Bias Correction of Humidty Measurements by Radio Sondes of Vaisala RS 92

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1 Introduction

Moisture is very important for many atmospheric processes. A correct description of the moisture of NWP models is essential to simulate the hydrological cycle precisely. An appropriate way to get the model a realistic moisture field is to assimilate moisture observations. In all operational configurations of the COSMO model, radio sondes are the only source of observational information on humidity, except for sceen-level data, which are given very limited weight however. Therefore any systematic error in the radio sondes humidity data will likely be detrimental. Recently many investigations revealed that the humidity measurements of radio sondes seems to be biased compared to other humidity observations. In the two operational configurations of Deutscher Wetterdienst (DWD), COSMO-EU, which has a mesh width of 7 km and covers Europe, and COSMO-DE (2.8 km, Germany and environs) 56% resp. 81% of all radio sondes used are of type Vaisala RS 92. Miloshevich et al. (2009) investigated the accuracy of this type of radio sondes as a function of height, solar elevation angle and relative humidity. They mention two different reasons for the bias. First, there is a calibration error which leads to a small time-independent moist bias below 500 hPa and dry bias further above. The second error is caused by a solar radiation error and will lead to a significant dry bias during daytime. Keeping in mind that the radio sondes are mainly launched at about 00 and 12 UTC the dry bias will affect the COSMO models at daytime between 9 and 12 UTC. To reveal the influence on the COSMO models integrated water vapour (IWV) of the model analyses is compared to the independent IWV retrievals of GNSS zenith total delay measurements (Gendt et al., 2004). As shown in fig. , the model tends to be moister at night but is much drier about noon. A correction algorithm after Milosevisch et al. is now implemented within the COSMO code and briefly described in the following section. Section 3 presents the investigations of the application of the bias correction. A conclusion is drawn in section 4.

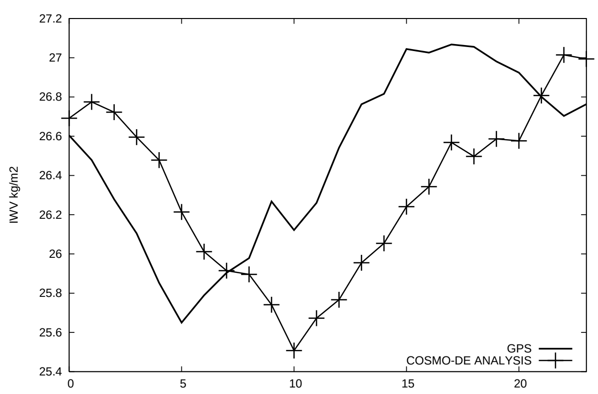

Figure 1: Comparison of integrated water vapour (IWV) retrieved by GNSS observations and analysed by the operational COSMO-DE for July 2010.

2 Bias correction algorithm

In Miloshevich et al. (2009) three inter-comparisons on the accuracy of Vaisala RS 92 in the mid-latitudes are combined and an empirical correction algorithm was designed. The algorithm takes into account that the accuracy is found to be dependent on pressure, relative humidity and the solar elevation angle. Two main sources of error are detected, a calibration error and a solar radiation error. As a matter of fact the latter depends on solar elevation angle and is affected by clouds, where the calibration error is time-independent and not affected by clouds. It has been found that the calibration error leads to a moist bias in the lower troposphere and to a dry bias in upper the troposphere. The solar radiation error leads to a dry bias. Both biases tend to be larger in higher altitudes and for dry conditions. The empirical correction algorithm is given in Eq. 1, with F(p,RH,time) as a polynomial function of pressure, relative humidity and solar elevation angle.

$$RH_{corr} = \frac{100 \cdot RH_{meas}}{100 + F(p, RH, time)} \tag{1}$$

$$\text{with} \quad F(p, RH, time) = \sum_{i=0}^{N} a_i(RH) \cdot p^i$$

The polynomial fit F(p,RH,time) is time-dependent, i.e. the order of the fit and the coefficients are different between night and day. Even more the daytime fit is only valid for a solar elevation angle $\alpha = 66°$. Therefore for daytime measurements another correction step is required to account for α. The component of solar radiation error (SRE) at $\alpha = 66°$ is given as the difference between the function F(p,RH,time) at day and at night. Any other angle is given by Eq. 2, where G is another polynomial function of α. All coefficients and more details can be found in Milosevisch et al. (2009).

$$SRE(\alpha) = (F(p, RH, 66°) - F(p, RH, night)) \cdot G(\alpha) \tag{2}$$

The correction algorithm described above is valid for clear sky conditions. This would restrict the operational usage in many cases. Therefore in addition to the algorithm of Milosevisch et al. (2009), in new bias correction in COSMO, cloudy conditions are accounted for. The bias caused by solar radiation error is reduced in dependence of the liquid water path above the measurement.
To apply the bias correction a new namelist switch $mqcorr92$ is defined, which can be set to

0 no bias correction

1 correction of solar radiation error

2 correction of total error (ie. the sum of calibration and solar radiation error

3 Experimental investigations

The bias correction has been tested experimentally for both COSMO configurations running operationally at DWD. The tests were performed over one month each in winter (March 2010) and summer (July 2010), applying the corrections of the total bias (see above). In the following the results will be described starting with the winter case. The attention is drawn to COSMO-DE.
The first half of March 2010 was dominated by cold winter weather with northerly wind. In the second half a south western flow established and the temperature increased. The IWV was low in the beginning and also arised towards the end of the month. In winter the bias in

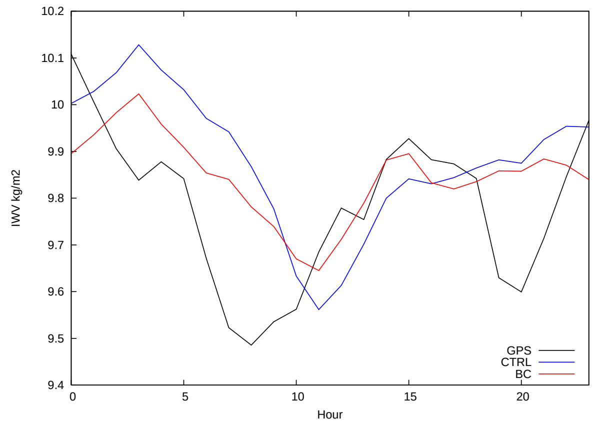

Figure 2: Comparison of IWV for March 2010 retrieved by GNSS observations (black line) and analysed by different COSMO-DE setups for March 2010: control run (blue), experimental run with bias correction of total bias (red).

terms of IWV is not as pronounced as in summer. Therefore the effect of the bias correction can not be expected to be very large. However, the bias could be reduced, as can be seen in Fig. . Besides the correction seen by the comparison of IWV only small effects of the bias correction on other parameters can be found. The impact on the humidity is visible in a verification against radio sondes (not shown). In the comparison between the operational run and the experimental run with bias correction the impact can be found at higher levels. Above 500 hPa the bias between model and observations as used in the respective assimilation set-up tends to be smaller in the experiment, which is mainly caused by the correction of the observation. As the observations in both runs are not equal, a comparison of the state of the model is difficult. Most of the other scores show an almost neutral impact.
This is different in summer. The test period was dominated by very hot conditions associated with several events of heavy rain fall and thunderstorms. The IWV reaches high values. In such conditions, which are organized more locally, moisture will have a greater influence as in winter, where the weather is more dominated by large scale advection. In summer the forecasts of both COSMO configurations are improved, when applying the bias correction. The positive impact is not restricted on moisture related variables (see fig.) but can be found for other variables, too. Fig. shows the verification against synoptical observations for temperature and dew-point depression. For both elements a small improvement is achieved

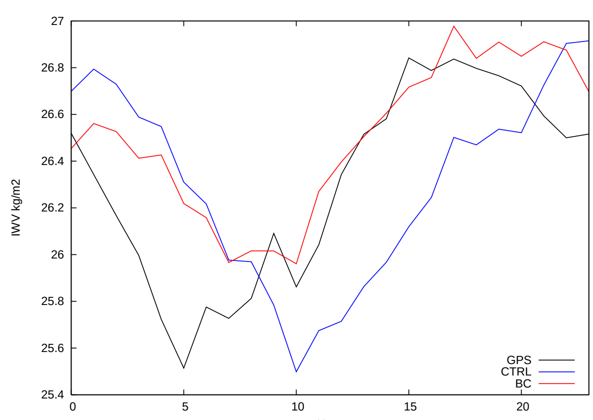

Figure 3: Comparison of IWV for July 2010 retrieved by GNSS observations (black line) and analysed by different COSMO-DE setups for March 2010: control run (blue), experimental run with bias correction of total bias (red).

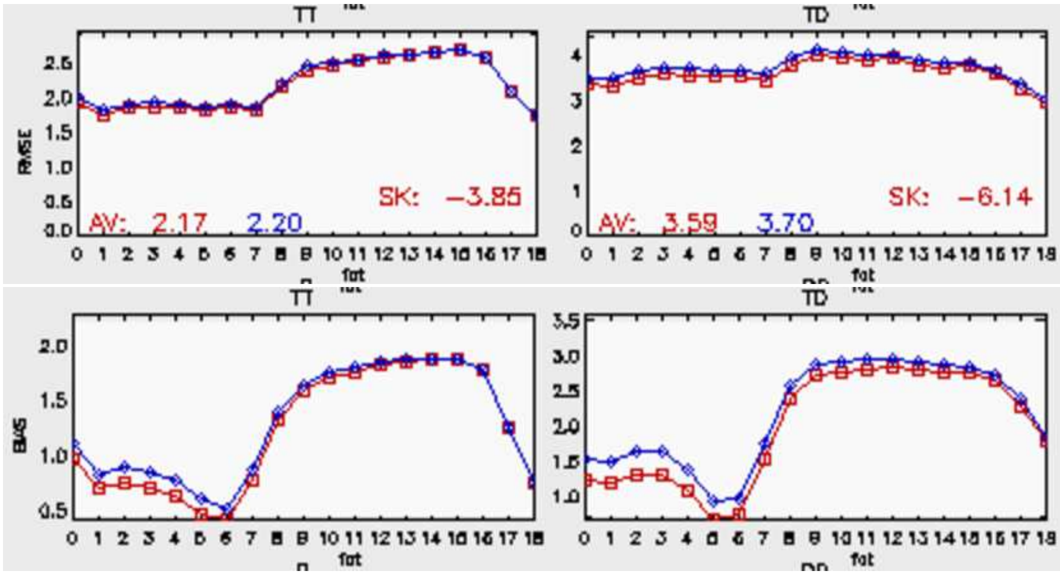

Figure 4: Verification of 2m temperature and 2m dew-point depression against synoptical observations for 12 UTC forecast runs in July 2010: control run (blue), experimental run with bias correction of total bias (red); top row: RMSE and bottom row: BIAS.

when applying the bias correction. The improvement is achieved mainly by decreasing the model bias of both elements. Of special interest is the improvement of precipitation forecast. Esp. 12 UTC forecast runs of COSMO-DE do not predict convective precipitation well in summer. Also in this regard an improvement due to the bias correction is visible, although the impact is not very large. In fig. ETS and FBI for a precipitation rate greater than 0.1 mm/h (calculated against radar observations) are shown for the 12 UTC forecast of control run and run with bias correction. A small improvement can be found within the first hours of the forecast when applying the bias correction.

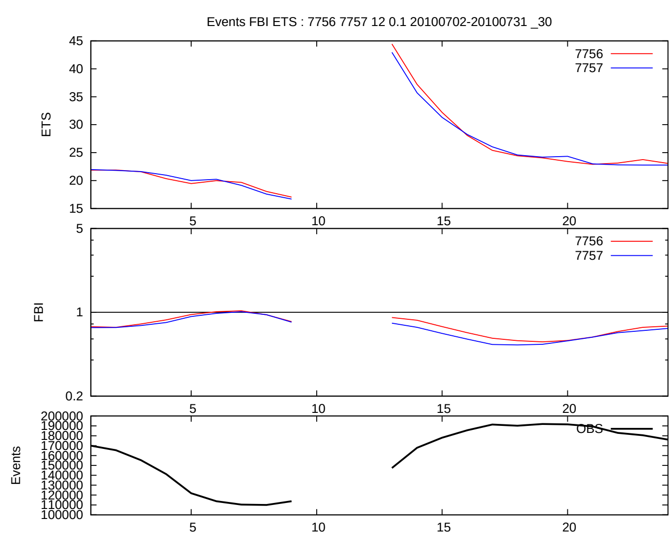

Figure 5: Verification of mean precipitation greater than 0.1 mm/h against Radar observations for 12 UTC forecast runs in July 2010: control run (blue), experimental run with bias correction of total bias (red).

4 Conclusions

A bias correction of relative humidity measured by Vaisala RS92 radio sondes is applied for COSMO configurations at DWD. The correction of the bias is found to be beneficial for the forecast. Especially in summer the improvement is visible in the verification, when correcting for the total bias of those humidity data. The correction of the total bias leads to a drier model state at nighttime and a moister state at daytime. An even more positive impact can be achieved if only the solar radiation error is corrected. Then the models become even more moist all over the forecast time. In winter both bias corrections are almost neutral compared to the control run.

In order to achieve a model state closer to reality, the decision was made to apply the correction of the total bias operationally. This will give the model developers the opportunity to tune the parametrization on the basis of a more realistic initial model state. However, the fact that the model performs better if its state is more moist might give evidence that there is a need to tune the parametrizations.

References

[1] Gendt, G., Dick, G., Reigber, C., Tomassini, M., Liu, Y. and Ramatschi, M., 2004: Near Real Time GPS Water Vapor Monitoring for Numerical Weather Prediction in Germany, *J. Meteo. Soc. Japan,* **82**, No. 1B, pp. 361–370

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