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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Rapid reduction in ecosystem productivity caused by flash drought based on decade-long FLUXNET observations" *by* Miao Zhang and Xing Yuan

Anonymous Referee #2

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The authors present first evaluation of GPP from FLUXNET in response to flash drought. This is an important topic and this submission is timely as well as novel. At the same time, I feel that a more detailed analysis is warranted before publication.

General comments:

1) I generally think that analyzing the relationships between flash drought and GPP is very important. I am wondering though, whether this paper leaves out a large part of the story by focusing narrowly on the 30-60 days of flash drought. Similarly, there is very little analysis that looks into the underlying mechanisms of GPP besides the WUE analysis. I am wondering how temperature, global radiation, SM, and VPD, which all

affect GPP behave. For example one would expect drought to be associated with elevated temperatures. In this context, the authors stress the GPP reduction associated with drought, but several other papers have shown that GPP reduction during drought can be associated with compensation effects before and after the drought. By only focusing strictly on the drought these are being missed.

2) Similarly, the authors bin data based on onset (which should probably rather be called intensification) and recovery time as well as 8-day intervals. They present 3 examples of flash droughts in Figure 4, but it is unclear to me to what extent these are being representative and whether it makes sense to lump all drought events together like this. For example, the FI-Sod event shows fast recovery in SM, GPP, and ET (i.e. is terminated by a strong rain event), while US-SRM and IT-Col show basically no recovery of GPP and only ET recovery for IT-Col, which indicates that there is no real recovery taking place. Based on this, I would not expect to find generalizable behavior during this period. I am not sure how to resolve this in detail, but I think that a deeper dive into data and individual events is merited.

3) The discussion is falling a bit short with respect to differences between plant functional type classes. Some discussion around differences between grasslands and forests as outlined in specific comments may help here.

4) Given that FLUXNET measures NEE rather than GPP and GPP is partitioned, some discussion on this partitioning may be warranted and NEE should probably also be shown.

Specific Comments:

L99: It might be a good idea to also look into other sources of soil moisture here, as there is little standardization across FLUXNET with respect to sensor depth etc.

L101: We select 34 sites from FLUXNET where, ... > are these all sites that fit the definition from this sentence or was there further subsetting done?

L147: "The negative anomalies of GPP during flash drought are considered as the signal of ecological deterioration." > This sounds not correct to me. Water stress will reduce GPP, which is a given, but I don't think it necessarily follows that this has a lasting consequence as is implied here. It would be interesting to see to what extent do these ecosystems compensate. I.e. is there a lasting effect from a flash drought even in the annual carbon balance.

L165: "influence of water and energy conditions" > " water and energy availability?"

L189-190: "and the mean durations were from around 30 days to 60 days among FLUXNET sites" > I am a bit confused by that given that I was under the impression that droughts longer than 2 months days were excluded from the analysis. How can then mean drought length be 60 days, if that is also about the maximum possible length?

Figure 2 is problematic. I would zoom into Europe. It is also not possible to link the sites from a) to b) and c) without consulting Table 1. As a side note: the 4 Canadian ENF sites are more or less directly adjacent to each other, with 3 of them showing almost the same behavior. It may be better to only keep two of them (CA-TP4 is different (Why?))

Figure 3 and associated text: I am a bit confused about onset and recovery. Are these singe 8 day periods or do they refer to several periods. I am not sure whether this is necessarily a good way of showing this data and what is really learned here, since everything is lumped together and there is an implied time-axis, which is not consistent in itself. The temporal evolution of these events is also already well established in the literature.

Figure 4: It looks as if these sites were chosen as representative for each class, but this should be made expicit in the text. I don't particularly like the fact that anomalies are being plotted at the site level. We need to calculate ET, GPP, and SM anomalies to compare sites and establish drought, but here there is no need and it makes it harder to understand the underlying dynamics. I also think that if these sites are chosen, one

should plot all drought events (all six or so per site) and not only specifically chosen year. Also, based on this figure, I feel that onset should be renamed as intensification.

Figure 5: a) It appears if there is a quick response of GPP at the beginning of the flash drought, which one would expect simply by having high VPD, which will lead to stomata closure, but SM seems to be much less affected. It would be nice to learn whether this is really unusual or whether this GPP responses related to soil moisture reduction (drought) or VPD forcing. For example Gerken et al. 2018 (https://www.hydrol-earth-syst-sci-discuss.net/hess-2018-211/) showed that potential evapotranspiration ($\sim$ VPD) happened before the onset 2017 Norther Great Plains flash drought. It would be interesting to see whether GPP reduction also occurs before drought onset. To what extent are panels c and d necessary.

L251: "that negative GPP anomalies occur during 81%" -> if this refers to the red line in Figure 5 a/b, then this number seems inconsistent with the figure, where it is more likle 78%.

L270: "The result is consistent with the high vulnerability of vegetation in semiarid regions" > I would caution against this interpretation. Semi-arid ecosystems are highly adapted to changes in water availability and show fast response to changes in water availability (e.g. Gerken et al. 2019, 10.1038/s41612-019-0094-4). Without additional analysis, this should not be taken as a sign of degradation or vulnerability; especially since the final cumulative values are practically the same as for forests (MF, DBF, ENF). Some discussion about isohydricity, VPD may also be helpful in this context (e.g. Novick et al, 2016, 10.1038/nclimate3114, Roman et al, 2015; 10.1007/s00442-015-3380-9)

L285: "Increasing VPD and deficits in soil moisture would decrease canopy conductance" -> The fact that uWUE stays invariant shows that GPP reductions are due to canopy conductance. During recovery SAV and CROP, which are both dominated by grasses are likely brown, while forests are still green and quickly respond. This again

likes directly to different biophysical responses of forests and grasslands and isohydricity effects. These should be discussed.

L315: "Eventually, 81% of flash drought events cause negative ecological impacts on GPP." > I am not sure that a reduction in GPP is necessarily an negative impact. This depends greatly on the annual carbon balance. For example Wolf et al, 2016 (PNAS) showed that there is GPP compensation (i.e. warmer temperatures before drought causes higher initial GPP). Without looking into potential compensation effects, I feel that this statement is too harsh.

L346: "The positive anomalies of WUE and uWUE for forests show the adaptation of vegetation to flash drought from physiological perspective." > Not sure that this is true. Forests have also access to more water in the soil due to deeper roots and have invested much more in biomass. Grasslands just become dry and then recover. I think that these are different strategies rather than one being more prepared than the other.

Technical (not complete): L36: (e.g. droughtS, heat waveS)

L40: in some -> during (some is also not needed because of can)

L269: impaired -> reduced

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