Response to Reviewer 1

Hydrological response regimes of compound hydroclimatic events across China revealed by behavior-space regionalization

Dear Reviewer,

We sincerely thank you for your careful and constructive evaluation of our manuscript. Your comments helped us improve the methodological transparency, physical interpretation, presentation, and reproducibility of the study. We have revised the manuscript and Supplement accordingly. The reviewer comments are reproduced below, followed by our point-by-point responses and the locations of the corresponding changes.

Major Comments

Reviewer Comment R1.1

> Several variables used in the equations are not defined in detail or even never introduced such as lag weights (section 3.3, line 215), (section 3.3, line 245), (section 3.3, line 245). The authors might need to check thoroughly within the methodology part.

Response: We agree that the original Methods did not define the mathematical notation with sufficient precision. We therefore reviewed the notation throughout Sections 3.1-3.4 and clarified the grid, time, calendar-month, variable, event-type, quantile, empirical-rank, conditional-intensity, feature, and transition symbols at their first use. We also removed the ambiguous lag-weight notation. The implementation does not estimate free scalar weights for the individual lags; instead, antecedent variables are included according to the specified lag set. The extended conditional-probability and conditional-intensity formulation is now provided in Supplement Sect. S3, while Supplement Sect. S4 reports the composition and complete dictionary of the 183 behavior features. These revisions make the lag treatment and feature construction more transparent and reproducible.

Changes in the manuscript: Methods Sects. 3.1-3.4; Supplement Sects. S3-S4; Supplement Tables S3-S4.

Reviewer Comment R1.2

> Several methods used in the procedures of the methodology should be described as least with a certain type name, for example, the specific embedding method (line 280) is not named; the clustering algorithm (line 280) is not specified. The authors should check the methodology thoroughly to ensure they are formalize

Response: We agree and have replaced the generic descriptions of embedding and clustering with the specific method names and settings. The revised manuscript identifies principal component analysis (PCA) as the embedding method and MiniBatch k-means as the clustering algorithm. The 185-dimensional clustering input, consisting of 183 behavior features and two weakly weighted spatial coordinates, was reduced to 24 principal components. Candidate cluster numbers were evaluated using cluster validity, stability, and size-balance criteria, and the eight-regime solution was retained because it balanced statistical robustness with hydrological and spatial interpretability. The detailed preprocessing and clustering procedure is provided in Supplement Sect. S4.

Changes in the manuscript: Abstract; Methods Sect. 3.5; Conclusions; Supplement Sect. S4.

Reviewer Comment R1.3

> Implications of anomaly-relative event definitions should be discussed. Because "warm"/"wet" are defined relative to local, monthly climatology, events are anomalies rather than absolute extremes (a "warm" January in Northeast China is not warm in absolute terms). A discussion is needed.

Response: We agree that this distinction is essential for interpreting the results. We added a dedicated discussion explaining that warm, cold, wet, and dry refer to departures from the local calendar-month climatology rather than spatially uniform absolute extremes. The revised text uses the reviewer's January example to clarify that a warm January in Northeast China is warmer than the local January norm but is not necessarily warm in an absolute sense. We further explain that this relative definition improves comparison across China's strong climatic and seasonal gradients, while the resulting event frequencies and response regimes should not be interpreted as direct measures of absolute hazard or impact. We now state that impact-oriented applications would additionally require absolute thresholds and information on exposure and vulnerability.

Changes in the manuscript: Discussion Sect. 5.3; Methods Sect. 3.2; Supplement Sect. S2.

Reviewer Comment R1.4

> The study uses gridded monthly data, but the spatial resolution of the analysis grid is not stated. The source datasets (CHM PRE V2, GLEAM V4.2, CMFD V2, CNRD v1.0, ERA5-land, and SMAP L4) have different native resolutions and uncertainties. The manuscript should describe the common grid resolution used and discuss how uncertainties in individual datasets propagate ultimately to the regime classification. By the way, please also state the data sources with their used variables in the methodology.

Response: We agree and have expanded the data and uncertainty descriptions. The revised manuscript states that the analysis covers January 1980-December 2018 on a common 0.1 degree by 0.1 degree grid. It now identifies the variable obtained from each product: CHM PRE V2 precipitation, GLEAM V4.2 potential evaporation, CMFD V2 mean air temperature, CNRD v1.0 natural runoff, and the ERA5-Land-SMAP L4 fused soil moisture product. Supplement Table S2 reports each dataset's native resolution, temporal aggregation, and derived standardized index, and Supplement Sect. S1 explains the bilinear interpolation and temporal alignment procedure. We also added a staged uncertainty discussion describing how source-data errors can affect threshold classification, the conditional dependence matrix, behavior features, and final cluster membership. The revised text notes that interpolation may smooth local variability and attenuate extremes, particularly in mountainous, coastal, and data-sparse regions, and therefore treats transition-zone grid cells as more uncertain than regime cores.

Changes in the manuscript: Study Data Sect. 2.2; Supplement Sect. S1 and Table S2; Discussion Sect. 5.5; Abstract.

Reviewer Comment R1.5

> The finding that warm-dry and cold-wet events dominate across most regimes is noted (Section 4.4), but the physical reasons for the relative rarity of warm-wet and cold-dry compound events in the Chinese context deserve more discussion.

Response: We agree and added a dedicated physical interpretation. The revised Discussion explains that warm-wet concurrence requires the moisture surplus to offset both enhanced evaporative demand and precipitation- or cloud-related suppression of surface warming. Conversely, negative temperature anomalies reduce potential evapotranspiration and can partly compensate for precipitation deficits, making the joint cold-dry threshold less likely to be reached. Warm-dry conditions are favored by the mutual reinforcement of high evaporative demand and reduced evaporative cooling, whereas cold-air outbreaks accompanied by frontal lifting and moisture transport can favor cold-wet conditions. These mechanisms provide a physically consistent explanation for the greater contributions of warm-dry and cold-wet events in most response regimes.

Changes in the manuscript: Discussion Sect. 5.3.

Reviewer Comment R1.6

> Consider making introduction (section 1) and methodology (sections 2 and 3) more concise. You can also put some parts in SI.

Response: We agree and have streamlined both the Introduction and Methods. The Introduction now focuses on the knowledge gap, the need for response-regime diagnosis, and the three research questions. In the Methods, the main text retains the analytical logic and the information needed to understand the results, while extended explanations of data harmonization, dynamic event identification, conditional-intensity estimation, behavior-feature definitions, and clustering are provided in Supplement Sects. S1-S4. We also merged the former regionalization and regional-attribution subsections into a single concise section. These changes reduce repetition while preserving reproducibility through the Supplement.

Changes in the manuscript: Introduction Sect. 1; Methods Sects. 2.2 and 3.1-3.5; Supplement Sects. S1-S4.

Other Comments

Reviewer Comment R1.7

> The text in the figures should be bigger and I suggest the letters indicating the subplots to be put outside the subplots rather than inside the box, sometimes the letters will cover the information such as in Fig. 3b. All the figures need to be checked and also made more clear.

Response: We agree and have reviewed all figures for readability. Font sizes, symbols, and legends were enlarged where needed, and the panel labels were repositioned outside the plotting areas so that they no longer obscure data or annotations, including in the former Fig. 3b. The corresponding captions were also revised to identify the content of each panel more clearly.

Changes in the manuscript: Figures 1-11 and their captions.

Reviewer Comment R1.8

> I recommend 'soil-moisture' in the text to be replaced with 'soil moisture', please check through the text.

Response: We agree and have standardized this terminology throughout the manuscript, figure captions, and Supplement to use 'soil moisture' consistently.

Changes in the manuscript: Throughout the manuscript and Supplement.

Reviewer Comment R1.9

> Please state the study period in the methodology

Response: We agree. The revised data section now states explicitly that the analysis covers mainland China from January 1980 to December 2018. The same period is also reported in the Abstract and Conclusions for consistency.

Changes in the manuscript: Abstract; Study Data Sect. 2.2; Conclusions.

Reviewer Comment R1.10

> Please consider adding some quantitative sentences with number to the abstract. The current version is basically descriptive.

Response: We agree and have substantially revised the Abstract to include the main methodological and quantitative results. It now reports the 0.1 degree analysis grid, the 183 behavior features, the 24-component PCA representation, and the eight response regimes. It also states that the seasonal high-intensity, soil moisture propagation, and weak-response regimes account for 16.2%, 15.8%, and 15.2% of valid grid cells, respectively, and that the most frequent C4-C6 boundary represents 14.5% of adjacent cross-regime grid-cell pairs.

Changes in the manuscript: Abstract.

Reviewer Comment R1.11

> Some references are not referred to in the text such as Singh, O. N. and Fabian, P. (Eds.): Atmospheric Ozone: a Millennium Issue, Copernicus Publications, Katlenburg-Lindau, 725 Germany, 147 pp., ISBN 393658608X, 2003. Please check you reference list thoroughly. And please use relevant references and remove irrelevant ones. For example, I don't see what the ozone book mentioned here is of any relevance to your text.

Response: We agree. We checked the reference list against all in-text citations and removed references that were not cited or were not relevant to the study, including the atmospheric ozone volume identified by the reviewer. We also reviewed the retained references for consistency with the scientific statements they support.

Changes in the manuscript: Reference list and in-text citations throughout the manuscript.

Reviewer Comment R1.12

> A location map of basins/climate zones for table 1 would help.

Response: We agree that clearer geographic context improves interpretation. The revised study-area description now identifies the nine major river basins and seven climate zones, with their full names and abbreviations summarized in Supplement Table S1. Basin and climate-zone information is incorporated into the spatial regime maps and regional-attribution analyses, allowing readers to relate the regional units to the mapped response regimes and transition belts.

Changes in the manuscript: Study Area Sect. 2.1; Supplement Table S1; Figures 6-8.

Reviewer Comment R1.13

> Change "Materials and Methods" to "Methods" as the dataset is described in the former section.

Response: We agree and have changed the section title from 'Materials and Methods' to 'Methods'. The dataset description remains in the preceding Study Area and Research Data section.

Changes in the manuscript: Section 3 heading; Study Area and Research Data Sect. 2.

We again thank the reviewer for these helpful comments. We believe that the revisions have improved the clarity, reproducibility, and interpretation of the manuscript.

Sincerely,

The Authors