The direct assimilation of principal components of IASI spectra in the ECMWF 4D-Var

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(with special thanks to Niels Bormann)

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Motivations for PC assimilation:

1) Exploit the dimension reduction property of Principal Component Analysis (PCA). This will allow, for instance, the more efficient use of larger portions of the IASI spectrum.

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

3) Pressure on communications bandwidth may result in only PC data being disseminated to users.

Objectives:

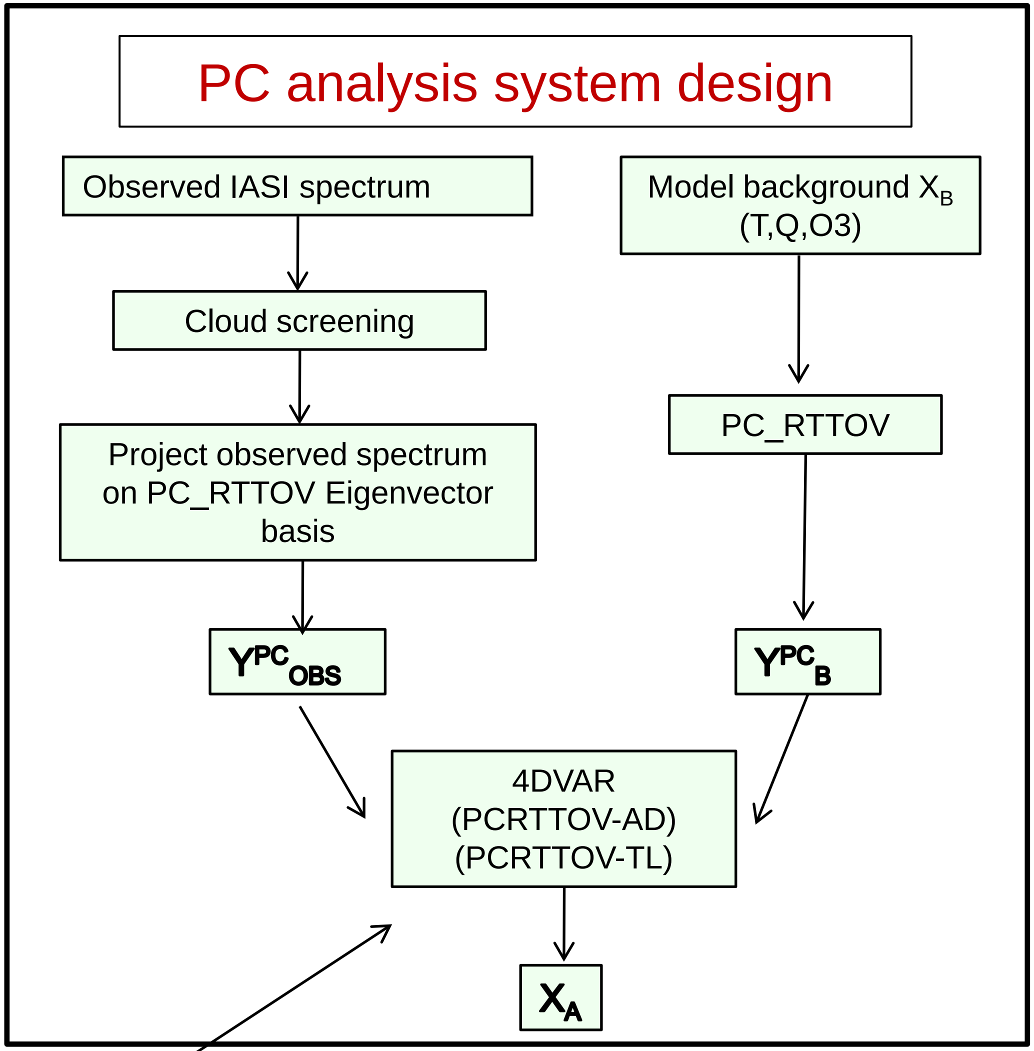
1) Develop a prototype 4D-Var assimilation system based on PCA.

2) Demonstrate the correct functionality of the PC based assimilation system.

3) Take the prototype system forward to a state where it can be considered as an option for the safe and efficient operational exploitation of high resolution sounder data.

Methods:

1) Develop a PC based fast model
2) Develop a pixel based cloud detection scheme
3) Modify the IFS to allow the ingestion of PC data
4) Develop a PC based quality control
5) Monitor the proper functionality of VARBC in PC space
6) Finely tune the number of PCs to be used in the assimilation
7) Finely tune the observation error

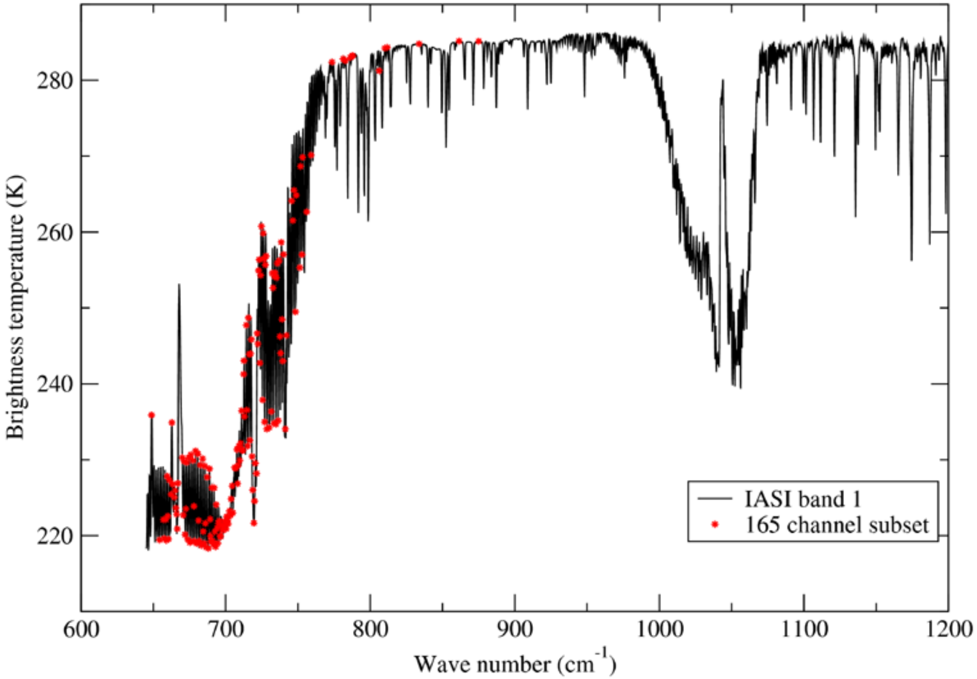


$$J(X)= [X-X_B]^T B^{-1} [X-X_B] + [Y^{PC}_{OBS} - Y^{PC}(X)]^T O^{-1} [Y^{PC}_{OBS} - Y^{PC}(X)]$$

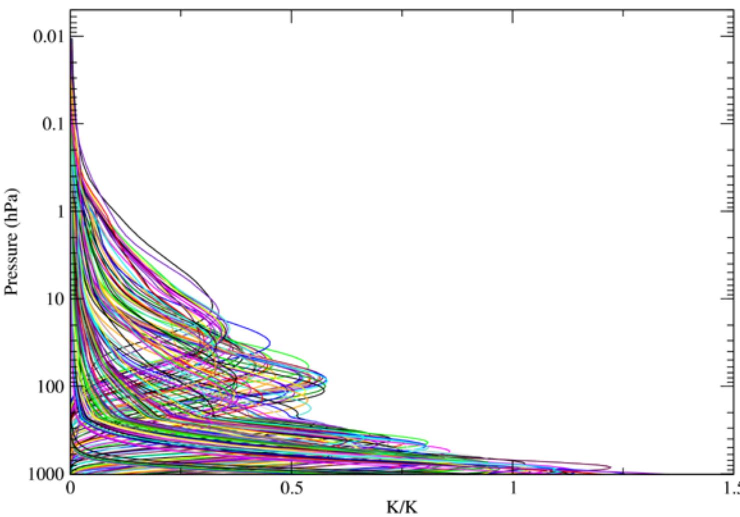
Assimilation of long wave PC scores

- Long wave PC score assimilation trials have been carried out using PC scores derived from 165 long wave radiances in IASI band 1 (645 cm^{-1} to 1200 cm^{-1}).

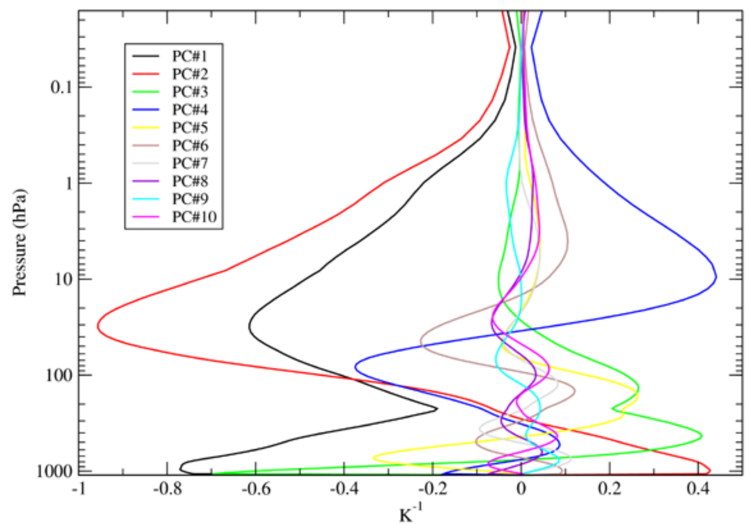
Selected long wave channels



Temperature Jacobians of selected long wave channels



Temperature Jacobians of first 10 Principal Components



Skin temperature Jacobian of PCs

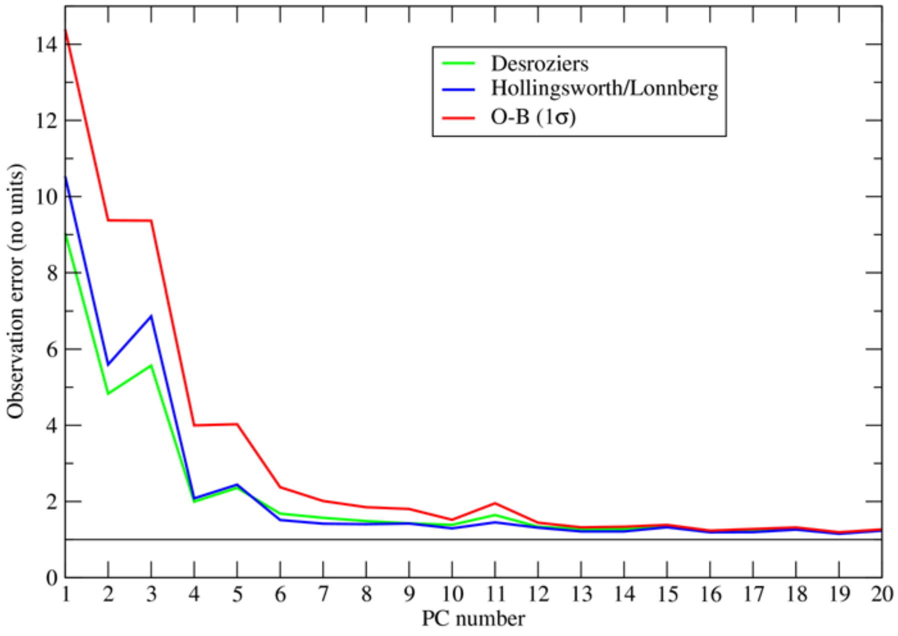
-9.181
5.459
-11.783
-2.428
4.281
-0.896
-0.797
0.487
-1.357
0.565

Error tuning: Desroziers and Hollingsworth/Lönnberg methods have been used to separate the contribution of the observation and background error.

Hollingswort/Lönnberg assumptions: background errors are spatially uncorrelated, observation errors are spatially uncorrelated, and, background and observation errors are uncorrelated.

Desroziers assumptions: background and observation errors are uncorrelated, the weights that are assigned to the observations in the analysis agree with the true background and observation error covariances.

Error tuning (data courtesy of Niels Bormann)



In the assimilation testing we have used the Desroziers error values because they give a marginal improvement over the Hollingsworth/Lönnberg error estimates.

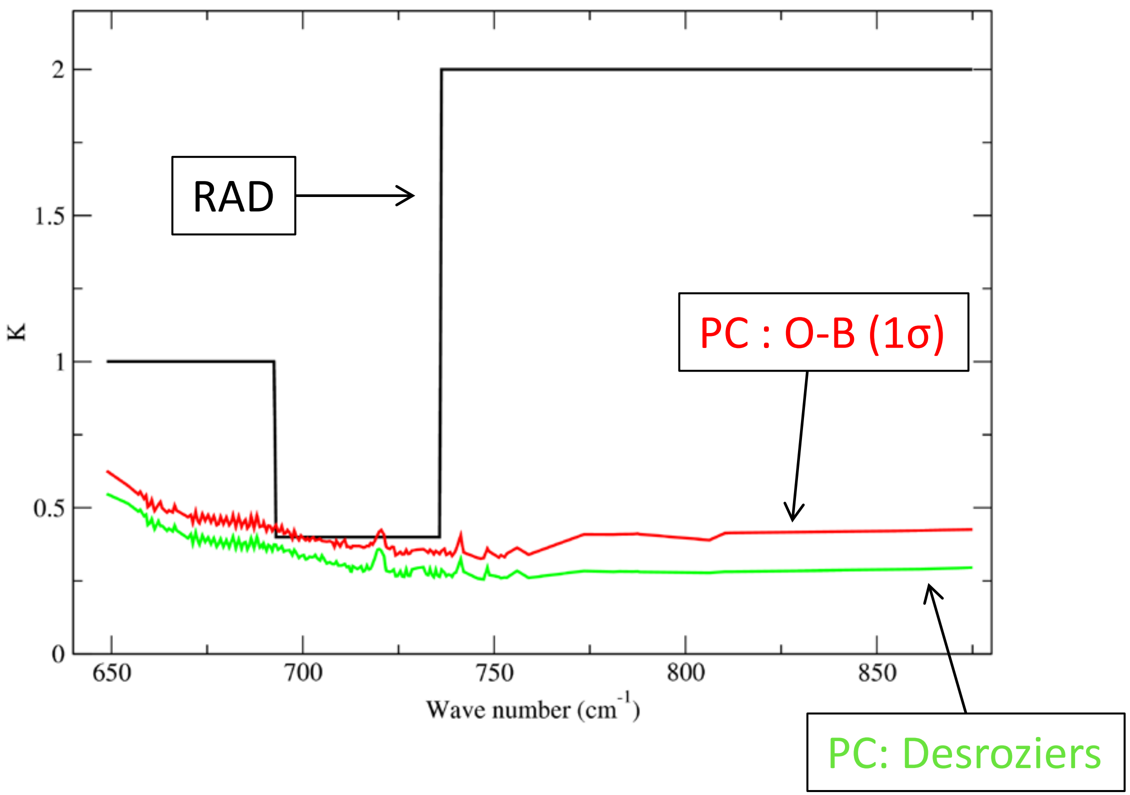
Assimilation of long wave PC scores: experiment design

To quantify the performance of the long-wave PC score assimilation system we have designed a set of 4D-Var assimilation experiments.

Experiment 1 (BASE)	Baseline: all operational observations (satellite and conventional) but do not assimilate IASI radiances.
Experiment 2 (RAD)	Control: identical to BASE but additionally assimilates 165 long wave IASI radiances (RAD)
Experiment 3 (PC)	Identical to base BASE but additionally assimilates 20 IASI PC scores derived from the165 radiances used in the RAD experiment

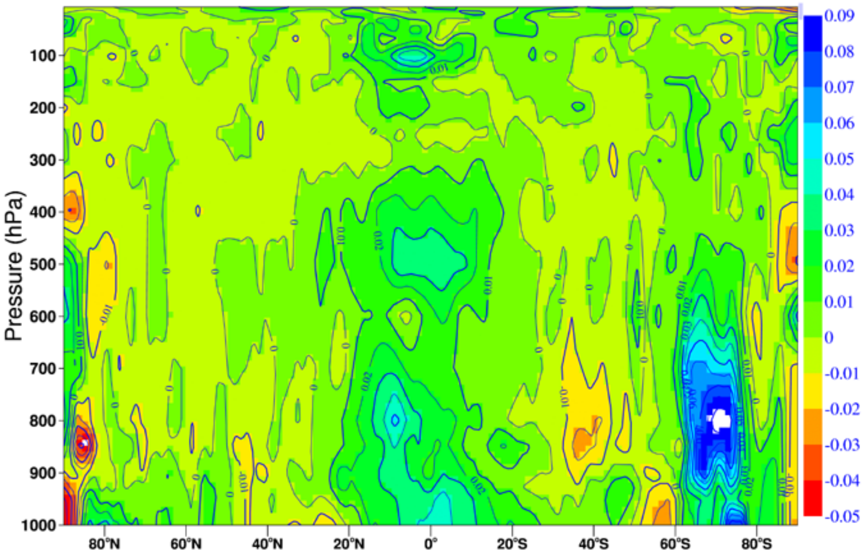
Experiments (cycle 36R1 – T511) have been carried out for the period 1 June 2010-15 July 2010.

Mapping of PC score error covariances into radiance error covariances (diagonal elements)

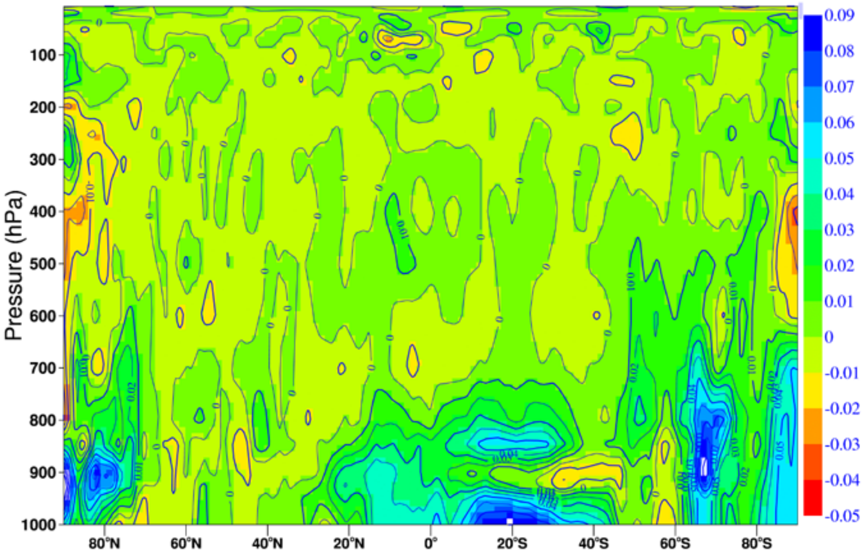


Temperature analysis increments

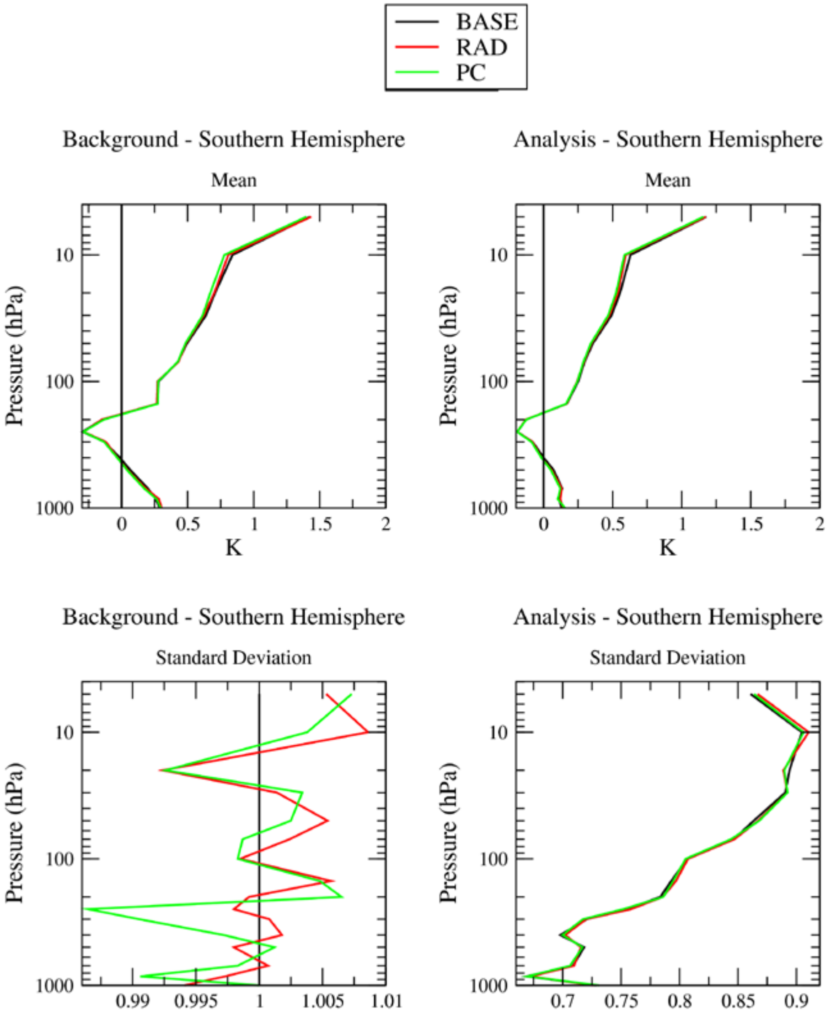
RAD experiment



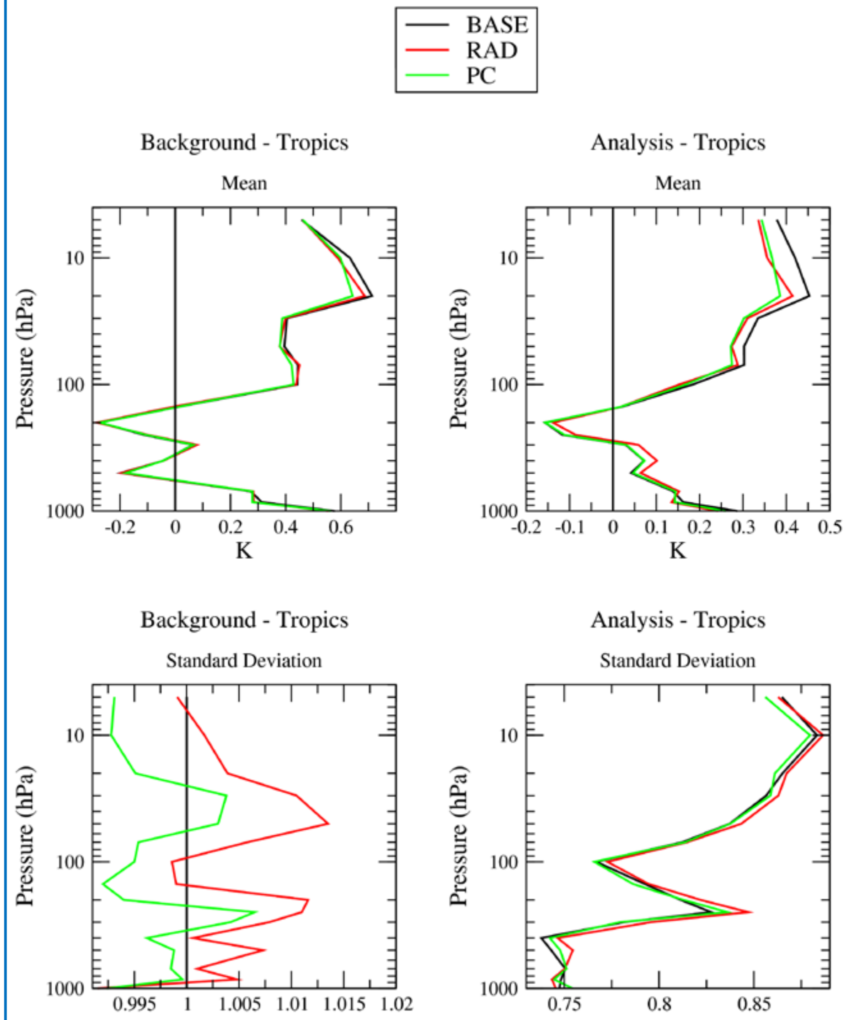
PC experiment



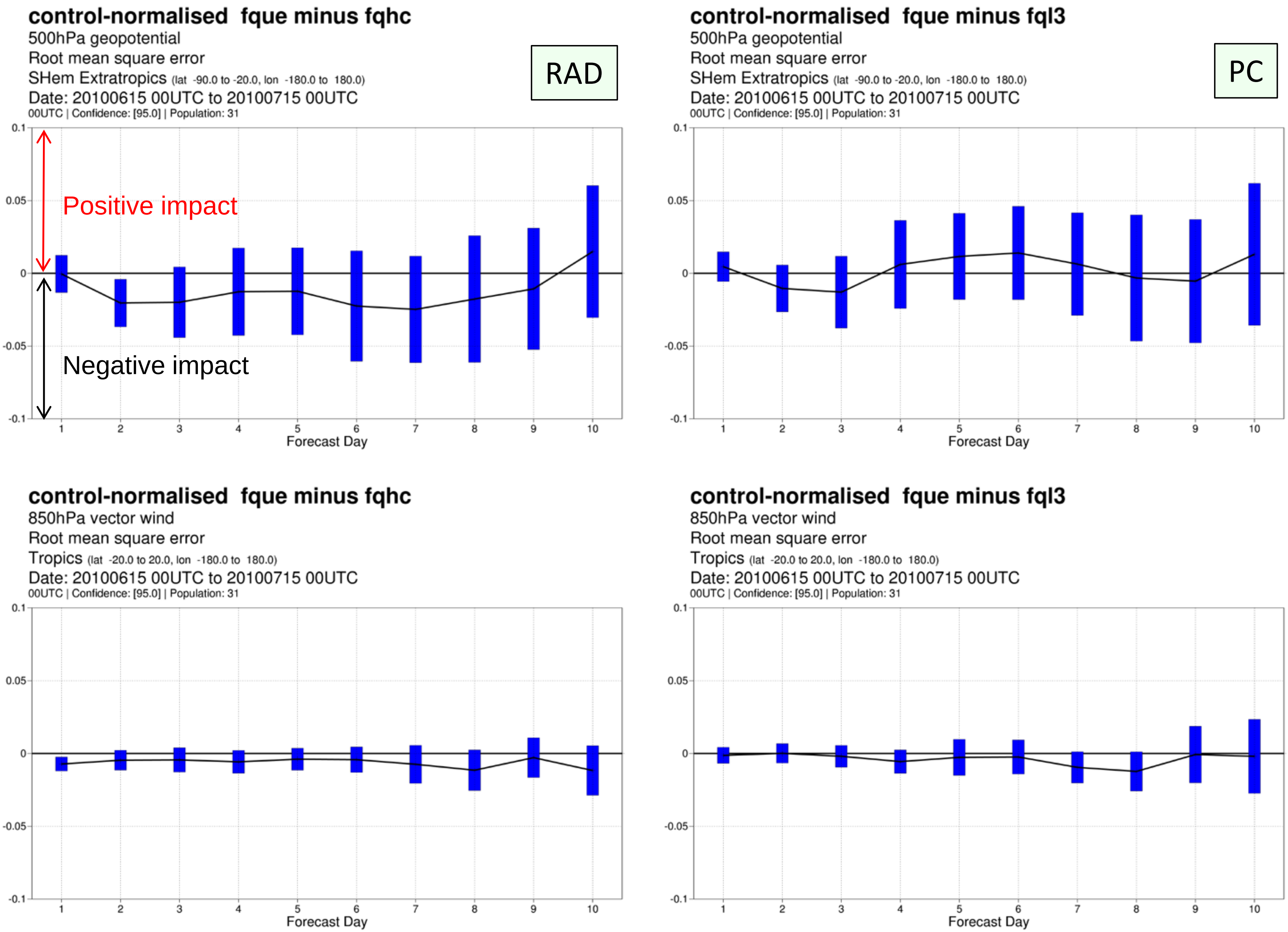
Fit to radiosonde temperature data. Southern Hemisphere



Fit to radiosonde temperature data. Tropics



Forecast scores

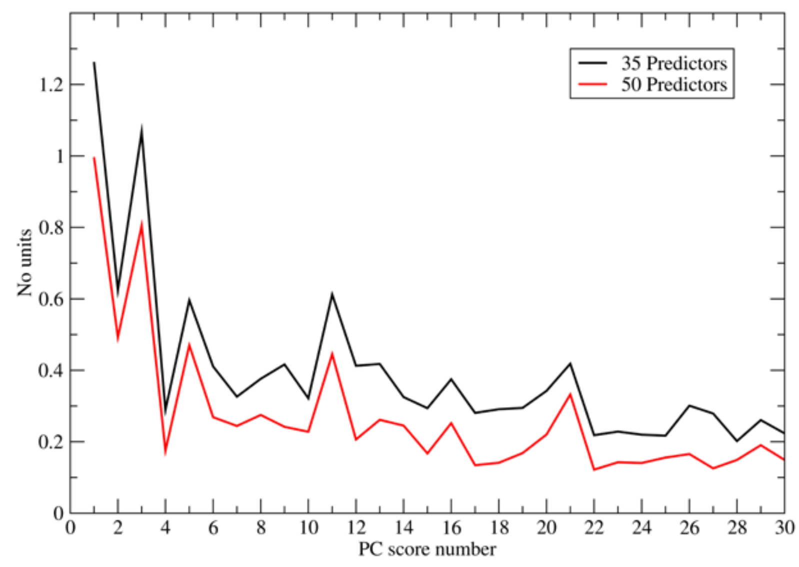


Computational efficiency of the data assimilation

- Performance tests indicate that the 4D-Var minimization requires 25% less computer resources (elapsed CPU time) when 20 PC scores are used compared to the system that uses 165 IASI radiances.

- This figure represents a significant saving inside the time critical processing path for NWP centres, but could potentially be improved even further by reducing (without significant loss of accuracy) the number of predictors used in the PC_RTTOV simulations.

Standard deviation of the difference between exact (i.e. line-by-line) and simulated PC scores for the 5190 profile training set.



Conclusions

- The ECMWF 4DVar assimilation system has been modified to allow the direct assimilation of PC scores derived from spectra measured by IASI.

- Testing of a prototype system where 165 IASI long wave radiances are replaced by just 20 PC scores shows significant computational savings with no detectable loss of skill in the resulting analyses or forecasts.

- A future step is to consider the extraction of information from the dedicated IASI water vapour and ozone bands towards the exploitation of the full IASI spectrum.