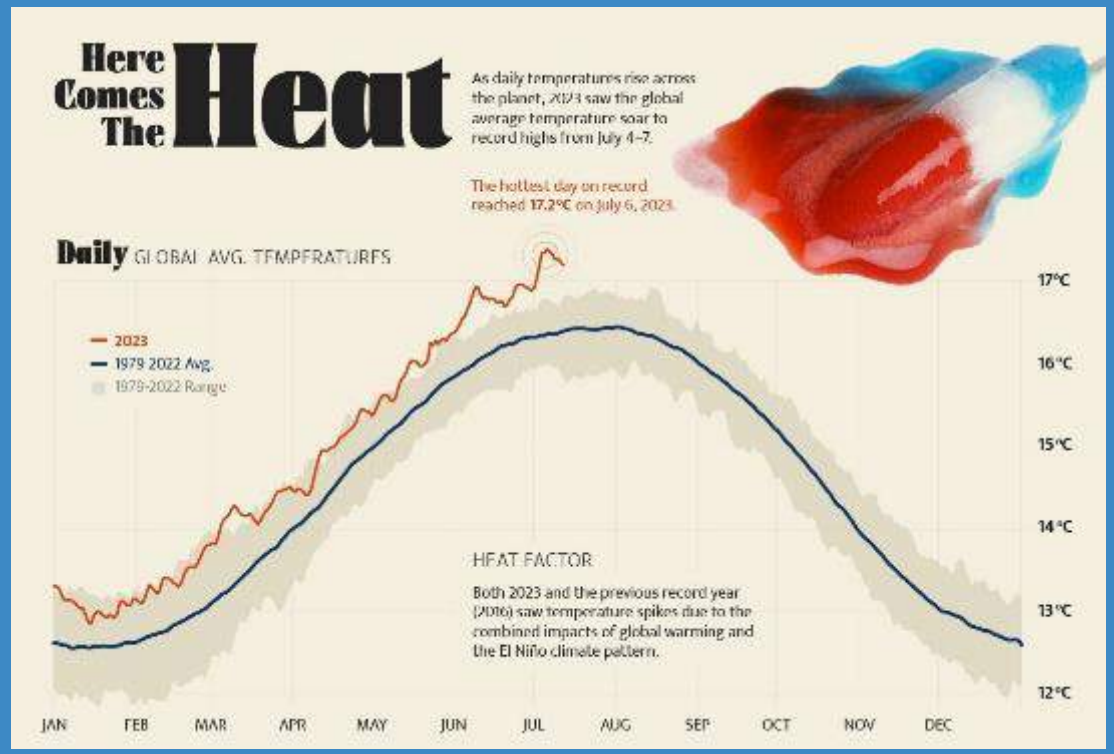
Human activities and climate change over Asia : Attribution and projection

Jie Jiang

Thanks to Pro. Tianjun Zhou and Dr. Wenxia Zhang

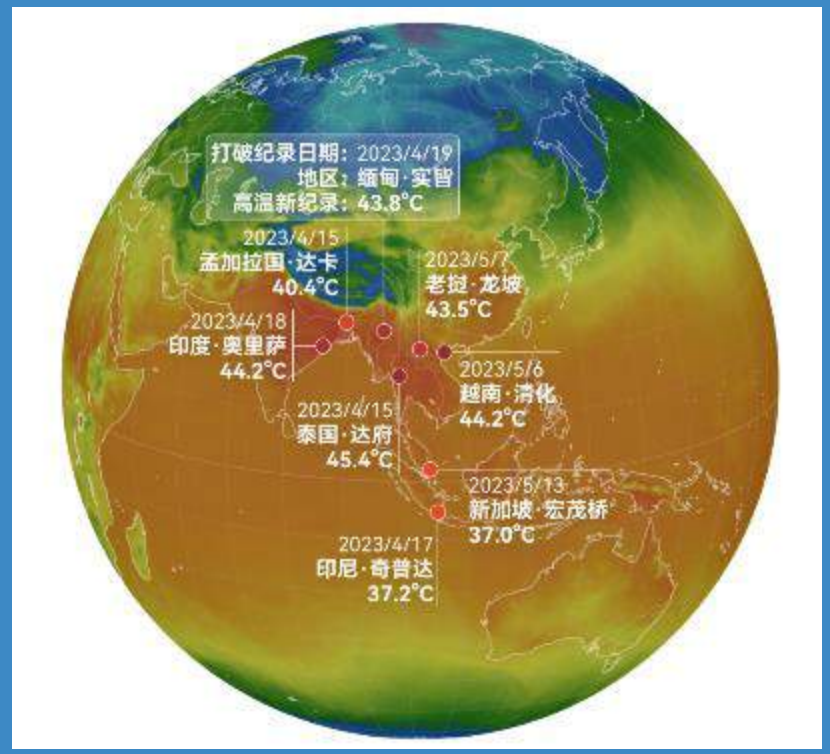
Institute of Atmospheric Physics, Chinese Academy of Sciences

Heat wave: global, 2023



The planet experienced its hottest day ever on 6 July

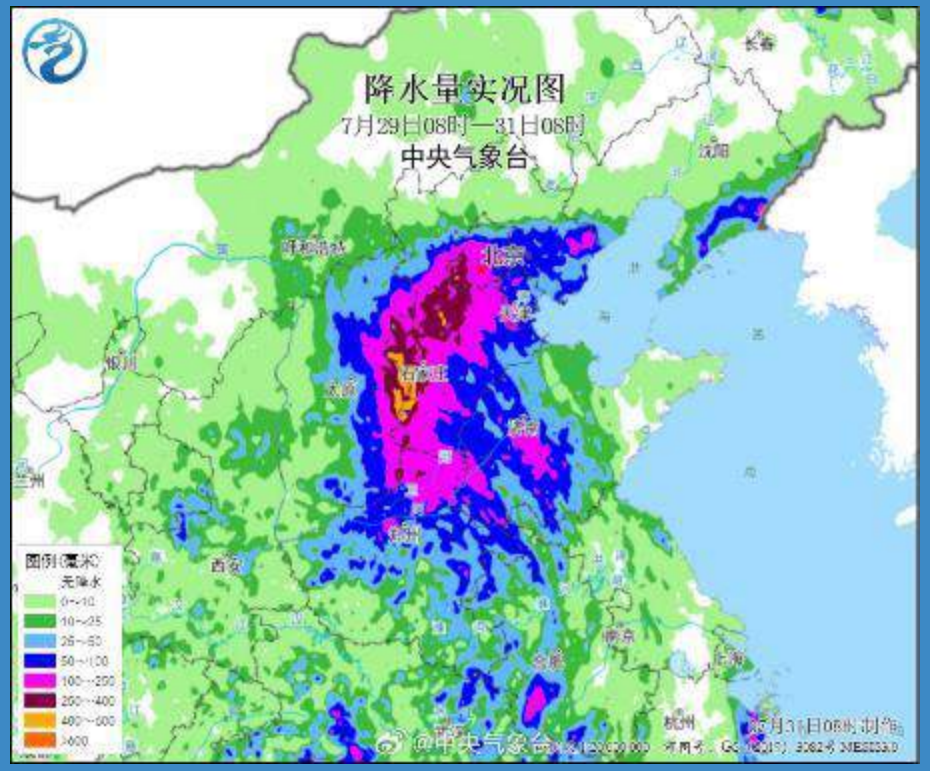
https://www.weforum.org/agenda/2023/07/climate-2023-hottest-year-on-record/



Record-breaking temperature in April-May

https://www.thepaper.cn/newsDetail_forward_23031789

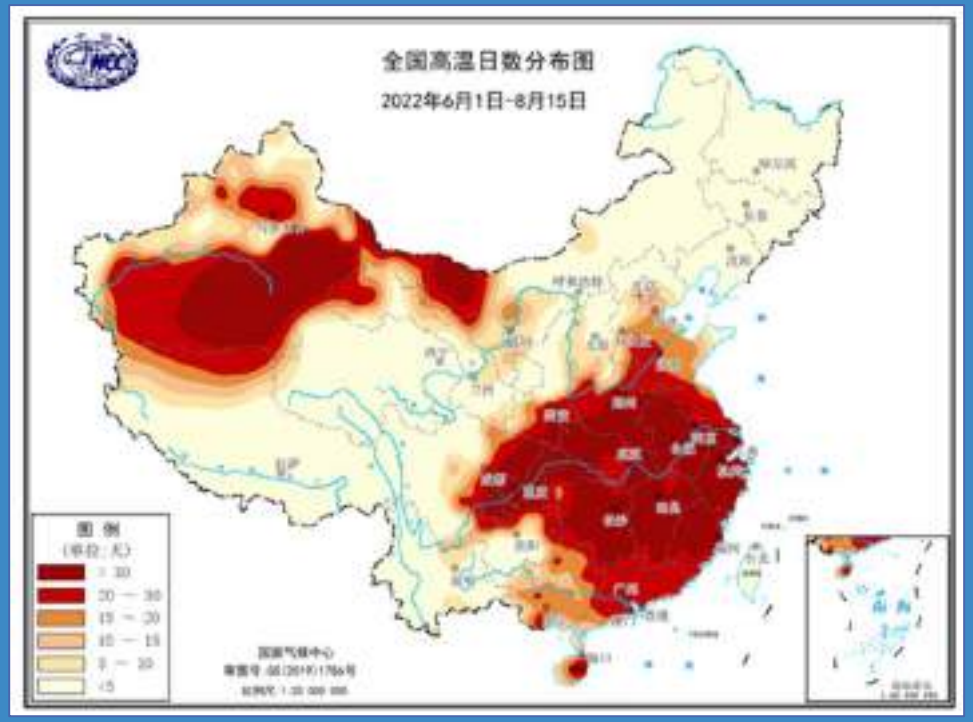
Extreme precipitation：North China，July 2023



Precipitation amount in 29-31 July

Floods triggered by heavy rains

Heat wave and drought：Yangtze valley，summer in 2022



The heat wave lasted for 79 days and more than 1 million square kilometers of the area is affected by high temperature more than 40℃

Hill fire induced by heat wave and drought in Chongqing on 19 August

Extreme precipitation：Pakistan，summer in 2022

Rainfall is equivalent to 2.9 times the national 30-year average on 27 August and caused widespread flooding and landslides. The floods submerged one third of the country, affecting 33 million people.

[Credit: NASA]

Recent changes in the climate are widespread, rapid, and intensifying, and unprecedented in thousands of years.

-- IPCC AR6

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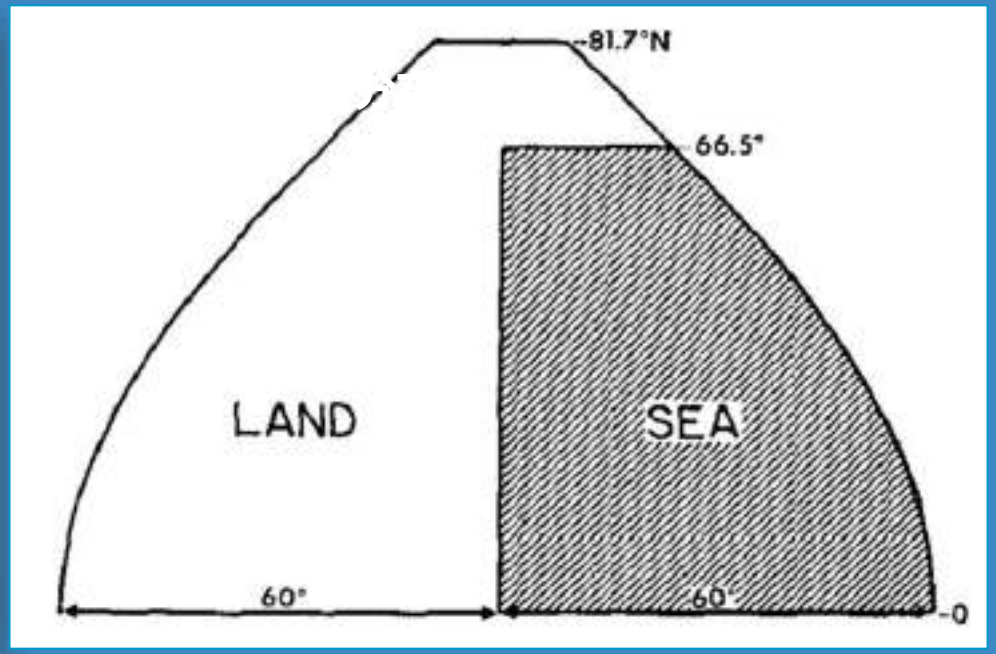
Why there are more frequent extremes?

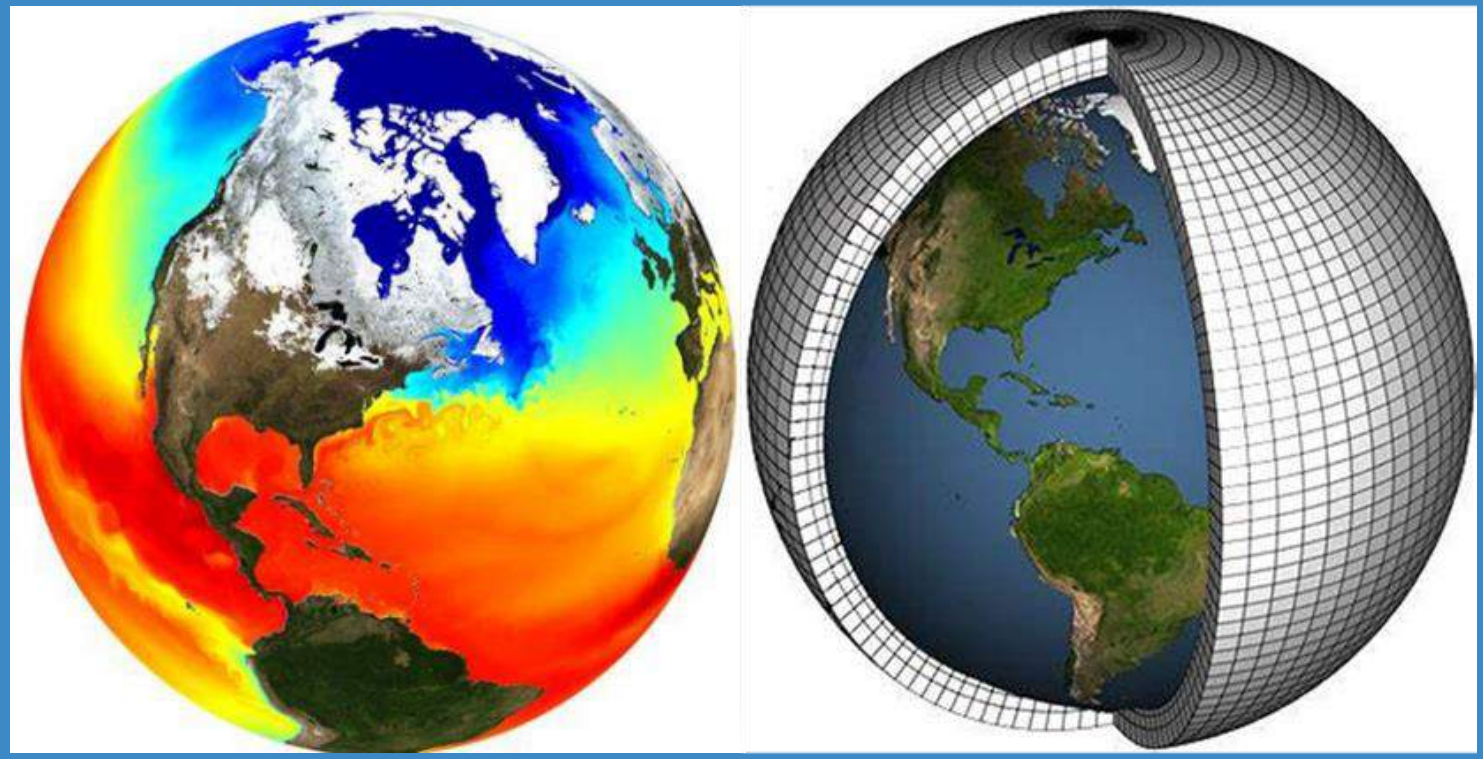
Climate model：An indispensable tool for climate change study



The first credible three-dimensional atmospheric climate model in 1975

Syukuro Manabe
Nobel Prize winners in physics (2021)

Climate model：Digital Twin Earth



Climate models use mathematical equations to characterize how energy and matter interact in different parts of the ocean, atmosphere and land.

Earth System Numerical Simulation Facility

Located in Huairou Science City in Beijing

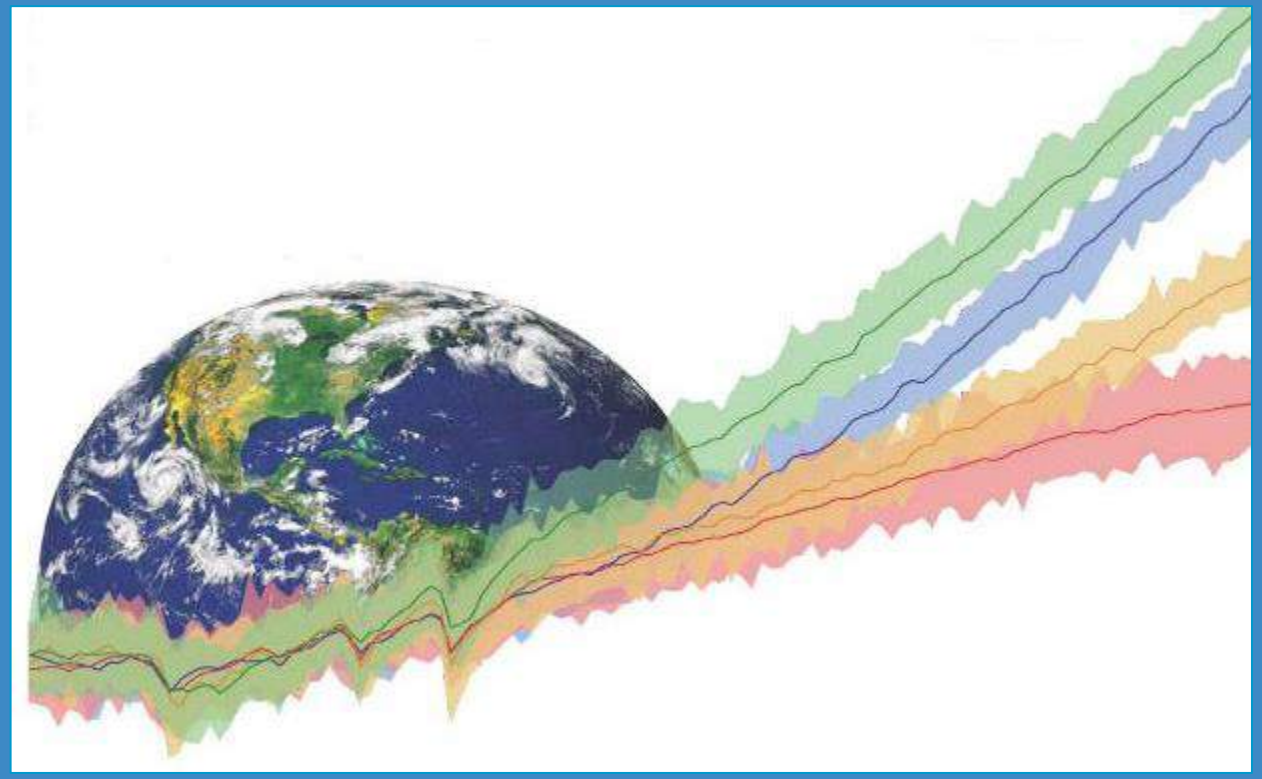
The gate for the science park

Earth System Numerical Simulation Facility

Interior of the super computer

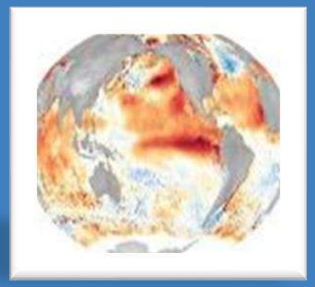
Data analysis center

Machine room



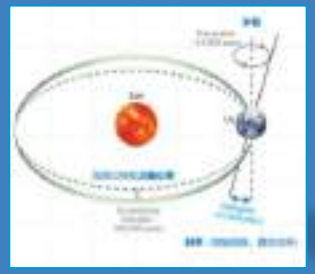
Climate models help us to understand the past climate changes and project future changes

Identify the ‘fingerprint’ of anthropogenic forcing

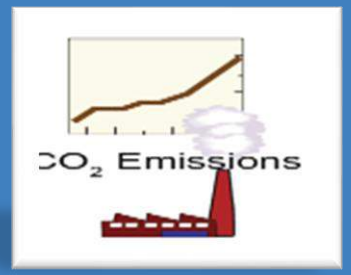


Internal variability

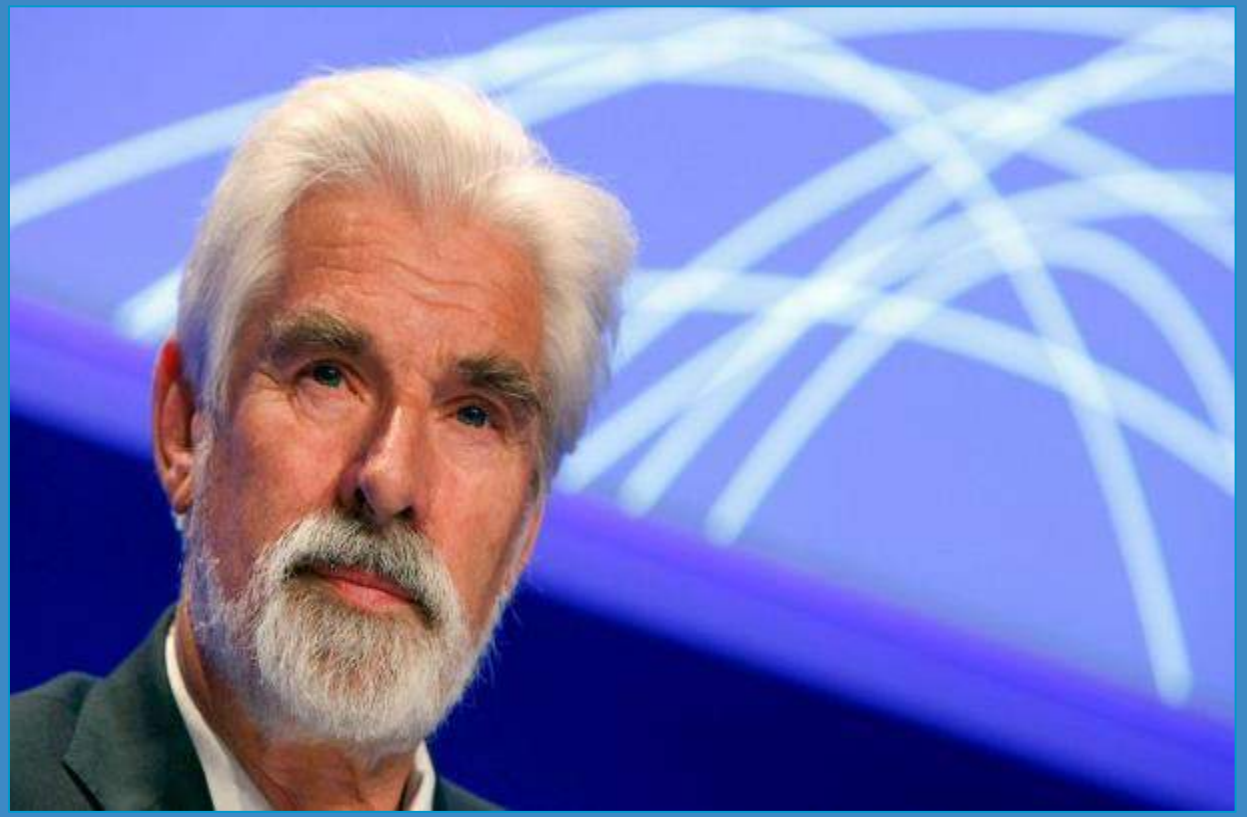
Volcano



Orbital parameter/
Solar activity



Anthropogenic forcing
(e.g., GHG, aerosol,
land use)



Klaus Hasselmann
Nobel Prize winners in physics (2021)

Climate change is already affecting every inhabited region across the globe, with human influence contributing to many observed changes in weather and climate extremes

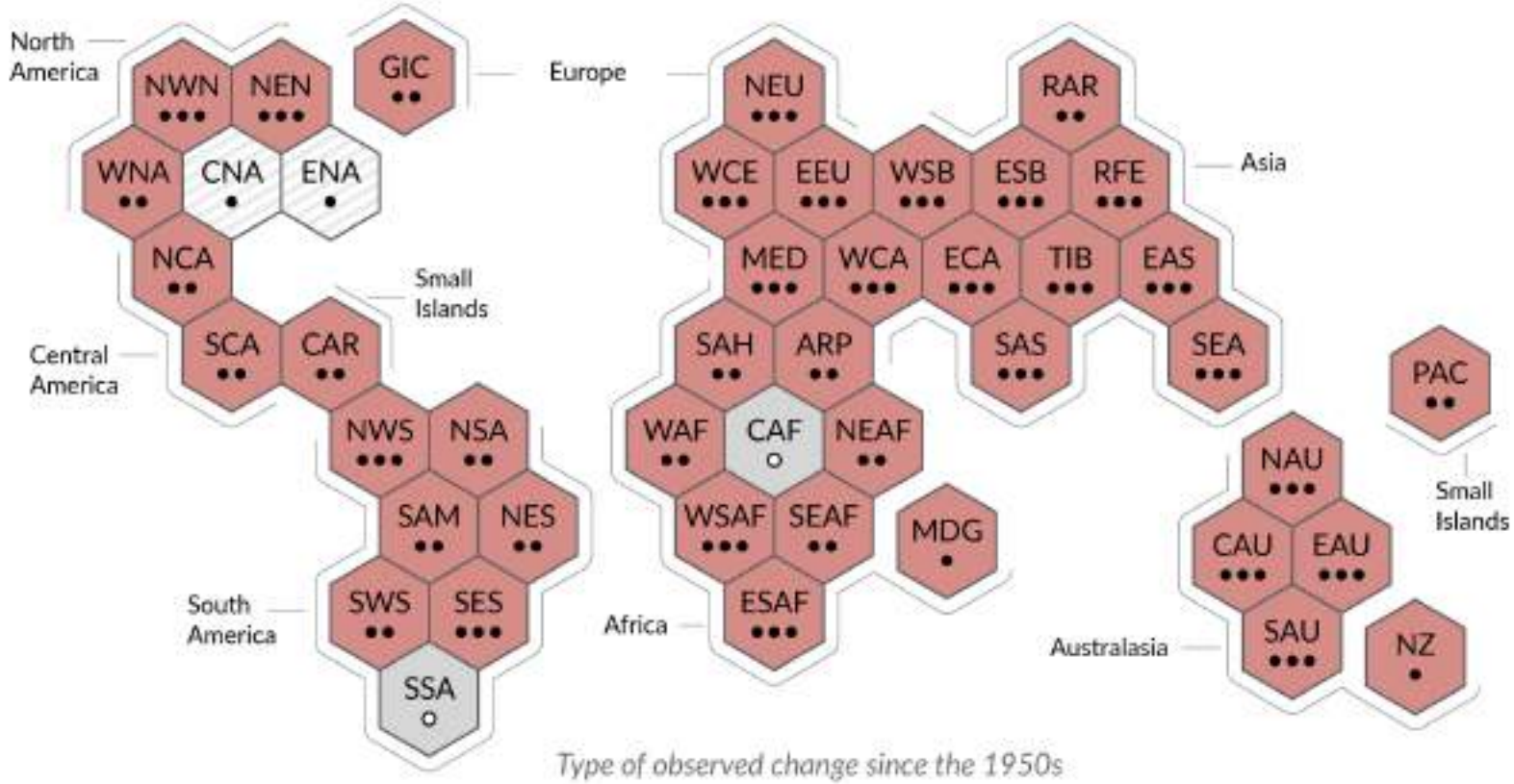
a) Synthesis of assessment of observed change in **hot extremes** and confidence in human contribution to the observed changes in the world's regions

Type of observed change in hot extremes

- Increase (41)
- Decrease (0)
- Low agreement in the type of change (2)
- Limited data and/or literature (2)

Confidence in human contribution to the observed change

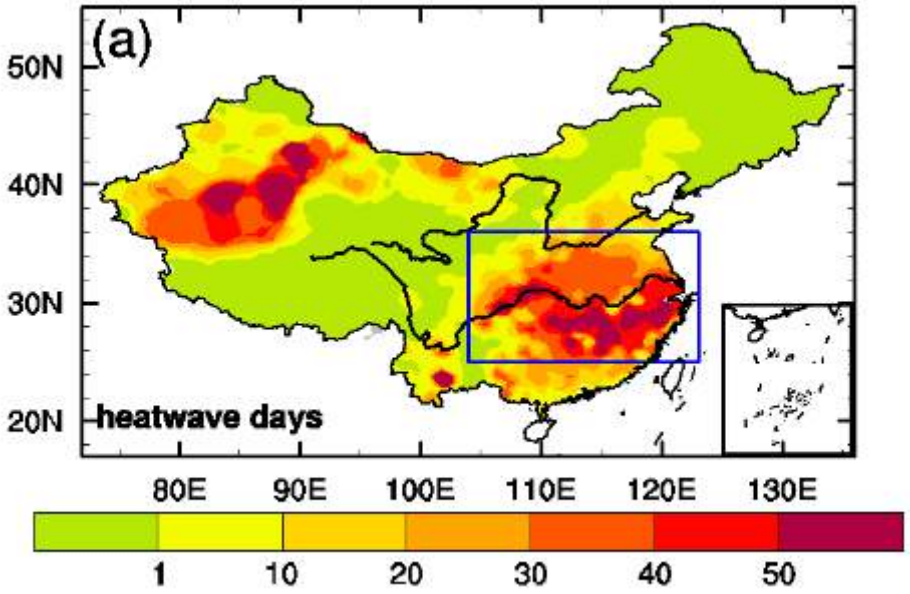
- ●●● High
- ●● Medium
- ● Low due to limited agreement
- ○ Low due to limited evidence



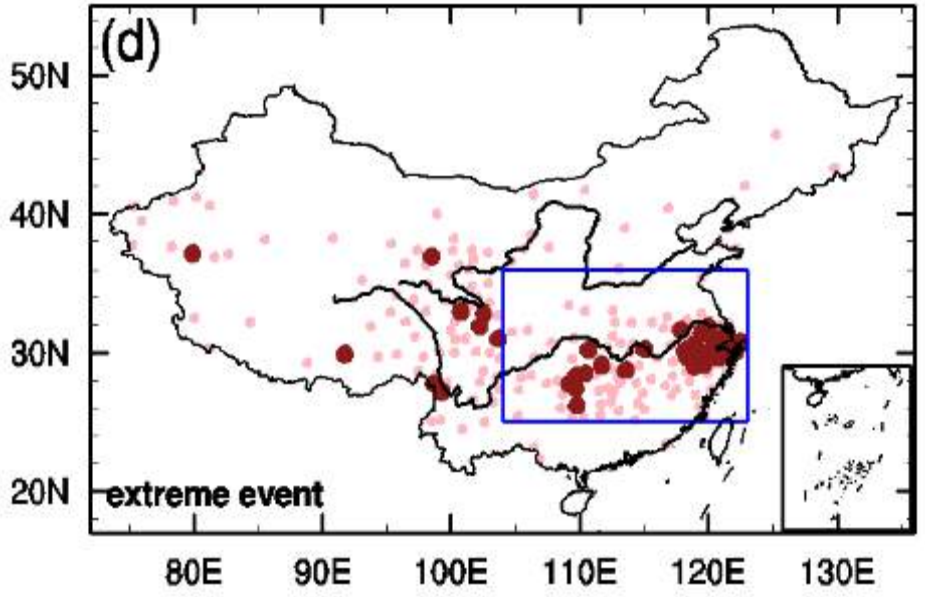
Type of observed change since the 1950s

IPCC AR6 Figure SPM.3

CASE#1: Record-breaking heatwave of 2013 over eastern China



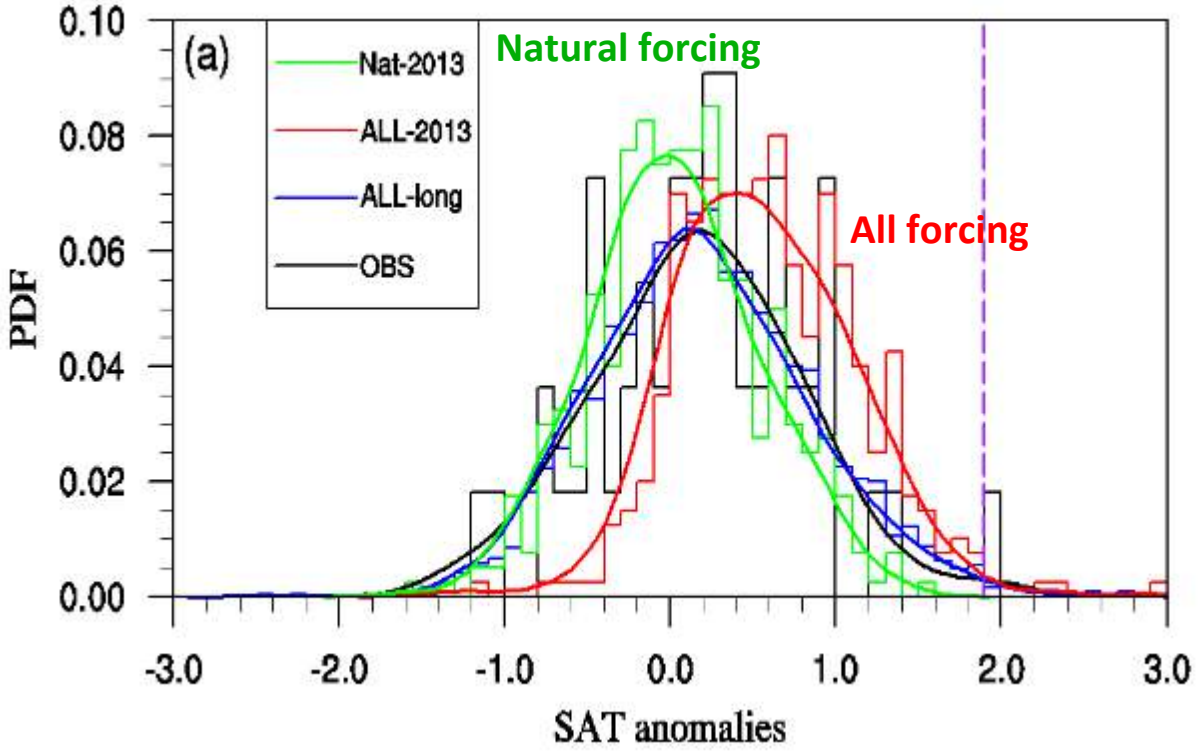
Number of heat-wave days (daily maximum temperature Tmax ≥ 35℃) in 2013



Stations where the daily maximum temperatures exceeded the observed records

Ma S., Zhou T., Stone D., Angelil O., Shiogama H. 2017: Attribution of the July-August 2013 Heat Event in Central and Eastern China to Anthropogenic Greenhouse Gas Emissions. *Environmental Research Letters*, 12 (2017) 054020.

Histogram (bars) and probability density functions (curve) of July–August SAT anomalies averaged over Central and Eastern China

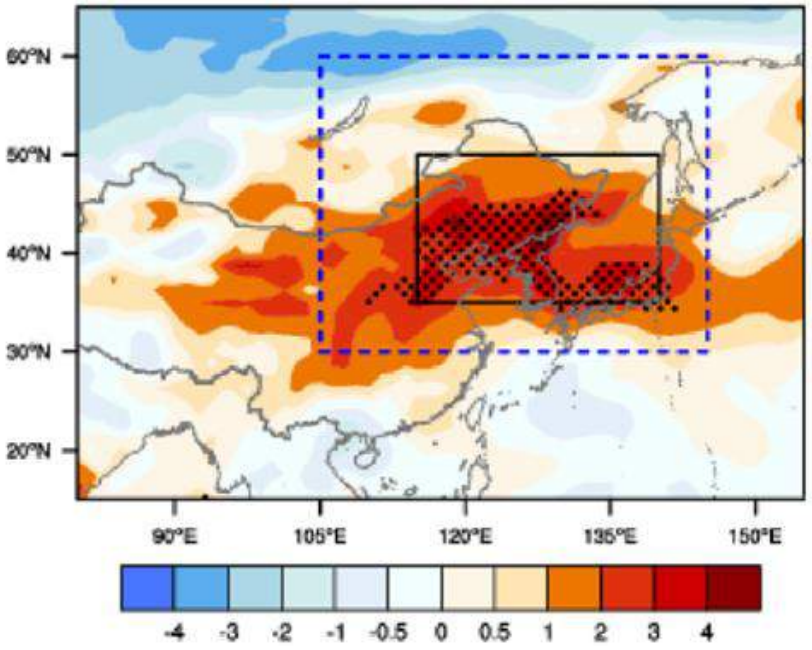


- **Probability Ratio : 17.8**
- Both internal variability and anthropogenic factors contributed to the observed heat extreme
- The anthropogenic influence has clearly increased the chance of heat wave occurrence such as the 2013 event

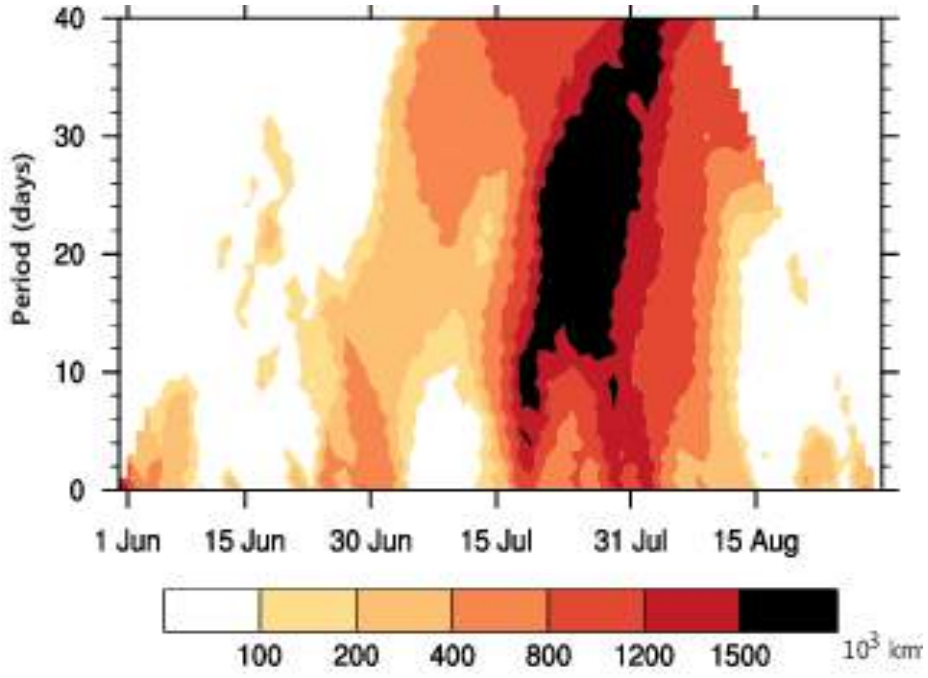
Ma S., Zhou T., Stone D., Angelil O., Shiogama H. 2017: Attribution of the July-August 2013 Heat Event in Central and Eastern China to Anthropogenic Greenhouse Gas Emissions. *Environmental Research Letters*, 12 (2017) 054020.

CASE#2: Record-breaking heat wave over Northeast Asia in summer 2018

Maximum T2m anomalies for 21days average in summer 2018



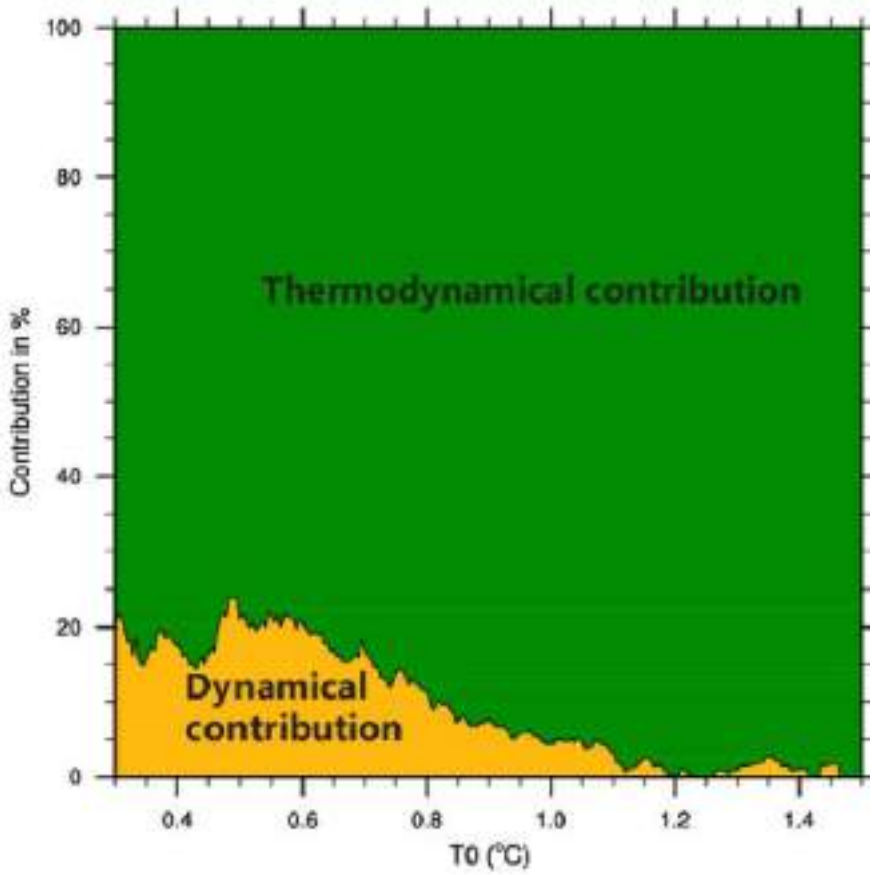
Temporal evolution of the spatial extent of areas with record-breaking temperatures



The July-August 2018 extreme heat wave lasted almost one month, affected a wide area in the northeast China, Korea peninsula and Japan, and displayed a record-breaking intensity since 1958.

Ren, L. et al. 2020. Attribution of the record-breaking heat event over Northeast Asia in summer 2018: the role of circulation. *Environmental Research Letters*, 15 054018.

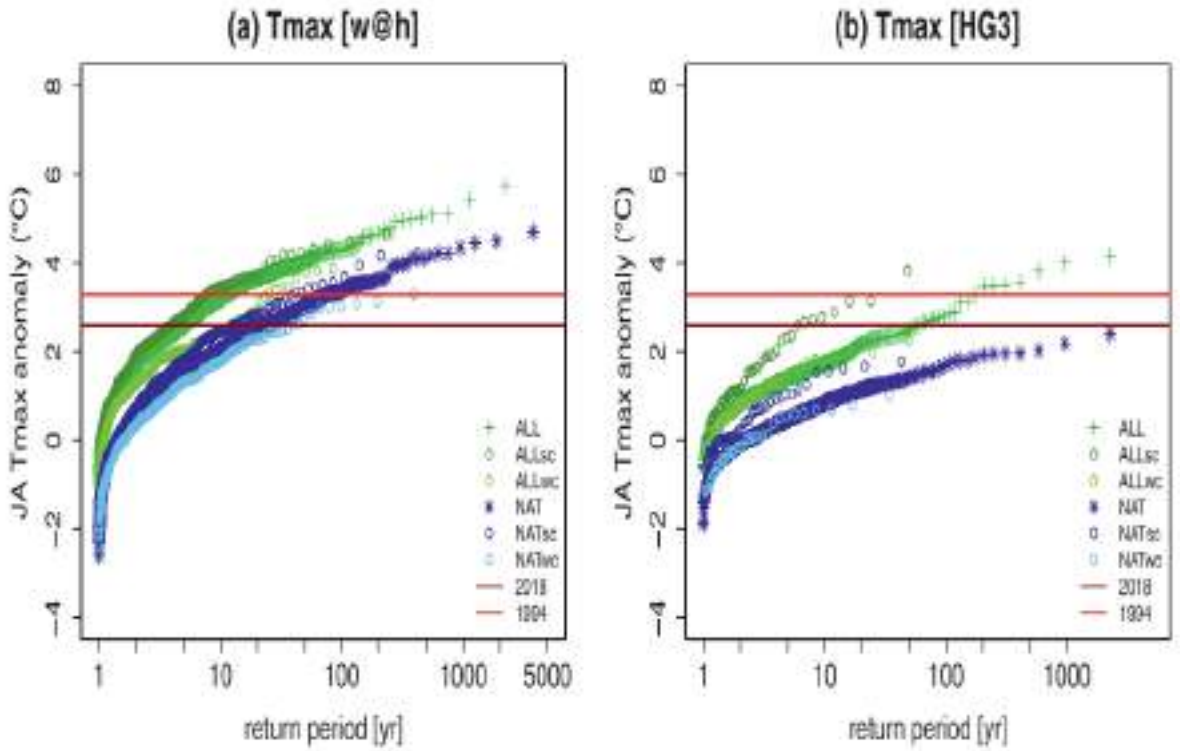
Dynamical and thermodynamical contributions to the increases in probabilities of heat events in recent decades



- **Dynamical change contribution:** less than 20% of the increases in probability of heat events
- **Thermodynamical change contribution:** increases with the rarity of extreme event
- **Implication:** the probability of 2018-like record-breaking heat event will increase associated with global warming

Ren, L. et al. 2020. Attribution of the record-breaking heat event over Northeast Asia in summer 2018: the role of circulation. *Environmental Research Letters*, 15 054018.

The 2018 summer longest heat wave in South Korea



Weather@home	HadGEM3-A-N216
HadRM3P RCM driven by the HadAM3P ~ 50km	AGCM ~ 0.83° × 0.56°
ALL: prescribed SST/SIC & observed GG/AA forcing; **NAT:** adjusted observed SST/SIC & ANT change removed GG/AA forcing;	
13 different estimate of the anthropogenic SST changes (delta-SST)	single estimate of the anthropogenic SST changes (delta-SST)
2300 members (ALL） 3700 members (NAT）	525 members (ALL） 525 members (NAT）
PR = 4.7	**PR = 6.5**

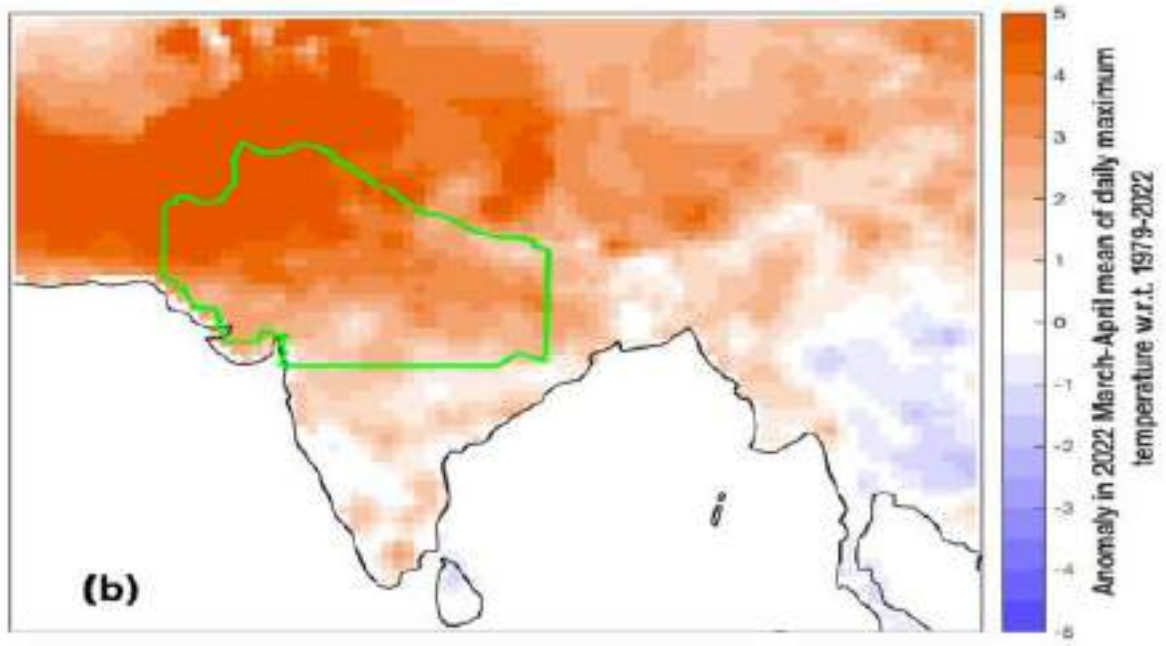
Human activities have at least quadrupled the probability

(Courtesy to Dr. Min)

Min, S. et al. 2020. Quantifying human impact on the 2018 summer longest heat wave in South Korea. *Bull. Amer. Meteor. Soc*. 101(1), S103-S108.

CASE#3: A heatwave hit India and Pakistan early in 2022

2022 Mar-Apr daily max temp anomaly



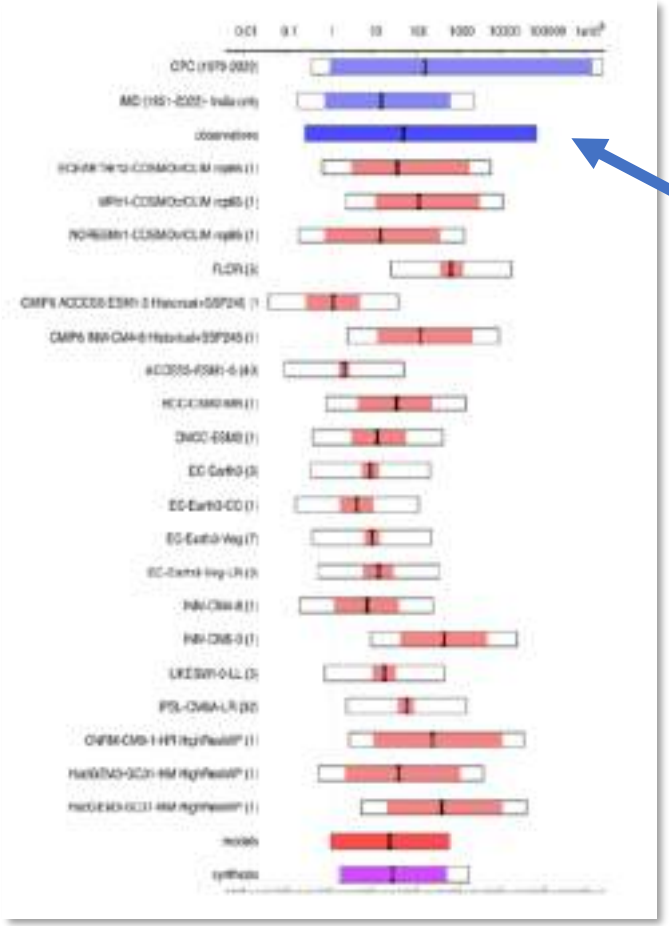
March 2022 was the hottest in India over the past 122 years

An intense heatwave has been sweeping through northern Indian with temperature hitting a record 49.2 ℃ in parts of the capital, Delhi

https://www.jagonews24.com/en/international/news/61817

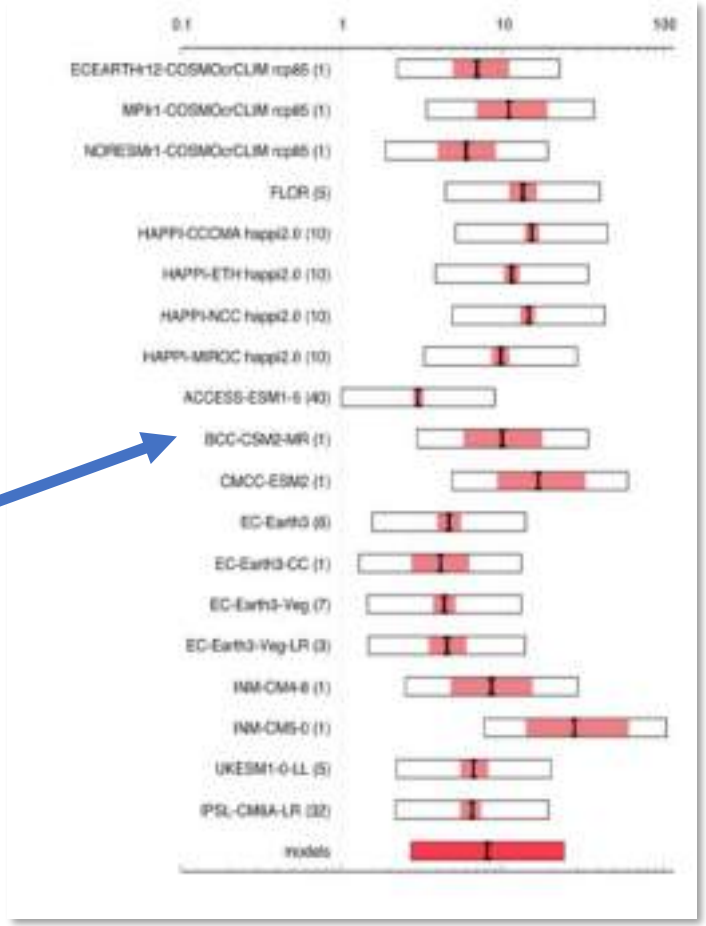
world weather attribution

Multi-model attribution: Probability ratio of the heatwave due to historical warming (left) and in a 2°C warmer future (right)



- Climate Change made devastating early heat in India and Pakistan 30 times more likely

- The change in probability for 2.0°C global warming is PR= 8 and an additional increase in intensity of 1°C.



(Courtesy to Dr. Zachariah)

Zachariah et al., 2022: Climate Change made devastating early heat in India and Pakistan 30 times more likely – World Weather Attribution

world weather attribution

Climate change is already affecting every inhabited region across the globe, with human influence contributing to many observed changes in weather and climate extremes

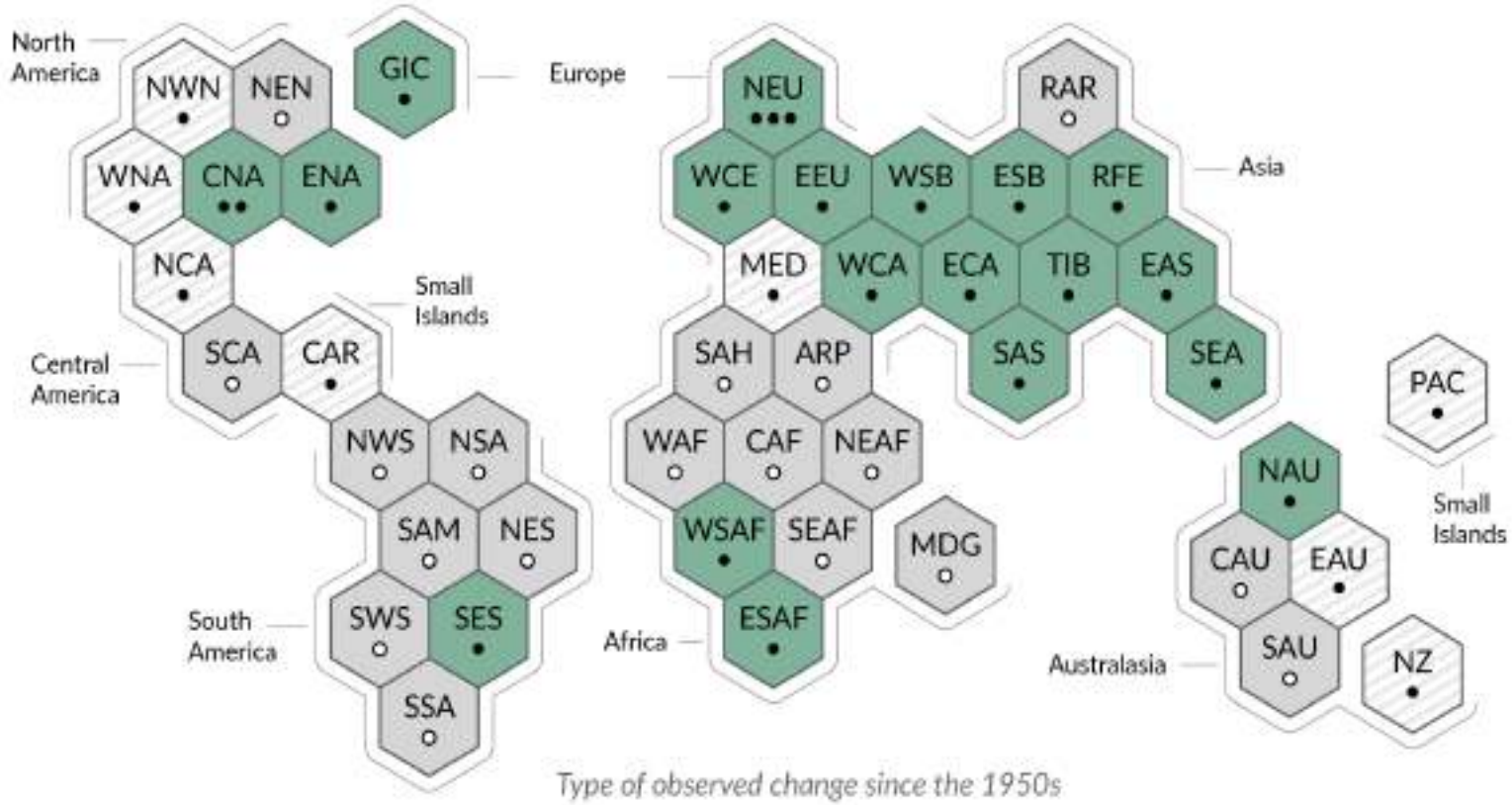
b) Synthesis of assessment of observed change in **heavy precipitation** and confidence in human contribution to the observed changes in the world's regions

Type of observed change in heavy precipitation

- Increase (19)
- Decrease (0)
- Low agreement in the type of change (8)
- Limited data and/or literature (18)

Confidence in human contribution to the observed change

- ●●● High
- ●● Medium
- ● Low due to limited agreement
- ○ Low due to limited evidence

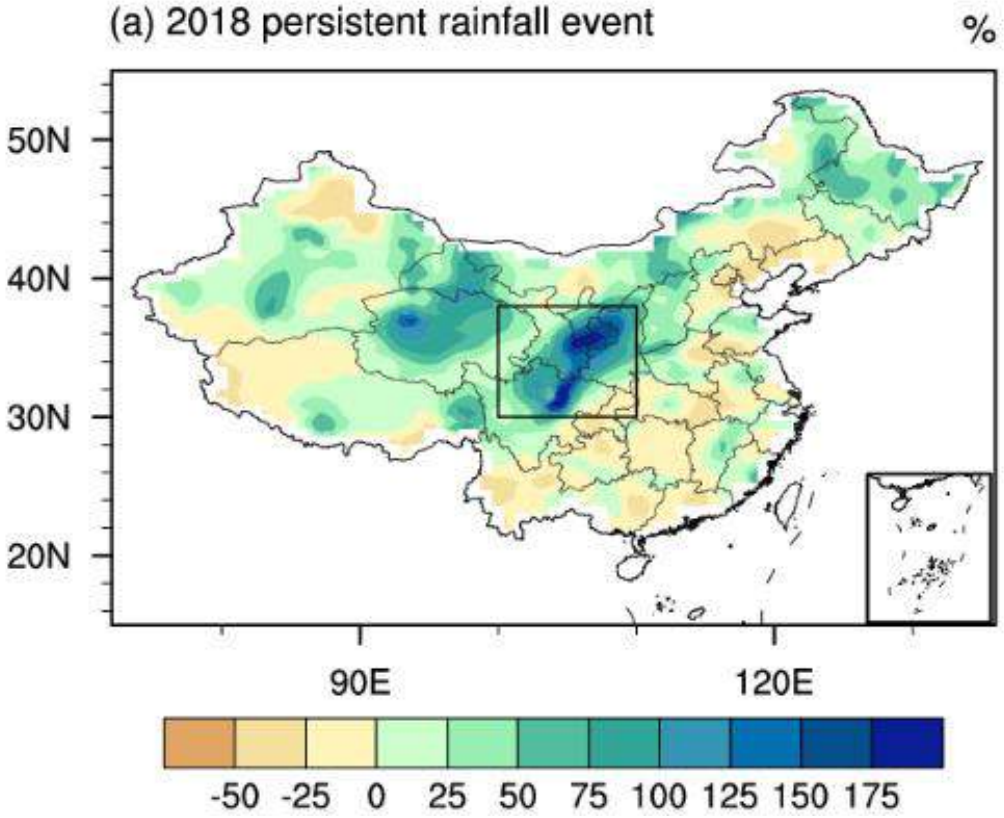


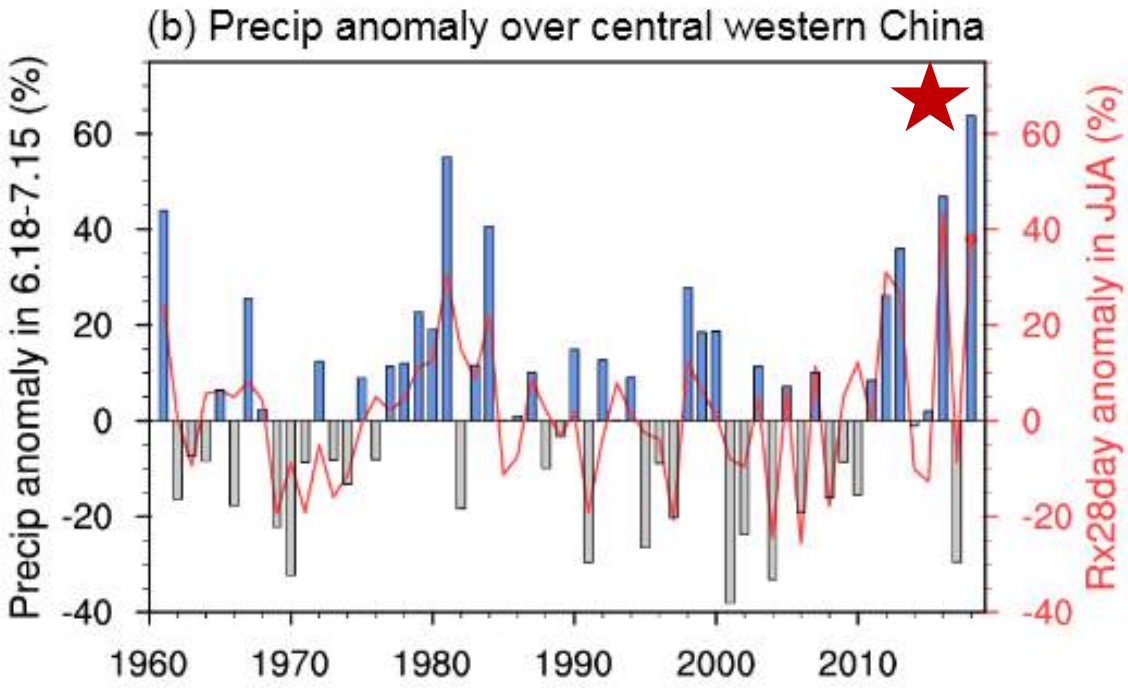
Type of observed change since the 1950s

IPCC AR6 Figure SPM.3

CASE#1: Persistent heavy rainfall in central-western China in summer 2018

4-week persistent heavy rainfall: 1-in-60-yr event in observations

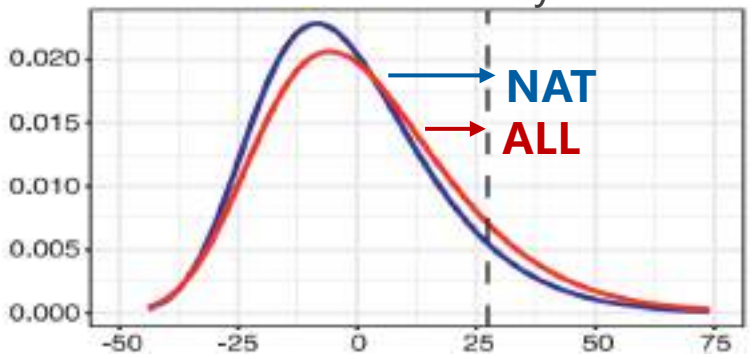




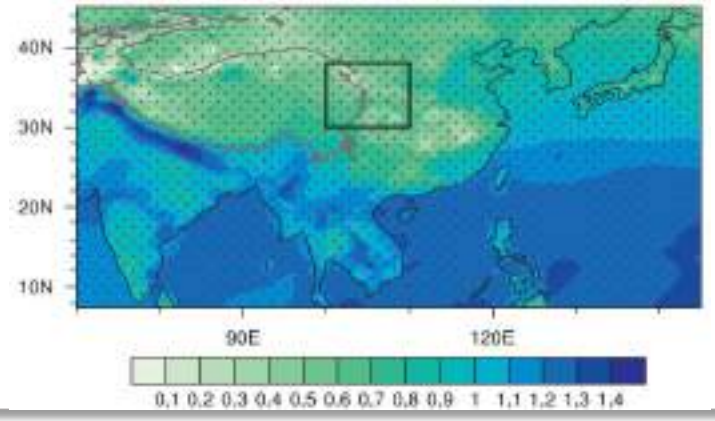
Zhang, W. et al. 2020. Anthropogenic influence on 2018 summer persistent heavy rainfall in central western China. *Bull. Amer. Meteor. Soc.* 101(1), S65-S70.

Anthropogenic forcing increases probability of Rx1day events

PDF of Rx1day

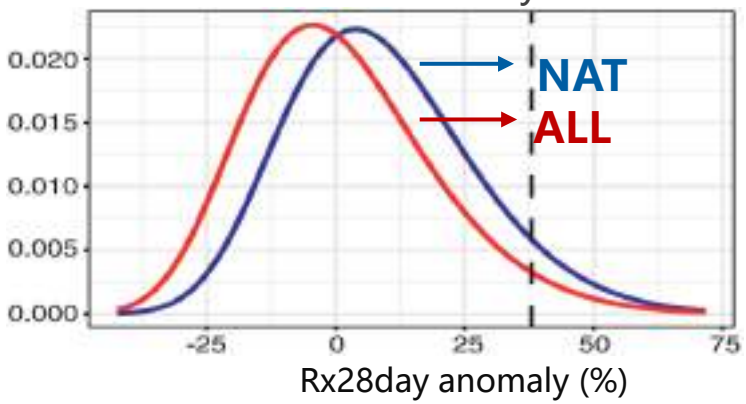


q850: ALL-NAT

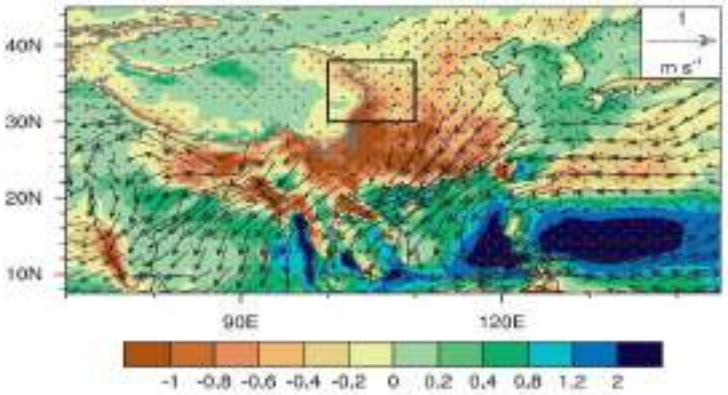


Anthropogenic forcing decreases probability of Rx28day events

PDF of Rx28day



EASM pr and circulation: ALL-NAT



Human influence on extreme precipitation depends on time scale

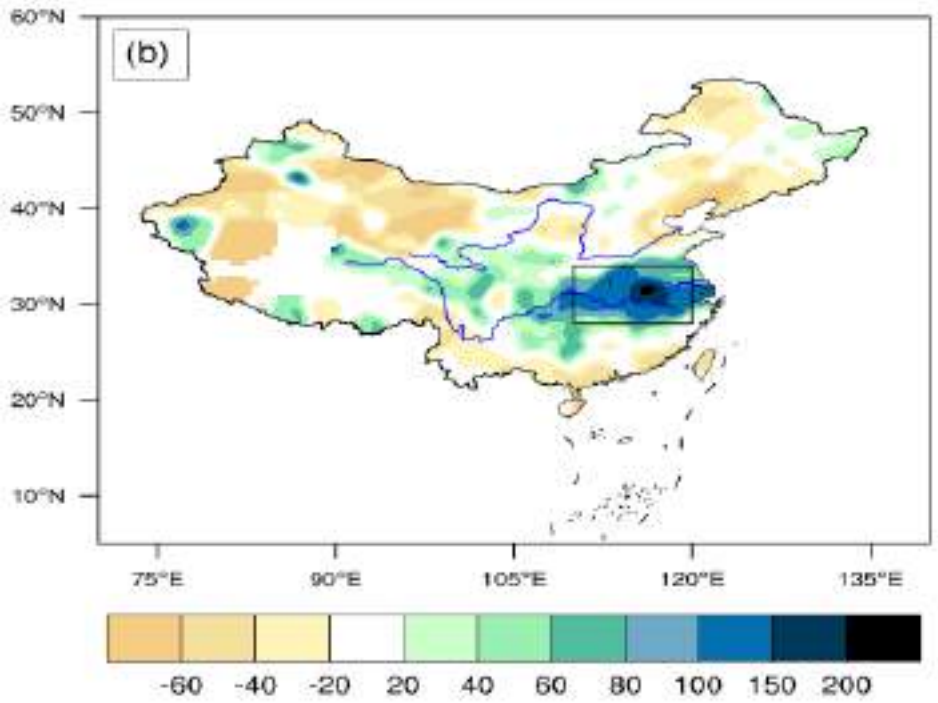
In East Asia, anthropogenic forcing:

- Increases daily precip extremes (related to increased moisture)
- Decreases persistent precip extremes (related to weakened EASM)

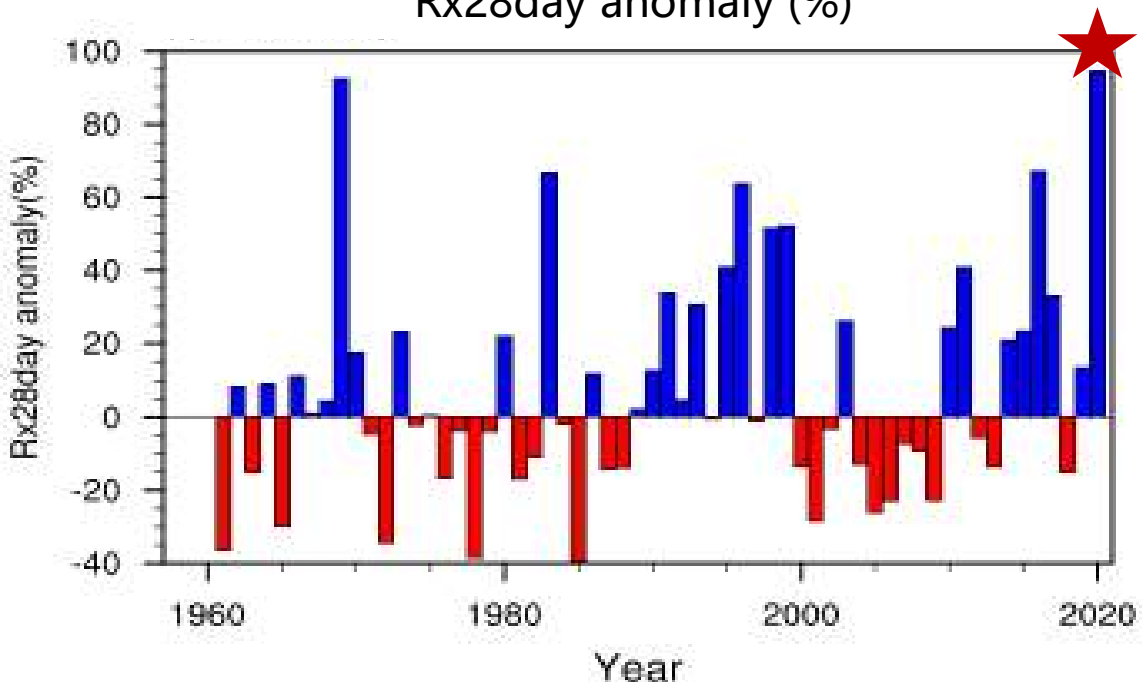
Zhang, W. et al. 2020. Anthropogenic influence on 2018 summer persistent heavy rainfall in central western China. *Bull. Amer. Meteor. Soc.* 101(1), S65-S70.

CASE#2: Record-breaking extreme Meiyu rainfall in 2020

Meiyu (Jun-Jul 2018) precip anomaly (%)



Rx28day anomaly (%)



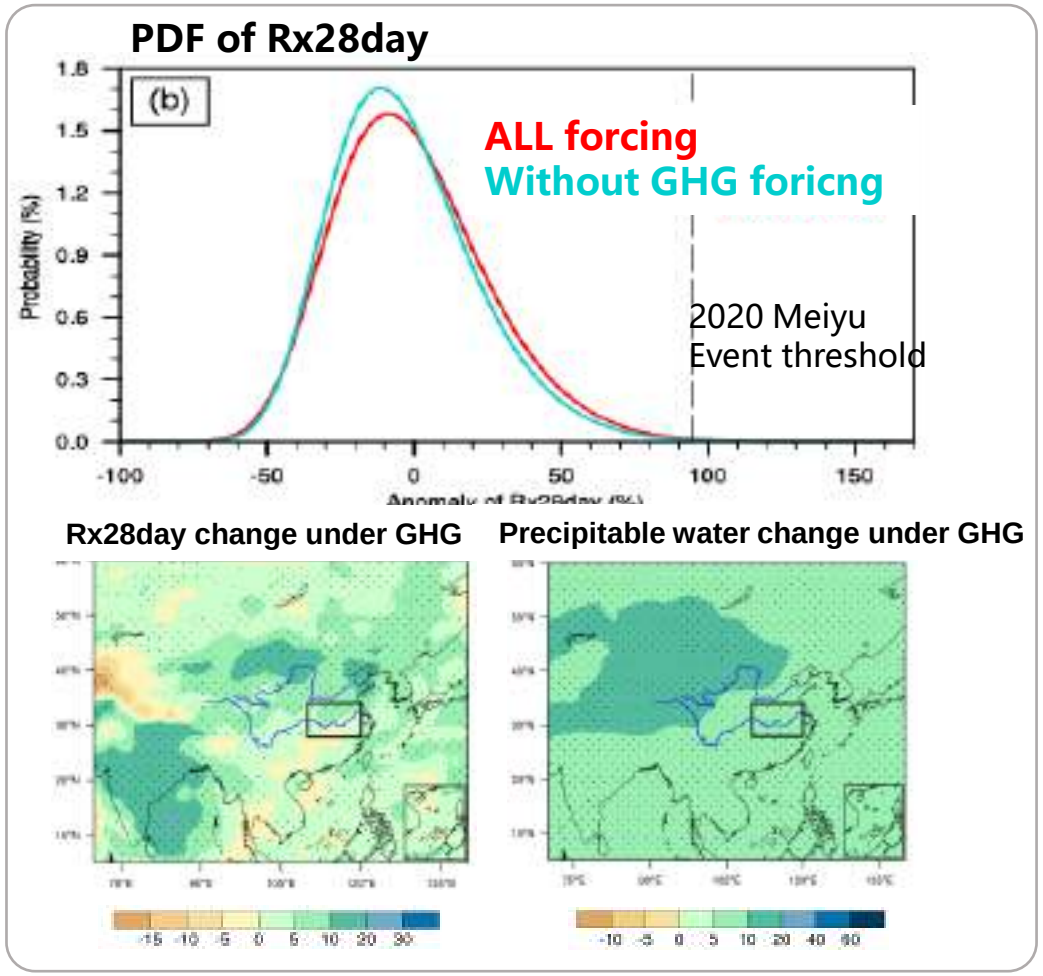
RxNday: maximum accumulated precip over N days in JJA

During the Meiyu season in 2020, persistent heavy rainfall (Rx28day) was 94% stronger than climatology, breaking the observational record since 1961.

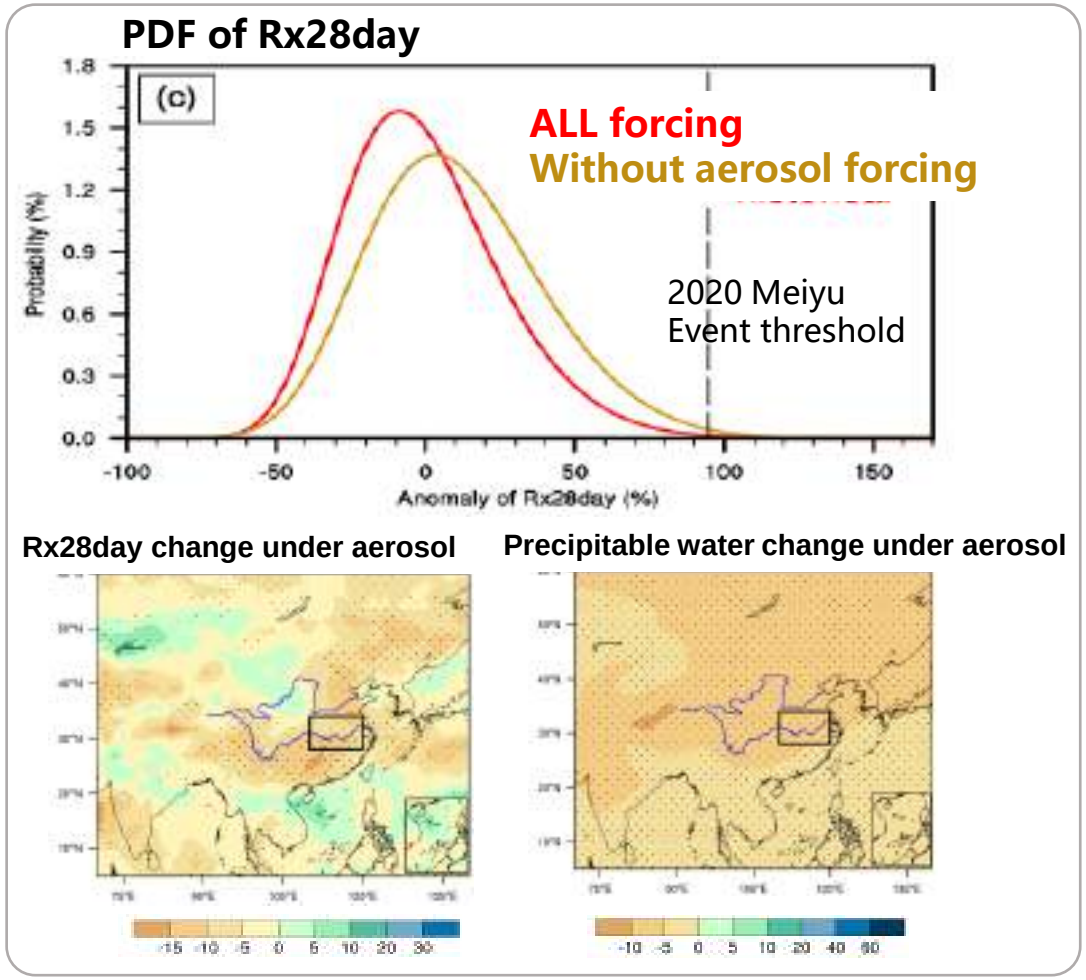
Zhou T. et al. 2021: Anthropogenic influence on extreme Meiyu rainfall in 2020 and its future risk. *Science China: Earth Sciences*, 64, 1633–1644

Competing role of GHGs and aerosols

Positive contribution of GHG forcing



Negative contribution of aerosol forcing

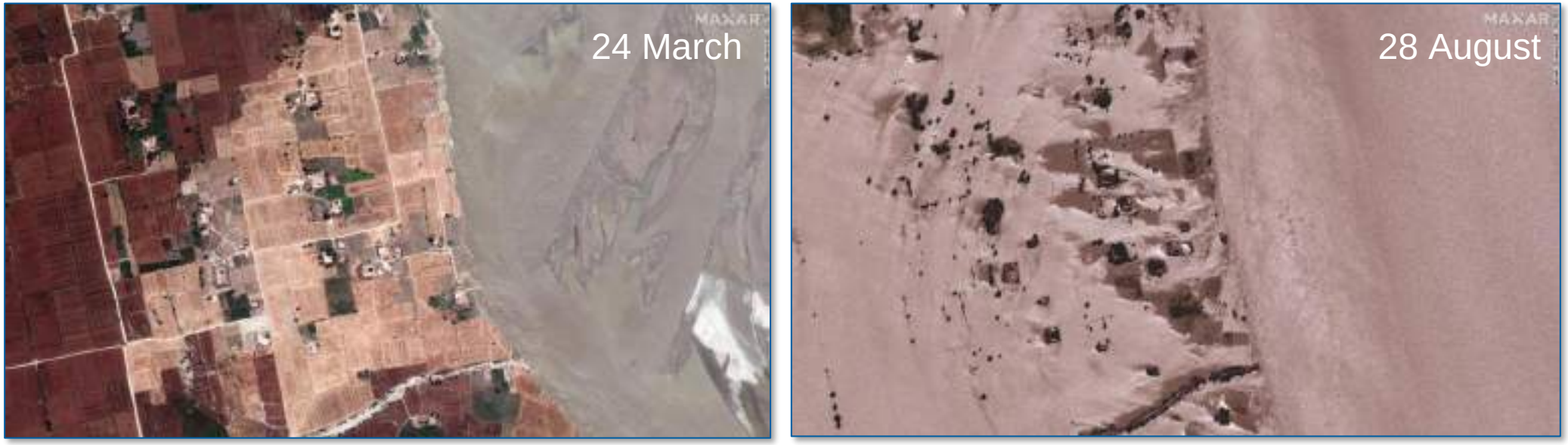


- **GHG forcing increased the probability by ~44%**
- **Aerosol forcing decreased the probability by ~73%**

Net effect → **Anthropogenic forcing decreased the probability**

(Zhou et al. 2021)

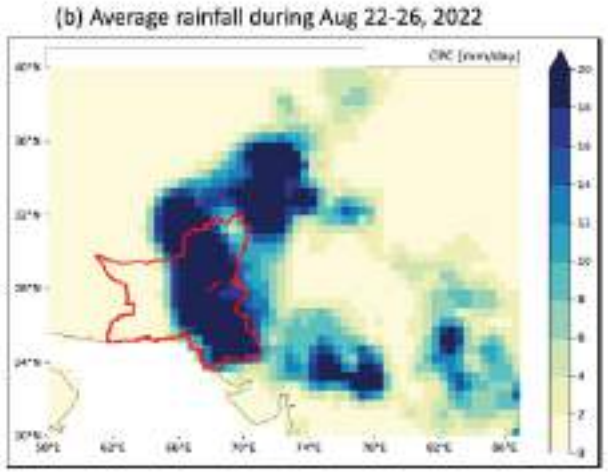
CASE#3: Extreme monsoon rainfall in Pakistan in 2022

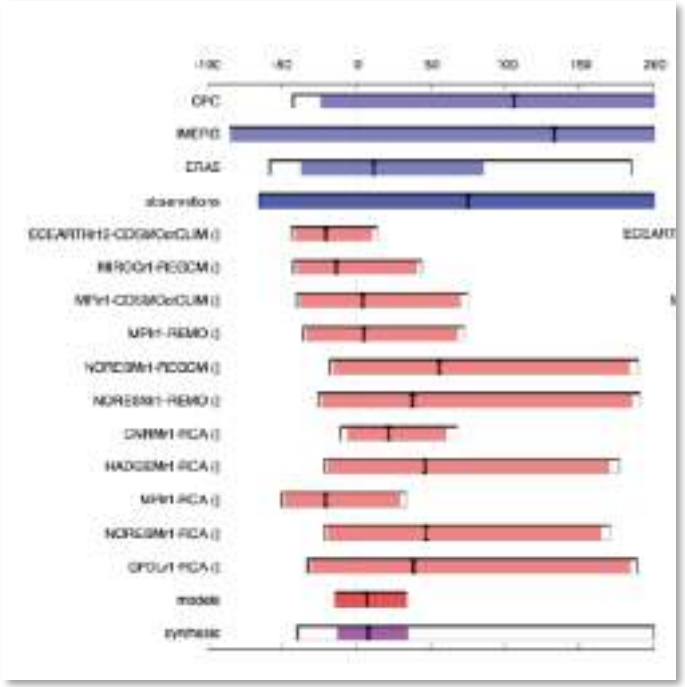


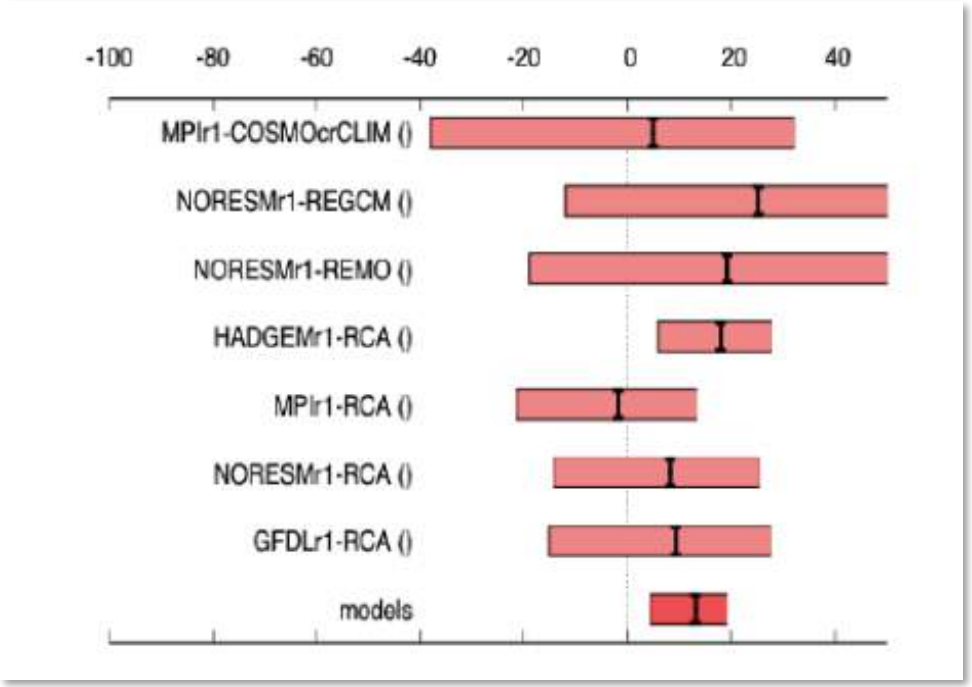
Rainfall is equivalent to 2.9 times the national 30-year average on 27 August and caused widespread flooding and landslides. The floods submerged one third of the country, affecting 33 million.

Multi-model attribution: Intensity change of the 100-year 5-day heavy rainfall event over the Indus river basin due to historical warming (left) and under 2°C warming future (right)

Observed 5-day rainfall







- The 5-day maximum rainfall over the provinces Sindh and Balochistan is now about 75% more intense than preindustrial era
- Rainfall intensity will significantly increase further for the 5-day event under 2°C warmer future

(Courtesy to Dr. Otto)

Otto et al. 2022 Climate change likely increased extreme monsoon rainfall, flooding highly vulnerable communities in Pakistan

world weather attribution

[Credit: Yoda Adaman | Unsplash]

It is indisputable that human activities are causing climate change, making extreme climate events, including heat waves, heavy rainfall, and droughts, more frequent and severe.

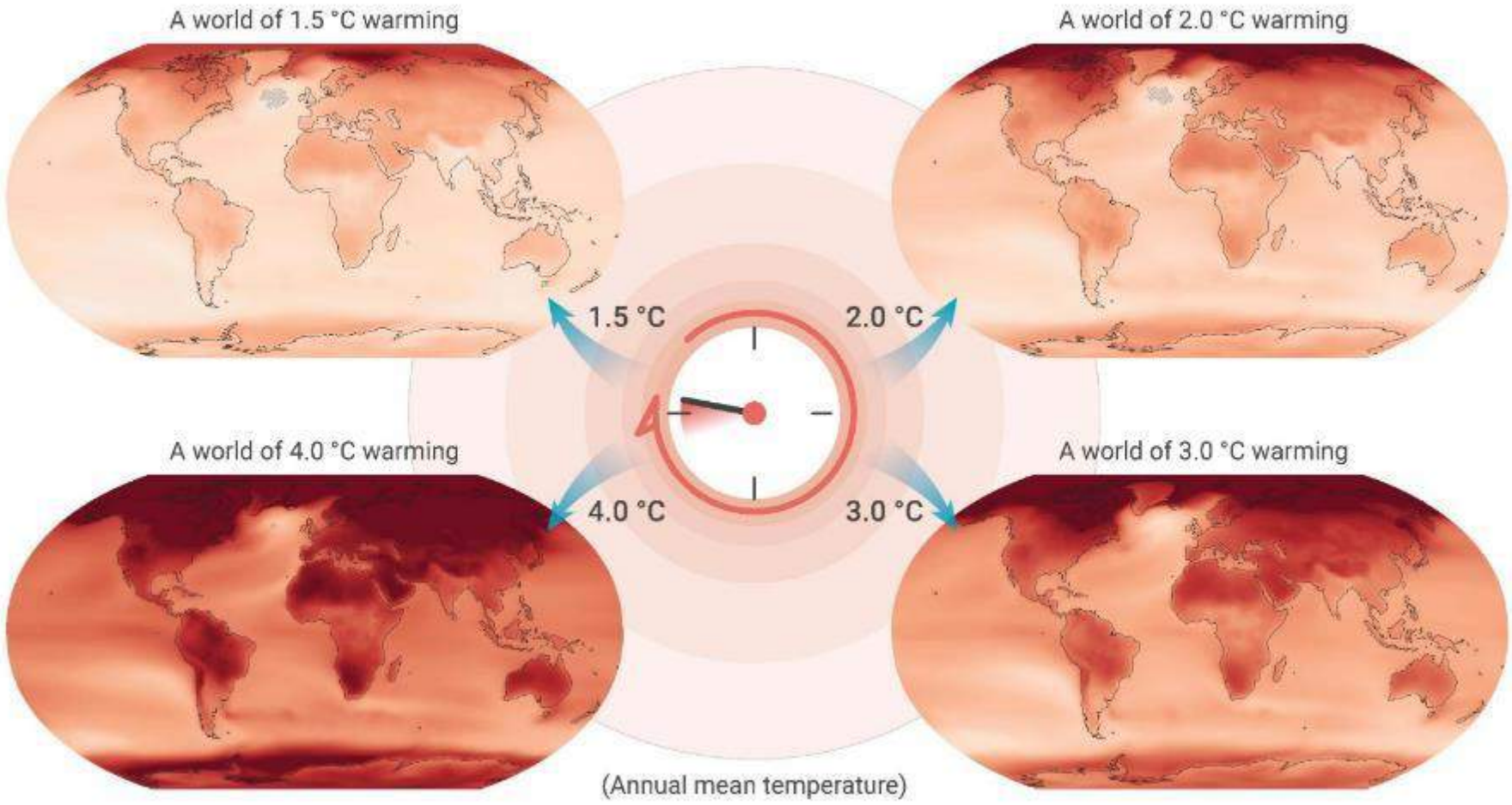
-- IPCC AR6

ipcc
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

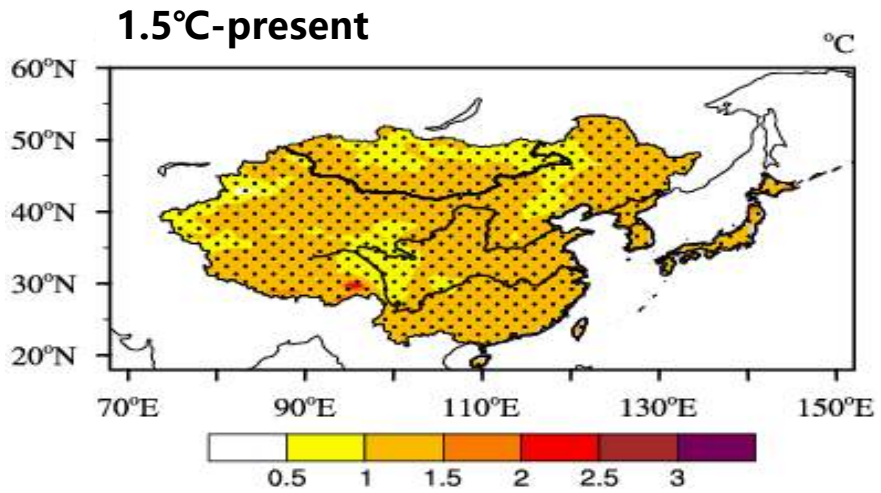
How will our climate look like in the future?

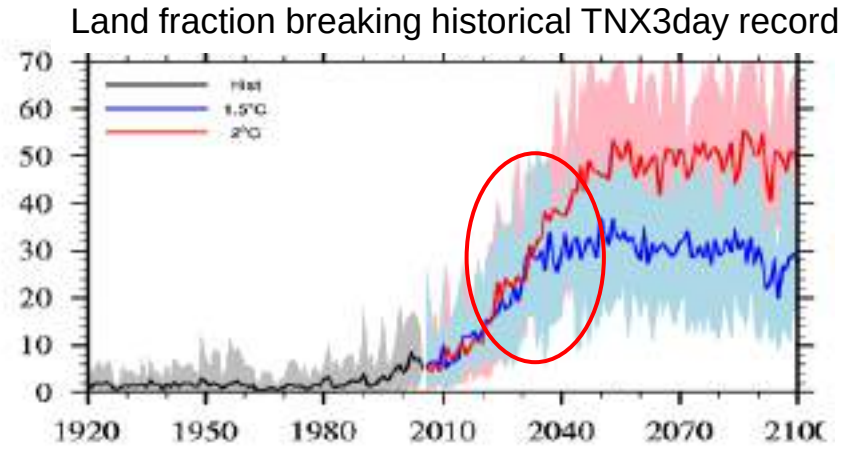
From 1.5ºC to 4ºC, we have a choice !

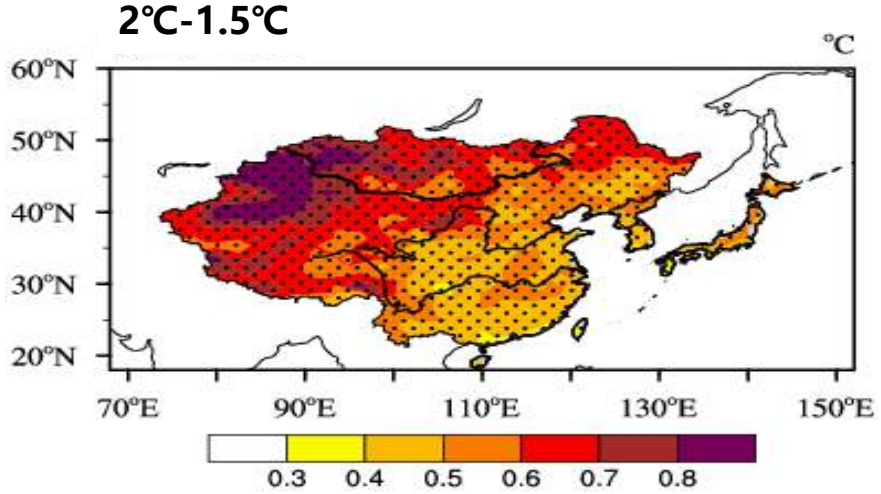


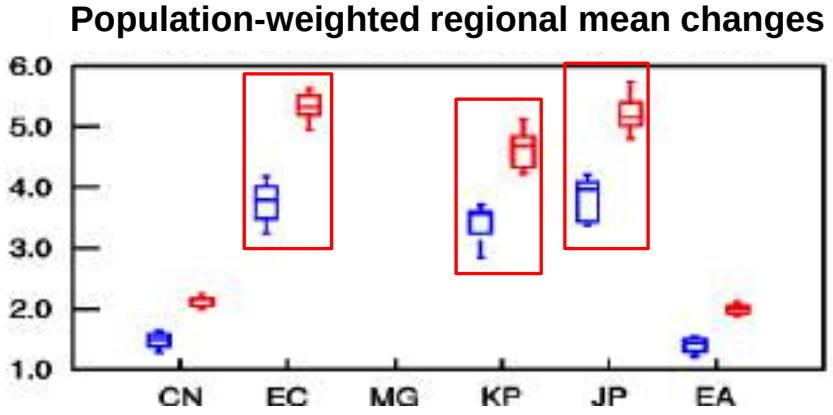
Zhou T. 2021 New physical science behind climate change: What does IPCC AR6 tell us? *The Innovation* 2(4), 100173

Changes in heat extremes





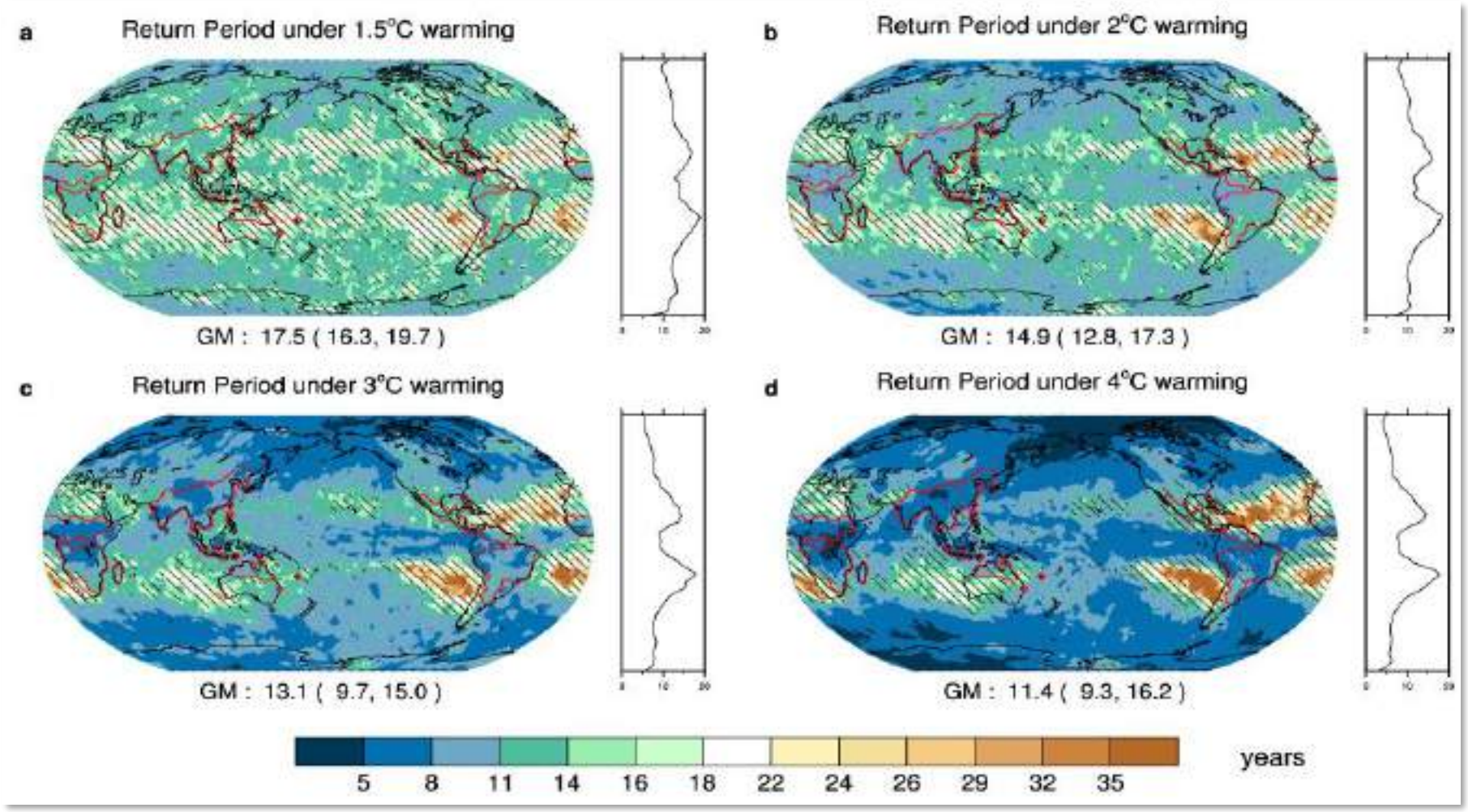




Li, D., T. Zhou, L. Zou, W. Zhang, and L. Zhang (2018), Extreme high-temperature events over East Asia in 1.5°C and 2°C warmer futures: Analysis of NCAR CESM low-warming experiments. *Geophysical Research Letters*, 45.

Changes of extreme precipitation in global monsoon regions

Dangerous extremes: Return periods of historical (1950-2005) once-in-20-year Rx5day events

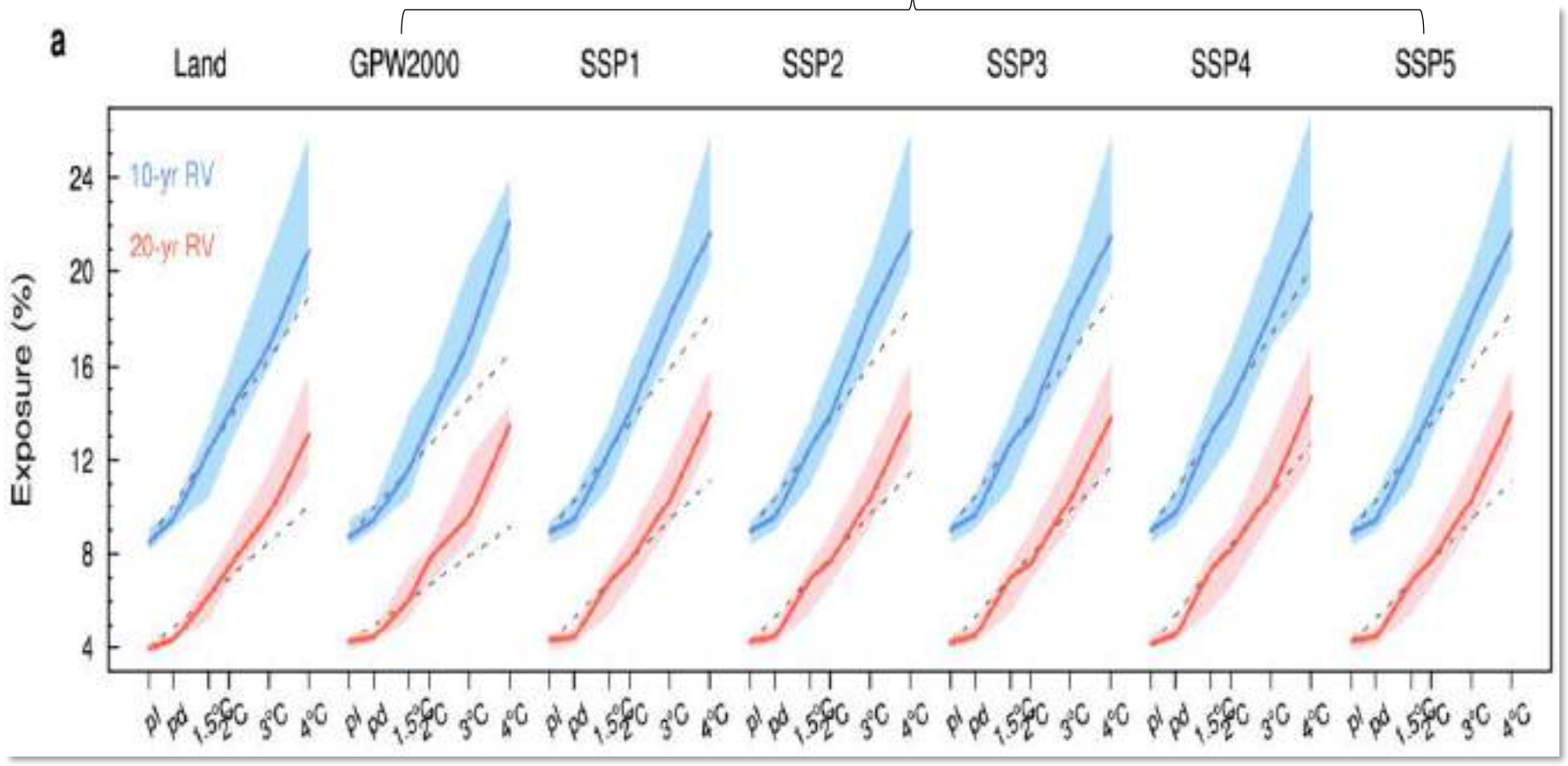


Zhang W., T. Zhou*, L. Zou, L. Zhang, X. Chen, 2018: Reduced exposure to extreme precipitation by 0.5° C less warming for global land monsoon regions . *Nature Communications* 9, : 3153 (2018)

Increases in population exposure with global warming levels

Land exposure

Population exposure



0℃ ⟶ 4℃

- Global monsoon region
- Consistent increases in exposure to dangerous extremes with warming
- Nonlinear increases for warming higher than 2℃

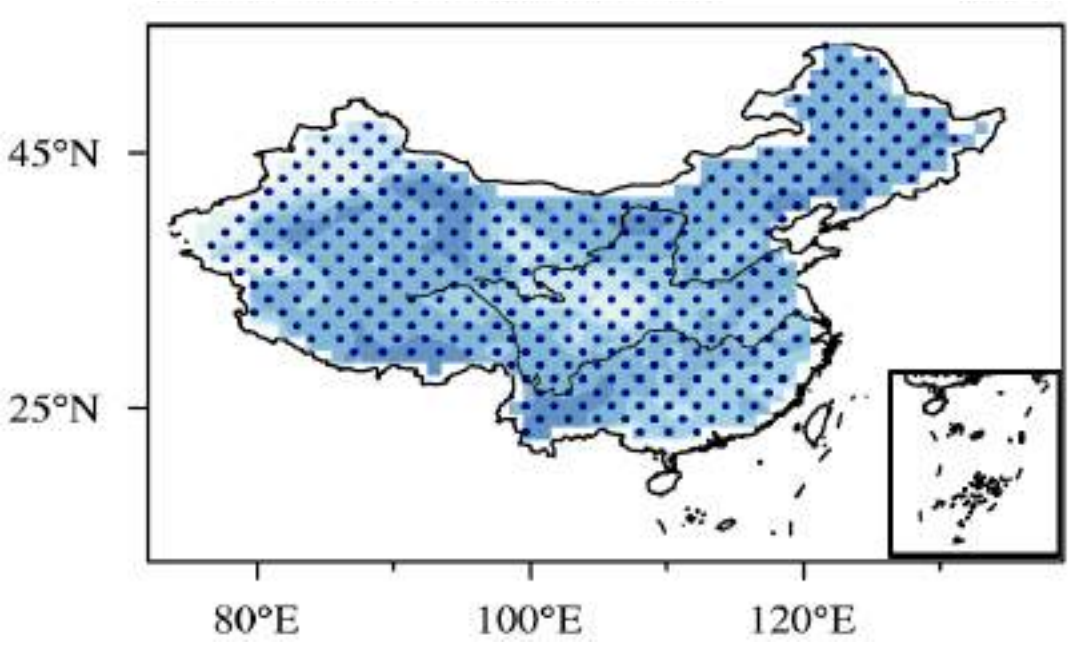
once-in-10-year events

once-in-20-year events

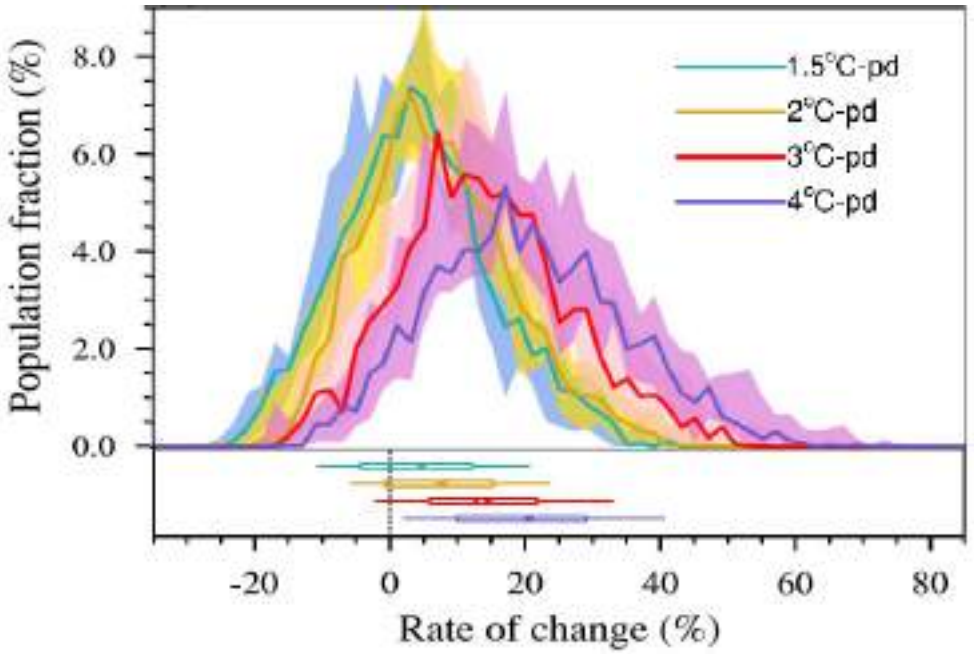
Zhang W., T. Zhou*, L. Zou, L. Zhang, X. Chen, 2018: Reduced exposure to extreme precipitation by 0.5° C less warming for global land monsoon regions . *Nature Communications* 9, : 3153 (2018)

Extreme precipitation changes over continental China

Extreme precip (Rx5day) response to global warming



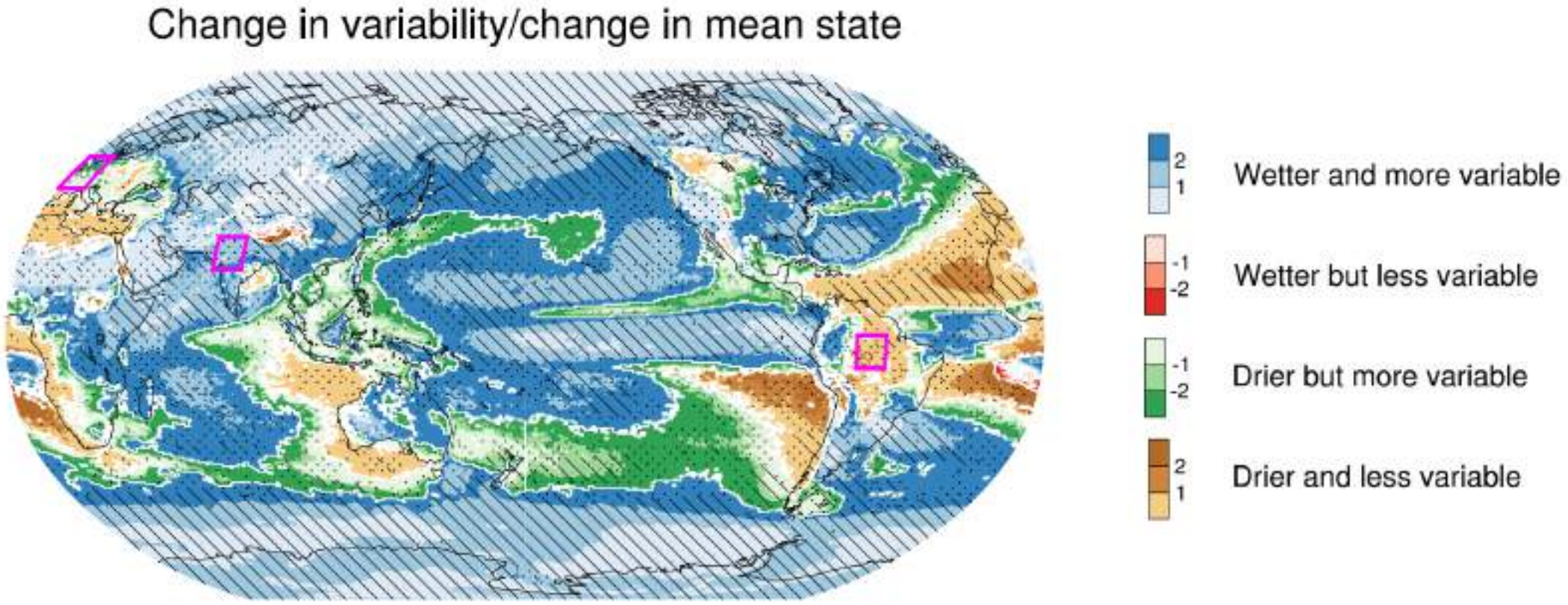
Population exposure under different warming levels



- Averaged over China, extreme precipitation (Rx5day) increases by 6.52 %/K
- One-quarter of the population would experience an intensification of 12%, 15%, 22%, and 29% in extreme precipitation under 1.5, 2, 3, and 4C warming relative to present day

Zhang W, Zhou T. 2020. Increasing impacts from extreme precipitation on population over China with global warming. *Science Bulletin*, 65(3): 243-252.

Regimes of precipitation change：Daily to multiyear time scales



The precipitation will be more variable over most of the Asia-Pacific region!

Zhang, W. *et al.* Increasing precipitation variability on daily-to-multiyear time scales in a warmer world. *Science Advances* 7, 1–12 (2021).

[Credit: Peter John Maridable | Unsplash]

- The change in the frequency, intensity and variability of climate extremes under global warming pose challenges to the climate resilience of infrastructures and human society over Asia.
- Limiting global warming to 1.5°C helps to reduce the exposure of the world population to climate extremes.

Thank you for your attention

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