Current status of the direct assimilation of Principal Component scores in the ECMWF NWP system

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■ A principal component based version of RTTOV has been developed with the aim of :

    1)   Investigate the direct assimilation of the Principal Component (PC) scores of IASI radiances into the ECMWF NWP system.

    2)   Improve the computational efficiency of RTTOV.

■ The principal component based version of RTTOV allows the fast computation of PC scores and/or IASI Level-1C and AIRS radiances.

■ By using PC analysis we can replace a large number of correlated variables (e.g. radiances computed or observed for a number of different atmospheric situations), with a smaller number of orthogonal variables (called principal components) that still contain most of the information in the original data set.

■ If we consider a data set of n observations on m radiances x_1, x_2,….x_m, the radiances for the jth observation can be expressed as a linear combination of the principal component scores z (the values of the principal component variables for the jth observation are known as principal component scores) :

$$x_{i,j} = \sum_{l=1,m} a_{l,i} z_{j,l} \qquad i = 1, m$$

Here the a's denote the eigenvectors of the covariance matrix of x_1, x_2,….x_m.

■ *If we can establish a direct or indirect statistical relationship between the principal component scores and the atmospheric situations included in a training set, we can then generate a radiance spectrum for any given input atmospheric profile.*

■ The development of the PC based RTTOV has involved the following stages:

1) The selection of a training set of atmospheric profiles.

2) The computation of accurate line-by-line radiances for the atmospheric situations included in the training set.

3) The computation of the covariance matrix of the simulated spectra and subsequent computation of the principal component scores.

4) *The formulation of a prediction scheme for the computation of the principal component scores.*

- We selected a total of 1039 profiles of temperature, water vapour and ozone over the sea. In addition to the profiles of temperature and absorber amount, the 1039 profile data set contains ancillary information on surface temperature, skin temperature, surface pressure and wind speed at 10m.

- The line-by-line database used in this study was calculated using version 11.1 of the LBLRTM model in conjunction with a model of the surface emissivity that takes into account the effect of reflected emission from the surface.

> The line parameters were obtained by merging data from HITRAN_2000, HITRAN_2004/2006 and GEISA 2003.

> Radiances were computed for each atmospheric profile and five surface zenith angles, namely, the angles for which the secant has equally spaced values from 1 to 2. This makes a total of 5195 observations for each channel.

The radiance reconstruction error for IASI as a function of the number of truncated principal components

Dotted curve is instrument noise
Solid curve is reconstruction error
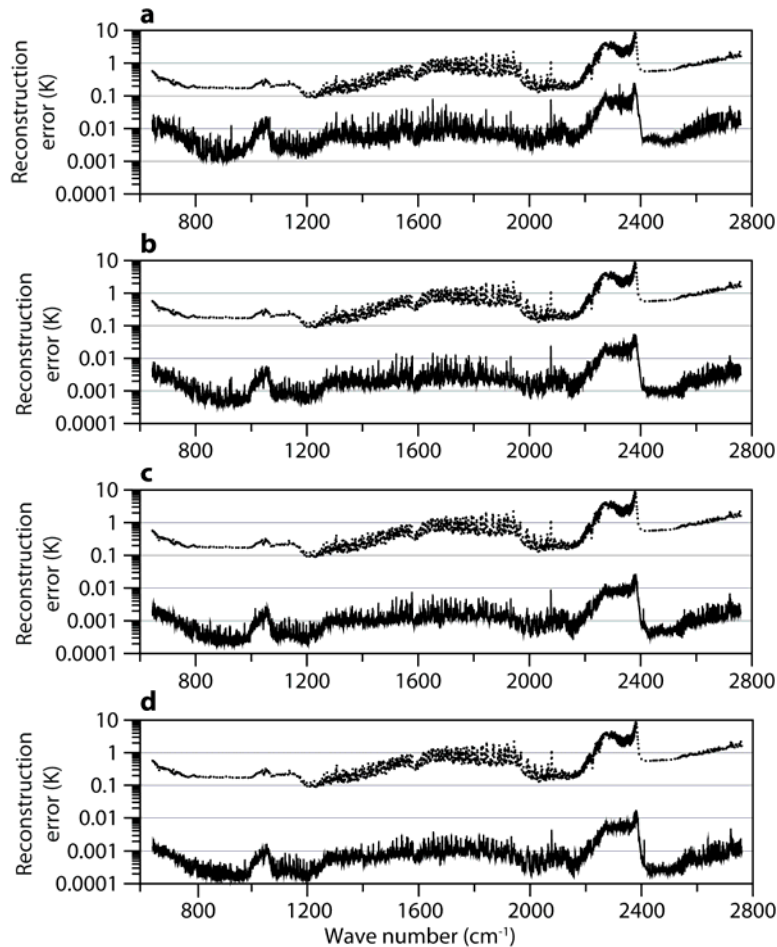
100 PC's

200 PC's

300 PC's

400 PC's

- In the PC based RTTOV, the simulated PC scores are computed using a linear regression scheme where the independent variables (predictors) are a selected number of polychromatic top of the atmosphere radiances computed using the standard RTTOV fast transmittance model.

- To determine the predictors we arrange the channels in clusters that contain highly correlated channels (McMillin and Goldberg, 1997). The lead channel in each cluster (i.e. the channel with the largest standard deviation) is used as a predictor in the regression.

- To choose the optimal value of the correlation threshold we finely tune the threshold to the value that allows the best fit to the line-by-line radiances.

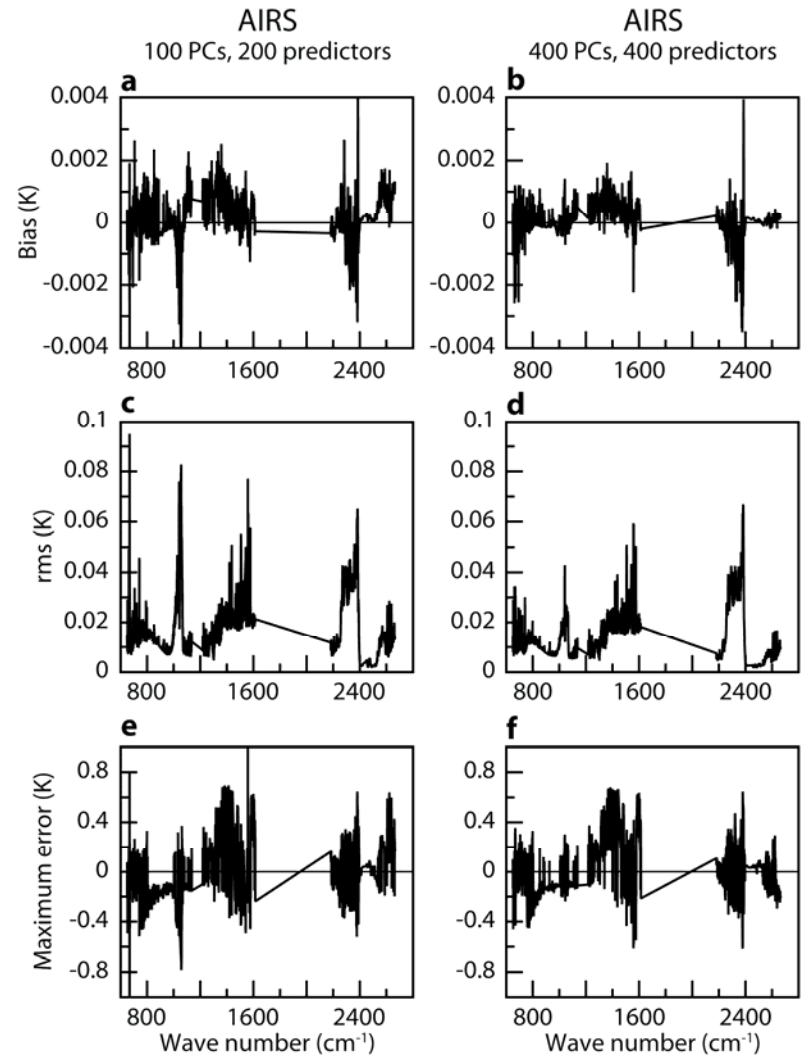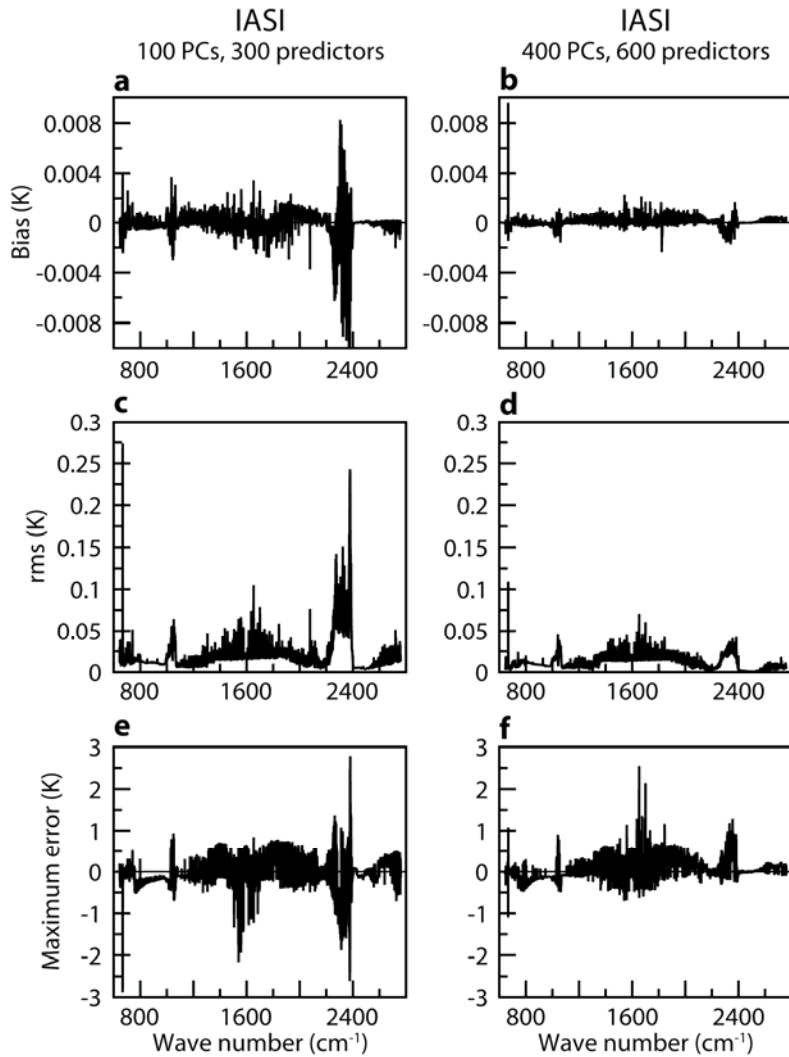The fitting rms error as a function of the correlation threshold
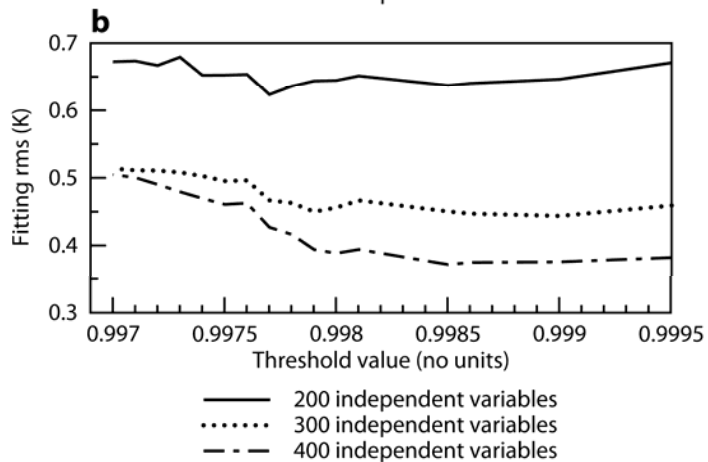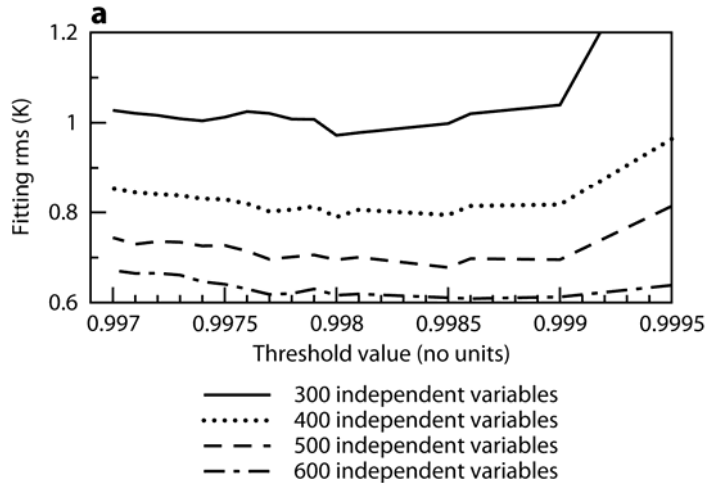
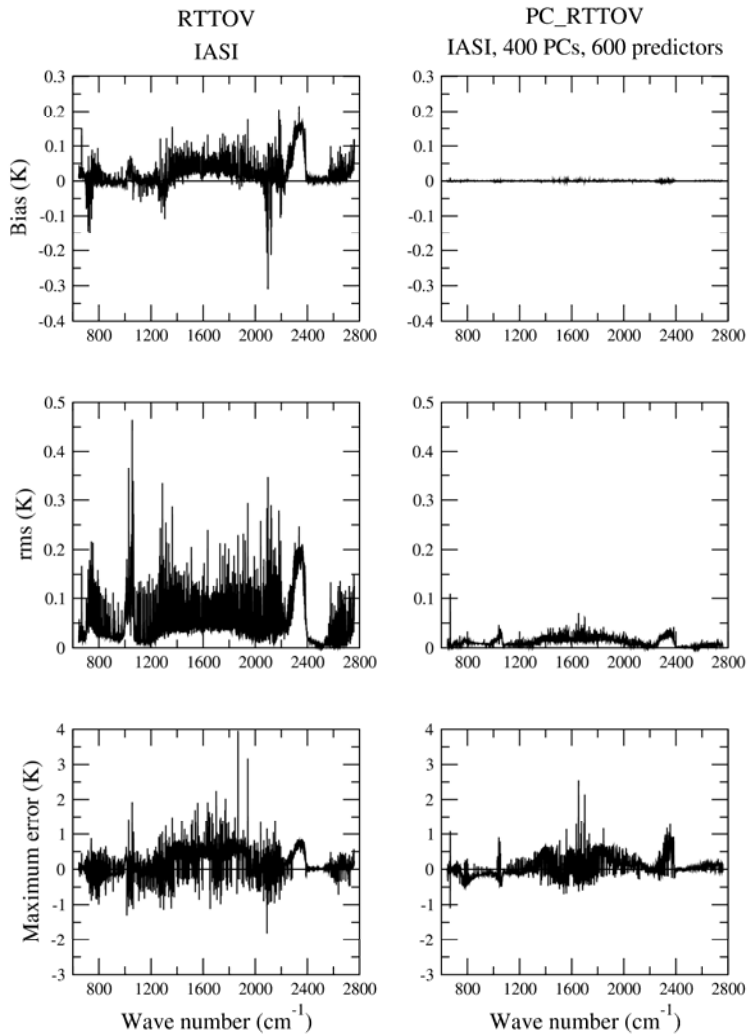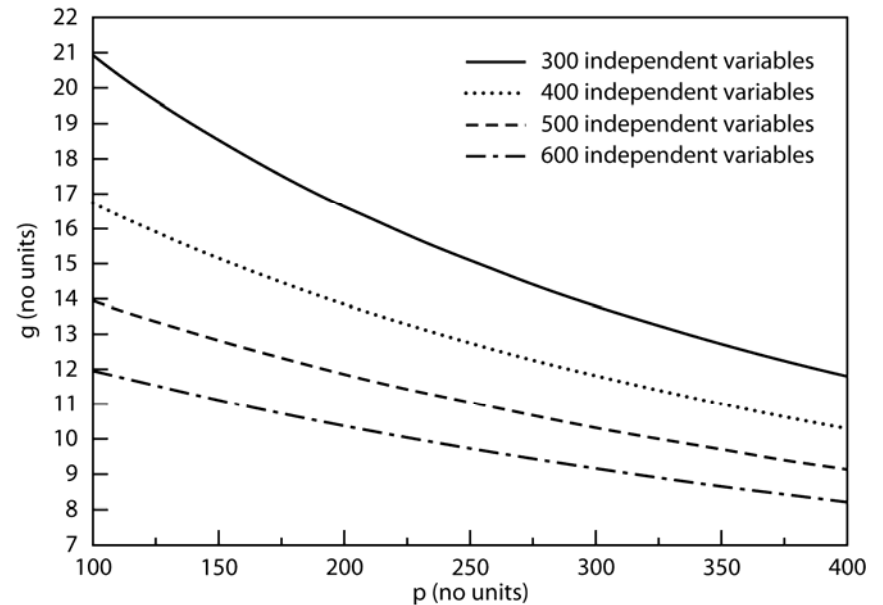The fitting rms error as a function of the number of predictors and the number of PC's
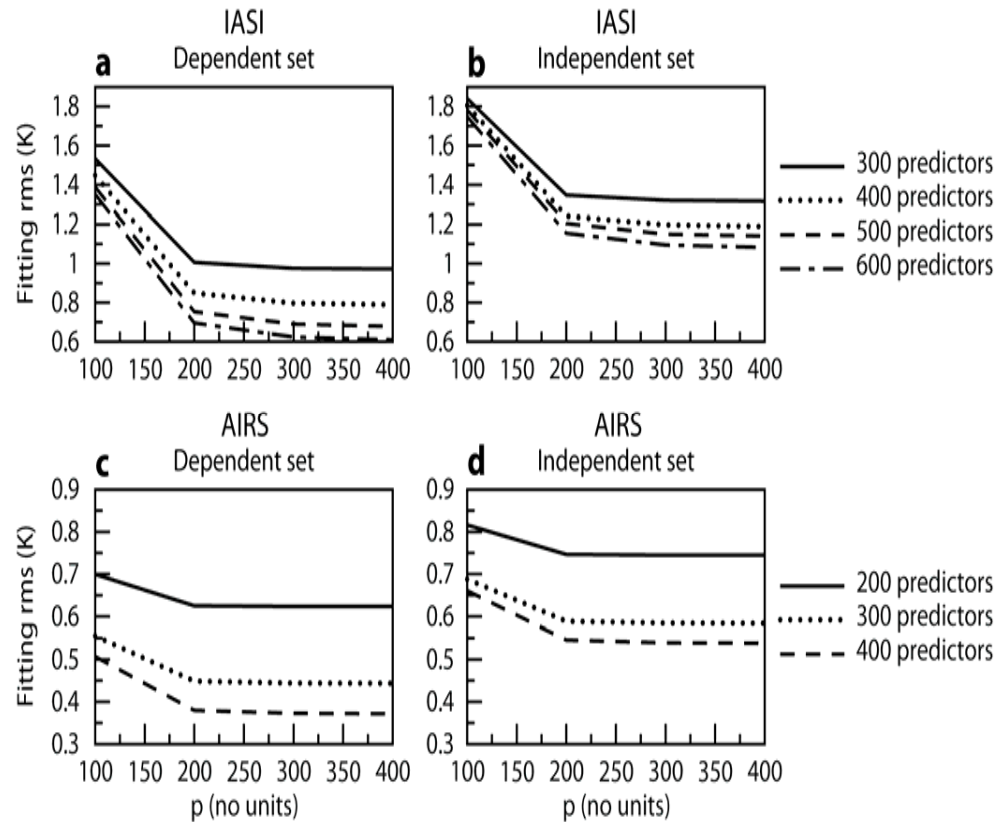
Fit of PC_RTTOV to line_by_line radiances: independent profiles

Fit of RTTOV and PC_RTTOV
to LBL radiances: independent profiles

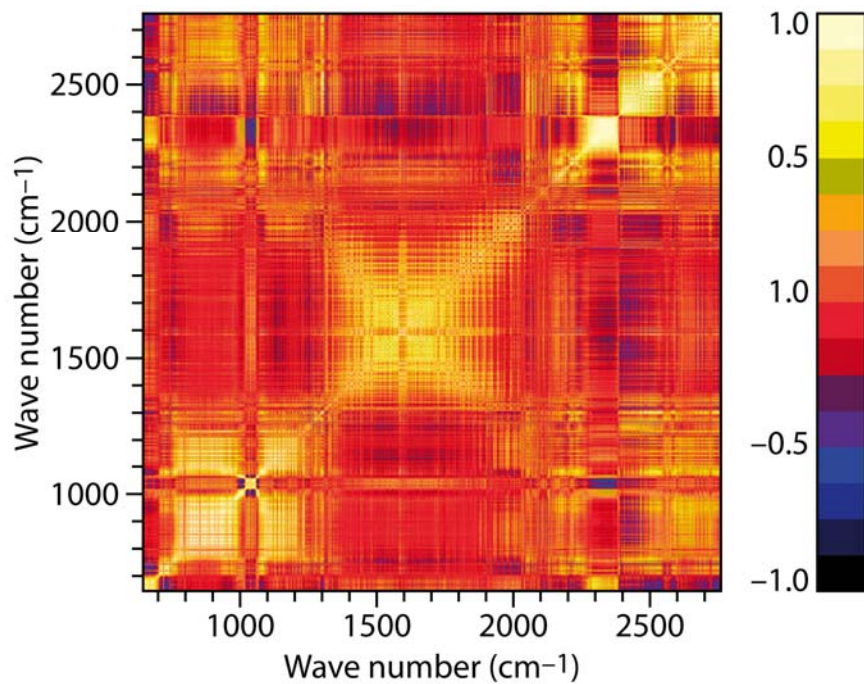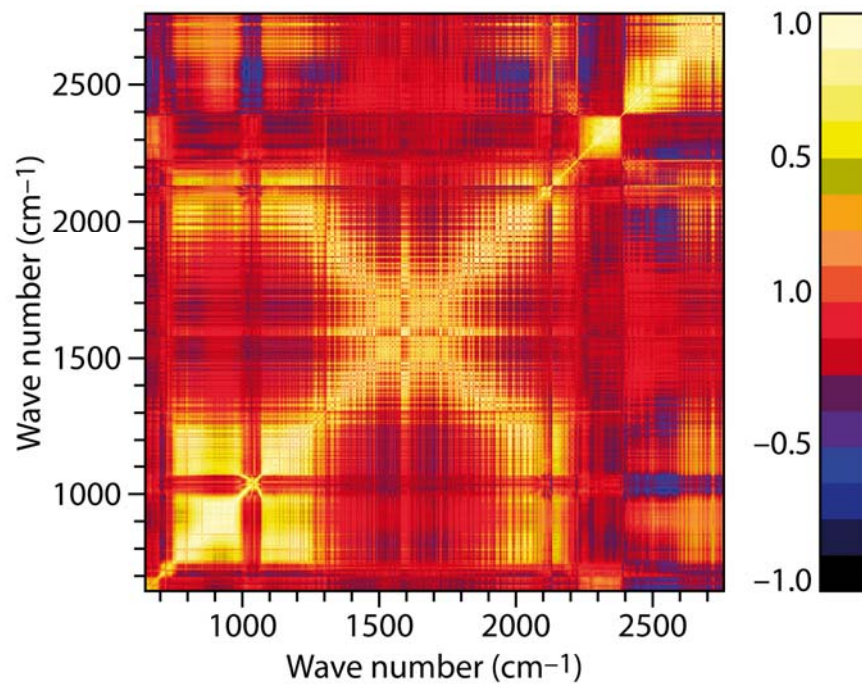Computational gain of PC_RTTOV over RTTOV

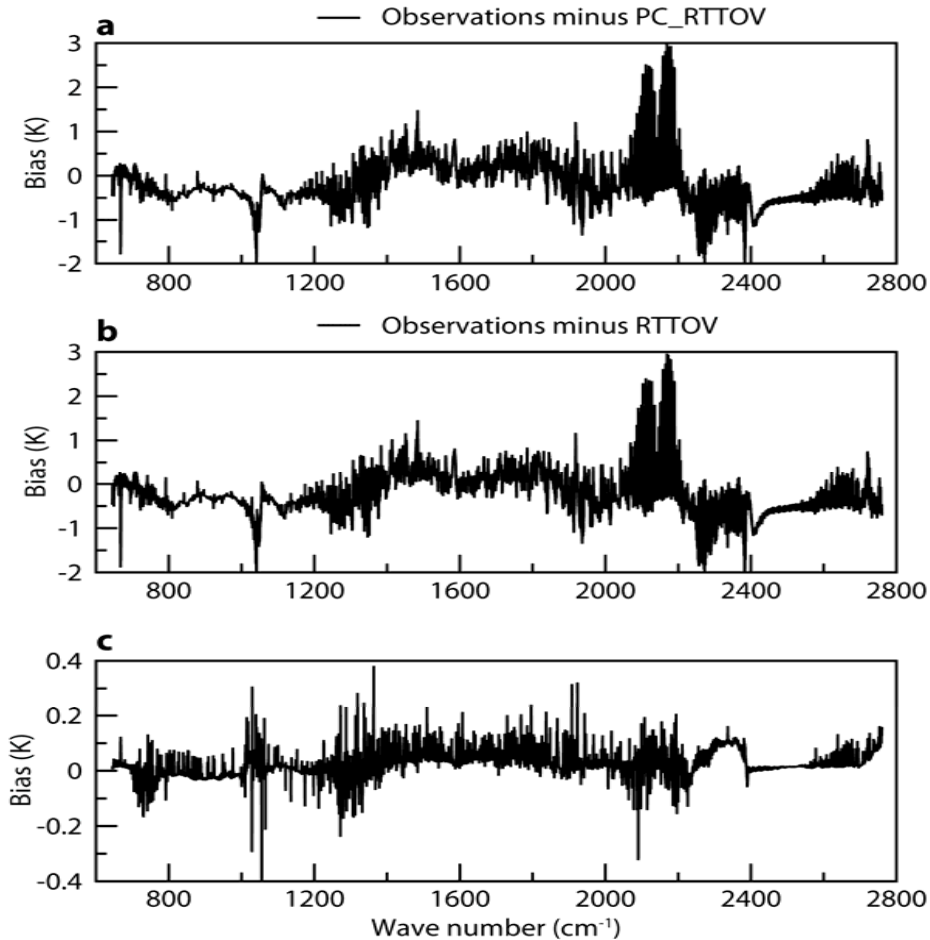# Fast model error correlation matrix for IASI: 5195 profile independent set

RTTOV

PC_RTTOV

■ The PC_RTTOV has been implemented in the ECMWF Integrated Forecasting System (IFS) and extensive trials have been carried out to check the correct functionality of the IFS-PC_RTTOV system.

IASI ten day monitoring experiment

■ The operational ECMWF cloud detection scheme requires the availability of parameters that cannot be obtained from PC_RTTOV (e.g. the radiance at the interface of each atmospheric layer).

■ A new cloud detection scheme has been developed and implemented in the IFS to be used in conjunction with PC_RTTOV for the direct assimilation of PC scores.

■ The new cloud scheme detects clear FOVs rather that clear channels and is based on three separate tests. A FOV is declared clear only if the three tests are passed simultaneously.

The three cloud tests consist of:

- A test based on the autocorrelation and cross correlation between the observed spectrum and the PC_RTTOV simulated spectrum in the range between 800 and 900 cm-1.

- A window channels test based on two "super channels" in the spectral intervals between 899.5-900.5 cm^{-1} and 1167.5-1168.5 cm^{-1}. This test is used to detect high cirrus clouds.

- A test based on the difference between simulated and observed radiances for a number of channels in the 10 μm window region.

Four day IFS monitoring experiment
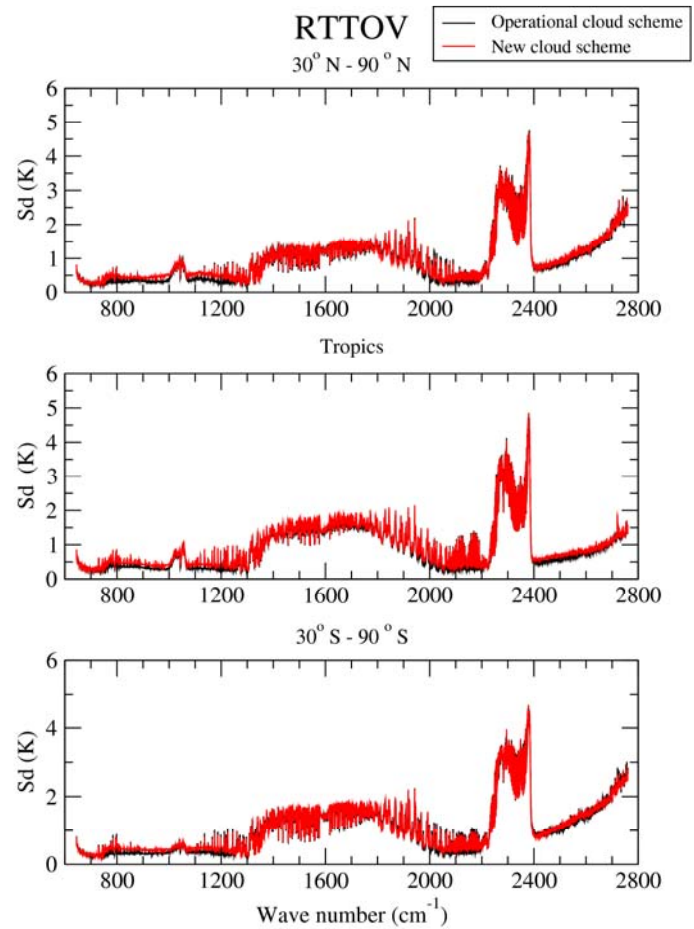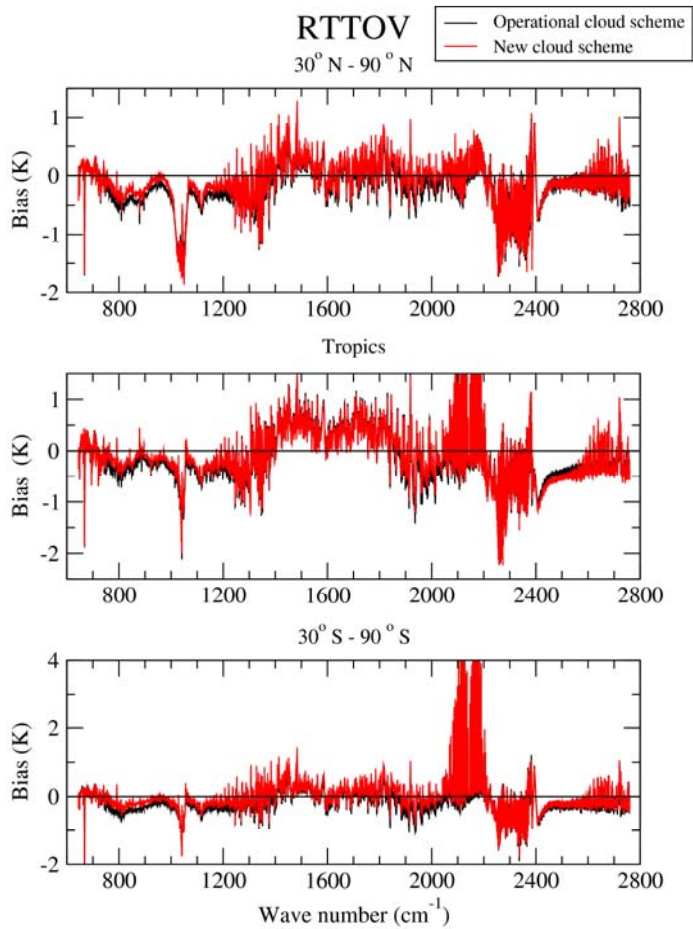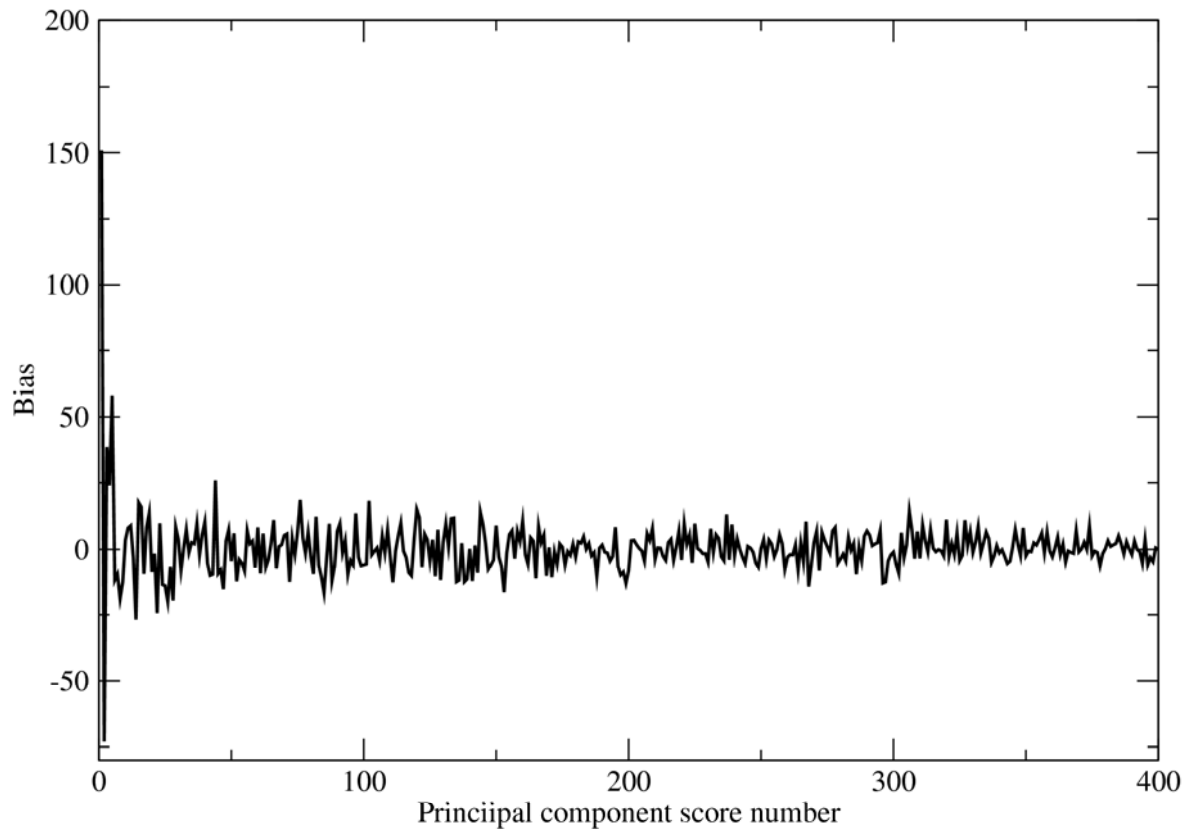
Four day monitoring experiment

Sample size

Reference channel
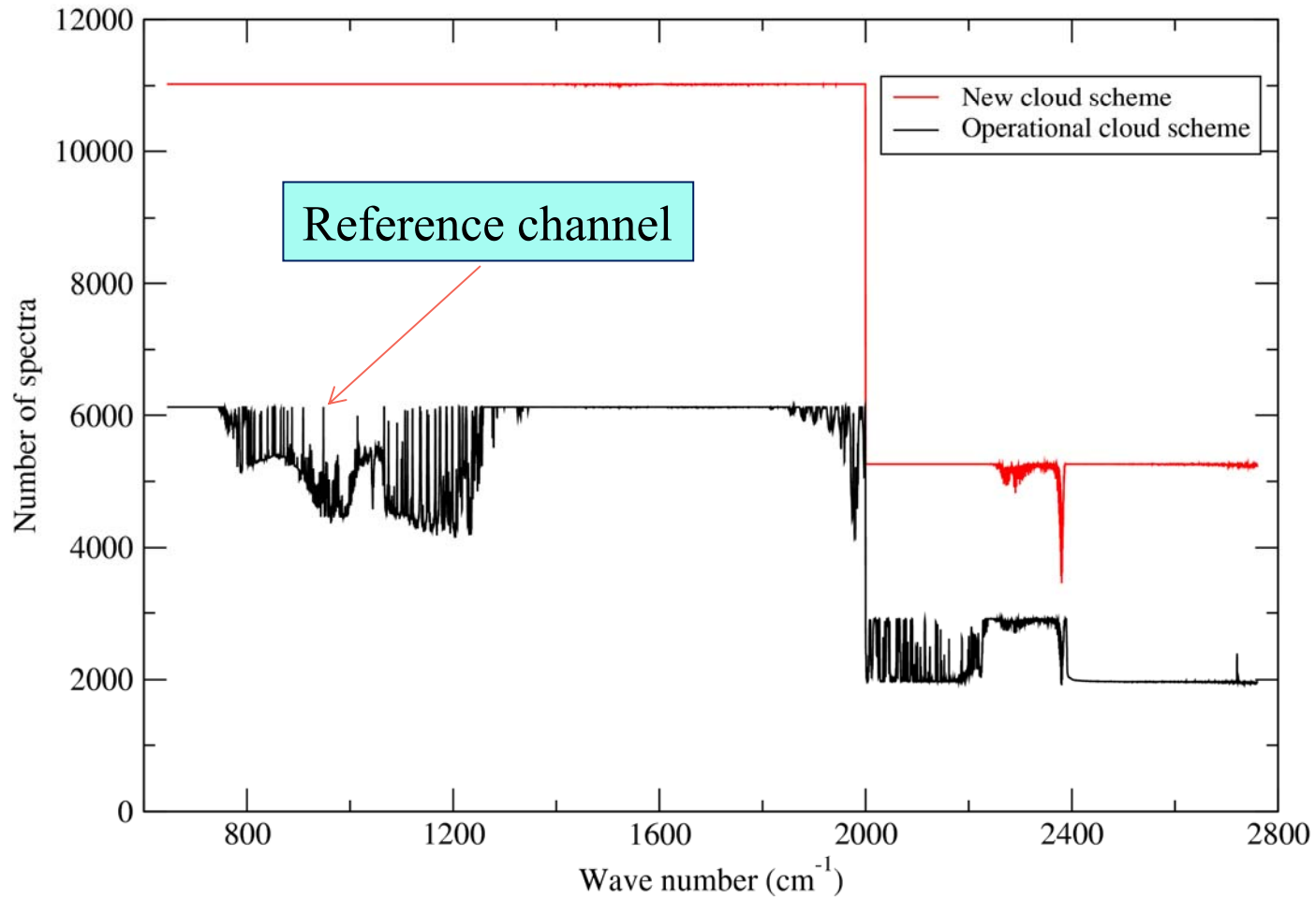
Four day monitoring experiment

Mean value of the difference between PC scores simulated by PC_RTTOV
And PC scores obtained by projecting the observed radiances on the PC_RTTOV
Eigenvector basis

- We are running monitoring experiments to accumulate a robust sample of the principal components departure statistics. The results of these experiments will be used to study the behaviour of the simulated and "observed" Principal Components and they will serve as a basis for the estimation of the Principal Components observation error term.

- We are currently evaluating the PC_RTTOV approach by using it for the direct assimilation of IASI radiances (i.e. using PC_RTTOV is radiance simulation mode). Once all quality checks have been passed satisfactorily, we can then move to the next stage and start the first preliminary trials involving the direct assimilation of PC scores.