Future changes in snow and its influence on seasonal runoff and low flows in Czechia

Michal Jeníček, Jan Hnilica, Ondřej Nedělčev, Václav Šípek

michal.jenicek@natur.cuni.cz, https://www.natur.cuni.cz/geography/physgeo

Charles University, Prague, Czechia

The Czech Academy of Sciences, Institute of Hydrodynamics, Prague, Czechia

FACULTY OF SCIENCE
Charles University

INSTITUTE OF HYDRODYNAMICS
The Czech Academy of Sciences

EGU General Assembly 2021

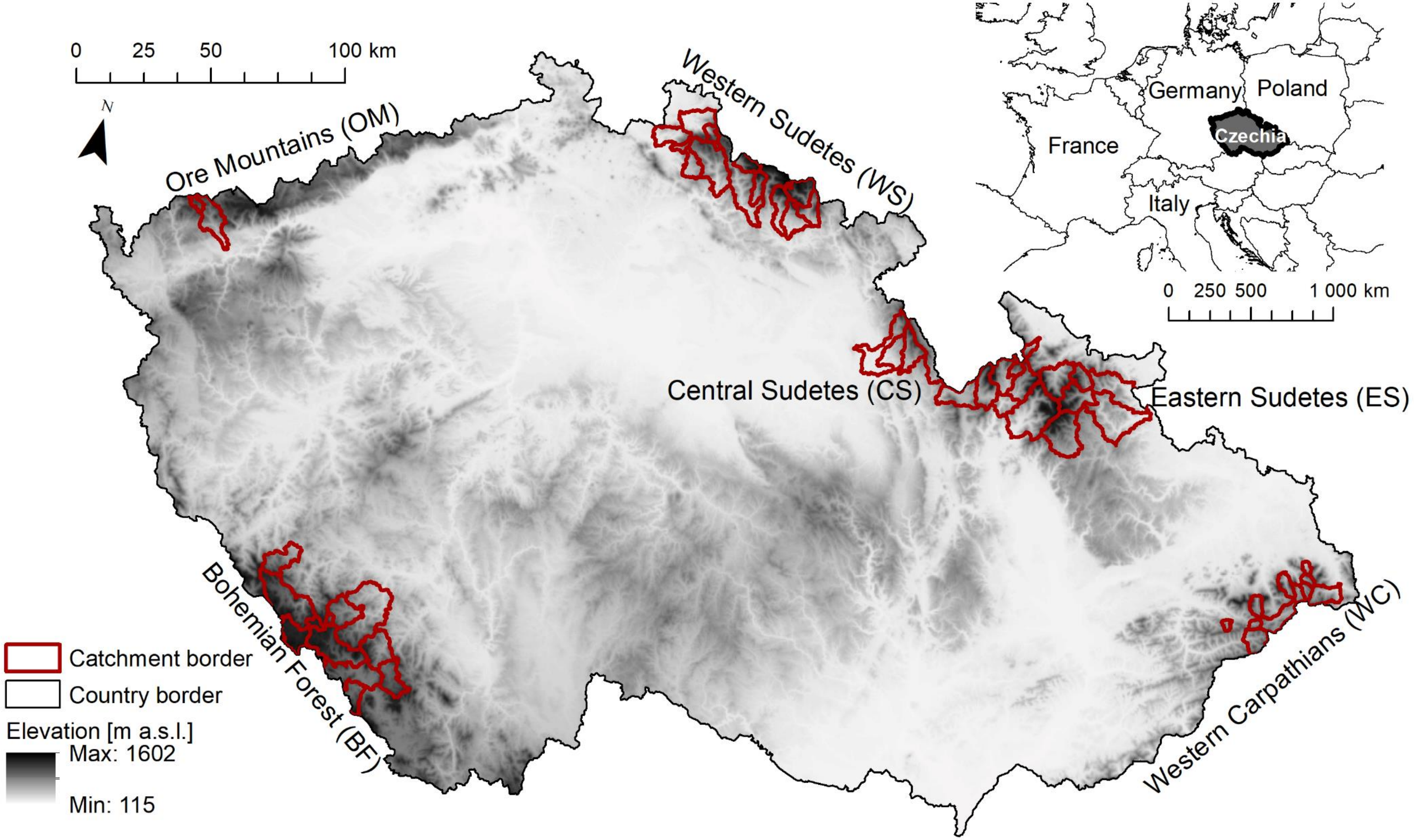
RESEARCH OBJECTIVES

1) to simulate the future changes in snow storages for a large set of mountain catchments, representing different elevations

2) to assess the mutual interplay of changing air temperature and precipitation for snow accumulation reflecting a wide range of climate projections

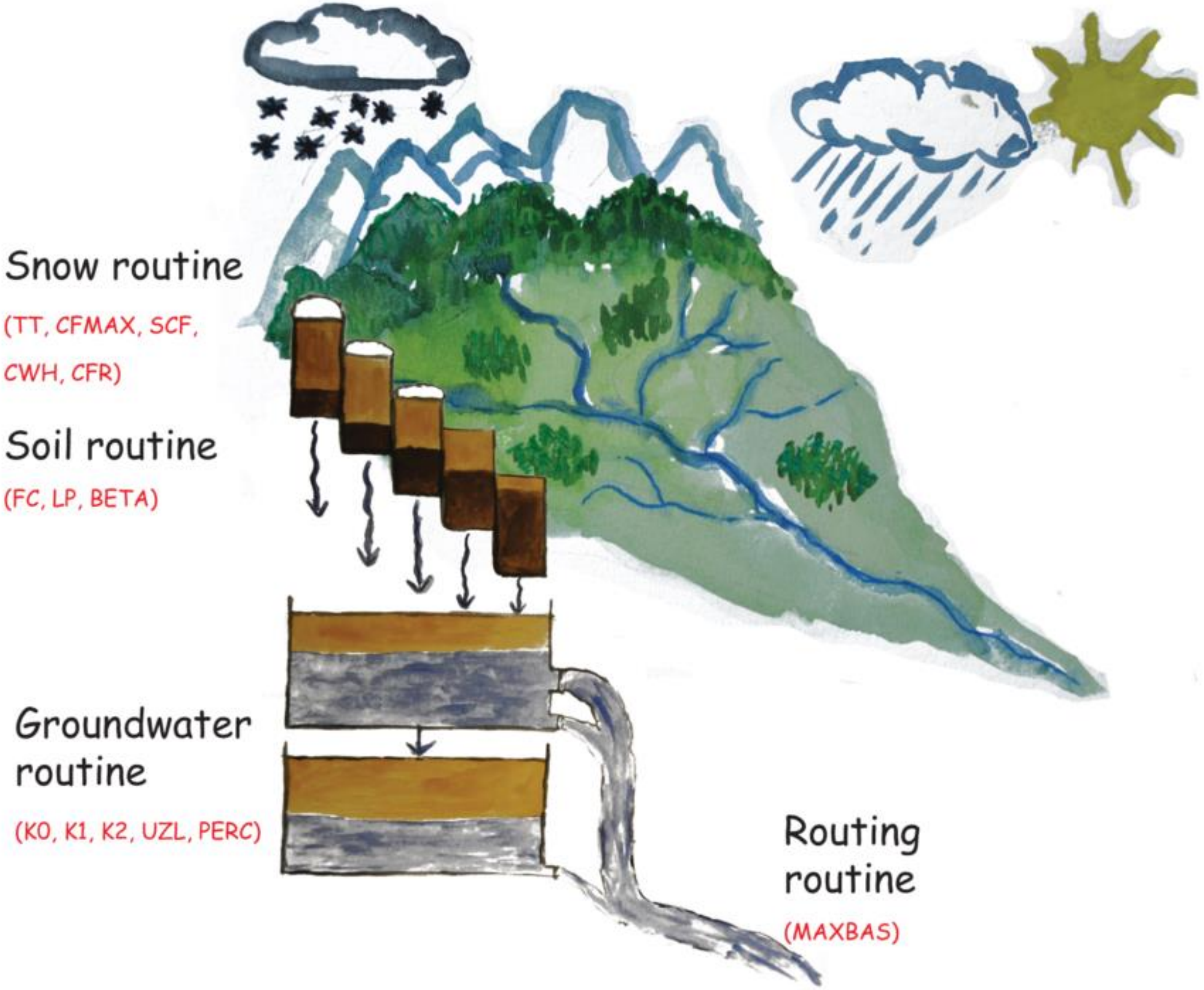
3) to analyse how the changes in snow storages will affect groundwater recharge, streamflow seasonality and low flows in the future

STUDY AREA: 59 MOUNTAIN CATCHMENTS



HBV-LIGHT MODEL

1. HBV-light model (Seibert and Vis, 2012)
2. Observed data (1980-2014): precipitation, air temperature, discharge and SWE (CHMI)
3. Three objective functions used to calibrate the model; goodness-of-fit assessed against Q and SWE.
4. 100 best parameter sets calibrated resulting in 100 simulations for each catchment



CLIMATE SCENARIOS

- Dynamically downscaled climate scenarios used (EURO-CORDEX); 17 combinations of GCMs and RCMs and RCPs (2.6, 4.5 and 8.5) used
- Simultaneous bias correction of temperature and precipitation
- Relative changes of the future periods (three periods until 2100) compared to the reference period (1980-2005)

Scenario preparation

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

Scenario simulation

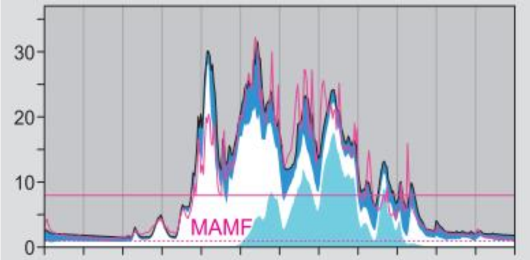
- 100 model parametrizations used to create 100 simulations for each climate scenario (ref. period and future periods)

Calculation of signatures

- Median simulation for each climate scenario used to further calculate the specific signature

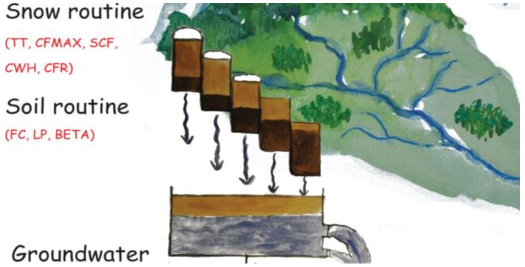
STREAMFLOW SIGNATURES

Snowmelt contribution to runoff (Q_s)



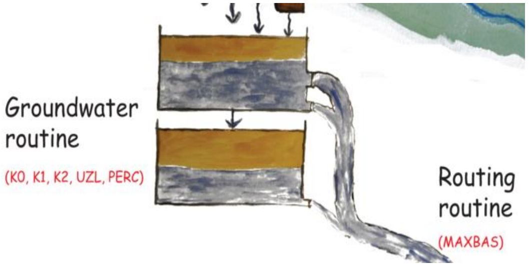
Simulated by the HBV model using „effect tracking“ (complete mixing in a virtual mixing tank)

Groundwater recharge (G_w)



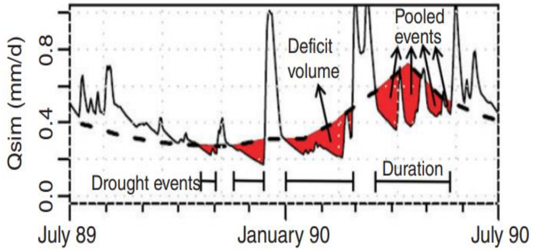
In the HBV, it represents the outflow from the soil box into groundwater boxes

Summer baseflow (Q_b)



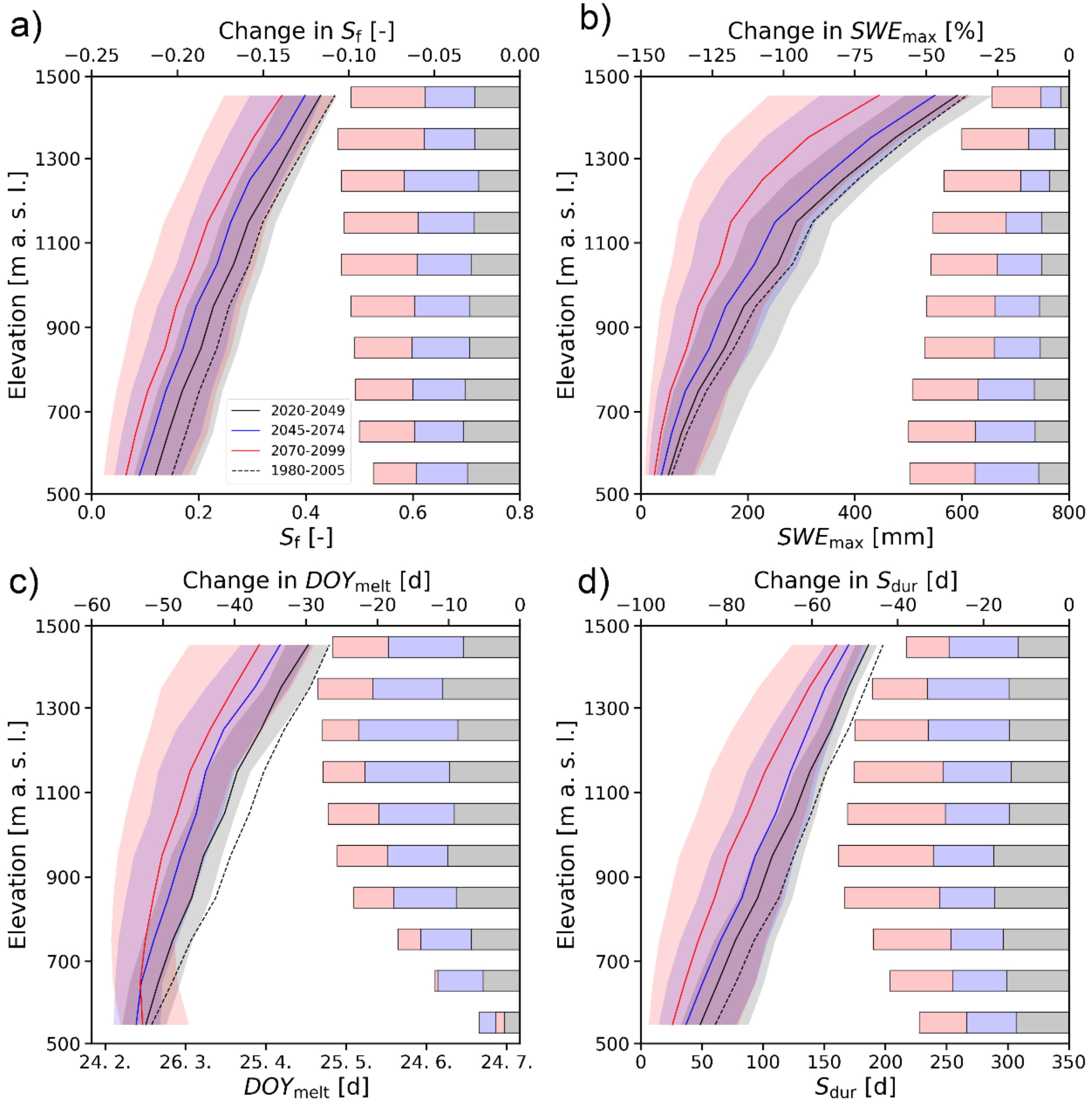
In the HBV, it represents an outflow from the lower groundwater box (Q2) controlled by a recession coeff. (K2)

Summer (JJA) deficit volumes D_v



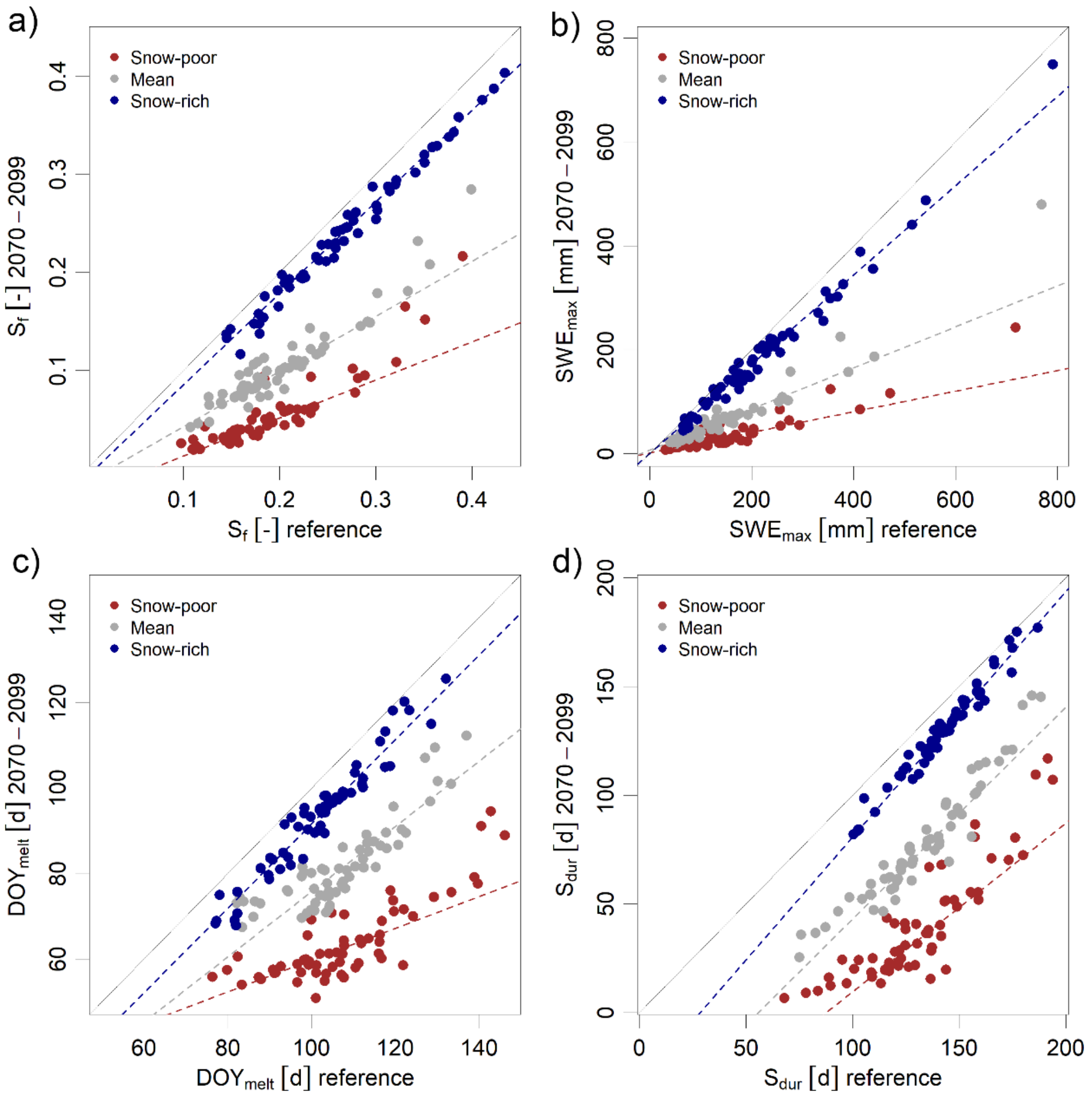
Calculated from simulated runoff using variable threshold level method ($Q_{90\%}$)

FUTURE CHANGES IN SNOW SIGNATURES



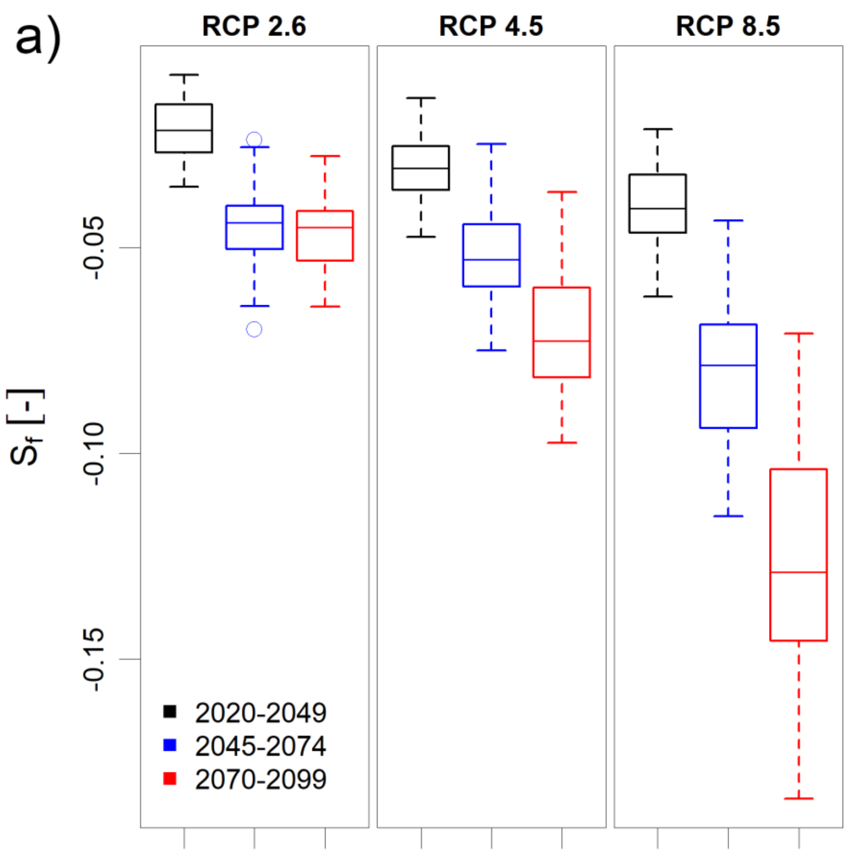
- Considerable decrease in snowfall fraction and SWE_{max} for all catchments at all elevations
- Melt-out day occurred earlier by four weeks at the highest elevations and by 2-3 weeks at the lowest elevations
- Snow-covered season will be significantly shorter in the future
- Shortening of the snow-covered season will be caused more by earlier melt-out rather than by later snow cover onset
- Changes in SWE_{max} and DOY_{melt} are, in absolute terms, larger at higher elevations compared to lower elevations

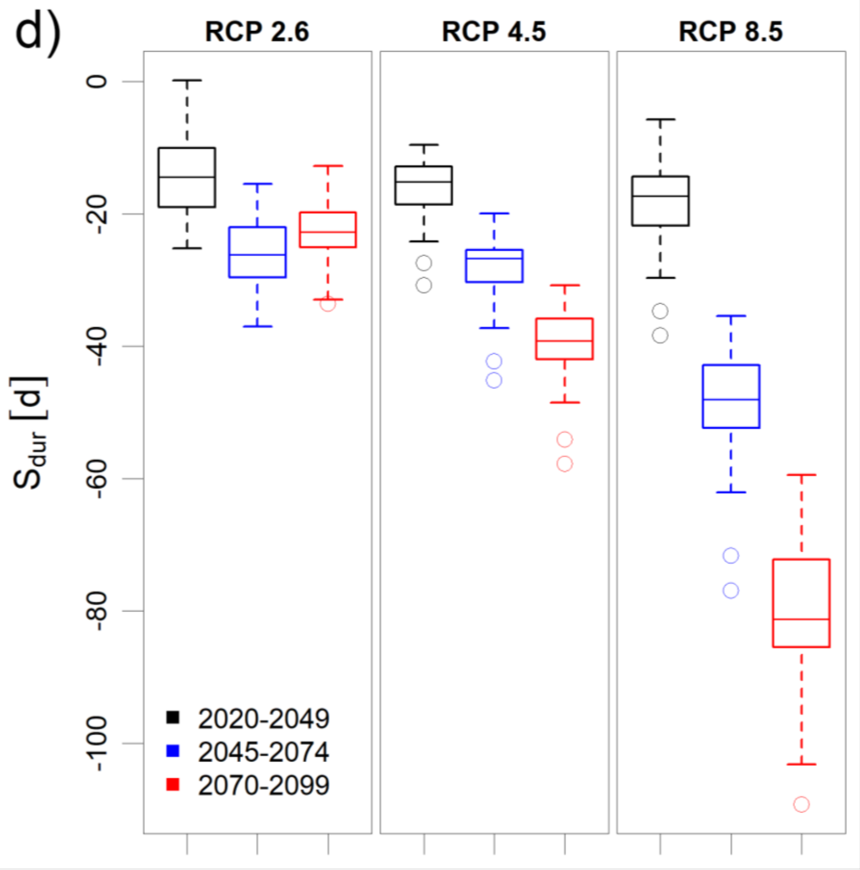
EFFECT OF DIFFERENT CLIMATE PROJECTIONS



- Climate chain leading to most snow-poor conditions showed a dramatic decrease in all snow signatures
- The relatively small decrease was simulated for snow-rich conditions (represents also one with the highest P during the cold period)
- The increase in air temperature causing the decrease in snowfall might be partly compensated by the increase in winter P
- Snow at highest elevations is more affected by the increase in air temperature in our study region

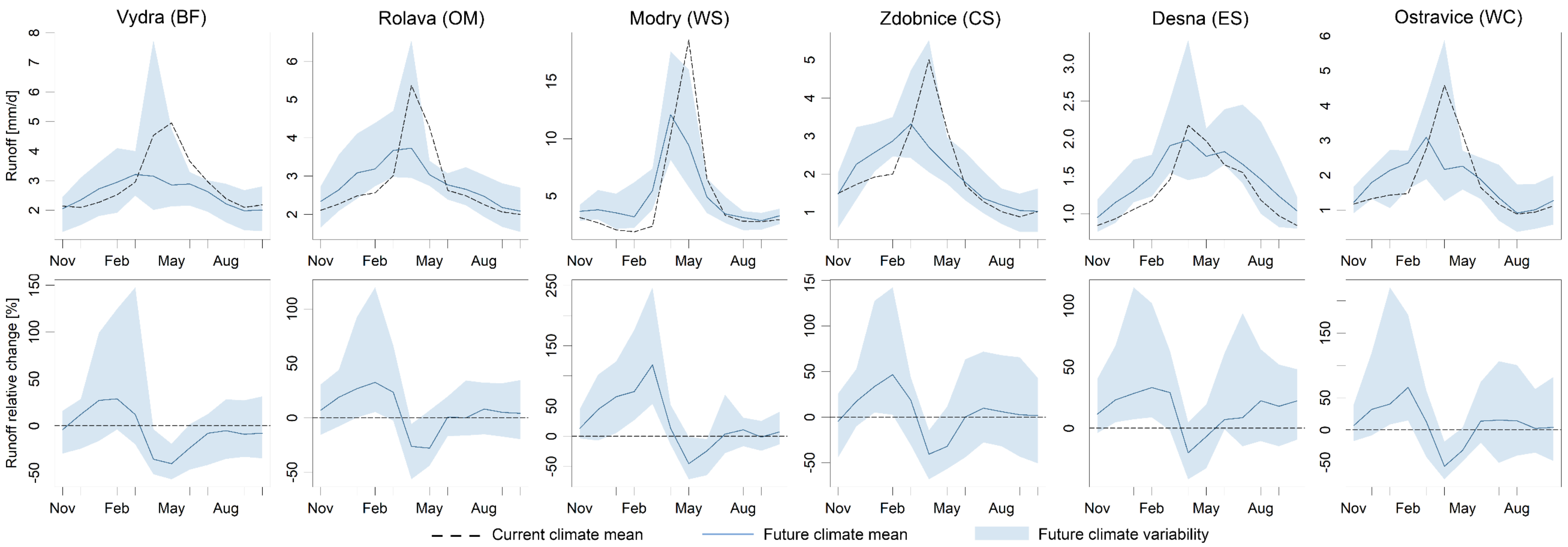
EFFECT OF RCPs





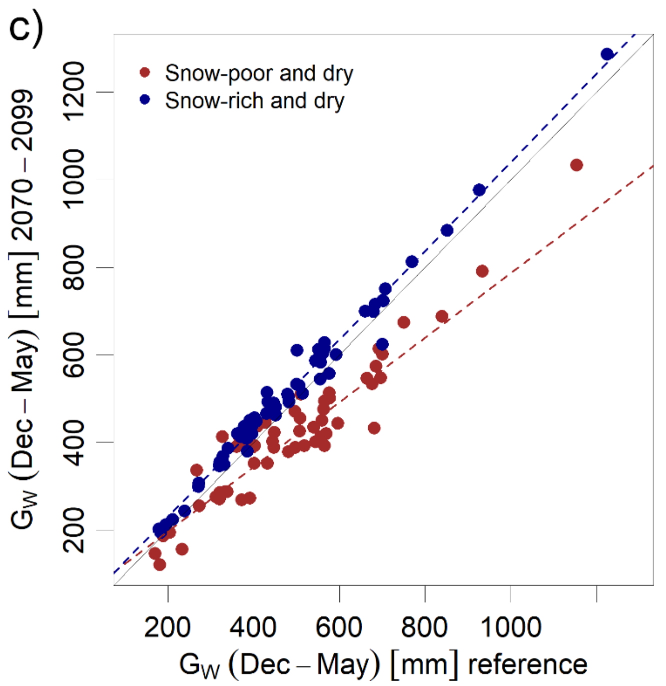
- RCP 2.6 predicted much lower decreases in snow compared to the most pessimistic RCP 8.5 scenario.

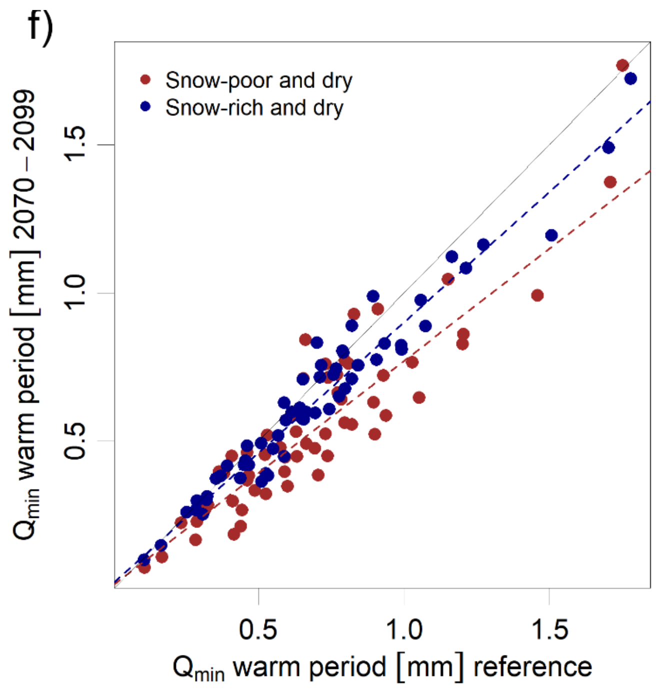
FUTURE CHANGES IN RUNOFF

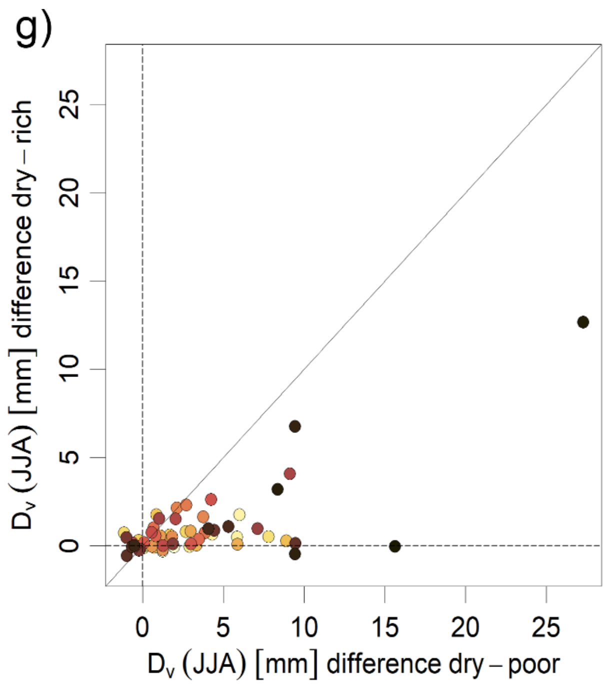


- Relative changes in monthly runoff for the period 2070-2099 compared to the reference period
- Period of highest streamflow will occur on average a month earlier following the earlier snowmelt
- Model predicted an increase in winter runoff for the future period

THE ROLE OF SNOW IN DRY FUTURE SCENARIOS

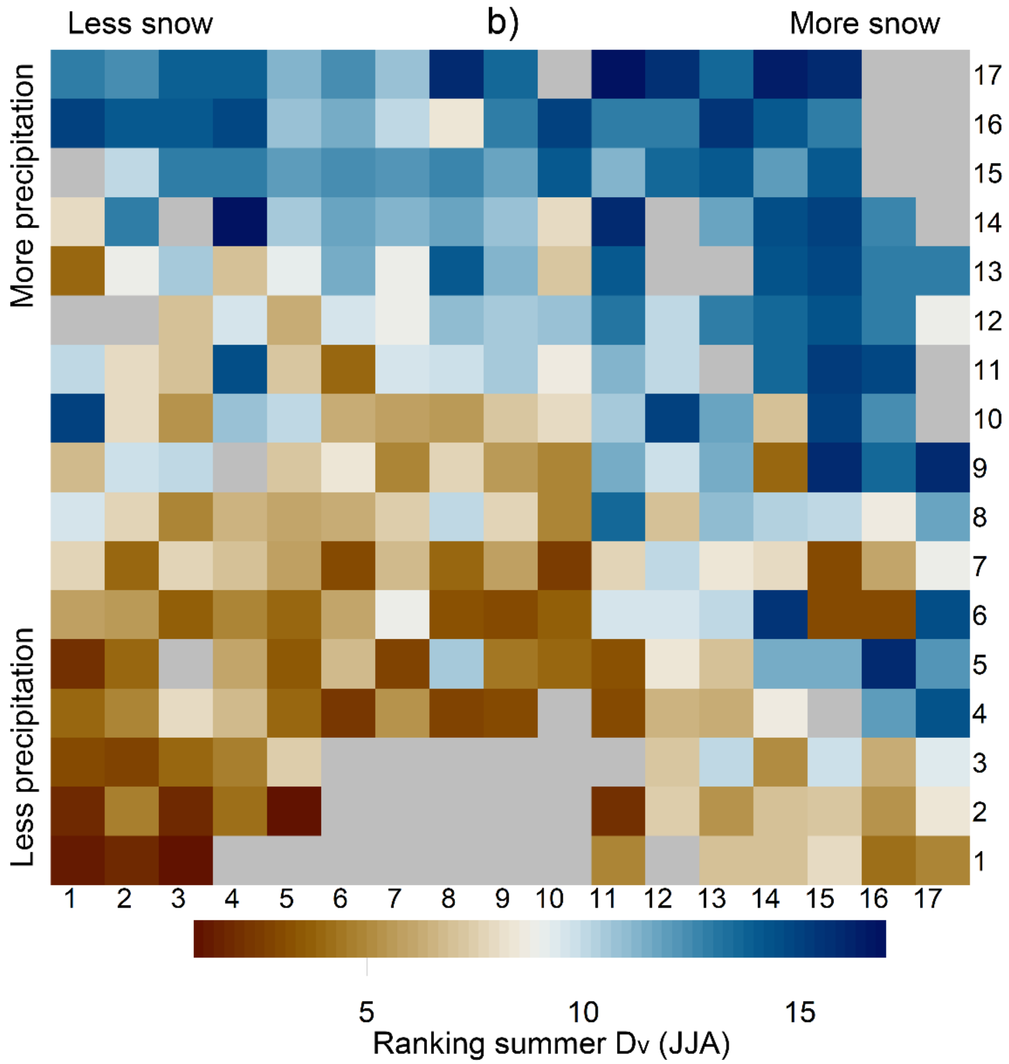






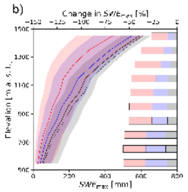
- Lower snow storages caused lower groundwater recharge during the cold period
- Summer minimum runoff is on average lower for snow-poor and dry conditions compared to snow-rich and dry conditions
- Summer deficit volumes will increase in the future, whereas the largest increase seems to be associated with catchments with higher S_f.

THE ROLE OF SNOW IN DRY FUTURE SCENARIOS

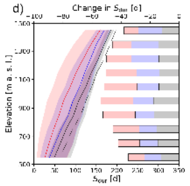


- Figure shows the climate chain ranking (dry to wet; snow-poor to snow-rich; P-poor to P-rich
- Driest climate chains are associated with both the lowest summer P and seasonal snow
- Lower deficit volumes were simulated for chains leading to more snow
- For the same low summer P, the summer deficit volumes are lower for climate chains with more snow
- The same amount of high summer P led to higher low flows for climate chains leading to more snow

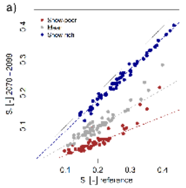
CONCLUSIONS



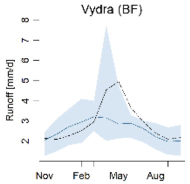
- Decrease in snow-related variables for all study catchments in Czechia at all elevations (e.g., SWE_{max} will decrease by 30%-70%).



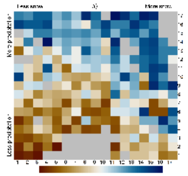
- Shorter snow-covered season by 40-60 days in the future. The shortening will be caused more by earlier melt-out rather than by later snow onset.



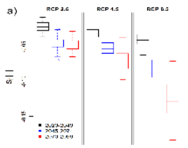
- The increase in air temperature causing the decrease in snowfall might be partly offset by the increase in winter P.



- The period of highest streamflow will occur a month earlier and the seasonal runoff volume will be lower. Increase in winter runoff was predicted.



- Climate chains leading to dry conditions are associated with both lowest summer P and seasonal snow -> more extreme summer low flow periods in the future.



- The RCP 2.6 showed significantly smaller changes compared to the RCP 4.5 and 8.5