CHAPTER 1

THE CHANGING ENVIRONMENT

北京大学
PEKING UNIVERSITY

The Earth System

10^{26} g

岩石圈
（陆地、土壤）

10^{22} g

冰圈
（冰川、两极）

10^{18} ~ 10^{19} g

生物圈

10^{24} g

水圈
（河湖海、降水）

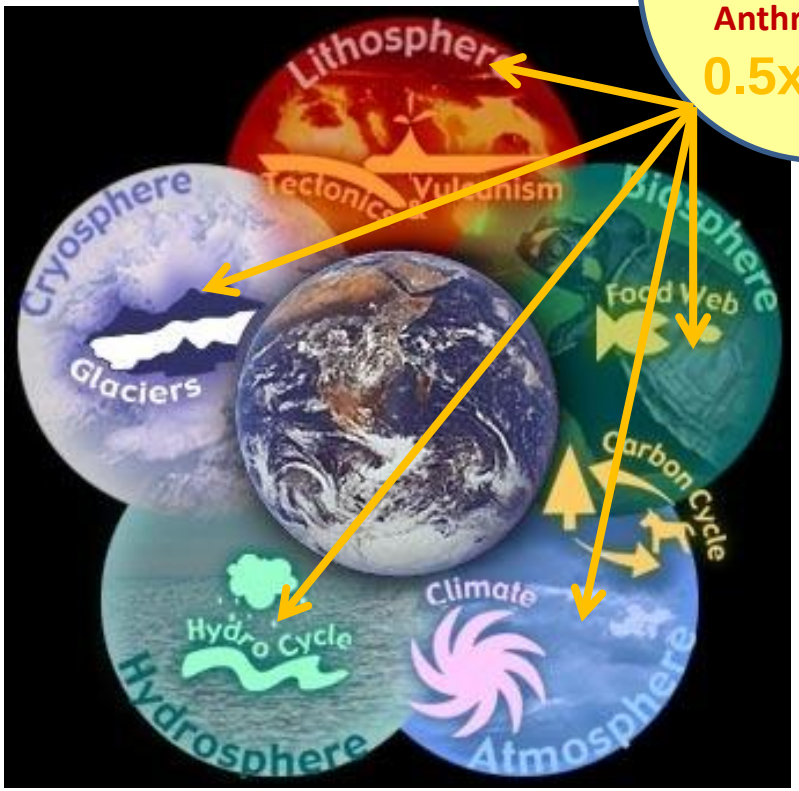
大气圈 10^{21} g

The Earth System

10^{26} g

岩石圈
（陆地、土壤）

人类圈
Anthrosphere
0.5×10^{15} g



10^{22} g

冰圈
（冰川、两极）

$10^{18} \sim 10^{19}$ g

生物圈

10^{24} g

水圈
（河湖海、降水）

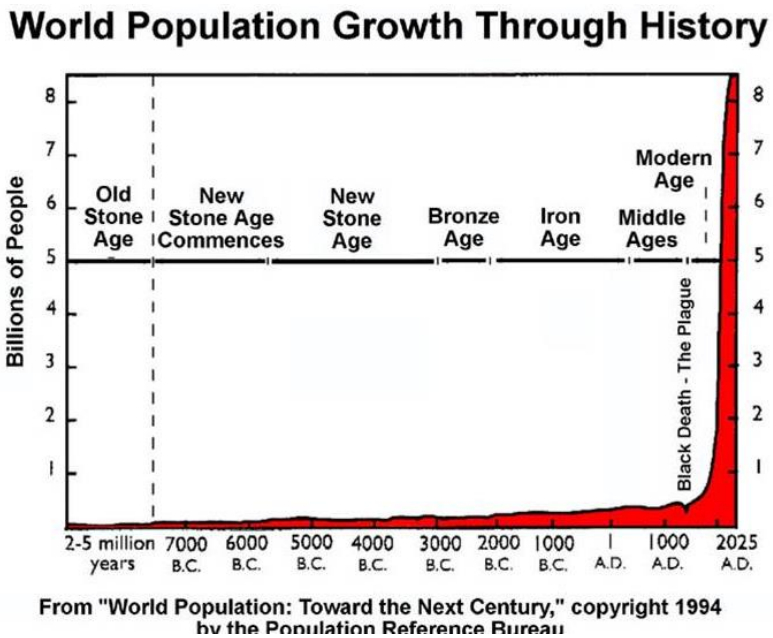
大气圈

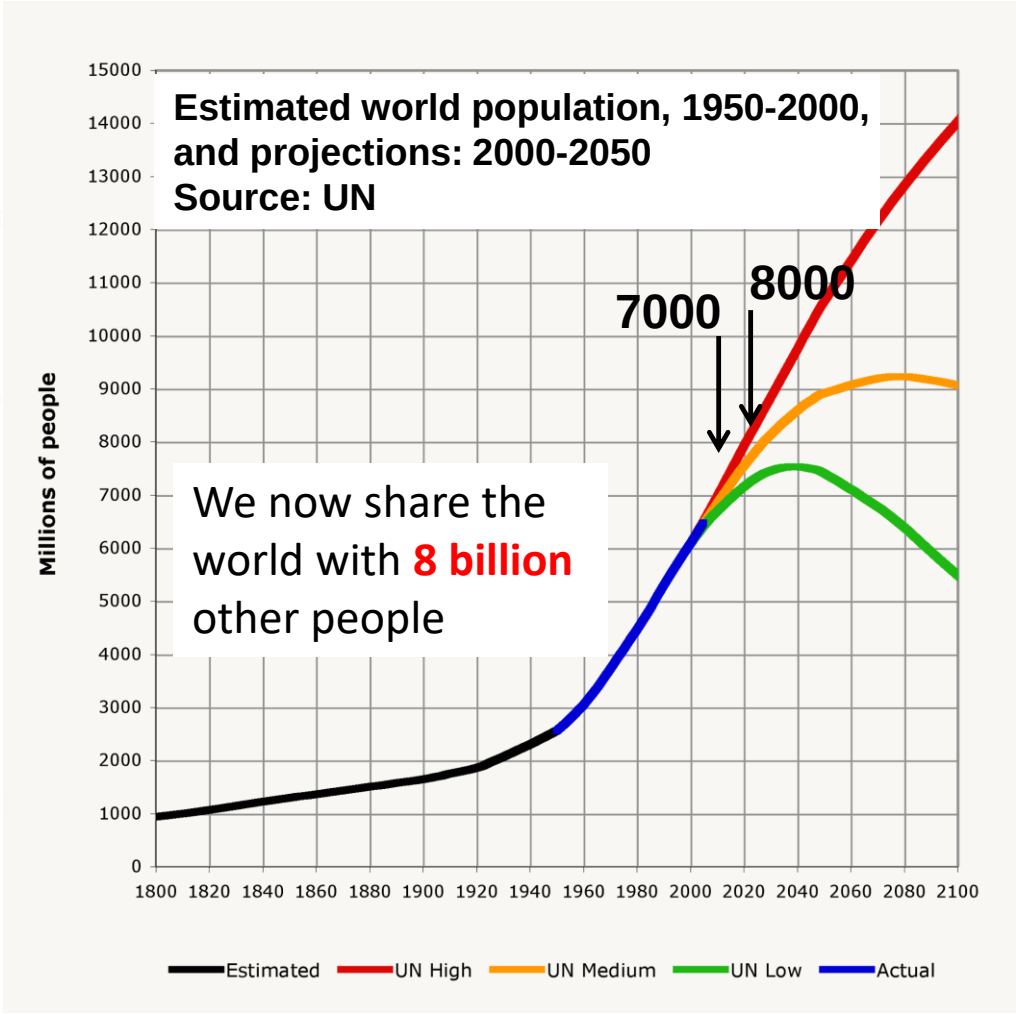
10^{21} g

Pressure of World Population

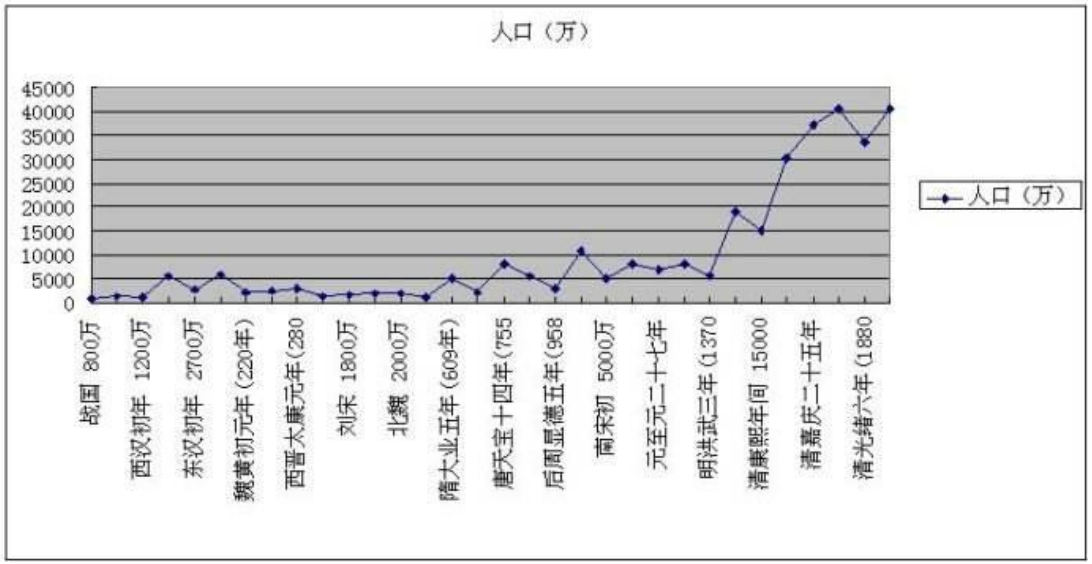
The power of population is indefinitely greater than the power in the earth to produce subsistence for man.

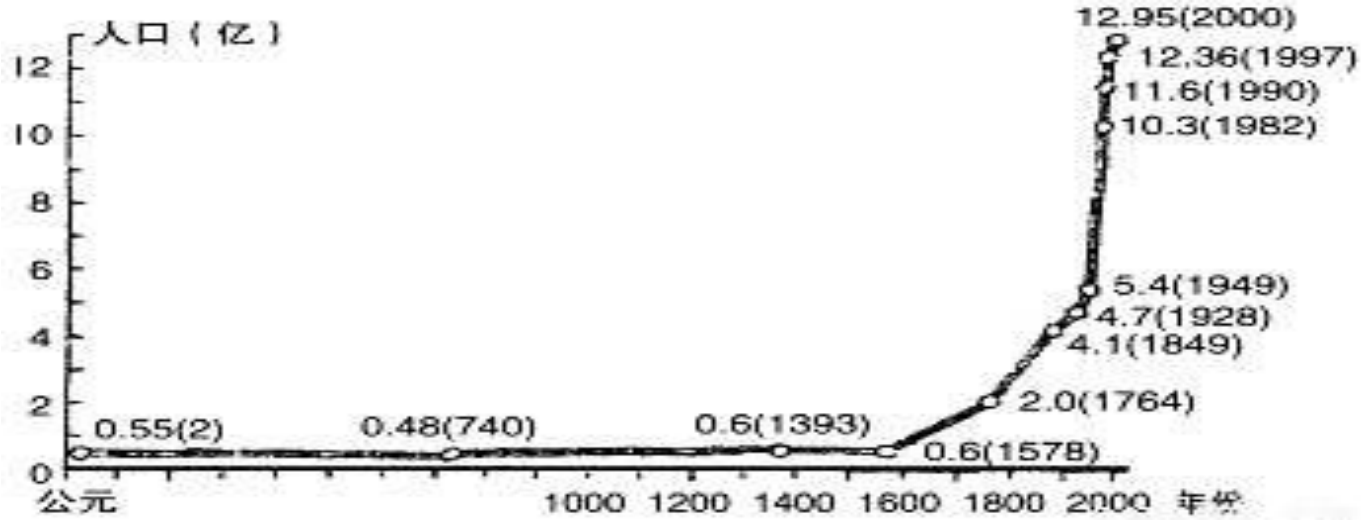
- Thomas Malthus, *An Essay on the Principle of Population*





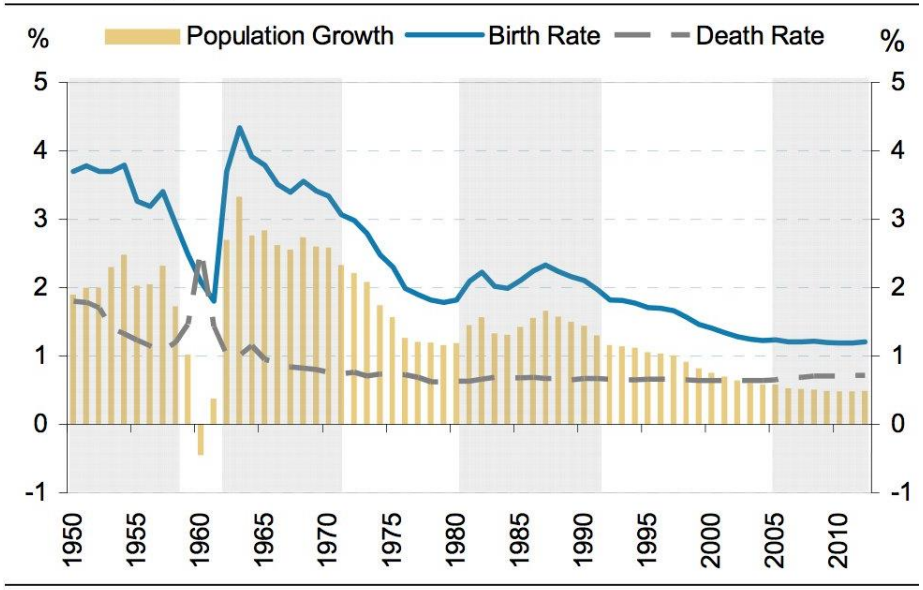
History of Chinese Population



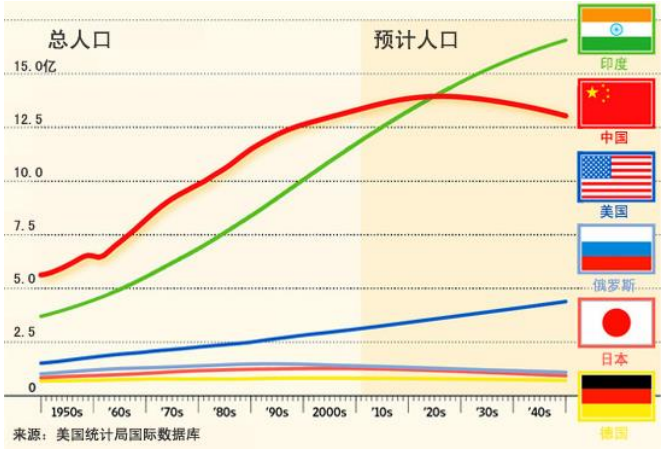


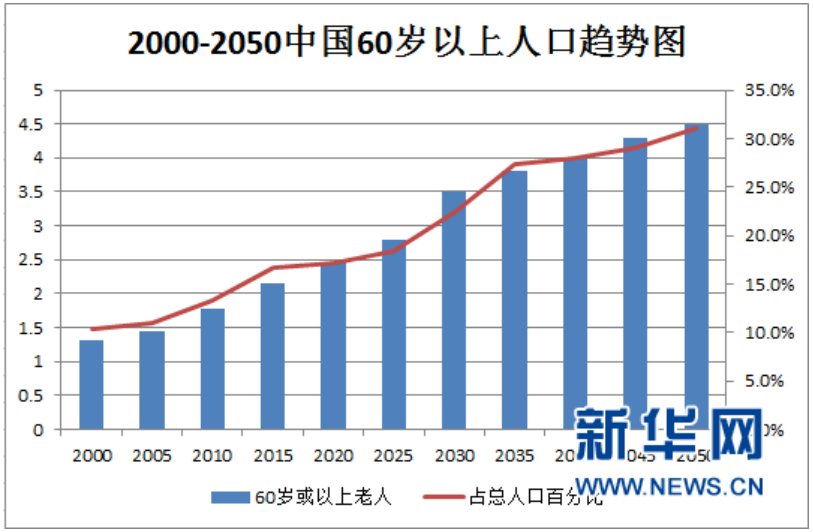
Chinese Population Growth

Declining Birth Rate vs. Stabilized Death Rate

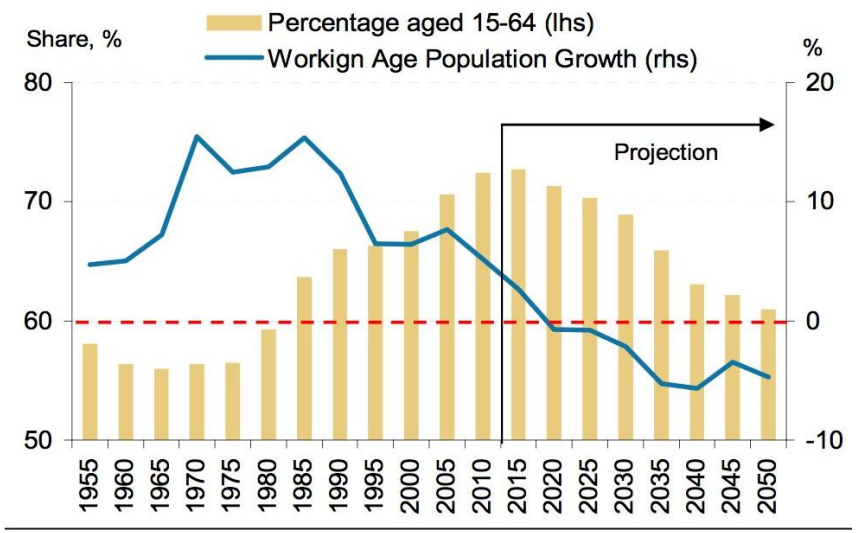


Source: NBS, Morgan Stanley Research; Note: Birth rate is the ratio of new birth to total population; death rate is the ratio of the death to total population.





Working Age Population Is Set to Contract Soon



Source: NBS, UNPD, Morgan Stanley Research

Chinese Population Growth

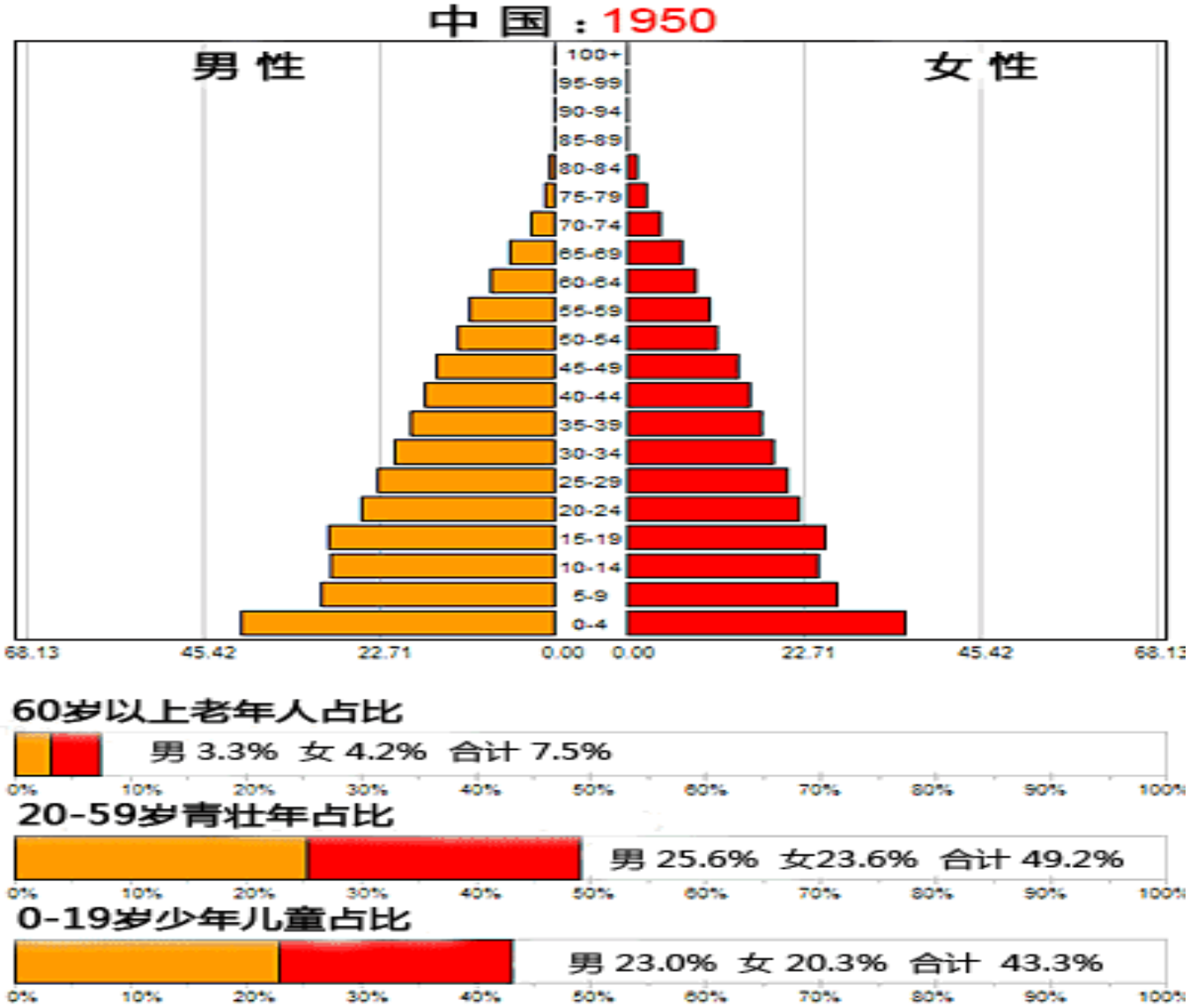
国家统计局数据：

2021年末，全国人口141260万人，比上年末增加48万人。全年出生人口1062万人，出生率为7.52‰；自然增长率为0.34‰

2022年末，全国人口141175万人，比上年末减少85万人。全年出生人口956万人，出生率为6.77‰；自然增长率为-0.60‰

2023年末，全国人口140967万人，比上年末减少208万人。全年出生人口902万人，出生率为6.39‰；自然增长率为-1.48‰

Chinese Population Structure Change: 1950–2050



http://www.360doc.com/content/15/0929/18/14590724_502277109.shtml

What Have Humans Done to the Environment?

- Land use change: agricultural activities starting from 5000 years ago; urbanization; afforestation
- Aqua/marine ecosystems: fishery, surface & ground water pollution, eutrophication, etc.
- Industry: emitting greenhouse gases and pollutants
- Eco-environmental protection

Ruddiman and Thomson, 2001 QSR: CH4 change since 5000 years ago

Global Change

科技部：全球变化是指由自然和人文因素引起的、地表环境及地球系统功能全球尺度的变化。全球变化已经并将持续影响着人类的生存和发展，成为当今世界各国和社会各界关注的重大政治、经济和外交问题。

"Changes in the global environment (including alterations in climate, land productivity, oceans or other water resources, atmospheric chemistry, and ecological systems) that may alter the capacity of the Earth to sustain life."

- U.S. Global Change Research Act of 1990

"A transformation that occurs on a worldwide scale (e.g., an increase in carbon dioxide in the atmosphere) or exhibits sufficient cumulative effects to have worldwide impact (e.g., local species extinction resulting in global loss of biodiversity)"

- National Geographic

Climate Change

"Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use."

- IPCC

"a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods"

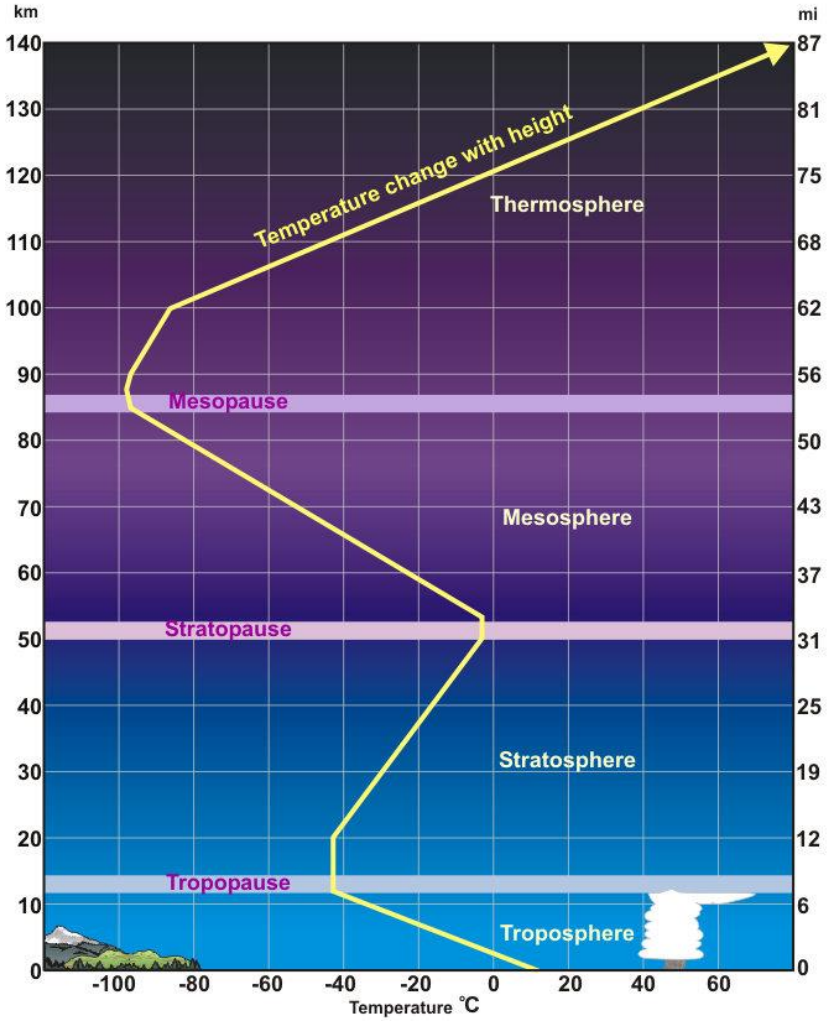
- UNFCCC

In my view, the aspect of climate change we care most is:

SO RAPID AND SEVERE ANTHROPOGENIC CLIMATE CHANGE THAT CANNOT BE ADAPTED WITHOUT ENORMOUS AND UNACCEPTABLE CONSEQUENCES

The Fragility of the Atmosphere

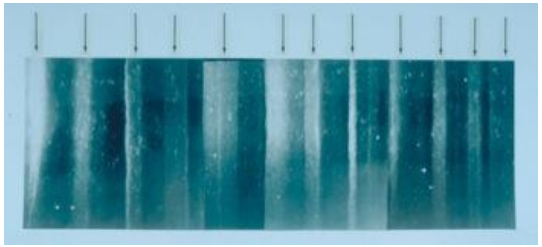
Source: NASA

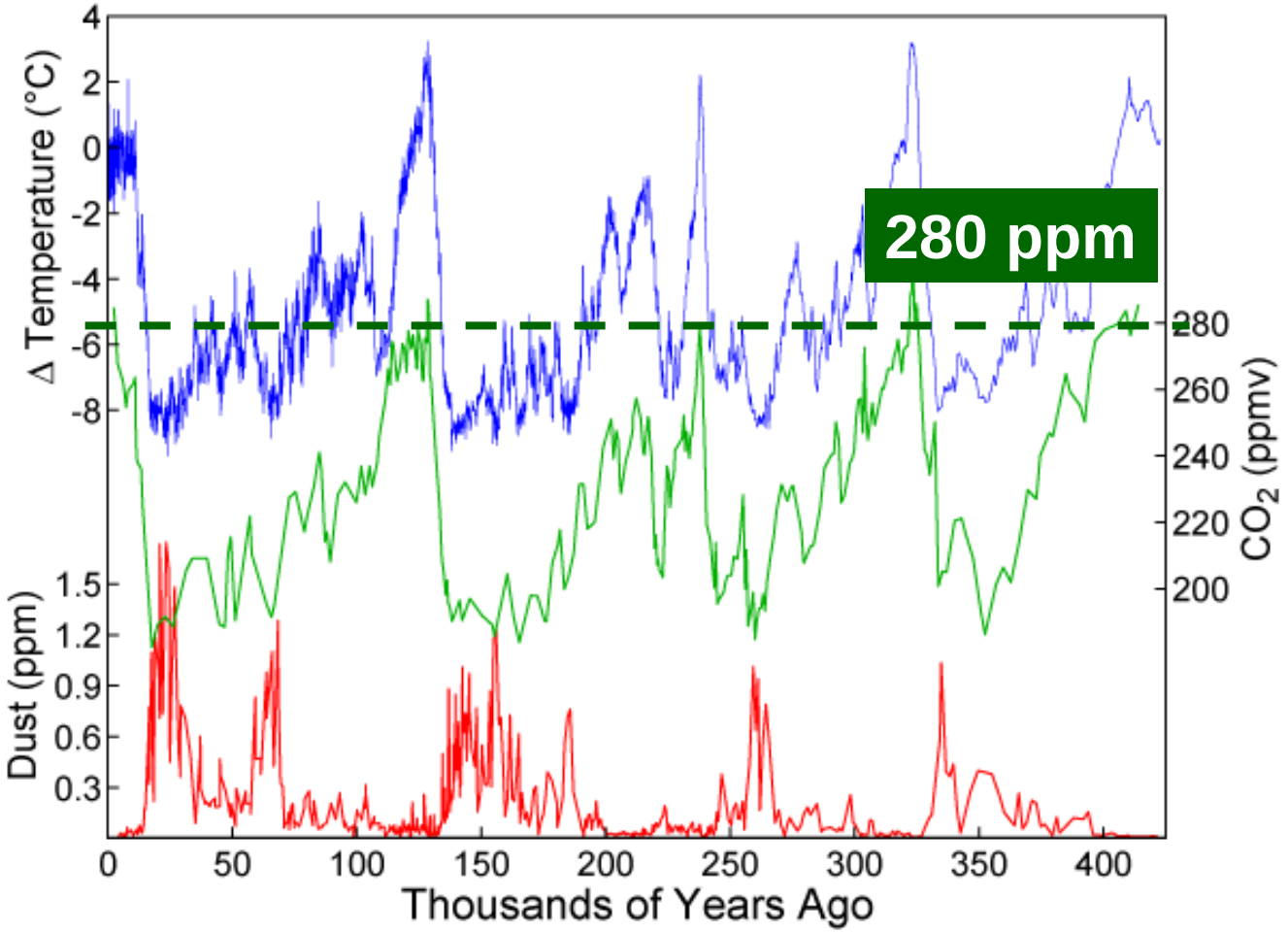


Earth's radius	**6400 km**
Atmosphere thickness	**~150 km**
Troposphere thickness	**~12 km**
Boundary layer thickness	**1-2 km**

History of Earth's Climate

Temperature & atmospheric composition reconstructed from Antarctic ice core:

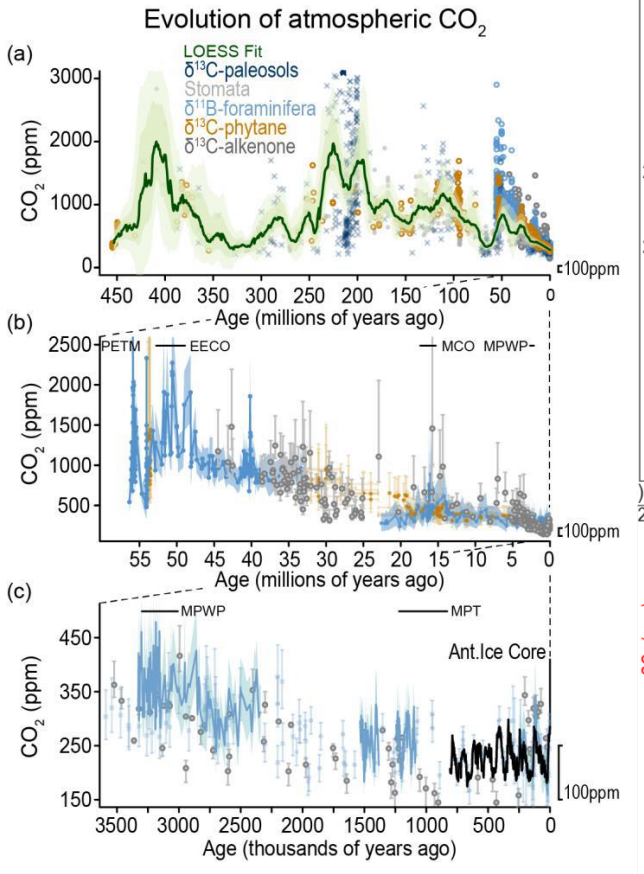


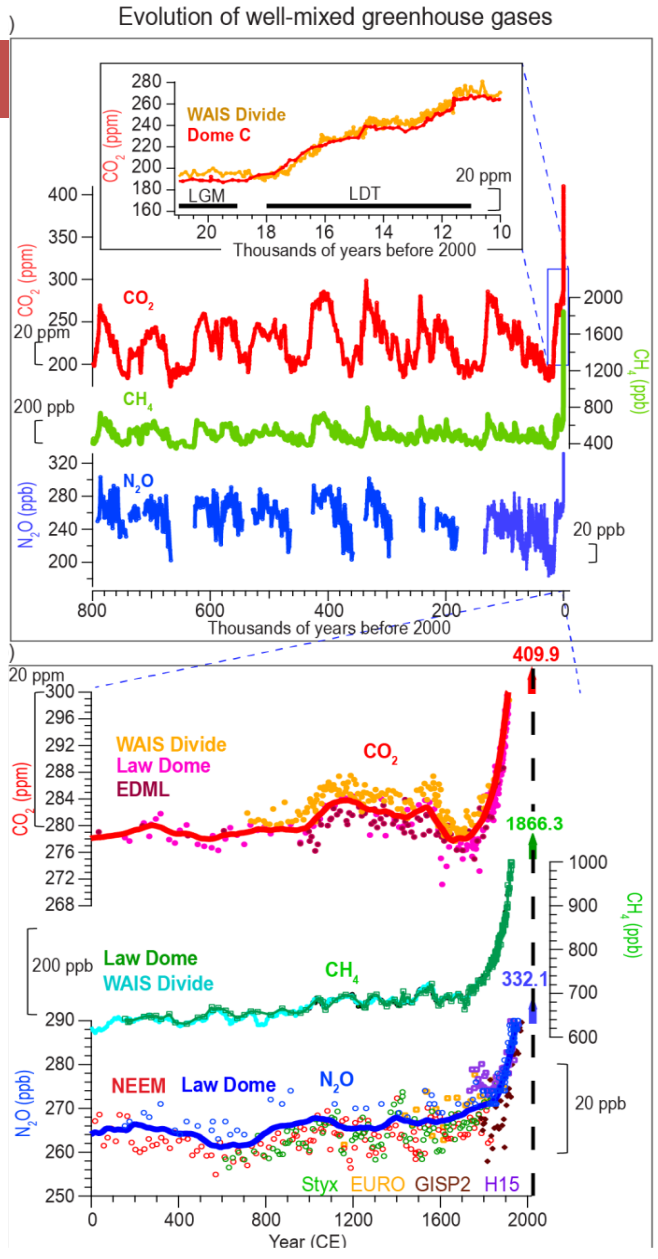


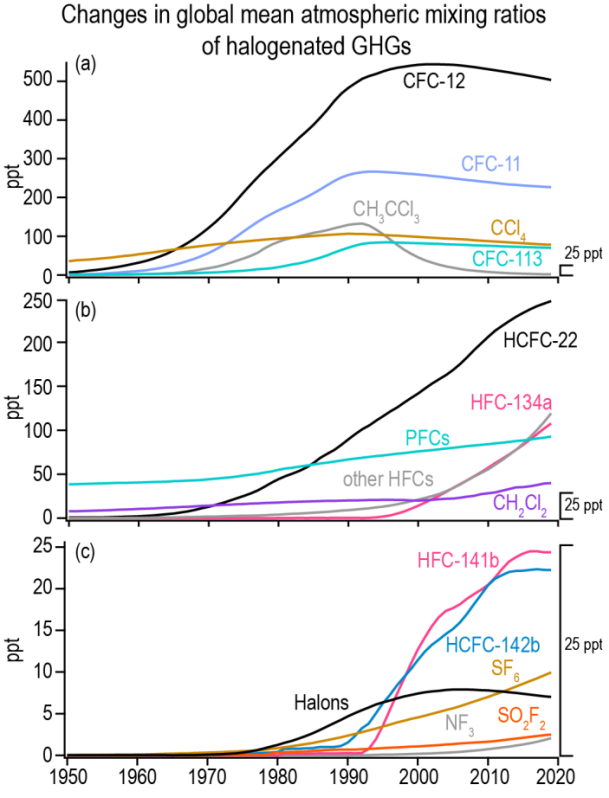
Petit et al. [1999]

Trends in Long-lived GHGs Concentrations

[CO_2] in 2024/05: 423.43 ppm

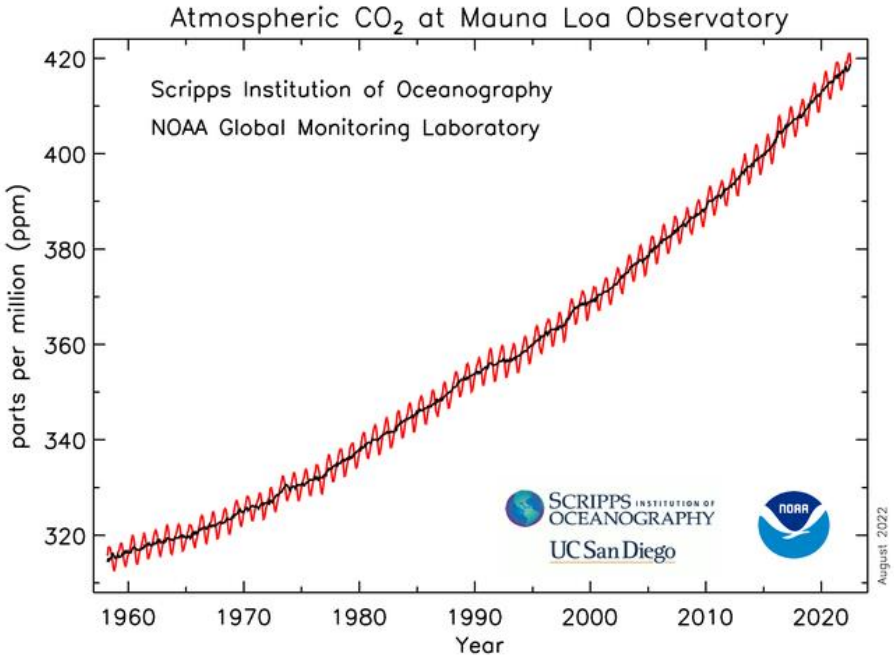


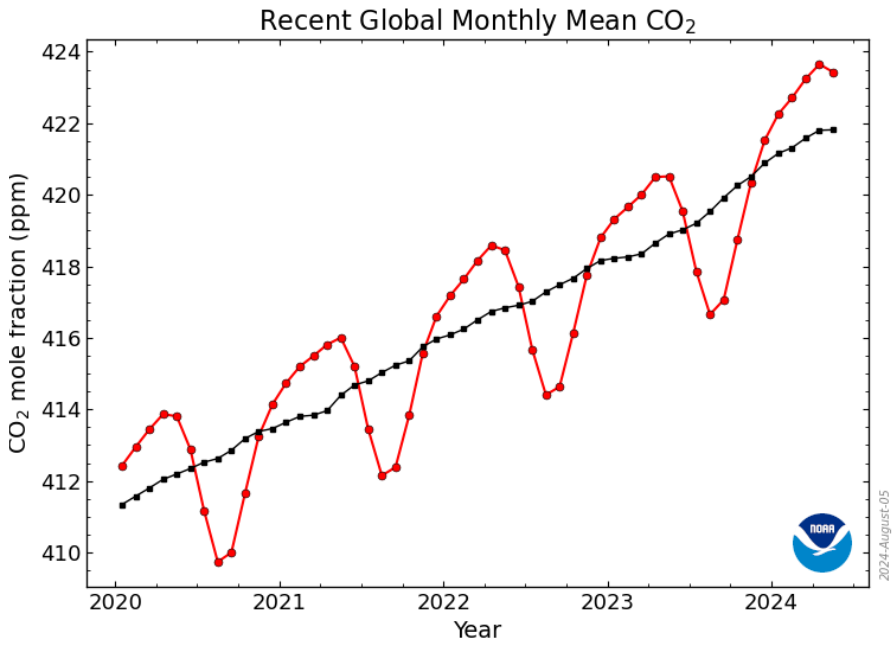




IPCC, 2021

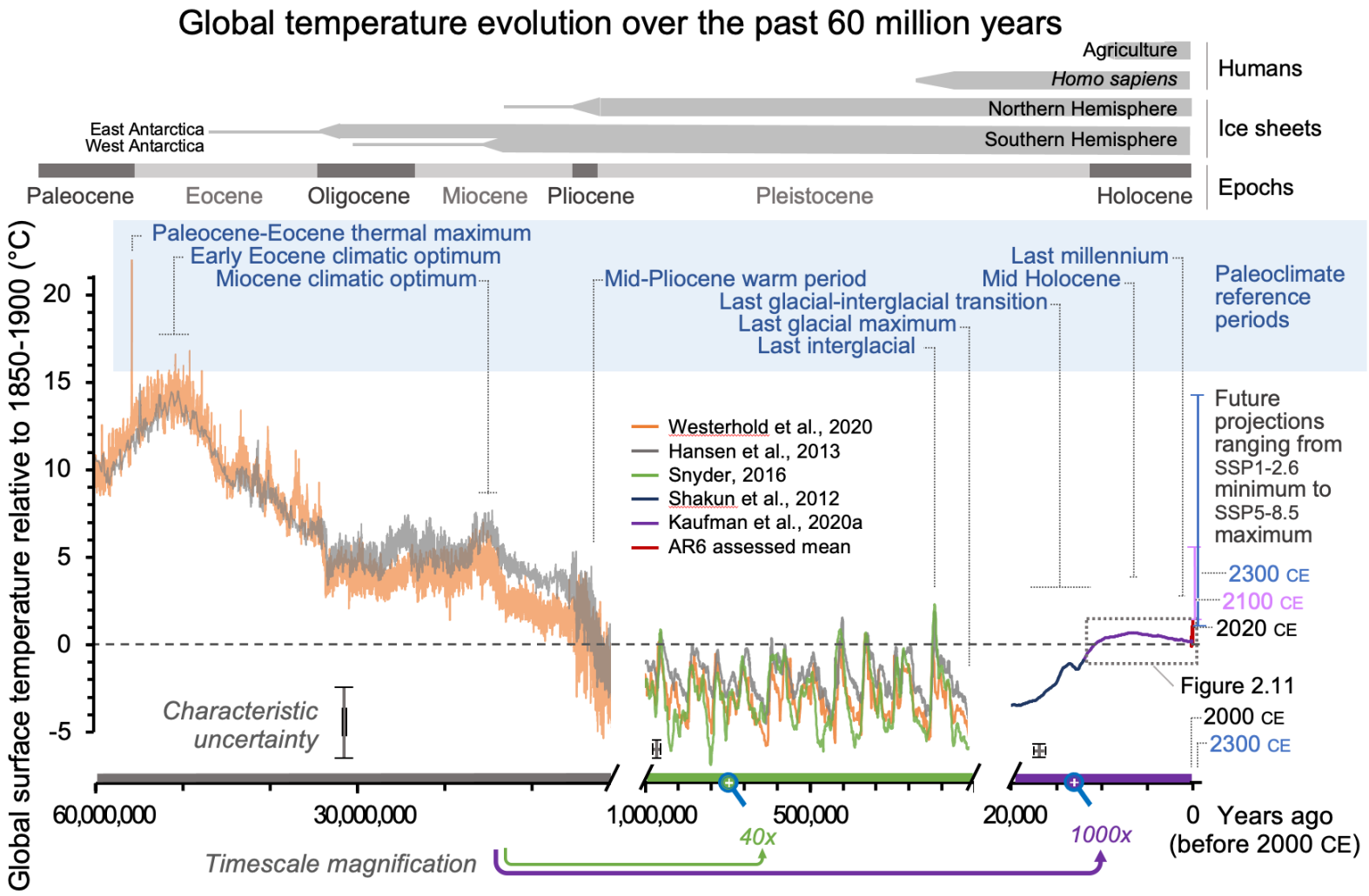
Recent Trend in CO_2 Concentrations





https://gml.noaa.gov/ccgg/trends/

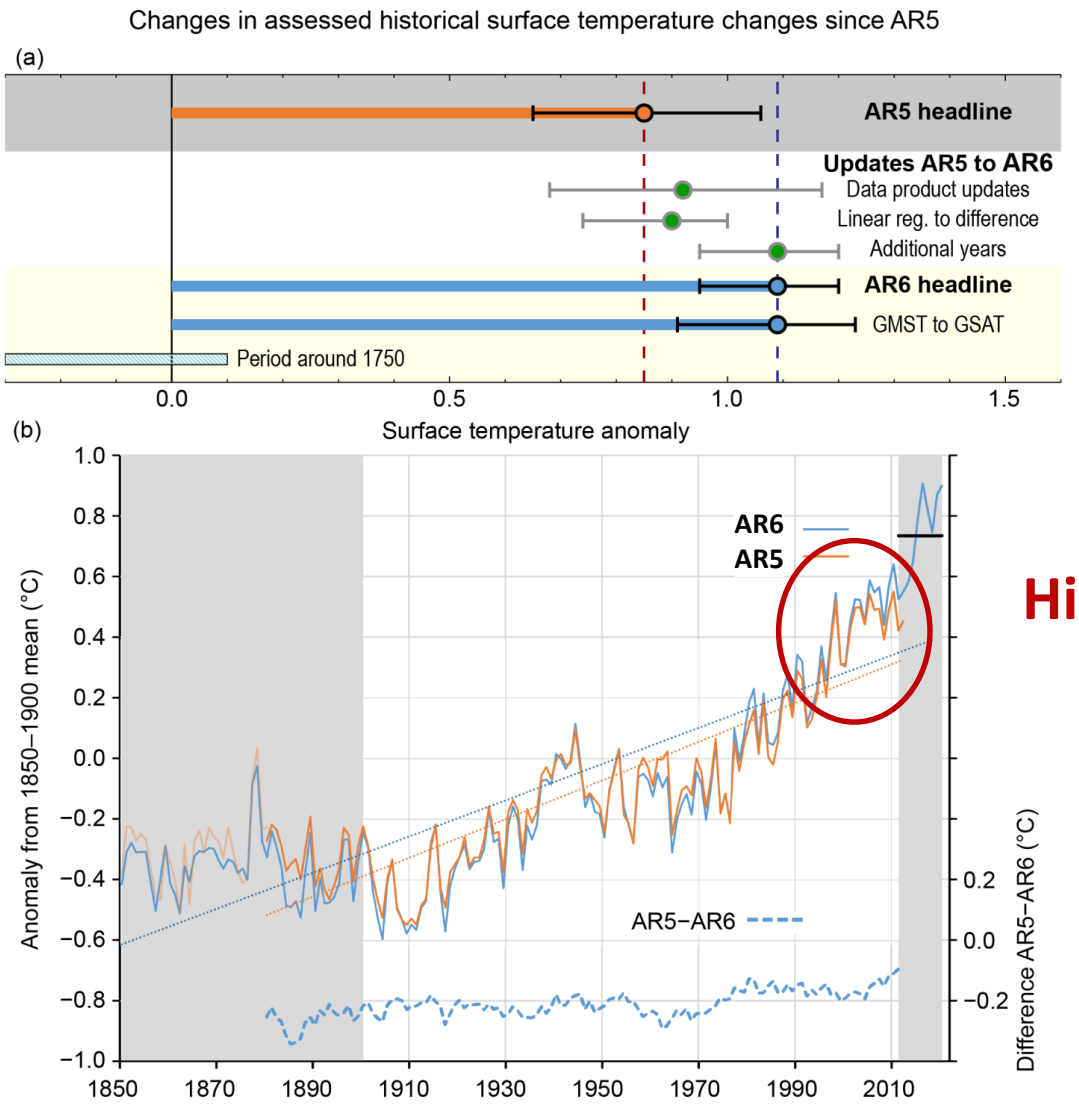
Global Temperature Evolution



Paleocene 古新世；Eocene 始新世；Oligocene 渐新世；
Miocene 中新世；Pliocene 上新世；Pleistocene 更新世；
Holocene 全新世；Quaternary 第四纪

IPCC, 2021

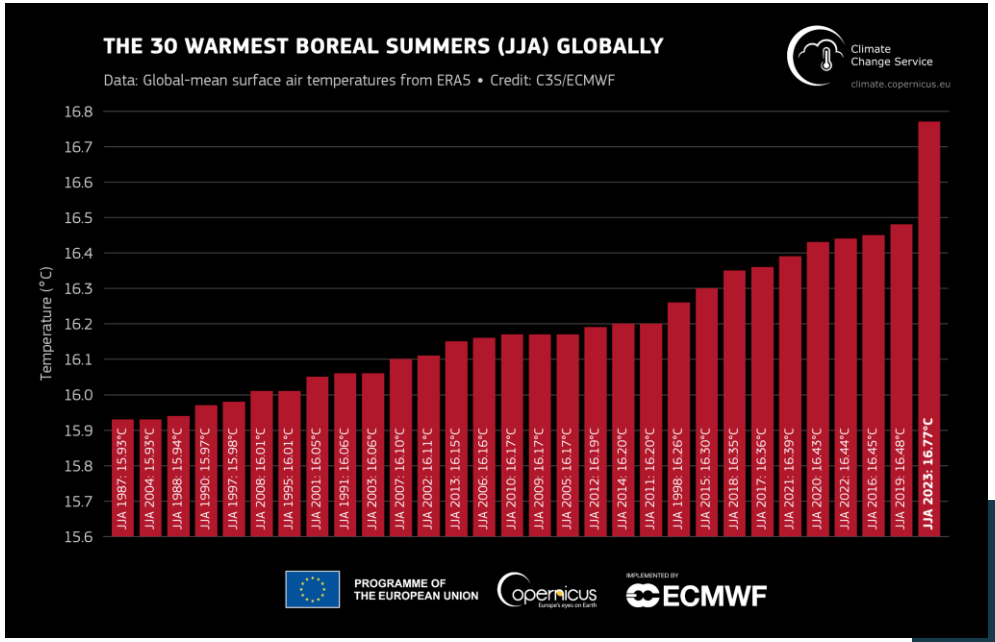
Global Temperature Anomaly: 1850-2020



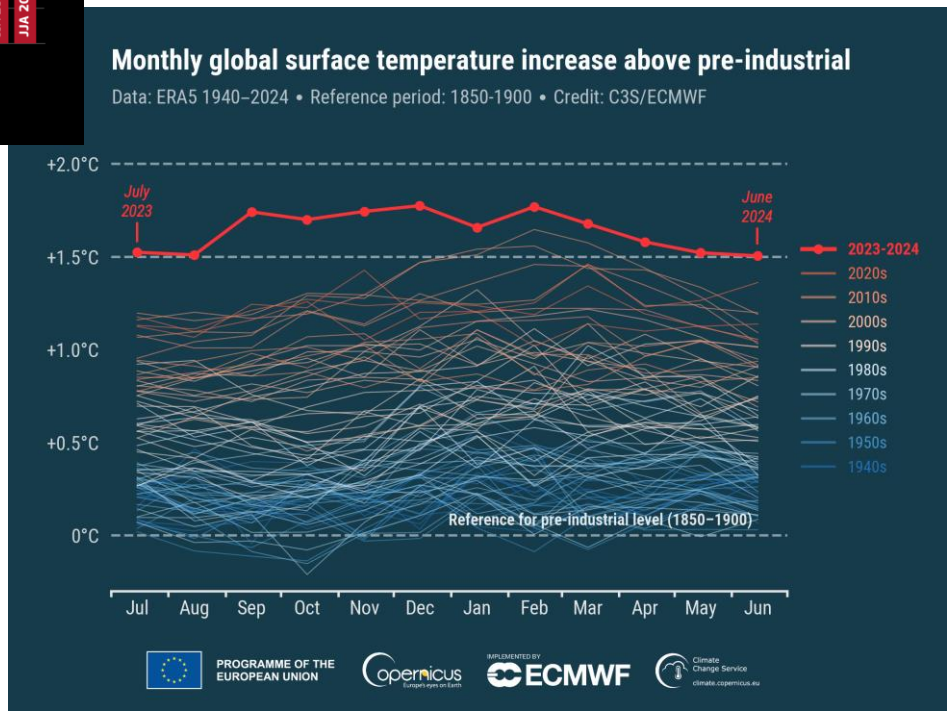
Hiatus

IPCC, 2021

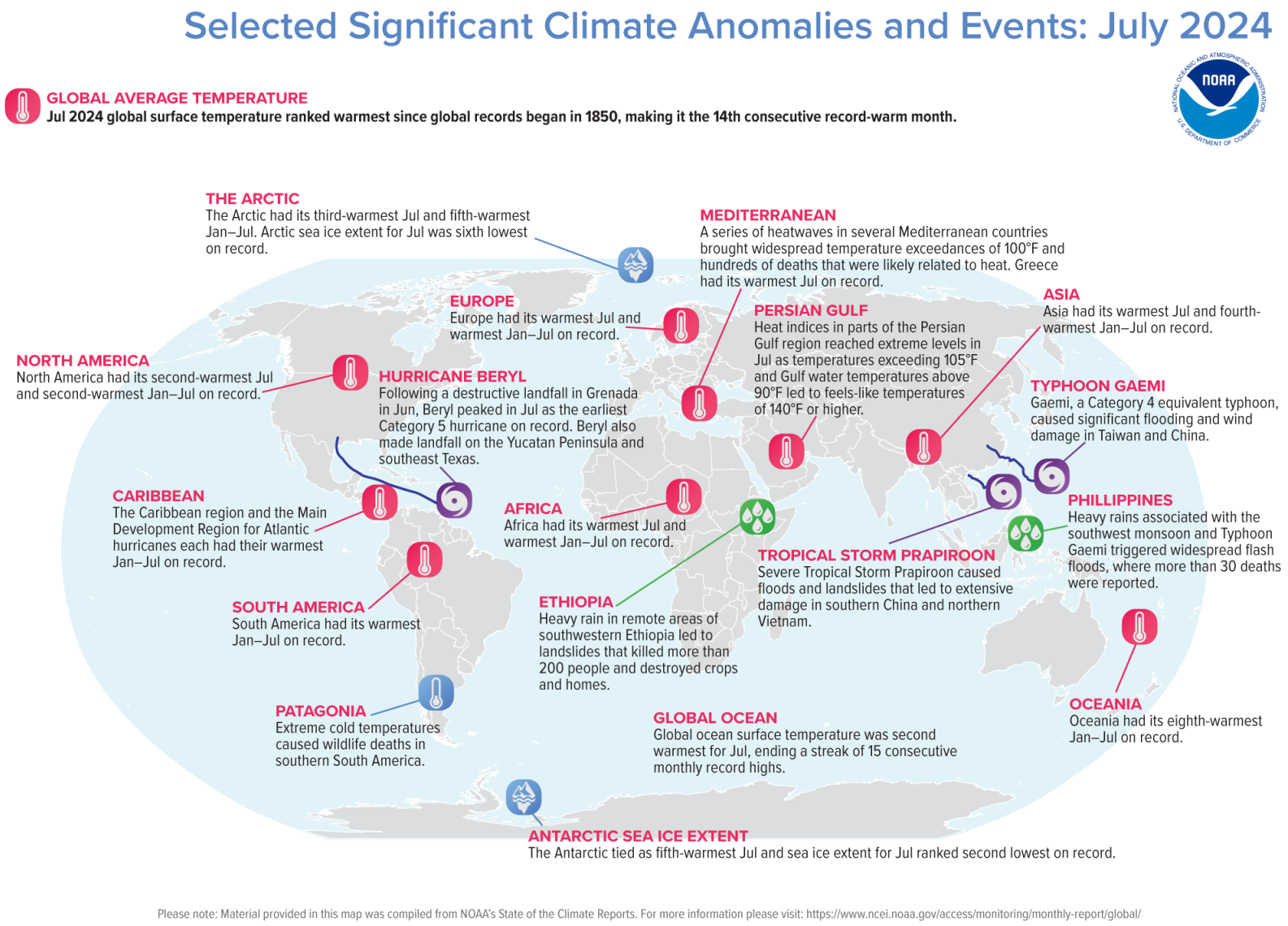
Global Temperature in 2023 and 2024



June 2024 was warmer globally than any previous June in the data record, with an average ERA5 surface air temperature of 16.66° C, 0.67° C above the 1991-2020 average for June and 0.14° C above the previous high set in June 2023.

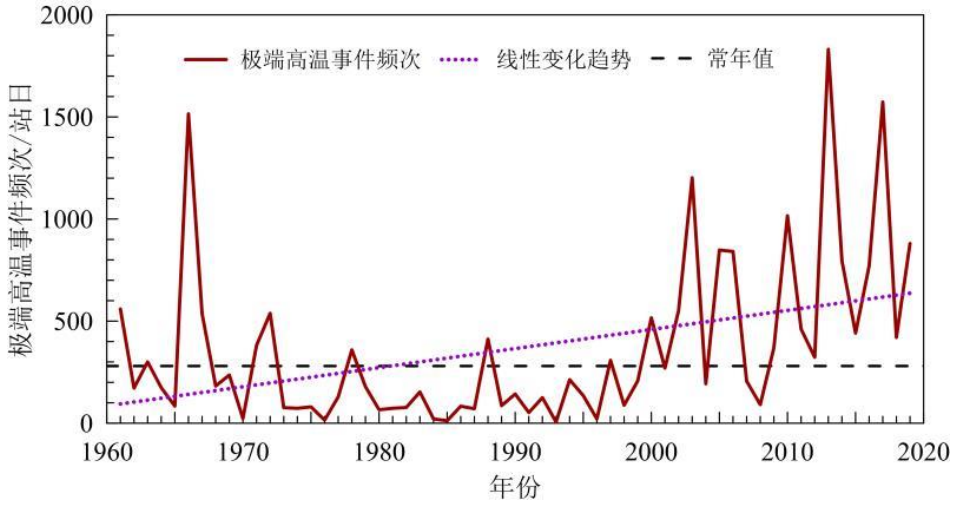


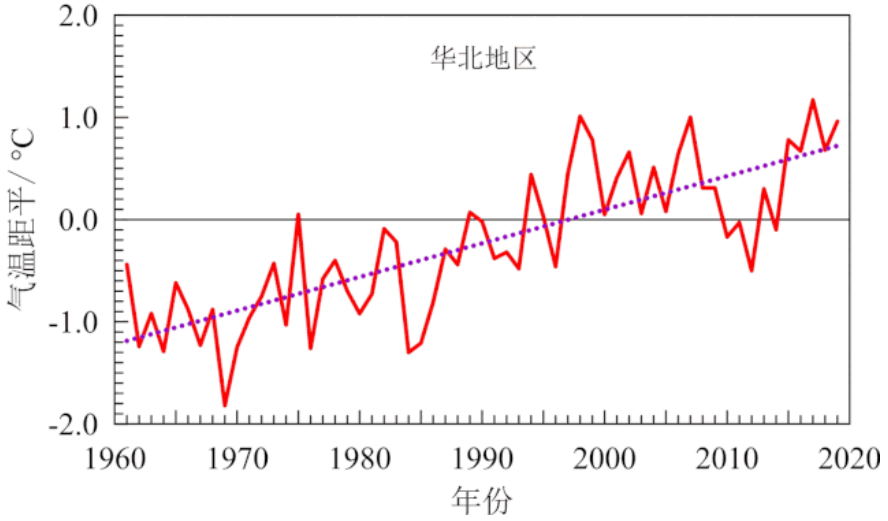
World Extreme Climate Status: July 2024



https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202407

Changes in Surface Air Temperature in China



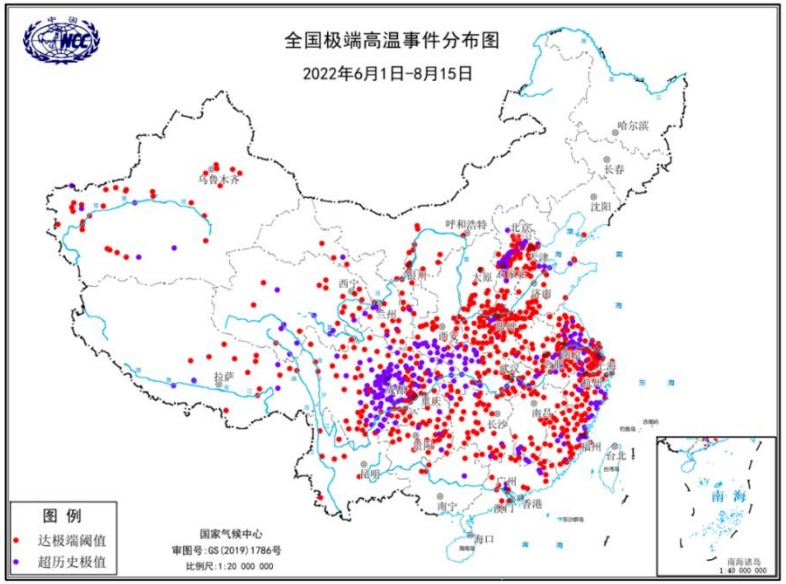


- 1951~2019年，中国年均气温每10年升高0.24℃，升温速率明显高于同期全球平均水平
- 近20年是20世纪初以来的最暖时期
- 20世纪90年代中期以来，中国极端高温事件明显增多
- 2019年，云南元江（43.1℃）等64站日最高气温达到或突破历史极值
- 2023年，我国地表平均气温较常年值偏高0.84℃，为1901年以来的最暖年份

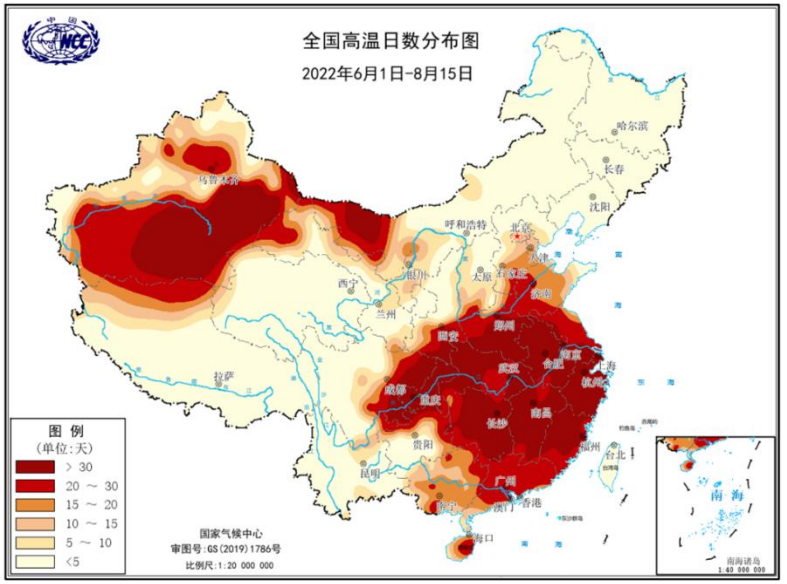
中国气候变化蓝皮书 2020、2024

Heatwave in 2022 in China

极端高温事件（6月1日-8月15日）



高温日数（6月1日-8月15日）



国家气候中心：

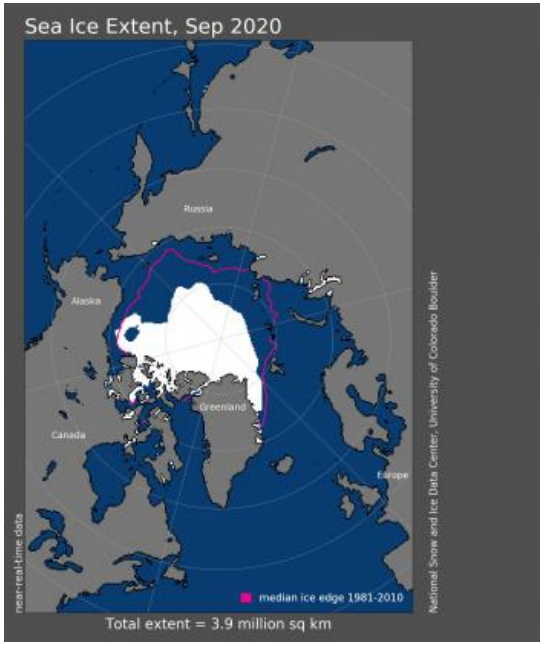
综合考虑高温热浪事件的平均强度、影响范围和持续时间，从今年6月13日开始至8月17日的区域性高温事件**综合强度已达到1961年有完整气象观测记录以来最强**

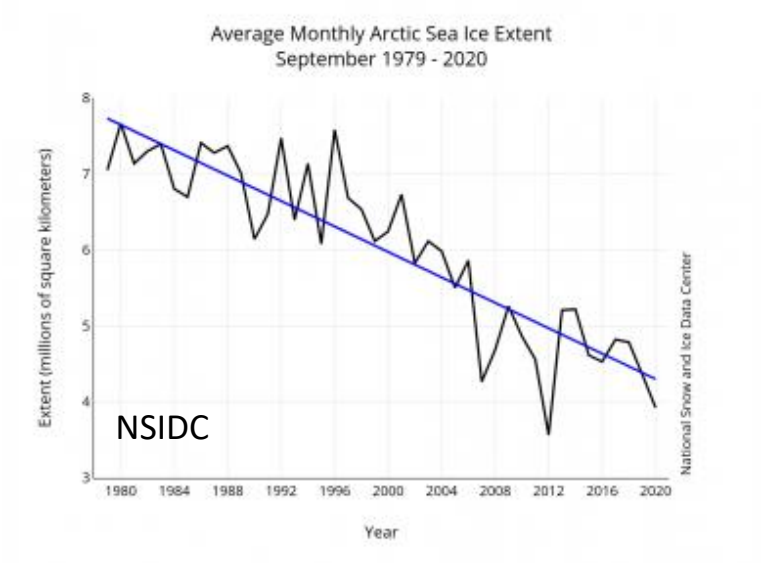
Cryosphere: Shrinking

2022

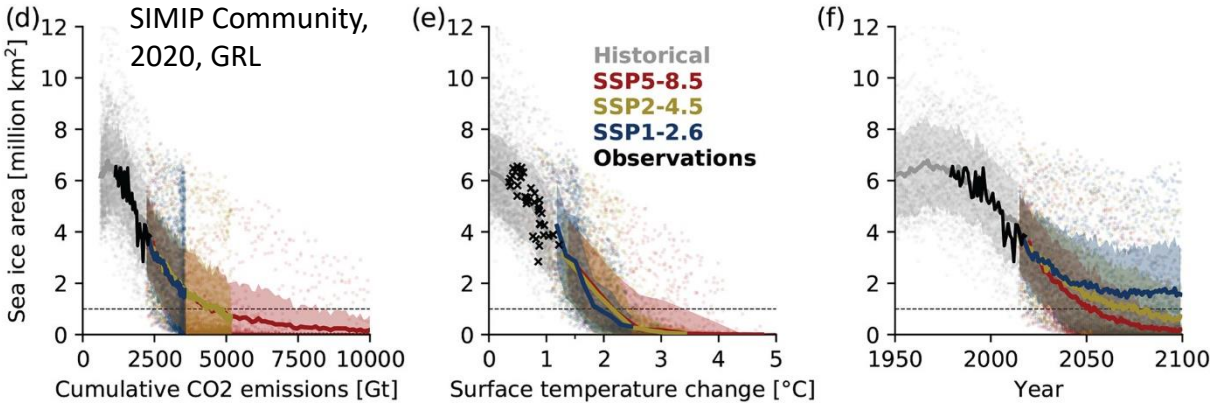
Cryosphere: Arctic Summer Ice Cap May Soon Be Gone

Summer ice cap may be gone by 2050

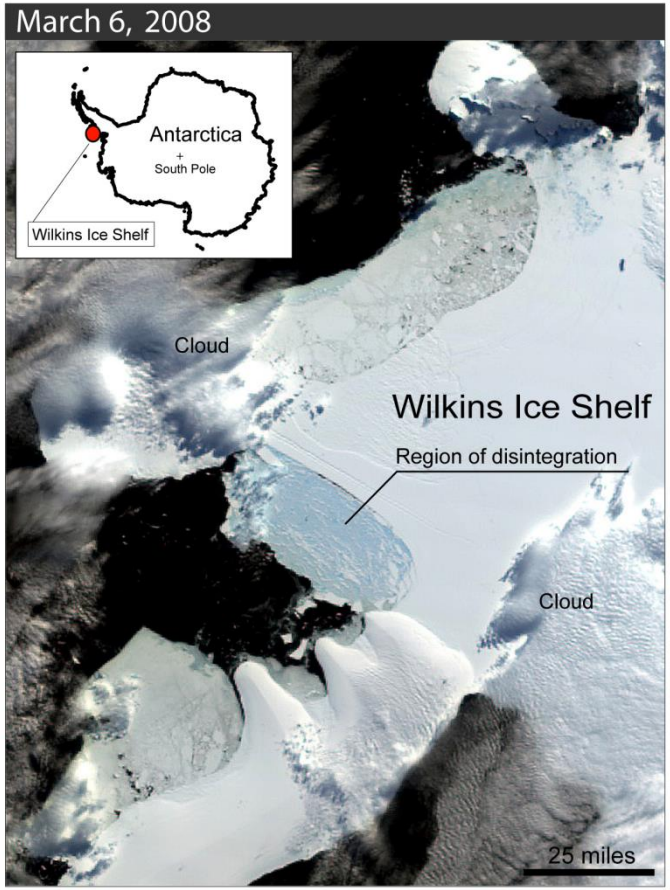


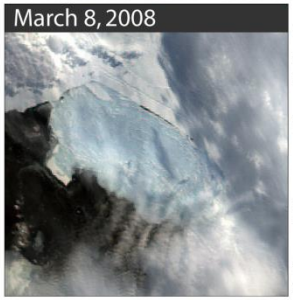


September

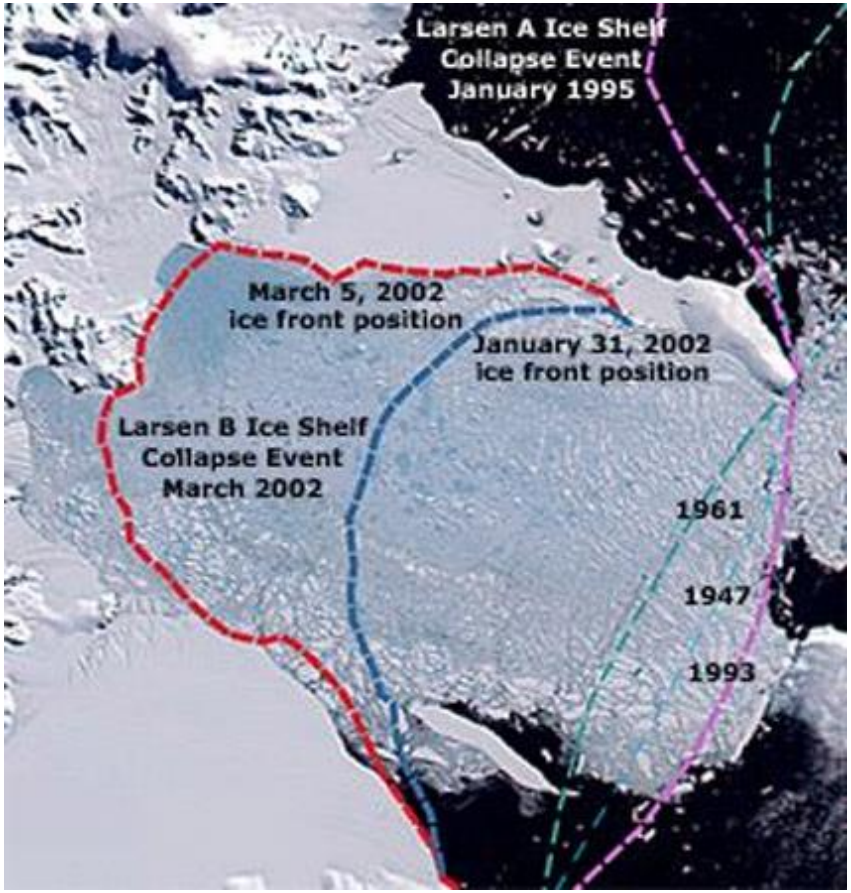


Cryosphere: Antarctic



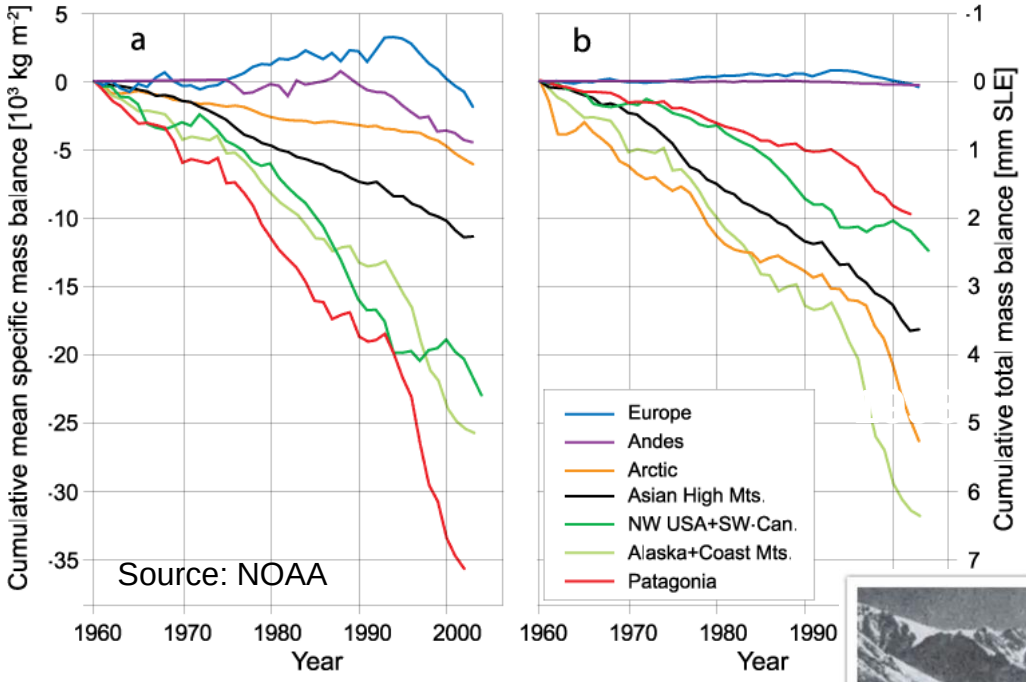


National Snow and Ice Data Center, Boulder, CO



Source: NASA

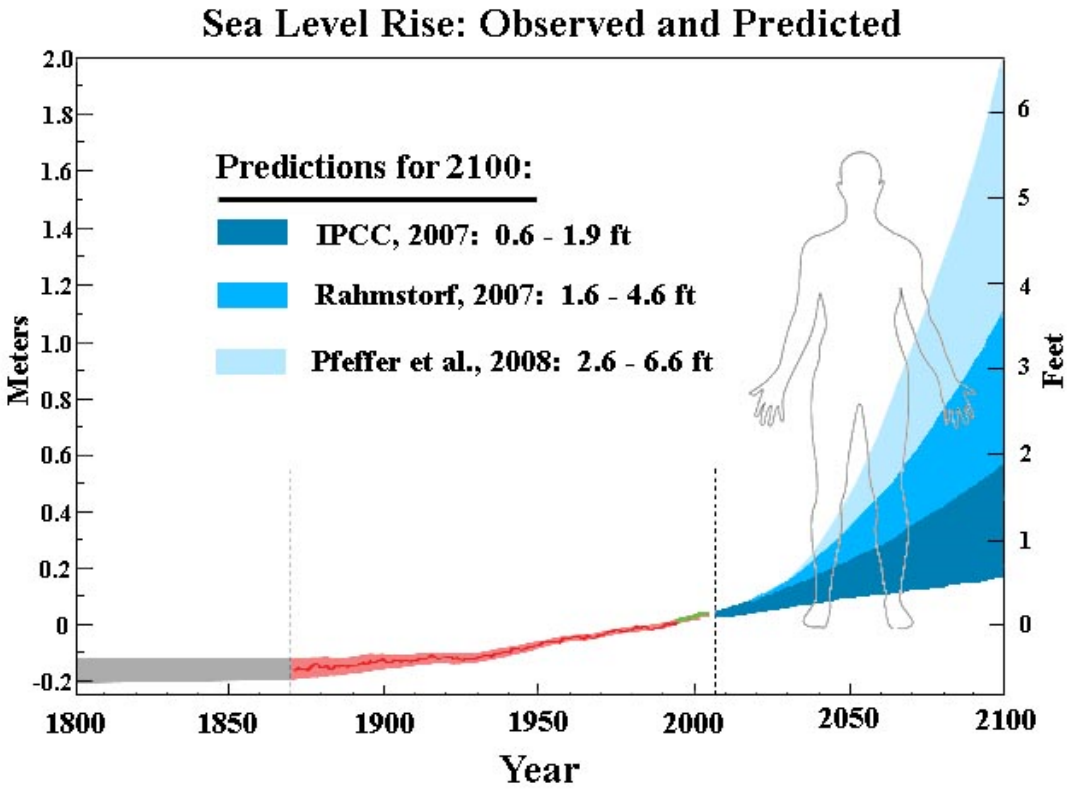
Cryosphere: Glaciers Are Retreating

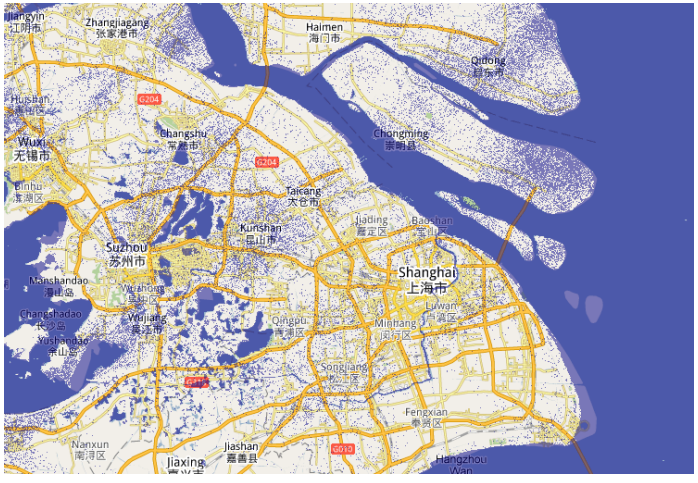


天山乌鲁木齐河源1号冰川

中国气候变化蓝皮书（2021）

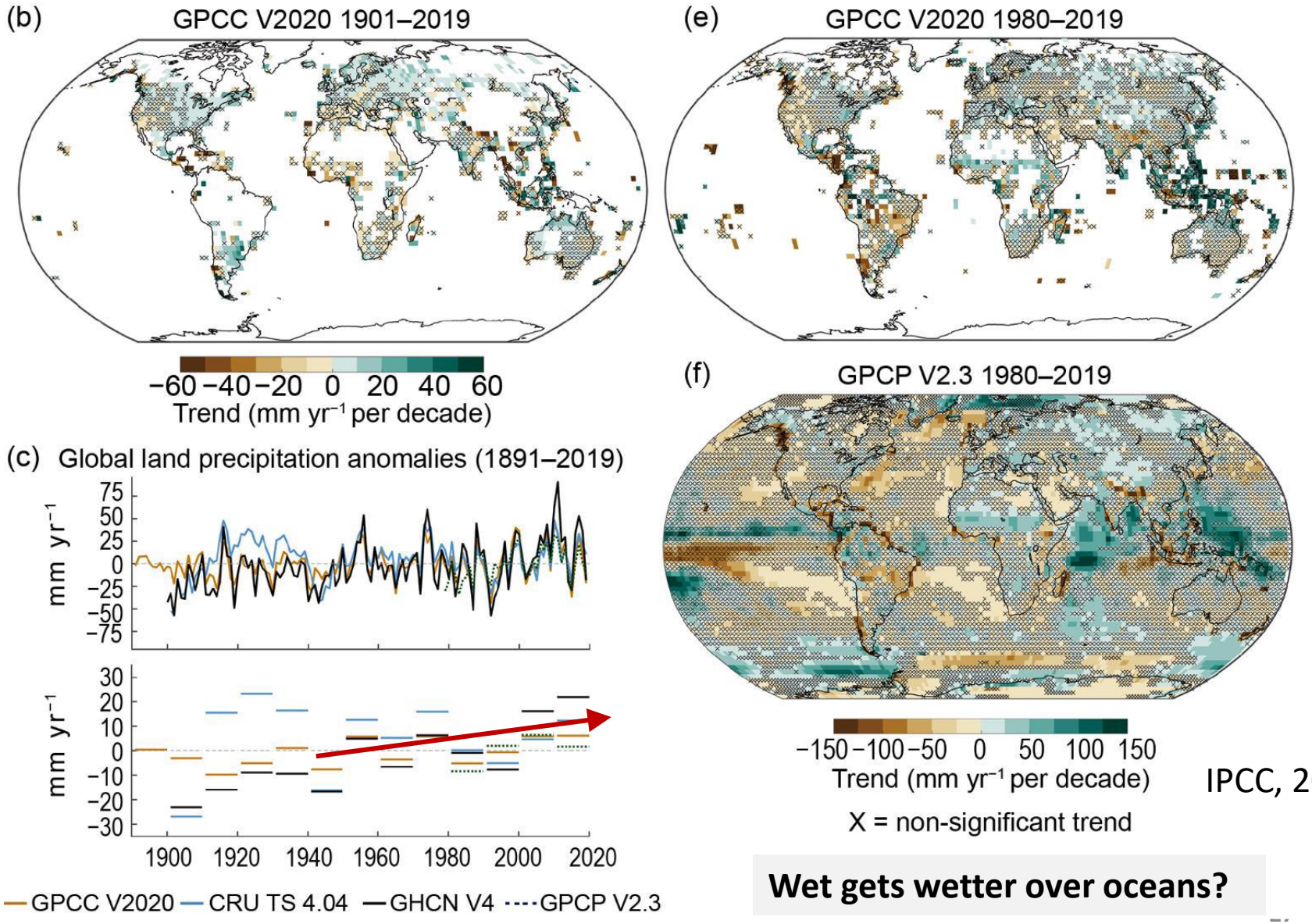
Hydrosphere: Sea Level Is Rising





Contributors to sea level rise:
https://youtu.be/Q15gTMXjwCc

Hydrosphere: Changes in Precipitation

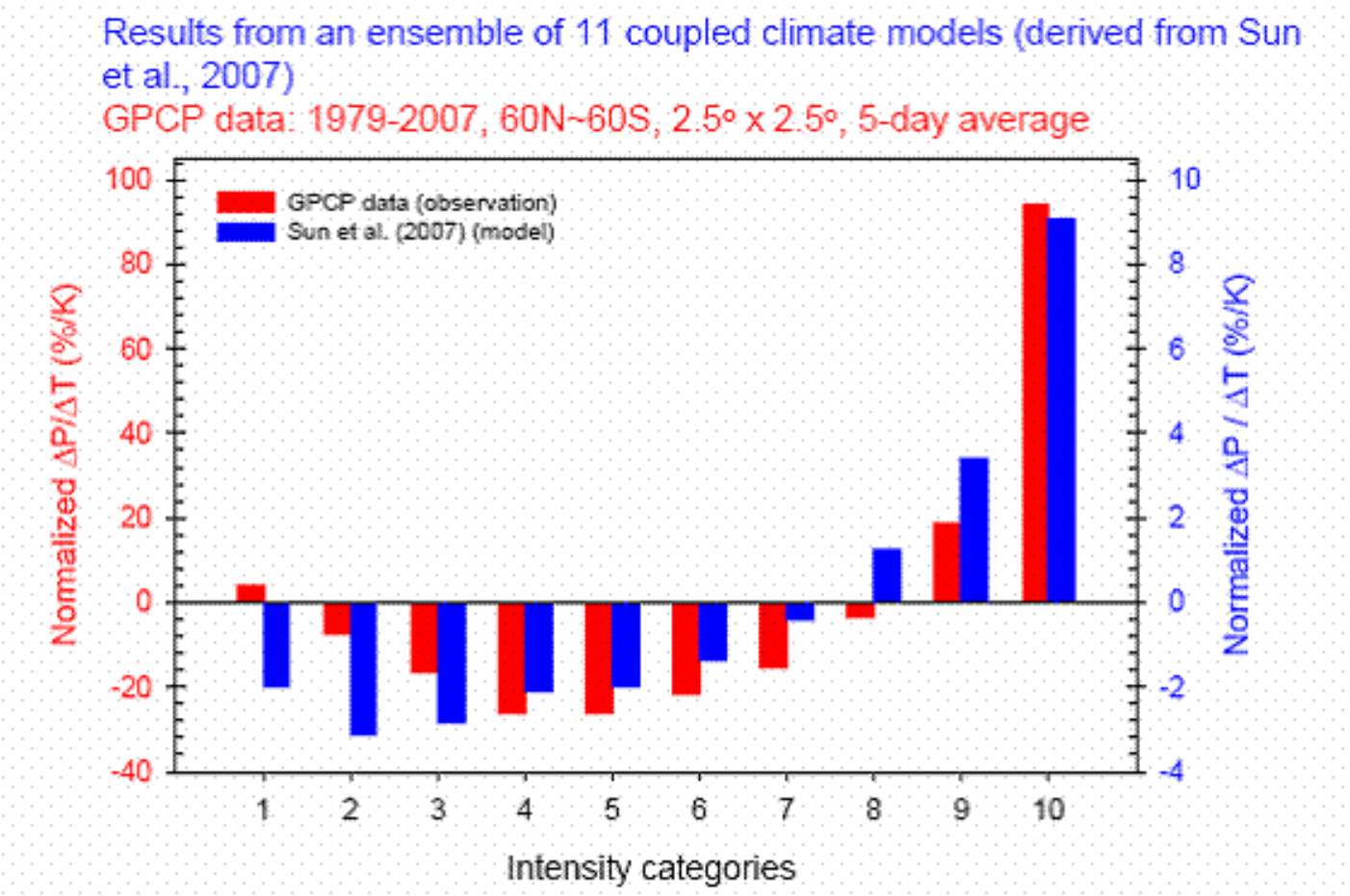


IPCC, 2021

Wet gets wetter over oceans?

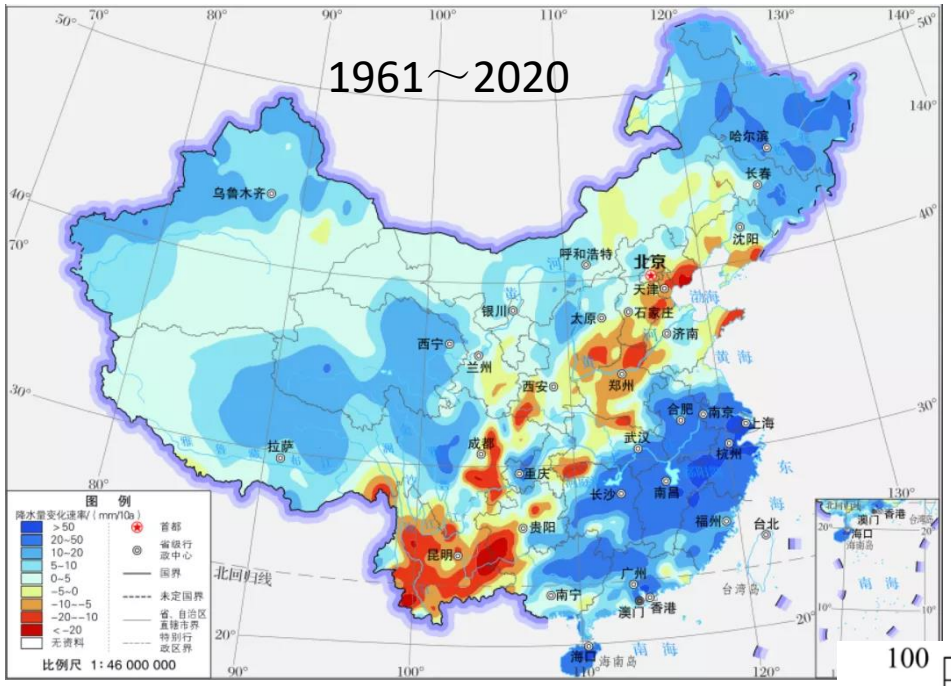
Hydrosphere: Storm Intensity

More frequent strong rainfall events as temperature rises

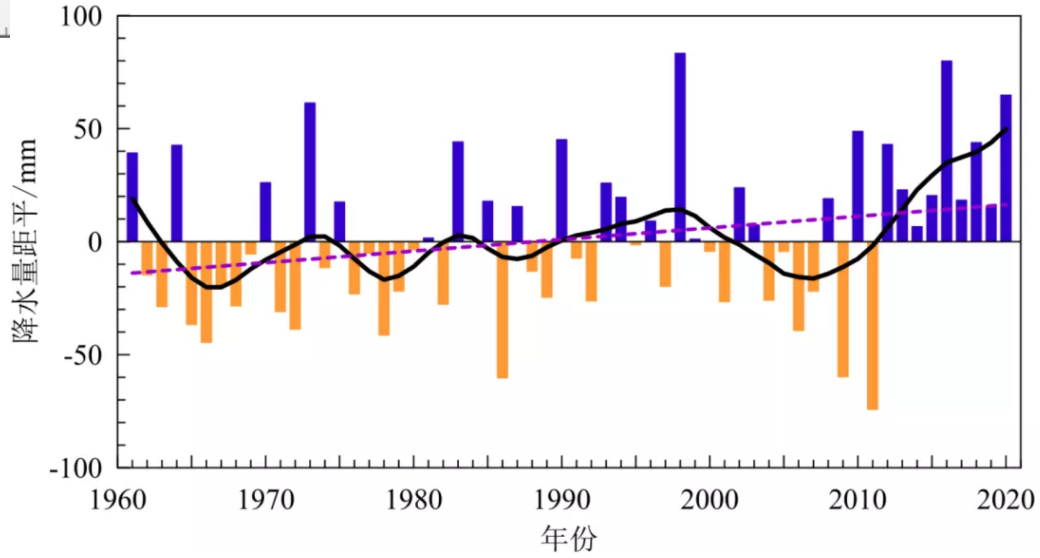


Liu et al., 2009

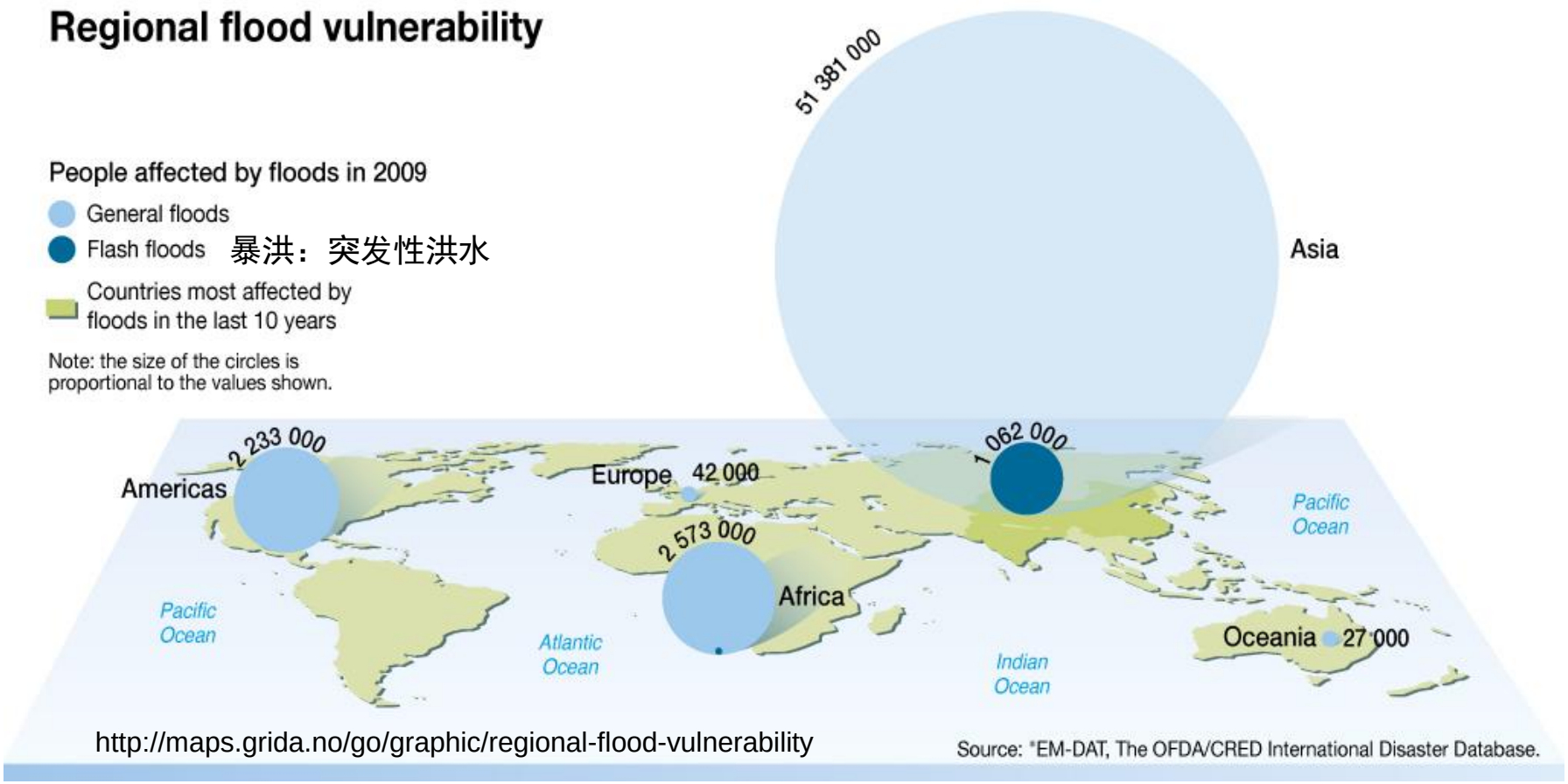
Hydrosphere: Changes in Precipitation in China



中国气候变化蓝皮书（2021）

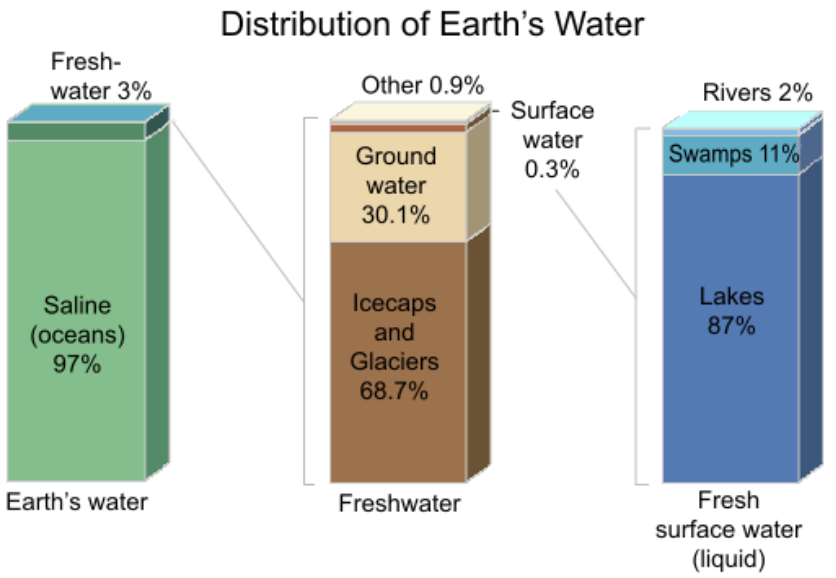


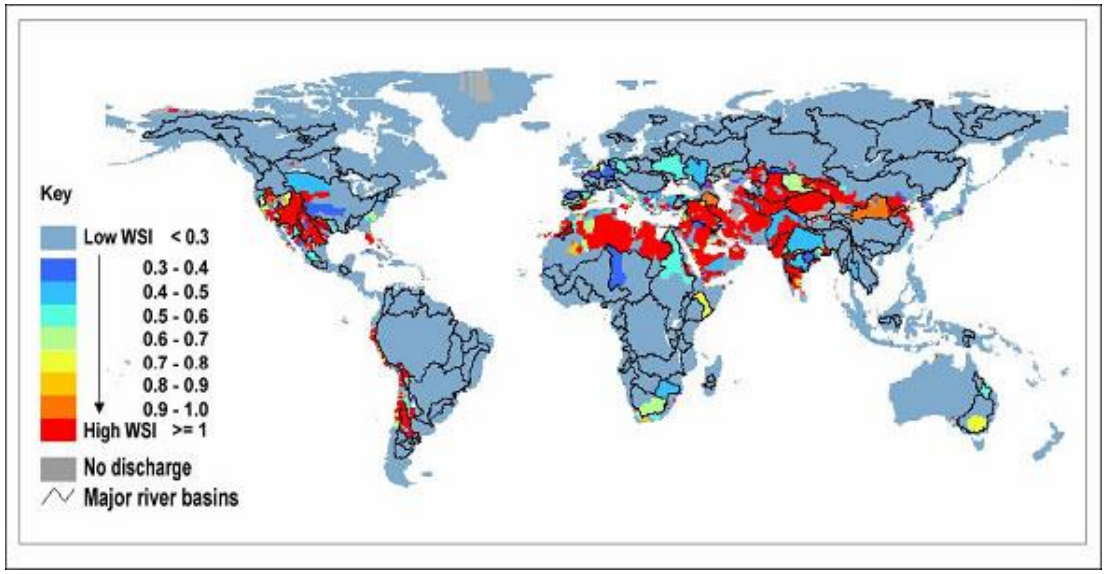
Hydrosphere: Flood Vulnerability



四川山洪：https://www.bilibili.com/video/BV1aY4y1c7Fd?t=95.5

Hydrosphere: Freshwater Resources





Lithosphere: Land Use Changes

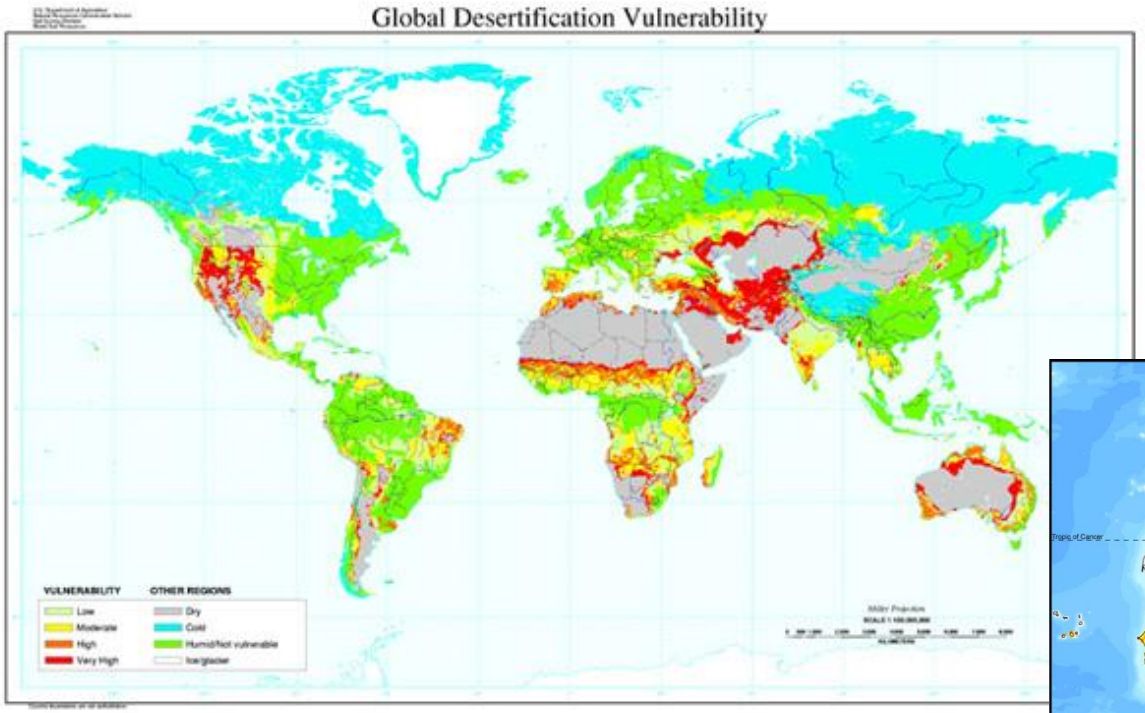
Widespread Conversion of Natural Ecosystems

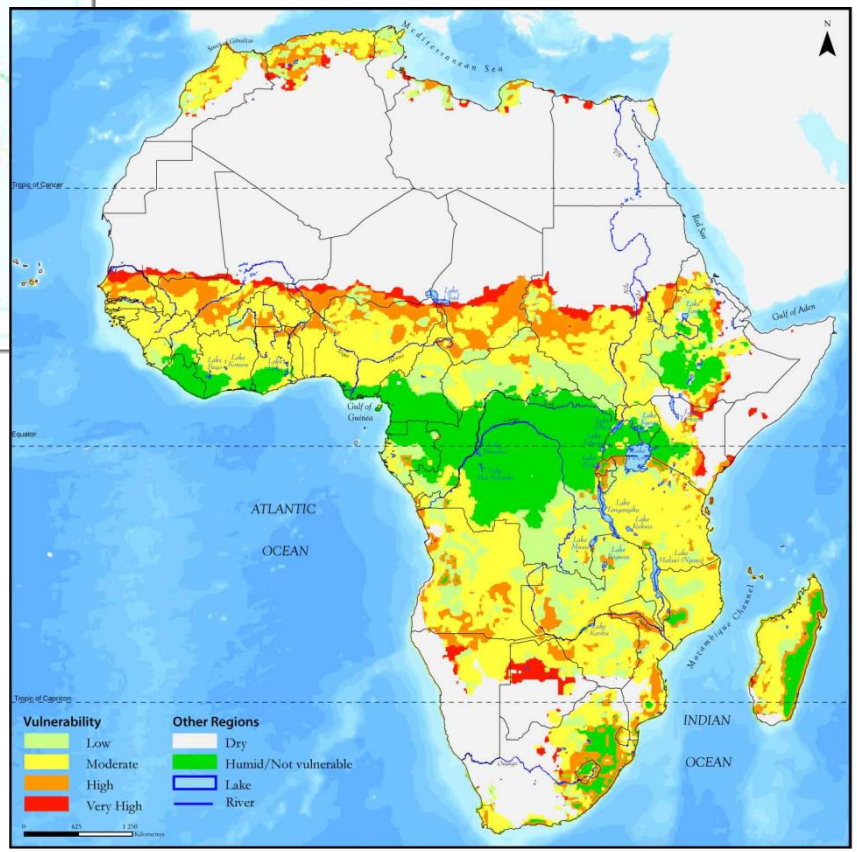
Region	Percentage of Land Converted
Asia	44
Central America & Caribbean	28
Europe & Russia	35
Middle East & North Africa	12
North America	27
Oceania	9
South America	33
Sub-saharan Africa	25

Source : WRR calculations.

www.india-reports.in

Lithosphere: Desertification





中国西北地区变绿?

Changes in the Biosphere

- Human impacts:
  - Over-harvest of desirable species
  - Land use change
  - Pollution, climate change

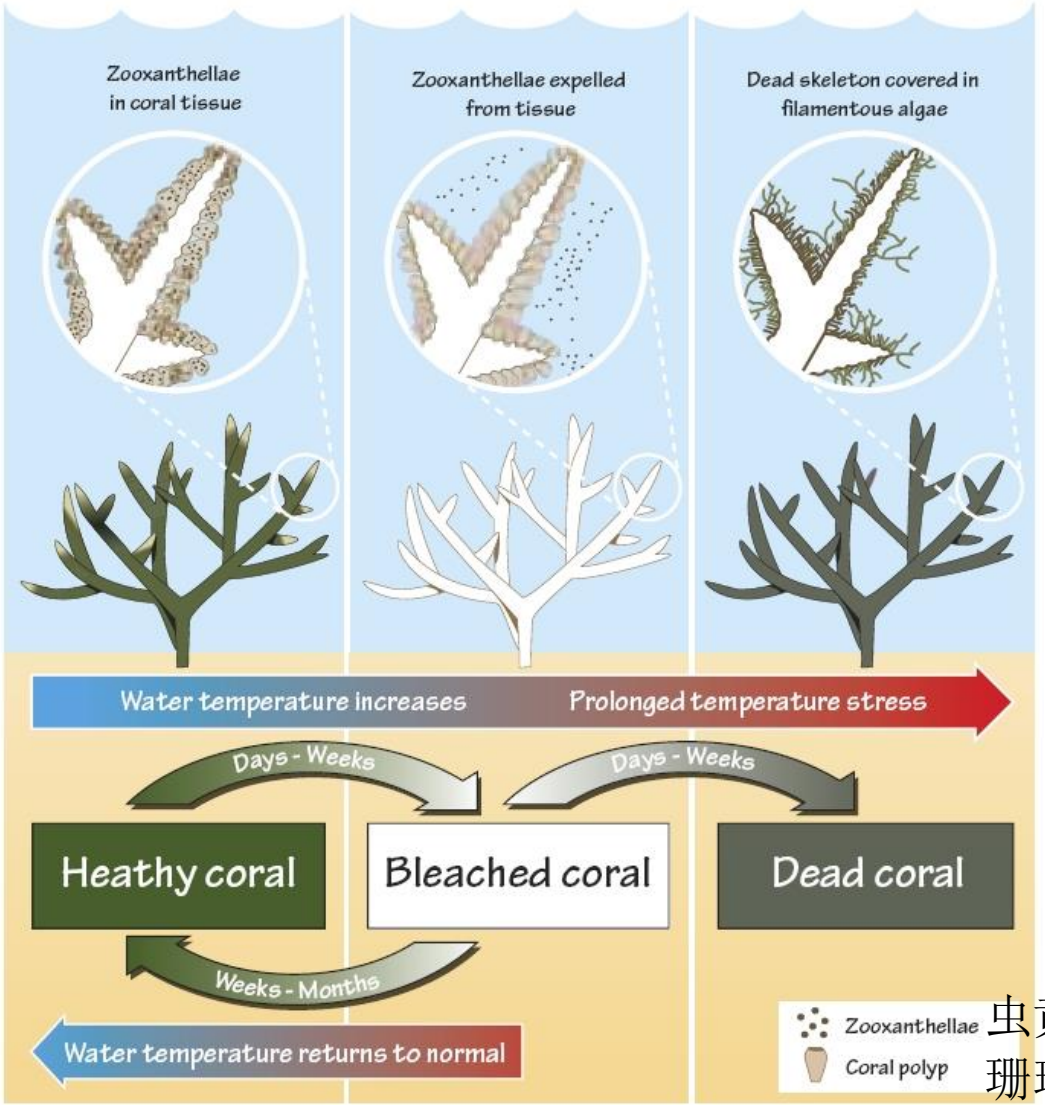
- Migration of flora（植物群）and fauna（动物群）habitats
- Change in species behavior or ecological relationships
- Extinction of species

Biosphere: World-wide Reef Bleaching

Healthy coral

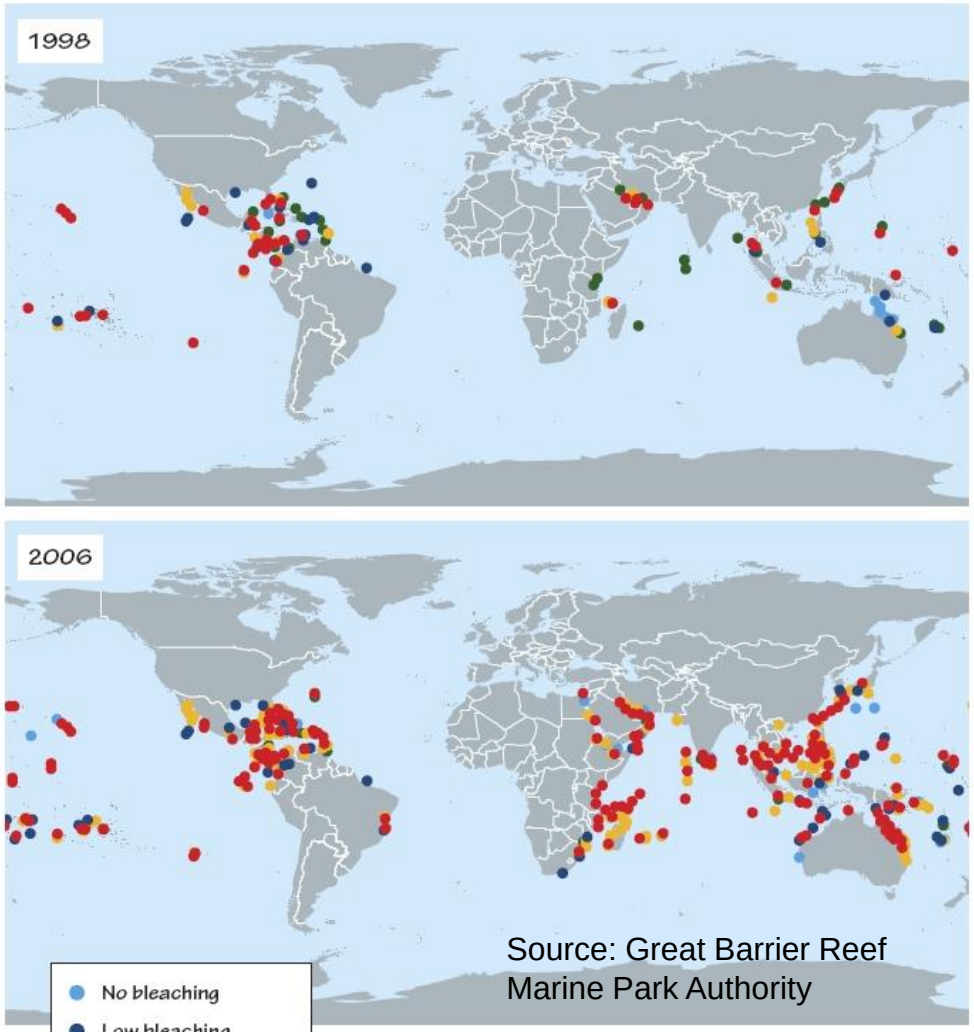
Bleached coral

Dead coral



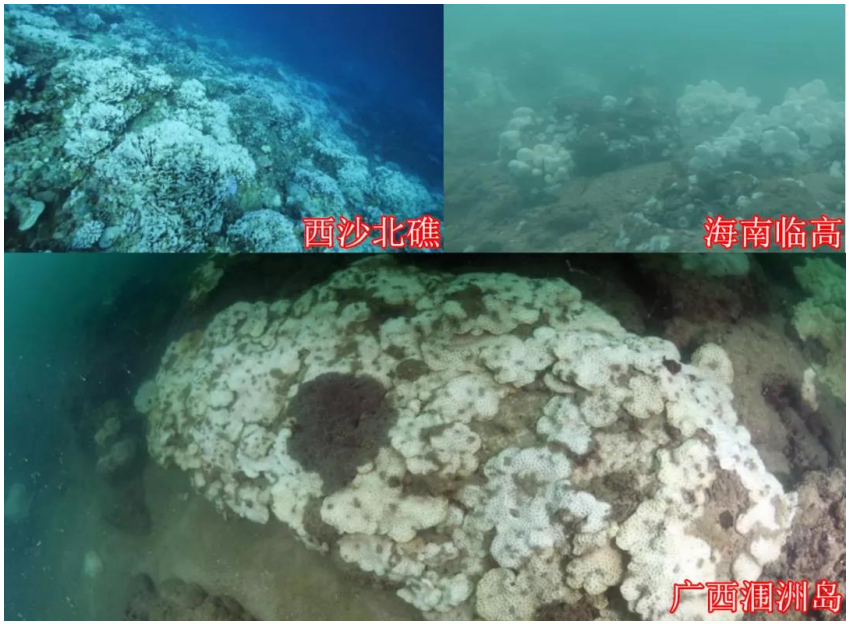
Source: Great Barrier Reef Marine Park Authority

Biosphere: World-Wide Reef Bleaching



Source: Great Barrier Reef Marine Park Authority

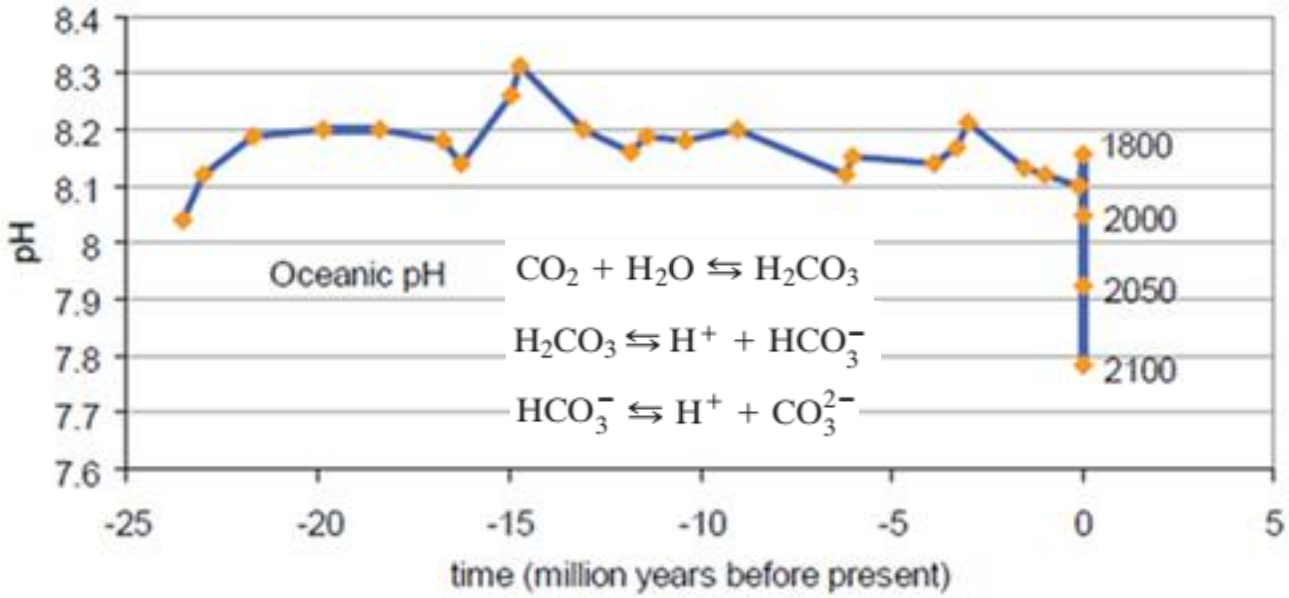
2020年中国领海珊瑚白化事件



中国气候变化蓝皮书（2021）

Biosphere: Acidification of Global Oceans

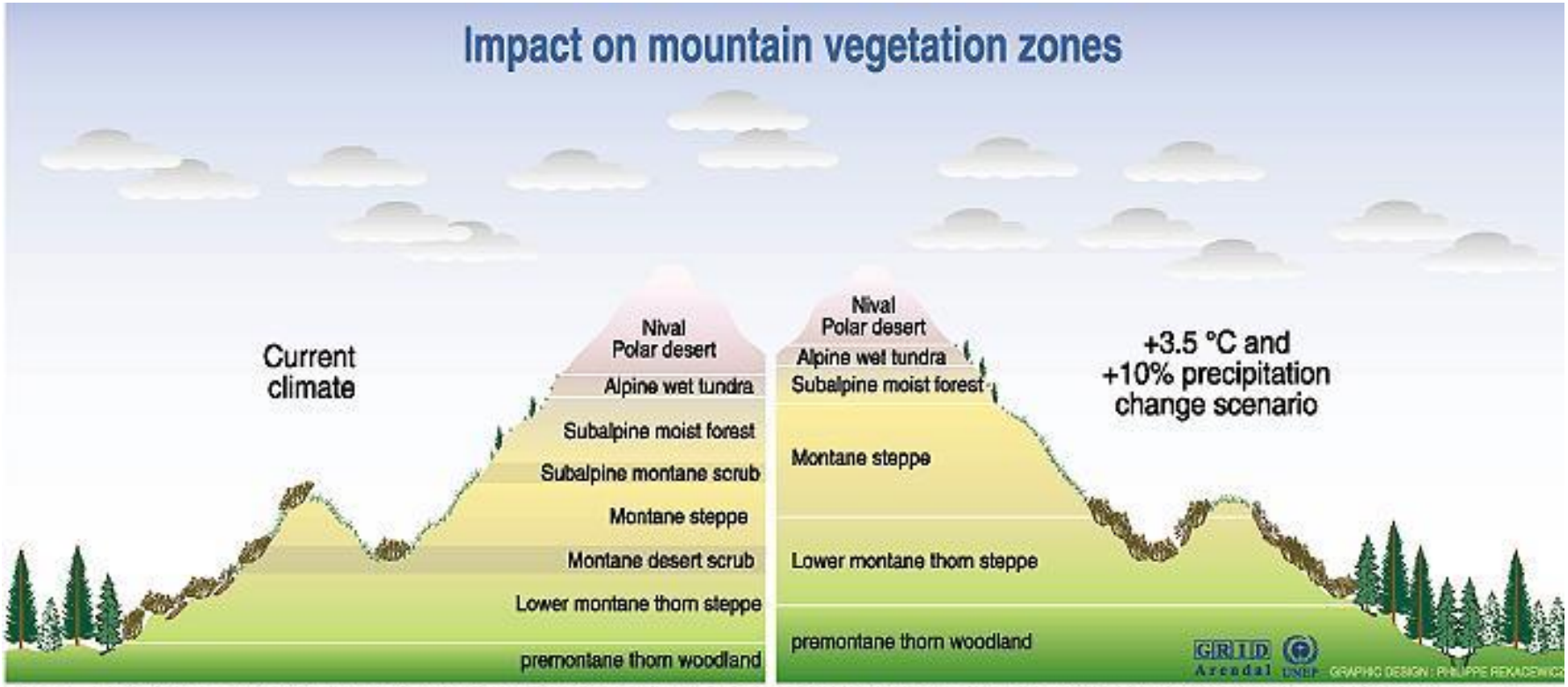
$CO_{2\,(g)} \leftrightarrow CO_{2\,(aq)}$ $\qquad$ $CO_{2\,(aq)} + CO_3^{2-} + H_2O \leftrightarrow 2HCO_3^-$



At pH = 8.1
- HCO_3^- = 90%
- CO_3^{-2} = 9%
- CO_2 = 1%

Figure 1. Past and contempory variability of marine pH. Future predictions are model derived values based on IPCC mean scenarios (from Turley *et al*, 2006. Cambridge University Press, 8, 65-70).

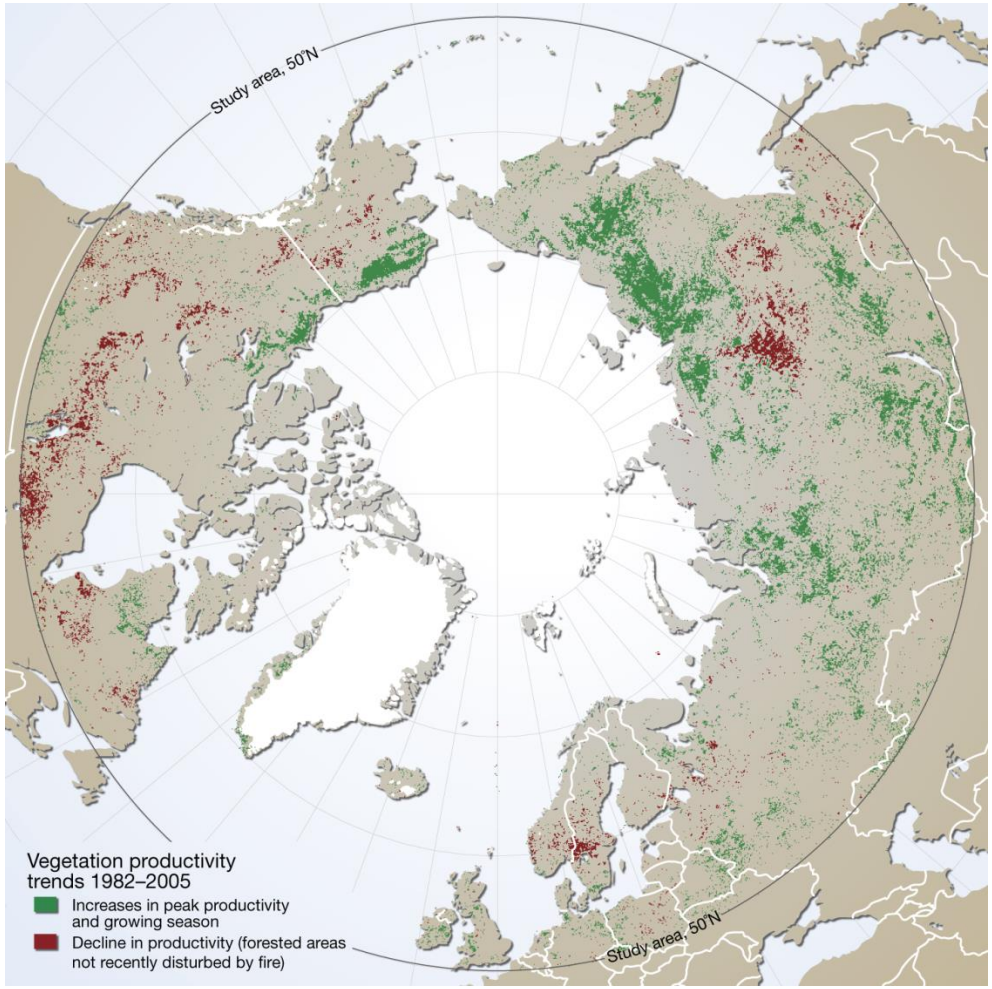
Biosphere: Ecosystem Migration



Sources: Martin Benitson, Mountain environments in changing climates, Routledge, London, 1994; Climate change 1995, Impacts, adaptations and migration of climate change, contribution of working group 2 to the second assessment report of the intergovernmental panel on climate change (IPCC), UNEP and WMO, Cambridge press university, 1996.

Biosphere: Ecosystem Migration

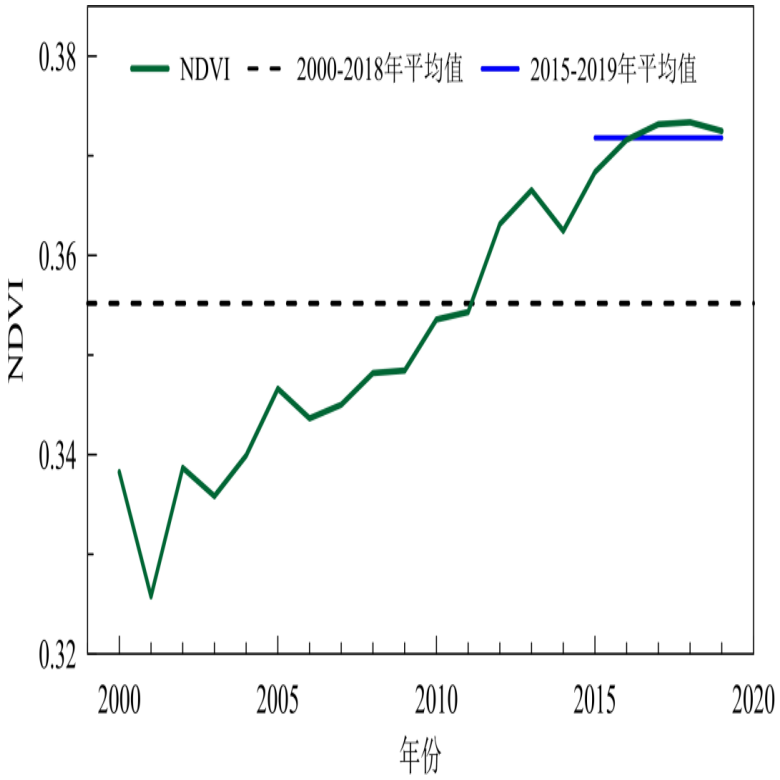
Arctic "greening"

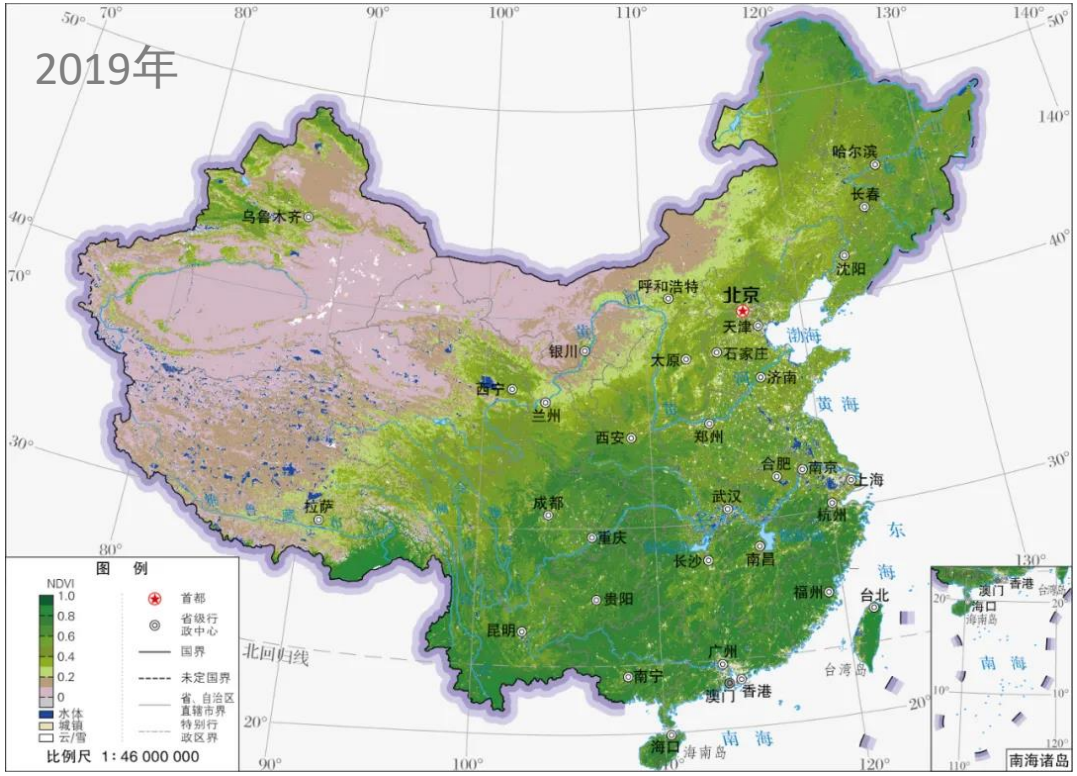


http://maps.grida.no/go/graphic/trends-in-arctic-vegetation-productivity-1982-2005-greening-of-the-arctic

Biosphere: Greening in China in the 21st Century

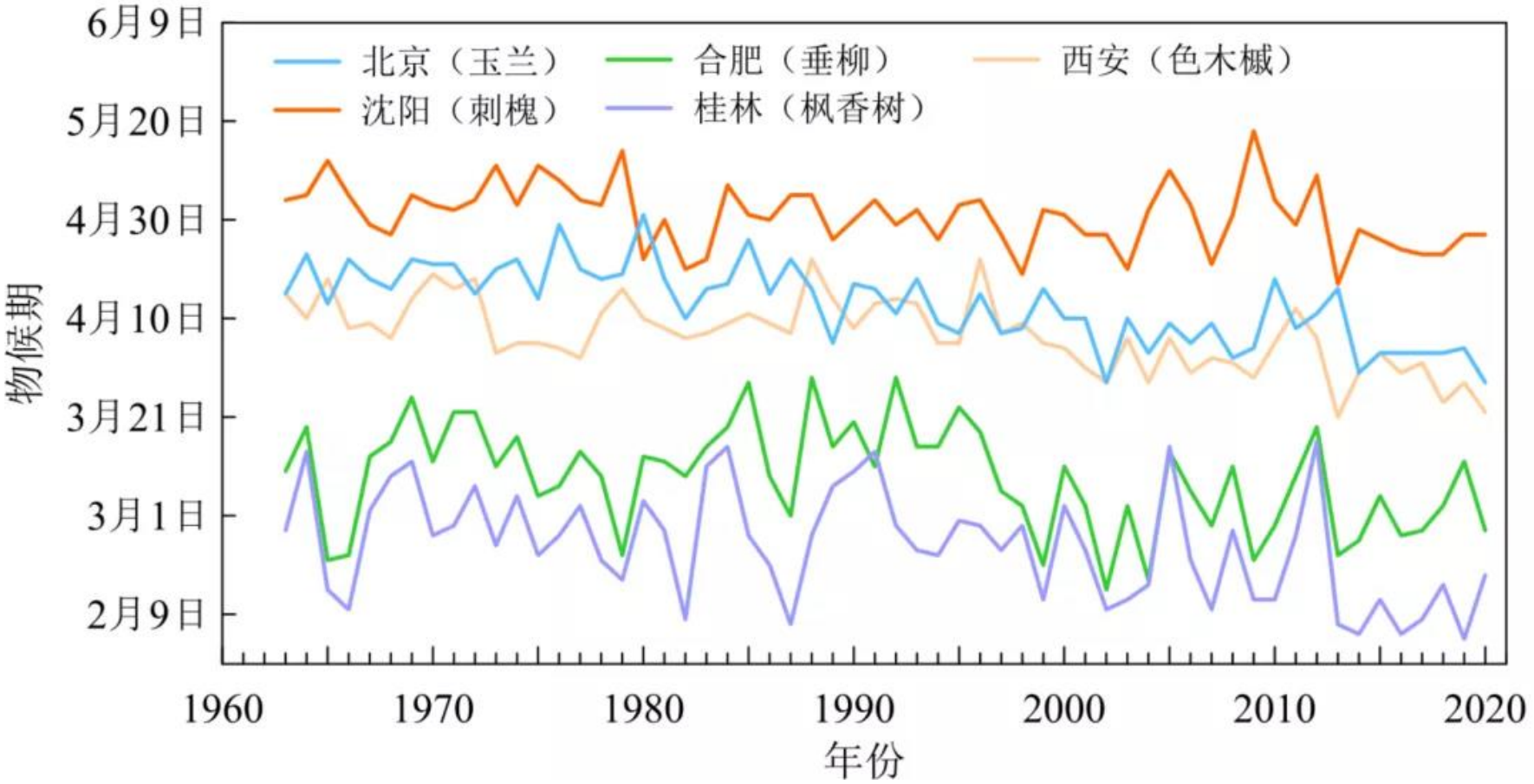
中国归一化差植被指数(MODIS)





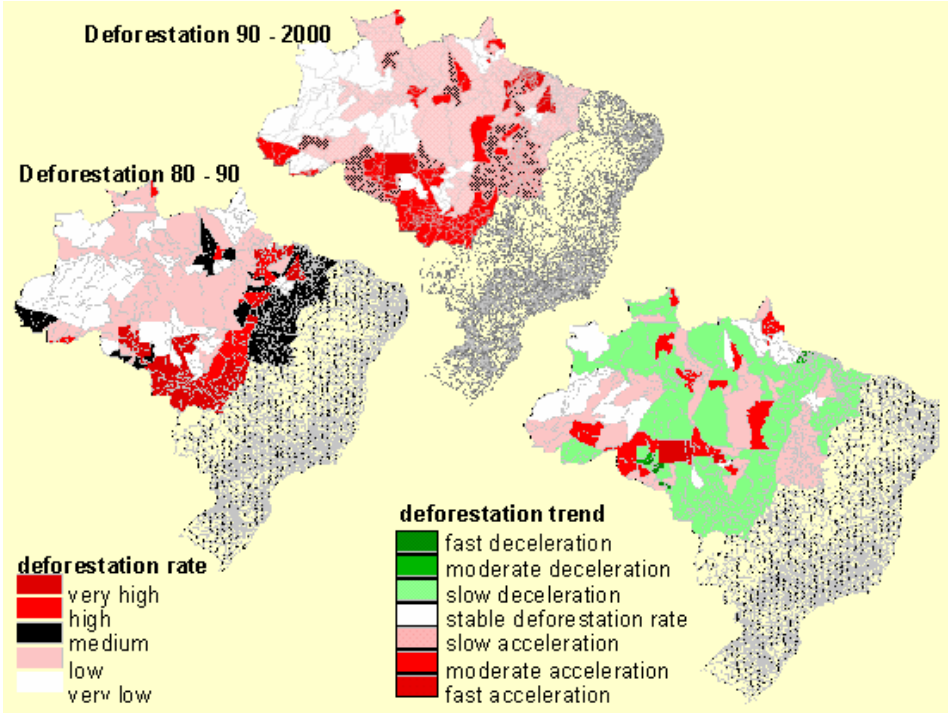
中国气候变化蓝皮书 2020

Biosphere: Eco-structure Change

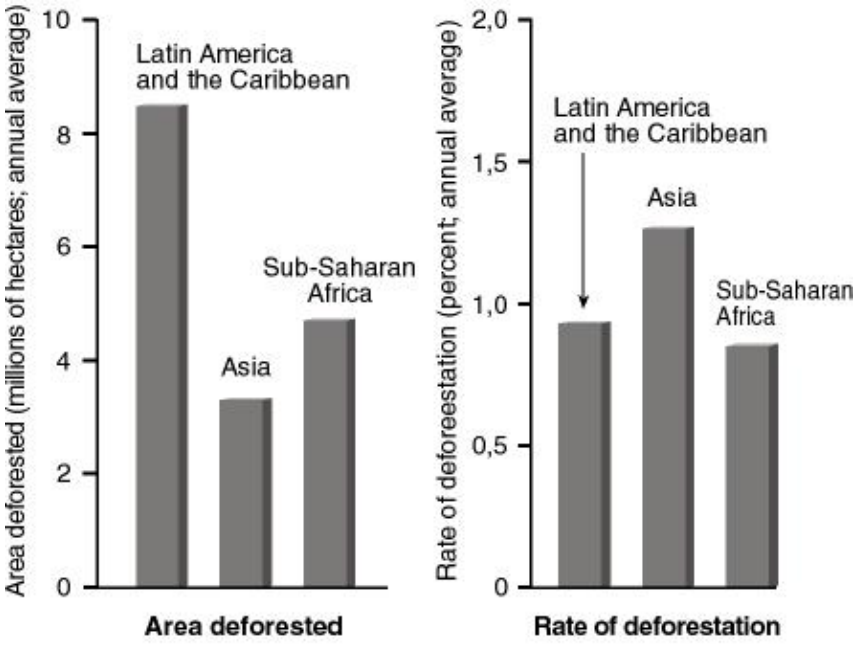


中国气候变化蓝皮书（2021）

Biosphere: Deforestation

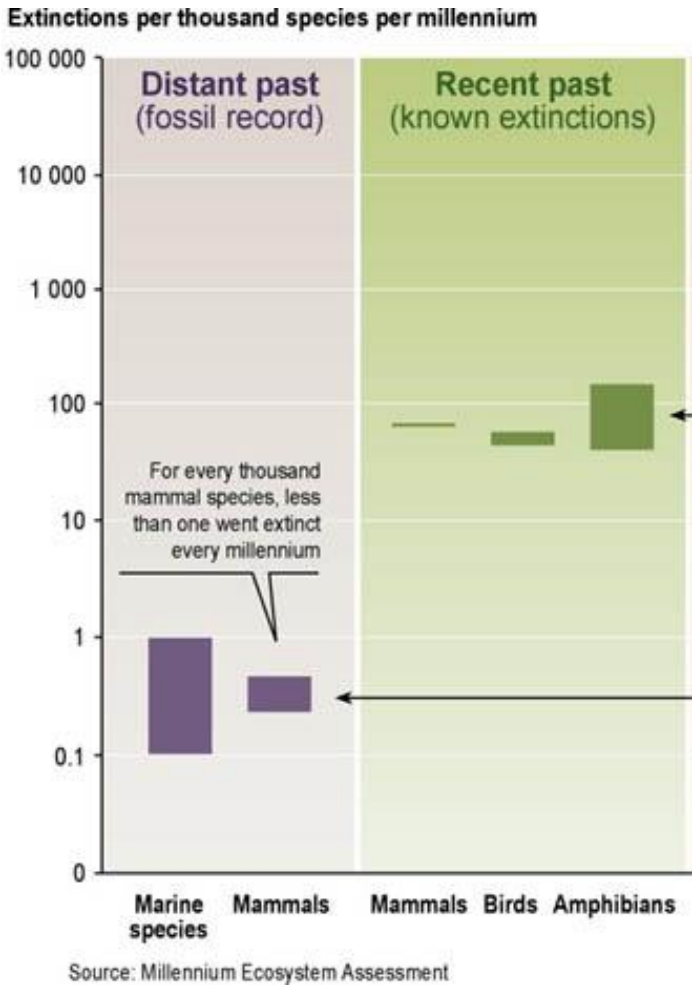


Loss of tropical forest in developing regions, 1980-1990

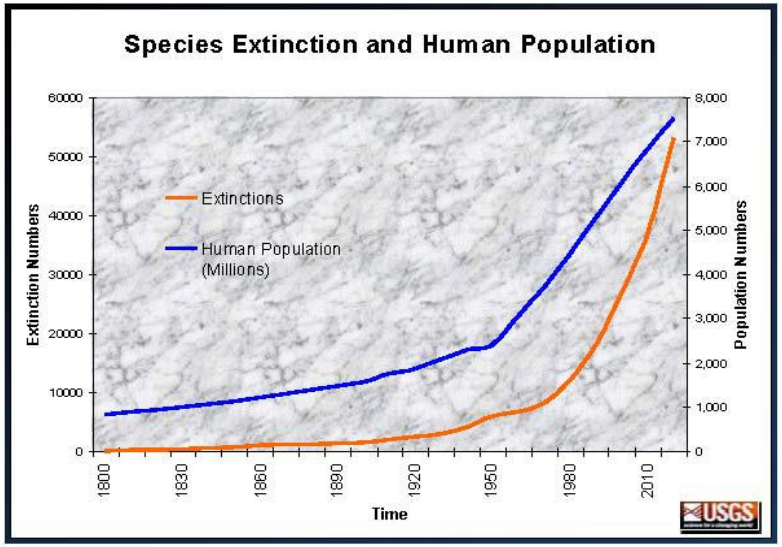


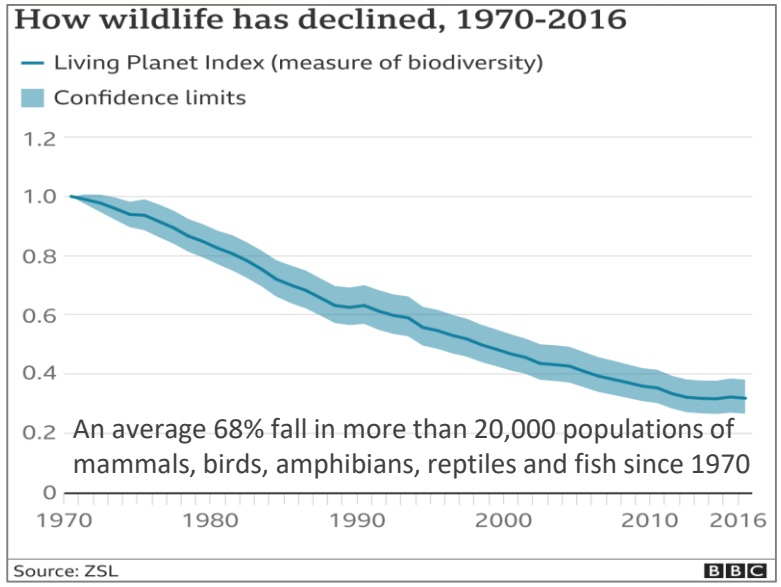
Source: FAO, Rome.

Biosphere: Species Extinction

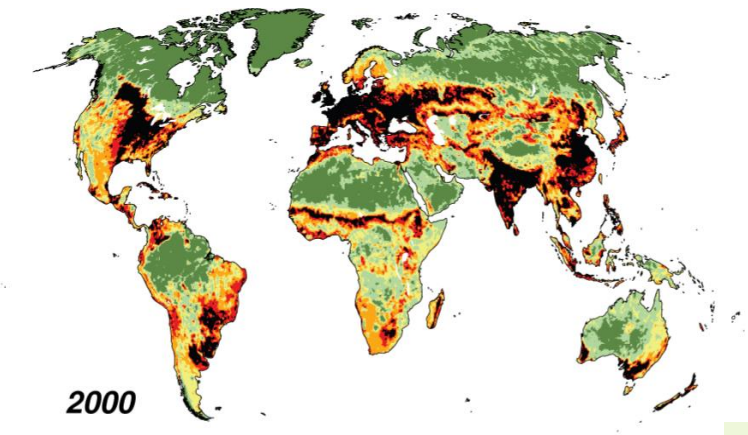


Source: Millennium Ecosystem Assessment

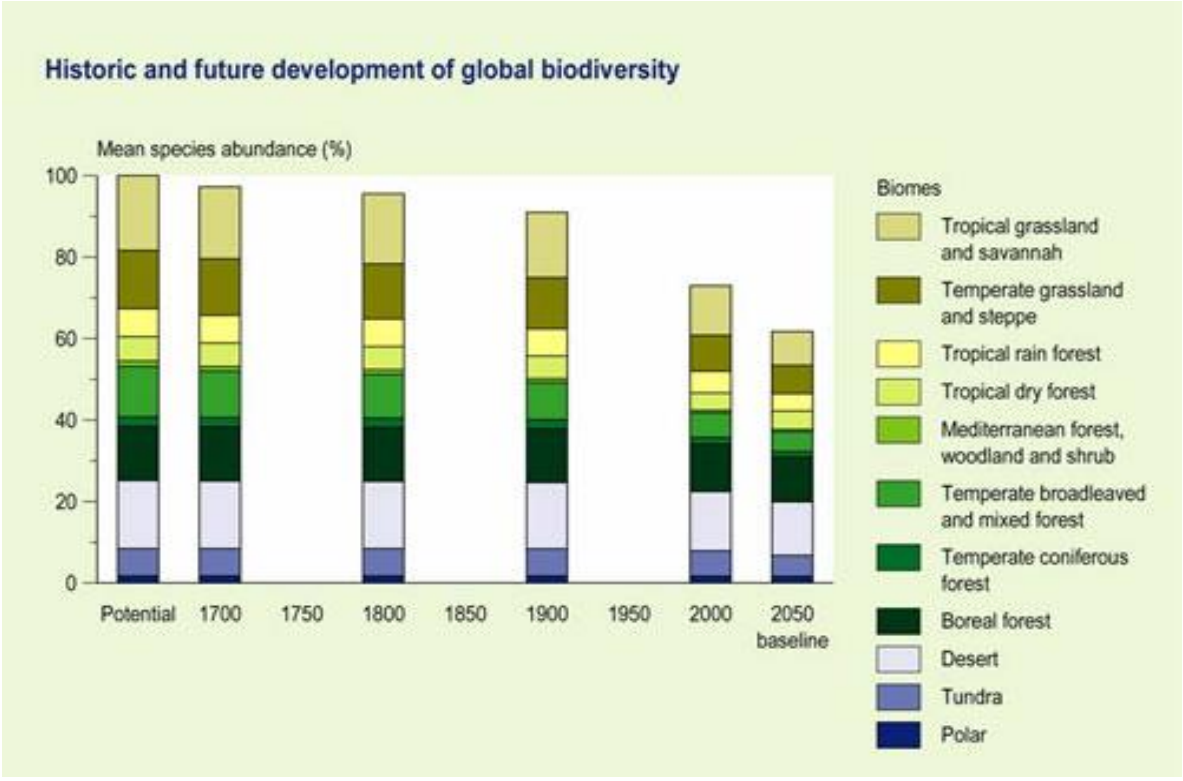




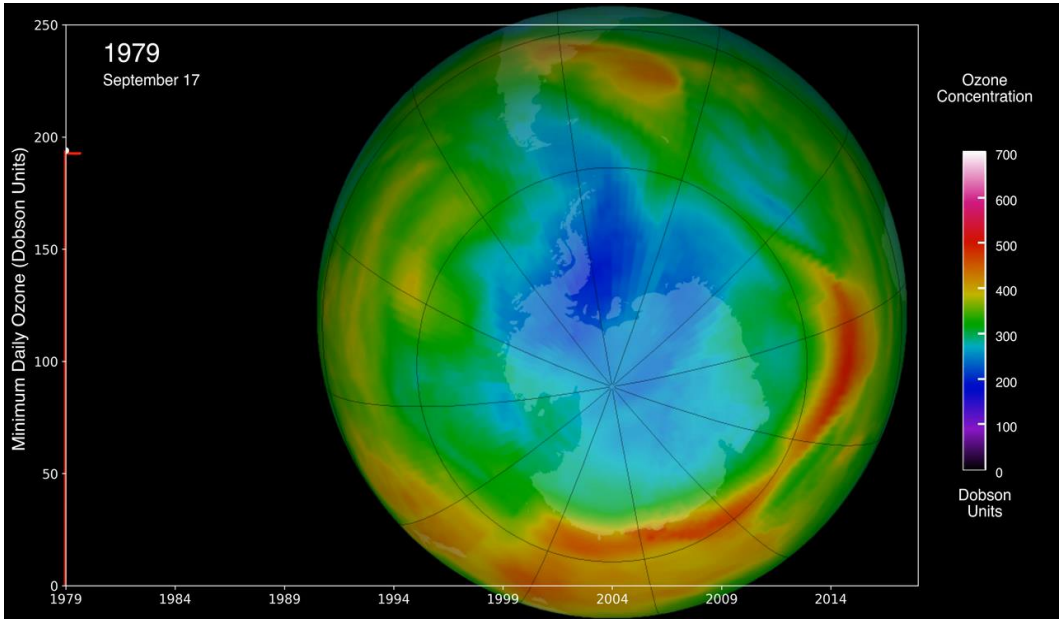
Biosphere: Biodiversity



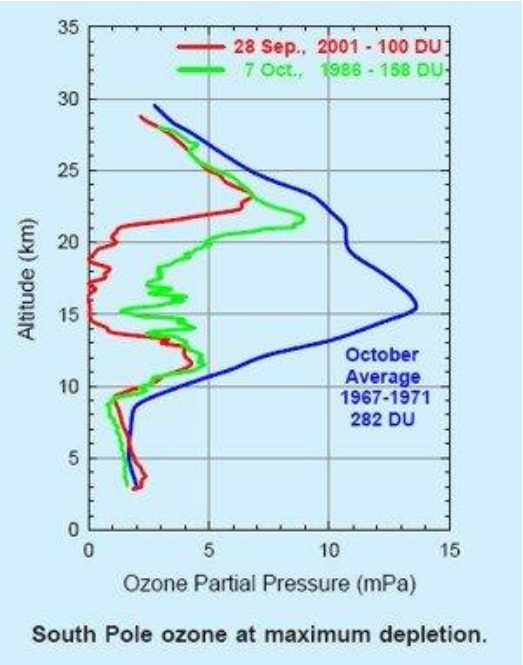
"Biological diversity is the variety and variability among living organisms and the ecological complexes in which they occur."



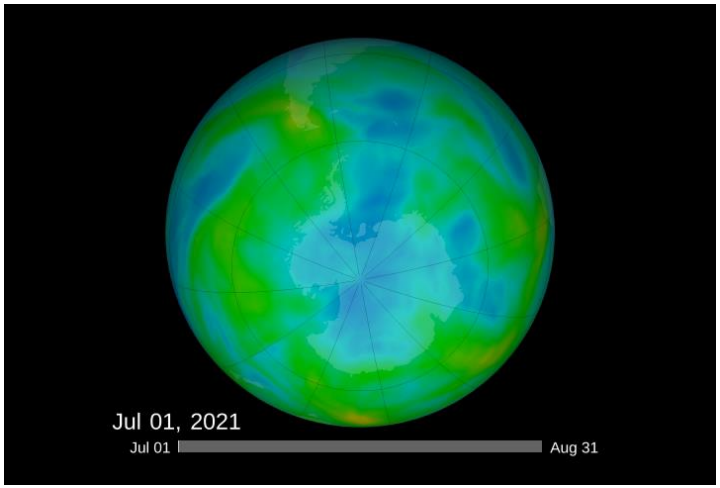
Ozone Hole and Recovery

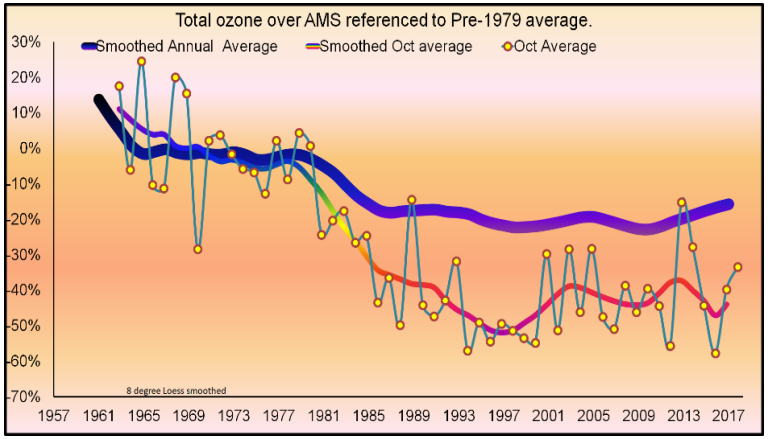


Source: NASA

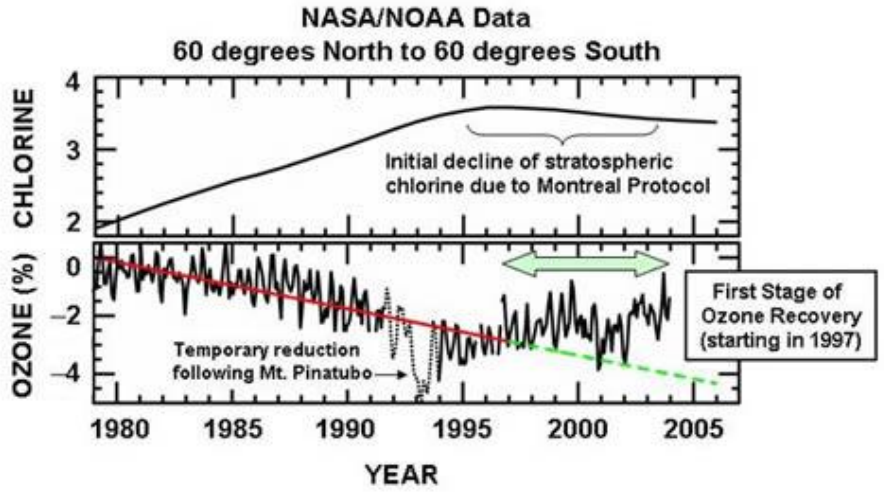


Source: NOAA

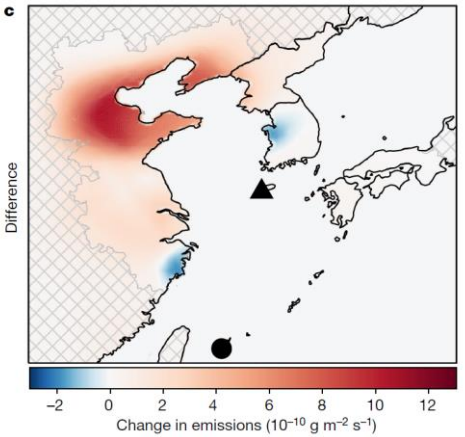




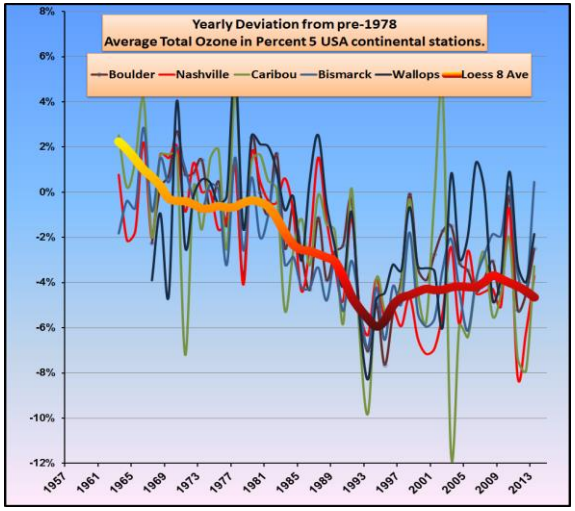
Stratospheric Ozone Loss and Recovery



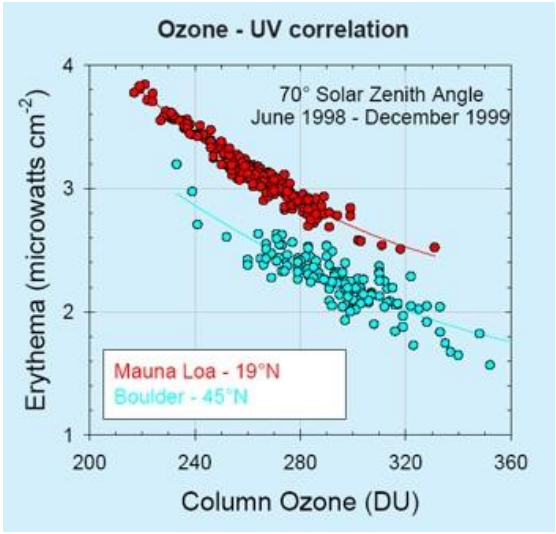
Data: TOMS; Source: CSIRO



Illegal CFC-11 emis in China
Rigby et al., 2019, Nature



Source: NOAA



The Great Smog of London, 1952

Cold and stagnant weather
Inversion
Burning of coal
12000+ people died

Haze in China

- Emissions of PM and precursors
- High humidity, sunlight
- Stagnant atmosphere
- Wind direction/speed

Summary

- There are real, rapid and severe changes in the natural environment all over the World
- Many of the changes are caused directly or indirectly by human activities
- The impact of the changes can be magnified through complex interactions and feedbacks in the Earth system

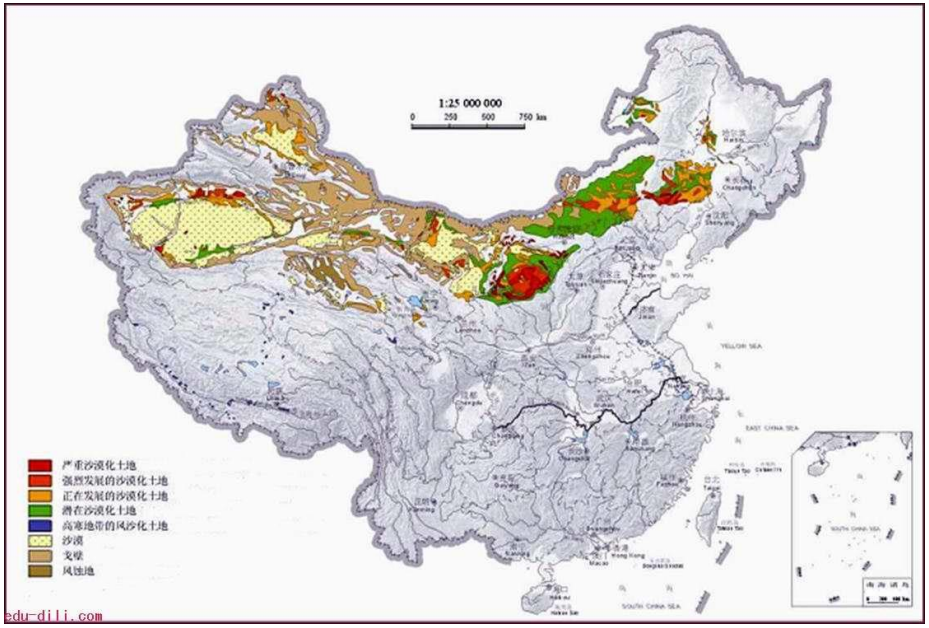
Suggested Reading

- United Nations Environment Programme
  https://www.unenvironment.org/explore-topics/environment-under-review
- NOAA Global Climate Report
  https://www.ncdc.noaa.gov/sotc/global/201807
- NASA World of Change
  http://earthobservatory.nasa.gov/Features/WorldOfChange/index.php
- 中国气候变化蓝皮书（2021、2022、2023、2024）
- Movie: An Inconvenient Truth
- Movie: The Day After Tomorrow
- 采访：柴静采访丁仲礼
- 博弈论：囚徒困境、零和游戏 v.s. 非零和游戏

Quiz

1. Causes of vertical distribution of air temperature
2. Causes of seasonal variation of CO2
3. Causes of different magnitudes of change in CO2, CH4 and N2O
4. Why do we care about the Amazon?
5. Why does ozone hole happen over the Antarctic in spring?

Lithosphere: Desertification



截至2014年：

- 全国荒漠化土地总面积261.16万平方公里，占国土总面积的27.20%
- 分布于北京、天津、河北、山西、内蒙古、辽宁、吉林、山东、河南、海南、四川、云南、西藏、陕西、甘肃、青海、宁夏、新疆18个省（自治区、直辖市）的528个县（旗、市、区）

第五次中国荒漠化和沙化状况公报

http://www.forestry.gov.cn/main/69/content-831684.html