Precision Validation of MIPAS-Envisat products

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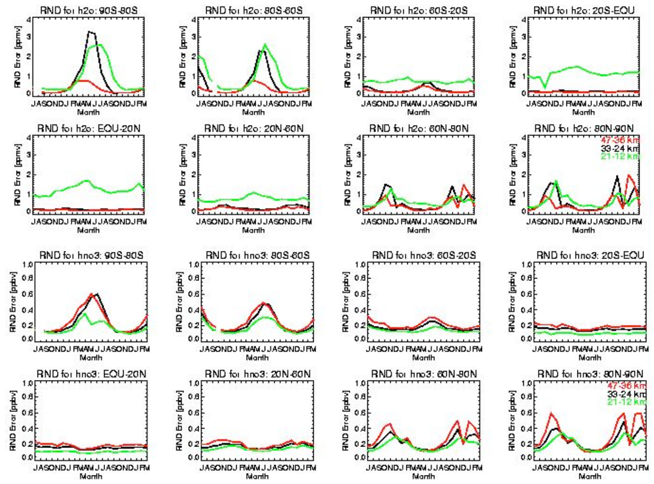
This paper discusses the variation and validation of the precision (defined as the dispersion of an ensemble of retrievals obtained from measurements of the same atmospheric state) of the ESA L2 products from the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS).
The MIPAS L2 products contain estimates of random error derived from the propagation of the radiometric noise through the retrieval. The noise itself varies with time, steadily rising between decontamination events, but its contribution to the L2 random error also depends on the atmospheric temperature, which controls the total radiance received. Hence, for all species, the random error varies latitudinally/seasonally with atmospheric temperature, with a superimposed time dependence on decontamination events.
The precision validation involves comparing two MIPAS retrievals at the intersections of ascending/descending orbits. For every 5 days per month of high resolution MIPAS operation, the standard deviation of the statistic of the matching profile pairs is computed and compared with the predicted random error given in the MIPAS Offline L2 data. Even taking into account the propagation of the pressure-temperature retrieval errors into the VMR retrieval, the observed scatter is usually a factor 1-2 larger than the predicted error. This is thought to be due to effects such as horizontal inhomogeneity of the atmosphere.

MIPAS

MIPAS (Michelson Interferometer for Passive Atmospheric Sounding) is a high resolution Fourier transform spectrometer flying on board ESA Envisat satellite. MIPAS measures infrared (685-2410 cm^{-1}) atmospheric limb emission spectra with a spectral resolution of 0.025 cm^{-1}. MIPAS observes sequences of spectra at different limb heights (6-68 km) to allow for the retrieval of species concentration profiles. The instrument has been operating at a reduced spectral resolution of 0.0625 cm^{-1} since January 2005, following problems with the interferometer slide mechanism. For the high-resolution mission ESA have processed pT (pressure-temperature) and 6 "key species" (H_2O, O_3, HNO_3, CH_4, N_2O and NO_2).

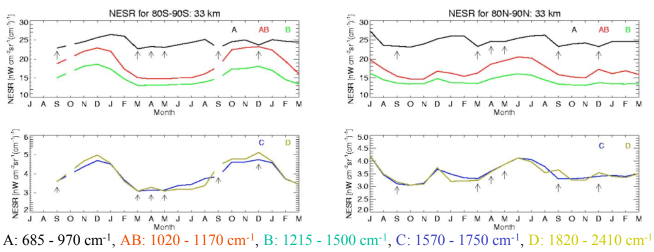
Predicted Random Error

The main source of the random error of the ESA L2 Offline MIPAS profiles is the noise error due to the mapping the radiometric noise in the retrieved profiles. This predicted random error is proportional to the NESR (Noise Equivalent Spectral Radiance) and inversely proportional to the Planck function (therefore atmospheric temperature). Another contribution to the predicted random error for the species retrieval is given by the propagation of the pressure-temperature retrieval errors into the VMR retrieval.

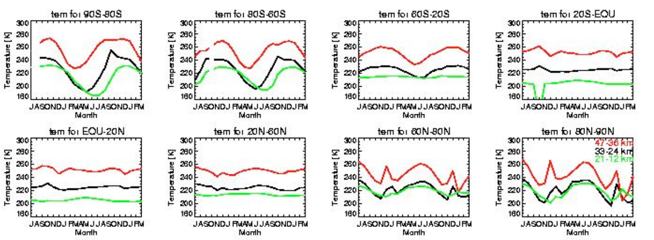


Predicted Random Error time series:

The predicted random error given in the MIPAS Offline L2 data has been averaged for every 5 days per month of high resolution MIPAS operation.
The figures show an example for H_2O (top) [ppmv] and HNO_3 (bottom) [ppbv] from July 2002 to March 2004, split in eight latitude bands. The gaps in the southern hemisphere in July-August 2002 and October 2002 are caused by missing Antarctic L2 profiles. All other target species present a similar behavior with time. The predicted random error shows a distinct peak in the polar winter cases for the three height ranges in both hemispheres. The North polar winter shows a sharp dip in the middle of the peak probably corresponding to a stratospheric warming in December 2003.



A: 685 - 970 cm^{-1}, AB: 1020 - 1170 cm^{-1}, B: 1215 - 1500 cm^{-1}, C: 1570 - 1750 cm^{-1}, D: 1820 - 2410 cm^{-1}

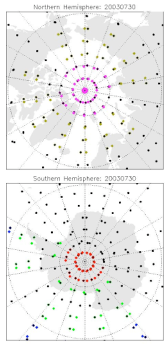


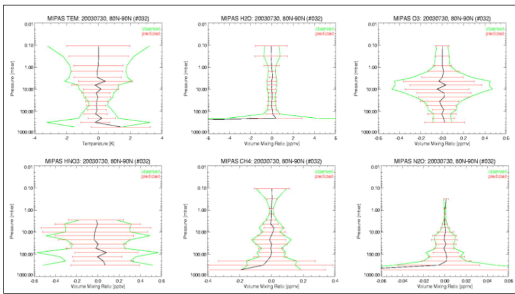
NESR and Temperature time series

The NESR varies with time, steadily rising between decontamination events (shown by arrows in top panels). The effect of this ice decontamination is a reduction of the gain increase and of the noise level. This time dependence contribution to the predicted random error also depends on the atmospheric temperature, which controls the total radiance received.
The temperature time series explains reasonably well the time series of the predicted random error for both hemispheres. The increase of random error at polar winters corresponds to decrease of temperature.

Validation

The precision of the retrievals is defined as the dispersion of an ensemble of retrievals obtained from measurements of the same atmospheric state.
In practice MIPAS does not make repeated measurements of the same limb path, an approximation is available from the pairs of measurements located at the intersections of the MIPAS viewing tracks. Therefore the precision of the retrievals can be estimated by examining these pairs of collocated measurements.
Profile locations were matched to within 300 km in distance for every 5 days per month. Limiting the comparisons of profile locations to 6 hours time difference and 300 km horizontal difference produces regular matches at two latitudes, near the poles, in the 80S-90S and 80N-90N regions.
Extending the comparisons to 12 hours time difference produces matches at three additional latitudes in the regions 20S-60S, 60S-80S and 60N-80N.
In order to check the actual scatter of the measurements, where orbital tangent tracks intersect, the standard deviation of the ensemble of profile pairs is compared to the predicted random error given in the L2 data. The predicted random error takes into account also the pT error contribution for the species VMR.

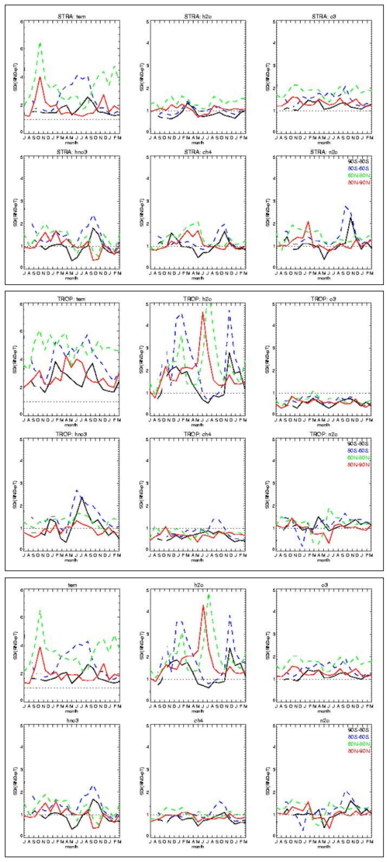




Example of polar summer comparisons at 80N - 90N latitudes for 30 July 2003.
It shows comparisons for temperature (top left), H_2O (top centre), O_3 (top right), HNO_3 (bottom left), CH_4 (bottom centre) and N_2O (bottom right), but NO_2 since for NO_2 there is a large diurnal difference at the intersections of any two orbits.
The black line is the bias between the matched pairs profiles, the red bars are the predicted scatter (pT error contribution included for VMR plots) and the green line is the observed scatter.

Time series of observed scatter over predicted scatter

In order to compare the time series of the observed scatter in the measurements with the predicted random error, the ratio of the statistic of observed scatter over the predicted random error is computed for the four latitudes bands and averaging over the whole profile of the target species.
These figures present the time series of the observed over the predicted scatter for each species for the July 2002 - March 2004 period.
In top figure the stratospheric components of the profiles have been averaged up to the nominal tangent height of 15 km (after filtering the profiles outside 100% of the mean latitudinal value).
The middle figure shows the same ratio time series where only the lowest three points of the profiles (nominal tangent heights between 6 and 12 km) are included in the averaged profile.
The bottom figure includes the whole profile in the average of the observed scatter over the predicted random error.
Even taking into account the propagation of the pressure-temperature retrieval errors into the VMR retrieval, the observed scatter is usually a factor 1-2 larger than the predicted error.
For temperature, the ratio time series may be affected by the seasonal variation of atmospheric temperature for both polar regions since it increases in polar winters.
In general the observed scatter for all species should be larger than the predicted since the standard deviation of the ensemble of profile pairs is an approximation of the random uncertainties and it includes the variability of the atmosphere. The larger observed scatter compared to the predicted one could be due to the assumption of an horizontally homogeneous atmosphere in the retrieval.



References

Dudhia, A. et al.: Microwindow selection for high-resolution sounders, Appl. Opt., 41, Issue 18, 2002.
ESA, SP-1229: ESA ENVISAT-MIPAS: an instrument for atmospheric chemistry and climate research, European Space Agency, ESTEC, Noordwijck, The Netherlands, 2000.
Fischer, H. et al.: MIPAS: an instrument for atmospheric and climate research, Atmos. Chem. Phys. Discuss, in preparation, 2006.
Kleinert, A. et al.: MIPAS Level 1B algorithms overview: operational processing and characterization, Atmos. Chem. Phys. Discuss, under review, 2006.
Raspollini, P. et. al.: MIPAS level 2 operational analysis, Atmos. Chem. Phys. Discuss, accepted, 2006.
Ridolfi, M. et al.: Optimised forward model and retrieval scheme for MIPAS near-real-time data processing, Appl. Opt., 39, No 8, 2000.