Modeled impact of atmospheric ionisation by solar protons and magnetospheric electrons on upper stratospheric constituents compared with MIPAS measurements

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Outline

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Motivation

Figure: Daily mean AIMOS ionisation rates for protons (red) and electrons (blue) for October 1, 2003 - February 29, 2004
Motivation

Figure: $\Delta$NO$_x$ near NyÅlesund, Svalbart
Motivation

Figure: $\Delta O_3$ near NyÅlesund, Svalbart
The Bremen 3d CTM

- global 3d Chemistry and Transport Model (CTM)
- driven by meteorological data (temperature, pressure, wind fields): ECMWF operational
- horizontal transport along isentropes calculated from analysed wind fields
- vertical transport across isentropes calculated from diabatic heating rates
- neutral chemistry model, 57 tracer, families ($O_x$, $NO_x$, $HO_x$, $ClO_x$, $BrO_x$)
- JPL 2006
- ionisation rates from AIMOS model [Wissing et al., 2008]
- parameterised $NO_x$ and $HO_x$ production:
  - $1.25 \; NO_x$ (55% NO, 45% N) [Porter et al., 1976]
  - $\leq 2 \; HO_x$ [Solomon et al., 1981]
The Bremen 3d CTM

- horizontal resolution
  - 96 longitudes
  - 72 latitudes
  - $3.75^\circ \times 2.5^\circ$
- vertical resolution
  - 28 isentropes
  - 10 - 65 km
  - 1 - 4 km

adapted from Jan Aschmann
Modeled impact of atmospheric ionisation by solar protons and magnetospheric electrons

**Motivation**

**Simulations & Results**

**Model comparison**

**Conclusion**

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### Bremen 3d CTM simulations

- **Met.data:** ECMWF operational
- **AIMOS Ionisation rates**

#### Scenario Overview:

- **Scenario A:** no ionisation rates
- **Scenario B:** protons
- **Scenario C:** protons + electrons

Parameterised production rates for NO$_x$ and HO$_x$
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**NO\textsubscript{x} response to different ionisation forcing**

Figure: $\Delta$NO\textsubscript{x} [ppbv] at 56km altitude. Absolute differences for scenarios B and C to scenario A [Wissing et al., 2009]
O₃ response to different ionisation forcing

Figure: ΔO₃ [%] at 56km altitude. Percentage difference for scenarios B and C to scenario A [Wissing et al., 2009]
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Ozone

Bremen 3d-CTM $\Delta(D\Delta O_3)$ [ppmv] 56km October 26, 2003 DAY

AIMOS ionisation rates (protons+electrons - protons)

Figure: $\Delta O_3$(scenario C - scenario B)

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Ozone VMR [ppmv] (324°, 80°) October 26, 2003 DAY

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Ozone

Bremen 3d-CTM  \(\Delta (\Delta O_3)\) [ppmv] 56km October 31, 2003 DAY

AIMOS ionisation rates (protons+electrons - protons)

Figure: \(\Delta O_3\) (scenario C - scenario B)

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Ozone VMR [ppmv] (339°, 80°) October 31, 2003 DAY

- MIPAS
- B3DCTM no SPE
- B3DCTM p+e
- B3DCTM p

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Figure: NO at 56km altitude, October 26, 2003 for scenario B (left) and C (right)
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Figure: NO at 56km altitude, November 1, 2003 for scenario B (left) and C (right)
Figure: HNO$_3$ at 56km altitude for scenario B (left) and C (right), model results underlying, circles: MIPAS
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**HNO_3 & NO_2**

**Figure:** HNO_3 at 40km altitude for scenario B (left) and C (right), model results underlying, circles: MIPAS
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### HNO₃ & NO₂

![Bremen 3d-CTM ∆HNO₃ ZM VMR [ppbv] November 1, 2003 DAY AIMOS ionisation rates (protons)](image1)

![Bremen 3d-CTM ∆HNO₃ ZM VMR [ppbv] November 1, 2003 DAY AIMOS ionisation rates (protons + electrons)](image2)

![MIPAS ∆HNO₃ ZM VMR [ppbv] November 1, 2003 DAY MIPAS-E_IMK.20031101.V3O_HNO3_9](image3)

![Bremen 3d-CTM ∆NO₂ ZM VMR [ppbv] November 1, 2003 NIGHT AIMOS ionisation rates (protons)](image4)

![Bremen 3d-CTM ∆NO₂ ZM VMR [ppbv] November 1, 2003 NIGHT AIMOS ionisation rates (protons + electrons)](image5)

![MIPAS ∆NO₂ ZM VMR [ppbv] November 1, 2003 NIGHT MIPAS-E_IMK.20031101.V3O_NO2_9](image6)

**Figure:** ∆HNO₃ and ∆NO₂ (Difference to October 26, 2003)

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Conclusion

- \( \text{NO}_x \) increase due to ionisation by electrons before the SPE
- enhanced \( \text{NO}_x \) production during SPE
- a larger decrease of ozone
- larger ozone depletion in mid latitudes
- enhanced HNO\(_3\) production in high altitudes due to too high amounts of NO\(_2\)
Thank You!
Modeled impact of atmospheric ionisation by solar protons and magnetospheric electrons

### Motivation

