

Biogeosciences Discuss., author comment AC1
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Reviewer #1

Josephin Kroll et al.

Author comment on "Spatially varying relevance of hydrometeorological hazards for vegetation productivity extremes" by Josephin Kroll et al., Biogeosciences Discuss., <https://doi.org/10.5194/bg-2021-206-AC1>, 2021

Reviewer: The study analyzed the connections between different types of hydrometeorological hazards and vegetation productivity extremes. The topic is important and worth exploring considering the scenario of more intense and frequent extreme weather events. Current work relies on limited datasets and statistical approaches, while lacking more comprehensive and in-depth analysis.

Answer: We thank the reviewer for highlighting the relevance of the topic of our study. All (updated) figures and literature referred to in the answers to the reviewers questions can be found in "Supplement_on_RC.pdf". A short note on the numbering in this document: Apart from Fig. 1*, the numbering in this document will be equal to the numbering in the main manuscript and the supplementary material of the manuscript.

Reviewer: My major concerns are as follows

Reviewer: Considering the uncertainties related to both SIF and re-analysis data sets, I would suggest the authors include additional data in the analysis to enhance the robustness of the work. For example, the NOAA vegetation health index (VHI) data have been widely used in monitoring global vegetation health and predicting crop yield (Kogan et al., 2004), which could be complementary to SIF in quantifying vegetation status. Similarly, the surface wetness anomalies derived from long-term satellite observations (e.g. Du et al., 2019) could serve as additional metrics to quantify extreme events.

Answer: We thank the reviewer for the suggestions. The VHI is an additive combination of a normalized NDVI index (VCI; Kogan et al., 1995) and a normalized Land Surface Temperature (LST) Condition Index (TCI), where one parameter alpha tweaks the relative contribution of both separate indices. This alpha is usually set to 0.5, indicating equal relative contributions from VCI and TCI to VHI. VCI can change due to either energy or water stress, but as Fig. 5 c-d) shows for the Enhanced Vegetation Index (EVI, and also NDVI in the last version of the manuscript), tends to already have a bias towards water stress, as described in lines 233-238. On top of that, the VHI relies on a negative relation between NDVI and LST, which is typically not the case in energy-controlled regions in northern latitudes (Fig. 4), VHI should be used cautiously there (Karnieli et al., 2006). This slight bias towards water control and questionable results in energy-controlled regions (aridity < 1) are reflected when we analyse the variables most important for VHI extremes (Fig. 1* in Supplement_on_RC.pdf) and is also the reason we chose not to include VHI in the analysis, since we intend to focus on both heat and water stress.

Lines 233-238: "However, the overall extent of water-controlled areas is clearly larger in the case of EVI compared with the SIF results. This could (i) partly be related to the fact that EVI, being less dynamic than SIF because it is more related to vegetation greenness and structure, tends to vary at time scales more in line with that of soil moisture (Turner et al., 2020), which can support stronger correlations. Or (ii) it could be due to confounding effects of the changing soil/vegetation color between dry and wet states on the EVI signal."

However, several steps were taken to enhance robustness across different proxies for vegetation productivity: 1) we have chose to replace NDVI with EVI, as NDVI tends to saturate towards vegetation productivity maxima and 2) we included evapotranspiration (ET) from GLEAM as an extra proxy for vegetation productivity, to highlight similarities between the carbon and water cycle. Reviewer #2 asked to include ET in the analysis. As Fig. S6 shows, global distributions of hydrometeorological controls on ET extremes appear to be similar to that of SIF extremes, albeit generally slightly stronger water-control. We elaborate on these findings in lines 286-293:

"Fig. S6 illustrates similar controlling hydro-meteorological variables for SIF and evapotranspiration (ET) extremes. This suggests that carbon and water cycles are sensitive to similar hazards, which in turn enhances their impact on the land climate system via both carbon and water pathways. This further demonstrates the usefulness of SIF observations for reflecting plant transpiration (Jonard et al., 2020). Further, Fig. S6 shows that GLEAM ET extremes relate much more strongly to surface soil moisture than SIF extremes. This could be due to the part of ET that partitions into an unproductive part, bare soil evaporation, which evaporates water from the surface layer directly and a productive part, transpiration, which is connected to carbon uptake and therefore SIF. Surface soil moisture affects the unproductive part, while overall enhancing the role of surface soil moisture for ET."

Regarding the use of long-term satellite observations of soil moisture: In this analysis, we have chosen to focus on the respective role of the depth from which plants extract soil moisture. Therefore, this unfortunately excludes satellite observations of soil moisture of any kind, since they usually represent only the surface layer. Instead of satellite observed soil moisture, we use soil moisture from different depths from reanalysis data, in which station and satellite observations are being assimilated. Therefore, satellite observations of soil moisture are still indirectly represented in this analysis. To validate the robustness of the results, we re-compute the results using another soil moisture data set: SoMo.ml, on which we elaborate in lines 88-91:

"In addition to this, and to validate the robustness of our results, we use an alternative soil moisture product, SoMo.ml, which provides data for three layers (1: 0-10 cm, 2: 10-30cm, 3: 30-50cm), and which is derived through a machine learning approach that is trained with in-situ soil moisture measurements from across the globe (O and Orth, 2021)."

Reviewer: It would be valuable to add analysis based on plant physiology (e.g. Porporato et al., 2001; Kunert et al., 2017) for better clarification of the inner connections between vegetation growth and hydrometeorological hazards as compared to the correlation-based analysis.

Answer: We thank the reviewer for this comment, which alludes to better understanding biome-specific responses of plants to hydrometeorological hazards. As mentioned in Porporato et al., (2001), physiology and rooting depth modulate responses of plants to hydrometeorological hazards. We clarified this point in lines 298-306:

"To additionally explore the influence of different vegetation types and their respective

plant physiological differences on the main controls of vegetation productivity, we bin the grid cell results by the respective fraction of tree cover of the entire vegetation cover, and by aridity in Fig. S7. We find that the radiation control of SIF extremes in humid regions is mostly associated with forests, and that the water control in semi-arid regions largely occurs for shorter vegetation, with presumably more shallow root systems, while productivity extremes in more forested semi-arid regions tend to be energy-controlled. But generally, hardly any changes in the most important variables can be seen with variations in tree cover, suggesting that on a global scale plant physiological differences only have a limited effect on determining the most important control for SIF extremes.”

Reviewer: It seems to me the lagged vegetation responses to hydrometeorological hazards and the accumulated impacts from pro-longed drought/heat wave on vegetation need to be carefully addressed. Such component is currently missing in the manuscript.

Answer: We appreciate the point made by the reviewer. A similar point has been risen by reviewer #2. On top of response of SIF to concurrent anomalies in hydrometeorological variables, there might be lagged effects in the SIF response. To this end, Fig. S4 shows the most important hydrometeorological variables for SIF extremes in the respective following month. Patterns are comparable to Fig. 5a-b), which suggests that in the month preceding SIF extremes, energy/water deficits/surpluses are already developing. This is evidenced especially in arid regions, where precipitation and shallow soil moisture of the preceding month replace root-zone soil moisture as the most important variable. In the hottest, humid regions, preceding shallow soil moisture replaces radiation as the most important variable for the concurrent months, suggesting that water is typically abundant (SIF maximum) or lacking (SIF minima) a month ahead of the extreme. This indicates that in these regions, both energy and water should be present or lacking to obtain a SIF extreme. We have clarified this in lines 274-281:

“Fig. S4 indicates that hydrometeorological anomalies do not solely elicit immediate, but also lagged vegetation responses. A clear difference between water- and energy-controlled conditions is already visible when correlating hydrometeorological anomalies of the preceding month with the respective SIF extreme. Energy and water surpluses and deficits establish over time, which is most clearly evidenced in arid regions, where precipitation and shallow soil moisture of the preceding month is found to be the most important variable. With time, deeper soil moisture becomes more important (Fig. 5a-b), as in case of SIF maxima, precipitation needs time to infiltrate the soil and in case of SIF minima, the soil dries most rapidly from the top down.”

Please also note the supplement to this comment:

<https://bg.copernicus.org/preprints/bg-2021-206/bg-2021-206-AC1-supplement.pdf>