Response to the comments on the paper by Referee 2

Semi-Annual Variation of Excited Hydroxyl Emission at Mid-Latitudes

By Mykhaylo Grygalashvyly, Alexander I. Pogoreltsev, Alexey B., Andreyev, Sergei P. Smyshlyaev, and Gerd R. Sonnemann

Dear Referee,

We appreciate positive judgment on our paper, constructive comments, and not formal approach to the review. We have taken your suggestions into account when preparing the revised version of our manuscript. In following we mention point by point how the manuscript has been changed according to your suggestions.

1. We add it at line 93 of the revised manuscript: “The analysis presented in this paper uses data averaged over the years 2010-2017.”

2. We add the explanation at lines 113-115 of the revised manuscript: “We calculates volume emission for transition $OH^*_{v=6} \rightarrow OH^*_{v=2}$ as the product of the Einstein coefficient for given transition by concentration of excited hydroxyl at corresponding vibrational number, i.e. $V_{62} = E_{62}[OH^*_6]$.”

3. We add such description at lines 136-141 of the revised manuscript, as well necessary references in the reference list:” This run is based on the dynamics and temperature of LIMA (Leibniz Institute Middle Atmosphere) model for the so-called “realistic case”, in which carbon dioxide, ozone, and Lyman-α flux are taken from observations, and the horizontal winds and temperature of ECMWF (European Centre for Medium-Range Weather Forecasts) are assimilated below ~35 km (Berger, 2008; Lübken et al., 2009, 2013).”

4. We add such a comment at lines 133-135:” (the choice of this year does not affect our conclusions because calculations for other years show similar semi-annual variations)”.

5. We add such notation at lines 159-162: “Note, that the observed intensity is directly proportional to the vertical integral of the volume emissions; hence, they reveal similar

variations and dependencies on surrounding conditions near the peak of the excited hydroxyl layer."

6. We add such statements ant lines 156-157: "because we display monthly mean values and standard deviations commonly exceed the errors of measurements".

7. Following by your suggestion we add Eq. (A6) into the Section 3 with explanations about mean states and perturbations, as well we modified the description of the Fig. 3:" In order to assess the input into annual variability from different sources, we calculate relative to annual averaged variations of volume emissions due to atomic oxygen, temperature, and air density ~~(Eq. A6)~~:

$$RD'_O = 100\% \cdot \frac{V'_O}{\bar{V}} = 100\% \cdot \frac{[O]'}{\overline{[O]}},$$
$$RD'_T = 100\% \cdot \frac{V'_T}{\bar{V}} = 100\% \cdot -2.4\frac{T'}{\bar{T}}, \quad (2)$$
$$RD'_M = 100\% \cdot \frac{V'_M}{\bar{V}} = 100\% \cdot \frac{[M]'}{\overline{[M]}},$$

where overbar denotes annually averaged values and prime denotes difference of actual (modeled or observed) values from annually averaged (in our case this is difference between nightly mean one month sliding averaged values (Fig. 2) and nightly mean annually averaged values)."

We did not add the equation (A7) because second momentum have not essential impact on volume emission variability and in future investigations their consideration could be omitted.

Technical comments:

Line 86. This technical but very large problem was comprehensively described in large number of works of Lopez-Gonzalez, which we refer in our reference list.

Part 2.2. Following by your suggestion, we collected description of coefficients for Eq. (1) in the Table (1) and add in the text at lines 116-118 of the revised mynuscript: "All reactions used in Eq. (1) and in appendix, together with corresponding reaction rates, branching ratios,

quenching rates and spontaneous emission coefficients, besides those for multi-quantum processes, are collected in Table 1."

Table 1. List of reactions with corresponding reaction rates (for three-body reactions [cm^6 $molecule^{-2}$ s^{-1}] and for two-body reactions [cm^3 $molecule^{-1}$ s^{-1}]), branching ratios, quenching coefficients, and spontaneous emission coefficients (s^{-1}) used in the paper.

	Reaction	Coefficient/branching ratios	Reference
1	$H + O_3 \xrightarrow{\varsigma_v a_1} OH_{v=5,\dots,9} + O_2$	$a_1 = 1.4 \cdot 10^{-10} exp\left(\frac{-470}{T}\right)$ $\varsigma_{v=9,\dots,5} = 0.47, 0.34, 0.15, 0.03, 0.01$	Burkholder et al. (2015), Adler-Golden (1997)
2	$O + HO_2 \xrightarrow{\psi_v a_2} OH_{v=5,\dots,9} + O_2$	$a_2 = 3.0 \cdot 10^{-11} exp\left(\frac{200}{T}\right)$ $\psi_{v=3,\dots,1} = 0.1, 0.13, 0.34$	Burkholder et al. (2015), Kaye (1988), Takahashi and Batista (1981)
3	$O + OH_{v=1,\dots,9} \rightarrow O_2 + H$	$a_3(v = 9, \dots, 5) = (5.07,$ $4.52, 3.87, 3.93, 3.22, 3.68,$ $3.05, 3.19, 3, 42) \cdot 10^{-11}$	Varandas (2004), Caridade et al. (2013)
4	$O + O_2 + M \rightarrow O_3 + M$	$a_4 = 6 \cdot 10^{-34} (300/T)^{2.4}$	Burkholder et al. (2015)
5	$O + O_3 \rightarrow 2O_2$	$a_5 = 8 \cdot 10^{-12} exp\left(\frac{-2060}{T}\right)$	Burkholder et al. (2015)
6	$OH_v + O_2, O, N_2 \rightarrow OH_{v'<v} + O_2, O, N_2$	$B_{vv'}, D_{vv'}, C_{vv'}$	Adler-Golden (1997), Caridade et al. (2013), Makhlouf et al. (1995)
7	$OH_v \rightarrow OH_{v'<v} + hv$	$E_{vv'}$	Xu et al. (2012)

Line 600. Thank you for this note, it is true. We corrected the description of the Fig. 1.

Figures 2 and 3. We changed the time scale of these figures according with your suggestion.

Line 83. We change this nomenclature according with common nomenclature of our manuscript.

All of your language and stile corrections at lines 167, 171, 179, 200, 232, and 249-250 were applied completely.

Other changes are related to the recommendations and demands of other referee.
Thank you for taking the time to review our manuscript.

With respect,
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