Snowmelt contribution to seasonal runoff
Lessons learned from using a bucket-type model on a large set of catchments

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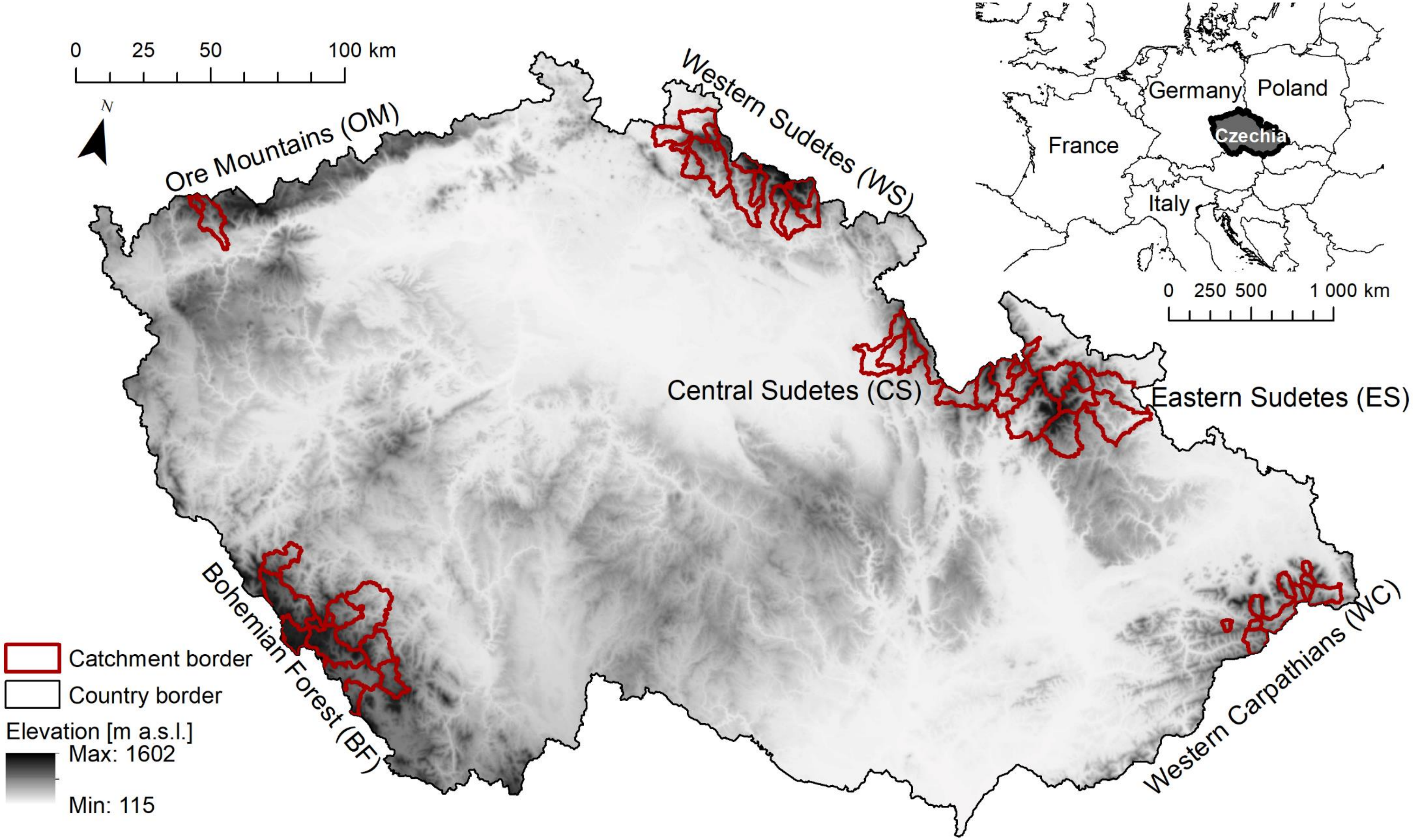
MOTIVATION, RESEARCH QUESTIONS, OBJECTIVES

1) to quantify how inter-annual variations in snow storages affect spring and summer runoff, including summer low flows

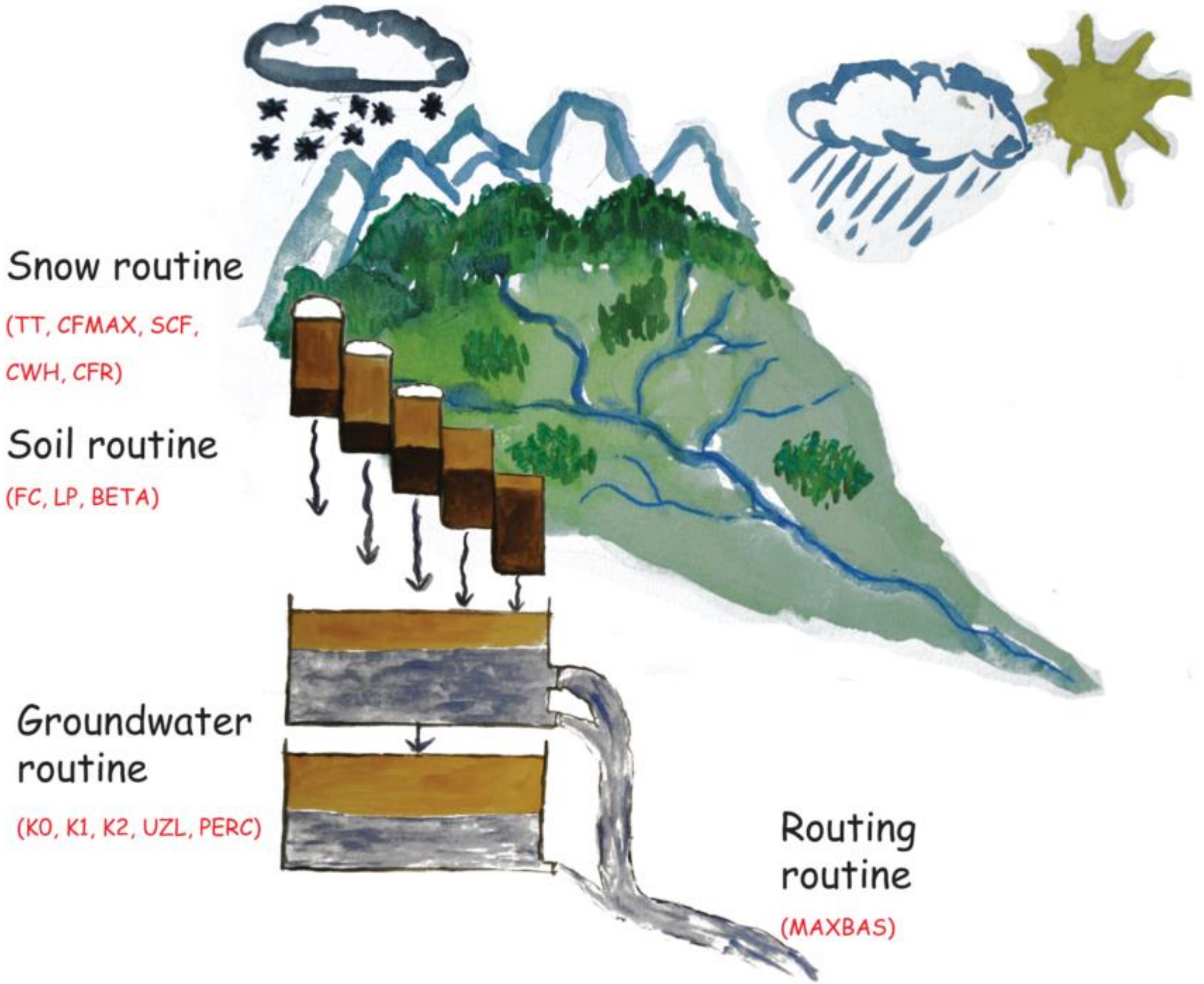
2) to assess the importance of snowmelt in generating runoff compared to rainfall

STUDY AREA: 59 MOUNTAIN CATCHMENTS



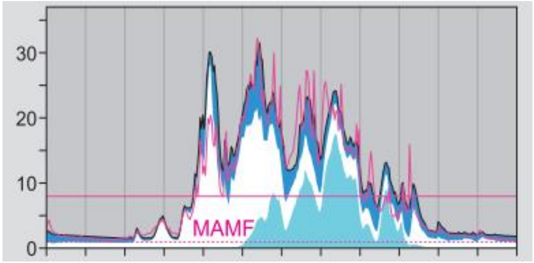
HBV-LIGHT MODEL

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



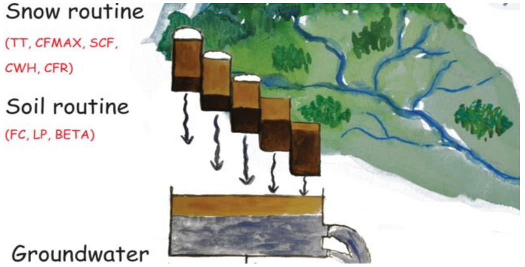
STREAMFLOW SIGNATURES

Snowmelt contribution to runoff (Q_s)



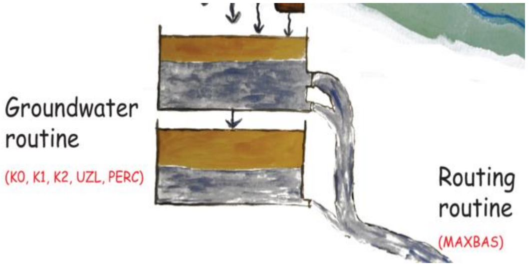
Simulated by the HBV model using „effect tracking“ (complete mixing in a virtual mixing tank)

Groundwater recharge (G_w)



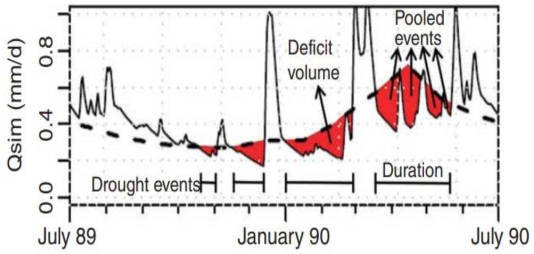
In the HBV, it represents the outflow from the soil box into groundwater boxes

Summer baseflow (Q_b)



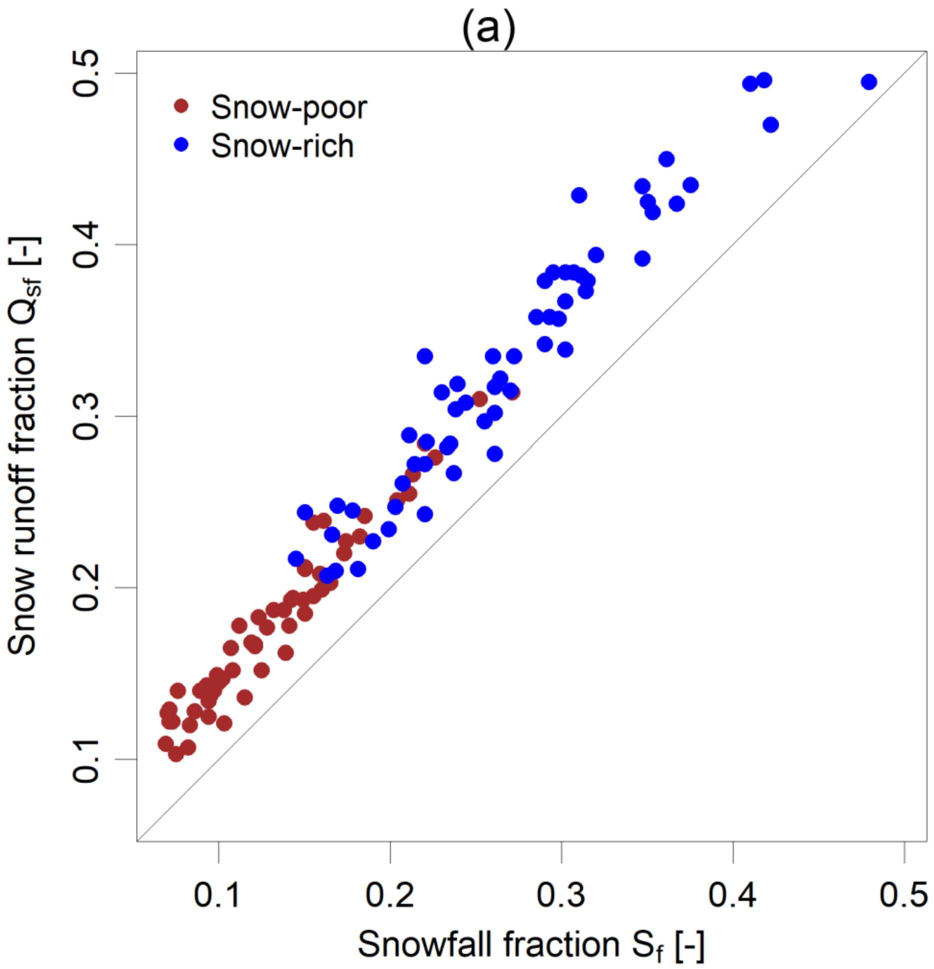
In the HBV, it represents an outflow from the lower groundwater box (Q2) controlled by a recession coeff. (K2)

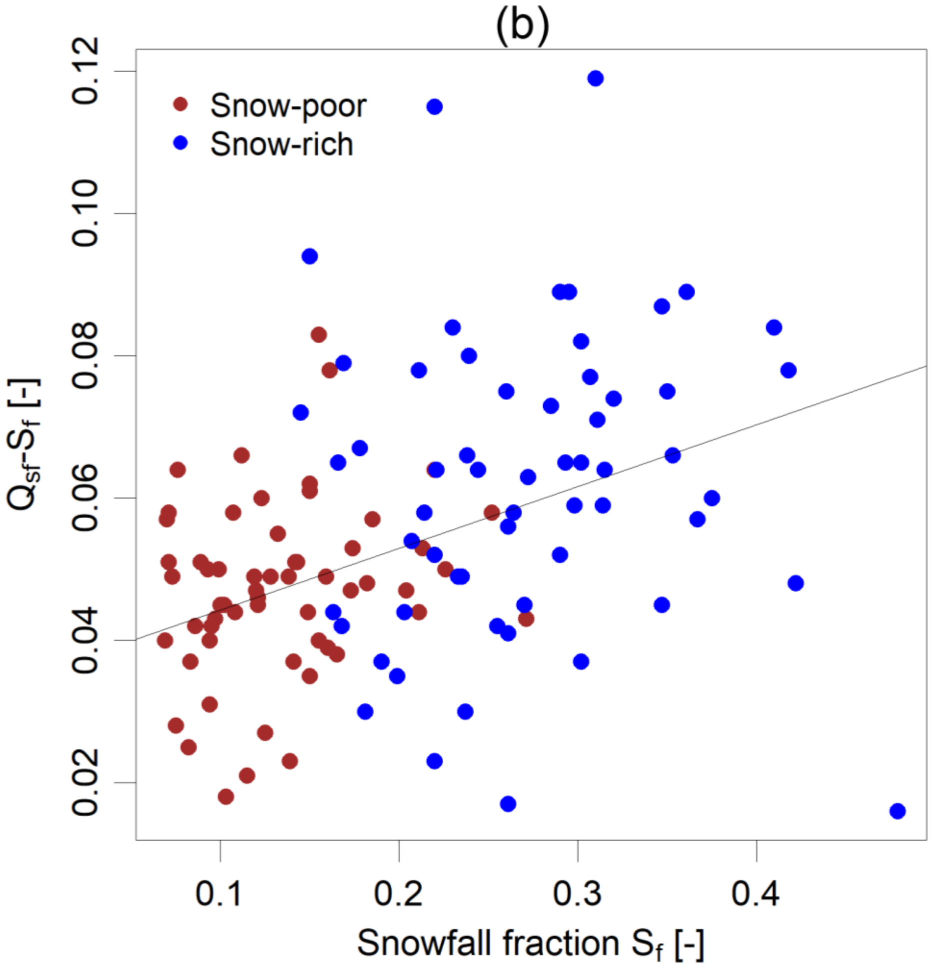
Summer (JJA) deficit volumes D_v



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

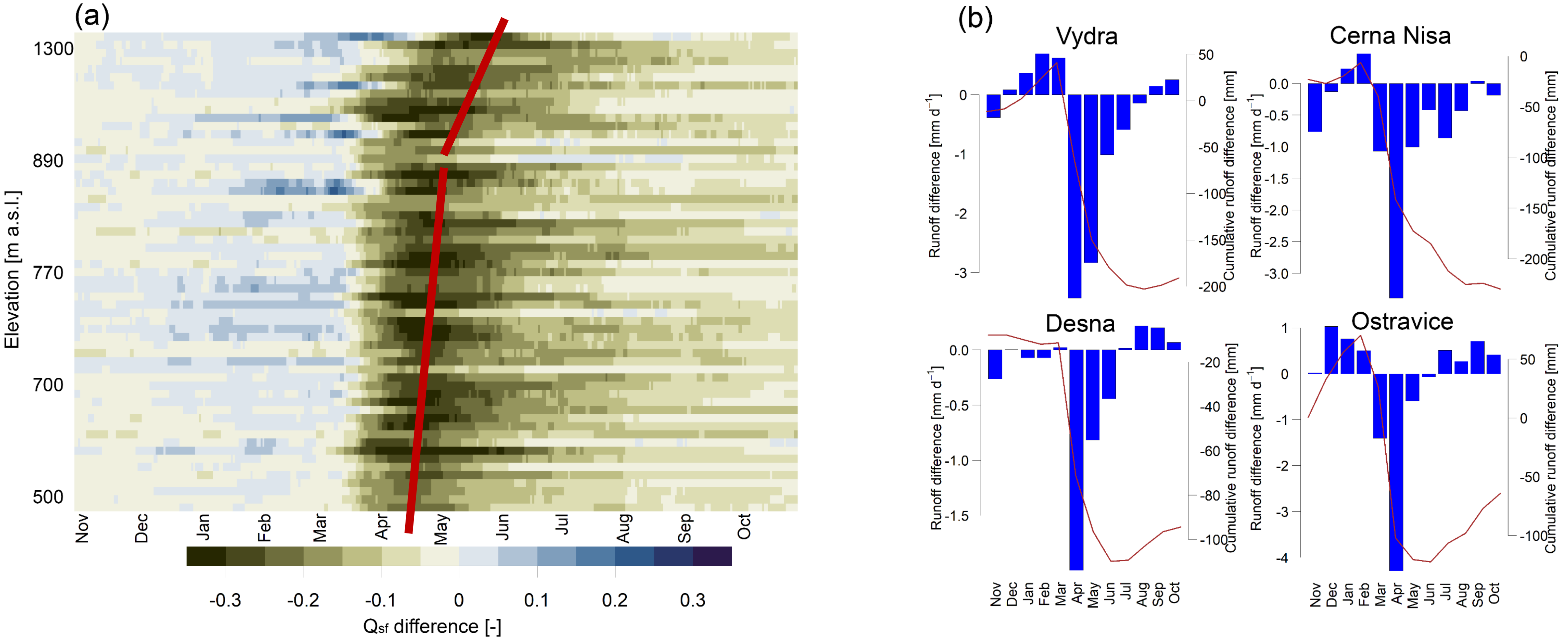
RELATIVE IMPORTANCE OF SNOW ON RUNOFF





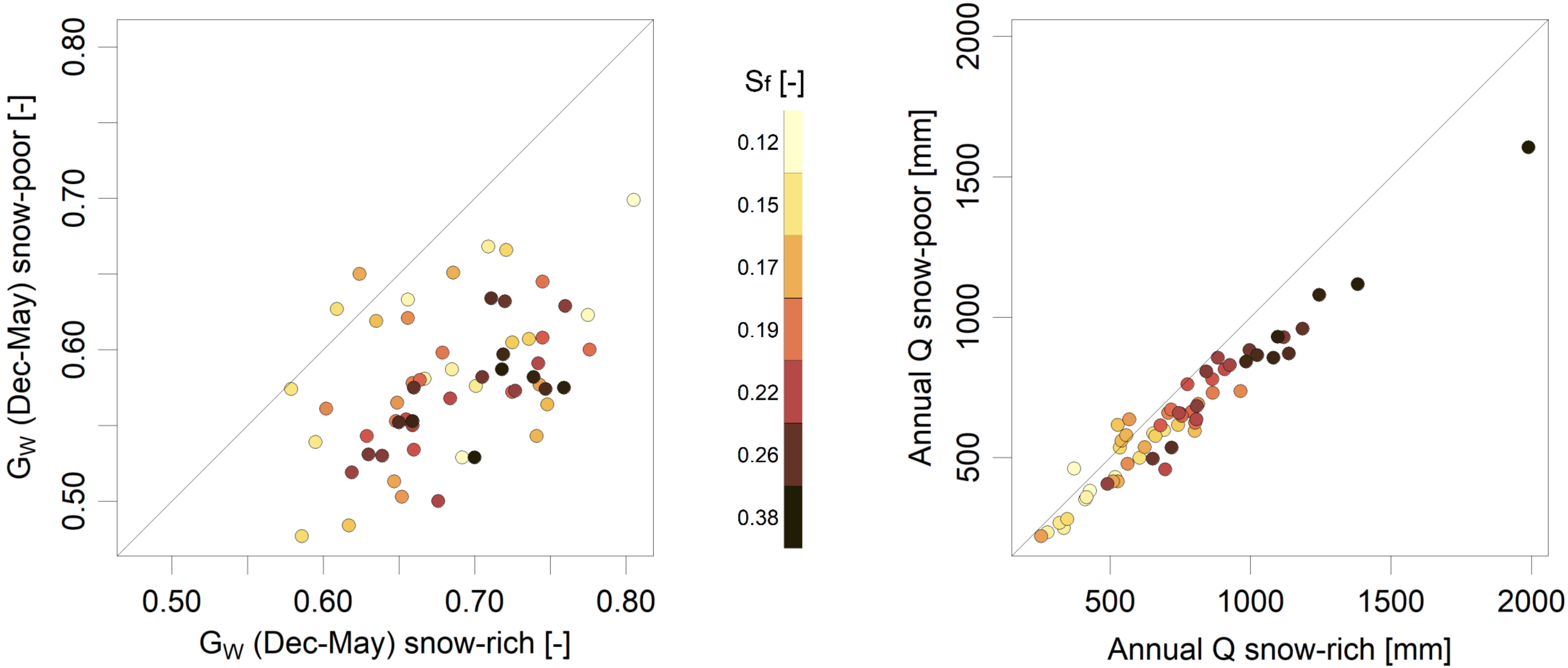
(a) A relation between snowfall fraction (S_f) and snow runoff fraction (Q_{sf}) for all study catchments. (b) A dependence of Q_{sf} and S_f difference on snowfall fraction. Individual points represent mean snowfall fractions and snow runoff fractions for snow-poor years (brown points) and snow-rich years (blue points) for individual catchments.

SNOW RUNOFF FOR SNOW-POOR AND SNOW-RICH YEARS



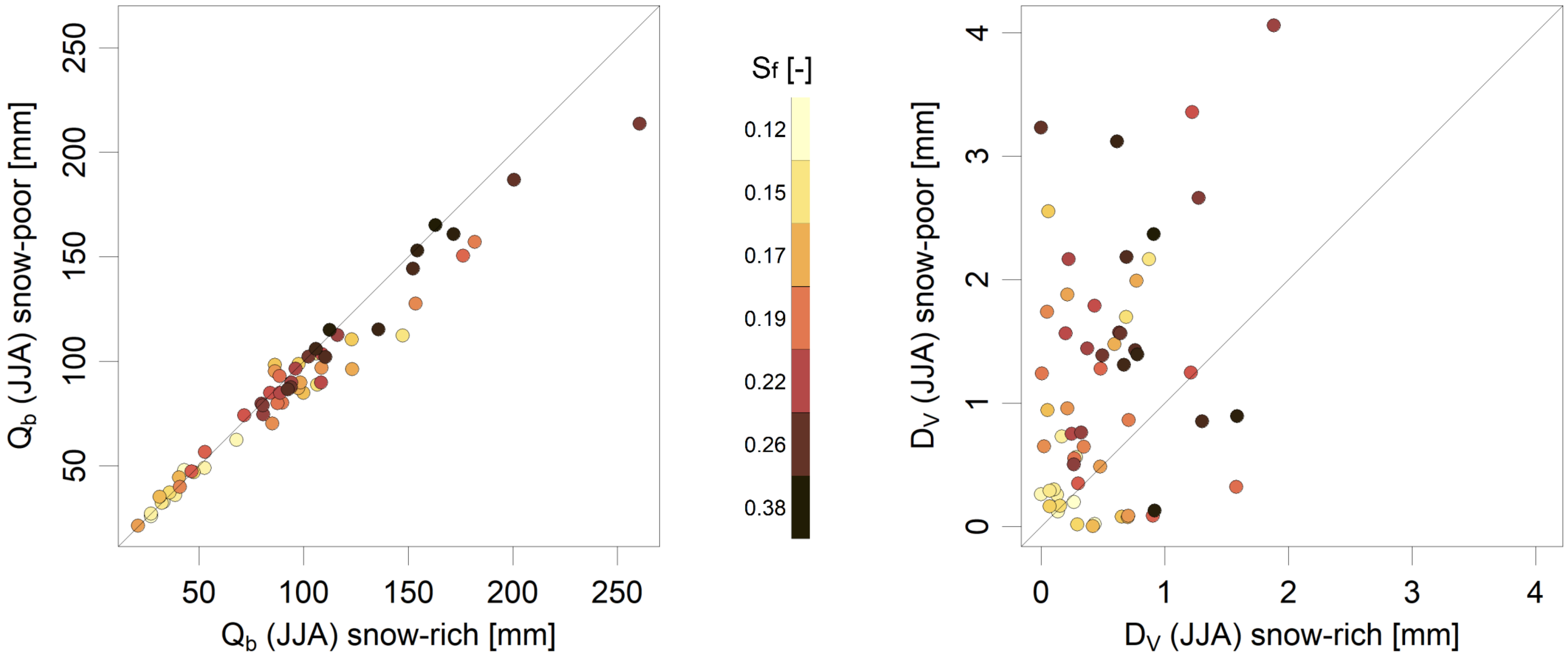
(a) Difference between mean daily Qsf [-] for snow-poor and snow-rich years. Rows represent individual catchments sorted from top to bottom according to mean catchment elevation from highest to lowest (y-axis not-to-scale), columns represent day of year. (b) Difference between mean monthly runoff (blue bars) and cumulative monthly differences in runoff (red line) for snow-poor and snow-rich years.

RECHARGE AND RUNOFF FOR SNOW-POOR AND SNOW-RICH YEARS



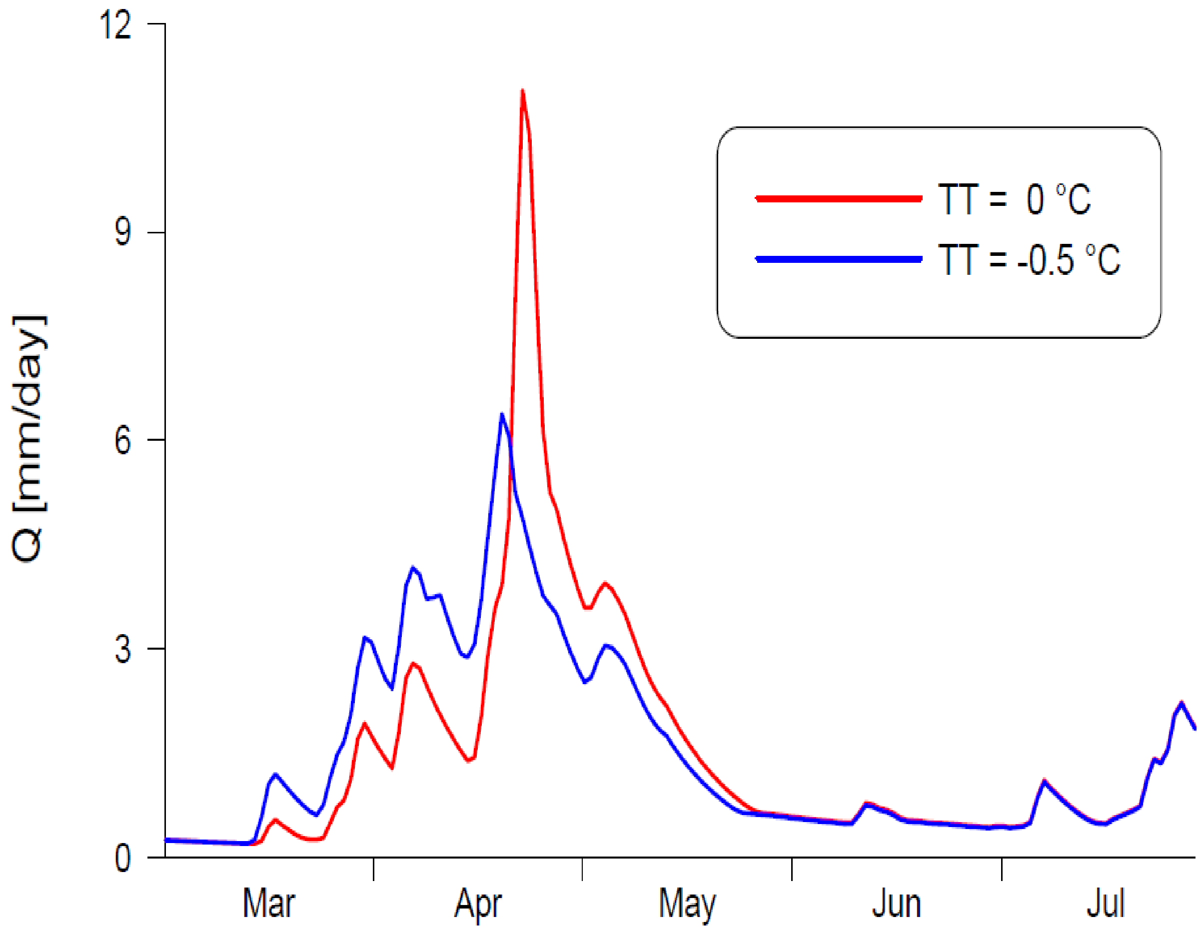
Difference in selected signatures for snow-rich and snow-poor years for study catchments; (left) Seasonal recharge fractions (Dec-May), (right) Annual runoff. Colour scale used for snowfall fraction.

LOW FLOW FOR SNOW-POOR AND SNOW-RICH YEARS



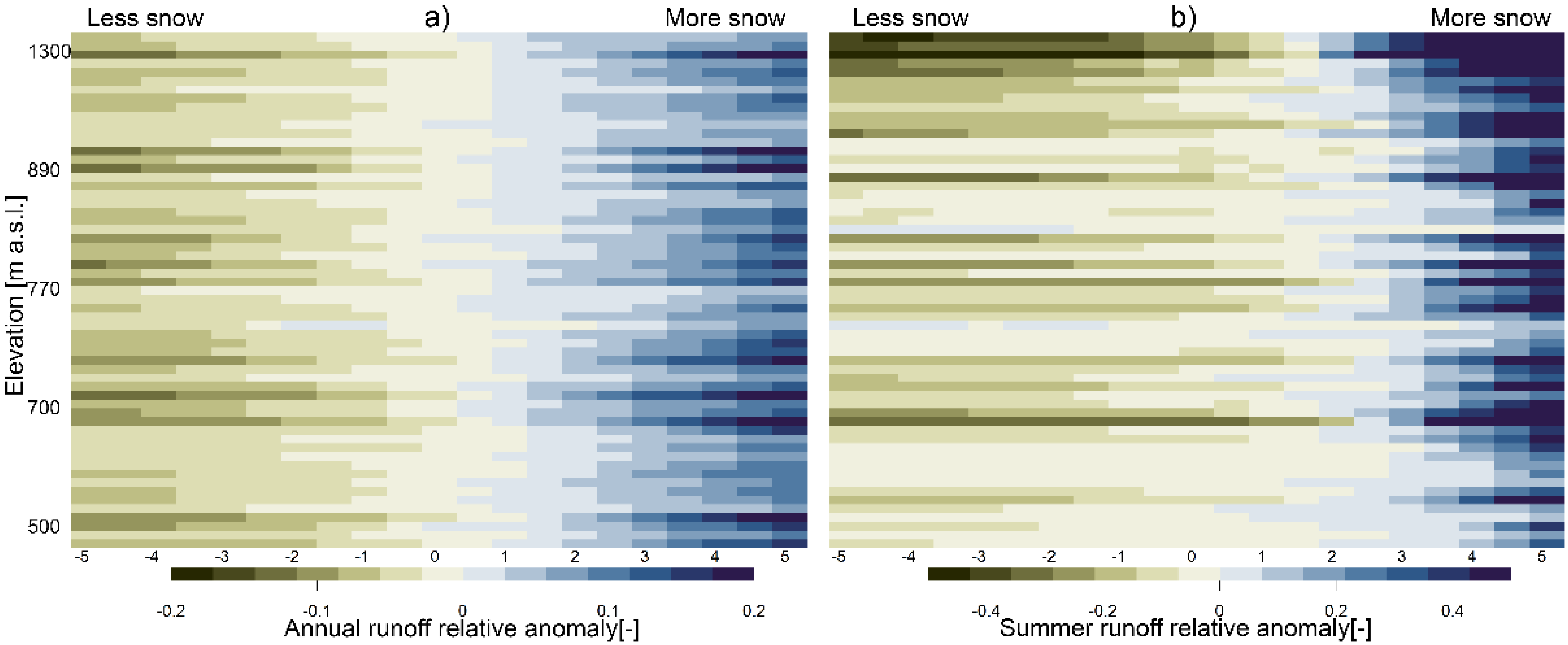
Difference in selected signatures for snow-rich and snow-poor years for study catchments; (left) Summer baseflow (JJA), (right) Deficit volumes (JJA). Colour scale used for snowfall fraction.

HBV SNOWFALL/RAIN SEPARATION: MODELLING EXPERIMENTS



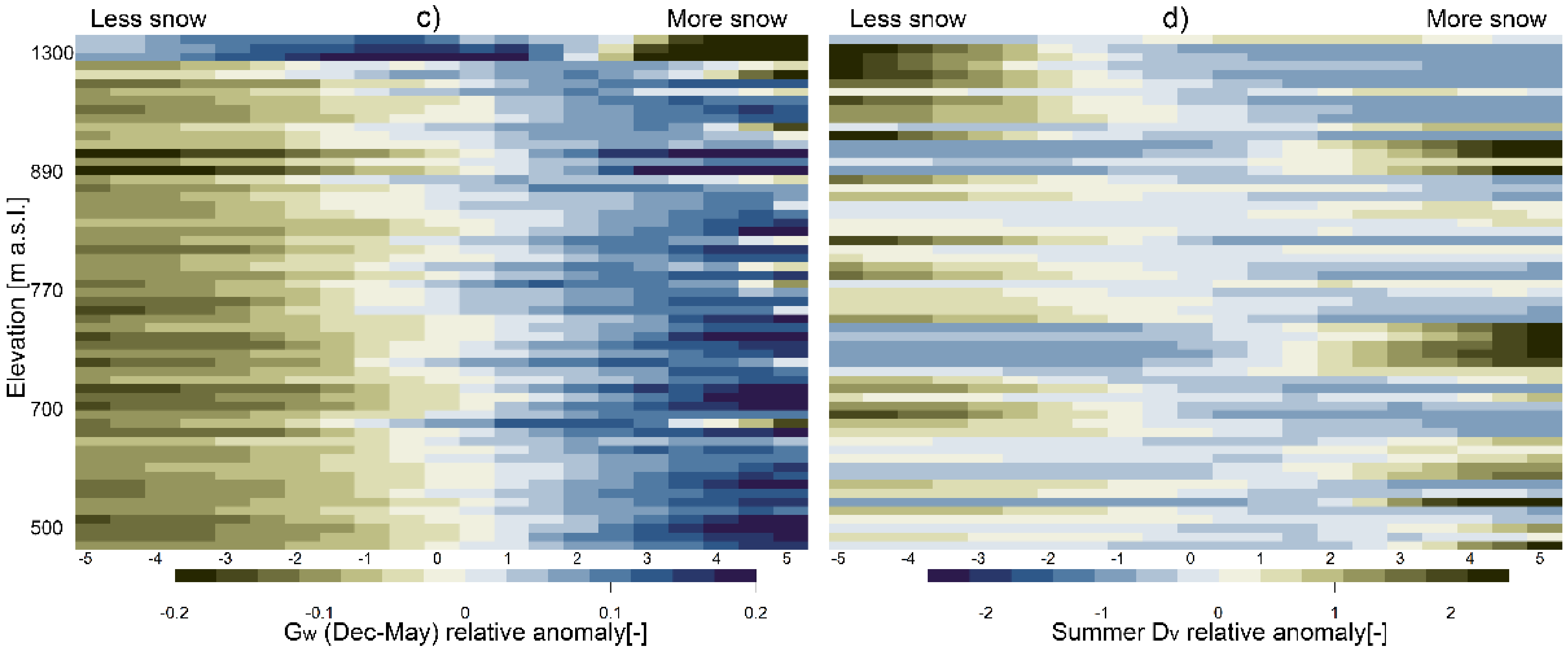
- **Threshold temperature T_T:** a parameter included in the HBV snow routine which separates precipitation to snowfall and rain.
- By changing the T_T, the amount of accumulated snow and snowmelt timing can be controlled, while other variables remain unaffected (e.g. precipitation)
- The T_T was progressively changed from -5°C to +5°C. Changes in this parameter influenced the simulated snowfall and thus SWE, snowmelt onset, melt rates and melt-out.
- This way, we simulated what would happen if snowfall turns to rain due to increase in air temperature.
- **Results in next two slides.**

CHANGES IN ANNUAL AND SUMMER RUNOFF WITH DECREASING S_f



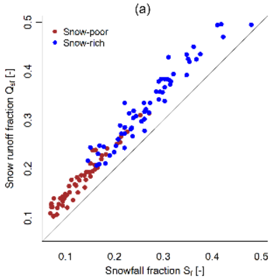
Relative change of selected signatures with increasing T_T for study catchments. (a) annual runoff, (b) summer (JJA) runoff. Rows represent individual catchments sorted from top to bottom according to mean catchment elevation from highest to lowest (y-axis not-to-scale), columns represent T_T used in model simulations. Colours show normalized values relative to their means (different scales used for individual panels).

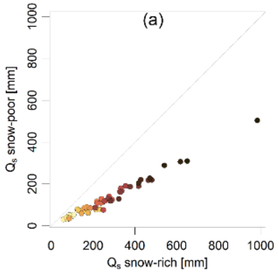
CHANGES IN G_W AND D_V WITH DECREASING S_f

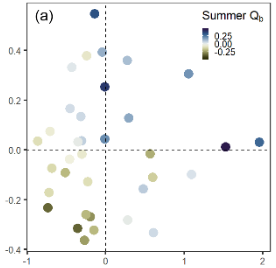


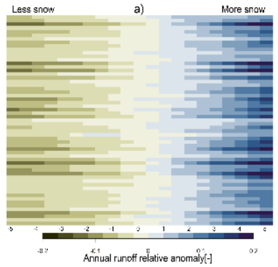
Relative change of selected signatures with increasing T_T for study catchments. (c) groundwater recharge (Dec-May) and (d) summer (JJA) deficit volumes. Rows represent individual catchments sorted from top to bottom according to mean catchment elevation from highest to lowest (y-axis not-to-scale), columns represent T_T used in model simulations. Colours show normalized values relative to their means (different scales used for individual panels).

CONCLUSIONS









- About 17-42% of the total runoff originates as snowmelt, despite the fact that 12-37% of the precipitation is falling as snow -> snow is more effective to generate catchment runoff compared to liquid precipitation.

- Snow-poor years are characterized with lower snow runoff and earlier snowmelt compared to snow-rich years. Snow in snow-poor years contributes for shorter period to runoff.

- Combined effect of summer precipitation and winter snowpack on summer baseflow -> the summer low flows might drop in the future.

- Lower snowfall fraction -> lower recharge -> lower baseflow -> lower annual runoff -> higher summer deficit volumes (the latter is unclear for many catchments)

MORE INFORMATION …

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Importance of snowmelt contribution to seasonal runoff and summer low flows in Czechia

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