Variability in glacier hydrographs around the world

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EGU 2018 HS1.10 Large sample hydrology: characterising and understanding hydrological diversity

BACKGROUND

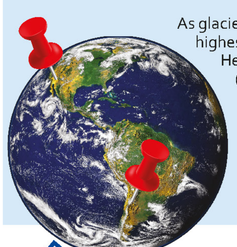
Partly glacierized catchments are essential hydrological systems for water supply in mountain regions. Glacier melt shapes the hydrograph and acts as a moderator of streamflow due to its different response to warm and cool and wet and dry years compared to the non-glacierized (part of the) catchments. This **glacier compensation effect** and shape of the hydrograph, however, are the result of the interplay between catchment and glacier characteristics and different climate variables.

OBJECTIVE

To study the **spatial and temporal variability** in the **hydrographs** to gain insight in the similarities and differences of glacier influences on the hydrograph.

APPROACH

Explore the relation between percentage glacier cover in the catchment and various hydrograph characteristics.

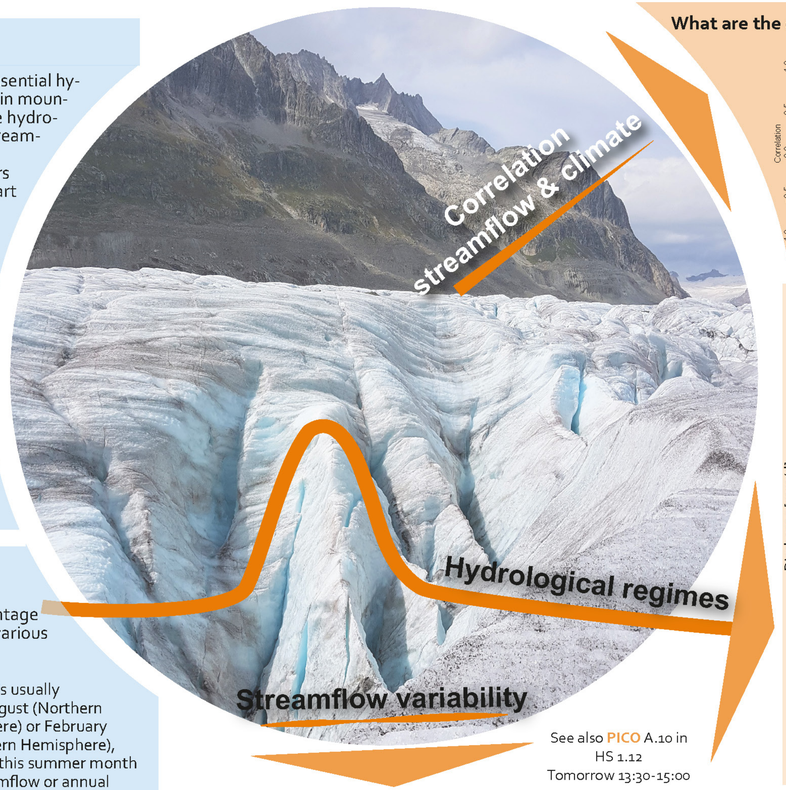


As glacier melt is usually highest in August (Northern Hemisphere) or February (Southern Hemisphere), either this summer month streamflow or annual streamflow was used.

Common time period ~1980-2016

Data

	# catchments	Streamflow & mean length (y)	Precipitation & Temperature
Austria	23	daily - 51	daily
Switzerland	18	daily - 80	daily
Norway	15	daily - 68	daily
Chile	49	daily - 52	monthly
Canada	35	daily - 58	monthly
Alaska	8	daily - 48	daily



See also PICO A.10 in HS 1.12
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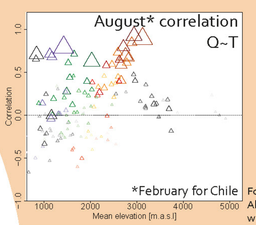
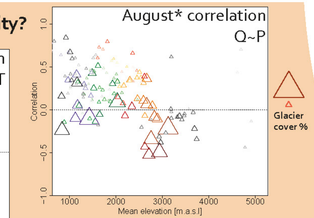
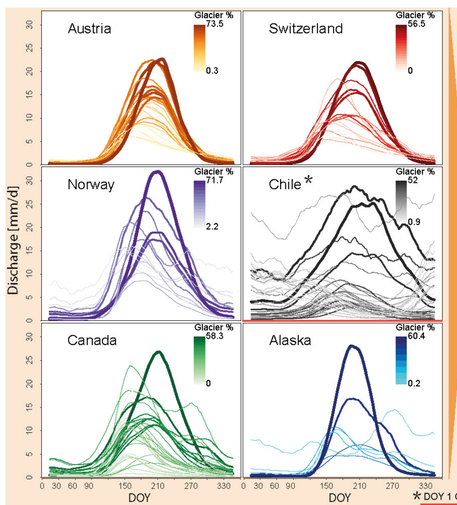
What are the climate drivers of variability?

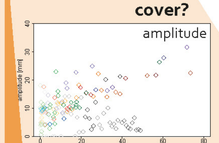


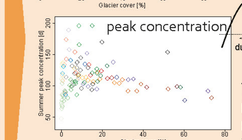


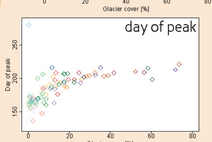
For temperature, correlation is highest for highest glacier cover and in the Alps (positive correlation). For precipitation the relationship is reversed where lower glacier covers show a higher correlation with precipitation.



How do regimes vary with glacier cover?

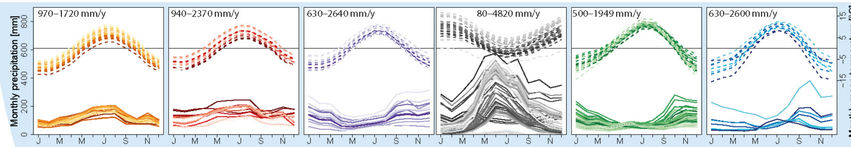




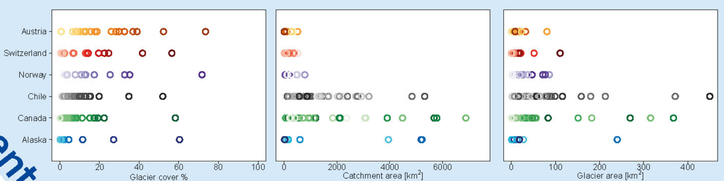


The regimes show a typical snow and glacier melt peak in summer and low flows in winter. Some low glacier covered catchments in Norway, Canada and Alaska have higher flows in the last part of the year. Chilean regimes show a high variety. Highest specific streamflow occurs in Norway for the most glacierized catchment. In general, the concentration of the summer peak decreases with increasing glacier cover, which is however not the case for Canada. The day of maximum streamflow occurs later in the year and amplitude is larger for higher glacier cover.

Catchment Characteristics

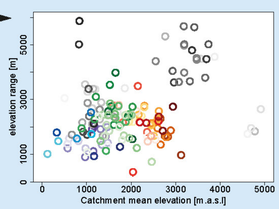


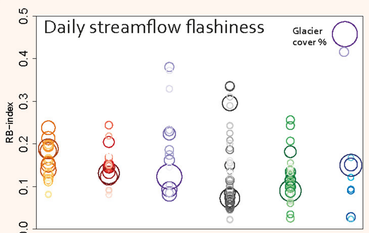
Catchment average temperature shows a seasonal pattern with a warm season (T> 0 °C) in June, July and August in the Northern Hemisphere and in December, January and February for Chile (Southern Hemisphere). The summer season (T> 0 °C) is longer in Canada and Chile. Seasonality in monthly catchment average precipitation is different in the regions. Monthly precipitations sums are highest during summer in Austria and Switzerland. For Norway, Canada and Alaska, precipitation is higher in winter, especially September - December. In Chile, most precipitation falls in the Southern Hemisphere winter.



Most catchments in the different regions have a glacier cover ranging between 0% and 20%. All regions include some catchments with high glacier cover (> 50%). The maximum glacier cover is 73.5% (Vernagtbach, Austria). The catchments in Switzerland, Austria and Norway are mostly small catchments, up to 800 km². The catchments in Chile, Canada and Alaska are significantly larger. The largest glaciers in the dataset are also located in Chile, Canada and one in Alaska.

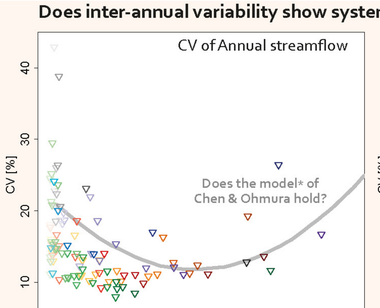
Most of the Chilean catchments have the highest elevation range and the highest mean elevation. The Austrian and Swiss catchments have similar elevation characteristics. The Alaskan and Norwegian catchments have the lowest mean elevation and elevation range.



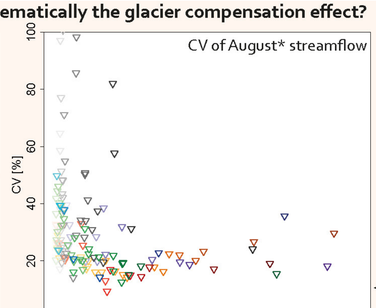


Two different aspects of temporal streamflow variability are day-to-day variability and inter-annual variability. The Richard Baker (RB) index is a measure of flashiness. Highly glacierized catchments do not show the highest flashiness for most regions, apart from Alaska. The range of the flashiness index is highest in Norway, Chile and Canada.

Does inter-annual variability show systematically the glacier compensation effect?



*note that Chen & Ohmura used streamflow data in the Alps from before 1985



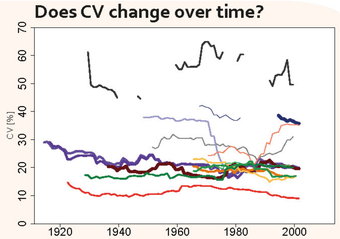
*February for Chile

According to Chen & Ohmura (1990) and others, streamflow variability is high(er) for low and high glacierized catchments and low for intermediate glacier cover (~30-40%). The melt from glaciers can compensate for the variability in precipitation: a warm and dry year will have more glacier melt compared to a wet and cold year.

Does the model hold for a large worldwide dataset? Low glacier covers have a large range of CV within and between the regions. Moving to higher glacierier cover, CV is increasing, although dependent on the region.

Does CV change when glaciers recede? The CV 's for a 30 years moving window of catchments with long time series show different directions of change.

Does CV change over time?



CONCLUSIONS

- Despite differences in latitude and elevation the hydrological **regimes** from glacierized catchments around the world show in general **similar** characteristics

  However, the dataset also shows **differences**:

- The regions show a different **precipitation seasonality**. In the Alps precipitation maximum coincides with the summer melt peak.
- **Glacier cover** influences streamflow **variability** and strength of streamflow **seasonality within** region. **Climate and catchment characteristics** influence variability **between** regions.
- **Glacier cover–CV relation** suggests lower optimum glacier cover than shown in other studies. However, the relation is not clear and the dataset is biased towards low glacier coverages.

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References: Alvarez-Garreton, C., Mendoza, P. A., Boisier, J. P., Addor, N., Galleguillos, M., Zambrano-Bigiarini, M., Lara, A., Puelma, C., Cortes, G., Garreaud, R., McPhee, J., and Ayala, A.: The CAMELS-CL dataset: catchment attributes and meteorology for large sample studies – Chile dataset, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2018-23, *in review*, 2018.

Chen, J., & Ohmura, A. (1990). On the influence of Alpine glaciers on runoff. IAHS Publ, 193, 117-125.