Stratospheric and Mesospheric Ozone Derived from MIPAS/ENVISAT under Consideration of non-LTE

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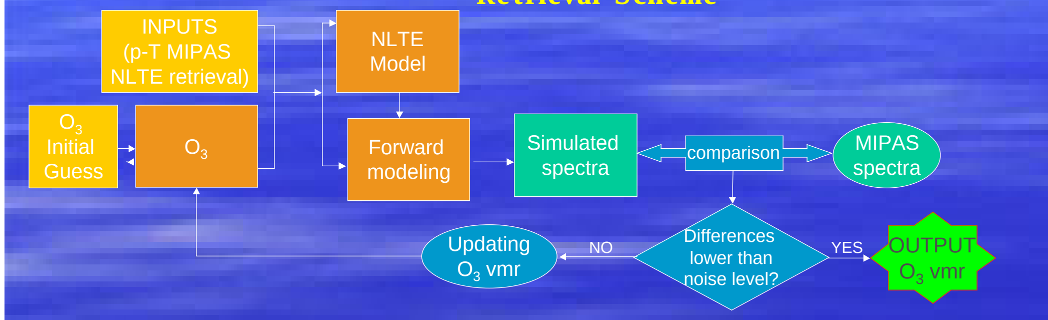
Introduction

The Michelson Interferometer for Passive Atmosphere Sounding (MIPAS) on board the Polar orbiter ENVISAT, successfully launched on March 1st, 2002, is a high resolution mid-IR limb sounder, designed to infer temperature and chemical composition of the stratosphere. While the standard measurements cover tangent altitudes from 6 to 70 km, its upper atmosphere mode scans the atmosphere up to 100 km. These measurements allow to derive the spatial ozone distribution from the lower stratosphere up to the lower thermosphere. Since ozone emissions from above around 50 km are in non-local thermodynamic equilibrium (NLTE), a dedicated NLTE retrieval scheme is required to infer ozone accurately above the stratosphere. We present here preliminary ozone distributions derived from MIPAS data in its upper atmosphere mode taken on 1 Jul 2002. We use the IMK/IAA data processor which includes NLTE with a generic NLTE model.

Retrieval Scheme



The retrieval process:

- An iterative constrained non-linear least square global fit
- Tikhonov type regularization as a function of altitude
- Forward model (KOPRA): Line by line radiative transfer model
- Altitude fixed retrieval grid
- 25 microwindows in 4 spectral regions (see Table)
- Pressure, temperature and LOS from MIPAS NLTE retrievals (see Poster P0811)
- O_3 initial guess from MIPAS climatology (mainly UARS)
- Upper Atmosphere MIPAS data from 18 Km up to 101 km
- Inclusion of contaminant gases (i.e. CO_2) in NLTE if required
- Use of **non-LTE model** in each iteration:
  - Uses the Generic RAdiative traNsfer AnD non-LTE population Algorithm (GRANADA) [1]
  - The setup for O_3 includes:
    - The 105 lowest vibrational energy levels, including the major emitters at 15, 10, 6 and 5 µm.
    - Chemical excitation:

      $O_2 + O + M \_ O_3(v_1,v_2,v_3) + M$ (Inverse zero suprisal)
    - V-V and V-T relaxations

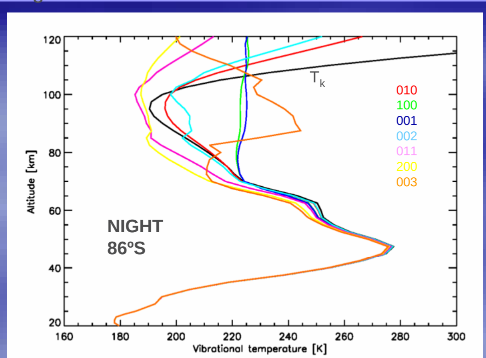
      $O_3(v_1,v_2,v_3) + M \_ O_3(v_1',v_2',v_3') + M$
    - Losses in chemical recombination

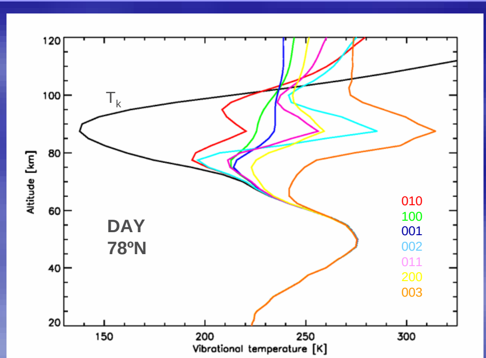
      $O_3(v_1,v_2,v_3{>}0) + O \_ 2\ O_2$

•Spectral range • (cm^{-1})	•Altitude coverage • (km)	•Main transitions
•719-800	•14-65	•010-000 •020-000
1027-1140	68-100	100-000 001-000
1689-1744	14-74	011-000
1934-1979	14-65	002-000 003-100

Non-LTE populations

These figures show the vibrational temperatures (non-LTE populations) of the upper states of the most prominent emitting levels in the selected microwindows for two atmospheric conditions: left, for nighttime in the polar winter (86ºS) and, right, for the daytime in the summer pole (78ºN). Both cases clearly show the NLTE deviations above the stratopause. For the polar winter (left figure), most levels are underpopulated relative to LTE in the lower mesosphere, which would underestimate O_3 vmr if LTE is assumed. In the polar summer, the NLTE populations appear at higher altitudes, where they are larger. Uncertainties of a factor of 2 in the NLTE parameters and the inverse zero surprisal cause radiance changes within MIPAS noise for these microwindows selected.

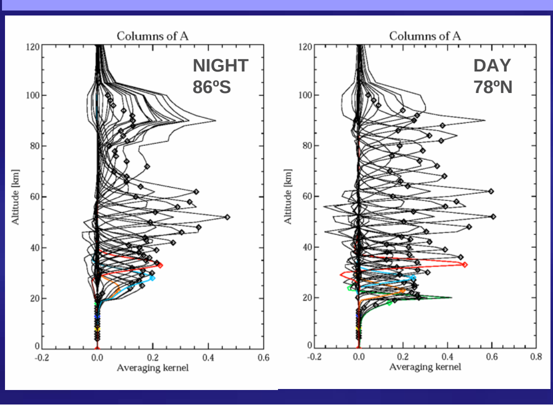


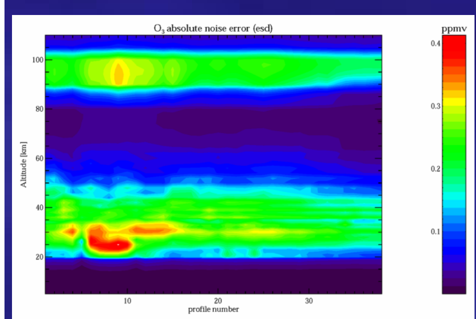


Quality of the results

The figures below show the averaging kernels for two profiles of typical atmospheric conditions: left, for nighttime in the polar winter (86ºS) and, right, for the daytime in the summer pole (78ºN). Information content and vertical resolution is better in the daytime case (note the different x-axis scale). At lower altitudes it is due to the warmer stratosphere in the summer, while at high latitudes mainly due to the more enhanced NLTE populations. Vertical resolution is ~4 km in the stratosphere and increase with height up to ~8 km in the mesosphere.

The absolute noise error of the retrieved O_3 for all profiles of orbit 1749 are shown in the right-side figure. The larger errors correspond to the region of less information content at the polar winter latitudes: in the stratosphere, because of colder temperatures and in the mesosphere due to the smaller non-LTE excitation.

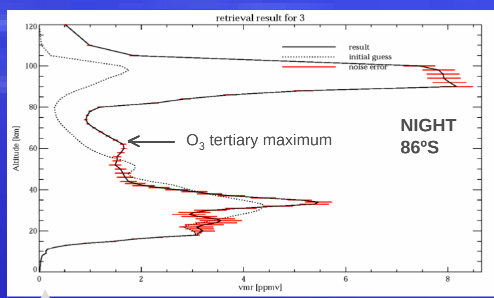


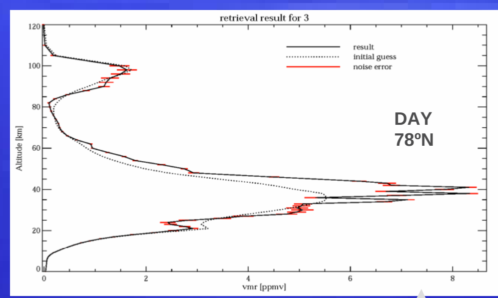


Typical O_3 profiles

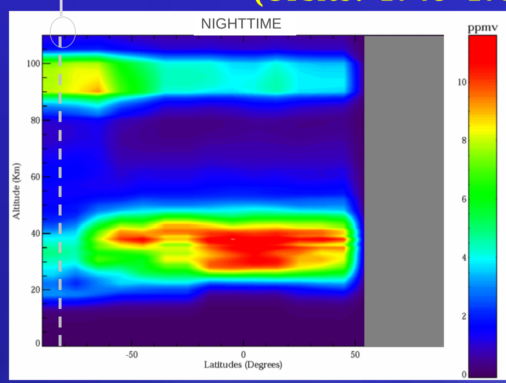
The figures below show individual O_3 vmr profiles retrieved for very distinct atmospheric conditions: left, for nighttime in the polar winter (86ºS) and, right, for the daytime in the summer pole (78ºN). The profiles show the typical features of O_3 vmr distribution: 1) The primary maximum in the stratosphere, larger at the tropics, smaller in the summer pole, and significantly depleted in the polar winter; 2) The secondary maximum in the upper mesosphere, being larger at nighttime conditions (left figure) than in the daytime (right figure). We also see that in both cases and in the whole region, the retrieved profiles are very different from the a priori (e.g., winter polar mesosphere) demonstrating the good quality of the measurements and of the retrieval.

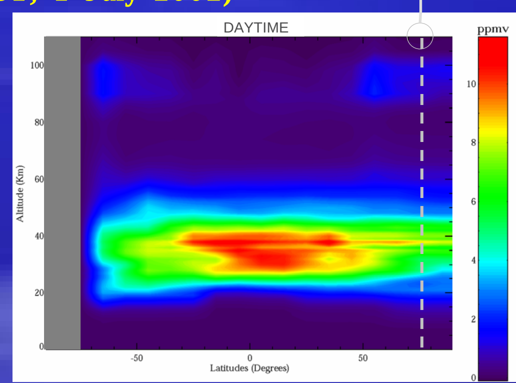
The O_3 tertiary maximum.
The data seem to show also the tertiary maximum that appear in the polar winter just below the secondary maximum (left figure) [2]. The retrieved values are significantly larger than the ***a priori*** and the vertical resolution is sufficient to resolve this tertiary maximum (see bottom figures of left column).



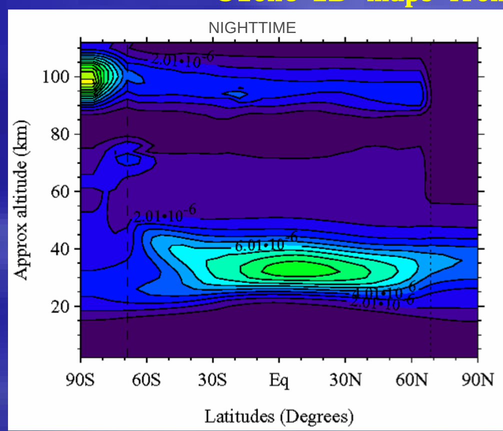


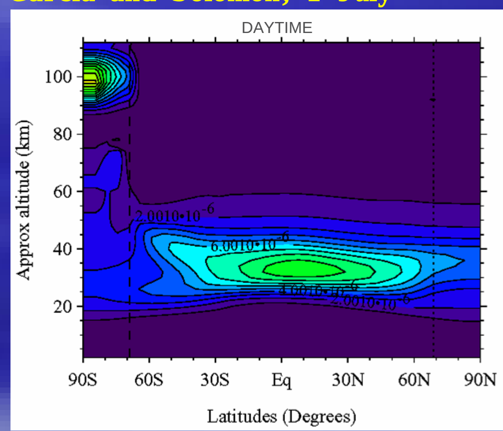
Average results from upper-atmosphere MIPAS data (Orbits: 1748-1751; 1 July 2002)





Ozone 2D-maps from Garcia and Solomon, 1 July





Zonal mean 2D maps

The figures above show the zonally averaged O_3 profiles for day and nighttime retrieved from 4 orbits (215 profiles) taken by MIPAS on 1 Jul 2002. Again, both plots show the typical O_3 structure in the stratosphere and mesosphere, from polar winter to polar summer, and for night and daytime conditions. Peak values in the **stratosphere** range from 4 ppmv (polar winter), to 12 ppm in the tropics, and 8 ppm in the polar summer. In the **nighttime mesosphere** values are 8 ppm at the winter pole to 4 ppm at other latitudes. In the **daylight mesosphere** O_3 is about 2 ppm at the summer pole and at latitudes just outside the dark polar winter. The tertiary maximum is also exhibited in the nighttime map.

We also show a **comparison with the Garcia and Solomon** (GS) model results for 1 July. Qualitatively, MIPAS measurements agree very well with model predictions. All main features in the model are seen in the data, even the extension of the tropical ozone maximum to mid-latitudes in the upper stratosphere. Absolute values differ in about 2 ppm in the stratosphere (MIPAS larger) and agree very well in the mesosphere for both night and daytime.

Summary and Conclusions

- Ozone vmr has been retrieved from the stratosphere up to the mesosphere, globally, from pole-to-pole and for day and nighttime conditions from MIPAS/Envisat measurements taken in its upper atmosphere mode on 1 Jul 2002.
- A non-LTE retrieval scheme has been used, which performs very well.
- O_3 vmr can be retrieved, in the stratosphere with a vertical resolution of 4 km and a precision of 0.3 ppmv, and of 8 km and a precision of 0.2 ppmv in the mesosphere.
- The retrieved O_3 shows the expected features in its spatial and temporal distribution:
  - Stratospheric max.: larger in the tropics, lower in the summer pole and even lower in the winter
  - The diurnal mesospheric variation with larger concentration in the polar winter
  - The tertiary maximum in the night polar winter
- A comparison with the Garcia and Solomon model shows a very good qualitative agreement. O_3 vmr's agree very well in the mesosphere and MIPAS vmr's are approx. 2 ppmv larger in the stratosphere.

References
1. Funke et al., ***J.Geophys. Res***., in preparation, 2003 .
2. Marsh et al., ***J. Geophys. Res***., **28**, 4531, 2001.

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