Operational Verification of Vertical Profiles at DWD

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1 Introduction

The operational upper-air verification at the Deutscher Wetterdienst uses all available radiosonde stations over the integration domain of LM to verify the vertical structure of the forecasts. The parameters considered are geopotential, relative humidity, temperature, wind direction and wind velocity.

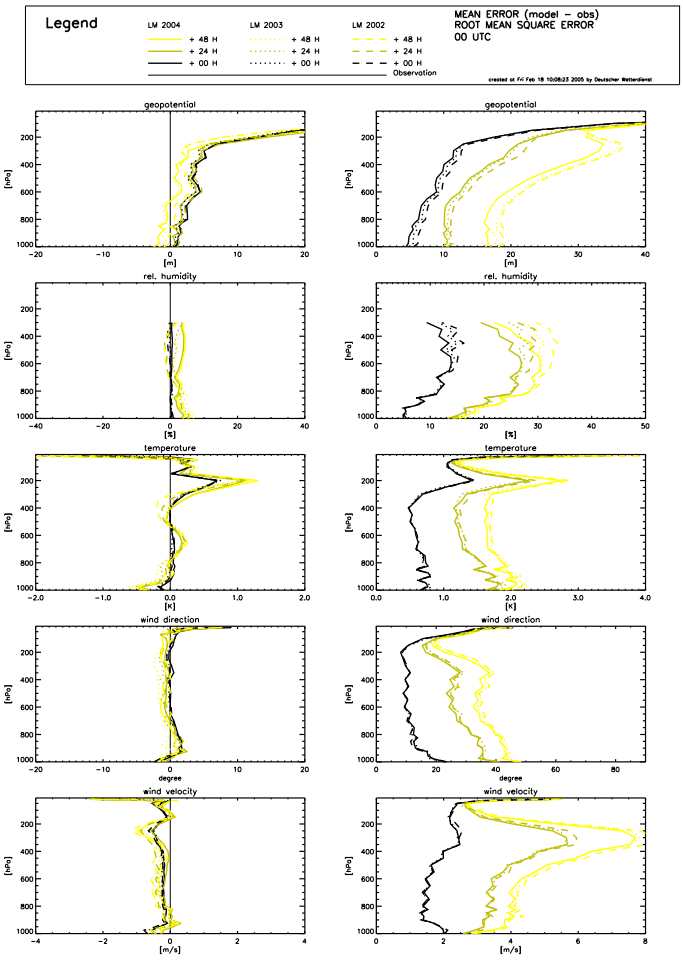

Figure 1: Vertical profiles of annual mean of bias (left columns) and rmse (right columns) at all radiosonde stations for different forecast times of LM runs and different years at DWD. Solid lines: 2004 00UTC, dotted lines: 2003 00 UTC, dashed lines: 2002 00 UTC. From top to bottom at each column: geopotential, relative humidity, temperature, wind direction and wind velocity.

Vertically the atmosphere is divided into bins of 25 hPa below the 800-hPa level and of 50 hPa between the 800-hPa and 100-hPa levels. Above 100 hPa, the bins are bounded by the pressure levels 100, 70, 50, 30, 20 and 10 hPa. Complying with the height, every observation, respectively every forecast increment is allocated to one bin.

2 Annual Mean Profiles of BIAS and RMSE

Figure 1 displays the profiles of the annual mean error (bias, left column) and the annual root mean square error (rmse, right column) against all radiosonde data at 00 UTC within the LM domain for different forecast times (analysis, 24h, 48h) and different parameters (geopotential, relative humidity, temperature, wind direction and wind speed from top to bottom) for 2004 (solid lines), 2003 (dotted lines) and 2002 (dashed lines).

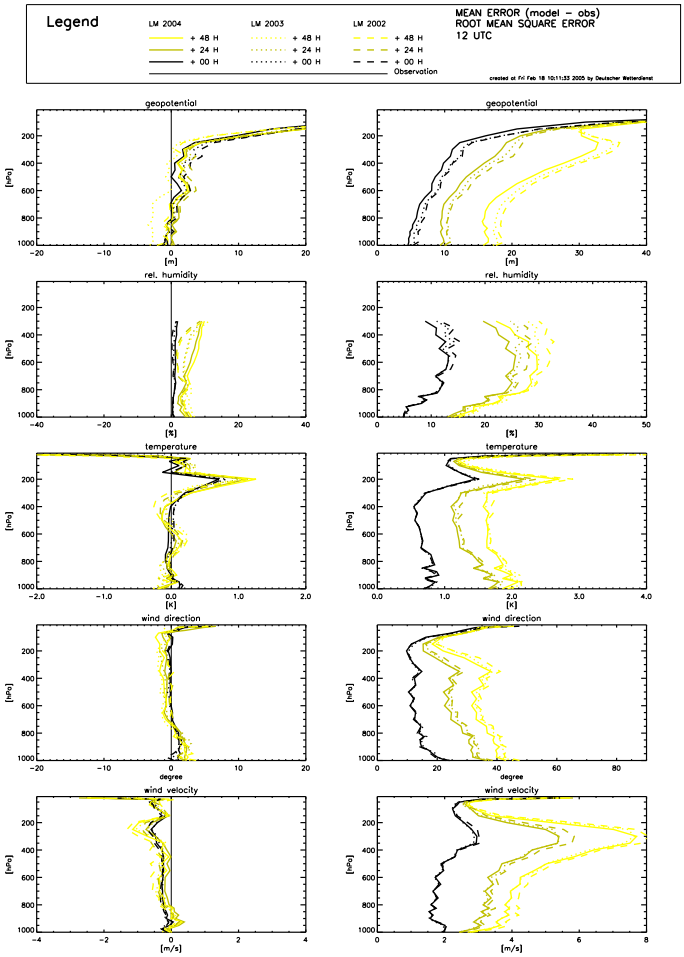

Figure 2: Vertical profiles of annual mean of bias (left columns) and rmse (right columns) at all radiosonde stations for different forecast times of LM runs and different years at DWD. Solid lines: 2004 12UTC, dotted lines: 2003 12 UTC, dashed lines: 2002 12 UTC. From top to bottom at each column: geopotential, relative humidity, temperature, wind direction and wind velocity.

Figure 2 shows the same illustration for verification time 12 UTC. The comparison of the corresponding profiles demonstrates that generally the annual mean profiles of bias and rmse do not change very much between the three years, but there are some exceptions. The bias of geopotential for 2004 remains in the range of the bias which is given with that of the years 2003 and 2002. The negative bias of the 48 h forecast below 600 hPa in 2003 at verification time 12 UTC seems to have been an exception. Changes in rmse are small but clearly visible, against 2003 a systematic rmse reduction of about 1 - 2 m has occurred, with increasing reduction the longer the forecast time is. Between 700 hPa and 300 hPa, there are some changes in the bias of relative humidity. At verification time 00 UTC the 24 h and 48 h forecasts show compared to 2002 and 2003 yet another increase of the bias, the slight positive bias in 2003 is partly more than reduplicated, but at 300 hPa the profiles of 2003

and 2004 meet together. At verification time 12 UTC, the stronger positive bias of 2003 increases for 2004 clearly and the profiles for all three years are meeting together at 300 hPa. The further reduction of rmse of relative humidity above 400 hPa in 2004 is ascribed to the implementation of a prognostic cloud ice scheme at 16 th of September 2003. Since that time there is a reduction of up to 10 monthly mean profiles. Unlike 2004 in the year 2003 only 3 and a half months are contributing to this effect, so in the year 2004 a stronger reduction of the rmse should occur. As remarked in the last Newsletter (Pflüger 2004), this is partly resulting form the smaller range of humidity values because, in contrast to the old scheme, the ice scheme rarely produces relative humidity values close to 100% at that height.

The differences in the bias of temperature remain in the range of the years before and also rmse of temperature remains predominantly unchanged, at the most a very slight improvement between 700 hPa and 400 hPa can be seen. The negative bias of wind direction, which has appeared above 700 hPa in 2003 up to 2 degrees, has mostly weaken. The rmse profiles of wind direction show a very slight improvement above 700 hPa. The bias of wind velocity has the same structure in 2004 as in the years before, the slight tendency for a decrease in 2003 hasn't continued in 2004. The rmse of wind velocity has very few changes between the years 2003 and 2004.

3 Time Series of Monthly Mean Profiles of BIAS and RMSE

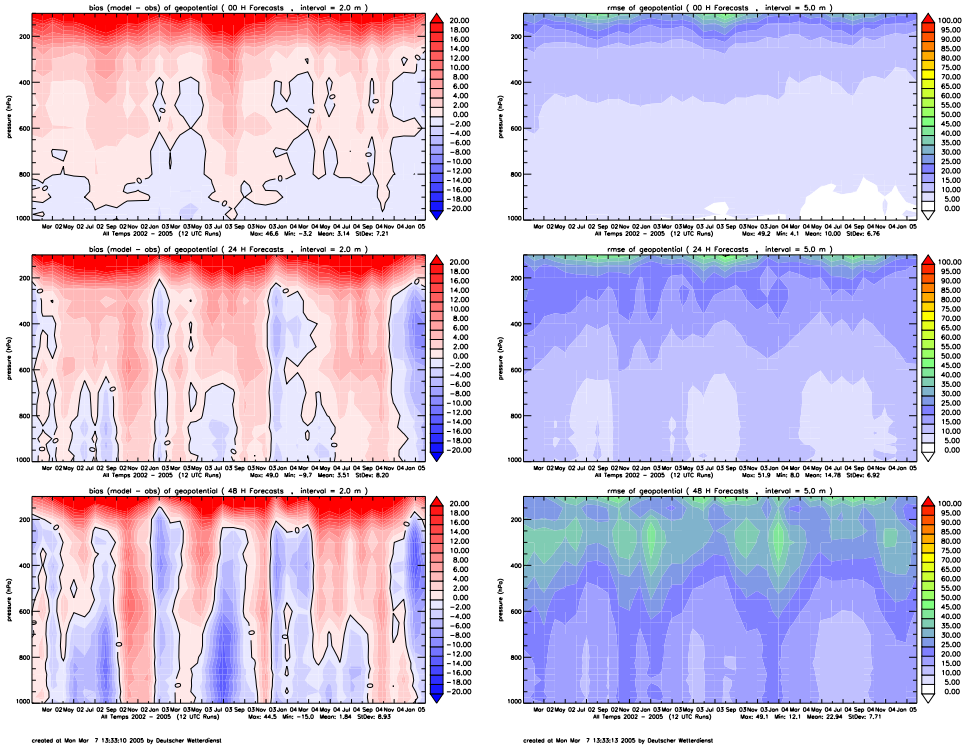

Figure 3: Time Series (January 2002 – Februray 2005) of gepotential bias (left columns) and rmse (right columns) against radiosondes based on monthly mean profiles for 12 UTC LM runs at DWD. From top to bottom: Analysis, 24 h, and 48 h forecast.

In order to show both, the seasonal and inter annual variation of the bias and rmse, time series (January 2002 until February 2005) of the vertical distribution of the monthly bias (left column) and rmse (right column) are presented in Figures 3, 4, 5, 7 and 8 for geopotential height, relative humidity, temperature, wind direction and wind velocity. Figure 6 displays for December 2004 additionally the daily mean values for temperature bias and rmse. All

Figures show the verification time 12 UTC for 3 forecast times (analysis, 24 h and 48 h, from top to bottom). Verification time 00 UTC has basically the same behaviour and is not shown.

Figure 3 displays the time series of the vertical profiles of the monthly geopotential bias and rmse against radiosonde data. It can be seen that the seasonal variation of the bias stated in the last Newsletter (Pflüger 2004), with values less than -10 m in summer and up to +8 m during the rest of the year, isn't that strong in 2004. The rmse is reduced in 2004 up to 5 m mainly in Summer in the lower troposphere and in Winter above 400 hPa.

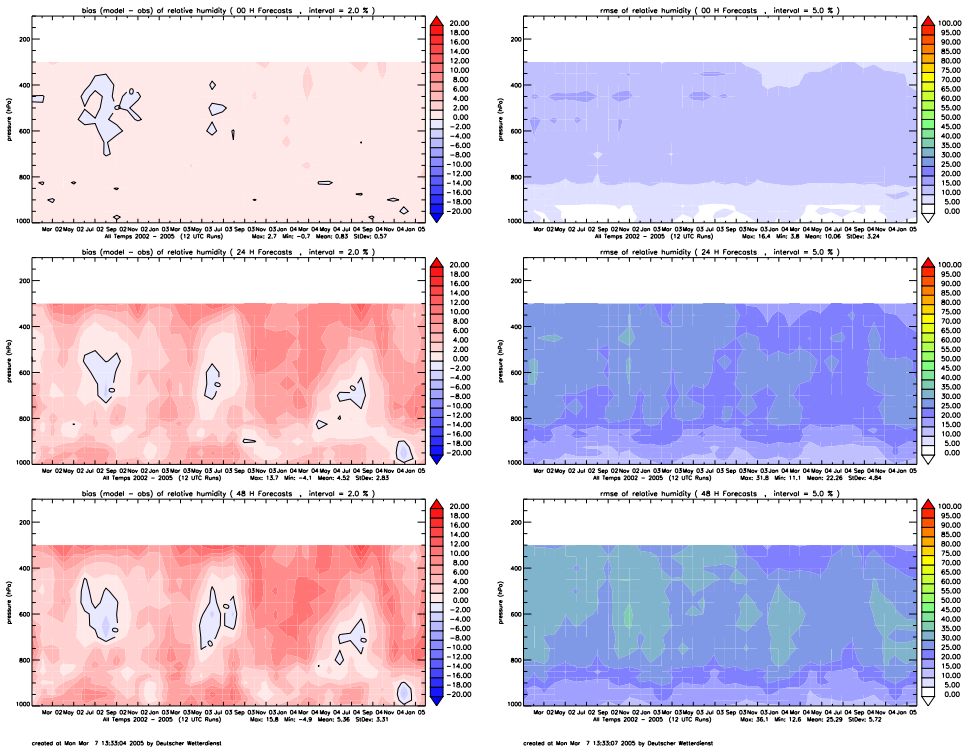

Figure 4: Time Series (January 2002 – February 2005) of relative humidity bias (left columns) and rmse (right columns) against radiosondes based on monthly mean profiles for 12 UTC LM runs at DWD. From top to bottom: Analysis, 24 h, and 48 h forecast.

Figure 4 shows that in 2004 compared to 2003 and 2002, there is a further increase of the positive bias of relative humidity in the middle atmosphere during the autumn and winter months and a slight decrease of the negative bias during summer at forecast times 24 h and 48 h. This can also be seen in the profiles of the annual means as aforementioned. Below 800 hPa, a positive bias during spring and summer months is found. It was larger in the year 2003 and has reduced again in 2004 to that of the 2002. The aforementioned decrease of rmse of relative humidity above 400 hPa due to the implementation of prognostic cloud ice in October 2003 is left in the year 2004.

Figure 5 displays the time series of the vertical profiles of the monthly temperature bias and rmse against radiosondes. The bias patterns of the years 2002 and 2003 are recurring more or less in the year 2004. The positive bias in summer in the middle troposphere is reduced and also the negative bias in the lower troposphere is less pronounced in 2004. The rmse of temperature in the middle troposphere is reduced to values below 2 degrees in 2004, however in December 2004 there is a maximum rmse of 3.2 K at 950 hPa.

This was caused by a 10 day period with an strong temperature inversion in the boundary layer which wasn't resolved by the LM. Figure 6 displays the daily mean of temperature bias

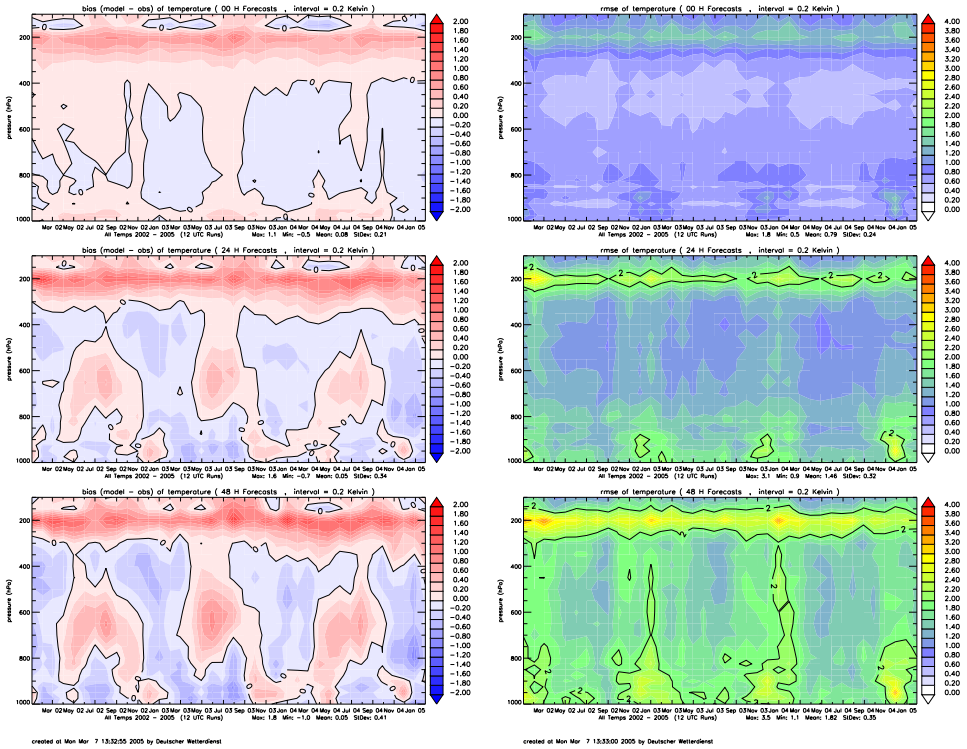

Figure 5: Time Series (January 2002 – February 2005) of temperature bias (left columns) and rmse (right columns) against radiosondes based on monthly mean profiles for 12 UTC LM runs at DWD. From top to bottom: Analysis, 24 h, and 48 h forecast.

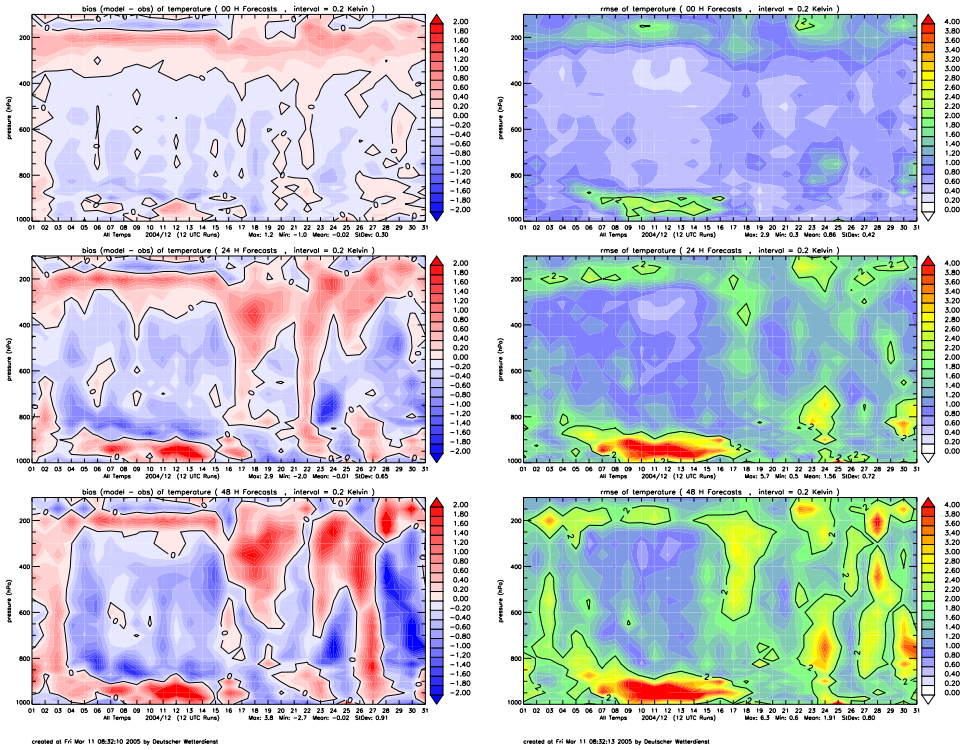

Figure 6: Time Series (December 2004) of temperature bias (left columns) and rmse (right columns) against aircraft data based on daily mean profiles for 12 UTC LM runs at DWD. From top to bottom: Analysis, 24h, and 48h forecast.

and rmse for December 2004. In the period with the temperature inversion, the daily mean of rmse reached values up to 6.3 K at the 950 hPa level and a daily mean bias of + 3.8 K.

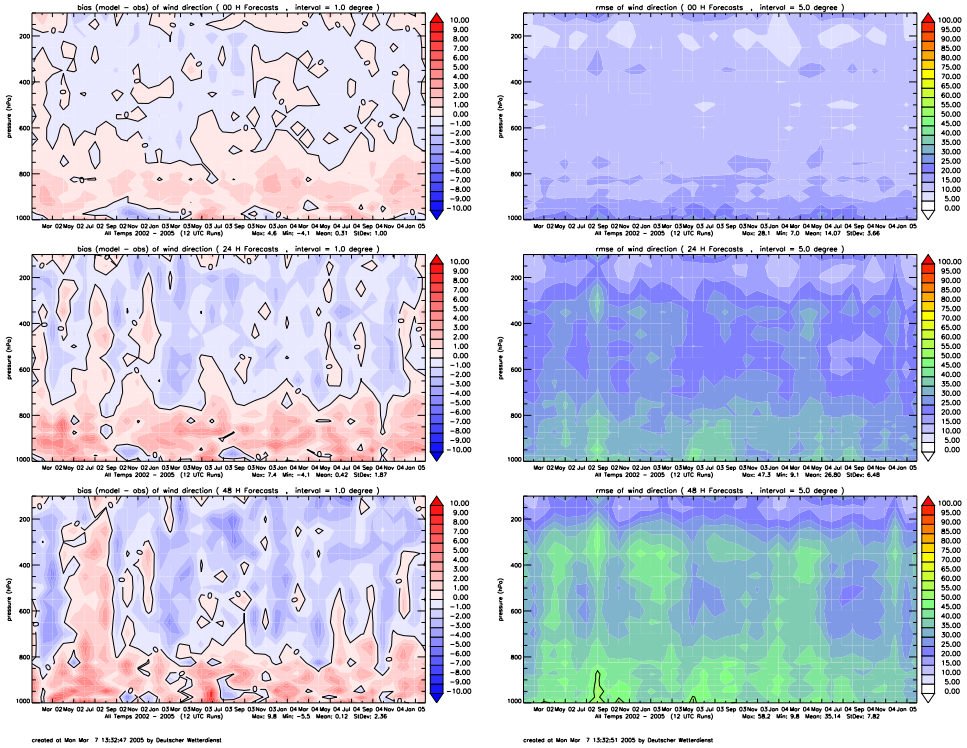

Figure 7: Time Series (January 2002 – February 2005) of wind speed bias (left columns) and rmse (right columns) against radiosondes based on monthly mean profiles for 00 UTC LM runs at DWD. From top to bottom: Analysis, 24 h, and 48 h forecast.

Figure 7 displays bias and rmse for the wind direction. The bias of wind direction is mainly positive in the lower troposphere and negative in the middle and upper troposphere. No significant change in the behaviour over the years 2002 until 2004 is recognisable. The rmse of wind direction below 700 hPa shows a seasonal variation with lower values in winter and higher values in summer. In the middle and upper troposphere the behaviour of rmse is viceversa and between 500 and 600 hPa the minimum value of rmse occur. Overall in 2004, compared to 2003 a slight reduction of rmse can be seen.

Figure 8 displays bias and rmse for the wind velocity. The bias of wind velocity is mainly positive in the lower troposphere in winter and negative in summer, whereas in the upper troposphere a negative bias through the whole year is prevailing. Since October 2004 this has changed, now a stronger positive bias from ground until up to 400 hPa can be seen. The reason for this change is quite not clear but in October 2004 the resolution of the global model which delivers the boundary values for LM was increased to a 40 km grid (from 60 km before) and to 40 vertical layers (from 31 before). Rmse of wind velocity remains nearly unchanged in summer half, whereas between winter half 2003/2004 and winter half 2004/2005 a rmse reduction of about 0.5 m/s can be stated below 600 hPa. In the 300 hPa level the maximum value of more than 9 m/s in winter 2003/2004 is reduced to 8 m/s in winter 2004/2005.

References

Pflüger U., 2004: Operational verification of vertical profiles at DWD. COSMO Newsletter no 4, pp. 95 - 103, available at www.cosmo-model.org

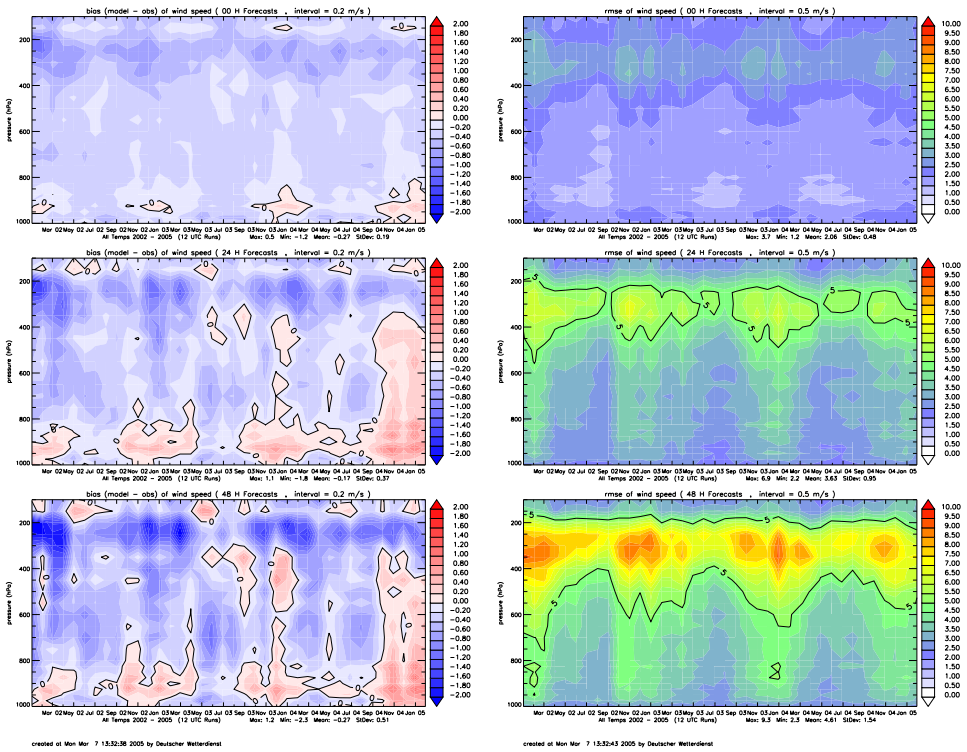

Figure 8: Time Series (January 2002 – February 2005) of wind direction bias (left columns) and rmse (right columns) against radiosondes based on monthly mean profiles for 00 UTC LM runs at DWD. From top to bottom: Analysis, 24 h, and 48 h forecast.