Correction of errors in the simulation of AMSU-A observations

1 Introduction

The simulation of observations from short-range forecast model fields (or model first guess) plays a crucial role in the estimation of the optimal state of the atmosphere as it is used to fit the analysis to the measured radiances. We have estimated the value of a correction factor, termed γ, for the simulations of all the 5 AMSU-A microwave temperature sounder instruments currently assimilated at ECMWF.

γ is a scaling factor for the optical depth $\sigma(p)$ in the channel transmittance $\tau(p)$ from pressure level p to space used in the radiative transfer simulation of the AMSU-A observations:

$$\tau(p) = e^{-\gamma\sigma(p)}.$$

γ can model radiative transfer errors (e.g. errors in the spectroscopy) or errors in the instrument characterisation (e.g. errors in the specification of the channel passband).

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2 Estimation of a γ correction

The bias between observed (Obs) and model-simulated (FG) radiances for some AMSU-A channels can be modeled through a constant fractional error in the optical depth (γ) and a global constant (δ):

$$mean\,[Obs - FG] = \delta + mean\,[FG_\gamma - FG].$$

Under a linear assumption for γ, following a previous work done in 2004 by P. Watts and A. McNally [1], the correction factors can be estimated from the statistics of assimilation experiments which use a fixed γ value (e.g. $\gamma^* = 1.05$) versus experiments which do not apply a γ correction (see Figure 1 and 2):

$$mean\,[Obs - FG] = \delta + \beta\,(\gamma)\,mean\,[FG_\gamma - FG].$$

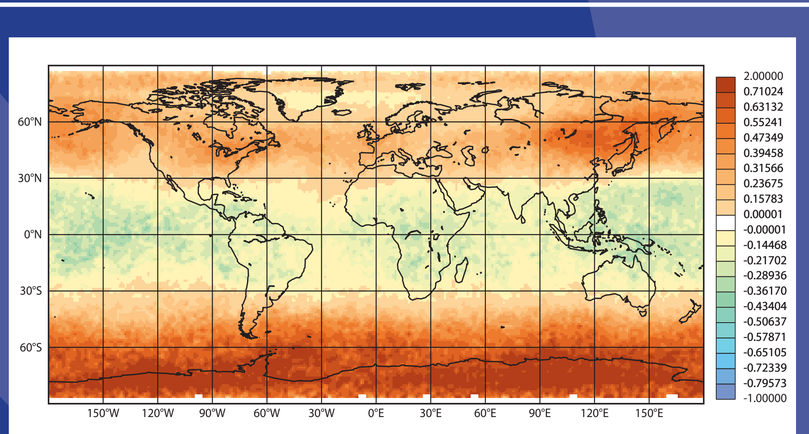

Figure 1 NOAA-19/AMSU-A channel 8 departures from model estimates (mean[Obs-FG]) in the control experiment (i.e. with no γ correction).

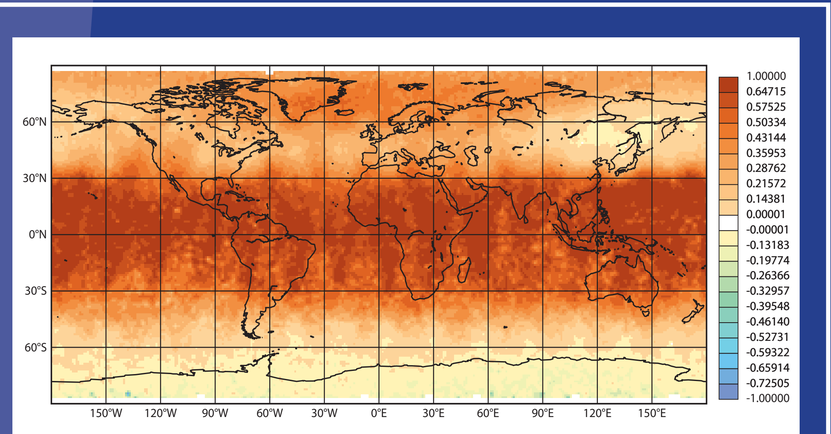

Figure 2 NOAA-19/AMSU-A channel 8 difference of departures from model estimates between an experiment with γ=1.05 and the control experiment (mean[FG_γ-FG]).

3 Results

A set of data assimilation experiments were run with/without the new γ estimates (γ experiment/control experiment) for AMSU-A channel 5 to 8.

- The experiment results show that a γ factor smaller than 1.05 reduces significantly air-mass dependent biases in channels 5 to 8 (see Figure 3 and 5).
- The new results for γ are quite similar to the ones estimated in 2004 and used operationally for NOAA-15, NOAA-18 and Aqua (see Table 1).
- When no correction is applied, the variational bias correction (VarBC)[2] is however able to correct the systematic differences between the observations and the model (see Figure 4 and 6). VarBC is an adaptive scheme employing a linear bias model that includes for AMSU-A a global constant, scan and air-mass dependent predictors. The predictor coefficients are estimated in the variational analysis together with the optimal state of the atmosphere.
- The forecast impact of the γ experiment versus the control experiment is not uniformally in favour of one or the other experiment. This result is coherent with the small differences in departure statistics of the first-guess and analysis after the bias correction.

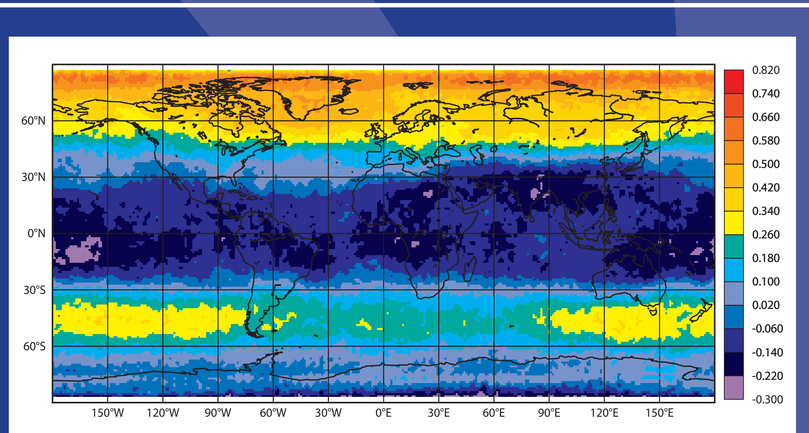

Figure 3 NOAA19/AMSU-A channel 8 departures from model estimates before bias correction in the control experiment.

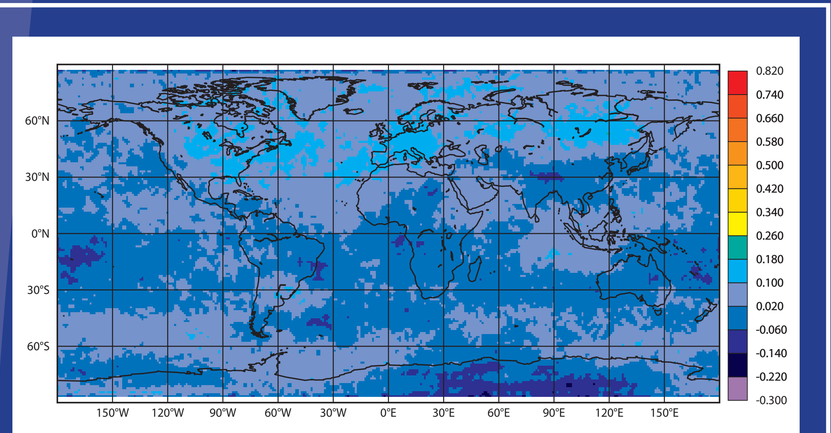

Figure 4 NOAA19/AMSU-A channel 8 departures from model estimates after bias correction in the control experiment.

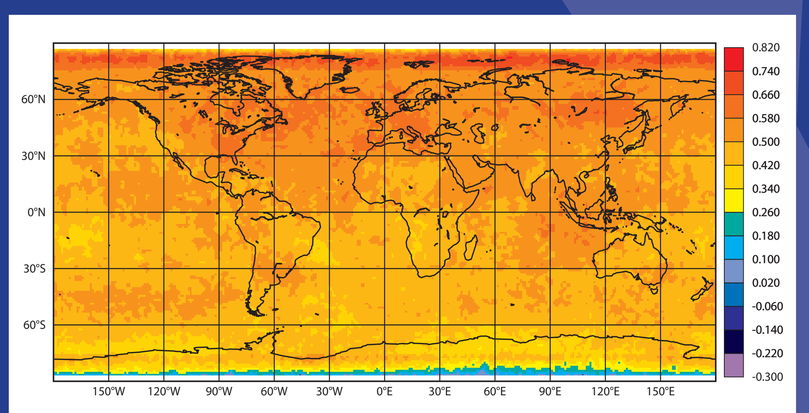

Figure 5 NOAA19/AMSU-A channel 8 departures from model estimates before bias correction in the γ experiment.

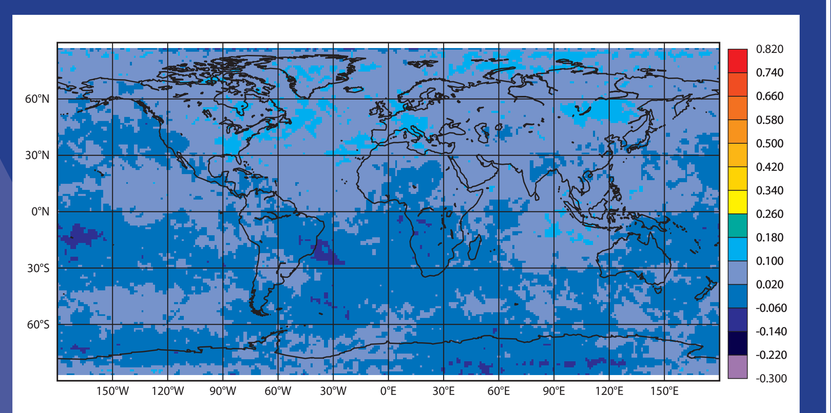

Figure 6 NOAA19/AMSU-A channel 8 departures from model estimates after bias correction in the γ experiment.

Satellite	Channel	Operational γ	New γ
NOAA-15	5	1.0500	1.0419
	6	1.0500	NA
	7	1.0339	1.0321
	8	1.0400	1.0386
NOAA-18	5	1.0420	1.0344
	6	1.0180	1.0204
	7	1.0390	1.0370
	8	1.0350	1.0414
NOAA-19	5	1.0000	1.0348
	6	1.0000	1.0199
	7	1.0000	1.0309
	8	1.0000	1.0430
Aqua	5	1.0500	1.0305
	6	1.0390	1.0297
	7	1.0450	NA
	8	1.0460	1.0438
MetOp-A	5	1.0000	1.0322
	6	1.0000	1.0165
	7	1.0000	NA
	8	1.0000	1.0436

Table 1 Values of γ used in operations and new estimates. (AMSU-A channels 5 to 8 on NOAA-15, NOAA-18 and AQUA are currently corrected at ECMWF by a factor γ estimated in 2004 [1]).

4 Conclusions

- Correcting systematic errors off-line prior to the application of VarBC is preferable as the γ correction is less likely to correct effects which are not radiative transfer simulation biases, while VarBC can erroneously attribute model errors to observation bias.
- Depending on the actual sources of the bias, there might be alternatives to the γ correction. Work is going on at ECMWF to partition bias in spectroscopy errors and instrument characterisation errors. Estimates of passband shifts as estimated at ECMWF by Qifeng Lu and William Bell [3] for the FY-3A instrument might provide an alternative correction to the simulation of AMSU-A channel 5 to 8.

5 References

[1] **Watts, P.** and **A. P. McNally**, (2004), Identification and correction of radiative transfer modelling errors for atmospheric sounders: AIRS and AMSU-A. In Proceedings of the ECMWF Workshop on Assimilation of High Spectral Resolution Sounders in NWP. ECMWF, Reading, UK.

[2] **Dee, D. P.** (2004), Variational bias correction of radiance data in the ECMWF system. In Proceedings of the ECMWF Workshop on Assimilation of High Spectral Resolution Sounders in NWP. ECMWF, Reading, UK, 97–112.

[3] **Qifeng Lu, W. Bell, P. Bauer, N. Bormann** and **C. Peubey**, Characterising the FY-3A Microwave Temperature Sounder Using the ECMWF Model, Accepted by *Journal of Oceanic and Atmospheric Technology*, **March 2011**, doi: 10.1175/JTECH-D-10-05008.1.

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