Past and future decrease in snow in the central European rain-snow transition zone

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Motivation

Mountain snowpack significantly influences the spatial and temporal distribution of runoff in downstream areas. However, snow storages will decrease in the future due to the increase in air temperature which will affect streamflow regime and water availability.

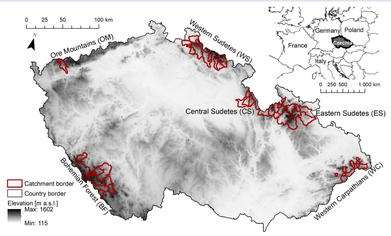
Research objectives

1) To quantify past and future changes in snow storages for a large set of mountain catchments representing different elevations
2) To analyze how snow responds to climate variability

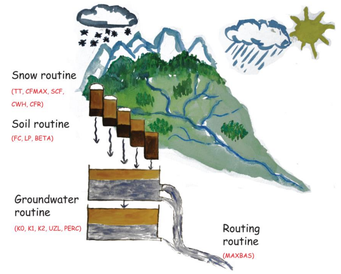
Data and methods

Study area

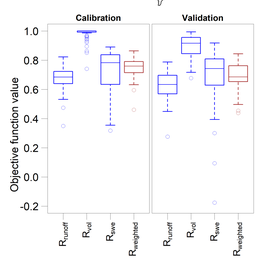
- 59 mountain near-natural catchments in Czechia
- Catchments located at different elevations



HBV-light model



HBV-light model structure and routines



Values of individual objective functions for each catchment for calibration and validation periods.

Observed data used to model calibration and simulations

- Stational data: daily precipitation, air temperature for 1965-2019
- Model calibrated against mean daily discharge and SWE with split-sample approach. Runoff simulations performed for 1965-2019 period
- EURO-CORDEX climate data used for future projections; 17 combinations of GCMs, RCMs and RCPs (2.6, 4.5 and 8.5)

Modelling workflow

Model set-up and calibration
- Model calibration and validation based on historical observations

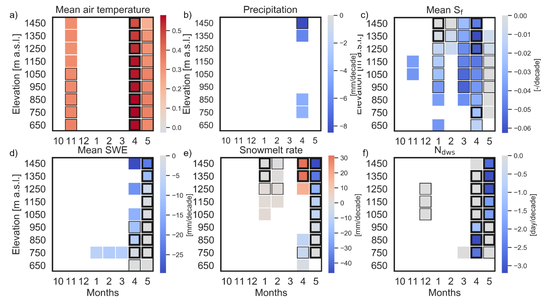
Scenario preparation
- Daily corrections of temperature and precipitation applied to the reference period
- Considers e.g. CO_2 evolution

Scenario simulation
- Application of different climate scenarios in a hydrological model
- Simulation of ensemble of future hydrological projections

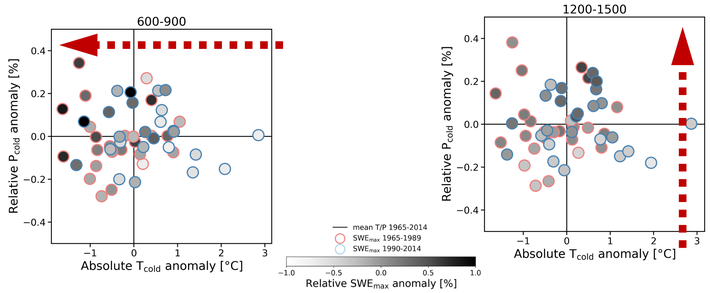
Results analysis
- Changes in snow storages
- Changes in runoff seasonality
- Changes in runoff extremity
- etc.

Results

Changes in snow and climate signatures at different elevations (1965-2014)

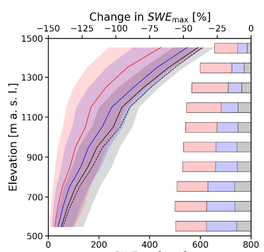


- Strong **increase** in air temperature caused **decrease** in snowfall fraction, and SWE during spring and shifted the snowmelt period
- Major changes in winter and early spring at **middle elevations**, and in later spring at **high elevations**
- **Decreasing trends** in snow storages in western Czechia (by up to −45 mm per decade), while **no trends** were detected in eastern Czechia

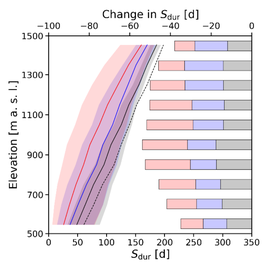


- At elevations below 900 m a.s.l., values of SWE_{max} were mainly **affected by T_{cold}**
- In contrast, at elevations above 1200 m a.s.l., **P_{cold} was an essential factor** that affected SWE_{max}

Future changes in snow

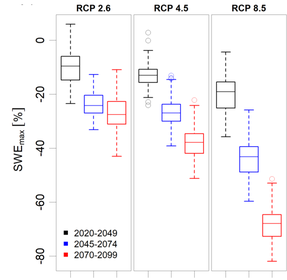


- **Decrease** in snowfall fraction and SWE for all catchments **at all elevations**
- **Changes** in SWE are, in absolute terms, **larger at higher elevations**

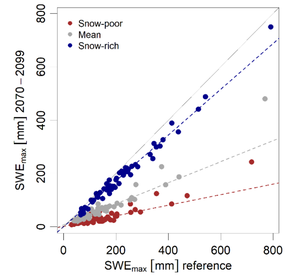


- Snow-covered season will be significantly **shorter in the future**
- Shortening **more due to earlier melt-out** rather than later snow cover onset

Effect of different climate projections

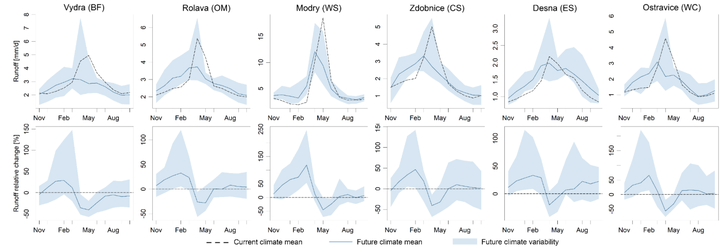


- A significant **decrease in SWE** projected for the future
- **RCP 2.6 predicted lower decreases** in snow compared to the most pessimistic RCP 8.5 scenario.



- Large **variability** in different climate projections
- The effect of increasing air temperatures on snow may be **partly compensated** by the increasing winter precipitation

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

Conclusions

- Changes in snow signatures in recent decades occurred, however, with **different intensity across elevations** and regions
- **Future decrease in snow-related variables** for all study catchments at all elevations (e.g., SWE_{max} will decrease by 30%-70%).
- **Shorter snow-covered season** by 40-60 days is expected. 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 precipitation**.
- The period of highest streamflow will occur **a month earlier** and the seasonal **runoff volume will be lower**. Increase in winter runoff is projected.

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