

# ***Interactive comment on “The use of O<sub>2</sub> 1.27 μm absorption band revisited for GHG monitoring from space and application to MicroCarb” by Jean-Loup Bertaux et al.***

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Interactive comment on “The use of O<sub>2</sub> 1.27 μm absorption band revisited for GHG monitoring from space and application to MicroCarb” by Jean-Loup Bertaux et al. Response to comments of Anonymous Referee #2: responses are in Arial character, with new text in blue, more visible in the attached .pdf file.

General comments: This paper deals with an interesting and relevant aspect, i.e. the contamination of nadir O<sub>2</sub> measurements in the 1.27 micron IR atmospheric band caused by the corresponding airglow emission. The paper will be relevant for the community and the approaches employed in the study appear to be robust. However, there

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are two major issues with the paper. It is unnecessarily long (which distracts from the main content) and it is full of typos, minor inconsistencies and little errors. Many sections make the impression of hastily written drafts that were not proof read. It took me two full days to go through this manuscript, which is not acceptable. We expect from young scientists and postdocs that manuscripts are in tip-top shape and it should also be expected from senior scientists. It is certainly not the reviewer's task to correct all the mistakes. Please correct the manuscript carefully.

General Response to general comments. We are very much grateful for the great amount of time spent by Referee #2 in reading carefully our manuscript. Not only he (she) identified a large number of english-language typos or mistakes; he (she) also identified sentences that seemed to be obvious for the authors, but whose meaning is not obvious for an outside reader. These sentences were corrected with a more appropriate rephrasing. We apologize for not being english-language born scientists. We hope there is still some room in science for those scientists.

Length of the paper: We recognize that this paper is long, but we still believe that its overall length is deserved. At an early stage one reviewer suggested to split the paper in several papers but we have been quite reluctant to continue along this line (split or shorten substantially) for the following reasons. All parts of the paper are relevant to the same subject: is it possible to use the O<sub>2</sub> 1.27  $\mu$ m absorption band for CO<sub>2</sub> mixing ratio retrieval, in spite of the strong airglow contamination? The team that was assembled for this scientific research had to cover several scientific aspects: our understanding of this airglow, building a model for the intensity, and a model for the spectral shape, validation with comparisons with SCIAMACHY/ENVISAT data, separation of airglow from absorption. One reader is not obliged to read carefully all sections, he can pick up what he is most interested in. We estimate that if we would split our paper into two papers, the overall total length of the two papers would be longer than the present version, because of unavoidable repetitions (each paper must be self-consistent, including references). It would require also twice more reviewers and Editor work. AMT

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stands for Atmospheric Measurements Techniques and therefore our paper is perfectly in scope with the profile of the publication. Our paper is long because it is deliberately rather detailed, because we wish to ease the possibility that anybody else to be able to reproduce our results.

Remember that the results of about 30% of all scientific papers cannot be reproduced by other scientists, and this comes to 50% of papers in biology, a very embarrassing situation. One great advantage of AMT publication is that it does not require paper printing, therefore cancelling a source of CO<sub>2</sub> production. Only an interested reader would potentially print it. Therefore, with AMT we may reconcile CO<sub>2</sub> economy and detailed description for better reproducibility of results. Finally, we note that the length of the paper did not discourage a fairly large number of scientists to download the paper when discussed in AMTD: The paper has been viewed HTML 175 times and the pdf downloaded 91 times (25 august 2019), about half from the US.

Response to specific comments:

P. 1, line 18: "i.e. OCO-2 .." -> "e.g. OCO-2 .."; otherwise all instruments carrying out these measurements should be listed. Done.

Thank you for the correction, done. Google says indeed: "When you mean "for example," use e.g. It is an abbreviation for the Latin phrase exempli gratia. When you mean "that is," use "i.e." It is an abbreviation for the Latin phrase id est."

P. 1, line 38: "model underestimate" -> "model underestimates" Done Same line: "This is fully confirmed .." It is not entirely clear, what this refers to. Is it confirmed that the model underestimates by 15%? Or that the airglow intensity is mainly determined by the SZA. Please clarify. answer: We have added the sentence: " , and found that the nadir SCIAMACHY intensities are mostly dictated by SZA and larger than the model intensities by a factor  $\Delta$ Lij1.13" P. 2, line 13: "Dioxyde" ->"dioxide"Done P. 2, line 14: "The atmospheric fraction .." I suggest being more precise here. Mention CO<sub>2</sub> explicitly and that the fraction is a mass ratio – that's what it is, right? answer: we have rewritten

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the sentence: "The atmospheric fraction is the ratio of the atmospheric increase of CO2 mass to the mass of CO2 anthropogenic emission." P. 2, line 30: "The first satellites to be launched with the aim .." Why don't you list SCIAMACHY/Envisat? SCIAMACHY is certainly not as specialized to CO2 retrievals as the other instruments, but it was also built to measure CO2 and it should be listed here. The CO2 retrievals were also quite successful. answer: we have added : ENVISAT (ESA) with SCIAMACHY instrument,

P. 3, line 13: "mission" -> "missions" Done

Same line: "Airglow has a spectrum that is very similar .." This statement is not generally true for all airglow emissions occurring in the atmosphere and should be phrased more precisely. There are many other airglow emissions apart from O2, for which the statement is not valid. Rephrased: "Oxygen airglow at  $1.27 \mu\text{m}$  has a spectrum..."

P. 3, Figure 1: the figure shows O3 photolysis as the only source of the 1.27 micron emission. Ozone photolysis is only one of several excitation mechanisms. I suggest stating in the caption that it is the main mechanism on the dayside. the following sentence was added to caption for Figure 1 : Ozone photolysis indicated in the figure is the main source of O2 airglow at  $1.27 \mu\text{m}$ , but not the only one.

Caption Fig. 1, line 3: "are crossing" -> "is crossing" Done Same line: "which emission" -> "whose emission" Done P. 4, line 6: "confirms" -> "confirmed" Done P. 4, line 9: "mission" -> "missions" Done P. 4, line 12: "to determine from nadir viewing observations the CO2 vertical columns" Word order wrong. Please replace by: "to determine CO2 vertical columns and mixing ratios from nadir viewing observations" We have rewritten : "...to determine CO2 vertical columns and mixing ratios from nadir viewing observations (which needs associated O2 columns), Kuang et al. ... P. 4: "secular variation" -> "secular variations" Done P. 4, line 21: "plugged to a" -> "combined with a" Done P. 4, line 22: "We also note that the TCCON ground-based spectrometer array, observing the sun, uses this  $1.27 \mu\text{m}$  band to derive the CO2/dry air mixing ratio" This is the third time this is mentioned and can be removed. Answer: Indeed, it is redundant.

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However, here we explain why TCCON is selecting the  $1.27 \mu\text{m}$  band rather than the A band. If we delete the sentence as proposed, then the following sentence would be difficult to understand. Therefore, we have re-arranged the sentence a little. P. 4, line 32: "intimately intricated." Grammar wrong, please correct. Done Replaced by "closely blended" P. 4, line 38: "Second, the transmittance  $\text{Tr}=\exp(-\tau)$  saturates at high optical thicknesses  $\tau > 1$ , while the emission does not." I don't understand this statement and think it's wrong. Emission is certainly also limited if the optical depth becomes quite large. What you probably mean is that extinction is not important for the emission, because the emission mainly occurs above 30 km. But this is not what the sentence states. answer: No we do not mean what you suggest. We rephrased for more clarity: "Second, the emission at  $1.27 \mu\text{m}$  increases linearly with the column of  $\text{O}_2^*$  at all wavelengths (re-absorption by  $\text{O}_2$  is negligible at emission altitude), resulting in a constant relative shape of the emission spectrum, while the absorption spectrum is not linear: the transmittance  $\text{Tr}=\exp(-\tau)$  saturates at high optical thicknesses of  $\text{O}_2 \tau > 1$ , and the absorption spectral shape is not constant but depends on the air-mass factor"

P. 5, line 1: "on Fig." -> "in Fig." Done P. 5, line 3: "which positions" -> "whose positions" Done P. 5, line 5: "rending" ?? Do you mean "rendering"? Word order is also wrong: "rendering this proposal unpractical" yes, correction done as you suggest. Done P. 5, line 7: "contributes" -> "contribute" Done Caption Fig. 2, line 1: "The transmittance within an individual  $\text{O}_2$  line (red) is much larger than" "transmittance .. much larger" is not well phrased. The transmittance is zero in the center of the line. Please be more precise. Answer : we agree that the meaning of Fig.2 caption is not clear at all. The caption of figure has been rephrased. "Comparison at high spectral resolution of spectral shape of atmospheric  $\text{O}_2$  transmission (transmittance) and spectral shape of  $\text{O}_2^*$  emission. The FWHM of an individual  $\text{O}_2$  line (red) is much larger than the FWHM of its counterpart in emission (black line), allowing in principle to disentangle absorption from emission at selected wavelengths. The channels recommended..." P. 5, line 22: "compared" -> "compare" Done Same tense as in previous sentences P. 6, line 1: "while in Section 6 are detailed the accuracy and bias results of" Word order



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incorrect Corrected. P. 6, line 4: "In section 7 are examined briefly" Word order wrong: "In section 7 some other cases . . . are examined" Done P. 6, line 20: suggest to define Rayleigh the first time it is used. Done P. 7, line 3: "strong solar light scattered component" -> "strong contribution of scattered solar radiation" P. 7, line 5: "From high altitude the O<sub>2</sub> absorption will be a little bit reduced." This is incomprehensible? Do you mean that the absorption is weaker at higher altitudes? Answer: no. Rephrased for more clarity: "From a ground based observing station located at high altitude the O<sub>2</sub> absorption will be a little bit reduced."

P. 7, line 26: please cite Bovensmann and/or Burrows here. For all the other instruments you provide a citation, but not for SCIAMACHY. Done P. 7, line 37: "On Fig. 3 (from Khomich et al., 2008) are represented the various electronic" "On Fig." -> "In Fig" and the word order is incorrect: "Fig. 3 presents the various .." Done P. 7, last line: "on Fig." -> "in Fig." Done P. 8, line 2: "on Fig." -> "in Fig." Done P. 8, equation (4): "C" -> "c" Done Same equation: the units are incorrect, i.e. the equation is not valid as is. Please correct. Corrected. P. 8, line 18: "Fraunhofer" -> "Fraunhofer's" Done P. 9, line 24: "solar effect" One can tell what you mean, but it is not well phrased, too unspecific. Replaced by "solar photolysis of various species" P. 9, line 31: "emitted photon" -> "emitted photons" Done P. 9, equation (5): the middle part of the equation is incorrect. During the day, there will essentially be a steady state, i.e. O<sub>2</sub>\* is produced by O<sub>3</sub> photolysis (mainly) and removed by emission, i.e.  $d[O_2^*]/dt = 0$ . Answer : You are perfectly right ; the middlepart of the equation (5) has been deleted. P. 10, title section 2.3.3: remote (remove ?) period from section title Done P. 10, line 15: "A -coefficients" -> "A-coefficients" Done P. 10, line 16: "second members" Unclear, what you mean. The sentence is rephrased for more clarity : "...second members of equation (6) for all allowed transitions Li, giving the rate of emission of the corresponding spectral line VER(Li)".

P. 10, line 34: please provide k\_B in SI units Done k<sub>B</sub> = 1.38065 x10-23 joule K-1 C5  
P. P. 11, line 4: "on all" -> "over all" (2 occurrences) Done P. 11, line 11: "on Fig." ->

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"in Fig." Done P. 11, line 12: "term by" -> "term and" Done P. 11, caption Fig. 4, line 3: "There are 5, 7, or 8 values (and transitions) for each black circle on the figure" Not clear to me, why there are 5, 7 or 8 values for each black circle. Please explain. Answer : This is a consequence of the fact that HITRAN contains only the transitions which have a strength above a certain threshold.. Added in the caption : "in the figure, present in the HITRAN list, because weak lines (below a certain threshold) are not in HITRAN." Same line: "on the figure" -> "in the figure" Done P. 11, line 21: "On Fig. 5 are represented the various energy" "On" and word order incorrect: "Fig. 5 presents .." Done P. 12, Title section 2.3.4: add space at beginning Done P. 12, line 6: "sate" -> "state" Done Next line: "sum on" -> "sum over" Done P. 12, line 21: "We found that the total decay rate is  $A_{21\text{tot}}=2.29 \times 10^{-4} \text{ s}^{-1}$ ." Above you determined the total decay rate to be  $2.22 \times 10^{-4} \text{ s}^{-1}$ . What does "We found" refer to? This is not clear. answer : rephrased for better clarity : We found from the HITRAN data that the total decay rate is  $A_{21\text{tot}}=2.29 \times 10^{-4} \text{ s}^{-1}$ , slightly different from  $2.22 \times 10^{-4} \text{ s}^{-1}$  derived from the rounded value 75 mn of the lifetime quoted by Lafferty et al. (1998). We may compute the lifetime  $1/ A_{21\text{tot}} = 4367 \text{ s} \approx 73 \text{ mn}$ . Next line: "in average" -> "on average" Done P. 13, line 9: "on Fig." -> "in Fig." Done Figure 6: spell out "eps" in Figure caption Done. Caption has been modified for more clarity. P. 14, line 16: "on Fig." -> "in Fig." and word order needs to be adjusted Done P. 15, line 30: "to the study" -> "for the study" or "for studying" Done P. 15, line 32: "Osiris" -> "OSIRIS" Done C6 P. 15, line 34: "Gao et al." Please cite the main SABER paper by Russell. Done Same line: Please also cite a SCIAMACHY paper (Bovensmann and/or Burrows). Done. There was already a reference in the following paragraph. It almost seems as if the authors avoid citing SCIAMACHY papers. This is a certainly a wrong impression ! On the contrary we emphasize the importance of SCIAMACHY in the problem of O<sub>2</sub>\* emission and make a heavy use of these excellent measurements. P. 16, line 12: "At each tangent point, the vertical resolution is 2.6 km" That's the FWHM of the FOV, the vertical resolution is worse. Correction done : sentence rephrased : "the FWHM of the FOV is 2.6 km (with a somewhat coarser vertical resolution)..." P. 16,

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lines 20 – 28: please show sample spectra and illustrate the correction procedure. answer: the explanation of correction procedure is now illustrated by four Figures put in an Appendix B for convenience, reproduced at the end of this document. Done P. 17, line 5: Onion peeling is prone to noise, particularly lower down and is usually not the method of choice, but OK .. P. 17, line 15: "radiuses" -> "radii" Done. P. 18, equation (21): this usually does not work well, but leads to unrealistic oscillations. Section 3.2.2: is the model atmosphere divided into several angular segments in order to describe the attenuation within a given atmospheric layer properly? This doesn't seem to be the case and this should be stated explicitly, i.e. the technique applied is only an approximative treatment of the self-absorption. Answer : In the standard onion-peeling technique, the atmosphere is divided into spherical shells where the density (or emissivity ) is assumed to be constant. Each LOS is divided into segments which belong to various spherical shells. In this way, the vertical inversion is reduced to a linear system of equation (our equation (21) with a unique solution. Of course, this is an approximation, but we cannot do better with the finite sampling of the LOS. Adding the attenuation by O2 does not introduce any additional approximation. P. 19, line 2: "each .. spectra" -> "each .. spectrum" Done. P. 19, line 17: "the more the lower latitude." Done. Why should it depend on latitude? Do you mean altitude? This part of the sentence is also incomplete. altitude, of course !!! rephrased : Åž.. they must underestimate their emissivities more and more with lower altitudes.. P. 19, line 38: "at (lat" -> "(at lat" Done. P. 20, line 12: "Absorption by O2 may be computed in the nadir viewing geometry, though attenuation in this geometry is small (2% for the Q branch, less outside of the Q branch)." This is only valid for  $z > 30$  km, right? I suggest mentioning this explicitly. answer : yes. We added (altitude  $z > 30$  km) P. 20, line 20: "On Fig." -> "in Fig." and word order needs to be adjusted Done. P. 21, Caption Fig. 10, line 1: "form" -> "from" Done. Same Caption, line 4: "ADAPTEE" -> "ADAPTED" Done. P. 21, line 19: "On Fig." -> "in Fig." and word order needs to be adjusted Same on line 29. Done. P. 22, Figure 11: Figure is truncated at bottom Corrected with original figure not truncated Caption Fig. 11: "for ENVISAT orbit 20070101\_1256." Done This is not

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the orbit number. Please provide orbit # and date. answer : we rephrased the caption : ... ENVISAT orbit 25293, starting 1th January 2007 at 01h 12mn.

P. 23, line 6: "The ratio of spectra measured /model, Sobs/ Smod" This phrase is sloppily, please be more precise. sentence rwritten as : Ân The ratio of measured spectra /model spectra, Sobs/ Smod ..." P. 23, line 10: "validates completely" Well, there is roughly a systematic 10% difference in the right panel of Figure 13, i.e. I would not speak of "complete" validation.

We have rephrased : "This comparison validates completely the approach that we developed in Section 2, except that the overall level of the ratio is slightly below 1." and we explain the reason for this exception right away. Caption Fig. 12: "Ratios of measurements/model of limb spectra" Sloppy phrase, please be more precise. Done. P. 24, line 11: "(some limb scans do not reach low enough altitudes)." What does this mean? Does it refer to the MLT measurements? Please clarify. sentence repharsed : Ân ... containing 12,400 limb scans in the normal mode which go down sufficiently for our purpose (some limb scans do not reach low enough altitudes to allow retrieval of the full VER profile above 30 km)."

P. 24, line 14: "aerosols" -> "aerosols" ??? aerosol P. 24, line 14: "and pollutes the SCIAMACHY measurements" C8 This sounds like this is an instrumental problem, which is certainly not the case. Most of the SCIAMACHY limb data procts are based on scattered radiation. Scattering does not generally "pollute" the limb measurements. I also suggest using a different word. this sentence has been rephrased : (the useful signal for SCIAMACHY limb mode ozone retrieval) which dominates over the O2\* radiance. P. 24, line 23: "On Fig." -> "in Fig." and word order needs to be adjusted Done. P. 25, line 7: "On Fig." -> "in Fig." and word order needs to be adjusted Done. P. 26, Fig. 15 16: "Brightness = f(SZA.." and "Color scale -> latitude" This should be mentioned in Figure caption, not overplotted onto the Figure. This seems like an unfinished figure from a presentation, unsuitable for a paper. Done. answer : The figure 16 has been redone, and one sentence was added in the caption : The

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airglow brightness is mostly correlated with SZA. P. 28, line 21: "radiation, atmosphere + aerosols+ surface)." Please form a sentence. sentence rephrased :  $\text{Án} \dots$  of the solar radiation back-scattered by the gaseous atmosphere, aerosols and the surface). P. 28, line 28: equality sign in equation is subscript. Done P. 29, line 10: "Fig." -> "Figs." Done P. 31, line 27: "which is almost polar and descending" As it is "which" appears to refer to "month", which doesn't make sense. Please adjust. Done P. 31, line 29: "on the intensity" -> "for the intensity" Done P. 32, line 1: "which is incorrect" It is specified like that in the SCIAMACHY documentation, I think, i.e. it's not correct to state, that this is incorrect. It's not the natural choice, but it is as documented, I believe. Maybe I'm wrong. answer : You are right. The definition of SZA extracted from the document "SCIAMACHY Command Line Tool Software User's Manual (SUM) for SciaL1c" : "Solar zenith angles of the start, middle and end of the integration time at TOA". We find the same definition in the "Sciamachy Level-1b IODD" Therefore, we have rewritten this paragraph: "Note regarding the SZA of the SCIAMACHY data: We noted that the SZA value provided in the SCIAMACHY ESA products in limb viewing, as defined in the data product, is the SZA of one of the two points corresponding to the intersection between the LOS and TOA (Top of Atmosphere defined at 100 km altitude). But what we need is the SZA of the tangent point of the line of sight (LOS), which is different. Therefore, we systematically calculated the SZA at the tangent point of the SCIAMACHY LOS using an external tool (IDL routine). All results presented in this report are obtained using this recalculated SZA."

P. 32, Figure 19: Order of panels not specified. Which is which? Same Figure: the legends in the individual panels overlap. Overall, the quality of the figure not suitable for publication. Please improve. Also: It's essentially impossible to C9 separate the SCIA and the model symbols. Needs to be replotted.

The figures have been replotted for improvement. P. 32, line 15: which local time was used for the model data? answer : We do not use  $\text{Án}$  local time  $\text{Áz}$  here. We use UT time (Universal Time) of the measurement and in the model. P. 33, Figure20: increase

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spacing between legend lines. Done P. 34, Figure 21: increase spacing between legend lines. Done Caption Fig. 21: "Fig.20" -> "Fig. 20" Done P. 37, line 2: "At night, GOMOS ozone profiles show a strong ozone depletion around 80 km" I suggest using "minimum" rather than "depletion", because the phrase suggests that there is less ozone during night than during the day, which is not the case. answer : Done .we have changed the  $\Delta$  depletion  $\Delta$  by  $\Delta$  minimum  $\Delta$ .

P. 38, line 1: "on Fig." -> "in Fig." Done Same line: "observed on" -> "observed in" Done P. 38, Caption Fig. 25: you need two GOMOS measurements for occultations with two different stars, right? Were both on the same day? Done answer: yes, two different stars. The left occultation is star S005 observed on 5th August 2007 22h13mn (orbit number 28397) at SZA=38° and the right occultation is star S008 observed on 15 February 2007 16h36mn (orbit number 25946) at 94°. Although the high atmosphere is still illuminated, the photochemical situation is ambiguous, and this figure has been deleted, keeping only one occultation. The caption of Fig 25 (now figure 24) has been modified accordingly: Figure 24:Left: One example of comparison of a GOMOS vertical dayside ozone profile (black curve) vs. REPROBUS prediction (red curve). The GOMOS profile was observed on August 5 2007, at an SZA angle of 38°. Right: relative difference (GOMOS-REPROBUS)/ REPROBUS .

P. 39, line 1: "GOMOS ozone concentration vertical profiles show quite similar values below 60 km between day and night, and quite lower values of O3 at night above 60 km, a feature well understood from mesospheric chemistry." ?? Statement unclear. Do you mean the comparison of GOMOS with the model or the comparison of GOMOS night vs. day measurements? Nighttime O3 in the mesosphere is significantly larger than daytime O3 (photolysis during the day). The statement is not correct as is. answer : This was a typo in the submitted manuscript. Nighttime O3 above 60 km is indeed larger than during the day, and this is well observed by GOMOS. We changed "quite lower" for "larger" in the revised version.

P. 39, line 18: "11h30 ascending node or 13h30 descending" This is impossible. One

of the two times is incorrect (at least). Answer: yes, it is possible, because MicroCarb is not yet launched ! So, this is one or the other. We have rephrased :  $\text{Á} \dots 11\text{h}30$  ascending node or alternately  $13\text{h}30$  descending node helio-synchronous orbit (to be decided later)."

Next line: "consists in" -> "consists of" Done C10

P. 40, line 12: "lands" -> "land" Done P. 40, line 13: "over seas" -> "over lakes" ? (sea = ocean) Done P. 40, line 18: "e.g" -> "e.g." Done P. 40, line 22: "slope of albedo" ?? slope with respect to what? This is unclear : wavelength slope Same line: "for each bands" -> "for each band" Done Same line: "aerosols properties" -> "aerosol properties"  $\text{Á} \dots$  Done P. 40, line 24: define "CAMS" : (Copernicus Atmosphere Monitoring Service) Next line: "Sentinel 2" Which instrument on Sentinel 2? answer : There is only one instrument on board Sentinel 2 : MSI (Multi Spectral Instrument). We have added the name of the instrument and the sentence : (from the Multi Spectral Instrument MSI, the unique instrument on-board Sentinel-2)

Same line: please add reference for "PlanetObserver" answer : we have added the reference : (<https://www.planetobserver.com/products/planetdem/planetdem-30/>) P. 41, last line: "scattered solar radiation by the surface" There is also scattering by the atmosphere we have added the sentence :  $\text{Á} \dots$  The contribution of atmospheric Rayleigh scattering is small at this wavelength and ignored in this exercise." P. 42, line 18: "to O<sub>2</sub> absorption is a continuous function of the wavenumber" What exactly does that mean? The ratio will certainly be a function of wavenumber. answer : It means that it can be computed for any wavenumber, independently of the existence of any spectral line. We have modified the sentence : "...the ratio of O<sub>2</sub>\* emission to O<sub>2</sub> absorption is not a constant, but a changing continuous function..." P. 43, line 10: "then applied IT to" Done P. 43, line 19: "spectral resolution" -> "resolving power" Done P. 44, line 6: I suggest speaking of higher / lower temperature, not warmer / colder. Temperature cannot be warm or cold, strictly speaking. answer : for temperatures, we change to high or low ; for spectra or components, we keep warm and cold, it has some meaning

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in the mesosphere. P. 44, line 14: "spectrum." Done 2 lines below: "SCHIAMACHY"  
-> "SCIAMACHY" Done

P. 44, line 27: "spectru" Done Next line: "spectel" I assume this is not a typo, please explain. answer: The word spectel is commonly used to designate a spectral element, which may be constituted of several pixels in 2D imaging spectrometers. we have added : : Åž... each spectel (spectral element) is... P. 44, second line bottom-up: "resolution" -> "resolving power" Done There are several more cases, where "resolution" is used rather than the correct "resolving power". Please search for them all and correct them. P. 48, caption Fig. 31, line 3: "g" in the term symbol should be subscript. Done P. 49, Caption Fig. 32: "SCHIAMACHY" -> "SCIAMACHY" Done P. 49, line 7: "spectral resolution" (see comment above) Done P. 49, line 16: "spectra resolution" (see comment above) Done P. 50, line 6: "resolution power" (see comment above) Done P. 50, line 25: "slope on albedo" Unclear, specify. changed to Ån spectral slope of albedo Åž P. 50, line 29: "Lmoy" we rephrased : "... a median intensity luminance Lmoy..." Please define. If this is french, please change to english. Answer :Change refused. Lmoy corresponds to a number of MicroCarb official documents and is a standard name designating a reference luminosity case of about median intensity. Remember Ån bremstrhalung Åž, Ån gedanken experiment Åž... We have added to the explanation of Lmoy : This reference luminance value Lmoy corresponds P. 50, line 48: "which associated" -> "whose associated" Done P. 51, line 11: "which peak" -> "whose peak" Done P. 51, line 13: "These two spectra are then normalized at the intensity of the airglow spectrum that is put inside the simulated spectrum to invert." I read this sentence several times, but didn't get it. Please rephrase. We have added some rephrasing : "These two spectra are then normalized to the intensity of the airglow spectrum that is put inside the simulated spectrum which we wish to invert. The model spectrum that we wish to best approximate this simulated spectrum will be a linear combination of these two normalized spectra, with a sum of coefficients near unity, which is more convenient for the description of the mesosphere." Figure 33: "VER moy" Done C12 Replace by english term. Figure 34: legends overlap with figures, please correct. Done



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P. 53, line 22: "which intensity" -> "whose intensity" Done Same line: move "respectively" after the numbers. Done P. 54, caption Fig. 35, line 2: "value" -> "values" Done P. 55, line 1: "spectral resolution" (see comment above) Done P. 55, line 35: "non-ETL" -> "non-LTE" Done 2 lines below: "transition at  $1.58 \mu\text{m}$  of the O<sub>2</sub> (1Delta) around  $1.58 \mu\text{m}$ " Done 2 lines below: "CO<sub>2</sub> band" -> "CO<sub>2</sub> bands" Done P. 56, line 7: "nw" ?? Next line: "nw" ?? answer : nw is the official abbreviation of nanowatt. P. 56, line 19: "spectral resolution" (see comment above) Done P. 57, line 10: "of 2007 SCIAMACHY 12,833 limb-scans" Word order wrong. changed to "12,833 limb-scans acquired by SCIAMACHY in 2007..." Next line: "with though" -> "although with" Done P. 57, line 16: "the O<sub>2</sub>\* airglow is well organized" What is this supposed to mean? Airglow is well organized? Rephrased : "... the intensity of the O<sub>2</sub>\* airglow is well organized (with a weak horizontal variability), and quite predictable, P. 57, line 39: "on Fig." -> "in Fig." P. 57, last line: "and the reflected solar flux is far to be" This makes no sense. Answer : The sentence has been modified. Also, while for the shape of the airglow emission, all the spectral lines are proportional to each other, on the contrary the radiance factor ( $=\pi B/\text{solar flux cos(SZA)}$ , B brightness) is modulated by the O<sub>2</sub> transmittance spectrum ( $\text{Tr}(\tau)=\exp(-\tau)$ ) which is not linear for the strong lines with large  $\tau$ . P. 58, lines 10, 13, 20, 27, 30, 38: "resolution" (see comment above) Done C13 P. 58, line 32: "which broad" -> "whose broad" Done Same line: "on Fig." -> "in Fig." Done P. 58, line 34: "for a better constraining" -> "allow to constrain the .. absorption better" Rephrased : "would be measured and would allow to constrain the CIA absorption better.." P. 59, lines 1, 7, 9: "resolution" (see comment above) Done P. 59, line 4: "Mission space mission" Is the repetition intended? Answer : Yes, we have seen documents with the name CO<sub>2</sub> Mission. Rephrased : The CO<sub>2</sub> Mission (space mission CO<sub>2</sub>-M).. P. 67, line 27: "From the pressure and temperature are also calculated the total density an" Word order incorrect. Done P. 71, line 2: "the loss term .. becomes very long" ? Do you mean "large" rather than "long"? "Long" doesn't really make sense. answer : we have rephrased the sentence : "when the solar photolysis rate of O<sub>2</sub> varies significantly over the natural lifetime ( $\sim 75 \text{ mn}$ ) of the O<sub>2</sub>(a1 $\Delta$ ) excited state,  $d[\text{O}_2^*]/dt$  is  $\neq$

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0, as it is the case at very large zenith angles with  $d[O2^*]/dt < 0$  at dusk and  $d[O2^*]/dt > 0$  at dawn (Fig. 31).

P. 72, line 13: "present" -> "presents" Done P. 74, line 7: "On Fig. A6 (left) are represented the" Word order incorrect. Done Same comment on line 16 on the same page. Done P. 74, line 8: comma missing in "40 S 40N" Done

Appendix B: Processing of SCIAMACHY Level-1c radiance data Here we show some figures describing our processing of Level-1c SCIAMACHY radiance data, as explained in Section 3.1. , in order to get a "pure" radiance spectrum of the O<sub>2</sub>\* airglow.

Figure B1. This high altitude spectrum recorded above 105 km contains some residual spectral (readout) patterns left from the calibration step and is subtracted from all measurements obtained at lower altitude in the same scan limb.

Figure B2. Spectra corrected from high altitude spectrum showing still two bad pixels at wavelength 1262.267 nm and 1282.128 nm. We replaced their value by the average of their two surrounding pixels to obtain spectra of Figure B3. The tangent altitude of the LOS is colour coding each spectrum.

Figure B3: Same as Figure B2, after correction of the two bad pixels. In addition to the O<sub>2</sub>\* airglow, there is the radiance of solar light scattered by air and aerosols, increasing when tangent altitude is decreasing. In addition, the strong absorption of O<sub>2</sub> in the 1.27  $\mu$ m band becomes obvious at lowest altitudes.

Figure B4. Airglow spectra obtained from Figure 4 by subtracting a linear interpolation based on the two constant values of the continuum (one on each side) estimated from the median value of all points outside the O<sub>2</sub>\* band. This correction is valid above  $\sim$ 20 km of tangent altitude.

Please also note the supplement to this comment:

<https://www.atmos-meas-tech-discuss.net/amt-2019-54/amt-2019-54-AC1->

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