Response to Comments of Reviewer #1

Manuscript number: acp-2019-935
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Title: Ozone-vegetation feedback through dry deposition and isoprene emissions in a global chemistry-carbon-climate model

Gong et al. present research using the NASA ModelE2-YIBs model to estimate the impact of ozone damage to vegetation on atmospheric composition. They implement a more detailed representation of ozone damage in a coupled land-atmosphere model and find that, in general, inhibition to stomatal conductance leads to ozone increases. Quantifying biosphere-atmosphere exchange processes such as ozone damage in coupled models is an important line of research, and this work will likely be fit for publication in ACP once the following comments are addressed.

Response:

Thank you for the helpful comments and suggestions. We have revised the manuscript carefully and the point-to-point responses are listed below.

General comments:

My major concern is with seemingly inconsistent results in various heavily vegetated areas, specifically Africa. In Figure 2, ozone concentrations in central Africa look to be ~48 ppbv in a region with a lot of vegetation. This is higher than ozone in other regions (e.g. North America) that do show ozone damage impacts. However, in Figures 3, 5, 7, and 8, there are no discernable ozone damage impacts shown in this area. Why is that the case? This is surprising and should be explained further in the manuscript.

Response:

Sorry for the confusion due to the low resolution of figures. If we zoom in Figure 2 on Africa (Figure R1), the 'heavily vegetated areas' (enclosed by the green rectangle), which is mainly covered by evergreen broadleaf forest (Figure R2), show low O_3 concentrations. Meanwhile, the region with high O_3 concentrations (enclosed by the blue rectangle) show quite low GPP and IPE. As a result, the weak O_3-vegetation interactions are reasonable in Africa.

In Sitch et al. (2007) schemes, different vegetation types show different performance to the O_3 exposure. Compared with evergreen or deciduous broadleaf forest, C3/C4 grassland and cropland have higher threshold $F_{O3,crit}$ (Supplementary Table S1). As a result, C3/C4 grassland and cropland in African would suffer lower level of O_3 damage than the deciduous broadleaf forest in North America even under the similar level of O_3 exposure, leading to trivial ozone damage impacts in African in Figure 3, 5, 7, and 8.

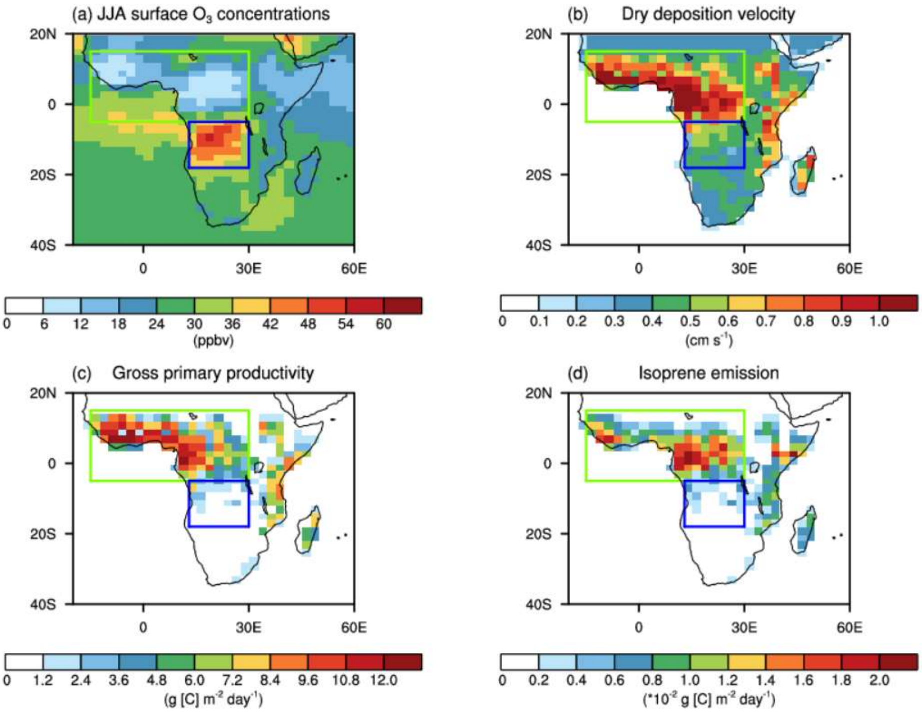


Figure R1. The same as Figure 2 but zoomed in on Africa. The green box encloses the 'heavy vegetated areas' with high GPP and IPE. The blue box encloses areas where surface O_3 concentrations are high.

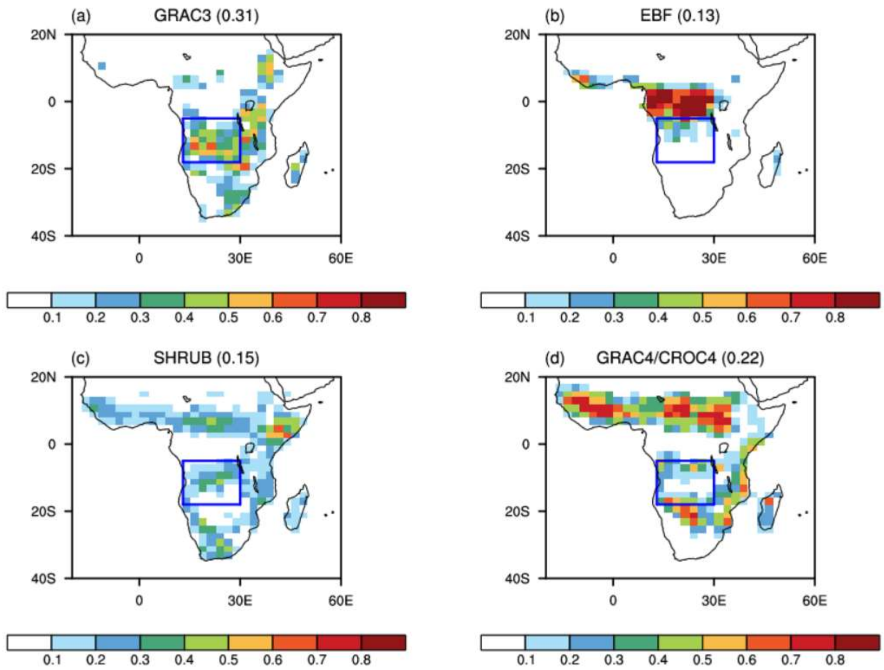


Figure R2. Land cover fraction of (a) C3 grassland , (b) evergreen broadleaf forest, (c) shrubland and (d) C4 grassland and cropland. The average cover of each PFT over the areas with high surface O_3 concentrations (blue box) is given in the subtitles.

Specific Comments:

P2 L31: Citation needed for the statement that the majority of ozone deposition is through stomatal pathways.

Response:

The sentence has been revised as:

'O_3 dry deposition is one of the important sink of tropospheric O_3 and mainly occurs over vegetation (Wesely, 1989). The stomatal uptake of vegetation plays an important role in this removal process. (Wesely and Hicks, 2000)' (Page 3, Lines 1-2)

P3: Despite the text critical of previous work, the authors here find a very similar ultimate impact of ozone damage on vegetation. This should be acknowledged here or elsewhere in the manuscript.

Response:

We have added the correspondingly statement in the second paragraph of Sect.4 Conclusion and discussion:

'Sadiq et al. (2017) also showed positive O_3-vegetation feedback on the surface O_3 in a global model. Compared to their results, we find an ultimate positive feedback with similar magnitude of surface O_3 concentrations but different spatial pattern. The strongest feedback in eastern China….' (Page 12, Lines 25-27)

P4: A description of biogenic emissions is necessary in this section.

Response:

The description of biogenic emissions has been added in the second paragraph in Sect. 2.1:

'…The LAI and tree growth are dynamically simulated with the allocation of carbon assimilation. The emissions of isoprene are calculated online as a function of Je photosynthesis (Eq. (1)), canopy temperature, intercellular CO_2, and CO_2 compensation point (Arneth et al., 2007; Unger, 2013), and have been fully validated by Unger et al. (2013). Carbon fluxes, phenology, LAI, GPP, and net ecosystem exchange (NEE), ….' (Page 5, Lines 1-5)

P6 Eq 10: What are the variables "n" and "i"?

Response:

The Eq. (10) in origin manuscript and the correspondingly explanation has been revised as:

$$\mathrm{POD_1} = \int_1^n (F_{O_3} - 1)dt$$

(14)

'where F_{O3} is the O_3 uptake rate by stomata (nmol O_3 m^{-2} s^{-1}), which is the same as that in Eq. (11). *dt* indicates the time integration step and *n* indicates the total number of time steps during the growing season.' (Page 7, Lines 10-13)

P6 L28: What does "because of the data limit" mean?

Response:

As we described above, 'To date, only one study (Yuan et al., 2017) has explored the responses of IPE to different levels of O_3 damage for two poplar clones', so here we have to apply the PDI function for all vegetation types even though it is based on poplar observations. We have revised this sentence to clarify:

'Limited by the data availability, we apply the PDI function (Eq. (13)) for poplar to all vegetation types as follow:' (Page 7, Lines 16-17)

P7: The CTRL statement as described here is confusing. The text states that damage is calculated offline using the Sitch et al. (2007) scheme, but Table 1. states "None". Which is it?

Response:

Sorry for the confusion.

The CTRL run calculates offline ozone damaging, which does not feed back to affect vegetation growth and the stomatal uptake of ozone. As a result, we denote "None" for this run in original Table 1. To clarify, we change "None" in Table 1 to "Offline". In text, we revised as follows:

'In the CTRL run, the effects of O_3 damage to photosynthesis, stomatal conductance, and IPE are calculated offline; such damages are not fed back to affect vegetation growth and dry deposition of O_3.' (Page 7, Lines 27-29)

P7 L30: The linear fit in Figure 7d indicates and absolute bias of 32 ppbv. This should be acknowledged in the text as a limitation of this modeling approach.

Response:

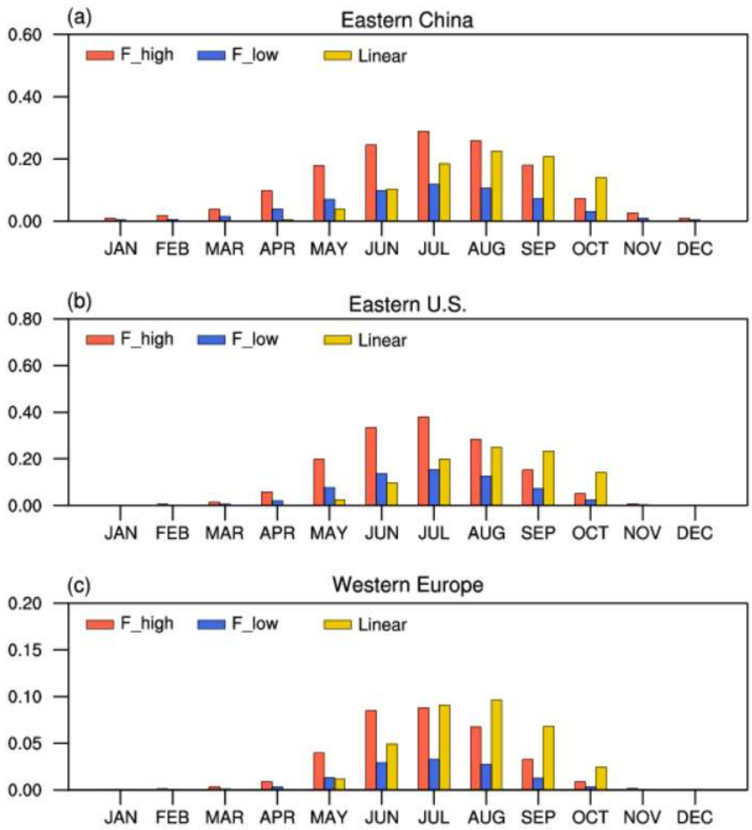
The sentences have been revised as follow:

'Figure 1 shows a comparison of the simulated summer O_3 concentrations to the observations. The model in general captures reasonable spatial patterns with a correlation coefficient of 0.41. The NMBs between simulations and observations in U.S and Europe are 11.7% and 13.2%, respectively, which are comparable with the simulation performed by CESM (Lamarque et al., 2012; Sadiq et al., 2017). However, the model overestimates O_3 concentrations by 29.3% with a regression intercept of 32 ppbv, suggesting that simulated O_3 vegetation damage might be overestimated especially over some regions with low ambient O_3 level. The large overestimate is mainly a result of overestimation in China…' (Page 8, Lines 17-22)

P9 L10: If the justification for focusing on northern hemispheric summer is that absolute changes to IPE are most significant during this time, why not show this in a figure instead of merely suggesting it?

Response:

A new supplementary Figure S4 is added to show the absolute changes in IPE:



Supplementary Figure S4. Monthly mean absolute O_3 damage to IPE (10^{-2} g[C] m^{-2} day^{-1}) averaged over (a) eastern China, (b) the eastern U.S. and (c) western Europe by using the F scheme with high/low sensitivities and the linear scheme, respectively.

The main reason for focusing on boreal summer is that surface O_3 concentrations are high and vegetation grows vigorously in the northern hemisphere. Consequently, the O_3-vegetation-IPE interactions are supposed to be the strongest. In the text, we clarify as follows:

'…However, the IPE peaks during summer (Fig. S3), suggesting that absolute changes in IPE are most significant during this season (Fig. S4). Meanwhile, since the surface O_3 concentrations and the vegetation growth both peak during boreal summer in northern hemisphere, the O_3-vegetation interactions are supposed to be the strongest in this season. As a result, we focus our analyses on the summer to explore the O_3-vegetation interactions and feedback.' (Page 10, Lines 1-5)

P10 L10: The authors speculate that the changes are no due to IPE changes, but instead meteorology. This should be explained further in more detail or stated more clearly as speculation.

Response:

The sentence has been revised as follow:

'Nevertheless, inclusion of IPE reductions helps increase surface O_3 over the eastern U.S. (Figs. 5d/5f vs. Fig. 5b), which is unexpected since the reduction in IPE is supposed to decrease O_3 concentrations. These changes are speculated to be indirectly related to O_3-vegetation feedback to meteorology and would be further examined in the next section.' (Page 11, Lines 4-6)

P11 L22: "likely related to the increased temperature…" further speculation. The sensitivity of the simulated ozone to temperature is not disentangled from other confounding factors. This should either be explicitly done, or the statement softened

Response:

The sentence has been revised as follow:

'The increased temperature following reduced SOA concentrations are speculated as a possible cause for this result.' (Page 12, Lines 19-20)

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