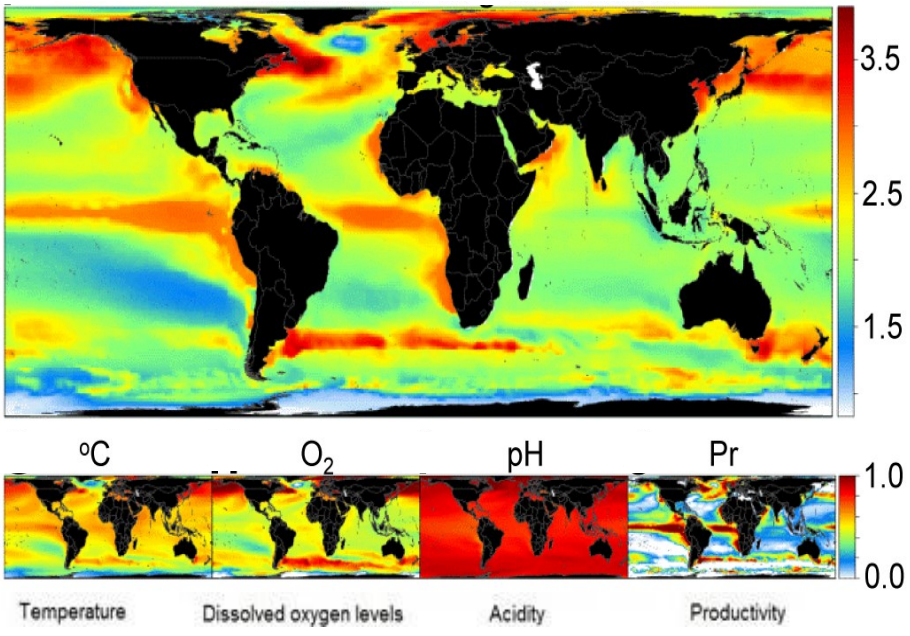
Global warming

and its equally evil twin

ocean acidification

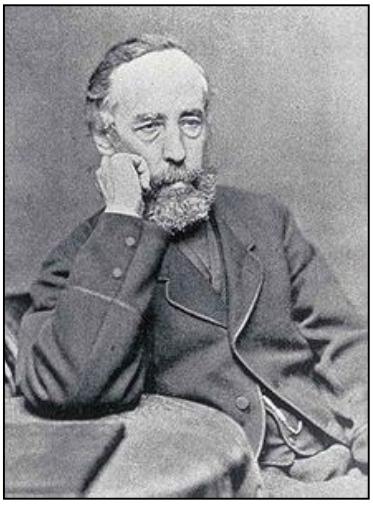
Prof Roy Thompson, FRSE

Predicted changes in the oceans



Climate change

1. **How the climate system works**
   (Greenhouse effect)
2. **The fundamental dilemma**
   (Overpopulation & overconsumption)
3. **Global signals of a changing climate**
   (Many)
4. **Can science fix climate change?**
   (No)
5. **Economics of climate change**

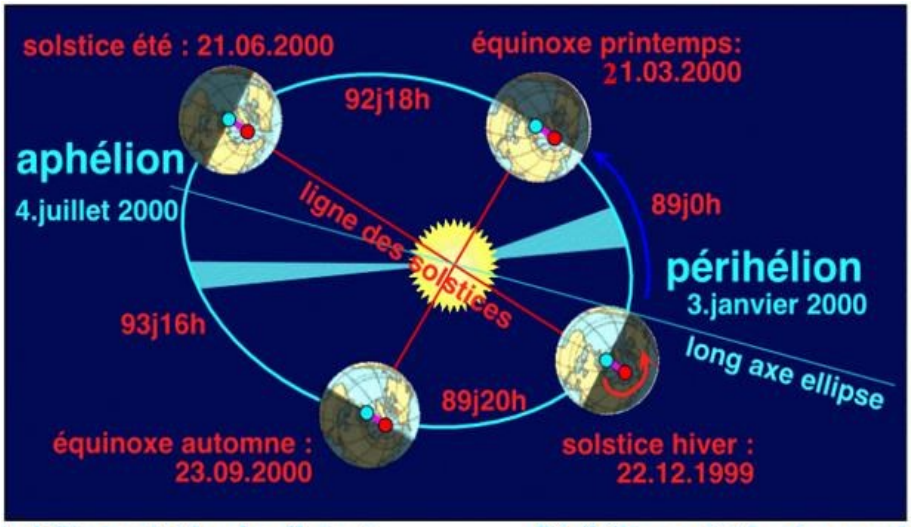


James Croll - visionary 19th-century Scottish scientist (1821 – 1890)

When James was three years old, the family croft was cleared by the landowner, Lord Willoughby, and displaced to an area of bog-land a mile to the west at Wolfhill.

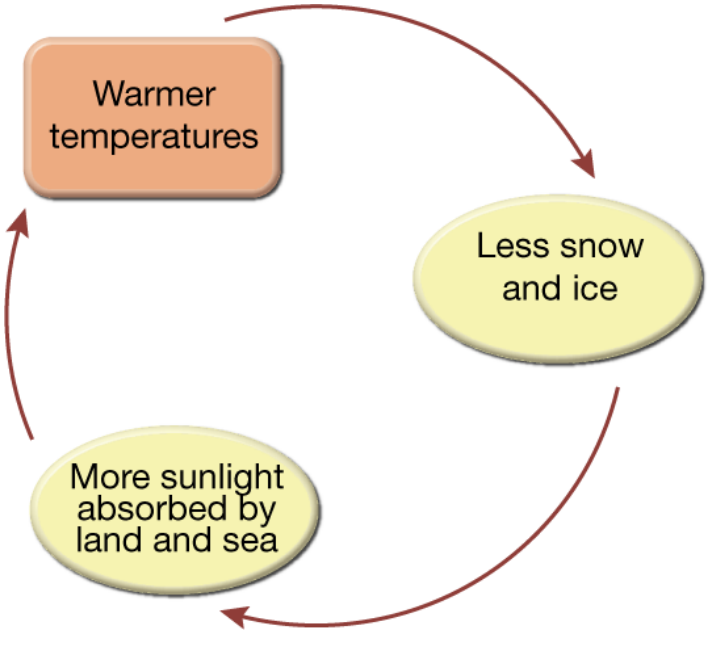
Probable birthplace, Little Whitefield, Tuesday 2nd of January 1821

Correctly interpreted the influence of eccentricity on the duration of the seasons, and hence on climate



Aphélie : point le plus éloigné
329 W/m2

Périhélie : point le plus proche
351 W/m2

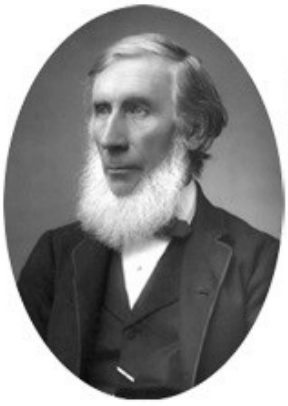


Croll pioneered the idea of feedback effects in climate studies.

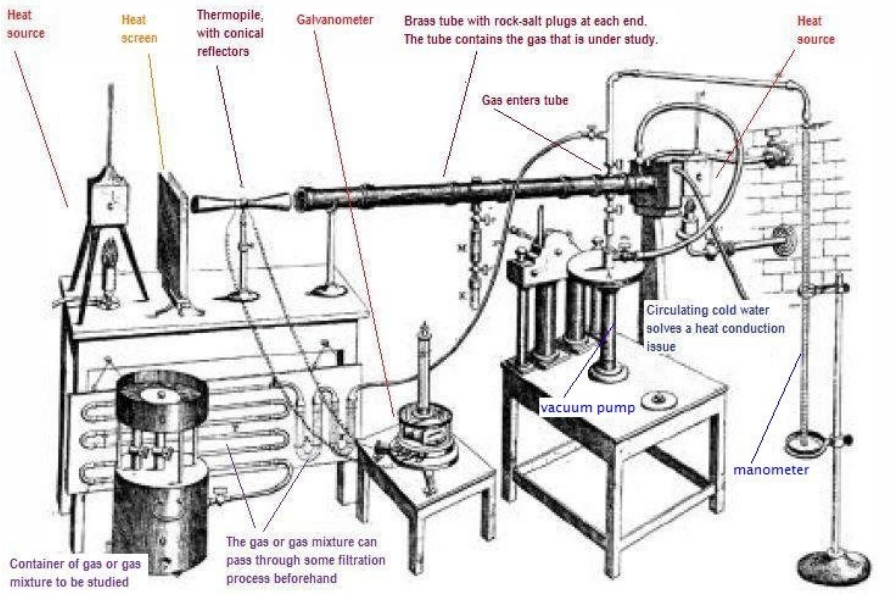
Greenhouse pioneers

FOURIER, 1766-1830

TYNDALL, 1820-1893

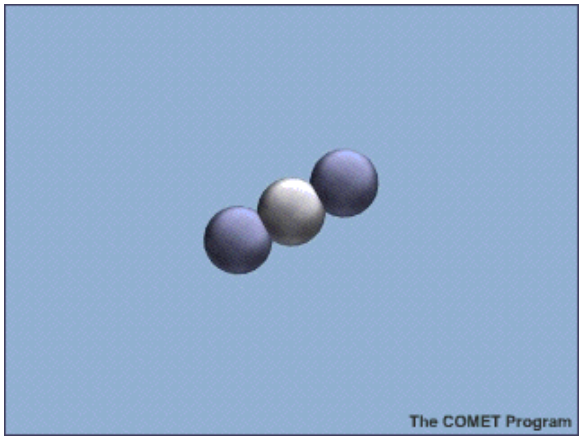


ARRHENIUS, 1859-1927

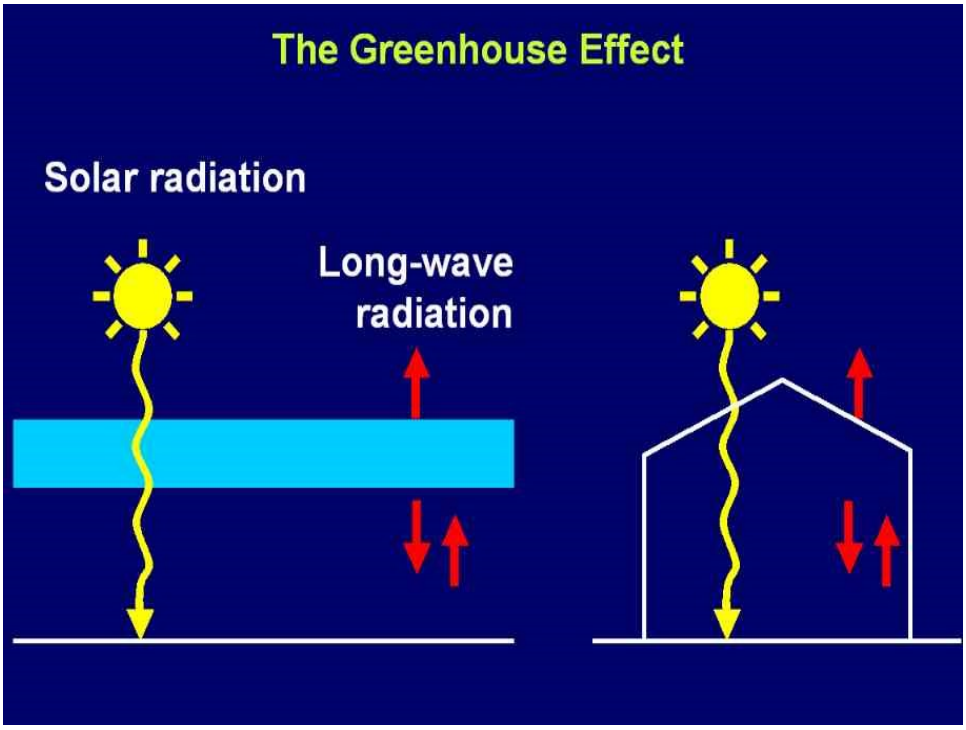


Tyndall's 1872 setup for measuring the heat absorption of gases.

Spectroscopy:
The interaction between matter and electromagnetic radiation



MOLECULES: The combination of atoms into molecules leads to the creation of numerous unique energetic states ,and hence to the selective emissivity and absorptivity which underlie the greenhouse effect.



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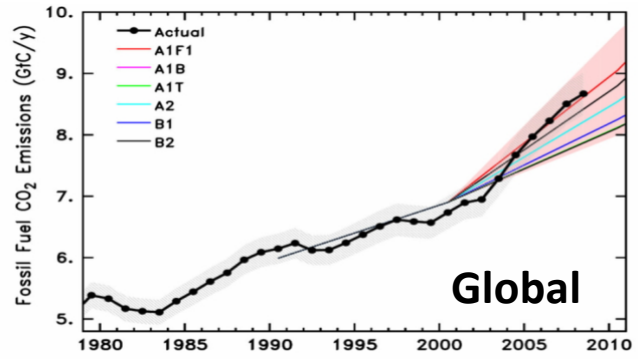


Where are we now?

Despite Kyoto, Copenhagen, & Rio global CO_2 emissions are rising even faster than previous business-as-usual projections.

Global Change's Terrifying Maths

Three simple numbers that add up to a global catastrophe…

The First Number: 2°C

A 2°C target is often used in International negotiations as a guide line for avoiding dangerous climate change.

The Second Number: 900 Gigatons

Humans can pour roughly 900 Gt of carbon dioxide into the atmosphere and still have some hope of staying below two degrees.

The Third Number: >11,000 Gigatons

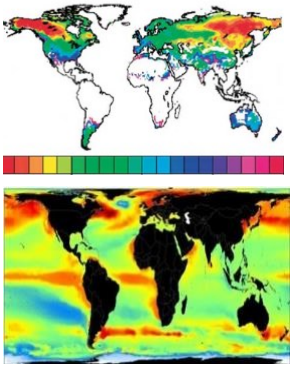
This number – the scariest of all – describes the amount of carbon contained in coal, oil, gas & hydrofracking resources. In short, the fossil-fuel mankind can burn is over 10 times higher than the 900 Gt 'limit'.

Climate change: three steps to ruin

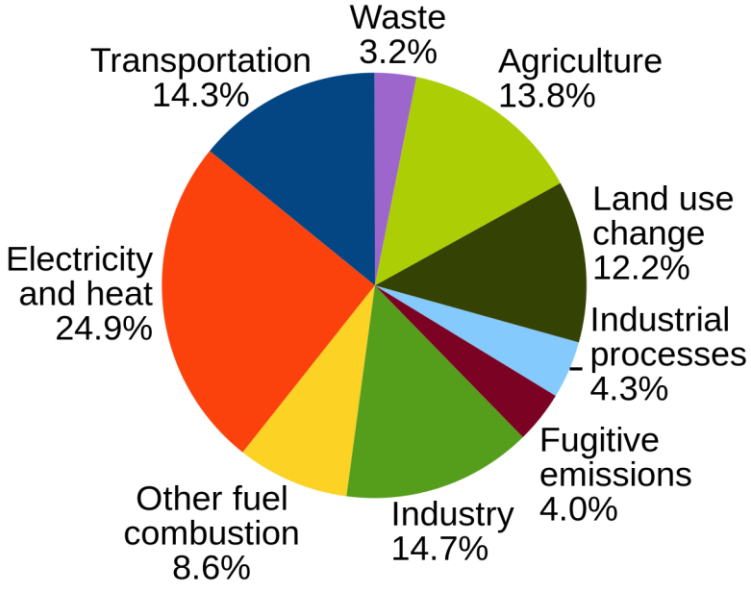
1. Our ever rising global population, with its over consumption, generates atmospheric pollutants especially CO_2.

2. CO_2 is a powerful, long-lived greenhouse gas. It's fluctuations have been the primary driver of geological climate change and ocean pH.

3. Impacts of the two evil twins ➡ ice melt, sea-level rise, food supply & ecosystem disruption, droughts, biodiversity loss & a 5% fall in global GDP forever.



Annual greenhouse gas emissions by sector



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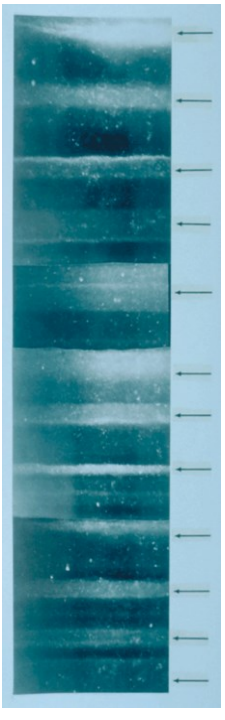
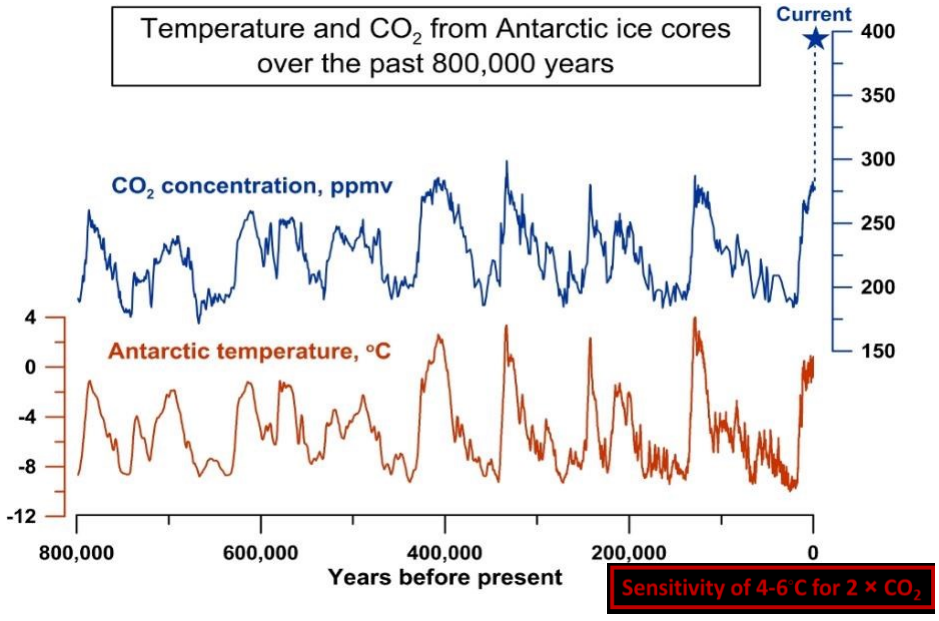
Ice cores

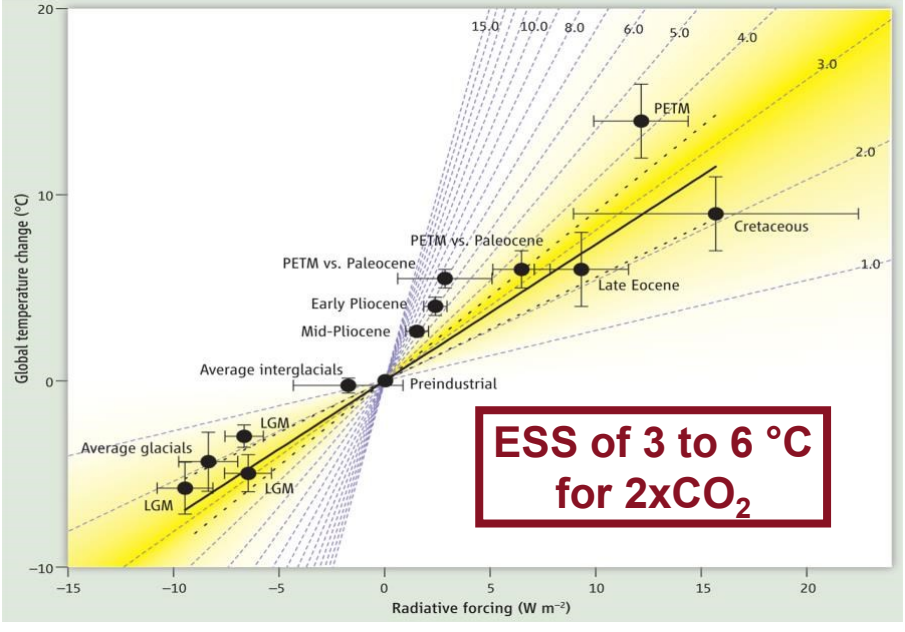


19 cm long section of GISP 2 ice core from 1855 m showing annual layer structure illuminated from below by a fiber optic source. Section contains 11 annual layers with summer layers (arrowed) sandwiched between darker winter layers.

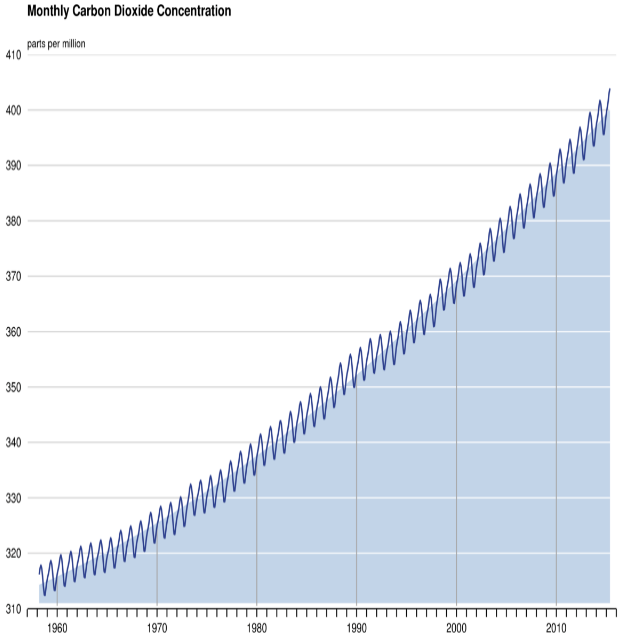
Antarctic ice: the world's air museum

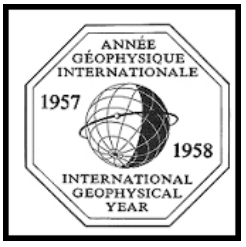


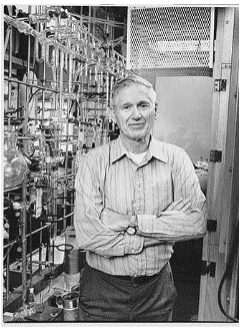
Climate Sensitivity Estimated From Earth's Climate History



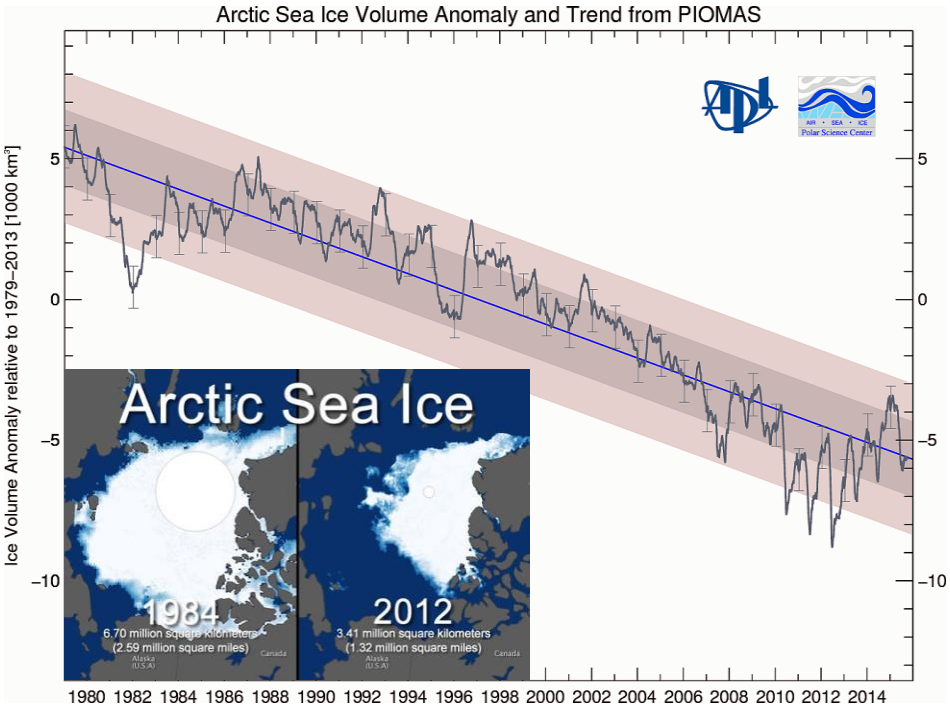
IGY (actually 18-months from July 1957 to December 1958)







Charles David Keeling



Continent-wide response of mountain vegetation to climate change (2001-8)

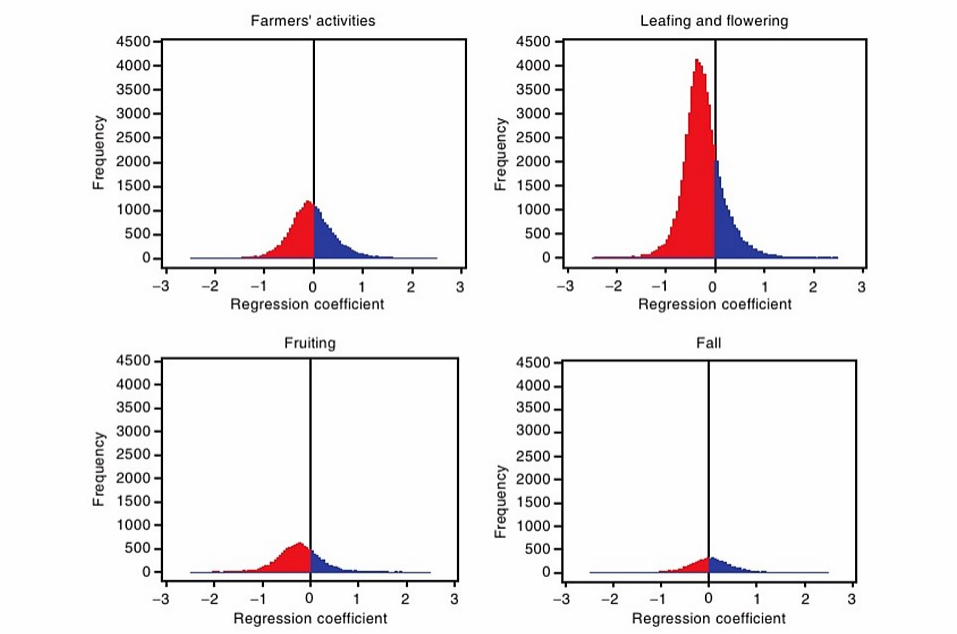


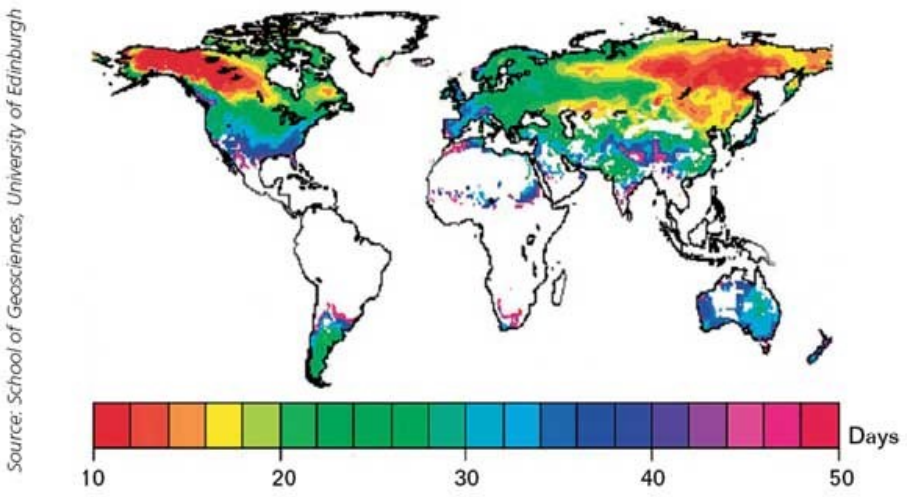
Fig. 3 Histograms of phenological trends in Europe. All temporal trends (1971–2000, time series 15+ years) as linear regression coefficients (days yr^{-1}) systematically reported to the COST725 meta-analysis ($n = 103\,199$) for four different groups.

Managing Daylength in Commercial Greenhouse and Nursery Production

High-pressure sodium lamps with oscillating reflectors cast moving beams of light to crops below in order to increase yield, inhibit dormancy, or accelerate flowering

Recent developments in LED technology create new opportunities for lighting of greenhouse crops.

Desynchronisation



Colour-coded regions are where plant life will be affected by 2080. Figures reveal the number of days by which plants will flower earlier than expected

Royal Botanic Garden Edinburgh

DATA DREDGING

- Apparent statistical significance is achieved by mere repetition (of non-standard, eccentric assessments and of invalid procedures) until a success occurs.

FAKE SCIENCE

- Create scientific-sounding terms (e.g. '*botanical regression*', '*thermal deceleration*') in order to add weight to their claims and thereby persuade non-experts to believe statements that are meaningless.

OUT OF TOUCH

- Our work is commercially valuable.

Director

RELUCTANT TO LET GO

- *"While I appreciate your concerns, it must be understood that my colleague got in touch with you as a courtesy to inform you and only ask for your "blessing" as it were…"*

Head of Publications

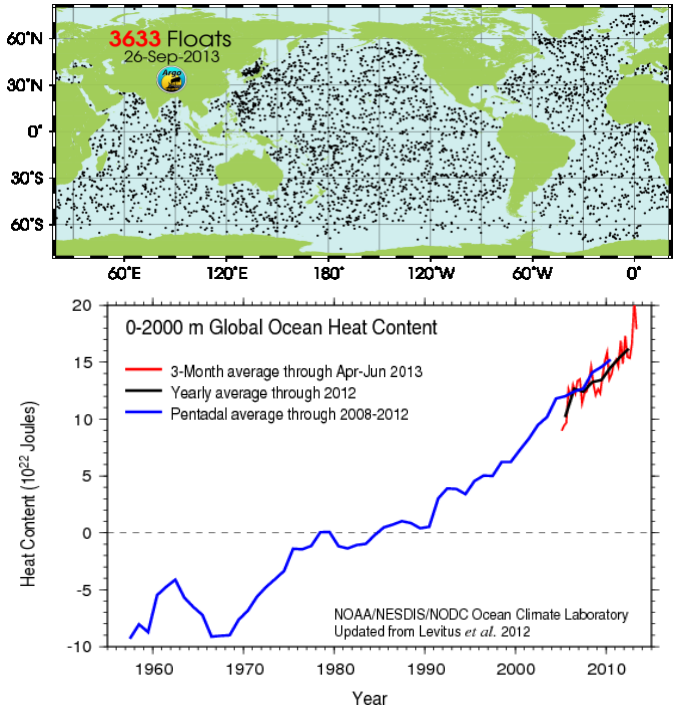
FRAUD

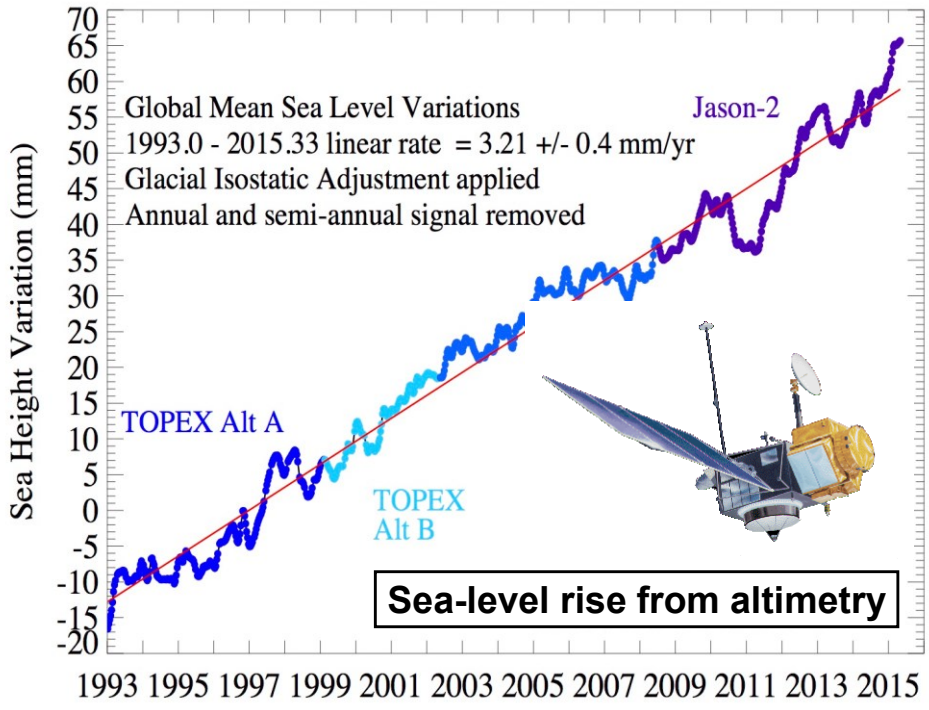
- *"If statistical advice [is needed] we will look for it outside Edinburgh",*

VANITY PUB

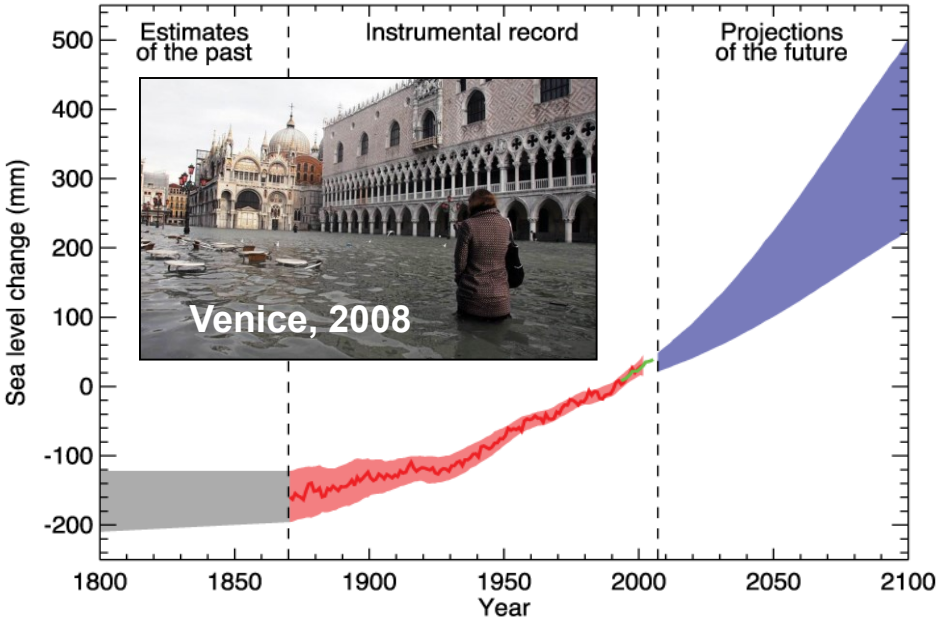
- Not one RBGE phenological publications in over 190 years in an open scientific journal.

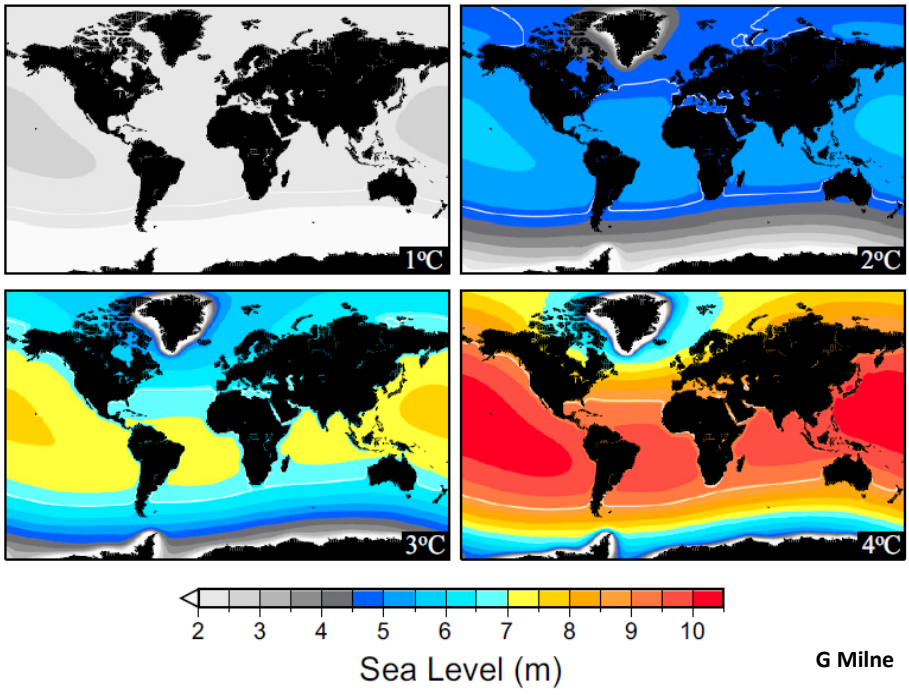

Three billion people rely on wild-caught or farmed seafood as their primary source of protein
Oceans


3633 Floats
26-Sep-2013
60°N
30°N
0°
30°S
60°S
60°E
120°E
180°
120°W
60°W
0°
0-2000 m Global Ocean Heat Content
3-Month average through Apr-Jun 2013
Yearly average through 2012
Pentadal average through 2008-2012
Heat Content (10²² Joules)
20
15
10
5
0
-5
-10
1960
1970
1980
1990
2000
2010
Year
NOAA/NESDIS/NODC Ocean Climate Laboratory
Updated from Levitus et al. 2012

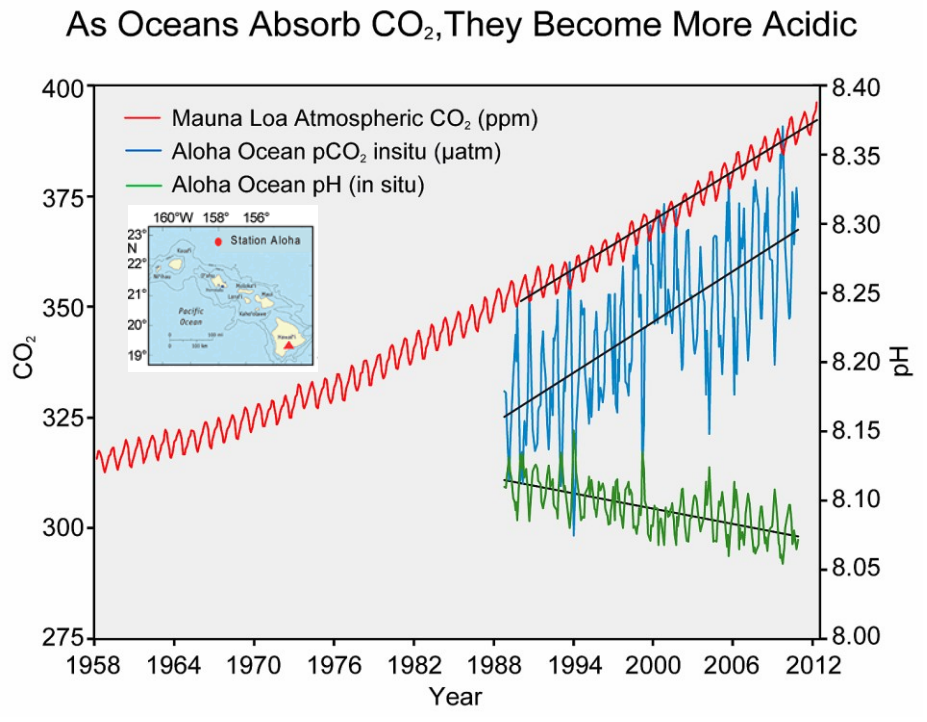


Ocean Levels Are Getting Higher

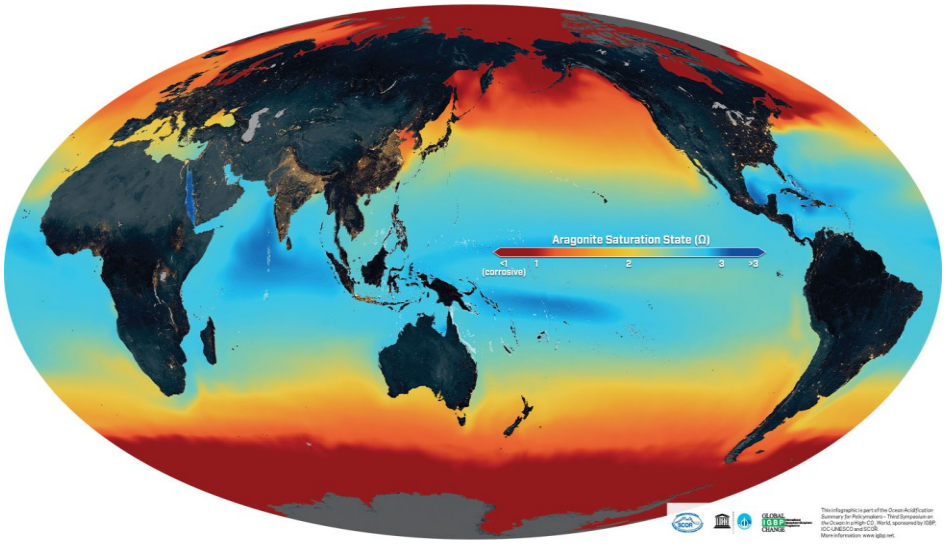



1ºC
2ºC
3ºC
4ºC
2
3
4
5
6
7
8
9
10
Sea Level (m)

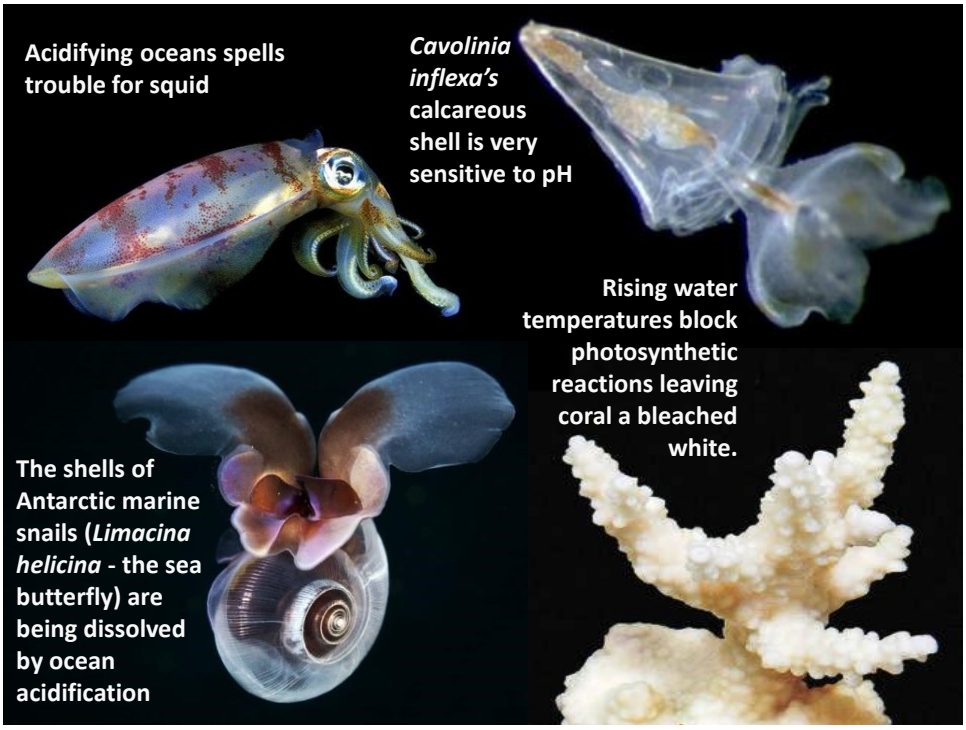
G Milne


As Oceans Absorb CO_2, They Become More Acidic
Mauna Loa Atmospheric CO_2 (ppm)
Aloha Ocean pCO_2 insitu (µatm)
Aloha Ocean pH (in situ)
160°W 158° 156°
23° N
22°
21°
20°
19°
Station Aloha
Pacific Ocean
CO_2
pH
400
375
350
325
300
275
8.40
8.35
8.30
8.25
8.20
8.15
8.10
8.05
8.00
1958
1964
1970
1976
1982
1988
1994
2000
2006
2012
Year

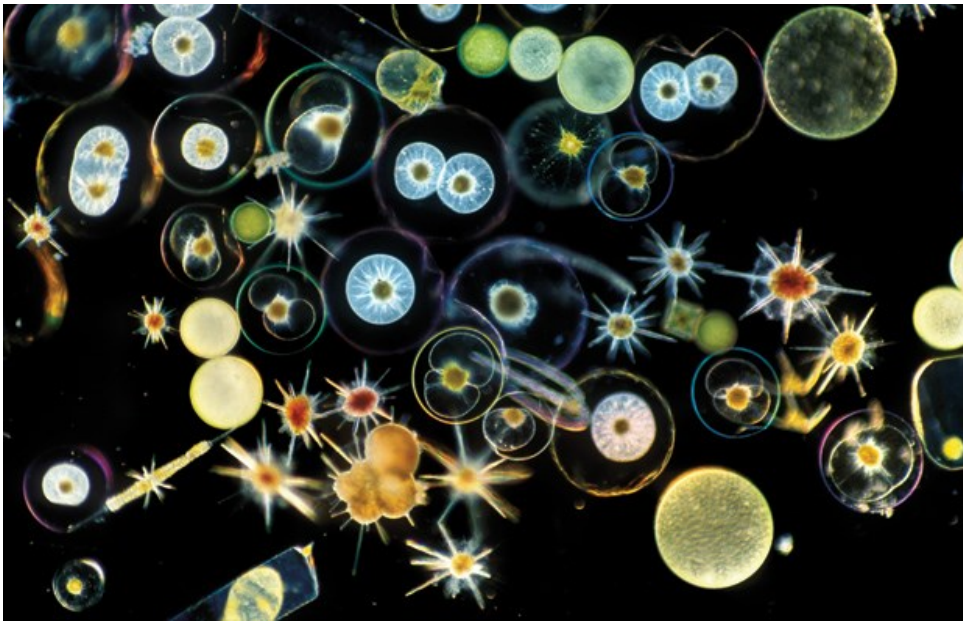
Aragonite saturation as projected in 2100. Only in the blue regions will corals and carbonate-shelled creatures continue to grow. In red regions they will have a hard time.

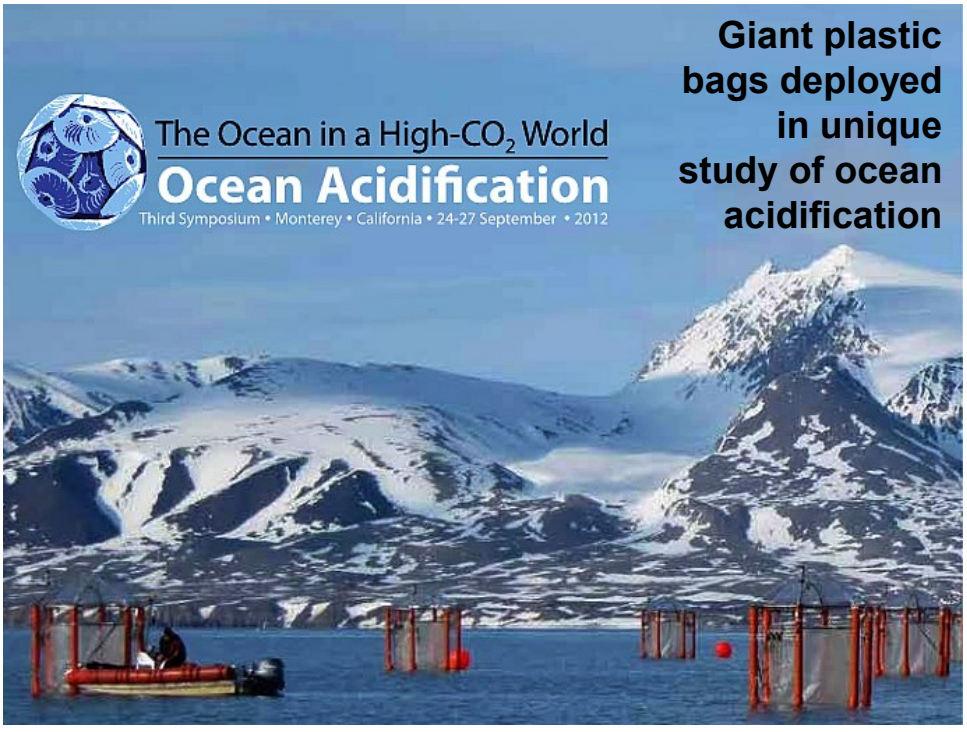


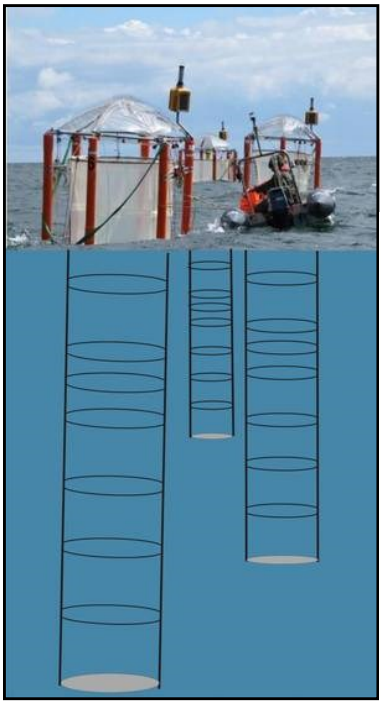
In a lab experiment, a sea butterfly (pteropod) shell placed in seawater with increased acidity slowly dissolves over 45 days.



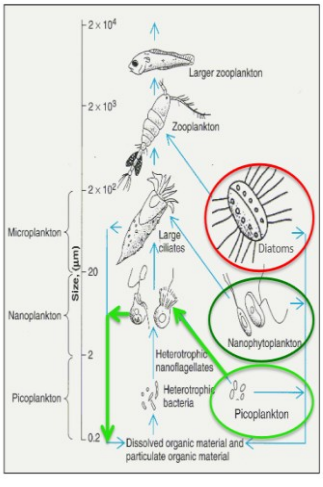
Acidification even effects organisms without shells or skeletons:– especially pico- & nano-plankton







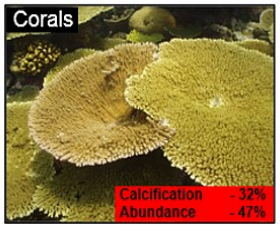
Smallest plankton grow fastest (with rising CO_2) depriving larger phytoplankton of nitrates

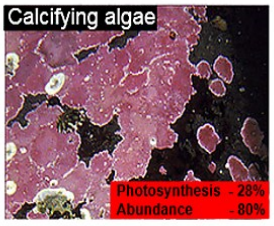


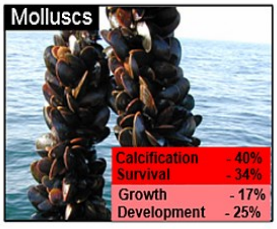
outcompeted at high CO_2

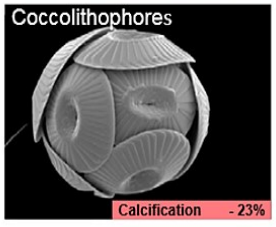
moderately stimulated at high CO_2

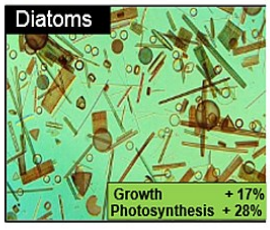
strongly stimulated at high CO_2

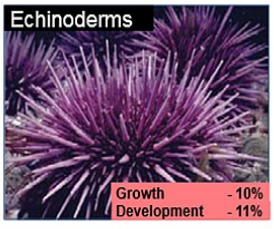




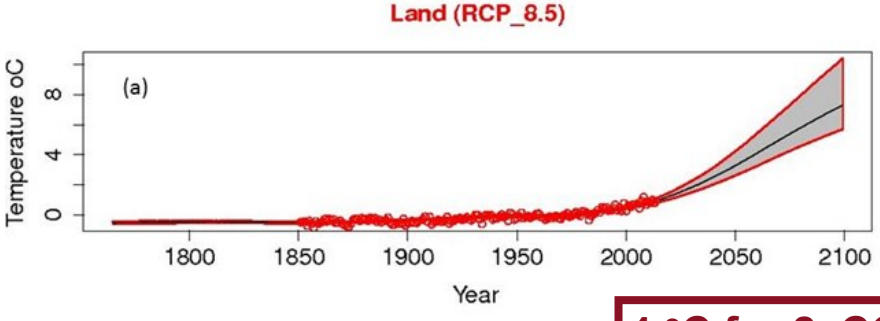




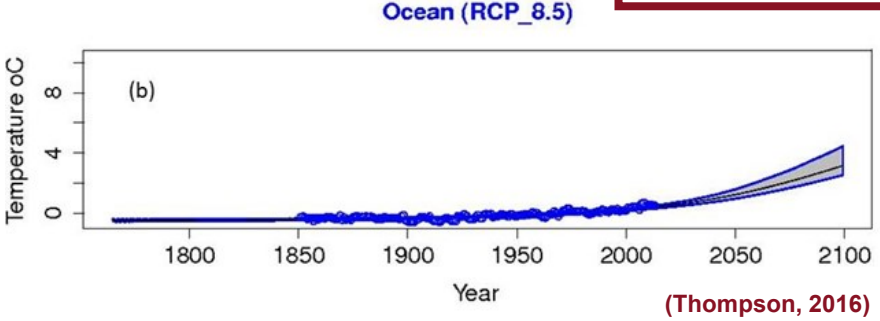




The United Nations has warned that ocean acidification could cost the global economy US$1 trillion per year by the end of the century.

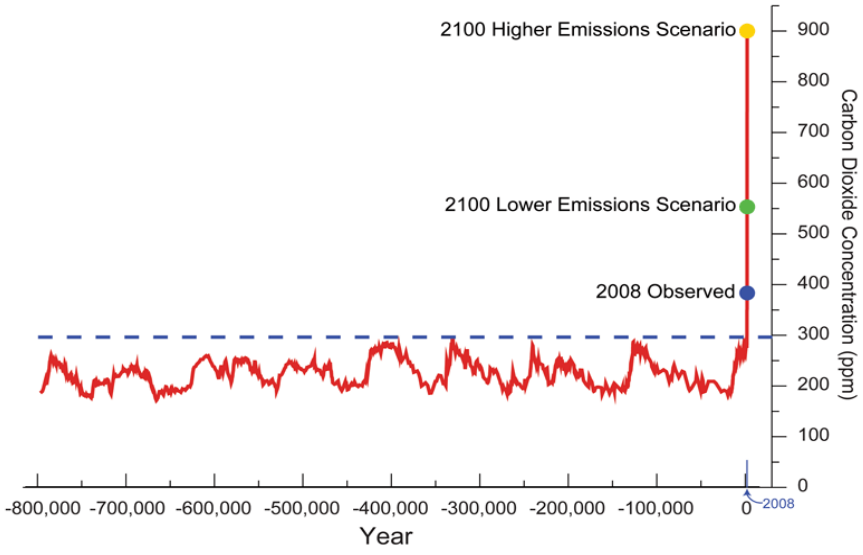


4 °C for $2xCO_2$



(Thompson, 2016)

Big changes ahead!



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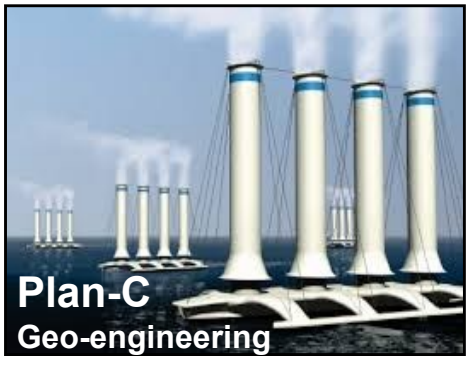
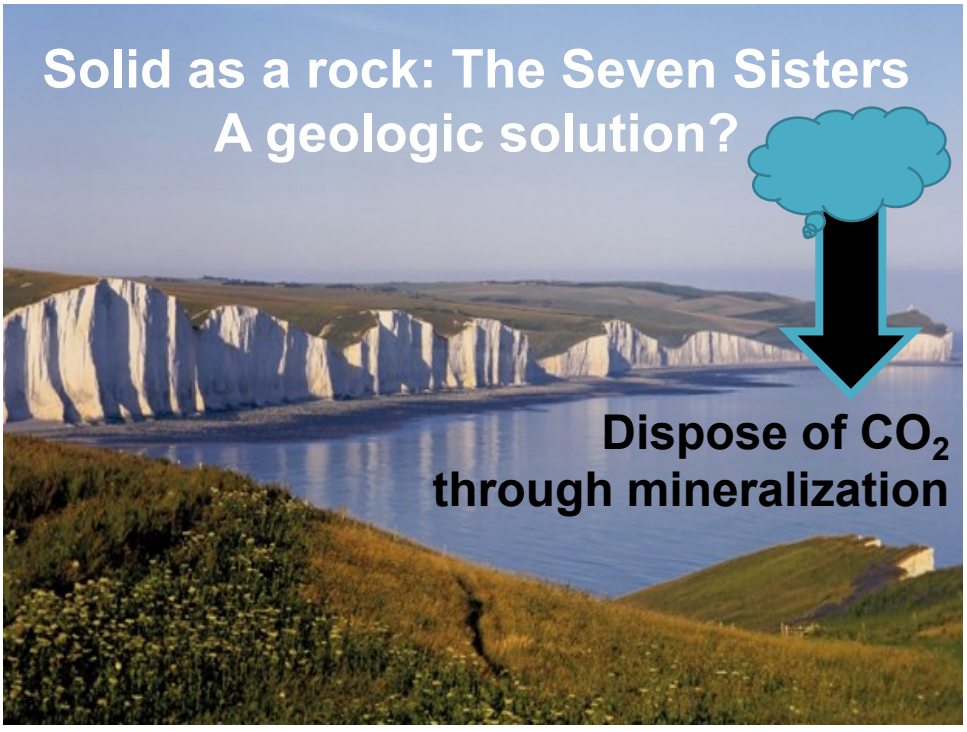
What can we do about Climate Change?

A. Fix the problem
B. Cope with the problem
C. Re-engineer it.



Plan-C: Geo-engineering



ENHANCED CHEMICAL WEATHERING AS A GEOENGINEERING STRATEGY TO REDUCE ATMOSPHERIC CARBON DIOXIDE
Jens Hartmann et al. May, 2013

(left) A "hardpan" of carbonate formed on waste slag mounds at former steelworks in Consett, United Ki
ɔrecipitation in waters egressing from a waste landfill in Scunthorpe steelworks (photograph courtesy of
ıe). In both cases, rainwater has percolated through the material (dissolving Ca^{2+} and Mg^{2+}) and cor
ıe precipitation of carbonate

CO_2 Mineralisation Project to turn released carbon into commercial products.

Industrial flue gas is fed into a high temperature and high pressure environment to create a reaction between the CO_2 and chemical solutions and produce useful mineral-based products.

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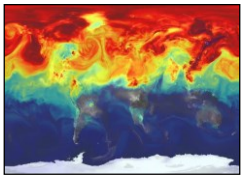
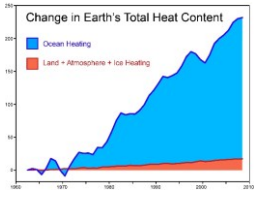
Cost-benefit analysis

"The economics problem from hell"



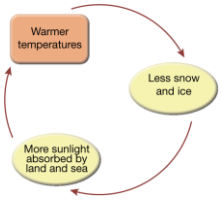
1. Multi-national problem

2. Irreversibilities

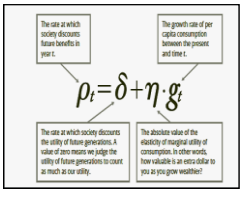


3. Long time-scale

4. Low-probability catastrophic outcomes

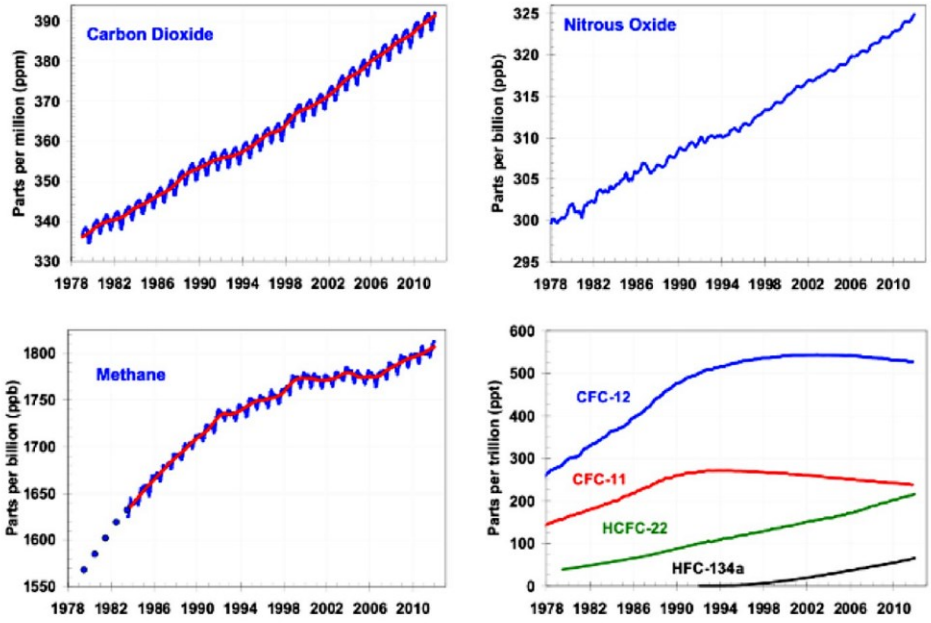


5. Large uncertainties

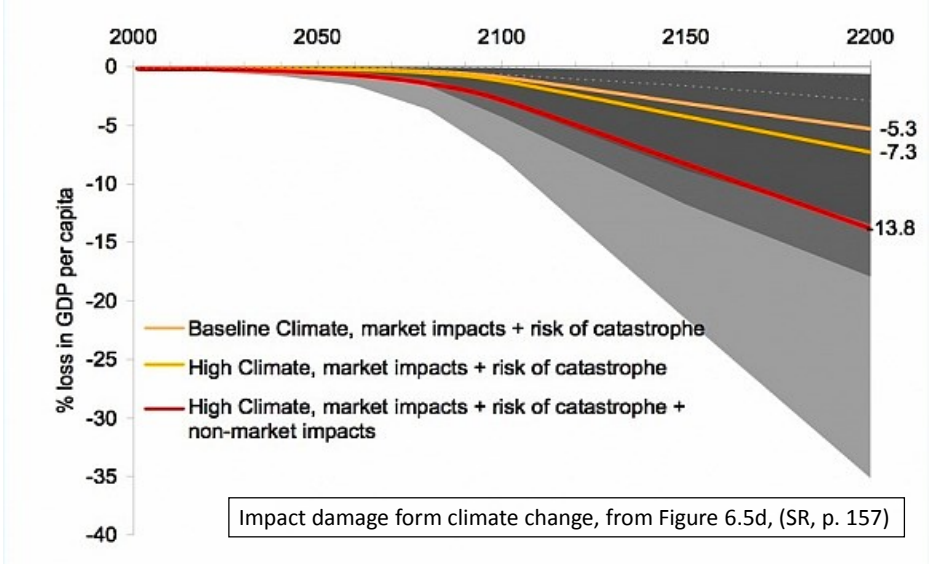


6. Externalities

Global trends of the major well-mixed greenhouse gases



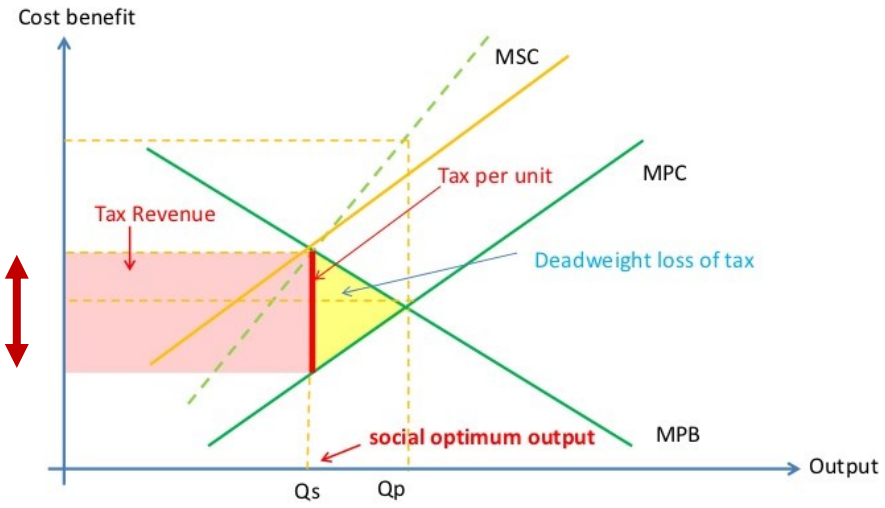
People living in industrialised countries and indifferent to the fate of humankind after 2050 do not really need to worry overmuch about climate change.



Impact damage form climate change, from Figure 6.5d, (SR, p. 157)

Negative Externalities

Government can implement tax to solve this situation, but how much tax? ☺
(Let's say it's fixed tax)

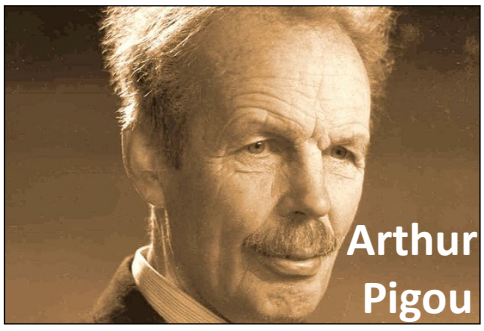


Disentangling the Nordhaus/Stern controversy

Nordhaus: strongly favours a carbon tax (around $10/ton), and has criticised the Stern Review for its use of a low discount rate.

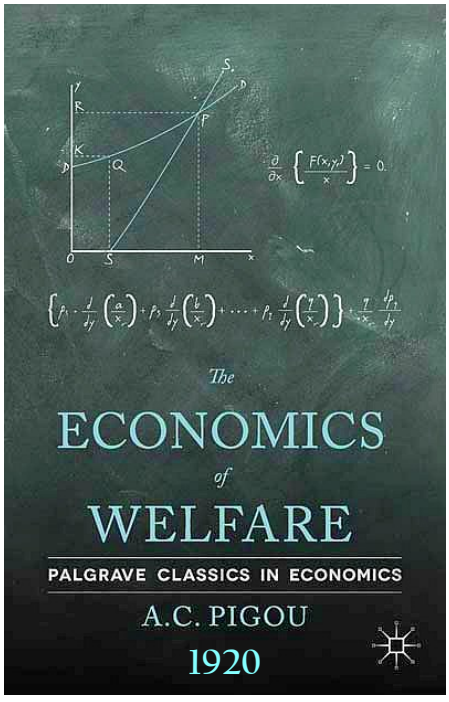
Carbon Tax, or Cap & Trade?

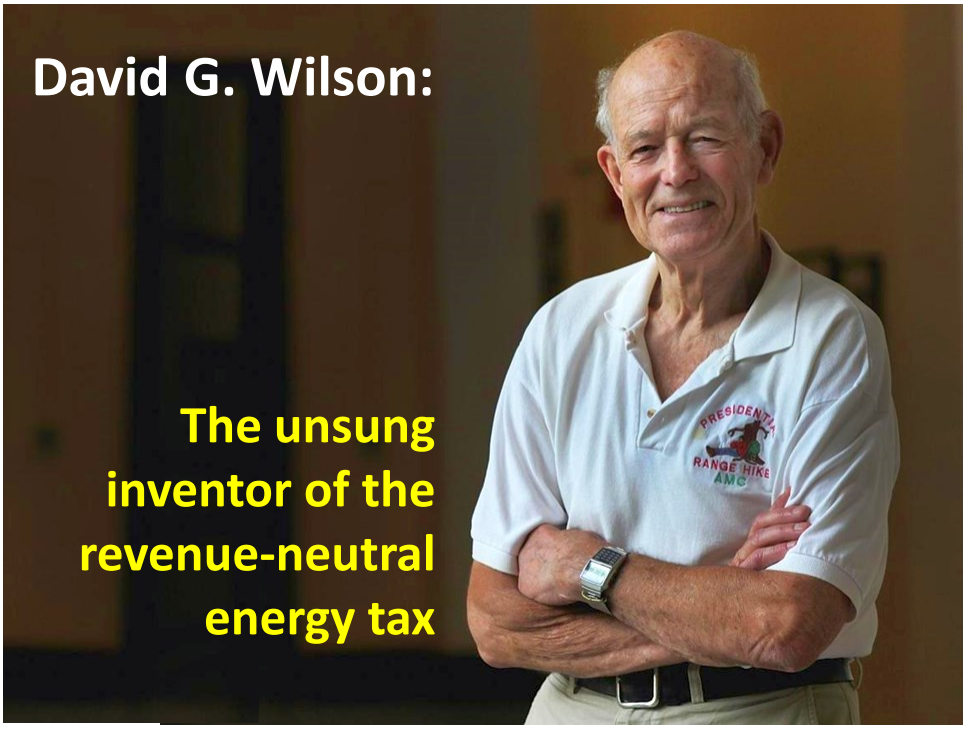
Lord Stern:
The benefits of strong, early action outweigh the costs. Prefers cap and trade. Is calling for counties to raise the ambition of their climate pledges



A Pigovian tax is a levy on an environmental externality (damage) as an incentive to avert the costs (to society).

In a true market economy a Pigovian tax is the most efficient and effective way to correct a negative externality.





Carbon Dividend

(A smart 'revenue neutral' carbon tax)

- All money collected is returned to households
  (None goes to the politicians)
- Innovation & investment in low-carbon technologies stimulated by Adam Smith's invisible hand
- Simple and inexpensive to administer
- Scope for corruption greatly reduced
- Gradual, so predictable for business
- Can receive bipartisan political support

Having flogged for 21 years, the dead horse of legally binding emission targets, the UN should close that chapter and try something new.


The United Nations
Climate Change
Conference, COP21
will be held in a
Paris from Nov 30
to Dec 11, 2015