Impact of a Bias Correction Scheme for Vaisala RS80 Radiosonde Relative Humidity Observations

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Introduction and Outline of the Bias Correction Scheme

For most types of radiosondes, observed humidity is known to have a dry bias near saturation in general. Hence in the current operational version of the observation processing in the LM, saturation is assumed for observed relative humidity values greater than 96 % irrespective of temperature. The assumption for saturation, however, is not made for data which have already been comprehensively bias-corrected before being written to the AOF, as is the case for the Lindenberg radiosonde data. (For model runs without prognostic cloud ice, the observed humidity below freezing is additionally enhanced in a later step by the fraction of saturation vapour pressure over water e_{sat}^{water} and saturation vapour pressure over ice e_{sat}^{ice}, irrespective of the bias correction applied. This ice-to-water adjustment renders the observational data model compatible in the sense that it accounts for neglecting cloud ice.)

The current study evaluates a new type of bias correction. It is applied to the observed relative humidity $U_{ob\,V80}$ from the Vaisala RS80 A-Humicap sondes (except for the Lindenberg sonde) in two steps as derived from parallel ascents with Vaisala RS90 H-Humicap sondes (see Nagel et al., 2001). The first step, the so-called weather screen ground check correction,

$$U_{ob}^{corr,1} \;=\; U_{ob\,V80} \;+\; 0.056 \cdot U_{ob\,V80} \tag{1}$$

is applied at any temperature. The temperature-dependent second step

$$U_{ob}^{corr,2} \;=\; U_{ob}^{corr,1} + \frac{U_{ob}^{corr,1} \cdot (0.005 \cdot (T - T_0)^2 \;+\; 0.112 \cdot (T - T_0) \;+\; 0.404)}{100 \cdot e_{sat}^{ice} / e_{sat}^{water} \;-\; (0.005 \cdot (T - T_0)^2 + 0.112 \cdot (T - T_0) + 0.404)} \tag{2}$$

is applied only if temperature $T \;<\; T_0 - 12[\mathrm{K}]$ (where $T_0 \;=\; 273.15\,\mathrm{K}$).

Note that this correction is derived statistically purely from the observations themselves. It does not attempt to render the observational data explicitly model-compatible by making use of the model's relative humidity – cloud fraction relationship, as is done e.g. in Sharpe and Macpherson (2002).

Trial 1: A Case of Thick Cirrus

Since the bias correction is greatest at a very low temperature and near saturation (i.e. up to 15 %, or even more than 20 % relative humidity after the ice-to-water adjustment), the largest impact is expected on the simulation of high-level cloudiness. In a first experiment with a parallel assimilation cycle and 2 daily forecasts, it was applied for the period of 28 March to 1 April 2002 and compared to the operational version as a reference. This period included the event of a thick cirrus cloud band extending from the Mediterranean to Northern France and moving northeastward across Germany. The operational LM forecasts did not capture well the cloudiness and hence severly overestimated the daytime surface-level temperature in the western half of Germany on 30 March (Easter Saturday). Note that below 500 hPa, the air was very dry over Germany and its near environs at that day.

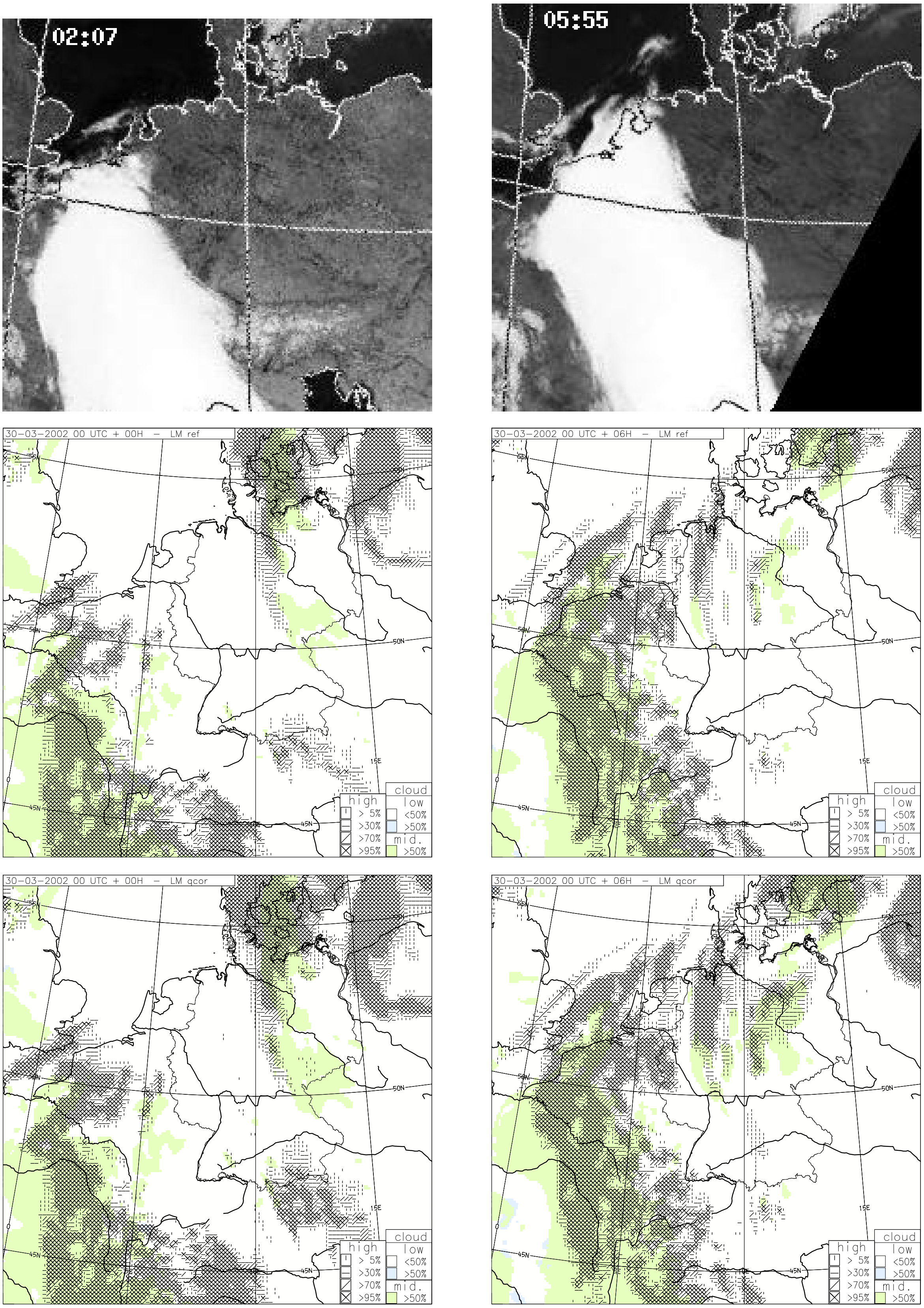

Figure 1: Top row: NOAA IR satellite images; middle row: *high* cloud cover (patterns), mid-level cloud cover (green shading), and low cloud cover (grey shading) of reference LM forecasts without new bias correction; bottom row: as middle row, but for LM forecasts with new bias correction. Left column (a): IR image at 02:07 UTC and LM analyses valid for 00 UTC on 30 March 2002; right column (b): IR image and 6-hour LM forecasts valid for 06 UTC on 30 March 2002.

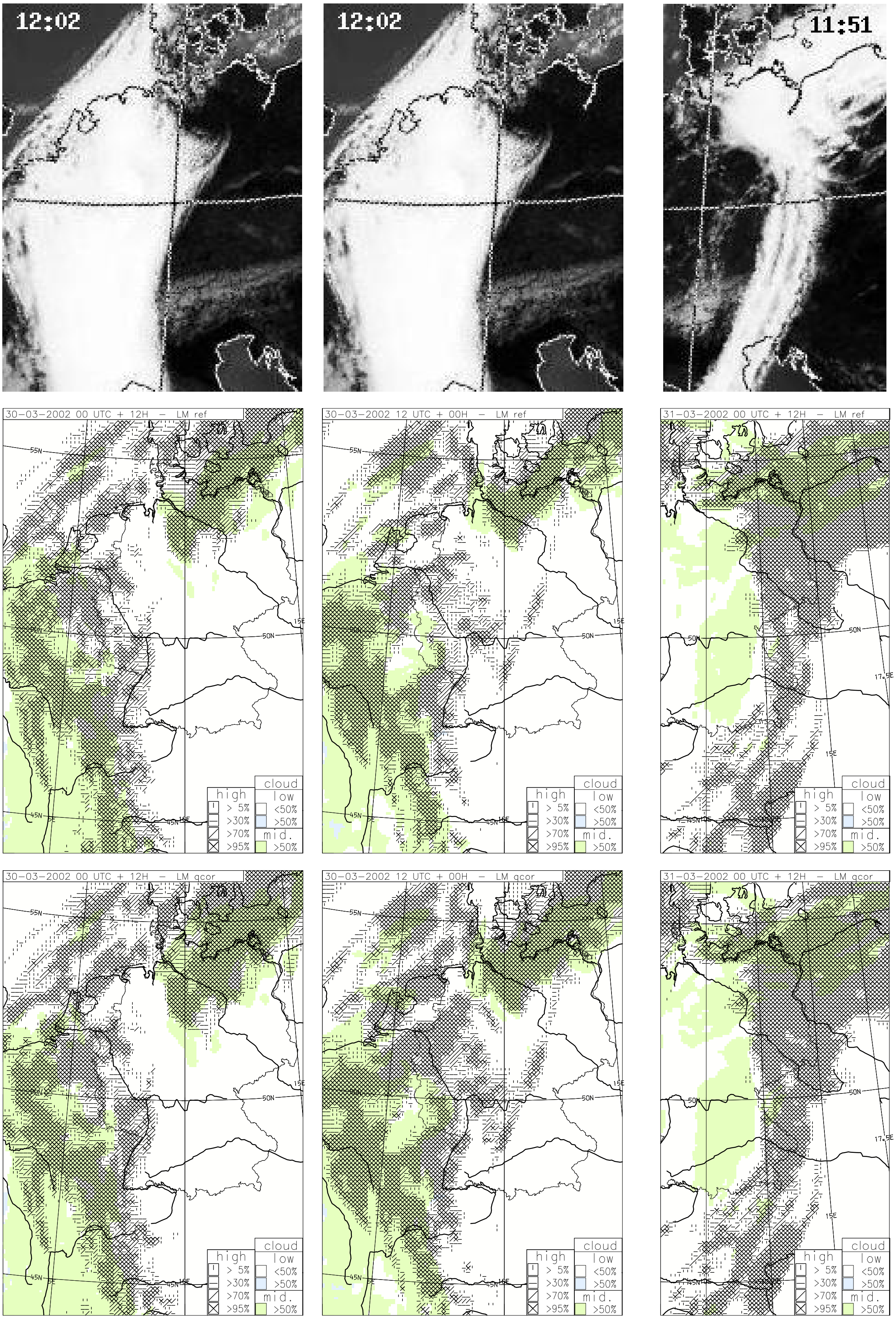

Figure 2: Set-up as in Figure 1. Left column (a): IR image and 12-hour LM forecasts valid for 12 UTC on 30 March 2002; middle column (b): IR image and LM analyses valid for the same time; right column (c): IR image and 12-hour LM forecasts valid for 12 UTC on 31 March.

In the forecasts starting at 29 March 12 UTC or before, the enhancement of the cloud band at 12 UTC on 30 March is very limited in the experiment. In the analysis of 30 March 00 UTC (Figure 1a), the cloud band is moderately enhanced e.g. over northeastern Italy and northern France. A more pronounced increase in high and partly even mid-level cloudiness, however, is found over Austria, the eastern half of Germany, and Poland, i.e. areas, where the 02 UTC (and subsequent) IR satellite images do not appear to indicate any cloudiness. (Thin cirrus extends from Czechia to Denmark on 29 March, 16 UTC.) In the subsequent 6-hour and 12-hour forecasts (Figures 1b, 2a), the differences decrease gradually, yet tend to remain to be largest in the cloud-free areas in northern Germany. In contrast, the enhancement in cloudiness in the 12-UTC analysis (Figure 2b) is largest in the area of the observed cloud band (i.e. between western Germany and the North Sea). The same is true in subsequent forecasts, but the enhancement is small. The 12-hour forecast for 31 March 12 UTC (Figure 2c) is another example for such a (limited) positive impact and also for the fact, that the bias correction does not decrease phase errors (the cloud band propagates eastward too slowly).

In the upper-air verification against radiosonde data for this period (Figure 3), the impact of the bias correction on humidity is moderately negative up to $+24\,\text{h}$, if the model fields are verified against those observation values that have been used in the respective model versions. If, however, the new bias correction is assumed to correct for the true observation bias and hence the bias-corrected radiosonde data are taken as reference observations used to verify both model runs, then the impact is neutral. The relative humidity bias between the two model versions decreases from $2-3\,\%$ ($4-5\,\%$ above $400\,\text{hPa}$) at the analyses to $1\,\%$ at the 24-hour forecasts. This decrease may be due to the lateral boundary conditions provided by GME to which the bias correction is never applied. The impact on temperature tends to be negative but is negligibly small.

Trial 2: A Low Stratus Period

In a second parallel assimilation and forecast experiment, the bias correction is tested for the period of 7 to 13 February 2003, which was characterized by the alternation of low stratus and clear sky over Germany and its environs. In such situations, the operational model forecasts typically underestimate the low cloudiness, and increasing the humidity due to the bias correction has a potential to improve these forecasts. This is shown in Figure 4a to apply to Bavaria and around Denmark in the 14-hour forecast for 11 February 02 UTC. However, erroneous cloudiness can also be enhanced, as is the case e.g. over northeastern France in the 10-hour forecast for 10 UTC on the same day (Figure 4b). Note also that the examples shown here belong to the cases with maximum impact, and the impact on most other cases is smaller. The results in the upper-air verification (not shown) are very similar to those of the first period.

Summary

A new bias correction for Vaisala RS80 humidity data has been tested on two periods with thick cirrus and low stratus respectively. It tends to generally increase the cloudiness very moderately, however it does so both when cloudiness is underestimated and when it is already overestimated. As the main problem in the cases examined is an underestimation rather than overestimation of cloudiness in the forecasts, the overall impact tends to be slightly positive. It is noted that the bias correction does not change the cloud patterns significantly or decrease phase errors. A negligible impact is found on upper-air wind, temperature, and also humidity provided that merely the bias-corrected radiosonde data are used for the verification. However, the errors of the operational reference humidity forecasts are slightly smaller if the latter are verified against the uncorrected radiosonde humidity data.

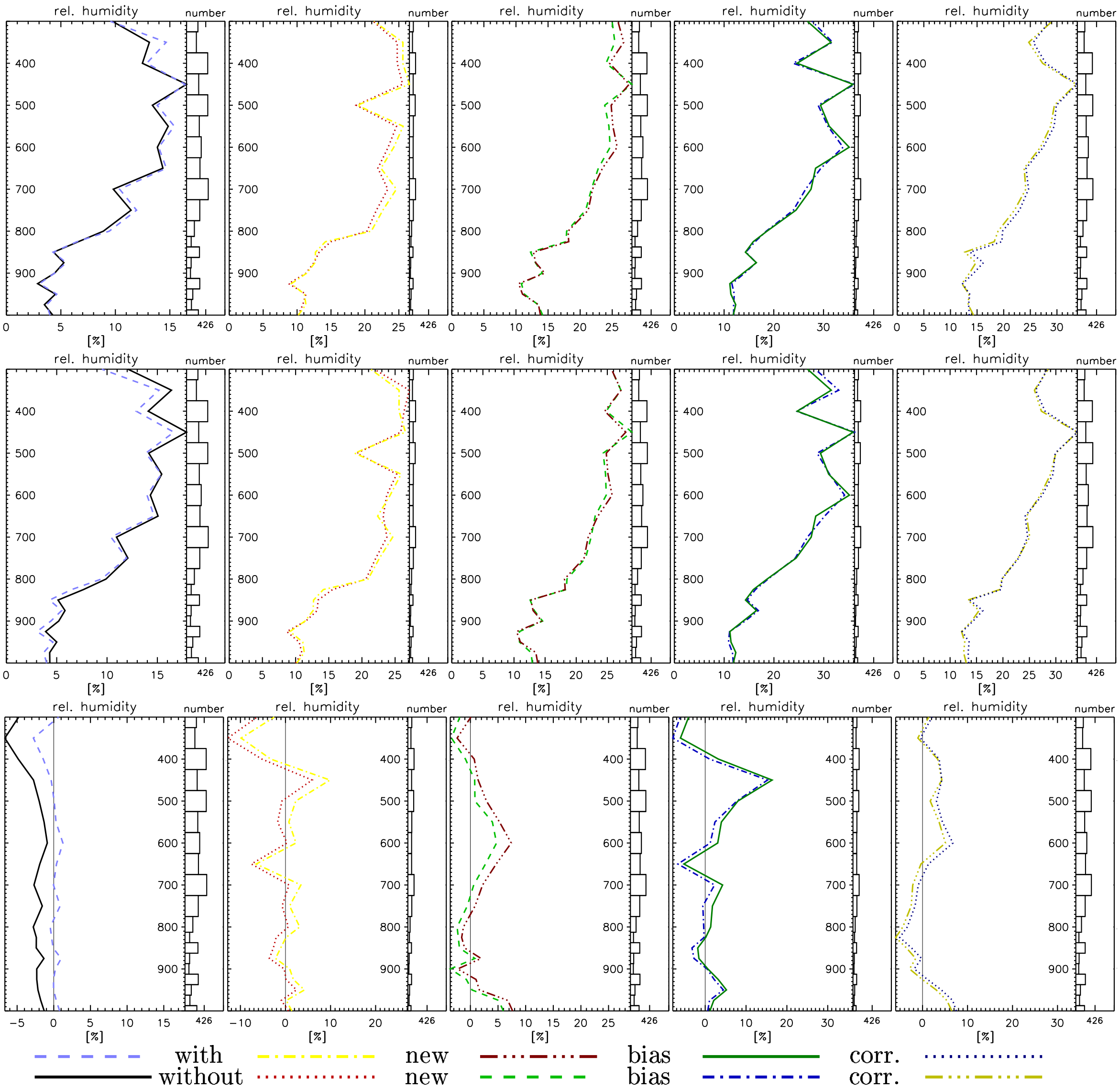

Figure 3: Upper-air verification of relative humidity against all radiosonde data (except those within 60 grid points from lateral boundaries of the LM domain) for the period of 30 March, 6 UTC, to 2 April 2002, 0 UTC. Top row: rms errors against the observation values that have been used in the respective assimilation cycles (i.e. uncorrected data for the operational forecasts, bias-corrected data for the experimental forecasts); middle row: rms errors against bias-corrected observation values; bottom row: bias against bias-corrected observation values. Columns from left to right: analyses, 6-h, 12-h, 18-h, resp. 24-h forecasts. Each panel consists of vertical profiles of errors between 1000 hPa and 300 hPa for the two model versions with line style and color as given below the bottom row, and a histogram for the numbers of observations entering the vertical bins.

With respect to forecast quality, there is no strong argument in favour or against introducing the bias correction operationally. Believing in the correction to reflect the true bias and to render the observation values more realistic would promote to introduce it. Note that the correction should become obsolete as soon as the A-Humicap sensors of the Vaisala RS80 sondes currently used operationally by about 90 % of the radiosonde stations within the LM domain are replaced by H-Humicap sensors of the Vaisala RS90 sondes.

References

Nagel, D., U. Leiterer, H. Dier, A. Kats, J. Reichardt, A. Behrendt, 2001: High accuracy humidity measurements using the standardized frequency method with a research upper-air sounding system. *Meteorol. Zeitschrift*, **10**, No. 5, 395–405 .

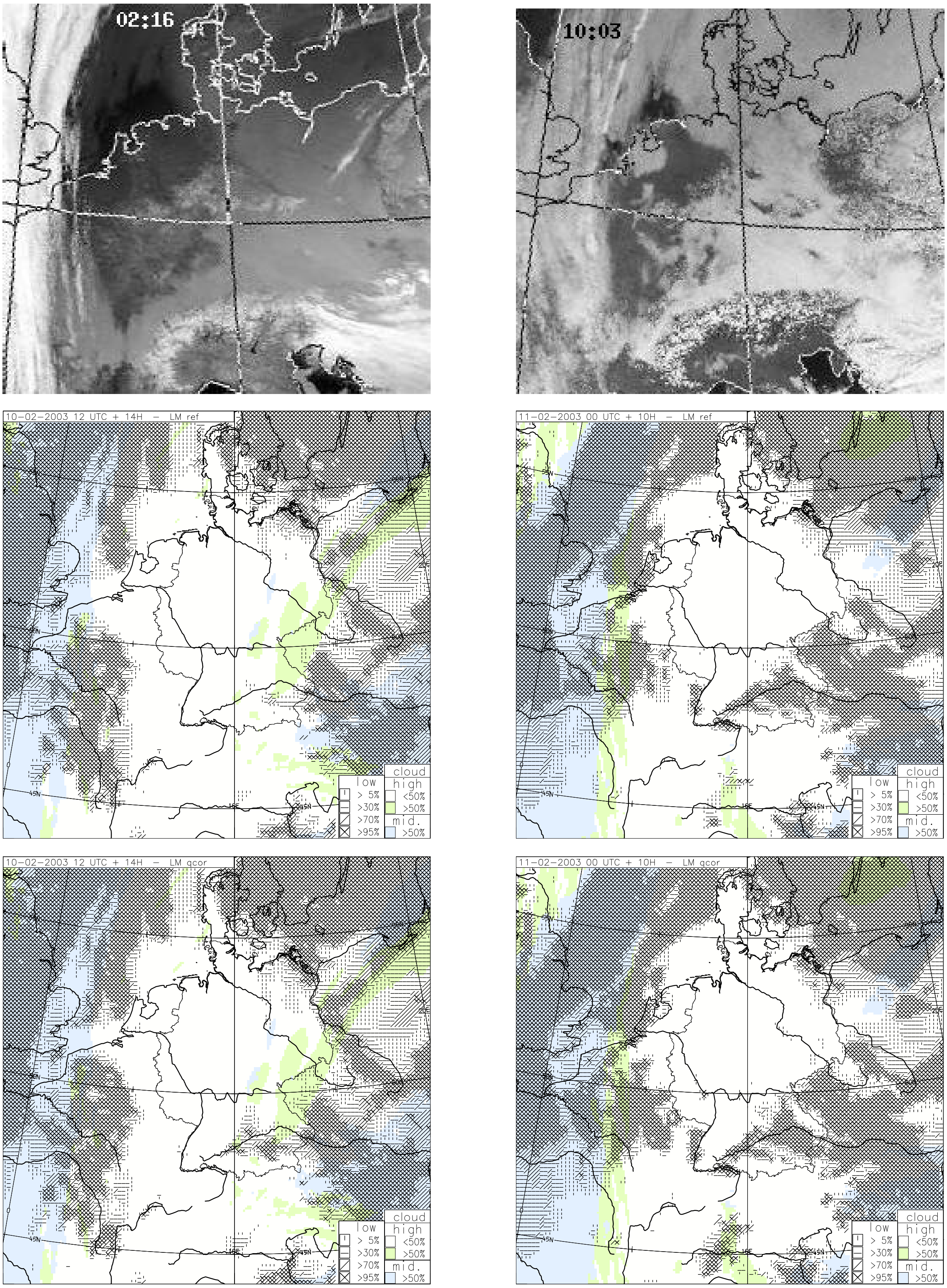

Figure 4: Top row: NOAA satellite images; middle row: *low* cloud cover (patterns), mid-level cloud cover (green shading), and high cloud cover (grey shading) of reference LM forecasts without new bias correction; bottom row: as middle row, but for LM forecasts with new bias correction. Left column (a): IR image and 14-hour LM forecasts valid for 02 UTC on 11 February 2003; right column (b): VIS image and 10-hour LM forecasts valid for 10 UTC on 11 February.

Sharpe, M., and B. Macpherson, 2003: Developments in the correction of radiosonde relative humidity biases. *Forecasting Research Technical Report No. 389, UK Met Office.*