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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Extended use of Humidity Sensitive Radiances in the ICON/EnVar system

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In the last years more and more humidity sensitive radiances were introduced into DWD's operational system. Currently, humidity channels from IASI, MHS, ATMS, SSMI/S, GMI, SEVIRI, GOES sounder, ABI and AHI are assimilated operationally with a positive impact. In this poster ongoing work to extend the use of humidity sensitive radiances even further is presented. In contrast to previous changes an increased use of humidity information seems to degrade the scores at least partially. To some extent the system appears to be "saturated" with respect to humidity sensitive radiances. Analyses show that this is due to a model bias in the tropical upper troposphere humidity and the interaction between model bias and radiance bias correction. This problem is analyzed, and possible solutions are presented.

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.
MHS	3-5	2 K	Buehler et al. (2007)
ATMS	18, 20, 22	2 K	Buehler et al. (2007)
SSMI/S	9, 10, 11	2 K	Buehler et al. (2007)
GMI	12, 13	2 K	Scatt. ind., fg. dep., polar. diff.
IASI	16 channels in band 3	Desroziers (inflat.), correlated **R**	McNally-Watts
SEVIRI CSR	2, 3	2 K	fg. dep.
AHI CSR	2, 4	2 K	fg. dep.
ABI CSR	2, 4	2 K	fg. dep.
GOES im. CSR	2	2 K	fg. dep.

All channels are thinned to one observation per gridded box of 160 km.

2. Plans

Ongoing projects concerning humidity sensitive radiances in the DWD system:

- Assimilation of MWHS-2
- Assimilation of SAPHIR
- Assimilation of additional channels:
  - ATMS channels 19, 21
  - IASI additional channels in bd. 3
  - AHI/ABI channel 3
- Less thinning
- Less strict cloud detection, in particular for MHS/ATMS and SSMI/S. The currently used Buehler et al (2007) scheme discards too many good observations. A revised, less conservative scheme is illustrated in figure 1.
- Observation error tuning

Modified Buehler (2007) scheme

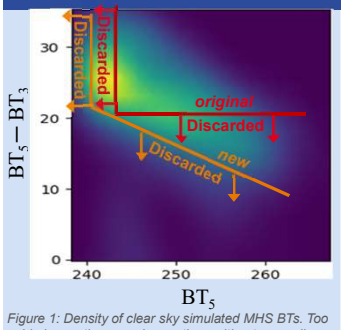

Figure 1: Density of clear sky simulated MHS BTs. Too cold observations or observations with a too small difference between channel 5 and 3 are discarded. The modified/original scheme is sketched in orange/red. The original scheme by Buehler et al 2007 discards too many good observations.

3. The Problem

With each of the abovementioned actions humidity sensitive radiances get a stronger impact onto the analyses. In the current global operational system this leads to an increase of a moist bias in the upper tropical troposphere (see red and grey lines in Figure 2).

The verification against radiosondes shows that the analyses have a humid bias (not shown). In figure 2 it is clearly visible, that the model is working against the moist bias in the analyses.

Humidity bias (against analyses)

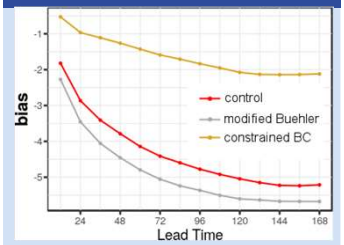

Figure 2: Relative humidity bias against analyses for the 250hPa layer in the tropics.

4. Hypothesis

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

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

where o are observations, f are first guesses, b is a standard bias correction ansatz and $\langle\,\rangle$ denotes a temporal average. 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.
Figure 3a shows that the bias correction for the upper tropospheric MHS channel 3 adapts itself to the moist model bias in the tropical upper troposphere.

MHS bias correction

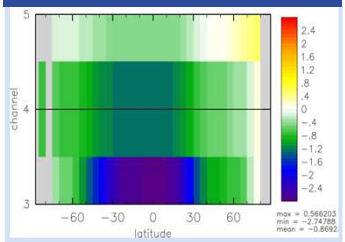

Figure 3a: Zonal means of MHS bias correction for the operational system. Please note the strongly negative values for channel 3 in the tropics.

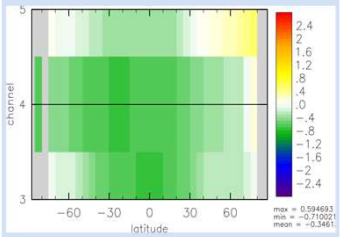

Figure 3b: Zonal means of MHS bias correction for the contrained bias correction experiment. The adaptation of the bias correction of channel 3 to the humid model bias in the tropical upper troposphere is much smaller than in the operational system (see Figure 3a above).

5. Solution strategies

1) Eliminate the source of the moist bias. We suppose that this bias is linked to the fact, that our model system overestimates the convection in the tropics (if satellite radiances are assimilated). This results in too strong humidity transport into the tropical upper troposphere. We currently do not see any way out of this problem. 🤔
2) Weighting observations with the normalized observation error $\frac{e_{obs}}{e_{bg}}$ in the calculation of the bias correction. This reduces the weight of observations in the tropics. 😐
3) Currently radiosonde humidity observations are not assimilated above 300 hPa. In experiments with radiosonde humidity assimilated up to 200 hPa the humid bias was hardly diminished. 😐
4) Re-initialization of the system
   - with long-term model run (which lacks the strong humid bias) 😐
   - Starting with a bias correction from an experiment where radiances are not assimilated. 🙂
5) A constrained bias correction for MHS channel 3 might help to anchor humidity biases. A penalty term is added to equation (I) (see Han et al 2016):
   $\langle (o - f + b)^2 \rangle + \alpha \langle (b - b_0)^2 \rangle = min!$
   First experiments with $\alpha = 1$ and $b_0 = 0$ for MHS channel 3 are promising (please see Figure 3b and the brown line in Figure 2). 😊

6. Conclusion/Outlook

- A moist bias of the forecast system in the tropical upper troposphere is strengthened by additional humidity sensitive radiances. This is due to the bias correction, that adapts itself to the the bias of the system.
- Various approaches to counteract/eliminate the bias were considered. The use of a constrained bias correction (see Han et al 2016) for MHS channel 3 and ATMS channel 22 is the most promising way forward.
- Further tuning of the constrained BC is required.

- 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.
- Han, Wei and Bormann, Niels: Constrained adaptive bias correction for satellite radiance assimilation in the ECMWF 4D-Var system, ECMWF Tech Memo 783, 2016.

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