Assimilation of IASI data II

report from LACE stay in Budpaest, 10/04/2011 - 18/05/2011

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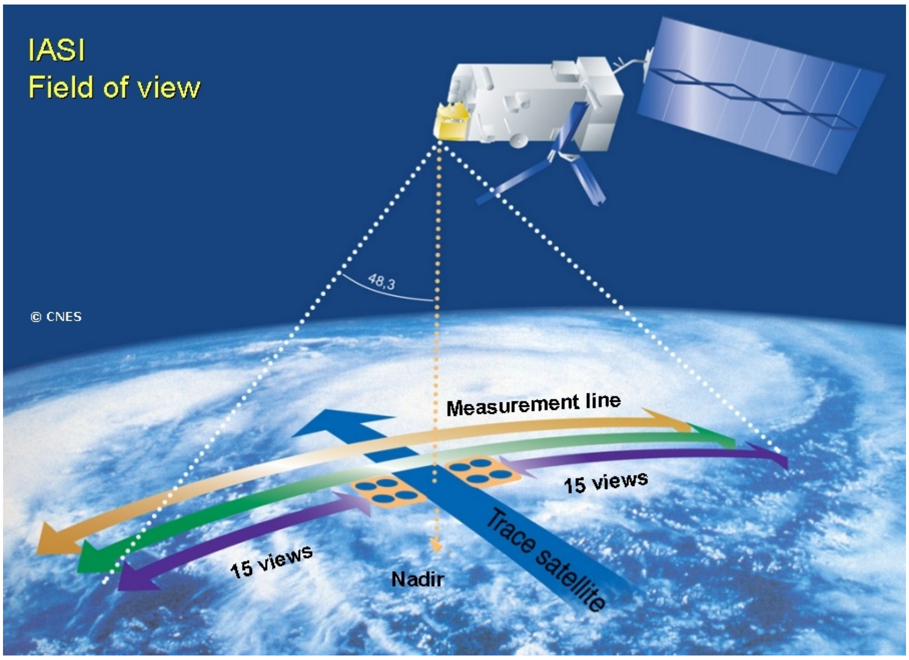

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Contents

1 Introduction

The aim of this study was to gain experiences with IASI (The Infrared Atmospheric Sounding Interferometer) in ALADIN 3DVAR system at Hungarian Meteorological Service (HMS) and following the results of first part of stay by A. Trojakova. Assimilation of IASI data was technically prepared and tested with ALADIN 3DVAR data assimilation system for new cycle cy36t1 at HMS by Alena Trojakova [1]. These previous tests brought surprising behavior in coldstart variational bias correction (VarBC) and unexpected impact on the analysis with passive data assimilation. Impact studies was found to be more and less neutral [1].
The main aim of this work is to understand the mentioned behavior in previous VarBC tests, create new channel selection for IASI sensor and run experiments with impact study on forecast.

2 Coldstart VarBC

2.1 Introduction to the problem

Variational bias correction (VarBC) is used for correction of systematic errors (biases) in satellite data. This errors arisen mainly from different thermodynamics properties of scanned atmosphere/surface and varying scanning angle. Using biased data is contrary to 3D-Var assumption and can lead to analysis degradation. If we don't have any information about bias for new sensor, we start from **coldstart** setting when bias parameters in VarBC are set to zero at the beginning and they are updated every term of analysis. We except that bias value will converge ideally to zero in every assimilation cycle.

Passive IASI data assimilation with coldstart VarBC setting was tested in one of the first experiment by A. Trojakova. Experiment's setting and description can be found in [1] and some results are in figure 1. There are shown time series of corrected and non-corrected OG (observation minus guess) departure (separately for land–green and sea–blue pixels) for IASI channel 16 and 49. Notice the absence of convergence period in the first days. No data passed screening in first day and already second day of the cycling we found good fit with respect to the provided background fields (operational guesses) [1].

The problem is due to VarBC coldstart setting and is more described in the next section 2.2.

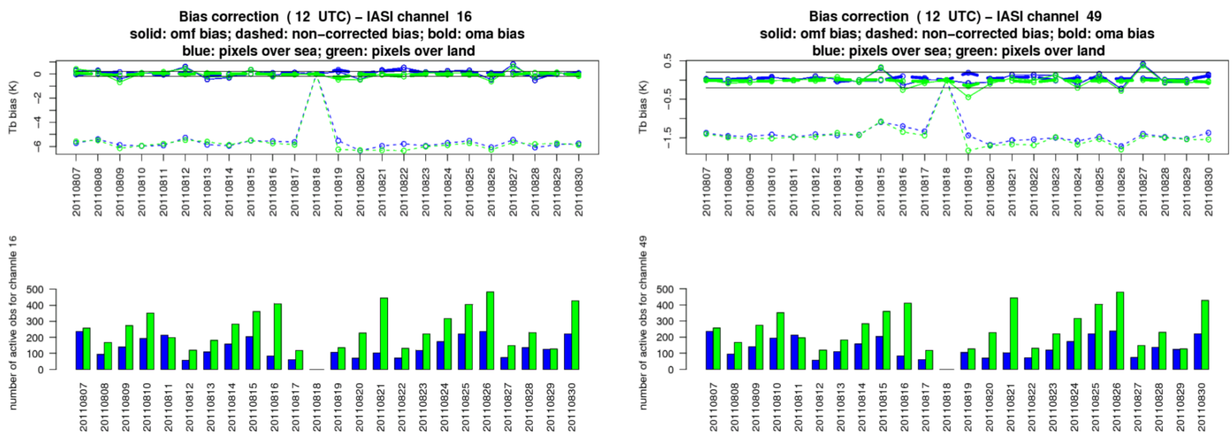

Figure 1: Time series of corrected (solid) and non-corrected (dashed) departures [K] and number of active pixels for over land (green) and sea (blue) of channels 16 and 49 at 12UTC analysis time. Bold line represents observations minus analysis departures.

2.2 Coldstart setting

The cycle cy36t1 includes a lot of innovations for VarBC, which could lead to problems with VarBC setting. Coldstart is switch-on when is not available input varbc file. There are 3 possibilities how to set coldstart setting (in screening namelist group &NAMVARBC_RAD):

1. YCONFIG(sensor,channel)%NCSTART=0 – set the bias parameters to zero for all groups
2. YCONFIG(sensor,channel)%NCSTART=1 – use available bias parameters information (like warmstart option)
3. YCONFIG(sensor,channel)%NCSTART=2 – use mode of FG departures as the first information (default)

Default setting for coldstart is mode of FG departures (NCSTART=2), but this option doesn't work correctly (Roger) and leads to the problem with bias convergence mentioned above. To avoid this problem we should ensure starting from zero value (NCSTART=0)! How to set coldstart VarBC is shown in **Appendix A**.

Correct behavior of bias correction is shown on figure (2), when we passively assimilate IASI satellite data and ensure start from zero bias parameters (NCSTART=0). Note that no data passed screening first two days, because of too big FG departures. After that is bias about -6K (it's systematic errors of channel without correction) and it converges correctly to zero value.

Taking into account that all observations were assimilated passively, we found quite big impact on the analysis during the testing period (differences between solid and bold line). This problem is described in the next section 3.2.

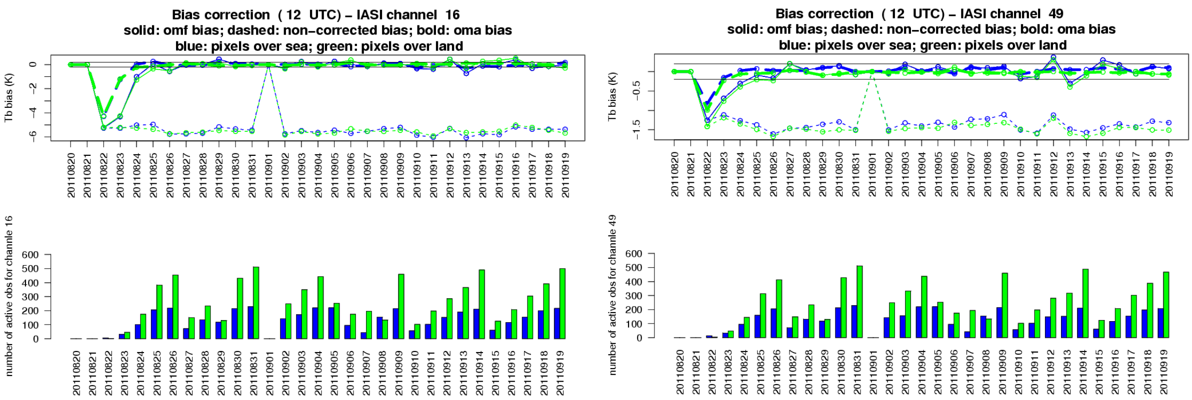

Figure 2: Time series of corrected (solid) and non-corrected (dashed) departures [K] and number of active pixels for over land (green) and sea (blue) of channels 16 and 49 at 12UTC analysis time. Bold line represents observations minus analysis departures. Experiment starting from coldstart with setting NCSTART=0.

3 VarBC predictors

3.1 Introduction to the problem

The aim of bias correction is to remove the systematic errors corresponding to the observation, the radiative transfer and pre-processing steps. Radiance biases are corrected with adaptive VarBC scheme using a set of predictors to remove systematic errors in satellite radiances. Predictors include nadir viewing-angle to correct bias due to satellite scan angle and then include air-mass quantities to account for air-mass related errors. Overview of all predictors used in VarBC is in table 1. VarBC predictors are updated daily in ALADIN/HU for each assimilation time.

$p_i(x)$	**Character**
1	Thicknesses of pressure level 1000-300 hPa
2	Thicknesses of pressure level 200-50 hPa
3	Skin temperature
4	Total column precipitable water
5	Thicknesses of pressure level 1-10 hPa
6	Thicknesses of pressure level 5-50 hPa
7	Surface wind speed
8	Satellite nadir viewing angle
9	Satellite nadir viewing angle**2
10	Satellite nadir viewing angle**3
11	Satellite nadir viewing angle**4
12	cosine solar zenith angle
14	TMI diurnal bias
15	0 over sea, 1 over land
16	0 over sea, nadir viewing angle over land
17	0 over sea, nadir viewing angle **2 over land
18	0 over sea, nadir viewing angle **3 over land

Table 1: Predictors for variational bias correction.

Taking into account that all observations were assimilated passively, we found quite big impact on the analysis during testing period, well obviously in the first 5 days of experiment (see differences between OG and OA in the figure 2). This impact was detected for all channels that include stratospheric predictors 5 and 6 from the table 1. These predictors represents thicknesses of pressure level 1-10hPa and 5-50hPa and are used to reduce observation bias for stratospheric channels. Take into account strange impact to analysis and that the top of model ALADIN/HU is around 5hPa, there arises question, if these stratospheric predictors are still appropriate to use in ALADIN/HU.

3.2 Stratospheric predictors

We investigated passive data assimilation with coldstart VarBC with regard to stratospheric predictors 5 and 6 (from table 1) and we evaluated impact of passive observation data to analysis. For this purpose we run 3 experiments:

- **Iasi030** – used default predictor settings
- **Iasi035** – not used predictor 5
- **Iasi040** – not used predictors 5 and 6

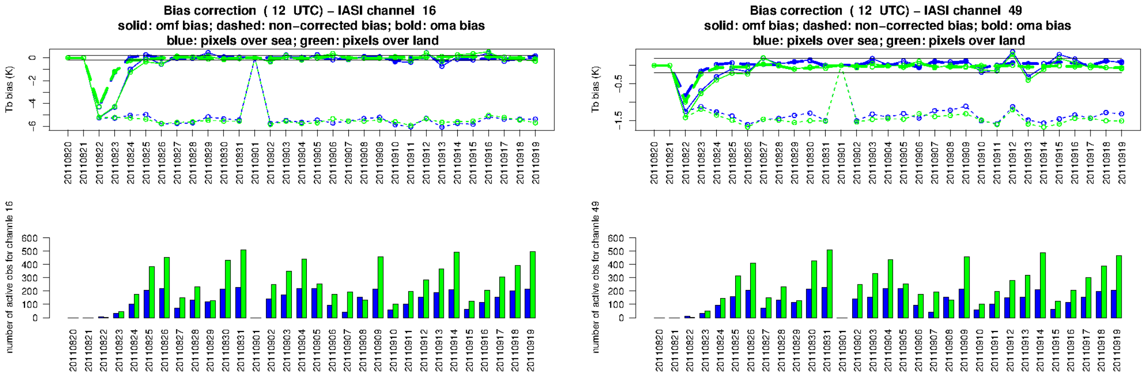

Figure 3: Time series of departures for experiment Iasi30 - used all predictors

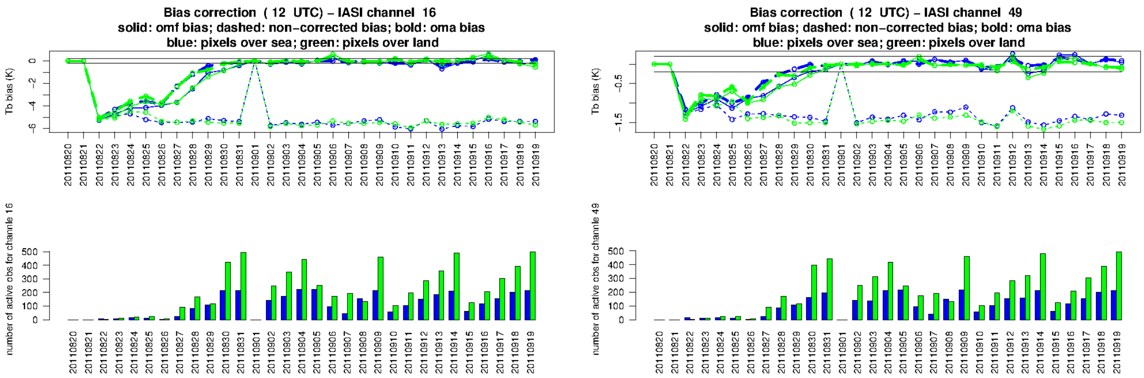

Figure 4: Time series of departures for experiment Iasi35 - not used predictor 5

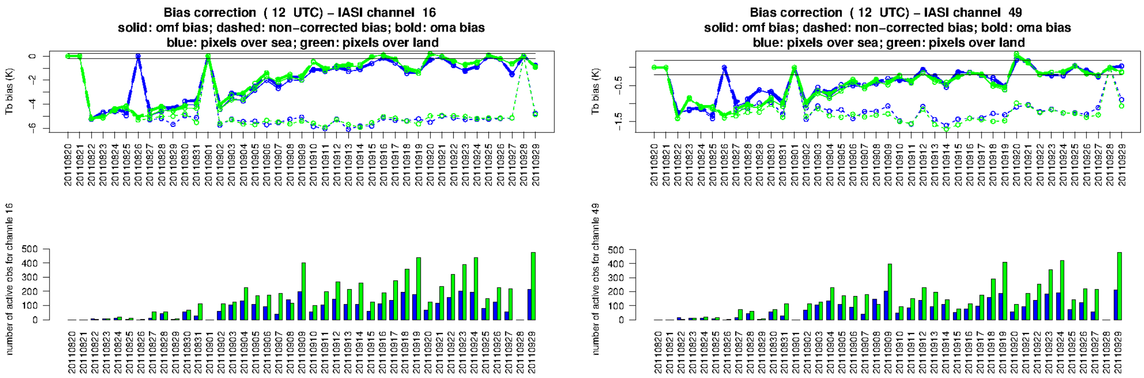

Figure 5: Time series of departures for experiment Iasi40 - not used predictors 5,6

There are time series of corrected (solid) and non-corrected (dashed) departures [K] and number of active pixels for over land (green) and sea (blue) of channels 16 and 49 at 12UTC analysis time on the figures above. Experiment with default (all) predictors (Iasi030) on figure 3, experiment without predictor 5 (Iasi035) on figure 4 and experiment without predictors 5 and 6 (Iasi040) on figure 5. Bold line represents observations minus analysis departures. Notice that removing of stratospheric channels leads to longer 'warm up' period for coldstart VarBC and smaller impact of passive data assimilation on the analysis.

Experiments with passive assimilation of ATOVS radiances was run in ALADIN/CE at CHMI (Czech Hydrometeorological Institute). They leads to almost neutral impact of stratospheric predictors 5 and 6 to the analysis which could be a consequence of higher top of the model (0.8hPa) and more vertical levels in upper troposphere and lower stratosphere in the model, but we need more investigation to conclude.

Impact of the predictors on forecast

Impact of predictors 5 and 6 on the forecast was investigated. We prepared two experiments, when the VarBC files from previous passive experiments (Iasi40 and Iasi30) were used to warmstart active assimilation.

- **IASI36a2** – predictors 5 and 6 not used; initialization VarBC file from experiment Iasi40
- **IASI36a3** – all default predictors; initialization VarBC file from experiment Iasi30

There were sensors IASI, AMSU-A,B, MHS and SEVIRI **activelly** assimilated for 15 days (01.-15.2011) in the experiments. On the one hand experiment without predictors 5 and 6 leads to slightly analysis improvement for bias in temperature above 20-50hPa (shown in figure 6), geopotential and relative humidity (RH) above 500-300hPa. Slightly analysis improvement was detected in rmse for RH as well (shown in figure 7). On the other hand removing of predictors 5 and 6 from VarBC leads to slightly degradation of analysis in stratosphere above 10-20hPa which could be related to worse bias correction for stratospheric levels (not shown).

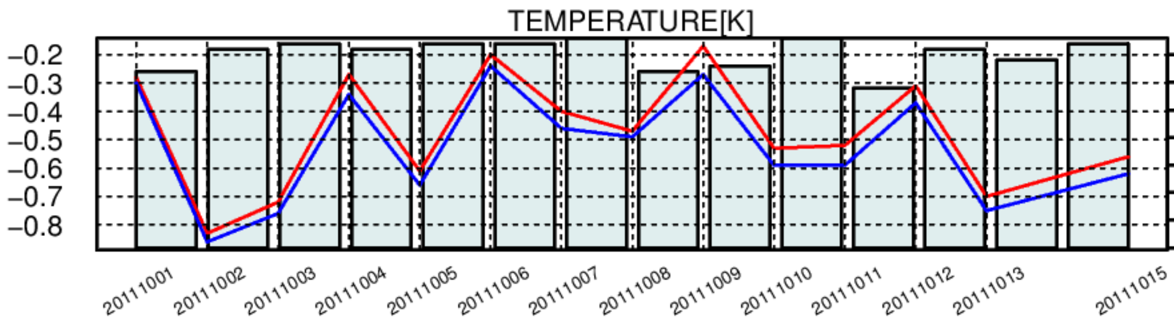

Figure 6: Bias evolution for temperature for 50hPa. Blue line represents experiment IASI36a3 (used all predictors), red line represents experiment IASI36a2 (not used predictors 5 and 6).

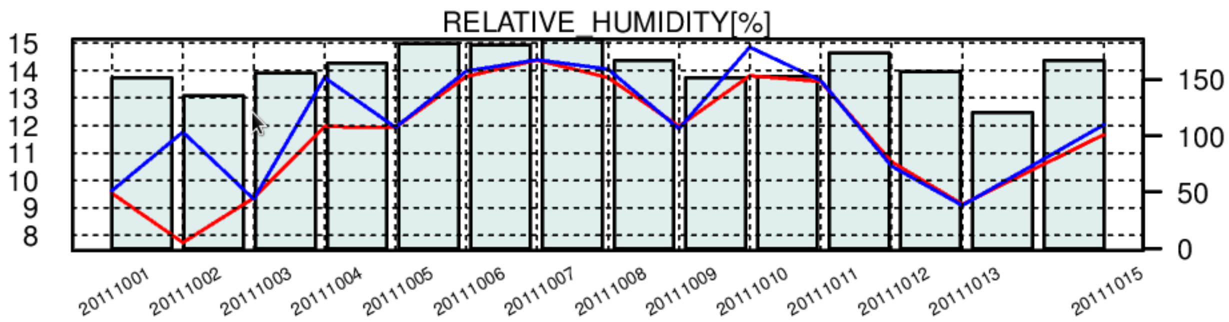

Figure 7: Evolution of rmse for relative humidity for 500hPa. Blue line represents experiment IASI36a3 (used all predictors), red line represents experiment IASI36a2 (not used predictors 5 and 6).

4 Channel Selection

A set of 366 channels available through EUMETCAST was used in this study, more details of this selection can be found in [3], [4]. One field of view (FOV) of the four available from each field of regard collocated with the one corresponding to AMSU-A FOV was used (IASI data settings via Bator namelist could be found in [1]). IASI were assimilated also in the presence of cloud. The cloud detection scheme of McNally and Watts [5] was used, where active channels having peak above the cloud top are assimilated.

Active IASI channels were selected after experimental passive assimilation by applying monitoring technique described in Randriamampianina [6]. The time series of bias evolution of observation-minus-guess (OG) and of the observation-minus-analysis (OA) were studied separately for each channel. We were looking for channels displaying bias reduction in time. Pixels over land and over sea were studied separately. Furthermore we were looking for peak of channel's weighting function and remove those which have peak above the top of model. Actively were assimilated channels with impact to temperature profile (**CO_2** absorption) and with impact to humidity profile (**H_2O** absorption) listed below:

- channels **over sea and land**
  38, 49, 51, 55, 57, 61, 63, 70, 83, 85, 87, 104, 109, 116, 122, 128, 135, 141, 146, 148, 154, 159, 161, 165
  167, 173, 178, 179, 180, 185, 187, 191, 193, 195, 197, 199, 201, 203, 205, 207, 210, 212, 214, 217, 219
  222, 224, 226, 228, 230, 232, 234, 236, 241, 242, 243, 249, 254, 256, 262, 299, 301, 303, 3098, 3168
  3248, 3252, 3256, 3312, 3378, 3440, 3577, 3586

- channels **over land only**
  3281, 3309, 3442, 3444, 3446, 3448, 3450, 3452, 3454, 3491, 3504, 3506, 3509, 3522, 3555, 3575, 3580
  3582, 3589, 3599, 3653, 3658, 3661, 4032, 3105, 3136, 3175, 3207, 3263

5 Impact studies

The impact of IASI data assimilation was evaluated for period 01.-15.10.2011. The objective scores (BIAS, RMSE, and STD), with respect to SYNOP and TEMP observation were computed for +48H forecast starting from 12UTC short cut-off analysis. Both short and long cut-off cycle were considered in the experiments. Technical settings:

- ALADIN/HU, horizontal resolution 8km, 49 vertical levels, CY36t1
- active assimilation of sensors IASI, AMSU-A,B, MHS, SEVIRI (without predictors 5 and 6)
- thinning distance for IASI data 80km
- channel selection for sensor IASI (in the section 4)
- VarBC, 24h-cycling ([6])
- initialization VarBC from experiment IASI36a2 (no predictors 5 and 6)

We prepared two experiments for impact study IAS2 and REF. Experiment IAS2 differs from the reference REF only in adding predefined IASI channels. On following figures the RMSE differences of the IAS2 and REF experiments scores are displayed.

Impact of predefined IASI channels is quite small, more and less neutral. We got slightly negative significance impact for RH above 100-500hPa during the first 12H of the forecast (figure 8 top right). Notice that IASI WV channels bring more moisture in the middle and high troposfere. We got neutral impact for temperature, whereas geopotential and wind speed was characterized by change of significantly positive and negative impacts. No impact was found for the surface parameters (figure 8 below). Slightly positive impacts were found for geopotential bias above 20-30hPa in the first 24H of the forecast and for temperature bias in analysis above 30-50hPa (not shown).

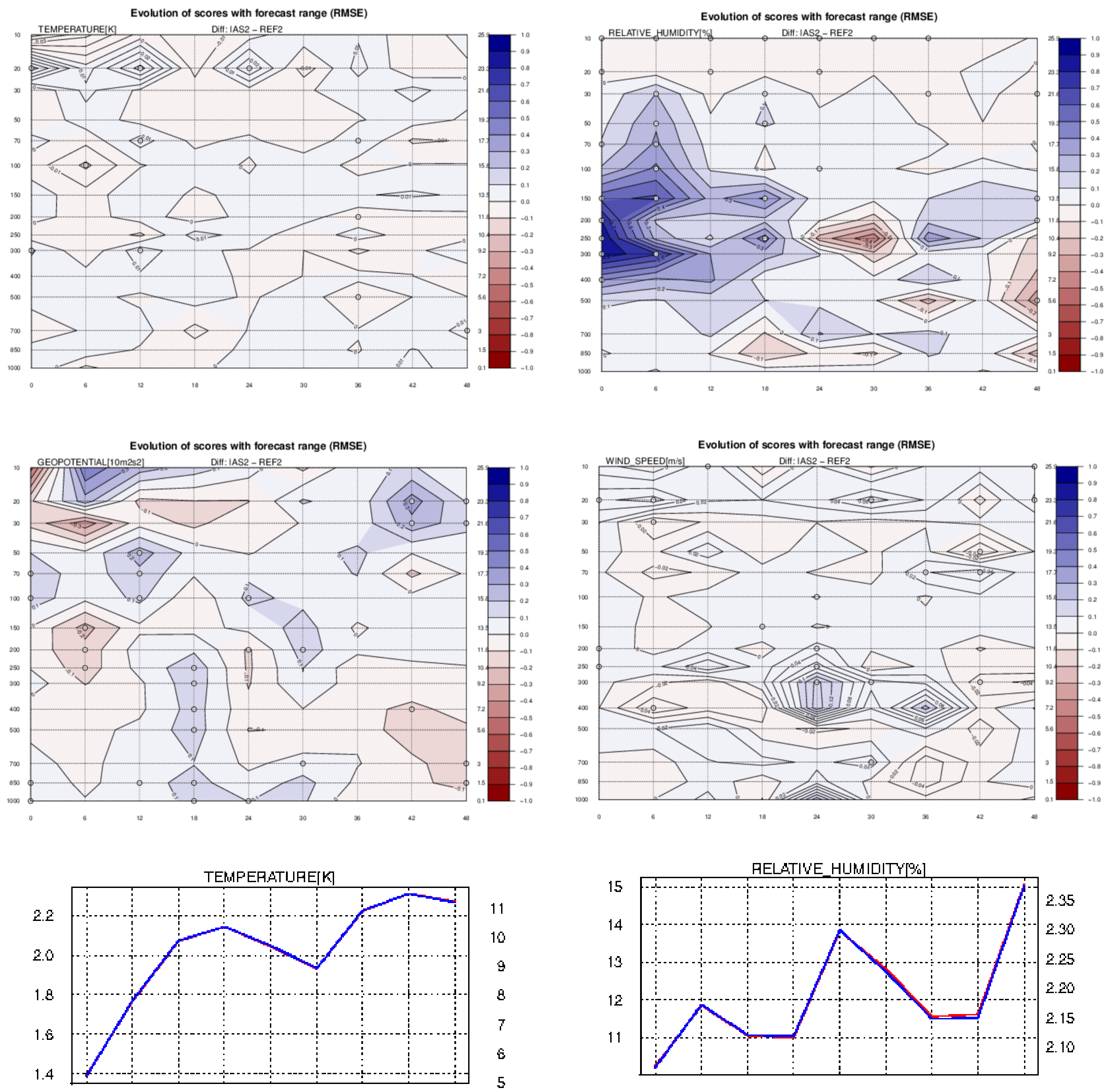

Figure 8: RMSE differences against observation of T (top left), RH (top right), ϕ (middle left) and wind speed (middle right). Red areas denote positive impact of IASI assimilation (IAS2). The white circles point that RMSE difference is better/worse with significance 95% two-side confidence interval. RMSE against observation of T2m (left bottom) and RH2m (right bottom). IAS2 experiment (red line) and reference REF (blue line) are depicted.

6 Conclusion

Variational bias correction was tested, when we fixed problem with coldstart setting and apart from that we focused on stratospheric predictors 5 and 6 (thicknesses of atmospheric layers 1-10hPa and 5-50hPa). To summarize experiments with the stratospheric predictors contribute to the analysis for passive data assimilation. Reducing of the stratospheric predictors leads to smaller impact in analysis, although longer 'warm up' period for passive assimilation experiment was detected (see figure 5). The impact of the predictors 5 and 6 to analysis was slightly negative for middle and high troposphere for RH, T and ϕ (see figure 6 and 7), however, the impact was positive for temperature in lower stratosphere.
Finally the impact study with IASI data was performed, when the new channel selection was done (considering weighting function of channels and time series of bias evolution) and we not used the predictors 5 and 6 for active IASI data assimilation experiments. The impact was found to be more and less neutral, although for some parameters and forecast ranges both significantly positive and negative differences were found. Sensor IASI is very promising instrument for data assimilation in limited area models, however, we need more investigation and evaluation before IASI can be used operationally.

References

[1] *Trojakova A. 2011.* **Assimilaton of IASI data.**
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[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 Resuolution Sounders in NWP., ECMWF, Reading, UK, 97-112

[3] *A.D. Collard 2007.* **Selection of IASI channels for use in numericl weather prediction.**
Q.J.R. Meteorol. Soc., 133:1977-1991

[4] *Collard A.D., McNally A.P. 2009.* **The assimilation of Infrared Atmospheric Sounding Interferometer radiances at ECMWF.**
Q.J.R. Meteorol. Soc., 135:1044-1058

[5] *McNally A.P., Watts P.D. 2003.* **A cloud detection algorithm for highspectral-resolution infrared sounders.**
Q.J.R. Meteorol. Soc., 129:3411-3423

[6] *Randriamampianina R., Iversen T., Storto A. 2011.* **Exploring the assimilation of iasi radiances in forecasting polar lows.**
Q.J.R. Meteorol. Soc., 137:1700-1715

A How to set coldstart VarBC

There are 2 options how to set coldstart settings:

- via namelist – set condition (1) for selected sensors and channels in namelist group &NAMVARBC_RAD (little bit tricky for iasi's cca 8000 channels). If we have available varbc file, we can combine coldstart and warmstart settings.

```
&NAMVAR
  NITER=1,
  NSIMU=1,
  NGRATS(0)=1,
  NGRATS(1)=1,
  NFRANA=10000,
  NUPTRA=-1,
  LJCNMTL=.FALSE.,
  RCVGE=1.E-3,
  L_CHECK_CONVERGENCE=.FALSE.,
  LTOVSCV=.TRUE.,
  LVARBC=.TRUE.,
  LCLDSINK=.FALSE.,
/
&NAMVARBC
/
&NAMVARBC_ALLSKY
  LBC_ALLSKY=.FALSE.,
/
&NAMVARBC_RAD
  LBC_RAD=.TRUE.,
  YCONFIG(3,1:15)%NCSTART=0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
  YCONFIG(4,1:5)%NCSTART=0,0,0,0,0,
  YCONFIG(15,1:5)%NCSTART=0,0,0,0,0,
  YCONFIG(29,1:8)%NCSTART=0,0,0,0,0,0,0,0,
/
&NAMVARBC_TCWV
  LBC_TCWV=.FALSE.,
/
&NAMVARBC_TO3
  LBC_TO3=.FALSE.,
/
```

Figure 9: Set coldstart for all channels of sensors AMSU-A(3), AMSU-B(4), MHS(15) and SEVIRI(29)

- modification in varbc_rad.F90 - set default value for ncstart to zero. Coldstart for all sensors and satellites.

```
! default settings:
! ----------------
DO is = 0, MXSENSOR
  DO ic = 1, JPMXTOCH
    yconfig(is,ic)%nparam      = 0
    yconfig(is,ic)%npredcs(:) = 0
    yconfig(is,ic)%zparams(:) = RMDI
    yconfig(is,ic)%llconst(:) = .false.
    yconfig(is,ic)%ncstart     = 2
    yconfig(is,ic)%dfgdep      = 20.0_JPRB
    yconfig(is,ic)%nbgstdv     = 0
    yconfig(is,ic)%llmode      = .false.
    yconfig(is,ic)%llmaskrs    = .false.
    yconfig(is,ic)%llmaskcld   = .false.
  ENDDO
ENDDO
```

Figure 10: Default value for ncstart is set to use mode of FG departures (ncstart=2). Modification to ncstart=0 ensure correct behavior in case of coldstart settings.