Long-term monitoring and hydrological responses to changing climate at Lysina catchment

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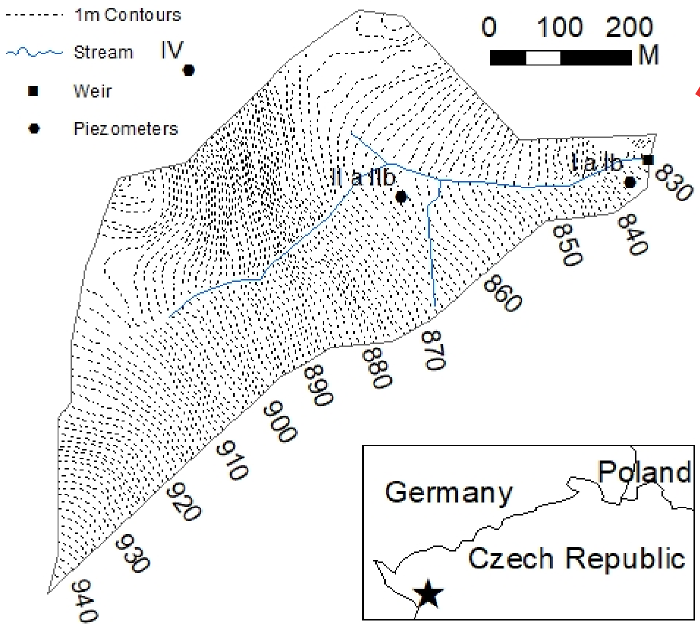
CZECH GEOLOGICAL SURVEY 1919

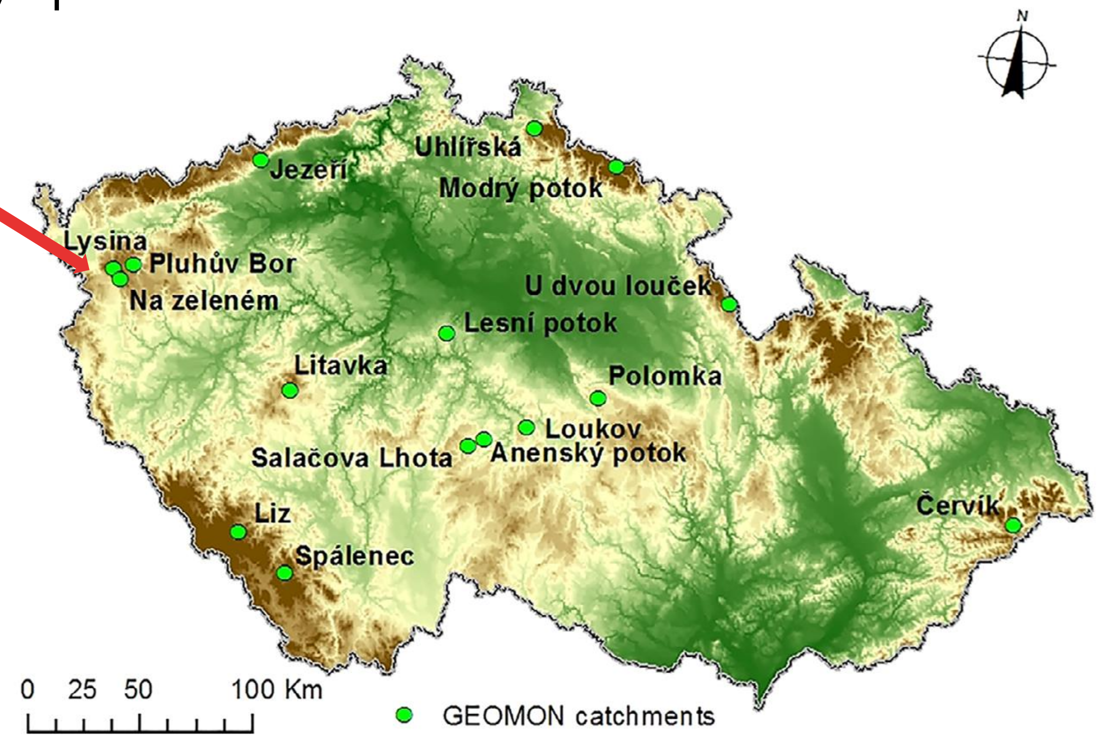
Introduction

- Headwater catchments = ecosystems sensitive to changes
- Anticipated climate change – increase of temperature and seasonal redistribution of precipitation
- Are there any changes in water balance of headwater catchments already today?
- What are the future perspectives of hydrological pattern?

Lysina catchment

- ICP IM, ICP Waters, LTER - Long-Term Ecological Research
- GEOMON – monitoring network
- Area 27.3 ha; elevation range 829-949 a.s.l.
- Vegetation cover: Norway spruce >99%

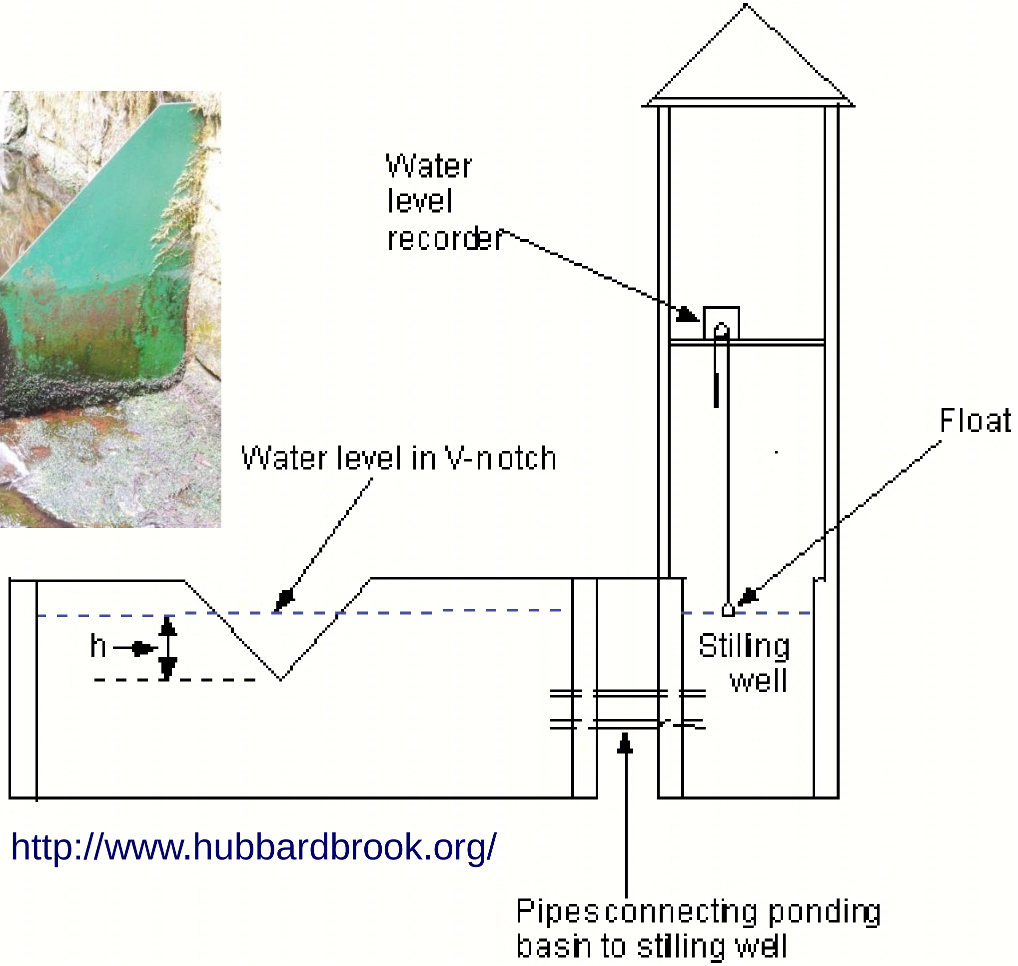




>33 years of monitoring (11/1989),
Soils: Podzols with low base saturation
Bedrock: leucocratic granite
Strongly acidic runoff (pH < 5.0) with a high concentration of disolved organic carbon and nitrogen (DOC and DON) and toxic aluminium (Ali)

Streamflow measurements

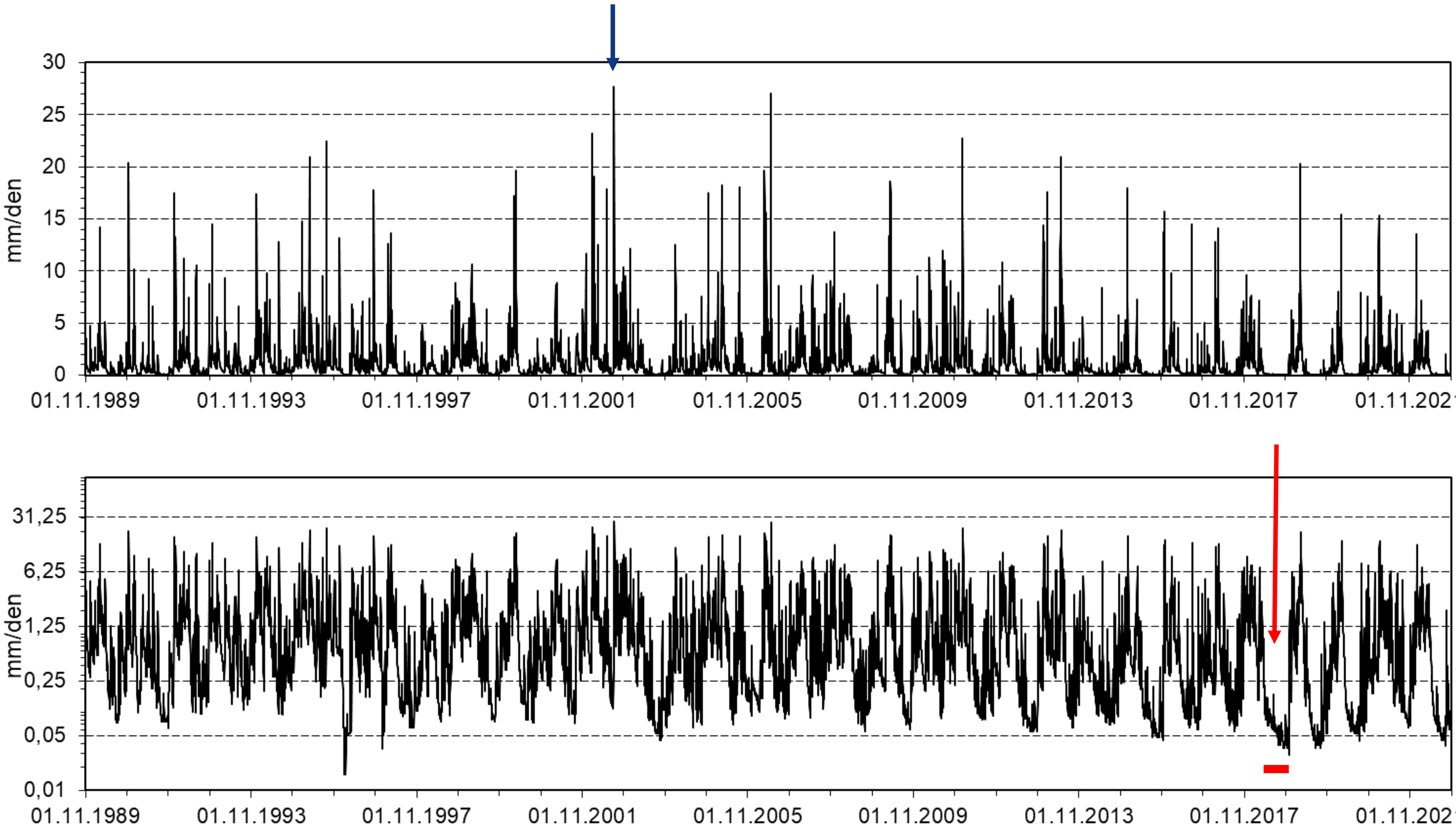
V-notch (90°)
Pressure probe for water level measurement
A float-operated OTT Thalimedes shaft encoder with integral data logger



http://www.hubbardbrook.org/

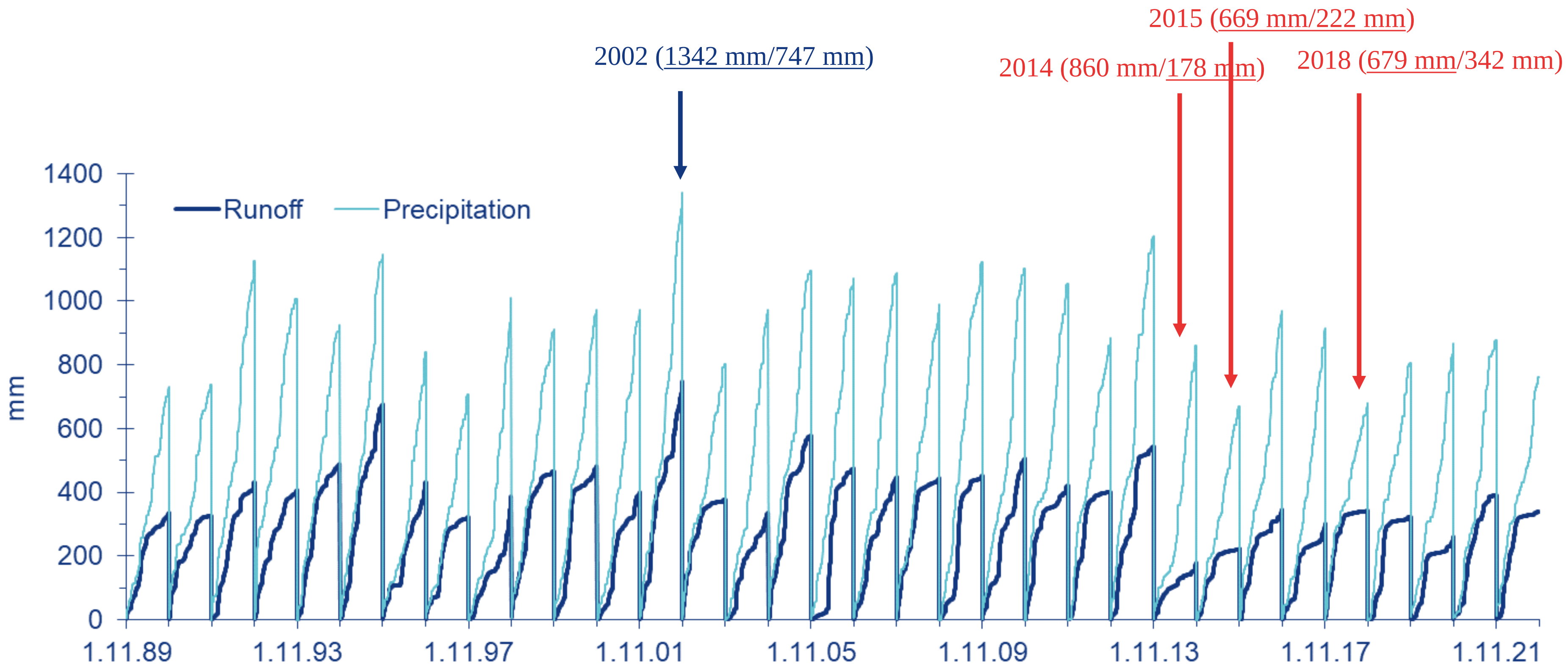
Daily runoff 1990 – 2022

Qd_{max} 12.8. 2002   27.7 mm day^{-1} (88 l s^{-1})



Qd_{min} AUTUMN 2018

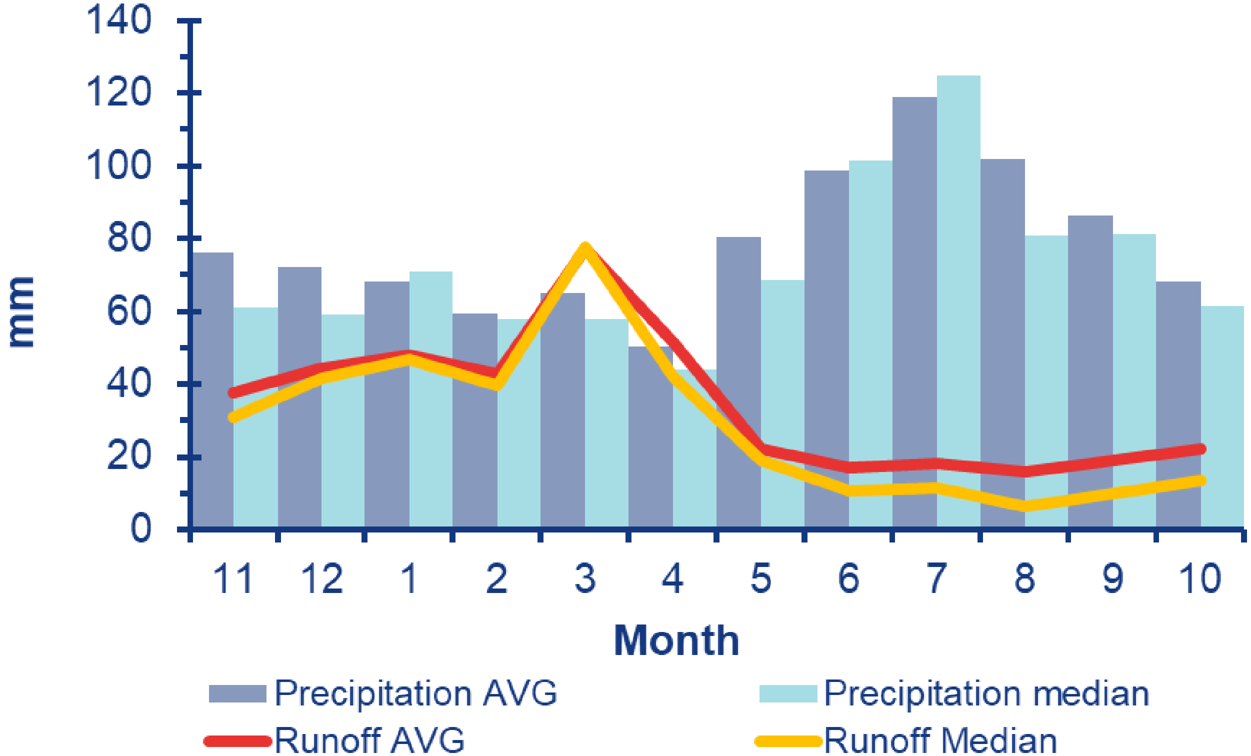
Lysina - precipitation and runoff 1990-2022



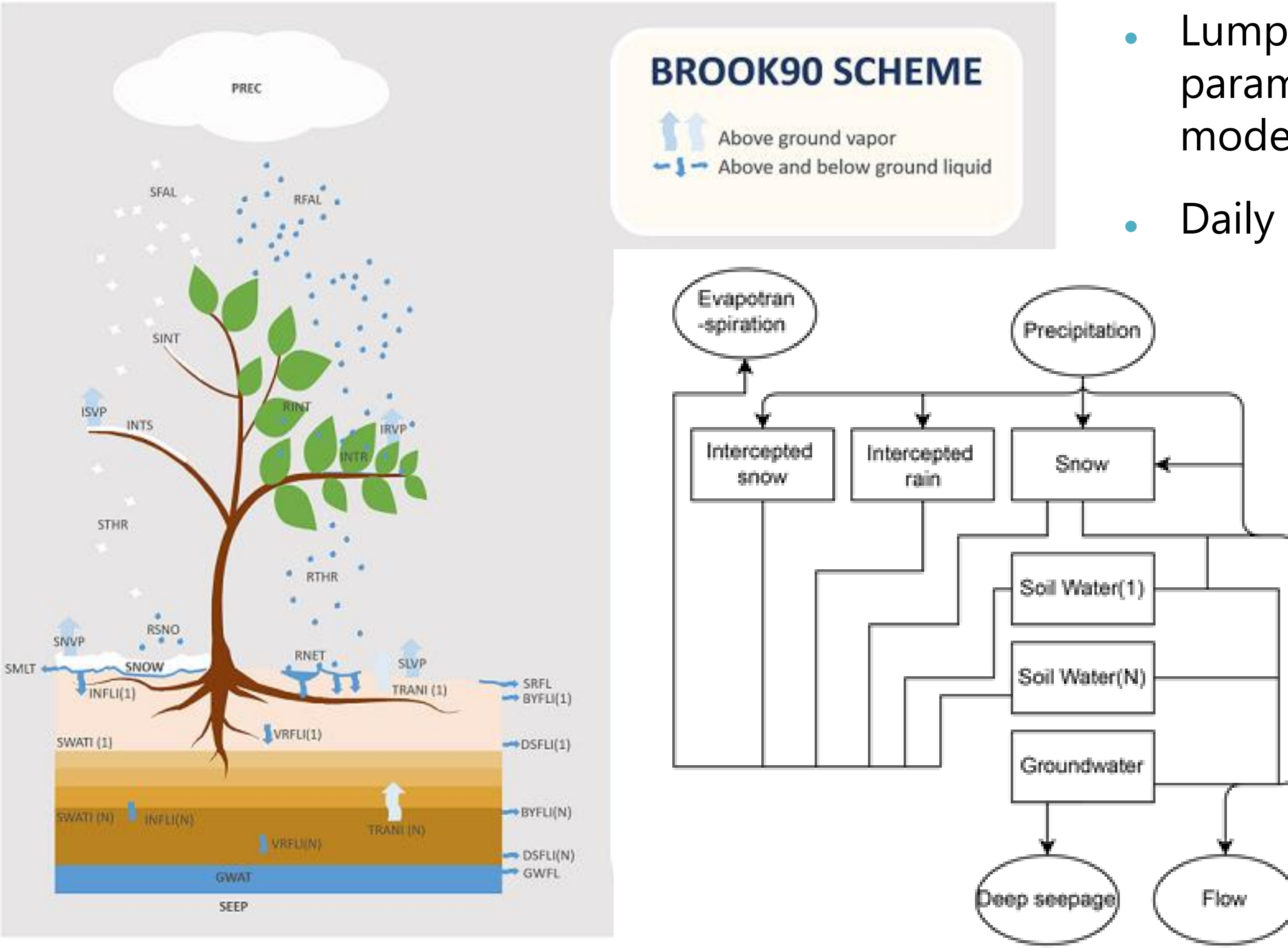
Precipitation 946 mm yr^{-1}, runoff 412 mm yr^{-1} (rainfall-runoff coefficent 0.43), evapotranspiration 534 mm, mean annual temperature 5.9°C

Lysina - precipitation and runoff 1990-2022

- Annual runoff maximum – 77 mm in March, minimum in August 16 mm (AVG), 7 mm (Median), mean annual precipitation maximum – July (119 mm), minimum – April (50 mm)



Hydrological model Brook90

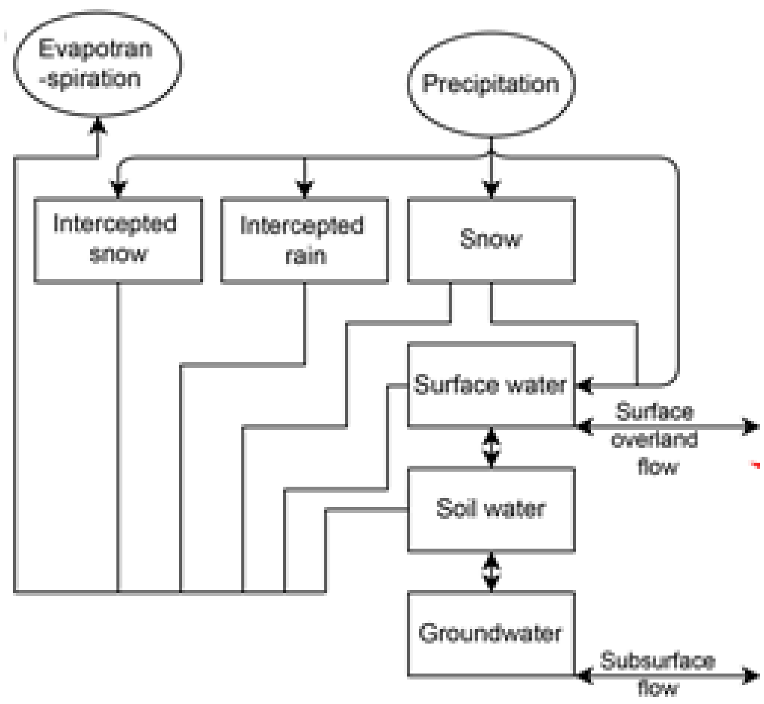


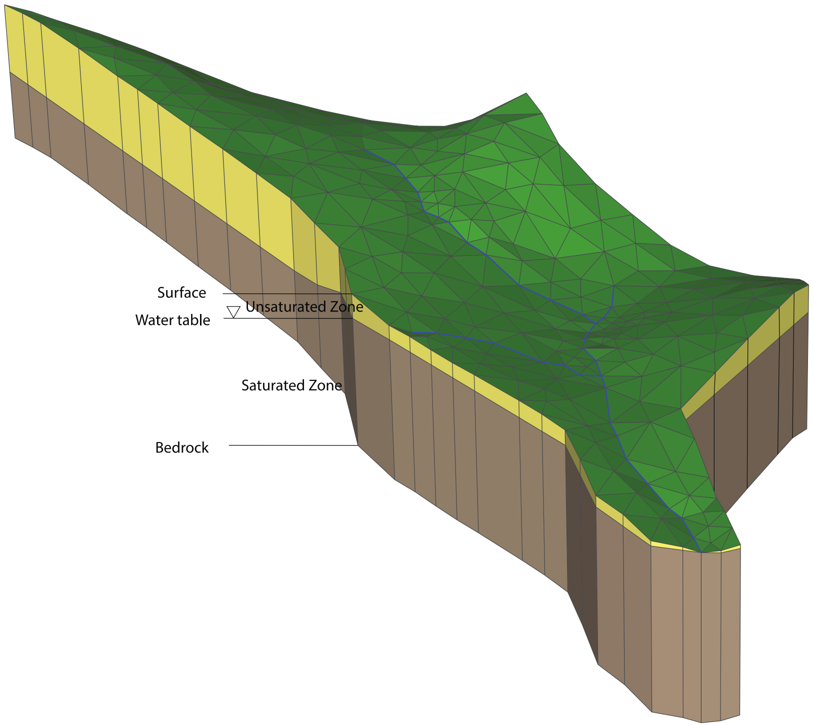
- Lumped parameter model
- Daily step

. (Kronenbergand Oehlchlagel, 2019)

Hydrological model PIHM

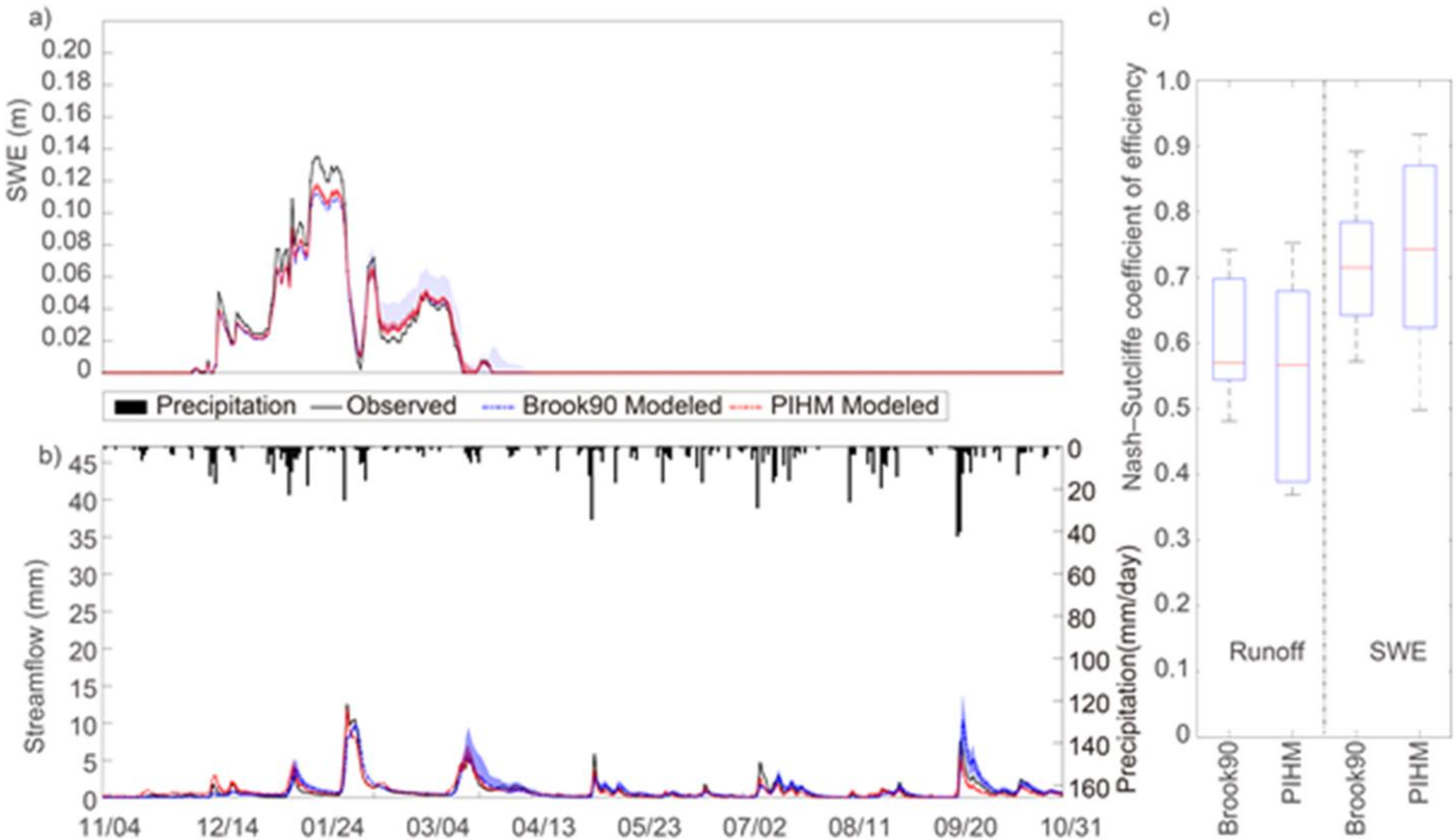
- Distributed, coupled surface-subsurface hydrological model
- Hourly time step





Hydrological models calibration

Simulation of runoff and snow water equivalent (SWE) on Lysina catchment in calibration year 2004



The boxplot shows variability of NSE (Nash Sutcliffe coeficient of efficiency) in each year from 1990 to 2019

Zheng, Lamačová, Yu, Krám, Hruška, Zahradníček, Štěpánek, Farda (2021)

Hydrological parameter validation

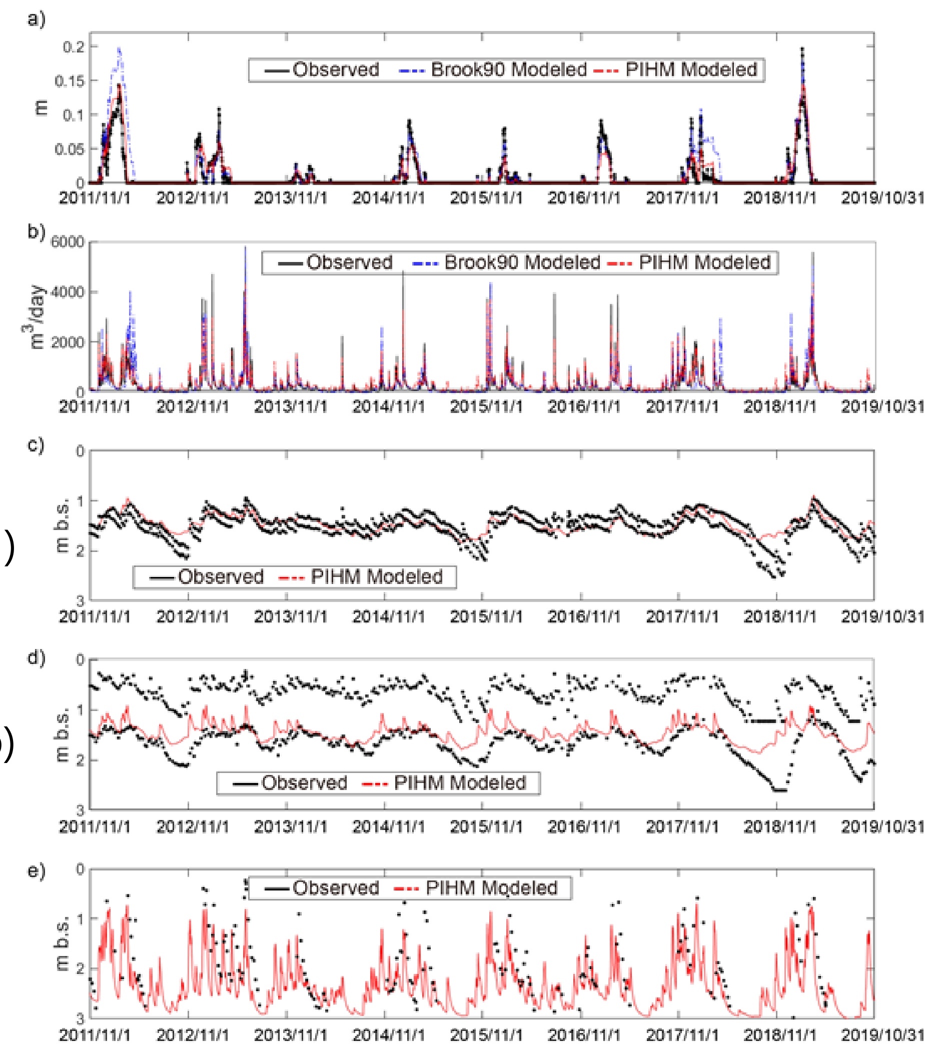
Snow water equivalent (SWE)

Runoff

Groundwater depth (piezometers Ia, Ib)

Groundwater depth (piezometers Ia, IIb)

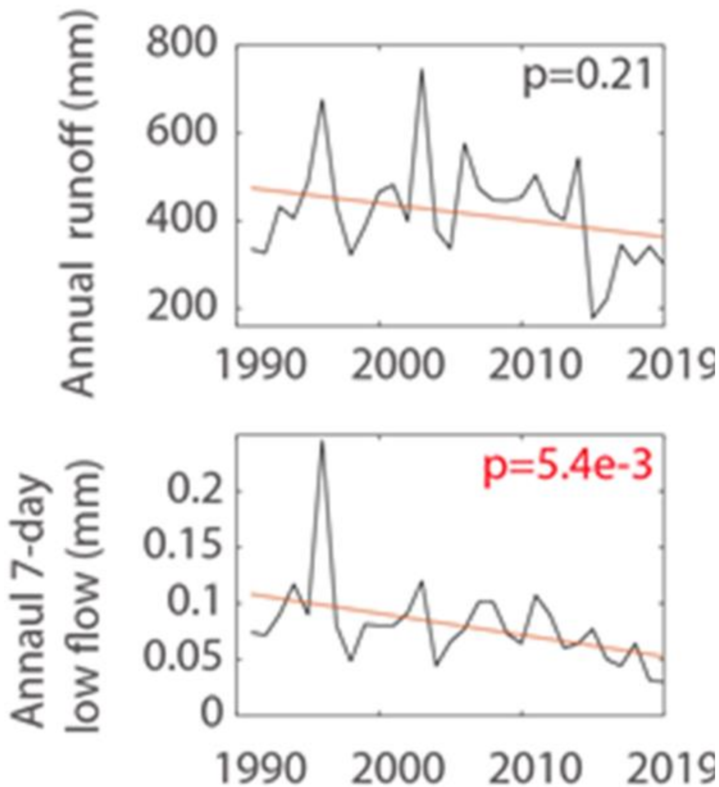
Groundwater depth (piezometers IV)



Zheng, Lamačová, Yu, Krám, Hruška, Zahradníček, Štěpánek, Farda (2021)

Runoff and precipitation trends

Significant increase of 0.39°C per 10 ($p<0,01$)
Precipitation: No trend in annual data, January increase 1.4 mm/month



1990-2021

Runoff: negligible significant decrease
 4 mm/yr, and significant decrease in July
(0.7 mm/yr)

The 7-day low flow (the average flow during the seven consecutive days of lowest flow throughout the year) decreased significantly during the study period

Mann-Kendall test

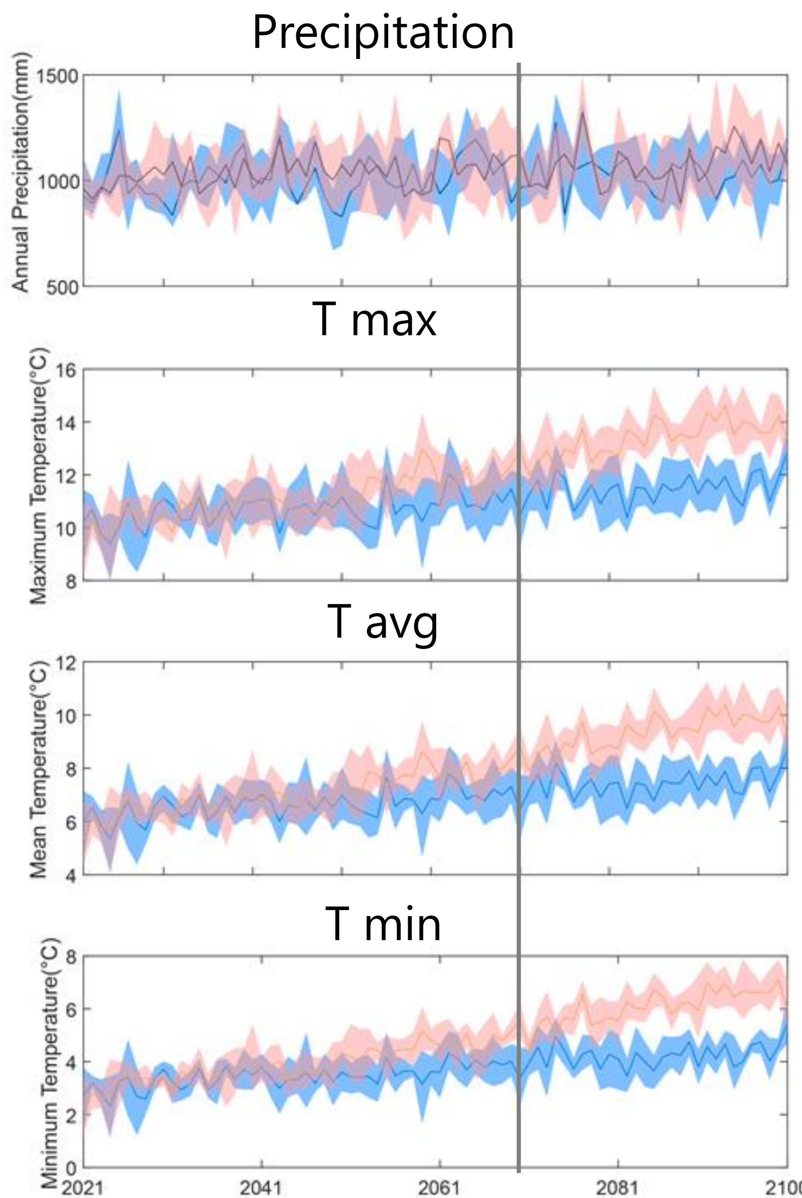
Zheng, Lamačová, Yu, Krám, Hruška, Zahradníček, Štěpánek, Farda (2021)

Projected climate for Lysina (2021-2100)

Climate projections are based on regional climate model simulations (RCM) prepared within the Euro-CORDEX program.
Data from 5 RCM, spatial resolution 0.11 degree (aprox. 12.5 km) – corrected by Quantile matching method to fix systematic deviations from the observed climate
2 emission scenarios: RCP – representative concentration pathways (radiative forcing in W . M^{-2})

„more optimistic scenario“
RCP 4.5

„pesimistic scenario“
RCP 8.5



Increase:
8 % (RCP 8.5)
4 % (RCP 4.5)

Increase:
3.5°C (RCP 8.5)
1.5°C (RCP 4.5)

Hydrological response to climate change projections at Lysina catchment 2071-2100

Model Brook90 | Model PIHM

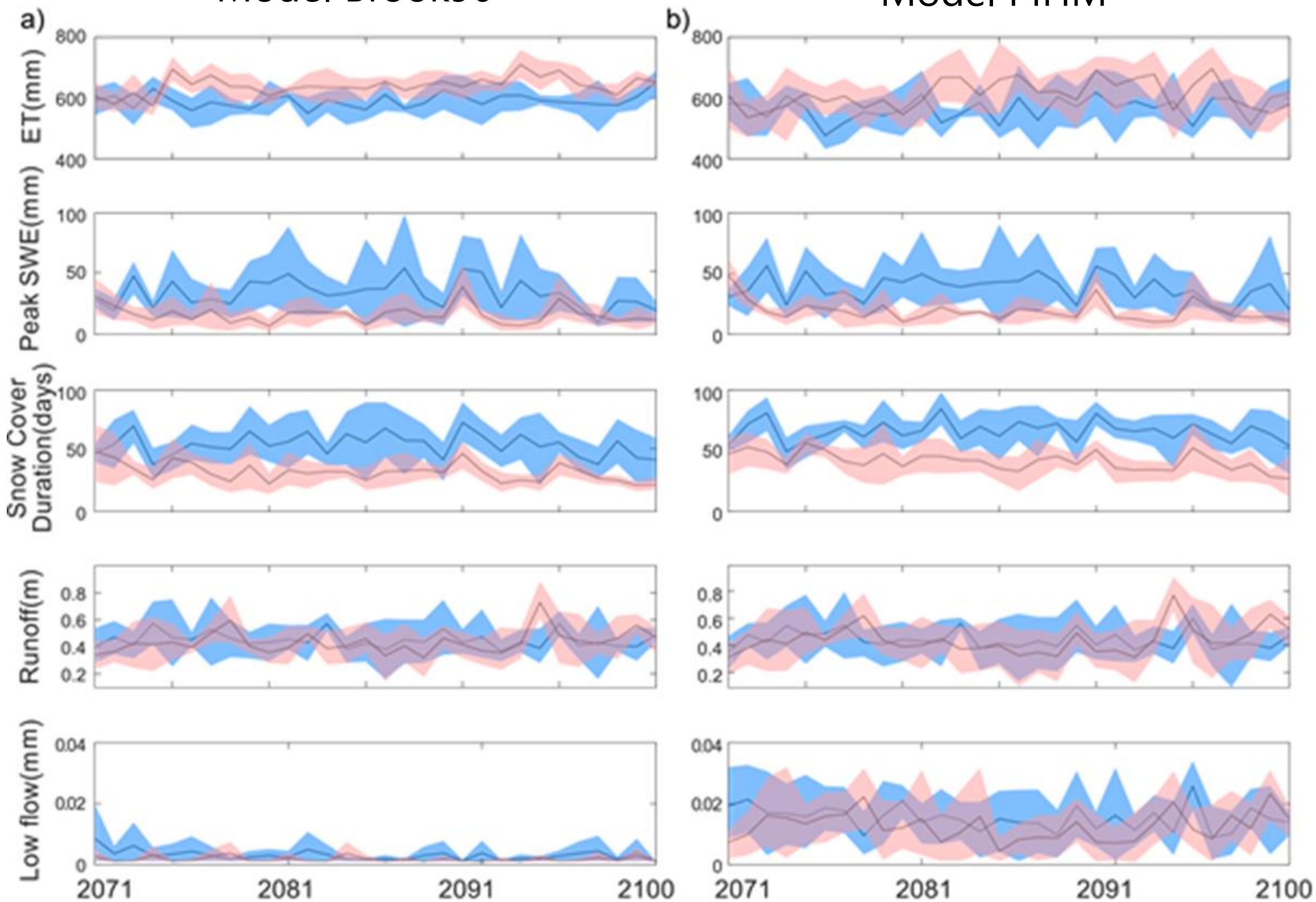
Evapotranspiration

Peak snow water equivalent

Snow cover duration

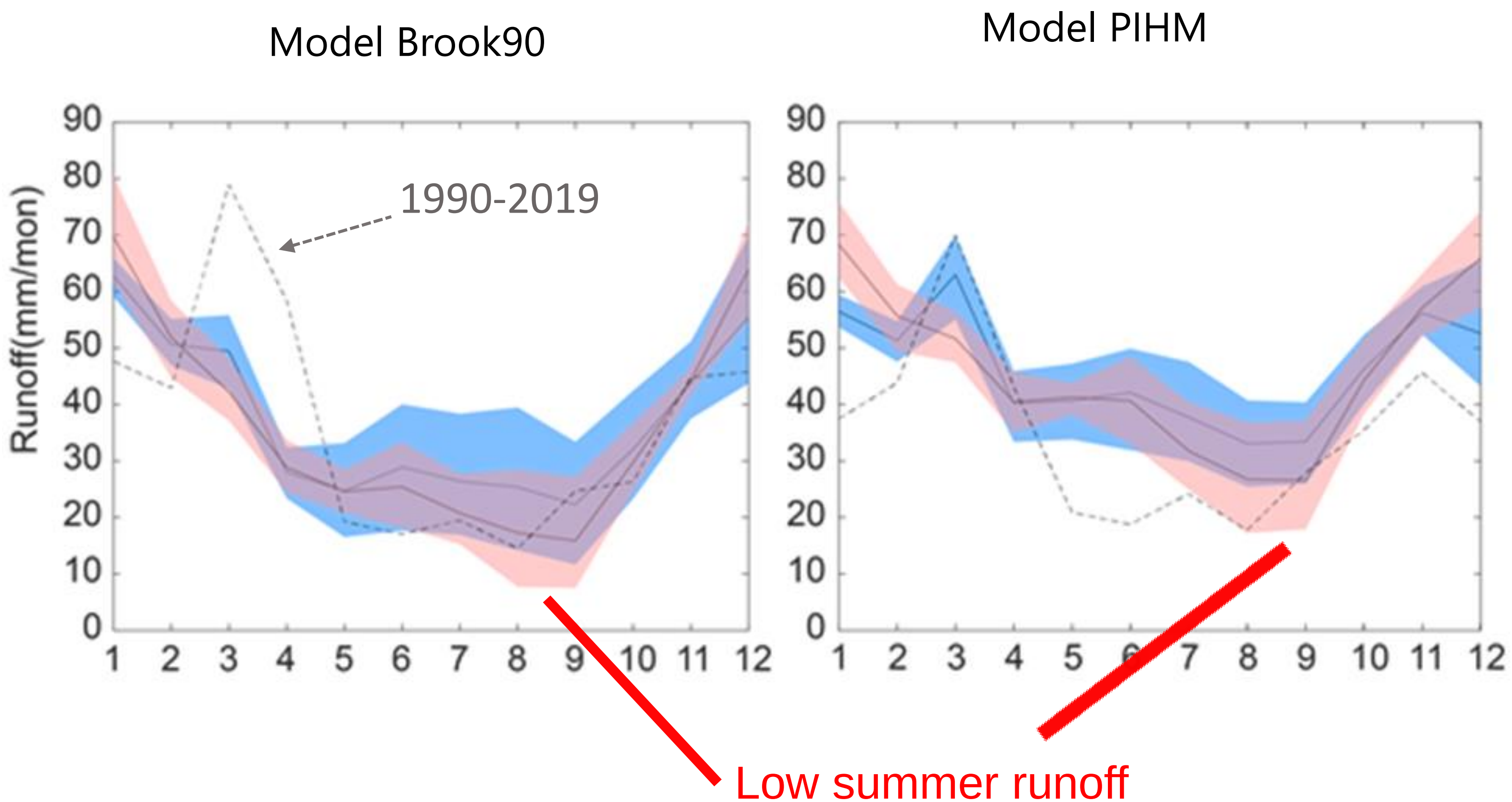
Runoff

Low-flow



Projected runoff for Lysina (2071-2100)

Precipitation increase will cause an increase in mean annual runoff (by 7% on average Brook90 respective 14% PIHM, 2071-2100, RCP 8.5).
Runoff increase Dec-Feb. The shift of the spring maximum from March to January and at the same time significant summer periods of drought with low flows.



Conclusions

- Climatic and hydrological conditions in the Lysina catchment in the period 33 monitored years (1990-2021) are characterized by a significant increase in air temperatures, insignificant changes in annual precipitation and a mild decrease in annual outflows
- The regional climate models predicts in the most pessimistic scenario RCP 8.5 for the period 2071-2100 in the studied catchment a large increase of average temperatures (by 3.5°C), but also higher annual precipitation. According to the hydrological models Brook90 and PIHM it will cause an increase in annual average runoff, formed mainly in the three winter months.
- The runoff maxima are projected to shift from March to January and significant summer periods of drought with very low flows are expected

Hydrological modelling papers - Lysina

- Benčoková A., Krám P., Hruška J. **2011**. Future climate and changes in flow patterns in Czech headwater catchments. *Climate Research* 49: 1-15.
  (model Brook90, Lysina and Pluhův Bor catchment)

- Lamačová A., Hruška J., Krám P., Stuchlík E., Farda A., Chuman T., Fottová D. **2014**. Runoff trends analysis and future projections of hydrological patterns in small forested catchments. *Soil and Water Research* 9: 169-181
  (model Brook90, GEOMON network)

- Yu X., Lamačová A., Duffy C., Krám P., Hruška J., White T., Bhatt G. **2015**. Modeling long term water yield effects of forest management in a Norway spruce forest. *Hydrological Sciences Journal* 60: 174-191.
  (models Brook90 and PIHM, Lysina)

- Yu X., Lamačová A., Duffy C., Krám P., Hruška J. **2016**. Hydrological model uncertainty to spatial evapotranspiration estimation method. *Computers and Geosciences* 90: 90-101.
  (models Brook90 and PIHM, Lysina)

- Zheng W., Lamačová A., Yu X., Krám P., Hruška J., Zahradníček P., Štěpánek P., Farda A. **2021**. Assess hydrological responses to a warming climate at the Lysina Critical Zone Observatory in Central Europe. *Hydrological Processes* 35: e14281, 1-17.
  (models Brook90 and PIHM, Lysina)

Interception

- Annual interception on catchment was 26% (254 mm) of the open area precipitation in the period of 1994–2019
- The mean annual simulated interception was only 14% (142 mm)
- The difference was in evapotranspiration components, especially transpiration, that compensated the lower interception loss compared to observed.
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