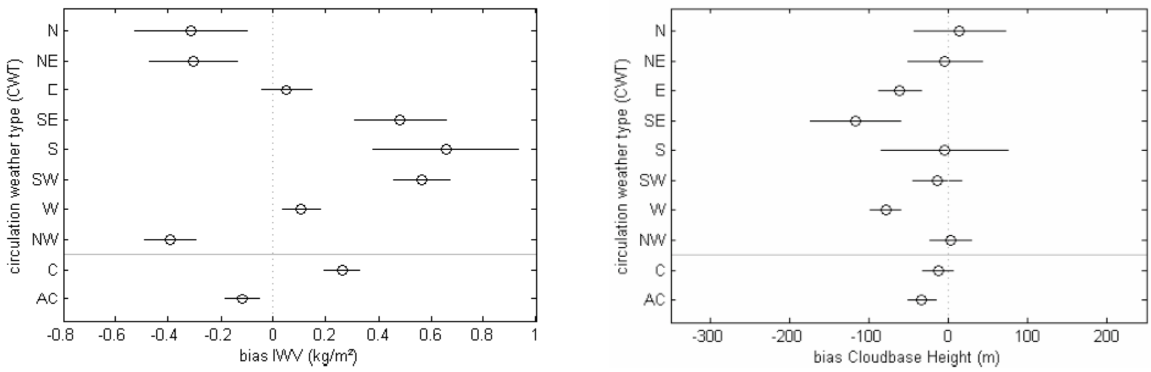

Figure 4. *Dependence of bias in IWV (left) and cloud base height (right) on circulation weather type for the full domain.* The grey horizontal line separates the 8 directional CWT classes from the vorticity classes (cyclonic and anticyclonic). The grey vertical dotted line indicates the zero-bias (where the mean bias between model and observations equals zero).

6. REGIME-DEPENDENT MODEL EVALUATION

The previous analysis concentrated on the model bias over the full period of two years. Compensating model biases might not show up in such an analysis. A regime dependent model evaluation can identify compensating biases, but can also help in finding the underlying causes for the model biases.

The classification scheme used here [2] is a variant of the Jenkinson-Collison technique, which is in turn an automated version of the Lamb classification. Every 3 hours the main weather type is calculated from the COSMO-EU analysis of the geopotential height field at 850 hPa for the whole domain and separately for a southern, central and northern Germany. In total 10 different regimes (circulation weather type CWT) are discriminated with 8 directional (, North – N, North East – NE, East – E, South East – SE, South – S, South west – SW, West – W, North West – NW) and two vorticity classes (cyclonic – C and anticyclonic – A).

From a multiple comparison of means (MCM) test, it appears that model biases are dependent on the circulation weather type, especially for IWV but also – to a lesser extent – for CBH (Fig. 4). The COSMO-DE model underestimates IWV by -0.3 to -0.4 kg m^{-2} during the northerly flow conditions, whereas it overestimated IWV +0.5 to +0.6 kg m^{-2} during southerly flow conditions. This means that for northern CWTs the air is modeled too humid and for the southern CWTs too dry. A somewhat similar pattern is recognizable if the classification is based on the 500 hPa level, but here the underestimation is less clear and for the northern and northeastern regimes even not significantly different from zero.

When looking at the CWT dependency of the cloud base height (Fig. 4 right) an inverse picture to IWV emerges. During southerly flow the model overestimates humidity and therefore ascending air parcels reach saturation earlier leading to a lower cloud base. Although the CWT dependency of the CBH is weak compared to the IWV for the entire domain the signal becomes much clearer if only Northern Germany is considered (not shown). Because Northern Germany is much flatter than the rest of the country orographically induced clouds might mask the signal in the Central and Southern Germany.

7. CONCLUSIONS

An approach for long-term model evaluation using GPS and ceilometer network together with surface precipitation observations is presented. The analysis of the COSMO-DE and COSMO-EU forecasts over a period of two full years yields the following results:

1) Data assimilation has a strong influence on the diurnal cycle through the dry bias of radiosondes launched during noon. During 12h of forecast COSMO-DE has compensated initial water vapour deficits and developed even a slightly stronger diurnal IWV cycle (1.0 kgm^{-2}) than observed (0.8 kgm^{-2}).

2) Diurnal cycle in cloud base height is predicted too weakly while the seasonal cycle is predicted too strongly. The poorest forecasts occur during night in summer indicating that the parameterization of stable boundary layer needs further attention. The connection between cloud base height and atmospheric moisture is most pronounced in summer during undisturbed conditions when the boundary layer is often too moist and not deep enough.

3) The 20% larger models forecast of precipitation during winter compared to the measured values indicates that precipitation is the most difficult parameter to model and to measure.

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