We thank the reviewers for the constructive comments and suggestions, which are very helpful to improve scientific content of the manuscript. We have revised the manuscript accordingly and addressed all the reviewers' comments point-by-point for consideration as below. The remarks from the reviewers are shown in black, and our responses are shown in blue color. All the page and line numbers mentioned following are refer to the revised manuscript without change tracked.

Reviewer #1

The manuscript Parameterized reactivity of hydroxy radical, ozone, nitrate radical and atmospheric oxidation capacity during summer at a suburban site between Beijing and Tianjin by Yang et al. describes atmospheric reactivities towards OH, ozone and nitrate of several trace gases and their oxidation capacities from measurements of trace gases conducted during one-month of field campaign in Xiang he during summer 2018. The authors use an extensive dataset of concentrations of trace gases, including O3, NOx, NOy, SO2, CO and VOCs, with meteorological parameters and photolysis frequencies for calculating OH, O3 and NO3 reactivities as well as their atmospheric oxidation capacities and describe the current air chemistry over the region during summertime when photochemistry is enhanced. I find the manuscript interesting in the way it addresses the air chemistry regime over a sensitive highly polluted region and suggests how to implement current environmental policies for improving the quality of air. I would have found the manuscript more accurate if OH/NO3 reactivities could be measured along with the trace gases during the campaign. Calculated reactivities need the associated uncertainty (from the measurements and from the reactions constants). Additionally, the parametrization used to determine the oxidation capacity needs better description and the associated uncertainty. Nevertheless, I find the manuscript suitable for the journal ACP and I recommend its publication after some changes will be considered.

General comment:

I suggest to include a short comment in the discussion of the results considering the missing reactivity fractions reported in highly polluted urban/suburban environments and studies in China, where available. This could possibly lead to different (more pessimistic or optimistic) scenarios than the one reported in the present study that is worth knowing to the reader. The manuscript is sometimes not very fluent either for the intensive use of acronyms or language phrasing, making the reading at times a bit complicated. I suggested some rephrasing but you might want to improve the fluency by making some concepts more concise and use a simplified nomenclature. I also suggest to revise the length of the abstract, of keywords used, number of figures and some parts of the discussion. You might also want to reconsider the title for a shorter one (for example, something like: parameterized atmospheric reactivity and oxidation capacity during summer :).

Response: we thank the reviewer for the positive comments. We added discussions about the missing reactivity reported in polluted environment in China (Line 384-391 in the revised version). Also, the manuscript has been shortened considerably and the title has been changed according to the suggestion.

Specific comments:

p.2 L26 “that result”

Response: Thanks for the suggestion. We have corrected the ‘resulted’ to ‘result’. Please refer to Line 32 in the revised version.

p. 2 L27 “the air chemistry” instead of self-cleansing capacity

Response: The ‘self-cleansing capacity’ have been corrected to ‘the air chemistry’. Please refer to Line 33 in the revised version.

p.2 L30 which network? Specify. Avoid references in the abstract as the personal communication.

Response: Thanks for the suggestion. Relying on the Campaign on Atmospheric Aerosol Research network of China

(CARE-China) launched by the Chinese Academy of Sciences (CAS) in 2011 (Xin et al., 2015), field VOC samples were collected simultaneously at 29 sites across China from 2012 to 2014. In order to avoid references in the abstract as the personal communication, we decided to delete the statement 'The site had suffered the most abundant annual mean VOCs concentrations according to a network observation from 2012-2014 (personal communication)'.

Reference:

Xin, J. Y., Wang, Y. S., Pan, Y. P., Ji, D. S., Liu, Z. R., Wen, T. X., Wang, Y. H., Li, X. R., Sun, Y., Sun, J., Wang, P. C., Wang, G. H., Wang, X. M., Cong, Z. Y., Song, T., Hu, B., Wang, L. L., Tang, G. Q., Gao, W. K., Guo, Y. H., Miao, H. Y., Tian, S. L., and Wang, L.: The Campaign on Atmospheric Aerosol Research Network of China Care-China, B Am Meteorol Soc, 96, 1137-1155, do i:10.1175/Bams-D-14-00039.1, 2015.

p.2 L35 use 48-99%

Response: Thanks for the suggestion. 47, 99 and 99% were used instead of 43-99%. Please refer to Line 39 in the revised version.

p.2 L 36-40 try rephrasing with less acronyms

Response: We have rewritten the sentence as follows:

Alkenes dominated the OH, NO_3 and O_3 reactivities towards total non-methane volatile organic compounds (NMVOCs), accounting for 42.9%, 77.8% and 94.0%, respectively. The total OH, NO_3 and O_3 reactivities displayed a similar diurnal variation with the lowest during the afternoon but the highest during the rush hours, and the diurnal profile of NOx appears to be the major driver for the diurnal profiles of the three oxidant reactivities. Please refer to Line 39-43 in the revised version.

p.2 L40-43 give less details as the calculation is not yet explained

Response: Thanks for the suggestion. We have explained the calculation. The AOC was confirmed by quantifying the loss rates of NMVOCs, CH_4 and CO via reactions with OH, O_3 and NO_3 (Line 295-301 in the revised version).

p.2 L43-47 Leave out this information

Response: We have left out this information.

p.3 L47-49 Keep this information

Response: Thanks for the suggestion. We have kept this information. Please refer to Line 49-50 in the revised version.

p.3 L49-51 For conclusions

Response: Thanks for the suggestion. we revised this sentence as 'We suggest that further studies, especially direct observations of OH and NO_3 radicals concentrations and their reactivities, are required to better understanding the trace gas reactivity and AOC.' Please refer to Line 50-52 in the revised version.

p.3 L52 suggested keywords: VOCs, atmospheric oxidants reactivity, atmospheric oxidizing capacity, North China Plain

Response: We have followed the comments and the keywords has been corrected to 'VOCs, atmospheric oxidants reactivity, atmospheric oxidation capacity, North China Plain'. Please refer to Line 54 in the revised version.

p.4 L70 give an estimate

Response: Thanks for the suggestion. We cannot give an estimate. So, we have restructured this sentence as follows: In the planetary boundary layer, high concentrations of primary pollutants, such as carbon monoxide (CO), nitrogen oxides ($NOx=NO+NO_2$) and volatile organic compounds (VOCs) from both biogenic and anthropogenic origins, are transformed by reactions with atmospheric oxidants, such as hydroxyl (OH) radicals, nitrate (NO_3) radicals, chlorine atom and ozone (O_3) on local to global scales (Atkinson and Arey, 2003;Heard and Pilling, 2003;Lu et al., 2018), with the dominant reaction depending on the time of day and specific trace gases. Please refer to Line 57-62 in the revised version.

References:

Atkinson, R., and Arey, J.: Atmospheric Degradation of Volatile Organic Compounds., Chemical Reviews, 103,

4605-4638, doi:10.102/cr0206420, 2003.

Heard, D. E., and Pilling, M. J.: Measurement of OH and HO_2 in the troposphere, Chemical Reviews, 103, 5163-5198, doi:10.1021/cr020522s, 2003.

Lu, K., Guo, S., Tan, Z., Wang, H., Shang, D., Liu, Y., Li, X., Wu, Z., Hu, M., and Zhang, Y.: Exploring the Atmospheric Free Radical chemistry in China: The Self-Cleansing Capacity and the Formation of Secondary air Pollution, National Science Review, doi:10.1093/nsr/nwy073, 2018.

p.4 L72 remove a major part

Response: We have removed 'a major part'. Please refer to Line 59 in the revised version.

p.4 L72 by reactions with atmospheric oxidants

Response: The 'by reactions with free radicals' have been replaced with 'by reactions with atmospheric oxidants.' Please refer to Line 59 in the revised version.

p.4 L80 comparative reactivity method cit. Sinha et al., 2008

Response: Thanks for the suggestion. Sinha et al., 2008 has been cited after "… a comparative rate method" as follows: The online techniques used to determine OH reactivity include the flow tube with sliding injector method (Kovacs et al., 2003), a comparative rate method (Sinha et al., 2008) and a laser flash photolysis pump probe technique (Whalley et al., 2016). Please refer to Line 72-75 in the revised version.

References:

Kovacs, T. A., Brune, W. H., Harder, H., Martinez, M., Simpas, J. B., Frost, G. J., Williams, E., Jobson, T., Stroud, C., Young, V., Fried, A., and Wert, B.: Direct measurements of urban OH reactivity during Nashville SOS in summer 1999, J Environ Monitor, 5, 68-74, doi:10.1039/b204339d, 2003.

Sinha, V., Williams, J., Crowley, J. N., and Lelieveld, J.: The Comparative Reactivity Method – a new tool to measure total OH Reactivity in ambient air, Atmos. Chem. Phys., 8, 2213-2227, doi:10.5194/acp-8-2213-2008, 2008.

Whalley, L. K., Stone, D., Bandy, B., Dunmore, R., Hamilton, J. F., Hopkins, J., Lee, J. D., Lewis, A. C., and Heard, D. E.: Atmospheric OH reactivity in central London: observations, model predictions and estimates of in situ ozone production, Atmos Chem Phys, 16, 2109-2122, doi:10.5194/acp-16-2109-2016, 2016.

p.5 L93 you can add the study of Helsinki (Praplan et al.) and of Seoul (Kim et al.)

Response: We added the study of Helsinki (Praplan et al.) and of Seoul (Kim et al.) as follows:

The urban areas investigated included Nashville, USA (SOS) (Kovacs et al., 2003), New York, USA (PMTACS-NY2004) (Ren et al., 2006a), Mexico City, Mexico (MCMA-2003) (Shirley et al., 2006), Houston, USA (TRAMP2006) (Mao et al., 2010), Paris, France (MEGAPOLI) (Dolgorouky et al., 2012), London, UK (ClearfLo) (Whalley et al., 2016), Helsinki, Finland (Praplan et al., 2017), Seoul, South Korea (Kim et al., 2016) and Beijing, China (Yang et al., 2017). Please refer to Line 76-81 in the revised version.

References:

Dolgorouky, C., Gros, V., Sarda-Esteve, R., Sinha, V., Williams, J., Marchand, N., Sauvage, S., Poulain, L., Sciare, J., and Bonsang, B.: Total OH reactivity measurements in Paris during the 2010 MEGAPOLI winter campaign, Atmos Chem Phys, 12, 9593-9612, doi:10.5194/acp-12-9593-2012, 2012.

Kim, S., Sanchez, D., Wang, M., Seco, R., Jeong, D., Hughes, S., Barletta, B., Blake, D. R., Jung, J., Kim, D., Lee, G., Lee, M., Ahn, J., Lee, S. D., Cho, G., Sung, M. Y., Lee, Y. H., Kim, D. B., Kim, Y., Woo, J. H., Jo, D., Park, R., Park, J. H., Hong, Y. D., and Hong, J. H.: OH reactivity in urban and suburban regions in Seoul, South Korea - an East Asian megacity in a rapid transition, Faraday Discuss, 189, 231-251, doi:10.1039/c5fd00230c, 2016.

Kovacs, T. A., Brune, W. H., Harder, H., Martinez, M., Simpas, J. B., Frost, G. J., Williams, E., Jobson, T., Stroud, C., Young, V., Fried, A., and Wert, B.: Direct measurements of urban OH reactivity during Nashville SOS in summer 1999, J Environ Monitor, 5, 68-74, doi:10.1039/b204339d, 2003.

Mao, J., Ren, X., Chen, S., Brune, W. H., Chen, Z., Martinez, M., Harder, H., Lefer, B., Rappenglück, B., Flynn, J., and Leuchner, M.: Atmospheric oxidation capacity in the summer of Houston 2006: Comparison with summer measurements in other metropolitan studies, Atmos Environ, 44, 4107-4115, doi:10.1016/j.atmosenv.2009.01.013, 2010.

Praplan, A. P., Pfannerstill, E. Y., Williams, J., and Hellén, H.: OH reactivity of the urban air in Helsinki, Finland, during winter, Atmos Environ, 169, 150-161, doi:10.1016/j.atmosenv.2017.09.013, 2017.

Ren, X., Brune, W. H., Mao, J., Mitchell, M. J., Lesher, R. L., Simpas, J. B., Metcalf, A. R., Schwab, J. J., Cai, C., and Li, Y.: Behavior of OH and HO_2 in the winter atmosphere in New York City, Atmos Environ, 40, 252-263, doi:10.1016/j.atmosenv.2005.11.073, 2006.

Shirley, T. R., Brune, W. H., Ren, X., Mao, J., Lesher, R., Cardenas, B., Volkamer, R., Molina, L. T., Molina, M. J., Lamb, B., Velasco, E., Jobson, T., and Alexander, M.: Atmospheric oxidation in the Mexico City Metropolitan Area (MCMA) during April 2003, Atmos Chem Phys, 6, 2753-2765, doi:10.5194/acp-6-2753-2006, 2006.

Whalley, L. K., Stone, D., Bandy, B., Dunmore, R., Hamilton, J. F., Hopkins, J., Lee, J. D., Lewis, A. C., and Heard, D. E.: Atmospheric OH reactivity in central London: observations, model predictions and estimates of in situ ozone production, Atmos Chem Phys, 16, 2109-2122, doi:10.5194/acp-16-2109-2016, 2016.

Yang, Y., Shao, M., Keßel, S., Li, Y., Lu, K., Lu, S., Williams, J., Zhang, Y., Zeng, L., Nölscher, A. C., Wu, Y., Wang, X., and Zheng, J.: How the OH reactivity affects the ozone production efficiency: case studies in Beijing and Heshan, China, Atmos Chem Phys, 17, 7127-7142, doi:10.5194/acp-17-7127-2017, 2017.

p.5 L100 you can add the study done in the PO valley (Kaiser et al., 2015) and in India (Kumar et al., 2018)

Response: Thanks for the suggestion. We have added the study done in the PO valley (Kaiser et al., 2015) and in India (Kumar et al., 2018) as follows:The suburban areas investigated included Whiteface Mountain, USA (PMTACS-NY2002) (Ren et al., 2006), Weybourne, UK (TORCH-2) (Lee et al., 2010), Yufa, China (CAREBeijing-2006) (Lu et al., 2010), Backgarden, China (PRIDE-PRD) (Lou et al., 2010), Jülich, Germany (HOx Comp) (Elshorbany et al., 2012), Ersa, Corsica (CARBOSOR-ChArMeX) (Zannoni et al., 2017), Po Valley, Italy (Kaiser et al., 2015), Indo-Gangetic Plain, India (Kumar et al., 2018) and Heshan, China (Yang et al., 2017). Please refer to Line 84-89 in the revised version.

References:

Elshorbany, Y. F., Kleffmann, J., Hofzumahaus, A., Kurtenbach, R., Wiesen, P., Brauers, T., Bohn, B., Dorn, H. P., Fuchs, H., Holland, F., Rohrer, F., Tillmann, R., Wegener, R., Wahner, A., Kanaya, Y., Yoshino, A., Nishida, S., Kajii, Y., Martinez, M., Kubistin, D., Harder, H., Lelieveld, J., Elste, T., Plass-Dülmer, C., Stange, G., Berresheim, H., and Schurath, U.: HOx budgets during HOxComp: A case study of HOx chemistry under NOx-limited conditions, Journal of Geophysical Research: Atmospheres, 117, doi:10.1029/2011jd017008, 2012.

Kaiser, J., Wolfe, G. M., Bohn, B., Broch, S., Fuchs, H., Ganzeveld, L. N., Gomm, S., Häseler, R., Hofzumahaus, A., Holland, F., Jäger, J., Li, X., Lohse, I., Lu, K., Prévôt, A. S. H., Rohrer, F., Wegener, R., Wolf, R., Mentel, T. F., Kiendler-Scharr, A., Wahner, A., and Keutsch, F. N.: Evidence for an unidentified non-photochemical ground-level source of formaldehyde in the Po Valley with potential implications for ozone production, Atmos. Chem. Phys., 15, 1289-1298, doi:10.5194/acp-15-1289-2015, 2015.

Kumar, V., Chandra, B. P., and Sinha, V.: Large unexplained suite of chemically reactive compounds present in ambient air due to biomass fires, Sci Rep-Uk, 8, 626, doi:10.1038/s41598-017-19139-3, 2018.

Lee, J. D., Young, J. C., Read, K. A., Hamilton, J. F., Hopkins, J. R., Lewis, A. C., Bandy, B. J., Davey, J., Edwards, P., Ingham, T., Self, D. E., Smith, S. C., Pilling, M. J., and Heard, D. E.: Measurement and calculation of OH reactivity at a United Kingdom coastal site, J Atmos Chem, 64, 53-76, doi:10.1007/s10874-010-9171-0, 2010.

Lou, S., Holland, F., Rohrer, F., Lu, K., Bohn, B., Brauers, T., Chang, C. C., Fuchs, H., Häseler, R., Kita, K., Kondo, Y., Li, X., Shao, M., Zeng, L., Wahner, A., Zhang, Y., Wang, W., and Hofzumahaus, A.: Atmospheric OH reactivities in the Pearl River Delta – China in summer 2006: measurement and model results, Atmos Chem Phys, 10, 11243-

11260, doi:10.5194/acp-10-11243-2010, 2010.

Lu, K., Zhang, Y., Su, H., Brauers, T., Chou, C. C., Hofzumahaus, A., Liu, S. C., Kita, K., Kondo, Y., Shao, M., Wahner, A., Wang, J., Wang, X., and Zhu, T.: Oxidant (O_3+ NO_2) production processes and formation regimes in Beijing, Journal of Geophysical Research, 115, doi:10.1029/2009jd012714, 2010.

Ren, X., Brune, W. H., Oliger, A., Metcalf, A. R., Simpas, J. B., Shirley, T., Schwab, J. J., Bai, C., Roychowdhury, U., Li, Y., Cai, C., Demerjian, K. L., He, Y., Zhou, X., Gao, H., and Hou, J.: OH, HO_2, and OH reactivity during the PMTACS-NY Whiteface Mountain 2002 campaign: Observations and model comparison, Journal of Geophysical Research: Atmospheres, 111, doi:10.1029/2005jd006126, 2006.

Yang, Y., Shao, M., Keßel, S., Li, Y., Lu, K., Lu, S., Williams, J., Zhang, Y., Zeng, L., Nölscher, A. C., Wu, Y., Wang, X., and Zheng, J.: How the OH reactivity affects the ozone production efficiency: case studies in Beijing and Heshan, China, Atmos Chem Phys, 17, 7127-7142, doi:10.5194/acp-17-7127-2017, 2017.

Zannoni, N., Gros, V., Sarda Esteve, R., Kalogridis, C., Michoud, V., Dusanter, S., Sauvage, S., Locoge, N., Colomb, A., and Bonsang, B.: Summertime OH reactivity from a receptor coastal site in the Mediterranean Basin, Atmos Chem Phys, 17, 12645-12658, doi:10.5194/acp-17-12645-2017, 2017

p.5 L101 the range will change with the measurements done in India

Response: Yes, the range has changed with the measurements done in India. Here we restructured this sentence like 'The ranges of total OH reactivity in these suburban areas ranged from 4.6 to 64 s^{-1}.' Please refer to Line 89-90 in the revised version.

p.5 L106 metric instead of matric, check also other parts of the manuscript

Response: We are apologized for the mistake. metric was used instead of matric and we have check other parts of the manuscript. Please refer to Line 94, 96 and 98 in the revised version.

p.6 L112 You can cite the study of Mogensen et al.

Response: Thanks for the suggestion. We have cited the study of Mogensen et al. as follows: The concentrations (in molecules cm^{-3}) of trace gases and the reaction rate constants (in cm^3 $molecule^{-1}$ s^{-1}) of the respective trace gases with the OH radical are the key factors for computing OH reactivity (Mogensen et al.,2011; Mogensen et al., 2015). Please refer to Line 100-102 in the revised version.

References:

Mogensen, D., Smolander, S., Sogachev, A., Zhou, L., Sinha, V., Guenther, A., Williams, J., Nieminen, T., Kajos, M. K., and Rinne, J.: Modelling atmospheric OH-reactivity in a boreal forest ecosystem, Atmospheric Chemistry & Physics, 11, 9709-9719, doi:10.5194/acp-11-9709-2011, 2011.

Mogensen, D., Gierens, R., Crowley, J. N., Keronen, P., and Smolander, S.: Simulations of atmospheric OH, O_3 and NO_3 reactivities within and above the boreal forest, Atmospheric Chemistry & Physics, 15, 3909-3932, doi:10.5194/acp-15-3909-2015, 2015.

p.6 L114 "as reported."

Response: The 'Reportedly' has been corrected to 'As reported'. Please refer to Line 103 in the revised version.

p.6 L114 contribution from NOx

Response: We have deleted 'the' before 'NO_X'. Please refer to Line 104 in the revised version.

p.6 L117 Does this comparison point at the use of different fuels/vehicles used?

Response: This comparison points at the differences of anthropogenic emissions. Mexico City sharing high NMHC due to higher biomass fuel being burned (de Gouw et al., 2006) and higher contributions from aromatics due to high industrial solvent emissions in Houston (Leuchner and Rappenglück, 2010). So, we have rewritten this sentence into 'the contribution from the VOCs reaches 50% in Mexico and Houston due to high biomass fuel being burned and industrial solvent emissions.' Please refer to Line 106-108 in the revised version.

References:

de Gouw, J. A., Warneke, C., Stohl, A., Wollny, A. G., Brock, C. A., Cooper, O. R., Holloway, J. S., Trainer, M., Fehsenfeld, F. C., Atlas, E. L., Donnelly, S. G., Stroud, V., and Lueb, A.: Volatile organic compounds composition of merged and aged forest fire plumes from Alaska and western Canada, Journal of Geophysical Research: Atmospheres, 111, D10303, doi:10.1029/2005jd006175, 2006.

Leuchner, M., and Rappenglück, B.: VOC source–receptor relationships in Houston during TexAQS-II, Atmos Environ, 44, 4056-4067, doi: 10.1016/j.atmosenv.2009.02.029, 2010.

p.6 L123 due to NO_3 elevated concentrations at night

Response: we have rewritten this sentence into ‘As OH levels are vastly reduced during nighttime due to missing photolysis, the NO_3 formed by the slow reaction of $NO_2 + O_3 \rightarrow NO_3 + O_2$ is the main initiator of nighttime oxidation chemistry in the troposphere at night.’ Please refer to Line 109-111 in the revised version.

p.7 L141 of the reactions for some alkenes…

Response: We have followed the comments and rewritten this sentence into ‘The rate constants of the reactions for some alkenes with O_3 are even comparable to those with NO_3.’ Please refer to Line 132-133 in the revised version.

p.7 L146 BERLIOZ and NOTOMO/ before write the type of environment and where then you can add in brackets the name of the campaign.

Response: Thanks for the suggestion. We have followed the comments and rewritten related sentences as follows: For instance, the total NO_3 reactivity obtained in Hyytiälä, Finland (Influence of Biosphere-Atmosphere Interactions on the Reactive Nitrogen budget (IBAIRN) campaign), displayed a strong diel variation with a campaign-averaged nighttime mean value of 0.11 s^{-1} compared to a daytime value of 0.04 s^{-1} (Liebmann et al., 2018a), but varied from 0.005 to 0.1 s^{-1} during nighttime and reached values as high as 1.4 s^{-1} in the daytime at the Taunus, Germany (NOcturnal chemistry at the Taunus Observatorium: insights into Mechanisms of Oxidation (NOTOMO) campaign) (Liebmann et al., 2017). Please refer to Line 121-128 in the revised version.

The calculated O_3 reactivity obtained at Pabstthum, Germany (Berliner Ozonexperiment (BERLIOZ) campaign) revealed that terpenes (20%), isoprene (20%), and other alkenes (60%) were the dominant contributors during the night of 20 and 21 July but arose mainly (83%) from non-biogenic alkene during the night of 4 and 5 August (Geyer, 2003). Please refer to Line 137-140 in the revised version.

References:

Geyer, A.: Nighttime formation of peroxy and hydroxyl radicals during the BERLIOZ campaign: Observations and modeling studies, Journal of Geophysical Research, 108, doi:10.1029/2001jd000656, 2003.

Liebmann, J., Karu, E., Sobanski, N., Schuladen, J., Ehn, M., Schallhart, S., Quéléver, L., Hellen, H., Hakola, H., Hoffmann, T., Williams, J., Fischer, H., Lelieveld, J., and Crowley, J. N.: Direct measurement of NO_3 radical reactivity in a boreal forest, Atmos Chem Phys, 18, 3799-3815, doi:10.5194/acp-18-3799-2018, 2018.

Liebmann, J. M., Schuster, G., Schuladen, J. B., Sobanski, N., Lelieveld, J., and Crowley, J. N.: Measurement of ambient NO_3 reactivity: design, characterization and first deployment of a new instrument, Atmos Meas Tech, 10, 1241-1258, doi:10.5194/amt-10-1241-2017, 2017.

p.7 L151-152 remove sentence

Response: We have removed the sentence.

p.8 L156 in this study, we calculated the OH, O_3 and NO_3 reactivities from VOCs measurements…

Response: We have followed the comments and rewritten this sentence into ‘In this study, we calculated the OH, O_3 and NO_3 reactivities at a suburban site (Xianghe) in the North China Plain during an intensive measurement campaign in the summer of 2018.’ Please refer to Line 144-146 in the revised version.

p.8 L158 we calculated the oxidation capacities of xx xx xx and estimated their relative contributions.

Response: We have followed the comments and rewritten this sentence into ‘By combining simulated OH and NO_3 concentrations using a box model SOSAA, we calculated the oxidation capacities of OH, NO_3 and O_3 and estimated their relative contributions' Please refer to Line 146-147 in the revised version.

p.8 L175 detection limit instead of lowest detection limit, please modify also where else is mentioned.

Response: We have changed 'lowest detection limit' to 'detection limit' and modified also where else is mentioned. Please refer to Line 160-169 in the revised version.

p.9 L190 Please refer to Wang et al., (2014b) for more details about the techniques used.

Response: Thanks for the suggestion. According to Wang et al., (2014b), we have reviewed the related statements (Line 159-181 in the revised version) as follows:

O_3 was measured using a UV photometric O_3 analyzer (Model 49C/I, Thermo-Fisher Scientific, United States) with the detection limit of 2.0 ppb, precision of ±1.0 ppb, zero drift of less than 1.0 ppb (24 h)$^{-1}$, span drift of less than 1% full scale per month, and response time of 10 s. NO_x was measured using a chemiluminescence NO_x Analyzer (Model 42C/I) with the detection limit of 0.4 ppb, precision of ±0.4 ppb, zero drift of less than 0.4 ppb (24 h)$^{-1}$, span drift of less than 1% per 24 h, and response time of 40 s. NO_y was measured using a chemiluminescence NO-DIF-NOy Analyzer (Model 42C/I) with the detection limit of 50 ppt, span drift of less than 1% per 24 h, and response time of 60 s. SO_2 was measured using a pulsed fluorescence SO_2 analyzer (Model 43C/I) with the detection limit of 0.5 ppb, precision of 1% of reading or 1 ppb, zero drift of less than 1 ppb (24 h)$^{-1}$, span drift of less than 0.5% full scale per 24 h, and response time of less than 20 s. CO was measured with a nondispersive infrared analyzer (Model 48I) with the detection limit of 0.4 ppm, a precision of 0.1 ppm, zero drift of less than 0.1 ppb (24 h)$^{-1}$, span drift of less than 0.1% full scale per 24 h, and response time of less than 60 s. These measurement instruments were housed in a container that was equipped with an air conditioner. Ambient air samples were drawn through a 3m PFA Teflon tube (outside diameter: 12.7 mm; inside diameter: 9.6 mm), and the sampling tube inlets were located 1m above the conditioner. High resolution (5 min averages) data sets of O_3, NO, NOx, NOy, SO_2 and CO were obtained, and hourly averaged data were used after applying strict data quality control. The sampling methods and instrument protocols as well as quality assurance/quality control (QA/QC) procedures for air quality monitoring are described in detail in the Chinese National Environmental Protection Standard, Automated Methods for Ambient Air Quality Monitoring (HJ/T 193–2005; State Environmental Protection Administration of China, 2006). The measurement techniques are the same as those used in Wang et al. (2014b) and Xin et al. (2012).

References:

Wang, Y. H., Hu, B., Ji, D. S., Liu, Z. R., Tang, G. Q., Xin, J. Y., Zhang, H. X., Song, T., Wang, L. L., Gao, W. K., Wang, X. K., and Wang, Y. S.: Ozone weekend effects in the Beijing–Tianjin–Hebei metropolitan area, China, Atmos Chem Phys, 14, 2419-2429, doi:10.5194/acp-14-2419-2014, 2014.

Xin, J. Y., Wang, Y. S., Tang, G. Q., Wang, L. L., Sun, Y., Wang, Y. H., Hu, B., Song, T., Ji, D. S., and Wang, W. F.: Variability and reduction of atmospheric pollutants in Beijing and its surrounding area during the Beijing 2008 Olympic Games, Chinese Sci Bull, 55, 1937-1944, doi: 10.1007/s00376-012-1227-4, 2012.

p.9 L193 remove samples

Response: We have deleted the 'samples'. Please refer to Line 182 in the revised version.

p.9 L193 Is the GC system having 2 columns or columns were exchanged on different campaign periods? Please specify

Response: The GC system have 2 columns. Column 1 is a PLOT-Al_2O_3 column (15 m × 0.32 mm ID×3 μm, J&W Scientific, USA) separating C2-C5 hydrocarbons and then measured by the FID; Column 2 is a semi polar column (DB624, 60 m × 0.25 mm ID×1.4 μm, J&W Scientific, USA) separating other compounds and then quantified using a quadrupole MS detector. The two columns were not exchanged during the intensive measurement campaign from 6 July 2018 to 6 August 2018.Please refer to Line 199-205 in the revised version.

p.9 L193 How was the sampling conducted? Which type of inlet was used? Was there any O3 scrubber used to measure alkenes? In general, are the VOC measurements and atmospheric events from this campaign described elsewhere?

Response: Briefly, Samples are collected into GC-MS/FID at a flow rate of 60 mL min^{-1} with sampling time of 5 min at the beginning of each hour. The sampling lines for ambient air and standard gases were both Teflon tubes with a 1/4-inch outside diameter (OD). A Teflon filter was placed in the inlet to prevent particulate matters from entering the instrument, and a water trap was used to remove H_2O from the air samples. Ascarite II was used to remove CO_2 and O_3 before the FID channel, whereas a Na_2SO_3 trap was used to remove O_3 in the MS channel. Please refer to Line 194-205 in the revised version. The NMVOCs measurements and atmospheric events from this campaign are not described elsewhere.

p.12 L243 Please specify how close the sensors were to the measurement area.

Response: Thanks for the suggestion. The sensors are about 3000 meters away from the measurement area. Please refer to Line 243 in the revised version.

p.12 L247 the nomenclature of radical reactivity where O_3 is considered is incorrect. Please change this word where used in the text with “atmospheric oxidants reactivity” or something similar that can commonly include OH, NO3 and O3.

Response: Thanks for the correction. Speciated oxidant reactivity was used instead of speciated radical reactivity. Please refer to Line 274 in the revised version.

p.12 L248-253 Needs rephrasing. You can express the same concept with one sentence, for example: atmospheric oxidants reactivity is a measure of the strength of reaction of trace gases to the three main atmospheric oxidants: : You can cite the first studies that introduced this concept (check for Brune et al., or Kovacs and Brune) and remove the references not needed here.

Response: We have followed the comments and expressed the same concept with one sentence as follows: Atmospheric oxidant reactivity is a measure of the strength of reaction of trace gases to the oxidant (= OH, O_3, NO_3) (Kovacs et al., 2003;Mogensen et al., 2015). High oxidant reactivity values correspond to short lifetimes and long-lived species have low reactivities. The total OH, NO_3 and O_3 reactivities can be calculated by Eq. (1)-(3), respectively. Please refer to Line 275-278 in the revised version.

References:

Kovacs, T. A., Brune, W. H., Harder, H., Martinez, M., Simpas, J. B., Frost, G. J., Williams, E., Jobson, T., Stroud, C., Young, V., Fried, A., and Wert, B.: Direct measurements of urban OH reactivity during Nashville SOS in summer 1999, J Environ Monitor, 5, 68-74, doi:10.1039/b204339d, 2003.

Mogensen, D., Gierens, R., Crowley, J. N., Keronen, P., and Smolander, S.: Simulations of atmospheric OH, O_3 and NO_3 reactivities within and above the boreal forest, Atmospheric Chemistry & Physics, 15, 3909-3932, doi:10.5194/acp-15-3909-2015, 2015.

p.12 L 247&274 You can include a table with all rate coefficients used and respective references for these 2 sections

Response: Thanks for the suggestion. We have added a table with all temperature-dependent reaction rate coefficients used and respective references, and listed them in Table S1 in supplement information as follows:

Table S1. The temperature-dependent reaction rate coefficients of trace gases with OH radical, O_3 and NO_3 radical used in this study.

Species	Temperature-dependence of k_{OH} (cm^3 $molecule^{-1}$ s^{-1})	Temperature-dependence of k_{O3} (cm^3 $molecule^{-1}$ s^{-1})	Temperature-dependence of k_{NO3} (cm^3 $molecule^{-1}$ s^{-1})
CH_4	$1.85\times10^{-12}exp(-1690/T)$	$<1\times10^{-23}$	$<1 \times 10^{-18}$
Alkanes			
Ethane	$6.9 \times 10^{-12}exp(-1000/T)$	$<1\times10^{-23}$	$<1\times10^{-17}$
Propane	$7.6 \times 10^{-12}exp(-585/T)\times0.736$	$<1\times10^{-23}$	$<7\times10^{-17}$

iso-Butane	$1.16\times10^{-17}\times T^{2}\times\exp(225/T)\times0.794$	$<1\times10^{-23}$	1.06×10^{-16}
n-Butane	$9.8\times10^{-12}\exp(-425/T)\times0.873$	$<1\times10^{-23}$	$2.8\times10^{-12}\exp(-3280/T)$
Cyclopentane	4.97×10^{-12}	$<1\times10^{-23}$	1.4×10^{-16}
iso-Pentane	3.6×10^{-12}	$<1\times10^{-23}$	1.62×10^{-16}
n-Pentane	$2.44\times10^{-17}\times T^{2}\times\exp(183/T)\times0.568$	$<1\times10^{-23}$	8.7×10^{-17}
2,2-Dimethylbutane	$3.22\times10^{-11}\exp(-781/T)\times0.632$	$<1\times10^{-23}$	4.4×10^{-16}
2,3-Dimethylbutane	$1.24\times10^{-17}\times T^{2}\times\exp(494/T)\times0.877$	$<1\times10^{-23}$	4.4×10^{-16}
2-Methylpentane	5.4×10^{-12}	$<1\times10^{-23}$	1.8×10^{-16}
3-Methylpentane	5.2×10^{-12}	$<1\times10^{-23}$	2.2×10^{-16}
n-Hexane	$1.53\times10^{-17}\times T^{2}\times\exp(414/T)\times0.061$	$<1\times10^{-23}$	1.1×10^{-16}
2,4-Dimethylpentane	4.77×10^{-12}	$<1\times10^{-23}$	1.5×10^{-16}
Methylcyclopentane	5.2×10^{-12}	$<1\times10^{-23}$	1.4×10^{-16}
2-Methylhexane	5.65×10^{-12}	$<1\times10^{-23}$	1.5×10^{-16}
2,3-Dimethylpentane	1.5×10^{-12}	$<1\times10^{-23}$	1.5×10^{-16}
Cyclohexane	$2.88\times10^{-17}\exp(309/T)$	$<1\times10^{-23}$	1.4×10^{-16}
3-Methylhexane	5.6×10^{-12}	$<1\times10^{-23}$	1.5×10^{-16}
2,2,4-Trimethylpentane	3.34×10^{-12}	$<1\times10^{-23}$	9.0×10^{-17}
n-Heptane	$1.59\times10^{-17}\times T^{2}\times\exp(478/T)$	$<1\times10^{-23}$	1.5×10^{-16}
Methylcyclohexane	4.97×10^{-12}	$<1\times10^{-23}$	1.4×10^{-16}
2,3,4-Trimethylpentane	6.6×10^{-12}	$<1\times10^{-23}$	1.9×10^{-16}
2-Methylheptane	7×10^{-12}	$<1\times10^{-23}$	1.9×10^{-16}
3-Methylheptane	7×10^{-12}	$<1\times10^{-23}$	1.9×10^{-16}
n-Octane	$2.76\times10^{-17}\times T^{2}\times\exp(378/T)$	$<1\times10^{-23}$	1.9×10^{-16}
Nonane	$2.51\times10^{-17}\times T^{2}\times\exp(477/T)$	$<1\times10^{-23}$	2.3×10^{-16}
n-Decane	$3.13\times10^{-17}\times T^{2}\times\exp(416/T)$	$<1\times10^{-23}$	2.8×10^{-16}
n-Undecane	12.3×10^{-12}	$<1\times10^{-23}$	
Alkenes			
Ethylene	$9.0\times10^{-12}\,(T/300)^{-0.85}$	$9.1\times10^{-15}\exp(-2580/T)$	$3.3\times10^{-12}\exp(-2880/T)$
Propylene	$3.0\times10^{-11}(T/300)^{-1}$	$5.5\times10^{-15}\exp(-1880/T)$	$4.6\times10^{-13}\exp(-1155/T)$
trans-2-Butene	$1.01\times10^{-11}\exp(550/T)$	$6.64\times10^{-15}\exp(-1095/T)$	3.9×10^{-13}
1-Butene	$6.6\times10^{-12}\exp(465/T)\times0.87$	9.64×10^{-18}	1.35×10^{-14}
cis-2-Butene	$1.1\times10^{-11}\exp(487/T)$	$3.22\times10^{-15}\exp(-968/T)$	3.52×10^{-13}
1,3-Butadiene	$1.48\times10^{-11}\exp(448/T)\times0.649$	$1.34\times10^{-14}\exp(-2283/T)\times0.5$	1.0×10^{-13}
1-Pentene	$5.86\times10^{-12}\exp(500/T)\times0.87$	1.06×10^{-17}	1.5×10^{-14}
trans-2-Pentene	6.7×10^{-11}	1.6×10^{-16}	3.7×10^{-13}
cis-2-Pentene	6.5×10^{-11}	1.3×10^{-16}	3.7×10^{-13}
Isoprene	$2.7\times10^{-11}\exp(390/T)$	$1.03\times10^{-14}\exp(-1995/T)$	$3.15\times10^{-12}\exp(-450/T)$
1-Hexene	3.7×10^{-11}	1.31×10^{-17}	1.8×10^{-14}
OVOCs			
HCHO	$5.4\times10^{-12}\exp(135/T)$	$<1\times10^{-20}$	5.6×10^{-16}
Acrolein	18.3	$<1\times10^{-20}$	
Propanal	$5.1\times10^{-12}\exp(405/T)$	$<1\times10^{-20}$	6.4×10^{-15}
Acetone	$8.8\times10^{-12}\exp(-1320/T)+$	$<1\times10^{-20}$	$<3\times10^{-17}$

	1.7×10^{-14} exp(423/T)		
MTBE	2.94×10^{-12}	$<1\times10^{-20}$	
Methacrolein	8.0×10^{-12}exp(380/T)	1.4×10^{-15}exp(-2100/T)	3.4×10^{-15}
n-Butanal	6.0×10^{-12}exp(410/T)	$<1\times10^{-20}$	1.7×10^{-12}exp(-1500/T)
MethylVinylKetone	2.6×10^{-12}exp(610/T)	$<1\times10^{-20}$	6.0×10^{-16}
Methylethylketone	1.5×10^{-12}exp(-90/T)×0.462	$<1\times10^{-20}$	
2-Pentanone	4.4×10^{-12}	$<1\times10^{-20}$	
Pentanal	6.34×10^{-12}exp(448/T)×0.19	$<1\times10^{-20}$	1.5×10^{-14}
3-Pentanone	2×10^{-12}	$<1\times10^{-20}$	
Hexanal	3.0×10^{-11}	$<1\times10^{-20}$	1.6×10^{-14}
Aromatics			
Benzene	2.3×10^{-12}exp(-190/T)×0.53	$<1\times10^{-20}$	3.0×10^{-17}
Toluene	1.8×10^{-12}exp(340/T)×0.18	$<1\times10^{-20}$	7.0×10^{-17}
Ethylbenzene	7×10^{-12}	$<1\times10^{-20}$	6.0×10^{-16}
m/p-Xylene	1.89×10^{-11}	$<1\times10^{-20}$	2.6×10^{-16}
o-Xylene	1.36×10^{-11}	$<1\times10^{-20}$	4.1×10^{-16}
Styrene	5.8×10^{-11}	1.7×10^{-17}	1.5×10^{-12}
Isopropylbenzene	6.3×10^{-12}	$<1\times10^{-20}$	6.0×10^{-16}
n-Propylbenzene	5.8×10^{-12}	$<1\times10^{-20}$	6.0×10^{-16}
m-Ethyltoluene	1.18×10^{-11}	$<1\times10^{-20}$	8.6×10^{-16}
p-Ethyltoluene	1.86×10^{-11}	$<1\times10^{-20}$	8.6×10^{-16}
1,3,5-Trimethylbenzene	5.67×10^{-11}	$<1\times10^{-20}$	8.8×10^{-16}
o-Ethyltoluene	1.19×10^{-11}	$<1\times10^{-20}$	8.6×10^{-16}
1,2,4-Trimethylbenzene	3.25×10^{-11}	$<1\times10^{-20}$	1.8×10^{-15}
1,2,3-Trimethylbenzene	3.27×10^{-11}	$<1\times10^{-20}$	1.9×10^{-15}
Criteria pollutants			
CO	2.4×10^{-13}		
NO	$3.3\times10^{-11}(T/300)^{-0.3}$	1.4×10^{-12}exp(-1310/T)	1.8×10^{-11}exp(110/T)
NO_2	4.1×10^{-11}	1.4×10^{-13}exp(-2470/T)	$1.9\times10^{-12}(T/300)^{0.2}$
SO_2	$1.3\times10^{-12}(T/300)^{-0.7}$		$<1.0\times10^{-19}$
O_3	1.7×10^{-12}exp(-940/T)		

Note: The temperature-dependent reaction rate coefficients of VOCs and CO are from Atkinson et al. (1983), Atkinson and Arey (2003), Atkinson et al. (2006), Salgado et al. (2008) and the Master Chemical Mechanism, MCM v3.3.1 via the website: http://mcm.leeds.ac.uk/MCM (last accessed: 25 March 2020); The temperature-dependent reaction rate coefficients of NO, NO_2, SO_2 and O_3 are from Atkinson et al. (2004). T denotes temperature.

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p.16 L331 Define OVOC

Response: Thanks for the suggestion. OVOCs is the acronym of oxygenated VOCs. Please refer to Line 212 in the revised version.

p.16 L335 I suggest to avoid the use of many acronyms when is not extremely needed, TVOC can be written as total VOC. There are many acronyms in the manuscript and the reader is sometimes lost.

Response: Thanks for the suggestion. We have avoided the use of many acronyms, which is not extremely needed. TVOCs have been written as total NMVOCs. Please refer to Line 349-351 in the revised version.

p.16 L348 for secondary species

Response: We have deleted the 'a' before secondary species. Please refer to Line 368 in the revised version.

p.16 L351-352 remove lines

Response: We have deleted the lines.

p.23 L503-505 You can shorten the discussion by removing from which are 3 etc.

Response: We have shortened the discussion as follows:

This result can be largely accounted for by the generally large NO reaction rate coefficients with O_3 (1.8×10^{-14} cm^3 $molecule^{-1}$ s^{-1}) (Atkinson et al., 2006a), which are several orders of magnitude higher than the NO_2, alkanes, alkenes, aromatics, OVOCs and isoprene reaction rate coefficients with NO_3 (Atkinson et al., 2006b;Atkinson and Arey, 2003;Yuan et al., 2013;Ferracci et al., 2018;Jenkin et al., 2015). Please refer to Line 502-506 in the revised version.

References:

Atkinson, R., and Arey, J.: Atmospheric Degradation of Volatile Organic Compounds., Chemical Reviews, 103, 4605-4638, doi:10.102/cr0206420, 2003.

Atkinson, R., Baulch, D. L., Cox, R. A., Crowley, J. N., Hampson, R. F., Hynes, R. G., Jenkin, M. E., Rossi, M. J., and Troe, J.: Evaluated kinetic and photochemical data for atmospheric chemistry: Volume II – gas phase reactions of organic species, Atmos Chem Phys, 6, 3625-4055, doi:10.5194/acp-6-3625-2006, 2006a.

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p.25 L543-555 Please make the concept more concise and present it in the methods part

Response: Thanks for the suggestion. We have made the concept more concise and presented it in the methods part (Line 302-316 in the revised version) as follows:

2.5 O_3 formation regime

Photochemical formation is the main source of ground-level O_3, and VOCs, CO and NO_x are they key precursors of tropospheric O_3 (Atkinson, 2000). The production of O_3 is generally limited by VOCs or NO_x or by both VOCs and NO_x (Lu et al., 2010; Tang et al., 2012; Li et al., 2019). However, O_3 formation is neither linearly dependent on NO_x concentration nor VOCs reactivity (Pfannerstill et al., 2019); reductions in the emissions of these precursors can decrease, increase, or leave the O_3 production rate unchanged (Pusede and Cohen, 2012). Considering that the impact of VOCs on O_3 formation was more closely related to the reactivity of individual VOC species than to the amount of total VOCs, defining O_3 production regimes in terms of the OH reactivities of VOCs and NOx is also a way of assessing the sensitivity of O_3 production to the prevailing conditions (Kirchner et al., 2001; Lyu et al., 2019; Pfannerstill et al., 2019; Sinha et al., 2012). In this study, we used the relative reactivity (s) of OH towards NO_x and VOCs to evaluate the O_3 production sensitivity, as suggested by Kirchner et al. (2001). The thresholds of the s are 0.2 and 0.01. When $s > 0.2$ it indicates VOC limitation, $0.01<s<0.2$ it is limited by both VOCs and NO_x, and $s < 0.01$ it is limited by NO_x.

References:

Atkinson, R.: Atmospheric chemistry of VOCs and NOx, Atmos Environ, 34, 2063-2101, doi:10.1016/S1352-2310(99)00460-4, 2000.

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Pfannerstill, E. Y., Wang, N. J., Edtbauer, A., Bourtsoukidis, E., Crowley, J. N., Dienhart, D., Eger, P. G., Ernle, L., Fischer, H., Hottmann, B., Paris, J. D., Stonner, C., Tadic, I., Walter, D., and Williams, J.: Shipborne measurements of total OH reactivity around the Arabian Peninsula and its role in ozone chemistry, Atmos Chem Phys, 19, 11501-11523, 10.5194/acp-19-11501-2019, 2019.

Pusede, S. E., and Cohen, R. C.: On the observed response of ozone to NOx and VOC reactivity reductions in San Joaquin Valley California 1995–present, Atmos Chem Phys, 12, 8323-8339, doi:10.5194/acp-12-8323-2012, 2012.

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Tang, G., Wang, Y., Li, X., Ji, D., Hsu, S., and Gao, X.: Spatial-temporal variations in surface ozone in Northern China as observed during 2009–2010 and possible implications for future air quality control strategies, Atmos Chem Phys, 12, 2757-2776, doi:10.5194/acp-12-2757-2012, 2012.

p.26 L569 This is an interesting section. Can you implement the discussion by indicating the sources of the VOCs whose concentration could be limited and make some concrete examples for the region under study?

Response: Thanks for the suggestion. We agreed that identifying the possible sources of the VOCs whose concentration could be limited is important to provide recommendations for future policies. So, the origin of key species was initially identified based on the certain chemical tracers which are generally presumed to be emitted from specific sources and present in significant amounts in the collected samples. Please refer to Line 567-570 and 584-588 in the revised version.

p.30 L644 what do you mean exactly by integral of the oxidation rate? This concept needs to be clarified. Can you (briefly) illustrate the 2 type of concepts of the oxidation rate results in the method section? Same for what you are illustrating in figures 10 &13. Also, it is confusing using both approaches, you might want to make a table with the results from the 2 approaches and discuss the differences rather than discuss the two of them separately, it will make the discussion part also clearer.

Response: Thanks for the suggestion. We are sorry for this confusing statement of integral of the oxidation rate in the previous manuscript, and ‘averaged loss rates’ was used instead of ‘integral of the oxidation rate’ in the revised version. Please refer to Line 662 in the revised version.

The concept of the oxidation rate is same as AOC. The Figure 10 in the previous manuscript (Figure 9 in the revised version) shows the overall loss rate of NMVOCs, CH_4 and CO via reactions with OH, O_3 and NO_3, but Figure 13 in the previous manuscript (Figure S17 in the revised version) shows the loss rate of NMVOCs groups, illustrating the relative importance of speciated NMVOCs oxidation pathways.

p.31 L682-683 is overestimated

Response: We have removed the sentence in that we have simulated the OH and NO_3 mixing ratios using atmospheric chemistry transport model SOSAA.

Figures

Fig 2. Move the legends of the panels out of the graphs. Add minor ticks on the left /right axes

Response: Thanks for the suggestion. We have moved the legends of the panels out of the graphs and added minor ticks on the left /right axes.

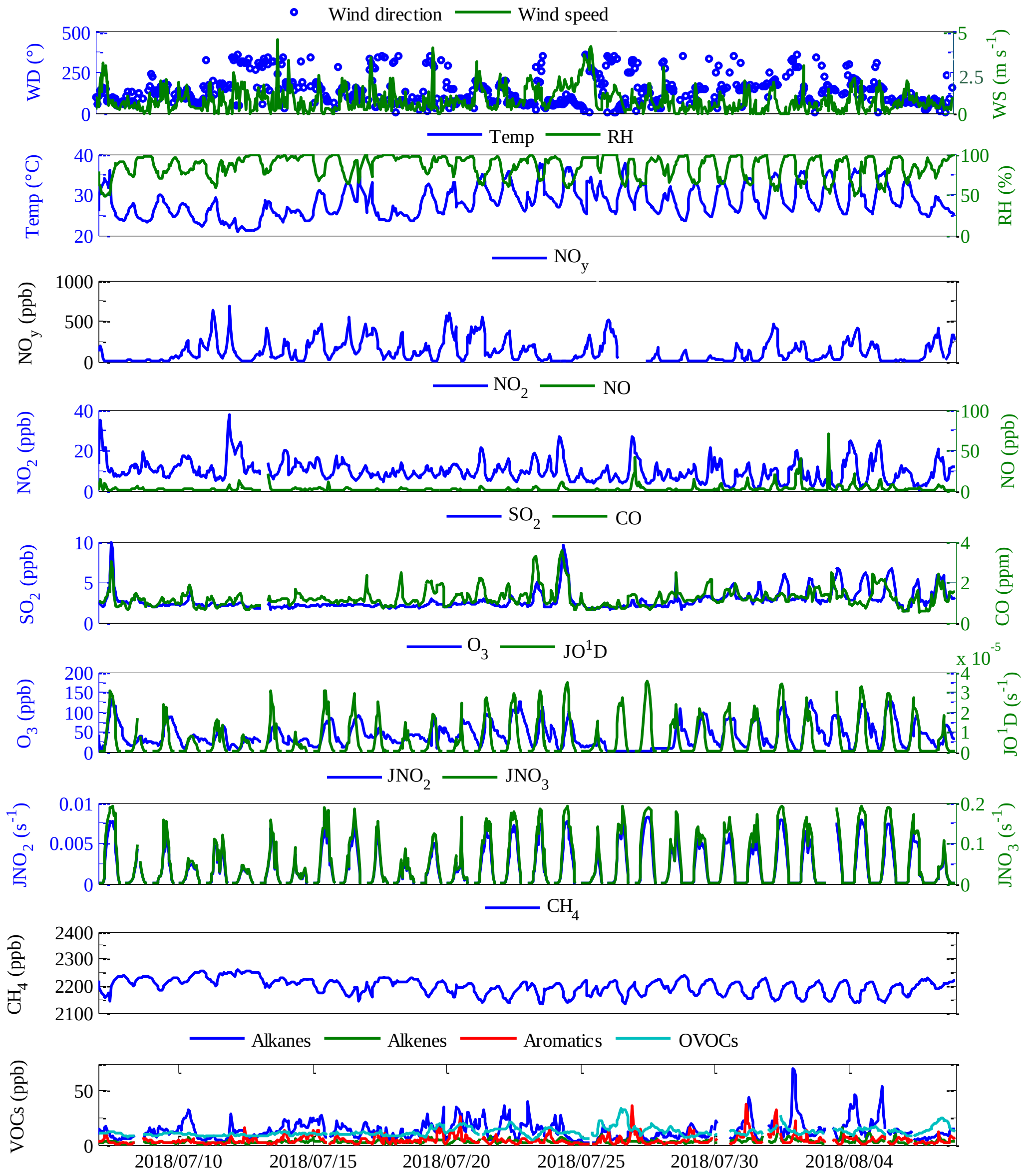

Figure 2. Time series of meteorology parameters, trace gases, photolysis rates and VOCs concentrations during the field campaign at Xianghe from 6 July to 6 August 2018.

Fig. 3 where is NO2 in the right panel?

Response: Thanks for the suggestion. We have redrawn the Fig. 3 focusing on the NMVOCs.

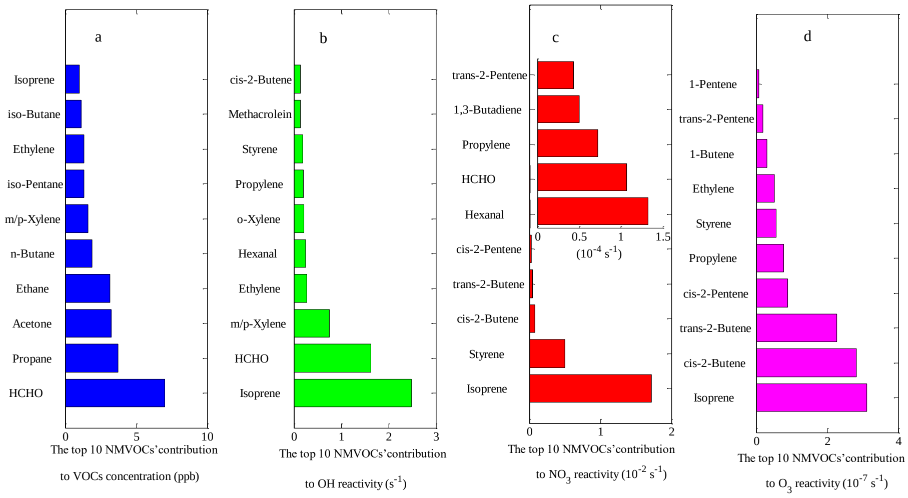

Figure 3. The top 10 NMVOCs' contribution to VOCs concentration (a), OH reactivity (b), NO_3 reactivity (c) and O_3 reactivity (d)during the field campaign at Xianghe from 6 July to 6 August 2018.

Fig. 5 include a table clarifying which are the BVOC considered and OVOC considered

Response: We have added a table clarifying VOCs groups and species included, and listed them in Table S1 in supplement information.

Fig.10 Unsaturated VOC: there should be a larger contribution during daytime given by O3, why this is not the case?

Response: In terms of alkenes, O_3 indeed make a larger contribution during daytime. This can be accounted for by the following facts: the alkenes reaction rate coefficients with O_3 are much higher than alkanes, aromatics and OVOCs reaction rate coefficients with O_3; 2) the orders of magnitude of the differences of alkenes reaction rate coefficients with OH, O_3 and NO_3 are much smaller than that alkanes, aromatics and OVOCs reaction rate coefficients with OH, O_3 and NO_3. However, in this study, unsaturated VOCs including cyclopentane, methylcyclopentane, cyclohexane, methylcyclohexane, alkenes, OVOCs (excluding MTBE) and aromatics. These mentioned alkanes, aromatics and OVOCs reaction rate coefficients with O_3 are much lower than the alkenes reaction rate coefficients with O_3, which largely counteracted the larger contribution made by the reactions of alkenes and O_3.

13 figures are many. You might want to simplify the manuscript keeping only the most relevant ones in the main body and leave the others to the supplementary information (I suggest to keep 1, 2, 3, 4, (5 could be presented as a table instead of graphically), 6 or 7, 8& 9) Table 1& Table S1. Please readapt these tables to a table/ tables where: concentration, SD, reactivities, reaction coefficients, and refs are included. If the table is too big you can split it in two tables (concentration, SD, reactivities) and reaction coefficients and references. The chemicals should be grouped according to the nomenclature used in the manuscript (BVOC, OVOC…etc.) Supplementary material: Please include some explanations between the figures.

Response: Thanks for the suggestion. We have followed the comments and simplified the manuscript keeping only the most relevant ones in the main body and leave the others to the supplementary information. The tables included concentration, SD, reactivities, reaction coefficients, and refs, and the chemicals were grouped according to the nomenclature used in the manuscript and supplementary material. Some explanations between the figures have been added in supplementary material.

Reviewer #2

Oxidation capacity is an important parameter to understand the atmospheric chemistry of air pollutants. This work analyzed the ROH, RO3 and RNO3 based on the measured VOCs and traditional trace gases concentrations in Xiang He. Overall, the methods are reasonable and the data are robust. After the following questions have been well addressed, it is publishable.

Response: we thank the reviewer for the positive comments.

1. Isoprene is also an alkene. I understand the authors want to differentiate the anthropogenic VOCs from the biogenic VOCs. I suggest to define them more strictly and accurately.

Response: Thanks for the suggestion. Indeed, in this article, we do not distinguish the source of isoprene from biogenic or anthropogenic. The reason is that in urban environment, anthropogenic emission also contribute to isoprene emission (e.g., vehicles) (Wagner and Kuttler, 2014), so it is hard to distinguish it in the study. Please refer to Line 350-351 in the revised version.

Reference

Wagner, P. and Kuttler, W.: Biogenic and anthropogenic isoprene in the near-surface urban atmosphere - A case study in Essen, Germany, Science of the Total Environment, 475, 104–115, doi:10.1016/j.scitotenv.2013.12.026, 2014.

2. In equations 1-3, the “k” should be lower case letters for rate constant.

Response: Thanks for the suggestion. We have corrected ‘K’ to ‘k’ in equations 1-3. Please refer to Line 279-284 in the revised version.

The total OH reactivity $= \sum k_{OH+NMVOC_i}[NMVOC_i] + k_{OH+CH_4}[CH_4] + k_{OH+CO}[CO] + k_{OH+NO}[NO] + k_{OH+NO_2}[NO_2] + k_{OH+SO_2}[SO_2] + k_{OH+O_3}[O_3] + \cdots$ (1)

The total NO_3 reactivity $= \sum k_{NO_3+NMVOC_i}[NMVOC_i] + k_{NO_3+CH_4}[CH_4] + k_{NO_3+NO}[NO] + k_{NO_3+NO_2}[NO_2] + k_{NO_3+SO_2}[SO_2] + \cdots$ (2)

The total O_3 reactivity$= \sum k_{O_3+NMVOC_i}[NMVOC_i] + k_{O_3+CH_4}[CH_4] + k_{O_3+NO}[NO] + k_{O_3+NO_2}[NO_2] + \cdots$ (3)

3. When calculating the reactivity, did you consider the influence of temperature on the rate constants? How about the uncertainties for the calculation? Can you give a comment on the possible difference for the measured R and estimated R?

Response: Thanks for the information. The reactivity is predominately determined by reaction rate constant and concentration of the compounds. During the summer campaign, the temperature is around 293K ~308K. According to temperature dependency of reaction rate constants in Table S1, we think the influence of temperature on reactivity is limited. It should be noted that the OH reactivity in this study calculated from the sum of the products of measured and their rate coefficients for reactions with OH, and does not involve species that are not measured like monoterpenes and alcohols. Previous studies have showed that there are some discrepancies between the actual measured values and the calculated values of OH reactivity, which may be attributed to missing OH reactivity that originates from VOCs oxidation products of both biogenic and anthropogenic origin (Di Carlo et al., 2004;Dolgorouky et al., 2012;Yoshino et al., 2006;Zhu et al., 2020). Therefore, the OH reactivity calculated in this study is somewhat underestimated. Please refer to Line 384-391 in the revised version.

Table S1. The temperature-dependent reaction rate coefficients of trace gases with OH radical, O_3 and NO_3 radical used in this study.

Species	Temperature dependence of k_{OH} (cm^3 molecule^{-1} s^{-1})	Temperature dependence of k_{O3} (cm^3 molecule^{-1} s^{-1})	Temperature dependence of k_{NO3} (cm^3 molecule^{-1} s^{-1})

CH_4	$1.85\times10^{-12}\exp(-1690/T)$	$<1\times10^{-23}$	$<1\times10^{-18}$
Alkanes			
Ethane	$6.9\times10^{-12}\exp(-1000/T)$	$<1\times10^{-23}$	$<1\times10^{-17}$
Propane	$7.6\times10^{-12}\exp(-585/T)\times0.736$	$<1\times10^{-23}$	$<7\times10^{-17}$
iso-Butane	$1.16\times10^{-17}\times T^2\times\exp(225/T)\times0.794$	$<1\times10^{-23}$	1.06×10^{-16}
n-Butane	$9.8\times10^{-12}\exp(-425/T)\times0.873$	$<1\times10^{-23}$	$2.8\times10^{-12}\exp(-3280/T)$
Cyclopentane	4.97×10^{-12}	$<1\times10^{-23}$	1.4×10^{-16}
iso-Pentane	3.6×10^{-12}	$<1\times10^{-23}$	1.62×10^{-16}
n-Pentane	$2.44\times10^{-17}\times T^2\times\exp(183/T)\times0.568$	$<1\times10^{-23}$	8.7×10^{-17}
2,2-Dimethylbutane	$3.22\times10^{-11}\exp(-781/T)\times0.632$	$<1\times10^{-23}$	4.4×10^{-16}
2,3-Dimethylbutane	$1.24\times10^{-17}\times T^2\times\exp(494/T)\times0.877$	$<1\times10^{-23}$	4.4×10^{-16}
2-Methylpentane	5.4×10^{-12}	$<1\times10^{-23}$	1.8×10^{-16}
3-Methylpentane	5.2×10^{-12}	$<1\times10^{-23}$	2.2×10^{-16}
n-Hexane	$1.53\times10^{-17}\times T^2\times\exp(414/T)\times0.061$	$<1\times10^{-23}$	1.1×10^{-16}
2,4-Dimethylpentane	4.77×10^{-12}	$<1\times10^{-23}$	1.5×10^{-16}
Methylcyclopentane	5.2×10^{-12}	$<1\times10^{-23}$	1.4×10^{-16}
2-Methylhexane	5.65×10^{-12}	$<1\times10^{-23}$	1.5×10^{-16}
2,3-Dimethylpentane	1.5×10^{-12}	$<1\times10^{-23}$	1.5×10^{-16}
Cyclohexane	$2.88\times10^{-17}\exp(309/T)$	$<1\times10^{-23}$	1.4×10^{-16}
3-Methylhexane	5.6×10^{-12}	$<1\times10^{-23}$	1.5×10^{-16}
2,2,4-Trimethylpentane	3.34×10^{-12}	$<1\times10^{-23}$	9.0×10^{-17}
n-Heptane	$1.59\times10^{-17}\times T^2\times\exp(478/T)$	$<1\times10^{-23}$	1.5×10^{-16}
Methylcyclohexane	4.97×10^{-12}	$<1\times10^{-23}$	1.4×10^{-16}
2,3,4-Trimethylpentane	6.6×10^{-12}	$<1\times10^{-23}$	1.9×10^{-16}
2-Methylheptane	7×10^{-12}	$<1\times10^{-23}$	1.9×10^{-16}
3-Methylheptane	7×10^{-12}	$<1\times10^{-23}$	1.9×10^{-16}
n-Octane	$2.76\times10^{-17}\times T^2\times\exp(378/T)$	$<1\times10^{-23}$	1.9×10^{-16}
Nonane	$2.51\times10^{-17}\times T^2\times\exp(477/T)$	$<1\times10^{-23}$	2.3×10^{-16}
n-Decane	$3.13\times10^{-17}\times T^2\times\exp(416/T)$	$<1\times10^{-23}$	2.8×10^{-16}
n-Undecane	12.3×10^{-12}	$<1\times10^{-23}$	
Alkenes			
Ethylene	$9.0\times10^{-12}(T/300)^{-0.85}$	$9.1\times10^{-15}\exp(-2580/T)$	$3.3\times10^{-12}\exp(-2880/T)$
Propylene	$3.0\times10^{-11}(T/300)^{-1}$	$5.5\times10^{-15}\exp(-1880/T)$	$4.6\times10^{-13}\exp(-1155/T)$
trans-2-Butene	$1.01\times10^{-11}\exp(550/T)$	$6.64\times10^{-15}\exp(-1095/T)$	3.9×10^{-13}
1-Butene	$6.6\times10^{-12}\exp(465/T)\times0.87$	9.64×10^{-18}	1.35×10^{-14}
cis-2-Butene	$1.1\times10^{-11}\exp(487/T)$	$3.22\times10^{-15}\exp(-968/T)$	3.52×10^{-13}
1,3-Butadiene	$1.48\times10^{-11}\exp(448/T)\times0.649$	$1.34\times10^{-14}\exp(-2283/T)\times0.5$	1.0×10^{-13}
1-Pentene	$5.86\times10^{-12}\exp(500/T)\times0.87$	1.06×10^{-17}	1.5×10^{-14}
trans-2-Pentene	6.7×10^{-11}	1.6×10^{-16}	3.7×10^{-13}
cis-2-Pentene	6.5×10^{-11}	1.3×10^{-16}	3.7×10^{-13}
Isoprene	$2.7\times10^{-11}\exp(390/T)$	$1.03\times10^{-14}\exp(-1995/T)$	$3.15\times10^{-12}\exp(-450/T)$
1-Hexene	3.7×10^{-11}	1.31×10^{-17}	1.8×10^{-14}
OVOCs			

HCHO	$5.4\times10^{-12}\exp(135/T)$	$<1\times10^{-20}$	5.6×10^{-16}
Acrolein	18.3	$<1\times10^{-20}$	
Propanal	$5.1\times10^{-12}\exp(405/T)$	$<1\times10^{-20}$	6.4×10^{-15}
Acetone	$8.8\times10^{-12}\exp(-1320/T)+$ $1.7\times10^{-14}\exp(423/T)$	$<1\times10^{-20}$	$<3\times10^{-17}$
MTBE	2.94×10^{-12}	$<1\times10^{-20}$	
Methacrolein	$8.0\times10^{-12}\exp(380/T)$	$1.4\times10^{-15}\exp(-2100/T)$	3.4×10^{-15}
n-Butanal	$6.0\times10^{-12}\exp(410/T)$	$<1\times10^{-20}$	$1.7\times10^{-12}\exp(-1500/T)$
MethylVinylKetone	$2.6\times10^{-12}\exp(610/T)$	$<1\times10^{-20}$	6.0×10^{-16}
Methylethylketone	$1.5\times10^{-12}\exp(-90/T)\times0.462$	$<1\times10^{-20}$	
2-Pentanone	4.4×10^{-12}	$<1\times10^{-20}$	
Pentanal	$6.34\times10^{-12}\exp(448/T)\times0.19$	$<1\times10^{-20}$	1.5×10^{-14}
3-Pentanone	2×10^{-12}	$<1\times10^{-20}$	
Hexanal	3.0×10^{-11}	$<1\times10^{-20}$	1.6×10^{-14}
Aromatics			
Benzene	$2.3\times10^{-12}\exp(-190/T)\times0.53$	$<1\times10^{-20}$	3.0×10^{-17}
Toluene	$1.8\times10^{-12}\exp(340/T)\times0.18$	$<1\times10^{-20}$	7.0×10^{-17}
Ethylbenzene	7×10^{-12}	$<1\times10^{-20}$	6.0×10^{-16}
m/p-Xylene	1.89×10^{-11}	$<1\times10^{-20}$	2.6×10^{-16}
o-Xylene	1.36×10^{-11}	$<1\times10^{-20}$	4.1×10^{-16}
Styrene	5.8×10^{-11}	1.7×10^{-17}	1.5×10^{-12}
Isopropylbenzene	6.3×10^{-12}	$<1\times10^{-20}$	6.0×10^{-16}
n-Propylbenzene	5.8×10^{-12}	$<1\times10^{-20}$	6.0×10^{-16}
m-Ethyltoluene	1.18×10^{-11}	$<1\times10^{-20}$	8.6×10^{-16}
p-Ethyltoluene	1.86×10^{-11}	$<1\times10^{-20}$	8.6×10^{-16}
1,3,5-Trimethylbenzene	5.67×10^{-11}	$<1\times10^{-20}$	8.8×10^{-16}
o-Ethyltoluene	1.19×10^{-11}	$<1\times10^{-20}$	8.6×10^{-16}
1,2,4-Trimethylbenzene	3.25×10^{-11}	$<1\times10^{-20}$	1.8×10^{-15}
1,2,3-Trimethylbenzene	3.27×10^{-11}	$<1\times10^{-20}$	1.9×10^{-15}
Criteria pollutants			
CO	2.4×10^{-13}		
NO	$3.3\times10^{-11}(T/300)^{-0.3}$	$1.4\times10^{-12}\exp(-1310/T)$	$1.8\times10^{-11}\exp(110/T)$
NO_2	4.1×10^{-11}	$1.4\times10^{-13}\exp(-2470/T)$	$1.9\times10^{-12}(T/300)^{0.2}$
SO_2	$1.3\times10^{-12}(T/300)^{-0.7}$		$<1.0\times10^{-19}$
O_3	$1.7\times10^{-12}\exp(-940/T)$		

Note: The temperature-dependent reaction rate coefficients of VOCs and CO are from Atkinson et al. (1983), Atkinson and Arey (2003), Atkinson et al. (2006), Salgado et al. (2008) and the Master Chemical Mechanism, MCM v3.3.1 via the website: http://mcm.leeds.ac.uk/MCM (last accessed: 25 March 2020); The temperature-dependent reaction rate coefficients of NO, NO_2, SO_2 and O_3 are from Atkinson et al. (2004). T denotes temperature.

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4. Although the authors compared the calculated R values with different places. It is difficult to follow it in the text. I suggest to list them in a supplement table.

Response: Thanks for the suggestion. The comparison of speciated OH reactivity with former studies in China has been added in the revised version, as shown in Table 1. Please refer to Line 1251-1252 in the revised version.

Table1. Comparison of speciated OH reactivity with former studies in China.

Species	This study	Beijing[a]	Shangdianzi[a]	Heshan[b]	Guangzhou[c]	Chongqing[c]	Beijing[d]	Shanghai[e]
CH_4	0.346							0.34
Ethane	0.019	0.01	0.01	0.023	0.24	0.59		
Propane	0.100	0.32	0.10	0.081				
iso-Butane	0.058	0.45	0.12	0.075				
n-Butane	0.111	0.09	0.08	0.104				
Cyclopentane	0.001	0.08	0.03	0.011				
iso-Pentane	0.119	1.18	0.25	0.168				
n-Pentane	0.067	0.60	0.16	0.136				
2,2-Dimethylbutane	0.002	0.08	0.08	0.003				
2,3-Dimethylbutane	0.017	0.23	0.11	0.013				
2-Methylpentane	0.016	0.56	0.10	0.077				
3-Methylpentane	0.018	0.44	0.10	0.047				

n-Hexane	0.020	0.60	0.08	0.055				
2,4-Dimethylpentane	0.001			0.069				
Methylcyclopentane	0.019	0.49	0.07	0.024				
2-Methylhexane	0.003	0.22	0.04	0.035				
2,3-Dimethylpentane	0.001		0.00	0.007				
Cyclohexane	0.048	0.26	0.05	0.015				
3-Methylhexane	0.004	0.28	0.05	0.039				
2,2,4-Trimethylpentane	0.002	0.04	0.01	0.036				
n-Heptane	0.006	0.24	0.04	0.033				
Methylcyclohexane	0.003	0.25	0.03	0.015				
2,3,4-Trimethylpentane	0.001	0.03	0.01	0.031				
2-Methylheptane	0.002	-	0.00	0.007				
3-Methylheptane	0.001	0.11	0.03	0.007				
n-Octane	0.004	0.38	0.11	0.014				
Nonane	0.004	0.19	0.03	0.010				
n-Decane	0.003			0.008				
n-Undecane	0.002			0.006				
Ethylene	0.273	0.35	0.18	0.617	0.29	0.73		
Propylene	0.202	4.86	1.00	0.464	0.40	0.52		
trans-2-Butene	0.067	1.98	0.31	0.063				
1-Butene	0.100	1.65	0.73	0.077				
cis-2-Butene	0.145	1.33	0.32	0.084				
1,3-Butadiene	0.034	-	-	-				
1-Pentene	0.023	0.50	0.22	1.136				
trans-2-Pentene	0.006	0.64	0.13	0.066	0.31	0.26		
cis-2-Pentene	0.034	1.20	0.29	0.080				
Isoprene	2.463	5.59	2.81	0.862	0.31	0.92		
1-Hexene	0.007	-	-	0.018				
HCHO	1.797			1.153				
Acrolein	0.027			0.009				
Propanal	0.067			0.139				
Acetone	0.013			0.010				
MTBE	0.009			-				
Methacrolein	0.146			0.072				
n-Butanal	0.024			0.059				
MethylVinylKetone	0.138			0.039				

Methylethylketone	0.014			0.020				
2-Pentanone	0.001			0.001				
Pentanal	0.042			0.028				
3-Pentanone	0.001			0.002				
Hexanal	0.247			0.055				
Benzene	0.017	0.34	0.13	0.030				
Toluene	0.092	2.22	0.39	0.518	0.73	0.15		
Ethylbenzene	0.085	0.88	0.18	0.188				
m/p-Xylene	0.749	3.05	0.43	0.754	0.74	0.31		
o-Xylene	0.216	0.93	0.12	0.194	0.35	0.10		
Styrene	0.193	0.34	014	0.900	0.26	0.16		
Isopropylbenzene	0.002	0.04	0.01	0.004				
n-Propylbenzene	0.002	0.25	0.16	0.004				
m-Ethyltoluene	0.016			0.026				
p-Ethyltoluene	0.013			0.027				
1,3,5-Trimethylbenzene	0.031	2.90	1.08	0.042				
o-Ethyltoluene	0.006			0.018				
1,2,4-Trimethylbenzene	0.028			0.080	0.16	0.17		
1,2,3-Trimethylbenzene	0.008			0.028				
CO	7.196	6.90	5.37				9.13	3.15
NO	2.139						0.58	0.78
NO_2	9.947						4.08	2.87
SO_2	0.088						0.33	
O_3	0.076							

[a] (Xu et al., 2011); [b] (Yang et al., 2017); [c] (Tan et al., 2019); [d] (Liu et al., 2009); [e] (Zhu et al., 2020).

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5. Traffic is not the only source of NOx. Thus, it is not reasonable to ascribe the ROH to traffic Line 385.

Response: We agree that traffic is not the only source of NOx. However, traffic-related emissions are the main sources of CO and NOx. Thus, We think it is reasonable to ascribe the ROH (OH reactivity) to large influence of traffic-related emissions. However, we have deleted related statements because the comparison of VOCs composition is necessary among different researchers.

6. When comparing the ROH(TVOCs) with other researches, the comparison of VOCs composition is necessary among different researchers (lines 399-419).

Response: The comparison of speciated OH reactivity with former studies in China has been added in the revised version, as shown in Table 1. Please refer to Line 1251-1252 in the revised version.

Table1. Comparison of speciated OH reactivity with former studies in China.

Species	This study	Beijing[a]	Shangdianzi[a]	Heshan[b]	Guangzhou[c]	Chongqing[c]	Beijing[d]	Shanghai[e]
CH_4	0.346							0.34
Ethane	0.019	0.01	0.01	0.023	0.24	0.59		
Propane	0.100	0.32	0.10	0.081				
iso-Butane	0.058	0.45	0.12	0.075				
n-Butane	0.111	0.09	0.08	0.104				
Cyclopentane	0.001	0.08	0.03	0.011				
iso-Pentane	0.119	1.18	0.25	0.168				
n-Pentane	0.067	0.60	0.16	0.136				
2,2-Dimethylbutane	0.002	0.08	0.08	0.003				
2,3-Dimethylbutane	0.017	0.23	0.11	0.013				
2-Methylpentane	0.016	0.56	0.10	0.077				
3-Methylpentane	0.018	0.44	0.10	0.047				
n-Hexane	0.020	0.60	0.08	0.055				
2,4-Dimethylpentane	0.001			0.069				
Methylcyclopentane	0.019	0.49	0.07	0.024				
2-Methylhexane	0.003	0.22	0.04	0.035				
2,3-Dimethylpentane	0.001		0.00	0.007				
Cyclohexane	0.048	0.26	0.05	0.015				
3-Methylhexane	0.004	0.28	0.05	0.039				
2,2,4-Trimethylpentane	0.002	0.04	0.01	0.036				
n-Heptane	0.006	0.24	0.04	0.033				
Methylcyclohexan	0.003	0.25	0.03	0.015				

e								
2,3,4-Trimethylpentane	0.001	0.03	0.01	0.031				
2-Methylheptane	0.002	-	0.00	0.007				
3-Methylheptane	0.001	0.11	0.03	0.007				
n-Octane	0.004	0.38	0.11	0.014				
Nonane	0.004	0.19	0.03	0.010				
n-Decane	0.003			0.008				
n-Undecane	0.002			0.006				
Ethylene	0.273	0.35	0.18	0.617	0.29	0.73		
Propylene	0.202	4.86	1.00	0.464	0.40	0.52		
trans-2-Butene	0.067	1.98	0.31	0.063				
1-Butene	0.100	1.65	0.73	0.077				
cis-2-Butene	0.145	1.33	0.32	0.084				
1,3-Butadiene	0.034	-	-	-				
1-Pentene	0.023	0.50	0.22	1.136				
trans-2-Pentene	0.006	0.64	0.13	0.066	0.31	0.26		
cis-2-Pentene	0.034	1.20	0.29	0.080				
Isoprene	2.463	5.59	2.81	0.862	0.31	0.92		
1-Hexene	0.007	-	-	0.018				
HCHO	1.797			1.153				
Acrolein	0.027			0.009				
Propanal	0.067			0.139				
Acetone	0.013			0.010				
MTBE	0.009			-				
Methacrolein	0.146			0.072				
n-Butanal	0.024			0.059				
MethylVinylKetone	0.138			0.039				
Methylethylketone	0.014			0.020				
2-Pentanone	0.001			0.001				
Pentanal	0.042			0.028				
3-Pentanone	0.001			0.002				
Hexanal	0.247			0.055				
Benzene	0.017	0.34	0.13	0.030				
Toluene	0.092	2.22	0.39	0.518	0.73	0.15		
Ethylbenzene	0.085	0.88	0.18	0.188				
m/p-Xylene	0.749	3.05	0.43	0.754	0.74	0.31		
o-Xylene	0.216	0.93	0.12	0.194	0.35	0.10		
Styrene	0.193	0.34	014	0.900	0.26	0.16		
Isopropylbenzene	0.002	0.04	0.01	0.004				
n-Propylbenzene	0.002	0.25	0.16	0.004				

m-Ethyltoluene	0.016			0.026				
p-Ethyltoluene	0.013			0.027				
1,3,5-Trimethylbenzene	0.031	2.90	1.08	0.042				
o-Ethyltoluene	0.006			0.018				
1,2,4-Trimethylbenzene	0.028			0.080	0.16	0.17		
1,2,3-Trimethylbenzene	0.008			0.028				
CO	7.196	6.90	5.37				9.13	3.15
NO	2.139						0.58	0.78
NO_2	9.947						4.08	2.87
SO_2	0.088						0.33	
O_3	0.076							

[a] (Xu et al., 2011); [b] (Yang et al., 2017); [c] (Tan et al., 2019); [d] (Liu et al., 2009); [e] (Zhu et al., 2020).

References:

Liu, Y., Shao, M., Kuster, W. C., Goldan, P. D., Li, X., Lu, S., and de Gouw, J. A.: Source identification of reactive hydrocarbons and oxygenated VOCs in the summertime in Beijing, Environ Sci Technol, 43, 75-81, doi:10.1021/es801716n, 2009.

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7. When discussing the implication for control strategies, I think it is more reasonable to normalize the reactivity to secondary pollutants formation potential.

Response: Thanks for the constructive comments. This study was aiming to explore the atmospheric oxidation capacity and photochemical reactivity rather than secondary formation. Therefore, we would like to keep discussing the implication for control strategies based on reactivity. In order to provide recommendations for possible future policies, we have also identified the possible sources of the VOCs whose concentration could be limited based on the certain chemical tracers which are generally presumed to be emitted from specific sources and present in significant amounts in the collected samples. Please refer to Line 567-570 and 584-588 in the revised version.

Reviewer #3

This paper shows OH, NO3, and O3 reactivity from VOC and traces gas measurements conducted in Xianghe in 2018 from 6 July to 6 August. In addition, the authors estimate the trace gases oxidation rate using parametrized OH, NO3, and observed O3 concentrations, which is defined as oxidation atmospheric oxidation capacity. This data set helps to add to the increasing knowledge of the oxidant reactivity. The atmospheric oxidation capacity highly depends on the parametrization. Though this method is not new, a detail uncertainty analysis related to the calculation is missing. This reviewer suggests using a box model to calculate the OH and NO3 concentrations or prove the justification of the parameterization. Besides, it's difficult to follow the writing, especially the authors tried to compare their results with other campaigns. The manuscript needs a significant reduction to be concise and informative before reconsidering.

Response: we thank the reviewer for the comments. We think these comments are important to improving the manuscript. According to your comments, a box model SOSAA was used to simulate concentrations of OVOCs, OH and NO_3 (Line 244-273 in the revised version). The modeled concentration of OVOCs and observed ones, as well as OH and NO_3 concentrations, were compared and discussed (Line 598-616 in the revised version).

Specific comments:

1.Line 266-270, It's not clear which values are used from which literature. If there is difference between different literatures, e.g. OH+NO2, which one is used?

Response: We are sorry for this confusing in the previous manuscript. The related sentences have been revised as follows (Line 285-293 in the revised version):

In the above equations, the temperature-dependent reaction rate coefficients (in cm^3 $molecule^{-1}$ s^{-1}) for OH-$NMVOC_i$ ($k_{OH+NMVOC_i}$), OH-CO (k_{OH+CO}), NO_3-$NMVOC_i$ ($k_{NO_3+NMVOC_i}$) and O_3-$NMVOC_i$ ($k_{O_3+NMVOC_i}$) are from Atkinson and Are (2003), Atkinson et al. (2006), Atkinson et al. (1983), Salgado et al. (2008) and the Master Chemical Mechanism, MCM v3.3.1 via the website: http://mcm.leeds.ac.uk/MCM (last accessed: 25 March 2020). OH-NO (k_{OH+NO}), OH-NO_2 (k_{OH+NO_2}), OH-SO_2 (k_{OH+SO_2}), OH-O_3 (k_{OH+O_3}), NO_3-NO (k_{NO_3+NO}), NO_3-NO_2 ($k_{NO_3+NO_2}$), NO_3-SO_2 ($k_{NO_3+SO_2}$), O_3-NO (k_{O_3+NO}) and O_3-NO_2 ($k_{O_3+NO_2}$) are from Atkinson et al. (2004). The temperature-dependent reaction rate coefficients are listed in Table S1 in the Supplementary Materials.

References:

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Atkinson, R., and Arey, J.: Atmospheric Degradation of Volatile Organic Compounds., Chemical Reviews, 103, 4605-4638, doi:10.102/cr0206420, 2003.

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Atkinson, R., Baulch, D. L., Cox, R. A., Crowley, J. N., Hampson, R. F., Hynes, R. G., Jenkin, M. E., Rossi, M. J., Troe, J., and IUPAC Subcommittee: Evaluated kinetic and photochemical data for atmospheric chemistry : Volume II - gas phase reactions of organic species, Atmos Chem Phys, 6, 3625-4055, doi:10.5194/acp-6-3625-2006, 2006.

Salgado, M. S., Monedero, E., Villanueva, F., Martín, P., Tapia, A., and Caba?as, B.: Night-Time Atmospheric Fate of Acrolein and Crotonaldehyde, Environ Sci Technol, 42, 2394-2400, doi:10.1021/es702533u, 2008.

2. Line 270. Why not use the newest version of Master Chemical Mechanism v3.3.1.

Response: We have used the newest version of Master Chemical Mechanism v3.3.1. Please refer to Line 288-289 in the revised version.

3. OH is parameterized to jo1d, jno2, and NO2 using the results from a rural site in Germany, which could be different from the present study. A box/regional model to simulate OH concentration is helpful to validate the parameterization at Xianghe. On the other hand, previous field OH observations in China demonstrate that a strong correlation exists between OH and jO1D with a relatively constant slope 4.50.51011cm^{-3} s^{-1} (Lu et al. 2012 10.5194/acp-13-1057-2013; Tan et al. (2017) 10.5194/acp-17-663-2017; Tan et al. (2018) 10.5194/acp-18-12391-2018). Maybe it's also a good idea to show the parametrized OH concentrations in supplement.

Response: Thanks for the suggestion. We have followed the comments to simulate OH and NO_3 concentration using a box model SOSAA (Line 244-273 in the revised version). The modeled results are then used to calculated AOC. According to the validation of OVOCs, we think the simulated concentrations are reasonable (Line 598-616 in the revised version). The detailed description as follows:

Atmospheric chemistry transport model SOSAA

SOSAA (a model to Simulate the concentrations of Organic vapours, Sulfuric Acid and Aerosol) is a column (or one-dimensional) chemical transport model, which was first developed by Boy et al. (2011). A more detailed description of its newest version can be found in Zhou et al. (2017a) and Zhou et al. (2017b). In this study, a box model version of SOSAA was used, in which the meteorological variables, including air temperature, air pressure, relative humidity and incoming global radiation, were directly read from the measurement data. The chemistry scheme was generated by MCM v3.3.1 (Master Chemical Mechanism version 3.3.1, http://mcm.leeds.ac.uk/MCMv3.3.1) (Jenkin et al., 1997; Jenkin et al., 2015; Saunders et al., 2003) and then converted to Fortran code with KPP (kinetic pre-processor; Damian et al., 2002). The mixing ratios of chemical species included in the chemistry scheme were read from the measured data when available, e.g., O_3, NO, NO_2, SO_2, CO, HONO, HCHO, isoprene, acetone, etc. Ten OVOCs (ACR, C_2H_5CHO, MACR, C_3H_7CHO, MVK, MEK, MPRK, C_4H_9CHO, DIEK, $C_5H_{11}CHO$) were excluded from the input list although they were also measured, because their simulated concentrations were used to compare with the measurement data to validate the model performance. Seven photolysis rates (J_O^{1}D, J_HCHO_M, J_NO_2, J_H_2O_2, J_HONO, J_NO_3_M, J_NO_3_R) were also read from the measurement data, the related photochemical reactions are shown below:

O_3 -> O_2 + O1D: J_O^{1}D (R1)
HCHO -> H_2 + CO: J_HCHO_M (R2)
NO_2 -> NO + O^{3}P: J_NO_2 (R3)
H_2O_2 -> 2 OH: J_H_2O_2 (R4)
HONO -> OH + NO: J_HONO (R7)
NO_3 -> NO + O_2: J_NO_3_M (R8)
NO_3 -> NO_2 + O^{3}P: J_NO_3_R. (R9)

The other photolysis rates were calculated using the incoming global radiation. The deposition velocities of all non-input species were set to 0.01 m s^{-1} and the boundary layer height was assumed to be 1 km (Lu et al., 2013; Zhu et al., 2020). The simulated OVOCs were also considered to be condensing onto pre-existing aerosols. Their condensation sinks were set to make their simulated concentrations approach the measurement data. The model time step was set to 10 s, and the data were output every half an hour. All the input data were interpolated to the model time step.

Model validation

The modeled and measured OVOCs

With the appropriate set up of the condensation sinks for these ten calculated OVOCs, the modeled diurnal mean pattern generally follows well the measured pattern within the 1 standard deviation of measurement data, although the model underestimates the measurement with less than 1 ppb from 19:00 to 24:00 (Figure 1a). With the inclusion of input MTBE and CH_3COCH_3 (acetone) which constitute more than 50% of the total OVOCs, the modelled total OVOCs concentration agree better with the measurement as expected (Figure 1b).

The modeled concentrations of OH, HO_2, RO_2, NO_3

The modeled diurnal median number concentrations of OH, HO_2 and RO_2 show an apparent diurnal pattern with peaks during noon while approaching zero during night, which results from the dependent of their chemical production reactions on the incoming solar radiation (Figs. 2a, b and c). The noon time (12:00 - 16:00) median values of OH, HO_2 and RO_2 are 1.2×10^7, 5.9×10^8 and 3.7×10^8 molec cm^{-3}, which are comparable to previous studies (e.g., Tan et al., 2017). The diurnal variability of hourly-median NO_3 concentration shows two peaks which are consistent with the high values of the chemical production from $NO_2 + O_3$, which even dominates the photochemical loss of NO_3 (Fig. 2d).

The correlation between OH and JO^1D

Figure 3 shows the relationship between modeled OH mixing ratio and the measured JO^1D. The coefficient of determination (R^2) is 0.86, and the linear regression fit shows the slope is 6.1×10^{11} cm^{-3} s^{-1} and the intercept is 0.9×10^6 cm^{-3}. These values are comparable to Tan et al. (2017) except the slope is about 36% higher than the observation fit in Tan et al. (2017).

References:

Boy, M., Sogachev, A., Lauros, J., Zhou, L., Guenther, A., and Smolander, S.: SOSA – a new model to simulate the concentrations of organic vapours and sulphuric acid inside the ABL – Part 1: Model description and initial evaluation, Atmos. Chem. Phys., 11, 43-51, doi:10.5194/acp-11-43-2011, 2011.

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Zhu, J., Wang, S., Wang, H., Jing, S., Lou, S., Saiz-Lopez, A., and Zhou, B.: Observationally constrained modelling of atmospheric oxidation capacity and photochemical reactivity in Shanghai, China, Atmos. Chem. Phys., 20, 1217-1232, doi:10.5194/acp-20-1217-2020, 2020.

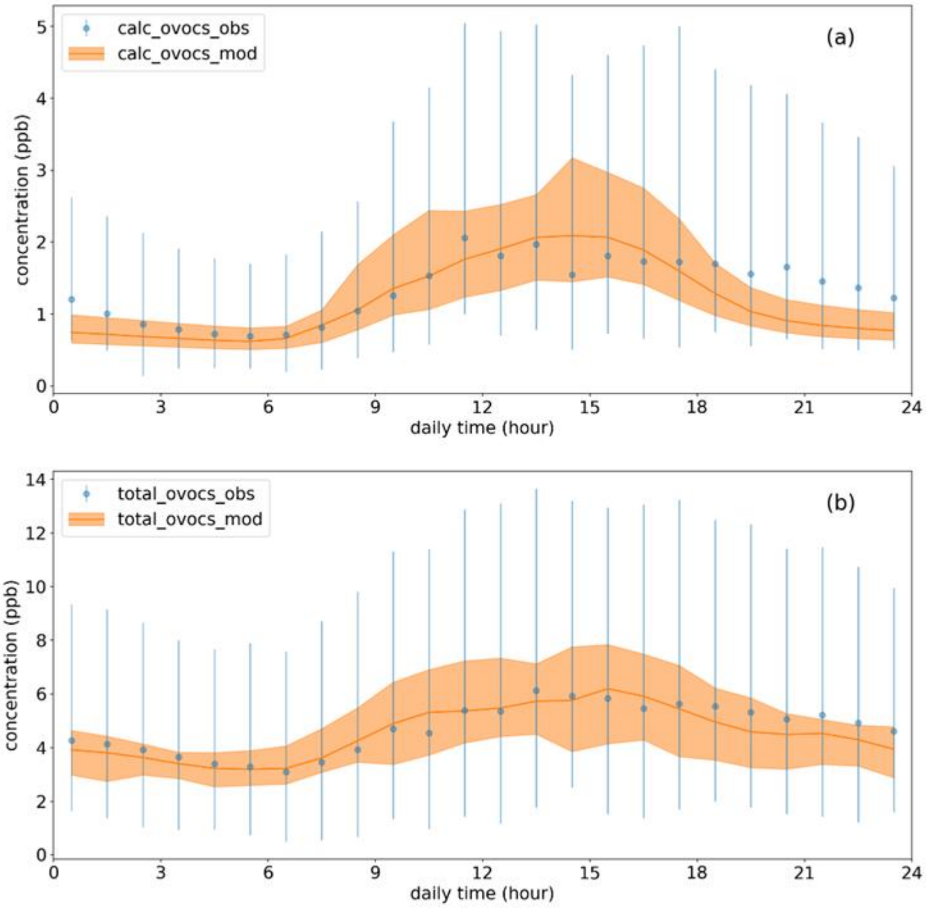

Figure 1: Diurnal mean of modeled (orange solid line) and measured (blue points) mixing ratios of (a) ten calculated and (b) all OVOCs, respectively. The ±1 standard deviation are also shown for modeled (orange shade) and measured (vertical sticks) data.

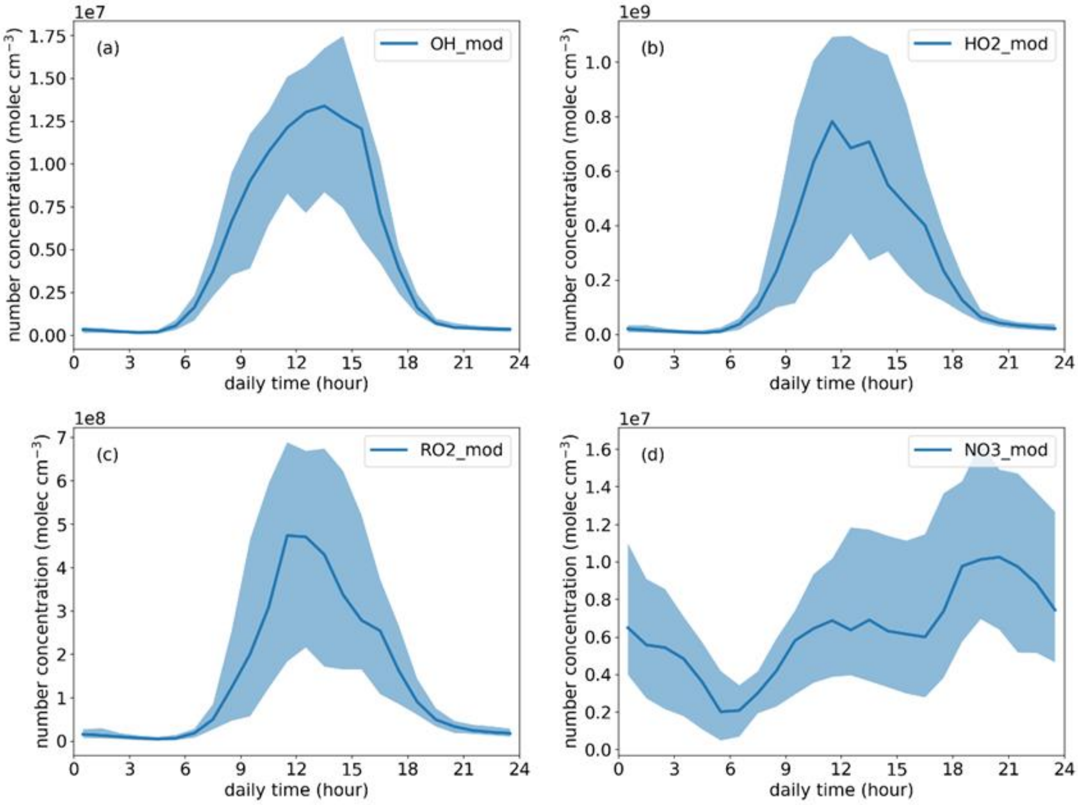

Figure 2: Modeled diurnal median (solid line) of (a) OH, (b) HO_2, (c) RO_2 and (d) NO_3. The 25th and 75th percentiles are shown as shade.

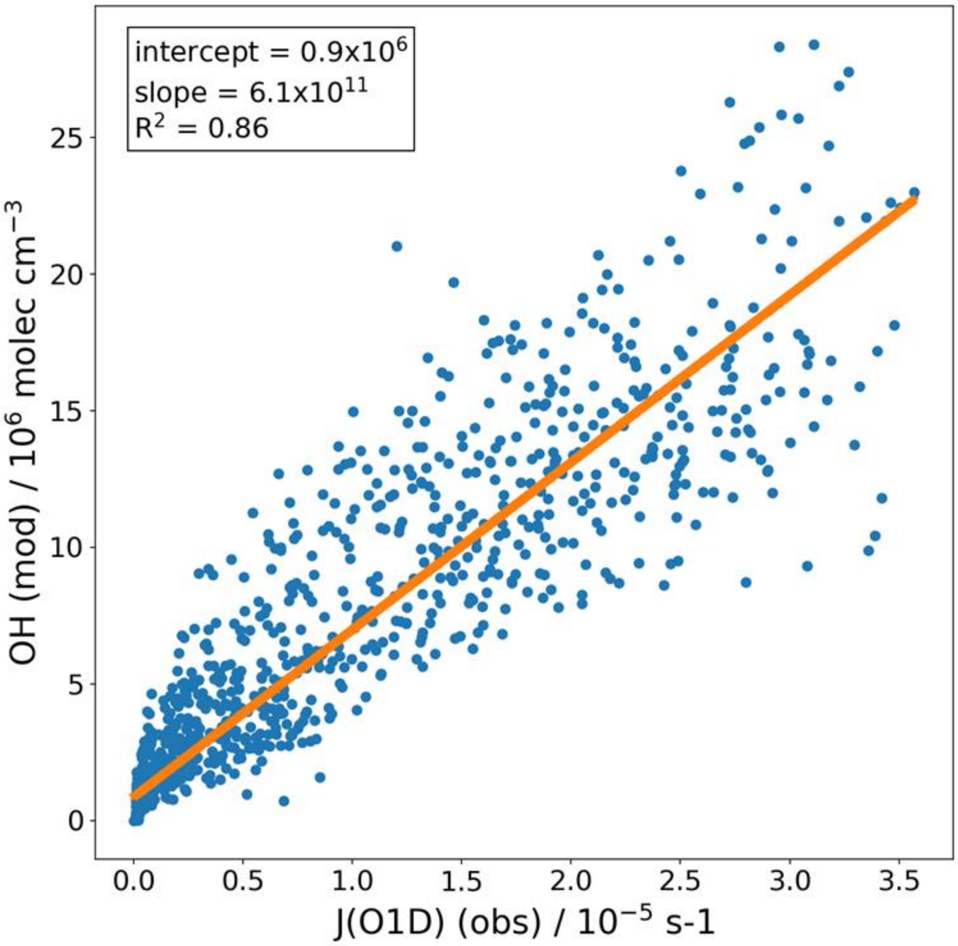

Figure 3: Correlation between modeled OH number concentration and measured JO^1D. A linear fit is shown by an orange line, the intercept, slope and R^2 values are shown in the legend.

4.The parameterization of NO3 is improved by considering the conversion to N2O5 compared to the first version. A proper discussion related to this uncertainty is missing. In equation (4), AOC is defined as the sum of all trace gases oxidation rate by OH, NO3, and O3. Is NO included? Please declare it clearly.

Response: Thanks for the comment. We have used a column chemical transport model SOSAA to simulate NO_3 concentration. Please refer to the responses to the comments #3.

NO is not included in. The term "oxidation capacity" of an oxidant X (= NO_3, OH and O_3) is defined as the sum of the respective oxidation rates of the molecules Y_i (NMVOCs, CH_4 and CO) (Geyer et al., 2001).

$$\mathrm{AOC} = \sum_{i=1} k_{Y_i-X}[Y_i]\,[X] = \sum_{i=1} R_X^{Y_i}\,[X] \qquad (4)$$

Here, $[Y_i]$ and $[X]$ are number concentrations of molecule Y_i and oxidant X, respectively. k_{Y_i-X} is the temperature-dependent reaction rate coefficients of the molecule Y_i with oxidant X. $R_X^{Y_i}$ is the oxidant X reactivity of molecules Y_i. Please refer to Line 295-301 the revised version.

References:

Geyer, A., Alicke, B., Konrad, S., Schmitz, T., Stutz, J., and Platt, U.: Chemistry and oxidation capacity of the nitrate

radical in the continental boundary layer near Berlin, Journal of Geophysical Research: Atmospheres, 106, 8013-8025, doi:10.1029/2000jd900681, 2001.

5. Figure 10. It's good to have one more role showing the integral oxidation over a day.

Response: We have showed the integral oxidation over a day in Figure 10 (Figure 9 in the revised version).

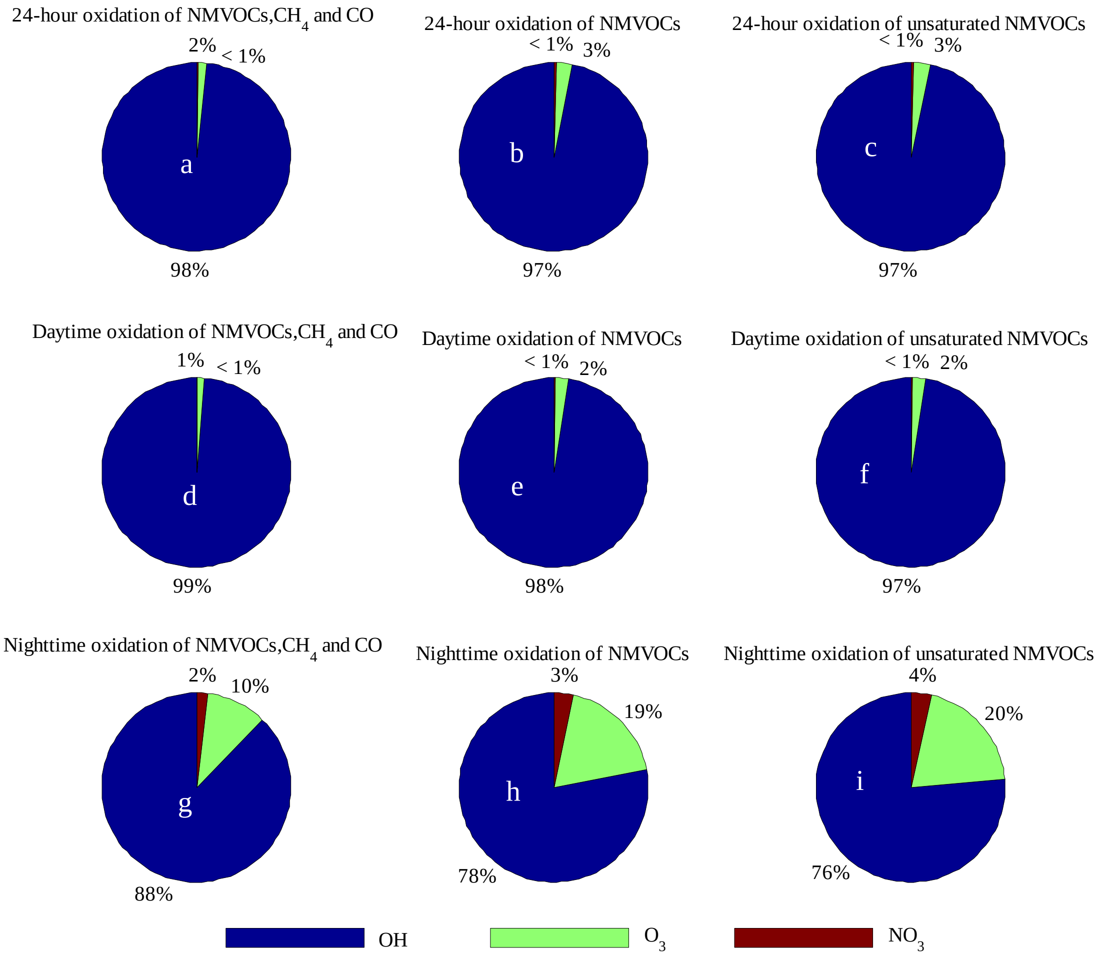

Figure 9. Comparison of the relative contributions of OH, NO_3 and O_3 to the 24-h, daytime and nighttime averaged loss rates. Data are calculated for the oxidation of (a, d and g) NMVOCs, CH_4 and CO, (b,e and h) NMVOCs only, and (c,f and i) unsaturated NMVOCs only.

6. Figure 11. Why alkenes show a significant variation in RNO3 and RO3 but not ROH?

Response: Thanks for the information. Figure 11 (Figure S12 in the revised version) showed the time series of NMVOCs loss rates due to the reactions with OH radical, O_3 and NO_3. However, the differences of alkenes variation in OH, NO_3 and O_3 reactivities can be largely accounted for by the discrepancies of reaction rate coefficients with OH, O_3 and NO_3. First, the alkenes reaction rate coefficients with O_3 and NO_3 are much higher than alkanes, aromatics and OVOCs reaction rate coefficients with O_3 and NO_3. Second, the alkenes reaction rate coefficients with OH are comparable with alkanes, aromatics and OVOCs reaction rate coefficients with O_3 and NO_3. Third, the orders of magnitude of the differences of alkenes reaction rate coefficients with OH, O_3 and NO_3 are much smaller than that alkanes, aromatics and OVOCs reaction rate coefficients with OH, O_3 and NO_3.

7. Figure 12. Maybe it's better to use the same scale for all panels.

Response: We have used the same scale for all panels in Figure 12 (Figure 10 in the revised version).

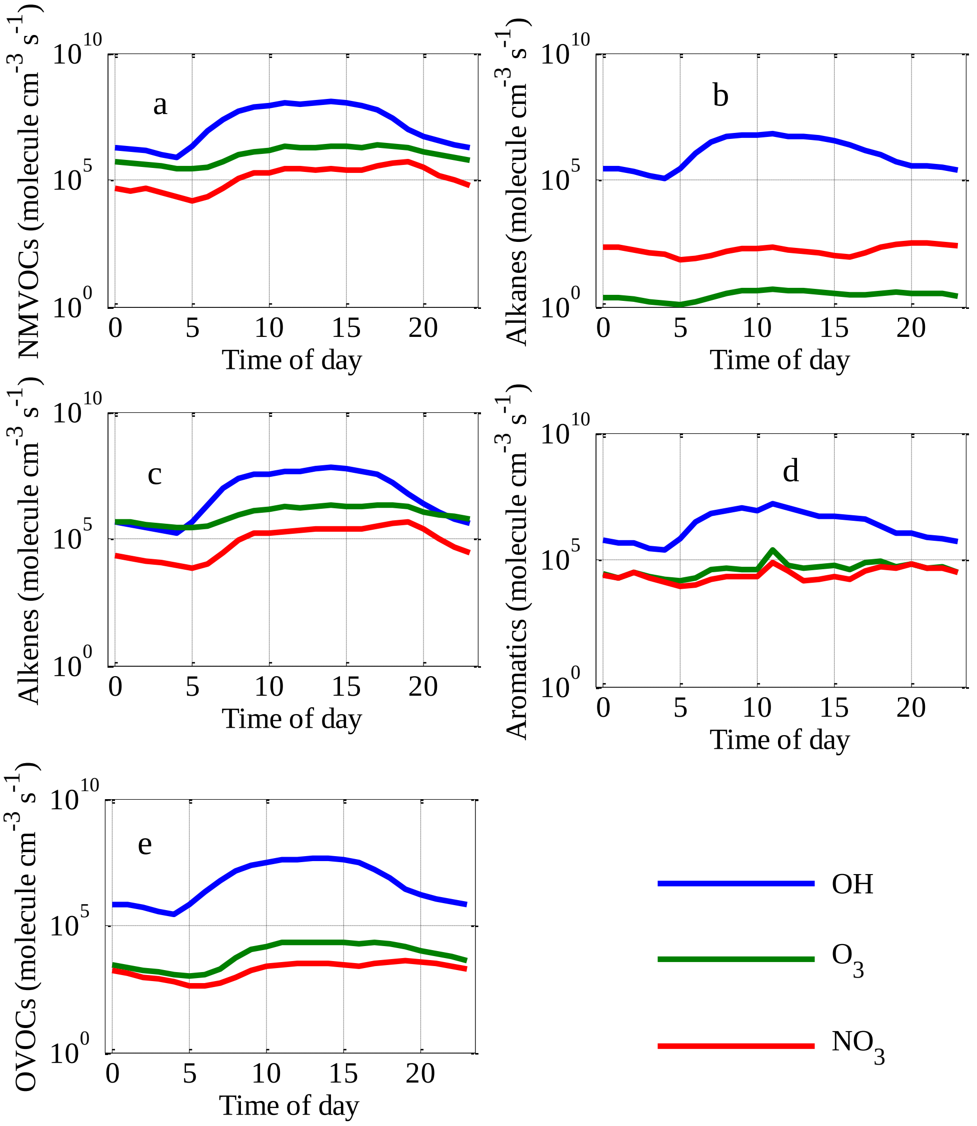

Figure 10 . Diurnal variations of NMVOCs loss rates due to the reactions with OH radical (blue lines), O_3 radical (green lines) and NO_3 (red lines).