Author's response to comments from Anonymous Referee #3:

"BVOC emission flux response to the El Niño-Southern Oscillation "

by Ryan Vella et al.

We thank editor and referees for taking the time to review our manuscript and for the valuable feedback. Here, the comments from Anonymous Referee #3 (from June 05, 2023) are reproduced in black, while our comments are presented in blue.

From Anonymous Referee #3's response:

Reviews for "BVOC emission flux response to the El Nino-Southern Oscillation"

Isoprene and monoterpene emissions from the terrestrial biosphere play a significant role in major atmospheric processes. Biogenic volatile organic compound (BVOC) emissions are sensitive to climatic influences. This manuscript attempts to understand the relationship between BVOC emission and ENSO events using a global atmospheric chemistry-climate model with enabled interactive vegetation. Overall, the results are reasonable, and I recommend a major revision before acceptance.

Many thanks for considering our manuscript for review in BG. Detailed response below.

Major comments:

(1) In Section 2.2 EMAC-LPJ-GUESS configuration, I prefer that you can list some key equations for the parameterizations of BVOC emissions in this study. So we can easily understand why you choose temperature, radiation, AI, NPP, and LAI to investigate their impacts on BVOC emission anomalies.

Section 2.1 was extended and now includes more details on the model configuration. Also included the key formula for the BVOC parameterisation in ONEMIS. We explain why we evaluate temperature, radiation, AI, NPP, and LAI to study changes in BVOC emissions.

"While efforts for a fully coupled configuration are ongoing, in this work, we use the standard EMAC-LPJ-GUESS coupled configuration, where the vegetation in LPJ-GUESS is entirely determined by the EMAC atmospheric state, soil, N deposition, and fluxes (Forrest et al., 2020). After each simulation day EMAC computes the average daily values of 2-meter temperature, net downwards shortwave radiation, and total precipitation and passes these state variables to LPJ-GUESS. Vegetation information (LAI, foliar density, leaf area density distribution, and PFT fractional coverage) from LPJ-GUESS is then fed back to EMAC for the calculation of BVOC emission fluxes using EMAC's BVOC submodules (Vella et al., 2023), namely ONEMIS (Kerkweg et al., 2006) and MEGAN (Guenther et al., 2006). Both ONEMIS and MEGAN are based on the Guenther algorithms (Guenther et al., 1993), where the BVOC emission flux (F) is calculated as a function of the foliar density and its vertical distribution (D [kg dry matter m^{-2}]), ecosystem-specific emission factors (ϵ), and a non-dimensional activity factor (γ) that accounts for the photosynthetically active radiation (PAR) and temperature:

$$F = [D]\ [\epsilon]\ [\gamma] \quad (1)$$

In this work, we evaluate fluxes from ONEMIS, which is the standard and most established emission module in EMAC. Emissions are calculated at four distinct canopy layers, which are defined by the leaf area density (LAD) and the leaf area index (LAI). The attenuation of the PAR is determined for each level by considering the direct visible radiation and the zenith angle. Using the proportions of sunlit leaves and the overall biomass, emissions from both sunlit and shaded leaves within the canopy are estimated. Further technical details for canopy processes employed in ONEMIS can be found in Ganzeveld et al. (2002). While validating pure BVOC fluxes from models using observations remains challenging, this setup was evaluated and demonstrated to well-capture global BVOC estimates and responses when compared to other modelling studies (Vella et al., 2023). As described in Eq. 1, BVOC emission calculations in this setup are governed by vegetation states (D) from LPJ-GUESS that are largely based on temperature, radiation, and soil moisture. Furthermore, the instantaneous surface radiation and temperature levels (γ) have a large impact on the emission rates. On the the basis of such model parameterisations, we explore the impact on BVOC emission anomalies by evaluating changes in the surface temperature and radiation, the aridity index (AI), the NPP, and the LAI."

(2) Lots of sentences in the main text should appear in the figure captions. Please revise them through the whole text. For example, Page5 Line117-118, "The base year (ie. The 30-year average SST .... Blue (La Nina)." should be placed in the Figure 1 caption. Page 9 Line 191-192 "The r value for each grid is shown and correlations with $p < .01$ are marked with a start sign" should be placed in the Figure 3 caption.

All figure caption were updated accordingly.

(3) Page 8 Line 176-177 "During El Nino and the subsequent two years, SWUSA experiences a rise of 15.6% and 14.3%, respectively, while a decline of 24.4% is found in SWUSA during the two years following La Nina". The responses seem to be asymmetrical for El Nino and La Nina. So why the response of BVOC to La Nina has the lowest decline in the following two years?

If we look at the driving variables over SWUSA, we see asymmetrical responses during El Niño and La Niña e.g., warmer and cooler surface temperatures, higher NPP/LAI and lower NPP/LAI during El Niño and La Niña, respectively (see Fig. 4 & 5). These changes could explain the response of BVOC emissions

- higher during El Niño because of higher temperatures and elevated NPP/LAI, lower during La Nina because of cooler temperatures and lower NPP/LAI.
We added a new table (Table 2) that shows the correlations during and following the event, separately. During La Nina in SWUSA, we see a moderate-to-strong correlations between the isoprene flux and the NPP, LAI, and AI (especially with NPP/LAI in the following 2 years), but not so much with the temperature and srface radiation. Therefore, the response of BVOC to La Niña has the lowest decline in the following two years because of ENSO-induced anomalies in the vegetation states with longer-lasting effects.

Furthermore, even though the emission fluxes depend on several input parameters, their sensitivity across the occurring values is not linear, such that even though La Niña shows cooler temperatures (and therefore not that much heat stress) without significantly reduced NPP and LAI as a direct response, the decline in the emissions is weaker than the increase during El Niño.

(4) English writing need to be improved further.

The manuscript was sent to a professional proofreader. We hope that it reads better now.

Some minors:

(1) Page 1 Line 1: “major atmospheric processes”, could you show one or two specific examples.

Updated.

(2) Page 2 Line 45-46: “Several studies explored the sensitivity of the terrestrial biosphere to different ENSO phases (e.g. Ahlstrom et al., 2015; Chang et al., 2017; Bastos et al., 2018; Teckentrup et al., 2021)”, here is another paper well suitable here. See “Wang, J., Zeng, N., Wang, M., Jiang, F., Chen, J., Friedlingstein, P., Jain, A. K., Jiang, Z., Ju, W., Lienert, S., Nabel, J., Sitch, S., Viovy, N., Wang, H., and Wiltshire, A. J.: Contrasting interannual atmospheric CO2 variabilities and their terrestrial mechanisms for two types of El Ninos, Atmos. Chem. Phys., 18, 10333-10345, 2018.”

Citation was added.

(3) Page 6 Line 142: “give realistic insights on changes” => give insights into changes. I think simulated results are not necessarily “realistic”.

Updated.

(4) Page 10 Line 210: “... anomalies from very strong El Nino and La Nina scenarios”, the results in Figure 4 is composite results?

Fig. 4 shows results from the sustained ENSO scenarios. On the left hand-side we show the spatial distribution of the variables in "base conditions" i.e. using climatological SST/SIC (1980-2009), while in the middle and right-hand side we show anomalies by comparing simulations with sustained El Niño / La Niña SST/SIC with the "base" simulation.

The sentence was updated as follows:
"Fig. 4 shows global distributions of surface temperature, net solar radiative flux at the surface, and the AI averaged over 30 years for the base scenario as well as anomalies from Very Strong El Niño (Very Strong El Niño – Base) and La Niña (Very Strong La Niña – Base) scenarios."

(5) Page 13 Line 240-244: Two sentences are duplicate.

Fixed, thank you.

(6) Page 13: “TeBe” => “TeBE”

Updated.

(7) Page 14 Line 262-263: “statistically significant anomalies only occur in the very strong El Niño scenario with and increase from 34.13 Tg yr-1 to 38.13 Tg yr-1 (+11.72%) from base scenarios to very strong El Nino” => statistically significant anomalies only occur in the very strong El Niño scenario with the increase from 34.13 Tg yr-1 during the base scenarios to 38.13 Tg yr-1 (+11.72%) during the very strong El Nino.

Updated.

(8) Figure 8 figure caption: The Person’s correlation => The Pearson’s correlation

Updated

References

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.

Ganzeveld, L., Lelieveld, J., Dentener, F., Krol, M., Bouwman, A., and Roelofs, G.-J.: Global soil-biogenic NOx emissions and the role of canopy processes, Journal of Geophysical Research: Atmospheres, 107, ACH–9, 2002.

Guenther, A., Karl, T., Harley, P., Wiedinmyer, C., Palmer, P. I., and Geron, C.: Estimates of global terrestrial isoprene emissions using MEGAN (Model of Emissions of Gases and Aerosols from Nature), Atmospheric Chemistry and Physics, 6, 3181–3210, 2006.

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Kerkweg, A., Sander, R., Tost, H., and Jöckel, P.: Implementation of prescribed (OFFLEM), calculated (ONLEM), and pseudo-emissions (TNUDGE) of chemical species in the Modular Earth Submodel System (MESSy), Atmospheric Chemistry and Physics, 6, 3603–3609, 2006.

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