Manuscript egusphere-2024-4186: Response to reviewer #1
Hörður B. Helgason, Andri Gunnarsson, Óli G. B. Sveinsson and Bart Nijssen, Understanding Changes in Iceland's Streamflow Dynamics in Response to Climate Change

Original reviews in black
Responses in blue and bold

RC1: Comment on egusphere-2024-4186 by Referee #1:
Manuscript Review: "Understanding Changes in Iceland's Streamflow Dynamics in Response to Climate Change"

1) Impact

This study makes a significant contribution to our understanding of how climate change affects Icelandic streamflow dynamics. By utilizing the extensive LamaH-Ice dataset, the authors provide valuable insights into long-term hydrological trends in Iceland. The findings have important implications for hydropower management, water resource planning, and ecological sustainability. Moreover, the regional focus on Iceland enriches the global discussion on climate-induced hydrological changes.

2) Strengths

Comprehensive Data Utilization: The use of the LamaH-Ice dataset, which covers a broad network of largely undisturbed catchments, increases the reliability of the study.

Multi-Decadal Analysis: The examination of streamflow trends over both 30- and 50-year periods allows for a nuanced understanding of short- and long-term hydrological changes.

Climatic Correlations: The study effectively links streamflow variations with large-scale climate drivers such as the Arctic Oscillation (AO) and North Atlantic Oscillation (NAO), which strengthens the analysis.

Operational Relevance: The discussion on hydropower implications makes the study practically useful for policymakers and energy managers.

Clear Visualization: The figures—including maps, heatmaps, and rolling mean analyses—effectively convey trends and spatial variations.

3) Weaknesses

Limited Discussion on Anthropogenic Influence: Although the study excludes heavily regulated rivers, it does not sufficiently explore how human interventions (e.g., land use changes, hydropower infrastructure) might interact with climate-driven changes. In particular, the catchment of the Kárahnjúkar Hydropower Plant is scarcely considered because the paper focuses on gauging stations where the river is minimally affected by human activities. But wouldn't the effect of a changing stream flow be particularly interesting for Iceland's biggest hydropower plant?

The primary focus of this study is to assess natural hydrological changes driven by climate change, and therefore, anthropogenic influences such as land use changes and hydropower infrastructure are beyond the scope of this analysis. We will clarify the study's scope in the introduction to explicitly state that this research examines climate-driven streamflow trends in near-natural catchments and does not aim to assess anthropogenic influences on streamflow.

Uncertainty in Precipitation Data: The reliance on ERA5-Land reanalysis for precipitation introduces potential biases, as noted by the authors. A discussion on alternative precipitation datasets or validation techniques could strengthen the results.

We discussed the uncertainty with and biases in the precipitation of the ERA-5 Land reanalysis in the original Lamah-Ice paper (Helgason and Nijssen, 2024). A large part of these biases stemmed from an underestimation of orographically enhanced precipitation along the Icelandic coast. We recognize the limitations associated with using ERA5-Land reanalysis data for precipitation trends. We will perform the same trend analysis for precipitation from the CARRA reanalysis (Schyberg et al., 2020), to assess similarities and differences between the two datasets.

Glacial Dynamics Interpretation: The study links decreasing glacial river flow trends over the past 30 years to glacier retreat, but it does not explore potential non-linear meltwater contributions or threshold effects. In large glaciers such as Vatnajökull, enhanced ice melt may play a more dominant role than glacier retreat in influencing meltwater contributions. For instance, Figure 5 shows the precipitation trend, which correlates well with results from Kárahnjúkar watershed (Heger et al. 2025) where contributions to streamflow increase in spring and autumn while snowmelt decreases. Specifically, Figure 5 indicates that in the region of Kárahnjúkar, spring precipitation has increased by approximately 10%, whereas winter precipitation has decreased.

We appreciate the reviewer's comment on non-linear meltwater contributions and potential threshold effects in glacial streamflow trends. We acknowledge that the relationship between glacier response to climate change and streamflow changes is complex and varies between different glacier types. The presence of both mountain glaciers and large ice caps further complicates this relationship due to differences in meltwater storage and dynamics. We will add this to the discussion in the manuscript.

Limited Policy Discussion: Although the manuscript mentions implications for hydropower management, it does not propose specific adaptive strategies.

We will propose adaptive strategies for hydropower management in the revised manuscript.

Statistical Significe: Figure 6 illustrates sub-seasonal trends in temperature and precipitation and shows that in the second period analyzed, the trends are considerably stronger, which could be interpreted as an intensification of extremes. The authors mention that many trends are not statistically significant, a point that is reflected in the data. Some variables decrease between 1973 and 2023 but then increase again between 1993 and 2023. Additionally, glacier melt was less intense in the last decade compared to the 1990s, reflecting not only variability in annual weather but not necessarily a robust trend. This variability could be discussed in the context of the uncertainty of a weakening of the Atlantic Meridional Overturning Circulation (AMOC) (see Rahmstorf 2024), which may influence both climate extremes and glacier dynamics.

We appreciate this suggestion and agree that discussing the observed variability in trends within the context of potential drivers, including the weakening of the Atlantic Meridional Overturning Circulation (AMOC), will strengthen the manuscript. We discuss this in the revised manuscript and reference relevant studies, such as Rahmstorf (2024), to provide additional context on how AMOC variability may influence climate extremes and glacier dynamics.

4) Specific Editorial Suggestions

Line 80 "it's location" "its location" (remove the apostrophe)

Line 115 "which only returns as runoff up to decades later": Consider rewording for clarity: "which contributes to runoff decades later"

Line 199 "The warming appears to have slowed in recent years.": Consider adding a reference or supporting data for this claim

Line 390 "An overlying dashed black line indicates that the trend is significant (p < 0.05)." Consider rewording to match the style of other trend significance descriptions

Line 414 "We see that the trend is negative in most cases, although there are only 4 significant trends.": Suggest quantifying "most cases"

Line 505 "While a large majority of annual trends are positive...": Consider rewording for clarity: e.g. "Although most annual trends are positive, only eight out of 25 stations show statistically significant increases for 1973-2023."

We appreciate the reviewer's detailed editorial suggestions and will incorporate the revisions to improve clarity and consistency.

Final Recommendations

To enhance the impact of the conclusions, the authors could emphasize some key quantitative findings (please check the numeric values):

Temperature Rise: Annual average temperatures have increased by approximately 0.2°C per decade.

Precipitation Increase: Total precipitation rises by about 1.5% per decade, with notable seasonal variations (around a 10% increase in spring(?) and decreases in winter).

Streamflow Variability: While 21 out of 25 gauges show positive streamflow trends for 1973–2023, glaciated rivers display predominantly negative summer trends in the recent 30-year period— this could possibly be linked to a weakening of the AMOC (Rahmstorf 2024)?

Highlighting quantitative results in the conclusions would strengthen the paper's data-driven arguments and improve its relevance for climate impact assessments and policy formulation.

Address some of the identified weaknesses: Expand the discussion on anthropogenic influences (perhaps the watershed of Kárahnjúkar Hydropower Plant could be used as a representative example), address uncertainties in precipitation data by comparing with alternative datasets or validation techniques, and consider non-linear responses in glacier melt.

Enhance policy relevance: suggest specific adaptive strategies for hydropower and water management to improve the applied value of the study.

Correct Editorial Errors: Implement the minor editorial corrections listed above to enhance clarity and precision throughout the manuscript.

In the updated manuscript we will address all these valuable recommendations as outlined above, except for an analysis of anthropogenic influence on streamflow since this is outside of the scope of this study.

References

Schyberg, H., Yang, X., Køltzow, M. A. Ø., Amstrup, B., Bakketun, Å., Bazile, E., Bojarova, J., Box, J. E., Dahlgren, P., Hagelin, S., Homleid, M., Horányi, A., Høyer, J., Johansson, Å., Killie,

M. A., Körnich, H., Le Moigne, P., Lindskog, M., Manninen, T., Nielsen Englyst, P., Nielsen, K. P., Olsson, E., Palmason, B., Peralta Aros, C., Randriamampianina, R., Samuelsson, P., Stappers, R., Støylen, E., Thorsteinsson, S., Valkonen, T., and Wang, Z. Q.: Arctic regional reanalysis on single levels from 1991 to present, Copernicus Climate Change Service (C3S) Climate Data Store (CDS), https://doi.org/10.24381/cds.713858f6 (last access: 15 February 2023), 2020.