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Review of bg-2022-25 "Observed Water- and Light-Limitation Across Global Ecosystems"

Rene Orth (Referee)

Referee comment on "Observed water and light limitation across global ecosystems" by François Jonard et al., Biogeosciences Discuss., https://doi.org/10.5194/bg-2022-25-RC1, 2022

Review of Jonard et al., bg-2022-25
"Observed Water- and Light-Limitation Across Global Ecosystems"

This study investigates the emergent relationship of vegetation functioning with water and energy availability across the globe. This is done largely with satellite-derived datasets, where vegetation functioning is characterized with Sun-induced fluorescence data and energy availability is represented by the photosyntetically active radiation. The authors test different linear models including breakpoints to show that the vegetation response to climate is non-linear in many areas for both energy and water limitation, as expected from physical principles.

Recommendation:
I think the paper requires major revisions.

The topic of this study is interesting and timely. The response of vegetation to climate drivers is well known at small spatial scales from laboratory and field experiments, but it remains more unclear at larger spatial scales. At the same time, these vegetation-climate interactions are particularly relevant as they affect surface climate and need to be taken into account, and accurately captured by Earth system models, e.g. for projections of future climate scenarios. In this context, satellite-based datasets present an excellent opportunity to study these processes, and involved non-linearities and thresholds at model-relevant spatial scales.

I think that the manuscript is easy to read and understand and is a great match for the readership of Biogeosciences. However, before it is ready for publication some concerns regarding the analysis approach and robustness should be resolved, as detailed below.

General comments:

(1)
I think the fact that the seasonal cycles are not removed from the SIF, PAR and soil moisture data is a major shortcoming in this analysis. This way, confounding impacts by for example temperature can introduce artifacts in the results. For example, the positive correlation between soil moisture and SIF across a band across Canada in Figure 2 does not make sense from a physical point of view and could be related to such effects. I realize that the authors mention this point in section 4.3, and think it would be important if they could actually demostrate the negligible impact of the seasonal cycles by showing that similar results can be obtained with a shorter growing season of 1-2 months. Another way could be a synthetic experiment with e.g. evapotranspiration, radiation and soil moisture data from reanalysis where a similar time period can be used and the analysis can be done without removing the seasonal cycle (as here), and with the removal (while a representative seasonal cycle can be computed from many available years).

(2)
There is no consideration of uncertainty for the performed analyses. In this context it would for example be informative to see some goodness-of-fit metric for the for the chosen model type (linear/two-regime/zero-slope), and possibly to introduce another category in case no reasonable fit was found for any of these types. Further, it would be interesting to which extent the model selection holds when for example synchronous bootstrapping would be performed for soil moisture and the other investigated variable. Moreover, in this context it would also be relevant to understand to which extent the results depend on the selected input datasets. I appreciate that the authors mention this aspect in section 4.3 in the case of alternative SIF datasets and think it would be important to demonstrate this in the
supplementary material. Additionally, also the role of the soil moisture dataset should be tested by replacing the SMAP data with e.g. satellite-derived ESA-CCI soil moisture (https://www.esa-soilmoisture-cci.org/data) or upscaled in-situ soil moisture from the SoMo dataset
(https://springernature.figshare.com/collections/Global_soil_moisture_from_in_situ_measurements_using_machine_learning_-_SoMo_ml/5142185).

(3)
I like that the authors recognize and determine non-linearities in the soil moisture-climate relationships. I think they could move a bit further in this direction by assessing the degree of non-linearity, for example as the difference in BIC scores between linear and non-linear models in each grid cell, or using the bootstrapping approach mentioned above. Further, it would be interesting to evaluate the spatial distribution of non-linearities as

displayed in Figures 6a and 7a against climate and land surface characteristics, as done for the thresholds.

(4)
I appreciate the analysis of the spatial patterns of the thresholds displayed in Figure S3 against climate and land surface characteristics. I think this analysis should additionally cover the role of the vegetation type (averaged across each grid cell), as this also affects the SIF-climate relationships. I realize this is mentioned by the authors in the conlusions section, and encourage them to include this into the analyses.

(5)
I did not quite understand why LAI was only obtained from a relatively short 4.5 year period only. The MODIS record extents further back in time, and a longer data record would allow to infer a more robust seasonal cycle.

I do not wish to remain anonymous - Rene Orth.

Specific comments:

lines 38/39: this is not only true for increasing temperatures

line 41: what is meant with "rate-limiting"?

lines 42 & 62-68: the work from Li et al. (2021) is similar and relevant in this context and could be mentioned here

line 116: "day" should be singular, and a space should be removed in "Sentinel-5"

lines 142/143: what is the source of the soil texture data?

lines 169-171: Why not selecting the growing seasons as the 6 months with the highest LAI, independent on whether or not they would be consecutive, in order to better capture the highest LAI months in regions with more than one peak in the seasonal cycle?

line 177: replace "." with "x"

lines 291-296: the work from Denissen et al. (2020) is similar and relevant in this context and could be mentioned here

lines 332-334: temperature limitation of vegetation functioning might play a role here, as mentioned also a few lines below

Figure S1:
Why is LAI in the mean seasonal cycles in b) and d) always the same across some consecutive days?

References:

Denissen, J., A.J. Teuling, M. Reichstein, and R. Orth,
Critical soil moisture derived from satellite observations over Europe
J. Geophys. Res. - Atmospheres, 125 (6), e2019JD031672 (2020).

Li, W., M. Migliavacca, M. Forkel, S. Walther, M. Reichstein, and R. Orth,
Revisiting global vegetation controls using multi-layer soil moisture, Geophys. Res. Lett. 48(11),
e2021GL092856 (2021).