Responses to Referee 1's comments

This study employs ozone measurements from urban sites across 17 cities, a background site (Waliguan), four satellite products, and integrate two models (GEOS-Chem CTM and trajectory models) to analyze ozone variations over the TP region. The authors find a notable increase in ozone levels at urban stations, surpassing trends observed at Waliguan and those derived from satellite data. Analysis of model results and emission inventories suggests that this ozone rise is driven by increased local anthropogenic emissions and enhanced contributions from non-local sources. The study offers valuable new insights into understanding ozone changes in the region. The manuscript is well-written and structured. I recommend addressing the following points before publication:

Reply: We thank a lot the Referee #1 for the comments. We have studied the comments carefully and tried to incorporate as many suggested changes as possible, which have greatly helped us in improving the manuscript. Our responses to the comments and suggestions are as follows. The original comments are in green while our replies are in black.

1. Line 171: Please clarify the rationale behind selecting a 192-hour time frame for analysis.

Reply: As suggested, we have added the explanation in Lines 183-189 and cited it here:

"The choice of the 192 h run time was obtained by considering both the previous work and the transport source region. In previous work, backward simulation run time were set from a few days to a few weeks (Cooper et al., 2010; Xu et al., 2018; Yin et al., 2017), varying depending on the study area. Here we add 24 h of simulation time to the 168 h (7 days) setting of Xu et al. (2018) for the Waliguan station on the TP, considering the possible variability of the urban stations on the TP, and finally determine a simulation duration of 192 h. Sensitivity experiments show that 192 h run time has resulted in a stabilization of the footprint layer residence time – the effect of increasing or decreasing the run time by 24 hours on the calculated QNR is about ±3%."

2. Figure 2: Are all 30 sites consistently showing an increasing trend? If not, please elaborate on any variations.

Reply: As suggested, we have elaborated on the sites that did not show an upward trend in Lines 243-247 and further discussed the possible reasons in Lines 394-397, and cited it here:

Lines 243-247: "Note that six of the thirty sites showed a non-significant downward trend ($p>0.05$). Lhasa in the southern part of the TP had a total of six sites, three of which had negative linear trends (-0.04 to -0.09 ppb yr^{-1}, $p=0.15$), which contributed to the non-significant increase in its urban mean ozone trend (0.46 ppb yr^{-1}, $p=0.15$). Both of the two sites in Changdu on the central TP had negative linear trends (-0.10 to -0.50 ppb yr^{-1}, $p=0.16$ to 0.71). Hainan in the northern TP also had a negative linear trend (-0.41 ppb yr^{-1}, $p=0.15$)."

Lines 394-397: "We further analyzed the average QNR for the three cities with decreasing trends. As shown in Fig. S7, the trend of non-local contributions is slightly smaller than the average of the other cities on the TP, while the local contributions show a decreasing trend (-0.02 ppb yr^{-1}). This decline combined with meteorological effects may have offset the non-local QNR trend, which resulted in the ozone not showing a significant increase in these regions."

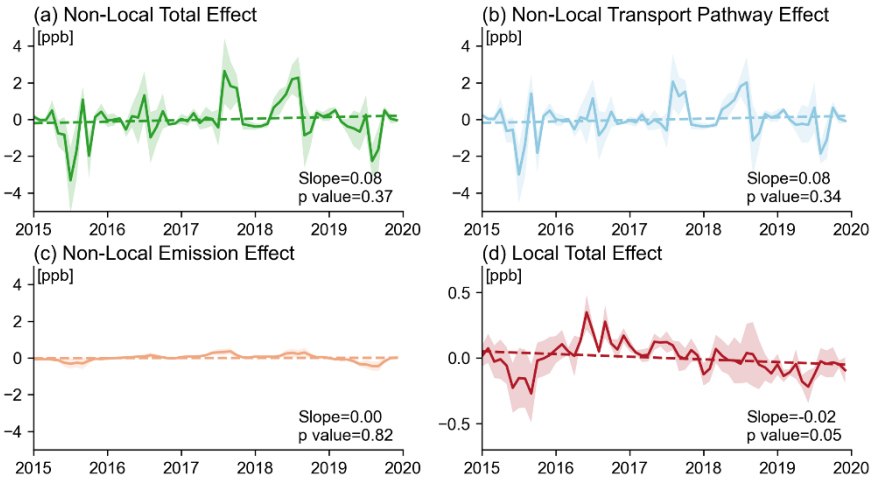

Figure S7 Deseasonalized monthly variation of QNR over 3 cities (Changdu, Hainan and Lhasa). (a) Non-local QNR changes due to the combined effect of changes in anthropogenic emissions and in transport pathway. (b) Non-local QNR changes due to changes in transport pathway alone. (c) Non-local QNR changes due to changes in anthropogenic emissions alone. (d) Local QNR changes due to the combined effect of changes in anthropogenic emissions and in transport pathway.

3. Section 4.2: While generally reasonable, the discussions could be more informative. Why does the residence time show an increasing trend, and is it linked to changes in meteorological patterns? Could you present and discuss the non-local emission trends over TP, along with foreign source regions derived from the PHLET-OMI inventory? Additionally, since the PHLET-OMI only quantifies NO_x emissions, and VOC emissions can differ significantly, do we have robust estimates of VOC emissions over TP and the surrounding source regions?

Reply: Thanks for the suggestion. We have added the discussion of non-local QNR in Lines 342-355 and the description of VOC changes in Lines 379-382, and cited it here:

Lines 342-355: "The non-local QNR is mainly driven by changes in South Asia (India, Bangladesh, etc.) and the central and western provinces of China (Sichuan, Gansu, etc.). Although the non-local emissions in Qinghai and Tibet are increasing (Fig. S5c), the absolute amount of emissions in these two regions are too low to dominate the non-local QNR. Emissions in Southeast Asia have not changed significantly in recent years, and the short residence time of the air mass makes it not a major contributor to the non-local QNR changes. The upward trend of QNR is related to the peaks in 2017 and 2018, but the drivers of these two peaks are not completely the same. As shown in Fig. S5, the 2017 QNR peak was more due to QNR growth in South Asia, such as India and Bangladesh. Although the total South Asian emissions peaked in 2018, in northern South Asia, closer to the TP, emissions peaked in 2017 (not shown), which could be a possible reason besides the change in transport pathway for the high QNR values seen in 2017 (Fig. S5c). The peak in the summer of 2018, instead, was caused more by the increase in QNR in Sichuan and other central regions of China. Emissions in China's central and western provinces have been declining in recent years (Fig. S5c). As mentioned above, the subtropical high pressure anomaly in the summer of 2018 caused the source of air mass transport to expand eastward and pass more through the high-emission regions in central China, and this change in the transport path of the air mass is what dominated the emergence of the peak of QNR in 2018."

Lines 379-382: “Besides the rapid increase in NO_x emissions, an observational study suggests that the increase in VOCs concentrations may be even more intense in the urban areas of the TP. In particular, Tang et al. (2022) found that VOCs concentrations in urban areas of the TP increased to 2.5 times from 2012-2014 to 2020-2022, which may lead to greater sensitivity of ozone to NO_x emissions on the TP.”

Unfortunately, there is no reliable VOC emission dataset for the TP and surrounding areas to allow a full exploration of the role of VOC in ozone growth. Although the bottom-up inventories like MEIC contain VOC emissions, they do not account for the local sources (such as burning of cow dung and other biofuels for cooking and/or heating, and burning of incense in religious practices) and their emission factors (such as the evaporation of oil, gas, and solvent in its low-pressure environment) very well, resulting in large uncertainties in the calculated VOC emission magnitudes and spatial distributions (Chen et al., 2022; Tang et al., 2022).

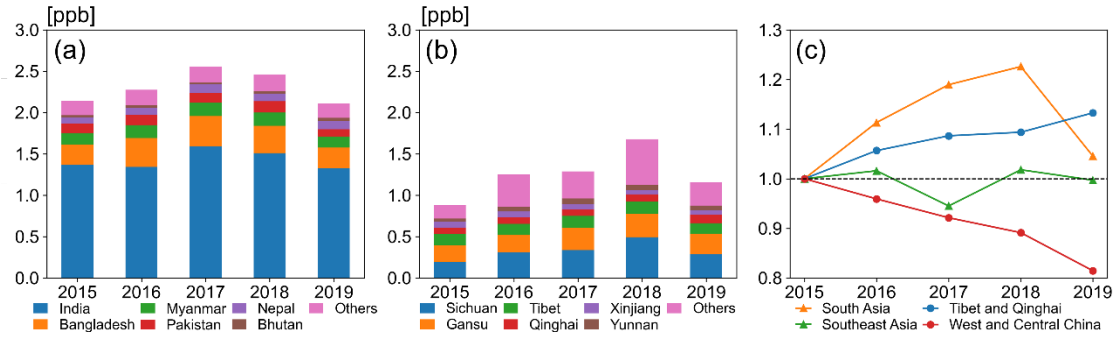

Figure S5 Annual variation of non-local QNR over 17 cities from (a) foreign countries and (b) provinces of China. Each of the five provinces or countries with the largest average QNR contribution in 2015 is marked with a separate color. (c) Normalized time series of three-year moving average PHLET-OMI NO_x anthropogenic emissions in summer for different regions, with summer 2015 emissions as a baseline. Here, the value for 2015 represents the average over 2014–2016, and so on. South Asia includes India, Maldives, Bhutan, Sri Lanka, Pakistan, Bangladesh and Nepal; Southeast Asia includes Philippines, Vietnam, Laos, Cambodia, Myanmar, Thailand, Malaysia, Brunei Darussalam, Singapore, Indonesia, Timor-Leste; and West and Central China includes Inner-Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Ningxia, Xinjiang, Shanxi, Anhui, Jiangxi, Henan, Hubei, Hunan.

4. Line 341: The increase in NO_x emissions is surprising, given that most regions in China have seen significant reductions in NO_x emissions. Could the authors discuss possible reasons for this increase, possibly referencing relevant literature?

Reply: Thanks for the suggestion. We have added the discussion and cited it here:

Lines 370-376: “This growth may be associated with multiple factors. Compared to 2015, possession of private vehicles in Qinghai and Tibet in 2019 has increased by 58% and 79% respectively, the urban population has risen by 16% and 26% respectively, and industrial GDP and electricity consumption have also increased significantly (National Bureau of Statistics of China, https://www.stats.gov.cn/, last accessed on January 11, 2025). In addition, the relatively more lenient emission reduction targets (13th Five-Year Plan, http://www.gov.cn/zhengce/content/2017-01/05/content_5156789.htm, last accessed on January 11, 2025) in the provinces of Qinghai and Tibet may have led to relatively less stringent regulation, ultimately resulting in an upward trend in NO_x emissions.”

5. Lines 359-369: I am uncertain about the robustness of this method and its interpretation. First, it overlooks the non-linear interactions between meteorology, local, and non-local emissions. Second, Lines 364-367 assume that Waliguan and the 17 MEE cities share similar ozone formation mechanisms. Is this assumption reasonable? If the same method is applied individually to each of the 17 cities, would we obtain similar values for a and b for each city pair?

Indeed, the model does not consider the non-linear interactions between meteorology, local and non-local factors, and it also ignores the differences in ozone formation mechanisms between different regions. We initially intended to use this linear model to roughly estimate the relative magnitude of local and non-local contributions, but the above rough assumptions might lead to oversimplification in the quantification of the relative contributions. In particular, the anthropogenic emissions at the background station in Waliguan are clearly smaller than those in the TP urban area, and the sensitivity of ozone production to NO_x may differ a lot between different regions. These factors may lead to large differences in the a and b values between cities. Thus we have decided to delete this discussion in the revised manuscript.

Responses to Referee 2's comments

The manuscript presents a comprehensive analysis of ozone trends over the Tibetan Plateau, particularly highlighting urban areas, and successfully identifies the contributions of local emissions and regional transport to ozone changes, based on ground observation data, different satellite data, CTM model and HYSPLIT model. The authors concluded that the ozone trends at urban areas of TP were caused by a combination of local and non-local factors, especially from the local anthropogenic emissions. The multiple methods adopted in this study were appreciated. However, there were some logistic issues the authors need to address.

Reply: We thank a lot the Referee #2 for the comments. We have studied the comments carefully and tried to incorporate as many suggested changes as possible, which have greatly helped us in improving the manuscript. Our responses to the comments and suggestions are as follows. The original comments are in green while our replies are in black.

In this study, the authors did not use the CTM to quantify the contribution of non-local factors on ozone issues in TP but the HYSPLIT (the QNR method), quoting that there were large uncertainties for the VOCs (line 305-306). However, the QNR method also had uncertainties due to the fact it did not consider the nonlinearity in ozone formation chemistry (line 179). So how the authors justify their choices of one method over another? At least by using the CTM, the comparisons will be consistent. So in quantifying their contributions of ozone trends for cities and Waliguan (line 359-369), the simplified linear model were not acceptable since the three factors (T_{met}, $Q_{non\text{-}local}$, Q_{local}) were not derived at the same ground.

Reply: Thank you for your suggestion. We have considered using CTM as the main tool to analyze ozone changes on the TP, and have also performed high-resolution GEOS-Chem simulations (0.5° × 0.625°, other configurations are the same as that described for the low-resolution GEOS-Chem simulation in the main paper), but the simulation performance in the TP region is not desirable. Specifically, the high-resolution GEOS-Chem fails to show the upward ozone trend, and has difficulty in capturing the urban

signal (Fig. R1). There are several possible reasons for this limitation:

First, our top-down emission data are only for NO_x. Currently there is no reliable VOC emission dataset for the TP and surrounding areas to allow a full exploration of the role of VOC in ozone growth. Although the bottom-up inventories like MEIC contain VOC emissions, they do not account for the local sources (such as burning of cow dung and other biofuels for cooking and/or heating, and burning of incense in religious practices) and their emission factors very well, resulting in large uncertainties in the calculated VOC emission magnitudes and spatial distributions. Previously observation-based analysis has suggested that the VOC emissions in TP may be significantly underestimated. For example, enhanced evaporation of oil, gas, and solvents due to the low-pressure environment of the plateau was not considered in the inventory, resulting in an underestimation by several times for VOC emissions from the transportation sector in TP (Tang et al., 2022). In addition, burning of cow dung and other biofuels for cooking and/or heating, and burning of incense in religious practices are prevalent in TP, and the lack of statistics for these activities contributes to the underestimation of VOC emissions (Cui et al., 2018; Lu et al., 2020). Similar problems exist for CO emissions.

Second, the human activity on the TP is small in spatial scale and dispersed in space, mostly at the township scale except for Xining and Lhasa. The local terrain is also complex (Fig. R2). Thus it is difficult to accurately simulate ozone changes at this scale even with high-resolution CTM simulations.

In lack of reliable high-resolution CTM simulations, we have decided to adopt the backward trajectory model, which has been widely used in the past studies on the TP. The use of trajectory model together with our top-down NO_x emissions, allows an analysis of transport trajectory and associated QNR. Such an approach is limited by lack of full consideration of ozone chemistry. And we have acknowledged this limitation and suggested further studies using reliable CTM simulations, as in Line 427-430 for the revised manuscript:

"Nonetheless, the HYSPLIT model does not provide a complete description of the nonlinear chemistry of ozone. Future work should focus on obtaining reliable information on ozone precursor emissions, utilizing the CTM to delve deeper into the ozone chemistry on the TP, together with statistical and/or artificial intelligence methods, to better quantify the individual and combined effects of various emission and meteorological factors on the TP ozone."

For the part of the linear model, we agree that it is overly simplified and cannot account for the varying situations from one city to another. Thus we have decided to delete this discussion in the revised manuscript.

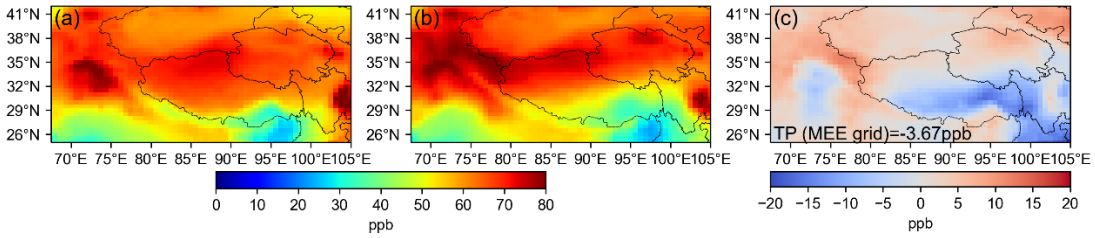

Figure R1. Spatial distribution of the simulated surface maximum daily 8 h average (MDA8) O_3 mixing ratios in July of (a) 2015, (b) 2019, and (c) the change from 2015 to 2019.

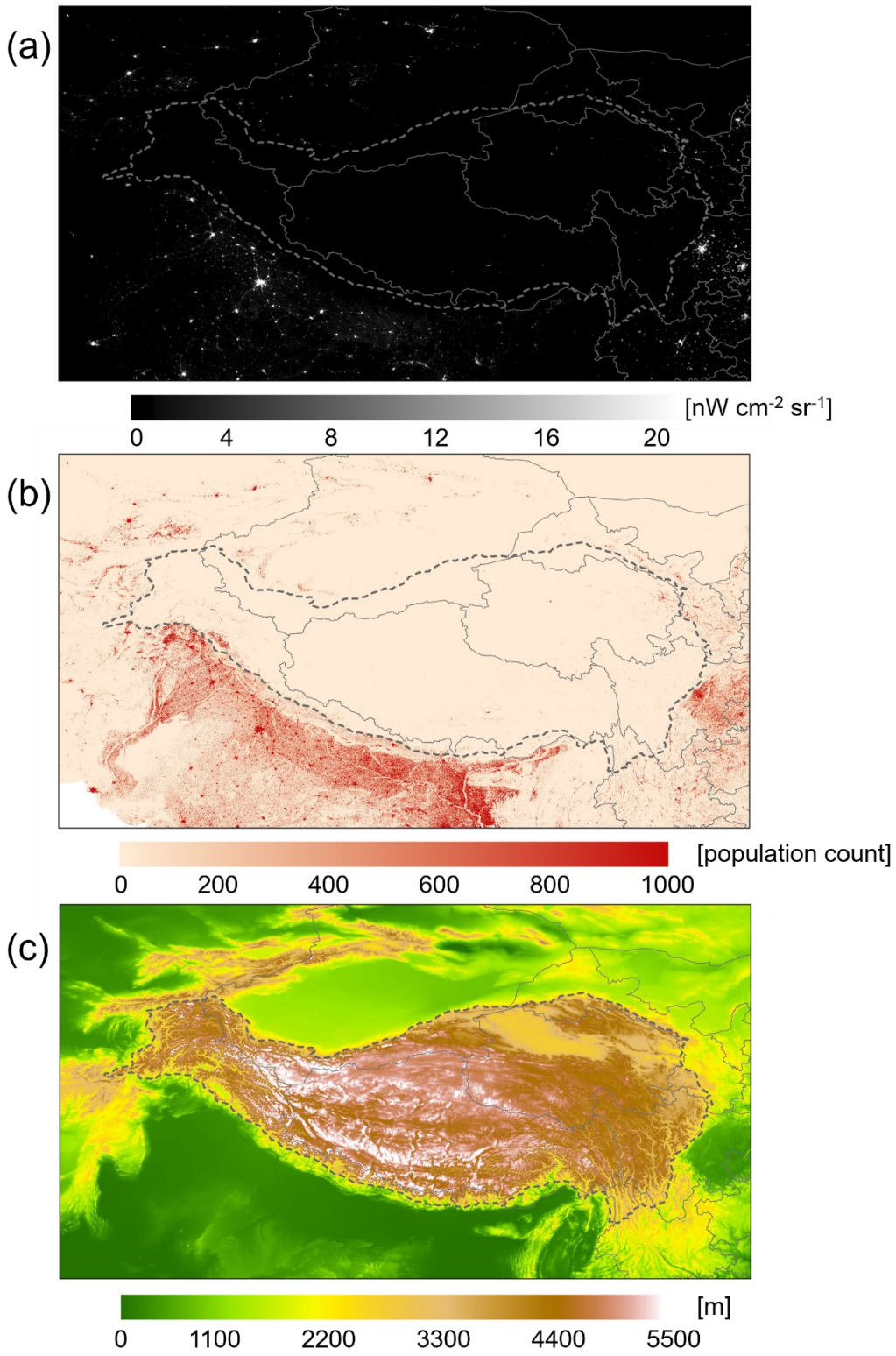

Figure R2. Spatial distribution of (a) VIIRS nighttime lights (Elvidge et al., 2021) in 2019, (b) population counts from LandScan Global (Rose et al., 2020) in 2019 and (c) Ice surface elevation from ETOPO 2022 (NOAA National Centers for Environmental Information. 2022: ETOPO 2022 15 Arc-Second Global Relief Model. NOAA National Centers for Environmental Information. https://doi.org/10.25921/fd45-gt74, last accessed on January 11, 2025). Also shown are administrative (solid line) and TP boundaries (dashed line). The TP boundaries are downloaded from the Integration

dataset of Tibet Plateau boundary (https://data.tpdc.ac.cn/zh-hans/data/61701a2b-31e5-41bf-b0a3-607c2a9bd3b3/, last accessed on June 3, 2024).

1. Explain QNR.

Reply: Apologies for any confusion, we have added the explanation and cited it here:

Lines 180-181: "The QNR of a given grid cell can be regarded as the amount of NO_x that is emitted into the air mass as it passes through the footprint layer of that grid cell."

2. Line 93: put the abbreviation of NO_x where it was first introduced in the main content. The same for O_3 in line 102.

Reply: Thank you for pointing this out. The abbreviation of NO_x and O_3 now have been put in the right place.

3. Line 132: Please double check the OMI website. I think OMI ozone products start from 2004.

Reply: We feel sorry for our mistake. In our revised manuscript, the start time is corrected (Line 133).

4. Line 171: The authors chose 192 hours for their back-trajectory simulations; what was the basis for this time choice? Please provide a clear explanation of why 192 hours is sufficient to capture the majority of air mass transport influencing TP. For example, is this duration chosen based on previous studies, the lifetime of ozone precursors, or the distance from major emission source regions? Or discuss whether shorter or longer durations would significantly change the results of the transport analysis.

Reply: As suggested, we have added the explanation in Lines 183-189 and cited it here:

"The choice of the 192-hour run time was obtained by considering both the previous work and the transport source region. In previous work, backward simulation run time were set from a few days to a few weeks (Cooper et al., 2010; Xu et al., 2018; Yin et al., 2017), varying depending on the study area. Here we add 24 h of simulation time to the 168 h (7 days) setting of Xu et al. (2018) for the Waliguan station on the TP, considering the possible variability of the urban stations on the TP, and finally determine a simulation duration of 192 h. Sensitivity experiments show that 192 hours run time has resulted in a stabilization of the footprint layer residence time – the effect of increasing or decreasing the run time by 24 hours on the calculated QNR is about ±3%.

5. Add a note on the accuracy of model simulations.

Reply: As suggested, we added a note about the accuracy of HYSPLIT model simulations in Lines 169-171 and cited it here:

"The HYSPLIT model has undergone extensive testing by comparing its simulations with actual measurements of atmospheric concentrations and deposition (Chai et al., 2015; Kim et al., 2020; Stein et al., 2015)."

6. Line 182: change to (Chen et al., 2022a)

Reply: We were really sorry for this mistake. The typo is corrected.

7. Please double check the different MERRA2 resolution used for the HYSPLIT and GEOS-Chem model.

Reply: Thanks for your feedback, different resolutions of MERRA2 meteorological data are indeed used

here. Here we used coarse-resolution MERRA2 meteorological data to drive the CTM for a 5-year simulation to study the meteorological impact on ozone on the TP, while in the back-trajectory simulation we chose to use high-resolution MERRA2 data to drive the back-trajectory model in order to obtain relatively finer transport characteristics. Thus, there is a difference in resolution between them.

As explained above, the lack of reliable VOC emissions, among others, prevents us from using the high-resolution CTM to simulate urban ozone over the TP. Instead, we have decided to use the low-resolution CTM to simulate the influence of (large-scale) meteorology.

8. From Fig. 4, the authors stated that none of the satellite products captured the rapid ozone growth observed at the MEE stations. So it looks to me that these multiple satellite products were redundant, and not did not add extra merits to this study. Section 2.2 were really not necessary.

Reply: Thank you for your suggestion, the reason we added a section on the satellite data was to provide an understanding of ozone changes across the whole region of TP. Although the results of the satellite products vary greatly due to differences in detectors and inversion methods, none of the products show a strong upward trend similar to that from the urban measurement sites. This helps confirm the finding from the Waliguan background station that the background ozone of the whole plateau does not experience as strong growth as the urban ozone. Therefore we have decided to retain the satellite results.

9. In discussing QNR, the role of NO_x as ozone precursors has been emphasized. However, it is recognized that NO_x can also reduce ozone concentrations through NO titration under certain conditions, especially in high NO_x environments or at night. Consider adding analysis (satellite data: HCHO and NO_x) or references that illustrate the dependence of O_3 production on NO_x in the study area.

Reply: Thank you for your suggestion, NO_x emissions on the TP have increased significantly in recent years, but the absolute values of emissions are much smaller than those in the cities of east-central China (Kong et al., 2022), and the NO titration effect will be relatively small. In addition, anthropogenic VOC emissions in the urban areas of the TP are large (relative to the amount of NO_x emissions), because of incomplete fuel combustion (Nagpure et al., 2011). A study of ozone sensitivities showed that one of the largest cities on the TP, Lhasa, remained consistently NO_x-limited sensitivity between 2016 and 2019 (Wang et al., 2021). Li et al. (2021) used satellite HCHO and NO_2 ratios to determine ozone formation regimes in China, and they found that the TP in 2019 was largely in the NO_x-limited regime. This makes NO_x emission increases significantly elevate ozone levels, and this sensitivity is likely to increase further with the rapid growth of VOC emissions in the TP urban areas (Tang et al., 2022). We have added the explanation of the dependence of O_3 production on NO_x and cited it here:

Lines 376-382: "The TP is a remote region, and the ozone sensitivities of its urban areas are very different from those of cities in eastern China. Satellite formaldehyde (HCHO) and NO_2 ratio data shows that TP is largely in the NO_x-limited regime in 2019 (Li et al., 2021). Lhasa, the capital city of the Tibet Autonomous Region, has remained NO_x-limited sensitivity between 2016 and 2019 (Wang et al., 2021). Besides the rapid increase in NO_x emissions, an observational study suggests that the increase in VOCs concentrations may be even more intense in the urban areas of the TP. In particular, Tang et al. (2022) found that VOCs concentrations in urban areas of the TP increased up to 2.5 times from 2012-2014 to 2020-2022, which may lead to greater sensitivity of ozone to NO_x emissions on the TP."

10. Please unify the abbreviation/full name of the journal in the References as required.

Reply: Sorry for this mistake. It has been corrected in the revised version.

Author's changes

We have further corrected a minor error. In the original manuscript, we performed regridding and sliding average in an incorrect order, when combining the PHLET-OMI inventory with the CEDS inventory. In the old version, PHLET-OMI underwent a sliding average first, followed by regridding to match the CEDS. This resulted in slightly higher calculated emissions because of the effect of missing values in PHLET-OMI in some years. The order of processing was reversed in the new version. The change in the process has a very minor effect on some of the trend estimates and does not change the main conclusions. The corrections are as follows:

Lines 217-220:

Former Text: "To make use of the PHLET-OMI anthropogenic NO_x emissions within its spatial domain and account for the monthly variation in emissions, we combine PHLET-OMI with the monthly variation from the CEDS inventory (Eq. (1))"

Revised Text: "To make use of the PHLET-OMI anthropogenic NO_x emissions within its spatial domain and account for the monthly variation in emissions, we first regrid the PHLET-OMI to match the CEDS, followed by a three-year sliding average (the value for 2015 represents the average over 2014–2016, and so on) to minimize the effect of fluctuations in the number of valid satellite data, then combine PHLET-OMI with the monthly variation from the CEDS inventory (Eq. (1))."

Former Figure:

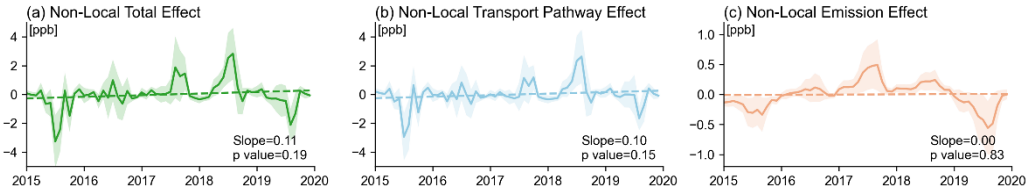

Figure 7 Deseasonalized monthly variation of non-local QNR averaged over the 17 cities. (a) Non-local QNR changes due to the combined effect of changes in anthropogenic emissions and in transport pathway. (b) Non-local QNR changes due to transport pathway alone. (c) Non-local QNR changes due to anthropogenic emissions alone. The shaded area represents the standard deviation of the data across 17 cities.

Revised Figure (We changed the range of the y-axis in Fig. 7c to match Fig. 7a-b):

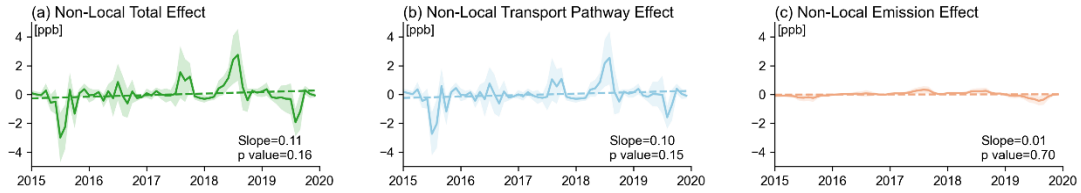

Figure 7 Deseasonalized monthly variation of non-local QNR averaged over the 17 cities. (a) Non-local QNR changes due to the combined effect of changes in anthropogenic emissions and in transport pathway. (b) Non-

local QNR changes due to transport pathway alone. (c) Non-local QNR changes due to anthropogenic emissions alone. The shaded area represents the standard deviation of the data across 17 cities.

Lines 340-341:

Former Text: "From 2015 to 2019, the non-local QNR increases at a rate of 0.11 ppb yr-1 (p-value = 0.19) (Fig. 7a)."

Revised Text: "From 2015 to 2019, the non-local QNR increases at a rate of 0.11 ppb yr^{-1} (p-value = 0.16) (Fig. 7a)."

Former Figure:

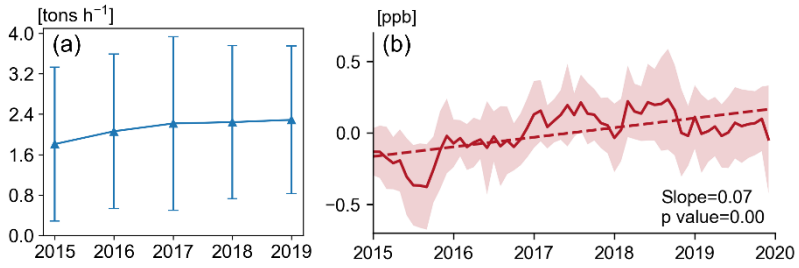

Figure 8 Changes in local anthropogenic emissions and QNR for within 1.5° of the 17 cities. (a) Time series of three-year moving average PHLET-OMI NO_x anthropogenic emissions in summer. Here, the value for 2015 represents the average over 2014–2016, and so on. (b) Deseasonalized monthly variation of local QNR. The error bar in (a) and shaded area in (b) represent the standard deviation of data across 17 cities.

Revised Figure:

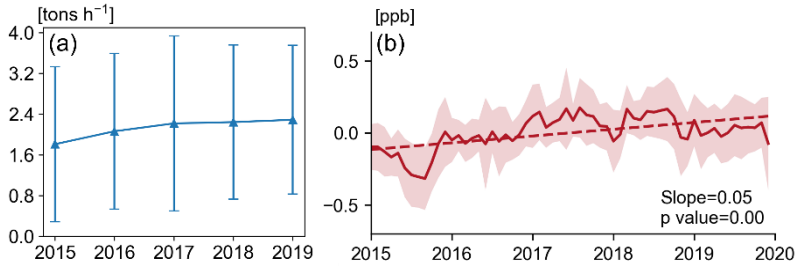

Figure 8 Changes in local anthropogenic emissions and QNR for within 1.5° of the 17 cities. (a) Time series of three-year moving average PHLET-OMI NO_x anthropogenic emissions in summer. Here, the value for 2015 represents the average over 2014–2016, and so on. (b) Deseasonalized monthly variation of local QNR. The error bar in (a) and shaded area in (b) represent the standard deviation of data across 17 cities.

Lines 390-392:

Former Text: "Figure 8b further shows that for the 17 cities, the local contribution to QNR increases significantly from 2015 to 2019 with a trend of 0.07 ppb yr^{-1}, with a total growth of 30% over these years. This trend is contributed mainly by the growth in local NOx emissions (26.5%)."

Revised Text: "Figure 8b further shows that for the 17 cities, the local contribution to QNR increases significantly from 2015 to 2019 with a trend of 0.05 ppb yr^{-1}, with a total growth of 23% over these years. This trend is contributed mainly by the growth in local NO_x emissions (26.5%)."

Former Figure:

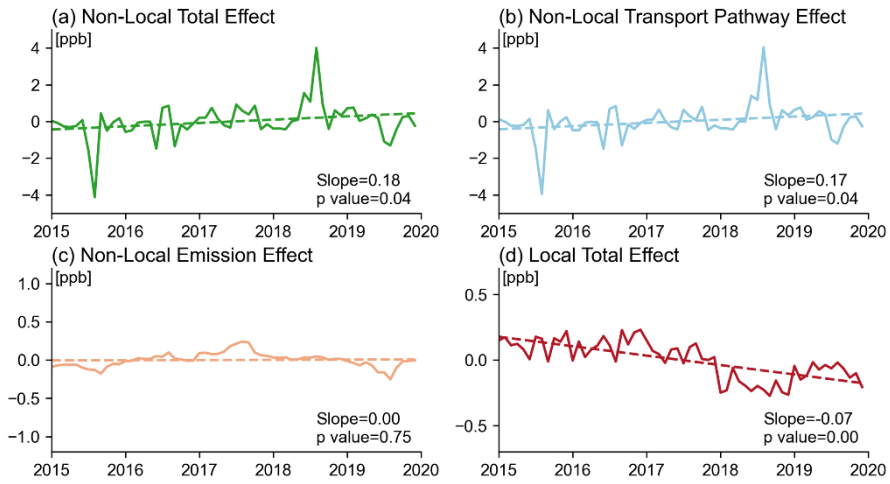

Figure S6 Deseasonalized monthly variation of QNR at Waliguan. (a) Non-local QNR changes due to the combined effect of changes in anthropogenic emissions and in transport pathway. (b) Non-local QNR changes due to changes in transport pathway alone. (c) Non-local QNR changes due to changes in anthropogenic emissions alone. (d) Local QNR changes due to the combined effect of changes in anthropogenic emissions and in transport pathway.

Revised Figure (We changed the range of the y-axis in Fig. S6c to match Fig. S6a-b):

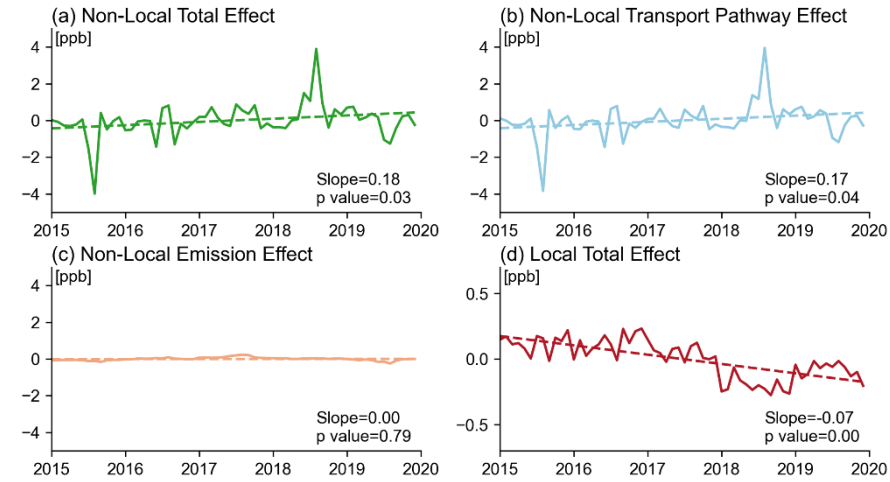

Figure S6 Deseasonalized monthly variation of QNR at Waliguan. (a) Non-local QNR changes due to the combined effect of changes in anthropogenic emissions and in transport pathway. (b) Non-local QNR changes due to changes in transport pathway alone. (c) Non-local QNR changes due to changes in anthropogenic emissions alone. (d) Local QNR changes due to the combined effect of changes in anthropogenic emissions and in transport pathway.

Lines 421-422:

Former Text: "The local QNR for the 17 cities exhibits a growth of 0.07 ppb yr^{-1} (or 30% in total) from

2015 and 2019, with the majority caused by the increase in local NO_x emissions (by 26.5%)."

Revised Text: "The local QNR for the 17 cities exhibits a growth of 0.05 ppb yr^{-1} (or 23% in total) from 2015 and 2019, with the majority caused by the increase in local NO_x emissions (by 26.5%)."

Reference

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