Response to Reviewer #2

We sincerely thank Reviewer #2 for the positive and constructive comments, which remarkably improved our manuscript. Our point-to-point response is provided below.

Q2.1: *L15–16. As shown by the author's analysis, shallower intrusions account for a larger proportion. So, besides near-surface atmospheric composition and extreme weather events, I think this tropopause folding dataset might be more important for climate research on stratosphere-to-troposphere exchange (STE).”*

A2.1: We thank the reviewer for this insightful comment. We fully agree that the tropopause folding dataset we developed is valuable not only for investigating impacts on near-surface air constituents and extreme weather events, but also for climate research on stratosphere-to-troposphere transport (STT). Thus, we have revised the abstract and relevant sections to include more implications of this study as follows:

“This dataset provides a solid foundation for in-depth investigations into the mechanisms and climatological characteristics of STT, as well as the subsequent impacts of tropopause folds on near- surface atmospheric composition and extreme weather events, thereby serving as a valuable resource for the atmospheric science community.”

“Moreover, it establishes a foundation for investigating STT processes and the subsequent impacts on near-surface ozone concentrations and regional extreme weather events. Additionally, this dataset serves as a critical resource for climate research on STT.”

Please also see **L15-16** and **L82-83** in the revised manuscript.

Q2.2: *L18–24. STE in the vicinity of the tropopause fold occurs in regions of turbulence and diabatic processes. Specifically, stratospheric air near the tropopause fold, characterized by high ozone, low water vapor, and high potential vorticity (PV), descends into the troposphere; meanwhile, tropospheric air with abundant water vapor, carbon monoxide, aerosols, and low PV is also transported into the stratosphere.*

A2.2: We thank the reviewer for this detailed and insightful comment. We fully acknowledge that STE is a bidirectional process, encompassing both stratosphere-to-troposphere transport (STT) and troposphere-to-stratosphere transport (TST). In this study, however, we focus on the tropopause fold, which represents a key mechanism of STT. Consequently, TST is outside the scope of the current dataset. To clearly convey the focus of our work, we have emphasized STT in the manuscript without extensive discussion of TST. Please see **L24-27** in the revised manuscript. We hope this explanation clarifies the scope of our study.

Q2.3: *L29. What do you mean by 'downward advection'? Convection?"*

A2.3: We thank the reviewer for pointing it out. We agree that the term may cause some confusion. In this study, "downward advection" refers to the large-scale downward transport of air from the stratosphere into the troposphere, which is different from convection. To clarify it, we modified the term to "downward transport" in the revised manuscript as follows:

"... can strongly affect local weather conditions through a downward ~~advection~~ transport of air with high potential vorticity (Akritidis et al., 2021)."

Q2.4: *L69-70. The phrase 'the folding data provided by this dataset ... alongside 37 vertical pressure levels' sounds strange. How can tropopause folding be divided into 37 levels? This is not clear in this study, please rephrase it.*

A2.4: We thank the reviewer for pointing it out. We fully agree that this sentence causes some confusion. In this study, the identification of tropopause folding events is based on ERA5 meteorological data with 37 vertical pressure levels, but the folding data have only a single level, rather than 37 layers. We revised this sentence as follows:

"Regarding the resolutions, the folding data provided by this dataset possess an hourly temporal resolution and a horizontal resolution of 0.25°×0.25° (~28 km) ~~alongside 37 vertical pressure levels, ranging from 1000 hPa to 1 hPa~~."

Q2.5: *L91-93. Please describe in detail how you assign the five labels.*

A2.5: We thank the reviewer for this comment. We now provide a more detailed description in Section 2.2 of the manuscript about how these five labels are assigned. The revised part is as follows:

"Next, the method assigns various types of the air with five labels (see Fig. 1): 1 = troposphere, 2 = stratosphere, 3 = stratospheric cutoff or diabatically produced cyclonic PV anomaly, 4 = tropospheric cutoff, and 5 = surface-bound cyclonic PV anomaly. Label 1 denotes typical tropospheric air, characterized by low PV values (<2 PVU). Label 2 represents stratospheric air, defined by high PV (>2 PVU), low specific humidity (< 0.1 g/kg), and three-dimensional connectivity with the stratospheric reservoir. Label 3 corresponds to stratospheric cutoffs, which are isolated stratospheric air masses suspended in the troposphere, or high-PV tropospheric anomalies resulting from dissipative processes, characterized by high specific humidity (> 0.1 g/kg). Label 4 indicates tropospheric cutoffs, defined as isolated tropospheric air masses with low PV surrounded by stratospheric air. Label 5 identifies surface-bound PV anomalies, distinguished by high PV values extending down to the surface."

Q2.6: *Sect. 3.2.2. As seen in Figs. 7 and 8, fewer deep intrusions occurred on the rear (west) side of the cut-off low, while more occurred ahead of the low. Typically, there are strong downdrafts on the west side and updrafts on the east side of a cut-off low, so the results seem inconsistent with known dynamics. Could the cyclonic PV near the tropopause fold in the upper troposphere ahead of the cut-off low have been misidentified as stratospheric signals?*

A2.6: We thank the reviewer for raising this question. In our original analysis, the 200 hPa trough was identified solely based on the wind speed, which led to a deviation in position of the trough. To address this issue, we have refined the method by incorporating 200 hPa geopotential height contours to define the trough location (see Fig. 1 in this rebuttal).

The improved results now show that the vast majority of medium and deep folds occur on the western (rear) side of the low, which is consistent with the comment of the reviewer and the related references. Regarding the small portion of deep folds remaining on the eastern side (see Fig. 1d in this rebuttal), we attribute this to the eastward advection of folds after their formation under the influence of strong upper-level westerly winds. These results further confirm that our dataset is capable of accurately capturing the spatial characteristics of regional SI cases.

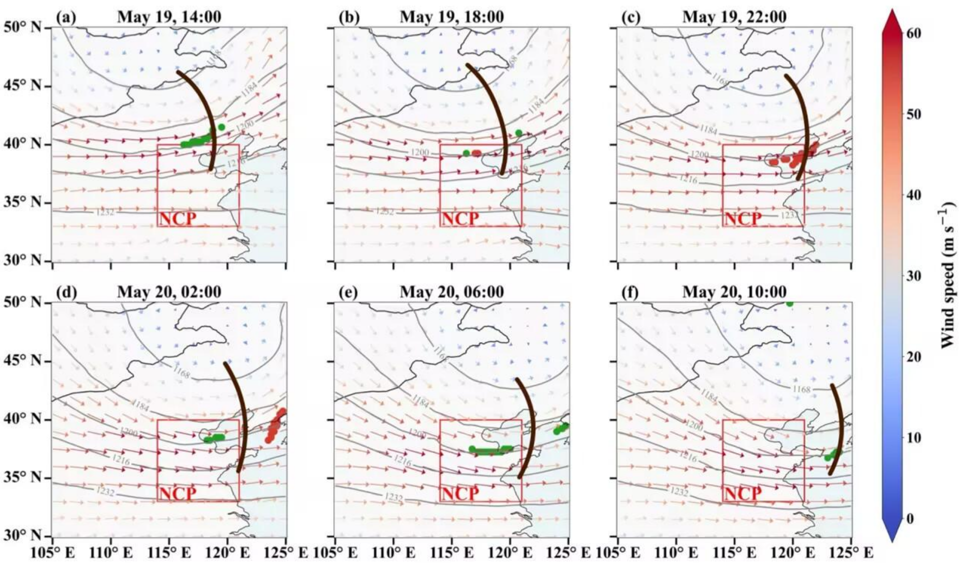

Fig. 1 Spatiotemporal evolution of medium and deep tropopause folds over the NCP on (a–c) May 19 and (d–f) May 20, 2019, shown at 4-hour intervals. Colors indicate fold type (green: medium, red: deep). Wind vectors (arrows) show 200 hPa wind speed and direction, scaled by color and length. Brown lines represent the upper-level trough, and the red box delineates the NCP. Gray solid lines indicate contours of the 200 hPa geopotential height (unit: dagpm).

The improved results and the related discussions have been added to the revised manuscript. Please see **Fig. 8**, **Fig. S2** in the Supplement, **L259** and **L263-265** in the revised manuscript. Thanks a lot for the suggestion.

Q2.7: *Sect. 3.2.3. I think this is not a good case. I would suggest using an event with tropospheric air entering the stratosphere, which would be more interesting and would also avoid overlap with existing studies.*

A2.7: We thank the reviewer for this valuable suggestion. We acknowledge that TST events are indeed an interesting topic in STE research. However, as clarified in our previous response **A2.2**, stratosphere-to-troposphere transport (STT) and troposphere-to-stratosphere transport (TST) are two distinct processes of stratosphere–troposphere exchange (STE). Our database specifically focuses on tropopause folding events, which represent an important mechanism of STT and are only weakly related to TST. Therefore, selecting a TST case to validate our database would not be appropriate. Thus, we keep this case as it is. We appreciate the reviewer’s understanding regarding this choice.