Response to Reviewer 2 comments
Manuscript Number: EGUsphere-2024-1144
Manuscript title: Spatial and temporal variation in long-term temperature and water vapor in the mesopause Region, by Chaman Gul et al.,

30th July 2024

Dear anonymous reviewer,

Thanks for the comments, suggestions, and recommendations for the EGUspher-2024-1144 manuscript. Comments are constructive and we quite improved the manuscript after addressing all the comments. We have thoroughly considered and carefully addressed all issues mentioned in the comments and have properly outlined every single change made in response to reviewer comments as suggested. We have made the required corrections in the revised manuscript (visible in tracked change mode) and prepared a list of point-by-point responses as given below starting from page #2 of this document. We have attached two copies of the revised manuscript, one with track change mode having all edits/corrections and the other is a fair copy of the manuscript where we have accepted all the mentioned edits/corrections. The reviewer's comments are in **black** text, the author's responses are in **blue** text, the modified/corrected text from the revised manuscript is in bold **brown** text, and references are in green text. Modified line numbers are in **yellow highlighted** text.

Response to reviewer 2 (R2) comments (Cs):

(R2-C1) This paper has interesting topic, which is well in scope of ACP. However, there are various flaws in the paper. English of the paper needs substantial improvement; some suggestions are below. I recommend major revision.

Response to (R2-C1):

Thank you very much for your precious time and constructive comments. We have modified /revised the manuscript (including the language) based on the reviewers' comments. We have made the required corrections in the revised manuscript (visible in tracked change mode) and prepared a list of point-by-point responses as given below.

Comments:

(R2-C2) The results of this paper generally confirm previous findings with longer datasets analyzed here. Authors should clearly describe in Conclusions, what is new in their results compared to the current state-of-the-art.

Response to (R2-C2): Numerous studies have examined the SABER data set previously to investigate temperature or WV. This article investigates long-term changes in temperature and WV (both) and their long-term comparison within a unique selection of time and space domains. We think the selected narrow latitude bins from each selected geographical location, excluding transitional months, and inclusion of high latitude regions (beyond ~53ºN or ~53ºS) from both hemispheres make this article different from other previous works. The majority of the past studies focused on one variable (temperature or water vapor) for a limited time or over a specific location. This is the first study to compare temperature and water vapor variability for 22 years of the SABER instrument. We processed hundreds of monthly data sets for all three selected latitude bins (for temperature and WV). Multiple studies (e.g; Forbes et al., 2021; Liu et al., 2017; Mlynczak et al., 2022; Das et al., 2021) are limited to latitude band ~50°S to ~50°N, mainly due to TIMED ~60 days yaw cycle. In the present study, we have included high-latitude regions from both hemispheres along with some missing data. Our results generally showed similar seasonality and trends (as presented in the past), but different in magnitude. We have described these similarities and dissimilarities in multiple places of the revised manuscript including the conclusion sections (lines 795-802 of the revised manuscript) and the same is given below

"The selected narrow latitude bins (2º each) at the three extreme geographical positions (NH, SH, equator), excluding transitional months, use of monthly SABER data set, and use of constant altitude range (80-100 km) throughout the study period made our results slightly different in magnitude as compared to the past reported results. Very few researchers (e.g: Hervig et al., 2015) focused on both temperature and water vapor. Therefore, our temperature and water vapor results, obtained from 22-year SABER

observations, are expected to be a robust measure of the mesopause temperature and water vapor variability."

(R2-C3) You are working with monthly data. However, trends based on SABER monthly data are not correct, trends should be based on data averaged over yaw cycle of SABER/TIMED.

Response to (R2-C3): In the revised text trends for three selected latitude bins (~0° ± 1º, ~80° ± 1ºN, and ~80° ± 1ºS) are based on the data averaged over the yaw cycle of SABER/TIMED (Figure 1) along with some limitation discussed in section 6 of the revised manuscript. We agree that using monthly data for high-latitude regions is a source of uncertainty in results and the best "global" representation of SABER data is 52°S – 52°N, as has been done by previous authors. We have included sections explaining the yaw cycle, and availability of data at high latitudes, particularly related to this paper dataset. Additionally, we have included a section on associated uncertainty and limitations in this manuscript and provide relevant uncertainties in that section.

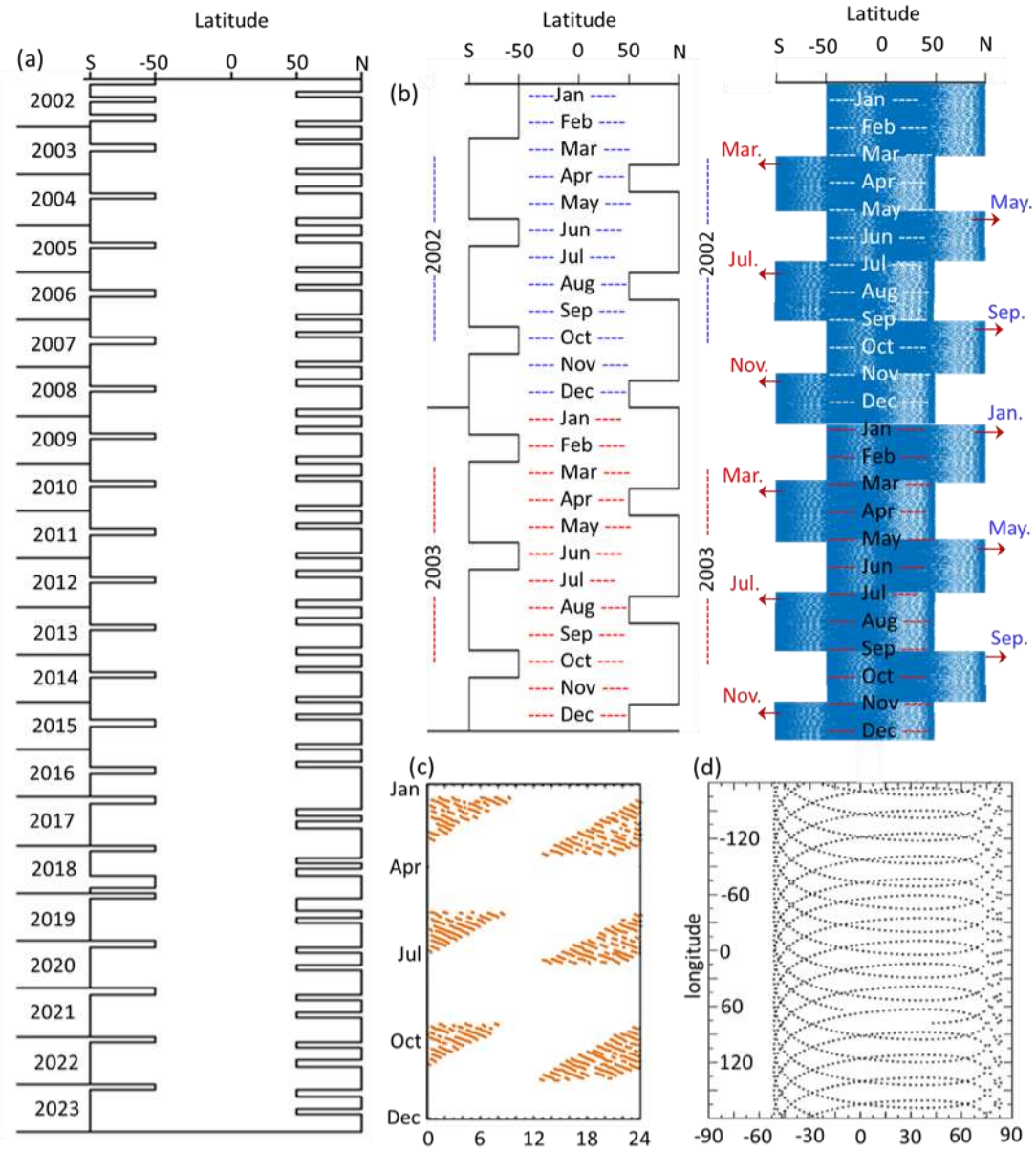
Section 2.2 of the revised manuscript (pages 26 and onward, of the revised manuscript) describes the yaw cycle of the SABER instrument as given below.

"2.2. TIMED-SABER instrument

The TIMED-SABER satellite views 90° to the right of the velocity vector of the TIMED spacecraft, and completes a full 24-hour local time coverage in 60-63 days (Russell III et al., 1999; Mlynczak et al., 2003; Figure 1). The SABER instrument scans the atmosphere from the troposphere up to the lower thermosphere and obtains vertical profiles kinetic temperature and volume mixing ratio of WV (Russell et al., 1999). The instrument performs near-global measurements and provides an excellent quality of the measured infrared limb radiances (Esplin et al., 2023). Technical description of the SABER instrument and further relevant information are discussed by Mlynczak, (1997) and Russell III et al. (1999). TIMED satellite rotates 180° about its yaw axis and provides latitude coverage continuously in the range of 53°S to 83°N and then switching to 83°S to 53°N every ~60 days (Russell III et al., 1999). Due to the asymmetrical latitudinal coverage of the SABER instrument, there are some missing measurement months at high latitudes (52°N-83°N or 52°S-83°S). Multiple studies (e.g; Forbes et al., 2021; Liu et al., 2017; Das, 2021) are limited to the latitude band ~50°S to ~50°N, mainly due to the TIMED ~60 days yaw cycle. In the present study, we have included high-latitude regions from both hemispheres along with some missing data. For example, coverage of high northern latitudes included July in the early years, but not

during the recent several years (2017-2023)……" Please have a look at this section in the revised manuscript for full details.

Revised Figure 1: (page # 7 of the revised manuscript)



Revised Figure 1. SABER instrument latitude coverage versus time for observation. a) Monthly data coverage in selected months versus latitude ranges from January 2002 to December 2023, excluding transitional months. b) Comparison of SABER latitude coverage and monthly data versus time during years (2002-2003). c) Typical temporal coverage of TIMED-SABER instrument measurements. d) Latitude versus longitude tangent point locations for one day of observations in its north viewing phase (83°N to 52°S) – a north viewing yaw mode.

Uncertainties related to high latitude regions: (line numbers 713 and onward)

"Section 6. Associated uncertainties and limitations

The possible sources of uncertainties during the analysis of long-term temperature and WV are mentioned below.

1. **Large uncertainty is related to the analysis of temperature and WV over SH and NH (above ~53⁰ latitudes) and has a relatively larger bias in results as compared to the results over the equator. The yaw cycle is ~60 days, and only one polar region (SH or NH) is observed in each yaw cycle, and the selected polar regions are only alternatively observed half of a year owing to the yawing of the TIMED satellite. In other words, the latitudinal coverage is governed by a 60-day yaw cycle that allows observations of latitudes from 83⁰S to 52⁰N in the south-viewing phase or from 53⁰S to 82⁰N in the North-viewing phase (further details are given in the text). Multiple studies (e.g; Forbes et al., 2021; Liu et al., 2017; Mlynczak et al., 2022; Das, 2021) are limited to the latitude band ~50°S to ~50°N. In the present study, we have included high-latitude regions from both hemispheres along with some missing months. Missing months are usually April, August, or December in the NH and February, June, or October in the SH. As a result, the choice of these months for high latitudes introduces a systematic bias in the time series.**
2. **Temperature and WV trends over NH and SH are calculated for six months because April and December data were insufficient for long-term trends over NH. Similarly, June and October data was limited for SH trend estimation. Therefore, trends over the equator are more accurate than those of NH and SH trends.**

   “

So, we present our results along with the above-mentioned uncertainties in the revised text.

(R2-C4) Page 6: Shorter-term decreases and increases of temperature reflect primarily the 11-year solar cycle.

Response to (R2-C4): Agree we have included the recommended sentence as suggested (lines 239-241 of the revised manuscript) and the same is given below

“A second decrease in temperature by ~4 K was observed from 2014 to 2018. A decrease of ~0.37 K and ~0.14 K was observed during 2002-2018, and 2002-2023 respectively. The cyclic temperature variations reflect primarily the 11-year solar cycle.”

(R2-C5) Lines 166-167: The greater solar flux in December/January due to orbital eccentricity contributes to difference in temperature for sure.

Response to (R2-C5): We have modified the sentences as suggested (lines 281-282 of the revised manuscript) and the same is given below

"The greater solar flux in December/January than in June/July is due to the Earth's orbital eccentricity, as discussed by Chu et al. (2003)."

(R2-C6) Lines 195-197: Variations of temperature with height are similar in June and December but evidently different in April (Fig. 2c). Correct your sentence.

Response to (R2-C6): We have removed these lines from the revised text, and restated these sentences according to the revised Figure 2.

The vertical profiles of annual mean temperature and WV gradient (vertical profiles with respect to changing altitude) are plotted as a function of year in Figure 2. Plots in Figure 2 are for three latitude bins NH, SH, and equator during three months (January, June, and September). We obtained mean temperature and mean WV content for these months by averaging all January, June, and September values from 2002 to 2023. We did a similar 22-year average for other months (March, April, July, and October) but not shown in Figure 2. There is an inverse relation between temperature and WV. An anticorrelation between WV with the solar cycle was also shown by Yue et al. (2019); Dalin et al. (2023) and Hervig and Siskind, (2006). The precise relationship between WV saturation mixing ratios and cold point temperature depends upon the temperature as well as exact pressure (altitude), with Seidel et al. (2001) giving a value of ~0.6 ppmv/K, Fueglistaler and Haynes, (2005) ~0.5 ppmv/K, and Nedoluha et al. (1998) ~0.7 ppmv/K. In the present study, the maximum and minimum WV change between 81-100 km altitude was ~4.3 and ~1.6 ppmv respectively.

(R2-C7) Table 1: Table 1 is amazing collection of trend information. Differences in temperature trends may be partly from different changes of ozone in different periods. Water vapor – different periods may include or not water vapor drops in 2001-2002 and 2014, which affects trends.

Response to (R2-C7): Agree we updated the sentence as suggested (Line number 357-360 of the revised manuscript) and the same is given below

"References shown in Table 1 are focused on temperature and wv variation at different latitudes and altitude ranges of the mesopause region. Differences in temperature trends may be partly from different changes of ozone in different periods. Different periods

may include or not WV drops in 2001-2002 and 2014 (solar maxima's), which affects WV trends given in Table 1."

(R2-C8) Lines 298-300: I do not understand these two sentences. What would you like to say?

Response to (R2-C8): Sorry for writing a confused sentence. We have replaced the sentence with a new sentence, in a new position (lines 387-390 of the revised manuscript) and the same is given below

"Generally, temperature decreases with increasing altitude however, this temperature gradient is small during June and July as compared to other selected months. Temperature decreased from 80 to 100 km altitude by 10 to 20 K during January, June, and September (Figure 2a). "

(R2-C9) Lines 83-84: WV controls the concentration of O_3 – add at least one reference.

Response to (R2-C9): Agree, we included a reference as suggested (lines 81-82 of the revised manuscript) and the same is given below

"WV content in the atmosphere controls the concentration of ozone that, in turn, affects mesospheric cooling (Smith, 2004)."

Reference

Smith, A. K.: Physics and chemistry of the mesopause region, J. Atmos. solar-terrestrial Phys., 66, 839–857, https://doi.org/https://doi.org/10.1016/j.jastp.2004.01.032, 2004.

(R2-C10) Line 330 and 331: ""June showed" should be "June and July showed"; "seven months" should be "six months (Figure 5)".

Response to (R2-C10): Agree, sentence modified as suggested (lines 437-438 of the revised manuscript) and the same is given below

"June and July temperature gradients are different than the vertical temperature gradients of other selected six months (Figure 2b)."

(R2-C11) Lines 335-338: Where these statements are documented/illustrated in the paper?

Response to (R2-C11): We couldn't show vertical profiles of all selected months in previous Figure 2. Therefore we analyzed for indicated months (lines 335-338) but not shown in

Figure 2. In the revised Figure 2 we have increased the number of months (January, June, and September). But again information related to March is given in the text but not shown in Figure 2, so we slightly changed the sentence (lines 443-444 of the revised manuscript)as given below

"There is a clear temperature decrease between 84 km (~202 K) to 96 km (~172 K) during September (Figure 2). The mean temperature at 80 km during March was ~210 K and decreased to ~185 K at an altitude of 100 km (March is not shown in Figure 2)."

Revised Figure 2 is given below:

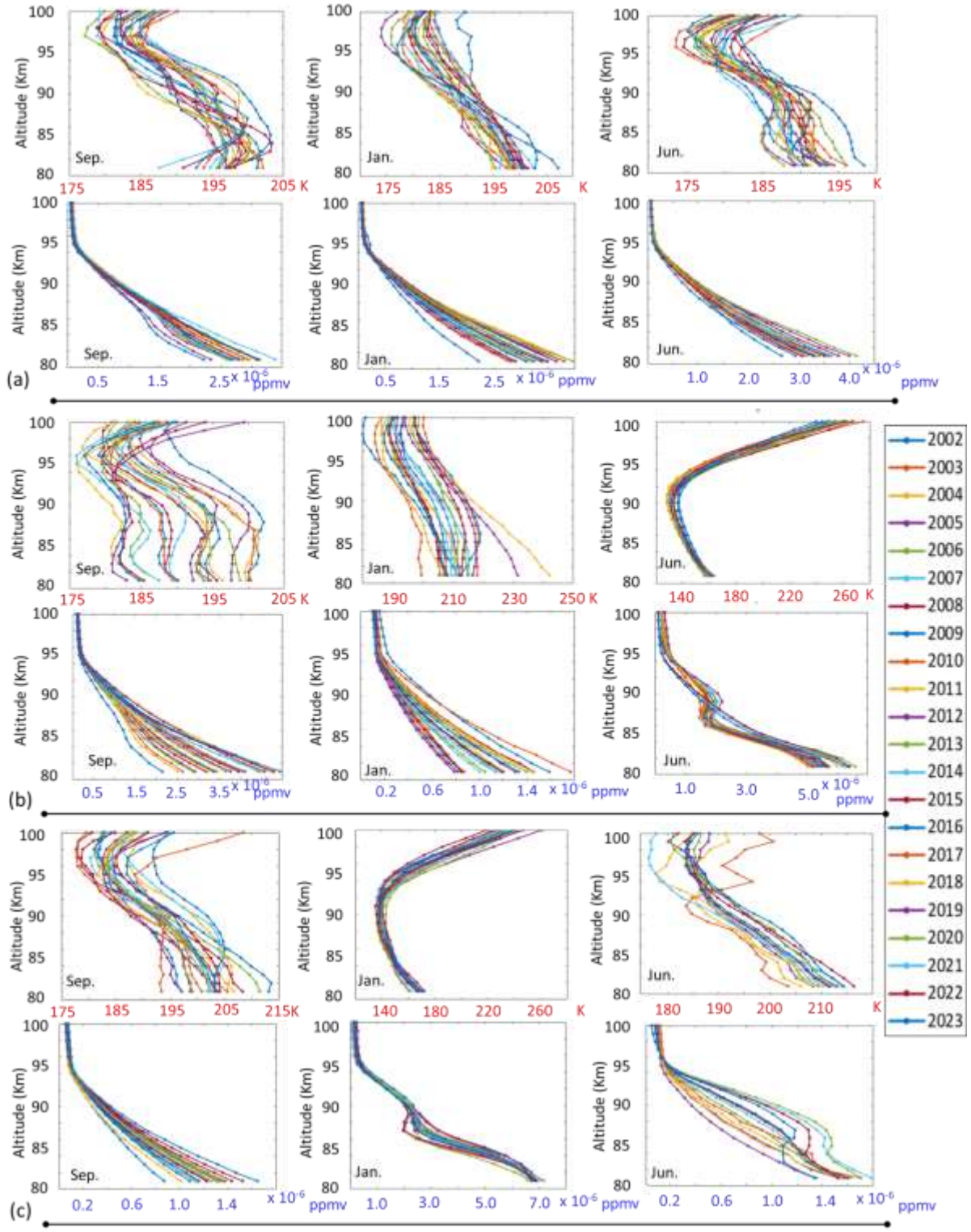


Figure 2. Temperature and water vapor gradient between 80-100 km altitudes from SABER observations at the three selected latitude bins during 200-2023. a) Equator (0° ± 1º). b) Northern hemisphere (80°N ± 1º). (c) Southern hemisphere (80°S ± 1º), in the indicated months, by averaging all January, June, and September values from 2002 to 2023.

(R2-C12) Lines 352-353: This statement requires a citation.

Response to (R2-C12): We include a reference as suggested (lines 463-464 of the revised manuscript) and the same is given below

"December and January; this is because, at middle and high latitudes, the general transport of H2O is directed upward in summer and downward in winter (Sonnemann et al., 2005)."

Reference:

Sonnemann, G. R., M. Grygalashvyly, and U. Berger (2005), Autocatalytic water vapor production as a source of large mixing ratios within the middle to upper mesosphere, J. Geophys. Res., 110, D15303, doi:10.1029/2004JD005593.

(R2-C13) Lines 421-423: Differences 156, 210 and 183 k are nonsense and do not correspond to Fig. 8.

Response to (R2-C13): Agree, we have removed the text from the revised manuscript (lines 557-559 of the revised manuscript), and the removed sentence is visible in the track change version of the manuscript only.

(R2-C14) List of references:

Response to (R2-C14): We have rechecked and updated all references using Mendeley software and made all references according to the requirements of ACP.

- **(R2-C15)** Important reference Guo (2024) is missing.

Response to (R2-C15): Thanks for mentioning an interesting review paper "A review of atmospheric water vapor lidar calibration methods by "Guo et al., 2024". We cited this paper in the introduction part of the revised manuscript (lines 99-100 of the revised manuscript) and the same is given below

"The latest progress and applications of atmospheric WV lidar calibration have been recently reviewed by Guo et al. (2024)."

Reference

The latest progress and applications of atmospheric WV lidar calibration have been recently reviewed by Guo et al. (2024).

- **(R2-C16)** Wherever possible add either doi index or https address.

Response to (R2-C16): We have included the doi index or https address as suggested. A few examples are mentioned below

Proceedings of the NATO Advanced Study Institute held at Spåtind, Norway, April 12–22, 1977, 93–127, 1977. 10.1007/978-94-010-1262-1_10

Berger, U. and Lübken, F.: Mesospheric temperature trends at mid-latitudes in summer, Geophys. Res. Lett., 38, 2011. https://doi.org/10.1029/2011GL049528

Berger, U. and Von Zahn, U.: Icy particles in the summer mesopause region: Three-dimensional modeling of their environment and two-dimensional modeling of their transport, J. Geophys. Res. Sp. Phys., 107, SIA-10, 2002. https://doi.org/10.1029/2001JA000316

Bevilacqua, R. M., Olivero, J. J., Schwartz, P. R., Gibbins, C. J., Bologna, J. M., and Thacker, D. J.: An observational study of water vapor in the mid-latitude mesosphere using ground-based microwave techniques, J. Geophys. Res. Ocean., 88, 8523–8534, 1983. https://doi.org/10.1029/JC088iC13p08523

Bittner, M., Offermann, D., and Graef, H. H.: Mesopause temperature variability above a midlatitude station in Europe, J. Geophys. Res. Atmos., 105, 2045–2058, 2000. https://doi.org/10.1029/1999JD900307

Brasseur, G. and Solomon, S.: Aeronomy of the Middle Atmosphere, 452 pp., D, 1986. https://doi.org/10.1029/EO067i009p00114-03

Brasseur, G. P. and Solomon, S.: Aeronomy of the middle atmosphere: Chemistry and physics of the stratosphere and mesosphere, Springer Science & Business Media, 2005. 10.1007/1-4020-3824-0

Chabrillat, S., Kockarts, G., Fonteyn, D., and Brasseur, G.: Impact of molecular diffusion on the CO2 distribution and the temperature in the mesosphere, Geophys. Res. Lett., 29, 11–19, 2002. https://doi.org/10.1029/2002GL015309

Chandra, S., Jackman, C. H., Fleming, E. L., and Russell III, J. M.: The seasonal and long term changes in mesospheric water vapor, Geophys. Res. Lett., 24, 639–642, 1997. https://doi.org/10.1029/97GL00546

Wording or misprints:

- **(R2-C17)** Line 72: Start with "Water vapor (WV)"

Response to (R2-C17): Agree, sentences modified as suggested (lines 70 of the revised manuscript) and the same is given below

"Water vapor (WV) is one of the strongest greenhouse gases and plays a crucial radiative balance role in the atmosphere. WV in the upper atmosphere can affect global surface climate (Solomon et al., 2010)."

- **(R2-C18)** Line 84: "water-mixing" should be "water vapor-mixing"

Response to (R2-C18): Sentence removed on the recommendation of the reviewer 3 (R3-C2).

- **(R2-C19)** Line 91: reference should be “Chandra et al. (1997)”

Response to (R2-C19): The mentioned sentence is deleted from the revised text because the sentence was not fit in the flow of information.

- **(R2-C20)** Line 135: “(Figure 2)” should be “Figure 2”

Response to (R2-C20): Sentence removed from the revised manuscript.

- **(R2-C21)** Lines 174-176: :warming, and the causes adiabatic cooling” should be “warming and adiabatic cooling, respectively”

Response to (R2-C21): We have modified the sentences as suggested (lines 279-280 of the revised manuscript) and the same is given below

“Downwelling in the winter hemisphere and upwelling in the summer hemisphere cause adiabatic warming, and adiabatic cooling, respectively”

- **(R2-C22)** Line 236: “(Hervig et al., 2003) should be “Hervig et al. (2003)

Response to (R2-C22): Agree, citation corrected as suggested (lines 337-338 of the revised manuscript) and the same is given below

“There are few studies including Hervig et al. (2003) which showed WV enhancement above 86 km altitudes.”

- **(R2-C23)** Line 246: “bysolar” should be “by solar”

Response to (R2-C23): Agree, the word changed as suggested (lines 343-344 of the revised manuscript) and the same is given below

“At mesospheric heights, WV is strongly photo-dissociated by solar Lyman alpha (Brasseur and Solomon, 1986).”

- **(R2-C24)** Line 248: “The solar” should be “the solar”

Response to (R2-C24): Sentence removed from the revised text.

- **(R2-C25)** Lines 264 and 267: “Figure 3” should be “(Figure 3)”; similarly Figure 4 on line 313, Figure 5c on line 360.

Response to (R2-C25): Section removed from the revised text. We rechecked the whole manuscript for similar mistakes and corrent it accordingly.

- **(R2-C26)** Line 265: "(Dalin et al., 2023)" should be "Dalin et al. (2023)"; similarly citations at line 278.

Response to (R2-C26): Section removed from the revised text. We rechecked the whole manuscript for similar mistakes and corrent it accordingly.

- **(R2-C27)** Line 323: "temperatures at" should be "temperatures (Figure 5) at"

Response to (R2-C27): Agree, sentence modified as suggested (lines 426-427 of the revised manuscript) and the same is given below

"Similarly, monthly mean temperatures (Figure 5) at solstices (Jun/July and Dec/Jan) were ~162.64 K and ~201.14 K respectively,"

- **(R2-C28)** Lines 325-326:"those Xu et al., 2007), showed" should be "those of Xu et al. (2007) showed"

Response to (R2-C28): We have modified the sentences as suggested (line 431 of the revised manuscript) and the same is given below

"Our results are similar to those of Xu et al. (2007) showed a warmer mesopause at high latitudes during the December solstice than it is in the June solstice."

- **(R2-C29)** Line 334: "altitude" should be "with altitude"

Response to (R2-C29): Agree, we have included "with" in the sentences as suggested (line 442 of the revised manuscript) and the same is given below

"Average temperature during January was ~208 ± 5 K almost constant with increasing altitude and showed very little decrease in temperature (~8 K/20 km) with altitude in temperature."

- **(R2-C30)** Line 350: "temperature" should be "WV"

Response to (R2-C30): Sorry for this mistake, we have corrected the sentences as suggested (lines 460-461 of the revised manuscript) and the same is given below

"Monthly mean WV at solstices (Jun/July and Dec/Jan) was ~1.90 ppmv and ~0.49 ppmv respectively, indicating relatively high WV content during June and July and low during December and January"

- **(R2-C31)** Line 352: “January this” should be “January; this”

Response to (R2-C31): Sorry for this common mistake. Corrected as suggested (line 463 of the revised manuscript) and the same is given below

“indicating relatively high WV content during June and July and low during December and January; this is because, at middle and high latitudes, the general transport of H2O is directed upward in summer and downward in winter”

- **(R2-C32)** Line 358: “WV 5a (yearly averaged)” should be “WV (Figure 5a, yearly averaged).

Response to (R2-C32): We revised the text and removed the mentioned sentence, from the revised manuscript, visible in the track changed version.

- **(R2-C33)** Line 366: delete “of the”

Response to (R2-C33): We have deleted “of the” from the sentences as suggested (lines 480 of the revised manuscript) and the same is given below

“There is a cooling trend in temperature (~0.58 K/decade) in the SH mesopause region.”

- **(R2-C34)** Line 368: “months and (December and January) were” should be “months, and December and January were”

Response to (R2-C34): Agree, we modified the sentences as suggested (lines 480-481 of the revised manuscript) and the same is given below

“On average April (~197.64 K) followed by June and July were the hottest months, and December and January were the coldest months throughout the 22-year study period.”

- **(R2-C35)** Line 375: delete “was”

Response to (R2-C35): Agree, we have deleted “was” as suggested.

- **(R2-C36)** Line 386: “ppmv respectively” should be “ppmv, respectively”

Response to (R2-C36): We have modified the sentences as suggested (line 505 of the revised manuscript) and the same is given below

"The monthly mean WV at two equinoxes (Mar/Apr and Sep/Oct) was ~0.82 and ~0.54 ppmv lower than the monthly mean WV at solstices (Jun/July and Dec/Jan) which were ~0.67 ppmv and ~2.3 ppmv, respectively"

- **(R2-C37)** Line 388: "had relatively" should be "which however had relatively"

Response to (R2-C37): We have modified the sentences as suggested (lines 505-507 of the revised manuscript) and the same is given below

"This indicates relatively high WV content during summer (December and January). In the SH temperature is colder at mid-to-high latitudes during January (Wang et al., 2022), which however had relatively high WV content."

- **(R2-C38)** Line 399: "soloists" should be "solstices"

Response to (R2-C38): Agree, we have corrected the spelling as suggested (line 504 of the revised manuscript) and the same is given below

"The monthly mean WV at two equinoxes (Mar/Apr and Sep/Oct) was ~0.82 and ~0.54 ppmv lower than the monthly mean WV at solstices (Jun/July and Dec/Jan)"

- **(R2-C39)** Line 405: "however it look" should be "however the difference look"

Response to (R2-C39): We have modified the sentences as suggested (Line 540 of the revised manuscript) and the same is given below

"The difference between NH and SH temperature and WV at the solstice position is higher than the difference at the equinoxes, indicating that the magnitude of temperature and WV content near poles are relatively close at equinox positions however the difference looks to increase in the future (Figure 7)."

- **(R2-C40)** Line 414: "Intra-annual" should be "inter-annual"

Response to (R2-C40): We have revised the caption along with recommended changes as suggested (lines 550-551 of the revised manuscript) and the same is given below

"Figure 8. Inter-annual variations in monthly mean temperature and water vapor from SABER observations over selected bins of latitudes during 2002-2023."

- **(R2-C41)** Lines 429, 432-433: "(Wang et al., 2022)" should be "Wang et al. (2022); the same with Xu et al.

Response to (R2-C41): We have modified the references as suggested (lines 651-653 of the revised manuscript) and the same is given below

"Wang et al. (2022) and Xu et al. (2007) found that the mesopause during the June solstice is ~6–9 K colder than that during the December solstice. Huaman and Balsley, 1999 showed a predominant warmer SH"

We made similar changes throughout the manuscript, as suggested.

- **(R2-C42)** Line 435: "month North" should be "month for the North"

Response to (R2-C42): Agree, we have modified the sentences as suggested (lines 561-562 of the revised manuscript) and the same is given below

"The winter solstice (January) was the higher temperature month for the NH and the lower temperature month for the SH (Figure 8)."

- **(R2-C43)** Line 477: "(Dalin et al., 2020) should be "Dalin et al. (2020)"

Response to (R2-C43): We have updated the text as suggested (line 622 of the revised manuscript) and the same is given below

"At the same time, Dalin et al. (2020) showed relatively stronger cooling at the summer mesopause (−2.4 K/decade)."

- **(R2-C44)** Line 488: "in (Xu et al., 2007)" should be "by Xu et al. (2007)"

Response to (R2-C44): We have updated citations as suggested (lines 638-639 of the revised manuscript) and the same is given below

A clear hemispheric asymmetry in temperature (Figure 7) was observed, possibly related to solar and gravity waves further discussed in Xu et al. (2007).

- **(R2-C45)** Line 497: "; Xu" should be "and Xu". Similar at line 509

Response to (R2-C45): We have modified the text as suggested (lines 651-652 of the revised manuscript) and the same is given below

"Wang et al. (2022) and Xu et al. (2007) found that the mesopause during the June solstice is ~6–9 K colder than that during the December solstice."

We applied similar changes in other places of the manuscript shown in the track change version of the manuscript.

- **(R2-C46)** Line 510: delete "almost"

Response to (R2-C46):

We deleted the whole sentence from the revised text because the sentence was presenting repeating information that was already stated.

- **(R2-C47)** Line 574: delete “year”

Response to (R2-C47): Agree, we have deleted “year” in the revised text as suggested (lines 786-789 of the revised manuscript) and the same is given below

“Based on the monthly mean WV content for the selected eight months of analysis shows that 2018 had a relatively higher amount of WV content (~1.14 ppmv) followed by 2008 (~1.14 ppmv), and 2002 had the least amount of WV (~0.89 ppmv) followed by 2014 and 2003 (~1.0 ppmv).”

Deletion is visible in the track change version of the manuscript.

Thanks to anonymous reviewer 2 for his/her constructive comments and suggestions.

---------- End of the response to reviewer 2 ----------