Analysis of MIPAS Residual Spectra

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ABSTRACT

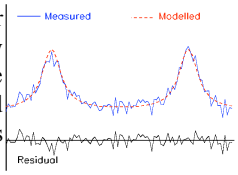
Residual spectra are the difference between spectra measured by the instrument and spectra generated by the retrieval forward model at the final iteration.

Ideally, these should contain only random measurement noise but in practice a number of features are present indicating systematic errors either in the forward model or the instrument characterisation. Residual spectra for each microwindow are included in the distributed MIPAS Level 2 product.

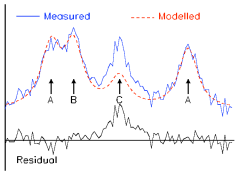
Residual and Error Correlation (REC) analysis is a statistical technique for analysing such data. The priniciple is to identify correlations between persistent features in the residual spectra and the signatures expected from known sources of error such as calibration uncertainties or interference from non-retrieved species. This is now performed routinely as part of the monitoring of MIPAS data quality.

REC ANALYSIS

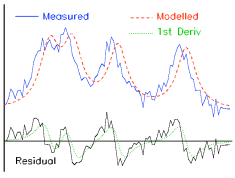
In the ideal case after convergence the only difference between the measured spectrum and the forward model is random noise



More typically there will be some additional features due, for example, to imperfectly modelled contaminants



Imperfect calibration may also introduce characteristic residual signatures associated with the instrument line shape

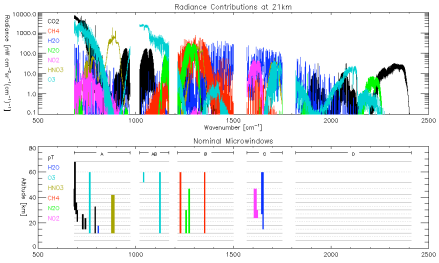


REC analysis attempts to model the residual spectra **y**, covariance $\mathbf{S}_y$, in terms of a set of precomputed error spectra **K** whose magnitudes are represented by the set of coefficients **x** obtained by minimising

$$\chi^2 = (\mathbf{y} - \mathbf{K}\,\mathbf{x})^T\,\mathbf{S}_y^{-1}\,(\mathbf{y} - \mathbf{K}\,\mathbf{x}) + \mathbf{x}^T\mathbf{x}$$

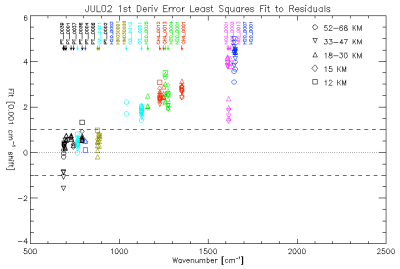
where $\mathbf{x}^T\mathbf{x}$ is an optional *a priori* constraint assuming that the error spectra represent 1σ perturbations (i.e. covariance **I**) and that the *a priori* estimate of **x** is zero.

MIPAS MICROWINDOWS

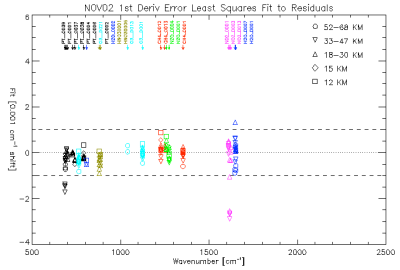


The figure above shows the principle emitting molecules in the MIPAS spectral range together with the locations of microwindows selected for the ESA retrievals. Each microwindows has a maximum width of 3cm^{-1} (narrower than shown) and is applied over a subset of the tangent altitude range. Residual spectra are generated only within each microwindow.

SPECTRAL CALIBRATION



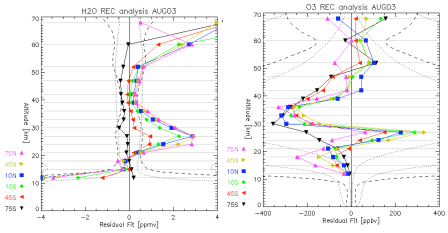
The figure above shows an early result obtained using the REC analysis which was to identify a linear shift in the MIPAS spectral calibration. Each point represents the best fit of the 1st derivative signature to the residuals in a particular microwindow and tangent altitude averaged for July 2002. By Nov 2002 the problem had been rectified (below) and spectral calibration errors are now generally within the specified uncertainty ±0.001cm^{-1} indicated by the dashed lines



Apart from the trend with wavelength, note also a small trend with altitude. Some of this (0.0002cm^{-1}) is attributable to the Doppler shift caused by the relative motion of the high and low tangent points

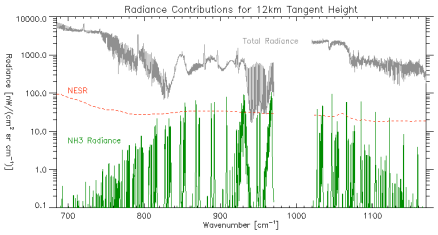
RETRIEVED SPECIES

For the retrieved species the residuals should be close to zero. By converting residual signatures (radiances) to equivalent tangent point concentrations (ppmv) it is possible to summarise the latitudinal and vertical fit for each molecule's spectra across all microwindows in terms of a perturbation profile.

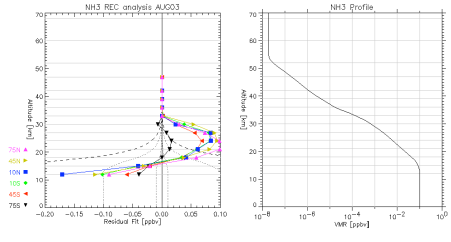


Water Vapour (left) and Ozone (right) residual spectra for August 2003 converted to equivalent concentration. Positive values are consistent with *underestimating* the true atmospheric concentration.

CONTAMINANT SPECIES



Ammonia (NH3) is one of several molecules which contribute to the infrared spectrum but are not retrieved by the ESA processor. These are included in the forward model calculations assuming a climatological profile. Analysis of residual ammonia signatures in the MIPAS microwindows (below left) indicates that the climatology (below right) may overestimate the true concentration at low altitude but underestimate by up to 0.1ppbv at 25km



Monthly REC analyses which form part of the routine monitoring of MIPAS data quality can be found on http://www.atm.ox.ac.uk/group/mipas/rec