上海交通大学
SHANGHAI JIAO TONG UNIVERSITY

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上海交通大学海洋学院

气候学与全球变化
Climate and Global Change

2022.05.27

SCHOOL OF OCEANOGRAPHY
SHANGHAI JIAO TONG UNIVERSITY
上海交通大学 海洋学院

Emission of greenhouse gases

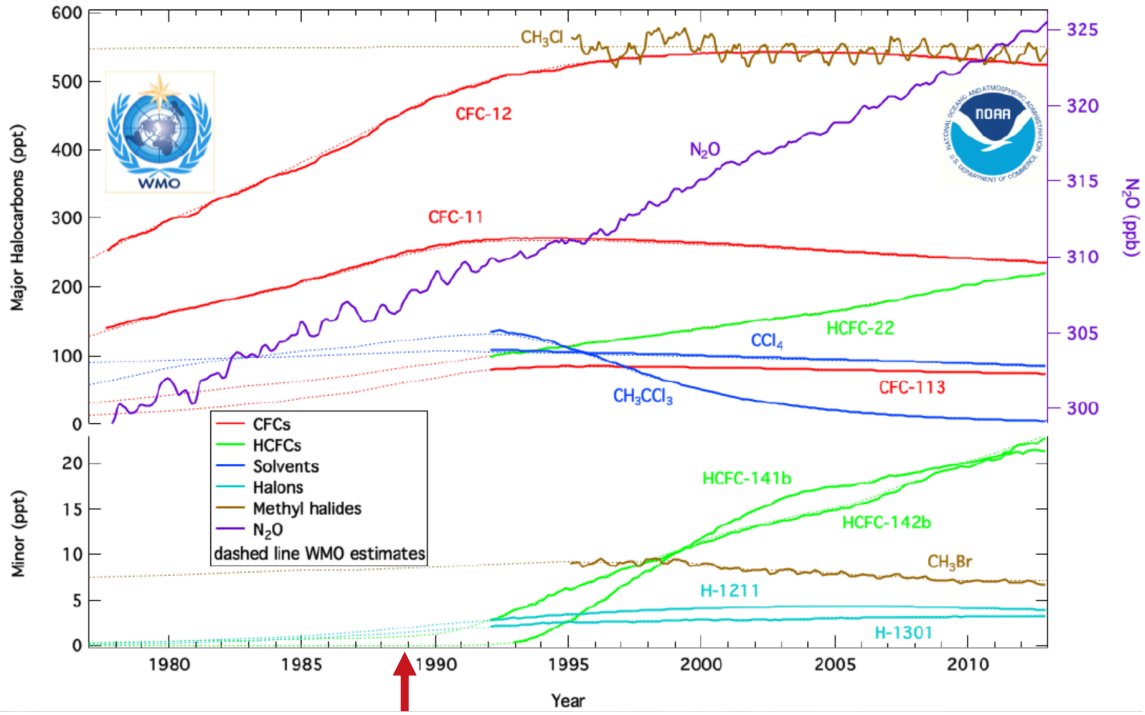
TABLE 13.1 Characteristics of Some Key Greenhouse Gases That are Influenced by Human Activities

Parameter	CO_2	CH_4	CFC-11	CFC-12	N_2O
Preindustrial atmospheric concentration (1750)	278 ppm	715 ppb	0	0	270 ppb
Current atmospheric concentration (2011)	390 ppm	1803 ppb	238 ppt	527 ppt	324 ppb
Current annual rate of atmospheric accumulation	2.0 ppm (0.5%)	4.8 ppb (0.27%)	−2.25 ppt (−0.93%)	−2.25 ppt (−0.42%)	0.8 ppb (0.25%)
Atmospheric lifetime (years)	(50–200)	10	65	130	150

$$\text{lifetime} = \frac{\text{atmospheric content}}{\text{rate of removal}}$$

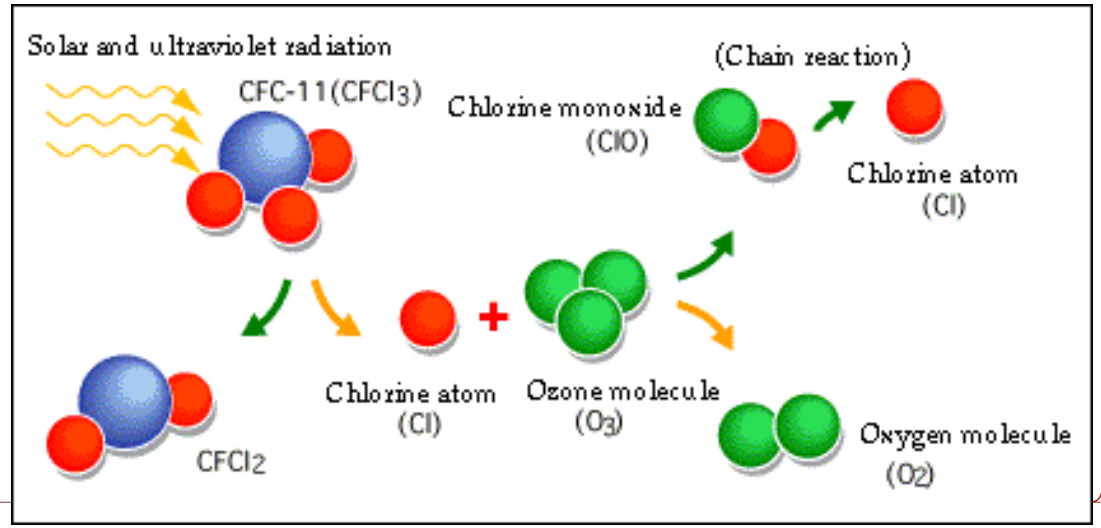
man-made GHG

Emission of greenhouse gases: CFCs

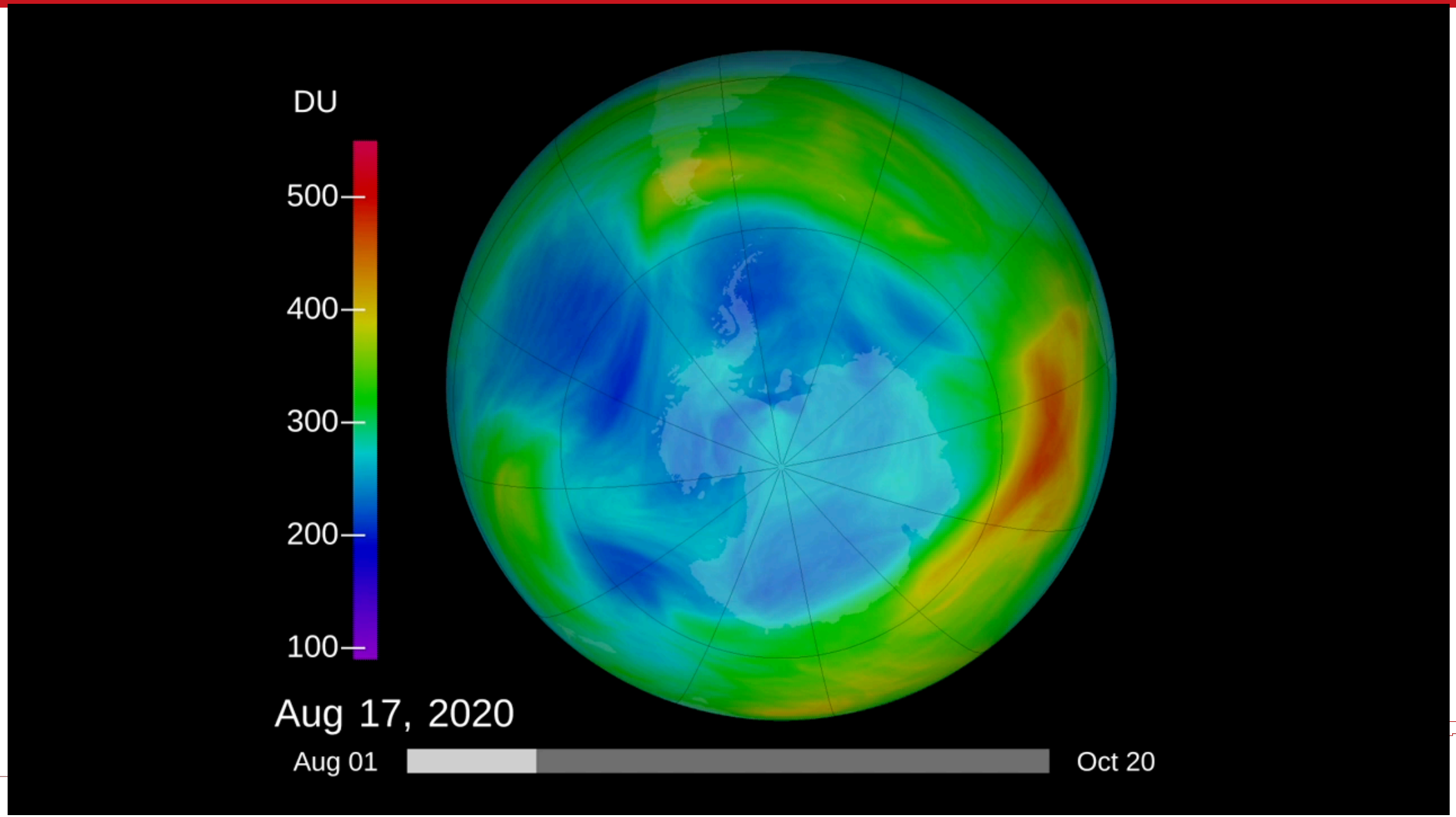


Montreal Protocol, effective1989

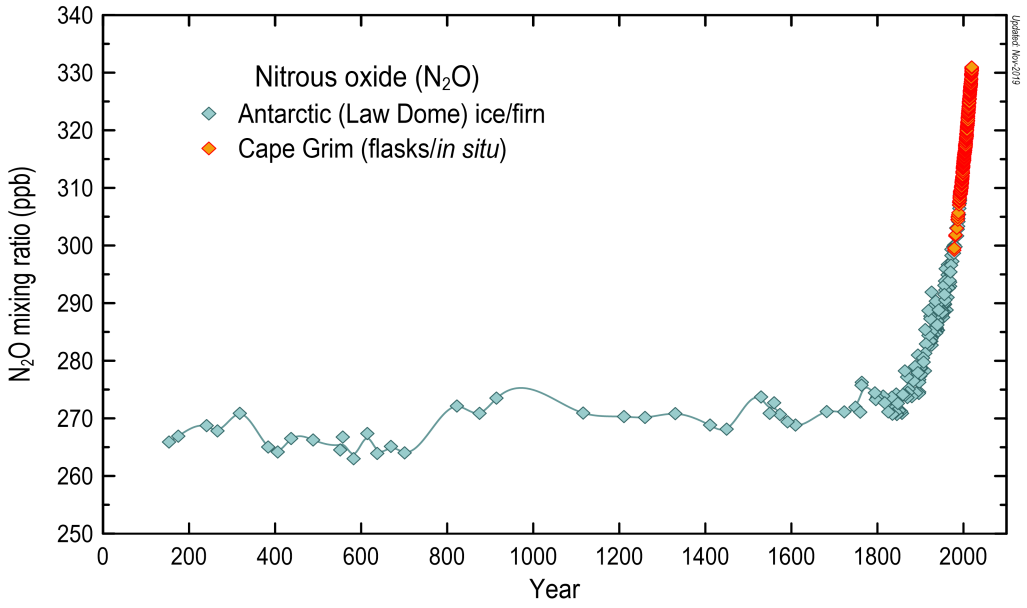
- strong greenhouse effect: strong absorption lines in the 8–12 μm region of the longwave spectrum where the surface emission is large;
- cause ozone depletion in the stratosphere

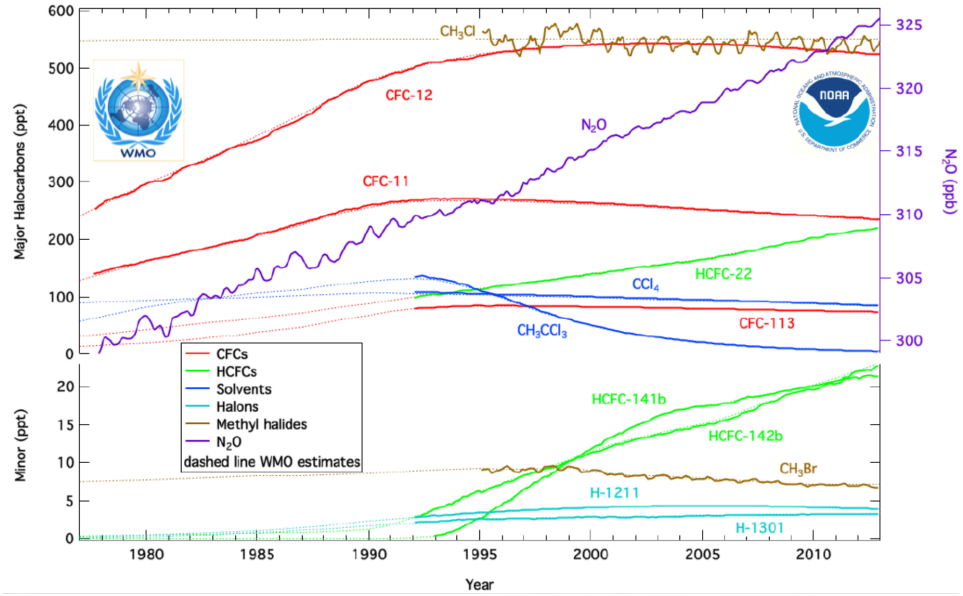


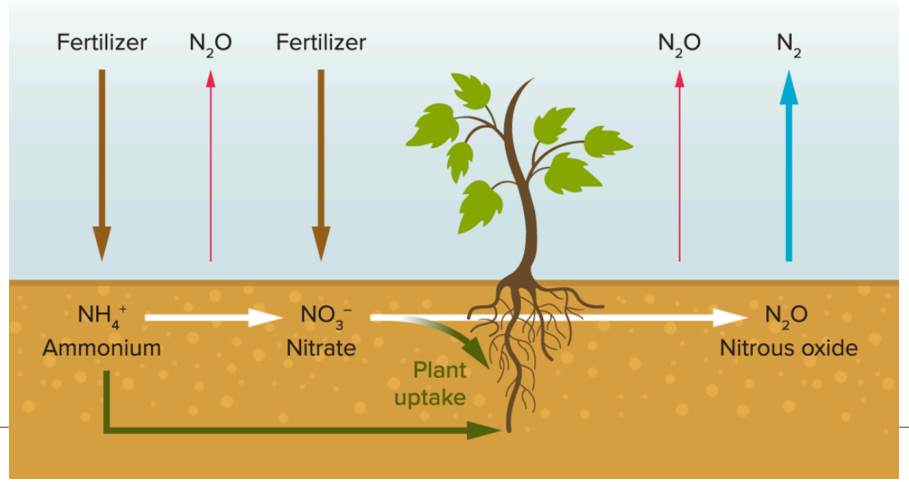
Ozone Hole in 2020



Emission of greenhouse gases: N_2O

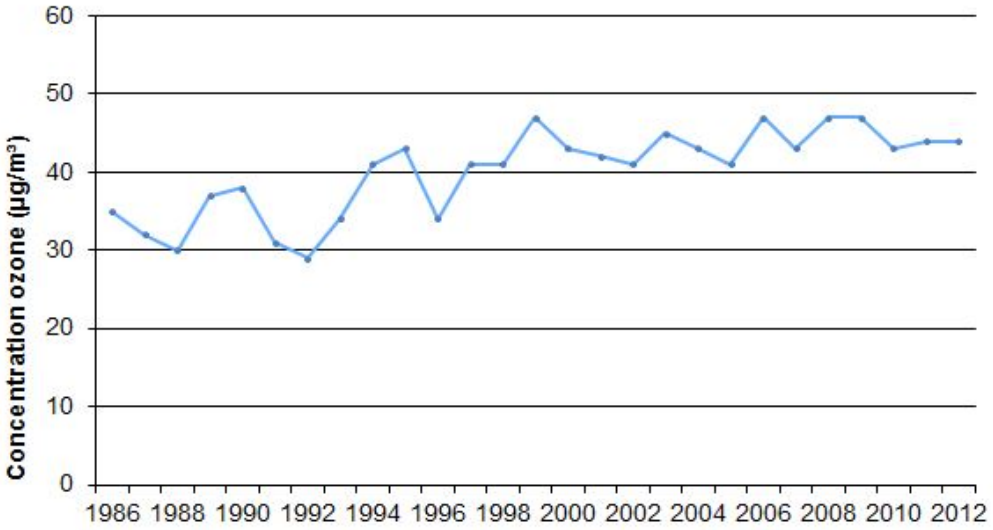


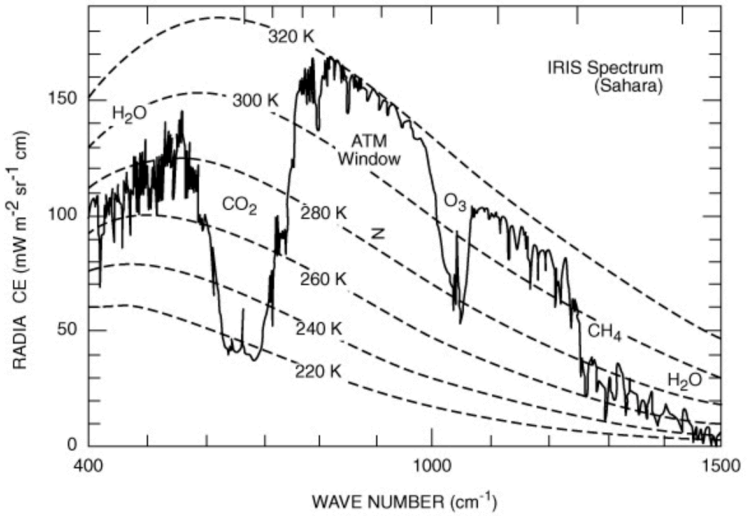


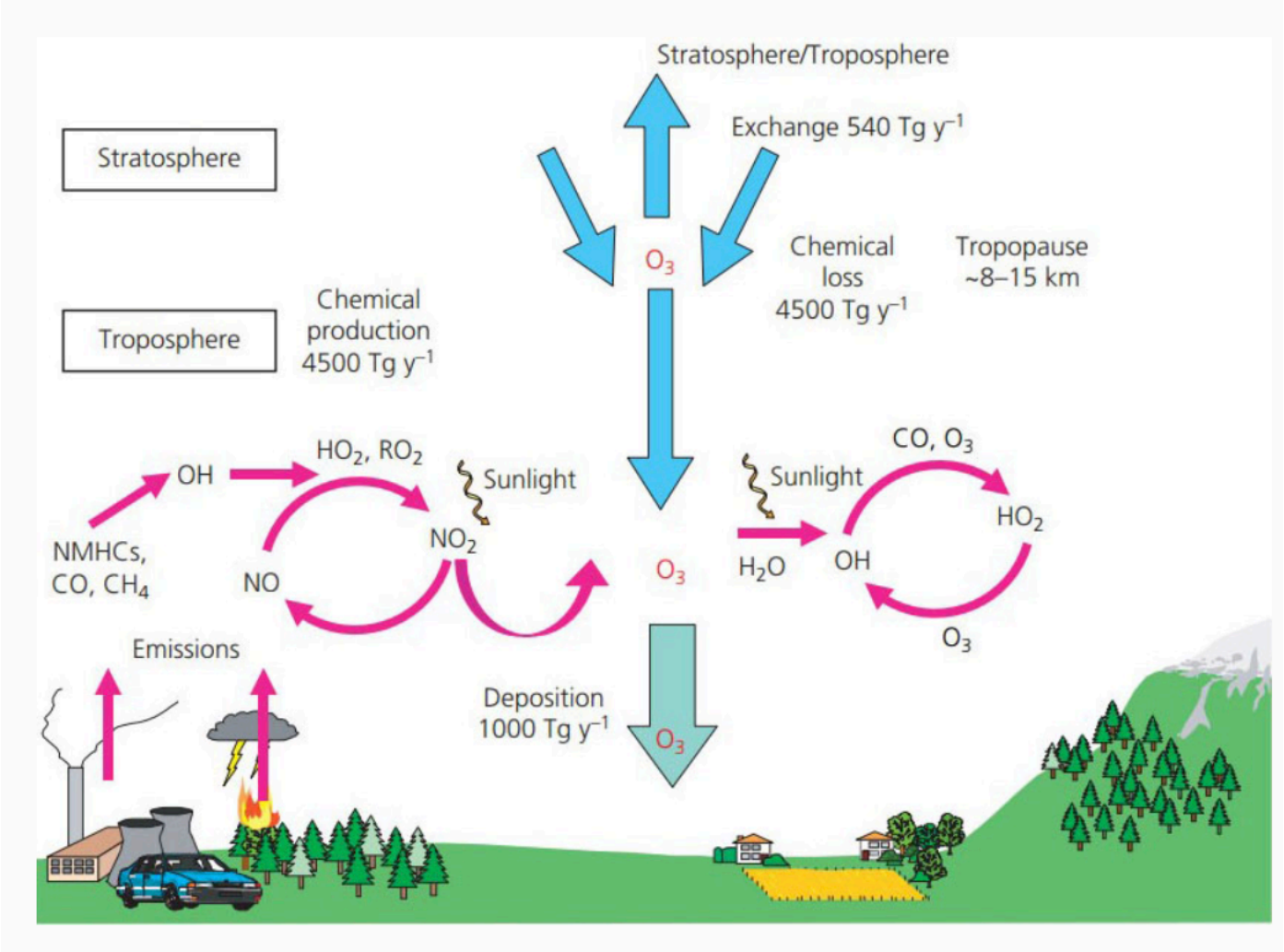


- ❖ Long-lived (~150yrs) effective greenhouse gas
- ❖ Anthropogenic sources:
- **Agriculture**
- Fuel Combustion
- Industry

Emission of greenhouse gases: O_3







Emission of aerosols

Aerosols: tiny suspended solid particles (dust, smoke, etc.) or liquid droplets in the atmosphere.

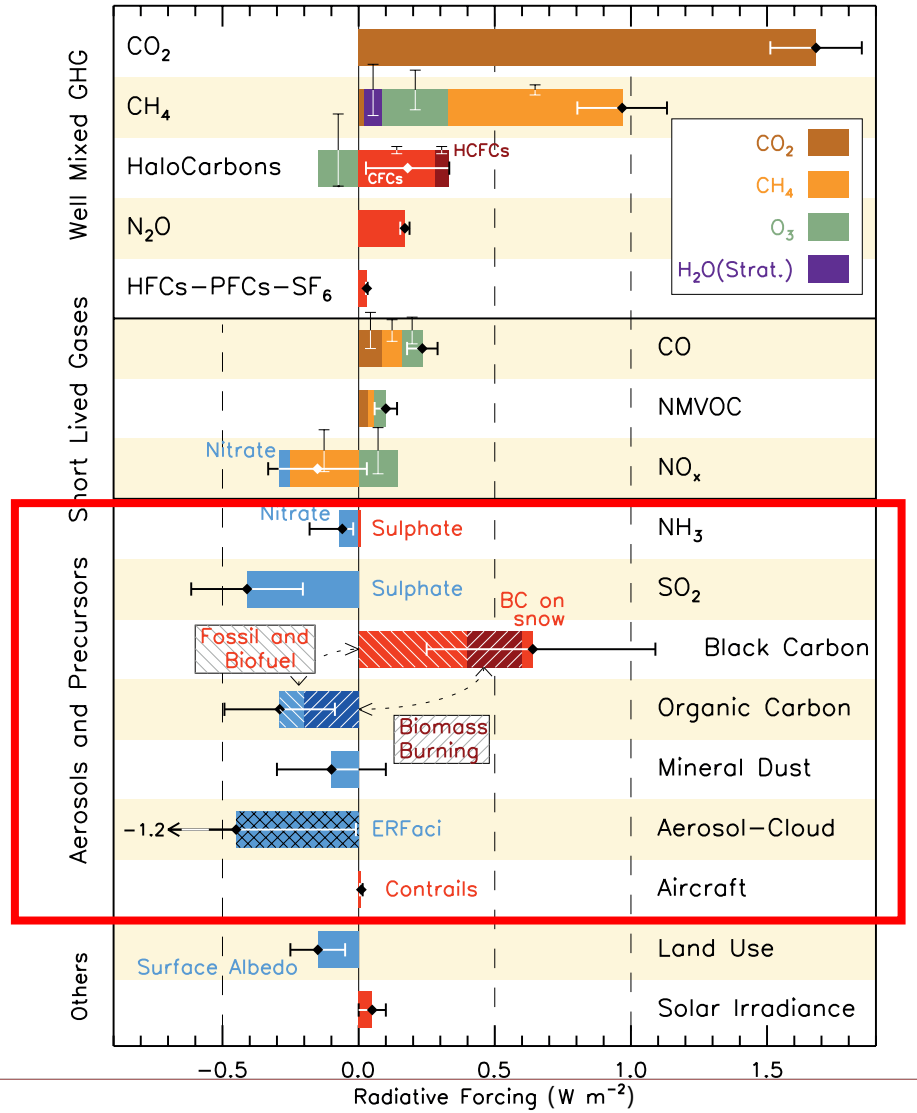
Sources of aerosols:

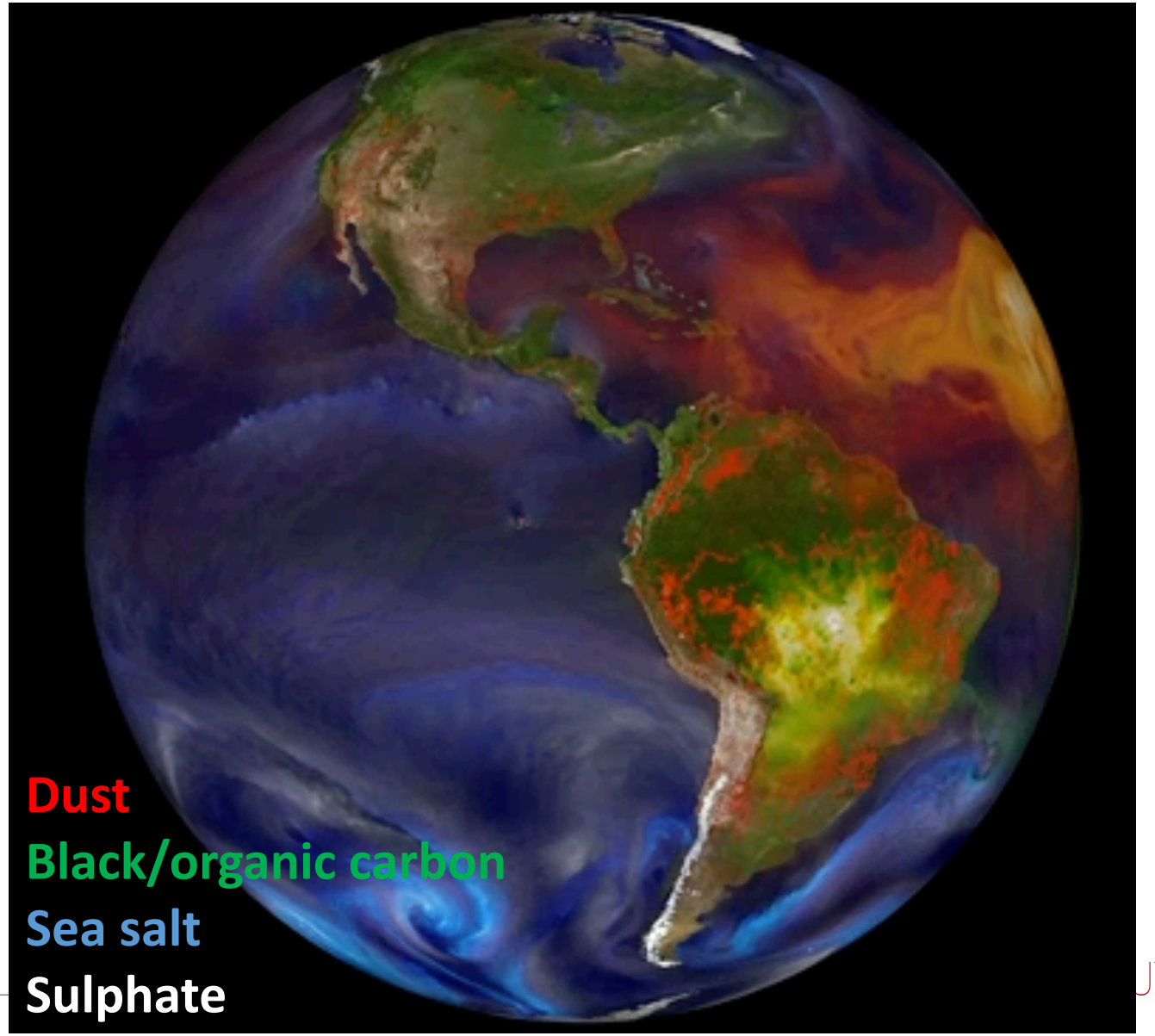
- dust
- black/organic carbon (from factory smoke, fires)
- salt from ocean spray
- Sulphate (SO_2 from burning fossil fuels)

Climate effect:

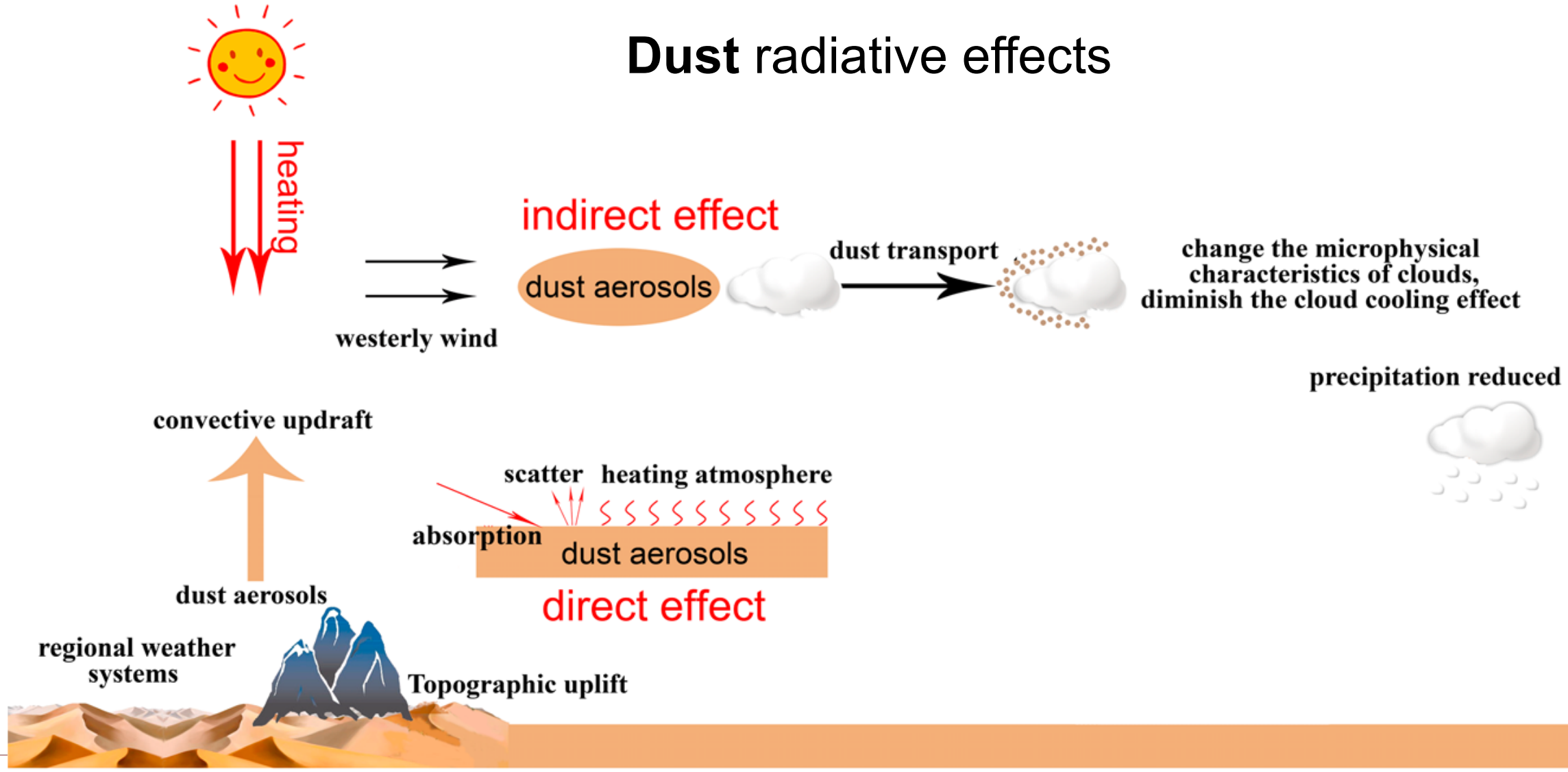
- Direct: influence solar and longwave radiative transmission
- Indirect: as cloud condensation nuclei

Emission of aerosols





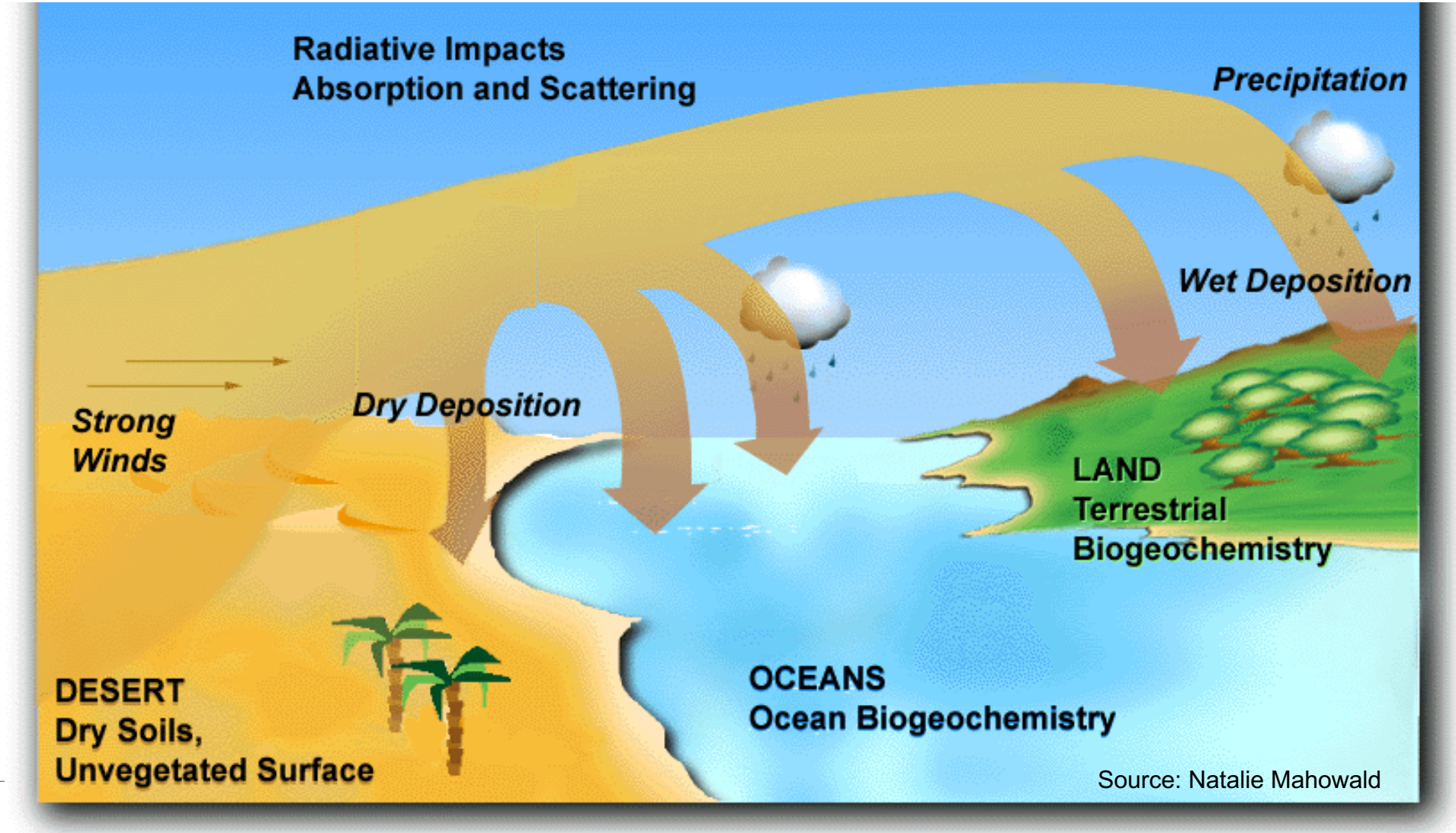
Emission of aerosols



Huang et al. (2014)

Emission of aerosols

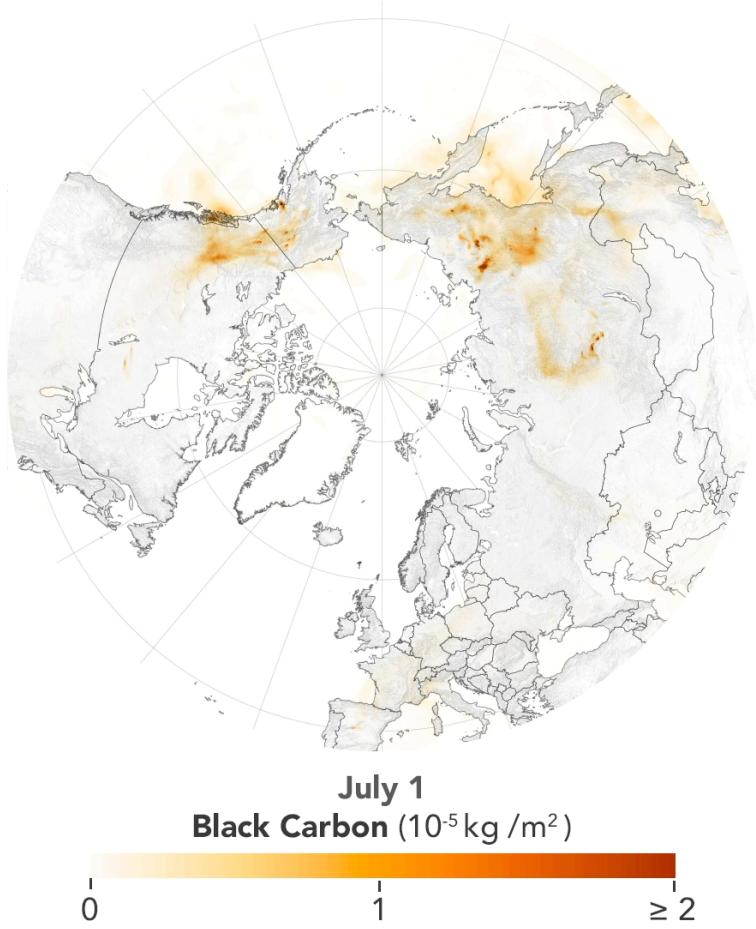
Dust radiative and biogeochemical influences



Emission of aerosols

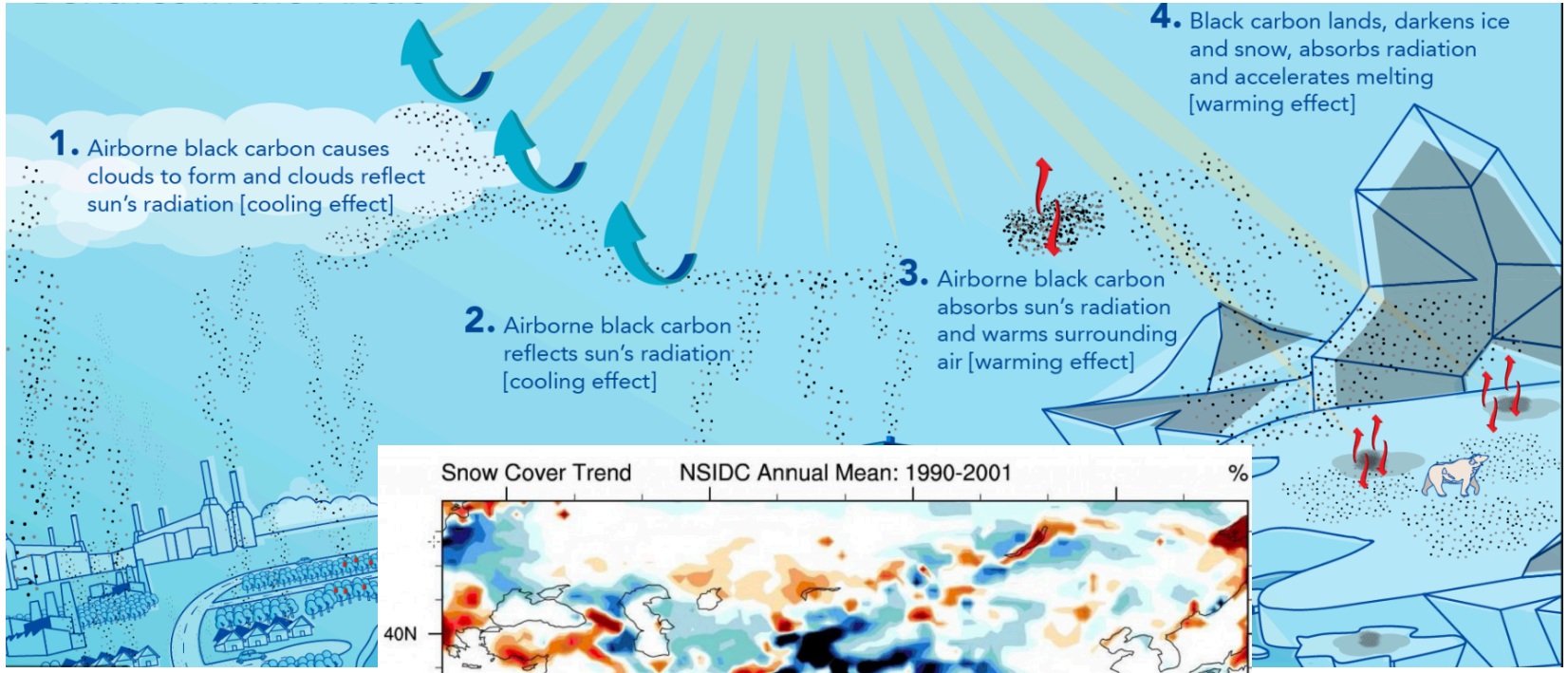
Black carbon

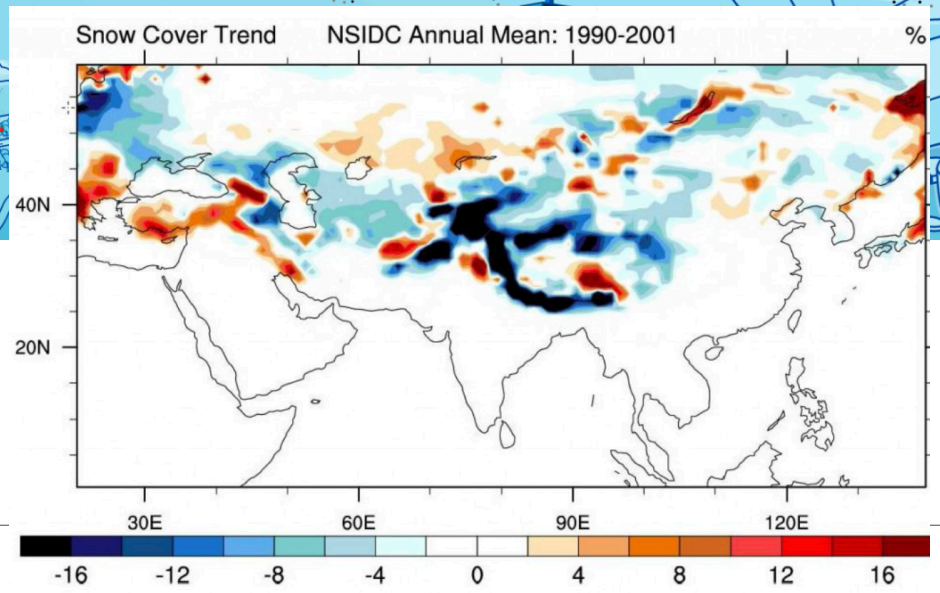
Northern high latitude fires from anomalous heat in 2019



Emission of aerosols

Black carbon accelerates snow melting





Land cover and land use change

- Deforestation increases CO_2;
- Deforestation influences albedo;
- Deforestation influences water cycle;

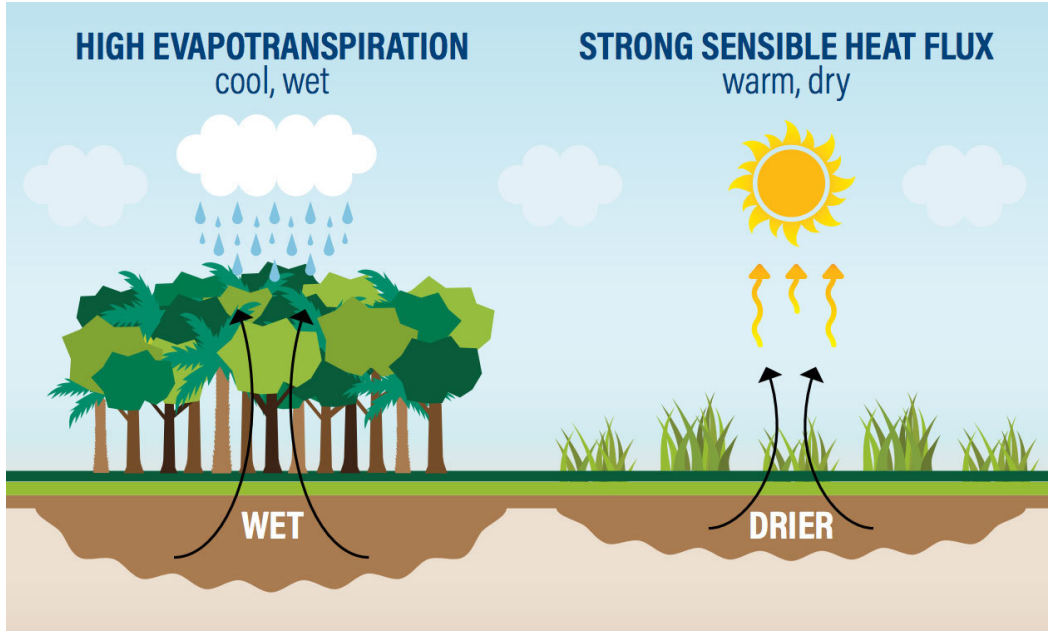


TABLE 2-1 Average Albedo Range of Earth's Surfaces

Surface	Albedo range (percent)
Fresh snow or ice	60–90%
Old, melting snow	40–70
Clouds	40–90
Desert sand	30–50
Soil	5–30
Tundra	15–35
Grasslands	18–25
Forest	5–20
Water	5–10

Adapted from W. D. Sellers, Physical Climatology *(Chicago: University of Chicago Press, 1965), and from R. G. Barry and R. J. Chorley,* Atmosphere, Weather, and Climate, *4th ed. (New York: Methuen, 1982).*

Future projections

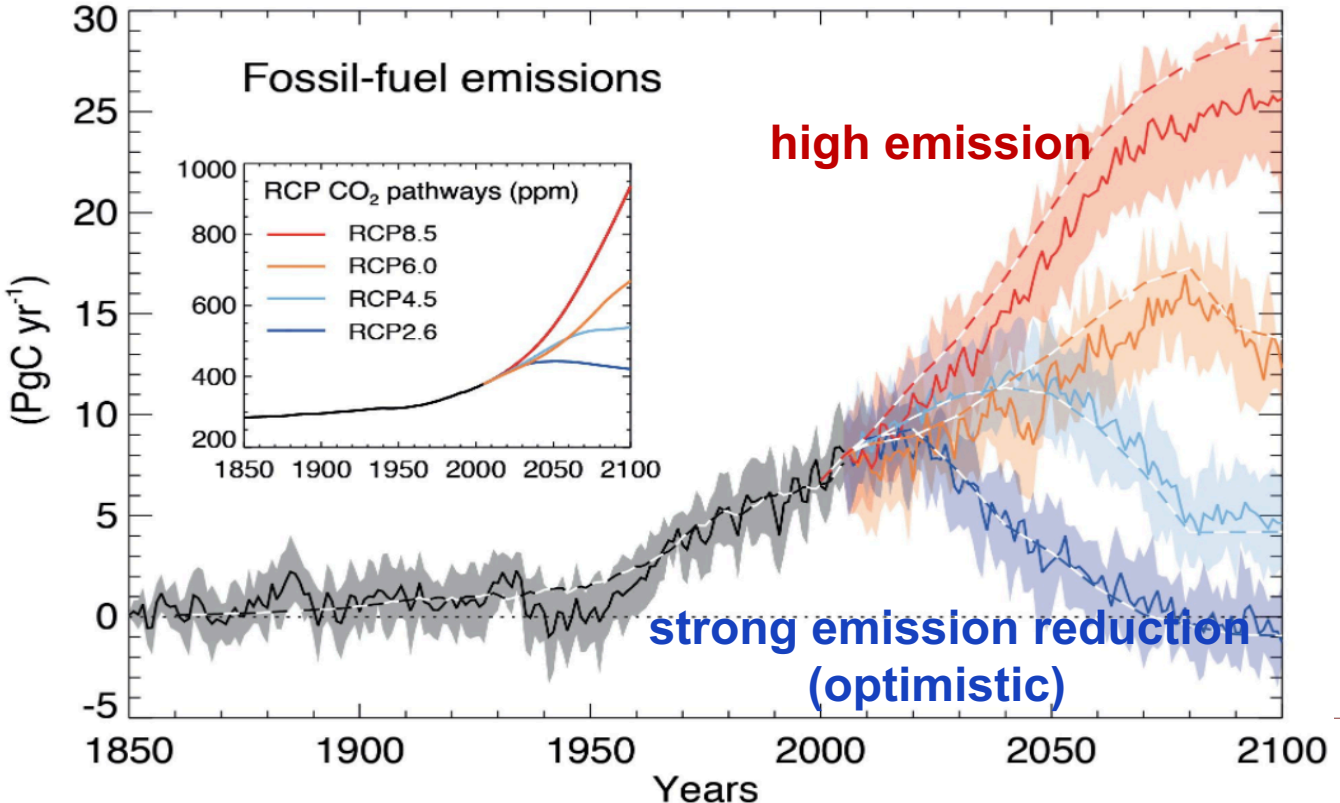
"If we had observations of the future, we obviously would trust them more than models, but unfortunately observations of the future are not available at this time."

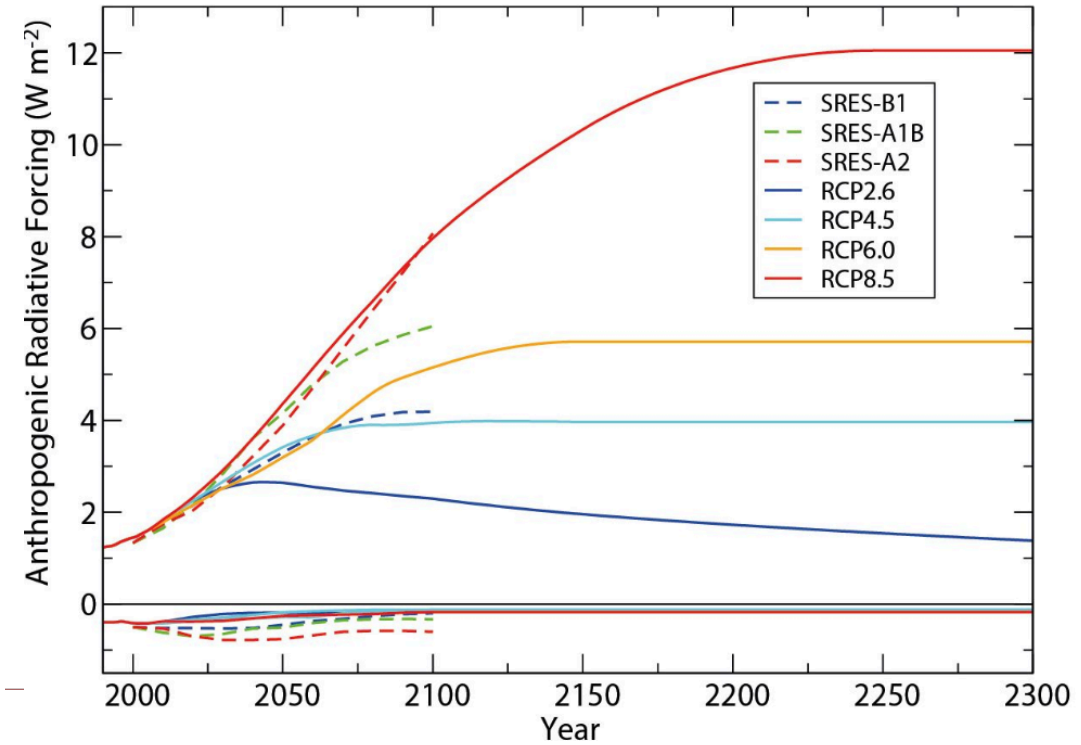
Tom Knutson and Robert Tuleya

Future projections

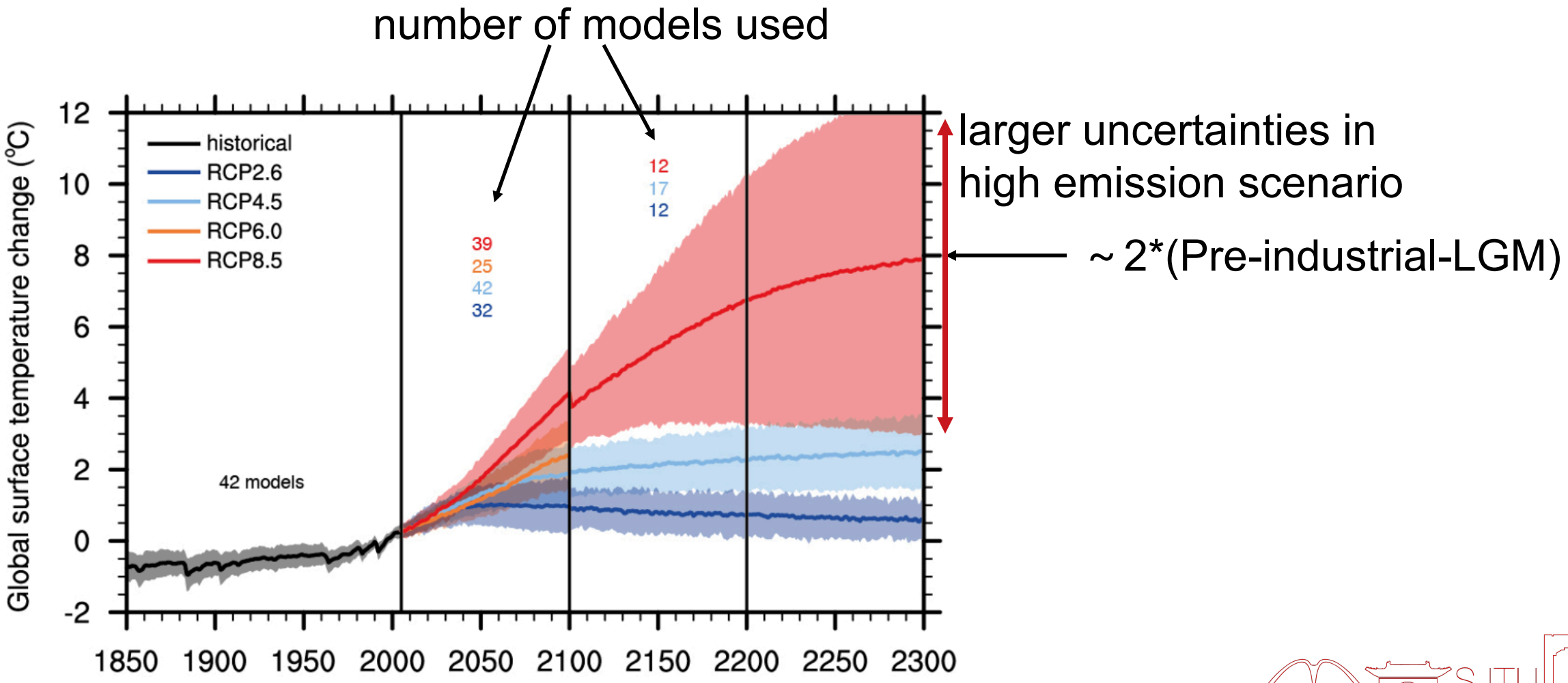
Representative Concentration Pathways (RCPs) (IPCC AR5)& Shared Socioeconomic Pathways (SSPs) (IPCC AR6)

- "What if" experiments
- Depends on economics and policy

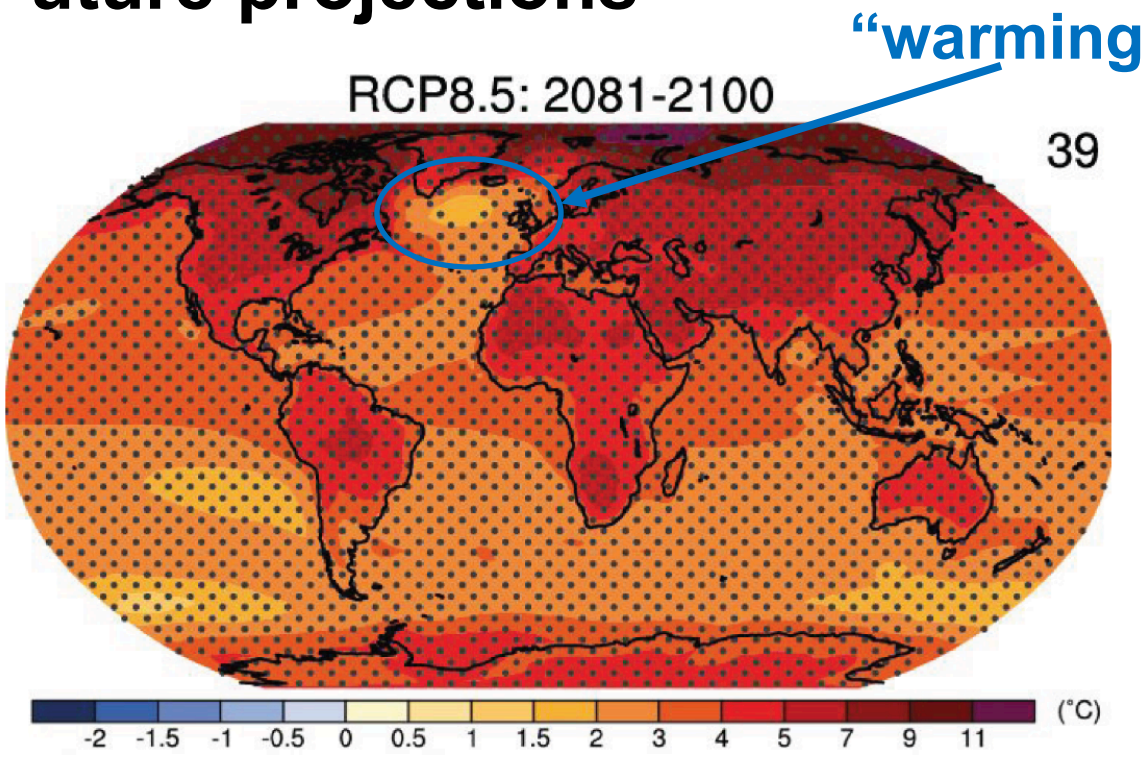


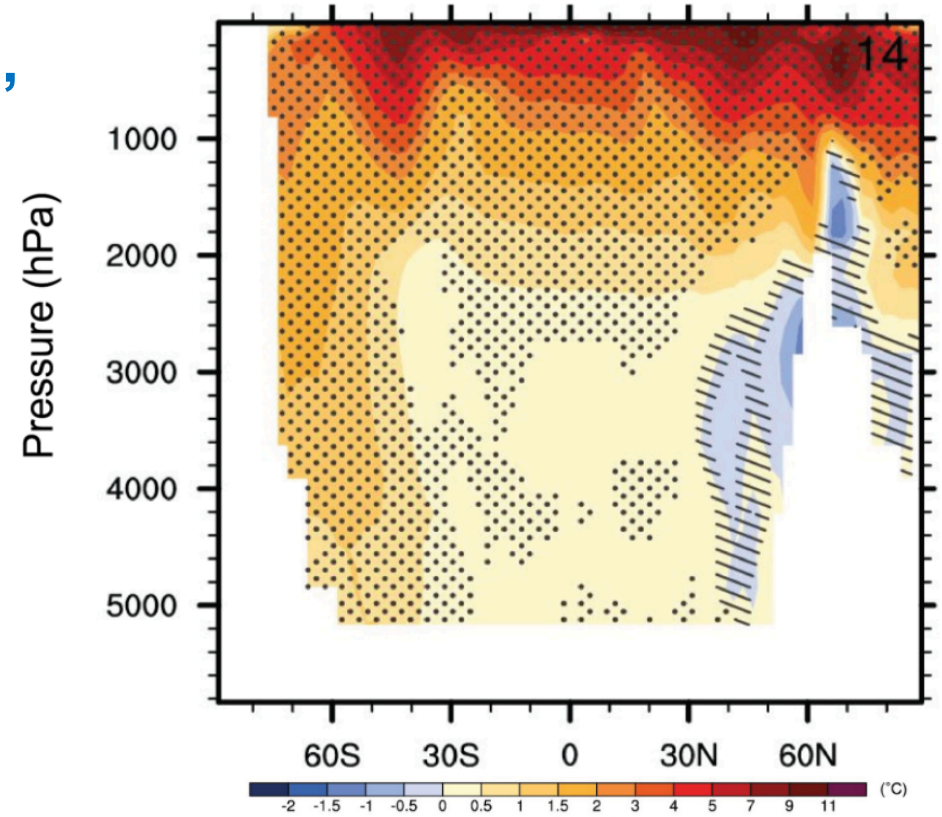


Future projections



Future projections





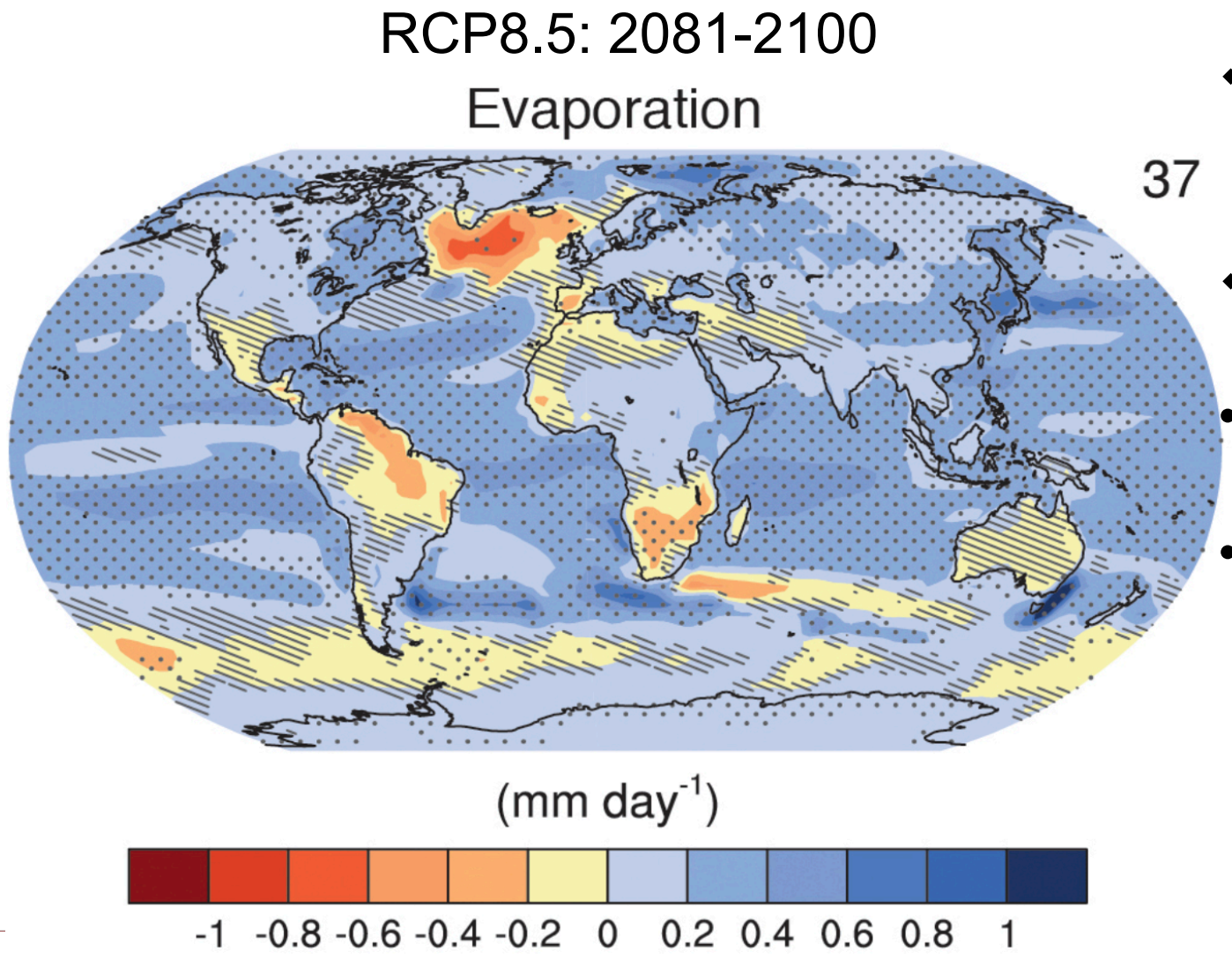
- More warming over land than the ocean:
  1. larger ocean heat capacity
  2. water availability limits evaporative cooling
- More warming in Arctic
  1. ice albedo feedback
  2. increase latent heat (water vapor)

- More warming in the surface ocean

(->increase of stratification and reduce vertical mixing ->weaken the meridional overturning circulation and nutrient delivery to the euphotic zone)

- Warming penetrate deeper into the ocean interior particularly in regions of deep water formation such as the Southern Ocean

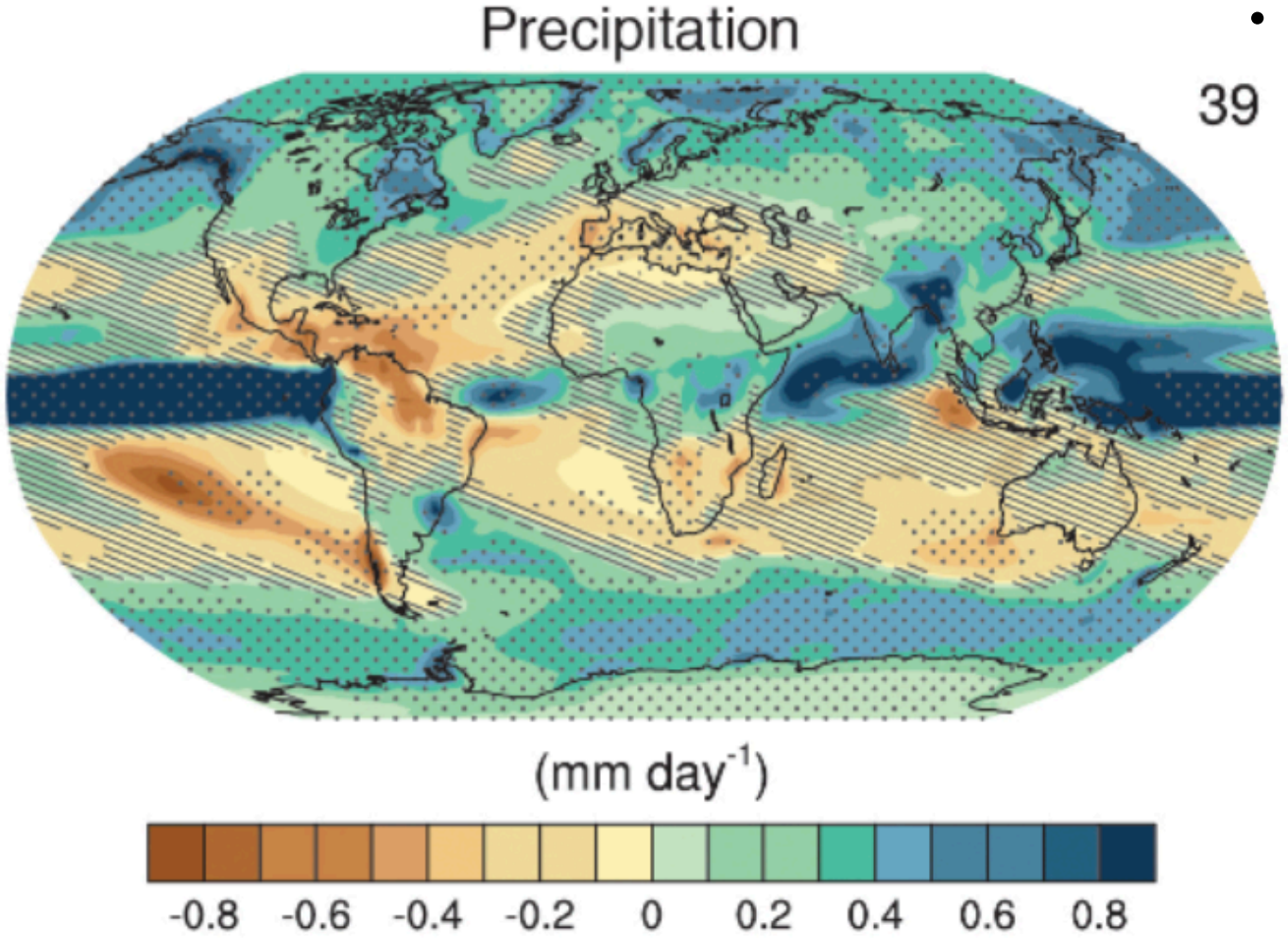
Future projections



- More evaporation almost everywhere due to increased temperature;
- Reduced evaporation over surface ocean regions with little warming:
  - North Atlantic (AMOC->warming hole)
  - Southern Ocean

Future projections

RCP8.5: 2081-2100

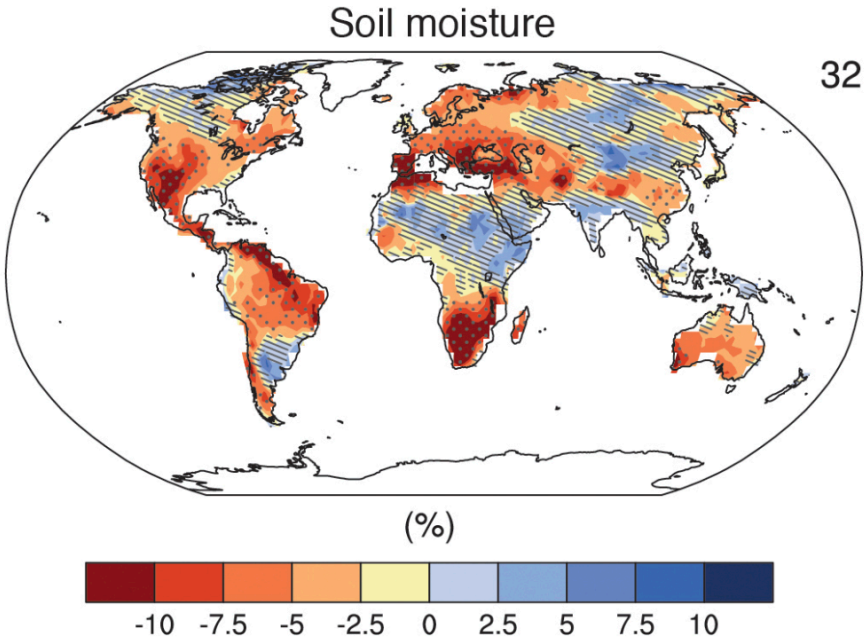


Wet get wetter, dry get drier

- More precipitation where it is already wet: High latitudes & Tropics
- Reduced precipitation where it is already dry: Subtropics

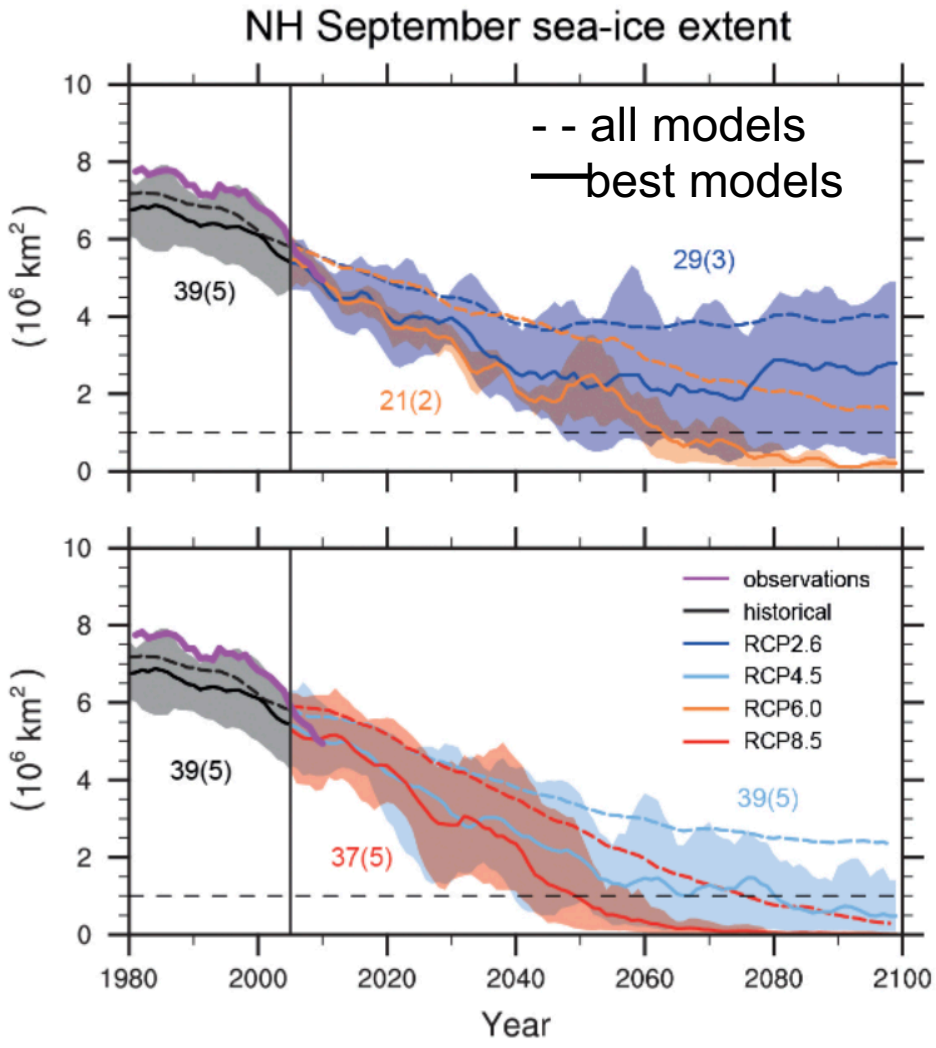
Why?

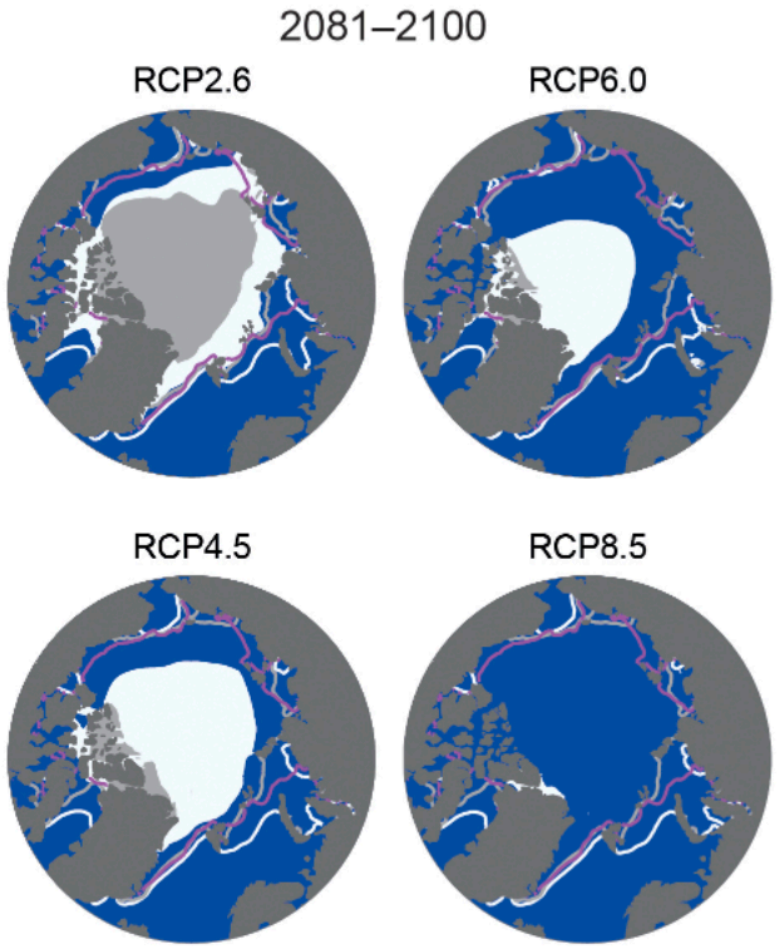
Warmer atmosphere holds more water vapor->more water vapor transport



Future projections

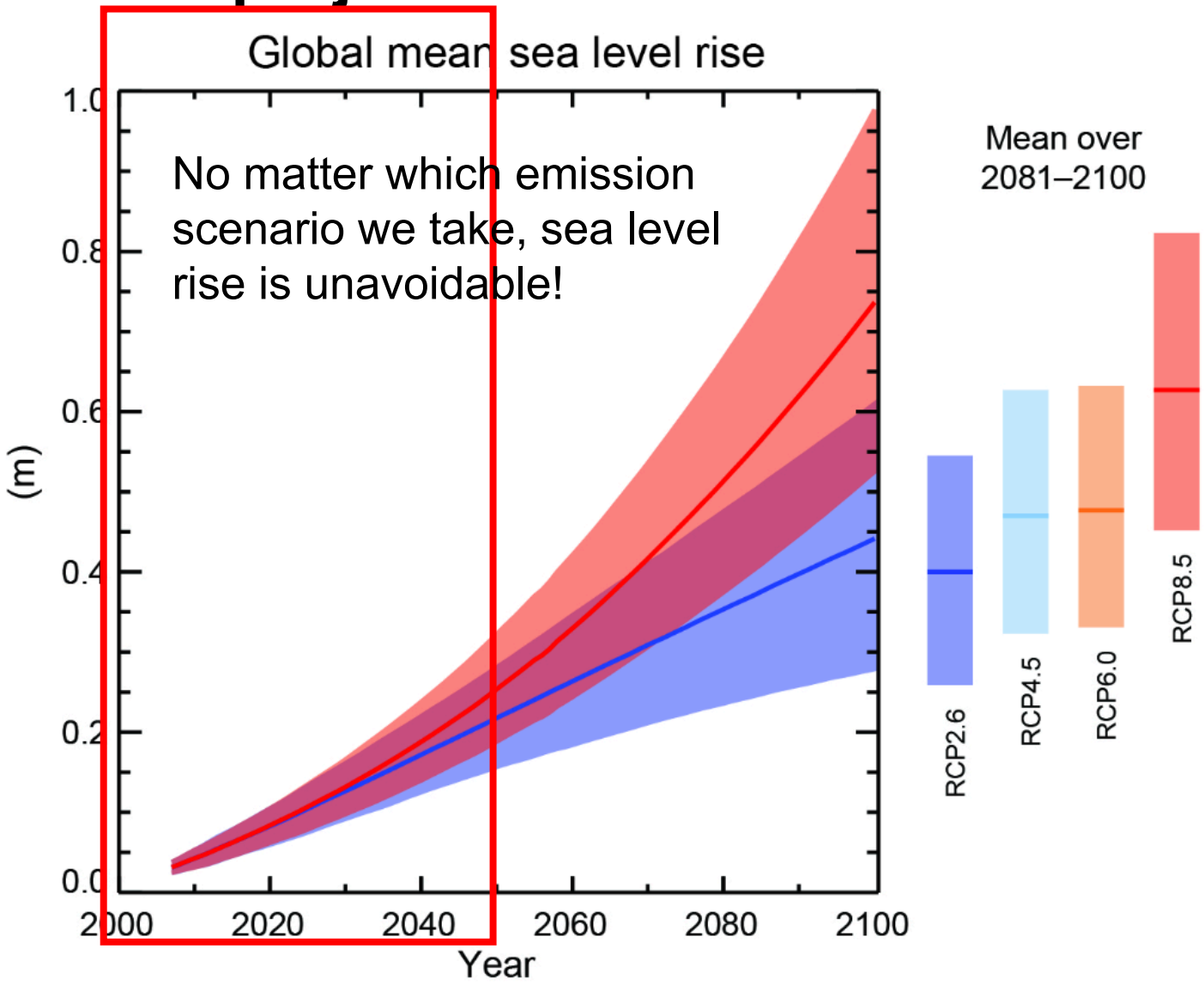
Arctic Sea Ice





white: all models
grey: best models

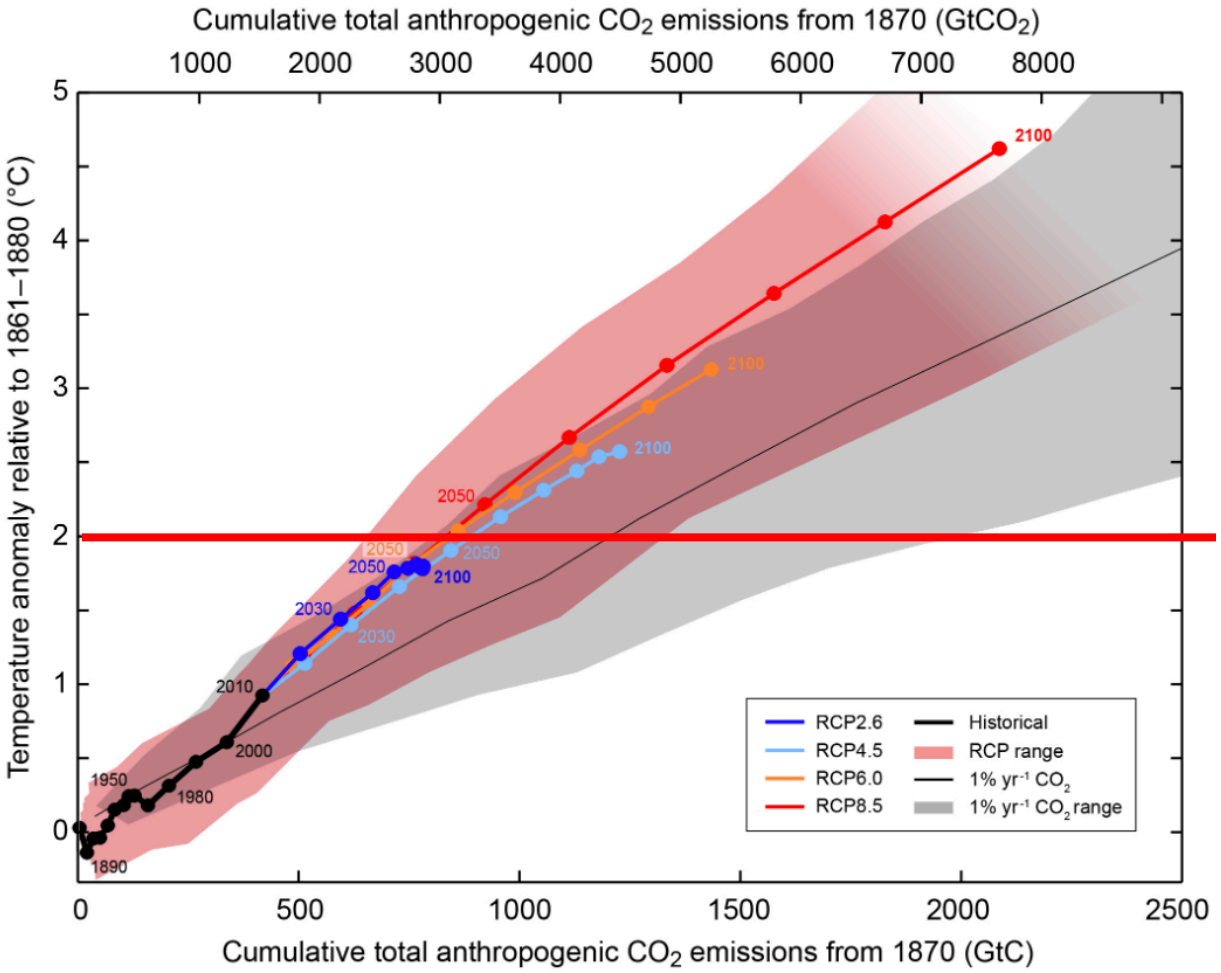
Future projections



Sea Level rise by:

- Ice sheets & Glacier melting
- Thermal expansion

Future projections



Global mean temperature can be well approximated by **cumulative carbon emissions**:

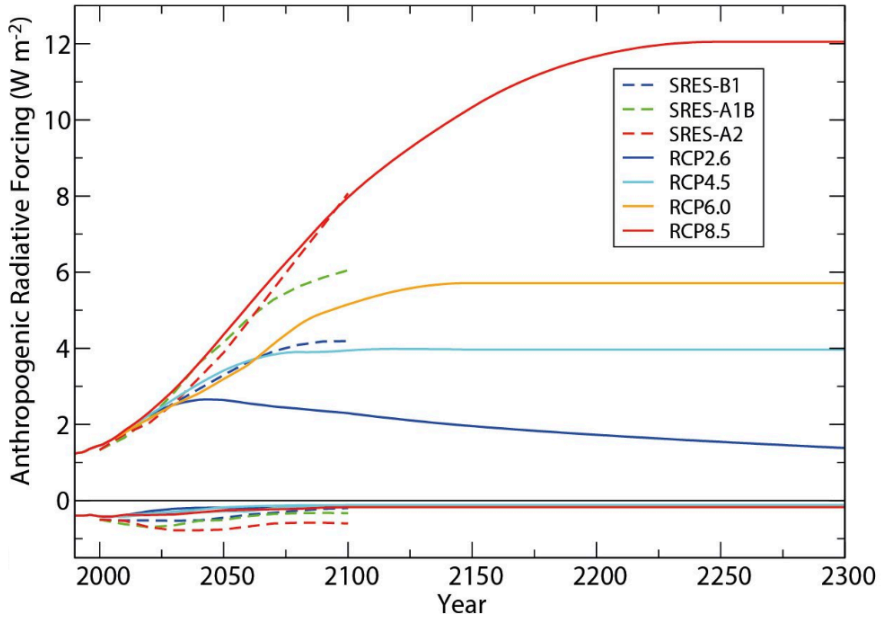
500GtC~1℃

Paris Agreement

Future projections
Uncertainties

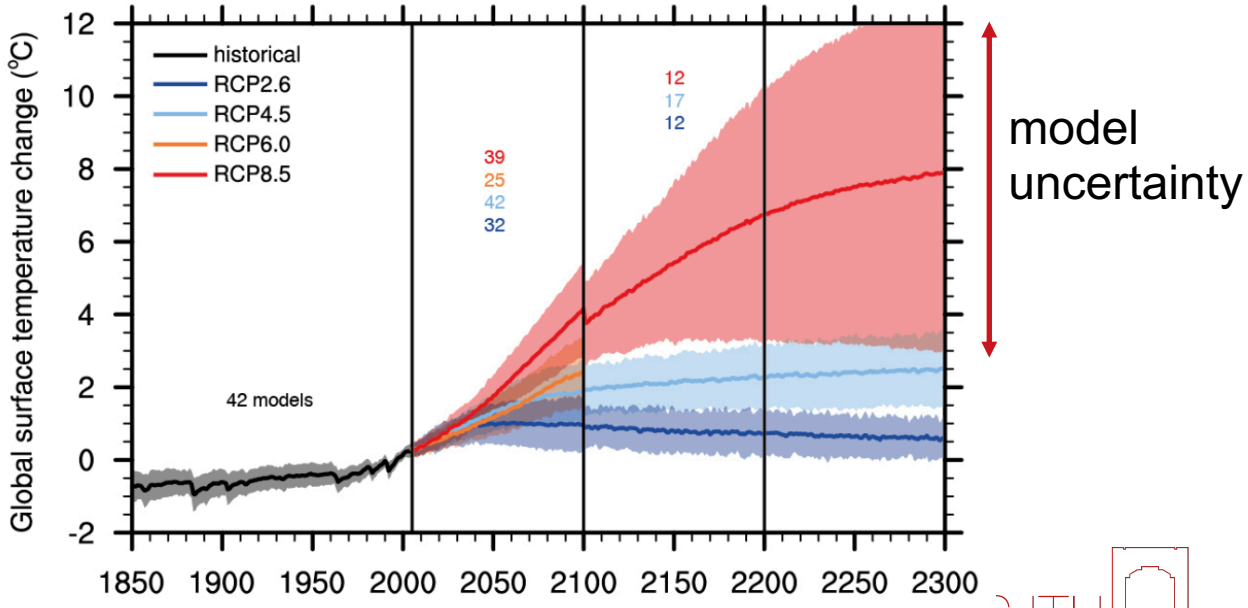
- **Emissions**

Future economic development?
Different Scenarios result in different emissions of substances that affect climate (CO_2, CH_4, SO_2, N_2O…)



- **Climate sensitivity in climate models**

For a given CO2 concentration scenario, we don't know exactly how much climate will warm (cloud feedbacks)



Future projections

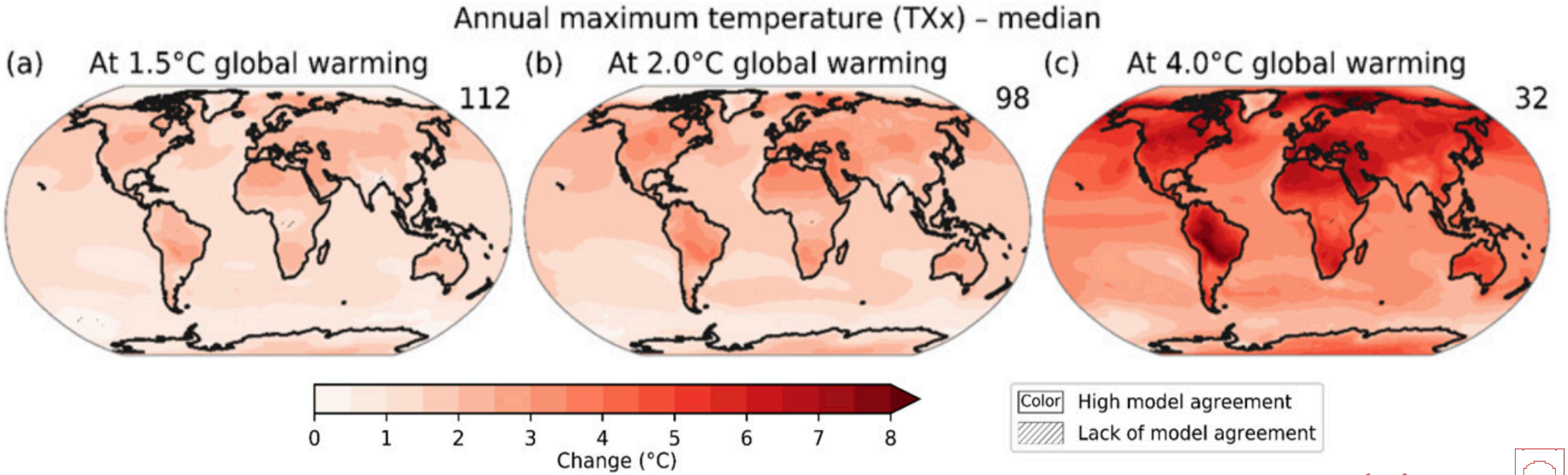
Summary

- Current trends will continue (warming, ice melt, sea level rise…);
- Temperature changes will be unequal (land vs ocean; Arctic vs tropics);
- Hydrological cycle: wet get wetter, dry get drier;
- Cumulative carbon emissions will determine future levels of global warming;
- Projection uncertainties: emission scenarios & climate model

Impacts of climate change

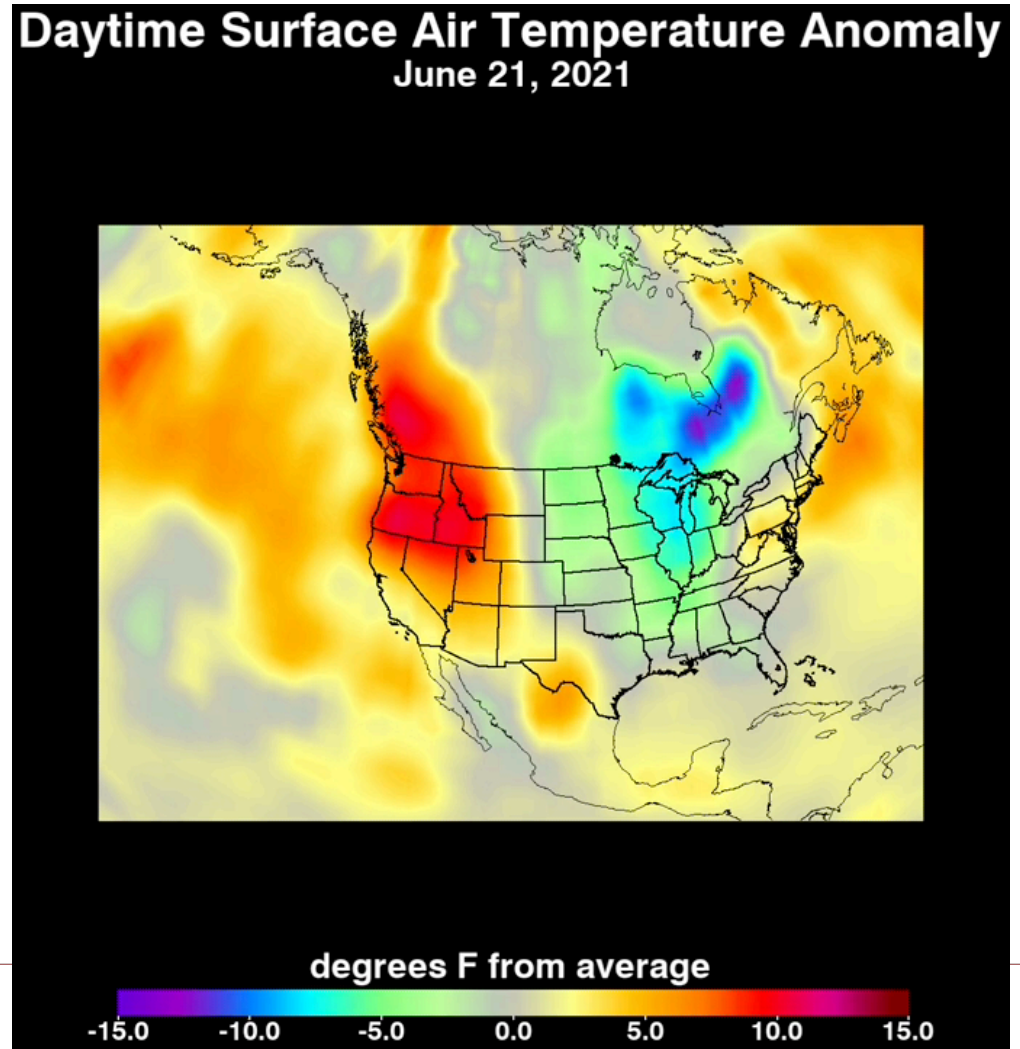
Extreme Events: Hot extremes

Increase of the length, frequency, and/or intensity of heat waves



Impacts of climate change

Extreme Events: Hot extremes



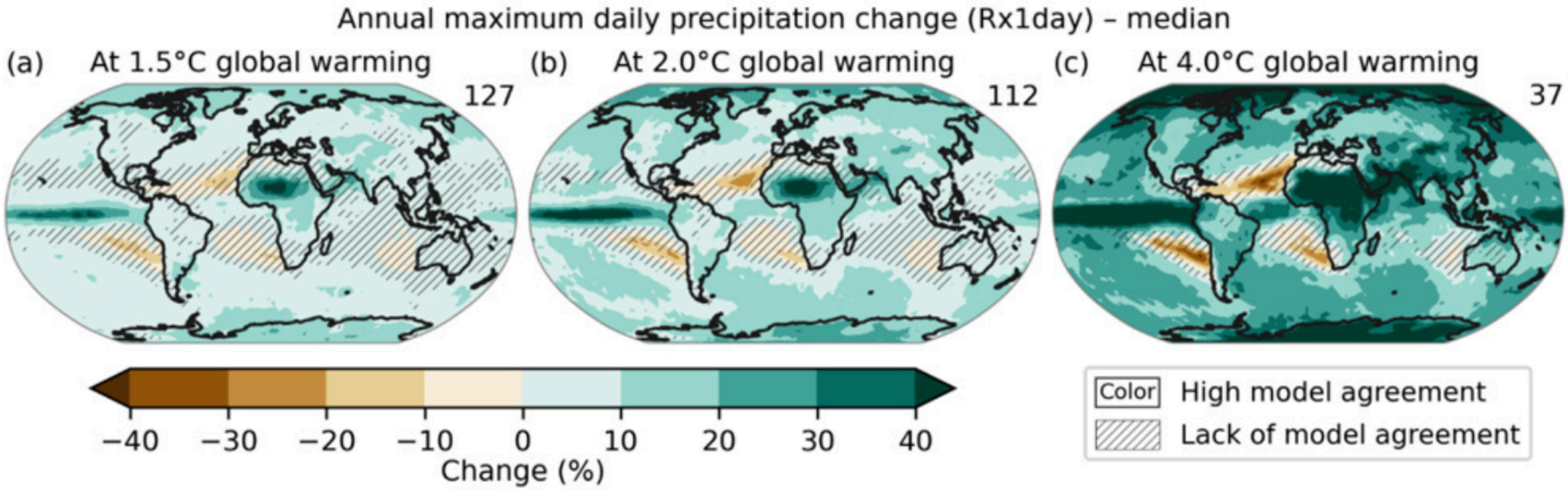
Record-breaking Pacific northwest “heat dome”

A cooling center in Oregon as Portland endures historic record-breaking temperatures in 2021

Impacts of climate change

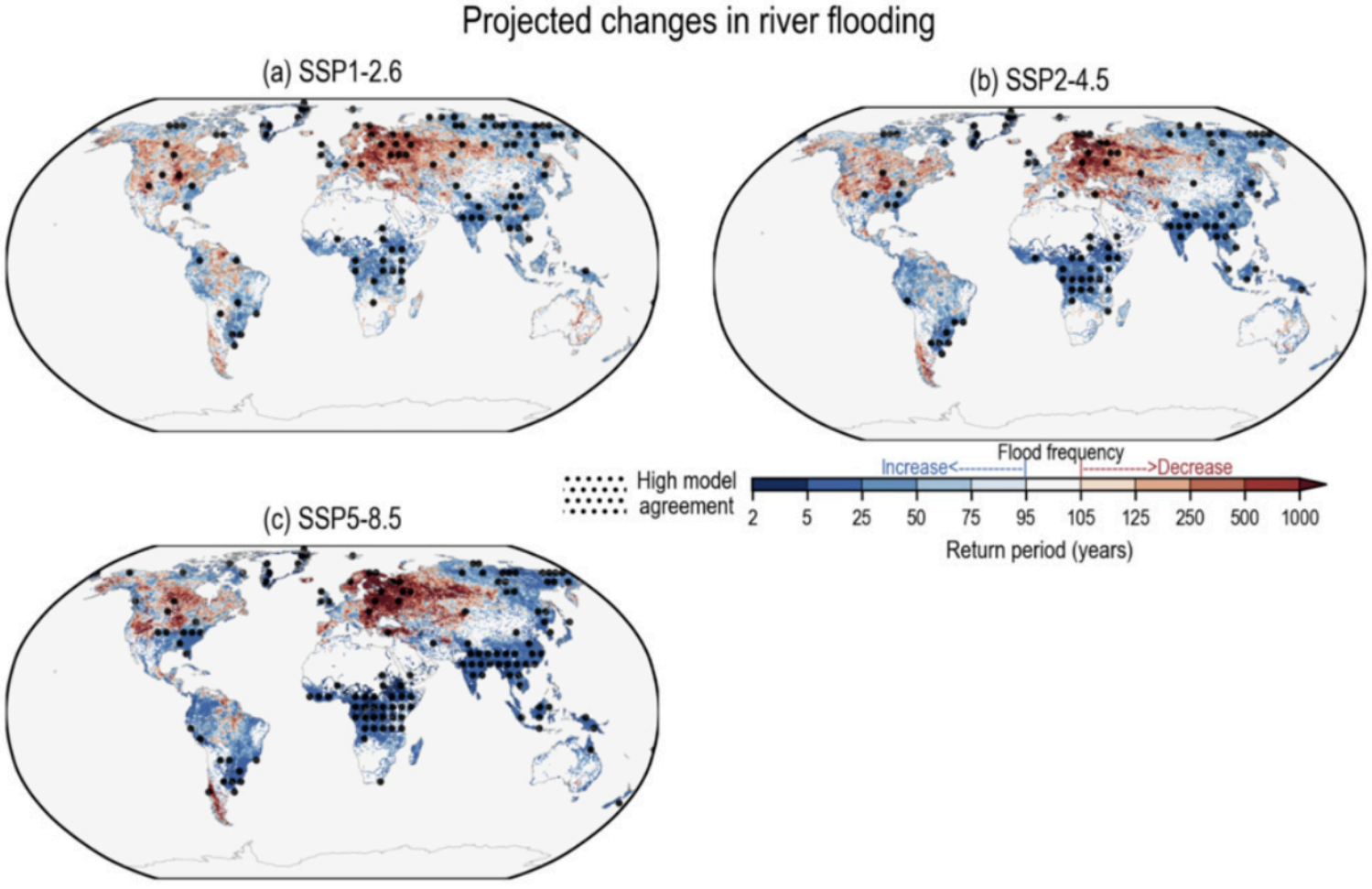
Extreme Events: Heavy rainfalls

Heavy precipitation events will become more frequent and more intense
(Water vapor content increase ~7%/1℃ of warming)



Impacts of climate change

Extreme Events: Heavy rainfalls -> More flooding



Impacts of climate change

Extreme Events: Droughts

- Thermodynamic processes: increase evaporation by temperature, wind speed and relative humidity.
- Dynamic processes: change in precipitation by occurrence, duration and intensity of weather anomalies.