Understanding human influence on climate change in China

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Outline

- Introduction
- Human influence on climate change since 1950s
  - Mean temperature
  - Extreme temperature
  - Extreme precipitation
- Attribution of high-impact extreme events
  - Heat wave
  - Cold surge
  - Heavy precipitation

Outline

- **Introduction**
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Human influence on climate change
Key issue of IPCC

- **IPCC FAR（1990）：** Human use of fossil fuels had substantially increased the concentration of atmospheric greenhouse gases, leading to an enhanced warming effect and resulting in a warming of the Earth’s surface
- **IPCC SAR（1995）：** Global warming was “unlikely to be entirely caused by nature" and that human activities have had a "discernable" impact on the global climate system.
- **IPCC TAR (2001)：** Most of the warming observed over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations.
- **IPCC AR4（2007）：** Most of the warming observed since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.
- **IPCC AR5（2013）：** It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century.
- **IPCC AR6（2021）：** It is unequivocal that human influence has warmed the atmosphere, ocean and land.

Detection and attribution of climate change （Hasselmann方法的后续发展）

Understand how much human activities have caused the change in climate

- Since 1950s, global warming is unequivocal.
- What is the reason? How much is the contribution from human activities, such as greenhouse gases and aerosols? How much will this affect future climate change?

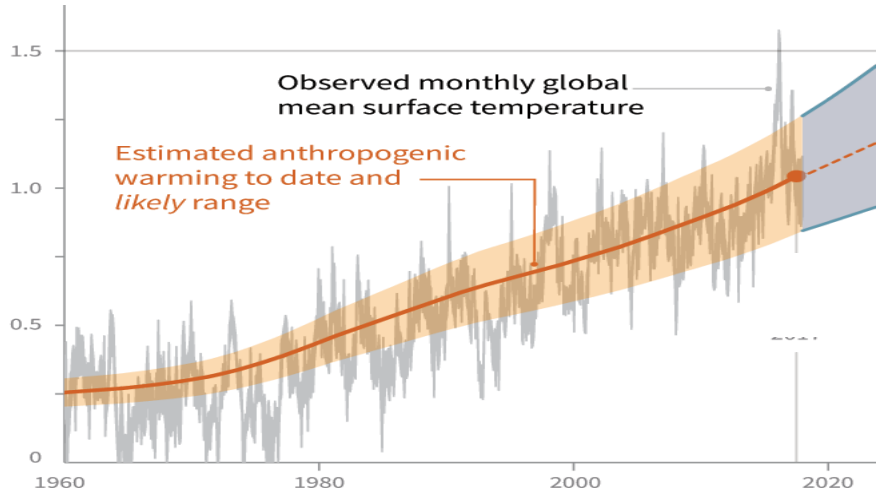
D&A of Climate Change:

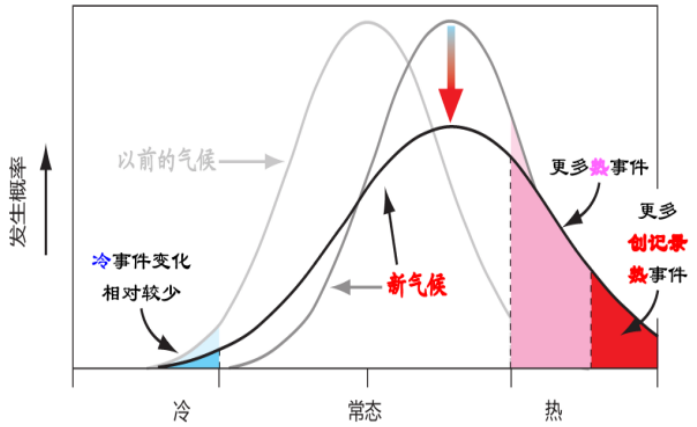
Attribution of long-term changes:

Identify the relative contribution from external forcing and internal variability of climate system

Attribution of extreme events:

Whether or not anthropogenic forcings change the probability of extreme events





D&A of Climate Change

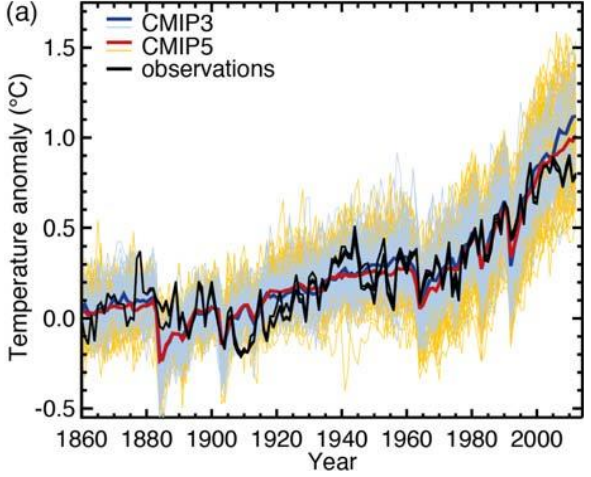
Category I: Long-term changes

- are observed changes consistent with

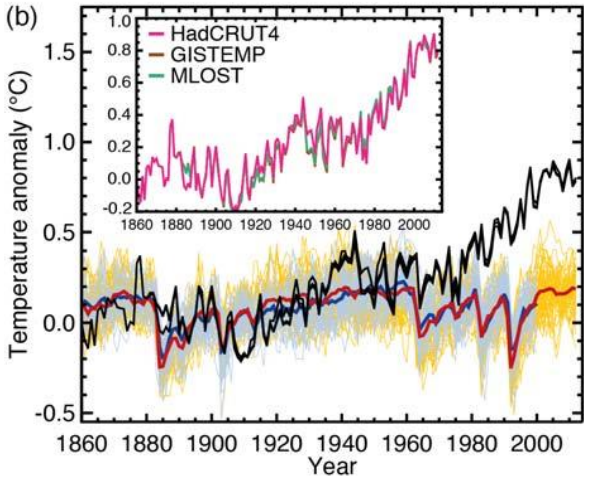
☑ expected responses to forcings

☒ inconsistent with alternative explanations

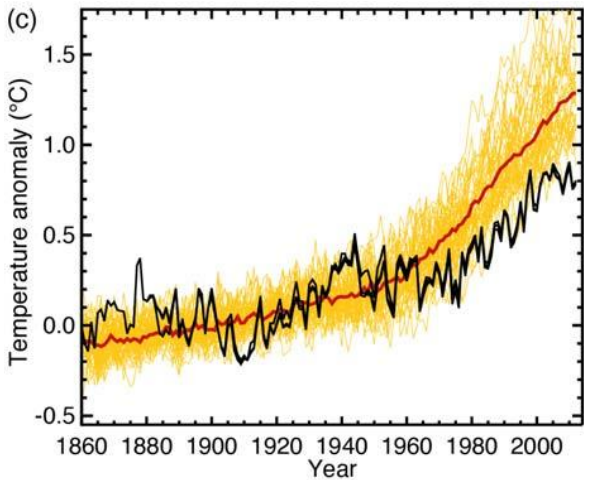
All forcing



Solar + volcanic



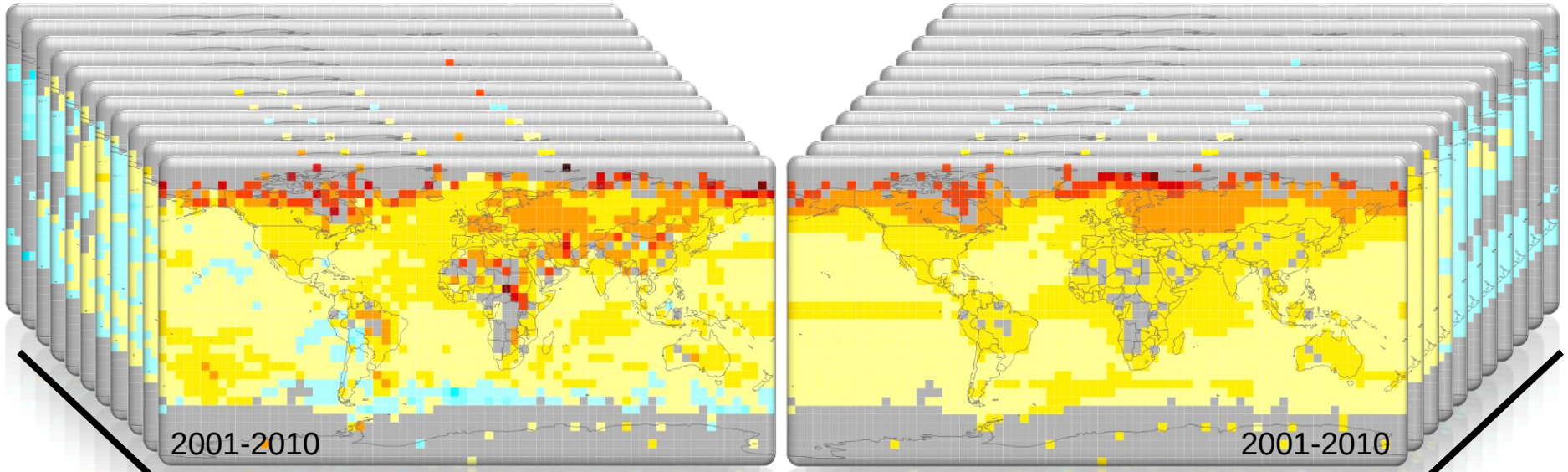
GHG forcing



IPCC WG1 AR5 Fig TS-9

Observations (HadCRUT4)

Multi-model mean (ALL forcings)



11 decades (1901-1911 to 2001-2011)

Optimal Fingerprinting Method

$\mathbf{Y}$

$\mathbf{X}$

$$\mathbf{Y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}$$

Evaluate scaling factors

$\hat{\boldsymbol{\beta}}$

$\hat{\boldsymbol{\varepsilon}}$

Evaluate residuals

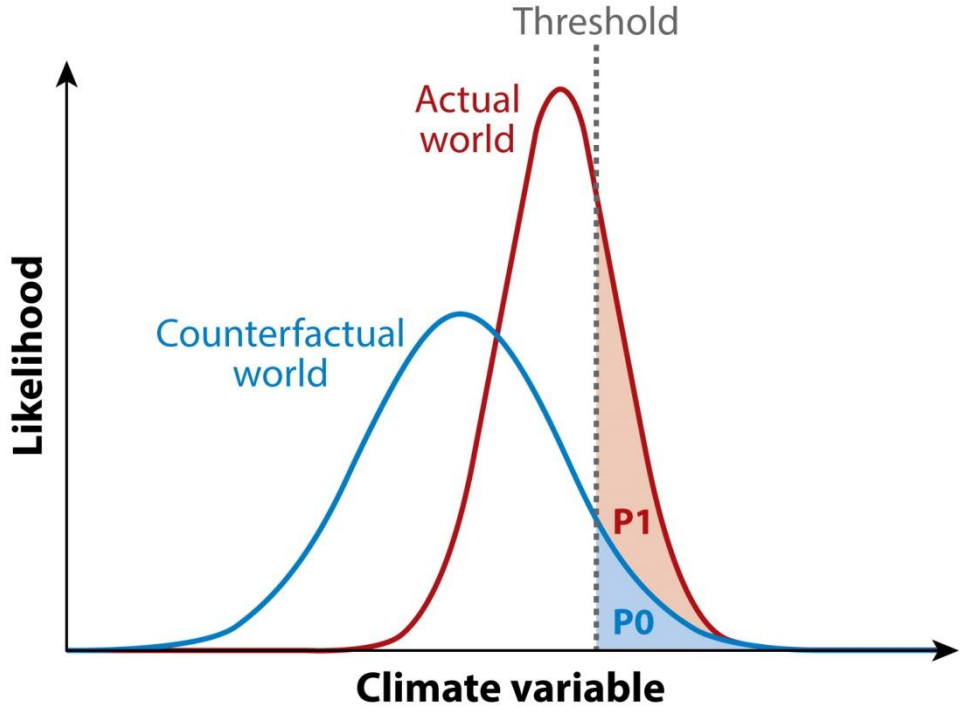
Category II: Attrition of high-impact extreme events

(Focused on an individual extreme event but not long-term changes)

- **How much anthropogenic climate change has contributed to the change of the probability (risk) or magnitude (severity) of observed event and how often similar events will happen in future.**

- **Main methods**
  - **Coupled Model Approaches**
  - **Sea Surface Temperature Forced Atmosphere Only Model Approaches**
  - **Analogue-Based Approaches**
  - **Empirical Approaches**

Attribution Steps



Current literature stresses risk ratio ($RR=p_1/p_0$): The probability of the event in the "real" world(p_1) /the probability of the event in the "natural" world(p_0) . How much have human activities increased the occurrence of event
Older literature used concept of Fractional Attributable Risk ($FAR=1-p_0/p_1$. This quantifies the fraction of events attributable to human caused climate change.

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  - **Mean temperature**
  - **Extreme temperature**
  - **Extreme precipitation**
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  - Heat wave
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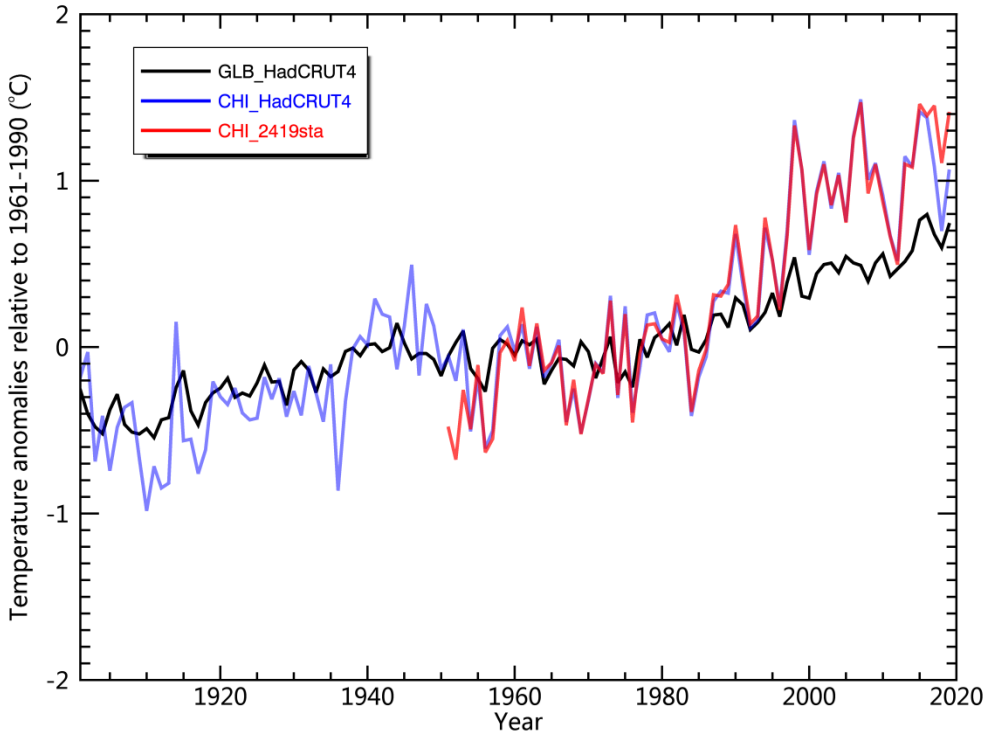
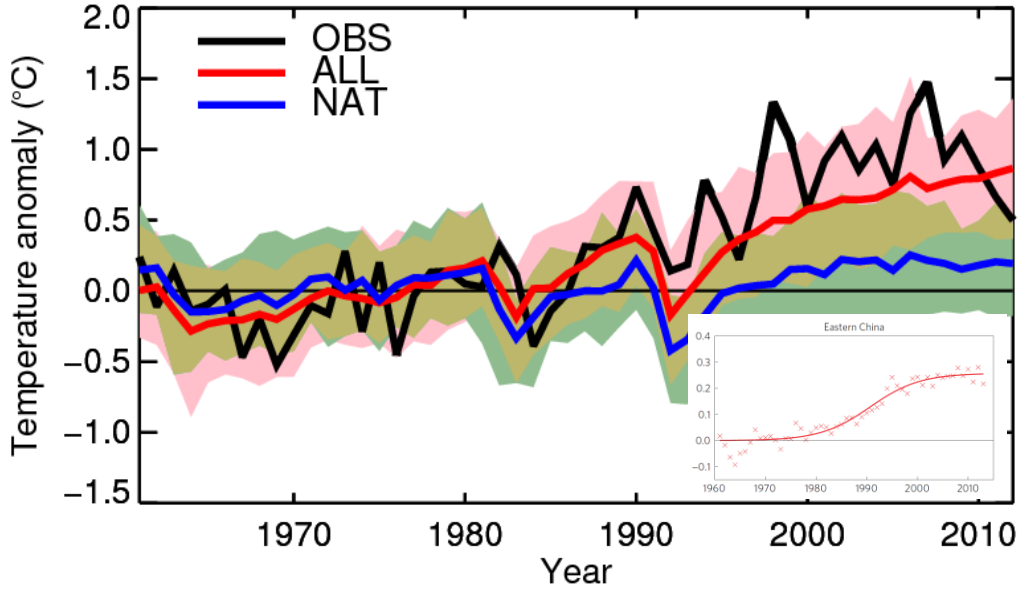
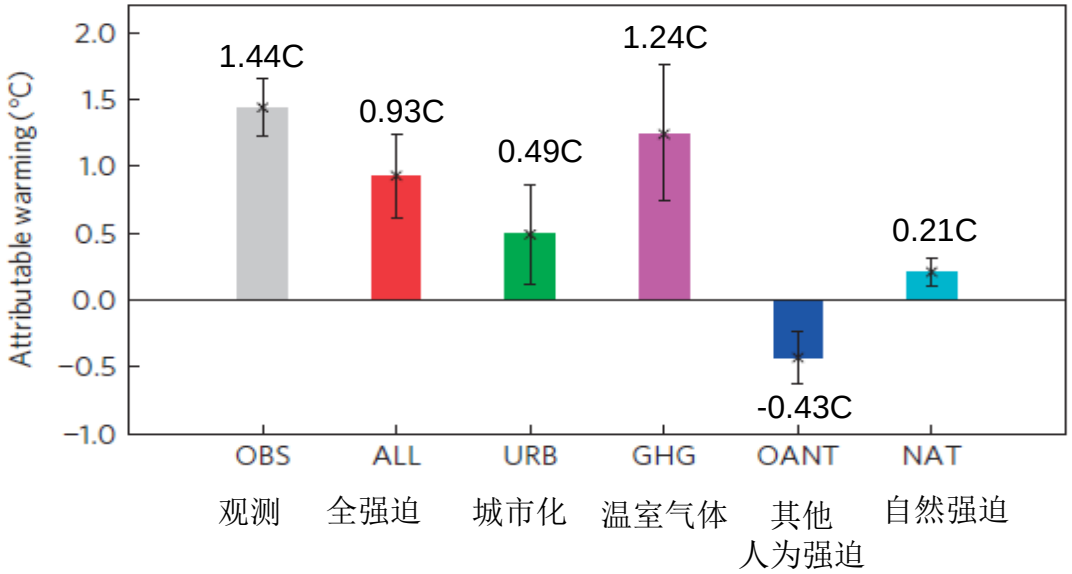
Mean temperature: Anthropogenic forcings, dominated by greenhouse gas emissions, are the main drivers for the observed warming



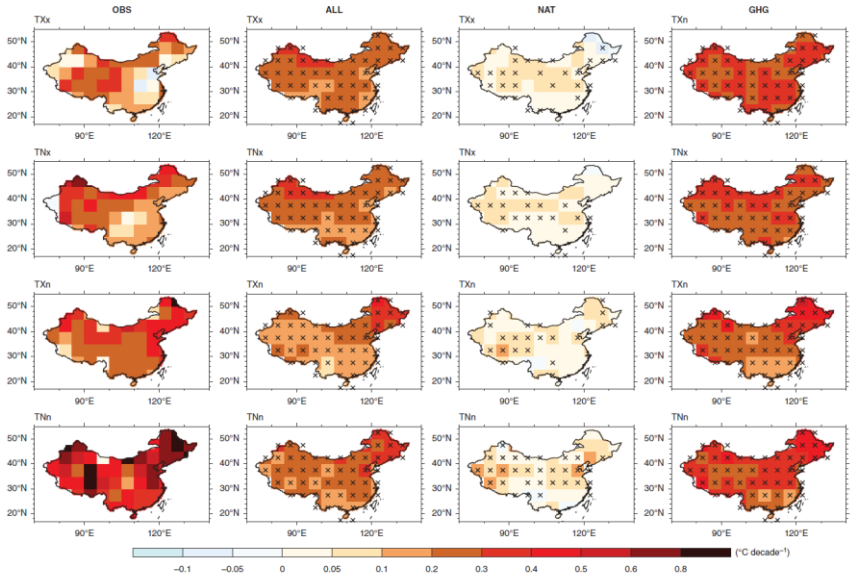


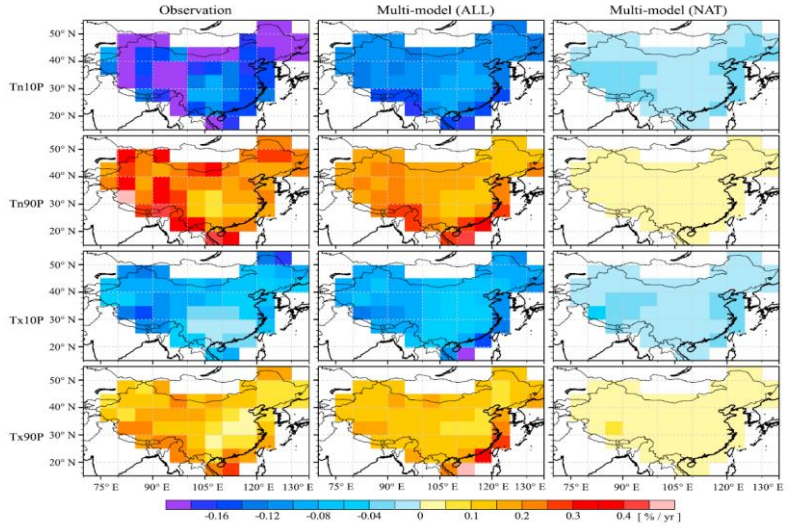


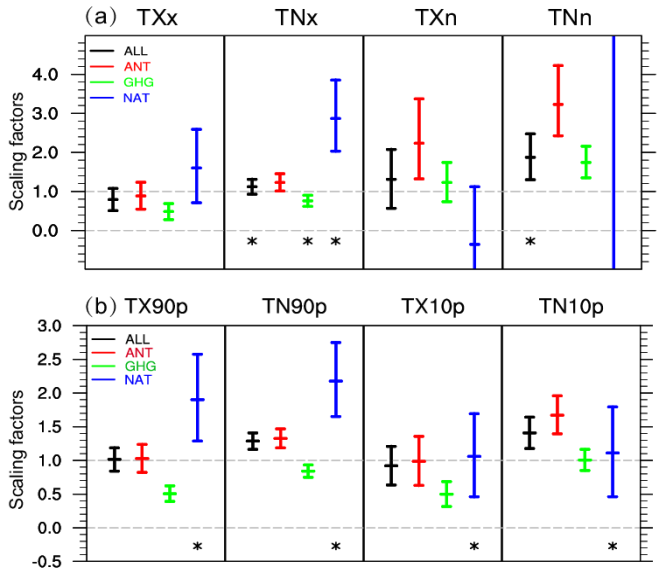
- **Greenhouse gases: contribute about 90% of warming**
- **Other anthropogenic forcings: cooling effects**
- **Urbanization effects: exacerbating the GHGs induced warming**

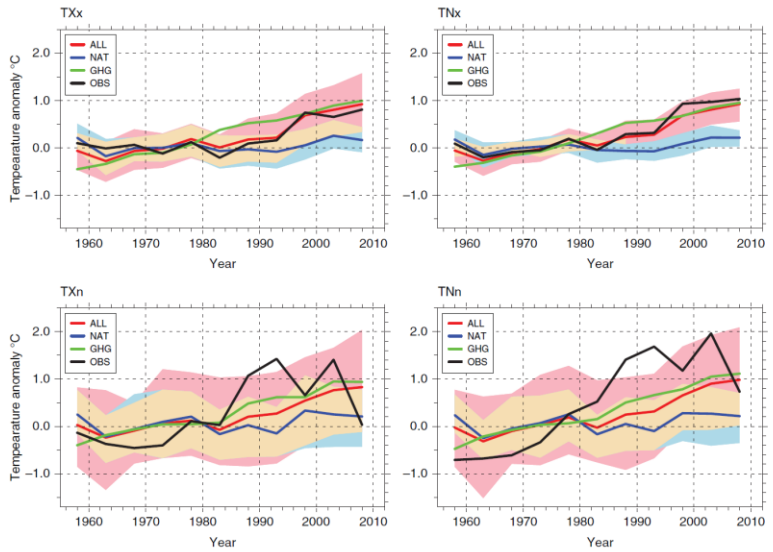
Sun et al. 2016, Nature Climate Change; Sun et al. 2016, BAMS

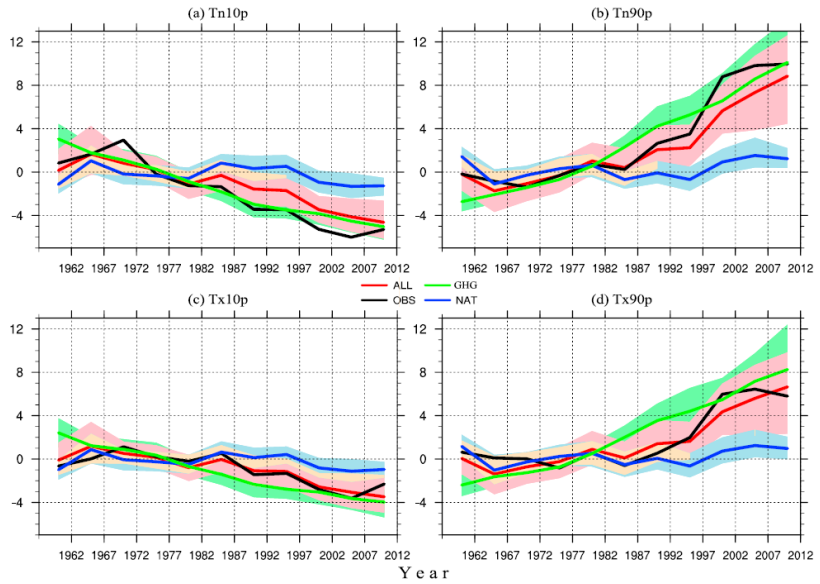
Extreme Temperature: Human influence is the main driver for the changes in frequency, intensity and duration of extreme temperature (CMIP5)





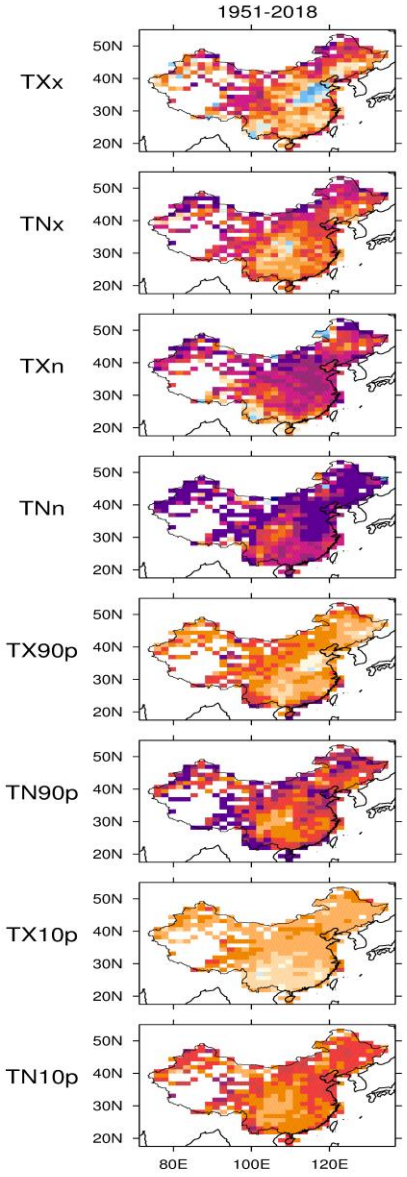


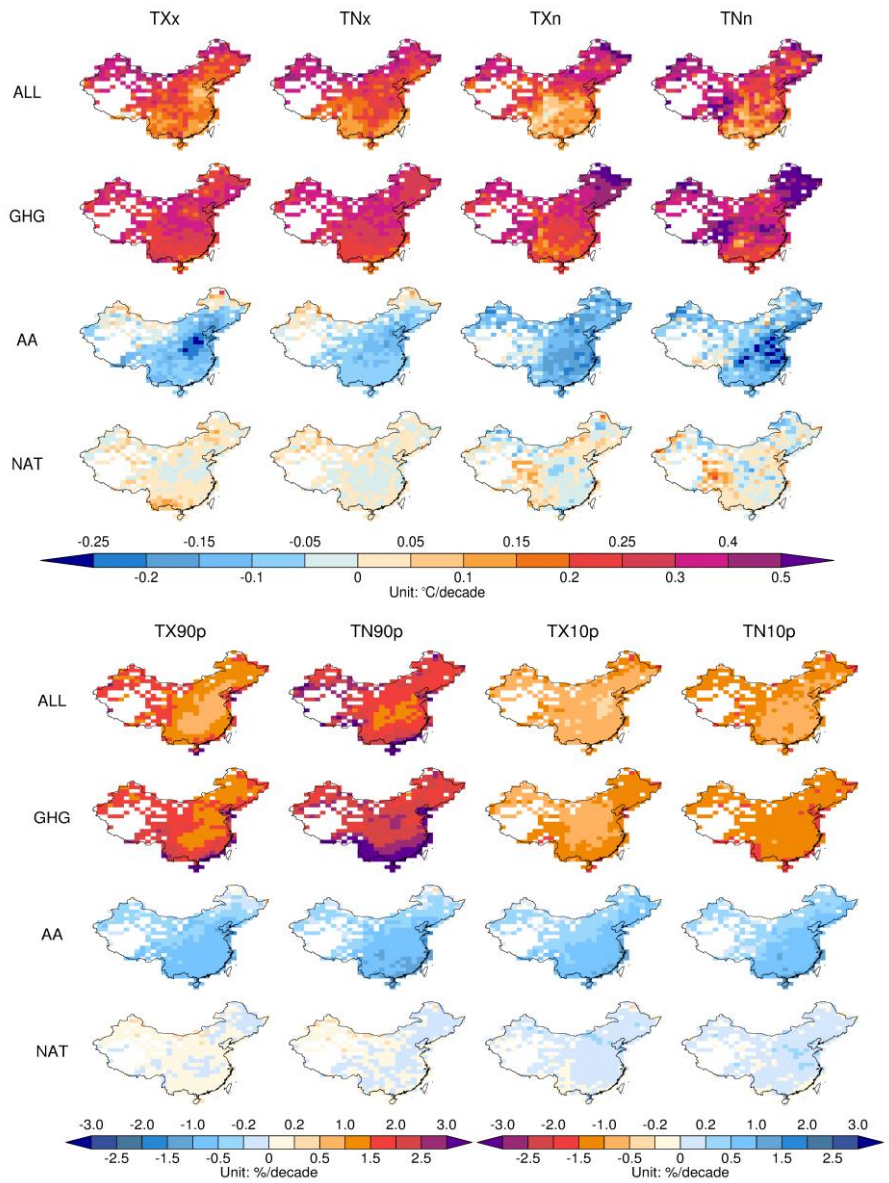


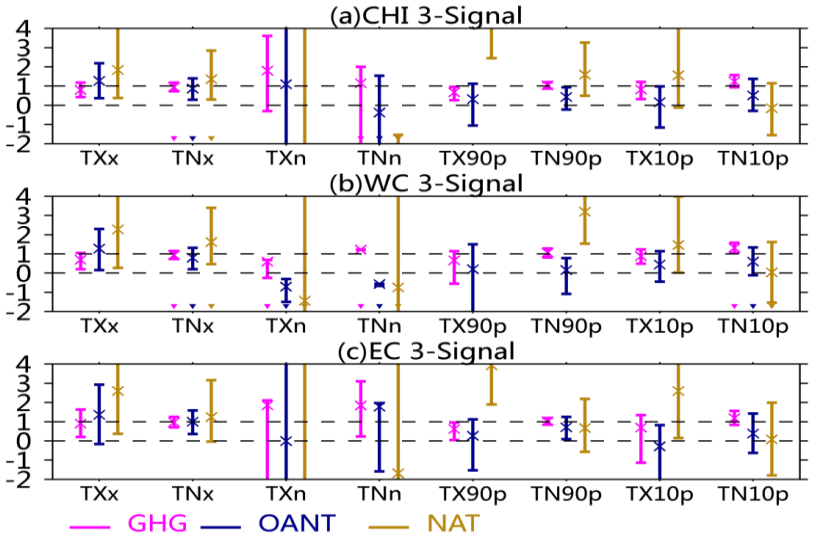


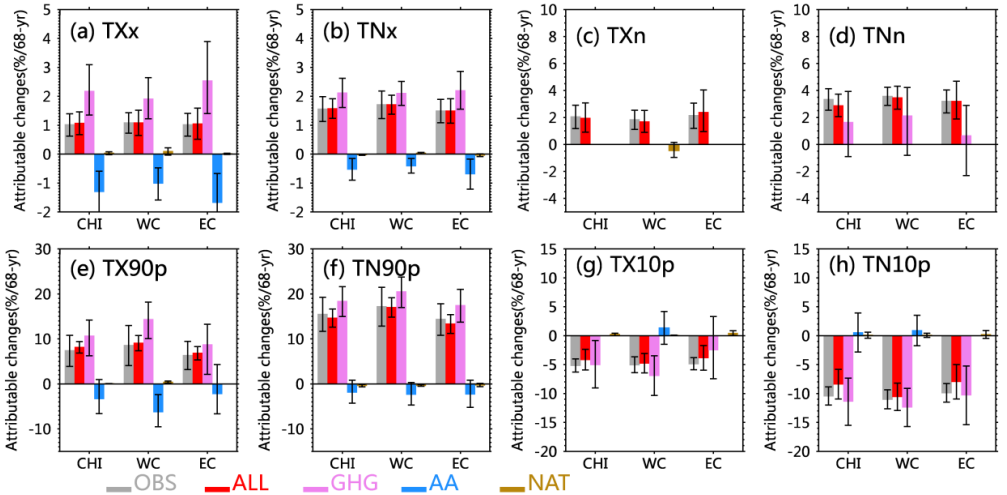
(Yin et al. IJOC; Lu et al. GRL; 2018)

Extreme Temperature：Newest observation and CMIP6 show the dominant role of GHGs in the changes, while the contribution of aerosols is small

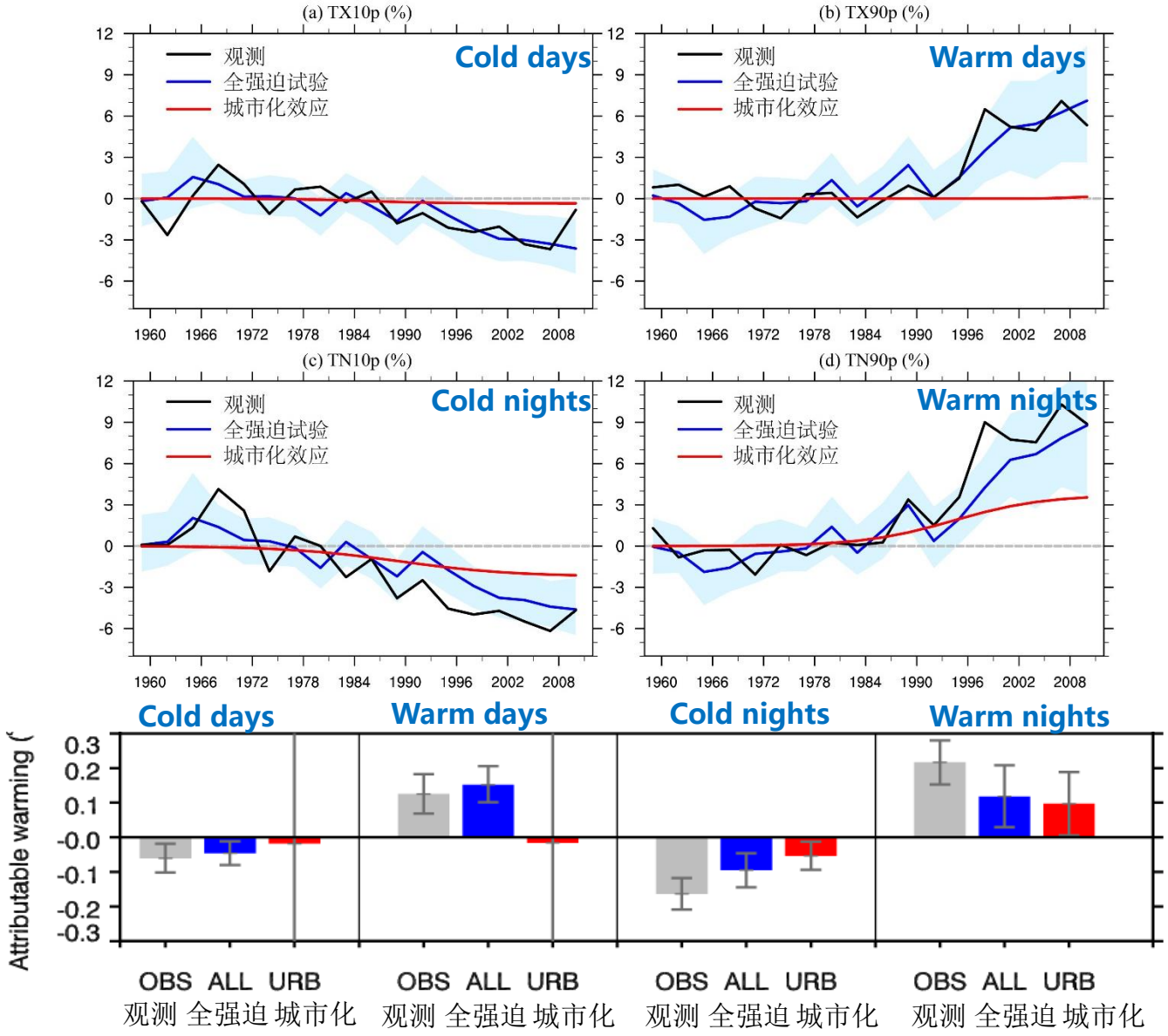


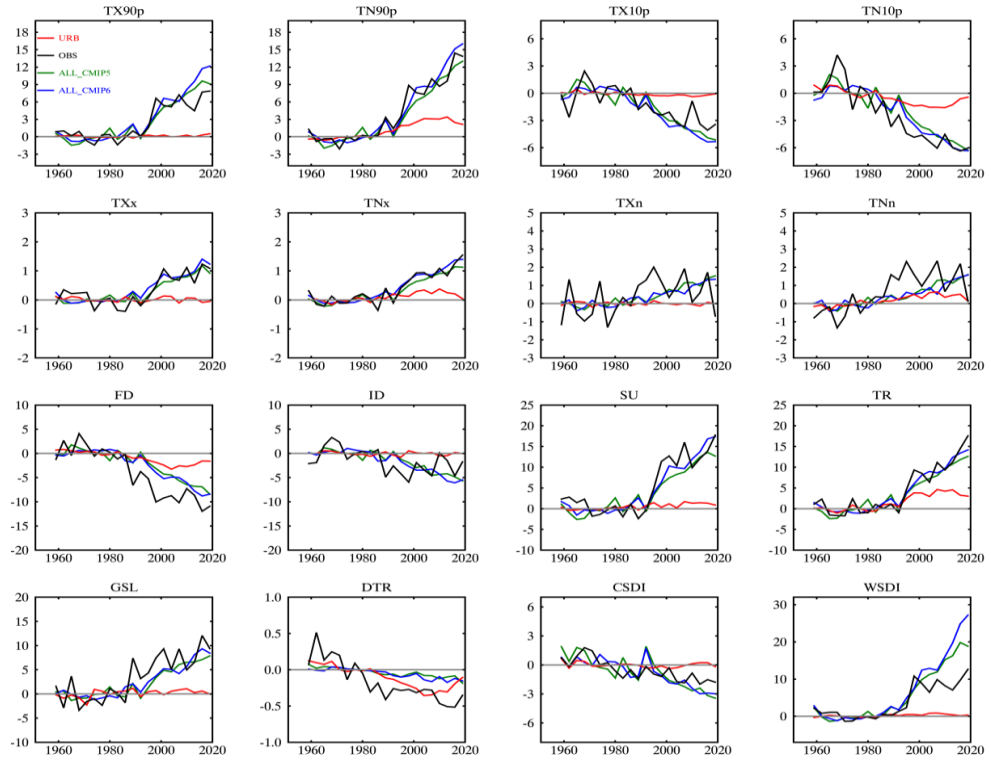






Extreme temperature：Contribution from urbanization can be detected in the frequency of extreme temperature （CMIP5 and CMIP6)

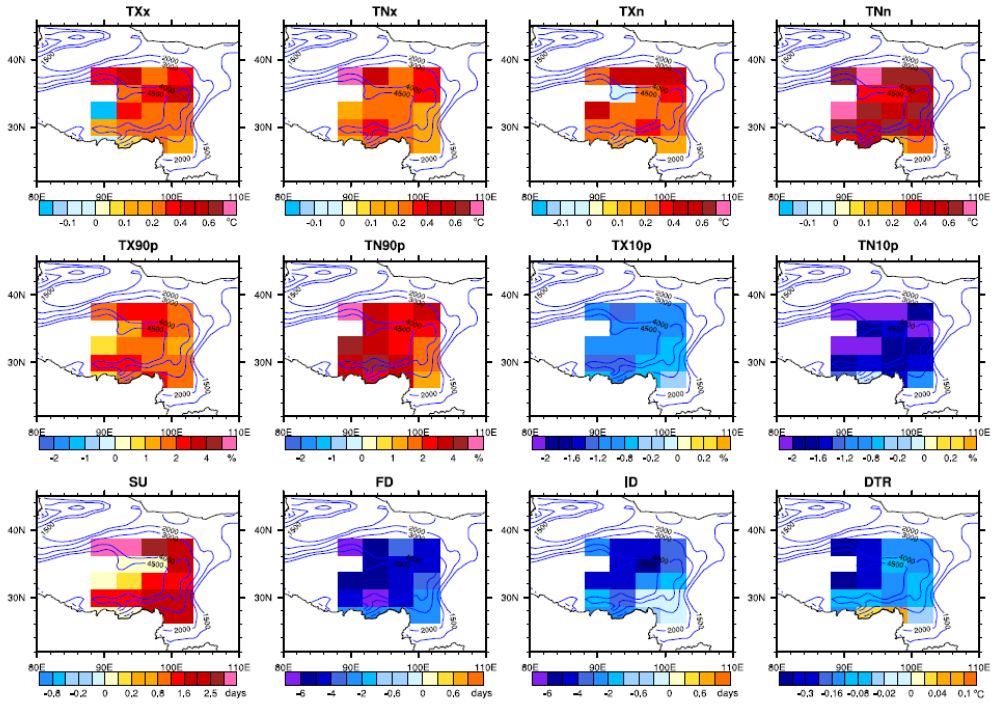




- **GHGs: contribute more than 90% of change in warm and cold days**
- **GHGs and urbanization signal are detected in the nighttime extreme temperature**

Sun et al. 2019, GRL; Lu, Sun* et al. 2016, GRL; Yin, Sun* et al. IJOC

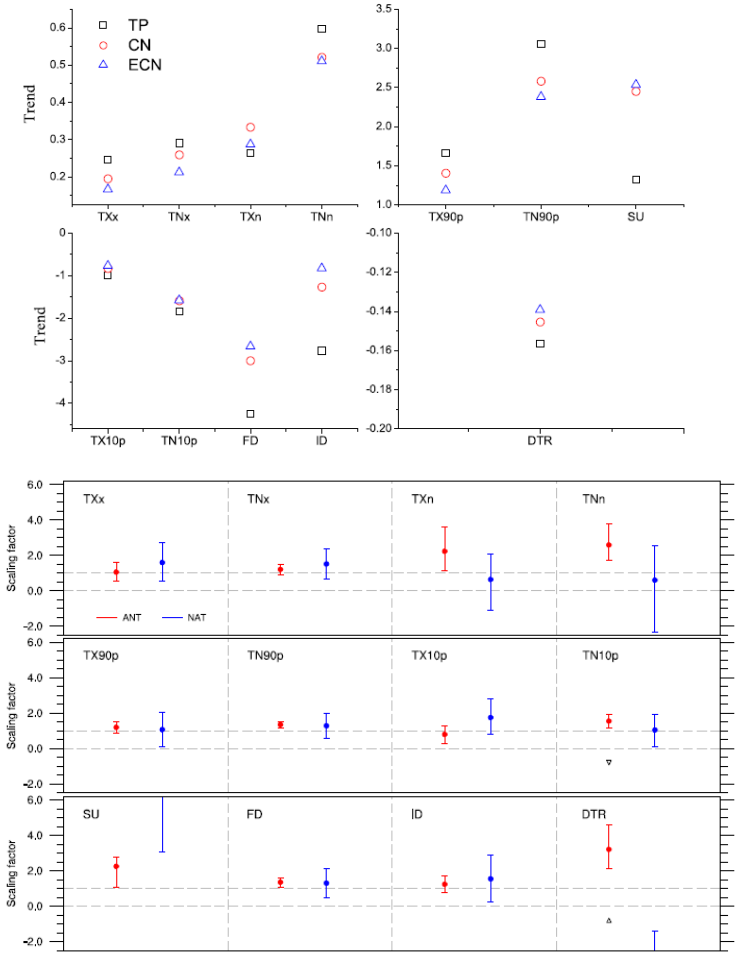
Extreme Temperature：Human influence is the main driver for the changes of extreme temperature in the Tibetan Plateau (Anthropogenic signal can be detected at a small regional scale)



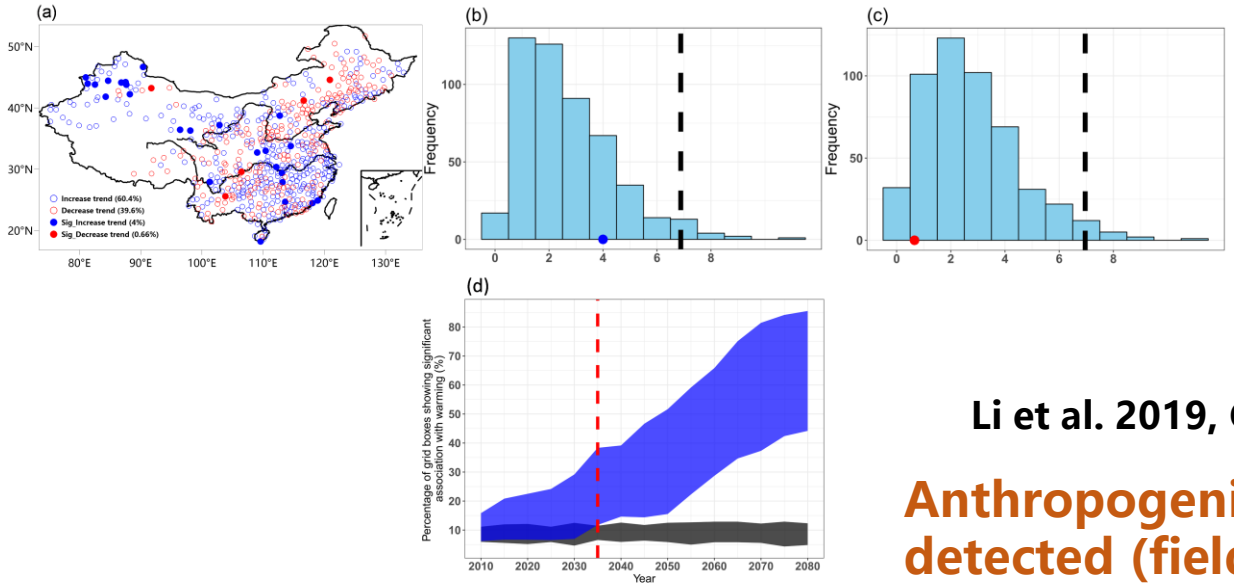
Warming in most extreme temperature indices are larger than China and Eastern China

（Yin et al. 2019 *Environ. Res. Lett.*）

1958-2017：
Warm extremes: More intense and more frequent
Cold extremes: Less intense and less frequent

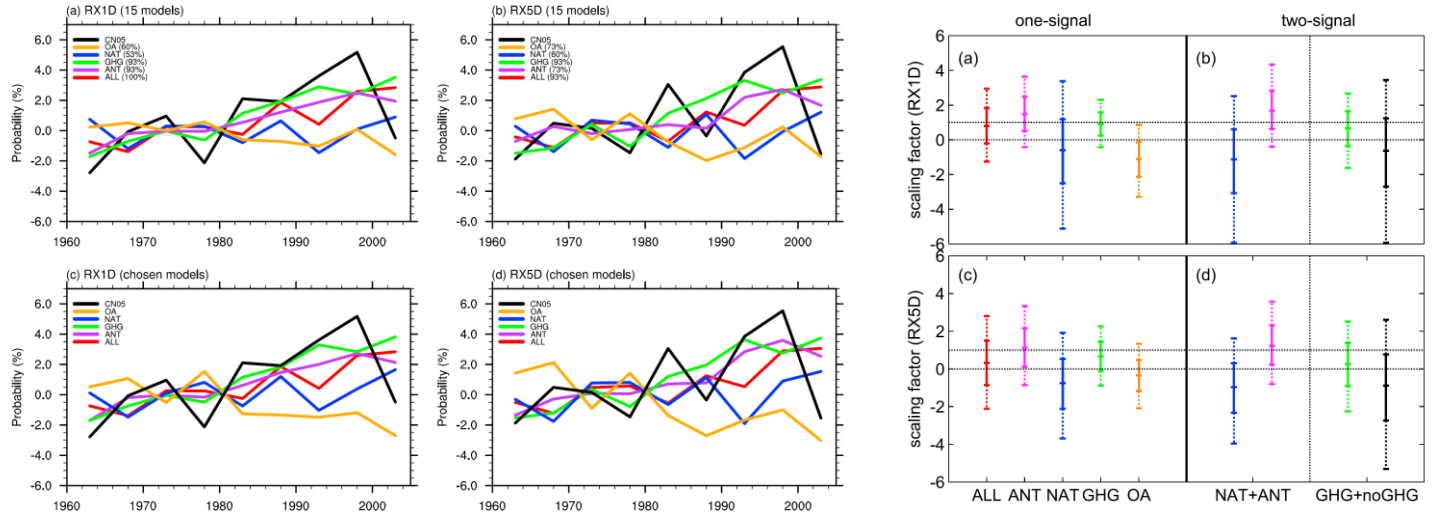


Extreme Precipitation: Human influence on extreme precipitation is still uncertain



Li et al. 2019, GRL

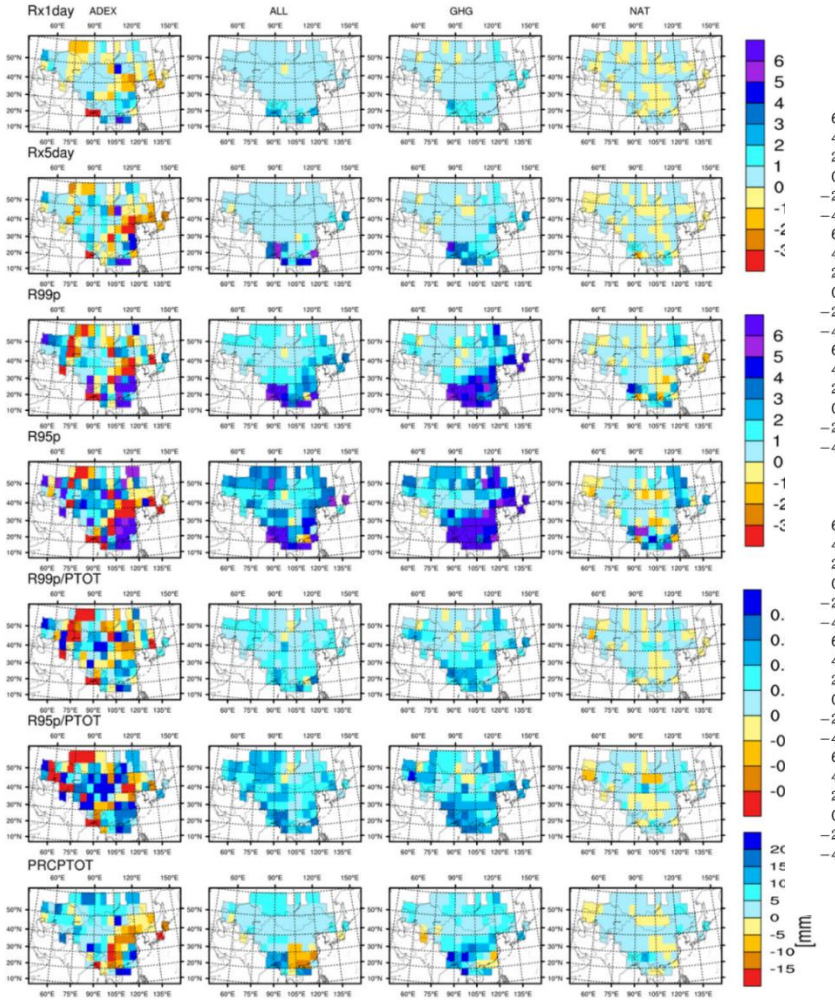
Anthropogenic signal cannot be detected (field significance test)

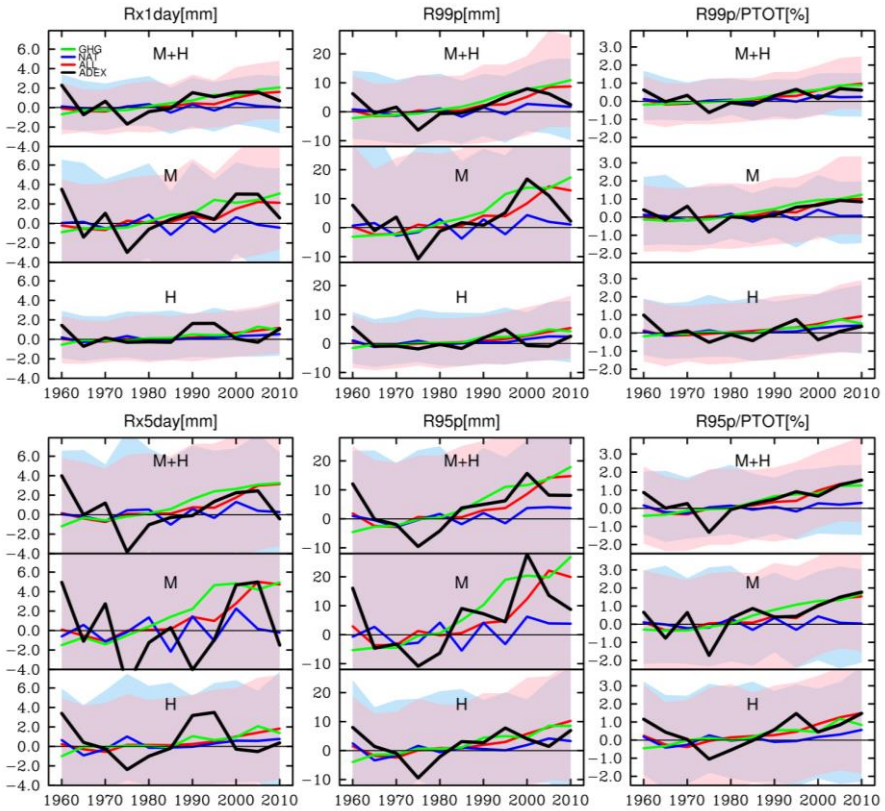


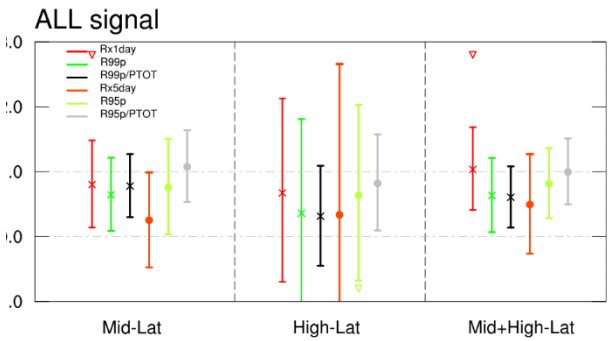
Li, Chen, Wang 2016, JGR

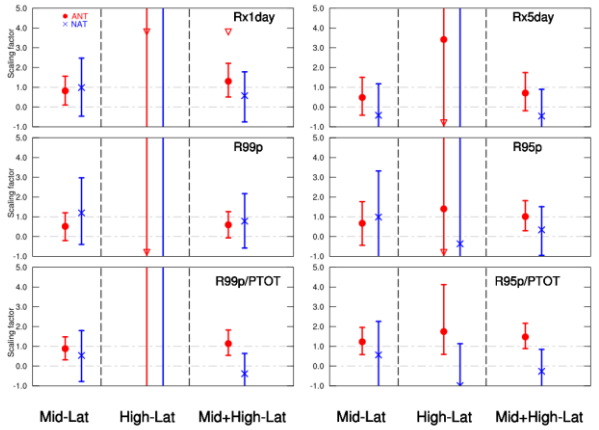
Anthropogenic signal can be detected in extreme precipitation, but ALL signal cannot be detected (optimal fingerprinting method)

Extreme precipitation: Anthropogenic signal can be detected in the changes of extreme precipitation in mid-high latitudes of Asia









- ✓ **A few indices show high signal-to-noise ratio**
- ✓ **Anthropogenic signal is detected in mid-and high-latitudes**
- ✓ **But cannot be detected in China extreme precipitation**

（Dong et al. 2020. Journal of Climate)

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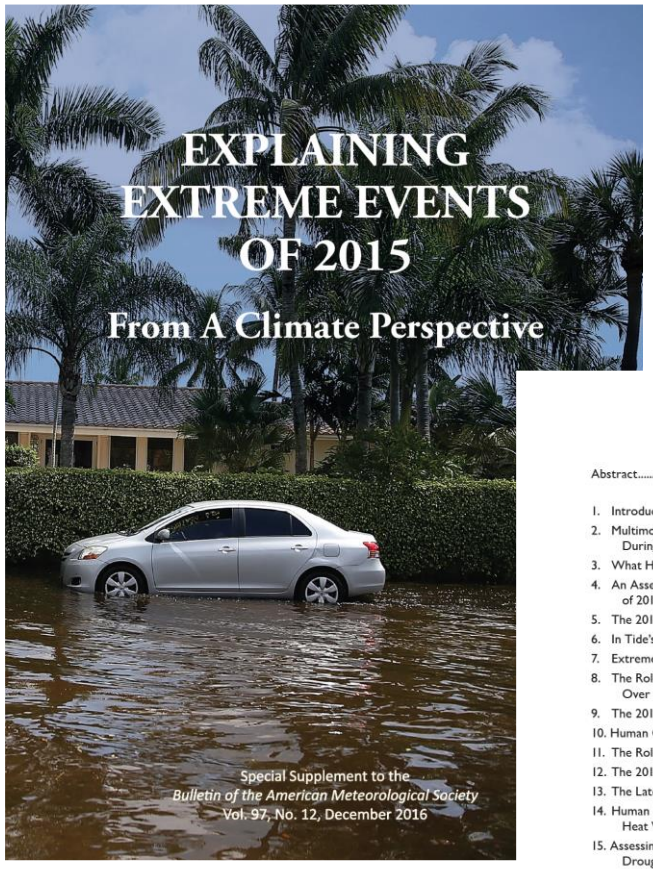
Attribution of extreme events: Increasing contribution from China



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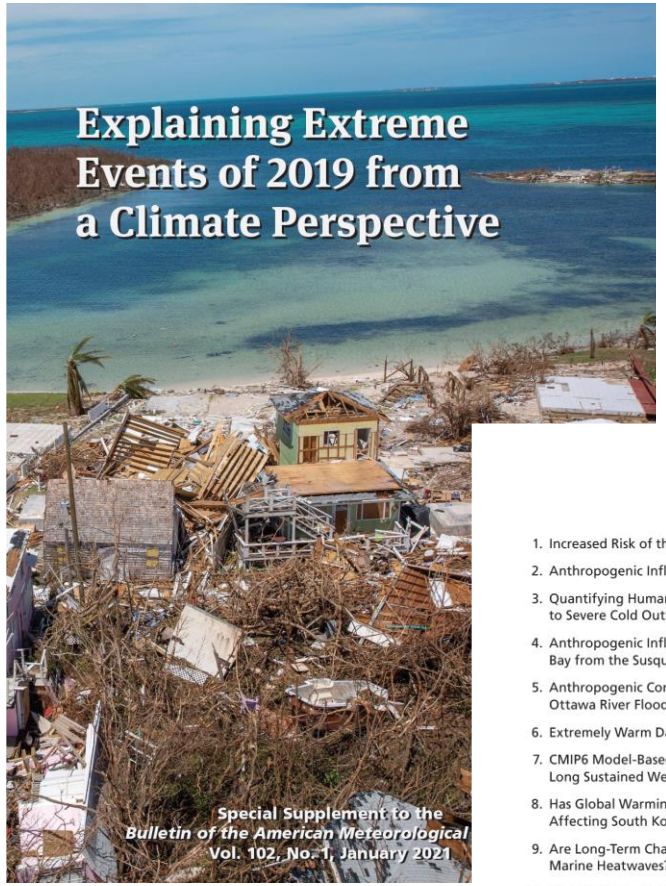

2/28 to 6/15

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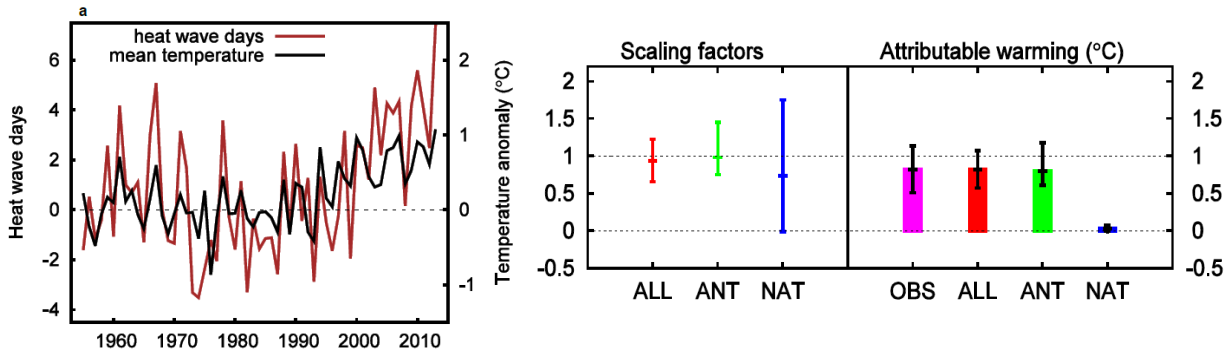
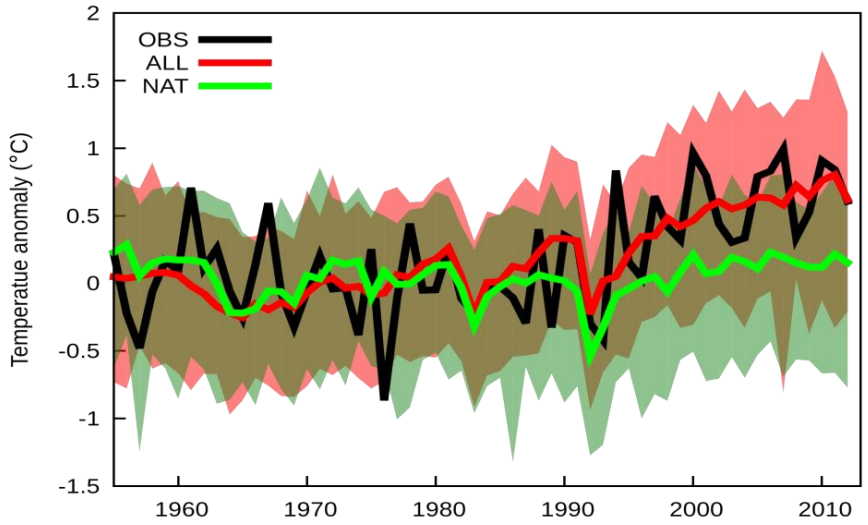
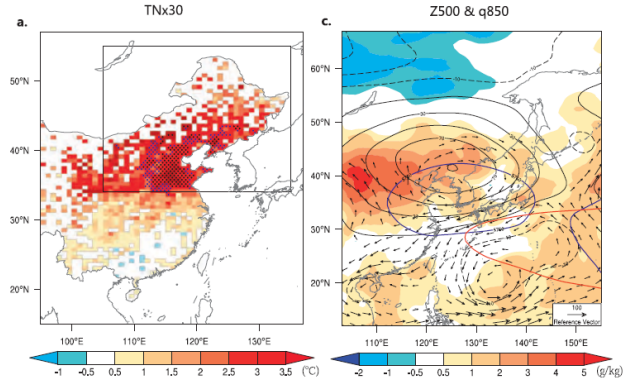
Heat wave: Human influence has increased the probability of extreme high-temperature events (daytime, nighttime, compound events)

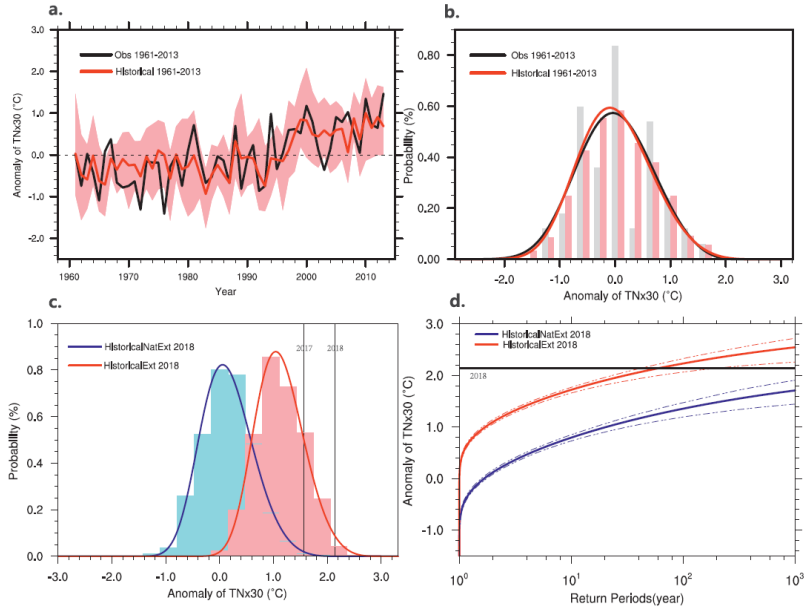




2013 Heat wave in eastern China



2018 Nighttime heat wave in northeastern China (HadGEM3-A)

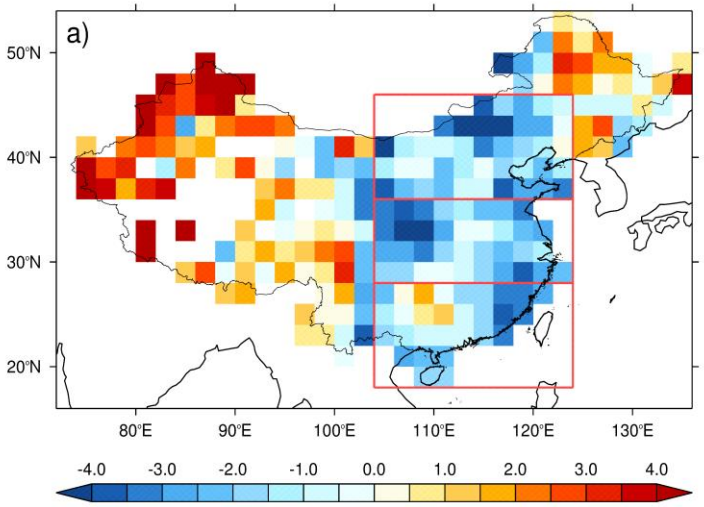


- Two-step and one-step attribution methods
- Human influence has increased the probability of heat wave
- Conclusions from multiple studies on attribution of high temperature are consistent

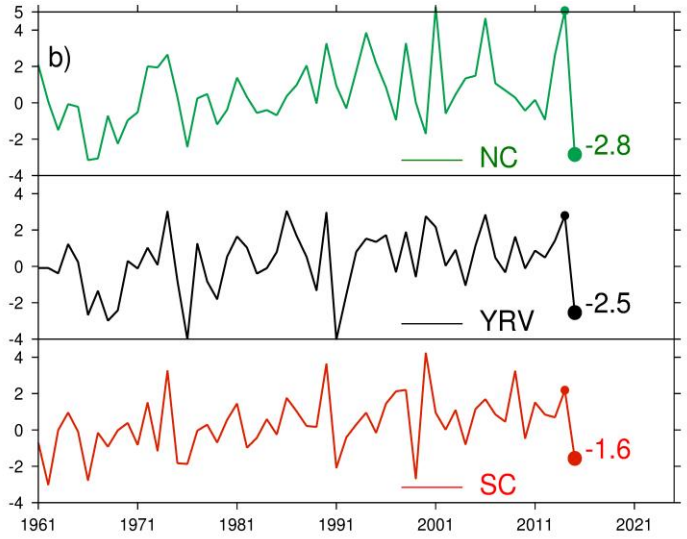
(Sun et al. 2014,Nature Climate Change; Ren et al. BAMS, 2019)

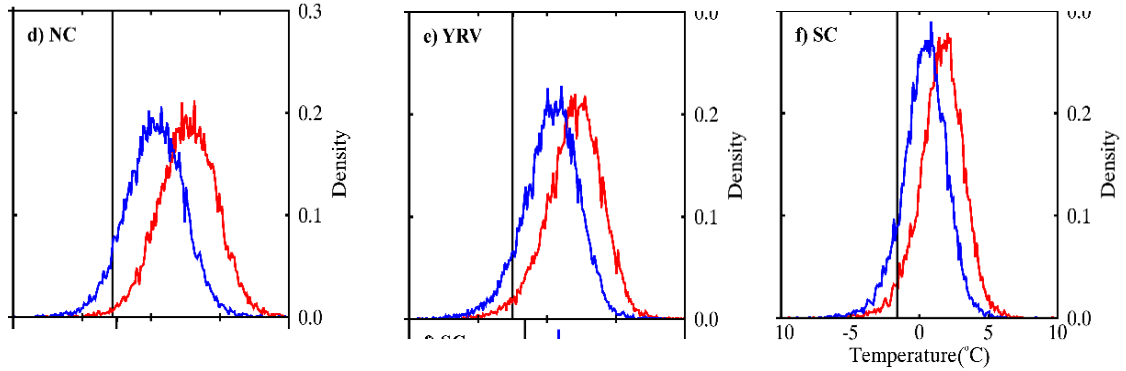
Cold surge: Human influence has decreased the probability of extreme low-temperature events

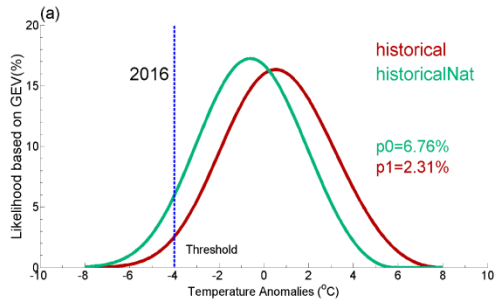
TNn anomalies in the 2015/2016 winter

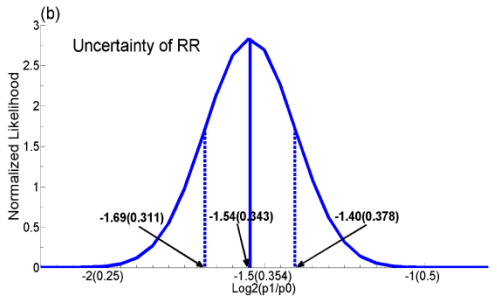


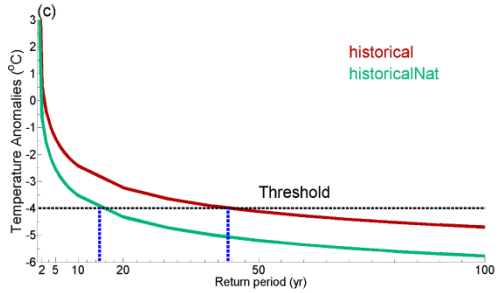
Winter TNn anomalies 1961/62 -2015/16











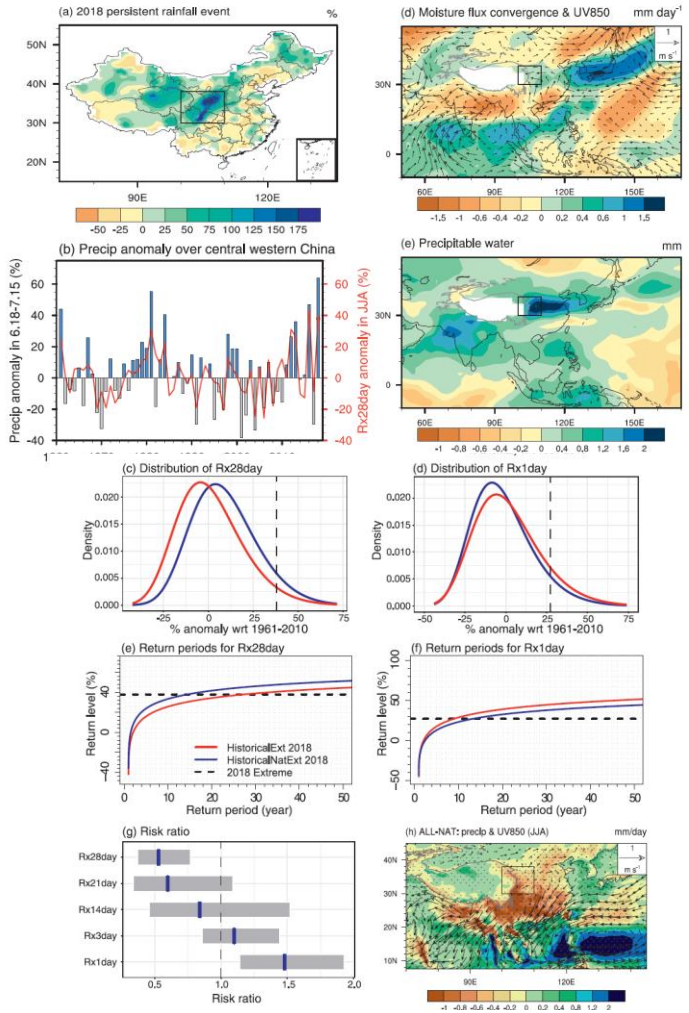
Human influence decreased the probability of a cold surge occurrence in China.

- The 2015/2016 winter cold surge would have been **much stronger without anthropogenic induced warming**.
- **Human influence may have respectively reduced the occurrence** of such a cold event by 89%, 73%, and 69%.

(Sun et al, 2018, BAMS; Qian et al. 2018, BAMS)

Heavy Precipitation: There is still uncertainty in human influence on the occurrence probability of regional heavy precipitation

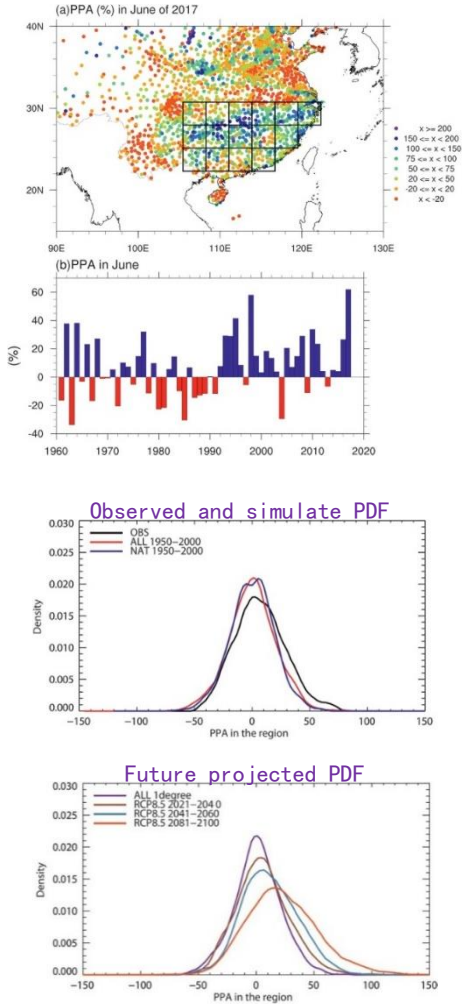
2018 Heavy precipitation in central part of China (Sichuan Province)



- **Increase the probability of RX1day, but decrease the probability of Rx28day**

Zhang et al. 2020, BAMS

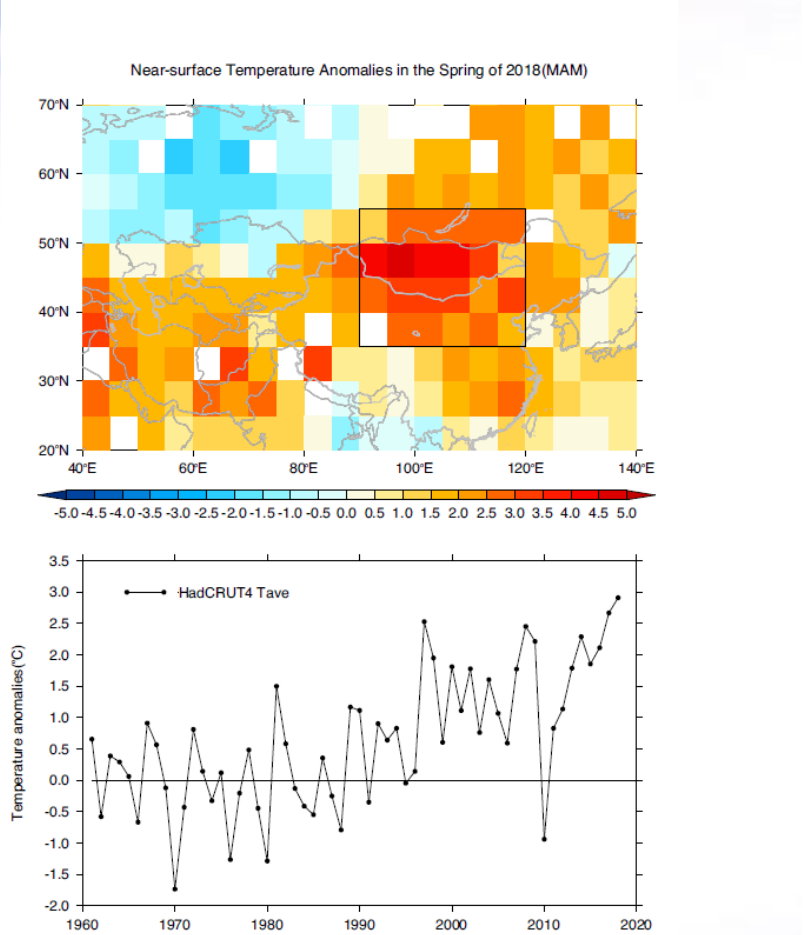
2017 Heavy precipitation in southern China

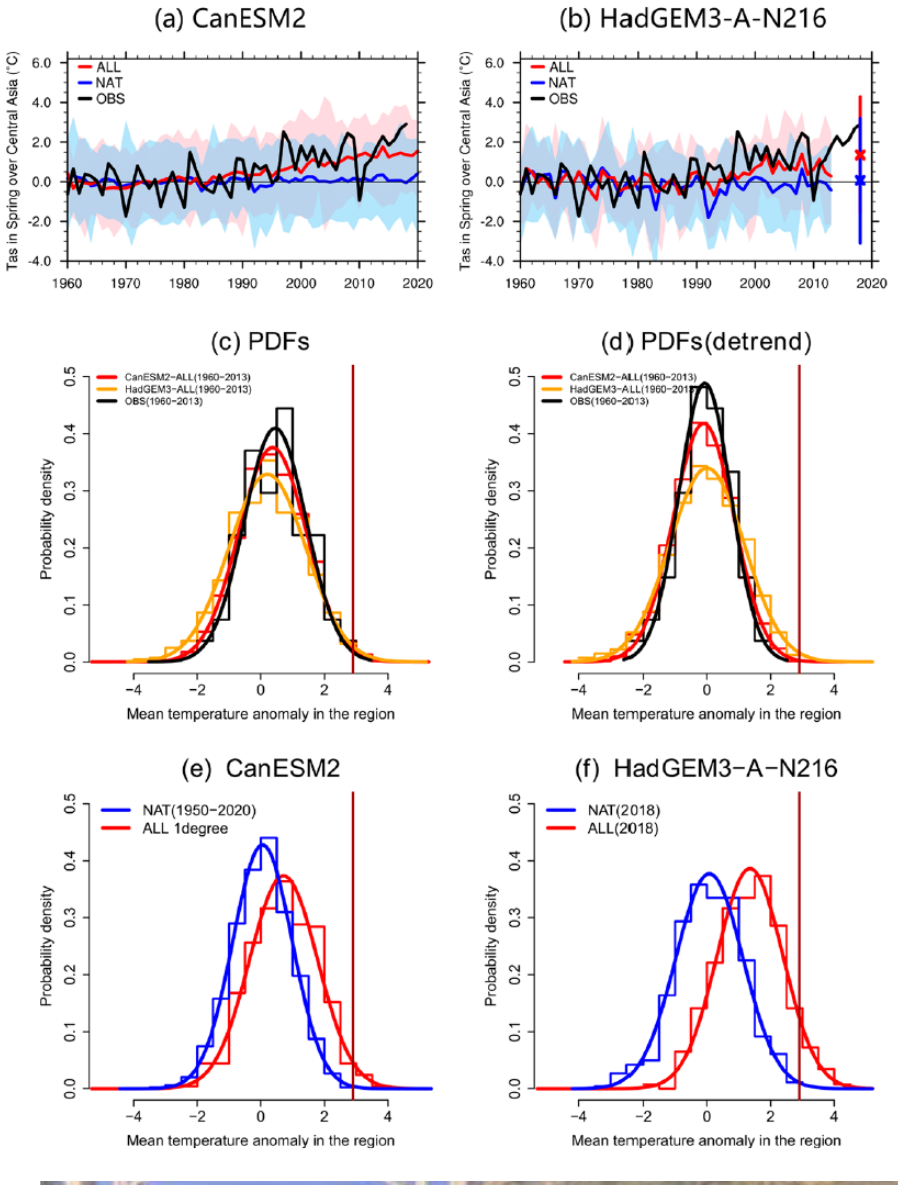


- **Increase the probability of June heavy precipitation in Southern China**

Sun et al. 2018, BAMS

Framing issues: Multi-model attribution of the warmest spring of 2018 in central Asia (CanESM2 and HadGEM3-A)





✓**Human activities have increased the probability 18 times of the warm temperature events**

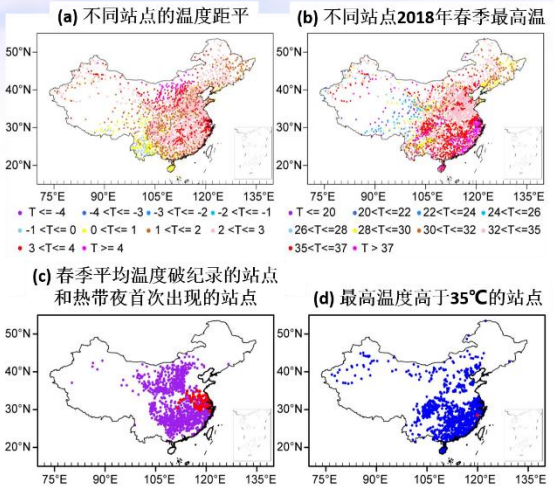
✓CanESM2: PALL=2.02%, PNAT= 0.11% RR=18.4

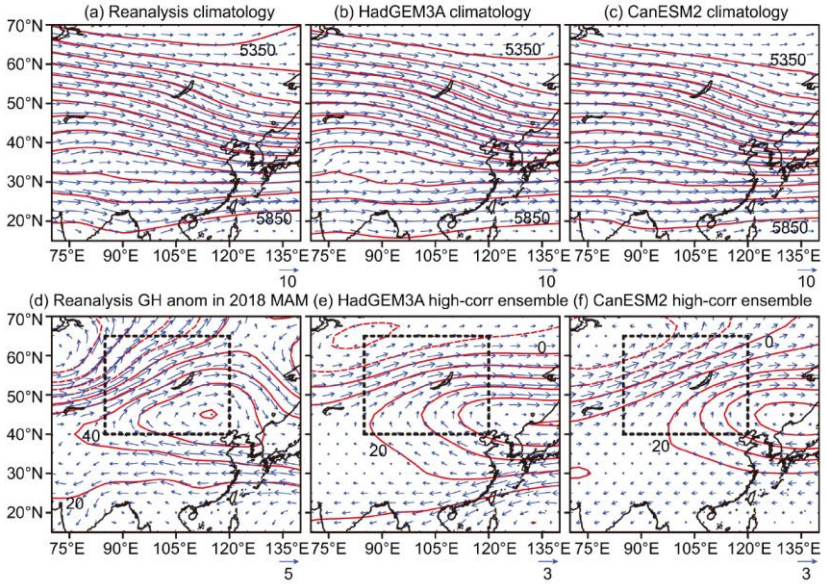
✓HadGEM3: PALL=6.67%, PNAT=0.38% RR=17.5

(Sun et al., 2020, *Bull. of the American Meteor. Soc.*)

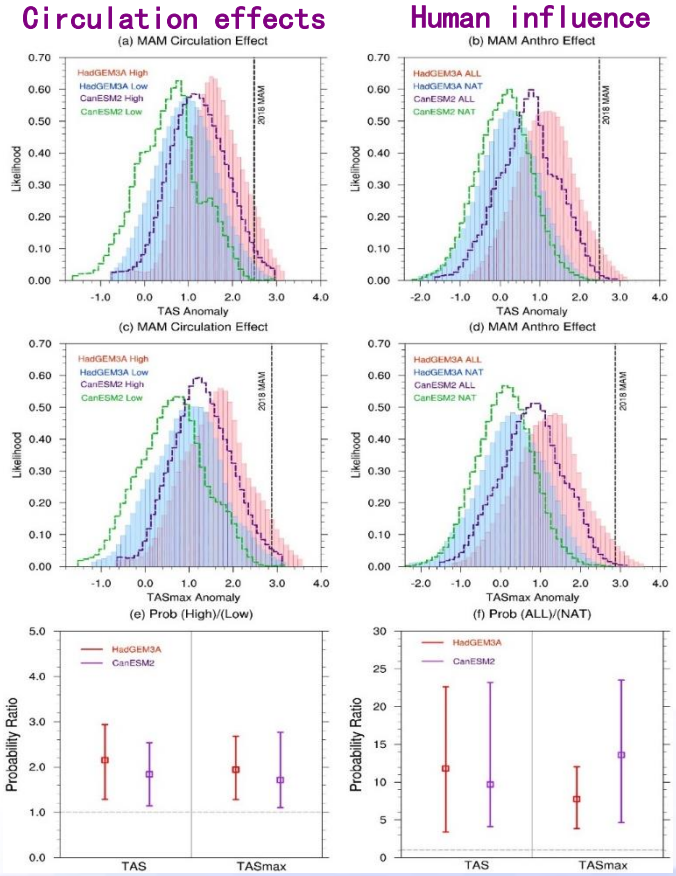
Uncertainty in relative contribution of human activities and atmospheric circulation

2018 Warm Spring in Eastern China





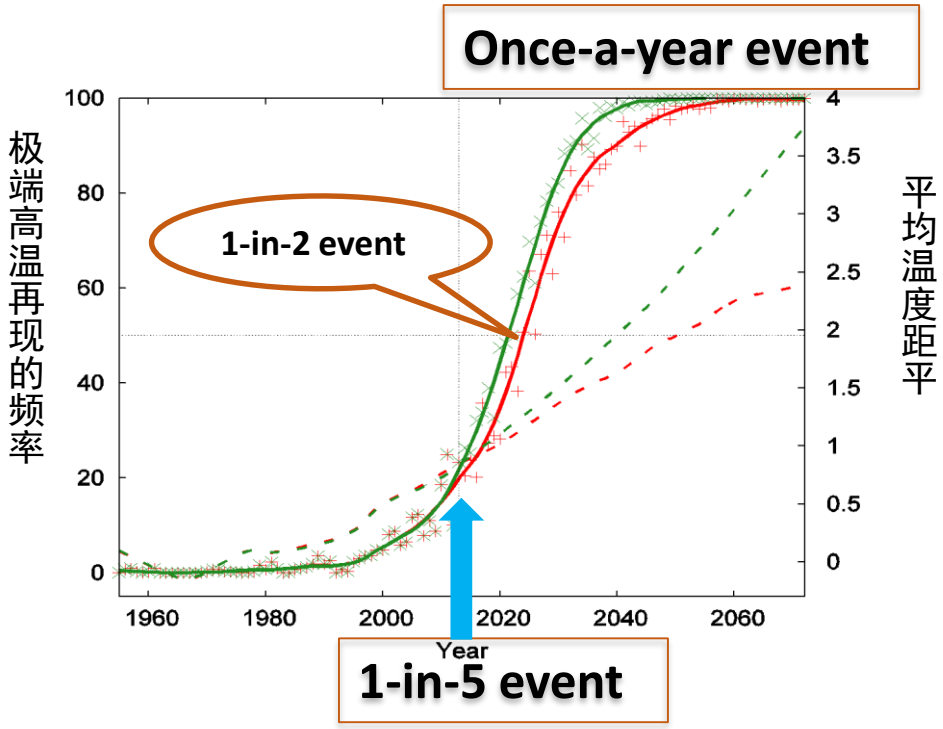
Influence from human activities and local circulation anomalies

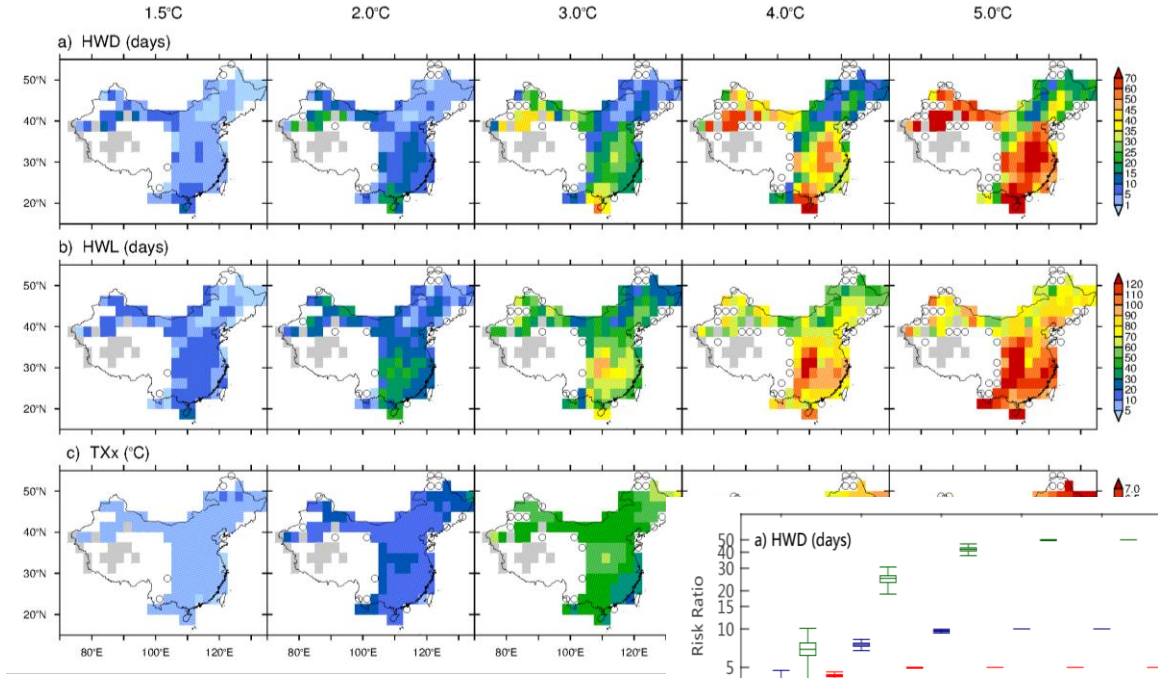


Hadley极端事件归因系统的数据研究表明：人类活动使得2018年春季高温这样的极端事件发生概率增加了10倍；而异常的局地反气旋环流使得这一事件的发生概率增加了约两倍。

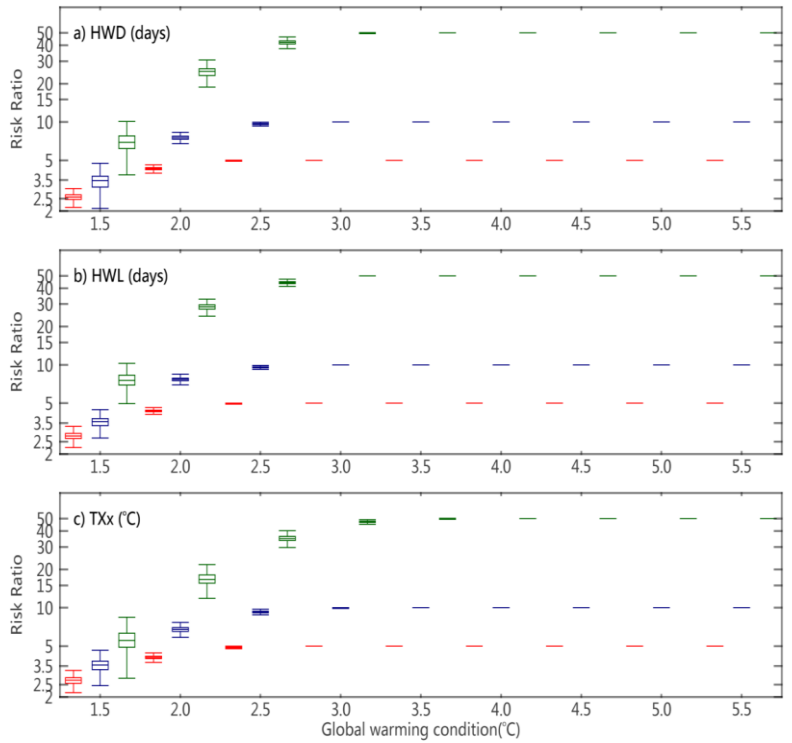
(Lu et al., *Advances in Atmospheric Sciences*, 2020)

Observational-constrained future projection (attribution constrained and model-bias adjustment model results)





RR = p1/p0



- In 2030s，the 2013-like heat wave will become once-a-year event（Different methods and models show consistent conclusion)

Risk ratio for extremes of heatwave metrics with 5-yr (red), 10-yr (blue), a 50-yr (green) return periods in the current climate under different global warming levels

Sun et al. 2014, Nature Climate Change, Earth’s Future

Conclusion：Current understanding of human influence on climate change in China

Chang in indicator/Phenomenon	Human contribution
Changes in mean temperature and precipitation	
Mean temperature	Very likely the main driver for the observed increase
Mean precipitation	Lack of change in observations
Warm/hot extremes: Frequency, intensity and duration	Very likely the main driver for the observed increase
Cold extremes: Frequency, intensity and duration	Very likely the main driver for the observed decrease
Heavy precipitation: Frequency, intensity and/or amount	Human influence for an increase in heavy precipitation emerging
Drought	Limited evidence for increase in droughts
Attribution of extreme events	
High temperature events	Very likely increase in occurrence probability
Cold temperature events	Very likely decrease in occurrence probability
Heavy precipitation events	Mixed signal (increase in probability for some events but decrease for other events)

Thanks!