Stream temperature and discharge evolution over the last 50 years in Switzerland

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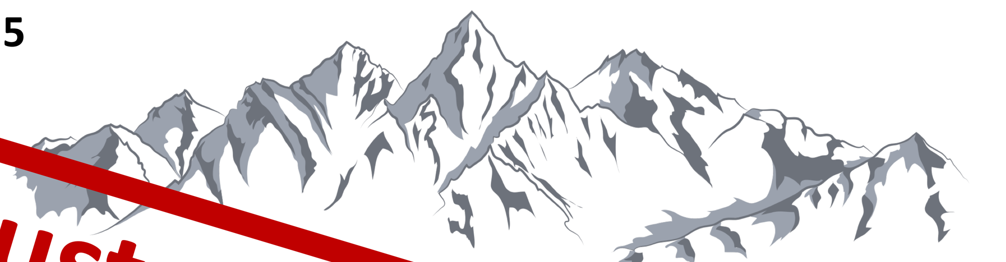


Just accepted for publication in HESS [1]

General context

- River water temperature (RWT) and discharge are crucial variables of freshwater ecosystems
- River systems are complex and react non-linearly to perturbations
- Impacts of climate change are already visible

Goals: investigate the **evolution of stream temperature and discharge** in Switzerland since the beginning of automatic measurement networks.

52 gauging stations were selected with data since the **1900's for discharge** and the **1960's for river water temperature** (for the oldest).

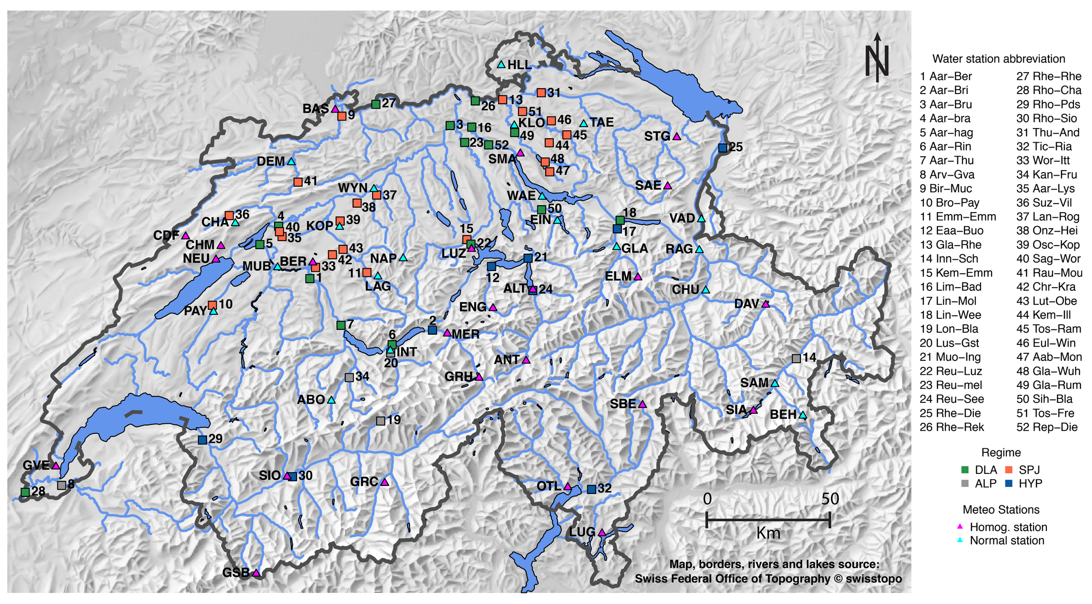
The basins were classified in four **hydrological regimes**:

Swiss Plateau and Jura regime (SPJ): The response is driven by precipitation and evapotranspiration with a moderate annual cycle in discharge.

Alpine regime (ALP): The regime is strongly influenced by snow and glacier melt, which exhibits a pronounced annual cycle.

Downstream lake regime (DLA): Switzerland has many regulated lakes. As a result, downstream rivers are strongly influenced.

Regime strongly influenced by hydropeaking (HYP): Storage facilities at high elevation impact the regime in the lowlands by release of cold water.



Methods

Seasonal signal removal

Using the Seasonal-Trend decomposition based on 'Loess' (**STL**) method [2], data vector Y_i is decomposed into:

$$Y_i = T_i + S_i + R_i$$

where T_i is the trend term, S_i the seasonal term and R_i the residual term.

Linear regression

A linear regression is applied to de-seasonalized variables with the classical least squares estimation technique for the periods **1979-2018** and **1999-2018**.

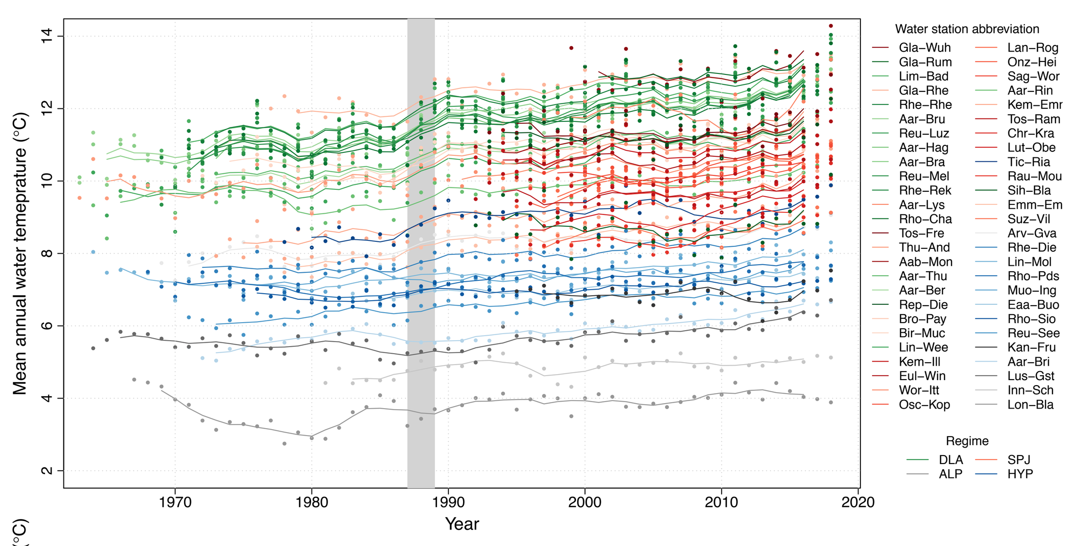
Ecological indicator

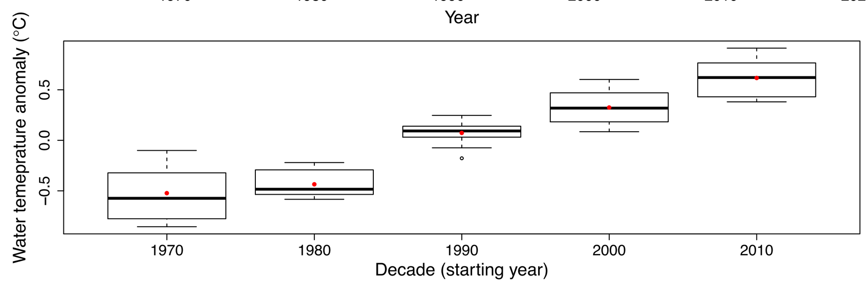
The stream temperature must be smaller than 25°C for water intake and release in rivers (legal limit). We computed the number of days per year when this threshold is exceeded as an indicator.

Results

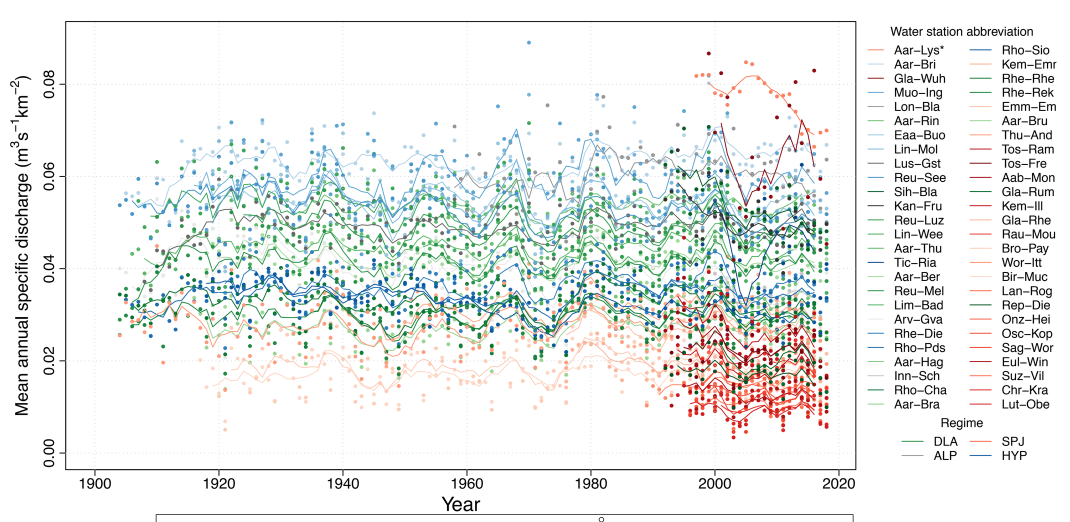
Stream temperature and discharge

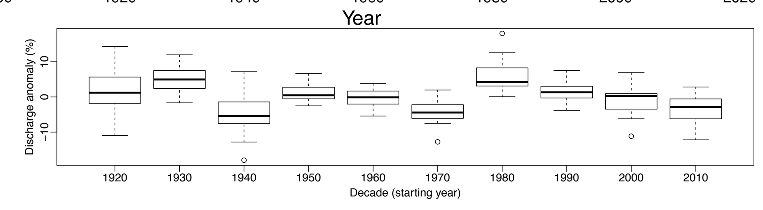
- A warming trend is visible in most rivers
- Differences in decadal temperature anomalies are significant (except between the 70's and the 80's)
- The "end-of-80's" shift isn't visible everywhere and the warming continues after this shift (contrary to [3])

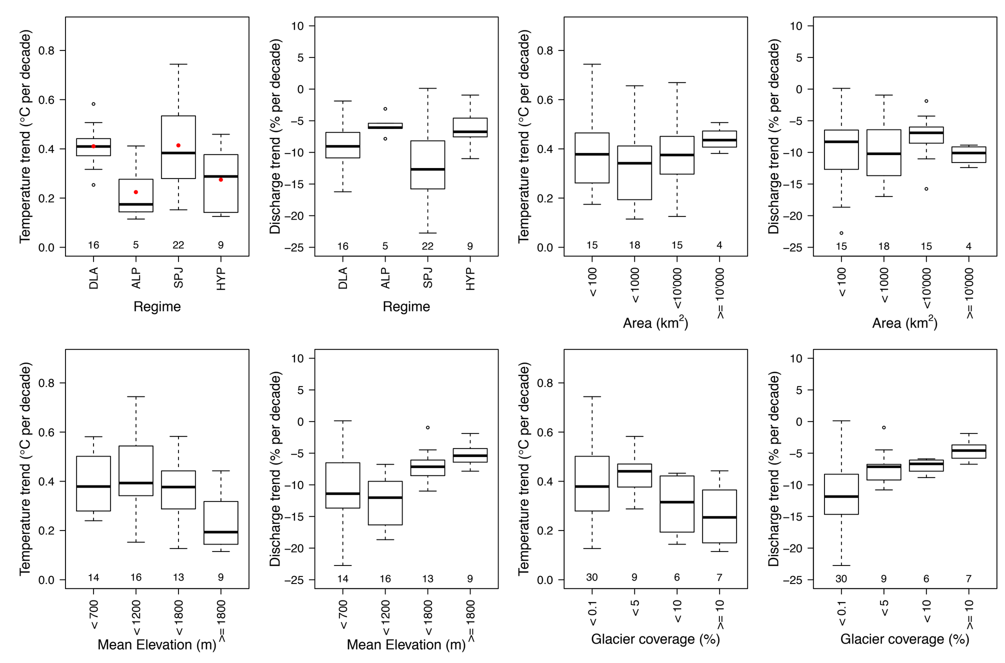




- No trend on the long-term for mean discharge
- A negative trend is visible since 2000 but its reason is hard to infer (climate change, natural variability)







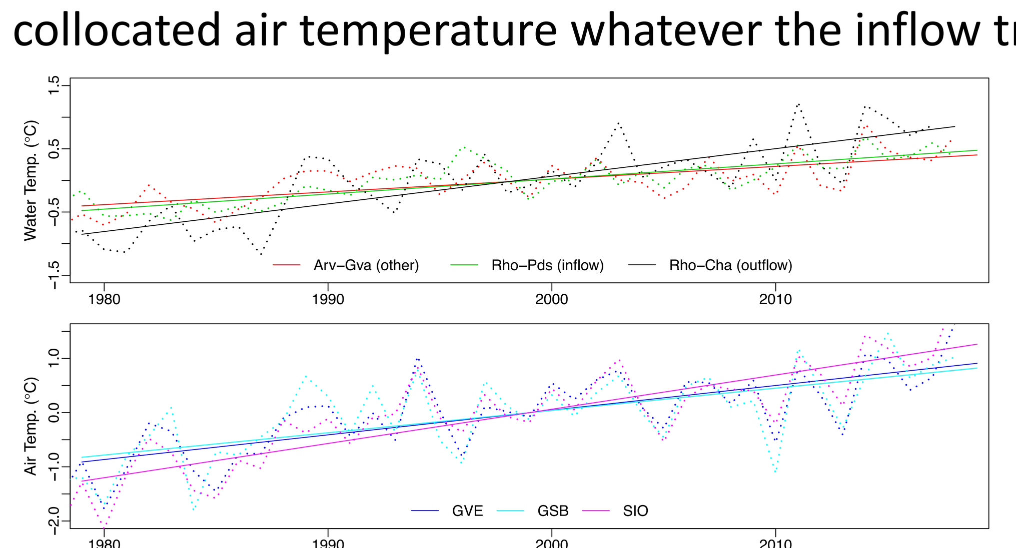
Water temperature and discharge trends for the period 1999-2018 classified upon the 4 hydrological regimes, the basin area, mean elevation and glacier coverage.

- Trends clearly depend on the hydrological regime
  1. Positive RWT trends are smaller for ALP and HYP
  2. Discharge decreases are less pronounced for ALP and HYP
- Glacier melt acts as a buffer in high-elevation basins

	1979-2018	1999-2018
Water temp. [°C/decade]	+0.33±0.03	+0.37±0.11
Air temp. [°C/decade]	+0.46±0.03	+0.39±0.14
Discharge [%]	-3.0±0.5%	-10.1±4.6
Precipitation [%]	-1.3±0.5%	-9.3±3.4

Effect of lakes

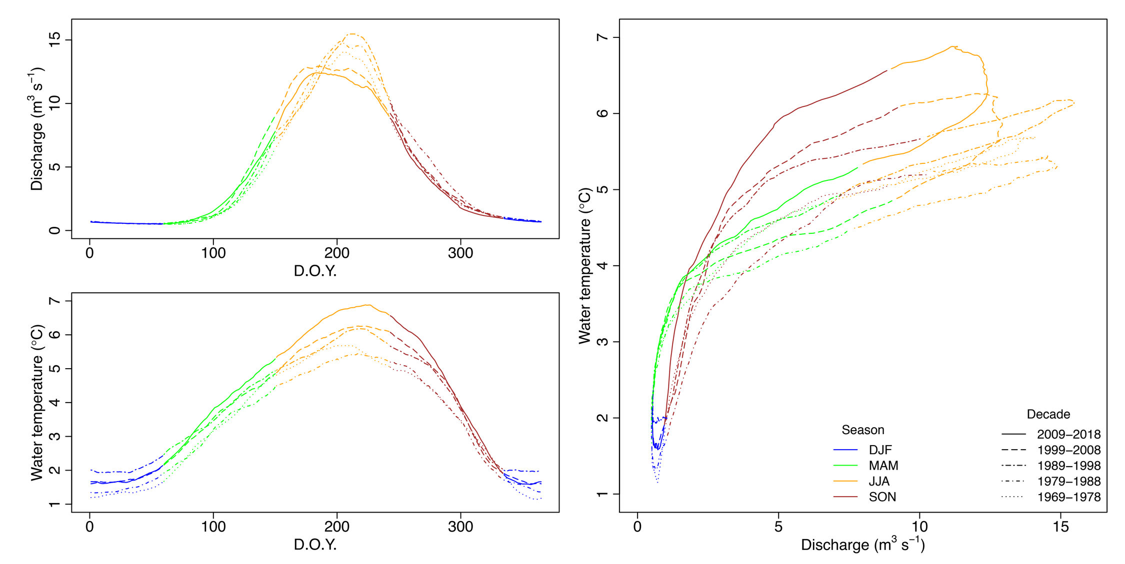
Lakes act as buffers: the outlet trend is almost equal to the collocated air temperature whatever the inflow trend



Lake Geneva, Water temperature anomalies and trends (top). Air temperature anomalies and trends for MeteoSwiss stations (bottom).

Alpine streams

On the long-term, a shift of the thermal and hydrological regimes of alpine catchments is evident.



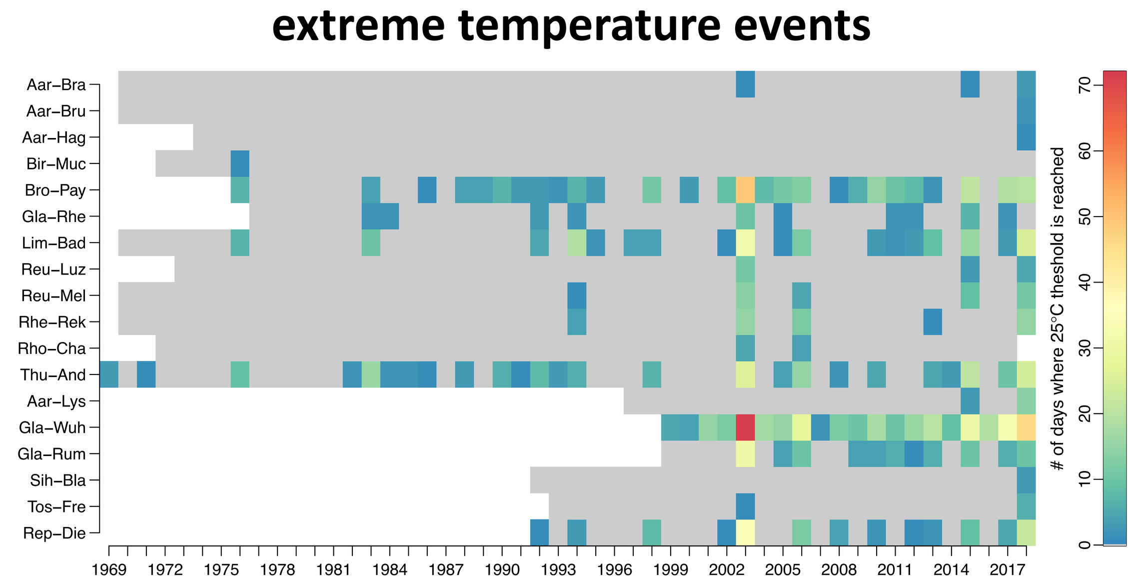
Left: Hydrological (top) and thermal (bottom) regimes per decade for the Lonza river in Blatten averaged for each day of the year (DOY). Right: Decadal temperature plotted against decadal discharge.

Ecological indicator

There is a noticeable increase in warm water events in the last decades:

- Extreme years (2003, 2018) are clearly visible
- Often linked to a discharge deficit in the 70's and 80's
- This is not necessarily the case anymore in the last decades (1994, 2007 and 201)

➤ **Swiss river system is becoming more sensitive to extreme temperature events**



Number of days per year when the 25°C threshold is reached (i.e. water temperature is above 25°C for at least 1 hour during the specific day).

Conclusion

- Strong evidence that climate warming has a **clear influence on the stream temperature and discharge**
- For the period 1999-2018, the **mean warming rate is +0.37 °C per decade** (around 95 % of the air temperature warming rate)
- **Snow and glacier melt are creating resilience to warming** in high alpine stream. This **resilience is however likely to reduce in the near future** due to expected further decreases in future snow and glacier cover.

References

[1] Michel, A., Brauchli, T., Lehning, M., Schaefli, B., & Huwald, H.: Stream temperature evolution in Switzerland over the last 50 years, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-366, accepted on the 20th of November 2019, 2019.

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