1 Answer to the second referee

We thank the referee for reading such a quite long paper and suggesting improvements. For each referee's comment (reported in italics) the answer is provided below it.

1.1 Second Referee

L11 IG2 not defined Now it is defined

L23 . . . could also mention pyroCb events arising from wildfires e.g. Australian New Year fires in 2020. Done

L23 [Taken together] these changes Done

L29 "of the atmospheric emission" . . . perhaps you meant to say "of the infrared emission" otherwise better to just say "of the atmosphere" We have changed with: 'of the infrared emission of the atmosphere'

L30 Which is correct . . . ENVISAT (as in the title and elsewhere) or Envisat? We have replaced Envisat with ENVISAT all over the paper.

L33 probably should jam "infrared" in this line before "emitting" I have written '... constituents emitting in the middle infrared'

L34 10 years is a long time. . . CO2 increased quite a bit - how was that handled for the retrieval of temperature? As mentioned in Sect. 4.3.1, CO2 (as well as CFC's) trends are accounted for in the IG2 climatology. Thus, temperature is retrieved assuming the CO2 profile valid at the time of the measurement.

L67 I'm sure you have stories of "what not to do" that would be similarly helpful! Yes, we agree, however a full book would be necessary to tell all of them...

L80 10 hour => 10:00 Corrected

L97 maximum [interferometetric] path ? Added

L100 reducing the spectral resolution to Yes, corrected.

We have written: '... corresponding to a FTS spectral resolution $\delta\sigma = 1/(2 \cdot \mathrm{MOPD}) = 0.025$ cm^{-1}' and: 'corresponding to a coarser FTS spectral resolution of $\delta\sigma' = 1/(2 \cdot \mathrm{MOPD}') = 0.0625$ cm^{-1}.'

L107 MIPAS was not operating routinely for a long period. Since a 20 cm path was causing mechanical problems, what was the largest path thought to still be safe? Was a new max path limit determined from in-orbit testing? You are right that our description seems to indicate that the changes in the settings of the instrument was decided to optimise the trade-off between spectral and spatial resolutions, while the change was forced by mechanical problems, as also written at line 99. The new "safe" max path limit was determined from in-orbit testing.

In the revised manuscript we have removed the sentence 'Having already obtained information on the spectral characterisation in the first part of the mission, for the long-term operations an improvement of both vertical and latitude resolution was considered to be a good compromise.'

The new text is: 'After the detection of this anomaly, on the basis of in-flight tests, a new *safe* value of 8 cm was established for the maximum interferometric optical difference (MOPD). With this MOPD, an unapodized spectral resolution $\delta\sigma' = 1/(2 \cdot \mathrm{MOPD}') = 0.0625$ cm^{-1} is achieved, with a total time of 1.8 s required for the measurement of a limb spectrum. The savings in measurement time were then exploited both to implement a finer vertical sampling of the atmospheric limb, and to acquire additional limb scans within each orbit. Due to this optimised (more dense) spatial sampling, the measurements acquired from January 2005 onward are referred to as optimized resolution (OR) measurements.'

L108 In the OR scan the lowest tangent height was increased from 6 to 7 km. Was that for an engineering mechanism reason or was it decided to trade-off the the 6-7 km region in order to add 4km in the mesosphere? Actually, in order not to repeat information reported in the paper of Dinelli et al., 2021 it was not said that, associated with the change of the retrieval vertical

grid, this grid became floating, that is changing with latitude to better follow the tropopause height. Hence the lowest altitude is 5 km in the polar region, 7.05 km at 45° and 12 at the equator.

This information is now included in the revised paper and a reference is added to the paper of Dinelli et al. 2021

L139 non-LTE Done

L145 What about the (approximate) reference height so you can vertically locate the limb scan. Where does that come from? Do you have an internal a geopotential height product? This is explained in Sect. 5.4 of Dinelli et al. 2021, https://doi.org/10.5194/amt-2021-215, 2021. We have added the reference to this paper also here. We have added the sentence:

'Then the altitude grid is re-built starting from the lowest engineering tangent altitude corrected using information from co-located ECMWF altitude/pressure profiles (see Dinelli et al., 2021). '

L210 Could you give some indication of the error incurred in assuming no horizontal gradient across the line-of-sight in the refractive index? Also this is the only mention of the Curtis-Godson approximation (CGA) and should have a reference to the original work at least and possibly to other documented retrieval codes for ir limb sounders. What led to the choice of CGA and were any other alternatives considered e.g. Emissivity Growth Approximation (EGA) or Correlated-k (presumably not needed as the micro windows are quite narrow)? A previous study (Ridolfi and Sgheri, AMT, 2014) assessed the error on the retrieved tangent heights by assuming the standard 1976 US atmosphere versus the retrieved atmosphere. The error is due to the difference in the calculated refractive index needed to solve the Eikonal equation to calculate the ray-tracing.

The error assessed is less than 200 m, and reaches these values only at the lowest tangent altitudes. Now, since the difference in the atmosphere introduced by the horizontal variability is much smaller than that considered in Ridolfi and Sgheri, 2014, the difference in the tangent altitudes due to the change in the refractive index is also much smaller.

The same paper of Ridolfi and Sgheri, 2014 is the source of the line-tracing algorithm implemented in the ORM V8. The paper also compares the ray-tracing algorithm implemented in the ORM to other known methods.

In the revised manuscript we included the reference to the paper introducing the CG integrals and to the initial ORM paper were the all the adopted choices are analysed / justified.

L211 What is the spacing of the angular grid used to represent the climatology along the line of sight? In order to speed up the computation of the CG integrals, the Eikonal equation is solved in Cartesian coordinates with respect to the arc parameter s. In each layer the arc parameter increment (ds) is kept fixed. Each time we cross a layer we check the second derivatives of the integrand function, in order to define the new ds.

In fact, due to the horizontally changing atmosphere, the CG are really line integrals, that can be transformed into simple Riemann sums if the increment ds is constant. Also, ds should change according to the curvature of the line of sight, with a smaller ds in the lower layers where the refraction is more relevant.

Tests have been performed to set the ds, balancing speed and accuracy in the calculation of the CG integrals.

L228 Do you really have the horizontal resolution to achieve a 2nd order correction? Please check also the related answer to the first referee. The correction on the single retrieval is not statistically significant, so we do not claim that we reproduce a 2nd order effect on the 2D atmosphere.

The improvement can be seen as the reduction on the AX-DX differences, calculated on latitude band averages.

However, the reduction is not only due to a climatological effect. Values of the horizontal gradients calculated from the actual profile values (either from ECMWF or from a previous MIPAS reprocessing) have to be inserted in the model to improve the reduction. On the other hand we do use some simplifications, such as neglecting the fine-scale inter-scan profile variations, and assuming that the gradient is constant in each interval defined by the scan pattern.

L342 What is the effect on temperature on the discontinuous CO2 concentration change on crossing a year boundary? Within the IG2 climatology, profiles like CO2 and CFCs are corrected for their trend also seasonally, in addition the profiles are varied continuously by linearly interpolating with time the IG2 profiles relative to each season. As a consequence, no discontinuity is present in CO2 profiles. The text will be changed accordingly.

L455 How about a joint retrieval of H2O and the HDO/H2O ratio? Thanks for the suggestion, this should be tried indeed. Actually, the microwindows have been defined in order to reduce the interference between H2O and HDO lines and, thus, the correlation between the retrieved profiles. However, we have found that the use of retrieved H2O profile as a priori for the HDO

profile may introduce some bias in the averaged HDO profiles, and we are using a dedicated approach to reduce the bias (see Ceccherini et al., 2014)

L454 Where does the magic number 31.6 come from? Need some context here e.g. over what values does the continuum range? The a priori error for the offset was defined by looking at the typical variability of the offset retrieved for the MWs relating to gases for which optimal estimation is not used. A reasonable value for the a-priori error is obtained by putting a value of 1000 on the diagonal of the a priori covariance matrix. The value of 31.6 corresponds to the square root of 1000.

L470 What is the size of the matrices that need to be furnished to accomplish this feat. Would representative matrices suffice i.e. if they be aggregated over seasons and latitude bands? For this analysis it is sufficient to provide the a priori profile, the covariance matrix and the averaging kernel matrix for each retrieved profile. These quantities are already provided in the current output files. The aggregation of the data can be decided by the user, no other information has to be provided to perform this analysis.

L593 and L683 not-good -> bad I suppose Yes, changed

L594 So are the VMR retrievals also marked as "bad" or some other specific flag that indicates missing data because the temperature retrieval failed?

No profiles are reported in this case, because retrieval was not performed. No specific flag are available indicating the missing data, but it is possible to reconstruct the cause of the missing data by looking at the flag of temperature profile.

L603 and Page 33 Fig 22 Representative retrieval [product]? What product and OR or FR? If this distribution appears (or not) in Fig 1 or 2 then please indicate which one. Ok, done

L608 the values of the thresholds [for each product] Corrected.

L601 derive [atmospheric] trends Done

L636 and Fig 23 Fig 23 is not very good for showing the temporal variation. The sequence of colors/symbols bears no relation to the time domain. I suggest taking only three pressure levels for UTLS, LS and MS and plotting the Tdiffs vs time. Also then you could indicate where the decontaminations (L653) occur on this figure. Fig. 23 has been redone using the colours of the rainbow to better associate how the differences change with time. We have done also the plot suggested by the referee, see Figure 1, but we think that the information provided by this plot is very similar to the one of Figure 23. We notice an abrupt change in the first part of the mission, and then the slope significantly reduces. This will be highlighted in the revised paper.

L686 Some indication of file sizes would be useful

We have added the sentence: 'The size of the files varies with species and observation mode, since it depends on the number of fitted parameters. On average the size of a standard file is about 1 MB, while that of a extended file is about 3 MB.'

L698 If 2nd order effects are a big deal (I doubt that the auxiliary model data can be used to correct to this order anyway) then you should indicate that these gradients are limited to a linear assumption along the line of sight. Yes, we agree with the reviewer, in the revised manuscript we have modified this paragraph.

The new paragraph is: 'The L2 processor ORM V8 and its auxiliary data are significantly different as compared to the ESA L2 processor ML2PP V7. The radiative transfer model was improved by allowing for a linear variation of the atmospheric state (with a gradient) to approximate the actual horizontal variability of the atmosphere sounded by the instrument line of sight. Horizontal gradients computed from ECMWF ERA-Interim reanalysis were assumed in the ORM V8 processing. This improved model implied a significant reduction of the ascending-descending differences that, initially, were erroneously attributed to day / night differences in profiles that actually, are not affected by a diurnal variability.'

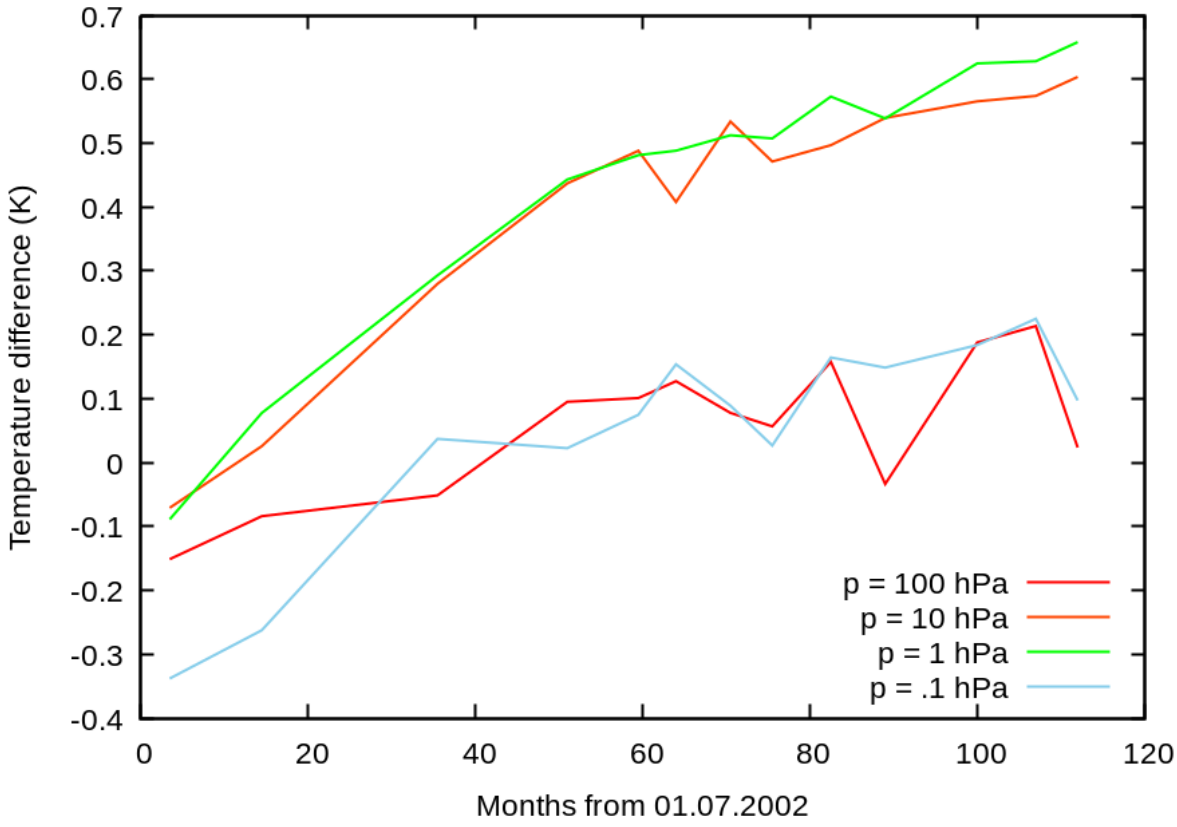

Figure 1. Temperature differences retrieved from V8 and V5 L1b files for the 4 pressures indicated in the key as a function of time