Glacier melt contribution to the runoff in Alpine catchments

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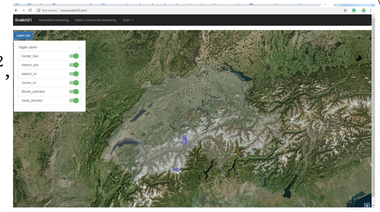
1 Motivation and Objectives

Motivation:
SWATCH21 project: A project for linking eco-hydrologic processes and services to aquatic biodiversity at river and catchment levels

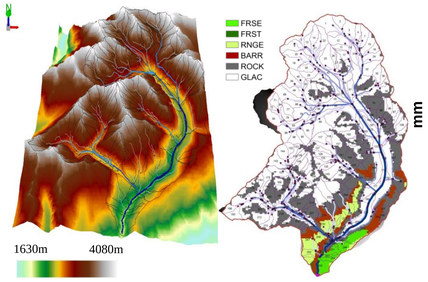
The aims of this work were to
i) develop a realistic approach to integrate a glacier evolution model with the SWAT hydrologic model, and
ii) examine the improvements in the simulated runoff using the coupled glacier-SWAT model.

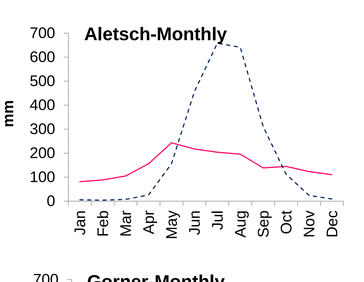
2 Study Area

- Aletsch Catchment
  Total Area: 196 km^2, Glacier area: 81.7 km^2, 15 km^3 ice (20% of Swiss ice, 2014)
- Gorner Catchment
  Total Area: 79 km^2, Glacier area: 57 km^2, 4.2 km^3 ice (2007)

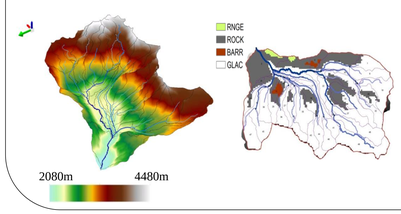


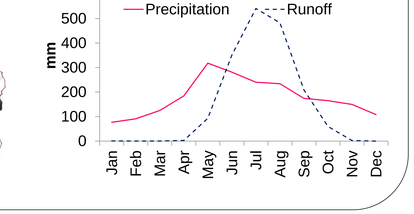
Aletsch Catchment





Gorner Catchment





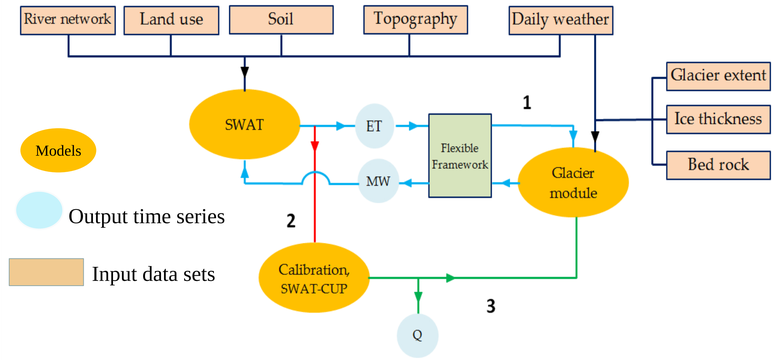
3 Solution

To achieve our objects, first we developed a framework with a flexible architecture for model coupling.

In this approach, the meltwater derived from glacier retreat is calculated based on the daily mass balance of the glacier and added to the SWAT model's water balance as a point source.

Finally, we tested the simulated discharge from SWTA and G-SWAT in two glacierized Alpine catchments.

4 Modeling Framework, G-SWAT (Glacier-SWAT)



Glacier module-Accumulation component

$$Psoild_{i,t} = \left[P_{ref,t}(1 + C_{perc}) + \frac{Elev_i - Elev_{ref}}{1000} \times dP\right] \times Dsnow_i \times r_{s,t}$$

- $Psoild_{i,t}$: *Accumulated precipitation at grid i, time t*
- $P_{ref,t}$: *Precipitation at reference climate station, time t*
- C_{perc} *Gauge deficit factor*
- $Elev_i$: *Elevation at grid i,* $Elev_{ref}$: *Elevation at reference climate station*
- dp: *Precipitation lapse,* $Dsnow_i$: *snow redistribution factor at grid I*
- $r_{s,t}$: *fraction of solid precipitation to the total precipitation*

Glacier module-Ablation component

$$Melt_{i,t} = \left[f_{m,i} + (r_{\text{snow},i} \text{ or } r_{ice,i}) \times I_{pot,i}\right] \times T_{i,t}$$

$$T_{ave} \leq -1 \rightarrow r_{s,t} = 1, \quad T_{ave} \geq 1 \rightarrow r_{s,t} = 0, \quad -1 \leq T_{ave} \leq 1 \rightarrow r_{s,t} = \frac{1 - T_{ave}}{2}$$

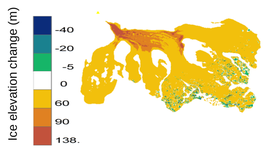
- f_m: melt factor
- Ablation is modeled with a distribution temperature-index approach
- r_{snow} or r_{ice} two distinct radiation factors for snow and ice
- $I_{pot,i}$: the potential direct clear sky solar radiation at grid cell I
- T_i: mean daily air temperature (C) , for T_i < 0 melt does not occur

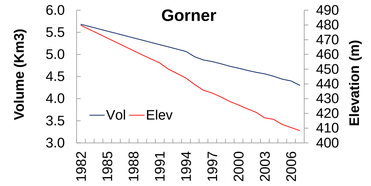
Glacier module-Evolution component

Huss et al 2008

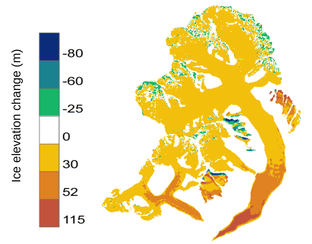
5 Results

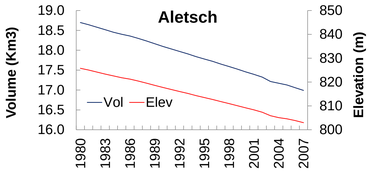
A) Gorner 1982-2007



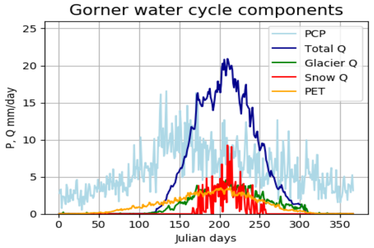


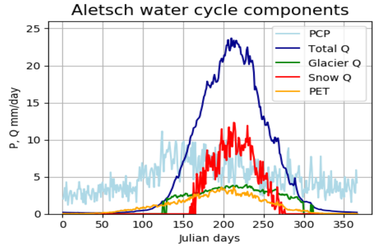
B) Aletsch 1982-2007





Illustrating the (A) changes in the spatial distribution of ice elevation in the Gorner catchment, (B) changes in the volume and elevation of ice in Gorner, (C) changes in the spatial distribution of ice elevation in the Aletsch catchment, (D) changes in the volume and elevation of ice in Aletsch.





Average temporal distribution of simulated Total runoff (Total Q), simulated Glacier-melt runoff (Glacier Q), simulated Snow-melt runoff (Total Q), potential evapotranspiration (PET), and precipitation (P) in the (A) Gorner and (B) Aletsch catchments during the study period.

Table 2.

Calibration steps of discharge in the Aletsch catchment using conventional SWAT model without ice-melt from glaciers.

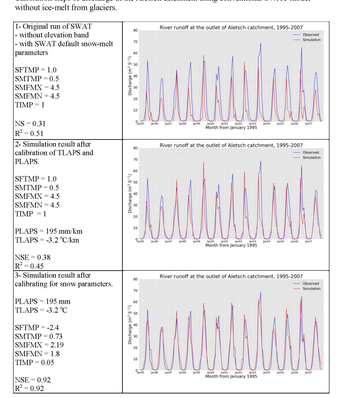
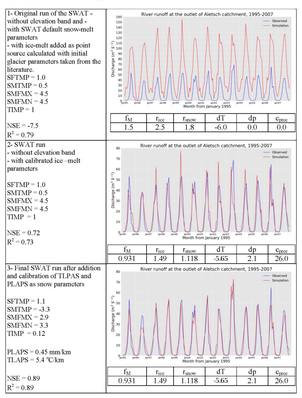


Table 3.

Calibration steps of discharge in the Aletsch catchment using snow-melt as well as ice-melt in the GERM-SWAT model as a point source.



6 Conclusion

- A correct representation of ice-melt is essential for parameter calibration in glacierized catchments
- A glacier retreat module was linked to the SWAT model
- Calibrating precipitation and temperature lapses and snow parameters such as snowpack temperature lag factor and snowfall temperature, SWAT could produce very acceptable discharge values (NSE=0.92). This, however, came at the expense of greatly overestimating PLAPS.
- An important conclusion is that good calibration results do not always imply correct parameter values.

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