

The ABC's of Climate Change

G. Metcalf

Economics of Climate Change
AEA Continuing Education Workshop
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Outline of Lecture

- What is climate change?
- Greenhouse gases
 - What are they?
 - Global trends
 - Top emitters
- Stock rather than a flow pollutant
- But is climate change real?
 - Addressing misconceptions
- Role of economics

The Greenhouse Effect



Two Extreme Environments

Our Moon

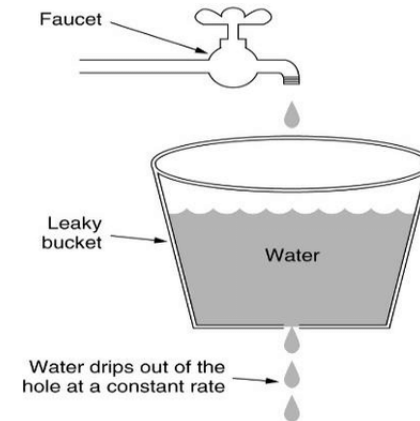
- No atmosphere
- No greenhouse effect
- Temperature varies from -200°F (night) to $+240^{\circ}\text{F}$ (day)
- No atmospheric buffering of temperature

Venus

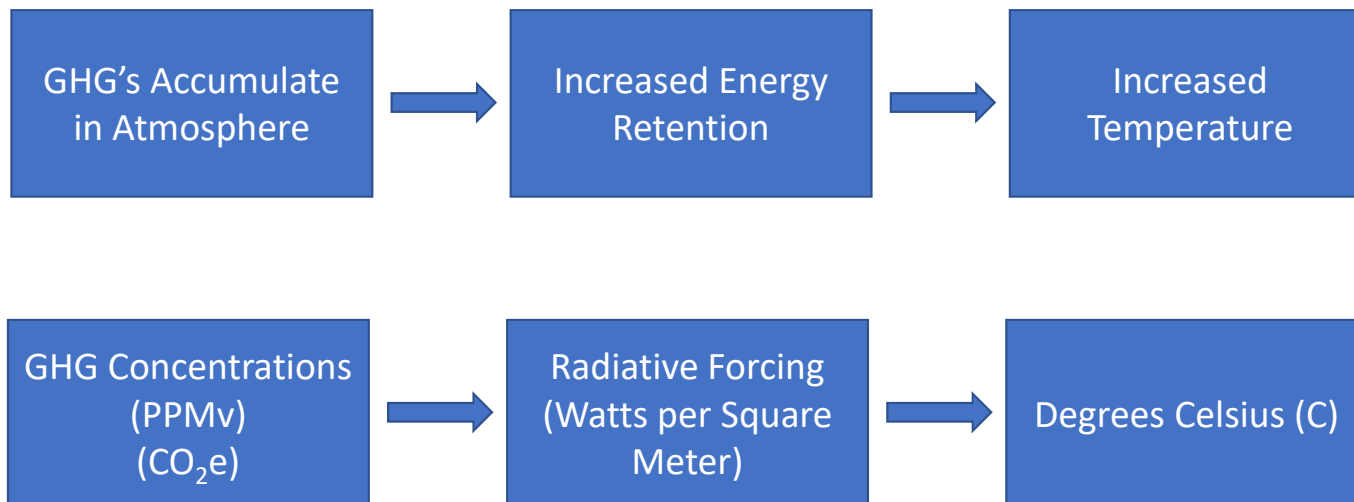
- CO_2 accounts for 96.5% of Venus's atmosphere
 - 0.04% on Earth
- Higher pressure (92x Earth) makes CO_2 more absorbing
- Surface temperature of 850°F

A Delicate Balance

- Greenhouse gases in the atmosphere trap some of the solar energy warming the planet
- Balance of incoming and outgoing energy leads to equilibrium planetary heating
 - Warmth akin to the level of water in a leaky bucket with water constantly being added at just the right rate
- Adding greenhouse gases to atmosphere akin to reducing the size of the leak out of the bucket
 - Level of water in bucket rises
 - Planet warms

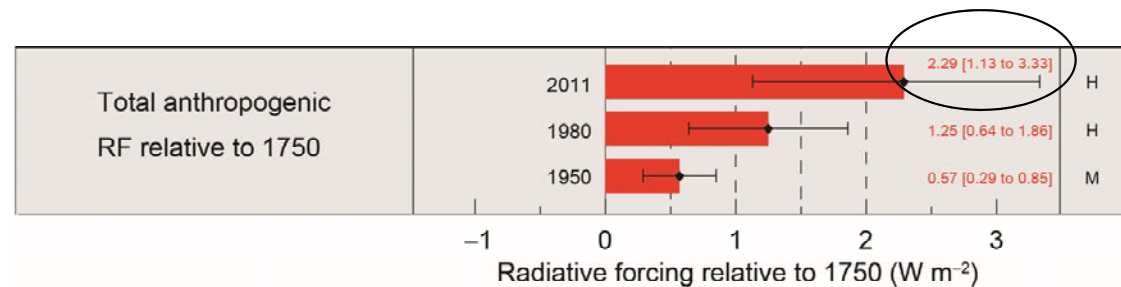


Overview of Concepts Covered

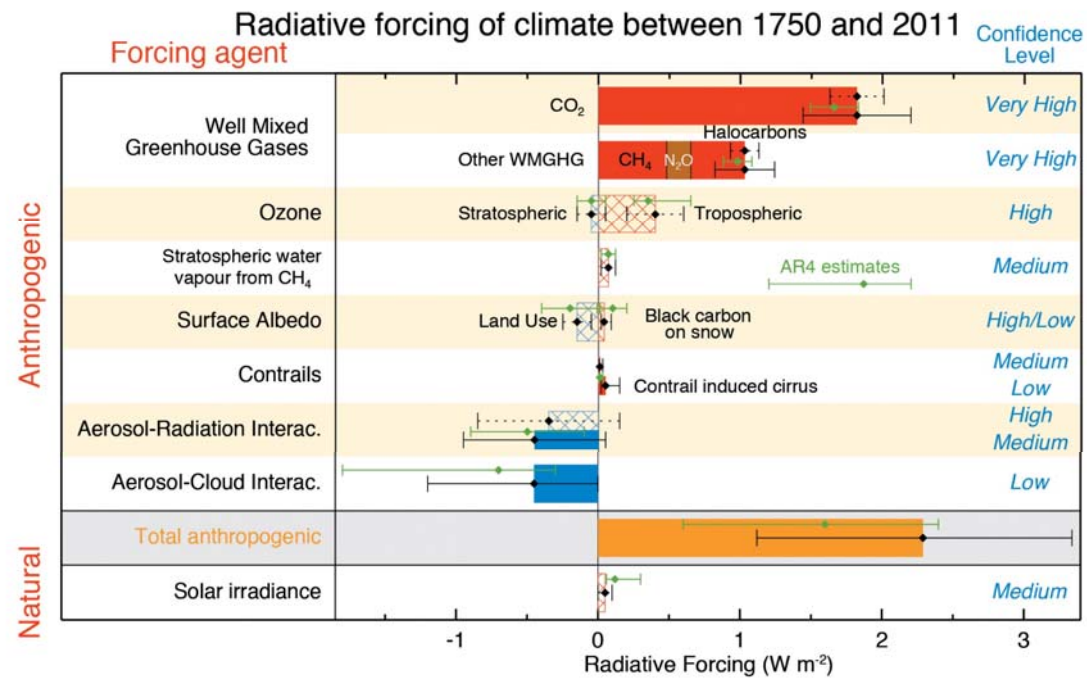


Radiative Forcing

- Measured in watts per square meter
- Typically measured relative to 1750
- As greenhouse gases accumulate...
 - Radiative forcing goes up...
 - More heat trapped on the earth...
 - Warming occurs



Forcing as of 2011



Radiative Forcing: Implications

- Forcing is already happening
- It is only going to increase in a business as usual world
- Implications for climate?

Value in 2011:
2.3 W/m²

Forcing in 2100 Compared to 1750 (Wm ⁻²)	Climate Policy	Projected Global Temperature Increase by 2100 from 1986- 2005 (°C)	
2.6	Mitigation	1.0	0.3 to 1.7
4.5	Stabilization	1.8	1.1 to 2.6
6.0	Stabilization	2.2	1.4 to 3.1
8.5	No Policy	3.7	2.6 to 4.8

Greenhouse Gases

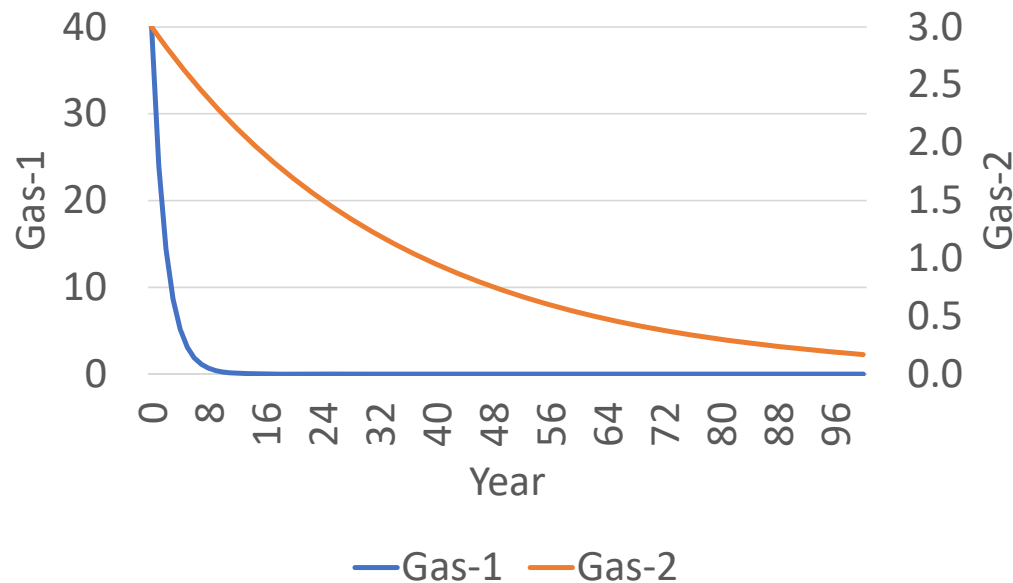
- Carbon dioxide
- Methane (CH_4)
- Nitrous Oxide (N_2O)
- Other Gases
 - Halocarbons
 - Fluorocarbons (HFC's, PFC's)
 - Sulphur hexafluoride (SF_6)

Global Warming Potential

- GHG's differ in impact and persistence in atmosphere
- Global warming potential (GWP) converts gases into a “carbon dioxide equivalent”
 - GWP measures the amount of forcing from CO₂ equivalent to one unit of a GHG
 - GWP depends on the time period over which the comparison is made
 - GWP over 100 years typically reported
- No theoretically correct measure – GWPs are *not* exchange rates

A Problem with GWP's

- Consider two gases:
 - Gas 1 has high initial forcing and a high exponential decay rate
 - Gas 2 has low initial forcing and a lower exponential decay rate



$$F_{it} = F_{i0}e^{-\rho_i t}$$

Gas	F_0	ρ	GWP
1	40	0.511	100
2	3	0.029	100

Forcing versus Damages

$$GWP_{iS} = \int_0^S F_i e^{-\rho_i s} ds$$

Instantaneous
Forcing

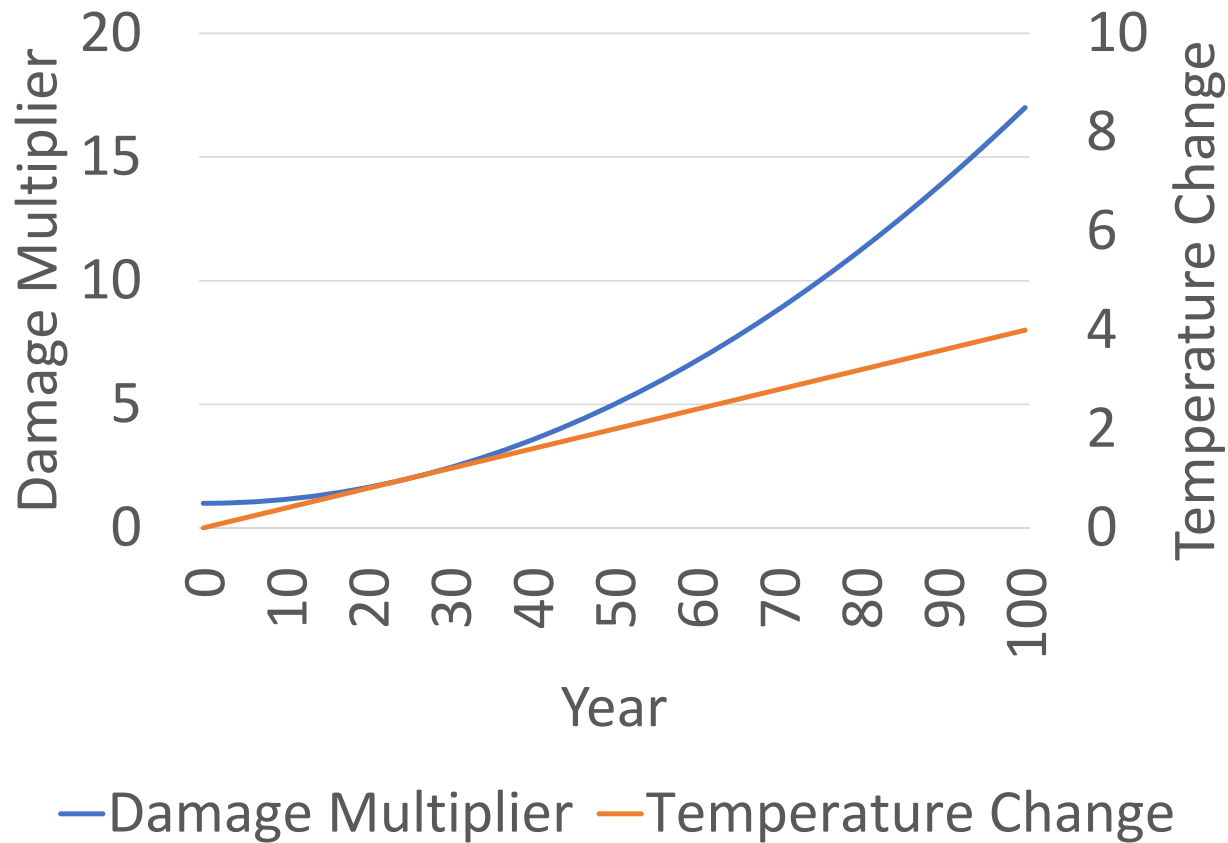
Global Damage
Potential

$$GDP_{iS} = \int_0^S (F_i e^{-\rho_i s}) D(\Delta t_s, r, s) ds$$

Real Damage
Multiplier

Function of
Temperature
Change and
Discount Rate

Damages and Temperature Change

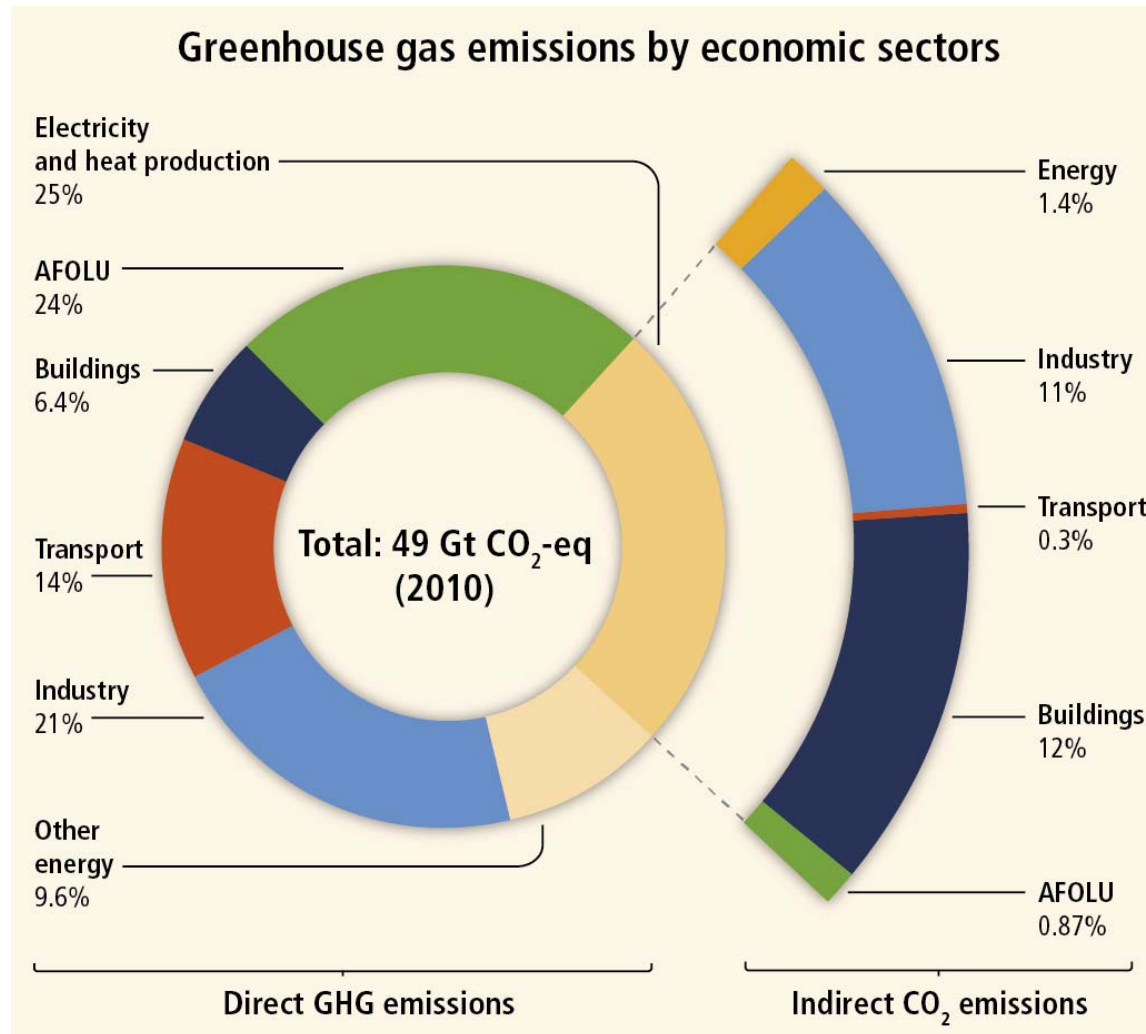


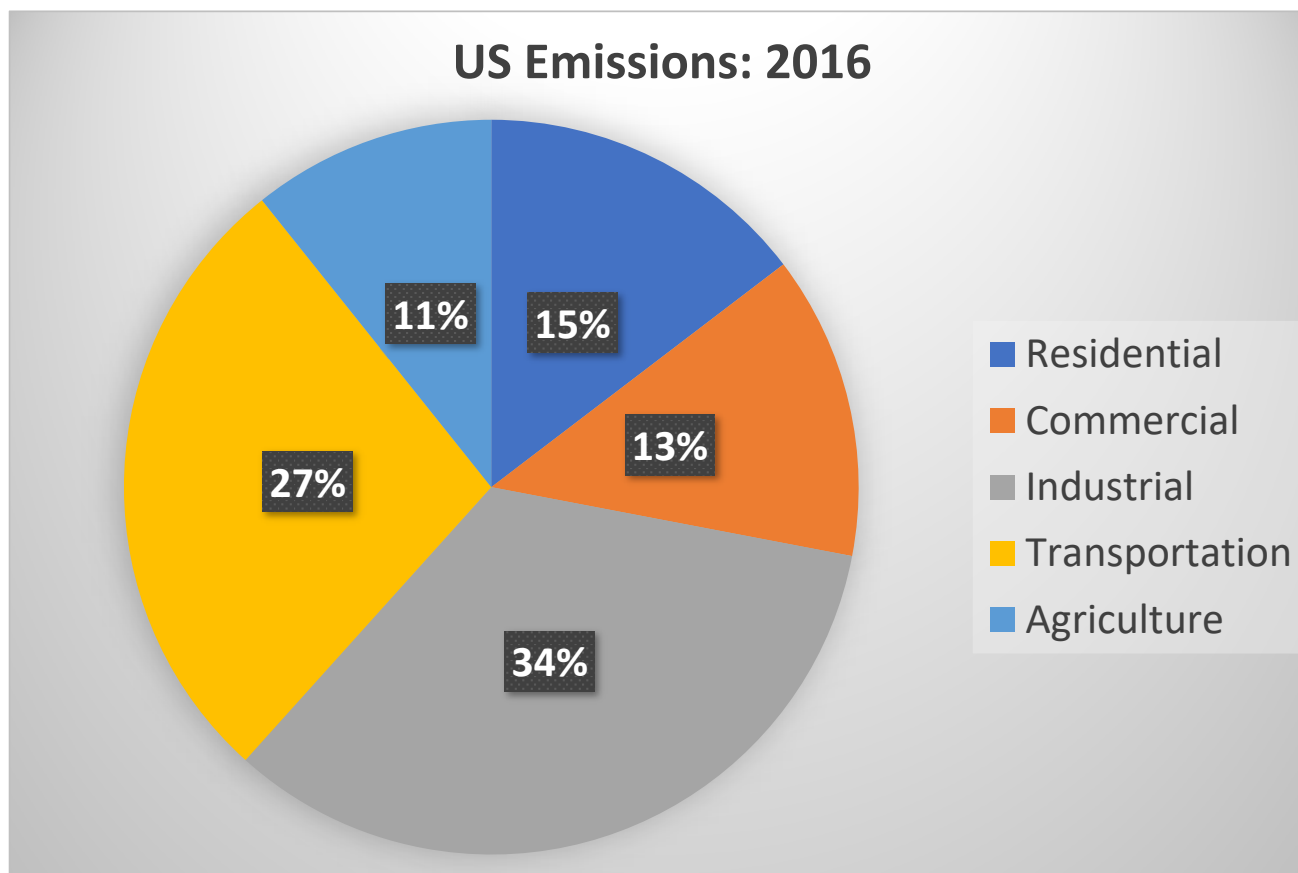
Gas	F_0	ρ	GWP	GDP
1	40	0.511	100	101
2	3	0.029	100	323

Global Warming Potential

	Lifetime (years)		GWP ₂₀	GWP ₁₀₀
CH ₄ ^b	12.4 ^a	No cc fb	84	28
		With cc fb	86	34
HFC-134a	13.4	No cc fb	3710	1300
		With cc fb	3790	1550
CFC-11	45.0	No cc fb	6900	4660
		With cc fb	7020	5350
N ₂ O	121.0 ^a	No cc fb	264	265
		With cc fb	268	298
CF ₄	50,000.0	No cc fb	4880	6630
		With cc fb	4950	7350

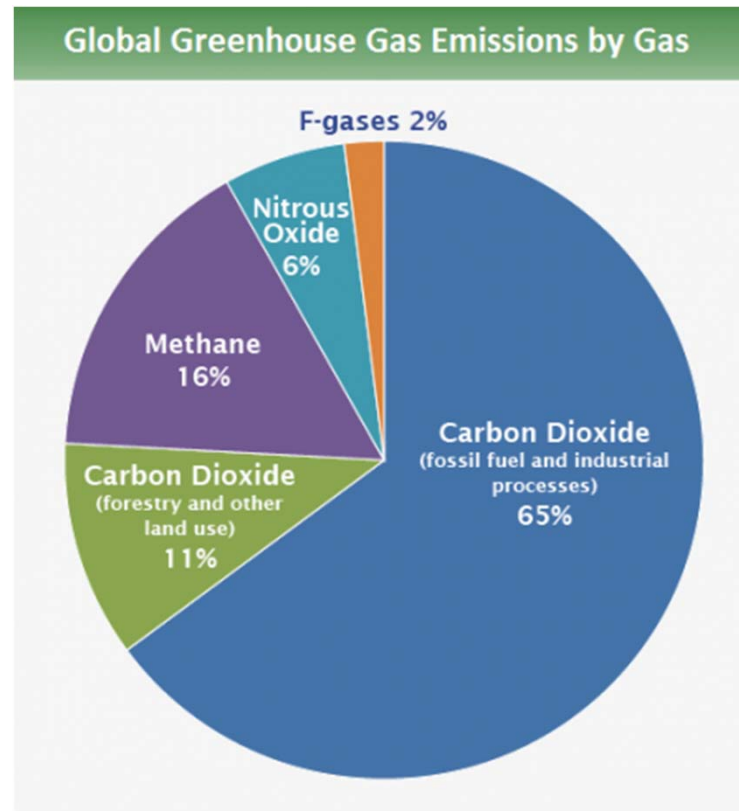
Climate change
feedback



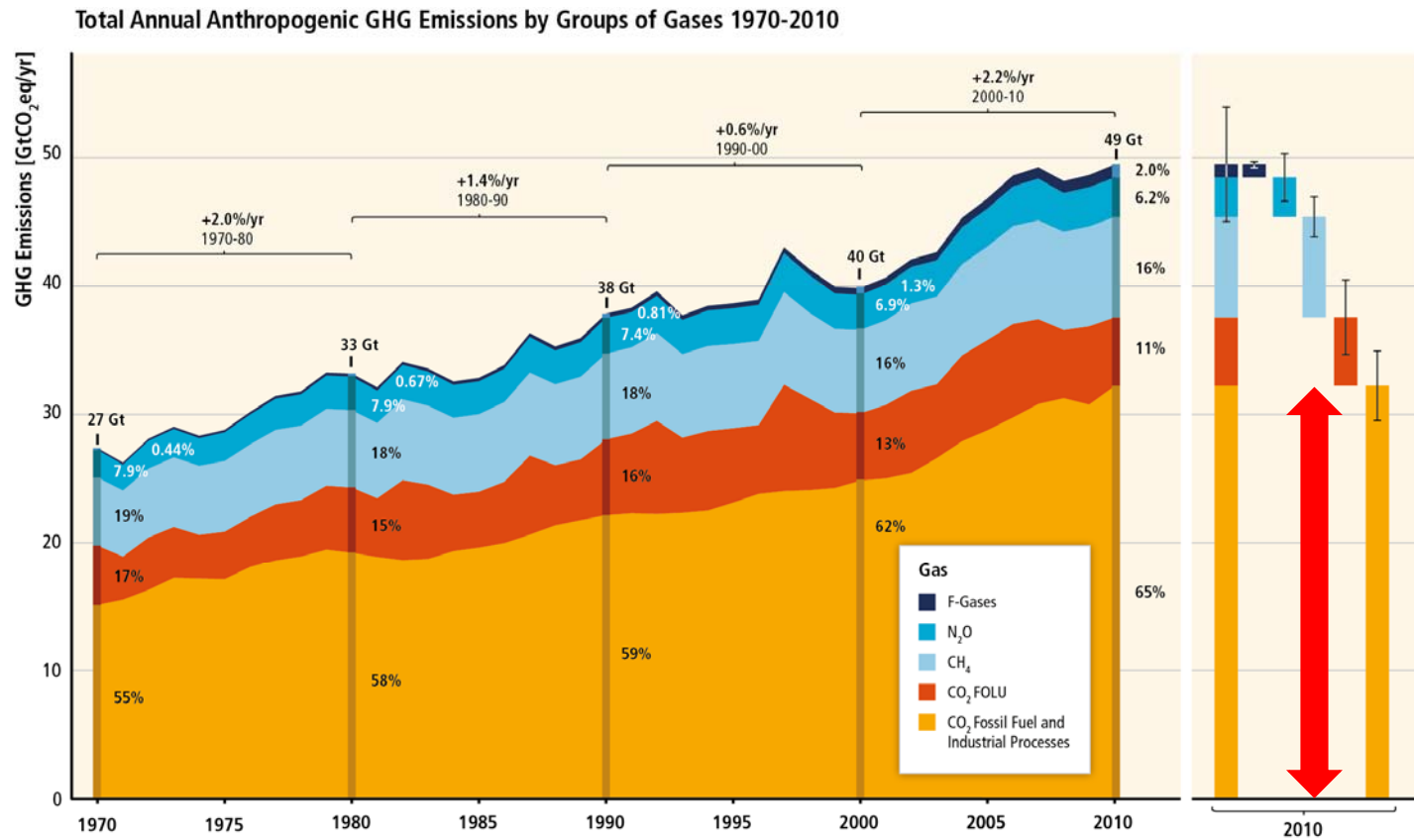


EPA (2018) – Forestry and Land Use Not Included

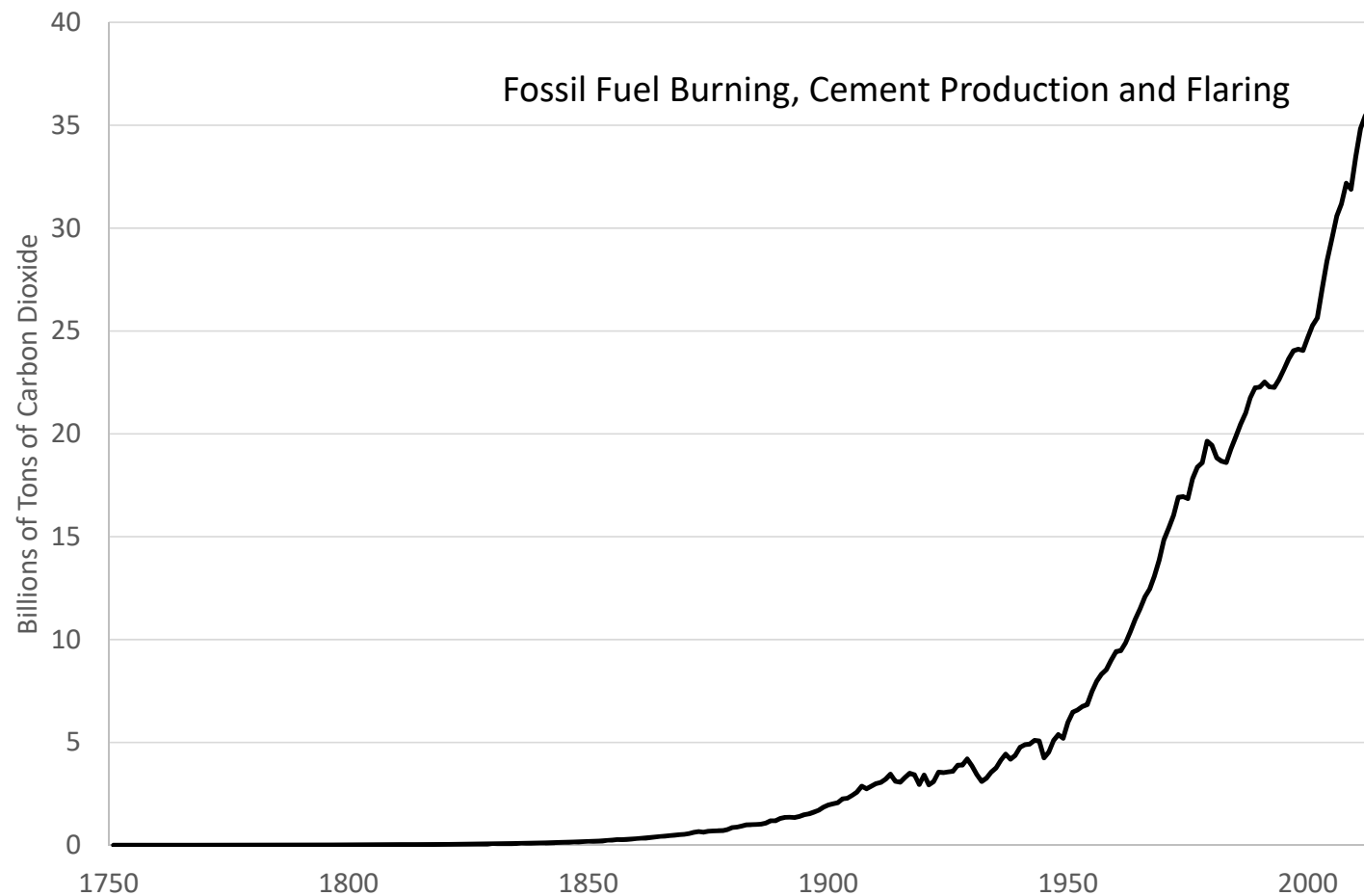
Global Emissions Breakdown in 2010



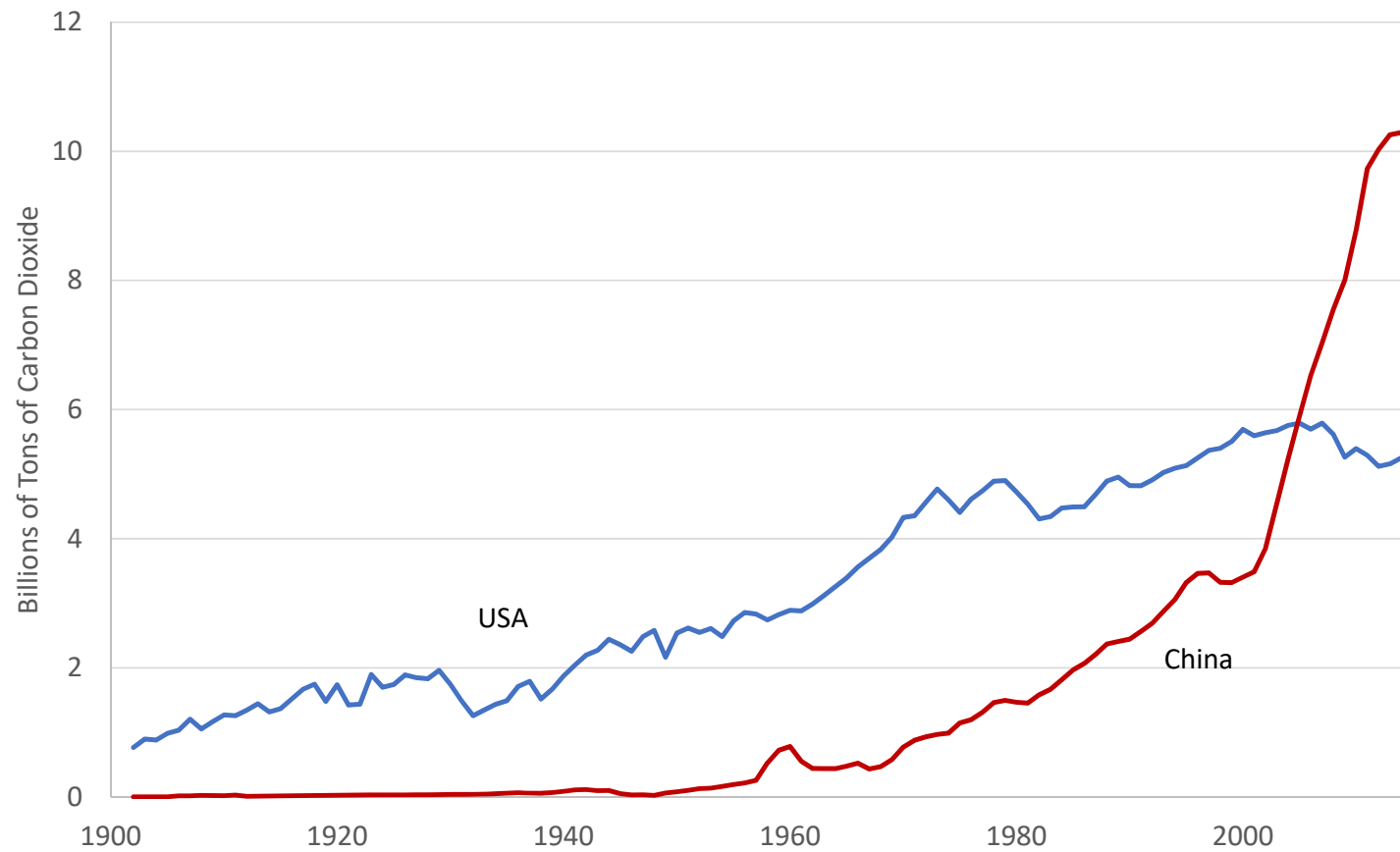
Global Emissions Trends



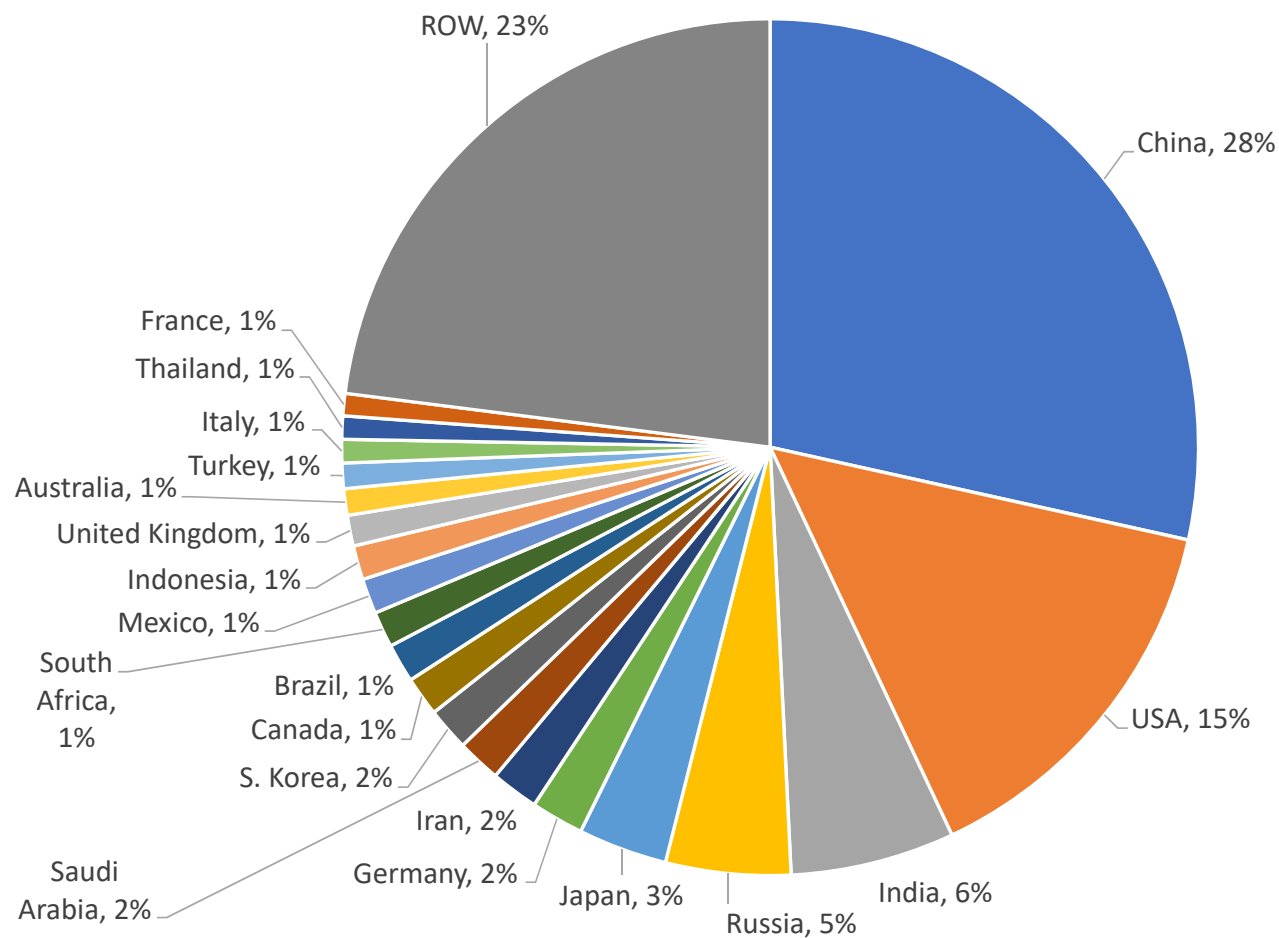
Global CO₂ Emissions: 1751-2014



China and USA: Top Emitters



Top 20 Emitters: 2014



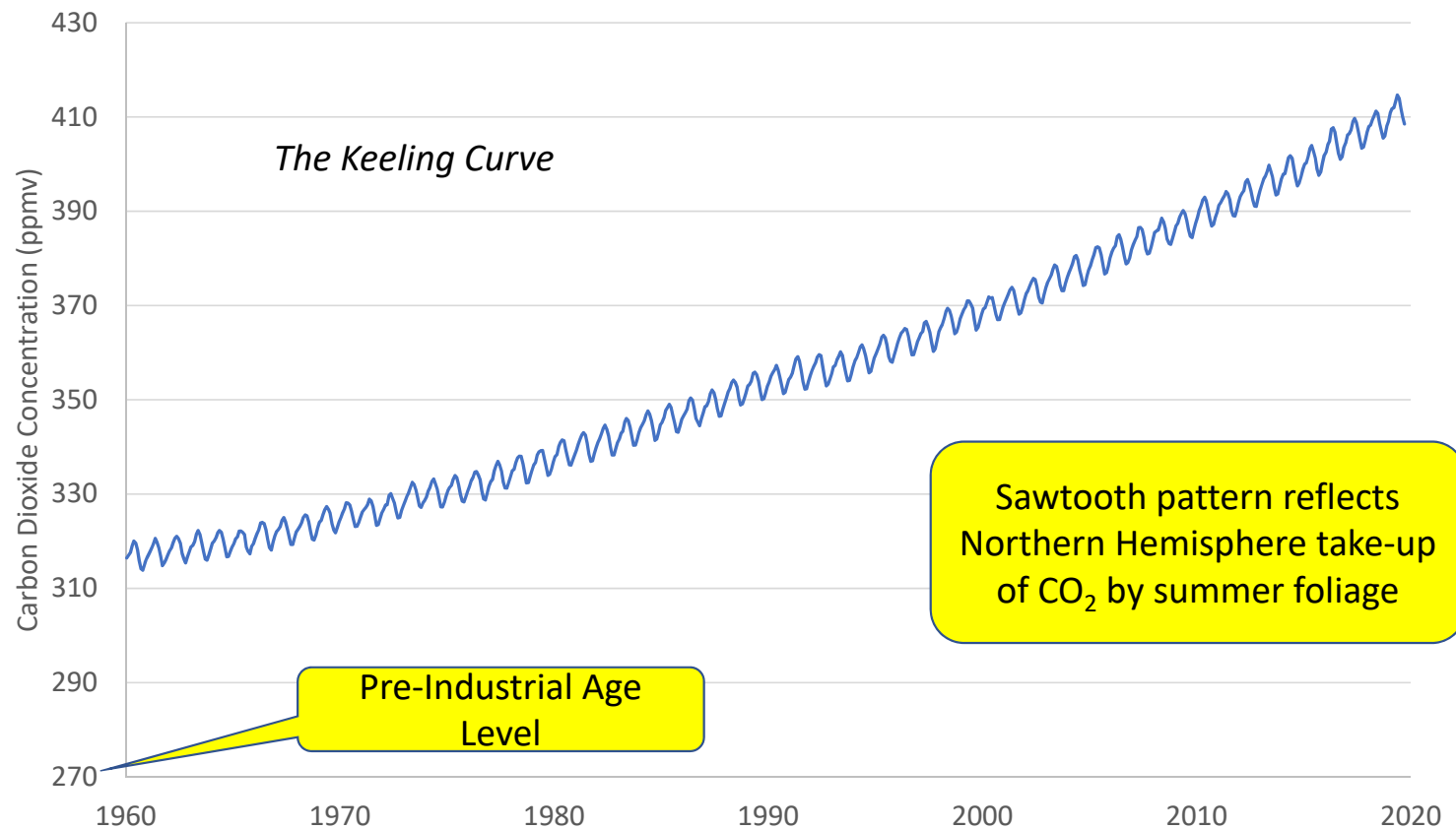
A Global Externality

- Stock of GHG's matter for climate change
- Global, not local, pollutant
- Emissions persist for very long time in atmosphere



Some of Henry
Ford's CO₂ from his
first ride in 1908
still up there

Carbon Dioxide Concentrations: 1960 - 2018



Forcing, CO₂, and Temperature

A simple relationship between CO₂ concentrations and warming:

$$\Delta T = \phi \log_2 \left(\frac{S_t}{S_0} \right)$$

where

ΔT – change in temperature from time 0 to t

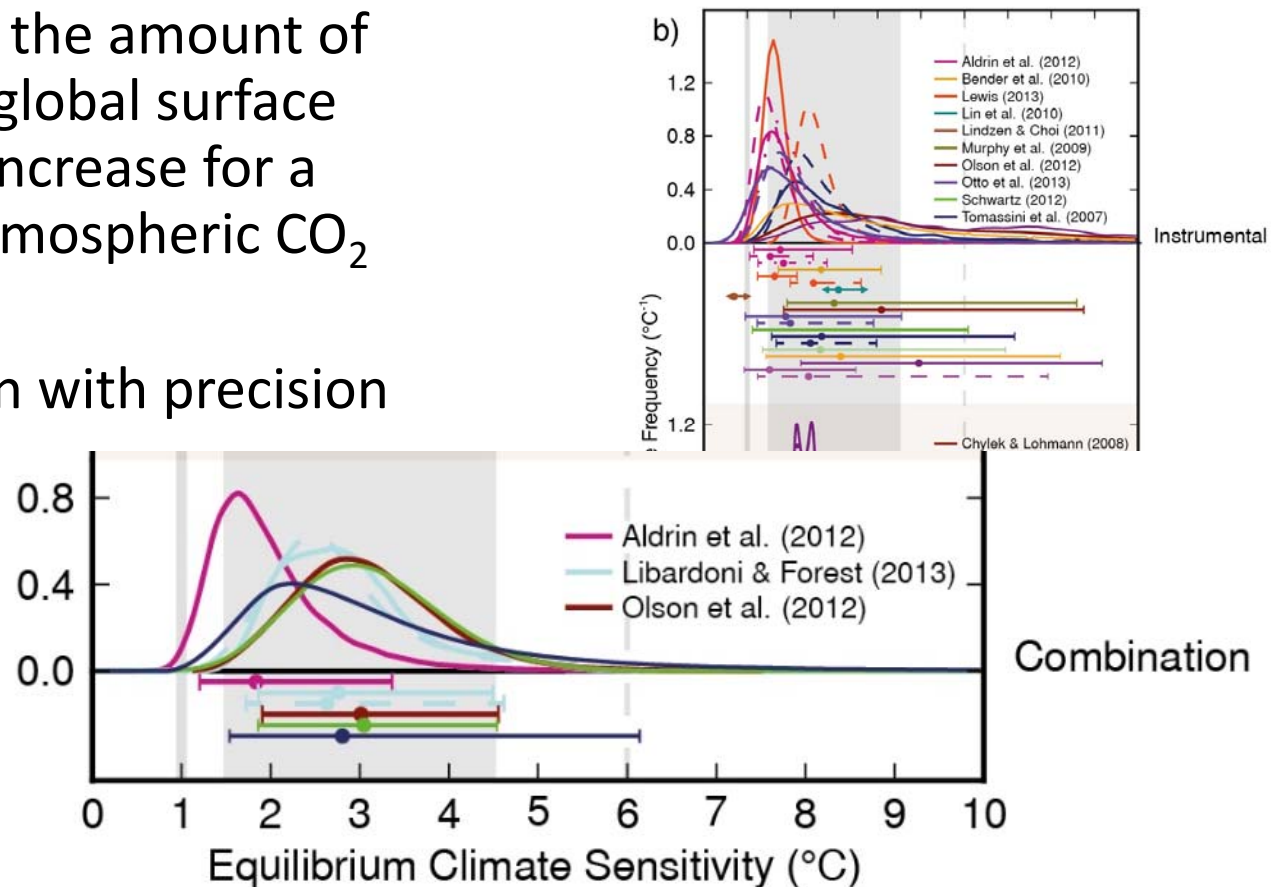
ϕ – equilibrium climate sensitivity (ECS)

S_t – CO₂ stock (ppm) in year t

Note: ~270 ppm in 1750

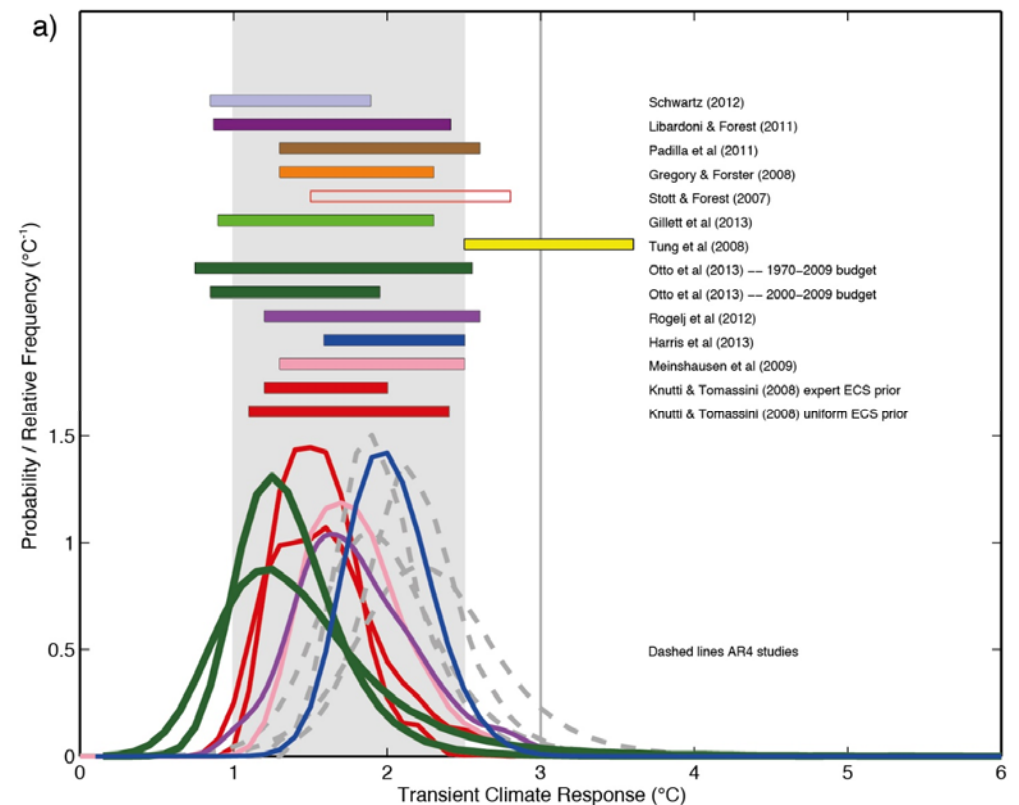
Equilibrium Climate Sensitivity

- ECS measures the amount of annual mean global surface temperature increase for a doubling of atmospheric CO₂ concentration
- ECS not known with precision

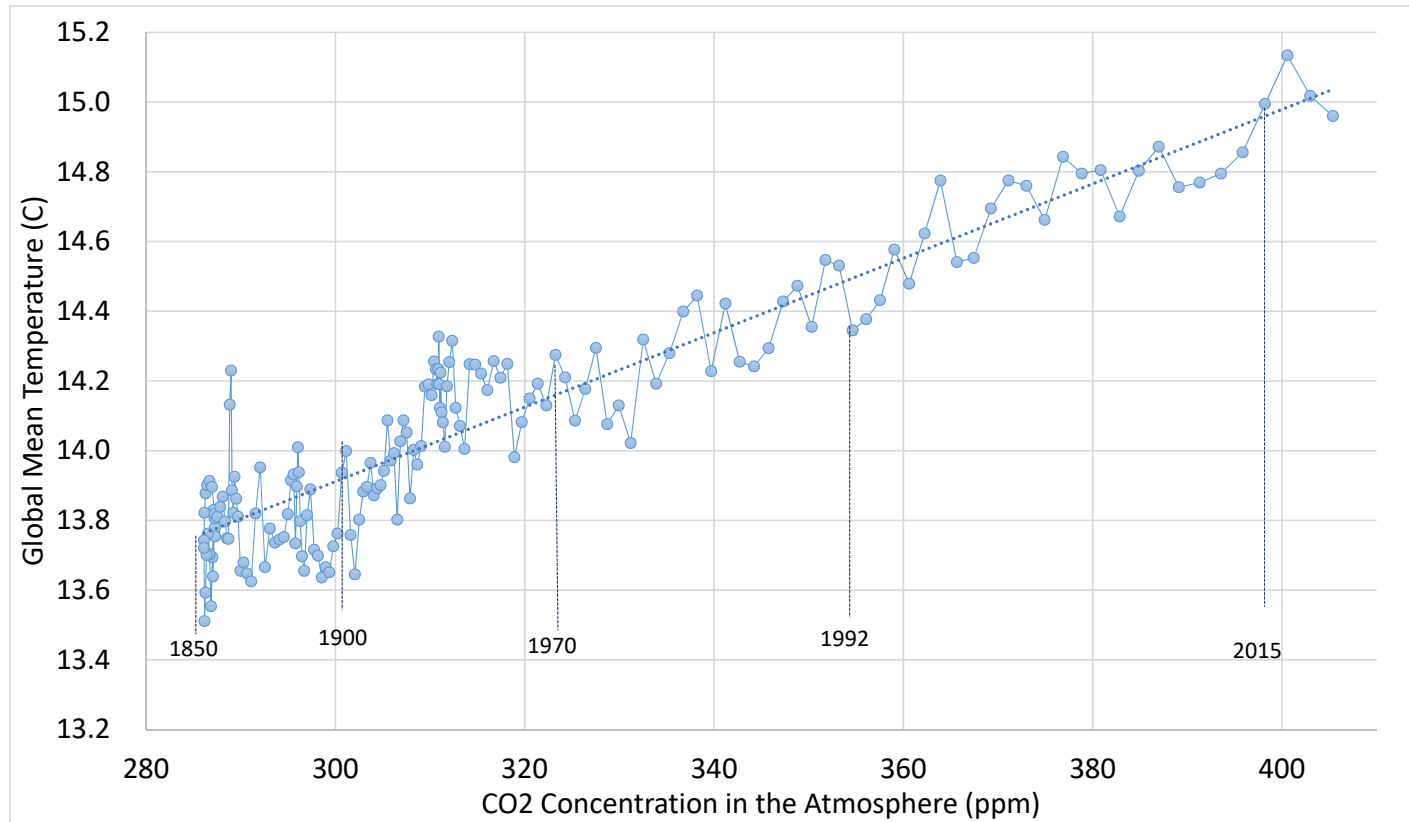


Transient Climate Response

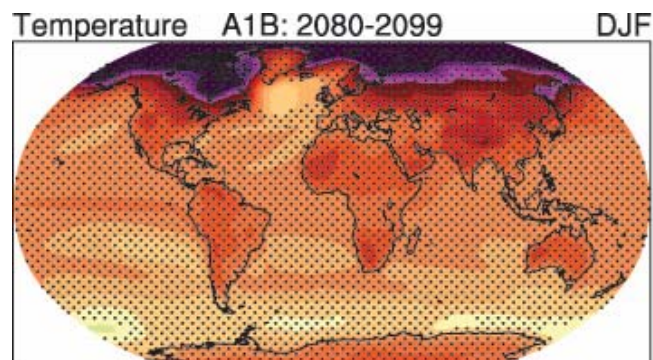
- Warming response to a linear doubling of CO₂ concentrations over a 70 year period
- Also uncertain



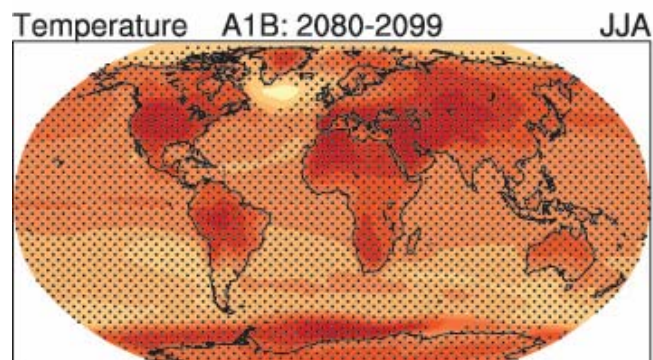
Recent Data: 1850 - 2018



Averages Mask Significant Variation



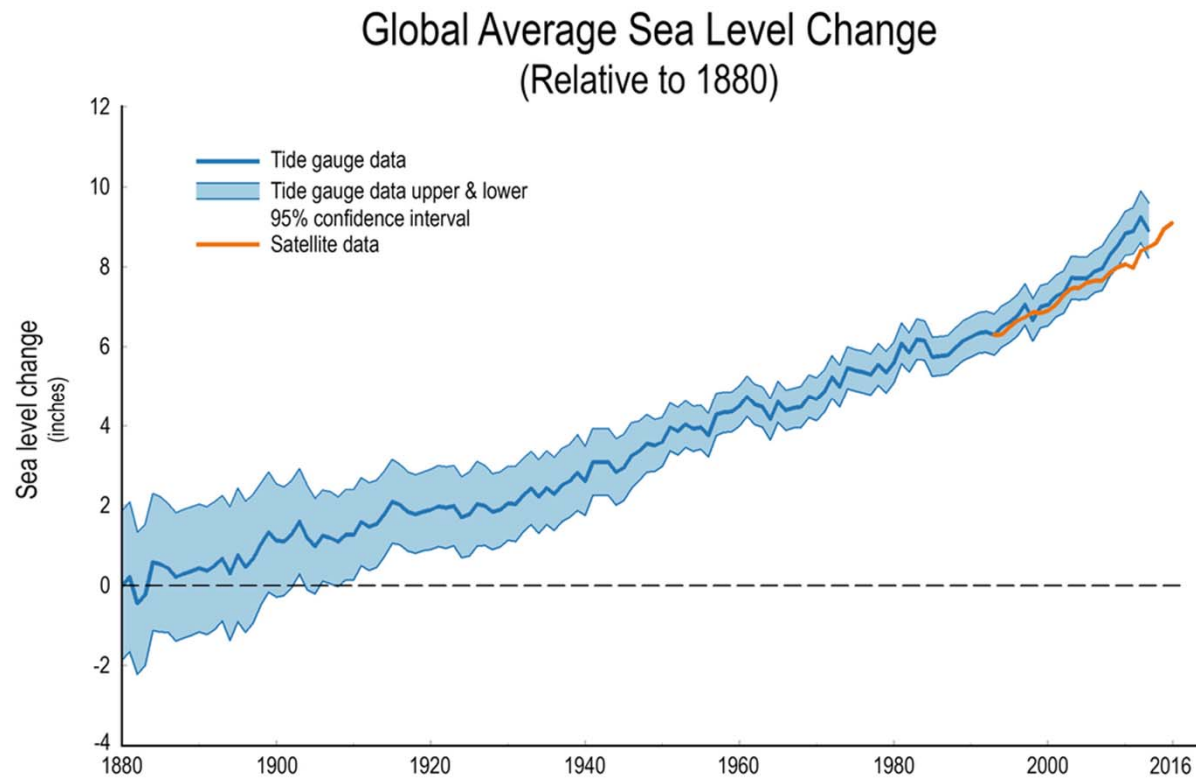
Winter, N. Hemisphere



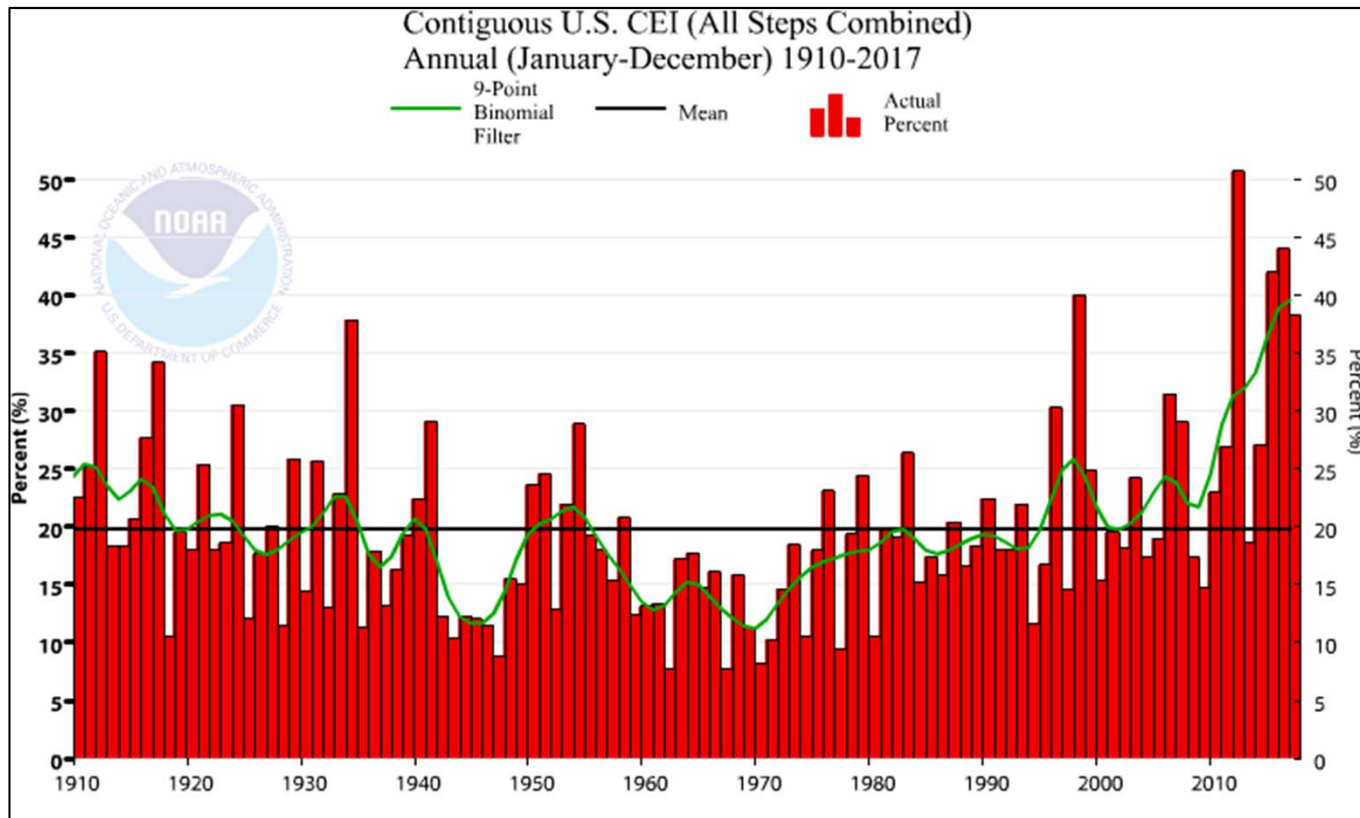
Summer, N. Hemisphere



Impacts Go Beyond Temperature



Increasing Climate Extremes



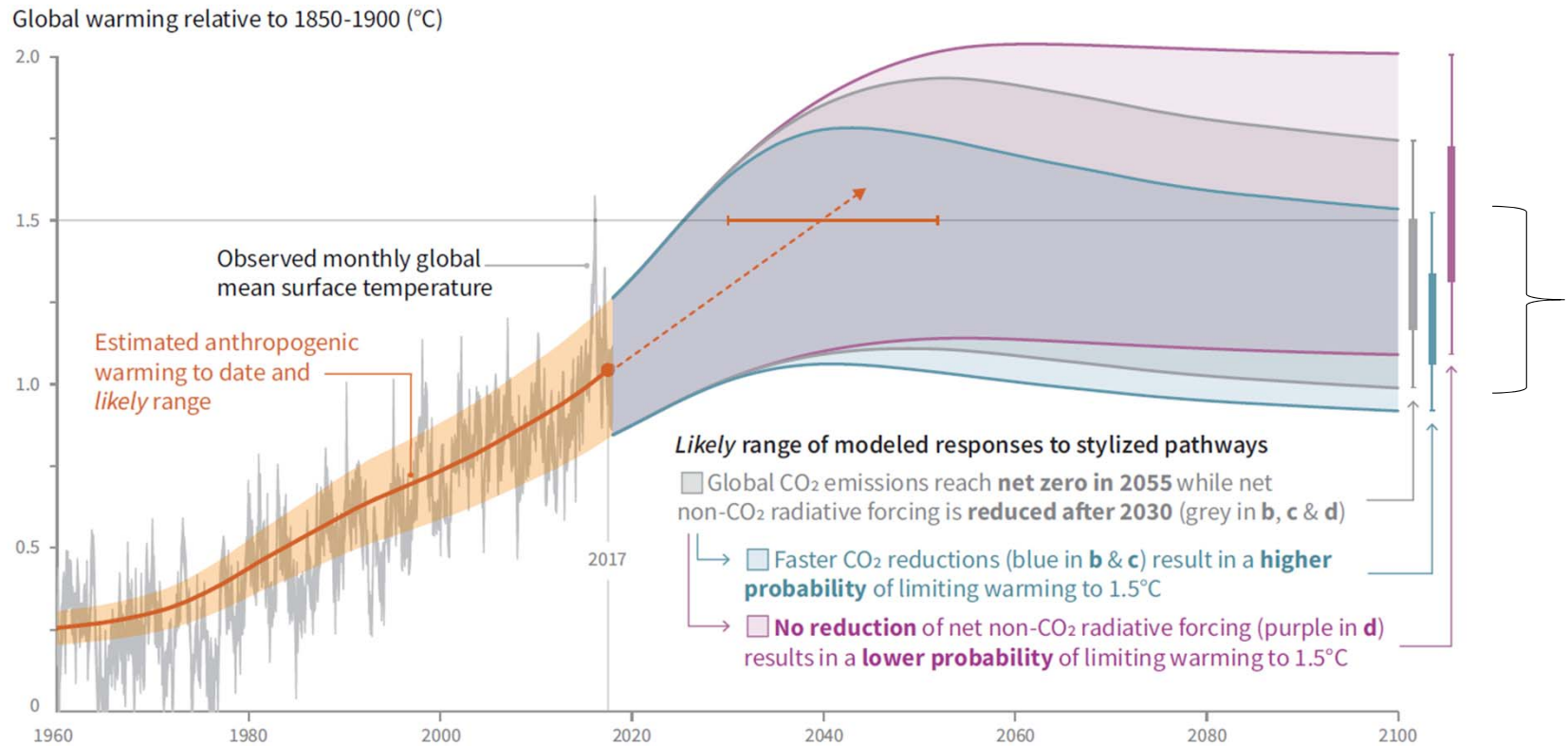
Impact of Increased Stock of CO₂

- Radiative Forcing and its analogue in the stock of carbon dioxide by the end of the century



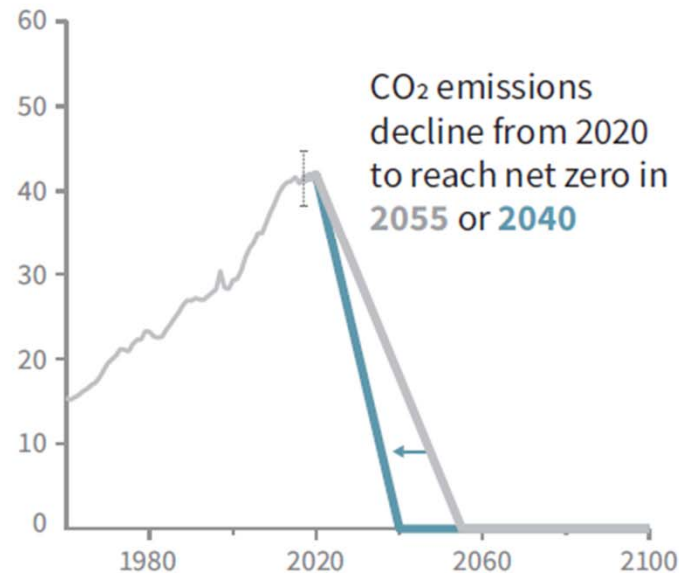
Forcing in 2100 Compared to 1750 (Wm ⁻²)	Climate Policy	CO ₂ Equivalent (ppm)	Projected Global Temperature Increase from 1986-2005 (°C)	
2.6	Mitigation	475	1.0	0.3 to 1.7
4.5	Stabilization	630	1.8	1.1 to 2.6
6.0	Stabilization	800	2.2	1.4 to 3.1
8.5	No Policy	1313	3.7	2.6 to 4.8

Can We Limit Temperature Increase to 1.5°C?

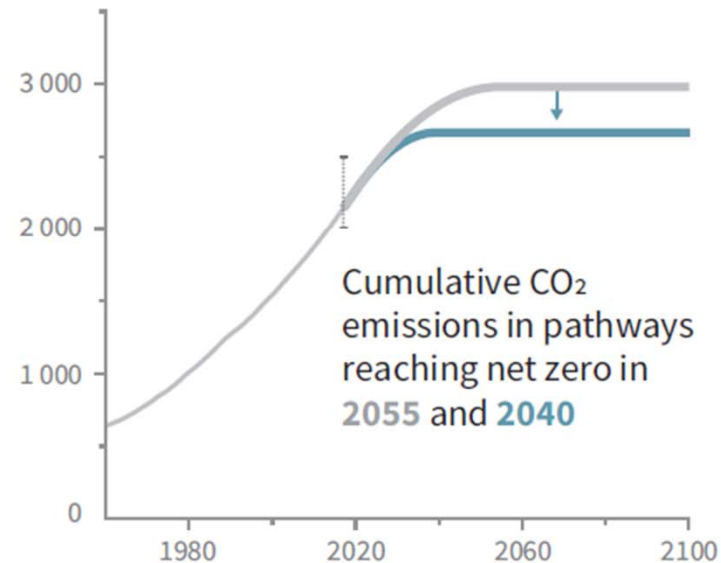


Emission Reductions Required

b) Stylized net global CO₂ emission pathways
Billion tonnes CO₂ per year (GtCO₂/yr)



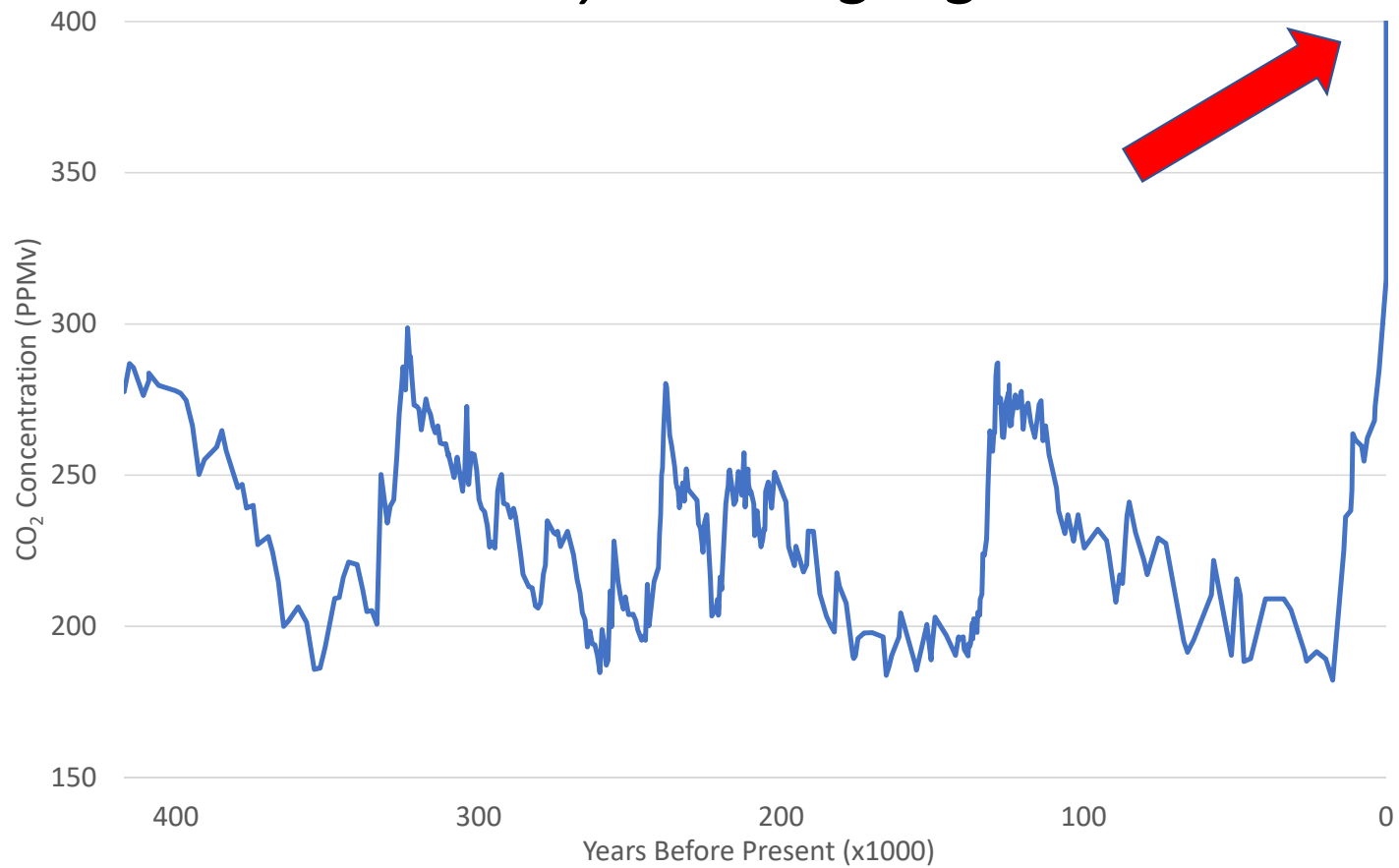
c) Cumulative net CO₂ emissions
Billion tonnes CO₂ (GtCO₂)



Is Climate Change a *Real* Problem?

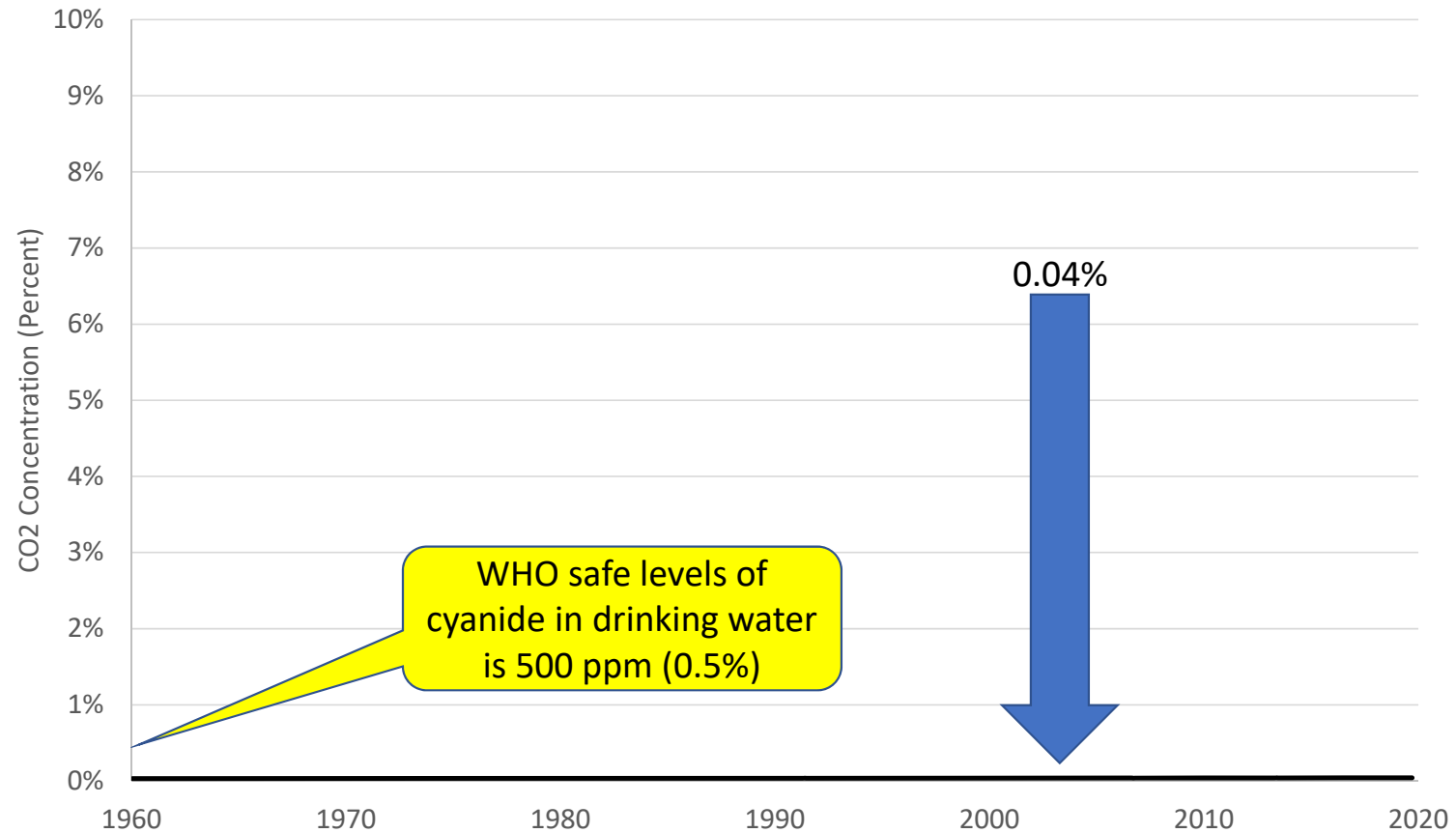
- Some question the science behind climate change
- As academics, we should be able to consider and address some of these arguments
- Keep in mind that we are economists, not climate scientists
 - Not our role to defend climate science
 - But understanding a few of the main arguments may be helpful

1. “The climate is *always* changing”

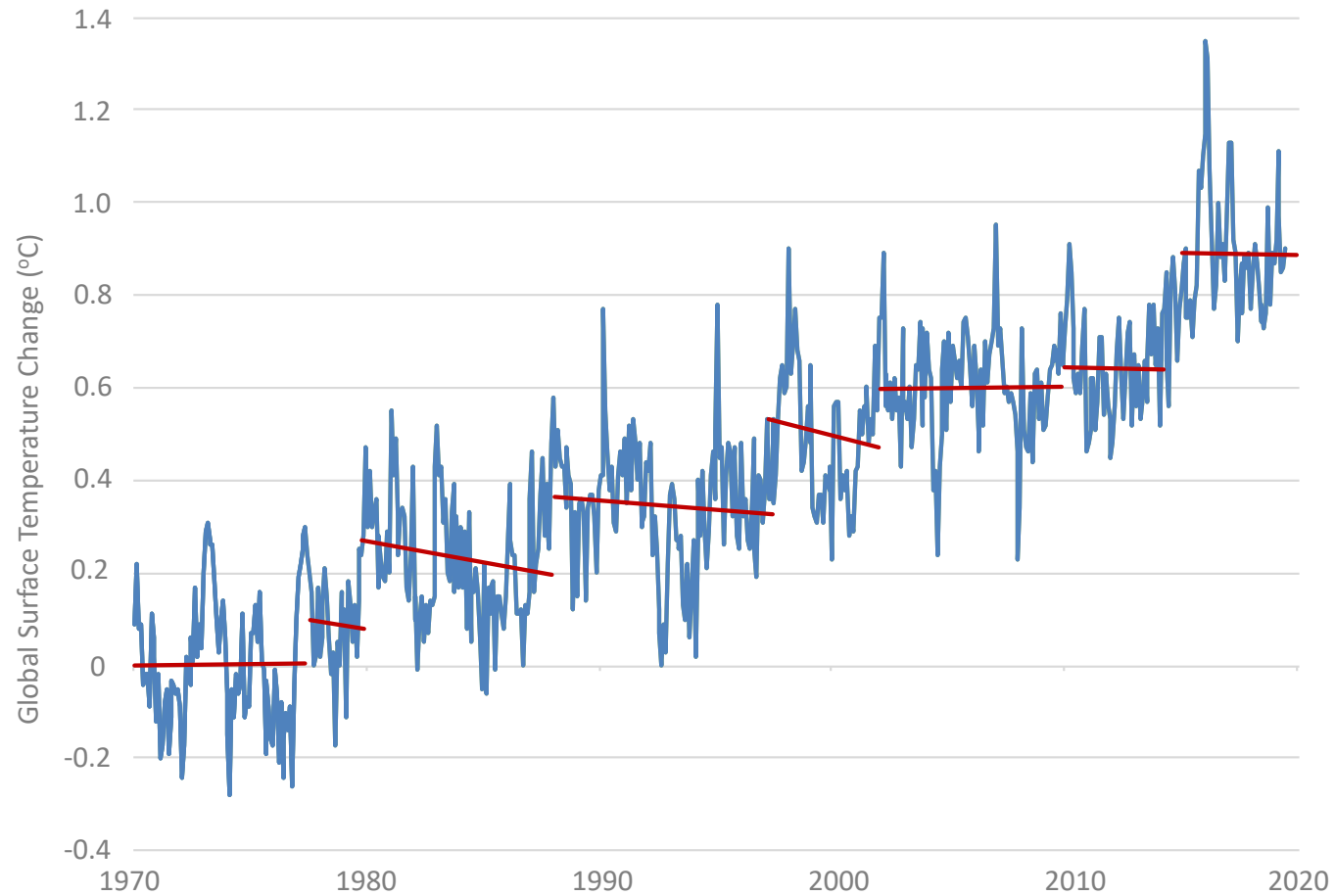


Vostok and Keeling data

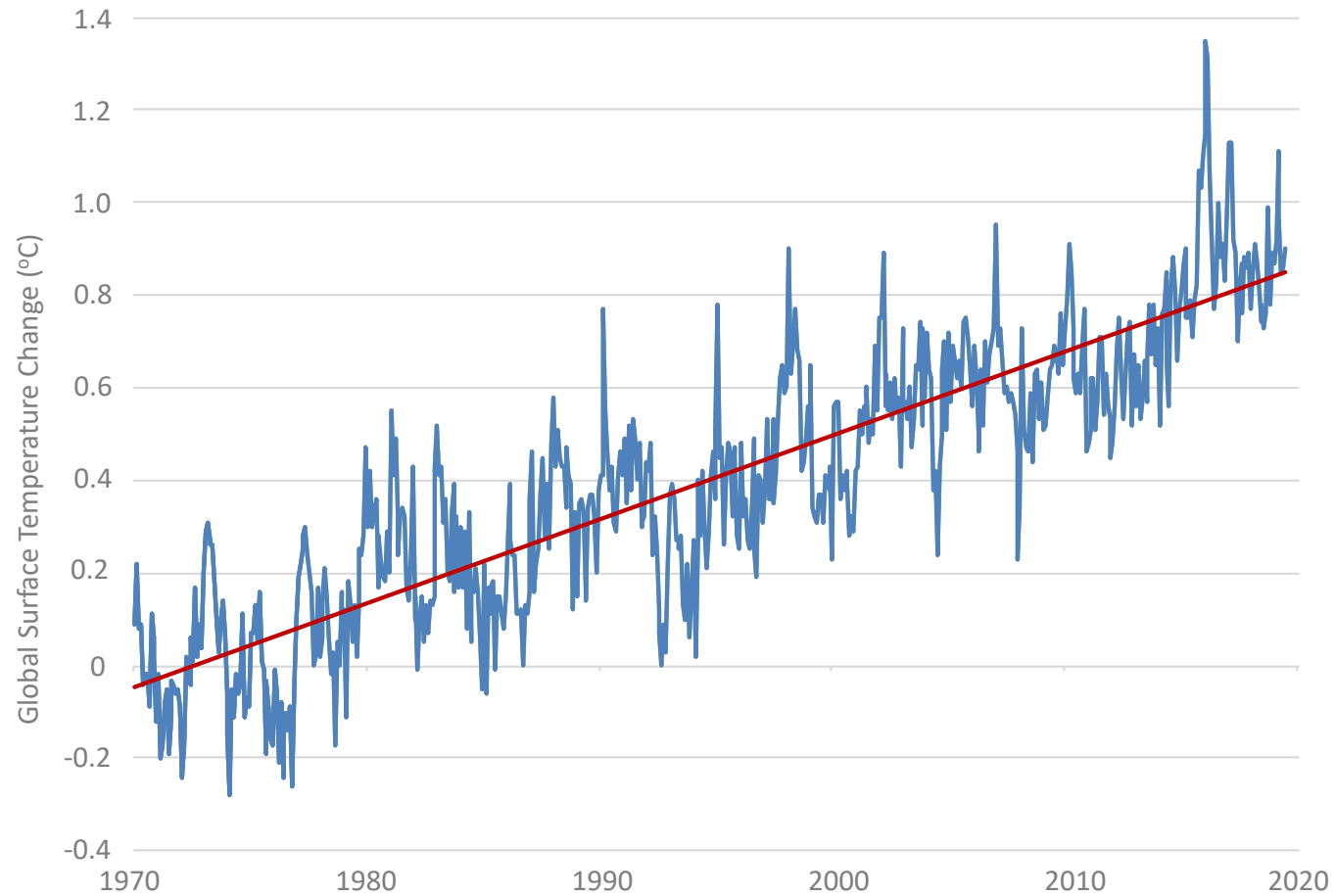
2. “GHG’s are a trace element”



3. “The climate is cooling”



3. “The climate is cooling”

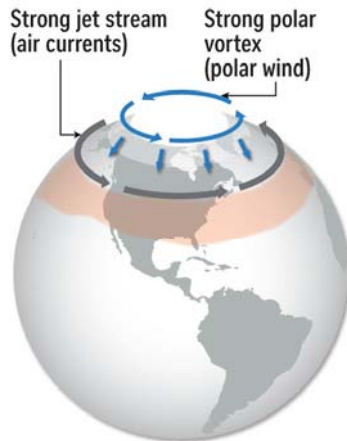


4. “What climate change? It’s freezing outside!”

Changes in the Arctic

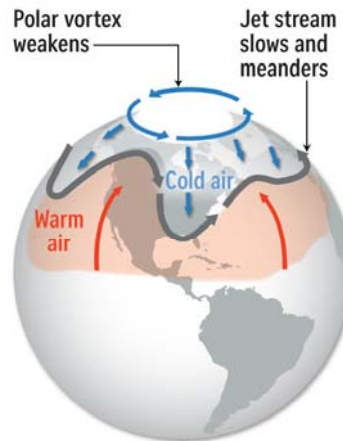
NORMAL CIRCUMSTANCES

Strong polar vortex and jet stream trap freezing air in the Arctic and warm air in lower latitudes

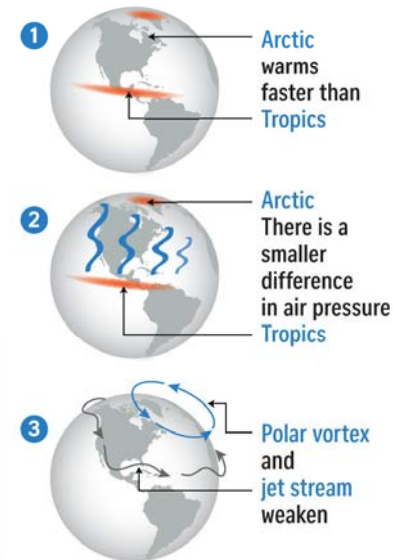


ARCTIC WARMS FASTER THAN LOWER LATITUDES

Polar vortex and jet stream weaken, so Arctic air moves south and warm air moves north



HOW CLIMATE CHANGE DISRUPTS THE POLAR VORTEX

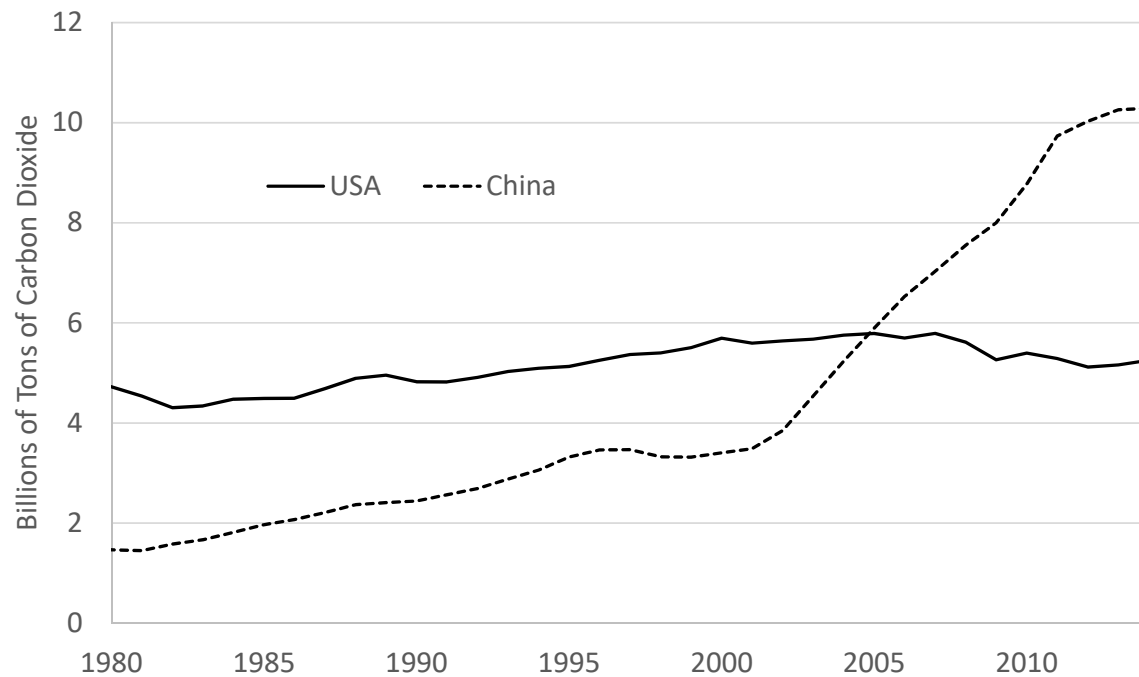


Source: AFP STRAITS TIMES GRAPHICS

5. “What’s the big deal: 1.5 or 2.0°C?”

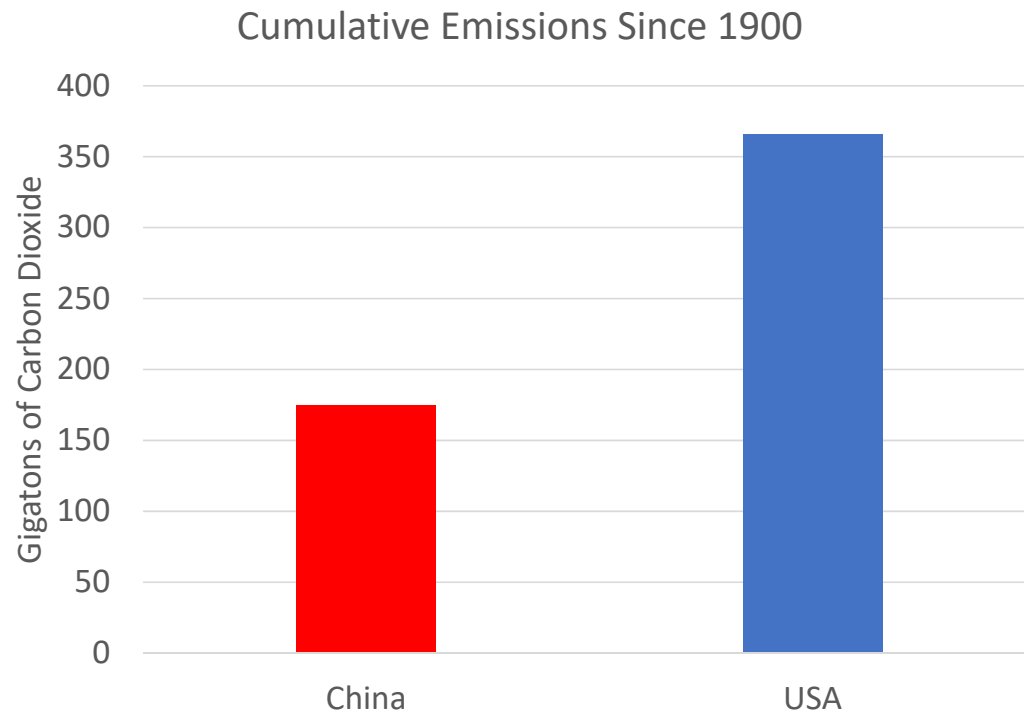
1.5°C increase	2.0°C increase
Sea ice remains during most summers	Ice-free summers 10x more likely
~14% of global pop’n exposed to hot days	~37% of global pop’n exposed to hot days
Coral reef decline of 70-90%	Coral reef decline exceeds 99%

6. “Why should we act? Our emissions aren’t growing:”



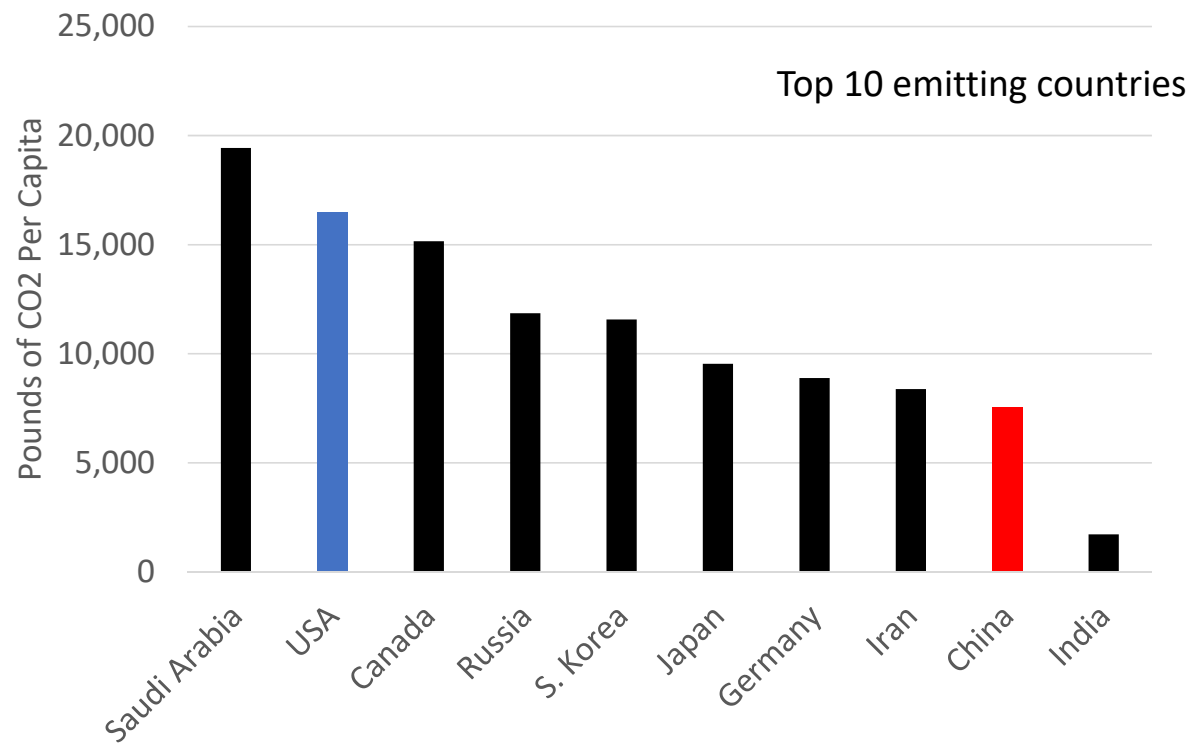
Why should we act?

- Historic responsibility



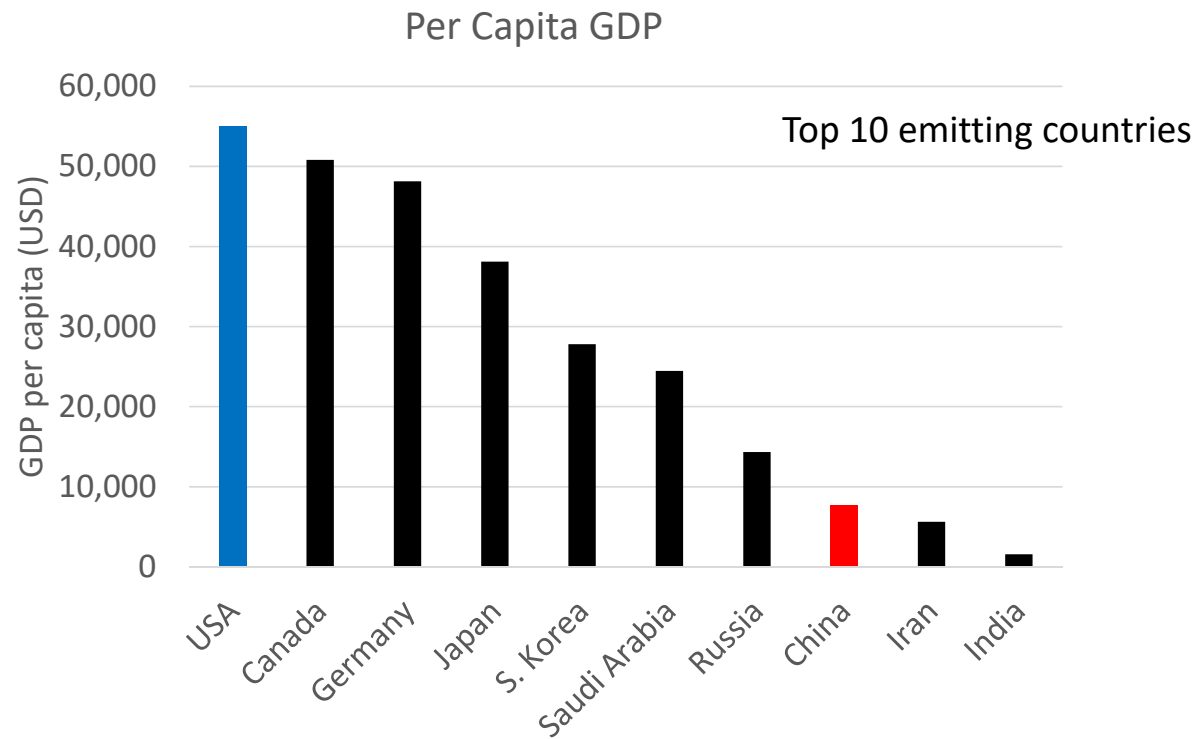
Why should we act?

- Per capita emissions



Why should we act?

- USA is the richest country in the world



Role of Economics

- Damage estimation
- Costs and benefits of mitigation
 - Social costs of carbon
- Costs and benefits of adaptation
- Policy assessment
 - Optimal policy design
 - Cost effectiveness
- Covered in following lectures