RADIANCE BIAS CORRECTION IN LAM

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Introduction

The Variational Bias Correction (VarBC) method, developed at NCEP (Derber and Wu, 1998) and implemented in most of global models, is currently tested in our high-resolution Limited Area Model (LAM) Aladin/CZ. The main aspects of a satellite bias correction are examined with regards to LAM restrictions such as an assimilation window, a limited area or a model vertical resolution. In addition, we examine a response of VarBC to the errors concerning the observation sample issue in LAM. Finally, a new background error constraint on bias parameters is proposed to control the VarBC adaptivity in LAM.

Model, data and method

Model

- LAM Aladin/CZ, domain shown in Fig. 1
- Horizontal resolution 4.7 km; 87 vertical levels (model top ~0.5 hPa)
- BlendVar scheme: DFI-Blending with model Arpege + 3D-Var
- 6h-assimilation cycle at 0, 6, 12 and 18 UTC; 6h-assimilation window
- VarBC - 24h-cycling of bias parameters

Satellite data

- NOAA-18, NOAA-19, MetOp-A, MetOp-B, Meteosat-10
- Data coverage: spatial (Fig. 1) and temporal (Fig. 2)

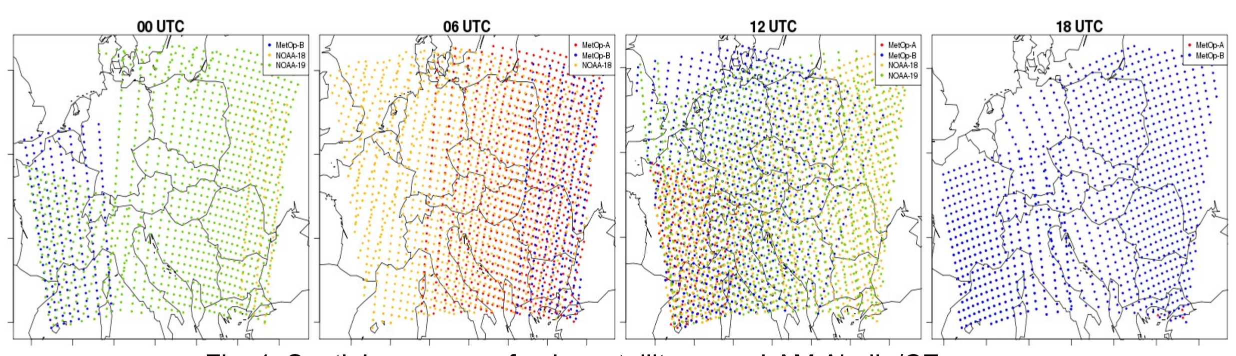


Fig. 1: Spatial coverage of polar satellites over LAM Aladin/CZ.

VarBC method

- an adaptive bias correction method implemented into a variational data assimilation (DA) system :

$$J(x,\beta) = J_b + (\beta_b - \beta)^T B_\beta^{-1}(\beta_b - \beta) + [y - h(x,\beta)]^T R^{-1}[y - h(x,\beta)] \quad (1)$$

$$h(x,\beta) = h(x) + \sum_{i=0}^{N} \beta_i P_i \quad (2)$$

$$B_\beta = diag(\sigma_{\beta_1}, \cdots, \sigma_{\beta_n}) \quad ; \quad \sigma_\beta^2 = \sigma_o^2 / N_{bg} \quad (3)$$

The linear prediction model in (2) explains systematic errors detected as the space-averaged Observation-minus-Guess (OmG) of the radiance data. Regression coefficients β_i (bias parameters) weighting predictors P_i are adapted in each cycle. This adaptation is controlled by a background error constraint on β (1) and weighted by a covariance error matrix B_β in (3). In practice, the B_β is taken diagonal and represented by standard observation error σ_o and N_{bg} parameter (default N_{bg} = 5000).

Assimilation window

The 3D-Var system assumes a stationary model field within a wide time-range called assimilation window (AW). The observations collected within the 6h-AW (±3h around analysis time) in Aladin/CZ are considered as observations of the analysis time. The longer time-delay between observations and analysis time (δt), the higher observation error (standard deviation of OmG) in analysis time.

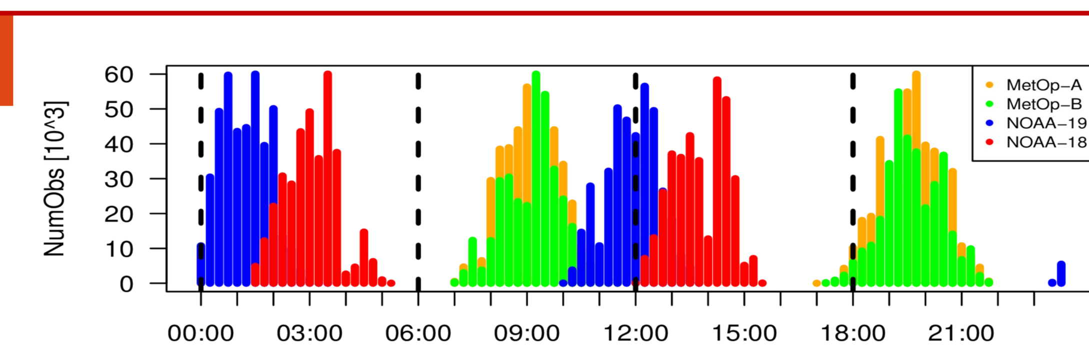


Fig. 2: Temporal coverage of polar satellites in Aladin/CZ during a day (based on one-month period statistic). The terms of analysis are at 0, 6, 12 and 18 UTC (dashed black lines).

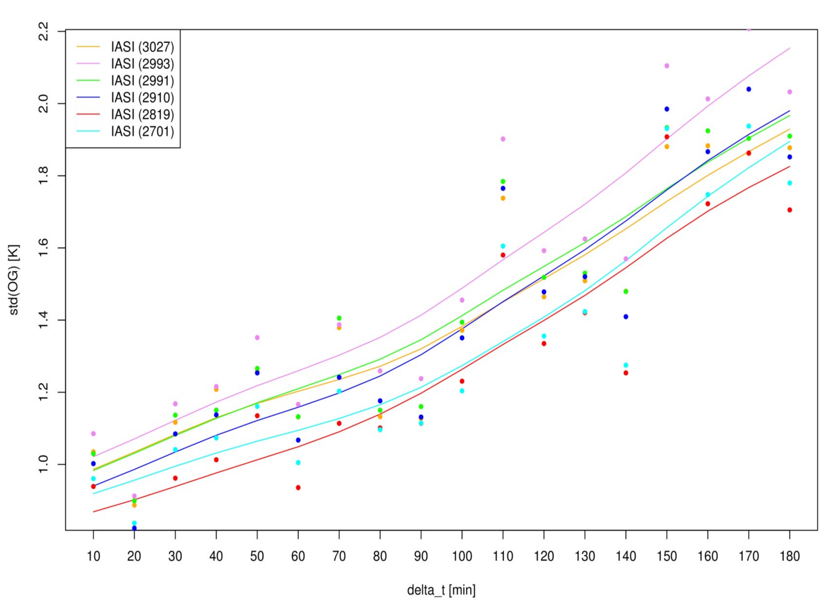


Fig. 3: Observation error increase within AW for IASI-H_2O channels. The dependence is based on the one-month period data in 09/2013.

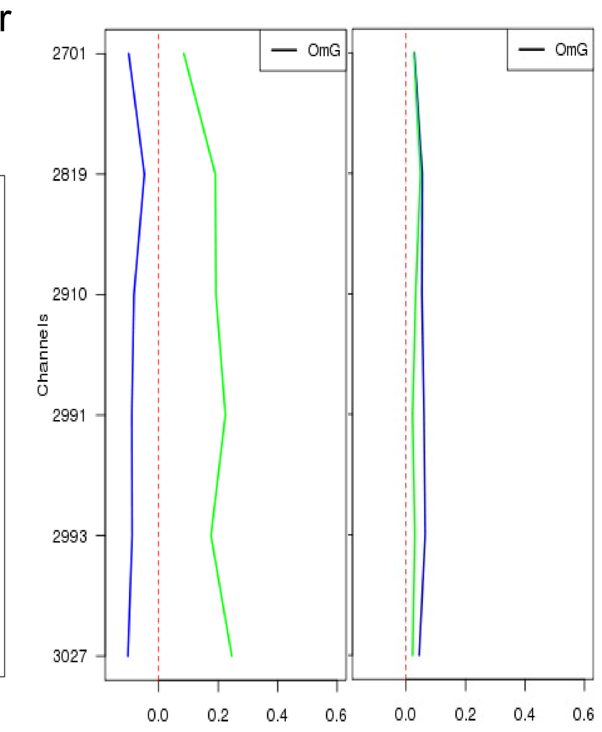


Fig. 4: Observation bias (OmG) over land (green) and sea (blue) after the bias correction for IASI-H_2O. Data are delayed ~30 min (right) and ~180 min (left) from analysis time.

This problem is related with polar satellites crossing the domain at the edge of AW (Fig. 2). The observation error increase is detected primarily for humidity-sensitive sensors MHS (not shown) and IASI-H_2O (see Fig. 3). Moreover, it affects also a bias correction quality, when the VarBC scheme using air-mass and limb-correction predictors is not able to explain the bias due to the data time-delay (Fig. 4).

Vertical resolution

The channels peaking in stratosphere are rejected from DA system in the model Aladin/CZ. This model has a sparser vertical resolution in stratosphere (above 30 hPa) compared with the global model Arpege (Fig. 5). Thus the quality of OmG is depreciated in the LAM detected for the sensors AMSU-A channels 11-13 (Fig. 6) and IASI channels 16-217 (not shown).

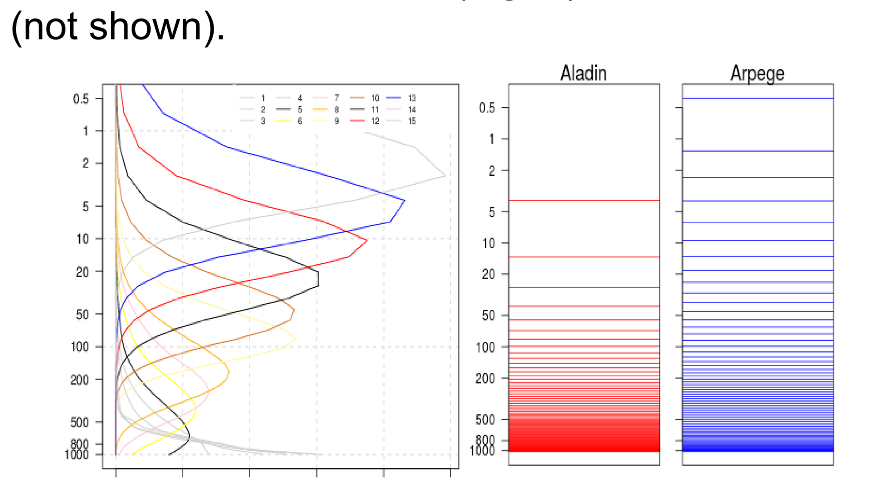
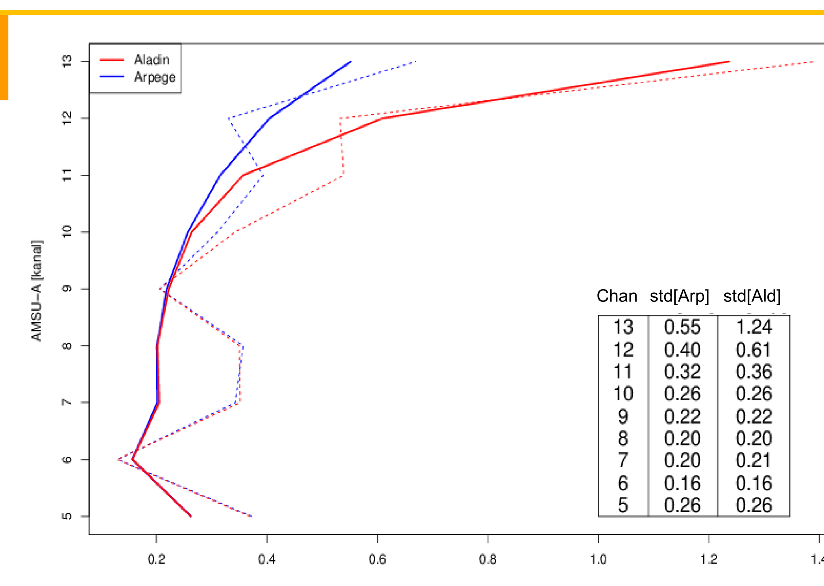


Fig. 5: Weighting functions of the sensor AMSU-A (left) compared with the vertical resolutions between Aladin/CZ (middle) and Arpege (right) models.



Chan	std[Arp]	std[Ald]
13	0.55	1.24
12	0.40	0.61
11	0.32	0.36
10	0.26	0.26
9	0.22	0.22
8	0.20	0.20
7	0.20	0.21
6	0.16	0.16
5	0.26	0.26

Fig. 6: The OmG departures for the NOAA-19/AMSU-A based on the first-guess from Aladin/CZ and Arpege models. The bias of OmG (dashed line) and the standard error of OmG (solid line).

Moreover, the predictor P_5 (thickness of a layer between 10-2 hPa) in VarBC scheme is rejected due to the higher model error as well as a multi-collinearity problem with predictors P_2 and P_6 (not shown).

VarBC adaptivity challenge for LAM

Problem description

Undesirable oscillations are detected in time-evolution of β-parameters for VarBC (Fig. 7). These β-updates occur despite the fact that there is no sudden/slow instrument shift (satellite bias). Considering that a satellite bias detection is based on OmG, the detected bias is affected (apart from the satellite bias) by the first-guess and data pre-processing errors. In LAM domain, these errors are enhanced by the undersized observation sample and can affect quality of β-parameters (Fig. 8) as well as a bias-correction.

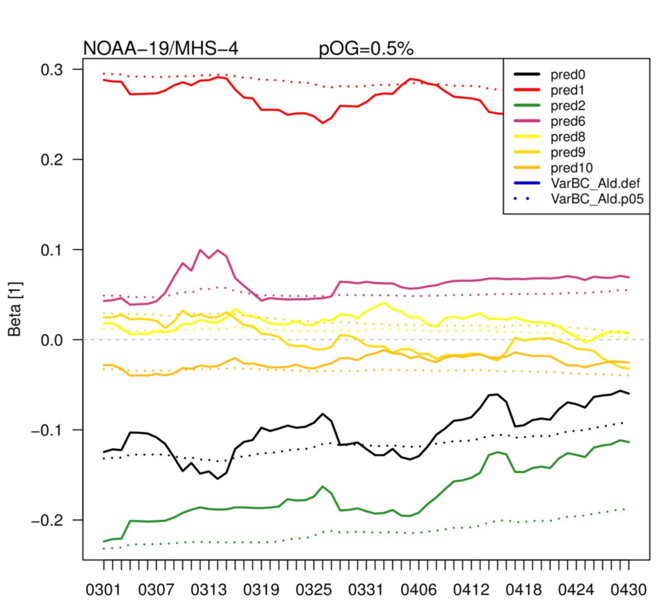


Fig. 7: Time-evolution of β-parameters in VarBC scheme for default (solid) and modified (dashed) settings of VarBC adaptivity.

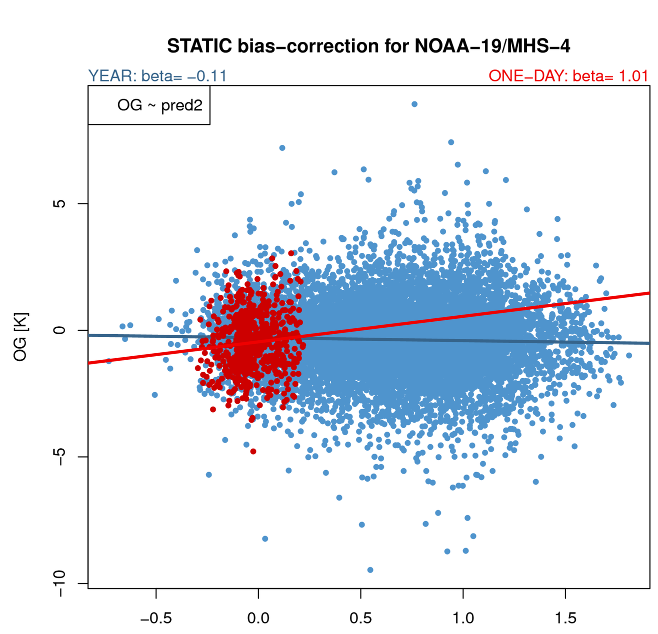


Fig. 8: An example how data sample size can influence β-parameters. Linear regression based on the predictor P_2 for a particular day (18/03/2014) and a year (2014) data sample.

An effect of the observation sample on a bias-correction quality is studied as a difference between STATIC and VarBC bias-corrections (Fig. 9a). The STATIC scheme obtains data sample over a long-time period and thus it is supposed to reduce the errors concerning the observation sample issue. Two types of biases are detected (see Fig. 9a): a **seasonal bias** and a **daily bias**.

VarBC adaptivity in LAM

We aim to reduce the daily bias inside the VarBC that cause about 30 % of observation increments. The VarBC response to the daily bias is examined with respect to the observation number N. Finally, a new background error constraint on β-parameters in (3) is proposed to control their adaptivity in each cycle:

$$\sigma_\beta^2 = \frac{\sigma_{obs}^2}{[C \cdot log(\frac{N}{N_{min}}) + N_{min}^{bg}]} \quad \text{where } N > N_{min} \quad (4)$$

$$\sigma_\beta^2 = \frac{\sigma_{obs}^2}{N_{min}^{bg}} \quad \text{where } N < N_{min} \quad (5)$$

It allows to change β-parameters slowly when N is larger than a reference number N_{min}. The N_{min} is set empirically to avoid an over-estimation of β. The parameters C and N^{bg}_{min} in (4) and (5) allow keeping a pre-defined value of β-adaptivity in each cycle.

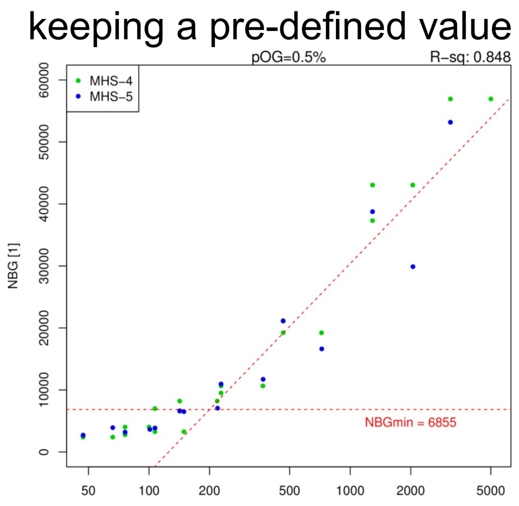


Table 1: The regression coefficients for p05%

Sensor/Coefficient	C [10^2]	N^{bg}_{min} [10^2]	N_{min}
AMSU-B/MHS	146 ± 15	69 ± 18	200
AMSU-A	46 ± 5	61 ± 6	50
SEVIRI	280 ± 35	45 ± 35	400

Fig. 8: The modified VarBC scheme is set to keep p05% bias-correction in each cycle. The adaptivity parameter N_{bg} is shown with respect to the observation number N (left). The corresponding parameters in (4) and (5) are described in the Table 1.

In the first study we allow to change the bias-corrections up to 0.5 % of observation error (marked as p05%, see Fig. 8). Although this new scheme is able to reduce the daily bias (Fig. 9b), there are still open questions: how to find the optimal adaptivity of VarBC in LAM that will keep a balance between satellite and daily bias corrections? Is it reasonable to decrease the VarBC adaptivity or should we even come back to use a static bias correction in LAM?

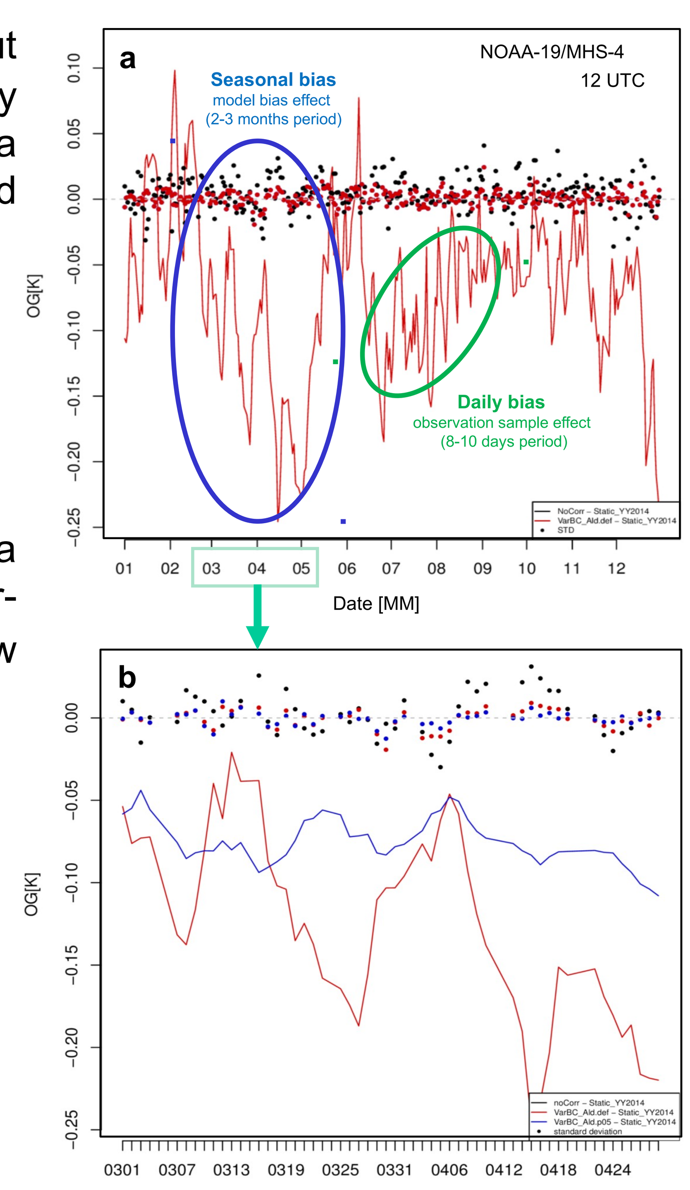


Fig. 9a: The impact of observation sampling error in VarBC on a bias-correction. To assess we use a diagnostic based on a difference between VarBC and STATIC (data sample over 2014) bias-correction.

Fig. 9b: The diagnostic (VarBC-STATIC) for the default (red) and the modified (blue) VarBC scheme.

Summary

1) The main aspects of VarBC are investigated for LAM Aladin/CZ. We found out that most of polar satellites cross our model domain 2-3 hours before/after analysis time (Fig. 2) affecting the observation error (Fig. 3) and a bias correction quality (Fig. 4). The satellite data measured less than ±60 min (MHS, AMSU-B, IASI-H_2O) and ±90 min (AMSU-A, IASI) around the analysis times are used in our DA system.
2) The stratospheric-peaking channels of sensors AMSU-A (channels 11-13) and IASI (channels ≤ 217) are blacklisted due to the sparse vertical resolution in LAM (Fig. 5 and 6). The stratospheric predictor P_5 is rejected from VarBC because of its poor quality and collinearity with other predictors.
3) The VarBC scheme is adapted to avoid the observation sample problem in LAM. The new formulation of β-parameters error is proposed in (4, 5) to control the adaptivity of VarBC. The less adaptivity shows promising results in reducing the daily bias (Fig. 9b), however, the question regarding a prompt response of VarBC to a satellite bias remains unsolved.

Acknowledgements and References

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