State of Cryosphere in Central Asia

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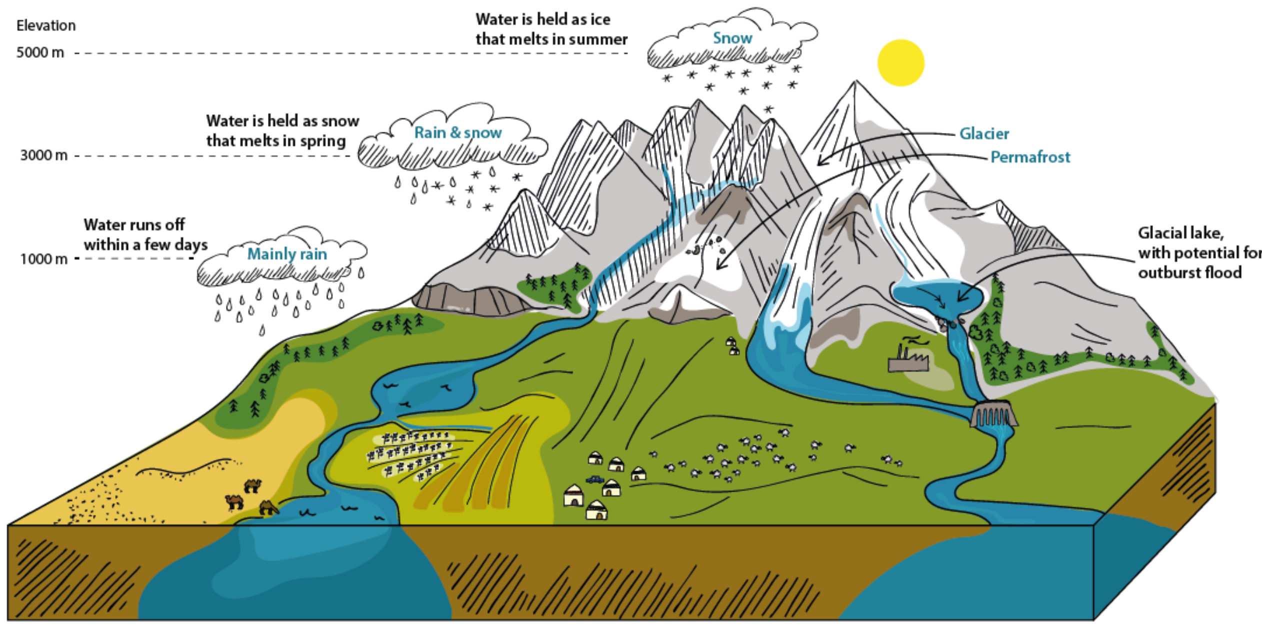
Impacts of global warming on the cryosphere is acting on different scales

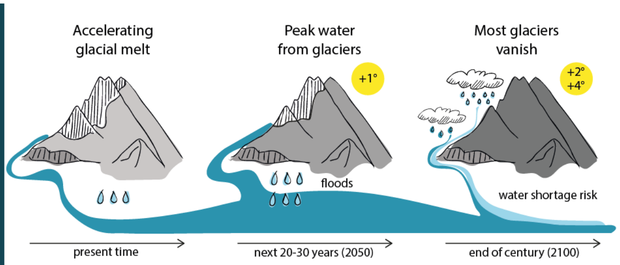
Water resources of Central Asia

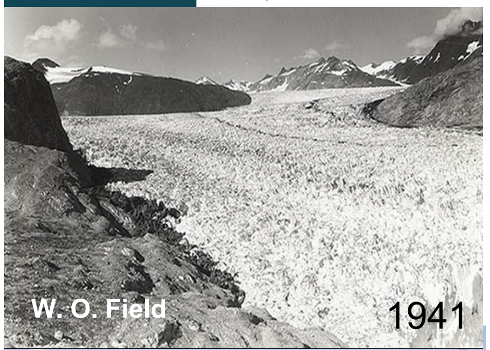
Vital roles of mountains, snow and glaciers

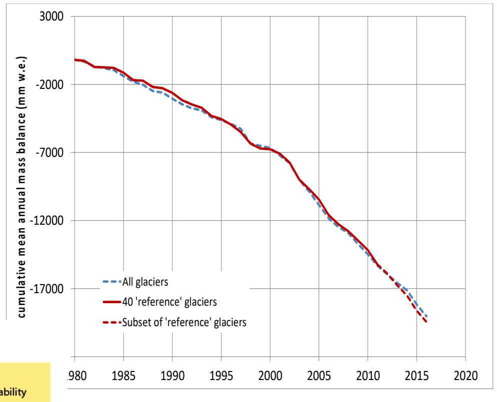


Climate change impact on cryosphere and beyond

Water flow increases with glacial melting, then declines when the glaciers are gone.

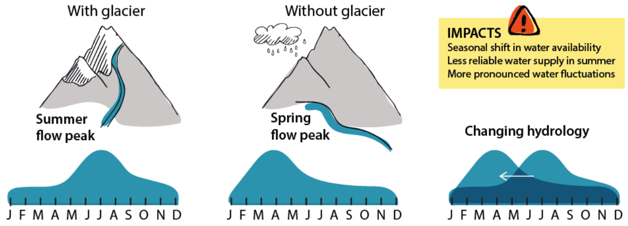




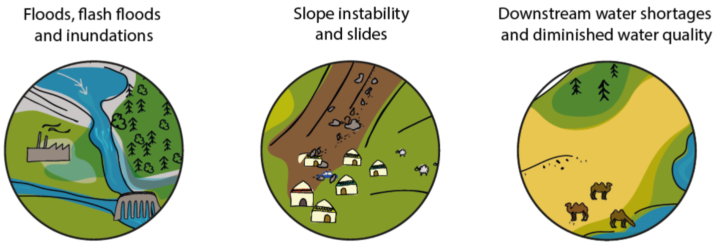


WGMS, 2016

As glaciers retreat, the water flow peak shifts from summer to spring.



The changes in the mountains carry risks all the way to the lowlands.



Why in Central Asia?

mountain region	**glacier area according to RGI 5.0 in km2**	**number of mass balance glaciers**
European Alps	ca. 2’000	64
Tien Shan & Pamir	> 25’000	11

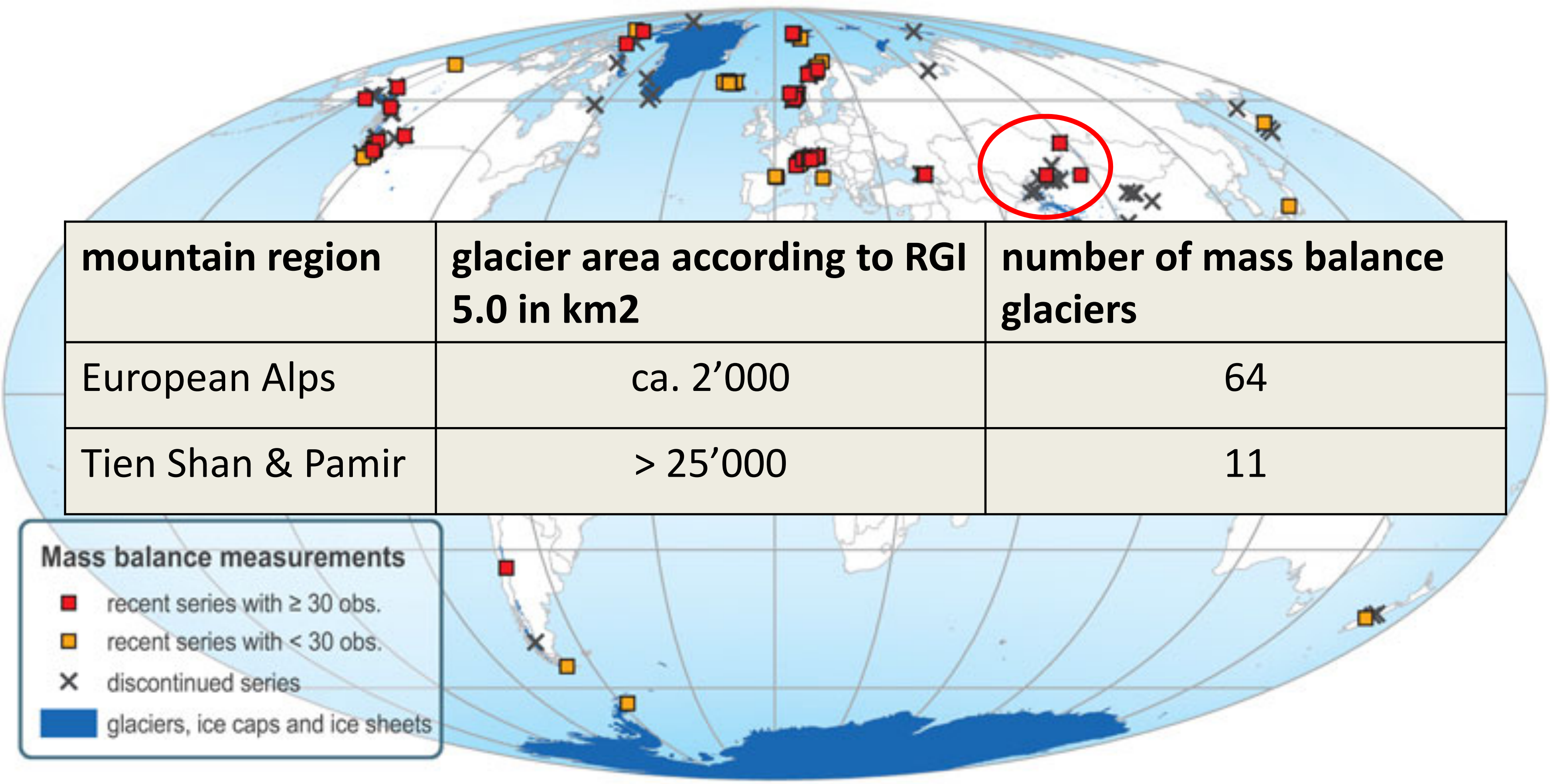
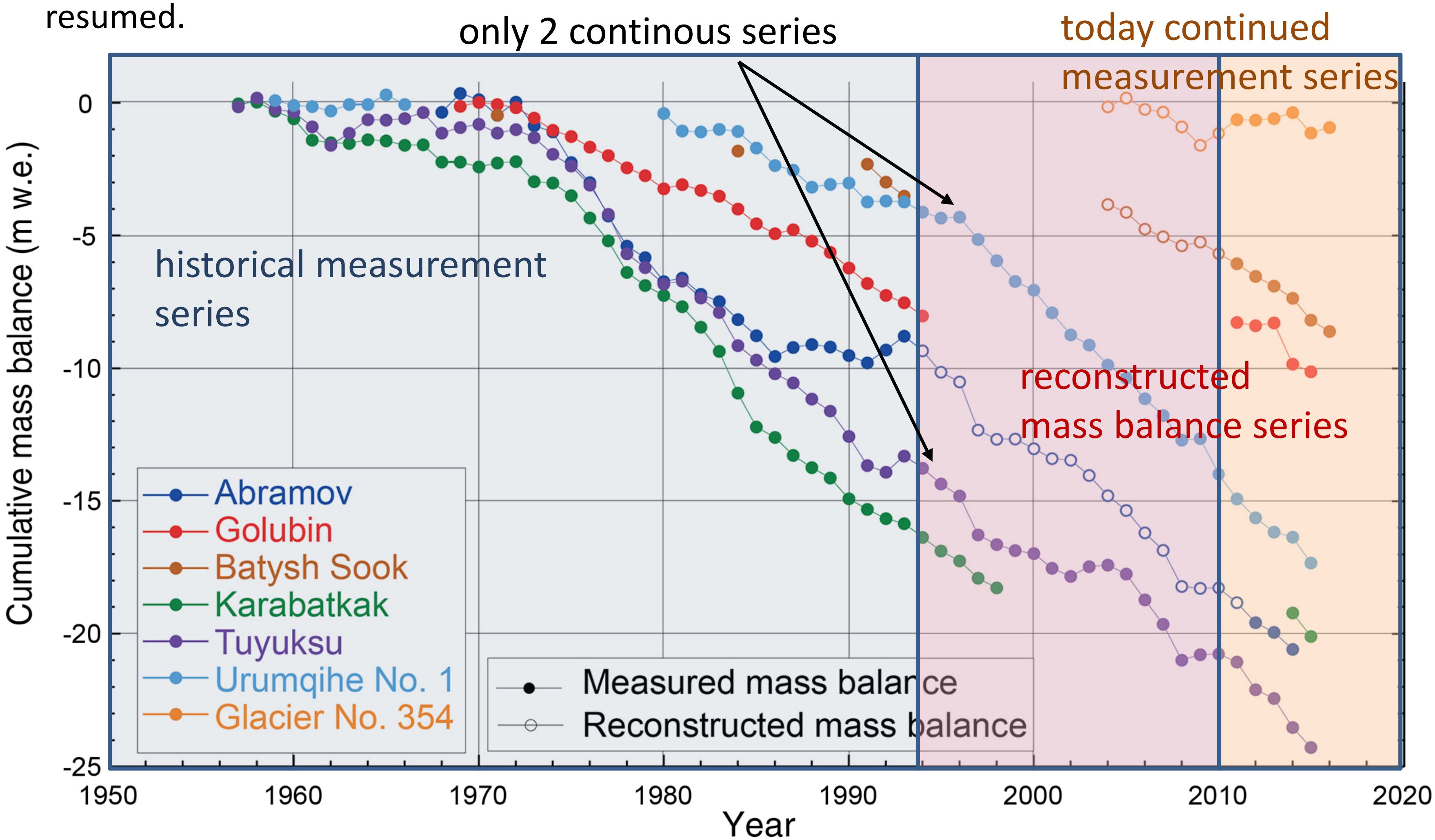


Fig. 4.7 Worldwide mass balance measurements

(Roer, 2008)

Mass Balance series in CA

Glacier mass balance monitoring stopped in the late 90's (except for Tuyuksu glacier), and through several international and national inititatives it is gradually being resumed.



General approach in Mass Balance

glaciological Method

+ good temporal resolution
- restricted spatial resolution

geodetic Method

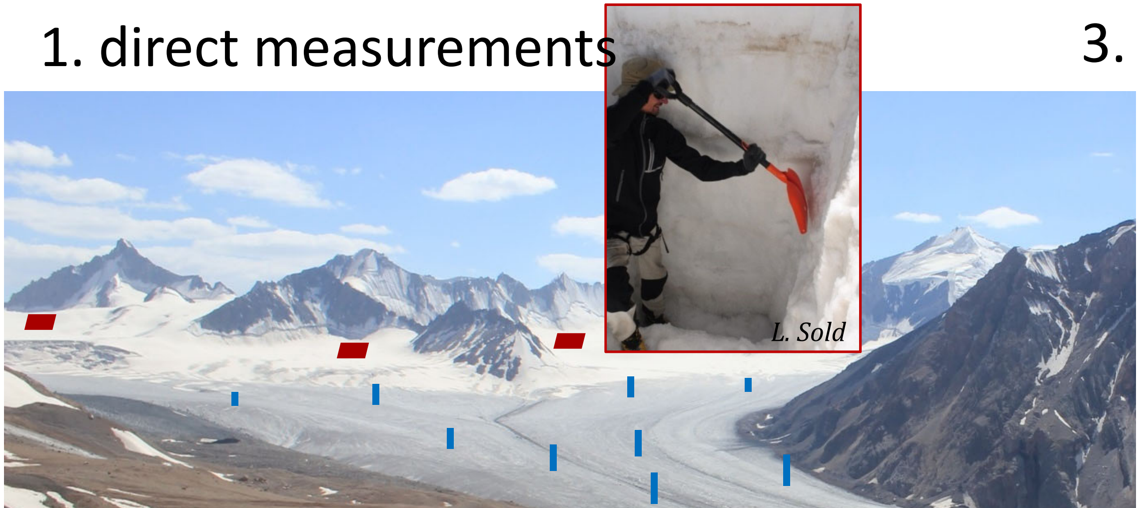
+ good spatial resolution
- restricted temporal resolution

mass balance modelling validated / calibrated with transient snowline observations

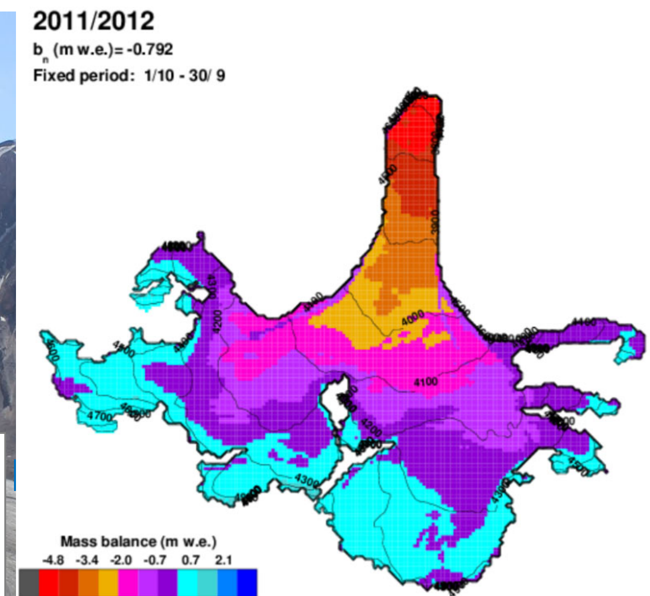
+ good temporal resolution
+ applicable on extended, remote areas
- simulation (not purely observation based)

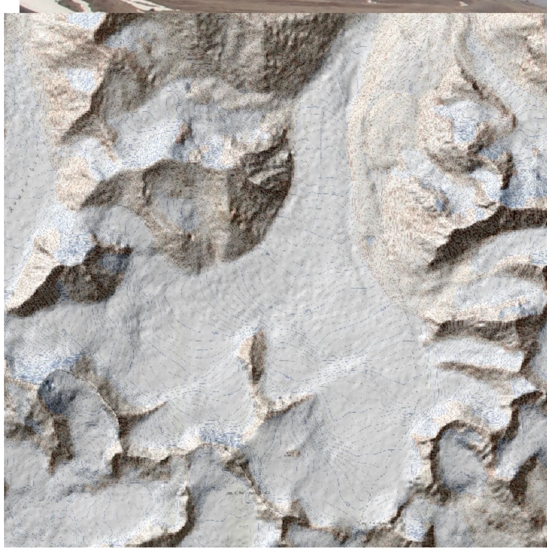
glacier mass balance observation

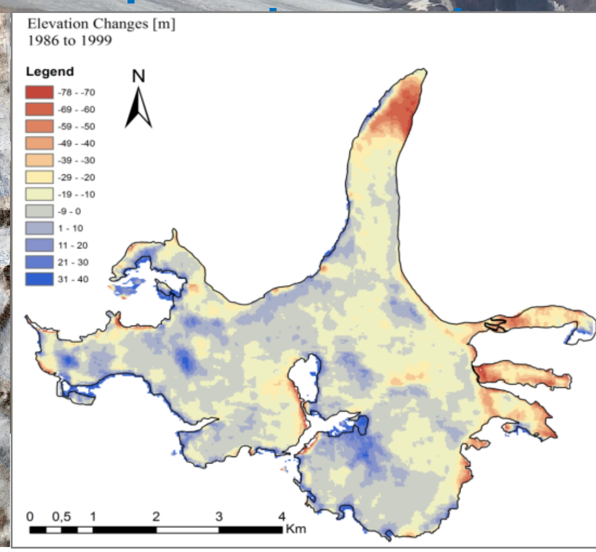
1. direct measurements



3. modelling mass balance

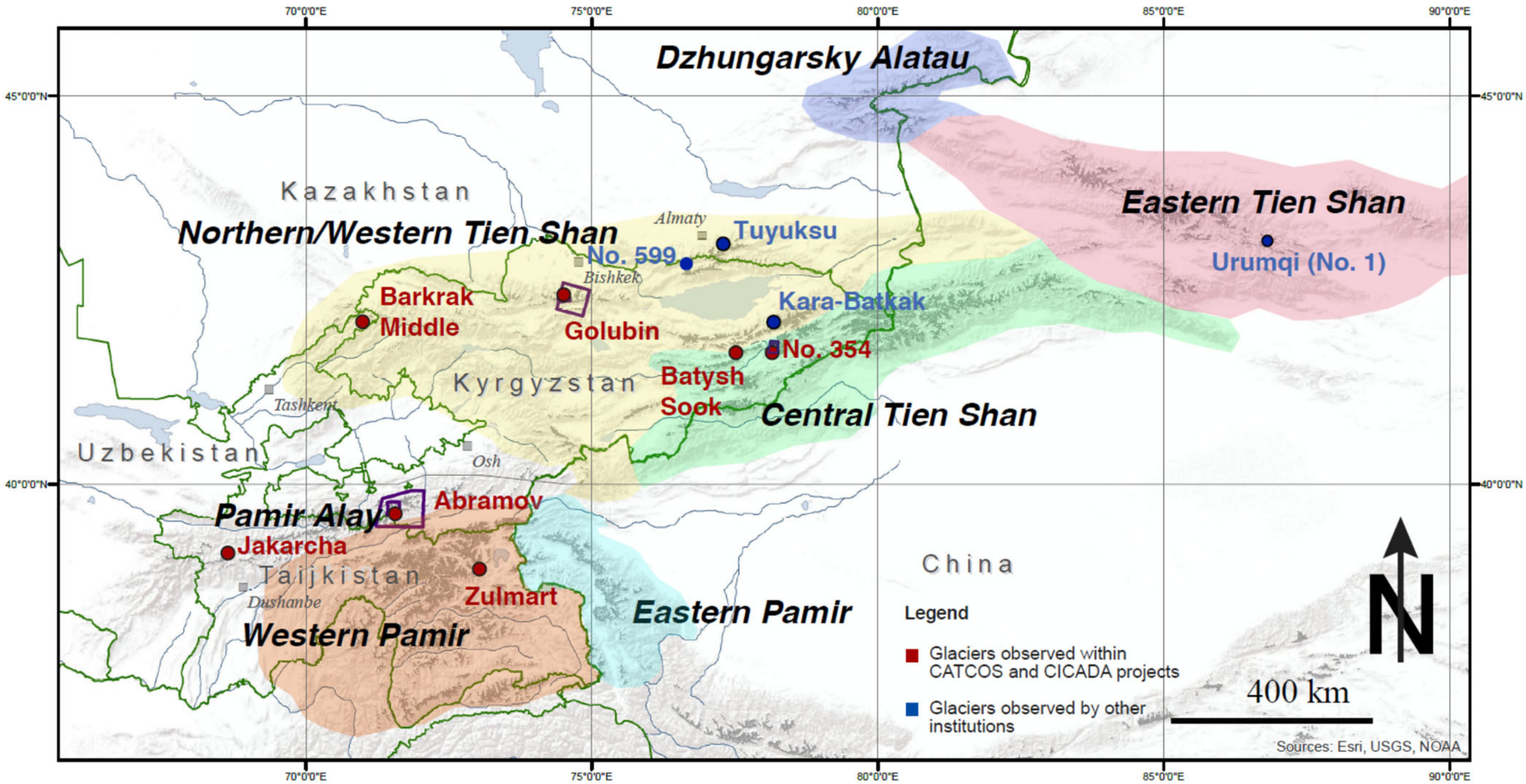




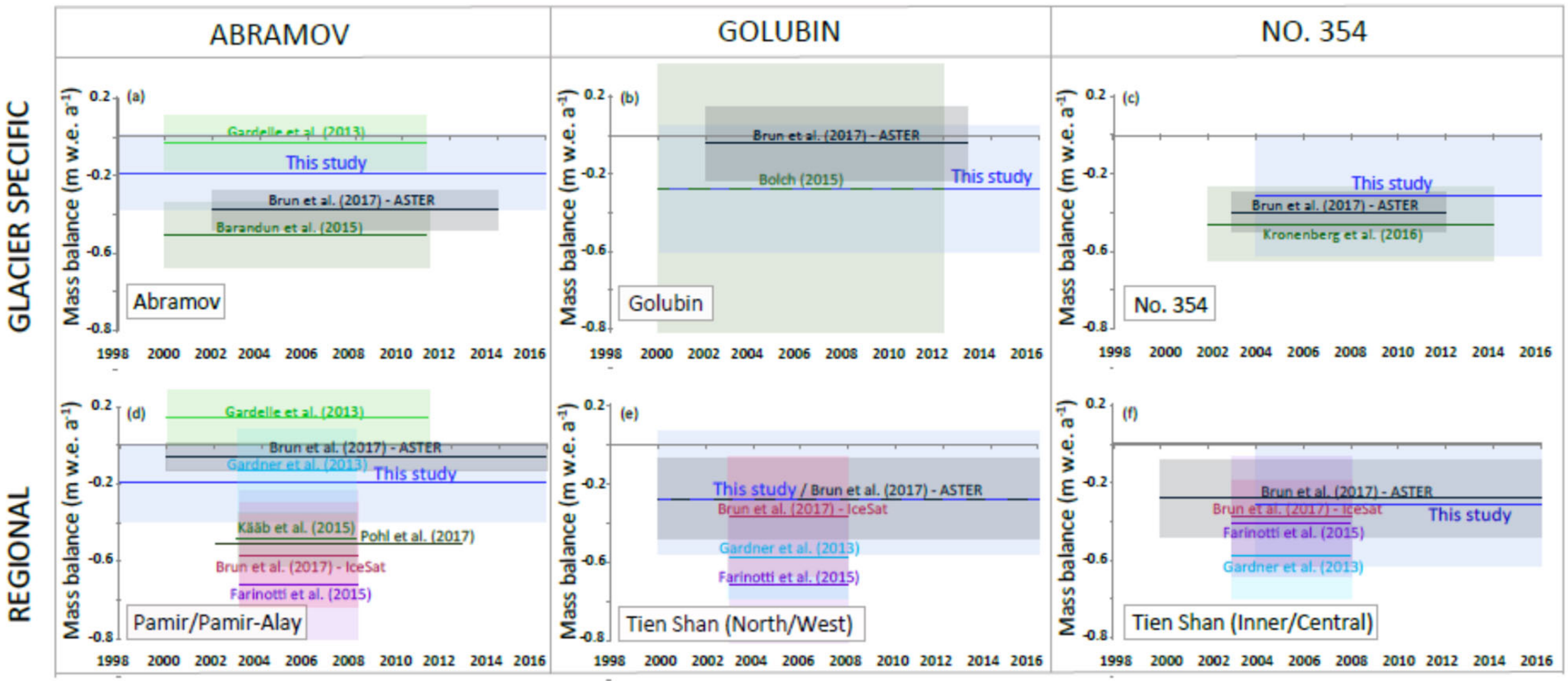


2. geodetic measurements

Mass Balance glacier network in CA

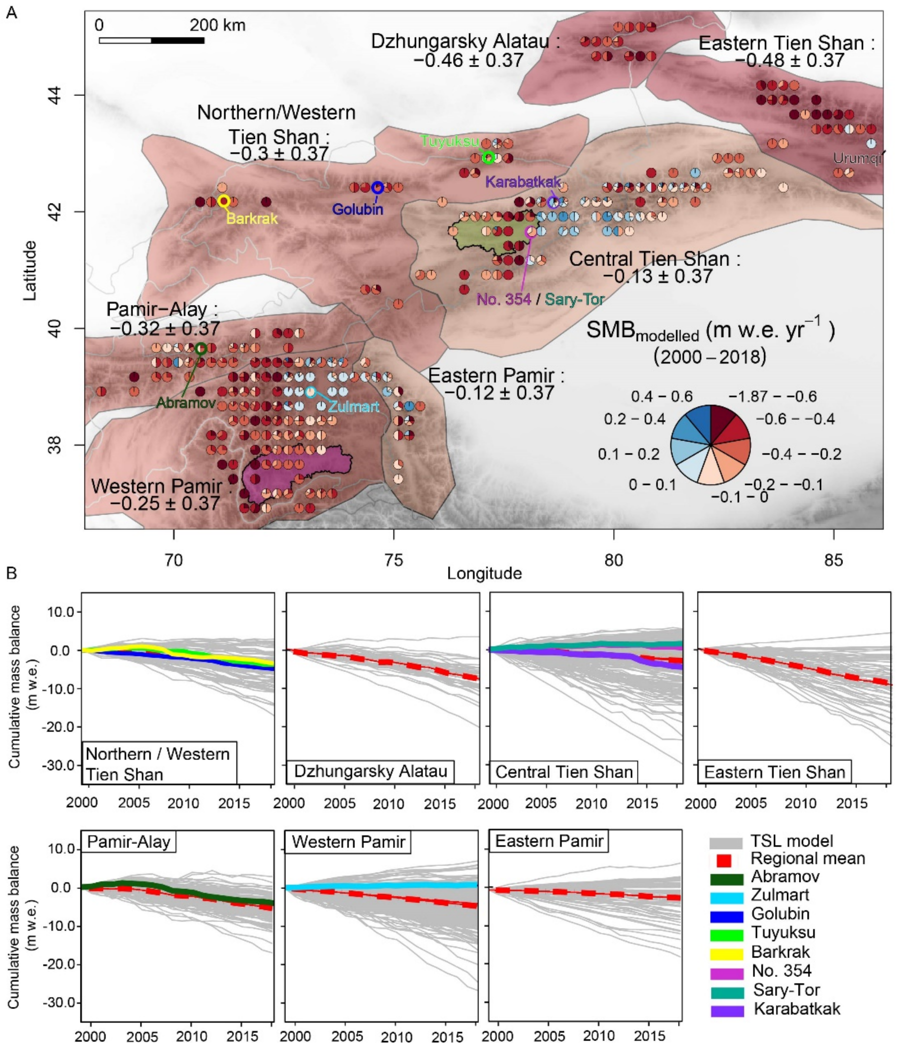


Regional MB estimates through remote sensing



Barandun et al, in press

Increasing variability of MB



Modelled glacier mass balance after Barandun et al 2021

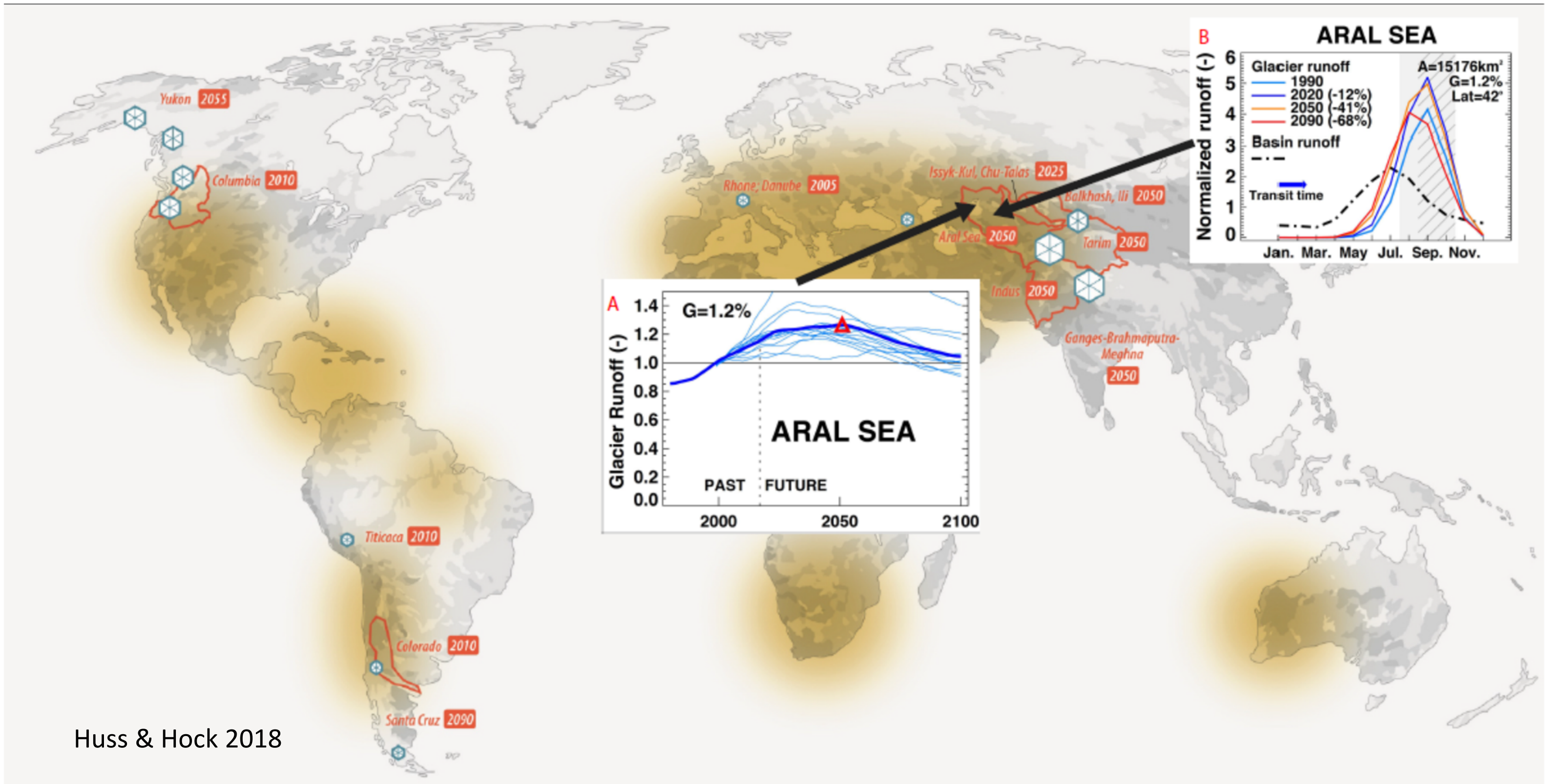
Overall negative trend of mass balance (with some exceptions)

Glacier monitoring network represents relatively well the respective region

Increase in glacier mass balance heterogeneity –continuous monitoring essential!

Barandun et al 2021

Glacier share in runoff

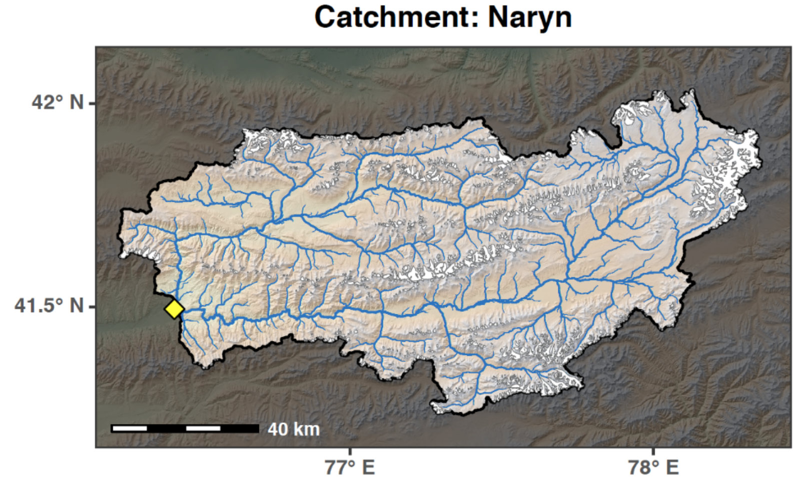


Huss & Hock 2018

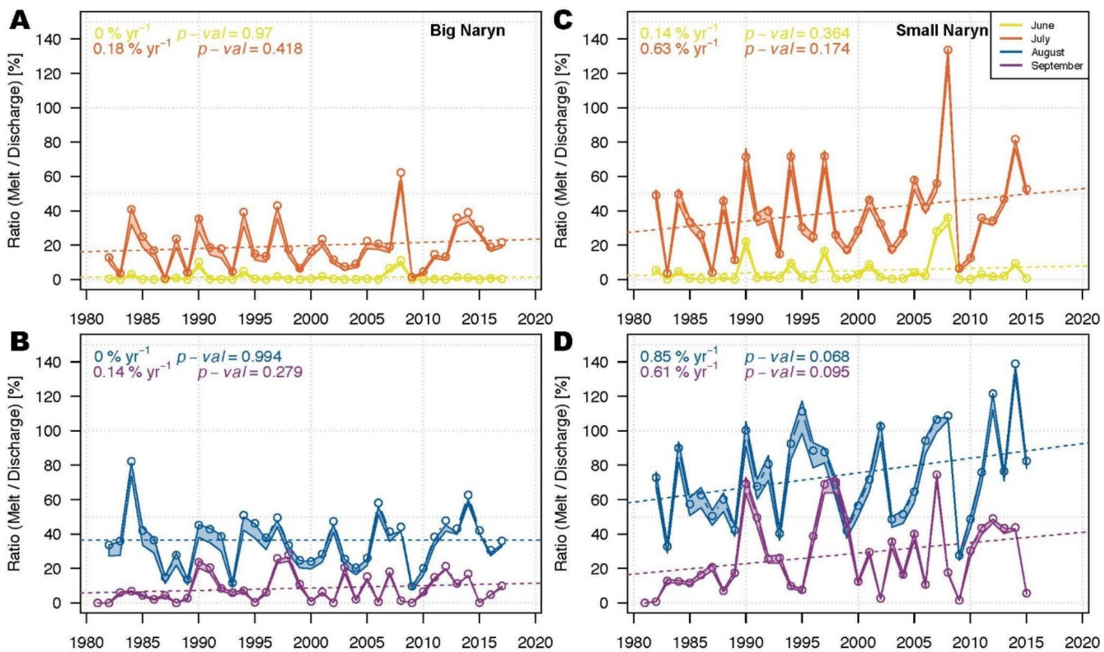
Runoff in CA is heavily impacted by the glacier meltwater in dry summer months

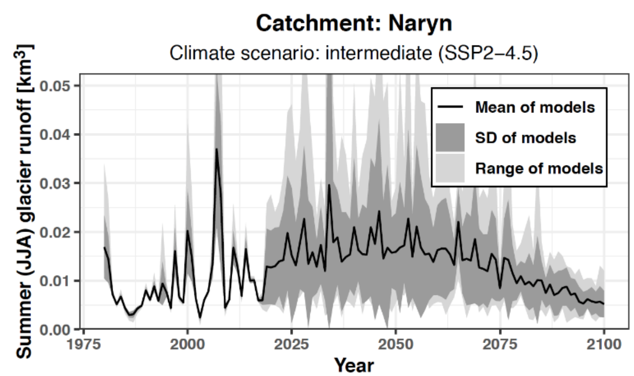
ST2
ST3

Glacier share in runoff



Glacier monitoring allows to better estimate the glacier contribution to streamflow





E. Mattea

Saks et al, in review

Slide 12

ST2 SAKS Tomas, 10/1/2021

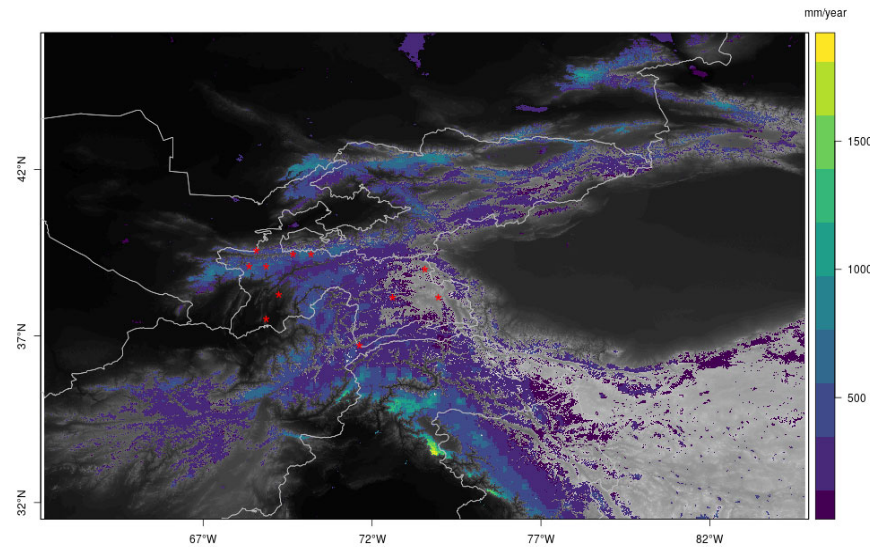
ST3 SAKS Tomas, 10/1/2021

ST4

Snow

Many ground-based stations measuring snow were abandoned after the breakup of the Soviet Un the early 1990s, and a new observational netv only slowly evolving in the region.

High altitude snow processes are likely to play large role in annual water balances, however h altitude measurements are extremely rare in t region.



*CHIRPS mean annual precipitation totals (2001-2018) as a proxy for expected snow accumulation is shown for mean March snowcovered regions. The mean March (2001-2018) snowcover extent derived from MODIS platform (Aqua/Terra).**show winter P only***

Fig is not included in text.

J. Fiddes

Slide 13

ST4 SAKS Tomas, 10/1/2021

ST4

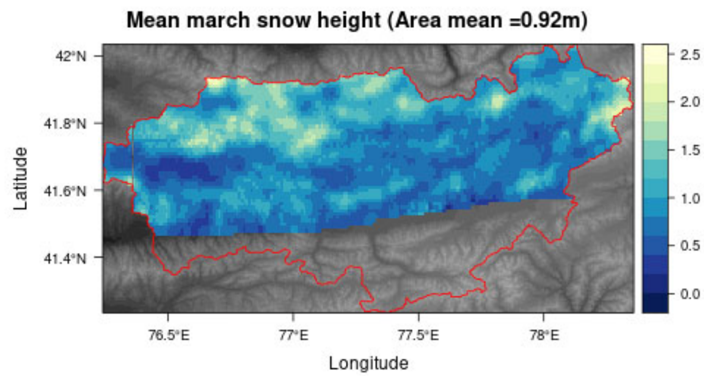
Snow

There are just a few studies available on long-term trends and shorter-term variability of the snow cover in Central Asia:

A decrease of mean annual snow depth for the time period from 1940 to 1991 Aizen et al 1997).
A decrease in snow cover duration by 9 days for the same time period (Aizen et al 1997).

Slightly negative trends since 1930's for NW Tien Shan (Glazirin 2006).

Remote sensing products have become an important source of data, especially in remote areas (e.g. MODIS and AVHRR).
Peters et al. (2015) indicated for the Tarim basin a snow cover reduction in lower elevations (< 3600 m a.s.l.) and found also evidences for a rise in snow cover duration at higher elevations (> 5000 m a.s.l.).



March snow height (m) 2017-2019 computed from Sentinel-1 radar data at 1km scale (source data: Lieven et al. 2019) for Naryn catchment.

J. Fiddes

Slide 14

ST4 SAKS Tomas, 10/1/2021

Permafrost

Permafrost is defined by ground temperatures, which are continuously below 0°C over a period of at least one year.

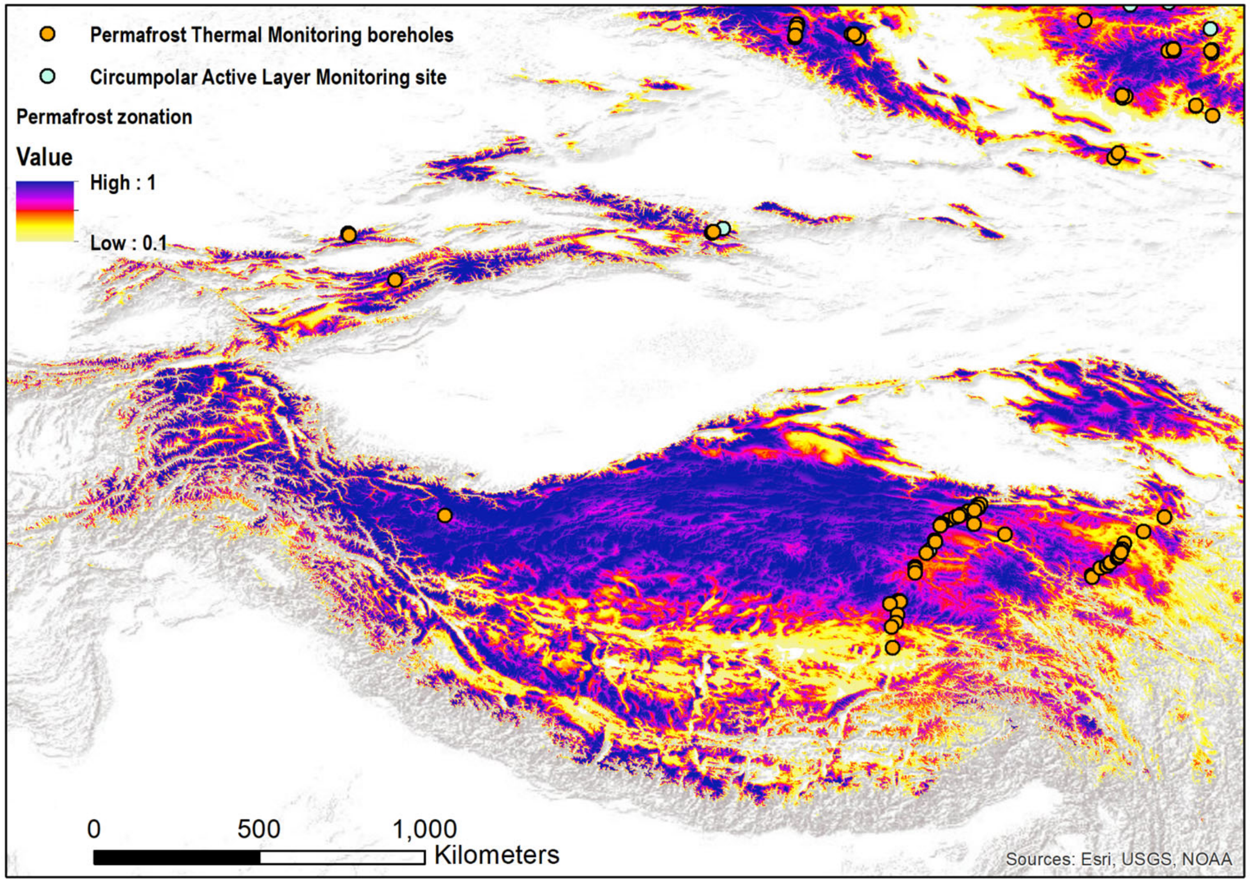
CA and the Tibetan Plateau host the largest permafrost area outside the polar regions. It covers around $3.5x10^6$ km^2, which corresponds to about 15% of the total areal extent of permafrost in the Northern Hemisphere.

In high mountain regions, recent increases in air temperature cause rockfalls, landslides, debris flows and increased creep rates in rock glaciers (Bolch and Gorbunov, 2014; Delaloye et al., 2010; Sorg et al., 2015), as well as increased runoff from permafrost zones with high ground ice contents (Bolch and Marchenko, 2006; Mateo and Daniels, 2018).

Climate-induced changes in permafrost can lead to strong feedbacks to the climate system.

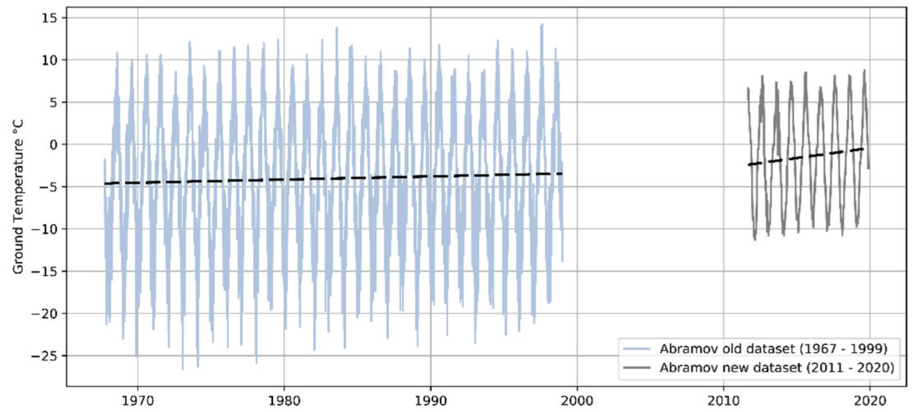
Permafrost

Permafrost distribution and temperature regime in Tien Shan and Pamir is poorly known



Permafrost

Few surface temperature measurements indicate continuous warming



Observed ground temperature measurement at the Abramov site, Koksu valley, South Kyrgyzstan. Clear trends are visible at the old and new observation sites. (Data source: Pertziger 1996 and Abramov Meteorological Station)

Future challenges

- Glacier melt is accelerating, as well as heterogeneity in mass balance patterns is increasing
- It is expected that **seasonal runoff** peak will shift towards the beginning of summer**.** Depending on the scenario, in Aral basin peak water will be reached in the timeframe from 2030 ± 2 (RCP2.6) until 2044 ± 15 (RCP8.5). However, on the scale of **individual catchments** there is high variability.
- In the second half of the 21st century the role of **permafrost** in runoff will increase.
- **Permafrost degradation** will increase the likelihood of mountain hazards, therefore it is essential to establish a comprehensive monitoring network
- **Water reservoirs** will become one of the main mitigation measures for the changing runoff pattern, though country cooperation is essential for this to work

Ways forward

- Ensuring sustainability of the established **glacier monitoring** network in the future
- Application of the Cryospheric **baseline data** in the fields of WRM and DRR
- **Capacity building** and twinning programs have to be continued
- Cryospheric sciences strengthened in the **University curriculum**
- (Re-) Establishing of the **permafrost monitoring** network
- Integration of new technologies in **snow monitoring**

Conclusions

- Glacier observation data should be **freely accessible** and provided, via the corresponding **data centres** according **to international standards and strategies.**

- **In-situ Monitoring** is still very important and can be performed on several levels of sophistication.

- **High-quality cryosphere data** is an indispensable prerequisite to any sound **water and hazard related studies in high mountains.** They have to be ensured and internationally shared in the regional and world wide data centers

- **Regional cooperation** on **WRM** and **DRM** and **awareness** has to be increased based on the **national efforts**

- **Education and capacity building** by introducing up to date **student courses on BSc and MSc level,** by **summer schools** and by **specialized field training**

THANK YOU FOR YOUR ATTENTION

Many thanks to all people contributing to this work

Matthias Huss, Bolot Moldobekov, Ruslan Kenzhebaev, Abror Gafurov, David Sciboz, Aleksandr Merkushkin, Andrey Yakovlev, Maxim Petrov, Almazbek, Tynstykbek, Leo, Mauro, Florian, Daniel, Sergiy, Willi, Philipp, Kathrin, Stefan, Anton, David, Michi, Nico, Antoine, Julia, Aithurok, Muhamed, Avas, Jura, Vladimir, Anton, Kuba, Zarylbek, Bektur …