The Tien Shan mountain range in Central Asia is home to approximately 15,000 glaciers which play a crucial role in providing water during dry summer periods when other water sources have dried up and precipitation is scarce. The glaciers release meltwater that supports agriculture, industry, hydropower production and daily life, acting as natural water reservoirs. However, the effects of global climate change have led to an alarming rate of glacier melt in the Tien Shan, posing a significant threat to the region’s water supply.

This PhD project aimed to understand the present state and future evolution of the Tien Shan glaciers. It involved fieldwork and delving into historical and ongoing monitoring efforts, focusing on mass balance, ice thickness and thermal conditions. Six glaciers in Kyrgyzstan were selected for detailed analysis, due to their inclusion in monitoring initiatives. Our team conducted more than 1,600 ice thickness measurements, revealing a maximum ice thickness of 201 ± 12 m. Comparing these measurements with global estimates made without in-situ data provided a reasonable estimate of the ice volume, though local ice thickness varied notably. Mass balance observations over the past two decades showed a strong negative signal under the present climate. Examining the thermal structure of the glaciers revealed distinct thermal regimes, primarily influenced by variations in snow cover, ice thickness and refreezing meltwater.

We refined, calibrated and applied a 3D ice flow and 1D energy balance model to these glaciers using collected and existing data. Future glacier evolution was simulated under various climate scenarios, whereas a comparison between the results of detailed versus simplified models served to assess the impact of simplifications on future ice volume. At the end of this project, we employed GloGEMflow to estimate future changes of all Tien Shan glaciers, focusing on future glacial runoff in various Tien Shan basins.

Our results show that under moderate warming, most Tien Shan glaciers are projected to significantly retreat. This will heavily impact glacial runoff, yielding peak water in all basins before 2050, followed by a strong decline of on average 35% relative to current quantities. Additionally, the annual runoff peak is anticipated to shift from summer to late spring, distancing from dry summer months characterised by highest water demand. These findings underscore the urgency of implementing strategies in agricultural, industrial and energy sectors to secure long-term water resources and prevent water conflicts in the Tien Shan region.