Reply on RC1

Xueyuan Gao et al.

Author comment on "Exploration of a novel geoengineering solution: lighting up tropical forests at night" by Xueyuan Gao et al., Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2021-85-AC3, 2021

Thank you for your comments! (1) In this study, we discussed the impacts of nighttime artificial lighting on energy balance (incoming radiation, latent heat, and sensible heat in Fig.1), climate (local surface air temperature, local precipitation, and global surface air temperature in Fig.2), and carbon sequestration. However, we realized that we did not give enough discussion to the negative impacts of this strategy, especially on ecosystem biodiversity, and we will make a supplement to this part in our revisions. (2) We apologize for missing this part in the manuscript. We have provided the calculations of the energy requirement in our reply to Richard Rosen's comments (reply on CC1), and we will incorporate the calculations into the manuscript. (3) We agree that model simulations have large uncertainties due to a lack of understanding of forests' physiological responses to nighttime lighting as we discussed in Discussion (lines 193-204). Ideally, small-scale field experiments should be conducted to get a better knowledge of forests' physiological responses to nighttime lighting, after which we modify modern models. However, the physiological responses of tropical trees to longer photoperiods overall have received little attention, and field experiments are lacking. Numerical simulation is currently the only available tool for us, and it provides us with one possible outcome scenario of the lighting experiment. We expect to see more field experiments to be conducted in the future to improve our understanding of the ecosystem responses of tropical forests to longer photoperiods. (4):

- Overall, the physiological and ecosystem responses of tropical forests to longer photoperiods receive little attention. A few greenhouse studies show that some tropical tree species' seedlings respond positively to longer photoperiods. However, ecosystem-level field experiments are lacking. We would like to make a supplement to the current introduction and provide a more detailed literature review on this aspect.
- Normally, cosine (solar zenith angle) is used in two places in each module. First, the sign of the cosine is used by the model to determine if a grid column is at daytime or nighttime. A negative cosine indicates the grid column is at nighttime and the incoming solar radiation would be assigned with zero. A positive cosine indicates daytime, and the cosine value would be used to calculate incoming solar radiation. In our case, a tropical forest grid column is normally at nighttime. We change the sign of the cosine from negative to positive to turn on the calculation of atmospheric and land processes in this grid column. The new cosine value is now used to calculate incoming solar

radiation by the model. However, we don't really need the model-calculated incoming solar radiation as we have to specify the value of each component in incoming solar radiation manually. This is why the sign of cosine (solar zenith angle) matters while its absolute value does not. We may have not stated this point clearly in the manuscript and we would like to clarify this point in the revision stage.

- The nighttime NEP is higher than daytime because nighttime surface radiation is solely diffuse visible light while daytime surface radiation is composed of direct NIR (~16%), diffuse NIR (~30%), direct visible light (~15%), and diffuse visible light (~39%).

During daytime in the control simulation, the maximum NEP is at the time of 13:00-15:00 (UTC), or local time 9:00-11:00 am. It is not likely to be due to clouds according to the diurnal pattern of the surface downward shortwave radiation (Fig.1-a). We examined the diurnal curve of the soil moisture, and it seems to be due to soil moisture stress. Soil moisture was consumed quickly in the morning which led to water stress for plant growth in the afternoon. The diurnal curve of the Amazonian forest soil moisture can be accessed in the Supplement, soil moisture.pdf, or here:

https://drive.google.com/file/d/1UGspMcBj_PHpIUwdEaO6y1ZhDCM79D5_/view?usp=sharing

The soil moisture pattern also explains the biased distribution of daytime surface air temperature (Fig.1-c), and slightly biased daytime latent heat (Fig.1-d), and daytime sensible heat (Fig.1-e). We will add the above analysis to the manuscript.

We will add a local time axis to Fig. 1, Fig. S2, and Fig. S3. Thanks for the good suggestion.

- No radiation was added to forests during the daytime. The nighttime radiation influences energy balance and atmospheric processes, and may have exerted impacts on cloud processes, which leads to slight differences in daytime surface radiation.
- Overall, Amazonian, African, and Asian tropical forests show similar nighttime NEP responses to nighttime radiation. Slight differences (e.g. blue and yellow lines in Fig. 1 and Fig. S2) may be due to the divergent ambient surface air temperatures (Amazonian tropical forests have an overall higher surface air temperature with respect to the other two tropical forests) or soil moisture conditions.
- The wildfire risk estimation in CESM2 is associated with soil moisture. We examined the long-term soil moisture changes and found that nighttime lighting experiments increased soil moisture because of enhanced precipitation in tropical forests. The global tropical forest soil moisture changes can be accessed in the Supplement, soil moisture.pdf, or here:

https://drive.google.com/file/d/1UVxCKByuuPls3V1HuBlD_825_ILiWmus/view?usp=sharing

Therefore, increased soil moisture would reduce wildfire risks despite the increase of biomass and potential burning materials. We will make modifications to the manuscript.

- The annual gross primary production dropped quickly, ultimately reaching levels that were even lower than the control period due to a reduction in atmospheric CO2 (CO2 has a fertilization effect in the model). (lines 178-181)
- The shaded area in Fig.2-f denotes carbon released back to the atmosphere after the termination of the lighting experiment (line 151). We will make some improvements in the visualization. As to the second question, we attribute it to two possible reasons. First, different regions tend to have diverse air temperature responses to global CO2 changes. Arctic regions show a much larger temperature increase in response to CO2 increase, while the temperature increase in tropical regions is not that significant.

Similarly, the CO_2 reduction may exert diverse impacts on temperature changes in different regions. Second, the temperature change in tropical forests at the termination of the experiment is controlled by two factors in this study, decreased incoming shortwave radiation and reduced CO_2. The former has a much larger impact on the local energy balance than the latter. Therefore, the influence of CO_2 reduction on local tropical forests is not as large as on the global scale. We will add the above analysis to the manuscript.

- We understand the reviewer's concern which is mainly associated with the potential fossil fuel consumption when providing light to forests. If fossil fuel is used to provide energy for nighttime lighting, extra carbon would be emitted, and our conclusion could be wrong. In this study, we assume this strategy only uses clean energy coming from solar, wind, or nuclear farms. Therefore, no additional carbon emissions would be happening. As to where the clean energy would be coming from, we have made a detailed discussion in our reply to Richard Rosen's comments (reply on CC2). We will incorporate that discussion into the manuscript.
- We have provided the calculations in our reply to Richard Rosen's comments (reply on CC1), and we will incorporate the calculations into the manuscript.

Thank you very much for your constructive comments and suggestions again!

Please also note the supplement to this comment:
https://esd.copernicus.org/preprints/esd-2021-85/esd-2021-85-AC3-supplement.pdf