

Climate change

A photograph of an industrial facility, likely a power plant or refinery, situated along a body of water. Numerous tall smokestacks are visible, each emitting thick, white plumes of smoke or steam that rise into the sky. The smoke is dense and billowing, particularly from the central part of the facility. The sky is a deep blue with scattered white clouds. The entire scene is reflected in the calm water in the foreground, creating a symmetrical image. The overall tone is serious and industrial.

Prof. Roy Thompson, FRSE

Climate change

1. The basic problem.

2. Are temperatures really rising?

3. The next 100 years.

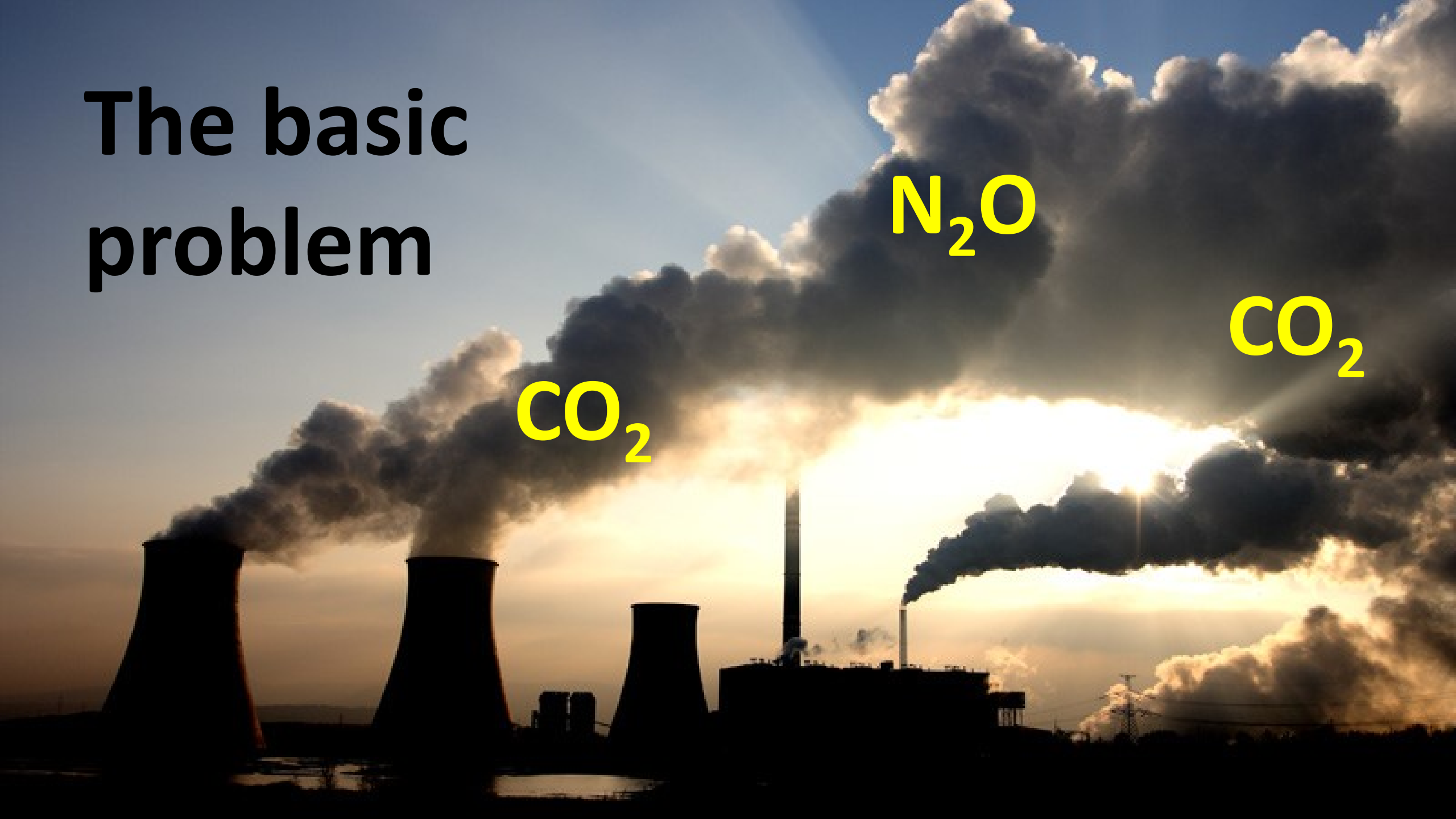
4. Is there any hope?

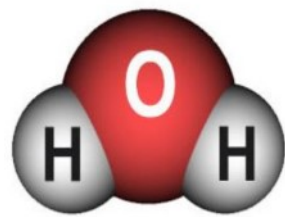
The basic problem

N_2O

CO_2

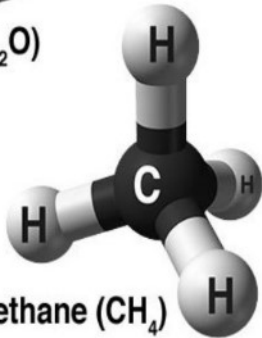
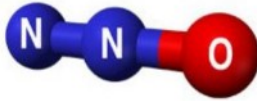
CO_2



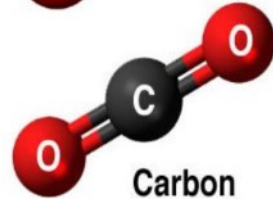


Water vapor (H_2O)

Nitrous oxide (N_2O)



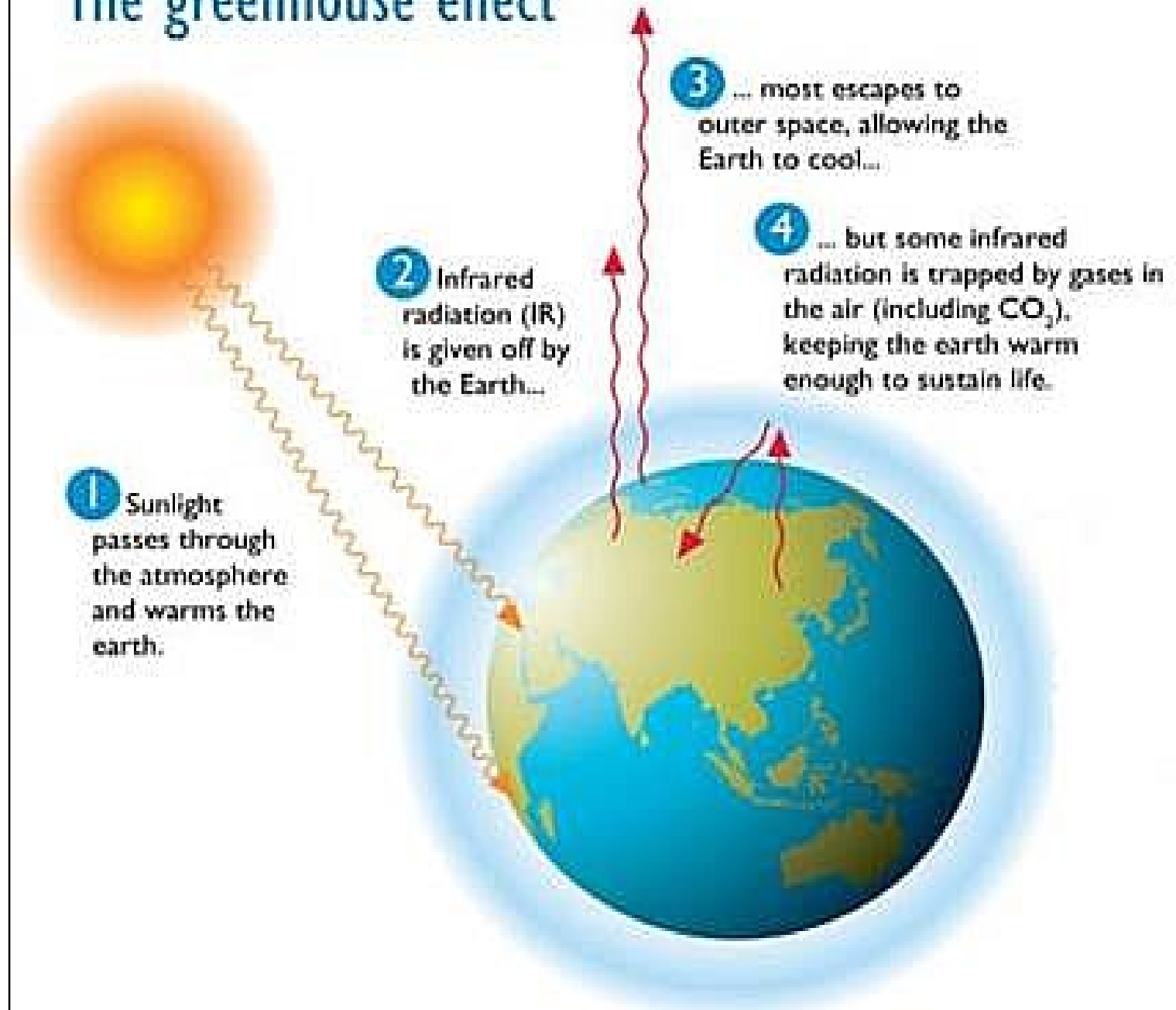
Methane (CH_4)



Carbon dioxide (CO_2)

Long-lived gases that do not respond physically or chemically to changes in temperature are described as "forcing" climate change. Gases, such as water vapour, which respond physically or chemically to changes in temperature are seen as "feedbacks."

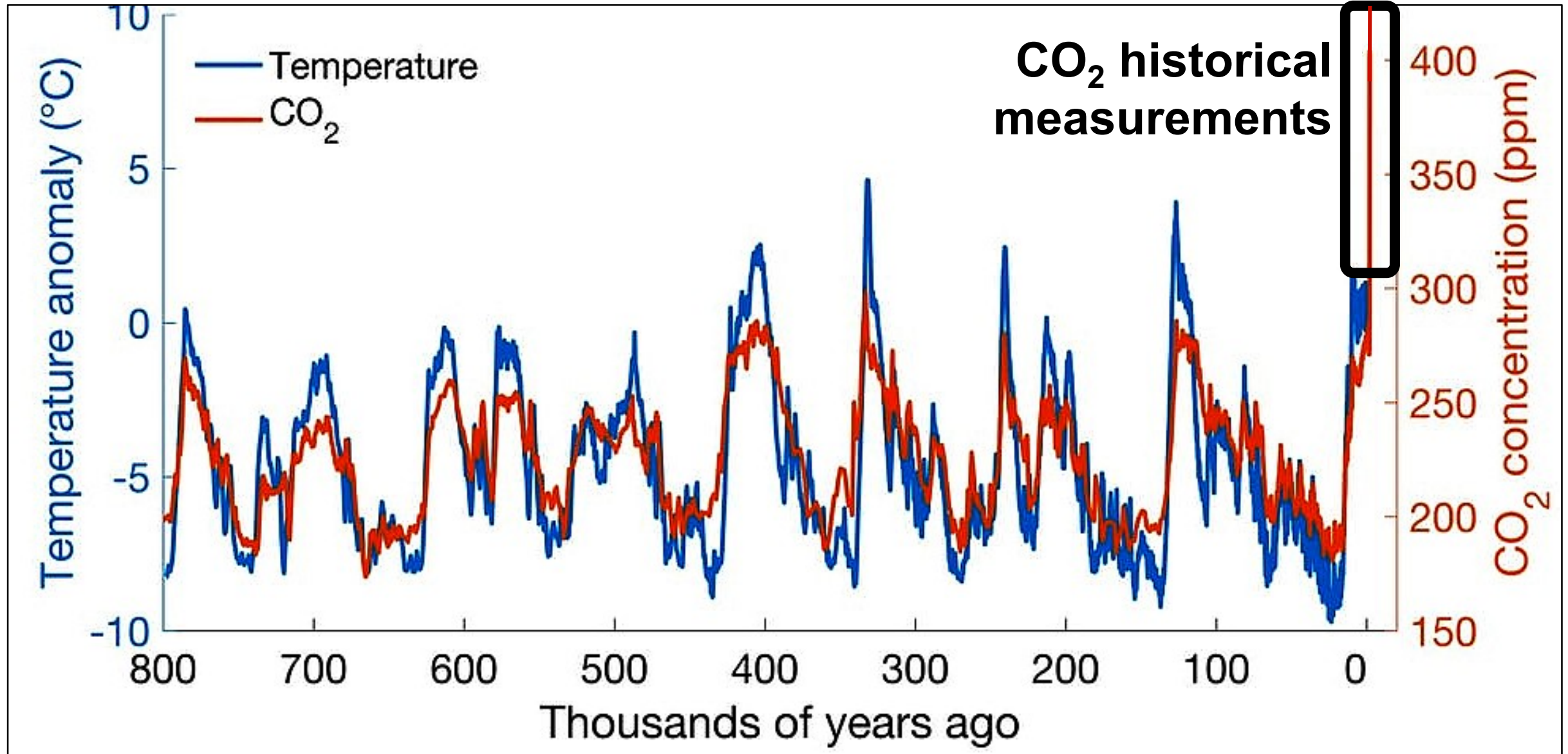
The greenhouse effect





Ice Cores – Measuring Earth's
atmosphere thousands of years ago

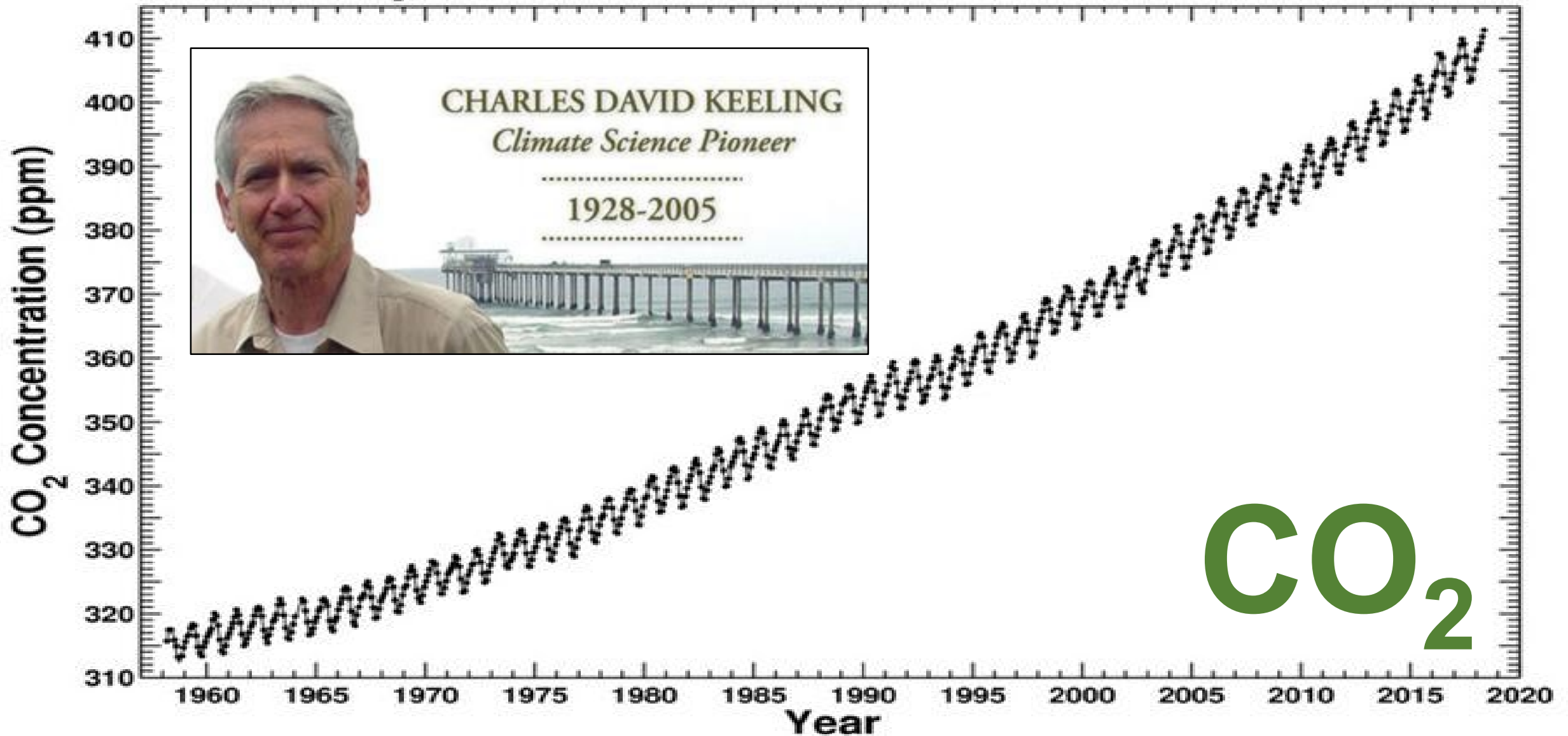
Antarctic ice: the world's air museum



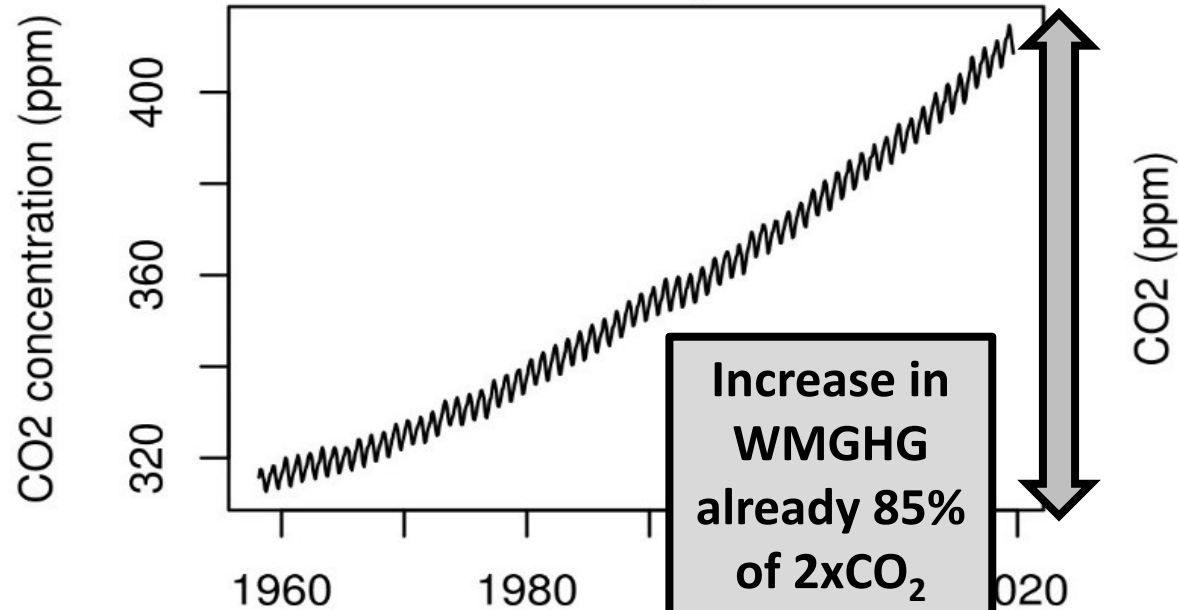
Mauna Loa Observatory, Hawaii

Monthly Average Carbon Dioxide Concentration

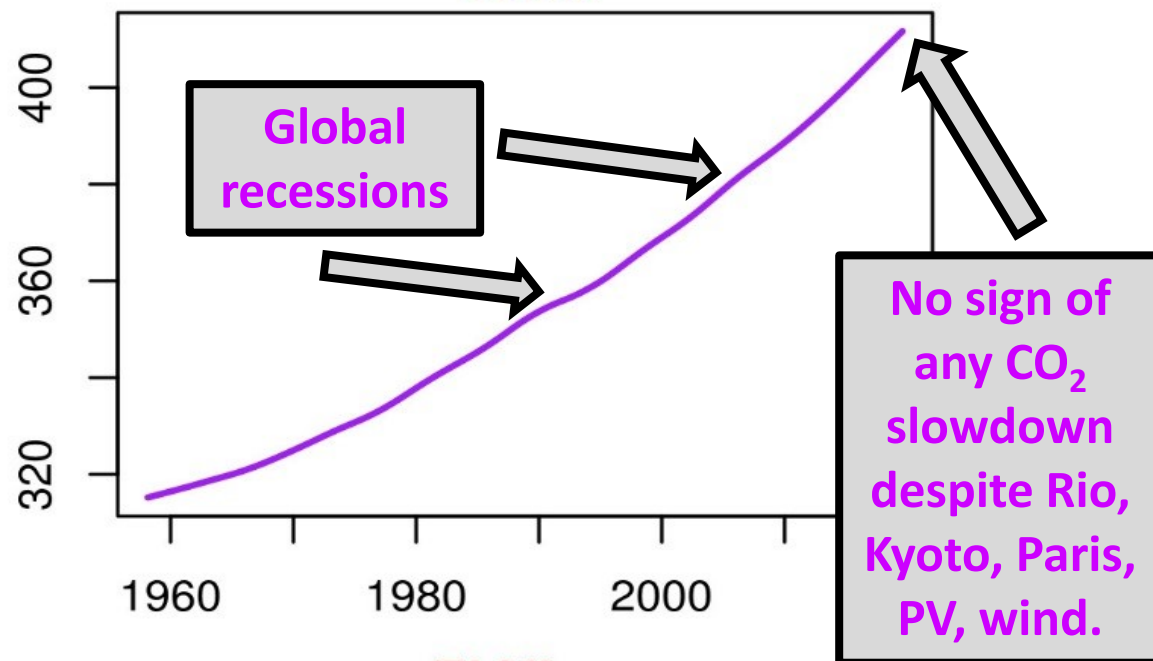
Data from Scripps CO₂ Program Last updated June 2018



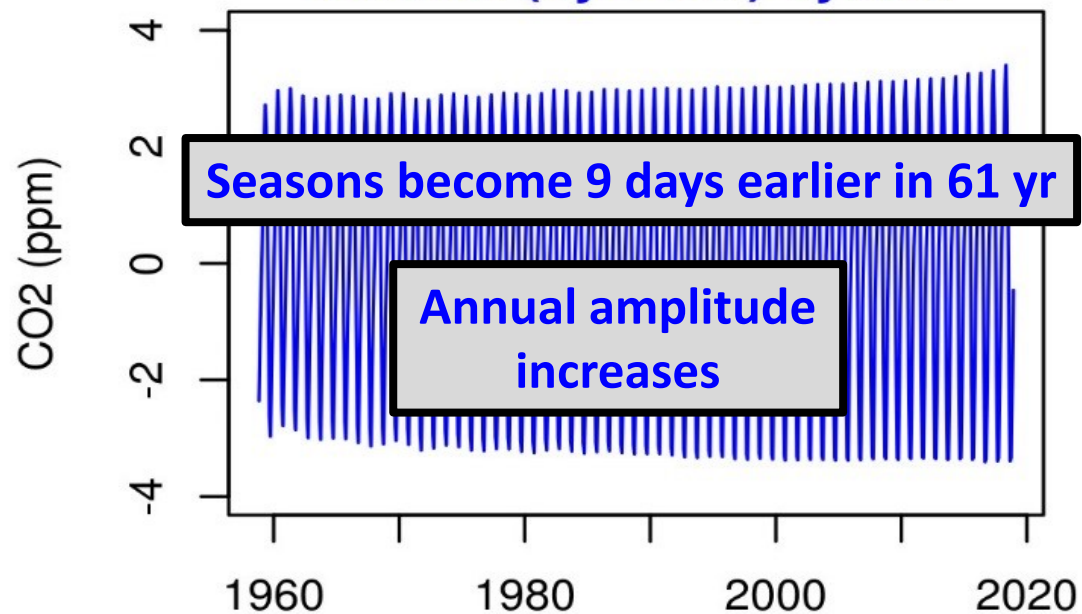
Mauna Loa: Monthly observations



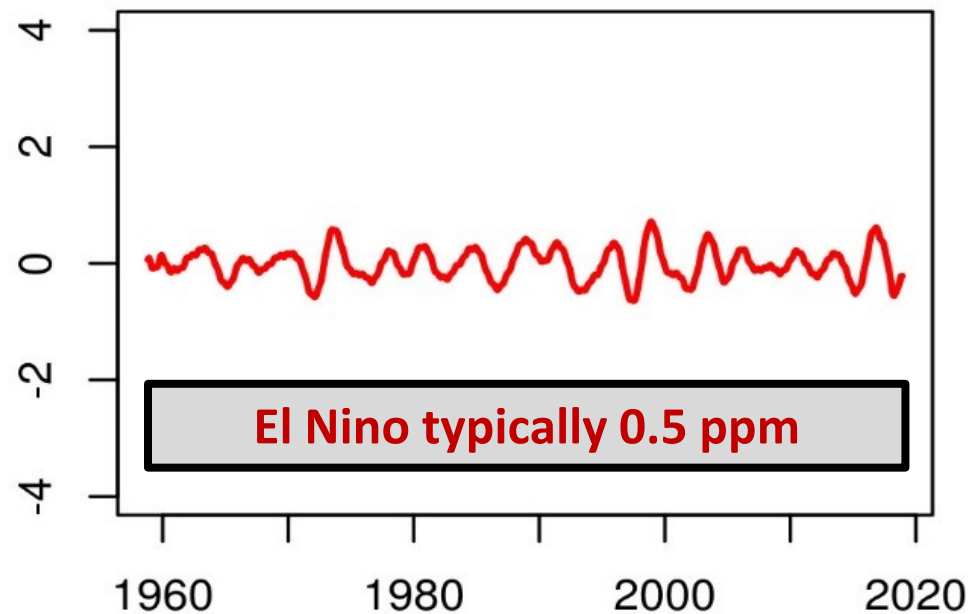
Trend



Annual (1y + 6m) cycles



El Nino



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**Stevenson's
screen**

International Journal of Climatology

The Royal Meteorological Society Journal of Climate Science



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Radan Huth

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EDINBURGH SUMMER AND WINTER EXTREME MONTHS

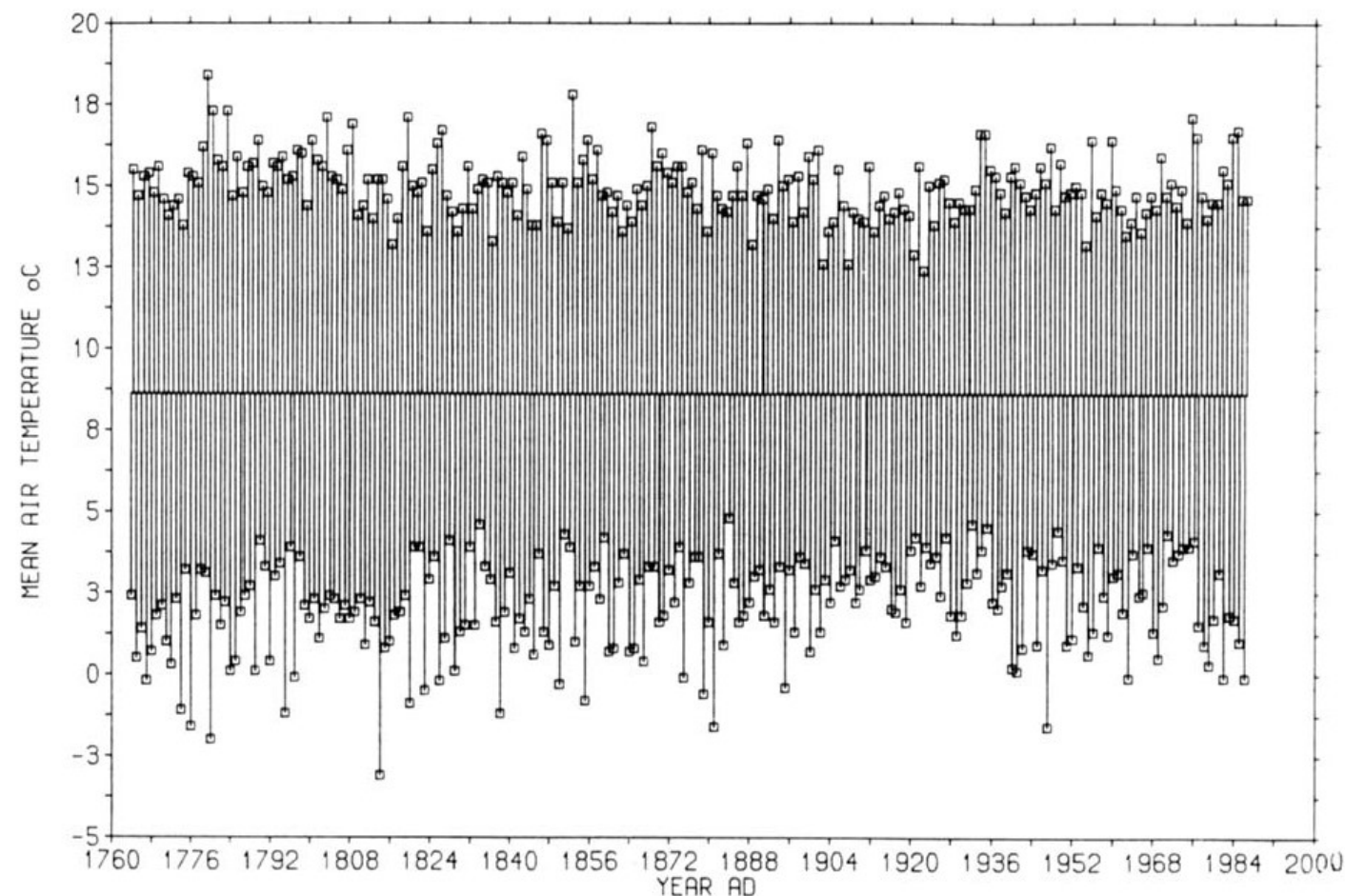
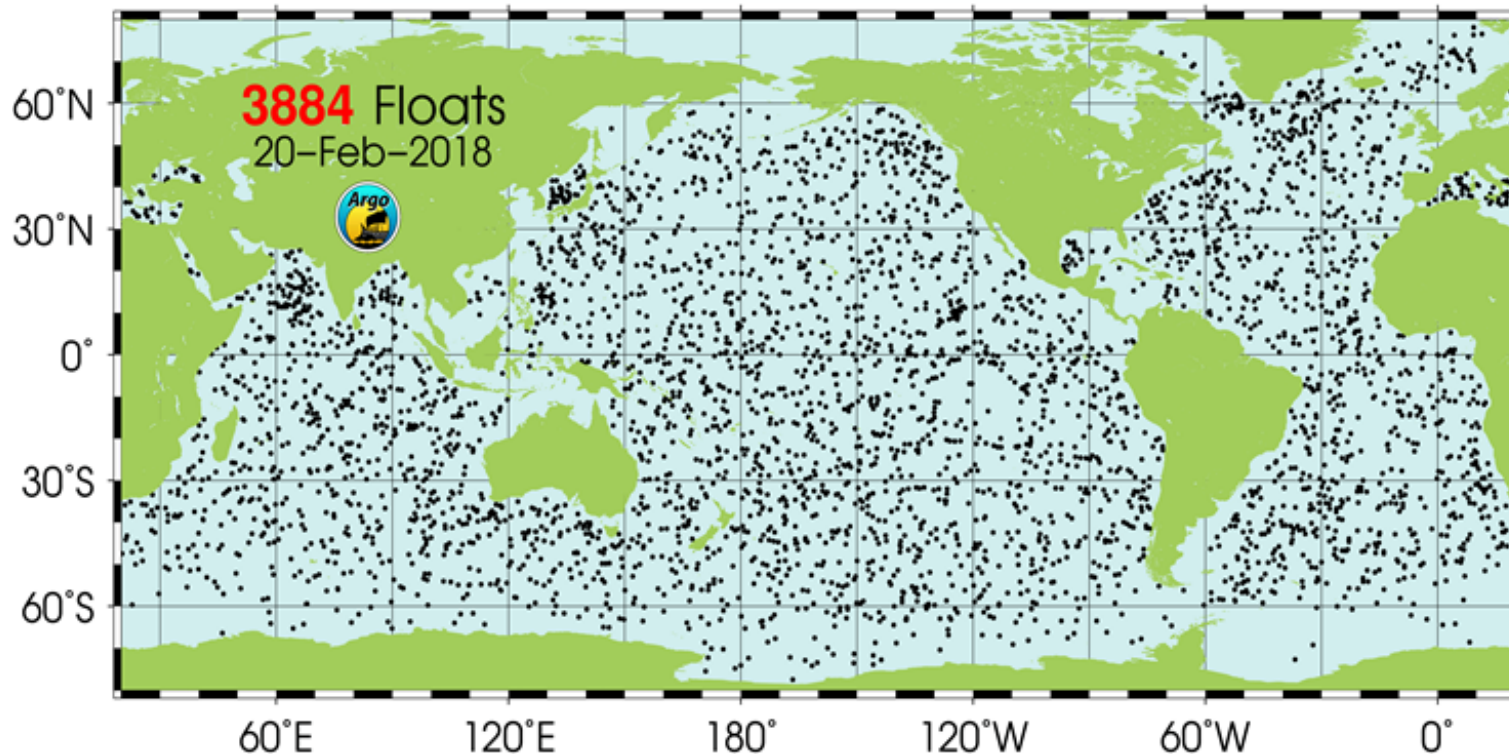
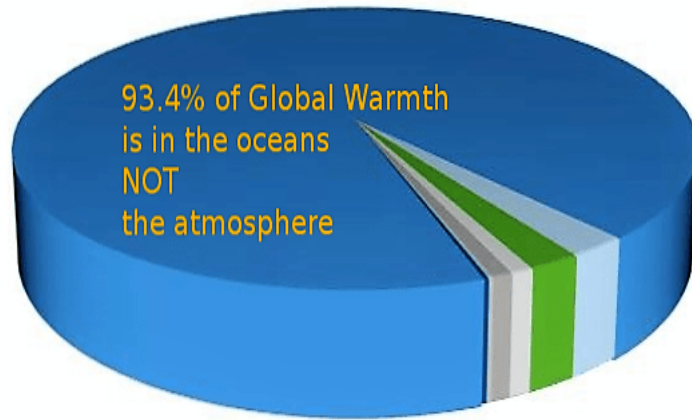


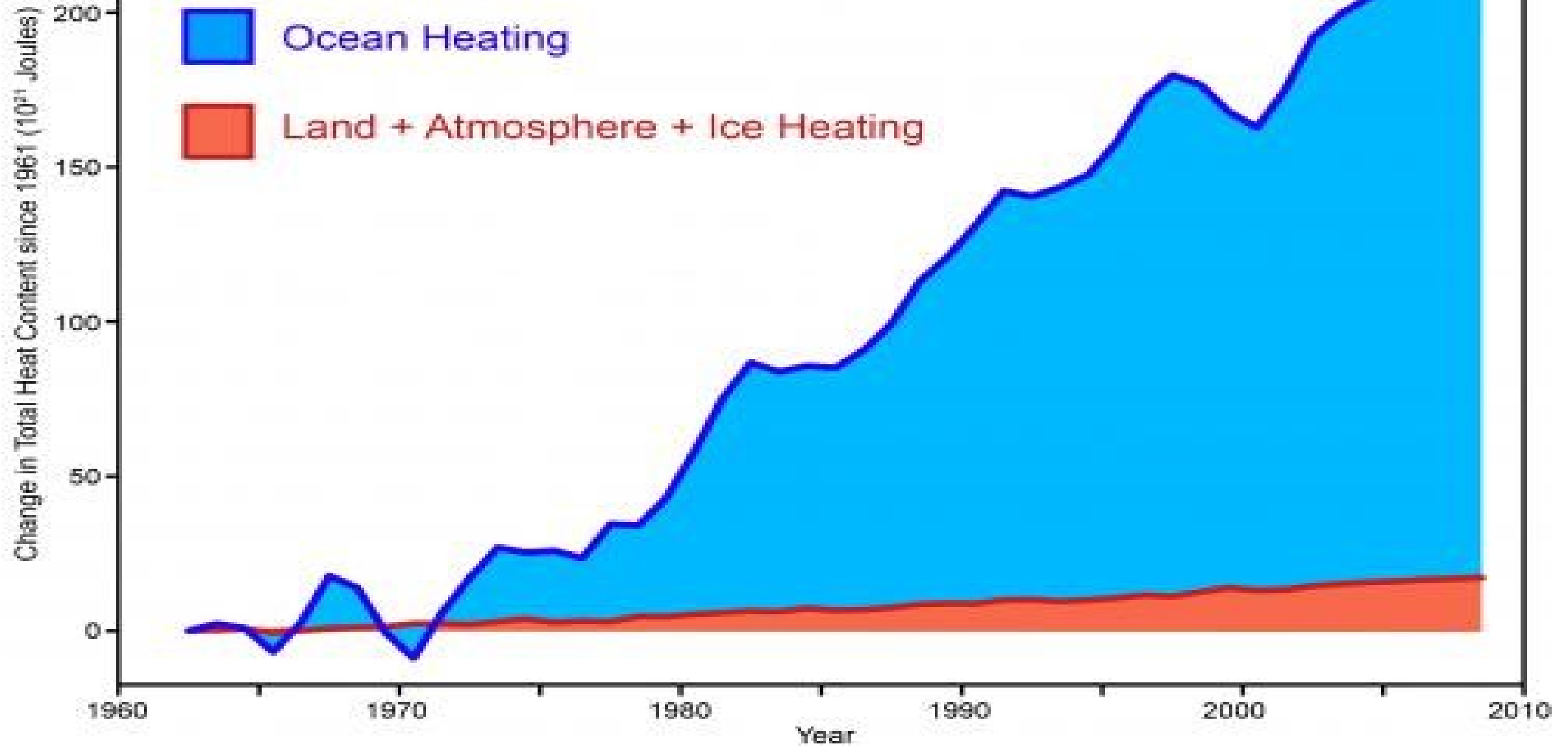
Figure 2. Mean monthly air temperature ($^{\circ}\text{C}$) at Edinburgh for extreme months of the summer and winter seasons. Note the 20 years between AD 1902 and AD 1922 that had cool summer extremes (14.1 on average) coupled with generally warm winters (1.6 to 4.2). In contrast, observe the block of 17 years from AD 1798 to AD 1815 that had consistently cool extreme winter months (-3.1 to 2.4) combined with relatively warm extreme summer months (14.0 to 17.1)

Where is greenhouse warmth going?



Boris Johnson holding an Argo float used for ocean temperature and salinity measurement.

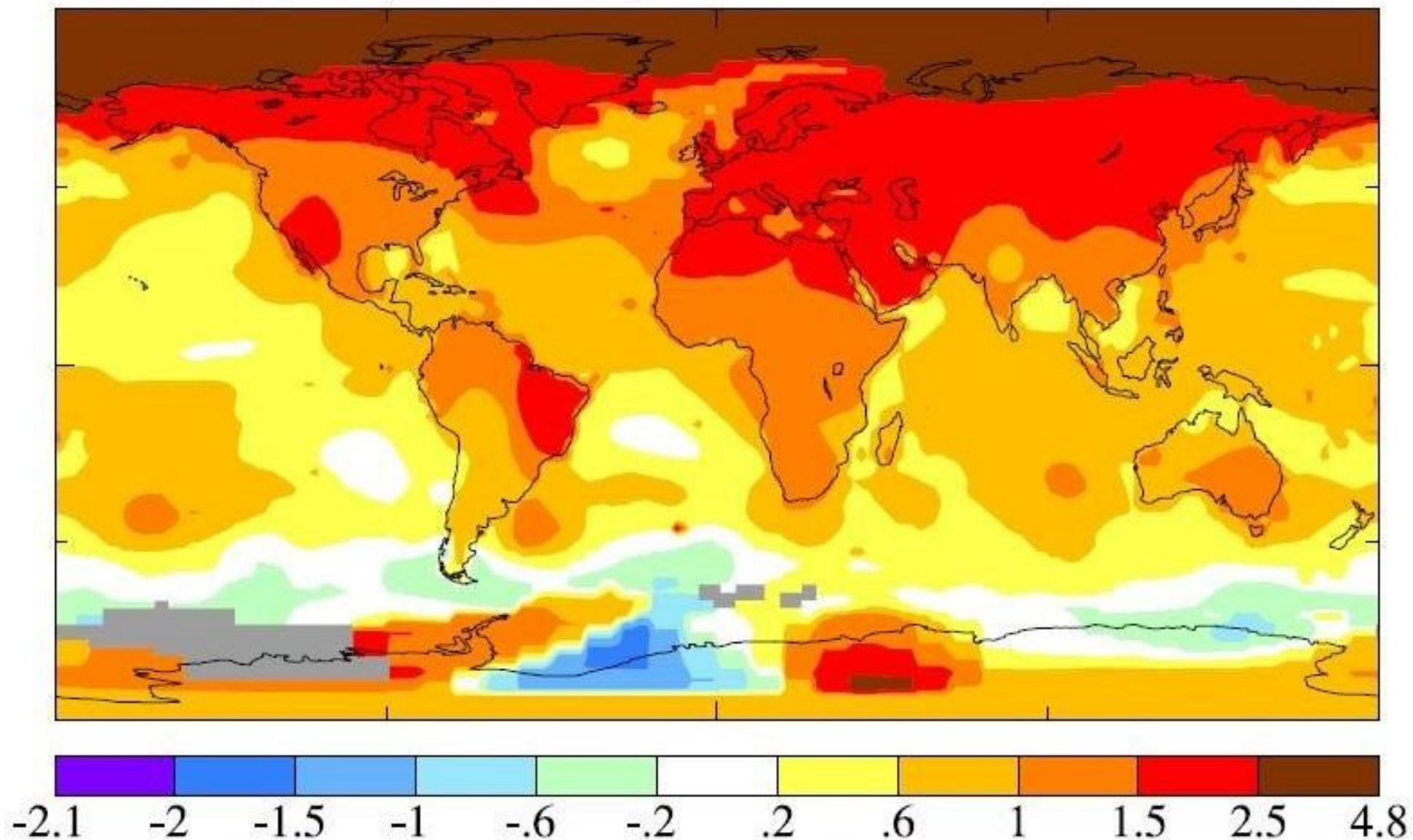
Change in Earth's Total Heat Content



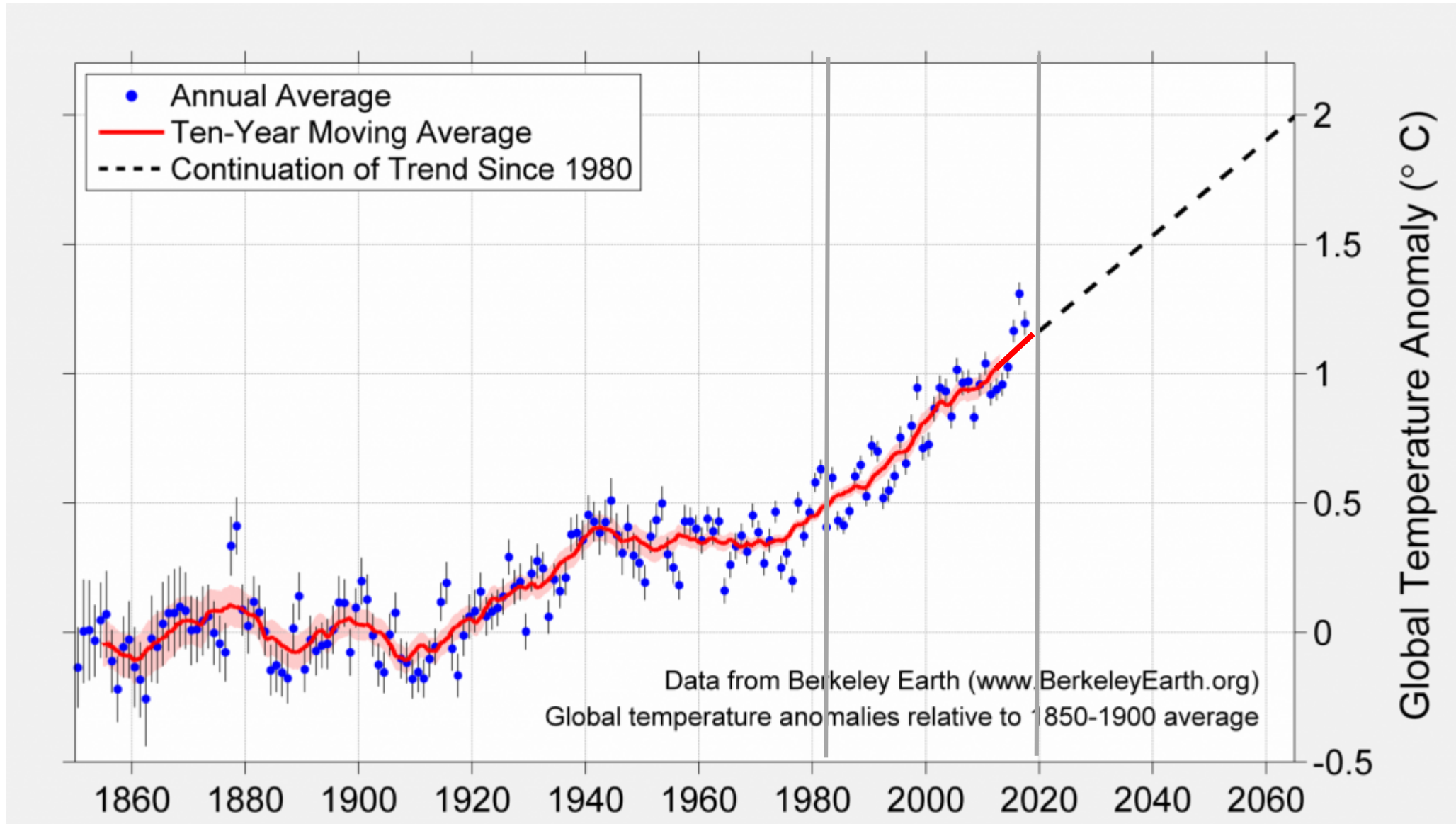
Surface Temperature Change (°C)

Last 50 Years (1968-2018)

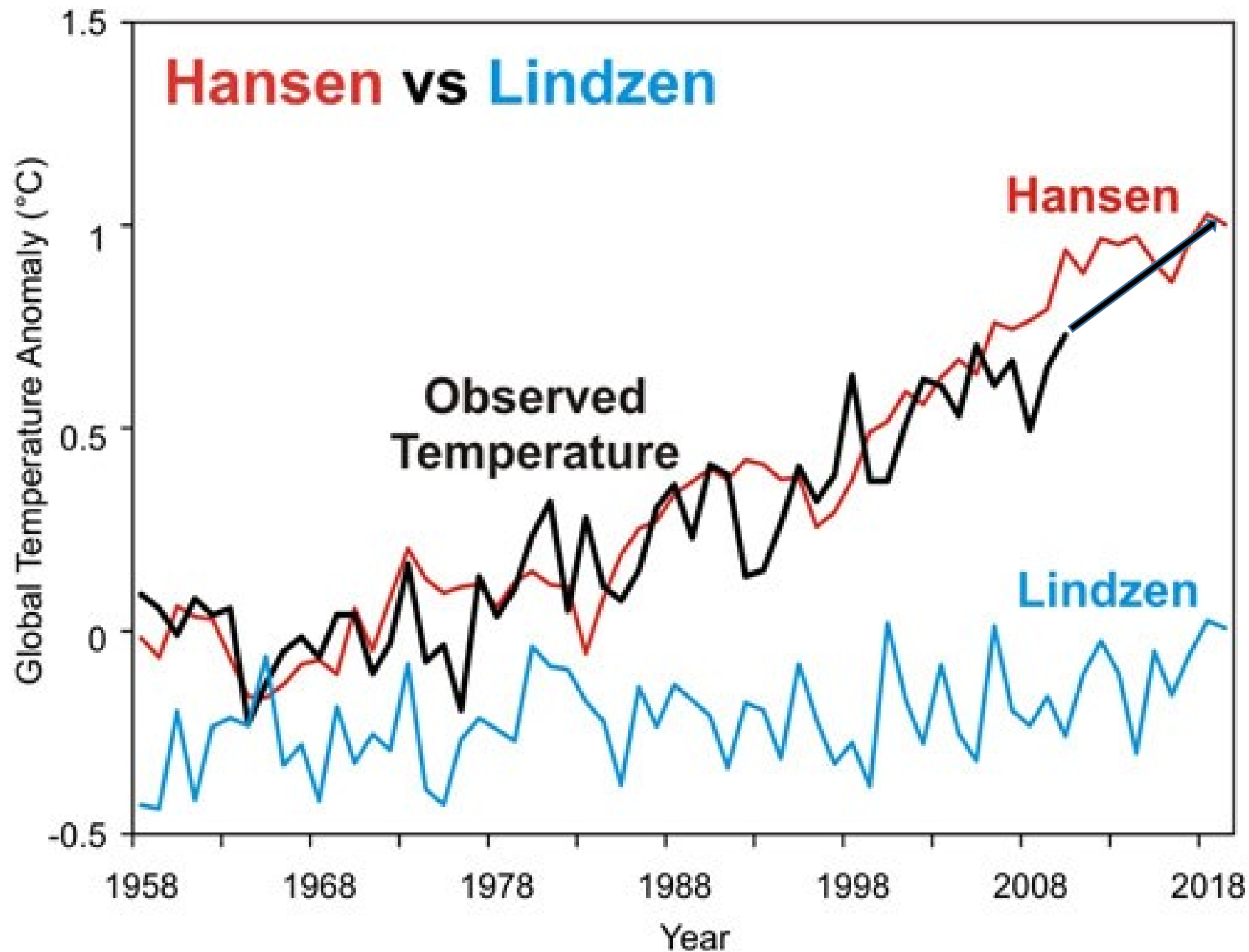
0.92



Global Long-Term Trend



Since 1980, the overall trend is $+0.18\text{ }^{\circ}\text{C/decade}$ and has changed little during this period. By continuing this trend, we can make a rough guess for how near-future climate may develop.



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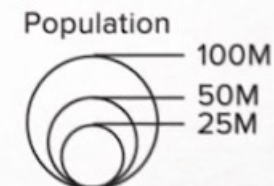
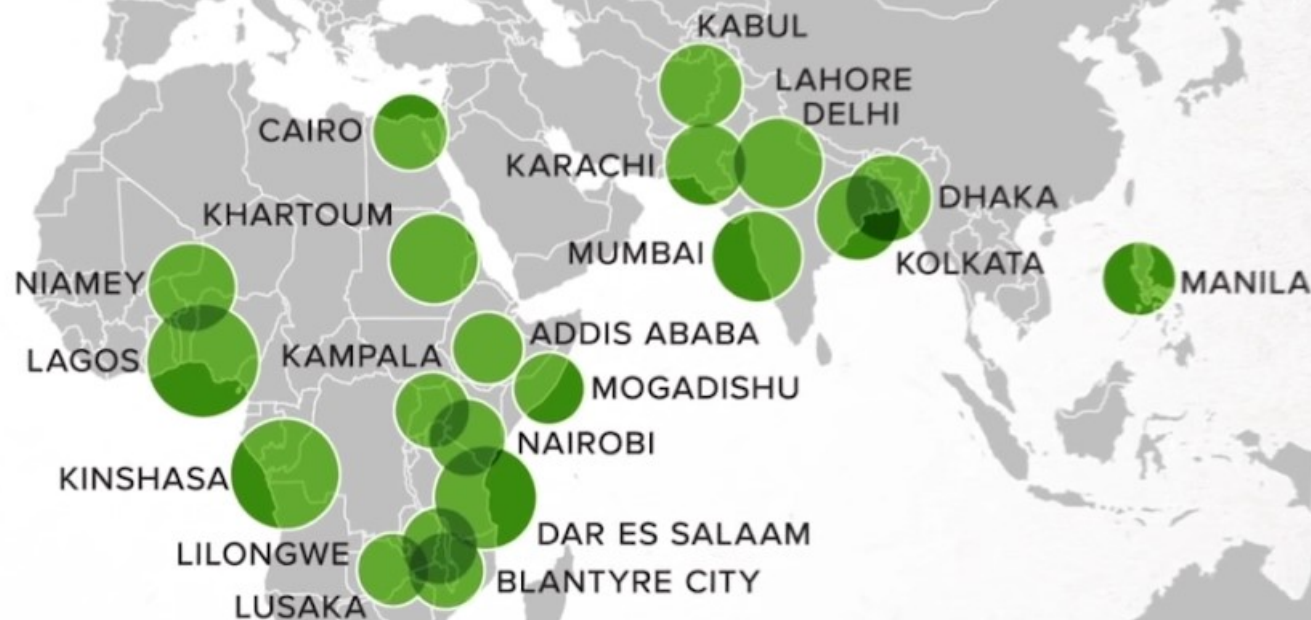
2100

The world's largest cities in 2100

#1: LAGOS - 88M

#2: KINSHASA - 83M

#3: DAR ES SALAAM - 73M



Paris, France

ipcc

INTERGOVERNMENTAL PANEL ON climate change

Global Warming of 1.5°C



Glasgow will host city the UN's next climate change conference in 2020, bringing together over 30,000 delegates from around the world.

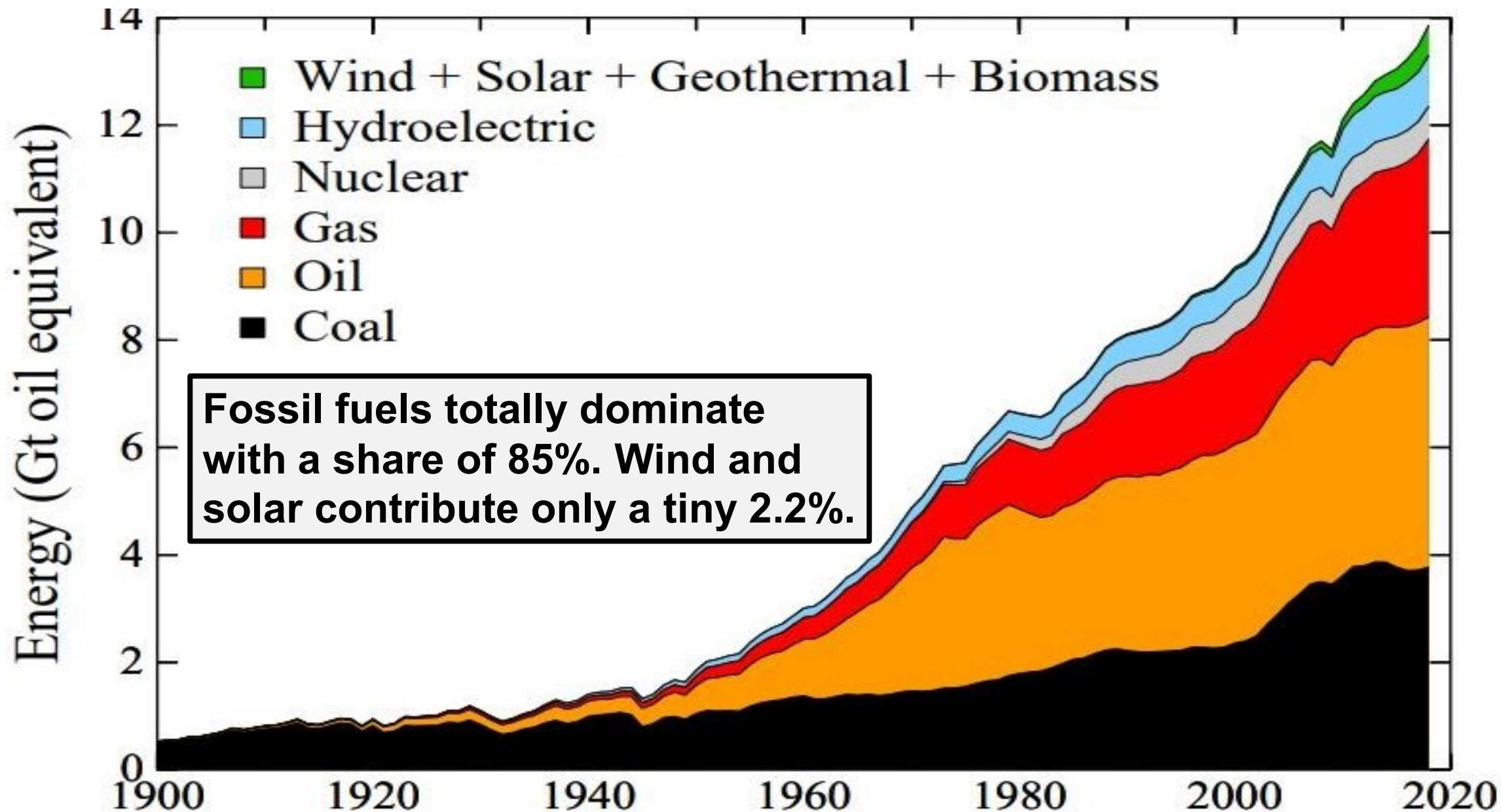


World Energy growth

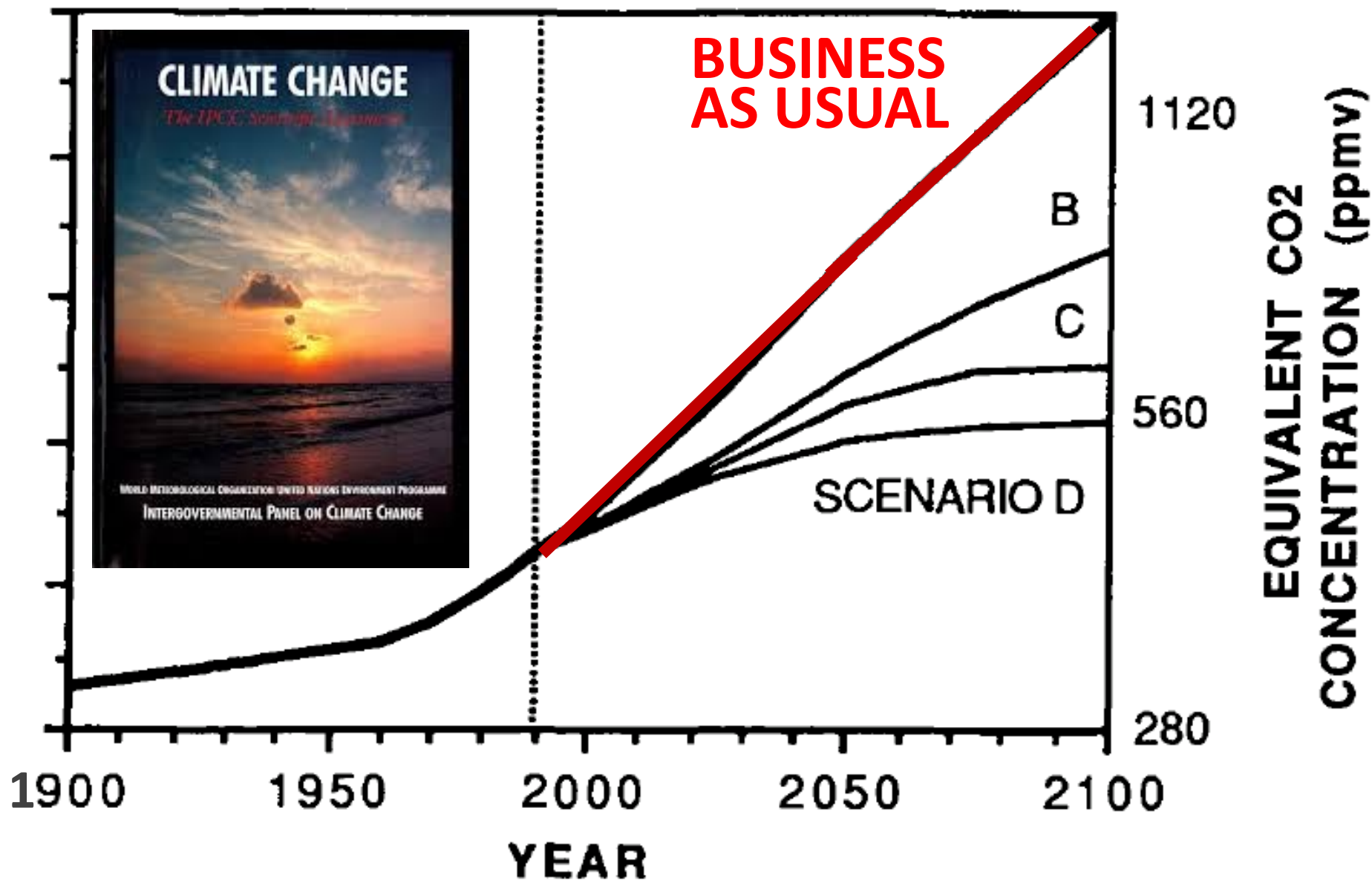
Medium population forecast sees 30 billion toe in 2100, a doubling of today's 15 billion toe.



How much energy does the world currently consume?



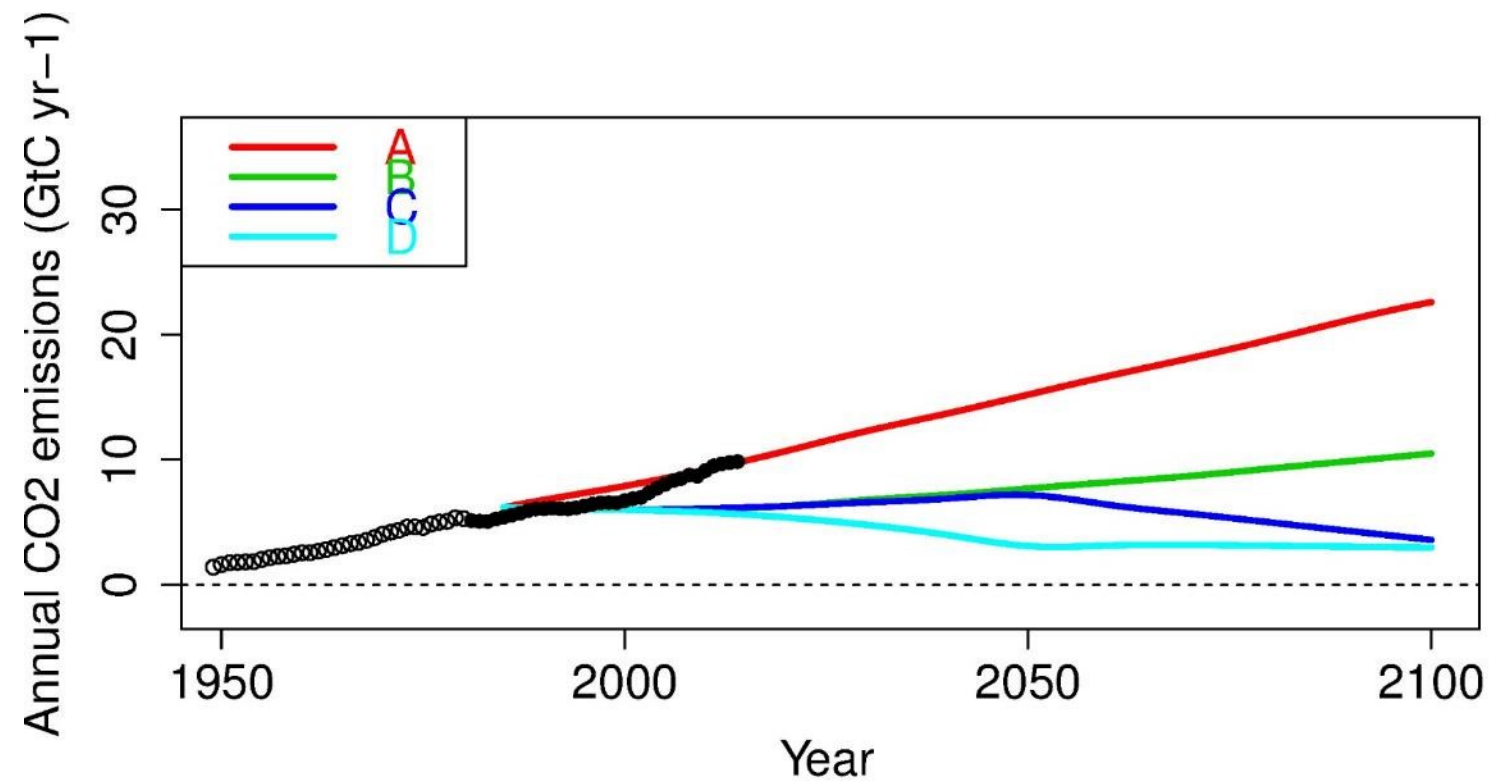
What next?



The 1990 report used energy balance models with four CO₂ emission scenarios (A-D).

The business-as-usual (BAU) projection of a 2% increase in anthropogenic CO₂ production year-on-year has stood the test of time remarkably well.

IPCC 1st report published 1990.



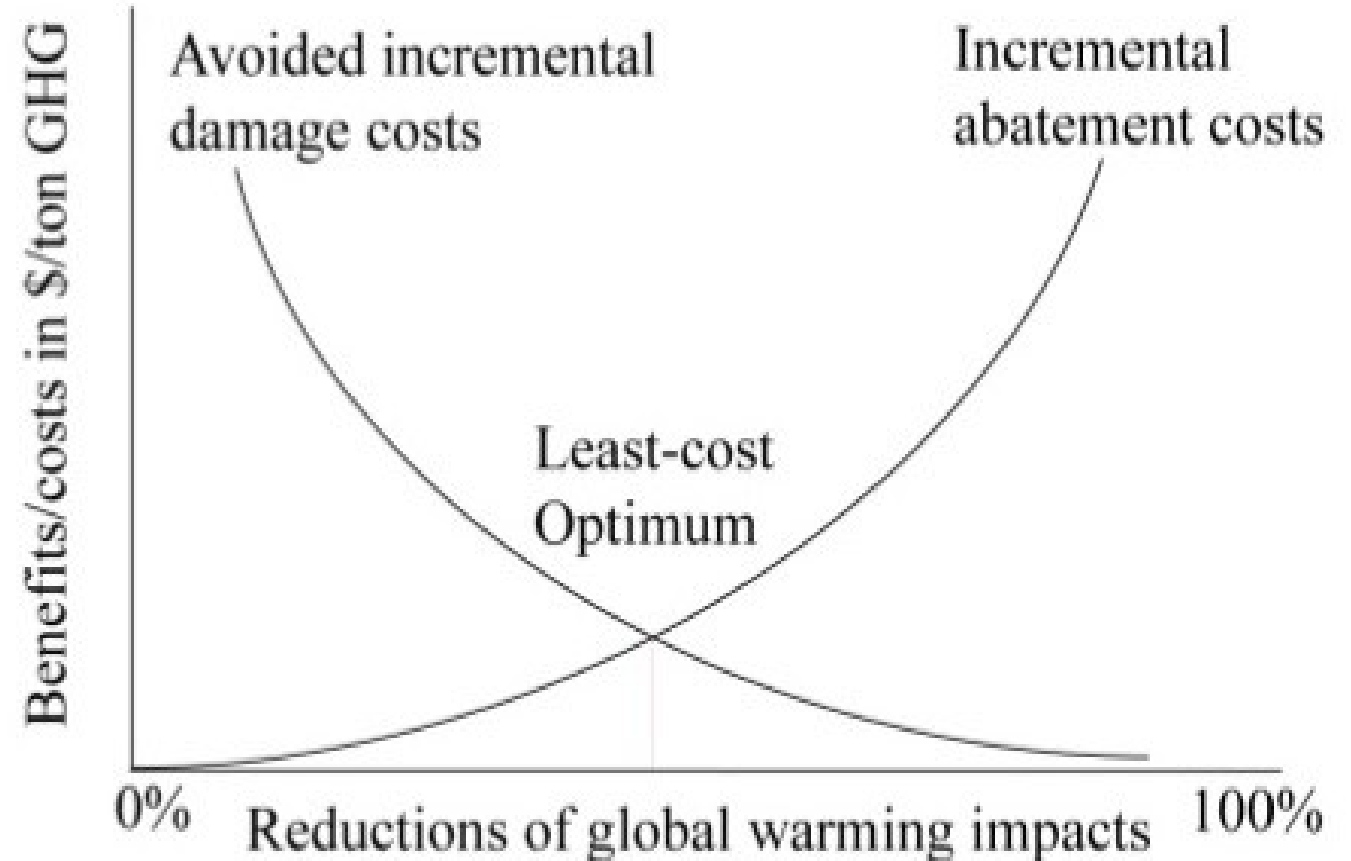
Can we control CO₂? Nordhaus, 1975



Bill Nordhaus received the Nobel prize for economics in 2019

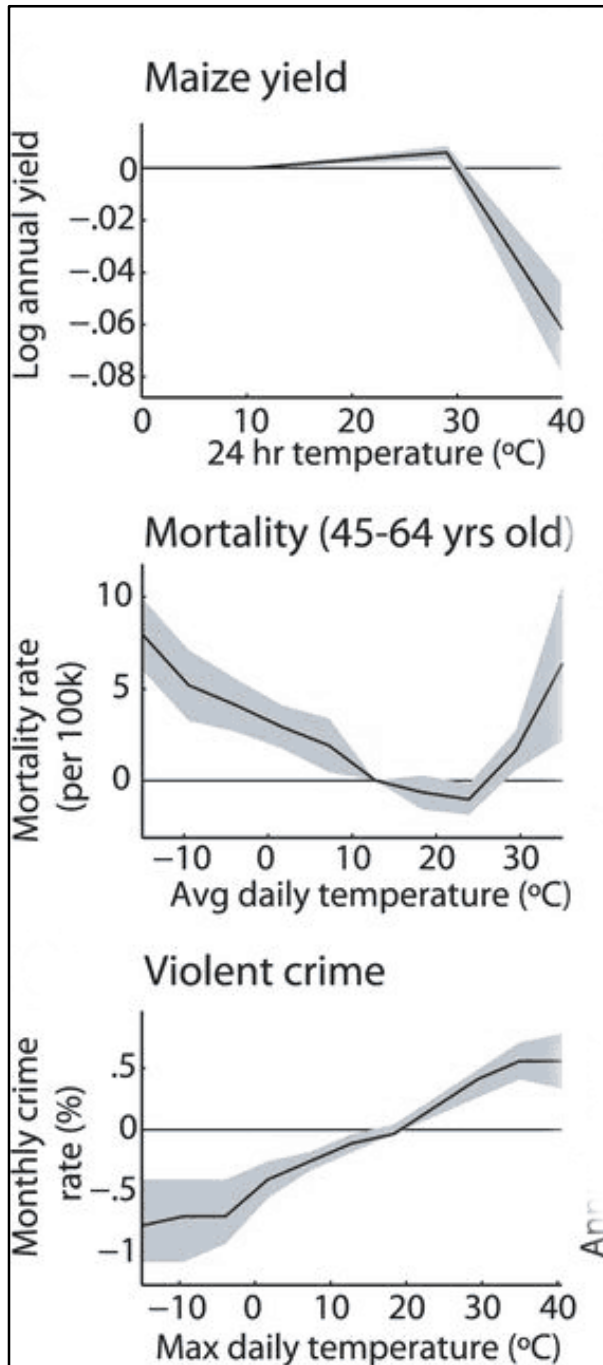
"for integrating climate change into long-run macroeconomic analysis".

Cost-benefit analysis: the standard approach



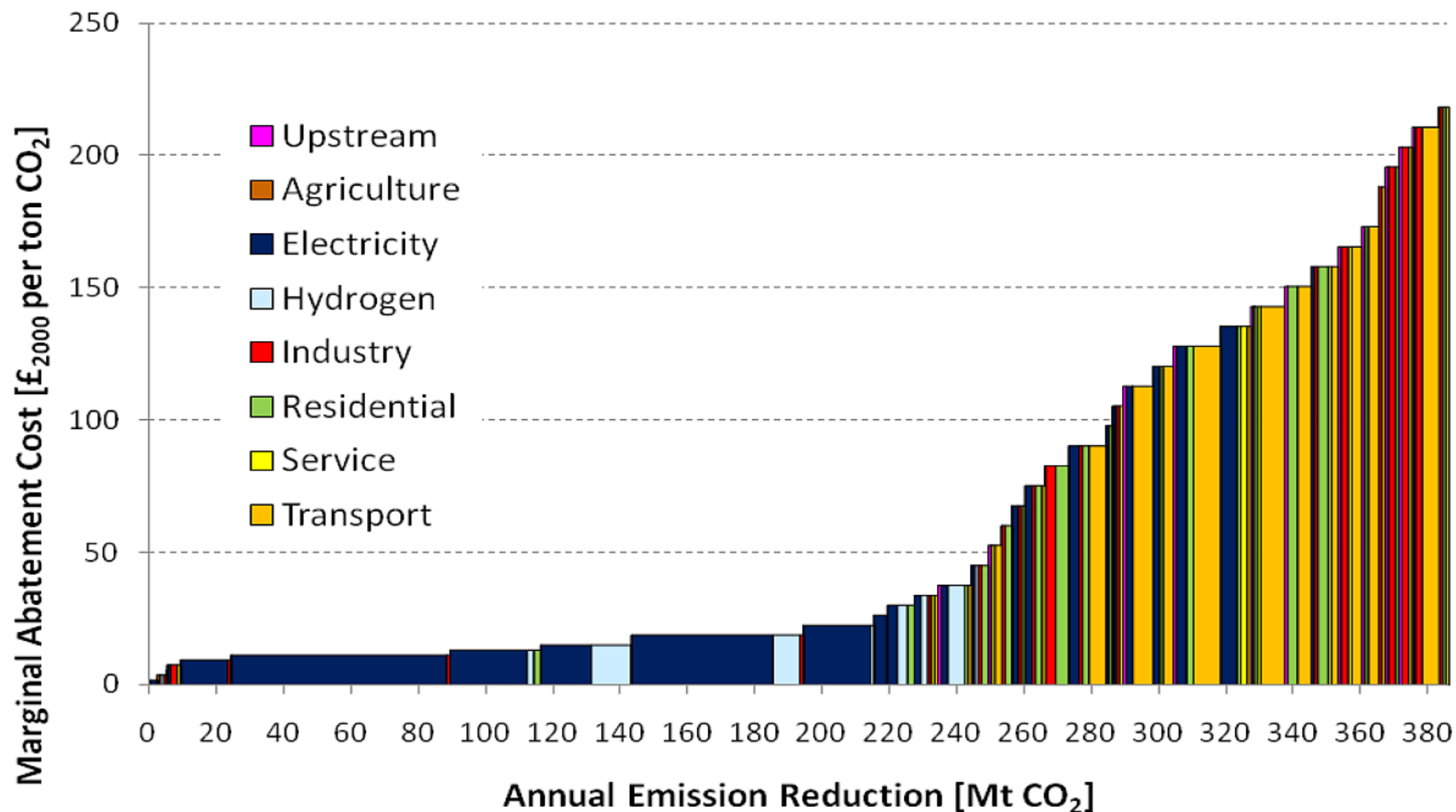
Estimating economic damage from climate change

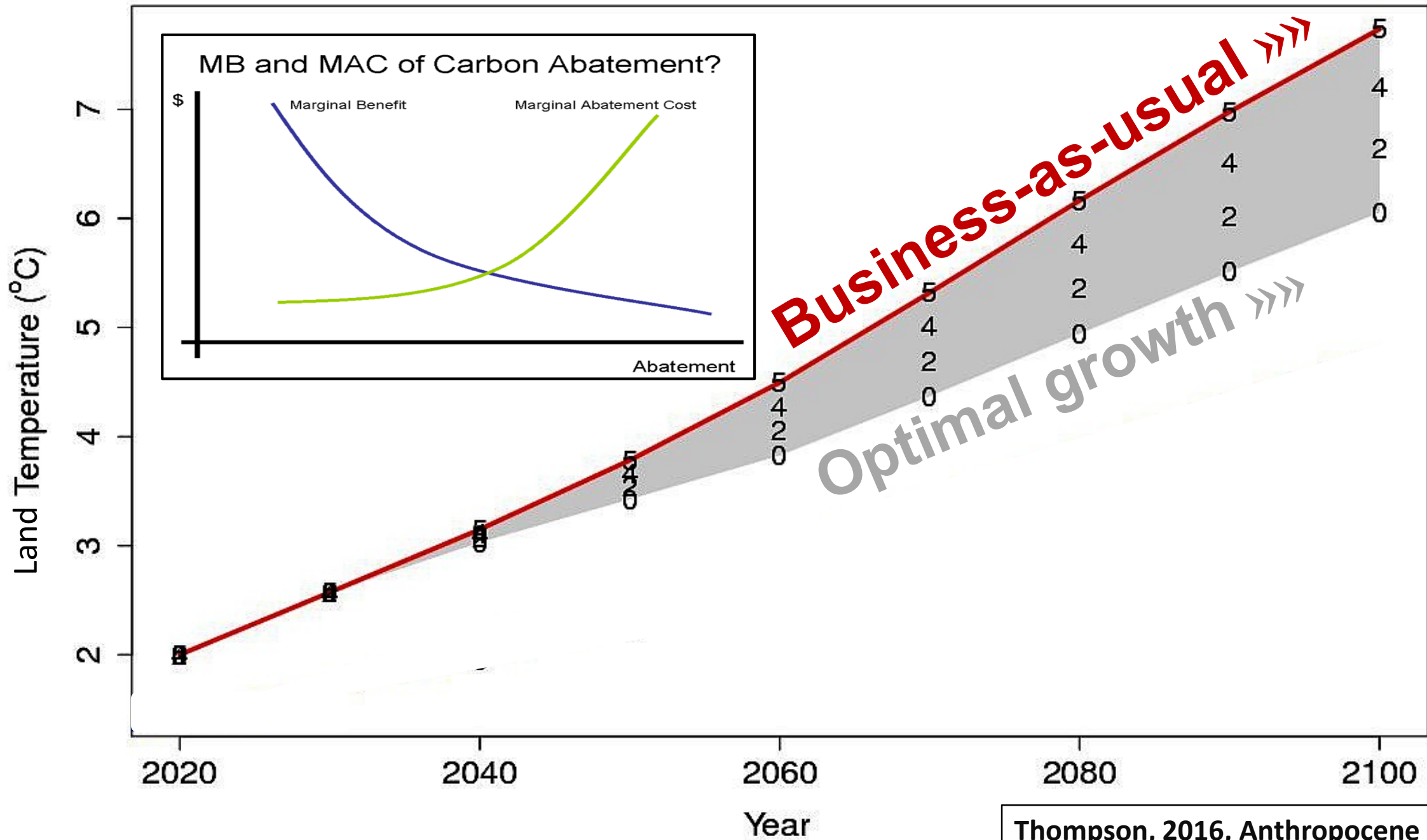
Solomon Hsiang et al,
2017



- (A) **Agricultural impact** (maize, wheat, soybeans, and cotton).
- (B) **Mortality** for all ages.
- (C) **Electricity** demand.
- (D) **Labour** supply for outdoor workers.
- (E) **Property-crime** rates.
- (F) **Violent-crime** rates.
- (G) **Sea-level** rise, cyclones, coastal storms.

Fig. 4: Marginal Abatement Cost Curve for the UK Energy Sector in 2030 (low fossil fuel production costs)







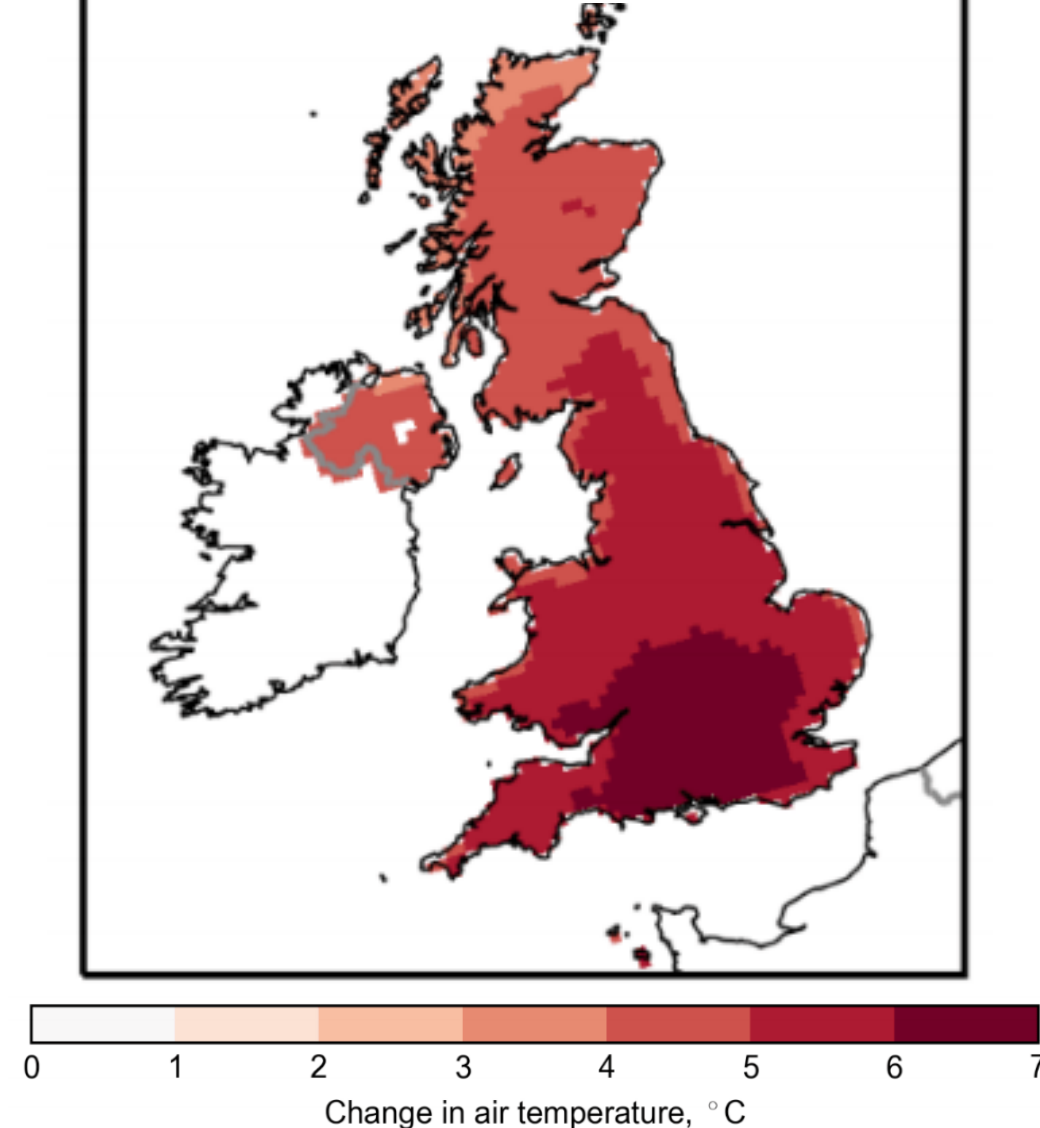
Huge waves hitting the west coast of Scotland, near Ardrossan, Jan 2014

Climate projections for Scotland

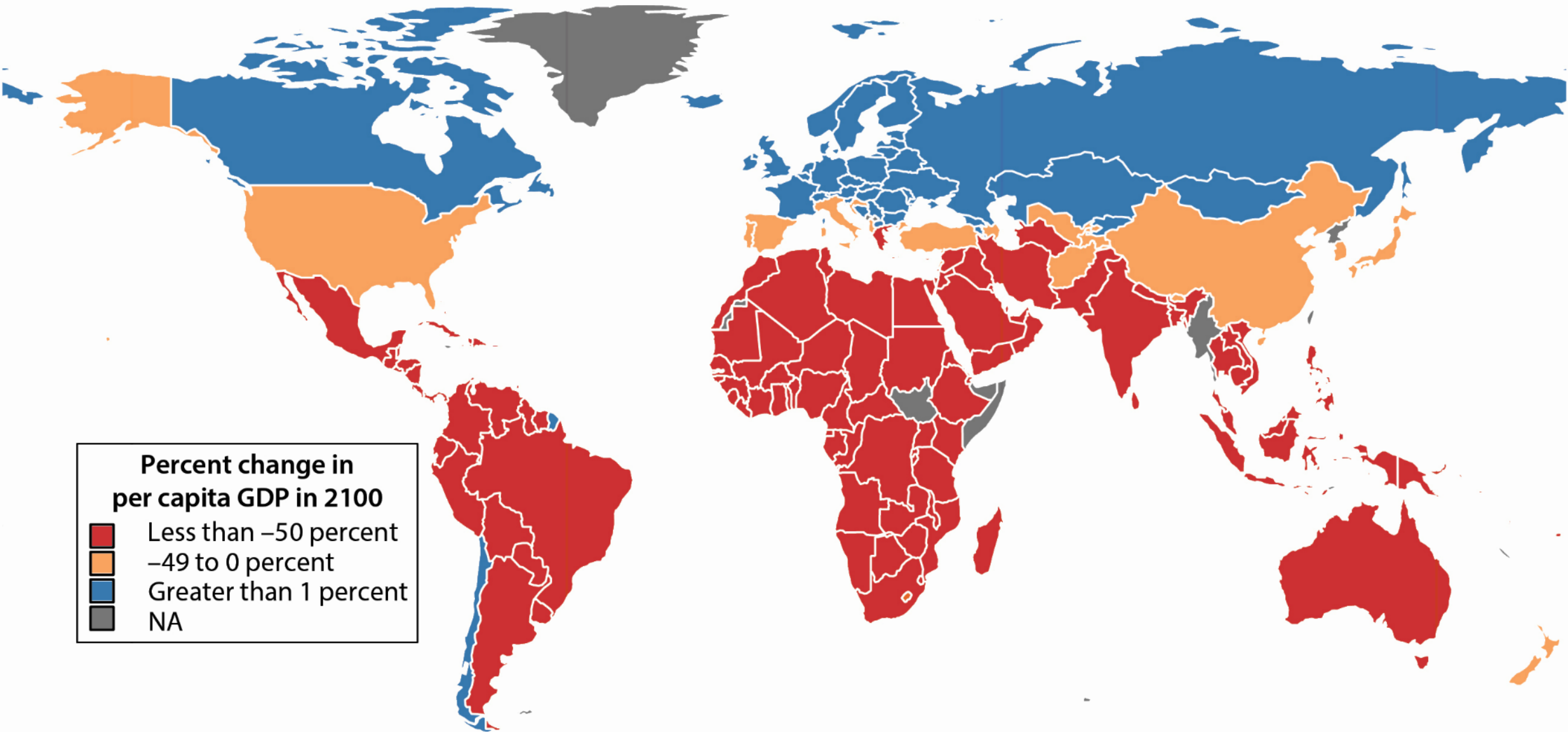
UKCP18 finds that by the end of the century

- All areas of the UK are projected to warm significantly (4-6.5 °C). England will warm more than Scotland.
- Rainfall in Scotland is expected to change quite significantly. Despite overall summer drying trends, an increase in the intensity of heavy summer rainfall events is to be anticipated. Winter rainfall, especially in the northwest is likely to be +25% higher.
- Peak river flow, e.g. in Argyll and the West Highlands is projected be over 50% higher.
- For Edinburgh, sea level rise by the end of the century is very likely to be between 0.50 m and 0.90 m.

Projected change in
summer air temperature
2080-2099



Climate Change Effect on per Capita GDP in 2100 by Country



Source: Burke, Hsiang, and Miguel (2015); authors' calculations.

Acidifying oceans spells
trouble for squid



*Cavolinia
inflexa's*
calcareous
shell is very
sensitive to pH



Rising water
temperatures block
photosynthetic
reactions leaving
coral a
bleached
white.

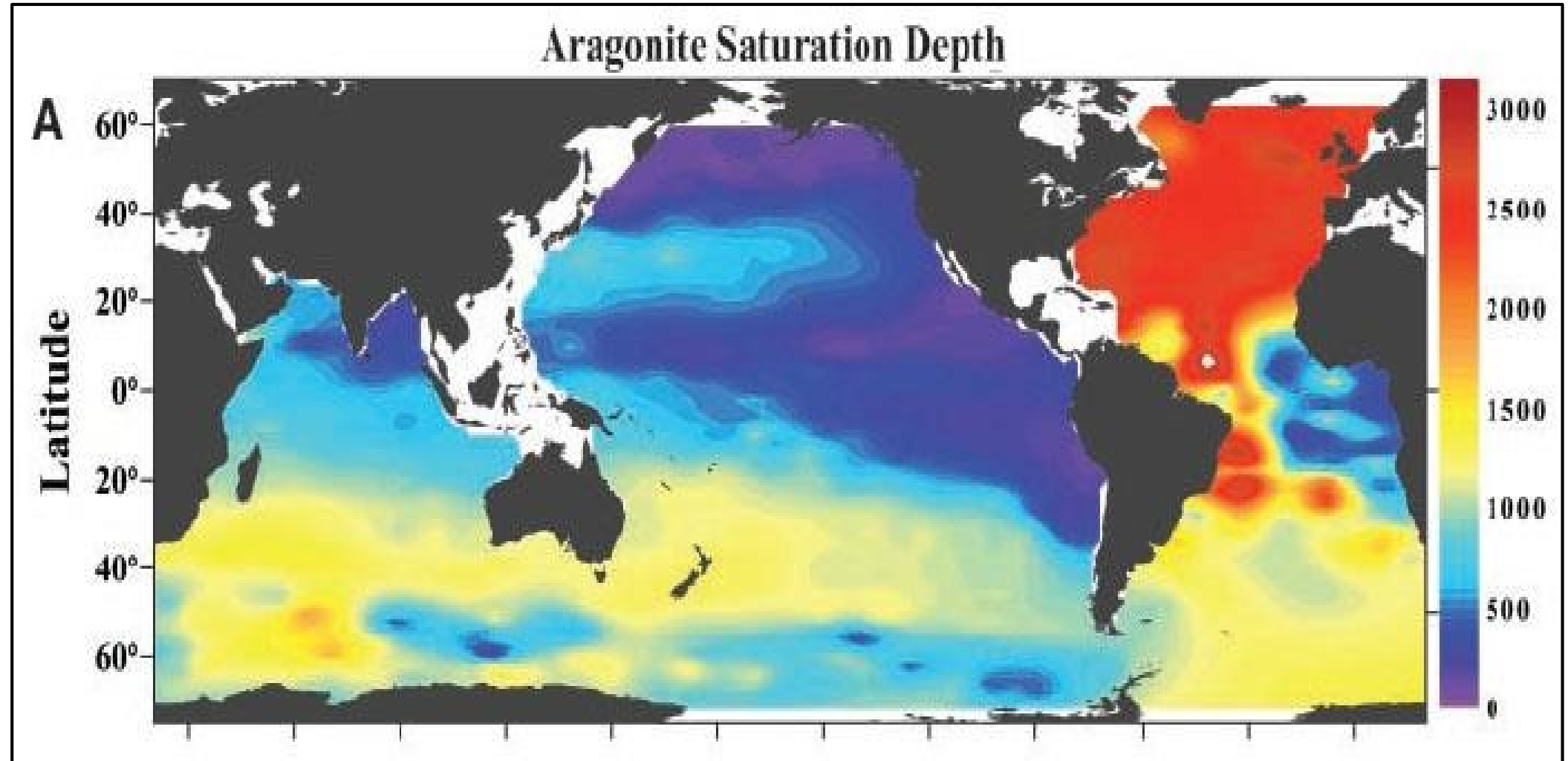


The shells of
Antarctic marine
snails (*Limacina
helicina* - the sea
butterfly) are
being dissolved
by ocean
acidification



Ocean acidification – a tipping point for ecosystem collapse

Rising CO₂ concentrations are causing acidification of the ocean, as CO₂ binds with water to form carbonic acid, thereby negatively impacting many calcifying marine organisms by impairing their ability to build protective shells and skeletons.



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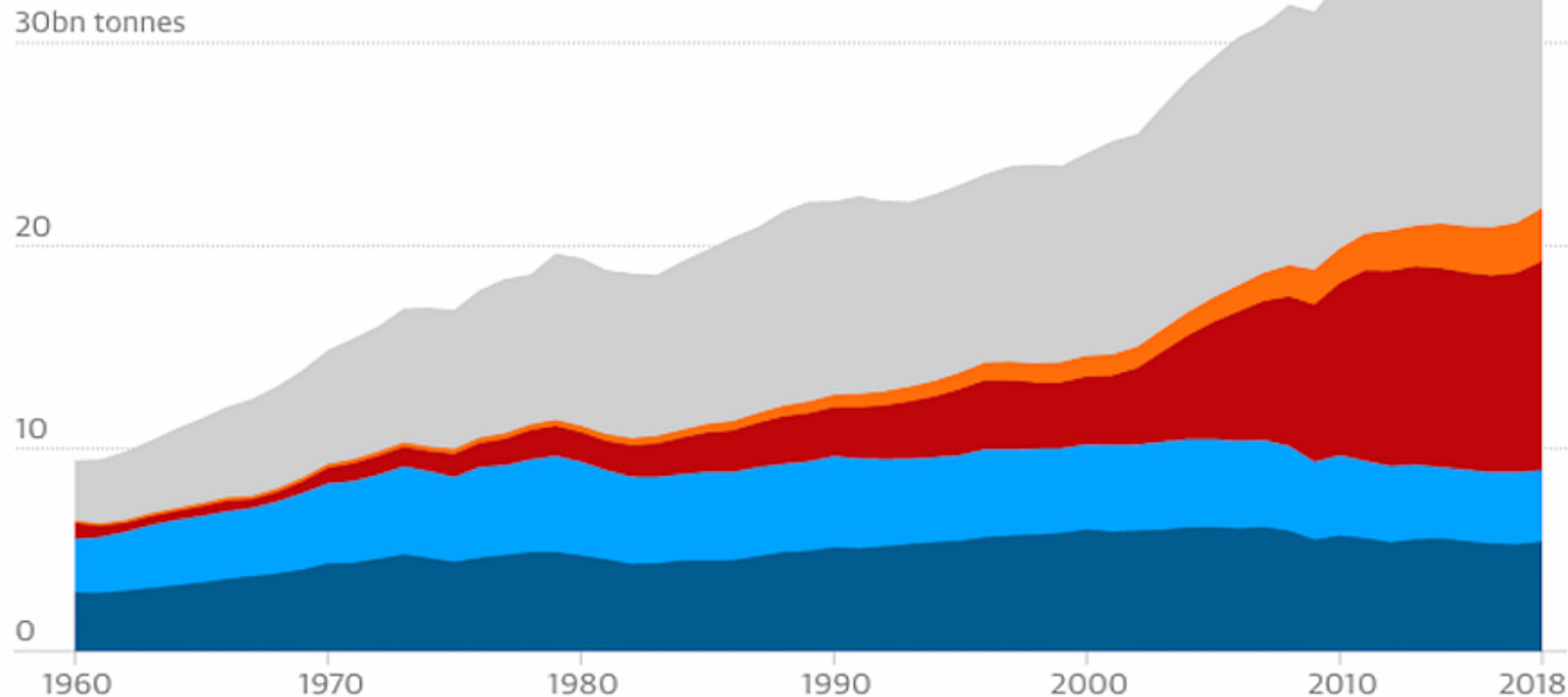
3. The next 100 years.

4. Is there any hope?

Global carbon emissions in 2018 are set to hit an all-time high of 37.1bn tonnes of CO₂

■ US ■ EU28 ■ China ■ India ■ All others

Today →



As 5p charge starts in England, shoppers face tangle of red tape

PLASTIC BAGS CHAOS LOOMS

By Sean Poulter and Rosie Taylor

SHOPPERS will be charged 5p for every plastic carrier bag they use from today in a bid to halt the damage being caused to our planet.

But the scheme being introduced in many stores across England risks becoming a shambles because of the bizarre and complicated rules laid down by ministers, campaigners warn.

Polls show most people support the charge, which follows the Daily Mail's Banish The Bags campaign to reduce the terrible damage to the environment caused by the billions of plastic bags given away every year.

However, critics say the red tape surrounding the scheme will confuse and anger shoppers, meaning the predicted 70 per cent

**BANISH
THE BAGS**
Daily Mail

reduction in bags issued at tills – or 5.4 billion bags a year – will not be delivered. One said the 'totally superfluous and unhelpful exemptions' to the charge will cause problems for both retailers and customers.

There are also concerns that shoppers' frustrations could be taken out on till staff.

While 4p of each charge will go to charities, Chancellor George Osborne has angered campaigners by insisting that the Treasury will take the remaining 1p in VAT.

The new charge excludes paper bags but will be payable on each plastic bag handed out in major stores – those with more than

Turn to Page 4



Carole Middleton watches England crash out of the Rugby World Cup on Saturday

**Oh Carole! Middleton misery
at World Cup humiliation** PAGE SEVEN

Osborne declares war on the shires

GEORGE Osborne will take on the Tory shires over planning today as he outlines proposals to tackle the housing crisis.

The Chancellor will pledge to 'shake Britain out of its inertia' by making it harder for rural and provincial councils and 'Nimby' activists to frustrate plans.

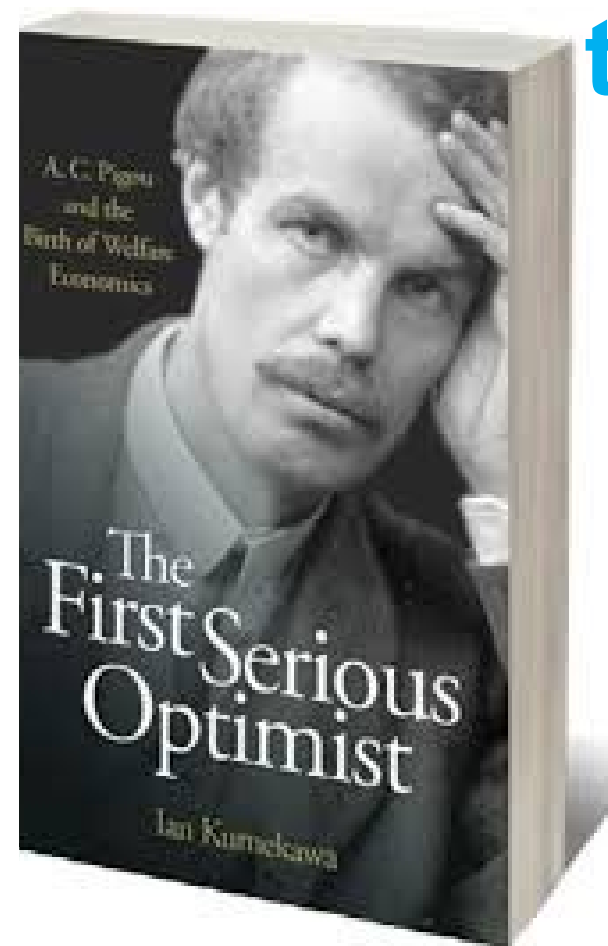
Mr Osborne will use his speech to the Tory conference in Manchester to announce a new commission dedicated to speeding up progress in areas such as transport and housing. And in a major coup, the Chancellor will announce that former Labour Cabinet minister Lord Adonis is to be the commission's chairman.

Mr Osborne is said to have wooed him at a series of clandestine meetings. The Blairite peer's move will be a blow to Labour moderates.

A Tory source said 'The Chancellor is showing his willingness to confront the Tory shires. Britain has got to do better on infrastructure.'

SEE PAGES 8-11

**A. C. Pigou
(the father of
environmental
taxes)**



British Columbia's approach to carbon pricing

- **All revenues returned to households**

A high-enough carbon price shapes behaviour through choices, small and large, about what to buy, and how to invest. People, rather than Government, stimulate innovation.

- **Simple and inexpensive to administer**

Scope for corruption / lobbying greatly reduced.

- **Gradual**

Predictable for business.



Summary

- Global land-temperatures have already risen 1.6°C since pre-industrial.
- Increasing WMGHG production from human activities shows no sign of peaking.
- Cost-benefit analysis points to GHG emissions doubling by 2100.
- Global temperatures can be expected to rise by 4-6°C over the next 100 years.
- We need to be planning for a much warmer world.
- Humankind's best hope is to put equal effort into adaptation and mitigation.
- Carbon pricing provides a route forwards to low-carbon innovation.