Technical Note

Calibration and measurement scenario for MIPAS after reduction of spectral resolution

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Abstract:

A proposal for a new calibration scenario is made, taking into account the experiences made with MIPAS so far and the reduction of spectral resolution to 41% of the nominal value. In addition, a modified measurement scenario, using pairs of spectra at each tangent height, is put forward.

1) Boundary conditions

a) Due to mechanical problems with the interferometer slides and due to the risk of instrument loss during initialisation, MIPAS will have to operate in a mode with reduced maximum optical path difference (MOPD) of 8.2 cm for a yet unknown time span. In addition, the MOPD will be fixed, no shorter slide travel will be allowed for calibration measurements. The spectral sampling will be ~0.061 cm^{-1}. The integration time will be 1.64 s per interferogram, the total travel time per interferogram including turnaround (450 ms) will be in the order of 2.1 s.
It can be expected that the NESR of a single spectrum will be improved, following the square root of the relation of the spectral resolutions.

Current and expected mean $NESR_0$ per channel in nW/(cm² sr cm^{-1}):
(deduced from figure 11, monthly report March 2004)

	NESR high res.	NESR reduced res.	NESR red./ pairs
Ch. A	25	16	11.3
Ch. AB	15	9.6	6.8
Ch. B	12	7.7	5.4
Ch. C	3.5	2.2	1.6
Ch. D	3.5	2.2	1.6

MIPAS has shown in the last two years that a level of radiometric accuracy above the initial specifications is feasible. Therefore we suggest aligning the new calibration scenario with higher radiometric accuracy requirements. In addition, lower spectral resolution and higher NESR tend to increase the impact of systematic errors on the retrieval, so a moderate tightening of the requirements is probably advisable.

We propose to use the following radiometric accuracy requirements as baseline for the considerations:

	Target	Threshold	Initial
Ch. A	1.0%	1.5%	5.0%
Ch. AB	1.0%	1.5%	5.0%
Ch. B	2.0%	2.0%	5.0%
Ch. C	2.0%	2.0%	2.0%
Ch. D	3.0%	3.0%	3.0%

The contribution to the requirement that is proportional to NESR has been omitted in the table, since we concentrate on systematic contributions to the radiometric accuracy in this note.

The systematic error generated by residual noise in the gain and offset measurement should not be the leading error contribution.

2) Proposed calibration scenario

a) Gain function determination

Daily gain and offset measurements with 100 sweeps per sweep direction are proposed.
The interferograms of the measurements shall be cut to 1/5 of their length and zerofilled in all channels except D. In channel D, the interferograms of the measurements shall be cut to 1/30 of their length and zerofilled.
The total time necessary for the gain function determination will be ~840 s (= 14 min)

The following considerations were made for this scenario:
-We determined the lowest spectral resolution that does not degrade the filter function significantly (including features like channeling etc.). This is illustrated in the figures in the annex.
-We defined a number of sweeps, that keeps the relative error of the gain function due to noise below a threshold of 20% of the systematic error.

The table below shows the relative error of the gain function due to noise in percent for a co-addition of 100 interferograms (i.e. the gain measurement consists of 100 blackbody and 100 deep space sweeps per sweep direction) for selected wave numbers in different bands. It can be seen, that the 20% criterion can be met everywhere even for the target radiometric accuracy requirements, except at the high wavenumber edge of channel D. Also in this spectral region the error is below the target error, however, and the SNR is so low that here noise will be the leading error source anyhow.

wave number (cm-1)	NESR_T (nW/(cm^{2}srcm-1))	NESR_new (nW/(cm^{2}srcm-1))	B(240 K) (nW/(cm^{2}srcm-1))	hi_res	low_res	#_sweeps	factor	rel. err. [%]
690	80	51.2	6436	0.061	0.305	100	2	0.10
700	60	38.4	6325	0.061	0.305	100	2	0.08
750	40	25.6	5752	0.061	0.305	100	2	0.06
970	40	25.6	3326	0.061	0.305	100	2	0.10
1060	40	25.6	2535	0.061	0.305	100	2	0.13
1170	25	16.0	1769	0.061	0.305	100	2	0.11
1350	20	12.8	929	0.061	0.305	100	2	0.17
1500	20	12.8	521	0.061	0.305	100	2	0.31
1750	5	3.2	187	0.061	0.305	100	2	0.22
2000	4	2.6	62.8	0.061	1.830	100	2	0.21
2200	5	3.2	25.4	0.061	1.830	100	2	0.65
2410	6	3.8	9.6	0.061	1.830	100	2	2.08

The (relative) error due to noise has been calculated by:

sqrt(2) * NESR / B(240 K) * sqrt(hi_res/low_res) * sqrt(1/#_sweeps) * factor
The term sqrt(2) originates from the fact, that blackbody and deep space spectra are used. NESR denotes the NESR of a high-resolution single spectrum. The NESR_T-values are estimated for the old resolution (0.025 cm^{-1}), the new NESR is scaled to the new resolution. For this estimation we suggest to take the NESR of a blackbody spectrum for both the blackbody and deep space measurements. B(240K) is the Planck function of a blackbody with 240K, which is the approximate temperature of the MIPAS blackbody, and hi_res/low_res is the ratio between full and reduced resolution. #_sweeps is the number of sweeps for the blackbody or deep space measurement in one sweep direction. The factor of 2 is added to account for the 2-sigma value of the NESR.
A daily measurement (every 14 orbits) of the gain function is preferred to keep gain drift errors in channel A also safely below the 20% threshold and to have redundant measurements in case of instrument failures. A safe measurement every two days (or 28 orbits) might be sufficient, however.

b) Offset determination
We propose to modify the offset calibration in the following way:
-perform 6 deep space measurements in every sweep direction (~25 s + ~5 s scan mirror travel time = ~30 s total)
-perform this measurement every 20 elevation scans, or every 10 elevation scans if the modified measurement scenario with interferogram pairs is used (~every 714 s = ~12 min).
-the interferograms of the measurements shall be cut to 1/5 of their length and zerofilled in all channels except D, where the interferograms shall be cut to 1/30 of their length and zerofilled.

The reasoning behind this scenario is:
-the NESR degradation shall be kept at the same level as up to now (1.6%)
-the disturbance of the measurement pattern shall be minimised
-since the offset variation over orbit is smaller than 6 nW/(cm² sr cm^{-1}) in the most critical Ch. A (see presentation of Anne Kleinert at QWG #3), the offset error generated by this approach is smaller than < 1 nW/(cm² sr cm^{-1}) and therewith below 10% of the NESR.

If gain calibration and offset calibration are implemented following this proposal, the time used for calibration will be less than 5% of total available measurement time (<1% for gain determination, ~4% for offset determination).

3) Discussion proposal: modification of measurement scenario

We suggest considering a new measurement scenario, where pairs of interferograms (forward and backward) are subsequently measured for each tangent height. The data sets shall be co-added after Fourier transformation and calibration before being fed to the L2 processor. The advantages would be:
-improvement of NESR (partial compensation for loss of spectral resolution)
-reduced work-load for L2 processor
-avoidance of any forward-backward oscillation[1]
-reduced wear on the elevation scan mirror.
With a slight modification of turnaround time (or scan length), this measurement scenario could even be kept consistent with the old one (two interferograms need 4.2 s, a long interferogram took 4.45 s).
Obvious disadvantages of this scenario are the necessity to change the L1-processor and that we miss the chance to enhance the spatial resolution of MIPAS.

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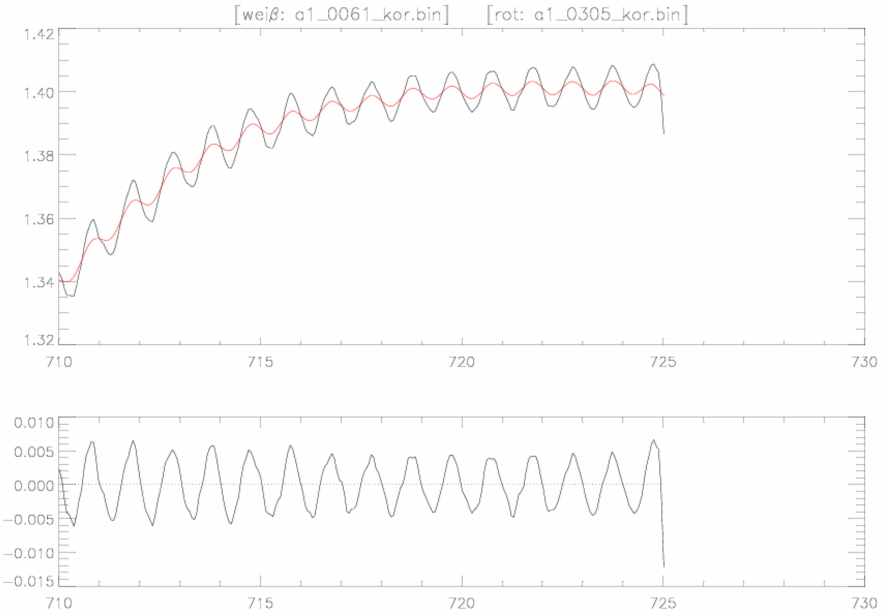
[1] Our on-going analysis of radiances indicates that this problem is only partly solved.

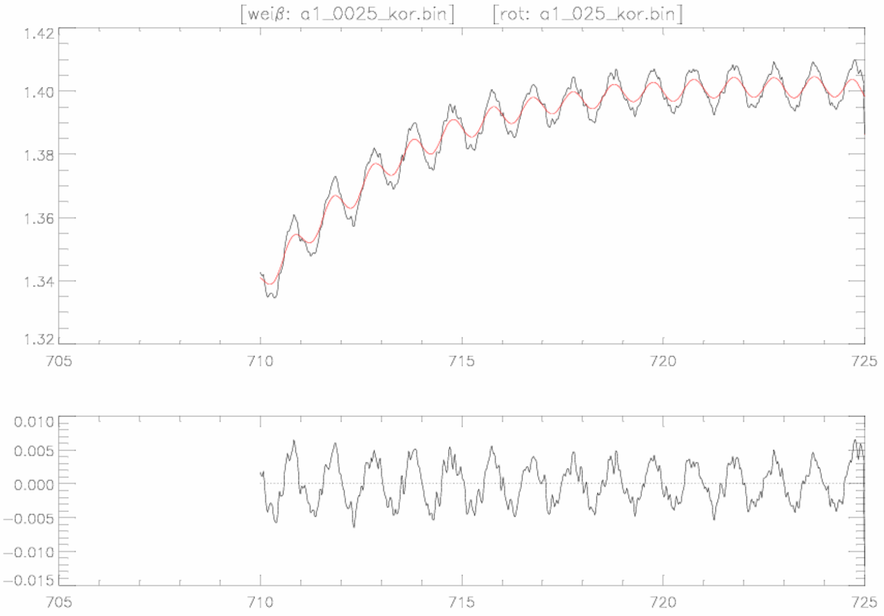
Annex:

Degradation of channel spectra:

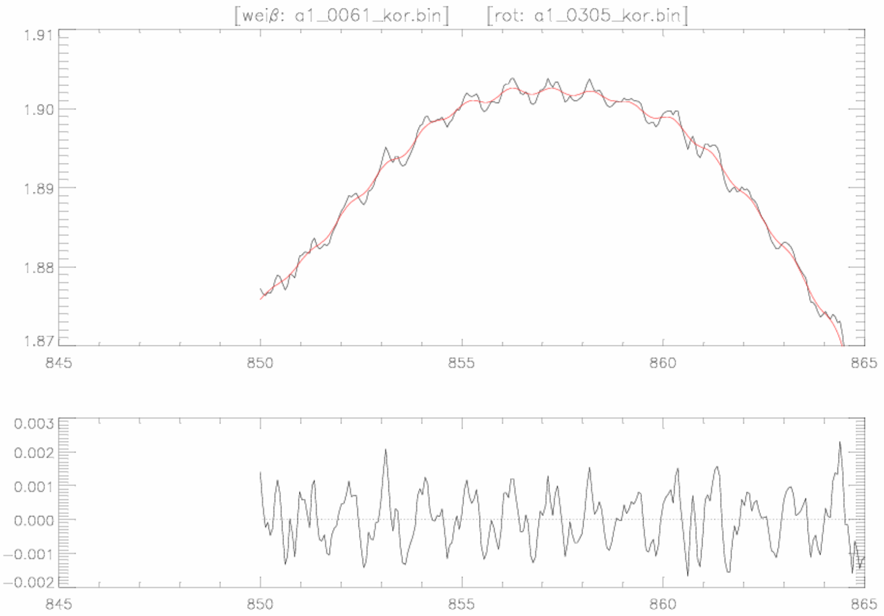
Comparison of new nominal spectral resolution (0.061 cm-1) with reduced spectral resolution of 0.305 cm-1. The error in this worst case spectral region (Ch. A) is ~0.43%.



Comparison of old nominal spectral resolution (0.025 cm-1) with reduced spectral resolution of 0.25 cm-1. The error is in the same order of magnitude as above.



Comparison of new nominal spectral resolution (0.061 cm-1) with proposed reduced spectral resolution of 0.305 cm-1. In this spectral region (Ch. A), the error is negligible (~0.05%)



Comparison of new nominal spectral resolution (0.061 cm-1) with proposed reduced spectral resolution of 1.83 cm-1 in channel D. The degradation of the filter curve is already visible, but not yet a leading error term in the budget. A further degradation is not advisable, however.