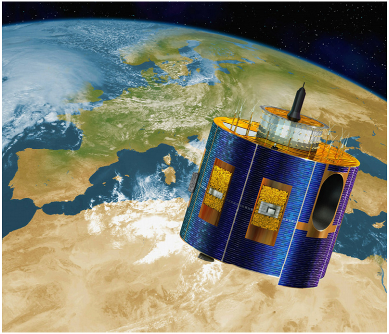
Satellite data assimilation in LAM



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Introduction

- data assimilation (DA) methods were developed/tuned for large-scale global models
- still many questions in using this methods in LAM at convective scale
- simplification of DA methods – currently best compromise **3D-Var** (Montmerle, 2011):
  - cheap, fast – no TL/AD, no integration, B not flow dependent
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   - initialization methods for LAM
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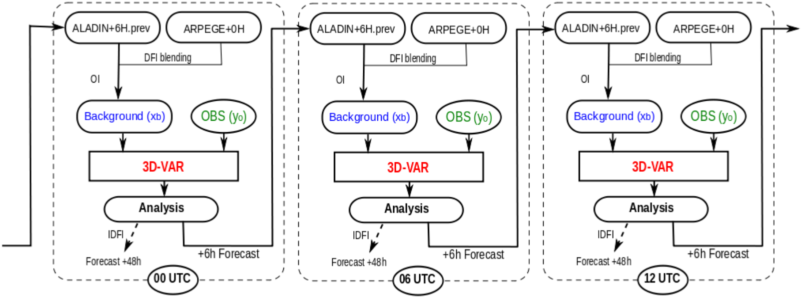
3. satellite DA using short assimilation cycle (3h-RUC):
   - a new channel selection for satellite data

Outline

Model Setup

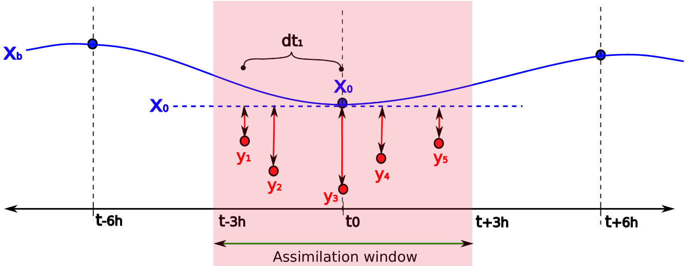
Experimental setting Aladin/CZ

- CY38, Middle Europe (2.1W-27.4E, 40.6N-55.7N), 3h-coupling with Arpege
- $\delta x = 4.7$ km, 87 vertical levels (up to 0.1 hPa)
- BlendVar scheme = DFI blending + surface analysis (OI) + 3D-VAR
- 6h-forward intermittent cycle
- RTTOV-9, ensemble B-matrix (Beere et al., 2006), VarBC
- OBS: SYNOP, TEMP, SATEM (NOAA-18, 19, MetOp-A, B, MSG-10)



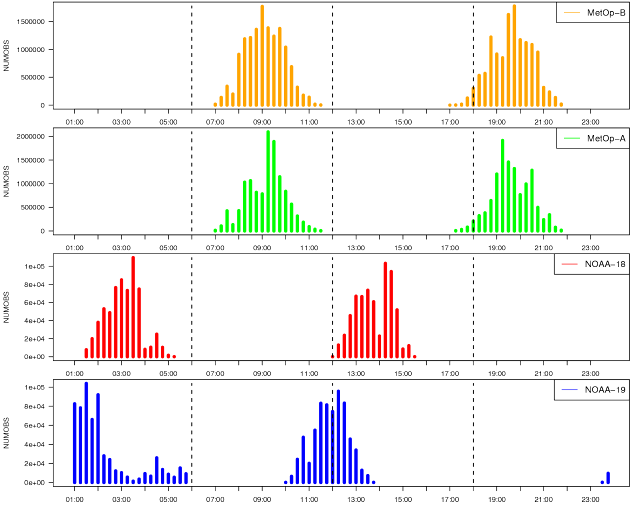
Definition

- simplification of 3D-Var making assumption $M_i = I$ over AW (stationary problems)
- supposing stationary model field x_b within AW (no integration)
- observations y_i collected within AW are compared with stationary model field valid at analysis time x_0
- increasing time-delay δt between observation and analysis time leads to **time-delay bias**
- the bias depends on AW length, weather conditions (cyclones/front lines), measured quantities (T, RH)



Satellite data coverage

- satellite crossing-times over LACE/CZ domain (collected data over 1-month period)
- time-delay 2 – 3 h between observation and analysis time (except of N19)



Time-delay effect

Case study experiment

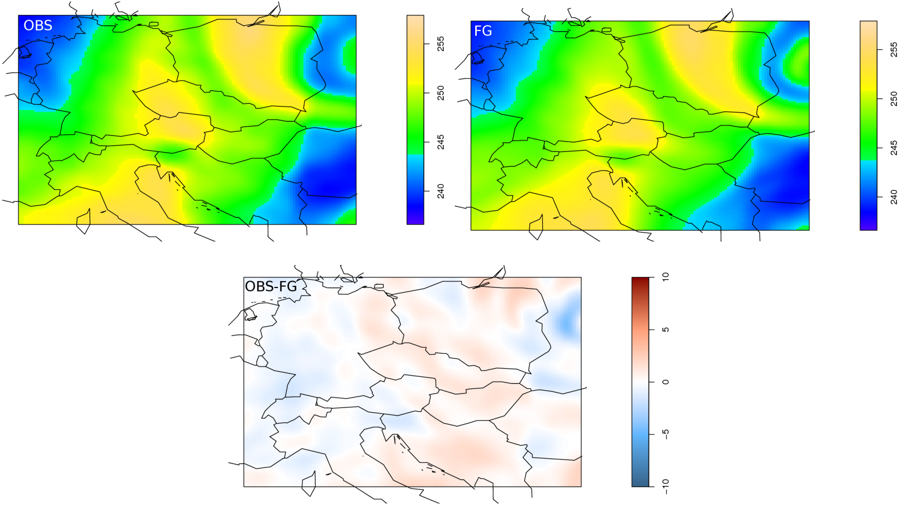
- passive assimilation of MetOp-B data on 3.9.2013 measured at 9:20 UTC (non-stationary weather conditions)
- time-delay simulation by:
  - DA at 09 UTC $\rightarrow \delta t = 20$ min
  - DA at 12 UTC $\rightarrow \delta t = 160$ min
- spatial assessment of obs-fg (OG) differences (from ECMA db)
- 2D-grid point field generated by Gaussian kernel smoothing method
- separately for sensors sensitive to
  - T (AMSU-A, IASI-CO2)
  - RH (MHS, IASI-RH)

Passive assimilation mode:

- data passed to the assimilation with a status both *active* and *passive*
- artificial inflation of observation error (STD)
- in order to estimate satellite bias correction without analysis degradation
- set flag `FAIL(EXPERIMENTAL)` in `mf_blacklist.h`

Time-delay bias

- Humidity channels affected by strong humidity dynamics in troposphere (by cold/warm front, clouds)



OG departures for **MHS/channel-3** at 09 UTC.

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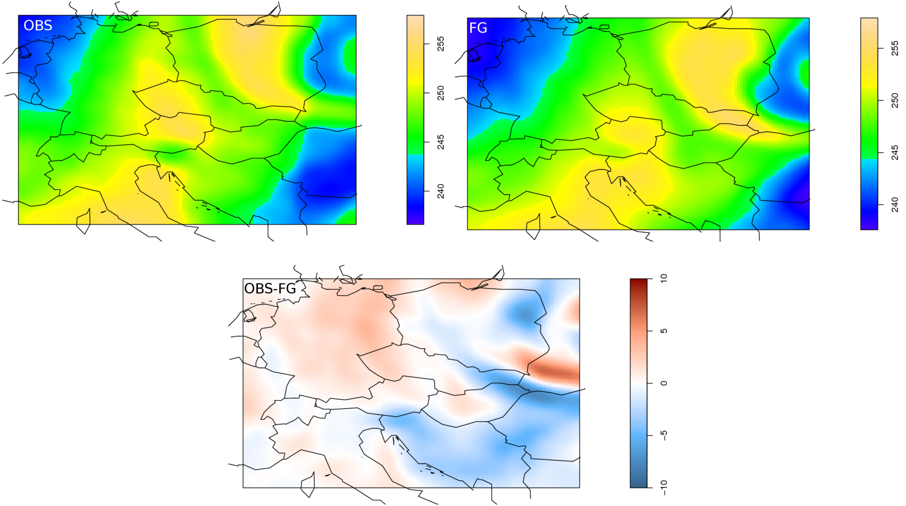

OG departures for **MHS/channel-3** at 12 UTC.

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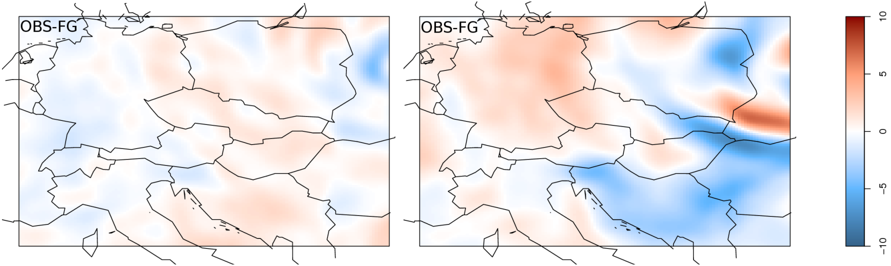
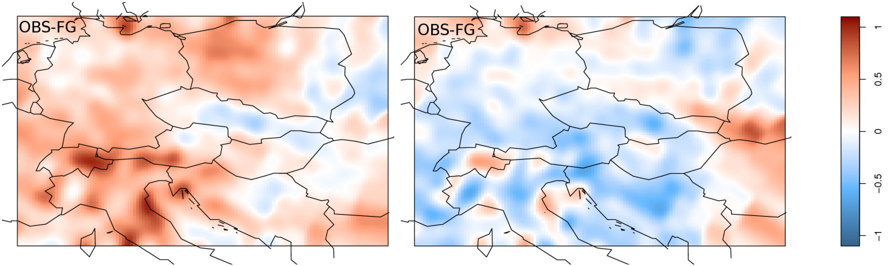


OG departures for **MHS/channel-3** at 09 UTC (right) and 12 UTC (left).

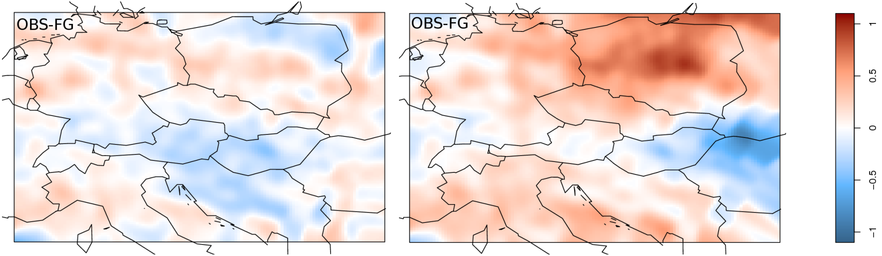
- Low-T, surface-T sensitive channels affected due to solar insolation during a day:
  - measurements (9:20) assimilated at 09/12 UTC have warm/cold impact



OG departures for **AMSU-A/channel-5** at 09 UTC (right) and 12 UTC (left).

Time-delay bias

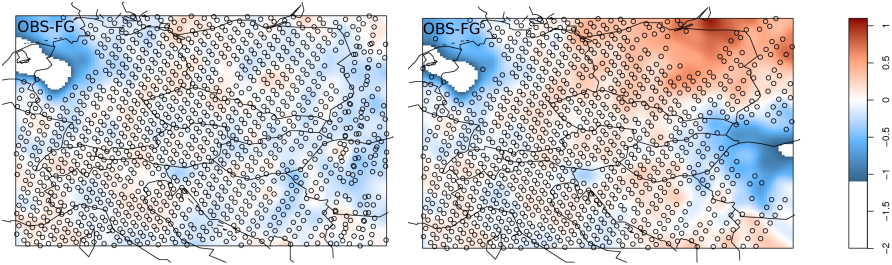
- High-T, middle-T sensitive channels affected due to temperature advection:



OG departures for **AMSU-A/channel-8** at 09 UTC (right) and 12 UTC (left).

Time-delay bias

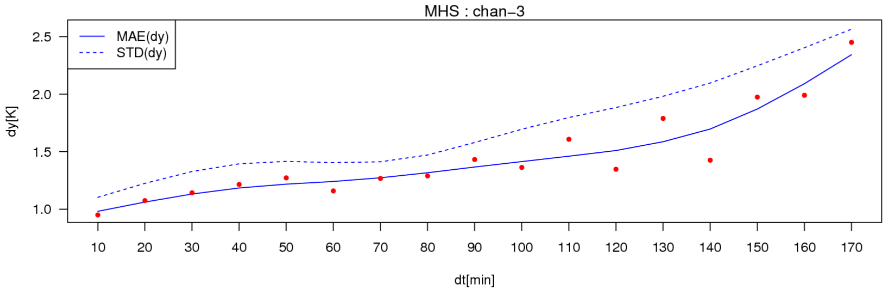
- Reduction of time-delay bias due to cloud detection scheme (IASI):



OG departures for **IASI/channel-219** at 09 UTC (right) and 12 UTC (left).

AW length assessment

- based on monitoring of bias value depending on observation time-delay
- one-month period data assimilated at 0,6,9,12,15,18 UTC (sample size)
- increasing bias due to time-delay detected for:
  - **MHS** – affecting all humidity channels (3-5)



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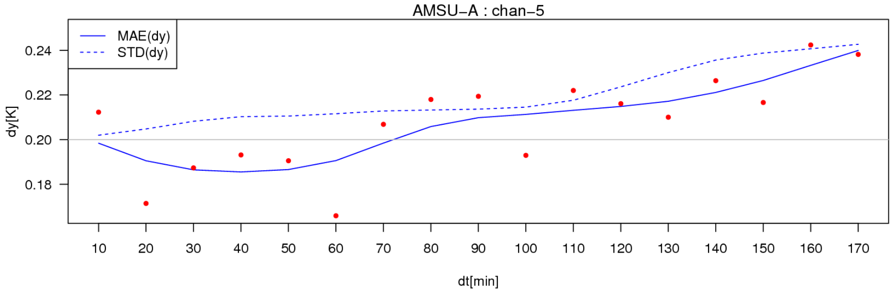

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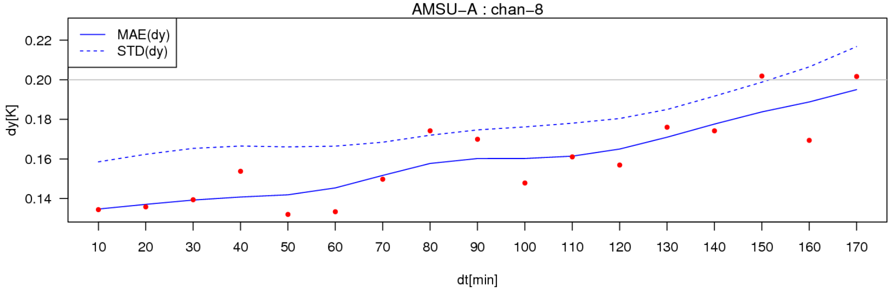

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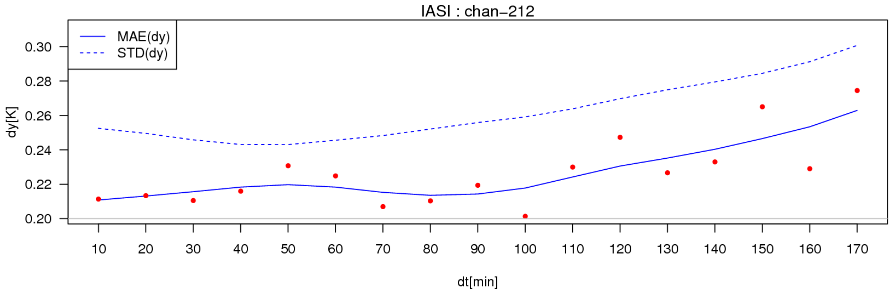
  - **IASI** – low, middle, high-troposphere channels + bias reduction (CLD scheme)



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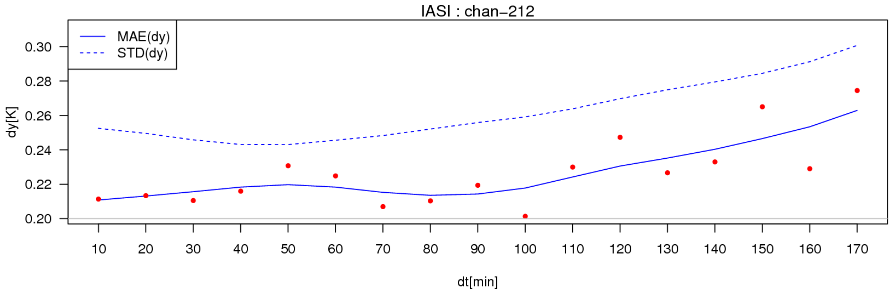
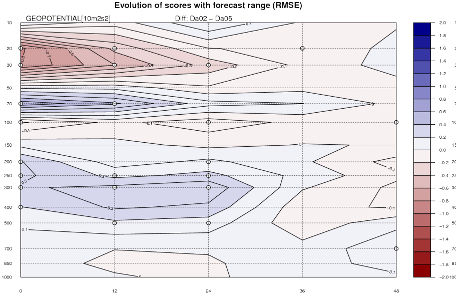
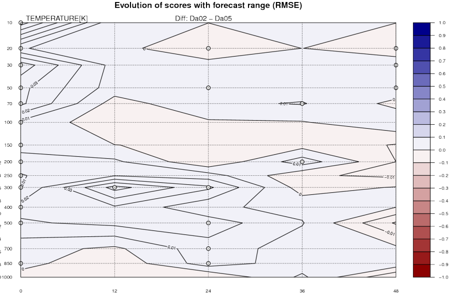
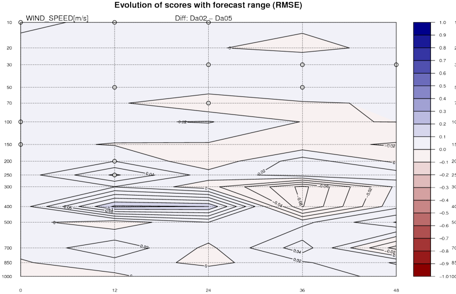
- compromise between time-delay bias and observation sample size (AW=±90 min)

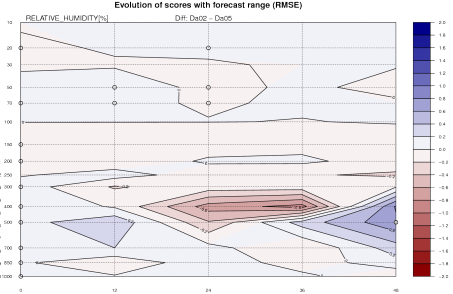


Forecast impact of 6h-AW to 3h (positive)









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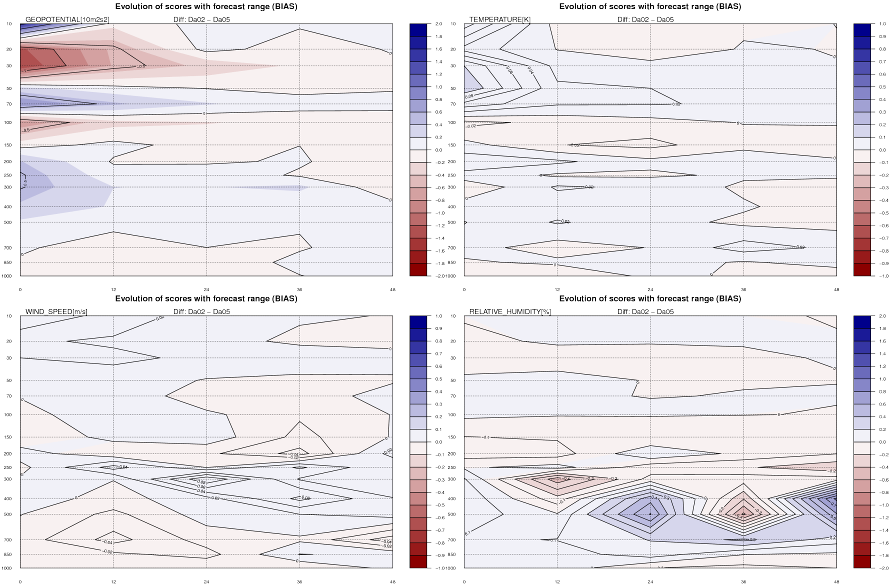
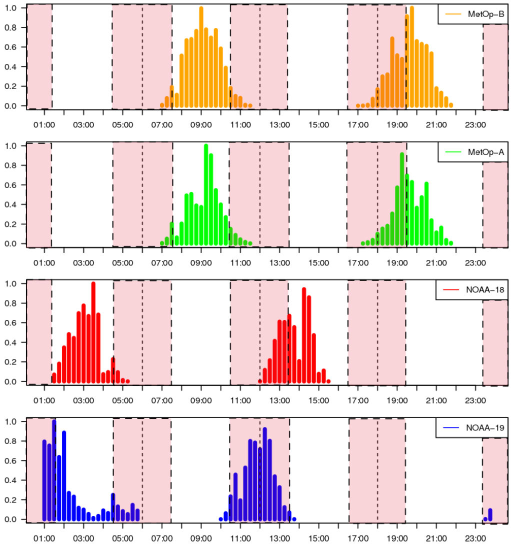


Data coverage

- observation sample size reduction for ±90 min AW



Variational Bias Correction (VarBC)

- a bias correction algorithm implemented in DA-Var system (3D-Var)
- continuous/automatic update of radiance bias correction in response to changes in DA
- minimization of cost function:

$$J(x,\beta) = (x_b - x)^T B^{-1} (x_b - x) + (\beta_b - \beta)^T B_\beta^{-1} (\beta_b - \beta) + [y - H(x) - C(\beta)]^T R^{-1} [y - H(x) - C(\beta)]$$

where:

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- Bias parameter adaptation by B_β (variations on diagonal):

$$\sigma_\beta^2 = \sigma_o^2 / N$$

σ_o . . . pre-defined observation error

N . . . adaptivity parameter of β

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Initialization methods

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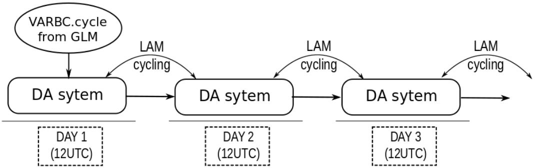
- **Warmstart (LAMBC)** – initialization from global model & cycling β in LAM



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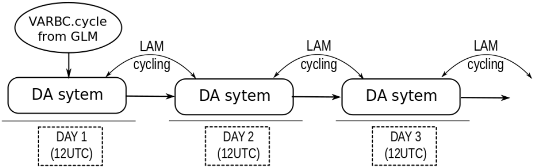
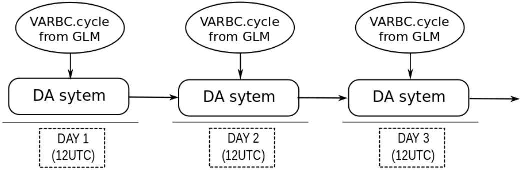


- **Repetitive restart (GLMBC)** – repetitive initialization β from global model



VarBC difficulties in LAM

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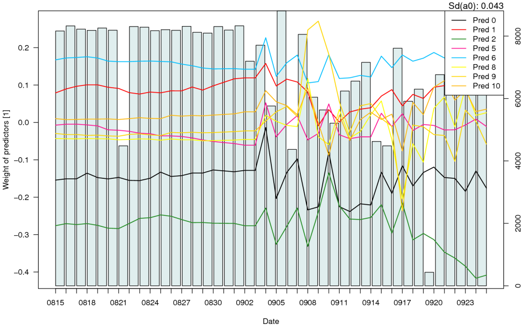

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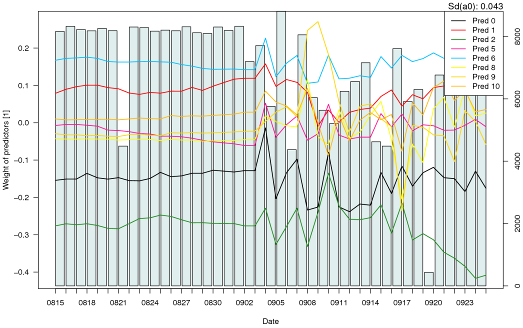

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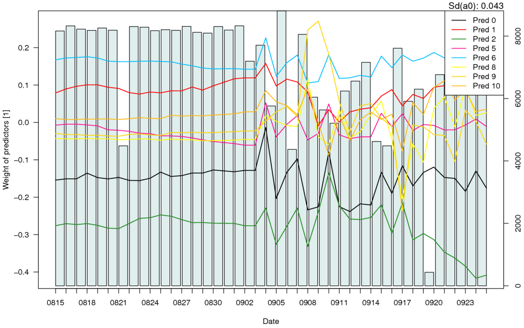

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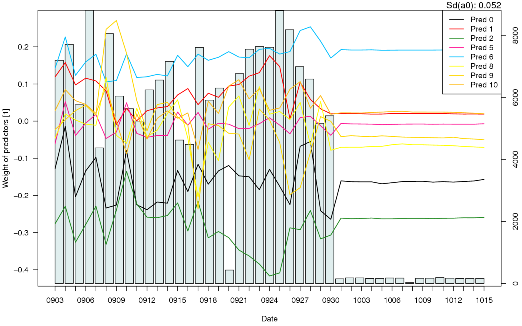

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VarBC tuning:

1. detection/elimination of time-delay bias (penalization of GLMBC)
2. re-tuning β-parameters adaptivity in LAMBC
3. initialization for sensor IASI – technical issues
4. assessment of initialization methods (GLMBC vs. LAMBC)

Time-delay bias affecting

- passive GLMBC/LAMBC experiment; assimilation MetOp-A,B at:
  - 09 UTC, 3h-AW, $\delta t_1 \sim 0 - 1$ h
  - 12 UTC, 6h-AW, $\delta t_2 \sim 2 - 3$ h

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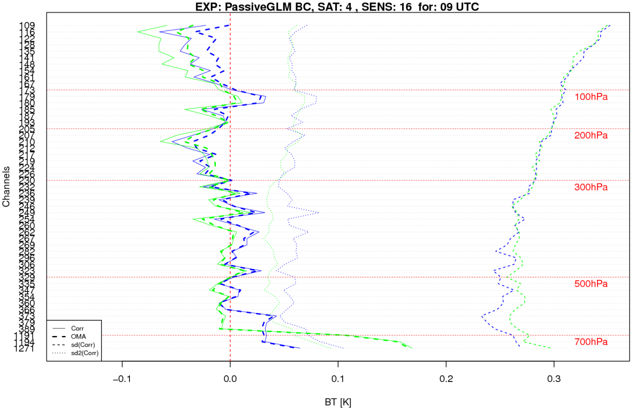

OG statistics for sensor IASI: GLMBC, $\delta t_1 \sim 0 - 1$ h

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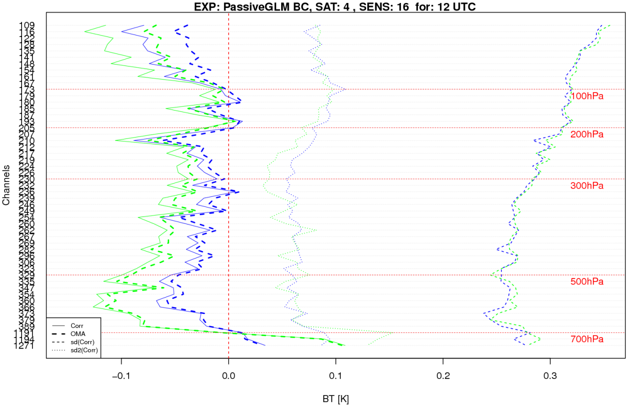

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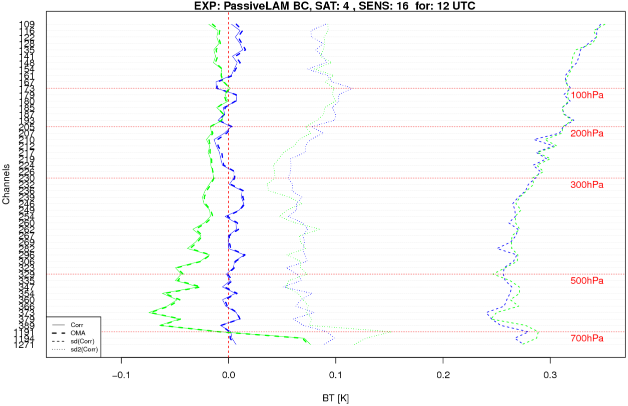
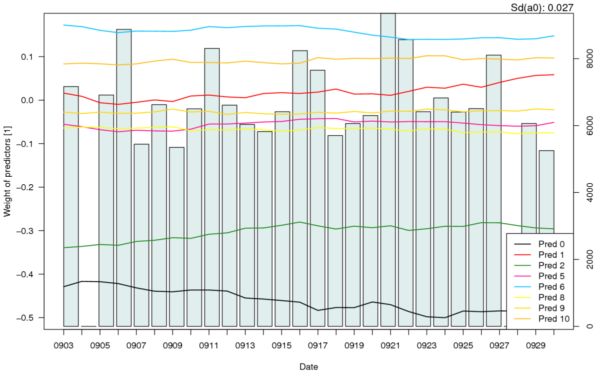
- reduction of time-delay bias using LAMBC



OG statistics for sensor IASI: LAMBC, $\delta t_2 \sim 2 - 3$ h

Adaptivity of β

- passive assimilation of MetOp-B data with $\delta t \sim 0 - 1$ h
- reference are bias parameters from global model (GLMBC)
- tuning adaptivity in LAMBC to reach similar adaptivity as in GLMBC
- tunable by parameter `NBG_${SENSOR}` in namelist



Time-evolution of β for MHS/channel-4 for GLMBC.

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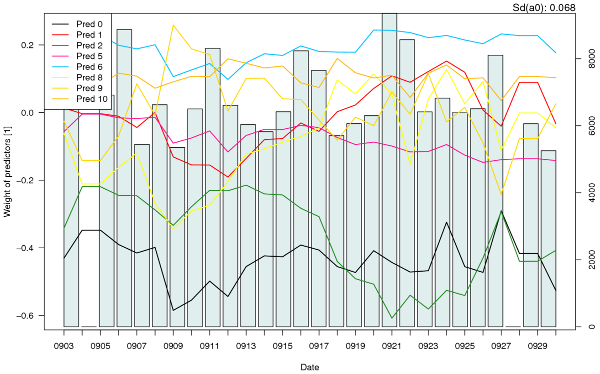

Time-evolution of β for MHS/channel-4 for LAMBC: NBG_MHS=5000 (default).

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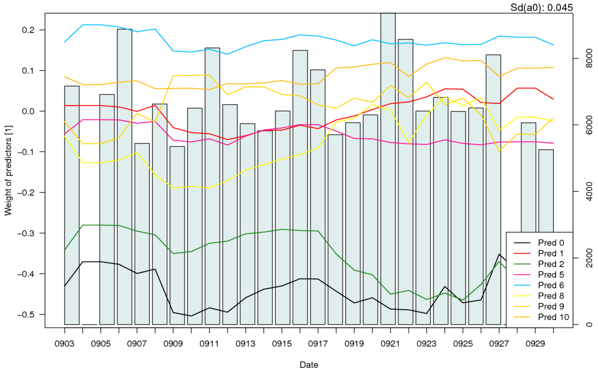

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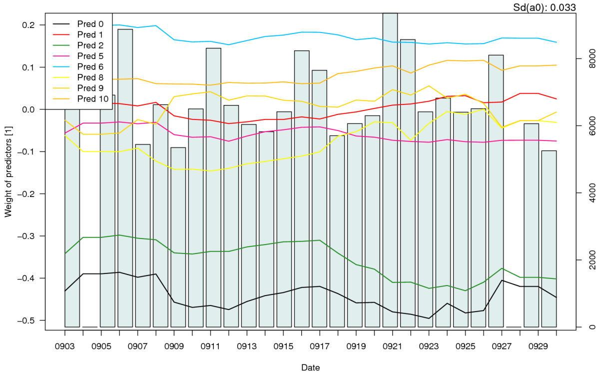

Time-evolution of β for MHS/channel-4 for LAMBC: NBG_MHS=80000.

Adaptivity of β

- passive assimilation of MetOp-B data with $\delta t \sim 0-1$ h
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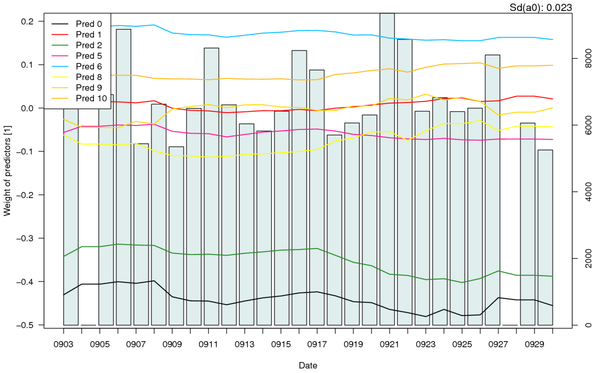

Time-evolution of β for MHS/channel-4 for LAMBC: NBG_MHS=120000.

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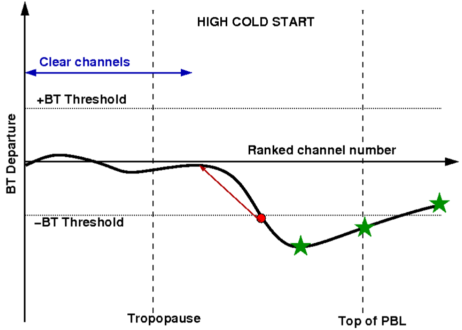
Adaptivity of β for warmstart initialization

Sensor	NBG parameter	NBG value
AMSU-A	NBG_AMSUA	10000
IASI	NBG_IASI	20000
MHS	NBG_MHS	120000
SEVIRI	NBG_MSG_HR	20000

VarBC - Technical Issues

VarBC initialization for sensor IASI

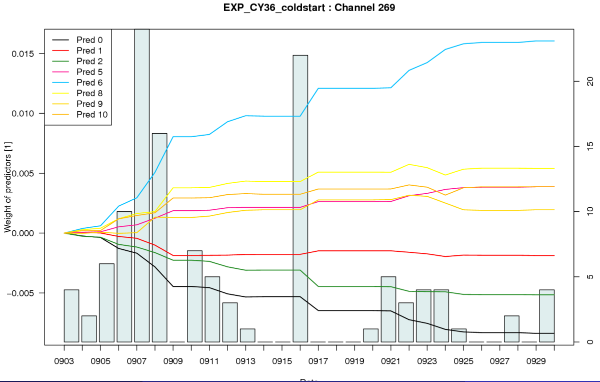
- current NWP restricted to assimilation only clear-sky IASI channels
- cloud detection schemes (DS) reject cloudy-channels – using Watts&McNally (McNally, 2003):
  - cloud-effect is judged on the basis of FG departure check and window-gradient check
  - DS works correctly supposing unbiased satellite data



Source: www.nwpsaf.eu

Initialization methods

- **Coldstart:**
  - biased satellite data assessed as cloud-contaminated (in QC) and rejected



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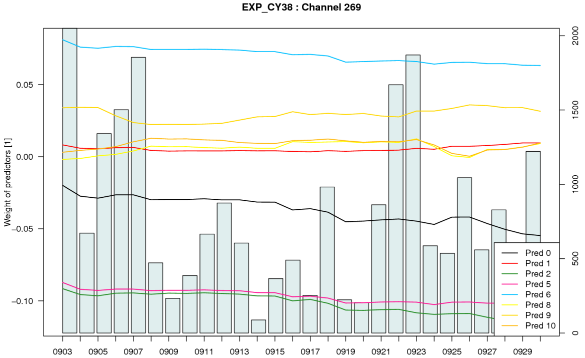

Initialization methods

- **Coldstart:**
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- **Warmstart:**
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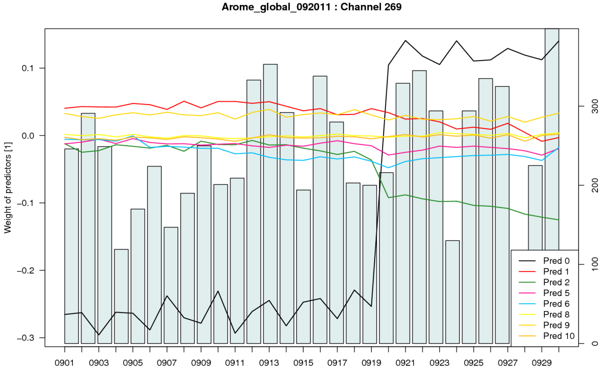
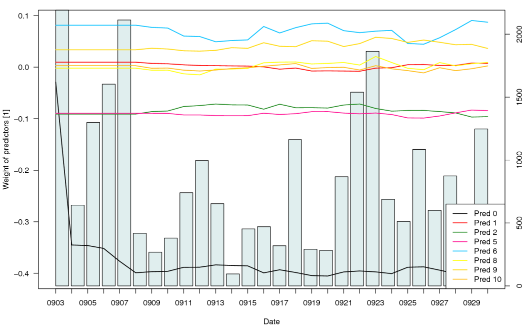
  - BE CAREFULL – use global parameters produced in the same version as LAM model
  - specific bias parameters for IASI between ARPG_CY38 and ARPG_CY37



Fast-adapting method

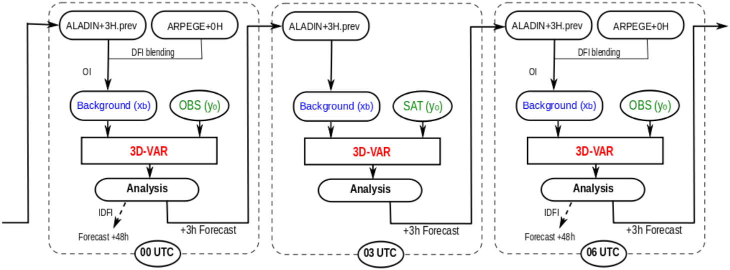
- developed during LACE stay in HMS/2013 (details in Report)
- VarBC initialization for IASI in case of coldstart option (any VarBC information)
- based on fast adaptation of global offset β_0 during first few clear-sky days to reduce satellite bias



Fast adaptation of Arpege_CY38 (warmstart) to LAM_CY36 for IASI/channel-269.

Initialization method - assessment

- 3h-forward intermittent cycle (3H-RUC):
  - time-delay error reduction (3h-AW)
  - increasing observation sample size



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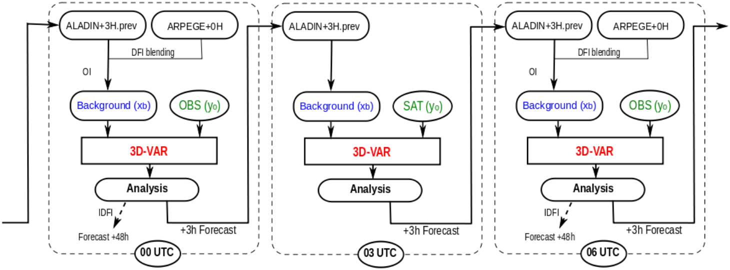

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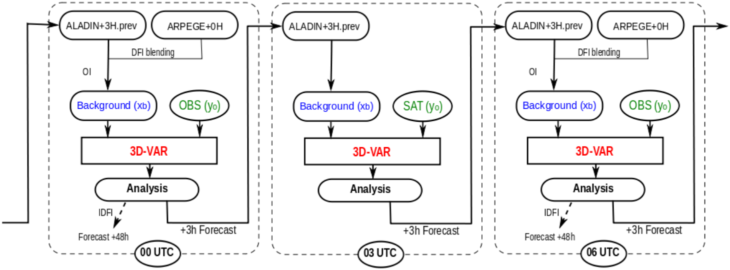

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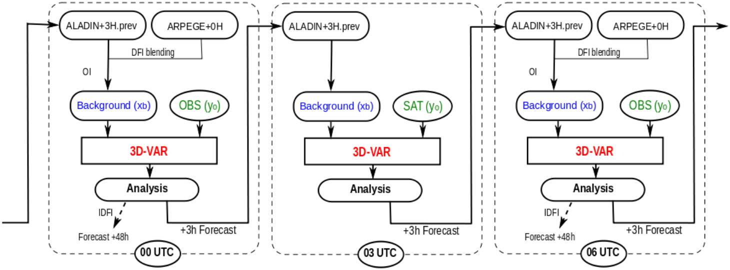

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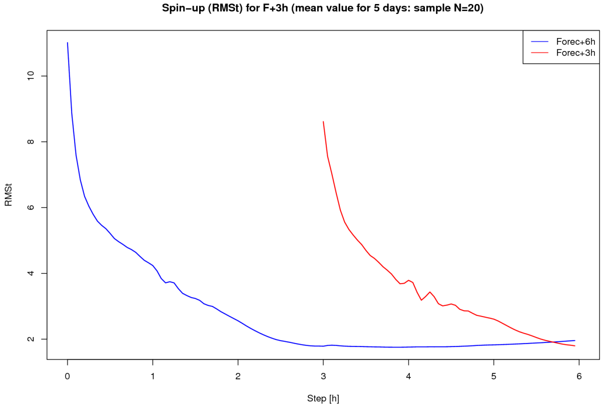

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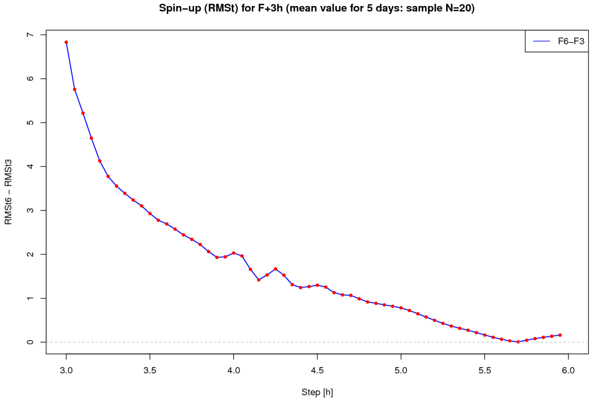

Initialization method - assessment

Experiment setting:

- 20.3.-30.4.2014 (passive) using GLMBC/LAMBC
- tuned NBG parameters, 3h-AW
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- based on OG monitoring
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  - [+] AMSU-A (7-11): T sensitive above 100 hPa
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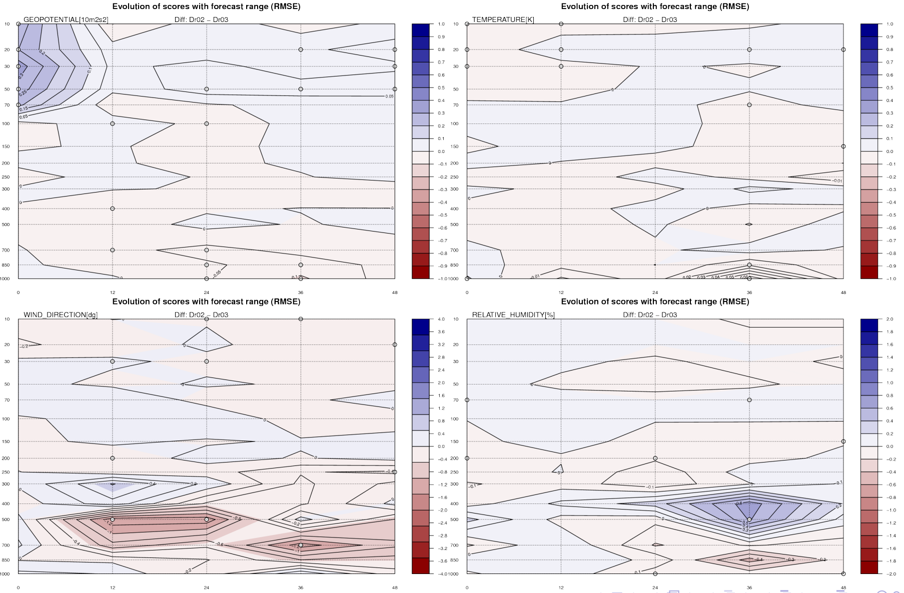
Forecast impact:

- verification against radiosonde (VERAL)
- LAMBC better than GLMBC – except of RH:400-700 hPa

Initialization method - assessment



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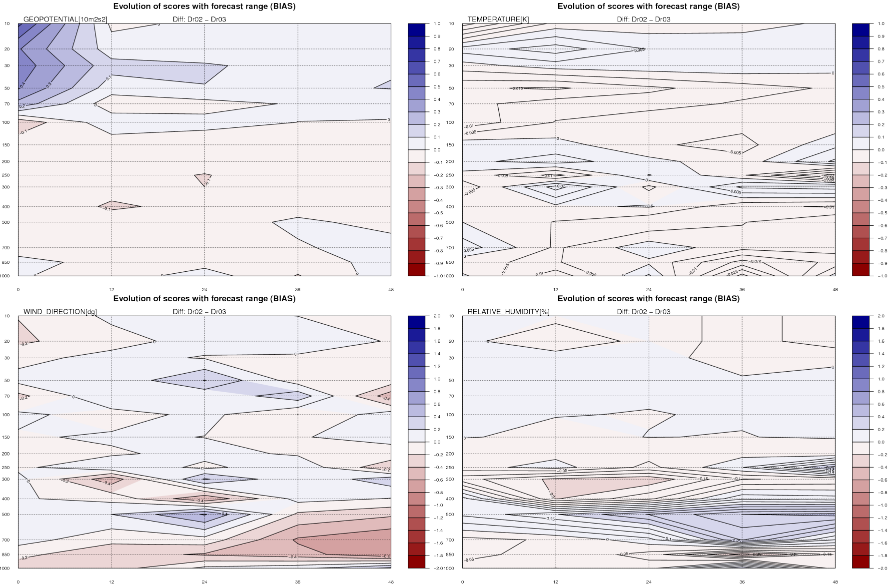

Conclusion

Summary

- **AW investigation:**
  - time-delay error affecting (RH-channels up to 10 K; T-channels up to 1 K)
  - best compromise – decreasing AW-lenght to $\pm$90 min (all sensors)
- **VarBC shortcomings in LAM:**
  - effect of time-delay
  - tuning of β-parameters adaptivity
  - initialization of VarBC for sensor IASI
  - initialization methods (warmstart/repetitive restart) assessment

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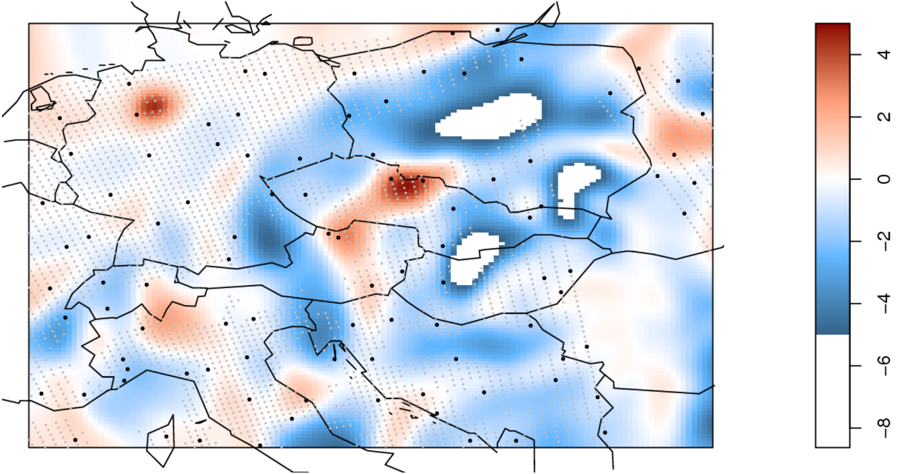
Plans

- better assessment of MW sensors (AMSU-A, MHS) in DA (no clouds restrictions)
- 3D-FGAT, 3H-RUC: spin-up, DFI tuning
- finding new VarBC predictors for sensor MSG (Vienna 2013)
- optimal thinning of satellite data

Current thinning of satellite data



Smoothed OG departures for **MHS/channel-4**. Thinned data (black) and not-thinned data (grey) after QC.

References

Berre, L., Ştefănescu S., and Pereira B.P, 2006: **The representation of analysis effect in three error simulation techniques.** Tellus, Ser. A, 58, 196–209

Desroziers G., Berre L., Chapnik B., Poli P., 2005: **Diagnosis of observation, background and analysis error statistics in observation space.** QJRM, 131, 3385-3396

Montmerle T., 2011: **Data Assimilation Strategies for Operational NWP at Meso-scale and Implication for Nowcasting.** WMO/WWRP Workshop on Use of NWP for Nowcasting UCAR, Boulder, CO, USA (presentation)

McNally AP., Watts PD., 2003: **A cloud detection algorithm for high-spectral-resolution infrared sounders.** Q.J.R. Meteorol. Soc. 129:3411-3423

Thank you for your time/attention.

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- in `mf_blacklist.h` – permanently blacklisted channels
- in `LISTE_LOC_${NT}` – blacklist in bator (e.g. for specific analysis time)

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- Corrupted/affected channels [OG statistics]
  - **corrupted channels** – comparing STD (OGdep) between different satellites (NOAA18/19, MetOp-A/B)
    - NOAA19/AMSU-A (7,8) [corrupted]
    - NOAA19/MHS (3) [corrupted]
    - MetOp-A(004)/AMSU-A (7) [corrupted]
  - **affected channels** [IASI channel selection]
    - sorting channels (from high to low) – comparing STD (increasing due to HT sensitivity for broader peaks)
    - comparing OG statistics (STD, bias) MetOp-A/B

Satellite channel selection

Local blacklisting

- specific blacklist for each analysis time??
- observation (satellite/sensor/channel) error should be similar at each analysis time
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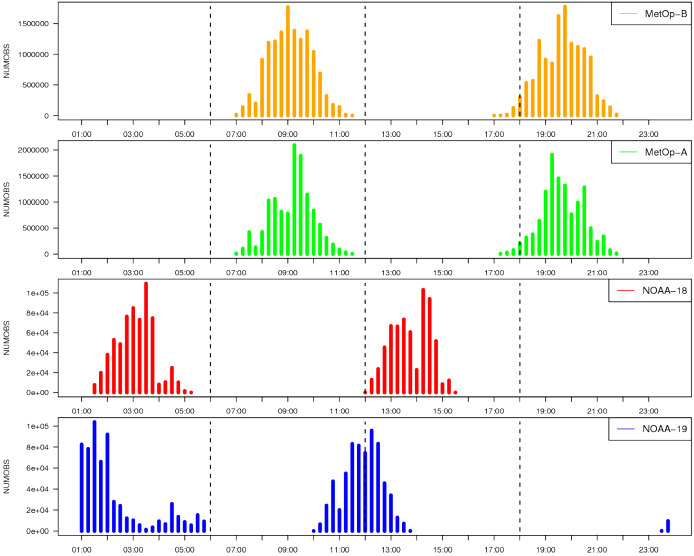
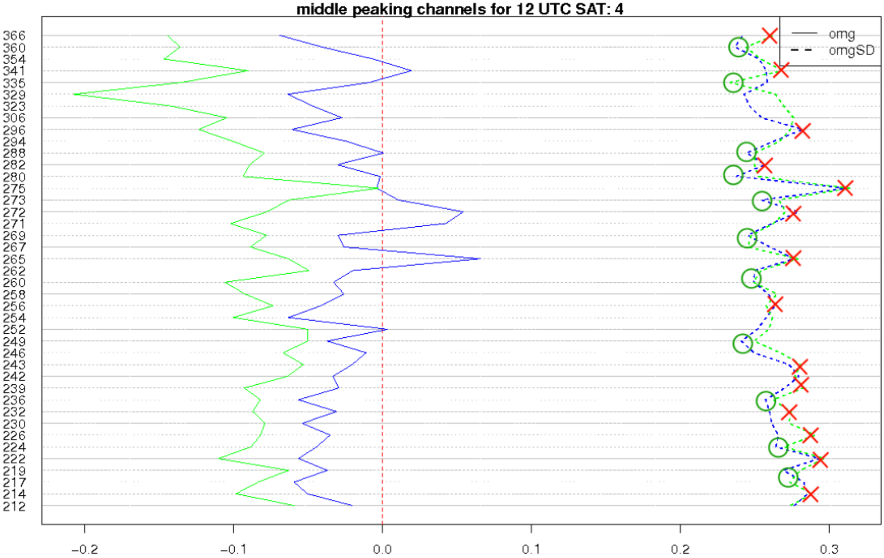
- **How to do local blacklisting?**
- For long-time passive experiment check at each analysis time:
  - observation sample size – full/edge cover (less sample size – suspicious)
  - OG statistics (bias) – VarBC correction quality (large bias – suspicious)
  - time-delayed data + scan-edge – suspicious
- recommendation: shorter AW (3h) – NOT to combine model/observation/time-delay errors (MHS/AMSU-B)

Satellite data time-delay

Channel selection for data close to analysis time.



IASI channel selection/CZ



Satellite channel selection/CZ

Satellite/Time	0	3	6	9	12	15	18	21
N16 [207]								
AMSU-A	-	-	-	-	-	-	-	-
N18 [209]								
AMSU-A	-	5-9	5-9	-	5-9	5-9	-	-
AMSU-B	-	3-5	3-5 : Td	-	3-5 : Td	3-5	-	-
N19 [223]								
AMSU-A	5,6,9 (no 7,8)	5,6,9 (no 7,8)	-	-	5,6,9 (no 7,8)	-	-	-
MHS	4,5 (no 3)	4,5 (no 3) : Td	-	-	4,5 (no 3)	-	-	-
MetB [004]								
AMSU-A	-	-	-	-	-	-	-	-
MHS	-	-	-	-	-	-	-	-
IASI	-	-	-	SELECTION	*little*	-	*Bias – VarBC21*	SELECTION
MetA [003]								
AMSU-A	-	-	-	5-9	*little*	-	5-9	5-9
MHS	-	-	-	3-5	*little*	-	3-5 : Td	3-5
IASI	-	-	-	SELECTION	*little*	-	*Bias – VarBC21*	SELECTION
MSG10 [073]								
SEVIRI	2,3,4,6,7	2,3,4,6,7	2,3,4,6,7	2,3,4,6,7	2,3,4,6,7	2,3,4,6,7	2,3,4,6,7	2,3,4,6,7

suspicious (tested)	
active	
varbc changes	