Dear editor,

We thank you very much for handling our manuscript. We have carefully revised the manuscript according to the remaining concerns from both reviewers, which were detailed responded one by one as follows. We have also rechecked and revised inappropriate aspects throughout the manuscript, including sentence phrasing, grammar, citations, and references. Regarding the reference check, we have specifically added the missing DOIs/ISBN information for some references. The reference list has been updated accordingly.

Thanks for your hard work again.

Best regards,

Jia Qin

Response to Referee #1

General comments

Thank you for the opportunity to review this manuscript again. Compared with the previous version, the manuscript has been improved, and the authors have revised and clarified several points raised in my previous review. However, some issues have not yet been adequately addressed. The authors should carefully consider the following comments before the manuscript proceeds to the next stage.

Major comments

(1) The three components of the SAP framework are not consistently defined.

In the Abstract and earlier sections, the SAP framework consists of: (i) surface hydrological processes, (ii) hydrological functions of the active layer, and (iii) hydrological effects of permafrost change. However, Section 7.2 describes the three components as: (i) surface hydrological processes, (ii) suprapermafrost hydrological processes, and (iii) thermal–hydrological interactions between the active layer and permafrost.

These two classifications do not correspond directly to each other. The hydrological functions of the active layer are related to suprapermafrost hydrological processes, but the two concepts are not equivalent. Similarly, the hydrological effects of permafrost change involving runoff, groundwater, and hydrological connectivity, whereas thermal–hydrological interactions between the active layer and permafrost refer more specifically to processes occurring at their interface. It is therefore unclear whether Section 7.2 redefines the SAP framework or provides a further interpretation of the original framework.

In addition, the manuscript describes these components as “three spatial dimensions”. Surface and active-layer hydrological processes have a clear vertical spatial relationship, whereas the hydrological effects of permafrost change represent a category of hydrological responses rather than a spatial dimension.

The authors should: (i) define the three components of the SAP framework consistently throughout the manuscript; if the classification in Section 7.2 is intentionally different, explain the correspondence between the two classifications and the reason for the change; and (ii) clarify the spatial relationships, process linkages, and interactions among the three SAP components.

Response: We thank the reviewer for raising this critical issue. We agree that the descriptions of three components in Section 7.2 were inconsistent with the SAP framework in the Abstract and earlier sections, which could lead readers to assume that Section 7.2 redefined the SAP framework. In the revised manuscript, we have unified the definition of the SAP framework, and clarified the spatial relationships, process linkages, and interactions among the three SAP components.

We have revised Section 6 and Section 7.2 to unify the definition of the SAP framework throughout the manuscript. The framework is now consistently defined as comprising three coupled domains along the surface–active layer–permafrost continuum: The SAP framework comprises three coupled domains along the surface–active layer–permafrost continuum: (S) surface hydrological processes; (A) active-layer hydrological functions, including infiltration, soil water storage, interflow, and suprapermafrost groundwater; and (P) hydrological effects of permafrost change, including permafrost table lowering, talik development, ground-ice melt, and altered surface water–groundwater connectivity.

In Section 7.2, we have revised it so that it no longer introduces a separate three-part classification. We have clarified the correspondence between the earlier and revised classifications. The "suprapermafrost hydrological processes" mentioned in Section 7.2 now correspond to the active-layer domain (A), while the "thermal–hydrological interactions between the active layer and permafrost" are treated as a key interface mechanism within the permafrost-change domain (P), not as a third parallel domain. This clarification ensures that Section 7.2 provides a further interpretation of the original SAP framework rather than redefining it. (The revisions were marked in the last paragraph of Section 7.2).

In addition, we have deleted the phrase "three spatial dimensions" and replaced it with "three coupled SAP domains" in Section 7.2. We agree that "permafrost change effects" represents a category of hydrological response rather than a purely spatial dimension parallel to the surface and active layer. The revised text therefore uses "three coupled SAP domains" consistently and avoids the misleading spatial connotation. We also have added a paragraph clarifying the spatial relationships, process linkages, and interactions among the three SAP components (marked in the third paragraph of Section 6)

(2) The effects of permafrost degradation on runoff and baseflow are not described sufficiently accurately. Lines 253–254 state that "Permafrost thaw also increases river discharge". This wording may suggest that permafrost degradation leads to increased river discharge. However, the hydrological response to permafrost degradation varies considerably among regions. In some regions, active-layer thickening and enhanced groundwater connectivity may increase subsurface runoff or winter baseflow. In other

regions, increased infiltration, subsurface storage, and evapotranspiration may reduce surface runoff, seasonal runoff, or even annual runoff.

Response: We agree. The original statement "Permafrost thaw also increases river discharge" was too absolute. We have revised this statement and checked the Abstract, Section 5.3, and Table 1 for similar overgeneralizations.

We have replaced the sentence"Permafrost thaw also increases river discharge, with Arctic-wide studies demonstrating significant increases in water export and changes in spring freshet and summer stream intermittency (Feng et al., 2021)." by "Permafrost thaw can also alter river discharge, but the sign and magnitude of change are region-dependent. Arctic-wide studies have reported significant changes in water export, spring freshet, and summer stream intermittency (Feng et al., 2021)."(Lines 242-244)

In Abstract, the sentence"... and ultimately increased baseflow and modified runoff partitioning." Was revised to"... and can ultimately increase baseflow and modify runoff partitioning in many regions." (Lines 22-23)

Also, the sentence in Section 5.3.3"Permafrost degradation generally increases baseflow and winter runoff, reduces seasonal variability in stream discharge, and enhances surface water–groundwater interactions-----" has been revised to "In many permafrost regions, permafrost degradation has been associated with increased baseflow and winter runoff, reduced seasonal variability in stream discharge, and enhanced surface water–groundwater interactions----". (Lines 672-674)

In Table 1, the Caption "Table 1. Quantitative synthesis of permafrost thaw contributions to runoff and baseflow" was revised to "Table 1. Quantitative synthesis of reported permafrost thaw contributions to runoff and baseflow"

(3) The treatment of conference abstracts requires clarification.

Lines 115–118 state that conference abstracts or grey literature without detailed methodological descriptions were excluded. However, several AGU and EGU conference abstracts are cited in the main text to support specific statements. One example is:

van Meerveld, I.: The (ir)relevance of plot- and hillslope scale processes for catchment runoff, EGU General Assembly 2024, Vienna, Austria, EGU24-6684, https://doi.org/10.5194/egusphere-egu24-6684, 2024.

The authors should clarify whether these conference abstracts are included among the 225 studies retained for the final synthesis.

Response: We thank the reviewer for identifying this inconsistency. We have now clarified the distinction between studies included in the formal evidence synthesis and references used only for methodological, background, or contextual purposes. Conference abstracts are not included in the core synthesis. They are now listed separately in a new Supplementary Table S2.

In the Section 2.2, we have deleted the sentence "Studies lacking direct relevance to hydrology, as well as conference abstracts or grey literature without detailed methodological descriptions, were excluded.", and the last sentence in the paragraph were revised to "Ultimately, 219 peer-reviewed studies were retained for the formal

evidence synthesis, and their full list is provided in Supplementary Table S1. In addition, Supplementary Table S2 lists seven other items cited in the main text—conference abstracts, methodological references, and non-permafrost comparative/background studies—which were not included among the 219 studies used for the formal evidence synthesis."

(4) Winter runoff, baseflow, and low flow should not be treated as synonymous terms.
Lines 600–601 state that "Winter runoff, also referred to as baseflow, low-flow, or cold-season runoff, has exhibited a clear upward trend." This wording treats these terms as equivalent. However, winter runoff and cold-season runoff are defined by the period of flow, baseflow is a component of streamflow, and low flow describes a flow condition. Although baseflow may account for a large proportion of winter runoff in some permafrost regions, these terms are not interchangeable. The authors should revise this sentence and use the relevant terms consistently throughout the manuscript.
Response: We agree that these terms are not interchangeable. We have revised the first sentence in Section 5.3.1 and checked the inconsistent terms throughout the manuscript.

(5) Figure 1 does not clearly represent the seasonal dynamics of the active layer.
Figure 1 does not clearly represent the seasonal changes in the active layer. The active-layer boundary and the frozen/thawed ground conditions appear nearly identical in the spring, summer, and autumn panels. Consequently, the figure does not clearly show how the active
layer changes among the three seasons. The authors should revise Figure 1 to make the seasonal differences more apparent.
Response: We agree, and have redrawn Figure 1 to make the seasonal differences in the active layer more apparent. The "melting front" also was revised to "thawing front" in the Figure 1.

(6) Permafrost terminology still requires systematic correction.
In my previous review, I asked the authors to standardize the use of "melt" and "thaw", but these terms are still misused in the latest version. "Thaw" should be used for permafrost or frozen ground, whereas "melt" should be used for solid water such as ground ice or soil ice. For example, "partial melting of permafrost" and "melted permafrost" are still used at Lines 387–390, and "melting front" is also used in the figures. In addition, "permafrost meltwater recharge" on Page 32 and "Permafrost thaw meltwater" in Table 1 should be further checked and standardized.
The term "seasonal permafrost" is used at Lines 358 and 379, but its intended meaning is unclear. If the authors intend to refer to ground that freezes seasonally, "seasonally frozen ground" should be used.
Response: Thanks a lot. We agree and have systematically corrected the terminology. In the revised manuscript, "thaw" is used for permafrost, frozen ground, the active layer, and the permafrost table, whereas "melt" is used for solid water such as ground ice, soil ice, snow, and glaciers. We have also replaced "seasonal permafrost" with

“seasonally frozen ground” where that is the intended meaning. All the revisions have been marked in the manuscript. And the Figure 2 also has been revised: replacing“Melting front” by“Thawing front”, and replacing“Melting process” by“Thawing process”.

(7) The references and DOIs require systematic verification.
The DOI provided for Ye et al. (2009), “10.1029/2009JD10537”, does not match the original publication. The correct DOI is “10.1029/2008JD010537”.
The authors should systematically verify all references against the original publications, including the authors, publication years, volumes, issues, page ranges, DOIs, and citation-year suffixes.
Response: We thank the reviewer for pointing out the incorrect DOI for Ye et al. (2009). The incorrect DOI “10.1029/2009JD10537” has been replaced by “10.1029/2008JD010537”. We also have systematically verified all references against the original publications, including authors, publication years, volumes, issues, page ranges, DOIs, and citation-year suffixes.

Response to Referee #3

The authors have satisfactorily addressed my main concerns from the previous round, and I appreciate the substantial revisions made to improve the methodological transparency and synthesis of the review. I have only one remaining concern regarding Supplementary Table S1. The manuscript presents this table as the complete set of 225 studies retained for the final synthesis, but some entries do not appear fully consistent with the stated inclusion/exclusion criteria or with the definition of an “included study.” Typical examples include the following:
1. Conference abstracts, although Section 2.2 states that conference abstracts were excluded. Examples include Jones (2014) and Karlsson et al. (2011), both from AGU Fall Meeting Abstracts, as well as van Meerveld (2024) from the EGU General Assembly.
Response: Thanks a lot. We have removed Jones (2014), Karlsson et al. (2011), van Meerveld (2024), Yoshikawa et al. (2006), and other conference abstracts from Supplementary Table S1 and placed them in a new Supplementary Table S2, which lists background, methodological, and contextual references. These sources may still be cited in the main text where appropriate, but they are explicitly not part of the 219 core studies.

2. Methodological or background references that do not themselves provide evidence on permafrost hydrology. For example, Haddaway and Bayliss (2015) concerns systematic-review methodology and is listed with N/A for study region, permafrost type, and hydrological focus.
Response: We agree. Haddaway and Bayliss (2015) concerns systematic-review methodology and does not provide evidence on permafrost hydrology. We have removed it from Supplementary Table S1 and listed it in Supplementary Table S2 as a methodological reference. The main text still cited it in Section 2 to support the

review methodology, but it was not counted among the core synthesis studies.

3. Studies outside the stated permafrost domain. For example, Bayard et al. (2005) is explicitly classified as "Seasonal frost (non-permafrost)," while Li et al. (2022) is classified as a glacier study with "N/A (glaciers)" for permafrost type.
These references may certainly be relevant as methodological, background, or comparative literature, but it is unclear whether they should be counted among the 225 studies retained for the formal evidence synthesis. Please carefully check the consistency between the stated inclusion/exclusion criteria and Supplementary Table S1, and clarify the distinction, if any, between studies included in the synthesis and references used only for methodological, background, or contextual purposes.
Response: We agree. These studies fall outside the core permafrost hydrology domain. They are relevant for comparison or background purposes, but they should not be counted among the 219 (original 225) studies retained for the formal evidence synthesis.

In the revised manuscript, Bayard et al. (2005) and Li et al. (2022) have been removed from Supplementary Table S1, and they are now listed in Supplementary Table S2 under "Comparative/background references. The total number of core studies has been recalculated (new number is 219) and updated throughout the manuscript. In addition, the text describing the Supplementary Table S1 and the new Supplementary Table S2 also were revised in Section 2.2.