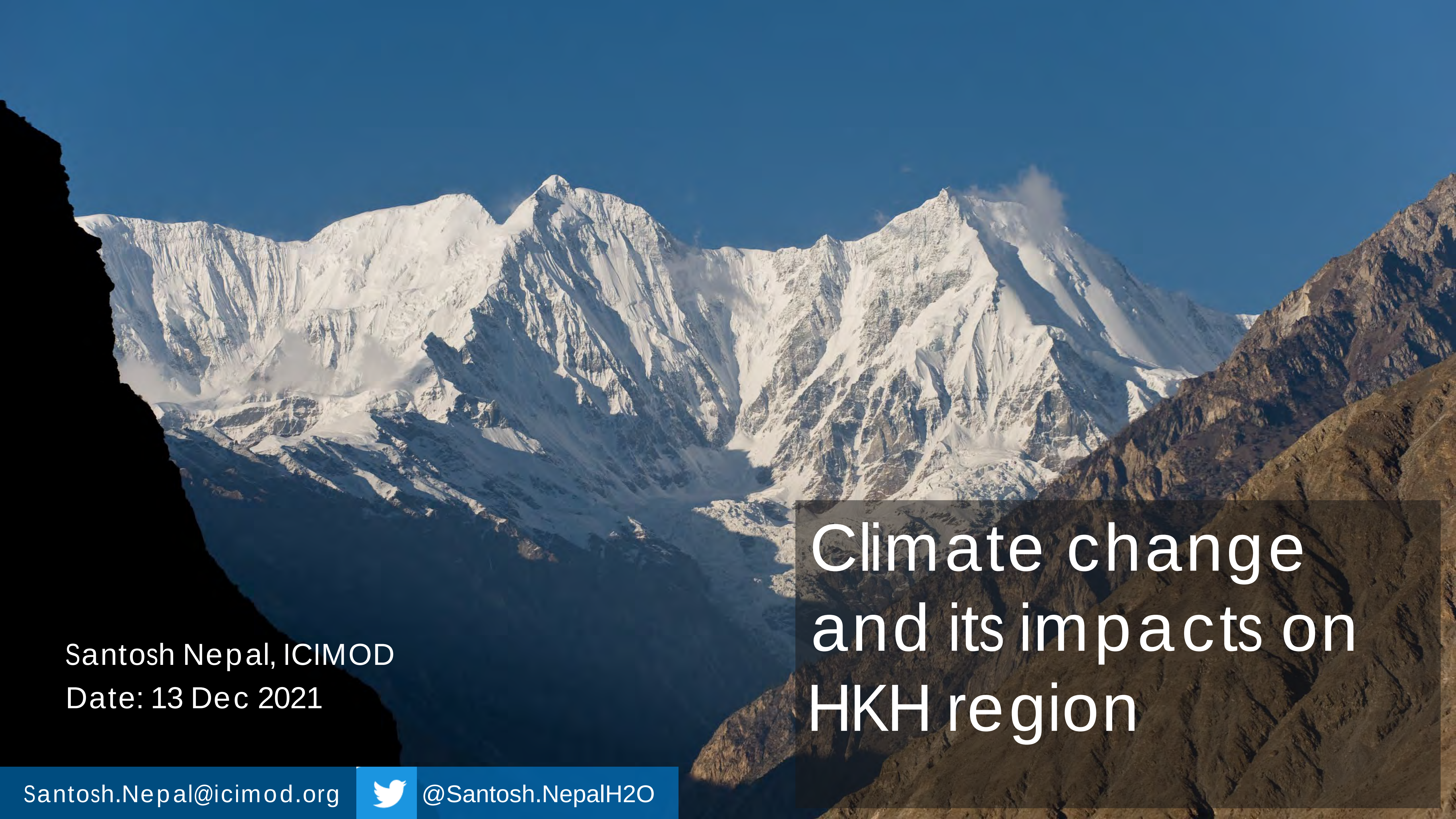


Climate change and its impacts on HKH region

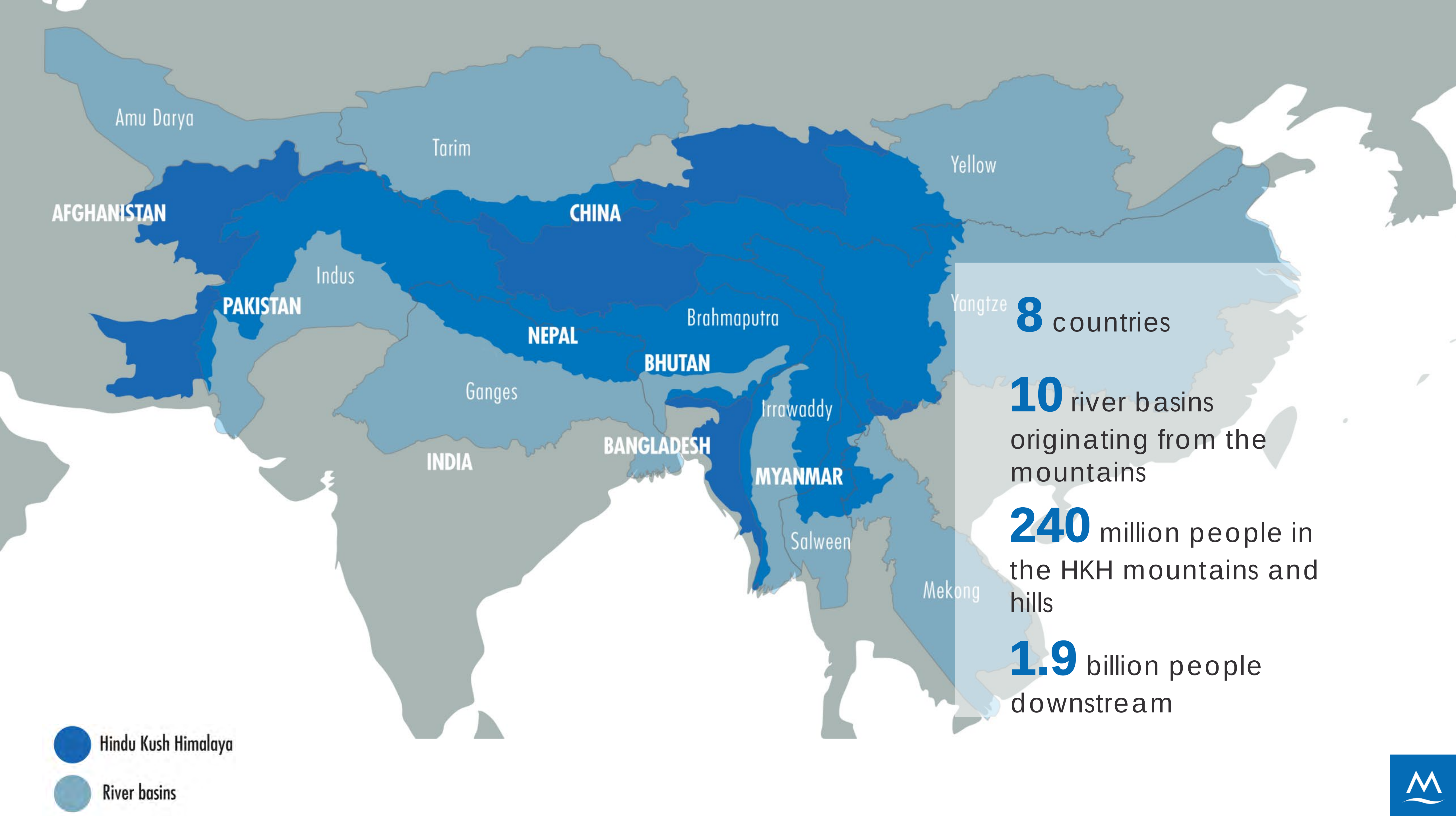
Santosh Nepal, ICIMOD

Date: 13 Dec 2021

Santosh.Nepal@icimod.org

@Santosh.NepalH2O


The Hindu Kush Himalaya
Global asset for food, energy, water, carbon, and cultural and biological diversity
Monsoon dominated climate
Westerly
Summer Monsoon



8 countries

10 river basins originating from the mountains

240 million people in the HKH mountains and hills

1.9 billion people downstream

Upstream-downstream Linkages

Snowmelt

Glacier melt

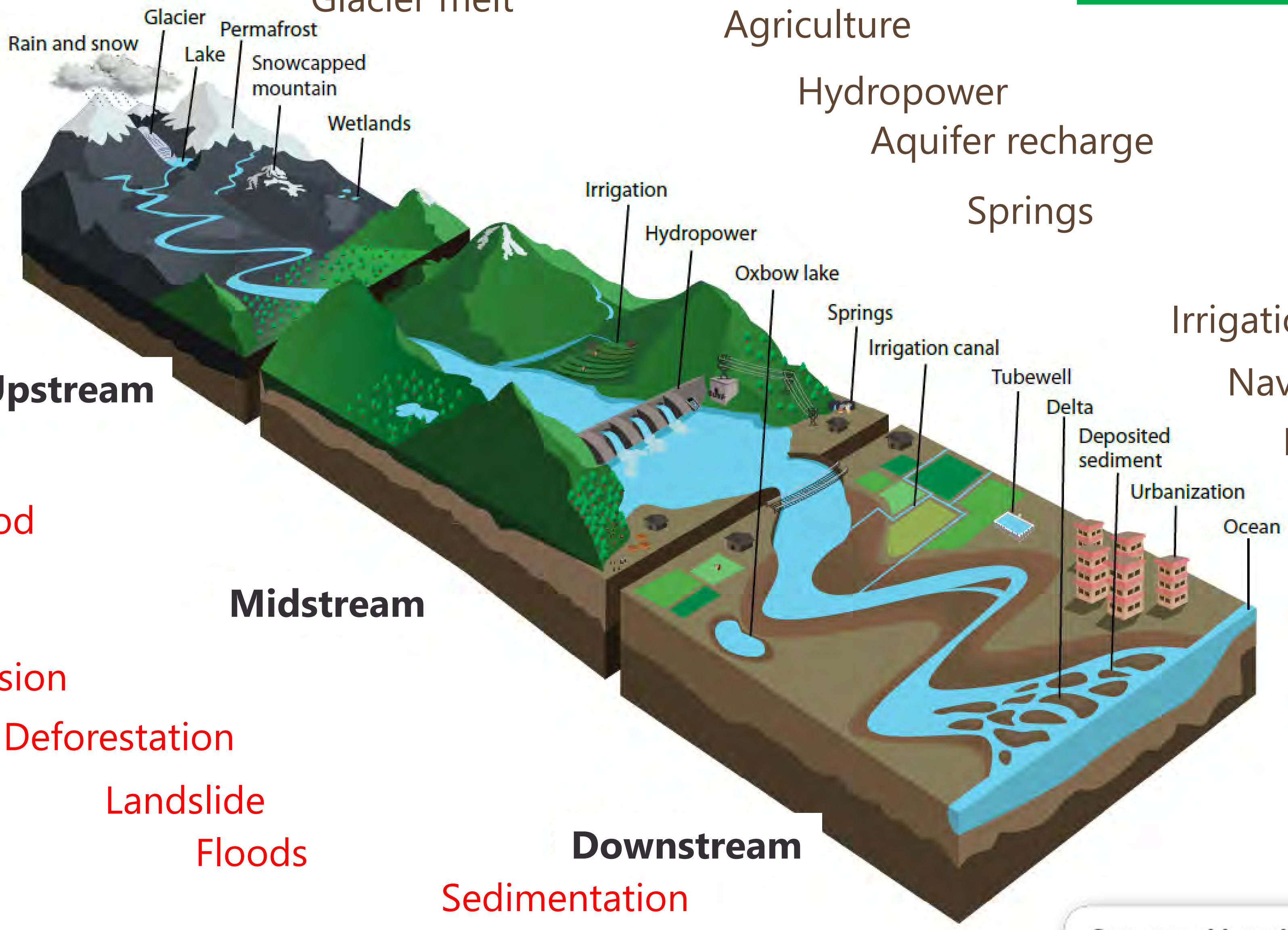
Opportunities

Agriculture

Hydropower

Aquifer recharge

Springs



Irrigation

Navigation

Large settlements

GLOF

Landslide

Upstream

Avalanche

Flash flood

Midstream

Erosion

Deforestation

Landslide

Floods

Downstream

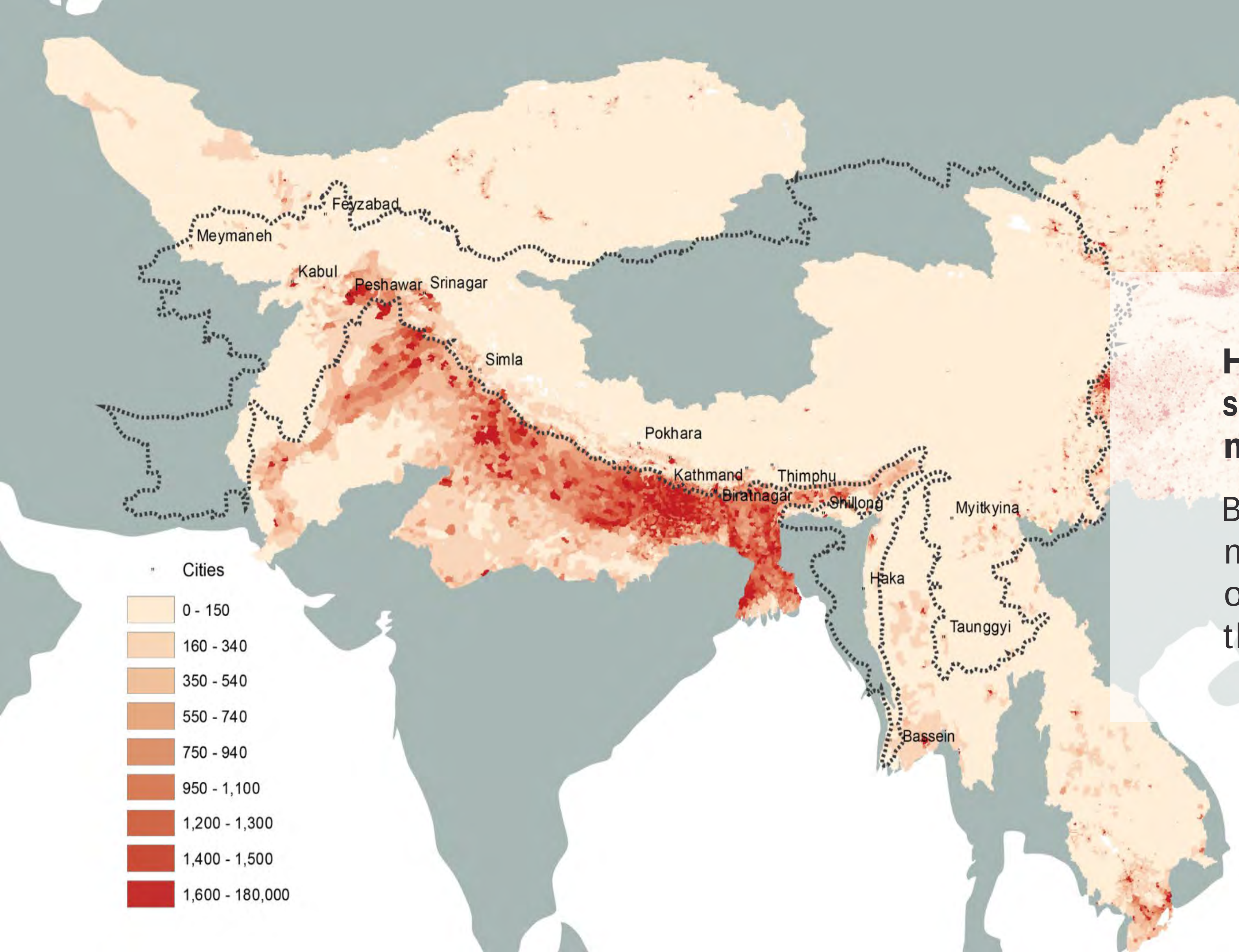
Threats

Sedimentation

Flood

GW depletion

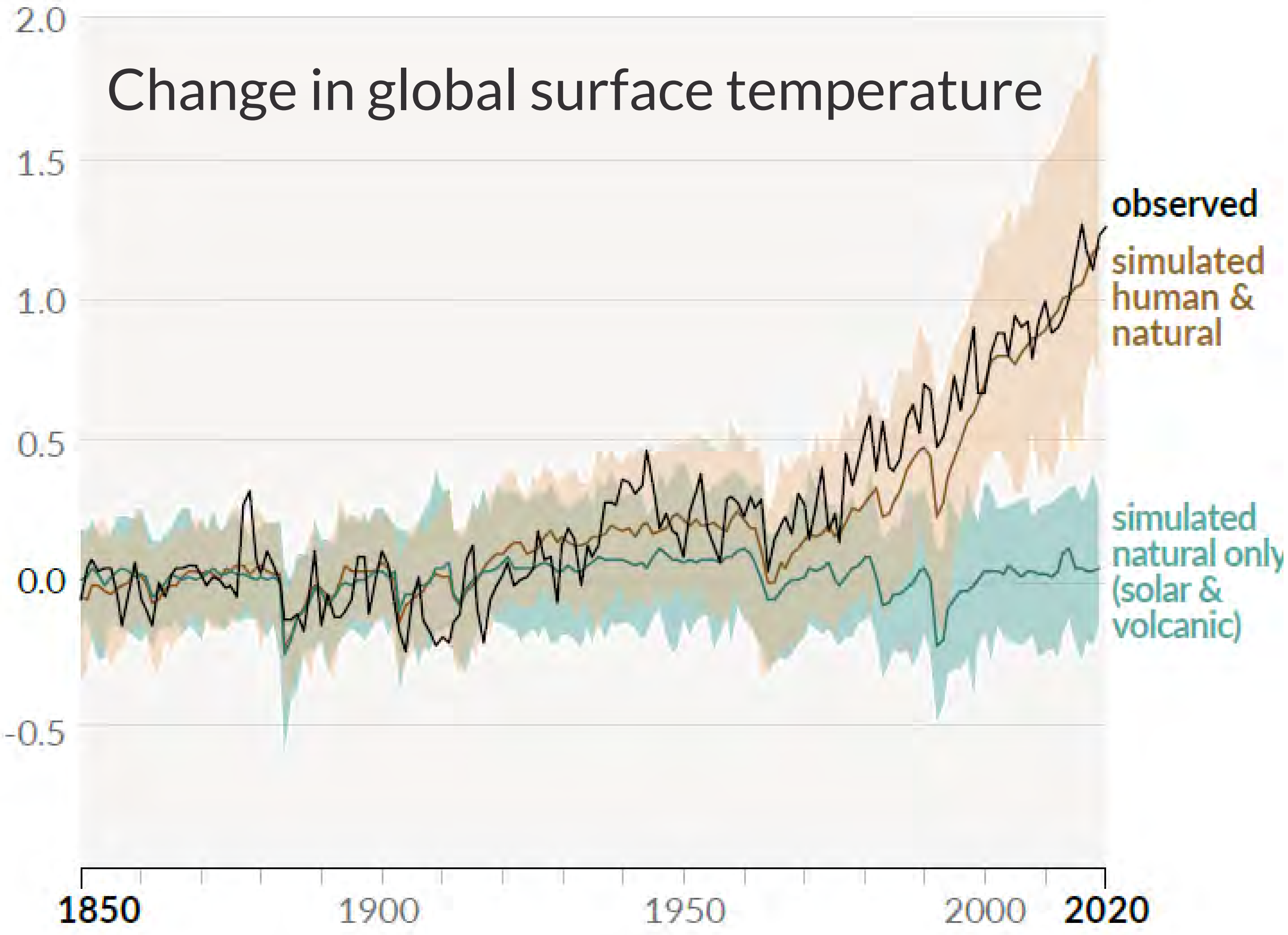
Source: Nepal et al. 2018



HKH basins support some of the world's most populated areas

But decisions about mountain resources are often made outside of the mountains

Global climate change



Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years (IPCC AR6, 2021)

Clear signal of human induced climate change

Very close to 1.5 degree Celsius threshold

IPCC AR6 (2021), summary for policy makers

What is Ensemble approach?

Conventional approach

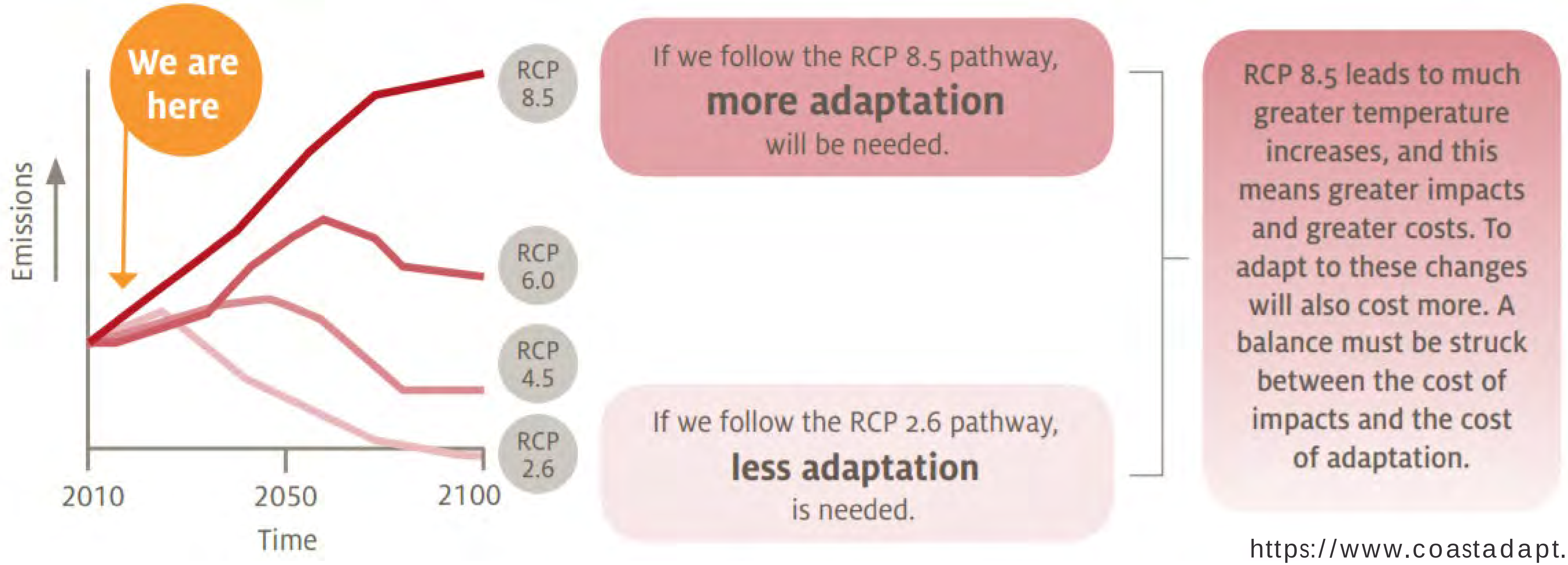
- Limited (or one) model (GCM)
- Limited (or one) scenarios (eg. A1B scenarios)
- Does not consider the possible range of changes in future

Ensemble approach

- Consider possible range of future changes
- Prediction of future can never be absolutely certain (change in policy, climate negotiation, etc.)
- Adaptation planning requires a range of possible options !

In which direction the future climate change will

What are Representative Concentration Pathway (RCPs)



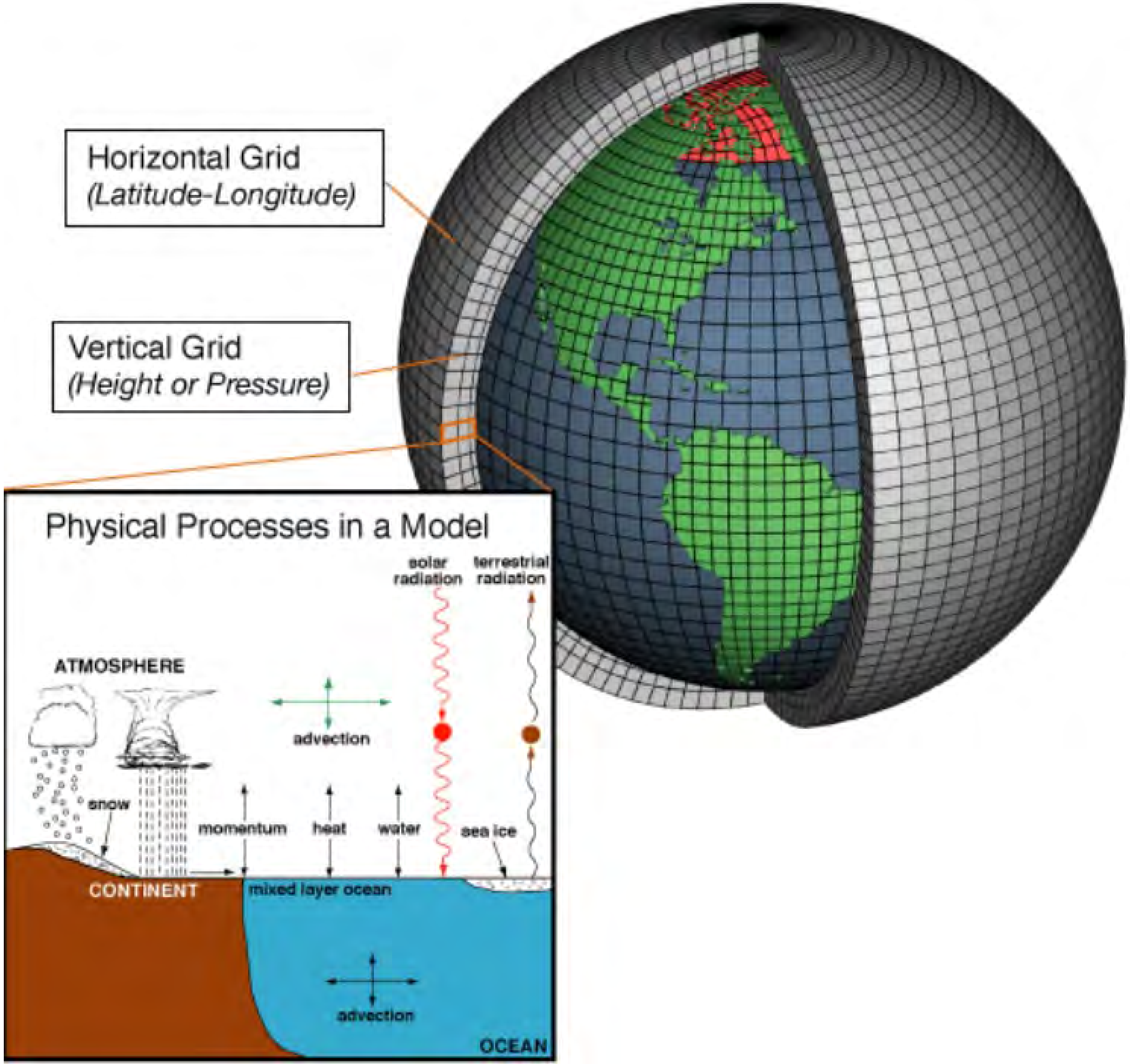
https://www.coastadapt.com.au/

RCPs represents GHGs concentrations trajectories adopted by IPCC for AR5

How our climate may change in future by making predictions of how concentrations of greenhouse gases in the atmosphere will change in future as a result of human activities.

Global climate models

Climate models, also known as general circulation models or GCMs, use mathematical equations to characterize how energy and matter interact in different parts of the ocean, atmosphere, land.



Source: climate.gov & wikipedia

Global climate models

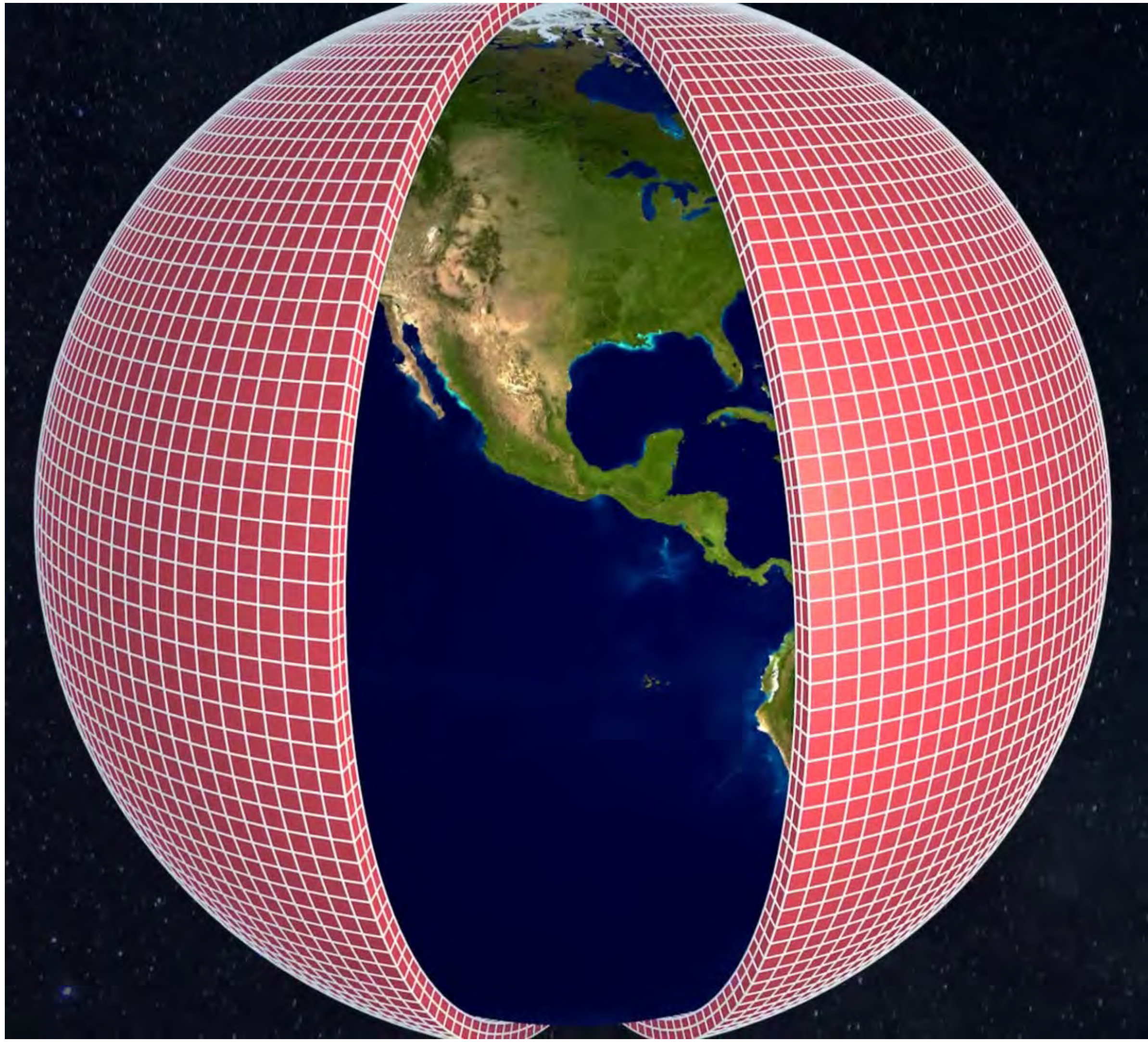
GCMs represents physical processes that occur in atmosphere, biosphere, ocean and land surface

These processes represent heat, moisture, momentum, and chemicals move across space and time

Represent space in grid cells and runs in super computers

Basic laws of physics, fluid motion, and chemistry to represent variables such as temperature, precipitation, wind, pressure are solved at each grid cells and interact with each other at space and time

All major climate system drivers are represented in current climate models



Lets watch the video of GCM

What is Global Climate models (GCMs)

How does it work?

How does it represent present and future climate change?

Video time: 5 mins

https://www.youtube.com/watch?v=ZouTDk9icbA

Downscaling

Why downscaling?

- Global Climate Model provide low resolution data (eg. 100 -200 km grid)
- Poor representation of atmospheric process (monsoon, extremes)

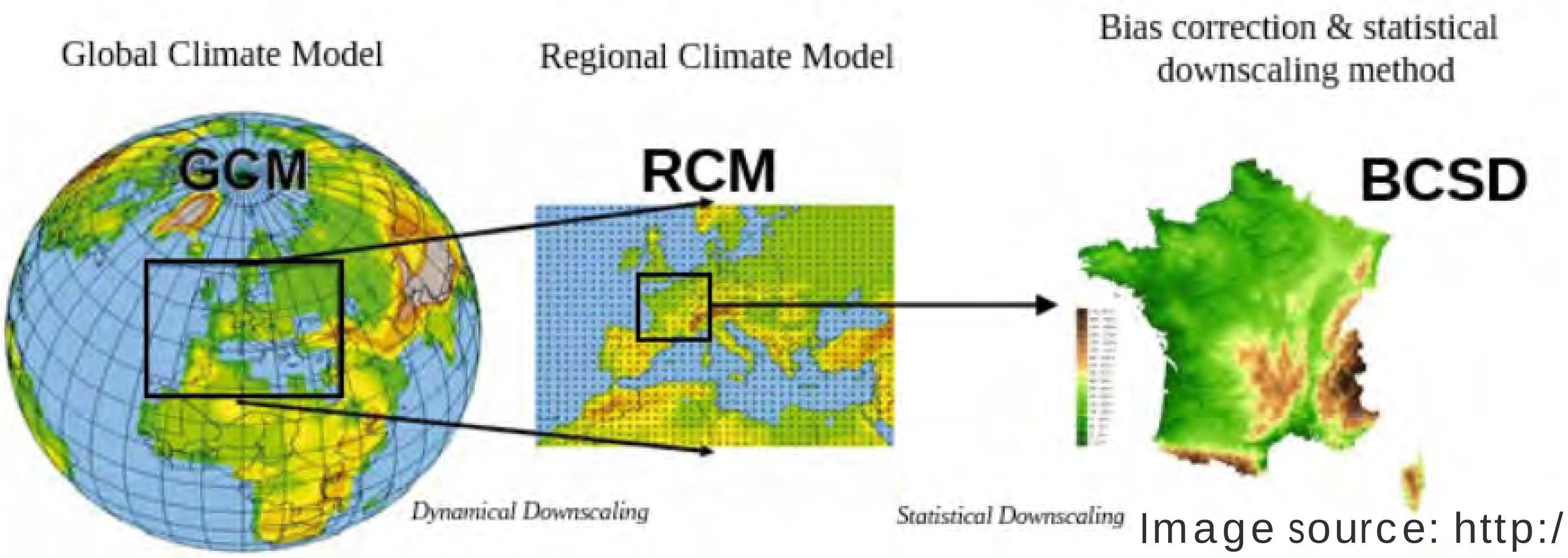


Image source: http://www.drias-climat.fr

Dynamical vs statistical downscaling

Regional Climate model provides finer resolution information than GCMs

RCMs are run at regional scale (South Asia)

RCMs represent regional variability (such as topography and typical process like monsoon and westerlies)

Statistical downscaling provides even finer information at a local scale where the local data (observed stations) helps to bias correct the RCMS information

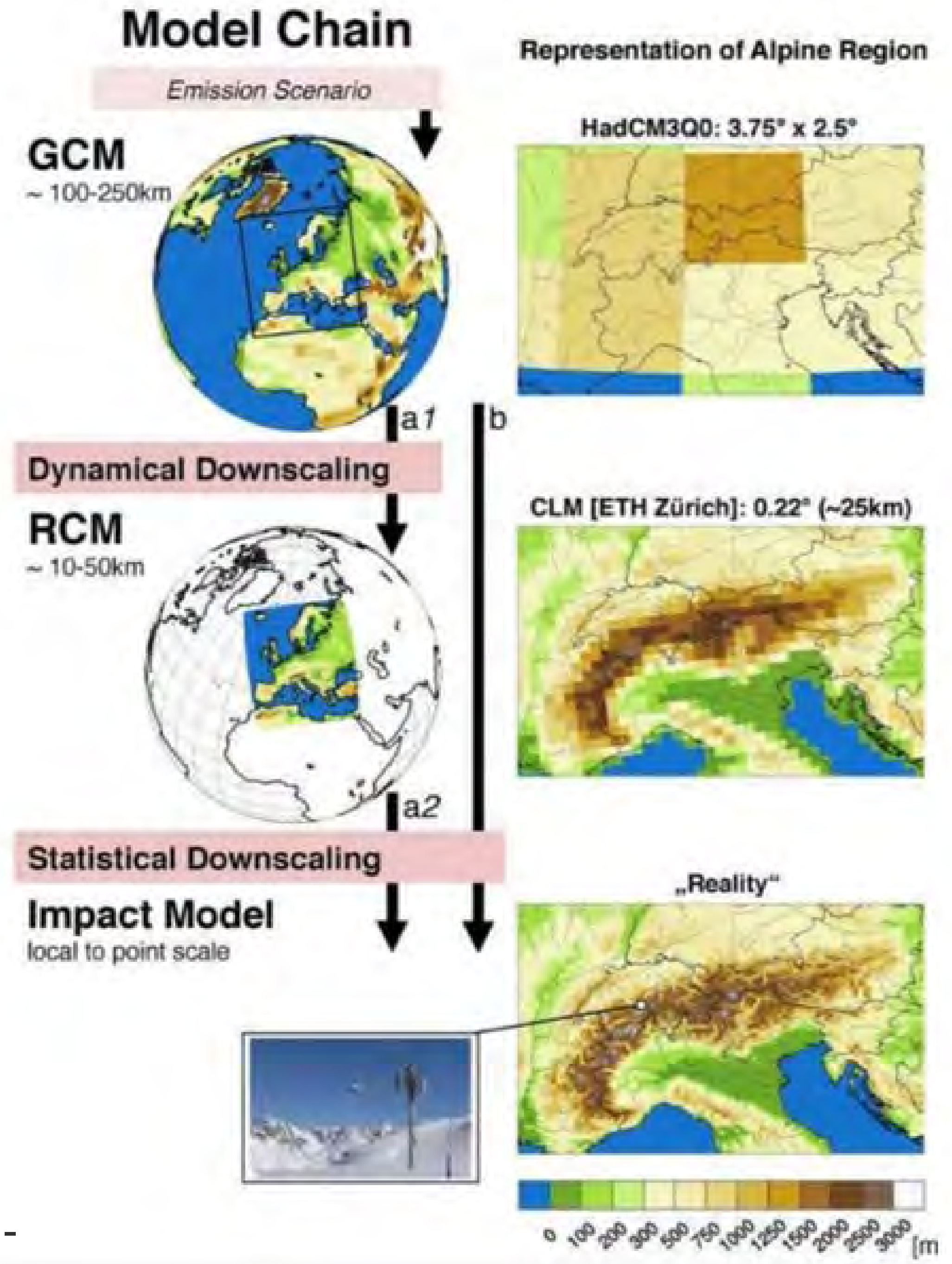


Image source: https://bookdown.org/floriandierickx/bookdown-demo/climate-data-discovery.html

Dynamical vs statistical downscaling

Dynamical downscaling:

Regional climate model uses the global climate model (GCM) as boundary condition:

Uses high-resolution climate models for a regional sub-domain, often using lower-resolution global climate models as boundary conditions

Statistical downscaling is a 2-step process:

Statistical relationship is derived **between observed small-scale variables and larger global climate model scale variables**

Statistical relations are used to **estimate the future climate at the smaller scale based on the largescale variables from GCM projections** of the future climate. (eg. Large scale predicators and local predicants)

Dynamical vs statistical downscaling

Statistical Downscaling

Strengths

Computationally Cheap

Can be applied to a large number of ensemble realizations

Requires a limited number of input GCM fields at relatively coarse temporal resolution

Can downscale GCM simulated variables directly into impacts-relevant parameters

Weaknesses

Assumes stationarity of large-small scale transformation factors

Transformation factors not always based on Well understood physical mechanisms

Does not capture systematic changes in Regional forcing

Downscaled variables limited in number and not (always) internally consistent

Dependent on the availability and quality of (regional) observations

Dynamical Downscaling

Strengths

Transformation factor (largely) based on understood numerical methods.

Full set of internally-consistent downscaled variables (multi-level & high time frequency)

Not (directly) dependent of availability of observations (e.g. applicable anywhere).

Can encompass non-stationary relationships between large and small scales, as well as potential changes in regional forcing.

Weaknesses

Computationally expensive. Therefore difficult to apply to a large ensemble of hindcasts (as needed for bias-correction)

Requires a large amount of (multi-level, high time frequency) driving GCM data.

Systematic errors also exist in RCMs

Does not (directly) produce impact-relevant Parameters.

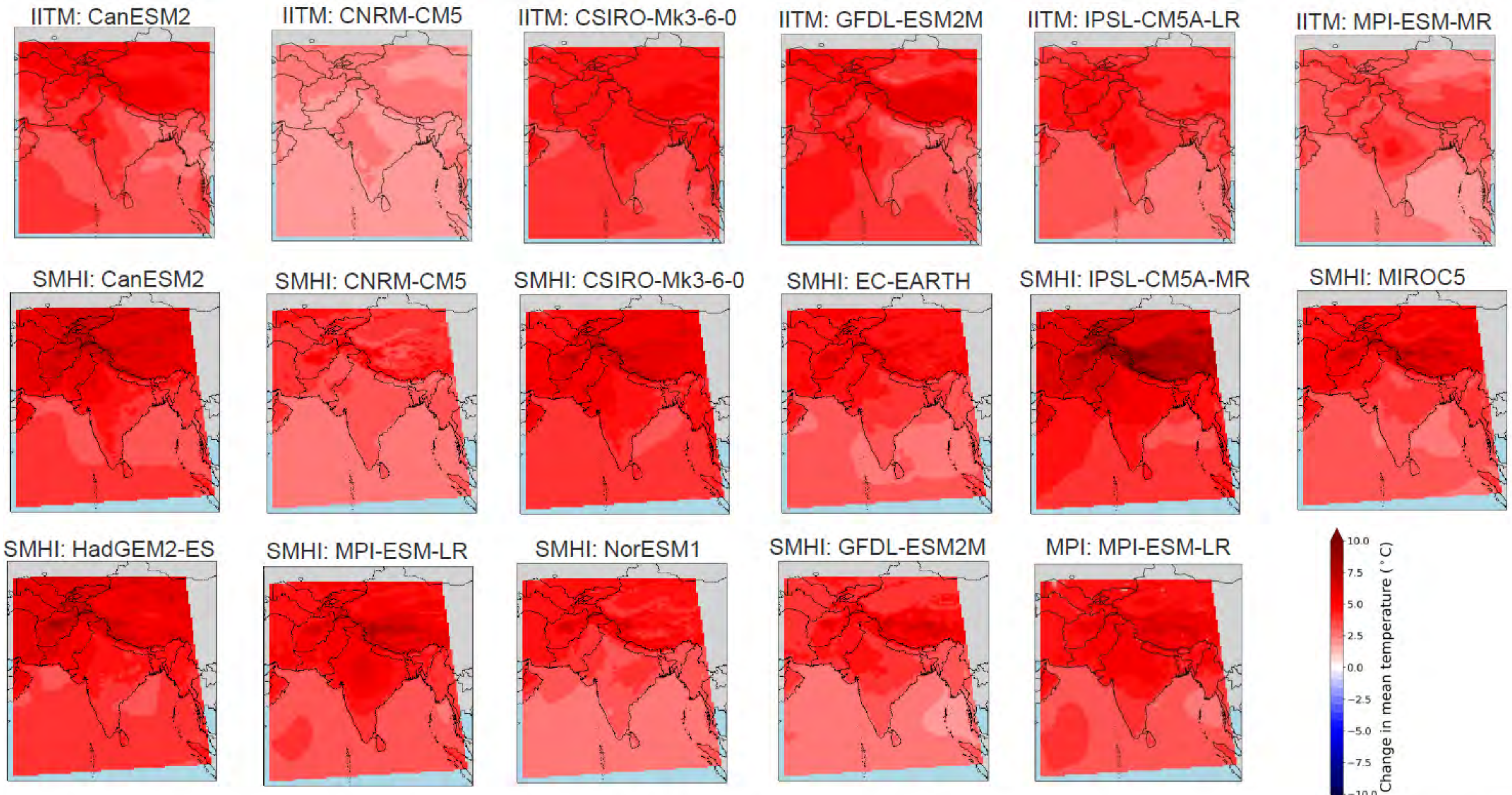
https://bookdown.org/floriandierickx/bookdown-demo/climate-data-discovery.html

Projections from the GCMs or RCMs

Temperature projections from 17 RCMs from CORDEX

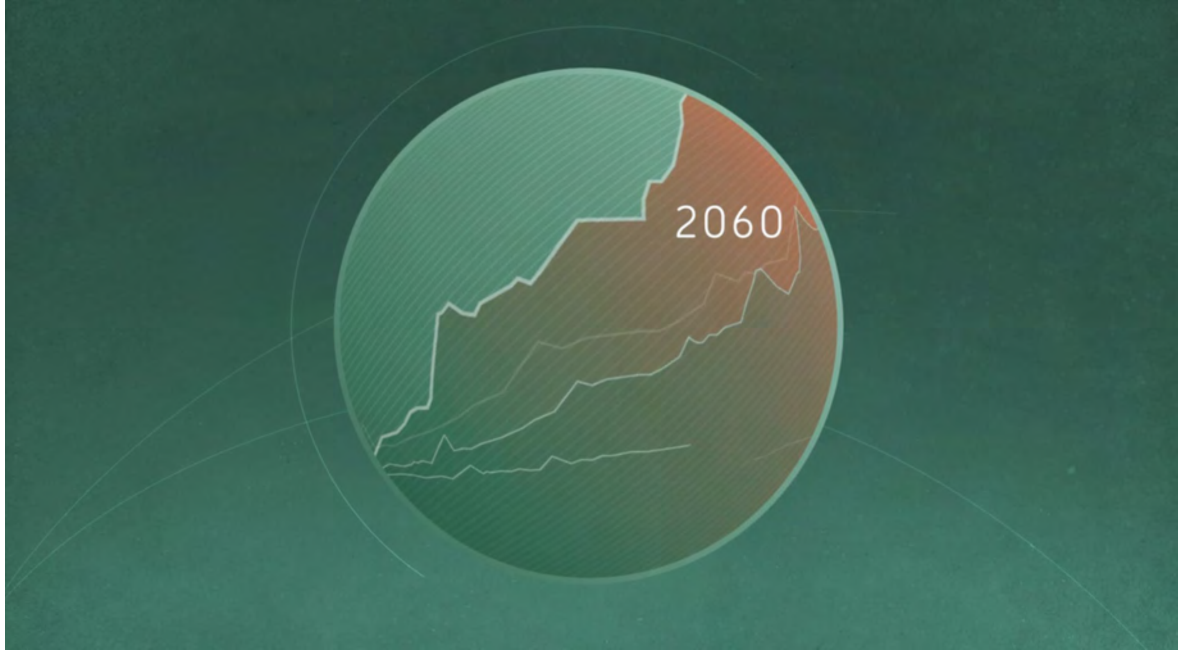
How do we make sense from the variation of these projections? Which model(s) to chose? Which model(s) to exclude?

WHY???



Projected change in annual average temperature for the CORDEX WAS regional climate model ensemble of models for 2071-2100 under RCP8.5

Variation in model projections



Lets watch the video by Australian climate futures

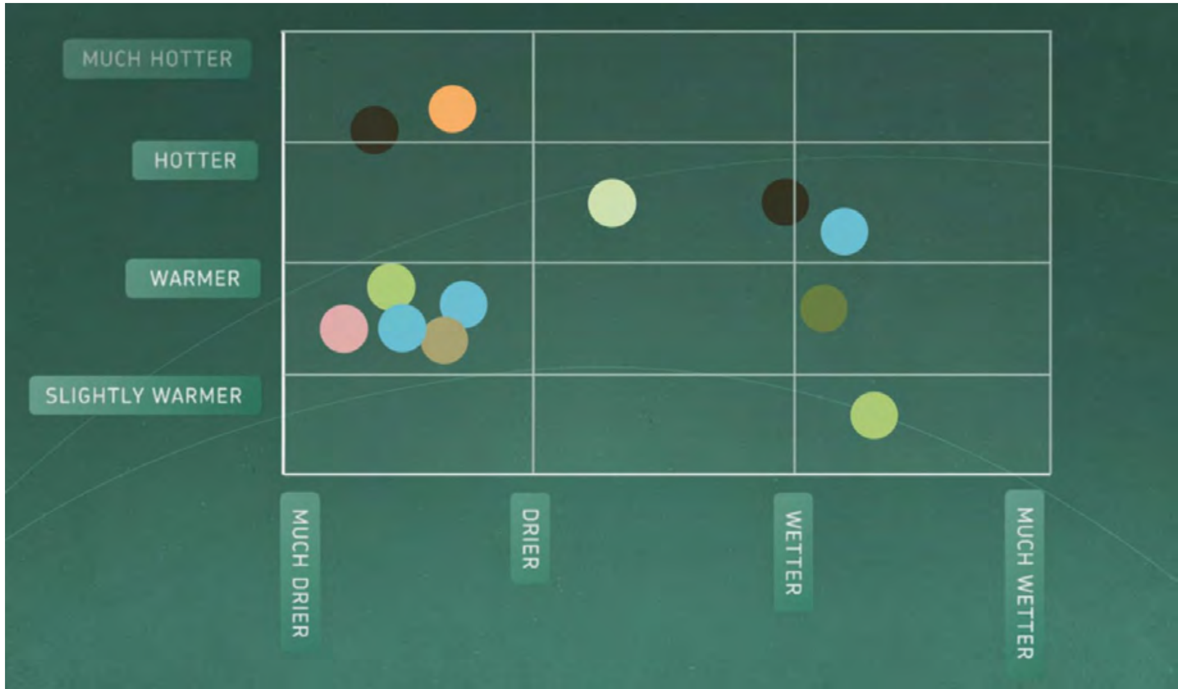
[Introduction to Climate Futures (climatechangeinaustralia.gov.au)]

Please think:

The range of projections?

How best they represent climate of a typical areas?

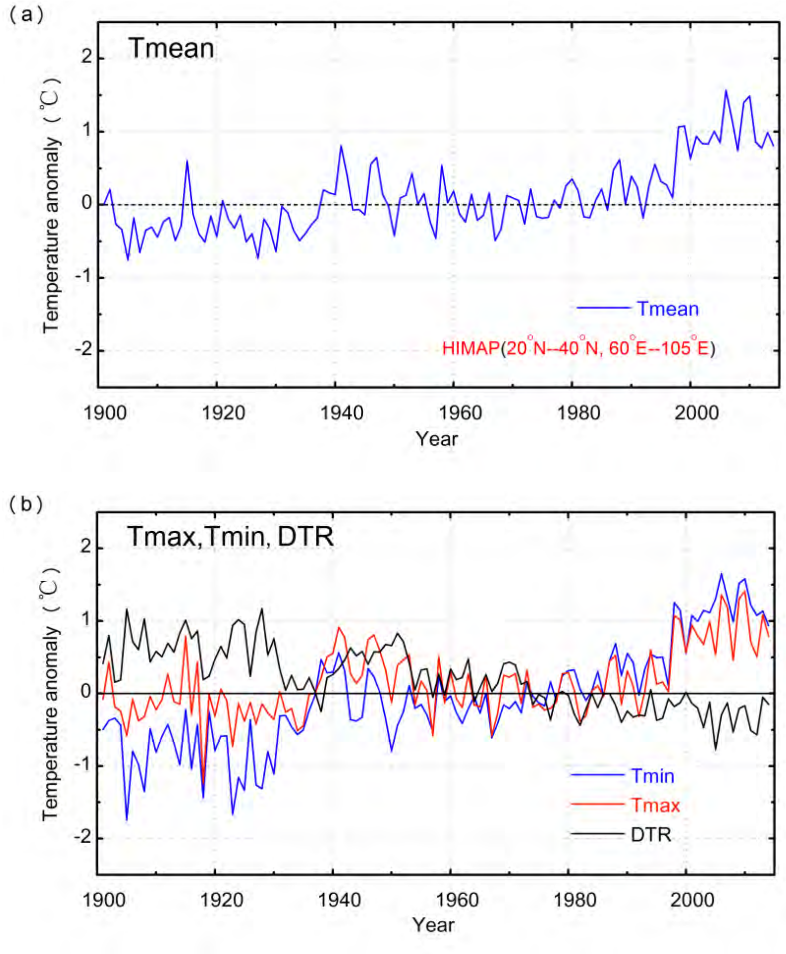
How do we make decisions based on these projections?



IPCC WGI Interactive Atlas: Regional information (Simple)

https://interactive-atlas.ipcc.ch/

Climate change in the Hindu Kush Himalaya



Region	Data source	Period	Trend (°C/decade)			
			Tmax	Tmin	DTR	Tmean
HKH	CMA	1901-2014	0.077*	0.176*	-0.101*	0.104*
		1951-2014	0.156*	0.278*	-0.123*	0.195*
Globe (Lands + Oceans)	GHCN	1901-2014				0.084*
		1951-2014				0.129*

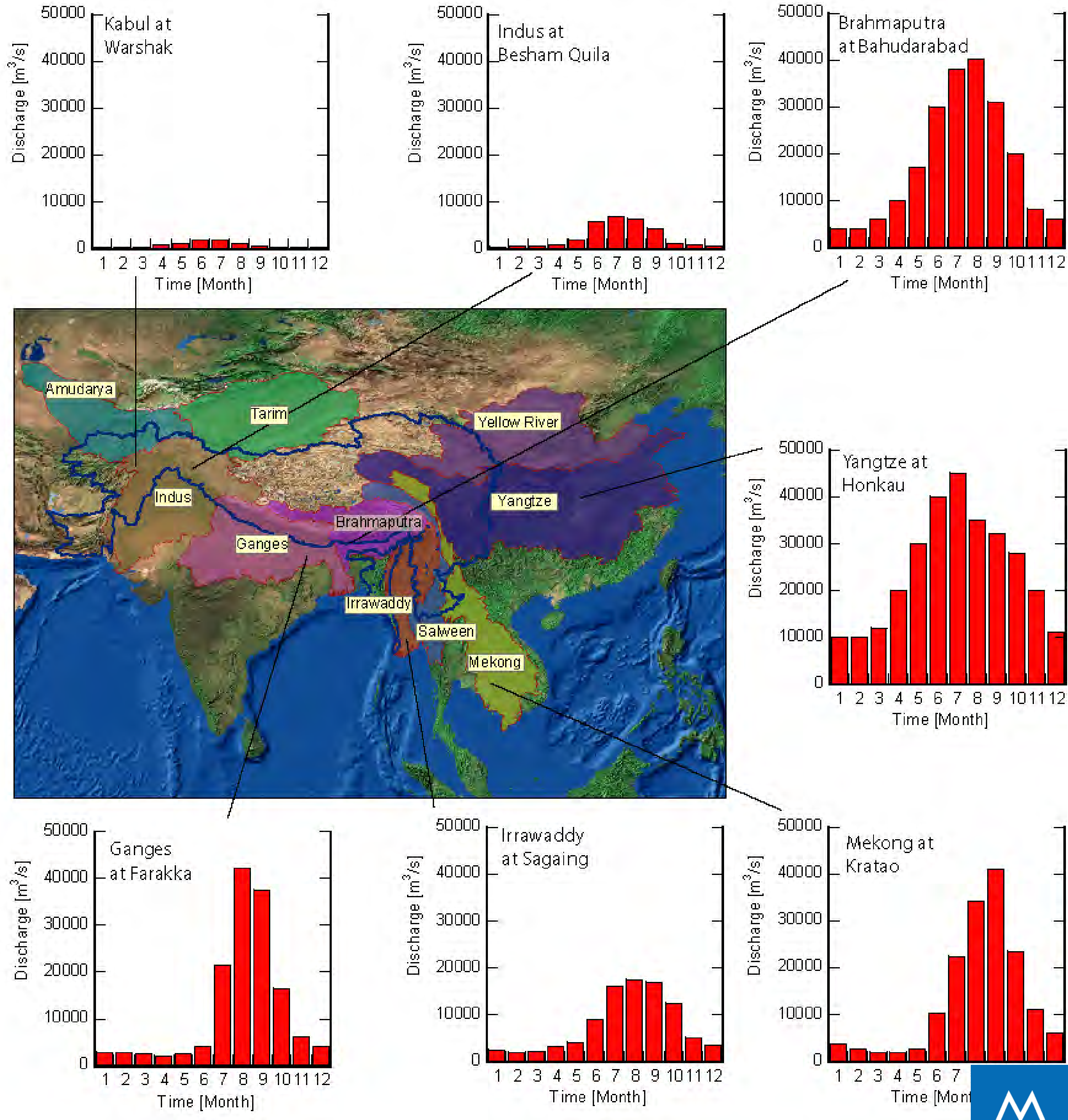
HKH warming comparable to the global average

Krishnan et al., 2019 (HKH Assessment) based on CMA GLASAT dataset (Xu et al., 2014)

Flow regime

Hydrographs location dependent

Monsoon domination in flow regime



Shrestha et al., 2013

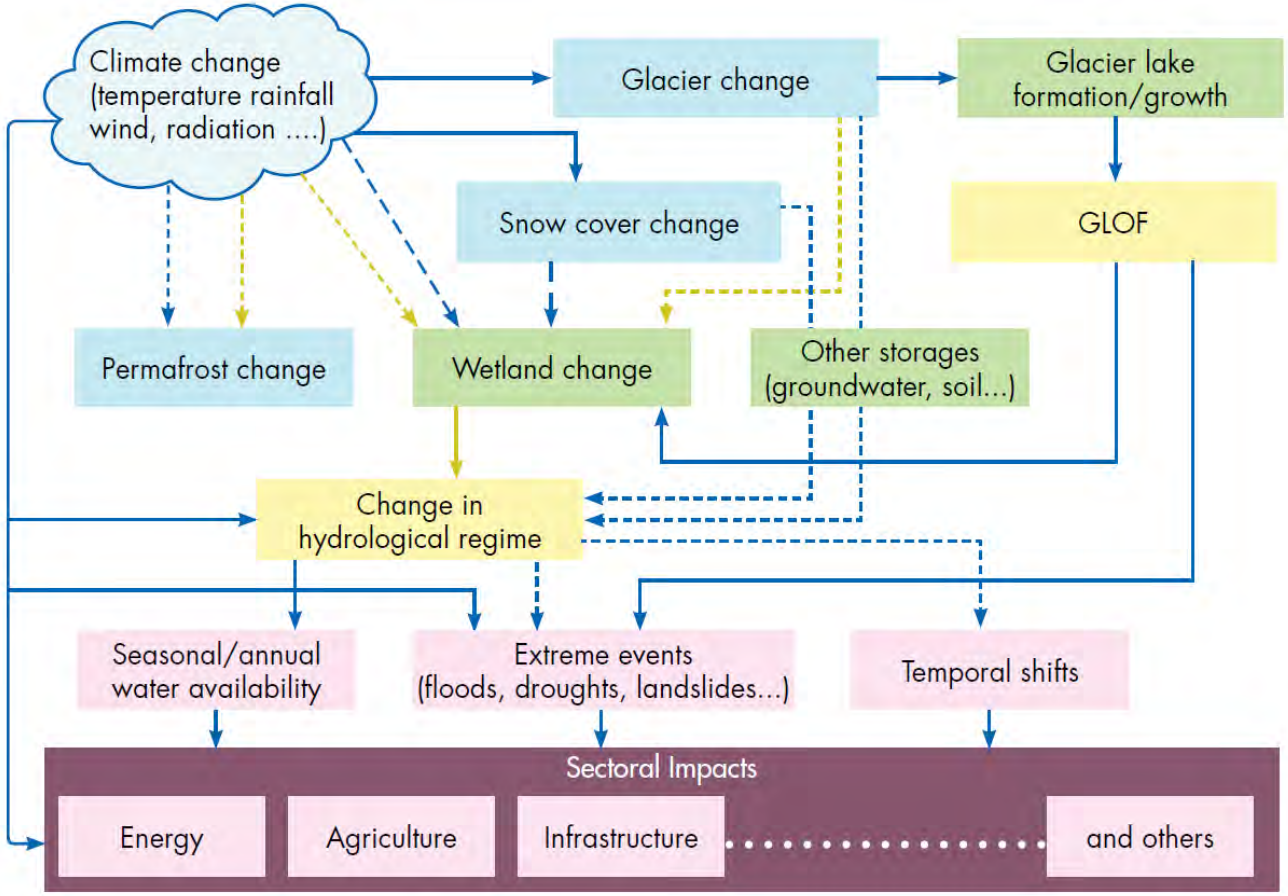
Climate change impact on different sectors

Climate change and extreme impacts

Cryosphere to water resources

Impact on physical system to human system to ecosystems

Impact on different sectors (water, agriculture, food security, livelihood, energy, infrastructure, ecosystem)



Lutz et al. 2016

Even 1.5 Degrees is Too Hot for the HKH

...amplified by elevation dependent warming

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

HKH will warm more compared to global mean and warm more rapidly at higher elevations

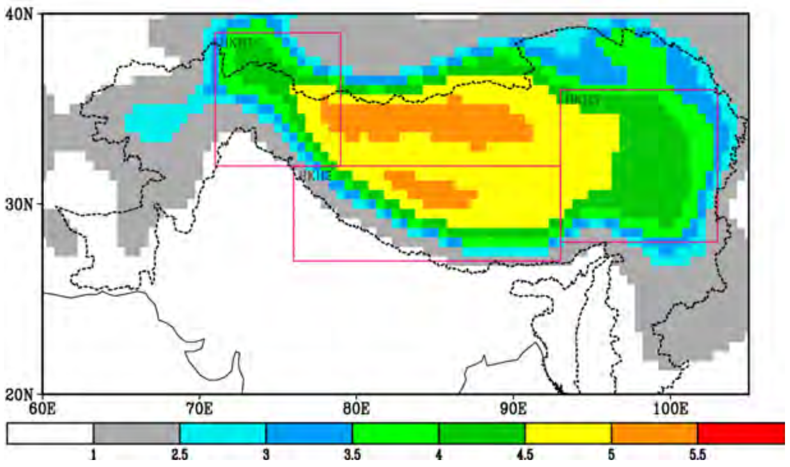
- 5.5 ± 1.5°C by 2100 relative to 1976-2005 at current emission trends
- 2.5 ± 1.5°C by 2100 relative to 1976-2005 (RCP 4.5)
- 2.1 ± 0.1°C (relative to pre-industrial) in a 1.5 degree world

For areas above 2,000m, if 1.5°C EOC then:

- Karakoram 2.2 ± 0.4°C
- Central Himalayas 2.0 ± 0.5°C
- Southeast Himalayas 2.0 ± 0.5°C

HKH in 1.5 Degree world

RCP	Model	Global	HKH	HKH1	HKH2	HKH3
RCP2.6	GISS-E2-R_r1i1p3	1.48	1.82	1.87	1.73	2.35
RCP2.6	MIROC5_r1i1p1	1.48	1.95	2.54	2.46	2.28
RCP2.6	NorESM1-ME_r1i1p1	1.44	1.68	2.05	1.85	1.63
RCP2.6	HadGEM2-AO_r1i1p1	1.57	1.47	2.04	1.49	1.50
RCP2.6	MPI-ESM-MR_r1i1p1	1.58	2.16	2.58	2.42	2.11
MEAN		1.51	1.82	2.22	1.99	1.97
RANGE		0.14	0.69	0.71	0.97	0.85
SD		0.06	0.26	0.32	0.43	0.39



Krishnan et al., 2019 (HKH Assessment)

For HKH domain a 1.5 ˚C global temperature increase would mean a temperature increase of 1.8 ± 0.4 ˚C

Warming is even more pronounced for mountain regions

For the Karakoram, Central Himalayas, and Southeast Himalayas this would imply regional temperature increases of

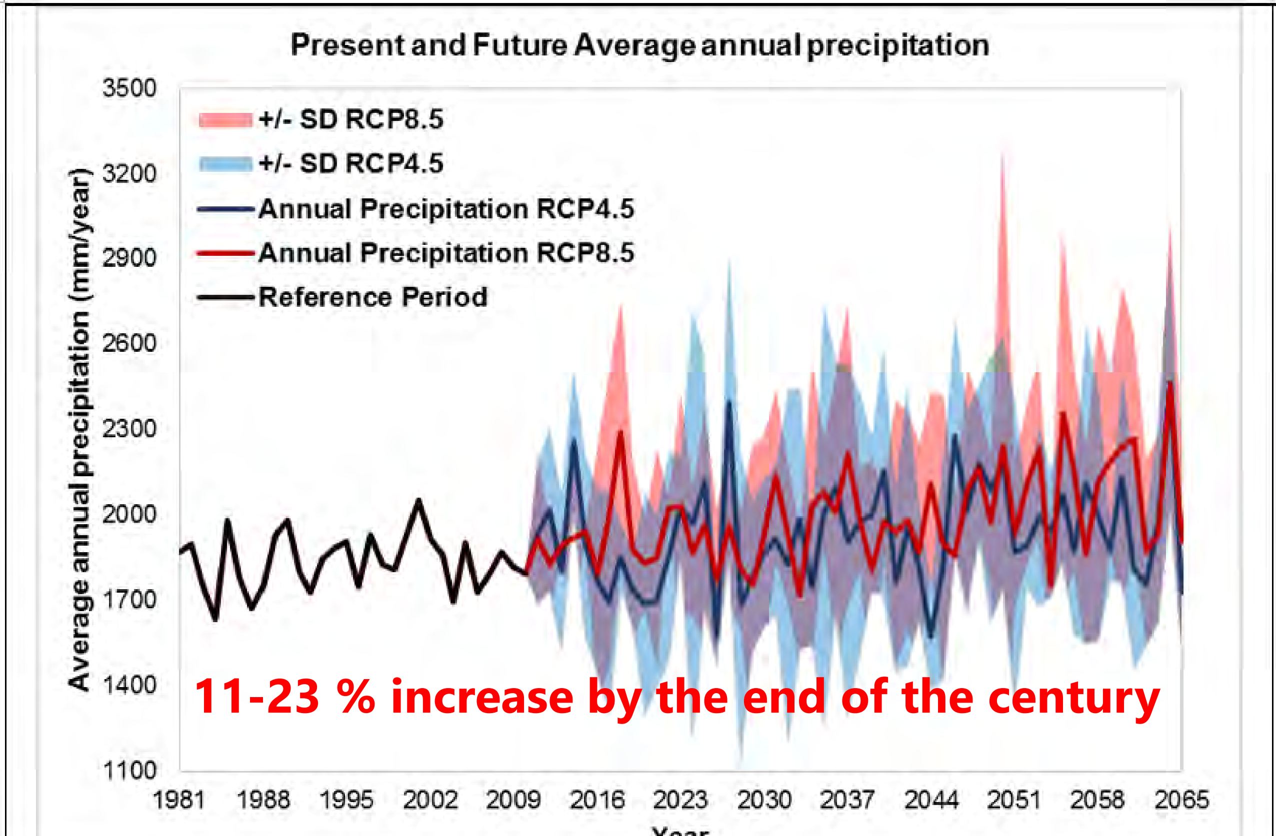
2.2 ± 0.4 ˚C

2.0 ± 0.5 ˚C

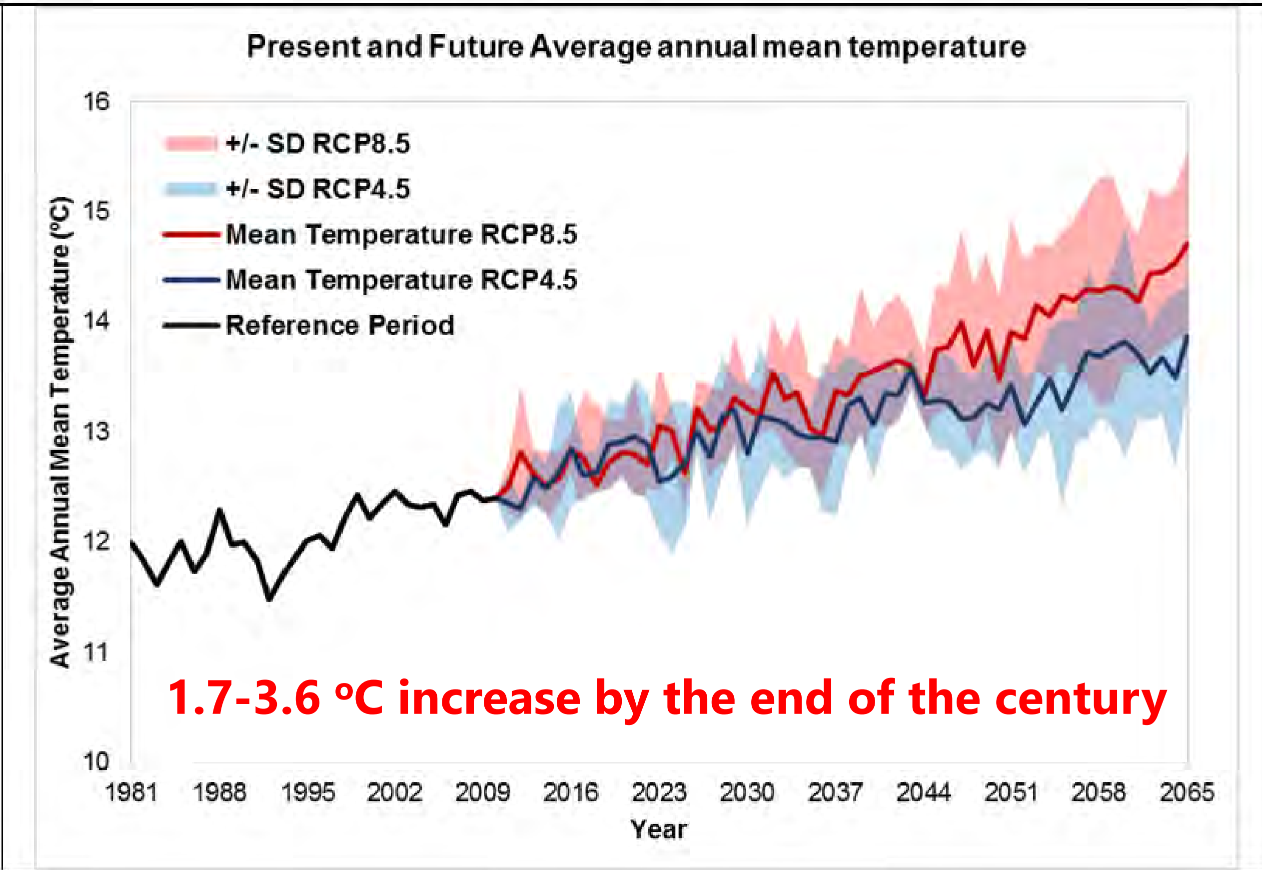
2.0 ± 0.5 ˚C

Future climate change scenarios for Nepal

- Wetter and Hotter climate towards the end of the century
- National Adaptation Plan (NAP) formulation process by MOFE, DHM and ICIMOD



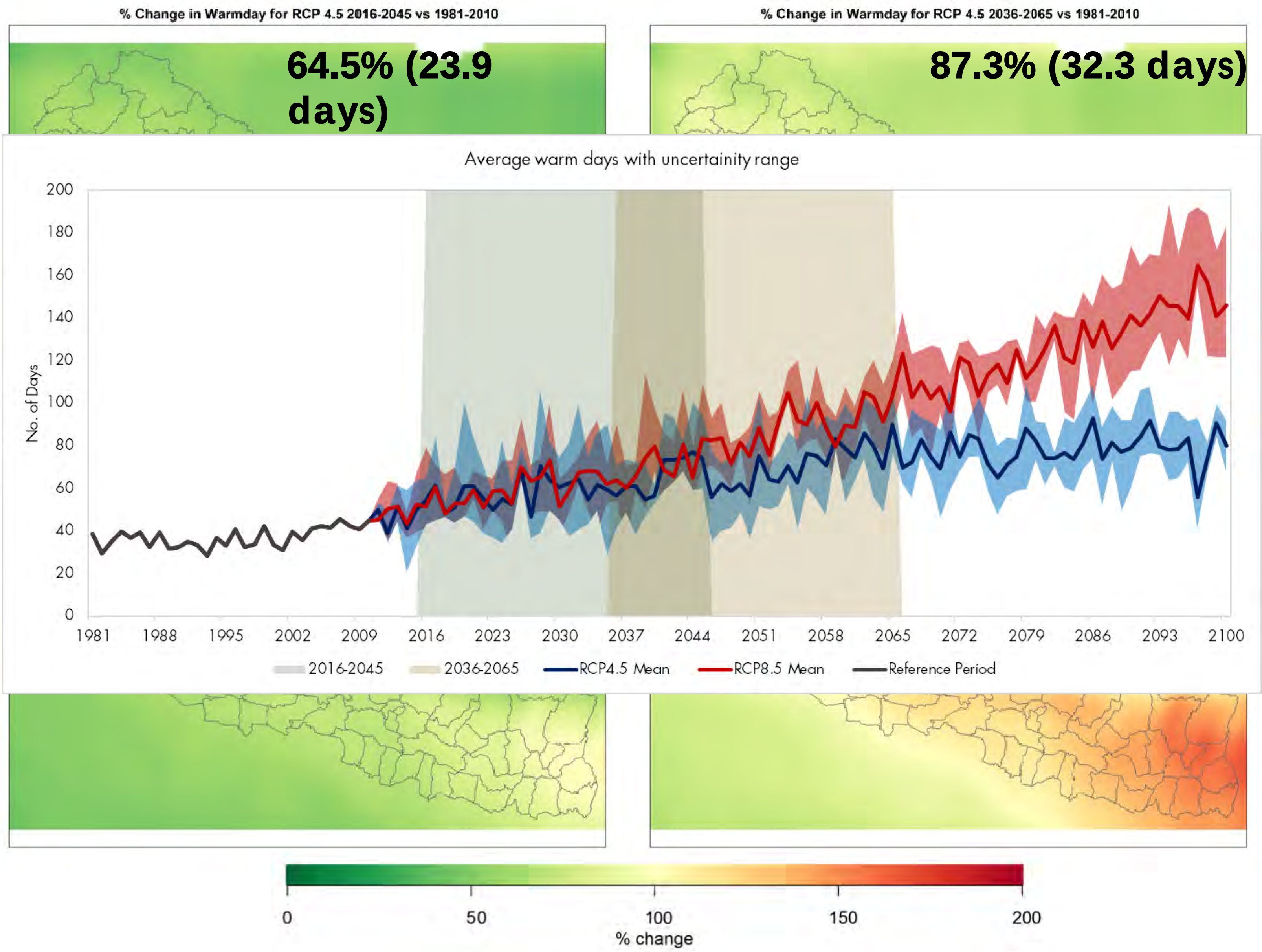
MOFE, 2019



Warm days_max temperature >90th percentile

Medium-term

Long-term



Highlights

Consistent increase in warm days

Increase in average up to 46 days (up to 70 days in some places)

Eastern region has higher increase than western

MOFE, 2019

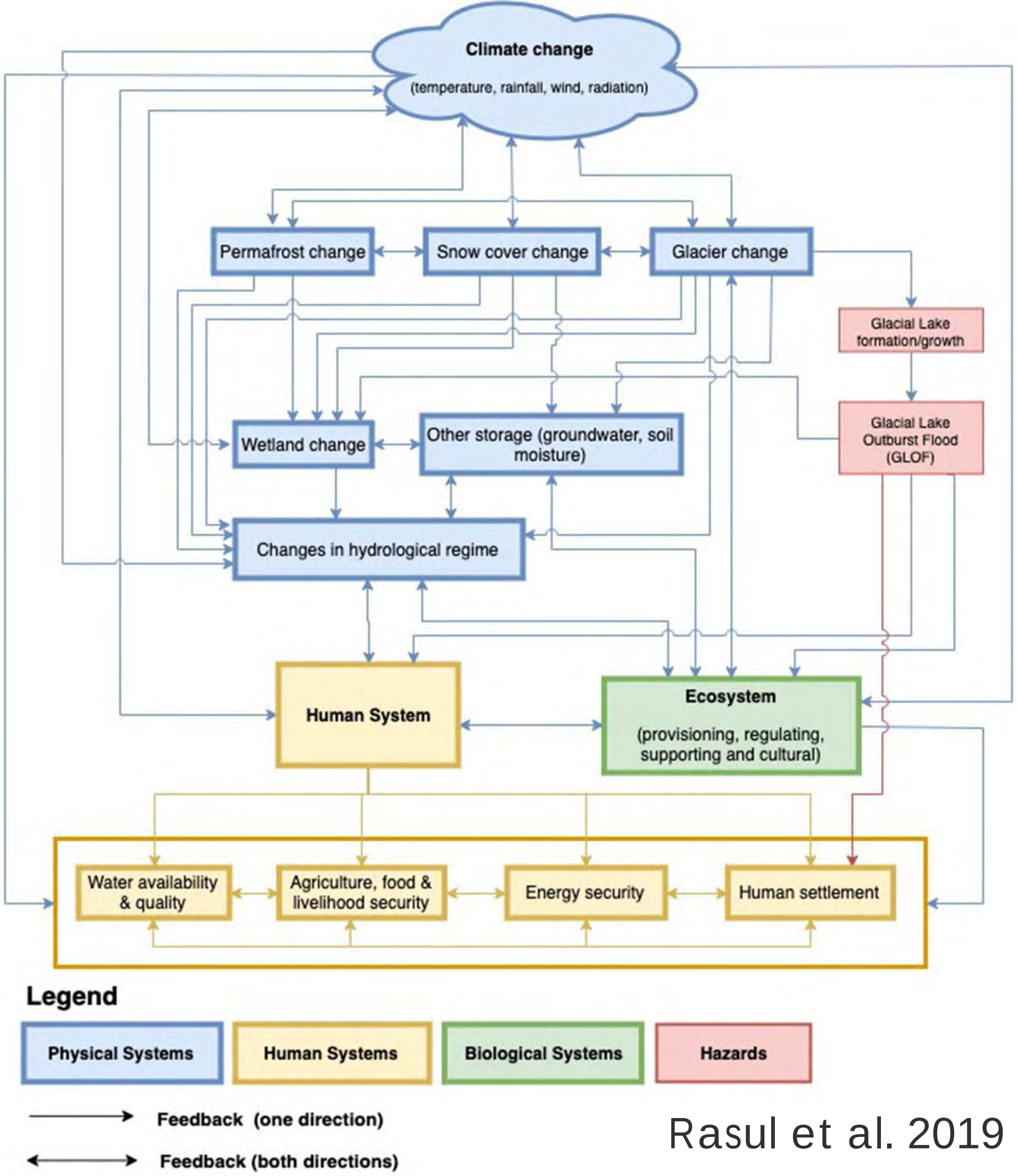
Climate change impact on different sectors

Climate change and extreme impacts

Cryosphere to water resources

Impact on physical system to human system to ecosystems

Impact on different sectors (water, agriculture, food security, livelihood, energy, infrastructure, ecosystem)



Rasul et al. 2019

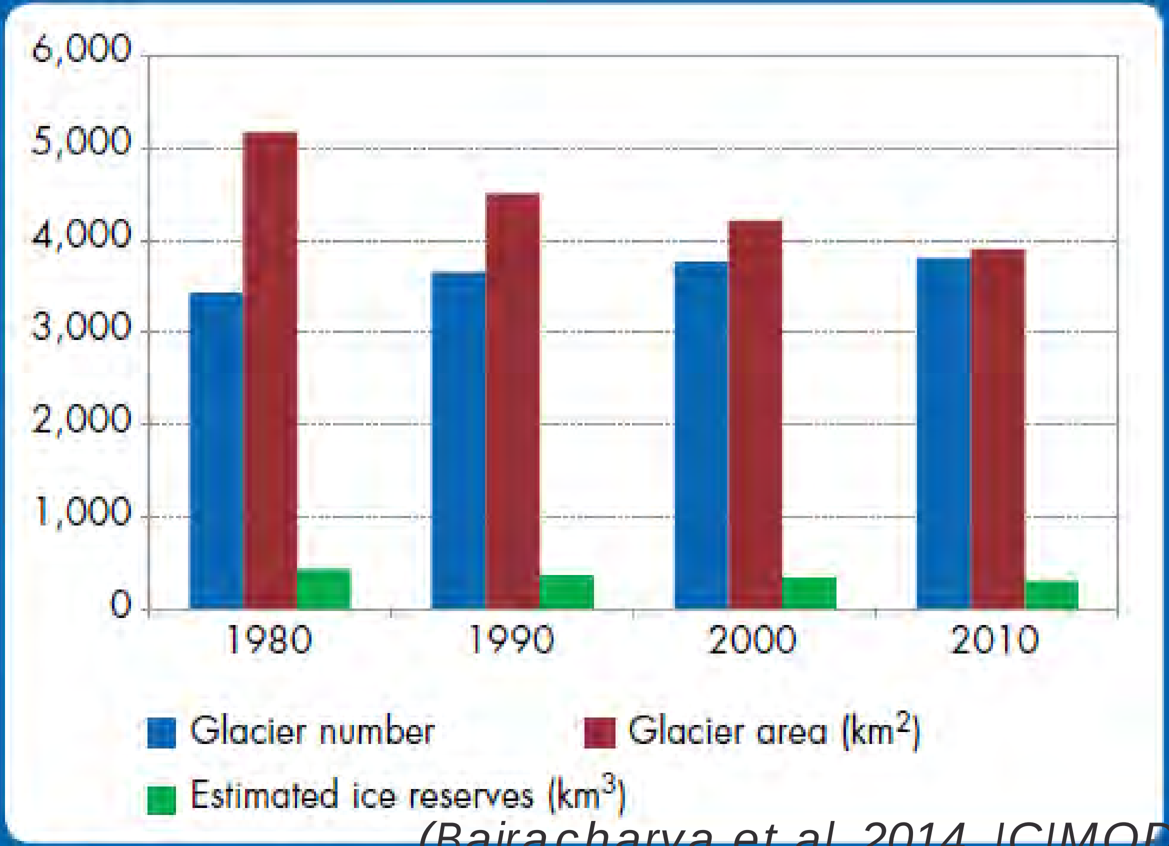
Changes in glaciers

Equivalent to 100 meter

Impact on glaciers

25% decrease in glacier area in Nepal from 1980 to 2010

Figure 4.1: Glacier number, area, and estimated ice reserves in Nepal in ~1980, 1990, 2000, and 2010



(Bajracharya et al. 2014, ICIMOD)

Glacier area decreased from

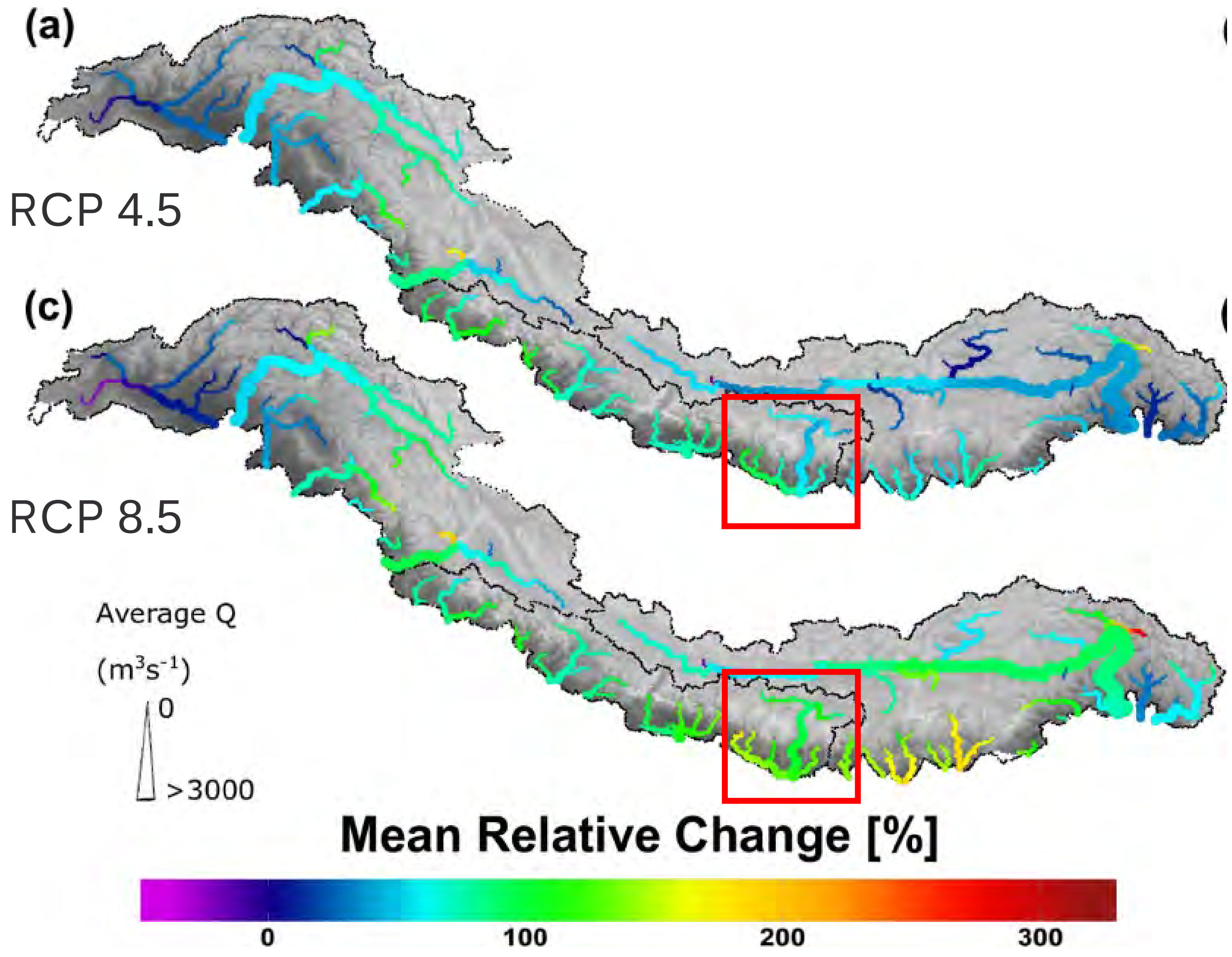
- ~1980: 5168 km^2
- 2010: 3902 km^2

Bhutan: 23% loss of glacier area

One third of the Himalayan ice will be gone by 2100
(kraaijenbrink2017, HKH Assessment, 2019)

What could be the impact on downstream water availability?

Increase in flood events in the future



Understanding the impact of climate change on hydrological extreme (Floods and droughts) is important

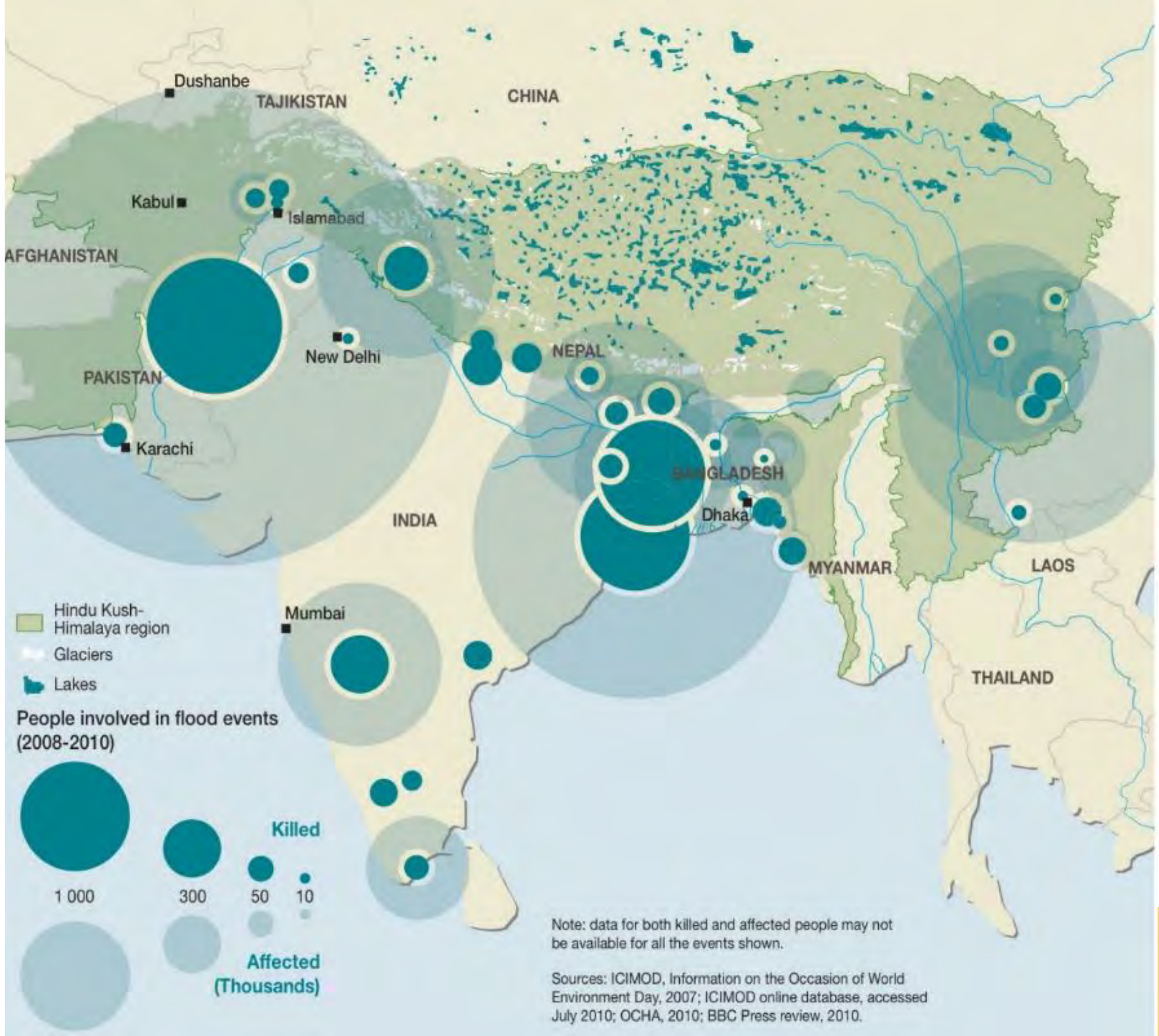
50 year return period of flood events are likely to increase

- Koshi : at least 100%

Floods and flash floods might be more frequent in future compared to present period

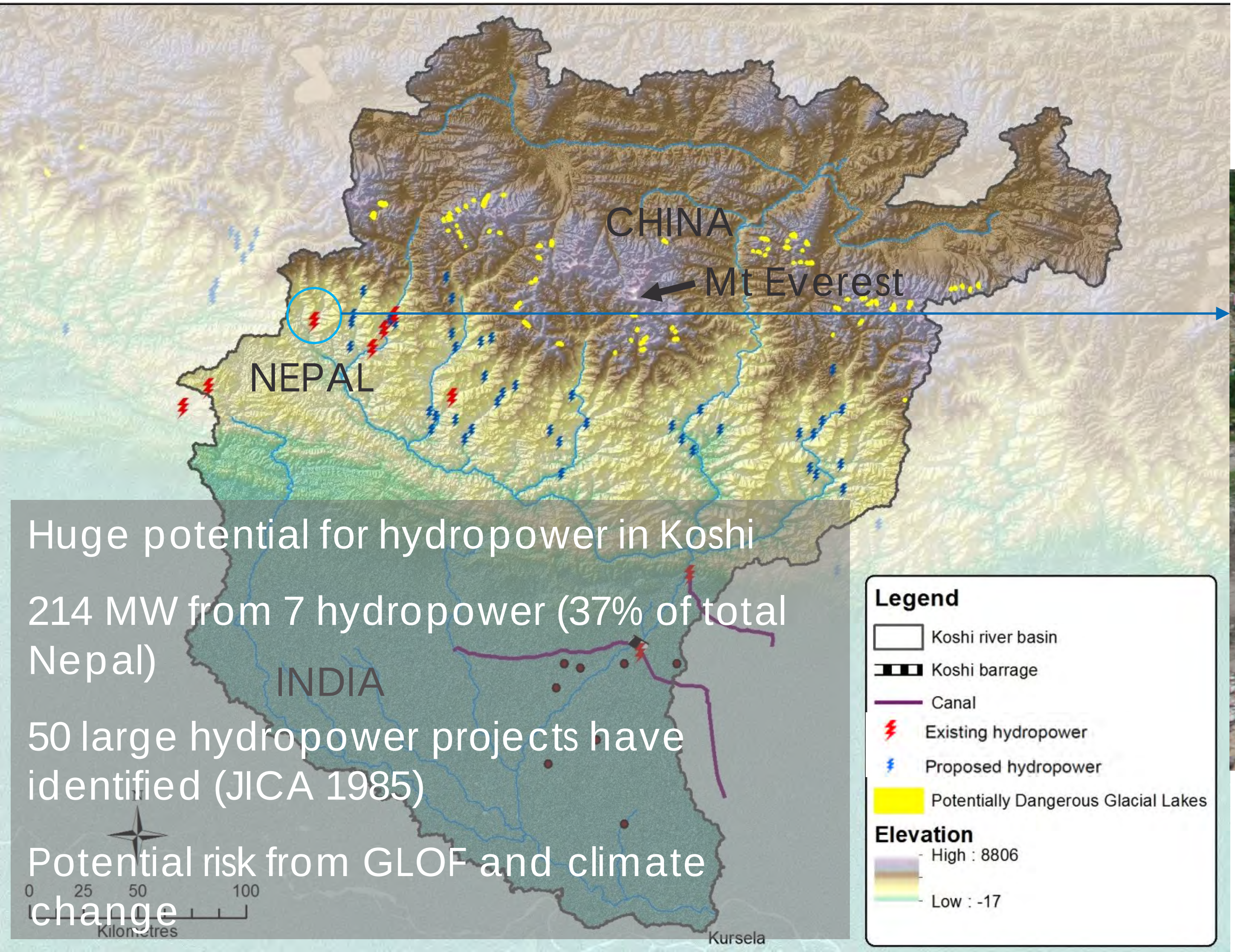
Wijngaard, et al. 2017, PlosOne

Disaster risk increasing with more extreme events



Big unknown: understanding hydrological extreme and seasonal shifts?

Extreme events and infrastructure



Huge potential for hydropower in Koshi

214 MW from 7 hydropower (37% of total Nepal)

50 large hydropower projects have identified (JICA 1985)

Potential risk from GLOF and climate change

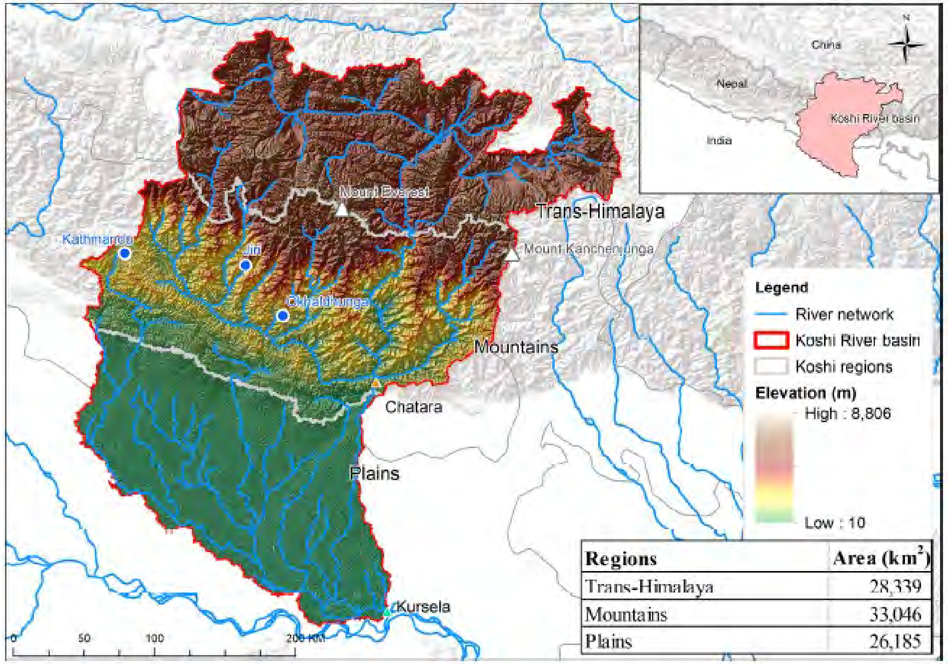
Data Source: Koshi Basin Information System, ICIMOD

Soil moisture drought

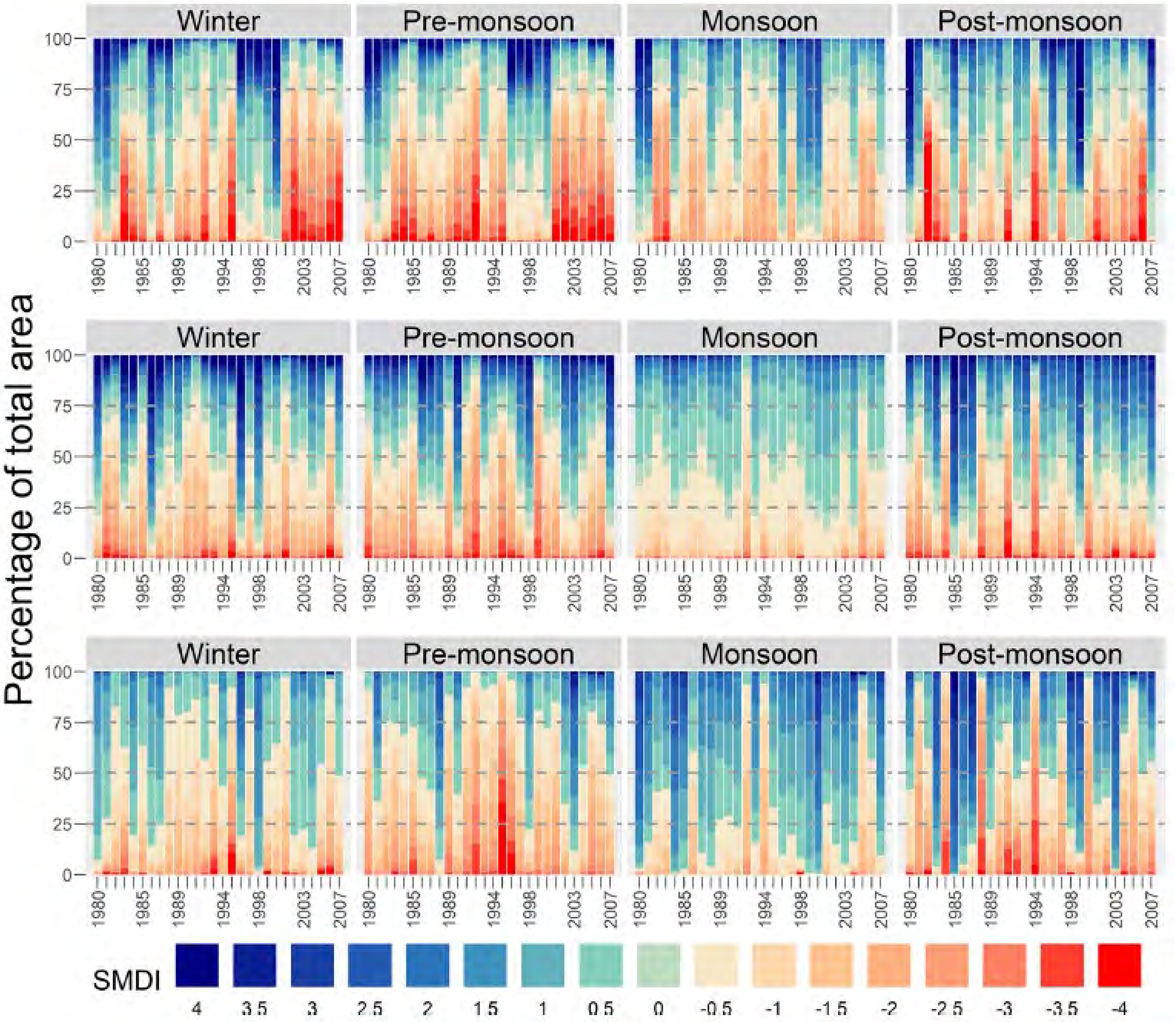
Spatial and seasonal variability in the SMDI in trans-Himalaya (**top row**), the mountains (**middle row**), and the plains (**bottom row**).

Note: each colour band shows the respective HRU areas combined.

Nepal, et al 2021, HESS



Regions	Area (km²)
Trans-Himalaya	28,339
Mountains	33,046
Plains	26,185



Drought

The years 1991, 1992, 2005, 2006 and 2009 are found to be rainfall deficient years (Dahal et al. 2015)

More than 90 % of stations recorded drought during the winter season of year 2006 and 2009 (Dhahal et al. 2015)

330 million people were affected by drought in India in 2016 due to severe water shortages and farmers suffer crop losses

Impact of climate change on different forms of drought and livelihood

The Himalayan Times > Nepal > Drought forces Bajura men to leave villages for livelihood

Drought forces Bajura men to leave villages for livelihood

Published: November 17, 2016 4:16 pm On: Nepal

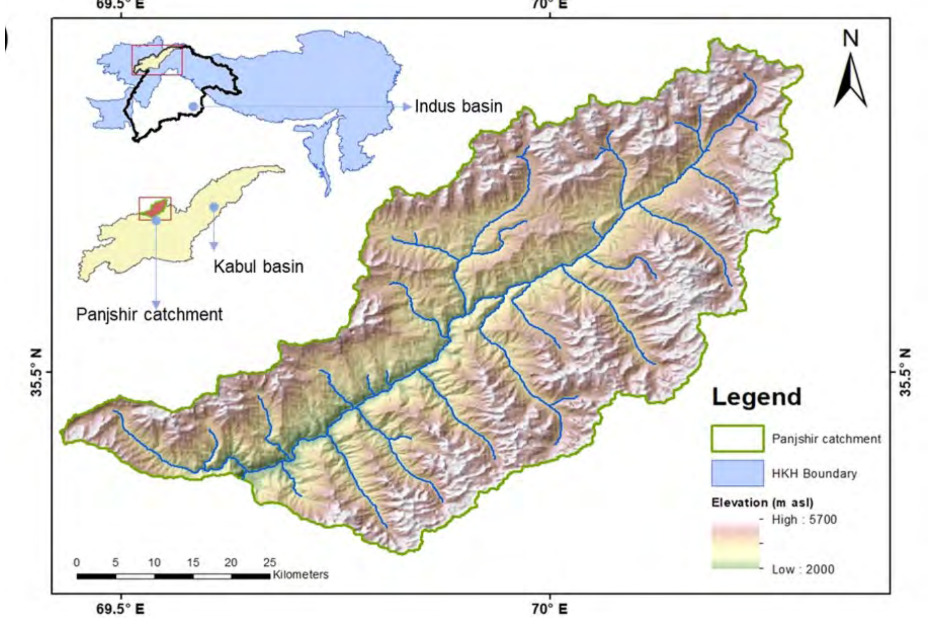
Share 0 Tweet Save

PRAKASH SINGH

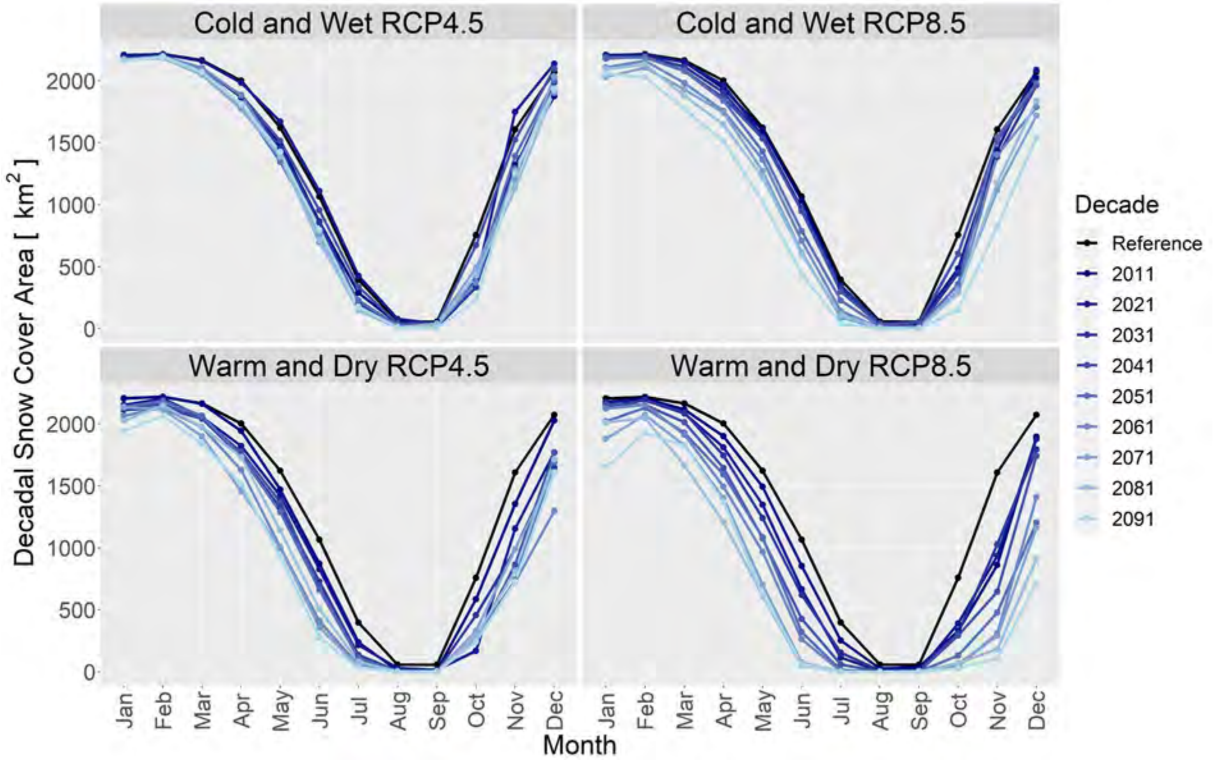
File – Locals of northern Bajura district heading to India for jobs after drought destroyed their crops, in the district.

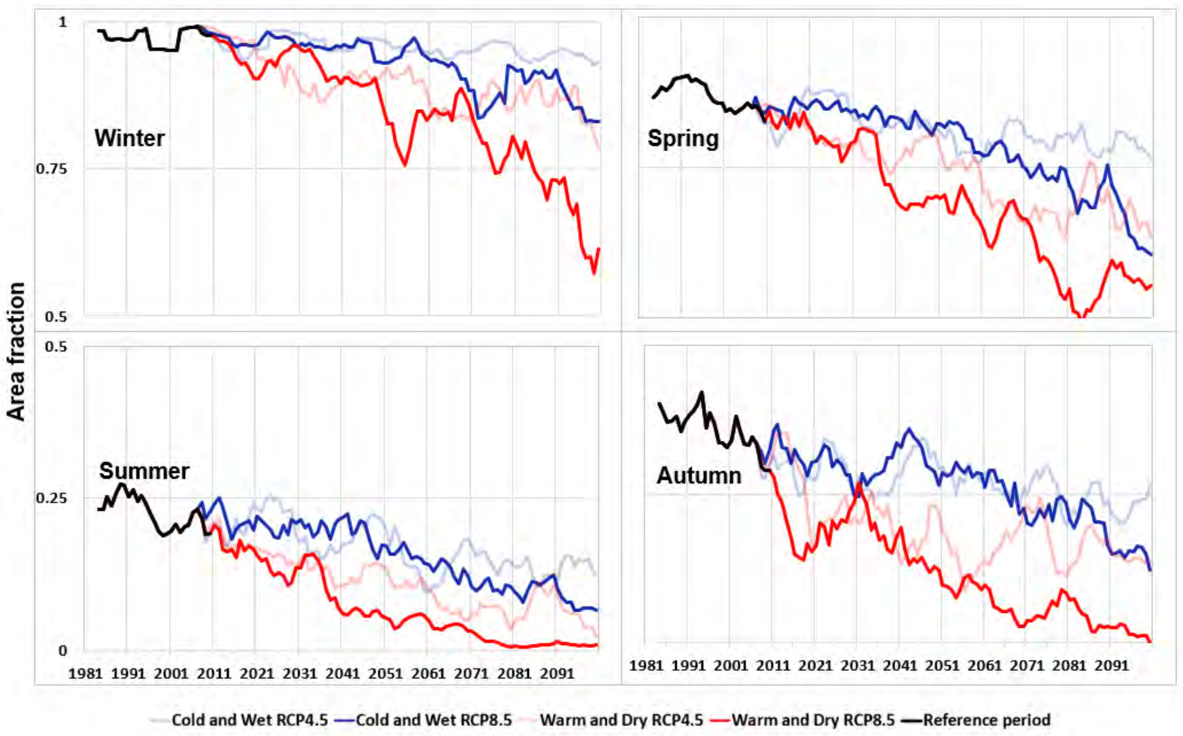
Future snow cover, Panjshir

Consistent decrease in snow in the future in the small catchment of the western Himalaya

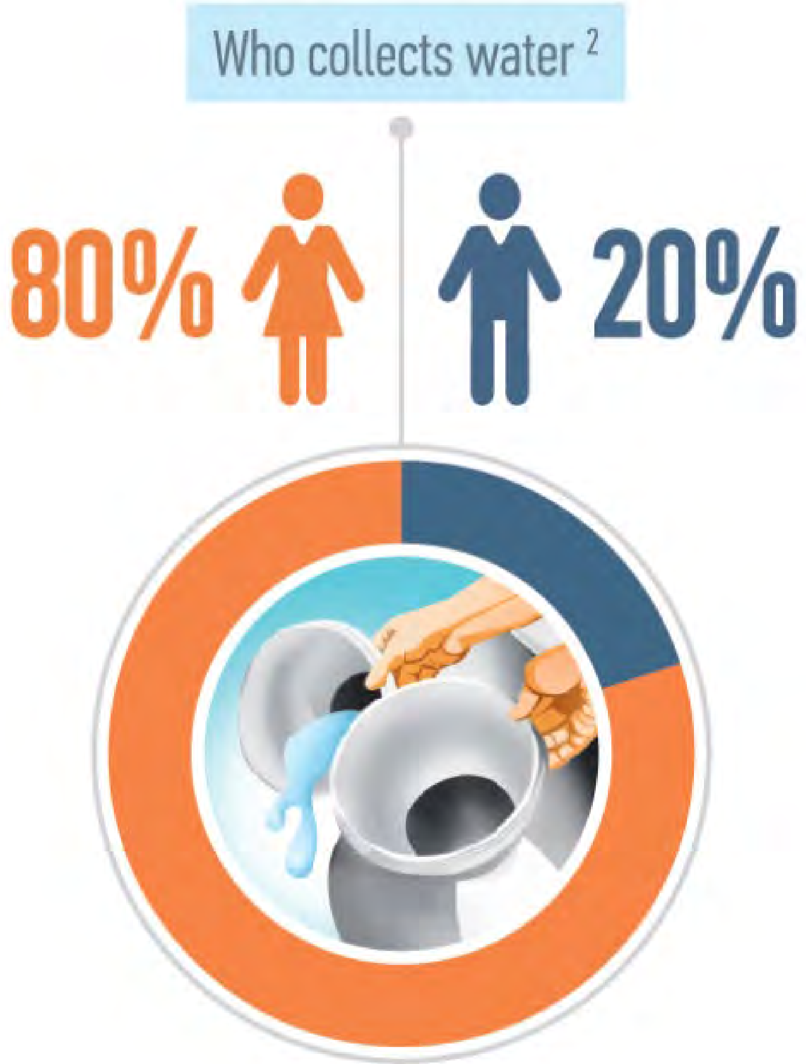


Nepal, et al 2021, STOTEN, under review





Impact on gender and society



Summary

Climate change is impacting different aspect of societies

The impact of gradual climate change and climatic extremes will be more common in the coming day

Poor and vulnerable communities will be hard hit

Better understanding of climate change will help to design adaptation strategies


Thank you