Changes in the Earth System and Response to Perturbations of the Earth's Energy Balance

---Visions from CHINA

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Content

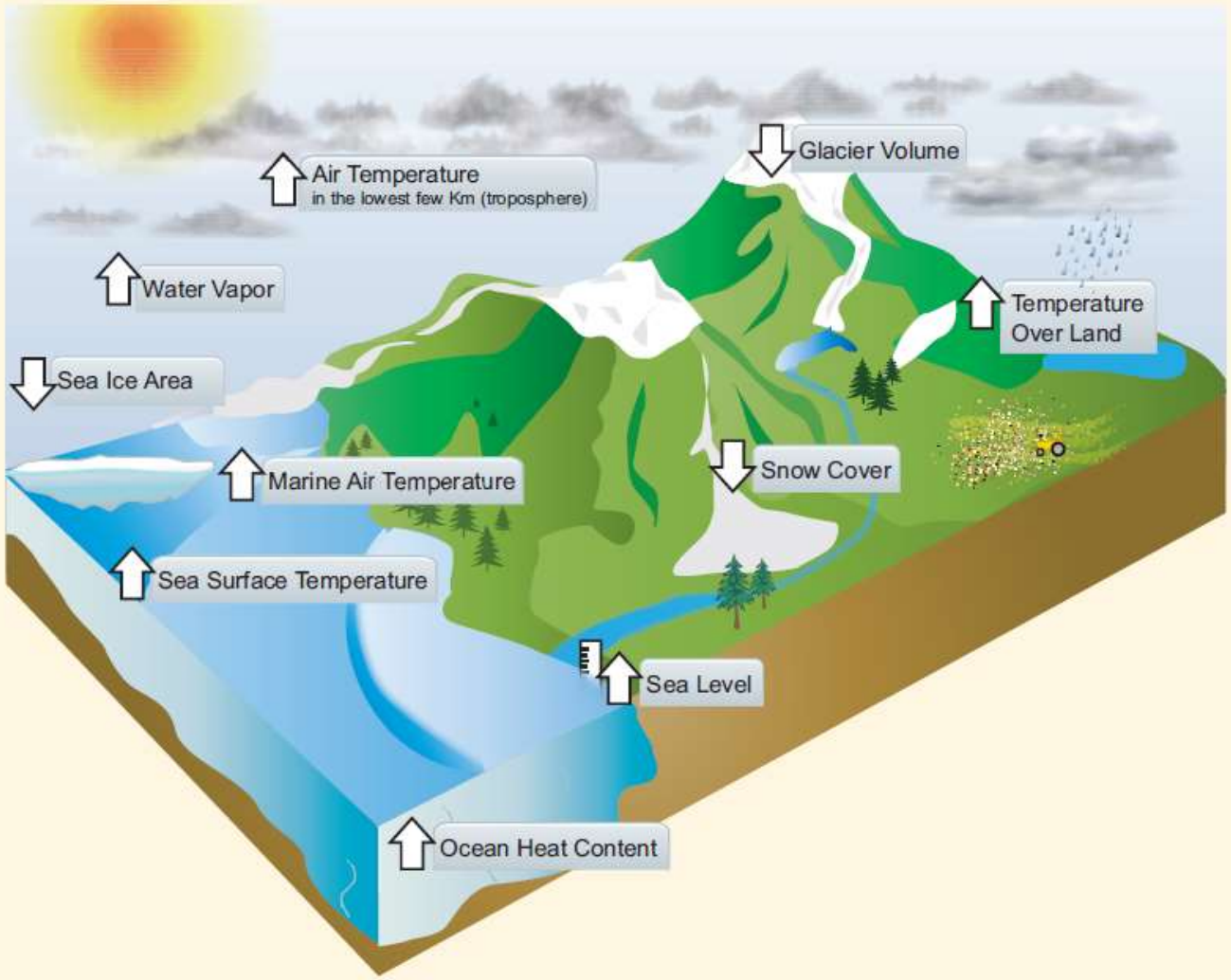
1. Observed changes in the climate system

2. Climate response to the Earth's energy balance

3. Continued emissions will cause further warming and changes in all components of the climate system

4. Some issues concerned

1. Observed Changes in the Climate System

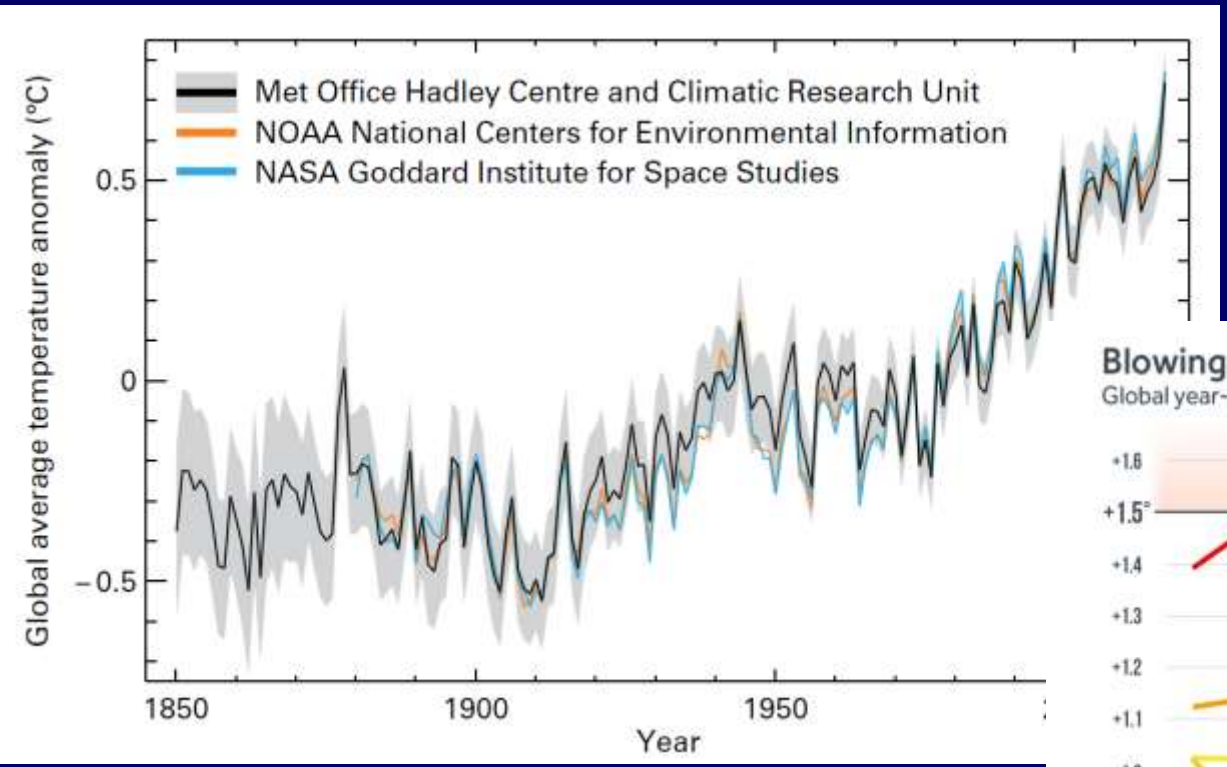


FAQ 2.1, Figure 1 | Independent analyses of many components of the climate system that would be expected to change in a warming world exhibit trends consistent with warming (arrow direction denotes the sign of the change), as shown in FAQ 2.1, Figure 2.

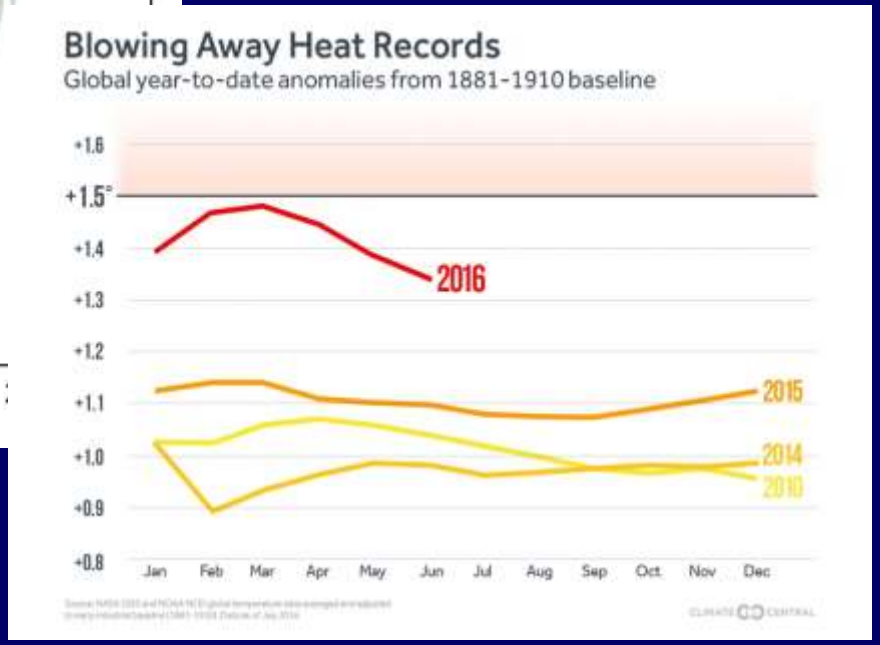
Independent observation analyses of many components of the climate system collectively exhibit trends consistent with warming!

The global mean annual surface temperature in 2015

(1℃ higher than the preindustrial era)

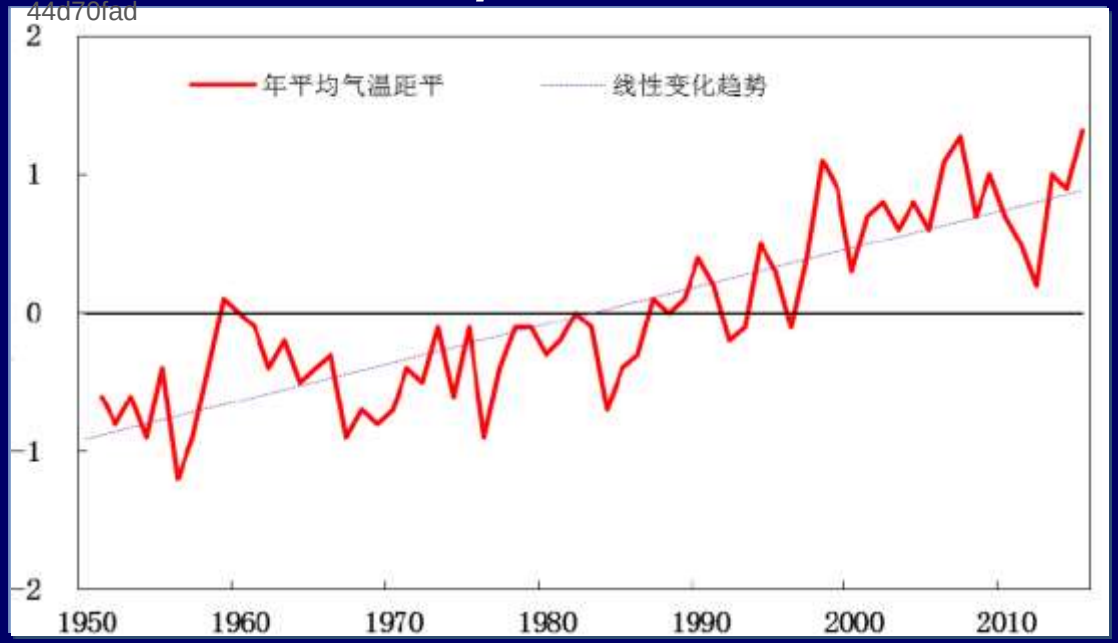


Global annual average temperature anomalies (relative to 1961–1990) for 1850–2015



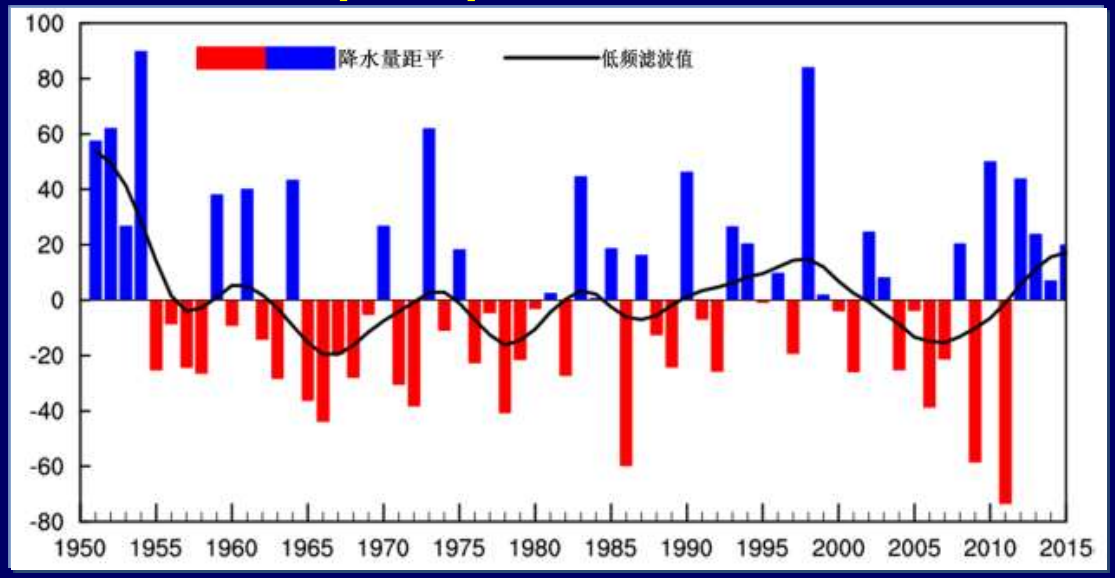
- **2015 was the warmest year on instrumental record**
- **0.76℃ higher than the 1961-1990 mean;**
- **1℃ higher than pre-industrial era**

Annual average ***temperature*** anomalies of CHINA



- A significant upward trend
- 2015 (10.5℃) was the warmest year since 1951
- 1.3℃ warmer than the normal

Annual average ***precipitation*** anomalies of CHINA



- No obvious trend
- Significant interannual change
- 649.1 mm in 2015

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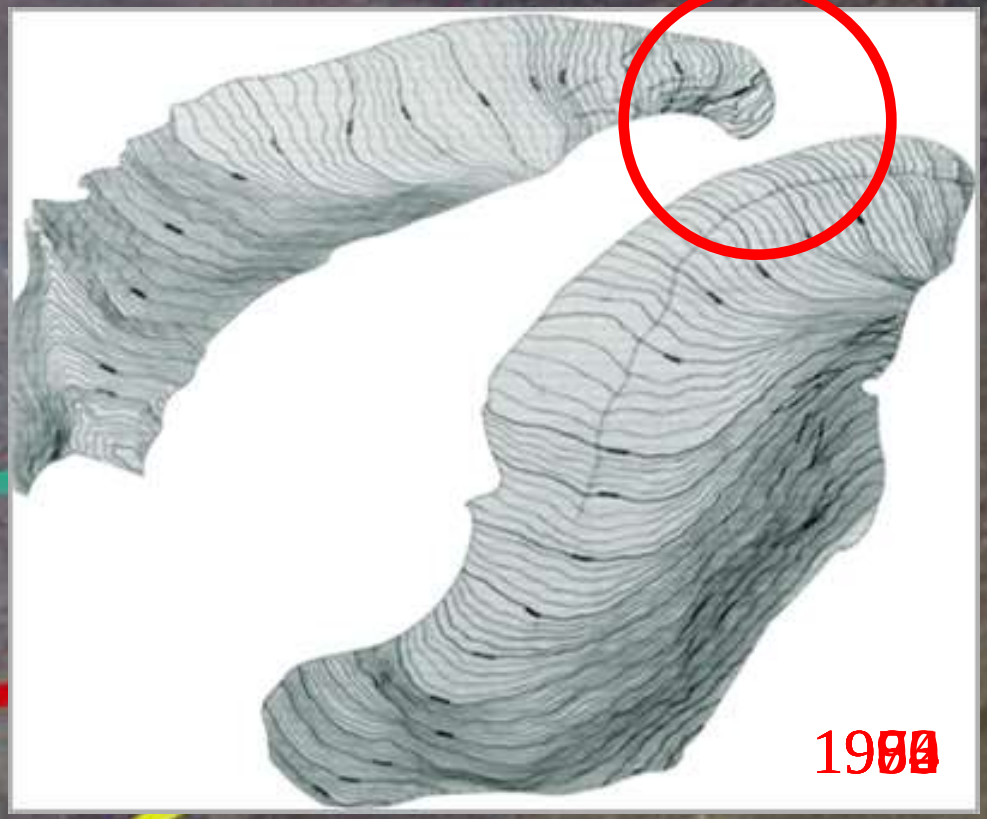
Retreat of Glacier No. 1 in head water of Urumqi River, Tianshan Mountains

Separated in 1994

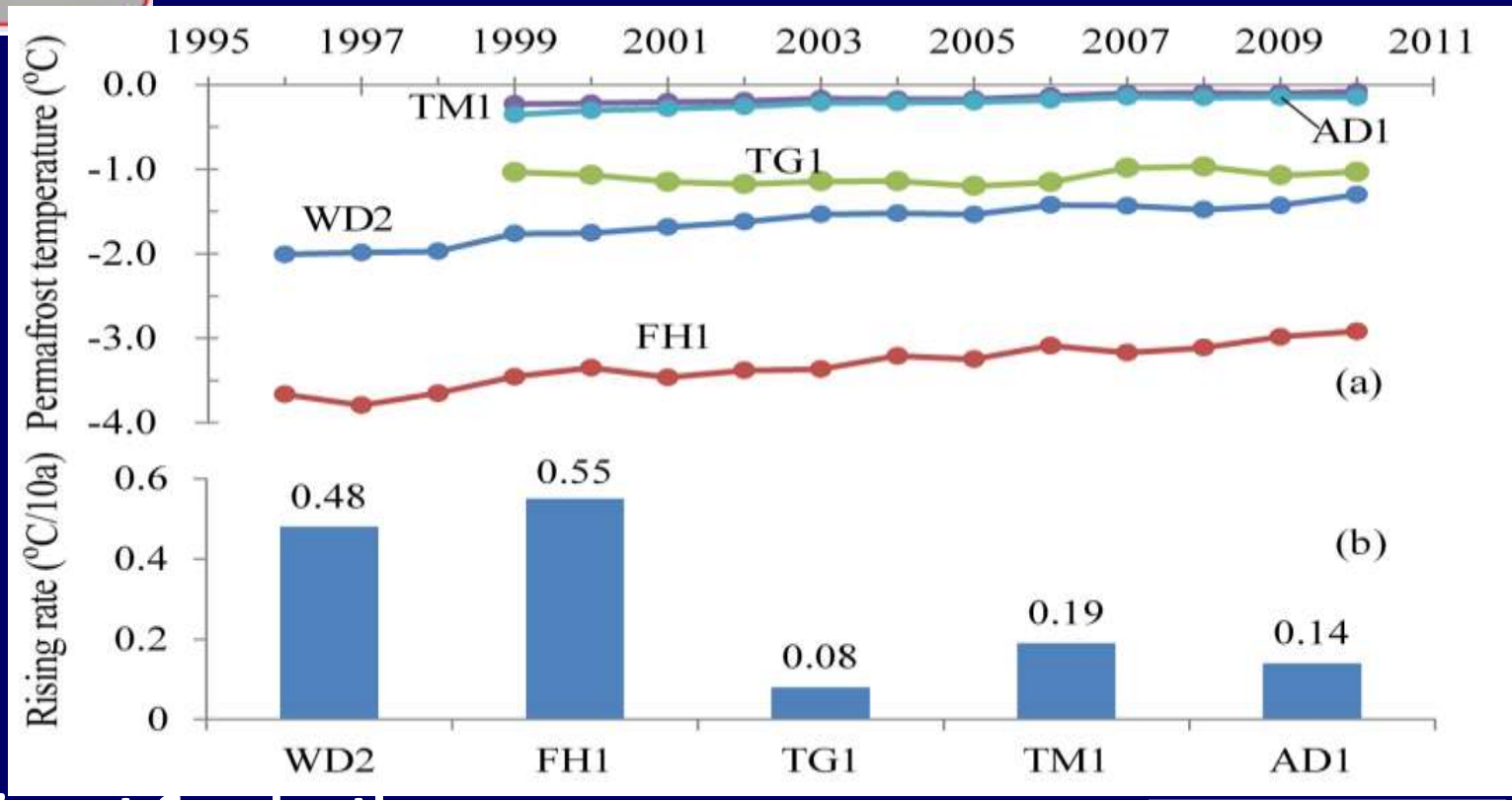


Retreat since LIA and 1962

1. Observed: Cryosphere

August 2016

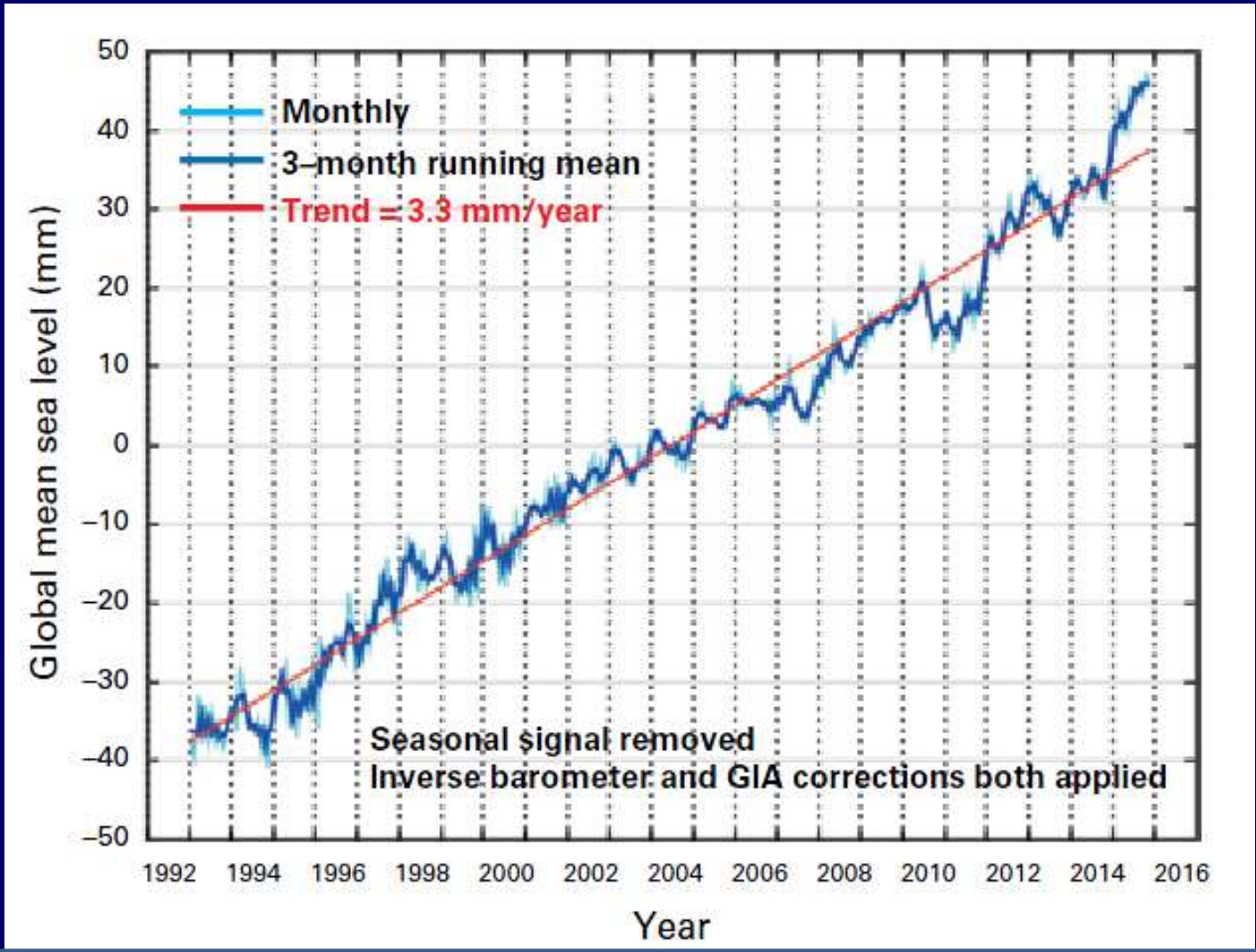
Change in permafrost temperature along the Tibet Highway during 1995/1998-2010



- Warming at 6m depth
- Rising rate higher in mountains than the lower area

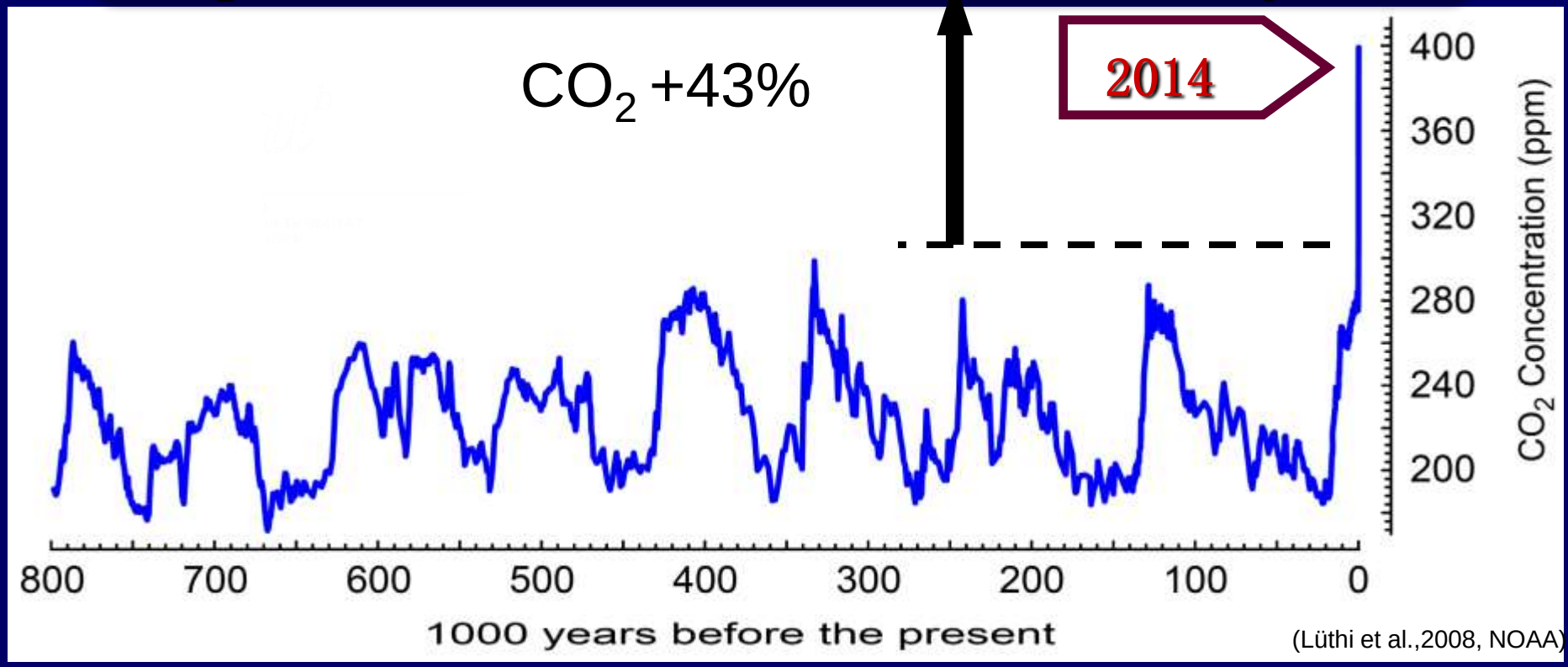
Ann Rep. CNC-IACS2011

Global Sea-Level Raising (1993 – 2015), with annual cycle removed from the data



Global sea level of 2015 was the highest ever recorded by satellites

The concentrations of CO_2 have increased to levels unprecedented in at least the last 800,000 years.



- In 2014, globally averaged CO_2, CH_4 and N_2O are 397.7ppm, 1833ppb and 327ppb, increased by 43%, 154% and 21% compared to the pre-industrial times, respectively
- In March 2015: Mauna Loa over 400ppm, SH too!

2. Climate response to the Earth's energy balance

- ***Total radiative forcing is positive***, **and has led to an uptake of energy by the climate system.**
- **The largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO_2 since 1750**

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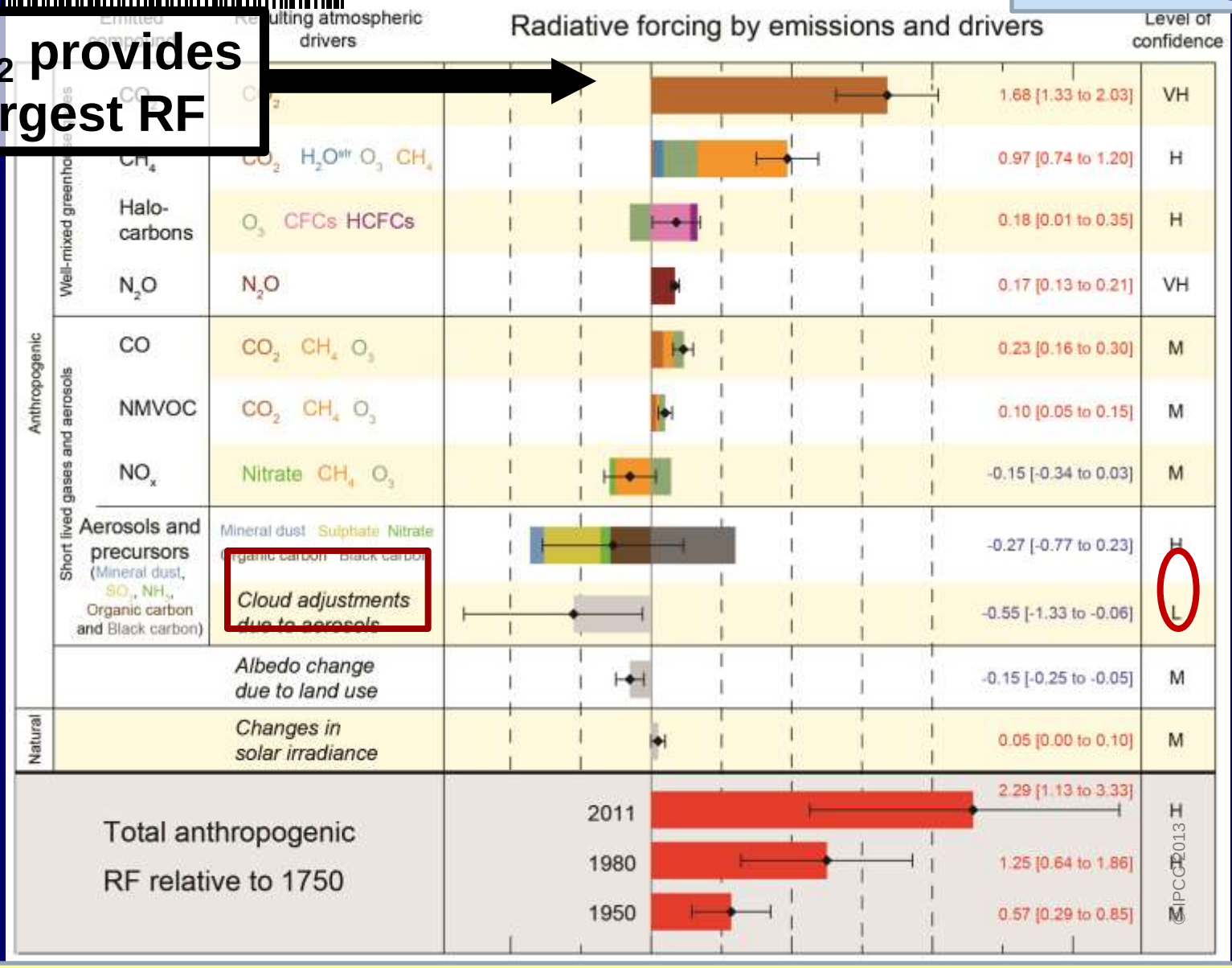
CO_2 provides largest RF



Total anthropogenic RF for 2011 was 2.29 [1.13~3.33] W m^{-2}, 43% higher than that in AR4 for the year 2005

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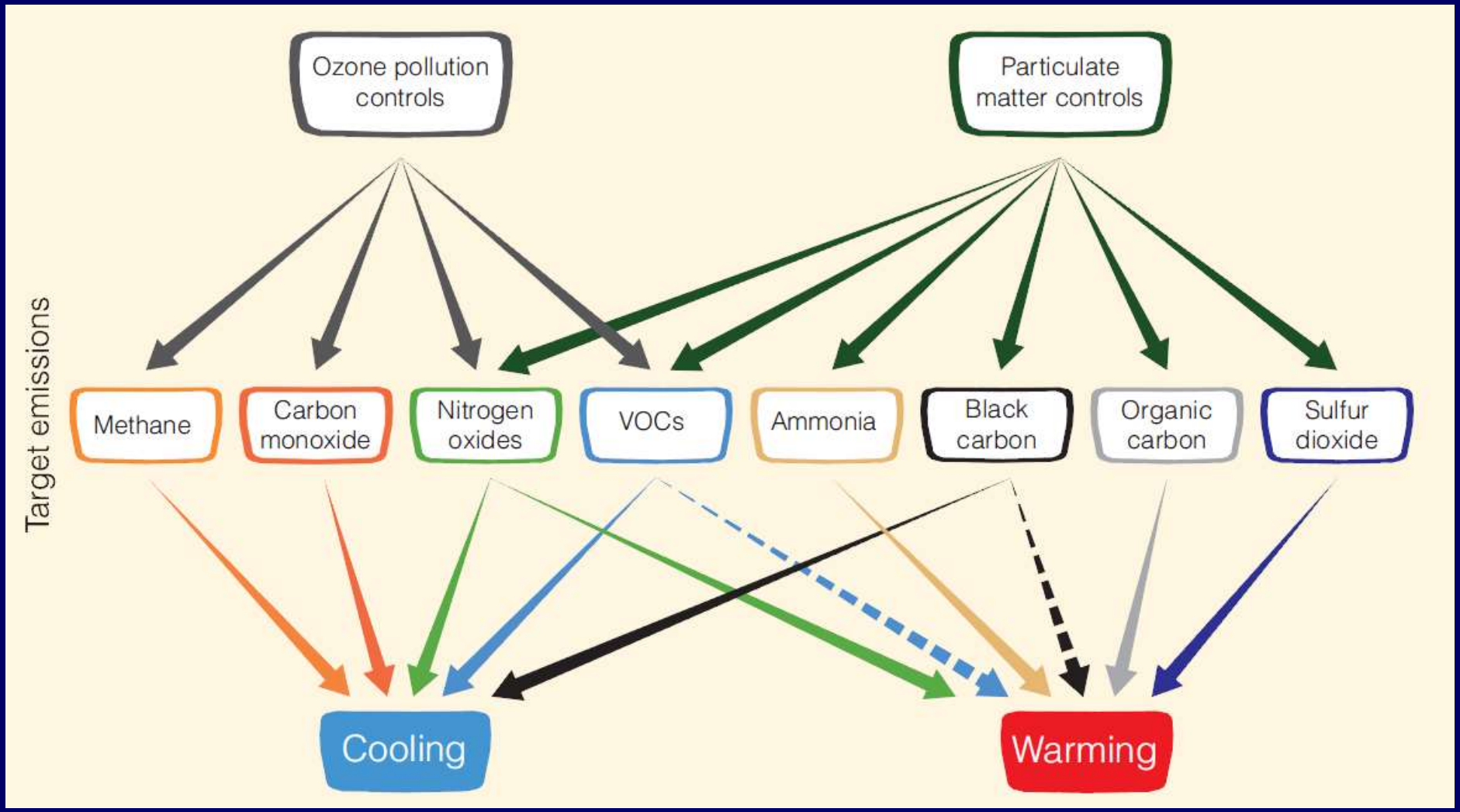

Schematic diagram of the impact of pollution controls on specific emissions and climate impact.

Solid black line indicates known impact; dashed line indicates uncertain impact.

Attribution
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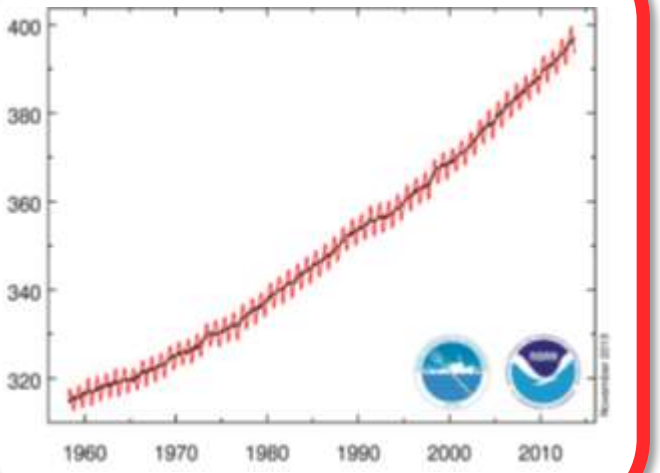
Worldwide Effects

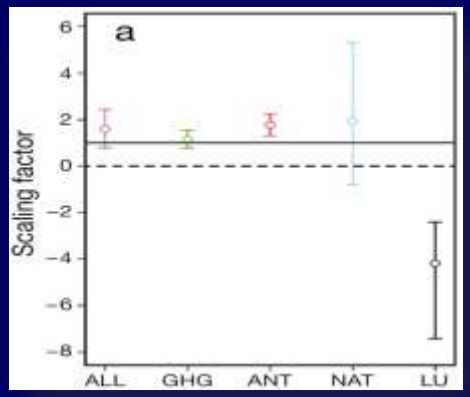
Cause

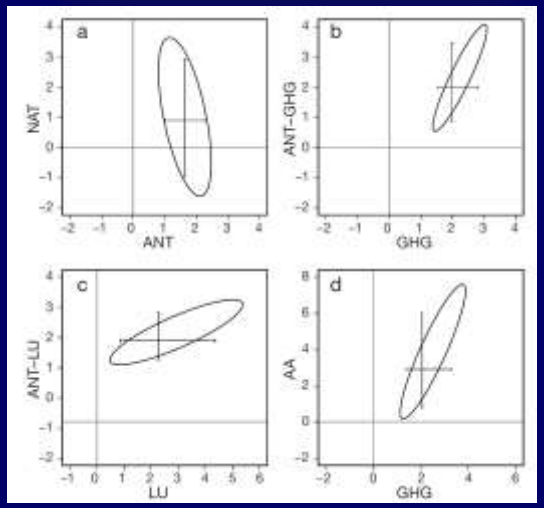


- atmosphere, land, ocean
- extreme events
- water cycle
- sea ice, glaciers, ice sheets
- global mean sea level

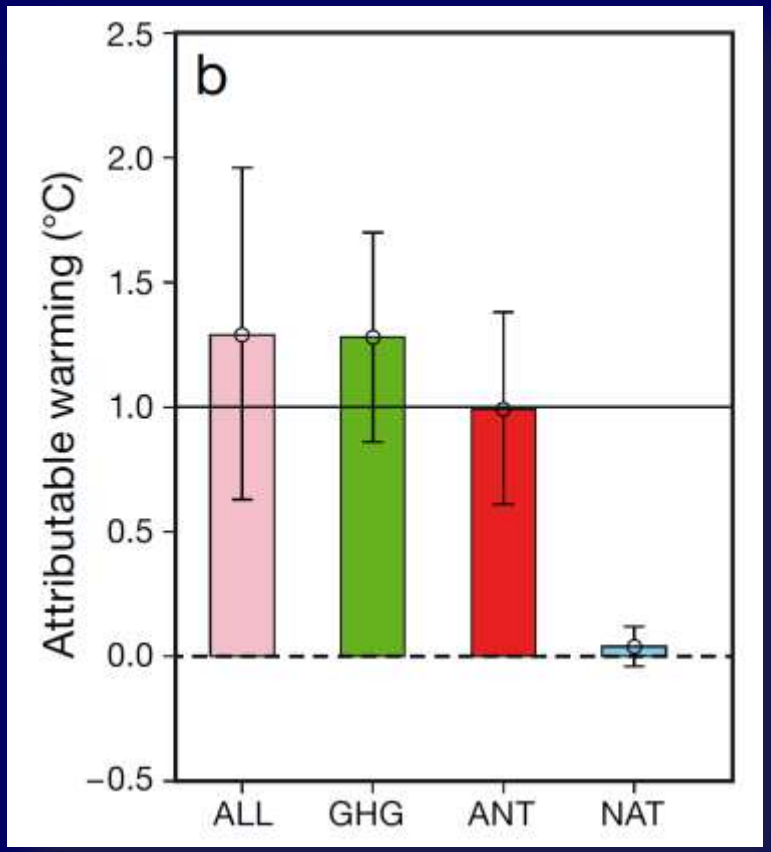
Human influence on the climate system is clear

Attribution of change in annual mean temperature in CHINA during 1961-2005





Scaling factors



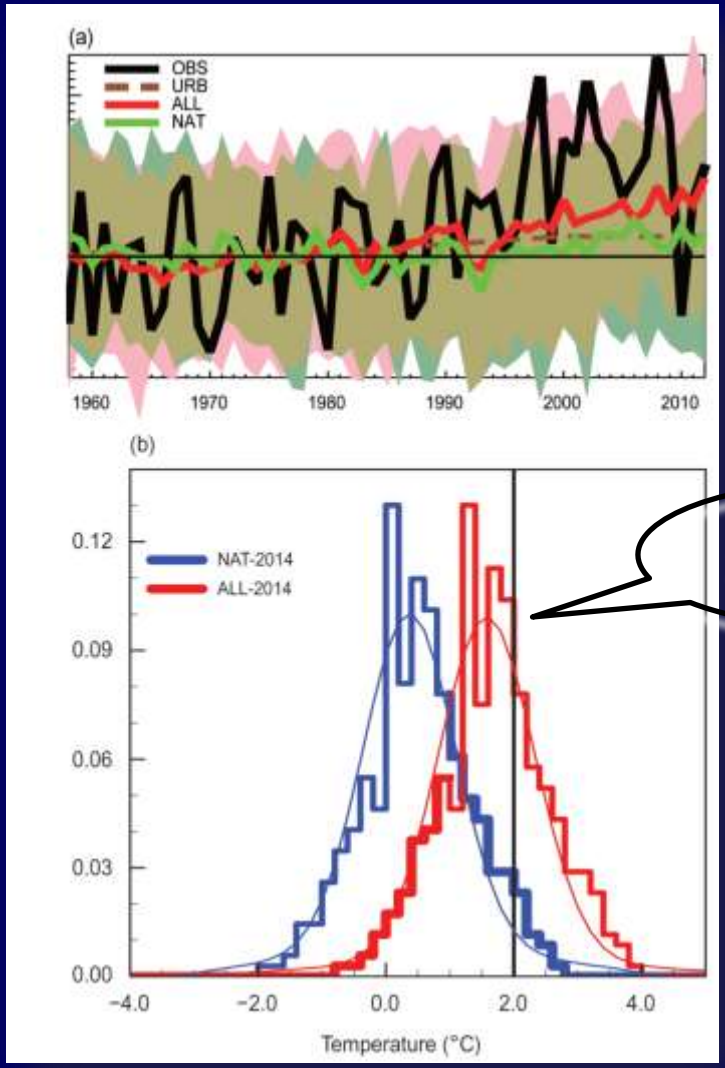
attributable warming

Factors	Trend ℃/10a
OBS	0.28
ALL	0.18
ANT	0.17
GHG	0.25
LU	-0.04
AA	-0.08
NAT	0.09

(Xu et al., 2015)

Anthropogenic forcing increased the probability of the high temperature event in spring in Northern CHINA

Attribution of 2014 spring high temperature event in China



2014 spring, the 3rd warmest year in Northern China. The maximum temperature in May exceeded 40℃

Without anthropogenic forcing, climate models could not reproduce the increased high temperature in recent years in Northern China

2014 Ta=2℃

- Only with NAT, the probability is 2.31% (once every 43.3years)
- With anthropogenic forcing (All-2014), the probability is 25.7% (once every 3.9 years)

(Song et al., 2015)

3. Continued emissions will cause further warming and changes in all components of the climate system

Projection

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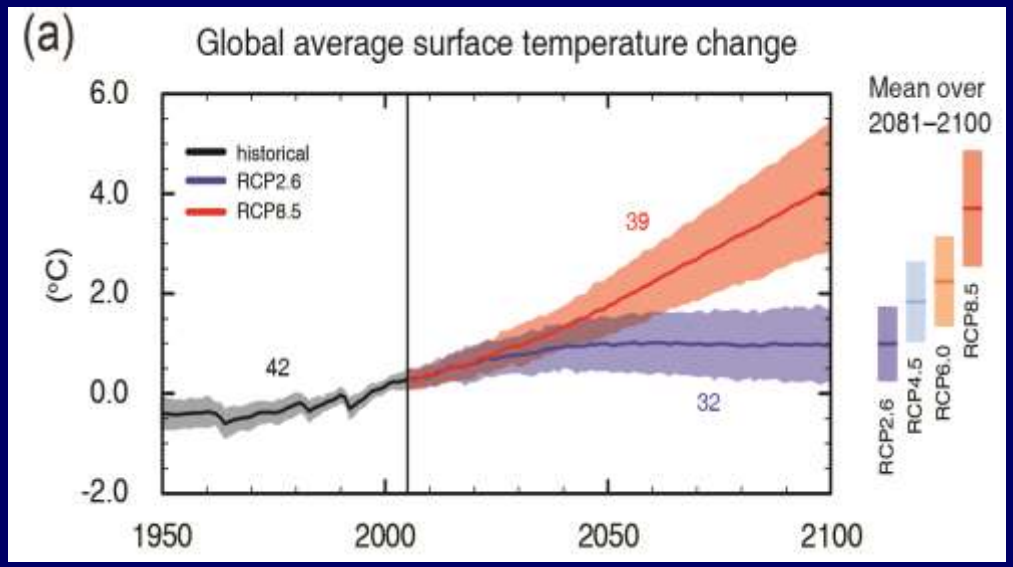
Global mean surface temperature change from 1986-2005

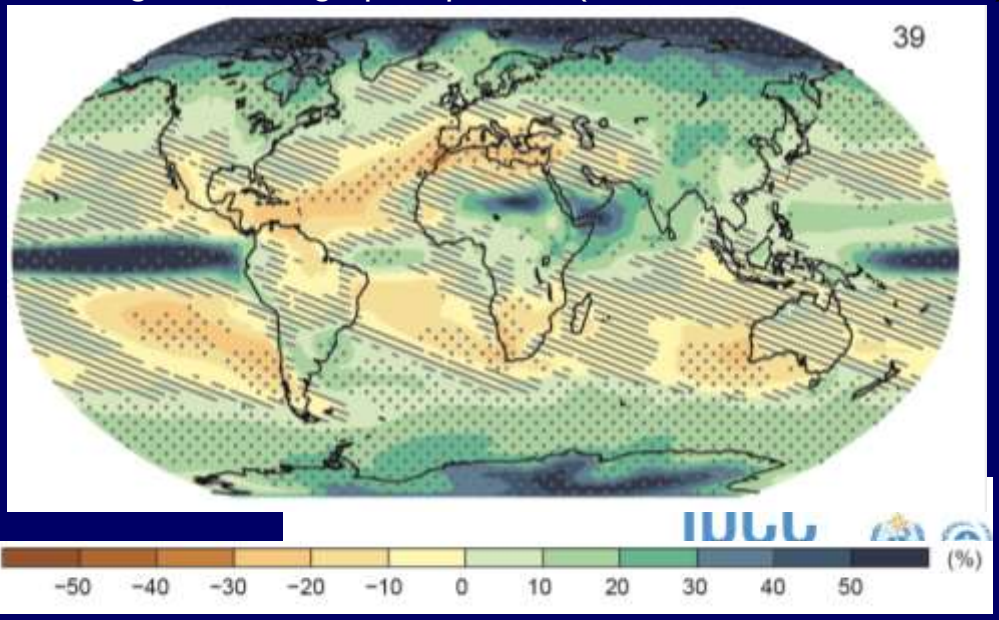


Relative to 1986–2005, global mean surface temperature will likely increase 0.3–0.7℃ for the period 2016–2035, and 0.3–4.8℃ for the period 2081–2100

Change in average precipitation (1986-2005 to 2081-2100)

RCP8.5

The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, [...]



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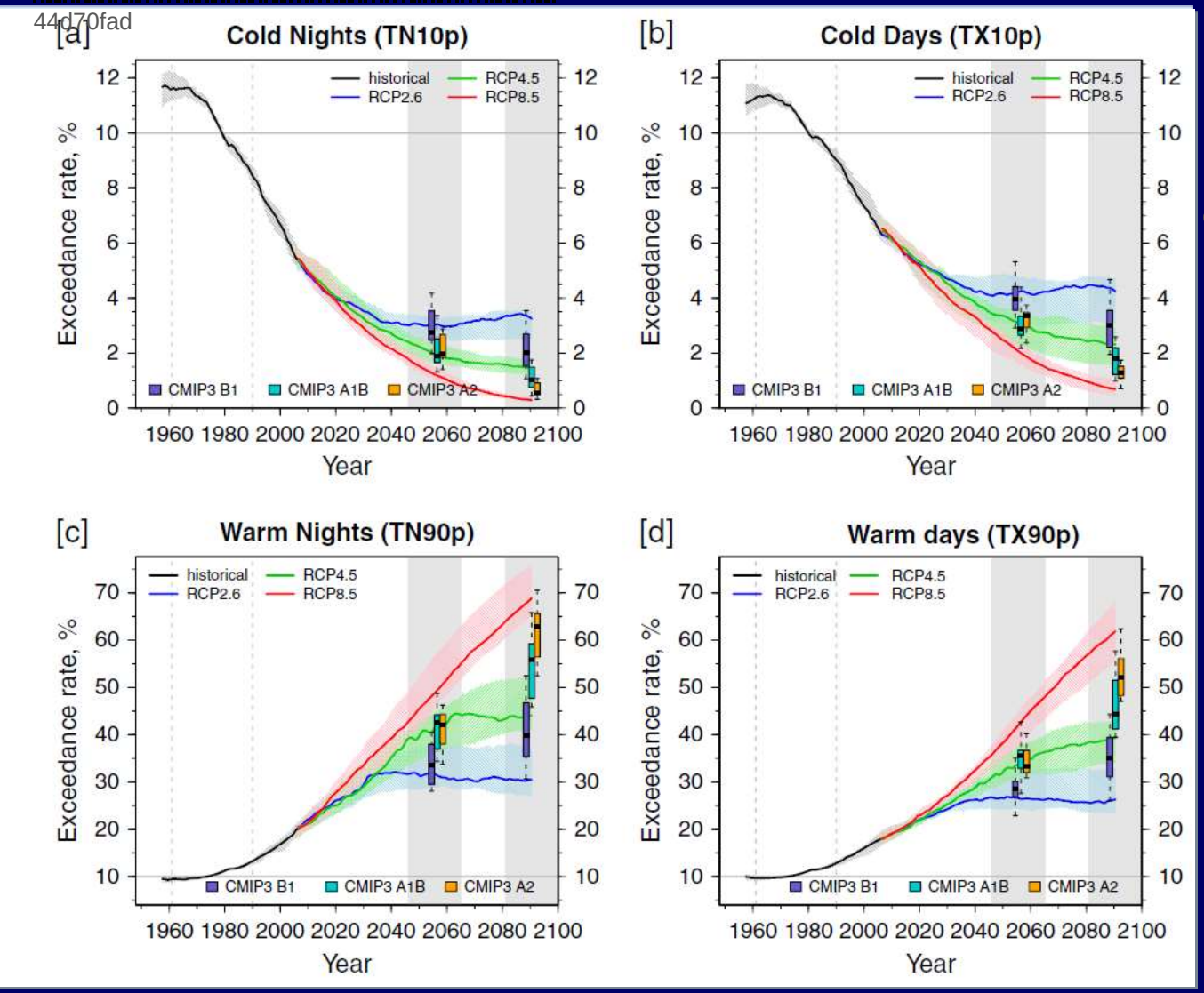
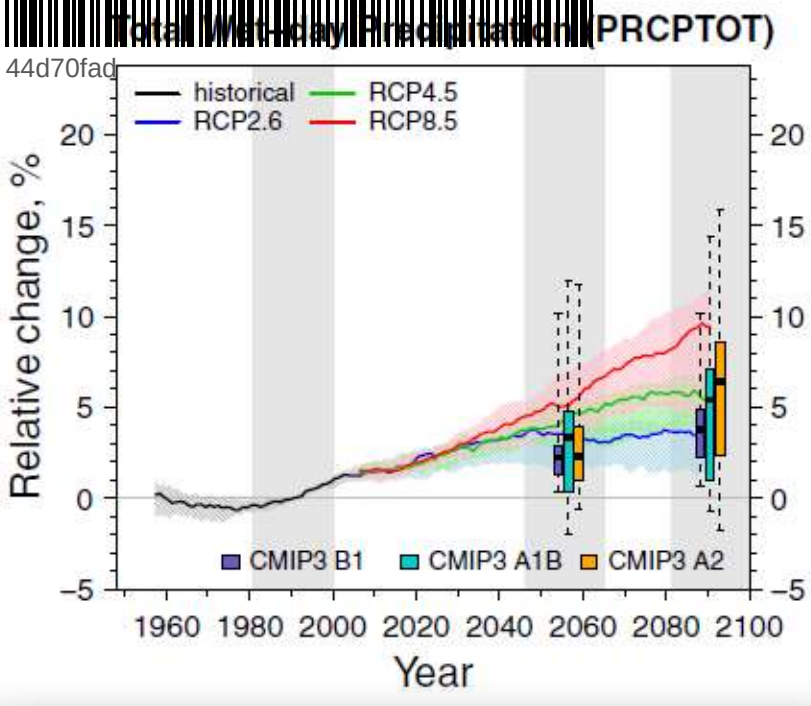


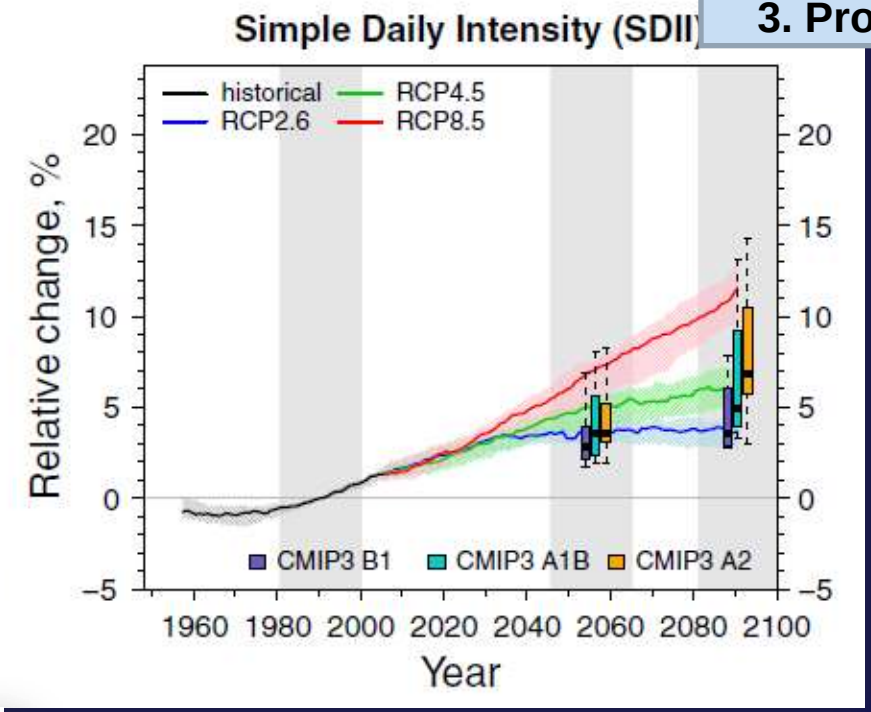
Global Climate extremes

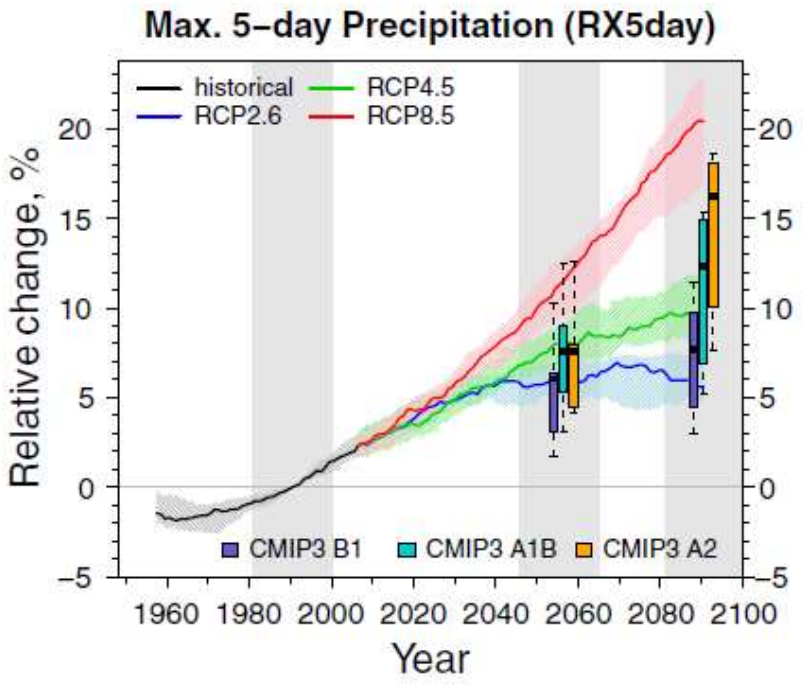
Heat waves

- It is ***very likely*** that heat waves will occur with higher frequency and duration.
- Occasional cold winter extremes will continue to occur.

Sillmann et al., 2013







Global Climate extremes precipitation

generally increases faster than total wet-day precipitation

INTERGOVERNMENTAL PANEL ON clim

Sillmann et al., 2013

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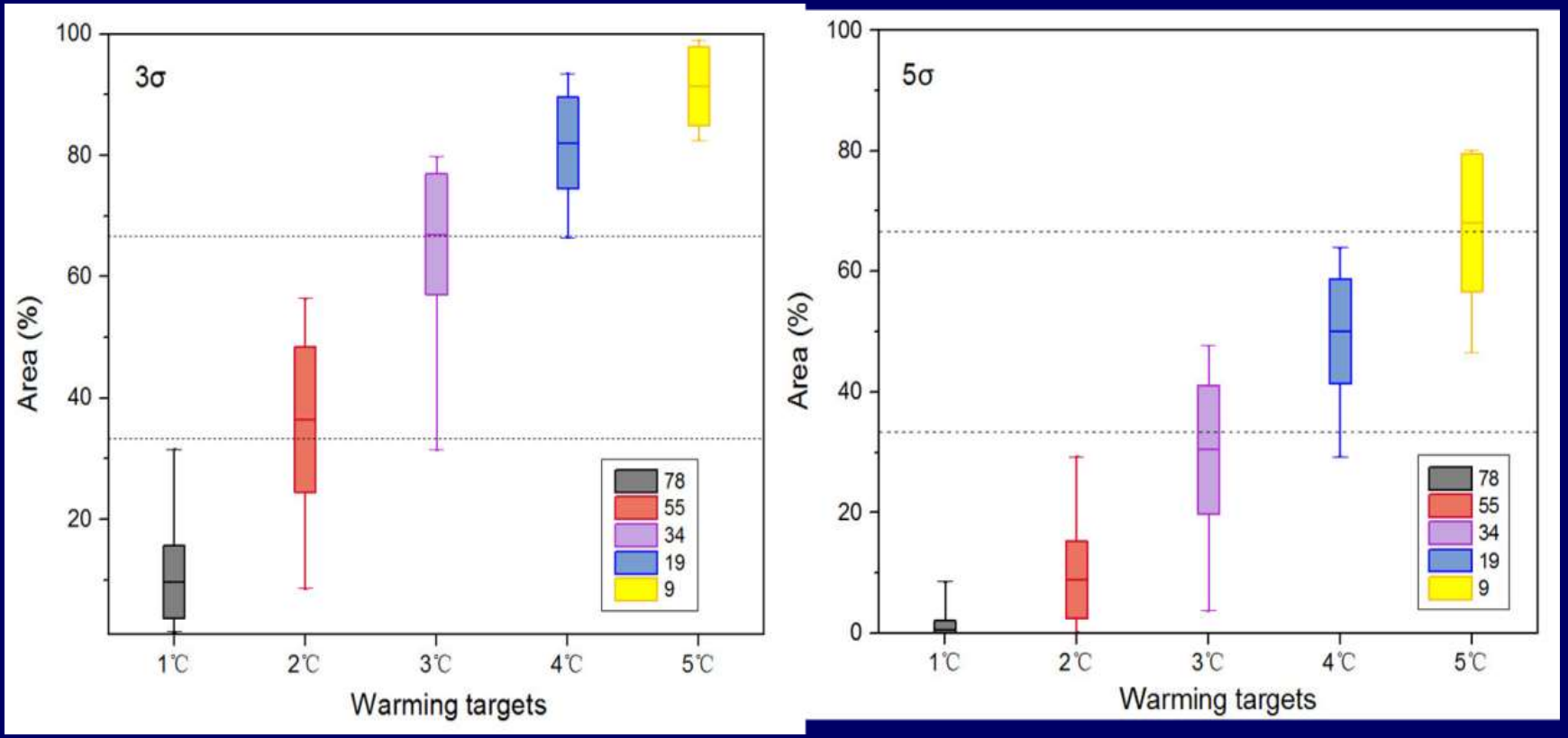
Area ratios affected by global extreme high temperature



Extremely hot (>3σ) and exceeding 5σ hot (>5σ)

不同温升“extremely hot” (>3σ) 和“exceeding 5σ hot” (>5σ)影响面积的比例。颜色代表模拟个数。中线为集合平均，上下边为1σ的代表不确定性范围，方格外上下横线表示最大值和最小值。

Wang et al., 2015

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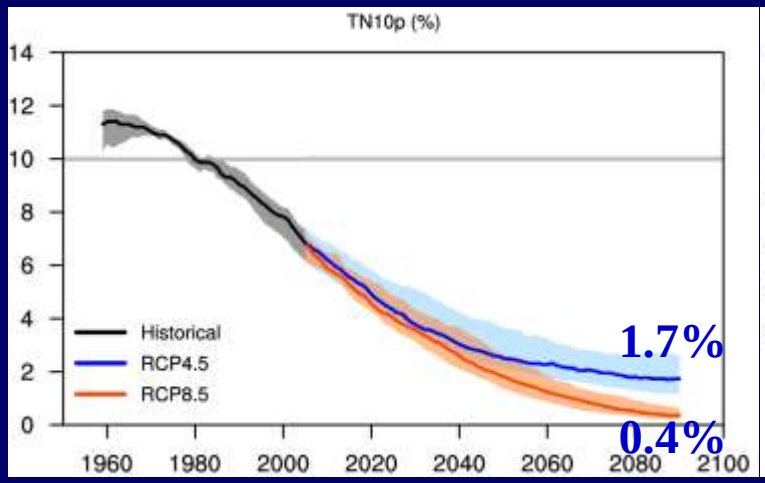
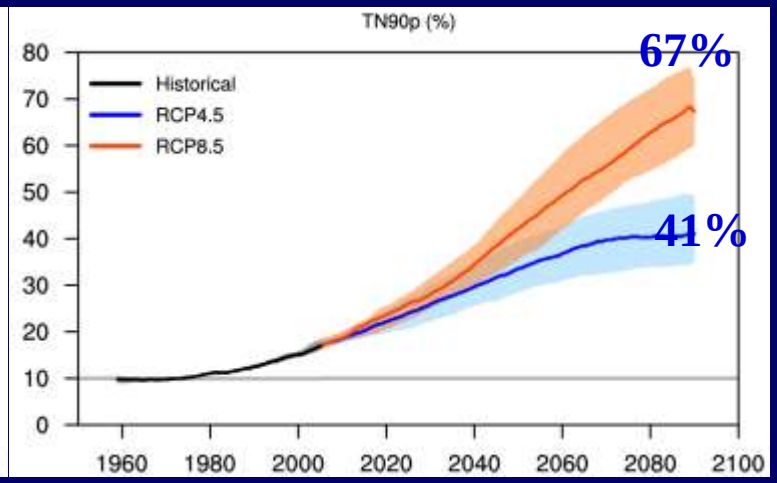
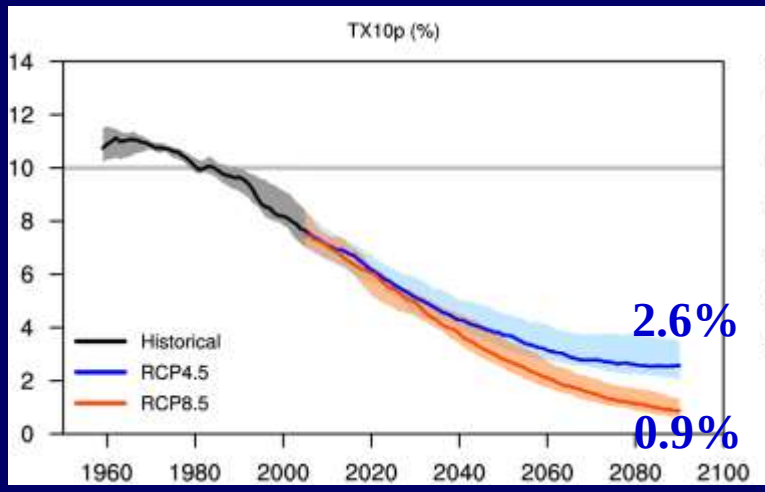
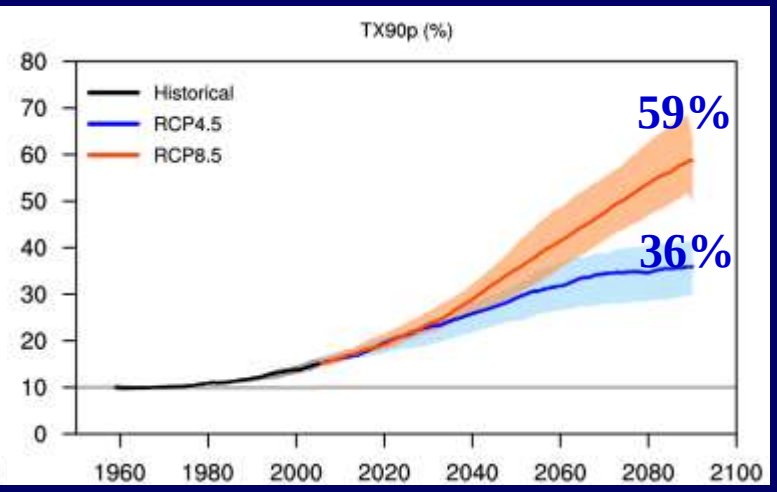
Projection of climate extremes in *CHINA*









Cold and Warm

Night and Day

- Decrease in cold nights and days and increase in warm nights and days
- Changes in nighttime indices are stronger than in daytime indices

Zhou et al., 2014

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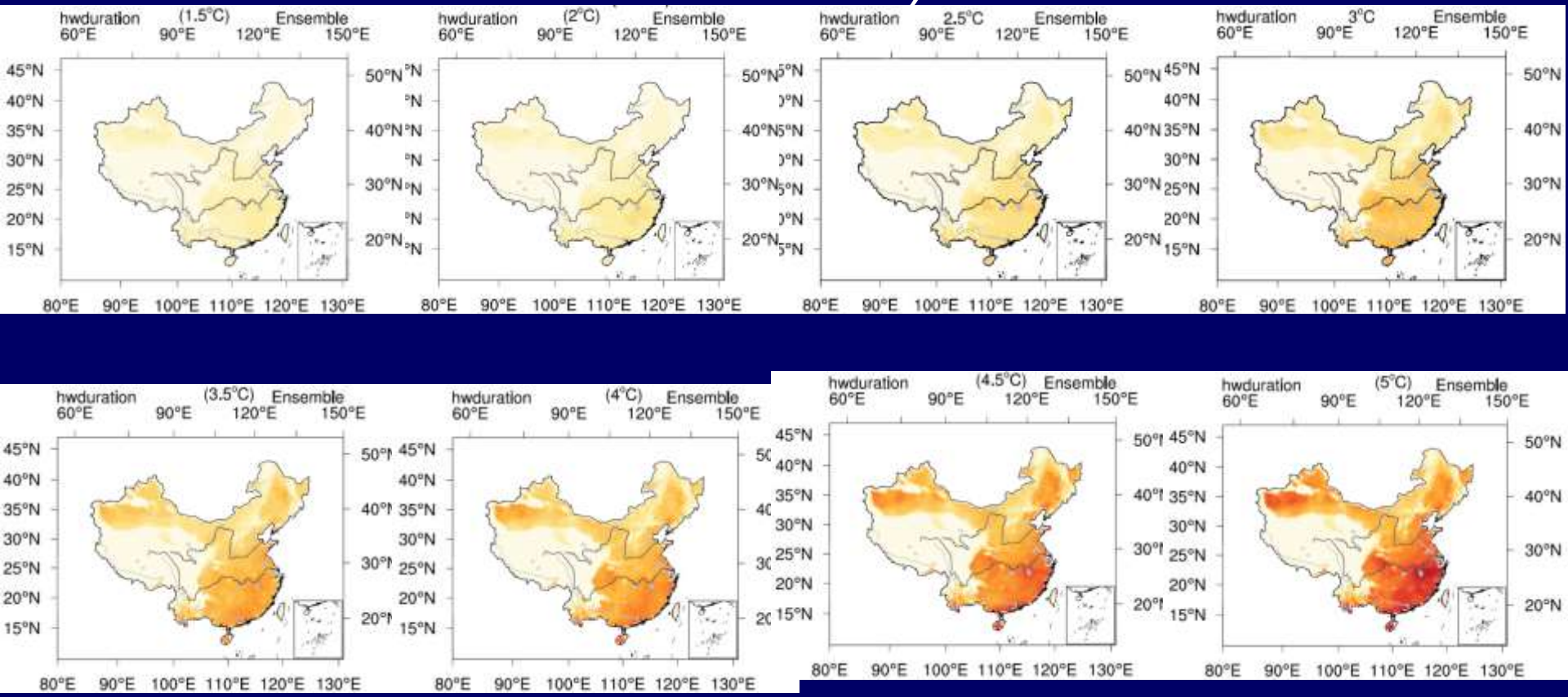
Projected maximum duration days of heat wave in May-September in ***CHINA*** by multi-models at mitigation targets of 1.5℃, 2.0 ℃, 2.5℃, 3℃, 3.5℃, 4℃, 4.5℃ and 5℃, (Refers to 1971-2000)

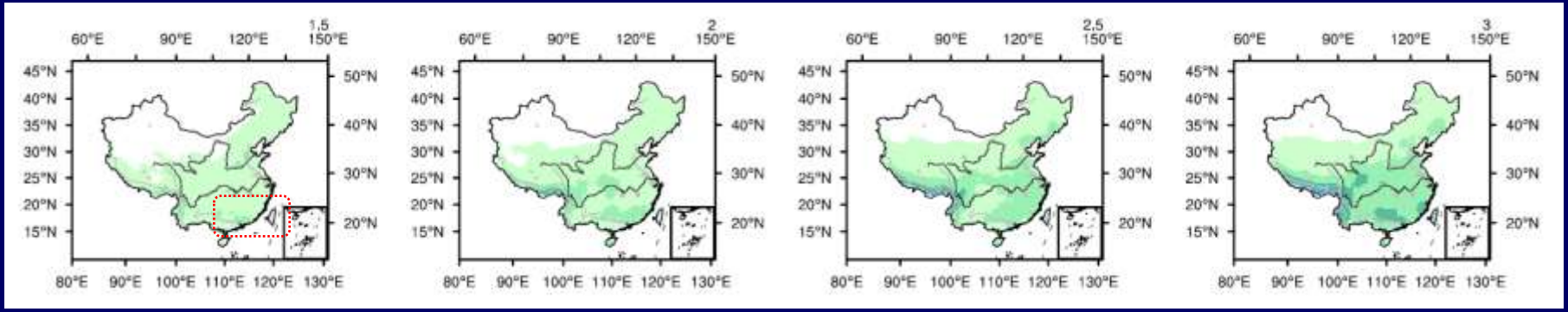


Guo et al.,2016

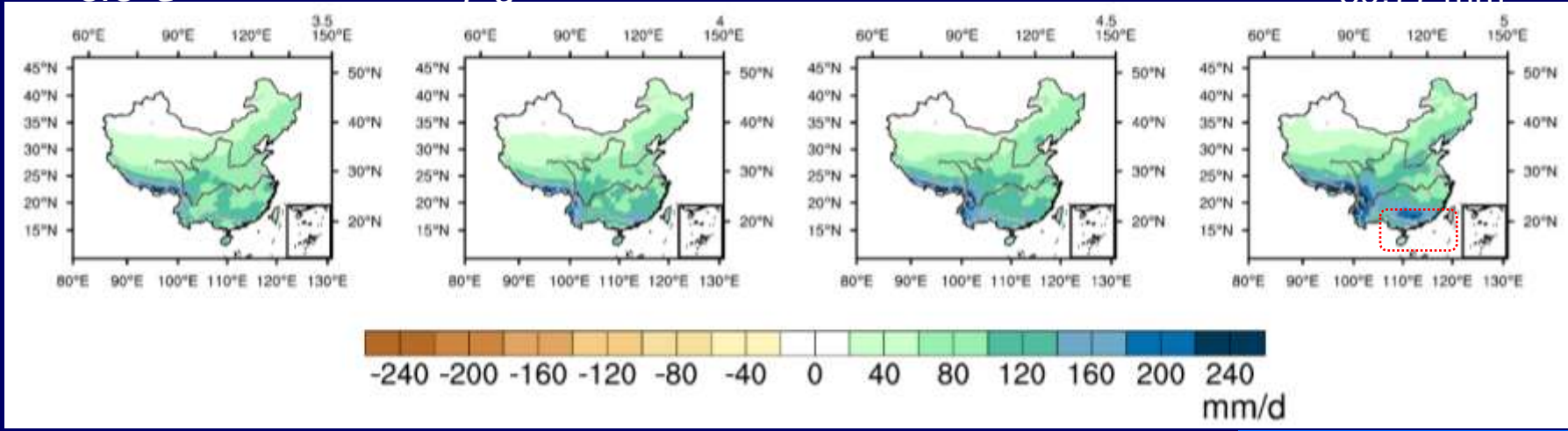
Projected *heavy precipitation* in May-September in CHINA by multi-models at mitigation targets of 1.5℃, 2.0 ℃, 2.5℃, 3℃, 3.5℃, 4℃, 4.5℃ and 5℃ (Refers to 1971-2000)

R99p

1.5℃ 30.50 mm *2℃* 38.33 mm *2.5℃* 48.47 mm *3℃* 59.46 mm

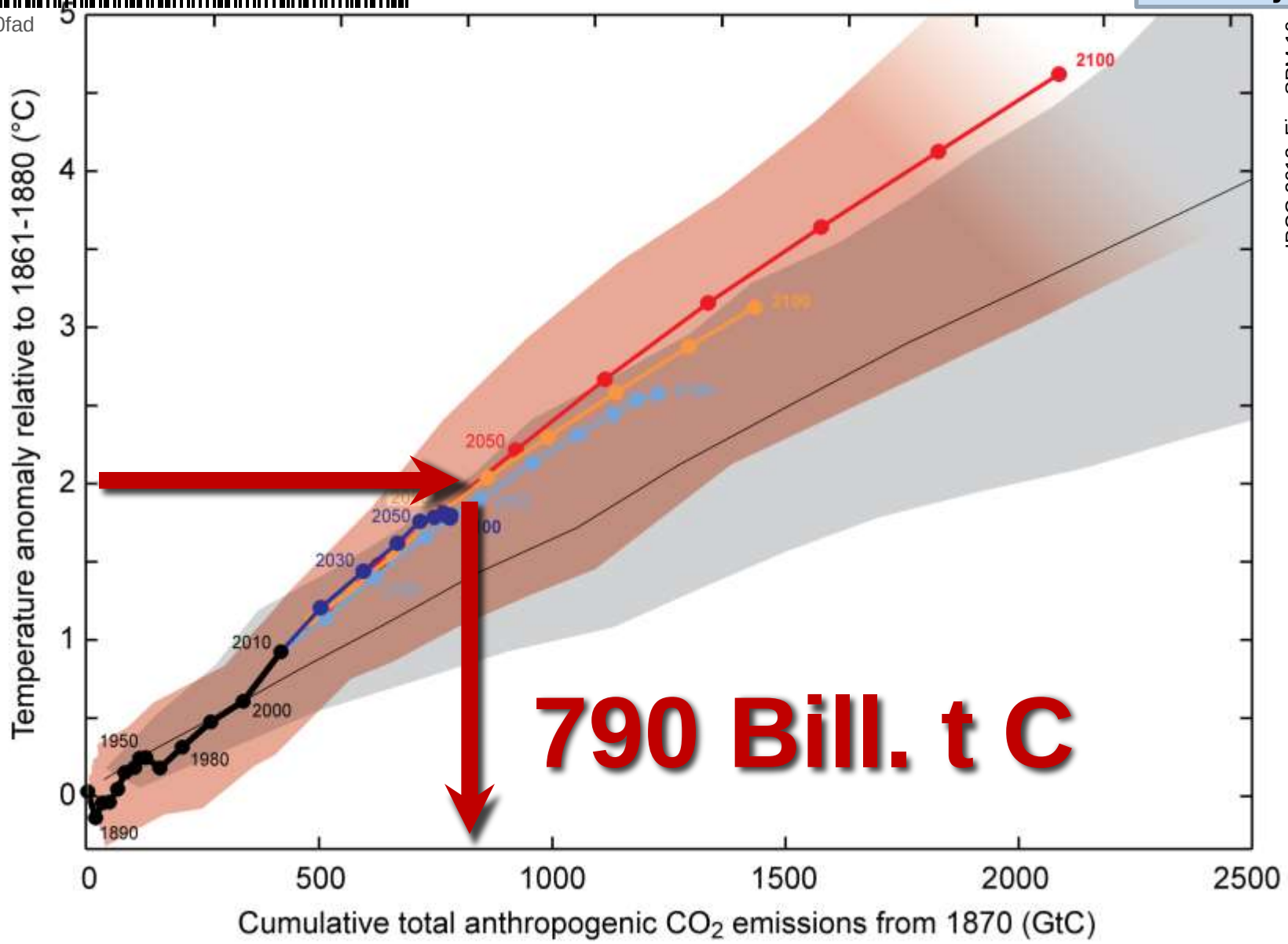


3.5℃ 69.58 mm *4℃* 71.65 mm *4.5℃* 81.24 mm *5℃* 89.77 mm



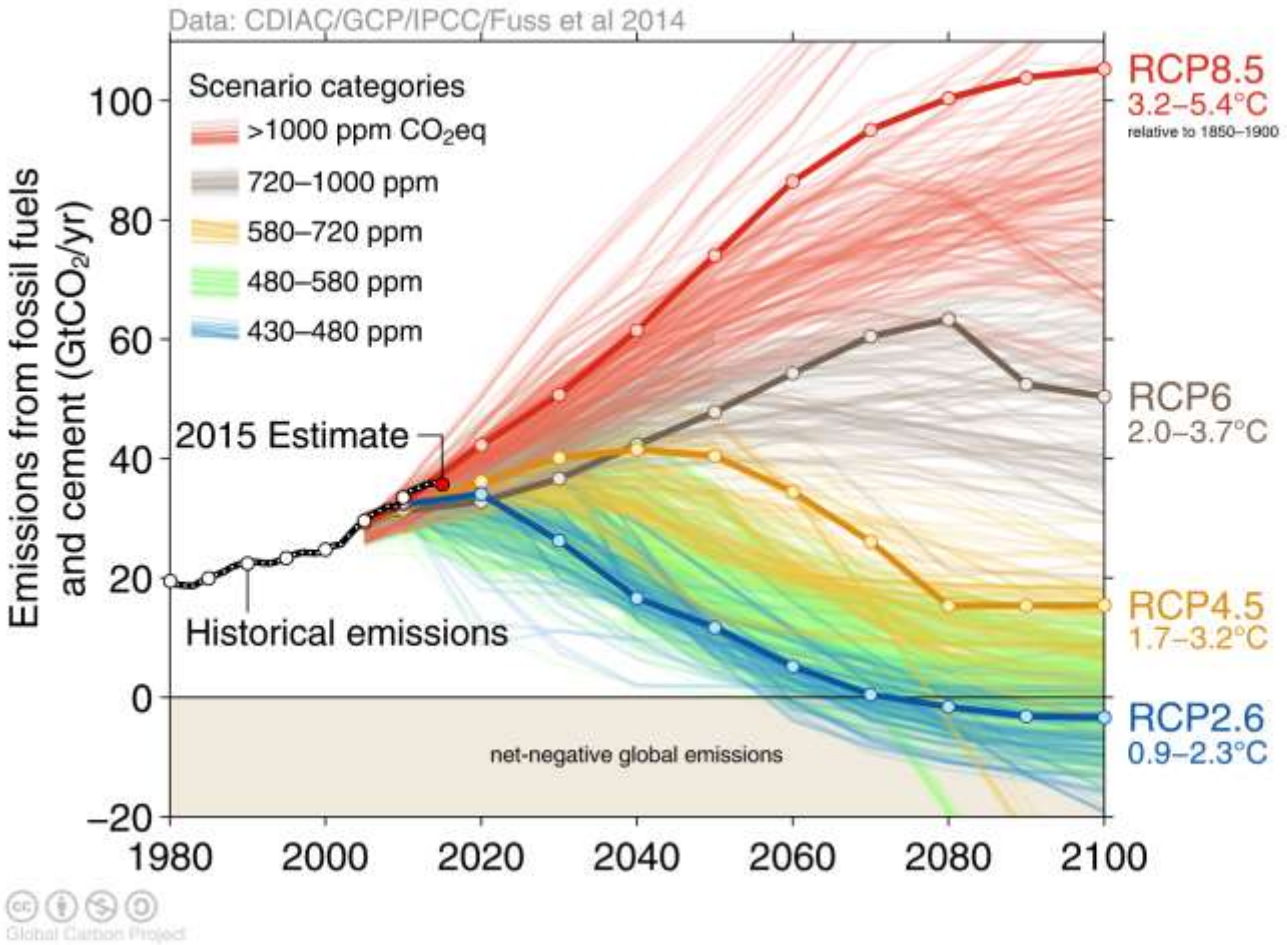
The white fonts are for the R99p averaged over China (relative to 1971-2000)

Guo et al. 2016



IPCC 2013, Fig. SPM.10

The emission pledges submitted to the Paris climate summit avoid the worst effects of climate change (red), ***most studies suggest a likely temperature increase of about 3 ° C (brown)***



Over 1000 scenarios from the IPCC Fifth Assessment Report are shown (Source: Fuss et al 2014; CDIAC; Global Carbon Budget 2015)

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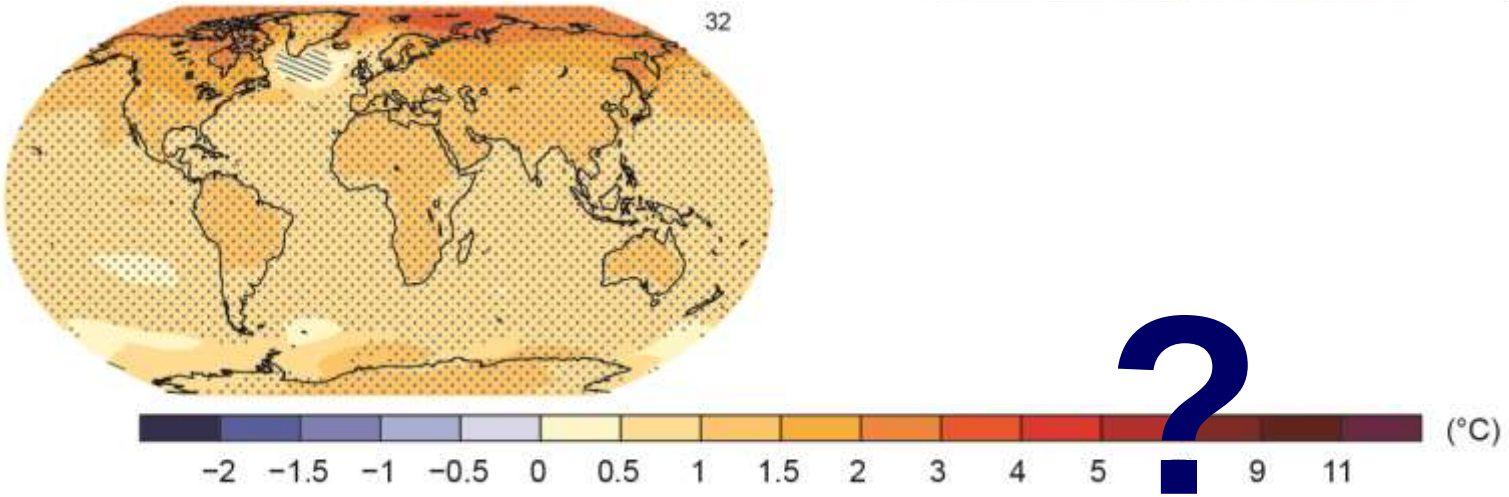
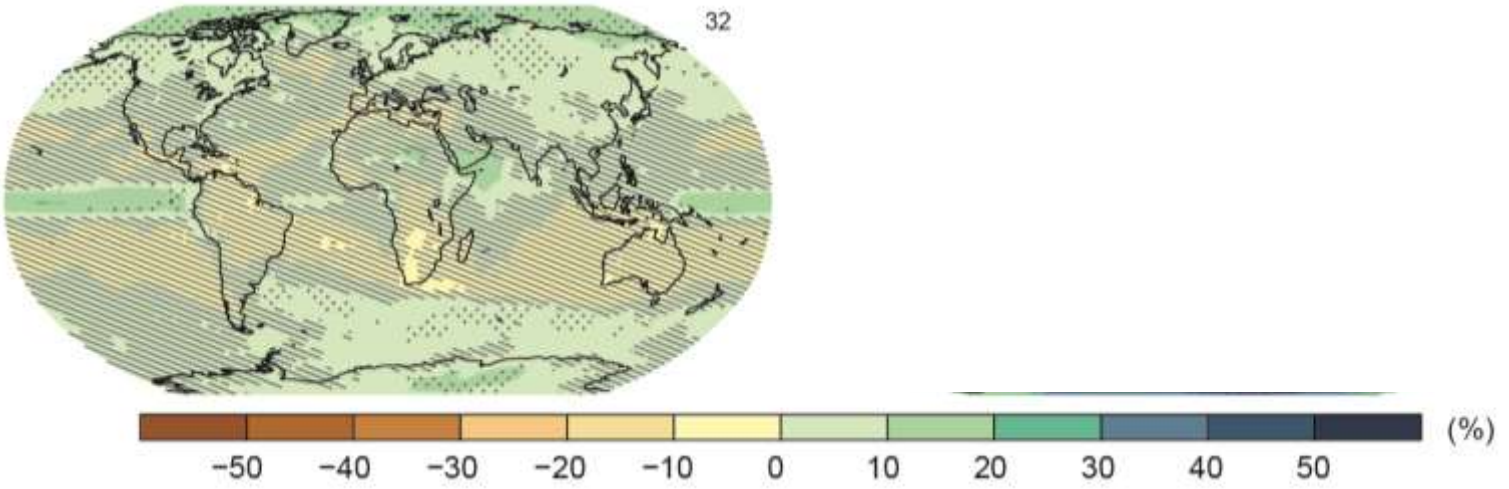
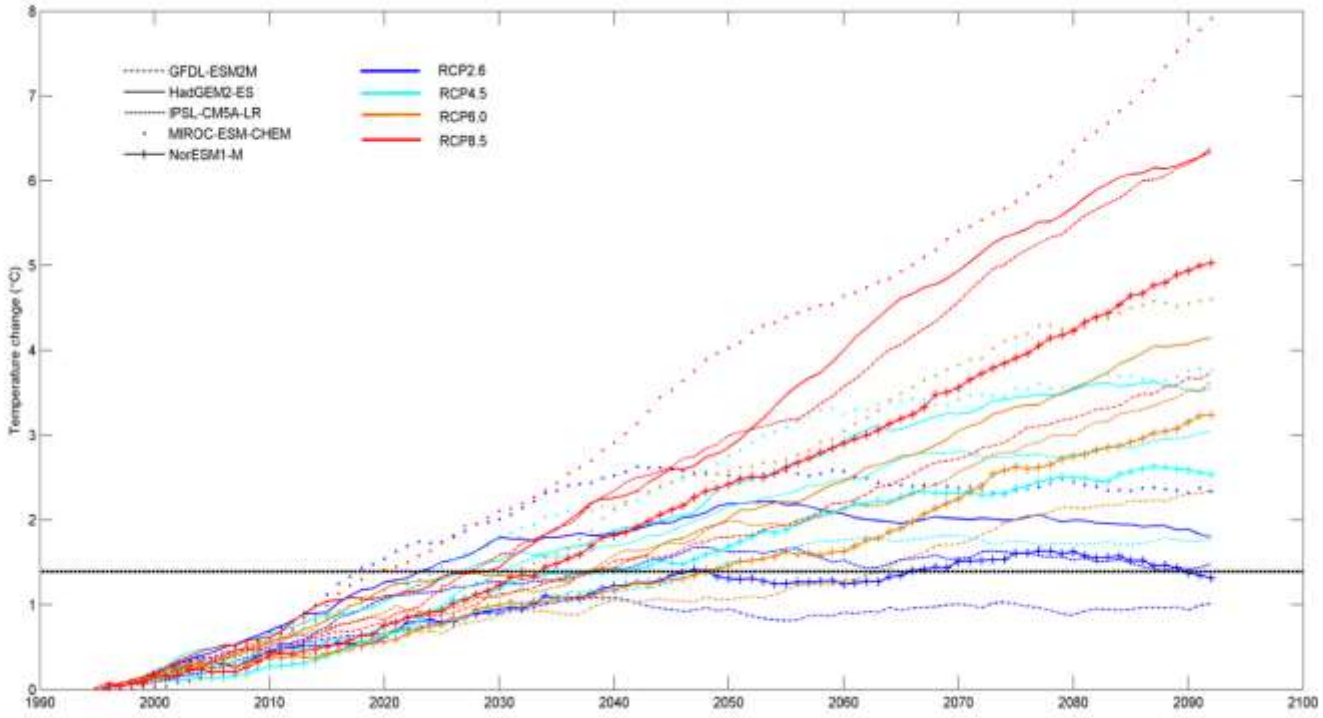
2°C world

1.5°C world





Projections for CHINA

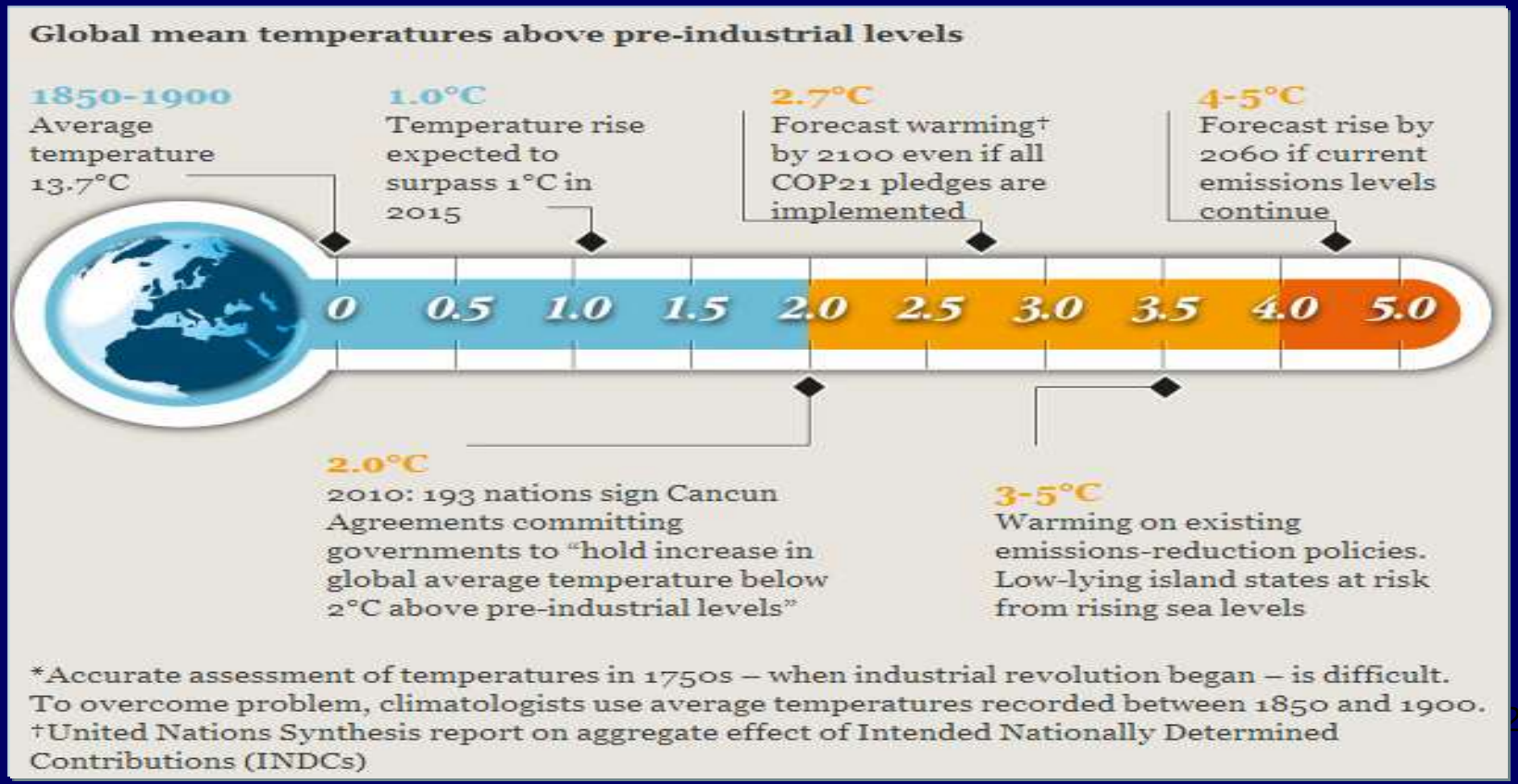


中	1.5℃					2℃					3℃				
国	HadGEM2-ES	IPSL-CM5A-LR	MIROC-ESM-CHEM	NorESM1-M	GFDL-ESM2M	HadGEM2-ES	IPSL-CM5A-LR	MIROC-ESM-CHEM	NorESM1-M	GFDL-ESM2M	HadGEM2-ES	IPSL-CM5A-LR	MIROC-ESM-CHEM	NorESM1-M	GFDL-ESM2M
RCP8.5	2012	2016	2019	2020	2019	2025	2026	2019	2033	2036	2044	2042	2035	2050	2064
RCP6.0	2014	2017	2015	2025	2027	2037	2038	2030	2049	2063	2060	2068	2043	2072	*
RCP4.5	2015	2016	2014	2022	2023	2026	2030	2024	2035	2047	2049	2057	2045	2076	*
RCP2.6	**2012**	**2016**	**2011**	**2024**	**2025**	2023	2038	2018	2048	*	*	*	*	*	*

4. Some issues concerned

Definition of 1.5℃:

- Temporal scale: 1750-2100
- Spatial scale: global
- Overshooting permitted



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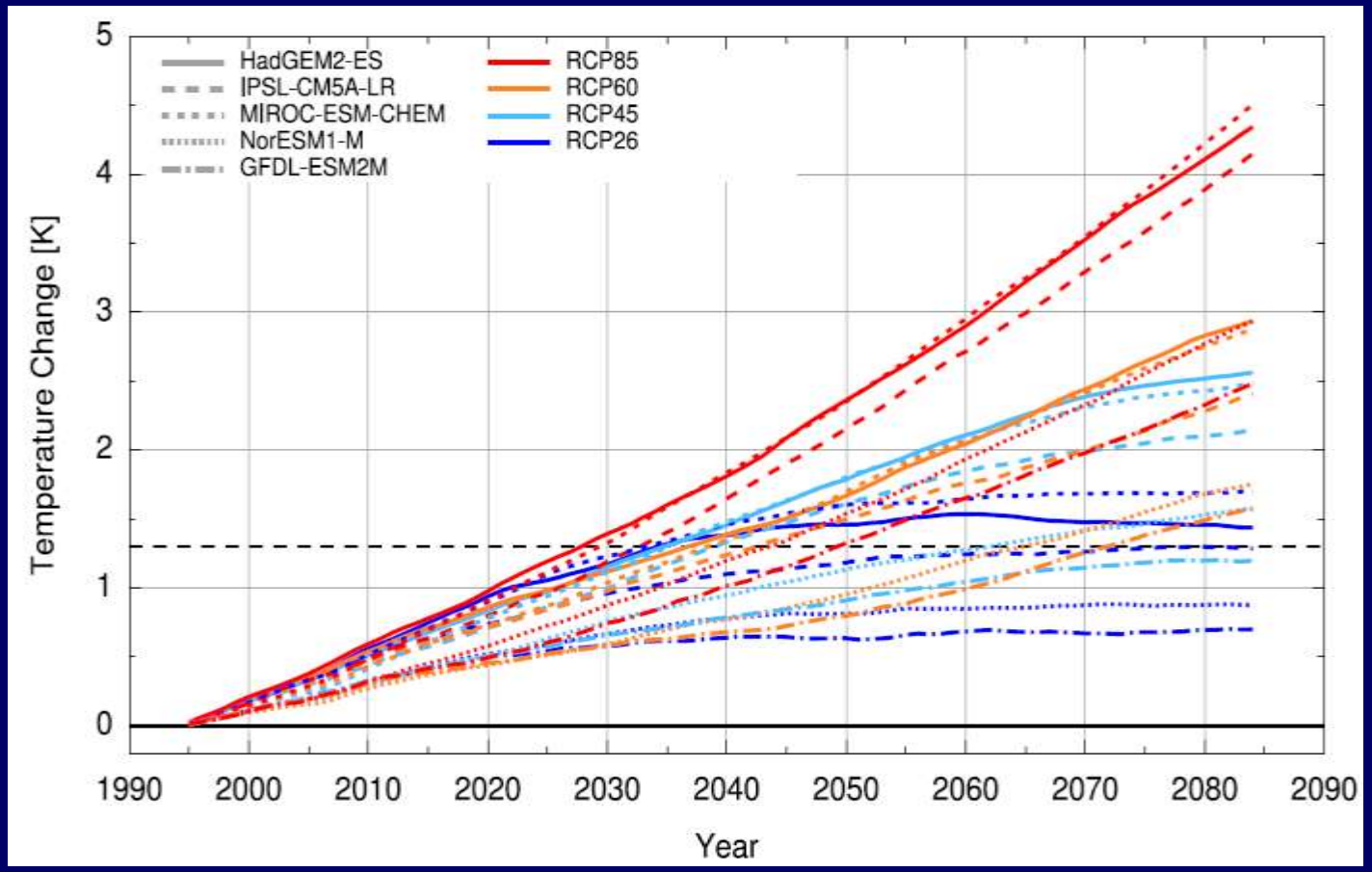
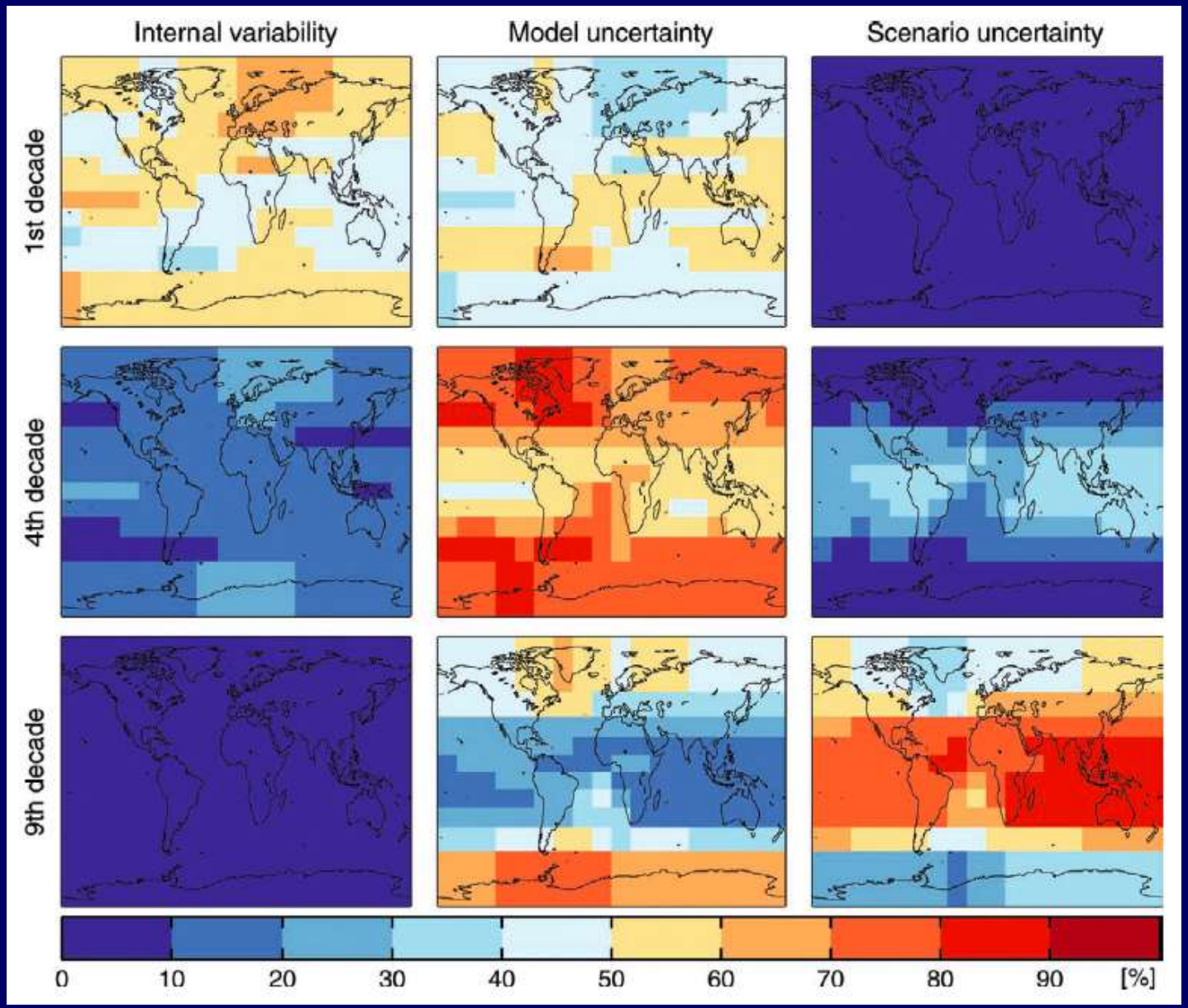
Climate sensitivity and uncertainty of climate models



Large difference exists in different models to project the time period when global temperature reaches 1.5℃ or 2℃.

Contributions to uncertainty of surface temperature projections



(Hawkins & Sutton, 2009)

Thank you !