Comment 1

General Comments

This paper describes the differences in BVOCs simulations using updated MEGAN. The concentrations of ozone, NO_2 and other trace gases over the two cases are also examined. Evaluation of the three updates made to the MEGAN coupled in WRF-Chem (v3.9) is useful to the model community. However, the value of this study has not been proved in the case that previous studies have already evaluated and compared the difference of V2.1 and V2.0 in WRF-Chem (Zhao et al., 2016; Zhang et al., 2021). It isnot surprising that the updates to emission factors and activity factors would lead to the changes in BVOCs emissions. Therefore, it is important to quantitatively evaluate these differences and explain the reason. I appreciate that you collected the station and flight observations for evaluation. However, some analysis of OH, formaldehyde, and other necessary species may help explain the difference of the simulations. Most importantly, if the analysis found that the older version performances better against the observationsthan the newer version, the authors need to give some explanation and provide suggestion and guidance for further development or optimization of the model.

Answer to the general comments

We thank the reviewer for the comprehensive comments, they are very helpful for improving the quality of the manuscript. One of the main objectives of the present paper is to help the community recognize the differences between different MEGAN model versions (i.e., 2.04 and 2.10) implemented within WRF-Chem and to provide guidance for next steps in developing MEGAN in chemistry transport models. We are glad that we got the message out.

We believe our paper is valuable because Zhao et al. (2016) investigated the sensitivity of WRF-Chem simulated BVOC emissions with different land surface schemes (i.e., Community Land Model version and Noah land surface model) considering also different vegetation maps. On the other hand, Zhang et al. (2021), used three versions of MEGAN (i.e., MEGAN v1.0, MEGAN v2.0, MEGAN v3.0). MEGAN v1.0 is the first model version coupled in WRF-Chem as it considers only the response of emission to radiation and temperature and MEGAN v2.0 is the second model version coupled with WRF-Chem that considers the emission factor of BVOCs for each grid calculated with a prescribed vegetation distribution and emission factor for each PFT (Guenther et al., 2006). Lastly, MEGAN v3.0 employed in the Zhang et al. (2021) study is updated from MEGAN v2.1 as implemented by Zhao et al. (2016). The main update in MEGAN v3.0 from MEGAN v2.1 is to consider the drought activity factor as an environmental forcing for biogenic emissions. Although Zhao et al. (2016) and Zhang et al. (2021) have

implemented MEGAN v2.1 in WRF-Chem with the CLM4 land model, (i.e., CLM surface scheme and associated subroutines in the physics and chemistry packages have been modified to be consistent with the MEGANv2.1 biogenic emission) in this work, we explore the effect of making simple changes to the existing WRF-Chem MEGAN v2.04 emissions scheme (Guenther et al., 2006). That is, the version implemented in WRF-Chem using the Noah land surface model, which is the same version called MEGAN v2.0 in the Zhang et al. (2021) paper). The version we present employs MEGAN emissions updates that can be used independently of the land surface model chosen. The changes made are consistent with MEGAN version described in Guenther et al. (2012).

We agree that it is not surprising that there are differences in modeling results among different versions of parameterization. We also expected that the update in the newer version can improve the model performance, which, however, is not true as we learned in this study. In the revised paper, we discuss and clarify the differences between MEGAN versions, some comparison with OH or formaldehyde, and recommend clearly that the MEGAN developers should re-examine the new coefficients. However, we disagree on providing improvements to MEGAN ourselves, as we do not have the expertise that the experimentalists have to guide possible improvements.

Specific Comments

Line 265-266: Please explain the difference of MG and MGPFT simulations in more details. Why is the activity factor related to the PFT emission factors?

Thanks for the clarification, the sentence "The third simulation (MGPFT) adds the changes in the activity factors due to the variation of the PFTs emission factors." is just meaningless, so we corrected to: "The third simulation (MGPFT) adds to the changes in the activity factors the variation of the PFTs emission factors."

Line 310-325: As the authors mentioned, BOVCs predicted by MEGAN are highly related to the environmental conditions. Therefore, there still need some comparisons of radiation, soil moisture, and other meteorological fields between the simulations and the observations (or reanalysis data) to confirm the reliability of the model.

Thanks for the suggestion. For the Europe case, we did analyze the temperature and geopotential height across Europe comparing WRF-Chem results with NCEP/NCAR reanalysis.

For final version of the paper, we plan to add new plots for solar radiation and precipitation.

Line 345-349: Adding similar plots of Figure 9 to show the PFT weighted emission factor (consider the PFT emission factor and PFT percentage) would make it clearer that the PFT percentage in four cities contributes to the difference of overall emission factors.

Thank for the very valuable comment. You gave us a very delightful idea: we replaced the figure 6 (i.e., the plots with the % of PFTs) with the PFT emission weighted factor plots, for Isoprene and Alpha-pinene (Figure 8 and Figure 10).

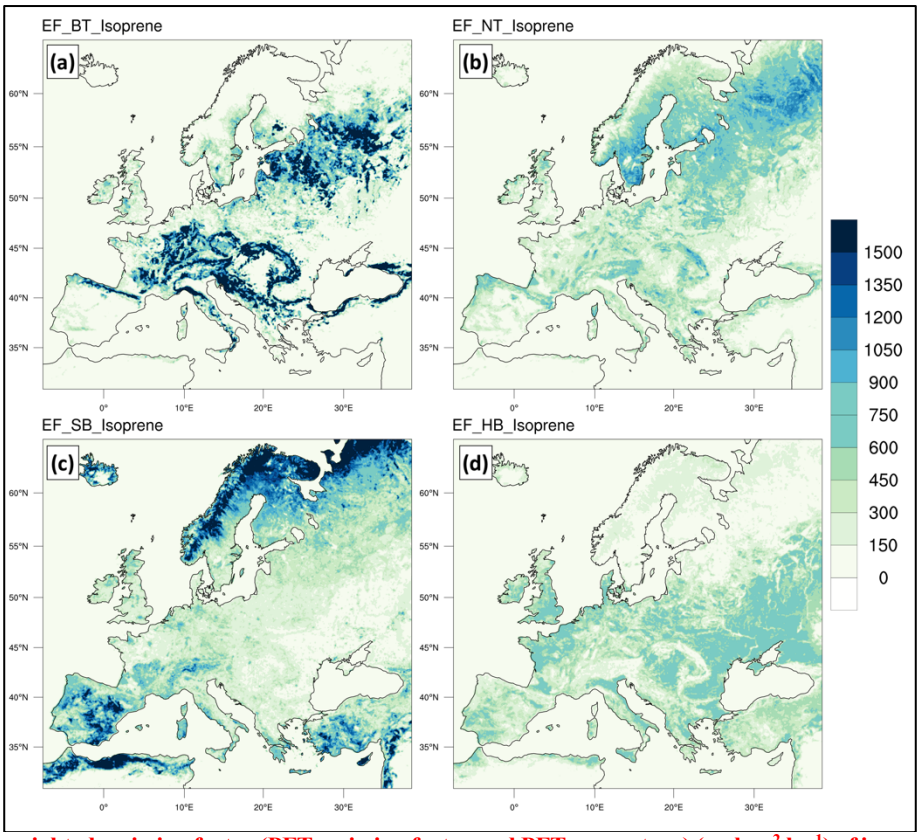

Figure 8: PFT weighted emission factor (PFT emission factor and PFT percentage) (ug km^{-2} hr^{-1}) of isoprene, computed in August 2015. The emission factor values used are from the Error! Reference source not found. **(2.10 column). From the upper left map: (a) PFT weighted emission factor of broadleaf trees (PFTP_BT), (b) needleleaf trees (PFTP_NB), broadleaf shrubs (PFTP_SB), and (d) grass and other (PFTP_HB).**

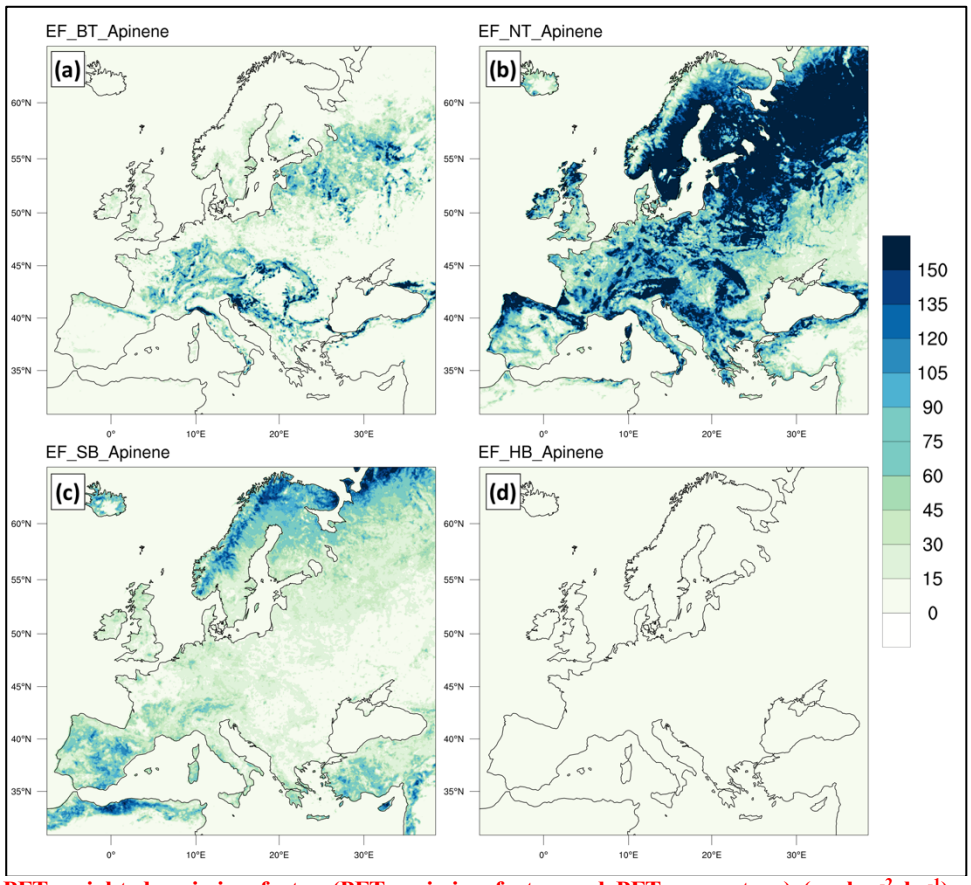

Figure 10: PFT weighted emission factor (PFT emission factor and PFT percentage) (ug km^{-2} hr^{-1}) of α-pinene, computed in August 2015. The emission factor values used are from the Error! Reference source not found. **(2.10 column). From the upper left map: (a) PFT weighted emission factor of broadleaf trees (PFTP_BT), (b) needleleaf trees (PFTP_NB), broadleaf shrubs (PFTP_SB), and (d) grass and other (PFTP_HB).**

Line 392-393: Please explain a little more about the method of disaggregating station types here other than just citing a reference.

We introduced the meaning of the station type: urban, suburban and rural surface station, now the sentence is:

Since discrepancies between modelled and measured values might be related to the type and location of a measurement station, the selected stations were also disaggregated into categories based on the study done by Henne et al., 2010, which includes a more complete analysis of the surroundings of each station. The alternative classification (see Supplement S3) provides three class station types: urban, suburban and rural surface stations. Urban means a continuously built-up urban area (buildings with at least two floors), the built-up area is not mixed with non-urbanized areas; suburban area is largely built-up urban area, it means, contiguous settlement of detached buildings of any size, the built-up area is mixed with non-urbanized areas (e.g., agricultural, lakes, woods). All areas, that do not achieve the criteria for urban or suburban areas, are defined as rural areas.

Line 405-406: Is soil NOx changed in different MEGAN simulations or do you turn off the soil NOx in these simulations? If soil NOx is different, the impact may not be from BVOCs only. In addition, please compare your results (the resulted impacts to NO2 and CO are small) to other similar studies and provide some discussion.

Thanks for the question, it is a very interesting observation.
The soil NOx does not change in different MEGAN simulations, since the value of PFT percentage (i.e., PFTP_BT, PFTP_NB, PFTP_SB and PFTP_HB) from the wrfbiochemi file remains unchanged.
Following your suggestions, we added to the paper the following comments:

For the different model runs anthropogenic, biogenic and biomass burning NOx emissions did not vary. Specifically, soil NOx emissions were evaluated with MEGAN as a function of environmental variables (i.e., temperature and vegetation types) that were the same for each model run. Therefore, no substantial changes were noted for the NOx concentration levels for the different model runs. Recent studies regarding the effects of NOx soil emissions on O3 levels in California (USA) (Sha et al., 2021) and Europe (Visser et al., 2019) have pointed out that NOx levels were underestimated with large biases because of the low NOx soil emissions estimated with WRF-Chem/MEGAN. NOx soil emissions are important both on the tropospheric NOx budget and surface O3 level perspectives (Sha et al., 2021). Considering that the model runs with increases in BVOC emissions showed higher O3 levels, it is likely that the O3 formation was not NOx limited.

The increase in CO concentration values is small compared to the increase observed for isoprene, because both emission factor and emission activity factor of isoprene are higher in 2.10 version compared to 2.04 version.
We added to the paper the following comments:

MEGAN estimates carbon monoxide emissions as biogenic emission class unlike NO_x soil emissions. Higher CO emissions were noted for the MG simulation compared to the control run (M2.04) because of the changes in emission activity factors (γ_i). As reported in **Error! Reference source not found.**, CO emission factor differs between MG and MGPFT runs, with a lower value for MGPFT (600 CO $\mu g\ m^{-2}\ hr^{-1}$) compared to MG (1000 CO $\mu g\ m^{-2}\ hr^{-1}$). Moreover, the higher emission activity factor and lower CO emission factor in MGPFT compared to the control run resulted in only slight differences in CO levels between the two runs. This results in the different model runs showing slight variations in CO levels.

Technical corrections

Line 31: It is not clear here about M2.04 and M2.10.

I changed the sentence as follow, I hope it is clearer:

The comparison between the modeled data and aircraft observations shows that isoprene mixing ratios measured agree well with M2.04 simulation but are overpredicted considerably by the M2.10 simulation.

Line 195: There may be some errors in reference insertion.

Yes, it is a reference error, I corrected it.

Figure 11: "M10" and "M04" may cause confusion, please change to "M2.04" and "M2.10" or give some explanation.

I modified the caption of figure 11, 12 and 13:

Figure 1: Comparison between M2.04 (M04) and M2.10 (M10) ….

Figure 2: Comparison between M2.04 (M04) and M2.10 (M10) ….

Figure 3: Scatter plot and linear regression for the simulations M2.04 (M04 - a-green dots) and M2.10 (M10 - b-red dots) ….

References

Guenther, A., Karl, T., Harley, P., Wiedinmyer, C., Palmer, P. I. and C., G.: Estimates of global terrestrial isoprene emissions using MEGAN, Atmos. Chem. Phys. Discuss., 6(1), 107–173, doi:10.5194/acpd-6-107-2006, 2006.

Guenther, A., Jiang, X., Heald, C. L., Sakulyanontvittaya, T., Duhl, T., Emmons, L. K. and Wang, X.: The model of emissions of gases and aerosols from nature version 2.1 (MEGAN2.1): An extended and updated framework for modeling biogenic emissions, Geosci. Model Dev., 5(6), 1471–1492, doi:10.5194/gmd-5-1471-2012, 2012.

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