MIPAS NO$_2$
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Diurnal variation of NO\textsubscript{x} species

Midlat. Summer: 35 km

- NO
- NO\textsubscript{2}
- NO\textsubscript{3}
- N\textsubscript{2}O\textsubscript{5}

SR: $\Delta$NO\textsubscript{2} $\sim$ -3.6 ppbv/0.5 h
SS: $\Delta$NO\textsubscript{2} $\sim$ +5.4 ppbv/0.5 h

$\rightarrow$ Temporal variation of NO\textsubscript{2} has to be taken into account during validation process, especially during SR and SS.

Atmospheric Chemistry Validation of ENVISAT - ESRIN - 3-7 May 2004
SPIRALE (in-situ) - Balloon (courtesy: M. Pirre)

(LPCE/CNRS, Orléans, France)

Midlatitudes (late morning), Aire-sur-l'Adour, 43°N, (Sep./Oct. 2002):

SPIRALE: 2 October 2002, 9.30 - 10.00 LT
(no MIPAS data available on 2-10-2002)

- Backward trajectory calculations to match MIPAS (v4.61) on 25 Sep. (triangle) and 27 Sep. (squares) at 10:10 LT)
- Photochemical difference MIPAS - SPIRALE ≤ 0.3 ppbv
Arctic winter (night), Kiruna (Jan. 2003):

SPIRALE/MIPAS20032101_195233

21 21.5 22 22.5 23 23.5
local time

15 20 25 30 35
h (km)

edge region        inside vortex

MIPAS
SPIRALE
PV @ 670K, ~27 km, 2000 UT

SPIRALE/MIPAS21012003

35
30
25
20
15
21 21.5 22 22.5 23 23.5
local time

66 68 70 72
Latitude

edge region        inside vortex

MIPAS
SPIRALE
PV @ 796K, ~30 km, 2100 UT

MIP AS_195233
SPIRALE
MIP AS_195354
SPIRALE/MIPAS 20032101_195233

SPIRALE/MIPAS 20032101_195354

MIPAS-IMK (preliminary) offline V1/4.55 data, courtesy: B. Funke (IAA/IMK)
MIPAS-B (FTIR) - Balloon (Sep. 2002)

(IMK-ASF, Karlsruhe, Germany)

Midlatitudes (night), Aire-sur-l’Adour, 43°N, 24 Sep. 2002:
Match of ENVISAT evening overpass (orbit 2975).

<table>
<thead>
<tr>
<th>Seq. S</th>
<th>Seq. N3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>mean observation time:</strong></td>
<td></td>
</tr>
<tr>
<td>MIPAS-B:</td>
<td>21:50 UT</td>
</tr>
<tr>
<td>MIPAS-E:</td>
<td>22:06 UT</td>
</tr>
<tr>
<td>MIPAS-B:</td>
<td>22:21 UT</td>
</tr>
<tr>
<td>MIPAS-E:</td>
<td>22:07 UT</td>
</tr>
</tbody>
</table>

**mean meas. coordinates:**

| MIPAS-B:   | 39.9°N, 1.1°E 47.0°N, 0.7°E   |
| MIPAS-E:   | 41.7°N, 1.6°E 46.4°N, 0.6°E   |

→ Perfect coincidence in terms of time and location
Note:
MIPAS-B: 1-σ total error
MIPAS-E: 1-σ retrieval error
Comb. error without spectroscopy

MIPAS-E/IMK: courtesy: B. Funke

Mean abs. diff. (ppbv):
- MIPAS-B: 0.9026
- MIPAS-E/ESA: 0.7293
- MIPAS-E/IMK: 0.4660
- MIPAS-B: 0.3518

Aire: 24 September 2002, Seq. N3 and S
MIPAS-B: 24-Sep-2002 22:21:42 (Seq. N3)
MIPAS-B: 24-Sep-2002 21:50:26 (Seq. S)
MIPAS-E/ESA: 24-Sep-2002 22:06:29 (v4.61)

MIPAS-B - Envisat
Difference (solid)
Comb. error (dashed)
Late arctic winter (morning), Kiruna, 68°N, 20/21 Mar. 2003:
Match of ENVISAT evening (orbit: 5508) and morning overpasses (orbit: 5515).

Problem: No reprocessed operational data (v4.61) available so far!
Comparison only for v4.57 data for orbit 5515 possible.

mean obs. time/coordinates: (Seq. D15c):
MIPAS-B: 08:48 UT 65.6°N, 17.5°E
MIPAS-E: 09:08 UT 65.6°N, 17.1°E

→ Perfect coincidence in terms of time and location
MIPAS-B: $1-\sigma$ total error
MIPAS-E: $1-\sigma$ retrieval error
Comb. error without spectroscopy
SAOZ (UV-vis spectroscopy) - Balloon
(courtesy: F. Goutail, J.-P. Pommereau)

(AOID 701, Service d’Aéronomie, CNRS/IPSL, France)

- Three latitude regions (arctic, mid-latitudes, tropics)
- Various seasons (summer, winter inside and outside vortex)
- Coincidence criteria: 600 km, 4 h
- Only one coincidence found in data base

- SAOZ precision for NO$_2$: 10% (10-30 km)
- SAOZ converted into mixing ratios using on-board PTU
Vanscoy, Canada (52°N, 100°W), Sep. 4, 2002

SAOZ: sunrise and sunset
MIPAS v4.61: daytime

Future work:
Model to be used for NO₂ diurnal correction.
POAM III (solar occ.) – SPOT-4 sat. (courtesy: F. Goutail, A. Bazureau)

(AOID 317, Service d’Aéronomie, CNRS/IPSL, France)

- One latitude region: 60°-70°N
- Two periods: Aug. - Sep. 2002 → 112 coincidences
  Oct.- Dec. 2002 → 57 coincidences
- Coincidence Criteria: 600 km, 4 h

- POAM III precision for NO$_2$: < 10% (20-45 km)
- POAM III converted into mixing ratios using NMC analyses
Northern Hemisphere Oct-Dec 2002 (57 profiles)

- Direct coincidence in terms of latitude/longitude and time is alright
- Quality of agreement is variable (e.g. altitude shift in some MIPAS profiles)
- Positive bias (20%) between POAM III and MIPAS (27-40 km), "high quality" profiles
HALOE (solar occ., v19 data) – UARS satellite
(courtesy: A. Bracher, M. Sinnhuber, M. Weber, K. Bramstedt)

(AOID 651, Institute of Environmental Physics, University of Bremen, Germany)

- Solar zenith angle (SZA) of HALOE ~90° (occultation instrument, NO₂ acc. 15% at 25-45 km), MIPAS variable SZAs → photochemical corr. of NO₂ necessary
- HALOE NO₂ used as input for 1-D photochemical model and scaled to MIPAS SZA (described in Bracher et al., subm. to ACP)
- HALOE within 250 km of MIPAS observations during the same day
  - most at 30°N - 60°N (42)
  - 60°N - 90°N (29)
  - 2 in the tropics
  - 10 at > 30°S

Note: For SZA > 100° model output limited to pressure levels > 2 hPa
Statistics for all comparisons of MIPAS v4.61 to model with HALOE-input at different MIPAS SZAs:

\[(\text{MIPAS} - \text{HALOE\_Model})/\text{HALOE\_Model} \times 100\%\]

<table>
<thead>
<tr>
<th>MIPAS SZA</th>
<th>mean rel. deviation</th>
<th>RMS</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>25°-50°</td>
<td>at 1.5 - 25 hPa</td>
<td>-15 → +30%</td>
<td>30%</td>
</tr>
<tr>
<td>50°-80°</td>
<td>at 1.5 - 25 hPa</td>
<td>-8 → +25%</td>
<td>40%</td>
</tr>
<tr>
<td>(at 5.5 - 8.5 hPa &gt;100%!)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>94°-120°</td>
<td>at 1.5 - 25 hPa</td>
<td>-15 → +30%</td>
<td>30%</td>
</tr>
<tr>
<td>120°-155°</td>
<td>at 2 - 25 hPa</td>
<td>-10 → +15%</td>
<td>30%</td>
</tr>
</tbody>
</table>
MIPAS/E-IMK (V1/4.55) vs. MIPAS/E (v4.61) (courtesy: B. Funke, D.Y. Wang)
(IAA, Granada, Spain; IMK-ASF, Karlsruhe, Germany)

MIPAS IMK – ESA 14 Days No: 3790
Mean Difference and Standard Deviation

Mean daily profiles (all latitudes)
GASCOD (in-situ) – Geophysica (courtesy: A. Martinez, I. Kostadinov)
(ERS-Srl, Florence, Italy; ISAC-CNR, Bologna, Italy)

Geophysica mid-latitudes campaign:
- GASCOD: 14-Oct-2002, 08:48-12:03 UTC, 45.4°N, 11.6°E
- KASIMA 3-D CTM (courtesy: R. Ruhnke):
  - 14-Oct-2002, 12 UTC, 45°N, 12°E
  - 14-Oct-2002, 12 UTC, 46°N, 151°W
  - 14-Oct-2002, 12 UTC, 46°N, 176°W
  - 14-Oct-2002, 12 UTC, 46.0°N, 159°E

Why does MIPAS not measure lower down?
Ground-based FTIR in Kiruna (courtesy: T. Blumenstock)

(IMK-ASF, Karlsruhe, Germany)

Kiruna (NDSC station): morning overpasses, ~ 8.00 - 10.00 UT
Lowest $z_{\text{min}}$: ~ 25 km

→ ~ 40 % of total column subtracted
→ g.b. result is strongly dependent on lowest stratosph. altitude and the partial column below
→ MIPAS partial columns are larger compared to g.-b. measurements
→ Seasonal variation is captured fairly well by MIPAS

MIPAS v4.61 NO$_2$ column amounts vs. g.-b. FTIR at Kiruna (18 Jul. - 5 Nov. 2002)

Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft
Institut für Meteorologie und Klimaforschung

Atmospheric Chemistry Validation of ENVISAT - ESRIN - 3-7 May 2004
G.-b. UV-vis spectr. at the NDSC station Harestua (60°N)
(courtesy: F. Hendrick, M. Van Roozendael, M. De Mazière)

(Belgian Institute for Space Aeronomy, Brussels, Belgium)

- IASB-BIRA zenith-sky UV-vis spectrometers continuously operating since 1998
- Retrieval technique (optimal estimation [Rodgers, 2000]) is based on dependence of mean scattering height on solar zenith angle (SZA) [Preston et al., 1997], thoroughly validated by correlative measurements [Hendrick et al., submitted to ACPD, 2004]
- Stacked box photochemical model is included in the retrieval algorithm in order to reproduce the effect of the rapid variation of the NO₂ concentration at twilight
- Comparison with MIPAS NO₂ v4.57 and v4.59 for the period April-August 2003
- Criteria for the selection of coincident events:
  Spatial:  - Distance from the Harestua station < 500 km
  Temporal: - Days of MIPAS observations = days of ground-based UV-visible obs.
  - Comparisons performed at the same SZA: ~ 40-60° for daytime and ~ 95-105° for nighttime conditions according to the MIPAS overpasses in the April-August period
- Number of coincident events: 28 at daytime, 37 at nighttime
Ground-based UV-visible and MIPAS NO$_2$ averaging kernels:

→ 25-35 km is the altitude range where the comparison is relevant; smoothing of the MIPAS profiles is needed for the comparison.
25-35 km partial columns comparison (MIPAS v4.57 & 4.59)

Daytime Nighttime

HARESTUA (Norway, 60°N) - Daytime: 25-35 km NO₂ partial column

Mean
(
~ -20%
)

HARESTUA (Norway, 60°N) - Nighttime: 25-35 km NO₂ partial column

Mean
(~ -10%)
Conclusions

Inter-comparison aggravated by
- Diurnal variation of NO$_2$, especially for measurements around SR and SS
- Lack of reprocessed v4.61 data for 2003

Validation results obtained so far (quality rating: ++ very good, + good, o fair, ? unclear)
- Balloon
  - SPIRALE Sep./Oct. 2002 mid-latitudes ++
  - MIPAS-B Sep. 2002 mid-latitudes ++
  - SAOZ Sep. 2002 mid/high-lat. + ?
- Satellite
  - POAM III Aug.-Dec. 2002 high-latitudes o low bias in MIPAS (20%, 27-40 km)
  - HALOE Jul.-Dec. 2002 all latitudes ++ high bias in MIPAS (~5%, 1.5-25 hPa)
  - MIPAS-IMK Sep./Oct. 2002 all latitudes ++ between 20 and 0.2 hPa
- Aircraft
  - GASCOD Oct. 2002 mid-latitudes ? no alt. match, qualitatively reasonable
- Ground-based
  - FTIR Kiruna Jul.-Nov. 2002 high latitudes + high bias in MIPAS (4-20%)
  - UV-vis Har. Apr.-Aug. 2003 mid/high lat. o low bias in MIPAS (v4.5x, 10-20%)

Apart from retrieval instabilities (v4.61) NO$_2$ looks reasonable (25-45 km)
Some high biases (MIPAS) in IR comp. and low biases in Uv-vis comp. visible