# The Water Balance of the Issyk-Kul Basin under Climate Change

## *Part 1: Data Mining and Model Coupling*

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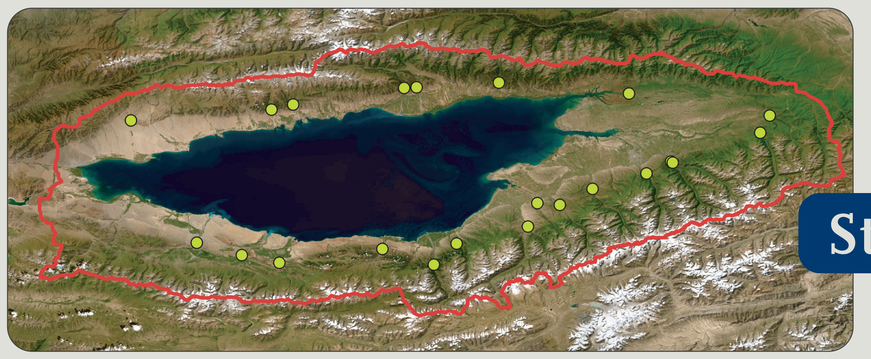
## 1. Background & Objectives

The endorheic **Issyk-Kul basin in Kyrgyzstan** has a history of more than 120y of environmental observations. We combine **hydrological & climatic data** from historical archives with modern datasets & **modelling** tools to investigate climate impacts on the basin's **water balance**. In the 1st part of the study, we ...

- digitized, harmonized and, analysed **historic data sources**
- evaluated the suitability of ERA5-Land, CHELSA-W5E5, and CHIRPS **precipitation products**
- coupled the Workflow for Modelling Water Resources in Glacierized Catchments (**MATILDA**) with the Global Glacier Evolution Model (**GloGEM**)




**Study Site**

- gauging stations

## Issyk-Kul - „the hot lake“

- worlds 2nd largest mountain lake
- Endorheic (closed) basin
- > 800 glaciers covering ~650 km²
- Surface area ~6,236 km², vol. ~1,738 km³;
- Negative Climatic Water Balance (Annual lake surface evaporation ~700–820 mm)
- max. depth ~668 m
- 118 tributaries
- 31 accessed discharge records (22 located)
- Never freezes (min. ~3–4 °C)

## 2. Model Setup

- **MATILDA** combines the HBV model with a simple glacier melt model
- **GloGEM** is a global model for glacier mass balance & geometric evolution
- **Both** use a temperature-index model & volume-area scaling (Δh-parametrisation)

**Why couple the models? Because GloGEM ...**

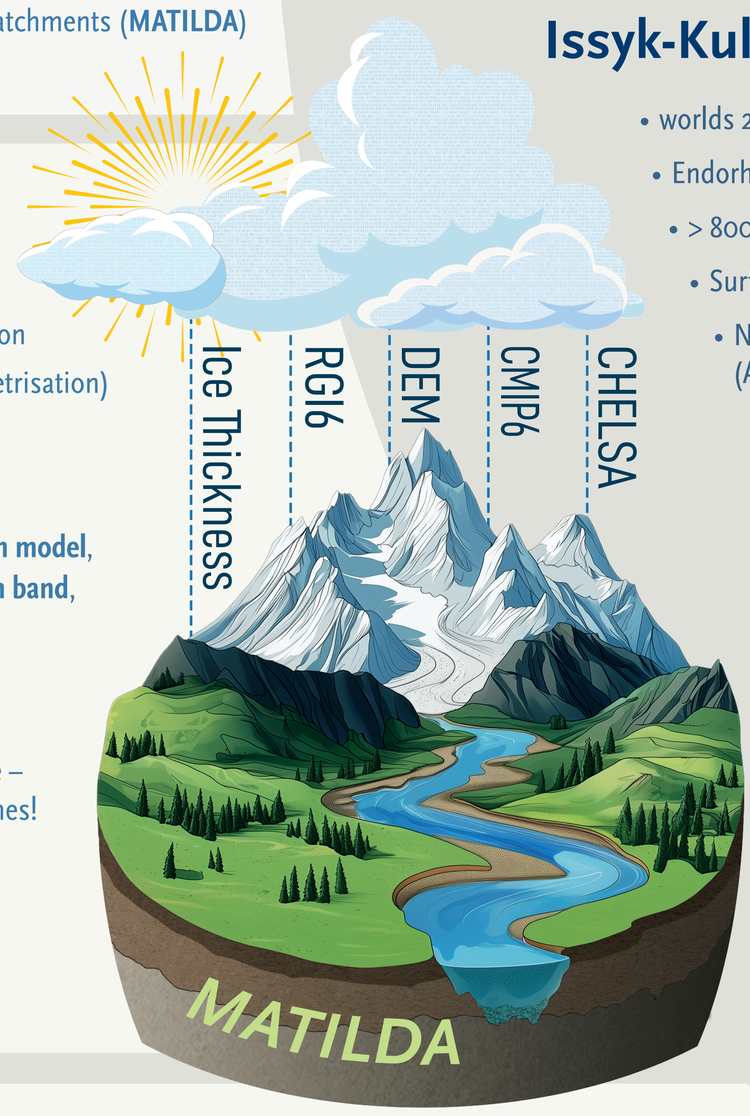
... explicitly models all **glaciers individually**,
... calculates refreezing using a **heat conduction model**,
... calculates accumulation & melt per **elevation band**,
... explicitly models glacier **length changes**.

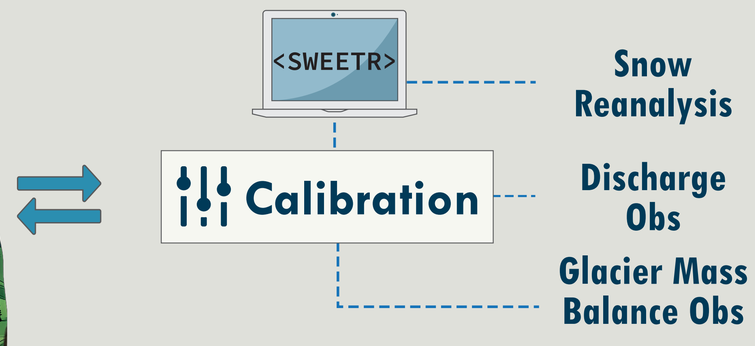
**Disadvantages:**

- Higher computational **costs**
- GloGEM does not (yet) calibrate to snow reanalysis or discharge – MATILDA does! ➔ Requires **separate calibration** of both routines!

**Study setup:**

- Manual calibration of 3 catchments with long discharge records
- Matching shared parameters where possible
- Comparison of setups with and without GloGEM




**Forcing & Calibration**

- **Calibration**: CHELSA-W5E5 at 30 arcsec resolution (1979-2016) with warm-bias adjustment based on ERA5-Land
- **Projections**: NEX-GDDP-CMIP6 (1979-2100) bias-adjusted based on CHELSA-W5E5
- **Glacier SMB**: Annual Mean 2000-2010 from Hugonnet et.al. 2021
- **Snow**: High Mountain Asia Daily Snow Reanalysis by Liu et.al. 2021
- **Discharge**: Observations provided by Kyrgyz HydroMet

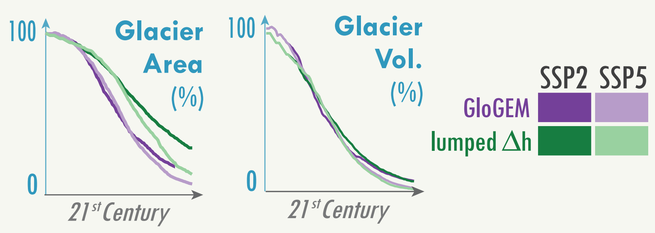
## 3. Results

### Basin-wide Trends

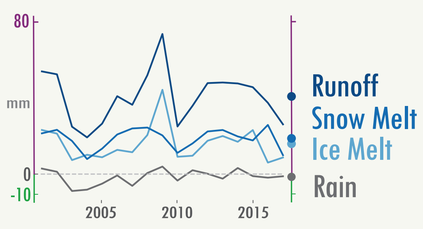

**Annual values aggregated to 0.6° grid cells.**
**Left**: CHELSA means for 1979-2017. **Right**: Mean anomalies for 2017-2040, 2041-2070, and 2071-2100 compared to the historical mean. Ensemble mean of 31 NEX-GDDP-CMIP6 members bias-adjusted with CHELSA. Prec. as per-grid-cell anomalies, Temp. as basin-wide mean anomaly (circles). All temperature values are elevation corrected.

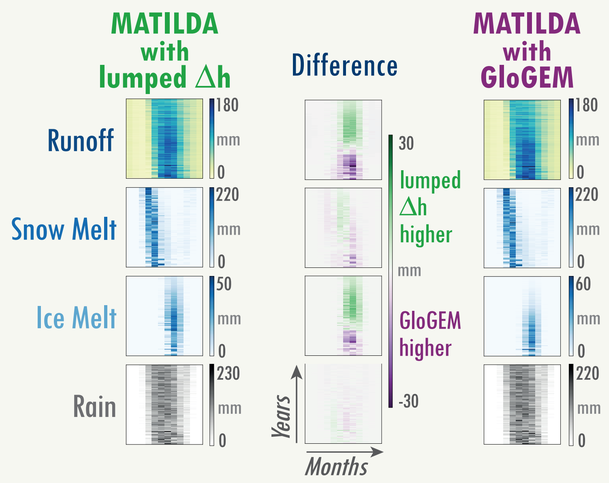
### Model Comparison

*Differences in the Projections*




*Differences in the Calibration Period*




**Model Results from MATILDA for the Kyzylsuu cacthment in two different Setups for SSP5**: (1) Default with a lumped Δh-based glacier routine & (2) coupled with GloGEM. Higher values for (1) are shown in green, and for (2) shown in purple. Models were forced with an ensemble of 5 bias-adjusted CMIP6 GCMs.

## Key Take-Aways

- The Issyk-Kul Basin has a **negative Climatic Water Balance** driven by high evaporation from the lake surface
- The northern mountain range is wetter, the southern range is warmer
- Projections see **increases in both temperature & precipitation**, with stronger precipitation increases in the south & east
- both setups model a similar decay of glacier volume, **GloGEM reduces the glacier area quicker** with higher melt rates
- this leads to **more runoff in the first half of the century** and less in the second
- The resulting **ice distribution is more realistic** in the GloGEM setup (low vol. ≙ low area)
- Both **scenarios lead to similar glacier responses** due to increases in both - temperature and precipitation
- melt season starts earlier, general streamflow reduction

## Next steps

- calibrate the coupled workflow for all gauged catchments
- model ungauged catchments using regionalization with hydro-climatic predictors
- analyse the role of the cryosphere in the lakes water balance

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MATILDA Website