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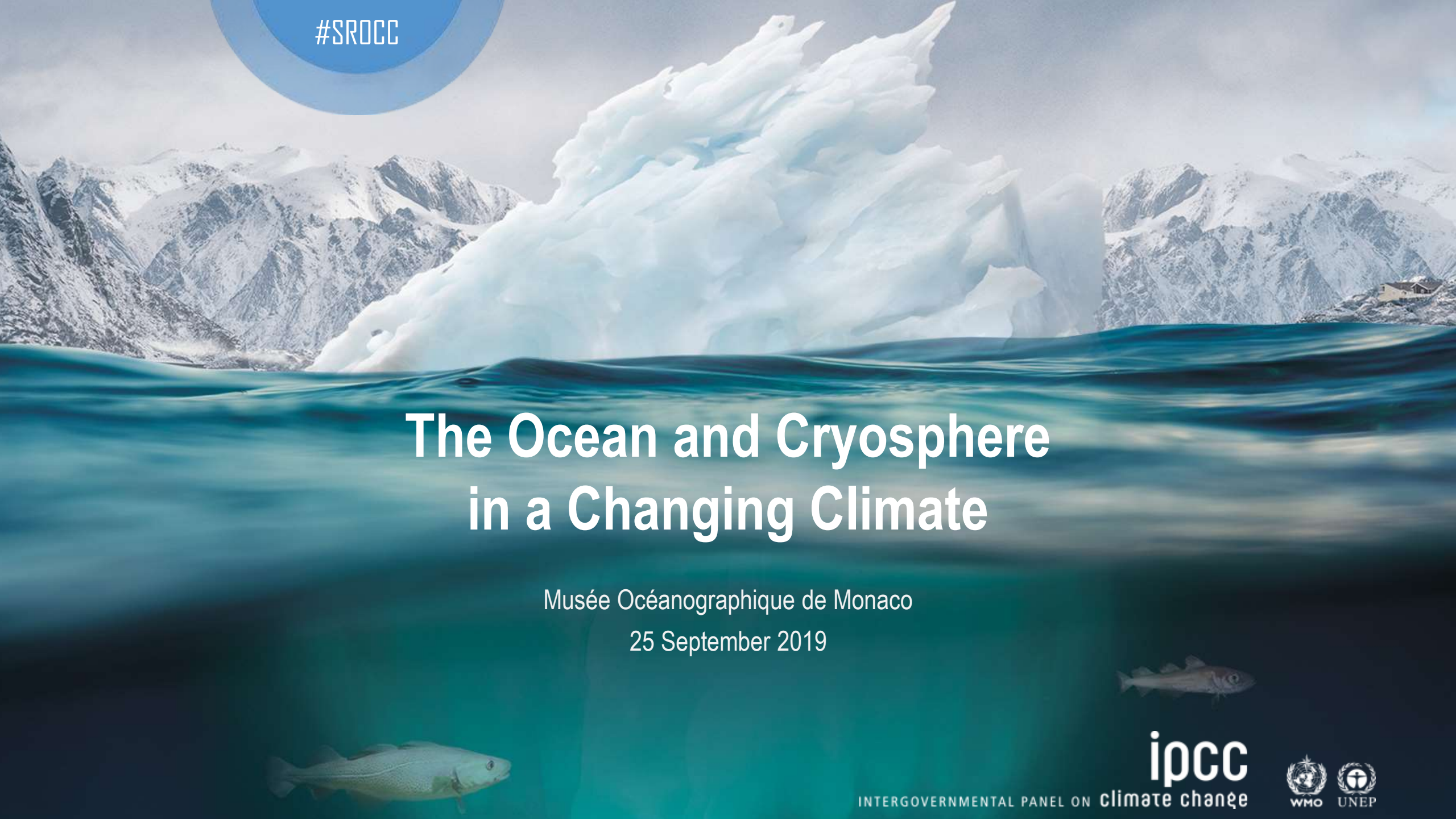

The Ocean and Cryosphere in a Changing Climate

Musée Océanographique de Monaco

25 September 2019

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INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

The world's ocean and cryosphere have been 'taking the heat' from climate change for decades.

Consequences for nature and humanity are sweeping and severe.

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Photo: Yungdrung Tsewang

Changes in the mountain cryosphere

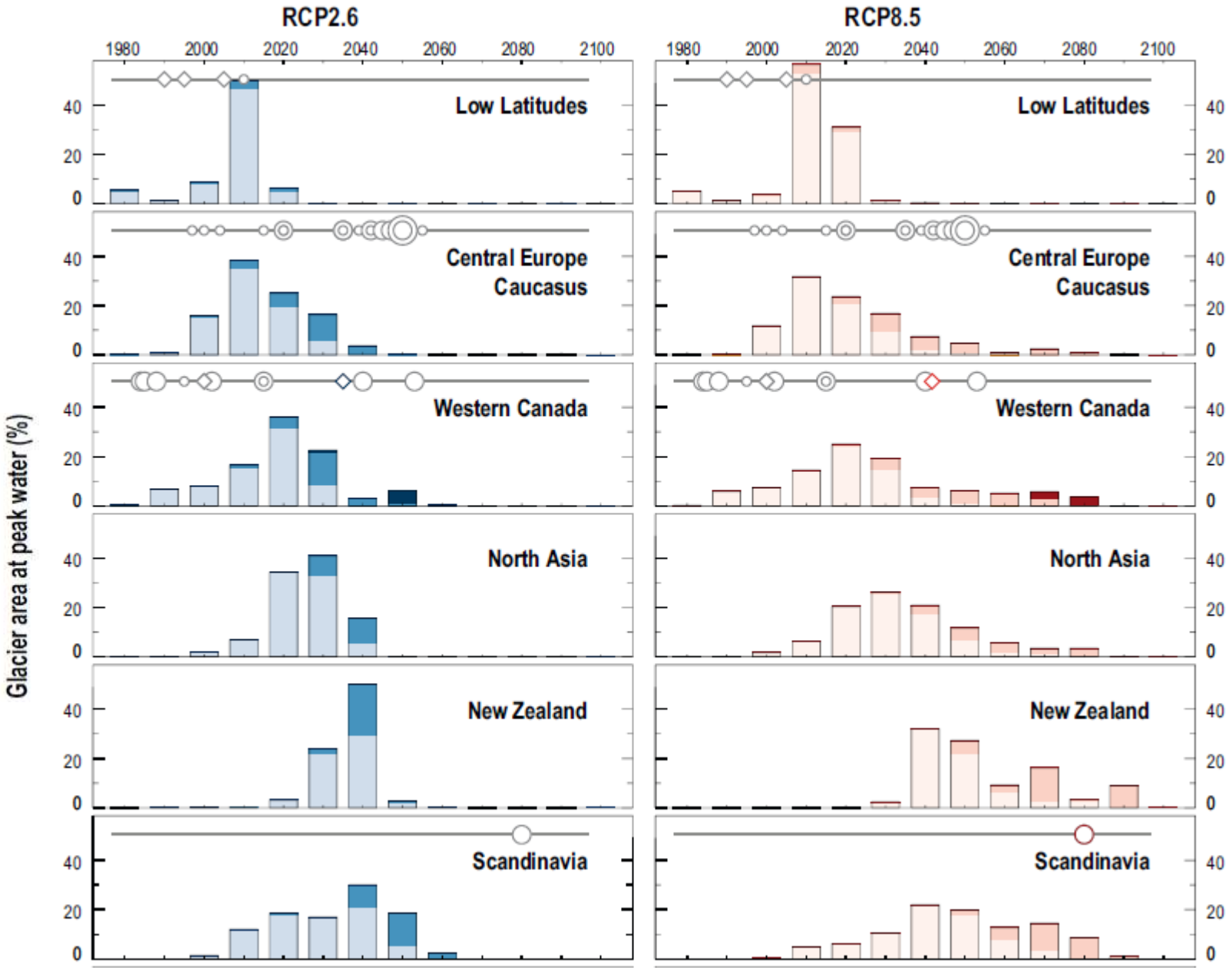
- **Smaller glaciers** found, for example, in Europe, eastern Africa, the tropical Andes and Indonesia are projected to lose **more than 80%** of their current ice mass by 2100 if emissions continue to increase strongly.
- Hazards for people, for example through **landslides, snow avalanches or floods** will increase as glaciers and permafrost decline.
- **Changing water availability and quality** affects households, agriculture, energy systems, and people both in the region and beyond.
- The retreat of the cryosphere will continue to adversely affect recreational activities, tourism and cultural assets.

Water and changing mountain cryopshere

- Mountains are the water towers of the world – runoff per unit generated in the mountains is ~ twice as much from low lands.
- For e.g. 10 major rivers of Asia originate from the Hindu Kush Himalayas
- Very high confidence that there are changes in seasonality of run-off in snow and glacier dominated river basins across the world – hence impact on **water quantity**

Water and changing mountain cryopshere

- Robust evidence that **peak water** in many of the glacier fed rivers has already passed in tropical Andes, Swiss Alps and Western Canada
- And peak water will pass by middle of this century in High Mountain Asia and European Alps


RCP2.6
RCP8.5
1980
2000
2020
2040
2060
2080
2100
Low Latitudes
Central Europe
Caucasus
Western Canada
North Asia
New Zealand
Scandinavia
Glacier area at peak water (%)
0
20
40

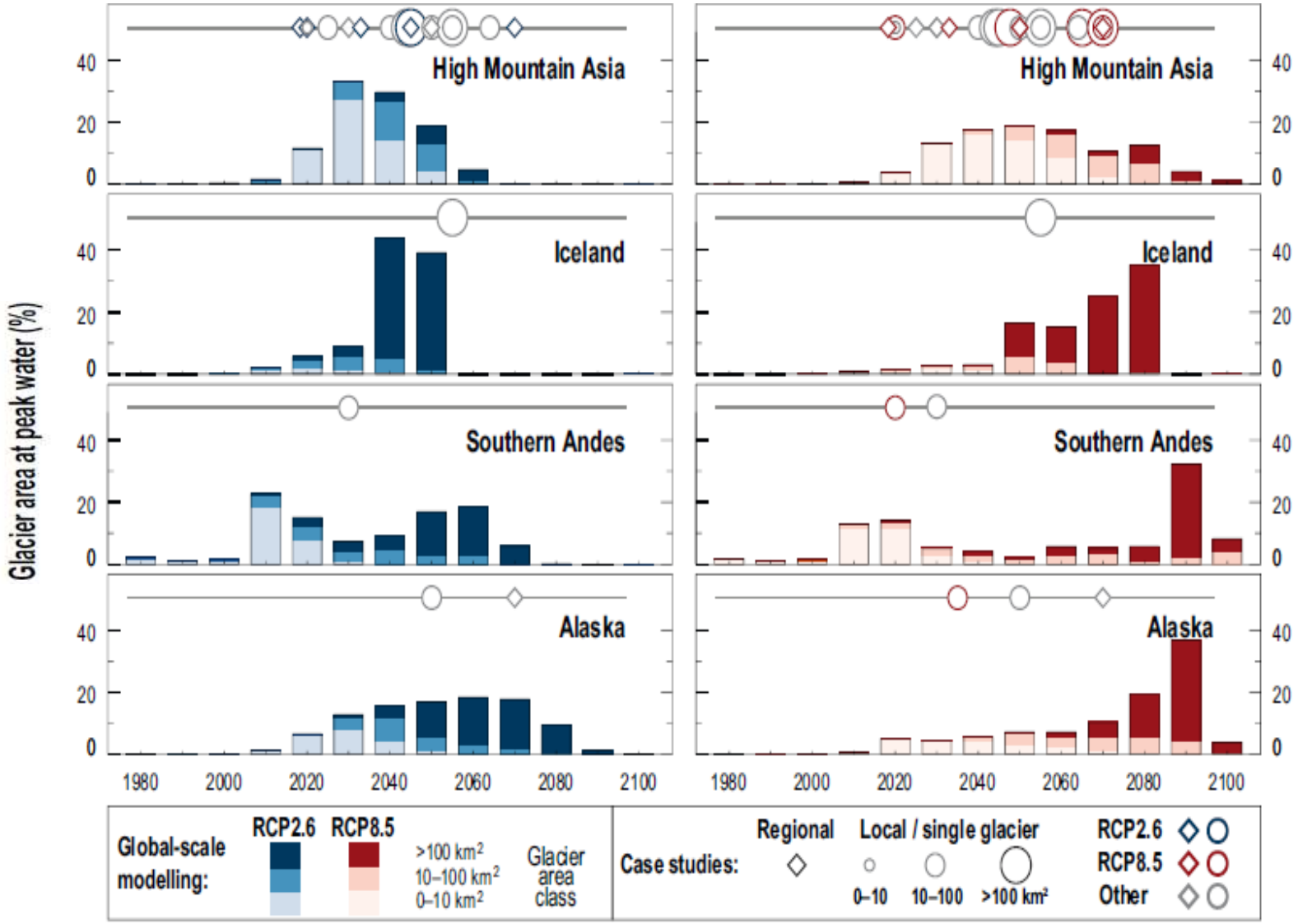
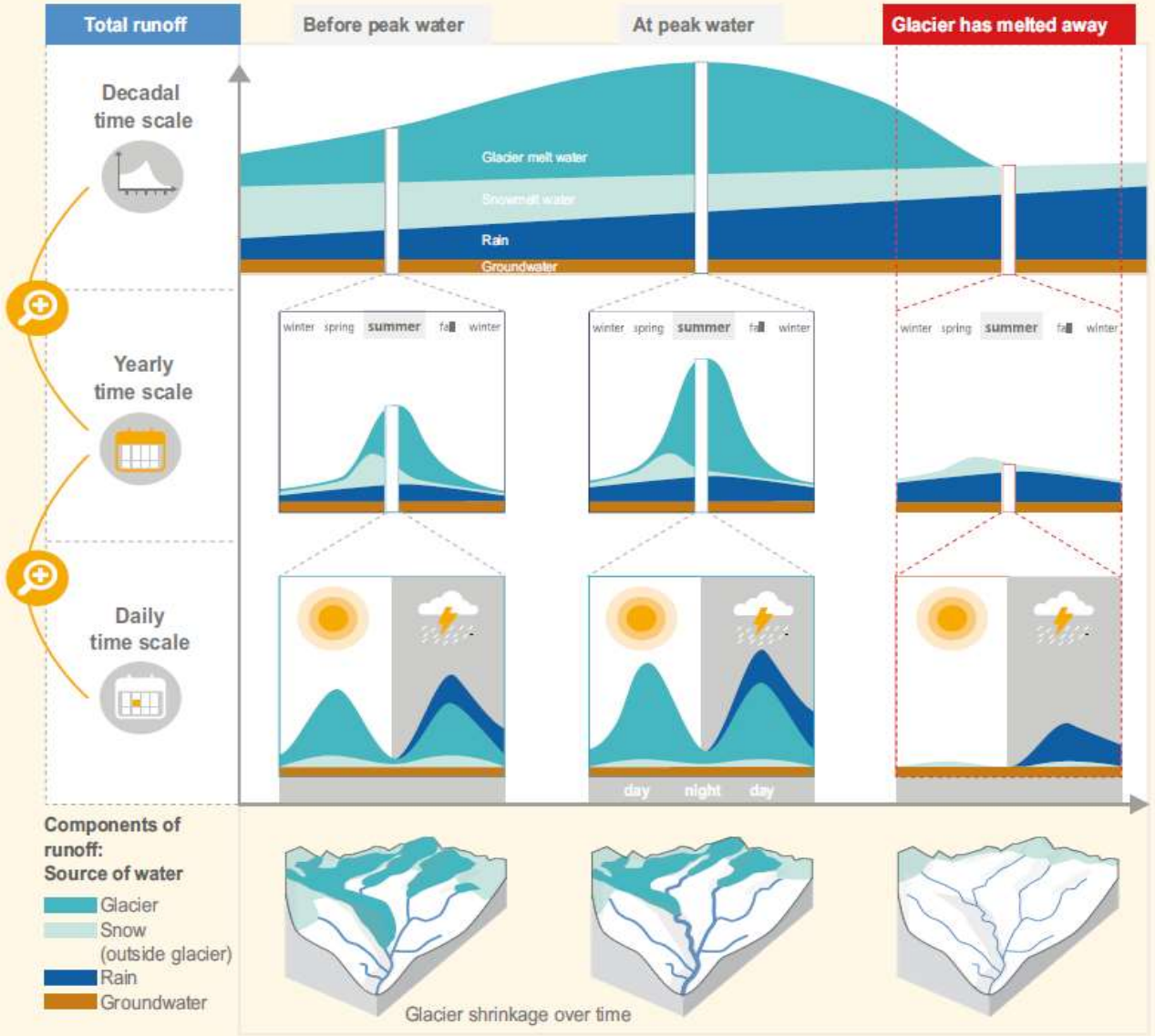


Figure 2.6 | Timing of peak water from glaciers in different regions (Figure 2.1) under two emission scenarios for Representative Concentration Pathways RCP2.6 and RCP8.5. Peak water refers to the year when annual runoff from the initially glacier-covered area will start to decrease due to glacier shrinkage after a period of melt induced increase. The bars are based on Huss and Hock (2018) who used a global glacier model to compute the runoff of all individual glaciers in a region until year 2100 based on 14 General Circulation Models (GCMs). Depicted is the area of all glaciers that fall into the same 10-year peak water interval expressed as a percentage of each region's total glacier area, i.e., all bars for the same RCP sum up to 100% glacier area. Shadings of the bars distinguish different glacier sizes indicating a tendency for peak water to occur later for larger glaciers. Circles/diamonds mark timing of peak water from individual case studies based on observations or modelling (Table SM2.10). Circles refer to results from individual glaciers regardless of size or a collection of glaciers covering <150 km² in total, while diamonds refer to regional-scale results from a collection of glaciers with >150 km² glacier coverage. Case studies based on observations or scenarios other than RCP2.6 and RCP8.5 are shown in both the left and right set of panels.



FAQ 2.1, Figure 1 | A simplified overview of changes in runoff from a river basin with large (e.g., >50%) glacier cover as the glaciers shrink, showing the relative amounts of water from different sources – glaciers, snow (outside the glacier), rain and groundwater. Three different time scales are shown: annual runoff from the entire basin (upper panel); runoff variations over one year (middle panel) and variations during a sunny then a rainy summer day (lower panel). Note that seasonal and daily runoff variations are different before, during and after peak flow. The glacier's initial negative annual mass budget becomes more negative over time until eventually the glacier has melted away. This is a simplified figure so permafrost is not addressed specifically and the exact partitioning between the different sources of water will vary between river basins.

Water and changing mountain cryopshere

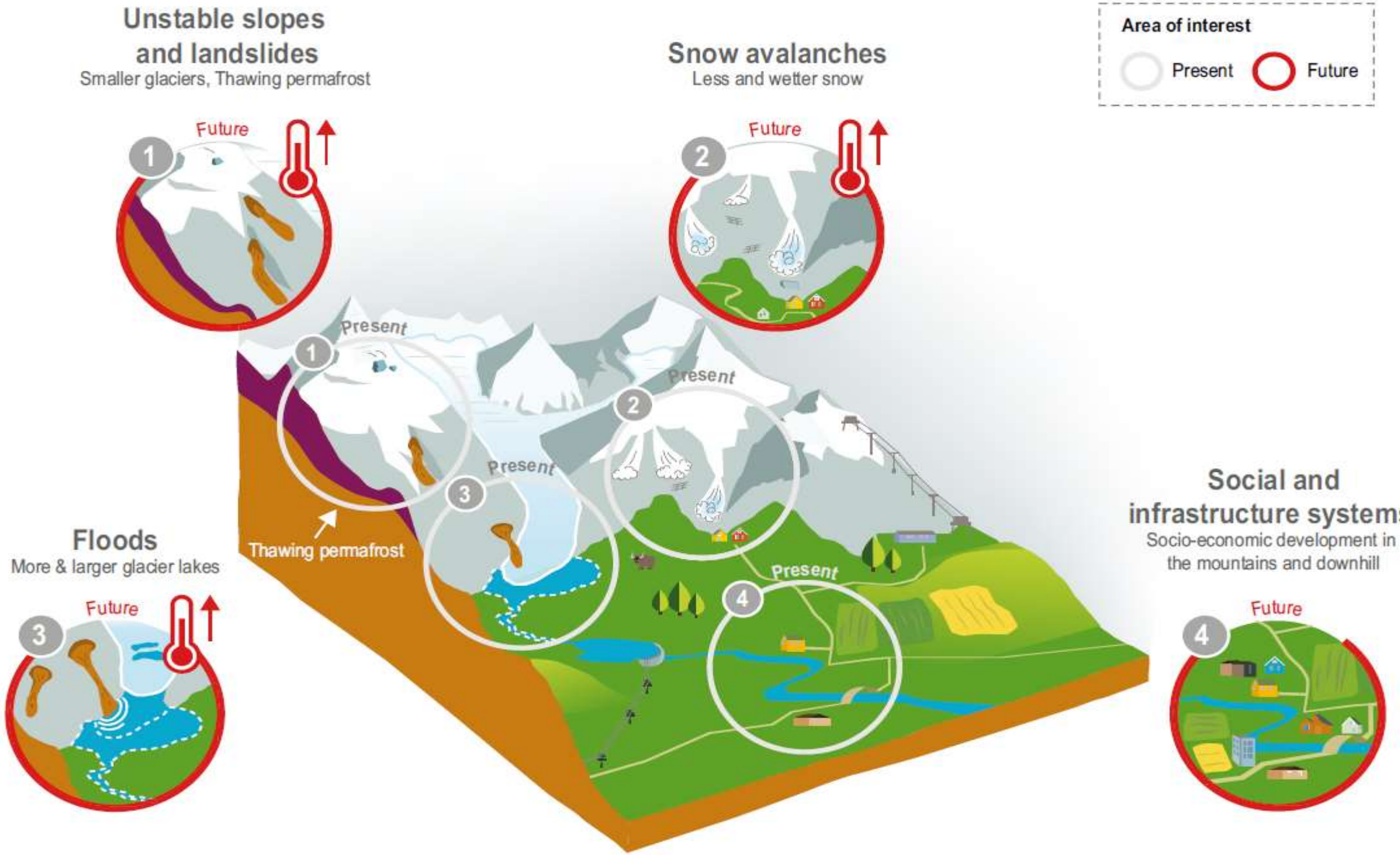
- There will be significant shifts in downstream nutrients and **water quality** (DOC, nitrogen, phosphorus) and influence water quality through increases in heavy metals, particularly mercury, and other legacy contaminants (medium evidence, high agreement)

Societal impacts of changes in water regimes due to cryosphere change

- *Robust evidence (medium agreement)* that water input to **hydropower** facilities will change in the future due to cryosphere-related impacts on runoff
- *Medium evidence (medium agreement)* that reduction in streamflow due to glacier retreat or reduced snow cover has led to reduced water availability for **irrigation of crops and declining agricultural yields** in several mountain areas, e.g. in HKH, parts of Andes, though periods before peak flow is reached, water may be temporarily abundant
- There have been local responses by farmers to cryospheric changes, e.g. shifting of cropping patterns, out migration, and additional water storage in the form of ice stupas

Societal impacts of due to water induced hazards

- **Glacier-related floods**, including floods from lake outbursts (GLOFs), are documented for most glacierised mountain ranges and are among the most far-reaching glacier hazards.
- High confidence that **glacier lakes** will increase
- Floods originating from the combination of rapidly melting snow and intense rainfall, referred to as **rain-on-snow events**, are some of the most damaging floods in mountain areas and high confidence these events are on the rise


Unstable slopes
and landslides
Smaller glaciers, Thawing permafrost
Snow avalanches
Less and wetter snow
Area of interest
Present
Future
Future
Future
Present
Present
Present
Present
Thawing permafrost
Floods
More & larger glacier lakes
Future
Social and
infrastructure systems
Socio-economic development in
the mountains and downhill
Future

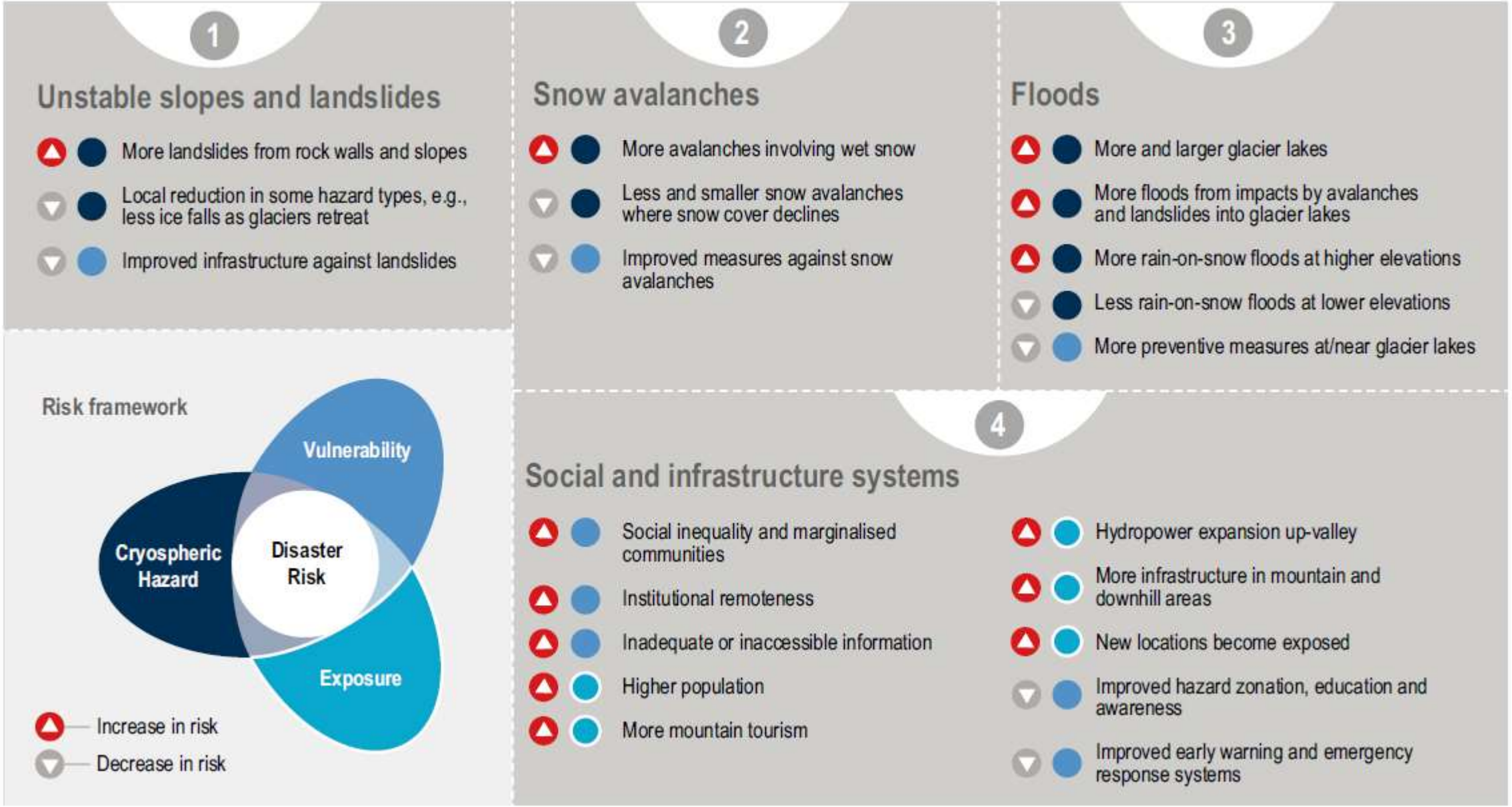


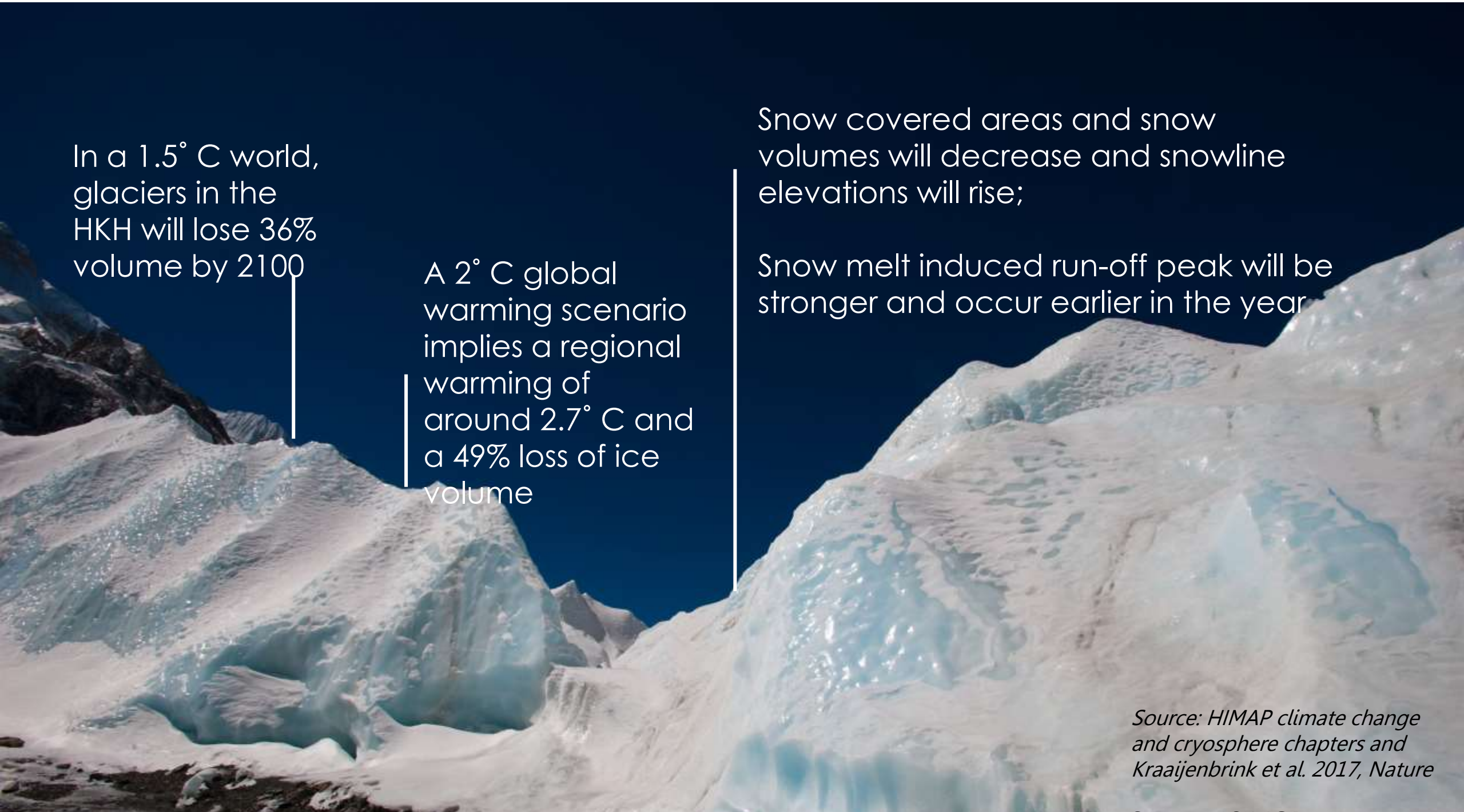
Figure 2.7 | Anticipated changes in high mountain hazards under climate change, driven by changes in snow cover, glaciers and permafrost, overlay changes in the exposure and vulnerability of individuals, communities, and mountain infrastructure.

Adaptation measures and way forward

- Limiting warming to 1.5°C would help people to adjust to changes in water supplies and limit risks related to mountain hazards.
- Integrated water management and transboundary cooperation provide opportunities to reduce the impacts of climate-related cryosphere changes on water resources.

Melting of Himalayan Glaciers

Source: ICIMOD



In a 1.5˚ C world, glaciers in the HKH will lose 36% volume by 2100

A 2˚ C global warming scenario implies a regional warming of around 2.7˚ C and a 49% loss of ice volume

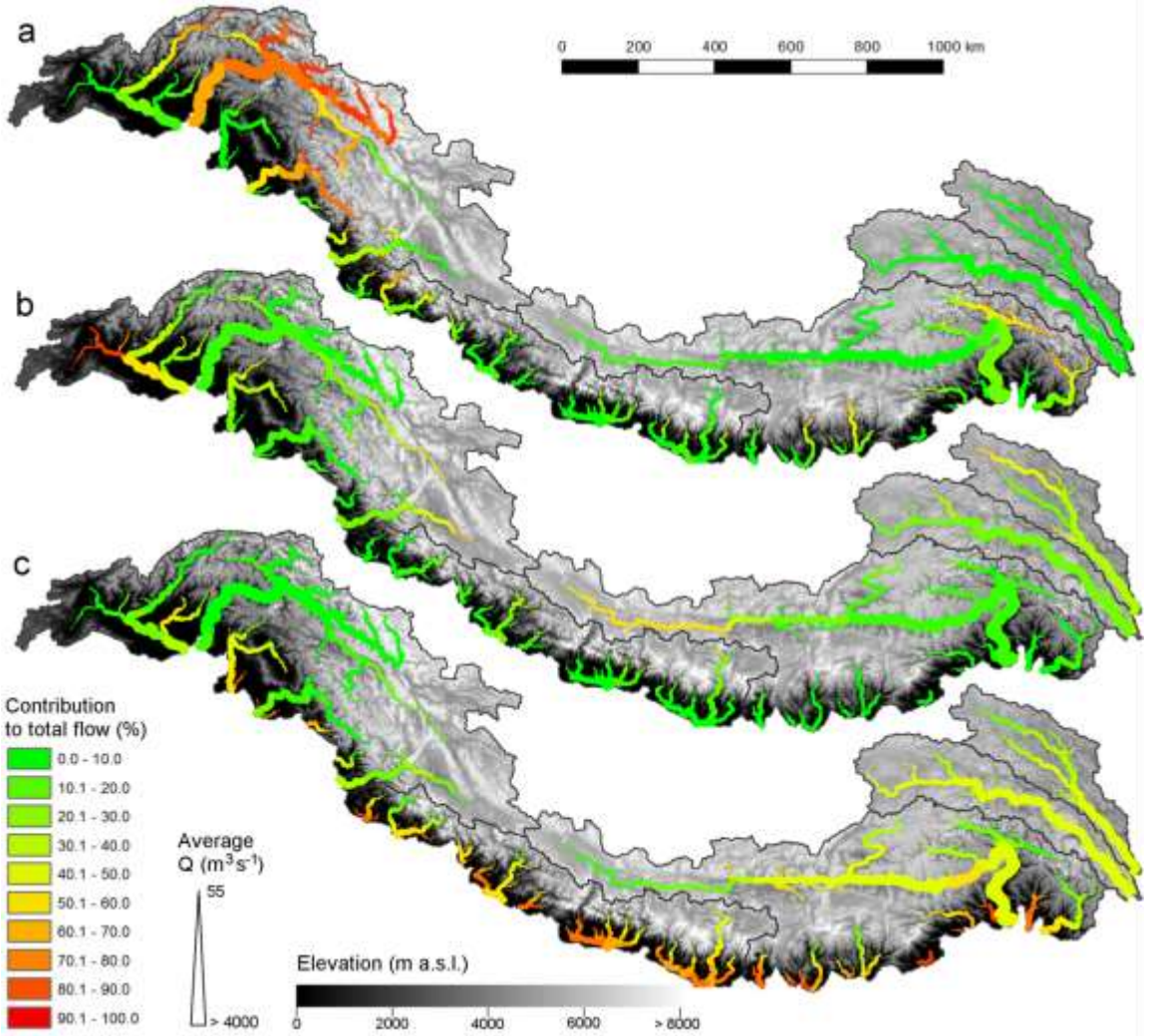
Snow covered areas and snow volumes will decrease and snowline elevations will rise;

Snow melt induced run-off peak will be stronger and occur earlier in the year

Source: HIMAP climate change and cryosphere chapters and Kraaijenbrink et al. 2017, Nature


2009
What do these changes mean for the region's water resources?
Source: ICIMOD
Photography: David Breashears, GlacierWorks


Communities dependent on glacier and snow melt are feeling the impacts
Nang, Ladakh, India
Mukherji, A., A. Sinisalo, M. Nusser, R. Garrard and M. Eriksson. 2019.
Source: @ICIMOD



Contribution to total flow by (a) glacial melt, (b) snowmelt, and (c) rainfall-runoff for major streams during the reference period of 1998–2007. Line thickness indicates the average discharge during the reference period. Source: Lutz et al. (2014)

Not running out of water, but…

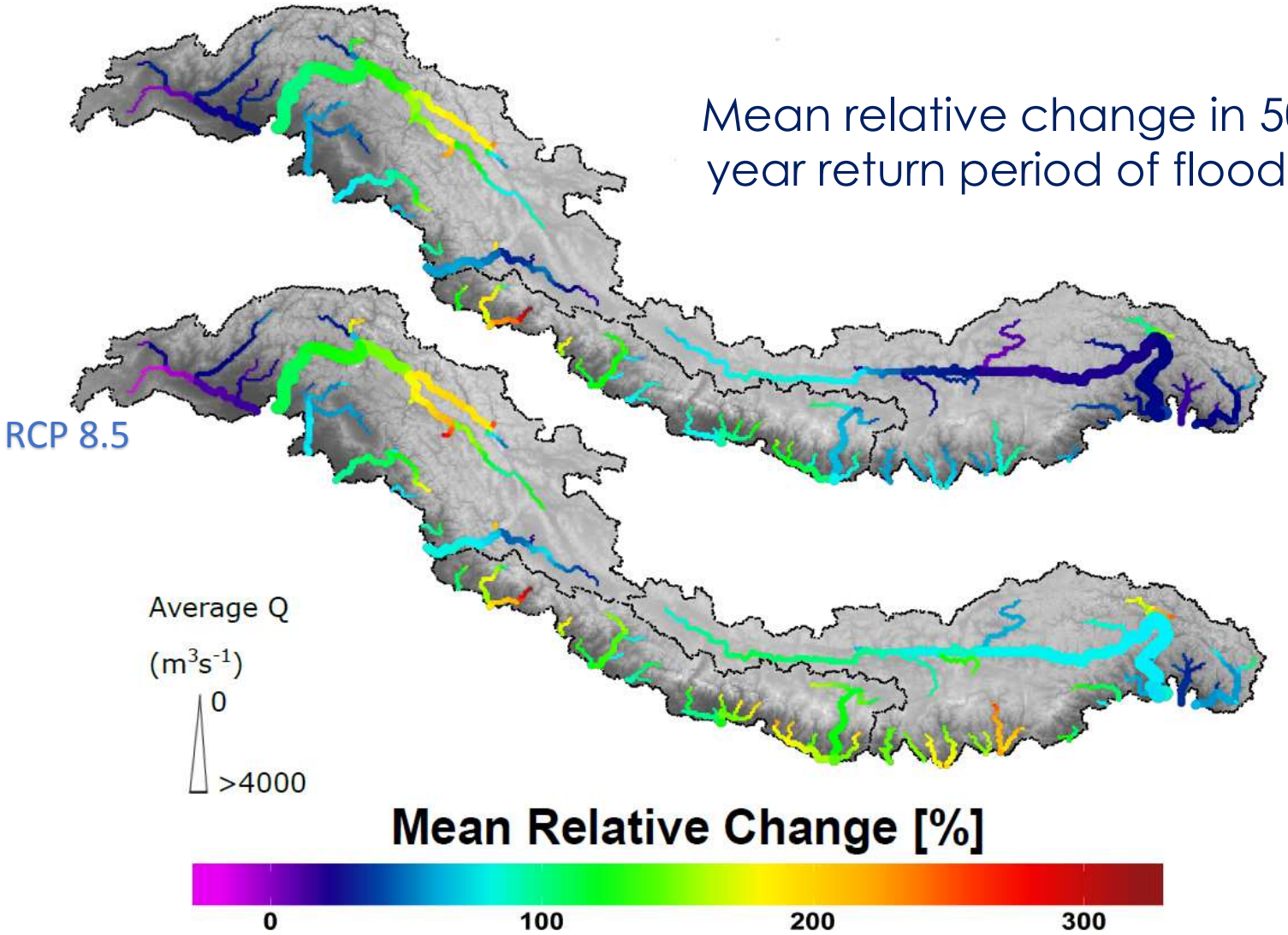
Greater impact for those living closer to glaciers

Climate change is expected to drive consistent increases in total runoff of the Indus (due to increased glacier melt), Ganges and Brahmaputra (due to increased precipitation)

Source: @ICIMOD

HIMAP

Flood magnitudes will increase..



Intensities of ‘once in 50 years’ flood events will increase:
40%–110% in upstream areas
115%–150% in downstream areas

Source: Wijngaard et al. 2017, PLOS One

The more decisively and earlier we act, the more able we will be to address unavoidable changes, manage risks, improve our lives and achieve sustainability for ecosystems and people around the world – today and in the future.

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Our ocean and cryosphere –

They sustain us.
They are under pressure.
Their changes affect all our lives.

The time for action is now.

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