Modelling of future changes in seasonal snowpack and impacts on summer low flows in Alpine catchments

Michal Jeníček, Jan Seibert, Maria Staudinger

Charles University, Czech Republic and University of Zurich, Switzerland

FACULTY OF SCIENCE
Charles University

University of Zurich[UZH]

Motivation, research questions, objectives

1) to simulate the effect of changes in selected snow signatures on low flows during the warm seasons

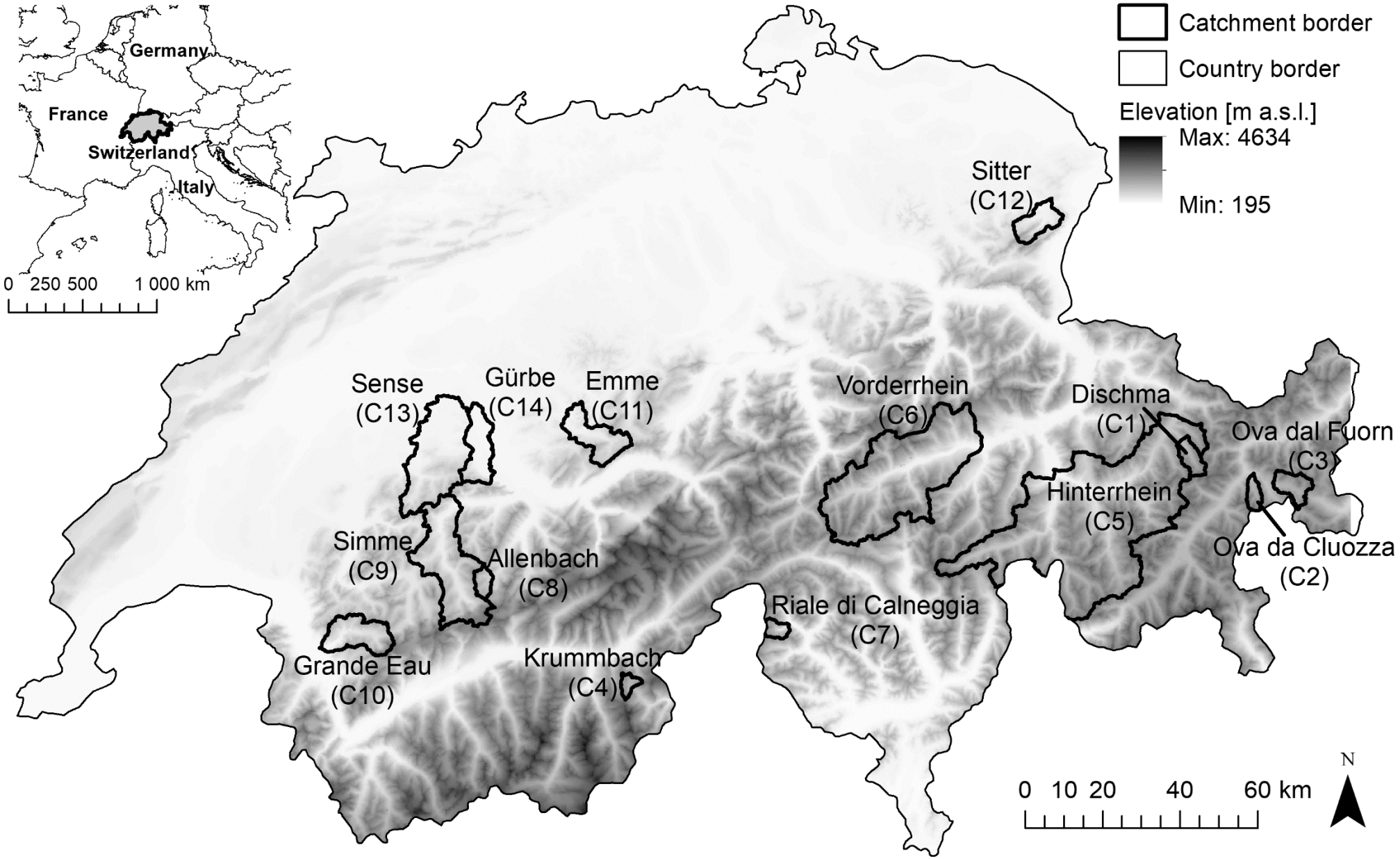
2) to relate drought sensitivity to the simulated snow storage changes in study catchments

January 18, 2013
SWE: normal conditions

January 18, 2014
SWE: 10-30% of normal

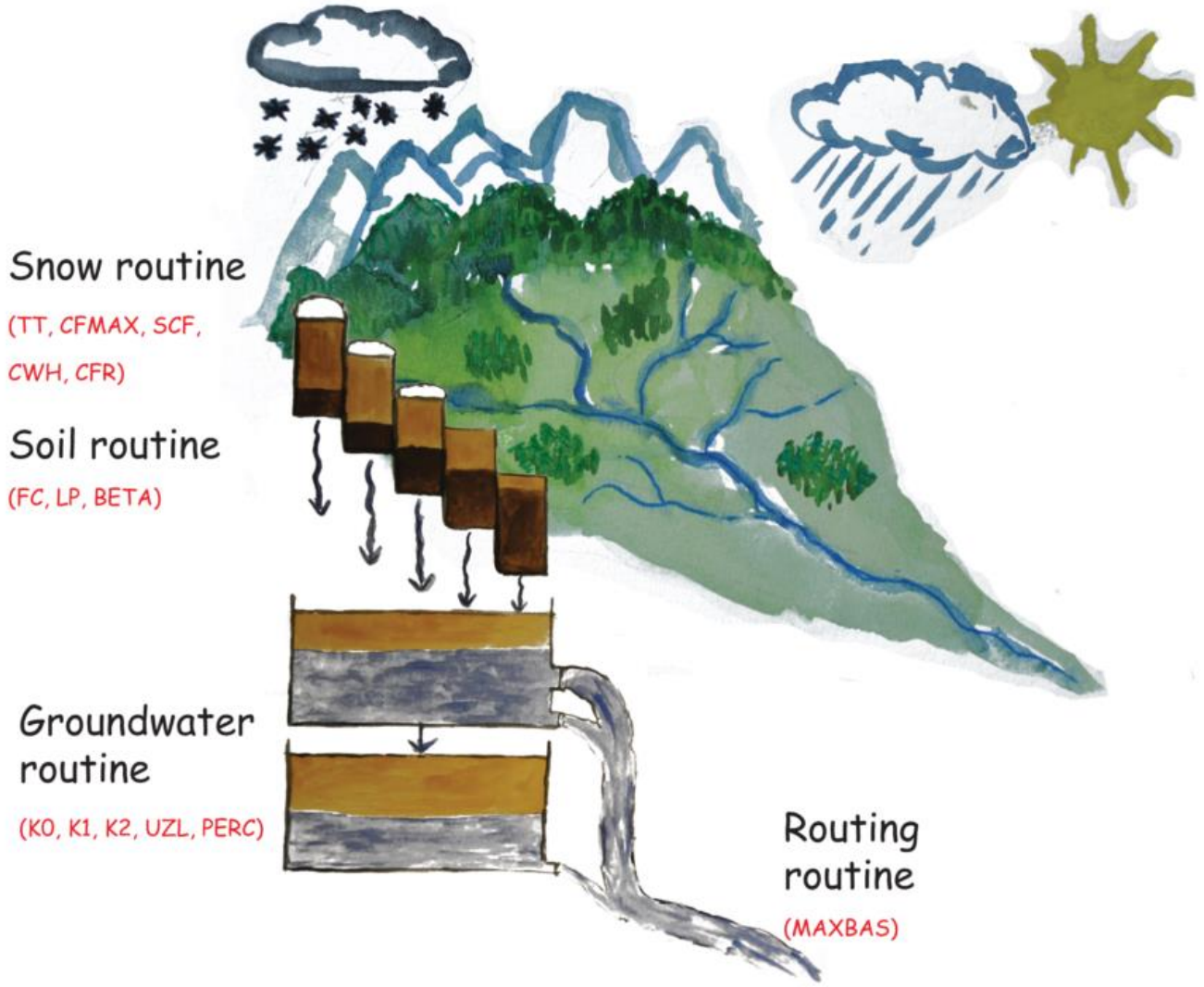
Source: NASA Earth Observatory (http://earthobservatory.nasa.gov/NaturalHazards/)

Study area


Germany
France
Switzerland
Italy
0 250 500 1 000 km
Catchment border
Country border
Elevation [m a.s.l.]
Max: 4634
Min: 195
Sitter (C12)
Sense (C13)
Gürbe (C14)
Emme (C11)
Vorderrhein (C6)
Dischma (C1)
Ova dal Fuorn (C3)
Hinterrhein (C5)
Ova da Cluozza (C2)
Simme (C9)
Allenbach (C8)
Riale di Calneggia (C7)
Grande Eau (C10)
Krummbach (C4)
0 10 20 40 60 km
N

HBV-light model

1. HBV-light model (Seibert and Vis, 2012)
2. Observed data (1971-2012): precipitation, air temperature (Meteoswiss), discharge (BAFU), SWE (SLF)
3. Four objective functions used to calibrate the model; goodness-of-fit assessed against Q and SWE.
4. 100 best parameter sets calibrated which were further used for scenario simulations



Climate scenarios and modelling experiments

- The Swiss Climate Change Scenarios 2011 data set (CH2011) was used
- The CH2011 data set provides daily changes in air temperature and precipitation (delta-change approach) relative to the reference period 1980-2009 for three scenario periods (2020-2049, 2045-2074 and 2070-2099) and the A1B emission scenario.

Scenario preparation

- Daily correction of temperature and precipitation applied to the ref. period

Scenario simulation

- 100 model parametrization used to create 100 simulations of each scenario

Calculation of signatures

- The specific signature calculated from these 100 model simulations

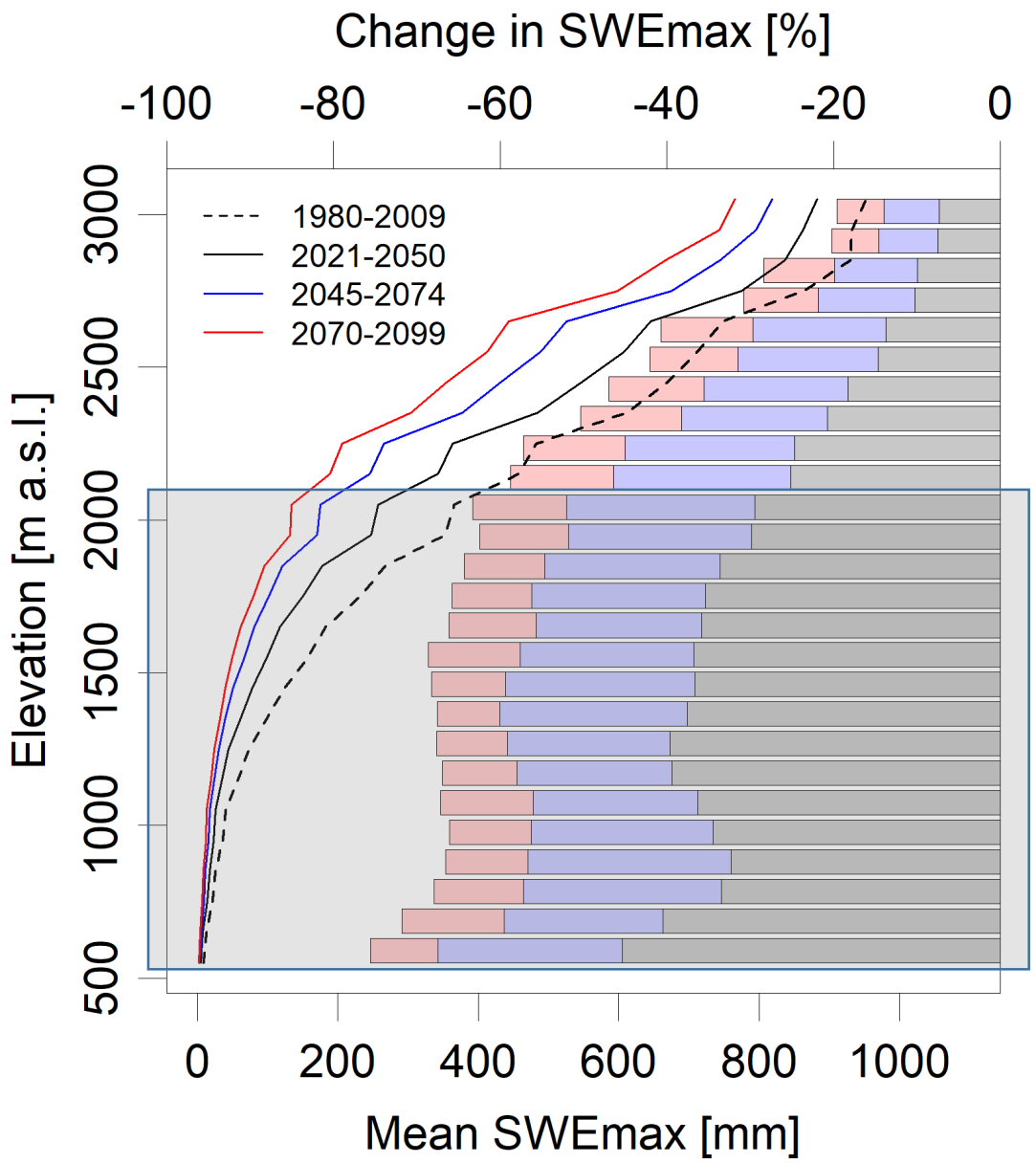
Climate elasticity

Climate elasticity

- Elasticity = % change of Q_{min} / % change of SWE_{max}

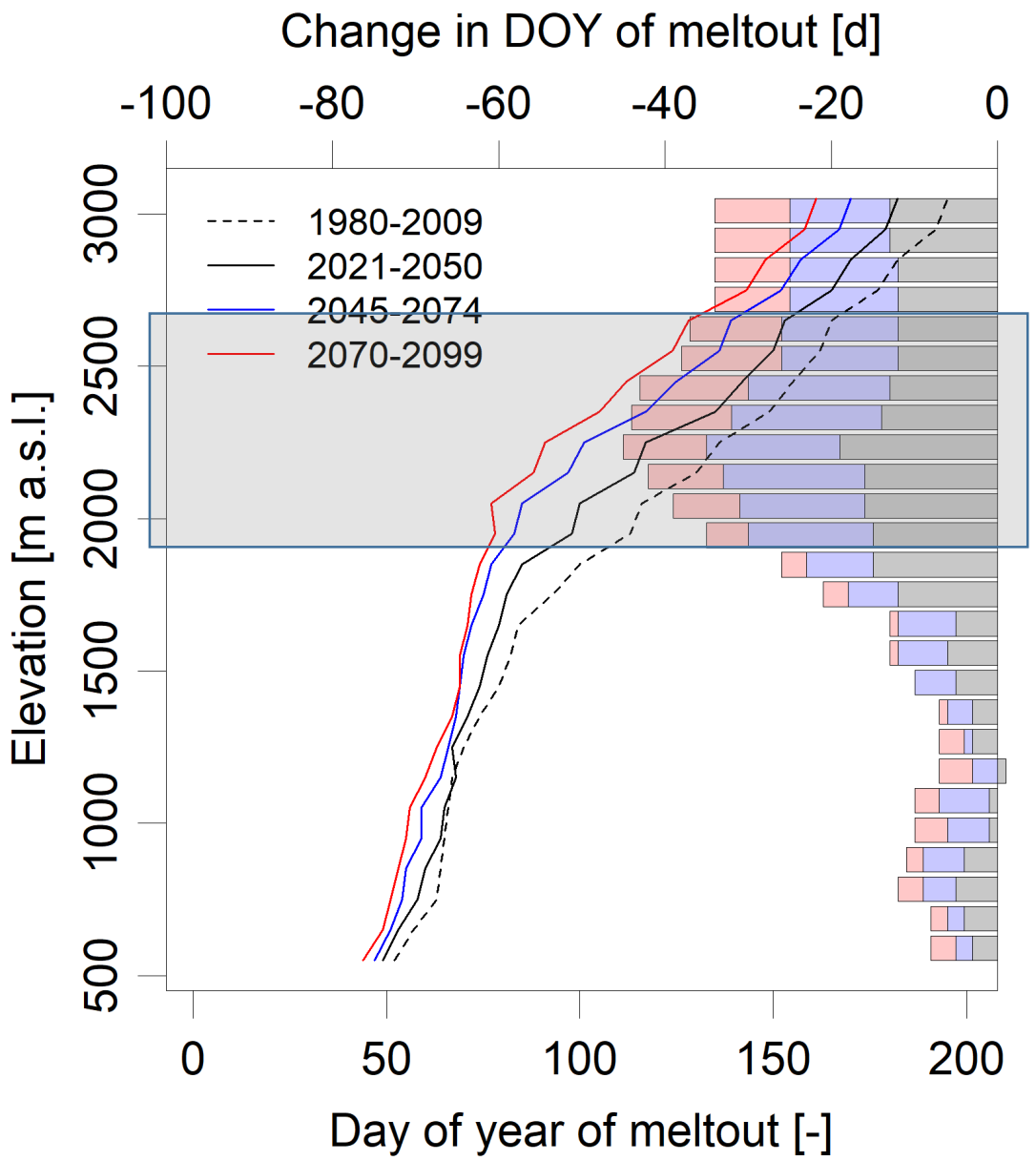
- Express low flow elasticity to SWE
- The higher the value, the more sensitive is Q_{min} to changes in *SWE*

Changes in snow signatures



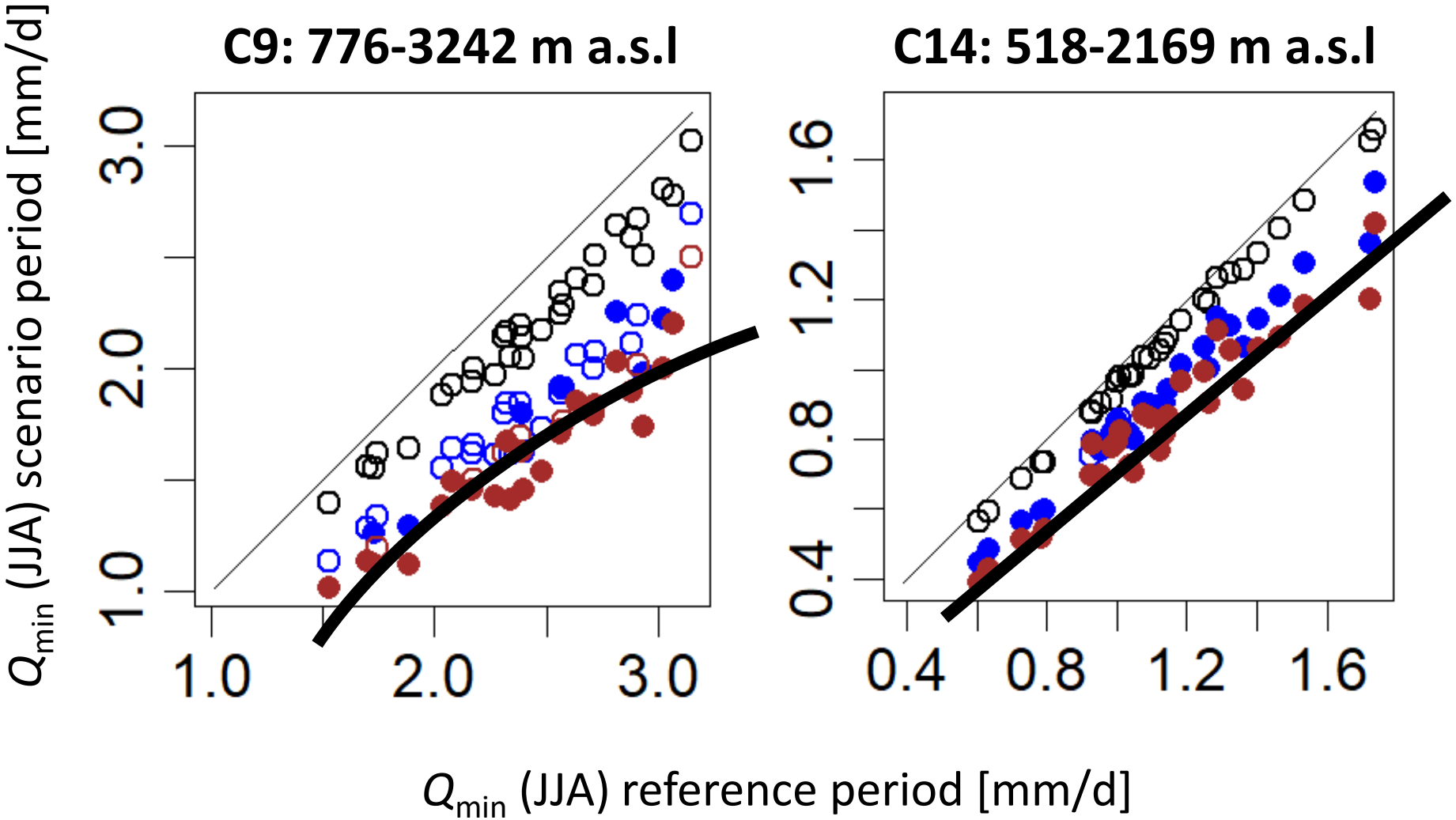
- The largest absolute decrease in SWE_{max} from 2200 to 2700 m a.s.l
- Relative decrease in SWE_{max} up to 80 % below 1500 m a.s.l.
- The decrease in SWE_{max} caused by decrease in snowfall fraction

Changes in snow signatures



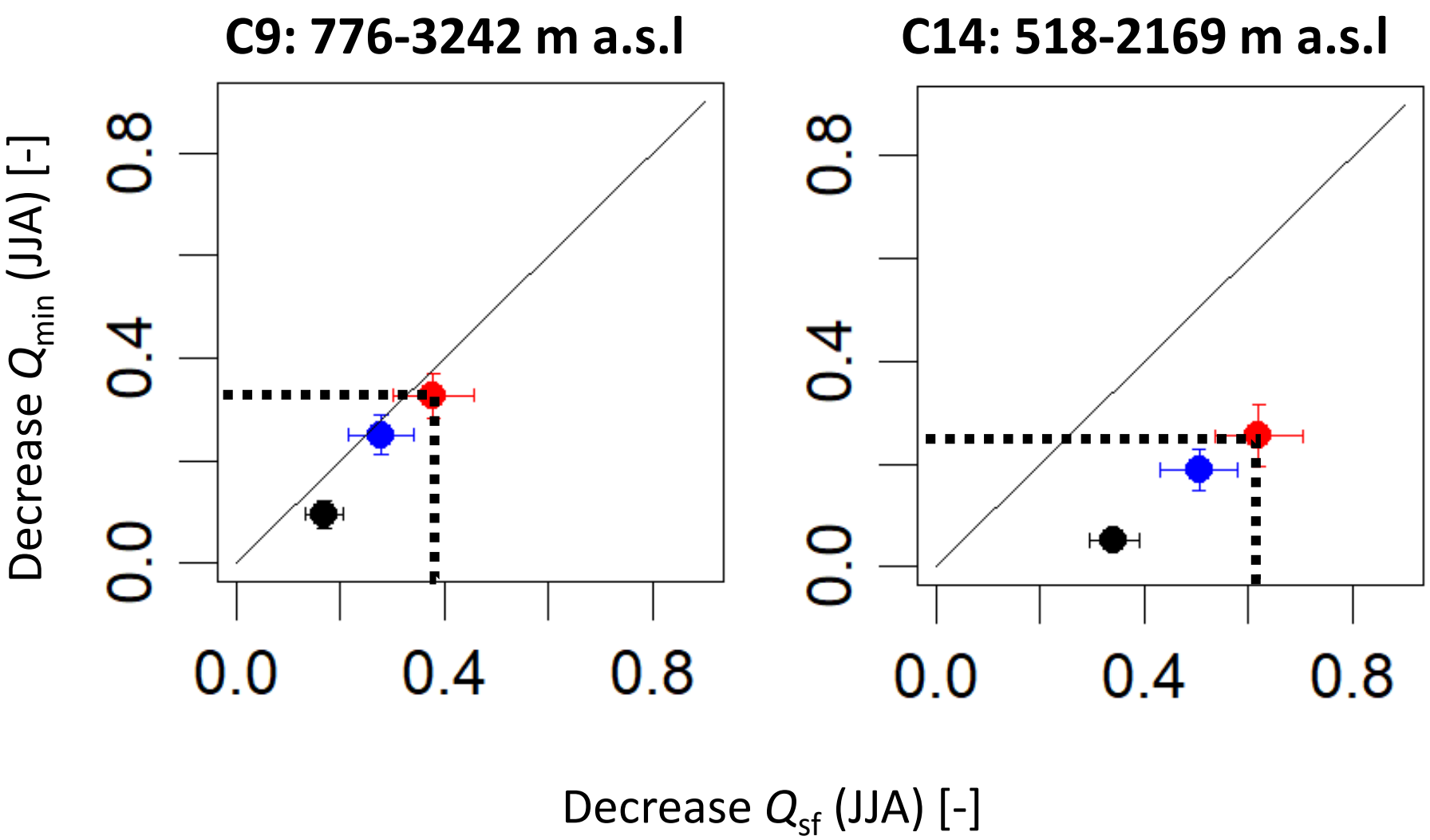
- Earlier onset of snowmelt and earlier melt-out (largest changes between 1800-2500 m a.s.l.
- Shortening of the snowmelt period

Influence of snow storage on low flows: decrease in Q_{min}



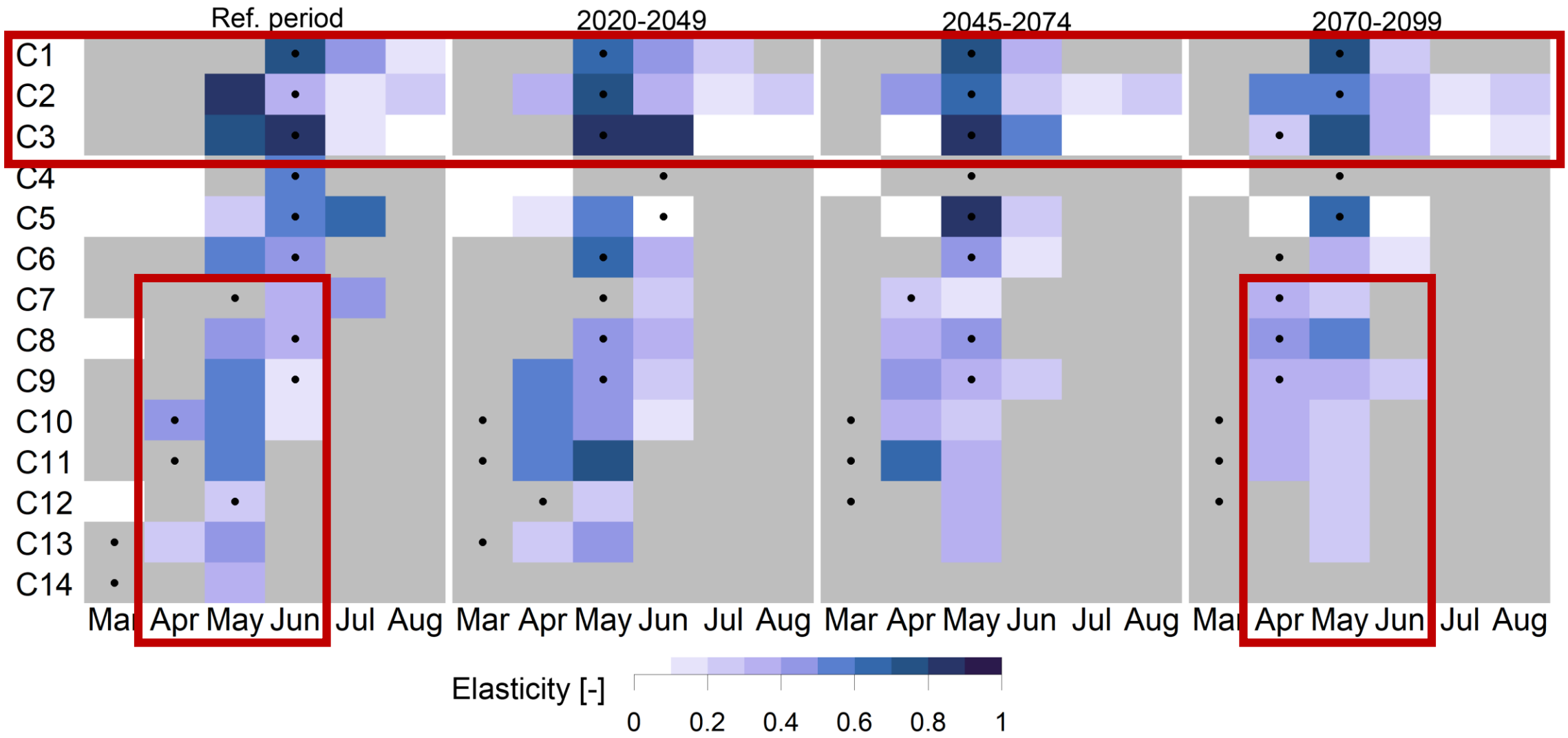
- Q_{min} from June to August for scenarios compared to the ref. period.
- Full-colored marks indicate years when SWE_{max} decreased to less than 50% of respective SWE_{max} in the ref. period
- Black: 2020-2049
  Blue: 2045-2074
  Red: 2070-2099

Influence of snow storage on low flows: decrease in snow runoff



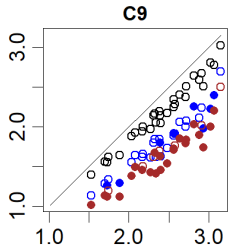
- Decrease in snow runoff (Q_{sf}) compared to the decrease in Q_{min} (JJA) for scenarios compared to the ref. period
- Marks: mean value; error bars: the inter-annual variability (standard deviation) within individual scenarios.
- Black: 2020-2049
  Blue: 2045-2074
  Red: 2070-2099

Influence of snow storage on low flows: elasticity

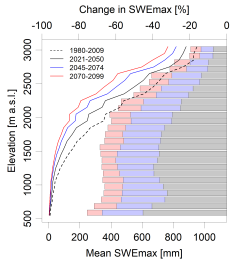


Elasticity of Q_{min} to SWE_{max} for the reference period and scenario periods.

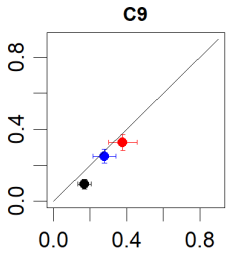
Conclusions



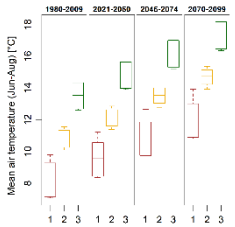
- Summer low flows will significantly decrease in the future in snow dominated areas.



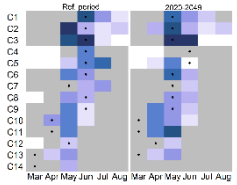
- Decrease in snowfall fraction, snow storage and the shift of snowmelt season are main causes of the low flow decrease



- Snow runoff in summer will decrease by more than 50% (highest elevations) and almost disappear (lowest elevations)



- Changes in AET and precipitation both played a minor role and cannot explain the changes in minimum runoff.



- Higher elevations are more sensitive to the decrease in snow storage → decrease of water availability in summer

More ...

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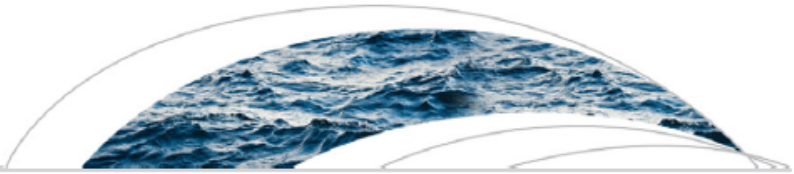

Water Resources Research

RESEARCH ARTICLE

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Key Points:

- In snow-dominated areas, summer low flows will significantly decrease in the future
- This decrease will be caused mostly by the decrease in snow storage and the shift of snowmelt season due to the increase in air temperature
- Low flows at higher elevations are more sensitive to the decrease in snow storage than low flows at lower elevations

Modeling of Future Changes in Seasonal Snowpack and Impacts on Summer Low Flows in Alpine Catchments

Michal Jenicek[1], Jan Seibert[2,3], and Maria Staudinger[2]

[1]Department of Physical Geography and Geoecology, Charles University, Prague, Czech Republic, [2]Department of Geography, University of Zurich, Zurich, Switzerland, [3]Department of Earth Sciences, Uppsala University, Uppsala, Sweden

Abstract It is expected that an increasing proportion of the precipitation will fall as rain in alpine catchments in the future. Consequently, snow storage is expected to decrease, which, together with changes in snowmelt rates and timing, might cause reductions in spring and summer low flows. The objectives of this study were (1) to simulate the effect of changing snow storage on low flows during the warm seasons and (2) to relate drought sensitivity to the simulated snow storage changes at different elevations. The Swiss