The Temperature and CO_2 Abundance of the Mesosphere and Lower Thermosphere as Measured by MIPAS/ENVISAT

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1. Introduction

The Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) is a high-resolution limb sounder on board the ENVISAT satellite, successfully launched on March 1, 2002. MIPAS has a wide spectral coverage (15-4.3 µm), high spectral resolution (0.05 cm^{-1} apodised), and high sensitivity (30-2.5 nW/(cm^2 sr cm^{-1})) which allows to measure, simultaneously, the kinetic temperature, the CO_2 volume mixing ratio, and non-LTE populations of vibrational levels emitting at 15, 10 and 4.3 µm in the upper atmosphere. This data set is very useful for better understanding the non-LTE processes in CO_2 and the composition and energetics of the upper atmosphere. MIPAS scans the limb operationally from 6 km up to 68 km and with this mode up to 100 km in its upper atmosphere mode. We present here **preliminary retrievals of temperature, CO_2 abundance and non-LTE CO_2-related parameters** from MIPAS data taken in its upper atmosphere mode during 1 Jul 2002.

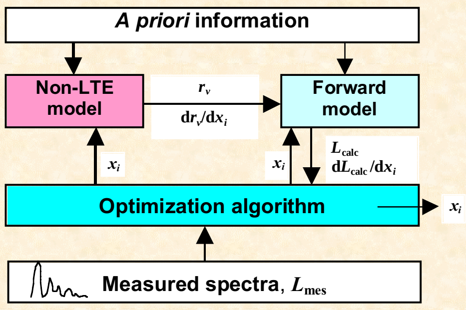
2. The retrieval scheme

Optimization algorithm [1]

- Iterative constrained nonlinear least squares global fit
- Regularisation: Temperature: Tikhonov 1st order
  LOS and CO_2: Optimal estimation

Forward model: KOPRA

- Line-by-line radiative transfer model
- Interface for NLTE-model
- Computes spectra and Jacobians for LTE and non-LTE [2]



The non-LTE model

Uses the Generic RAdiative traNsfer AnD non-LTE population Algorithm (GRANADA) [3]

The setup for CO_2 includes:

- Calculation of vibrational populations and their derivitavies w.r.t the NLTE retrieval parameters
- Inversion of multilevel steady state equation with the Curtis matrix formalism
- Line-by-line calculation of radiative transfer (KOPRA)
- Radiative processes, V-T and V-V collisional processes, and chemical productions
- Collisional rates and excitation processes for CO_2 as in [4,5].

More details on the retrieval scheme are given in [6].

3. The microwindows

The retrieval scheme uses only small fractions (1-2cm^{-1}) of the spectra (microwindows, MWs), which contain the maximum information. **Temperature, tangent altitude (pressure) and CO_2 vmr retrievals are carried out simultaneously** (18-101km). The MWs are taken in the 15µm region (the fundamental band in the upper region and the hot bands at lower heights), at 10µm and at 4.3µm (see Table). Information on temperature and altitude comes mainly from the 15µm bands, but temperature information in the 4.3µm second hot bands (see below) is also very important at higher altitudes. That on the CO_2 vmr comes mainly from the 4.3µm bands.

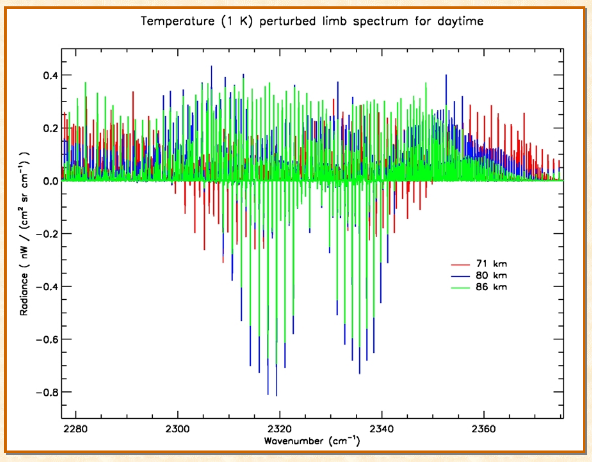
Microwindow (cm^{-1})	Nominal Altitude (km)	Main transitions*
687.150-687.350	33-36; 51-101	15: FB
690.150-690.450	33-46; 56; 76-101	15: FB
704.525-704.850	21-36; 46-91	15: SH, FH(636, 628)
748.650-748.800	18; 27; 36; 71-76	15: SH, TH
757.125-757.600	21-24; 30-33; 39-101	15: FH
759.550-759.700	18; 27; 33-66	15: TH
770.225-770.375	21; 36-39	15: SH
778.875-779.025	18; 51; 61-71	15: SH
1073.200-1073.350	66-101	10: LS
2316.750-2317.225	66-101	4.3: FB, FH, SH2; SH3
2321.050-2321.525	66-101	4.3: FB, SH1; FB-628
2333.950-2334.425	66-101	4.3: FB, SH1; FB-628
2337.675-2338.150	66-101	4.3: FB, SH2
2338.900-2339.375	66-101	4.3: FB, FH, SH2; SH3
2340.900-2341.375	66-101	4.3: FB, FH, SH1; SH2
2349.450-2349.925	66-101	4.3: FB, FH, SH1; SH2

*15: FB:01^10-000; FH: 02^20-01^10; SH: 03^30-02^20; TH: 04^40-03^30; 10LS: 001-02^00

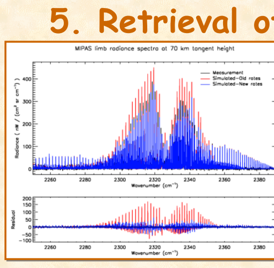
*4.3: FB:001-000; FH:01^11-01^10; SH1:02^01-02^00; SH2:02^21-02^20; SH3: 10^01-10^00

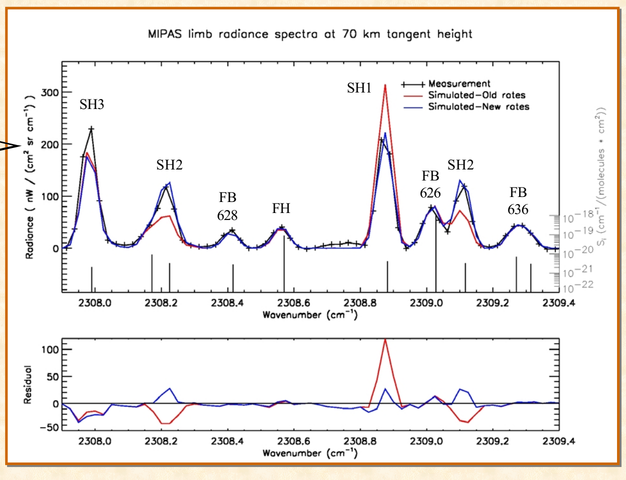
4. The microwindows in the 4.3µm second hot bands

One important finding is the **significant temperature information in the 4.3µm second hot bands radiance at 65-90km.** These bands are optically thick at these tangent heights, their upper state populations are largely enhanced by solar pumping and hence weakly dependent on temperature, but their lower (020) levels strongly depend on temperature. Thus, they are very sensitive (note the negative dependence) to temperature changes at 65-90 km tangent heights and, since they have a large signal in the daytime, they are very useful for the temperature sounding in this region.



5. Retrieval of the collisional rates of the 2.7µm levels



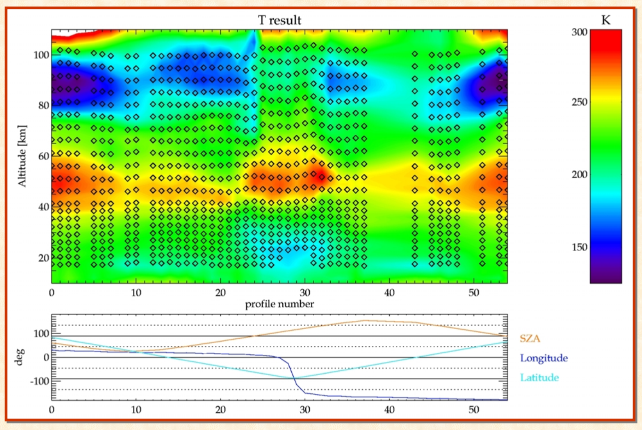


MIPAS limb spectra near 4.3µm measured and calculated with old and new collisional rate constants for the relaxation of the CO_2 2.7µm levels (02^01, 02^21, 10^01) (HITRAN: 23, 24, 25).

	k_a(cm^3 s^{-1}) (23_25)	k_b(cm^3 s^{-1}) (23,25_24)
Old values:	$3x10^{-11}$	$1.5x10^{-13}$
Retrieved:	**$1.5x10^{-12}$**	**$7.5x10^{-13}$**

Note in the figure the good agreement for all 4.3µm (fundamental, isotopic, and hot) bands.

6. Retrieved temperatures



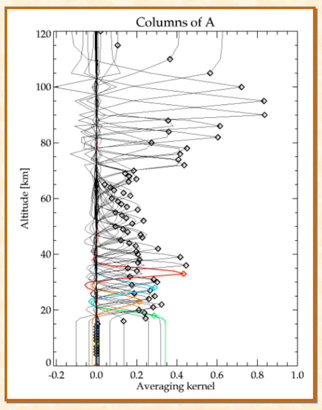
Temperatures retrieved from MIPAS spectra in its upper atmosphere mode, orbit #1750 on 1 Jul 2002. Scans 0-23, 53, 54 are taken in the daytime at 85ºN-60ºS; 25-50 cover 85ºS-60ºN in the nightside. The retrieved data shows the typical temperature structu-res of solstice conditions:

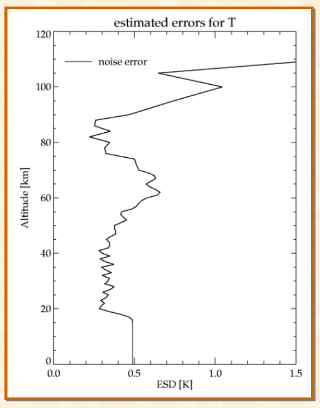
1) Warm stratopause in summer and colder in winter (although not much colder here). Note the warm lower mesosphere in the winter pole (25-30).
2) Very cold summer mesopause and warmer in the winter pole. The unrealistic change in the winter pole (scans 24-25) is induced by the smaller signal in the nighttime data.

Diagnostics: Vertical resolution, noise errors

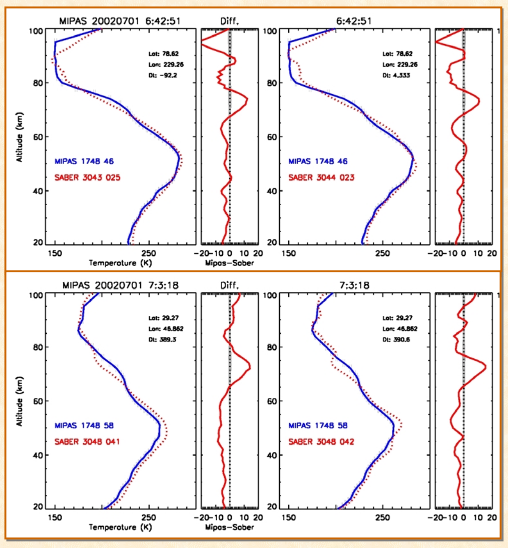
The spectra are taken at 21THs: 18-42 km @3km and 46-101 @5km. There are 19 degrees of freedom (very good) in the daytime and ~11 at night. Thus, vertical resolution is ~4km in the stratosphere, 7km in the lower mesosphere and then improves to 5km above due to the information in the 4.3µm hot bands (see Sec. 4).

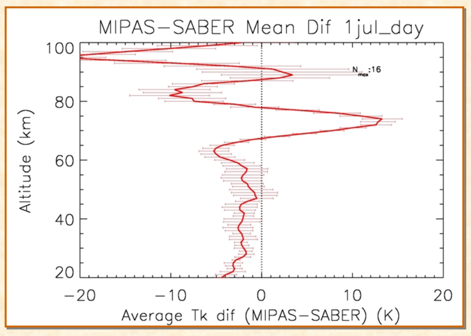
For that vertical resolution the noise error in the daytime measurements (right figure) is only 0.5K below 80 km and ~1K up to 100 km. At nigth it is below 1K up to 60km, 2K at 80 km and 6K at 100km.





Temperature comparison with SABER

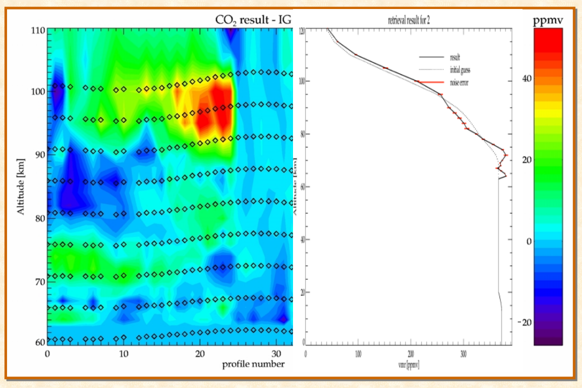




MIPAS daytime temperatures show a good agreement with SABER (v1.01, LTE), both in the summer pole (left-top) and tropics (left-bottom). Around 70km (top), SABER is colder, which is in line with Lidars/SABER comparisons [7]. Between 80 and 90 km MIPAS seems to be too cold.

7. Retrieved CO_2 abundances

Retrieved CO_2 vmr from MIPAS orbit 1750, 1 Jul 2002 at 60-100km in the daytime: scans 0-24, 85ºN-60ºS. The *a priori* profile is that derived from ISAMS [4]. The results show slightly larger vmr (+20ppm) than the *a priori* at 70-80km, smaller (-20ppm) at 80-95km, and ~20ppm larger at 95-110km. This suggests a CO_2 well-mixed atmosphere up to ~80km and vmrs even smaller than ISAMS at 80-95 km. Thus MIPAS confirms previous ISAMS and CRISTA low CO_2 vmr in the upper mesosphere [4,8,9]. The larger vmr at the terminator (scans 20-24) does not seem to be realistic but caused by inhomogeneities in the NLTE pop. along the LOS.



Left: Retrieved-a priori CO_2 vmr differences. Right: CO_2 vmr profile for scan 3.

Conclusions

- The CO_2 4.3µm second hot bands have been found to be very useful for temperature retrieval in the 65-90km at daytime.
- MIPAS allows the retrieval of NLTE parameters: the collisional rates between the CO_2 2.7µm levels have been found to be $1.5x10^{-12}$ and $7.5x10^{-13}$ cm^3 s^{-1}, that differ in factors of 0.05 and 5 from previous values.
- The NLTE temperature retrieval works well. Accurate temperatures can be retrieved up to 100km in the daytime and up to 70km at night. The retrieved temperatures for solstice conditions show the typical structures and compare well with SABER measurements.
- CO_2 vmr has been retrieved at 60-100 km during daytime (85ºN-60ºS). MIPAS measurements confirm previous ISAMS and CRISTA low CO_2 vmrs in the upper mesosphere and thus give further evidence that the homopause lies considerably below 100 km.

References

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