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## ***Interactive comment on “Impact of temperature field inhomogeneities on the retrieval of atmospheric species from MIPAS IR limb emission spectra” by M. Kiefer et al.***

**M. Kiefer et al.**

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We thank anonymous referee #2 for the wealth of comments and suggestions, and we feel that the points put forward help us to remove/change sources of possible misunderstandings and to improve the paper, especially our line of argument. Below we address all of the referee's general comments. Some of the specific comments can be answered to by the same arguments, we supply a more general reply hence.

### General comments:

The authors compare results obtained from various different MIPAS/Envisat level-2 processors by focusing on differences in trace gas abundances retrieved from ascending

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and descending parts of the orbits. They find substantial differences in the retrieved traces gas fields of selected species. The differences are attributed to thermal gradients which are according to the authors insufficiently treated in the so-called 1-dimensional processing schemes. Best results were obtained for a full 2-dimensional retrieval model, whilst a method of retrieving horizontal gradients was proposed to improve otherwise insufficient 1-dimensional retrieval models.

1) The authors highlight substantial differences in retrieved trace gas fields from ascending and descending parts of the orbits what in itself is very useful information for the user of MIPAS data as this information needs to be taken into account in the error budget of the different level-2 data products. Unfortunately, only some general recommendations are given and the manuscript doesn't provide a useful quantitative summary which will allow data users to easily account for the identified errors. This should be improved for the selected target species and retrieval algorithms (level-2 data versions) under study.

Reply: The actual correction depends on the atmospheric state and thus can not be represented by a simple number. All the requested information is included in the figures. To give a more complete overview on the problem a comprehensive representation of the ascending/descending differences for ESA L2 data will be given as an electronic supplement to the revised paper. This would allow the data user to get an impression on the magnitude of the error to be expected.

2) The attribution of the ascending-descending orbit differences to regions with strong temperature gradients and further to short-comings in the employed 1-d retrieval schemes (with respect to representation of the temperature structure in these regions) needs however further clarification. Results in the manuscript are based on MIPAS data processed by considerably different algorithms and software. It can not simply be concluded that studied differences in trace gas fields are due to treatment of temperature gradients, as there are most likely various other differences in the employed forward models and retrieval schemes. The explanation presented in the manuscript

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is so far not very convincing as important aspects have not been discussed. Results for pressure and temperature retrieval are not shown at all, although one might expect a first order effect in these primary retrieved parameters. Other possible sources of ascending-descending differences should also be discussed. For example, are corresponding differences noticeable in the MIPAS level-1 spectral data, if ascending-descending orbit or day-night spectra are compared? In order to prove attribution to the treatment of temperature (and trace gas) gradients, a classical way of showing this is to perform 2-d retrieval simulations with real MIPAS and with synthetic 2-d input data, and compare to 1-d retrieval simulations obtained with the same retrieval model, thus avoiding differences between the models.

Reply: We think the reviewer somehow misunderstood our approach: We do NOT draw any conclusion from the different behaviour of different 1D retrieval processors. On the contrary, we think that similar behaviour of different 1D processors suggests that problems are not related to one particular processor. The fact that inclusion of temperature gradients in a 1D processor largely removes the effect seen when these gradients are not included in the same processor, allows the unambiguous attribution to the horizontal temperature inhomogeneities. The final proof is given by the fact that full 2D processing entirely removes this effect which had been predicted for 1D processing by radiative transfer calculations. We missed to cite Stiller et al., JQSRT 72, no.3, 249-280, 2002. This work, which deals with the influence of simplifying approximations in radiative transfer calculations will be cited in the revised paper. The classic way as proposed by the referee is followed by Carlotti et al. 2001 and Steck et al. 2005 (both cited in the paper). We will add some more text to put these citations into the right context within our paper and furthermore add an electronic supplement which deals with this topic (technical note by Dinelli and Castelli).

To conclude, I feel that further work is needed on the latter aspect (attribution to temperature gradients), along with some changes to the manuscript structure, before this work can be recommended for publication. Alternatively, the authors might want to shift

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the focus (and the paper title) rather on the analysis and description of the retrieval error owing to differences in ascending-descending orbits, which along with practical recommendations would provide very useful information for the user of MIPAS level-2 data.

Reply: We will include a more concise presentation of our chain of arguments to avoid the misunderstanding which led to the referee's judgement.

## Specific comments:

## General reply to several specific comments:

First point: It is expected from thermal infrared radiation transfer calculations, that horizontal temperature gradients can cause a bias in 1D temperature/species retrievals (literature Stiller et al. will be cited in the revised version). This effect can be avoided using 2D retrievals, which also is known from literature (Carlotti et al., Steck et al., both cited). Second point: We find a very clear signature in the data, largely independent on the specific implementation of the 1D retrieval. In 2D this signature is not found. Third point: We show that by inclusion of a realistic temperature gradient in 1D retrievals, i.e. moving a step towards 2D, this signature can be considerably reduced. We think that these three points together are a clear demonstration of the connection between temperature field inhomogeneities and the effects seen in L2 data of 1D retrievals. To first order the differences between different 1D processors, which gave rise to several specific comments, should cancel out, because ascending and descending data for calculation of differences is consistently taken from one retrieval processor at a time (NLTE effects are known to be negligible for the spectral regions the retrievals were performed in). Note that we are talking of differences of order 20%. If this would be second order errors, all 1D retrievals should be discarded. Various MIPAS validation work shows that MIPAS 1D data in fact gives reasonable results. We will elaborate on this points in the revised paper. Generally we will rework the text to make our line of argument more clear.

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23-26 It is not shown in the manuscript that the discussed ascending-descending orbit differences in the level-2 products are also seen in other sensors data. This can well be a MIPAS artifact.

Reply: An instrument artefact which can only be seen in 1D, but not in 2D retrievals?

10-17 (on key species): Results of the temperature should be shown in the manuscript as this is a key parameter. An analysis for pressure - retrieved or assigned - would also be helpful in order to clarify attribution of day-night differences. A short paragraph on the expected diurnal variation of the selected species in the here investigated altitude range is recommended, as the paper focuses on differences between measurements taken at different local times.

Reply: Temperature indeed is a key parameter, as we already demonstrate in figures 11 (left column) and 13 (top row). Ascending/descending differences will be shown in the revised paper. However, pressure is not suited as indicator for ascending/descending differences, because it is retrieved on MIPAS tangent altitudes, which suffer from a systematic pointing error of the instrument, i.e. a reliable independent altitude coordinate is missing. A paragraph on the expected diurnal variations will be included in the revised paper.

p1723 24 and following : Here the authors state themselves (correctly) that temperature field inhomogeneities are not the only cause for the effect under study, but all kind of other effects might cause a deviation of the retrieved from the "true" atmospheric state. This should be made consistent throughout the manuscript.

Reply: But this is close to trivial: Here we refer to the species profiles, not to their ascending/descending differences. And of course species profiles are subject to many errors (instrument, spectroscopy, forward model, ...).

p1725 Conclusions Implications for MIPAS users: From results presented in the manuscript, a first conclusion could be that users are recommended to use data from

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the 2d-retrievals, instead of the 1-d processor data. Correct? I think this point needs some elaboration, in particular as the manuscript focuses only on a specific issue and doesn't compare overall error budgets of the different retrieval processors and data versions.

Reply: With respect to the problem of horizontal inhomogeneities the explicit 2D treatment is certainly the most appropriate solution. A generalization that a 2D processor is always superior to any 1D processor is not appropriate, because the general quality of the processor also depends on many other features. This paper deals with the 2D aspect only. The general rating of the processors involved is beyond the scope of this paper.

4 1) "In any worked it has to be checked whether the phenomenon ... has to be taken into account". This is a good point, please elaborate when this is the case and give recommendations, this would be very helpful for the user of MIPAS data.

Reply: Will be done.

16-19 Reformulate or remove. Which data/instruments are meant? Do these data sets show such differences? If not, the attribution of differences in MIPAS ascending/descending orbit data to temperature gradients would be incorrect. A comparison with level-2 data from other instruments might indeed help to clarify the issue raised in the manuscript.

Reply: We will replace infrared by thermal infrared. Radiative transfer calculations in the thermal infrared clearly show that effect. It is an effect of radiative transfer and of measurement geometry. We claim that our statement is fully justified.

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