

Referee Report

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Title: Photochemical modeling of molecular and atomic oxygen based on multiple *in-situ* emissions measured during the Energy Transfer in the Oxygen Nightglow rocket campaign.

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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 O₂ 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

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*", 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.

Specific suggestions/comments/questions in order of appearance

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

Page 1, lines 3-4: "The MAC model combines chemical processes of well-known photochemical models..."

Page 1, line 6: "...the multiple nightglow emissions measured *in situ* during the Energy Transfer..."

Page 1, line 7: "...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..."

Page 1, line 22: "...active MLT trace gas and a critical component..."

Page 2, lines 25-26: "Dynamic quenching reduces the apparent fluorescent lifetime, while static quenching rather reduces the apparent concentration..."

Page 2, line 28: "...the dynamic quenching, and can introduce difficulties..."

Page 3, line 25: "The ETON multiple airglow emissions described in Section 2 can be applied..."

Page 3, line 30: "...scattered in time and place and might have stopped Torr et al. (1985) from combining..."

Page 4, lines 19-20: "All VER profiles related to... ..by two ETON rockets. The Infrared Atmospheric band emission at 1.27 μm was measured..."

Page 4, lines 28-29: "...ground state [$\text{O}(^3P)$] were carried out by the P232H and P234H rockets launched at..."

Page 4, lines 32-33: "... (where peak [$\text{O}(^3P)$] values were measured)... .. (where low [$\text{O}(^3P)$] values were measured)"

Page 5, lines 1-6: I suggest adding a reference to the NRLMSISE-00 model here (Picone, J. M., A. E. Hedin, D. P. Drob, and A. C. Aikin, NRLMSISE-00 empirical model of the atmosphere: Statistical comparisons and scientific issues, J. Geophys. Res., 107(A12), 1468, doi:10.1029/2002JA009430, 2002.), and possibly also the MSIS-83 model (Hedin, A. E., A revised thermospheric model based on mass spectrometer and incoherent scatter data: MSIS-83, J. Geophys. Res., 88, A12, 1983)

Page 5, line 10: "Some of the O_2 transitions..."

Page 5, line 19: "...on the basis of the data sets obtained..."

Page 5, line 22: "..., see the next publication."?? Is there a manuscript in preparation with a title and author list that can be referenced here?

Page 6, Table 1 caption: The reference "na – Nagy et al. (2008)" is written twice.

Page 7, line 6: "...equation of McDade et al. (1986) provided below in the full form..."

Page 7, line 8: "The cubic equation in the full form is as follows:"

Page 7, equation 2: Why can't the equation be in a single line, as equation 1?

Page 7, line 26: "...using semi-empirical models, including MSIS-83, that are no longer available."

Page 7, line 29: "The lowest obtained values of C(0), C(1) and C(2), related to the O(¹S) precursor, were found..."

Page 7, line 31: "...their highest values were found to be..."

Page 9, line13: "...Kenner and Ogryzlo (1982). However, Johnston and Broadfoot (1993)..."

Page 10, line 23-24: "As for the well-known cubic Eq. (2), it was solved..."

Page 10, line27-28: "...in this study, the values of the reaction rates and empirical coefficients used are the ones provided by Murtagh et al. (1990)."

Page 10, line 32: "...photochemical models was provided in Section 1."

Page 10, line 35: "...second model, see section 3.2.2, developed using available data sets."

Page 12, line 6: Is "contiguously" the correct word to be used here or should "continuously" be used instead?

Page 13, line 8: "... (2014) (see Table 3 in section 3.2.1):"

Page 14, line 2-3: "...MAC model and are referred to as M-processes"

Page 14, line 10: "...MAC model and are referred to as H-processes"

Page 14, line 16: "...G-model are referred to as G-processes."

Page 14, line 23-25: Reformulate this sentence, e.g. "Although the Barth excitation transfer scheme was formulated with O₂^{*} considered as one not identified O₂ states, a group of many

not identified O₂ states coupled in a cascade of de-excitation reactions is also possible.” Or did I not understand the meaning of this sentence?

Page 14, lines 26-27: How can Slinger 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, line 29: “...the de-excitation of the O₂ states does not occur in a cascade-like process.”

Page 14, line 32: “...removed by conversion to very high vibrational...”

Page 14, line 32 to page 15, line 1: “...that ⁵Π is an electronically excited O₂ state with higher energy than...”

Page 15, lines 16-19: Reformulate.

Page 16, line 8: “The advantage of the ETON campaign compared to other rocket campaigns...”

Page 16, line 19: “...model are described in Section 2 and include VER profiles...”

Page 17, lines 6-10: Remove all “the” in front of “step”.

Page 18, lines 9-10: “...each retrieval step. These profiles also seem...”

Page 19, line 1: “...profile) enables the conclusion that all...”

Page 20-21, Figures 1 and 2: Only SCH04 is somewhat defined in the caption of figure 1, none of the other anywhere in the manuscript.

Page 20-21: What is the meaning of defining MMG⁺86 and LSE⁺15 in the text here? They are used later, and defined in the caption, in figure 4.

Page 21, line 7: Is “equidistant” the correct word to use here?

Page 21, line 8: “...two profiles of extreme values. ...averaging of the extreme...”

Page 21, line 9: “...see the violet crosses on the left in both figures.”?? There are violet crosses in both panels in figure 4, what do you mean?

Page 22, line 1: “...in relation to reaction rates in which...”

Page 22, line 2: “Note that processes...”

Page 22, line 8: “...retrieved at step 4.1 on the basis...”

Page 22, line 15: "...are equal to zero, whereas..."

Page 22, line 16-17: "...can not be shown in Fig. 5 because... ...the retrieval steps 2.1 and 2.2."

Page 23, lines 3-5: Reformulate this sentence.

Page 23, line 8: "...values retrieved at step 3.2 on the basis..."

Page 23, line 9: "...variable with a variability higher than those..."

Page 24, Figure 4 caption: "... (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, line 1: "...values retrieved at step 3.2 are in agreement..."

Page 24, line 5: "...in all possible levels $\forall$ in..."

Page 25, line 8: "Unfortunately, it would not be enough..."

Page 26, line 7: "...at each of the retrieval steps listed in Table 8."

Page 27, Figure 6 caption: "The retrievals were performed at steps..."

Page 28, line 34: "...peak values, see Section 2. Varying..."

Page 29, line 19: "..., 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 32, lines 20-21: Is there a manuscript in preparation with a title and author list that can be referenced here?

Page 32, line 34: "...not well known because it has recently been discovered by Cacace et al., (2001), may be..."

Page 33, lines 22-23: " ," missing between 1D and 3P in two places.

Page 35, line 5: "...were combined with suggested complementary processes to complete the list..."

Page 37, line 9: "...provided in Section 3.4 and in Table 8."

Page 37, line 13: "...are equal to zero."

Page 37, line 14: "...according to the processes of the different models adopted in the MAC model."

Page 37, line 5: "...in the next publication..."?? Is there a manuscript in preparation with a title and author list that can be referenced here?

Page 40, line 30: "...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 9: "...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"? 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"? 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"? Do you mean Tables 5 and 6, or Tables 6 to some other number higher than 6?

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

Page 56, Table 9 caption: "Processes of the provided rate values are shown in Table..."

Page 57, Table 10 caption: "Processes of the provided rate values are shown in Table..."

Page 58, Table 11 caption: "Processes of the provided rate values are shown in Tables..."

Page 59, Table 12 caption: "Processes of the provided rate values are shown in Tables..."