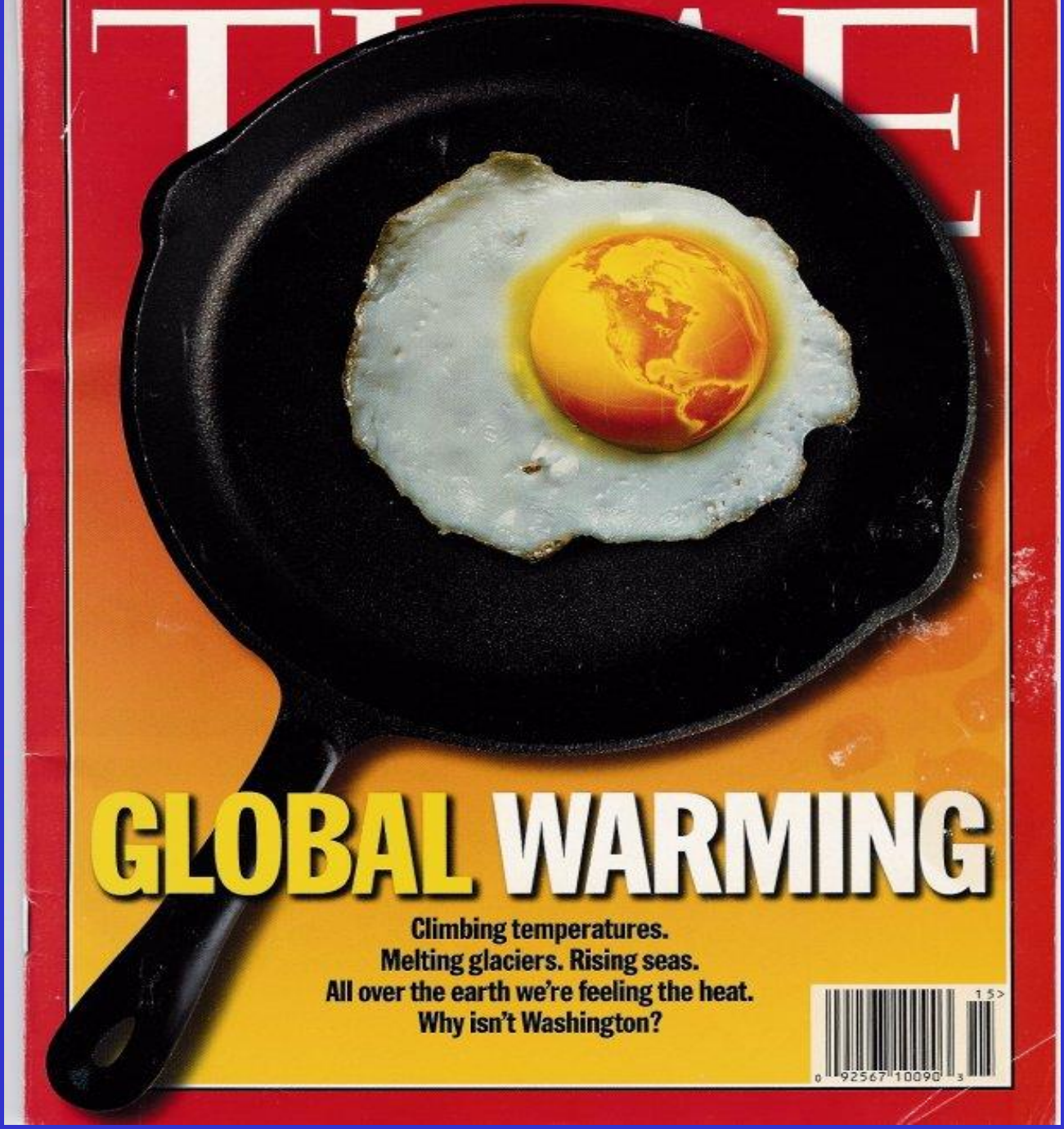
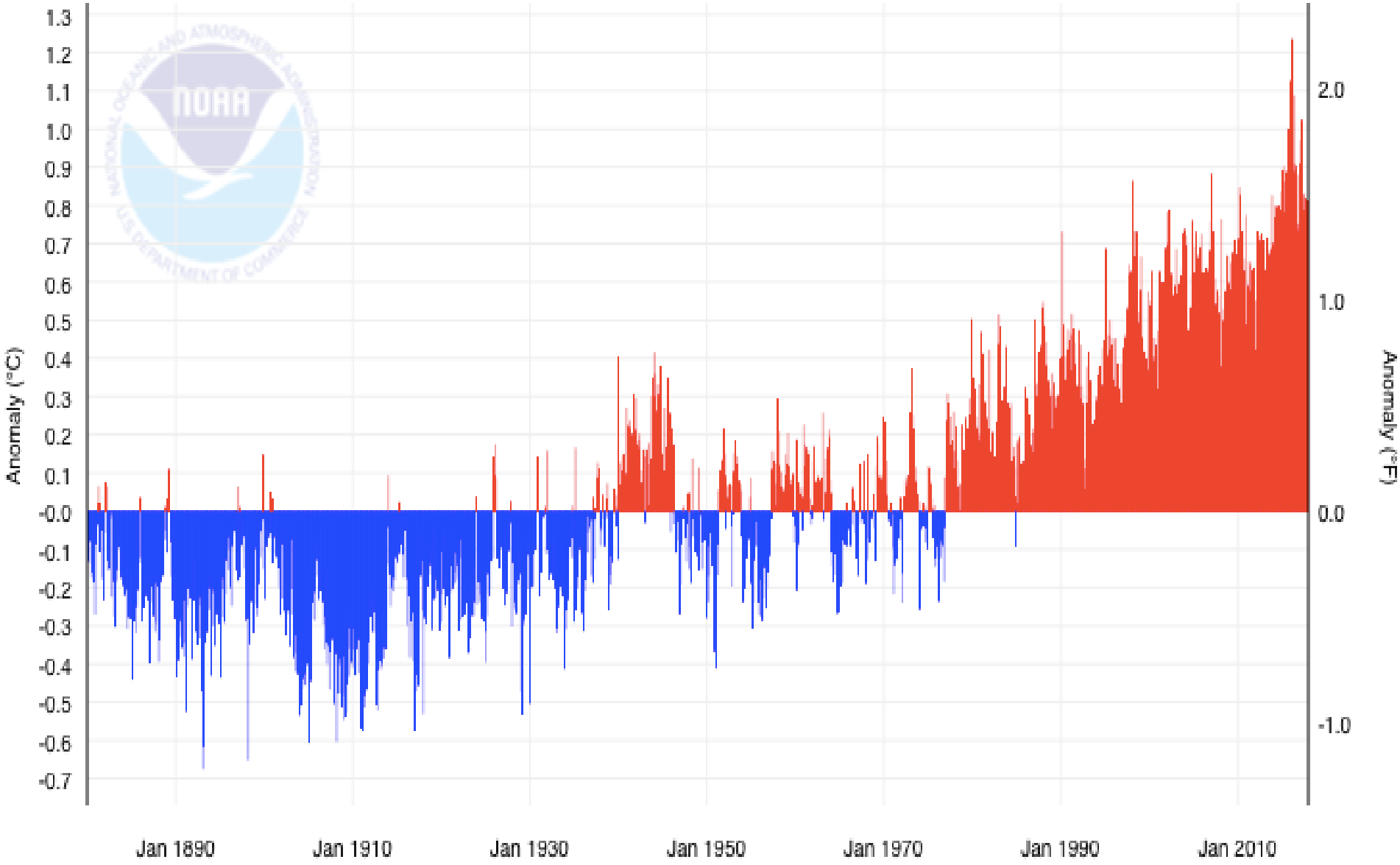

TIME
GLOBAL WARMING
Climbing temperatures.
Melting glaciers. Rising seas.
All over the earth we're feeling the heat.
Why isn't Washington?

BAL
CANADIAN SHORE DR
HAL
WILLOWRUN CIR
WILLOWAY DR
DAL
WEMBLETON CIR
GAL
DAL
FAL
WILLOWISP DR

NO
BOATS

Global Land and Ocean Temperature Anomalies

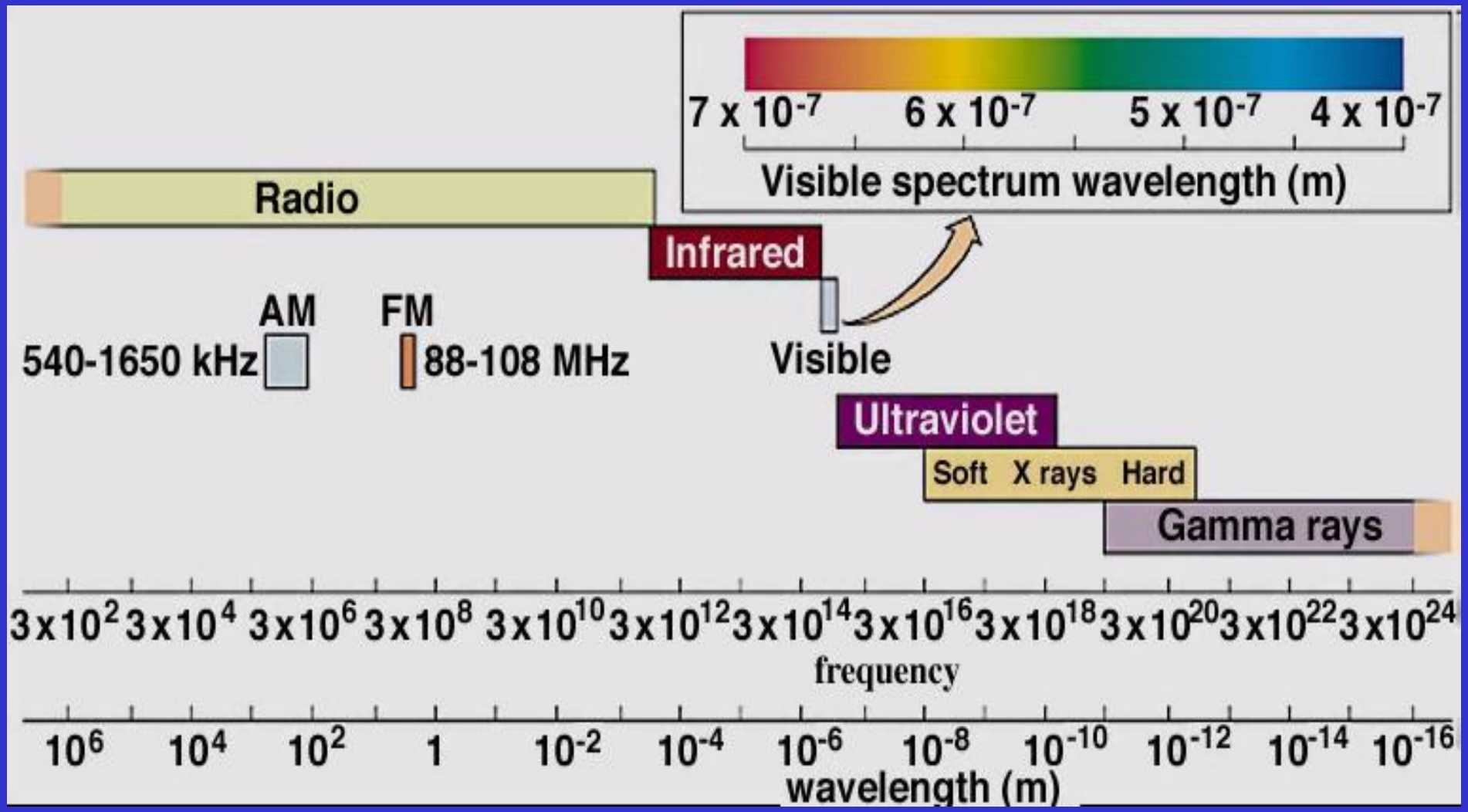


The Earth's Energy Balance

- Energy to drive the atmosphere comes from the sun

- Energy transmitted as Radiation

Electromagnetic Spectrum

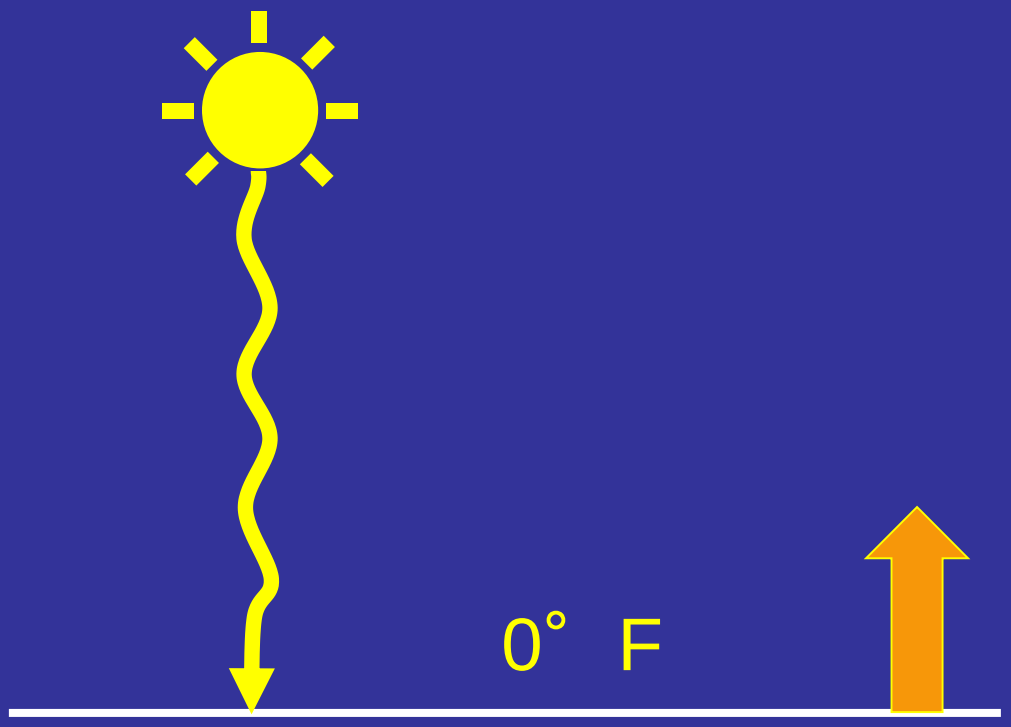


What is the Temperature of the Earth?

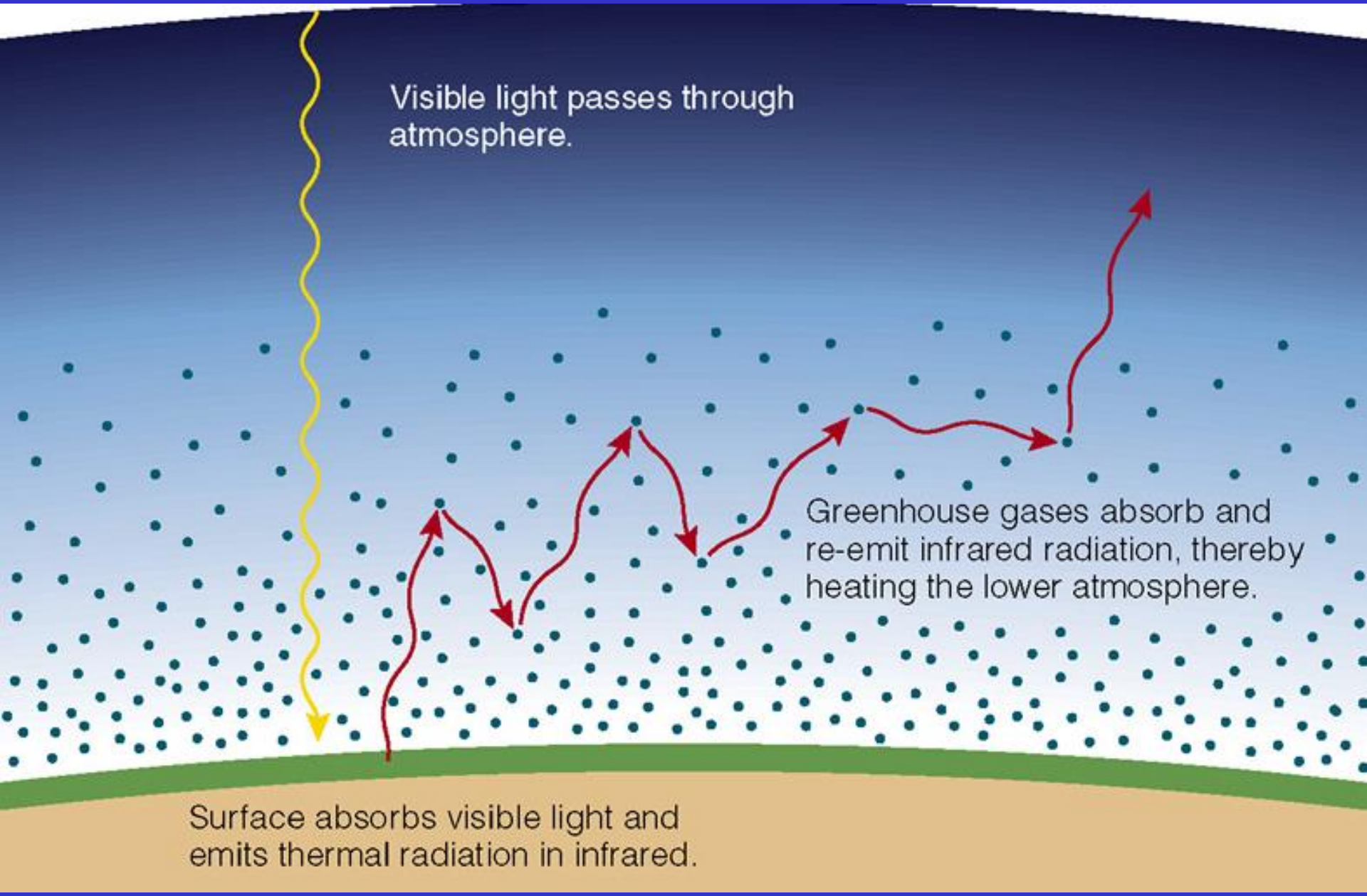
Provide an estimate

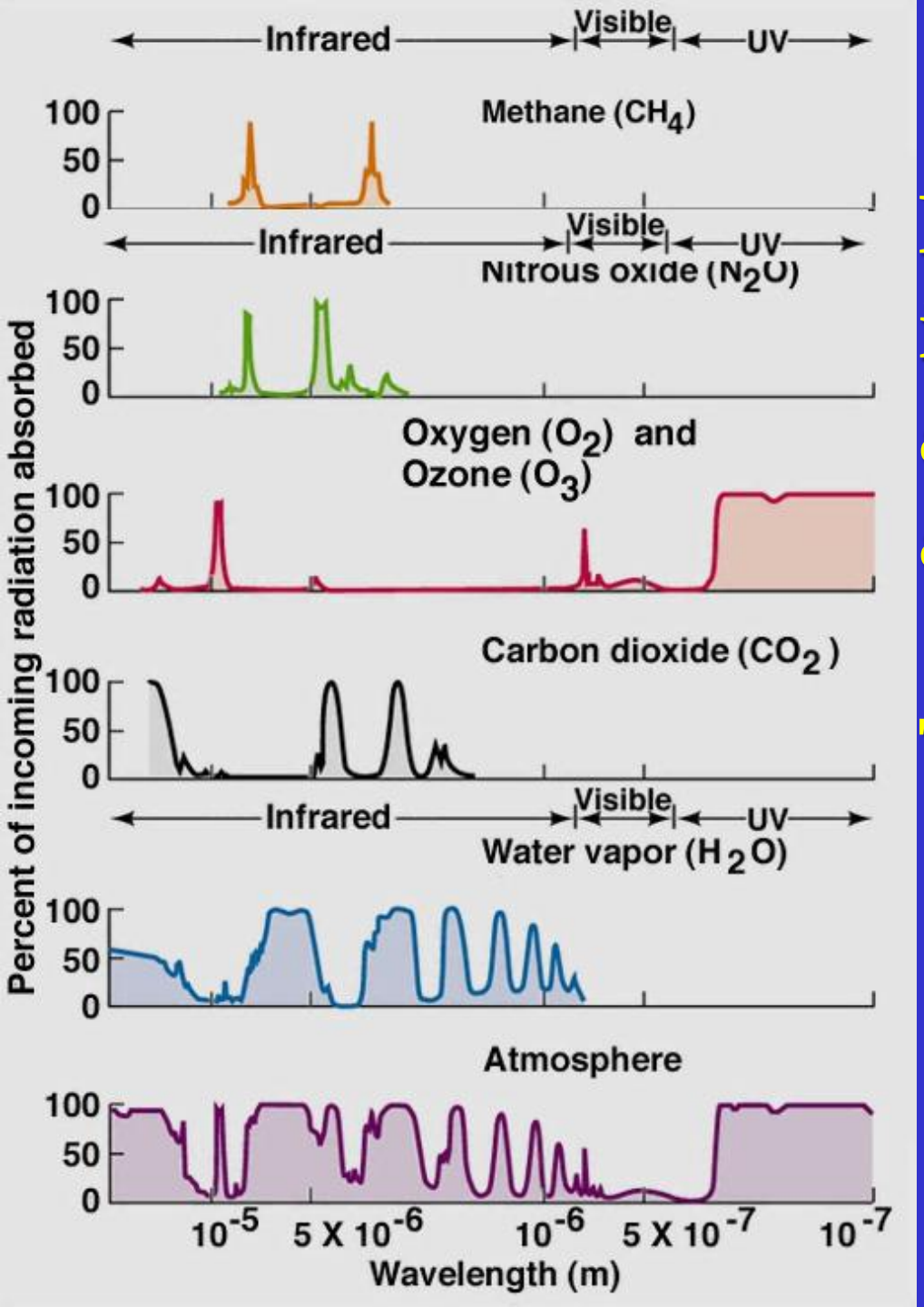
No Greenhouse Effect

- Solar radiation



The Greenhouse Effect



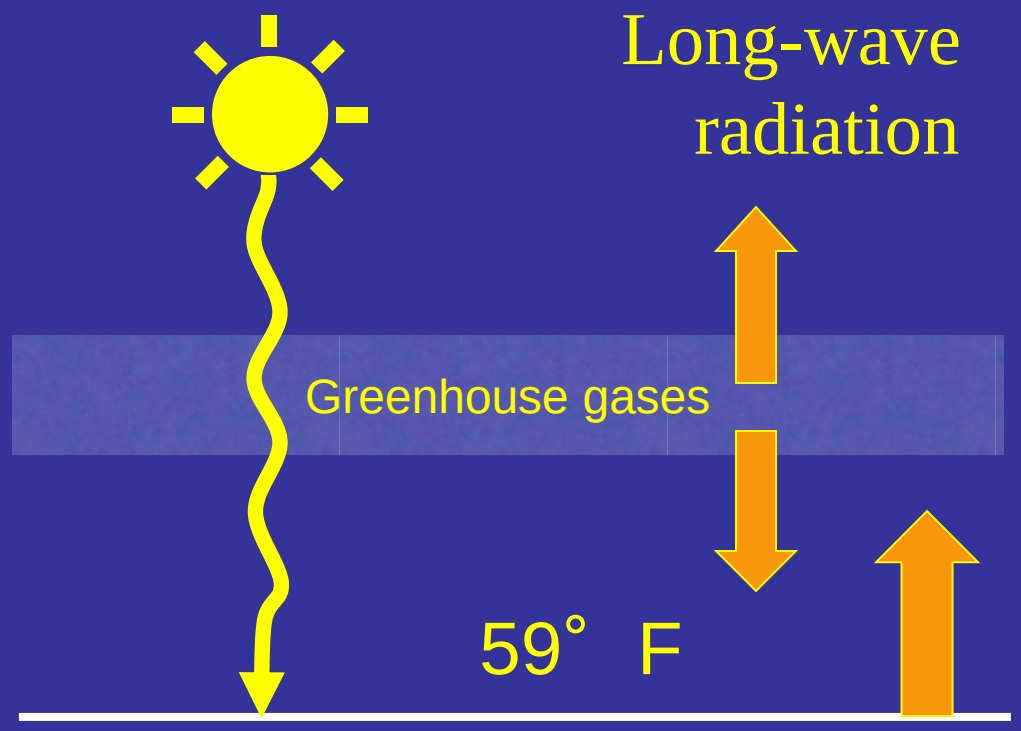


Different gases in the atmosphere are selective absorber and emitters

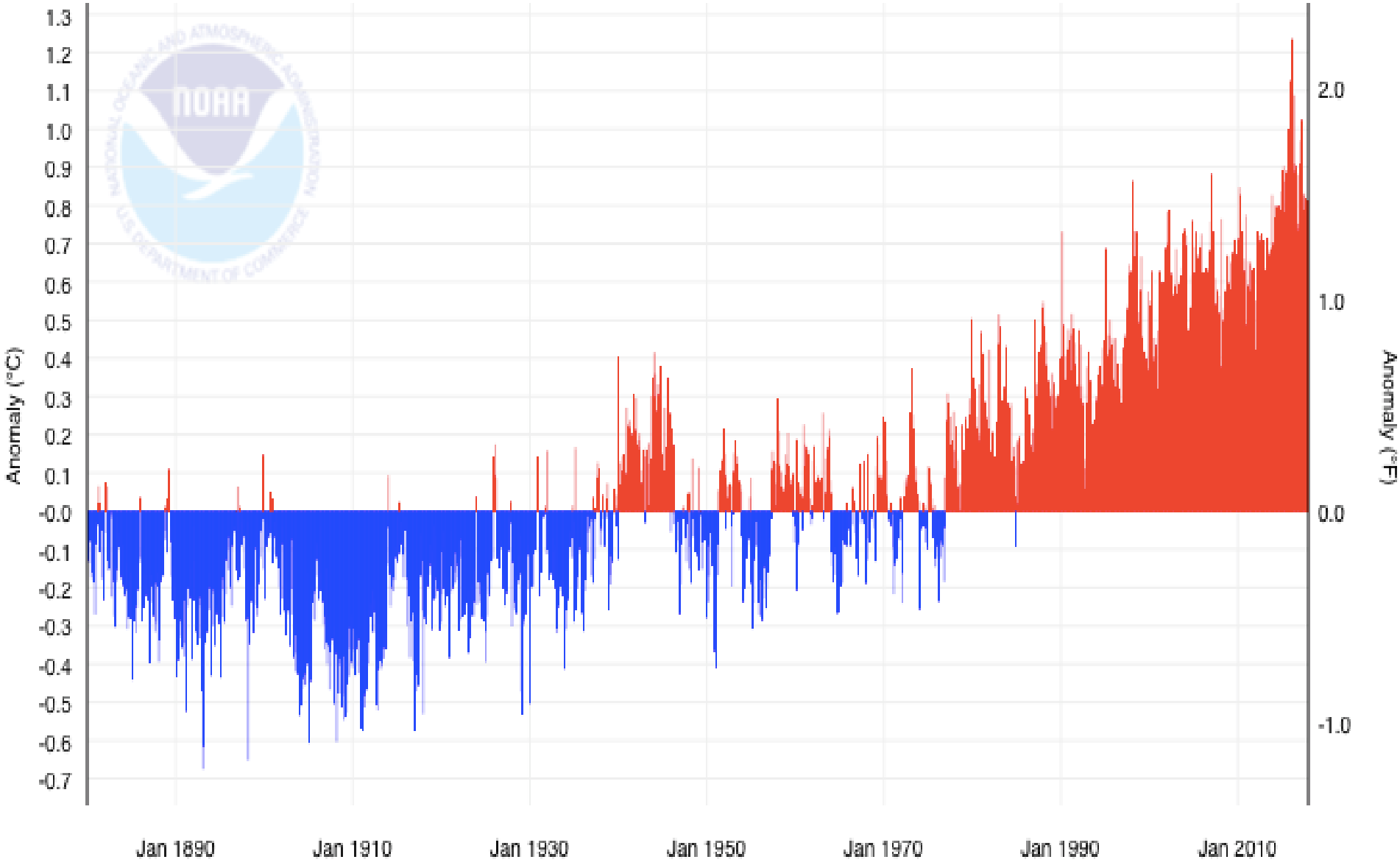
Thus, they are more important in the "Greenhouse effect"

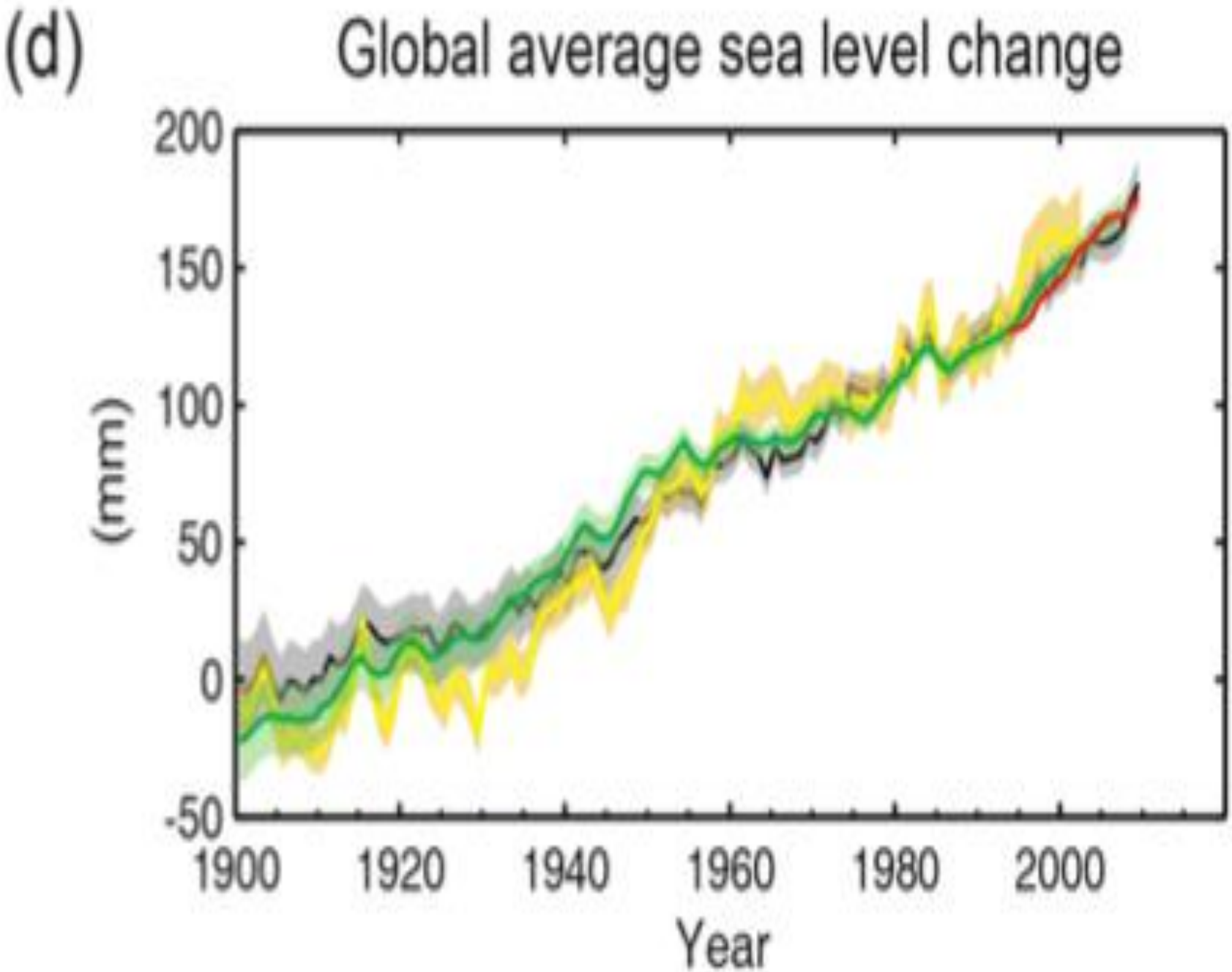
The Natural Greenhouse Effect

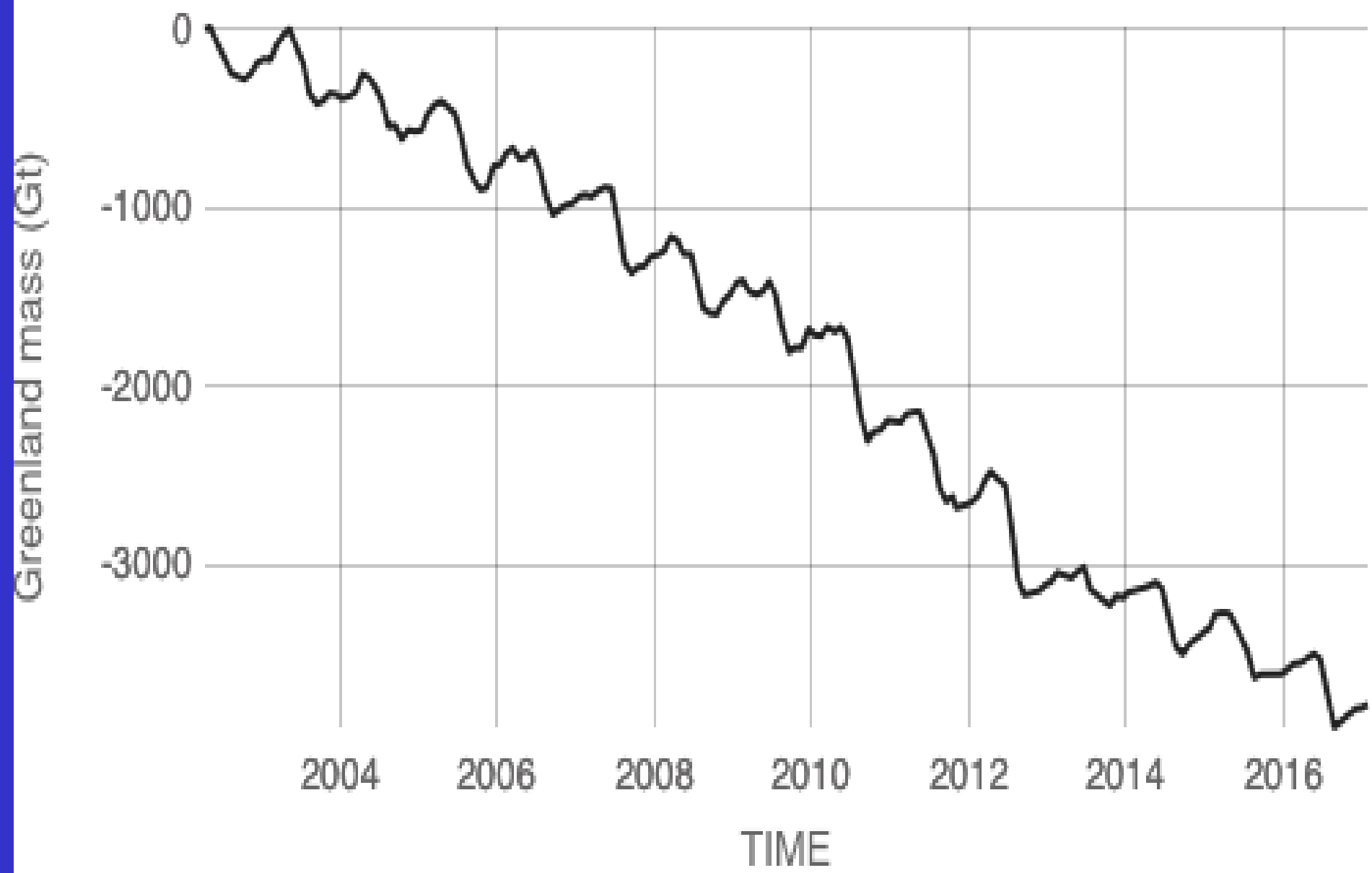
- Solar radiation



Global Land and Ocean Temperature Anomalies



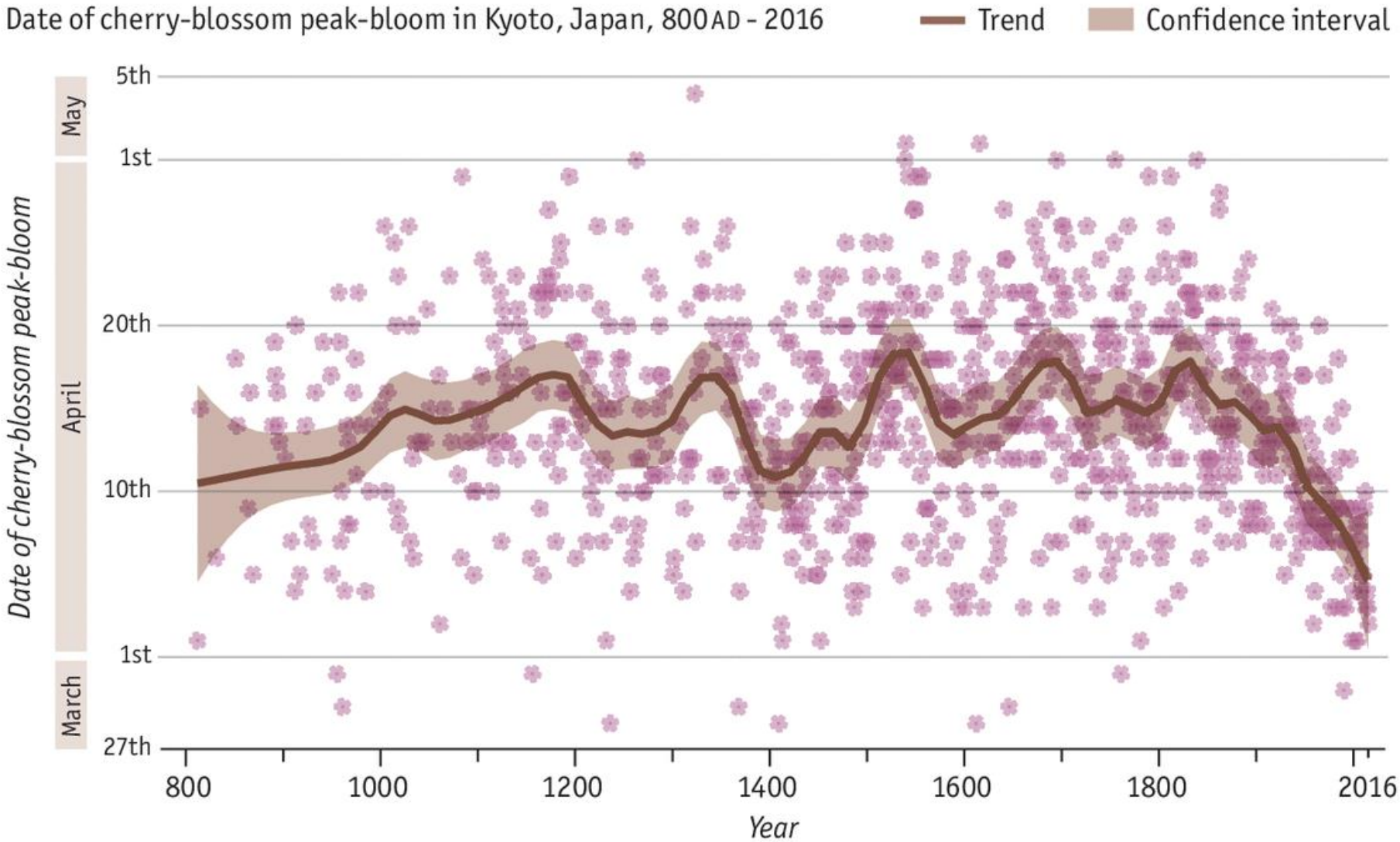

(d)
Global average sea level change
200
150
100
50
0
-50
(mm)
1900
1920
1940
1960
1980
2000
Year



Source: climate.nasa.gov

Cherry bomb

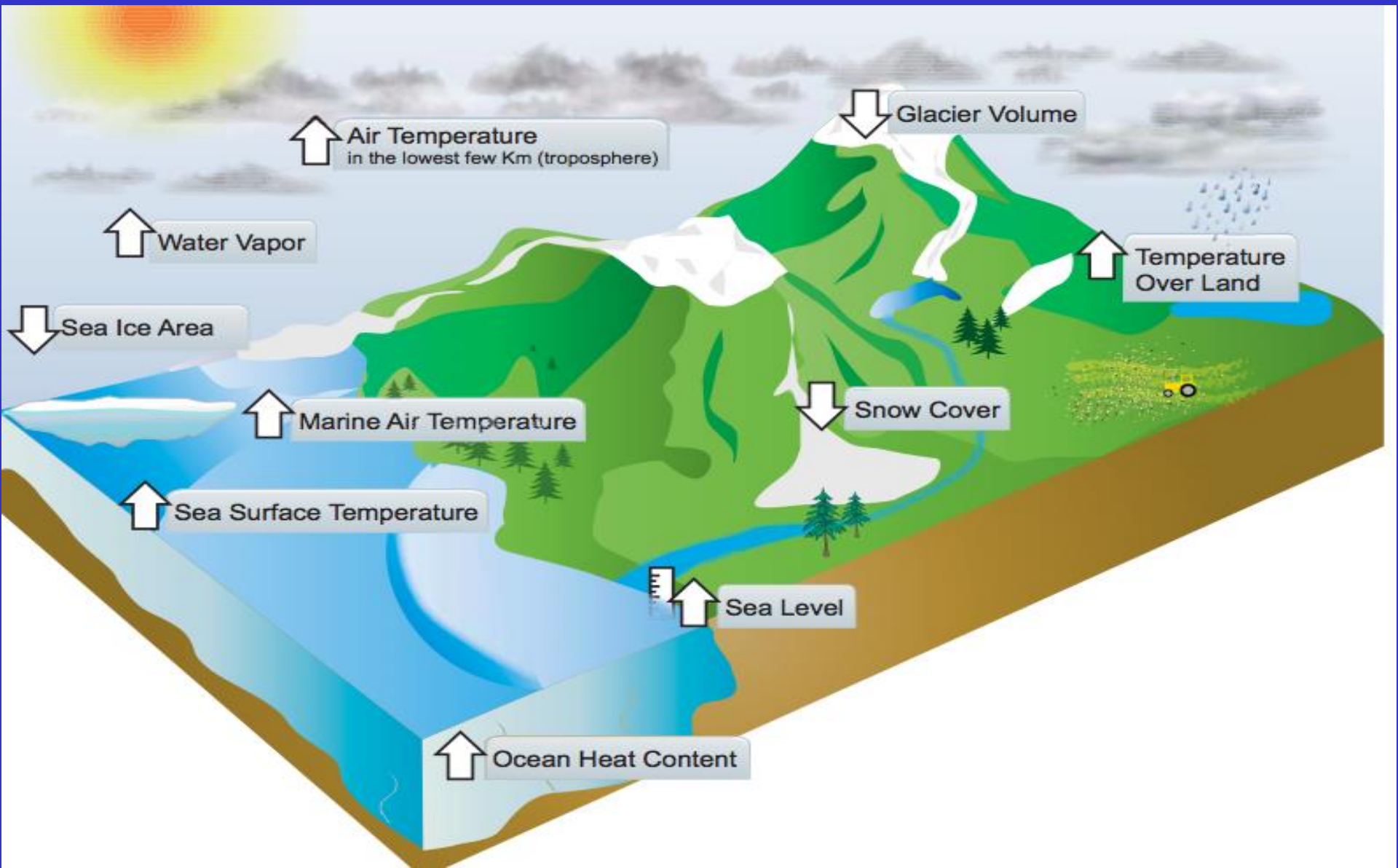
Date of cherry-blossom peak-bloom in Kyoto, Japan, 800 AD - 2016

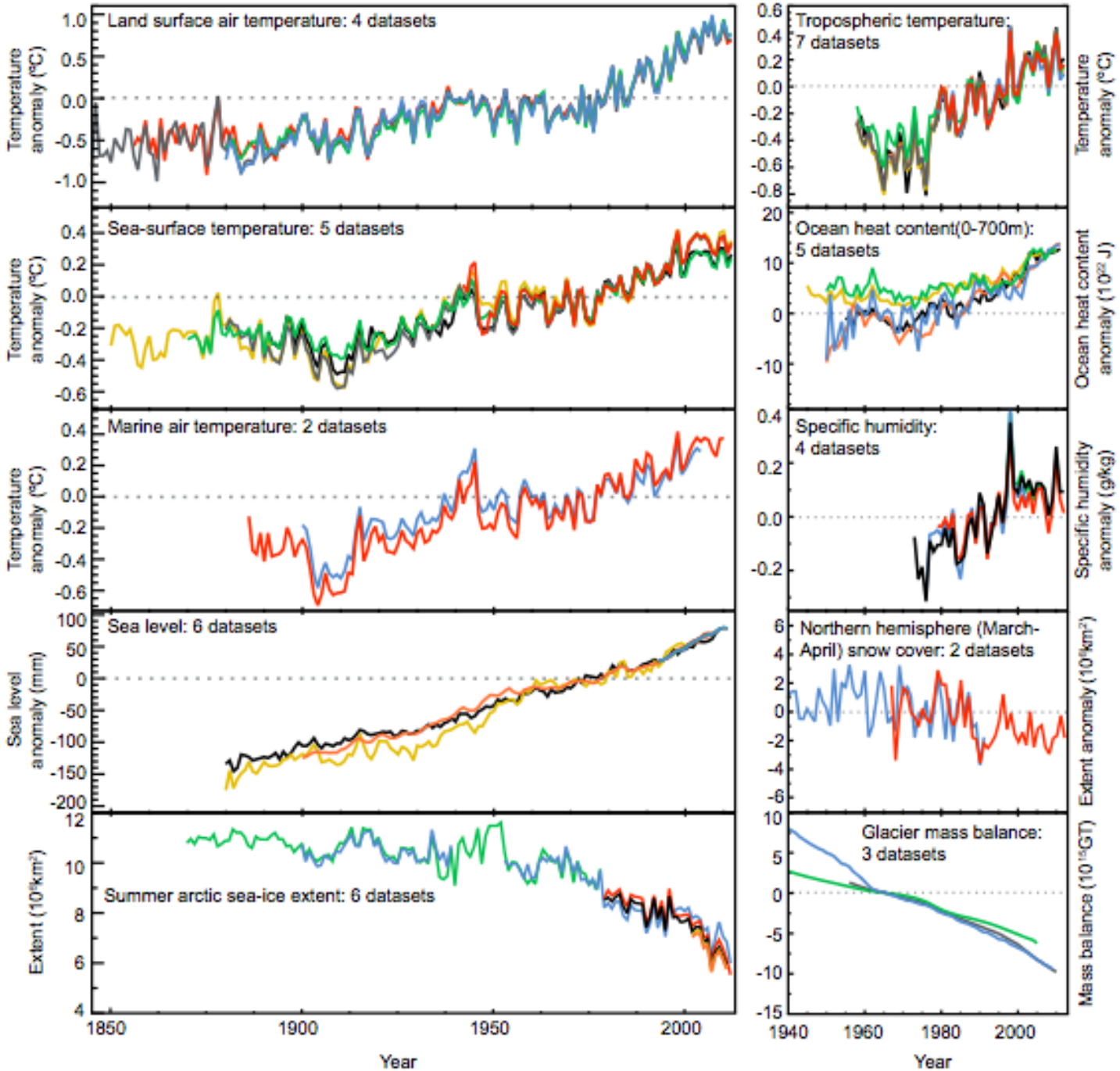


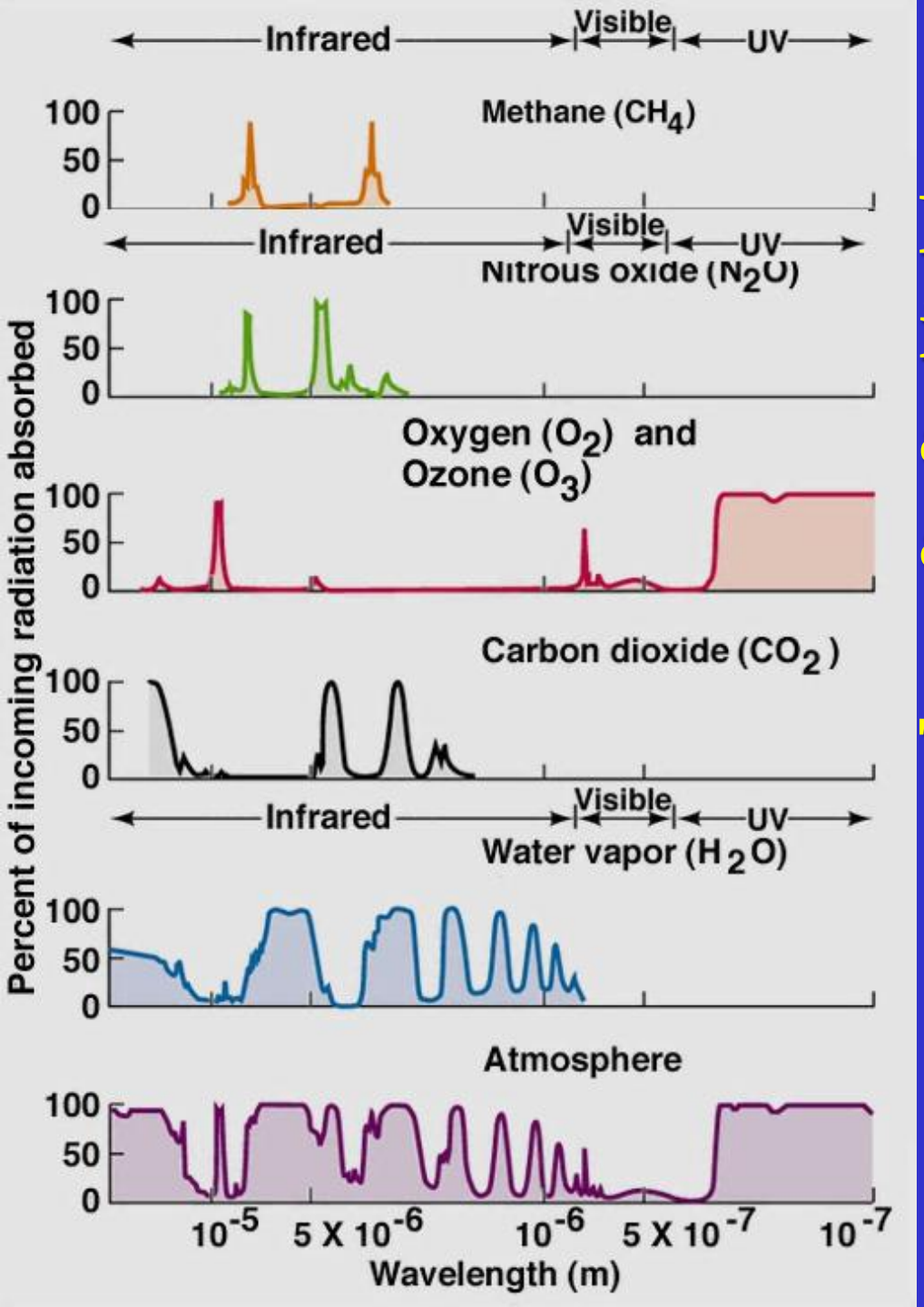
Source: Yasuyuki Aono, Osaka Prefecture University

Economist.com

Components of the climate system that would be expected to change in a warming world




Land surface air temperature: 4 datasets
Temperature anomaly (°C)
Tropospheric temperature: 7 datasets
Temperature anomaly (°C)
Sea-surface temperature: 5 datasets
Temperature anomaly (°C)
Ocean heat content(0-700m): 5 datasets
Ocean heat content anomaly (10^22 J)
Marine air temperature: 2 datasets
Temperature anomaly (°C)
Specific humidity: 4 datasets
Specific humidity anomaly (g/kg)
Sea level: 6 datasets
Sea level anomaly (mm)
Northern hemisphere (March-April) snow cover: 2 datasets
Extent anomaly (10^6 km^2)
Summer arctic sea-ice extent: 6 datasets
Extent (10^6 km^2)
Glacier mass balance: 3 datasets
Mass balance (10^15 GT)
Year
Year



Different gases in the atmosphere are selective absorber and emitters

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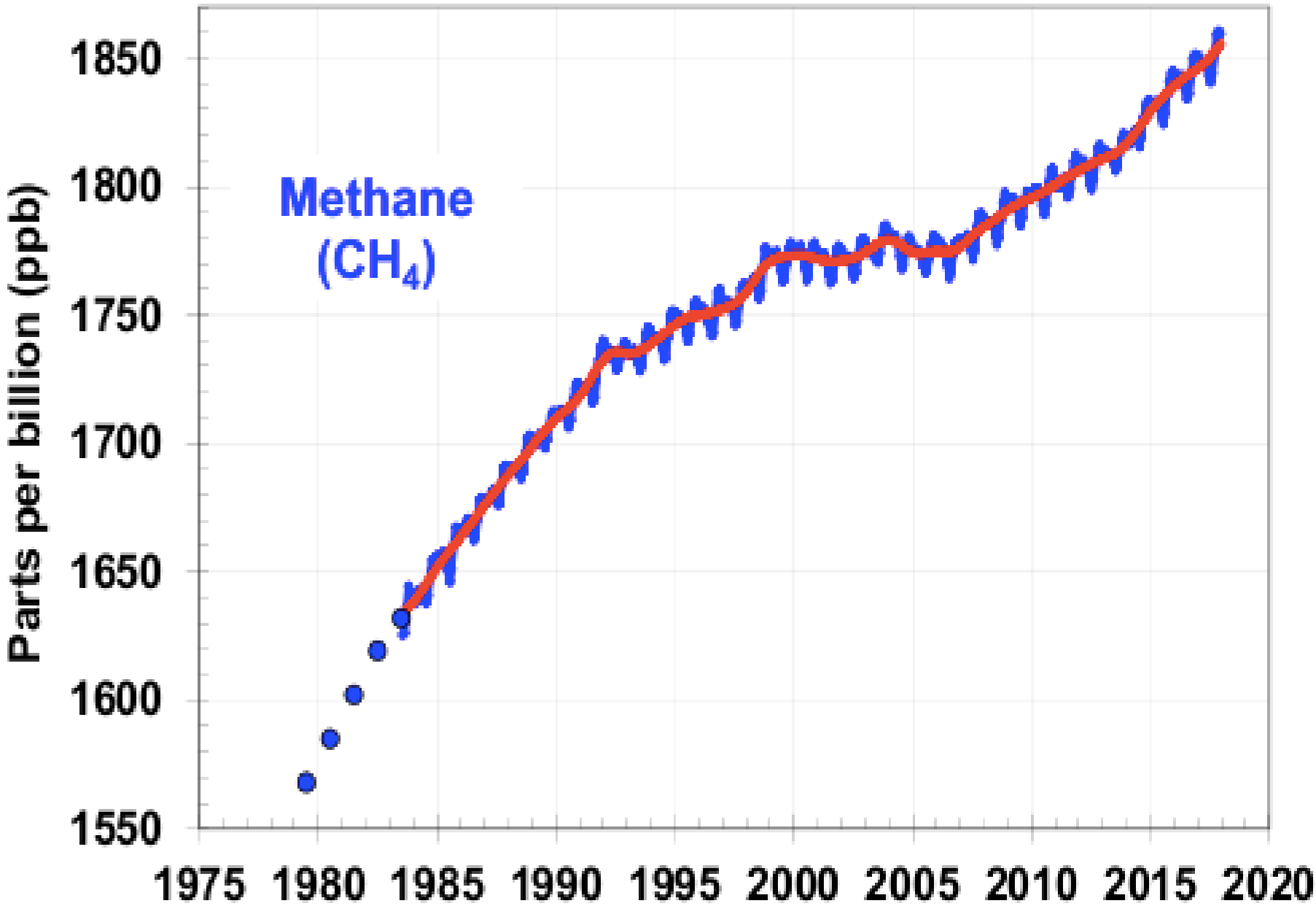
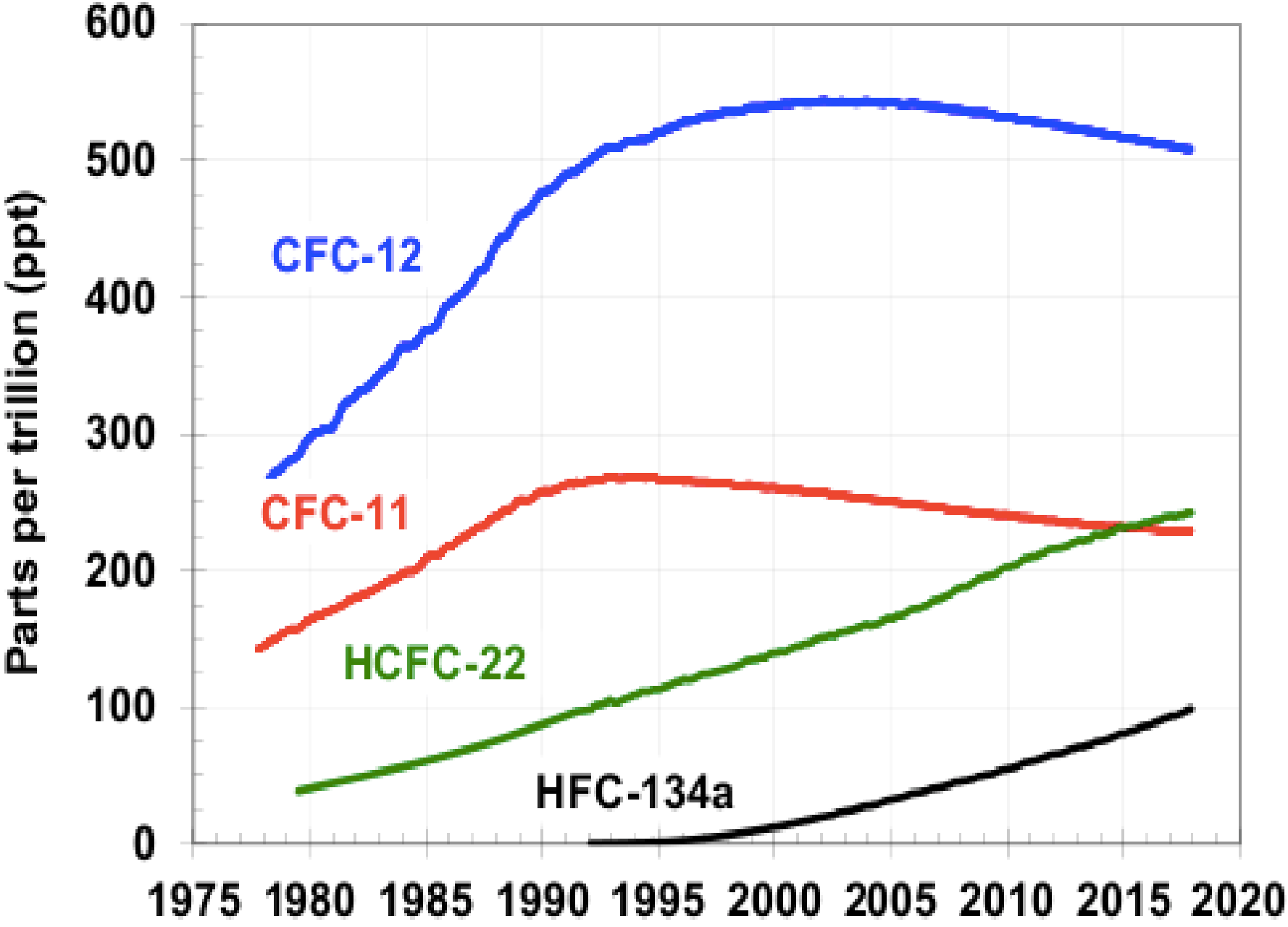
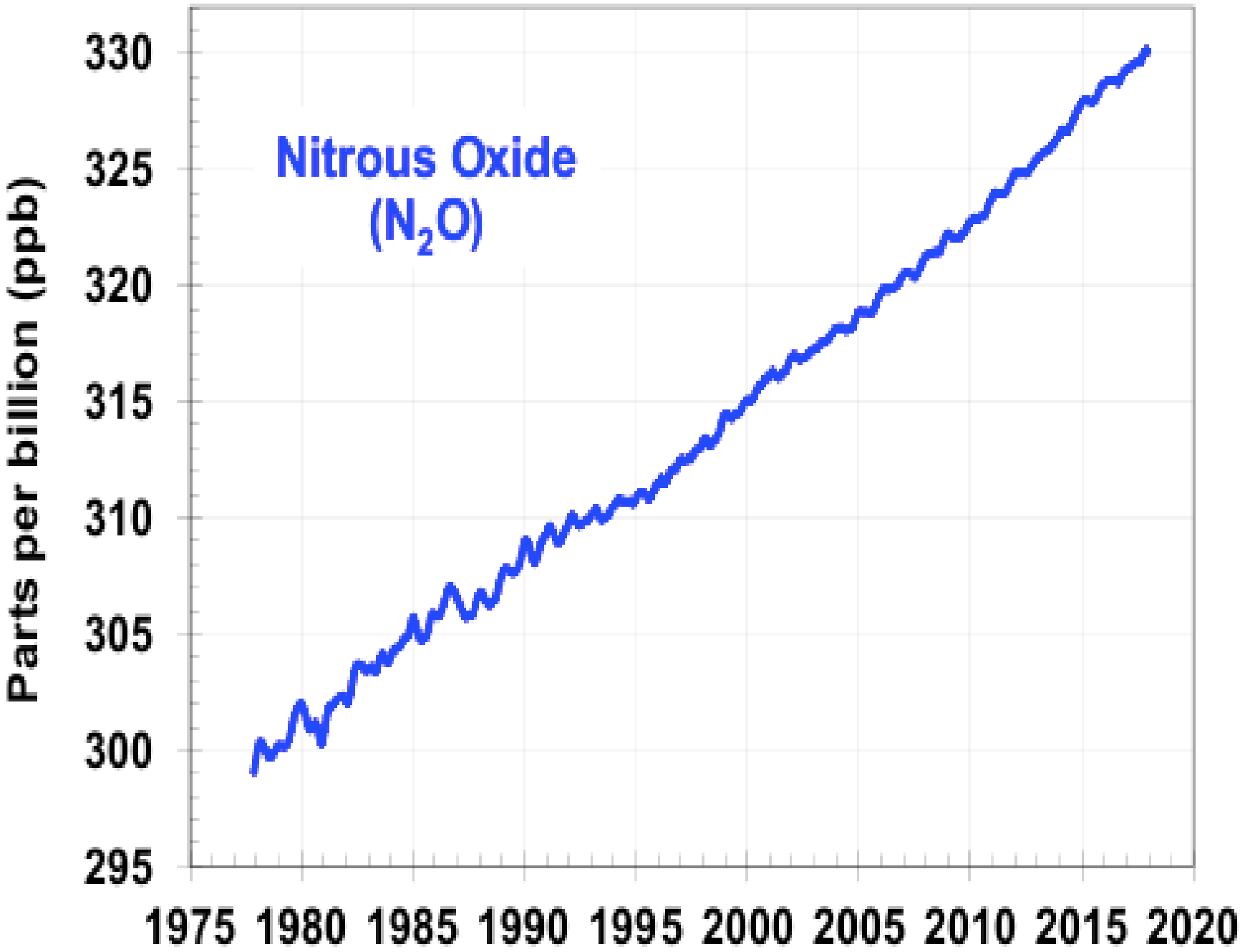
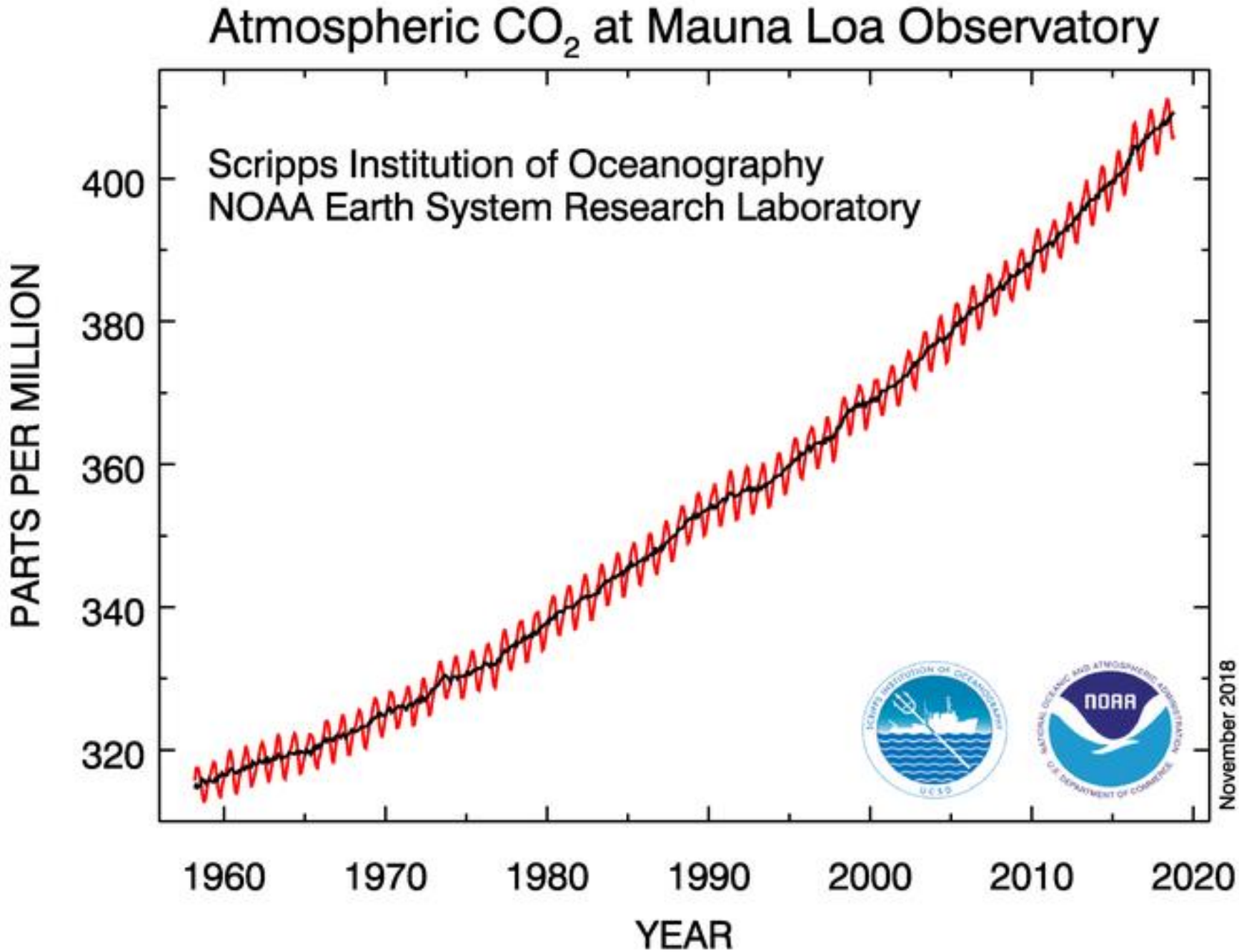
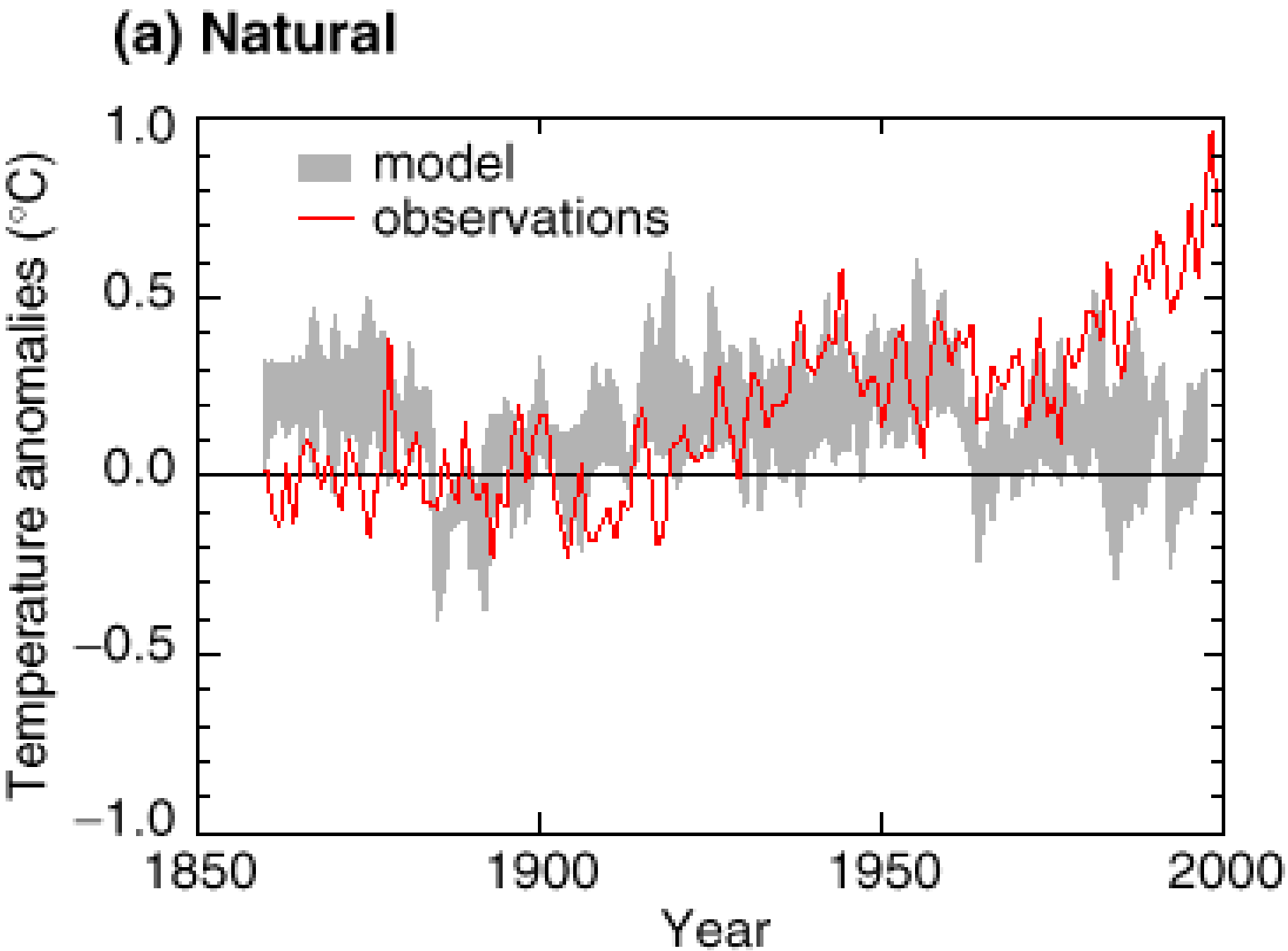
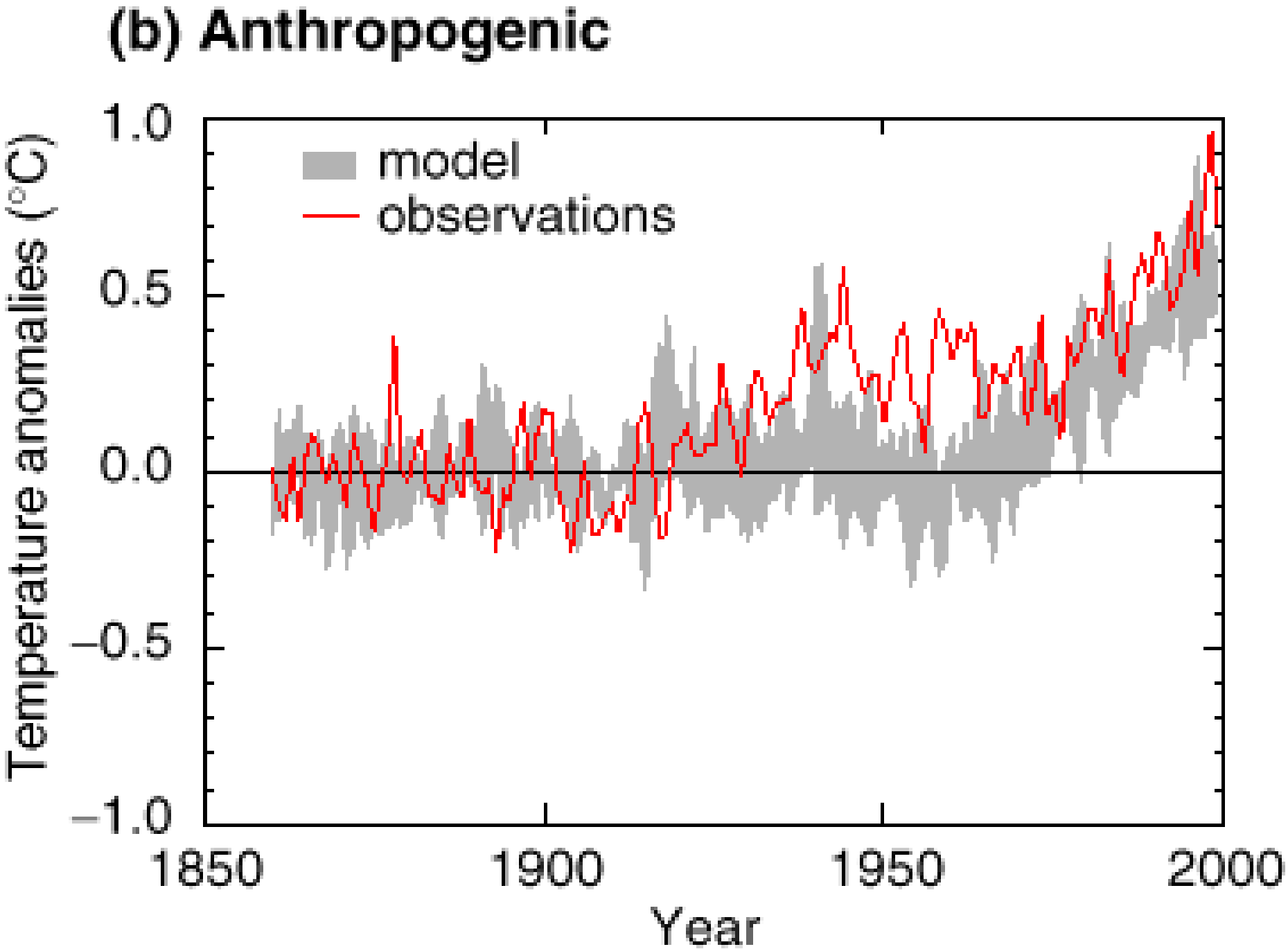

Methane
(CH_4)
Parts per billion (ppb)
1850
1800
1750
1700
1650
1600
1550
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020

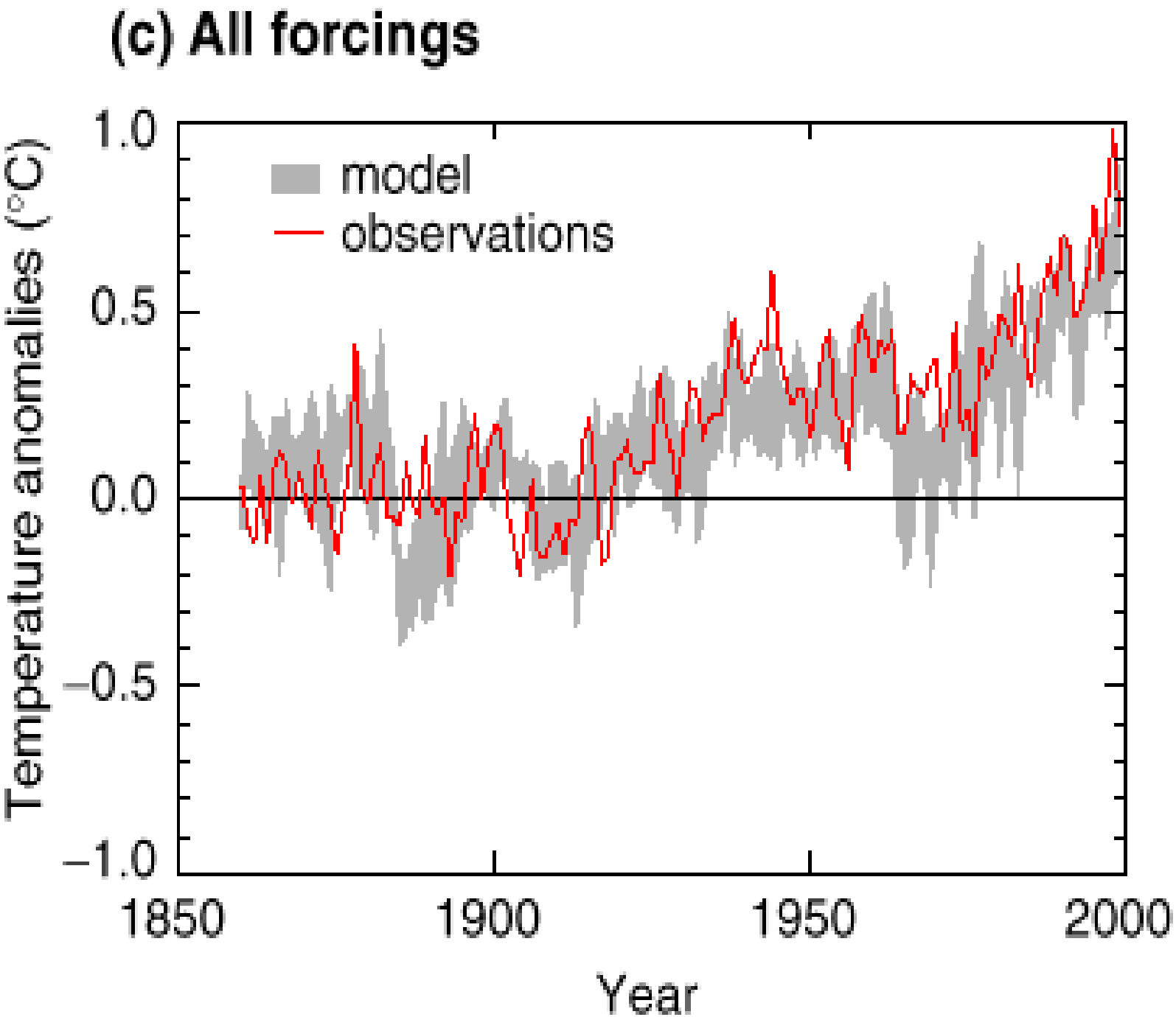

Parts per trillion (ppt)
600
500
400
300
200
100
0
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
CFC-12
CFC-11
HCFC-22
HFC-134a

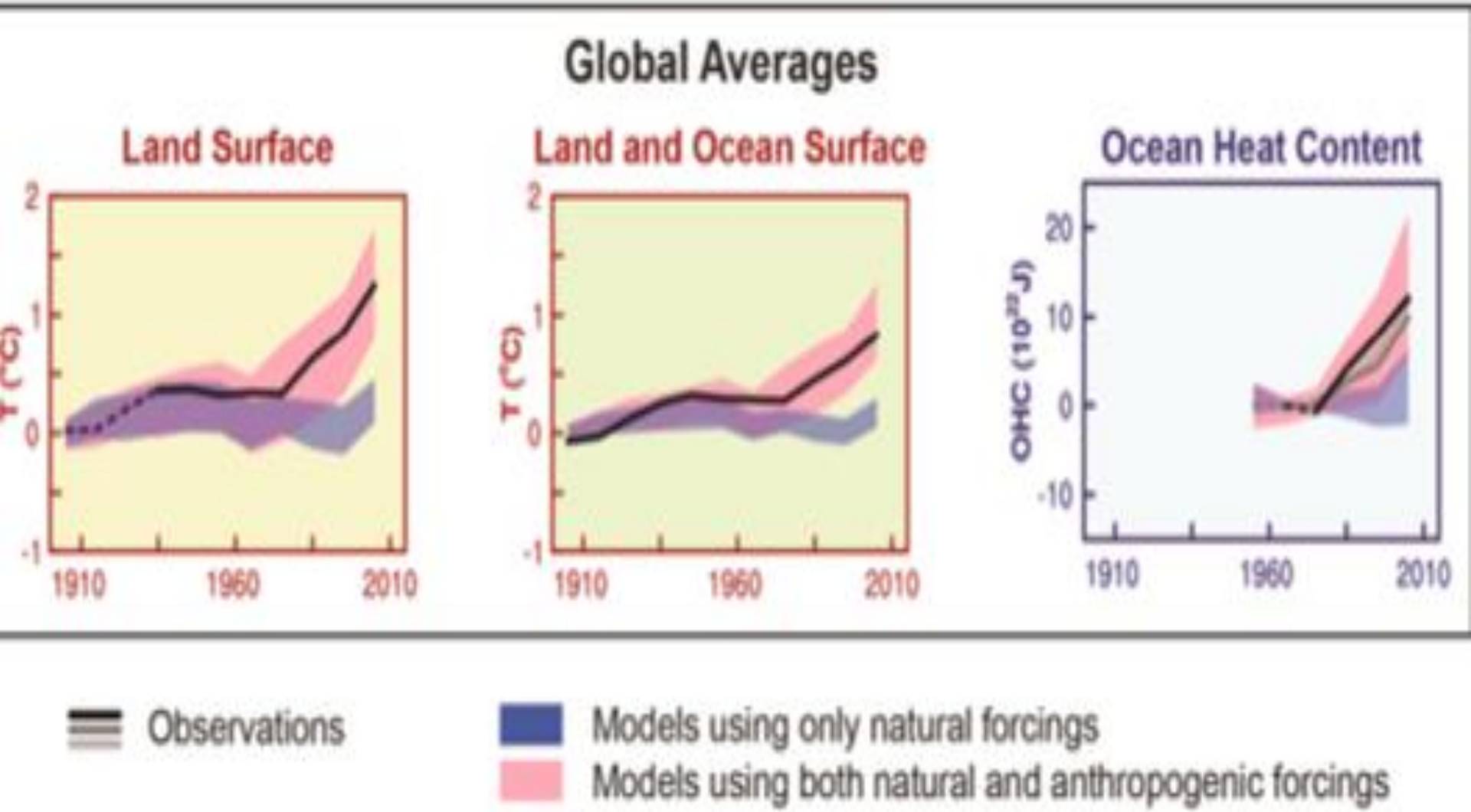

Nitrous Oxide
(N_2O)
Parts per billion (ppb)
330
325
320
315
310
305
300
295
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020


Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
400
380
360
340
320
1960
1970
1980
1990
2000
2010
2020
YEAR
NOAA
November 2018


(a) Natural
model
observations
Temperature anomalies (°C)
1.0
0.5
0.0
−0.5
−1.0
1850
1900
1950
2000
Year


(b) Anthropogenic
model
observations
Temperature anomalies (°C)
1.0
0.5
0.0
−0.5
−1.0
1850
1900
1950
2000
Year

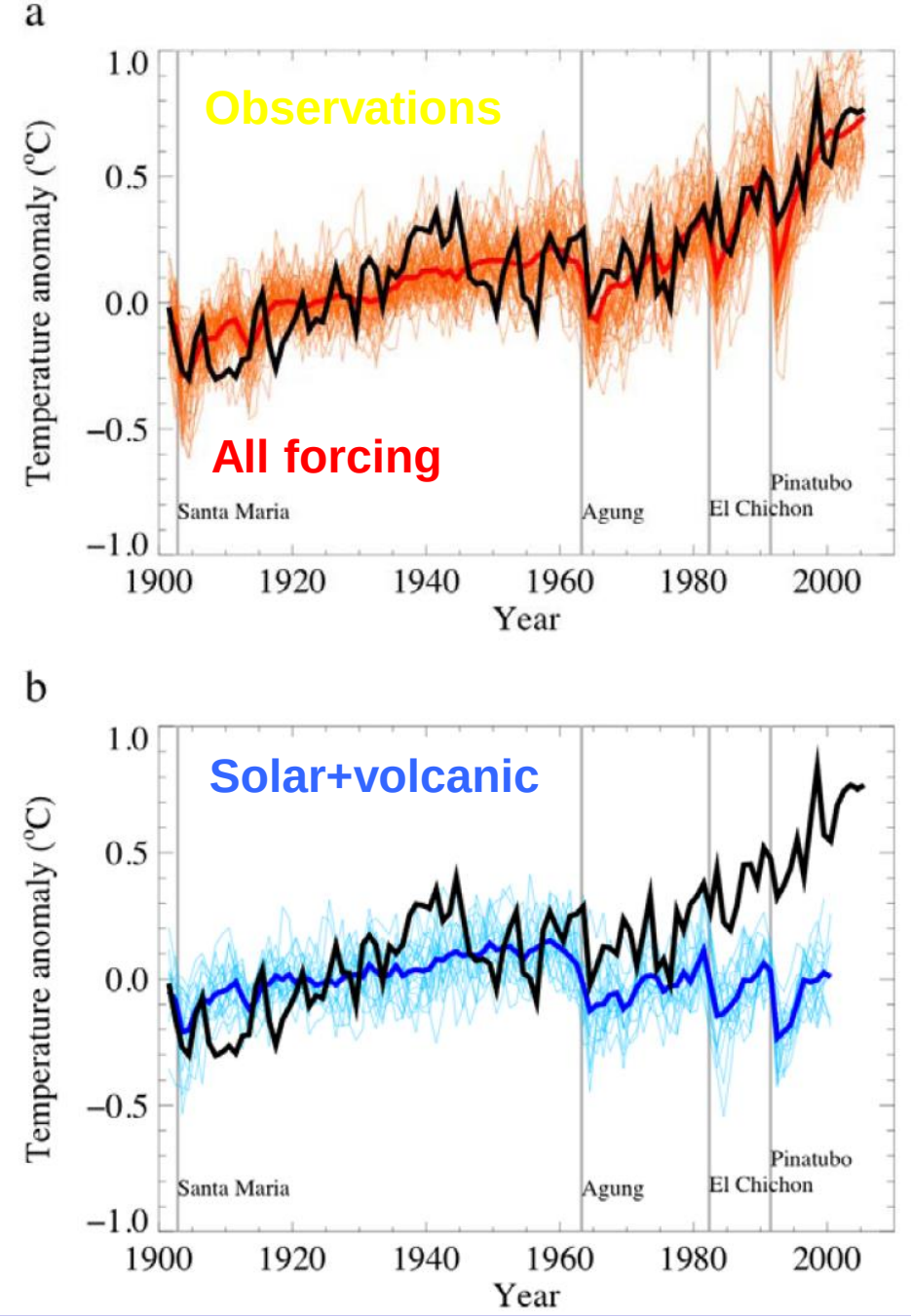

(c) All forcings
model
observations
Temperature anomalies (°C)
1.0
0.5
0.0
−0.5
−1.0
1850
1900
1950
2000
Year


Global Averages
Land Surface
Land and Ocean Surface
Ocean Heat Content
T (°C)
OHC (10^{22} J)
2
1
0
-1
20
10
0
-10
1910
1960
2010
Observations
Models using only natural forcings
Models using both natural and anthropogenic forcings

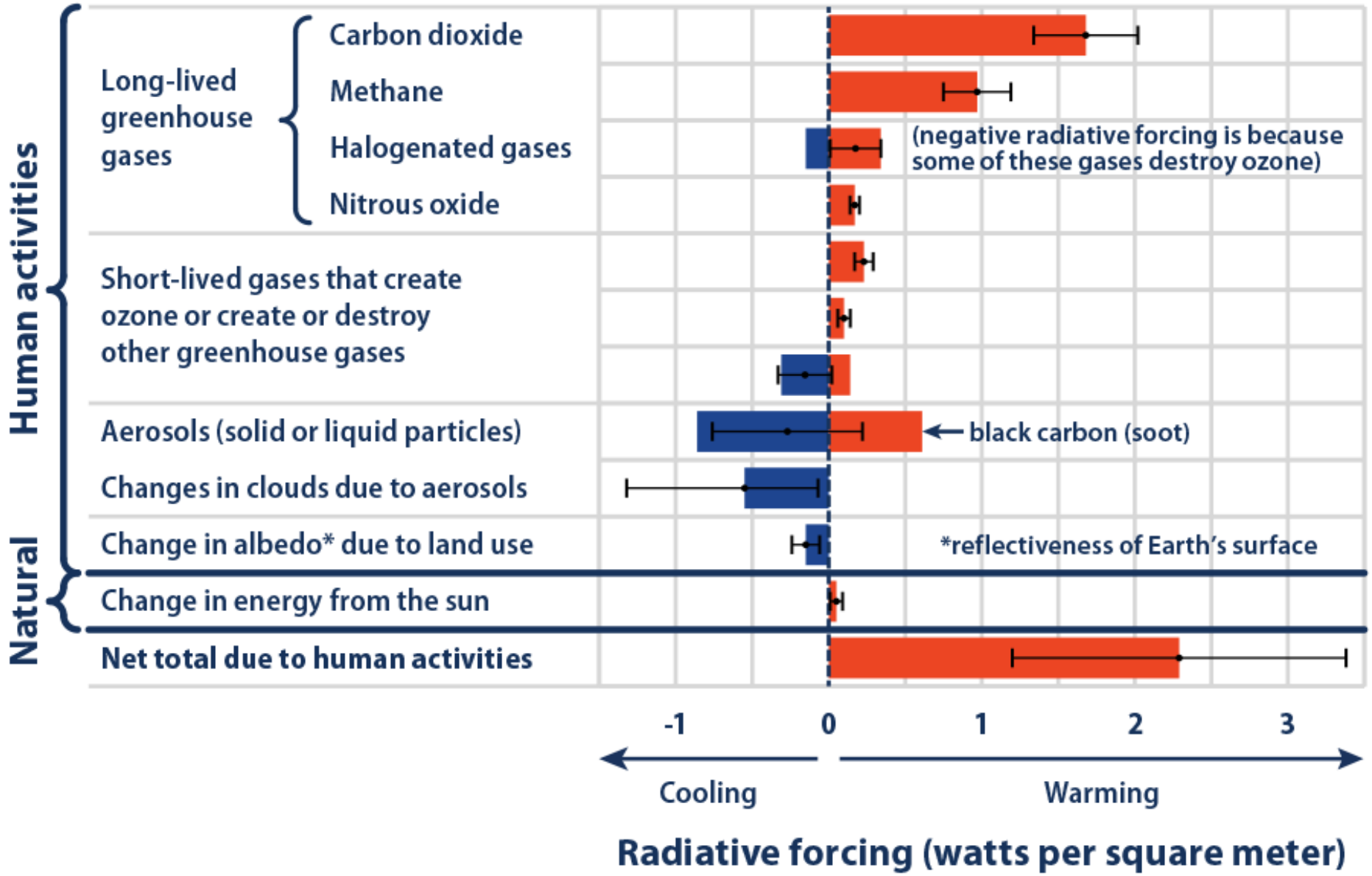
Attribution

- are observed changes consistent with expected responses to forcings

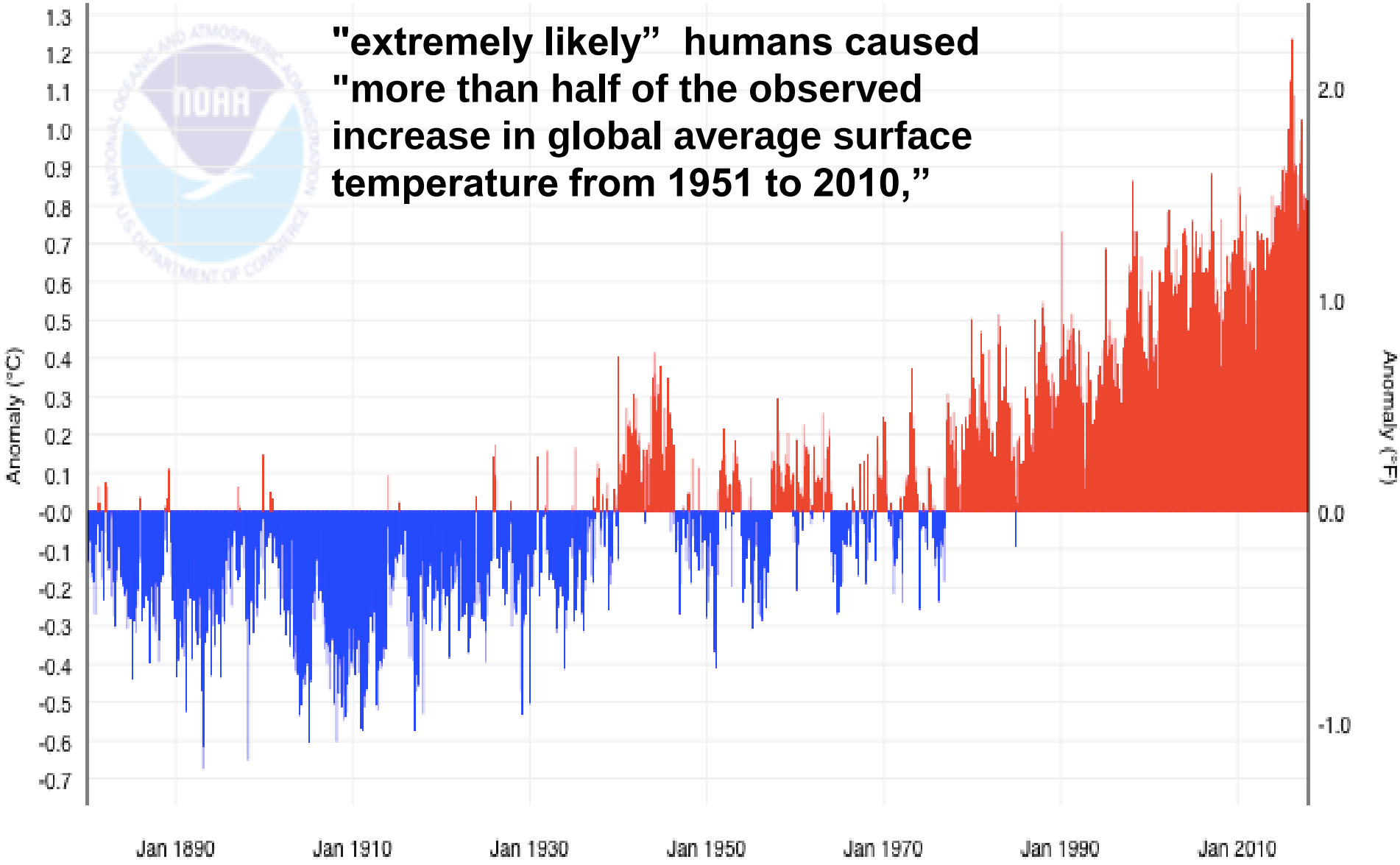
- inconsistent with alternative explanations



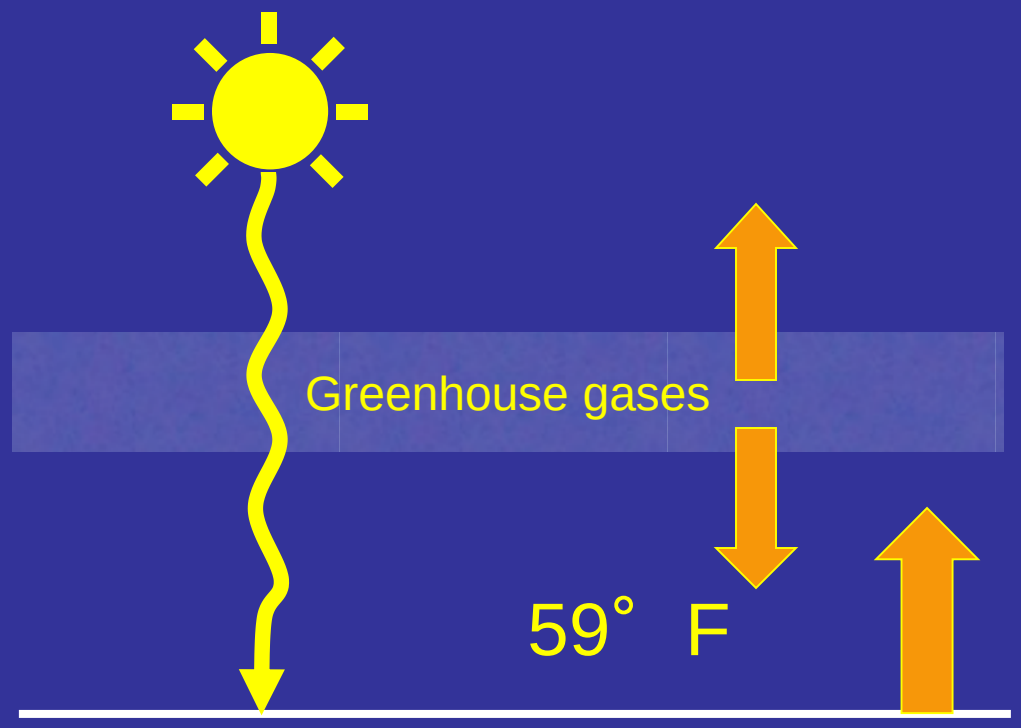
Global-average radiative forcing estimates and ranges



Global Land and Ocean Temperature Anomalies



The Enhanced Greenhouse Effect



Enhanced greenhouse effect

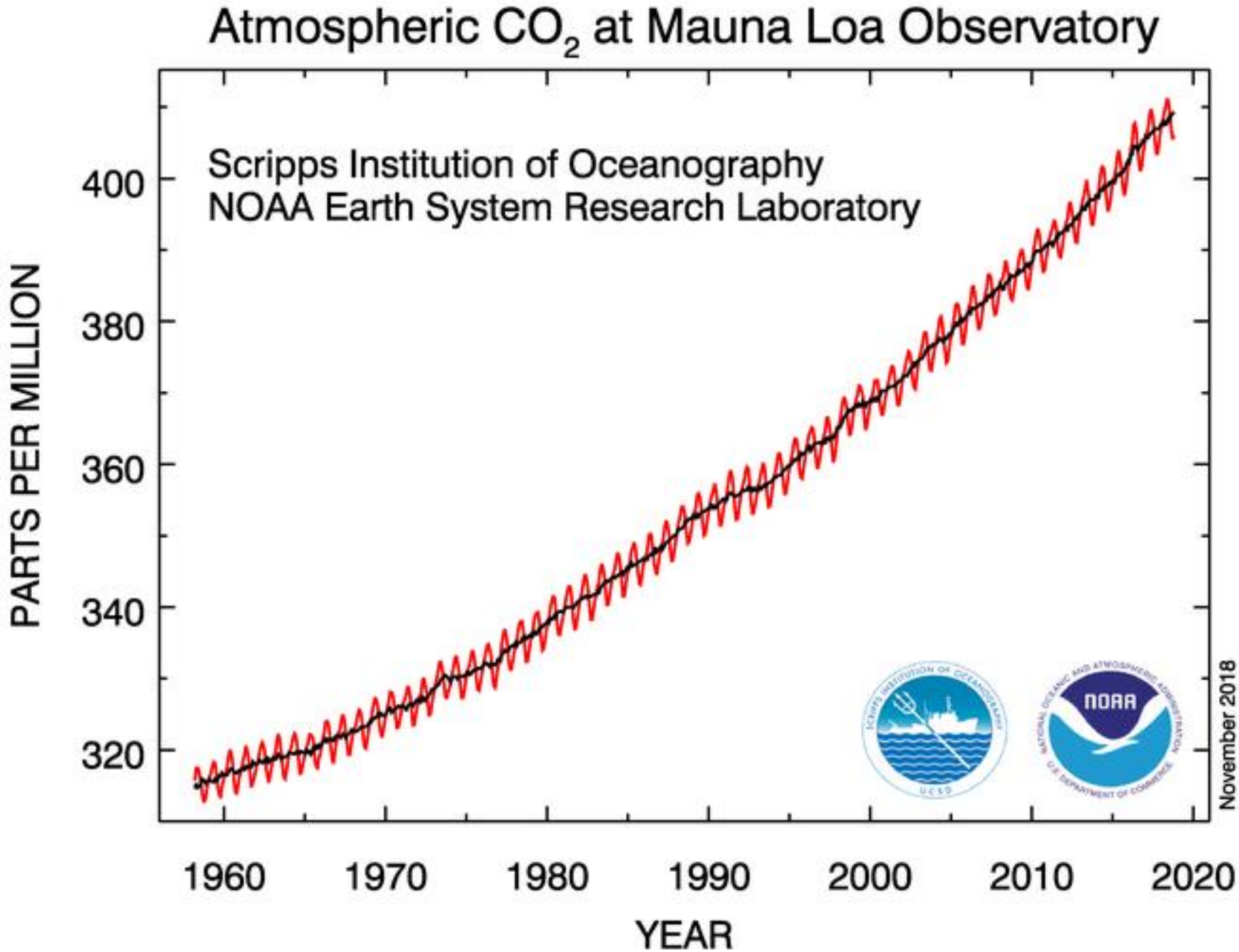
Double* CO_2 direct effect

+ 2-3° F

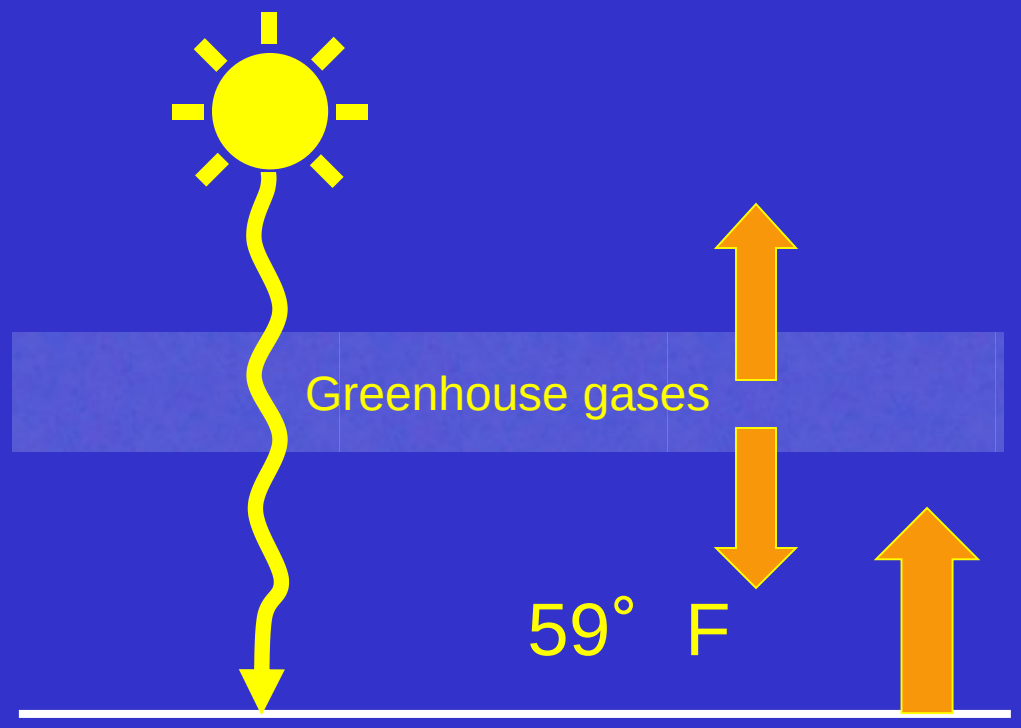
Double CO_2 plus feedbacks

+ 4-6° F +/-???

*Double the pre-industrial level, likely to be reached by 2050


Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
400
380
360
340
320
1960
1970
1980
1990
2000
2010
2020
YEAR
NOAA
November 2018

The Enhanced Greenhouse Effect



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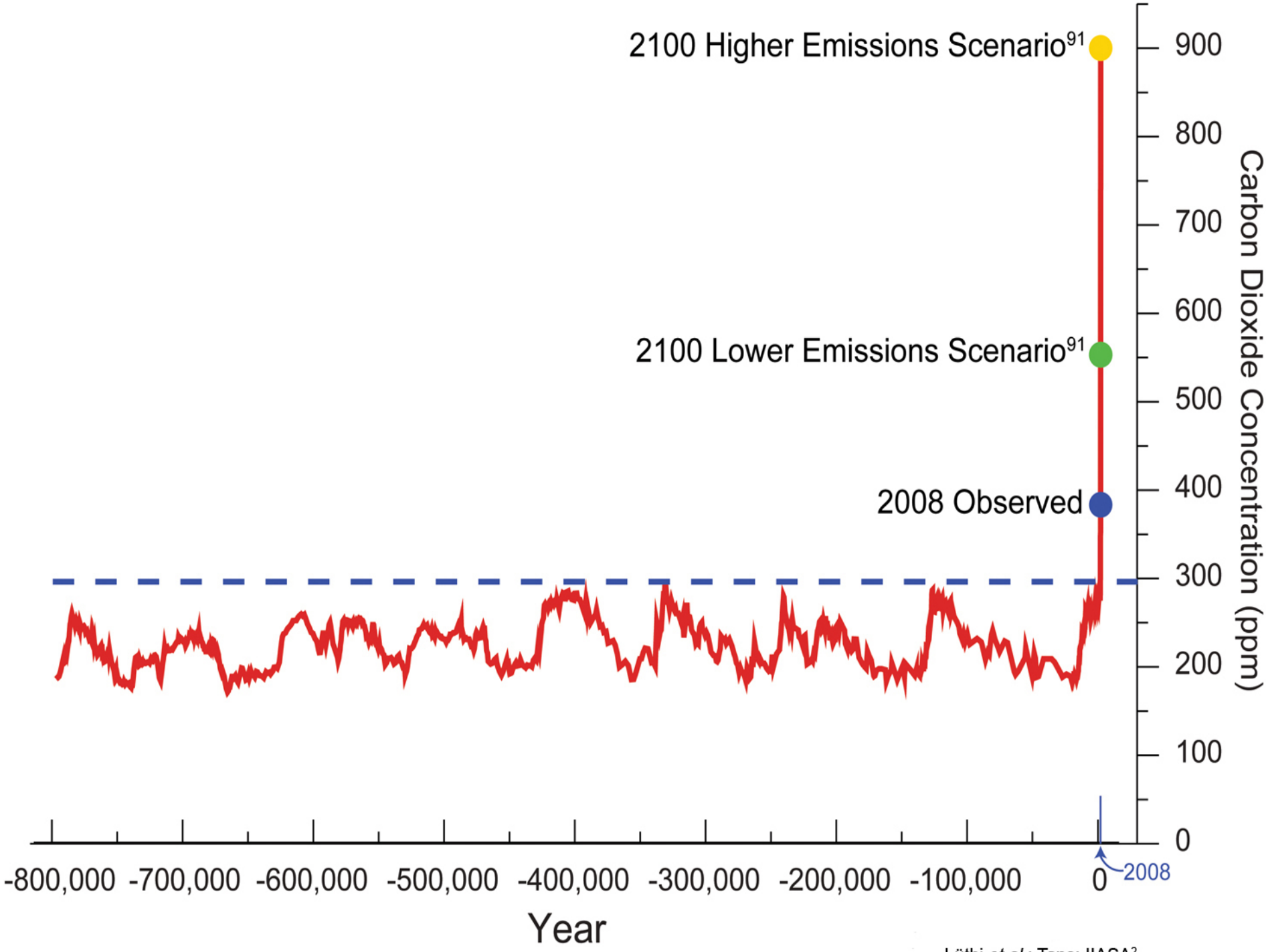
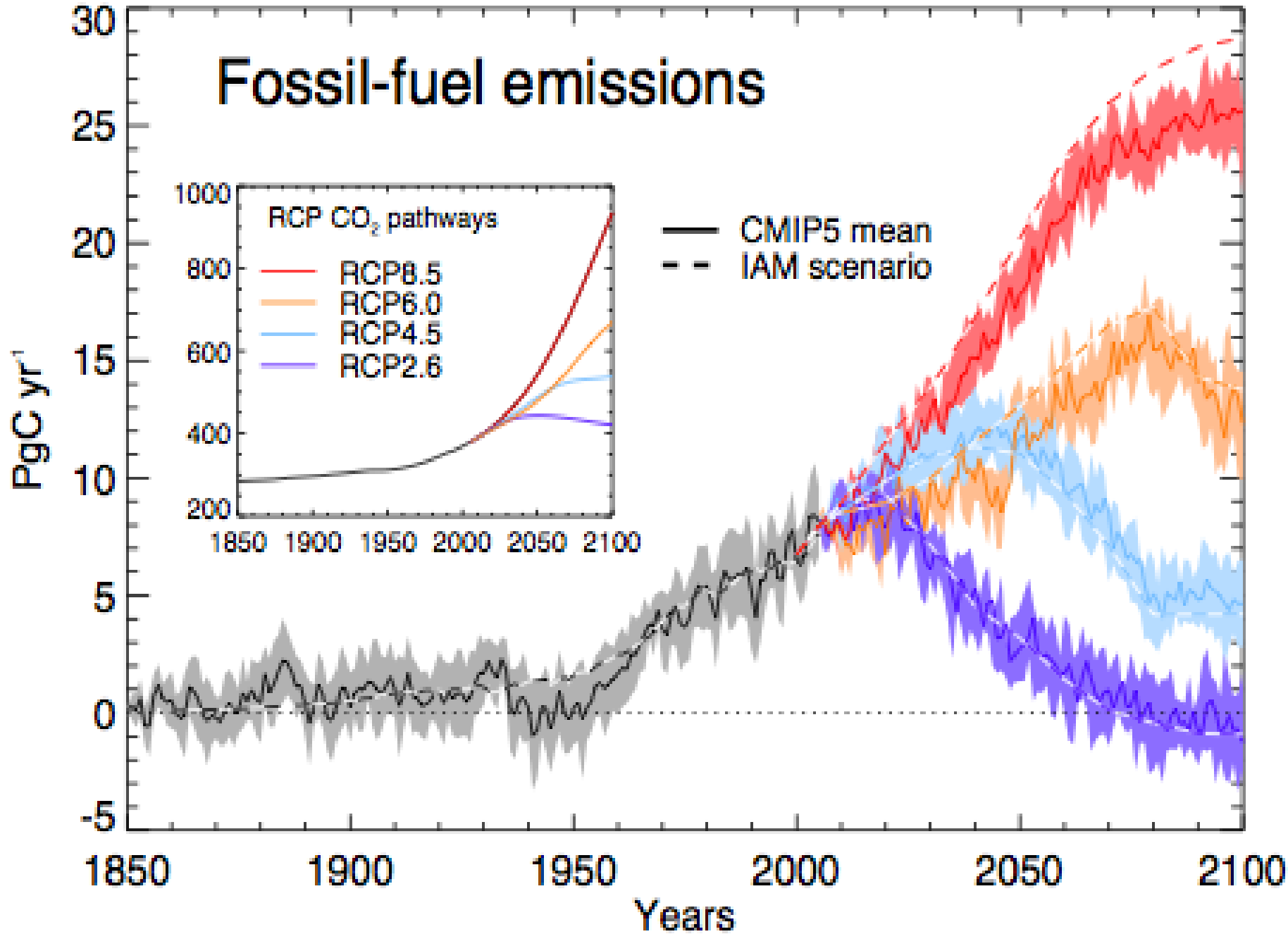
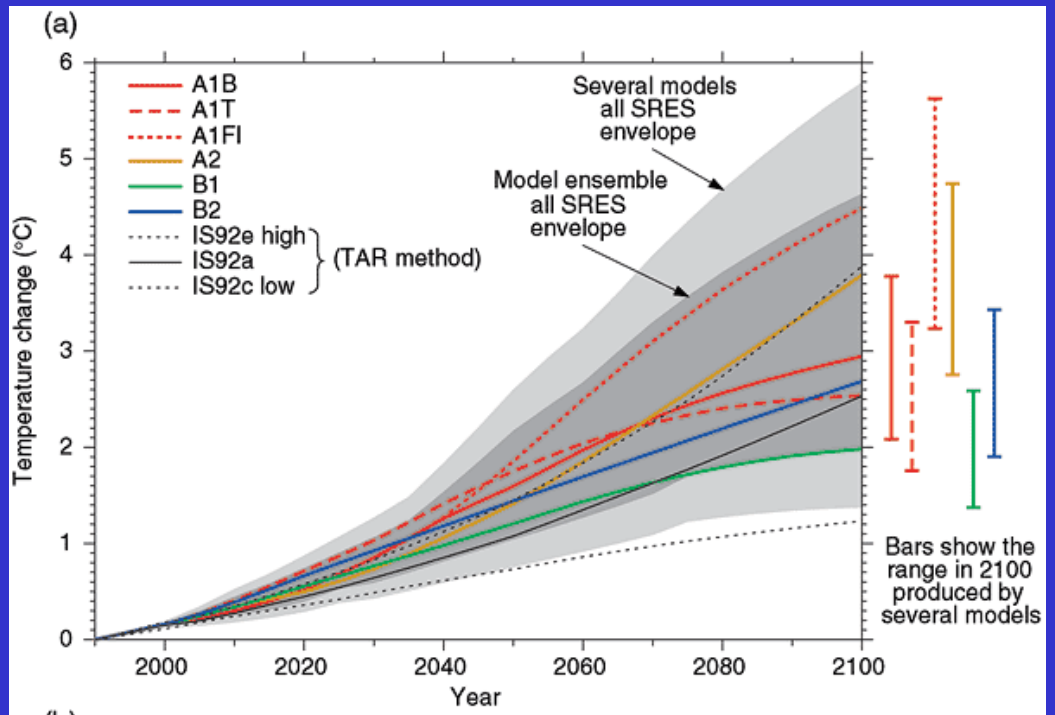
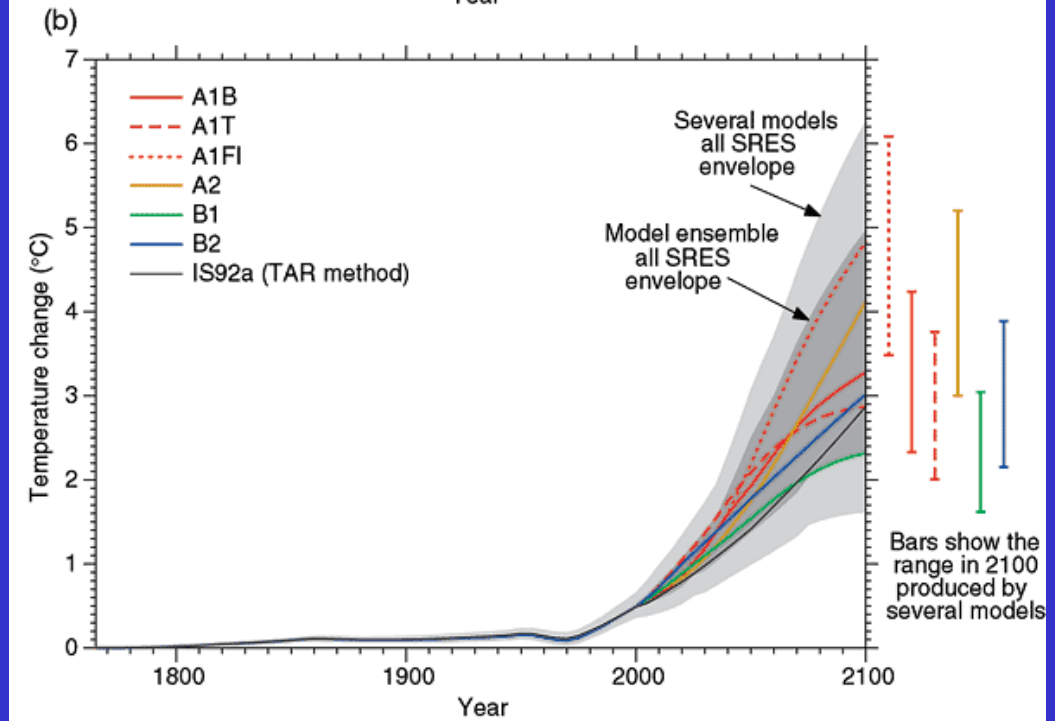

2100 Higher Emissions Scenario[91]
2100 Lower Emissions Scenario[91]
2008 Observed
900
800
700
600
500
400
300
200
100
0
Carbon Dioxide Concentration (ppm)
-800,000
-700,000
-600,000
-500,000
-400,000
-300,000
-200,000
-100,000
0
2008
Year

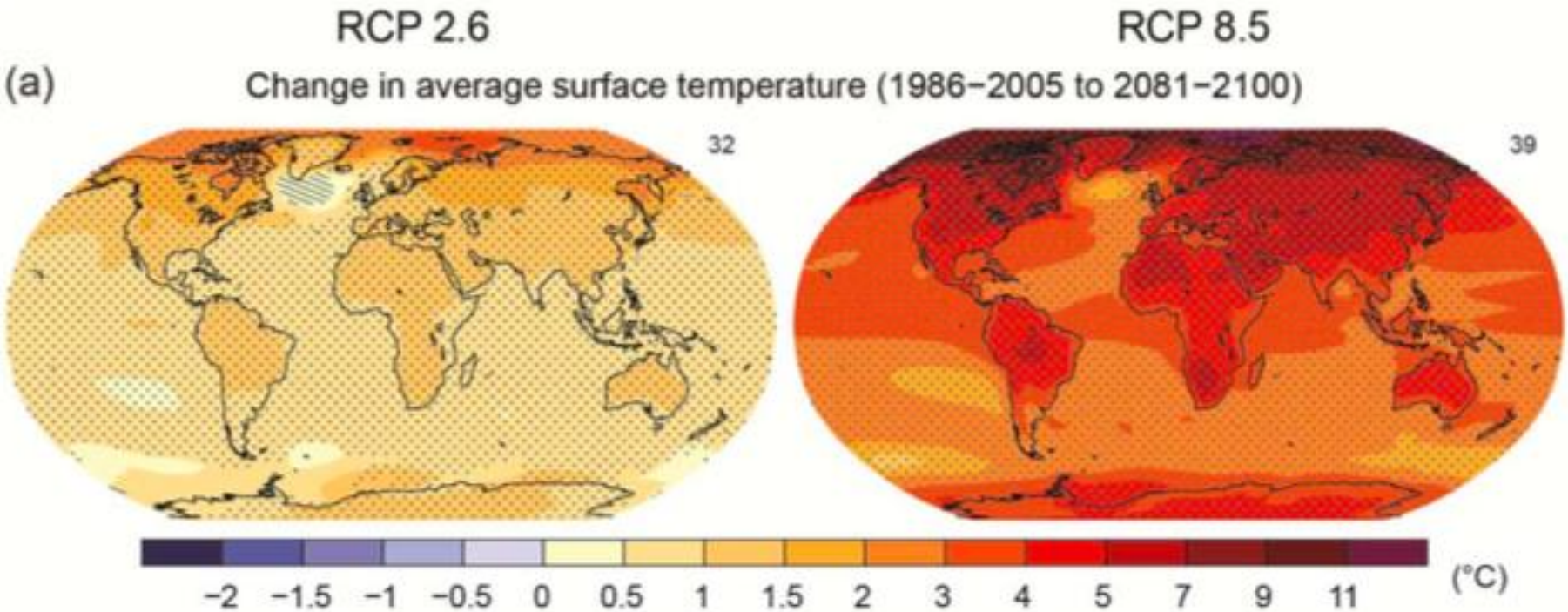

Fossil-fuel emissions
RCP CO_2 pathways
RCP8.5
RCP6.0
RCP4.5
RCP2.6
CMIP5 mean
IAM scenario
PgC yr^{-1}
Years
30
25
20
15
10
5
0
-5
1850
1900
1950
2000
2050
2100
1000
800
600
400
200

Surface temperature predictions





…since 1750


RCP 2.6
RCP 8.5
(a)
Change in average surface temperature (1986−2005 to 2081−2100)
32
39
−2 −1.5 −1 −0.5 0 0.5 1 1.5 2 3 4 5 7 9 11
(°C)

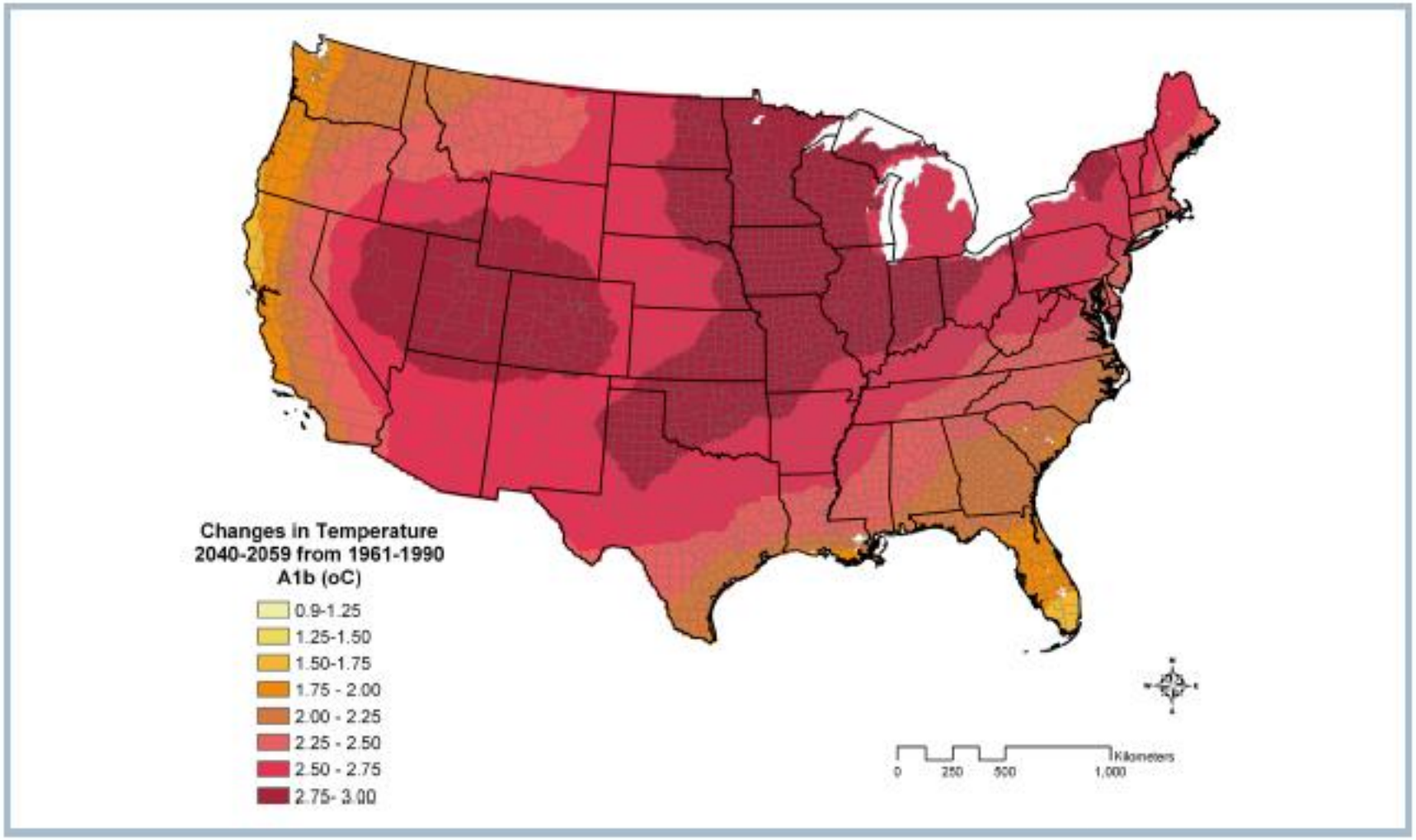


Figure 9. Predicted changes in mean temperature for the period of 1961-1990 to 2040-2059 (median of 20-year means computed from the 16 GCMs in Table 1).

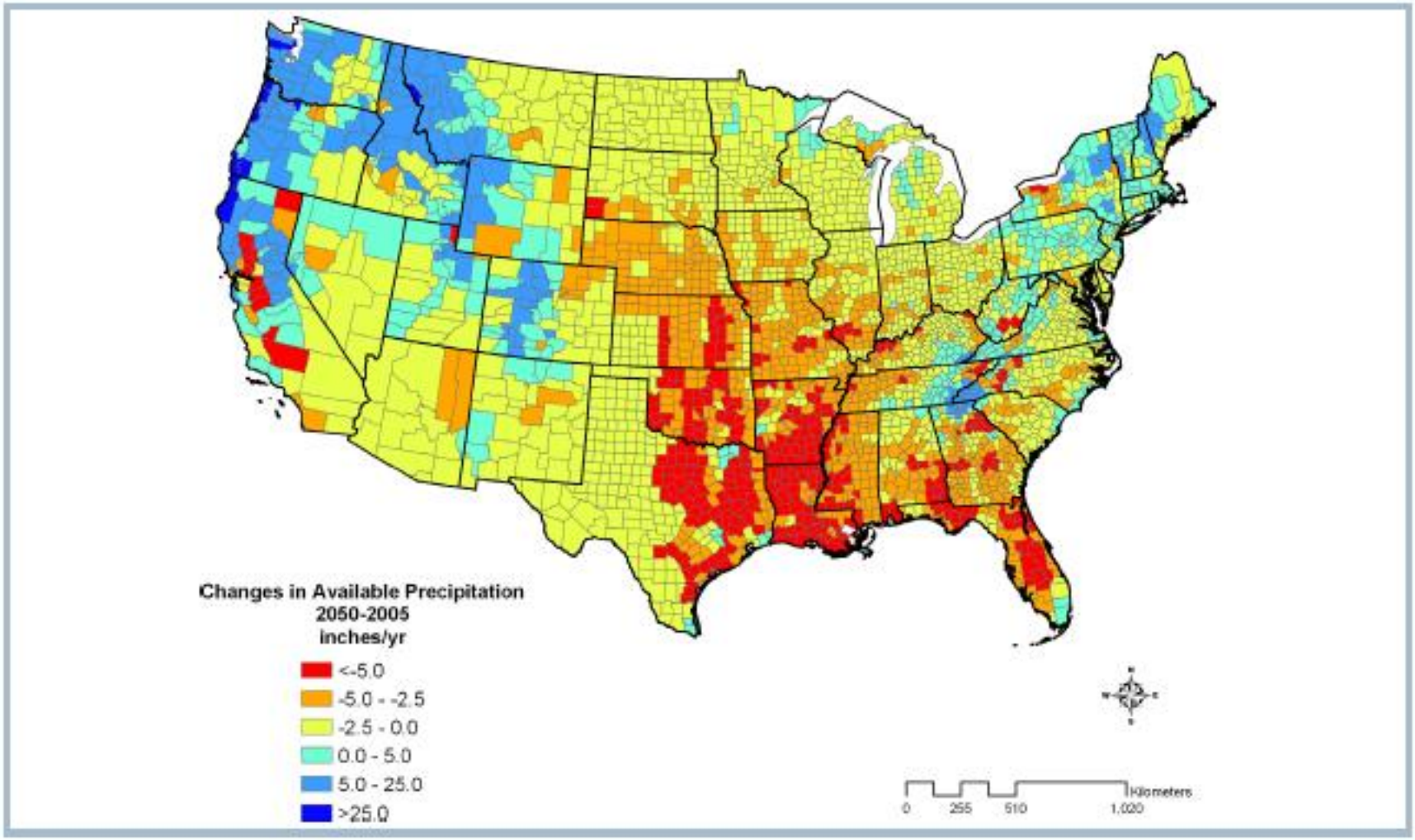
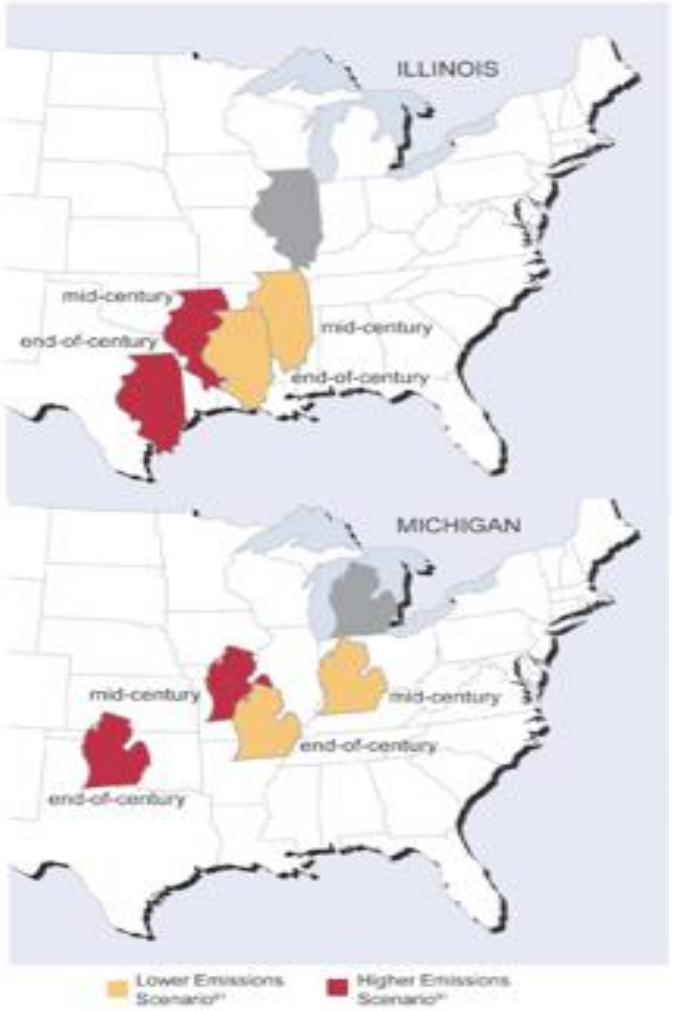
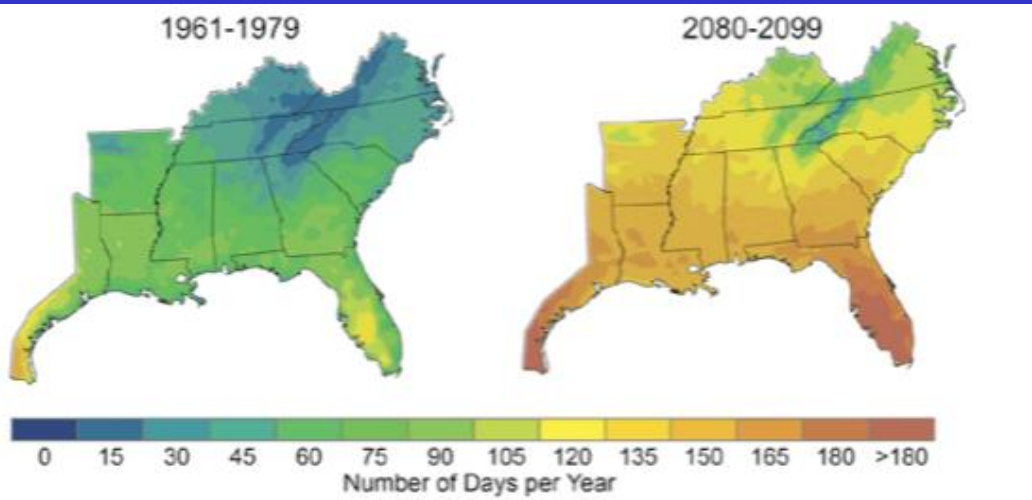


Figure 12. Changes in available precipitation from 2005 to 2050 in inches/yr. 2050 values are based on an ensemble of 16 GCMs and represent conditions between 2040 and 2059.



By the end of the century

+ 2.5° F to more than 13° F



From: Global Climate Change Impacts in the US

Potential Climate Change Impacts

Climate Changes

Temperature

Precipitation

Sea Level Rise

Health Impacts

Weather-related Mortality
Infectious Diseases
Air Quality-Respiratory Illnesses

Agriculture Impacts

Crop yields
Irrigation demands

Forest Impacts

Change in forest composition
Shift geographic range of forests
Forest Health and Productivity

Water Resource Impacts

Changes in water supply
Water quality
Increased Competition for water

Impacts on Coastal Areas

Erosion of beaches
Inundate coastal lands
Costs to defend coastal communities

Species and Natural Areas

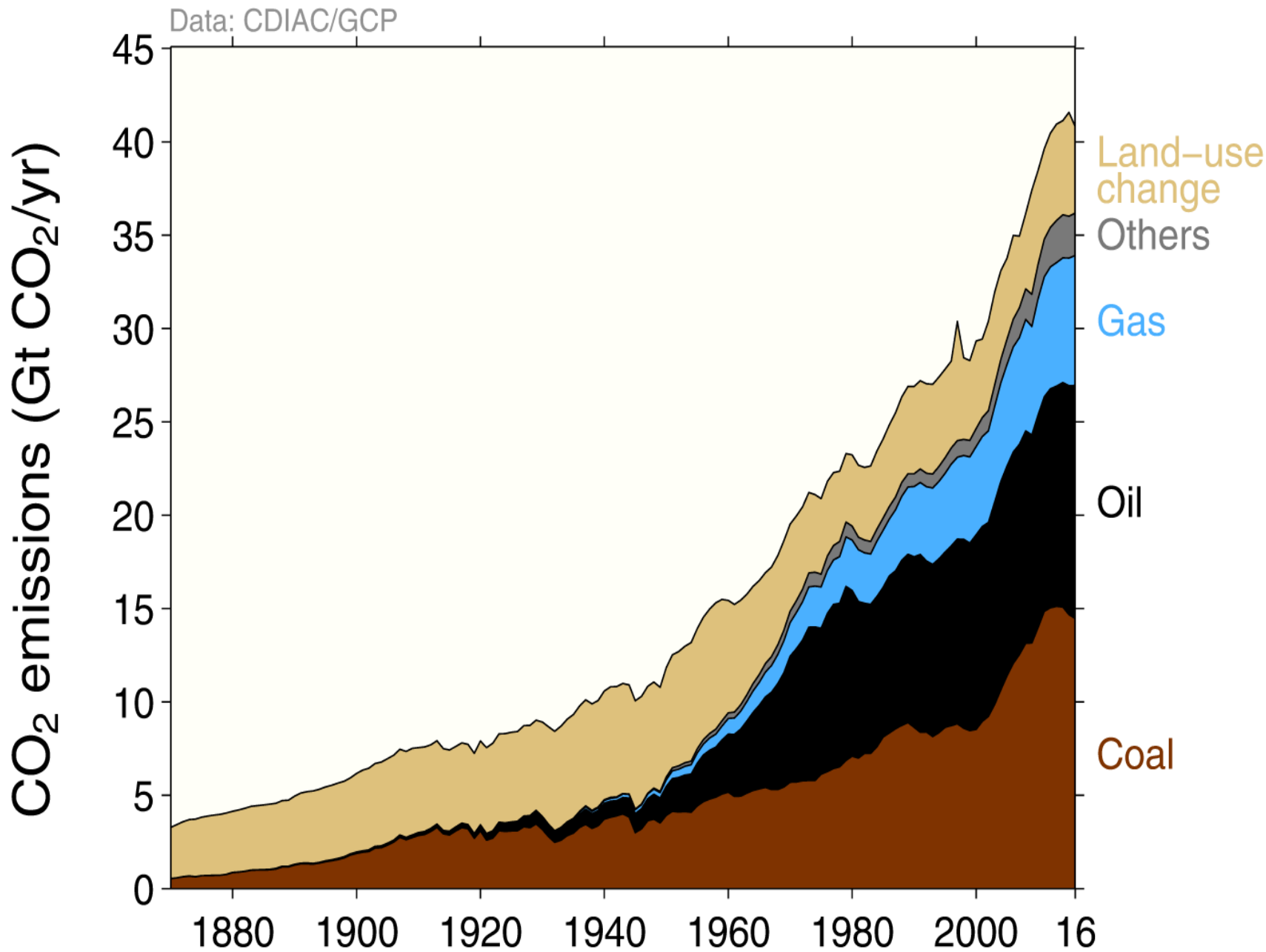
Shift in ecological zones
Loss of habitat and species

EPA

United States Environmental Protection Agency

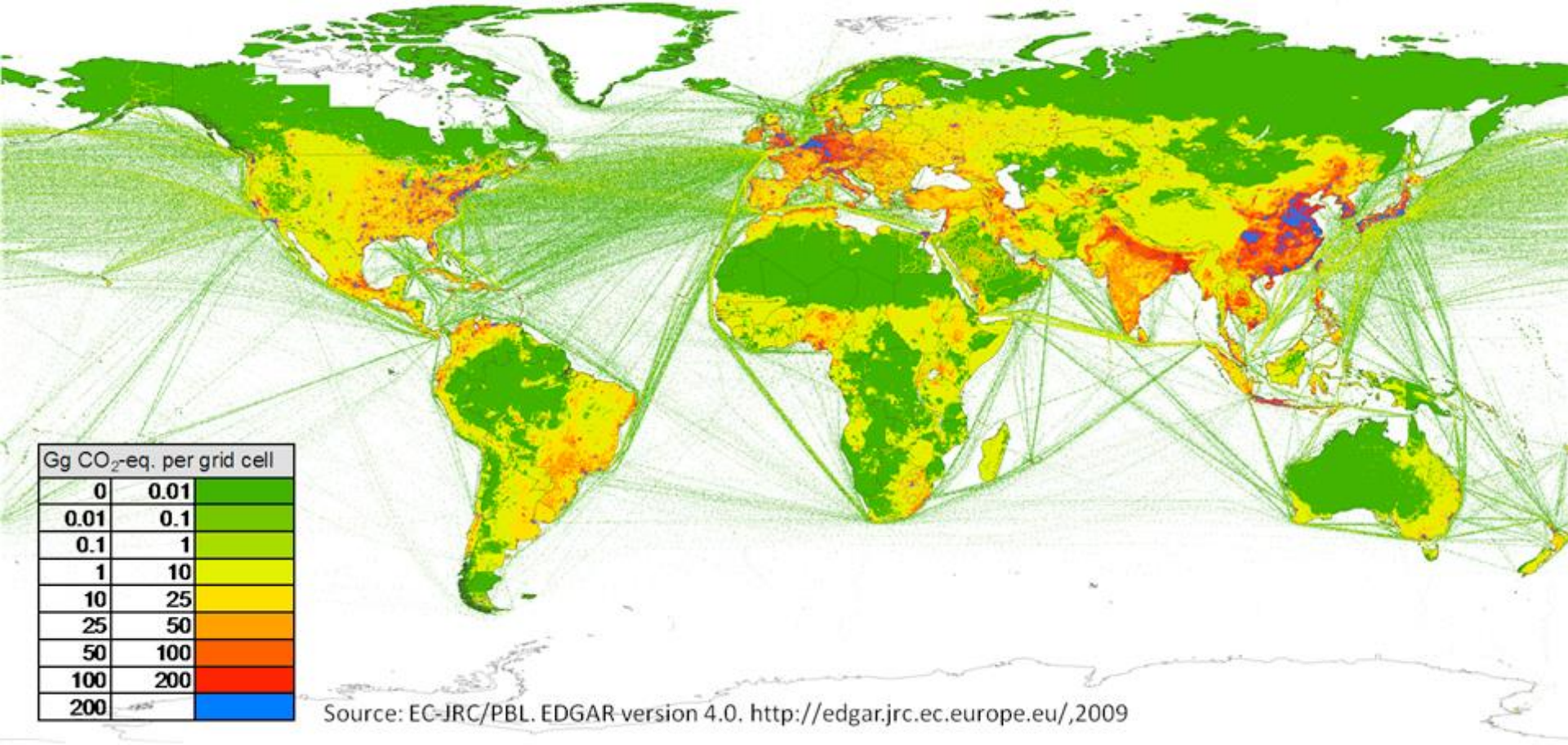
Who is responsible?

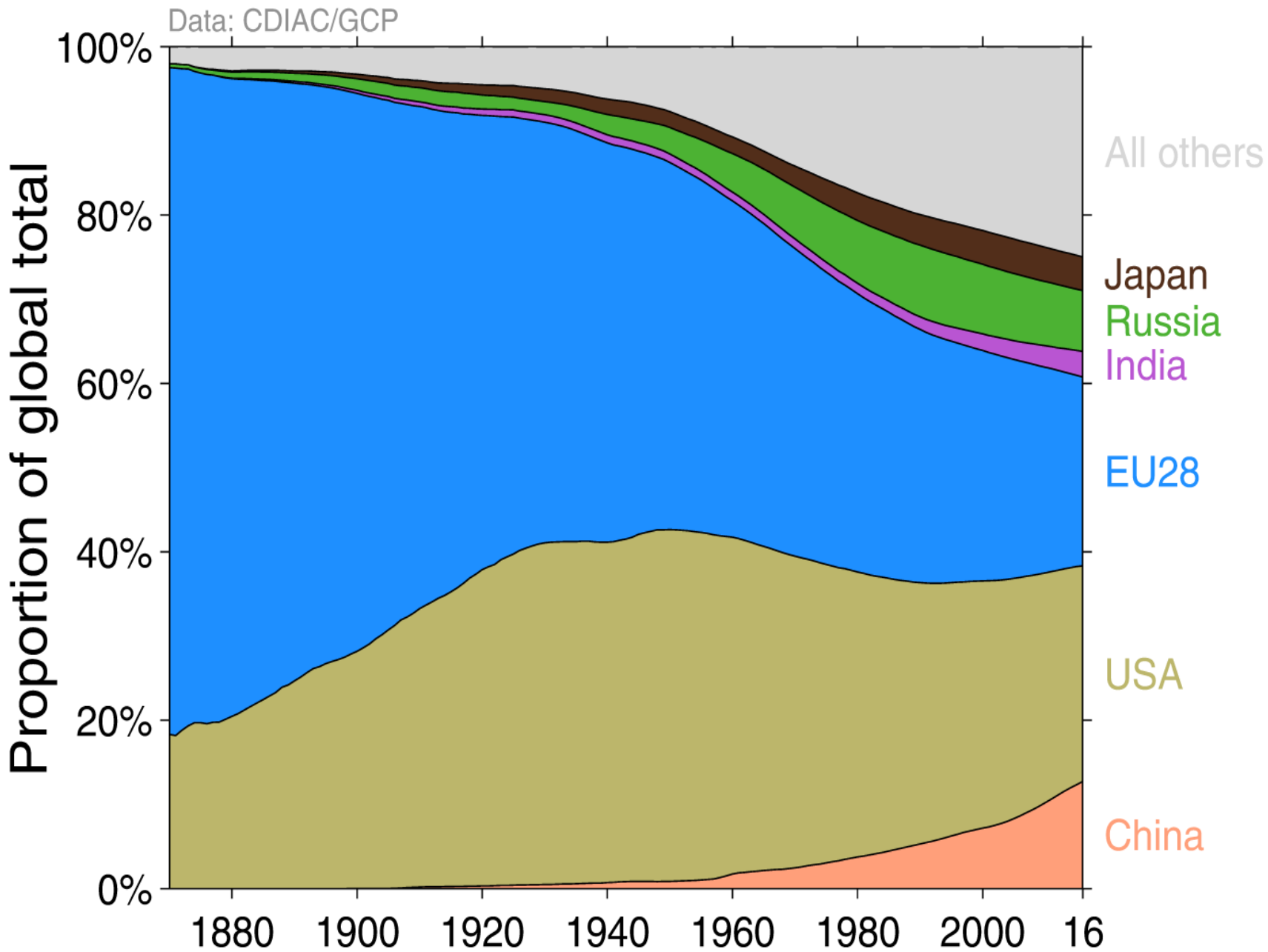
What can be (or has) done?



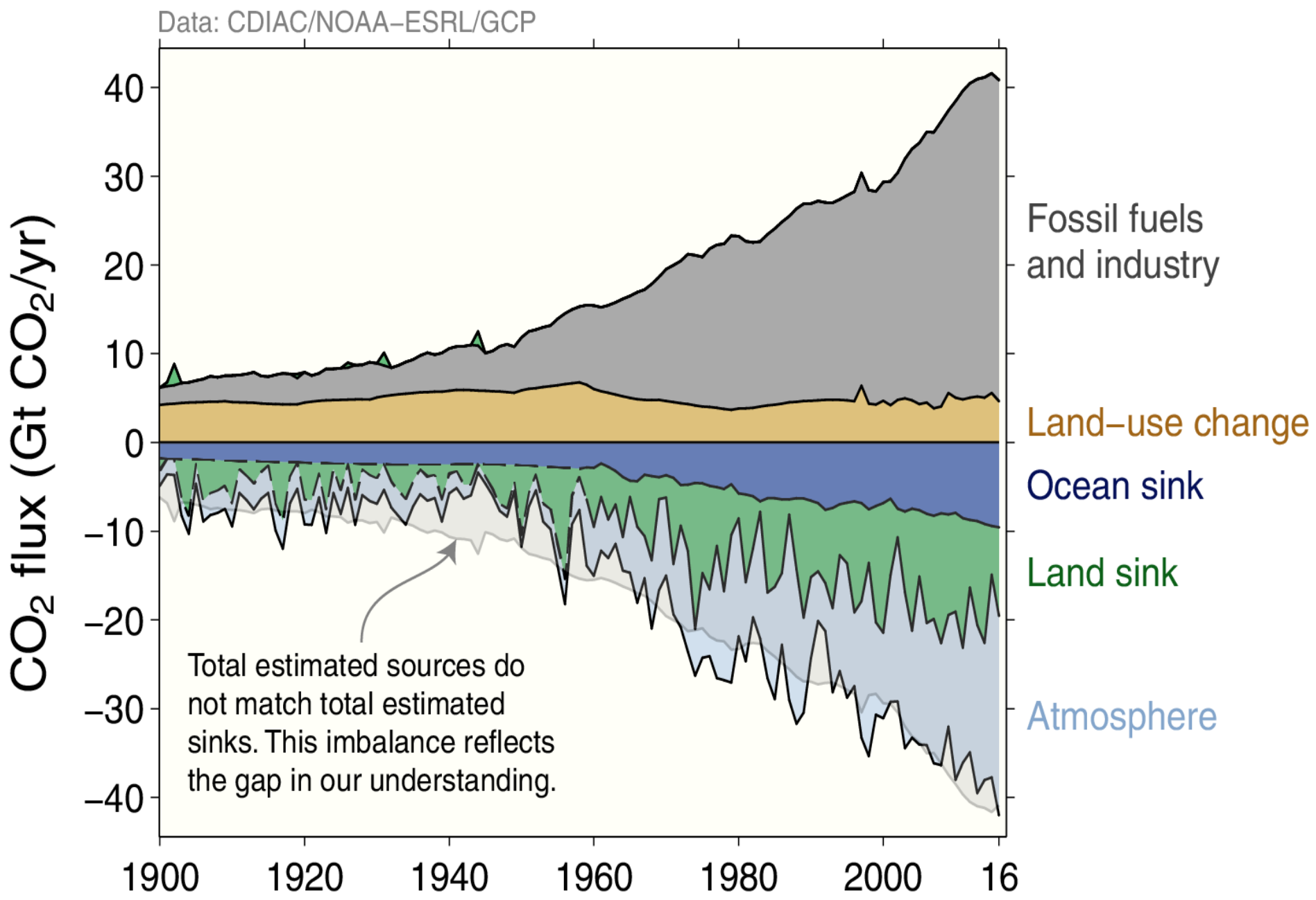
Global Carbon Project

Spatial Distribution of Greenhouse Gas Emissions

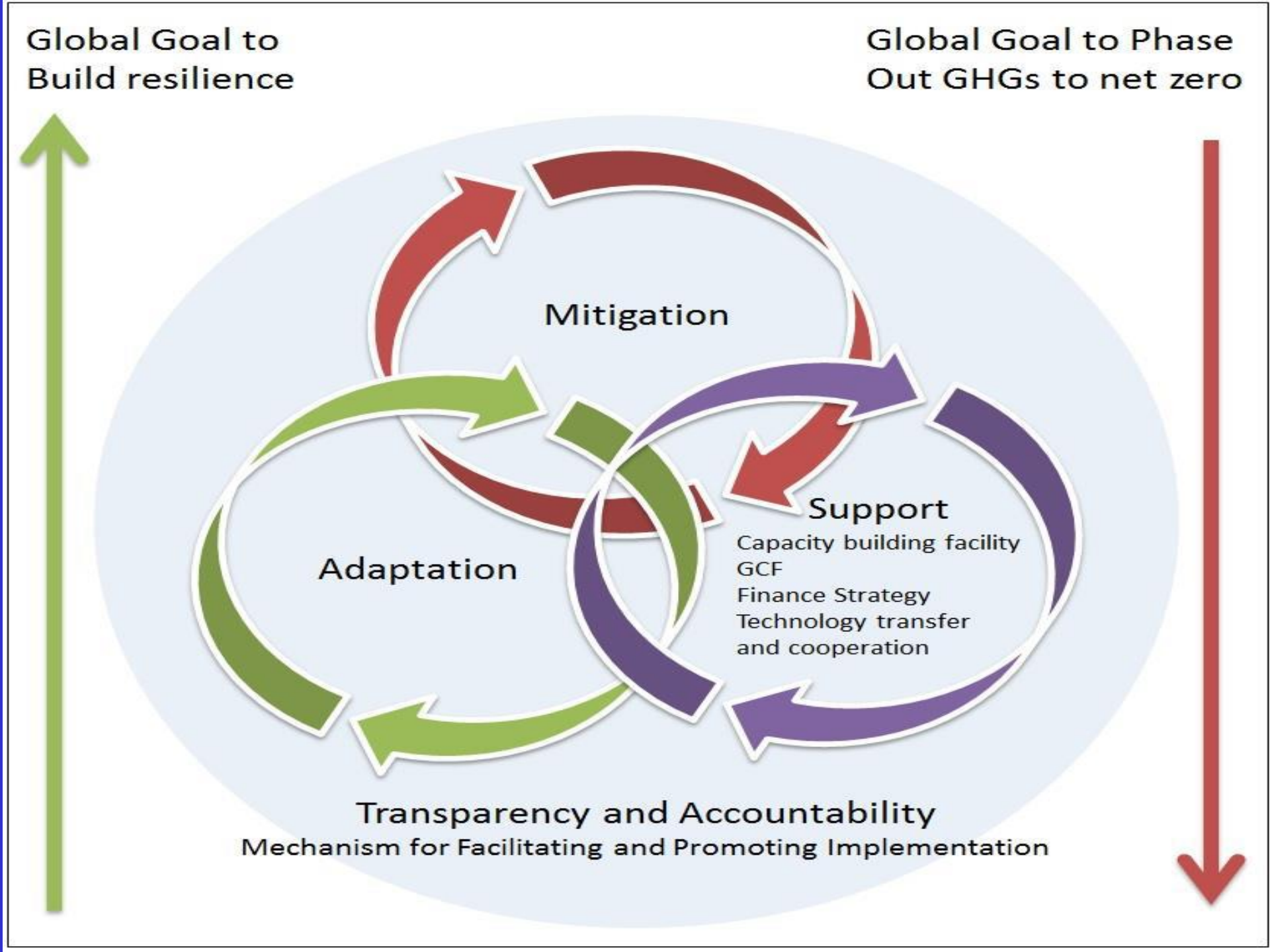




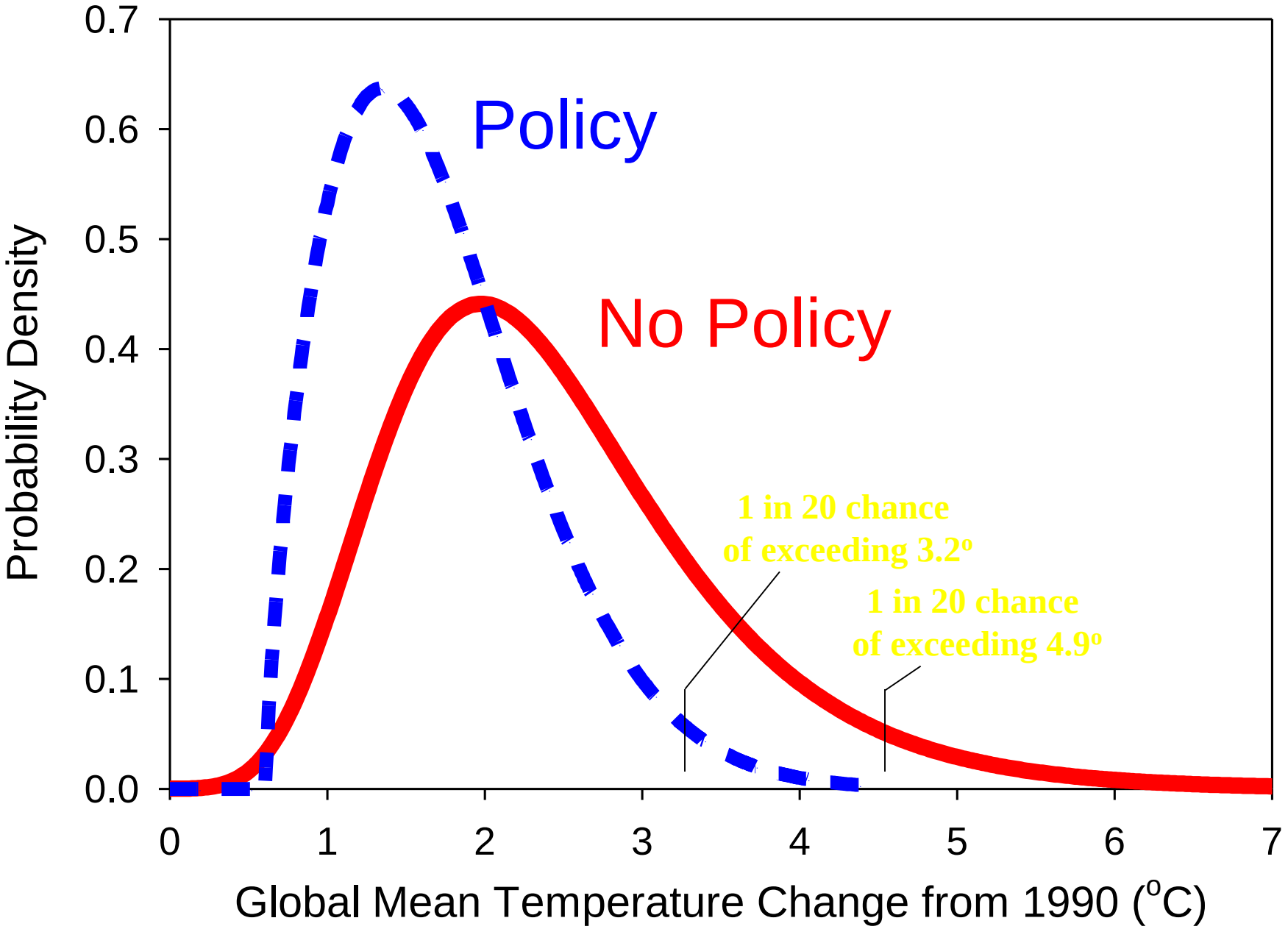
Global Carbon Project

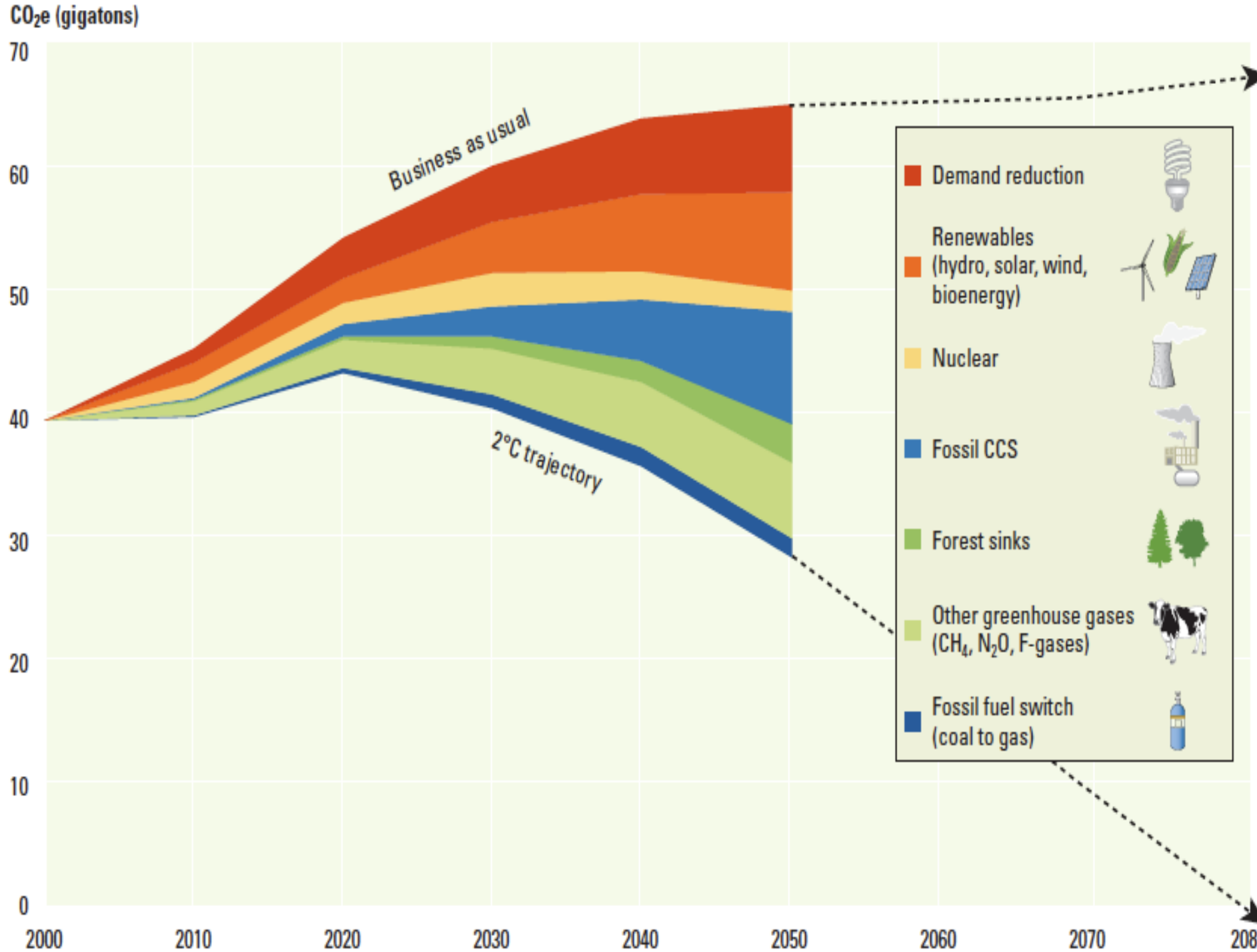


Global Carbon Project


Global Goal to
Build resilience
Global Goal to Phase
Out GHGs to net zero
Mitigation
Adaptation
Support
Capacity building facility
GCF
Finance Strategy
Technology transfer
and cooperation
Transparency and Accountability
Mechanism for Facilitating and Promoting Implementation

Global Mean Temperature Change by 2100




CO_2e (gigatons)
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
2060
2070
Business as usual
2°C trajectory
Demand reduction
Renewables (hydro, solar, wind, bioenergy)
Nuclear
Fossil CCS
Forest sinks
Other greenhouse gases (CH_4, N_2O, F-gases)
Fossil fuel switch (coal to gas)