Anonymous Referee #1

Liu et al., reviews publications that focus on addressing chemical loss from source analyses. They summarize the methods and their limitations for reducing losses and addressing the loss impact. They also discuss the chemical losses of VOCs in different cities in China and the source contributions of consumed VOCs. The authors need to reconsider the type of the manuscript, as this article is better suited to "Review article" than "Research articles".

Response: Thanks for your comments. The type of this manuscript was submitted as a "review article", not a "research article". We have revised the title of this manuscript based on your and other reviewers' suggestions to better reflect the type of article.

1. The title can be re-phrased to clearly convey the message of this review article.

Response: Thanks for your advice. Combined with other reviewer's suggestions, we have revised the title of this manuscript. The more details are as follows:

"Review of source analyses of ambient VOCs considering reactive losses: Methods of reducing loss effects, impacts of losses, and sources"

2. The sections 3.1.1 and 3.1.3 describe the methods for reducing the impact of reactive losses in PMF and CMB, respectively. Why does section 3.1.2 only discuss OVOC? Similarly, for Figure 1, why is PAPM presented as a method parallel to PMF and CMB while it only focuses on OVOCs?

Response: Thanks for your comments. Based on extensive literature reviews (Gu et al., 2020; He et al., 2019; Huang et al., 2020; Song et al., 2019; Yang, et al., 2022; Zhu et al., 2021; etc.), the current methods of source apportionment of ambient VOCs considering reactive losses primarily include positive matrix factorization (PMF), chemical mass balance (CMB), and the photochemical age-based parameterization method (PAPM) (on the lines 143-144). For PMF or CMB, many studies mainly included the Photochemical Assessment Monitoring Stations (PAMS) species for source apportionment (He et al., 2024; Mishra et al., 2023; Wu et al., 2023; etc.) (on the lines 145-146), and some studies also included PAMS and OVOCs together for conducting source apportionment (Li et al., 2023; Liu et al., 2023; Tan et al., 2021) (on the lines 150-151). However, compared to the PAMS species, the sources of OVOCs are more complex since they originate from both secondary oxidative formation and primary sources (on the lines 362-364) (Chen et al., 2014; Han et al., 2023; Huang et al., 2020; Seinfeld and Pandis, 1986). In PMF and CMB apportionment processes, it was necessary to obtain the actual secondary oxidative profile for factor identification or as model input data (Yang et al., 2022). In the actual situation where the secondary oxidative profile of ambient OVOCs cannot be obtained, using these two methods for conducting source analyses of OVOCs could result in high uncertainty in the apportioned results. Thus, some studies applied the PAPM to quantify the contributions of primary anthropogenic and biogenic emissions, secondary oxidative sources, and background to OVOCs (de Gouw et al., 2005; Yuan et al., 2012; Zhu et al., 2021) (on the lines 392-394). PAPM is an important supplemental method to the PMF and CMB, but it differs fundamentally from them. Therefore, PAPM, PMF, and CMB were analyzed in this study as shown in Figure 1. Thus, there was a need for a comprehensive literature review. Additionally, although some studies have also used two species ratios or PCA or PAC/MLR to qualitatively or quantitatively identify VOC sources (Sanchez et al., 2008; Jia et al., 2016; Wang et al., 2020), the issue of reactive losses in these studies has not been considered. Therefore, these methods have not been reviewed in this

study. Furthermore, PCA represents an invalid approach since eigenvector analysis provides an unweighted least squares fit and these data are heteroskedastic (Yang et al., 2022). It really should no longer be considered a receptor model given that it is portioning variance and not variation (Hopke, 2015; Hopke and Jaffe, 2020; Yang et al., 2022).

Furthermore, Section 3.1.1.2 of the main text mainly focused on the relevant research for the estimation the initial concentrations of ambient VOC species based on photochemical-age method, and then incorporating them into PMF for source analyses to reduce the impacts of photochemical reactive losses. Given that similar contents were also involved in the source analyses method (i.e., PAPM) of OVOCs, this study has placed PAPM as Section 3.1.2 at the end of Section 3.1.1 to make it easier for readers to follow and the manuscript more logical.

Reference:

Chen, W. T., Shao, M., Lu, S. H., Wang, M., Zeng, L. M., Yuan, B., and Liu, Y.: Understanding primary and secondary sources of ambient carbonyl compounds in Beijing using the PMF model, Atmos. Chem. Phys., 14, 3047-3062, https://doi.org/10.5194/acp-14-3047-2014, 2014.

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Gu, Y., Liu, B. S., Li, Y. F., Zhang, Y. F., Bi, X. H., Wu, J. H., Song, C. B., Dai, Q. L., Han, Y., Ren, G., and Feng, Y. C.: Multi-scale volatile organic compound (VOC) source apportionment in Tianjin, China, using a receptor model coupled with 1-hr resolution data, Environ. Pollut., 265, 115023, https://doi.org/10.1016/j.envpol.2020.115023, 2020.

Han, S. W., Tan, Y., Gao, Y., Li, X. W., Ho, S. S. H., Wang, M., and Lee, S. C.: Volatile organic compounds at a roadside site in Hong Kong: Characteristics, chemical reactivity, and health risk assessment, Sci. Total Environ., 866, 161370, https://doi.org/10.1016/j.scitotenv.2022.161370, 2023.

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He, Z. R., Wang, X. M., Ling, Z. H., Zhao, J., Guo, H., Shao, M., and Wang, Z.: Contributions of different anthropogenic volatile organic compound sources to ozone formation at a receptor site in the Pearl River Delta region and its policy implications, Atmos. Chem. Phys., 19, 8801-8816, https://doi.org/10.5194/acp-19-8801-2019, 2019.

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Huang, X.-F., Zhang, B., Xia, S.-Y., Han, Y., Wang, C., Yu, G.-H., and Feng, N.: Sources of oxygenated volatile organic compounds (OVOCs) in urban atmospheres in North and South China, Environ. Pollut., 261, 114152, https://doi.org/10.1016/j.envpol.2020.114152, 2020.

Jia, C. H., Mao, X. X., Huang, T., Liang, X. X., Wang, Y. N., Shen, Y. J., Jiang, W. Y. H., Wang, H. Q., Bai, Z. L., Ma, M. Q., Yu, Z. S., Ma, J. M., and Gao, H.: Non-methane hydrocarbons (NMHCs) and their contribution to ozone formation potential in a petrochemical

industrialized city, Northwest China, Atmos. Res., 169, 225-236, https://doi.org/10.1016/j.atmosres.2015.10.006, 2016.
Li, B. W., Yu, S. C., Shao, M., Li, X. H., Ho, S. S. H., Hu, X. Y., Wang, H. L., Feng, R., and Fang, X. K.: New insights into photochemical initial concentrations of VOCs and their source implications, Atmos. Environ., 298, 119616, https://doi.org/10.1016/j.atmosenv.2023.119616, 2023.
Liu, C. T., Xin, Y. Y., Zhang, C. L., Liu, J. F., Liu, P. F., He, X. W., and Mu, Y. J.: Ambient volatile organic compounds in urban and industrial regions in Beijing: Characteristics, source apportionment, secondary transformation and health risk assessment, Sci. Total Environ., 855, 158873, https://doi.org/10.1016/j.scitotenv.2022.158873, 2023.
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Sanchez, M., Karnae, S., and John, K.: Source characterization of volatile organic compounds affecting the air quality in a coastal urban area of South Texas, Int. J. Environ. Res. Public Health, 5, 130-138, https://doi.org/10.3390/ijerph5030130, 2008.
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Wang, Y., Yang, G., Wang, L., Zhao, L., Ji, S., Qi, M., Lu, X., Liu, Z., Tan, J., Liu, Y., Wang, Q., and Xu, R.: Characteristics and source apportionment of VOCs in a city with complex pollution in China, Aerosol Air Qual. Res. 20, 2196-2210, https://doi.org/10.4209/aaqr.2019.11.0608, 2020.
Wu, Y. T., Liu, B. S., Meng, H., Dai, Q. L., Shi, L. Y., Song, S. J., Feng, Y. C., and Hopke, P. K.: Changes in source apportioned VOCs during high O_3 periods using initial VOC-concentration-dispersion normalized PMF, Sci. Total Environ., 896, 165182, https://doi.org/10.1016/j.scitotenv.2023.165182, 2023.
Yang, Y., Liu, B. S., Hua, J., Yang, T., Dai, Q. L., Wu, J. H., Feng, Y. C., and Hopke, P. K.: Global review of source apportionment of volatile organic compounds based on highly time-resolved data from 2015 to 2021, Environ. Int., 165, 107330, https://doi.org/10.1016/j.envint.2022.107330, 2022.
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Zhu, B., Huang, X.-F., Xia, S.-Y., Lin, L.-L., Cheng, Y., and He, L.-Y.: Biomass-burning emissions could significantly enhance the atmospheric oxidizing capacity in continental air pollution, Environ. Pollut., 285, 117523, https://doi.org/10.1016/j.envpol.2021.117523, 2021.

3. Section 3.1.1.1: To my understanding, incorporating night only data into PMF is a way to diagnose emissions at night, and it is not considered as a **method** to reduce the reactive loss in PMF source analyses.

Response: According to the review of the related literature, it can be found that current approach of incorporating daytime and nighttime VOC data into PMF for source analyses (e.g., Gu et al., 2020; Li et al., 2020; Jain et al., 2022) assumes that the daytime and nighttime factor profiles are consistent. However, in fact, the daytime factor profiles can be substantially influenced by photochemistry (Liu et al., 2025). Therefore, the source contributions obtained by this method have relatively higher uncertainty. To reduce the impacts of reactive losses on the PMF apportioned factor profiles and contributions, some studies utilized nighttime only data for source analyses to obtain more accurate nighttime contributions of emission sources (Buzcu-Guven and Fraser, 2008; Buzcu and Fraser, 2006; Kim et al., 2005; Xie and Berkowitz, 2006). Meanwhile, Liu et al. (2025) also found that the apportioned factor profiles based on nighttime data were closer to the actual source profiles since they were not affected by losses, further making the apportioned source contributions more accurate.

Therefore, the related studies of source analyses based on the nighttime VOC data were aimed at reducing the impacts of photochemical reactive losses on the factor profiles and the apportioned contributions, to more accurately quantify the nighttime contributions of emission sources. Specific details can also be found in these relevant literature (i.e., Buzcu-Guven and Fraser, 2008; Buzcu and Fraser, 2006; Kim et al., 2005; Liu et al., 2025; Xie and Berkowitz, 2006).

However, the related analyses and descriptions in the main text were indeed inappropriate. Combined with your comments, we have implemented the related modifications in the revised manuscript (on the lines 166-174).

Reference:

Buzcu, B., and Fraser, M. P.: Source identification and apportionment of volatile organic compounds in Houston, TX, Atmos. Environ., 40, 2385-2400, https://doi.org/10.1016/j.atmosenv.2005.12.020, 2006.

Buzcu-Guven, B., and Fraser, M. P.: Comparison of VOC emissions inventory data with source apportionment results for Houston, TX, Atmos. Environ., 42, 5032-5043, https://doi.org/10.1016/j.atmosenv.2008.02.025, 2008.

Gu, Y., Liu, B. S., Li, Y. F., Zhang, Y. F., Bi, X. H., Wu, J. H., Song, C. B., Dai, Q. L., Han, Y., Ren, G., and Feng, Y. C.: Multi-scale volatile organic compound (VOC) source apportionment in Tianjin, China, using a receptor model coupled with 1-hr resolution data, Environ. Pollut., 265, 115023, https://doi.org/10.1016/j.envpol.2020.115023, 2020.

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Kim, E., Brown, S. G., Hafner, H. R., and Hopke, P. K.: Characterization of non-methane volatile organic compounds sources in Houston during 2001 using positive matrix factorization, Atmos. Environ., 39, 5934-5946, https://doi.org/10.1016/j.atmosenv.2005.06.045, 2005.

Li, Z. Y., Ho, K. F., and Yim, S. H. L.: Source apportionment of hourly-resolved ambient volatile organic compounds: Influence of temporal resolution, Sci. Total Environ., 725, 138243, https://doi.org/10.1016/j.scitotenv.2020.138243, 2020.

Liu, B. S., Yang, T., Kang, S. C., Wang, F. Q., Zhang, H. X., Xu, M., Wang, W., Bai, J. R., Song, S. J., Dai, Q. L., Feng, Y. C., and Hopke, P. K.: Changes in factor profiles deriving from photochemical losses of volatile organic compounds: Insight from daytime and nighttime positive matrix factorization analyses, J. Environ. Sci., 151, 627–639, https://doi.org/10.1016/j.jes.2024.04.032, 2025.

Xie, Y. L., and Berkowitz, C. M.: The use of positive matrix factorization with conditional probability functions in air quality studies: An application to hydrocarbon emissions in Houston, Texas, Atmos. Environ., 40, 3070-3091, https://doi.org/10.1016/j.atmosenv.2005.12.065, 2006.

4. Section 3.2: this section discusses the impact of quantifying reactive losses on source analyses, however, not many studies have described the impacts. I don't think it should be a result section, instead, it could be moved up to introduction.

Response: Thanks for your advice. We have re-reviewed recent relevant literature research, and have substantially added the analyses and descriptions of the impacts of reactive losses on source analyses, primarily including the impacts on factor profiles and source contributions (on the lines 466-499 of the revised manuscript). The specific details are provided below. Given that there has been a substantial increase in the literature and analysis descriptions in this section, moving this section to the introduction would make it lengthy and illogical. Therefore, this study has not moved this section to the introduction. Thanks!

"**3.2 Effects of reactive losses on source analyses**

According to the review of relevant publications, it was found that most of the current studies analyzed the impacts of VOC photochemical losses on the source analyses by comparing the PMF apportioned results based on measured and initial concentrations estimated by a photochemical age-based parameterization method (Gao et al., 2018; Gu et al., 2023; Kong et al., 2023; Li et al., 2023; Liu et al., 2023c; Zou et al., 2023) or comparing the apportioned results based on the daytime and nighttime VOCs data (Liu et al., 2025). Reactive losses substantially reduced the concentrations (ppbv/ppbv) of highly reactive VOC species in PMF resolved factor profiles based on the measured data. For example, Liu et al. (2023a) investigated the impacts of photochemical losses of ambient VOCs on the PMF resolved profiles by comparing the initial and measured data results. They found that the concentrations of VOC species with relatively low reactivities (e.g., ethane, propane, n-butane, and i-butane) were higher in the factor profiles apportioned from the measured data, while those of VOC species with relatively high reactivities (e.g., m,p-xylene, isoprene, and propene) were lower in the measured data resolved profiles. Gu et al. (2023) also reported the similar results. Meanwhile, Liu et al. (2025) also reported that reactive losses clearly reduced the concentrations of dominant VOC species with high reactivities in the profiles of solvent use, petrochemical industry emissions, and combustion sources by comparing the daytime and nighttime resolved profiles.

Additionally, VOC reactive losses can result in the substantial underestimation of the PMF apportioned contributions of sources that emitted highly reactive species, and emission sources with substantially underestimated contributions varied in different cities. For example, Wang et al. (2013) found that the contributions of biogenic and industrial emissions in Shanghai were underestimated by 30% and 10%, respectively, due to photochemical reactive losses. He et al. (2024) found that the underestimations of industrial source contributions in Guangzhou were markedly higher than those of other sources. Liu et al. (2023a) suggested that biogenic emissions

and polymer production-related industrial sources in Tianjin were underestimated by 73% and 50%, respectively. In addition, Wu et al. (2023a), Zhang et al. (2024), and Gu et al. (2023) also suggested that the underestimations of contributions of biogenic emissions in Beijing, Langfang, and Qingdao were substantially higher than those of any other sources. However, Wang et al. (2024a) found that the contributions of solvent usage and biomass burning in Zhengzhou were underestimated by 31.5% and 15.4%, higher than other sources. Cui et al. (2024) suggested that the contributions of petrochemical industries, diesel vehicle emissions, biogenic emissions, and oxidation formation in Shijiazhuang were underestimated by 72.0 %, 71.0 %, 64.5 %, and 44.0 %, respectively. However, due to the uncertainty of initial concentration estimation, the reliability of these results needs further validation and evaluation. Thus, further research is required."

5. Section 3.3: the authors should clarify the difference between "reducing the impact of chemical losses in section 3.1" and "estimating VOC reactive losses in Section 3.3". For instance, both sections discuss the photochemical age-based parametrization method, which may be redundant.

Response: Thanks for your advice. Sections 3.1 and 3.3 in this study were different. Section 3.1 primarily reviewed the methods of reducing the impacts of reactive losses to source analyses. **For PMF**, the main methods were to select low reactivity VOC species or use only night data for source analyses, or estimate the VOC initial concentrations by photochemical age-based parametrization method for source apportionment (on the lines 159-357). **For CMB**, the main method was to adjust the fractions of VOC species in source profiles using decay factors to make them more compatible with the data measured at the receptor site, thereby reducing the impact of reactive losses (on the lines 424-464). **For PAPM**, the impacts of photochemical reactive losses on the OVOCs were considered in the calculation process (on the lines 359-422). Thus, this section primarily reviewed the methods for reducing the impact of reactive losses on source analyses.

However, Section 3.3 mainly described and analyzed quantitative methods for VOC reactive losses, including quantification based on differences between initial and observed concentrations (on the lines 503-511), as well as quantification based on proportion relationship between isoprene losses and other VOC species losses (on the lines 512-525). The first method, although also involving initial concentration estimation based on photochemical age parameters, was only one step in the reactive loss estimation method (see Eq. (9) for details). Therefore, Section 3.3 was a continuation and development of Section 3.1, and the two were not duplicates. Section 3.3 did not repeat the analysis of the contents in Section 3.1 for this study. Furthermore, if Section 3.1 does not introduce the initial concentration estimation method based on photochemical age, then Section 3.3 lacks a prerequisite for obtaining reactive losses based on the differences between the initial and observed concentrations, which is unreasonable.

Combined with your suggestions, to make the contents described in Section 3.3 more distinct from Section 3.1, we have modified the relevant descriptions in Section 3.3 (on the lines 502-506). The specific details are as follows:

"There were two main methods for estimating the reactive losses of VOCs in the atmosphere. The first method was based on the differences between the initial and measured VOC concentrations (Table S9) (as shown in Eq. (9)) (Wang et al., 2023; Wu et al., 2023b). The initial concentration was generally estimated using the photochemical age-based parameterization method mentioned in Section 3.1.1.2 (as shown in Eq. (1)) (Liu et al., 2023a; Wu et al., 2023b)."

6. Line 487-488: why were studies on VOC photochemical losses mainly conducted in Chinese cities? How does these studies differ from those in other cities? I would suspect that the impact of VOC chemical losses would be larger over cities with higher BVOC abundance, such as those in Southeast US.

Response: Thanks for your comments. It was not that the research on photochemical losses in this study only considered the cities in China, but through extensive literature review, it was found that the related studies on estimation of photochemical reactive losses were all conducted in Chinese cities. China has invested in providing substantial numbers of hourly monitoring systems for VOCs providing more data than are available elsewhere. There are currently no relevant research reports in cities outside of China. Meanwhile, we also hope that cities outside of China (e.g., the cities in the Southeast US) can conduct the relevant studies, so that we could conduct more extensive comparative analyses. However, the cities in other countries have not conducted the related studies on the VOC photochemical losses so far.

Combined with your comments, we have re-reviewed and added all recent literature studies on photochemical losses of VOCs in the world to this manuscript (e.g., He et al., 2024; Hua et al., 2023; Zhang et al., 2024; Wang et al., 2024a,b; Cui et al., 2024; Ren et al., 2024; Sun et al., 2024). However, in the only literature report other than China, although Kalbande et al. (2022) estimated the initial concentrations of VOCs in Mumbai, India, they did not analyze the photochemical losses of VOC species.

Additionally, this study has also revised and improved the relevant comparative analysis contents in the main text (on the lines 550-570). Specifically, as follows:

"The photochemical reactive loss of ambient VOCs in Qingdao was the highest (45.1 ppbv), followed by Shijiazhuang (33.2 ppbv), Wuhan (23.7 ppbv), Shanghai (10.9 ppbv), Tianjin (10.4 ppbv), Zhengzhou (10.2 ppbv), and Handan (8.90 ppbv) (Fig. 2). VOC reactive losses were relatively lower in Zibo (6.8 ppbv), Beijing (6.00 ppbv), Guangzhou (4.65 ppbv), Chengdu (4.48 ppbv), Jinan (4.00 ppbv), and Taipei (3.69 ppbv). The chemical loss rates (i.e., the proportion of chemical loss in the initial concentration, %) in Qingdao (69.1%) and Shijiazhuang (58.9%) were the highest, followed by Wuhan (49.8%) and Tianjin (33.8%). In contrast, chemical loss rates in Zhengzhou (29.9%), Shanghai (25.1%), Jinan (25.0%), Handan (21.1%), Beijing (16.1%), Zibo (15.9%), Chengdu (15.8%), Guangzhou (15.1%), and Taipei (13.4%) were relatively lower. However, due to differences in observation periods and measured VOC species, the comparability of chemical reactive losses and loss rates between different cities is limited and differences uncertain.

Compared to other VOC groups, alkenes had the highest reactive loss (Figs. 3 and S1), accounting for 36.7%-93.3% of the total losses, followed by aromatic hydrocarbons (3.81%-24.3%), and alkanes (2.33%-13.6%) (Fig. 3 and Table S11). There were substantial differences in VOC species with high losses in different cities (Fig. 3). The losses of ethene, propene, and isoprene in most cities were relatively higher than those of other species (Fig. 3), likely closely related to their high reactivities (Table S4). The isoprene losses in Beijing, Chengdu, Jinan, and Taipei were all the highest compared to other species (Fig. 3). However, the reactive losses of trans-2-butene and cis-2-butene in Qingdao and Zhengzhou were substantially higher than other VOC species. The reactive loss of 1-hexene in Tianjin was remarkedly higher compared to other species. Meanwhile, the trans-2-butene loss in Tianjin was also relatively higher (Fig. 3)."

References:

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Zhang, J. Q., Liu, Z., Wu, Y. J., Zhu, Y., Cao, T., Ling, D. Y., Wang, H., and Wang, S. L.: The impacts of photochemical loss on the source apportionment of ambient volatile organic compounds: A case study in Northern China, Atmos. Environ., 333, 120671, https://doi.org/10.1016/j.atmosenv.2024.120671, 2024.

Anonymous Referee #2

Liu et al. present a review of methods used to estimate and account for reactive losses when assessing VOC emission sources and production of secondary pollutants. They also advocate for further investigations regarding consumed VOCs to elucidate secondary pollution. Overall, this article fits the scope of the journal as it addresses important questions regarding emission source characterization and photochemical processing. I would recommend publication after addressing the comments below.

1. Title should incorporate "review" for the sake of the reader.

Response: Thanks for your advice. We have modified the title of this manuscript, and the specific details are as follows:

"Review of source analyses of ambient VOCs considering reactive losses: Methods of reducing loss effects, impacts of losses, and sources"

2. Section 2 – Give more details of the literature search rather than make the reader go to the SI for more information. You note that 41% of the articles were in the last 5 years. Explicitly note that this fact suggests you're including some of the most up-to-date analyses in your review. Separately, how many of the 151 papers were on studies done in China vs N America vs Europe vs other (provides context for your statement on lines 487-488 about most studies being conducted in Chinese cities)? Are you missing major journal publishers (e.g., ACS or AGU)?

Response: Thanks for your comments and suggestions.

(1) We have supplemented and added more literature search details in Section 2, primarily including all literature search databases involved in this study, literature number and proportions published in different periods, the proportions of literature published in different countries, and the main research cities involved in the published literature (on the lines 101-102 and 109-117). Meanwhile, this study has also supplemented and added recent research literature on the VOC chemical reactive losses (e.g., He et al., 2024; Zhang et al., 2024; Wang et al., 2024a,b; Cui et al., 2024; Ren et al., 2024; Sun et al., 2024), and updated and improved the analysis descriptions in the main text (on the lines 550-570) and the contents of tables in the supplementary materials (e.g., Table S3).

(2) According to the literature review results, we found that all the papers currently reviewed mainly involve countries such as China, the United States, India, South Korea, Canada, and Japan, etc., with literature reports in China accounting for the majority (~60% of total papers), followed by the United States (~14%) (on the lines 111-114). However, the chemical losses of VOC species have not been estimated and analyzed in papers from North America and Europe. Thus, we could not obtain chemical loss data for different VOC species from relevant papers. They mainly focused on methods to reduce losses, not quantifying losses. This was also the reason why this study mainly analyzed Chinese cities. We have also conducted related explanations in the main text (on the lines 535-536).

(3) We have comprehensively searched databases from major global publishers, e.g., Science Direct (Elsevier), the Web of Science, Scopus, Springer, Wiley, and China National Knowledge Infrastructure (CNKI), etc., among which the Web of Science included publishers such as ACS and AGU. After careful search and screening of related literature, we believed that the literature in this study have covered all the current studies. Apart from the literature we have reviewed, there were no other studies on chemical losses available.

References:

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He, C. Q., Zou, Y., Lv, S. J., Flores, R. M., Yan, X. L., Deng, T., and Deng, X. J.: The importance of photochemical loss to source analysis and ozone formation potential: Implications from in-situ observations of volatile organic compounds (VOCs) in Guangzhou, China, Atmos. Environ., 320, 120320, https://doi.org/10.1016/j.atmosenv.2023.120320, 2024.

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Wang, T. T., Tao, J., Li, Z., Lu, X., Liu, Y. L., Zhang, X.R., Wang, B., Zhang, D., and Yin, S.S.: Characteristic, source apportionment and effect of photochemical loss of ambient VOCs in an emerging megacity of Central China, Atmos. Res., 305, 107429, https://doi.org/10.1016/j.atmosres.2024.107429, 2024a.

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3. Line 161 – specify **evaporative** gasoline sources were not resolved.

Response: Thanks for your comments. We carefully checked and found that it here indeed referred to **evaporative** gasoline sources, as shown in table below (cited from Buzcu and Fraser (2006)). We made modifications in the text (on the line 178).

Table 1
Comparison of the factor contributions to VOC mass for July data using all-day data and night-time data only at Wallisville and Lynchburg

Factor	Wallisville (all-day data)		Wallisville (night-time data)		Lynchburg (all-day data)		Lynchburg (night-time data)	
	Contribution (ppbC)	%	Contribution (ppbC)	%	Contribution (ppbC)	%	Contribution (ppbC)	%
Biogenic	7.35	5						
Industrial					13.46	4		
Gasoline (evaporative)					52.00	15		
Natural gas	26.10	19			31.29	9	76.46	22
Petrochemical production	48.06	35	62.43	38	68.25	20	75.48	22
Refinery	43.93	32	62.98	39	100.18	29	96.51	28
Aromatics	11.18	8	23.74	15	83.98	24	99.59	29
Transient industrial			14.14	9				

This table is cited from the studies of Buzcu, B., and Fraser, M. P.: Source identification and apportionment of volatile organic compounds in Houston, TX, Atmos. Environ., 40, 2385-2400, https://doi.org/10.1016/j.atmosenv.2005.12.020, 2006.

4. Line 240 – revise this sentence "…species had no the change…"

Response: Thanks for your advice. We have revised this sentence in the modified manuscript (on the lines 259-261). The specific details are as follows:

"and the concentration ratios of two homologous VOC species remained unchanged during the transport process from source emissions to the receptor measured sites"

5. Line 340 – Formed by oxidation **of precursors** with OH radicals, …

Response: Thanks for your advice. The related description has been modified in the revised manuscript (on the line 364).

6. Line 343 – Is there a reason why this tracer method is presented as only used with OVOCs? The same method can be used to retrieve emission ratios of hydrocarbons by simply removing the precursor term. In general, you should note equation 8 (and similar can be said for many other methods discussed here) represents one use case and can be adapted to an individual study. For example, more than one tracer can be used to address multiple emissions sources and apportion a VOC of interest.

Response: Thanks for your comments.

(1) The tracer method you mentioned was not only used for OVOCs. It was also used for the PAMS species in this study, as shown in Eq. (2). Tracers are low reactivity species (e.g., CO, benzene, and acetylene) listed in Table S7 of this study. The changes in the emission ratios of active VOC species to tracer species can be used to estimate the ages of photochemical exposure (de Gouw et al., 2005, 2017, 2018). The principle in Eq. (8) was mainly that the observed OVOC concentration was equal to the sum of the ambient OVOCs after chemical losses emitted from different sources (primary and secondary) as described in lines 400-406 of the text. Therefore, to deduct the impacts of photochemical losses, Eq. (8) used the emission ratios of active species to

tracer species to estimate the OVOC concentration after chemical losses from source emissions. Similarly, when estimating the photochemical exposure ages of PAMS species (as shown in Eq. (2)), the emission ratios of active VOC species to inert species (i.e., the initial species ratios) were also required (as shown in Table S6), where inert species were the tracer species. Meanwhile, this study systematically analyzed the estimation methods and specific values of the initial emission ratios of active species and tracer species in the reviewed literature (on the lines 238-288). Therefore, this tracer method has been used to estimate the photochemical age exposure of PAMS and OVOC species, but the wording or statement varied in different literature studies.

(2) Yes, the method based on the emission ratios of VOC reactive species to tracer species could be applied to many research fields, and Eq. (8) was also one of the application cases. For example, this method could be applied to estimate the reaction/exposure time between VOCs and ozone. de Gouw et al. (2017) have developed the related estimating method, and Wang et al. (2024) also used it for applied research. We have also added the related descriptions and analyses in the main text (on the lines 185-186). Of course, you mentioned that it was also feasible to use multiple tracers to apportion a VOC source of interest.

References:

de Gouw, J. A., Gilman, J. B., Kim, S. W., Alvarez, S. L., Dusanter, S., Graus, M., Griffith, S. M., Isaacman-VanWertz, G., Kuster, W. C., Lefer, B. L., Lerner, B. M., McDonald, B. C., Rappenglück, B., Roberts, J. M., Stevens, P. S., Stutz, J., Thalman, R., Veres, P. R., Volkamer, R., Warneke, C., Washenfelder, R. A., and Young, C. J.: Chemistry of volatile organic compounds in the Los Angeles Basin: Formation of oxygenated compounds and determination of emission ratios, J. Geophys. Res. Atmos., 123, 2298-2319, https://doi.org/10.1002/2017JD027976, 2018.

de Gouw, J. A., Gilman, J. B., Kim, S.-W., Lerner, B. M., Isaacman-VanWertz, G., McDonald, B. C., Warneke, C., Kuster, W. C., Lefer, B. L., Griffith, S. M., Dusanter, S., Stevens, P. S., and Stutz, J.: Chemistry of volatile organic compounds in the Los Angeles Basin: Nighttime removal of alkenes and determination of emission ratios, J. Geophys. Res., 122, 11843-11861, https://doi.org/10.1002/2017JD027459, 2017.

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7. Line 386-389 – Of the references used just here, Wang et al., 2017 introduced the *m* coefficient, not Huang et al., nor Zhu et al. Also, I think you mis-cite de Gouw et al., 2005 when mentioning that photolysis is proportional to OH – given that you mention that de Gouw et al., 2005 don't consider photolytic losses in the first place. Perhaps you meant de Gouw et al., 2018 (cited alongside Wang et al, 2017 by Huang et al.'s discussion of this topic)?

Response: Thanks for your comments. (1) We conducted careful verification and found that it was indeed Wang et al. (2017) who first introduced the *m* coefficient. Meanwhile, Huang et al. (2020) and Zhu et al. (2021) also used this coefficient for related applied studies. According to your comments, we have revised the relevant descriptions in the text (on the lines 410-415).

(2) Yes, the citation of de Gouw et al. (2005) was indeed incorrect. We checked the relevant literature again regarding the contents: "photolysis rate is proportional to the •OH reaction rate", and found that your comment was correct. We have changed de Gouw et al. (2005) to de Gouw et al. (2018) in the text (on the line 412).

References:

de Gouw, J. A., Gilman, J. B., Kim, S. W., Alvarez, S. L., Dusanter, S., Graus, M., Griffith, S. M., Isaacman-VanWertz, G., Kuster, W. C., Lefer, B. L., Lerner, B. M., McDonald, B. C., Rappenglück, B., Roberts, J. M., Stevens, P. S., Stutz, J., Thalman, R., Veres, P. R., Volkamer, R., Warneke, C., Washenfelder, R. A., and Young, C. J.: Chemistry of volatile organic compounds in the Los Angeles Basin: Formation of oxygenated compounds and determination of emission ratios, J. Geophys. Res. Atmos., 123, 2298-2319, https://doi.org/10.1002/2017JD027976, 2018.

Huang, X.-F., Zhang, B., Xia, S.-Y., Han, Y., Wang, C., Yu, G.-H., and Feng, N.: Sources of oxygenated volatile organic compounds (OVOCs) in urban atmospheres in North and South China, Environ. Pollut., 261, 114152, https://doi.org/10.1016/j.envpol.2020.114152, 2020.

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Zhu, B., Huang, X.-F., Xia, S.-Y., Lin, L.-L., Cheng, Y., and He, L.-Y.: Biomass-burning emissions could significantly enhance the atmospheric oxidizing capacity in continental air pollution, Environ. Pollut., 285, 117523, https://doi.org/10.1016/j.envpol.2021.117523, 2021.

8. Section 3.2 – there is no real discussion/synthesis of ideas here. This section reads more like an introduction than results.

Response: Thanks for your comments. Combined with the suggestions of other reviewers, Section 3.2 has been comprehensively modified (on the lines 466-499). This section primarily analyzed the impacts of VOC reactive losses on source analyses, including the impacts on the apportioned factor profiles (on the lines 472-482) and the impacts on the apportioned source contributions (on the lines 483-499). For the impacts of factor profiles, reactive losses substantially reduced the concentrations of highly reactive VOC species in the PMF apportioned factor profiles (on the lines 472-474), and then illustrated by examples (on the lines 474-482). For the impacts of source contributions, reactive losses can result in the substantial underestimation of the PMF apportioned contributions of sources that emitted highly reactive species (on the lines 483-485), and then illustrated by examples (on the lines 485-499). Specific modified details are as follows:

"3.2 Effects of reactive losses on source analyses

According to the review of relevant publications, it was found that most of the current studies analyzed the impacts of VOC photochemical losses on the source analyses by comparing the PMF

apportioned results based on measured and initial concentrations estimated by a photochemical age-based parameterization method (Gao et al., 2018; Gu et al., 2023; Kong et al., 2023; Li et al., 2023; Liu et al., 2023c; Zou et al., 2023) or comparing the apportioned results based on the daytime and nighttime VOCs data (Liu et al., 2025). Reactive losses substantially reduced the concentrations (ppbv/ppbv) of highly reactive VOC species in PMF resolved factor profiles based on the measured data. For example, Liu et al. (2023a) investigated the impacts of photochemical losses of ambient VOCs on the PMF resolved profiles by comparing the initial and measured data results. They found that the concentrations of VOC species with relatively low reactivities (e.g., ethane, propane, n-butane, and i-butane) were higher in the factor profiles apportioned from the measured data, while those of VOC species with relatively high reactivities (e.g., m,p-xylene, isoprene, and propene) were lower in the measured data resolved profiles. Gu et al. (2023) also reported the similar results. Meanwhile, Liu et al. (2025) also reported that reactive losses clearly reduced the concentrations of dominant VOC species with high reactivities in the profiles of solvent use, petrochemical industry emissions, and combustion sources by comparing the daytime and nighttime resolved profiles.

Additionally, VOC reactive losses can result in the substantial underestimation of the PMF apportioned contributions of sources that emitted highly reactive species, and emission sources with substantially underestimated contributions varied in different cities. For example, Wang et al. (2013) found that the contributions of biogenic and industrial emissions in Shanghai were underestimated by 30% and 10%, respectively, due to photochemical reactive losses. He et al. (2024) found that the underestimations of industrial source contributions in Guangzhou were markedly higher than those of other sources. Liu et al. (2023a) suggested that biogenic emissions and polymer production-related industrial sources in Tianjin were underestimated by 73% and 50%, respectively. In addition, Wu et al. (2023a), Zhang et al. (2024), and Gu et al. (2023) also suggested that the underestimations of contributions of biogenic emissions in Beijing, Langfang, and Qingdao were substantially higher than those of any other sources. However, Wang et al. (2024a) found that the contributions of solvent usage and biomass burning in Zhengzhou were underestimated by 31.5% and 15.4%, higher than other sources. Cui et al. (2024) suggested that the contributions of petrochemical industries, diesel vehicle emissions, biogenic emissions, and oxidation formation in Shijiazhuang were underestimated by 72.0 %, 71.0 %, 64.5 %, and 44.0 %, respectively. However, due to the uncertainty of initial concentration estimation, the reliability of these results needs further validation and evaluation. Thus, further research is required."

9. Figure 2 – I may be misunderstanding; should the sum of the measured concentration and reactive loss bars add up to the initial concentration bar?

Response: Thanks for your comments. Yes, your understanding was correct here. The sum of the measured and reaction loss concentrations was initial concentration. We carefully verified the data in Figure 2 and found that there was an error for Qingdao data. We have made the necessary corrections. Meanwhile, according to reviewing recent research literature, we have also added data from other cities.

10. Figure 2 – it would reduce ambiguity to add a line between the panels and the dots representing the cities.

Response: Thanks for your advice. Figure 2 has been revised in the modified manuscript. Meanwhile, for the convenience of red/green colorblind readers, the colors of the bar chart in Figure 2 have also been revised. The modified Figure 2 is as follows:

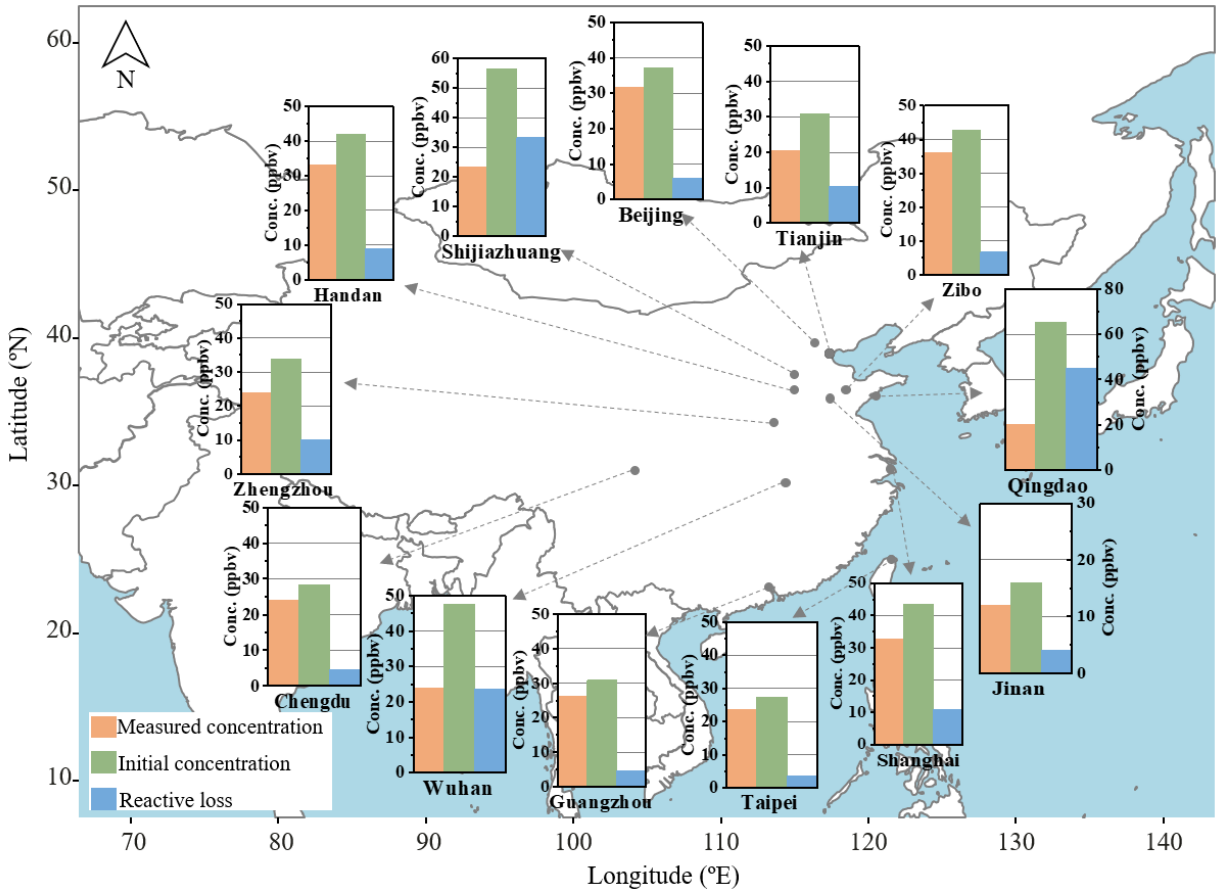

Figure 2. The measured, initial, and reactive loss concentrations of ambient VOCs in Beijing (Gao et al., 2018; Ma et al., 2022; Zhan et al., 2021), Tianjin (Liu et al., 2023a; Wang et al., 2023), Shanghai (Ren et al., 2024; Wang et al., 2013), Chengdu (Kong et al., 2023), Guangzhou (He et al., 2024; Wang et al., 2023), Qingdao (Gu et al., 2023), Shijiazhuang (Cui et al., 2024), Jinan (Liu et al., 2023c), Zhengzhou (Wang et al., 2024a), Wuhan (Xu et al., 2023), Handan (Wei et al., 2022), Zibo (Wang et al., 2024b), and Taipei (Chen et al., 2023). The data in Beijing, Tianjin, Shanghai, and Guangzhou was the average from all published papers data. The base map is from Natural Earth.

11. Figure 3 – Some clean-up is necessary. Beijing b panel, some percentages overlap. All pie charts, the small fractions (e.g., 0.2% in the Tianjin panel) are impossible to see the color/VOC class. Also, be mindful of red/green colorblind readers.

Response: Thanks for your comments. Figure 3 has been revised based on your suggestions. Meanwhile, according to recent literature review, this study has added data from some cities in Figure 3. Meanwhile, the data in Figure 3 has also been verified and appropriately modified. The modified Figure 3 is as follows:

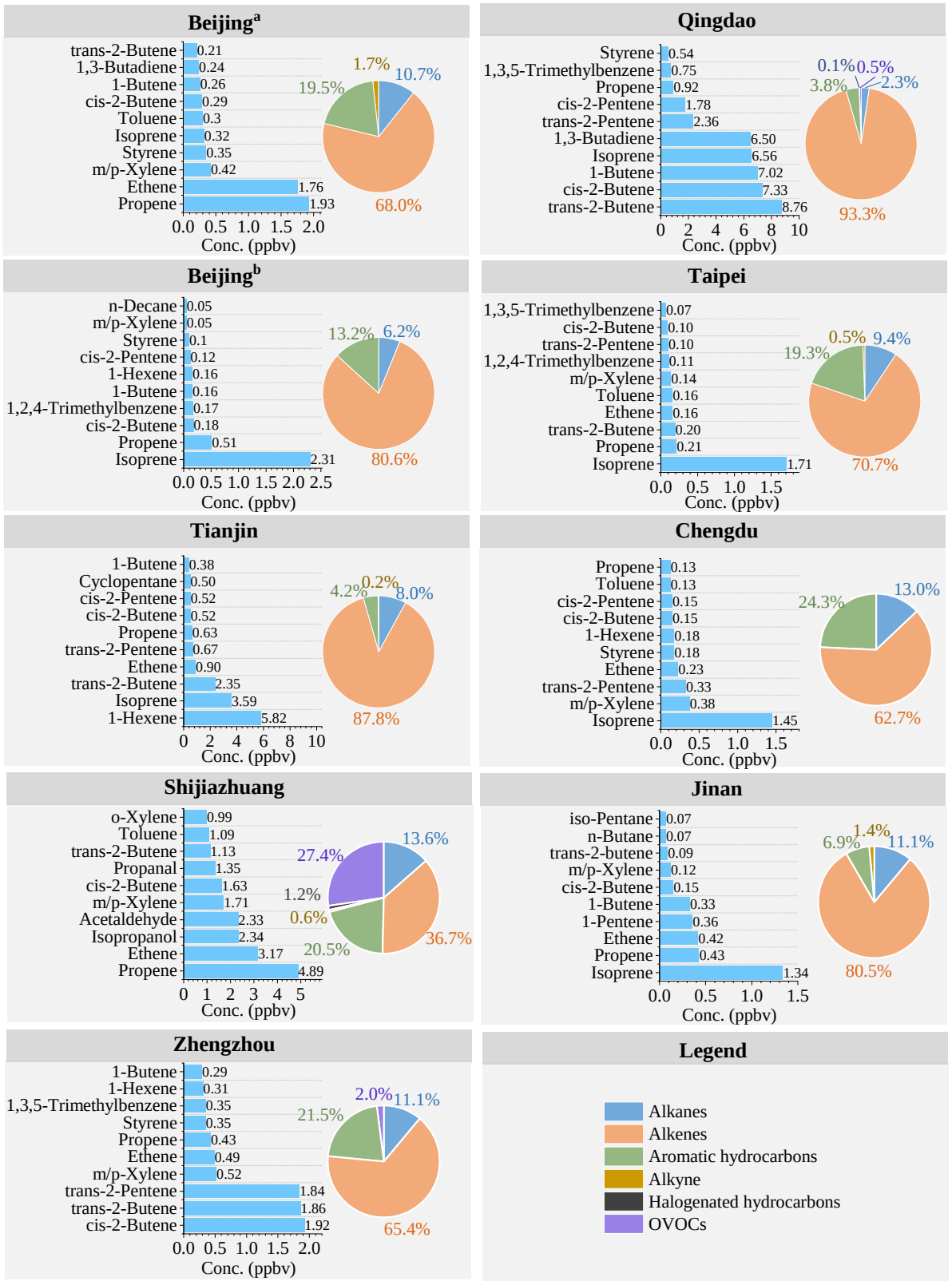

Figure 3. The photochemical losses and percentages of the main VOCs in Beijing (a: cited from publication (Gao et al., 2018) and b: cited from publication (Zhan et al., 2021)), Qingdao (Gu et

al., 2023), Taipei (Chen et al., 2023), Tianjin (Liu et al., 2023a), Chengdu (Kong et al., 2023), Shijiazhuang (Cui et al., 2024), Jinan (Liu et al., 2023c), and Zhengzhou (Wang et al., 2024a).

12. Table S6 – specify **local** time in the table header.

Response: Thanks for your advice. We have added local time (LT) to the table header in Table S6 of revised supplementary materials.

References

de Gouw, J. A., Gilman, J. B., Kim, S.-W., Alvarez, S. L., Dusanter, S., Graus, M., Griffith, S. M., Isaacman-VanWertz, G., Kuster, W. C., Lefer, B. L., Lerner, B. M., McDonald, B. C., Rappenglück, B., Roberts, J. M., Stevens, P. S., Stutz, J., Thalman, R., Veres, P. R., Volkamer, R., Warneke, C., Washenfelder, R. A., and Young, C. J.: Chemistry of Volatile Organic Compounds in the Los Angeles Basin: Formation of Oxygenated Compounds and Determination of Emission Ratios, J. Geophys. Res. Atmospheres, 123, 2298–2319, https://doi.org/10.1002/2017JD027976, 2018.