Detection, Attribution, and Projections of Jhelum Streamflow Changes to Climate Change

Dr. Shabeh ul Hasson

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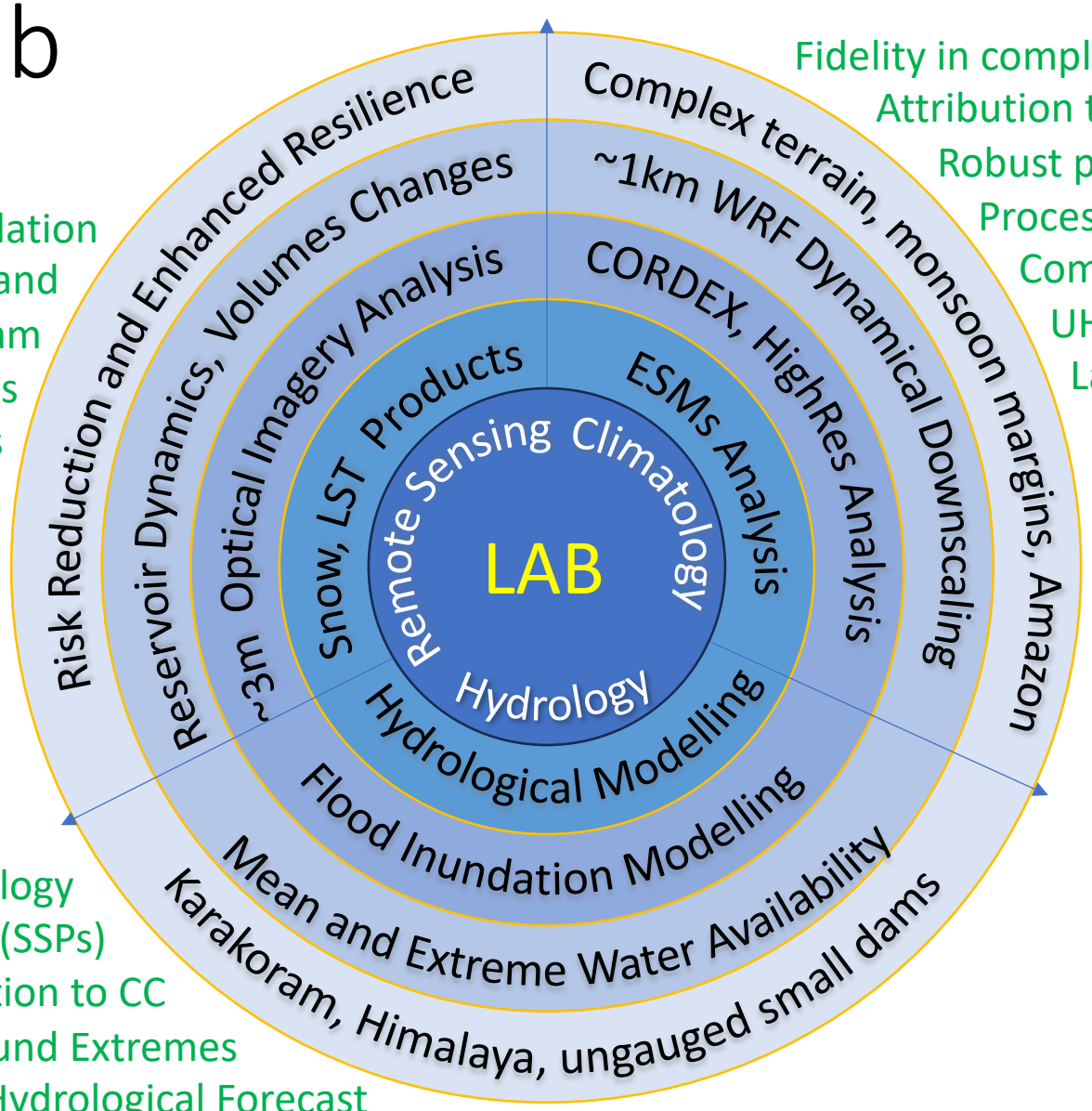
Outline

- Intro HAREME Lab

- Himalayan Basin of Jhelum at monsoon margins
- Detection, Attribution and Projection
- ISIMIP 3a and 3b Protocols
- Model Evaluation
- Attribution to trend in discharge and flood inundation
- Future projections

HAREME Lab



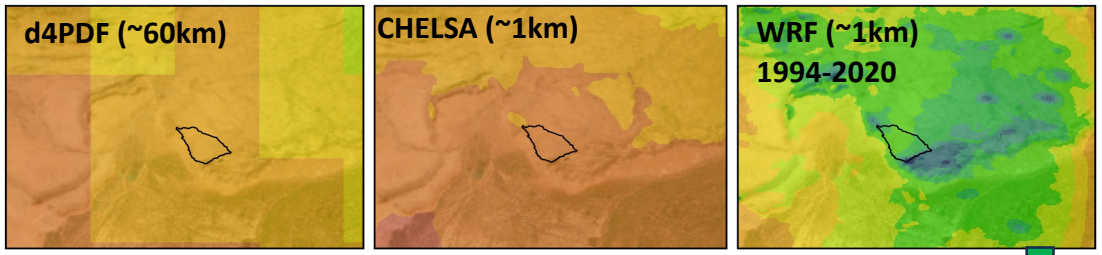
Snowline Oscillation
Urban Heat Island
Glacier Lake Inventory Karakoram
Lake volume dynamics
Glacier Lakes Outburst Floods
Flood Inundation Mapping

Fidelity in complex terrain (CPTP)
Attribution to climate change
Robust projections (CLM community)
Process understanding
Compound Extremes
UHI, Heatwaves …
Landuse change impacts

Cold Region Hydrology
Impact assessment (SSPs)
Impact Attribution to CC
Compound Extremes
Operational Hydrological Forecast

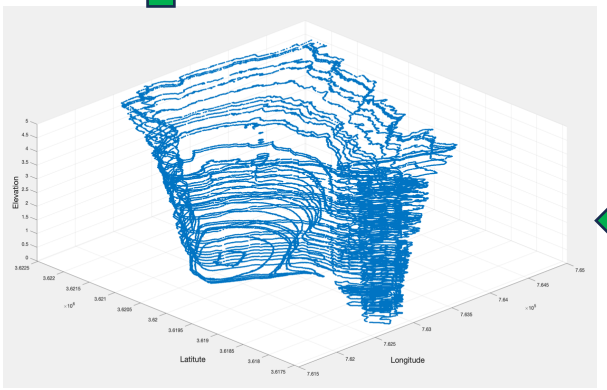
3 Ph.D. Students
2 Master Students
1 Bachelor Student
1 Research Assistant

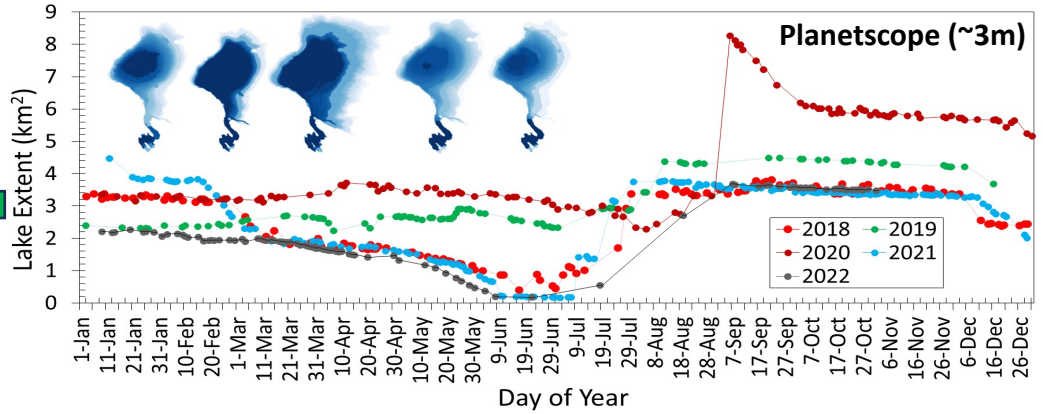
NAMAL Lake: Forecast Informed Resilience

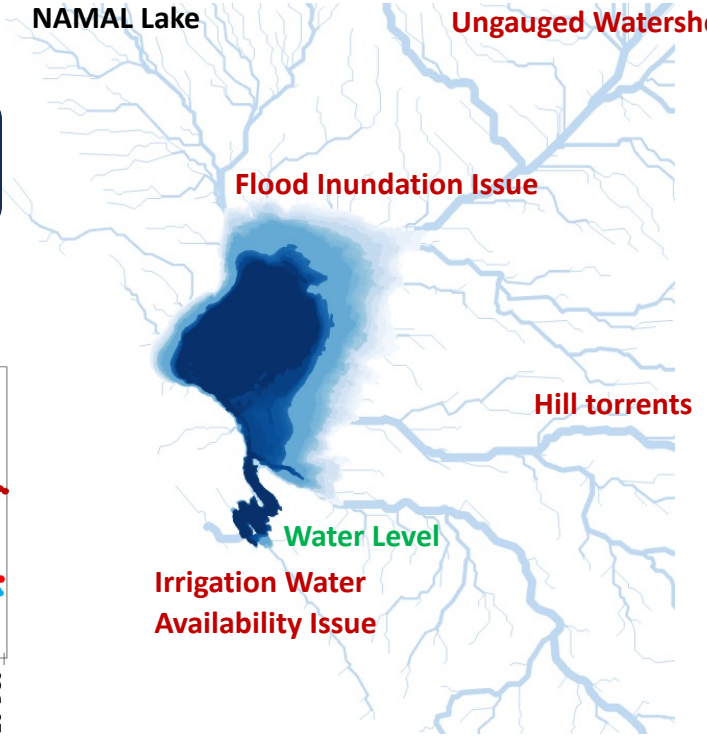


Downscaled Forecast

Observed Discharge → Hydrological Model Calibration → Simulated Discharge → Control Optimization







Climate Change Impact Attribution

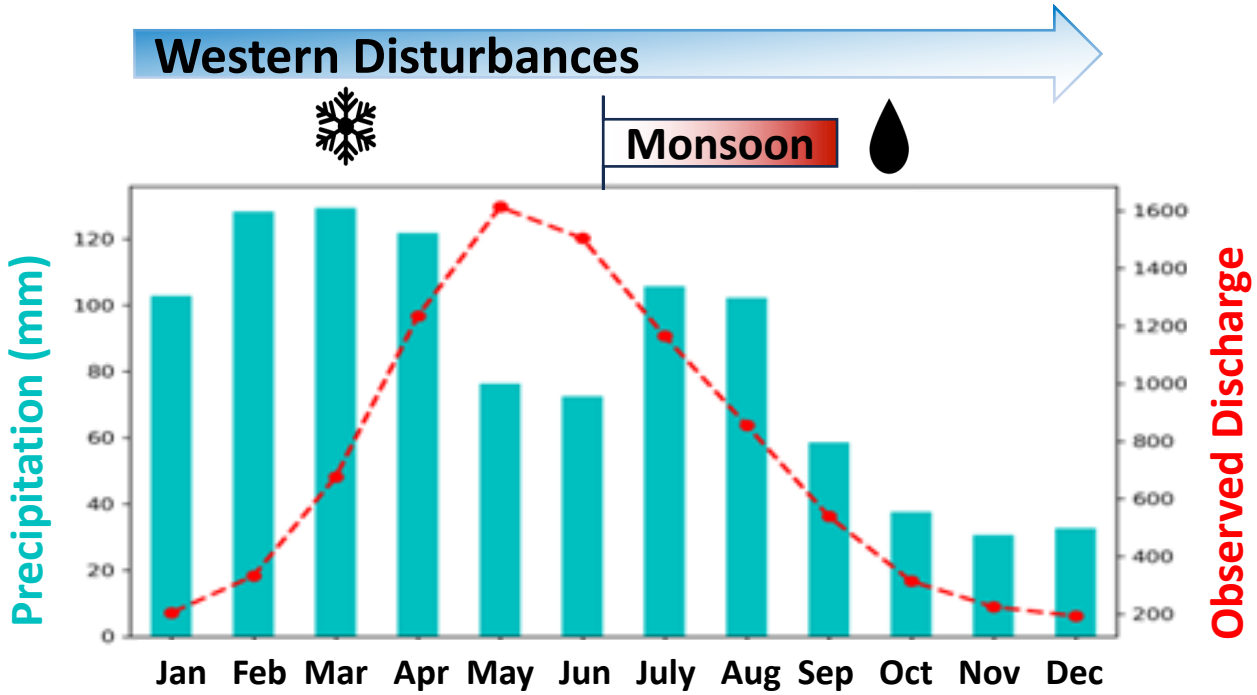
Importance of Himalayan Water Resources

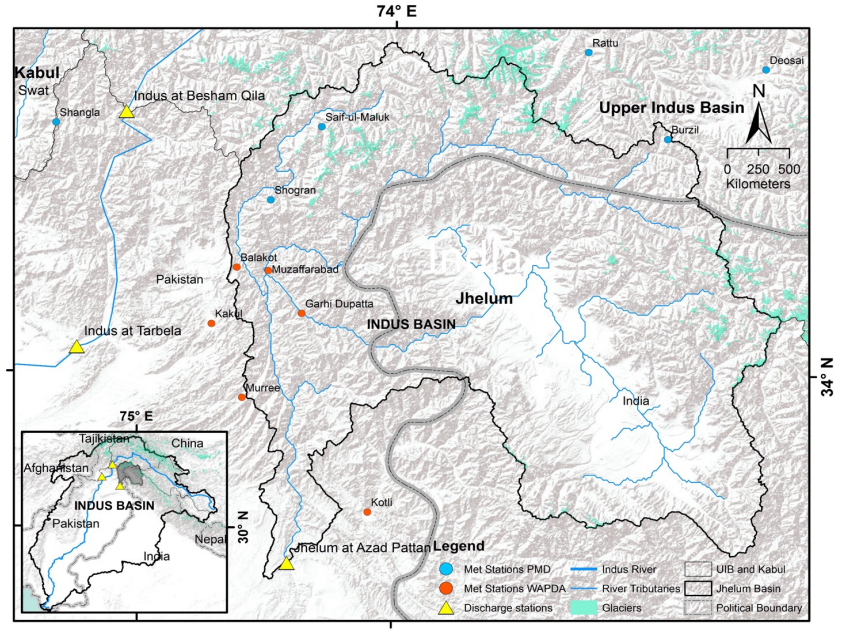
- Important for irrigation, hydropower generation, domestic and industrial use
- Direct effect on the social and economic development of more than a billion
- Climate change is affecting mean and extreme water availability and its timings
- High mountains are the earliest ones to feel the climate change brunt due to EDW

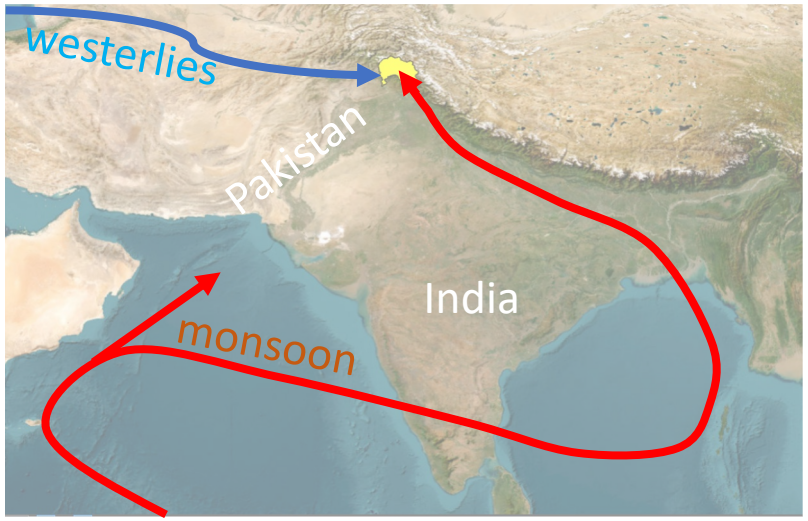
- Quantifying past changes and their stress on water resources
- Analysis for watershed at monsoon margins is difficult

Western Himalaya: Jhelum Basin

- Complex topography, transboundary nature
- Lying at Extreme margins of prevailing precipitation regimes
- Average annual precipitation of ~1200 mm
- Drainage area of 26426.23 Km^2, with 1% Glacier Cover
- Mainly snow-fed basin (peak discharge in May-June)







Detection, Attribution and Projections

Detection

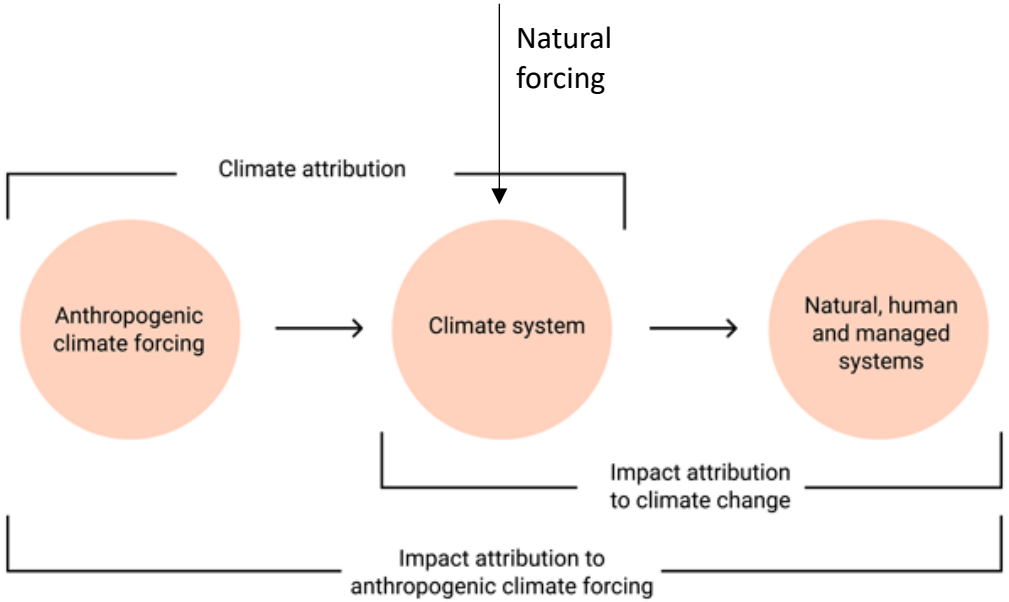
- process of establishing that climate has changed in some defined statistical sense, without giving a reason

Attribution

- establishing mechanisms responsible
  - Climate Change Attribution:
  - Impact Attribution: Trend Change, Extreme Event
  - Source Attribution:

Projections

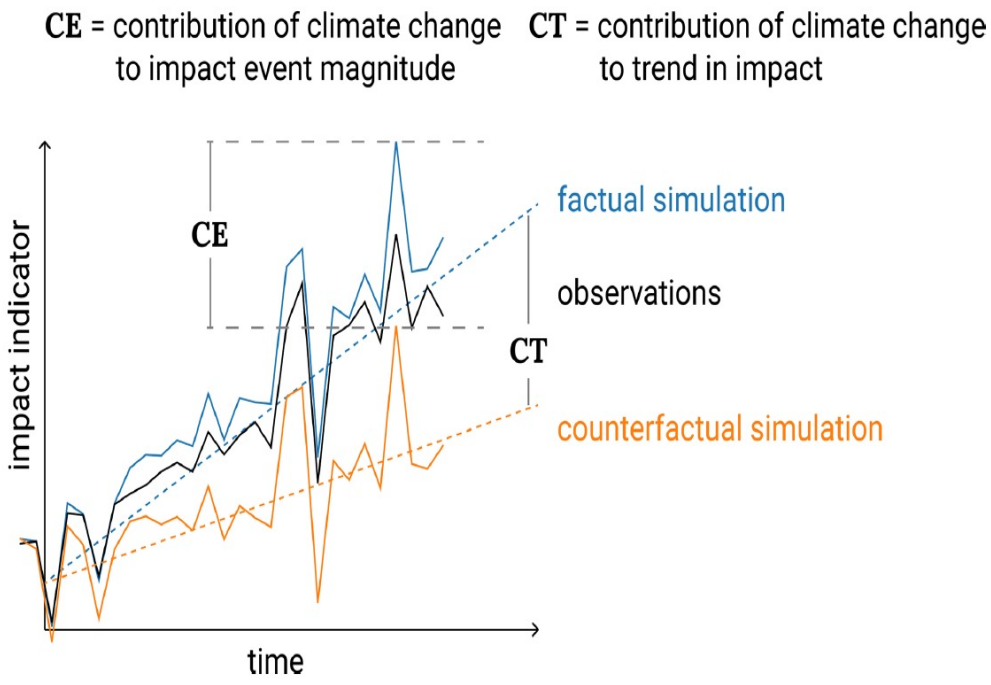
- How things could change further



(process-based) impact models

Attribution: Factual minus Counterfactual

- The impact model is evaluated against observations
- Impact model is forced with Factual climate (with observed CC)
- Observed trend reproduced (black vs blue)
- Impact model is forced with counterfactual climate (without observed climate change)
- Comparison (blue vs orange)

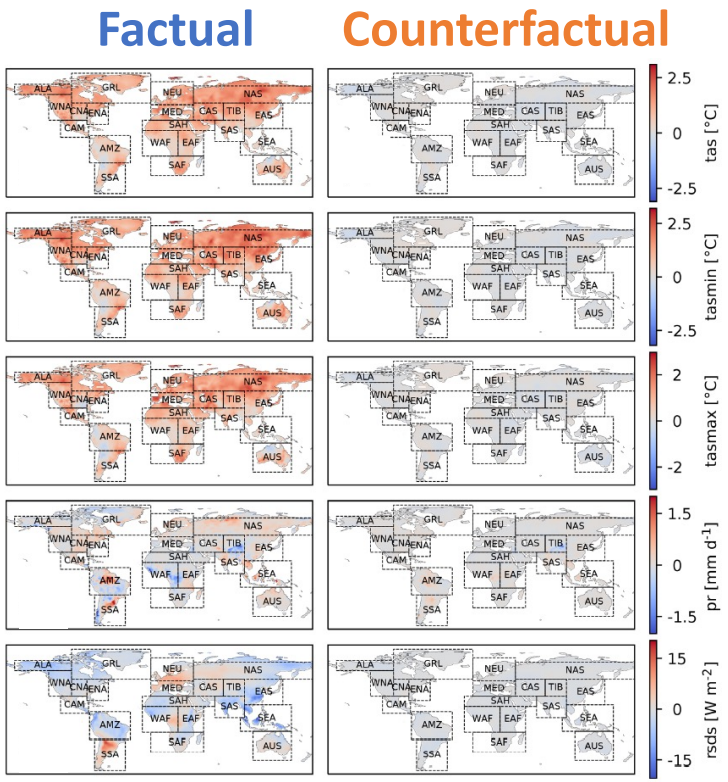


Mengel et al., 2021

ISIMIP3a: Factual & Counterfactual datasets

- Inter-Sectoral Impact Model Intercomparison Project
  - 3a Protocol: Model Evaluation & Trend Attribution to observed climate change
  - 3b Protocol: Future Projections

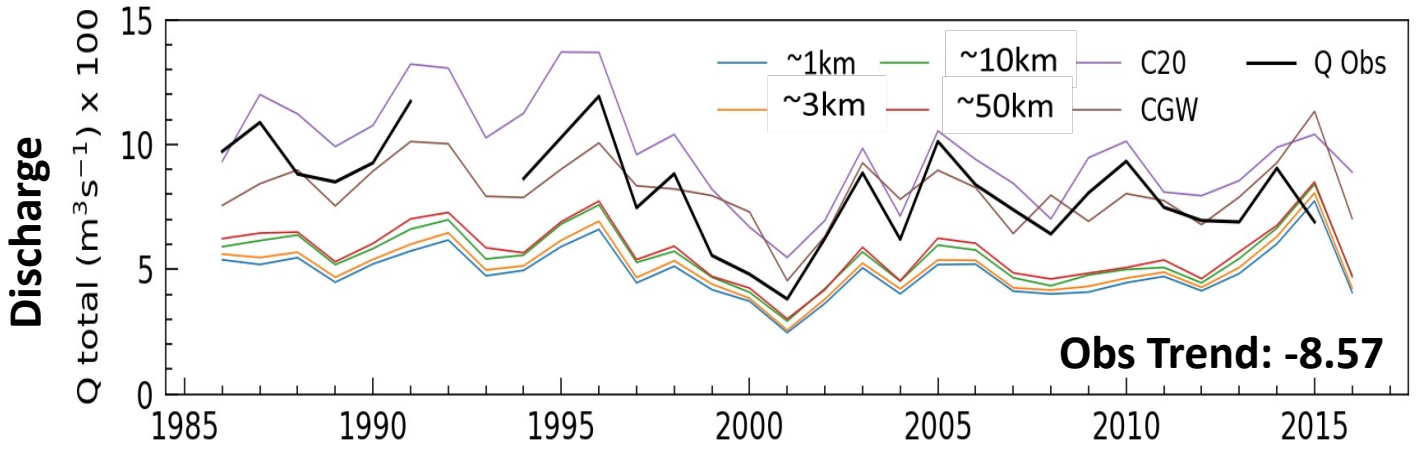
- Protocol 3a datasets (0.5º - 1901-2019)
  - Factual & Counterfactual climates
    - 20CRv3
    - 20CRv3-ERA5
    - 20CRv3-w5e5
    - GSWP3-w5e5
- Protocol 3b datasets (0.5º - 1850-2100)
  - Historical and Future climates from Six bias-corrected ESMs
    - SSP1-RCP2.6:
    - SSP3-RCP7.0
    - SSP5-RCP8.5

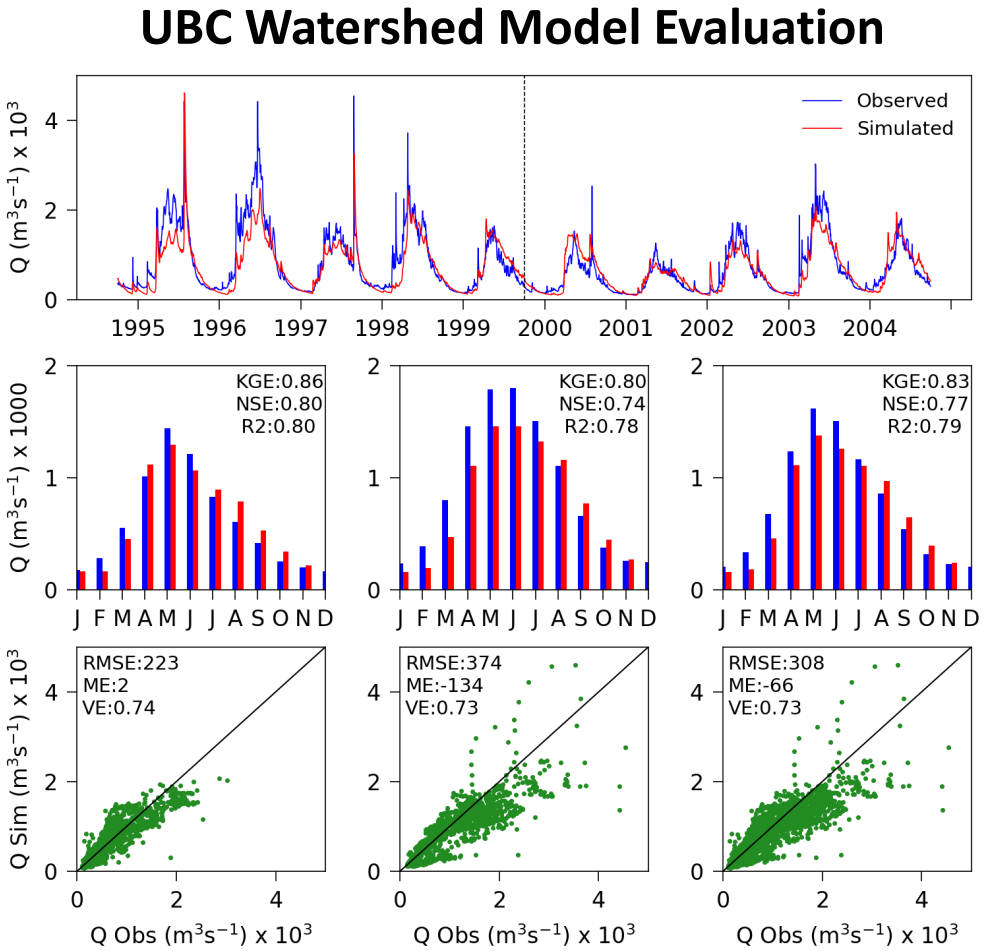


Mengel et al., 2021

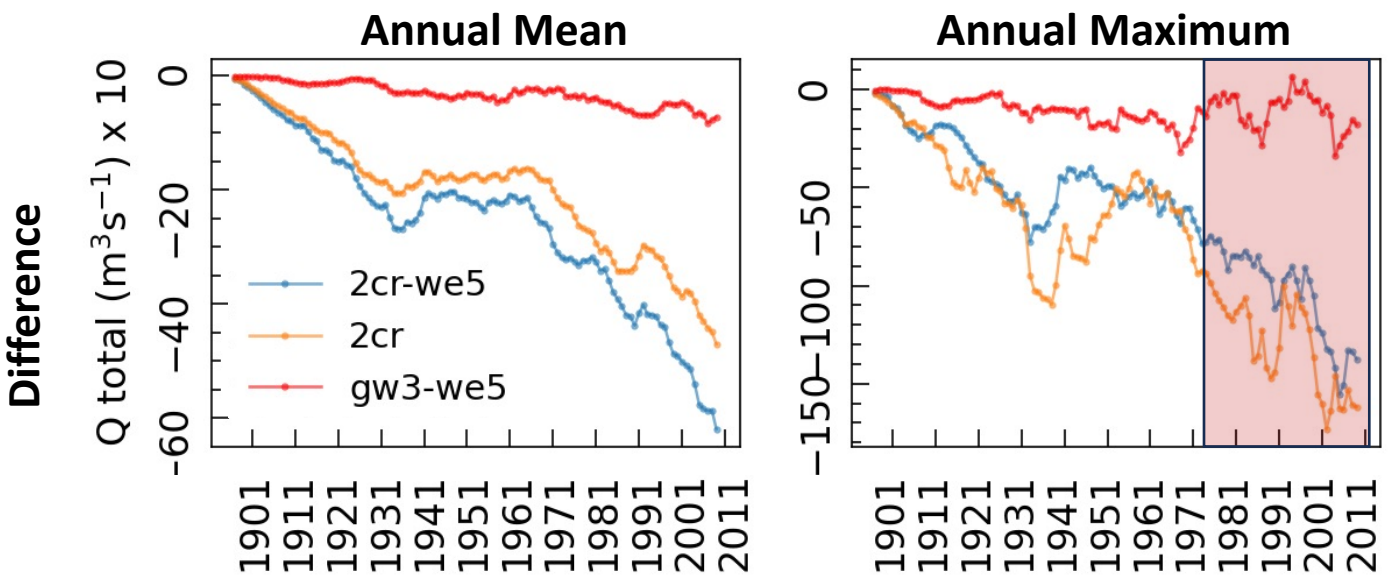
UBC Watershed & RRI Models: Evaluation

- Model Performance is ‘Very Good’ to ‘Good’
- A few discharge peaks are underestimated
- Coarse-grid resolution of ISIMIP datasets (0.5º)
- ISIMIP secondary high-resolution datasets (1km - 50km) see stark underestimation due to warm and dry bias
- RRI model features similar performance

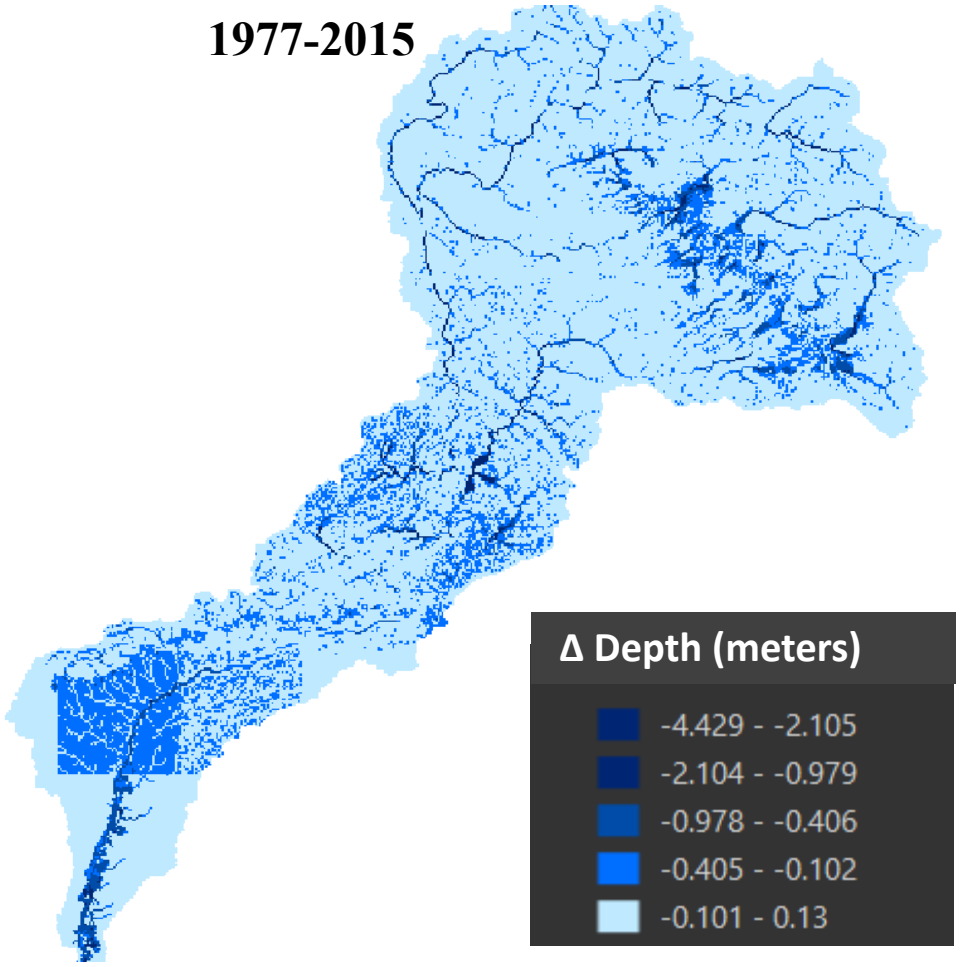




Attribution: Factual minus Counterfactual



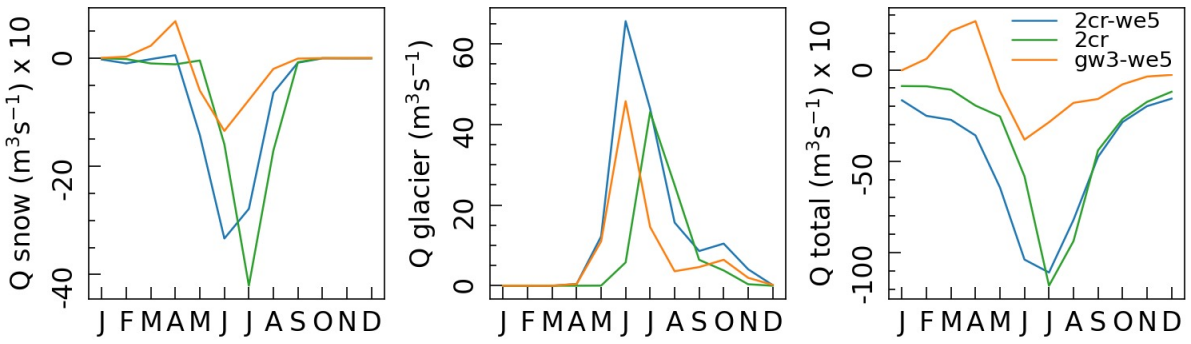
RRI - Flood Inundation

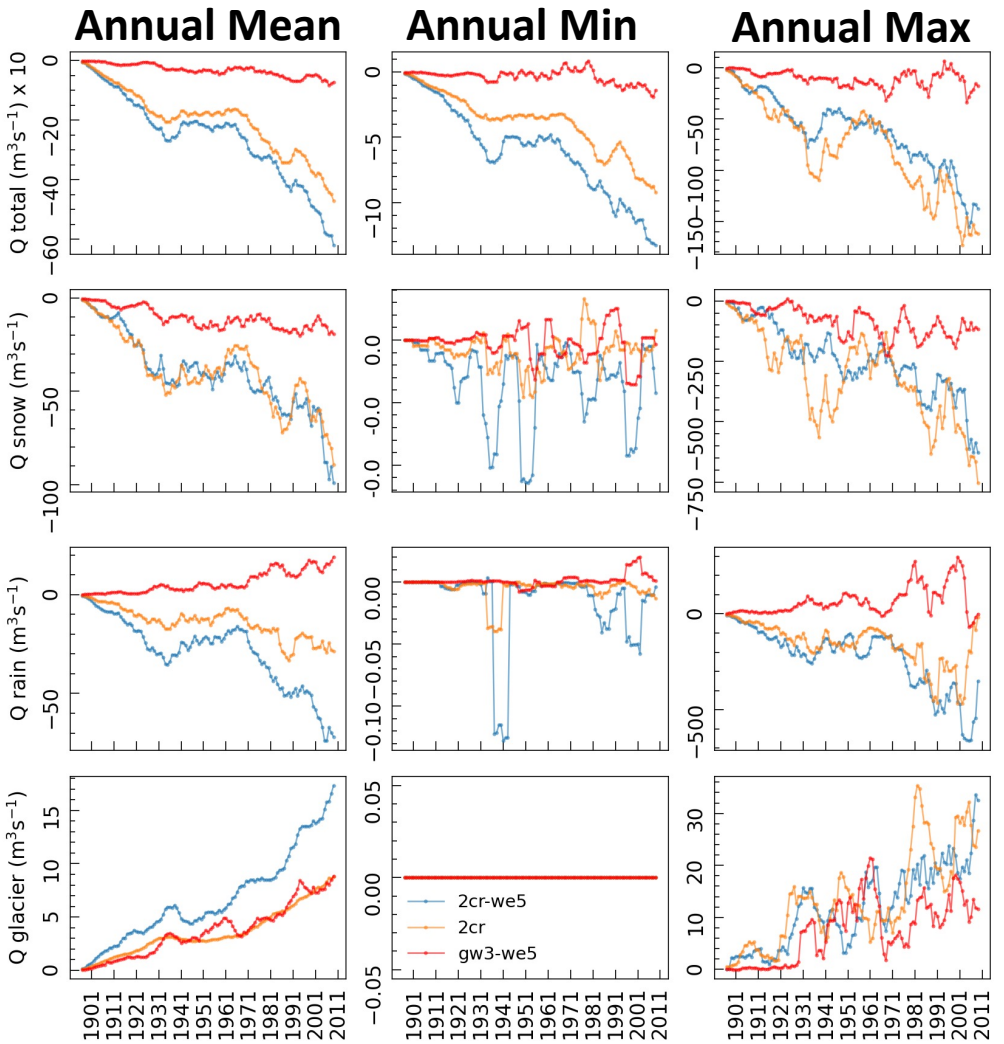


- The strongest change is observed for 2cr-we5 dataset
- The strongest change is observed for recent climate

Attribution: Factual minus Counterfactual

- Observed flows are decreasing
- Factual flows would not have decreased should there be no climate change
- Climate Change is responsible for:
  - Decreasing annual mean, minimum, and maximum total, rainfall and snowmelt discharges due to
  - GW3-WE5 shows an increase in rainfall-runoff
  - Increasing glacier melt discharge

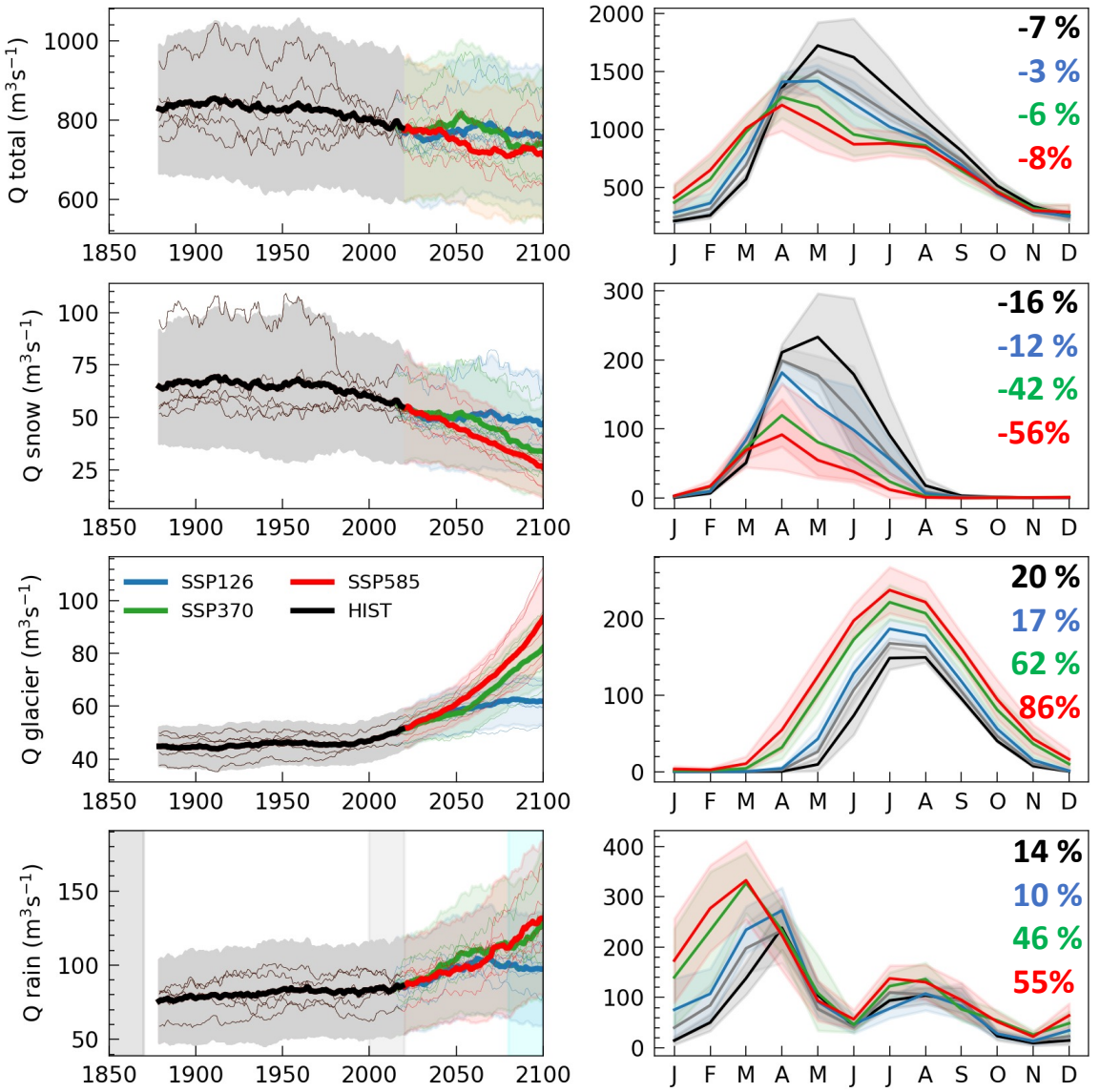




Projections

- Annual Mean Changes:
  - Decreasing annual mean discharge
  - Decrease in snowmelt discharge
  - Increase in rainfall discharge
  - Increase in glacier melt discharge
- Seasonality Changes:
  - Decreasing discharge for high flow period
  - Decreasing snowmelt discharges
  - Decreasing summer precipitation
  - Increase in winter discharge (Dec – Mar)
  - Increase in winter rainfall runoff

  - Early peak discharge due to early snowmelt



Conclusions

- Observed flows are decreasing
- Model performance is ‘Very Good’ and reproduces observed trend
- Resolution sensitivity suggests dynamically downscaled climatic fields
- Observed decrease can be attributed to observed climate change
- Nival regime is weakening with early spring
- Low flows will increase but high flows will decrease further in future
- Flood inundation depth is decreased
- …

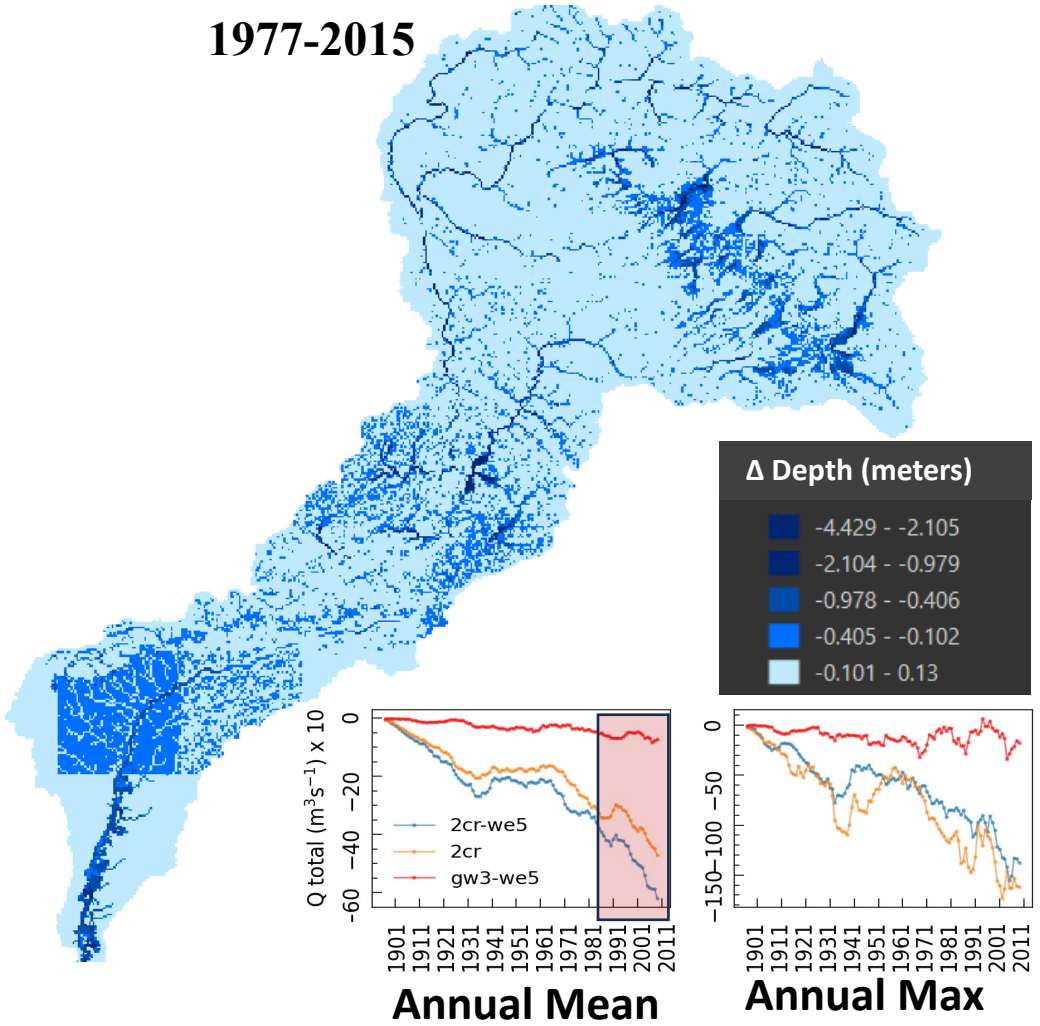
THANKS!

HAREME LAB Collaboration

Prof. Takahiro Sayama's Lab

- Attributing flood inundation changes to climate change
- Projected flood inundation scenarios at monsoon margins
- Integration of Rainfall-Runoff Model (RRI) from Prof. Sayama's Lab into SAGA-GIS from the Institute of Geography *(depending upon the funds)*

RRI - Flood Inundation



HAREME LAB Collaboration

Prof. Yosuke Yamashiki

- Supervision for Ph.D. student Ms. Sadaf
- Glacier Lakes Outburst Floods in Karakoram Region:
  - Mapping
  - Modelling
  - Projections

Prof. Tetsuya Takemi

- Dynamical downscaling for Pseudo Global Warming Scenarios