Author's response to editor comment (second round):

"Isoprene and monoterpene simulations using the chemistry-climate model EMAC (v2.55) with interactive vegetation from LPJ-GUESS (v4.0)"

by Ryan Vella et al.

We thank the editor once more for taking the time to handle our paper submission and we appreciate the comments to further improve our manuscript. We understand that we may have not fully addressed the editor's concerns in the last round of revisions and we thank the editor for providing further details on the matter. Here, the editor's comment (from November 25, 2022) is reproduced in black, while our comments are presented in blue. Further down in this document, we also address the comments from the fourth referee. We thank again all anonymous referees for their valuable contributions.

From the editor's response:

I don't believe that authors properly dealt with my concerns in the previous review process. Please understand my comments are important to figure out the important aspects of this study. The authors need to revise the manuscript not to mislead readers of this manuscript. Please understand that misleading possibility comes from Introduction and Abstract mainly and must clarify what are improved from Forrest et al. (2020). Also please give us proper responses to a new reviewer who also pointed out this point. I am also concerned that we may feel a salami slice issues if the issues below are not properly dealt with.

The above concerns are tackled in detail below.

(1) This study evaluates the dynamic vegetation state simulated b LPJ-GUESS. LPJ-GUESS is one of famous biosphere models which has been improved by many independent scientists and its evaluations have been done. Eventually, it seems that this study extended (Forrest et al., 2020) by coupling LPJ-GUESS to EMAC earth system model. This point should be mentioned clearly in Introduction and Abstract for better readability. The manuscript should clearly describe what this study did in abstract and introduction. Figure such as Fig. 1 in Forrest et al. (2020) is helpful to understand important aspect of this study quickly.

As stated, this study extends on Forrest et al. (2020) by further coupling LPJ-GUESS to EMAC. We enable vegetation-driven emissions in EMAC using LPJ-GUESS information. The abstract and introduction were updated based on this feedback. We reproduced the original roadmap of the model coupling strategy between EMAC and LPJ-GUESS (Fig. 1 in Forrest et al., 2020). Our new figure (Fig. 1 in the updated manuscript), clearly highlights the improvements, new developments, and how this study fits in the current and planned implementations to tighten the coupling between EMAC and LPJ-GUESS.

(2) Based on the introduction, it seems to us that this study considers a semi-process BVOC emission module by Niinemets (2010) in the EMAC ESM coupling work in this study. s authors pointed out, there are already BVOC modules of ONEMIS and MEGAN in EMAC GCM. Because LPJ-GUESS has a semi-process BVOC emission module by Niinemets (2010), we generally expect that your study combines the LPJ-GUESS BVOC module into the EMAC GCM and we may want to know how such process-based BVOC module improves the simulation.

The introduction gives a general overview of the current literature on modelling BVOC emissions, where we mention both empirical and process-based approaches. Few sentences were added (L. 53 & L. 59) to emphasise that we do not consider semi-process based BVOC emission modules in EMAC. The semi-process based module in LPJ-GUESS is explained in Section 2.2 ("BVOC emission routine"). Given that we only use emissions from this module to compare our new emissions from ONEMIS and MEGAN in EMAC, we think that the current description is sufficient. The reader could refer to the cited litterateur for technical details on the algorithm.

The implementation of the full emission scheme of LPJ-GUESS goes beyond the scope of this study. The LPJ-GUESS emission scheme has been designed to operate on at least daily time steps. An adaptation to the shorter (a few minutes) time step of EMAC is rather complicated, especially, when the current scheme uses daily average light fluxes and a daily temperature range instead of individual snapshots of radiative fluxes and temperature. This would require a complete re-tuning of the emission scheme, with the only benefit of the higher temporal resolution of the emission fluxes (which cannot be utilised in LPJ-GUESS, but in EMAC only). Even though the scheme of Niinements is semi-process based, the processes are also highly parameterised, such that the advantages against the Guenther et al. algorithms are also small. This information has been added in the manuscript (L. 140)

However, this is misleading because EMAC ESM uses ONEMIS and MEGAN by series of papers by A. Guenther, not Niinements et al. (1999). Introduction should properly describe this point and must be rewritten for better understanding of improvements by this study.

This point was highlighted as suggested in both the abstract and introduction.

It is also important to clearly mention that the BVOC emission module (i.e., process-based model) is not used in the EMAC ESM. For example, in introduction, the manuscript mentioned a few important improvements in the LPJ-GUESS for BVOC simulations (e.g., process-based model for BVOC emission), but such process based model in LPJ-GUESS is not used in the EMAC. It makes us difficult to catch up the important works of this study.

This clarification has been made (L. 17, L. 53, L.59, etc.)

(3) Fig. 6 says that LPJ-GUESS produces no shrub in our earth which may be not true. I ask the authors to explain why there is no shrub land by LPJ-GUESS and implications for BVOC emission.

Shrubs are not included in the currently applied LPJ-GUESS global PFT set, consequently they are not considered in the applied simulation setup. Studies by Forrest et al. (2015) did not use explicit shrub PFTs as well, and only in more recent studies they are explicitly included (e.g. Allen et al., 2020). Even though this leads to less competition among some PFTs in certain regions, this is a limitation of the current study. However, including the new shrub PFTs is planned for future studies. This information has been added (L. 285)

In the manuscript we note that the lower magnitudes in monoterpene fluxes from MEGAN compared to ONEMIS result from the lack of representation of shrubs and needleleaf tree PFTs in LPJ-GUESS. These species are considered strong emitters of monoterpenes.

(4) This manuscript compares ONEMIS and MEGAN empirical BVOC models to LPJ-GUESS module in Fig. 9 and I ask the authors to include how to calculate BVOC emission in the LPJ-GUESS.

This information can be found in Section 2.2 "BVOC emission routine".

(5) The manuscript is saying that BVOC emission from ONEMIS and MEGAN is different (e.g., differences in tropical regions) but it will be better to explain (although that is simple) what makes such differences (e.g., LAI difference, temperature difference) and its implications for future climate simulations and BVOC emission uncertainties.

We state that isoprene emissions from MEGAN are higher in tropical regions, compared to ONEMIS emissions. These changes result from different canopy processes employed in ONEMIS and MEGAN respectively. ONEMIS and MEGAN emission values (e.g. Fig. 8, panel a and b) are coming from the same simulation, meaning that the input parameters in both modules (e.g. temperature, LAI, etc.) are identical. This is now clarified (L. 302).

(6) Such as Figure C1-C3 in Forrest et al. (2020), it will be better to quantify EMAC climate biases after improving the coupling processes between EMAC and LPJ-GUESS.

In this study we use the same climate variable coupling as in Forrest et al. (2020). Our coupling only involved vegetation information going into ONEMIS and MEGAN in EMAC. This means that the climate biases are comparable to the ones presented in Forrest at al. (2020) and this information is not repeated in this study, but we refer to the previous analysis of the climate biases (L. 442).

(7) We feel that this study needs to mention previous studies to deal with dynamic vegetation model incorporated ESM (e.g., Levis et al., 2003) for clear understanding of what this study did. Also, it will be better if your work is compared to previous simulations (even though with simple or descriptive).

In the Introduction we mentioned various studies that incorporated vegetation representations in modelling BVOC emissions (including Levis et al. (2003)). We added a paragraph (L. 369) to compare our findings with results from Levis et al. (2003)

(8) Also, vegetation state such as LAI can be evaluated easily with remote sensed data such as MODIS and I am not sure if Fig. 4(d) corresponds to this reference data or not. Please provide more information on the data for Fig. 4(d) and please provide remote sensed LAI data for the reference.

The LAI product used in Fig. 4(d) (now Fig. 5) is indeed based on reference remotely sensed data (MODIS and AVHRR). This information is now included (L. 253).

From the fourth referee response:

The revision of the manuscript has been made suitable for publication through the major revision. This study developed a geoscientific model that calculates global BVOC emissions by connecting ONEMIS and MEGAN in EMAC modules to LPJ-GUESS, and tested the sensitivity of emissions through CO2 doubling experiments. I think that the experimental results of this study alone are scientifically meaningful findings and numbers. Here are some suggestions for minor fixes.

We thank the referee for the positive feedback and for pointing out mistakes in the text. Below we address the suggestions and minor fixes.

1. Please consider rephrasing sentences from Forrest et al., 2020, GMD - L90 91 and L105 108
- If there are more sentences, ...

We rephrased some text in the MS. Section 2.2 is based on an official LPJ-GUESS template - that's why some text is identical to Forrest et al. (2020). We now included a footnote referring to the official template.

2. Table 1 is hard to read. How about arranging it in one or two sentences?

A previous referee asked to provide more information about the difference between ONEMIS and MEGAN using a table. We however agree that the same information could be included in a paragraph as suggested.

3. Other minor comments are below:
@ abstract
- emissions from terrestrial vegetation, which represents
> emissions from terrestrial vegetation, which represent
- Please consider rephrasing this sentence:
and atmospheric chemistry is a recommended tool to address the fate of
> and atmospheric chemistry is recommended to address the fate of
- were found to be > were (delete "found to be")
- conclude that the proposed model setup is a useful tool for > conclude that the proposed model setup is useful for @L35
- the main precursor > the primary precursor

The MS was updated with all above-mentioned corrections.

References

Allen, J. R., Forrest, M., Hickler, T., Singarayer, J. S., Valdes, P. J., and Huntley, B.: Global vegetation patterns of the past 140,000 years, Journal of Biogeography, 47, 2073–2090, 2020.

Forrest, M., Eronen, J., Utescher, T., Knorr, G., Stepanek, C., Lohmann, G., and Hickler, T.: Climate-vegetation modelling and fossil plant data suggest low atmospheric CO_2 in the late Miocene, Climate of the Past, 11, 1701–1732, 2015.

Forrest, M., Tost, H., Lelieveld, J., and Hickler, T.: Including vegetation dynamics in an atmospheric chemistry-enabled general circulation model: linking LPJ-GUESS (v4. 0) with the EMAC modelling system (v2. 53), Geoscientific Model Development, 13, 1285–1309, 2020.

Levis, S., Wiedinmyer, C., Bonan, G. B., and Guenther, A.: Simulating biogenic volatile organic compound emissions in the Community Climate System Model, Journal of Geophysical Research: Atmospheres, 108, 2003.