Point to Point Reply

Referee#1 : The authors have done a great job in revising the manuscript. They have appropriately addressed the issues I raised in the review. I have no further suggestions, and recommend accepting as is.
Response: We greatly appreciate the referee for this time and efforts devoted to help us improve the manuscript.

Referee#2: The paper is focused on high-resolution simulations of CO2 mixing ratios over China during 2016-2018. A coupled atmospheric tracer model WRF-Chem was used to conduct CO2 simulations. I have a few comments to improve the quality of the paper.

Comment#1: The VPRM parameterization is included as one of the chemistry/tracer options within the WRF-Chem model. Therefore it's more accurate to call the model "WRF-Chem" rather than "WRF-VPRM".

Response: We appreciate the reviewer for pointing this detail out, we have revised to WRF-Chem in the manuscript. We mentioned the model in the abstract as: "In this study we apply the WRF-Chem model configured with the Vegetation Photosynthesis and Respiration Model (VPRM) option for biomass fluxes in China to characterize the dynamics of CO_2 in the atmosphere."

Comment#2: Lines 50-55: One of the objectives of the previous WRF-Chem (VPRM) modeling studies was to improve the simulations of mesoscale transport of atmospheric CO_2 by simulating meteorology, CO_2 fluxes, and transport in a tightly coupled model and high-resolution domain. The importance of capturing the mesoscale CO_2 transport in regional/local scales and significant improvements, which were demonstrated by previous WRF-Chem modeling studies (cited here) are not emphasized here.

Response: We agree with the referee that WRF-Chem has been demonstrated to successfully capture the mesoscale CO_2 transport through previous studies. We have added a few more modeling studies (Beck et al., 2013; Park et al., 2020; Pillai et al., 2012) into lines 50-55 and added the following emphasis into the manuscript:

"Previous modelling studies (Ahmadov et al., 2009;Kretschmer et al., 2012;Park et al., 2018;Beck et al., 2013;Park et al., 2020;Pillai et al., 2012) have demonstrated the weather-biosphere coupled model can successfully capture the mesoscale CO_2 transport at regional and local scales with significant improvements."

Additional References:

Beck, V., Gerbig, C., Koch, T., Bela, M. M., Longo, K. M., Freitas, S. R., Kaplan, J. O., Prigent, C., Bergamaschi, P., and Heimann, M.: WRF-Chem simulations in the Amazon region during wet and dry season transitions: evaluation of methane models and wetland inundation maps, Atmos Chem Phys, 13, 7961-7982, 2013.

Park, C., Park, S. Y., Gurney, K. R., Gerbig, C., DiGangi, J. P., Choi, Y., and Lee, H. W.: Numerical simulation of atmospheric CO2 concentration and flux over the Korean Peninsula using WRF-VPRM model during Korus-AQ 2016 campaign, Plos One, 15, 2020.

Pillai, D., Gerbig, C., Kretschmer, R., Beck, V., Karstens, U., Neininger, B., and Heimann, M.: Comparing Lagrangian and Eulerian models for CO2 transport - a step towards Bayesian inverse modeling using WRF/STILT-VPRM, Atmos Chem Phys, 12, 8979-8991, 2012.

Comment#3: Anthropogenic CO_2 emissions: Does the ODIAC emission inventory include hourly, day to day and seasonal variabilities? How the uncertainties in temporal variability of the anthropogenic CO_2 emissions affect the conclusions of the study?

Response: ODIAC provided monthly emissions, and the hourly scaling factor was recommended to follow the TIMES (Temporal Improvements for Modeling Emissions by Scaling) developed by Nassar et al. (2013) from the Vulcan emission product (Gurney et al., 2009) and EDGAR (The Emission Database for Global Atmospheric Research: http://edgar.jrc.ec.europa.eu/). Uncertainty in temporal variability of anthropogenic emission may induce bigger bias over urban area than rural are, as we also noticed that the simulation bias was larger at Lin'an than the ESRL sites (Figure 4). But our discussion (Line#300-321 and Figure 8) demonstrated that the simulation can reproduce diurnal pattern of CO_2 gradient at Lin'an, suggesting that the uncertainty in temporal variability of anthropogenic emission shall be unimportant. In-depth analysis and quantification of the associated uncertainty would require a modeling study with bottom-up local inventory which is currently unavailable. Considering the relatively smaller contribution and less variability of anthropogenic emission than the biosphere flux (Figure 5(d) and Figure 7), the uncertainty within temporal variability of anthropogenic emission shall not change the conclusion of this study.

Comment#4: The ODIAC CO_2 emissions are mostly based on the space-based nighttime light data. Thus, it may be less accurate compared to other fuel/energy-based emissions inventories. This needs to be discussed in the paper.

Response: ODIAC was developed through an integration of the CDIAC (Carbon Dioxide Information Analysis Center) global and national fossil fuel emission estimates, BP (British Petroleum) statistical review of world energy, power plants geolocation information from the CARMA (Carbon Monitoring and Action) global power plant database, and the satellite observed nightlight data as the referee mentioned. Essentially the fundamental fossil fuel emission estimate was from CDIAC, which was based on the United Nation Energy Statistics Database (Boden et al., 2017). The satellite nighttime light data was used mainly for constrain and spatial disaggregation. ODIAC was compared with another popular inventory EDGAR (The Emission Database for Global Atmospheric Research: http://edgar.jrc.ec.europa.eu/), and they show very close agreement (Figure 2 in Oda et al., 2018). Modeling study actually suggested better performance with ODIAC than EDGAR over the United States (Hu et al., 2020) According to this comment, we have included a brief discussion in the revised manuscript as: "ODIAC has been widely applied in recent modelling studies and demonstrated good agreement with other global inventories (Hedelius et al., 2017;Hu et al., 2020)."

Reference:

Oda, T., Maksyutov, S., and Andres, R. J.: The Open-source Data Inventory for Anthropogenic CO2, version 2016 (ODIAC2016): a global monthly fossil fuel CO2 gridded emissions data product for tracer transport simulations and surface flux inversions, Earth Syst Sci Data, 10, 87-107, 2018.

Hedelius, J. K., Feng, S., Roehl, C. M., Wunch, D., Hillyard, P., Podolske, J. R., Iraci, L. T., Patarasuk, R., Rao, P., O'Keeffe, D., Gurney, K. R., Lauvaux, T., and Wennberg, P. O.: Emissions and topographic effects on column CO2 (X-CO2) variations, with a focus on the Southern California Megacity, J Geophys Res-Atmos, 122, 7200-7215, 2017.

Hu, X. M., Crowell, S., Wang, Q. Y., Zhang, Y., Davis, K. J., Xue, M., Xiao, X. M., Moore, B., Wu, X. C., Choi, Y., and DiGangi, J. P.: Dynamical Downscaling of CO2 in 2016 Over the Contiguous United

States Using WRF-VPRM, a Weather-Biosphere-Online-Coupled Model, Jounal of Advances in Modeling Earth Systems, 12, 10.1029/2019MS001875, 2020.

Comment#5: 330: Fix "WRV"

Response: We thank the referee for pointing out this typo, it has been fixed in the revised manuscript.