Response to CC1:

This study implements a fully-integrated and fully-distributed surface-subsurface hydrological model using the WaSiM framework to examine water exchange processes in the high-elevation, glaciated Martell Valley in the Italian Alps. The authors utilize extensive field data, including rare in-situ high-elevation groundwater level observations—to constrain model parameters across snow, glacier, and subsurface modules.

This paper is worthy of publication as it addresses a significant gap in mountain hydrology: the quantification of surface-subsurface interactions in cryosphere-dominated environments. The integration of groundwater level observations into a distributed physics-based model for a high-alpine catchment is a notable technical achievement.

Answer: Thanks for your interest and appraisal of the value of our work.

1- While the model achieved satisfactory performance with subsurface lateral flow constrained to zero, this remains a counter-intuitive finding for steep alpine terrains. The authors acknowledge that their piezometers were placed in relatively flat floodplains. The finding might be a localized artifact of piezometer placement rather than a catchment-wide process. More discussion is needed on how this parameterization might affect the model's ability to simulate hillslope-to-stream connectivity in steeper parts of the catchment.

Answer: Thanks for raising this point regarding the interpretation of subsurface lateral flow. The constrained subsurface lateral flow to zero is physically plausible. Given that the steep areas in alpine catchments featured by shallow soil formation and strong vertical hydraulic gradients, the subsurface flow is often dominated by vertical drainage or rapid, transient pathways that do not result in sustained subsurface lateral flow. We placed the piezometers in relatively flat floodplain areas intentionally, as these areas integrate upslope contributions and have potential for groundwater storage. The finding is unlikely to be a local artifact but a landscape-scale impact in the alpine headwater environment where all piezometers observations and simulations in this study supported this hypothesis. If sustained subsurface lateral flow from steep hillslopes was a dominant control, it would be expected to manifest in the downstream valley floor but not in the upper headwater landscapes (see the conceptual diagram in Fig. 1 in the work of van Tiel, et al. 2024).

2- The study notes a specific numerical requirement in WaSiM where the lower boundary of the soil layers must be identical to the lower boundary of the aquifer (calibrated here to 1.30 m). This 1.30 m constraint is quite shallow for an entire catchment. While it may represent the shallow porous aquifers observed, it automatically excludes any simulation of deeper groundwater flow paths. The authors should explicitly clarify if this thickness (1.30 m) is applied uniformly across the entire 77 km2 catchment, including the valley floor where sedimentary deposits are likely much deeper.

Answer: The lower boundaries of the soil layers are calibrated with the observed groundwater heads at all piezometers (see S3 in the Supplementary Material). There are unfortunately no deep groundwater observations available in the valley floor where the deep groundwater may exist. We therefore applied the calibrated lower boundary depth in the gauged area to the ungauged area and presented the results in the manuscript in two ways: for the upper headwater landscapes

(including Subcatchments S7,8,9) with piezometers observations where the results have higher confidence, and for the whole catchment where the results may contain higher uncertainty due to the exclusion of deep aquifers but are still useful to provide a catchment overview. Excluding deep groundwater observations, however, does not compromise the merit of this study, as our aim is to apply an integrated hydrological model to achieve better partitioning of the liquid flux (sum of rainfall and melts) between surface and subsurface, i.e., a step forward compared with the commonly adopted linear reservoir or conceptual approach for subsurface representation. Despite the shallow soil formation, the soil zone plays a crucial role in the surface-subsurface water partitioning. Such fully-integrated hydrological modeling contributes to key hydrological process understanding in high-alpine landscapes.

3- In Section 6.3, the recommendation to match the TWI spatial resolution to the model resolution (25m×25m) is clear. It might be helpful to include a brief sentence advising how practitioners should handle areas where the 25m grid might smooth over critical local topographic features (like small moraines) mentioned earlier in the text.

Answer: The 25m×25m spatial resolution in fully-distributed hydrological modeling is actually already high enough for investigating the hydrological processes in this study. For practitioners who are interested in the impact of even smaller local features, it is recommended to develop a model focusing on their interested local features with higher spatial resolution if more information on the local features is available for performing such detailed study.

4- It would be beneficial to explicitly discuss if this "zero interflow" finding is a physical characteristic of the Martell Valley (e.g., due to high vertical conductivity in porous aquifers) or if it highlights a structural limitation in how current physics-based models distribute lateral flow in steep, shallow-soil alpine terrains. In Section 5.3, consider clarifying if "zero interflow" refers to the model parameter dr being set to 0, and briefly reiterate the physical implication for the reader.

Answer: The constrained subsurface lateral flow (so-called “interflow” in WaSiM) is physically plausible based on the site characteristics. The subsurface lateral flow is generated in the model based on the physical attributes such as the local slope, hydraulic conductivity, and water content in the soil. The subsurface lateral flow is constrained to zero when the river drainage density is constrained to zero (See Eq.2.14.11 in the work of Schulla, 2024). We will make this point clearer in the revision.

5- As you are working on surface-subsurface hydrological model I do strongly recommend to broad your literature review and cite "Assimilation of sentinel-based leaf area index for modeling surface-ground water interactions in irrigation districts"

References

Schulla, J.: Model Description WaSiM (Water balance Simulation Model), http://www.wasim.ch/downloads/doku/wasim/wasim_2024_en.pdf, 2024.

van Tiel, M., Aubry-Wake, C., Somers, L., Andermann, C., Avanzi, F., Baraer, M., ... & Yapiyev, V. (2024). Cryosphere–groundwater connectivity is a missing link in the mountain water cycle. Nature Water, 2(7), 624-637.