## **Reply to Reviewer 1**

We sincerely appreciate the two reviewers for their constructive comments to improve the manuscript. Reviewer 1's comments are reproduced below with our responses in blue. The corresponding edits in the manuscript are highlighted with track changes.

## Specific Comments

Line 74. The CO2 parameterisation serves to inhibit isoprene emissions (Heald et al., 2009)? **Response:** Thank you for the comment about the need to expand further on this topic. In MEGAN2.1 there is a parameterization used called  $y_{co_2}$  which inhibits and decreases nonlinearly isoprene emissions when CO<sub>2</sub> concentration rises above 400ppmv which is included in our MEGAN implementation in NASA GISS ModelE following (Heald *et al.* 2009; Guenther *et al.* 2012; Henrot *et al.* 2017) as described in line 182-183.

Please see line 71-75 for statement that clarifies our intent "Biogenic isoprene emissions affect atmospheric composition and climate, and in turn depend on environmental factors including light, temperature, photosynthetically active radiation (PAR), leaf area index (LAI), water stress, ambient O<sub>3</sub>, and CO<sub>2</sub> concentrations. Thus, the response of isoprene emissions to weather extremes and changing climates is highly uncertain."

Line 80-82. Very confusing sentence. 'During drought, increases in SOA and O3 are to be expected'. Why? What aspect of drought would cause this? (In my mind, less isoprene would mean less ozone?) Needs explanation. Then the second part of the sentence suggests isoprene reductions will decrease the magnitude of the increase.

**Response:** We agree that the message is not clearly conveyed and our discussion of SOA in relation to our study is inappropriate for the introduction, thus we have removed mentions of SOA in accordance with a suggestion from Reviewer 2.

We've expanded the explanation of ozone behavior during drought on line 882-889. "During drought there is elevated  $O_3$  and  $PM_{2.5}$ , compared to non-drought periods (Wang *et al.* 2017; Zhao *et al.* 2019; Naimark et al., 2021). Higher ozone compared to non-drought years is due to the reduction of vegetative deposition due to reduced stomatal conductance, higher temperatures stimulating precursors, and enhanced NO<sub>2</sub> (Naimark *et al.* 2021). By including isoprene drought stress into the simulations, isoprene emissions are decreased which will change  $O_3$ , and the direction of change depends on NO<sub>X</sub>-limited or VOC-limited regimes (Li *et al.* 2022). In summary, we better predicted isoprene emission response to drought by including isoprene drought stress."

Line 199. 1x10-9/3600 looks like it also contains the conversion from the emission factor units of ug to kg (rather than just being a timestep conversion). **Response:** Thank you for catching this typo. It is fixed on line 213-215. " $(1x10^{-9}/3600)$ : the numerator converts units from ug/m<sup>2</sup>/hr to kg/m<sup>2</sup>/s and the denominator is the timestep conversion for seconds in an hour."

Line 427 define USDM

**Response:** On line 402-407 we included the explanation of USDM. "The U.S. Drought Monitor (USDM) produces color-coded maps indicating drought severity across the U.S. and is produced through a partnership of the National Drought Mitigation Center at the University of Nebraska-Lincoln, the U.S. Department of Agriculture, and the National Ocean and Atmospheric Administration (NOAA). The USDM drought maps have five classifications to indicate drought condition: (D0) indicating abnormally dry, (D1) moderate drought, (D3) extreme drought, and (D4) exceptional drought."

Figure 1. there looks like a gap in the observations towards the end of the timeseries (mid august). Consider whether these time periods should be removed? **Response:** You are correct there was an equipment failure in mid-August 2011 at the MOFLUX site, which is documented in Potosnak *et al.* 2014. For the timeseries and analysis shown when there was missing data, we removed the corresponding simulated data to match only the periods with observations.

Lines 511-520. You talk about the general over/under estimation of the model but what about the shape of the fit details? Does the model hit or miss the daily peaks? What could be the reason for the missed peaks?

**Response:** The shape of the fit for the MAXVOC, severe drought, and drought recovery period is shown as the distribution of daily averaged values in **Fig. R1** shown below. During the MAXVOC period the means for Default\_ModelE and DroughtStress\_ModelE are below observed shown by yellow diamonds. During the severe drought period DroughtStress\_ModelE shown in green has a closer mean to observed shown in black indicating reduced emissions. During the drought recovery period there is little change in the distribution between Default\_ModelE and DroughtStress\_ModelE. In Fig. R2 are shown the time series of daily peaks in the observations, Default\_ModelE and DroughtStress\_ModelE. During the severe drought period, DroughtStress\_ModelE still is biased higher than the observed daily peak, but, except for one day (2012/08/01), consistently less than Default\_ModelE.



**Figure R1**: (a) boxplots to indicate the distribution of daily averaged isoprene emissions for the three simulations Default\_ModelE shown in red, DroughtStress\_ModelE shown in green, and observations show in black. (b) the distribution of isoprene during the severe drought and (c) the distribution during the drought recovery period with the averages shown by yellow diamond.

**Figure R2** shown below is the timeseries of hourly peak isoprene for each day for the time period MAY-SEP 2012. Default\_ModelE tends to underestimate the hourly peak of each day in the MAXVOC period. Default\_ModelE for much of severe drought period is higher than observed compared to observed hourly peak for each day. DroughtStress\_ModelE in green tends to reduce the daily peak and move it closer to observed during severe drought period. During drought recovery there is not much difference between Default\_ModelE and DroughtStress\_ModelE daily peaks.



**Figure R2**: the timeseries shows the daily peak of isoprene emissions from MAY-SEP 2012 during the time periods MAXVOC, severe drought, and drought recovery. Observations are shown in black, Default ModelE in red, and DroughtStress ModelE shown in green.

It is challenging to pinpoint what is making the model miss the daily peaks as there are too many uncertainties related to the MEGAN activity factors and the simplified canopy parameterization scheme used in our MEGAN implementation. For example, the model could be missing the peaks due to deposition values not being completely accurate, responsiveness of model to changing conditions could lag behind real time conditions, radiative properties, and chemistry could all contribute to the missing peaks. There is also the issue of comparing a site to a model grid which plays a factor. The model throughout MAY-SEP 2012 does reasonably capture the observed temperature quite well so its most likely not a temperature issue driving the missing peaks in daily isoprene as shown in **Fig. R3**. Other meteorological drivers at MOFLUX during 2012 as requested by Reviewer 2 are available in the supplement, such as monthly averaged (temperature, LAI, relative humidity, shortwave incoming solar radiation, CO<sub>2</sub> flux, vapor pressure deficit (VPD), and canopy conductance) are compared to observed when observations are available in **SI Fig. S12**. Soil moisture by layer is shown in **SI Fig. S14**.



**Figure R3**: shows the timeseries of daily averaged temperature at MOFLUX site for MAY-SEP 2012 in Celsius. The observed temperature is shown in black and red shows Default\_ModelE.

Figures R1, R2, and R3 are now included in the Supplementary Materials and related discussions added on line 134-173.

Section 3.2. MOFLUX\_DroughtStress is not one of the models shown in the fig 1 timeseries, yet promises to be a better fit. I'd like to see it compared with the observations at the MOFLUX site. **Response:** The timeseries showing MOFLUX\_DroughtStress in orange is shown below in **Fig. R4** and it's included in the supplement as **SI Fig. S2**. MOFLUX\_DroughtStress does work marginally better at the site, which is why we refer to it as a site-specific parameterization, but the water stress thresholds are not suitable for other grids in a global model which is why DroughtStress\_ModelE was developed for a more global representation. MOFLUX\_DroughtStress compared to DroughtStress\_ModelE only had a slightly higher correlation coefficient and slope as shown by the scatterplots included below.



**Figure R4**: (a) shows the timeseries of daily averaged isoprene emissions at MOFLUX during 2011 with MOFLUX\_DroughtStress in orange and (b) shows the timeseries of isoprene during 2012 severe drought. The scatterplots (d-f) show the hourly comparison of observed isoprene to simulated during MAY-SEP 2012 at MOFLUX with the points color coded by water stress values. The panels (d-f) show Default\_ModelE, MOFLUX\_DroughtStress, and DroughtStress\_ModelE, respectively.

Line 585. Soil moisture products 'resulted in' isoprene reductions.... **Response:** Fixed

Line 657. 'model agreement' here is a bit strong since the scatter plot shows the data points well spread from the 1:1 line.

**Response:** It is revised so it is not such as strong a statement in line 712-714. "Overall, there is an acceptable level of agreement between measured and modeled fluxes in

DroughtStress\_ModelE indicating it is a suitable model-tuned parameterization for estimating isoprene emissions during severe drought at the MOFLUX site."

Line 669. 'As shown below'. Below where? Underneath this line is a table of global emissions, not details on the south east US.

**Response:** Please see correction on line 723-724 "On a global scale these changes average under 3%, but for high isoprene emission regions such as the Southeast U.S. during drought periods there are larger impacts as shown below in Fig. 6."

Line 820. Affect, not 'effect'

Response: Fixed, please see track changes to see correction in manuscript.

Line 821. Higher mean O3. I need more explanation about what is leading to the higher ozone if the isoprene is reduced.

**Response:** In general there is higher ozone during drought years compared to non-drought years due to decreased deposition, increase in precursors, and increased NO<sub>2</sub> a proxy for NO<sub>x</sub> (Wang *et al.* 2015; Naimark *et al.* 2021). What this statement is focused on is comparing drought to non-drought periods. By including isoprene drought stress into the model there is reduced isoprene which can reduce O<sub>3</sub>, but this change is not linear and depends on the NO<sub>x</sub>/VOC limited regime, deposition, hydroxyl radical (OH) concentration, etc..

Please see line 909-910 for a clarification. "During the drought periods of 2007, 2011, and 2012 the model predicts higher mean  $O_3$  and  $\Omega$ HCHO than the non-drought years of 2008, 2010, and 2013."

## **References**

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