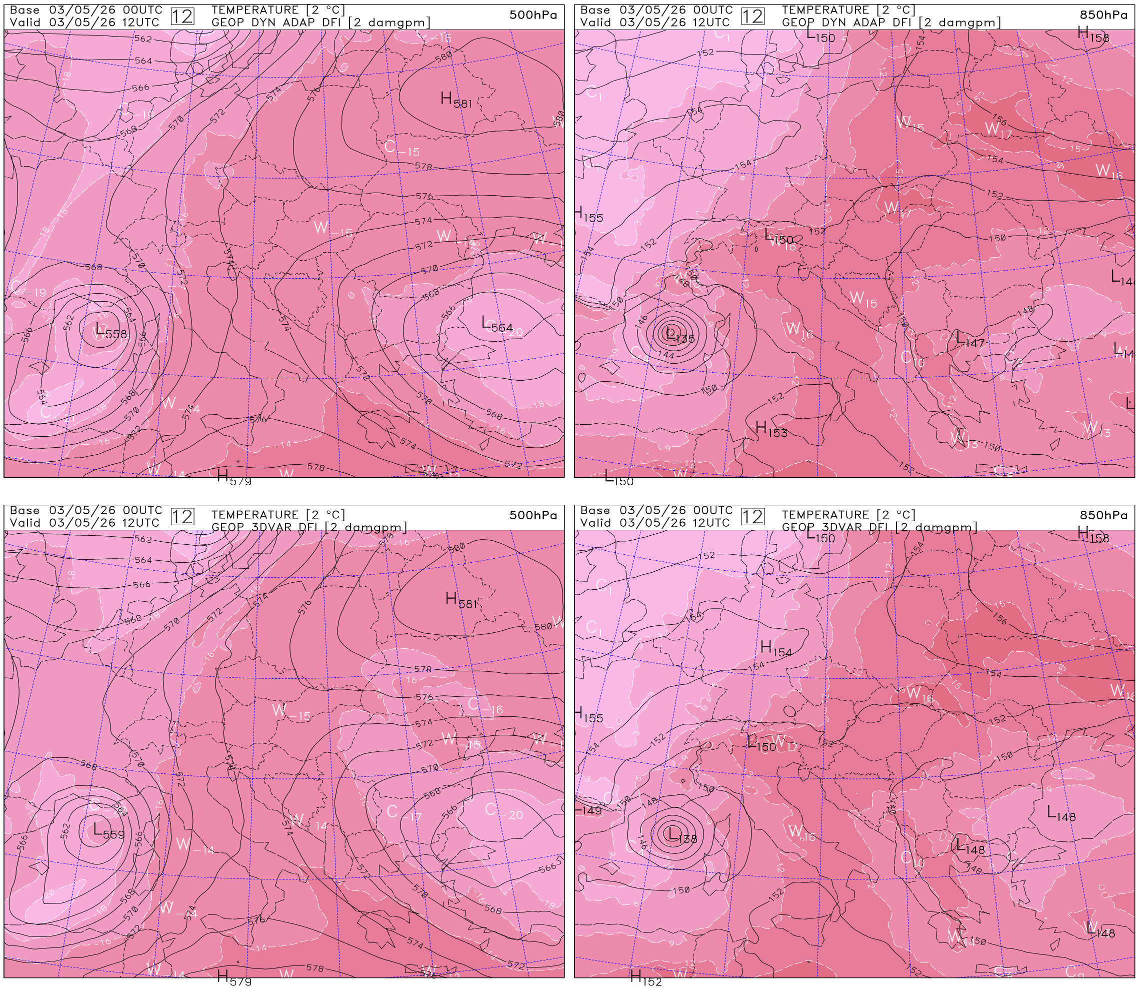

Figure 16: The 12h forecasts for geopotential and temperature at 500 hPa and 850 hPa of the operational model ("*dyn adap DFI*") (top) and using the 3D-Var scheme ("*3dvar DFI*") (bottom), from the 26.05.2003 00 UTC model run, valid at 26.05.2003 12 UTC

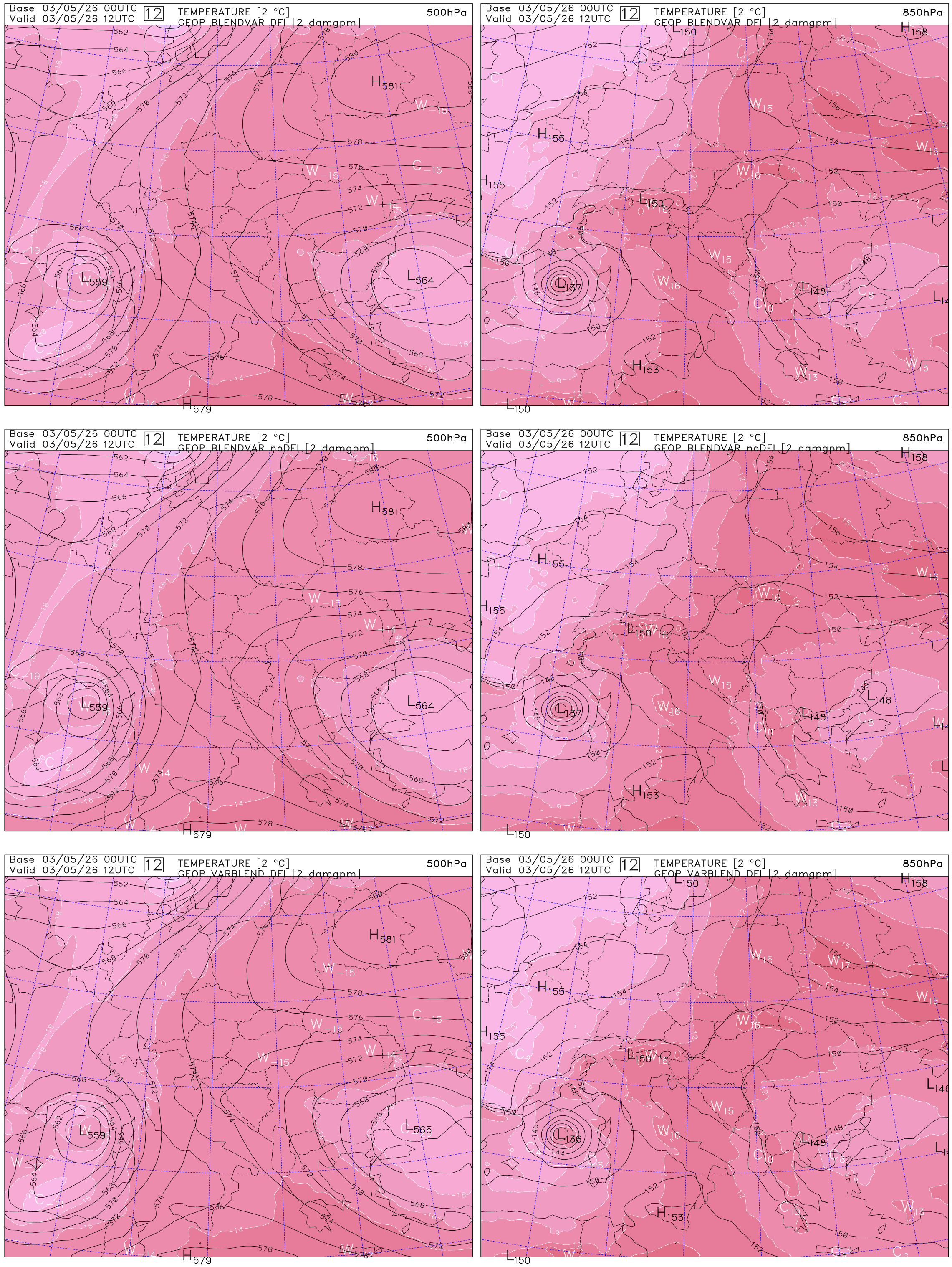

Figure 17: The 12h forecasts for geopotential and temperature at 500 hPa and 850 hPa of different experiments with the model using the 3D-Var scheme and the blending procedure ("*blendvar DFI*" (top), "*blendvar no DFI*" (middle) and "*varblend DFI*" (bottom)), from the 26.05.2003 00 UTC model run, valid at 26.05.2003 12 UTC

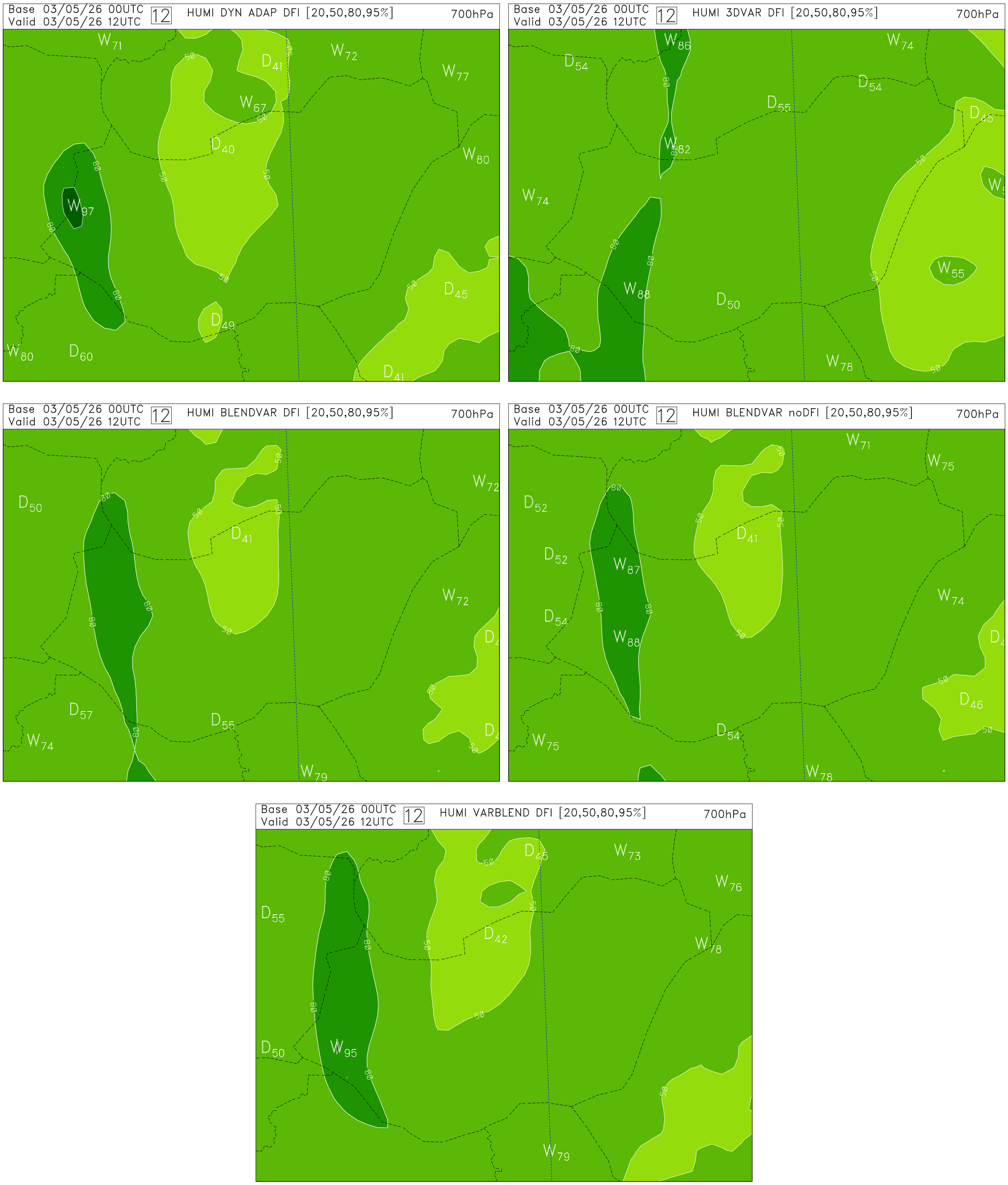

Figure 18: The 12h forecasts for relative humidity at 700 hPa of different experiments with the ALADIN/HU model ("*dyn adap DFI*" and "*3dvar DFI*" (top), "*blending DFI*" and "*blending no DFI*" (middle) and "*varblend DFI*" (bottom)), from the 26.05.2003 00 UTC model run, valid at 26.05.2003 12 UTC

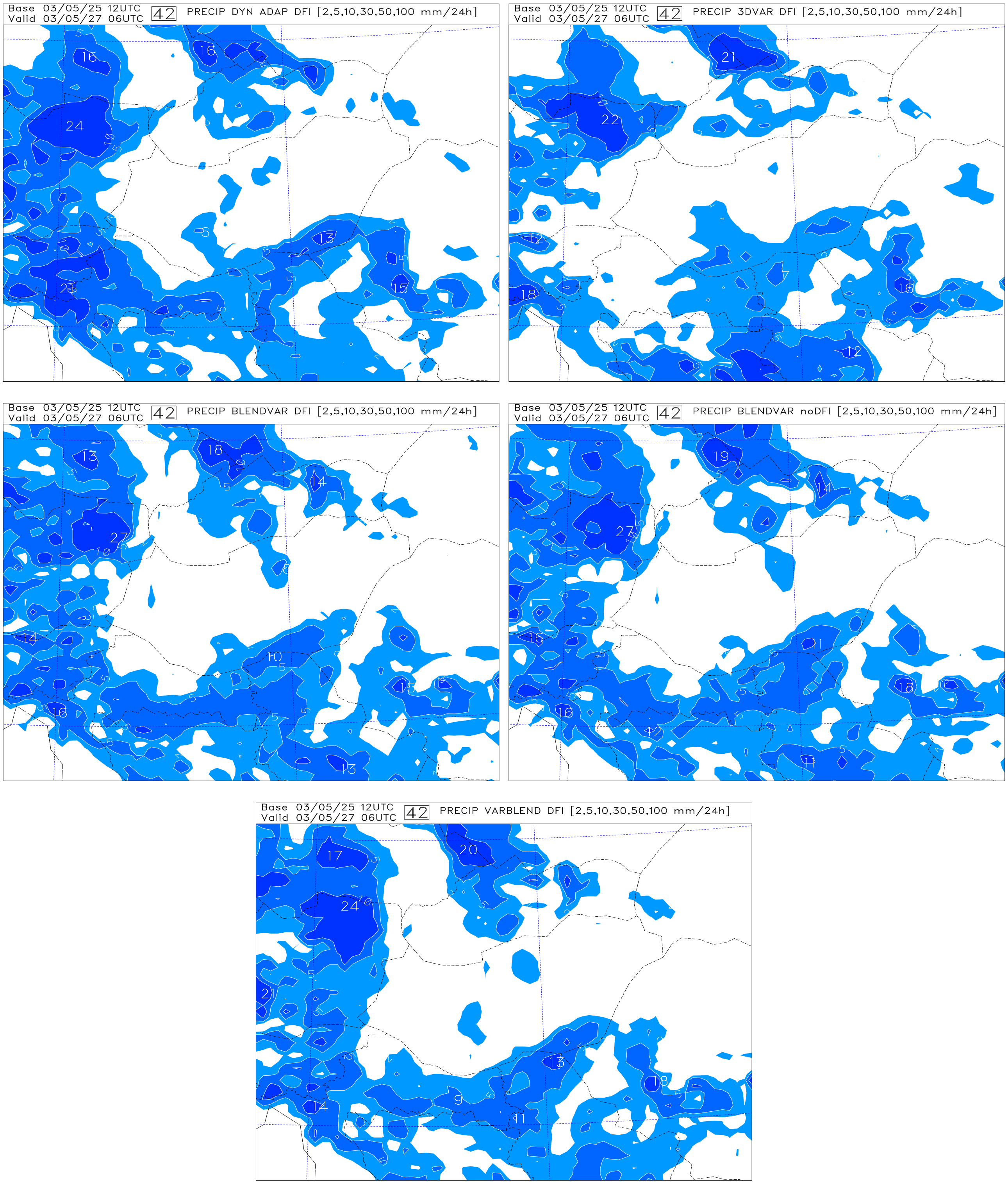

Figure 19: The quantity of precipitation (mm/24h) forecasted by different experiments with the ALADIN/HU model ("*dyn adap DFI*" and "*3dvar DFI*" (top), "*blendvar DFI*" and "*blendvar no DFI*" (middle) and "*varblend DFI*" (bottom)), from the 25.05.2003 12 UTC model run, between 26.05 06 UTC - 27.05 06 UTC

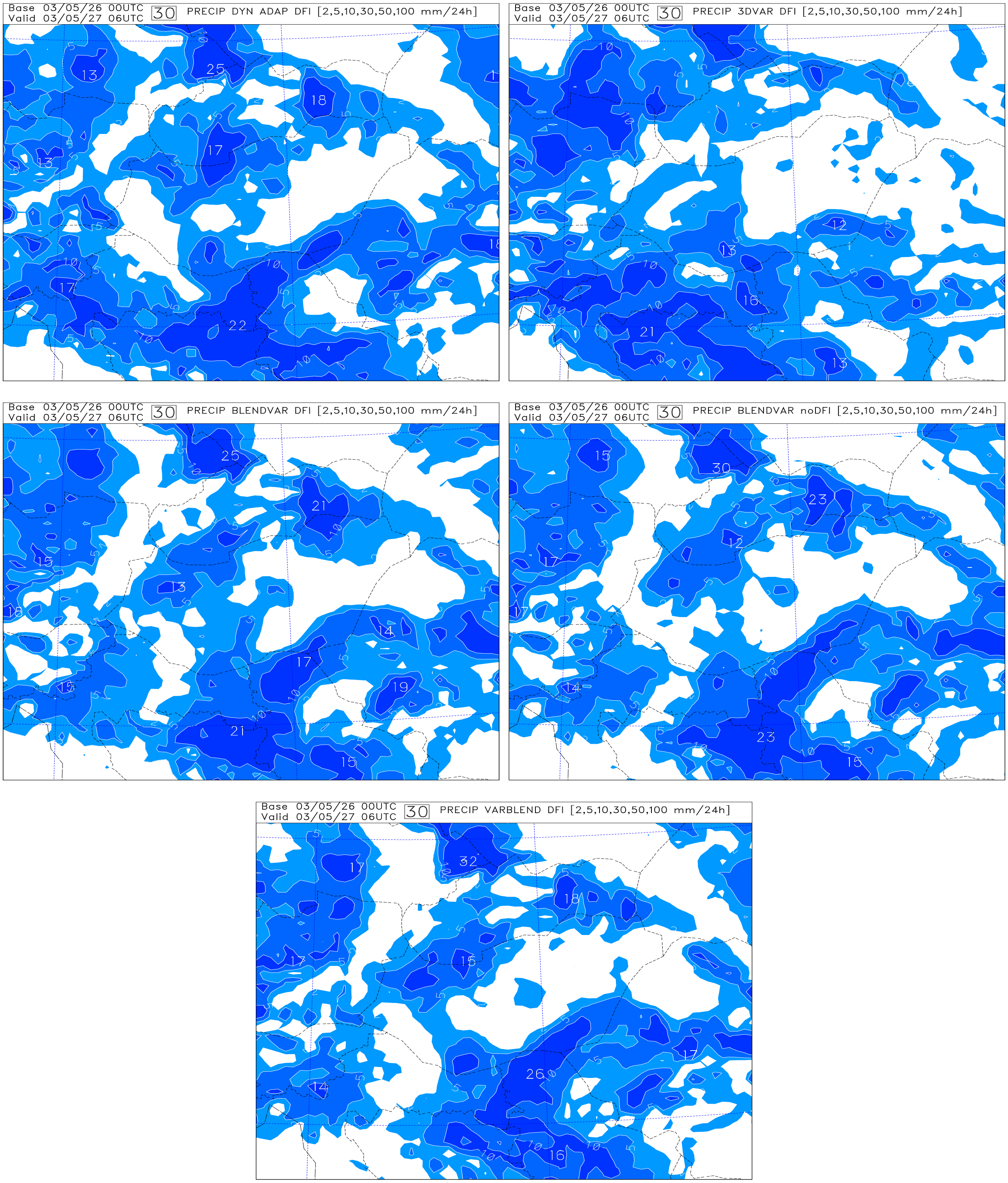

Figure 20: The quantity of precipitation (mm/24h) forecasted by different experiments with the ALADIN/HU model ("*dyn adap DFI*" and "*3dvar DFI*" (top), "*blendvar DFI*" and "*blendvar no DFI*" (middle) and "*varblend DFI*" (bottom)), from the 26.05.2003 00 UTC model run, between 26.05 06 UTC - 27.05 06 UTC

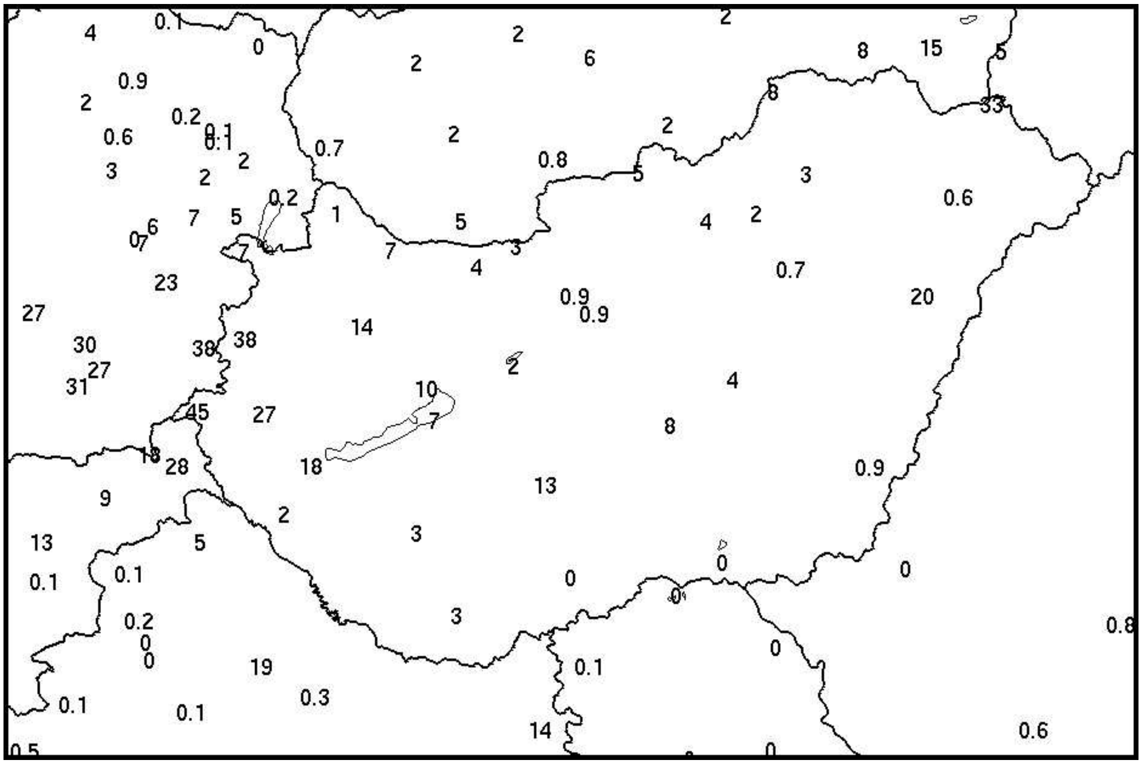

Figure 21: The quantity of precipitation (mm/24h) measured over Hungary between 11.06.2004 18 UTC - 12.06.2004 18 UTC

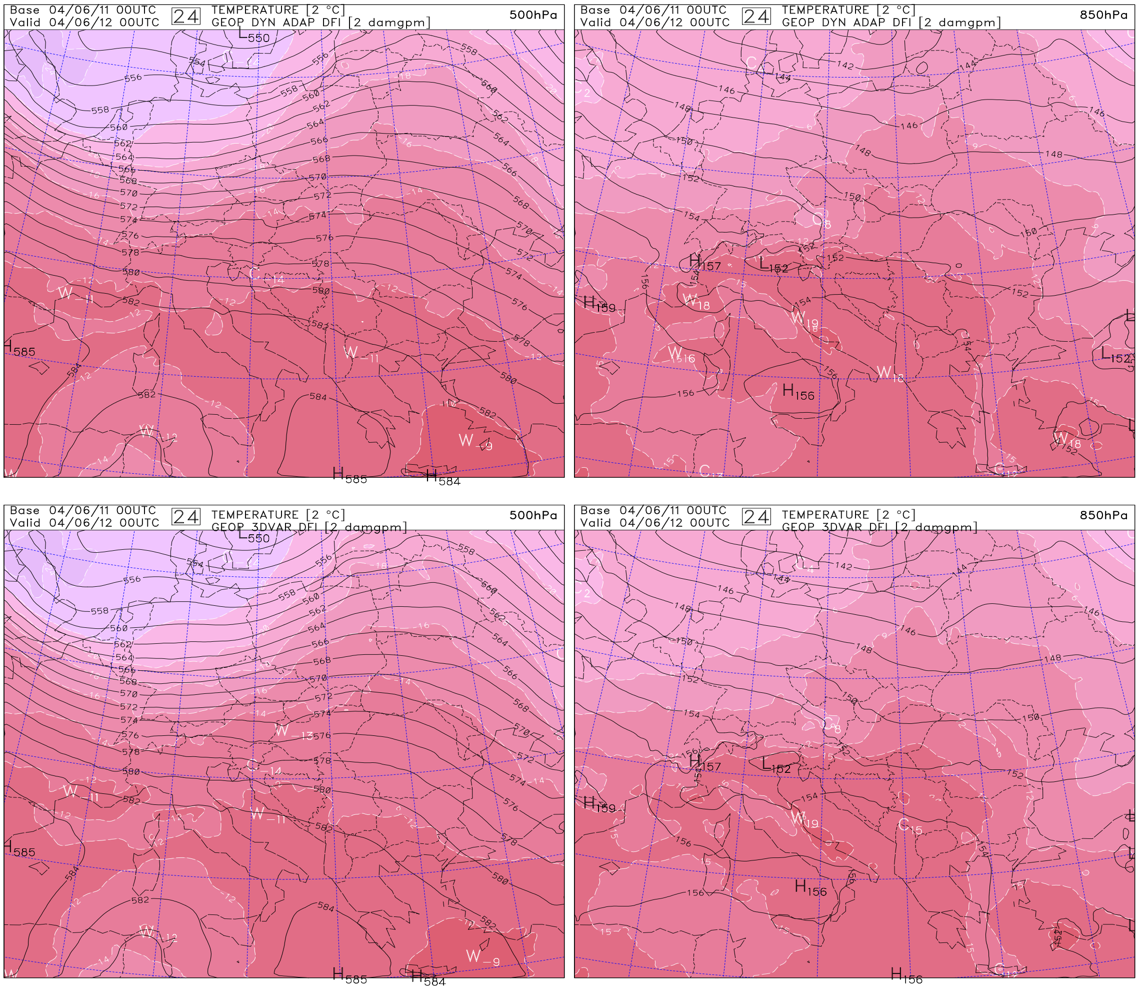

Figure 22: The 24h forecasts for geopotential and temperature at 500 hPa and 850 hPa of the operational model ("*dyn adap DFI*") (top) and using the 3D-Var scheme ("*3dvar DFI*") (bottom), from the 11.06.2004 00 UTC model run, valid at 12.06.2004 00 UTC

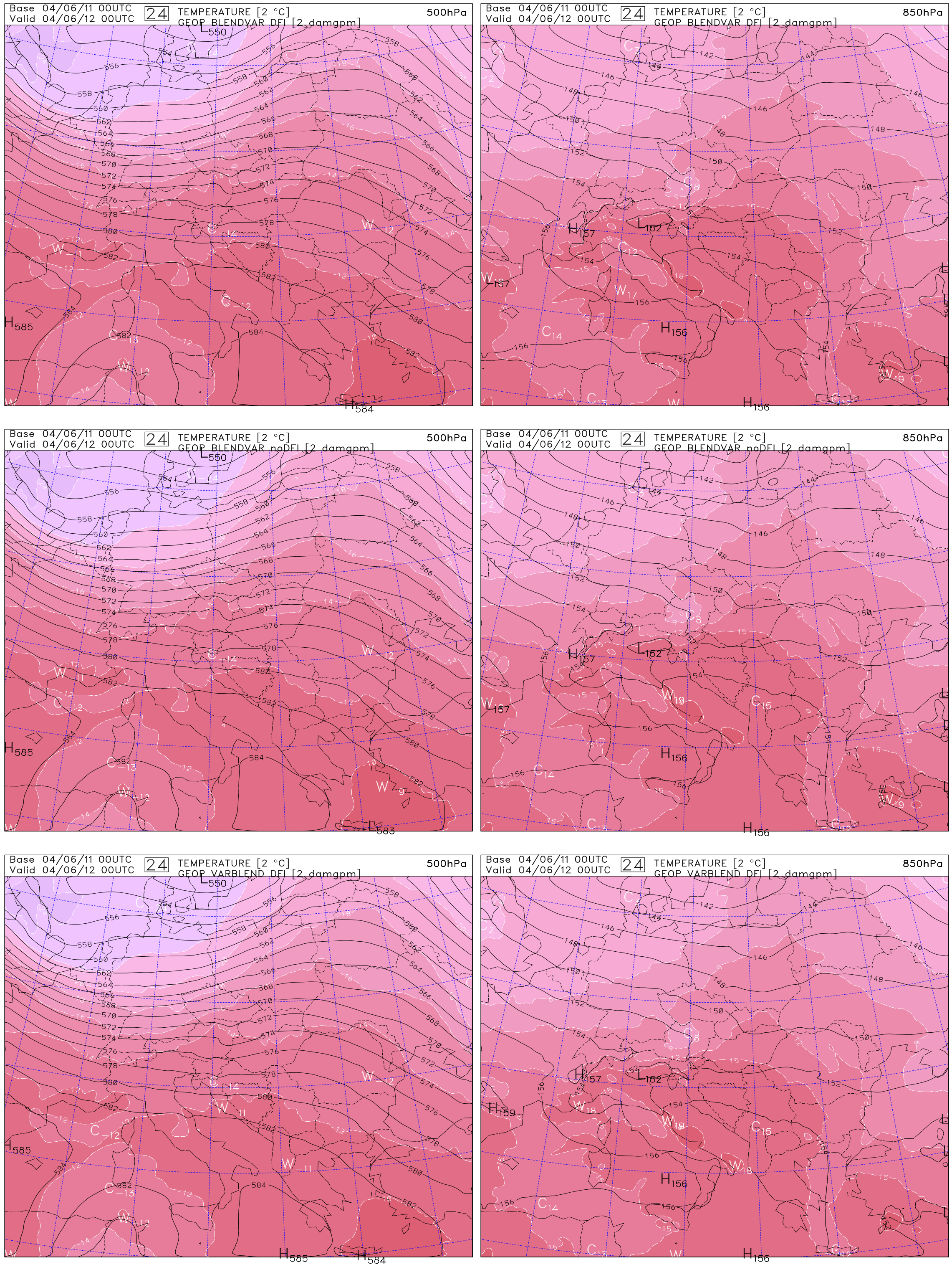

Figure 23: The 24h forecasts for geopotential and temperature at 500 hPa and 850 hPa of different experiments with the model using the 3D-Var scheme and the blending procedure ("*blendvar DFI*" (top), "*blendvar no DFI*" (middle) and "*varblend DFI*" (bottom)), from the 11.06.2004 00 UTC model run, valid at 12.06.2004 00 UTC

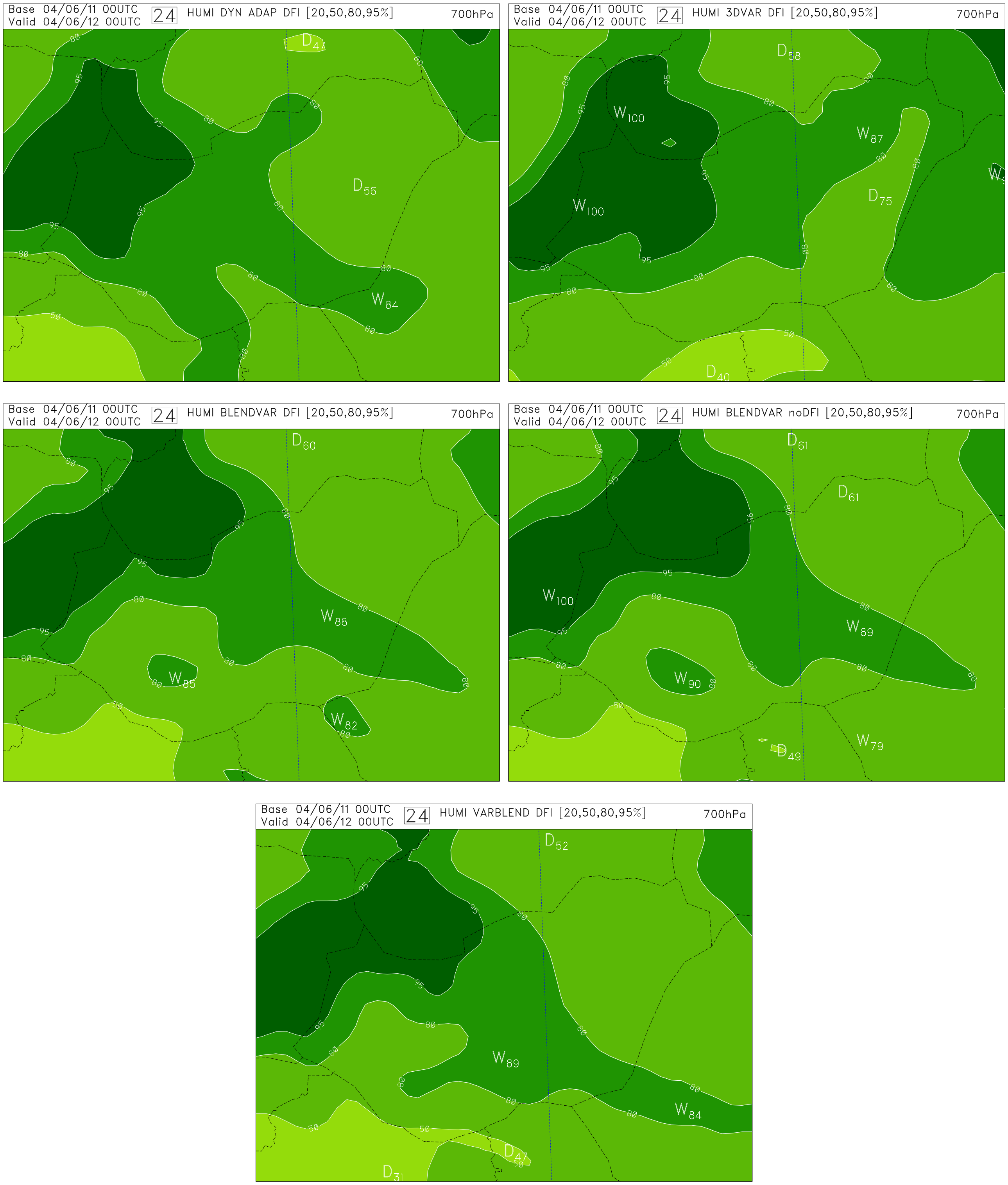

Figure 24: The 24h forecasts for relative humidity at 700 hPa of different experiments with the model using the 3D-Var scheme and the blending procedure ("*blendvar DFI*" (top), "*blendvar no DFI*" (middle) and "*varblend DFI*" (bottom)), from the 11.06.2004 00 UTC model run, valid at 12.06.2004 00 UTC

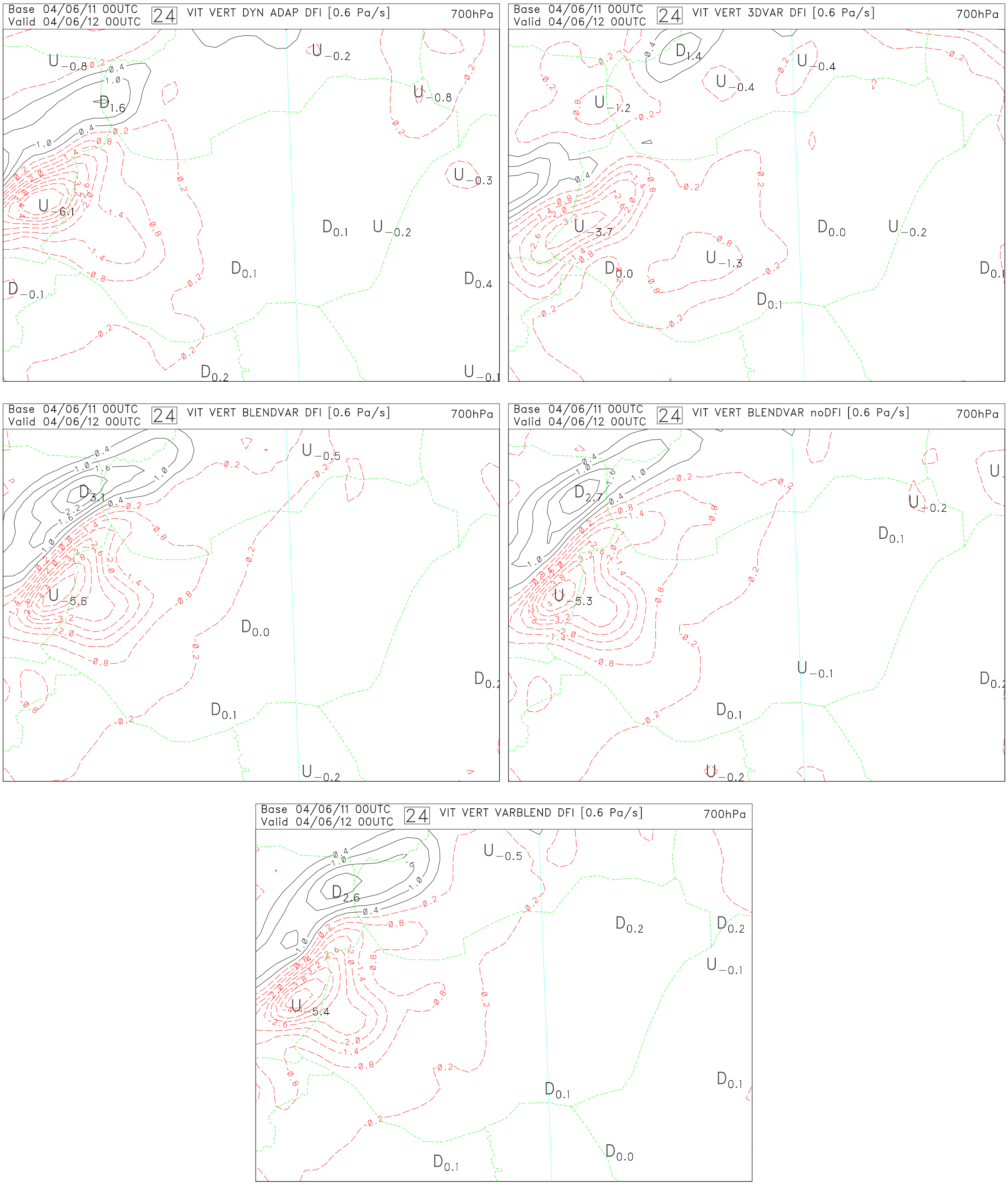

Figure 25: The 24h forecasts for vertical velocity at 700 hPa of different experiments with the model using the 3D-Var scheme and the blending procedure (”*blendvar DFI*” (top), ”*blendvar no DFI*” (middle) and ”*varblend DFI*” (bottom)), from the 11.06.2004 00 UTC model run, valid at 12.06.2004 00 UTC

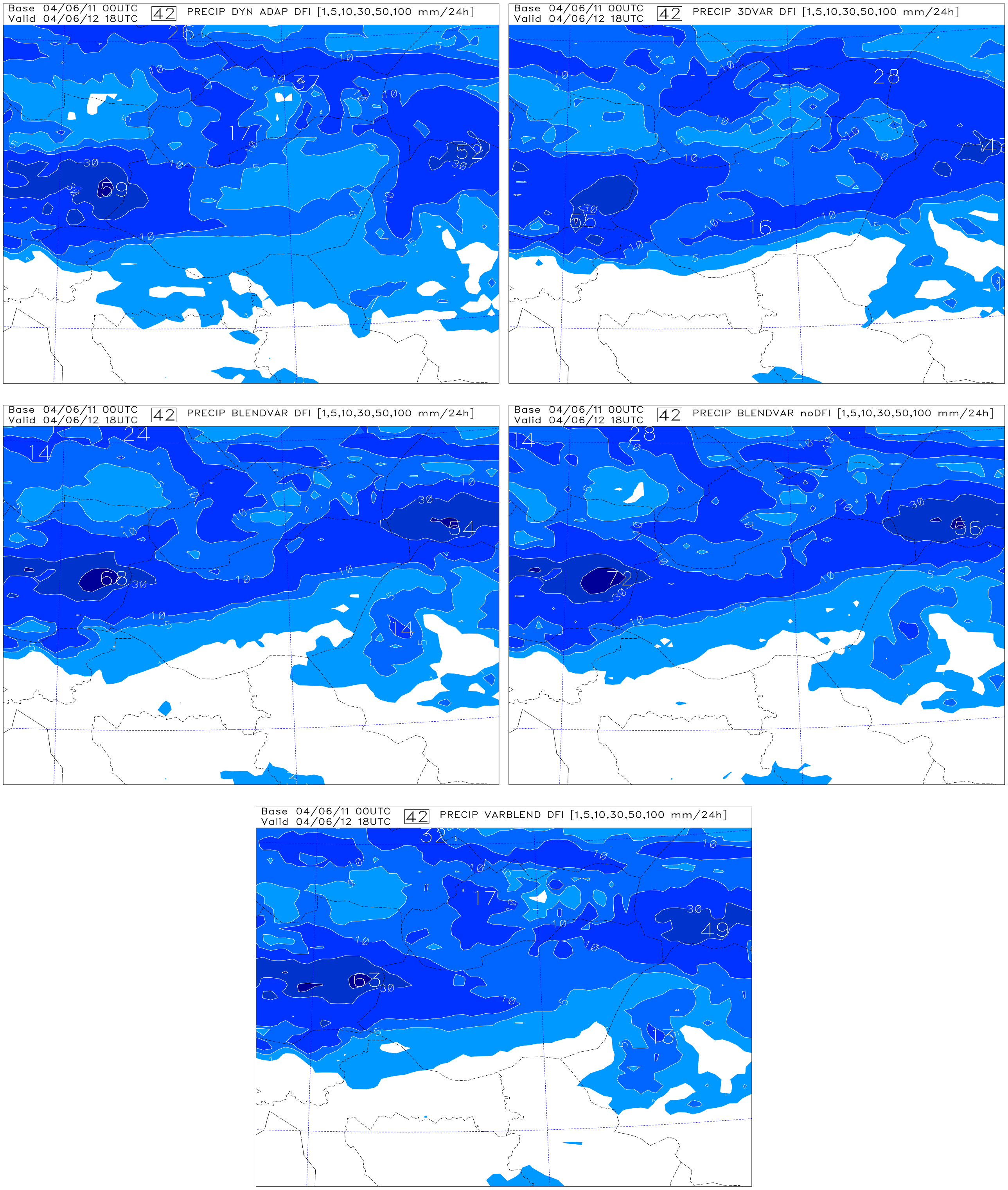

Figure 26: The quantity of precipitation (mm/24h) forecasted by different experiments with the ALADIN/HU model ("*dyn adap DFI*" and "*3dvar DFI*" (top), "*blendvar DFI*" and "*blendvar no DFI*" (middle) and "*varblend DFI*" (bottom)), from the 11.06.2004 00 UTC model run, between 11.06 18 UTC - 12.06 18 UTC

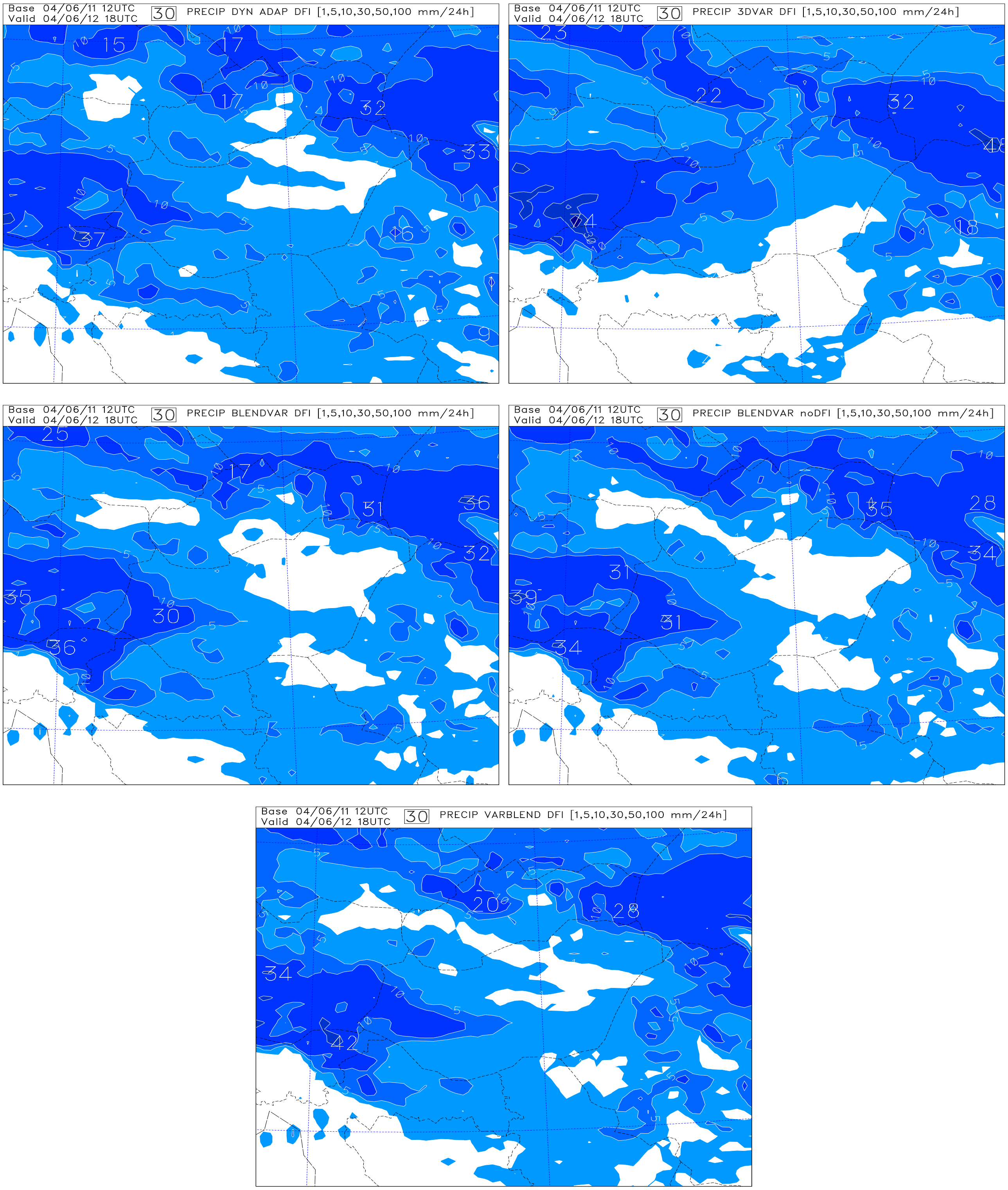

Figure 27: The quantity of precipitation (mm/24h) forecasted by different experiments with the ALADIN/HU model (”*dyn adap DFI*” and ”*3dvar DFI*” (top), ”*blendvar DFI*” and ”*blendvar no DFI*” (middle) and ”*varblend DFI*” (bottom)), from the 11.06.2004 12 UTC model run, between 11.06 18 UTC - 12.06 18 UTC