

# Direct assimilation of Principal Component data for operational Numerical Weather Prediction

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## Motivations for exploiting PC assimilation

- 1) Make a more efficient use of high resolution sounder data. This would allow, for instance, the use of a larger portion of the IASI spectrum.
- 2) Remove the noise from observations.
- 3) Directly assimilate PC scores disseminated by data providers.

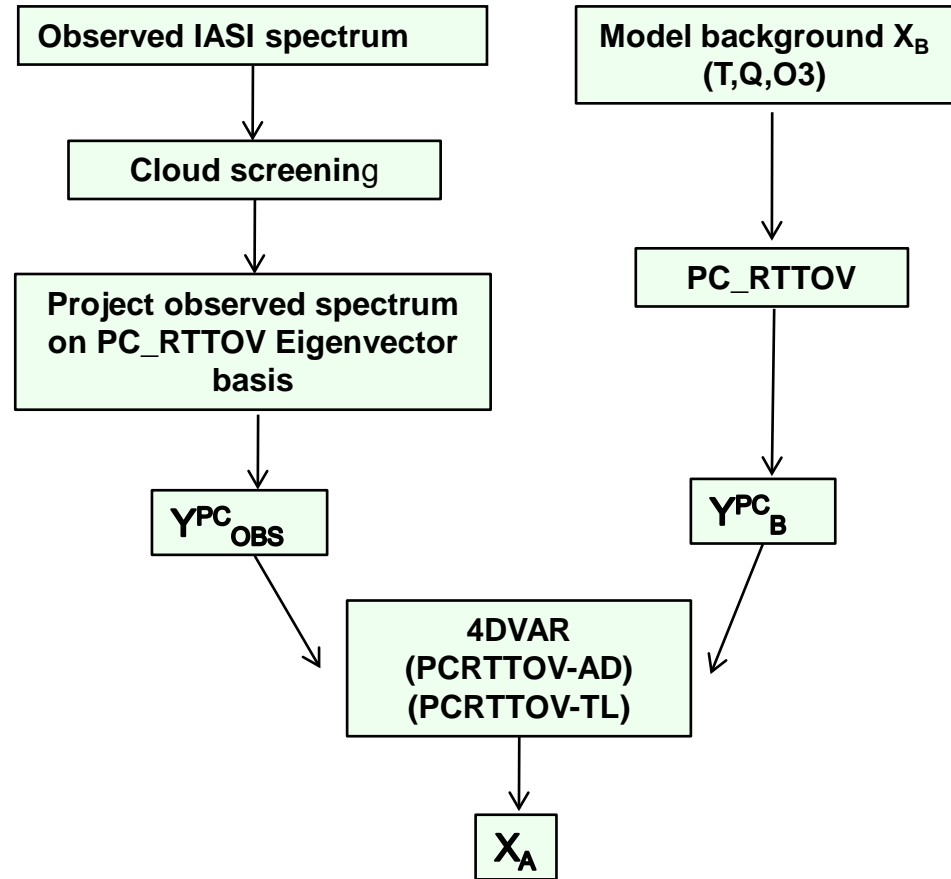
## Objectives of our work

- 1) Develop a 4D-Var assimilation system based on PCA.
- 2) Demonstrate the correct functionality of the PC based assimilation system.
- 3) Take the PCA assimilation 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 (PC\_RTTOV).
- 2) Develop a cloud scheme for the detection of cloudy scenes.
- 3) Modify the IFS to allow the ingestion of PC data.
- 4) Develop a PC based quality control to filter out residual cloud contamination.
- 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 PCs observation errors.

## PC analysis system design



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

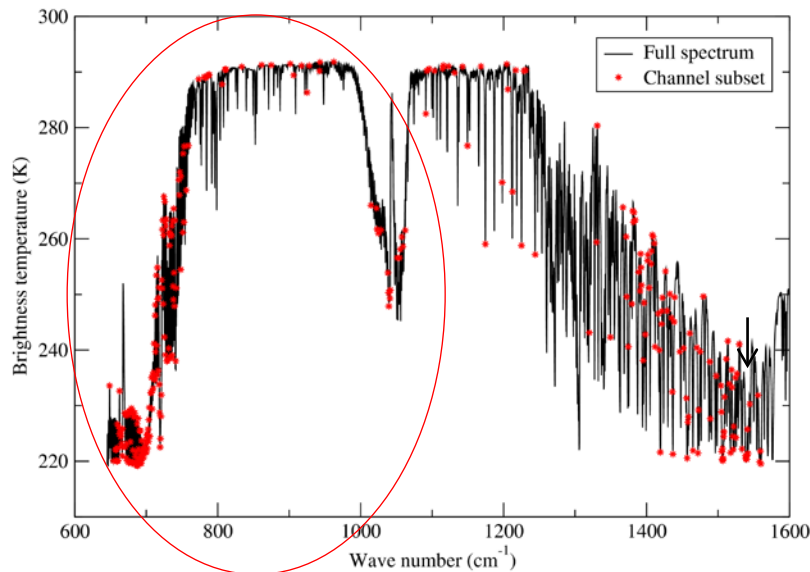
$$J(X) = [X - X_B]^T B^{-1} [X - X_B] + [Y_{OBS}^{PC} - Y^{PC}(X)]^T O^{-1} [Y_{OBS}^{PC} - Y^{PC}(X)]$$

## 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 ECMWF operations.
- 3) *Revised full data assimilation system :*** assimilation of PC scores derived from 305 IASI channels obtained by augmenting the 191 operational channels with additional surface, ozone, and water vapour sounding channels.

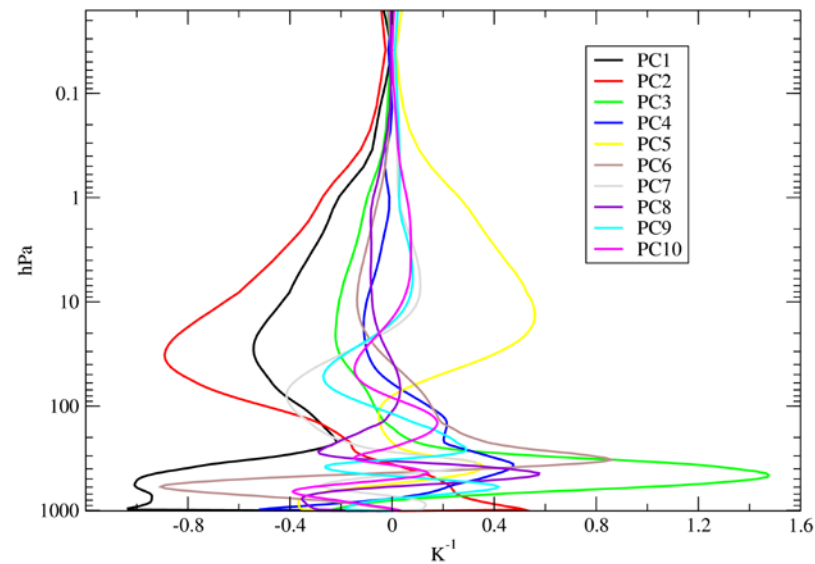
# Assimilation of PC scores derived from 305 IASI channels

The 305 channels on which the PC scores are based.



The bulk of the channels used in ECMWF operations is in this spectral region

The temperature Jacobian for the first ten PC scores



PC skin temperature Jacobian

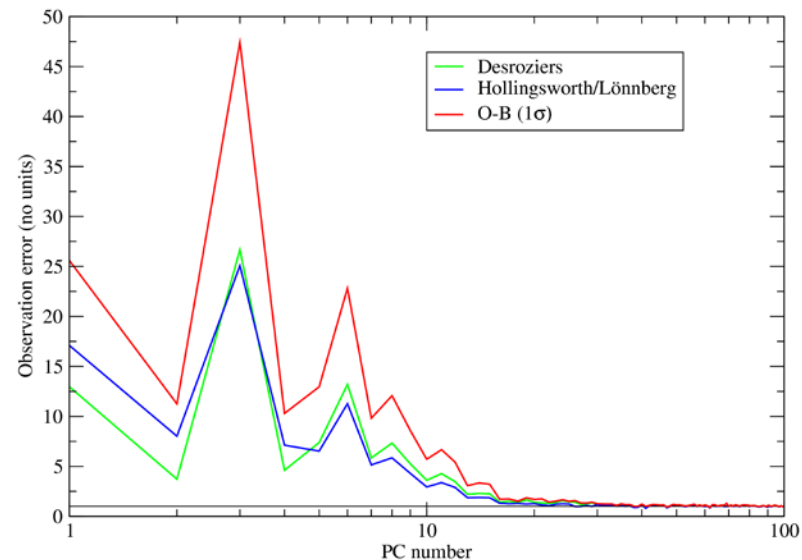
-22.34
16.39
-9.93
-17.67
-0.53
-2.23
3.55
0.16
1.57
-1.34

**Estimate of the observation error:** Desroziers and Hollingsworth/Lönnerberg methods have been used to separate the contribution of the observation and background error.

**Hollingsworth/Lönnerberg assumptions:** background errors are spatially uncorrelated, observation errors are spatially uncorrelated, and, background and observation errors are uncorrelated.

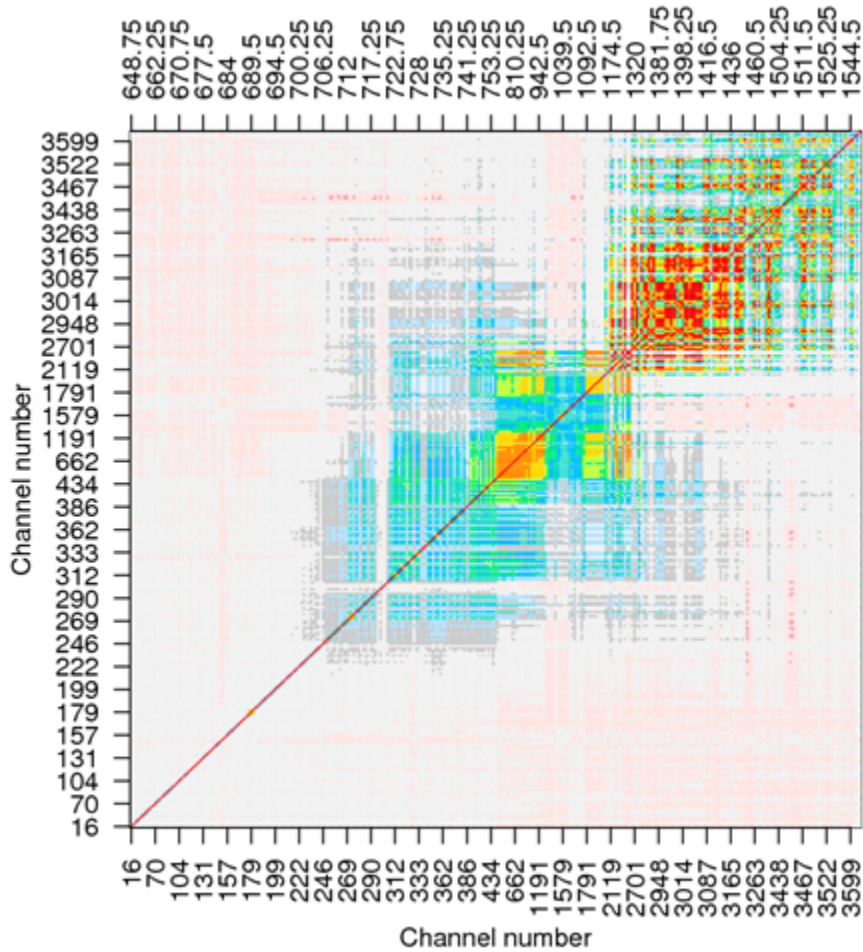
**Desroziers assumptions:** background and observation errors are uncorrelated, the weights that are assigned to the observations in the analysis agree with the true background and observation error covariances.

Diagnosed PC score observation errors (i.e. diagonal elements of the diagnosed PC error covariance matrix)

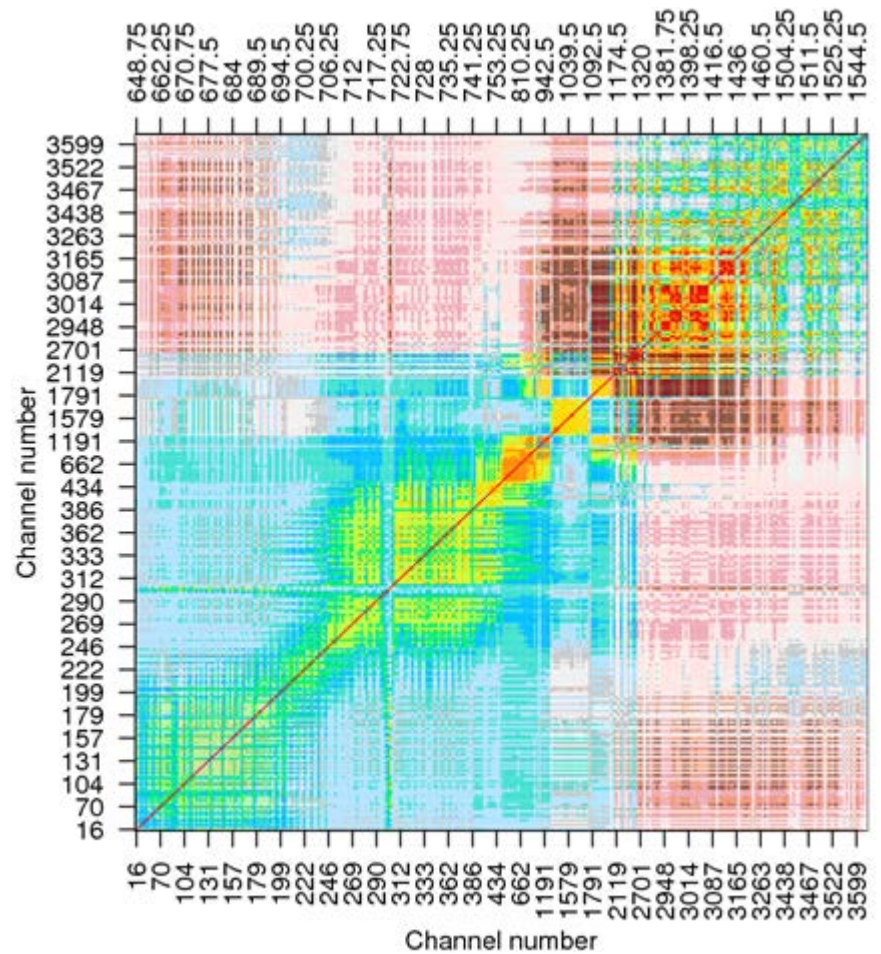


# Assimilation of PC scores derived from 305 IASI channels: diagnosed error correlations

*Full* PC correlation matrix is converted into radiance space



*Diagonal* PC correlation matrix is converted into radiance space



**To assess 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 191 channels used in the operational 4D-Var.
- 3) PC:** identical to BASE but additionally assimilates 50 PC scores derived from 305 IASI channels.

Experiments (cycle 38R2 – T511- 137 L) have been carried out for the period 15 June 2012-15 September 2012.

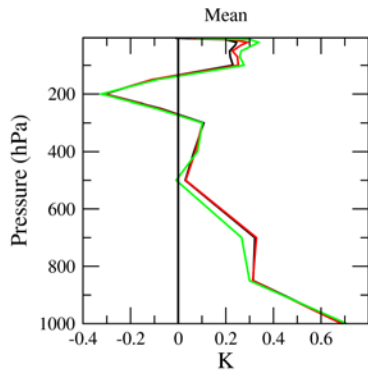
**NOTE: in the PC experiment we assimilate only cloud-free scenes whereas in the RAD experiment we assimilate fully overcast scenes and channels not affected by clouds.**



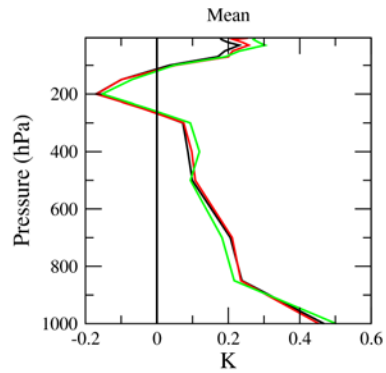
Change in the background fit to radiosonde temperature observations over the BASE system in the Tropics



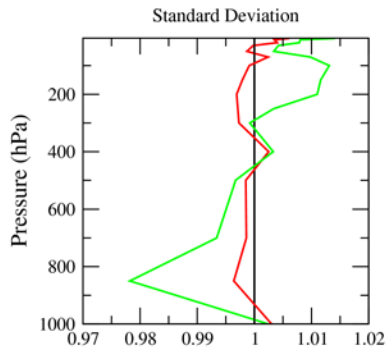
Background - Tropics



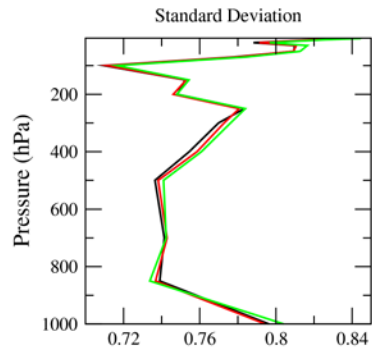
Analysis - Tropics



Background - Tropics



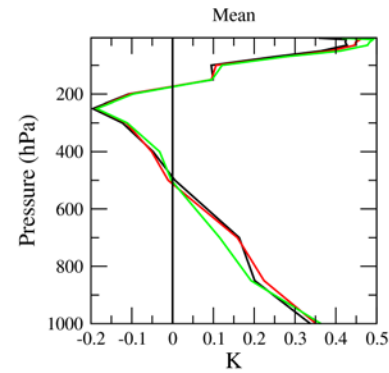
Analysis - Tropics



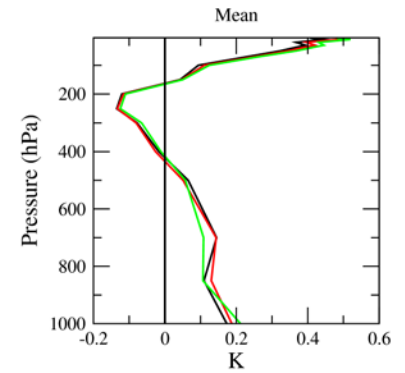
Change in the background fit to radiosonde temperature observations over the BASE system in the Southern Hemisphere



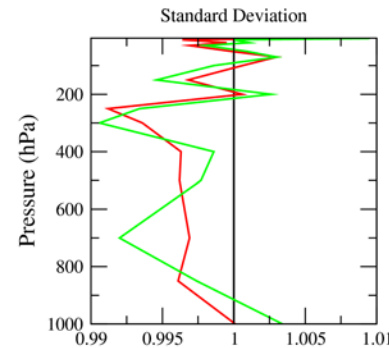
Background - Southern Hemisphere



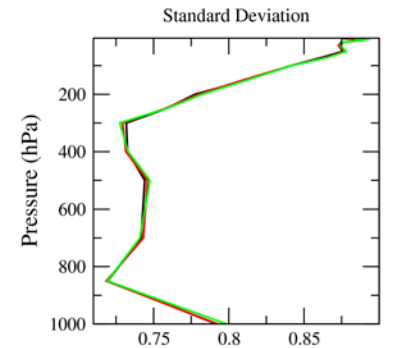
Analysis - Southern Hemisphere



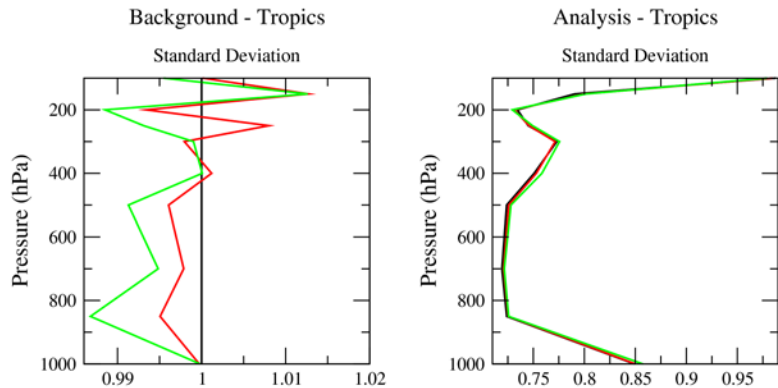
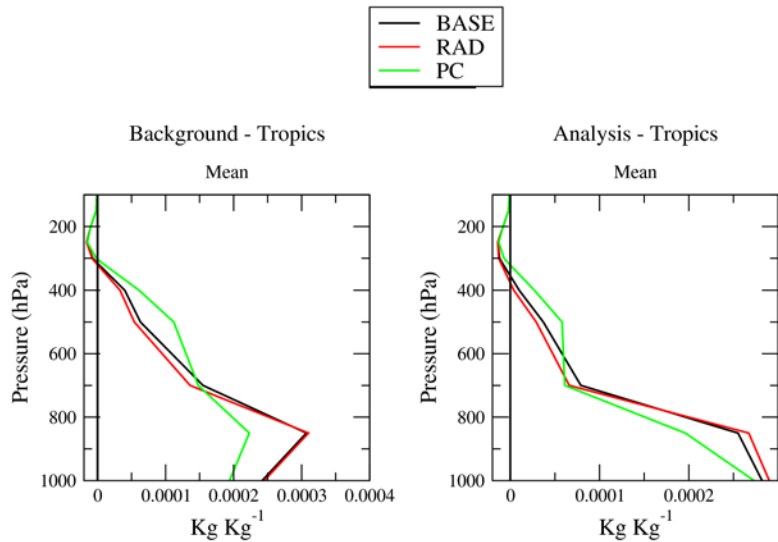
Background - Southern Hemisphere



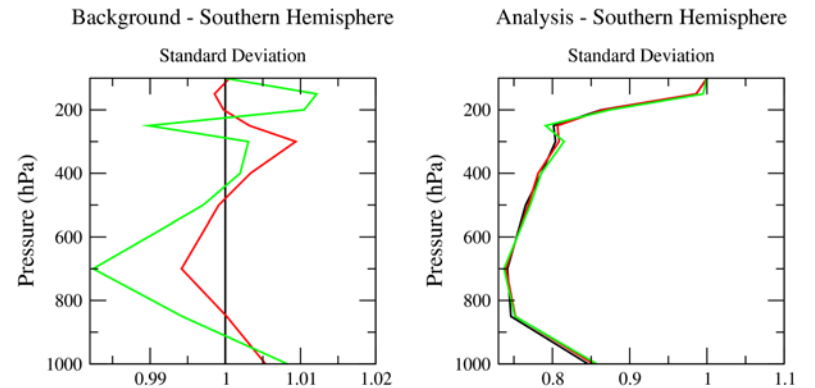
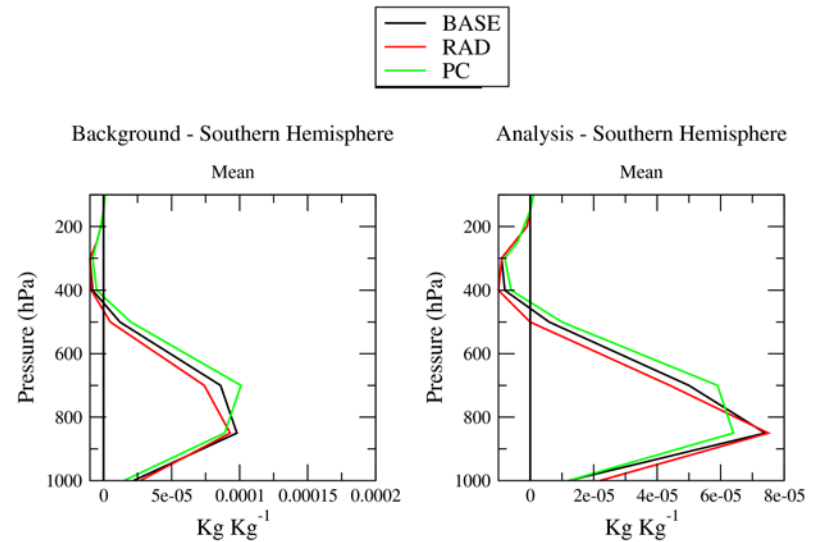
Analysis - Southern Hemisphere



Change in the background fit to radiosonde humidity observations over the BASE system in the Tropics



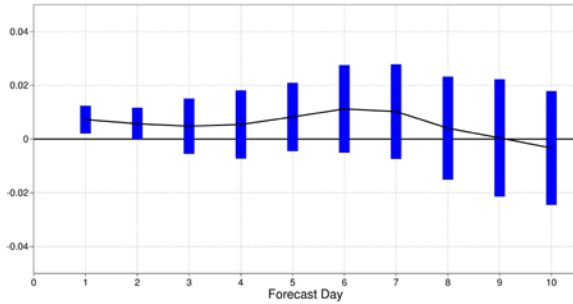
Change in the background fit to radiosonde humidity observations over the BASE system in the Southern Hemisphere



BASE-RAD

Control normalised: fv0z (ope) minus fuei (ope)

500hPa geopotential  
 Root mean square error  
 NHem Extratropics (lat: 20.0 to 90.0, lon: -180.0 to 180.0)  
 Date: 20120615 00UTC to 20120915 00UTC  
 00UTC T+24 T+48 ... T+240 | Confidence: [95.0] | Population: 93



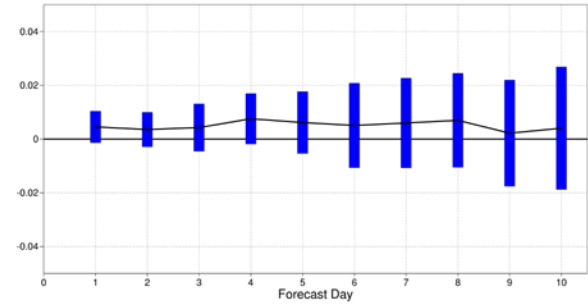
Forecast rms errors

500hPa Geopotential  
 Northern Hemisphere Extratropics

BASE-PC

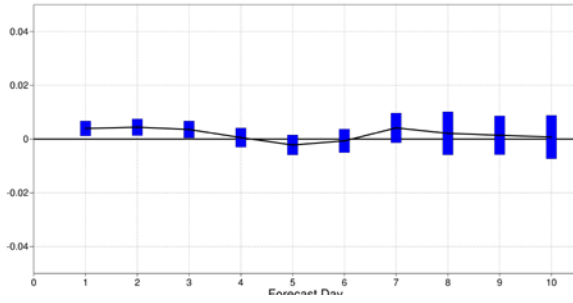
Control normalised: fv0z (ope) minus fw9l (ope)

500hPa geopotential  
 Root mean square error  
 NHem Extratropics (lat: 20.0 to 90.0, lon: -180.0 to 180.0)  
 Date: 20120615 00UTC to 20120915 00UTC  
 00UTC T+24 T+48 ... T+240 | Confidence: [95.0] | Population: 93



Control normalised: fv0z (ope) minus fuei (ope)

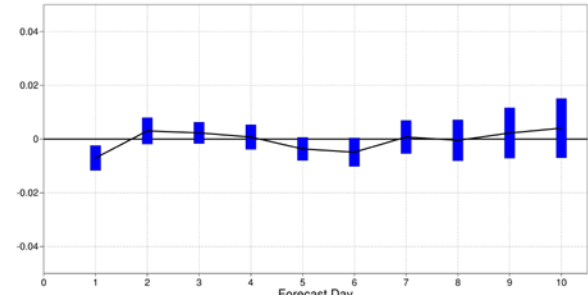
850hPa vector wind  
 Root mean square error  
 Tropics (lat: -20.0 to 20.0, lon: -180.0 to 180.0)  
 Date: 20120615 00UTC to 20120915 00UTC  
 00UTC T+24 T+48 ... T+240 | Confidence: [95.0] | Population: 93



850hPa vector wind  
 Tropics

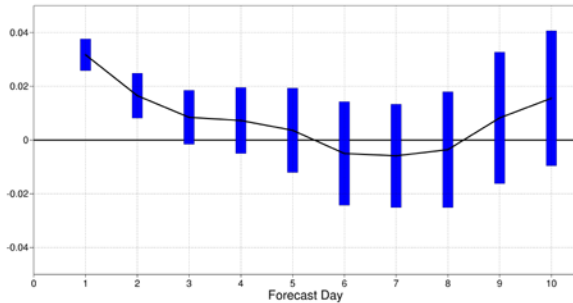
Control normalised: fv0z (ope) minus fw9l (ope)

850hPa vector wind  
 Root mean square error  
 Tropics (lat: -20.0 to 20.0, lon: -180.0 to 180.0)  
 Date: 20120615 00UTC to 20120915 00UTC  
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Control normalised: fv0z (ope) minus fuei (ope)

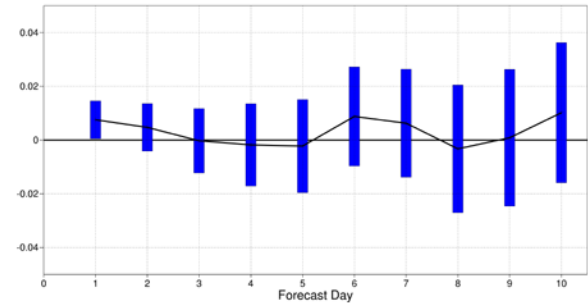
500hPa geopotential  
 Root mean square error  
 SHem Extratropics (lat: -90.0 to -20.0, lon: -180.0 to 180.0)  
 Date: 20120615 00UTC to 20120915 00UTC  
 00UTC T+24 T+48 ... T+240 | Confidence: [95.0] | Population: 93



500hPa Geopotential  
 Southern Hemisphere Extratropics

Control normalised: fv0z (ope) minus fw9l (ope)

500hPa geopotential  
 Root mean square error  
 SHem Extratropics (lat: -90.0 to -20.0, lon: -180.0 to 180.0)  
 Date: 20120615 00UTC to 20120915 00UTC  
 00UTC T+24 T+48 ... T+240 | Confidence: [95.0] | Population: 93



## Short and medium term work

- Update the spectroscopy used in the PC\_RTTOV simulations.
- Extend the assimilation of PC scores to METOP-B data.
- Account for observation error correlations in PC space (i.e. specify the full error covariance matrix rather than only the diagonal elements).
- Assimilate directly the IASI observation-based PC scores disseminated by EUMETSAT.

## Longer term work

- Handling of clouds in PC space

# Summary

- The viability of PC assimilation has been demonstrated for cloud-free scenes.

- The assimilation in cloud free-scenes of 50 PC scores based on 305 radiances, seems to produce a level of performance similar to that produced by the operational radiance assimilation system which is based on the use of fully overcast scenes and on channels unaffected by clouds.

- The above result is all the more important in light of the fact that the 50 PC score system uses ~20% less computer resources (during the 4D-var minimization) compared to the operational system that assimilates 191 radiances. This figure represents a significant saving inside the time critical processing path for NWP centres, but could potentially be improved even further.