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

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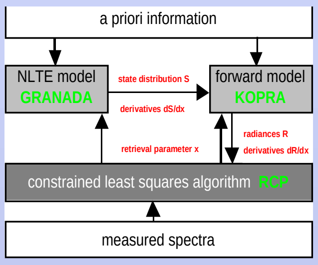
Introduction

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 mesospheric 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 these trace gases from MIPAS data taken in its upper atmospheric mode (orbits 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:



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

- Line-by-line radiative transfer model
- Interface for generic NLTE-model GRANADA
- supports vibrational and rotational non-LTE
- computes spectra and Jacobians for LTE and non-LTE

Retrieval Control Program (RCP) [3]

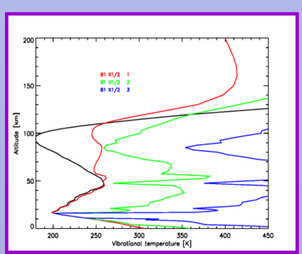
- global fit least squares algorithm with user defined regularisation

Non-LTE model: Generic RAdiative traNsfer AnD non-LTE population Algorithm (GRANADA) [4]

- Calculation of vib. and rotational populations and their derivatives wrt 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 (and spin-orbit) non-LTE
- Line-by-line and line independent radiative transfer (KOPRA)
- Inversion of multilevel steady state equation with the Lambda iteration or Curtis matrix formalisms

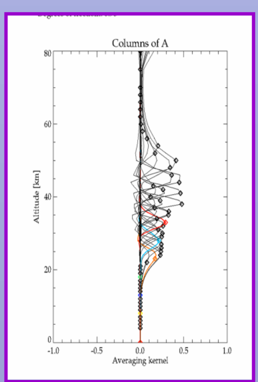
NO retrieval

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 _m region of the NO(v=1→0) 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.



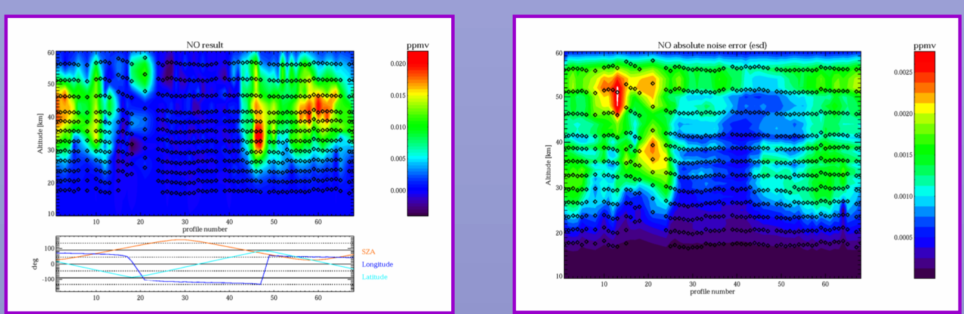
Vibrational temperatures of NO(v=1,2,3).

NO emissions are affected by vibrational non-LTE in the stratosphere mainly due to chemical excitation by NO_2 photolysis. Hence, NO_2 has to be retrieved prior to NO in order to well constrain this excitation in the non-LTE modelling.
Thermospheric NO is in rotational and vibrational non-LTE, controlled by chemical excitation due to N+O_2 and collisional quenching with atomic oxygen. The uncertainties of thermospheric O and kinetic temperature (which is only retrieved up to 100 km) limit accuracy of thermospheric NO retrieval.

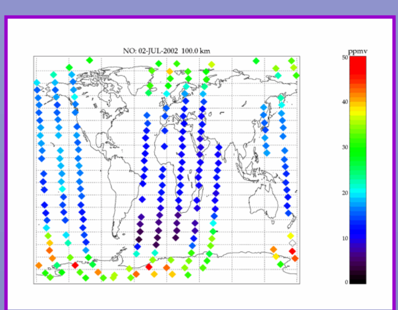


Columns of a typical averaging kernel of stratospheric NO retrieval

	stratospheric NO	thermospheric NO
tangent heights	17 -70 km	90 - 100 km
microwindows	1840 -1920 cm^{-1}	1840 – 1920 cm^{-1}
retrieval grid	0-200 km	0-200 km
regularisation	Tikhonov 1st order	Tikhonov 1st order
vertical resolution	10km @ 20 - 30 km 5 km @ 30 – 50 km	20 km @ 100 km
noise error	1-3 ppb	systematic errors dominant
non-LTE	rotational - vibrational	rotational - vibrational



Retrieved vertical NO vmr distribution along orbit 1748 — Noise error of retrieved stratospheric NO along orbit 1748

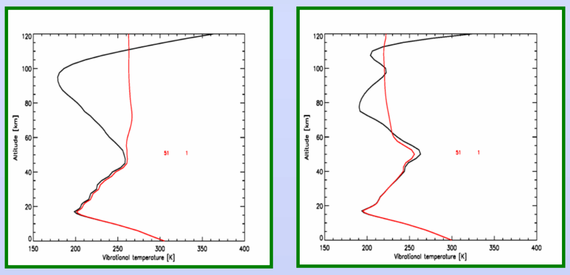


Thermospheric NO vmr at 100 km for orbits 1748 -1752

Retrieved stratospheric NO distributions show all expected features like disappearing NO concentrations at nighttime and a tropical maximum. Measured thermospheric NO is strongly enhanced over the polar regions due to geomagnetic activity. This leads to strong thermospheric gradients around ±70º latitude which degrades convergence of stratospheric NO retrieval and/or introduces systematic errors. These problems would be avoided by a 2D retrieval approach.

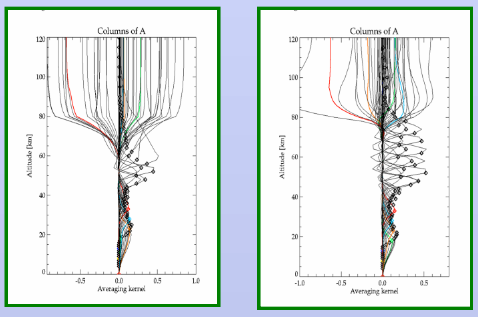
CO retrieval

CO is an important dynamic tracer in the upper stratosphere and mesosphere. It is retrieved from MIPAS spectra at the 4.6 _m region of the CO(v=1→0) fundamental band.



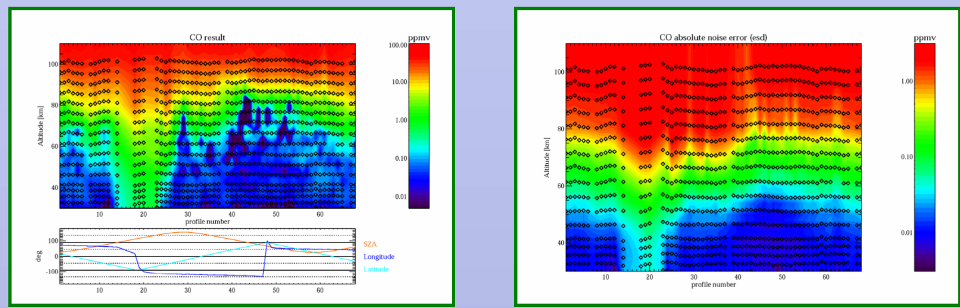
Vibrational temperatures of CO(v=1) at daytime (left) and nighttime (right)

The vibrational populations of the CO(1) states show strong non-LTE enhancements at daytime 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 daytime.



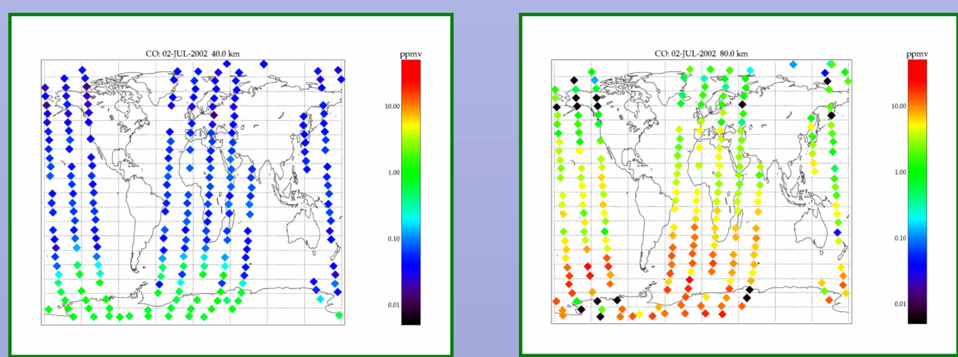
Columns of typical averaging kernels of the CO retrieval at nighttime (left) and daytime (right)

	CO
tangent heights	17 -70 km
microwindows	2024 -2217 cm^{-1}
retrieval grid	0-120 km
regularisation	Tikhonov 1st order
vertical resolution	10km @ <40 km 7 km @ 40 - 80 km (day) 7 km @ 40 - 60 km (night)
noise error	0.01 ppm @ 40 km 0.1 ppm @ 70 km
non-LTE	vibrational



Retrieved vertical CO vmr distribution along orbit 1748 — Noise error of retrieved stratospheric CO along orbit 1748

Retrieved CO distributions clearly show downward shifted CO over the winter pole due to the meridional circulation at solstice. The horizontal gradient towards the South pole is strongest at lower altitudes (see Figure below). The well pronounced symmetry between measured day- and nighttime CO of the same latitudes indicates that non-LTE is correctly taken into account.



Retrieved CO distribution at 40 km (left) and 80 km (right) for orbits 1748 - 1752

Summary & Conclusions

- Generally good performance of NO and CO non-LTE retrievals.
- Expected features in the spatial distribution of NO and CO can be detected:
  - diurnal variations of stratospheric NO
  - stratospheric NO maximum in the tropics
  - thermospheric NO increase over the poles
  - downward descent of CO over the winter pole
- CO can be detected in the upper stratosphere / mesosphere with a vertical resolution of 7 km and a precision of approx. 0.1 ppmv.
- Stratospheric NO can be detected with a vertical resolution of 5 – 10 km and a precision of 1 – 3 ppbv.
- The precision of derived thermospheric NO is restricted by uncertainties in thermospheric O and T_{kin}.
- Horizontal gradients in thermospheric NO degrades 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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[2] Stiller, editor, The Karlsruhe optimised and precise radiative transfer algorithm (KOPRA), ***Wissenschaftliche Berichte***, **FZKA 6487**, 2000.

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Acknowledgements

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