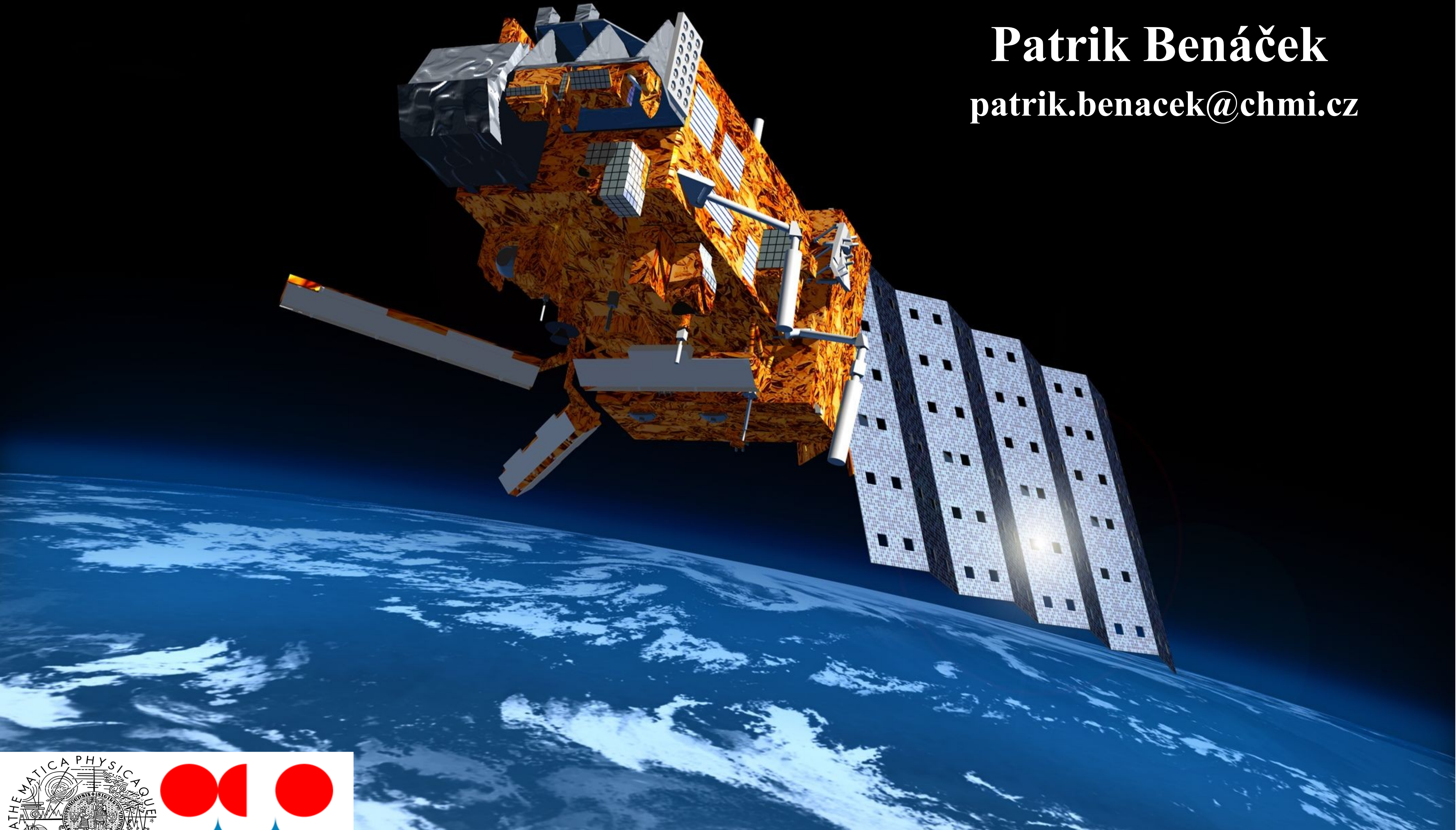
Radiance bias correction in LAM Aladin/CZ

Patrik Benáček
patrik.benacek@chmi.cz



Data Assimiliation Working Days 2015 - Bratislava

Satellite bias detection

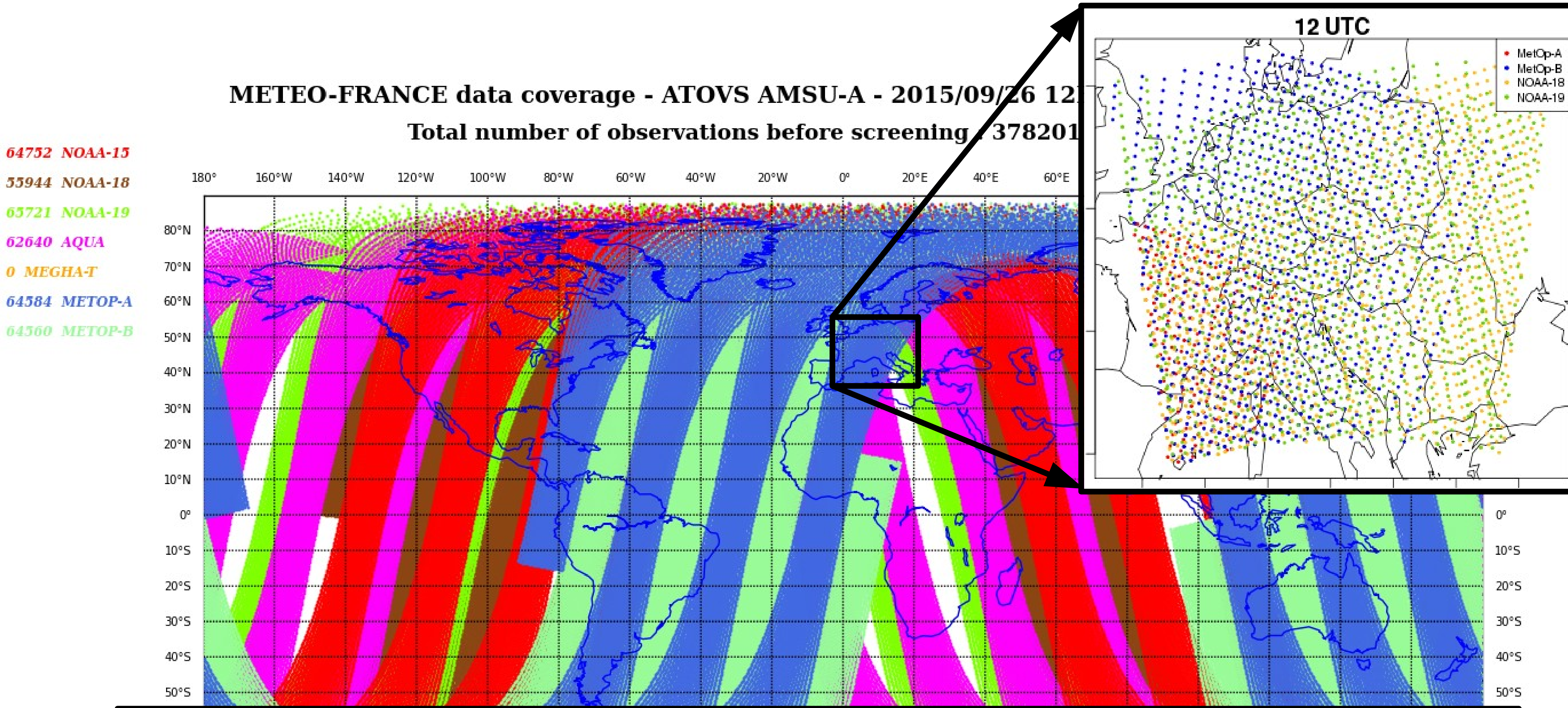
- Satellite bias detection based on Observation-minus-Guess departures (OmG) in observation space:

$$bias_{satellite} = \left\langle y - H\left(x\right)\right\rangle_{ij}$$

Assumption: *H(x)* is perfect

- Errors in NWP model
- Errors in observation operator *H* (RTTOV, ...)
- Errors in data pre-processing (QC, cloud-mask, ...)

Global vs. Limited Area Models (LAM)



- Observational sample size (12UTC, AMSU-A)
  - global: N ~ 10^4 (model bias reduction in OmG)
  - LAM : N ~ 10^2 - 10^3 (seasonal/flow-dependent bias in OmG)
- 4D-Var (± 15 min T_{slot}) vs. 3D-Var (± 3h T_{slot})
- Vertical resolution

How to deal with in LAM?

1) VarBC parameters from global (MF, Met-Office, JMA, …)

- availability
- model consistency:
  - model cycle (model error, RTTOV)
  - vertical resolution (predictor selection)

2) VarBC parameters cycling in LAM:

- Variational Bias Correction (VarBC)
  - assimilation window
  - vertical resolution
  - model bias

Outline

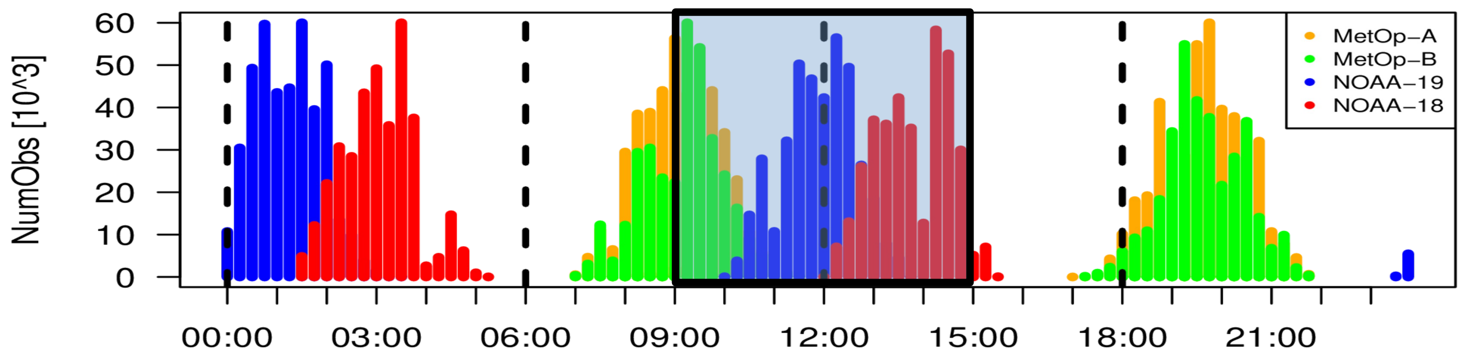
- Background
- LAM issues
  - Assimilation window
  - Vertical resolution
  - Model bias
- VarBC in LAM
- Summary
- Future plans

Background

- **Model Aladin/CZ**:
  - Cy38trt1, dx=4.7 km, 87 vertical levels (model top ~ 0.5 hPa)
  - BlendVar → DFI Blending + 3D-Var
  - 6h-guess cycling; 6h-AW; VarBC 24h-cycling
- **Observation**:
  - synop, temp, amv, amdar
  - NOAA-18, NOAA-19, MetOp-A, MetOp-B, Meteosat-10
  - AMSU-A, AMSU-B, MHS, IASI, SEVIRI

Assimilation window (AW)

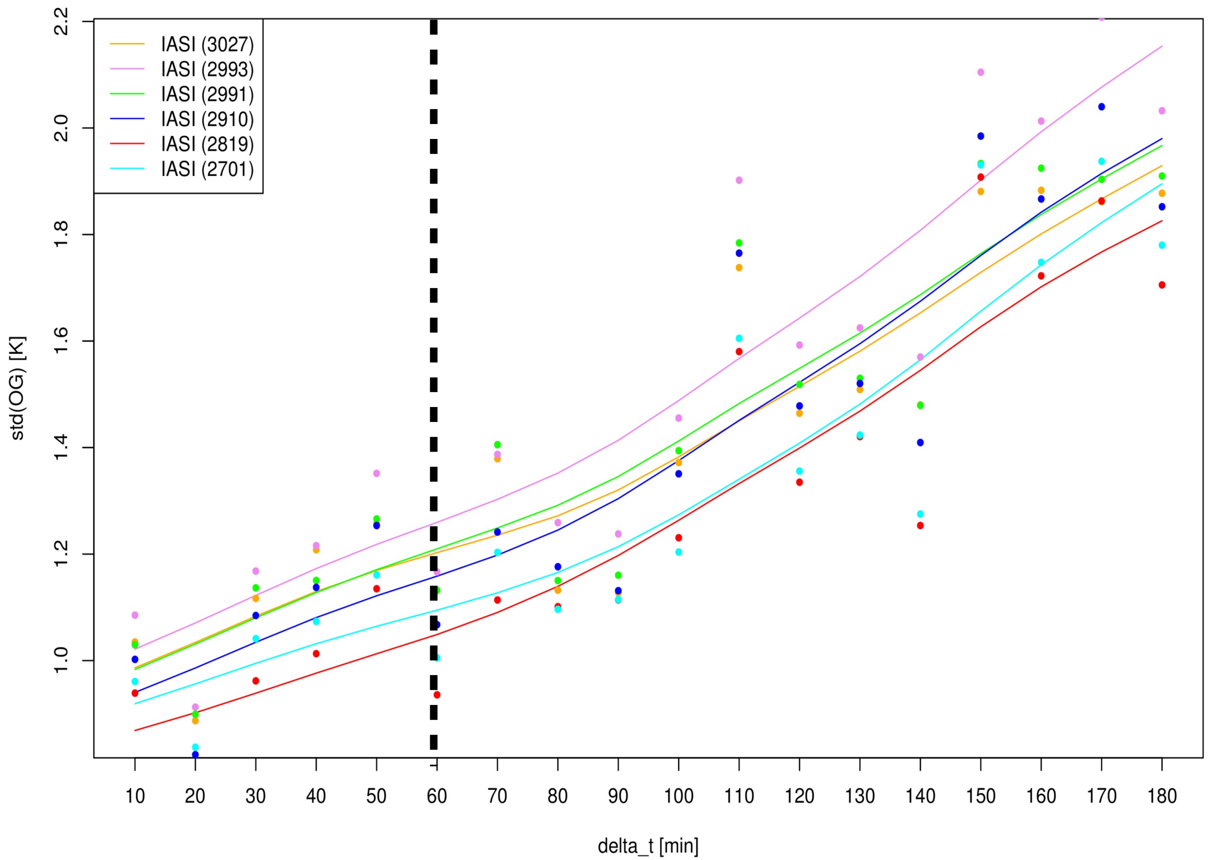
Temporal coverage of polar satellites in Aladin/CZ during a day



- Study of OmG within 6h-AW in 3D-Var system:
  - assumption in AW: $T_{H(x)} = T_y$
- **Results:** (more details in [1])
  - observation error (standard deviation of OmG) and satellite bias (mean of OmG) increase:
    - the edge of AW
    - non-stationary weather situations
  - worse bias correction quality
  - worse cloud detection scheme quality (based on OmG)

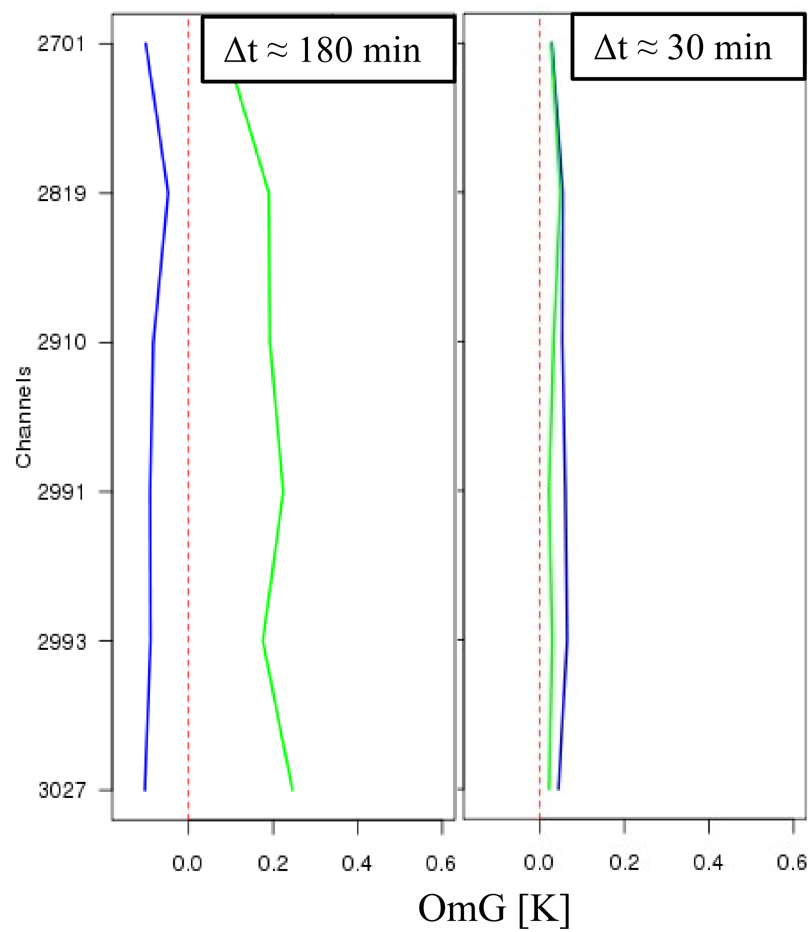
Results

Observation error increase within AW



Statistics for IASI-H_2O based on 09/2013

Bias correction quality within AW

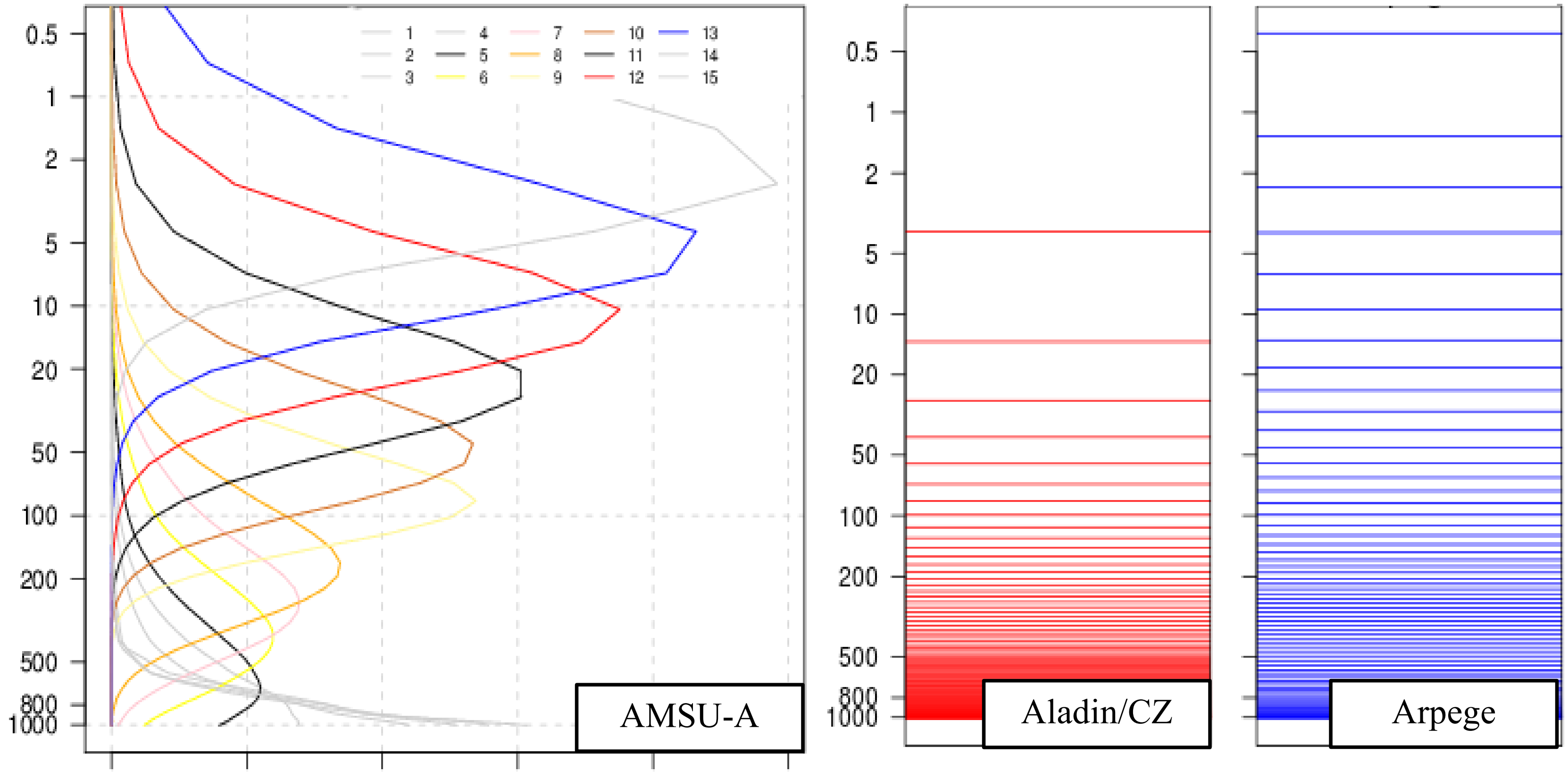


- AMSU-A, IASI-CO_2 (< 90 min)
- AMSU-B, MHS, IASI-H_2O (< 60 min)
- Other DA technique: <u>3h-RUC</u>, 3D-FGAT

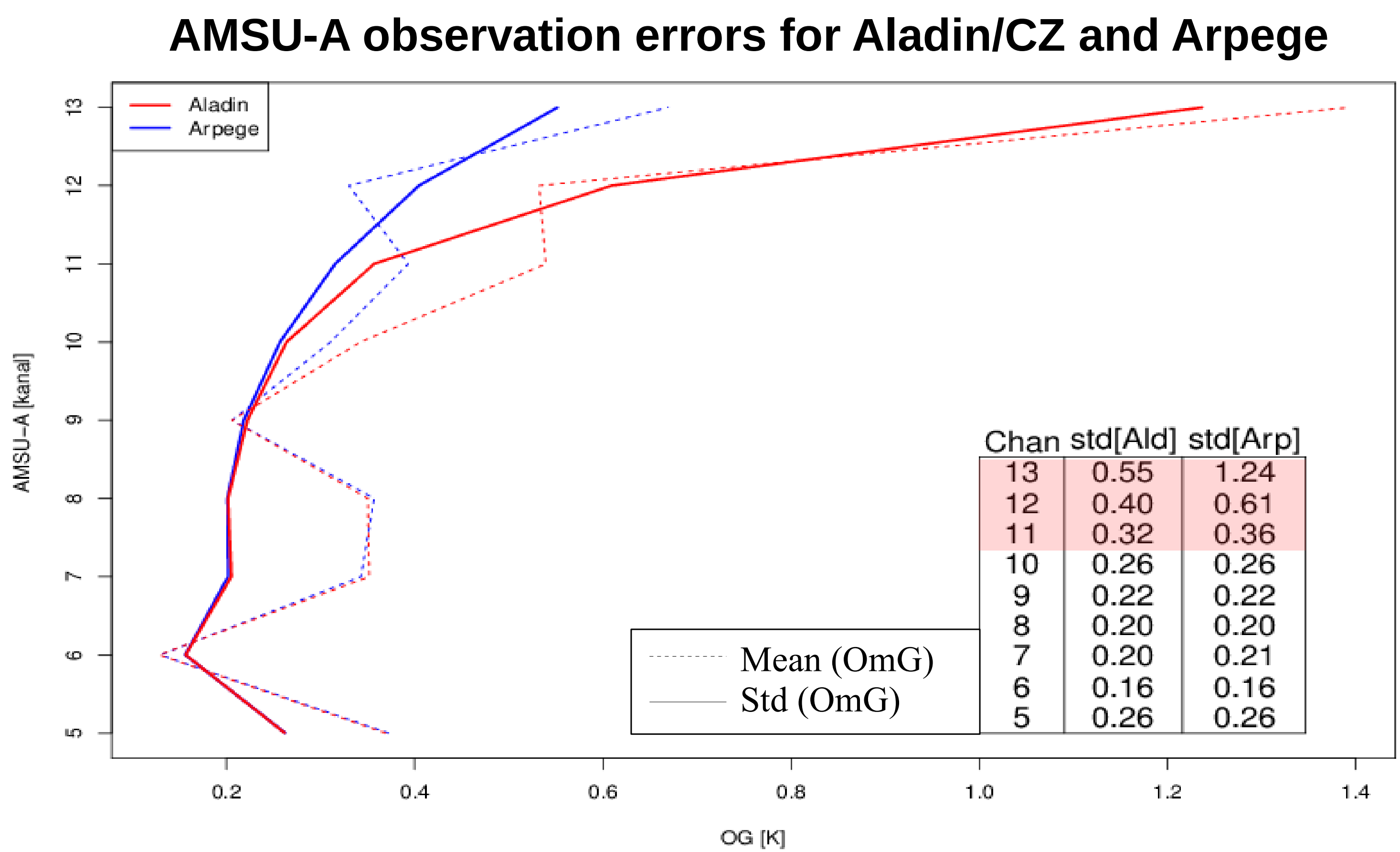
Vertical resolution

- Study of OmG departutres with regrads to a vertical resolution of NWP models
- Impact of a sparse resolution (in stratosphere) on a satellite bias and observation error

Vertical resolution between LAM and global models



Results



Chan	std[Ald]	std[Arp]
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

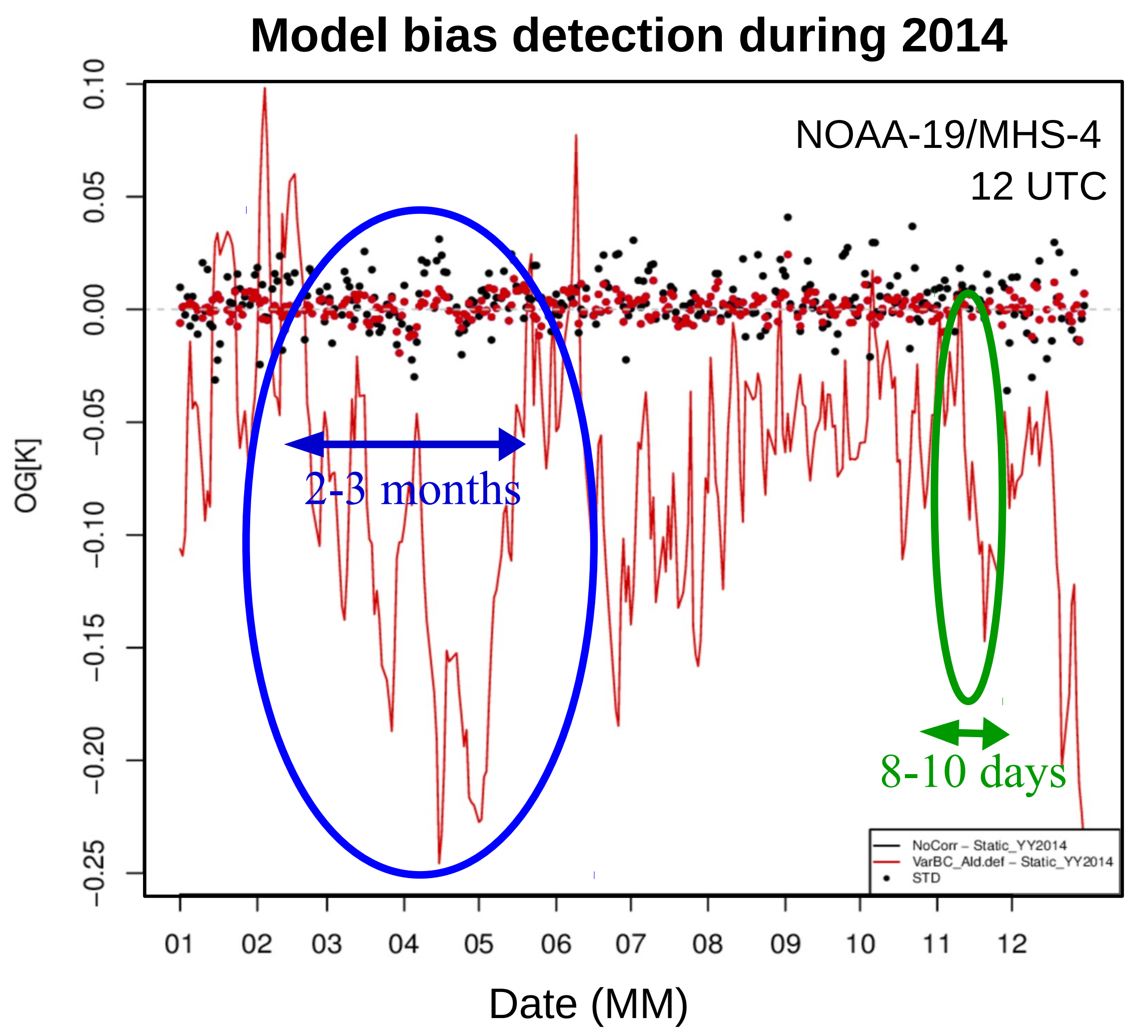
- **Results:**
  - rejection of VarBC predictor P_5 (thickness of the layer 10-2 hPa)
  - rejection of stratospheric peaking channels:
    - AMSU-A (ch 11-13); IASI-CO_2 (ch < 212)

Model bias

- study a response of VarBC scheme to a NWP model bias
- based on the difference in bias correction between [2]:

$$bias_{model} = bcorr_{VarBC} - bcorr_{StatBC}$$

- *VarBC*: adaptive scheme; response to model bias at each cycle
- *StatBC*: regression over one-year data; resistant to model bias



Results:

- bias detection: **seasonal** & **daily** (flow-dependent) bias

Model bias

Key Idea:

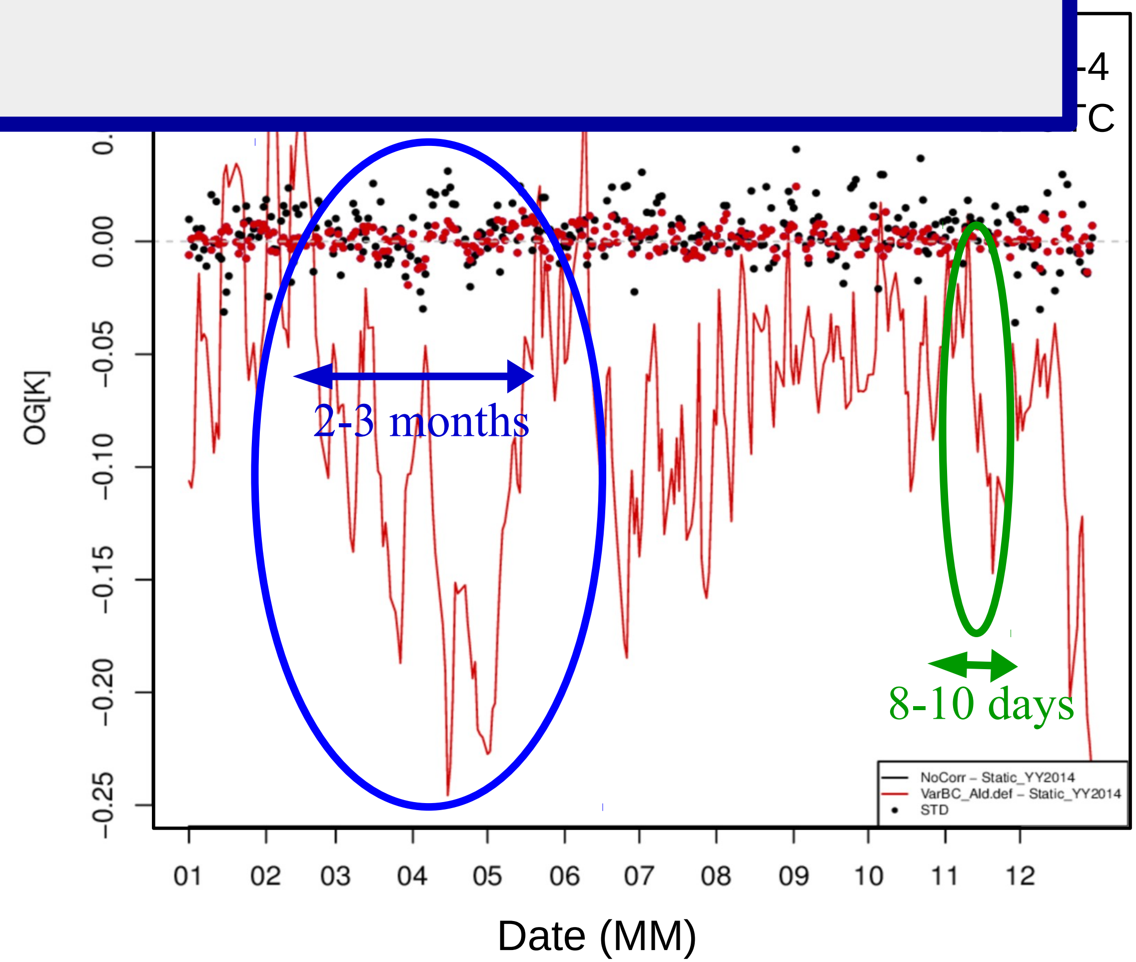
→ control changes of bias correction in each cycle (***δbcorr***) to reduce the flow-dependent model bias

– *VarBC*:
adaptive scheme; response to model bias at each cycle

– *StatBC*:
regression over one-year data; resistant to model bias

Results:

– bias detection: **seasonal** & **daily** (flow-dependent) bias



VarBC in LAM Aladin/CZ

Variational Bias Correction (VarBC) scheme [3]:

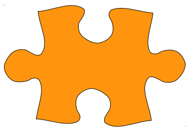
$$J(x,\beta) = J_b + (\beta_b - \beta)^T B_\beta^{-1}(\beta_b - \beta) + [y - h(x,\beta)]^T R^{-1}[y - h(x,\beta)] \quad (1)$$

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

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

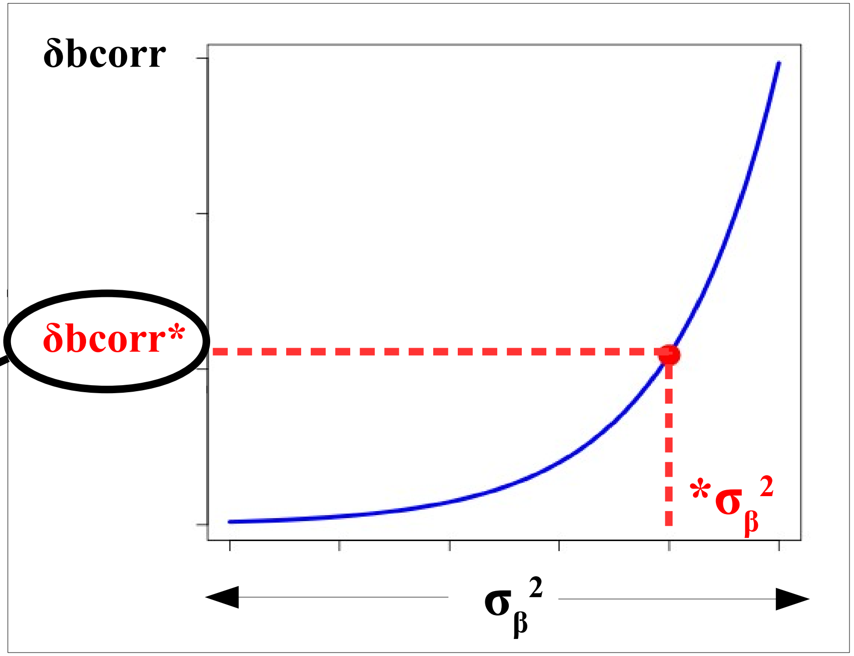
- Finding a new σ_β in (3) to control β-changes (δbcorr) in each cycle:

1) set limit for δbcorr* (empirically model bias vs. satellite bias):



$$\delta\, bcorr^x = 0.05 \cdot \sigma_o^2$$

2) find the corresponding $*\sigma_\beta$



Modifications

Old

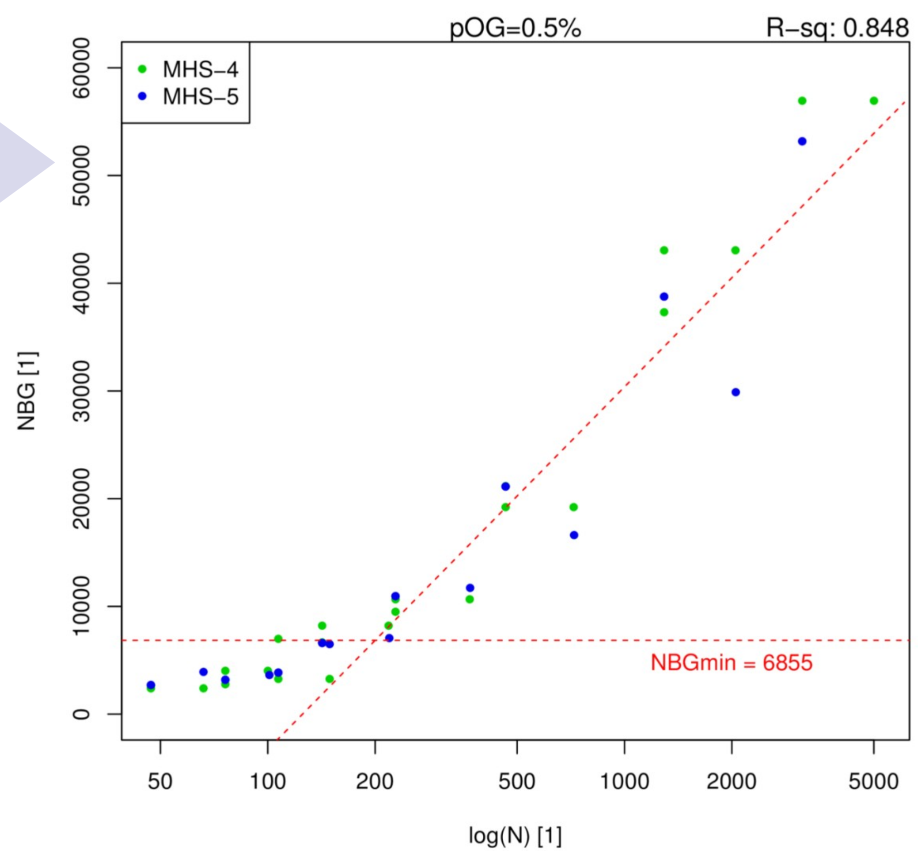
$$\sigma_\beta^2 = \frac{\sigma_{obs}^2}{N_{bg}^{df}} = \frac{\sigma_{obs}^2}{5000}$$

New

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

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

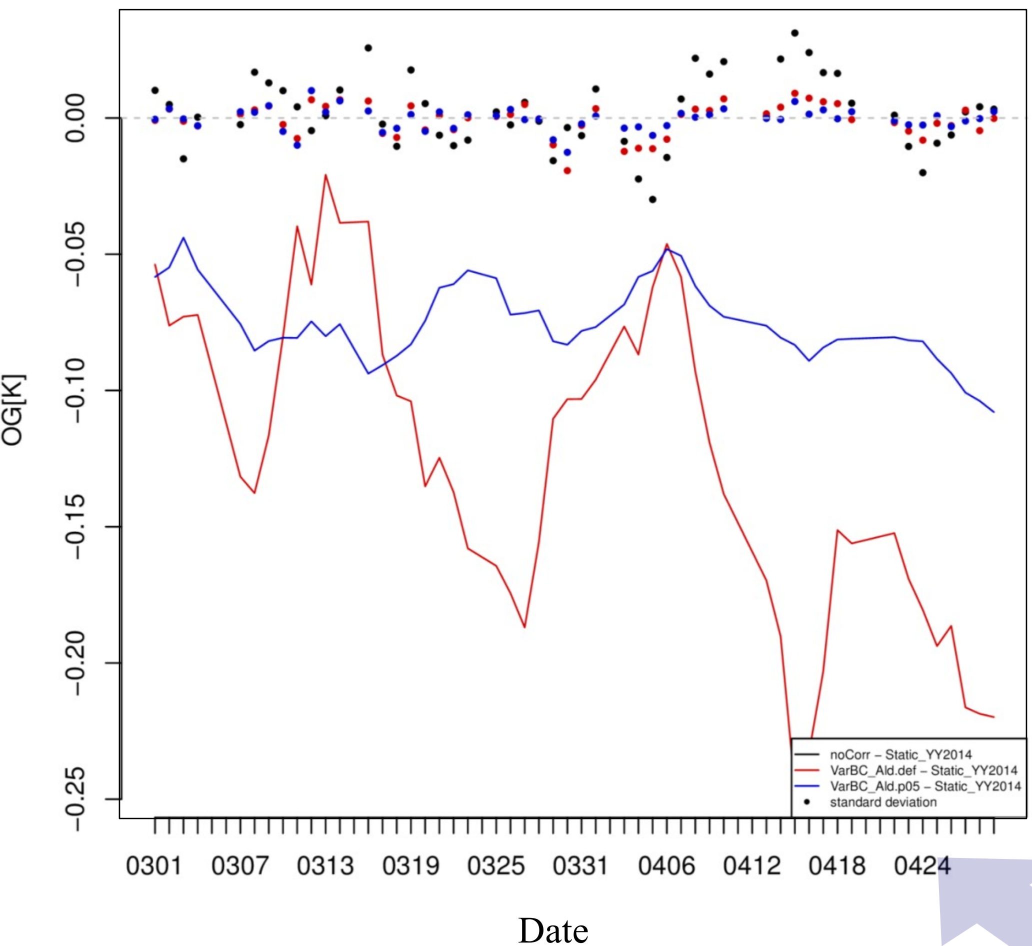
- New N_{bg} parameter in (4) depends on *observation number N* in each cycle



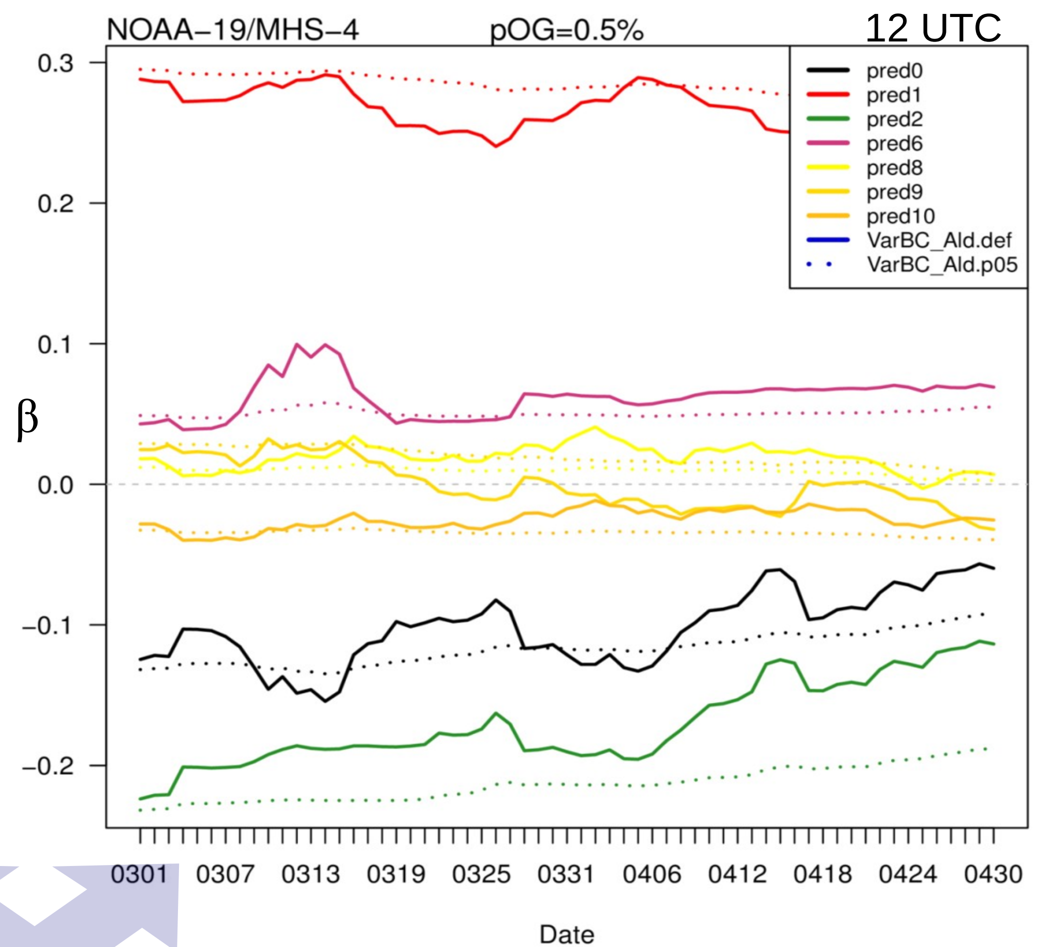
- Allows to change β (δbcorr) slowly when N is larger than a *reference number* N_{min}
- N_{min} is set empirically to avoid over-estimation of β

Results

VarBC response to model bias



Adaptivity of β-parameters



red line: old scheme blue line: new scheme	$N_{min} = N_{full} = const$	solid line: old scheme dashed line: new scheme

Conclusion

- **Observation error increase within 6h-AW:**
  - impact on a quality of VarBC and cloud-detection scheme
  - set the shorter AW length for each satellite instruments; 3h-RUC
- **Observation error increase due to a sparse vertical level coverage in stratosphere:**
  - rejection of the VarBC predictor P_5 and stratospheric-peaking channels for AMSU-A and IASI instruments
- **A response of VarBC scheme to the flow-dependent NWP model bias:**
  - new background error constraint B_β on β parameters depending on an observation number in each cycle
  - promising results in a reduction of VarBC response to the flow-dependent model bias
  - Shortcomings:
    - settings δbcorr* limit in each cycle
    - slower adaptation of β to satellite instrument corruptions:
      - using in combination with a monitoring system
    - how to distinguish between the model and the satellite bias in σ_β

Future work in satellite DA

- Finish the adjustment of VarBC scheme to LAM conditions.
- New VarBC predictors being more appropriate for LAM.
- Optimal thinning distance and observation error for satellite data

Acknowledgements and References

- This study was supported by the project TAČR TH01010503.

[1] Benacek, P. (2007): Assimilation window in 3D-Var. RC LACE websites: http://www.rclace.eu/File/Data_Assimilation/reports/AssimWin.pdf

[2] Auligné, T., McNally, A. P., Dee, D. P. (2007): Adaptive bias correction for satellite data in a numerical weather prediction system. Q. J. R. Meteorol. Soc. 133: p. 631-642

[3] Derber, J. C., W.-S. Wu (1998): The use of TOVS cloud-cleared radiances in the NCEP SSI analysis system. Mon. Weather Rev., 126: p. 2287-2299.

Thank you for your attention.

Regression coefficients used in (4)

Sensor/Coeficient	C [10^2]	NBG_{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

New background error constraint on β parameters

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

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