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Hydrology and Earth System Sciences
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Discussions

Interactive comment on "Flash drought onset over the Contiguous United States: Sensitivity of inventories and trends to quantitative definitions" *by* Mahmoud Osman et al.

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Anonymous Referee #2

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»Reply: We would like to thank the reviewer for the supportive and constructive comments. The original comments and our responses are noted after each comment.

Major concerns:

>Though there are a bunch of flash drought definition, it is generally accepted by the scientific community that flash drought should emphasize the intensification rate to dis-

tinguish other types of drought [1]. I think the HWD definition is not suitable for flash drought, considering two aspects: 1) this definition cannot descript the rapid intensification of flash drought; 2) this definition may not be able to distinguish between flash droughts and short-term compound dry-hot events, leading to miscalculate flash droughts. Assuming that during dry-hot summer, conditions of HWD definition are relatively easy to meet, but actually such conditions may not form flash drought. Please clarify how to distinguish between flash droughts and short-term compound dry-hot events in this paper.

Reference: [1] Otkin, J. A., Svoboda, M., Hunt, E. D., Ford, T. W., Anderson, M. C., Hain, C., Basara, J. B., Otkin, J. A., Svoboda, M., Hunt, E. D., Ford, T. W., Anderson, M. C., Hain, C. and Basara, J. B.: Flash Droughts: A Review and Assessment of the Challenges Imposed by Rapid-Onset Droughts in the United States, Bull. Am. Meteorol. Soc., 99(5), 911–919

»Reply: First, we thank the reviewer for clarifying the aspects required to define flash droughts and highlighting some deficiencies that may arise within definitions such as HWD. We agree with the reviewer that the HWD definition is not necessarily a definition suitable for capturing flash drought events as it does not count for rapid intensification and it is only based on anomalies within a short period. Both HWD and PDD are introduced in this paper since they are widely used in flash droughts identification literature despite their major limitation. The presented comparison emphasizes the limitation within these definitions in a fair and objective matter. We have clarified these points in multiple sections within the manuscript: Lines 161-169, Lines 291-292, Lines 365-366, Lines 391-392 and Lines 416-418.

>The presentation of typical flash drought events is weak and needs more specific cases. The authors may wish to show the temporal variation of real-world flash droughts in a Bukovsky Region, and further compare the differences of flash drought monitoring ability between definitions;.

»Reply: We thank the reviewer for pointing out the need for more specific case studies and clarification. The revised manuscript is updated with more of the suggested discussion. The main purpose of the paper is to compare different flash drought definitions and explore how different criteria – with careful selection - may be applied to define flash droughts in the context of proposed mechanisms of interest. The four case studies are intended to provide examples that may be familiar to readers and that can make the conceptual distinctions between definitions more concrete. We do not attempt fully detailed case analysis of these events. As the reviewer suggests, we do make use of Bukovsky Regions to understand variation of real-world flash droughts, though we do this for flash drought statistics rather than for time series analysis of the case study events. In section 3.1 we discuss the differences between the different definitions in terms frequency of occurrence and spatial differences and the possible reasons for these variations. Bukovsky regions are presented in more detail in the next sections as we look into the correlations, interannual variability, trends and climate drivers. Section 3.3 discusses the onset and conditions of the observed 1988, 2011, 2012 and 2017 flash droughts (2016 flash drought is added to the revised manuscript; Lines 333-335, Lines 355-366) and highlights the spatial and temporal differences in capturing flash droughts' onset between the different definitions. Figure 7 shows time series of variables relevant to different flash drought definitions for the selected case studies, and the associated text (Section 3.4) describes the relevance of those time series to the drought monitoring ability of different definitions.

>The climate variation during typical events should also be shown to help understand climate drivers, if climate data are availabe. In addition, in order to reflect whether these events have real impacts, it is better to analyze the changes of vegetation indicators (such as NDVI) , rather than just present description. Regarding these, I'm not very convinced that SMVI definition can well capture flash drought onset in both humid and arid regions.

»Reply: Thanks to the reviewer for emphasizing the importance of showing the veg-

etation impact to support the introduced definition. We agree that NDVI is a powerful vegetation impact indicator. We have included it in a descriptive way, as the reviewer notes; e.g, Figure 2 (Line 107) depicts an example for the SMVI definition for a selected grid point within the state of Montana in 2017 and shows how the NDVI drops below the climatological mean values for the same grid point. We do not pursue a full quantitative analysis of vegetation indicators of drought in this manuscript, in part because these analyses require careful consideration of metrics, timing, and ecological context that would require substantial expansion of the paper. We intend to undertake such analyses in future papers. In order to offer better vegetation context for the events analyzed in this manuscript, we have added Figures S2 and S3 (shown below as Fig.1 and Fig.2 respectively) to the revised manuscript to illustrate the tempo-spatial change in NDVI within selected flash drought impacted regions in 2012 and 2017 respectively. The change in NDVI anomalies show similar patterns and timing to these captured by SMVI. Regarding SMVI, In Section 3.3 we present examples for major flash droughts (1988, 2011, 2012, 2016 and 2017) that span a range of climatic regions. The SMVI definition appears to perform well across these diverse regions. For example, 1988 historical flash drought hit many parts of the US covering humid regions (such as the Great lakes region) and semi-arid regions (such as Northern plains). SMVI successfully captured the event as observed (Lines 324-331), and did so again for the climatically extensive 2012 flash drought (Lines 347-354). The 2011 flash drought is another example for which SMVI captures an event that includes semi-arid regions, this time in Texas. That said, we acknowledge the reviewer's implication that arid zones are not fully explored, and that vegetation might not respond to flash droughts in a truly arid region in a manner that would demonstrate SMVI performance. For this reason, we have replaced "arid" with "semi-arid" in all passages that refer to SMVI performance.

>The authors shows the climate variation for typical regions during 2011 and 2017 flash droughts. I think it cannot well descript climate driver for the occurrence of flash drought, because such long-term climate anomalies could also lead to traditional droughts. I suggest that authors only focus on climate anomalies during flash drought

events, such as extreme atmospheric anomalies (like rainfall defict, high surface temperatures, strong winds, or clear skies)..

»Reply: Thank you for the constructive suggestion and underlining the importance of focusing on climate anomalies during flash droughts. Assuming that the comment about section 3.4, the presented analyses show only the standardized anomalies for the main variables involved within the discussed definitions during the onset year only. The discussion is focused on the onset season as observed and calculated. In lines 383-389, we explain the observed climate conditions (in terms of anomalies) during the 2011 flash drought that show early signs of drought intensification during spring and remain for the summer before recovering in fall. In lines 390-395, the discussion is focused on the climate conditions as illustrated in Fig. 7b and how some climate variables may not be appropriate to use for identifying flash droughts; for example, depending on temperature anomalies only would lead to mischaracterization of the event, or even missing it completely, as happened for the HWD and (partially) the PDD definitions.

Other comments:

»Reply: Many thanks to the reviewer for the comments and suggestions.

>Line 48: Please illustrate here that each color represents the flash drought definition.

»Reply: Revised manuscript is updated to clarify that colors are used to represent the different definitions (Lines 109-110).

>Line 80: When the RZSM contains several layers, which layer of soil water should be selected?

»Reply: SMERGE dataset used contains RZSM of the 0-40cm layer. However, if the average of multiple layers from a different dataset is used, similar results would be achieved since the power of the SMVI definition is the relative comparison between two moving averages. Line 98 clarifies the confusion.

>Line 256: Please re-draw the Fig. 4. The legend can be a clear color segment.

»Reply: Thank you. Figure updated in the revised manuscript as suggested.

>Line 318: Figure 6 shows the frequency of flash drought during typical years or the values of the indices? Please make it clear.

»Reply: Figure 6 shows the onset of major flash drought events in the different discussed years (section 3.3) marked by seasons. Caption is edited in the revised manuscript for clarification.

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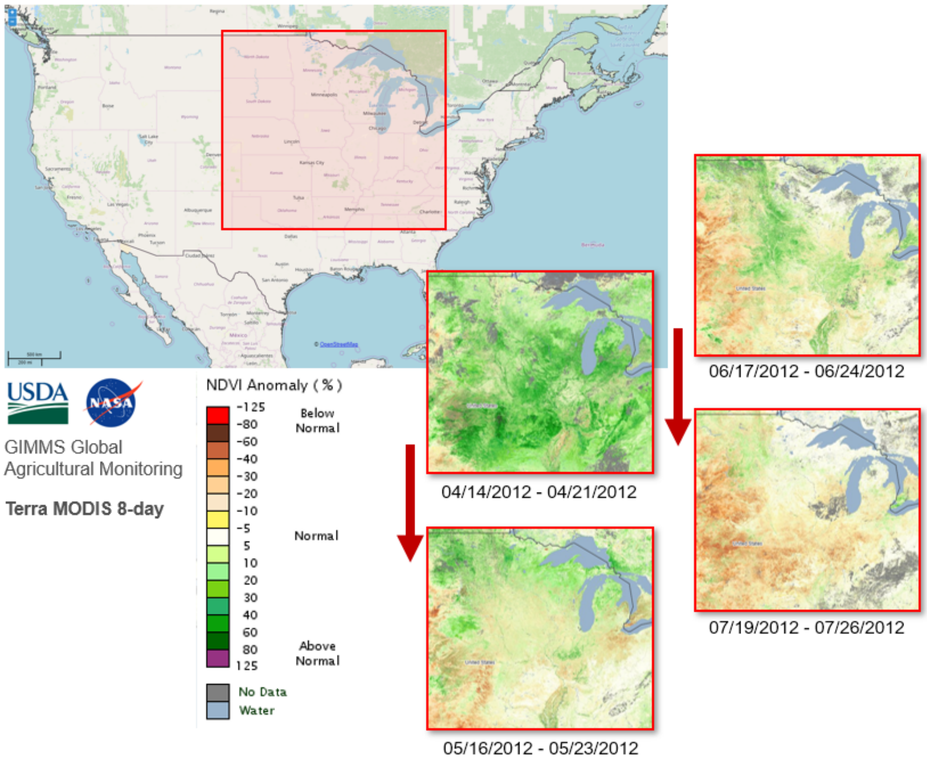

Fig. 1. Tempo-spatial change in NDVI within selected flash drought impacted regions in 2012.

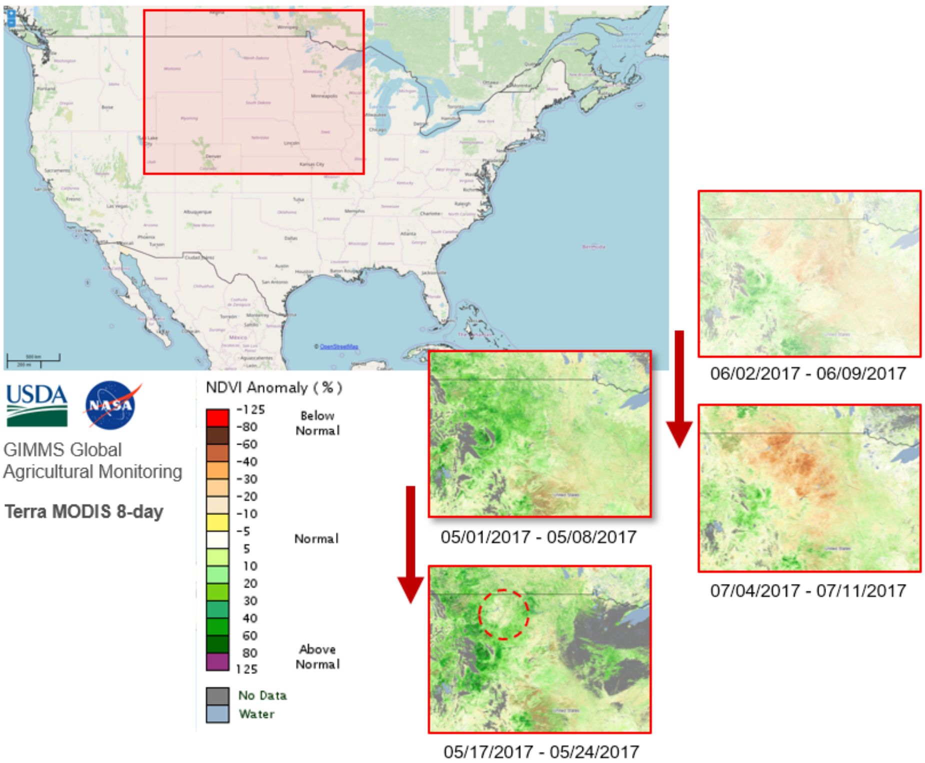

Fig. 2. Similar to Fig. S2 for 2017 flash drought.