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Wetter und Klima aus einer Hand

Humidity sensitive Radiances and constrained bias correction in the global DWD System

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In this poster the most recent updates of the assimilation of humidity sensitive radiances in the operational global DWD system are presented. An update of the cloud detection scheme increased the number of assimilated MW humidity data noticeably. Most forecast scores were improved by this update. However, an upper-tropospheric tropical humidity bias of the system was reinforced. We found that this was due to a positive feedback loop between model bias and radiance bias correction. In order to break this feedback loop and to diminish the upper-tropospheric tropical humidity bias we introduced a constrained bias correction for the uppermost ATMS and MHS humidity sounding channels.

Against this background the implementation of MWHS-2 in our system is problematic because its biases have a different sign and magnitude compared to the MHS/ATMS biases. The above-mentioned upper-tropospheric tropical humidity bias would be reinforced again, if we were assimilating MWHS-2 similarly to ATMS/MHS with a constrained bias correction. A solution to this problem is presented here. This so-called "offset bias correction" is a descendant of the constrained bias correction.

1. Current status

The following table summarizes the current status of the assimilation of humidity sensitive radiances in the global, operational ICON/EnVar system at DWD:

Instrument	Channels	Obs. error	Cloud det.	Biascorr.
MHS	3-5	2 K	**mod.** Buehler et al. (2007)	**Constr. BC**
ATMS	18, 20, 22	2 K	**mod.** Buehler et al. (2007)	**Constr. BC**
SSMI/S	9, 10, 11	2 K	**mod.** Buehler et al. (2007)	**Constr. BC**
MWHS-2	**11, 13, 15**	**2 K**	**mod. Buehler et al. (2007)**	**Offset BC**
GMI	12, 13	2 K	Scatt. ind., fg. dep., polar. diff.	Conventional
IASI	16 chans in band 3	Desroziers, non-diag. **R**	McNally-Watts	Conventional
SEVIRI ASR	2, 3	2 K	fg. dep.	Conventional
AHI ASR	2, 4	2 K	fg. dep.	Conventional
ABI ASR	2, 4	2 K	fg. dep.	Conventional

Recent operational updates are highlighted:
orange: 11th May 2022, **red:** 25th January 2023
Thinning: one observation per grid box of 160 km is selected for assimilation

2. Modified Buehler (2007) cloud detection scheme

The Buehler et al (2007) cloud detection scheme, that is used for most MW humidity sounders in our system, is illustrated in figure 1. A modified, less conservative scheme (orange in fig.1) allows us to use ~35% more MW humidity radiances. This has a significant positive impact on most forecast verification scores (not shown). However, a moist bias of the forecasts in the upper tropical troposphere is noticeably reinforced by this update. This has been traced back to a feedback between the model and the bias-correction

Modified Buehler (2007) scheme

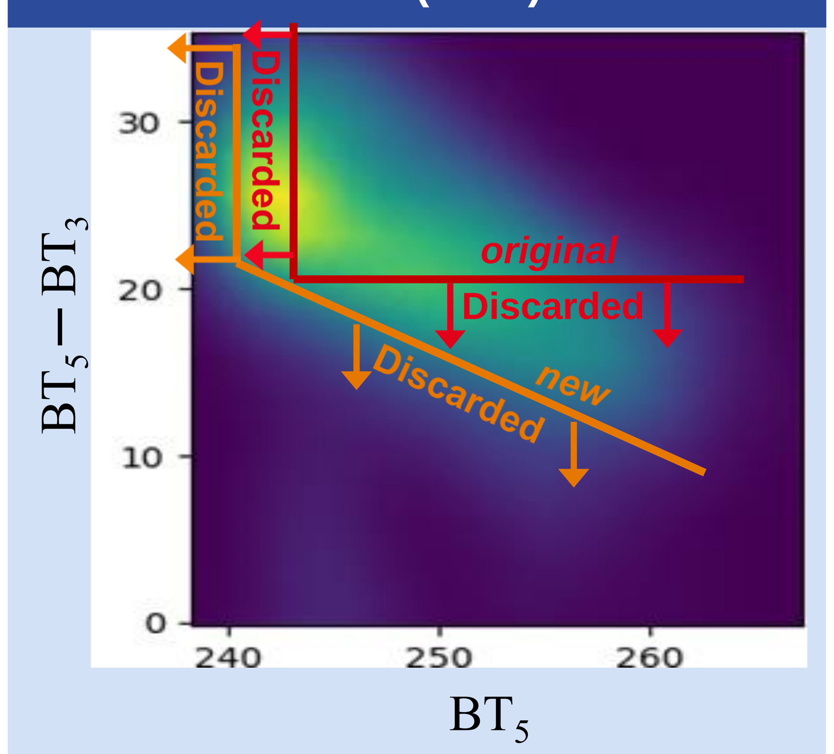

Figure 1: Density of clear sky simulated MHS BTs. Too cold observations or observations with a too small difference between channel 5 and 3 are discarded. The modified/original scheme is sketched in orange/red.

3. Model-Bias-correction feedback

The radiance bias correction coefficients are calculated within each analysis step by minimizing

$$\langle (o - f + b)^2 \rangle = min! \qquad (I)$$

where o are observations, f are model equivalents, b is a standard bias correction ansatz and $\langle\,\rangle$ denotes a temporal average (see Stiller et al 2021). It is obvious that the bias correction can not differentiate between observation and model biases. Therefore, if the model has a bias (that projects onto the bias correction predictors) the bias corrected observations are stabilizing the bias of the model system. If more such observations are added, the bias of the system might be strengthened. This mechanism explains why the upper-tropospheric tropical humidity bias of our system was reinforced by adding more MW humidity radiances.

- Buehler, S. A. Kuvatov, M., Sreerekha, T. R., John, V. O., Rydberg, B., Eriksson, P. and Notholt, J.: A cloud filtering method for microwave upper tropospheric humidity measurements, Atmos. Chem. Phys., 7, 5531-5542, 2007.
- Stiller, O., Rhodin, A.: Operational bias correction of satellite radiances at DWD, https://nwp-saf.eumetsat.int/site/download/Bias_DWD_RevN.pdf, 2021
- Han, Wei and Bormann, Niels: Constrained adaptive bias correction for satellite radiance assimilation in the ECMWF 4D-Var system, ECMWF Tech Memo 783, 2016.

4. Break the feedback loop: constrained BC

A constrained bias correction for MHS channels 3/4 might help to diminish humidity biases. A penalty term is added to equation (I) (see Han et al 2016):

$$\langle (o - f + b)^2 \rangle + \alpha \langle (b - b_0)^2 \rangle = min!$$

i.e. large deviations of the bias correction from b_0 are penalized. Here, we select $b_0 = 0$. We found that $\alpha = 0.5$ $(\alpha = 0.25)$ for MHS channel 3 (4) gives the best scores. The same values were chosen for the corresponding ATMS channels (20,22). The effect onto the bias correction is illustrated in fig. 2: channel 3/4 bias corrections adapt much less to the moist upper-tropospheric tropical model bias. As a result the moist upper-tropospheric tropical bias of the system is strongly improved (not shown).

MHS bias correction

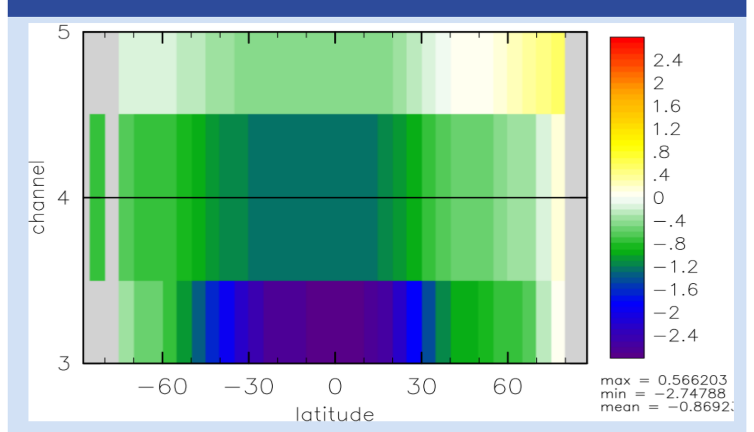

Figure 2a: Zonal means of MHS bias correction without constrained BC. Please note the strongly negative values for channel 3 in the tropics.

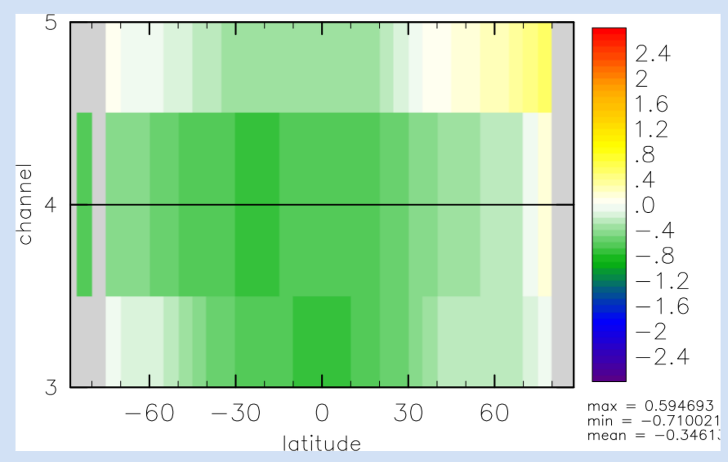

Figure 2b: Zonal means of MHS bias correction for the constrained BC experiment.

5. Offset bias correction

The constrained BC makes sense, if there is evidence, that the bias of the (uncorrected) observations is better than the bias of the system. This is the case for MHS and ATMS in the DWD system. However, the MWHS-2 observations apparently have much worse bias properties. In this case the constrained BC is not useful (see fig. 3a). As a workaround for MWHS-2 we use a conventional bias correction (equation (I)) and add an offset, that is calculated on the basis of the corresponding MHS and ATMS channels (see fig. 3b). This approach requires a careful monitoring of the "basis" MHS and ATMS channels.

Offset bias correction

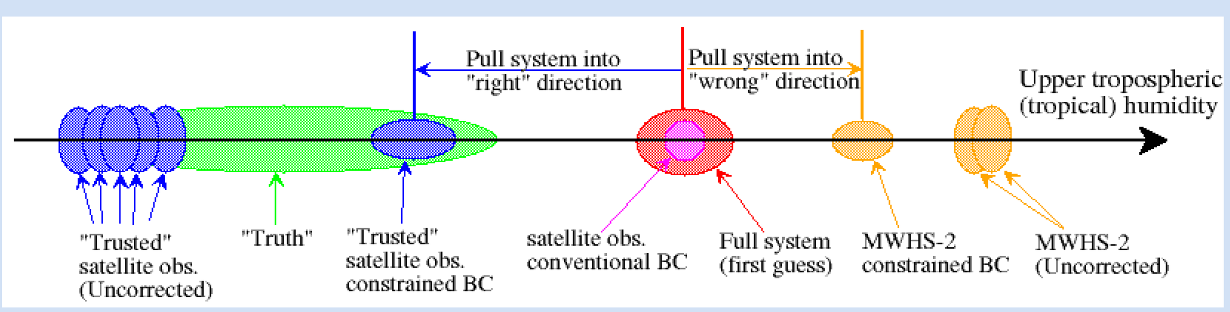

Figure 3a: Sketch of constrained BC and how it acts onto the system. Yellow colours show, how MWHS-2 would act onto the system if a constrained BC was used.

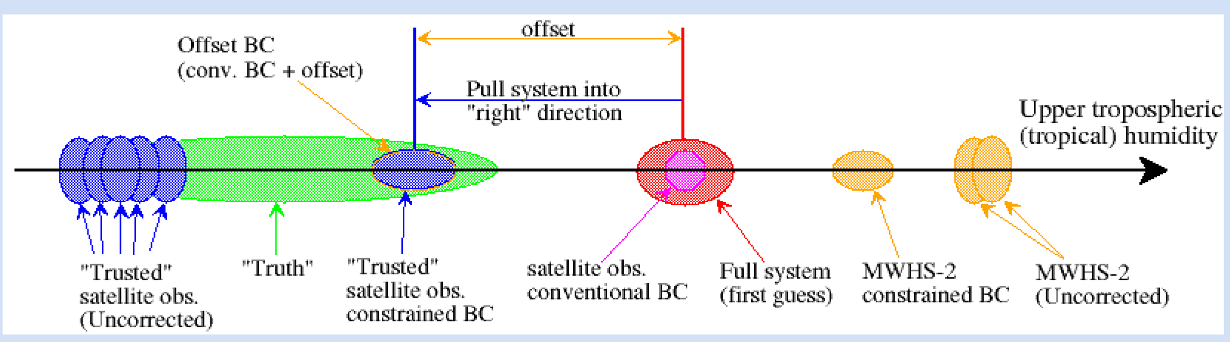

Figure 3b: Sketch of constrained BC and the descendant "offset BC". The offset is calculated on the basis of the "trusted" obs. and added to the conventional BC.

6. Conclusion/Outlook

- A model-bias-correction feedback in the DWD system was presented. The feedback loop can be broken with the aid of the constrained BC.
- A descendant of the constrained BC called "offset BC" was presented. This is useful for observations with bad bias properties.

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