We would like to thank the referee for their very helpful and constructive feedback. They have identified some areas where we are able to greatly improve the review.

We have responded to the referee's comments in blue font below.

Anonymous Referee #2

Comments:

As often mentioned in the manuscript, the goal of this work is to force the coupled model using climate change scenarios and assess the impact of climate change on the biogenic emissions. However, only a single year (2019) is presented in this paper. Unless you include long SURFEX-MEGAN simulation results in a revised version, it should be avoided to create more expectations than the manuscript can address.

This point was discussed in the paper to stress the motivation behind the work of coupling the land model SURFEX and the biogenic model MEGAN. We agree that this might create more expectation than the manuscript addresses. In a revised version, this point will only be mentioned in the introduction of the paper and briefly as a perspective in the conclusions section.

You mention that the vegetation-type specific treatment in SURFEX improves the accuracy of isoprene estimates. Please provide evidence to prove this. Data from isoprene flux measurement campaigns (Seco et al. 2022, Emmerson et al., 2020; and many others) should be used to assess the SURFEX-MEGAN emissions. In a revised version, a detailed evaluation of the model results against flux measurements should be included.

As stated in the paper, SURFEX includes routines that allow for the treatment of each vegetation type separately. This means that the estimation of several vegetation-related parameters (e.g., soil moisture, soil temperature, leaf area index) will be carried out for each vegetation type independently following parametrization governing the physics of each vegetation type. Since the estimation of isoprene flux in MEGAN relies on these parameters, our assumption is that using parameters for each vegetation type, as opposed to using a single averaged value for all vegetation types, results in a more accurate representation of input parameters. This should, in turn, lead to a more accurate estimation of isoprene following the MEGAN parametrization. More in-depth justification of this reasoning is provided below.

In fact, the ISBA scheme effectively captures the unique physics of different plant functional types (PFTs), such as grasslands and dense canopy forests. This differentiation is critical because each PFT is defined by specific parameters, including root depth. Root depth is a key factor in accurately representing how each vegetation type accesses soil moisture, which in turn influences the soil moisture activity factor within SURFEX. While certain ISBA variables like soil moisture and Leaf Area Index (LAI) have been validated through field measurements, the model estimations at the patch level were not validated due to measurement limitations. Nevertheless, ISBA has demonstrated reliable performance in estimating biomass, leaf area index, evapotranspiration, soil carbon, etc compared to other land surface models (Friedlingstein et al. 2022).

Therefore, when it is said that SURFEX improves isoprene estimation, it specifically refers to the technical capability of SURFEX to provide more accurate input parameters compared to the standalone MEGAN version, which uses an average value for all vegetation types.

While we think that it is important to validate the MEGAN estimations against field measurements, it is not the primary focus of this paper. This manuscript seeks only to validate the implementation of MEGAN in SURFEX by comparing the coupled model SURFEX-MEGAN isoprene emissions with other MEGAN-based isoprene inventories. To also include a validation of the coupled model SURFEX-MEGAN isoprene estimates against field measurements for each PFT would, we believe, significantly increase the size of an already long manuscript.

However, we have performed a preliminary comparison of the model isoprene estimations with some field observations made in some locations in 2019 (FR0045U/FR0046U, CH0053R and GB0010U) located in France, Switzerland and England, respectively (Figure 1). The results of this comparison show a good agreement between the model estimations and the observations, with a correlation coefficient ranging between 0.76 and 0.89. Therefore, we believe that the model has the ability to represent well daily isoprene variations throughout the year (Figure 1).

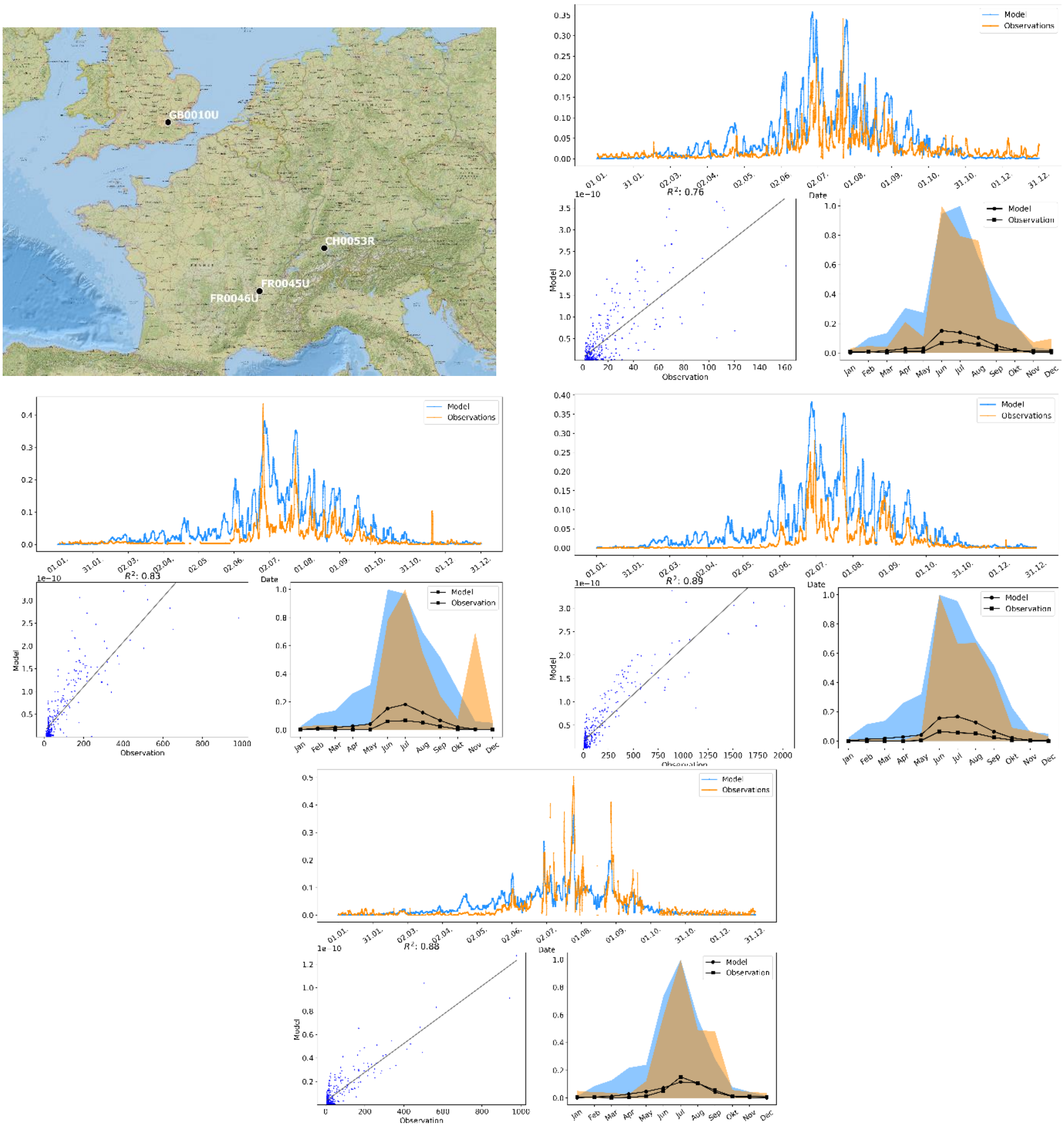

Figure 1: location of isoprene field measurements and daily and monthly isoprene estimation of the reference simulations variations against field observations.

References:

Friedlingstein, P., Jones, M. W., O'sullivan, M., Andrew, R. M., Bakker, D. C., Hauck, J., ... & Zeng, J. (2022). Global carbon budget 2021. *Earth System Science Data*, *14*(4), 1917-2005.

- The differences between the reference run and the sensitivity run using MERRA reanalysis are not adequately explained. To ease the discussion, could you include comparisons of the monthly temperature from ERA5 and MERRA for the regions of Figure 8? Could you quantify the differences between the two datasets for temperature and solar radiation, which are the main driving factors of the isoprene emissions? Where are those differences more significant and what is the induced uncertainty due to the meteorology?

We have added in this section the following paragraph to try to illustrate the differences between the ERA5 and MERRA temperature and PAR and the impact on isoprene estimation:

"A regional analysis was also conducted to quantify the impact of using different meteorological datasets on isoprene estimates. Figure 13 displays monthly isoprene emissions of the reference and S1-MERRA simulations across the globe regions shown in Figure 8. Isoprene flux absolute difference is

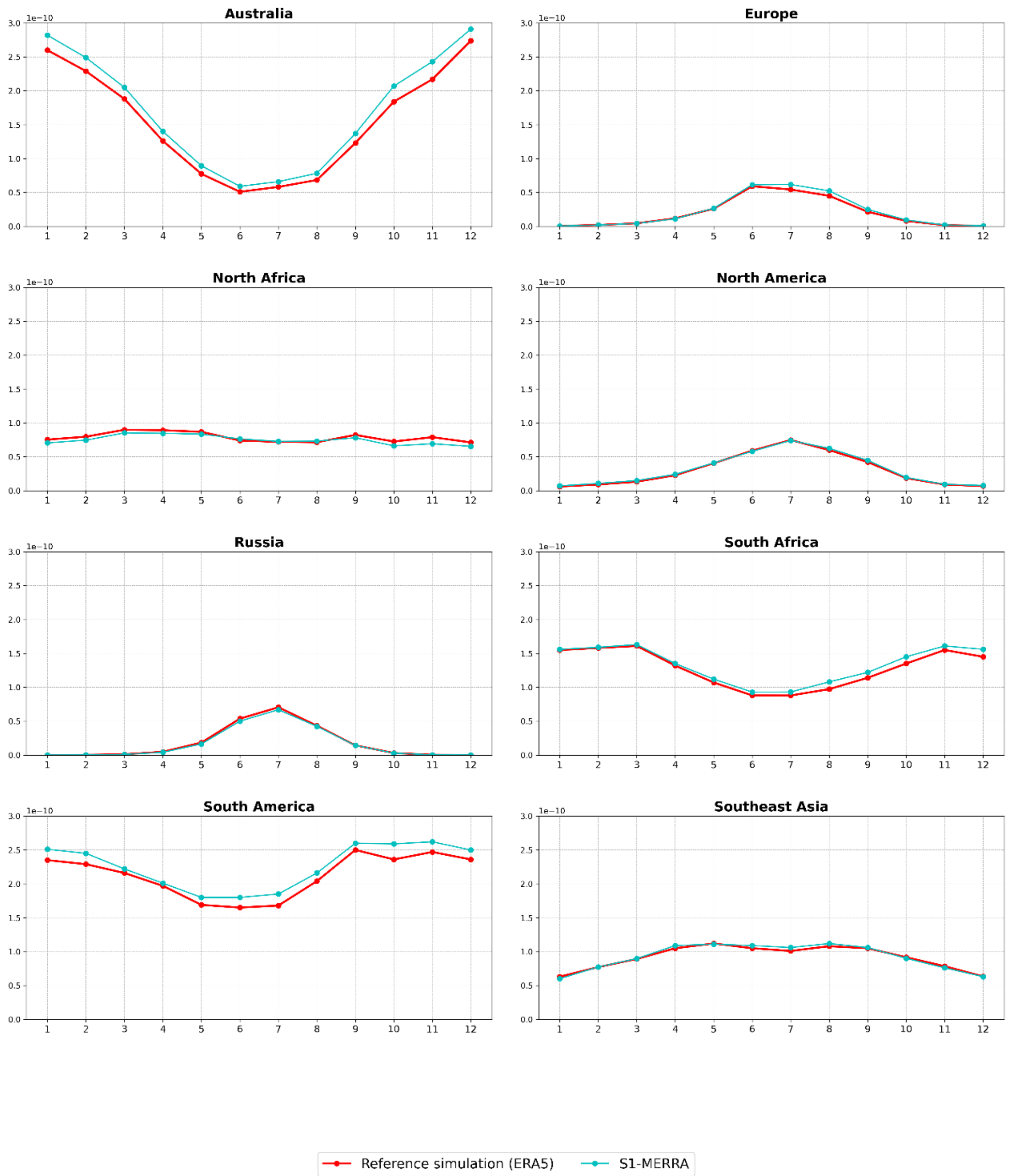

Figure 13: Monthly variation of reference and S1-MERRA simulations of the globe regions defined in Figure 8 in $kg/m^2/s$.

mostly pronounced in Australia, South America and Southern Africa, where S1-MERRA isoprene estimates are higher than the reference simulation. In South America, Southern Africa and Australia, S1-MERRA monthly isoprene emissions are higher than the reference simulation by a range of 2%-10%, 1%-11% and 6%-15%.

In these regions, although the temperature difference between MERRA and ERA5 is not significant (less than 0.5°), the photosynthetic active radiation PAR is different. In these regions, PAR variations range between -1-9w/m², -2-8w/m2 and -1-8w/m², respectively. Consequently, the main factor driving monthly variations in isoprene emissions between the reference simulation and the S1-MERRA simulation is PAR."

- It is not clear what parameterization is used for the activity factor accounting for the isoprene inhibition due to enhanced CO_2 levels (Equ. 2). The impact of CO_2 levels on isoprene fluxes is highly uncertain, as past work reported contradictory findings (Sun et al., 2013; Tai et al., 2013, Bauwens et al., 2018). I urge the authors to discussion this aspect and quantify the impact of the CO_2 inhibition on the total annual emission.

In our SURFEX-MEGAN model, we incorporate the CO2 inhibition parametrization from Heald et al. (2009). We chose not to focus on this aspect in our paper because the inhibitory effect of CO2 on isoprene emission becomes significant only when atmospheric CO2 levels exceed 400ppmv substantially, as indicated by Sindelarova et al.(2014). This consideration is primarily relevant for future scenarios where CO2 concentrations are expected to rise. For example, Sindelarova et al. (2014) showed that in 2003, the CO2 inhibitory factor (γ_(CO2)) was 1.0277. In our study, we used a fixed CO2 value of 410ppmv. Since the inhibitory factor is 1 at 400ppmv, the impact of CO2 on our current study is minimal and therefore the inhibitory effect of CO2 in this study can be neglected.

We have added this sentence in the Model setup section to explain the choice of setting this parameter to 1:

"Unless otherwise stated, in all coupled model simulations the estimation of isoprene flux was done based on isoprene potential map and the effect of soil moisture deficit and CO2 on BVOC emissions was not taken into account (the γ sm and γ CO2 factors were assigned to 1). This choice allows a better comparison with other emission inventories. Additionally, the impact of the CO2 inhibition factor becomes relevant only when CO2 atmospheric concentrations exceed significantly 400ppmv (Sindelarova et al. (2014))."

References:

Heald, C. L., Wilkinson, M. J., Monson, R. K., Alo, C. A., Wang, G., & Guenther, A. (2009). Response of isoprene emission to ambient CO2 changes and implications for global budgets. *Global Change Biology*, *15*(5), 1127-1140.

Sindelarova, K., Granier, C., Bouarar, I., Guenther, A., Tilmes, S., Stavrakou, T., ... & Knorr, W. (2014). Global data set of biogenic VOC emissions calculated by the MEGAN model over the last 30 years. *Atmospheric Chemistry and Physics*, *14*(17), 9317-9341.

- This study does not account for recent efforts to improve the soil moisture activity factor parameterization in MEGAN (Jiang et al., 2018; Wang et al., 2022; Opacka et al. 2022). A discussion is needed and an estimation of the isoprene fluxes using (at least) one different parameterization should be added in the manuscript.

We agree with the referee on this point. However, there are some limitations to conducting more analysis on soil moisture activity factor. First, As mentioned in Opacka et al.2022, the impact of soil moisture can be refined in MEGANv2.1 by improving the estimation of the empirical parameter $\Delta\theta$. In earlier studies this parameter was fixed to 0.06 but was re-adapted to a new value of 0.04. This new value was chosen so that the emissions are shut off only in extreme drought events. Therefore, this study focused on improving the estimation of the parameter $\Delta\theta$ based on isoprene flux measurements at the Missouri Ozarks AmeriFlux (MOFLUX) site. As mentioned in this paper, the adjustment of $\Delta\theta$ is influenced by soil moisture θ data and the soil depth of reference, thus, the $\Delta\theta$ adjusted value found in this paper can not be applied directly to our model. We believe that conducting a thorough study on the adjustment of this empirical parameter is not straightforward and it would require a consequent work. Therefore, this particular point will be addressed in a future paper focusing only on the optimization of soil moisture activity factor in the coupled model SURFEX-MEGAN.

Other approaches exist to improve the estimation of soil moisture impact on isoprene emissions. These approaches are based on the new soil moisture parametrization used in MEGANv3. As discussed in Jiang et al.2018, this new approach improves the estimation of isoprene in drought and non-drought events. The estimation of the soil moisture activity factor used in MEGANv3 is based on two parameters V_{cmax} and β_t. The former represents the maximum rate of carboxylation by the photosynthetic enzyme Rubisco and the latter the soil water stress function. This approach was tested in MEGANv2.1 embedded in the Community Land Model CLM4, which has detailed biogeophysical and hydrological cycles, and biogeochemical components, and can estimate carbon, water, and energy fluxes. As opposed to CLM4, SURFEX does not include a detailed photosynthesis parametrization that takes into account the physiological response of plants to drought stress through V_{cmax} and β_t. Therefore, we agree with the referee on the importance of exploring alternative approaches for the soil moisture activity factor, however, considering the potential time investment, we propose conducting separate tests for these approaches in a forthcoming paper.

References:

Opacka, B., Müller, J. F., Stavrakou, T., Miralles, D. G., Koppa, A., Pagán, B. R., ... & Guenther, A. B. (2022). Impact of drought on isoprene fluxes assessed using field data, satellite-based GLEAM soil moisture and HCHO observations from OMI. *Remote Sensing*, *14*(9), 2022.

Jiang, X., Guenther, A., Potosnak, M., Geron, C., Seco, R., Karl, T., ... & Pallardy, S. (2018). Isoprene emission response to drought and the impact on global atmospheric chemistry. *Atmospheric Environment*, *183*, 69-83.

- About Figures: (i) The readability of Fig 2 is quite low. Could you change the scale? (ii) Not clear where Fig 8 is used. The figure seems to be at lower resolution. Can you improve the resolution?

We will change the scale of Figure 2.

Figure 8 has been included to provide a visual representation of the geographical regions utilized in the analysis. However, we intend to substitute this figure with another one with a higher resolution.

- l 74-75, "the coupling between SURFEX and MEGAN can create a feedback loop that takes into account both the impact on climate on vegetation and the impact of vegetation on climate'. Poorly worded sentence. Furthermore, these impacts are not presented in the manuscript. Could you include a tentative quantification of these impacts?

We have amended this sentence to clarify the feedback loop between vegetation and climate:

"The coupling between SURFEX and MEGAN can take into account the impact of climate on vegetation through climate-induced changes in BVOCs emission-driving variables (e.g., temperature, solar radiation, atmospheric CO2 concentrations). The impact of vegetation on climate can also be investigated through the Earth System Model CNRM-ESM2-1 (Séférian et al.2019), which includes the land surface model SURFEX. This effect originates from the BVOCs-induced impact on aerosols and other greenhouse gases concentration, which can alter the Earth's radiative balance (Unger et al.2014(a) – Unger et al.2014(b) – Sporre et al.2019)."

References:

Séférian, R., Nabat, P., Michou, M., Saint-Martin, D., Voldoire, A., Colin, J., ... & Madec, G. (2019). Evaluation of CNRM Earth System Model, CNRM-ESM2-1: Role of Earth system processes in present-day and future climate. *Journal of Advances in Modeling Earth Systems*, *11*(12), 4182-4227.

Unger, N. (2014). Human land-use-driven reduction of forest volatiles cools global climate. *Nature Climate Change*, *4*(10), 907-910.

Unger, N. (2014). On the role of plant volatiles in anthropogenic global climate change. *Geophysical Research Letters*, *41*(23), 8563-8569.

Sporre, M. K., Blichner, S. M., Karset, I. H., Makkonen, R., & Berntsen, T. K. (2019). BVOC–aerosol–climate feedbacks investigated using NorESM. *Atmospheric Chemistry and Physics*, *19*(7), 4763-4782.

- l 291: 'In low isoprene emission regions, such as North America'. This is not correct. Southeast US is among the strongest isoprene emitting regions in the world (Wiedinmyer et al., 2005; Kaiser et al. 2017 and others).

Will be replaced with "In other globe regions, such as North America, Europe, and North Asia, isoprene emissions from SURFEX-MEGAN are particularly higher when compared to other isoprene inventories."

- l 314: 'by a very low activity', replace by 'a very low flux'

Changed as suggested.

- l 323: 'These regions are active', replace by 'These regions are emitting'

Changed as suggested.

- l 330: 'As stated in (Guenther et al., 2012), replace by 'As reported in Guenther et al. (2012)'. Here and throughout the manuscript, check your citations.

Changed as suggested.

- Table 4: can you add a column with the global total emission for each of the setups? Similarly in Figure 4: add the global emission estimate inside the subplots. In Table 4, the description 'use of isoprene emission potential' is vague. Be more specific.

Global total emission will be added in Table 4 and Figure 4. In Table 4 'use of isoprene emission potential' will be replaced with 'use of PFT-specific isoprene emission potential data e_{PFT}'.

- l 346: correct problems with spaces

Problem solved.

- Fig 13: Are the red dots over islands due to very low or zero e_{map} values over those regions? I recommand to add a global map of isoprene flux based on the e_{PFT} (with the global emission provided inset).

Red dots over islands are due to very low e_{map} values. S2 global isoprene flux map will be added.

- l 385: 'has been observed', replace by 'has been calculated' or 'has been found'

Changed as suggested.

- l 392: 'was done to cover', replace by 'accounts for'

Changed as suggested.

- l 425: correct the exponents

Corrected.

- l 421: '273Tg'. Add a space '273 Tg' here and throughout the manuscript.

Corrected.

- code availability: provide links for the datasets presented in the paper

We have provided a link for the datasets and for the model code.