Climate Change Hotspots

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ITM Colloq., 21-23 Nov. 2023, Nepal

- Climate Change
- Hotspots

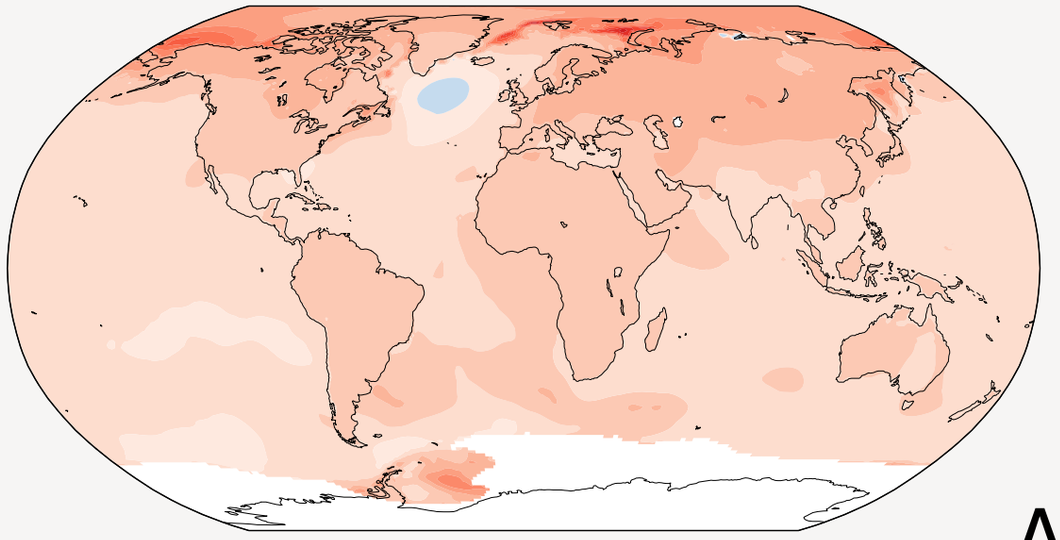
- Examples:

  a) Elevation-Dependent Warming

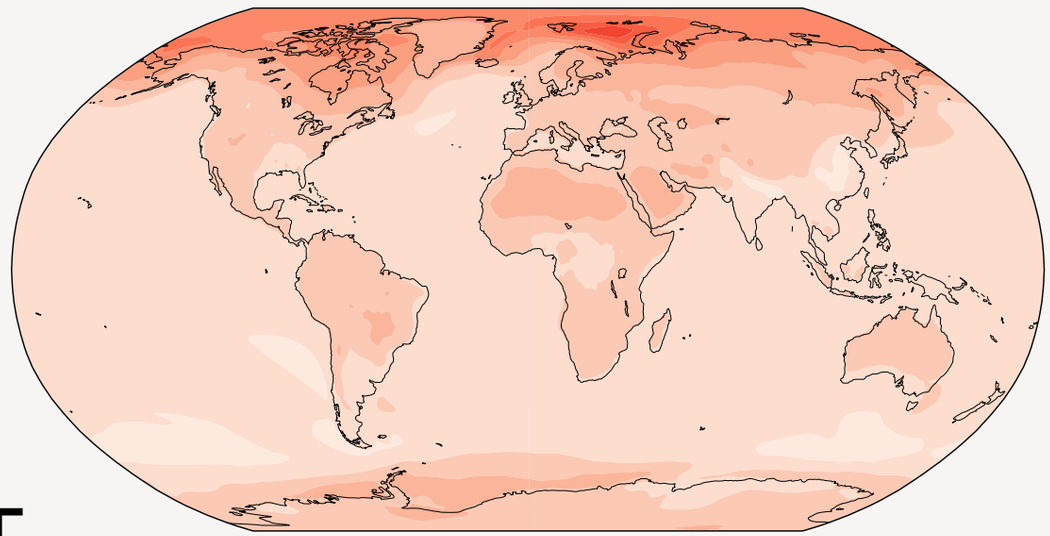
  b) Indian Summer Monsoon Rainfall

Climate Change

Observed change per **1 °C** global warming



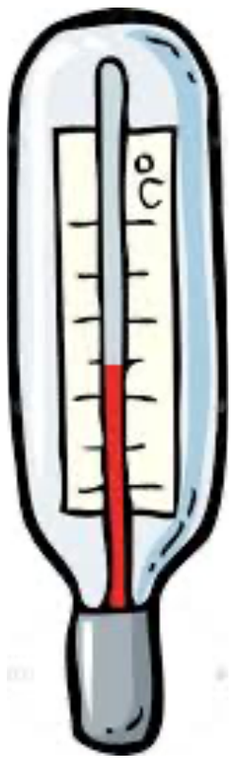
Simulated change at **1 °C** global warming

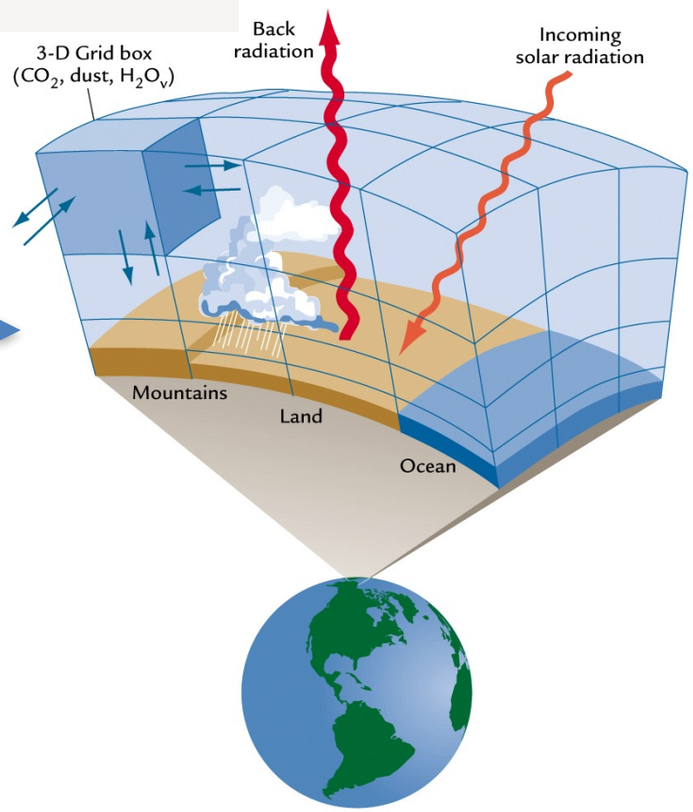


ΔT

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 --->

Change (°C) ⟶





=>

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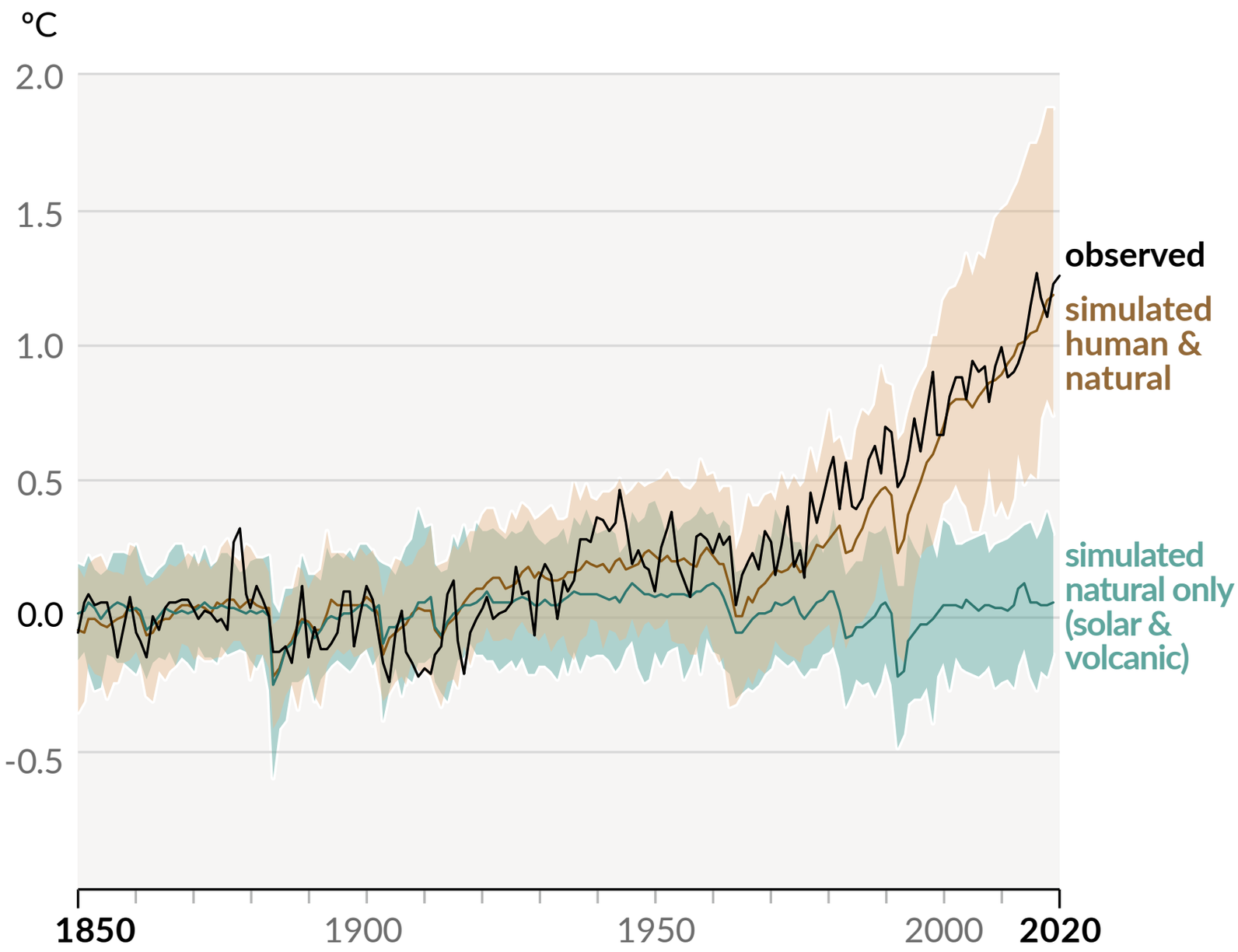
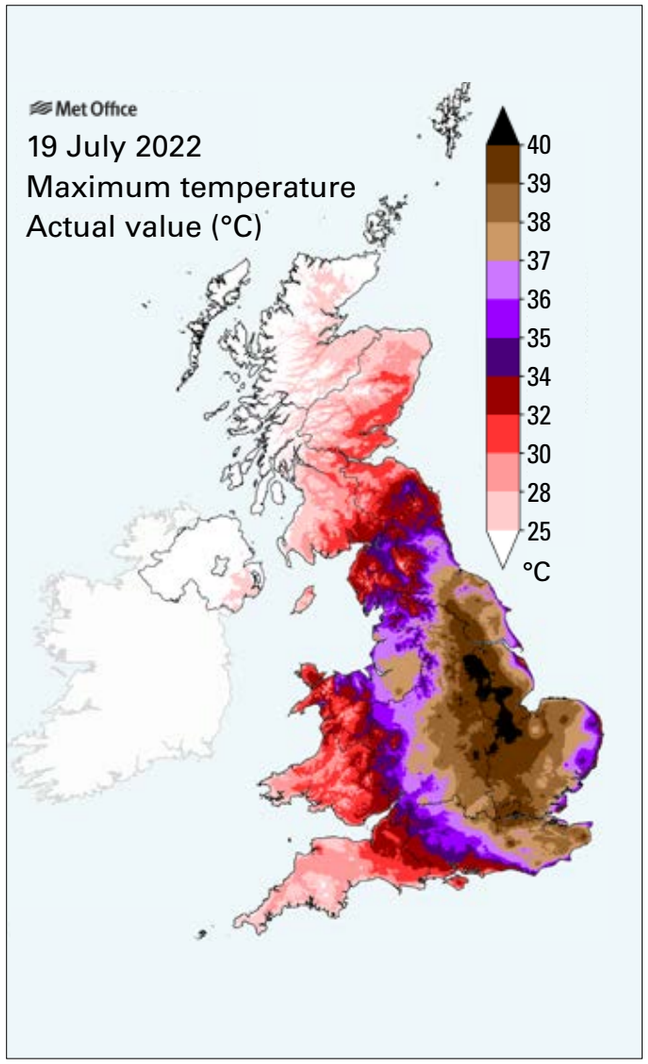
Anthropogenic?

Change in global surface temperature (annual average) as **observed** and simulated using **human & natural** and **only natural** factors (both 1850-2020)



IPCC AR6 WG1 (2021)

Consequences - Record-Shattering Climate Extremes



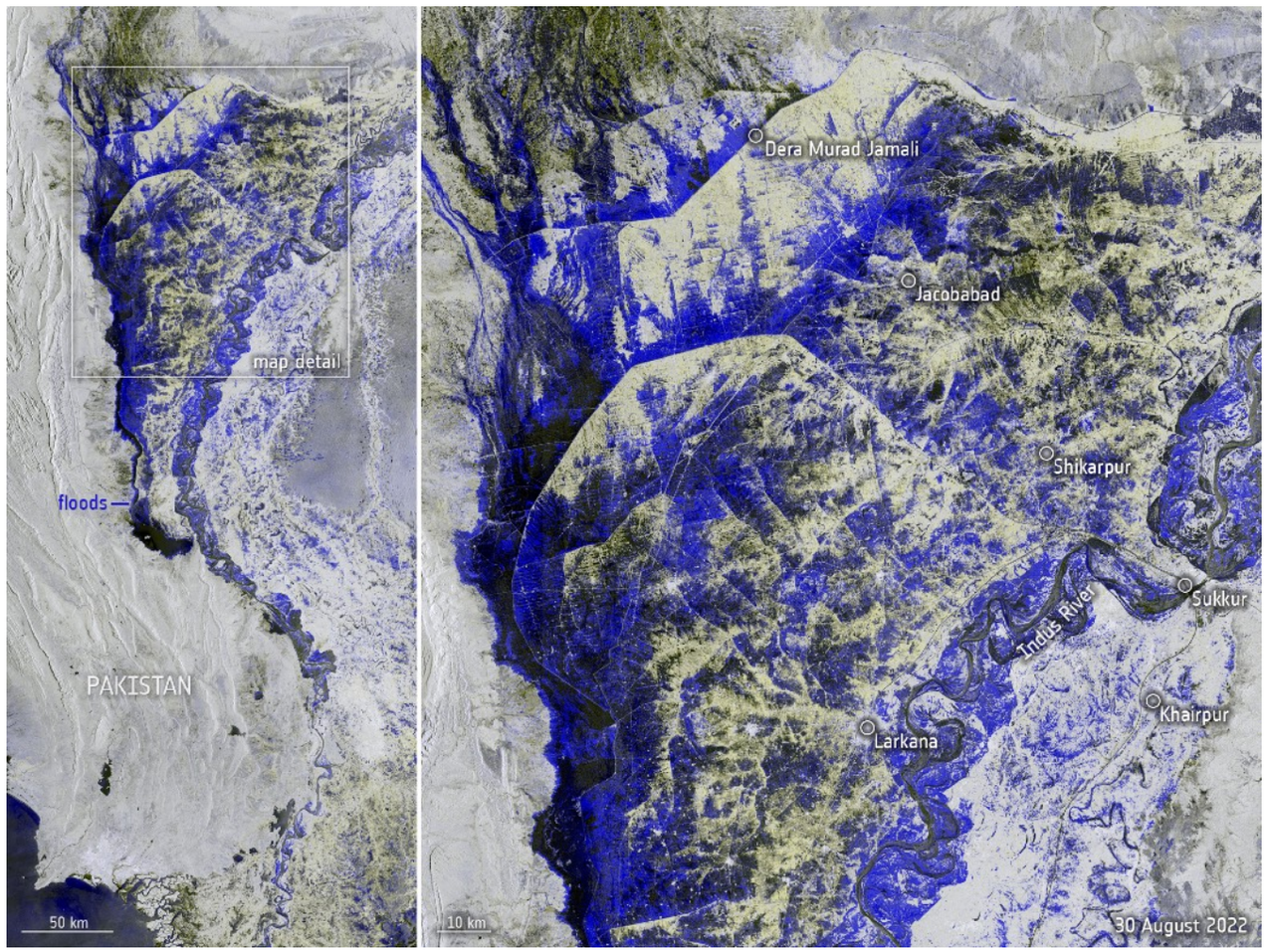
Return time estimated at 1 in 1000 years in the current climate

Human-caused climate change made the event at least 10 times more likely

Record TMax
Delhi (Palam): 48.4 °C
Frankfurt/Main: 40.2 °C

World Weather Attribution (2022)

Consequences - Record-Shattering Climate Extremes



Pakistan, 30 Aug 2022

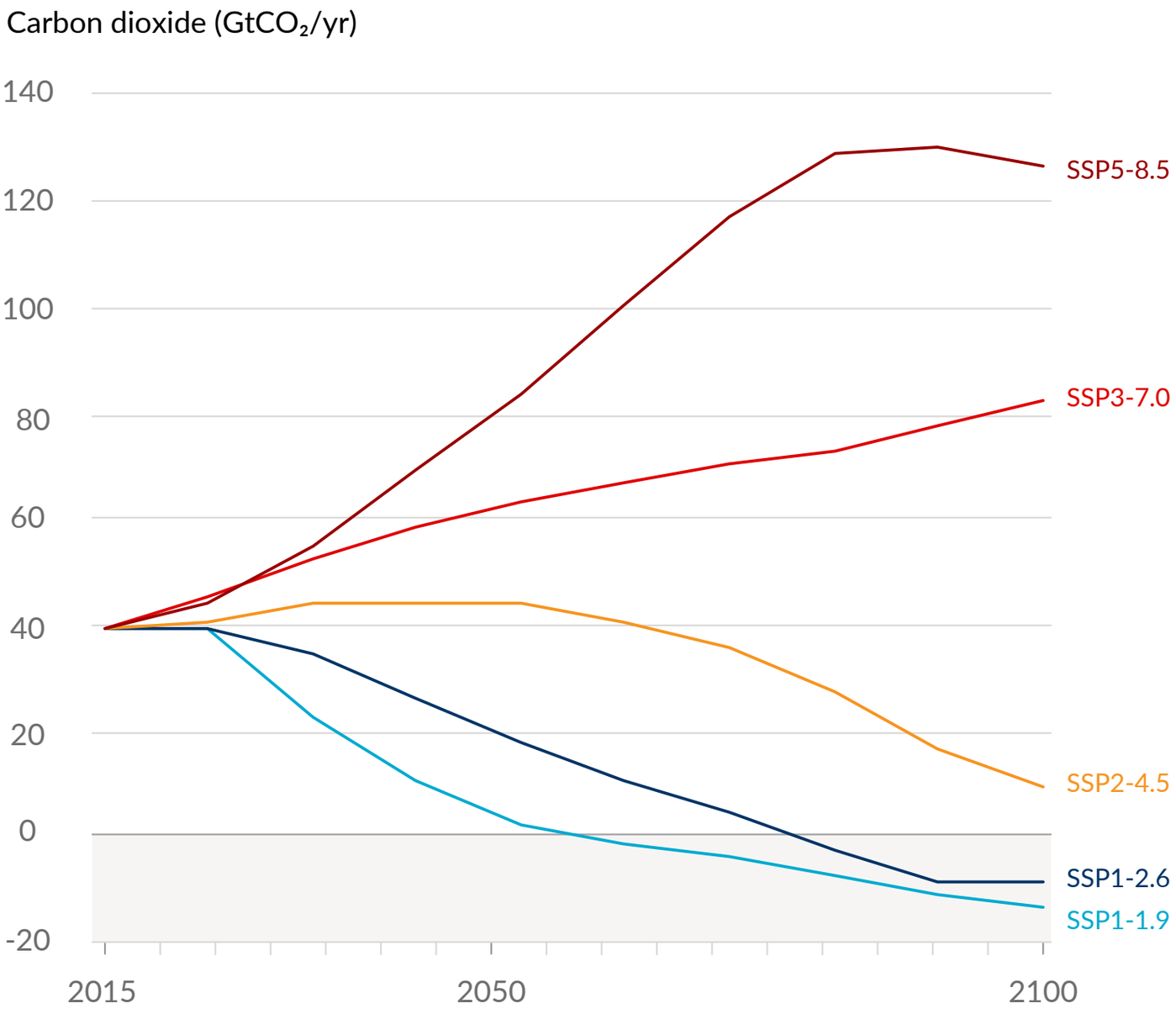
Up to ~9% of area inundated

CC Attribution more difficult: models suggest CC increased the rainfall intensity up to 50%

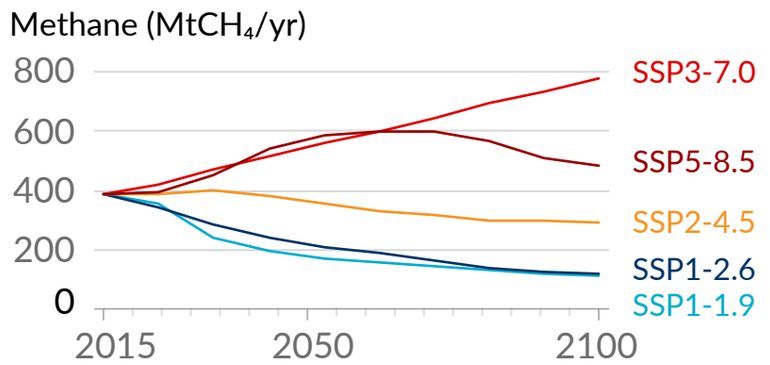
World Weather Attribution (2022)

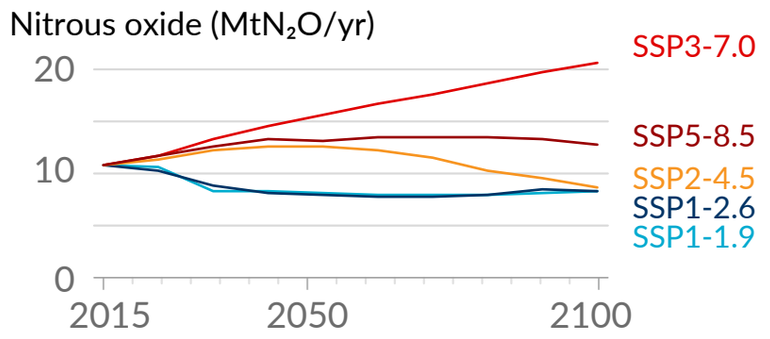
Possible Climate Futures

Future annual emissions of CO_2 (left) and of a subset of key non-CO_2 drivers (right), across five illustrative scenarios

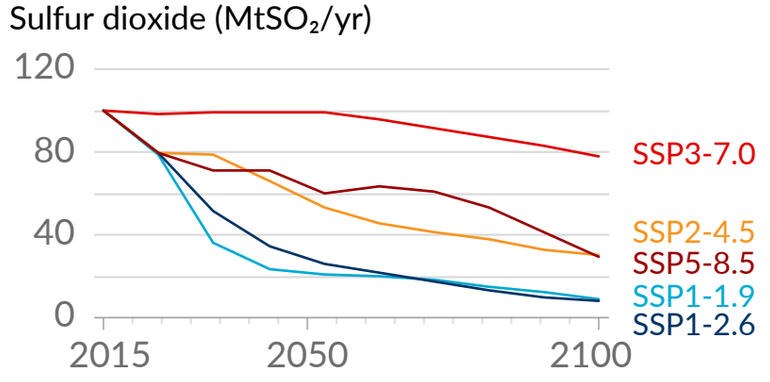


Selected contributors to non-CO_2 GHGs





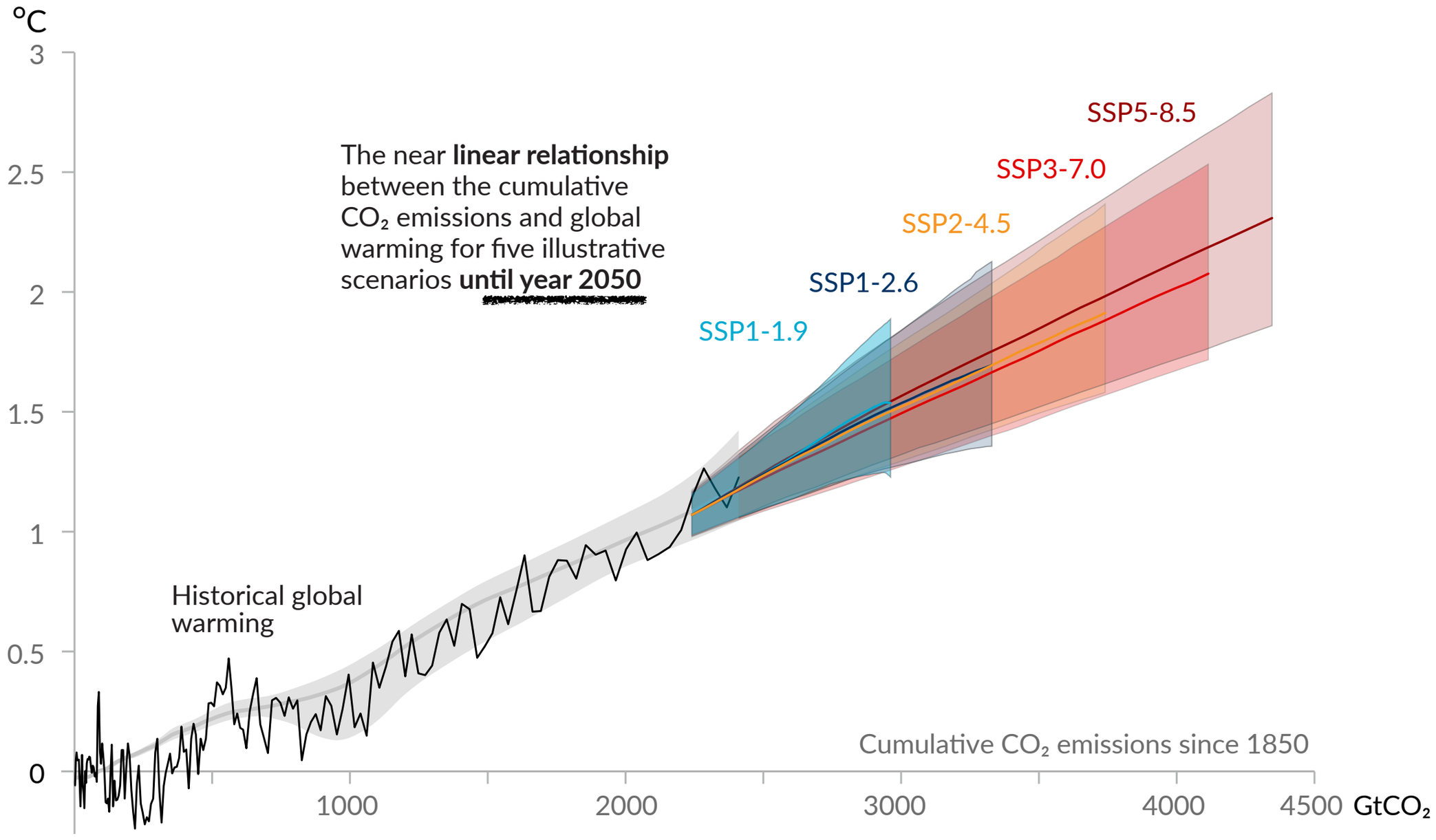
One air pollutant and contributor to aerosols



IPCC AR6 WG1 (2021)

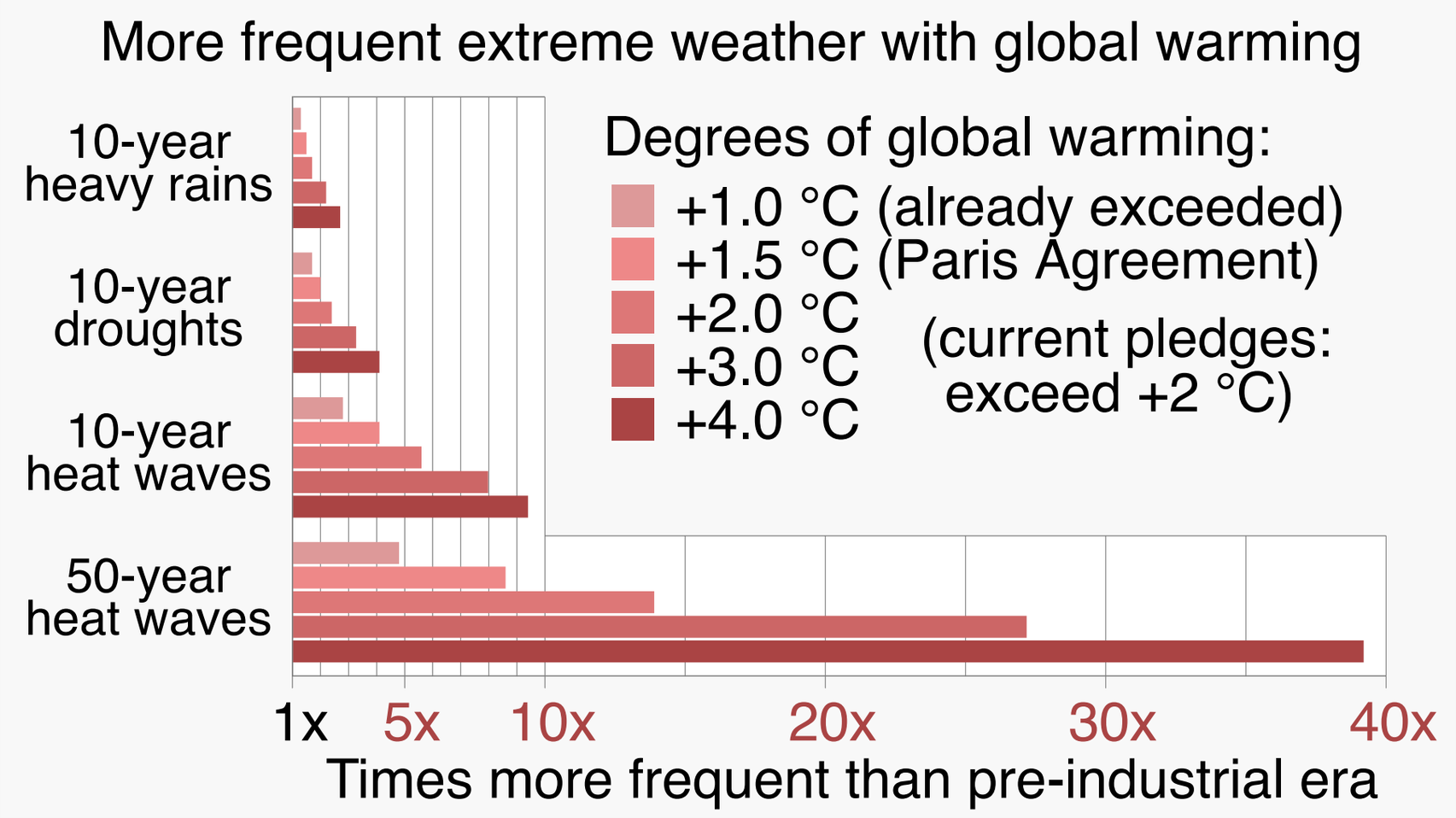
Possible Climate Futures

Global surface temperature increase since 1850-1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)



IPCC AR6 WG1 (2021)

Future Consequences



IPCC AR6 (2021)

Future Climate Change Hotspots?

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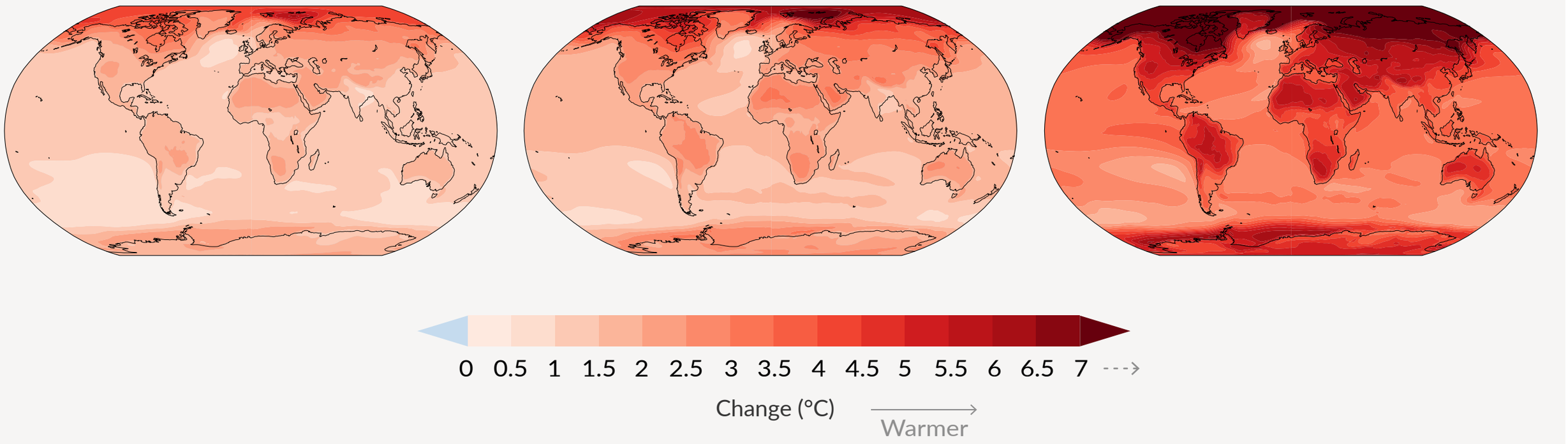
Simulated with Global Climate System Models:



relative to 1850-1900

IPCC AR6 WG1 (2021)

And …

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Gulf of Mexico warming at faster rate than global ocean, study finds

By Kristen Cabrera | The Texas Standard
Published February 28, 2023 at 9:14 AM CST

But a more immediate worry for Texans is the Gulf of Mexico, which scientists now say is warming at twice the speed of the rest of the oceans on earth.

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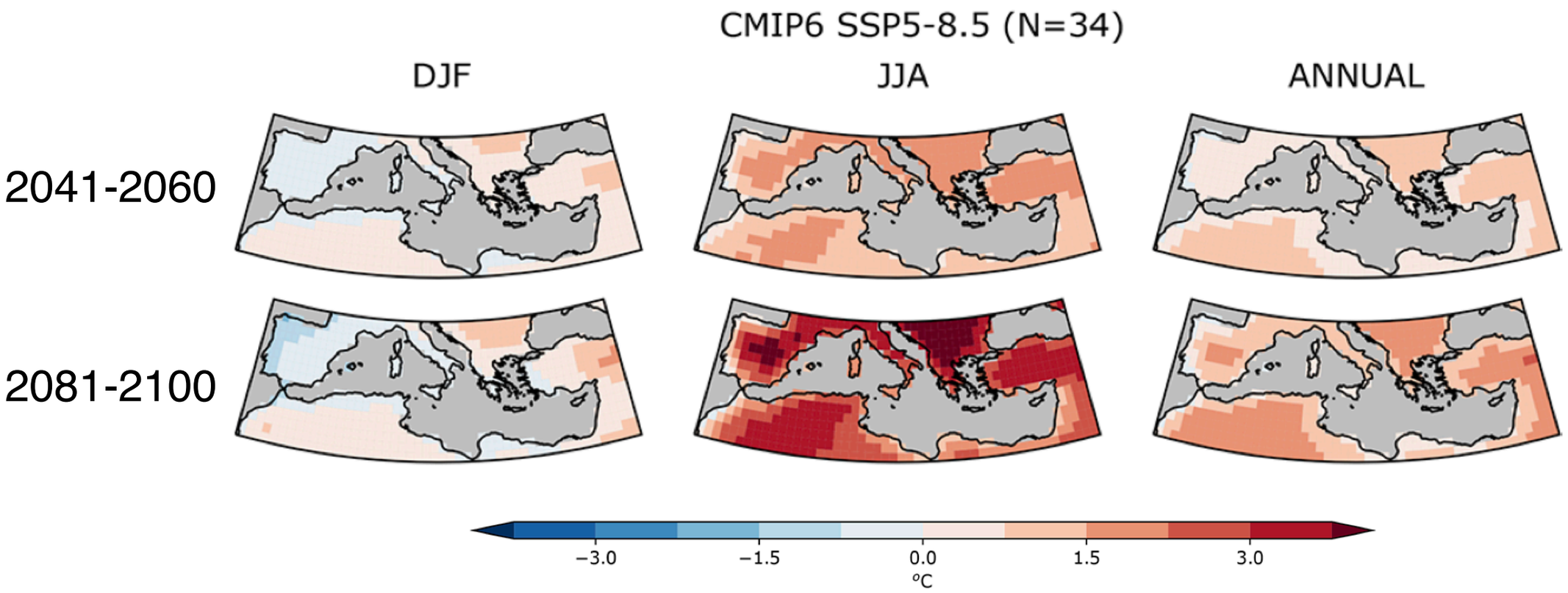
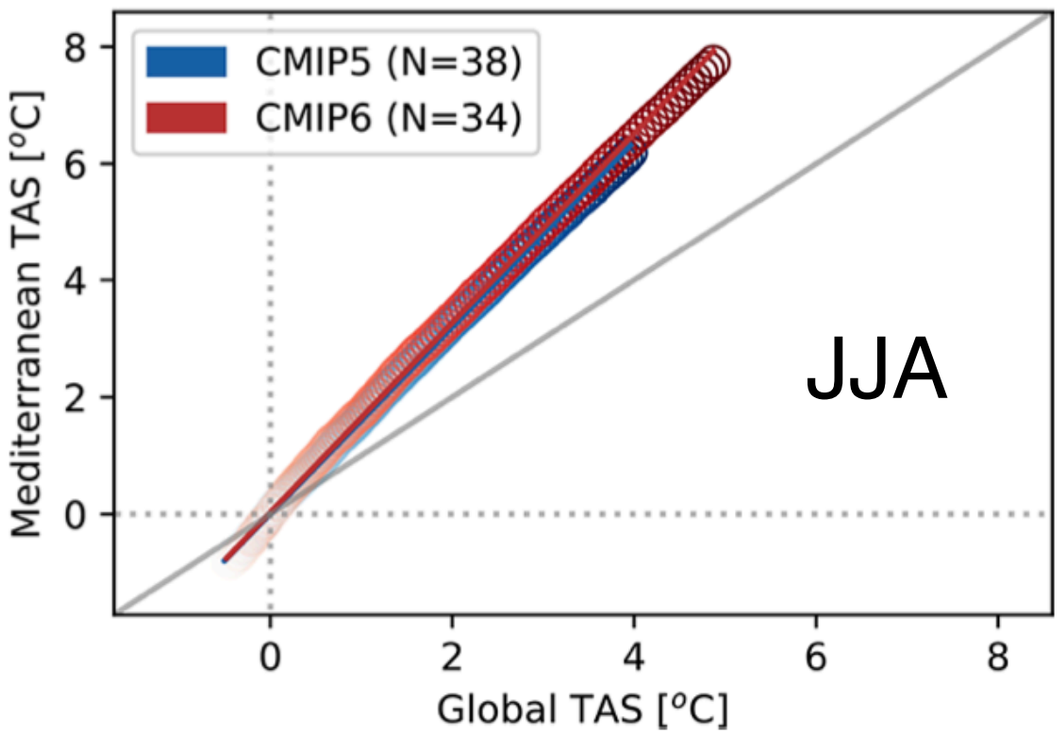
Mediterranean amplification



Temperature change wrt global mean temperature change

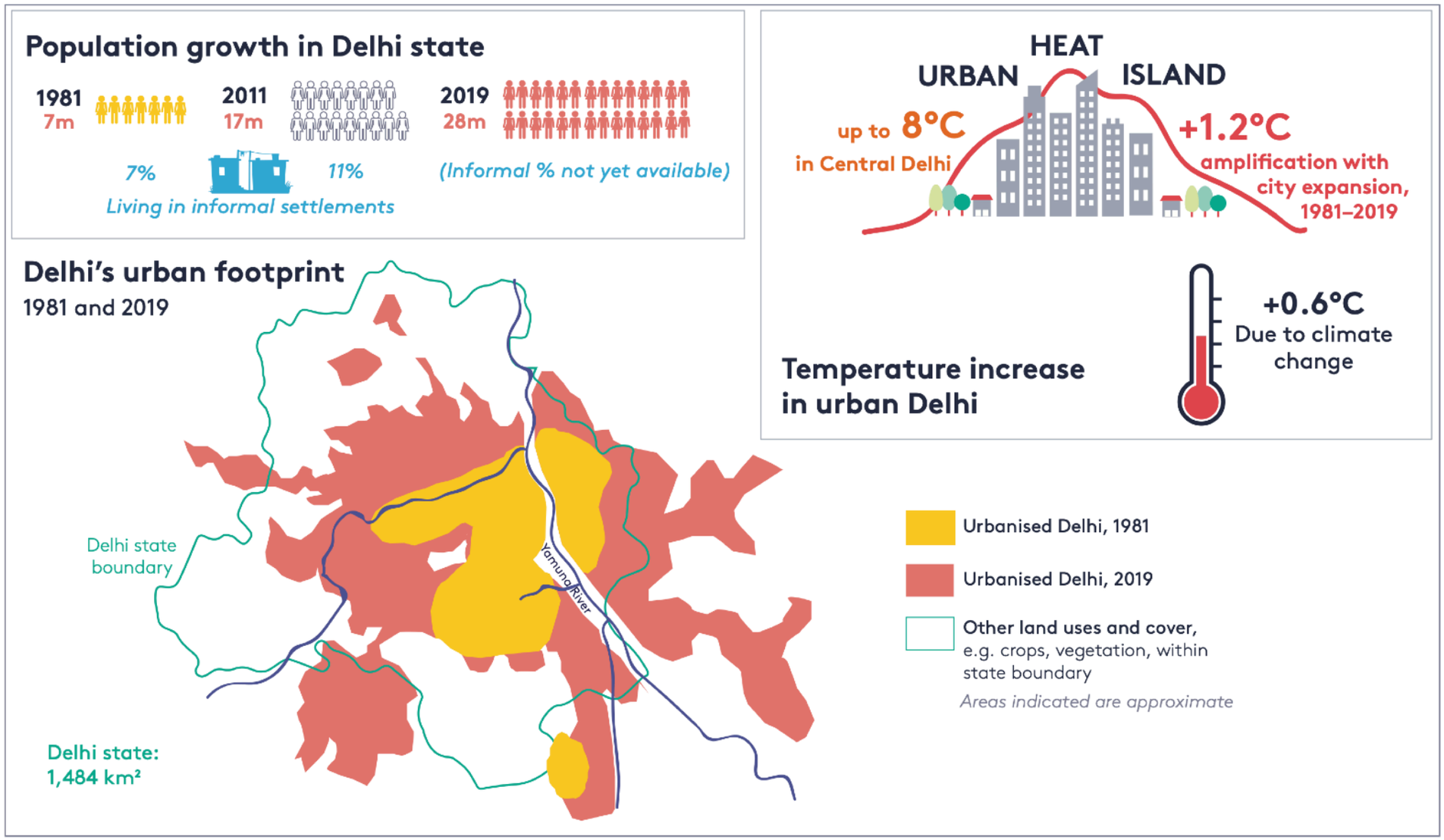
Ref. period: 1986–2005

Cos et al. (ESD, 2022)



DISTENDER | Equilibrium for the Climate Change
Funded by the European Union | UK Research and Innovation

Cities are hotspots of climate impacts: global climate change is compounded by the urban heat island effect



Curran et al. (2019)

- Examples:

  a) Elevation-Dependent Warming

  b) Indian Summer Monsoon Rainfall

Elevation-Dependent Warming

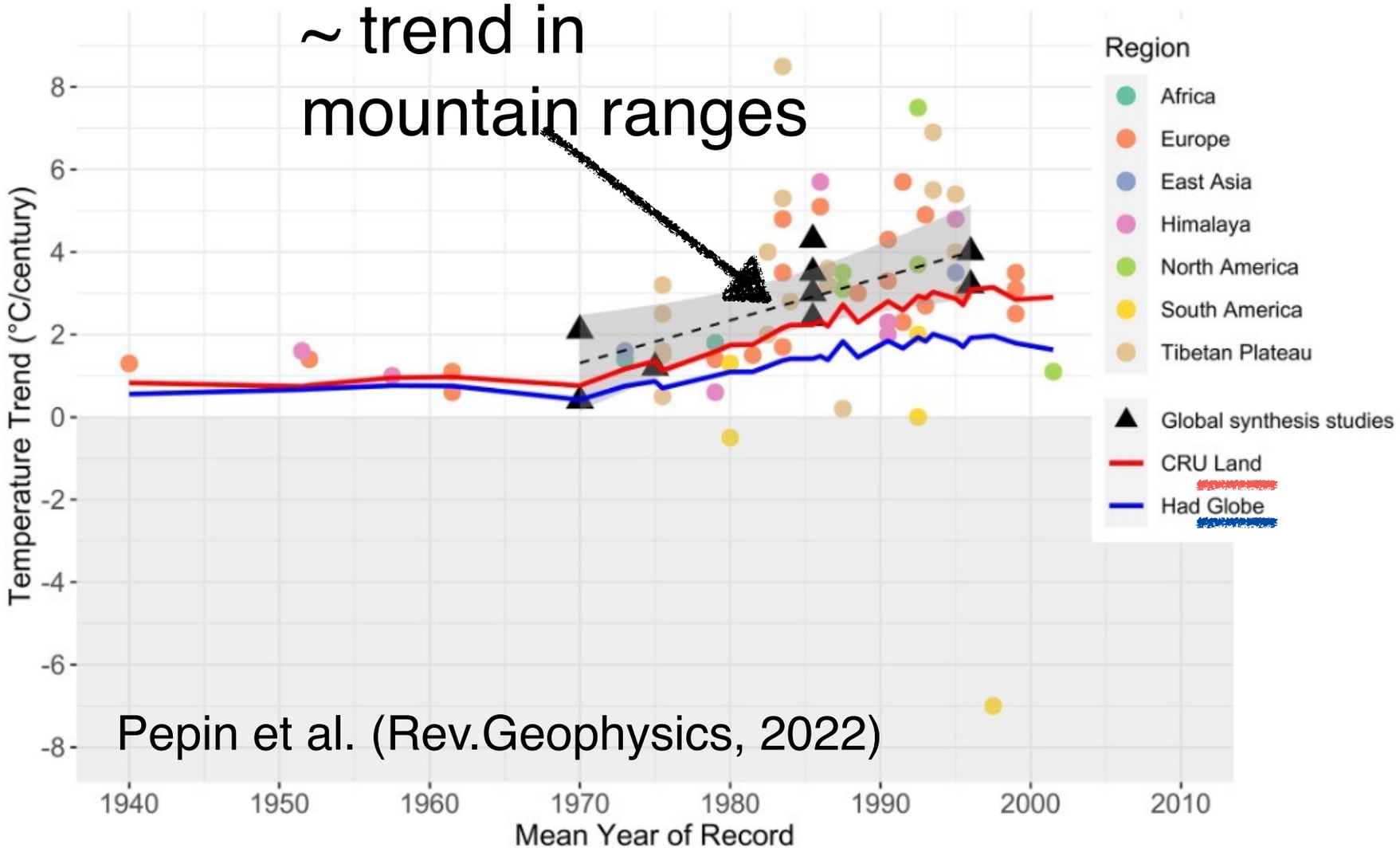
IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (2019):

Mountain surface air temperature observations in High Mountain Asia show warming …

at an average rate of 0.3°C/decade

outpacing the global warming rate 0.2°C/decade

Elevation-Dependent Warming



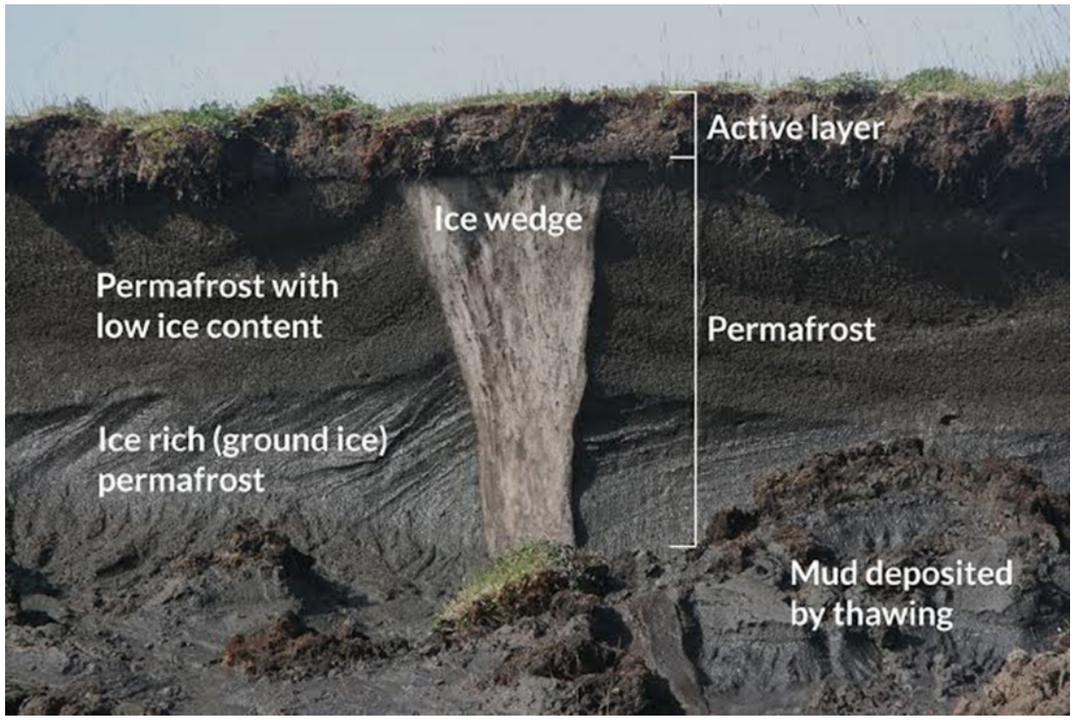
But: Warming not the same in all elevation bands,

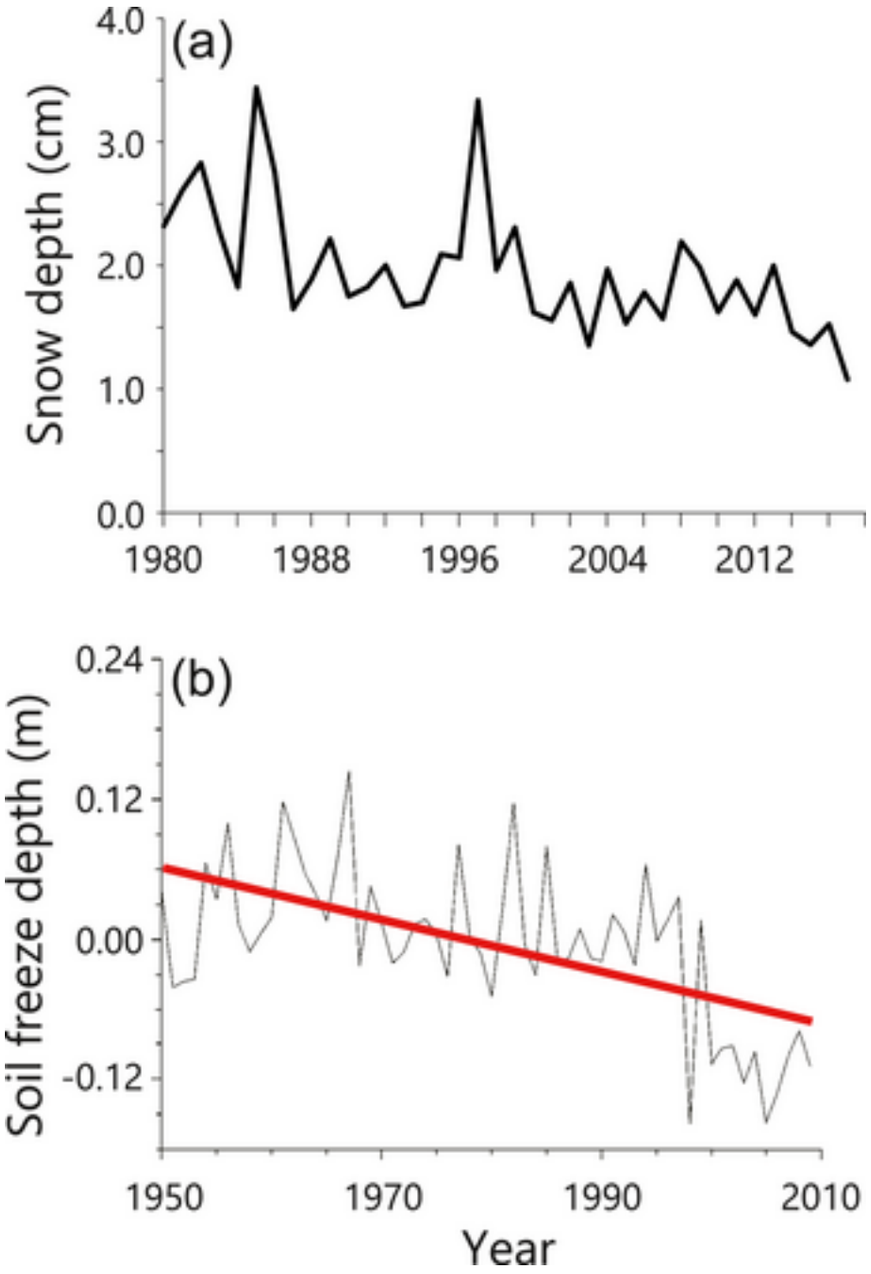
in all regions, … => **Elevation-Dependent Warming**

Motivation: Rain-On-Snowmelt

Decrease in frequency, shift in season, shift in elevation, predictability … ?

Motivation: Cryosphere Change





Huang et al. (Rev. Geoph., 2023)

Elevation-Dependent Warming

Relative contributions of processes not well understood:

- increase of atmospheric humidity drives warming stronger in cold & dry atmospheres

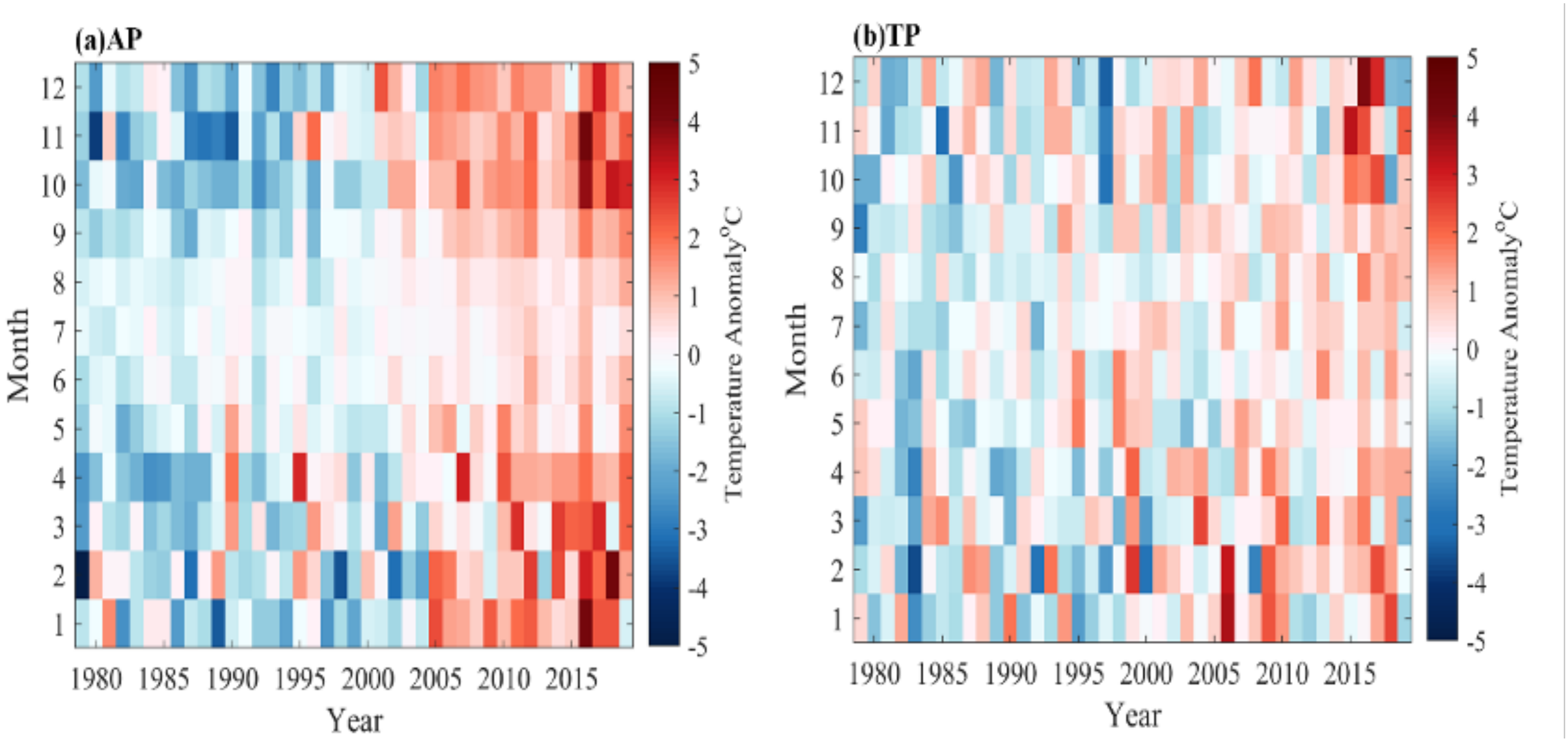
- decline in snow cover and snow-albedo feedback
  - enhanced warming due to increased latent heat release above the condensation level

- cooling effect of aerosols, which also cause solar dimming, is more pronounced at low elevation

-> similar processes as with polar amplification: **Third Pole amplification**

Arctic Pole (AP) and Third Pole (TP) warming

Results based on ERA5 reanalysis



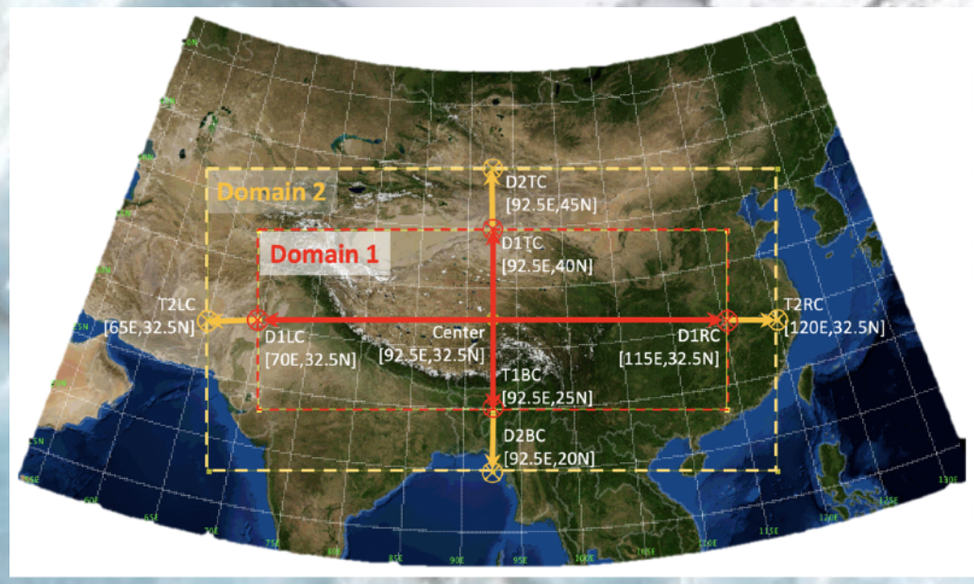
You et al. (2021)

Challenge: long-term high-resolution climate data

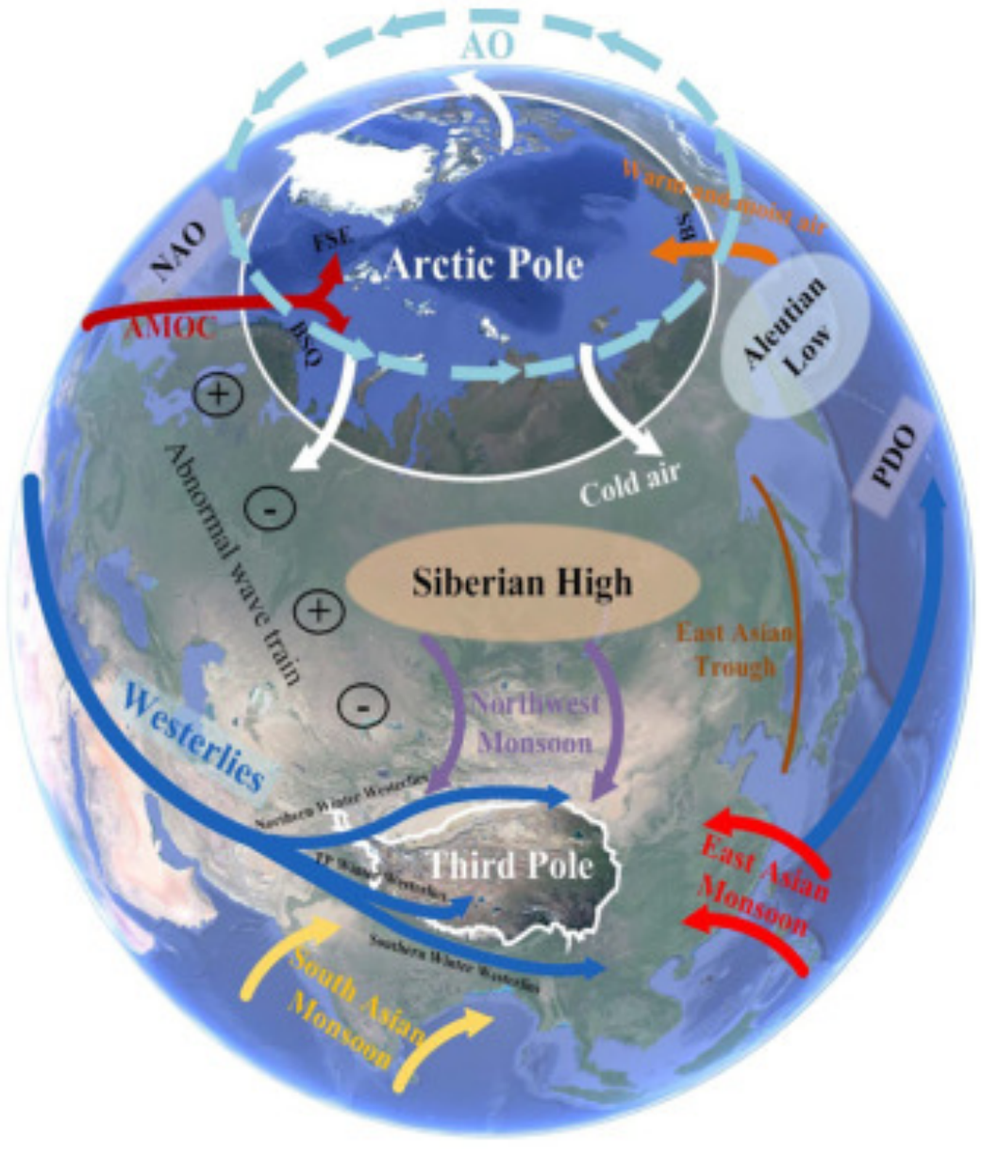
needed: more convection-permitting model research & projections

=> we participate in the "Convection-Permitting Third Pole" project within

WCRP CORDEX
FLAGSHIP PILOT STUDIES



Third Pole - Part of the Global Climate System



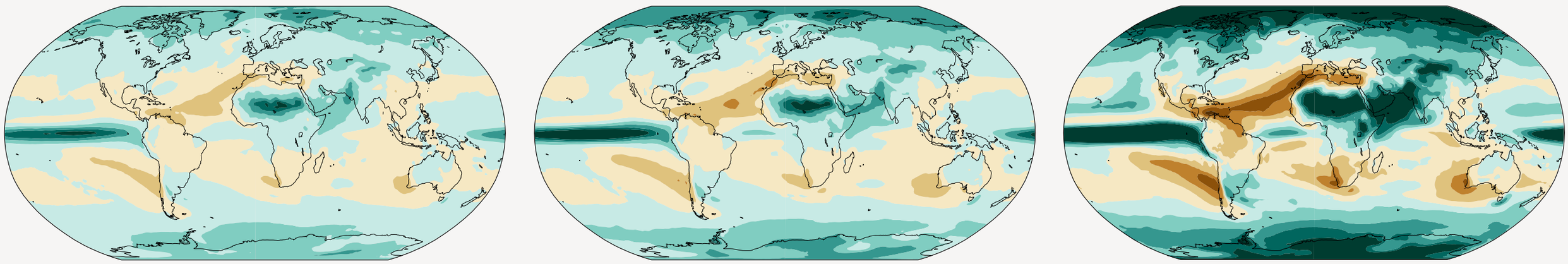
You et al. (ESR, 2021)

Future Climate Change Hotspots?

Simulated change at **1.5 °C** global warming

Simulated change at **2 °C** global warming

Simulated change at **4 °C** global warming



annual ΔPrecip in %

-40 -30 -20 -10 0 10 20 30 40

Change (%)

Drier

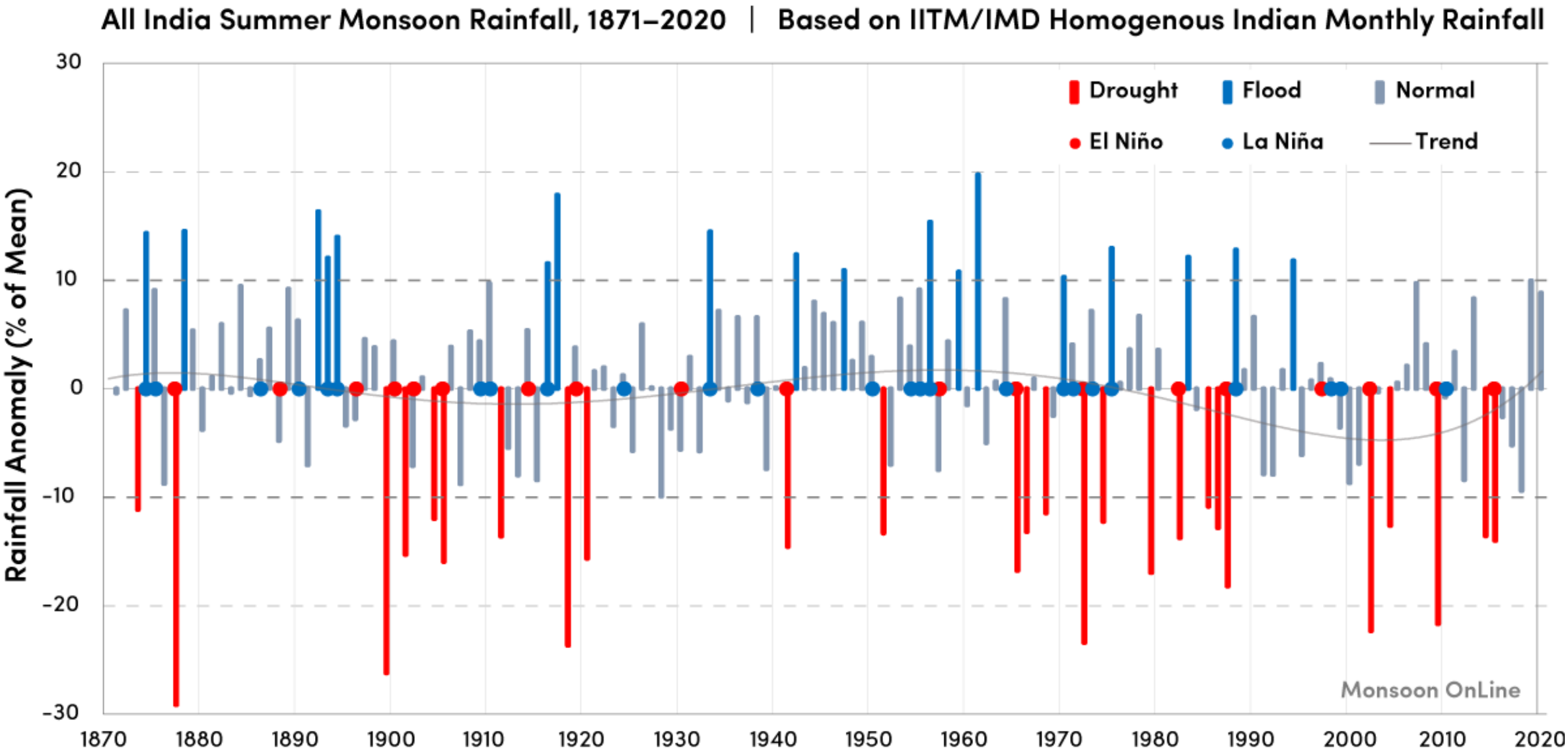
Wetter

Relatively small absolute changes may appear as large % changes in regions with dry baseline conditions

relative to 1850-1900

IPCC AR6 WG1 (2021)

Indian Summer Monsoon Rainfall



- ENSO link
- decrease late 20th century, increase early 21st century

Indian Summer Monsoon Rainfall

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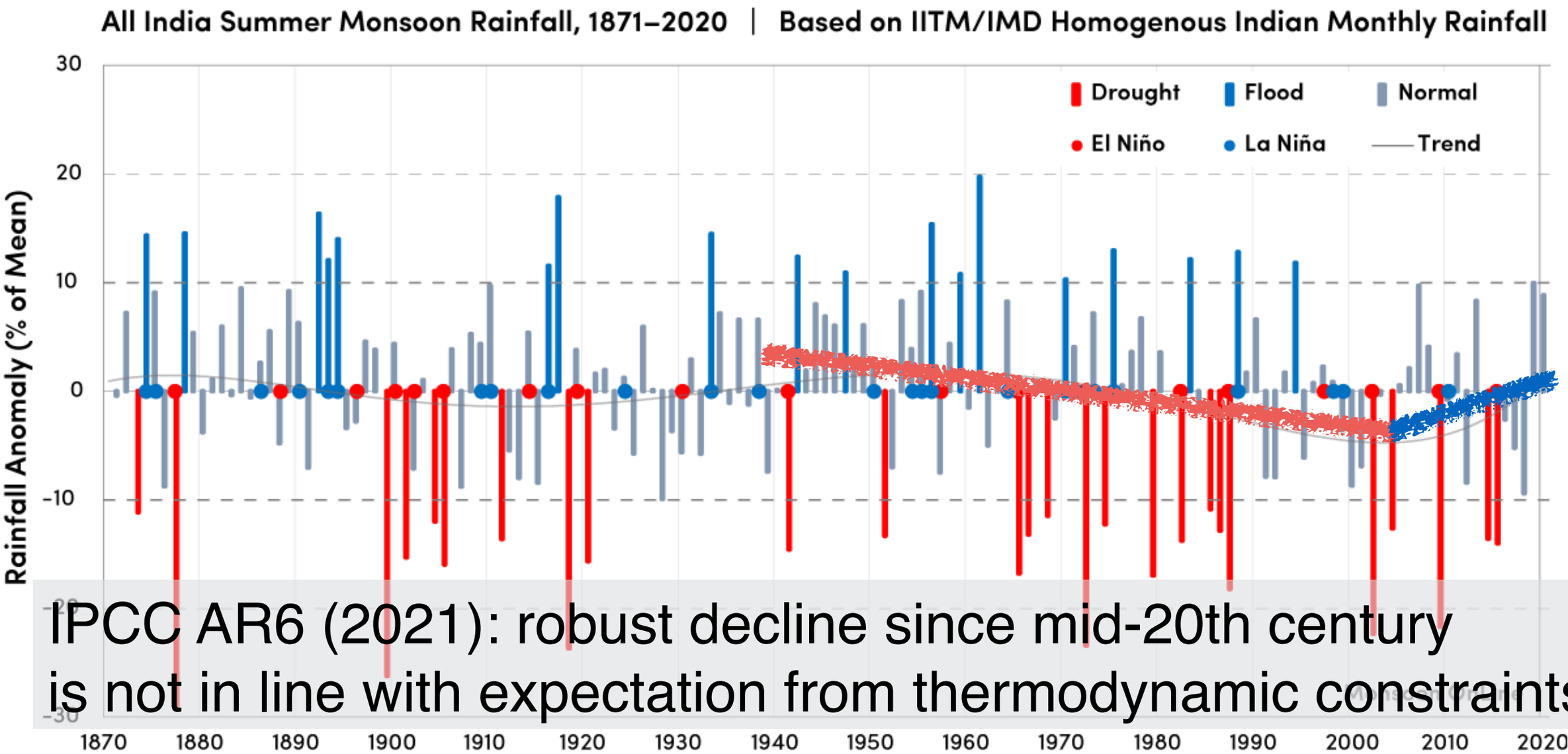

IPCC AR6 (2021): robust decline since mid-20th century
is not in line with expectation from thermodynamic constraints

-> internal variability (ENSO)
-> meridional temperature gradients (regional SST warming)
-> aerosol as important anthropogenic forcing

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Indian Summer Monsoon Rainfall

Intensity of Indian monsoon may decline due to rapid warming of Bay of Bengal, says new study

Hindustan Times, Panaji | By Gerard de Souza | Edited by Sohini Sarkar

Aug 02, 2020 04:36 PM IST

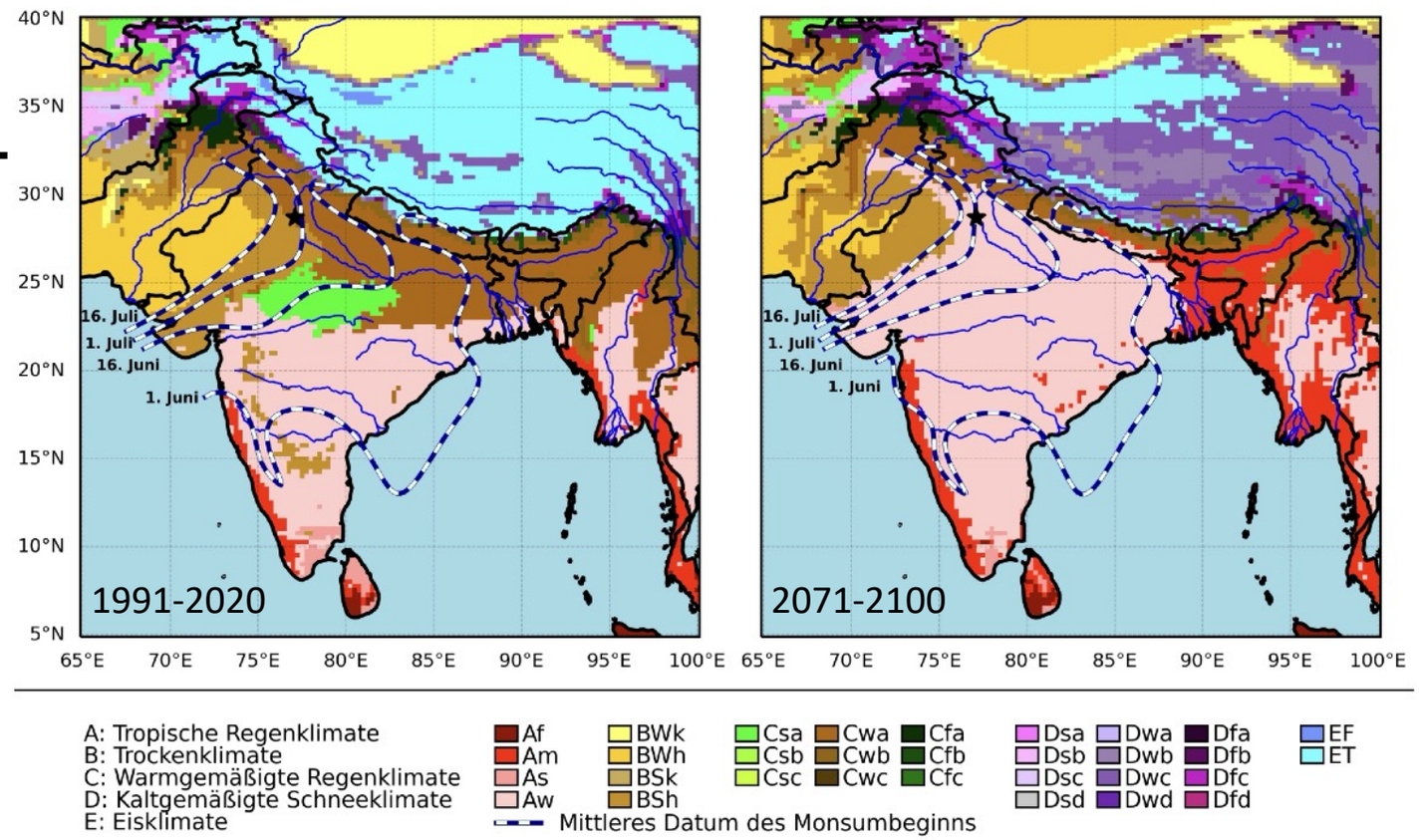
The study is significant as it reviewed the under sediment cores derived from the Krishna Godavari basin of the Bay of Bengal to understand how the monsoon rainfall pattern has changed in the past 2,000 years.

Indian Summer Monsoon Rainfall

IPCC AR6 (2021): "*high confidence* that anthropogenic aerosol emissions have dominated the observed [ISMR] declining trends".

With stronger warming & less air pollution trend reversal from ~2150.

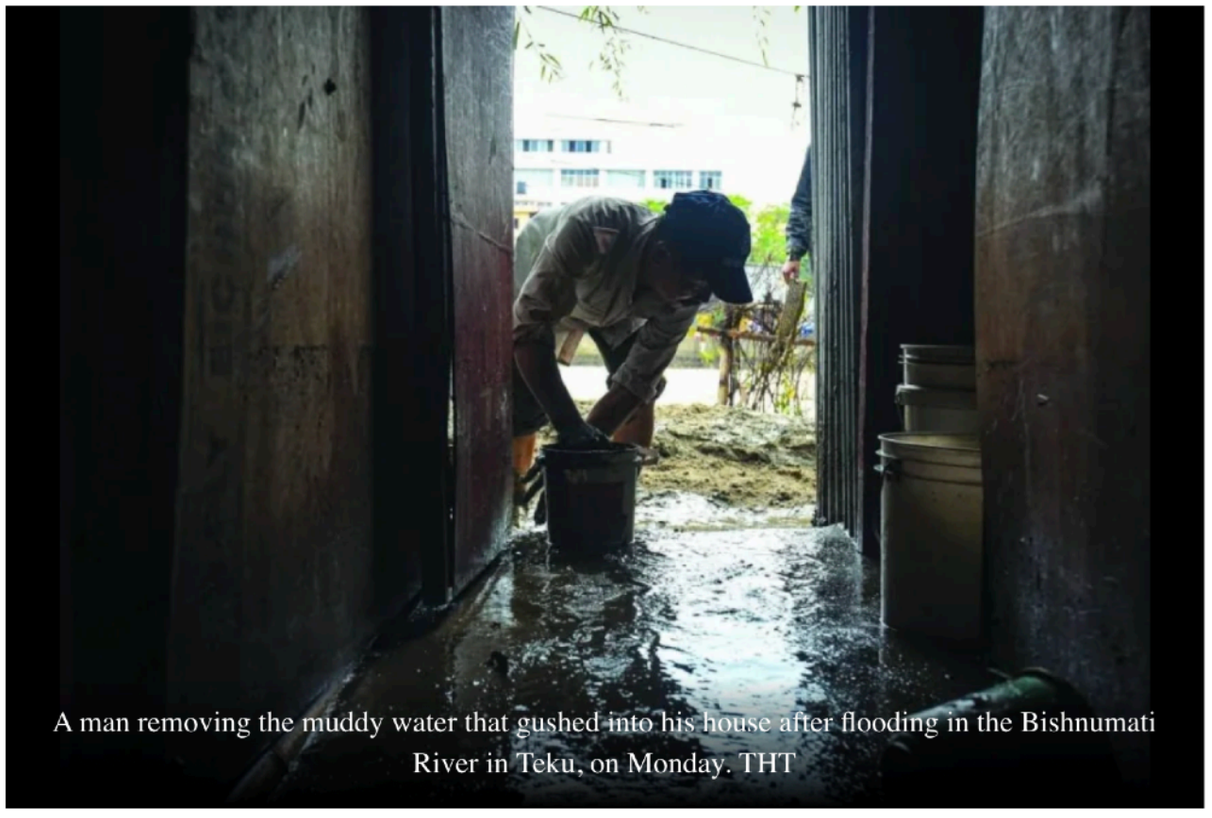
Koeppen-Geiger-C. + ISMR onset



Ahrens (GR, 2024)

Midnight flash flood wreak havoc in valley

By Ujjwal Satyal
Published: 10:41 am Sep 07, 2021



A man removing the muddy water that gushed into his house after flooding in the Bishnumati River in Teku, on Monday. THT

400 houses inundated Kathmandu records highest rainfall in last 13 years

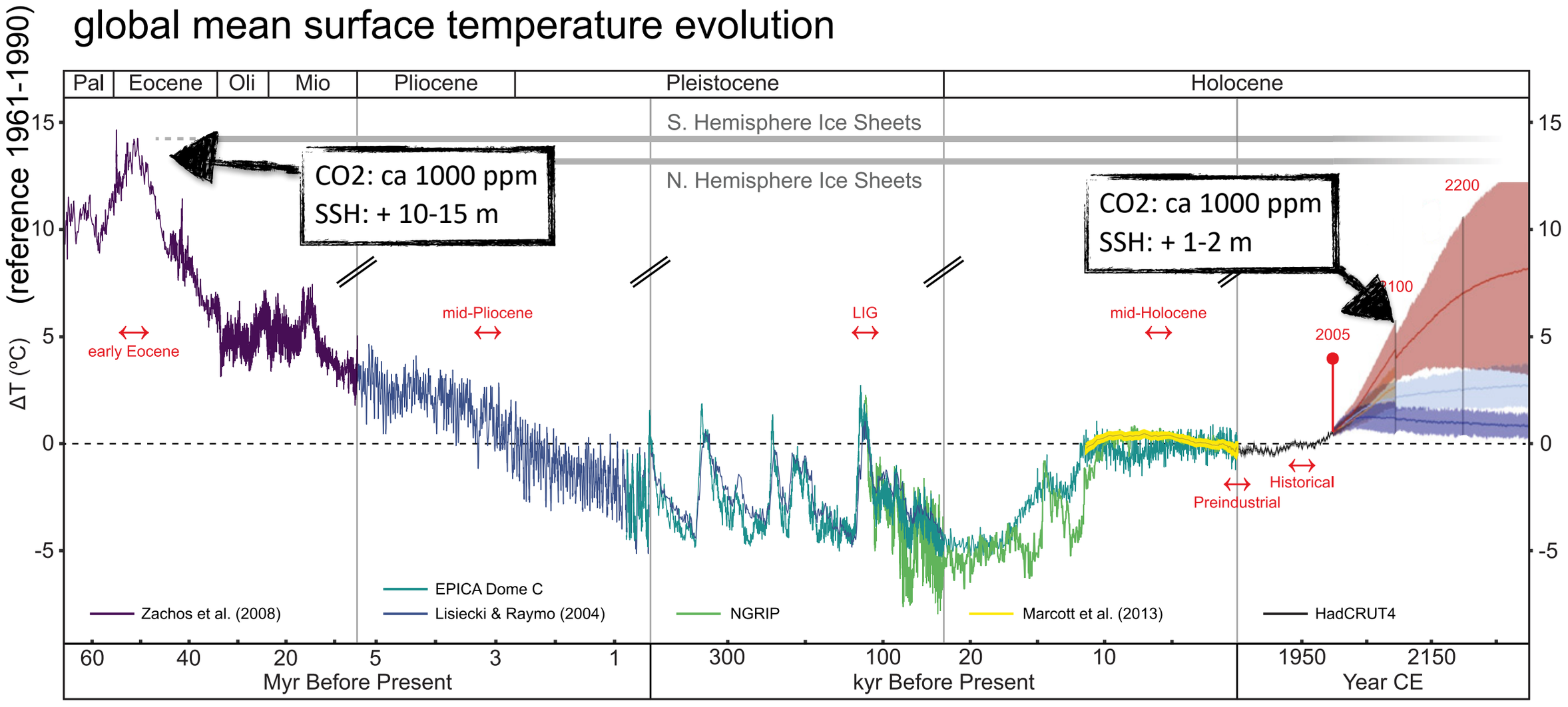
Conclusions

- global mean temperature raise unstoppable (virtually certain)
=> adapt + mitigate

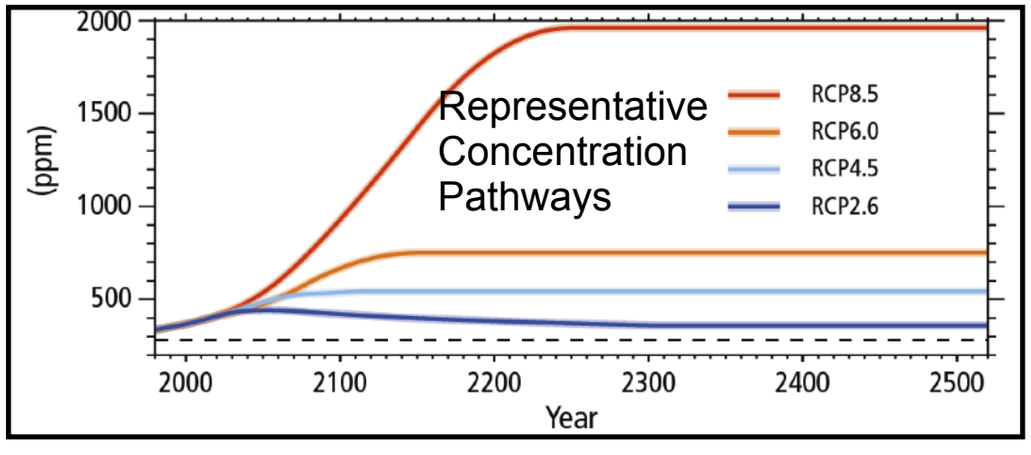
- change not homogeneous in space and time with locally different changes in extremes (e.g. more heat waves & more flash floods, but less rain-on-snowmelt floods)
=> strengthen resilience

scientific challenges:
* better, more detailed long-term climate system predictions
* better and reliable short-term warnings of the public

Climate Change - long-term perspective



climate reconstruction | -projections



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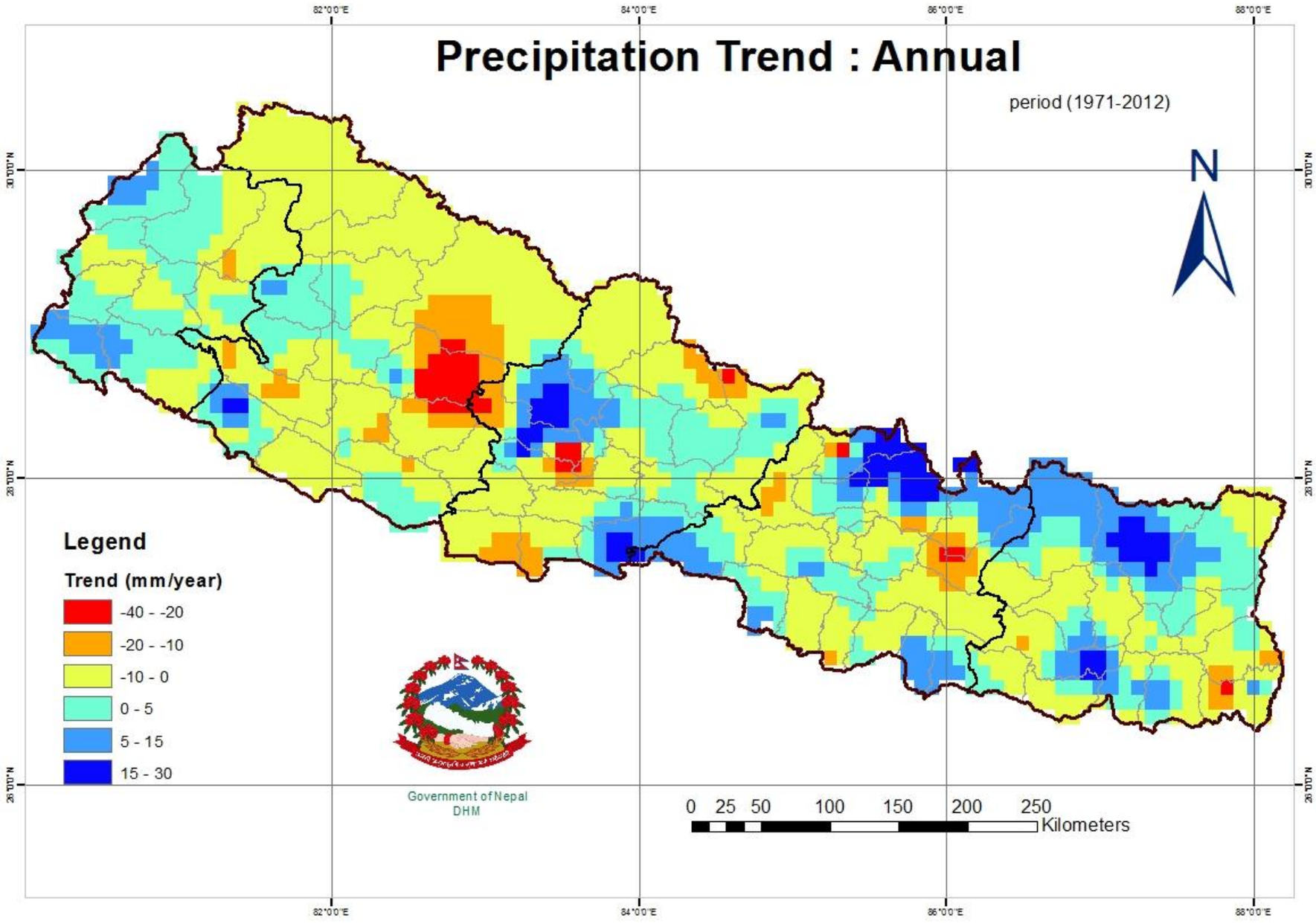
flood 2002

heatwave 2003

Precipitation trends?



DHM (2015)

Precipitation

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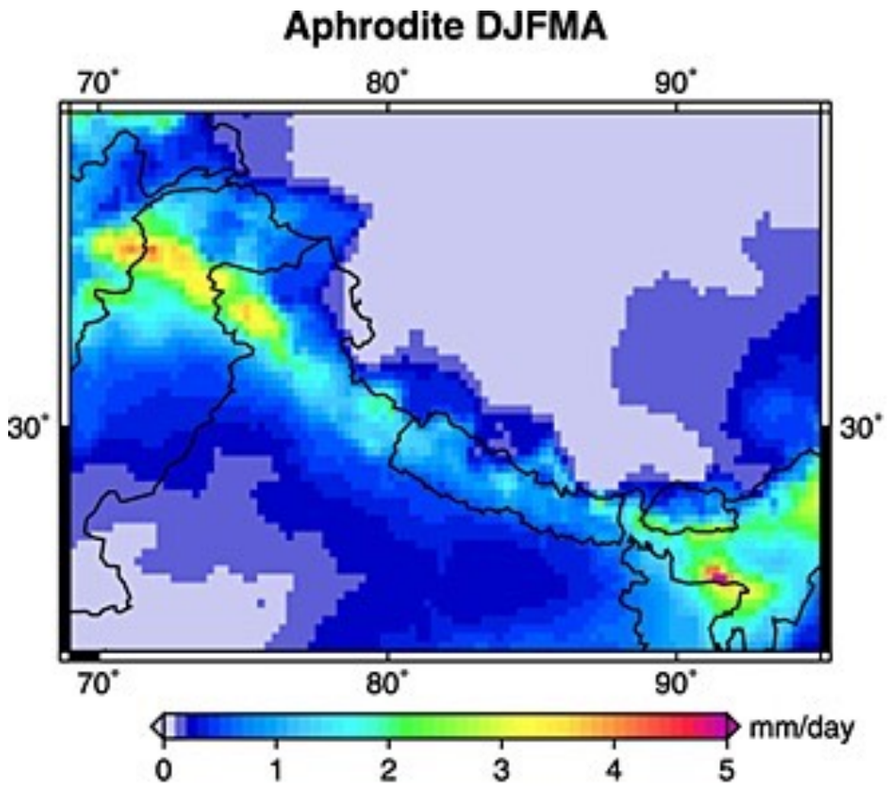
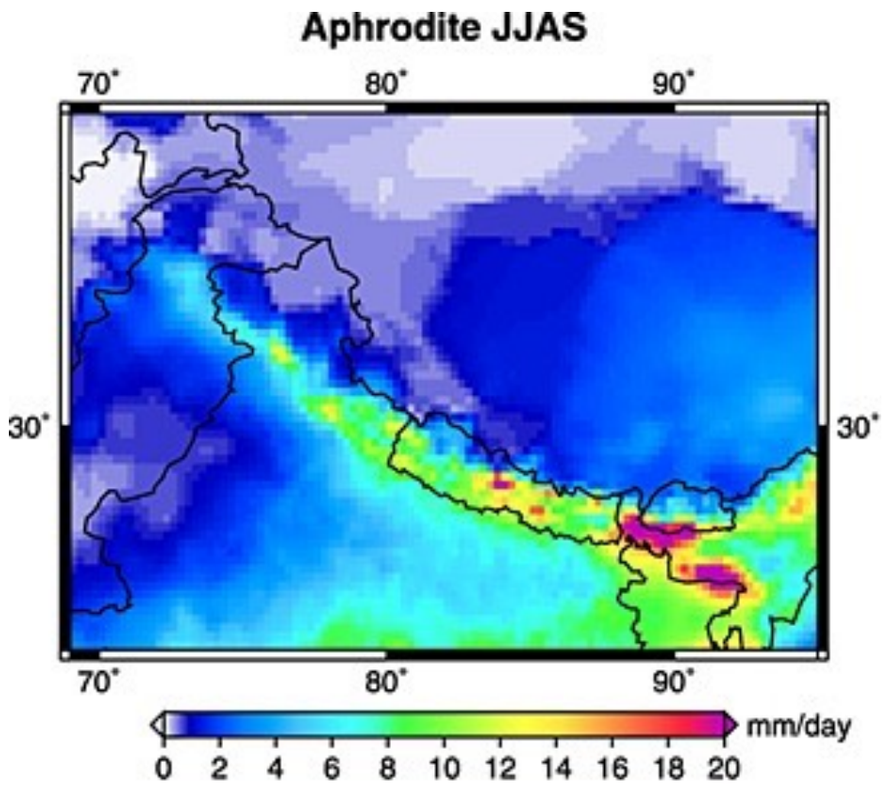
westerlies



summer monsoon



Palazzi et al. (2013)

!different scales!

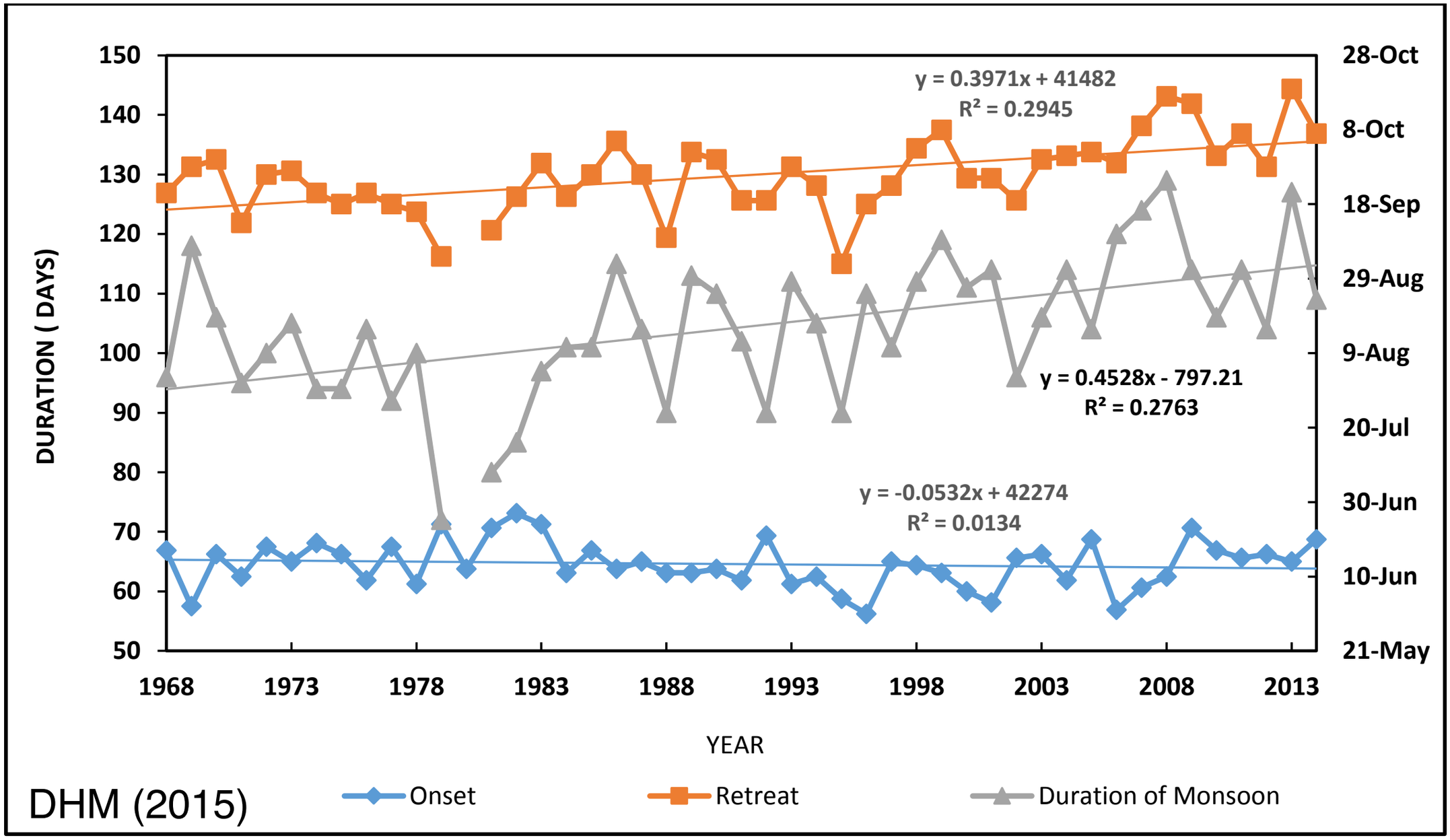
Nepalese Army removes avalanche victims

extremes in all seasons!

Oct. 2015: tropical storm Hudhud merged with a short-wave trough

-> rare tropical-extratropical interaction

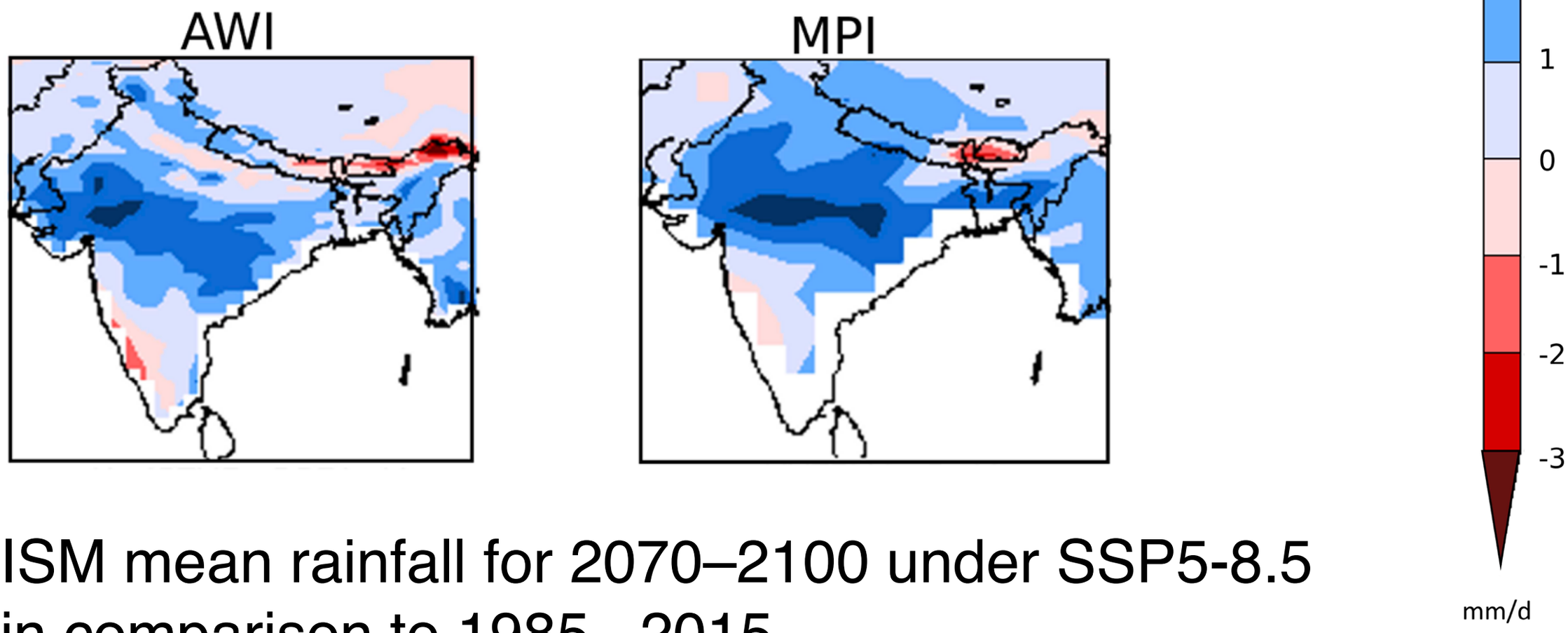
Monsoon Trends in Nepal?



-> duration of monsoon increasing by about 5 days/decade

Indian Summer Monsoon

Future:



ISM mean rainfall for 2070–2100 under SSP5-8.5 in comparison to 1985– 2015.

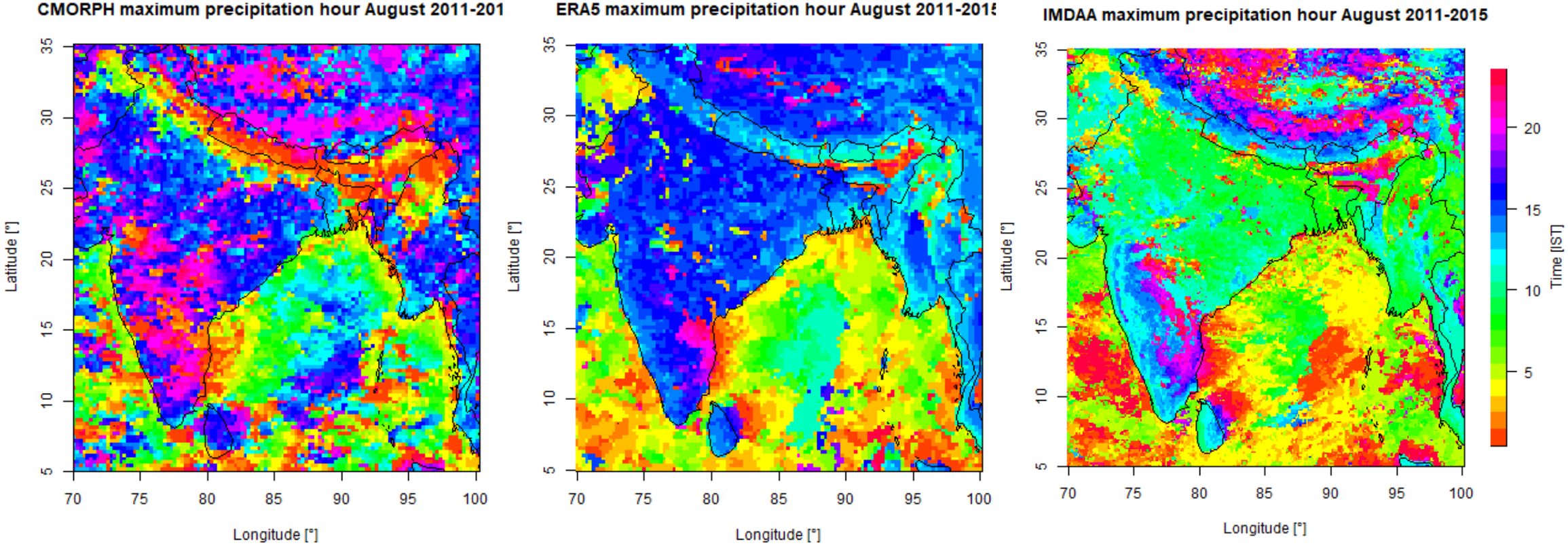
Katzenberger et al. (2021)

Indian Summer Monsoon

Projection challenges:

- difficulties in predictor (ENSO,IOD) - ISMR representation in Global Climate Models (e.g. Pothapakula et al. 2020)

- difficulties in repr. of local processes (Ahrens et al. 2020)



CMORPH ERA5 IMD RA

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