NO and CO vertical profiles derived from MIPAS/ENVISAT under consideration of non-LTE


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Introduction

The Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) is a mid-IR high-resolution limb sounder on board of the polar orbiter ENVISAT, successfully launched on March 1st, 2002. The analysis of the important trace gases NO and CO requires the consideration of non-LTE in the retrieval scheme due to strong thermospheric and/or thermospheric non-LTE emissions contributing to the measurements. Such an non-LTE retrieval processor has been developed at IAA/IMK [1]. We present and analyse non-LTE retrieval of trace gases from MIPAS data taken in its upper atmospheric mode (orbita 1748 – 1752) during July 1st, 2002. In this observation mode MIPAS scans the limb from tangent altitudes of 17 km up to 100 km.

The non-LTE retrieval processor

Since non-LTE populations of IR active species generally depend on retrieval target quantities such as volume mixing ratios (vmr) or pressure/temperature, these populations have to be calculated within each step of the retrieval. The main difference to a LTE retrieval scheme is thus the integration of a non-LTE population model in the inversion scheme:

- Calculation of vib. and rotational populations and their derivatives with respect to the NLTE retrieval parameters
- Generalized scheme: same algorithm used for populations of CO2,O3, CO, NO, NO2, H2O, OH, etc.
- User defined (states and transitions, altitude range, iteration strategies, process definition, etc.)
- Rotational - vibrational non-LTE
- Line-by-line and line independent radiative transfer (KOPRA)
- Line - by - line independent radiative transfer (KOPRA)
- Global fit least squares inversion algorithm with user-defined regularisation

Forward model: Karlsruhe Optimised and Precise Radiative Transfer Algorithm (KOPRA) [2]

- Line-by-line radiative transfer model
- Interface for generic NLTE model GRANADA
- Line-by-line non-LTE model

Non-LTE model: Generic Radiative Transfer And Non-LTE population Algorithm (GRANADA) [4]

- Calculation of vib. and rotational populations and their derivatives with the NLTE retrieval parameters
- Generalized scheme: same algorithm used for populations of CO2,O3, CO, NO, NO2, H2O, OH, etc.
- User defined (states and transitions, altitude range, iteration strategies, process definition, etc.)
- Rotational - vibrational non-LTE
- Line-by-line and line independent radiative transfer (KOPRA)
- Inversion of multi-level steady state equation with the Lambda iteration or Curtis matrix formalisms

NO retrieval

NO plays an important role in stratospheric chemistry. Furthermore, the analysis of thermospheric NO emissions is valuable for understanding energetics and chemistry of the upper atmosphere. NO is retrieved from MIPAS spectra at the 5.3 μm region of the NO(v=1–4) fundamental band. These emissions are dominated by stratospheric and thermospheric signal. The retrieval of stratospheric NO thus must take into account contributions of thermospheric NO.

NO emissions are affected by vibrational non-LTE in the stratosphere mainly due to chemical excitation by NO2 photolysis. Hence, NO2 has to be retrieved prior to NO in order to well constrain this excitation in the non-LTE modeling.

Thermospheric NO is in rotational and vibrational non-LTE controlled by chemical excitation due to N2O and collisional quenching with atomic oxygen. The uncertainties of thermospheric NO kinetic temperature and its altitude dependence are very well known and can be used in the inversion scheme.

The well pronounced symmetry between measured day- and nighttime CO of the same latitude indicates that thermospheric NO is correctly taken into account.

CO retrieval

CO is an important dynamic tracer in the upper atmosphere and mesosphere. It is retrieved from MIPAS spectra at the 4.6 μm region of the CO(v=1–0) fundamental band. The vibrational populations of the CO(1) states show strong non-LTE enhancements at daytimes due to solar excitation, while at nighttime populations can be even less than under LTE. Therefore, the sensitivity of measured non-LTE emissions with respect to the CO vmr is significantly lower at nighttime than at daytimes.

Summary & Conclusions

- Generally good performance of NO and CO non-LTE retrievals.
- Expected features in the spatial distribution of NO and CO non-LTE retrievals:
  - Small variations of stratospheric NO
  - Stratospheric NO increase over the polar regions
  - Thermospheric NO decrease over the polar regions
  - CO can be detected in the upper stratosphere / mesosphere with a vertical resolution of 7 km and a precision of 0.1 ppm.
  - Stratospheric NO can be detected with a vertical resolution of 5–10 km and a precision of 1–3 ppm.
- The precision of derived thermospheric NO is restricted by uncertainties in thermospheric O and T.
- Horizontal gradients in thermospheric NO degrade stratospheric NO retrieval in polar regions at solstice conditions.
- Non-LTE modelling of CO(v=1) populations within the retrieval seems to be correct.

References


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