Odd Nitrogen Variability Caused by Energetic Electron Precipitation: What Have We Learned from MIPAS?

B. Funke, M. López-Puertas
Instituto de Astrofísica de Andalucía (CSIC), Granada, Spain
G.P. Stiller, T. von Clarmann, U. Grabowski, A. Linden, S. Kellmann
Institut für Meteorologie und Klimaforschung, FZK and Univ. of Karlsruhe, Germany
The MIPAS instrument

Michelson Interferometer for Passive Atmospheric Sounding

- **Launch**: 1 March 2002 on board ENVISAT (sun-synchronous polar orbit, 98.5°).

- **Spectra** at 4.15-14.6 µm (685-2410 cm⁻¹) with 0.035 cm⁻¹ (0.0625 cm⁻¹) resolution.

- **Sensitivity**: 4-30 nW/(cm² sr cm⁻¹).

- **Radiometric error**: 1-3 %

- **Limb, altitude coverage**: 6-68 km @ 3 km steps in 85 s. (nominal mode), 20-100 km (middle atmosphere mode), 40-170 km (upper atmosphere mode)

- **Global coverage in latitude** (polar night!)

- **72 scans/orbit; ~1000 scans/day**
**The MIPAS instrument**

*Michelson Interferometer for Passive Atmospheric Sounding*

- **Launch:** 1 March 2002 on board ENVISAT (sun-synchronous polar orbit, 98.5°).
- **Spectra** at 4.15-14.6 µm (685-2410 cm⁻¹) with 0.025 cm⁻¹ (0.0625 cm⁻¹) resolution.
- **Sensitivity:** 4-30 nW/(cm² sr cm⁻¹).
- **Radiometric error:** 1-3 %
- **Limb, altitude coverage:** 6-70 km @ 3 km steps in 85 s. (nominal mode), 20-100 km (middle atmosphere mode, each 10 days), 40-170 km (upper atmosphere mode, each 10 days).
- **Global coverage in latitude** (polar night!)
- **72 scans/orbit; ~1000 scans/day**
HEPPA 2009, Boulder, CO
Indirect EPP effects
Thursday, 08/10/2009
B. Funke (bernd@iaa.es)

IMK/IAA MIPAS data products

- Data access via web: [http://www-imk.fzk.de/asi/ame/envisat-data/](http://www-imk.fzk.de/asi/ame/envisat-data/)
- Annual “IMK/IAA MIPAS Data User meeting” in Karlsruhe/Germany or Granada/Spain

Next meeting:
13-15 October 2009
at IMK/Karlsruhe/Germany
Mixing

Polar night

Illuminated

EEP: NOx polar winter descent

Productions

Energetic electron precipitation (EEP)
continuous+variable

\[ \text{N}_2 + e^- \rightarrow \text{N} + \text{N} + e^- \rightarrow \text{NO} + \text{O} \]

Transport

Polar winter

Photolysis & Chem. Reac.:

\[ \text{NO} + \text{hv} \rightarrow \text{N} + \text{O} \]

\[ \text{NO} + \text{N} \rightarrow \text{N}_2 + \text{O} \]

require illumination!

Losses

Planetary waves

Mixing
5 reasons for MIPAS in EEP research:

1. Observations at polar night conditions

2. Excellent spatial coverage (compared to solar occultation)

3. Measures both NOx species (NO+NO₂)

4. Measures secondary EPP products (HNO₃, N₂O, ClONO₂, N₂O₅, ClO, HOCl, BrONO₂)

5. Simultaneous measurements of stratospheric and mesospheric dynamical tracers (CO, CH₄)
• strongest EEP-NOX descent in 2003-2004 winters
• higher variability in NH winters
Energetic electron precipitation (EEP)

MIPAS NO2 from NOM nighttime observations

- White contour: 10 ppbv
- 30–60S average
- 30–60N average
Extraordinary NOx enhancements in January 2004 (NH) caused by rapid descent (1200 m/day) from the MLT (not in situ production)

In situ production? (Renard et al., 2006)
NOx and CO in 2003/2004

NOx: 20031026, poT = 1750 K (44.1 - 47.4 km)

CO: 20031026, poT = 1750 K (44.1 - 47.4 km)

ppmv

0.01  0.10

0.01  0.10  1.00
Quantification of strat. EEP-NOx

Stratospheric deposition of EEP-generated NOx during 2003/2004

- 2003 Antarctic: 2.4 GM
  Funke et al. JGR, 2005

- 2004 Arctic: 2.3 GM
  (1.5 EEP, 0.8 SPE)
  most NOx deposited above 35 km!

...9% of the annual production by N₂O oxidation!
Secondary EEP effects

2nd HNO₃ maximum at 35 km

Caused by descent of EEP-NOx.

Conversion NOₓ → HNO₃ requires ion chemistry.
Secondary EEP effects

EEP-related $N_2O$ enhancements

Mesospheric $N_2O$ enhancements as observed by MIPAS on Envisat during the polar winters in 2002–2004

B. Funke¹, M. López-Puertas¹, M. García-Comas¹, G. P. Stiller², T. von Clarmann², and N. Glatthor²

¹Instituto de Astrofísica de Andalucía, CSIC, Granada, Spain
²Forschungszentrum and University of Karlsruhe, Institut fur Meteorologie und Klimaforschung (IMK), Karlsruhe, Germany

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• Caused by $NO_2+N \rightarrow N_2O+O$ below 75 km
• Possible additional contribution of $N_2(A^3Σ_u^+)+O_2$
Solar cycle trends in global NOx and NOy

Is there an EEP signal?
(a preliminary analysis....)

Source: NASA
Stratospheric NOx

Solar Cycle Ap Progression
Data Through Jun 09

Planetary Index, Ap

1 Jan 2003 1 Jan 2004 1 Jan 2005 1 Jan 2006 1 Jan 2007 1 Jan 2008

35 30 25 20 15 10 5 0

7 \times 10^{15} 6 \times 10^{15} 5 \times 10^{15} 4 \times 10^{15} 3 \times 10^{15} 2 \times 10^{15} 1 \times 10^{15} 6 \times 10^{14}

3-4 GM

Gmole (60S-60N)

28 30 32 34 36

0 2 4 6 8

ENVISAT MPAS
NO production by N2O+O1D

Top: NO production/day (MIPAS target retrieval > 380K)
Bottom: Total amount (within 60S-60N = black, NP = blue, SP = red)

No correlation!

derived from MIPAS N2O +O3+TUV $J_{O_3}$ calculations

P$_{NO}$ cm$^{-3}$ d$^{-1}$
Stratospheric HNO3

Top: HNO3 columns /MIPAS target retrieval > 380 K,
Bottom: Tot. amount (within 60S-60N = black, NP = blue, SP = red)

1.5GM
~2%
Stratospheric N2O5

Top: N2O5 ngt columns /MIPAS target retrieval > 380K,
Bottom: Tot. amount (within 60S-60N = black, NP = blue, SP = red)

NOy partitioning (lower strat)

1 GM

~25%
Stratospheric ClONO2

Top: CLONO2 ngt columns /MIPAS target retrieval > 380K.
Bottom: Tot. amount (within 60S-60N = black, NP = blue, SP = red)

0.5 GM
~10%

NOy partitioning
MIPAS: perfectly suited for EPP studies (global coverage including polar night, simultaneous observations of many species affected by EPP (NO+NO₂, etc), and dynamical tracers)

- Dynamical modulations of EEP NOx descent most pronounced in NH (analysis by means of simultaneous tracer (CO) observations), no EEP-induced stratospheric/lower mesospheric in situ production detected by now.

- Quantification of EEP-NOx deposition into the stratosphere: 9% of N₂O oxidation in 2003/2004

- Identification of EEP-related productions of N₂O and HNO₃

- Solar cycle trends in global NOx and NOy (2002-2008):
  - NOx: 4 GM increase during 2003-2005 most likely due to EEP
  - HNO₃: 2% increase (solar max to solar min) due to reduced photolysis
  - N₂O₅ and ClONO₂: decreases due to changed partitioning in lower strat (HNO₃)
Thank you!