# Climate change in the Himalayan region and its link to downstream water availability

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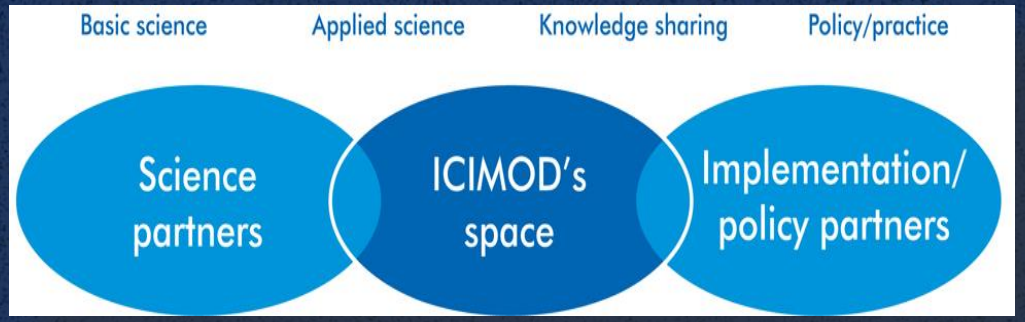
ICIMOD

# International Centre for Integrated Mountain Development (ICIMOD)


- Intergovernmental International organization working in the Hindu Kush-Himalayan Region
- Established in 1983



# In this presentation

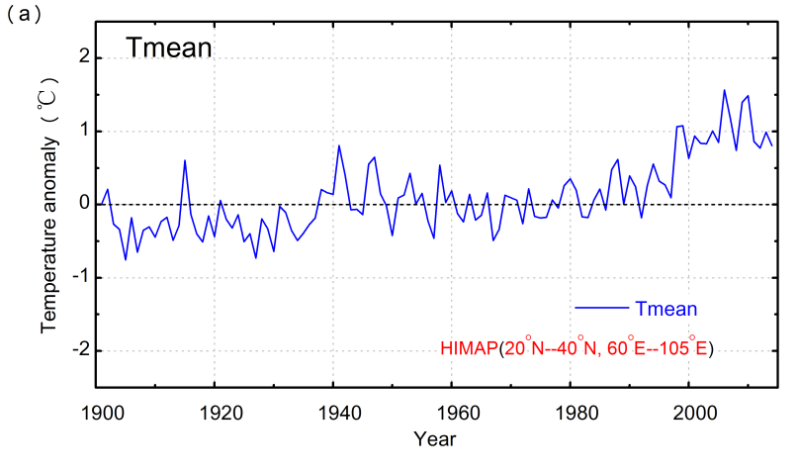
1. How climate is changing in the HKH region?

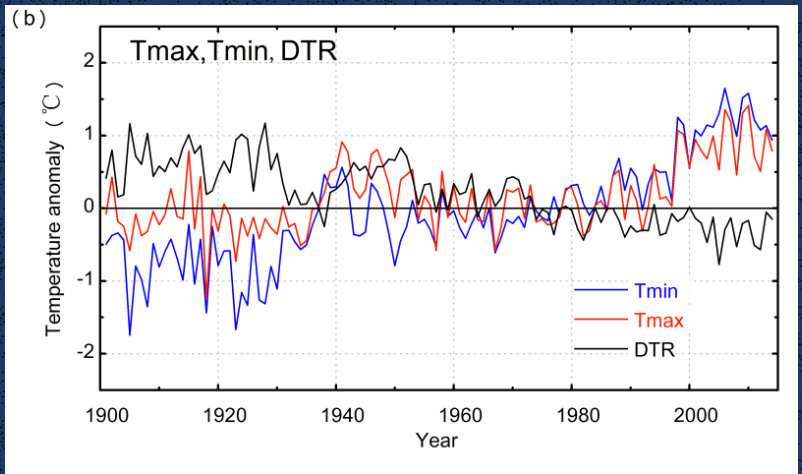
2. Impact on glaciers and

3. Impact on water availability

4. Too much water

# Climate change in HKH




| 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 globe

*HIMAP analysis based on CMA GLASAT dataset (Xu et al., 2014)*

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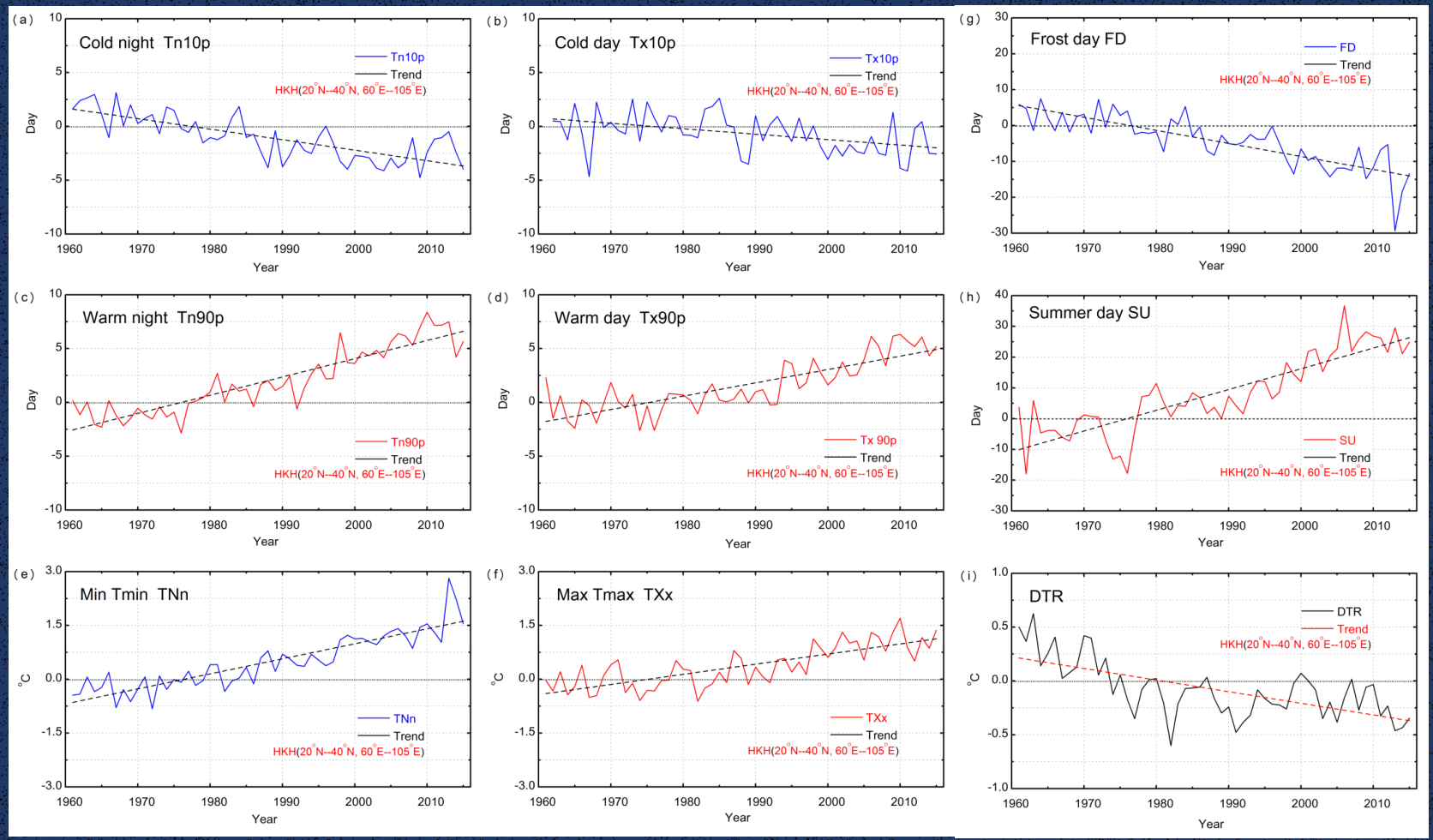
# Temperature extremes




Warm extremes increasing

HIMAP analysis based on CMA GLASAT dataset (Xu et al., 2014)

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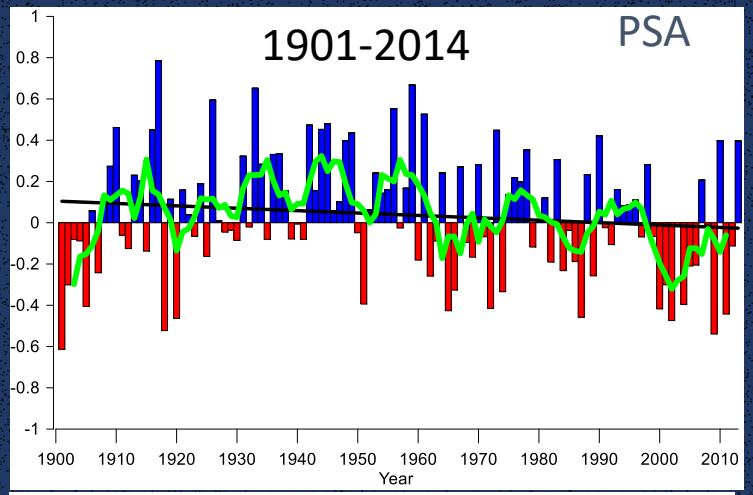
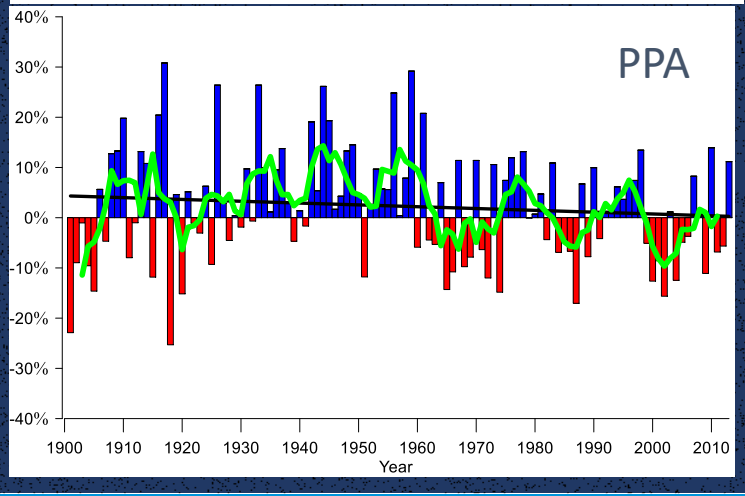
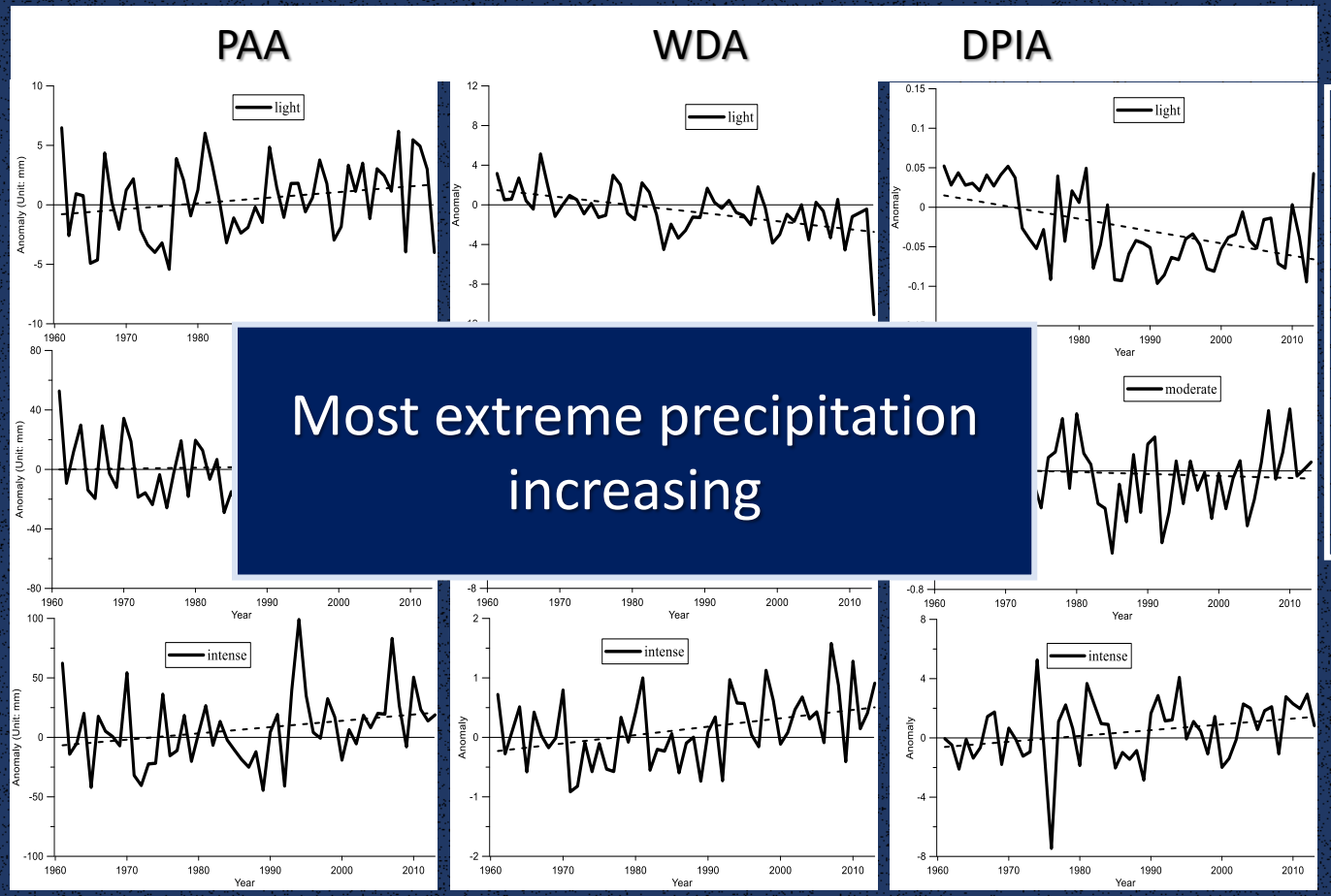
# Precipitation




Most extreme precipitation increasing

Light=<50p
Moderate=50-90p
Intense=>90p

HIMAP analysis based on CMA GLASAT dataset (Xu et al., 2014)

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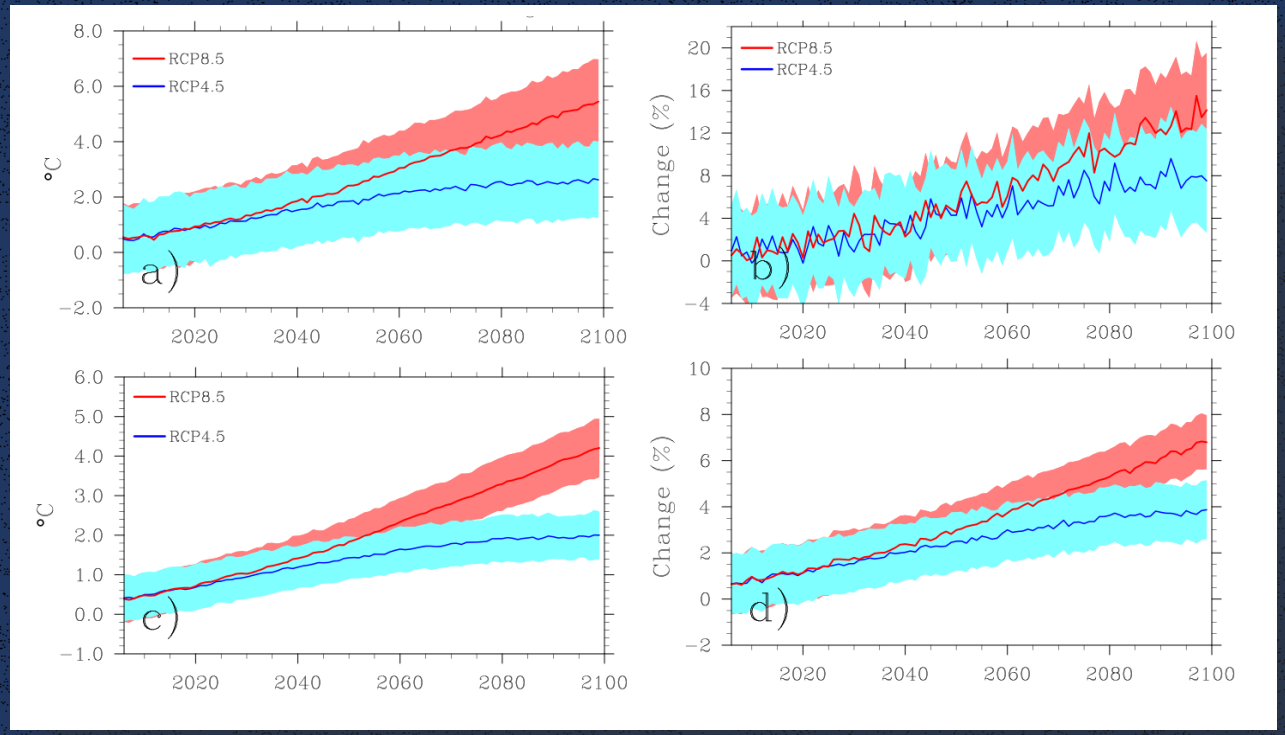
# Future Climate Change
# Climate projection - 25 CMIP5 GCMs

Temperature | Precipitation

HKH

Global

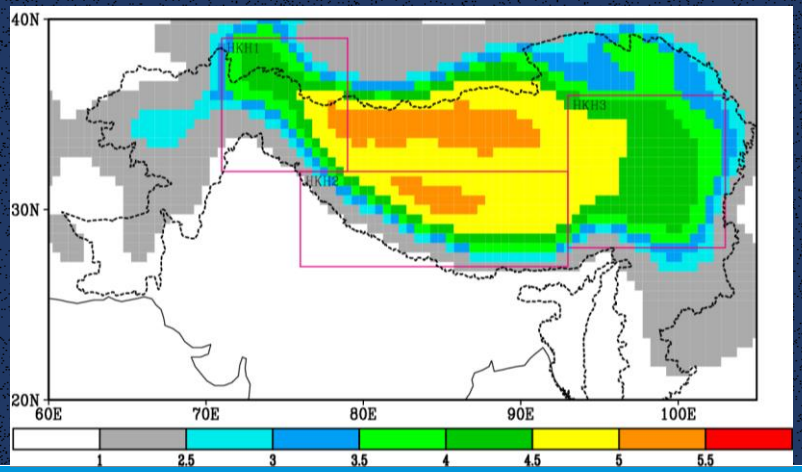



The projected temperature change in RCP4.5. is 2.5 ±1.5 in HKH by the end of the 21st century relative to the 1976–2005 [5.5 ±1.5 in RCP8.5]

Change from 2006 to 2100 relative to 1976–2005
RCP4.5 - blue RCP8.5 - red
25-model ensemble mean is shown by solid line

# 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 |




- 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

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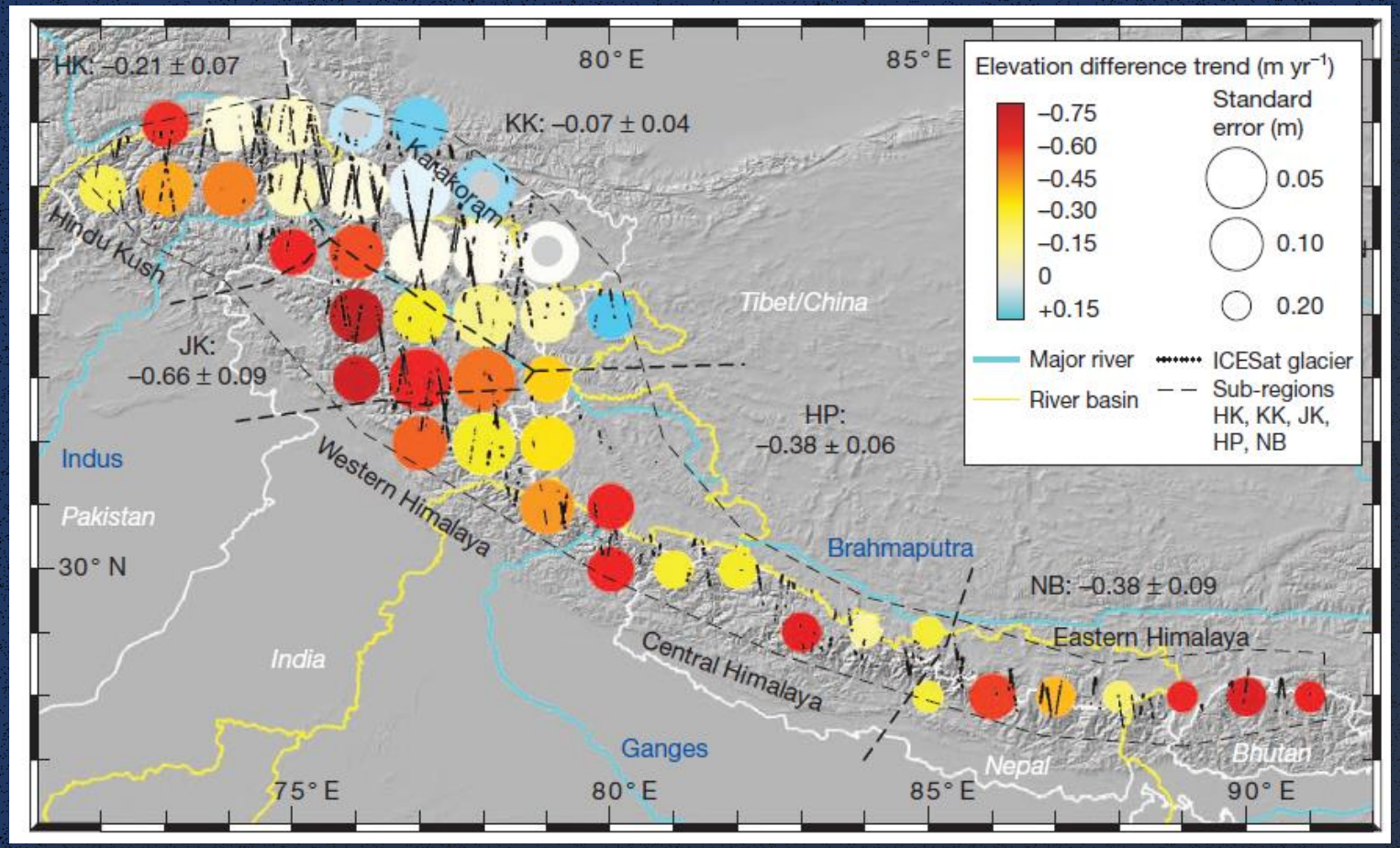
# Glaciers of HKH




- Glacier are generally shrinking
- The 2003–08 specific mass balance for the entire HKH study region was $-0.21 \pm 0.05$ m yr$^{-1}$

Kääb et al. 2012, Nature

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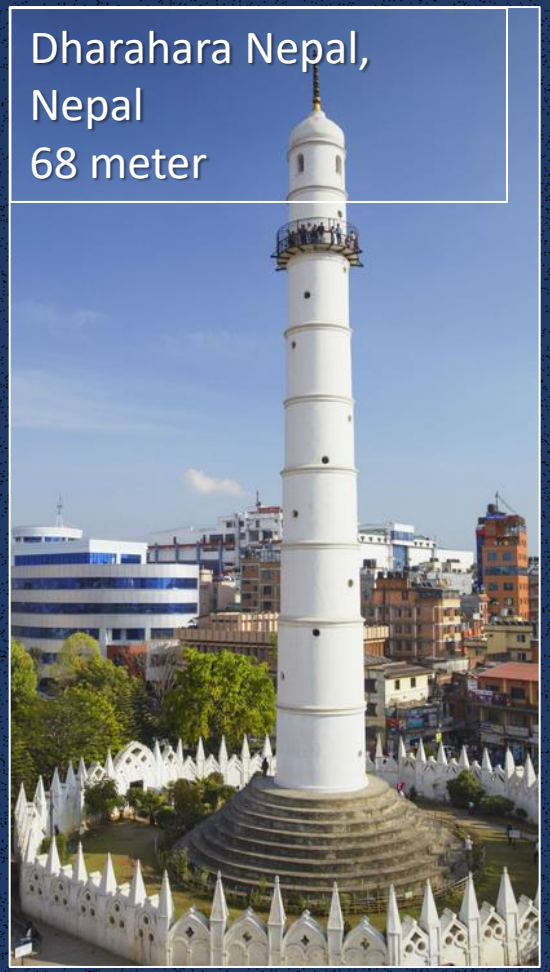
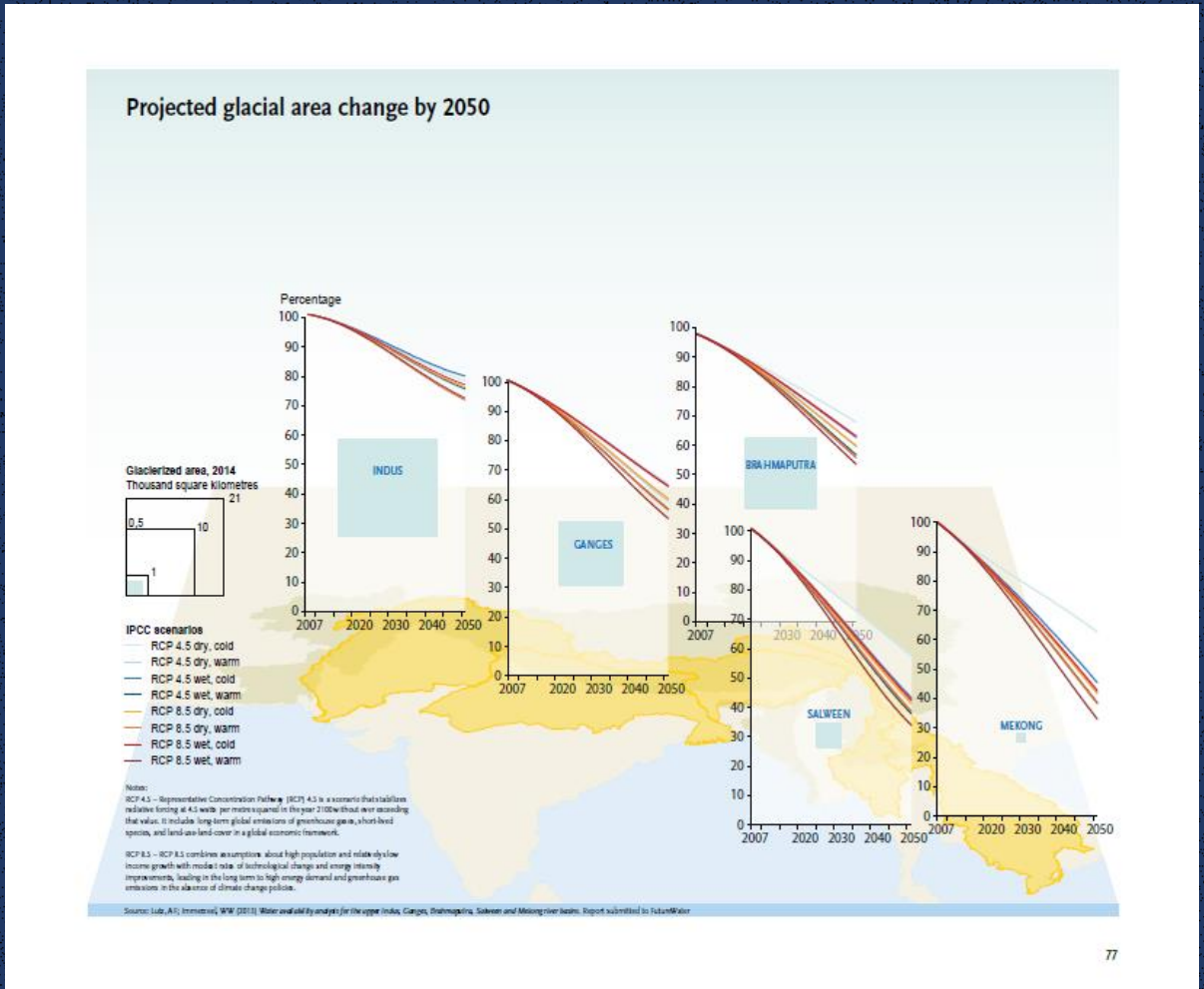
# Changes in glaciers



Dharahara Nepal,
Nepal
68 meter

Equivalent to
100 meter

# Glacier change 2050




Area change -20 to -55%

*Shrestha et al., 2015 (HKH Climate and Water Atlas, ICIMOD)*

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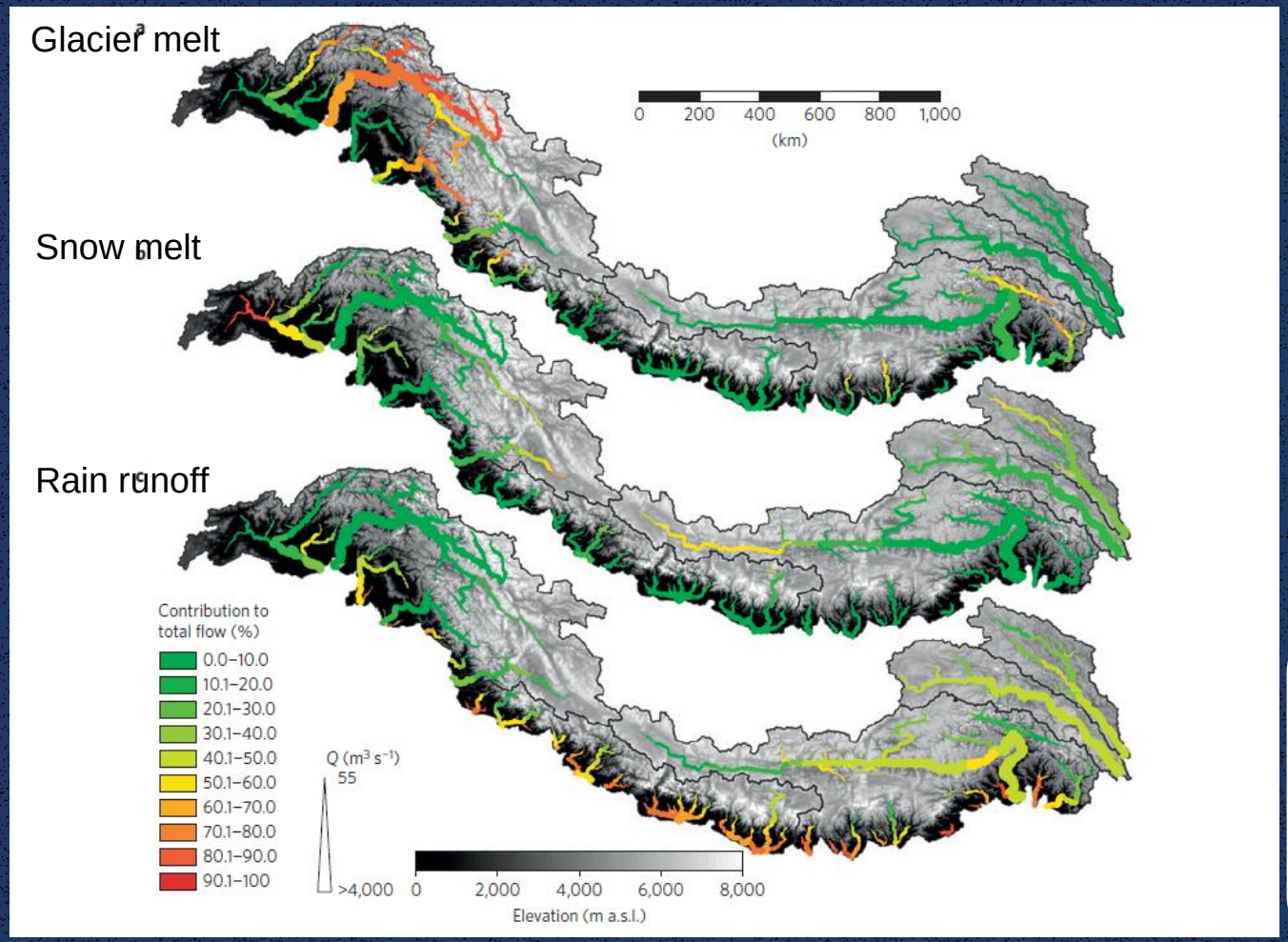
# Impact on water availability

## Present hydrology of the HKH rivers




| Basin | Contribution to total runoff (%) | | | |
|---|---|---|---|---|
| | Glacier melt | Snow melt | Rainfall-runoff | Base flow |
| UIB | 41 | 22 | 27 | 10 |
| UGB | 12 | 9 | 66 | 13 |
| UBB | 16 | 10 | 59 | 15 |

- Indus: Glacier melt dominates including flow peak during the summer season
- Brahamputra: glacier melt is important for the most easterntributaries
- Ganges: Rain runoff dominates the streamflow

*Shrestha et al., 2015 (HKH Climate and Water Atlas, ICIMOD; Lutz et al. 2014*

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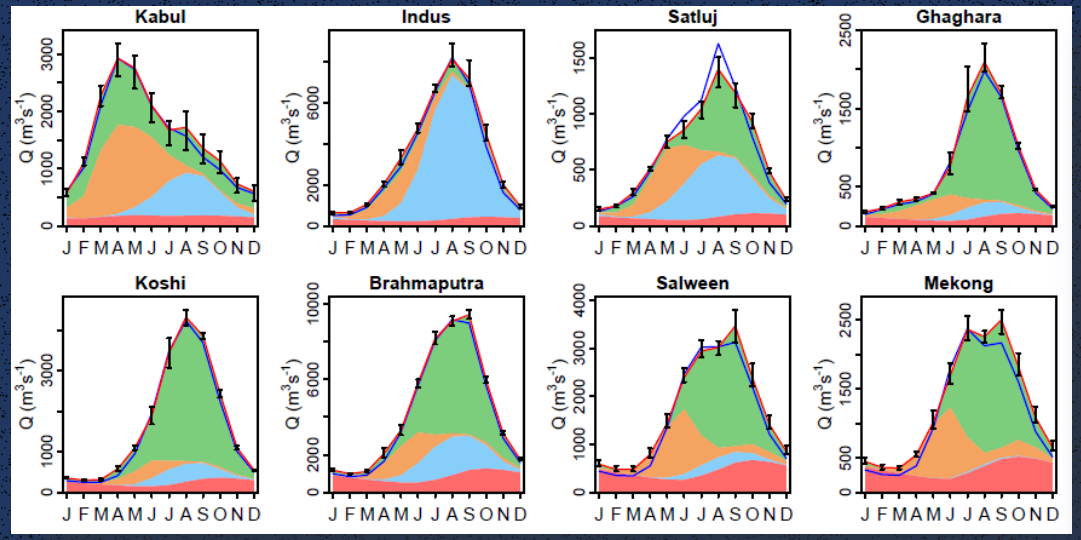
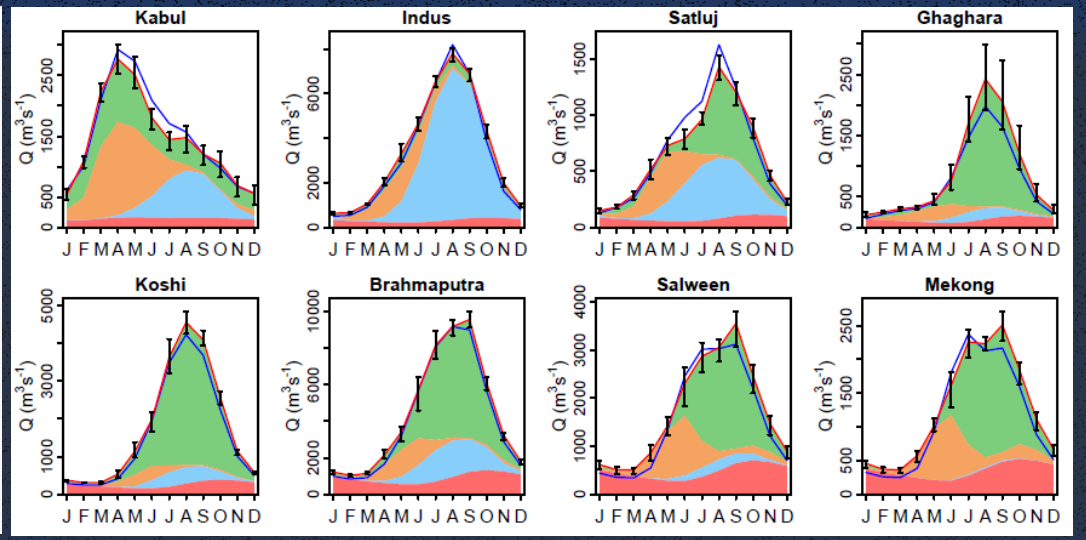
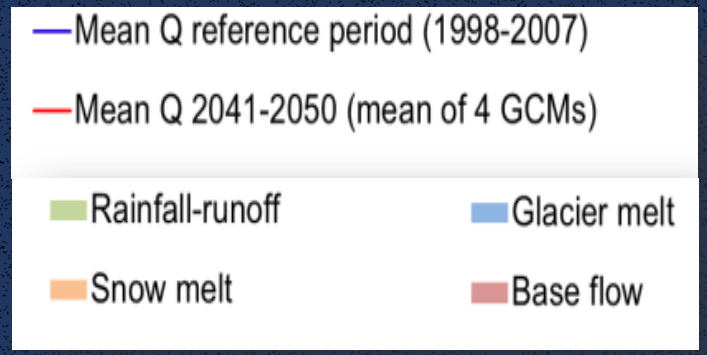
# Changes in hydrological regime

RCP4.5



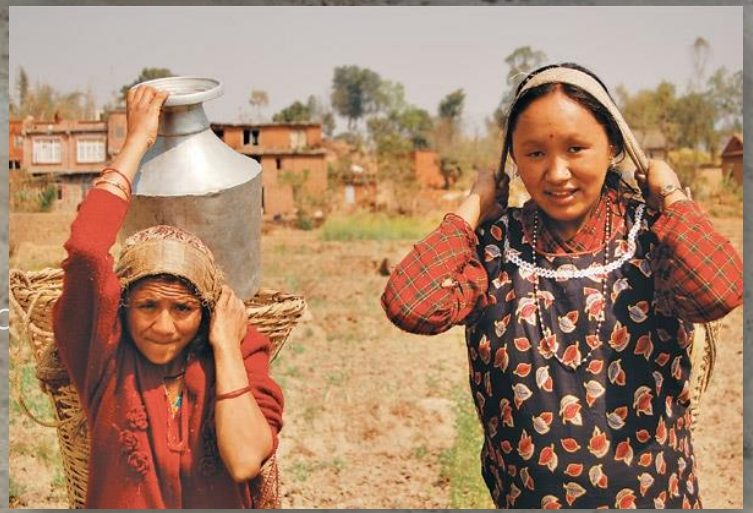

RCP8.5




No significant change in water availability

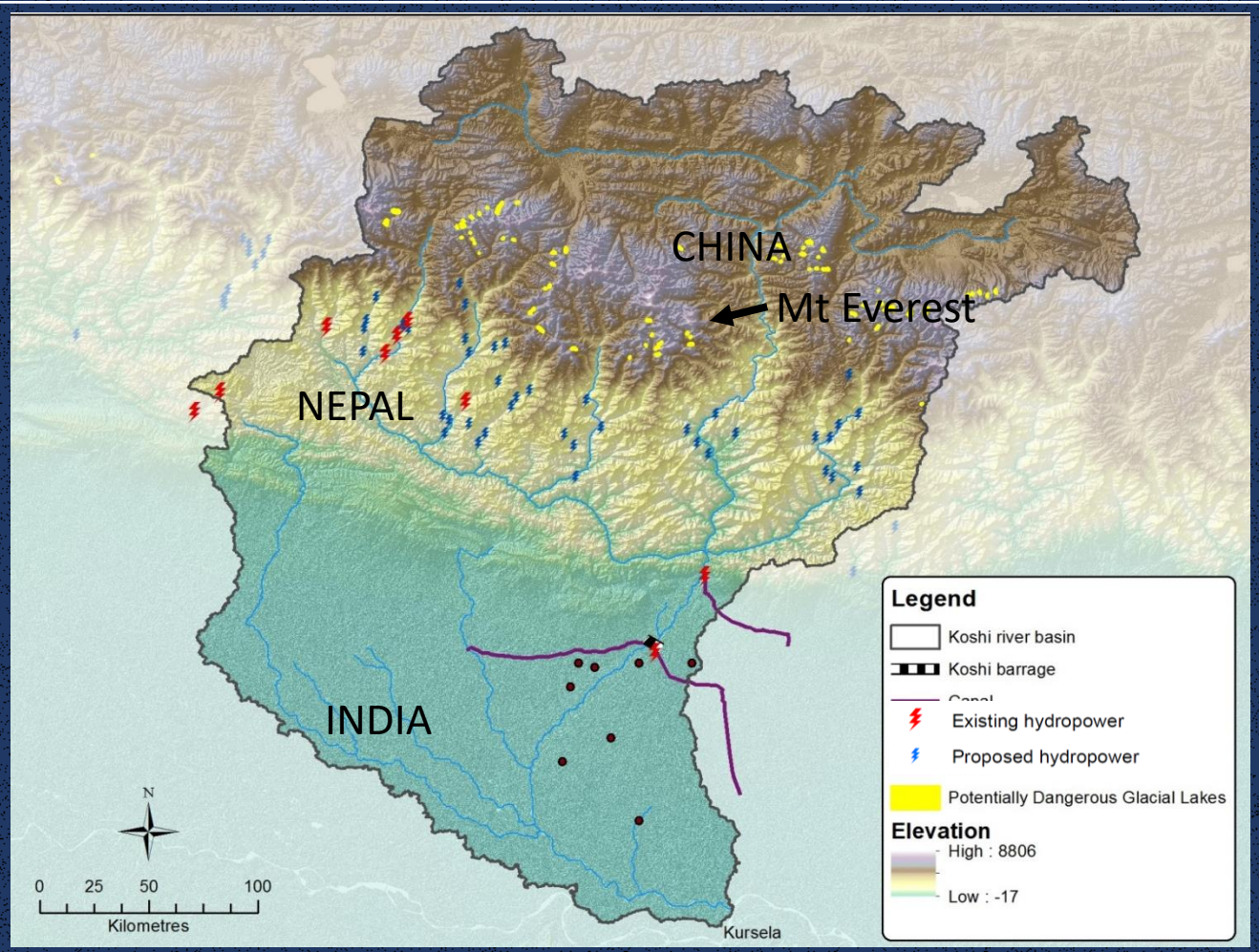
# Upstream communities dependent on glacier and snow melt are feeling the impacts



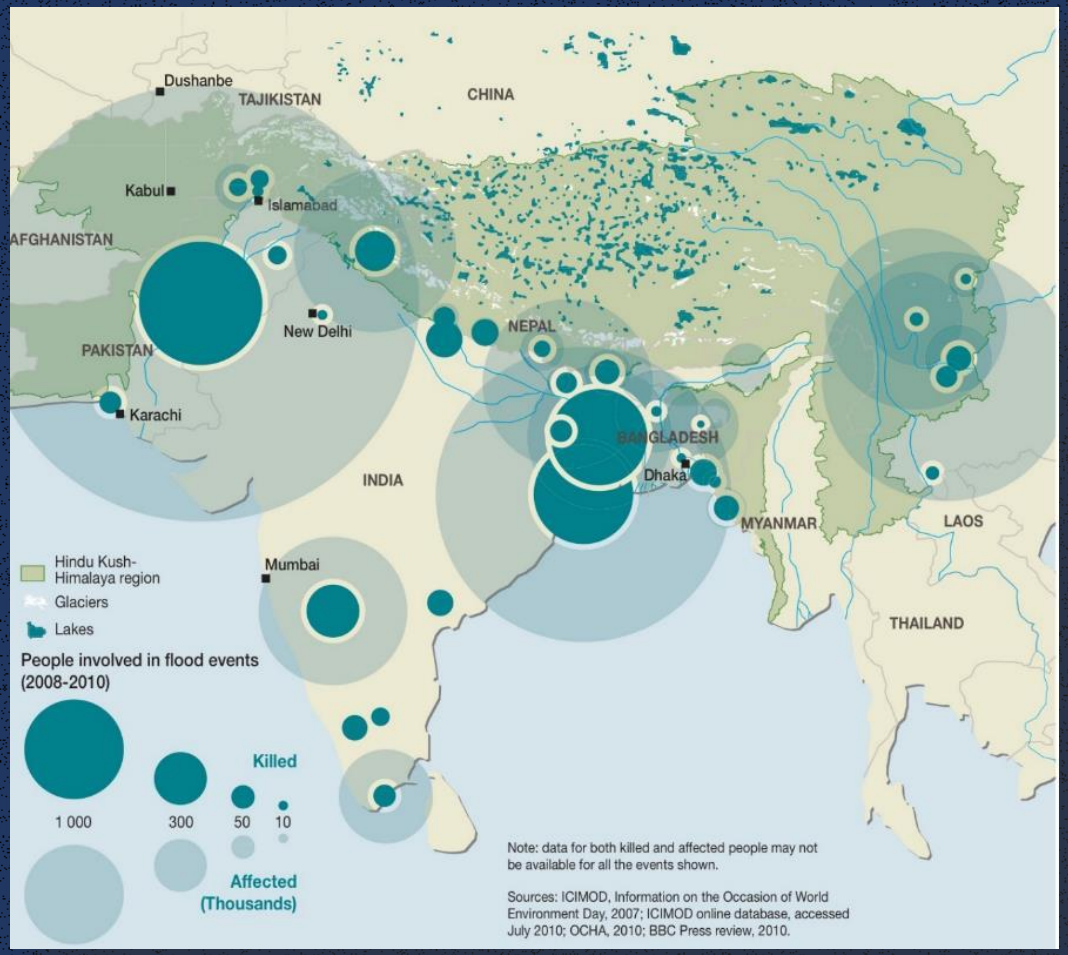
<u>Different story of middle mountains</u>

- The middle mountains are fed by rainfall and groundwater
- Springs are major source of water
- Springs are increasingly drying up in the HKH

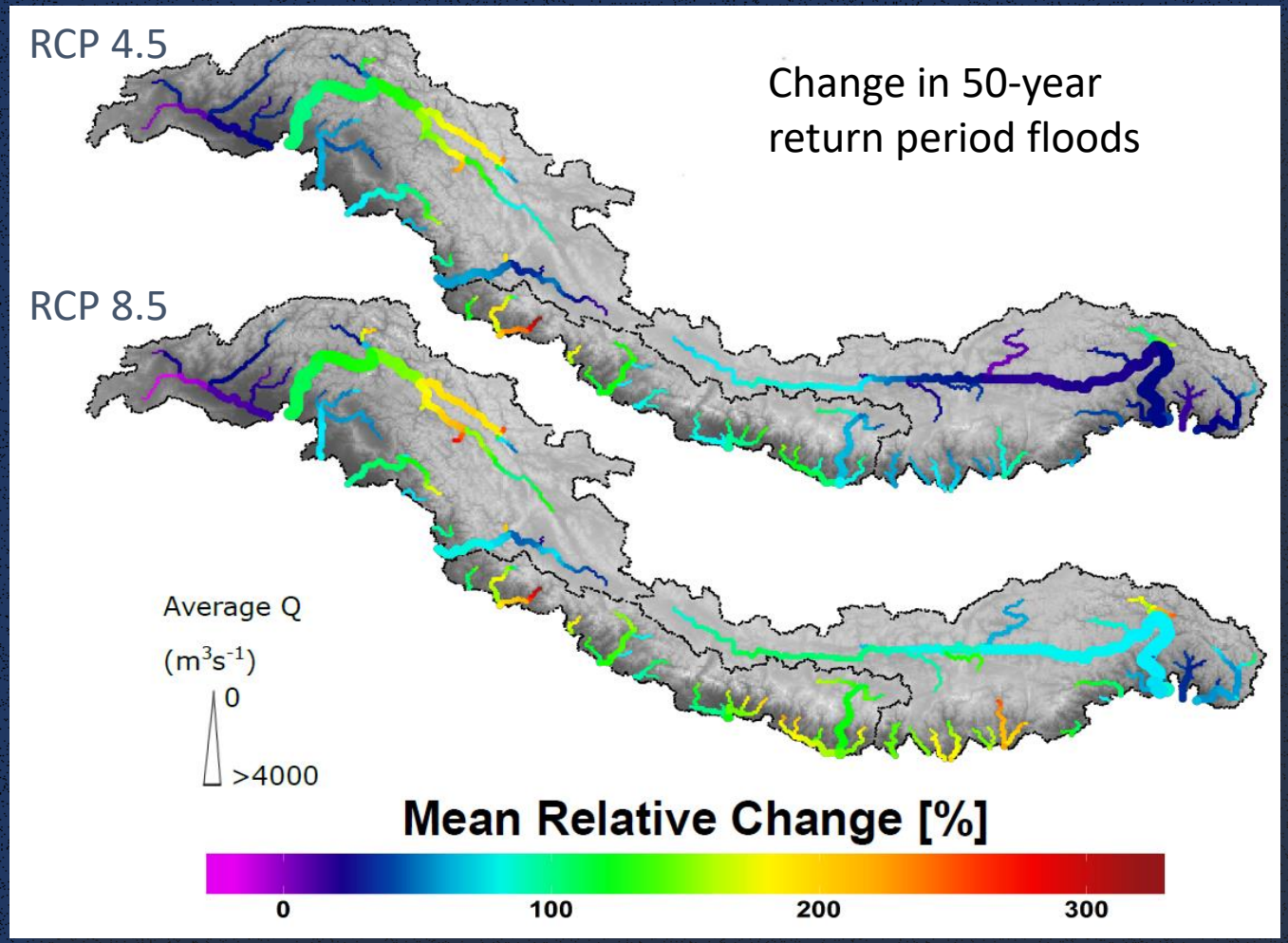
# Too much water



# Increasing floods and flash floods



# Changes in extremes: Floods




Extremes will increase strongly during the 21st century, almost doubling in magnitude by the end of the century

*Source: Wingaard et al. 2017, PlosOne*

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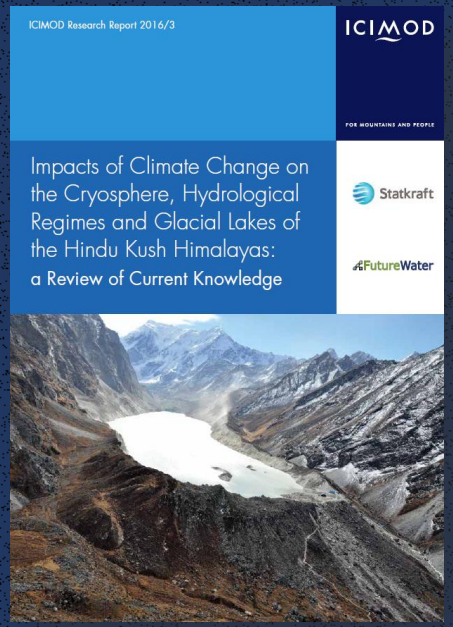
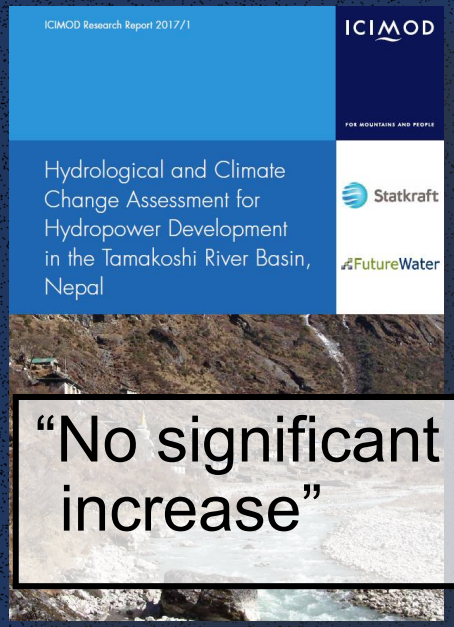
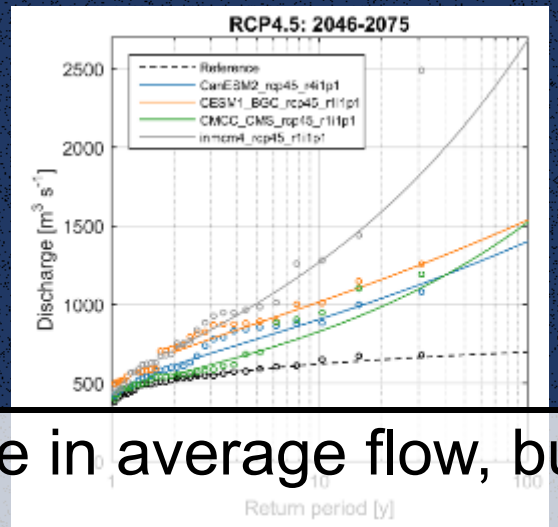
# Assessing climate change impacts on hydropower

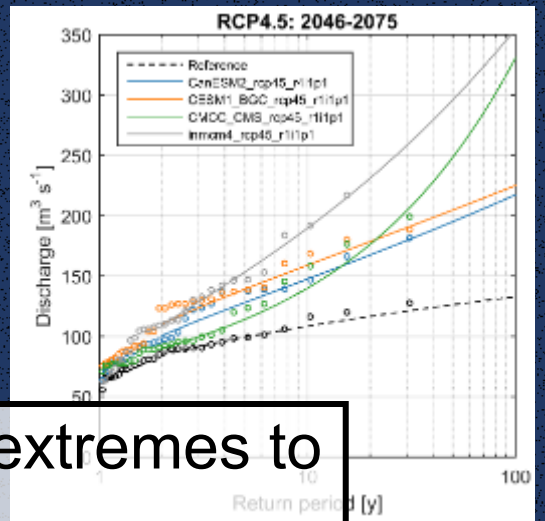


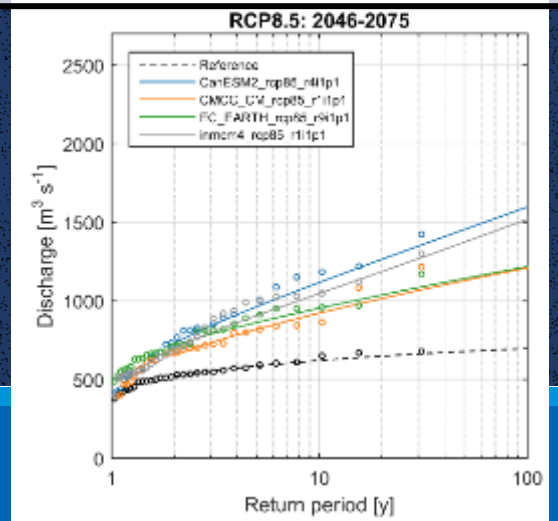

Tamakoshi-III

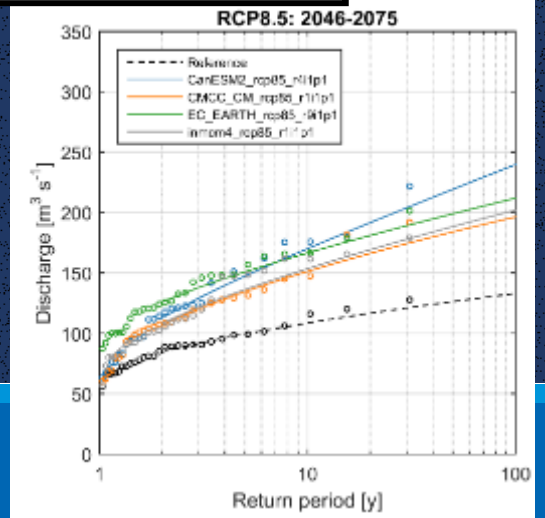



Khimti




"No significant change in average flow, but extremes to increase"



# In closing

Present understanding

- There are adequate evidences of temperature increase
- Both temperature and precipitation extremes increasing
- Elevation dependent warming
- Rapid retreat of glaciers; glaciers unlikely to vanish but to shrink significantly
- Future water availability depends on the location but not to be impacted at larger scales
- Extremes likely to be important

Major gaps to be address

- Understanding better roles of snow cover and permafrost
- High altitude precipitation, including estimation of future precipitation
- Uncertainty in climate projections
- Interlinkages between cryosphere – atmosphere – monsoon - hydrology
- Understanding the extremes and seasonal shift
- Adaptation under uncertainties

# Thank you