MIPAS (ESA ML2PP v7 & v6) vs. MIPAS-B

Gerald Wetzel, Hermann Oelhaf and the MIPAS-B Team
Before we start with V7....
Summary of long-term validation using V6 data

- UFRA in-situ sensor BONBON (Andreas Engel et al.)

<table>
<thead>
<tr>
<th>Species</th>
<th>Technique</th>
<th>Total uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>GC/FID</td>
<td>0,2% or 0,5 ppbv</td>
</tr>
<tr>
<td>N₂O</td>
<td>GC/ECD</td>
<td>0,5% or 1 ppbv</td>
</tr>
<tr>
<td>CFC-12</td>
<td>GC/MS</td>
<td>0,5 % or 1 pptv</td>
</tr>
<tr>
<td>CFC-11</td>
<td>GC/MS</td>
<td>1 % or 2 pptv</td>
</tr>
</tbody>
</table>

- MIPAS-B

N.b.: #of data pairs has been enhanced considerably by back/forward trajectory matching with the help of FUB (K. Grunow & J. Abalichin)
Balloon flights of UFRA in-situ sensor BONBON used for MIPAS validation

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Number of samples</th>
<th>Altitude range</th>
<th>Location</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>B39</td>
<td>14</td>
<td>12.2-32.4 km</td>
<td>44° N, Aire sur l’Adour</td>
<td>24.09.2002</td>
</tr>
<tr>
<td>B40</td>
<td>13</td>
<td>11.2-30.4 km</td>
<td>68° N, Kiruna</td>
<td>06.03.2003</td>
</tr>
<tr>
<td>B41</td>
<td>10</td>
<td>13.3-28.9 km</td>
<td>68° N, Kiruna</td>
<td>09.06.2003</td>
</tr>
<tr>
<td>B42</td>
<td>12¹</td>
<td>15.2-34.3 km</td>
<td>5° S, Teresina</td>
<td>08.06.2005</td>
</tr>
<tr>
<td>B43</td>
<td>14</td>
<td>15.2-33.6 km</td>
<td>5° S, Teresina</td>
<td>25.06.2005</td>
</tr>
<tr>
<td>B44</td>
<td>4</td>
<td>14.8-33.5 km</td>
<td>5° S, Teresina</td>
<td>01.06.2008</td>
</tr>
<tr>
<td>B45</td>
<td>11</td>
<td>10.3-31.8 km</td>
<td>68° N, Kiruna</td>
<td>10.03.2009</td>
</tr>
<tr>
<td>B46</td>
<td>8</td>
<td>12.5-23.3 km</td>
<td>68° N, Kiruna</td>
<td>01.04.2011</td>
</tr>
</tbody>
</table>
Summary from V6 comparisons (UFRA)

- **FR Envisat/MIPAS data covering 2002-2004:**
  - CFC-11 systematically overestimated, thus not recommended for scientific use (FR and OR period)
  - Underestimation of the CFC-12 mixing ratios is also observed, but this feature is closer to the uncertainty range
  - Significant overestimation of mixing ratios of CH4, N2O and CFC-12 below 20 km, which may be as large as 300 ppbv of CH4, 40 ppbv of N2O and 50 pptv of CFC-12.

- **OR MIPAS data from 2005 onwards:**
  - Generally agree better with the in-situ data. Above 20 km there is generally a good agreement which is within the estimated uncertainty limits for CH4, N2O and CFC-12
  - For CH4 a good agreement is also observed below 20 km, while there seems to be a tendency for an underestimation of the mixing ratios of N2O (20 ppbv at around 15 km) and also of CFC-12 (50 pptv at 10 km).

For more information see:
- Final Report for ESRIN/Contract No. 20752/07/I-OL ‘Balloon-borne Validation of Envisat Atmospheric Sensors (BalValEnv), Date: 23 September 2015
UFRA Example: CH4 MIPAS_ENV (V6.0) vs. the cryogenic whole sampler.

LEFT PANEL: Validation based on cryosampler (Bonbon)-flights B39, B40 and B41. MIPAS FR period. Red line: interpolated mean difference between MIPAS-E- and cryosampler-mixing ratios. Red error bars: Mean standard deviation of the difference between MIPAS-E- and cryosampler- mixing ratios for the respective altitude range. Blue line: Interpolated Mean error for CH4 mixing ratio values from MIPAS-E database.

RIGHT PANEL: as Left panel but using the cryosampler-flights B42, B43, B45 and B46 and the low spectroscopic resolution MIPAS data.
Balloon flights of MIPAS-B used for validation

Overview of MIPAS balloon flights used for intercomparison with MIPAS-E. Distances and times between coincident trace gas profile pairs observed by MIPAS-E and the validation instrument refer to an altitude of 20 km (Kiruna) and 30 km (Aire-sur-l’Adour and Teresina). In addition, 2-days forward/backward trajectories (FU Berlin) were calculated for each balloon flight to search further matches with the satellite sensor.

<table>
<thead>
<tr>
<th>Location</th>
<th>Date</th>
<th>Distance (km)</th>
<th>Time difference (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kiruna (Sweden, 68 °N)</td>
<td>20 Mar 2003</td>
<td>16 / 546</td>
<td>14 / 15</td>
</tr>
<tr>
<td></td>
<td>03 Jul 2003</td>
<td>Trajectories only</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11 Mar 2009</td>
<td>187 / 248</td>
<td>5 / 6</td>
</tr>
<tr>
<td></td>
<td>24 Jan 2010</td>
<td>109 / 302</td>
<td>5 / 6</td>
</tr>
<tr>
<td></td>
<td>31 Mar 2011</td>
<td>Trajectories only</td>
<td></td>
</tr>
<tr>
<td>Aire sur l’Adour (France, 44 °N)</td>
<td>24 Sep 2002</td>
<td>21 / 588 / 410 / 146</td>
<td>12 / 13 / 15/16</td>
</tr>
<tr>
<td>Teresina (Brazil, 5 °S)</td>
<td>14 Jun 2005</td>
<td>109 / 497 / 184 / 338</td>
<td>228 / 229 / 268 / 269</td>
</tr>
<tr>
<td></td>
<td>06 Jun 2008</td>
<td>224 / 284 / 600 / 194</td>
<td>157 / 158 / 169 /170</td>
</tr>
</tbody>
</table>
MIPAS-B experimental data

Overview of MIPAS-B spectral windows used for the analysis of atmospheric target parameters together with typical precision errors and total errors.

<table>
<thead>
<tr>
<th>Target parameter</th>
<th>Spectral range (cm(^{-1}))</th>
<th>Precision error</th>
<th>Total error</th>
</tr>
</thead>
</table>
| **Temperature**  | 801.1 – 813.2  
                   | 941.3 – 956.7    | 0.2 – 0.3 K  | 0.5 – 1.0 K |
| **H\(_2\)O**     | 808.0 – 825.3  
                   | 1210.2 – 1244.5 | 1 – 2 %     | 8 – 11 %    |
| **O\(_3\)**      | 763.5 – 824.4  
                   | 964.9 – 969.0   | 0 – 1 %     | 8 – 10 %    |
| **HNO\(_3\)**    | 864.0 – 874.0  | 0 – 2 %         | 8 – 9 %     |
| **CH\(_4\) & N\(_2\)O** | 1161.9 – 1229.8 | 1 – 3 %       | 6 – 10 %    |
| **NO\(_2\)**     | 1585.0 – 1615.0| 1 – 3 %        | 10 – 12 %   |
| **ClONO\(_2\)**  | 779.7 – 780.7  | 2 – 3 %        | 5 – 6 %     |
| **N\(_2\)O\(_5\)** | 1220.0 – 1270.0 | 0 – 2 %    | 5 – 7 %     |
| **CFC-11**       | 840.0 – 860.0  | 2 – 3 %        | 5 – 6 %     |
| **CFC-12**       | 918.0 – 924.0  | 2 – 3 %        | 5 – 6 %     |
Summary from V6 comparisons (MIPAS-B/KIT)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp.</td>
<td>Difference within ±2 K between 13 and 39 km</td>
</tr>
<tr>
<td>H₂O</td>
<td>Small positive bias (up to about 10 %) above 27 km (within combined errors)</td>
</tr>
<tr>
<td>O₃</td>
<td>Difference within ±10 % for all altitudes (10-39 km).</td>
</tr>
<tr>
<td>HNO₃</td>
<td>Positive bias (5-20 %), close to significant at the upper and lower altitude edges</td>
</tr>
<tr>
<td>N₂O₅</td>
<td>Differences &lt; 20 % between 24 and 36 km (no significant bias)</td>
</tr>
<tr>
<td>CFC-11</td>
<td>Significant positive bias of more than 10 % (increasing with altitude)</td>
</tr>
<tr>
<td>CFC-12</td>
<td>Differences within ±20 % for all altitudes (no significant bias)</td>
</tr>
</tbody>
</table>

For more information see e.g.:  
- Oelhaf, H., et al., Long-term validation of MIPAS-Envisat ESA operational products using balloon-borne measurements,  
- Final Report for ESRIN/Contract No. 20752/07/I-OL ‘Balloon-borne Validation of Envisat Atmospheric Sensors (BalValEnv), Date: 23 September 2015
Figure 1b. Same as Figure 1a (right panel), but separately for the period of FR mode observations (left) and OR mode observations (right). While the differences look very similar up to about 25 km, there appears a change in the sign of the slight biases above.

Oelhaf et al. 2015, in prep.
N2O-CH4 correlation as measured by MIPAS-B and MIPAS-E in comparison to previously determined trend-corrected relationships (in-situ, Engel et al., 1996, and Atmospheric Trace Molecule Spectroscopy Experiment, Michelsen et al., 1998). Error bars are omitted for clarity (Oelhaf et al., 2015).
Now to V7....
Please note:

• Only MIPAS-B data used

• So far assessment is based on only two balloon flights,
  • one for the FR period at mid-latitudes,
  • one for the RR period at Arctic latitudes in spring
Temperature (OR period)

MIPAS-B, 31 March 2011, Kiruna, Seq. 06 (~64°N), $z_{\text{obs}} \sim 35$ km, SZA ~83°, 04:38 UTC (06:34 LST)
2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E − MIPAS-B

- no significant change between v7 and v6
Temperature (FR period)

MIPAS-B, 24 Sep. 2002, Aire, Seq. N3 (~47°N), $z_{\text{obs}} \sim 38$ km, SZA $\sim 130^\circ$, 22:21 UTC (22:24 LST)

2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

- Below 27 km v7 shows cold bias vs v6 and MIPAS-B. v7 generally slightly colder than v6.
**H₂O** (OR period)

**MIPAS-B, 31 March 2011, Kiruna, Seq. 06 (~64°N), z_obs ~35 km, SZA ~83°, 04:38 UTC (06:34 LST)**

2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

**ESA ML2PP v7**

- no significant data change between v7 and v6 (v7 appears slightly improved)
H$_2$O (FR period)

MIPAS-B, 24 Sep. 2002, Aire, Seq. N3 ($\sim$47°N), $z_{\text{obs}}$ $\sim$38 km, SZA $\sim$130°, 22:21 UTC (22:24 LST)
2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

- clear wet bias and too dry TP in v7 data; less agreement with MIPAS-B (compared to v6 data)
**O$_3$ (OR period)**

**MIPAS-B, 31 March 2011, Kiruna, Seq. 06 (~64°N), $z_{obs}$ ~35 km, SZA ~83°, 04:38 UTC (06:34 LST)**

2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

- v7 O$_3$ VMRs slightly higher than v6 data; slightly reduced agreement with MIPAS-B
**O₃ (FR period)**


2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

- v7 O₃ data slightly higher than v6 data; reduced agreement with MIPAS-B
**CH$_4$ (OR period)**

MIPAS-B, 31 March 2011, Kiruna, Seq. 06 (~64°N), $z_{\text{obs}}$ ~35 km, SZA ~83°, 04:38 UTC (06:34 LST)
2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

- no significant data change between v7 and v6
**CH$_4$ (FR period)**


2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

- Lower VMRs in LMS in v7 CH$_4$ data, better agreement with MIPAS-B now
$N_2O$ (OR period)

MIPAS-B, 31 March 2011, Kiruna, Seq. 06 (~64°N), $z_{obs}$ ~35 km, SZA ~83°, 04:38 UTC (06:34 LST)
2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E − MIPAS-B

- no significant data change between v7 and v6
**N$_2$O (FR period)**


2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

- v7 N$_2$O data improved in LMS, better agreement with MIPAS-B now, cf. CH4
HNO$_3$ (OR period)

MIPAS-B, 31 March 2011, Kiruna, Seq. 06 (~64°N), $z_{\text{obs}}$ ~35 km, SZA ~83°, 04:38 UTC (06:34 LST)
2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

- no significant data change between v7 and v6
**HNO₃ (FR period)**


2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

**ESA ML2PP v7**

**ESA ML2PP v6**

-v7: altitude of VMR peak shifted downward compared to v6 and MIPAS-B
**NO$_2$ (OR period)**

MIPAS-B, 31 March 2011, Kiruna, Seq. 06 (~64°N), $z_{ob}$ ~35 km, SZA ~83°, 04:38 UTC (06:34 LST)

2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

- photochemical correction (1-D model) applied to MIPAS-E NO$_2$ data, extended altitude range in v7 fits well to MIPAS-B
NO$_2$ (FR period)

2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

- photochemical correction applied to MIPAS-E NO$_2$ data; positive bias, increasing with altitude
CFC-11 (OR period)

MIPAS-B, 31 March 2011, Kiruna, Seq. 06 (~64°N), z\textsubscript{obs} ~35 km, SZA ~83°, 04:38 UTC (06:34 LST)

2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

- v7 CFC-11 data slightly lower than v6 data; improved agreement with MIPAS-B
CFC-11 (FR period)

2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

- v7 CFC-11 data significantly lower than v6 data; much improved agreement with MIPAS-B, no bias anymore
CFC-12 (OR period)

MIPAS-B, 31 March 2011, Kiruna, Seq. 06 (~64°N), z\textsubscript{obs} ~35 km, SZA ~83°, 04:38 UTC (06:34 LST)

2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E − MIPAS-B

- no significant data change between v7 and v6
CFC-12 (FR period)

2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

- v7 CFC-12 data slightly lower than v6 data; improved agreement with MIPAS-B, bias disappeared
**CLONO$_2$ (OR period)**

**MIPAS-B, 31 March 2011, Kiruna, Seq. 06 (~64°N), z$_{obs}$ ~35 km, SZA ~83°, 04:38 UTC (06:34 LST)**

2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E - MIPAS-B

- no significant data change between v7 and v6
$\text{ClONO}_2$ (FR period)

**MIPAS-B, 24 Sep. 2002, Aire, Seq. N3 ($\sim 47^\circ$N), $z_{\text{obs}} \sim 38$ km, SZA $\sim 130^\circ$, 22:21 UTC (22:24 LST)**

2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

**ESA ML2PP v7**

**ESA ML2PP v6**

- v7 $\text{ClONO}_2$ data slightly higher than v6 data below 26 km, slight negative bias above persists
$\text{N}_2\text{O}_5$ (OR period)

MIPAS-B, 31 March 2011, Kiruna, Seq. 06 (~64°N), $z_{\text{obs}}$ ~35 km, SZA ~83°, 04:38 UTC (06:34 LST)
2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

- $\text{v7 N}_2\text{O}_5$ data (photochem. corr.) slightly lower than v6 data around altitude of VMR maximum
$\text{N}_2\text{O}_5$ (FR period)

MIPAS-B, 24 Sep. 2002, Aire, Seq. N3 ($\sim$47°N), $z_{\text{obs}}$ $\sim$38 km, SZA $\sim$130°, 22:21 UTC (22:24 LST)

2-days fw/bw trajectories (1h, 500 km, FU Berlin); difference: MIPAS-E – MIPAS-B

ESA ML2PP v7

ESA ML2PP v6

- v7 $\text{N}_2\text{O}_5$ data (photochem. corr.) slightly lower than v6 data around 30 km
# MIPAS (ESA ML2PP v7 & v6) vs. MIPAS-B

**Preliminary** summary of MIPAS-Envisat validation results, based on two MIPAS-B flights (FR&OR period). Indicated atmospheric parameter differences refer to MIPAS-Envisat minus the balloon instrument. **Needs to be confirmed vs. other MIPAS-B flights’ comparisons, still in work.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Comments (v6 data, 8 MIPAS-B flights)</th>
<th>Changes from v6 to v7 (2 MIPAS-B flights)</th>
<th>Tendency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp.</td>
<td>Difference within ±2 K between 13 and 39 km</td>
<td>No significant difference (slightly colder)</td>
<td>▼►►</td>
</tr>
<tr>
<td>H₂O</td>
<td>Small positive bias (up to about 10 %) above 27 km (within combined errors)</td>
<td>Enhanced positive bias in FR period</td>
<td>▼►►</td>
</tr>
<tr>
<td>O₃</td>
<td>Difference within ±10 % for all altitudes (10-39 km)</td>
<td>Slightly higher VMRs, reduced agreement with MIPAS-B data</td>
<td>►▼</td>
</tr>
<tr>
<td>HNO₃</td>
<td>Positive bias (5-20 %), close to significant at the upper and lower altitude edges</td>
<td>Maximum VMR altitude shift (FR period)</td>
<td>▼►►</td>
</tr>
<tr>
<td>NO₂</td>
<td>Positive bias of up to 20 % (increasing with altitude and significant above 33 km)</td>
<td>No significant difference. Extended alt. range</td>
<td>►▲</td>
</tr>
<tr>
<td>CH₄ &amp; N₂O</td>
<td>Positive bias for CH₄ (5-15 %) and N₂O (10-20%)</td>
<td>Lower N₂O/CH₄ VMRs (FR period), better agreement with MIPAS-B data now</td>
<td>▲▲</td>
</tr>
<tr>
<td>ClONO₂</td>
<td>Differences &lt; 10 % between 17 and 33 km (no significant bias)</td>
<td>Slightly higher VMRs below 26 km (FR period)</td>
<td>►►</td>
</tr>
<tr>
<td>N₂O₅</td>
<td>Differences &lt; 20 % between 24 and 36 km (no significant bias)</td>
<td>Slightly lower VMRs around altitude of VMR maximum</td>
<td>►►</td>
</tr>
<tr>
<td>CFC-11</td>
<td>Significant positive bias of more than 10 % (increasing with altitude)</td>
<td>Significantly lower VMRs, agreement with MIPAS-B data clearly improved</td>
<td>▲▲</td>
</tr>
<tr>
<td>CFC-12</td>
<td>Differences within ±20 % for all altitudes (no significant bias)</td>
<td>Slightly lower VMRs (FR period), improved agreement with MIPAS-B data</td>
<td>▲►</td>
</tr>
</tbody>
</table>
Summary and conclusions

- Improved agreement of ESA v7 data (compared to v6 data) with MIPAS-B for tropospheric source gases CH\textsubscript{4}, N\textsubscript{2}O, CFC-11, and CFC-12.

- For temperature and stratospheric species: no significant change or slightly reduced agreement with MIPAS-B measurements, particularly for FR operating period data.

- In general: Agreement between MIPAS-Envisat and MIPAS-B measured data appears to be better in the OR operating period than in the FR period.

- Assessment is based on (so far) only two balloon flights, one for the FR period at mid-latitudes, one for the RR period at Arctic latitudes in spring.

- Comparisons with other balloon data are in work.