We highly appreciate the constructive suggestion of the reviewer and the opportunity to submit a revised version of the manuscript. In the revision, we have implemented a number of changes, in particular:

- The explanation of run theory has been moved from the Supplementary Information to the main text.
- The evaluation of the SCDHI based on probability of detection, false alarm ratio and critical success index has been removed, as by definition the SCDHI captures conditions where the STI and SAPEI are extreme at the same time. However, depending on the dependence structure of the STI and SAPEI, the SCDHI events do not coincide to 100% with exceedance of high thresholds in STI and SAPEI (see Figure 2). We thus consider the correlation analyses SCDHI and STI/SAPEI and the evaluation against individual well-known high-impact drought-heat events more informative.
- We removed the future projections based on CMIP5 and instead added a comparison of compound event characteristics between observations and CMIP5 (Fig. 10 and 12 in the revision), complemented by an analysis of the correlations between STI and SAPEI in the CMIP5 models (Fig. S9). In the earlier version of the manuscript, we assessed future changes in CMIP5 compared to present-day observations. However, these changes were primarily due to changes in the copula, because STI and SAPEI where fitted separately to the model output. Further analysis revealed that the CMIP5 model have a strong bias in the dependence between STI and SAPEI, consequently strongly affecting compound event characteristics measured by SCDHI. Here we highlight and discuss these biases, which contributes another novelty to our study.
- We did a thorough language check and updated the colorbars in all maps.

This paper proposed an index "standard compound drought and heat index (SCDHI)" to identify the concurrent dry and hot event. The SCDHI is a combination of two indexes: drought index SAPEI and hot index STI. The advantage of SCDHI is to reflect the dry and hot condition at sub-monthly scale. Such a feature benefits from the use of the SAPEI index which is a daily drought index and enables the drought index calculation at different monthly time scales (e.g., 3, 6, 9, and 12 months). The authors validated the SCDHI index through three evaluation metrics and applied the SCDHI index to three future climate projections. The paper addresses a water resources management question which is within the scope of HESS. However, the innovation of this paper is unclear; the descriptions of the index and experiments are incomplete and not well organized; and a few method choices are not properly justified. Moreover, the paper needs more proofreading. The current presentation is far from the publication criteria of HESS.

Author's reply: We highly appreciate the constructive comments and suggestions. We have revised the manuscript thoroughly and carefully following your comments and suggestions. The line number was added in the manuscript with no changes marked.

Major comments to the authors

1. The innovation of this paper is unclear.

1.1 The development of SCDHI includes two steps. The first step is developing SAPEI, and the second step is merging SAPEI and STI into SCDHI. If I understand correctly, the development of SAPEI has been published in Li et al. (2020, JHM), and the development of SCDHI looks the same as Hao et al. (2019, JH). The innovation of this work to me is that the authors applied their previously developed SAPEI index to SCDHI. In this regard, I think the novelty of this work is limited and it is not worth publishing in HESS. If this is incorrect, I hope to see the authors explain their novelty compared with Li et al. (2020, JHM) and Hao et al. (2019, JH).

Author's reply: Thank you for your comment and suggestion.

Please allow us to explain the novelty of this study:

(1) The study of Hao et al. (2019) provides a useful tool for characterizing compound dry-hot events. However, the existing indices only allow for identifying compound dry-hot events at a relatively coarse (i.e., the monthly) temporal resolution (Hao et al., 2019; Wu et al., 2020). Many important characteristics of climate extremes (i.e., drought and heatwaves) are not detectable at monthly scale (Fang et al., 2020; Lu et al., 2014; Otkin et al., 2018). Within the period of a temporal scale, the existing indices use the simple average of temperature/precipitation to indicate the general hot/dry situation of the period (Hao et al., 2019). Nevertheless, the hot extremes usually occur at finer time scales (e.g., days and weeks), and recent research has indicated that severe drought can occur within such short periods as well (e.g., days and weeks) across most of the world, for instance when extreme weather anomalies persist over the same region (so-called flash droughts, Otkin et al., 2018; Zhang et al., 2019). Moreover, the drought index used in existing compound dry-hot indices often relies on precipitation-based drought index (SPI), and leaves out other important drought-related factors (e.g., relative humidity, wind speed, and radiation) (Trenberth et al., 2013; Vicente-Serrano et al., 2010a). To address these limitations, using the SAPEI, the STI and copula theory, we thus developed a compound dry-hot index that can monitor compound dry and hot conditions at multiple time scales (e.g., day, week, and month).

(2) Several studies have been carried out to study compound dry-hot events in China (Chen et al., 2019; Hao et al., 2019; Wu et al., 2020; Zhang et al., 2019; Zhou and Liu, 2018), and these studies help to better understand such events. However, they mostly focused on the frequency and severity of the compound dry-hot event at a relatively coarse (i.e., the monthly) temporal resolution during historical periods without considering their duration and intensity. In addition, the impact of climate model bias on the characteristics of compound dry-hot event in China remain unclear. Understanding climate model biases is a crucial step to assess future compound dry-hot event risk (Villalobos-Herrera et al., 2020). Recent compound dry-hot events have resulted in serious social and economic losses in China, providing a strong motivation for studying compound dry-hot events (Wu et al., 2020; Zhang et al., 2019). Therefore, here we quantify several characteristics of compound dry-hot event and evaluate the impact of climate model biases on its characteristics in China.

(3) Though the SAPEI has been introduced in Li et al. (2020, JHM), the primary limitation of this index is that it has a fixed temporal scale and cannot reflect dry and wet condition at different time scales (i.e., 3-, 6-, 9-, and 12-month). It is however widely accepted that drought is a multiscalar phenomenon. Drought indices must be associated with a specific time scale to be useful for monitoring and managing drought, such as the wide acceptance of the standardized precipitation index (SPI) and standardized precipitation evapotranspiration index (SPEI) (McKee et al., 1993; Vicente-Serrano et al., 2010b). For example, to modify the limitation of the fixed time scale in the Palmer drought severity index (PDSI), a multiple time scale self-calibrated PDSI (denoted as SC-PDSI variant) has been developed for monitoring drought (Liu et al., 2017). Hence, in this study, we modified the SAPEI by developing the multiple time scale (i.e., 3-, 6-, 9-, and 12-month) daily drought index.

Finally, here we evaluate the SCDHI against recently experiences compound dry-hot events and compare its values against the magnitude of vegetation anomalies.

We have illustrated our novelty of this study. Please see Lines 97-108 and 117-130.

Reference:

Chen, L., Chen, X., Cheng, L., Zhou, P., & Liu, Z. (2019). Compound hot droughts over China: Identification, risk patterns and variations. Atmospheric Research, 227, 210-219.

Fang, W., Huang, S., Huang, Q., Huang, G., Wang, H., Leng, G., & Wang, L. (2020). Identifying drought propagation by simultaneously considering linear and nonlinear dependence in the Wei River basin of the Loess Plateau, China. Journal of Hydrology, 591, 125287.

Liu, Y., Zhu, Y., Ren, L., Singh, V. P., Yang, X., & Yuan, F. (2017). A multiscalar Palmer drought severity index. Geophysical Research Letters, 44(13), 6850-6858.

Lu, E., Cai, W., Jiang, Z., Zhang, Q., Zhang, C., Higgins, R. W., & Halpert, M. S. (2014). The day-to-day monitoring of the 2011 severe drought in China. Climate Dynamics, 43(1-2), 1-9.

Hao, Z., Hao, F., Singh, V. P., & Zhang, X. (2019). Statistical prediction of the severity of compound dry-hot events based on El Niño-Southern Oscillation. Journal of Hydrology, 572, 243-250.

McKee, T. B., Doesken, N. J., & Kleist, J. (1993). The relationship of drought frequency and duration to time scales. In Proceedings of the 8th Conference on Applied Climatology (Vol. 17, No. 22, pp. 179-183).

Otkin, J. A., Svoboda, M., Hunt, E. D., Ford, T. W., Anderson, M. C., Hain, C., & Basara, J. B. (2018). Flash droughts: A review and assessment of the challenges imposed by rapid-onset droughts in the United States. Bulletin of the American Meteorological Society, 99(5), 911-919.

Trenberth, K. E., Dai, A., Van Der Schrier, G., Jones, P. D., Barichivich, J., Briffa, K. R., & Sheffield, J. (2014). Global warming and changes in drought. Nature Climate Change, 4(1), 17-22.

Vicente-Serrano, S. M., Beguería, S., López-Moreno, J. I., Angulo, M., & El Kenawy, A. (2010a). A new global 0.5 gridded dataset (1901–2006) of a multiscalar drought index: comparison with current drought index datasets based on the Palmer Drought Severity Index. Journal of Hydrometeorology, 11(4), 1033-1043.

Vicente-Serrano, S. M., Beguería, S., & López-Moreno, J. I. (2010b). A multiscalar drought index sensitive to global warming: the standardized precipitation evapotranspiration index. Journal of climate, 23(7), 1696-1718.

Villalobos-Herrera, R., Bevacqua, E., Ribeiro, A. F., Auld, G., Crocetti, L., Mircheva, B., ... & De Michele, C. (2020). Towards a compound event-oriented climate model evaluation: A decomposition of the underlying biases in multivariate fire and heat stress hazards. Natural Hazards and Earth System Sciences Discussions, 1-31.

Wu, X., Hao, Z., Zhang, X., Li, C., & Hao, F. (2020). Evaluation of severity changes of compound dry and hot events in China based on a multivariate multi-index approach. Journal of Hydrology, 583, 124580.

Zhang, Y., You, Q., Mao, G., Chen, C., & Ye, Z. (2019). Short-term concurrent drought and heatwave frequency with 1.5 and 2.0 °C global warming in humid subtropical basins: a case study in the Gan River Basin, China. Climate dynamics, 52(7-8), 4621-4641.

Zhou, P., & Liu, Z. (2018). Likelihood of concurrent climate extremes and variations over China. Environmental Research Letters, 13(9), 094023.

1.2 Given that this paper focuses on developing SCDHI based on SAPEI and the development of SAPEI have been published in Li et al. (2020, JHM), I suggest the authors merging the Sections 2.2.1 and 2.2.2 into one section, and adding details about the calculation of the STI index. In this way, the calculation of SCDHI is more complete.
Author's reply: We thank the reviewer for pointing this out. We modified the SAPEI introduced in Li et al. (2020), as discussed in our reply 1.1 above. We agree with the reviewer that the calculation of the STI should be described. We have reduced the introduction on SAPEI, added the calculation of the STI, and merged the content on SAPEI and STI into one section. Please see Section 2.2.1 (Lines 188-213).

1.3 Moreover, to make the calculation of SCDHI look clear, I suggest the authors moving the graphical illustration of the SCDHI construction (Figure S4) from supplementary to the main context.
Author's reply: Thank you for the constructive suggestion. We have moved the Figure S4 into the main context. Please see Figure 2 in the revision.

1.4 Considering the focus of this paper, I suggest the authors removing Section 3.1 Evaluation of SAPEI because the development process of SAPEI has been published in Li et al. (2020, JHM). The authors can cite the relevant reference to prove the validation of SAPEI, which will make this paper concise and focused.
Author's reply: Thank you for your comment and suggestion. As mentioned in 1.1, we modified SAPEI in this study, and evaluated the ability of SAPEI to monitor drought at different time scales. We would like to keep Section 3.1 but have reduced the content of Section 3.1 (Lines 292-347).

2. I'm not satisfied with the structure and descriptions of Section 2 Methods.
Author's reply: Thank you for the constructive comments and suggestions, and underlining the clarity of the structure and description of Section 2.

2.1 (1) Regarding PDSI and SPEI (Section 2.1 Data), the introduction of PDSI and SPEI should not be mixed with data (e.g., meteorological dataset), the authors can add a new sub-section to introduce the both indexes. (2) Moreover, please clarify what are the two indexes compared with, SCDHI or SAPEI (lines 136-138)? (3) Last, please explain in detail how to calculate PDSI and SPEI. Currently, there are no explanations for the variables of Equations S1-4, and there are no explanations for the calculation of SPEI.

Author's reply: We appreciate the comment and suggestion.

(1) We have added a new sub-section to introduce both indices (Please see Section 2.3, Lines 263-272).

(2) The two indices were used to compare with SAPEI, reflecting the ability of SAPEI to monitor drought at monthly scale. We have added the clarification in Line 265.

(3) We have explained in detail how to calculate the two indices. Please see the appendix.

2.2 (1) Regarding SCDHI (Section 2.2.2 Construction of SCDHI), how are the marginal distribution and the joint probability distribution calculated (equation (2))? Please add equations or references. (2) Moreover, as I mentioned earlier, please add the calculation equation for STI. (3) Last but not the least, please explain/justify in detail why the Frank copula was chosen based on the three goodness-of-fit measures (lines 260-263).

Author's reply: We appreciate the comment and suggestion.

(1) Since the SAPEI and STI are normally distributed by construction, the normal distribution is used as the marginal distribution. We have clarified this in the text. The Frank copula emerges as the most appropriate copula from a large set of copulas for the task at hand following several evaluation metrics (including AIC and BIC). References have been added in Lines 229-230.

(2) The calculation for STI has been added in Lines 205-213.

(3) A detailed explanation on why we chose the Frank copula has been added in Lines 248-259.

2.3 (1) Regarding the three verification metrics (Section 2.2.2 Construction of SCDHI), I think these metrics can be separate from the construction of SCDHI, after all, the three metrics are not part of the SCDHI index but part of the evaluation of SCDHI. (2) Moreover, the authors need to justify why the three verification metrics are selected, for instance, what can each of them reveal, what is the relationship between them, etc.

Author's reply: As explained in our main statement at the beginning of this document, we have removed the introduction of the three metrics and the analysis based on these three metrics from our study.

2.4 For ease of understanding, I suggest the authors adding a paragraph or sub-section describing the experiment of this work. For instance, after introducing all the data, developed indexes and evaluation metrics, the authors can explain the work flow of this paper, such as firstly validating the developed SCDHI index, and then applying SCDHI to three future climate scenarios. Now the structure of this paper is confusing, only after I read the results section, I understood what the authors want to do.
Author's reply: Thank you for the constructive suggestion. A paragraph to describe the structure of the paper has been added in Lines 131-134.

2.5 Section 2 Methods should also explain how are the frequency, duration, severity and intensity of the compound dry-hot events defined and calculated (Figs 10, 11). These metrics are used in Section 3.3 Application without proper explanations.
Author's reply: Thank you for your comment and suggestion. We have added these explanations when explaining the run theory in detail. This information has been added in Lines 274-289.

3. Presentation of the paper. The writing of this paper needs to be largely improved. I found it hard to understand some sentences, the definitions of several terms are missing, and the figures are not well titled and explained. Please see the below for details.
Author's reply: Thank you for your comment. We have revised the manuscript thoroughly and carefully, including all the comments and suggestions below.

Minor comments to the authors
Many thanks to the reviewer for the comments and suggestions.

1. Please define the term "compound dry-hot event" and give some examples. This term plays a key role in your work, but it lacks an appropriate definition (lines 43-45).
Author's reply: Thank you. We simply refer to a concurrent dry and hot conditions as a compound dry-hot event. A definition has been added in Lines 50-51.

2. Lines 30-31, I'm not sure the purpose of this sentence here.
Author's reply: Thank you. We have revised this sentence. Please see Lines 33-35.

3. Line 171, the reference "rlilpl" looks not being used in this article.
Author's reply: Thank you. We have revised this sentence. Please see Lines 178-179.

4. Line 237, "less than" should be "less than or equal to".
Author's reply: Thank you, this has been done. Please see Line 225.

5. Lines 331-333, I doubt that the first half sentence is supported by Fig. S6.

Author’s reply: Thank you. We have rephrased this sentence. Please see Lines 334-335.

6. Some references in writing are unclear. For instance,
1) Lines 57, “this approach”.
2) Lines 242-244, “p to the given marginal sets”.
3) Line 354, “It”.
4) Line 379, “detect” what?
5) Line 455, “they”.
Author’s reply: Thank you. We have revised these sentences.

7. Many sentences have grammatical errors or are unclear. Please correct them and add elaborations. Below are just some examples.
1) Line 131, change “perennial frozen soil” to “perennially frozen soil”.
2) Line 132, change “Chinese arid regions” to “the arid regions of China”.
3) Line 135, I guess “less meaningless” should be “less meaningful”.
4) Lines 154-156, two “well”.
5) Lines 161-165.
6) Lines 225-228
7) Lines 252-253. The citation format is incorrect.
8) Lines 269-274. “is” vs. “are”.
9) Lines 284-286.
10) Lines 320-322.
11) Lines 371-379.
12) Lines 403-405.
13) Line 417, change “twenty thousand km2” to “20,000km2”.
14) Line 420, change “first case studies” to “the first case study”.
15) Lines 454-457.
16) Line 467, past tense.
17) Line 472, please elaborate on the “run theory”.
18) Lines 510-516. Please re-write these sentences to make them clear.
19) Figure 12 title has grammar error.
20) Lines 536-538.
21) Lines 543-544.
22) Lines 570-571.
Author’s reply: Thank you. We revised all sentences accordingly.

8. Please add references for the following sentences:
1) Lines 146-148.
2) Lines 157.
Author’s reply: Thank you. We have added appropriate references. Please see Line 154-155/166

9. The section numbering of 3.2.1 and 3.2.2 has problems.
Author’s reply: Thank you. We have revised the numbering.