Further experiments with the 3D-VAR data assimilation scheme for ALADIN/Hungary model

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1 Introduction

The last experiments with 3D-VAR data assimilation scheme for ALADIN/ Hungary model are described in this paper. ALADIN/Hungary is a *double-nested limited area model*. ARPEGE, the French global model, provides the boundary conditions for ALADIN/LACE (a limited area model), which provides, at his turn, the boundary conditions for ALADIN/Hungary model. The resolution of ALADIN/LACE is 12 km, and of ALADIN/Hungary is 8 km.

The previous experiments with 3D-VAR scheme were performed only for one week (25.02.2002 - 02.03.2002). The aim of these experiments was to get a rough idea about the best possible strategy for the 3D-VAR scheme, trying to see which coupling technique, or initialization method, are better to be used. The main conclusions of these experiments were that as coupling technique, time-consistency seems to be a good choice, in cycling and in production we have to use digital filter initialization, and that the choice of the lateral boundary conditions (from the global model or limited area model) is important. It was showed that it would be better to use the files from the global model. Another conclusion was that it's better to use in cycling the analysis as the second lateral boundary condition file for the first-guess. (Alexandru, 2002).

So for these new experiments using 3D-VAR data assimilation scheme, the period was extended to one month, considering that the results will emphasize better the features of the variational assimilation, than those for one week only.

This report describes in section 2 the experiments performed with 3D-VAR scheme, then the results are presented in section 3, followed by conclusions.

2 3D-VAR experiments

3D-VAR data assimilation scheme consists in minimizing a cost-function in order to get the best fit to the available information sources. This function is a sum of three terms, the background term, representing the departures from the first-guess (usually, the 6h forecast from the previous integration of the model), the observation term, representing the departures from the observations, and the penalty term, measuring the departure from a filtered model state. At the moment for ALADIN model, only the two terms are defined. ALADIN/Hungary model is using for the background term, the standard NMC statistics (Parrish and Derber, 1992), and for the observation term, only SYNOP and TEMP data are considered.

We decided to perform experiments for one month's period (25.02.2002 - 25.03. 2002). We have chosen in cycling, to use the first-guess (the 6h forecast from the previous integration) obtained with ALADIN/LACE and ARPEGE files (from the assimilation cycle) as lateral boundary conditions (LBC), in space-consistency, with digital filter initialization, and with "Moroccan" solution (described below), as coupling method. In production, for 6h forecast (because we had only the first two LBC files), the digital filter initialization was applied.

The space-consistency coupling technique means that the first two LBC files are not coming from the same integration of the model. The first LBC file ("00h") is identical with the initial file, which is 3D-VAR analysis. Thus the information is consistent in space (Široká, 2001).

The "Moroccan" solution means that in cycling, the initial and the first LBC files are 3D-VAR analysis, and the second LBC file is ALADIN/LACE, respectively ARPEGE analysis. In production, the initial and the first LBC files are 3D-VAR analysis, and the second LBC file is the 6h forecast of the ALADIN/LACE, respectively ARPEGE models. And the only possible coupling technique was space-consistency.

For simplicity, the names of the experiments were chosen "*LACE*", when ALADIN/LACE LBC files were used and "*ARPEGE*" when the ARPEGE one's.

3 Results

The verification scores against observations (as vertical profiles, from the surface till 400 hPa), the echkevo scores for three chosen days, and maps of the mean sea level pressure increments were plotted.

3.1 Verification

We have to mention first about the number of observations used in the assimilation process. In Figures 1, 2, the geographical distribution of the stations is represented (the black circles show the location of SYNOP stations, and blue rhombus, TEMP stations). As we can see the number of observations at 06 UTC is much smaller, than at 00 UTC, especially for TEMP data, which means that also the statistical scores do not have the same precision, as those for 00 UTC. The number of TEMP observations decreases for 12 UTC (with respect to 00 UTC), and for 18 UTC (with respect to 06 UTC). But even in this situation the scores give us a rough idea about how the forecast using 3D-VAR data assimilation scheme is behaving compared to the operational one's.

The results of the verification are presented in Figures 3-18. In Figures 3-6, and 11-14, the verification scores are plotted for one week period (25.02.2002 - 02.03.2002), as reference for the last experiments.

One can see that:

- At the time 00h, the analyses for relative humidity and wind, using 3D-VAR scheme are better represented than the operational analysis, for all levels (Figures 7, 8, 15, 16). The temperature has also better scores using 3D-VAR scheme, but the difference is not significant as for the previous fields. The shapes for geopotential looks different when the base is 00 UTC or 12 UTC. Near the surface, the curves are the same. Then, for 00 UTC, the operational analysis at the model levels, near to the surface, has better scores (but the difference is small), and above 700 hPa, 3D-VAR improved the analysis (Figure 7). For the base 12 UTC, the operational analysis is better than the 3D-VAR one's (Figure 15).

- After 6h integration, the scores for temperature and geopotential are almost neutral, with small variations near the surface, for temperature, and also at some upper-levels for geopotential. But compared to the analysis we can say that the forecast of the geopotential, using 3D-VAR scheme, was improved. The 6h forecast of the relative humidity for the base 00 UTC, shows an improvement using 3D-VAR scheme especially near the surface, but for the upper-levels, the operational forecast is slightly better. For the base 12 UTC, at the surface the curves are identical, and for the upper-levels, the forecast of the relative humidity with 3D-VAR scheme is better, for some levels (Figures 9, 17).

- The scores of the 6h forecast for wind are the same at the surface. For upper-air, the meridional wind is better in the operational forecast, than with 3D-VAR scheme. For wind direction, the scores are almost neutral, and for wind speed and zonal wind, with 3D-VAR scheme, the forecast looks slightly better than in dynamical adaptation, but not for all levels. (Figures 10, 18).

- We can consider that one month's period is more representative for the results with 3D-VAR scheme for ALADIN/Hungary model. Comparing to the first experiments, it was shown that the forecast of the temperature using 3D-VAR scheme is not worse than the operational forecast. It seems that the meridional wind have better scores for 6h forecast in dynamical adaptation, while the zonal wind is keeping from the initial improvement for most of the upper-levels. And the forecast of the geopotential is improved when the 3D-VAR scheme was used.

- The last experiments emphasized that the choice of ALADIN/LACE or ARPEGE files as lateral boundary conditions is not so important. For analysis, the differences are very small, and for 6h forecast, the shapes are slightly different, especially for wind.

3.2 Echkevo

The time evolution of the mean sea level pressure was checked during 6h integration in production, for the model in dynamical adaptation, and using 3D-VAR scheme with ALADIN/LACE and ARPEGE LBC files.

Three days were chosen to plot the echkevo scores, in the first week (28.02.2002), at the middle (14.03.2002), and at the end (25.03.2002) of the selected period. The chosen points over the domain were kept as in the previous experiments:

◇ [5, 5] - a point in the coupling zone (bottom-left corner of the domain),

◇ [22, 52] - a point over the mountains,

◇ [51, 61] - a point over the mountains,

◇ [90, 70] - a point in the middle of the domain,

◇ [138, 93] - a point over the mountains,

◇ [170, 120] - a point in the upper-right corner of the domain.

Comparing the echkevo scores of the operational forecast (with digital filter initialization) to those using 3D-VAR scheme, we can see that generally, the curves are smooth. The biggest oscillations are for the points over the mountains. But we can conclude that the fields are in balance (Figures 19-21).

Also the scores for the model in dynamical adaptation without initialization were plotted. As we can see the impact of DFI is not so strong, which means that the fields provided by ALADIN/LACE model are already in balance.

3.3 Maps of increments

In Figures 22-24, the maps with the mean sea level pressure increments are drawn, for the same days as the echkevo scores. The plotted increments are:

- 3D-VAR analysis - first-guess
- DFI analysis - 3D-VAR analysis
- DFI analysis - first-guess

Comparing the increments from these three days we cannot say that one combination (with ALADIN/LACE or ARPEGE LBC files) shows smaller values. The difference between increments is not bigger than 0.2 hPa. Many increments have the same values.

In Figure 25, the mean sea level pressure of the operational analysis was plotted, from the same days as the echkevo scores, to compare to the 3D-VAR analysis. But the differences are very small.

4 Conclusions

In this paper, the results of the experiments using 3D-VAR data assimilation scheme of the ALADIN/Hungary model are described. The period of the experiments was extended to one month. We consider that the results should be representative now, compared to those from the previous stay (Alexandru, 2002).

We have to notice about the number of observations which are assimilated at different moments of time. For 06 UTC and 18 UTC the number of observations, especially for the TEMP data, is much smaller than at 00 UTC and 12 UTC. The SYNOP data are more numerous. But 3D-VAR is acting for the upper-air. The verification procedure for upper-levels uses only these data. Perhaps, one of the reasons that the scores of the verification of the forecast are so different from those of the analysis, is exactly the lack of data to be compared.

The 3D-VAR analysis fits closer to observations, as we expected. But after 6h integration, the forecast is losing from the initial improvement. The meridional wind is the only field that is better predicted in dynamical adaptation at all levels. The relative humidity, zonal wind and wind speed have better scores using 3D-VAR scheme, but not for all levels. The forecasts of temperature and wind direction are very close to the operational one. For geopotential, the scores show a slightly improvement after 6h integration, when 3D-VAR scheme was used.

The fields are in balance, confirmed by the echkevo scores, and the maps with mean sea level pressure increments didn't show big differences between the two combinations of the 3D-VAR experiments (with ALADIN/LACE and ARPEGE LBC files). This is in agreement with the verification scores, which were almost the same when different LBC files were used.

These first experiments with 3D-VAR scheme for ALADIN/Hungary model described in this paper and in Alexandru (2002), were performed to select from many options that we have (different first-guesses, lateral boundary conditions, initialization methods, coupling techniques, coupling methods, etc.), the best ones, to be able to study 3D-VAR scheme more in detail. Our future work will rely on the case studies, with some interesting meteorological situations.

5 References

Alexandru, S., 2002: 3D-VAR data assimilation experiments for the double-nested limited area model ALADIN/Hungary. *ALATNET Internal Note*.

Parrish, D., and Derber, J., 1992: The National Meteorological Center's spectral statistical interpolation analysis system. *Mon. Weather Rev.*, **120**, 1747–1763.

Široká, M., 2001: Report on experiments with ALADIN/LACE 3DVAR: combination of 3DVAR with lagged statistics and blending by DFI. *RC LACE internal report*.

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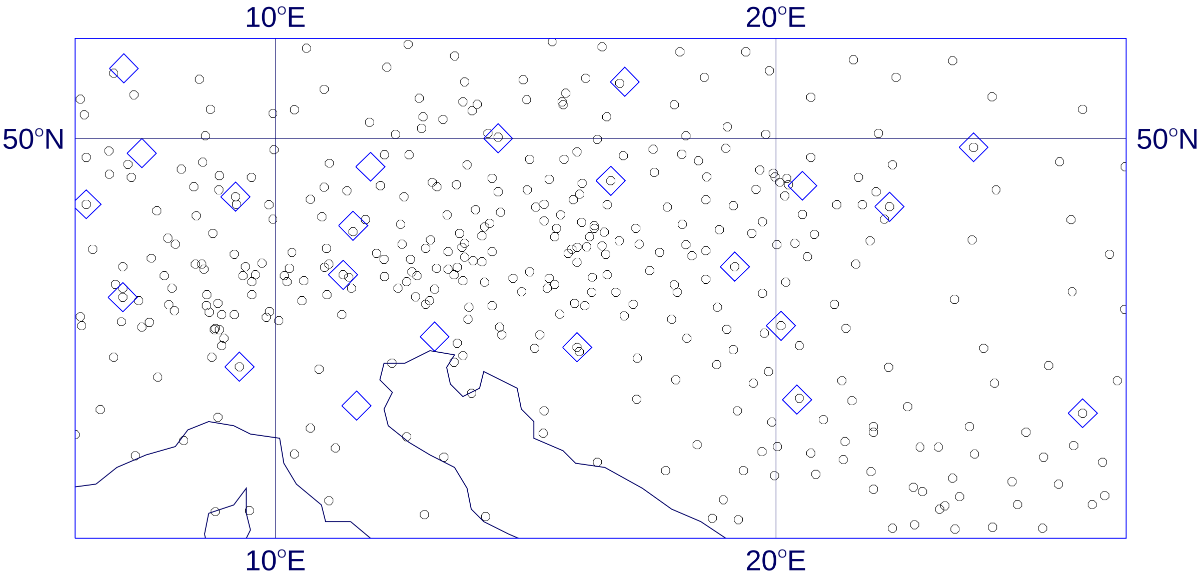


Figure 1: Typical distribution of observations at 00 UTC (black circles - SYNOP, blue rhombus - TEMP)

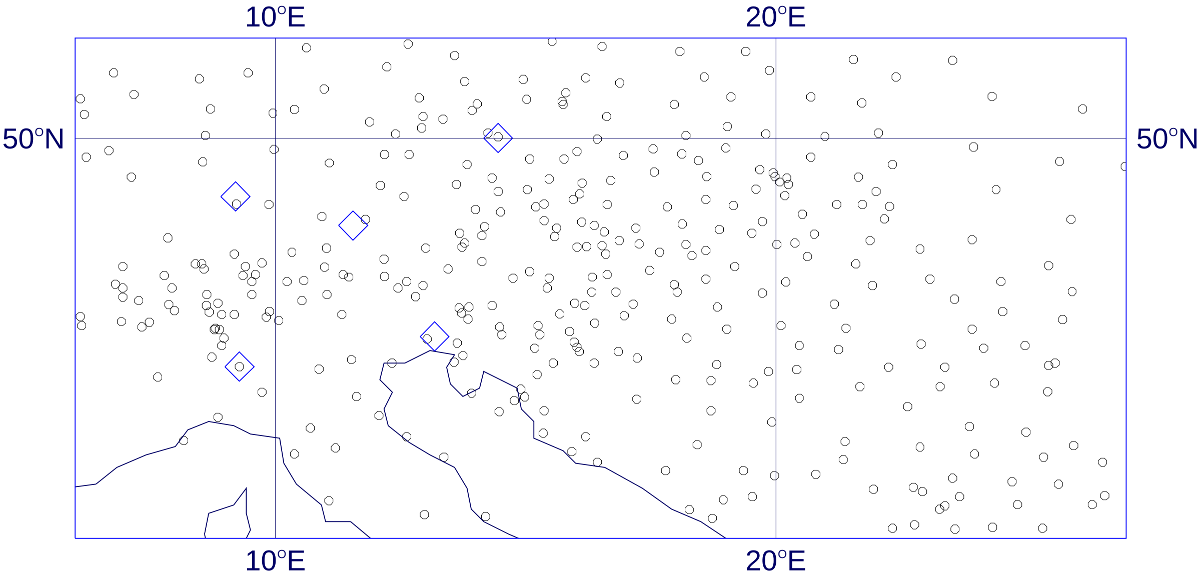


Figure 2: Typical distribution of observations at 06 UTC (black circles - SYNOP, blue rhombus - TEMP)

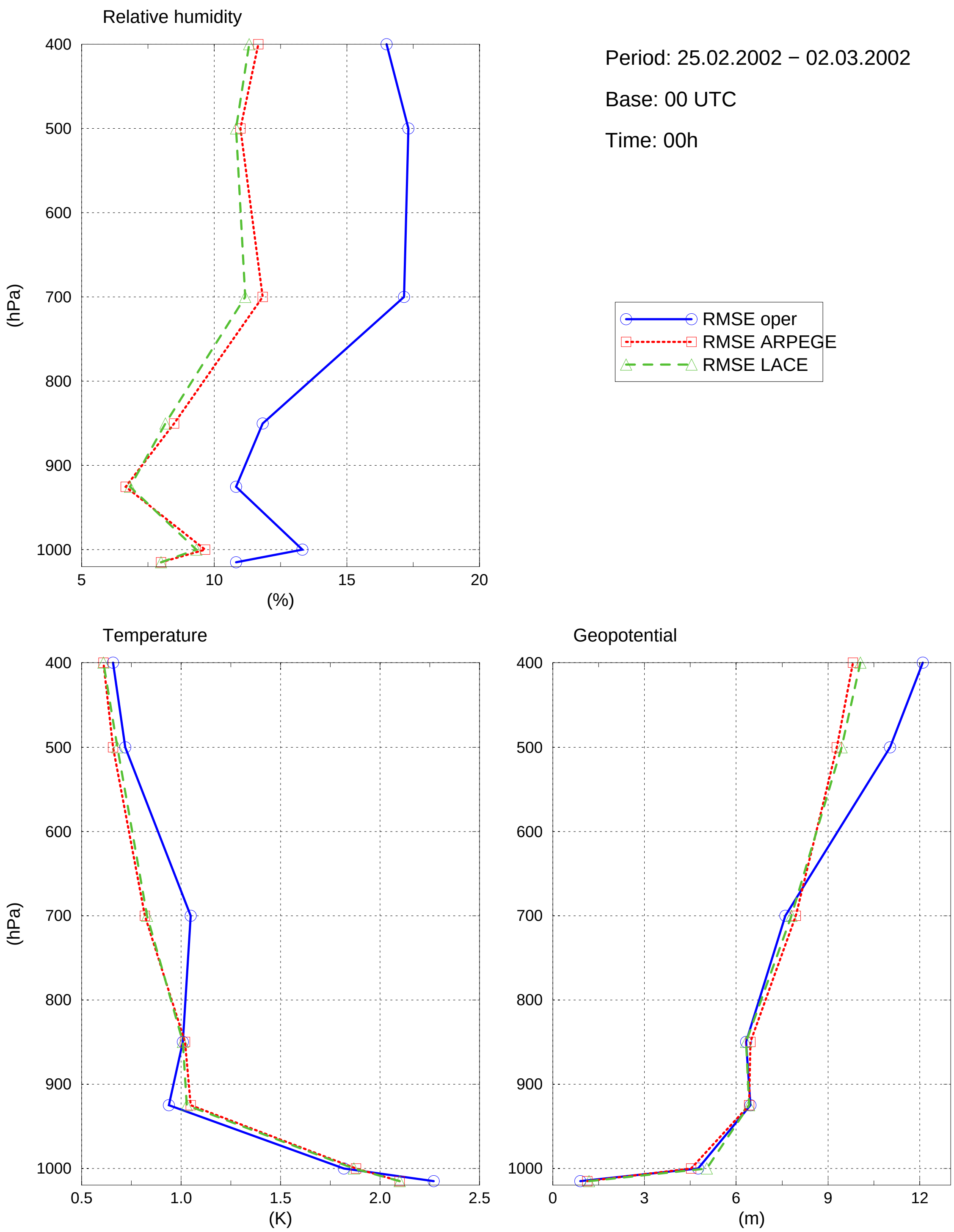
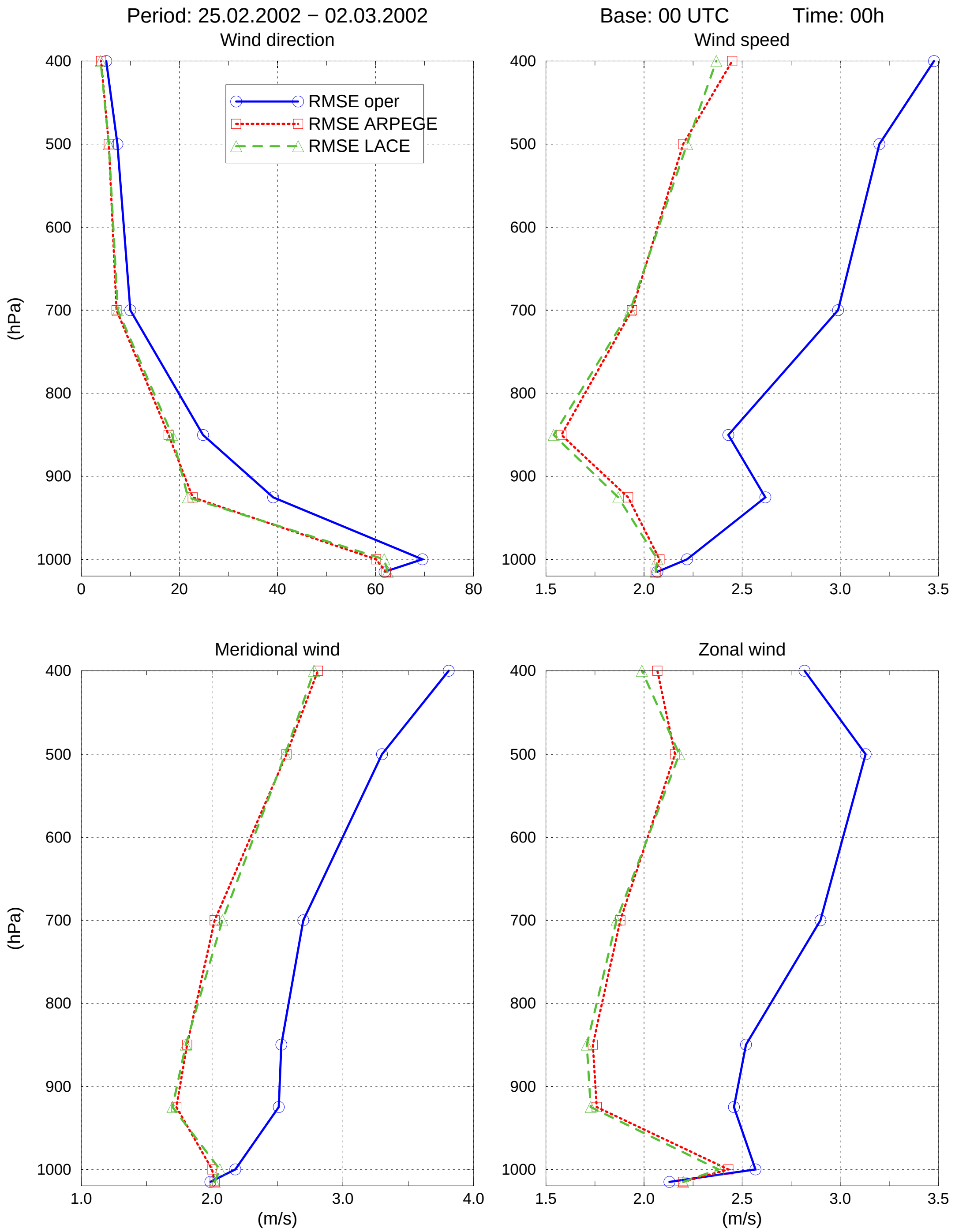


Figure 3: The vertical profile of RMSE for the operational analysis (*oper*), and using 3D-VAR scheme with ALADIN/LACE (*LACE*) and ARPEGE LBC files (*ARPEGE*) for relative humidity, temperature, geopotential for the period 25.02.2002 - 02.03.2002, base 00 UTC



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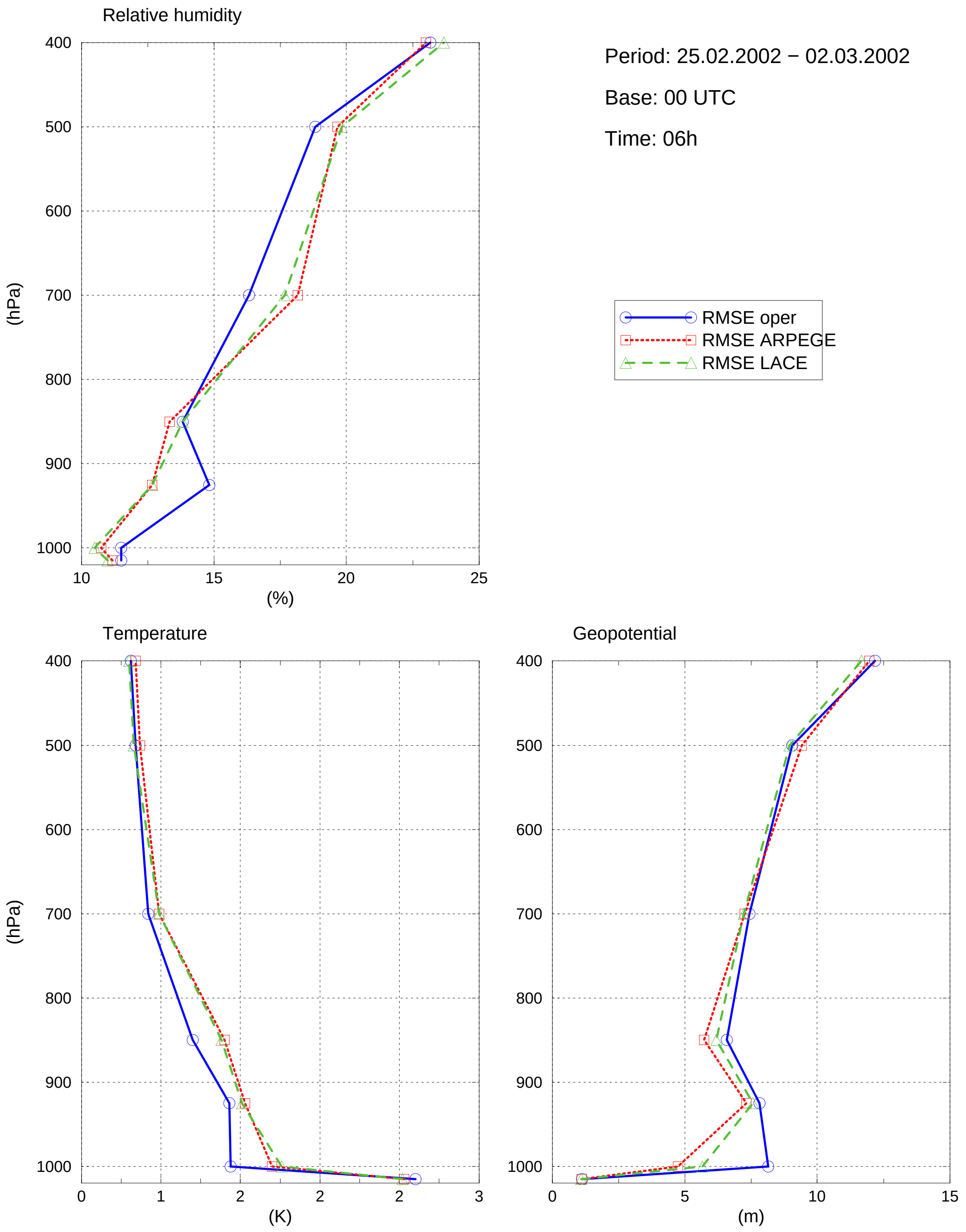
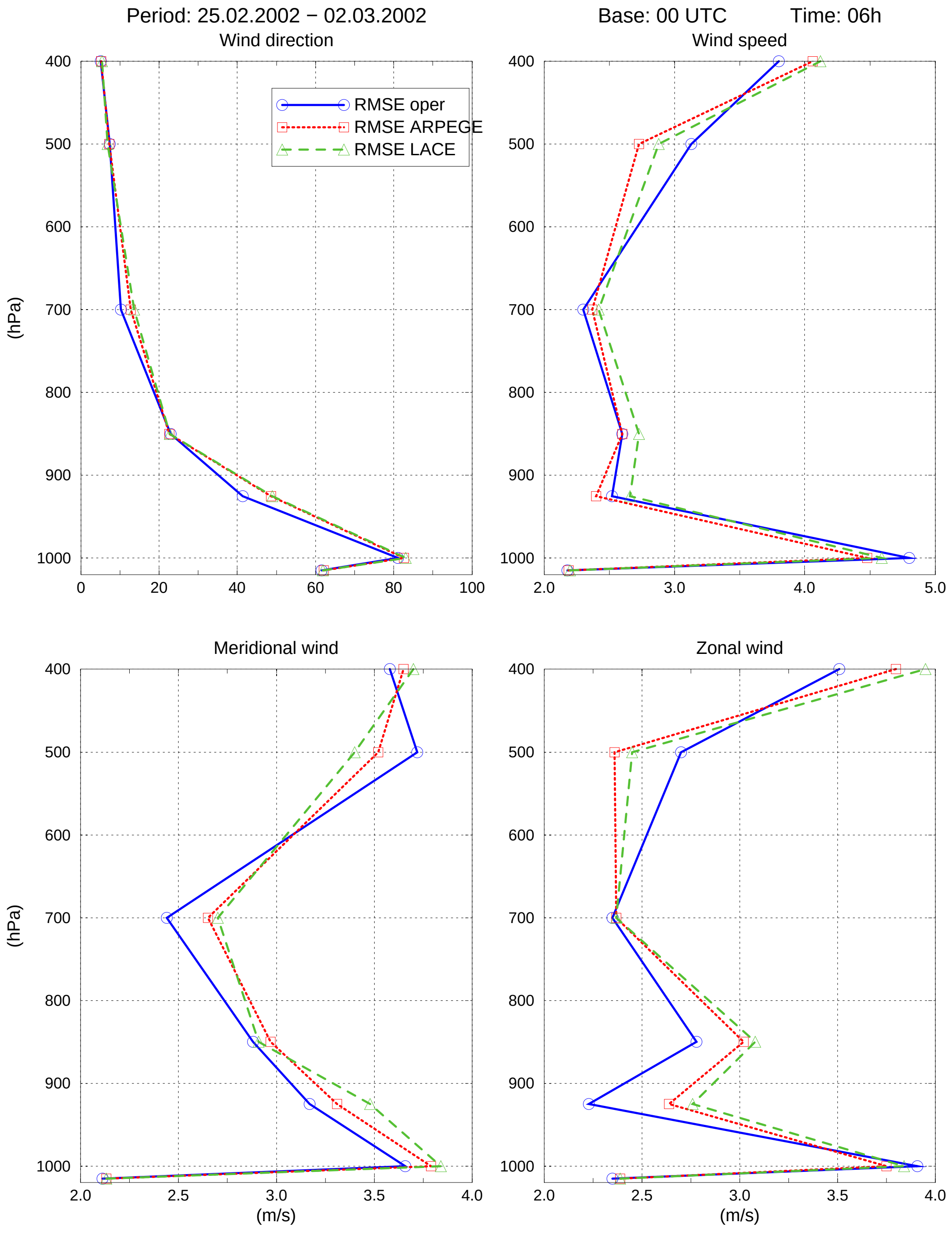


Figure 5: The same as Figure 3, but after 6h integration



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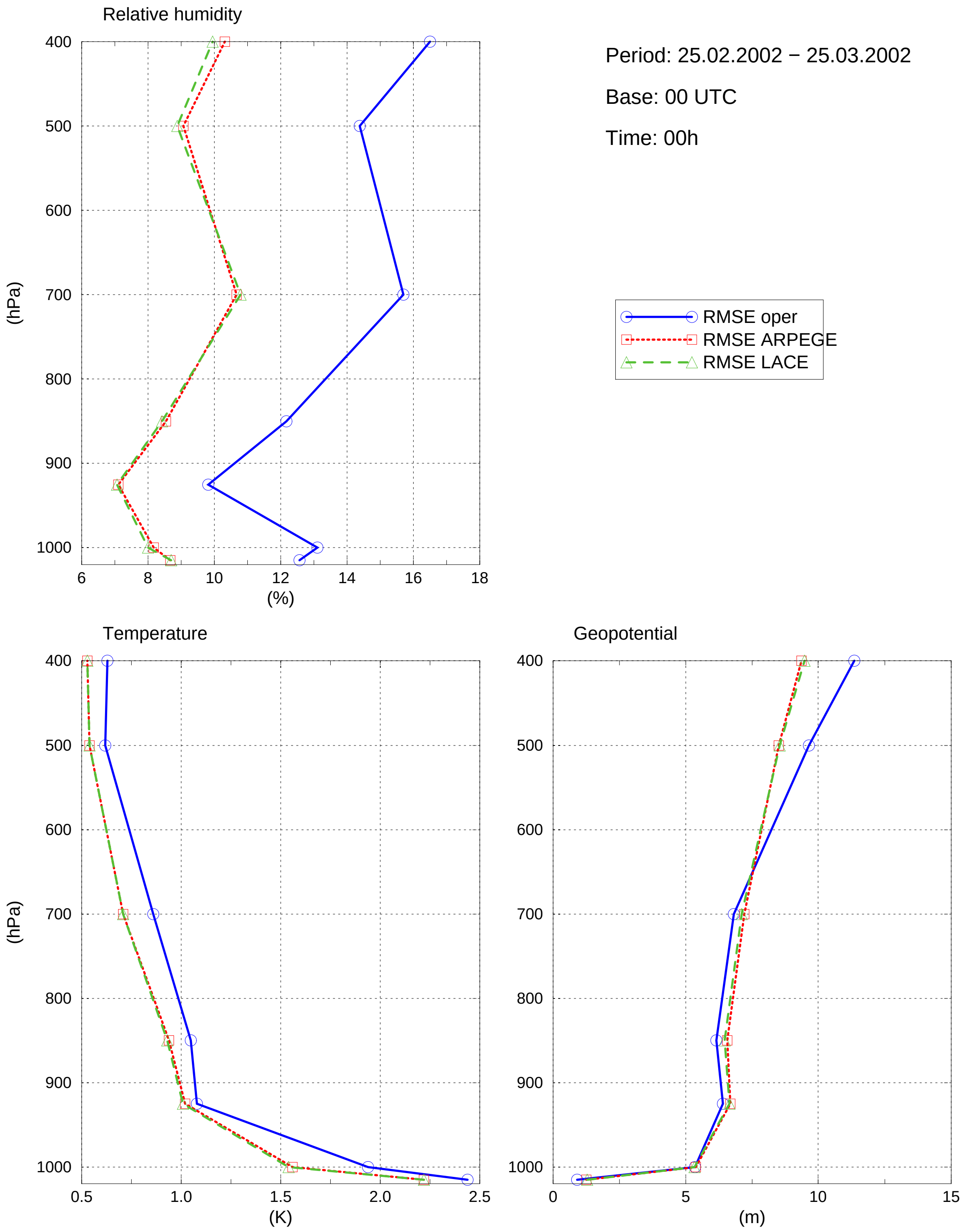

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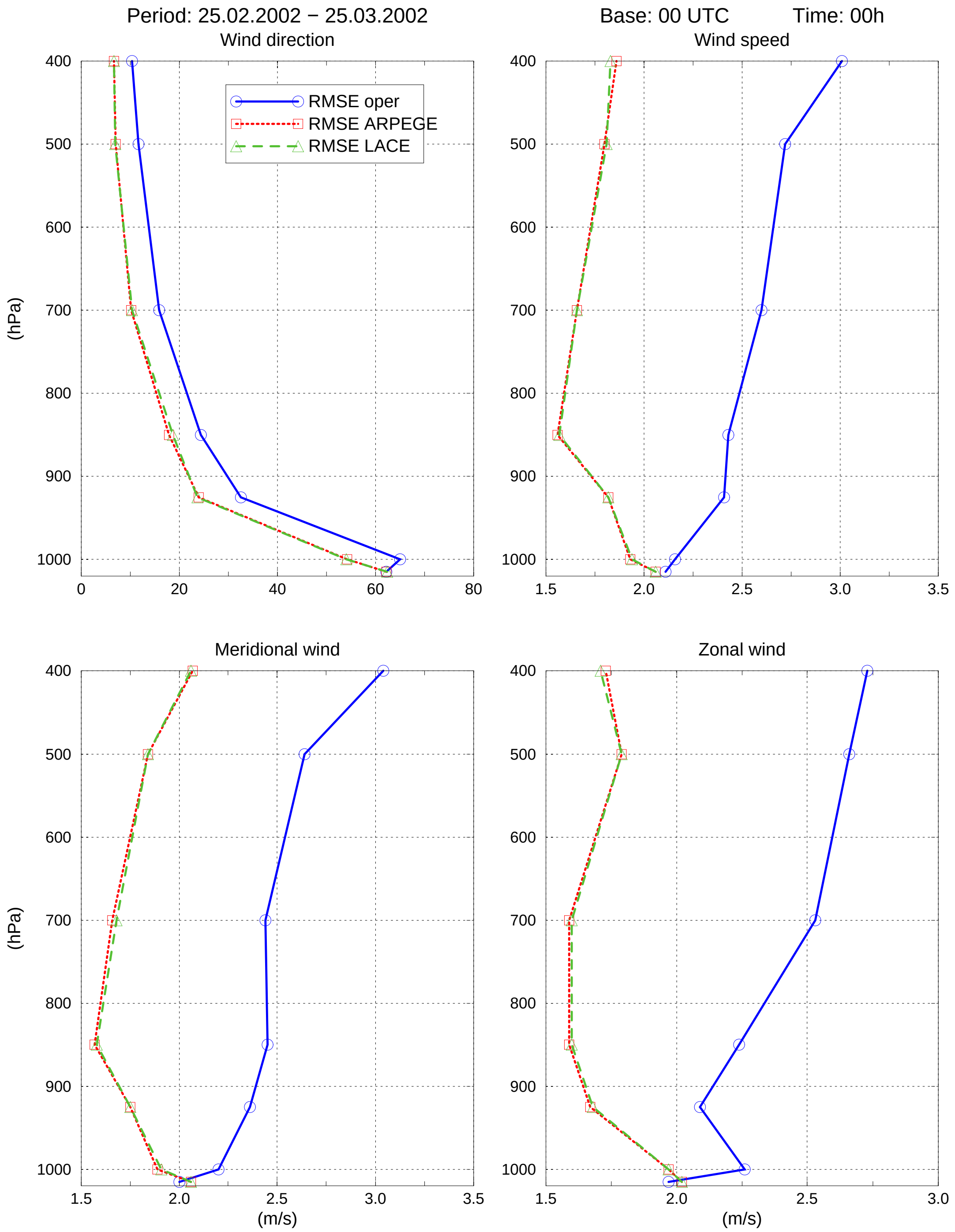

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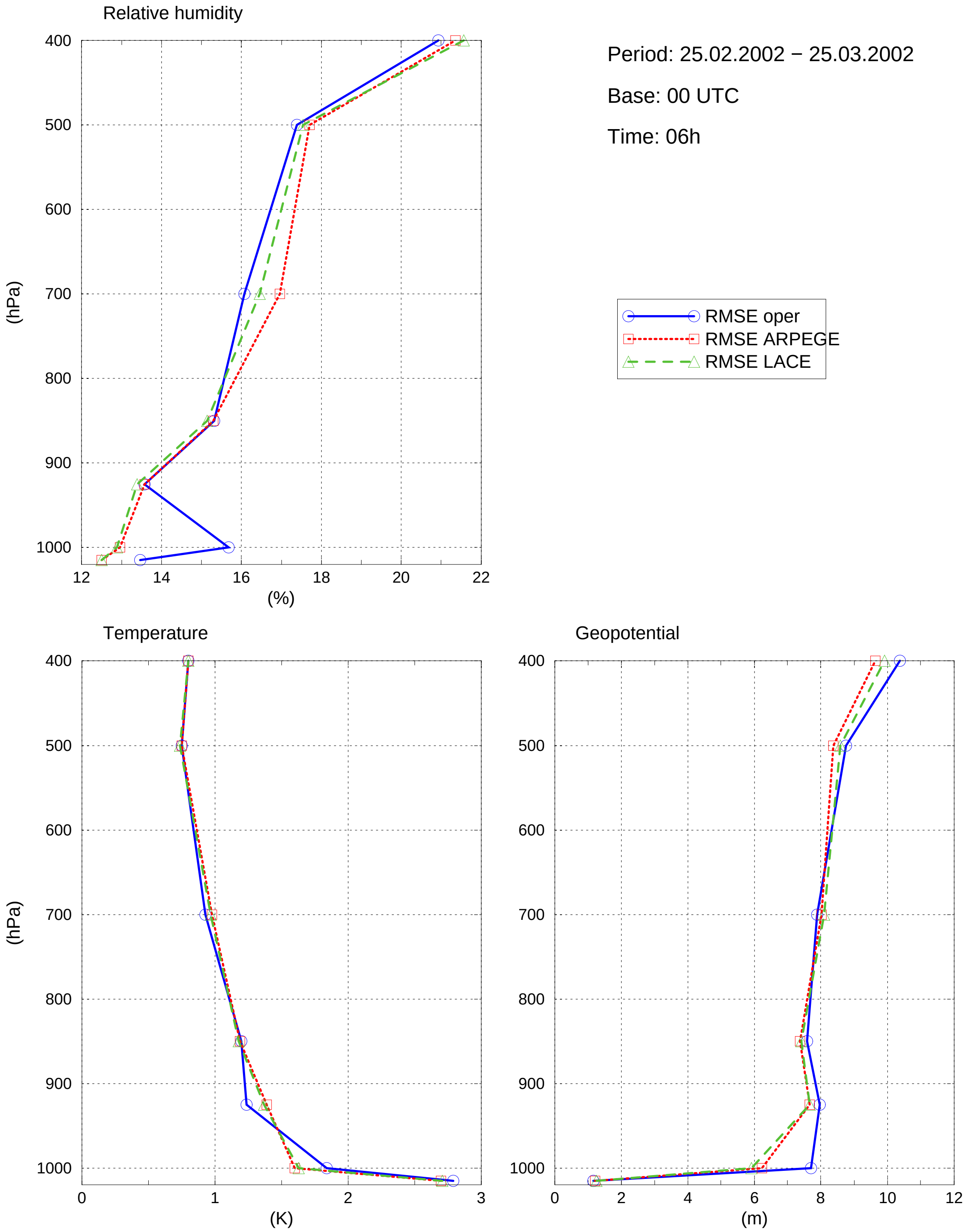

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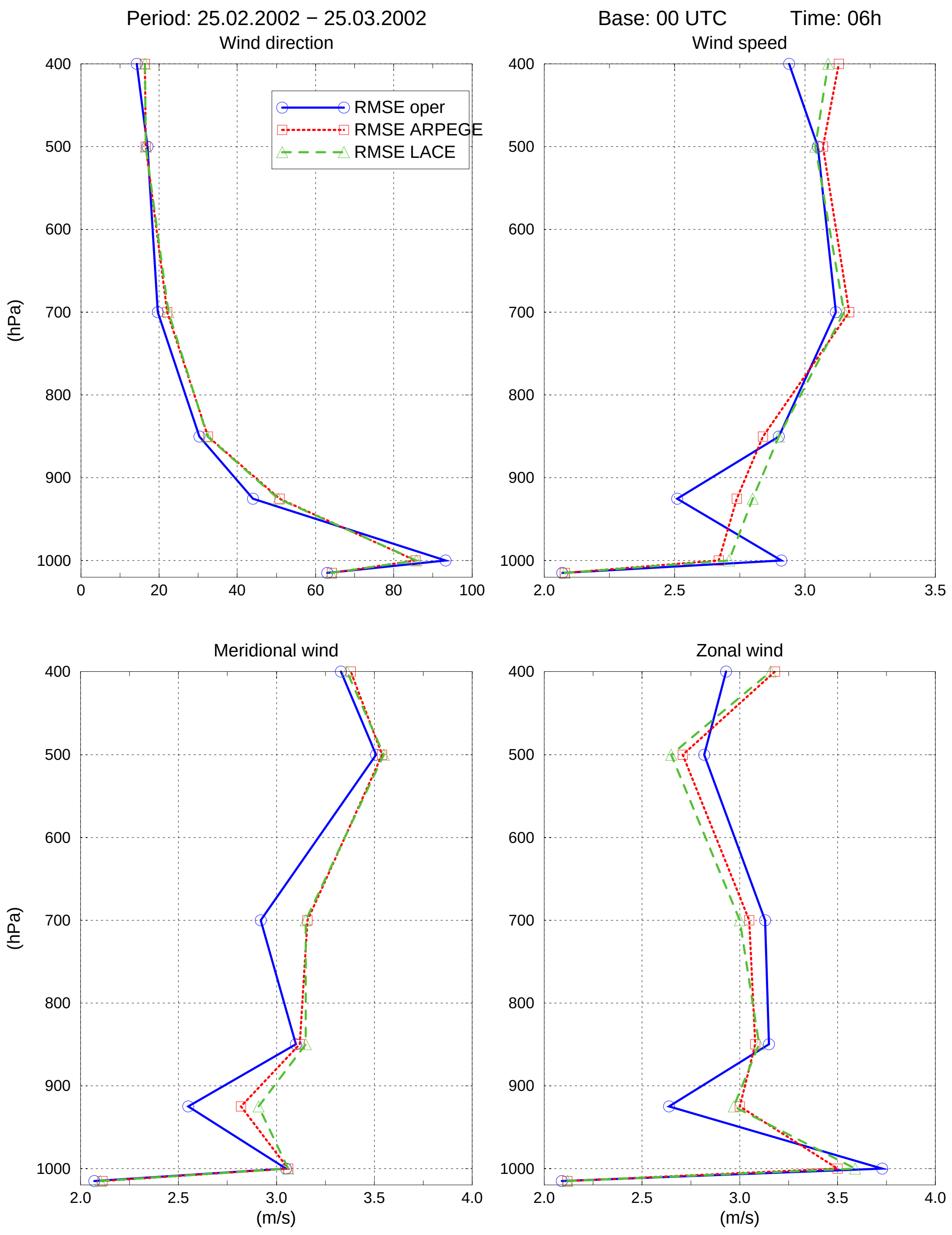

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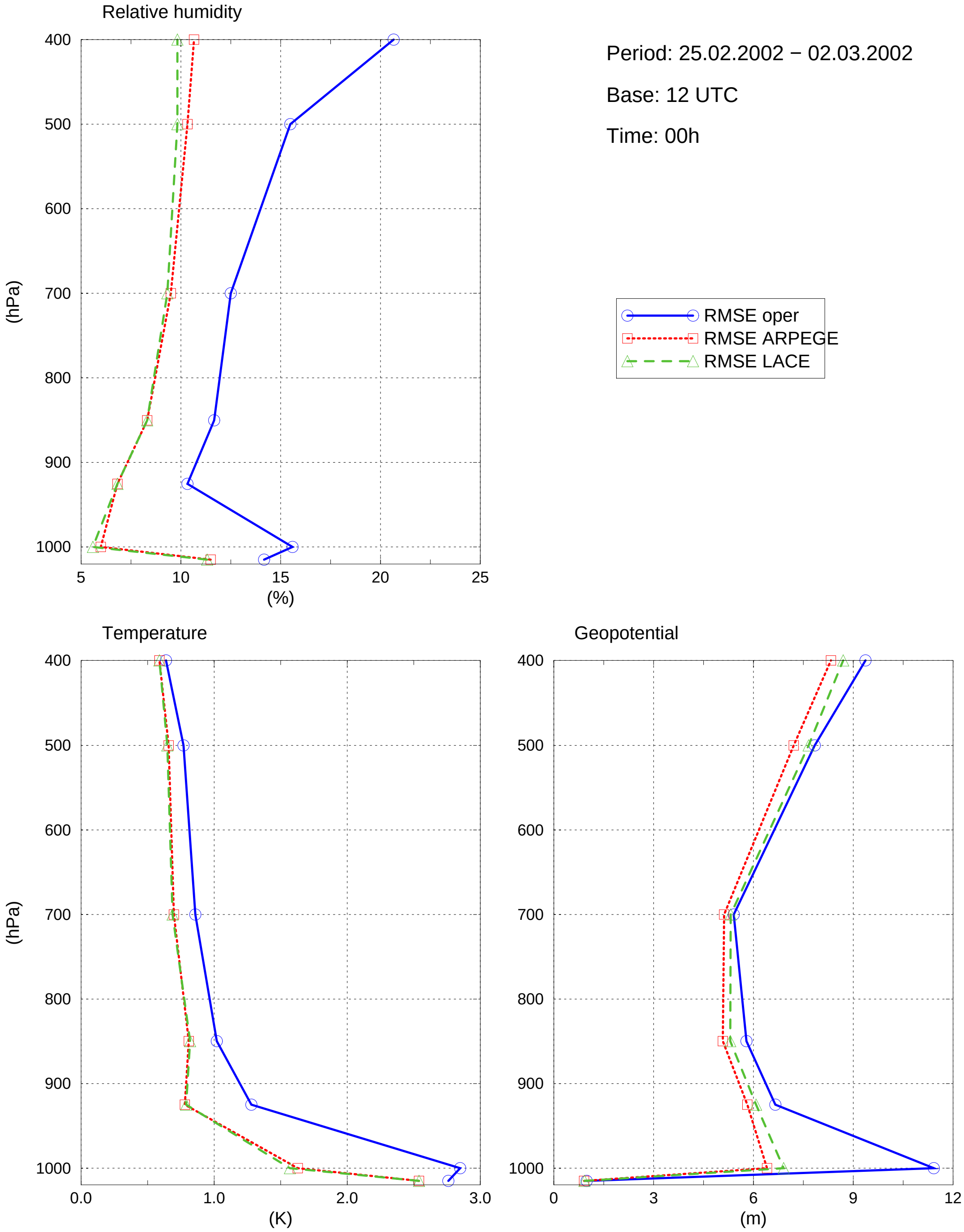

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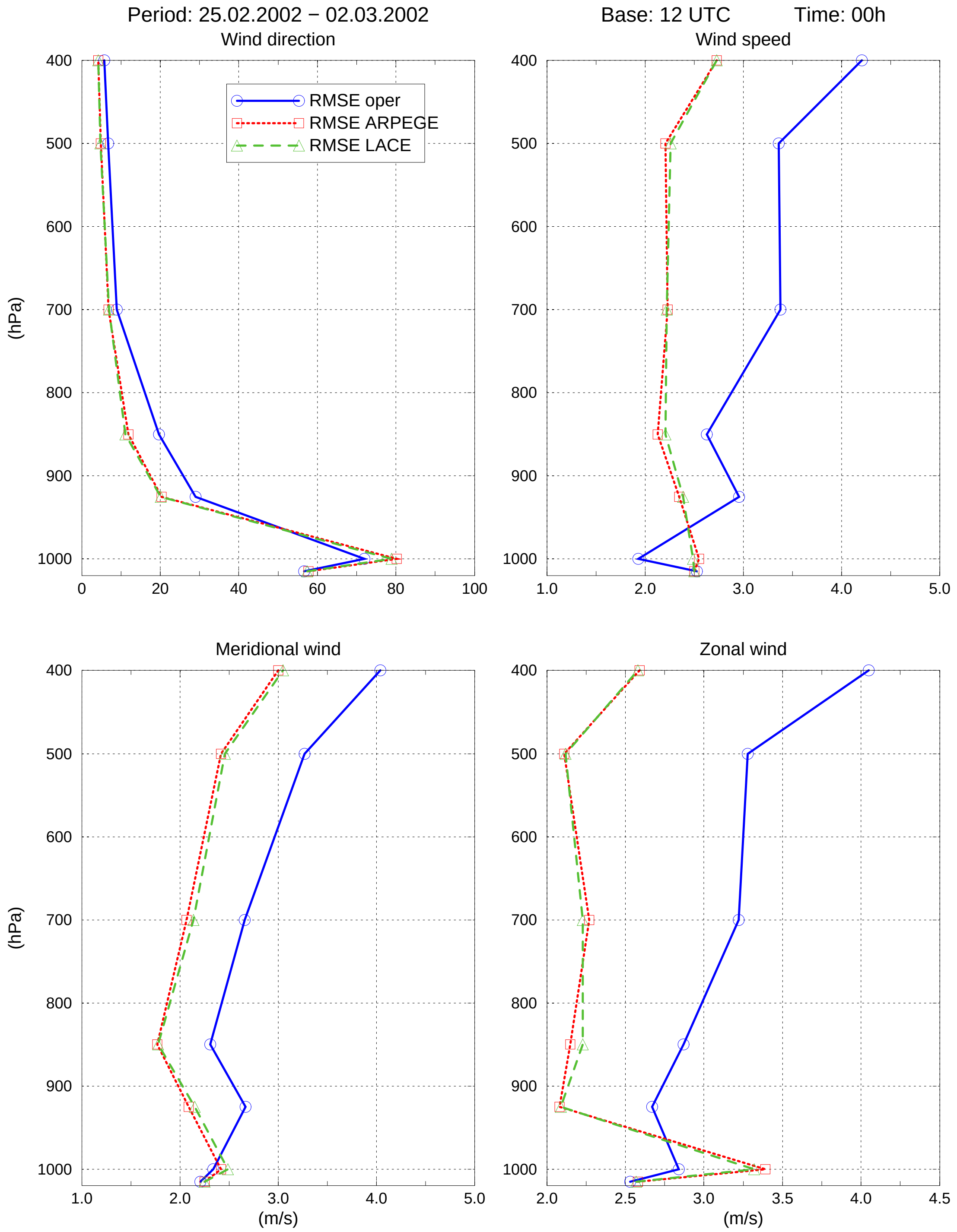

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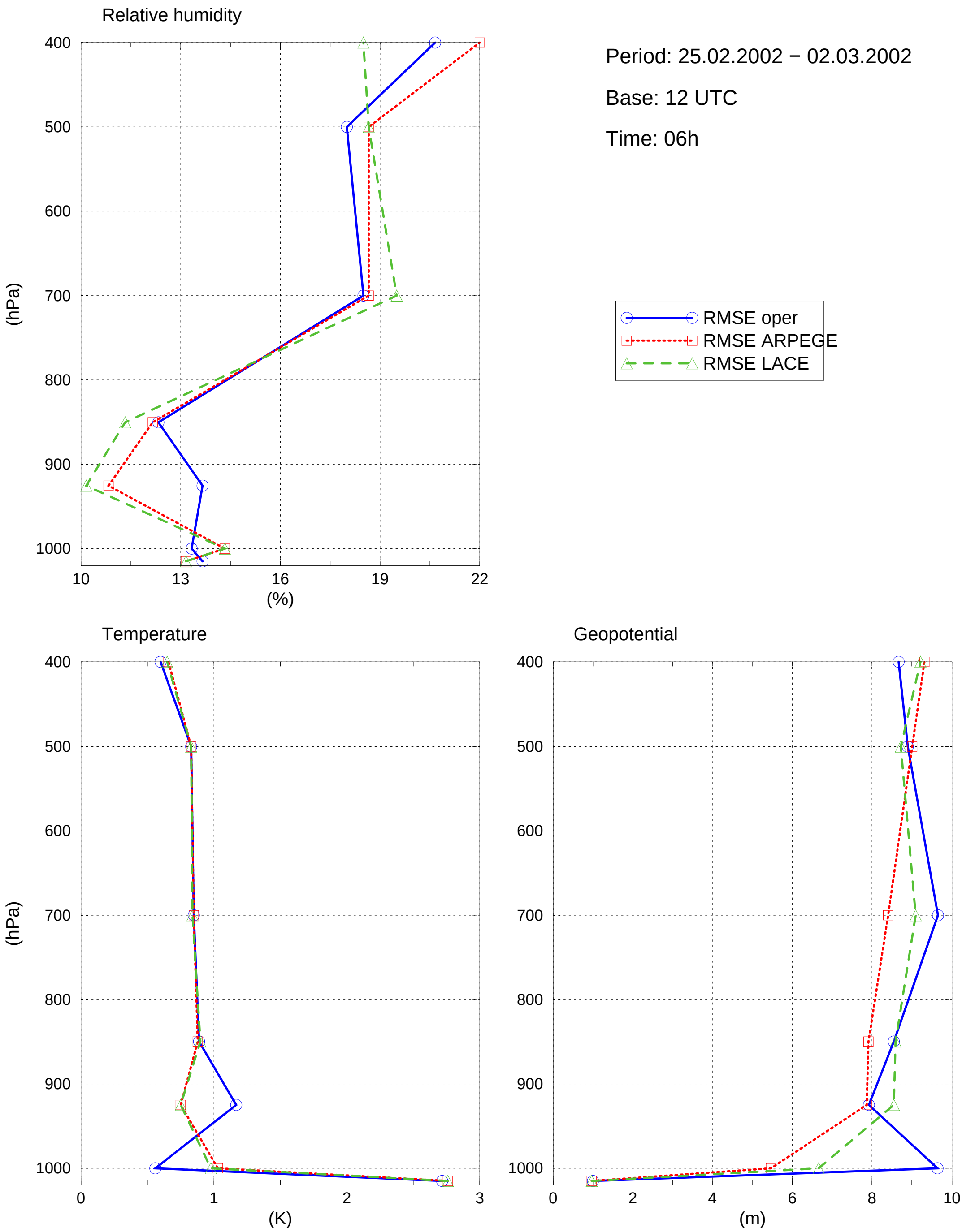
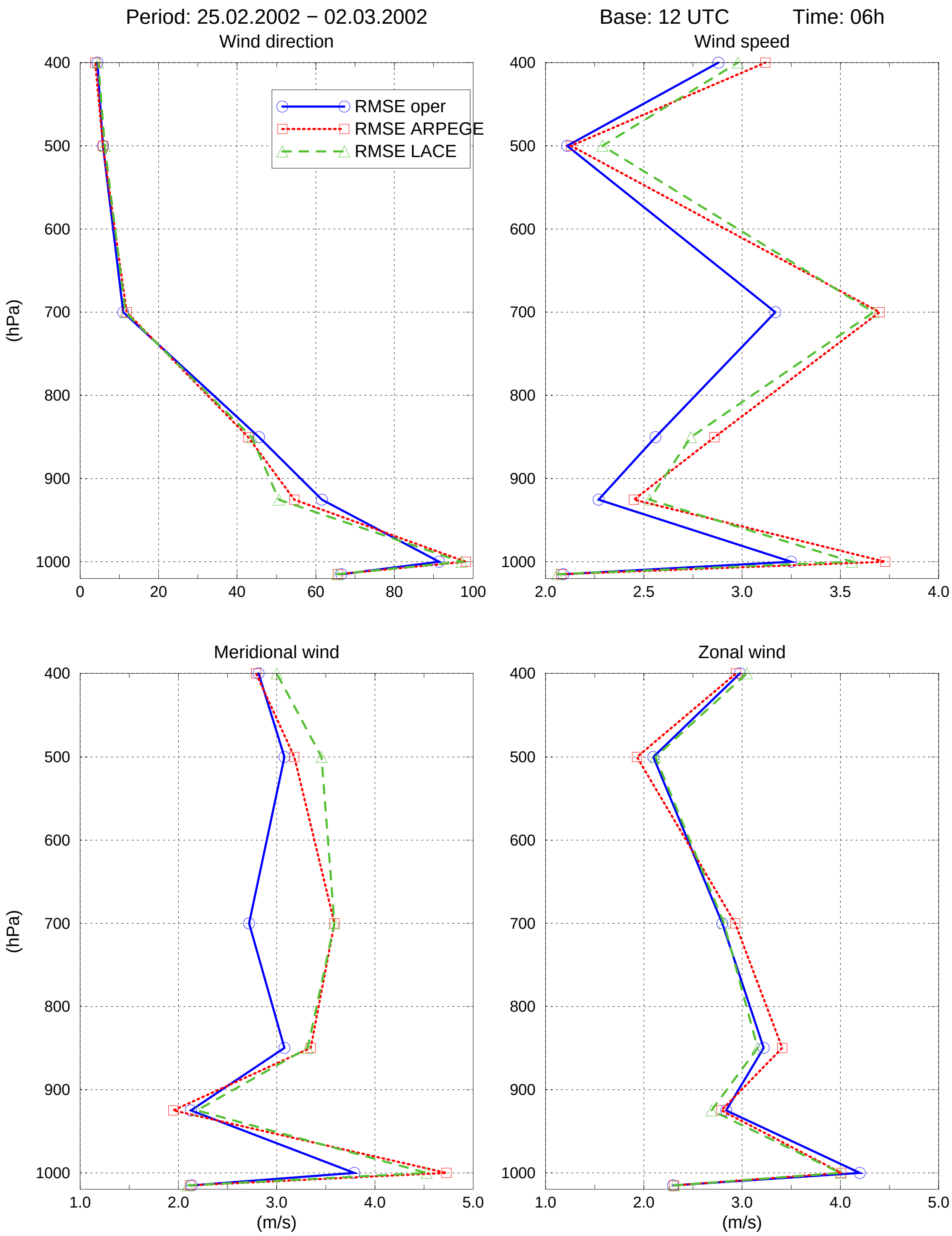


Figure 13: The same as Figure 11, but after 6h integration



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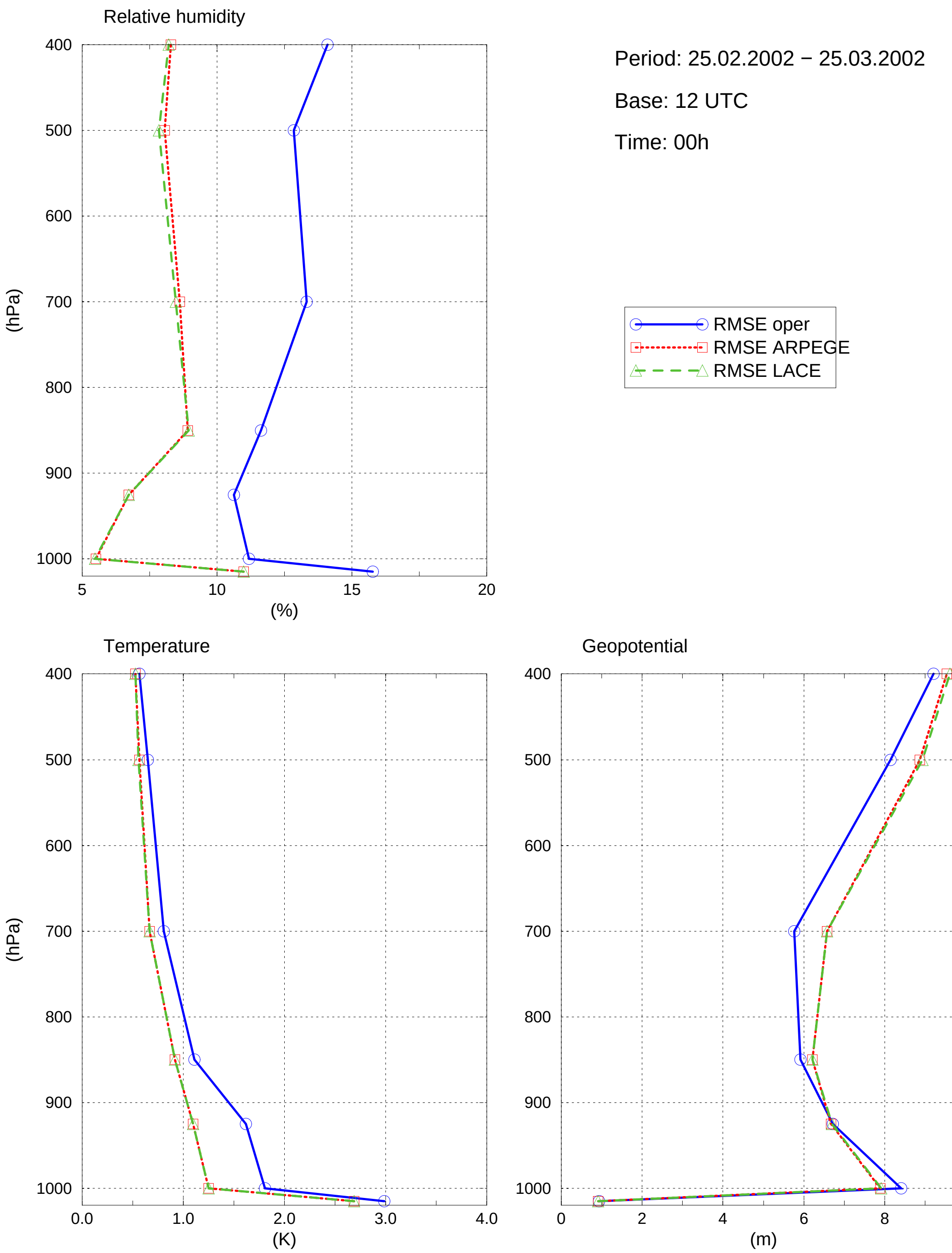

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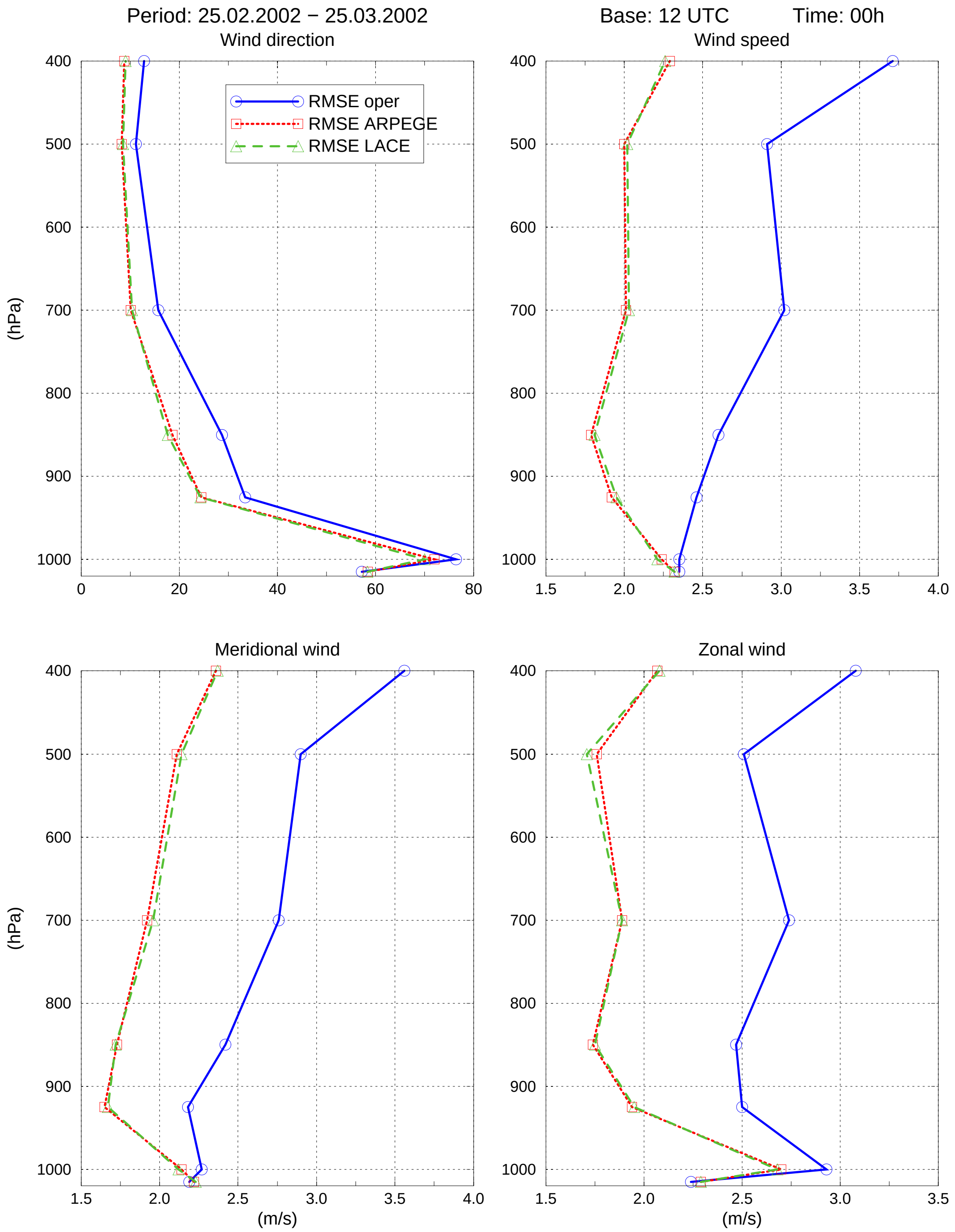

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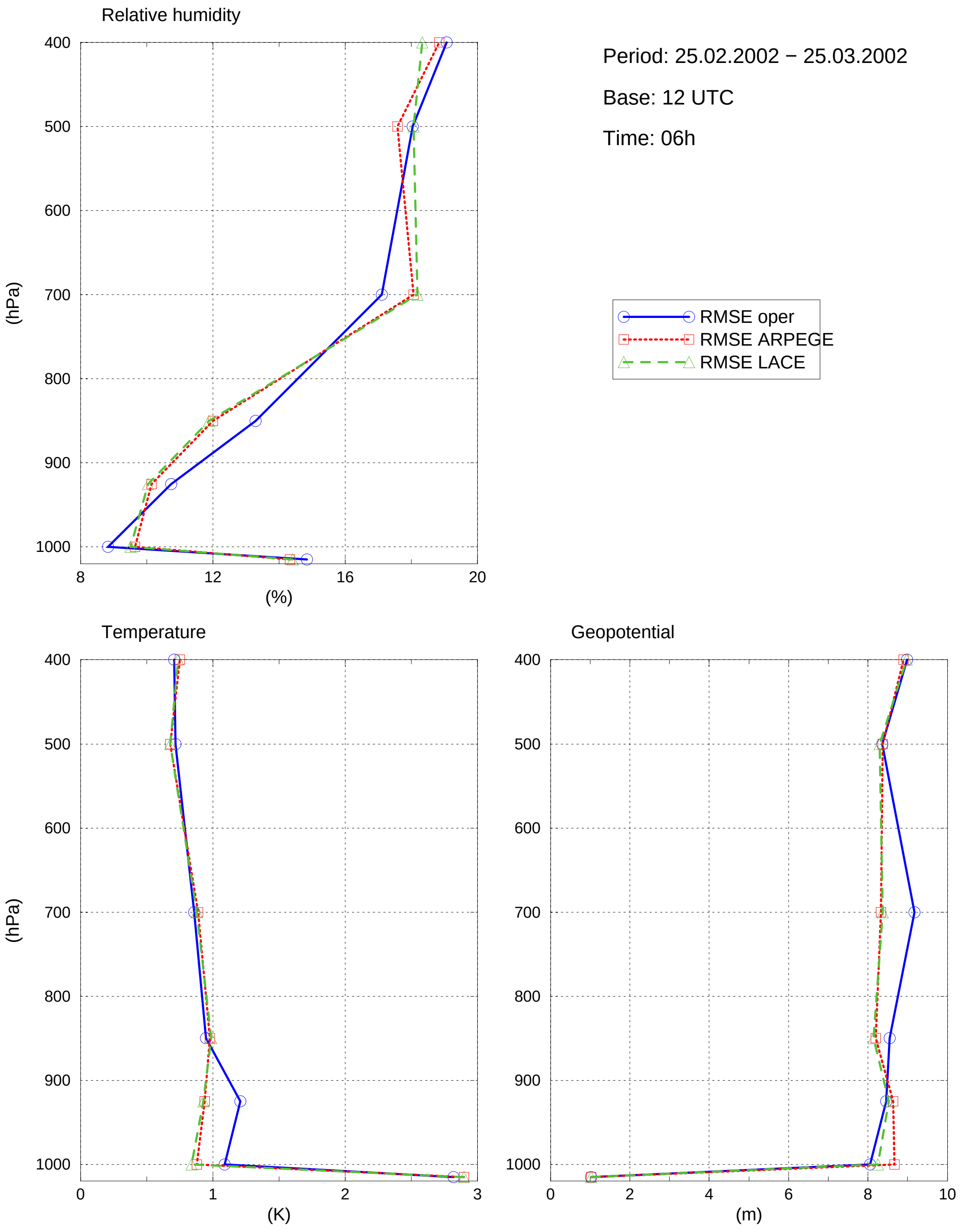
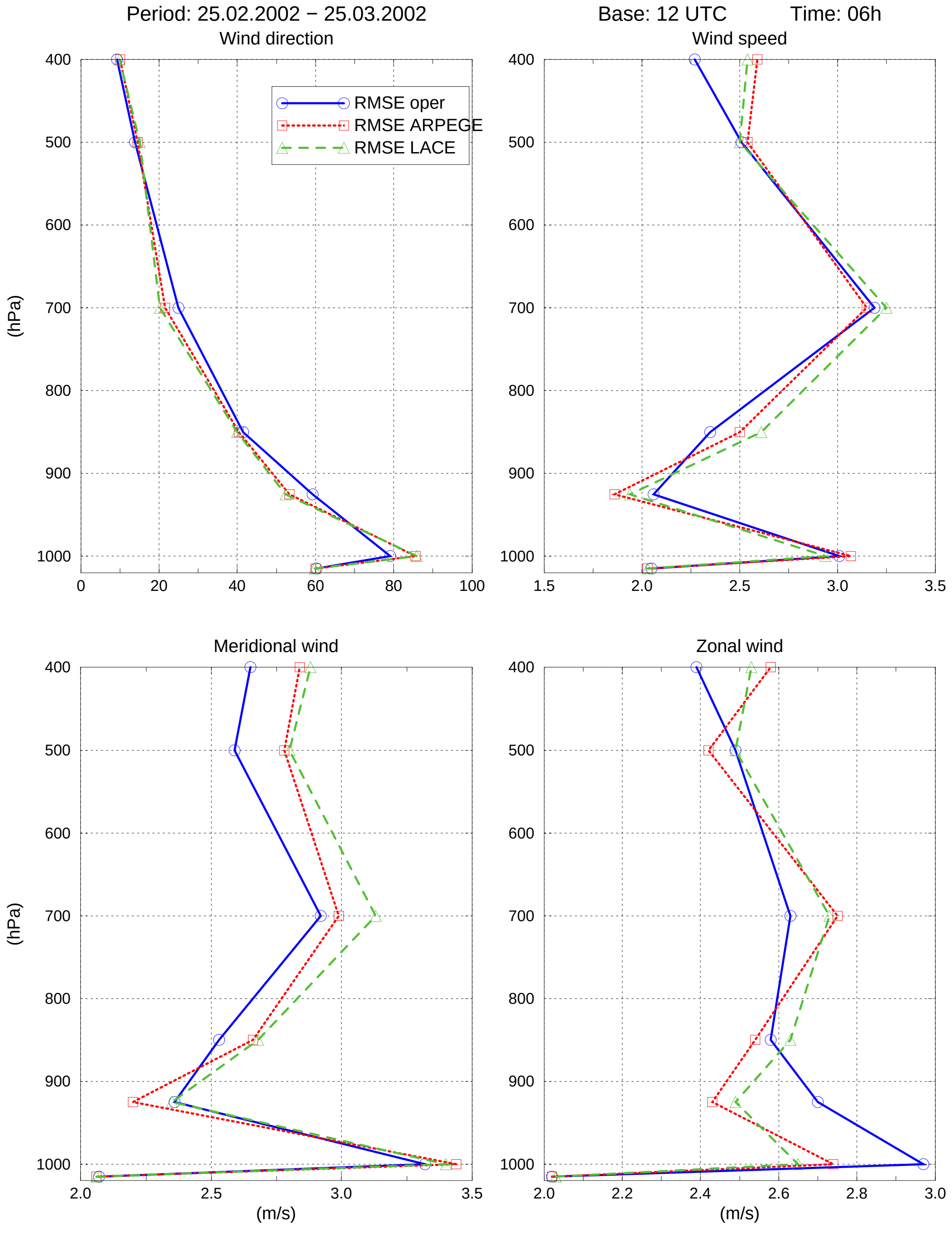


Figure 17: The same as Figure 15, but after 6h integration



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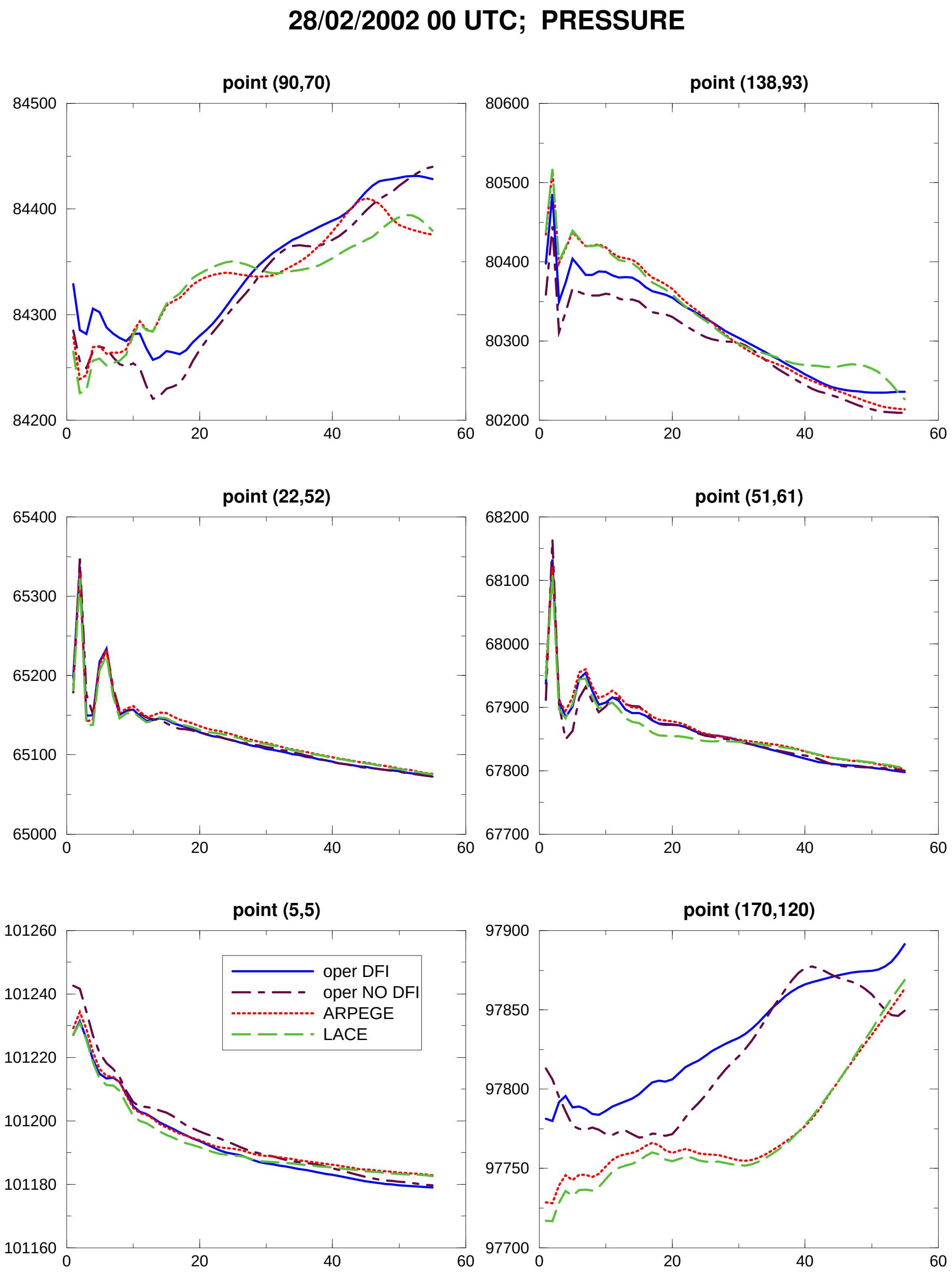

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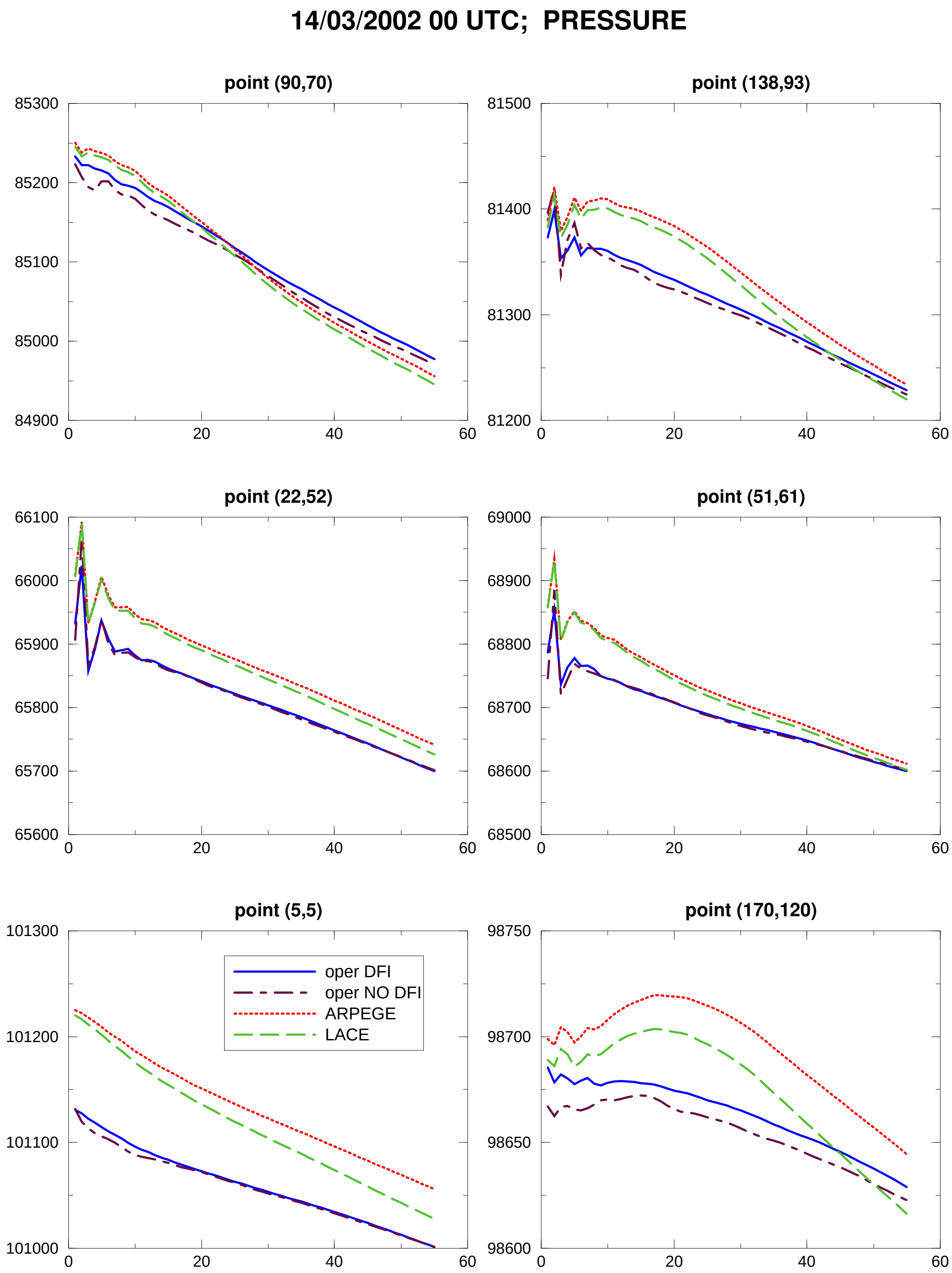

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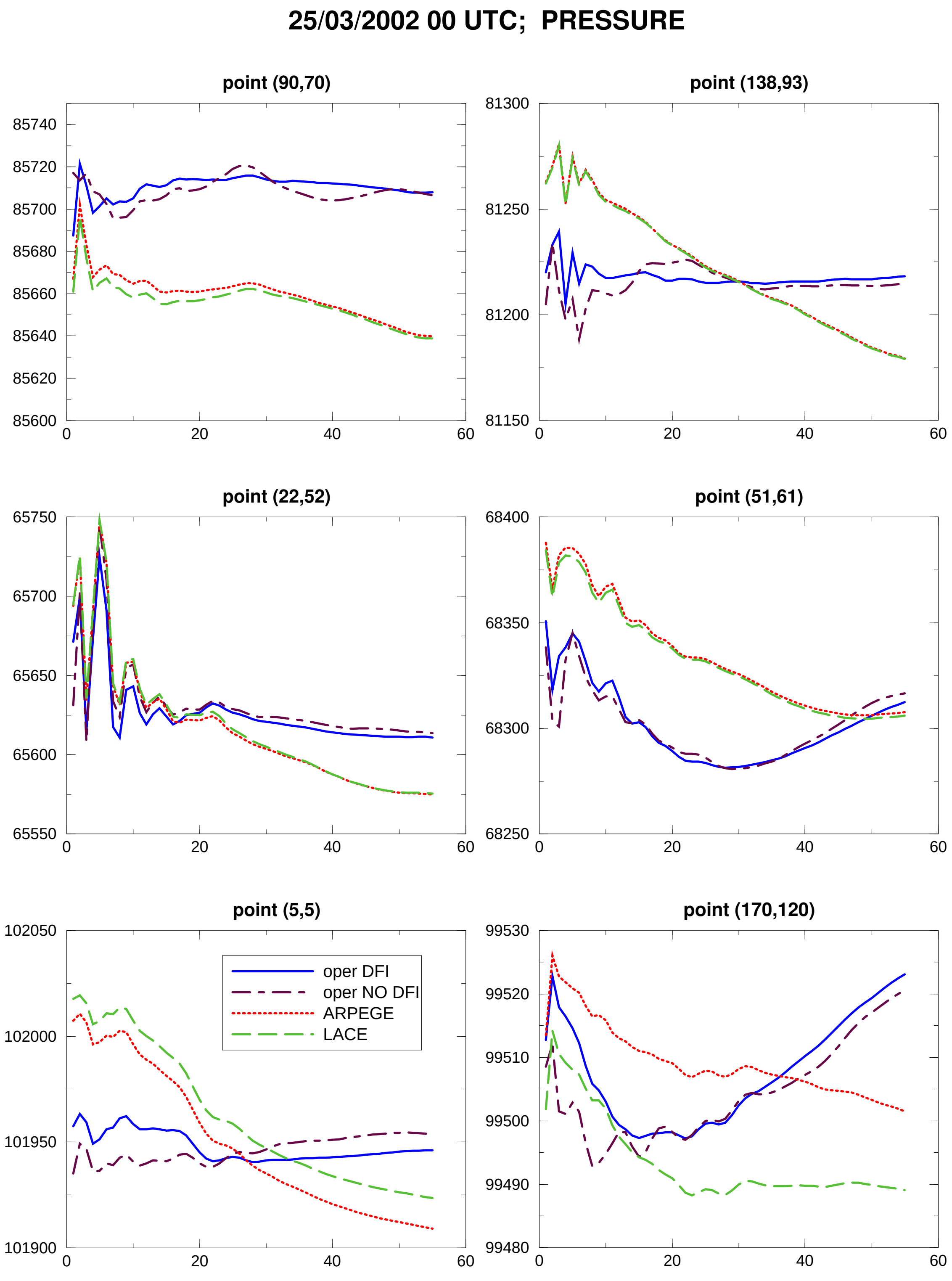

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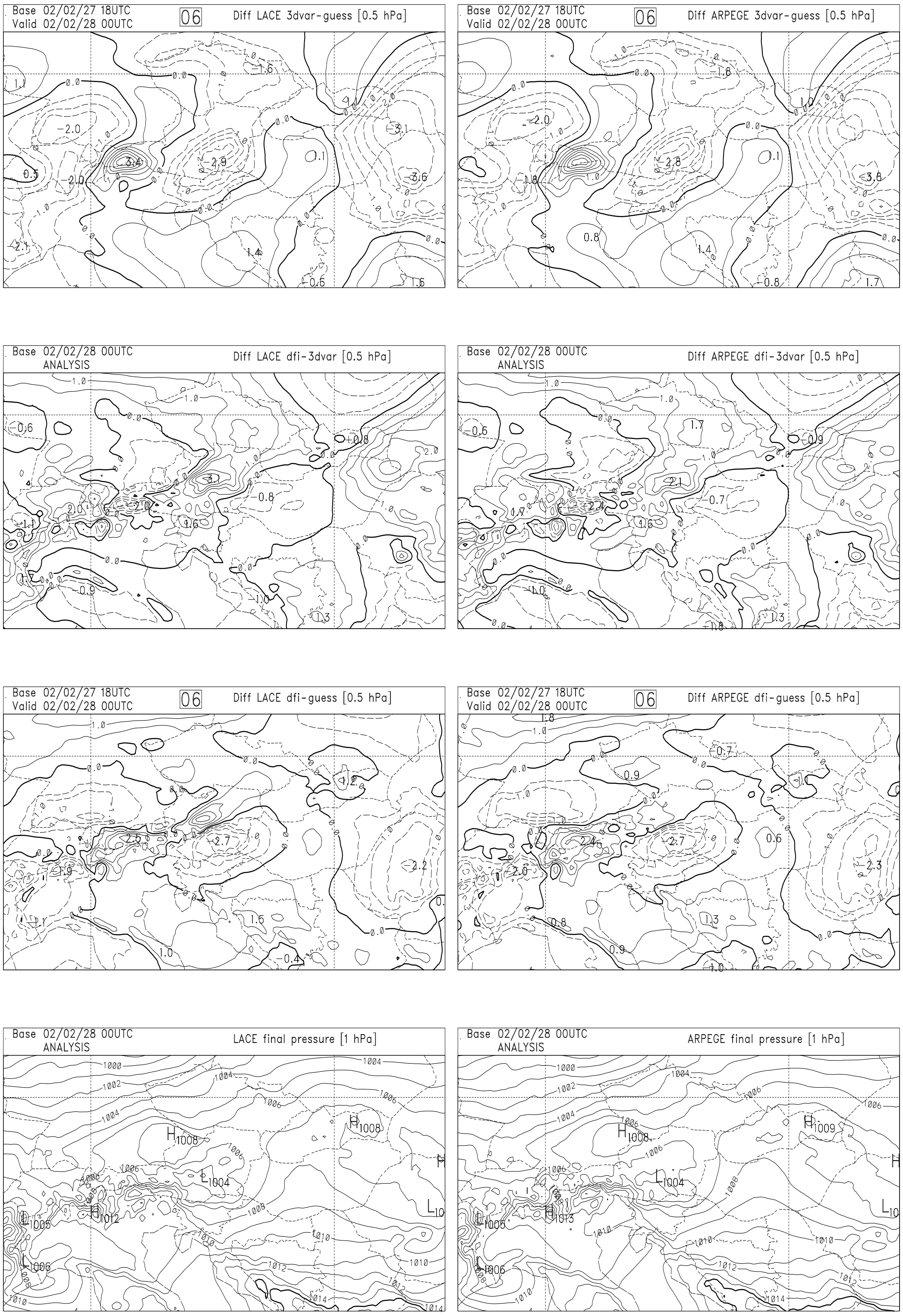
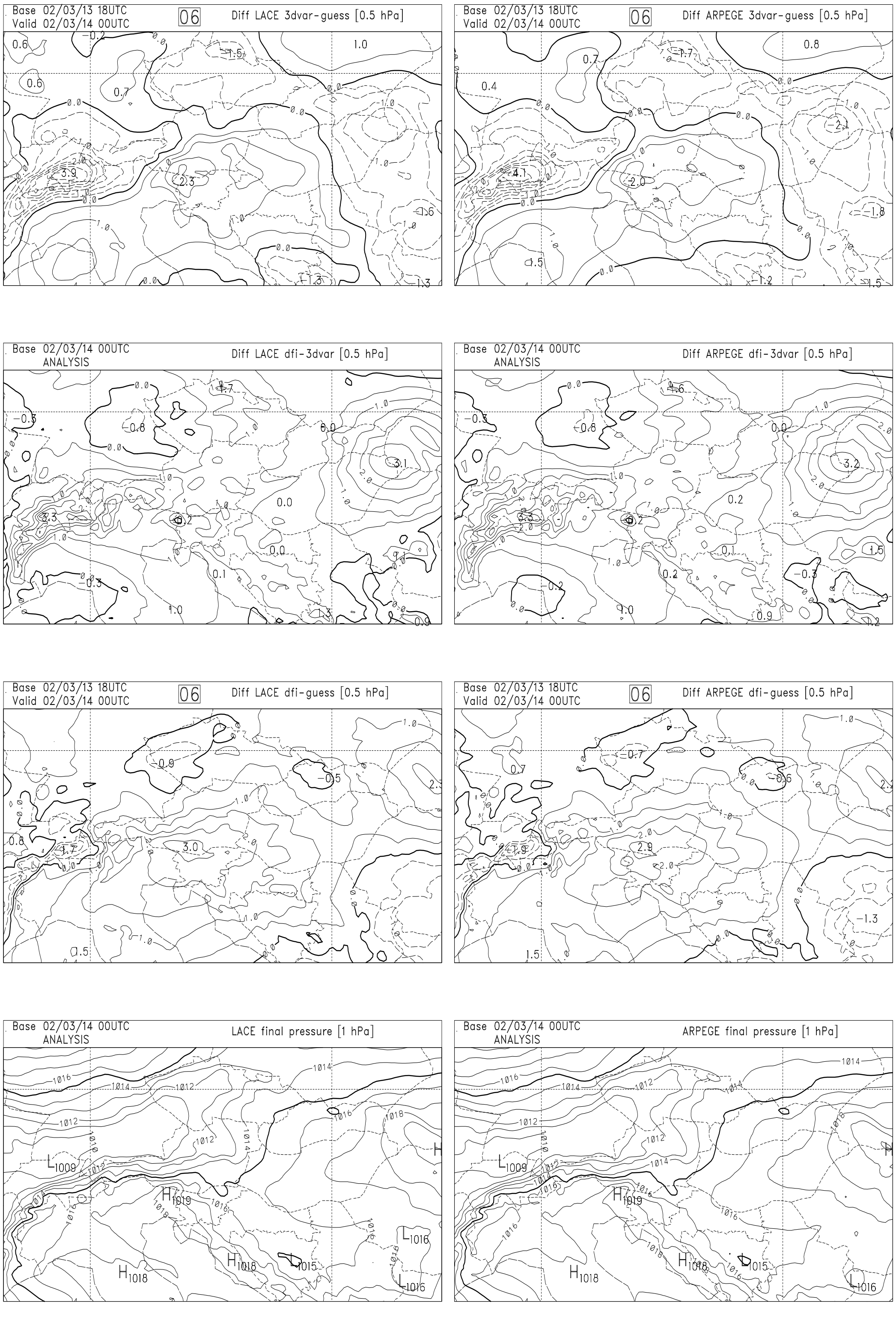


Figure 22: The mean sea level pressure increments and the final state, for the analyses with 3D-VAR with ALADIN/LACE (left column) and ARPEGE LBC files (right column), from 28.02.2002 00 UTC



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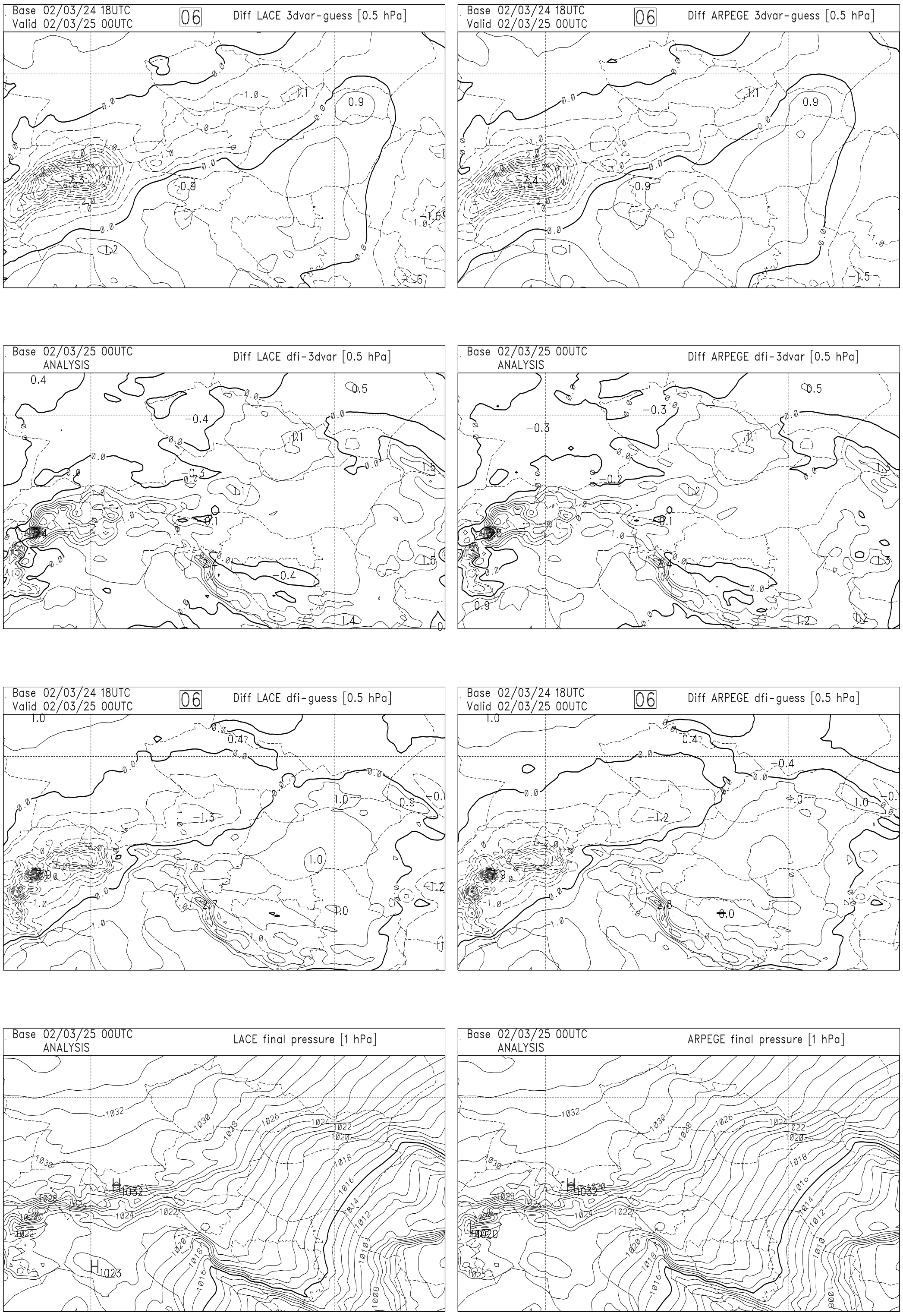
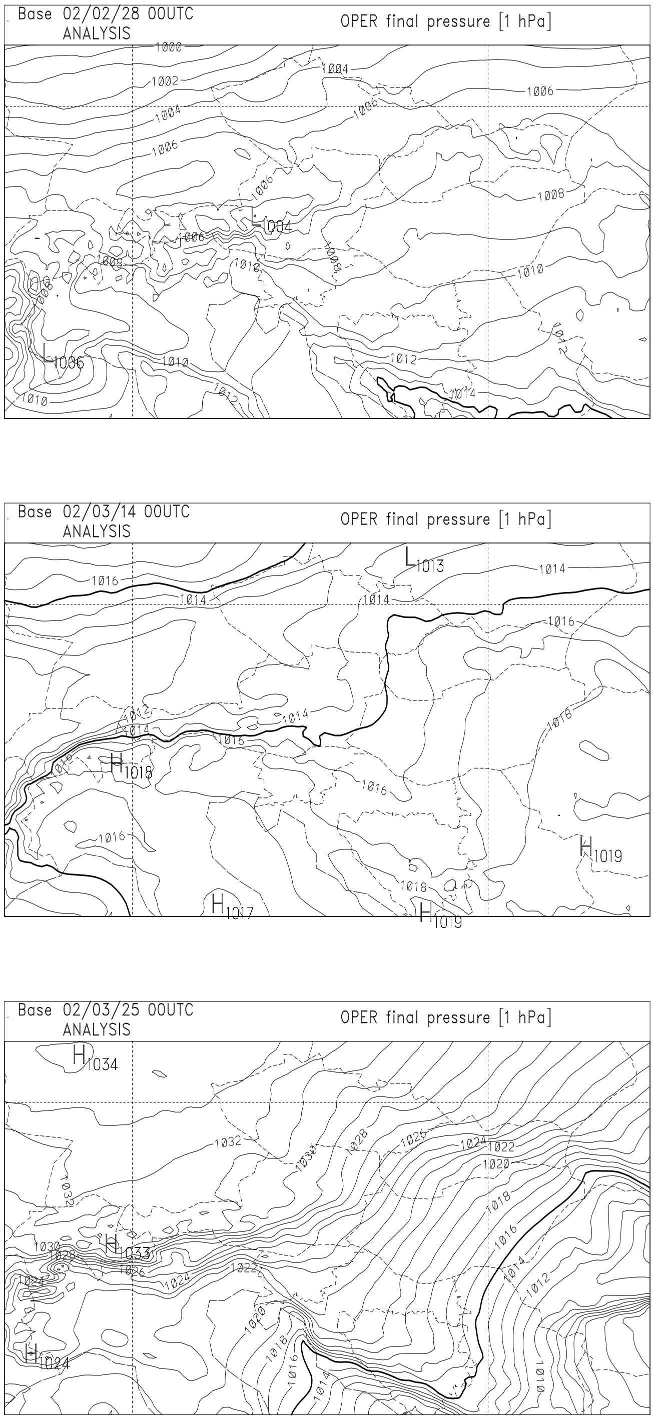


Figure 24: The mean sea level pressure increments and the final state, for the analyses with 3D-VAR with ALADIN/LACE (left column) and ARPEGE LBC files (right column), from 25.03.2002 00 UTC



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