# Unravelling the Hydrologic Impact of Climate Change in the Great Ruaha River Basin, Tanzania

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# Introduction

→ Climate change has a significant impact on river flows and water availability

- Changes in rainfall patterns (i.e. increased rainfall or drought → Changes in river flows
- Higher temperatures → increased evaporation → Changes in river flows

→ Leads to environmental & socioeconomic implications

→ Understanding the role of climate change is crucial for :-

- Developing effective adaptation strategies
- Mitigating their impacts

Daily News, 2024

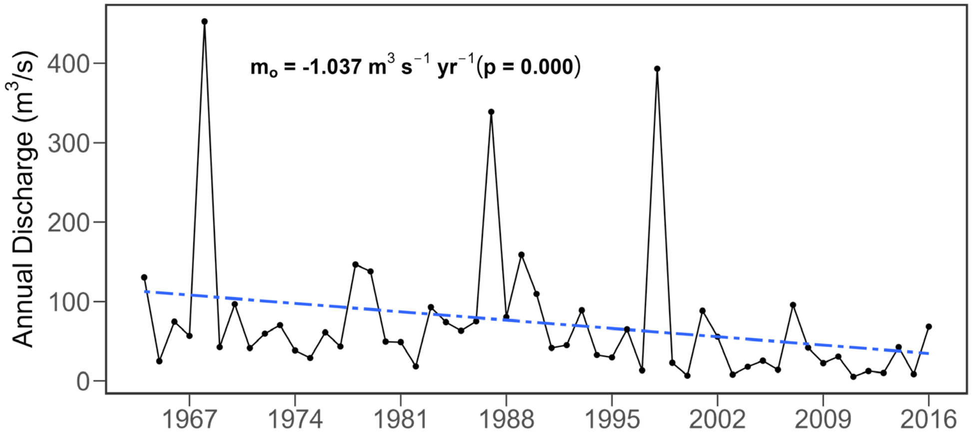
Daily News, 2022

# Challenge

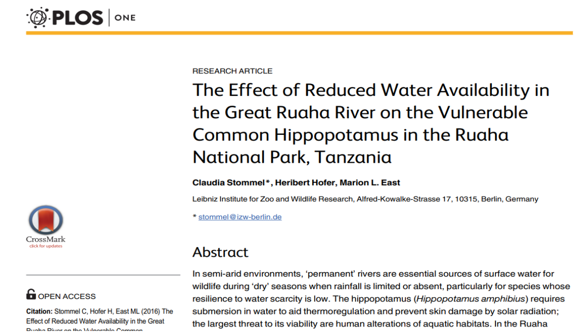
→ The Great Ruaha River is experiencing declining flows

→ Reduced water availability for:-

- Agriculture
- Energy production
- Domestic use
- Environment




Source: Daily river flow data for the Msembe Gauging Station from Rufiji Basin Water Office (RBWO)



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RESEARCH ARTICLE

The Effect of Reduced Water Availability in the Great Ruaha River on the Vulnerable Common Hippopotamus in the Ruaha National Park, Tanzania

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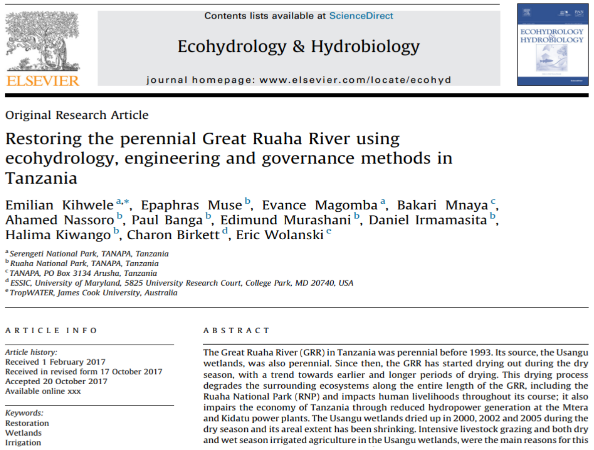
Abstract

In semi-arid environments, 'permanent' rivers are essential sources of surface water for wildlife during 'dry' seasons when rainfall is limited or absent, particularly for species whose resilience to water scarcity is low. The hippopotamus (*Hippopotamus amphibius*) requires submersion in water to aid thermoregulation and prevent skin damage by solar radiation; the largest threat to its viability are human alterations of aquatic habitats. In the Ruaha



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Original Research Article

Restoring the perennial Great Ruaha River using ecohydrology, engineering and governance methods in Tanzania

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ABSTRACT

The Great Ruaha River (GRR) in Tanzania was perennial before 1993. Its source, the Usangu wetlands, was also perennial. Since then, the GRR has started drying out during the dry season, with a trend towards earlier and longer periods of drying. This drying process degrades the surrounding ecosystems along the entire length of the GRR, including the Ruaha National Park (RNP) and impacts human livelihoods throughout its course; it also impairs the economy of Tanzania through reduced hydropower generation at the Mtera and Kidatu power plants. The Usangu wetlands dried up in 2000, 2002 and 2005 during the dry season and its areal extent has been shrinking. Intensive livestock grazing and both dry and wet season irrigated agriculture in the Usangu wetlands, were the main reasons for this

→ Is the decline due to climate change?

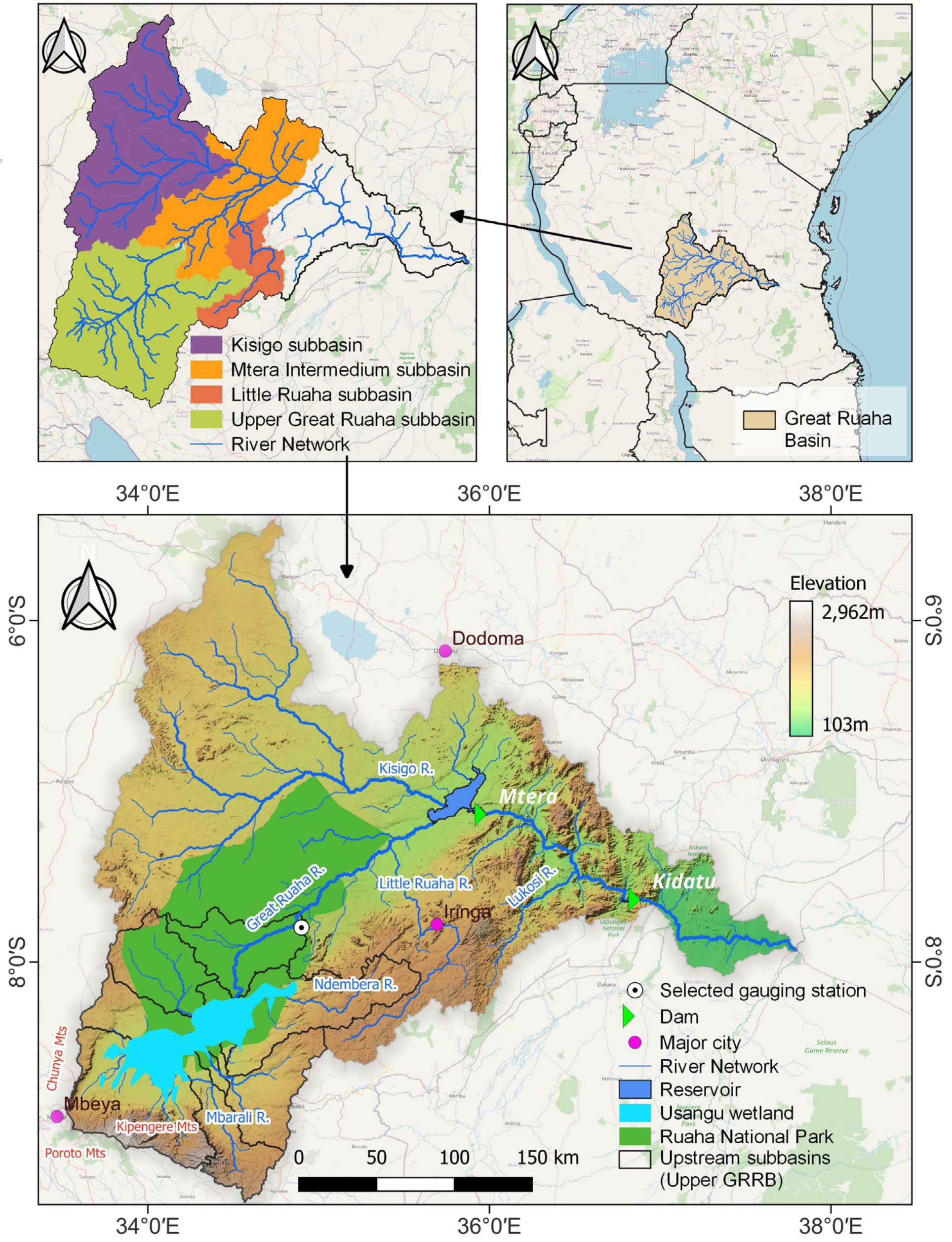
# Objectives

1. To derive trends in the factual and counterfactual climate data

2. To quantify the impact of climate change on hydrological system using the data

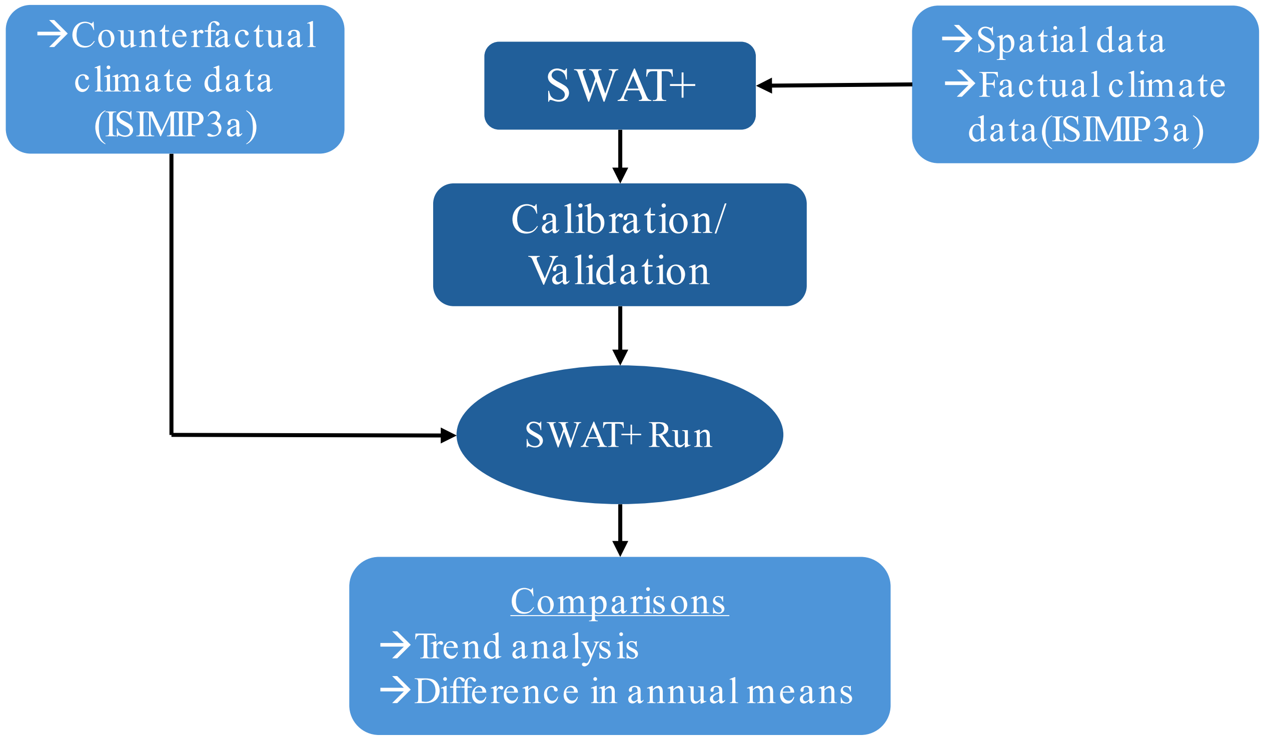
# The Study Area

- Located in Southwestern Tanzania
- Total basin area ~ 83,979 km²
- Diverse topography
- Usangu wetlands, Ruaha National Park & Mtera-Kidatu reservoir system
- Tropical climate with unimodal rainfall, → 1000 – 1900mm (highlands) & 700 – 800 mm (plains)
- Rainy season → Oct – May
- Activities → agriculture, livestock keeping, fishing & tourism



# Method – Attribution analysis

→ Quantify the contribution of climate change to the observed declining flows




→ From ISIMIP3a simulation protocol of impact attribution : -

- Factual: observed/ reanalysis data
- Counterfactual: Climate change signal removed

→ We used the GSWP3-W5E5 dataset, 1901 – 2019 at $0.5^0$ spatial resolution

# Method – Attribution analysis

→ Quantification of climate change

1) Trend analysis – Modified Mann-Kendall test at $\alpha = 0.05$

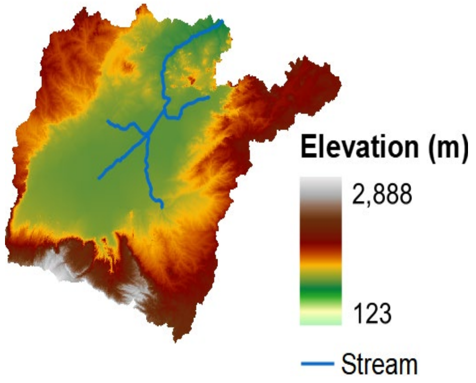
2) Historical impact of climate change → $CC_i = (\frac{S_f - S_c}{S_c}) \times 100$

*$CC_i$ = historical impact of climate change (%),*
*$S_c$ = annual average model output of simulations forced with counterfactual climate data,*
*$S_f$ = annual average model output of simulations forced with factual climate data*

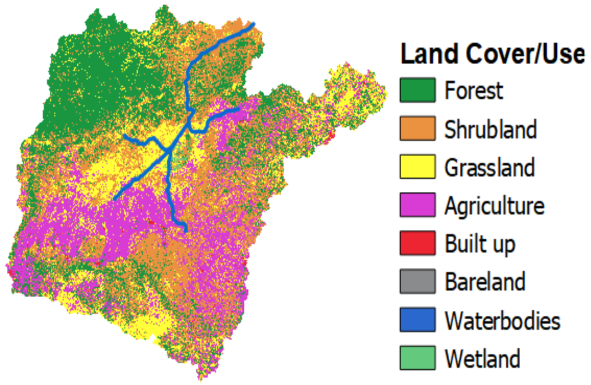
→ Climate Change Influence - Significant trends in factual data simulations

# Model setup and Evaluation

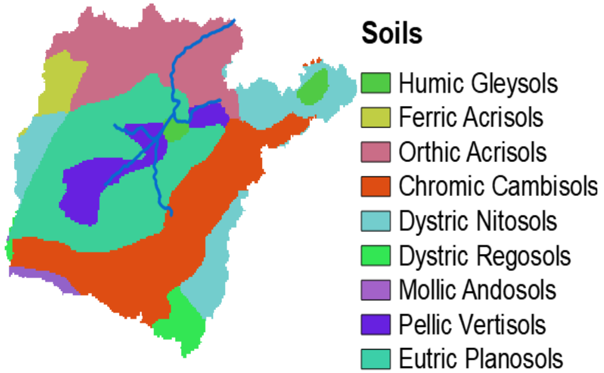
(a) Setup




DEM 90 m (SRTM)




Land use 10 m (ESA)




Soils 1 Km (FAO)

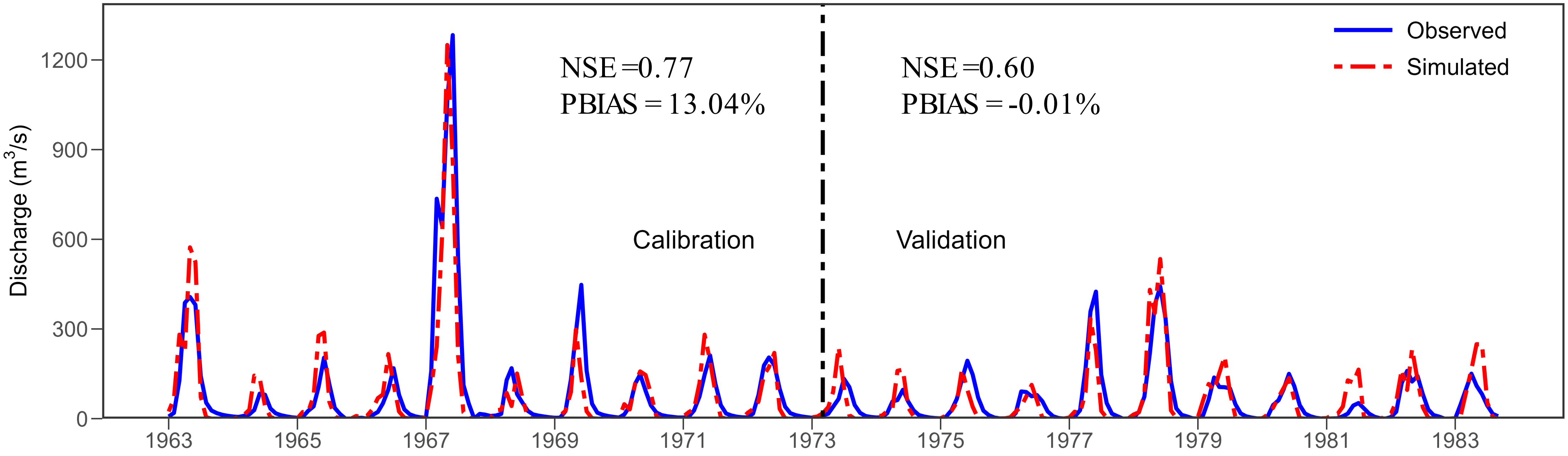
ISIMIP Inter-Sectoral Impact Model Intercomparison Project

Climate data (ISIMIP3a)

→ Simulation period: 1901 – 2019

# Model setup and Evaluation

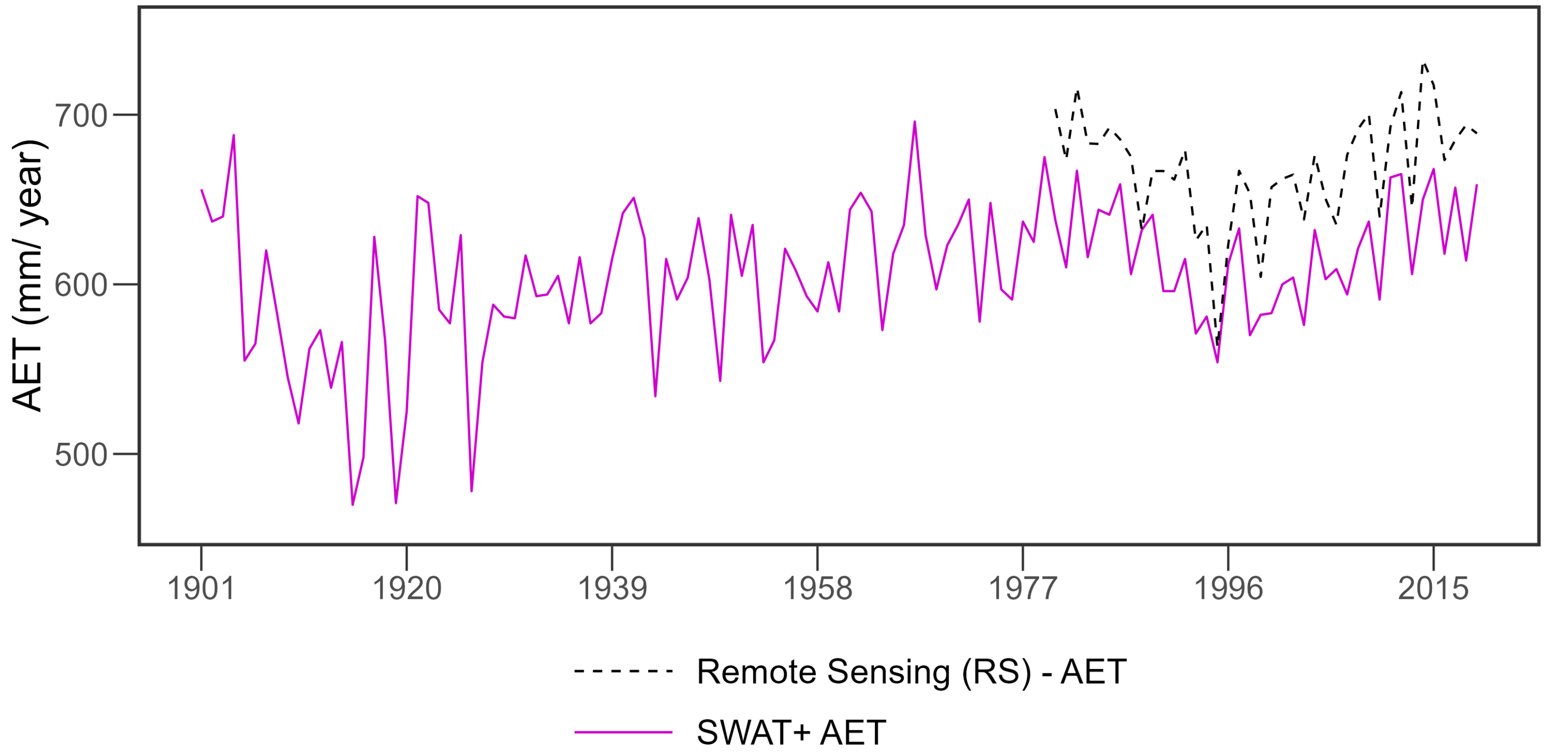
(b) Hydrological evaluation (Monthly timescale 1963 – 1984)




→ Satisfactory statistical performance → NSE ≥ 0.5 & PBIAS ≤ ± 15% (Moriasi et al., 2015)

# Model setup and Evaluation

(c) Actual Evapotranspiration (AET): SWAT+ vs Remote sensing

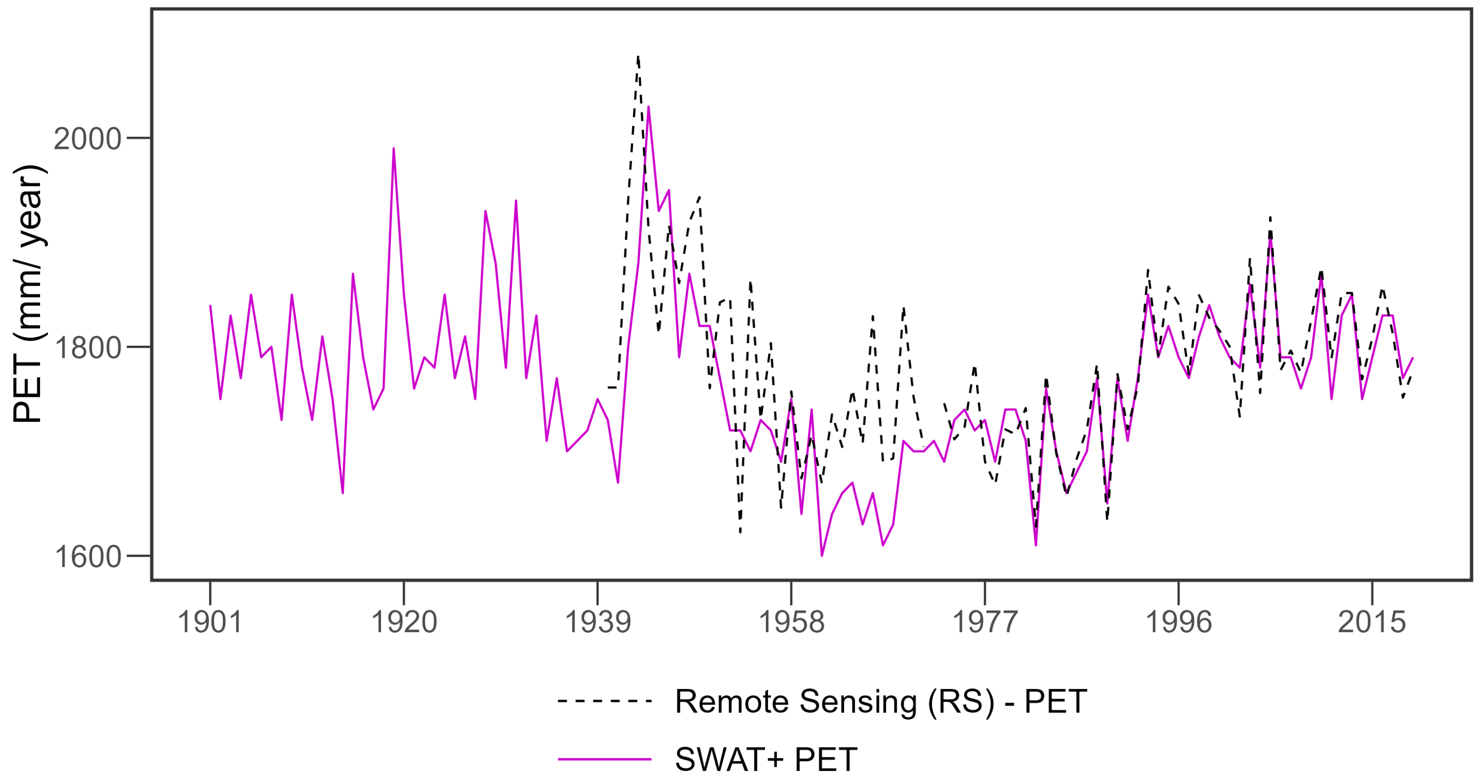



→ Strong correlation observed but a bias exists

→ $R^2 = 0.60$

# Model setup and Evaluation

(d) Potential Evapotranspiration (PET): SWAT+ vs Remote sensing



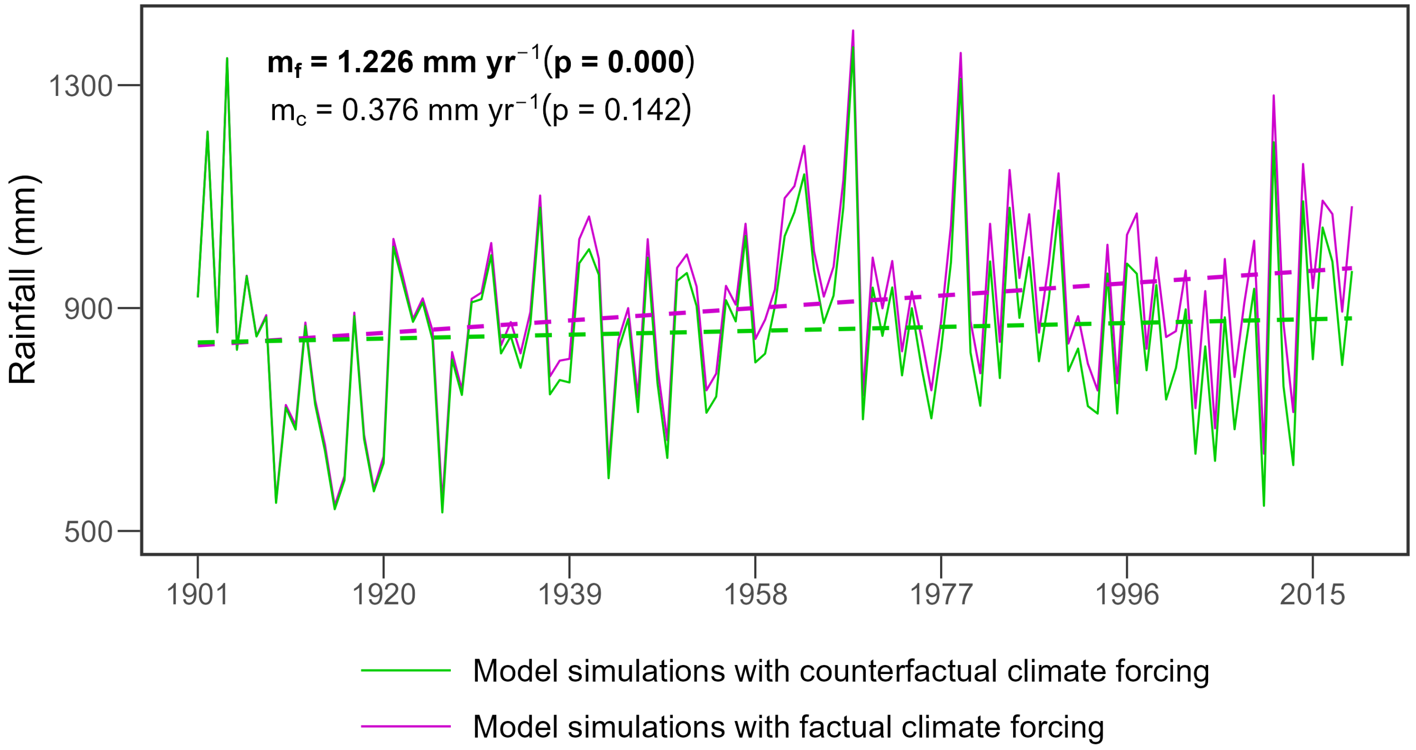

→ Strong correlation observed but a bias exists

→ $R^2 = 0.55$

# Results – Attribution

(Factual vs Counterfactual simulations)

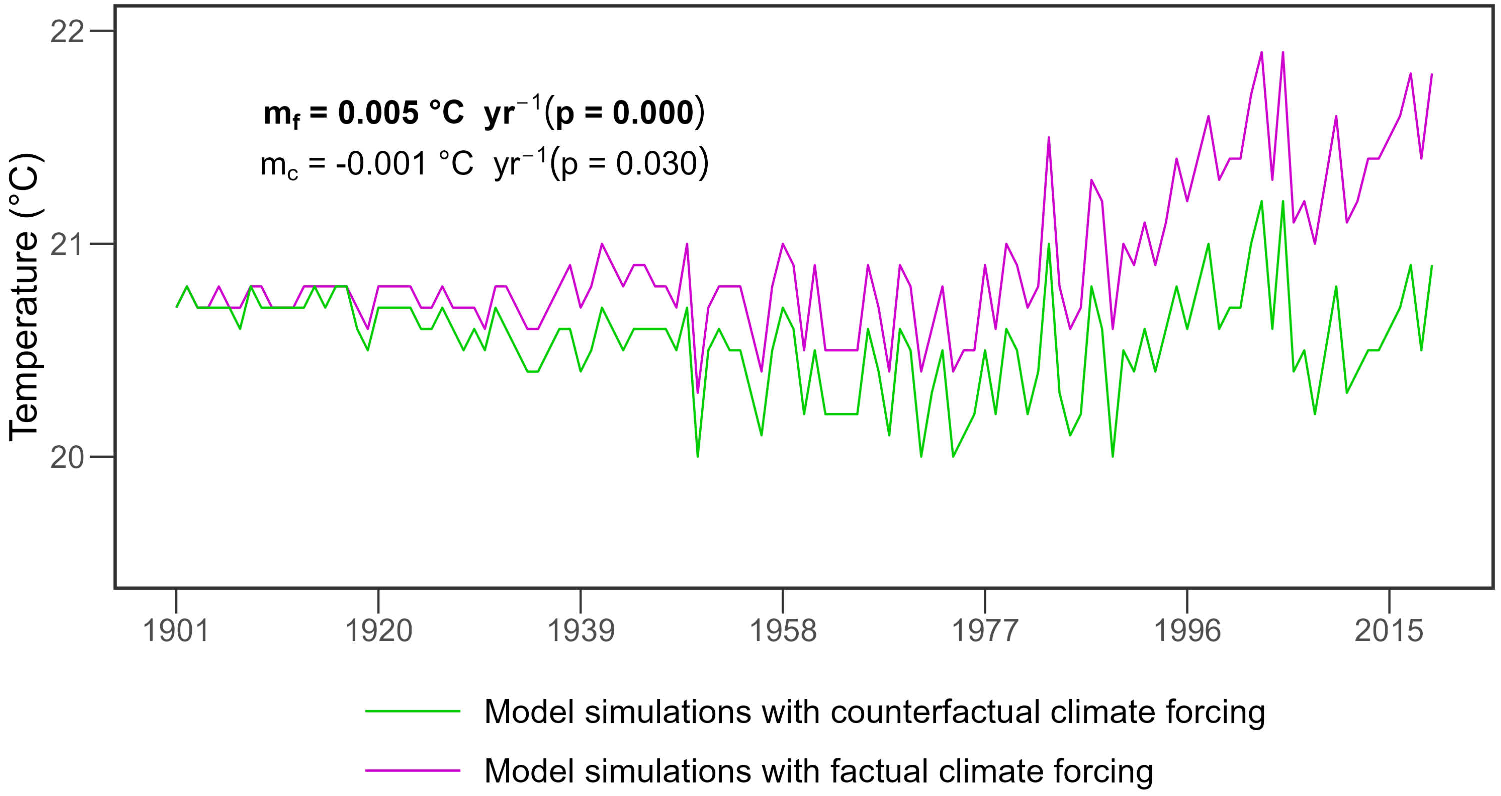
# Precipitation attribution - Trends




→ Climate change (CC) contributing to increase in precipitation

→ Climate change impact ($CC_i$) = 4.94%

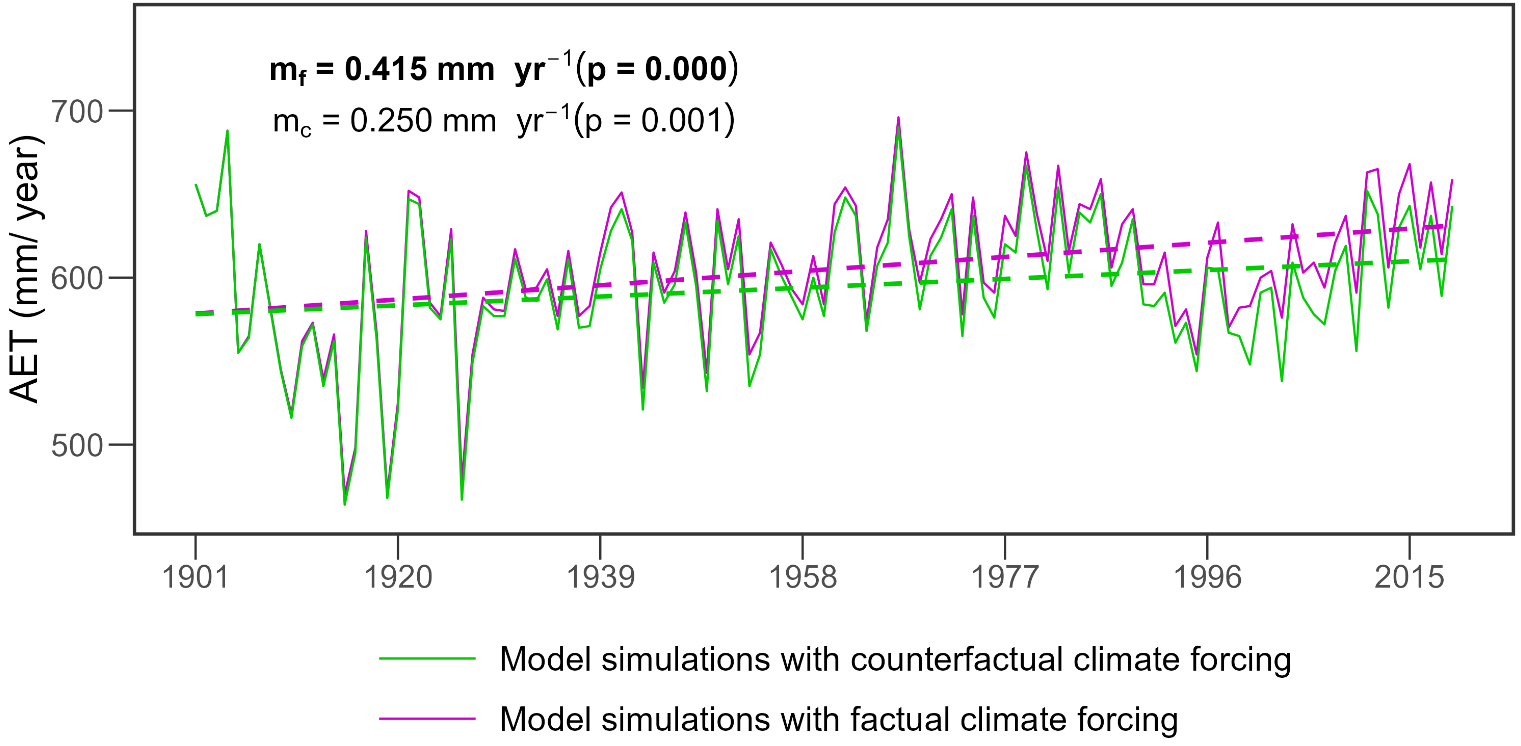
# Temperature attribution - Trends




→ CC contributing to increase in temperature

→ $CC_i$ = 1.74%

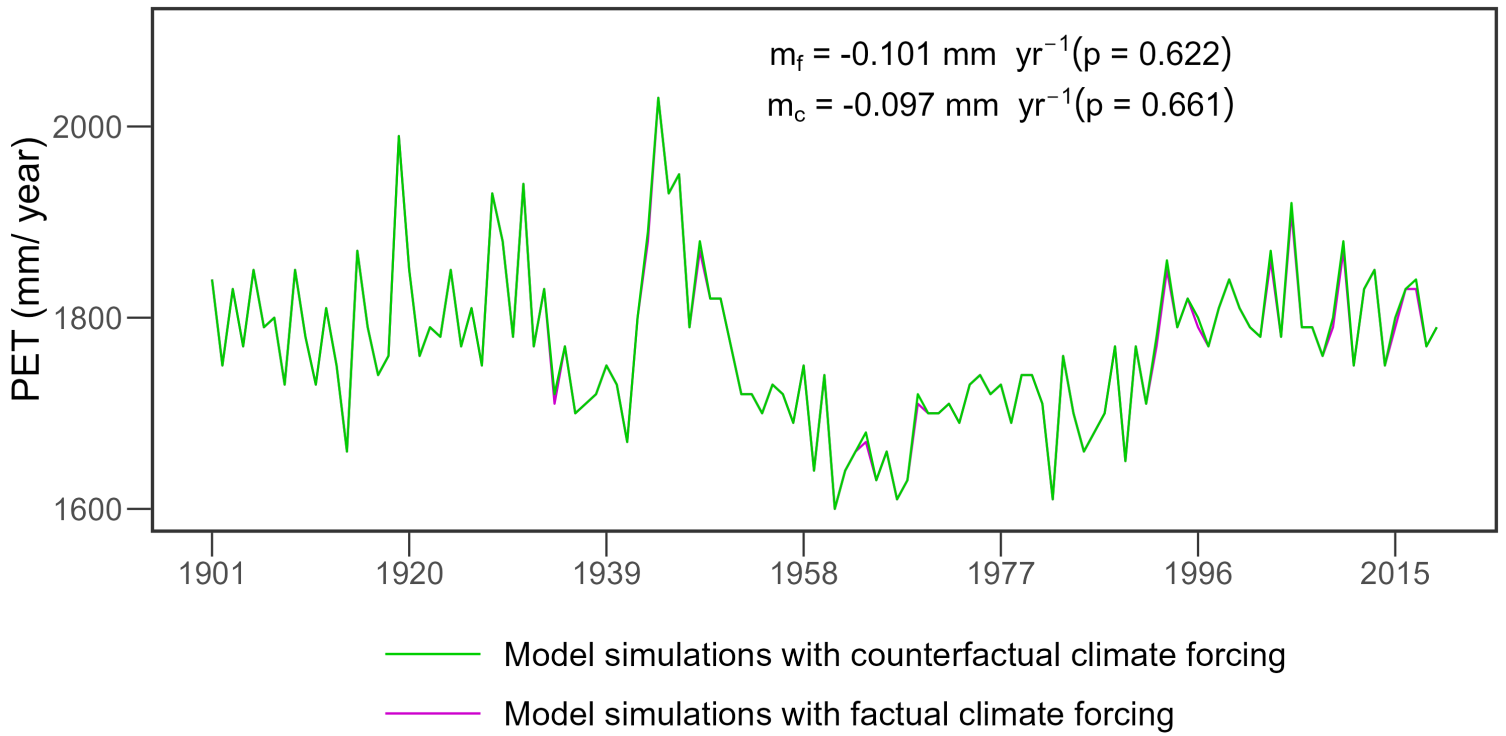
# Actual Evapotranspiration (AET) attribution - Trends




→ CC contributing to increase in AET

→ CCi = 1.73 %

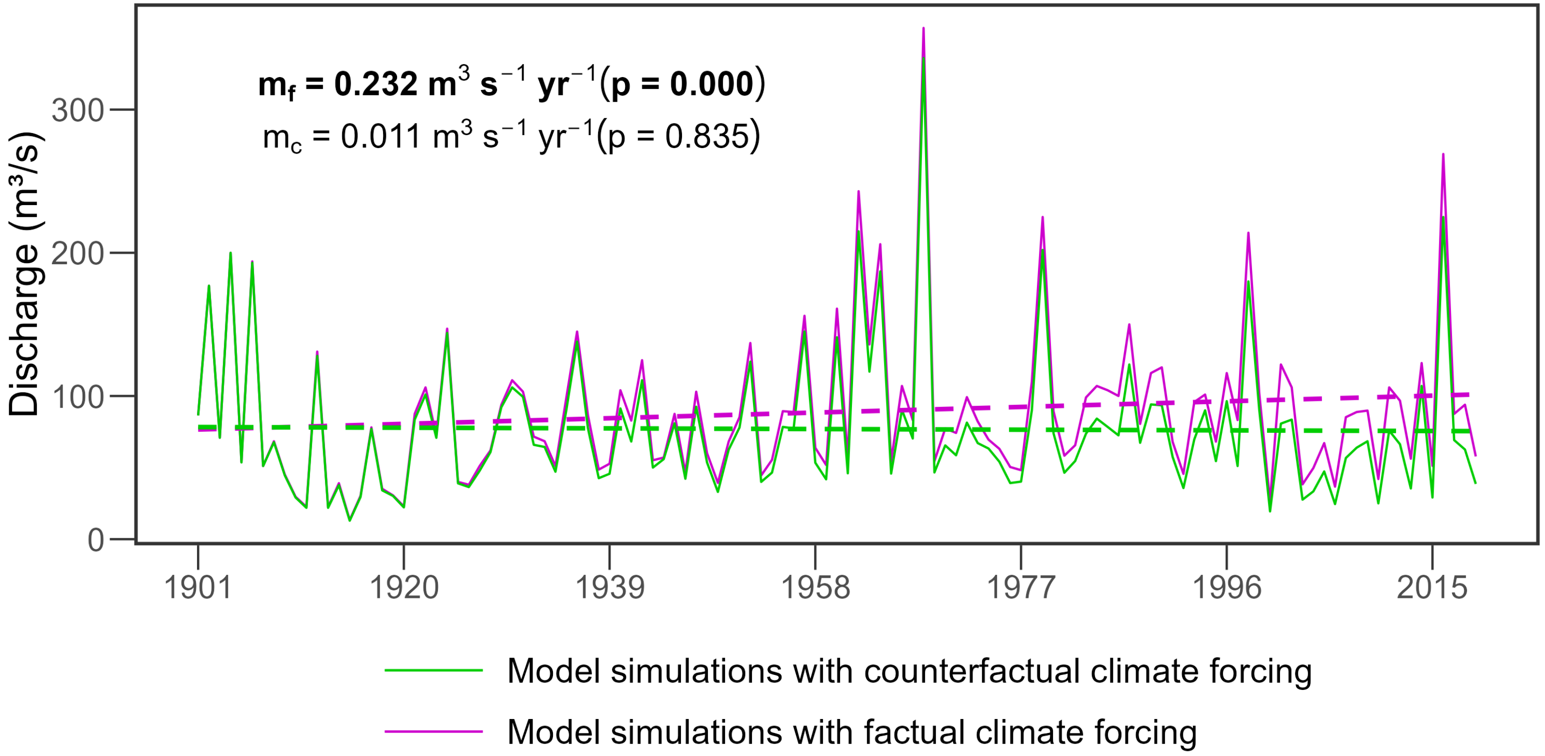
# Potential Evapotranspiration (PET) attribution - Trends




→ There is clear change in PET, though not very big

→ CCi = -0.07 %

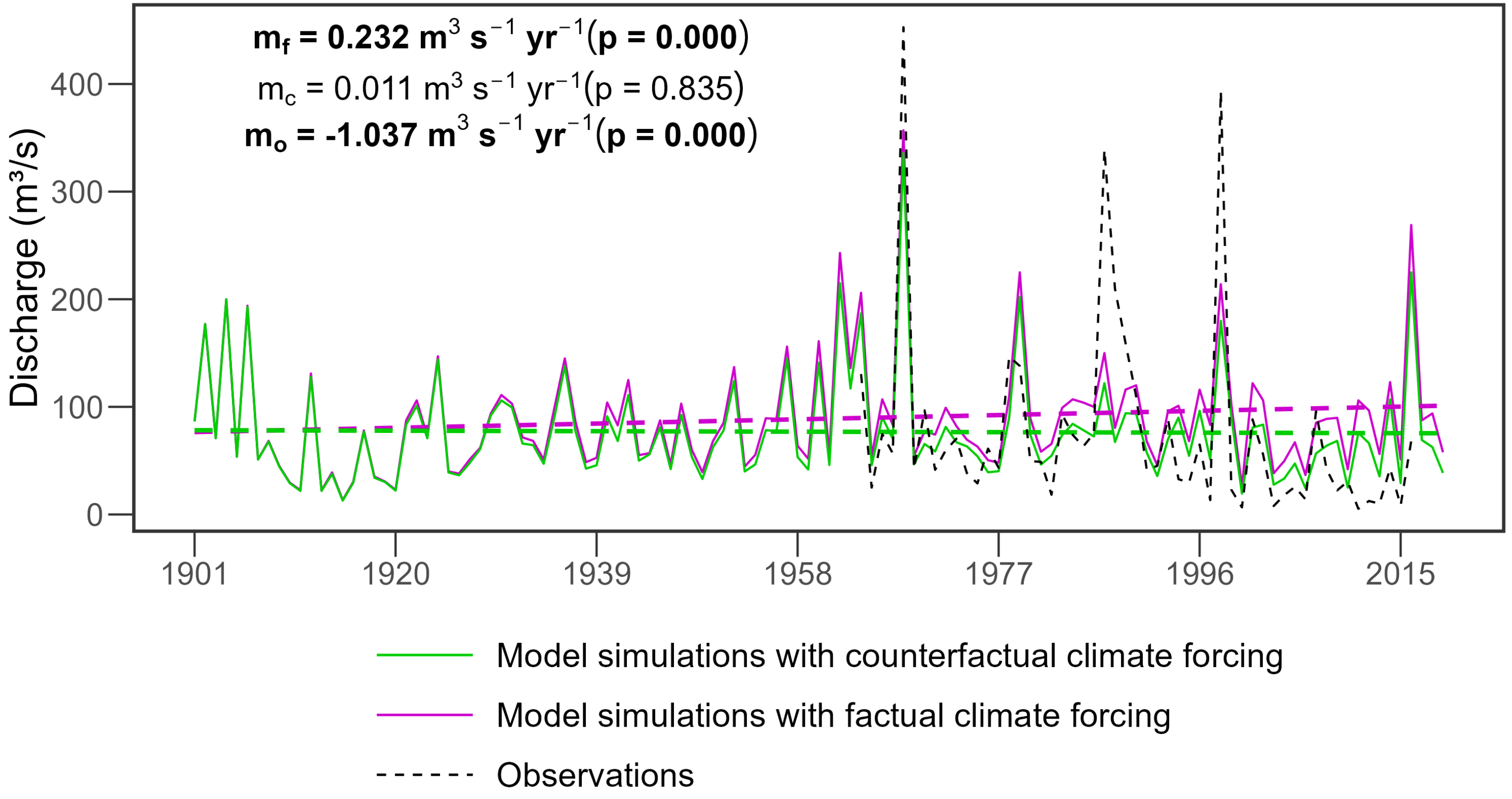
# Flow attribution - Trends




→ Flow increasing according to attribution

→ CCi = 15.5%

# Attribution vs. Actual Observations




→ Flow should be increasing according to attribution

→ Conversely, we observe a declining flow

→ The declining flow is more likely driven by land use change and water management

# Summary

→According to the attribution analysis:

- Precipitation is increasing due to climate change
- Evapotranspiration (ET) is increasing due to climate change
- Flow is increasing due to climate change

→According to the analysis of flow data:

- Flow is declining

# Takeaway(s)

→ The declining flow can not be explained by climate change, more likely driven by land use change and water management

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