Response to Referee #1:

Thanks very much for your comments, suggestions and recommendation with respect to improve this paper. The response to all your comments are listed below.

This paper investigate the mechanism of short-term surface ozone anomalies in the urban areas over the Qinghai-Tibet Plateau. The topic and presentation are fine in general. A revision according the following comments should be provided.

Response: All your comments listed below have been addressed. Please check the point by point response as follows.

Comment [1-1]: The description for producing meteorological normalized concentration in Section 3.3 is quite vague. For example, (1) how the final result be sensitive to the four-week period window? If it is chosen to reflect the seasonal variability, is it really considered to be superior/useful than traditional deseasonalization methods? (2) p6, l17, "This selection process was repeated 1000 times to generate a final input dataset." How is the final input being generated exactly? By using sample mean, median, or anything else? Since the figure results presented in this study are not as variable as I expected from the main text, I am not quite convinced that a random resampling method would lead to such smooth results. A time series plot of original data for each station is desired.

Response: Thanks for your suggestions. In the revised version, we believe the combination of section 3.2 and 3.3 can explain the meteorological normalized concentration clearly. (1) The method and the selection of "the four-week period window" in this study follow those of Vu et al. (2019) and Shi et al. (2021). We resample observed weather data within a four-week period for a longer period (1980 to 2020) rather than only the study period, which normalizes the impact of weather variations but not the seasonal variations. This method enables us to investigate the seasonality of weather normalized concentrations (Vu et al., 2019;Shi et al., 2021). The meteorological normalized method is more useful than traditional deseasonalization methods since it is able to separate the contributions of meteorology and anthropologic emission to surface ozone anomalies. (2) The 1000 predicted concentrations were then averaged to calculate the final weather normalized concentration for that particular hour, day, and year. For each measurement, we resample the observed weather data within a four-week period for a longer period (1980 to 2020) 1000 times so that all kinds of weather conditions around the measurement time have been considered in the model predictions. The purpose of this process is to collect enough data and eliminate the influence of abnormal meteorological conditions, and get concentrations under the averaged meteorological conditions. We have added the content to Page 6, Line 34-36. Because the weather normalized concentrations are the averaged values, it is normal for the time series by random resampling method to be smooth. Similarly, the results by Vu et al. (2019) and Shi et al. (2021) are also smooth. In the revised version, the time series plots of original data for each city are presented in Supplement Figure S3 (i.e., Figure R1 in this file).

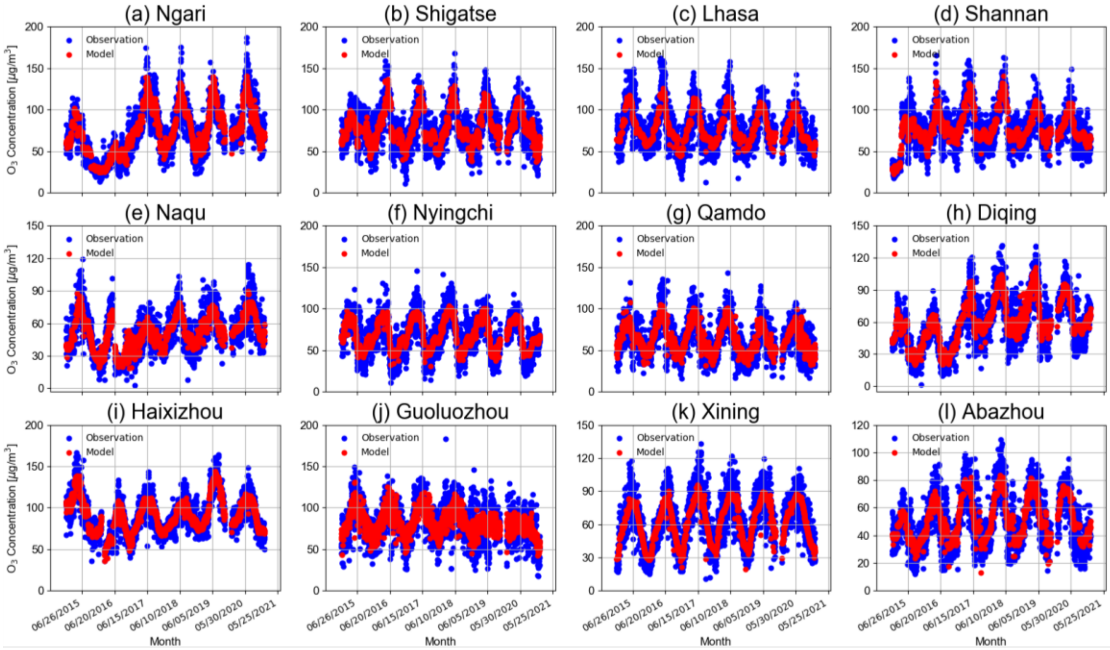

Figure R1 Time series of surface ozone observations and meteorological normalization data in each city over the QTP region.

Comment [1-2]: A significant portion of this study is devoted to the discussion of ozone extreme values. To provide a more systematic discussion, and to facilitate better communication, I suggest the authors should quantitatively work on the percentile variation instead (e.g. the 5th and 95th), as suggested by following references:

Cooper, O. R., Gao, R. S., Tarasick, D., Leblanc, T., & Sweeney, C. (2012). Long-term ozone trends at rural ozone monitoring sites across the United States, 1990–2010. Journal of Geophysical Research: Atmospheres, 117(D22).

Munir, S., Chen, H., & Ropkins, K. (2012). Modelling the impact of road traffic on ground level ozone concentration using a quantile regression approach. Atmospheric environment, 60, 283-291.

Chang, K. L., Schultz, M. G., Lan, X., McClure-Begley, A., Petropavlovskikh, I., Xu, X., & Ziemke, J. R. (2021). Trend detection of atmospheric time series: Incorporating appropriate uncertainty estimates and handling extreme events. Elem Sci Anth, 9(1), 00035.

Wells, B., Dolwick, P., Eder, B., Evangelista, M., Foley, K., Mannshardt, E., ... & Weishampel, A. (2021). Improved estimation of trends in US ozone concentrations adjusted for interannual variability in meteorological conditions. Atmospheric Environment, 248, 118234.

Response: Thanks for your suggestions. In revised version, we have presented the percentile variation of surface ozone concentration (units: $\mu g/m^3$) in each city over the QTP from 2015 to 2020 in Figure S2 (i.e., Figure R2 in this file). The percentile variation modes of surface ozone concentration in all cities over the QTP are similar. In this study, only mean plus standard variance of surface ozone concentration rather than its percentile variation in each city was investigated. This prevailing method has been used in a number of studies to describe the variabilities of atmospheric compositions over the QTP, such as Li et al. (2020), Liu et al. (2021), Ma et al. (2020), Xu et al.

(2018), Xu et al. (2016), Yin et al. (2019), and Yin et al. (2017). We have added these contents to Page 7, Line 38-43 and Page 8, Line 1-2. Please check it. The method (mean + standard variance) can also well reflect the trends and variabilities of ozone, and can also provide a more systematic discussion and communication.

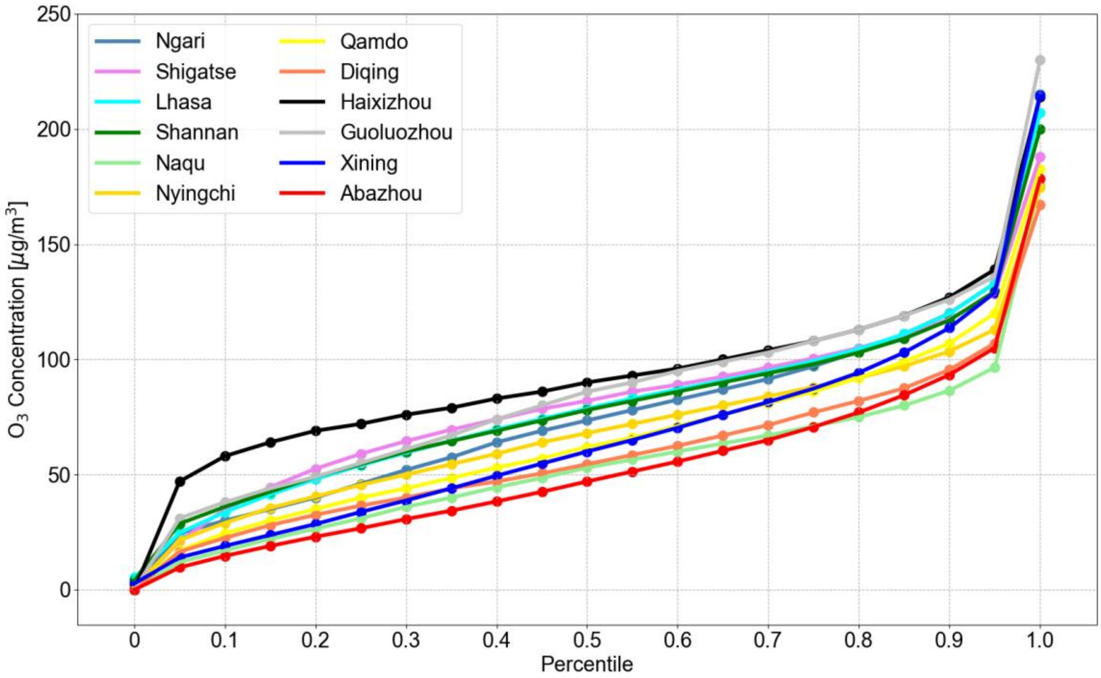

Figure R2. The percentile variation of surface ozone concentration (units: μg/m^3) in each city over the QTP from 2015 to 2020.

Minor suggestions:

Comment [1-3]: p4, l6-7, the data quality control procedures should be briefly stated.

Response: Thanks for your reminder. The filter criteria can be summarized as follows. Hourly observed data points were transformed into Z scores (Same as the uniformized process and will be refer below), and then, the observed data were removed if the corresponding Z_i met one of the following conditions: (1) Z_i is larger or smaller than the previous one (Z_{i-1}) by 9 ($|Z_i - Z_{i-1}| > 9$), (2) The absolute value of Z_i is greater than 4 ($|Z_i| > 4$), or (3) the ratio of the Z value to the third-order center moving average is greater than 2 ($\frac{3Z_i}{Z_{i-1}+Z_i+Z_{i+1}} > 2$). The uniformized process are presented as follows:

$$\boldsymbol{z_k} = \frac{\boldsymbol{x_k} - \boldsymbol{u_k}}{\boldsymbol{\sigma_k}} \tag{1}$$

where $\boldsymbol{u_k}$ and $\boldsymbol{\sigma_k}$ are the average and 1σ standard deviation (STD) of $\boldsymbol{x_k}$, and $\boldsymbol{z_k}$ is the pre-processed value for parameter $\boldsymbol{x_k}$. We have added the data quality control procedures in Page 4, Line 22-30. Please check it.

Comment [1-4]: p6, l1-2, this part seems to come from nowhere.

Response: Thanks for your reminder. We have moved this part to Page 4, Line 22-30. Please check it.

Comment [1-5]: p8, l4, Yin et al. (2017)

Response: Thanks for your reminder. We have corrected this mistake. Please check it.

Comment [1-6]: p10,l25, what does it mean for "seasonal cycles of surface ozone anomalies"? Should the anomaly is deseasonalized already in Eq (5)? If it refers to remaining seasonality variation, can it imply that the methodology in Eq (5) is not appropriate?

Response: We calculate surface ozone anomalies ($O_{3,anomalies}$) in each city over the QTP by subtracting their seasonal mean values ($O_{3,mean}$) from all hourly surface ozone measurements ($O_{3,individual}$). We then discussed the surface ozone anomalies and separated the contributions of anthropogenic emissions and meteorological conditions on different time scales. For example, when we discuss seasonal cycles of surface ozone anomalies, we calculate monthly mean values of surface ozone anomalies, and investigate the month-to-month variabilities of the anomalies throughout the year. Similarly, for diurnal scale, we calculate hourly mean values of surface ozone anomalies, and investigate the hour-to-hour variabilities of the anomalies throughout the day. As a result, we just summarize the anomalies on seasonal scale and it doesn't mean that the methodology in Equation (5) is not appropriate. The purpose of Equation (5) is only to find surface ozone anomalies.

Reference

Li, R., Zhao, Y. L., Zhou, W. H., Meng, Y., Zhang, Z. Y., and Fu, H. B.: Developing a novel hybrid model for the estimation of surface 8 h ozone (O_3) across the remote Tibetan Plateau during 2005-2018, Atmos Chem Phys, 20, 6159-6175, 2020.

Liu, S., Fang, S., Liu, P., Liang, M., Guo, M., and Feng, Z.: Measurement report: Changing characteristics of atmospheric CH_4 in the Tibetan Plateau: records from 1994 to 2019 at the Mount Waliguan station, Atmos. Chem. Phys., 21, 393-413, 10.5194/acp-21-393-2021, 2021.

Ma, J., Dörner, S., Donner, S., Jin, J., Cheng, S., Guo, J., Zhang, Z., Wang, J., Liu, P., Zhang, G., Pukite, J., Lampel, J., and Wagner, T.: MAX-DOAS measurements of NO_2, SO_2, HCHO, and BrO at the Mt. Waliguan WMO GAW global baseline station in the Tibetan Plateau, Atmos. Chem. Phys., 20, 6973-6990, 10.5194/acp-20-6973-2020, 2020.

Shi, Z. B., Song, C. B., Liu, B. W., Lu, G. D., Xu, J. S., Vu, T. V., Elliott, R. J. R., Li, W. J., Bloss, W. J., and Harrison, R. M.: Abrupt but smaller than expected changes in surface air quality attributable to COVID-19 lockdowns, Sci Adv, 7, 2021.

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Xu, W., Xu, X., Lin, M., Lin, W., Tarasick, D., Tang, J., Ma, J., and Zheng, X.: Long-term trends of surface ozone and its influencing factors at the Mt Waliguan GAW station, China – Part 2: The roles of anthropogenic emissions and climate variability, Atmos. Chem. Phys., 18, 773-798, 10.5194/acp-18-773-2018, 2018.

Xu, W. Y., Lin, W. L., Xu, X. B., Tang, J., Huang, J. Q., Wu, H., and Zhang, X. C.: Long-term trends of surface ozone and its influencing factors at the Mt Waliguan GAW station, China - Part 1: Overall trends and characteristics, Atmos Chem Phys, 16, 6191-6205, 2016.

Yin, X. F., Kang, S. C., de Foy, B., Cong, Z. Y., Luo, J. L., Zhang, L., Ma, Y. M., Zhang, G. S., Rupakheti, D., and Zhang, Q. G.: Surface ozone at Nam Co in the inland Tibetan Plateau: variation, synthesis comparison and regional representativeness, Atmos Chem Phys, 17, 11293-11311, 2017.

Yin, X. F., de Foy, B., Wu, K. P., Feng, C., Kang, S. C., and Zhang, Q. G.: Gaseous and particulate pollutants in Lhasa, Tibet during 2013-2017: Spatial variability, temporal variations and implications, Environmental Pollution, 253, 68-77, 2019.