Direct assimilation of PC data for global NWP

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Motivations for PC assimilation:

1) Make a more efficient use of high resolution sounder data (e.g. utilize a larger portion of the IASI spectrum).

2) Remove the noise from observations.

3) Data providers may evolve to the dissemination of PC scores.

Objectives:

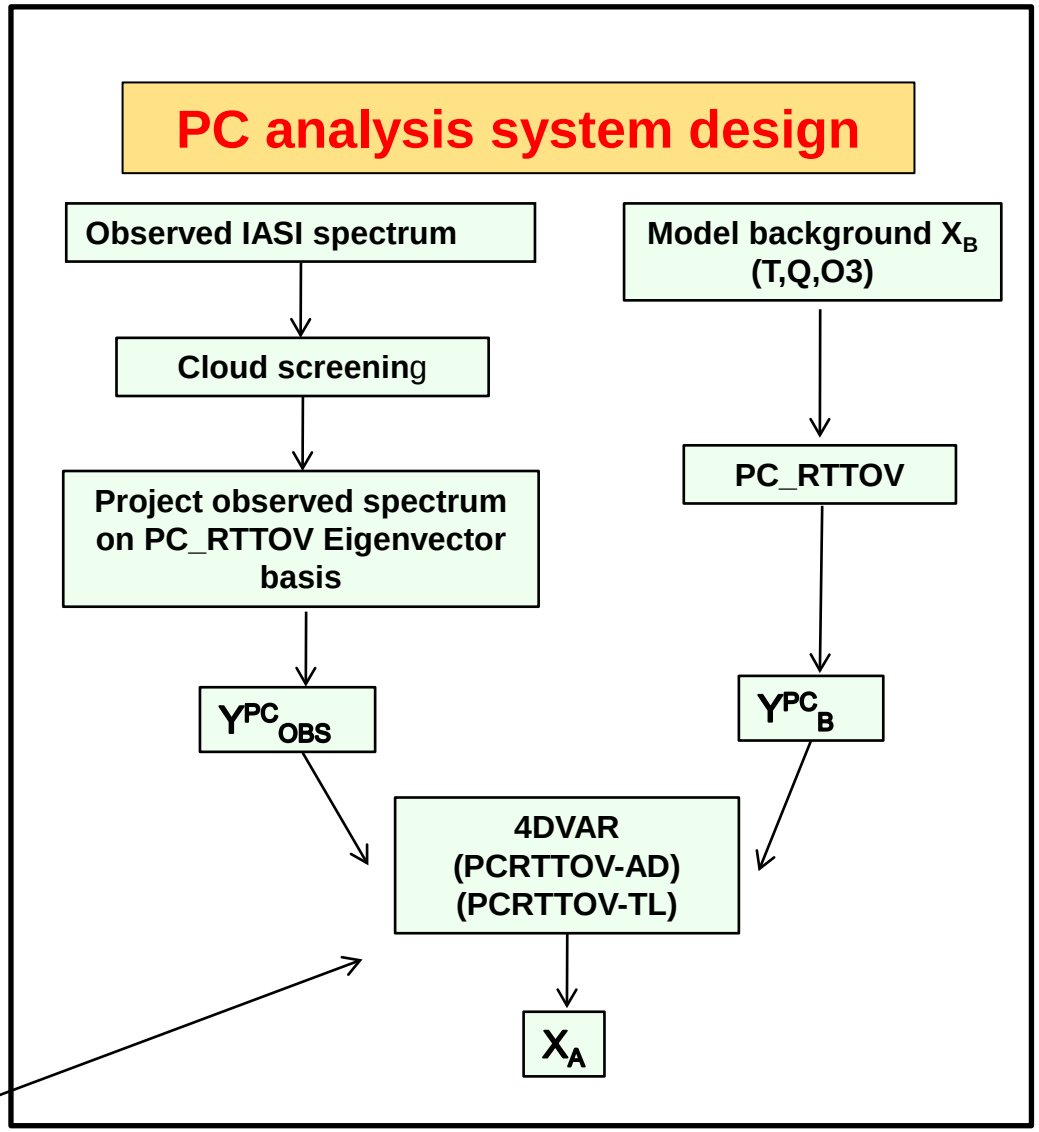
1) Develop a 4D-Var assimilation system based on PCA.

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.
2) Develop a cloud scheme based on 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.



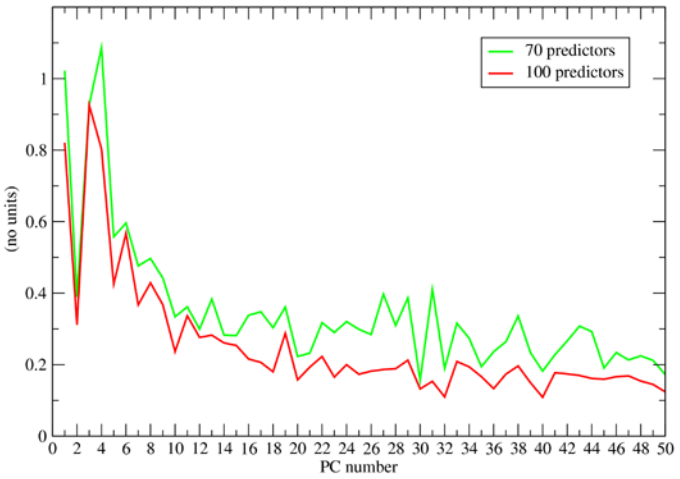
Minimization of cost function J(X)

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

The PC_RTTOV fast radiative transfer model

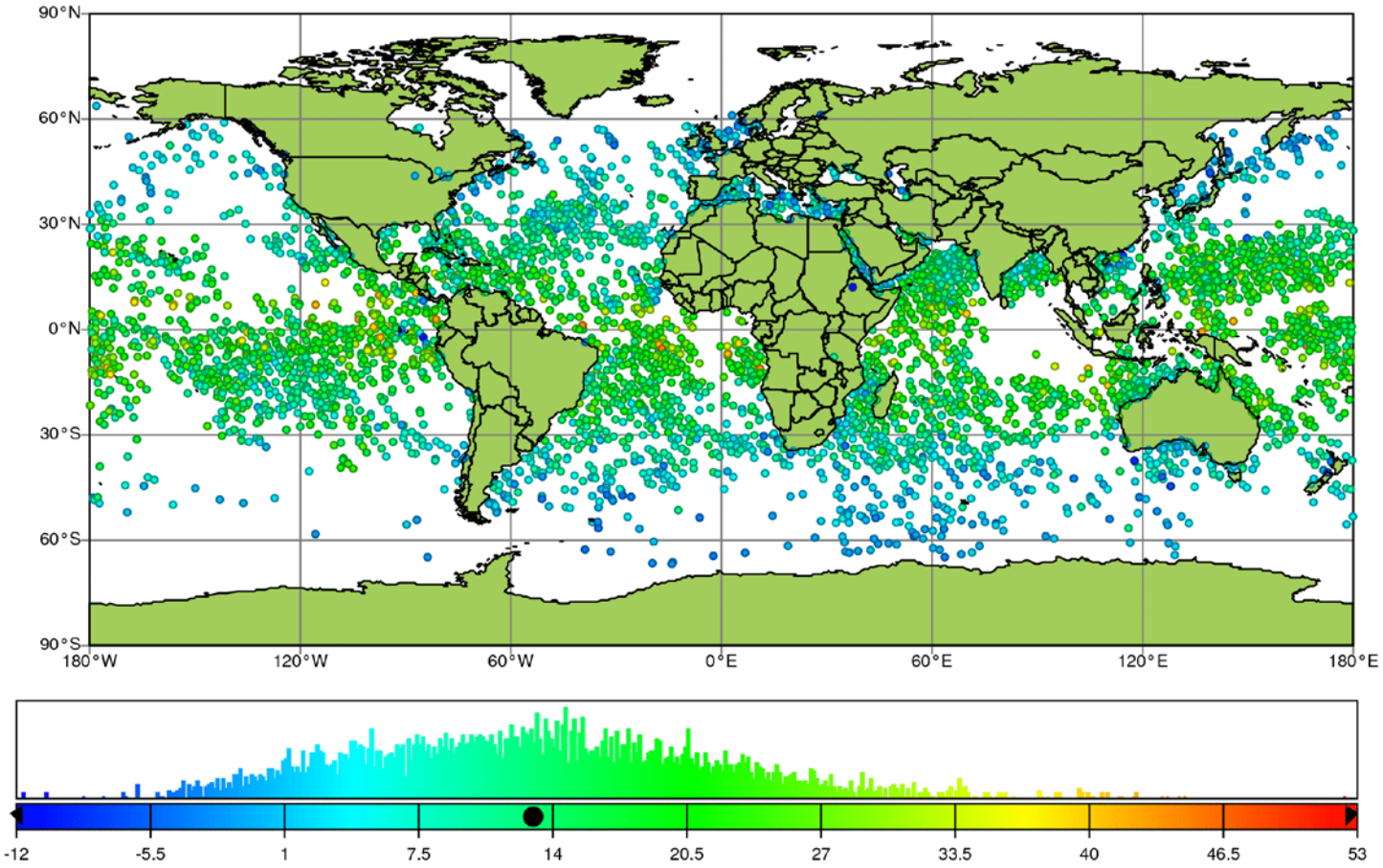
- The PC_RTTOV fast radiative transfer model performs rapid and accurate simulations of PC scores using a multiple linear regression scheme.
- In this scheme, the simulated PC scores are expressed as a linear combination of a selected number of polychromatic radiances simulated by the conventional RTTOV fast model.
- The regression coefficients are computed using the PC scores obtained from the eigenvectors of the covariance matrix of a large dataset of synthetic noise-free clear sky radiances calculated using an accurate line-by-line model.
- The number of predictor variables used in the regression algorithm is a tuneable parameter in the model.

Root-mean-square of the difference between exact (i.e. line-by-line) and simulated PC scores for 5190 independent profiles.



Quality control for residual cloud contamination

PC#1 has similar characteristics to an infrared window channel.
Large positive departures of the observed PC#1 score from the clear-sky computed value are an indication that the observation is affected by clouds.



Evolution of the 4D-Var PC score assimilation system:

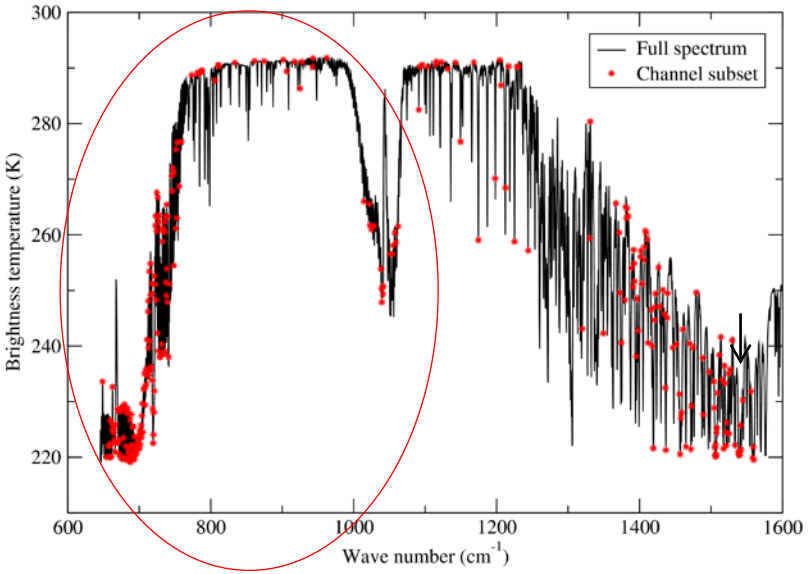
1) ***Prototype system (only conventional and IASI observations)***: assimilation of PC scores derived from channels in the short wave band of IASI (Matricardi and McNally, 2013).

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.

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.

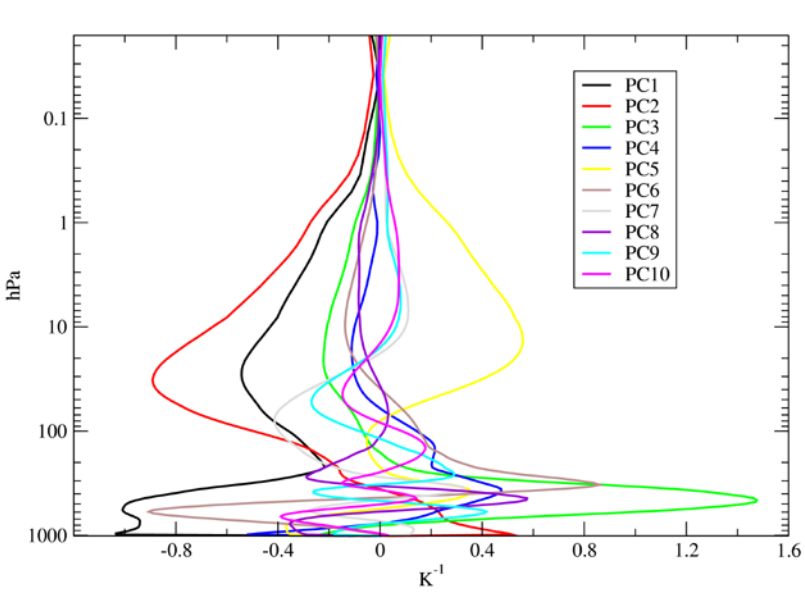
Assimilation of PC scores derived from 305 IASI channels

The 305 channels on which the PC scores are based.



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

The temperature Jacobians for the first ten PC scores



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

PC skin temperature Jacobians

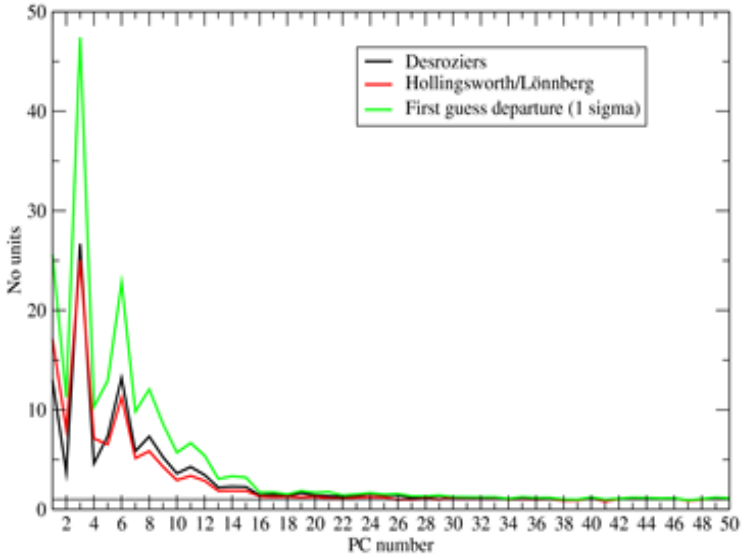
Assimilation of PC scores derived from 305 IASI channels

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

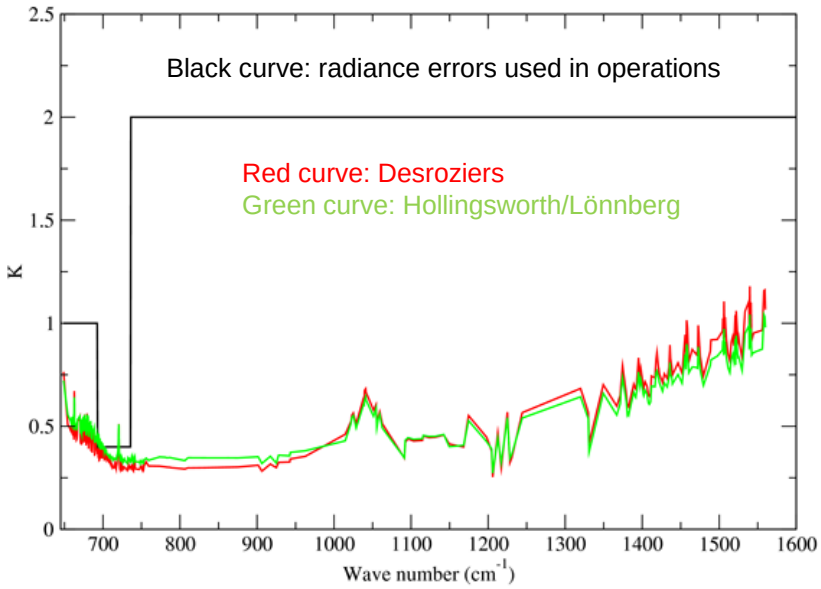
Hollingswort/Lönnberg assumptions: background errors are spatially uncorrelated, observation errors are spatially uncorrelated, and, background and observation errors are uncorrelated.

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.

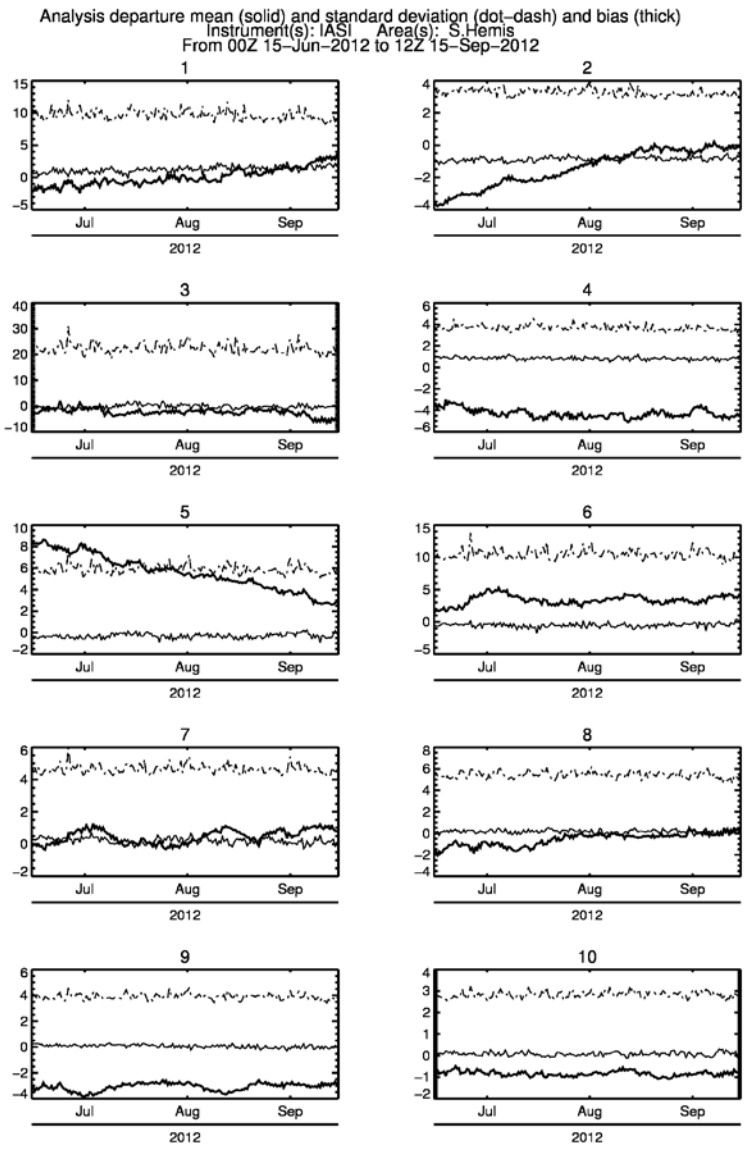
PC error tuning
(data courtesy of Niels Bormann)



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

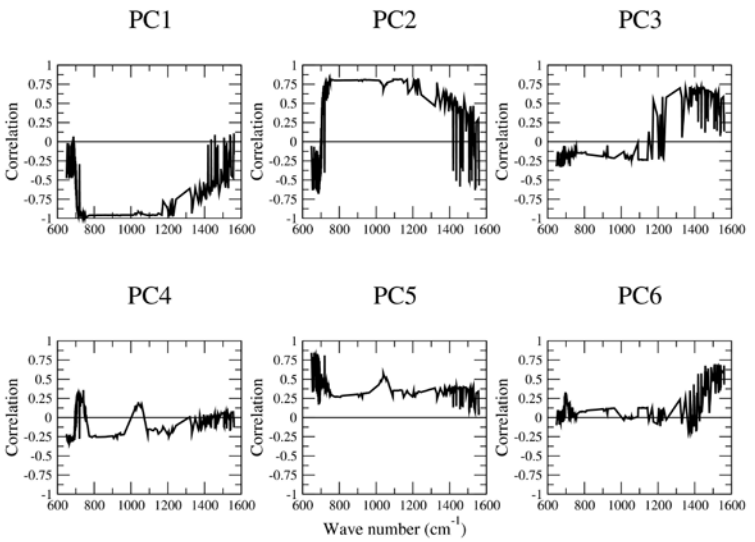


Assimilation of PC scores derived from 305 IASI channels



Thick line: Bias correction
Solid line: mean value of analysis departure
Dot-dashed line: standard deviation of analysis departure

Correlation between PCs and IASI channels



Assimilation of PC scores derived from 305 IASI channels

Experiment design:

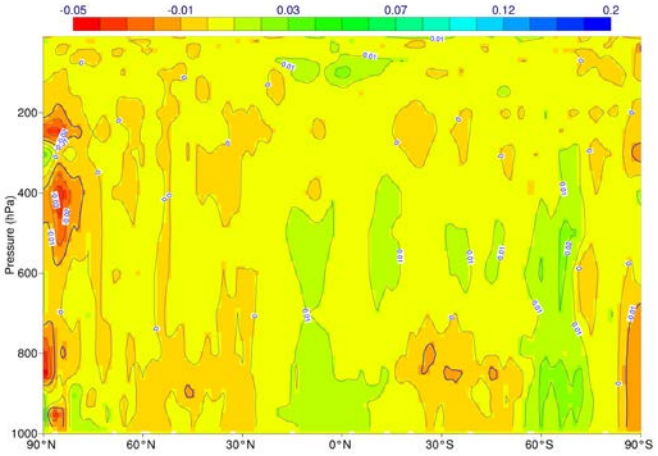
1) **BASE**: all operational observations (satellite and conventional) with the exception of IASI data.
2) **RAD**: identical to BASE but additionally assimilates 191 channels used in the operational 4D-Var.
3) **PC**: identical to BASE but additionally assimilates 50 PC scores derived from 305 IASI channels.

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

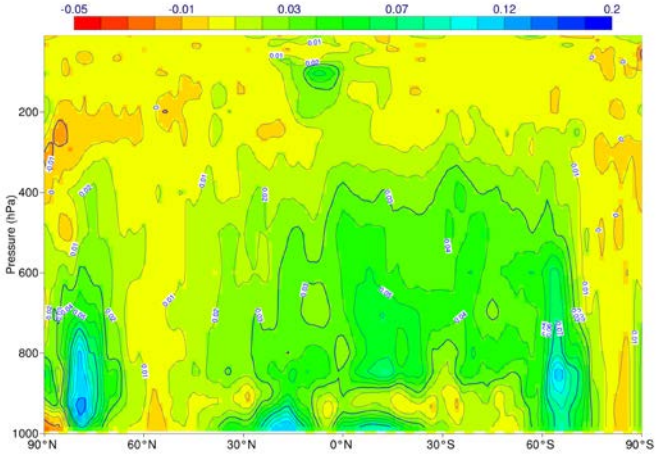
NOTE: in the PC experiment we assimilate only cloud-free scenes whereas in the RAD experiment we assimilate fully overcast scenes and channels not affected by clouds.

Zonally averaged root-mean-square temperature analysis increments

RAD-BASE



PC-BASE



Zonally averaged root-mean-square specific humidity analysis increments

RAD-BASE

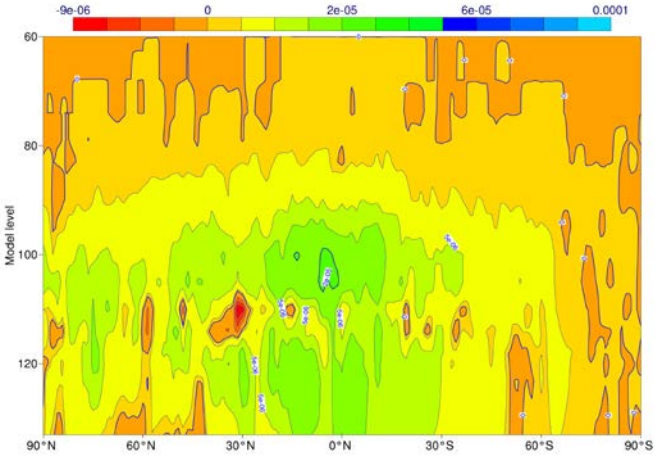
100 hPa

260 hPa

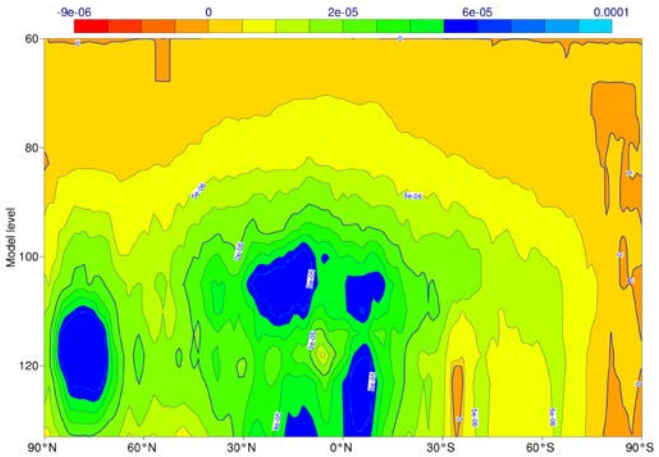
600 hPa

900 hPa

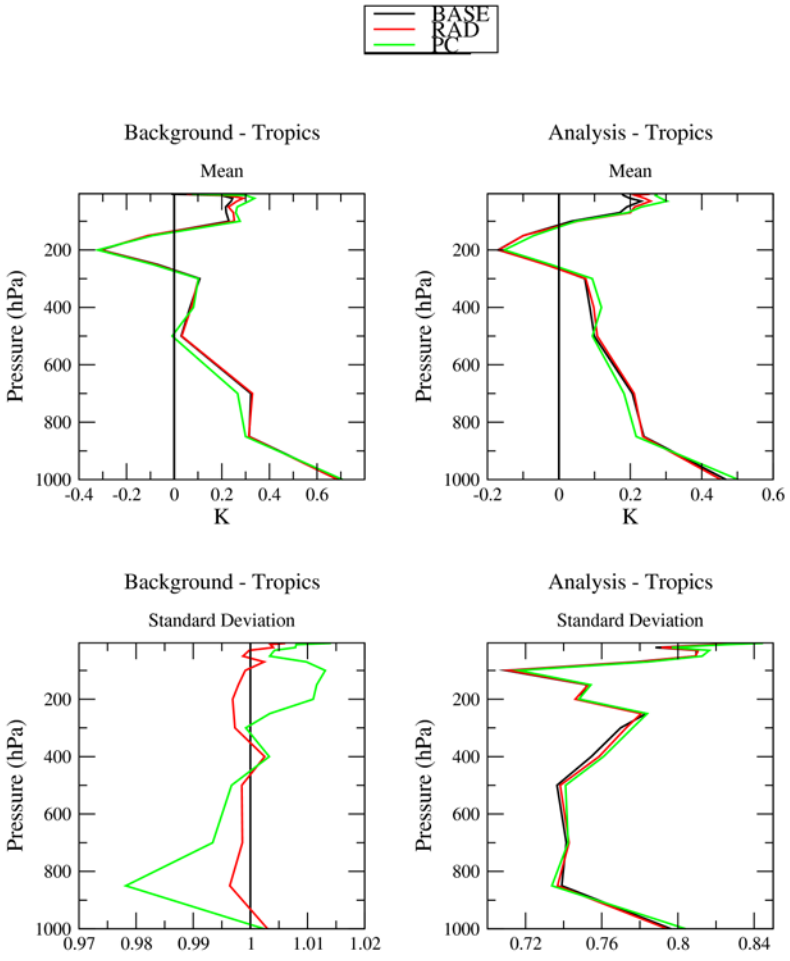
1000 hPa



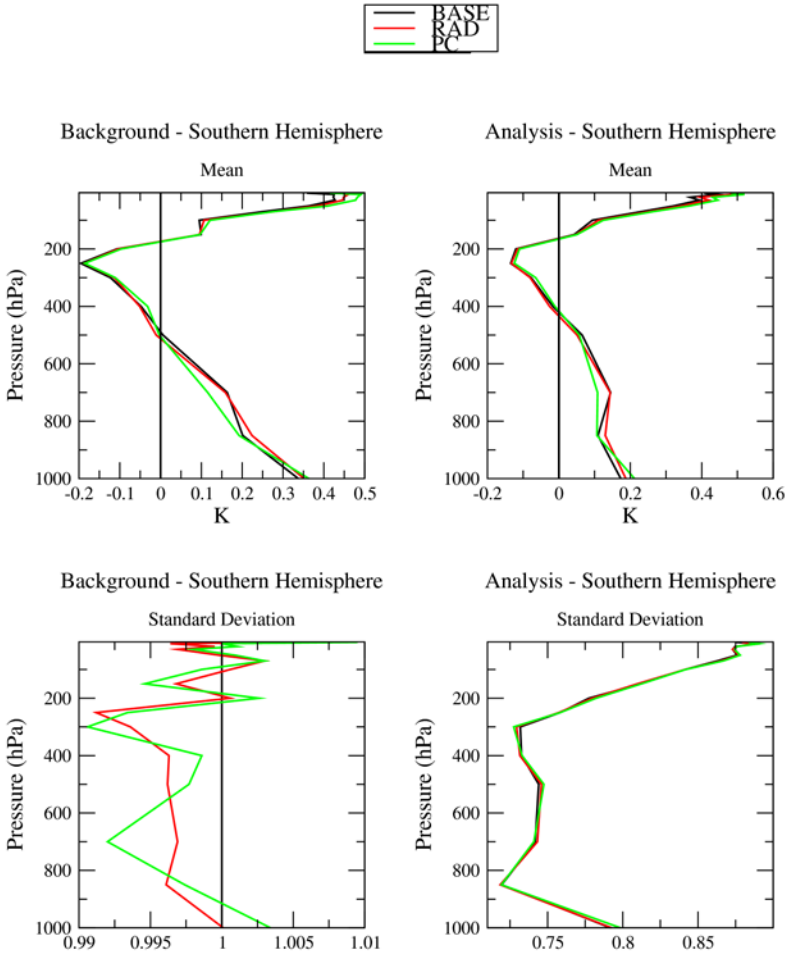
PC-BASE



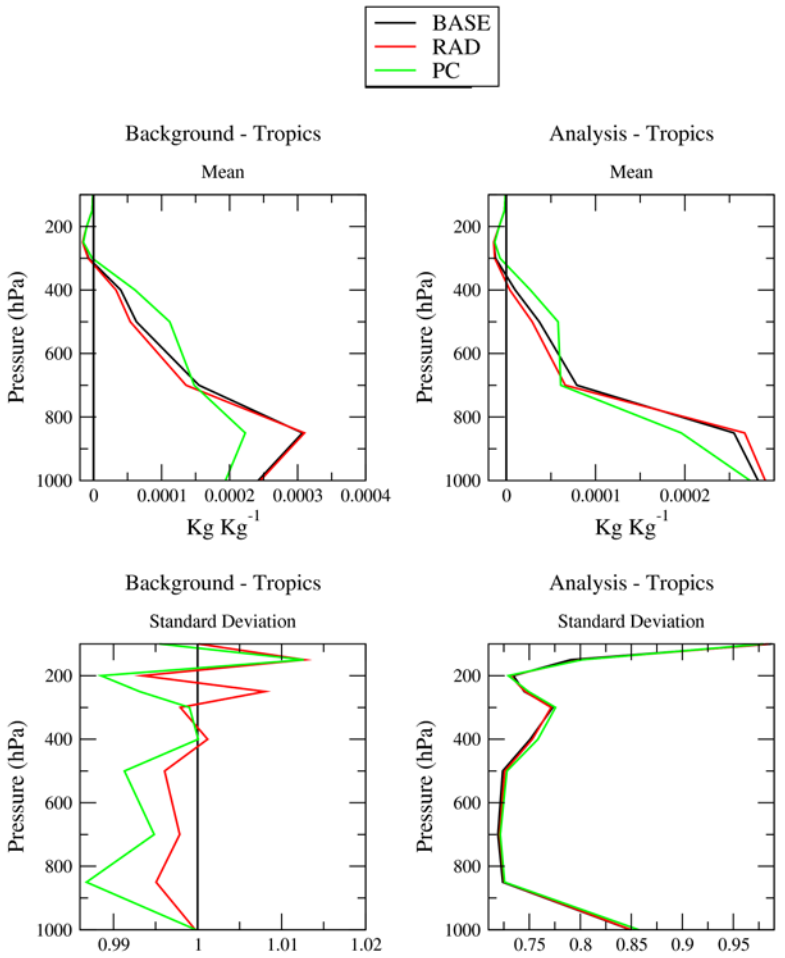
Change in the background fit to radiosonde temperature observations over the BASE system in the Tropics



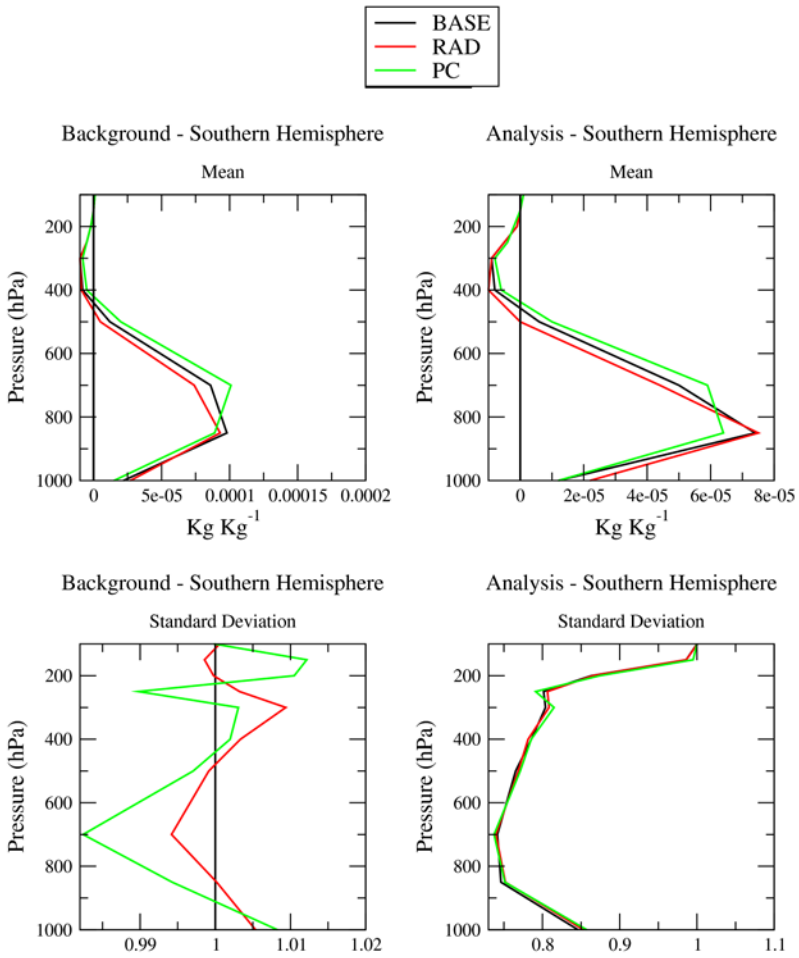
Change in the background fit to radiosonde temperature observations over the BASE system in the Southern Hemisphere



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

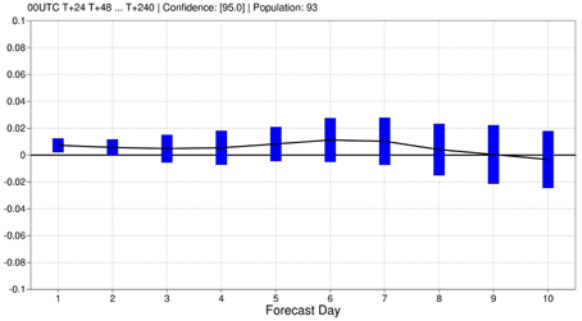


Forecast rms errors

BASE-RAD

BASE-PC

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



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
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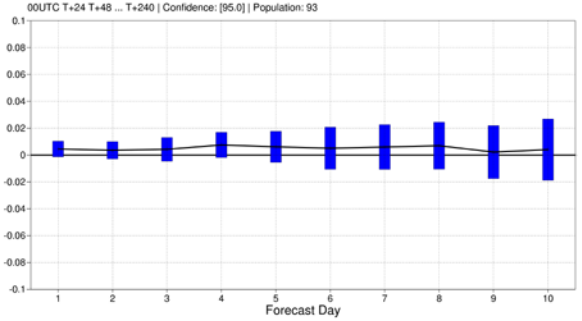
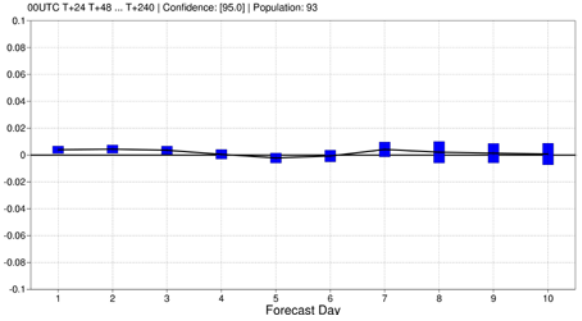


Control normalised: fv0z (ope) minus fuei (ope)
850hPa vector wind
Root mean square error
Tropics (lat -20.0 to 20.0, lon -180.0 to 180.0)
Date: 20120615 00UTC to 20120915 00UTC
00UTC T+24 T+48 ... T+240 | Confidence: [95.0] | Population: 93



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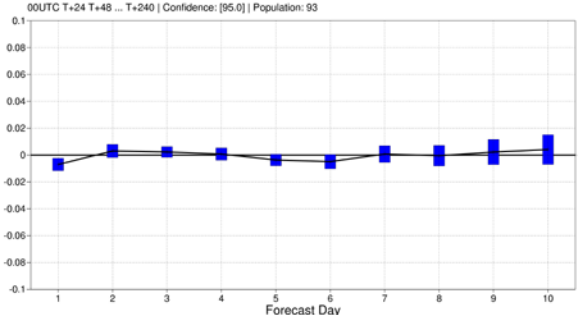

Control normalised: fv0z (ope) minus fuei (ope)
500hPa geopotential
Root mean square error
SHem Extratropics (lat -90.0 to -20.0, lon -180.0 to 180.0)
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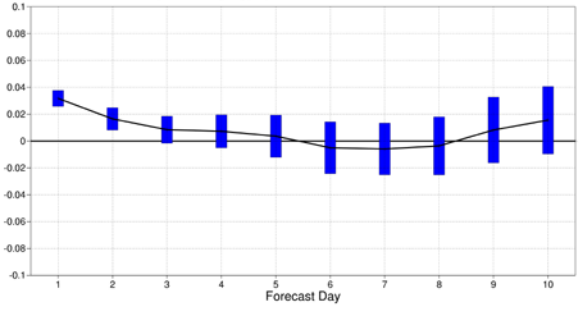

Control normalised: fv0z (ope) minus fw9l (ope)
500hPa geopotential
Root mean square error
SHem Extratropics (lat -90.0 to -20.0, lon -180.0 to 180.0)
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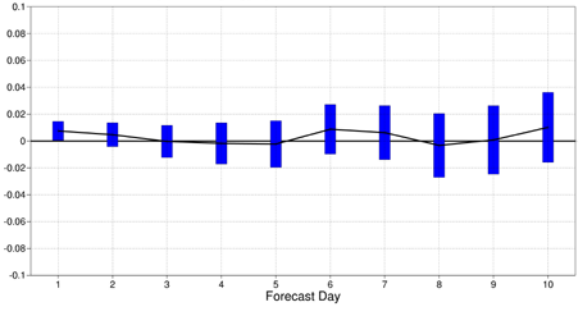
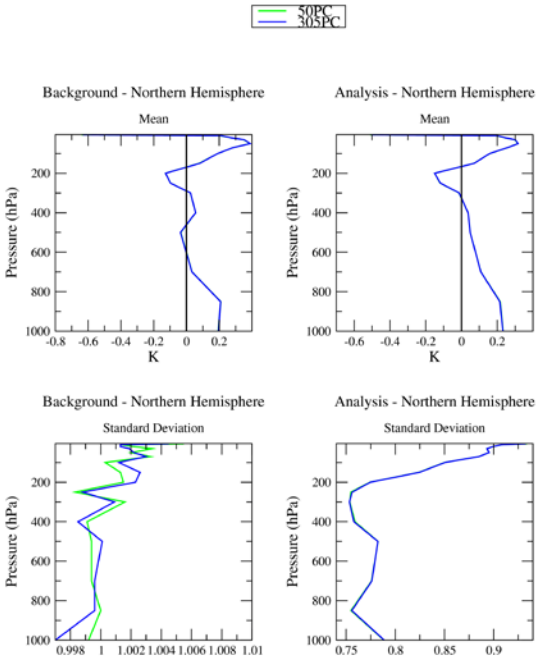
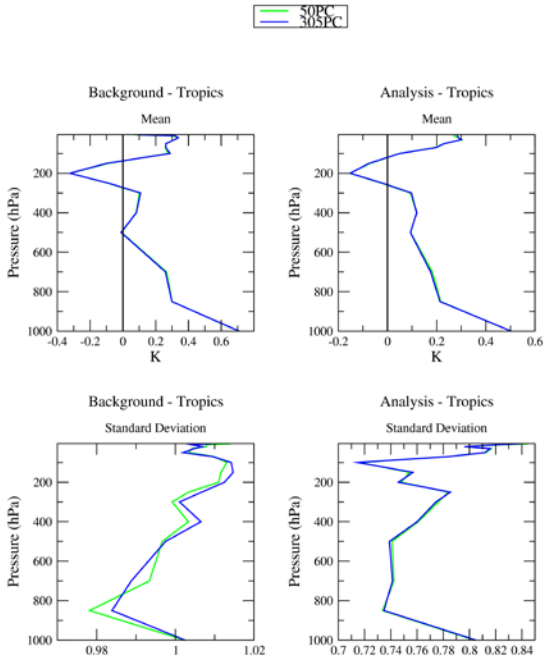


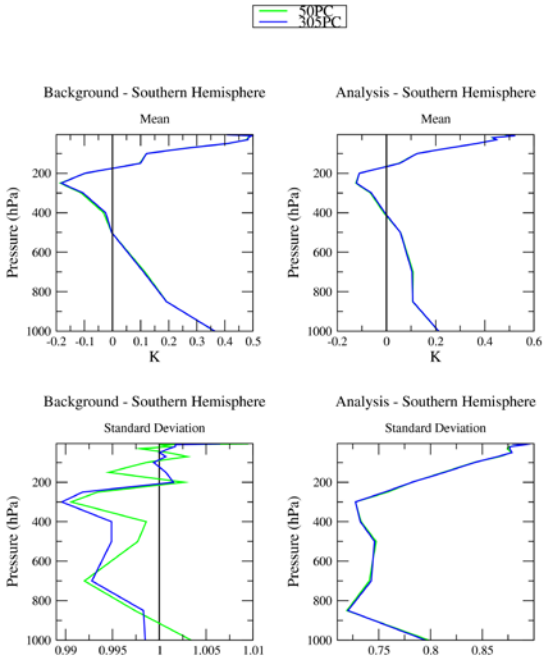
Change in the background fit to radiosonde temperature observations over the BASE system in the Northern Hemisphere



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



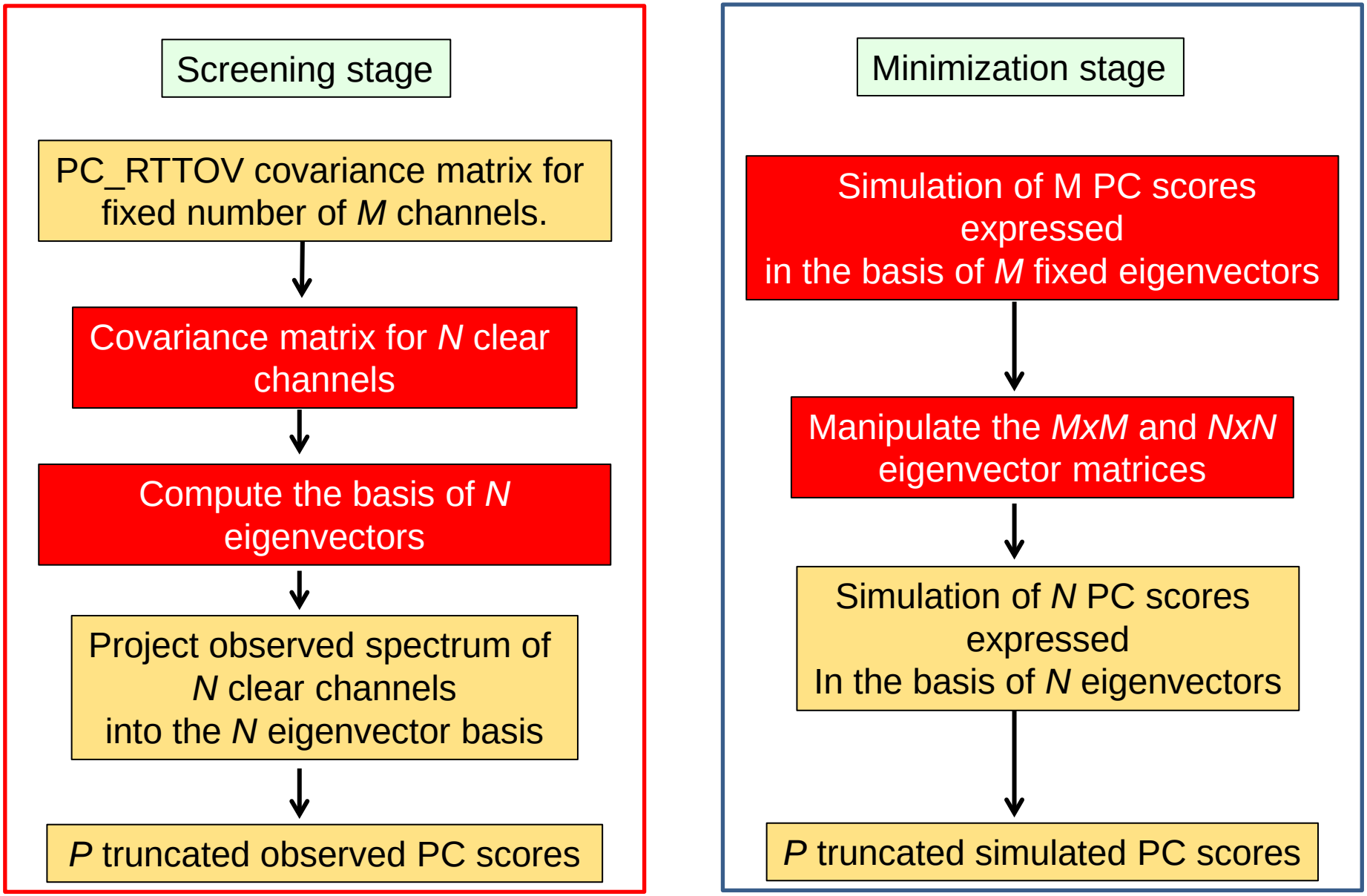
Change in the background fit to radiosonde temperature observations over the BASE system in the Southern Hemisphere



The green curve denotes results from the assimilation of 50 PCs

The blue curve denotes results from the assimilation of 305 PCs

Possible strategy for the assimilation of PC scores derived from ***clear channels***
(i.e. channels not affected by clouds)



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.

Issues we intend to address in the short term

- Account for observation error correlations in PC space (i.e. specify the full error covariance matrix rather than only the diagonal elements).

- Experiment the feasibility of assimilating PC scores derived from clear channels.