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

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Introduction

The Michelson Interferometer for Passive Atmospheric 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 a range of 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 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 larger errors correspond to the region of less information content at the polar winter latitudes: in the polar winter, the NLTE populations appear at higher altitudes, where they are larger. The retrieval process:

• Use of the Generic Radiative transfer And non-LTE model (GRANADA) [1]
• The setup for O3 vmr includes:
  - The 105 lowest vibrational energy levels, including the major emitters at 15, 10, 6 and 5 μm.
  - Chemical excitation:
    - O3 + O = O2 + O2 (Inverse zero surprisal)
    - V-V and V-T relaxations
    - Losses in chemical recombination
  - O3(v=1)_2,3 + M
  - O3(v=2)_2,3 + M
• Inclusion of contaminant gases (i.e. CO2, NO, NO2) in NLTE if required
• Spectral range: 10 to 115 μm
• Altitude coverage: 40 to 100 km
• Main transitions
  - O3(v=1)_2,3 + M
  - O3(v=2)_2,3 + M

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 stratosphere. For the solar winter (left figure), most levels are underpopulated relative to LTE in the lower mesosphere, which would understandably O3 vmr if LTE is assumed. In the polar summer, the NLTE populations appear at high 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). Both cases clearly show that 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 tropical stratopause. 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).

Typical O3 profiles

The figures below show individual O3 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 figures show the typical features of O3 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), and smaller in the summer pole, larger in the polar winter just below the stratosphere; 3) The tertiary maximum is also exhibited in the nighttime map. 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, the 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 conditions.

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

The figures above show the zonally averaged O3 profiles for day and nighttime retrieved from 4 orbits (215 profiles) taken by MIPAS on 1 Jul 2002. Again, both plots show the typical O3 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 ppm in the polar winter (12 ppm), to 12 ppm in the tropics, and 8 ppm in the polar summer. To the nighttime mesosphere values are 8 ppm at the winter pole to 4 ppm at other latitudes. In the daytime mesosphere O3 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, the 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 conditions.

Summary and Conclusions

- O3 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.
- O3 vmr can be retrieved, in the stratosphere with a vertical resolution of 4 km and a precision of 0.3 ppm, and 8 km and a precision of 0.2 ppm in the mesosphere.
- The retrieved O3 shows the expected features in its spatial and temporal distribution:
  - Stratospheric max.: larger in the tropics, located in the summer pole and even lower in the winter
  - Tertiary maximum: larger 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. O3 vmr’s agree very well in the mesosphere and MIPAS vmr’s are about 2 ppm larger in the stratosphere.

Average results from upper-atmosphere MIPAS data

(Orbits: 1748-1751; 1 July 2002)

Final mean 2D maps

The figures above show the zonally averaged O3 profiles for day and nighttime retrieved from 4 orbits (215 profiles) taken by MIPAS on 1 Jul 2002. Again, both plots show the typical O3 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 ppm (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 daytime mesosphere O3 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, the 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 conditions.

References


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