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Comment on gmd-2022-154

Ryan Vella et al.

Author comment on "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., Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2022-154-AC1, 2022

We thank the referees for taking the time to review our manuscript and for the valuable feedback. We have corrected our manuscript according to the referees' comments and think it is now significantly improved. Please find here our point-by-point response to the referees' comments.

The referee's comments are listed again in italics.

Anonymous Referee #1

This work gives very nice information on the recent development of global-scale BVOCs emissions modeling with multi-model and components interactions. And there are authors' efforts to evaluate the results with a lot of previous works including scientific reviews. I think this research shows an advanced way of estimating BVOCs with more realistic interactions with Earth components. I have only a few questions and suggestions for the publication as follows.

We would like to thank the referee for the positive feedback and the recommendation for publication.

Remarks:

- *Figure 7 and 8, and 9: Please make the same y-scale both at the ONEMIS and MEGAN results (middle and bottom panels), such as in Figure 11.*

  We updated the figures with the same colour-bar scales.

- *3.3. I understand the author wanted to measure the sensitivity of doubling atmospheric CO2 and vegetational CO2 separately. However, the increasing CO2 influences the vegetational CO2 in reality. The author should mention about "real" future conditions or add the case with scenarios of realistic future conditions of Bio and Atm.*

  We provide three further scenarios to compare with our standard case: one with doubling CO2 in the vegetation scheme, one with doubling CO2 in the radiation scheme, and both. The "Both x 2" case would be the more realistic scenario here but this exercise aimed to test the sensitivity of the coupled model rather than making realistic future predictions. The manuscript was modified to clarify better the aims of this section.

- *Line: 310: Why does the author think that Both x 2 scenarios showed some exceptions of lower LAI over some places in North America, Western Brazil, and Southern Europe? That needs a few scientific explanations like partially described in conclusions.*

  In Both x 2 scenarios, the LAI (i.e. vegetation growth) is influenced both by an increase in vegetational CO2 (fertilisation effect), as well as increased surface temperatures from increased CO2 in the radiation scheme. The decrease in LAI in the central USA, some parts of South America, and southern Europe results from competition between plant species resulting in shifts in vegetation between PFTs, e.g. grass species take over forested areas, partly decreasing the LAI. These shifts are mostly dominated by water stresses. The text was modified accordingly but we think providing too much detail here is beyond the scope of this paper. However, we indeed want to evaluate such vegetation shifts in future studies.

Anonymous Referee #2

"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.

The manuscript by Vella et al. documents the coupling between EMAC and two terpenoid emission schemes driven by dynamic vegetation from LPJ-GUESS. The results from the two schemes are compared against each other, as well as to emissions computed directly inside LPJ-GUESS. In addition, a series of doubled CO2 concentration simulations was performed to illustrate the sensitivities of the simulated terpenoid emissions to these.

Overall, the paper presents an important linkage between ecosystems and atmospheric chemistry, and it is good to see this linkage represented in the EMAC system. While the simulations themselves and their analysis may not be very novel, the implementation serves a clear purpose, and a manuscript like this documenting model development is well suited for GMD.

The description of the coupling may need some clarifications (see below) but is overall fine, and analysis and its description are understandable, but the manuscript would benefit from a better explanation of the simulation setup in the Methods section, to provide the information on the simulations on beforehand. In particular, it would be good to describe whether these simulations are run as bi-directional interactions (L. 336) including changes in the climate caused by the changes in atmospheric chemistry, or whether the setup *simply tests the emission response, but not the EMAC response to these (which I guess is the case). Also, it would help to understand the role of the results from the BVOC emission routine in LPJ-GUESS (Fig. 9), which are presented separately from those of the two other schemes – are these available for use in EMAC as well, or are they only presented here for comparison?*

Apart from that, it would be good to clarify more clearly in the Methods section which elements of the coupling come from LPJ-GUESS, and which are assumptions that are used to "interpret" the LPJ-GUESS results inside ONEMIS or MEGAN in the model description. I have indicated the places that are unclear below.

I expect that the manuscript will be suited for publication in GMD once these comments have been accounted for.

We thank the referee for the feedback and suggestions to improve our manuscript, as well as the recommendation for publication. Detailed responses are below.

Major remarks:

- *L. 23: Oxidative stress is one possible reason for BVOC emissions, but they can also be triggered by other chemical, physical or biological stresses and processes (e.g. herbivory, signaling between organisms, or also oxidative stress originating from the atmosphere, e.g. under elevated ozone concentrations.*

  We have modified the manuscript accordingly.

- *L. 25: I think that all plants emit BVOC, but they can emit very different compounds, and not all emit isoprene.*

  This is correct. The text was modified.

- *L. 91: It would be interesting to summarize the difference between ONEMIS and MEGAN a bit further. E.g., in the later text, it appears that the two treat canopy structure in a different way. It would be good if the authors could give a brief description of the two schemes, as they are so fundamental for the rest of the paper.*

  We included a table summarising the key differences between ONEMIS and MEGAN (Table1). The cited papers should provide all details about the algorithms.

- *L. 107: I think that LPJ-GUESS v4.0 contains a functional land use scheme, see Lindeskog et al. 2013. In general, I think that the fact that land use is not represented should receive more attention in the discussion, in particular because the original emission schemes appear to represent crops. How important is this omission for the outcomes generated by the LPJ-GUESS-informed emissions schemes (ONEMIS and MEGAN)?*

  Even though LPJ-GUESS v4.0 contains a land use scheme, the EMAC-LPJ-GUESS configuration has no land use implemented yet (Forrest et al., 2020 for reference). In the discussion section, we further emphasised that our emissions are from the natural biosphere. We are aware that this is a limitation, but it is good to note that climatological values for LAI also do not fully take managed land into account. Nevertheless, the impact of crops is going to modify the emission results to a certain degree - manuscript updated.

- *Section 2.3.2: The authors have chosen to use LPJ-GUESS to provide information on LAI and PFT distribution, but other characteristics that are required for ONEMIS or MEGAN are not taken from LPJ-GUESS, but rather computed with the help of database numbers.*

  This is not entirely correct. As explained in section 2.3.1, all vegetation variables (i.e. LAI, DM, LAD distribution for ONEMIS; and LAI, vegetation-type coverage for MEGAN) are taken from LPJ-GUESS. The BVOC output from ONEMIS and MEGAN is then compared to the "original" set-up, where all vegetation variables are taken from database numbers. In the EMAC-LPJ-GUESS configuration, the only characteristics required for ONEMIS and MEGAN that are not taken from LPJ-GUESS are (1) emission factors, (2) surface temperature, (3) short wave radiation, and (4) solar zenith angle.

  Foliar density (L. 135) is computed from simulated LAI, rather than from the foliar C simulated by LPJ-GUESS. Why is this done? And how similar or different are the applied specific leaf weights from those used in LPJ-GUESS itself?

  This is a good point, however, we opted to compute the foliar density (DM) as described in the papers for two reasons: (1) The use of S_LW values from Olson makes our estimations consistent with our emissions factors and the framework of the calculations, (2) the leaf mass (cmass_leaf) from LPJ-GUESS was not available on the EMAC side.

  In LPJ-GUESS the cmass_leaf could be calculated as follows:

  cmass_leaf = LAI/SLA

  where SLA is the specific leaf area per PFT. LPJ-GUESS calculates the SLA from the leaf longevity and leaf physiognomy values for each PFT.

  We compared our foliar density with the foliar C simulated by LPJ-GUESS (Fig. 1) and the differences aren't large. We think that for the purpose of this study, and given that our DM and the one from LPJ-GUESS are so similar, the presented values are sufficient. We understand that in future studies when land use is implemented, there might be differences in the spatial patterns when compared to observations. In that case, we would highly consider using the cmass_leaf directly from LPJ-GUESS.

  Figure 1 (Comments including this figure are found in the supplement document)

  The same applies to the LAD distribution, which is taken from some standardized profiles, rather than using LPJ-GUESS' vertical distribution of LAI. It would be nice to hear more about this, and mention explicitly which information comes from LPJ-GUESS, and which from other (literature) sources. E.g., I guess that the canopy height (h) in

Eq. 2 comes from LPJ-GUESS and does not use the fixed height of 25 m (L. 160), given the simulated variations in canopy height (Fig. 5), but I cannot find this in the description.

For the LAD distribution calculation, the PFTs are categorised into three vegetational types as previously done in ONEMIS using a 21-layer canopy DDIM point data. The improvement here is that the parametrisation employed allows for the LAD distribution to be calculated as a continuous function. We still use the PFT height from LPJ-GUESS to evaluate the LAD distribution of each PFT within an assumed canopy height of 25m.

We understand that this might not have been very clear. The text is now modified accordingly. We also make the distinction between PFT height (h) and total canopy height (h_{tot}).

- *Results: At several places, seasonal variations are displayed as global mean (Fig. 4 bottom panel; Fig. 7 and 8 third row, Fig. 9 second row). However, the opposite seasons in the Northern and Southern hemisphere make it hard to interpret these; it would be nice to see them separated for the two hemispheres, or have them shifted by 6 months before adding, to represent the true seasonal cycle.*

  We thank the reviewer for pointing this out. All figures showing the seasonal variation were updated. Values from the southern hemisphere were shifted by 6 months as suggested.

- *L. 225: I agree that the representation of LAI has improved, but for the isoprene emissions, it is also important that the vegetation distribution has improved. Is this the case? See also my earlier remark on the representation of crops.*

  In Forrest et al. 2020, it has been already shown that the vegetation distribution in reasonable in the coupled model. Even in case of worse agreement compared to the offline data, the consistency in the new setup is higher, such that feedback mechanisms can be investigated.

- *L. 267: Why is the BVOC emission routine from LPJ-GUESS presented separately here? Is it available for use in EMAC, or is it just for comparison here? It would be interesting to see the results compared to Fig. 7 and 8 (again, please ensure that colour scales are the same). The description of the BVOC emission routine in LPJ-GUESS should be part of the methods section – this would also help to clarify what the status of this is relative to the other two emission schemes.*

  BVOC emissions from LPJ-GUESS are presented for comparison only. Fig. 9 now has the same colour-bar scales as Fig. 7 and Fig. 8, and panels (c), (d), (e), and (f) also include data from ONEMIS and MEGAN. The description of the LPJ-GUESS routine was moved to the methods section.

  The LPJ-GUESS routine runs entirely on the LPJ-GUESS side. One major difference is that the EMAC routines (ONEMIS and MEGAN) run on short time step values (according to the model's time step e.g. 10 minutes), while LPJ-GUESS only give daily emission values. The manuscript was updated accordingly.
- *Section 3.3: The description of the setup of the sensitivity simulations should be part of the methods section.*

The description moved to the methods section.

Minor remarks:

- *Figures: It would help to add labels (a, b, etc.) to the panels in the figures, to make the references to the figures more accurate.*

  Figures now include labels.

- *L. 37: Check spelling of "monoterpene"*

  Corrected.

- *L. 48: Not all stress effects are represented (properly) in our current process-based models.*

  Text updated.

- *L. 90: "this schemes" – does this refer to the two emission modules?*

  Yes. Text updated for clarification.

- *L. 132: "number of leaves": Do you mean "amount of leaves"?*

  Yes. Text updated.

- *L. 202: Clarify that "broadleaf" and "needleleaf" are trees.*

  Text updated.

- *Fig. 7 and following figures: Please ensure that the colour scales for the ONEMIS and MEGAN panels are the same, so that the patterns can be easily compared. Also, please clarify the use of the "climatological input": Is this a climatological input to ONEMIS and MEGAN (and how do the two schemes compare when running these climatological results), or is this one set of climatological input of emissions to EMAC?*

  Figures caption slightly updated. "climatological input" indeed refers to vegetation inputs to ONEMIS and MEGAN from offline climatology datasets. We think this term is well defined in section 2.3.1 including Fig. 1. Albeit not compared in the same plot, ONEMIS and MEGAN emissions using climatological inputs are included in Fig. 7 (and following figures) in panels (e) and (f).

- *L. 213: "Elevated" isoprene emissions. Elevated relative to the climatological inputs? Please specify what the reference level is here.*

  Text updated.

- *L. 236: "cross-annual": do you mean interannual?*

  Yes. Text modified.

- *Fig. 11: Please check the figure quality/resolution for the final publication, it is a bit blurred in the discussion paper.*

  Figure resolution updated from 300 to 500 dpi.

- *L. 331: The first sentence could be removed.*

  Agreed.

- *L. 342: Check spelling of "climatology"*

  Thanks for pointing this out.

- *L. 349: "when the difference in the prescribed monthly LAI": Do you mean the year-to-year difference here?*

  No. Here we mean the monthly input LAI. It should be more clear now.

Reference:

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.

Please also note the supplement to this comment:

https://gmd.copernicus.org/preprints/gmd-2022-154/gmd-2022-154-AC1-supplement.pdf