Envisat-1 Ground Segment

Michelson Interferometer for Passive Atmospheric Sounding

REVIEW OF MIPAS L1B MICROWINDOW DATABASE FOR SPECTRAL CALIBRATION AND ILS RETRIVAL

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<td>Prepared by</td>
<td>Scientist</td>
<td>Yvan Dutil</td>
<td></td>
</tr>
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<tr>
<td>Approved by</td>
<td>Project Manager</td>
<td>Gaétan Perron</td>
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- Project Team
- Client
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1. INTRODUCTION

1.1 PURPOSE OF DOCUMENT

The purpose of this is to re-evaluate the spectral and instrument line shape calibration scenario to adjust it to its actual in-flight situation of MIPAS.

1.2 SCOPE

The document is performed under ESRIN contract no 17124/03/I-OL.

1.3 DOCUMENT OVERVIEW

After a few months of operations, some aspect of the spectral calibration procedure of MIPAS needed to be revised. First, the operational resolution of the MIPAS spectrometer has been largely reduced due to instrument stability concern. In addition, some reference lines originally used were not radio-metrically stable to the point of not being available at every points of the orbit. In this document, we select a list of potential candidates that could be use in the future to establish the spectral calibration and to characterize the ILS.

In addition, we re-evaluate the spectral calibration methodology for the suggested lines.

1.4 BIBLIOGRAPHY

1.4.1 Applicable Documents

AD 1

1.4.2 References

Ref. 1 IF10 results, QWG Meeting 3, Frascati, March 2004
Ref. 2 Tech. Note A. Kleinert & F. Frield-Vallon, April 2004
Ref. 3 ADF V3.2 MIP-MW1-AX
Ref. 6 MIPAS Validation review-ESRIN-9-13 December 2002
Ref. 7 M. Kiefer et al. Some Results on MIPAS/Envisat inflight instrument calibration, 11th International Workshop on Atmospheric Science from Space Using Fourier Transform Spectrometry (ASSFTS), Bad Wildbad, 8-10 October 2003, Germany
2. SPECTRAL LINE SELECTION PROCESS

We have re-examined the references lines based on the in-flight instrument performances. A series of measured atmospheric spectra taken by MIPAS at different points of the orbit (2 poles and equator) and at different altitude (33 and 47 km) were used to take account of the variability of the atmosphere. To match the new instrument operation mode, the spectral resolution was reduced from 0.025 cm\(^{-1}\) to 0.06 cm\(^{-1}\).

In a first step, all narrow isolated lines that were above 3\(\sigma\) of the noise background in every observations were put in a database for further analysis. In a second step, each candidate line was examined to insure there was no interference from other line within ±0.25 cm\(^{-1}\), neither obvious blend nor broadening. Tentative identification of the line meeting these criteria was then made. The next step was to evaluate the spectral calibration performance of those lines. This was done using a simplified version of the actual MIPAS calibration algorithm, which optimises the correlation coefficient between the observed line and a reference template. Then within this subset, search for line suitable for ILS characterisation was carried. The selection criteria were the absence of interfering line within ±0.75 cm\(^{-1}\) and no obvious line broadening.

The lines meeting all these selection criteria plus to original reference lines are listed in the table 2-1. In this table, the first column refer to the name of the micro-windows use in the MIPAS reference... Le second refers to the central wavelength from HITRAN2000. The third column refer the to molecule at the source of the line. The sixth column is the suitability of the line for ILS characterisation. The \(\sigma\) is the value of the RMS calibration wavelength fluctuation in the sample of six observations. Therefore, it includes noise contribution, neighbor line contamination and pressure sensitivity.

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<th>Wavenumber</th>
<th>Identification</th>
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<th>Comments</th>
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<td>N</td>
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<td>H₂O</td>
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</tbody>
</table>

Original reference rejected.

(The original reference O₃ line 1591.7225 cm⁻¹ cannot be seen in the spectra. H₂O line 1591.67185 cm⁻¹ is suspected. Ref 3)

Original reference rejected

Original reference

Original reference

(at High altitude is not O₃ 1591.7225 cm⁻¹ line but H₂O Line located at 1946.36431 cm⁻¹ Ref 3)
3. SPECTRAL CALIBRATION PROCEDURE

Noise sensitivity of possible calibration lines has been studied. In the previous section, line stability over variable condition has been measured (RMS wavelength fluctuation $\sigma_s$). These measurements were taking account the contamination by nearby lines, pressure fluctuation and noise effect. Here we only examine the impact of the noise of spectral calibration (RMS wavelength fluctuation $\sigma_n$). Again, we assume the observed worst-case situation for observations at 33 km. Instrumental noise level, were those given in the reference 1 and 2. When the results were inconsistent, the worst case was selected.

Based on those simulations, a set of 2-3 lines per band was selected for the spectral calibration algorithm.

Table 3–2 Noise level in Selected Reference Lines

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<tr>
<th>Line</th>
<th>$\sigma_n$ [cm$^{-1}$]</th>
<th>$\sigma_s$ [cm$^{-1}$]</th>
<th>Comment</th>
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<td>944.194039</td>
<td>0.0100</td>
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</tr>
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<td>945.980239</td>
<td>0.0069</td>
<td>0.0024</td>
<td>A_CO2a_alt</td>
</tr>
<tr>
<td>947.741988</td>
<td>0.0064</td>
<td>0.0016</td>
<td>A_CO2b_alt</td>
</tr>
<tr>
<td>949.47932</td>
<td>0.0113</td>
<td>0.0014</td>
<td>A_CO2d</td>
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<td>951.192272</td>
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</tr>
<tr>
<td>954.545095</td>
<td>0.0059</td>
<td>0.0022</td>
<td>A_CO2c_alt</td>
</tr>
<tr>
<td>956.184991</td>
<td>0.0091</td>
<td>0.0017</td>
<td></td>
</tr>
<tr>
<td>966.250368</td>
<td>0.0101</td>
<td>0.0021</td>
<td></td>
</tr>
<tr>
<td><strong>1128.75150</strong></td>
<td><strong>0.0020</strong></td>
<td><strong>0.0047</strong></td>
<td>AB_O3c(Not for ILS)</td>
</tr>
<tr>
<td><strong>1151.7325</strong></td>
<td><strong>0.0026</strong></td>
<td><strong>0.0031</strong></td>
<td>AB_O3a_alt (Not for ILS)</td>
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<td>1394.47451</td>
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<td><strong>1399.20425</strong></td>
<td><strong>0.0012</strong></td>
<td><strong>0.0013</strong></td>
<td>B_H20a_alt</td>
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<td>0.0014</td>
<td>B_H20b_alt</td>
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<td><strong>0.0043</strong></td>
<td><strong>0.0020</strong></td>
<td>B_H2Ob</td>
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</table>
### 3.1 Calibration Strategy

A minimum amount of time should be devoted to the co-addition. In the following table, we regroup all the selected lines we recommend for spectral calibration. For each band, we assume that all lines in a band will be used to produce an average spectral calibration. Since our goal is to establish the calibration to better than 0.001 cm\(^{-1}\), we can estimate how many observation will have to be co-added to average the spectral calibration below this threshold. By doing a root sum square of the noise in the spectral calibration and dividing by the number of line, we calculate the estimated error RMS on the spectral calibration within in band (\(\Sigma \sigma_n\)). From there, it is straightforward to estimate the number of co-addition needed.

For the band AB, B, C and D, the number of needed observations is quite low (<4). However, for the band AB, in the worst case at least 14 observations have to be averaged in order to meet the spectral calibration requirement. It should be noted however, that spectral calibration between bands should be correlated. Therefore, an average over all bands could also be used. This one would meet the requirement in all cases. Nevertheless, we should keep in mind than these calculations are based on the worst case. In more favorable condition, the calibration accuracy could be established within 0.001 cm\(^{-1}\) for the band A with only four co-additions. This is why we recommend using this number of co-addition in the calibration sequence.

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<th>Noise 1</th>
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<th>Line Type</th>
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<td>1429.94505</td>
<td>0.0012</td>
<td>0.0007</td>
<td>B_H20c_alt</td>
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<td>1435.64956</td>
<td>0.0027</td>
<td>0.0013</td>
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<td>0.0014</td>
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<tr>
<td>1464.90506</td>
<td>0.0017</td>
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<td></td>
</tr>
<tr>
<td>1576.18542</td>
<td>0.0002</td>
<td>0.0013</td>
<td></td>
</tr>
<tr>
<td>1616.71149</td>
<td>0.0002</td>
<td>0.0005</td>
<td>C_H2Oa_alt (Not for ILS)</td>
</tr>
<tr>
<td>1635.65184</td>
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<td>0.0010</td>
<td></td>
</tr>
<tr>
<td>1677.75049</td>
<td>0.0006</td>
<td>0.0017</td>
<td>C_H20b (Best in this band for ILS but still poor)</td>
</tr>
<tr>
<td>1866.38083</td>
<td>0.0024</td>
<td>0.0008</td>
<td>D_H2Oa_alt</td>
</tr>
<tr>
<td>1869.34560</td>
<td>0.0016</td>
<td>0.0019</td>
<td>D_H2Ob_alt (Not for ILS)</td>
</tr>
<tr>
<td>1889.56941</td>
<td>0.0021</td>
<td>0.0023</td>
<td>D_H2Oc_alt</td>
</tr>
<tr>
<td>1895.19736</td>
<td>0.0025</td>
<td>0.0029</td>
<td></td>
</tr>
<tr>
<td>1922.34083</td>
<td>0.0035</td>
<td>0.0012</td>
<td>D_H2Oc</td>
</tr>
<tr>
<td>1946.36431</td>
<td>0.0050</td>
<td>0.0026</td>
<td>D_O3a</td>
</tr>
</tbody>
</table>
Table 3–3 Final list of recommended lines

<table>
<thead>
<tr>
<th>Micro-window</th>
<th>Wavelength</th>
<th>$\sigma_n$ [cm$^{-1}$]</th>
<th>$\sigma_s$ [cm$^{-1}$]</th>
<th>$\Sigma \sigma_n$ [cm$^{-1}$]</th>
<th>$N_{\text{Coadd}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A_CO2a_alt</td>
<td>945.980239</td>
<td>0.0069</td>
<td>0.0024</td>
<td>3.702x10$^{-3}$</td>
<td>14</td>
</tr>
<tr>
<td>A_CO2b_alt</td>
<td>947.741988</td>
<td>0.0064</td>
<td>0.0016</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A_CO2c_alt</td>
<td>954.545095</td>
<td>0.0059</td>
<td>0.0022</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AB_O3c</td>
<td>1128.75150</td>
<td>0.0020</td>
<td>0.0047</td>
<td>1.640x10$^{-3}$</td>
<td>3</td>
</tr>
<tr>
<td>AB_O3a_alt</td>
<td>1151.73235</td>
<td>0.0026</td>
<td>0.0031</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B_H20a_alt</td>
<td>1399.20425</td>
<td>0.0012</td>
<td>0.0013</td>
<td>6.928x10$^{-4}$</td>
<td>1</td>
</tr>
<tr>
<td>B_H20b_alt</td>
<td>1404.98997</td>
<td>0.0012</td>
<td>0.0014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B_H20c_alt</td>
<td>1429.94505</td>
<td>0.0012</td>
<td>0.0007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C_H20a_alt</td>
<td>1616.71149</td>
<td>0.0002</td>
<td>0.0005</td>
<td>3.162x10$^{-4}$</td>
<td>1</td>
</tr>
<tr>
<td>C_H20b</td>
<td>1677.75049</td>
<td>0.0006</td>
<td>0.0017</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D_H20a_alt</td>
<td>1866.38083</td>
<td>0.0024</td>
<td>0.0008</td>
<td>1.189x10$^{-3}$</td>
<td>2</td>
</tr>
<tr>
<td>D_H20b_alt</td>
<td>1869.34560</td>
<td>0.0016</td>
<td>0.0019</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D_H20c_alt</td>
<td>1889.56941</td>
<td>0.0021</td>
<td>0.0023</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. SPECTRAL LINE SHIFT

We have compared the expected line shift calculated from a theoretical model of the ILS (Ref. 4Ref. 5), with the frequency shift observed at the Level 2 in the current system from two different sources in the literature. IFAC which gave a fitted function for the fit equal to $f_{\text{IFAC}} = -2.6051 \times 10^{-6} \sigma + 2.14084 \times 10^{-9} \sigma^2$ (Ref. 6). IMK has produced another fit with a linear function. $f_{\text{IMK}} = 2.03 \times 10^{-6} \sigma - 2.54 \times 10^{-3}$ (Ref. 7). This fit is indiscernible from our based on 21 selected micro-windows $f_{\text{ABB}} = 2.11 \times 10^{-6} \sigma - 2.58 \times 10^{-3}$ on the three spectra used.

Since these data have already be spectral calibrated, a linear residual is not expected since it should has been completely absorbed in the spectral calibration. The same is true for the spectral shift caused by the ILS effect, since it is grow linearly with the wavenumber. Nevertheless, the calibration procedure used at the level 1b assumes no offset in the spectral calibration scale. If such offset exists, the spectral calibration procedure is inadequate and linear residual is produced.

If the offset proves to be constant a simple algorithm modification could effectively correct it. The consistency between IMK and ABB fit, indicates this is probably the case but further analysis is needed to insure its long term stability.

Figure 4–1  MIPAS Spectral line shift from various source
5. CONCLUSION

After selection process applying successive filters to a line database, we have selected a subset of line susceptible to be used both for spectral calibration and as ILS reference. This selection is based on the observed properties of those lines on actual MIPAS spectra, which were degraded in resolution to match the new MIPAS resolution.

The bands A, B and D are endowed with a good selection of reference lines. However, bands AB and C have very few lines suitable for spectral calibration and ILS retrieval. Due to the exhaustive nature of this search, we do not expect that this situation will improve in the future. To meet the spectral calibration requirement of 0.001 cm\(^{-1}\) in all bands, we recommend using a co-addition of four spectra.

There is some residual error in the calibration procedure probably cause by an unexpected offset in the calibration. Simple algorithm modification could bring the residual calibration error with the required margins.

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