

Reviewer 2

Summary:

The study presents a method of re-scaling gridded water flow data on lake catchments. The method is developed within the framework of ISIMIP, the model intercomparison platform facilitating access to climate scenarios, models, and observational data for model validation. The manuscript is well-structured, clearly written, and addresses an important gap in coupling water flow and lake models on global scales. The proposed method uses a straightforward rescaling algorithm, differentiating between three options---the catchment is smaller than a single grid cell, the catchment is larger than, but the lake is smaller than a grid cell, and the lake is larger than a single grid cell. The approach has been validated against the long-term outputs of the operational regional hydrological model HYPE applied to 71 Swedish lakes and against a smaller observational dataset, demonstrating satisfactory performance. The results, summarized in two pages and two figures, are clear and concise. The impact on the modeling community can be however limited: while Swedish lakes provide a robust and diverse test case, the extrapolation to global conditions (particularly arid and tropical systems with highly variable evaporation and different hydrological regimes) remains speculative. Still, it is a valuable methodological contribution, with openly available code and datasets, which ensures reproducibility, and an initial step towards coupling lake and water flow modeling in climate models.

We thank the reviewer for the positive and constructive feedback. Regarding the concern about extrapolation to global conditions, we would like to clarify that our study focuses on rescaling streamflow inputs into lakes. All hydrological calculations are taken from the global hydrological model WaterGAP 2, which has been extensively validated across a range of climatic and hydrological regimes, including arid and tropical systems and thus encompassing variable hydrological and evaporation regimes. Our method does not perform new hydrological modeling but operates on the existing generated by WaterGAP 2, with the purpose to scale them to lake catchments. Therefore, the applicability of our approach globally relies on the underlying WaterGAP 2 outputs, not on the rescaling approach itself. The validation of our scaling approach was conducted on a wide variety of lake and catchment properties, particularly in terms of size, suggesting its suitability for global application.

The following sentences were removed from the Discussion section to avoid confusion: “While the Swedish climate is temperate to subarctic, factors such as evaporation may differ in arid and tropical conditions. Thus, although climate-related refinements may be necessary for certain regions, the core method grounded in topographic and geometric scaling is broadly applicable.”

Comments:

Comment 1:

The case of Lake Mälaren demonstrates that irregular morphologies can strongly affect scaling performance. The authors might consider providing more concrete recommendations for how to approach such cases practically.

Reply:

The case of Lake Mälaren indeed highlights the impact of irregular morphologies on scaling performance. However, despite the lake's very complex shape and bathymetry, the modeling results were still satisfactory. Specifically, for Lake Mälaren, Approach I.b yielded a good performance with a *KGE* of 0.71, while Approach II showed acceptable performance with a *KGE* of 0.47. These results demonstrate that even in lakes with complex morphologies, both approaches can deliver at least acceptable performance.

Moreover, when comparing these results to other lakes (Manuscript: Figure 6 and Table S2), Lake Mälaren is not an outlier. Several other lakes with less complex shapes showed similar performance metrics, indicating that while morphology can influence predictive performance, it is not the sole determinant of success. This suggests that practical application of the scaling approaches remains viable even in morphologically complex systems.

The Discussion section has been revised to reflect these points: “In contrast, for Lake Mälaren, which has a highly irregular shape (Figure S1), the choice of scaling approach significantly affected performance. The better performance of Approach I.b (*KGE*=0.71) compared to Approach II (*KGE*=0.47) highlights the importance of accounting for complex lake morphologies in streamflow scaling. Nevertheless, both scaling approaches achieved satisfactory performance comparable to other lakes with less complex morphologies, indicates that, although lake morphology can influence performance, it is not the sole determining factor, further supporting the robustness and practical applicability of the scaling approaches even for lakes with complex morphologies.”

Comment 2:

Only six lakes are compared against observed streamflow. While this is understandable due to data availability, a short description of the lakes representativity, in terms of lake size, geographical location, hydrological regime, would strengthen confidence.

Reply:

The observed streamflow records were extended to 10 lakes, which represent a diverse range of physical and hydrological characteristics. Geographically, these lakes are distributed across latitudes from 58.33° to 66.66°, covering southern, central and northern regions of Sweden (Table 1). The lake area spans three orders of magnitude from 7.68 km² (lake 142240) to 5486.23 km² (lake Vänern), with catchment areas that vary independently of lake size ($A_{catchment}$ ranged from 138.70 km² to 48421 km²). This includes both small lakes with small catchments ($A_{catchment} A_{lake}^{-1}$ of 5.99 – lake Erken) and large catchments ($A_{catchment} A_{lake}^{-1}$ of 139.91– lake Roxen), as well as large lakes with small catchments ($A_{catchment} A_{lake}^{-1}$ of 3.37 – Lake Vättern) and large catchments ($A_{catchment} A_{lake}^{-1}$ of 20.94 – Lake Mälaren), reflecting the diverse hydrological characteristics of the study. Overall, despite the limited availability of observed streamflow data, these ten lakes provide a representative cross-section of the variability in lake size, catchment characteristics and geographical distribution within the study area.

Table 1: Characteristics of the study sites with available streamflow observations.

Lake	Name	Longitude	Latitude	A_{lake} [km ²]	$A_{catchment}$ [km ²]	$A_{catchment} A_{lake}^{-1}$
102	Mälaren	16.79	59.49	1083.13	22682.20	20.94
104	Vättern	14.49	58.33	1888.04	6369.10	3.37
105	Vänern	13.55	58.88	5486.23	48421.00	8.83
1150	Siljan	14.77	60.86	290.88	12084.50	41.54
12423		14.15	62.05	63.59	8357.00	131.42

12791		15.57	60.07	34.77	2213.30	63.66
12809	Erken	18.60	59.84	23.14	138.70	5.99
12965	Roxen	15.63	58.49	94.55	13228.50	139.91
142240		22.22	66.66	7.68	1272.30	165.66
152977	Hasselasjön	16.78	62.08	8.36	610.00	72.97

The Discussion section has been revised to reflect these points: “Although validation against observed streamflow is constrained due to data availability, the 10 lakes used for validation are broadly representative of the 70 lakes included in the study. Geographically, these lakes are distributed across latitudes from 58.33° to 66.66°, covering southern, central and northern regions of Sweden (Table S3). The lake area spans three order of magnitude from 7.68 km² (lake 142240) to 5486 km² (lake Vänern), with catchment areas that vary independently of lake size ($A_{catchment}$ ranged from 138.7 km² to 48421 km²). This includes both small lakes with small catchments ($A_{catchment} A_{lake}^{-1}$ of 5.99 – lake Erken) and large catchments ($A_{catchment} A_{lake}^{-1}$ of 139.91 – lake Roxen), as well as large lakes with small catchments ($A_{catchment} A_{lake}^{-1}$ of 3.37 – Lake Vättern) and large catchments ($A_{catchment} A_{lake}^{-1}$ of 20.94 – Lake Mälaren), reflecting the diverse hydrological characteristics of the study. Validation against observed streamflow data for these representative lakes (Figure 6B; Table S3) confirmed the ability of the scaled simulations to match not only reference data, but also observed data. Seasonal-scale performance was slightly lower (KGE of 0.46±0.21) due to timing errors, compared to stronger annual-scale performance (KGE of 0.70±0.15), indicating that the method effectively captures long-term hydrological trends.”

Comment 3:

The validation method assumes negligible contribution of lake evaporation/precipitation compared to inflow/outflow budget. The assumption would be justified if supported by characteristic values of monthly/annual evaporation from the six lakes.

Reply:

Indeed, the validation against observed data did not include the atmospheric water exchange over the lake surface (precipitation and evaporation), since we compared scaled lake inflow with observed lake outflow. We therefore estimated the potential atmospheric water exchange for the ten lakes included in this comparison. Potential evapotranspiration (PET , cm) was estimated using the empirical equation proposed by Hamon (1961), assuming that evaporation from a water surface is similar to potential evapotranspiration:

$$PET = \frac{0.021 \cdot H \cdot e_s}{T_{air}}$$

where H is the number of daylight hours per day, e_s is the saturated water vapor pressure (mbar) and T_{air} is daily air temperature (°C). When $T_{air} \leq 0$, PET is assumed to be 0.

The saturated water vapor pressure (e_s) was calculated following Bosen (1960)

$$e_s = 33.8639 \cdot [(0.00738 \cdot T_{air} + 0.8072)^8 - 0.000019 \cdot (1.8 \cdot T_{air} + 48) + 0.001316]$$

PET was calculated for the 10 lakes with available outflow observations for the period 1981–2010, using observed climate-related forcing data from the GSWP3-W5E5 climate forcing data set (Cucchi et al., 2020; Lange et al., 2021; Zhao et al., 2022) provided by ISIMIP3a. In addition, we calculated average PET , precipitation (P), the net balance $P-PET$ and the contribution of $P-PET$ to the lake water balance, which was then compared with streamflow inputs to assess their relative importance in lake hydrology (Table 2).

For the majority of the lakes, the atmospheric water exchange over the lake surface, expressed as $P-PET$, contributed less than 2% of the streamflow inputs, confirming that evaporation and precipitation can be considered negligible when comparing simulated streamflow inflows with

observed outflows. However, for lakes with long water residence time, such as lakes Vänern and Vättern, residence times of 9.8 and 58 years respectively (Kvarnäs, 2001), the $P-PET$ contribution was higher, approximately 22 % and 8.5 % respectively, reducing the accuracy of the comparisons in these two particular lakes.

Table 2. PET , P , $P-PET$ and % contribution to Q .

Lake	Name	PET (mm year ⁻¹)	P (mm year ⁻¹)	$P - PET$ (mm year ⁻¹)	% contribution to Q
102	Mälaren	595.55	655.51	59.96	2.05
104	Vättern	579.53	741.82	162.29	22.33
105	Vänern	588.39	838.67	250.28	8.51
1150	Siljan	520.26	734.40	214.14	1.98
12423		481.19	710.76	229.57	0.39
12791		537.47	741.36	203.89	0.71
12809	Erken	596.88	628.67	31.79	2.03
12965	Roxen	594.74	662.11	67.36	0.24
142240		628.83	630.56	1.72	<0.01
152977	Hasselasjön	510.18	732.70	222.52	0.76

The Material and Methods section has been revised to reflect this point: “Although the observed data represent discharge downstream of the lakes (lake outflows), while the simulations estimate lake inflows, we assume that the atmospheric water exchange (precipitation and evaporation) over the lake surfaces in Sweden are relatively minor compared to total inflow and outflow volumes, particularly at monthly and annual timescales (Text S1).” Text S1, included in the supplementary material, details the calculation of the atmospheric water exchange over the lake surfaces as describe above.

References:

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