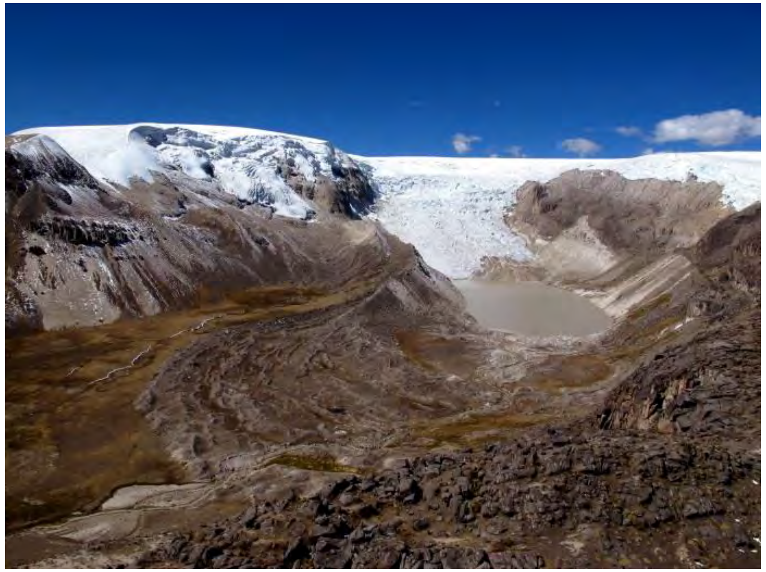
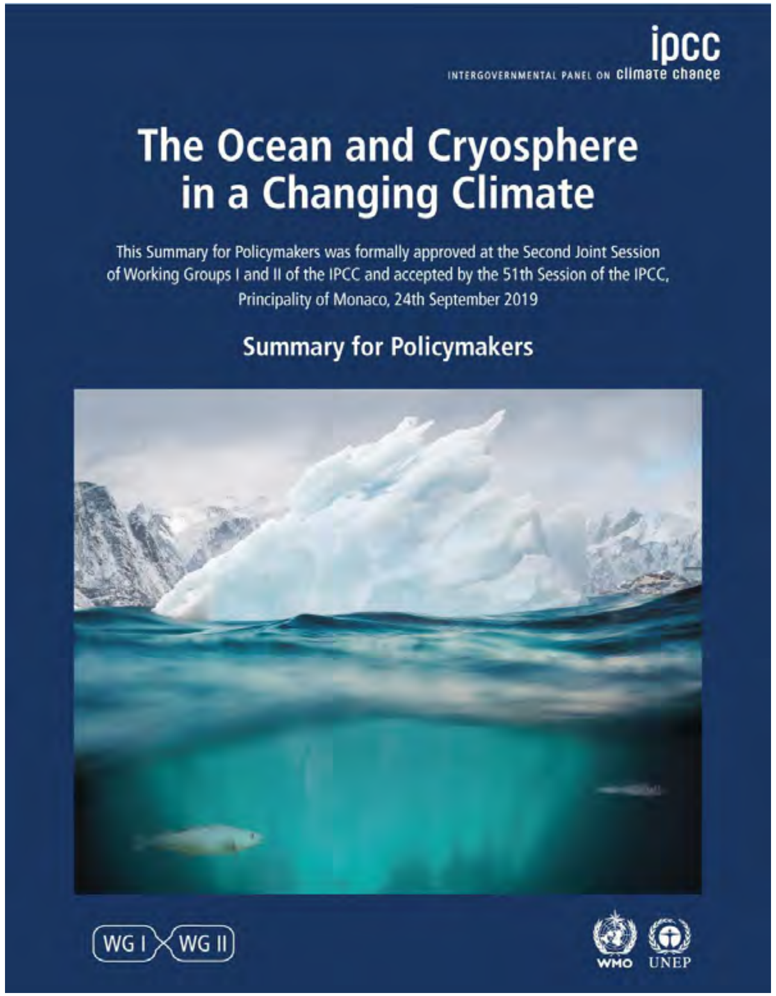
Glacier changes and associated impacts on natural and human systems in high mountain areas

Stanislav Kutuzov

Institute of Geography, Russian Academy of Sciences
National Research University Higher School of Economics

kutuzov@igras.ru





ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

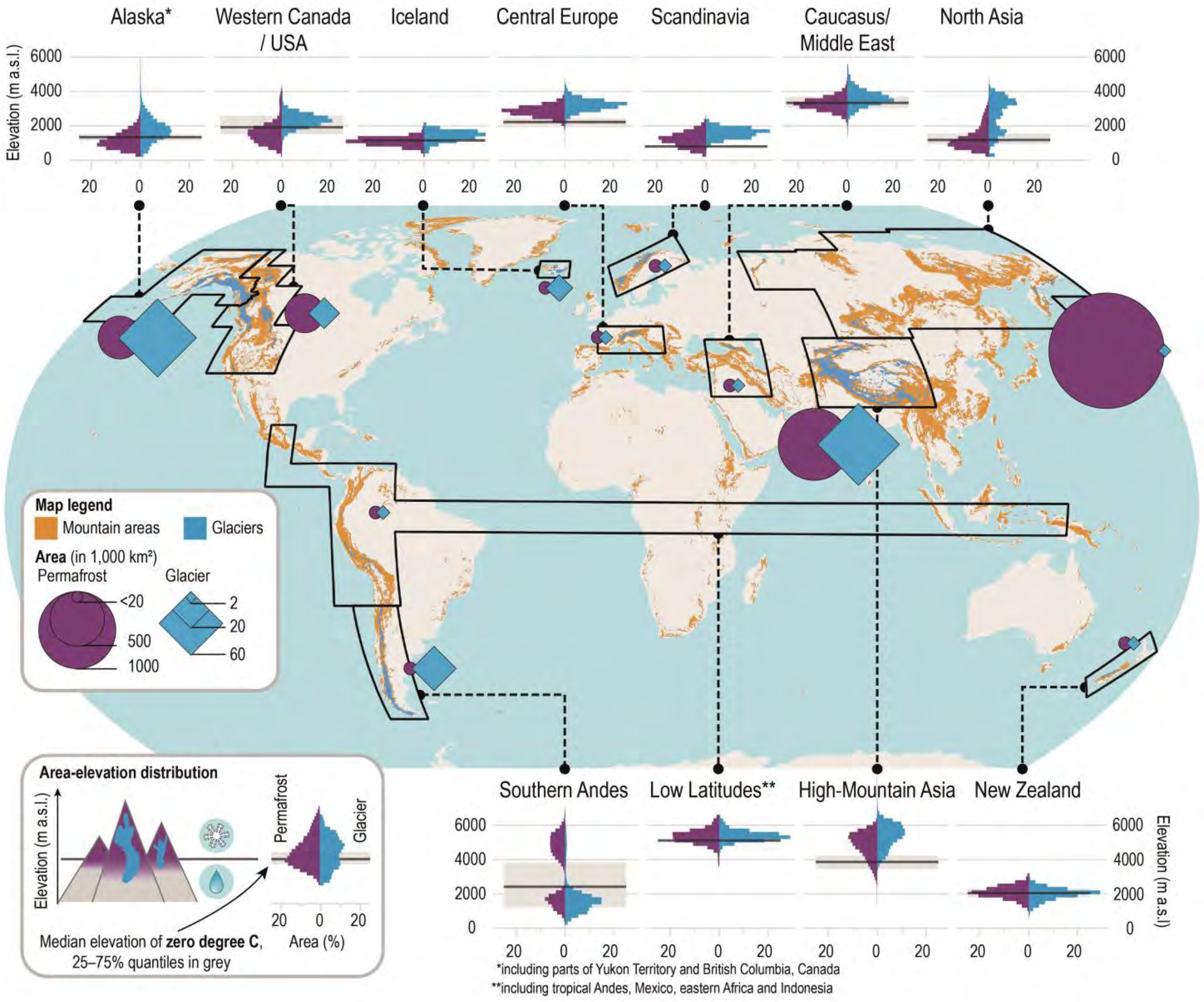
High Mountain Areas

The cryosphere (including, snow, glaciers, permafrost, lake and river ice) is an integral element of high mountain regions, which are home to roughly 10% of the global population.

Widespread cryosphere changes affect physical, biological and human systems in the mountains and surrounding lowlands, with impacts evident even in the ocean.


Photo: Yungdrung Tsewang

High Mountain Areas

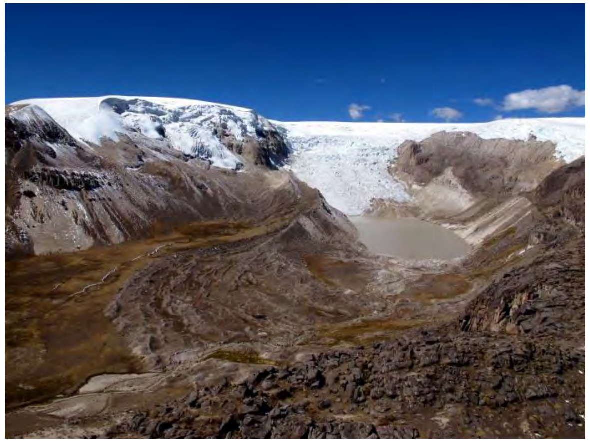


- The mountain cryosphere plays a major role in large parts of the world.

- ~ 700 million people live in high mountain areas

INTERGOVERNMENTAL PANEL ON climate change

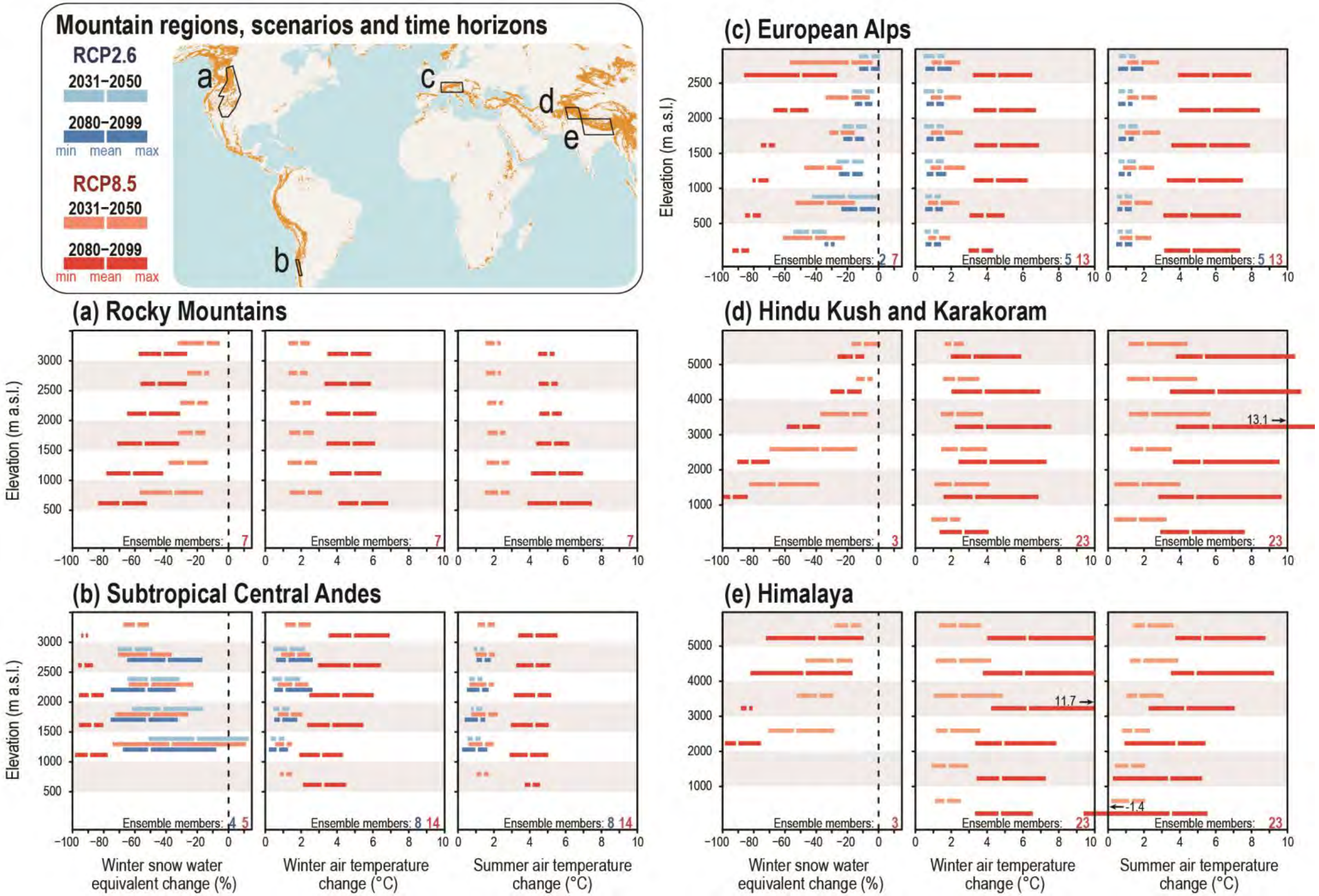
WMO UNEP



by Sarah Del Ben

by Andy Gibb

Climate change in mountains



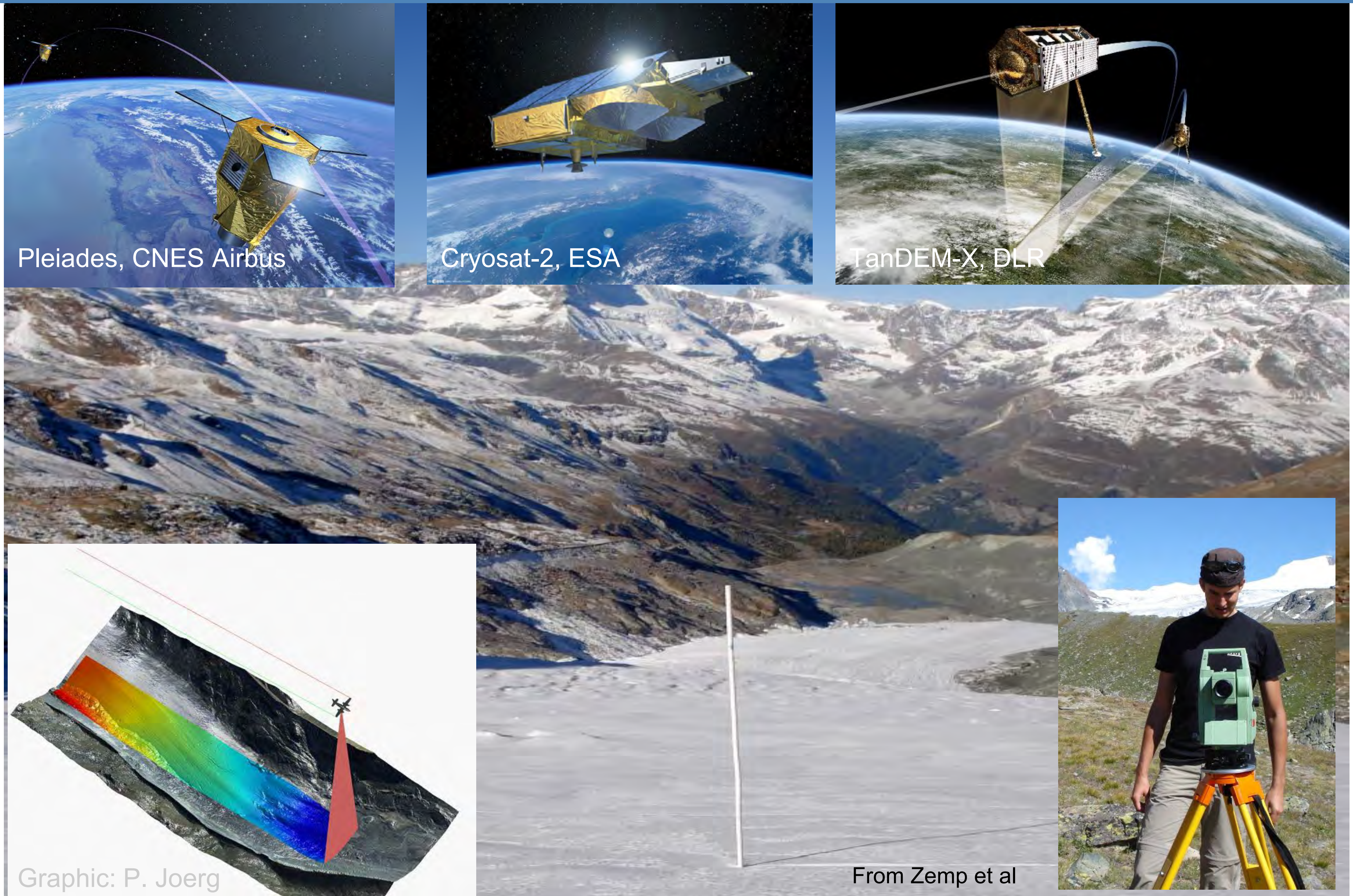
- Surface air temperature is projected to continue increasing (*very high confidence*) at an average rate of 0.3°C per decade

- **Observations show general decline in low-elevation snow cover** (*high confidence*), **glaciers** (*very high confidence*) and **permafrost** (*high confidence*) due to climate change in recent decades.

- Glacier, snow and permafrost **decline has altered the frequency, magnitude and location of most related natural hazards** (high confidence). Exposure of people and infrastructure to natural hazards has increased due to growing population, tourism and socioeconomic development (high confidence).

- Changes in snow and glaciers **have changed the amount and seasonality of runoff** in snow-dominated and glacier-fed river basins (very high confidence) with local impacts on water resources and agriculture (medium confidence).

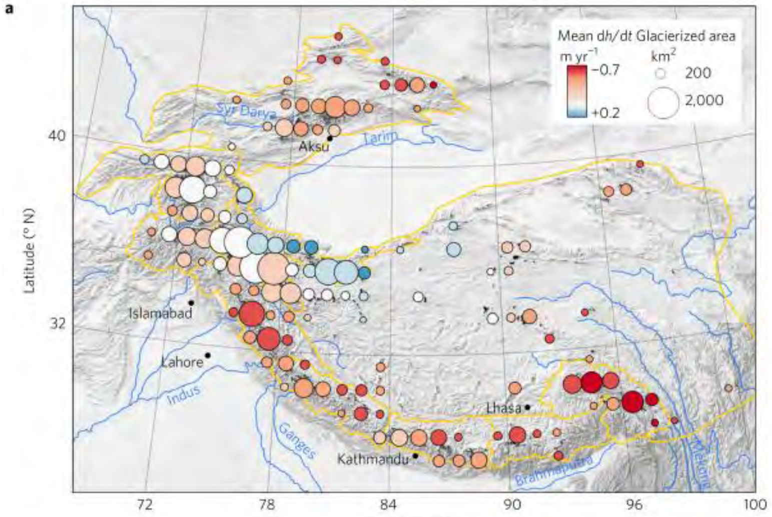
Glacier mass change How do we know?



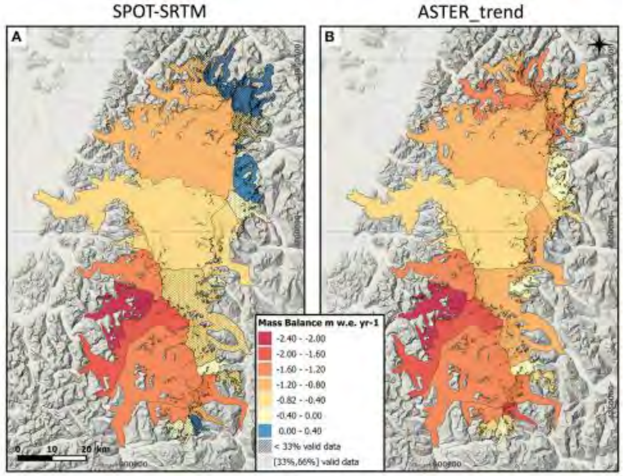
Glacier mass change

- Glacier mass balance is driven directly by meteorological variables and hence serves a good climate indicator.
- The geodetic method for estimating changes in the surface elevation and volume of glaciers has been widely used

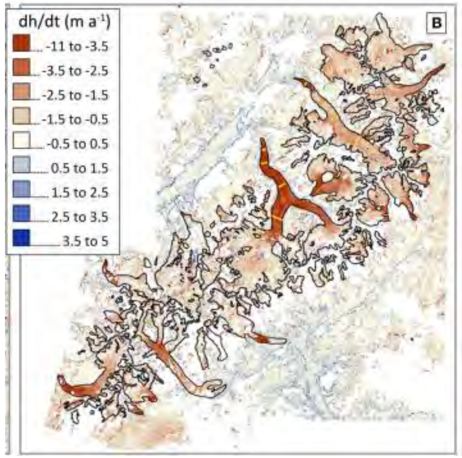
Brun et al., 2017

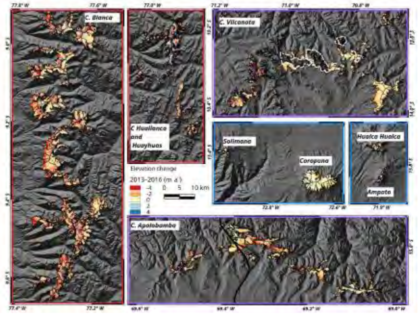


Dussaillant et al., 2018



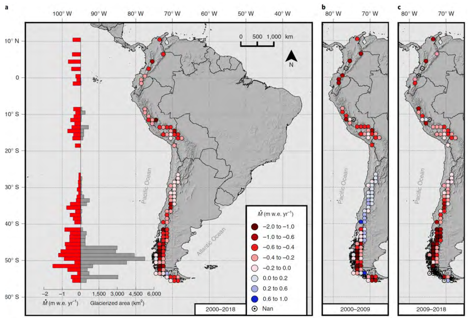
Berthier et al., 2016



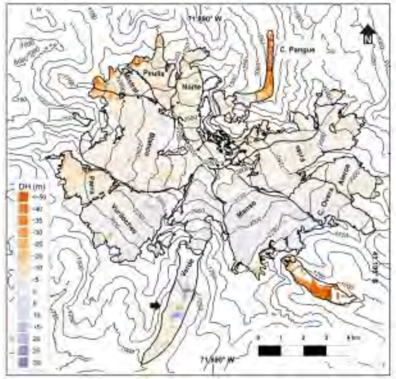


Seehaus et al., 2019

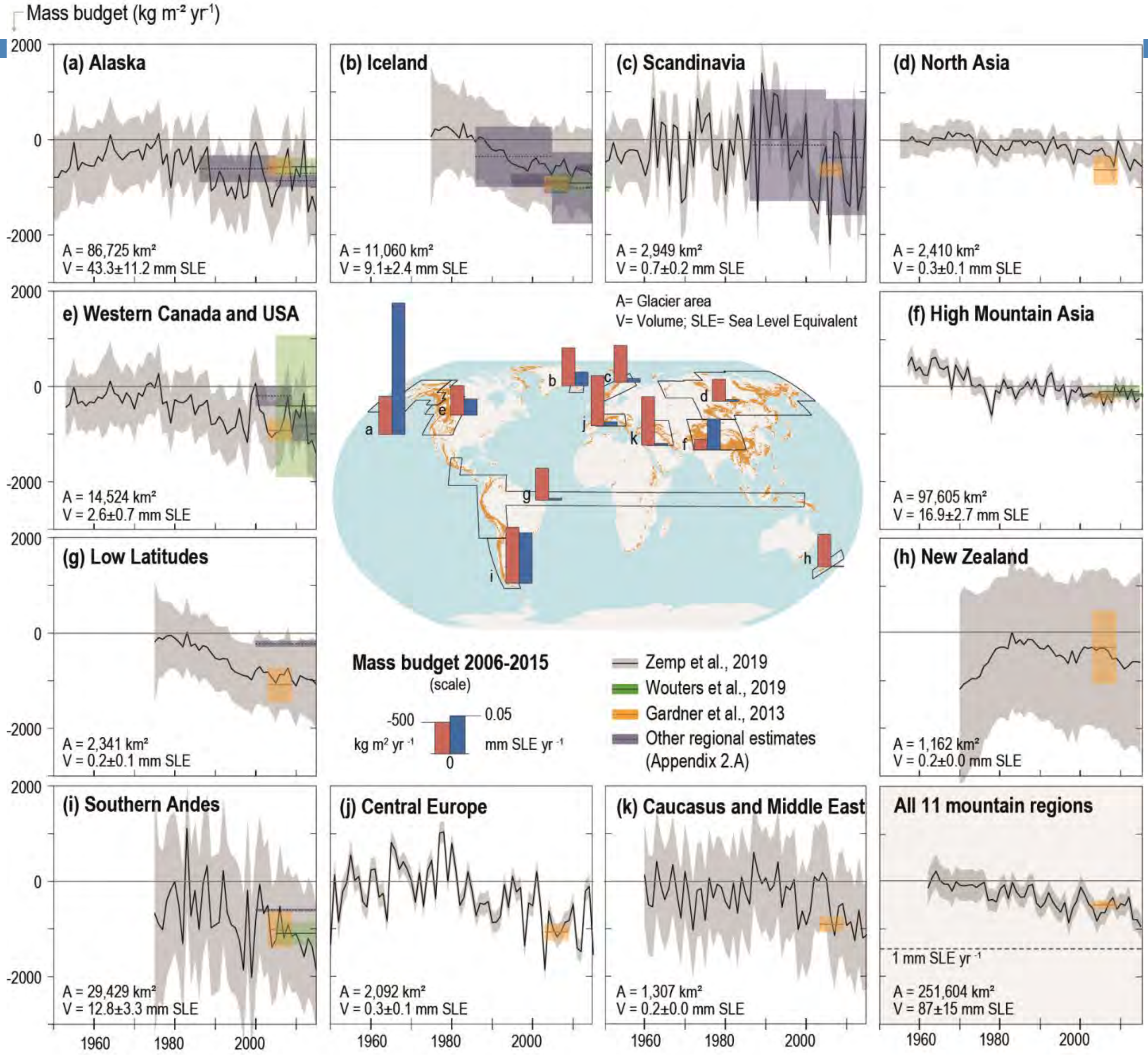
Dussaillant et al., 2019



Ruiz et al., 2017



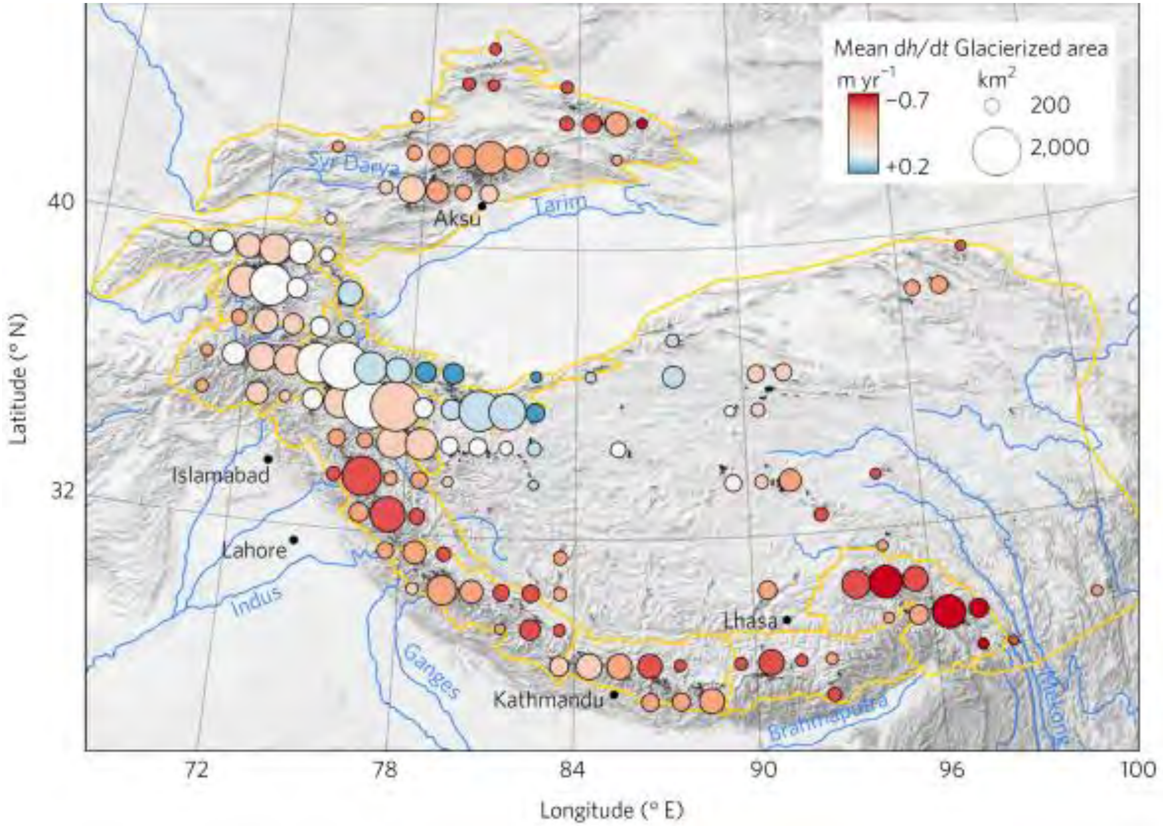
Glacier mass change



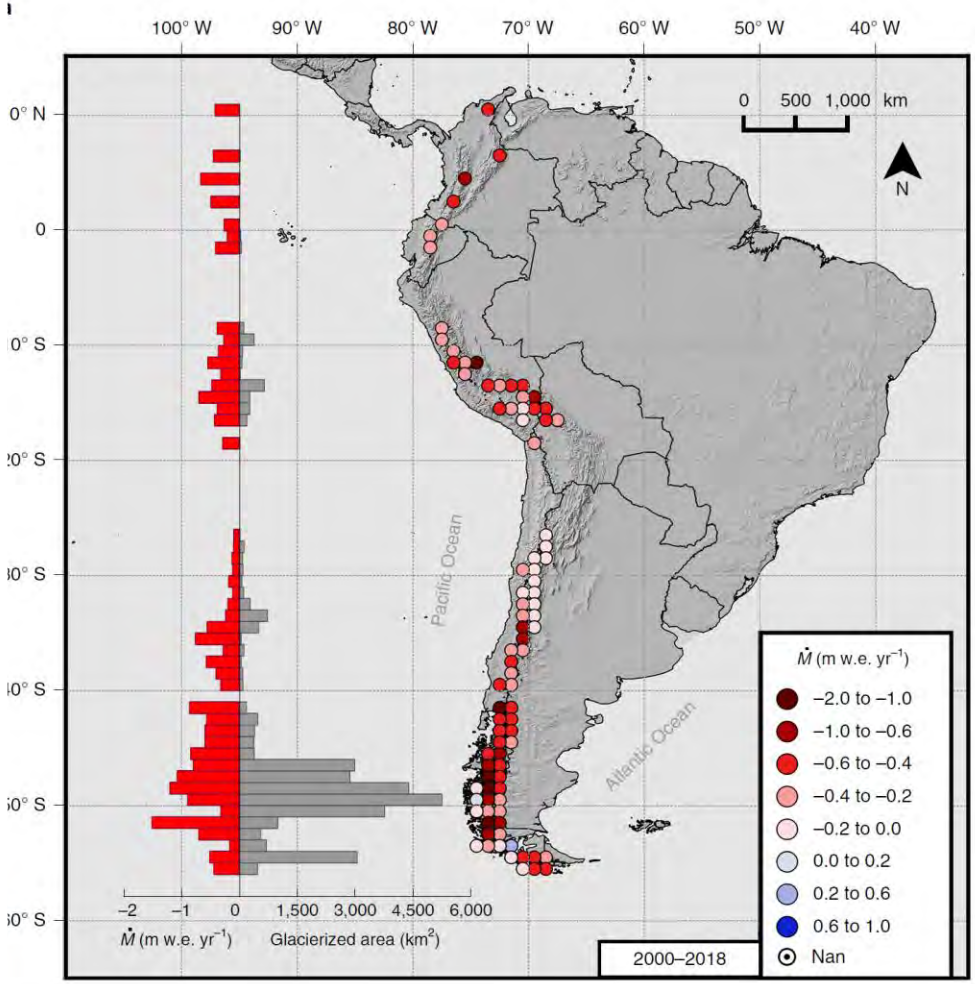
- Regionally averaged mass budgets were most negative in the southern Andes, Caucasus and the European Alps/Pyrenees, and least negative in High Mountain Asia but variations within regions are strong.

INTERGOVERNMENTAL PANEL ON climate change

Regional differences in glacier mass change



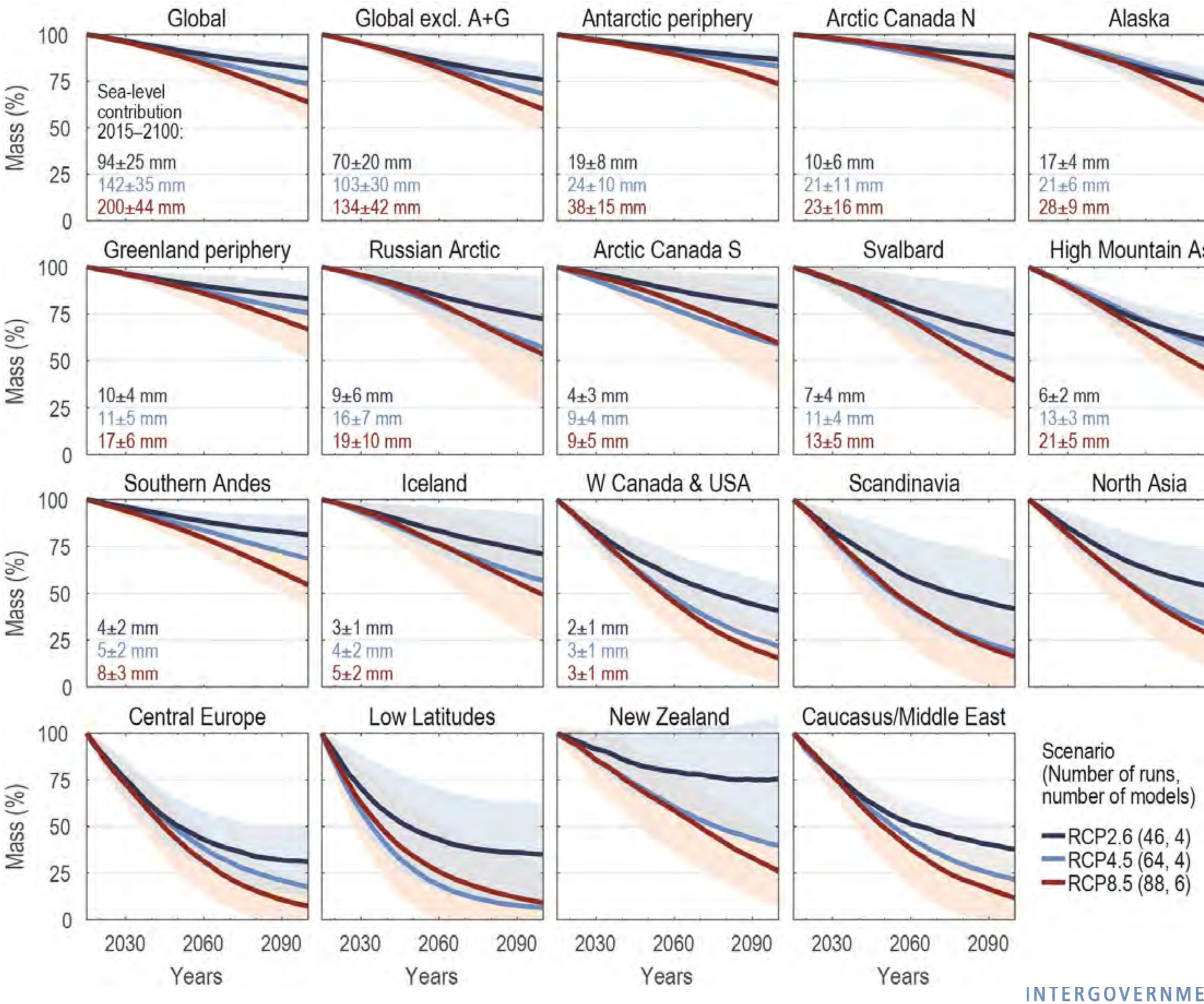
Brun et al., 2017



Dussaillant et al., 2019

INTERGOVERNMENTAL PANEL ON climate change

Projections

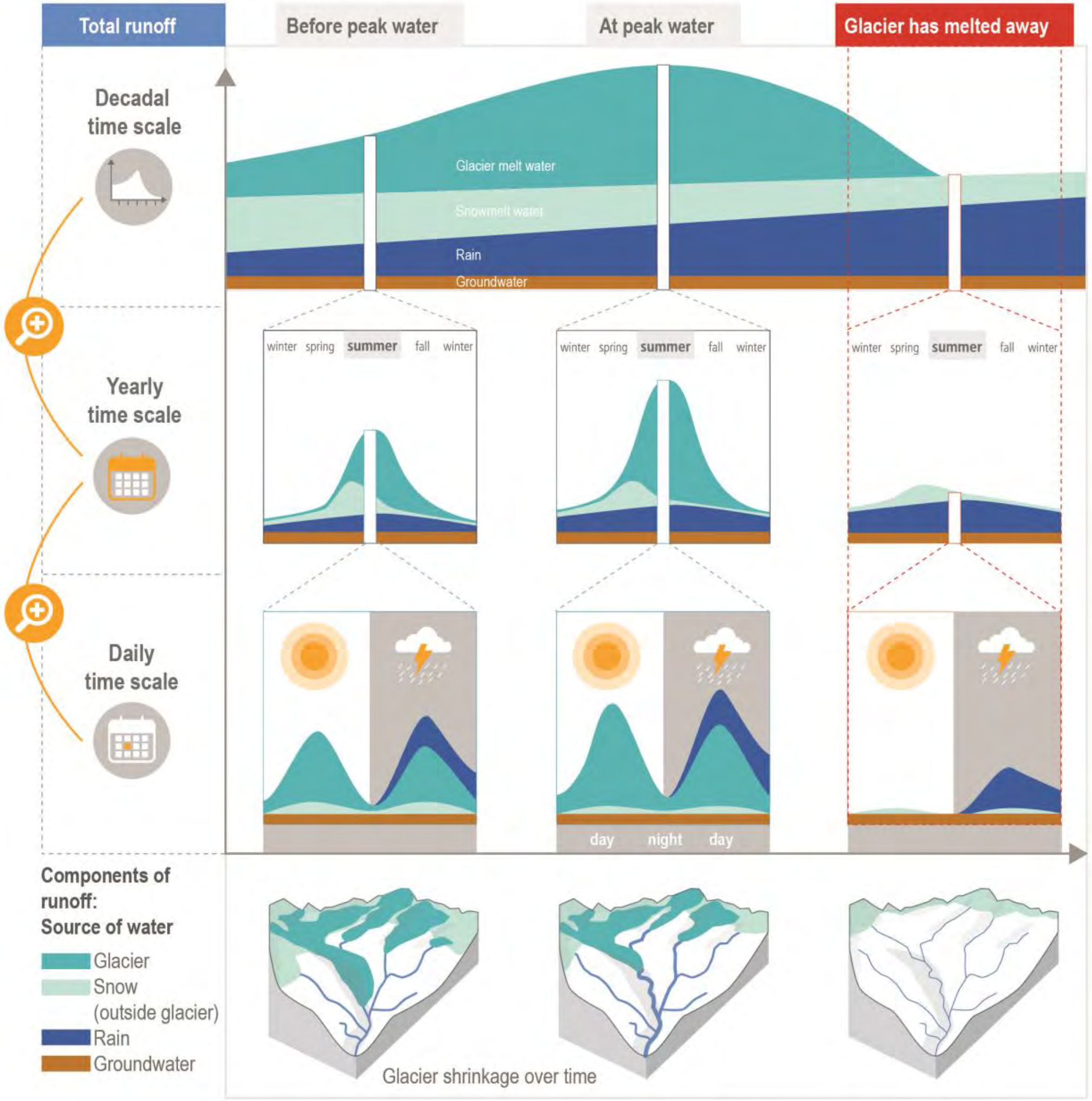


- Smaller glaciers found, for example, in Europe, eastern Africa, the tropical Andes and Indonesia are projected to lose more than 80% of their current ice mass by 2100 if emissions continue to increase strongly.

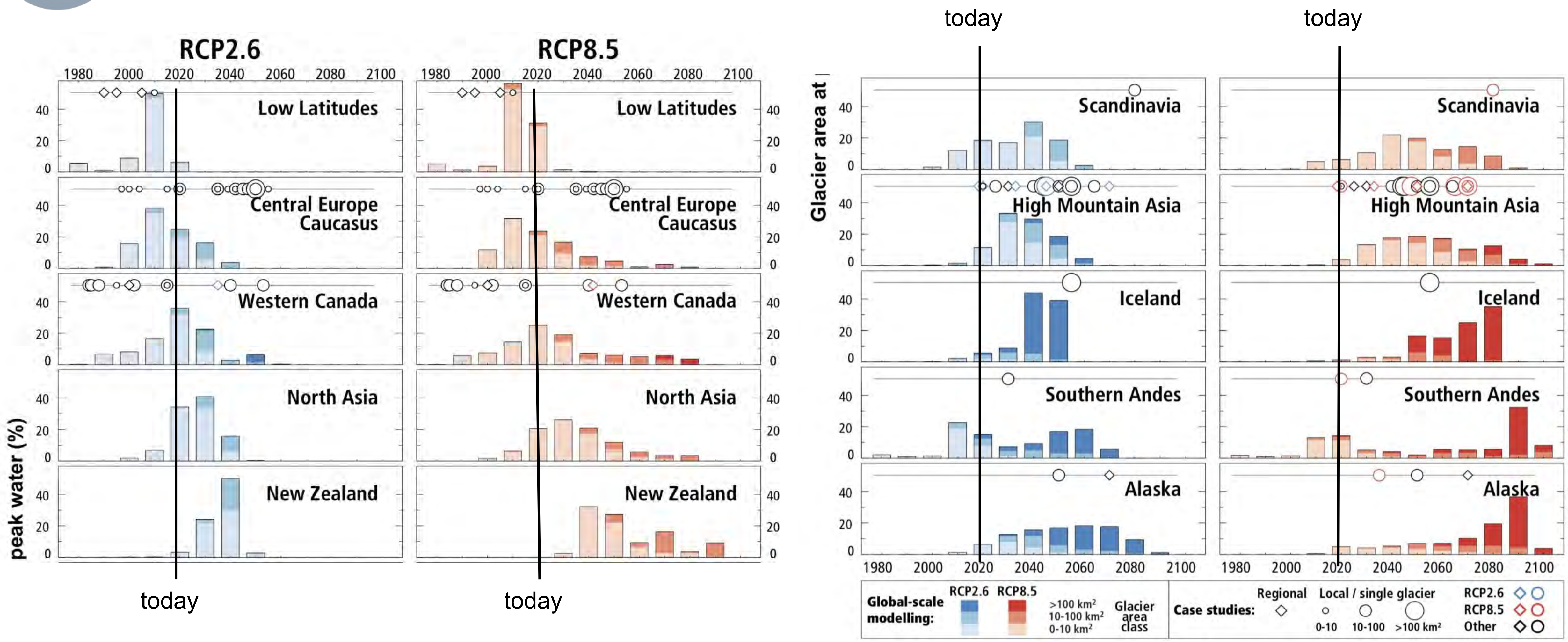
Runoff

As glacier shrinks, annual glacier runoff will first increase, but then reach a peak and decrease

peak water



Changes in the mountain cryosphere: Timing of peak water from glaciers



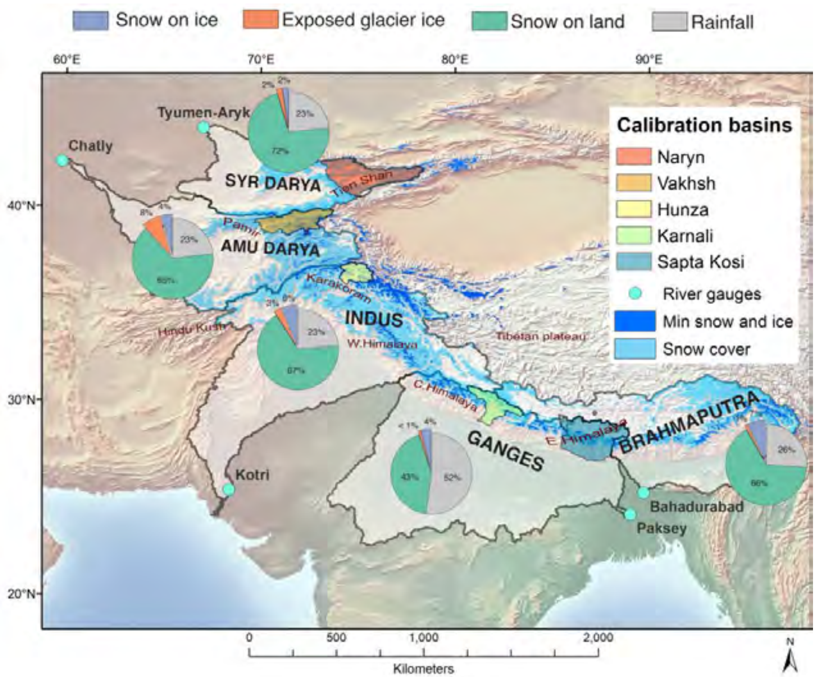
There is *robust evidence* and *high agreement* that peak water in glacier-fed rivers has already passed with annual runoff declining in some regions

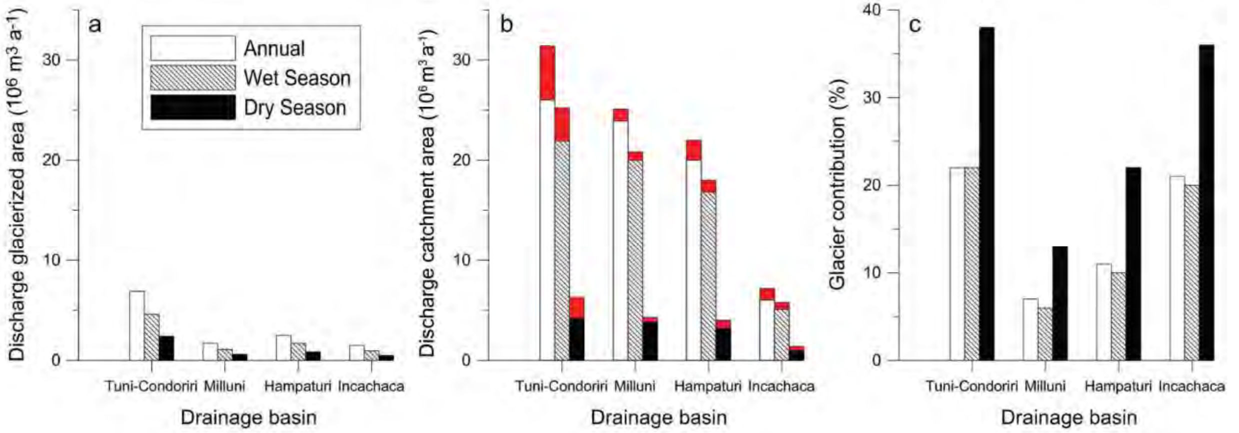
Contribution to the total runoff (above 2000 m) HMA rivers

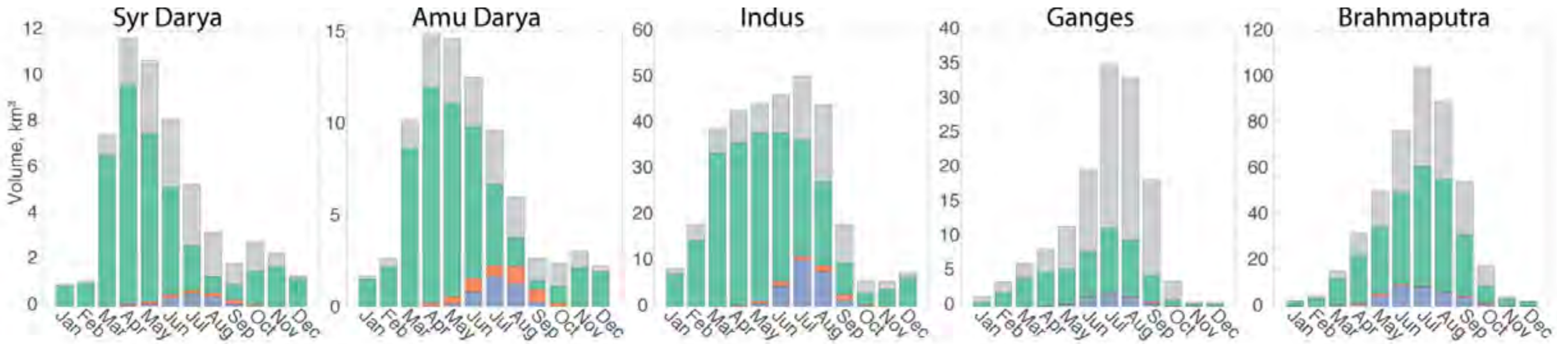
Snow – about 2/3.

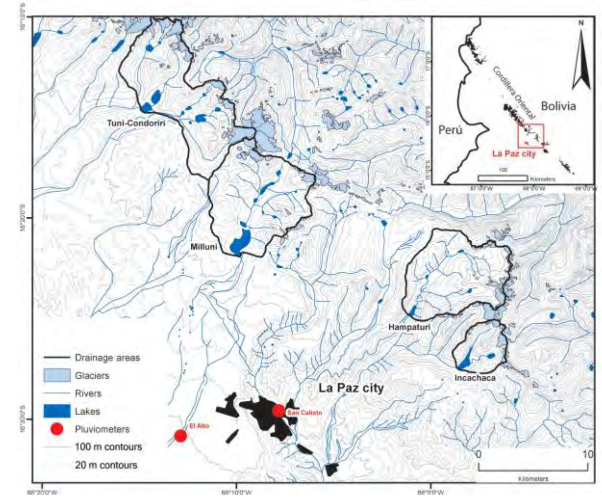
Glacier runoff 4 - 12%   Armstrong et al., 2018

For a complete disappearance of the glaciers near **La Paz** a reduction in annual runoff by **12% and 24%** in the dry season is expected (Soruco et al., 2015)

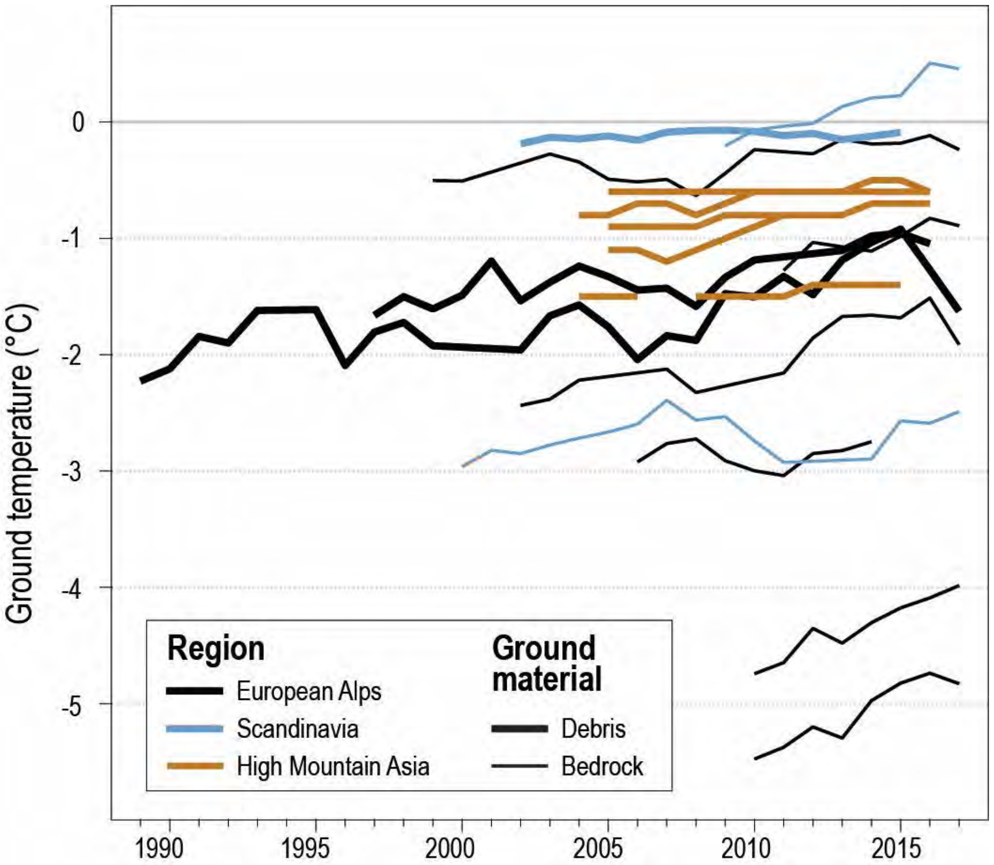






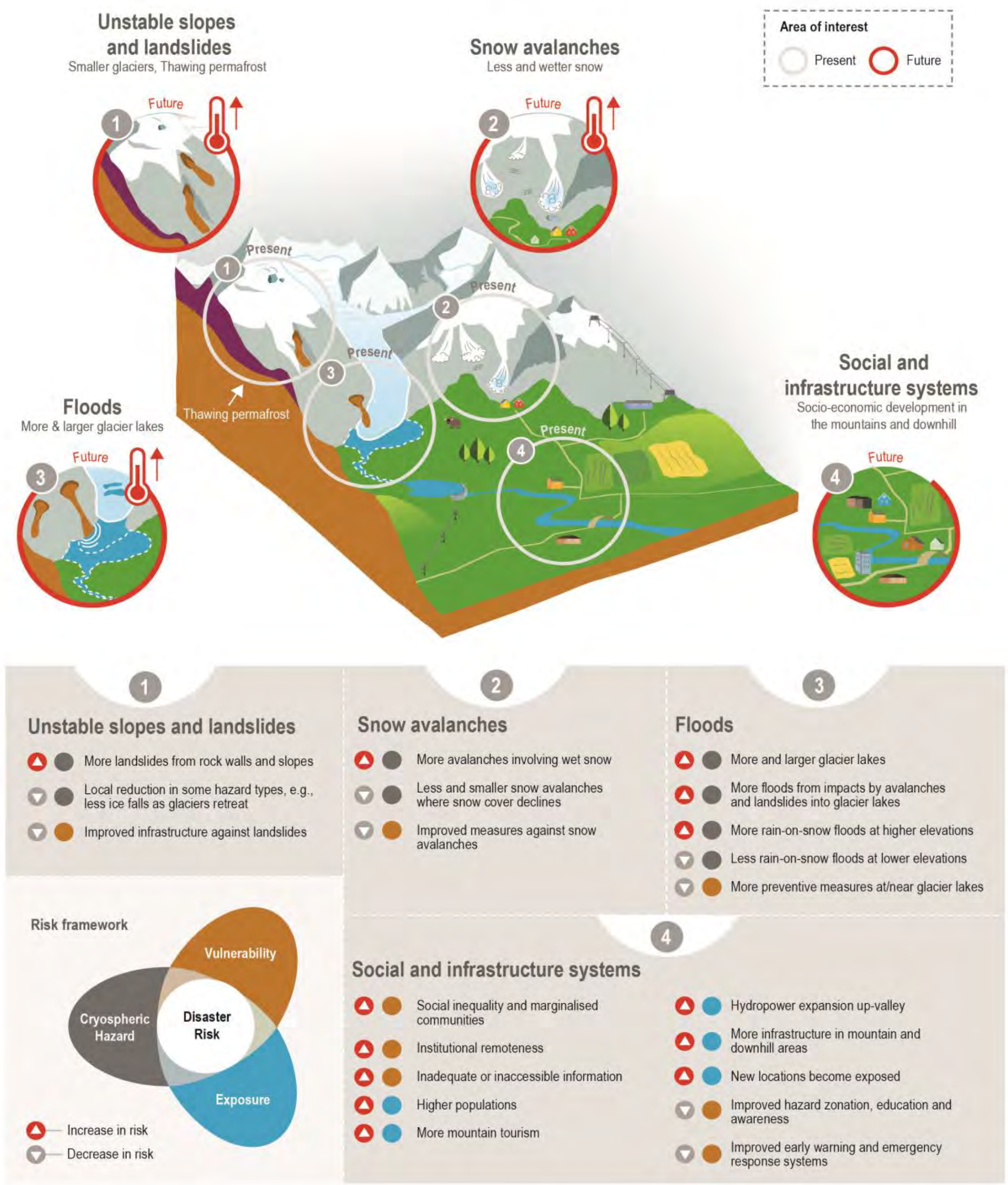


Permafrost

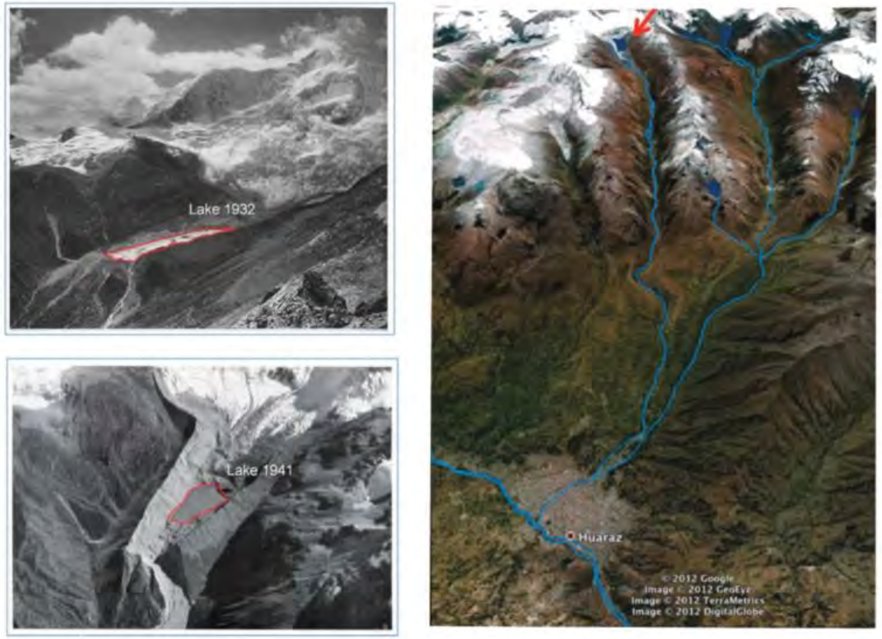


- Permafrost in the European Alps, Scandinavia, Canada, Mongolia, the Tien Shan and the Tibetan Plateau has warmed during recent decades and some observations reveal ground-ice loss and permafrost degradation (*high confidence*).

- The heterogeneity of mountain environments and scarcity of long-term observations challenge the quantification of representative regional or global warming rates.



Cryospheric hazards

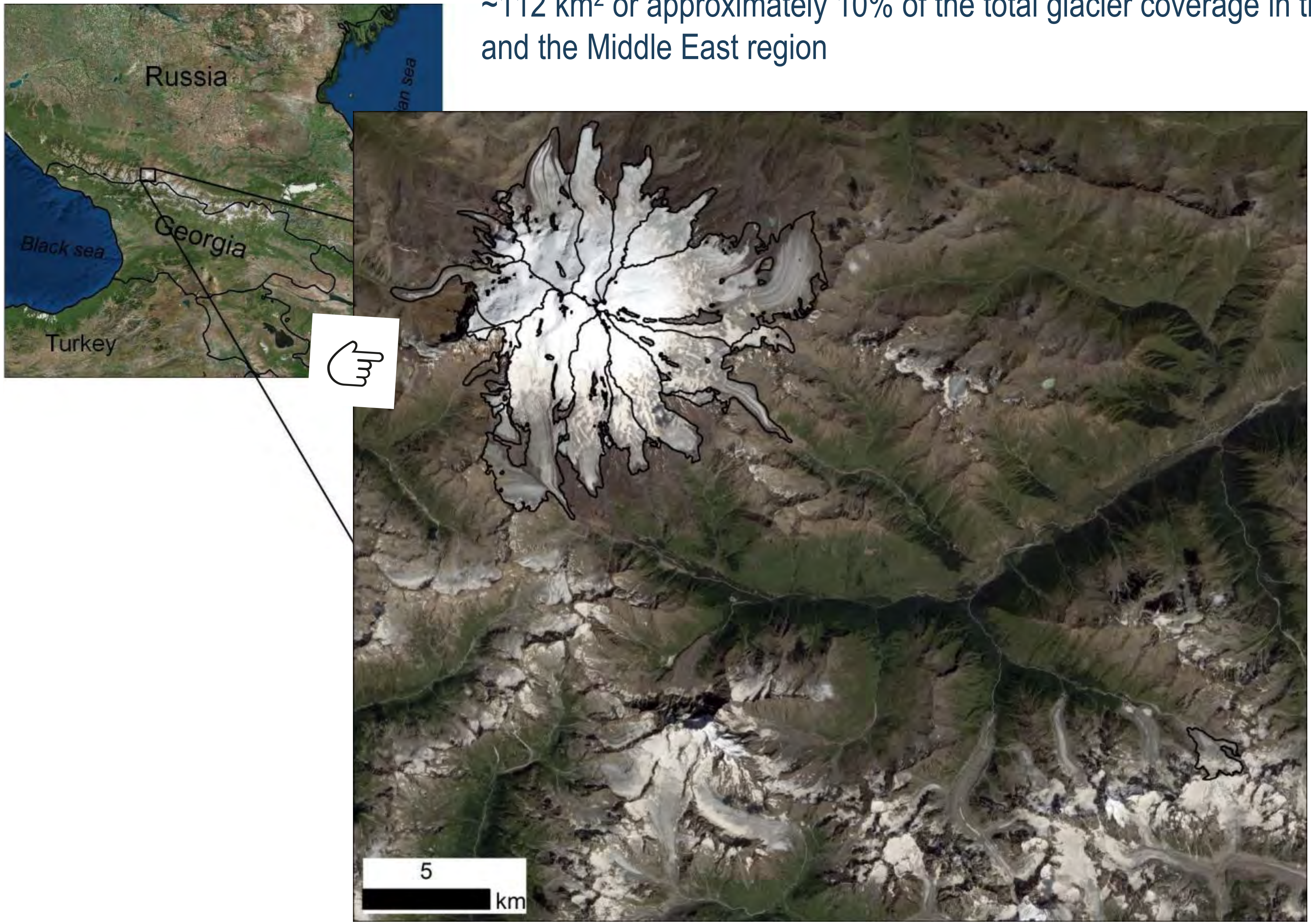


Palcacocha Lake in 1943 before the GLOF (top) and after. Right: The red arrow points to Lake Palcacocha in 2012; blue lines are streams leading from several glacial lakes into Huaraz. Top photo: Hans Kinzl. Bottom photo: Servicio Aerofotográfico del Perú (Peru's National Aerial Photography Service)

The GLOF's destructive path through the city of Huaraz in 1941. Servicio Aerofotográfico del Perú

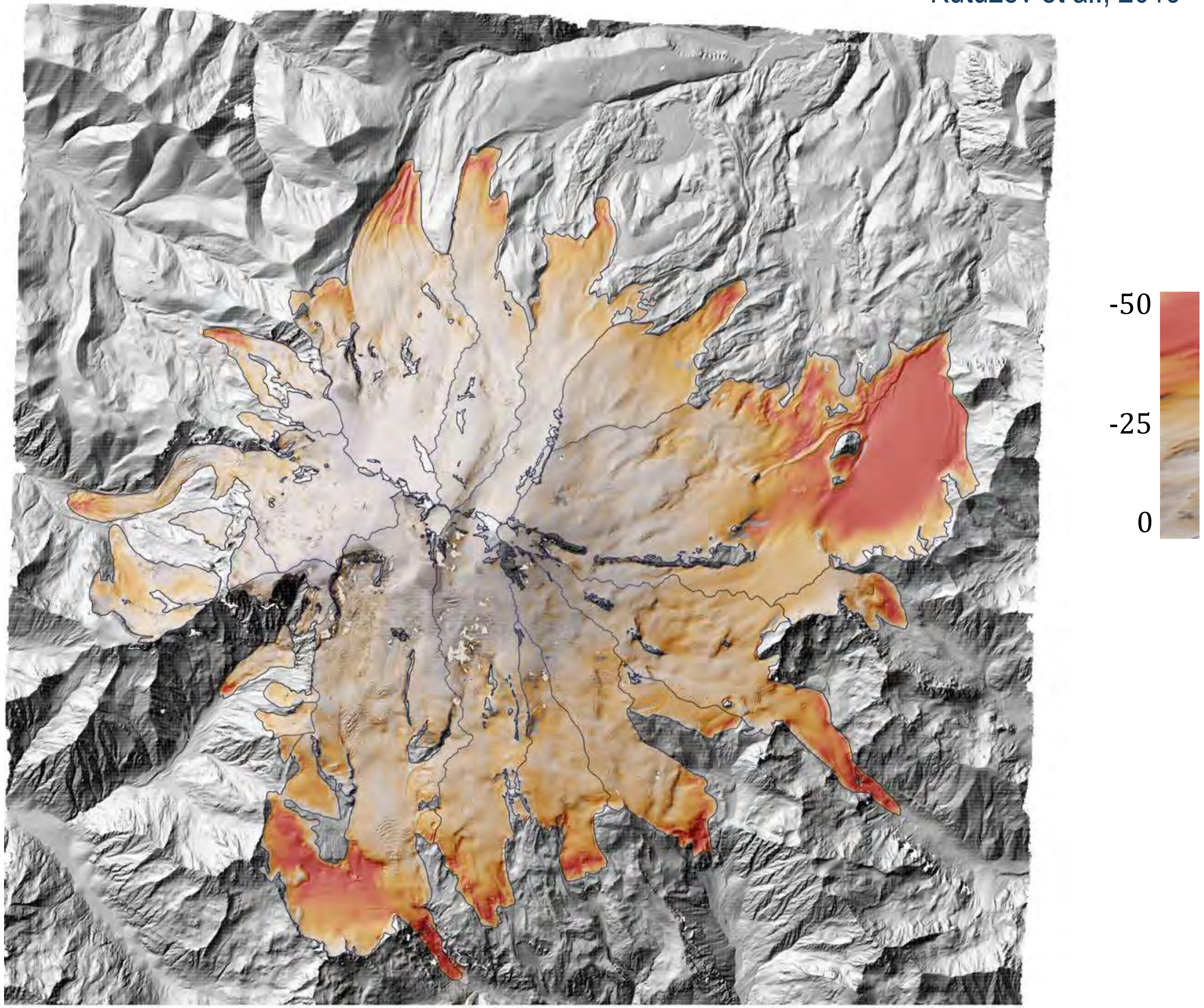
The case of Elbrus

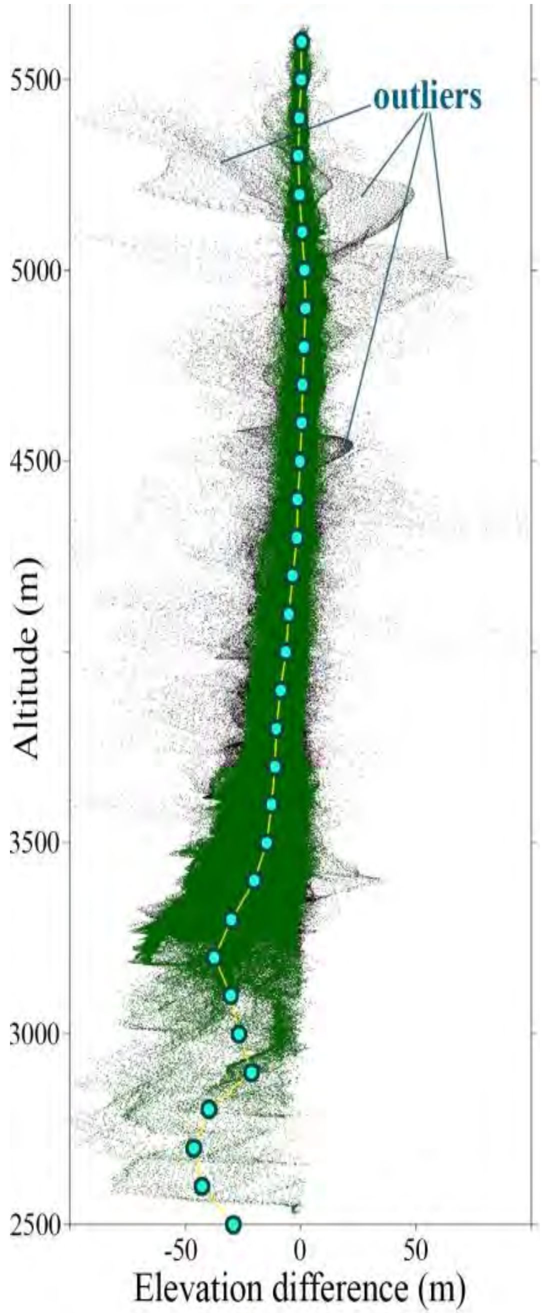
Elbrus Mountain is the highest in the Caucasus with total glacier coverage of ~112 km^2 or approximately 10% of the total glacier coverage in the Caucasus and the Middle East region

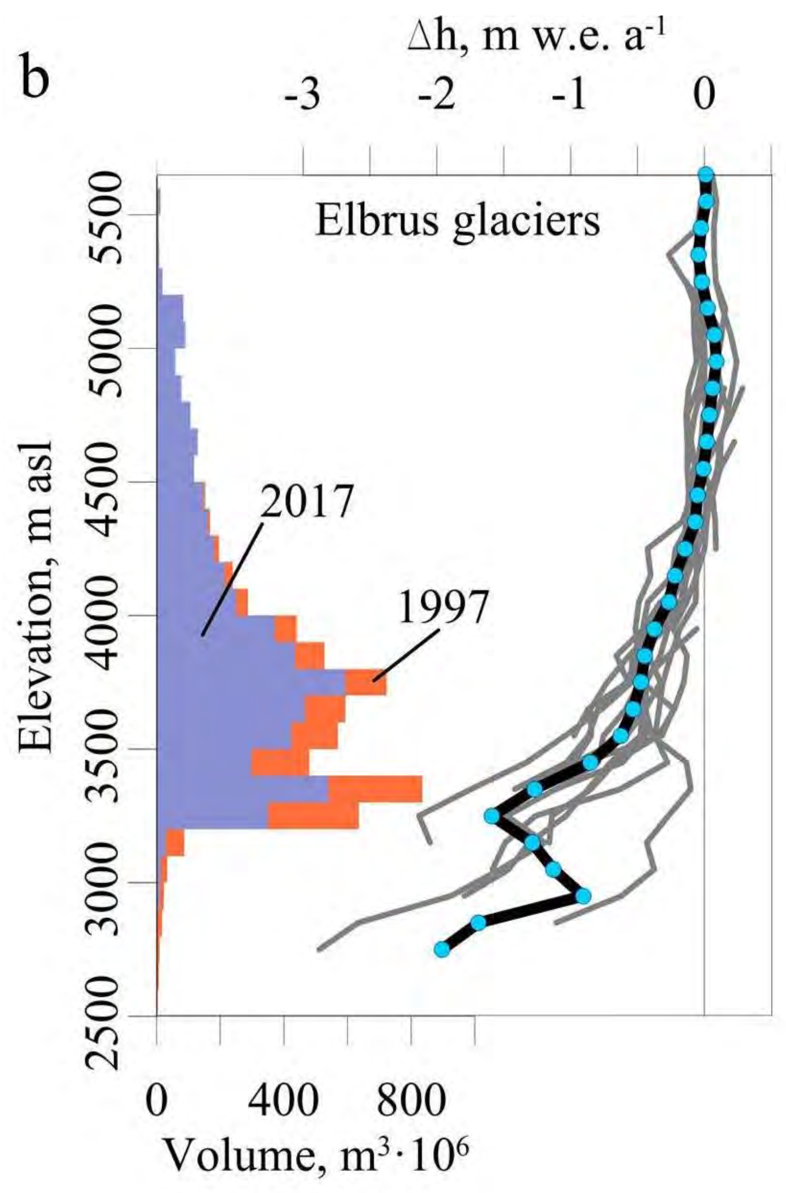


Volume change 1997-2017

Kutuzov et al., 2019



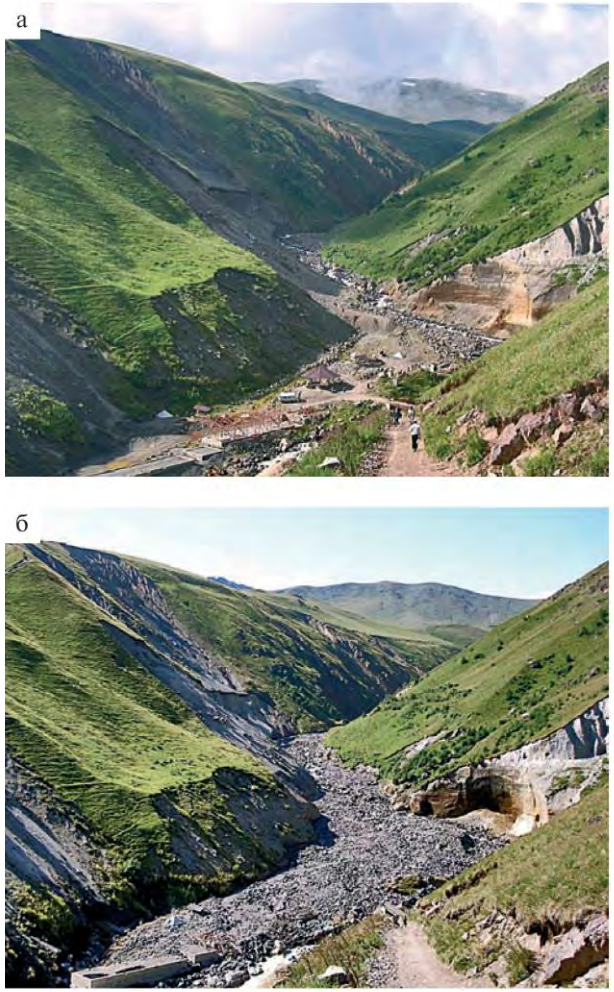




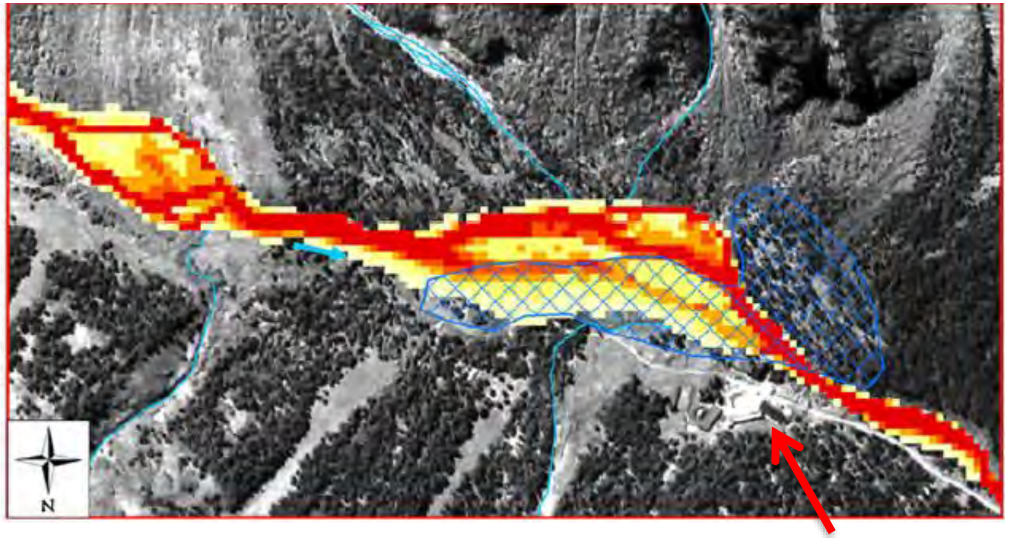
- **In 1997-2017 Elbrus glaciers lost 22.8% of the total volume.**
- Individual glaciers on average lost 21.4% Two glaciers on the southern slope, Irikchat and N25, lost the largest percentage of ice **47.4% (2.4% a^{-1})** and **43.2% (2.2% a^{-1})**, respectively.
- Elbrus glaciers lost more than **42%** of their total volume below 3500 m,

Glacier lake outburst flood 11 August 2006

(Chernomorets et al., 2007)



Glacier lake outburst flood Bashkara lake **01/09/2017**
(Chernomorets et al., 2018)

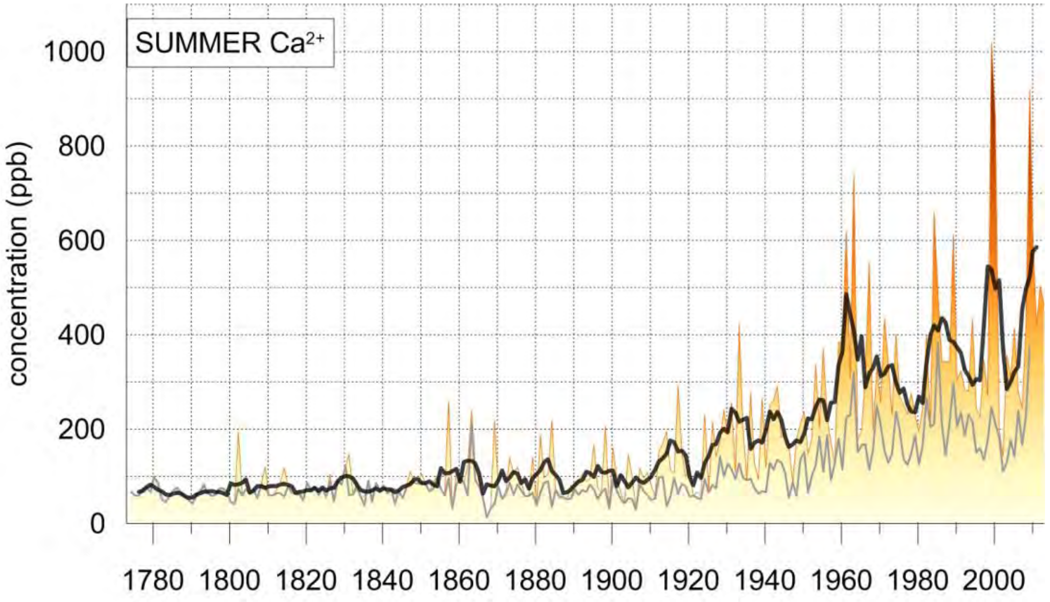


Petrakov et al. 2011

1/09/2017

High mountain glacial paleo records are under threat

e.g. valuable record from Elbrus



- Dust concentrations prominently increase in the Elbrus ice core, confirming that the recent droughts in the Middle East (1998–2012 CE) present the most severe aridity experienced in at least the past two centuries. (Kutuzov et al., 2019)

More Information:

Website: http://ipcc.ch

IPCC Secretariat: ipcc-sec@wmo.int

IPCC Press Office: ipcc-media@wmo.int

Find us on:

@IPCC_CH

@IPCCNews

@IPCC_Climate_Change

www.vimeo.com/ipcc

www.youtube.com/c/ipccgeneva

Knowledge gaps

- Uncertainties remain with detection and attribution of key atmospheric drivers that influence much of these climate-related changes, due to limited spatial density and/or temporal extent of observation records at high elevations. Trends in total or solid precipitation at high elevation remain highly uncertain, due to intrinsic uncertainties with *in situ* observation methods, and large natural variability.

- There are clear knowledge gaps in the distribution and characteristics of cryospheric variables, in particular the extent and ice content of permafrost in mountains, but also current glacier ice volumes, trends in lake and river ice, and the spatial and temporal variation of snow cover.

- Radiative forcing effects of light absorbing particles, and understanding their spatiotemporal dynamics, is a key knowledge gap for the attribution of changes in high mountain snow and glaciers and the understanding of regional feedbacks.

- Overall, few studies have taken a comprehensive risk approach to systematically characterise and compare magnitude and extent of past impacts and future risks across high mountain regions, including compound risks and cascading impacts where instances of deep uncertainty in responses and outcomes may arise.

- A key knowledge gap is the capacity to economically quantify cryosphere-specific impacts and potential risks.

- A major research gap is in our understanding of the fate of legacy pollutants such as mercury downstream of their release from glaciers and permafrost in terms of quantity and regional differences, freshwater sinks, and potential effects to ecosystems and human health.

- While adaptation measures are reported for high mountain cryosphere changes, it stands as a relatively new and developing area of research with particular gaps in terms of systematically evaluating their cost-benefits and long-term effectiveness in the mountain context.