Dear Editor,

We would like to say many thanks the Referee for taking the time to review our manuscript and valuable recommendations. We have tried to follow the referee remarks and have utilized all of them.

In the following, we address the comments point by point and show how the manuscript has been changed accordingly to the comments. Below comments by Referees are in red, our responses are in black, the changes in the manuscript are in blue and brackets.

Response to the comments on the paper by Referee 3

1. By the meaning, construction, and titles the work is "Technical Note", however, the number of figures seems excessive for this type of publication. I recommend the authors to consider reducing them. On my opinion, it is possible to remove a number of panels in Figs. 3-8 and merge the remaining panels. However, the complete figures for major reactions with all 12 panels for each month could be presented in Supporting Information if authors assume them important to a potential reader. In addition, Figure 11 could be moved in Supporting Information and Figure 12 removed at all. This modification may help better focus this work.

Following this remark and the remark by the Referee 1, we have organized the Supplement. In the revised manuscript, the Figures 3-8 have been reduced to Figures 3-4. However, the complete figures for the major reactions with all 12 panels for each month are presented in the Supplement. Figure 12 has been deleted. As a result, the number of Figures in the paper was reduced from 12 to 8, and the total number of panels in the paper was reduced from 143 to 75.

2. OH equilibrium boundary retrieving based on the data of Panka et al. (2021), presented in the Discussion, does not give much. The authors themselves say that most of these data do not allow us to determine the local altitude position of the boundary of the OH equilibrium region because they are cut off at 80 km. In addition, the authors have previously raised the question of the correctness of the Panka et al. approach for O retrieving below 85 km (that is based on proportionality atomic oxygen concentration to the ratio between the volume emission rates of OH* measured at 2.05 and 1.6 μm), see the discussion to the Kulikov et al. (2023, https://doi.org/10.5194/acp-23-14593-2023). It is therefore possible that the data of Panka et al. (2021) are in principle unsuitable for determining the OH equilibrium boundary. Although it is worth noting that even the small number of points presented in Fig. 12 show a seasonal and latitudinal dependence similar to the model curves in Fig. 10. However, I would suggest that this section be deleted and addressed in a separate paper along with the claimed reduction of O, H, OH, and HO_2 from SABER/TIMED data or some other data.

Following this remark and the remark by the Referee 1, we have excluded the OH equilibrium boundary retrieval with the Panka et al. data from the revised manuscript. Instead of deleted analysis, we give a detailed explanation in the Discussion, how the results of our paper can help to modify the Panka et al. method to extend its capabilities.

3. Lines 152-156. It seems to me that for the sake of clarity, it is necessary to specify where this statement comes from, and if we need accuracy not 10% but, for example, 1%, what would the criterion look like?

In the revised manuscript, this sentence was extended:

«Kulikov et al. (2023a) also showed, when $\tau_n \ll \tau_{n^{eq}}$, $n \cong n^{eq}(1 - sign(\frac{dn^{eq}}{dt}) \cdot \frac{\tau_n}{\tau_{n^{eq}}})$ in the first order approximation. Thus, the criterion

$\tau_n/\tau_{n^{eq}} \leq 0.1$ (4)

is sufficient, in order to the possible difference between n and n^{eq} to be no more than 0.1.»

4. Lines 227-229. I think that in Supporting Information it would be appropriate to show the interesting features noted for the reactions $H+O_3 \rightarrow OH+O_2$ and $HO_2+O \rightarrow OH+O_2$ at the 100-130 km altitudes.

Done. Please see Figure S12 and S13 in the Supplement.

5. Lines 424-427. The authors should add a couple of sentences clarifying their claim: "The simultaneous application of OH and HO_2 equilibrium conditions to the SABER data (O_3, volume emission rates at 2.0 and 1.6 μm) together with the criteria (16) and (24) to control this equilibrium validity is going to retrieve all unknown HOx - Ox components (O, H, OH, and HO_2), extending the altitude range of retrieval below 80 km and without external information."

In the revised manuscript, we give the detailed explanation to clarify this sense (see Discussion):

«The results of our paper allow modifying the Panka et al. method to extend its capabilities. The simplest development of this method seems to be the following. First of all, note that the HO_2 equilibrium condition (9) depends on H and O only and can be used within the self-consistent retrieval procedure, considering the following system of equations:

$$OH(v = 1 - 9) = \frac{k_{12} \cdot H \cdot O_3 \cdot M \cdot f(v) + \sum_{v' > v}(a_1(v',v) + a_2(v',v) \cdot O_2 + a_3(v',v) \cdot N_2 + (a_4(v',v) + a_5(v',v)) \cdot O) \cdot OH(v')}{a_6(v)) \cdot O + \sum_{v > v'}(a_1(v,v') + a_2(v,v') \cdot O_2 + a_3(v,v') \cdot N_2 + (a_4(v,v') + a_5(v,v')) \cdot O)},$$

$$OH(0) = \frac{\sum_{v' > 0}(a_1(v',0) + a_2(v',0) \cdot O_2 + a_3(v',0) \cdot N_2 + (a_4(v',0) + a_5(v',0)) \cdot O) \cdot OH(v') + k_{18} \cdot O \cdot HO_2 + 2 \cdot k_{14} \cdot H \cdot HO_2}{k_{17} \cdot O},$$

$$HO_2 = \frac{k_{20} \cdot H \cdot M \cdot O_2}{k_{18} \cdot O + (k_{14} + k_{15} + k_{16}) \cdot H},$$

$$VER_{2\mu m} = a_1(9,7) \cdot OH(9) + a_1(8,9) \cdot OH(8),$$

$$VER_{1.6\mu m} = a_1(5,3) \cdot OH(5) + a_1(4,2) \cdot OH(4),$$

where a_{1-6} are the constant rates of the processes OH(v) → OH(v'<v) + hv, OH(v) +O_2 → OH(v<v') + O_2, OH(v) +N_2 → OH(v<v') + N_2, OH(v) +O(^{3}P) → OH(v'≤v-5) + O(^{1}D), OH(v) +O(^{3}P) → OH(v'<v) + O(^{3}P), and OH(v) +O(^{3}P) → H + O_2, respectively. Note this system includes 13 equations with 13 unknown variables. Therefore, the solution to the system for a set of the SABER data (simultaneously measured profiles of O_3, T, pressure, $VER_{2\mu m}$, and $VER_{1.6\mu m}$) gives one simultaneously retrieved profiles of O, H, OH(v=0-9), and HO_2. By applying the criteria (16) and (24) to obtained O and H profiles, we verify the fulfillment of OH and HO_2 equilibrium conditions and determine the height below which the resulting profiles should be cut. More advanced retrieval procedure would be statistical, based on Bayesian theorem, taking into account the uncertainties in measurement data and rate constants. Similar, for example, to Kulikov et al. (2018a), it should include a derivation of posterior conditional probability density function of retrieved characteristics and numerical analysis of this function. Detailed development of this retrieval method is outside of this paper and should be carried out in a separate work.»

6. I recommend to check the text of the work with the help of a professional editor, as I am not sure about the correctness of wording of some sentences.

The final revised manuscript will be verified and corrected by a professional translator.

Other changes are related to the recommendations and demands of other referees.

Thank you for taking your time to review our manuscript.

With respect,

Michael Kulikov, Michael Belikovich, Alexey Chubarov, Svetlana Dementyeva, and Alexander Feigin