

## General comments:

The preprint by Lee and co-workers presents the design and implementation of the UBC ATMOX chamber - an innovative, modular 8 m<sup>3</sup> environmental chamber. A central aspect of the manuscript details the design of a light system for the chamber, based on LEDs, enabling wavelength-specific research on photochemical processes of aerosol particles and gases. For instance, the system enables experiments under light conditions that are simulating stratospheric, tropospheric, and indoor light conditions, as detailed in the presented work.

While many different atmospheric simulation chambers exist around the world, I find the design and use of an LEDs light system for an atmospheric simulation chamber as presented here a very interesting idea. I believe this concept has strong potential to influence future chamber designs and thus clearly aligns with the scope of *Atmospheric Measurement Techniques*. That said, the manuscript in its current form contains numerous (minor) inconsistencies that detract from its clarity and impact. I encourage the authors to carefully address the points listed below, along with the more detailed comments provided. Given the number and nature of the technical suggestions, I recommend a thorough revision followed by re-assessment for publication.

## Specific comments:

Title: Superscript “3” in m<sup>3</sup>

Abstract: The abstract would benefit from being shortened a bit and focus on the bigger picture of the manuscript. E.g., consider removing details such as the overall costs of the LEDs or the specifications of the T-slots used to collapse the chamber. For the latter, the description used on e.g., L121 “It is also equipped...” seems more appropriate for an abstract, and also in view of the fact that the squeezability of the chamber is not discussed much in the main part of the manuscript.

L11: change “LED grow plant lights” to “LED plant grow lights” for consistency with the remainder in the manuscript.

L44: Formatting of reference, i.e., write as: “Nguyen et al. (2023) have ...”

L46: Please introduce abbreviations of GEOS-CHEM and F0AM or generalize to “global climate and box-model simulations” or similar.

L47: change to : “peroxy radical (RO<sub>2</sub>)”

L55: Consider other chambers with temperature control, e.g., (Kristensen et al., 2020; Zong et al., 2023).

L70: This reference seems inappropriate, at least there are many other studies, where the material collection from atmospheric chambers is the focus of the paper. You might want to have a look at e.g.: <https://link.springer.com/book/10.1007/978-3-031-22277-1>, which might in general be of interest for your paper.

L79: RO<sub>2</sub> has been introduced above (L47), but the other have not. Consider to properly introduce OH and HO<sub>2</sub> here, or when first mentioning these.

L80: Please define "FEP". For the chambers, none of the acronyms seem to be defined in the text. While this is probably okay to improve readability, consider adding the definition of each acronym either to your Table 1 or in a list of acronyms at the end of the paper.

L82: consider saying "in China", to be consistent with wording on L80-81, where you state countries instead of cities.

L83: replace "simulations" by "studies"

L86: delete "proton"

L87: In Table 1 you write as "CaltTech", please use one of these consistently throughout.

L89: change to "applied to study e.g.. cellular..." to account for the many other types of studies that have been conducted at this facility.

L91: Please define what you mean with "UV blacklights".

L92: Subscript "x" in "NO<sub>x</sub>" here and elsewhere in manuscript.

L93: Change to "These examples..."

L94: delete "atmospheric" as you also cover examples of chambers used to study indoor chemistry.

L97: Does the UPatras chamber have a name? For all other examples in this sentence you use the chamber name, rather than the institute where it is located.

Table 1: Caption:

- Please add "some environmental chambers", to clarify that this list is not complete, but rather presents a list of chambers that have inspired the current chamber design.
- Consider changing the column title from "Characteristics" to "Key characteristics" or similar to again make clear that the listed features are examples. The lists of characteristics seems incomplete and or the choice of characteristics listed here unclear and inconsistent. For example, some of the other chambers also have the ability to control/vary T.
- UBC, Canada chamber: How is T-controlled in your chamber? Looking at Fig. 1b, it seems like the chamber T is determined via the temperature setting in the room. In addition, without quantification of e.g. the T-range and the accuracy of the T-control the wording of "precise T-control" seems inappropriate here and elsewhere in the table. Please adjust. Related, looking at some of your  $\Delta T$  values reported in Table 4, I would not call it "precise T control."

L130: While I appreciate the technical detail, I feel that the readability of text would benefit from removing some of the detail. E.g., the type of screws can probably be omitted. In addition, introduction of "BHSCS" seems unnecessary, as it is not further used in the text below. Please consider improving.

L140: rewrite to: "from light emitted from the 275 nm LEDs."

Figure 1:

- Panel d: The grow lights are hardly visible on this photograph. Consider exchanging this panel with a photo that more clearly shows the different light types, as this is key to your presented manuscript.

L143: change to: "...a scanning mobility particle sizer (...) was used to measure particles from 2 - 1000 nm."

L149: "Additional instrumentation can selectively be coupled to the chamber to monitor other parameters, including a relative ..." Please also give details on company and model of the RHTP sensor used. Clarify why it was wrapped in PTFE or omit this part of the sentence.

L154: change to: "by aerosols and gases" and "all directions,"

L159: add comma after "washer"; please check units, should be "18.2 M  $\Omega$  cm"

L169: Entire paragraph: This text can be improved. Consider removing the costs from the text and just keep it in Table 2. Just having a total cost as here in the text without further information on the type/model, and number of LEDs is not very useful.

Table 2:

- Caption: Delete "All totals..."
- Rows: Here it could be helpful to include e.g., the part number or similar for each LED, to enable other researcher to possibly reproduce your system. This could also help to link each LED listed here to your wording used below, e.g., on L178 "The UN-C LED..."
- Write as either "LED" or "LEDs", right now you have a mix.

L178: "The UV-C LED (VC1...)" move the part number/specification to the table and omit in the text to improve readability.

L185: Please introduce acronym as "electrostatic discharge (ESD)", and remove from L188.

L217: Do you mean chamber bag with "light box"? Please specify, as you use is throughout. I can also not find a Figure 11, please correct (also L230).

L219: Add space after "functions"

L221: Please define all parameters of equation, i.e., also “ $\theta$ ” and “ $I$ ”. Is  $I$  the relative intensity that you show in Fig. S10?

L233: This sentence appears incomplete, please check.

L234: Subscript in “NO<sub>x</sub>”

L242: Please write units as “cm<sup>3</sup> molecules<sup>-1</sup> s<sup>-1</sup>” for consistency; see also AMT style guide.

L246-248: Can you please provide some reasoning or references why the combination of the listed LEDs represent “stratospheric”, “tropospheric” and “indoor light” conditions? It could also help to follow parts of your discussion to add these definitions of “stratospheric”, “tropospheric” and “indoor” to your Table 2.

L262: do you mean “filled with a batch of gas”? Please check use of “batch gas” here and on L263.

L263: add “useful e.g., in chemical”

L264: add “useful e.g., in SOA”

Sect. 3.1.: Several of the aspects described here are already part of Sect. 2.1. E.g., the material type of the bag is already mentioned on L132. The fact that the black out curtains inhibit unwanted photochemistry from room light and are protecting people working in the lab, is already mentioned on L139. The instrumentation (e.g. VOCUS) attached to the chamber is already mentioned on L144. It would be good to remove some of this redundancy to improve readability.

L268: What “additional components” are you thinking of? It would be good to name some examples here.

L272: “Overall, these integrated features...”. Are these really “integrated” or are these instruments that can selectively be attached to the chamber, depending on the instruments needs? I like your description in the caption of Fig. 3 better. Consider to revise.

Fig. 3: Caption: I feel that some of the technical specifications could be removed from the caption, e.g., the type of RHTP sensor (“SP-003-1 OMEGA”) or the type of aluminum bar (“80/20”) seems unnecessary and repetitive here. Please also note different typing of “RH/T/P” here and “RHTP” on e.g. L150. I also recommend to state the LED wavelengths as “275-385 nm” and then state the wavelength of the growth lights separately; the use of “400+ nm” seems odd. You could also simply refer to your Table 2 that contains all the specifications, to make the caption of your Fig. 3 more succinct.

L276: change to “(Figure 4b)”

Sect. 3.2: This section should be shortened, as a lot of the information has already been provided. E.g., your Table 2 already specifies the number of LEDs used for each wavelength. The “60° lens” is already described

on L176. It would be helpful to focus the attention in this “Results and Discussion” section more on the actual data that you show e.g., in your Figs. 4 and 5, and discussion thereof..

- L279: delete “commercial”
- L282: change to “60°”
- L283: capitalize “Figure 2b”

Fig. 4, 5: Please introduce panel labels, e.g., (a), (b) and refer to these in the caption and text, rather than using “top” and “bottom”, to be consistent with the journal guidelines. As you have done for some of your other figures, e.g., your Fig. 6.

Fig. 4: What does “Pillow Bag” in your legend correspond to?

L284: I would not describe this as “stable temperature”. Your timeline in Fig. 5a shows distinct fluctuations, e.g., around 16:00, labelled “Stratospheric” (same in top panels of your Fig. S11). Looking at your values listed in Table 4, it seems like over the 22 min experiment of stratospheric conditions, the chamber temperature increased by 3.2 K, which is similar to the temperature increase observed with fluorescence light (over a longer time period). I might be miss-interpreting something here, but your statement further down (L380) suggests that the temperature inside the chamber was not stable with all LEDs on. Please explain better in the text what you consider “stable” . It could also help the structure of the manuscript to move the discussion of heatsinks and stability of chamber temperature (L283-286) to Sect. 3.4.1.

L290: change to “intensity ratio” or “ratio of intensities”

L291-293: I really like your idea to include a potentiometer to control the power of each LEDs. I am, however, unclear what the LED power settings are in your Figs., e.g., 4 and 5. Were the LEDs always fully powered unless specified? Please add this information to your text and/or figure captions.

L296: change to “... while reliably reproducing the same same light condition between independent experiments, if desired.”

L299: rephrase to “...output is 6 W, 23.94 W, ..., at wavelnegth of 275, 310... and 385 nm, respectively”.

L300-302: “For the quantification...”. Consider moving this sentence to the beginning of Sect. 3.3.1 to improve structure.

L309: Eq. (4) depends sensitively on the temperature inside the chamber. How were temperature fluctuations (e.g., top panel in Figs. 5 and S11) handled in calculating  $J_{\text{Nox}}$ ?

L310: These three categories “stratospheric, ...” should be introduced more prominently earlier in the manuscript. Could you add the wavelength of the LEDs that were turned on for each of these categories in

your Fig. 4? That could help to clarify that your stratospheric conditions were not limited to below 300 nm, as the coloring in your Fig. 4 suggests, but cover 275-600 nm, as you write on L246.

L311: Add comma before “as depicted”

L315: What is the typical lifetime of UV-A fluorescent lights that are traditionally used in chamber setups? Adding such a value here would be handy for comparison.

L318: Add comma before “which”

L321: Add comma after “we selected”

L323: Add comma after “of NO<sub>2</sub>”

L325: “plant”

L327: The “pillow bag setup” that is mentioned here and also already appears in Fig. 4 is confusing. Is this pillow bag connected to the ATMOX chamber? This pillow bag setup and how it compares or is different to the ATMOX chamber should be clarified. This information could be added to the “Methods” section (maybe in its own subsection), after it is first mentioned on L253. Further below on L392 you state that the pillow bag has a volume of 450 L. This is much smaller than the ATMOX chamber, and the irradiation conditions will be different. I am not fully clear how you can then directly compare the NO<sub>x</sub> photolysis rates between these two setups? Please expand on this in the text.

L335: Should this not be “(Figure 6b)”?

L339: Change to “(Figure 6b and Table S1)” add space after “chamber” here and on L340

Figure 6:

- Please change the x-axis label of the third item from the left from “Sunlight” to “UBC rooftop outdoor measurement” or appropriate, as the red color of the dot already indicates “Sunlight”.
- Consider removing the labels on top of the panels, as this is what you describe in the figure caption. Also writing of “J<sub>NO<sub>2</sub></sub>” vs. “JNO<sub>2</sub>” is inconsistent, and the general use of “J<sub>NO<sub>x</sub></sub>” vs. “JNO<sub>2</sub>” is inconsistent throughout the text; please fix.
- Caption:
  - o fix typo “could not be”
  - o change to “... air from Burrows et al. (1998)”
  - o Please clarify in the caption if the error bars denote one standard deviation, or other.

Table 3:

- Please add units of “nm” to the column “LED”

- Please check volume of pillow bag, which is stated as 400 L here, but as 450 L on L392.
- Units of “Irradiance” should be changed to “W m<sup>-2</sup>” for consistency.
- As mentioned above, it could be helpful to add an overview of the different LEDs used for “stratospheric”, “tropospheric” vs. “indoor” conditions further up in the manuscript. Then you could just refer to this specification, rather than repeating this information here and elsewhere (e.g., caption of Fig. 5). For instance, you could add 3 columns for “stratospheric”, “tropospheric” vs. “indoor” to your Table 2, and then check all the LEDs that were used for a given conditions.
- Caption: add space, i.e., write “× 10<sup>-6</sup>” and use the same symbol for “×”
- Caption: Do the uncertainties also correspond to one standard deviation? Please clarify in the caption.

L357: Please add appropriate reference to this statement.

L361: Please make formatting of “JNO<sub>2</sub>” consistent throughout text and use subscript, i.e., “J<sub>NO2</sub>”

L362: Please change to “Hence, we used photolysis of 2-nitrobenzaldehyde to explore the irradiance of the 275 nm LEDs to simulate photochemical conditions in the stratosphere (references).”

L366: “These LEDs effectively... with a  $k_{\text{observed}}$  of...” The discussion of Fig. 7 is insufficient. Please expand the explanation of remove the figure from the text. Fig. 7a is not discussed at all. Furthermore, it is unclear to me how the stated  $k_{\text{observed}}$  can be derived from Fig. 7b. The text discusses photolysis of 2-nitrobenzaldehyde, and Fig. 7b shows the temporal evolution of the parent ion C<sub>7</sub>H<sub>6</sub>NO<sub>3</sub><sup>+</sup>, but these should be connected/explained better in the text.

Figure 7:

- Please add panel labels (a) and (b).
- Caption: I do not see “shaded bands” that mark LEDs to be turned on.
- Caption: Specify, as “The gas phase signal of ... decreases while new aerosol particles are formed, indicating...”

L379: Here and elsewhere, consider using “temperature change per second” rather than “temperature ramp per second”

L377: “to compare the heating rate of both the LEDs and UV-A fluorescence lighting...”. It is unclear to me if both types of light sources were measured at the ATMOX chamber, or if the fluorescence lighting was used together with a pillow bag setup, as done above (e.g., your Table 3 and Fig. 4). Please clarify in the text.

L380: “... unless all 2760 LEDs were turned on (Table 4).” Where do I see this value in your Table 4? , This corresponds to the “stratospheric conditions”, correct?

Sect. 3.4.1: The discussion of the temperature increase inside the ATMOX chamber, seems to be based on the measurement of a single T-sensor connected to the side of the PFA bag (L378). What about temperature mixing/homogeneity inside the chamber volume? Is this single point measurement representative? Please add discussion thereof.

Table 4:

- Units are missing for  $\Delta T$ .
- Caption: change “total temperature change” to “absolute temperature change”

L387: change to: “ for kinetic experiments (e.g., Wang ...).”

L388: “The greater the amount of surface available...” Is this not an effect of surface-to-volume ratio of laboratory chambers? Please specify your discussion.

L389: delete “and diffuse through the chamber walls” or provide further explanation.

L389: “This size...” on L389 should probably be changed to: “Small chamber volume, and associated larger surface-to-volume ratios, could limit smaller chambers, as some ...”

Sect. 3.4.2. This section is focused around one value, the wall loss of NO<sub>2</sub>. However is unclear to me if the wall loss of gas species and aerosol particles directly comparable? About half of this section describes pillow bag experiments that are part of other publications of the group. I encourage the authors to provide some more details and discussion of the wall loss characterization of the ATMOX chamber, or move this section to the SI along with Fig. S13a.

Sect. 3.4.3 only extends over 4 rows. I encourage the authors to merge the content of Sect. 3.4.3 into Sect. 2.1.3, stating that the chamber can be effectively cleaned either by a purge flow or by washing. This would further help to focus the “Results” section of this paper more on the lighting system of the chamber and characterization thereof, which is the central aspect of the work presented.

L400: Units of MilliQ water resistance are wrong.

L407: Write units as “ $\mu\text{W cm}^{-2}$ ”

L407: “all LEDs”. Does this model really take into account ALL LEDs, including the grow lights? Looking at your Fig. 3 and Fig. 8a, it appears to me that for the model presented here only captures LEDs mounted along the side walls of ATMOX, i.e., LEDs with  $\lambda \leq 385$  nm. Please clarify. If the grow LEDs were to be included, I would expect the irradiation distribution shown in Fig. 8b to not be perfectly center-symmetric. Note that this also affects the legend and description of Fig. 9.

L414: Which “four corners”? If I count the corner of your cubic chamber, there should be 8.



L413: Looking at your Fig. 8c, what x,y,z position in the chamber (your Fig. 8a) does this correspond to?

Fig. 9: I am not clear what the purpose of the red, dashed line is? It is not discussed in the text, which is focussed on a comparison of the measured vs. modelled irradiance of the ATMOX chamber.

Sect. 3.5.2: Based on the section title, I would have expected some sensitivity studies on how different numbers and placements of LEDs affect the irradiance in the ATMOX chamber, or an example that applies this model to having more/less LEDs, LEDs of different wavelengths, or chamber of different type (volume). Having this model will certainly be very beneficial for the community. However, I feel that the discussion thereof in its current form remains somewhat superficial. Thus, I would encourage to merge the relevant aspects of this very short Sect. 3.5.2 with Sect. 3.5.1, or alternatively provide some more in-depth discussion of your model.

L424: Rephrase to: "... offer great potential for improved simulation of photochemical processes relevant for Earth's atmosphere."

Section 4: This conclusion and outlook section remains rather vague. Upon revising their manuscript, I would encourage the authors to rework this section a bit. E.g., you could include the potential use of your irradiation model presented in Sect. 3.5 and expand on your plans to use it to simulate different tropospheric environments ("locations") in your chamber, or further plans to add LEDs of other wavelengths, if applicable. In addition, the authors could maybe provide some thoughts on how the LEDs can be used to study wavelength-dependent photochemical reactions, something that I regard as very powerful and a unique feature of your setup.

Kristensen, K., Jensen, L. N., Quéléver, L. L. J., Christiansen, S., Rosati, B., Elm, J., Teiwes, R., Pedersen, H. B., Glasius, M., Ehn, M., and Bilde, M.: The Aarhus Chamber Campaign on Highly Oxygenated Organic Molecules and Aerosols (ACCHA): particle formation, organic acids, and dimer esters from  $\alpha$ -pinene ozonolysis at different temperatures, *Atmospheric Chemistry and Physics*, 20, 12549–12567, <https://doi.org/10.5194/acp-20-12549-2020>, 2020.

Zong, T., Wu, Z., Wang, J., Bi, K., Fang, W., Yang, Y., Yu, X., Bao, Z., Meng, X., Zhang, Y., Guo, S., Chen, Y., Liu, C., Zhang, Y., Li, S.-M., and Hu, M.: A new smog chamber system for atmospheric multiphase chemistry study: design and characterization, *Atmospheric Measurement Techniques*, 16, 3679–3692, <https://doi.org/10.5194/amt-16-3679-2023>, 2023.