

## ***Interactive comment on “Photochemical modeling of molecular and atomic oxygen based on multiple *in-situ* emissions measured during the Energy Transfer in the Oxygen Nightglow rocket campaign” by Olexandr Lednyts’kyy and Christian von Savigny***

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***Response regarding comments of the Anonymous Referee #1 on acp-2019-221: Photochemical modeling of molecular and atomic oxygen based on multiple *in-situ* emissions measured during the Energy Transfer in the Oxygen Nightglow rocket campaign***

C1

### ***Comments of the Anonymous Referee #1 Feedback to the pdf-paper:***

In this paper the authors present a new airglow model (MAC, Multiple Airglow Chemistry model) that includes electronically excited states of molecular and atomic oxygen (six of O<sub>2</sub> and two of O) and their ground states. The model is based on the measurements and findings of the ETON sounding rocket campaign conducted from South Uist, Scotland in March 1982 and extends this with later efforts by several authors to model the photochemistry of the MLT (Mesosphere/Lower Thermosphere) region, and updated reaction rates. Unfortunately, the *in situ* measurements of the atmospheric neutral temperature during the ETON campaign were not successful. Instead, the temperature (and neutral density) were taken from the NRLMSISE-00 model in the current study. A sensitivity study was conducted by the authors to investigate the influence of changes in temperature and neutral density in the retrieval of the different excited and ground states of molecular and atomic oxygen.

To take this model (and our knowledge of airglow photochemistry) further, dedicated simultaneous *in situ* measurements of relevant airglow emissions, atomic oxygen, neutral temperature and density are needed.

### ***General comments to the pdf-paper:***

The paper presents an extensive model to explain the excitation mechanisms responsible for the observed airglow emissions from the MLT region of the Earth’s atmosphere. It is a nice review of the current knowledge of airglow photochemistry, and it constrain the precursors responsible for the Atmospheric band, Infrared Atmospheric band and the Oxygen Green Line emissions. It is an important contribution to the scientific community.

However, in some parts of the manuscript, in particular section 3, the language (sentence structure) needs to be improved as I sometimes find it difficult to read certain sentences. Sections 4 and 5 are much easier to read. The manuscript would greatly benefit from being read and corrected by someone fluent in English.

Since “*in situ*” is a Latin phrase with a specific meaning it should be written “*in situ*”,

C2

not “*in-situ*”. It is, however, very common, and seems widely accepted, to write in-situ or even *in-situ* (both italicised and hyphenated) and I suppose it is ok as long as it is consistently done so throughout the manuscript (which it is). Sometimes it is written “datasets” and sometimes (most of the times) “data sets”. Both are widely used but it should be consistent in the manuscript. Remove “the” in front of “step” or “steps” when discussing the retrieval steps.

**List of corrections regarding general comments of the Anonymous Referee #1**

The authors of the manuscript are grateful to the Anonymous Referee #1 for the general comments. The manuscript was substantially revised and the english has been hopefully improved. We hope that the paper is now easier to follow. Changes in the manuscript are highlighted by bold font.

**Title:**

... and atomic oxygen based on multiple *in-situ* emissions measured during the Energy Transfer ...

was not highlighted, but it was changed to:

... and atomic oxygen based on multiple nightglow emissions measured *in situ* during the Energy Transfer ...

*Everywhere in the manuscript:*

*in-situ*

was not highlighted, but it was changed to:

*in situ*

**Page 5, line 17:**

datasets

C3

was changed to:

data sets

**Page 22, line 14:**

Profiles of VER and  $[O(^3P)]$  obtained at the retrieval steps 2.3, 3.1, 3.2, 4.1 and 5.1 are shown ...

was changed to:

Profiles of VER and  $[O(^3P)]$  obtained at steps 2.3, 3.1, 3.2, 4.1 and 5.1 are shown ...

*Additionally, a similar change was carried out in caption of Fig. 4 on page 24:*

Although the retrieval steps 2.1, 2.2, 2.3 and 3.2 applied on the basis of some ETON VER profiles result in lower  $[O(^3P)]$  values compared to the *in situ* ones, the retrieval step 4.1 applied on the basis of  $VER\{O(^1S-^1D)\}$  results in higher values.

was changed to:

Although steps 2.1, 2.2, 2.3 and 3.2 applied on the basis of some ETON VER profiles result in lower  $[O(^3P)]$  values compared to the *in situ* ones, the  $[O(^3P)]$  retrieval carried out at step 4.1 on the basis of  $VER\{O(^1S-^1D)\}$  results in higher values.

*Additionally, a similar change was carried out in caption of Fig. 5 on page 25:*

... at the retrieval steps 2.3, 3.2, 4.1 and 5.1 ...

was changed to:

... at steps 2.3, 3.2, 4.1 and 5.1 ...

*Additionally, a similar change was carried out on page 30, line 14:*

... at the retrieval step 3.2 shown in Table 8. ...

was changed to:

... at step 3.2 shown in Table 8. ...

*Additionally, a similar change was carried out on page 31, lines 31-33:*

C4

The dependence of  $[O(^3P)]$  values on  $O(^3P)$  loss processes is very high at the last retrieval step 5.1 because the  $R_{x1.1-2}$  reactions are taken into account in the continuity equations at this step.

was changed to:

The  $[O(^3P)]$  retrieval carried out at step 5.1 exhibits the dependence of the retrieved  $[O(^3P)]$  values on the additional  $O(^3P)$  loss processes implemented at this step, whereas the  $[O(^3P)]$  retrievals carried out at steps 2.1, 2.2, 2.3, 3.1, 3.2 and 4.1 do not involve the  $R_{x1.1-2}$  reactions in the corresponding steady state chemical balance equations.

*Additionally, a similar change was carried out on page 35, lines 31-35:*

Uncertainties in such VER values as  $VER\{O_2(A-X)\}$  and  $VER\{O_2(A'-a)\}$  at the retrieval steps 2.1 and 2.2 cause up to about 40% of  $[O(^3P)]$  variations, uncertainties in such VER values as  $VER\{O_2(b-X)\}$  and  $VER\{O_2(a-X)\}$  at the retrieval steps 2.3 and 3.2 cause about 12% of  $[O(^3P)]$  variations, but uncertainties in such VER values as  $VER\{O(^1S-^1D)\}$  at the retrieval step 4.1 cause up to about 20% of  $[O(^3P)]$  variations.

was changed to:

Uncertainties in values of  $VER\{O_2(A-X)\}$  and  $VER\{O_2(A'-a)\}$  cause  $[O(^3P)]$  variations of up to about 40% at steps 2.1 and 2.2, respectively; uncertainties in values of  $VER\{O_2(b-X)\}$  and  $VER\{O_2(a-X)\}$  cause  $[O(^3P)]$  variations of about 12% at steps 2.3 and 3.2, respectively; whereas uncertainties in values of  $VER\{O(^1S-^1D)\}$  cause  $[O(^3P)]$  variations of up to about 20% at step 4.1.

*Additionally, a similar change was carried out on page 37, line 4:*

The retrieval steps of  $[O(^3P)]$  are closely related to the development of the MAC model.

was changed to:

The development and application of the MAC model is closely related to the retrieval

C5

steps required to obtain  $[O(^3P)]$  profiles.

*Additionally, a similar change was carried out on page 41, lines 22-23:*

Calculations at the retrieval steps 2.1 and 2.2 are relevant for the MAC model involving  $O_2(A)$  and  $O_2(A')$ , but calculations at the retrieval step 2.3 only are relevant for the MAC model excluding  $O_2(A)$  and  $O_2(A')$ , see the following overview.

was changed to:

Calculations carried out at steps 2.1 and 2.2 are relevant for the MAC model involving  $O_2(A)$  and  $O_2(A')$ , but calculations carried out at step 2.3 only are relevant for the MAC model excluding  $O_2(A)$  and  $O_2(A')$ , see the following overview.

*Additionally, a similar change was carried out on page 42, lines 4-6:*

$[O_2(c)]$  values were retrieved ( $R-[O_2(c)]$ ) on the basis of  $[O_2(A)]$ ,  $[O_2(A')]$  and  $[O_2(b)]$  values (obtained at the retrieval steps 2.1, 2.2 and 2.3, respectively) as well as  $[O(^3P)]$  values (obtained at the retrieval step 2.3) according to the continuity equation for  $[O_2(c)]$  considering all relevant processes of the MAC model.

was changed to:

$[O_2(c)]$  values were retrieved ( $R-[O_2(c)]$ ) on the basis of  $[O_2(A)]$ ,  $[O_2(A')]$  and  $[O_2(b)]$  values (obtained at steps 2.1, 2.2 and 2.3, respectively) as well as  $[O(^3P)]$  values (obtained at step 2.3) according to the continuity equation for  $[O_2(c)]$  considering all relevant processes of the MAC model.

*Additionally, a similar change was carried out on page 43, lines 23-24:*

Calculations at the retrieval step 3.1 can not be tested for consistency because . . .

was changed to:

The corresponding calculations carried out at step 3.1 could not be tested for consistency because . . .

*Additionally, a similar change was carried out on page 43, line 27:*

C6

... calculations at the retrieval step 3.2 only can be tested for consistency.

was changed to:

... only calculations carried out at step 3.2 are tested for consistency.

*Additionally, a similar change was carried out on page 45, lines 7-8:*

... at the retrieval steps 2.1, 2.2, 2.3, 3.1, 3.2 and 4.1, respectively.

was changed to:

... at steps 2.1, 2.2, 2.3, 3.1, 3.2 and 4.1, respectively.

**Page 26, line 1:**

... retrieved at the step 3.2 ...

was changed to:

... retrieved at step 3.2 ...

*Additionally, a similar change was carried out on page 31, line 34:*

... retrieved at the steps 2.1, 2.2, 2.3, 3.1, 3.2 and 4.1 ...

was changed to:

... retrieved at steps 2.1, 2.2, 2.3, 3.1, 3.2 and 4.1 ...

*Additionally, a similar change was carried out on page 32, line 2:*

... e.g. the step 4.1, ...

was changed to:

... e.g. step 4.1, ...

*Additionally, a similar change was carried out on page 32, line 5:*

... retrieved at the steps 2.1, 2.2, 2.3, 3.1, 3.2, 4.1 and 5.1 ...

was changed to:

... retrieved at steps 2.1, 2.2, 2.3, 3.1, 3.2, 4.1 and 5.1 ...

C7

**List of corrections regarding specific comments of the Anonymous Referee #1**

The authors of the manuscript are grateful to the Anonymous Referee #1 for the specific comments. The manuscript was substantially revised and the English has been hopefully improved. We hope that the paper is now easier to follow. Changes in the manuscript are highlighted by bold font.

**Page 1, lines 3-4:**

The MAC model is proposed combining chemical processes of the well-known photochemical models ...

was changed to:

The MAC model combines chemical processes of well-known photochemical models ...

**Page 1, line 6:**

... the multiple *in situ* nightglow emissions measured during the Energy Transfer

was changed to:

... the multiple nightglow emissions measured *in situ* during the Energy Transfer ...

**Page 1, line 7:**

... obtain concentrations of these MLT minor species is implemented ...

was changed to:

... obtain concentrations of these minor species in the MLT region is implemented ...

**Page 1, lines 10-11:**

... considered in the MAC model are identified and validated by calculations with the MAC model.

was changed to:

... considered in the MAC model are identified and validated.

C8

**Page 1, line 22:**

... active MLT trace gas which is a critical component of ...  
was changed to:  
... active MLT trace gas and a critical component for ...

**Page 2, lines 25-26:**

Dynamic quenching reduces the apparent fluorescent lifetime, and static quenching rather reduces the apparent concentration ...  
was changed to:  
Dynamic quenching reduces the apparent fluorescent lifetime, while static quenching rather reduces the apparent concentration ...

**Page 2, line 28:**

... the dynamic quenching that can introduce difficulties ...  
was changed to:  
... the dynamic quenching, and can introduce difficulties ...

**Page 3, line 25:**

The ETON multiple airglow emissions are described in Section 2, they can be applied ...  
was changed to:  
The ETON multiple airglow emissions described in Section 2 can be applied ...

**Page 3, line 30:**

... scattered in the time and place that might have stopped Torr et al. (1985) combining ...  
was changed to:  
... scattered in time and place and might have stopped Torr et al. (1985) from

C9

combining ...

**Page 4, lines 19-20:**

The maximal number of VER profiles related to various  $O_2$  and  $O(^3P)$  transitions were obtained by two ETON rockets, which are discussed here. As for the Infrared Atmospheric band emissions at  $1.27 \mu\text{m}$ , they were measured ...  
was changed to:

All VER profiles considered in the MAC model were measured during flights of two ETON rockets. The Infrared Atmospheric band emission at  $1.27 \mu\text{m}$  was measured ...

**Page 4, lines 28-29:**

... ground state ( $[O(^3P)]$ ) were carried out directly by the rockets P232H and P234H launched at ...  
was changed to:  
... ground state  $[O(^3P)]$  were carried out by the P232H and P234H rockets launched at ...

**Page 4, lines 32-33:**

... (where  $[O(^3P)]$  peak values are measured) ... (where  $[O(^3P)]$  low values are measured) ...  
was changed to:  
... (where peak  $[O(^3P)]$  values were measured) ... (where low  $[O(^3P)]$  values were measured) ...

**Specific comment:**

I suggest adding a reference to the NRLMSISE-00 model here ..., and possibly also the MSIS-83 model ...

**Page 5, lines 1-6:**

The most recent version of the MSIS model, NRLMSISE-00 (Naval Research Labora-

C10

tory MSIS Extended, 2000) ...

was changed to:

The most recent version of the MSIS model, NRLMSISE-00 (Naval Research Laboratory MSIS Extended, 2000, see Picone et al. (2002)) ...

**Page 5, lines 1-6:**

... the MSIS-83 model, which is not available anymore.

was changed to:

... the MSIS-83 model (Hedin, 1983) that is no longer available.

**Page 5, line 10:**

Some of O<sub>2</sub> transitions ...

was changed to:

Some of the O<sub>2</sub> transitions ...

**Page 5, line 19:**

... on the basis of data sets obtained ...

was changed to:

... on the basis of the data sets obtained ...

**Specific comment:**

Is there a manuscript in preparation with a title and author list that can be referenced here?

**Page 5, lines 20-22:**

Then, the MAC model was applied on the basis of data sets obtained during three campaigns as follows: the WADIS-2 (WAVE propagation and DISSipation in the middle atmosphere), WAVE2000 (WAVes in airglow structures Experiment, 2000) and WAVE2004 campaigns, see the next publication.

was changed to:

C11

Then, the MAC model was applied by Lednyts'kyy et al. (2019) on the basis of data sets obtained during the following three campaigns: the WADIS-2 (WAVE propagation and DISSipation in the middle atmosphere), WAVE2000 (WAVes in airglow structures Experiment, 2000) and WAVE2004 campaigns.

**Specific comment:**

The reference "na – Nagy et al. (2008)" is written twice.

**Page 6, Table 1 caption:**

md – McDade (1998), na – Nagy et al. (2008), kh – Khomich et al. (2008).

was changed to:

md – McDade (1998), kh – Khomich et al. (2008).

**Page 7, line 6:**

... equation of McDade et al. (1986) provided here in the full form and in the short form ...

was changed to:

... equation of McDade et al. (1986) provided below in the full form ...

**Page 7, line 8:**

The well-known cubic equation provided by McDade et al. (1986) in the full form is as follows:

was changed to:

The cubic equation in the full form is as follows:

**Specific comment:**

Why can't the equation be in a single line, as equation 1?

**Response: Equation 2 on page 7 was changed to the equation in a single line. Additionally, Eqs. 3 and 4 on page 9 were changed to the equations in a single line. The changed equations were not highlighted.**

C12

**Page 7, line 26:**

... using the semi-empirical models including MSIS-83, which is not available now-days.

was changed to:

... using semi-empirical models, including MSIS-83 (Hedin, 1983), that are no longer available.

**Page 7, line 29:**

The minimal values of C(0), C(1) and C(2) from all obtained ones, which are ...

was changed to:

The lowest obtained values of C(0), C(1) and C(2), ...

**Page 7, line 31:**

... their maximal values were found to be equal to ...

was changed to:

... their highest values were found to be ...

**Page 9, line 13:**

... Kenner and Ogryzlo (1982), but Johnston and Broadfoot (1993) ...

was changed to:

... Kenner and Ogryzlo (1982). However, Johnston and Broadfoot (1993) ...

**Page 10, line 23-24:**

As for the well-known cubic Eq. (2), it solved ...

was changed to:

As for the well-known cubic Eq. (2), it was solved ...

**Page 10, line 27-28:**

C13

... in this study, values of reaction rates and empirical coefficients provided by ...

was changed to:

... in this study, the values of the reaction rates and empirical coefficients used are the ones provided by ...

**Page 10, line 32:**

... photochemical models is provided in Section 1.

was changed to:

... photochemical models was provided in Section 1.

**Page 10, line 35:**

... second model, see Section 3.2.1, developed using available data sets.

was changed to:

... second model, see Section 3.2.2.

**Specific comment:**

Is "contiguously" the correct word to be used here or should "continuously" be used instead?

**Page 12, line 6:**

and contiguously in the wavelength range

was changed to:

in the wavelength range

**Page 13, line 8:**

... (2014), see Table 3 in Section 3.2.1. These processes are related to:

was changed to:

... (2014) (see Table 3 in Section 3.2.1):

*Additionally, a similar change was carried out on page 14, line 5:*

C14

... (1997), see Table 4 in Section 3.2.2. These processes are related to:  
was changed to:

... (1997) (see Table 4 in Section 3.2.2):

*Additionally, a similar change was carried out on page 15, lines 11-12:*

... (1992), see Table 2 in Section 3.1. These processes are related to:  
was changed to:

... (1992) (see Table 2 in Section 3.1):

**Page 14, lines 2-3:**

... MAC model, they are also referred to as M-processes.  
was changed to:

... MAC model and are referred to as M-processes.

**Page 14, line 10:**

... MAC model, they are also referred to as H-processes.  
was changed to:

... MAC model and are referred to as H-processes.

**Page 14, line 16:**

... G-model are also referred to as G-processes.  
was changed to:

... G-model are referred to as G-processes.

**Specific comment:**

Reformulate this sentence, e.g. "Although the Barth excitation transfer scheme was formulated with  $O_2^*$  considered as one not identified  $O_2$  states, a group of many not identified  $O_2$  states coupled in a cascade of de-excitation reactions is also possible." Or did I not understand the meaning of this sentence?

C15

**Page 14, line 23-25:**

In fact, the Barth excitation transfer scheme was formulated with  $O_2^*$  considering it as one not identified  $O_2$  state or a one group of many not identified  $O_2$  states coupled in a cascade of de-excitation reactions is also possible.

was changed to:

Although the Barth excitation transfer scheme was formulated with  $O_2^*$  considered as one not identified  $O_2$  state, a group of many not identified  $O_2$  states coupled in a cascade of de-excitation reactions is also possible.

**Specific comment:**

How can Slanger et al. (2004b) have refuted the hypothesis by Huestis (2002) based on laboratory measurements discussed by Pejakovic et al. (2007)? A paper that was published 3 years after? I suggest to remove the reference of Pejakovic et al. (2007), or reformulate this section.

**Page 14, lines 26-27:**

... discussed by Huestis (2002), Slanger et al. (2004b) and Pejakovic et al. (2007) stating that energetically nearly resonant intermolecular processes are responsible for conversions of higher to lower excited  $O_2$  electronic states according to Slanger and Copeland (2003).

was changed to:

... discussed by Huestis (2002) and Slanger et al. (2004b), and summarized by Pejakovic et al. (2007). Slanger and Copeland (2003) stated that energetically nearly resonant intermolecular processes are responsible for conversions of higher to lower excited  $O_2$  electronic states.

**Page 14, line 29:**

... the de-excitation of  $O_2$  states occurs not in a cascade-like process.

was changed to:

... the de-excitation of the  $O_2$  states does not occur in a cascade-like process.

C16



**Page 14, line 32:**

... removed converting to very high vibrational ...

was changed to:

... removed by conversion to very high vibrational ...

**Page 14, line 32 to page 15, line 1:**

... that  $^5\Pi$  is the electronically excited  $O_2$  state with the higher energy than ...

was changed to:

... that  $^5\Pi$  is an electronically excited  $O_2$  state with higher energy than ...

**Specific comment:**

Reformulate.

**Page 15, lines 16-19:**

These C-processes are shown here in Table 5, they were considered and discussed by Lednyts'kyi et al. (2018). The corresponding reaction rates are shown in Table 9. The C-processes related to the G-, M- and H-processes complete the coupling of  $O_2(^5\Pi, c, b, a, X)$  with each other and  $O(^1S, ^1D, ^3P)$ , they are related to:

was changed to:

These C-processes and the corresponding reaction rates are provided in Tables 5 and 9, respectively. The C-processes related to the G-, M- and H-processes complete the coupling of  $O_2(^5\Pi, c, b, a, X)$  with each other and  $O(^1S, ^1D, ^3P)$ :

**Page 16, line 8:**

The advantage of the ETON campaign compared to another rocket campaigns ...

was changed to:

The advantage of the ETON campaign compared to other rocket campaigns ...

**Page 16, line 19:**

C17

... model are described in Section 2, they are: VER profiles ...

was changed to:

... model are described in Section 2 and include VER profiles ...

**Specific comment:**

Remove all "the" in front of "step".

**Page 17, lines 6-10:**

on the basis of  $R\text{-VER}\{O_2(A-X)\}$  by using all relevant processes of the MAC model.

This retrieval step is shown as the step 2.1 in Table 8 and the step 2.1 described in Section A2.1 in Appendix A. Then, the verification of calculations at the step 2.1 is carried out comparing  $R\text{-VER}\{O_2(A-X)\}$  with  $E\text{-VER}\{O_2(A-X)\}$  and  $R-[O_2(A)]$  with  $E-[O_2(A)]$ . The cubic equation is solved at the step 2.2 on the basis of T,  $[N_2]$ ,  $[O_2]$ ,  $R\text{-VER}\{O_2(A'-a)\}$  and  $R-[O_2(A)]$ . Then, the verification of calculations at the step 2.2 is carried out comparing  $R\text{-VER}\{O_2(A'-a)\}$  with  $E\text{-VER}\{O_2(A'-a)\}$  and  $R-[O_2(A')]$  with  $E-[O_2(A')]$ .

was changed to:

on the basis of  $R\text{-VER}\{O_2(A-X)\}$  using all relevant processes of the MAC model. This retrieval step is shown as step 2.1 in Table 8 and step 2.1 described in Section A2.1 in Appendix A. Then, the verification of calculations at step 2.1 is carried out comparing  $R\text{-VER}\{O_2(A-X)\}$  with  $E\text{-VER}\{O_2(A-X)\}$  and  $R-[O_2(A)]$  with  $E-[O_2(A)]$ . The cubic equation is solved at step 2.2 on the basis of T,  $[N_2]$ ,  $[O_2]$ ,  $R\text{-VER}\{O_2(A'-a)\}$  and  $R-[O_2(A)]$ . Then, the verification of calculations at step 2.2 is carried out comparing  $R\text{-VER}\{O_2(A'-a)\}$  with  $E\text{-VER}\{O_2(A'-a)\}$  and  $R-[O_2(A')]$  with  $E-[O_2(A')]$ .

**Page 18, lines 9-10:**

... each retrieval step; these profiles also seem ...

was changed to:

... each retrieval step. These profiles also seem ...

C18

**Page 19, line 1:**

... profiles) enables concluding that all ...  
was changed to:  
... profile) enables the conclusion that all ...

**Specific comment:**

Only SCH04 is somewhat defined in the caption of figure 1, none of the other anywhere in the manuscript.

**Page 20-21, Figures 1 and 2:**

All considered processes of the MAC model are provided in Tables 5, 6 and 7. Three-body recombination ...  
was changed to:

All considered processes of the MAC model are provided in Tables 5, 6 and 7. Greer et al. (1981) (GLS<sup>+</sup>81) and Huang and George (2014) (HG14) considered the G-processes, Mlynczak et al. (1993) (MSZ93) and Sharp et al. (2014) (SZB<sup>+</sup>14) – the M-processes, and Lednyts'kyy and von Savigny (2016) (LvS16) – the C-processes. Three-body recombination ...

**Specific comment:**

What is the meaning of defining MMG<sup>+</sup>86 and LSE<sup>+</sup>15 in the text here? They are used later, and defined in the caption, in figure 4.

**Page 20, line 3-21:**

... McDade et al. (1986) (MMG<sup>+</sup>86) was applied ...  
was changed to:  
... McDade et al. (1986) was applied ...

*Additionally, a similar change was carried out on page 21, line 2:*

... Lednyts'kyy et al. (2015) (LSE<sup>+</sup>15) and ...  
was changed to:

C19

... Lednyts'kyy et al. (2015) and ...

**Specific comment:**

Is “equidistant” the correct word to use here? Suggestion: “... two profiles of extreme values.”

**Page 21, lines 6-8:**

The  $[O(^3P)]$  profile values retrieved according to the well-known and extended cubic equations are almost equidistant with respect to the *in situ*  $[O(^3P)]$  profile values, and can be considered as two profiles of extrema values.

was changed to:

The  $[O(^3P)]$  profile values retrieved according to the well-known and extended cubic equations can be considered as two profiles of extreme values because the *in situ*  $[O(^3P)]$  profile values seem to be equidistant with respect to the retrieved ones.

**Specific comment:**

Suggestion: “... averaging of the extreme ...”. There are violet crosses in both panels in figure 4, what do you mean? “... see the violet crosses on the left in both figures.”??

**Page 21, lines 8-9:**

One could assume that the arithmetical averaging of the extrema  $[O(^3P)]$  profile values might be appropriate to finalize the  $[O(^3P)]$  retrievals, see the violet crosses on the left in both figures.

was changed to:

One could assume that arithmetical averaging of the extreme  $[O(^3P)]$  profile values might be appropriate to finalize the retrievals resulting in  $[O(^3P)]$  profile values denoted by the violet crosses shown in both figures.

**Page 22, line 1:**

... in relation to rates of reactions in which ...  
was changed to:

C20

... in relation to reaction rates in which ...

**Page 22, line 2:**

Note processes ...

was changed to:

Note that processes ...

**Page 22, line 8:**

... retrieved at the pre-last step 4.1 on the basis of ...

was changed to:

... retrieved at step 4.1 on the basis ...

**Page 22, line 15:**

... are equal zero, whereas ...

was changed to:

... are equal to zero, whereas ...

**Page 22, line 16-17:**

... can not be shown because of the division by transition probabilities set to zero at the retrieval steps 2.1 and 2.2 for Fig. 5.

was changed to:

... can not be shown in Fig. 5 because of the division by transition probabilities set to zero at steps 2.1 and 2.2.

**Specific comment:**

Reformulate this sentence.

**Page 23, lines 3-5:**

Comparing VER and  $[O(^3P)]$  profiles shown on the left in Figs. 3 and 5 with each other, it can be concluded that all calculations carried out using the MAC model excluding

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or involving  $O_2(A)$  and  $O_2(A')$  are all consistent with each other and coherent with measurements.

was changed to:

Values of VER profiles were compared with each other for two cases: (1) using the MAC model involving  $O_2(A)$  and  $O_2(A')$ , see the left panel of Fig. 3, and (2) using the MAC model excluding  $O_2(A)$  and  $O_2(A')$ , see the left panel of Fig. 5. This comparison enables concluding that the carried out calculations are consistent with each other leading to results coherent with measurements in both cases.

**Page 23, line 8:**

... values retrieved at the step 3.2 on the basis ...

was changed to:

... values retrieved at step 3.2 on the basis ...

**Page 23, line 9:**

... variable, and variabilities are higher than those ...

was changed to:

... variable with a variability higher than those ...

**Specific comment:**

"... (see the violet crosses on the left in this figure), ..."? Do you mean "... the violet crosses in the left panel of this figure, ..."?

**Page 24, Figure 4 caption:**

... (see the violet crosses on the left in this figure), ...

was changed to:

... (see the violet crosses in the left panel of this figure), ...

**Page 24, lines 1-2:**

$[O(^3P)]$  profile values retrieved at the other steps are in good agreement with those of

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the *in situ* ETON [ $O(^3P)$ ] profile, but [ $O(^3P)$ ] profile values retrieved at the step 3.2 are in disagreement with all [ $O(^3P)$ ] profile values mentioned here.

was changed to:

[ $O(^3P)$ ] profile values retrieved at step 3.2 do not agree with the *in situ* ETON [ $O(^3P)$ ] profile values to the degree the [ $O(^3P)$ ] profile values retrieved at the other steps agree.

**Page 24, line 5:**

It should be mentioned that the vibrational population of  $OH(\nu')$  has to be known in order to consider the reaction  $R_{h2.1}$  shown in Table 7 ( $OH^* + O(^3P)\eta^{3P_{OH}+O_2}$ , where  $OH^*$  describes the hydroxyl radical in all possible levels  $\nu'$ ) in the MAC model.

was changed to:

The reaction  $R_{h2.1}$  implemented in the MAC model and shown in Table 7 is similar to that considered by Llewellyn and Solheim (1978):  $OH^* + O(^3P)\eta^{3P_{OH}+O_2}$ , where  $OH^*$  describes the hydroxyl radical in all possible levels  $\nu'$ . It should be mentioned that it would be possible to retrieve [ $O(^3P)$ ] if the vibrational population of  $OH(\nu')$  were known.

**Page 25, line 8:**

Unfortunately, it would be not enough ...

was changed to:

Unfortunately, it would not be enough ...

**Page 26, line 7:**

... at each of the following retrieval steps provided in Table 8.

was changed to:

... at each of the retrieval steps listed in Table 8.

**Page 27, Figure 6 caption:**

The retrievals were performed at the steps ...

was changed to:

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The retrievals were performed at steps ...

**Page 28, line 34:**

... peak values, see Section 2). Varying ...

was changed to:

... peak values, see Section 2. Varying ...

**Specific comment:**

"..., see the next article to be submitted."?? Is there a manuscript in preparation with a title and author list that can be referenced here?

**Page 29, line 19:**

..., see the next article to be submitted.

was changed to:

..., see Lednyts'kyy et al. (2019) for details.

**Specific comment to page 32, lines 20-21:**

Is there a manuscript in preparation with a title and author list that can be referenced here?

**Response: The mentioned sentence was deleted.**

**Page 32, line 34:**

... not well known because it had been detected by Cacace et al. (2001) recently, may be ...

was changed to:

... not well known because it has only recently been discovered by Cacace et al. (2001), may be ...

**Specific comment:**

“,” missing between  $^1D$  and  $^3P$  in two places.

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**Page 33, lines 22-23:**

... and  $O(^1S, ^1D^3P)$  as well as related to  $O_2(^5\Pi, c, b, a, X)$  and  $O(^1S, ^1D^3P)$ .

was changed to:

... and  $O(^1S, ^1D, ^3P)$  as well as related to  $O_2(^5\Pi, c, b, a, X)$  and  $O(^1S, ^1D, ^3P)$ .

*Additionally, a similar change was carried out on page 35, line 2:*

... atomic oxygen,  $O(^1S, ^1D^3P)$ .

was changed to:

... atomic oxygen,  $O(^1S, ^1D, ^3P)$ .

**Page 35, line 5:**

... were combined with complementary processes suggested to complete the list ...

was changed to:

... were combined with suggested complementary processes to complete the list ...

**Page 37, line 9:**

... provided in Section 3.4 in Table 8 for the MAC model.

was changed to:

... provided in Section 3.4 and in Table 8.

**Page 37, line 13:**

... are equal to zero values.

was changed to:

... are equal to zero.

**Page 37, line 14:**

... according to the models, processes of which were adopted in the MAC model.

was changed to:

... according to the processes of the different models adopted in the MAC model.

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**Specific comment:**

“... in the next publication ...”?? Is there a manuscript in preparation with a title and author list that can be referenced here?

**Page 37, line 5:**

... described in the next publication provide data sets required in the prior retrieval to apply the MAC model.

was changed to:

... represent data sets required at the prior retrieval step applied by Lednyts'kyi et al. (2019).

**Specific comment:**

“... considering the processes shown in Tables 6...5...”? Do you mean Tables 5 and 6, or Tables 6 to some other number higher than 6?

**Page 40, line 30:**

... considering the processes shown in Tables 6...5 ...

was changed to:

... considering the processes shown in Tables 5 and 6 ...

*Additionally, a similar change was carried out on page 39, line 18:*

... considering the processes shown in Tables 6...5 ...

was changed to:

... considering the processes shown in Tables 5 and 6 ...

**Specific comment:**

“... considering the processes shown in Tables 6...5...”? Do you mean Tables 5 and 6, or Tables 6 to some other number higher than 6?

**Page 42, lines 8-9:**

... considering the processes shown in Tables 6...5 ...

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was changed to:  
... considering the processes shown in Tables 5 and 6 ...

**Specific comment:**

“... considering the processes shown in Tables 6...5...”? Do you mean Tables 5 and 6, or Tables 6 to some other number higher than 6?

**Page 42, line 28:**

... considering the processes shown in Tables 6...5 ...  
was changed to:  
... considering the processes shown in Tables 5 and 6 ...

**Specific comment:**

“... considering the processes shown in Tables 6...5...”? Do you mean Tables 5 and 6, or Tables 6 to some other number higher than 6?

**Page 44, line 8:**

... considering the processes shown in Tables 6...5 ...  
was changed to:  
... considering the processes shown in Tables 5 and 6 ...

**Specific comment:**

“... considering the processes shown in Tables 6...5...”? Do you mean Tables 5 and 6, or Tables 6 to some other number higher than 6?

**Page 45, line 11:**

... considering the processes shown in Tables 6...5 ...  
was changed to:  
... considering the processes shown in Tables 5 and 6 ...

**Specific comment:**

All references in the text are listed in the reference list and vice versa.

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**Response regarding the word “References” shown in page 48, line 1:**

The authors of the article thank the Anonymous Referee #1 for the suggestion, but will not adopt this suggestion. Instead, the authors follow the JASTP suggestion regarding the names in the reference list.

**Page 56, Table 9 caption:**

Processes of the provided here rate values are shown in Table 5.  
was changed to:  
Rate values of the processes listed in ...

**Page 57, Table 10 caption:**

Processes of the provided here rate values are shown in Table 6.  
was changed to:  
Rate values of the processes listed in ...

**Page 58, Table 11 caption:**

Processes of the provided here rate values are shown in Tables 6 and 7.  
was changed to:  
Rate values of the processes listed in ...

**Page 59, Table 12 caption:**

Processes of the provided here rate values are shown in Tables 7.  
was changed to:  
Rate values of the processes listed in ...