This study investigates the multi-scale characteristics of soil moisture memory (SMM) and its environmental drivers across three mountain watersheds in southwestern China (Dali River Basin, Anning River Basin, and Jiangjia Ravine). The authors employ Power Spectrum Analysis (PSA) and second-order Detrended Fluctuation Analysis (DFA-2) to quantify SMM persistence, and utilize the Boruta-Random Forest algorithm to identify dominant drivers across different temporal scales. The study reveals that SMM persistence generally weakens with increasing scale, with a structural transition in driver dominance from dynamic atmospheric variables to static soil/topographic properties occurring at approximately the 5-year scale.

This is a high-quality research paper with novel topic selection, robust methodology, and clear structure. The authors have successfully integrated established time series analysis methods in an innovative manner for SMM research in mountain watersheds, identifying a scale-transition threshold (~5 years) with significant theoretical and practical implications. Especially, it has significant indicative value for the study of the initiation and movement of landslides and debris flows. The transparent and honest discussion of methodological limitations is commendable, and the open availability of data and code aligns with open science principles. Overall, this study makes an important scientific contribution to understanding soil moisture dynamics in complex terrain and requires moderate revisions to meet the publication standards of HESS.

Major Comments

1. Recommend further clarifying the boundary between statistical associations and mechanistic interpretations. The authors have appropriately noted in Section 2.4 and Section 4.1 that the Boruta-RF method identifies statistical associations rather than causal relationships—this scientific rigor is commendable. To further enhance clarity, minor adjustments to certain expressions are suggested. In the title or footnote of Table 2, consider replacing "Dominant Environmental Associations" with "Dominant Statistical Associations" to maintain consistency with the main text. In the final sentence of the Abstract, consider changing "offering a conceptual framework" to "proposing a conceptual framework" to more accurately reflect the current research stage

Reply: We have made revision following your advise, see line 27 and 432.

2. Recommend enhancing visual distinction for long-timescale analyses. The authors have correctly identified the statistical limitations imposed by the 20-year record length for analyses at >7-year scales (Section 2.3). This distinction between the "Reliable Memory Window" and "Low-Frequency Background State" is well-articulated in the text. To ensure readers are reminded of this important caveat when viewing the figures, a brief clarifying note in the figure caption would be helpful. Consider adding a sentence to the Figure 3 caption noting that spectral estimates beyond the ~7-year scale should be interpreted as low-frequency background trends rather than statistically robust memory features, with reference to Section 2.3 for details.

Reply: We have revised the manuscript in accordance with your suggestion, and the updated figure caption can be found in Lines 307-308. "…estimates beyond the ~7-year scale should be interpreted as low-frequency background trends rather than statistically robust memory features"

3. Recommend brief discussion of basin area differences in main text. The three study watersheds differ considerably in area (JJR: 48.6 km² vs. ARB: 11,150 km²). The authors conducted a scale-matching sensitivity analysis in Appendix H, demonstrating that inter-basin differences reflect genuine hydrological characteristics rather than statistical artifacts. A brief mention of this important finding in the main text is recommended.

Reply: A scale-matching sensitivity analysis (Appendix H) was added to address this concern. Specifically, we have included the following context in Lines 157-160: "Despite the large difference in basin area (ARB: 11,150 km² vs. JJR: 48.6 km²), a scale-matching sensitivity analysis (Appendix H) confirms that the observed differences in soil moisture memory between basins reflect intrinsic hydrological and landscape characteristics rather than artifacts of spatial averaging or domain size."

4. Recommend clarifying the definition of rainy and dry seasons. The paper refers to "rainy season" and "dry season" analysis results in multiple places, but the seasonal classification criteria for the three watersheds are not consistently stated in the main text. Although Table B1 provides information on the precipitation seasonal distribution for each watershed, explicit clarification upon first mention in the main text would facilitate reader comprehension. In Section 2.1 or Section 3.1, explicitly state the specific monthly definitions of rainy and dry seasons for each watershed (e.g., DRB: rainy season June–September, dry season October–May). This addition requires only 1–2 sentences and will enhance the completeness of the methodological description

Reply: In line with your suggestion, we have explicitly defined the rainy and dry seasons in Section 3.1 where they are first discussed. The added sentence reads: "For seasonal classification, the rainy and dry seasons are defined based on local precipitation regimes: the Dali River Basin (DRB) rainy season spans July to September (dry season: October–June), while both the Anning River Basin (ARB) and Jiangjia Ravine (JJR) share a rainy season from May to October (dry season: November–April)."

5. Recommend expanding the discussion of future research directions. The authors propose a conceptual framework for applying SMM to hazard early warning in Section 4.2 and Conclusions—this direction is valuable. Further discussion of potential validation and application pathways for this framework is recommended. Consider adding 1–2 sentences in the Conclusions discussing how the SMM metrics from this study could be integrated with operational hazard monitoring systems in the future. For example, mention the possibility of incorporating SMM persistence thresholds into existing rainfall-landslide early warning models. Add 1-2 sentences in Section 3.4 or Section 4.3 summarizing the key conclusion from Appendix H. For example: "A scale-matching sensitivity analysis (Appendix H) confirmed that the stronger memory observed in the ARB reflects genuine hydrological contrasts rather than basin size artifacts." This addition will enhance the completeness of the main text and facilitate reader comprehension

Reply: We have added the following sentence in the concluding paragraph (Lines 709–714): "Looking forward, the SMM metrics and persistence horizons quantified in this study, such as the 18–31 day rainy-season memory, could be integrated into operational hazard early warning systems. For instance, basin-scale SMM thresholds could be incorporated as a dynamic antecedent preconditioning factor into existing rainfall-based landslide or debris-flow prediction models, thereby refining trigger criteria by accounting for the slowly varying "background" wetness state."

We have also added the following summary statement at the end of the first point in Section 4.3 (Lines 654–656): "In summary, the scale-matching sensitivity analysis (Appendix H) confirmed that the stronger memory observed in the ARB reflects genuine hydrological contrasts rather than basin size artifacts." At the end of first point in Section 4.3 (Lines 654-656): "In summary, the scale-matching sensitivity analysis (Appendix H) confirmed that the stronger memory observed in the ARB reflects genuine hydrological contrasts rather than basin size artifacts."

Minor Comments

Figure 5: Consider adding a sentence in the caption explaining why panels (a) and (b) use different metrics, helping readers understand that numerical values should not be directly compared.

Reply: **We thank the reviewer for this suggestion. The caption for Figure 5 has been revised to include the note:** "Note: Panels (a) and (b) use different metrics and are not directly comparable." (Lines 417-418).

Table 3: Consider briefly noting the area differences among the three watersheds in the table title or footnote to provide quick background information for readers

Reply: We have added the area of each watershed to the caption of Table 3 (Line 470): "…for the three watersheds (DRB: ~3,906 km^2; ARB: ~11,150 km^2; JJR: ~48.6 km^2)"

Consider explicitly defining the relationship between "persistence horizon" and "memory length" at first occurrence to facilitate understanding for non-specialist readers

Reply: We have added a definition clarifying the relationship between "persistence horizon" and "memory length" (Lines 225–227): **"**In this study, persistence horizon is used as the operational measure of memory length, specifically denoting the temporal range where significant long-range memory ($\alpha \geq 0.9$) is maintained."

When "catena concept" first appears in Section 2.4, consider adding a brief explanation (e.g., "the co-evolution of soil and topography along hillslopes")

Reply: We have explained the "catena concept" when it first occurs in the text (Lines 273–275): "… often described by the catena concept of co-evolved soil-topography relationships (i.e., steep upper slopes have thin, sandy, fast-draining soils while gentle lower slopes accumulate thick, clay-rich, water-retaining soils"

The second paragraph of Section 4.1 contains long sentences; consider splitting into 2-3 shorter sentences to improve readability.

Reply: We have thoroughly revised the second paragraph of Section 4.1. In addition, we identified other long sentences in the remaining paragraphs of this section and have split them into shorter ones to improve readability.

Specifically, the sentence "Partial correlation analysis (Appendix G) indicates that soil texture maintains a significant association with decadal-scale SMM (partial r = 0.43, p < 0.01) after controlling for topography, though approximately 30 % of the raw correlation may stem from landscape collinearity." was revised to "Partial correlation analysis (Appendix G) shows that soil texture maintains a significant association with decadal-scale SMM after controlling for topography (partial r = 0.43, p < 0.01). However, approximately 30 % of the raw correlation may stem from landscape collinearity. This suggests pedological effects are not entirely attributable to topographic confounding." (Lines 536-539).

Similarly, the sentence "In reality, this association likely reflects a bidirectional eco-hydrological feedback: while vegetation improves soil structure (driver), sustained soil moisture is also a prerequisite for maintaining high biomass (response)." was revised to "In reality, this association likely reflects bidirectional eco-hydrological feedback. Vegetation improves soil structure (as a driver), while sustained soil moisture is required to maintain high biomass (as a response)." (Lines 557-559).

Consider standardizing the format of journal names in references (some use italics, others do not)
Check completeness and format consistency of DOI links

Reply: We have carefully checked the format of references in the manuscript, and the updated version satisfies the journal's requirements.

The partial correlation analysis results in Appendix G are valuable for supporting the main conclusions; consider adding a sentence in Section 4.1 referencing this appendix

Reply: In Section 4.1, under the subsection "Acknowledging Physical Collinearity", we have incorporated a direct reference to Appendix G and summarized its key finding (Lines 536-539): "Partial correlation analysis (Appendix G) indicates that soil texture maintains a significant association with decadal-scale SMM after controlling for topography...". This reference directly links the methodological validation in the appendix to the main conclusions regarding landscape collinearity.

The data availability statement is complete and standardized, conforming to HESS open science policies—this is commendable

Reply: thanks so much.