Constraining the long-term hydrological modelling of the River Rhine's glaciated headwater catchments

Irene Kohn [1], Marc Vis [2], Daphné Freudiger [1], Jan Seibert [2], Markus Weiler [1], and Kerstin Stahl [1]

Overall Aim

The study aimed to model **daily streamflow Q** (and the specific contributions of ice and snow melt) for **all of the glaciated catchments of the Rhine** over the **long period 1901–2006**.

Catchments

HBV-light alpine+ Model

We used the HBV-light model software (see www.geo.uzh.ch). Recent **extensions** tailored to project requirements:

- snow melt
  - aspect factor
  - seasonally varying degree-day factor
- conceptual representation of **snow redistribution**
- **glacier modelling**
  - transient glacier **area adjustment** (yearly steps)
  - seasonally evolving glacier runoff response
- differentation of snow & ice melt streamflow components

Data

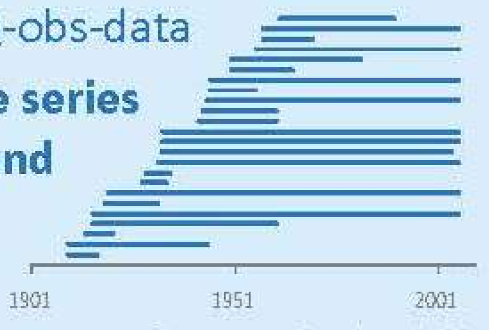
Precipitation Input

- gridded data set of daily P sums for 1901-2006 (HYRAS data + analog day resampling for 1901-1950)
- **wind drift correction** (based on Sevruk, 1989)
- for catchment mean P: **factor correction** based on a **water balance assessment** using available Q observation data

➡ **involvement in model calibration disabled**

Streamflow Observations

- 25 catchments: no Q-obs-data
- **24** catchments: **time series differing in timing and length**



Coverage of 1901-2006 through available Q obs time series from 24 catchments

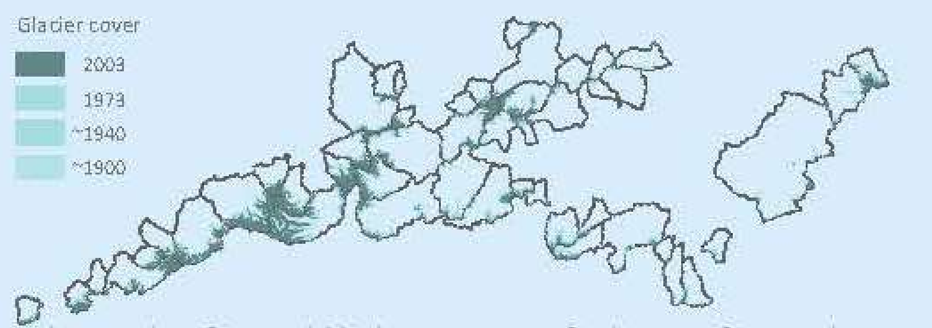
➡ calibration criteria: **Lindstrom Efficiency, Seasonal** Eff. for **Q(Jun-Sep)** & Eff. for **ln(Q)**

Snow Data

- source: WSL Institute for Snow and Avalanche Research **SLF**, Davos, Switzerland
- **gridded SWE** (snow water equivalent) **climatology (1x1km)**
- **daily** SWE for winter months (**Nov to May**) from **Nov-1 1971 to Dec-31 2006**

➡ calibration criteria: **SCA** (fraction of snow covered area) & **SWE** (mean of elev. zone 2000–2500m asl)

Glacier Benchmarks



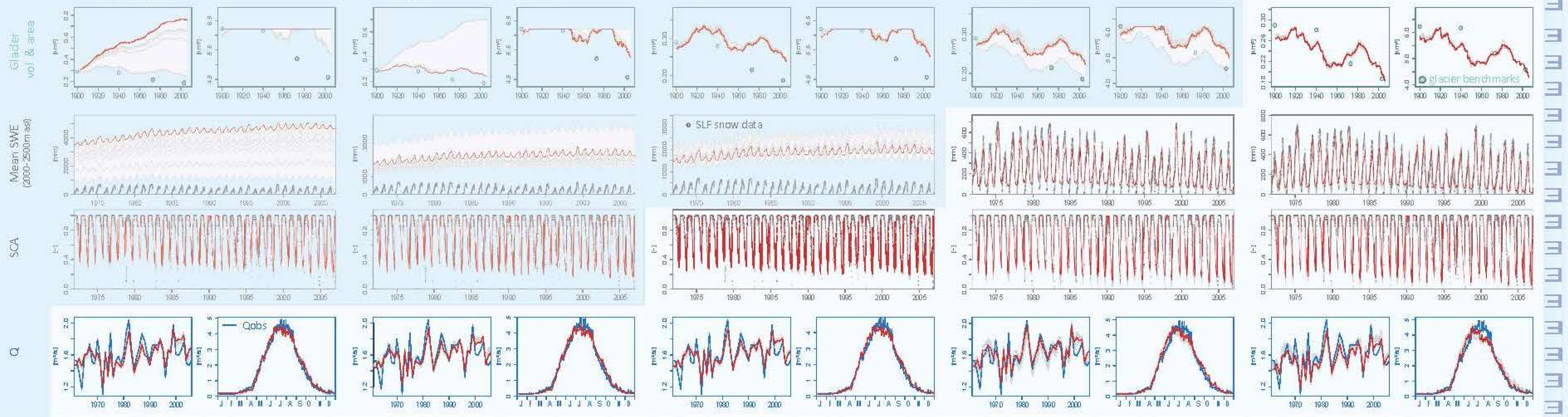
Glacier outlines from available glacier inventories for the years of 1973 and 2003 and from digitised historical maps for the status around 1900 and around 1940

➡ calibration criterion: glacier **volume changes** derived from maps & volume-area scaling

Calibration

- HBV-light genetic algorithm tool
- 10 calibrations (à 3000 runs)
- weighted objective function:
  - glacier volume change → 25%
  - mean SWE of the elevation zone 2000 – 2500m asl: mean absolute error → 15%
  - SCA : root mean square error → 10%
  - **Lindstrom** Efficiency → 20%
  - Efficiency for **ln(Q)** → 15%
  - Seasonal Eff. (**Jun-Sep**) → 15%

Calibration Results: Example Alpbach Catchment



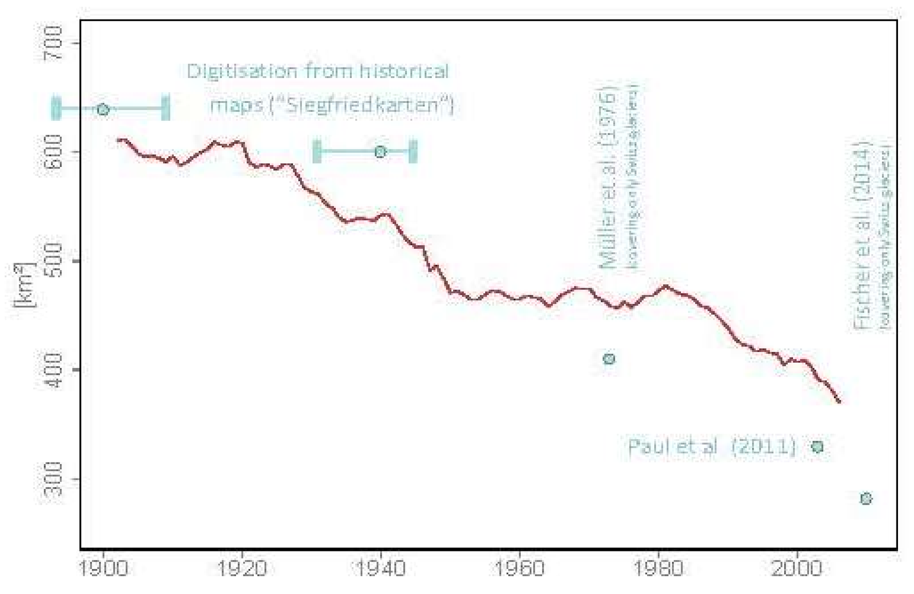
Key Challenges & Objectives

- **scales**
  simulation of 49 catchments over > 100 years in daily time steps
- modelling of **ungauged catchments**
- **alpine setting**
  - high complexity and spatial variability of processes
  - glaciers representing additional (long-term) storage elements
    → high **relevance of equifinality issues**
  - poor availability of ground-based data
    → **uncertainty of model input & limitations for calibration**

➡ High need **to find adequate model calibration criteria** based on streamflow, snow, and glacier observations which are **available for all catchments and cover the centurial simulation period.**

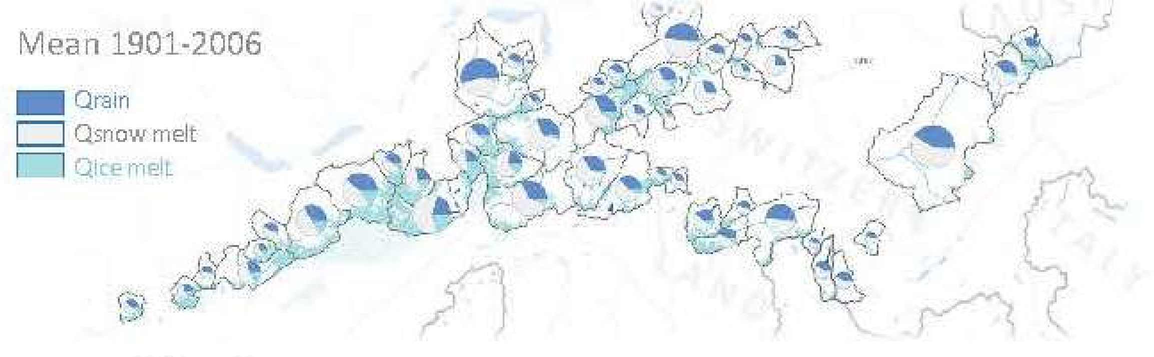
Simulation Results (all catchments)

Simulated glacier area vs. survey data

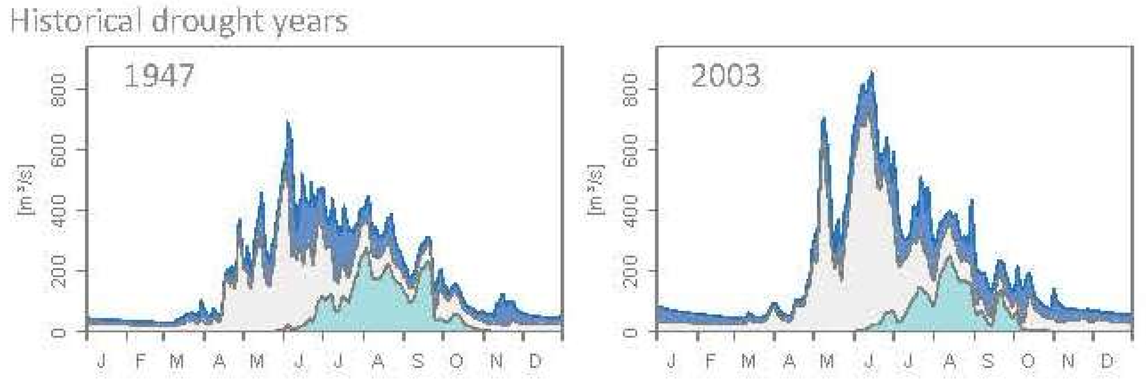


Streamflow components

Mean 1901-2006



Historical drought years



Conclusions

By incorporating multiple criteria into calibration, particularly related to SWE and glaciers, a reasonable agreement of Q, snow & glacier dynamics with observations could be achieved over the centurial simulation period. Parameter sets identifed by constraining the modelling framework in that way are supposed to be robuster in a long-term climate variability context than parameters resulting from using only Q data. In addition, the possibility to calibrate snow & glacier parameters proved to be crucial for the ungauged catchments. Overall, limitations were still evident in snow melt simulations beyond May when observational snow data were lacking. By the use of alternative snow cover data sets that might be improved in future studies.

Credits

* **BAFU** (Swiss Federal Office for the Environment) for streamflow data * **SLF,** Tobias Jonas & Nena Griessinger for SWE data set * **Matthias Huss** (Université Fribourg / ETH Zurich) for glacier data and advise for glacier modelling * **DWD / BfG** : HYRAS data set * **HYDRON project partners,** Kai Gerlinger, Mario Böhm & Nicole Henn for help with precipitation correction * **Staff & students from** the Universities **in Zurich and Freiburg:** Damaris De, David Finger, Barbara Frielingsdorf, Andreas Steinbrich, Simon Etter, Claudius Fleischer, Juliane Schillinger, Maria Staudinger * **Authors of glacier inventories**: Fischer et al. (2014), Müller et al. (1976) / Maisch et al. (2000); Paul et al. (2011) * **CHR/KHR** (International Commission for the Hydrology of the Rhine basin) for funding this work as part of the project *"ASG-Rhein – Abflussanteile aus Schnee- und Gletscherschmelze im Rhein und seinen Zuflüssen vor dem Hintergrund des Klimawandels"*

(1) Faculty of Environment and Natural Resources, University of Freiburg, Germany
irene.kohn@hydrology.uni-freiburg.de www.hydro.uni-freiburg.de
(2) Department of Geography, University of Zurich, Switzerland
www.geo.uzh.ch

Related posters at the TdH:
Freudiger et al. "A combined dataset of glacier outlines from digitized historical maps and remote sensing and its application in hydrology" # 41
Gerlinger et al. "Modellbasierte Quantifizierung der Abflussanteile aus Regen, Schnee- und Gletscherschmelze im Rheineinzugsgebiet 1901-2001" # 33