

# The assimilation of EUMETSAT reconstructed radiances for IASI data compression

Cristina Lupu<sup>1</sup>, Thomas August<sup>2</sup>, Dorothée Coppens<sup>2</sup>, Tim Hultberg<sup>2</sup> and Tony McNally<sup>1</sup>

<sup>1</sup> ECMWF, Reading, United Kingdom; <sup>2</sup> EUMETSAT, Darmstadt, Germany



Email: Cristina.Lupu@ecmwf.int

## 1 Introduction

Assume a situation where the EUMETSAT baseline dissemination system will only carry reconstructed-radiances data and the full Level-1 spectrum of conventional radiances will not be available in near real time. This study main aim is to establish if ECMWF (and by implication other NWP centres) could switch seamlessly to using the current EUMETSAT reconstructed radiance product with no modification of the data assimilation system.

The reconstructed radiances (RecRad) were generated locally at ECMWF using EUMETSAT PC compression basis (i.e., v1.04 and v2.01), applicable to all three MetOp IASI instruments.

The eigenvectors used for compression are characterized by: the noise normalisation matrix (e.g., v1.04 basis was derived using a diagonal noise-normalisation matrix applied to centred radiances; v2.01 basis was derived using a full noise-normalisation matrix and the radiances haven't been centred), the training set of spectra which consists of real L1C IASI spectra and the number of eigenvectors to retain (300 PC, regarded as an efficient encapsulation of the original data for transmission and assimilation).

Assimilation trials using reconstructed radiances equivalent of our IASI channels currently assimilated in ECMWF operations have been run, in an initial setup treating them similarly to conventional radiances (same observation error matrix and RTTOV). Their performance is presented here, in a depleted control system containing no active use of any infrared sounder radiances from polar orbiters.

## 2 Data and Experiments

Experiments for 1<sup>st</sup> Sept – 31<sup>st</sup> Dec 2020 and 1<sup>st</sup> Jan – 30 April 2021:

**CTRL(depleted):** similar to the ECMWF operational 4D-Var system, except for containing no active use of any IR sounder radiances from polar orbiters (3 IASI, 2 CrIS, 1 AIRS) and running at reduced horizontal resolution (TCo399, CY47R1.4)

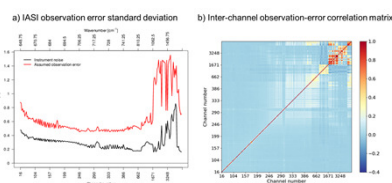
**Rad:** As CTRL, but with MetOp-A/B/C IASI radiances added. IASI radiances are assimilated in clear skies and above low or overcast cloud.

**RecRad v1.04:** As CTRL, but with MetOp-A/B/C IASI reconstructed radiances added (i.e., generated using EUMETSAT v1.04 eigenvectors basis).

**RecRad v2.01:** As CTRL, but with MetOp-A/B/C IASI reconstructed radiances added (i.e., generated using EUMETSAT v2.01 eigenvectors basis).

We used the RecRad equivalent of our current operational IASI channels with no modification of observation error matrix (Fig.1) and RTTOV.

**Fig. 1:** a) Assumed observation error standard deviation for IASI. b) Inter-channel observation error correlations derived using the departure-based diagnostic methods (Bormann et al., 2010).

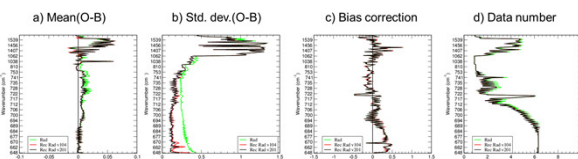


## 3 Impact on the data assimilation system

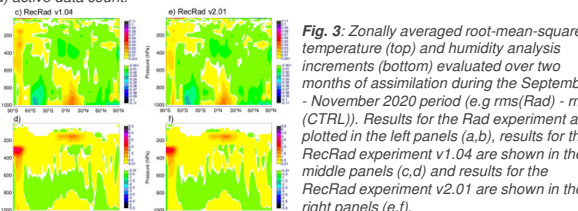
A comparison between the mean and standard deviation of the background departures for original and reconstructed IASI radiances was performed (Fig.2). Reconstructed radiances show small differences in the mean, but marked reduction in the standard deviations of the background departures; the biases are generally unchanged; comparable data volumes passes the cloud detection algorithm;

The RecRad and Rad experiments display very similar patterns of temperature and humidity analysis increments structures (Fig. 3), indicating that the assimilation of either radiances or reconstructed radiances results in similar adjustments of the background fields.

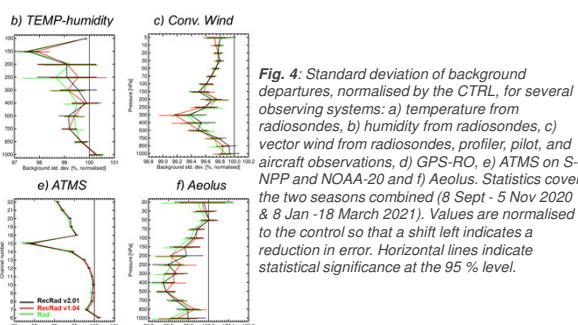
Standard deviation of background departures were reduced for many in situ and satellite observations for both Rad and RecRad experiments (Fig.4). RecRad assimilation system performance is similar to the Rad system.



**Fig. 2:** Global statistics of observation minus background (O-B) departure, bias correction and data numbers for IASI on MetOp-A/B/C radiances and reconstructed radiances (two seasons combined 8 September to 5 November 2020 and 8 January to 18 March 2021): a) Mean(O-B) after VarBC; b) standard deviation of O-B; c) mean bias correction; d) active data count.



**Fig. 3:** Zonally averaged root-mean-square temperature (top) and humidity analysis increments (bottom) evaluated over two months of assimilation during the September - November 2020 period (e.g rms(Rad) - rms(CTRL)). Results for the Rad experiment are plotted in the left panels (a,b), results for the RecRad experiment v1.04 are shown in the middle panels (c,d) and results for the RecRad experiment v2.01 are shown in the right panels (e,f).

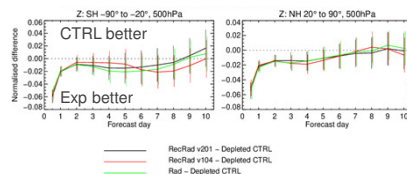


**Fig. 4:** Standard deviation of background departures, normalised by the CTRL, for several observing systems: a) temperature from radiosondes, b) humidity from radiosondes, c) vector wind from radiosondes, profiler, pilot, and aircraft observations, d) GPS-RO, e) ATMS on S-NPP and NOAA-20 and f) Aeolus. Statistics cover the two seasons combined (8 Sept - 5 Nov 2020 & 8 Jan - 18 March 2021). Values are normalised to the control so that a shift left indicates a reduction in error. Horizontal lines indicate statistical significance at the 95 % level.

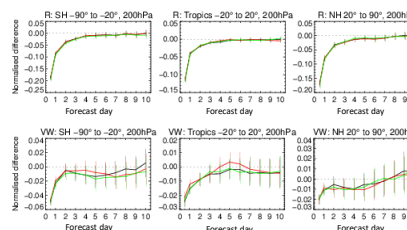
## 3 Forecast Impact

IASI Rad, as well as IASI RecRad provide statistically significant positive medium range forecast impact (Fig. 5)

Humidity skill translates to wind skill (4D-Var tracing, Fig. 6)



**Fig.5:** Normalised difference in RMSE of 500 hPa geopotential for Southern Hemisphere (left) and Northern Hemisphere (right). Negative values show an improvement from adding the IASI Rad (green) and IASI RecRad (v1.04 red and v2.01 black). Confidence range 95%. Each experiment has been verified against the operational analysis, with a total of 248 samples.



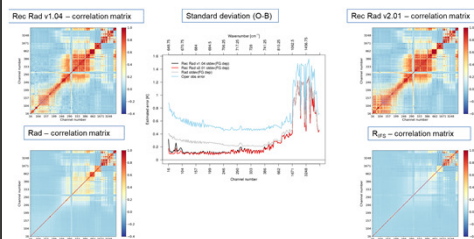
**Fig.6:** As above, but for humidity (top) and wind (bottom) at 200hPa over Southern Hemisphere (left), Tropics(middle) and Northern Hemisphere (right).

## 5 Conclusions

- The results obtained from the assimilation of IASI reconstructed radiances in a depleted observing system are very encouraging in terms of analysis and forecast impacts.
- They show the possibility of an alternative route to radiance assimilation for the exploitation of data from high spectral resolution infrared sounders in NWP.
- Preparatory and research work will continue to consolidate the understanding of using the reconstructed radiances.

## 6 Next steps

- Run full observing system experiments to investigate if conventional IASI radiances can be replaced by reconstructed radiances without system retuning and without forecast performance loss.
- Evaluate the sensitivity to "on-the-fly" changes to the eigenvector basis. While such updates are expected to be infrequent, they may be necessary to take account of instrument changes or significant changes in the atmosphere.



**Fig.7:** Observation error covariance diagnosed from innovation statistics. The reconstructed radiance process reduces the noise in the observations but introduces significant inter-channel correlations.

## References

- Bormann N, Bonavita M, Dragani R, Eresmaa R, Matricardi M, McNally A. 2016. Enhancing the impact of IASI observations through an updated observation-error covariance matrix. Q. J. R. Meteorol. Soc. 142: 1767 – 1780. <https://dx.doi.org/10.1002/qj.2774>.
- Hultberg T and August T, 2012. Hyperspectral retrieval and subspaces, ITSC-18 2012, [https://cimss.ssec.wisc.edu/itwg/itsc/itsc18/program/files/links/7.11\\_Hultberg\\_po.pdf](https://cimss.ssec.wisc.edu/itwg/itsc/itsc18/program/files/links/7.11_Hultberg_po.pdf)
- IASI Level 2 Product Generation Specification EPS.SYS.SPE.990013 <https://www.eumetsat.int/website/home/Data/TechnicalDocuments/index.html> [https://cimss.ssec.wisc.edu/itwg/itsc/itsc18/program/files/links/7.11\\_Hultberg\\_po.pdf](https://cimss.ssec.wisc.edu/itwg/itsc/itsc18/program/files/links/7.11_Hultberg_po.pdf)

## Acknowledgements:

The project is funded by EUMETSAT Contract No. EUM/RSP/SOW/19/112770