The direct assimilation in the ECMWF 4D-Var system of principal component scores derived from shortwave IASI spectra

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(with special thanks to Niels Bormann)

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- **We are investigating the direct assimilation of Principal Component (PC) scores of IASI radiances. Why are we doing that?**

1) Drastically reduce the number of “channels” used in the assimilation of high resolution sounder data (i.e. dimensionality reduction associated to PC analysis).

2) Mitigate the instrument noise by exploiting the noise reduction property of PC analysis.

3) We may be forced to use PC data, as future pressure on communications bandwidth may result in only PC data being disseminated to users.

- **Initial PC score assimilation trials have been carried out using PCs derived from the (noisy) short wave radiances in IASI band 3 (2000 cm^{-1} to 2760 cm^{-1}).**

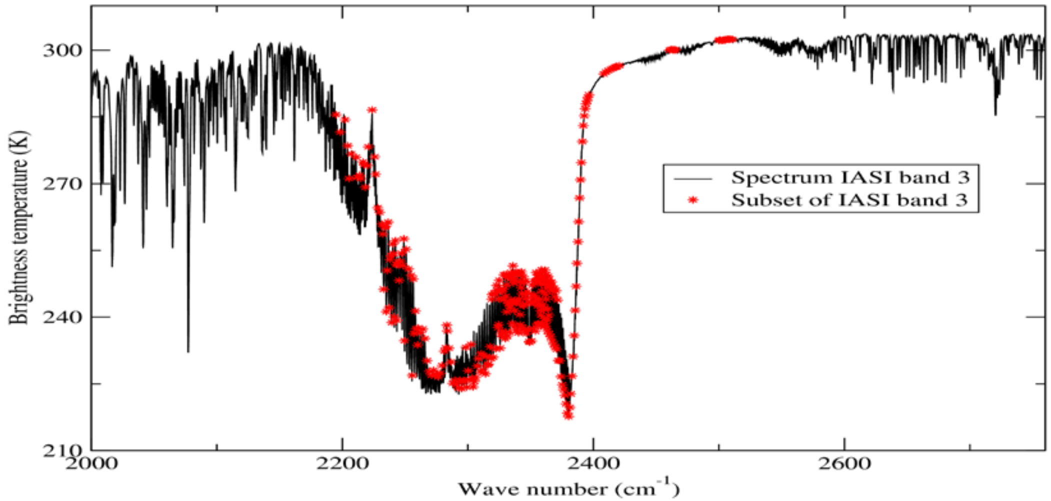
A subset of temperature sounding channels in IASI band 3 has been selected based on the following criteria:

1) Select channels affected only by CO_2 and N_2O whose concentrations are close to constant in space and time.

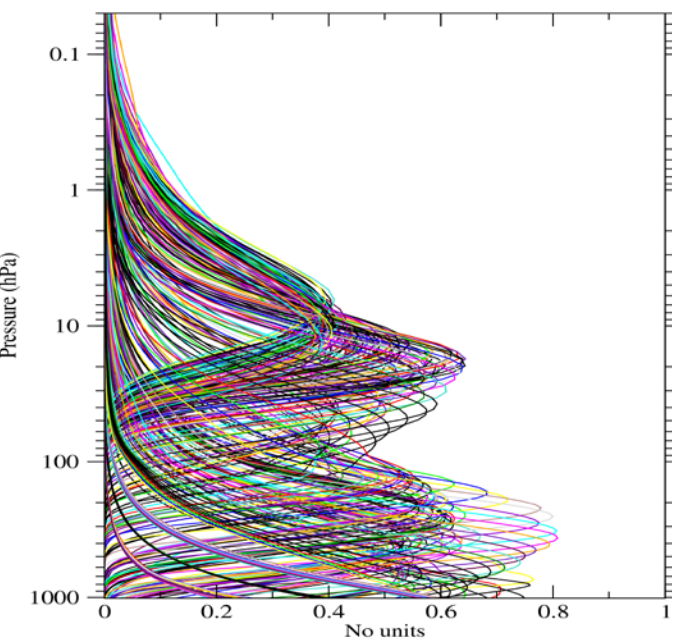
2) Select channels that have sharper weighting functions (i.e. channels located between absorption lines and channels located in the head of the R-branch of the fundamental v3 CO_2 band).

3) To cover the upper regions of the atmosphere, supplement channels between lines with channels located on top of lines.

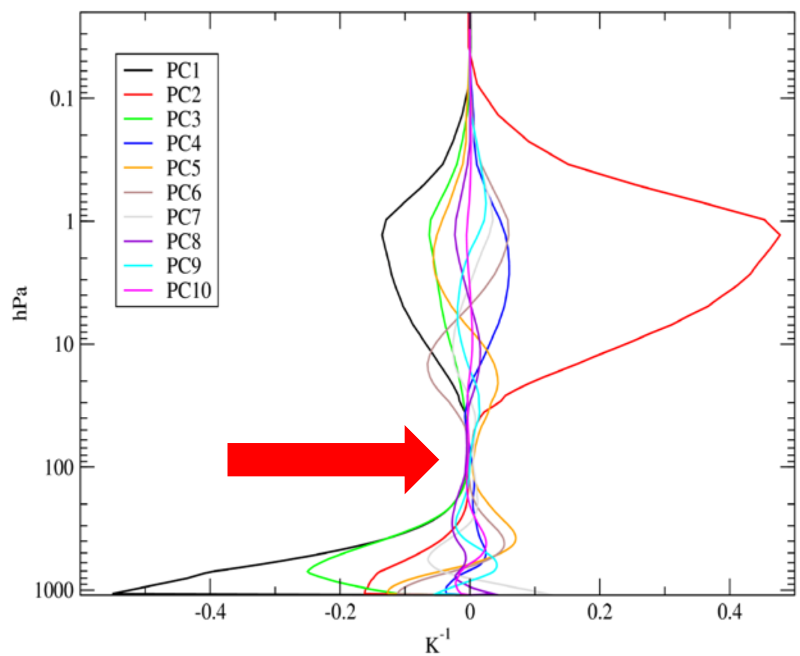
Selected short wave channels



Weighting functions of selected short wave channels



Temperature Jacobian of first 10 Principal Components

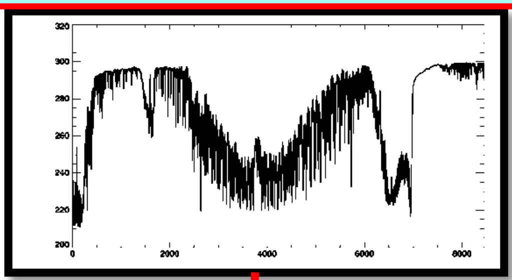


Skin temperature Jacobian of PCs

-9.499
-1.991
-5.197
-0.030
0.206
-0.011
0.357
-0.125
-0.183
-0.095

PC analysis system design

Observed IASI spectrum



Cloud screening
(Matricardi and McNally 2010)

Project observed spectrum on PC_RTTOV Eigenvector basis

Y^{PC}_{OBS}

Model background X_B
(T,Q,O3)

PC_RTTOV
(Matricardi 2010)

Y^{PC}_{B}

4DVAR
(PCRTTOV-AD)
(PCRTTOV-TL)

X_A

The cost function to be minimized in the 4D-Var PC assimilation system is essentially:

$$J(X) = [X - X_B]^T B^{-1} [X - X_B] + [Y^{PC}_{OBS} - Y^{PC}(X)]^T R^{-1} [Y^{PC}_{OBS} - Y^{PC}(X)]$$

- X → is the atmospheric state
- X_B → is the background atmospheric state
- Y^{PC}_{OBS} → are the observations in PC space
- $Y^{PC}(X)$ → are the PC_RTTOV model equivalents of the Y^{PC}_{OBS}

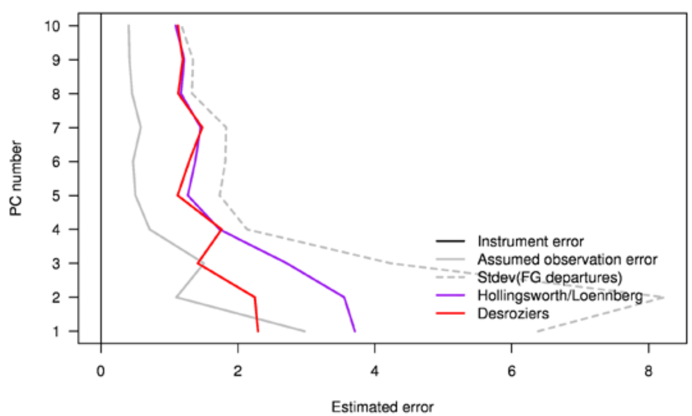
- **The background error covariance *B* is identical to that used in the ECMWF operational assimilation system.**
- **The error covariance *R* has been finely tuned starting from a basic specification of the observation error based on the standard deviation of the O-B PC departures.**

■ Experiment design

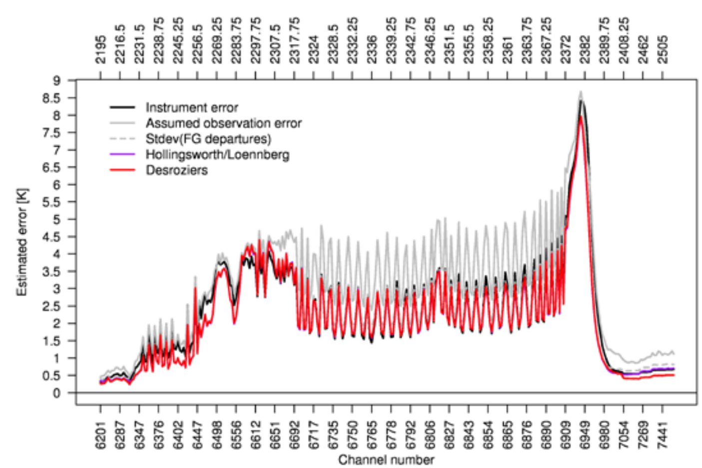
1) Conventional data baseline (NOSAT)
2) NOSAT plus IASI band 1 operational radiances (B1)
3) NOSAT plus IASI band 3 radiances (B3)
4) NOSAT plus IASI band 3 principal components (B3_PC)

■ **To avoid solar contamination and non-LTE effects in the short wave, all experiments (cycle 36R1 – T511) have been carried out in <u>night-time conditions</u> from 1 June 2010 to 15 July 2010 and from 1 December 2010 to 15 January 2011.**

B3_PC : PC observation error



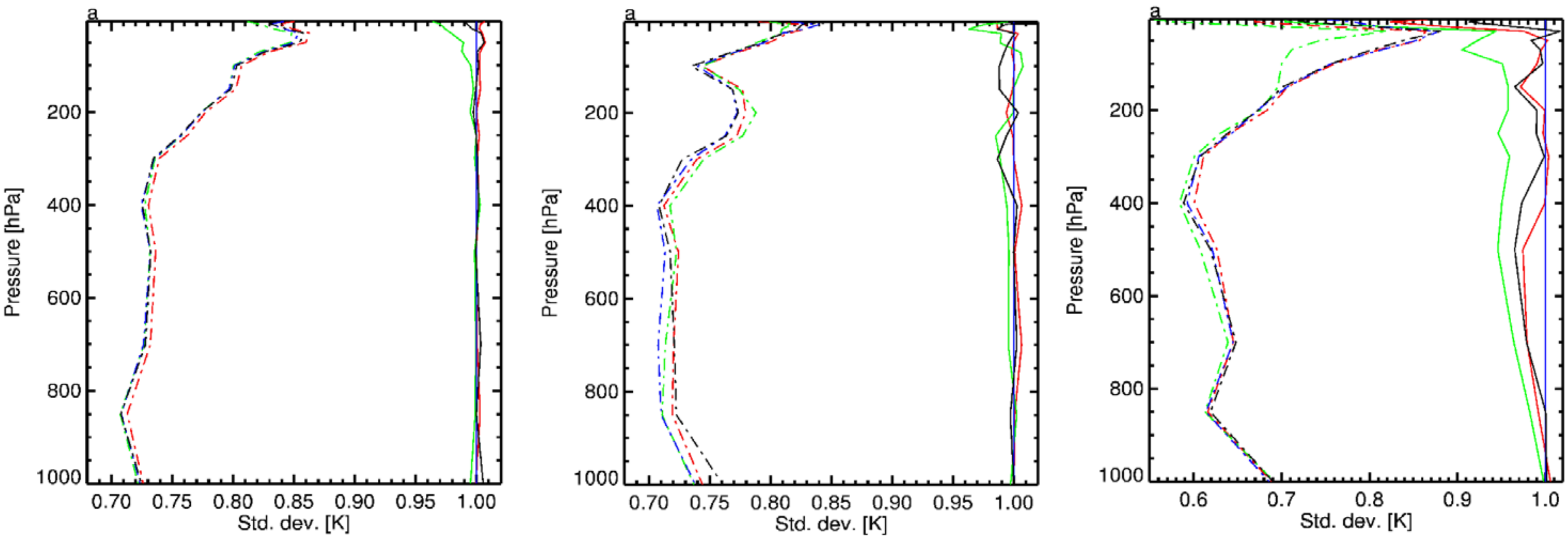
B3: Radiance Observation error



Verification against radiosondes of background (solid lines) and analysis (dot-dashed) temperature profiles.

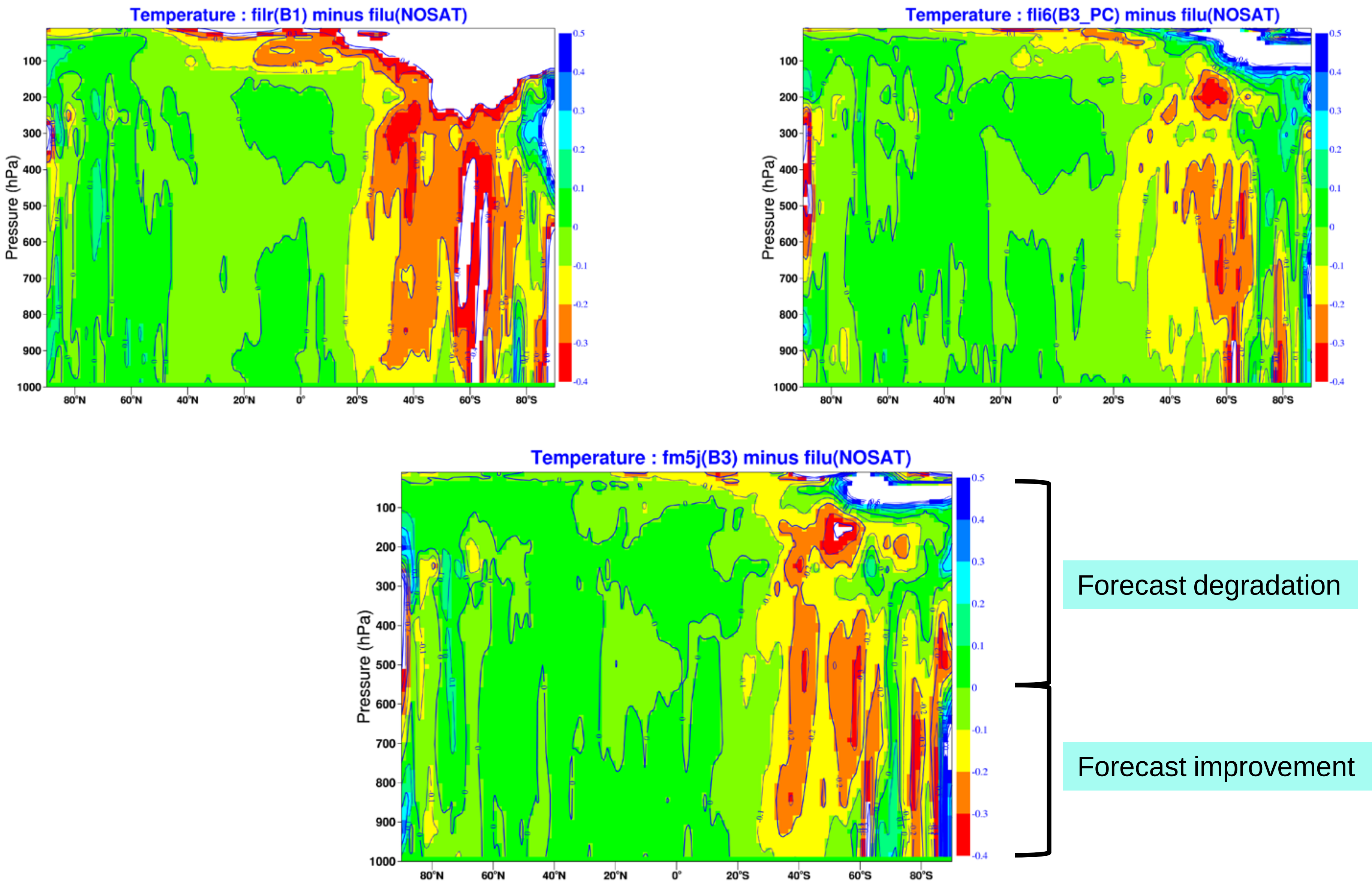
From 00Z 15-Jun-2010 to 12Z 15-July-2010

Northern Hemisphere | Tropics | Southern Hemisphere



B3_PC (Desrozier noise) — black
B3 — red
B1 — green
NOSAT — blue

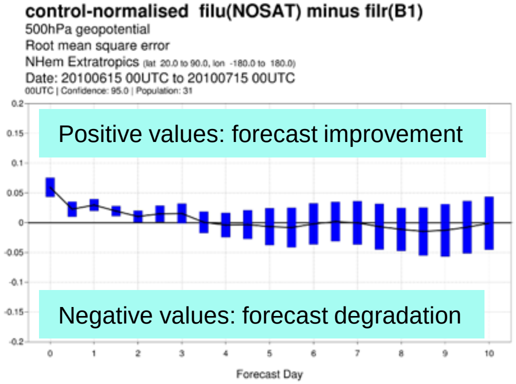
Cross section of the root-mean-square forecast error difference in geopotential for 120 hour forecasts. The forecasts are verified versus the operational analysis and are for the period 15 June 2010 – 15 July 2010.

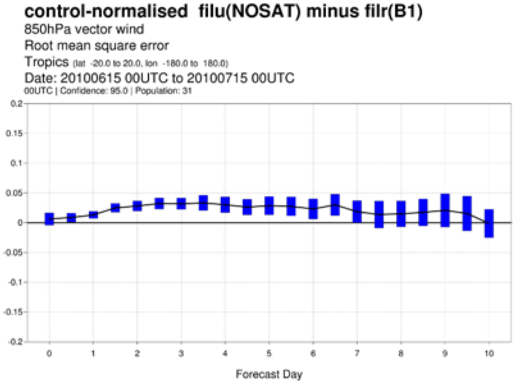


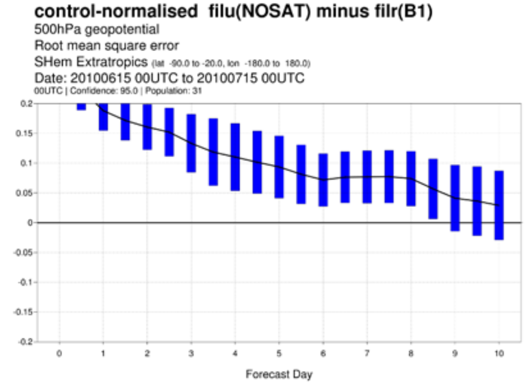
Normalized root-mean-square forecast error difference for the period 15 June 2010 – 15 July 2010
The forecasts are verified versus the operational analysis.

Northern Hemisphere 500 hPa Geopotential	Tropics 850 hPa Vector wind	Southern Hemisphere 500 hPa Geopotential

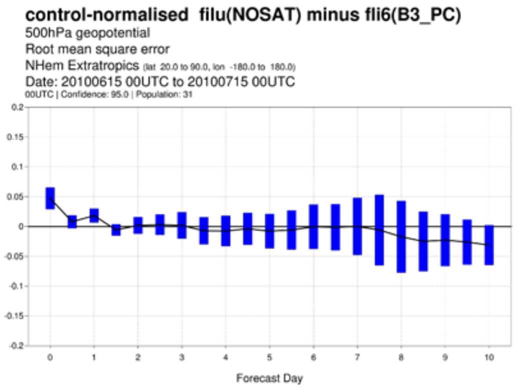
B1

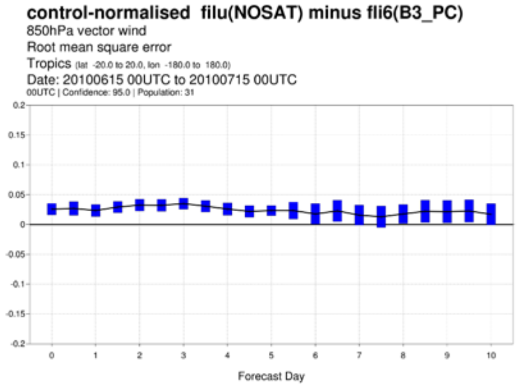


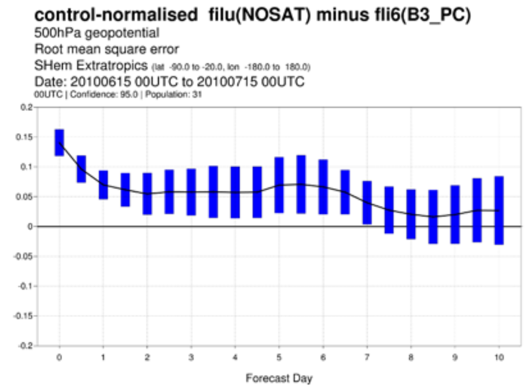




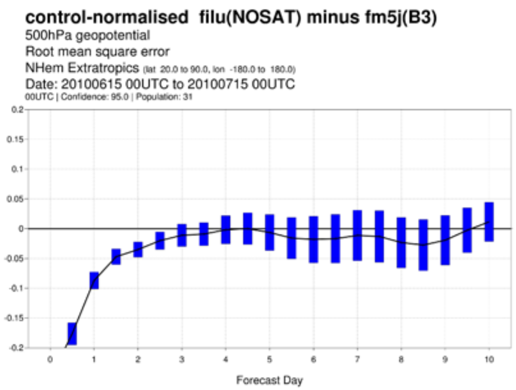
B3_PC

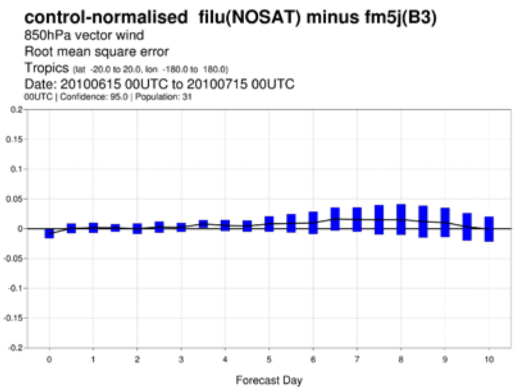


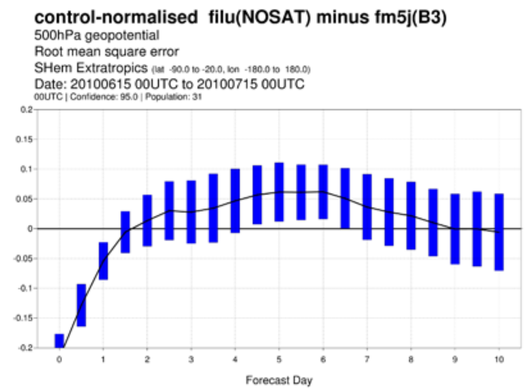




B3







Conclusions

- At ECMWF we have developed a Principal Component score 4DVar assimilation system. The PC score assimilation system has been implemented in the ECMWF Integrated Forecasting System and has undergone extensive technical and scientific trials.

- Results from assimilation experiments show that the direct assimilation of PC scores can improve the results produced by the assimilation of equivalent radiances at a significantly reduced computational cost.

- In the next phase, we will extend the assimilation of PC scores to IASI band 1 (this task is ongoing) and band 2 and we will investigate the options for the treatment of cloudy affected PC scores.