



Climate Induced Shifts in Seasonal Runoff of the Gunt River: Implications for Agriculture and Hydropower in the Pamirs

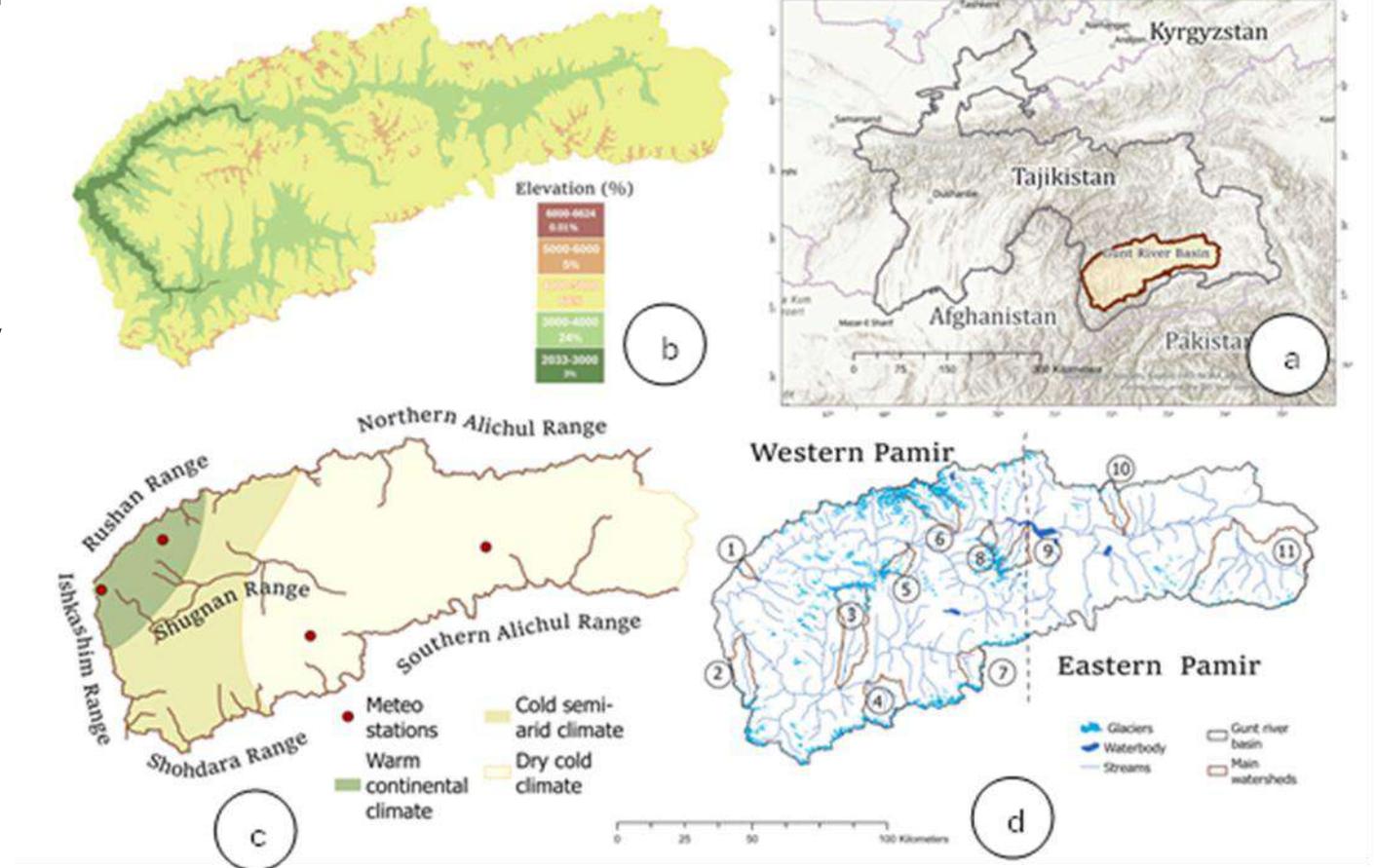


The importance of studying the water flow regime of the Gunt River:

- Glacial meltwater is a vital ecosystem service
- playing a key role in supporting key economic sectors (agriculture and energy production)
- and ensuring resource security for local communities throughout the valley

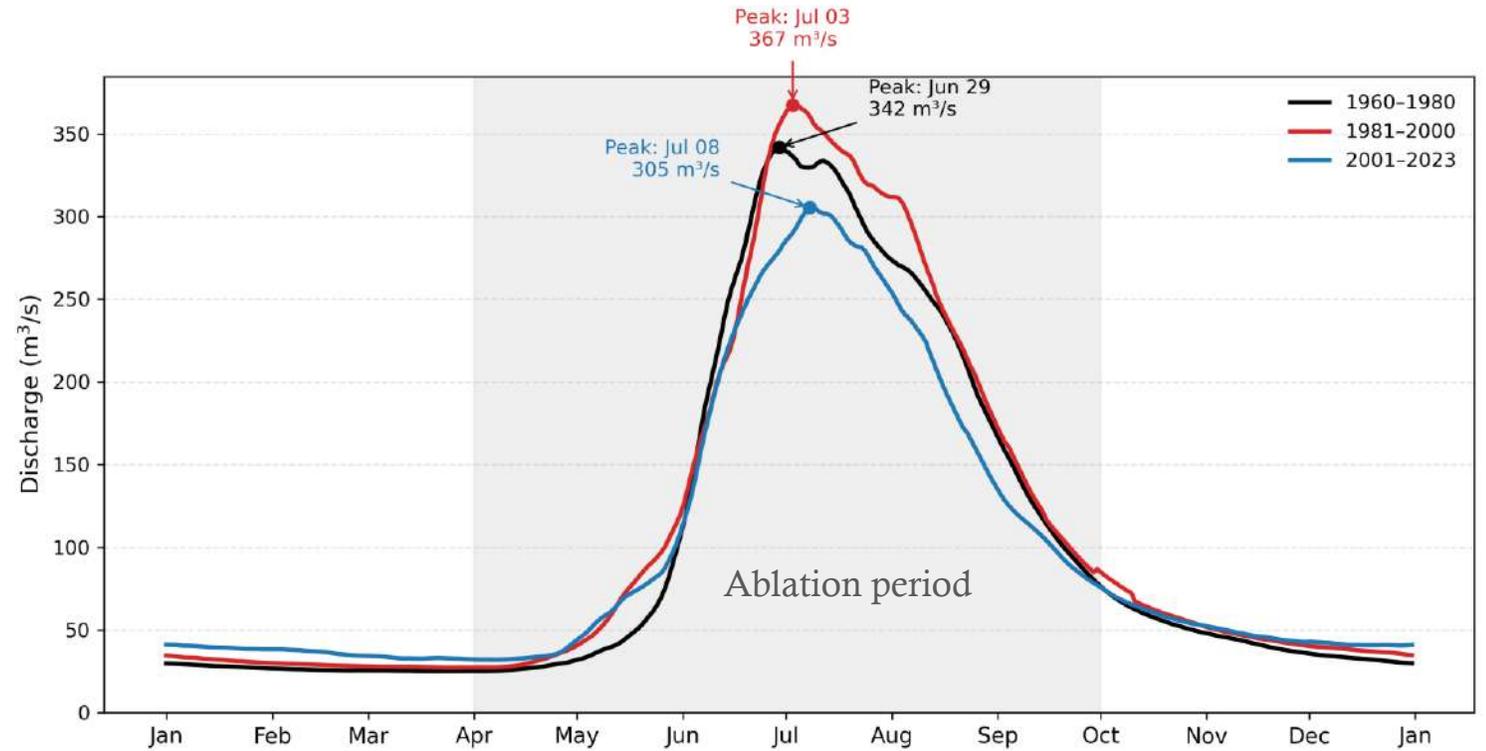


- The Gunt River Valley is located in the south-eastern Pamirs.
- The topography is extremely heterogeneous
- Altitude and climate significantly influence the basin's climatic conditions, glaciation patterns, and hydrological dynamics.

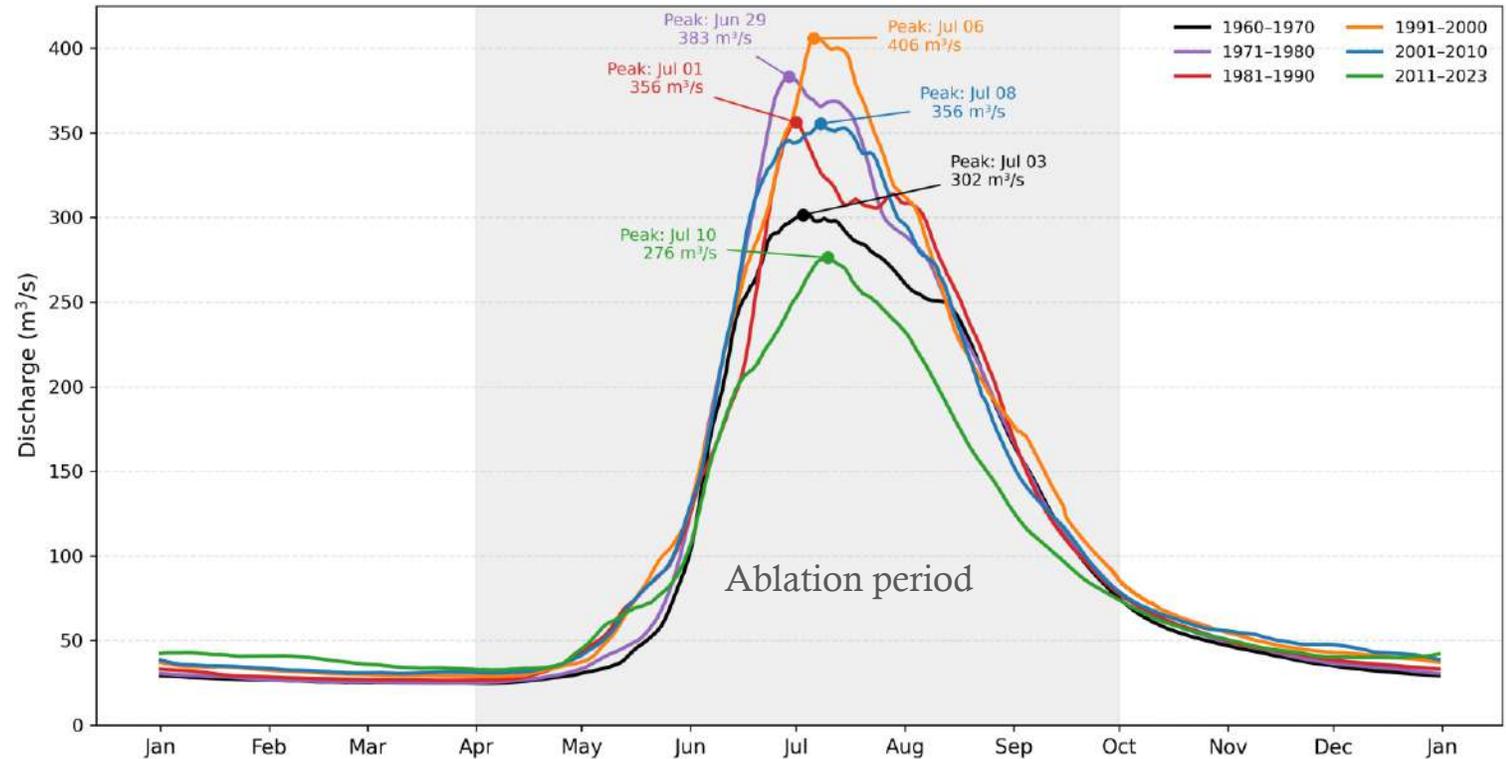


- Hydrological data were obtained from Tajik Hydromet (1960-2023)
- Climatic data were collected from four weather stations and analyzed in XLStat.
- Trend and change-point analysis, Mann–Kendall / Seasonal Kendall for discharge, T, P.
- Sen's slope for trend magnitude.
- Pettitt or Buishand test for regime shifts (timing of major change).
- One-way ANOVA (F-test) on means of key metrics across P1–P2–P3.
- Levene and Brown–Forsythe for homogeneity of variances

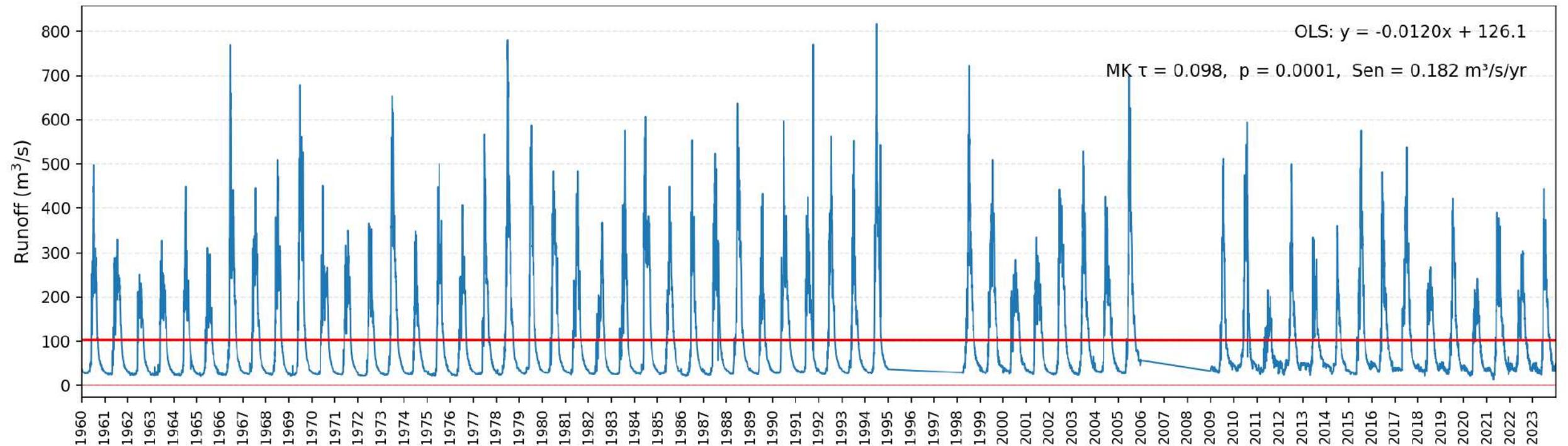
- River discharge exhibits pronounced spatio-temporal variability
- Lower summer but higher winter and spring baseflow
- Faster late-summer decline
- Notable decline in peak discharge



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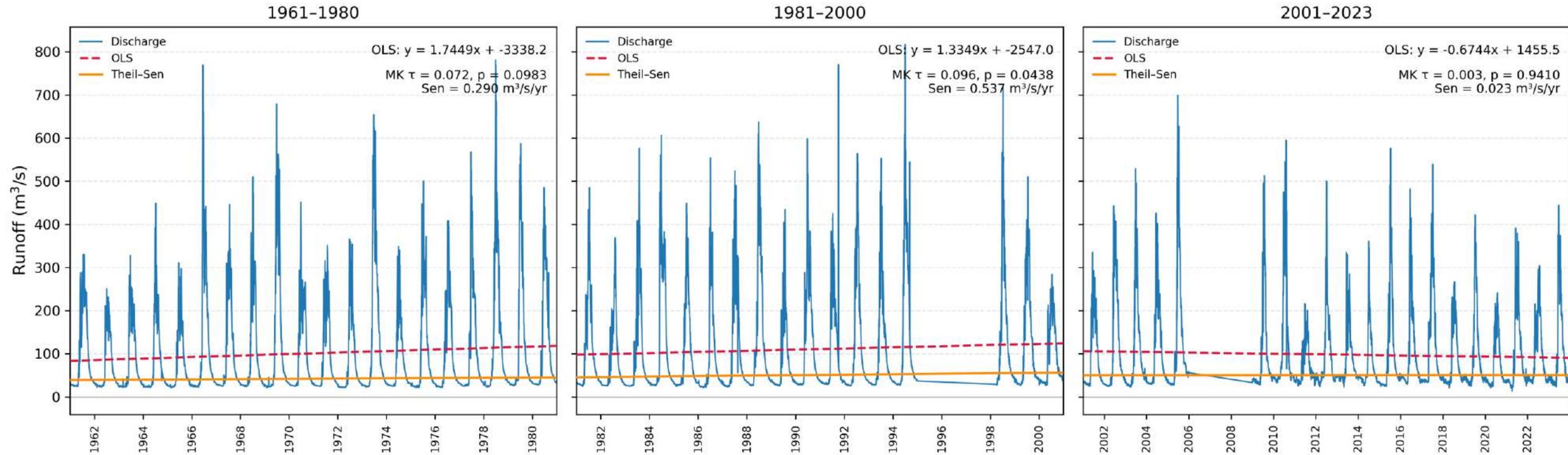
- MK $\tau = 0.098$, $p = 0.0001$, Sen = $0.182 \text{ m}^3/\text{s}/\text{yr}$



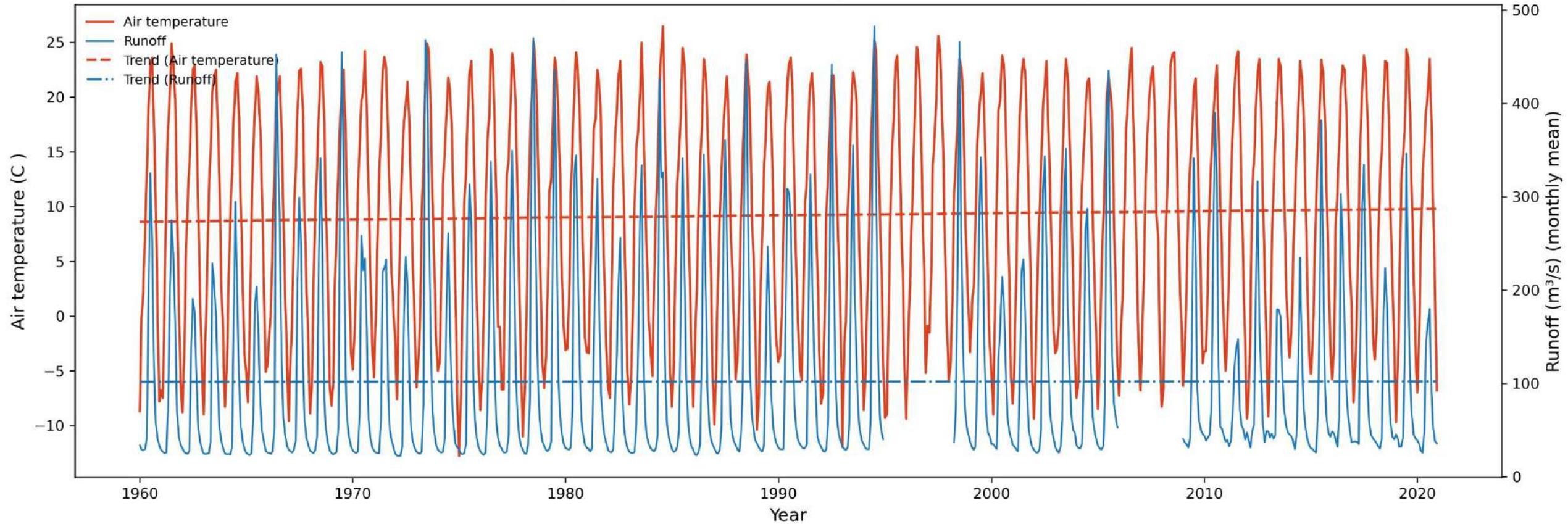
MK: $\tau \approx 0.072$, $p \approx 0.10$ → weak, borderline upward monotonic trend. Sen's slope: $+0.29 \text{ m}^3/\text{s}/\text{yr}$ (small increase). OLS line: gently positive

MK: $\tau \approx 0.096$, $p \approx 0.049$ → significant upward trend. Sen's slope: $+0.54 \text{ m}^3/\text{s}/\text{yr}$ (largest of the three periods). OLS line: positive, supporting the MK result

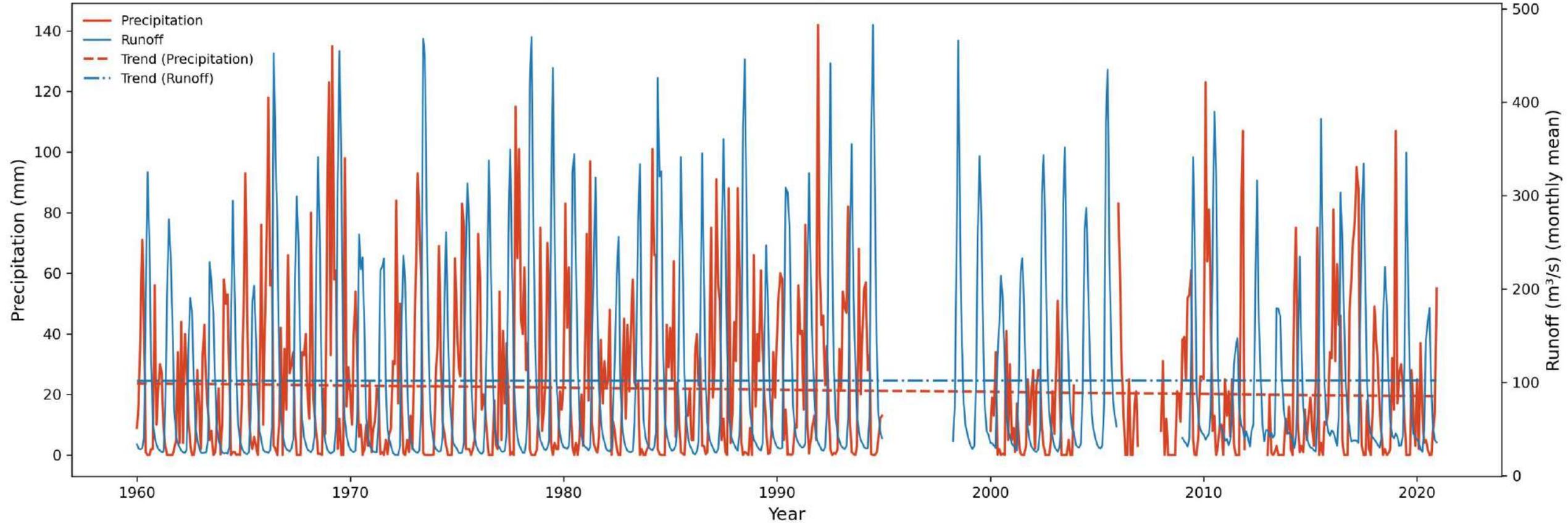
MK: $\tau \approx 0.003$, $p \approx 0.94$ → no monotonic trend. Sen's slope: $+0.02 \text{ m}^3/\text{s}/\text{yr}$ (essentially zero). OLS line: slightly negative



Air temperature vs Runoff (Monthly) — Gunt Basin / Khorog

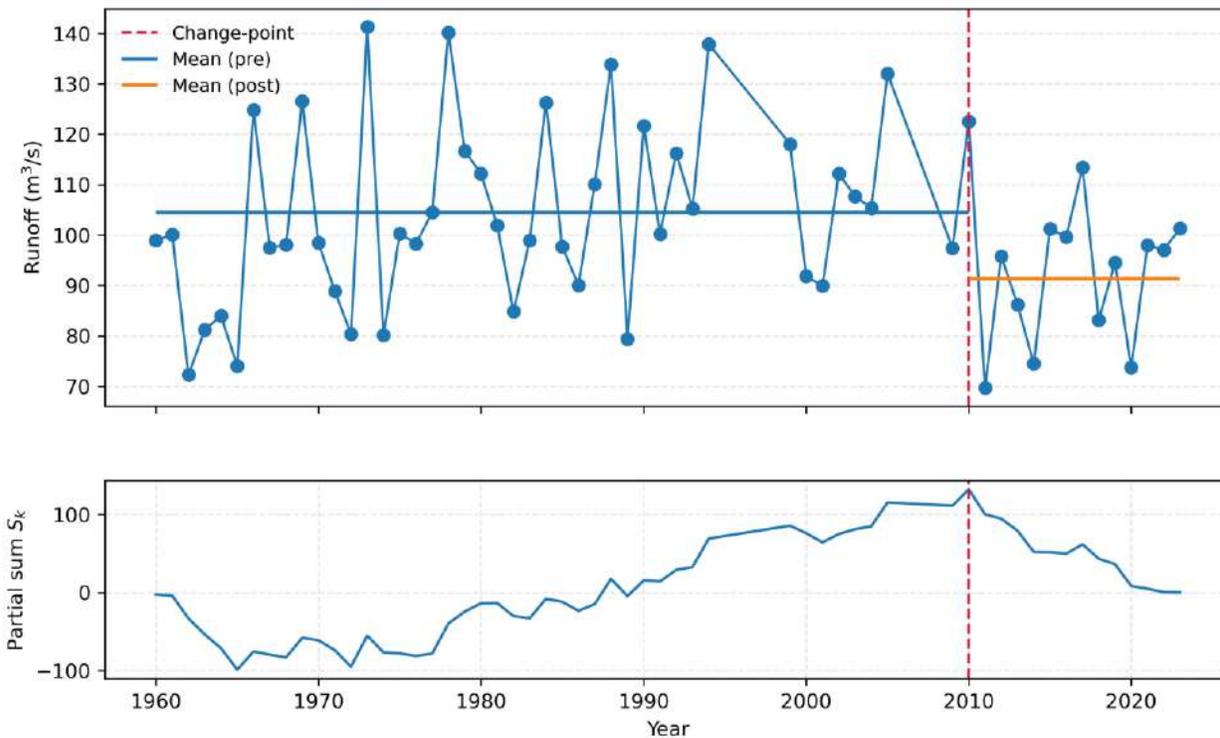


Precipitation vs Runoff (Monthly) — Gunt Basin / Khorog

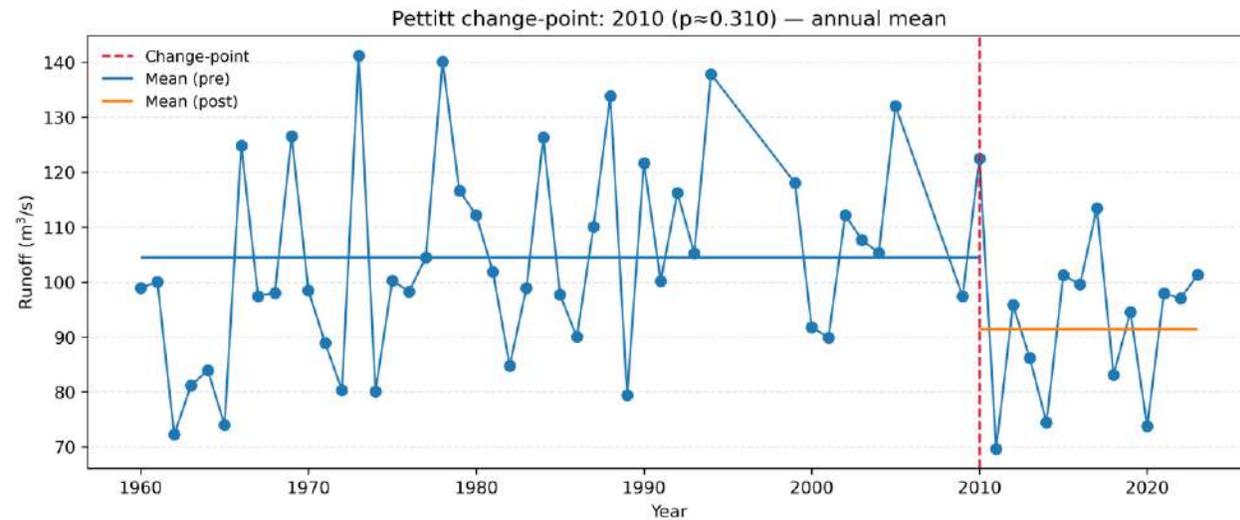


-statistically significant change-point at 2010 ($p \approx 0.02$)
with lower annual mean runoff after 2010 (drop from ~ 105 m^3/s to ~ 95 m^3/s)

Buishand range: CP 2010, $Q=12.84$, $p=0.019$ — annual mean



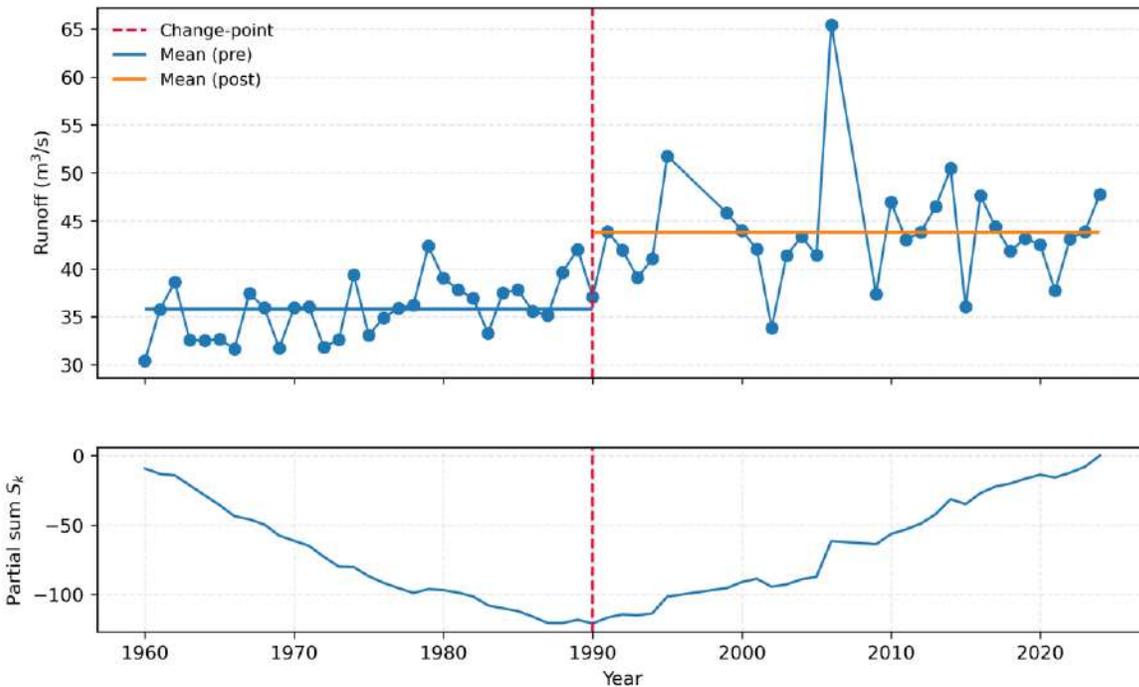
-2010 as the most likely change-point for annual data,
but with low significance ($p \approx 0.31$)



Change-point test (accumulation)

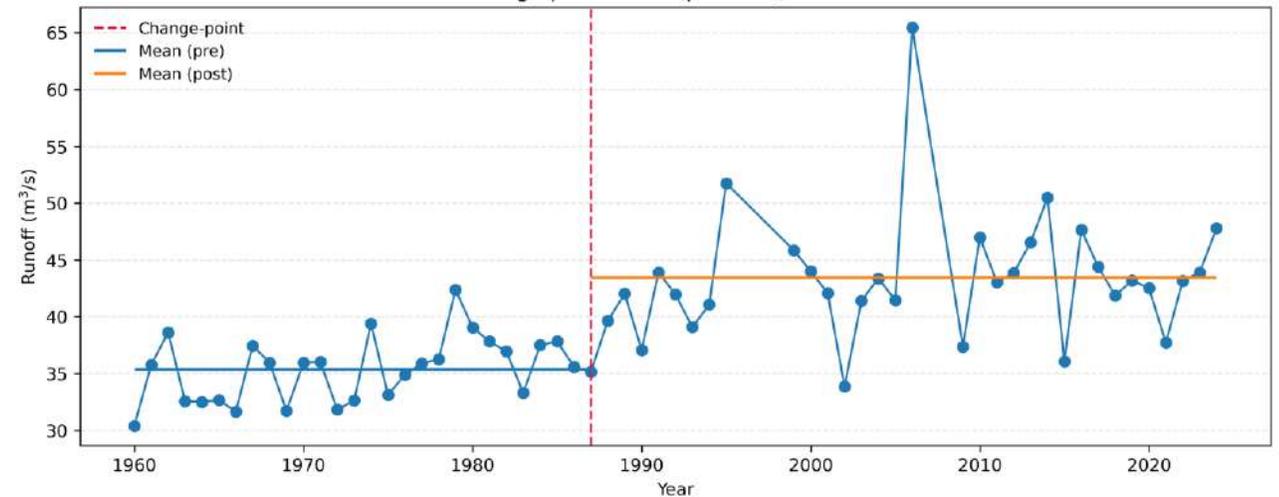
- significant upward shift in mean winter runoff
- change-point -1990 ($p < 0.001$)

Buishand range: CP 1990, $Q=19.89$, $p=0.000$ — accum mean



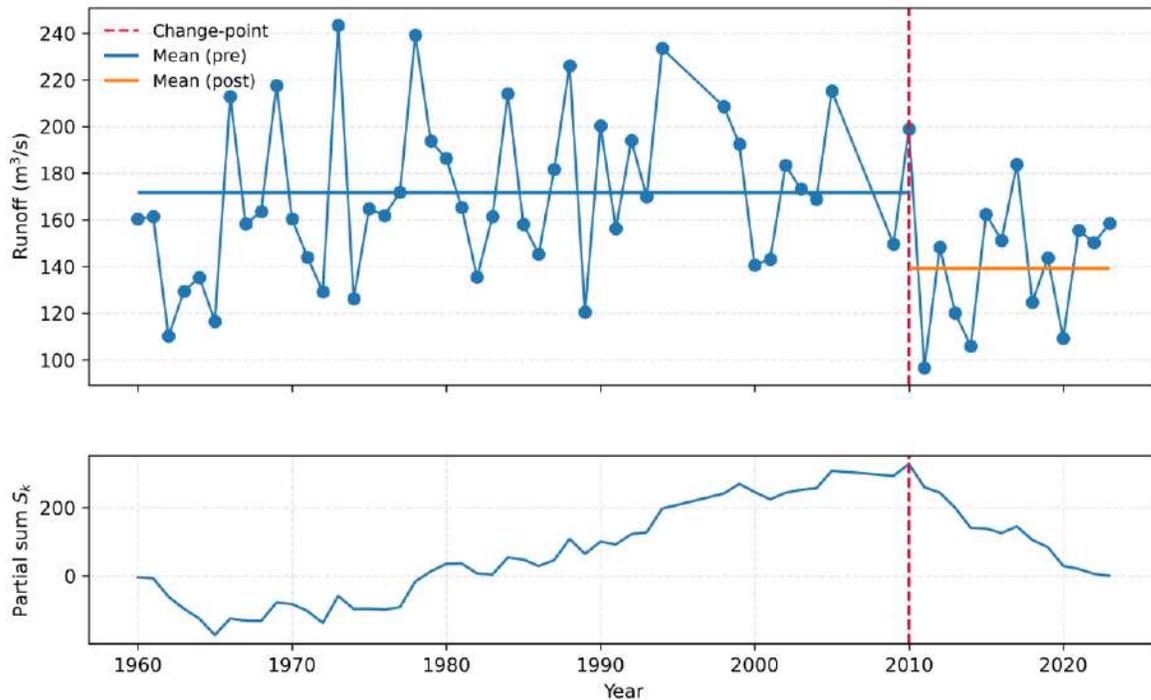
- significant upward shift in mean winter runoff
- 1987 as the change-point ($p < 0.001$)

Pettitt change-point: 1987 ($p \approx 0.000$) — accum mean

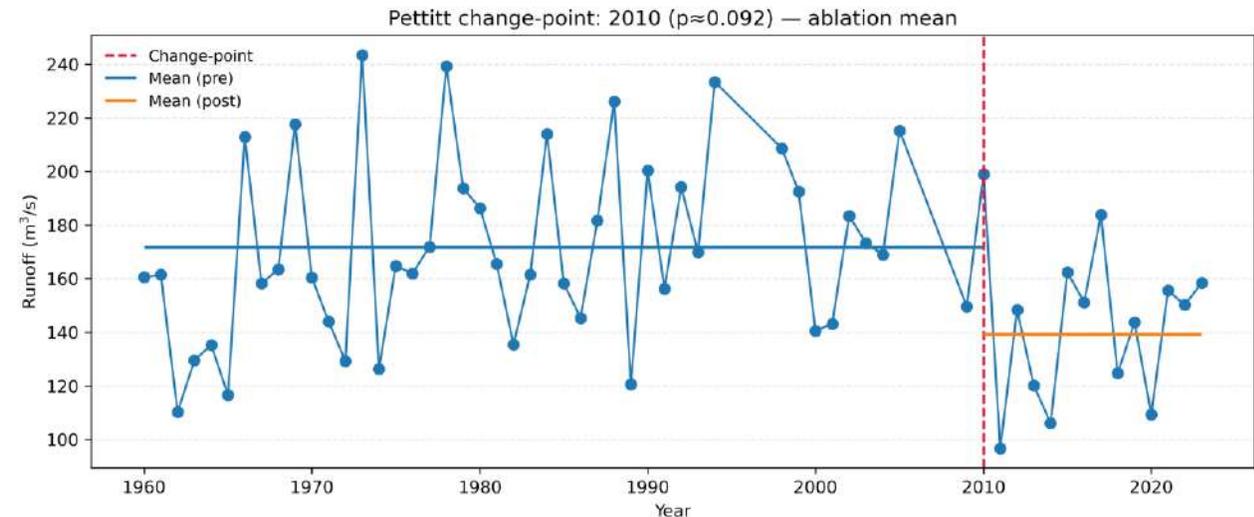


- abrupt change at 2010 ($p = 0.004$)
- lower post-2010 mean ($\sim 130\text{--}140 \text{ m}^3/\text{s}$) compared to pre-2010 ($\sim 170 \text{ m}^3/\text{s}$)

Buishand range: CP 2010, $Q=14.24$, $p=0.004$ — ablation mean



- 2010 as the likely change-point, but with marginal significance ($p \approx 0.09$)
- suggesting a downward shift in summer runoff after 2010

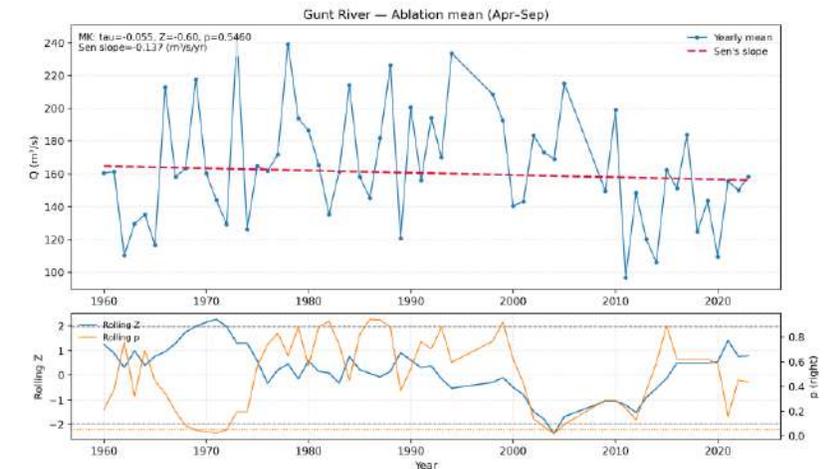
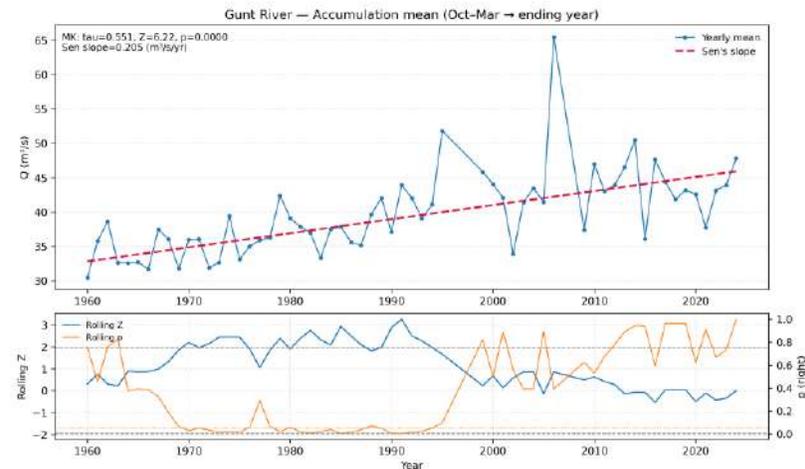
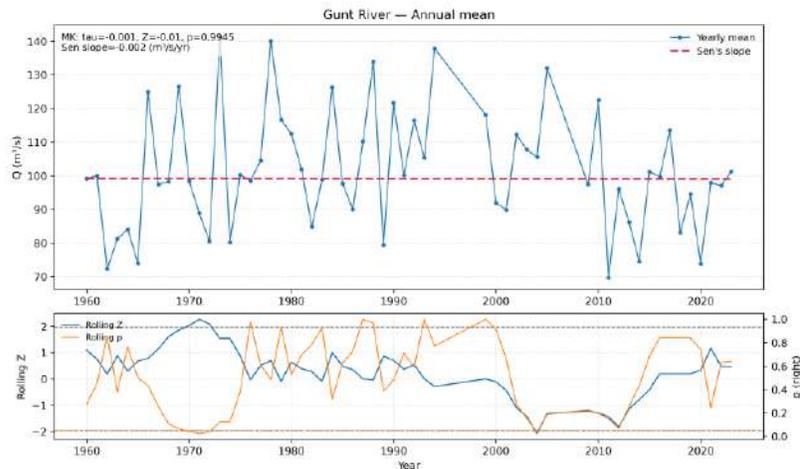


Trends in seasonal and annual runoff

- no significant long-term trend in total annual discharge
- Mann-Kendall test $\tau \approx 0$ ($Z \approx 0$, $p \sim 0.99$), and Sen's slope is essentially zero (≈ -0.002 m^3/s per year)

- significant upward trend in winter runoff. MK $\tau \approx +0.55$ ($Z \approx +6.22$, $p < 0.001$), Sen's slope $\approx +0.21$ m^3/s per year

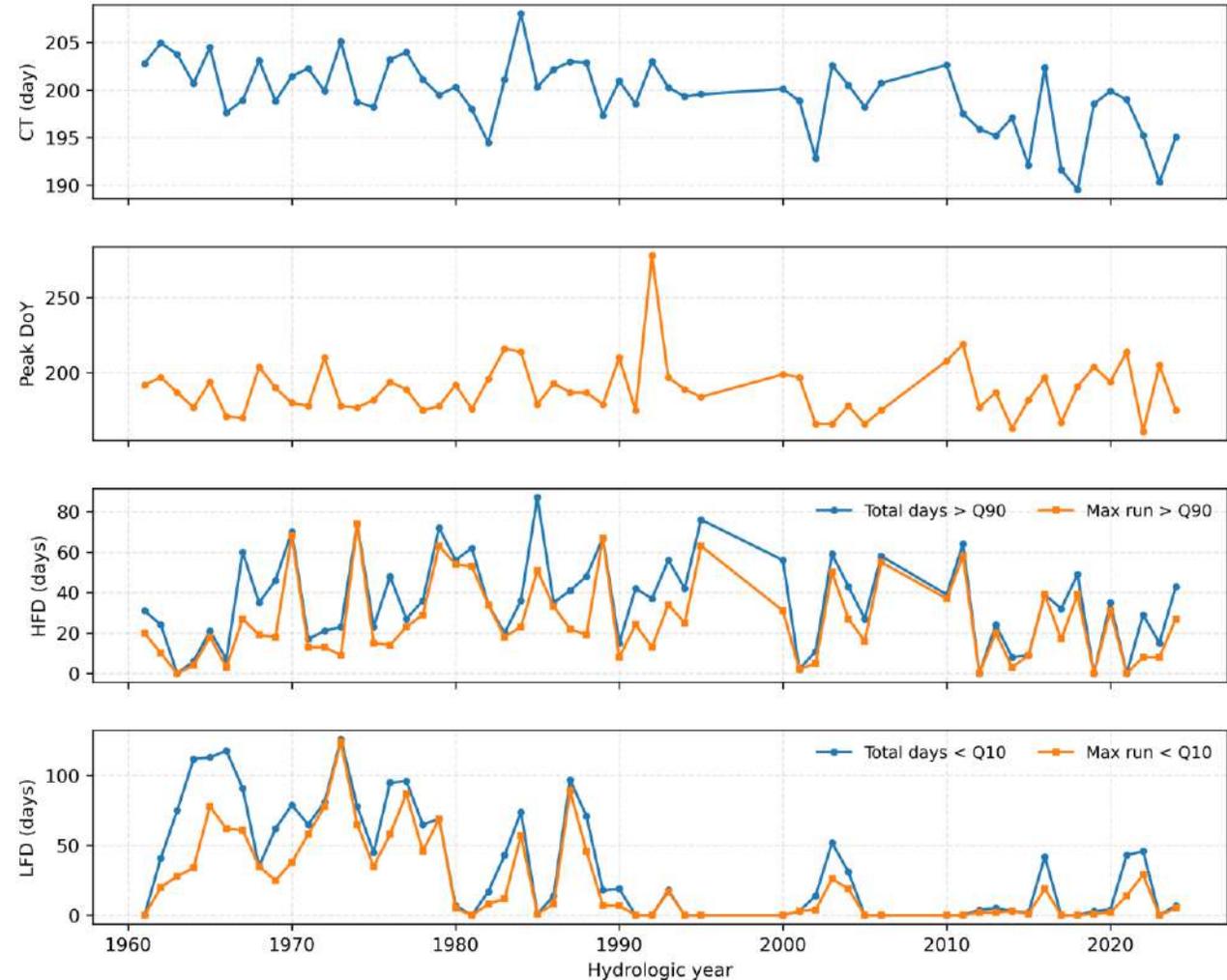
- slight downward tendency in summer runoff, but not statistically significant. MK $\tau \approx -0.06$ ($Z \approx -0.60$, $p \sim 0.55$), with a small Sen's slope of ~ -0.14 m^3/s



CT, DoY, HFD, LFD of annual flow

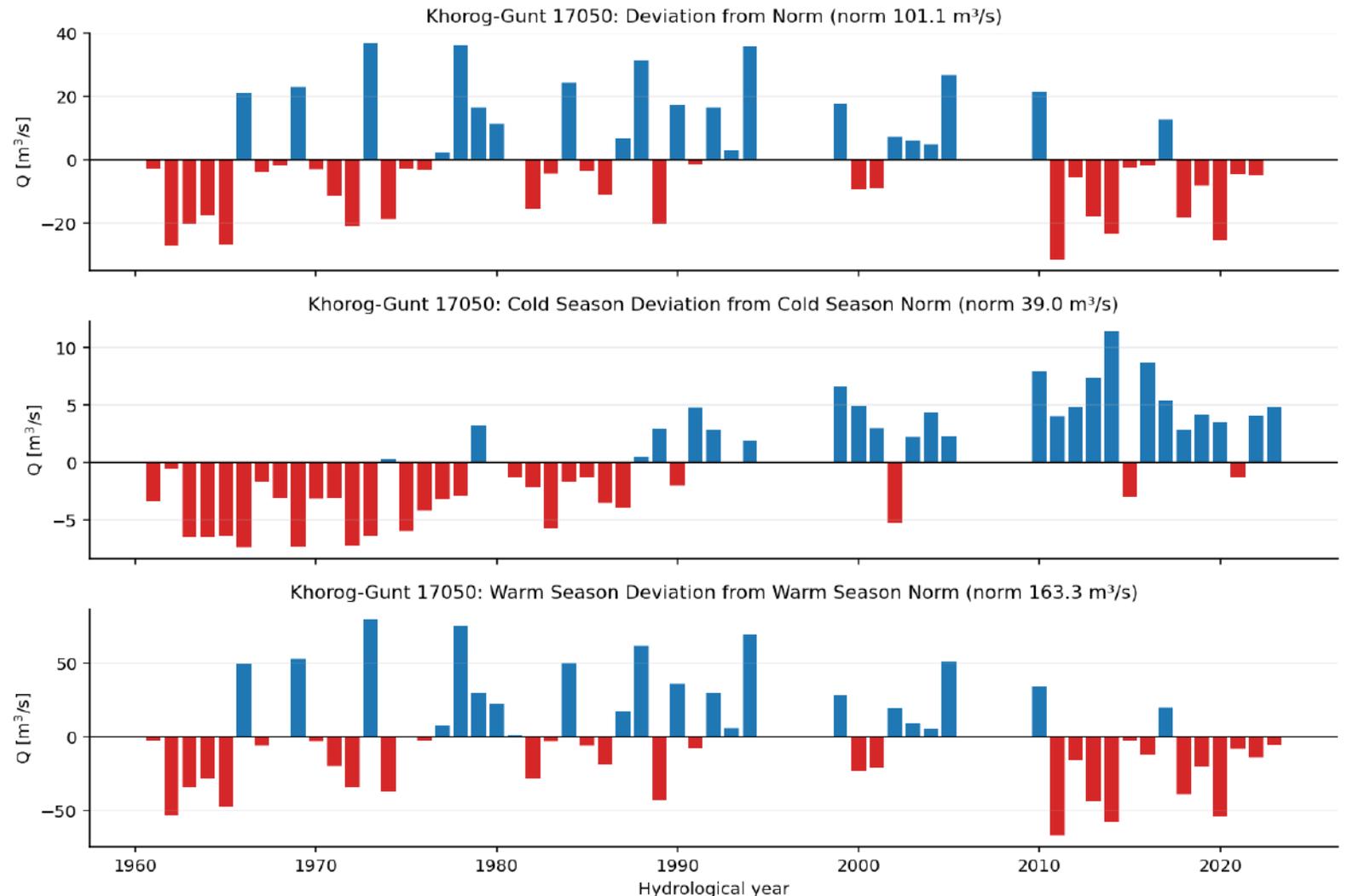
- CT of annual flow has shifted significantly earlier over 1960–2023
- DoY is occurring earlier in the summer on average
- HFD (days above the Q90 threshold of 270.0 m³/s) shows no clear long-term trend
- LFD (days below the Q10 threshold of 26.4 m³/s) exhibits a strong decreasing trend

Gunt River — Seasonality & Extremes (Q90=270.0, Q10=26.4)



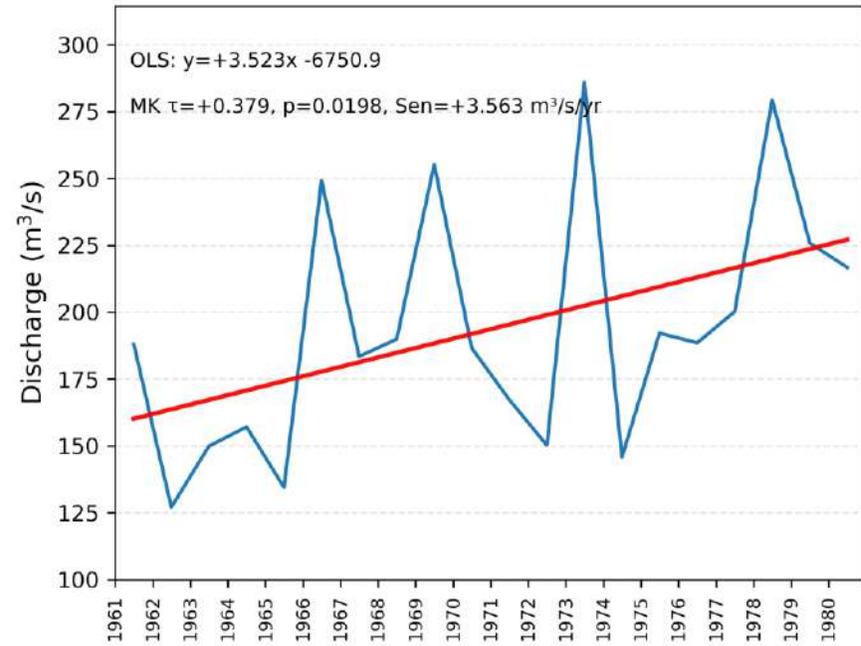
Trends in Gunt River Discharge Anomalies

- During the 1960s and early 1970s, negative deviations dominate
- By the 1980s, a clear shift occurred
- From 1980s to 2000s, annual and summer flows were often above the norm
- Cold-season anomalies also trended upward modestly

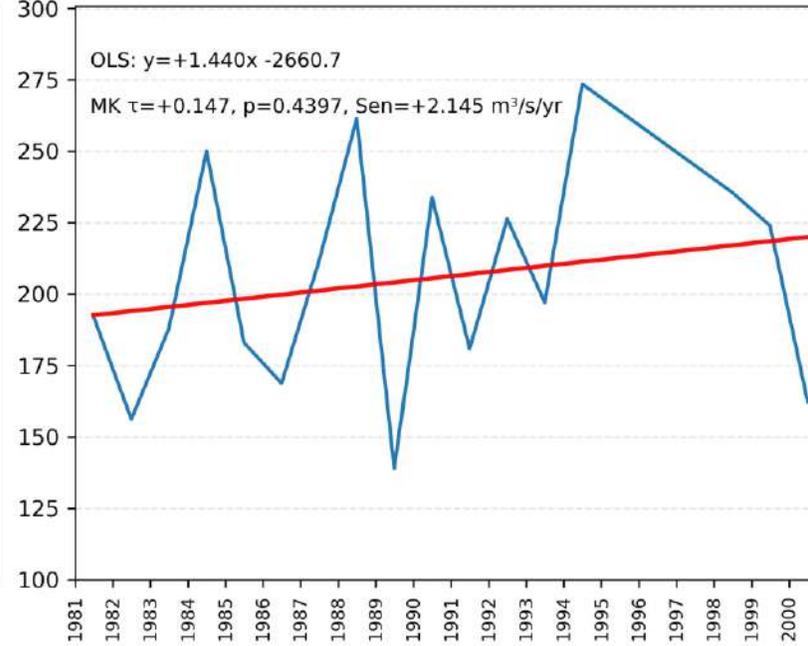


High-water (May-Sep)

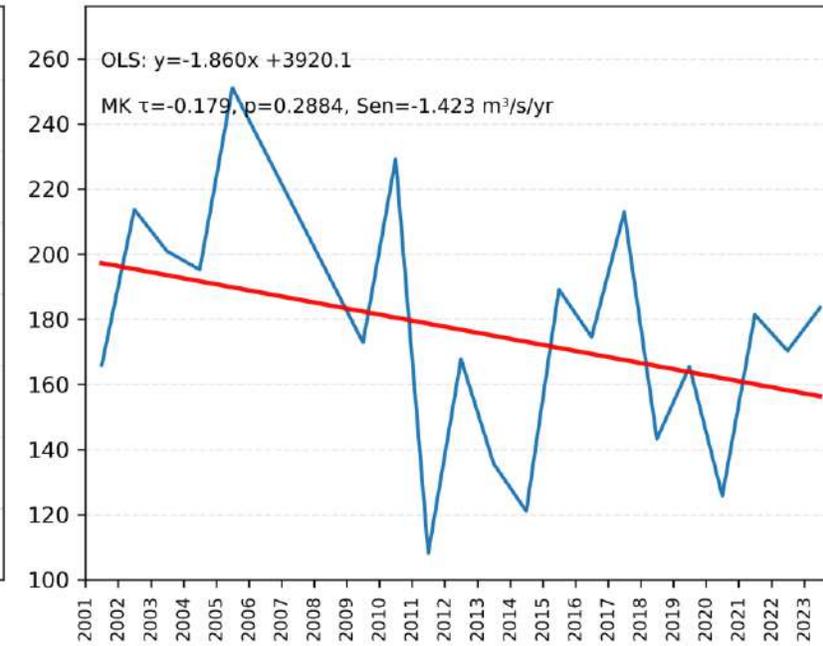
1961-1980



1981-2000

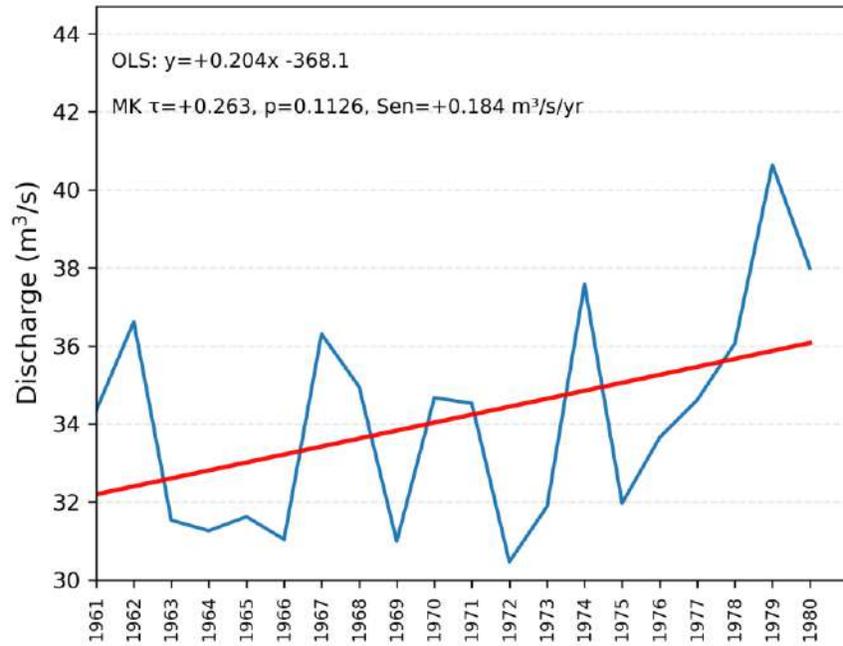


2001-2023

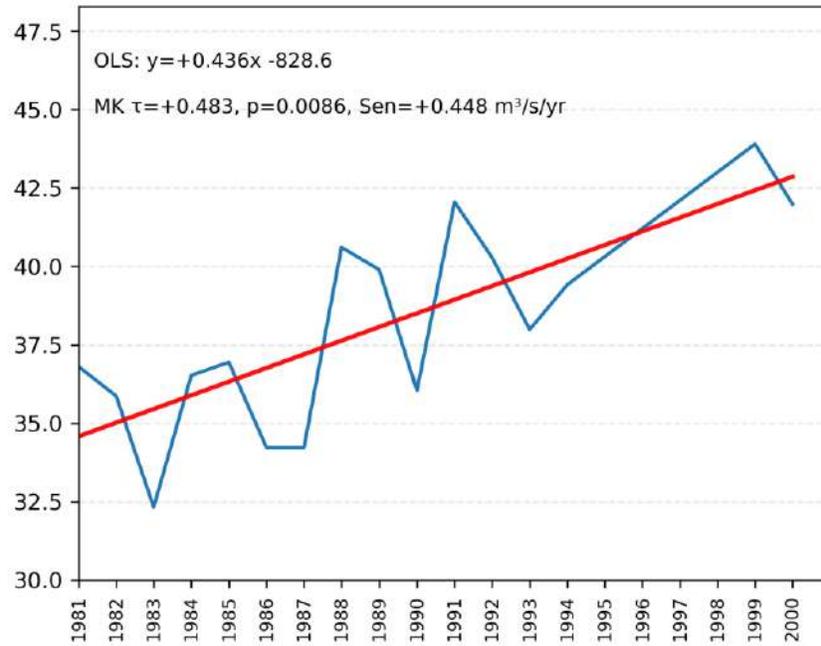


Low-water (Oct-Apr)

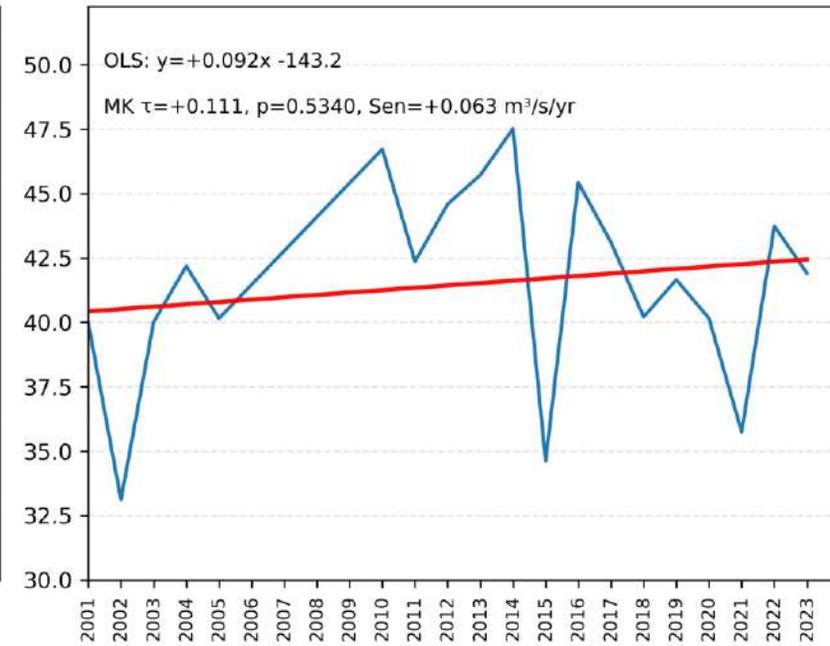
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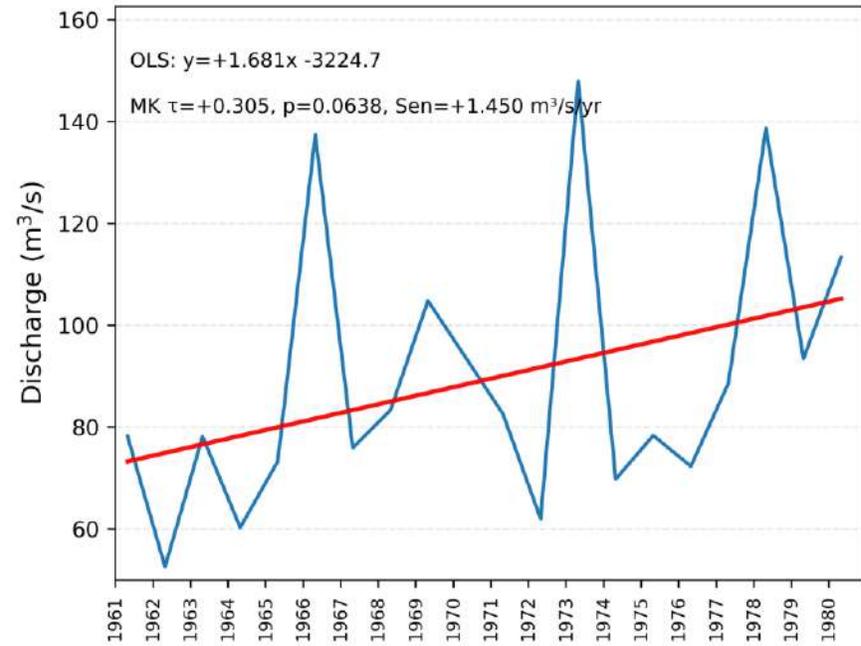


2001-2023

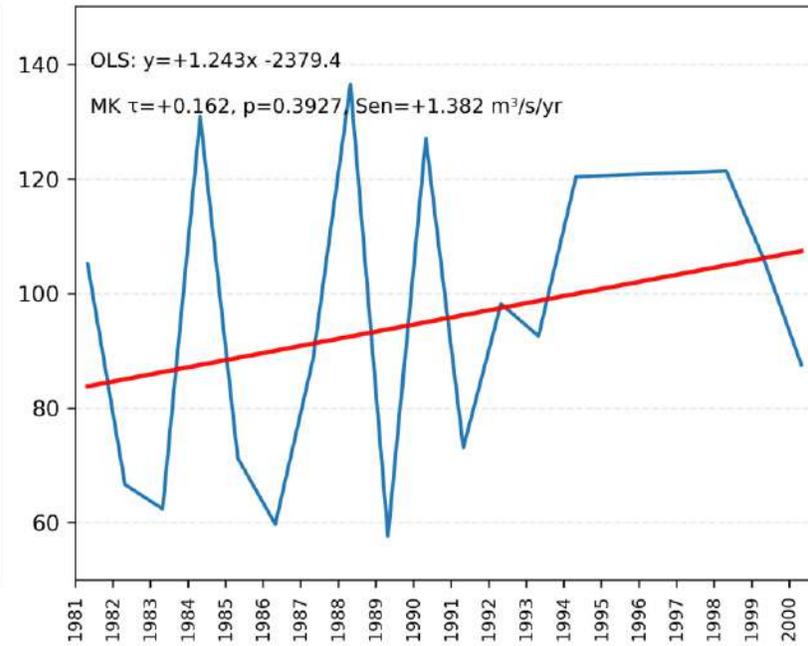


Snow-melt runoff (Mar-Jun)

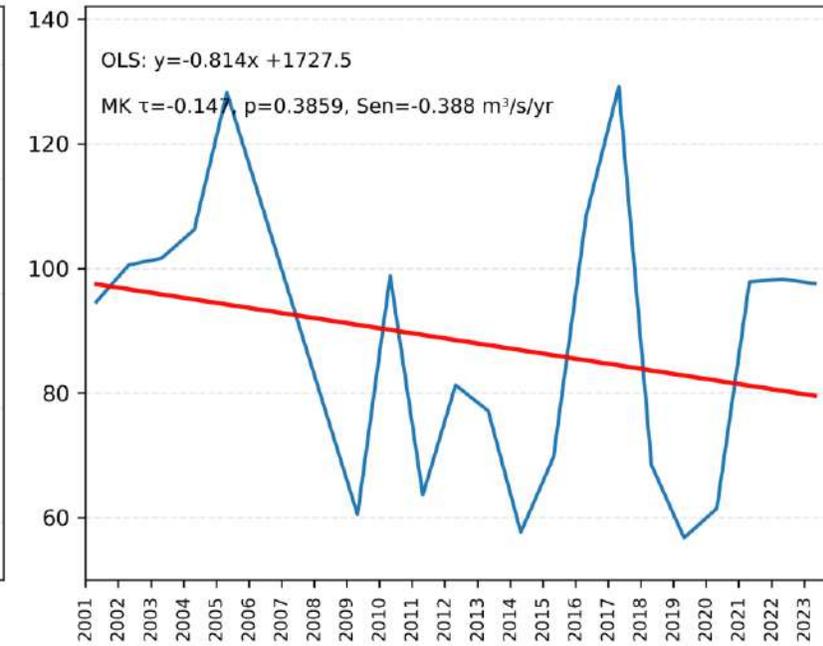
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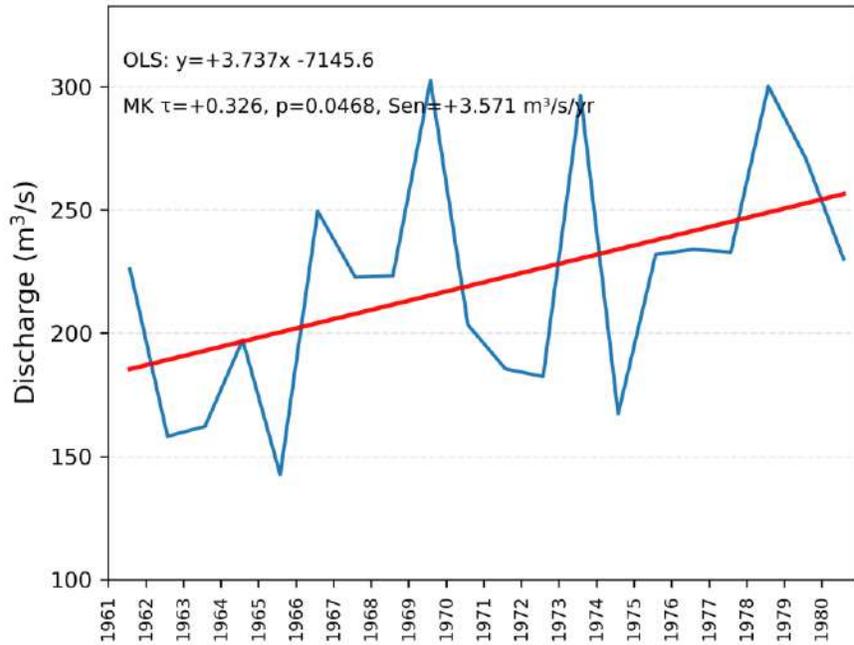


2001-2023

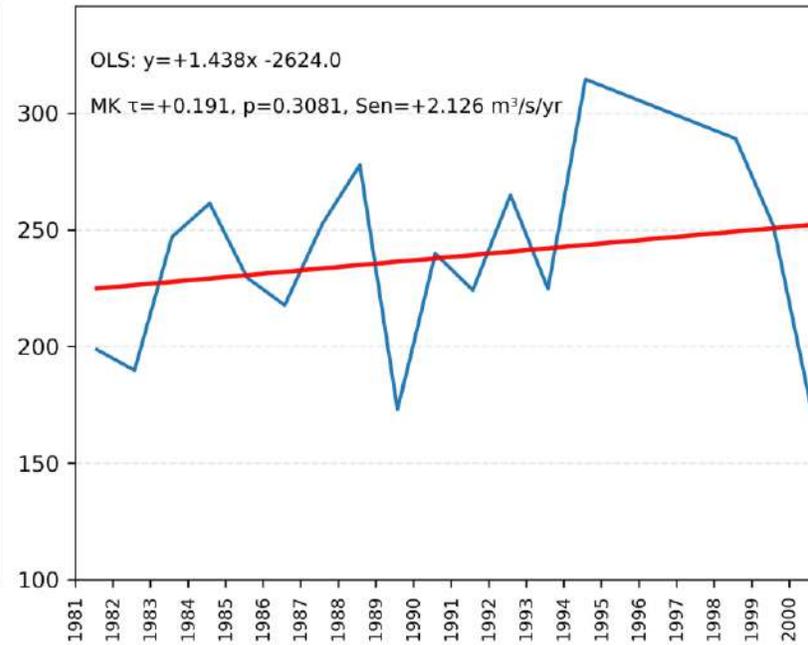


Glacier-melt runoff (Jul-Sep)

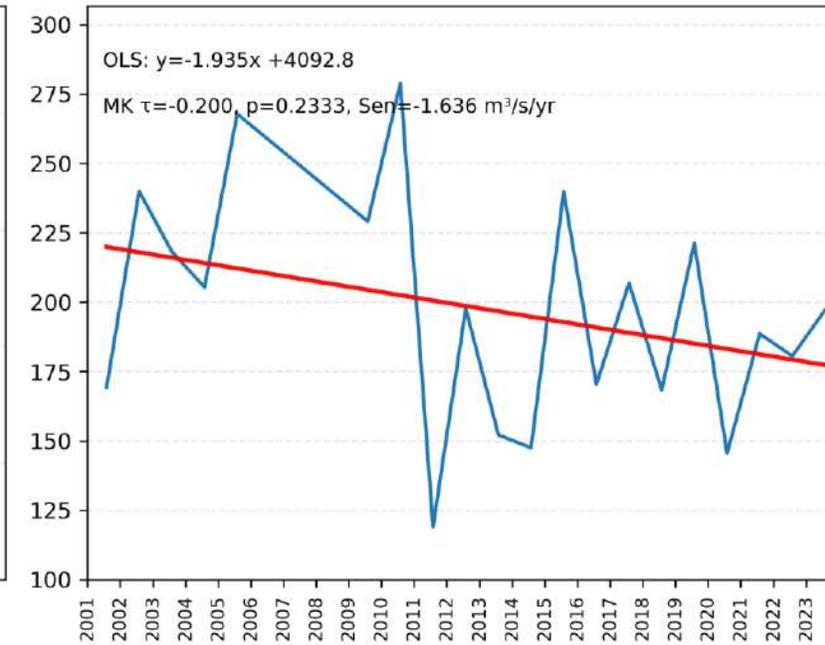
1961-1980



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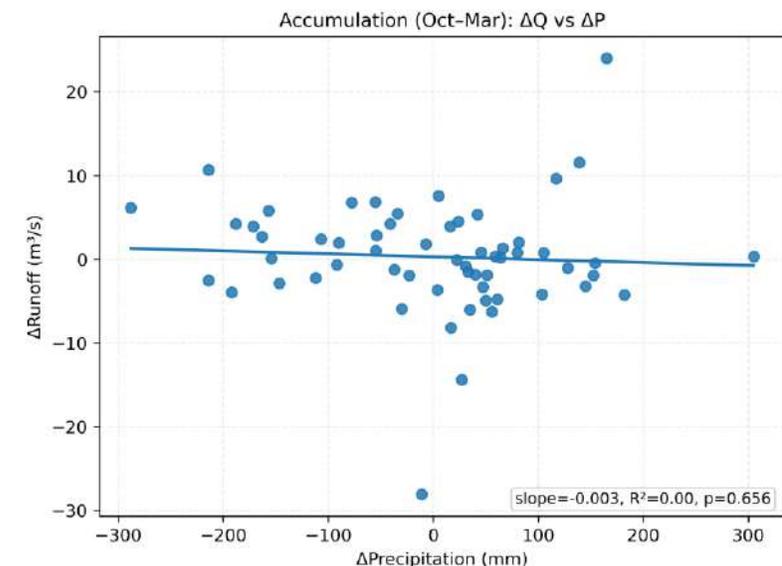
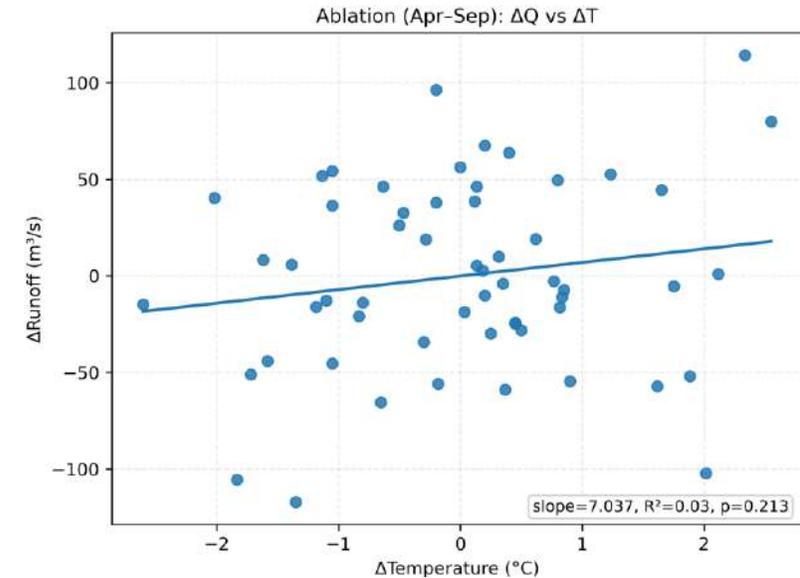
2001-2023



- Ablation (Apr–Sep): ΔQ vs ΔT
 - Small, positive slope ($\approx +7 \text{ m}^3/\text{s}$ per $+1 \text{ }^\circ\text{C}$, $R^2 \approx 0.03$, $p \approx 0.21$)

Warmer summers tend to have slightly higher melt-season flow, but the effect is weak and uncertain

- Accumulation (Oct–Mar): ΔQ vs ΔP
 - Slope $\approx -0.003 \text{ m}^3/\text{s}$ per 1 mm - near-flat line - no trend
 - $R^2 \approx 0.00$, $p \approx 0.66$ \rightarrow precipitation changes explain virtually none of year-to-year flow changes in this season.



Agriculture

- Reduced irrigation reliability
- Shift in planting calendars
- Increased drought risk
- Soil degradation pressure
- Need for adaptation measures

Energy

- Reduced hydropower efficiency
- Seasonal imbalance in supply and demand



- Long-term hydrological variability:
- Shift in flow seasonality:
- Rising winter flows, stable or declining summer flows:
- Reduced low-flow extremes:
- Recent downward anomalies:



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Thank You!



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