Radiance data assimilation in HIRLAM and ALADIN consortia - Recent developments

Roger Randriamampianina(1), Patrik Benacek(2), Máté Mile(3), Magnus Lindskog(4), Sigurdur Thorsteinsson(5)

1- Norwegian Meteorological Institute; 2-Czech Hydrometeorological Institute; 3- Hungarian Meteorological Service; 4- Swedish Hydrometeorological Institute; 5- Icelandic Meteorological Office.

Correspondence: rogerr@met.no

Further tuning of the variational bias correction scheme in the HARMONIE Model (Lindskog et. al., 2012) (having a spin up of predictor parameters within reasonable time)

NOAA-19 VARBC Bias parameter evolution

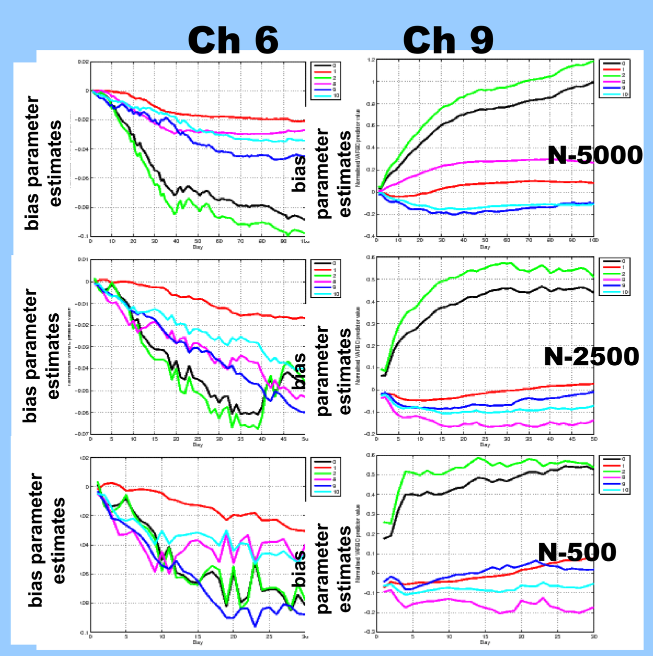
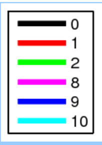


Figure 1.



Variational Bias Correction (VarBC)

Linear predictor model for bias in each channel:

$$\mathbf{b}(\mathbf{x}, \beta) = \sum_{i=0}^{N_p} \beta_i \mathbf{p}_i(\mathbf{x})$$

Cost function:

J_b: background constraint for x; J_β: background constraint for β

$$J(\mathbf{x}, \boldsymbol{\beta}) = (\mathbf{x}_b - \mathbf{x})^T \mathbf{B}_x^{-1} (\mathbf{x}_b - \mathbf{x}) + (\boldsymbol{\beta}_b - \boldsymbol{\beta})^T \mathbf{B}_\beta^{-1} (\boldsymbol{\beta}_b - \boldsymbol{\beta}) + [\mathbf{y} - \mathbf{b}(\mathbf{x}, \beta) - h(\mathbf{x})]^T \mathbf{R}^{-1} [\mathbf{y} - \mathbf{b}(\mathbf{x}, \beta) - h(\mathbf{x})]$$

J_o: bias-corrected observation constraint

β_b Parameter background value – final estimate from previous analysis

$\sigma_\beta^2 = \sigma_o^2 / N$ N large means strong constraint- less adaptivity (5000 default)

Table 1.

Predictor no.	Predictor
0	constant
1	1000-300hPa thickness
2	200-50hPa thickness
5	10-1hPa thickness
6	50-5hPa thickness
8	nadir view angle
9	nadir view angle **2
10	nadir view angle **3

One evident feature of *Figure 1* is that there appears to be a strong correlation between predictors 0 and 2. It might be that they should not be used together. To investigate that, an additional experiment was carried out. The additional experiment was identical to the one with NBG value of 2500, except for that predictor 2 was removed. As result, the predictor 0 is almost doubled (*Fig. 2*), as was expected from the parallel evolution of predictors 0 and 2. The conclusion is that it is sufficient to use predictor 0, and not both 0 and 2, as the default for the HARMONIE system.

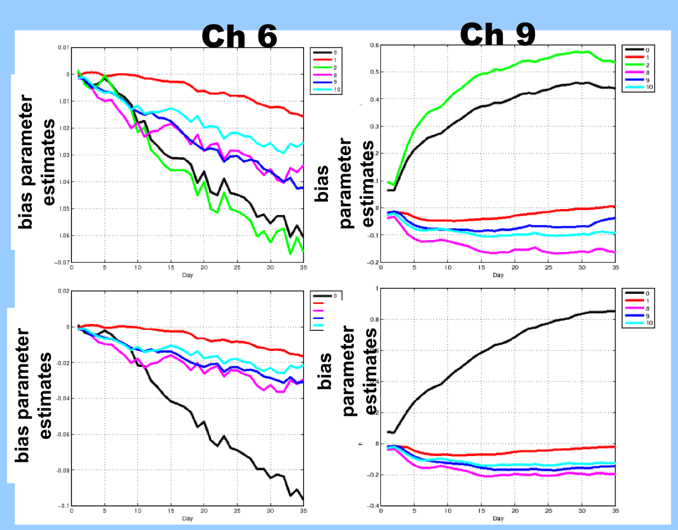
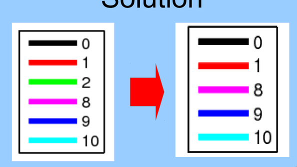


Figure 2.

Solution



Applying *Lindskog et al. (2012)* solution in the implementation of the IASI humidity sensitive radiances in the AROME-Norway data assimilation system

The AROME-Norway and RT model:

- The domain is shown on the Figure 3.;
- The model top is 10 hPa;
- RT model use RTTOV version 9;
  → LBLRTM coefficients, 43 levels;
- Use of full FOVs both for ATOVS and IASI.

Radiance bias correction coefficients update:

- Coefficients for VarBC estimated for August 2011.

Channels selection:

- For AMSU-A, channels 5-10;
- All channels peaking above 10 hPa are blacklisted for both ATOVS and IASI with more emphasis on humidity sensitive channels (38 of overall 73);
- Avoiding humidity channels that are sensitive to relatively thin tropospheric layers, we ended up to 22 active humidity sensitive Channels. See *Randriamampianina et al. (2013)* for more details.

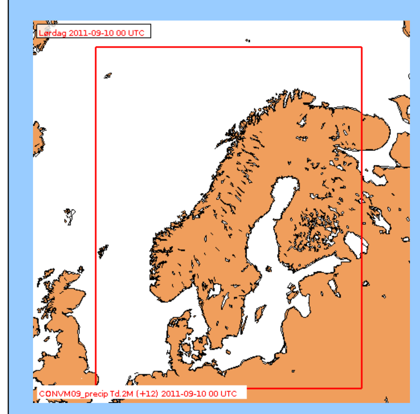


Figure 3.

Experiments design:
METATOV - reference run with conventional and ATOVS;
METIASI - run with reference data and all 73 IASI channels;
METIASIHU - run with reference data and 38 humidity channels;
METIASILH1 - run with reference data and 22 humidity channels;
Period: September 1-30, 2011, with the first 4 days a warming period

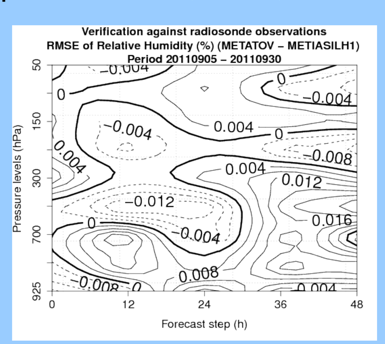


Figure 4.

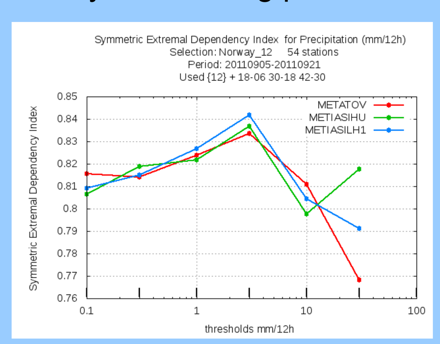
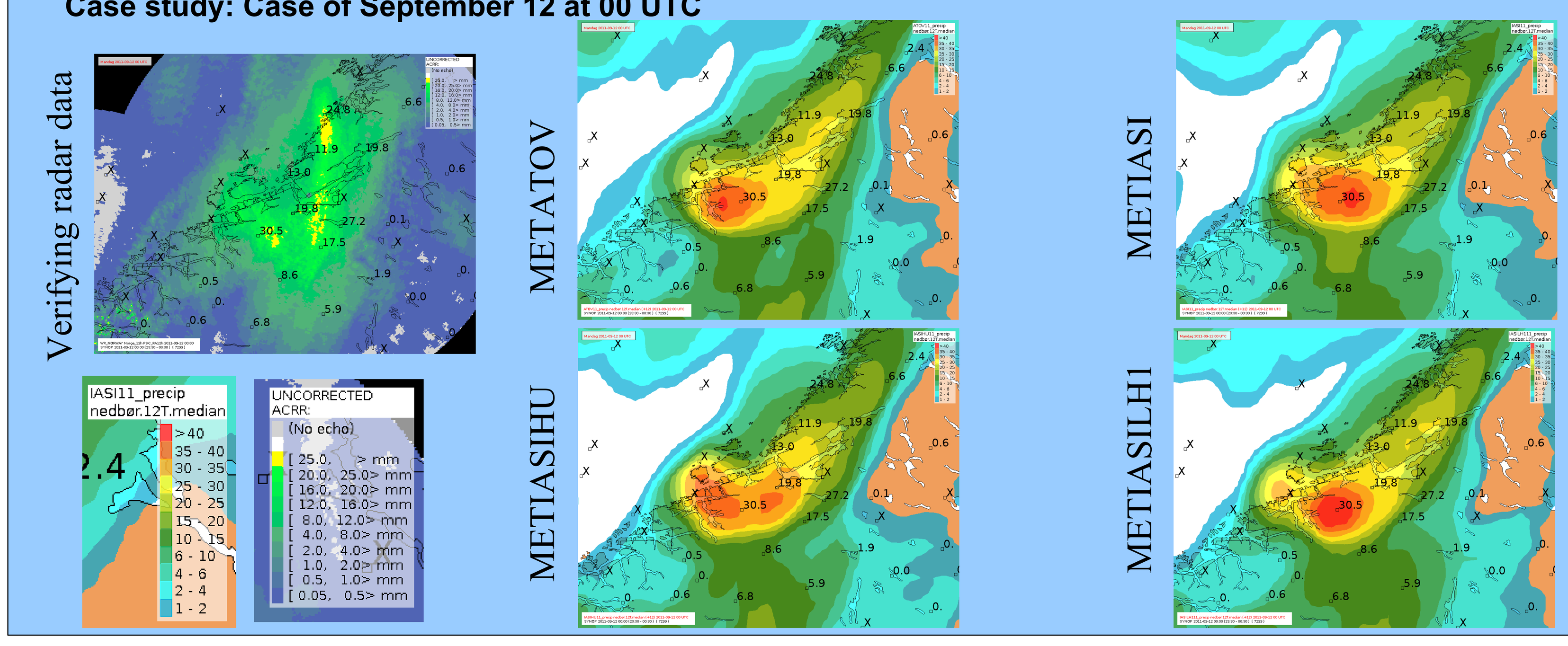


Figure 5.

Case study: Case of September 12 at 00 UTC



On the use of satellite radiances in regional models

- How to start new experiment without (bias) information from global Models?
  → *Do passive assimilation or independent analysis.*

- How to aggregate the bias coefficients for new experiment?
  → *In case of variational scheme, Randriamampianina et al. (2011) recommended to estimate the bias coefficients with 24 hour cycling. So, each assimilation time will have its own aggregated coefficients. Note also Lindskog et al. (2012) and Benacek (2013). For off-line (Harris and Kelly, 2001) case at MetOffice Fiona Smith have got a very promising results when checking few days statistics with daily (24 hour cycling) aggregates.*

- Can coefficients from global model help in doing warm start?
  → *No clear answer yet on this question. Benacek (2013) have got promising (better convergence to the nominal bias) results when using coefficients from ECMWF model. Note that ALADIN/Hungary uses the ECMWF forecasts as lateral boundary condition. Do yo have experience on this issue, please share it with us. Give your e-mail address with short comment in the box below.*

- How can we can use high peaking channels (around or above the model top), when having high top coupling model available?
  → *Do you have answer on this? Please share it with us. Use the box below.*

Do you have also alternative answers? Please put them into the box below

Further tuning of the variational bias correction scheme with the ALADIN/Hungary Model (Benacek, 2013) (Improving the use of low peaking channels)

Bias correction

Satellite bias was corrected using VarBC method. This method is based on multivariate linear regression implemented into the variational 3D-Var scheme. The set of predictors are described in the Tab. 1. The stratospheric predictors 5 and 6 were not used due to the spare model levels in the stratosphere. Regression coefficients have been initialized from global model ECMWF (warm start) and updated in each assimilation time (24-h cycling). Satellite data have been assimilated passively.
A problem with IASI data rejection (in quality control) was found due to the cloud contamination. This problem is related with cloud detection scheme used for hyper-spectral satellite instrument like IASI, AIRS and CrIS. This algorithm is based on the assumption that observation departures are unbiased. However, the satellite data have relatively larger bias in the beginning of the passive assimilation experiment, which leads to a data rejection (this concerns mainly low/middle tropospheric peaking channels). The problem have been solved by tuning the cloud detection scheme before starting the warm start passive assimilation. In fact, the warm start passive assimilation of radiance data was prepared the following way:

1- A relative large extension of clear sky days period over the ALADIN/Hungary domain (Fig. 6) was defined (5-9 June 2013)
2- Estimate the radiance departure bias specific for each IASI spectral band (see Fig. 7);
3- Change the BT threshold according to the estimated bias to ensure that most of the clear radiances pass through the quality control.
4- The IASI bias correction, NBG is set to 500 (ensuring fast adaptivity, see Lindskog et al., 2012) during the "adjusting period";
5- The threshold values for NBG were put back to default values for the warm start passive assimilation, where more middle- and low-peaking channels are able to pass through the quality control (see Figs 8,9)).

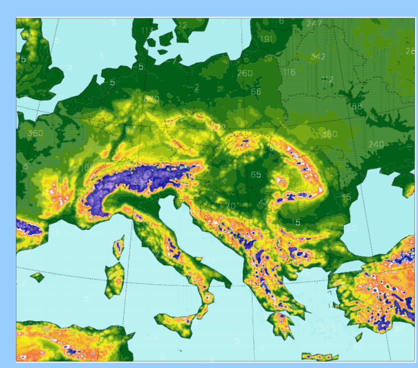


Figure 6.

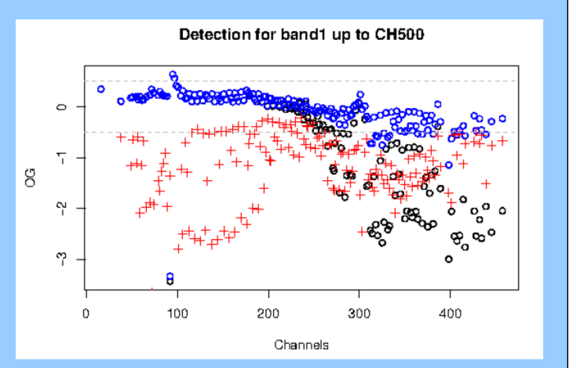


Figure 7. OMG departures for selected channels (spectral band1) for clear-sky day 8.6.2013 at 06UTC. Blue points represents clear-sky channels, black points represents cloudy channels and red cross represents the values of bias correction. The figure was used to re-tune BT thresholds (IASI channels in band1) in the cloud detection scheme.

Improved use of low peaking channels

A selection of clear-sky radiance was validated for random day to check the functionality of the cloud detection scheme. We compared a clear-sky pixel selection with cloud-type (CT) from SAF/NWC for selected IASI channels. The validation is shown for the "middle-peaking" channel 246 in the Fig. 8. It is obvious that the pixels (red points) are selected from the clear-sky conditions, whereas data contaminated by high/middle cloud types (pink/white colour) are rejected. Note that clear-sky radiation for middle-peaking channels are also selected over very-low clouds (the orange points over the North Sea).

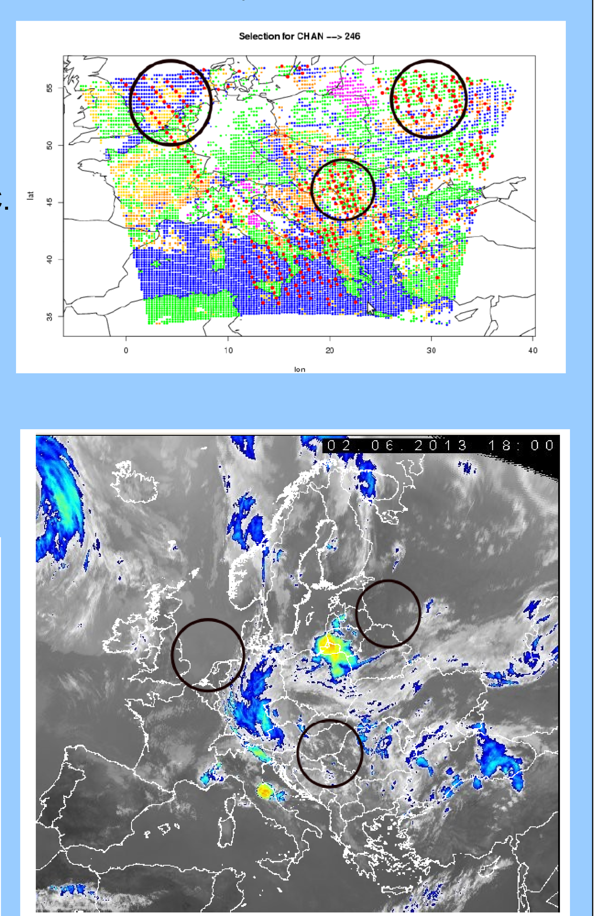


Figure 8. Clear-sky pixel selection was validated against CT from SAF/NWC. In the top figure active pixels are shown (red points) from middle-peaking IASI channel 246 and different cloud types from SAF/NWC (land/green, sea/blue, low-/orange, middle-/white, high-/pink cloud). The control MSG channel IR10.8 is shown in the bottom figure.

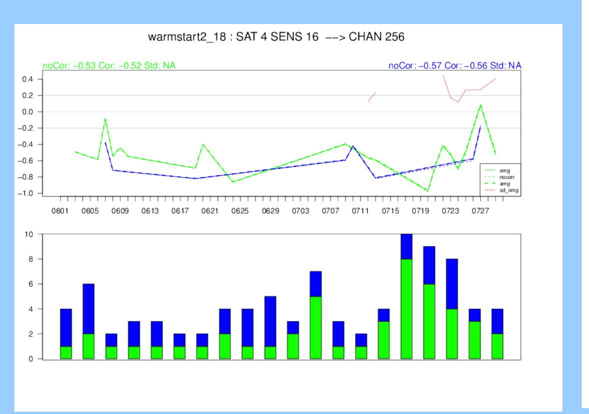
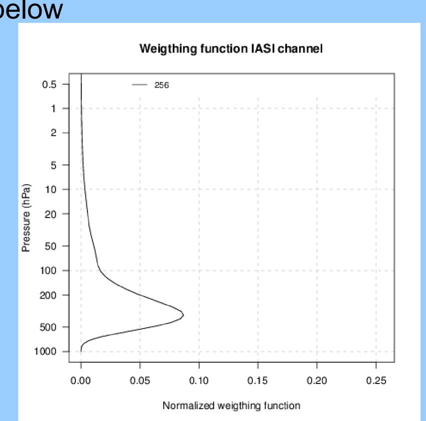
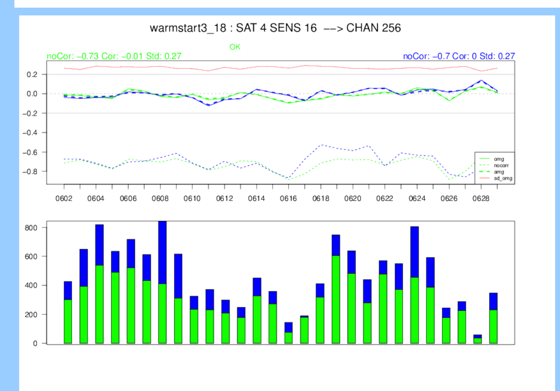
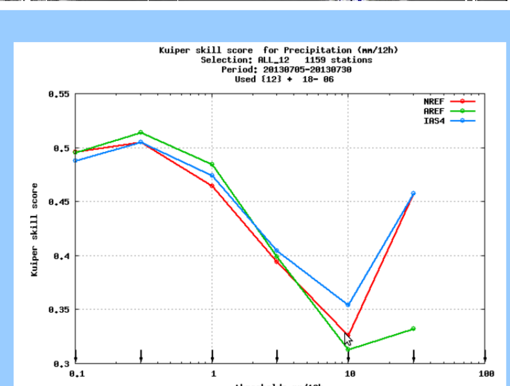


Figure 9. Monitoring of the channel 256 with (bottom plot) and without (top plot) cloud detection scheme adjustment before a passive radiance assimilation. The weighting function of the channel 256 is shown below

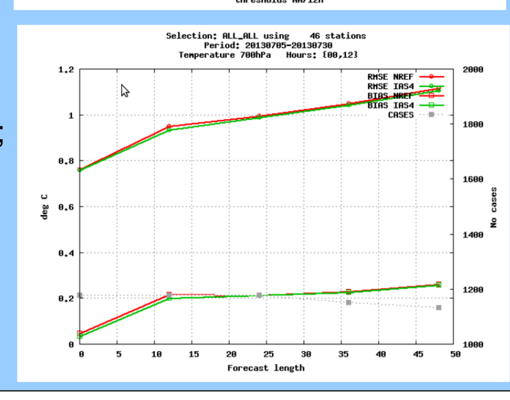






Experiments design:
AREF – Operational setting using conventional and ATOVS data;
NREF - Operational setting using the newly estimated bcor coefficients;
IASI4 - Run with IASI radiances using data from CO2 band and window channels;

The IASI data has slightly positive impact on temperature for a lower troposphere temperature (T700hPa and T925hPa) and wind speed in a middle troposphere (W300hPa-W700hPa). Slightly degradation was detected for wind speed in W925hPa. The main impact of IASI data was evaluated for precipitation. We found clear improvement in the forecast of high precipitating (above 3mm/12h) and slight degradation for the low precipitating (between 0.1 - 1mm/12h) areas.



References

Benacek, 2013. Assimilation of IASI data 3rd stay, report from LACE study stay in Budapest. Available from http://www.rclace.eu/?page=11; Harris BA, Kelly G. 2001. A satellite radiance-bias correction scheme for data assimilation. *Q. J. R. Meteorol. Soc.* **127**: 1453–1468; Lindskog M, Dahlbom M, Thorsteinsson S, Dahlgren P, Randriamampianina R, Bojarova J, 2012, ATOVS Processing and Usage in the HARMONIE Reference System, *HIRLAM Newsletter* ***59****: 33-43, available via* http://www.hirlam.org; Randriamampianina R**,** M Mile and H Schyberg, 2013, Assimilation and impact of IASI moisture channels, *MET report N 20/2013*, available on www.met.no; Randriamampianina R, Iversen T, and Storto A. 2011. Exploring the Assimilation of IASI Radiances in Forecasting Polar Lows. *Q. J. R. Meteorol. Soc.* 137: 1700–1715. DOI:10.1002/qj.838.