Responses to Reviewers' Comments on Manuscript ID Hess-2024-199

Article title: Accelerated soil moisture drought onset link to high temperatures and asymmetric responses associated with the hit timing

Corresponding author: Junliang Jin, Shanshui Yuan

List of authors: Yi Liu, Zhimin Wang, Xinyu Zhang, Ye Zhu, Liliang Ren, Shanshui Yuan, Junliang Jin

Contact e-mail: liuyihhdx@hhu.edu.cn

Dear reviewers and editor:

Thank you so much for your valuable comments and kind suggestions on our paper. Your illuminating comments and suggestions give us the possibility to properly fix several questionable issues, and to improve the overall quality of the paper. We highly appreciate your time and effort. Please find our point-to-point responses to your comments below.

Responses to Reviewer 2's Comments:

Comment 1: Introduction: this part seems too short, which does not clearly point out the gaps between existing studies and this study. The authors should further highlight their new contributions to this field.

Response: Thanks for your valuable suggestion. We supplemented descriptions on the gaps between existing studies and this study, and highlight the new contributions to this field in the third paragraph of the Introduction section.

Lines 49-56: "*Recent progresses of flash droughts include comparisons among different flash drought definitions, evaluations on the characteristics of flash drought in different regions of the world, unraveling the mechanism of flash drought based on causality analysis, incorporating multiple information for improving flash drought identification and monitoring strategies, and flash drought associated crop response (e.g., Osman et al., 2021; Shah et al., 2021; Ahmad et al., 2022; Ho et al., 2023; Zhou et al., 2023; Mahto and Mishra, 2024). These contribute a deep understanding on the accelerated drying process and its associated impacts. However, efforts for* *unraveling the formation process of drought under high temperatures, particularly for the changes during the onset stage of drought (e.g., the time consumed for moisture transition from a drought-free state to drought condition), are generally rare.* ”

Lines 58-59: “*This calls for depicting drought development process at fine temporal resolutions (e.g., a daily time step).* ”

Lines 67-70: “*The results are promising to improve our understanding on the driving mechanism of high temperatures on drought during the onset stage. Meanwhile, the modelling framework could also be an alternative for quantitative measurement on the changes of drought formation under future extreme high temperature scenarios.* ”

References:

Ahmad, S. K., Kumar, S. V., and Lahmers, T. M.: Flash drought onset and development mechanisms captured with soil moisture and vegetation data assimilation, Water Resour. Res., 58, e2022WR032894, https://doi.org/10.1029/2022WR032894, 2022.

Ho, S., Buras, A., and Tuo, Y.: Comparing agriculture-related characteristics of flash and normal drought reveals heterogeneous crop response. Water Resour. Res., 59, e2023WR034994. https://doi.org/10.1029/2023WR034994, 2023.

Mahto S S, Mishra V.: Global evidence of rapid flash drought recovery by extreme precipitation, Environ. Res. Lett. 19 044031, 2024. DOI: org/10.1088/1748-9326/ad300c, 2024.

Osman, M., Zaitchik, B. F., and Badr, H. S.: Flash drought onset over the contiguous United States: sensitivity of inventories and trends to quantitative definitions, Hydrol. Earth Syst. Sci., 2021(2).DOI:10.5194/HESS-25-565-2021.

Shah J., Hari V., and Rakovec O.: Increasing footprint of climate warming on flash droughts occurrence in Europe, Environ. Res. Lett, 17 (2022) 064017. DOI:10.1088/1748-9326/ac6888, 2022.

Zhou Z.Q., Ding Y.B., and Zhao Y.Y.: A new perspective for assessing hydro-meteorological drought relationships at large scale based on causality analysis. Environ. Res. Lett., 18(10), 104046,2023. DOI: 10.1088/1748-9326/acfe1e, 2023.

Comment 2: How to determine the level of *DDO*? Why 8 days for moderate, 14 days for severe, and 18 days for extreme drought?

Response: Thank you for your comment. In this study, the *DDO* was proposed to measure how rapid the drought develops under varied warming scenarios. We think "8 days for moderate, 14 days for severe, and 18 days for extreme drought" do not represent the level of *DDO*, rather they show the average days consumed for moisture transition from a normal state to below-average condition over China during the past 72 years. We think you provide an interesting direction in future researches like finding a reasonable level of *DDO* to recognize flash drought, or for drought monitoring and management strategies. We also carefully checked the descriptions of *DDO* and Figure 1, and made some modifications to improve clarity. We also supplemented descriptions corresponding to Figure 1 in the main text as follow.

Lines 116-117 and 127: "*As shown in Fig. 1, the drought event initiated from t_0 (i.e., the first blue square in the figure when SMP falls below 40% for the first time) and terminated at t_e (the second blue square in the figure)…… For example, Figure 1 shows the DDO_m, DDO_s, and DDO_e were of 5, 11, and 15 days, respectively.*"

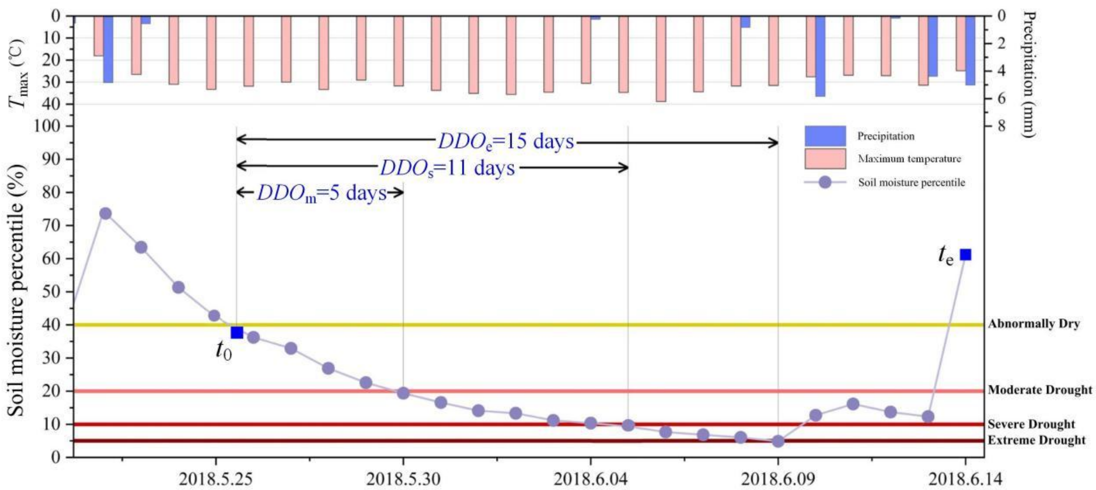

Figure 1. A schematic graph of the development process of drought. Data are from the grid cell (Beijing, 39.8°N 116.4°E). DDO_m, DDO_s, and DDO_e represent the time consumed for soil moisture percentile to reach categories of moderate, severe, and extreme drought, respectively.

Comment 3: There are also many areas with estimation errors larger than 10 days in the northwest region (Line 204).

Response: Thanks for your comment. The estimation errors larger than 10 days were mostly in the Qinghai-Tibet Plateau and alpine regions. The areas climatically receive very little precipitation, and were in a state of drought all the year round. Droughts generally persist for a long time period, and the number of drought events is small. This resulted in small data samples for model training and is a primary reason for the calculation errors. The reason for the errors in the northwest region has been supplemented as follow.

Lines 213-214: "*Larger estimation errors (of 10 days) were found in the northwestern alpine regions, where droughts generally persist for a long time period, resulted in small data samples for model training.*"

Comment 4: Why not present the results for DDO_e (Lines 215-216)?

Response: Thank you for your valuable suggestion. The results for DDO_e have been supplemented, with corresponding descriptions of the figure corrected.

Lines 220-228: "*Fig. 5 shows the spatial distribution of the number of drought events, mean duration, DDO_m, DDO_s, and DDO_e during 1950-2021 by using the ERA5-Land reanalysis data. As shown in Fig. 5a, the south region suffered more than 150 drought events during the past 72 years, which were two~three folds of the north region. For drought duration, drought persisted longer in the north than the south. Especially in the northeast and western regions, the drought duration were 60 days or longer. While drought duration in central and southern China (Yangtze River Basin) were less than 50 days (Fig. 5b). The duration of drought onset (Fig. 5c), i.e., the time period of moisture transition from normal to moderately dry (DDO_m), severely dry (DDO_s), and extremely dry (DDO_e), present a similar spatial pattern as in Fig. 5b. Overall, DDO_s were approximately 5~20 days longer than DDO_m, and DDO_e were 10~40 days longer than DDO_m. For example, in northeastern China, it took 18 days for the transition from a drought-free state to moderate drought (i.e., DDO_m), and the value of DDO_s almost doubled (more than 30 days), and DDO_e exceeded 42 days.*"

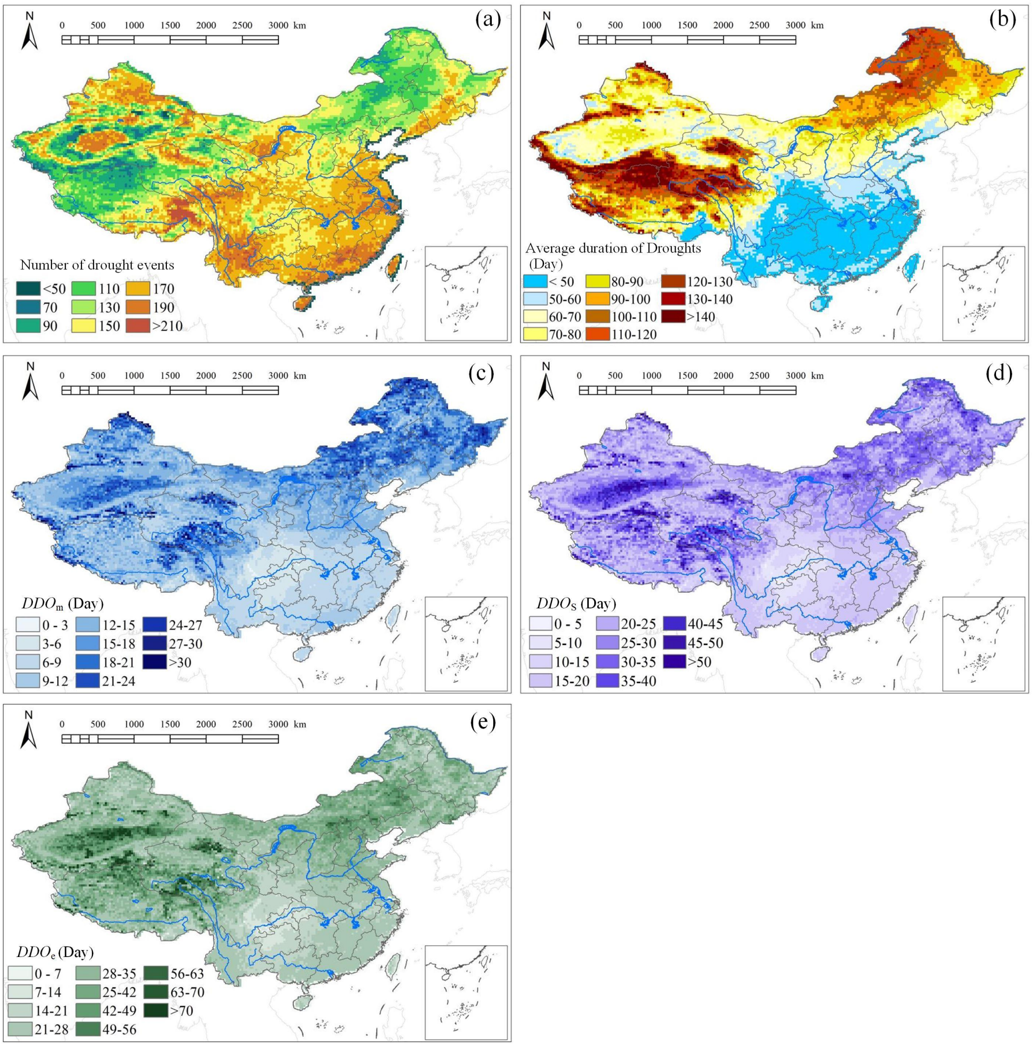

Figure 5. The spatial distribution of (a) the frequency of droughts, (b) the average duration of droughts, (c) the average time taken for reaching moderately dry (DDO_m), (d) the average time taken for reaching severely dry (DDO_s), and (e) for reaching extremely dry (DDO_e) of all drought events during 1950-2021.

Comment 5: Due to global warming, whether 35℃ can still be regarded as a threshold of high temperature days needs more discussion (Lines 242-243).

Response: Thank you for your valuable suggestion. We agree that in the context of climate warming, record-breaking high temperatures become more common, and it is an interesting topic to reconsider the threshold of high temperature days. Considering 35℃ is currently a threshold of high temperatures employed by the China Meteorological Administration and also researches focused on heat waves, we chose 35℃ as an example of high temperature scenario to show how *DDO* will change comparing to the mean temperature state. We also extended the high temperature scenarios into a higher range, as shown in Fig. 8, the horizontal axis was extended to as high as 40 ℃. The sensitivity results show that for majority of China, *DDO* generally stays in a steady state between 35℃ and 40℃, indicating that the threshold of 35℃ would not influence the main conclusion a lot and the results derived were generally representative. The reason for choosing 35℃ has been supplemented in the revised manuscript. Discussion on the threshold of high temperature days provides us a direction and we will focus on this issue in the future.

Lines 250-254: "*Fig. 7 shows the spatial distributions of the DDO under scenarios of annual mean temperature and temperature of 35℃ (this value is employed as a threshold of high temperature days by the China Meteorological Administration and researches focused on heat waves, and in this study it was chosen as an example of high temperature scenarios to show how DDO will change comparing to the mean temperature state), respectively.*"

Comment 6: There are some track changes in the main text. Please check carefully.

Response: Thank you for your reminding. We carefully checked the whole manuscript and removed track changes in the clean version of the revised manuscript.

Comment 7: There are also some editing errors in the text. Some examples are as follows: Line 106: "phage"? Lines 269-270: wrong sentence. Lines 281 and 282: "change rate" or "change ratio"? Fig. 11: "ndvi" -> "NDVI". Line 342: the full name of *VPD* is not given. Line 343: "there virtually no changes"? Line 345: "were" -> "was".

Response: Thank you for your valuable suggestions.

Line 116: we have replaced the relevant expression: "*As shown in Fig. 1, the drought event initiated from t0 (i.e., the first blue square in the figure when SMP falls below 40% for the first time) and terminated at te (the second blue square in the figure).*"

Line 291: we have corrected “change rate” to “change ratio”, and we also updated Figures 9, 10 , and 11 with the y-axis labels corrected.

We have changed “ndvi” into “NDVI” in Fig. 11.

Lines 349-350: The full name of *VPD*, i.e., vapor pressure deficit, has been added. “*Moreover, the coupling strength between vapor pressure deficit (VPD) and soil moisture also indicates the changing role of vegetation within a drying period.*”

Lines 354-356: we have reorganized the sentence as “there were virtually no changes within a drying period for low NDVI areas”.

Line 355: we have corrected “were” to “was”.

“*there were virtually no changes within a drying period for low NDVI areas. This to some extent explains why predrought high temperatures presented more prominent effects in high NDVI areas, while the role of vegetation in low NDVI areas was very limited.*”

We also carefully checked the entire manuscript to avoid such typos.