Attribution of Glacier Runoff in the Danube Basin

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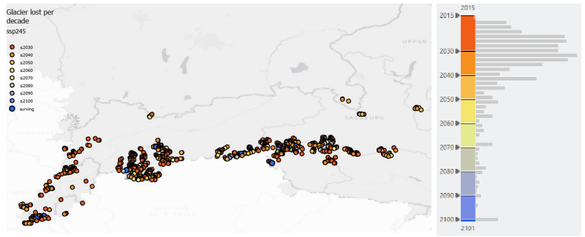
Motivation

Danube Basin

Dachstein Glacier

Glaciers in the Danube Basin are projected to disappear almost entirely by 2100. This study quantifies both the trajectory of glacier loss and its hydrological consequences across the basin.



Glaciers lost per decade for Scenario SSP 2-4.5

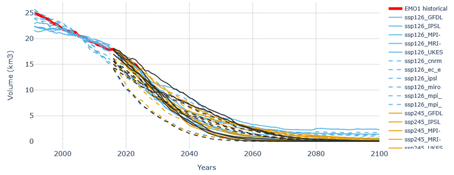
Similar to a global study from Van Tricht et al. 2026, this figure shows that most of the glaciers will be lost by 2040.

Modeling Glaciers with OGGM

OGGM (Maussion et al. 2019) uses glacier outlines from the Randolph Glacier Inventory (RGIv6.0) and simulates 810 glaciers in the Danube basin individually. For each glacier, OGGM (using the add-on from Schuster et al. 2023) calculates the glacier area (yearly) and the glacier runoff, including glacier melt and rainfall (daily).

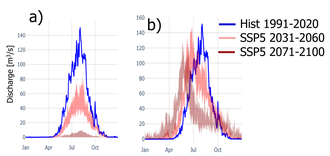
The EMO1-v2 arcmin meteorological dataset is used for the historical period from 1991 to 2020. For future projection, bias-corrected climate forcing is taken from 5 ISIMIP3b and 6 Restore4Life datasets for 3 SSPs.

810 Glaciers in the Danube (RGIv6.0)



Future scenarios of glacier volume in the Danube basin

According to all scenarios, glacier volumes in the Danube basin will rapidly decline. By 2050, only ~12% of the 1990 glacier volume is projected to remain, regardless of the SSP scenario used. By 2100, almost all glaciers will be gone.

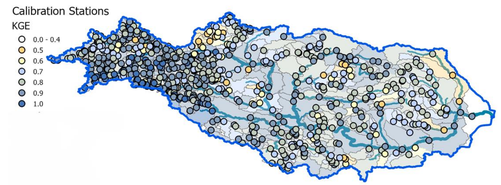


a) Change in outflow from glacier
b) Change in outflow from glacier + outflow from formerly glaciated area

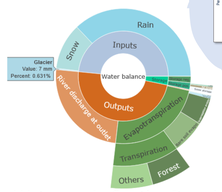
Discharge from all glaciers combined will be lower and the peak will shift from Aug.-Sept to May-June.

Hydrological modeling with CWatM

The CWatM model is set up for daily 1-arcmin resolution for the whole Danube and calibrated for 645 discharge stations with an average KGE of 0.79 using EMO1-v2 meteorological forcing data.

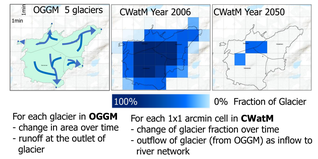


Calibration of CWatM for the Danube basin for 645 stations

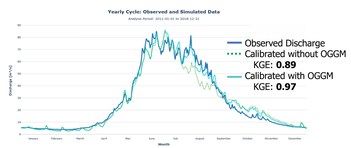


Water cycle for the Danube

OGGM results are used in CWatM to improve glacier representation (see Hanus et al. 2024). OGGM calculates glacier runoff per glacier. CWatM runs on a regular grid. Therefore, the OGGM output per glacier has to be translated into CWatM input per cell.



Representation of glacier in OGGM and CWatM

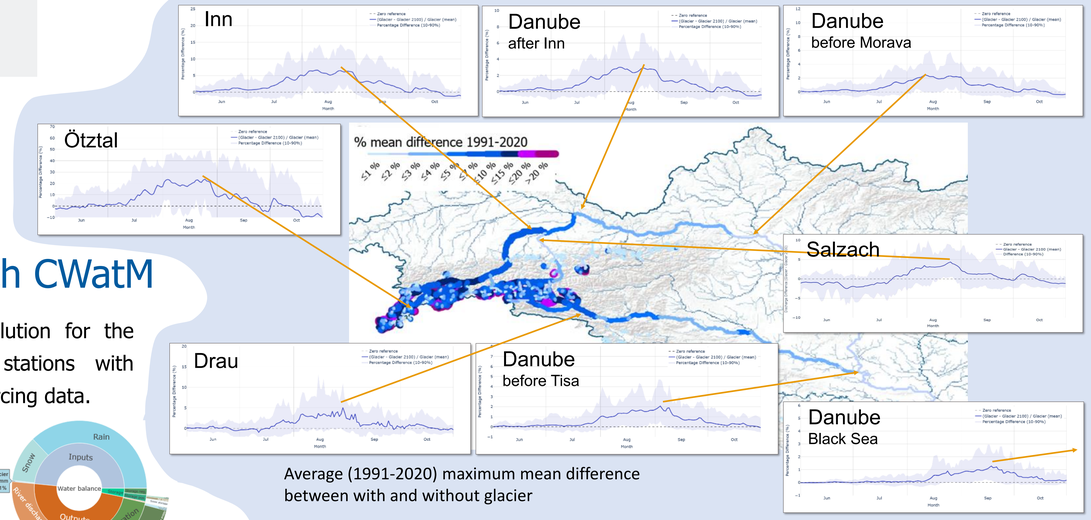


Calibration with and without glacier at station Tumpen, Ötztal

As calibration results show, using OGGM results in CWatM leads to a better representation of discharge in glaciated areas.

How is discharge changing without glaciers?

Comparison between: a) OGGM-CWatM linked simulation; b) simulation with all glaciered removed. Formerly glaciated areas are simulated using all processes in CWatM. Meteorological forcing is EMO1-v2 from 1991 to 2020.



Average (1991-2020) maximum mean difference between with and without glacier

The Öztal has an average discharge decrease of ~20% in August without glaciers, and the Inn before the Salzach confluence has an average decrease of ~6-7% in August. The Drau at the Austrian/Slovenian border shows an average decrease of 4-5% in August, and at the mouth of the Danube, the average decrease is 1% in September.

The next step is to evaluate the influence of the declining glacier contribution on navigation and irrigation.

References

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Danube Water Balance

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