# Future glacier and runoff evolution in the Tien Shan mountains

24/04/2023

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[Ashu-Tor glacier, August, 2019]

# Tien Shan

**Mountain range:**

- Uzbekistan <-> China (~ 3000 km)
- ~ 1 million km$^2$

**Glaciers:**

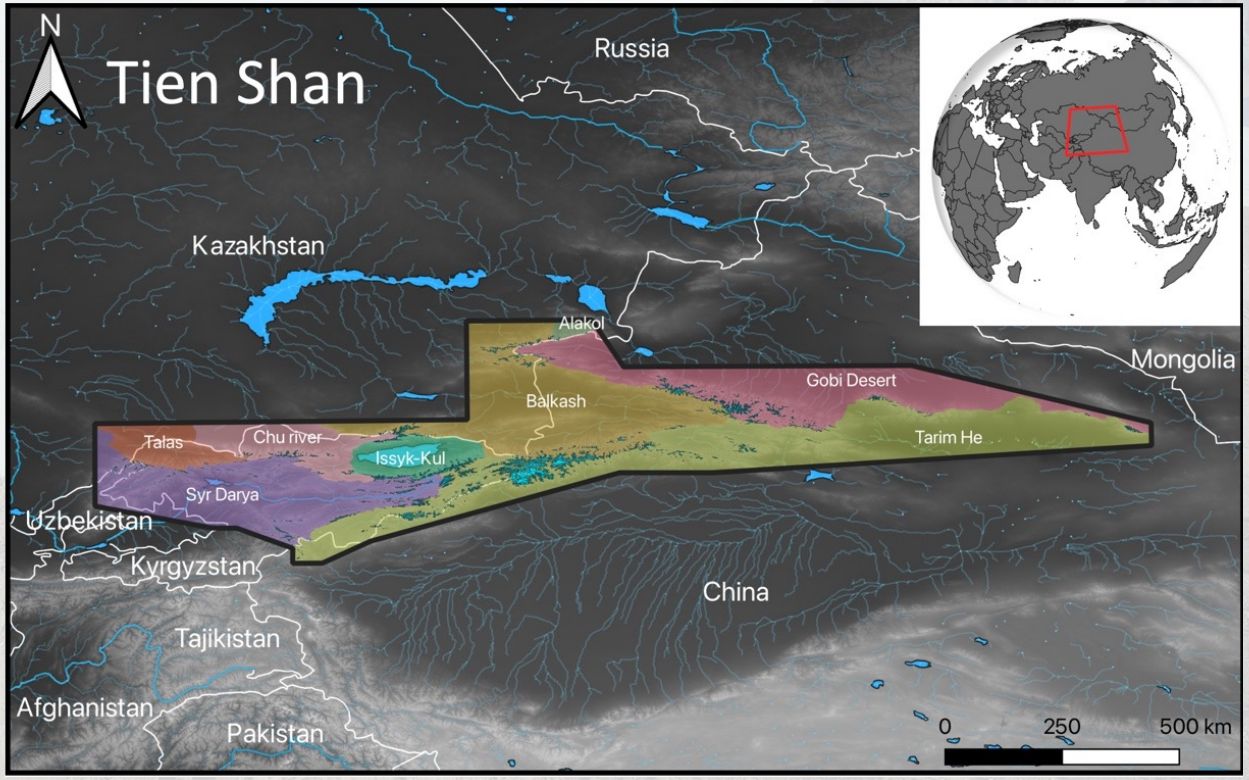
-> 14965 glaciers [RGI, 2017]

~ 770 km$^3$ [Farinotti et al., 2019]

~ 987 km$^3$ [Millan et al., 2022]

**Drainage:**

- Internal drainage
- 8 endorheic basins



# Importance of glaciers in the Tien Shan mountains

1. Natural **reservoirs** for **freshwater**, storing water in the form of ice and snow.

2. The freshwater is released during **spring and summer**

3. It **maintains the water supply** when other sources are depleted and precipitation is absent

4. Glaciers provide a **reliable source of water** for a variety of purposes such as **agriculture**, **hydropower generation**, **industry**, and **human consumption.**

**Climate change is putting the region's water supply at risk**

[Grigoriev ice cap, August, 2021]

**What is the evolution of the glaciers and their associated runoff in the future?**

# Glacier modelling

**GloGEMflow**

- Flowline, based on SIA, all glaciers > 1 $km^2$ [Zekollari et al., 2019]
- Elevation bands of 10 m
- Deformation-sliding factor, matched with consensus estimate [Farinotti et al., 2019]

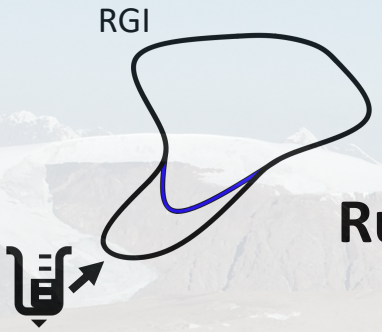
**Mass balance**

- GloGEM, calibrated with geodetic mass balance [Hugonnet et al., 2021]
- Debris [Rounce et al., 2021], spatiotemporal explicitly modelled

**Climatic data**

- ERA5 data for the historical period
- CMIP6 (SSPs) climate scenarios, 12 GCMs

# Runoff modelling




**Runoff?**

"All the water leaving the initially glacierised area, which includes runoff from ice-free areas after glacier retreat"

~ fixed-gauge glacier runoff

**Modelling?**

Following Huss and Hock, 2018 :

- Rain and melt (from ice, snow, and firn) are summed
- Refreezing is subtracted

Differences with Huss and Hock, 2018

- Glacier dynamics are modelled
- Debris is taken into account
- Geodetic MB is matched

# Strong glacier volume loss

**Tien Shan:**

-30% between 2020-2040

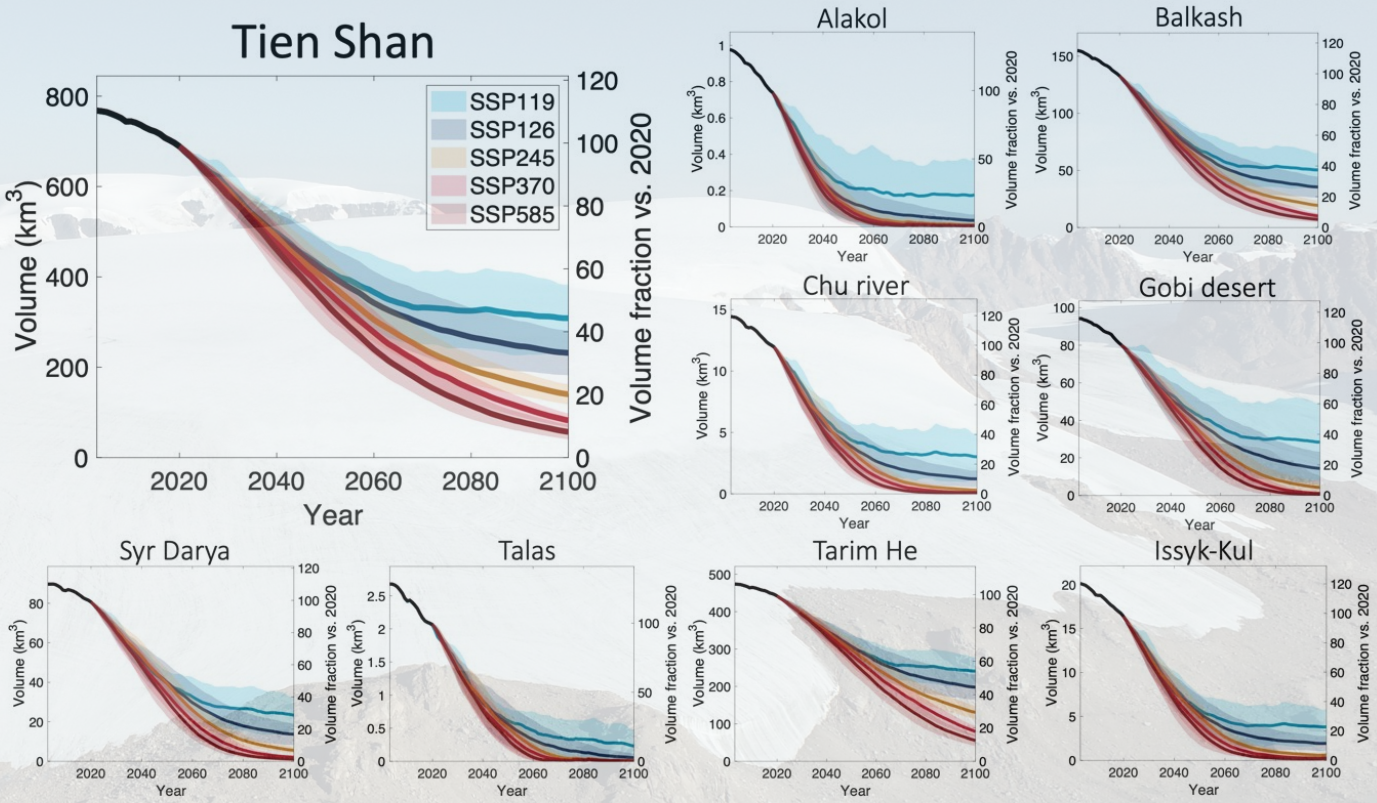
-55%  to - 95% by 2100

Signal of Tarim He basin

**Sub-basins:**

Much faster volume loss

Ice free in 2100



# Importance of initial ice thickness

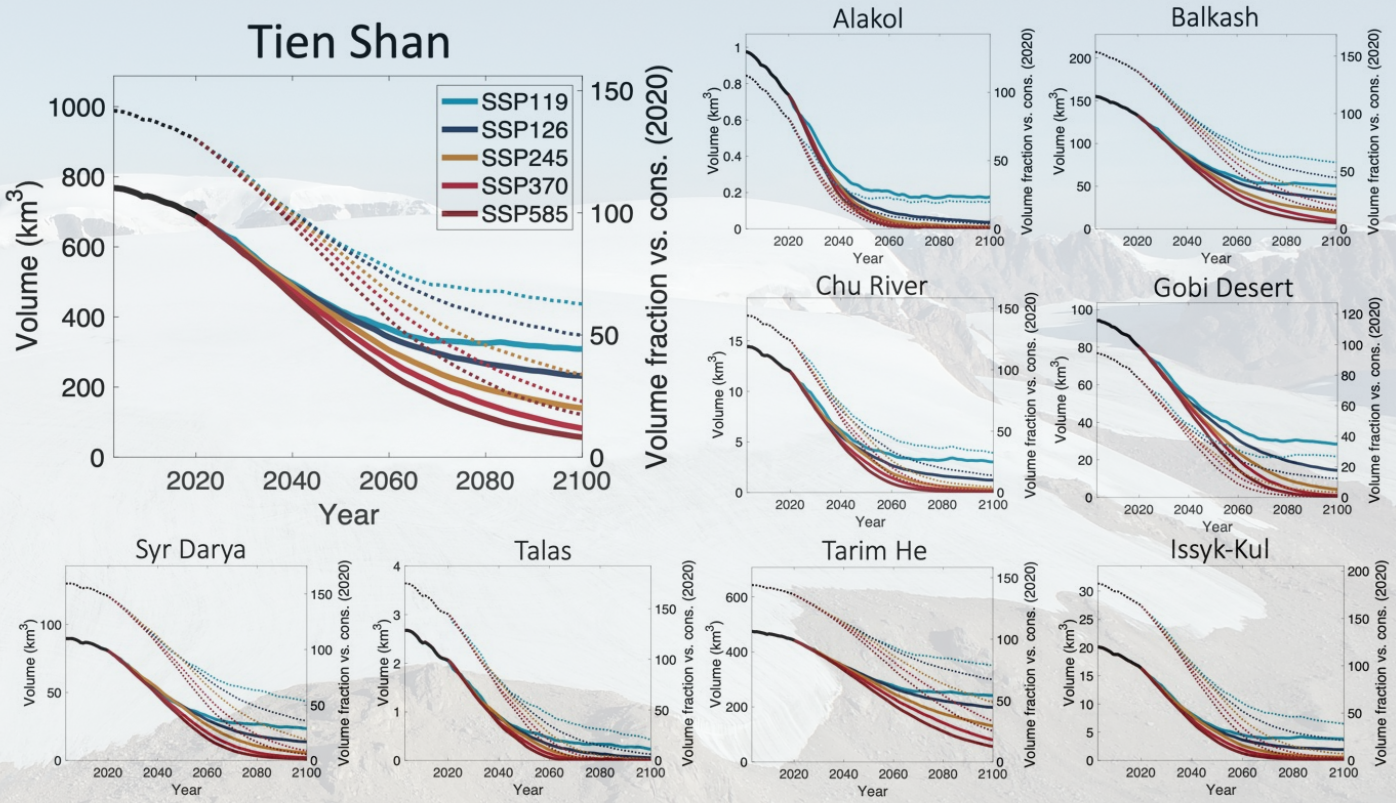
- Large importance of initial thickness

**Millan vs Consensus**

- Larger ice mass at inventory date
- More ice retained in the future

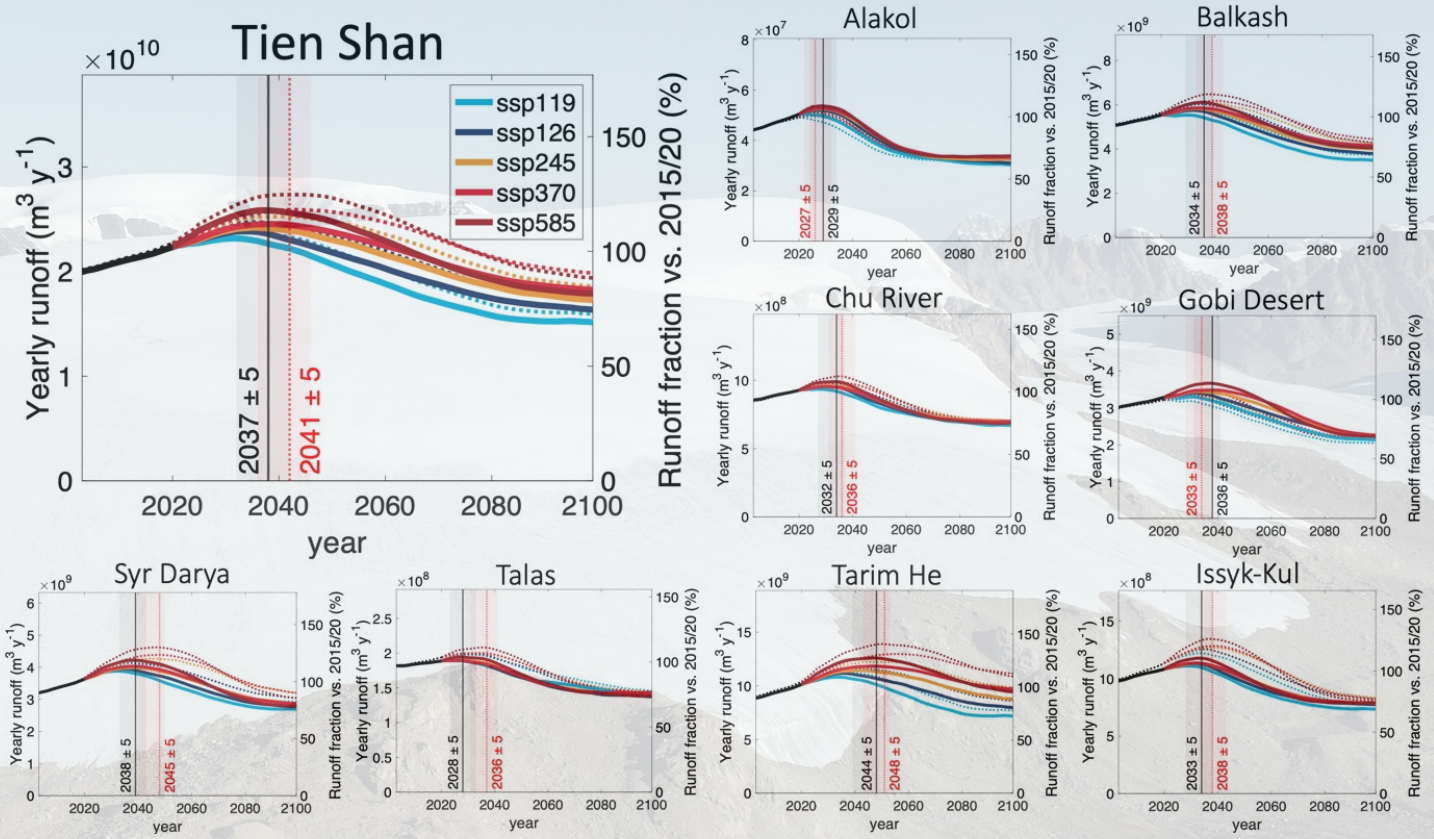
**BUT**

- Convergence near the end of the century
- Differences most outspoken in ablation area



# Total runoff

1) Upsurge coming years
2) Peak in [2028-2044]
3) +10-15% at peak water
4) -20 to -30% by 2100

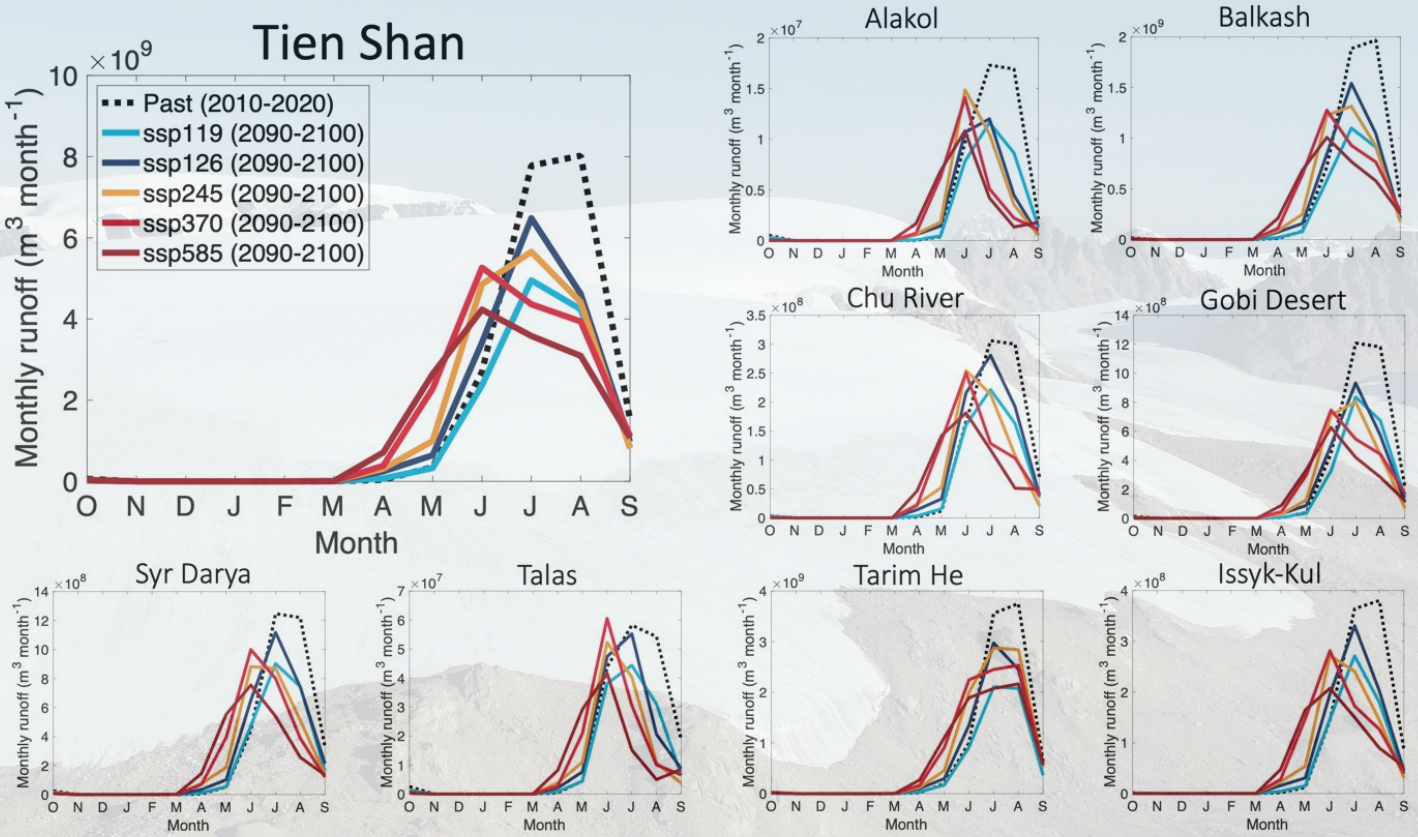



Striking:

- Higher peak for higher emission scenarios
- Basins with smaller volumes peak earlier
- Millan et al. (2022): peak is higher and later
- Issyk-Kul 15% greater peak runoff
- Syr Darya 7 year later peak

# Annual peak runoff shift

- Reduction in all basins
- 1-2 months earlier
- Shift to spring
- July/August: -40 to -92%
- Glacial-nival –> nival-pluvial



# What should you remember?

**Rapid loss of glacier mass in the Tien Shan**

**Drastic reduction of glacier runoff after 2040**

**Annual peak runoff shifts to 1-2 months earlier**

[Petrov glacier, August, 2022]