
Response to Reviewer #3

We greatly appreciate Reviewer #3's recognition of the novelty and usefulness of our folding dataset for China and surrounding regions. We also sincerely thank the reviewer for the constructive suggestions. Our point-to-point response to the comments is provided below.

Specific comments:

Q3.1: *In the introduction, the authors emphasised the importance of STT, particularly regarding tropospheric ozone. They could expand this to include ozone precursors (such as Br and I) and stratospheric aerosols, based on recent studies. For example, Schill et al. (2025) reported that STT can inject them into the Arctic free troposphere, impacting tropospheric ozone chemistry. Additionally, I noticed that a widely cited review paper, although somewhat dated, on STE by Stohl et al. (2003) was not mentioned.*

A3.1: We sincerely thank the reviewer for this helpful suggestion. We have expanded the Introduction section to highlight the important role of STT in transporting ozone-depleting precursors and stratospheric aerosols into the troposphere. We have also added the relevant references such as Schill et al. (2025) and Stohl et al. (2003) in appropriate places according to the reviewer's suggestion. The revised sentences are as follows:

“Beyond ozone transport, recent studies also indicate that STT in the Arctic injects ozone-depleting precursors (such as bromine and iodine) and stratospheric aerosols into the free troposphere, influencing local tropospheric chemistry (Schill et al., 2025).”

“STT is the general process of air mass transport from the stratosphere to the troposphere, playing a critical role in introducing ozone-rich stratospheric air into the troposphere (Hong et al., 2024; Stohl et al., 2003; Langford et al., 2015).”

Please see **L25-27** and **L29-31** in the revised manuscript for these modifications.

Technical corrections:

Q3.2: *Line 5: “decade-long coverage”: this statement is incorrect, as 2014-2023 only covers ~10 years.*

A3.2: We have modified the statement to “10-year long coverage (2014–2023)” for clarify. Thanks a lot for the correction.

Q3.3: *Line 27: Change “Akritidis et al., 2016; Lin et al., 2015; Akritidis et al., 2010” to Akritidis et al., 2016, 2010; Lin et al., 2015”*

A3.3: We have merged references with the same author according to the suggestion. Thanks.

Q3.4: *Line 63: Tibetan Plateau (TP) - TP should be defined early when it appear in the first time, eg in line 13, rather than here. Line 90: isofurface should be isosurface.*

A3.4: We thank the reviewer for the careful reading and suggestions. We now give the definitions of abbreviations such as “Tibetan Plateau (TP)” at their first appearance (e.g., L13 in the revised manuscript). However, for clarity, we also repeat the definition if an abbreviation reappears much later in the manuscript, in case the readers have forgotten its meaning. Other than that, we have removed all the redundant definitions of the abbreviations. We have also corrected the word “isofurface” according to the suggestion. Thanks.

Q3.5: *Line 100: Physical variables like *sfold*, *mfold*, and *dfold* should be better expressed in italic to distinguish them from normal words.*

A3.5: We have expressed the physical variables *sfold*, *mfold*, and *dfold* in italics throughout the manuscript. Thanks for the suggestion.

Q3.6: *Lines 109-111: I cannot see how “These cases demonstrate that our dataset can*

successfully capture the complete evolution of tropopause folds during stratospheric intrusion events.” Maybe you should add: “As shown below in Section XYZ, we demonstrated” If this is the case.

A3.6: We thank the reviewer for the helpful suggestion. We have modified the expression as:

“Additionally, we adopted three prior case studies on tropopause folds to further verify the accuracy of our dataset in identifying short-term folding events. As demonstrated in following sections 3.2.1 – 3.2.3, our dataset can successfully capture the complete evolution of tropopause folds during stratospheric intrusion events.”

Q3.7: *Line 117: When you see “a folding belt over China”, you need to specify their locations, e.g. between latitude A and B, for readers who are not familiar with the local topography.*

A3.7: We have specified the range (20°N–35° N, 70°E–135°E) of the folding belt over China in the revised manuscript. Please see **L137**. Thanks for the suggestion.

Q3.8: *Lines 125-126: “The difference is the highest (~209%) in spring and the lowest (~114%) in summer. “ Are they relative differences? And how did you calculate them?*

A3.8: The reported values represent relative differences. To clarify it, we have explained it in the revised manuscript and added the formula as follows:

“The relative difference in folding frequency f between our dataset and that of Lin et al. (2024) is calculated as $(f_{\text{our dataset}} - f_{\text{Lin}}) / f_{\text{Lin}}$”

It should be noted that during the revision, we revisited the definition of total folding frequency. We noted that previous studies (e.g., Lin et al., 2024; Škerlak et al., 2015) typically exclude very shallow folding events ($\Delta p < 50$ hpa). In contrast, our *fold* variable encompasses all events, including these weak cases. To ensure a fair comparison, we re-calculated the frequencies by summing only shallow, medium, and deep folds,

consistent with the literature. The revised manuscript now includes updated results and figures (Fig. 2, Fig. 4, and Fig. 5) reflecting this adjustment. Now, the relative difference in folding frequency f between our dataset and that of Lin et al. (2024) is $\sim 87\%$ in spring and $\sim 59\%$ in summer. Furthermore, the updated results show that our dataset consistently reports lower frequencies than the ETH dataset. This discrepancy is likely attributable to the different time periods and the different resolutions of the meteorological data used in these studies. The ETH dataset was derived from the 1° ERA-Interim reanalysis data with 60 model levels. The higher vertical resolution of the reanalysis data underlying the ETH dataset likely explains its higher folding frequencies compared to our results derived from data with 37 pressure levels. However, our dataset features higher temporal (1 hr) and horizontal (0.25°) resolutions. In contrast, the dataset of Lin et al. (2024) uses the 1° ERA5 reanalysis data with 37 pressure levels. As a result, although the vertical resolution is the same, the folding frequency reported by Lin et al. (2024) is lower than ours, likely due to the coarser horizontal resolution of their reanalysis data. Please see [L190-198](#) for the discussions.

Q3.9: *Line 148: remove “(TP)”*

A3.9: We have removed all the unnecessary definitions.

Q3.10: *Line 174: again, either use PT or Tibet Plateau.*

A3.10: We thank the reviewer for the helpful suggestion. As mentioned in our previous response **A3.4**, we give the definitions of abbreviations at their first appearances. However, in Section 3.2, because the first appearance of TP occurs much earlier, we briefly restate its meaning at the beginning of the section to help readers follow. All other redundant definitions have been removed. Thanks again for this suggestion.

Q3.11: *Line 154: Dfold should be dfold, as it is not a word.*

A3.11: Corrected. Thanks.

Q3.12: *Line 165: for $y = x$ line, it is better to use 1:1 line.*

A3.12: We replaced the “y = x line” by “1:1 line”. Thanks.

Q3.13: *Line 194: Dfold should be dfold in itaiic.*

A3.13: We modified Dfold to *dfold* in italics throughout the manuscript.

Q3.14: *Line 231: Tibetan Plateau (TP) and the Sichuan Basin (SCB), see my comments above.*

A3.14: All the unnecessary abbreviation definitions are removed. Thanks for the suggestion.

Reference

- [1] Hong, J., Wang, H., Wang, W., Zhu, J., Deng, H., and Wang, H.: Impacts of stratosphere-to-troposphere transport on tropospheric ozone in southeastern China: insights from ozonesonde observations, *Environ. Res. Lett.*, 19, 064068, <https://doi.org/10.1088/1748-9326/ad4ef9>, 2024.
- [2] Langford, A. O., Senff, C. J., Alvarez, R. J., Brioude, J., Cooper, O. R., Holloway, J. S., Lin, M. Y., Marchbanks, R. D., Pierce, R. B., Sandberg, S. P., Weickmann, A. M., and Williams, E. J.: An overview of the 2013 Las Vegas Ozone Study (LVOS): Impact of stratospheric intrusions and long-range transport on surface air quality, *Atmospheric Environment*, 109, 305–322, <https://doi.org/10.1016/j.atmosenv.2014.08.040>, 2015.
- [3] Schill, G. P., Froyd, K. D., Murphy, D. M., Williamson, C. J., Brock, C. A., Sherwen, T., Evans, M. J., Ray, E. A., Apel, E. C., Hornbrook, R. S., Hills, A. J., Peischl, J., Ryerson, T. B., Thompson, C. R., Bourgeois, I., Blake, D. R., DiGangi, J. P., and Diskin, G. S.: Widespread trace bromine and iodine in remote tropospheric non-sea-salt aerosols, *Atmos. Chem. Phys.*, 25, 45–71, <https://doi.org/10.5194/acp-25-45-2025>, 2025.
- [4] Stohl, A., Bonasoni, P., Cristofanelli, P., Collins, W., Feichter, J., Frank, A., Forster, C., Gerasopoulos, E., Gäggeler, H., James, P., Kentarchos, T., Kromp-Kolb, H., Krüger, B., Land, C., Meloen, J., Papayannis, A., Priller, A., Seibert, P., Sprenger, M., Roelofs, G. J., Scheel, H. E., Schnabel, C., Siegmund, P., Tobler, L., Trickl, T., Wernli, H., Wirth, V., Zanis, P., and Zerefos, C.: Stratosphere-troposphere exchange: A review, and what we have learned from STACCATO, *Journal of Geophysical Research: Atmospheres*, 108, 2002JD002490, <https://doi.org/10.1029/2002JD002490>, 2003.