Toward the NWP assimilation of the full IASI spectrum: recent experience using principal component data

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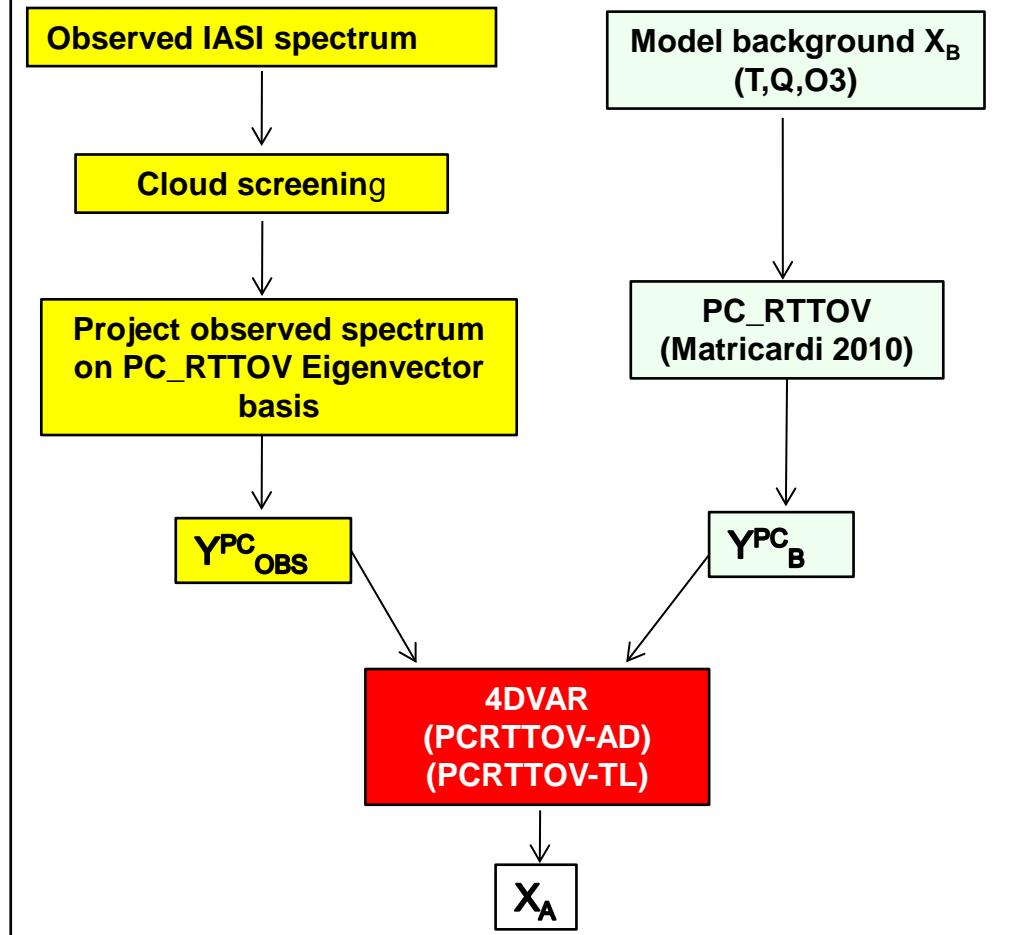
ECMWF

Shinfield Park, Reading, UK

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

Observed IASI spectrum

Cloud screening

Project observed spectrum on PC_RTTOV Eigenvector basis

Model background X_B (T,Q,O3)

PC_RTTOV (Matricardi 2010)

Y^{PC}_{OBS}

Y^{PC}_{B}

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

X_A

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:

   i) 191 long wave IASI channels used in operations (Matricardi and McNally 2013)

   ii) 305 IASI channels (Matricardi and McNally 2014, Matricardi and McNally 2015)

CURRENT SYSTEM

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 Desroziers and Hollingsworth/Lönnberg methods have been used to ***diagnose*** the full observation error covariance matrix in PC space

The Desroziers and Hollingsworth methods give an ***approximate estimate on the errors*** because they are based on assumptions that are generally incorrect

Hollingswort/Lönnberg assumptions:

i)   background errors are spatially uncorrelated
ii) observation errors are spatially uncorrelated
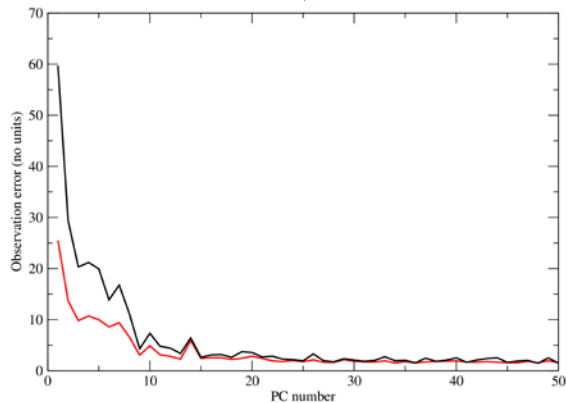iii) background and observation errors are uncorrelated.

Desroziers assumptions:

i)   background and observation errors are uncorrelated
ii) the weights that are assigned to the observations in the analysis agree with the true background and observation error covariances.

The 4D-Var assimilation of PC scores derived from 2221 and 5421 IASI channels
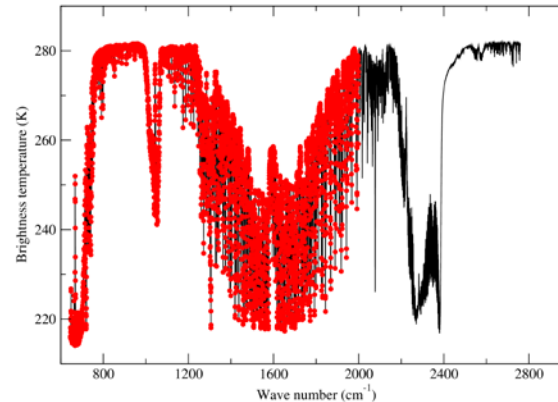
The 2221 IASI channels (26% of the total number)
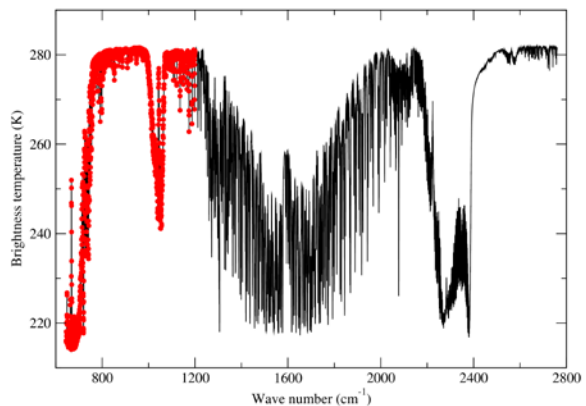
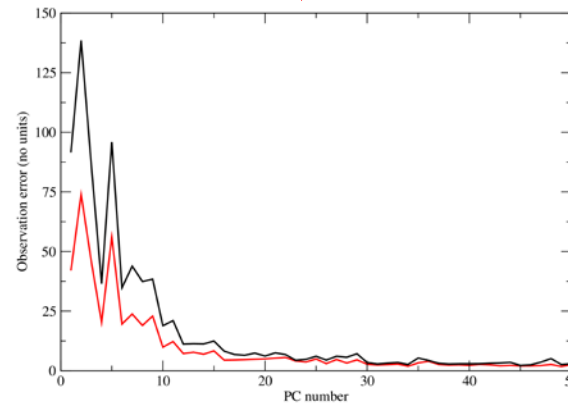In the assimilation the 2221 IASI channels are represented by 200 PC scores.

The 5420 IASI channels (64% of the total number)

In the assimilation the 5421 IASI channels are represented by 300 PC scores.

—— Standard deviation of first guess departures

—— Desroziers estimate of the error

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**: identical to BASE but additionally assimilates 200 PC scores derived from the radiances in 2221 IASI channels.

4) **PC_B1_B2** : identical to BASE but additionally assimilates 300 PC scores derived from the radiances in 5421 IASI channels.

Experiments (cycle 40R2 – T511- 137 L) are currently running and upon completion they will cover the period 1 February 2014-30 August 2014.
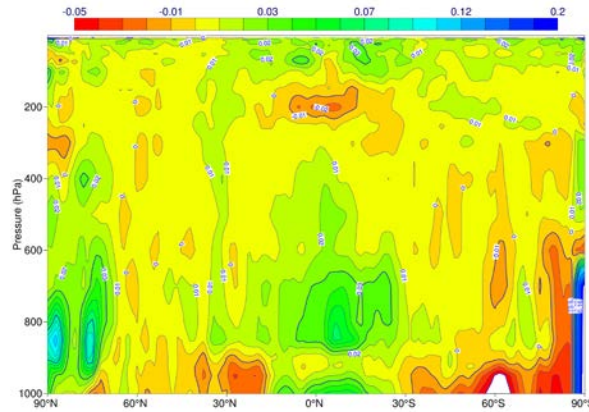
NOTE: in all experiment we assimilate only cloud-free scenes

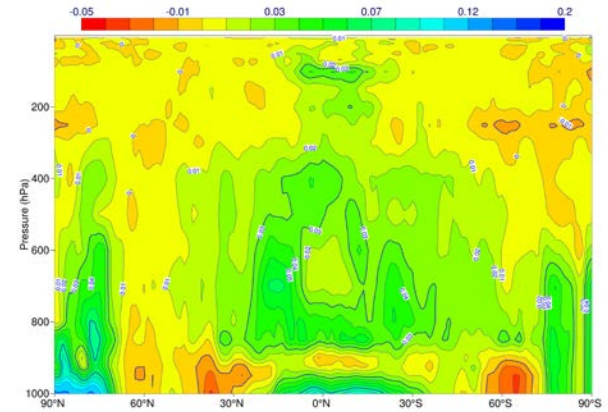Difference between zonally averaged root-mean-square temperature analysis increments
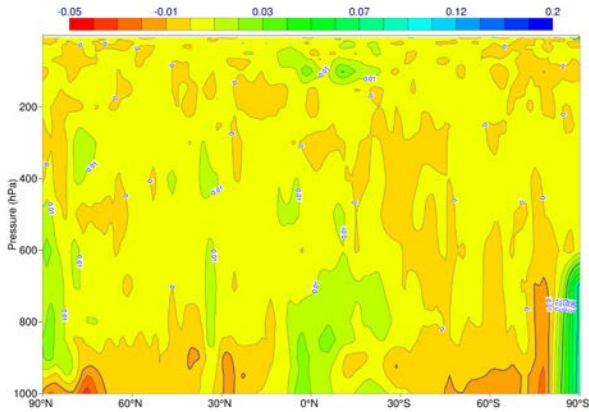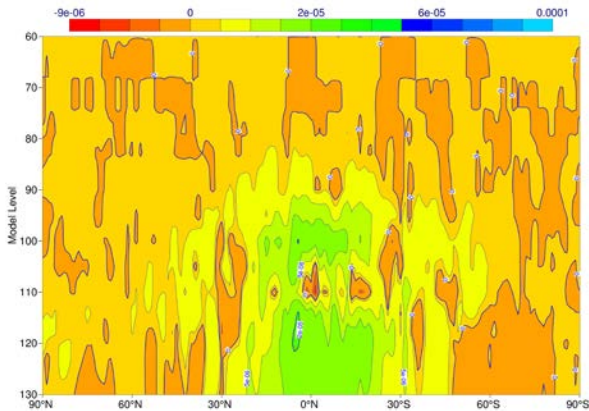
RAD-BASE

PC_B1-BASE

PC_B1_B2-BASE

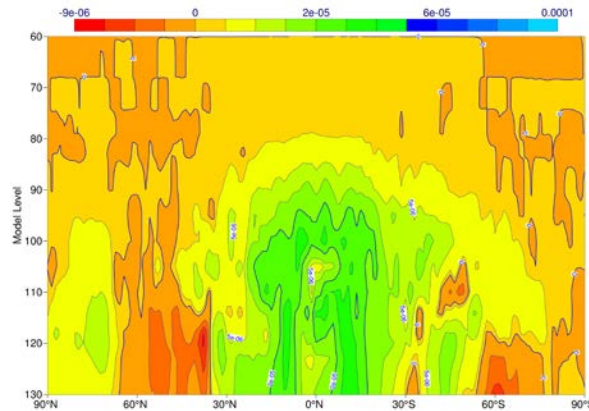Difference between zonally averaged root-mean-square humidity analysis increments
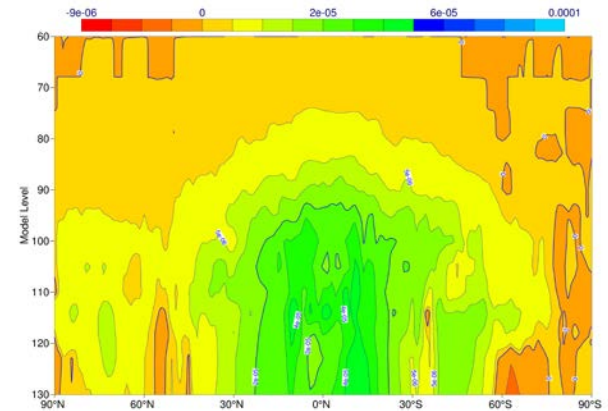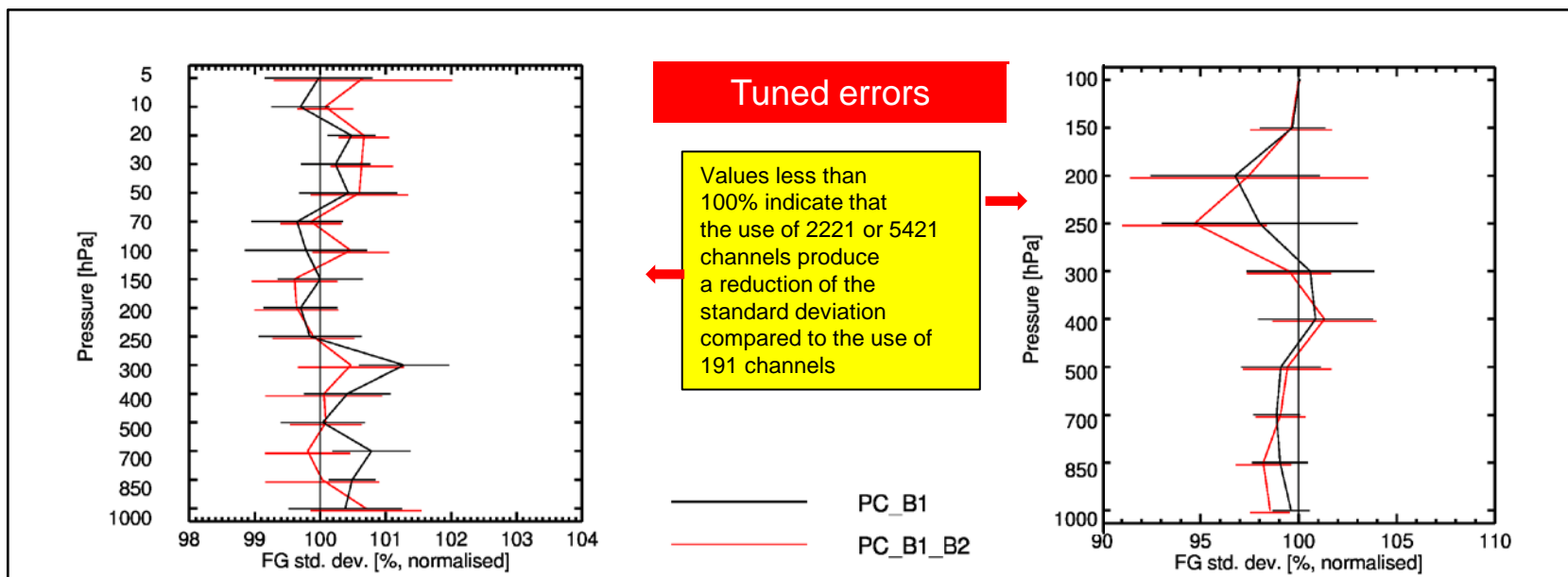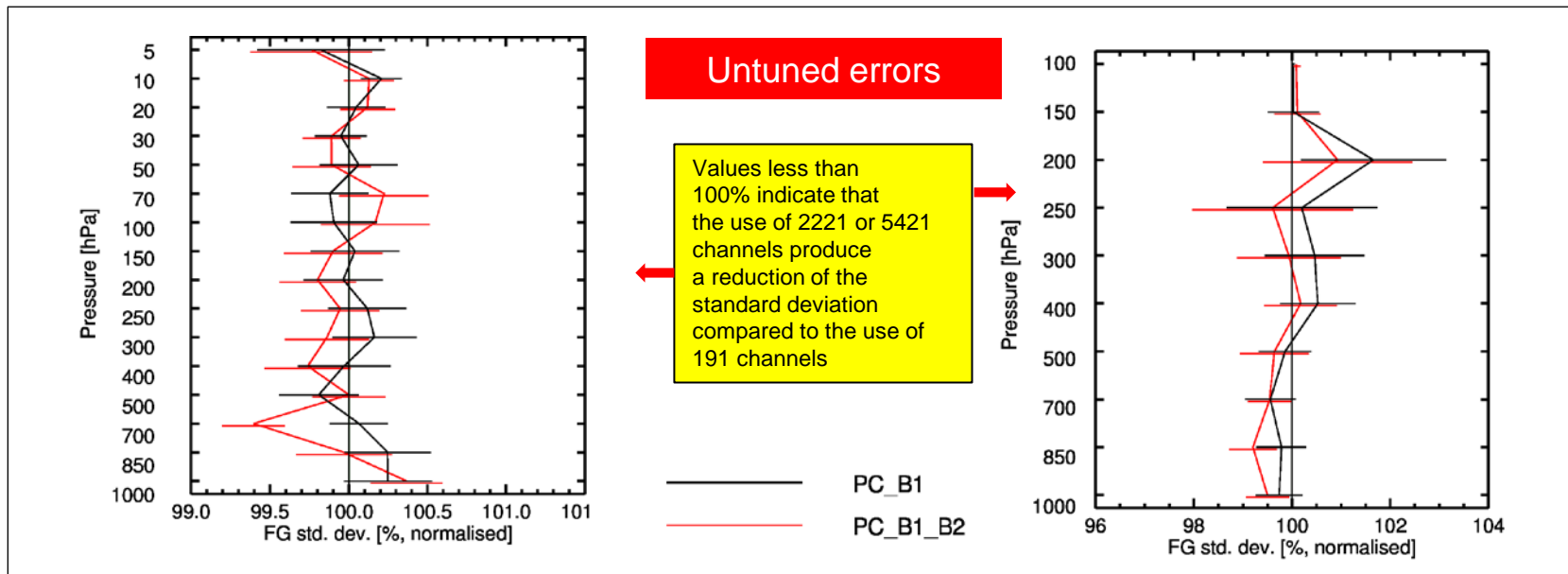
RAD-BASE

PC_B1-BASE

PC_B1_B2-BASE

The 4D-Var assimilation of PC scores derived from 2221 and 5421 IASI channels

Verification against global radiosondes: temperature

Verification against global radiosondes: humidity

Untuned errors

Values less than
100% indicate that
the use of 2221 or 5421
channels produce
a reduction of the
standard deviation
compared to the use of
191 channels

PC_B1

PC_B1_B2

Tuned errors

Values less than
100% indicate that
the use of 2221 or 5421
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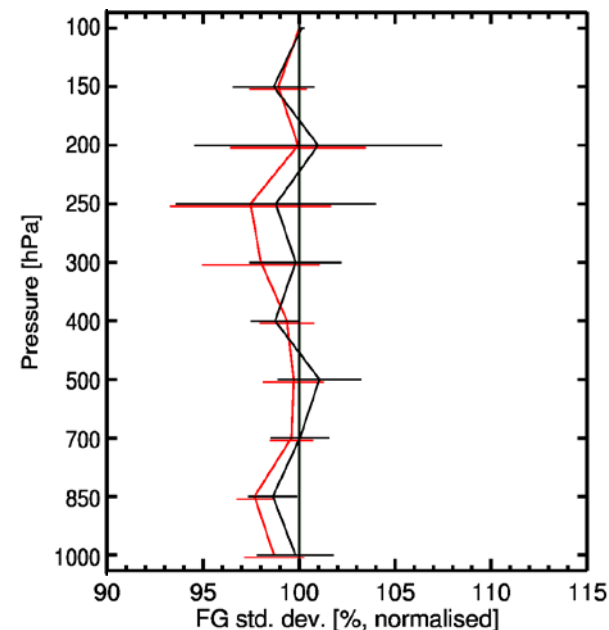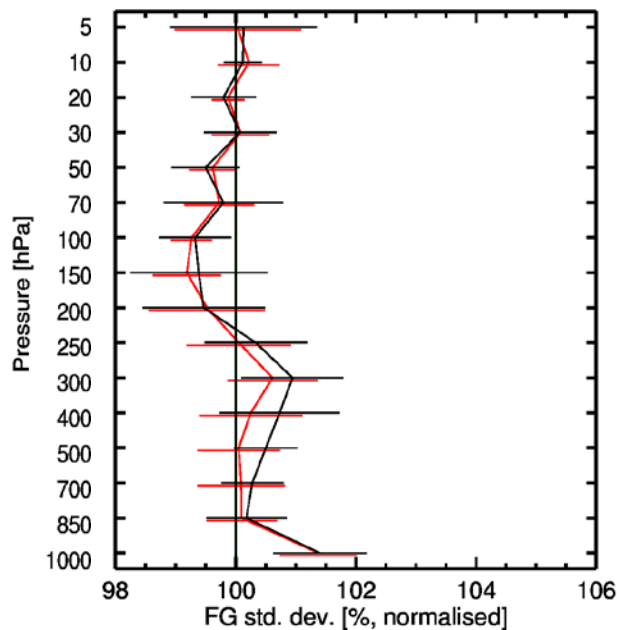191 channels

PC_B1

PC_B1_B2

The 4D-Var assimilation of PC scores derived from 2221 channels

We have inflated the diagonal elements of the error covariance matrix by a factor of 1.5

Verification against global radiosondes: temperature

Verification against global radiosondes: humidity

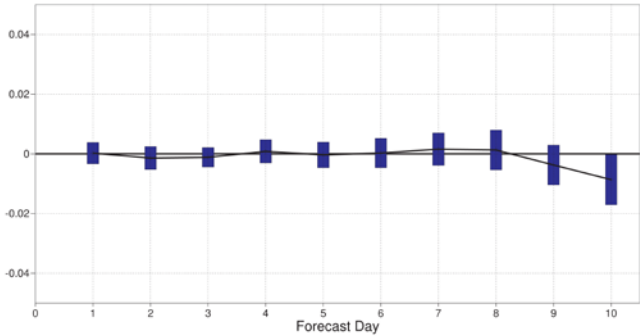Assimilation system based on 200 PCs derived from 2221 channels

PC_B1: Tuned errors

PC_B1: Inflated tuned errors

Forecast rms errors

BASE-RAD

BASE-PC_B1 (UNTUNED ERRORS)

200hPa vector wind
Tropics

Control normalised: BASE (ope) minus RAD (ope)
200hPa vector wind
Root mean square error
Tropics (lat -20.0 to 20.0, lon -180.0 to 180.0)
Date: 20140301 00UTC to 20140728 00UTC
00UTC T+24 T+48 ... T+240 | Confidence: [95.0] | Population: 150

Control normalised: BASE (ope) minus PC_B1 (ope)
200hPa vector wind
Root mean square error
Tropics (lat -20.0 to 20.0, lon -180.0 to 180.0)
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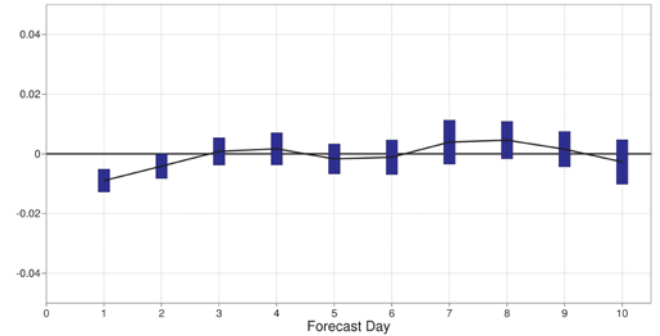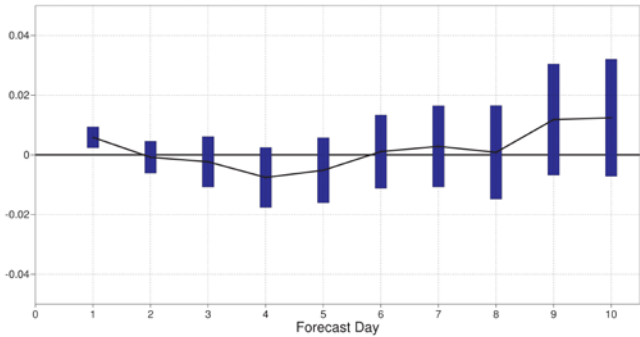00UTC T+24 T+48 ... T+240 | Confidence: [95.0] | Population: 150

Positive impact

Negative impact

500hPa Geopotential
Southern Hemisphere
Extratropics

Control normalised: BASE (ope) minus RAD (ope)
500hPa geopotential
Root mean square error
SHem Extratropics (lat -90.0 to -20.0, lon -180.0 to 180.0)
Date: 20140301 00UTC to 20140728 00UTC
00UTC T+24 T+48 ... T+240 | Confidence: [95.0] | Population: 150

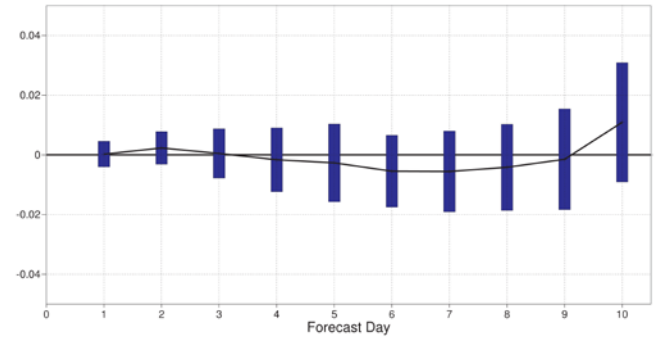**Control normalised: BASE (ope) minus PC_B1 (ope)**
500hPa geopotential
Root mean square error
SHem Extratropics (lat -90.0 to -20.0, lon -180.0 to 180.0)
Date: 20140301 00UTC to 20140728 00UTC
00UTC T+24 T+48 ... T+240 | Confidence: [95.0] | Population: 150

SUMMARY

- The PC based global 4D-Var assimilation system has evolved from a prototype to an operationally viable assimilation system. Current work is focused on 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 the temperature and humidity analysis

FUTURE WORK

- We are planning to experiment a PC error covariance matrix based on a physical approach (see presentation 5.2 by Hyong).

- We are going to work 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.

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

Control normalised: g6kj (ope) minus gdpf (ope)
500hPa geopotential
Root mean square error
NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)
Date: 20140301 00UTC to 20140730 00UTC
00UTC T+24 T+48 ... T+240 | Confidence: [95.0] | Population: 130
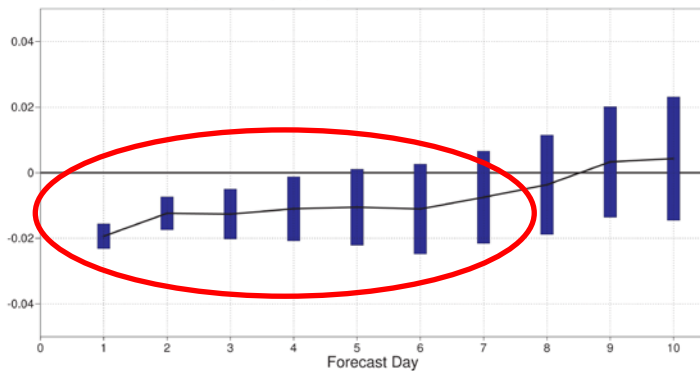
Restriction to clear spectra improves the forecast

Restriction to clear spectra degrades the forecast

Control normalised: g6kj (ope) minus gdpf (ope)
500hPa geopotential
Root mean square error
SHem Extratropics (lat -90.0 to -20.0, lon -180.0 to 180.0)
Date: 20140301 00UTC to 20140730 00UTC
00UTC T+24 T+48 ... T+240 | Confidence: [95.0] | Population: 130