Streamflow sensitivity regimes of alpine catchments

Sebastian Gnann [1], Markus Weiler [1], Kerstin Stahl [2]

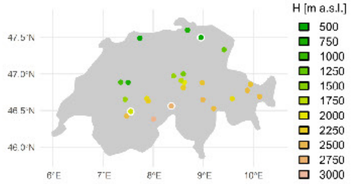
HYDROLOGY

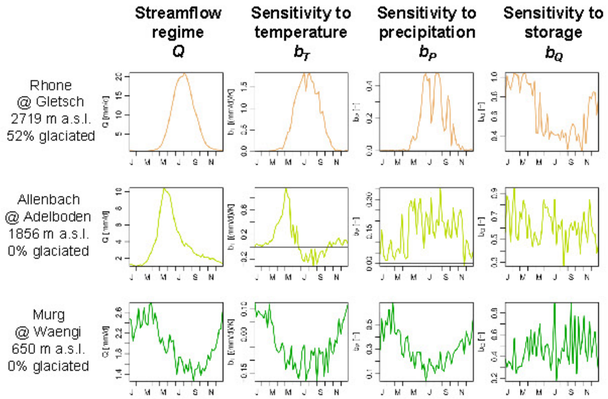
Motivation & Approach

- Alpine streams supply water to mountains and downstream regions, but their sensitivity to climatic variability is complex
- Approaches that focus on the annual scale omit sub-annual variability related to seasonality in water and energy supply, snow and glacier melt, and storage processes
- Here we derive weekly streamflow sensitivities *b* in response to temperature *T*, precipitation *P*, and catchment storage – using streamflow from the previous week *Q(t-1)* as proxy – for 25 Swiss catchments via multiple linear regression:

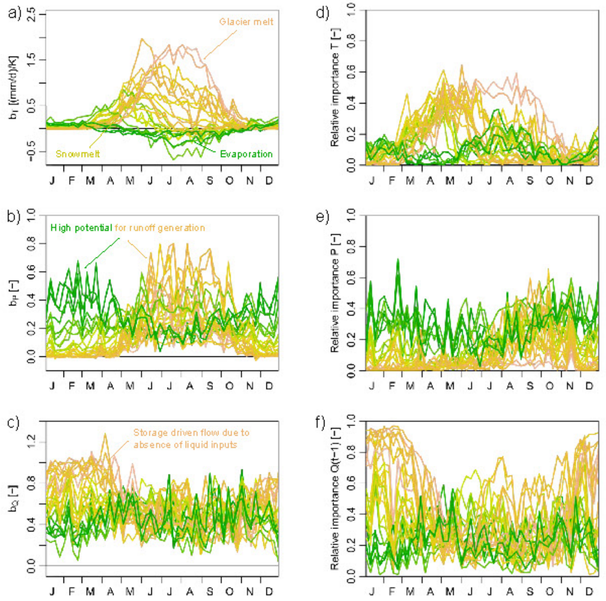
$$Q(t) = a_t + b_{T,t}\,T(t) + b_{P,t}\,P(t) + b_{Q,t}\,Q(t-1)$$

Map with all 25 study catchments and weekly sensitivities for three example catchments (white circles on map)



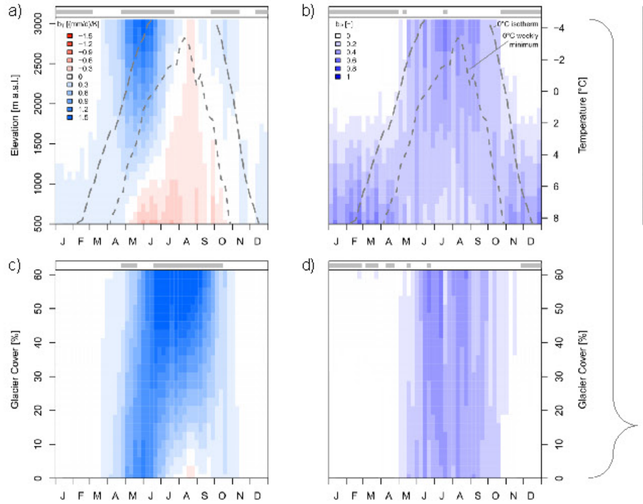


Sensitivities and variable importances for 25 study catchments in the Swiss Alps



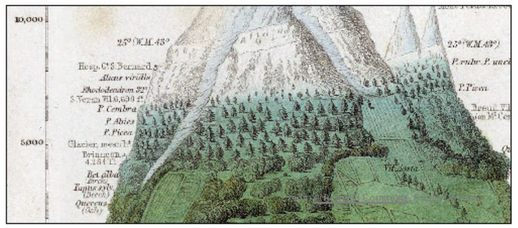
- Temperature sensitivities are positive or zero in winter but show divergent patterns in summer, being positive at high elevations and negative at low elevations (a)
- Precipitation sensitivities are highest in summer at high elevations and in winter at low elevations (b)
- Storage sensitivities are highest in winter at high elevations, but also important at lower elevations throughout the year (c)
- The multiple regression models explain between 19% and 98% (mean 64%) of the variation throughout the year (d-f)

Relationships between sensitivities and elevation, temperature, and glacier cover

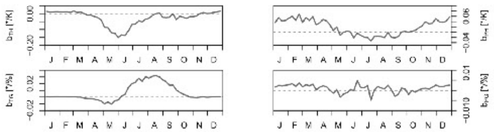


- Temperature sensitivities become negative at low elevations in spring and this effect increases up to the highest elevations in summer, while they are mostly positive at high elevations, peaking in late spring (a)
- Precipitation sensitivities at low elevations are highest in winter and decrease in summer, while at high elevations they are zero in winter and highest in summer (b)
- In glaciated catchments, temperature sensitivities are positive and increase with increasing glacier cover, especially in summer (c)
- Precipitation sensitivities are positive for all values of glacier cover in summer and zero in winter (d)

Humboldt's elevation zones in the Alps and Pyrenees



- Relationships between elevation, glacier cover, and sensitivities are quantified using multiple regression
- Regression coefficients (shown below) for elevation are converted to temperature (lapse rate = -5 K/km)



Discussion & Conclusion

- Weekly streamflow sensitivities show seasonal and elevational patterns and can be seen as **sensitivity regime curves** that characterize the key drivers of the flow regime
- The elevation at which temperature sensitivities change from positive to negative varies seasonally, suggesting that sensitivities are themselves **temperature-dependent**
- Weekly streamflow sensitivities may be used for **model evaluation** by comparing observation- to model-based sensitivities

(1) Hydrology, Albert-Ludwigs-Universität Freiburg, Germany
www.hydro.uni-freiburg.de

(2) Environmental Hydrological Systems, Albert-Ludwigs-Universität Freiburg, Germany
www.hydsys.uni-freiburg.de

Feel free to reach out:
sebastian.gnann@hydrology.uni-freiburg.de

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universität freiburg