**Response to referee comments**

**Response:** We would like to thank the referees and editor for their interest in our work and the helpful comments and suggestions to improve our manuscript. We have carefully revised the manuscript according to all the reviewers' comments. The changes have been marked in the text using blue color. Page and line numbers in this document refers to the revised version of the main manuscript.

With these revisions, we believe the quality of the manuscript has been greatly improved. We hope the editor and the reviewers can find that all the concerns have been addressed adequately.

Reviewer(s)' Comments to Author:

Reviewer: 2

The manuscript by Yin et al. presented an interesting topic related to the influence of stratospheric ozone input on tropospheric surface ozone variability. Through analyses of monthly surface ozone variability, modeled stratospheric O3 tracer (unjustified), and weather structure of the upper troposphere/lower stratosphere, the authors concluded that stratospheric ozone contributed ~ 65 % of surface ozone across the high mountain Asia. Although in general I agree that stratospheric ozone inputs may be important for surface ozone budget at midlatitudes & high mountain regions, ~ 65% contribution is too overwhelmed, and which is inadequately supported by evidence and assessments presented in the manuscript. I think there are sufficiently more analyses that the authors need to conduct to support the conclusion, and to promote the manuscript to be potentially publishable.

**Response:** Thank you so much for your valuable comments. We have carefully revised the manuscript and include more analyses and evidences to reinforce the conclusion. In revised manuscript, 1) ground observations of surface ozone at the sites over the Tibetan Plateau were used to reveal the difference of surface ozone variation over the Tibetan Plateau from south to north. 2) WRF-Chem and CAM-chem simulations were used to identify the impacts of long-range transport and in-situ photochemical production on surface ozone over the Tibetan Plateau. 3) Tropopause fold frequencies (calculated by ERA-5 data), position of westerly jet (U component of winds) and CAM-chem simulation was used to investigate the impact of stratospheric intrusion. We have updated the dataset and almost re-conducted the all the simulation for both WRF-Chem and CAM-chem and the contribution from stratospheric ozone intrusion was re-calculated.

Major comments:

1. sections 3.2, the rejection of the role of in-situ chemistry on surface ozone variations is a rush. Simply analyzing the seasonal patterns of O3 with NO2 and CO cannot rule out the role of in-situ chemistry, especially the author didn't explain why such correlated or uncorrelated data can reveal their causal relationships. In general, NO2 and VOCs, as well as CO are precursors of O3, but sunlight (photochemistry) is also necessary. In the plateau, soil emissions would be important sources of NOx and VOCs, which in general depends on temperature. How this precursors and local actinic flux varied with O3? And how was transport affects surface O3? All these need to be assessed. Meanwhile, don't forget CO is also an indicator of stratospheric air incursion as which is characterized as low CO and high O3.

**Response:** Thank you for your suggestion. In revised manuscript, we used Weather Research and Forecasting model coupled with Chemistry (WRF-Chem) results to investigate the impacts of local photochemical generation of ozone and long-range transport. WRF-Chem was conducted by the setup adopted in Yang et al. (2022) to investigate the long-range transport from South Asia and local photochemical generation of ozone over the Tibetan Plateau. Experiments with 2 setups were conducted as setup 1 (CO and $NO_2$ in South Asia were set to 0 to investigate the influence of long-range transport from South Asia) and setup 2 (CO and $NO_2$ in the Tibetan Plateau were set to 0 to investigate the influence of local photochemical generation of ozone over the Tibetan Plateau).

For in-situ chemistry, we revised the manuscript in line 145-154 as: "The local photochemical production of ozone is generated through a chain of photochemical oxidation of CO and VOCs (volatile organic compounds). The monthly variation in surface ozone at three different types of sites in the central Tibetan Plateau (Lhasa: urban site; Dangxiong: rural site; Nam Co: remote site) with varying conditions of ozone precursors were similar (Yin et al., 2017), implying the limited impact from local photochemical production of ozone on the monthly variation of surface ozone at these sites. Indicated by results in WRF-Chem simulation setup 2 (Figure 2b), local photochemical generation of ozone over the Tibetan Plateau contributed to the surface ozone in the Tibetan Plateau from 5.24% to 17.44% in each season with annual average in 10.46% (Table 1). Furthermore, the net ozone photochemical production was found to be negative in the summer when surface ozone reached a maximum in the northeastern Tibetan Plateau (Zhu et al., 2004; Ma et al., 2002). Therefore, the monthly mean surface ozone peaks in Tibetan Plateau were not mainly attributed to the local photochemical production of ozone".

2. Section 3.3, it is entirely unclear how the contribution of stratospheric O3 to surface O3 was estimated, by the ratio of stratospheric O3 tracer (O3s) to the **modeled** or the **observed** surface O3? How was the modeled surface O3 vs. the observed surface O3 in the model?

**Response:** O3s is a stratospheric ozone tracer that represents the amount of ozone in the troposphere originated in the stratosphere in CAM-chem simulation. We used the ratio of O3s and O3 at site to indicate the influence from stratospheric ozone on surface ozone.

In revised manuscript, modeled surface O3 and the observed surface O3 as well as meteorological fields were compared as described in line 126-131: "We compared the simulated surface temperature (T2), relative humidity (RH2), wind at 10 meters (wind10), and wind at 500 hPa, with surface observations provided by China Meteorological Data Service Centre (http://data.cma.cn/) and ERA interim reanalysis datasets provided by ECMWF (https://apps.ecmwf.int/datasets/). It was found that simulation configuration captured the meteorological fields well, which is crucial to assure prediction accuracy of air pollutant concentrations (Figure S2-S5). Besides, surface ozone concentrations from ground observations, WRF-Chem, and CAM-chem were compared and showed a good fit (Figure S6)".

3. section 3.4, the CAM model is partially driven meteorological parameters, where the interactions between the troposphere and the stratosphere are determined by jet stream and/or tropopause folding. Thus it is kind of a loop to compare the modeled O3s with such synoptic events as it is that these events transport air out and in the stratosphere (and vice versa) at the boundary of stratosphere and troposphere. This should put before or right after analyses on the effects of in-situ chemistry, but before the model analysis. The formers can be qualitative, but the latter should be quantitatively conducted. In fact, why not used the CAM model to also assess contributions of tropospheric processes to the observed surface O3? In general, most atmospheric chemistry model (online or offline coupled) has a better performance on tropospheric chemistry simulations than stratospheric chemistry simulations. Why don't show the modeled surface O3 concentrations as well as the fractions of tropospheric contributions by simply deducting O3s from total model surface O3.Without such comparisons, both section 3.2 and 3.3 are incomplete and are insufficient to support the conclusion.

**Response:** Thank you for your suggestion. As you suggested, section 3.4 (the qualitative evidences from reanalysis data) were placed to section 3.3 before quantitative WRF-chem simulation part (as in revised section 3.4).

Tropospheric contribution was investigated based on WRF-Chem simulation results in revised manuscript in line 145-154 as: "The local photochemical production of ozone is generated through a chain of photochemical oxidation of CO and VOCs (volatile organic compounds). The monthly variation in surface ozone at three different types of sites in the central Tibetan Plateau (Lhasa: urban site; Dangxiong: rural site; Nam Co: remote site) with varying conditions of ozone precursors were similar (Yin et al., 2017), implying the limited impact from local photochemical production of ozone on the monthly variation of surface ozone at these sites. Indicated by results in WRF-Chem simulation setup 2 (Figure 2b), local photochemical generation of ozone over the Tibetan Plateau contributed to the surface

ozone in the Tibetan Plateau from 5.24% to 17.44% in each season with annual average in 10.46% (Table 1). Furthermore, the net ozone photochemical production was found to be negative in the summer when surface ozone reached a maximum in the northeastern Tibetan Plateau (Zhu et al., 2004; Ma et al., 2002). Therefore, the monthly mean surface ozone peaks in Tibetan Plateau were not mainly attributed to the local photochemical production of ozone".

In addition, I suggest the authors to move SI materials to the main text, overall, the length of the main text is short and lacks of sufficient details in results and discussions, and putting related materials in SI makes further difficulties in understanding the arguments/assessments the authors stated.

**Response:** Thank you for your suggestion. Manuscript was revised and we add WRF-Chem and CAM-chem simulations to identify the impacts of long-range transport and in-situ photochemical production on surface ozone over the Tibetan Plateau to deliver more results and discussions.