



Global Warming

Content

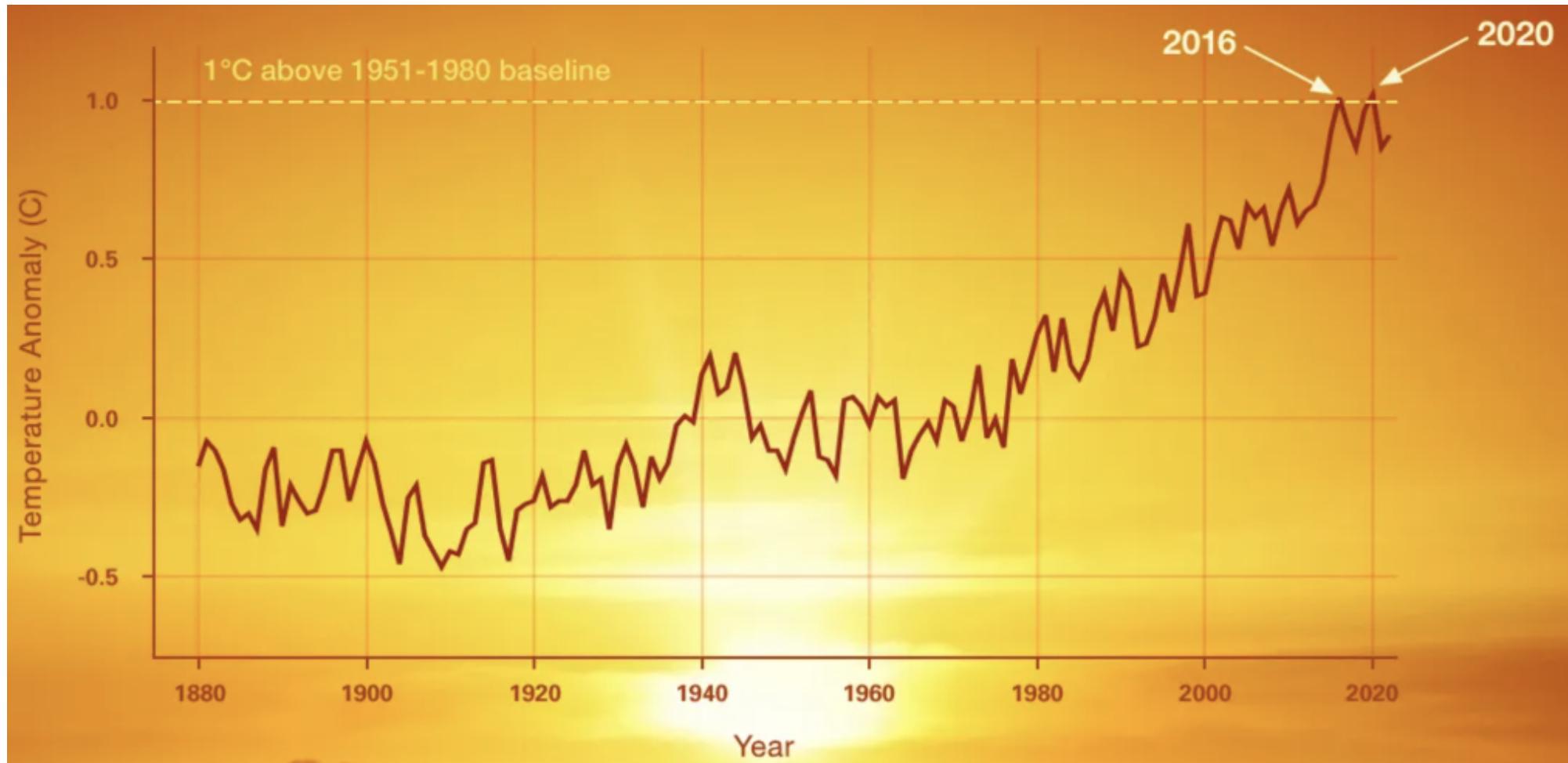
- What is global warming?
- Why is global warming?
- Why do we need to care about global warming?
- Monsoon climate over southern China



Is global warming true?

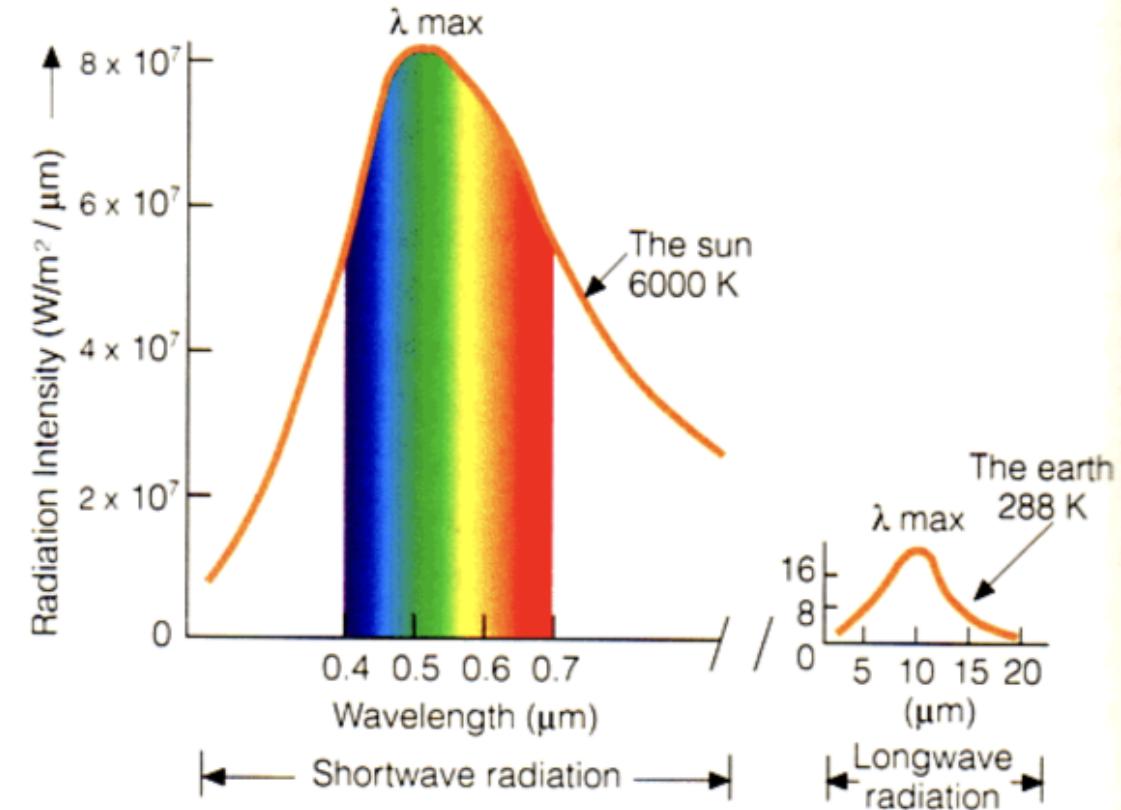
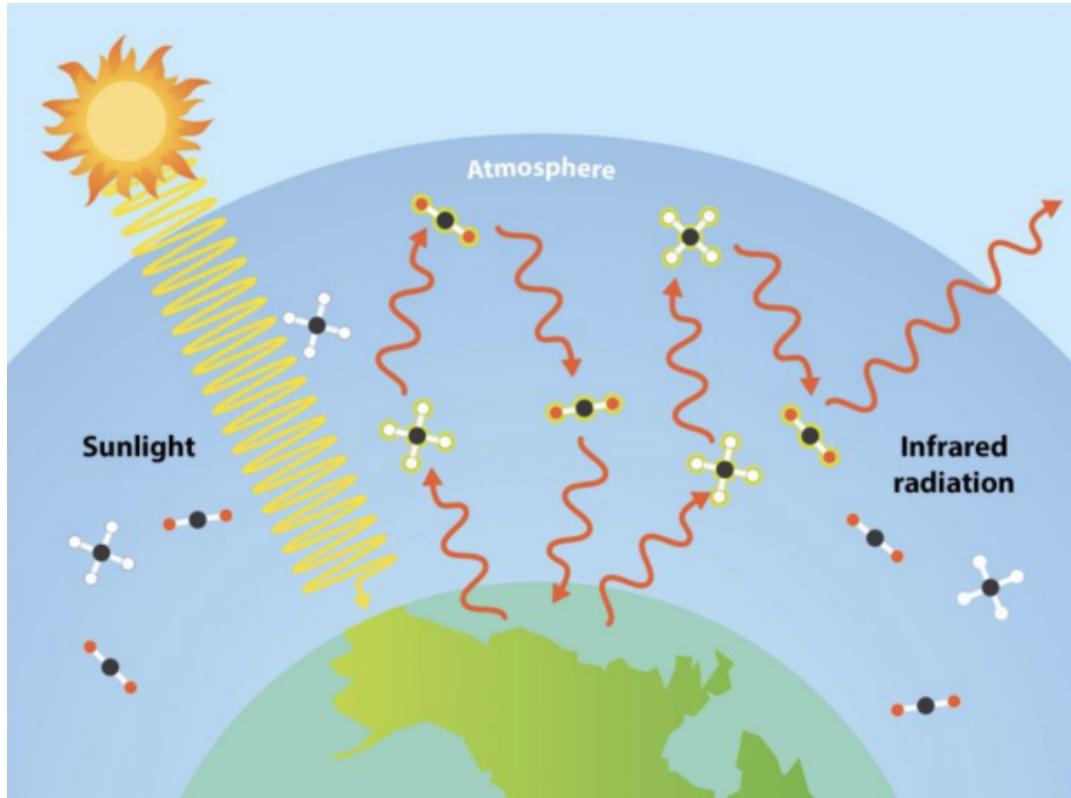


Global Warming



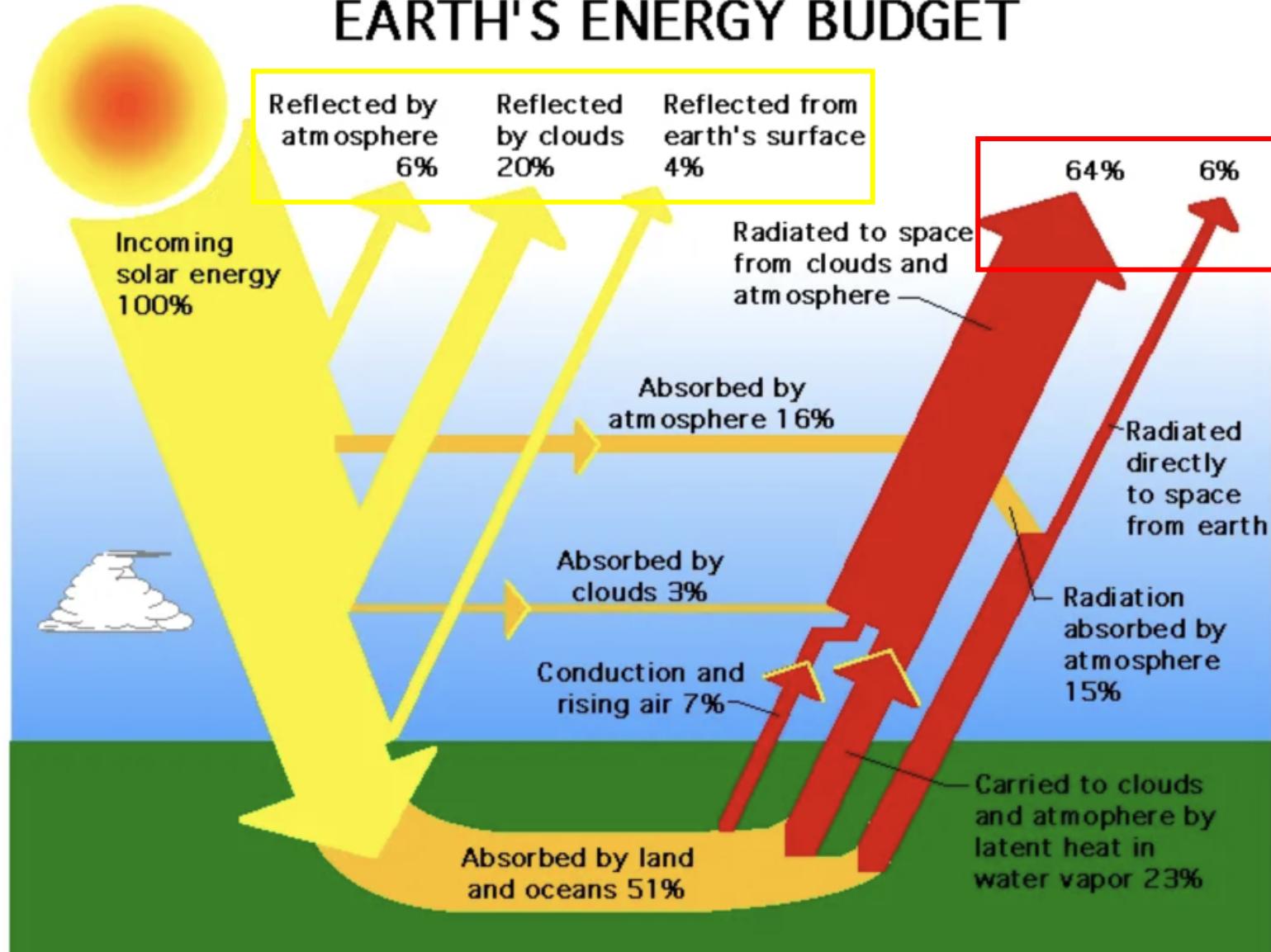
Why is global warming?





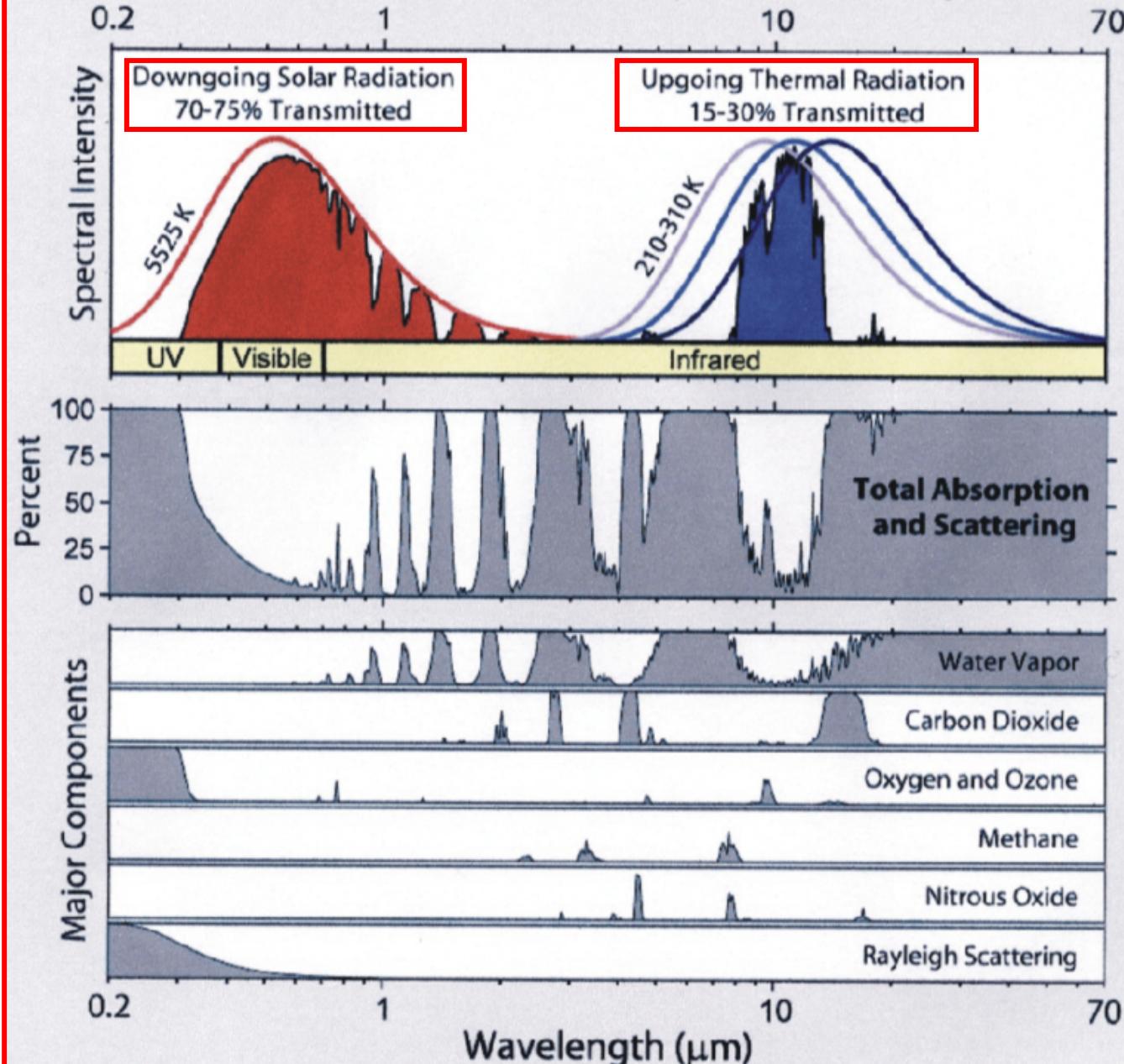
Solar radiation is often referred to as “shortwave radiation”.
Terrestrial radiation is referred to as “longwave radiation”.

EARTH'S ENERGY BUDGET



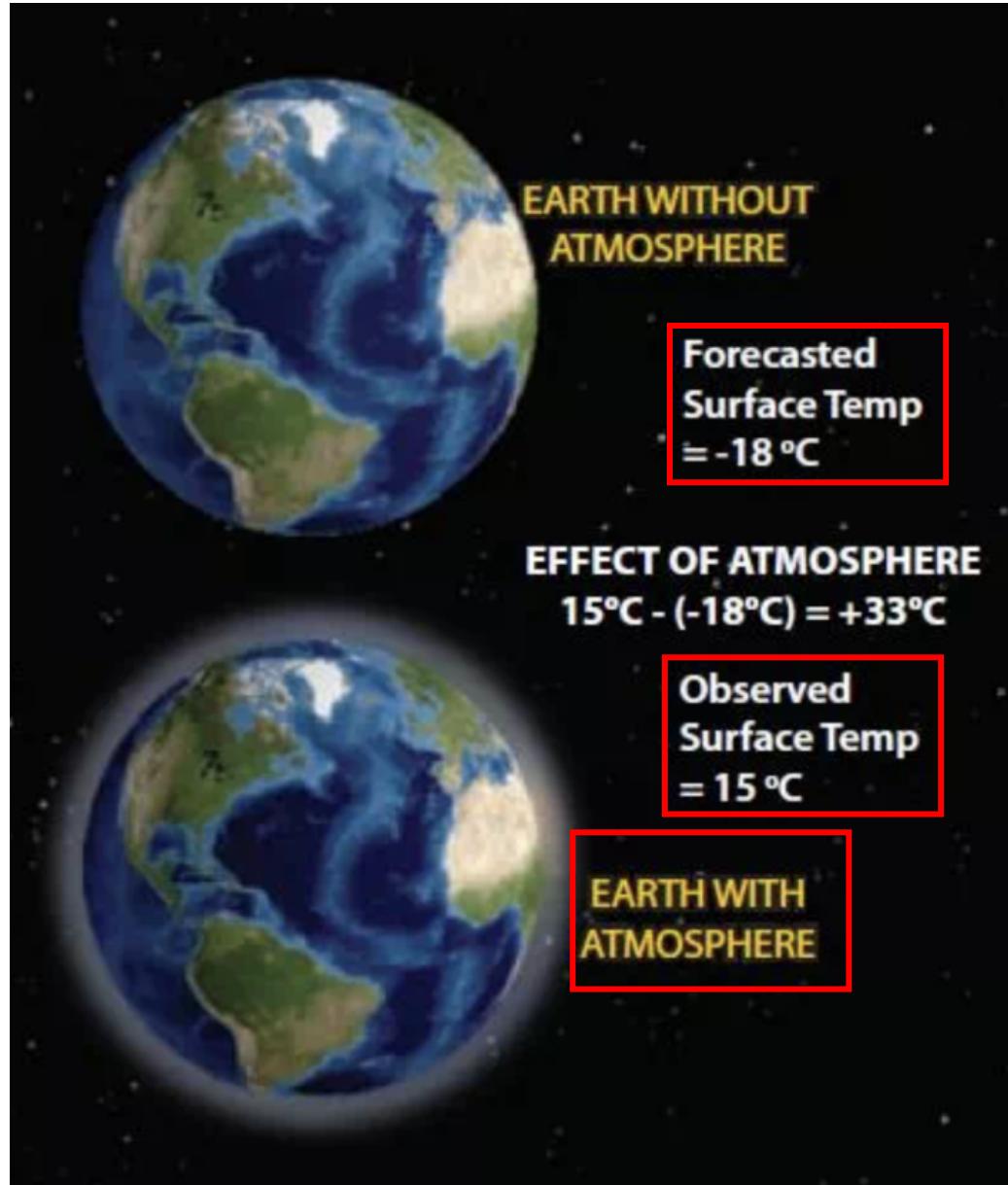
Absorbed shortwave from the Sun = Emitted longwave from the Earth

Radiation Transmitted by the Atmosphere

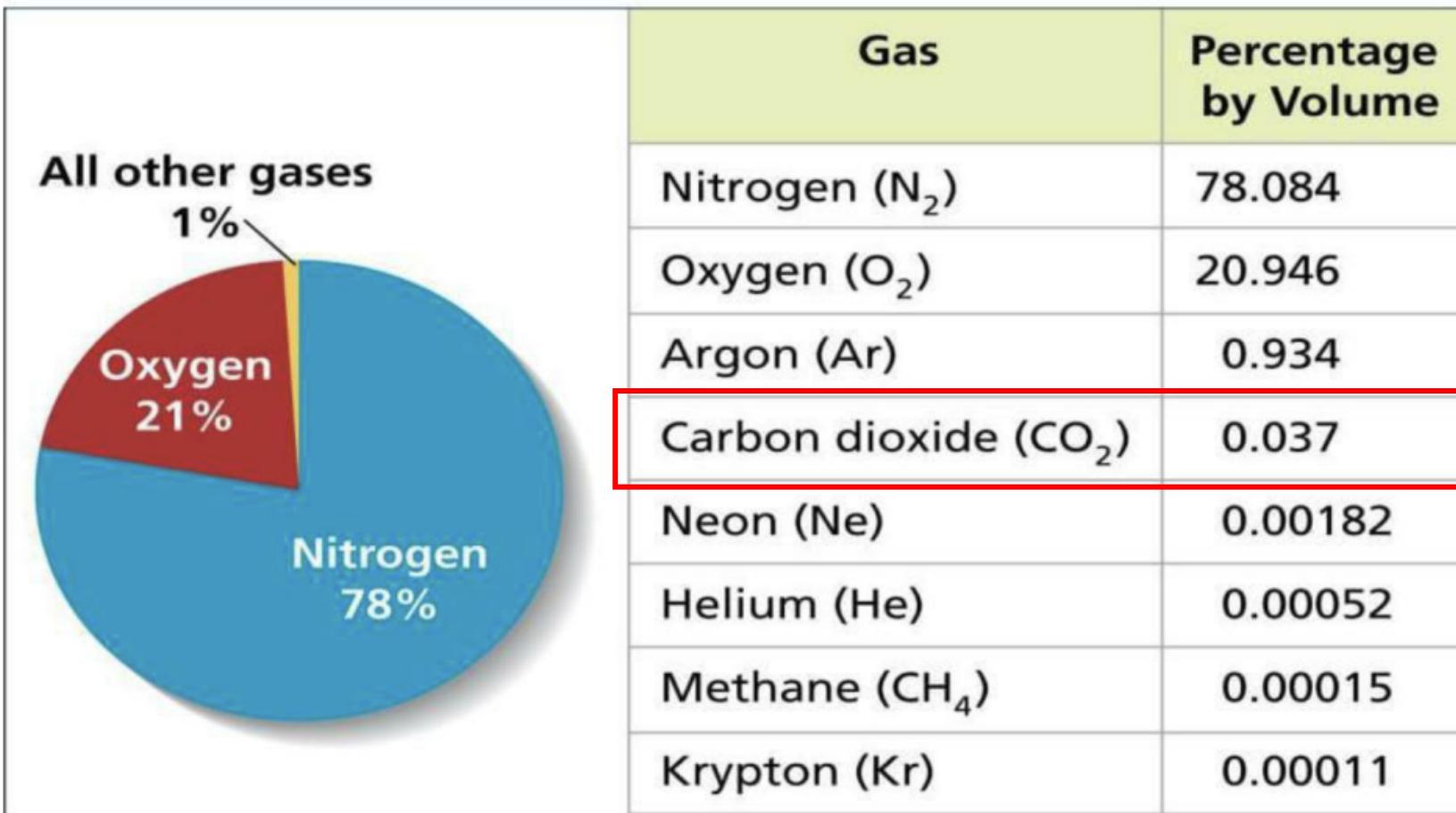


Atmosphere:
Transparent to solar
radiation
Opaque to thermal
radiation

Radiative Balance



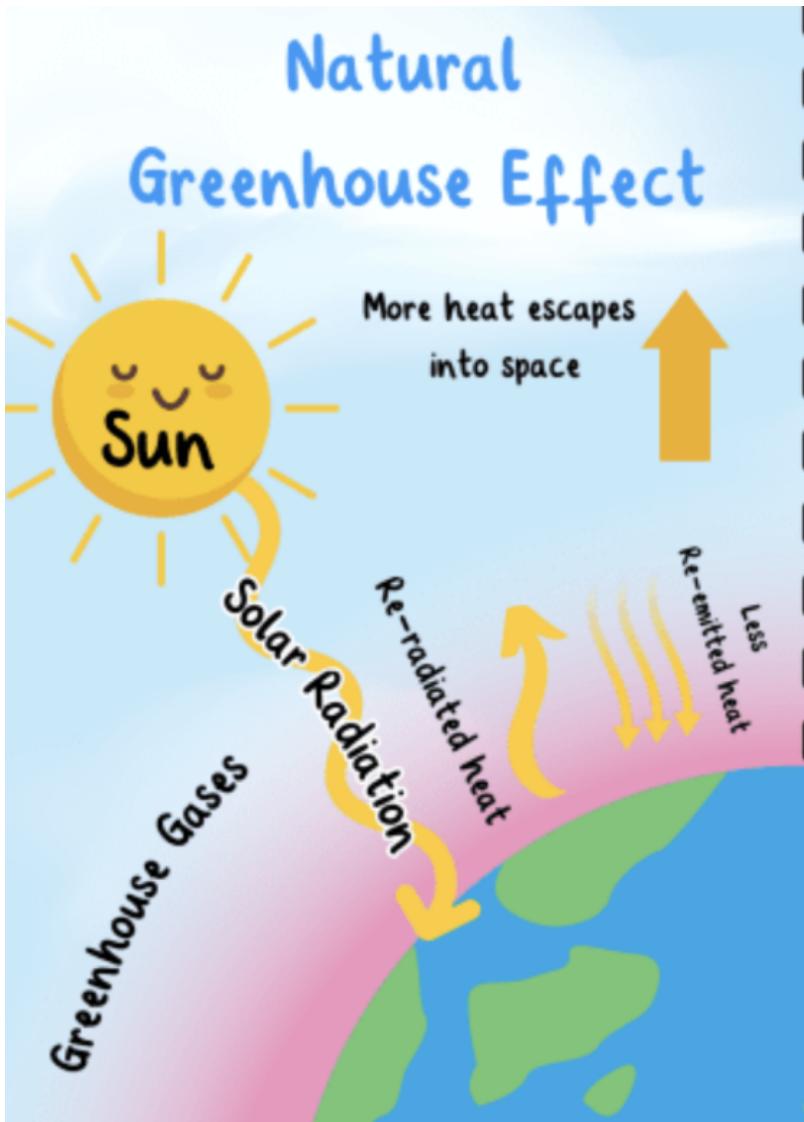
Atmospheric Composition



370 ppm



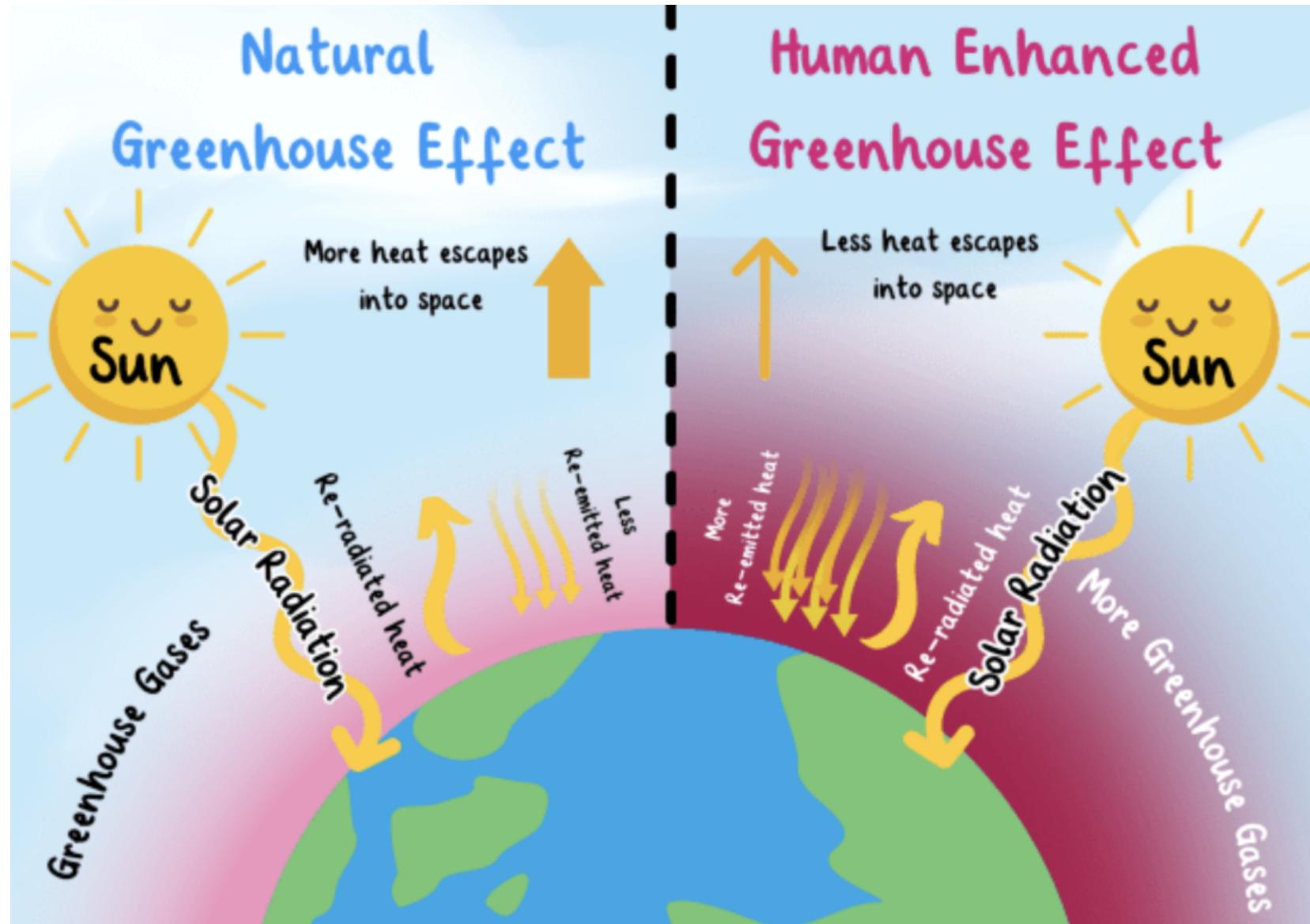
Greenhouse Effect: Atmospheric Blanket



The atmosphere contains **greenhouse gases** (H_2O , CO_2 , etc.)

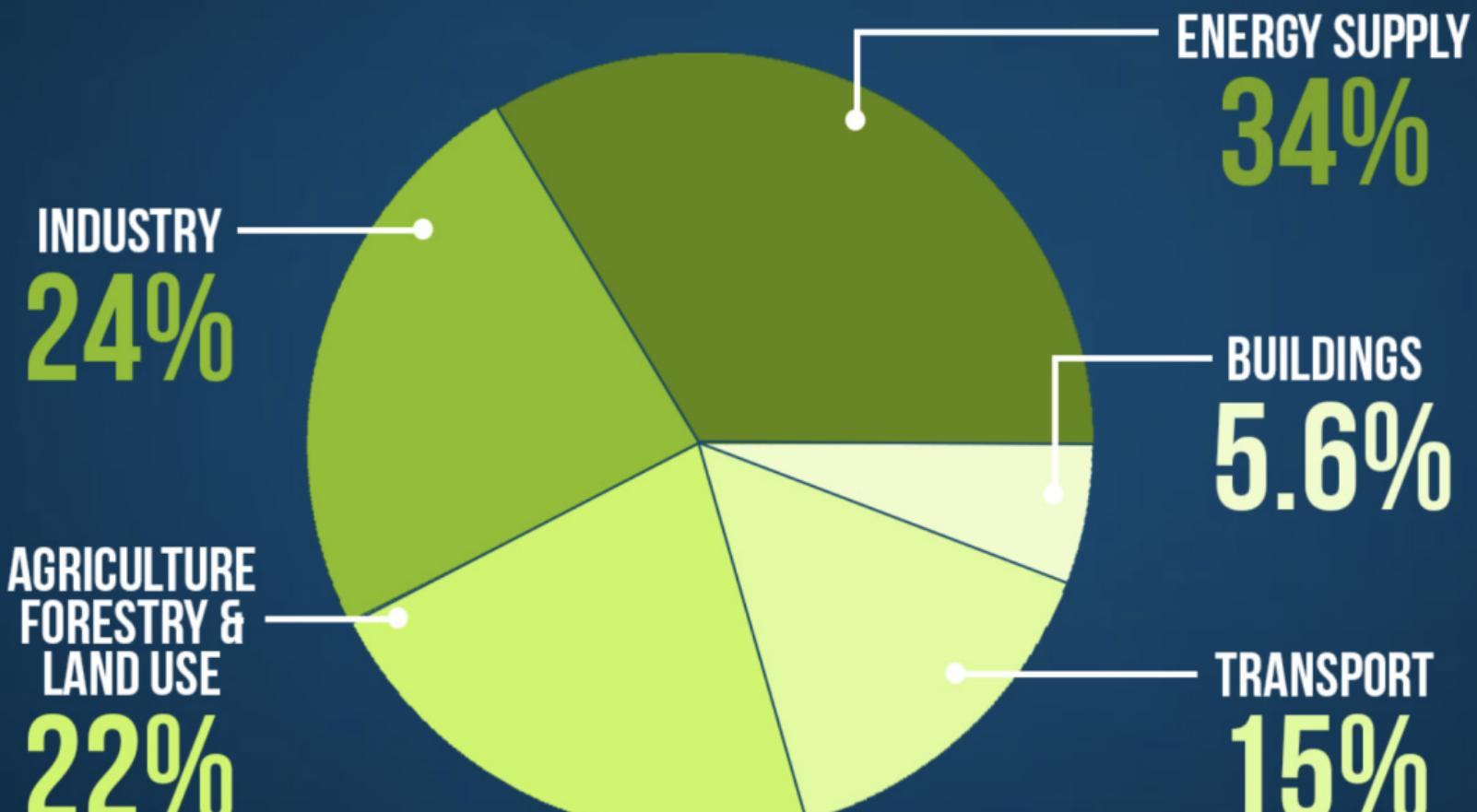
They absorb longwave radiation, altering the energy balance of the surface.

Too Much Greenhouse Gas



GREENHOUSE GAS EMISSIONS

Global Emissions by Sector



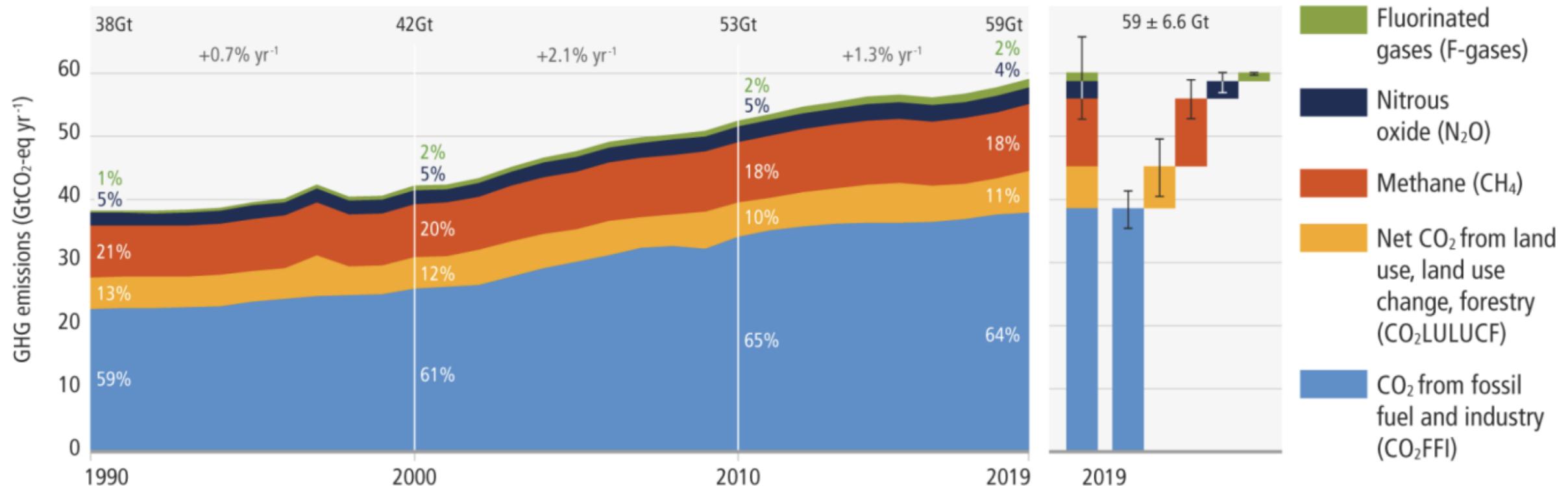
Global greenhouse gas emissions (2019) by sector.
Source: IPCC

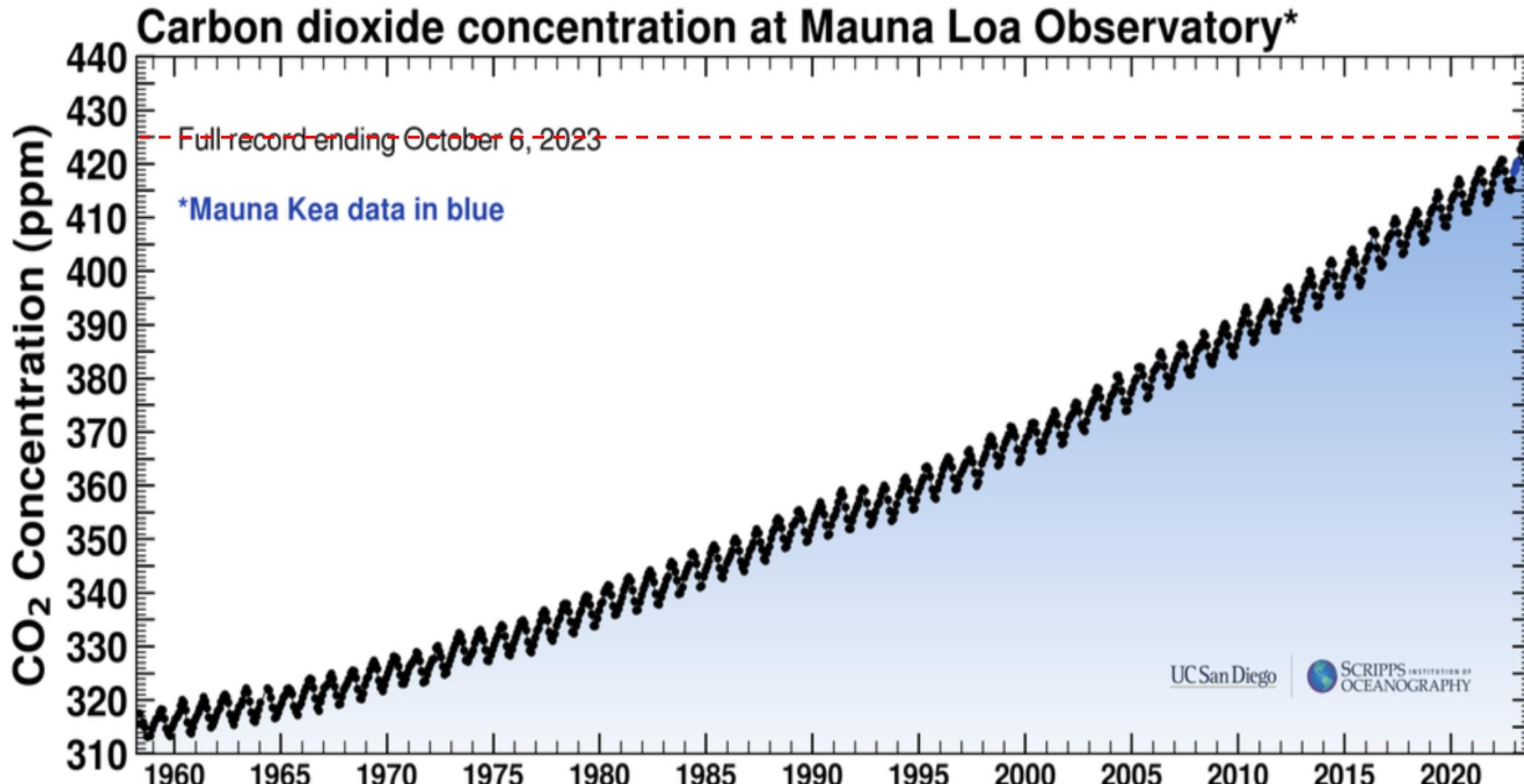
CLIMATE CO CENTRAL



Anthropogenic Greenhouse Gas Emissions

a. Global net anthropogenic GHG emissions 1990–2019⁽⁵⁾





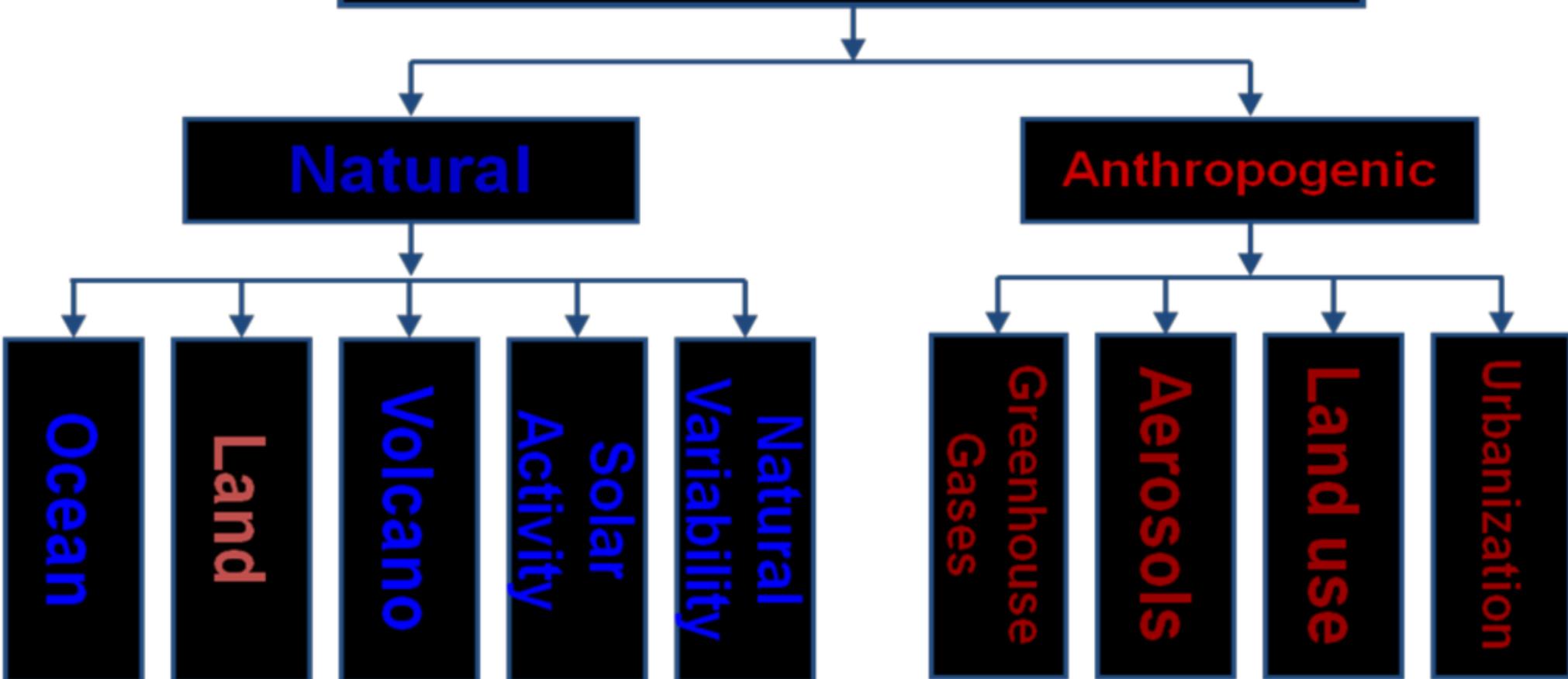
Pre-industrial (~1750) atmospheric CO₂ concentration ~ 280 ppm
Now increasing by ~ 2 ppm per year



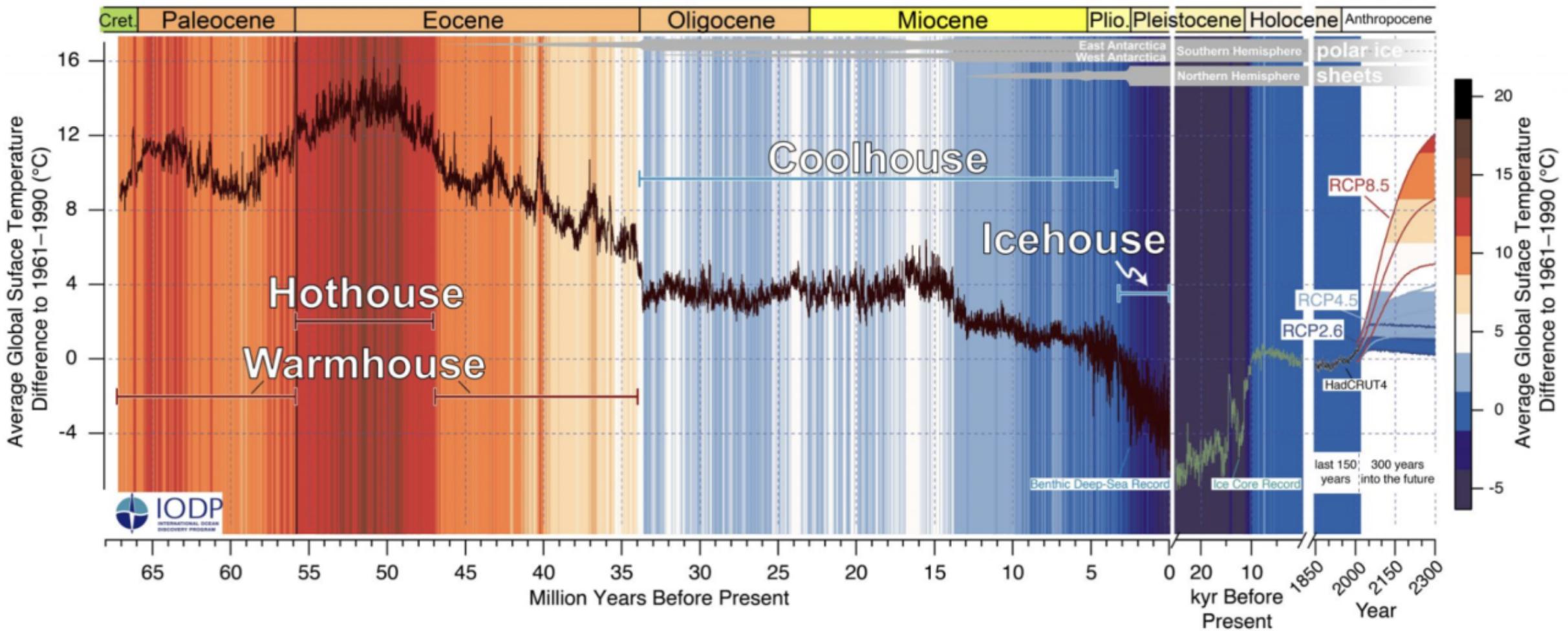
Is global warming man-made?



Reasons for Climate Change

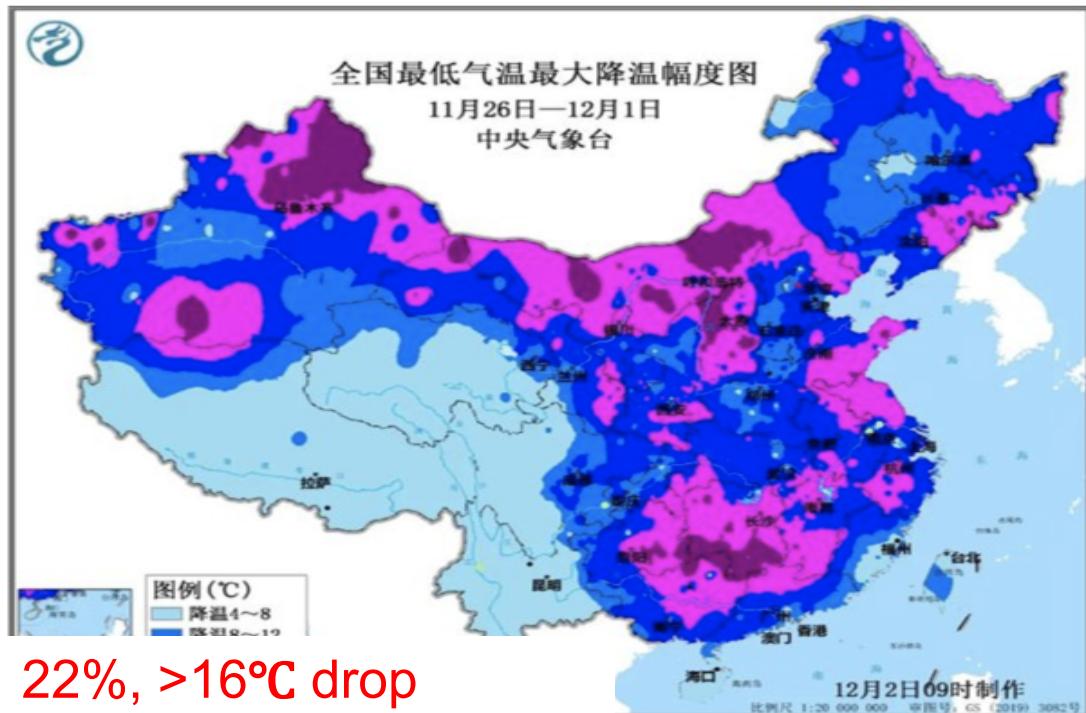


Global Mean Surface Temperature across the Last 66 Million Years



Extreme Cold Weather

Nov 2022 (5th)



Nov 2021 Shengyang



Global Warming?



Donald J. Trump @realDonaldTrump

Following

Snowing in Texas and Louisiana, record setting freezing temperatures throughout the country and beyond. Global warming is an expensive hoax!

RETWEETS 428 LIKES 358



1:27 AM - 29 Jan 2014

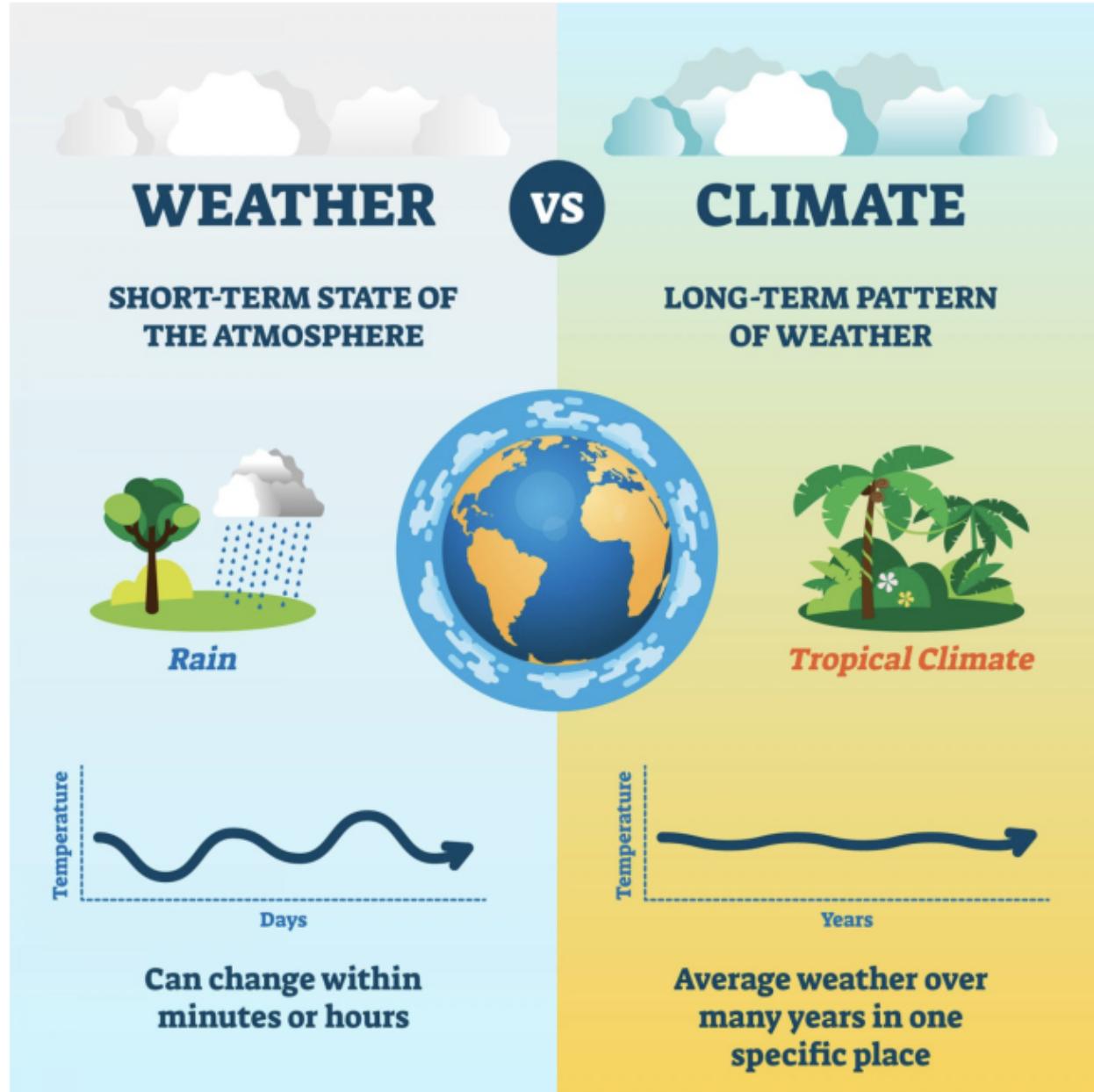


Donald J. Trump @realDonaldTrump

In the beautiful Midwest, windchill temperatures are reaching minus 60 degrees, the coldest ever recorded. In coming days, expected to get even colder. People can't last outside even for minutes. What the hell is going on with Global Warming? Please come back fast, we need you!

8:28 PM · Jan 28, 2019 · Twitter for iPhone





Weather versus climate illustration Copyright : [normaals](#)

What is Weather? What is Climate?

- **Weather:** the transient state of the atmospheric conditions over short periods ranging from hours to weeks
- **Climate:** the weather of a specific region averaged over a long period ranging from months to millennia (usually taken over 30-years)

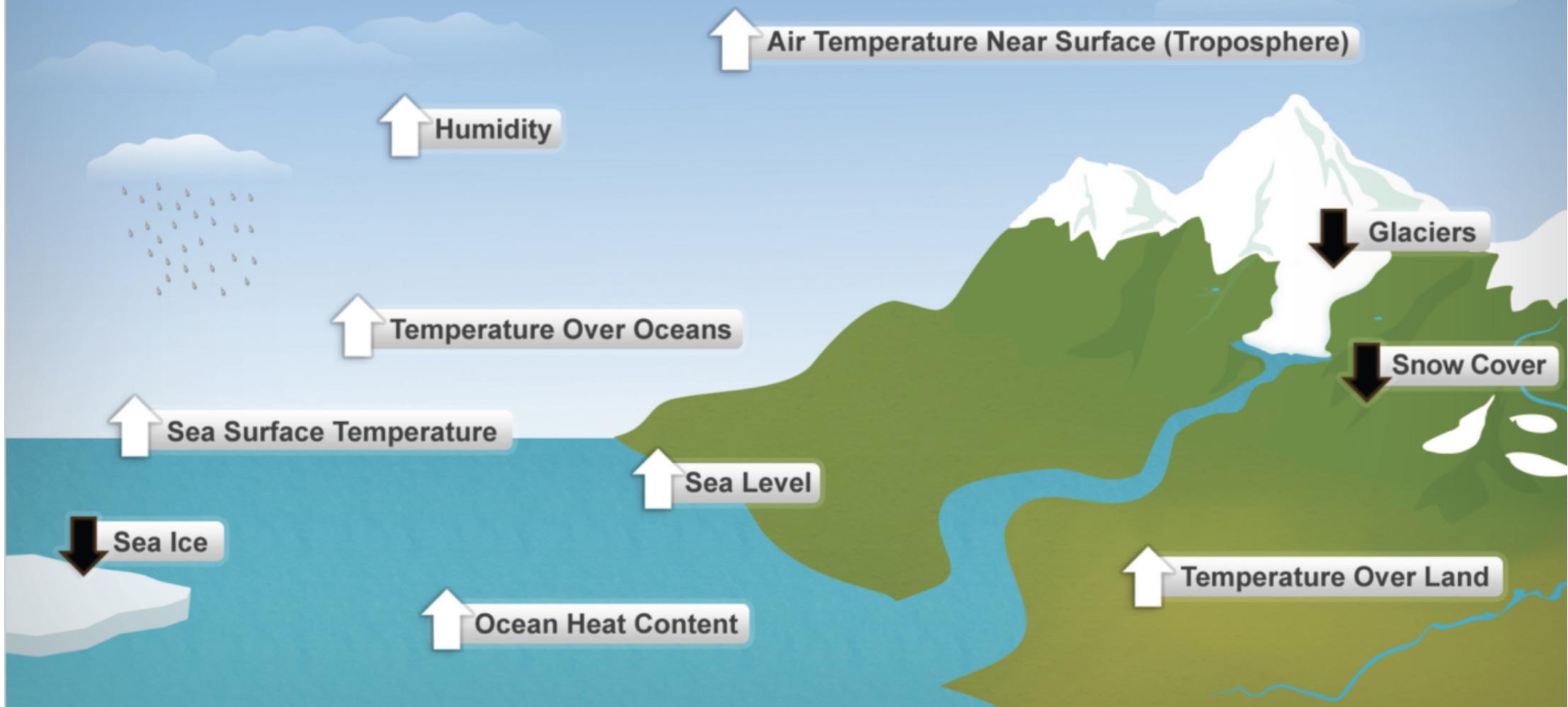


Weather or Climate?

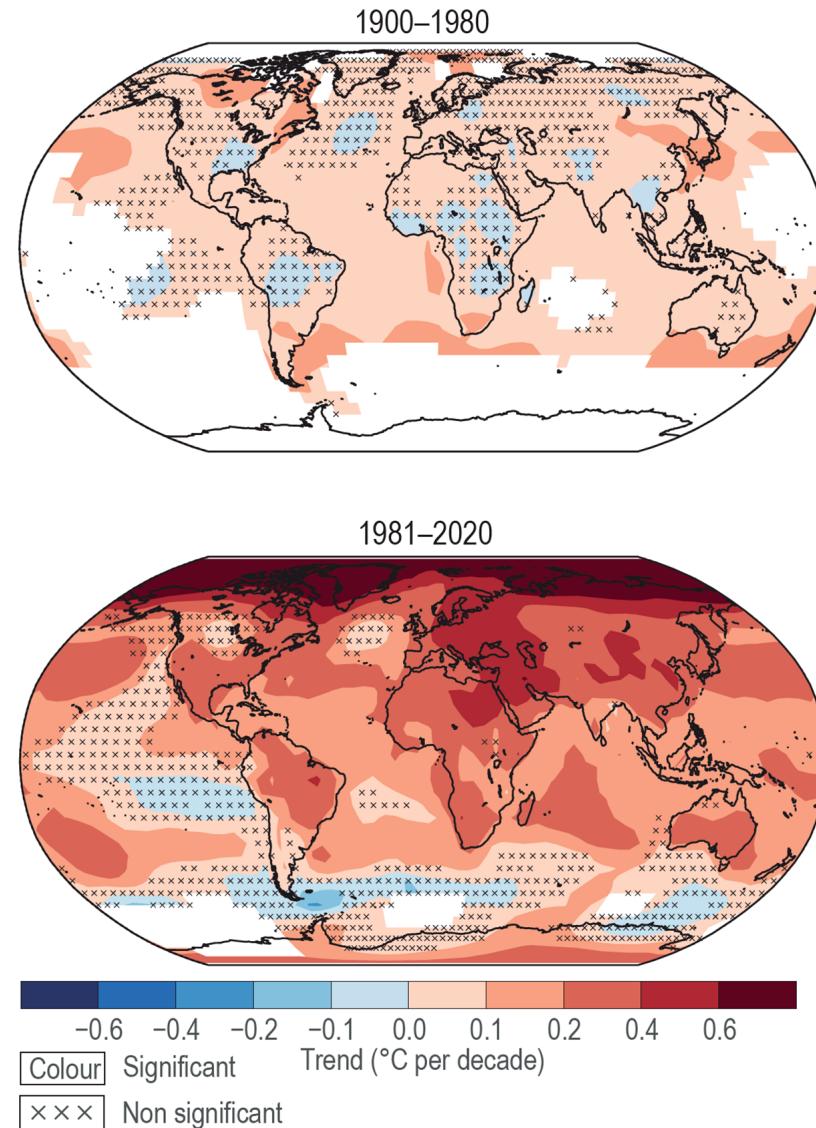
- Guangzhou has warm and humid summers.
- A typhoon is approaching Hainan Island.
- It is so hot today.
- The annual mean temperature and rainfall amount is 22.8°C and 2193.8 mm, respectively, in recent decades in Guangzhou.
- Southern China receives more annual rainfall amount than Northern China.



Ten Indicators of a Warming World

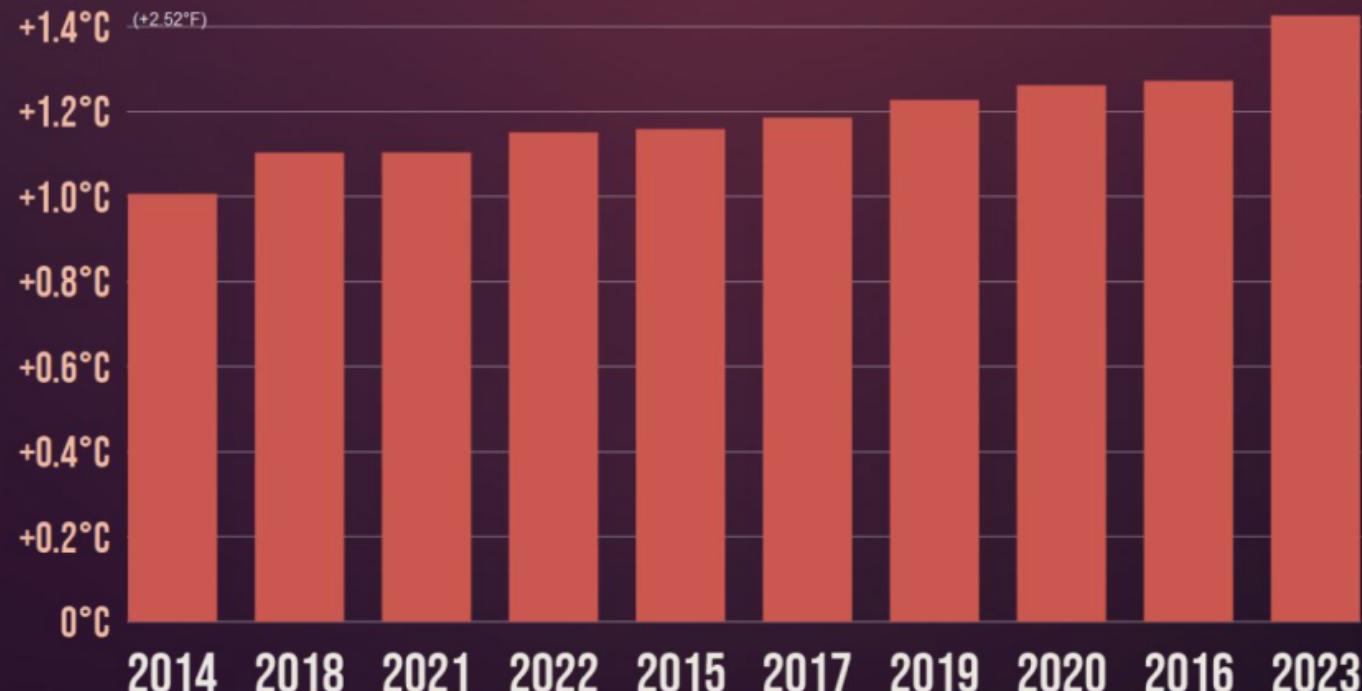


Long-term Trend of Temperature



Long temperature records that tell us how climate has changed. It has warmed largely over the last 40 years.

10 HOTTEST GLOBAL YEARS ON RECORD



Global temperature anomalies (°C) averaged and adjusted to early industrial baseline (1881-1910).

Data as of 1/12/2024.

Source: NASA GISS & NOAA NCEI

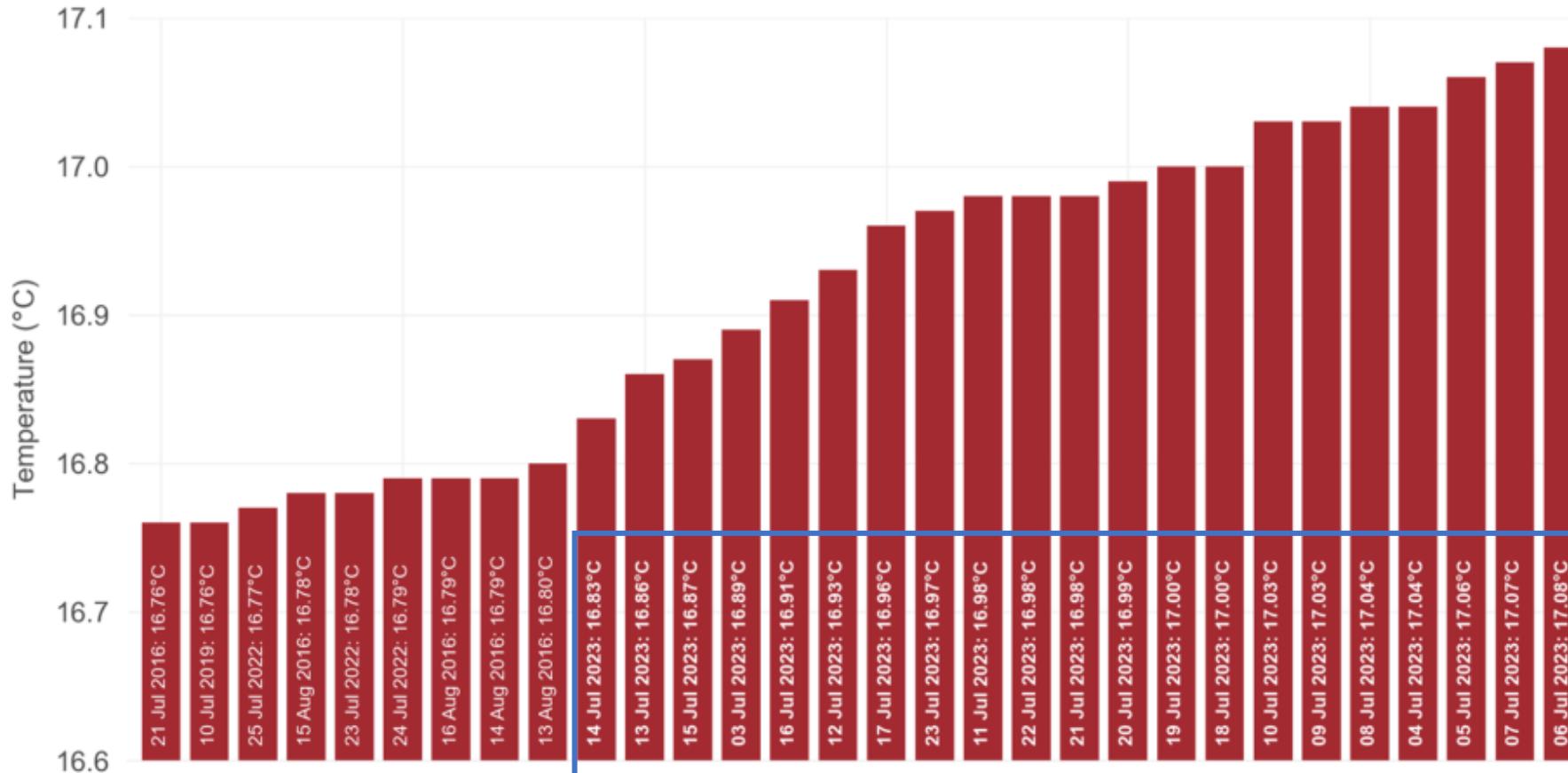
CLIMATE CENTRAL

The 10 warmest years since 1850 have all occurred in the past decade.



THE 30 WARMEST DAYS ON RECORD GLOBALLY

Daily global average surface air temperature data from ERA5 • Credit: C3S/ECMWF



PROGRAMME OF
THE EUROPEAN UNION



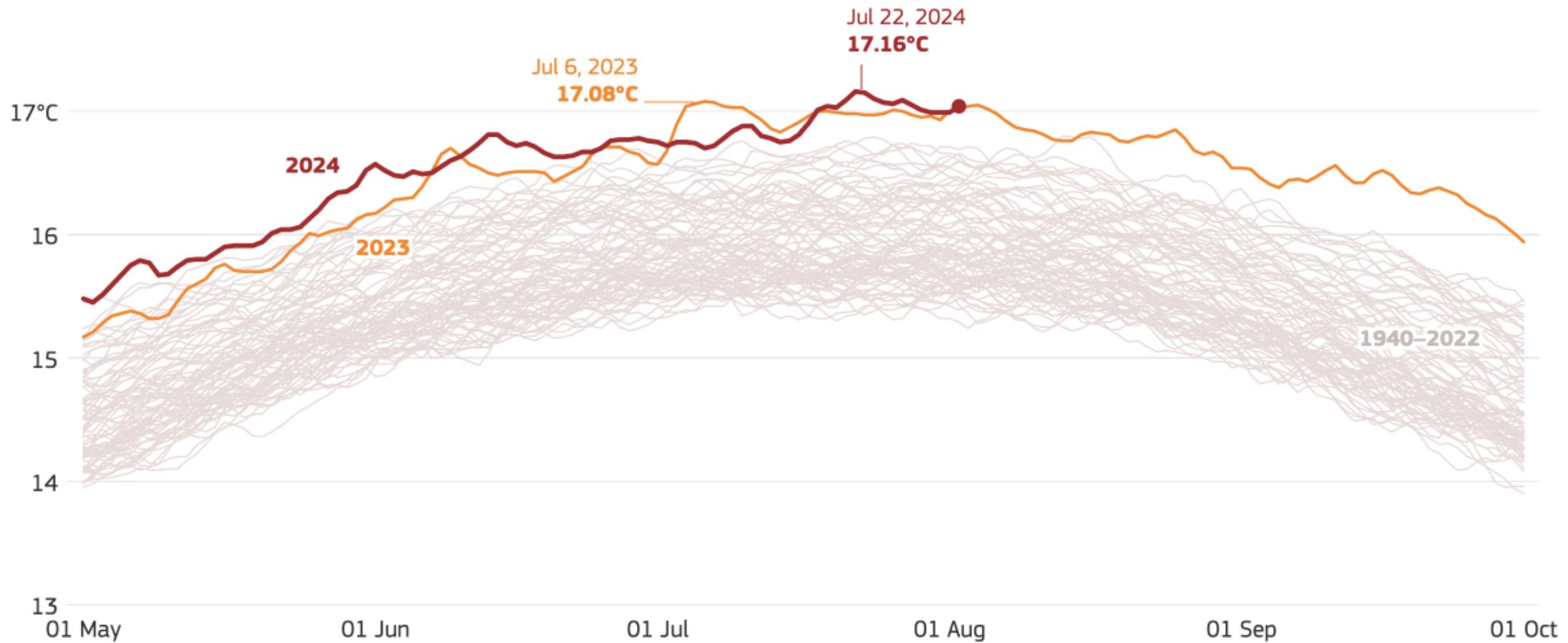
IMPLEMENTED BY
ECMWF

21 out of 30 occurs in 2023



1940–2024

Daily global surface air temperature



Data source: ERA5 • Credit: C3S/ECMWF



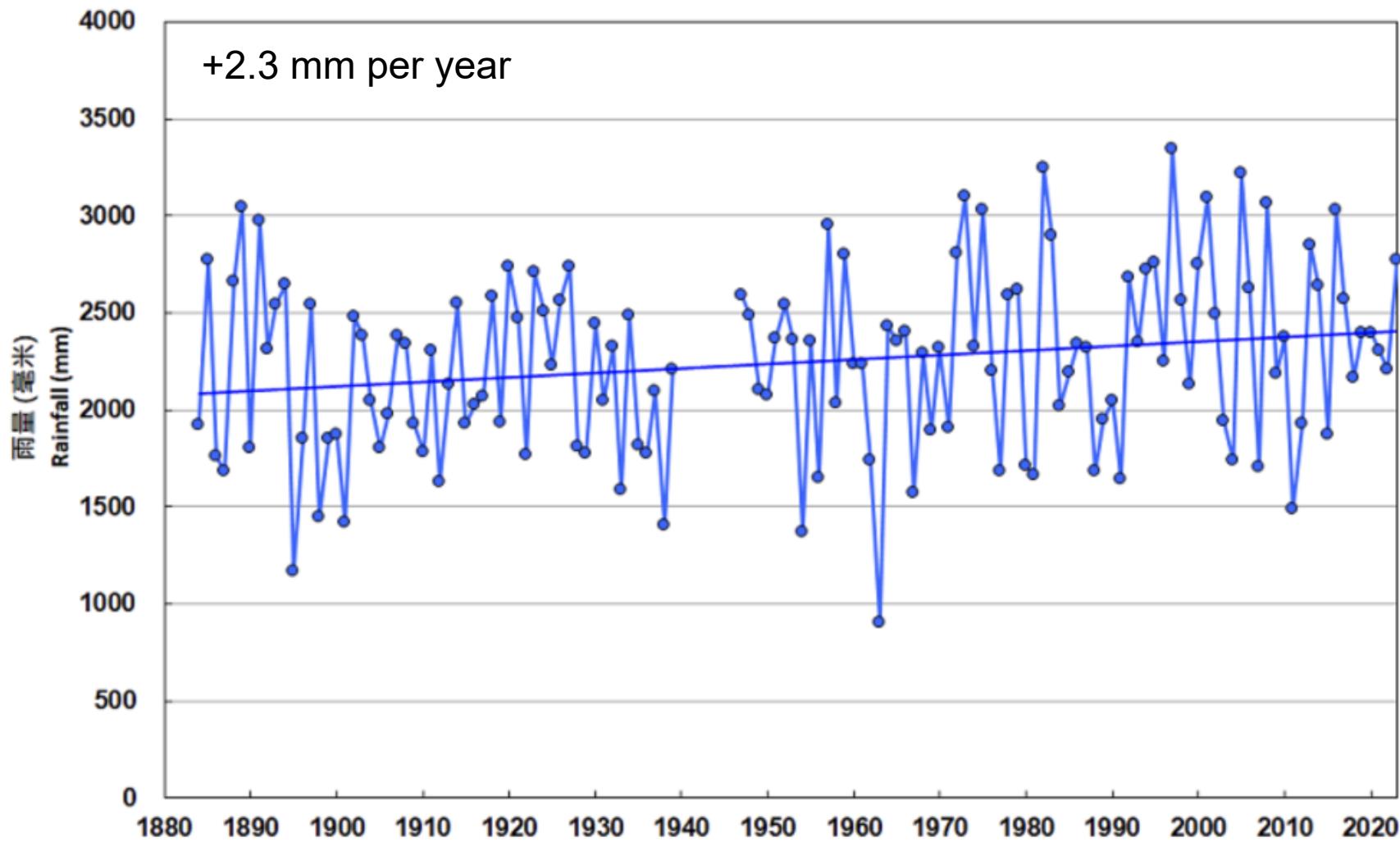
PROGRAMME OF
THE EUROPEAN UNION



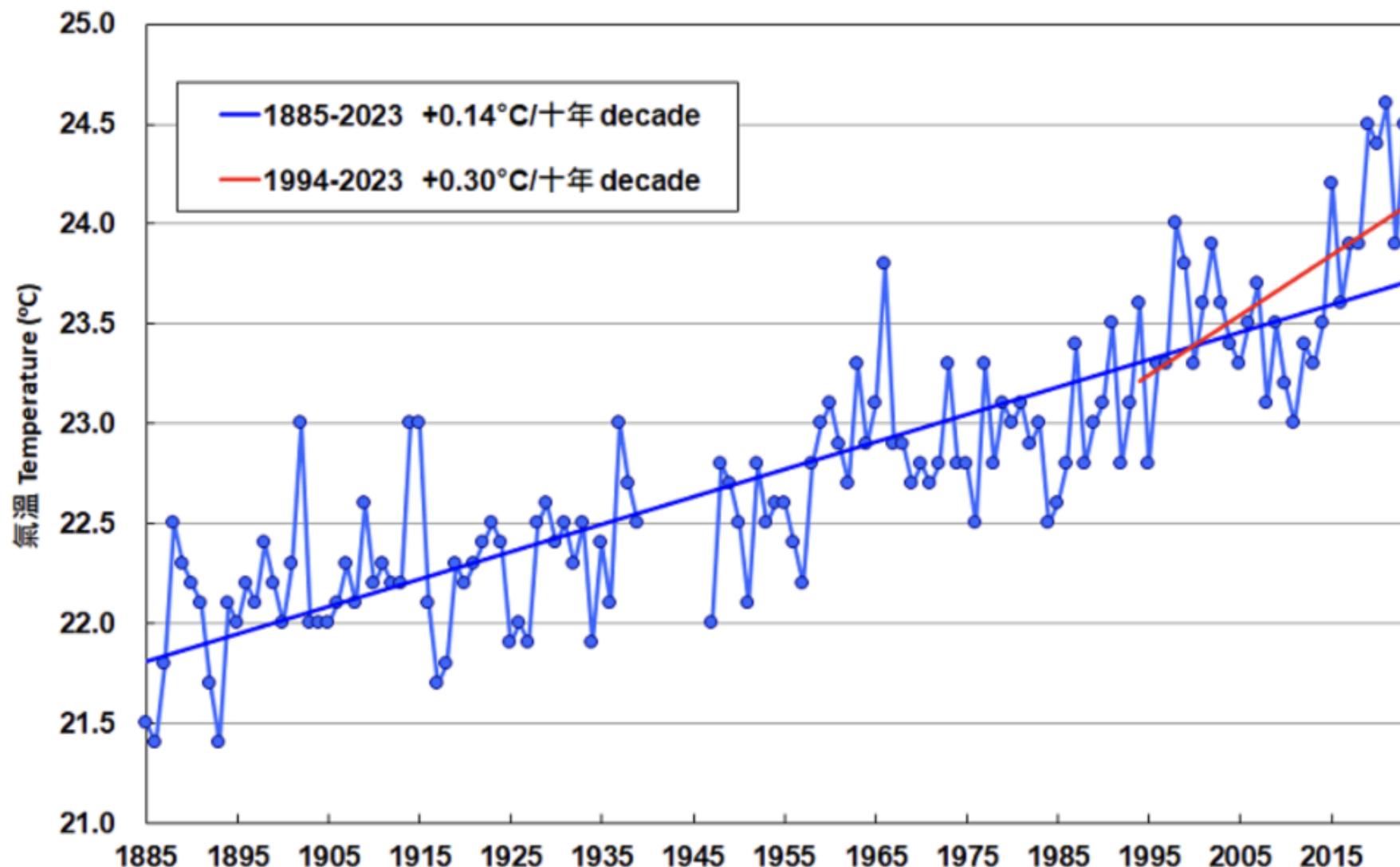
IMPLEMENTED BY
 ECMWF



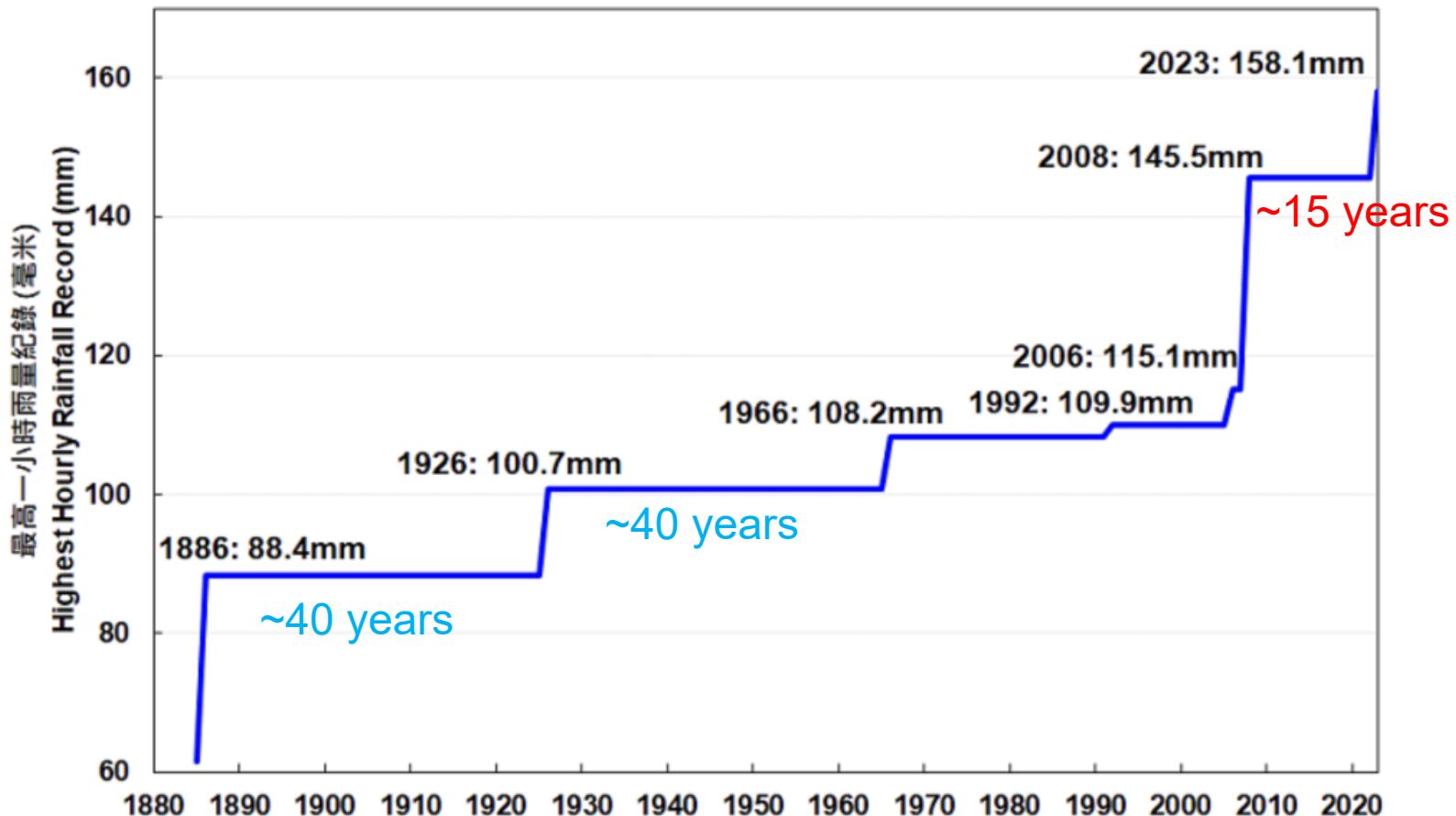
Precipitation in Hong Kong



Temperature in Hong Kong



Extreme precipitation in Hong Kong



Highest hourly rainfall records at the Hong Kong Observatory Headquarters (1885-2023)

How long it takes to break the houly extreme rainfall record?



Hong Kong's heaviest rain since records began 140 years ago (**1884**) has left **two** people dead. **158.1 mm** within one hour from **11 pm** on Sep 7.

#深圳特大暴雨打破7项历史极值#

截至8日14时00分，过去72小时罗湖小梧桐雨量达到614.6毫米），成为打破了深圳市1952年有气象记录以来的第7项历史极

收起 | 旋转 | 查看大图

9.7特大暴雨过程		过去历史极值	
滑动72小时最大雨量	614.6毫米 (罗湖小梧桐)	历史排名第1	611.1毫米
滑动48小时最大雨量	613.8毫米 (罗湖小梧桐)	历史排名第1	533.6毫米
滑动24小时最大雨量	557.8毫米 (罗湖小梧桐)	历史排名第1	517.4毫米
滑动12小时最大雨量	465.5毫米 (罗湖小梧桐)	历史排名第1	438.3毫米
滑动6小时最大雨量	355.2毫米 (罗湖东门)	历史排名第1	344.8毫米
滑动3小时最大雨量	246.8毫米 (盐田正坑)	历史排名第1	235.9毫米
滑动2小时最大雨量	195.8毫米 (盐田正坑)	历史排名第1	189.8毫米
最大1小时滑动雨量	116.8毫米 (罗湖梧桐村)	历史排名第10	142.2毫米

@深圳天气

广州多站降雨打破纪录

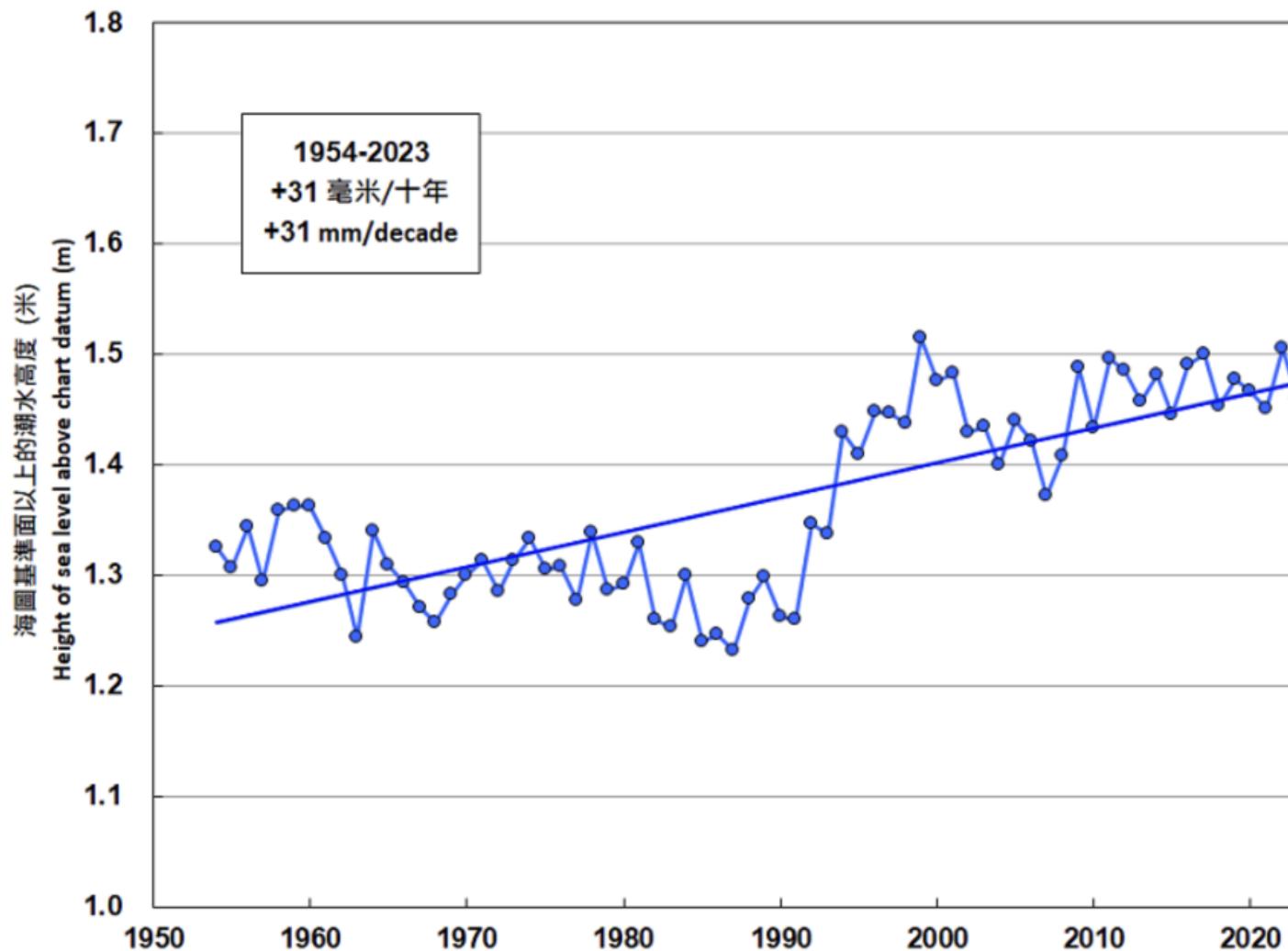
番禺区南村镇梅山村（G1071）录得6小时雨量267.7毫米，打破番禺区6小时雨量记录。

番禺国家气象观测站（59481）录得6小时雨量252.5毫米，打破该站历史6小时雨量记录。

番禺区南村镇梅山村（G1071）录得24小时雨量374.6毫米，打破番禺区24小时雨量记录。

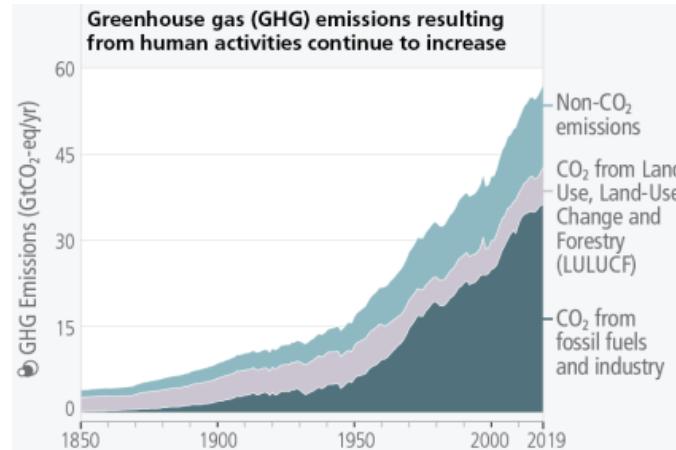
番禺国家气象观测站（59481）录得24小时雨量347.1毫米，为该站历史24小时雨量排名第2多。

Mean sea level in Hong Kong

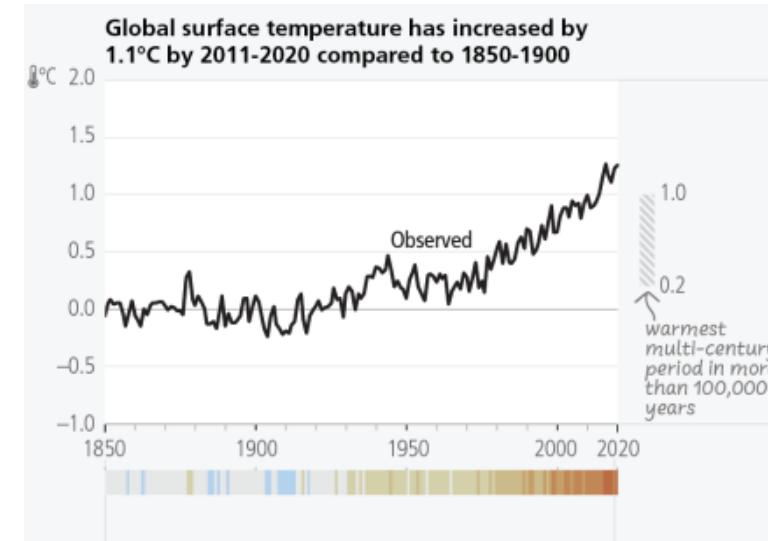


Human Activities are Responsible for Global Warming

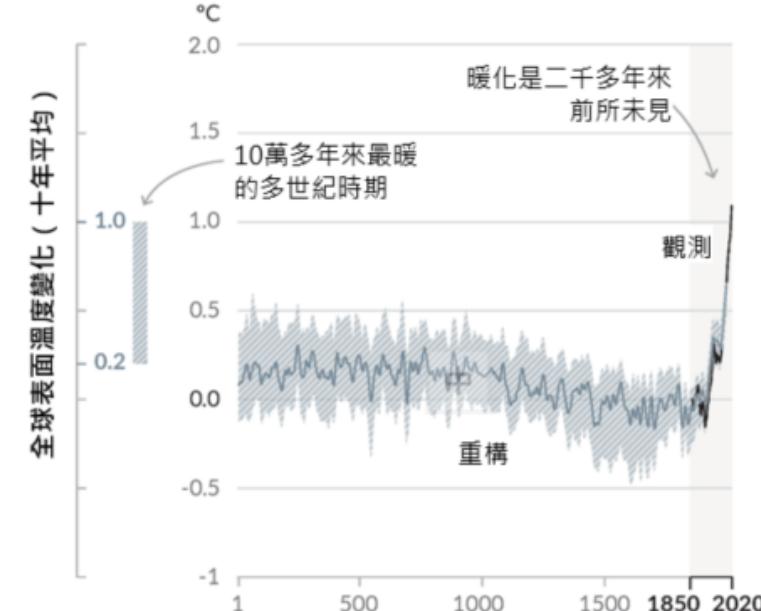
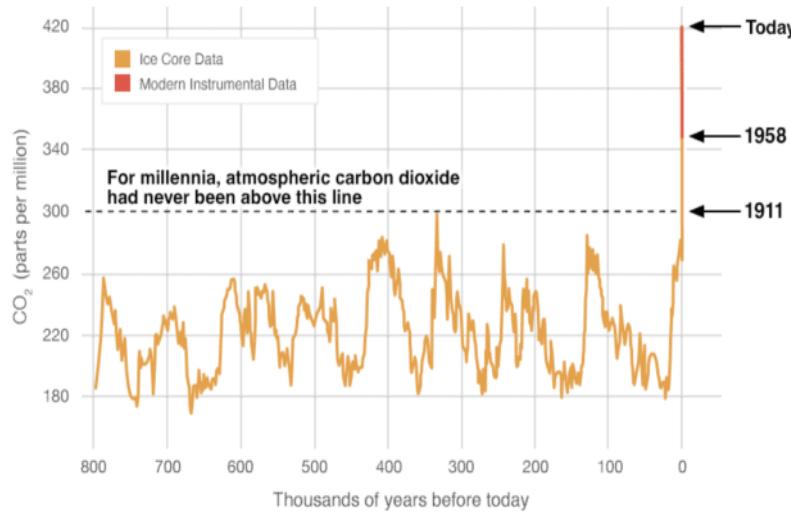
Increased GHGs emissions



Global mean surface temp.

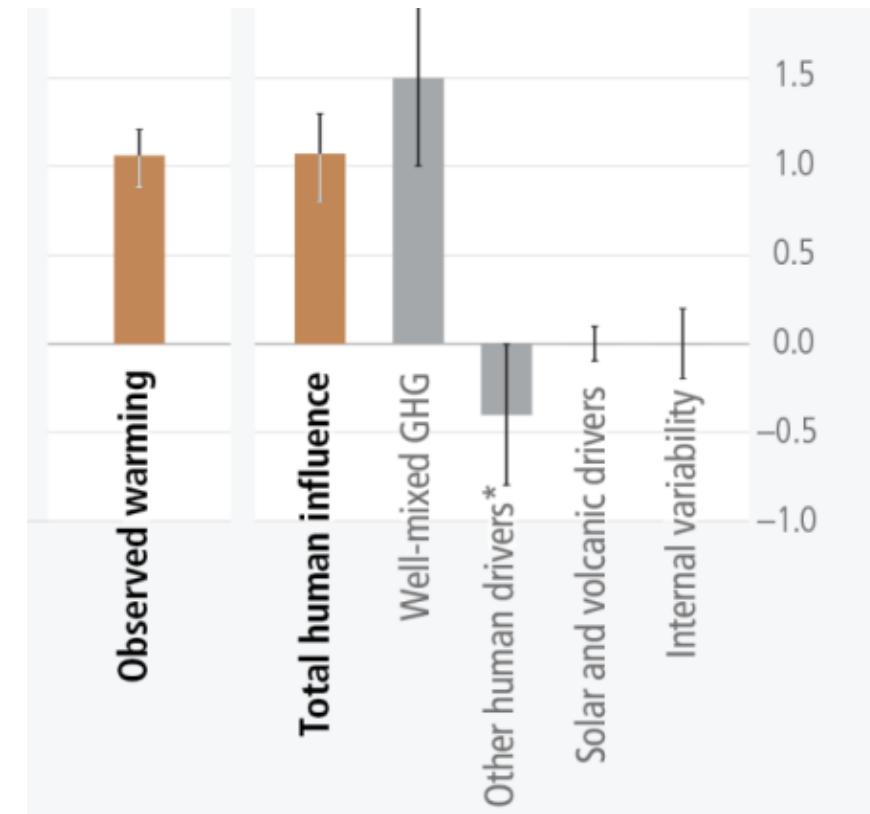
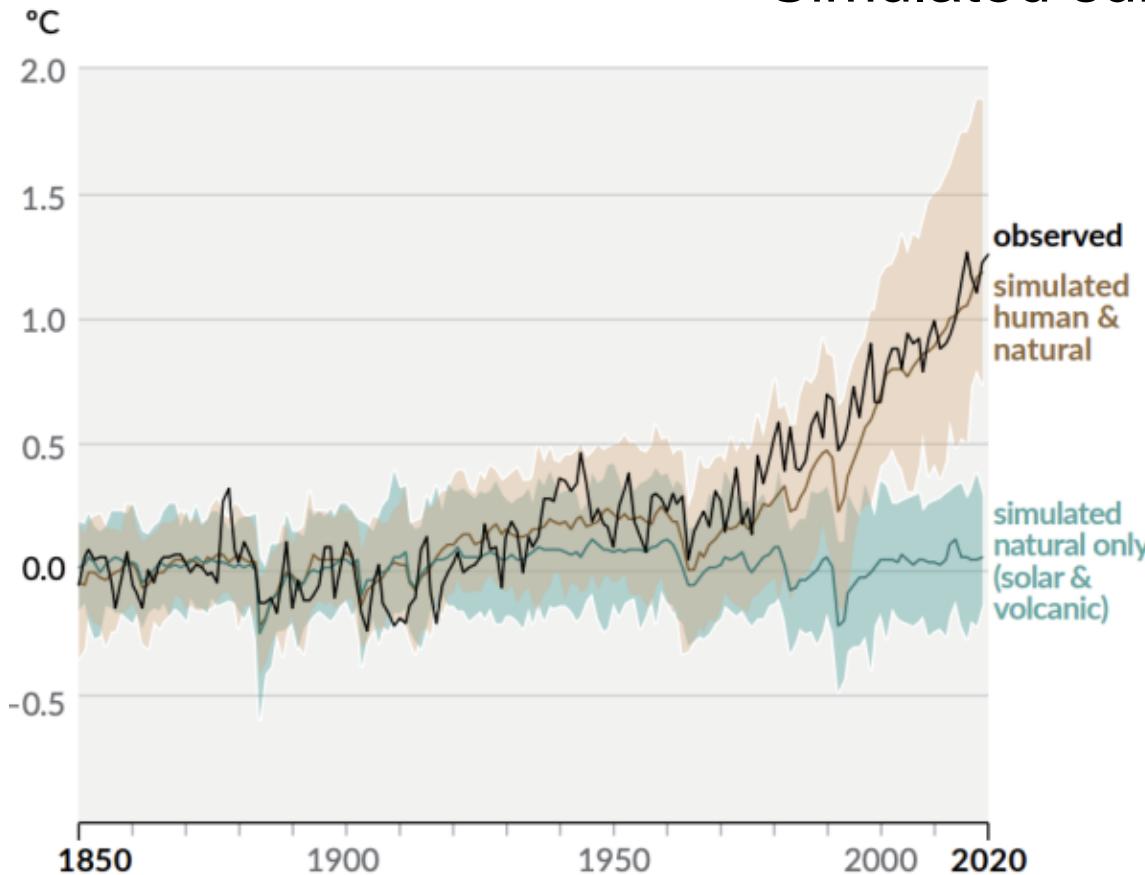


GHGs concentrations

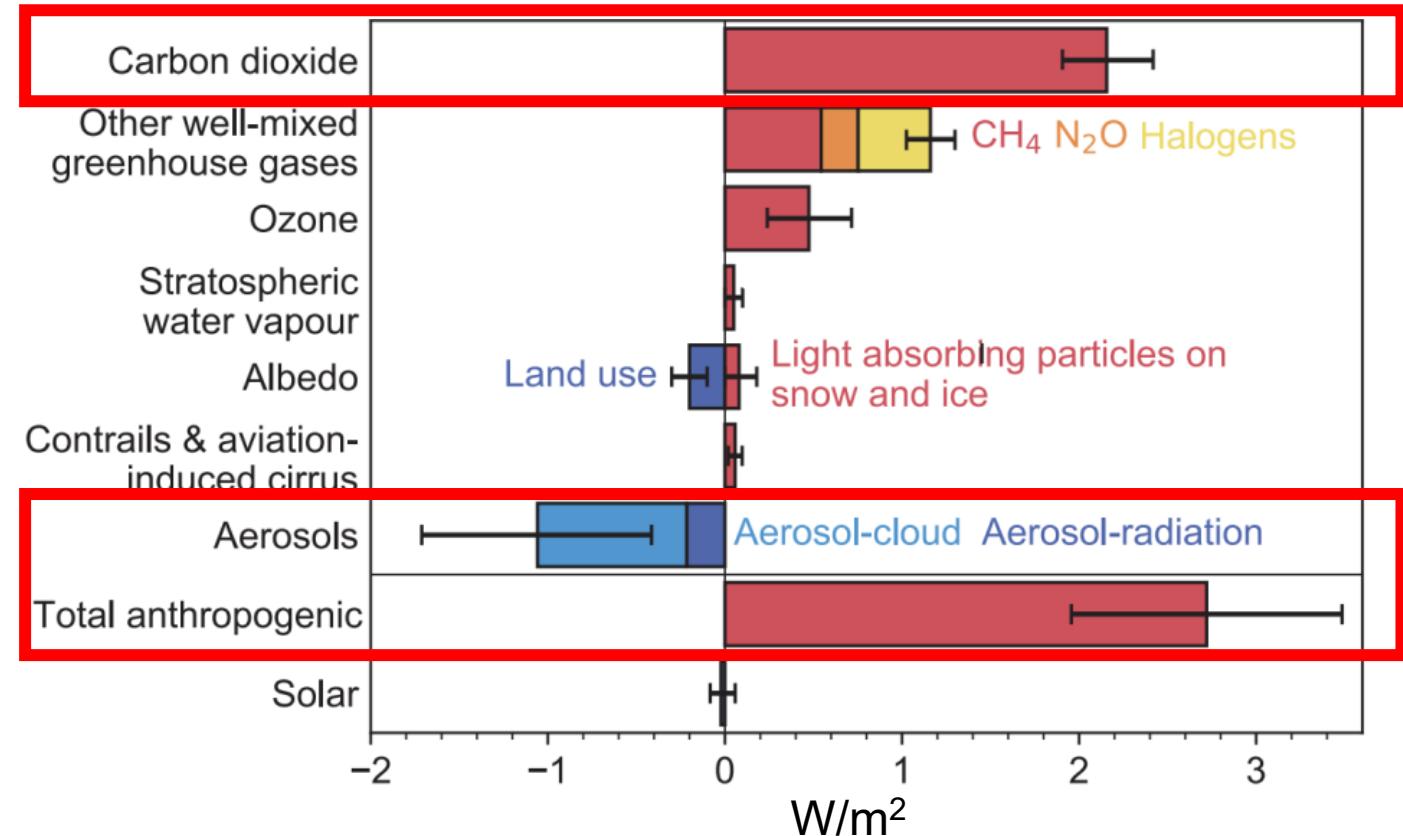
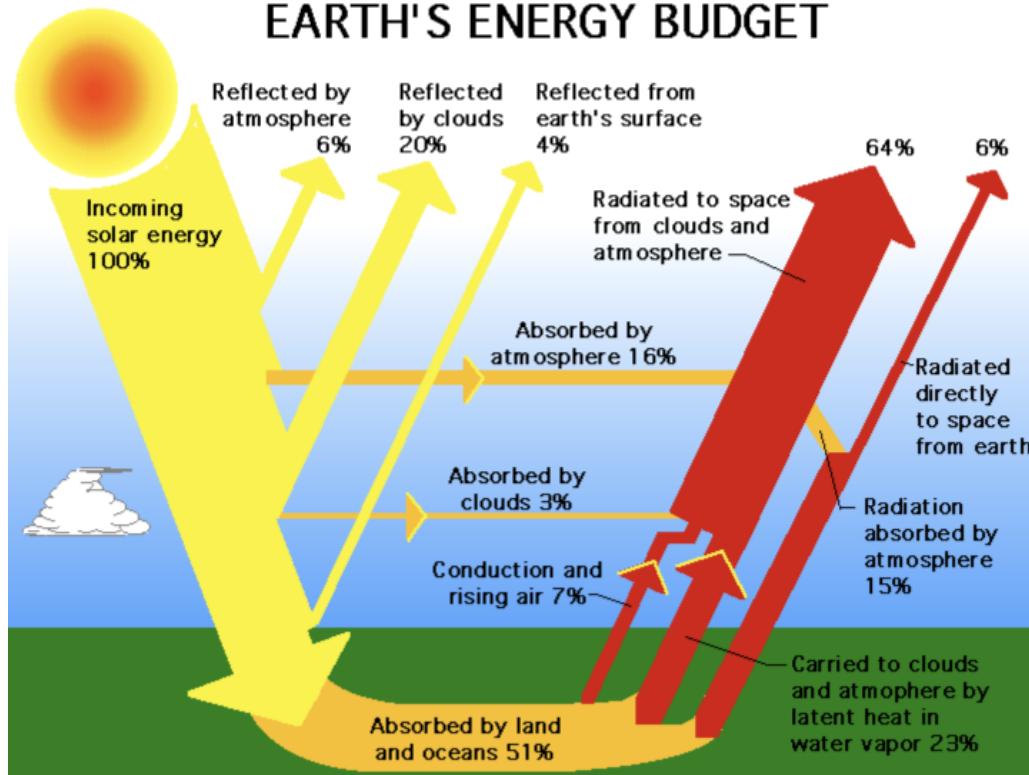


Human Activities are Responsible for Global Warming

Simulated surface temp.



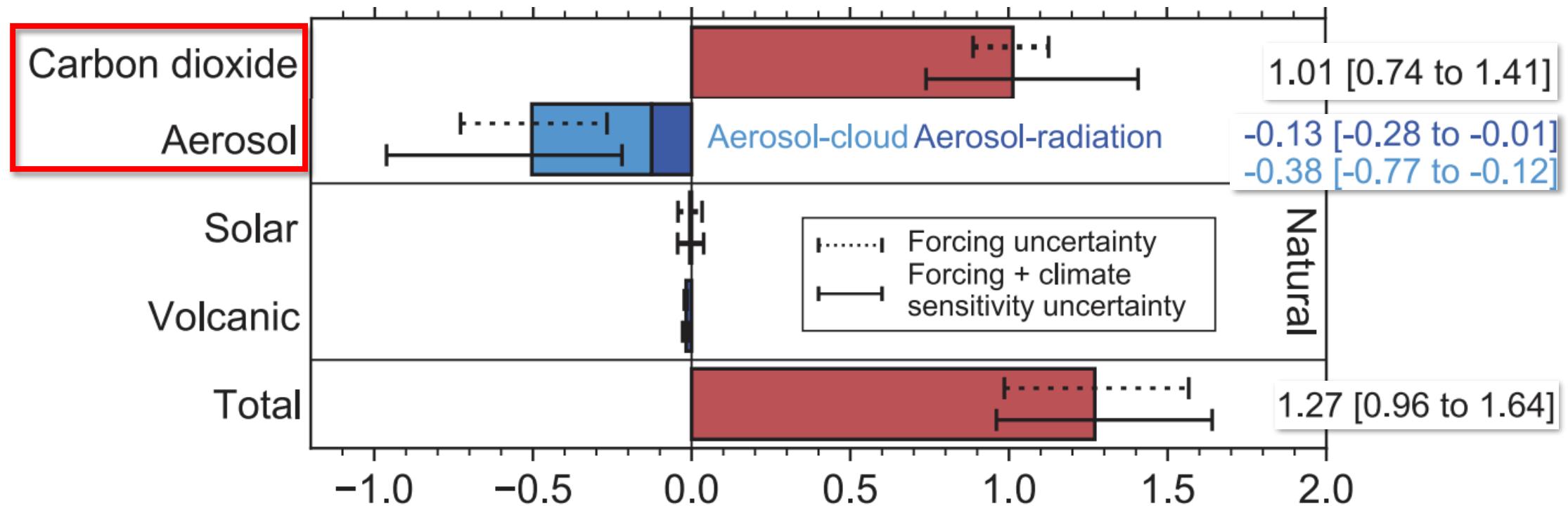
Anthropogenic-induced Effective Radiative Forcing



Aerosols account for the **largest** uncertainty

Aerosol-induced Cooling

Global mean surface temperature changes



Aerosol-induced cooling ≈ half CO₂-induced warming

What is IPCC



AR6 Working Group I in numbers

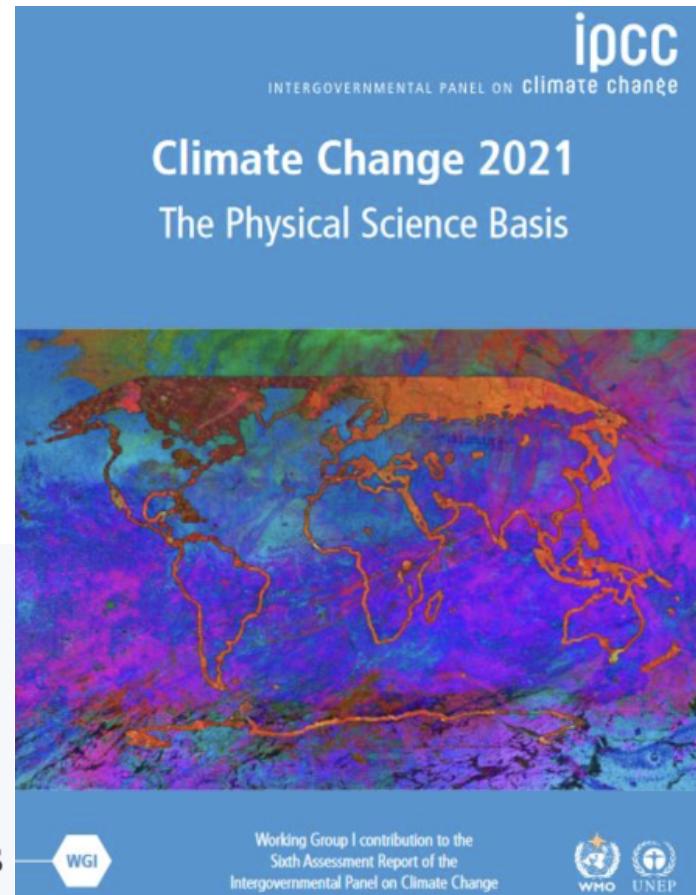
234 authors from 66 countries

- 31 – coordinating authors
- 167 – lead authors
- 36 – review editors
- 517 – contributing authors

Over 14,000 cited references

A total of 78,007 expert and government review comments

Created in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP)





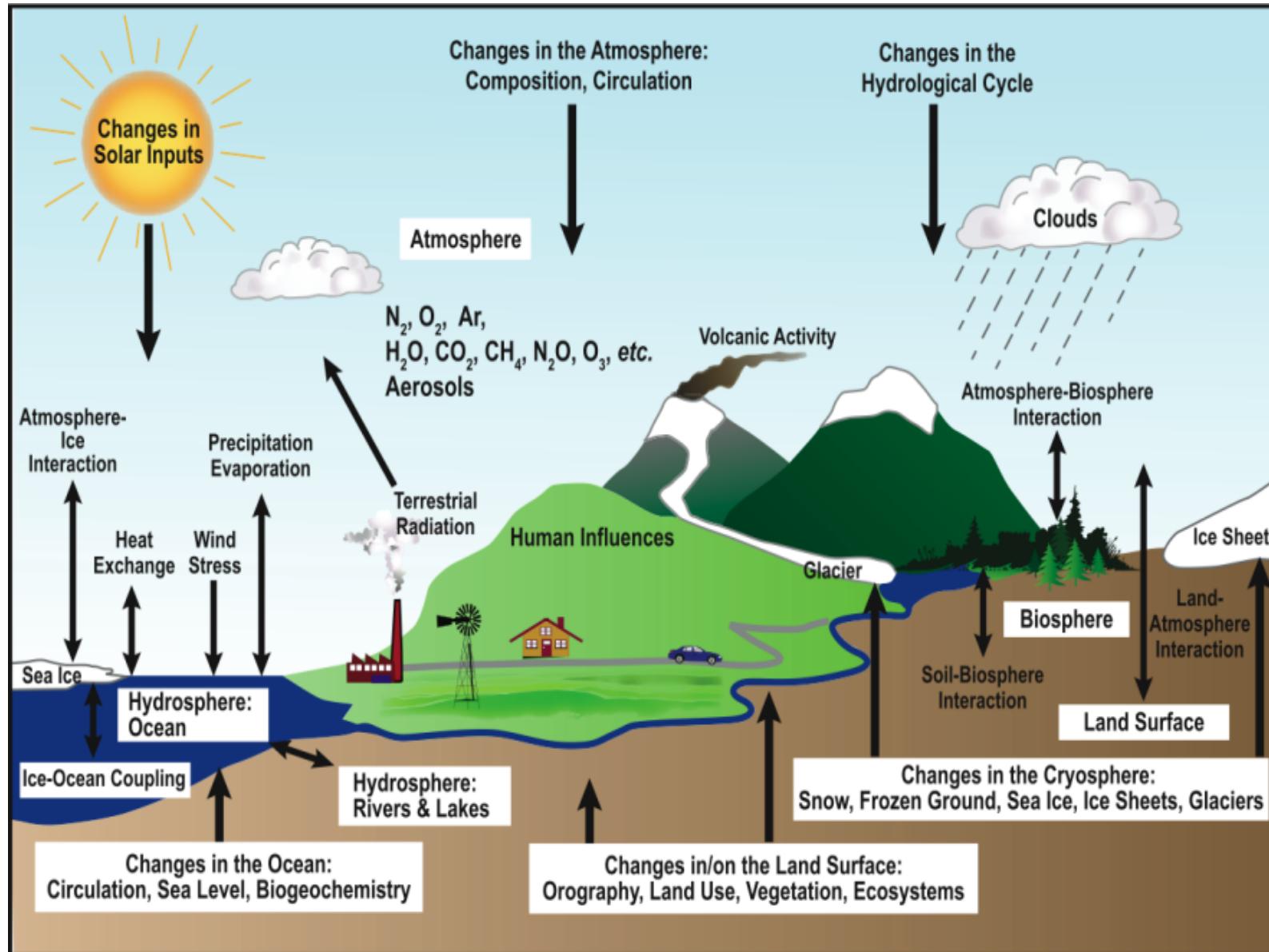


- For modelers, the computer is our lab.
- The computer model is our research tool.



Unfortunately, we don't have a twin planet earth that can be used to perform laboratory experiments.

Earth System



Global Climate Models

$$u_t = -\nabla \cdot (\mathbf{u} \mathbf{u}) + v \left(f + \frac{u \tan \phi}{a} \right) - \left(\frac{1}{a \rho_0 \cdot \cos \phi} \right) p_\lambda + (\kappa_m u_z)_z + F^u$$

$$v_t = -\nabla \cdot (\mathbf{v} \mathbf{u}) - u \left(f + \frac{u \tan \phi}{a} \right) - \left(\frac{1}{a \rho_0} \right) p_\phi + (\kappa_m v_z)_z + F^v$$

$$w_z = -\nabla_h \cdot \mathbf{u}_h$$

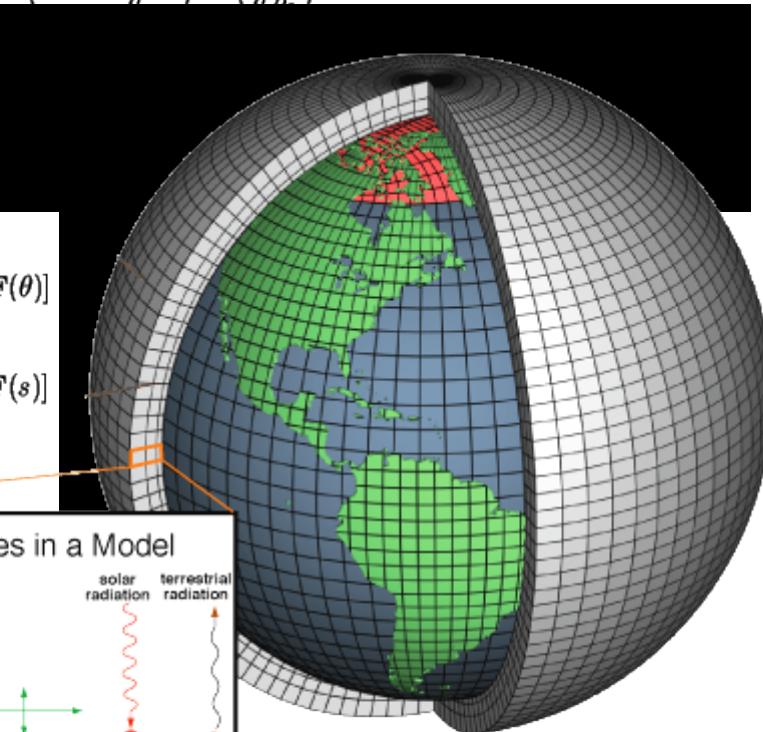
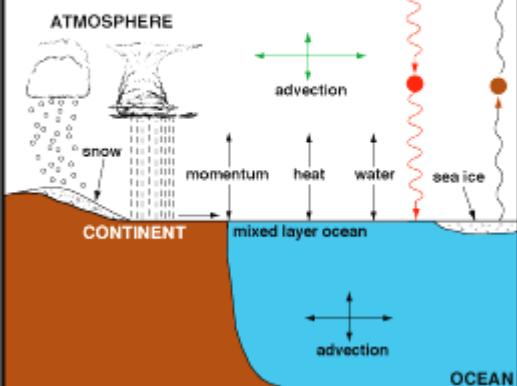
$$p_z = -\rho g$$

$$\theta_t = -\nabla \cdot [\mathbf{u} \theta + \mathbf{F}(\theta)]$$

$$s_t = -\nabla \cdot [\mathbf{u} s + \mathbf{F}(s)]$$

$$\rho = \rho(\theta, \varepsilon, z).$$

Physical Processes in a Model



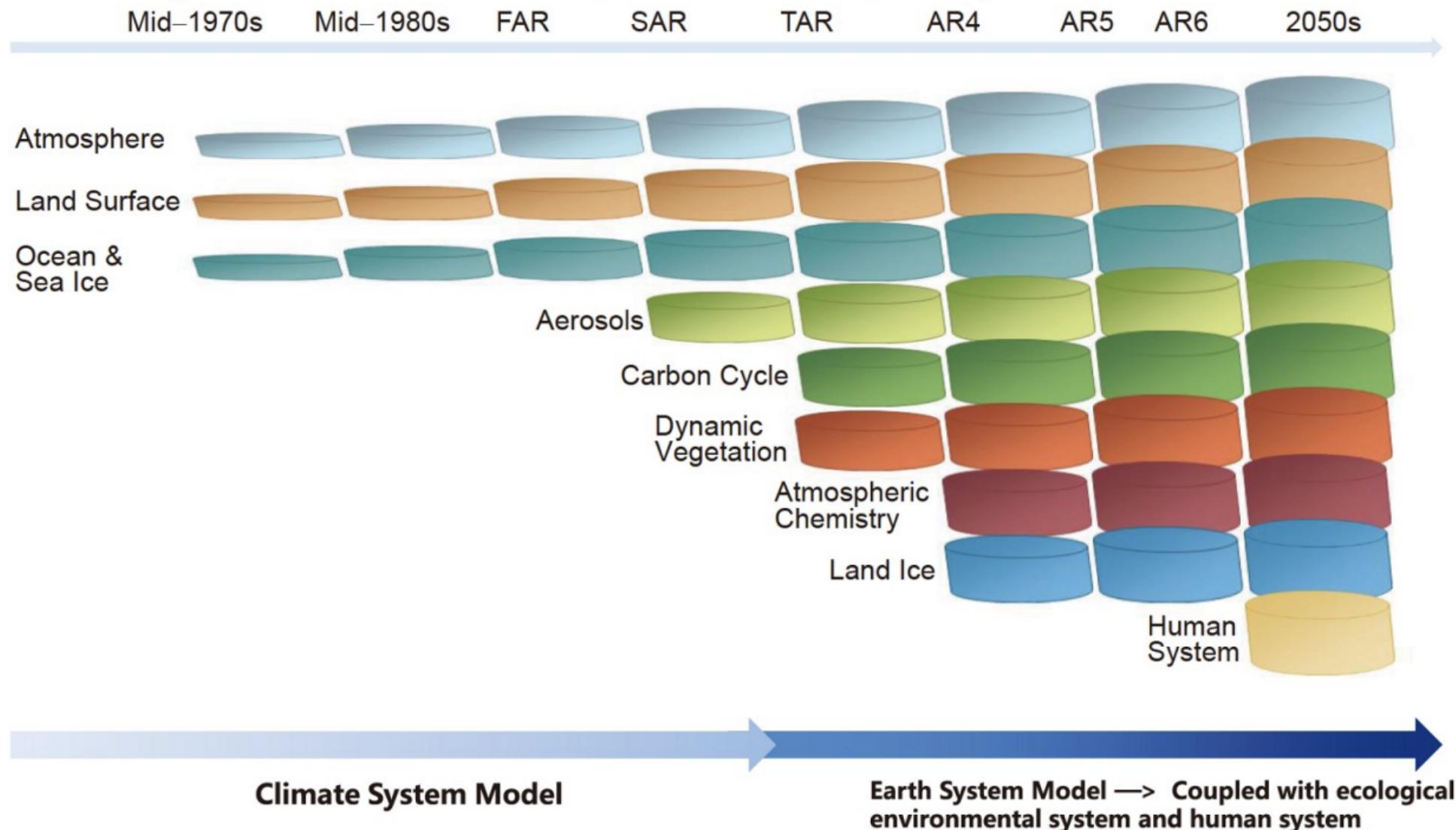
Our “workhorse” models have more than 300,000 atmospheric grid cells and a couple million ocean grid cells.

And there's thousands more grid cells for the land and sea ice model components.

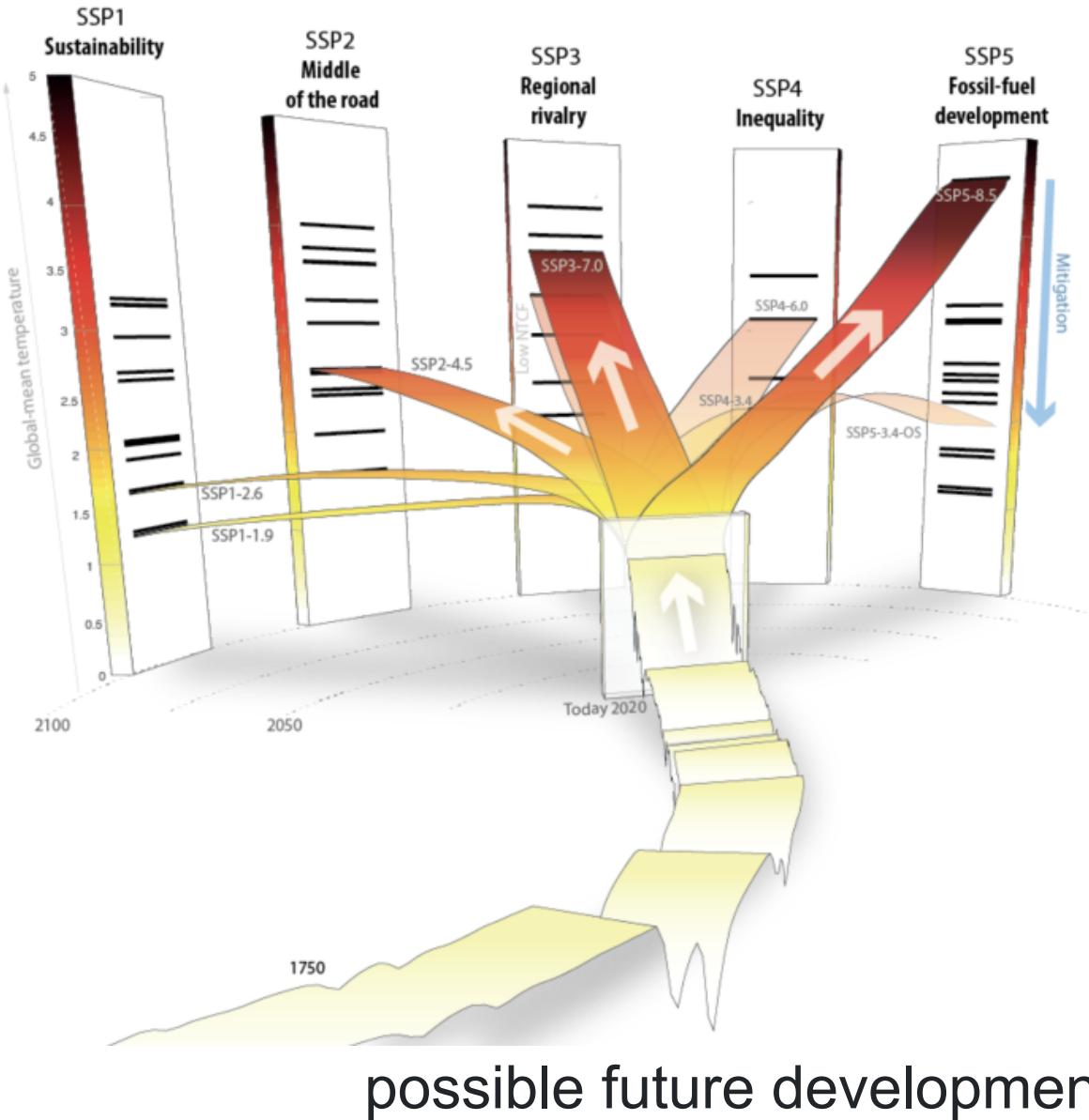


Evolving Complexity of Earth System Models

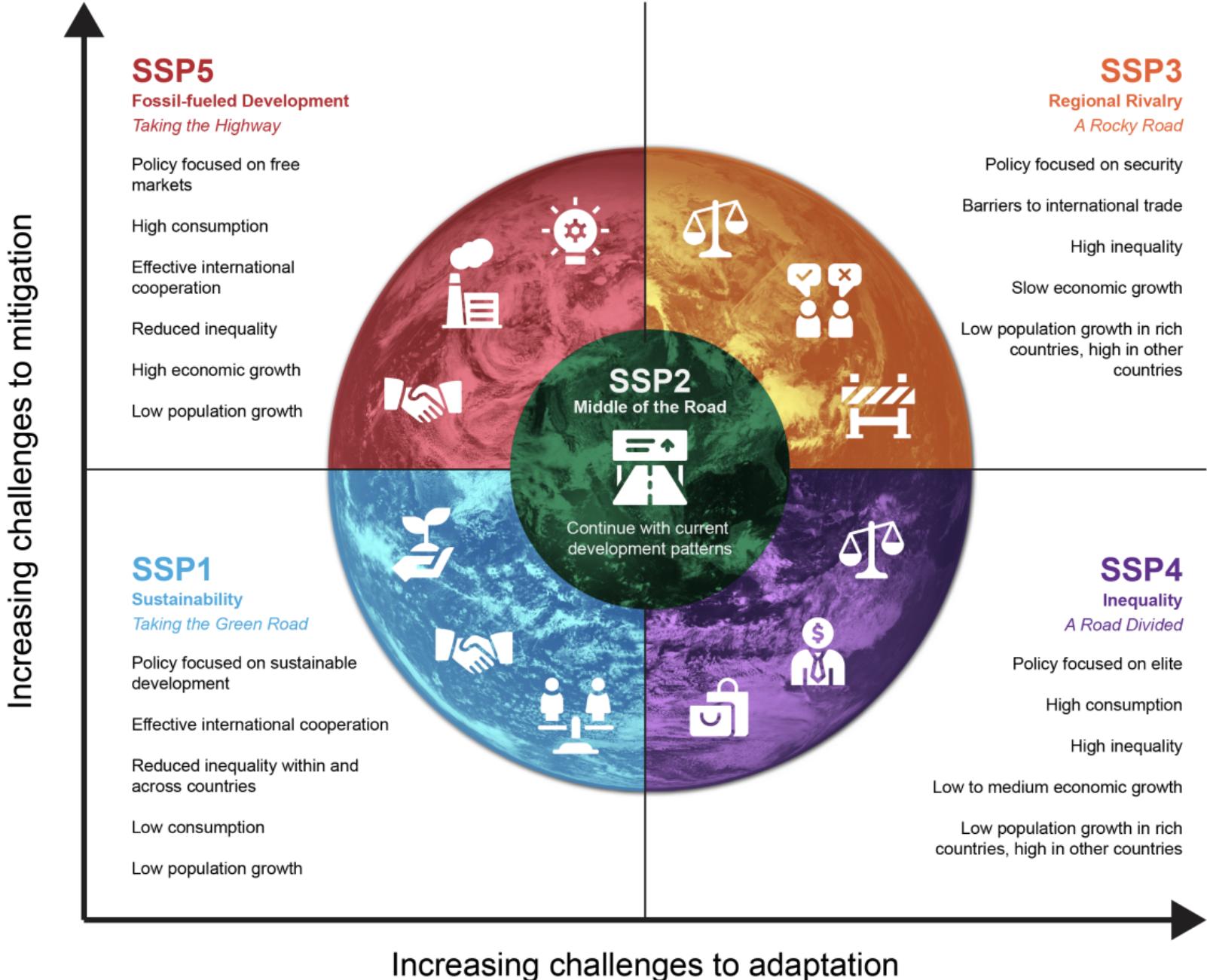
Earth System Model development: from past, present to future



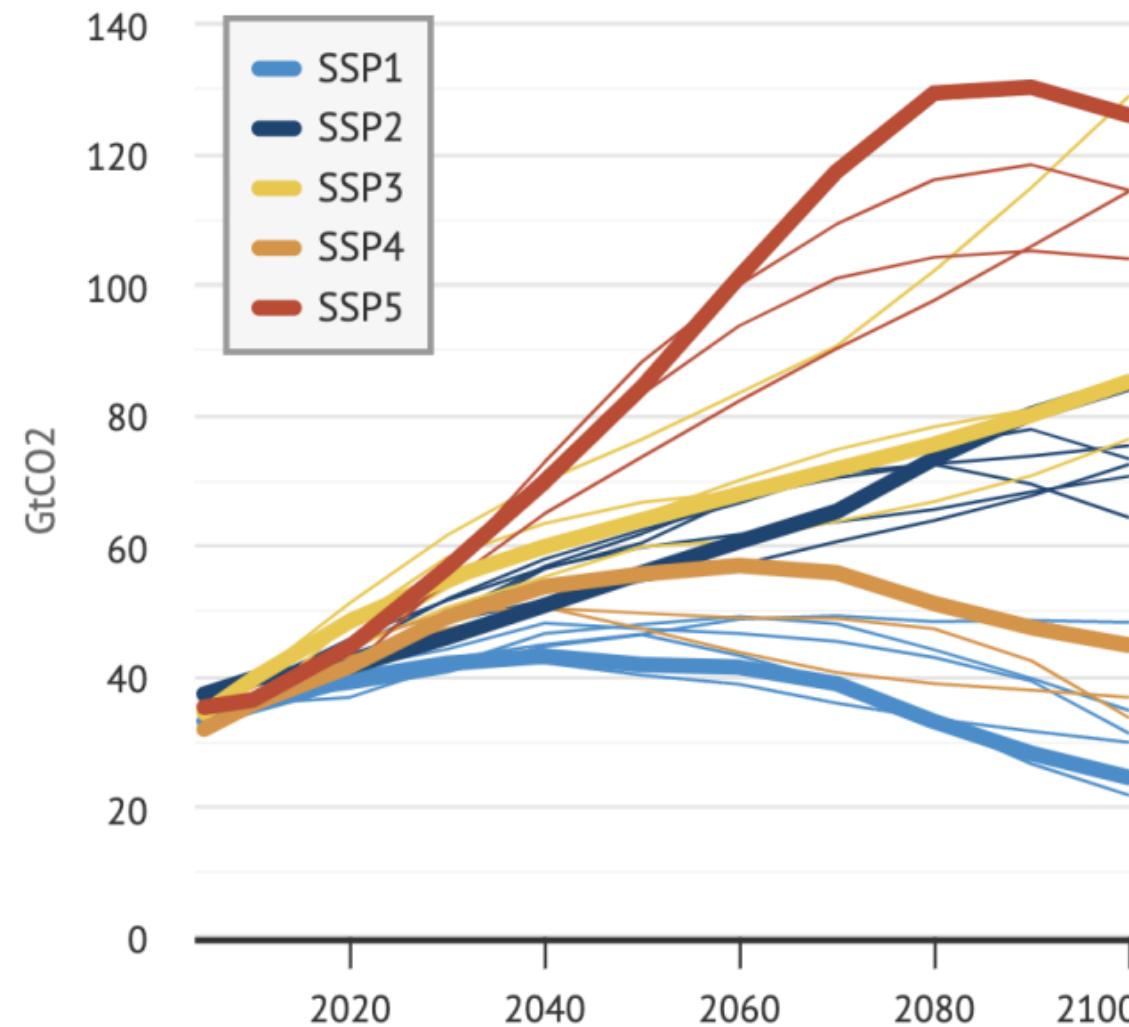
Shared Socio-economic Pathways (SSPs)



- Economic growth
- Technology
- Innovation
- Population growth
- Urbanization

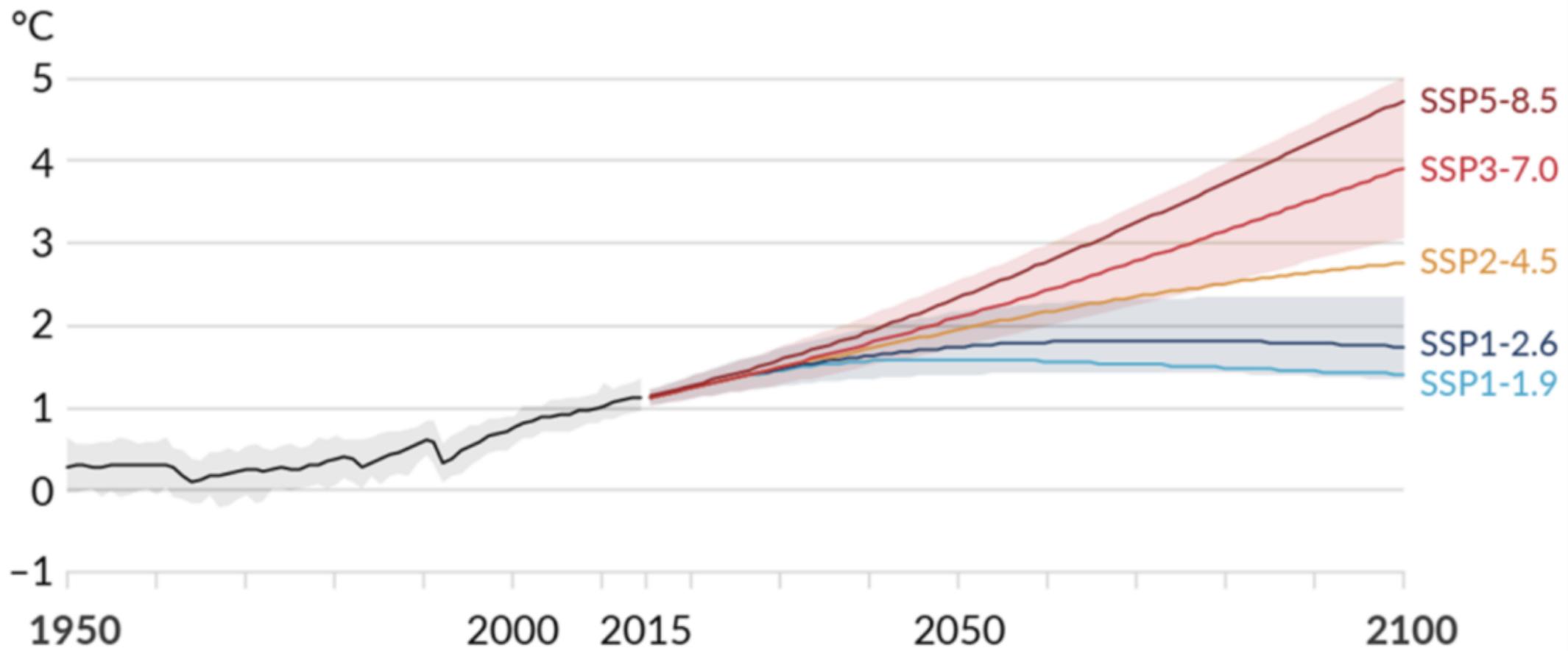


CO2 emissions for SSP baselines

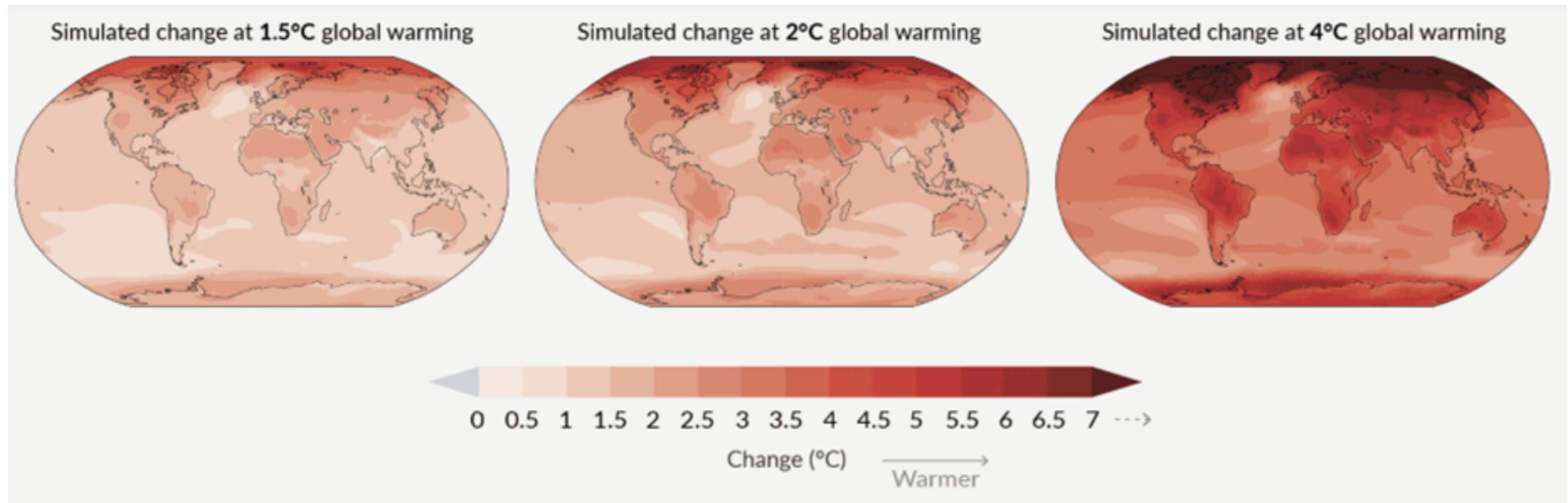


Future Temperature Changes

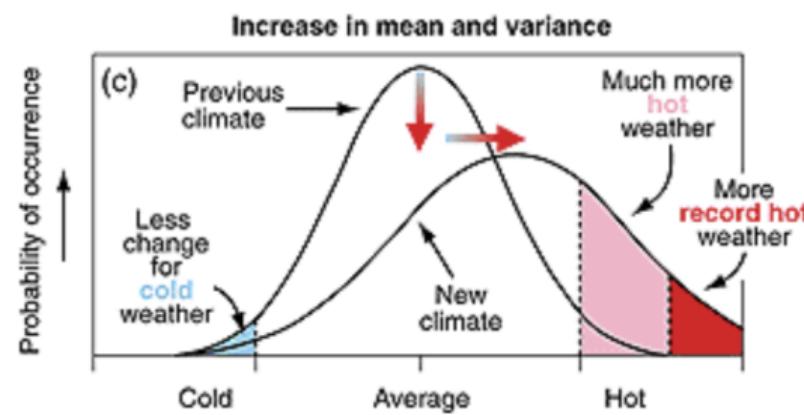
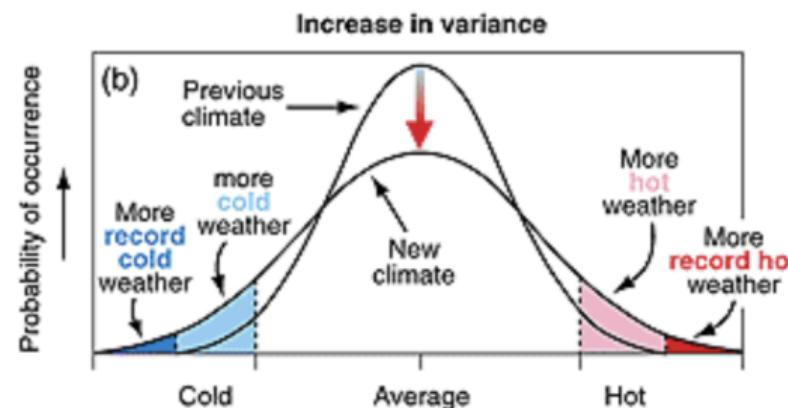
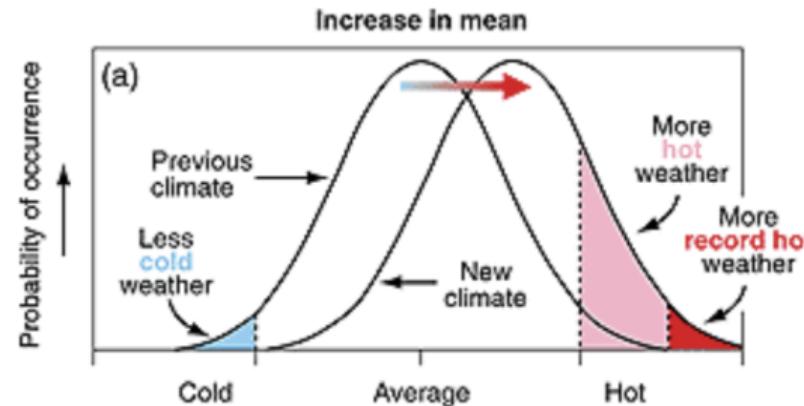
Global surface temperature change relative to 1850–1900



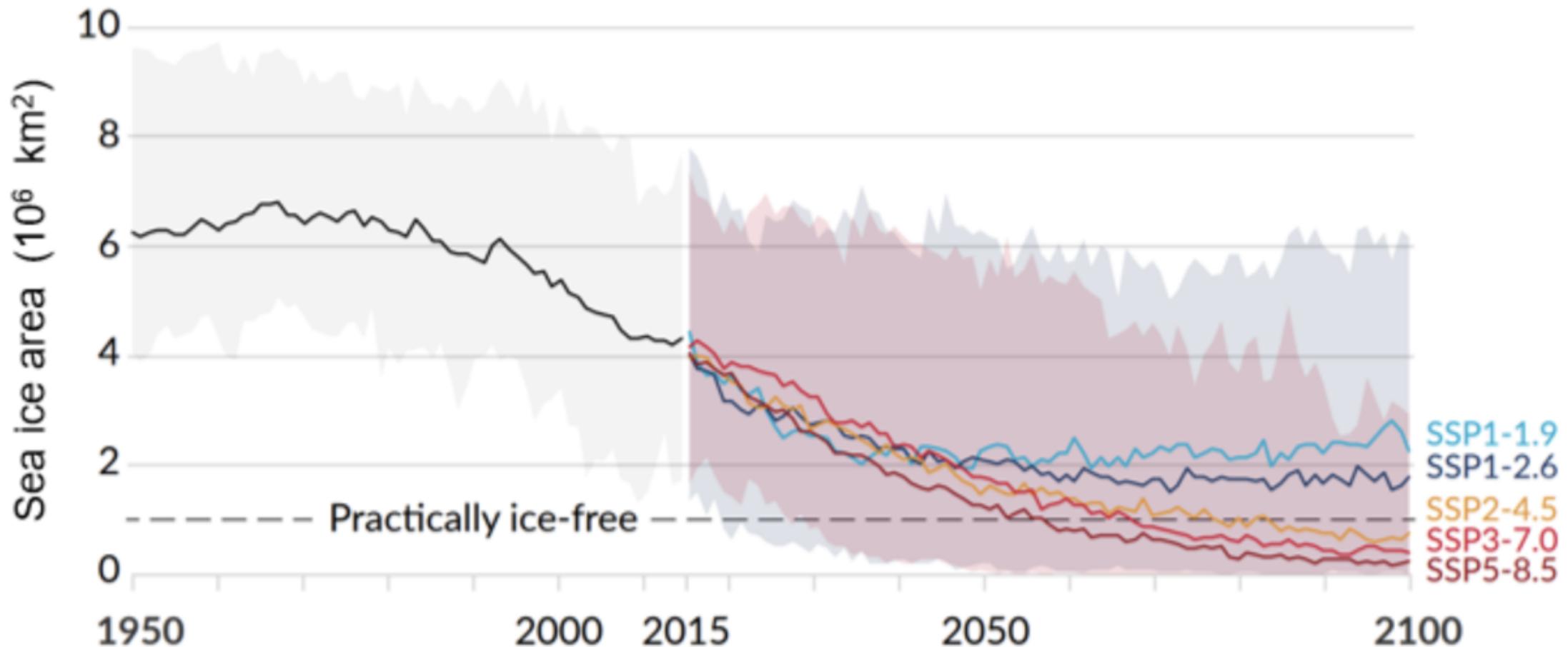
Future temperature changes



Extreme Temperature Changes



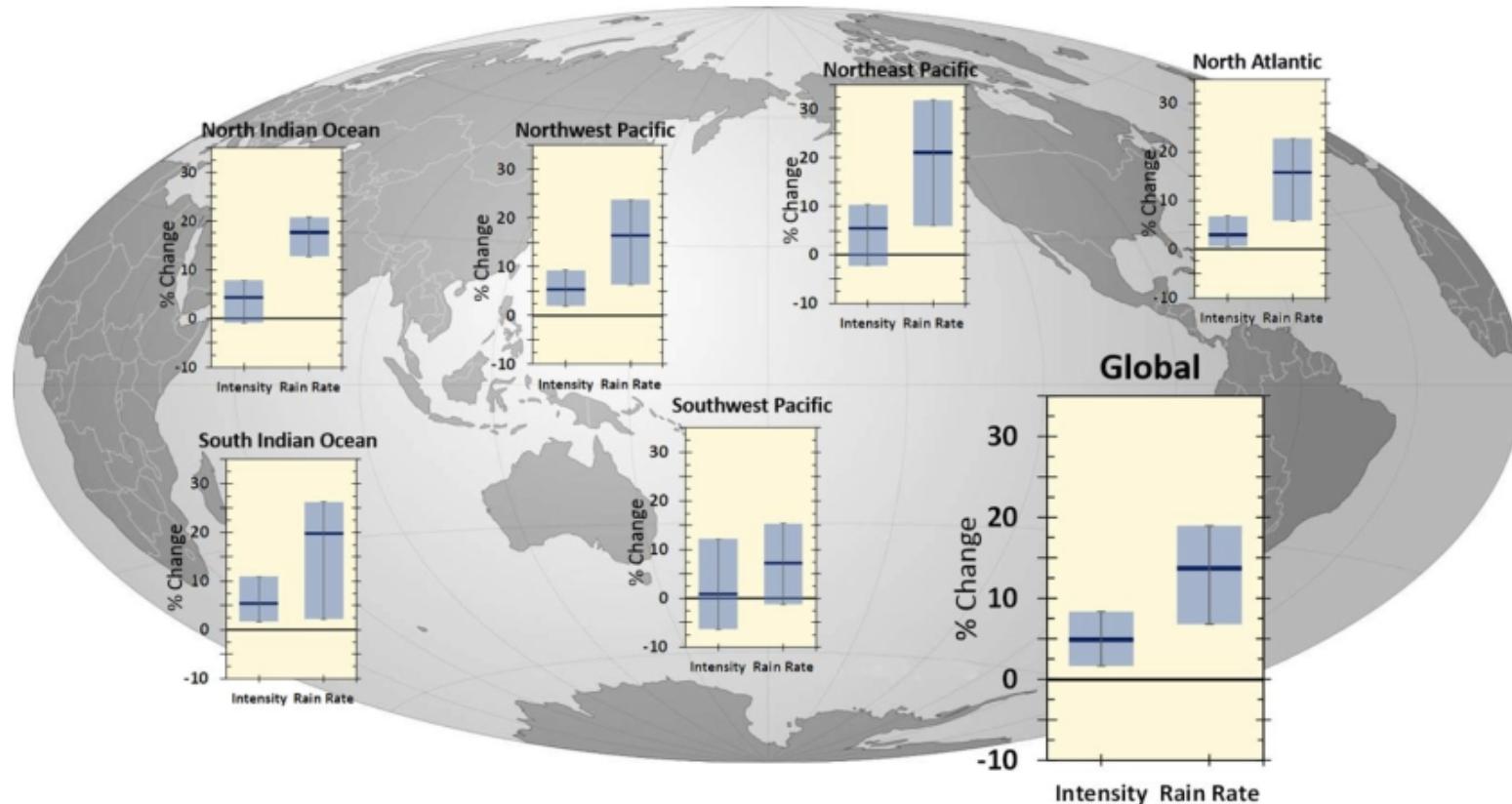
Future Sea Ice Area Changes



Future Tropical Cyclone Changes

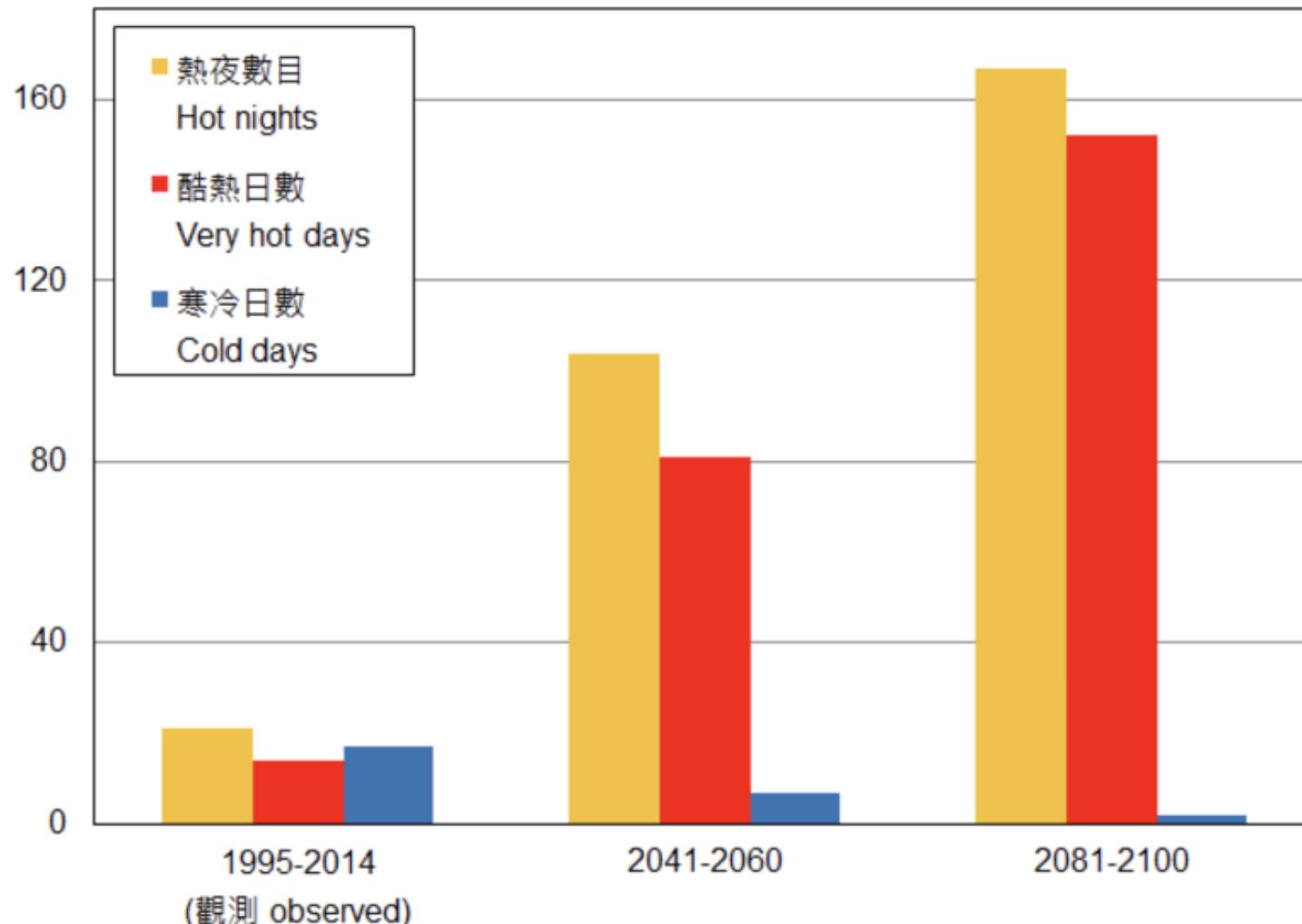
熱帶氣旋推算（全球變暖 2°C ）

Tropical Cyclone Projections (2°C Global Warming)



Stronger intensity and larger rain rate



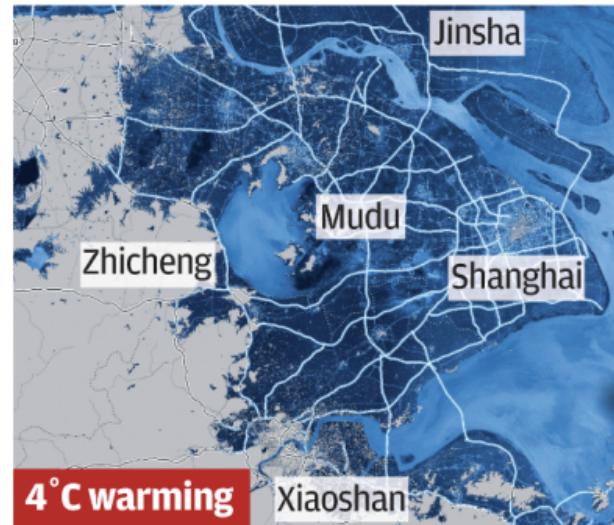
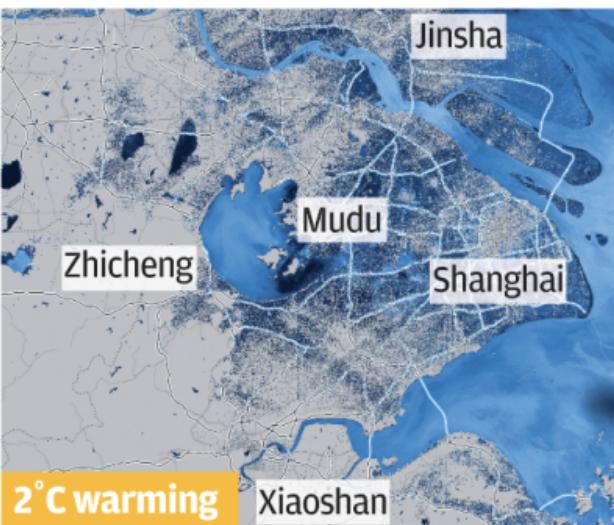
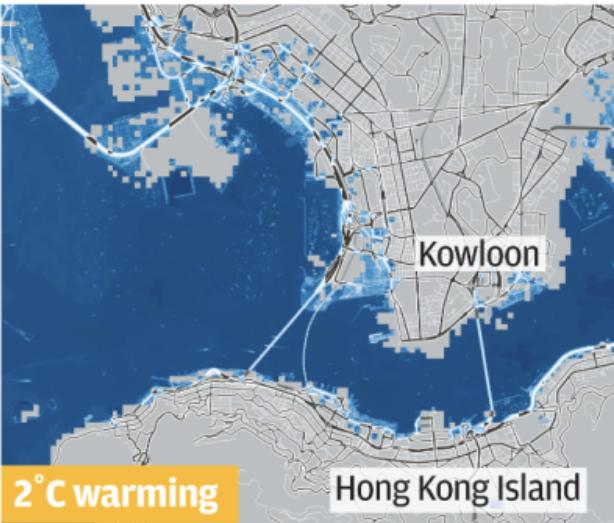


在非常高溫室氣體排放情景（SSP5-8.5）下，香港每年熱夜數目、酷熱日數和寒冷日數的未來推算

Projected annual number of hot nights, very hot days and cold days in Hong Kong
under very high greenhouse gas emissions scenario (SSP5-8.5)



Sea-level Rise in Hong Kong and Shanghai



SCMP

Source: Climate Central



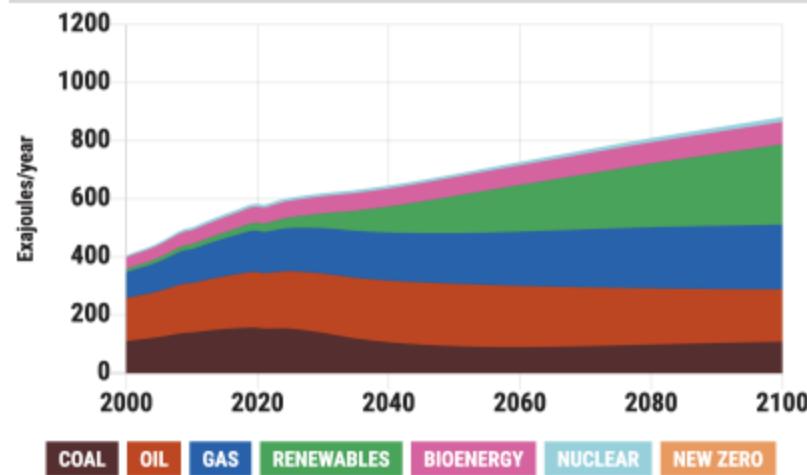
(Climate Central)

17 Sustainable Development Goals by the United Nations

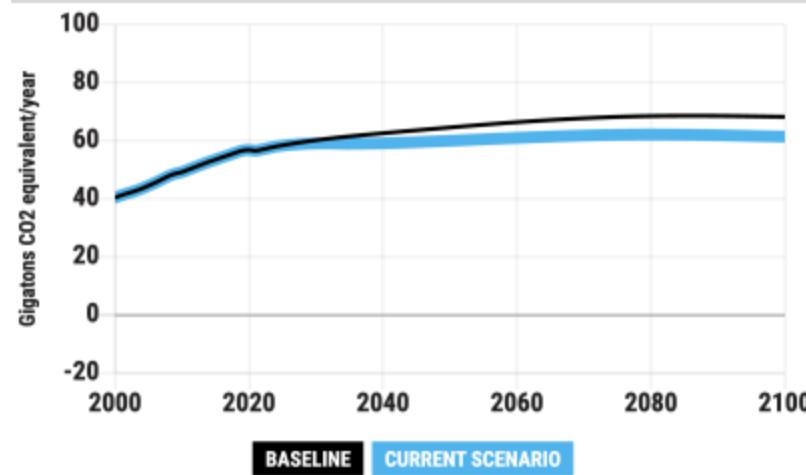


The primary objective of SDG13 is to take urgent action to combat climate change and its impacts.

▶ Global Sources of Primary Energy

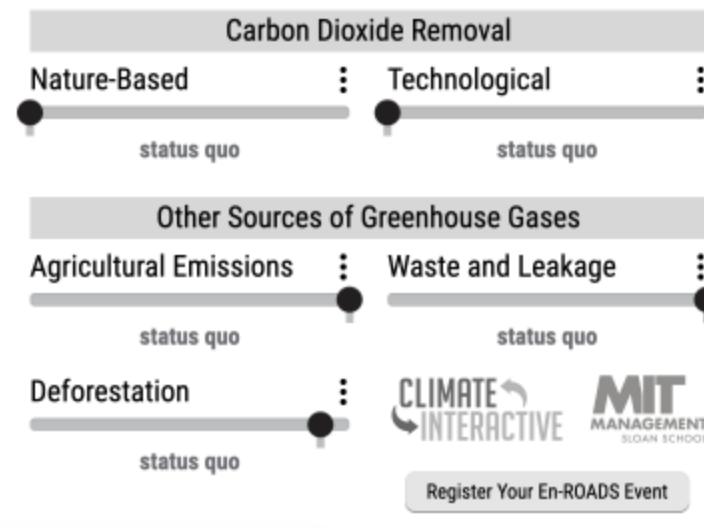
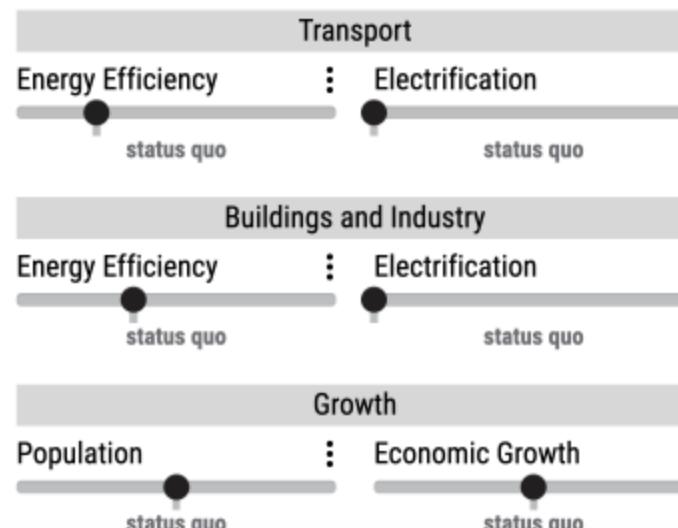
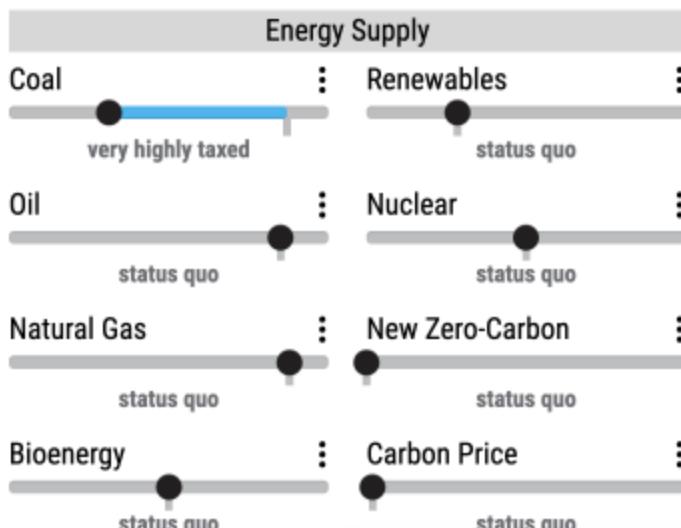


▶ Greenhouse Gas Net Emissions



+3.1 °C
+5.6°F

Temperature Increase by 2100



Register Your En-ROADS Event



Source

Monsoon Climate

Monsoon (Arabic “season”)

Monsoon is a climate feature that is characterized by the ***seasonal reversal in surface winds.***

The very different heat capacity of land and ocean surface is the key mechanism that produces monsoons.



Monsoon Climate



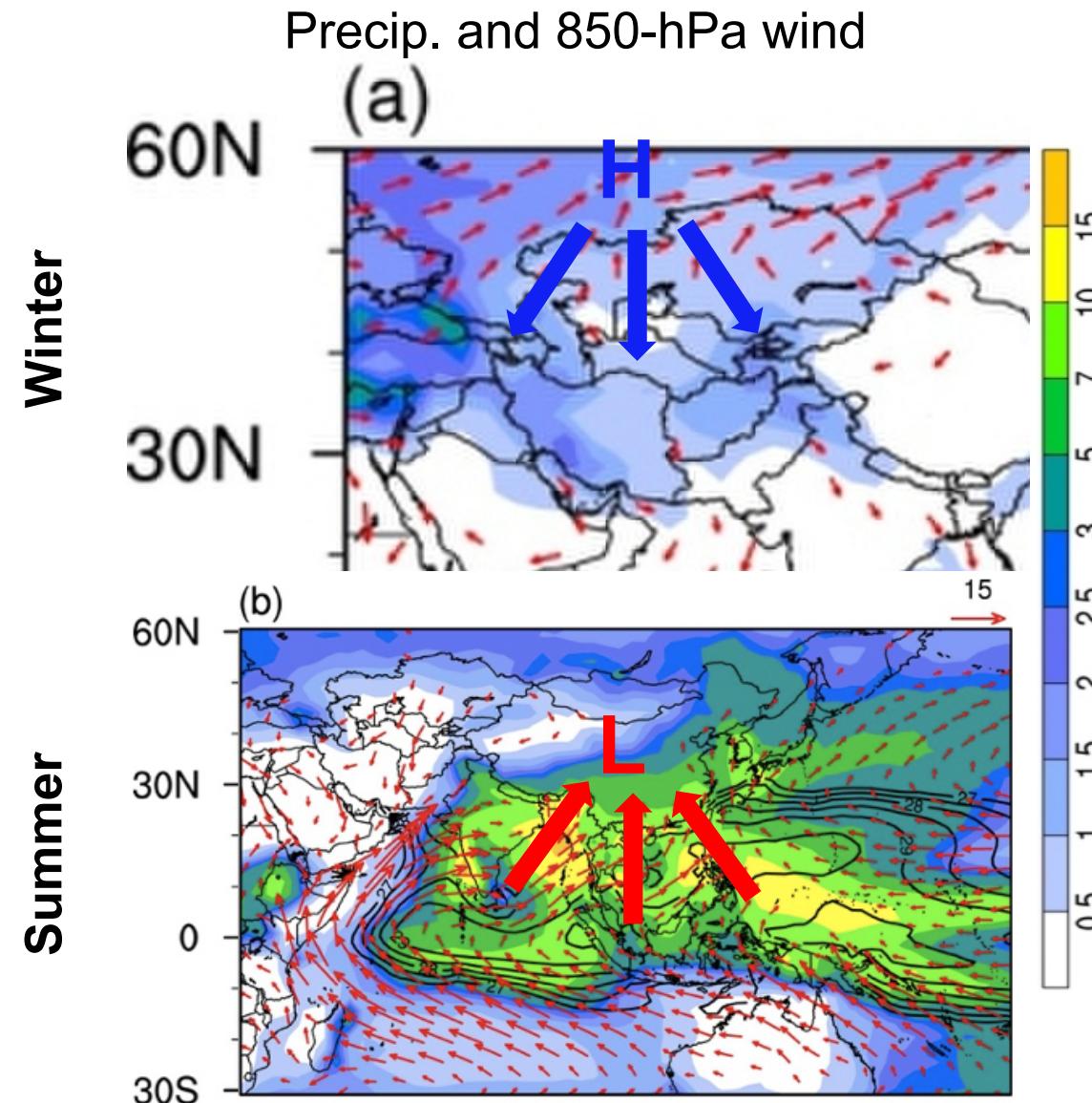
Winter



Summer



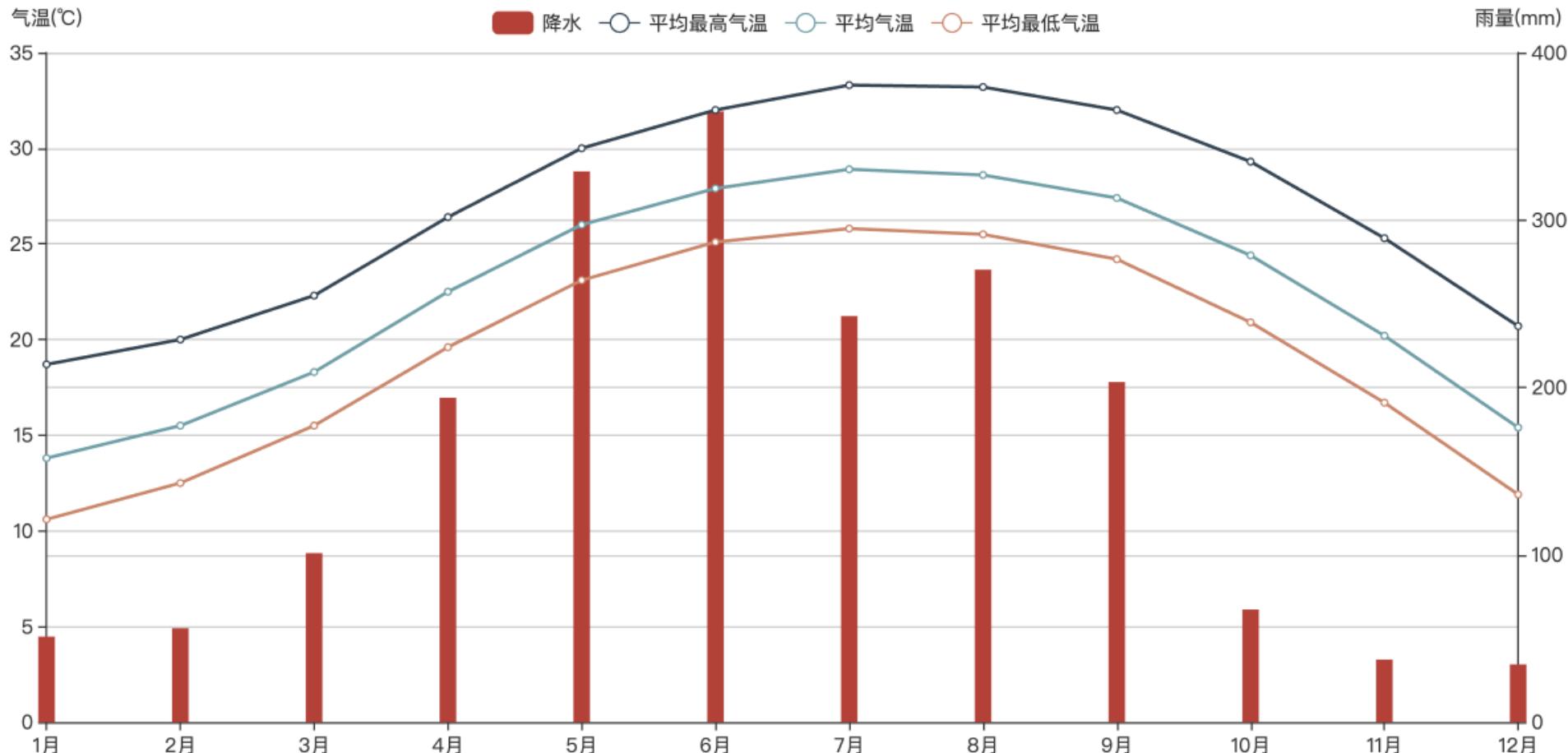
Monsoon Climate Climatology



Precipitation and Temperature

市区 番禺区 增城区 从化区 花都区

30年 (1991年-2020年) 整编月要素统计



Coldest in January (10.6°C); Hottest in July (32.0°C)



Precipitation in Guangzhou

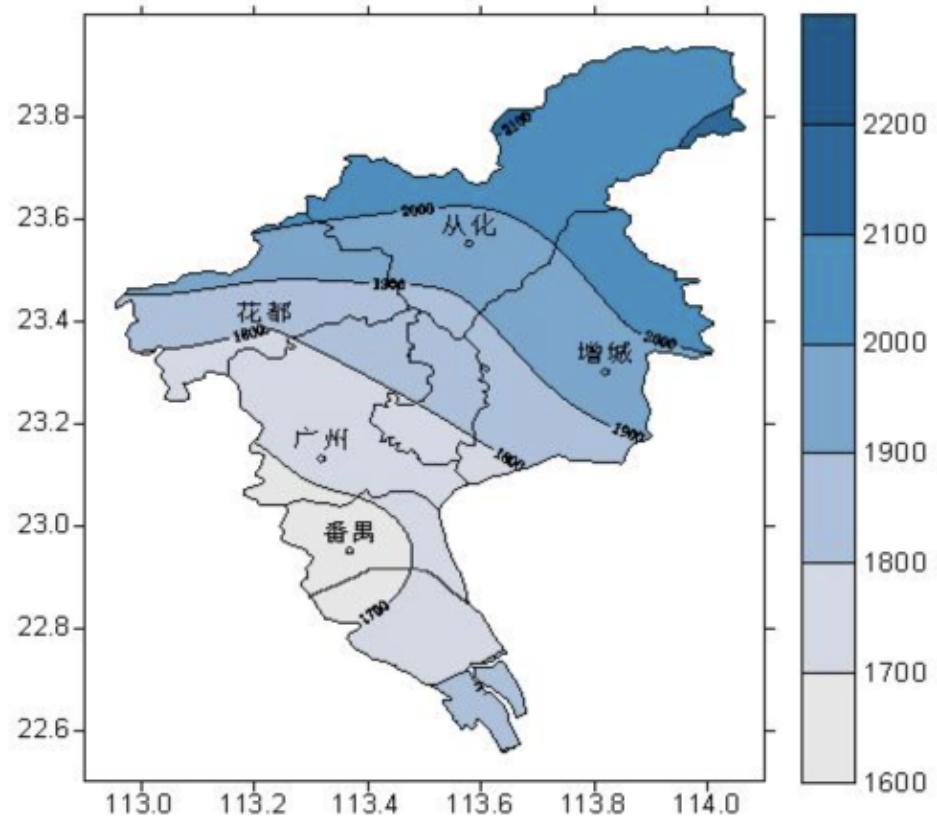
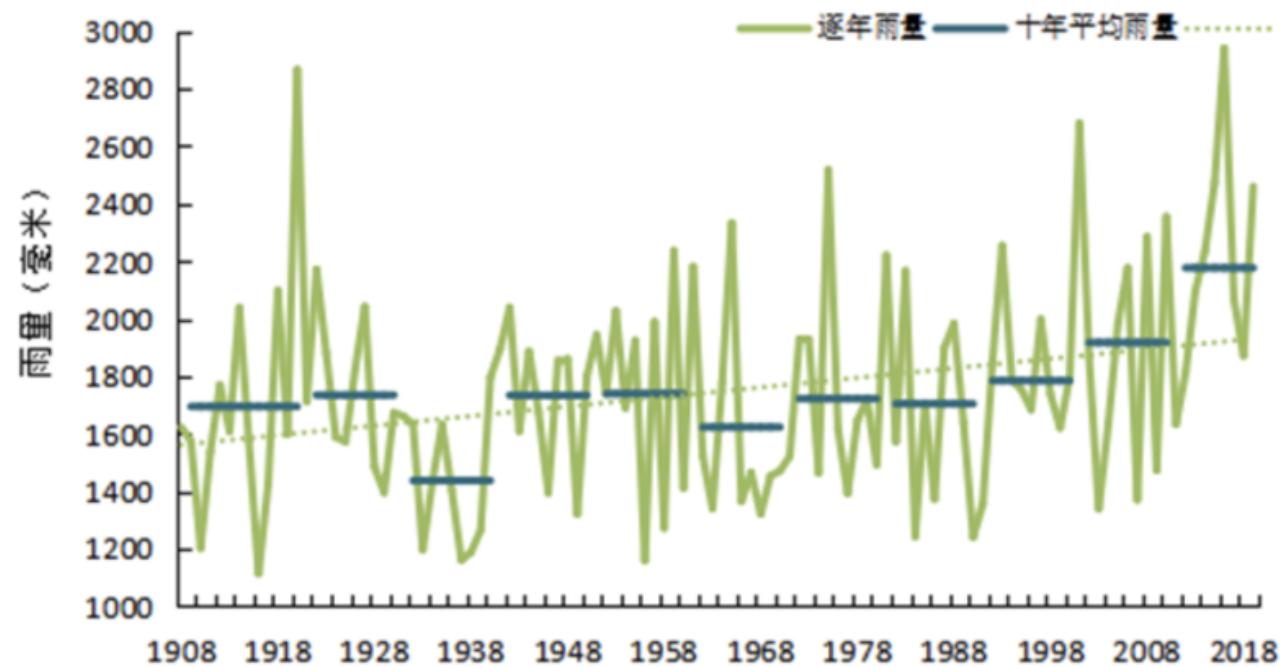


图4 广州市年平均降水量分布图 (单位: 毫米)



Temperature

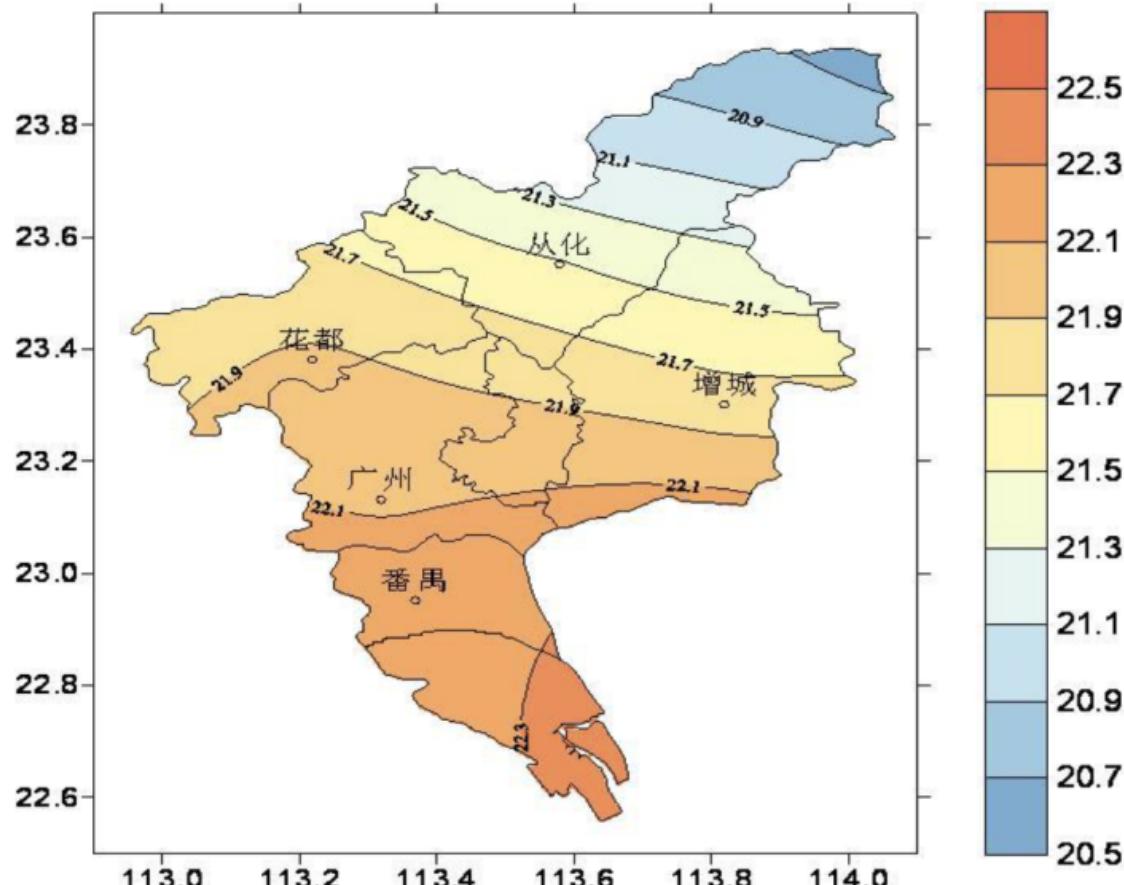
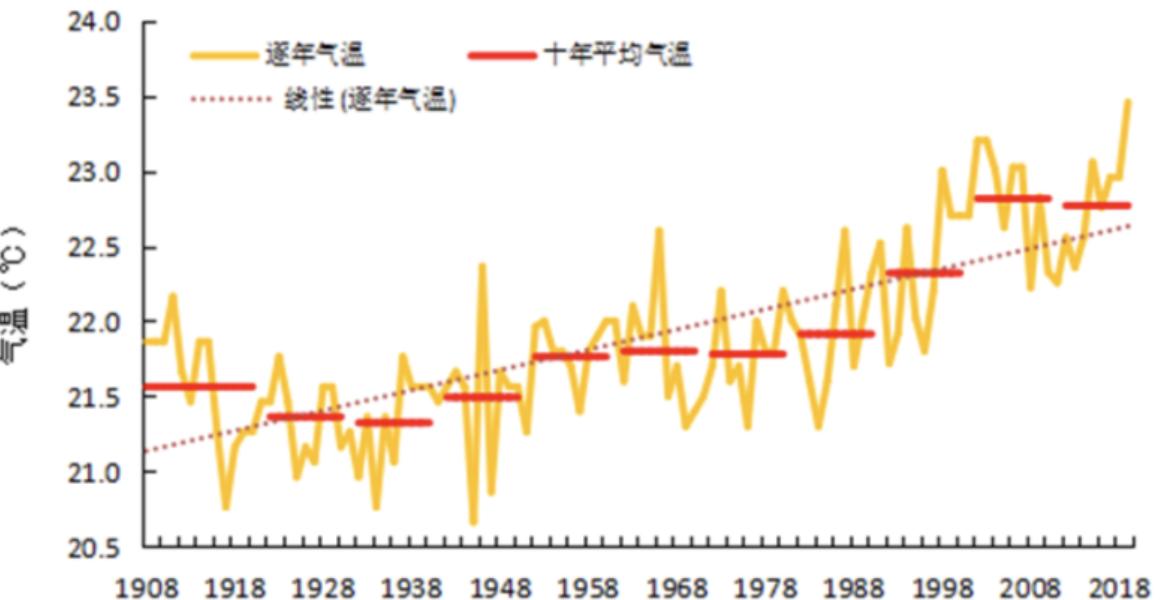


图2 广州市年平均气温分布图 (单位: °C)



Thanks

henryzhenliu@hkust-gz.edu.cn

