

## **Response to Referee**

**Thank you for identifying this issue during the review. We are very sorry for the time and effort you wasted.**

**I made a big mistake in my understanding of the tropopause as defined by the World Meteorological Organization, which made my algorithm wrong and on which a large part of the whole article is based. So, we decided to adjust the whole article by removing the part of modification to the definition of WMO and adding the long term trend analysis of the tropopause.**

**We would like to express our sincere gratitude to the referee for your exceptionally informative, constructive, and detailed comments, and we would like to answer your comments. We would appreciate it if you could give us your valuable comments for the revised manuscript.**

### **Omission of Relevant Prior Research**

1. One related and important general point I would like to make at this stage is that I noticed some glaring omissions of relevant prior work. In particular, given the focus on identification of the tropopause and its characteristics using high-resolution radiosonde data, decades of prior work with such a focus was unexplainably absent. This is especially true for the well-recognized series of early foundational studies by Birner:

Birner et al., 2002: How sharp is the tropopause at midlatitudes?, Geophys. Res.

Lett., 29, doi:10.1029/2002GL015142

Birner, 2006: Fine-scale structure of the extratropical tropopause, J. Geophys. Res., 111, D04104, doi:10.1029/2005JD006301

**Response:** We add Birner (2006) to our new manuscript.

2. These studies and many that follow have demonstrated well that the WMO definition, when applied appropriately, results in reliable definition of the tropopause that is insensitive to profile resolution. There are certainly failure modes

of the WMO definition, but resolution is not one of them (except for resolution that is very coarse, which can of course be ameliorated by interpolation).

Response: Yes, the WMO definition reliably defines the tropopause, the error was due to my mistake, and we have removed the improved section on the WMO definition in the new manuscript.

3. Another topic that I found to be poorly described and referenced relates to the statement at line 45 of the paper. In particular, the abrupt change in tropopause height near the subtropical jet streams is commonly referred to as the tropopause break. There is vast literature on the subject as well as its relation to Hadley Cell (or lack thereof, as several studies have shown that the tropopause break is not coupled to the HC). A search using the term "tropopause break" should turn up these relevant works. Additional studies that explore numerous tropical edge diagnostics to determine changes in the width of the tropics (a la Davis & Rosenlof, 2012, <http://dx.doi.org/10.1175/JCL1-D-11-00127.1> and others that follow) will help resolve the HC link argument.

Response: Thanks for the comment. We have added a new reference for a short description.

Line 45: "...The large-scale downwelling in the subtropical Hadley circulation sharply lowers the tropopause, sometimes creating a discontinuity known as the "subtropical tropopause break", which aligns with the STJ (Turhal et al, 2024)."

### **Specific comments**

1. The references for the radiosonde data sources appear to be inappropriate. In particular, the University of Wyoming page does not provide access to the full-resolution radiosonde data used in this study, but instead only includes mandatory and significant levels (as in the IGRA archive). The NOAA website referenced appears to only include surface observations and in real-time rather than a historical archive. I believe the most appropriate source of high-resolution radiosonde

observations in the United States is <https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.ncdc:C01500>. There are alternative copies of the data in BUFR format from other sites, which the authors may have used. Because the data I can easily grab from U. Wyoming are on mandatory and significant levels and I do not have time to otherwise download the full-resolution BUFR data, I cannot reproduce Figure 1 from the paper to demonstrate my main point above. Nevertheless, the authors should resolve this data citation issue so that the study could be easily replicated by any reader.

Response: We have elaborated this point in the revised manuscript. URL links are available in the Data availability section of the manuscript.

Line 115: "...Following Guo et al. (2021) and Zhang et al. (2022), we utilized a high-vertical-resolution radiosonde (HVRRS) dataset spanning 2000 to 2023 (24 years), compiled from multiple sources including the China Meteorological Administration (CMA), the National Oceanic and Atmospheric Administration (NOAA) of the United States, the German Deutscher Wetterdienst (Climate Data Center), the Centre for Environmental Data Analysis (CEDA) of the United Kingdom, the Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN), and the University of Wyoming."

2. Lines 74-75: I am not sure what this sentence means or implies.

Response: Original quote: "...We found that simulations with near-neutral convective lapse rate, which corresponds to cold climates in the moist GCM, have a poorly defined tropopause when applying the WMO definition. To circumvent this issue, we use a different definition of the tropopause height based on the meridional circulation structure."

And we have removed this paragraph in the new manuscript.

Levine, X. J., and Schneider, T.: Baroclinic Eddies and the Extent of the Hadley Circulation: An Idealized GCM Study, *J. Atmos. Sci.*, 72, 2744–2761, <https://doi.org/10.1175/JAS-D-14-0152.1>, 2015.

**3.** Line 85: “retrieve” should be “retrieval”

Response: Amended as suggested.