The direct assimilation of principal components of IASI band 1 and band 2 full spectra in the ECMWF 4D-Var

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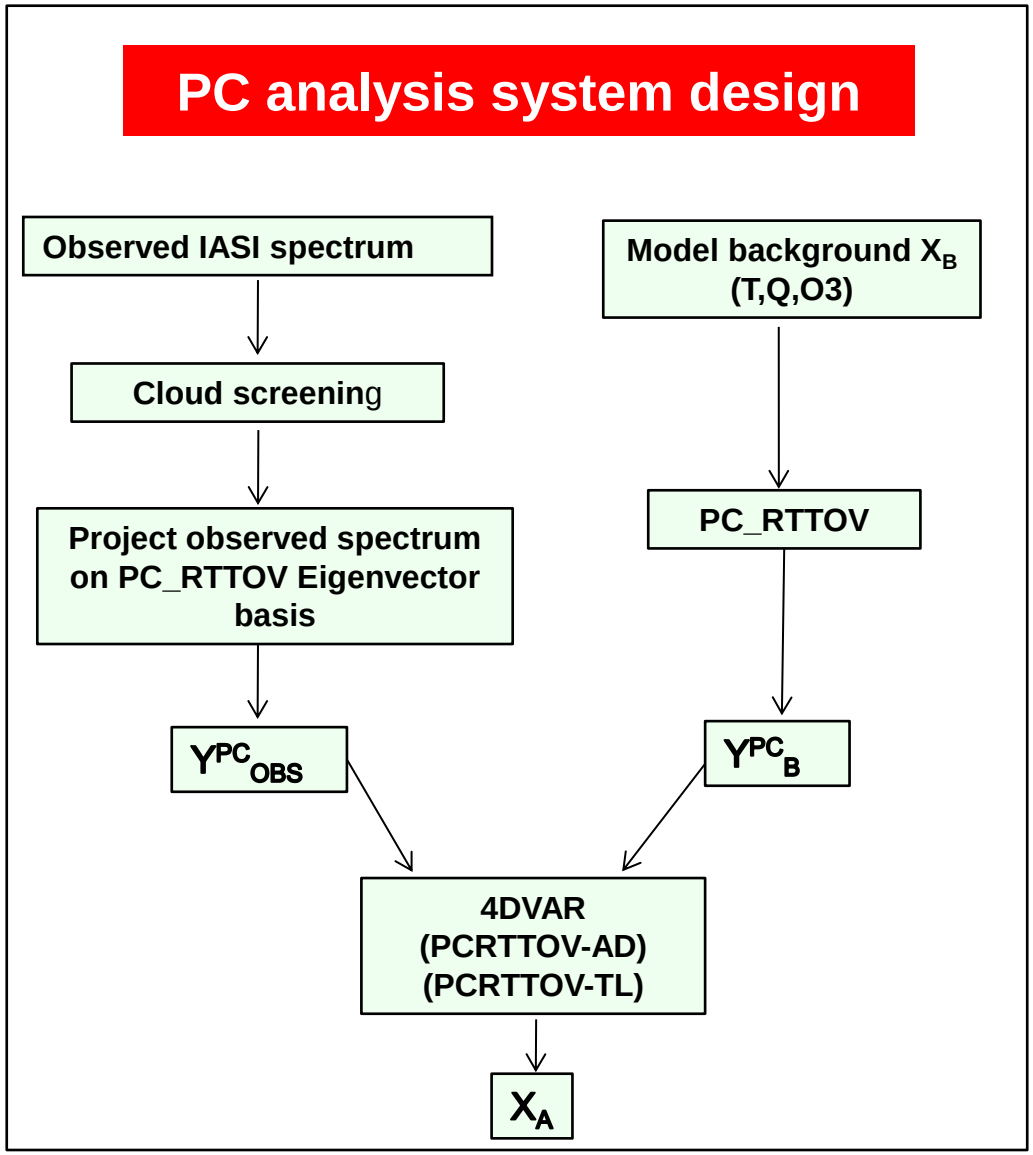
Motivations for developing a PC based assimilation system:

1) Assimilate directly into the 4D-Var system PC scores disseminated by data providers

2) Exploit the full information content of hyper-spectral sounders (e.g. IASI)

We currentlu use only 2% of the available IASI channels

PC analysis system design



In 4DVAR we minimise the cost function J(X)

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

Evolution of the 4D-Var PC score assimilation system

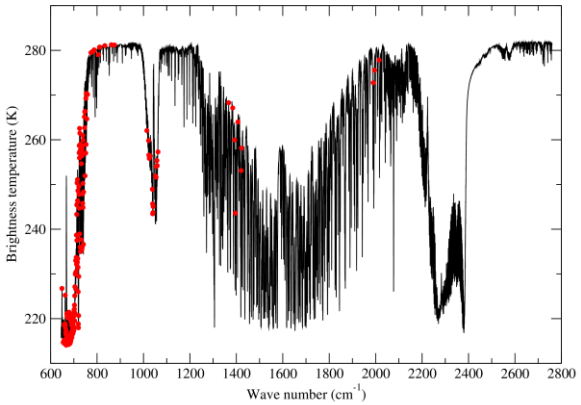
1) ***Prototype system (only conventional and IASI observations):*** assimilation of PC scores derived from channels in the short wave band of IASI

2) ***Full data assimilation system (all operational observations - satellite and conventional):*** assimilation of PC scores derived from the 191 long wave IASI channels used in operations (Matricardi and McNally 2013)

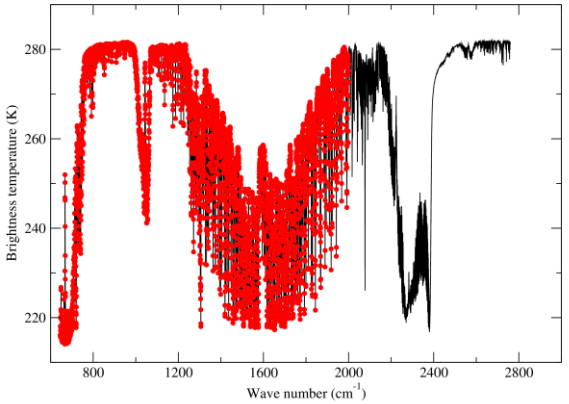
3) Full data assimilation system focused on maximising the spectral information of IASI using the full set of channels in IASI band 1 and 2

The 4D-Var assimilation of PC scores derived from 5421 IASI channels

The 191 operational IASI channels (2.3 % of the total number)

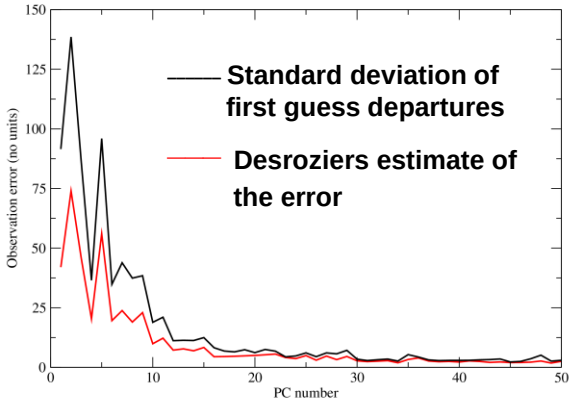


The full number (5421) of IASI channels in Band 1 and Band 2 (64% of the total number)



In the assimilation the 5421 IASI channels are represented by 400 PC scores.

In both systems, observation errors are specified using full covariance error matrices derived utilising Desroziers's error diagnostics.



Assimilation of PC scores derived from 5421 IASI channels

To asses the performance of the PC based assimilation system we have devised the following experiment design:

1) **BASE**: we use all operational observations (satellite and conventional) with the exception of IASI data.

2) **RAD** : identical to BASE but additionally assimilates radiances from the 191 channels used in the operational 4D-Var.

3) **PC_B1_B2** : identical to BASE but additionally assimilates 400 PC scores derived from the radiances in 5421 IASI channels.

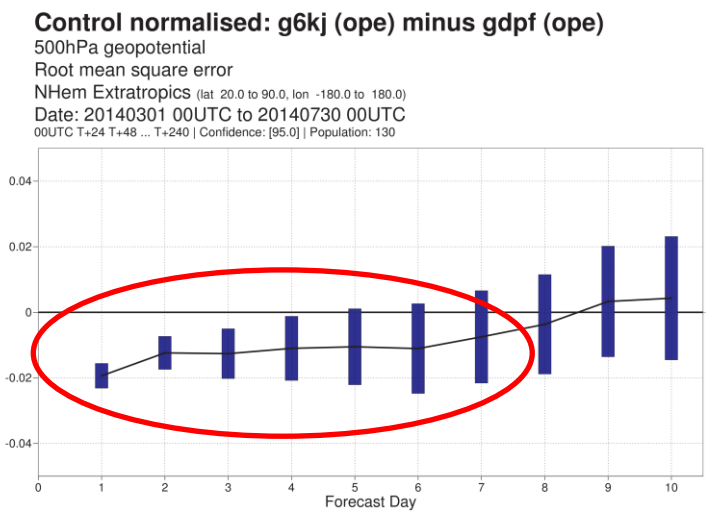
Experiments (cycle 40R2 – T511- 137 L) are currently covering the period 20 February 2014 - 28 May 2014.

NOTE: in all experiment we assimilate only cloud-free scenes

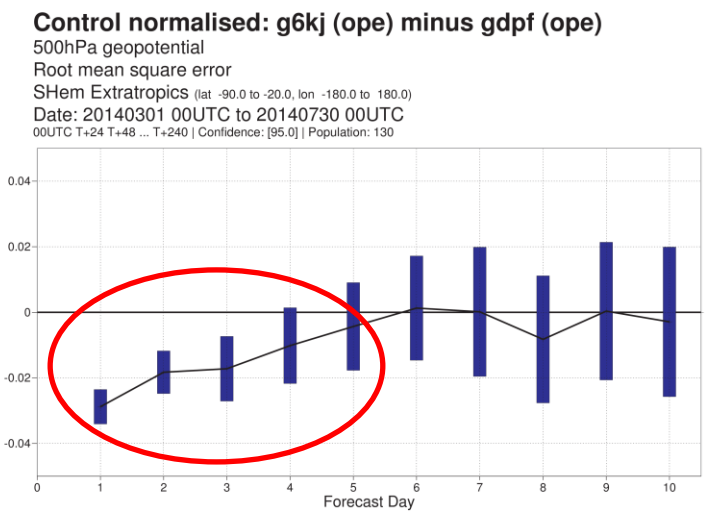
Clouds in PC space

Dealing with clouds in PC space is technically demanding within the context of a 4D-Var assimilation scheme and it would require an effort beyond the resources allocated to the study of PC assimilation in NWP.

The use of PC data is currently restricted to fully clear spectra and this is an important limitation to the use of the PC system in an operational environment

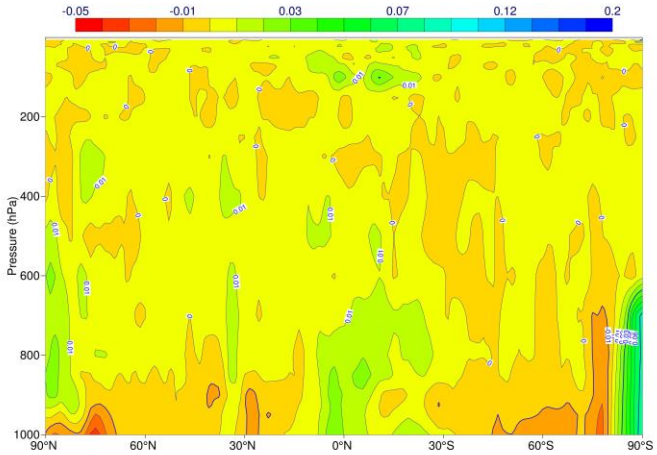


Restriction to clear spectra reduces the skill of the forecast

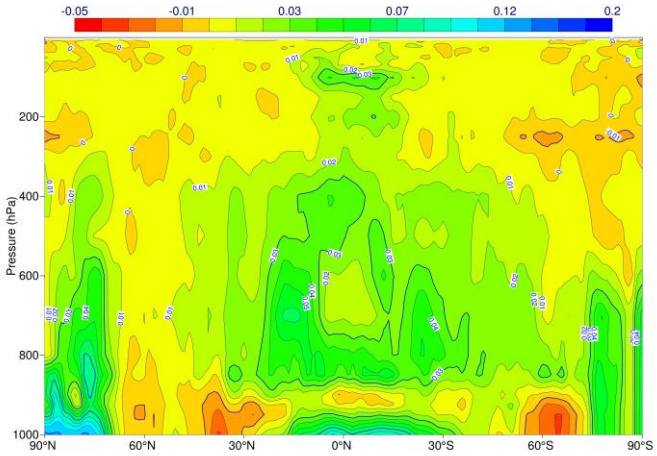


Difference between zonally averaged root-mean-square temperature analysis increments

RAD-BASE

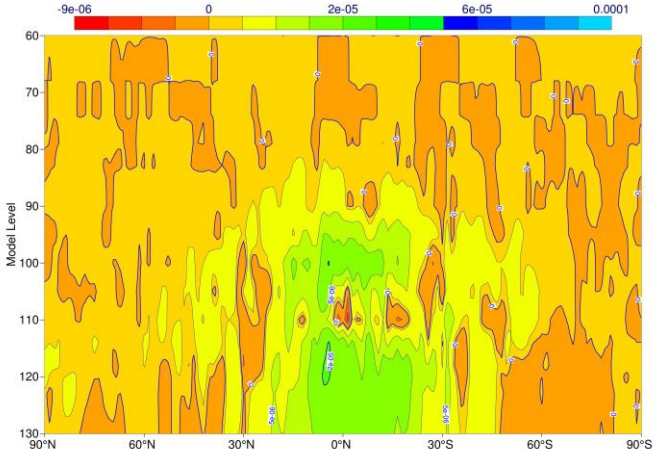


PC_B1_B2-BASE

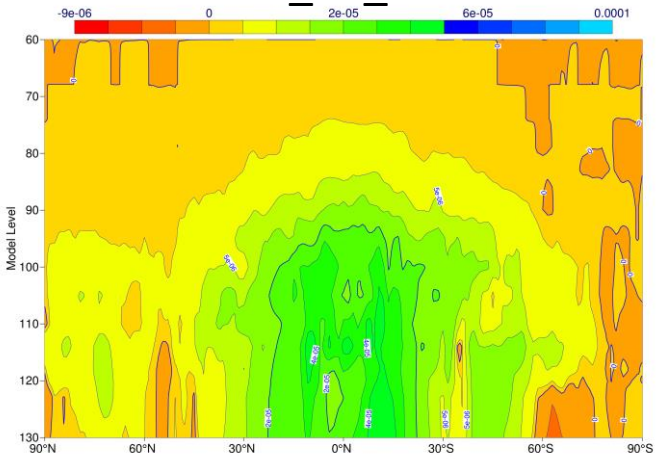


Difference between zonally averaged root-mean-square humidity analysis increments

RAD-BASE

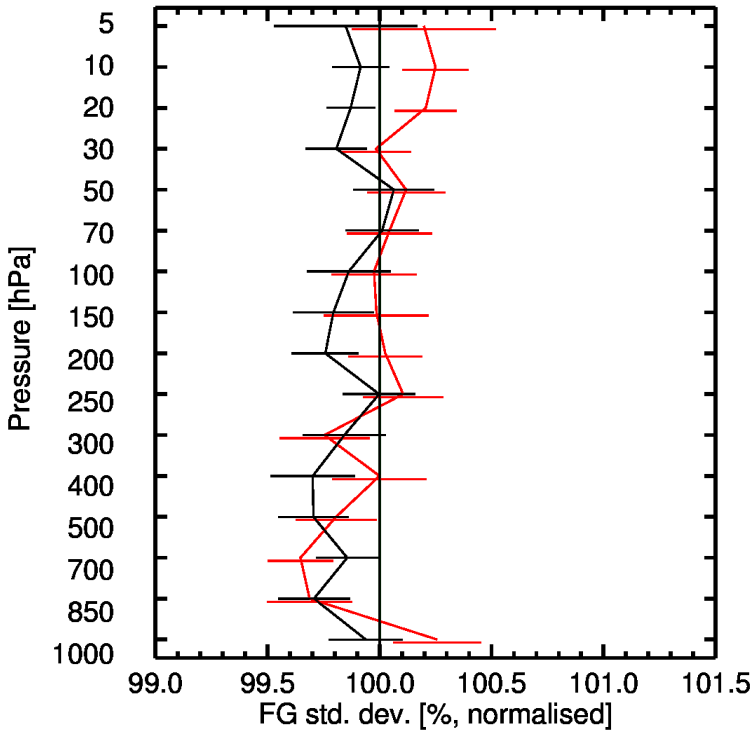


PC_B1_B2-BASE



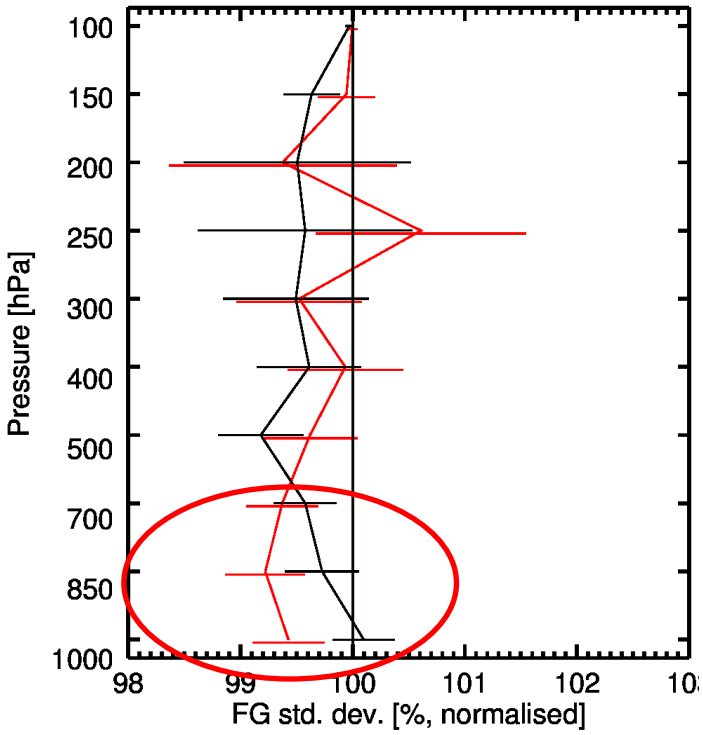
The 4D-Var assimilation of PC scores derived from 5421 IASI channels

Verification against global radiosondes: temperature



Values less than 100% indicate a reduction of the standard reduction compared to the BASE system

Verification against global radiosondes: humidity

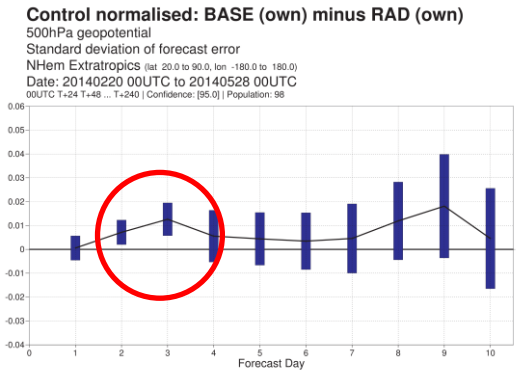


RAD

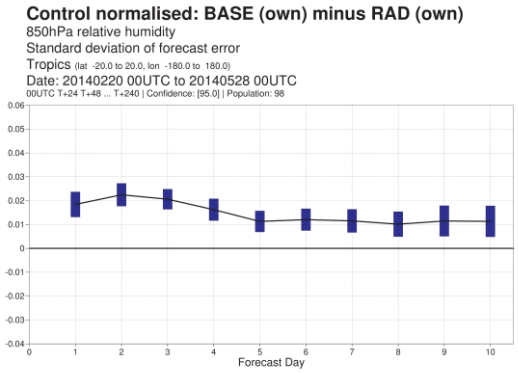
PC_B1_B2

Forecast rms errors

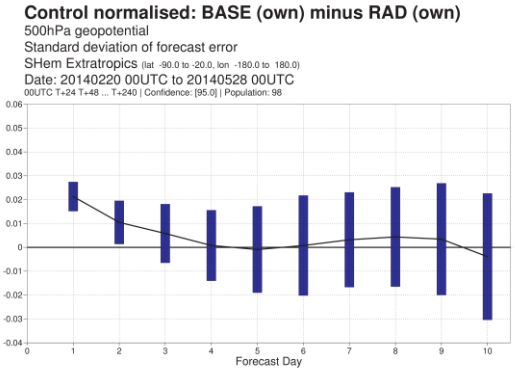
Operations



Northern Hemisphere
500hPa Geopotential

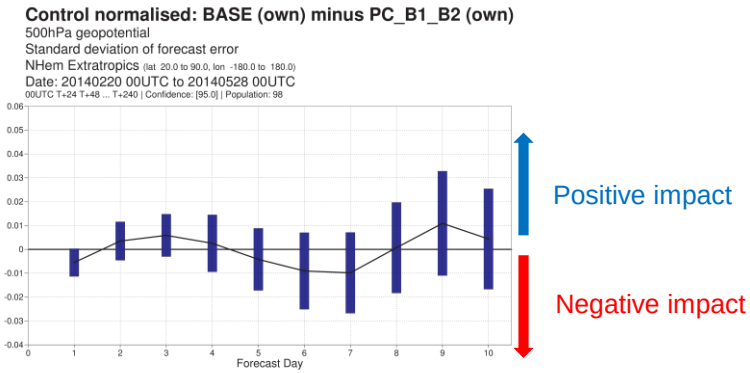


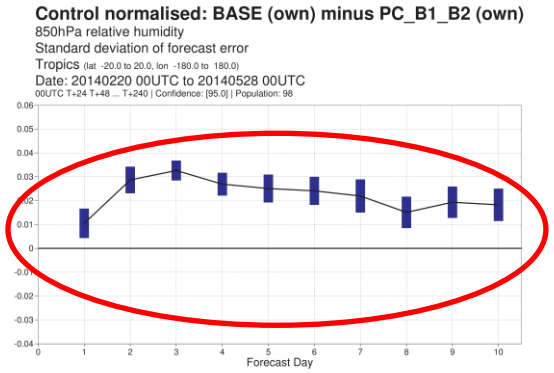
Tropics
850hPa relative humidity

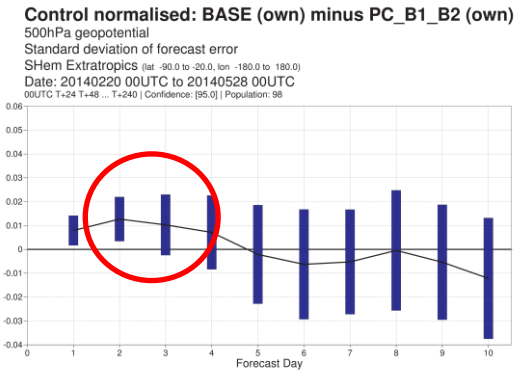


Southern Hemisphere
500 hPa Geopotential

PC based system







The 4D-Var assimilation of 400 reconstructed radiances based on 400 PC scores

The benefits of the PC methodology can be reproduced via the assimilation of reconstructed radiances with the added benefits of being able to deal with cloudy scenes

The information contained in the 400 PC scores can be encapsulated in a subset of reconstructed radiances of the same size.

It can be shown that the cost function in PC space is identical to the cost function in reconstructed radiances space if:

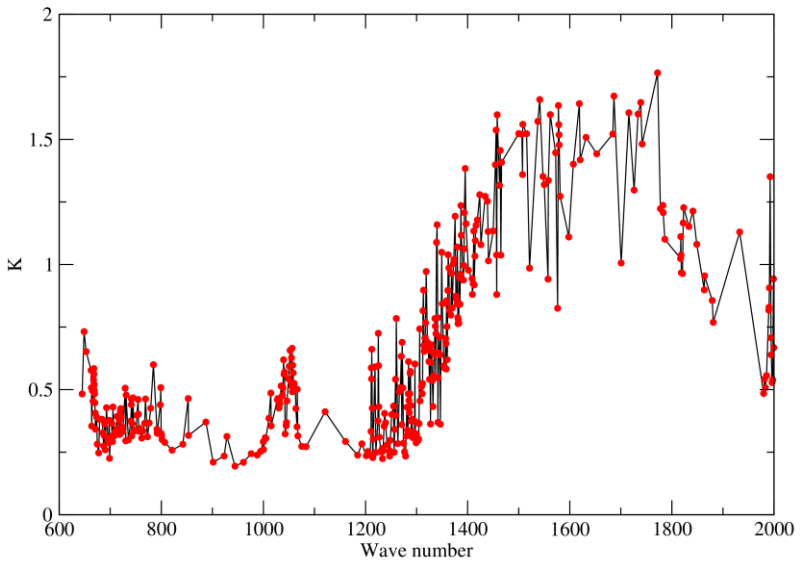
1) The transformation of the observation error covariance matrix from PC space to reconstructed radiance space yields a non-singular matrix.

2) The simulation of the reconstructed radiances is based on the same forward operator used to simulate the PC scores (e.g. PC_RTTOV).

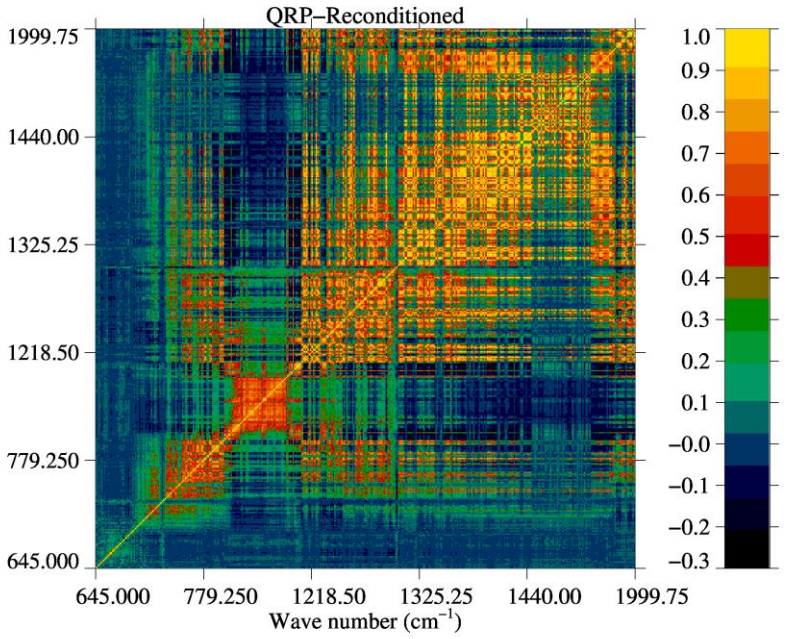
The 4D-Var assimilation of 400 reconstructed radiances based on 400 PC scores

- The indices of the reconstructed radiances have been determined by finding 400 independent rows in the 8461x400 matrix formed by the 400 eigenvectors used in the PC assimilation..

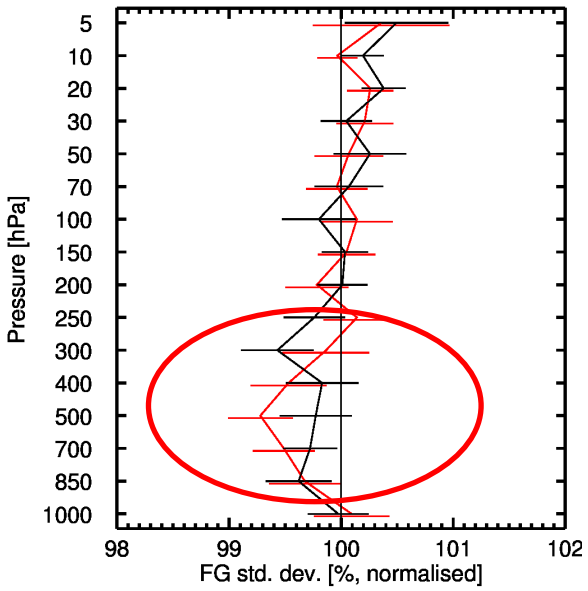
Square root of diagonal elements of covariance matrix



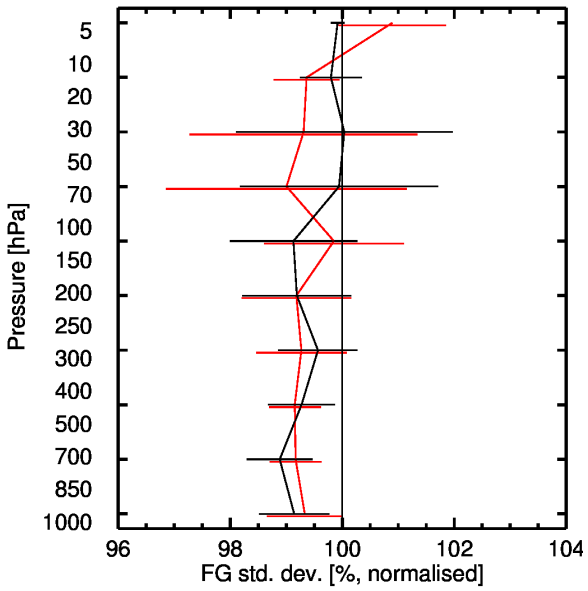
Error correlations



Verification against radiosondes: temperature



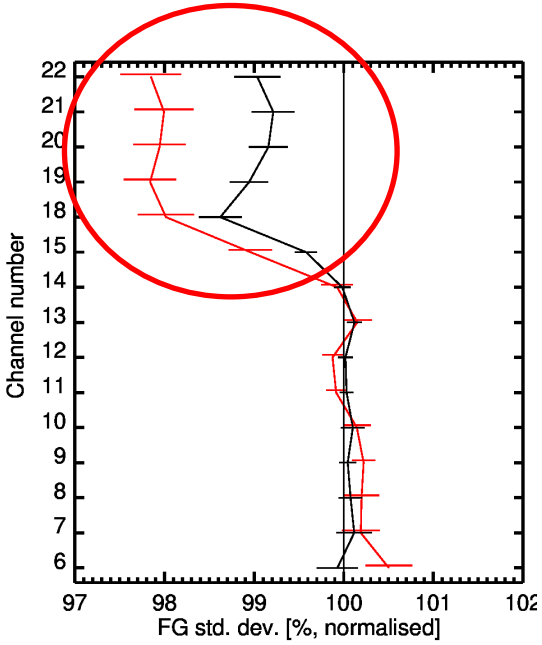
Verification against radiosondes: humidity



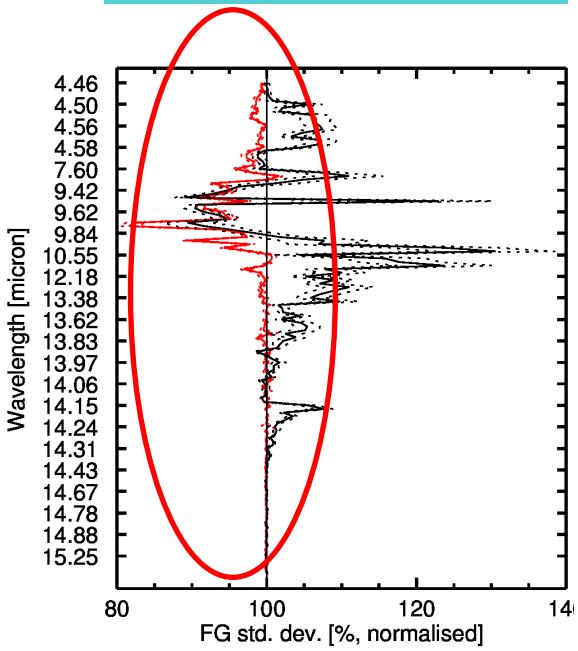
PC_B1_B2

REC_RAD

Verification against ATMS data



Verification against AIRS data

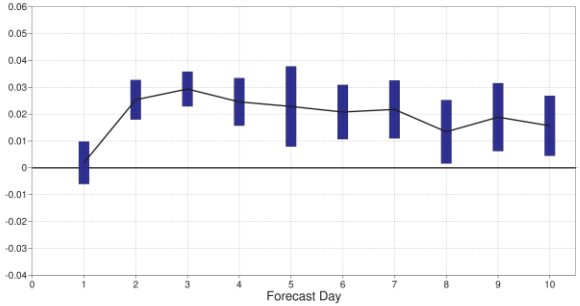


Forecast rms errors

PC based system

Equivalent system based on reconstructed radiances

Control normalised: BASE (own) minus PC_B1_B2 (own)
850hPa relative humidity
Standard deviation of forecast error
Tropics (lat -20.0 to 20.0, lon -180.0 to 180.0)
Date: 20140220 00UTC to 20140323 00UTC
00UTC T+24 T+48 ... T+240 | Confidence: [95.0] | Population: 31



Tropics
850hPa relative humidity

Control normalised: BASE (own) minus REC_RAD (own)
850hPa relative humidity
Standard deviation of forecast error
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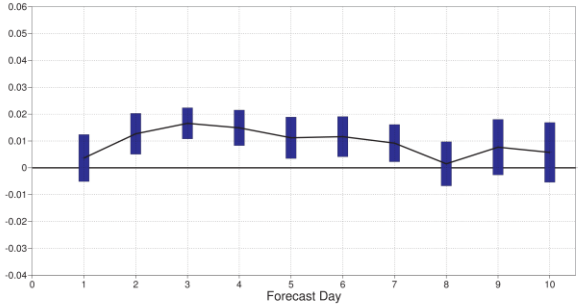
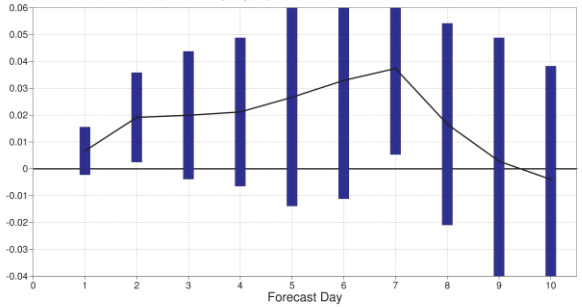


Control normalised: BASE (own) minus PC_B1_B1 (own)
500hPa geopotential
Standard deviation of forecast error
SHem Extratropics (lat -90.0 to -20.0, lon -180.0 to 180.0)
Date: 20140220 00UTC to 20140323 00UTC
00UTC T+24 T+48 ... T+240 | Confidence: [95.0] | Population: 31



Southern Hemisphere
500 hPa Geopotential

Control normalised: BASE (own) minus REC_RAD (own)
500hPa geopotential
Standard deviation of forecast error
SHem Extratropics (lat -90.0 to -20.0, lon -180.0 to 180.0)
Date: 20140220 00UTC to 20140323 00UTC
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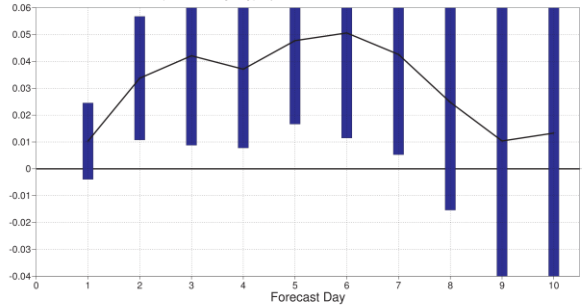

SUMMARY

- The PC based assimilation system has evolved for a prototype assimilation to an operationally viable assimilation system. The direct assimilation of PC scores in 4D-Var has allowed us to demonstrate the value of maximising the use of the available IASI spectrum.

- The latest results using 5421 IASI channels in the PC based 4D-Var suggest that there are benefits for humidity analysis

CURRENT AND FUTURE WORK

- We will be focused on reproducing the benefits of the PC methodology via the use of reconstructed radiances with the added advantage of being able to deal with cloudy scenes.

- Use a error covariance matrix based on a physical approach