


The climate problem ...



and our  
grandkids' future

**Dr John Price**

## People of the future ... who's batting for them?



Grandkids will know what we did and didn't do  
what we might have done  
their grandkids will begin to see the enormity

## There's a problem with the climate

Scientists know quite a lot about it ...

The rest of us not nearly enough



Two problems ...  
Surveys - around 70% ... priority  
knowledge gap



Knowing and imagining;  
knowing and not knowing  
not knowing has consequences

- **It's big** ... how can a whole planet heat up?
- **It's hard to imagine** ... how could we do this?
- **It's slow** ... by human standards
- **It's sneaky** ... effects are way down the track
- **It's very long-lasting** ... thousands of years
- **It's urgent** ... can't fix it once it's obvious
- **It's expensive** ... spend now; reward later
- **It's offensive** ... to business, and some of our ideas

Tricky problem

Plenty of scientific leaders have been plain about what's needed, but no political leader

Turn it into economic/political problem.



Cultural conflict



How could puny humans mess up a whole planet?

First imaginative failure



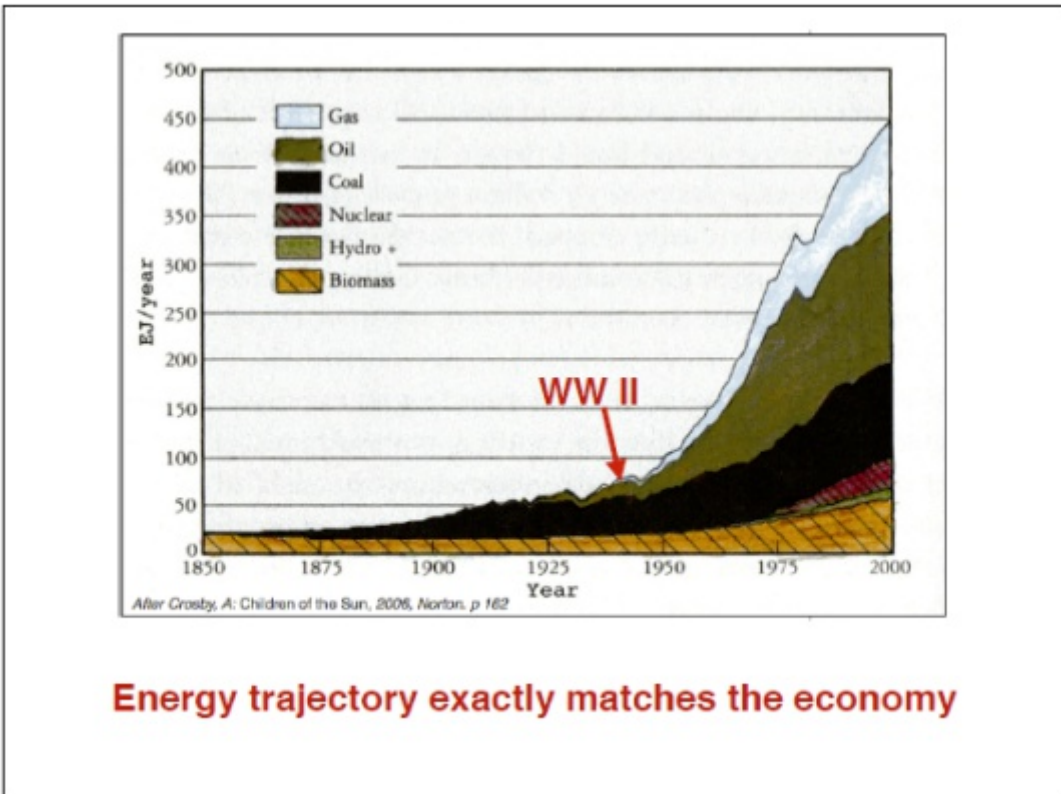
The energy economy was like this for 10,000 years, since we were all nomads

Confusion#1 ... humans dominate the biosphere. Dominance and the modern energy bonanza - a one-time, unique, finite episode whose extraordinary character is largely unknown



Then in no time  
it became  
like this

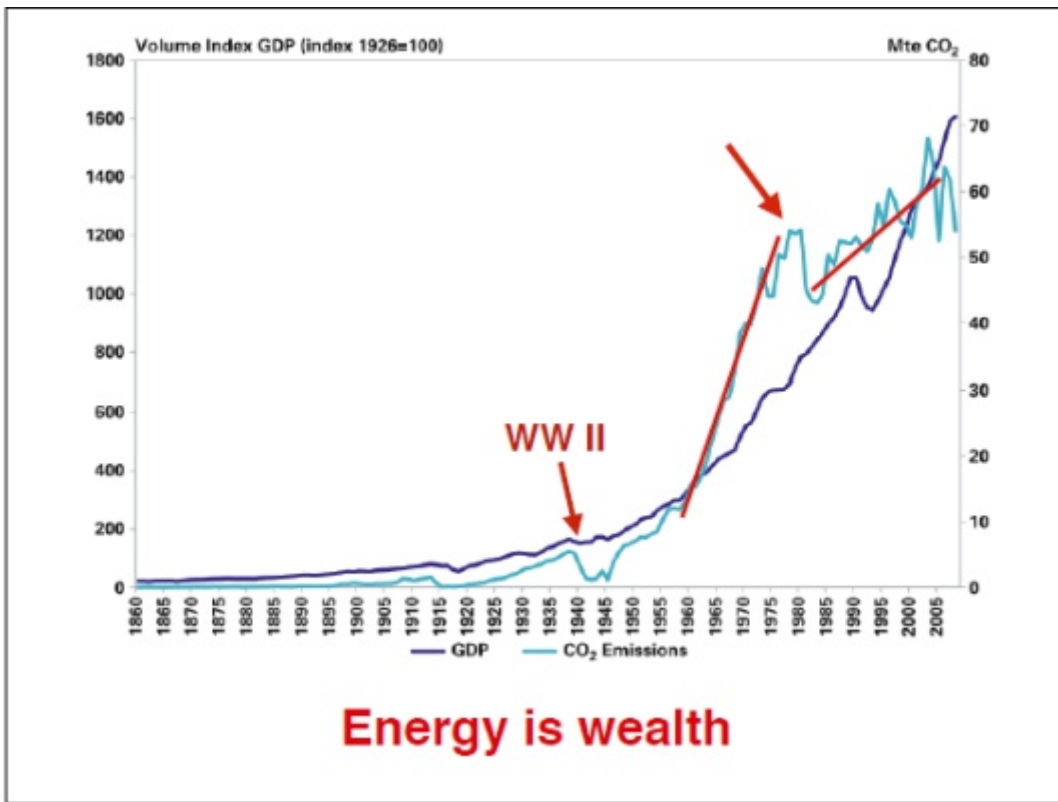
Sudden transformation of the energy economy



Energy trajectory exactly matches the economy

Mostly the last 60 years





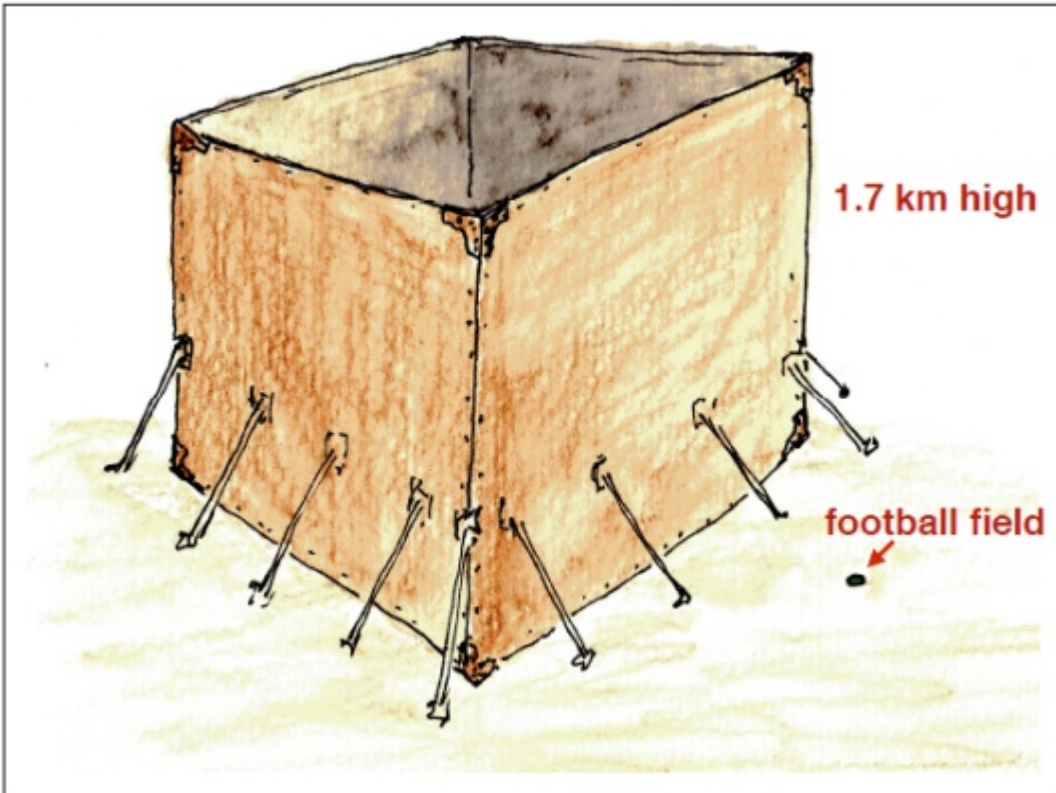
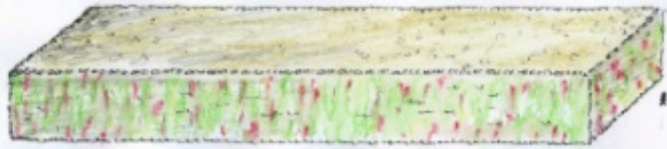
Energy is wealth



45m high  
1,000,000 tonnes CO<sub>2</sub>



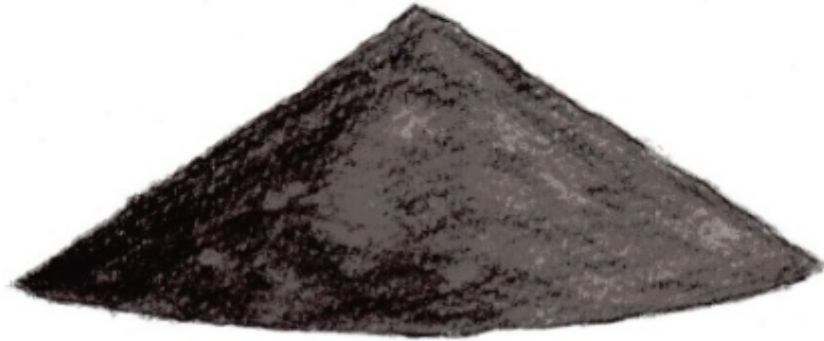
**Oil drums  
5 stories high**



Global oil for a year

**Coal mountain  
1.4 km high  
15 km around the base**

**one year**



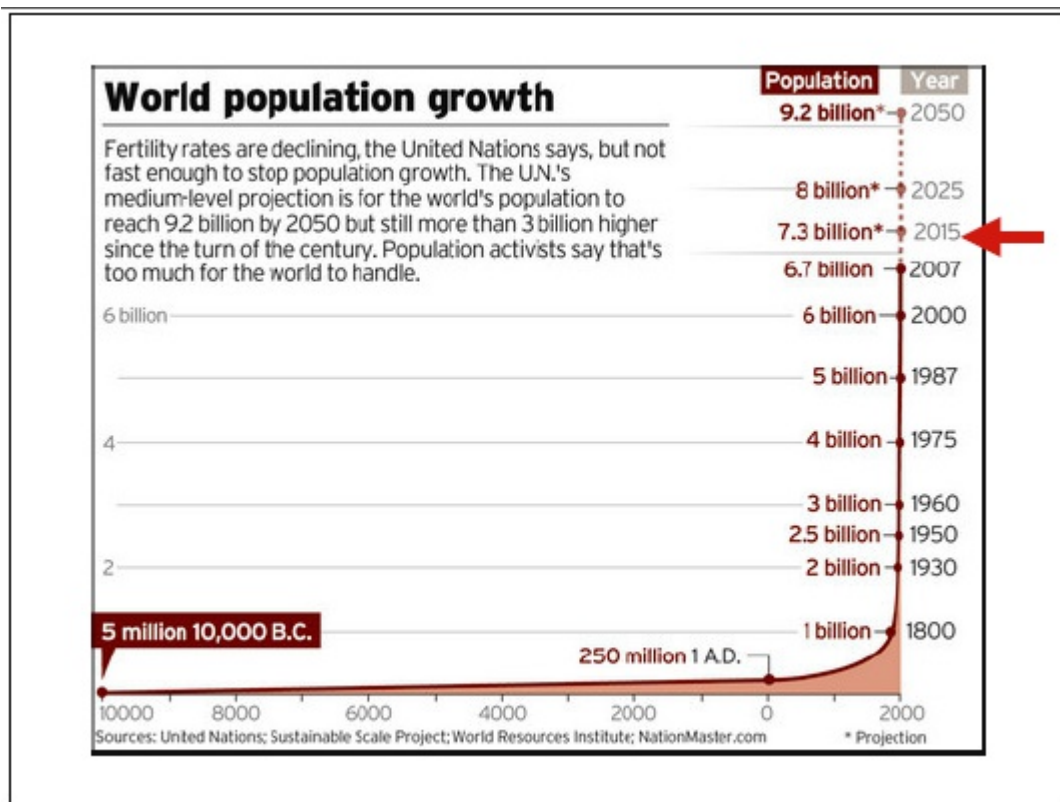
Coal for a year

**Gas  
3.3 trillion m<sup>3</sup>  
tank for a year  
15 km side**



Last year's gas

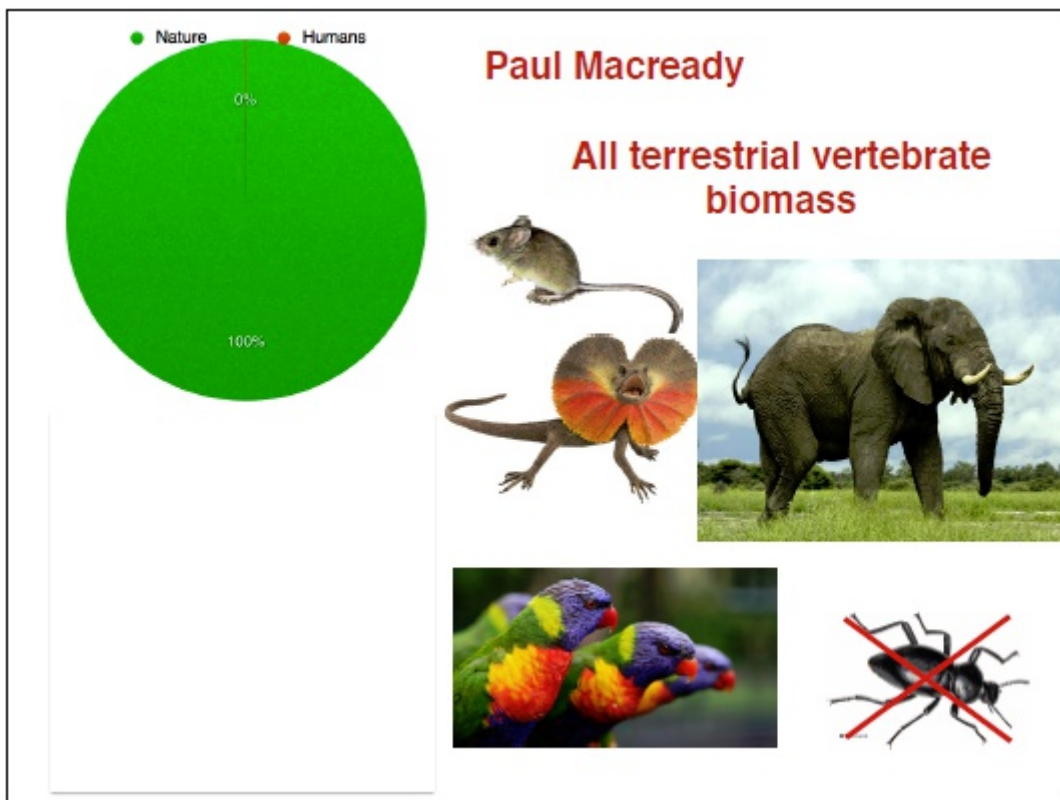




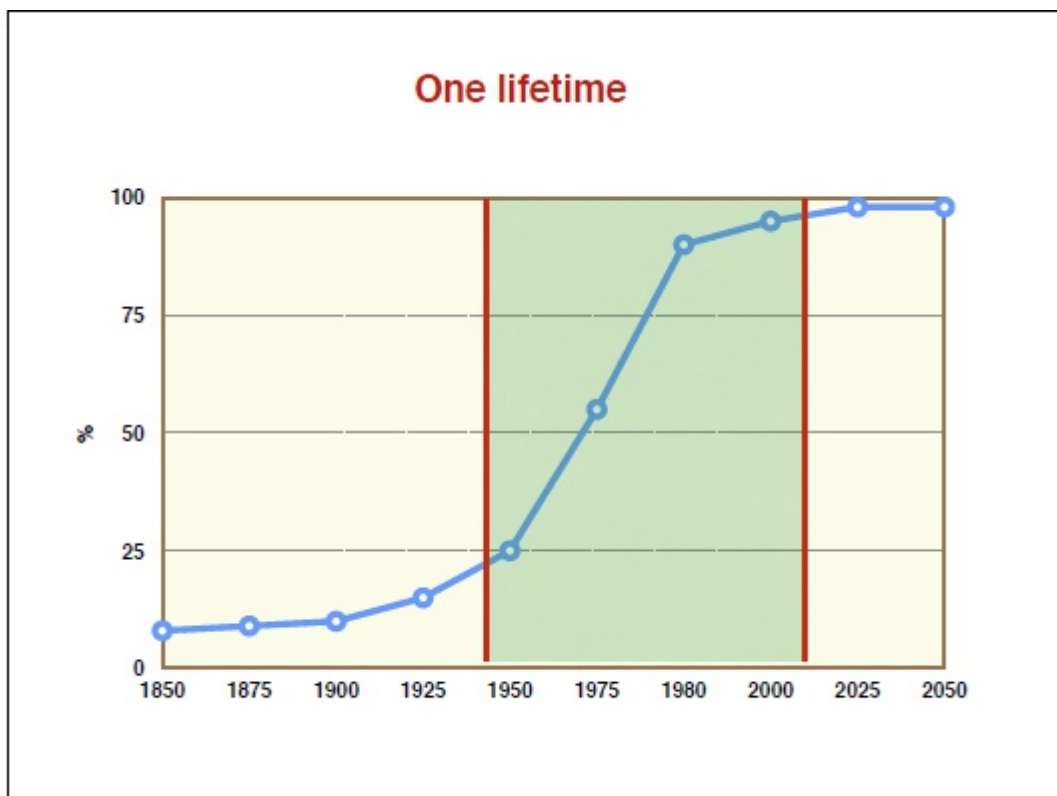
Biological/ecological success and its complex but necessary relation to economic success



3.5 years to add as many as lived in Jesus' time



Paul Macready & the 97%



One lifetime

one billion tonnes = 1 gigatonne = 1 Gt

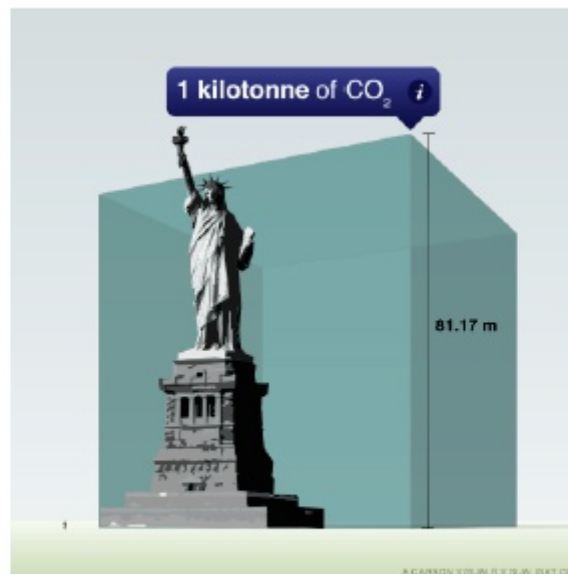
**38 Gt of CO<sub>2</sub>**

**from burning oil, gas & coal and making  
cement**

**43 Gt**

**counting land use, methane, CFCs, N<sub>2</sub>O, etc**

Fossil fuel energy means combustion ...  
Combustion means CO<sub>2</sub> ...  
CO<sub>2</sub> means warming



**A thousand tonnes of CO<sub>2</sub>**

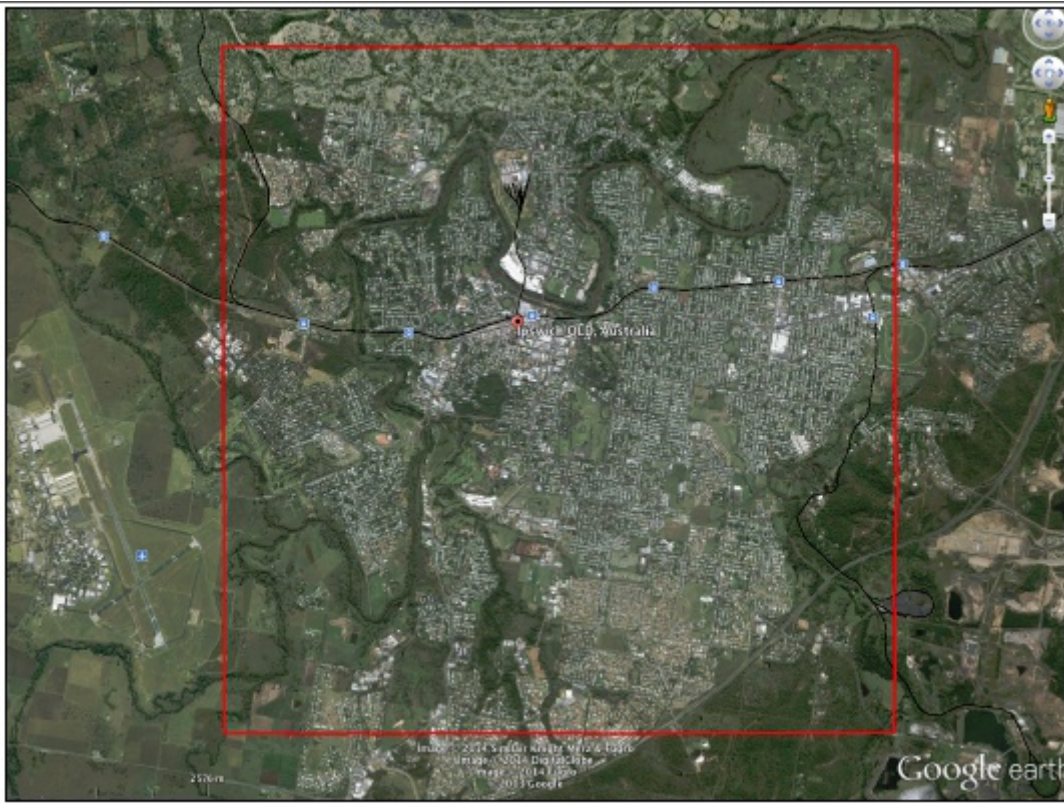


**A million tonnes of CO<sub>2</sub>**



**Mt Everest ... summit 8.8 km above sea-level**

Gigatonne box 8km high



8 km at the base



A gigatonne into the air every 8.5 days



Maurice Newman, chief business advisor to the government  
- an instructive instance of ignorance & prejudice and its consequences

**Scientists are still arguing**





**CO<sub>2</sub> doesn't cause warming**



**Warming has stopped**



**Study of climate history  
refutes the theory**





**It's all about models ...  
and models are wrong**



**The maverick scientist  
gets it right**



**Mr Newman gives Emma  
a science lesson**





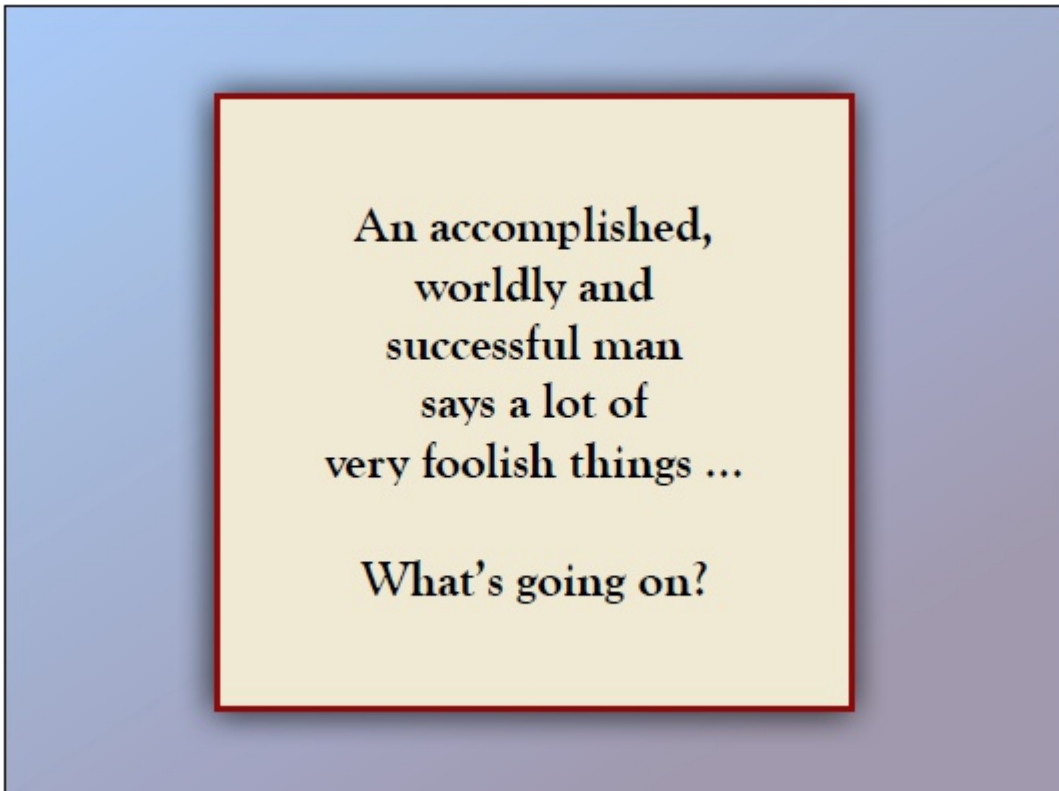
**It's the Sun**



## **Evidence ...**

**but which evidence?  
or who's evidence?**

**your favourite evidence?**



It's not that Mr Newman is a fool; on the contrary, what makes the vignette interesting is just that a very capable man can say such silly things.  
What can we learn from this?





Cook 2013 ... “global climate change”; “global warming”; 1991-2011; nearly 12,000  
 Oreskes 2004 ... 928 “climate change” 1993-2003



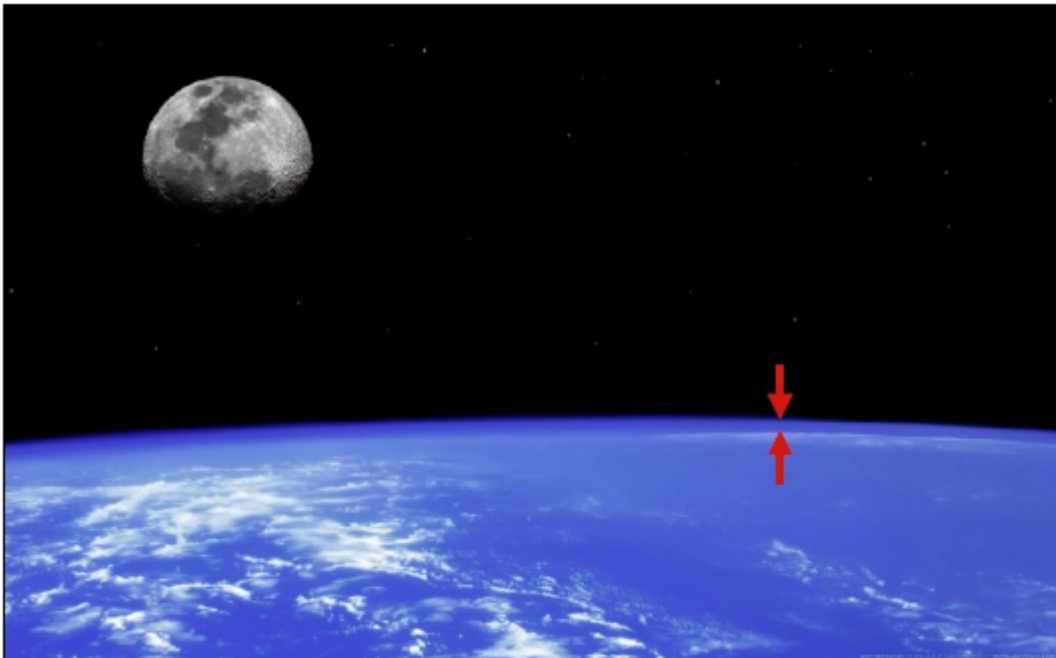
Newman makes it sound as if greenhouse theory was thought up a few years ago when the climate problem arose. It is a mature theory, as secure as the germ theory of disease.



## The atmosphere

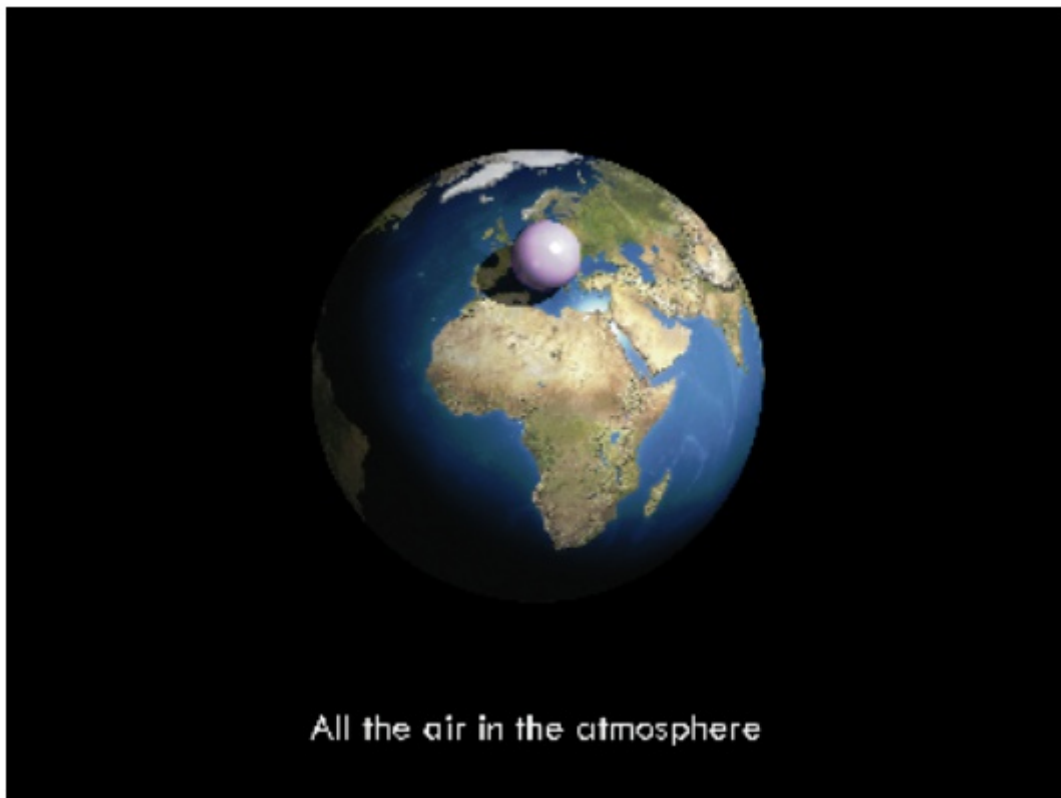


Atmosphere looks big from below ...

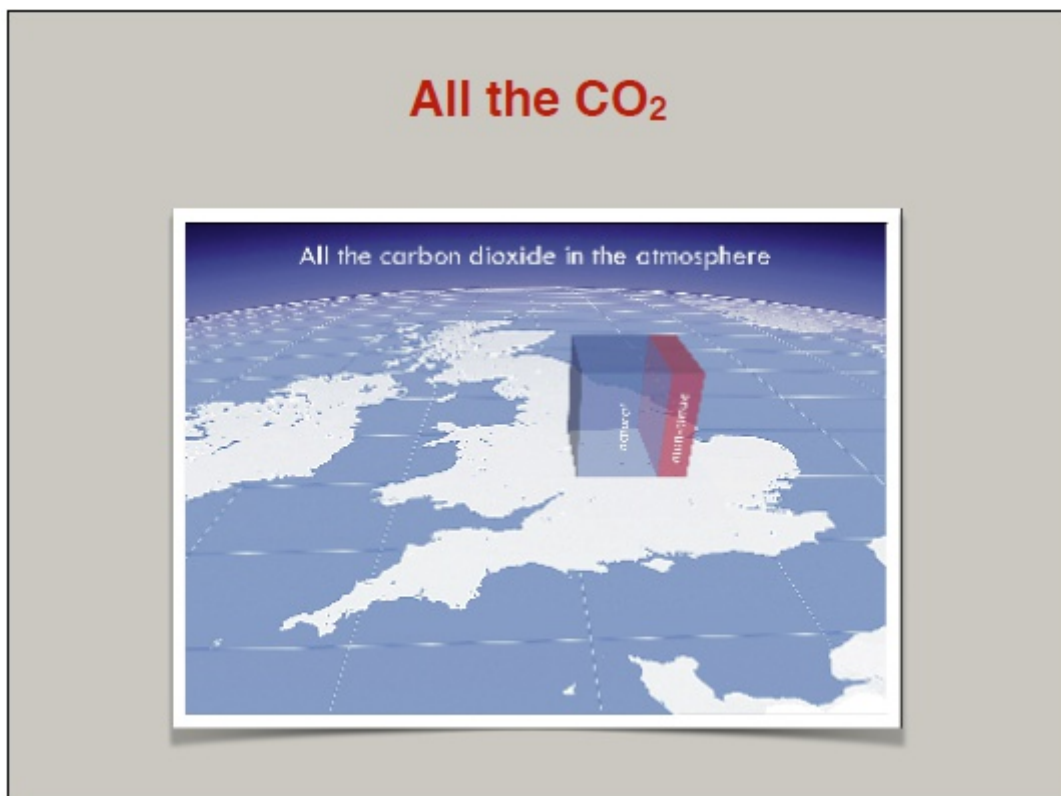


**The atmosphere**

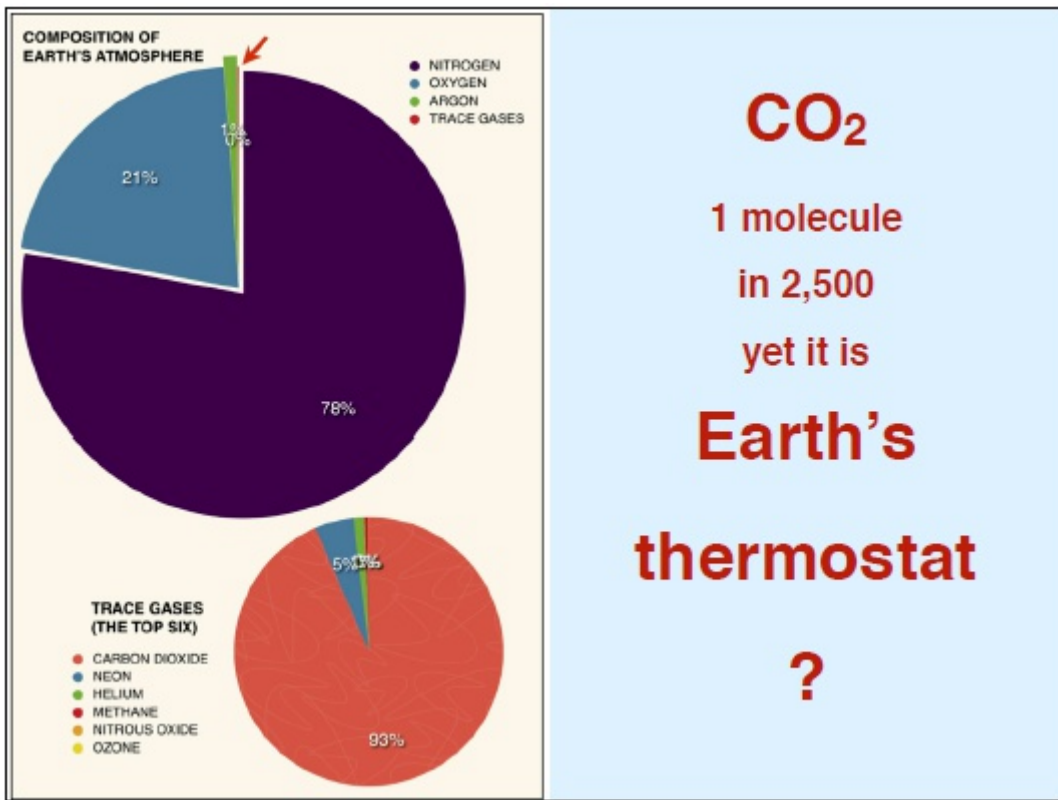
... but small from above  
Like an ocean  
thickness of a coat of varnish on a classroom globe



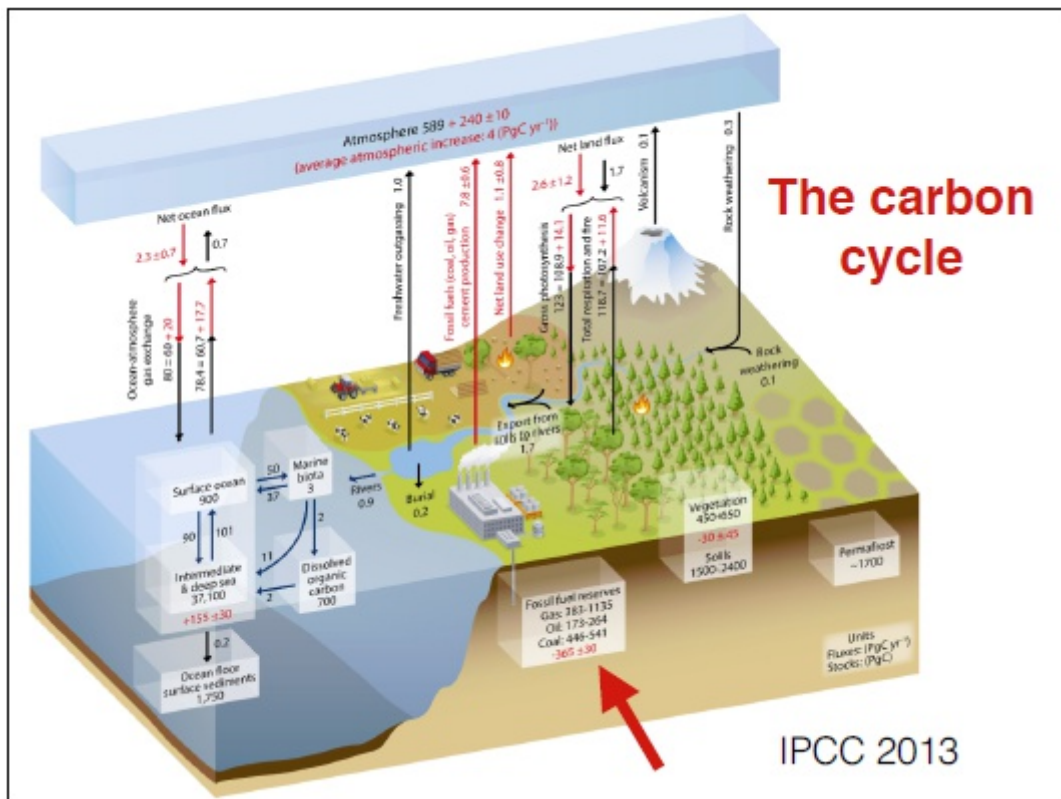
Half is below 5.5km ... 99% below 32km



Pre-industrial CO<sub>2</sub> in the blue box; retained anthropogenic part in the red.  
Another red box since sequestered in ocean and biosphere.



This is not controversial  
water vapour not there  
long-lived gases



Balance - the carbon cycles

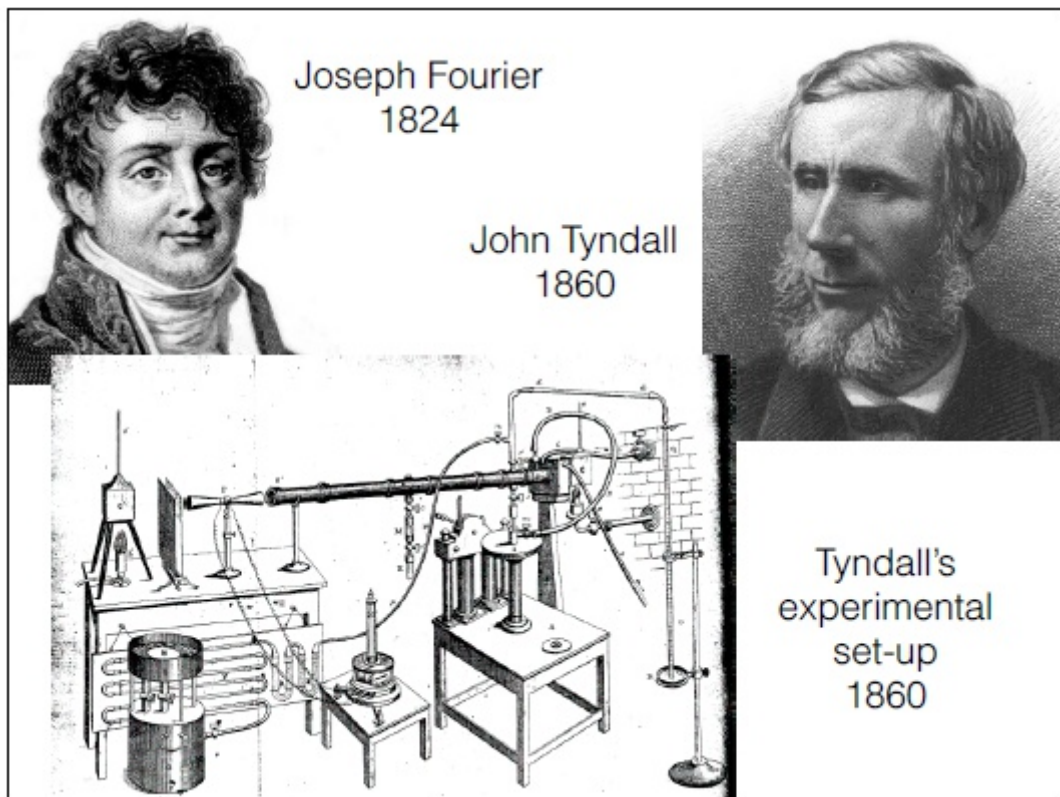
Fossil reservoir. If we had released this quantity over 10,000 years (the period of post-glacial warming) instead of 100, the system would have been much closer to equilibrium

In the time of James Watt,  
the atmosphere held  
**589 Gt** of carbon.

Since then, we added  
**240 Gt** more.


It stays there a very long time.

Large perturbation to the atmospheric reservoir in short time



Understanding of the greenhouse effect has been developing a long time





# CO<sub>2</sub> & water vapour

+

## methane


## nitrous oxide

## ozone

## CFCs


## etc

Arrhenius  
1896




**Greenhouse gases make Earth different**

Arrhenius 1896 understood water vapour feedback, the primary role of CO<sub>2</sub> as climate regulator, and a number of key geophysical consequences of enhancing the effect - all before they were observed.




CO<sub>2</sub> and the water vapour feedback



CO<sub>2</sub> and the oceans

Gilbert Plass

Hans Suess



CO<sub>2</sub> and the climate past

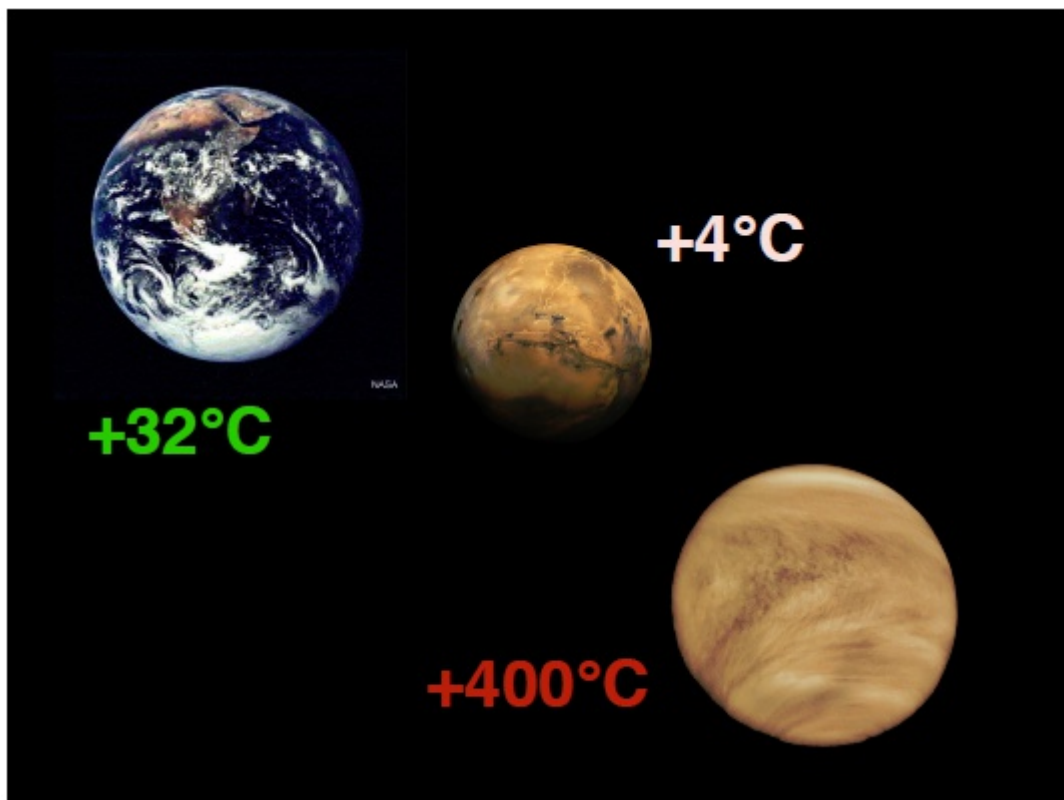
Measuring man-made CO<sub>2</sub>

Roger Revelle

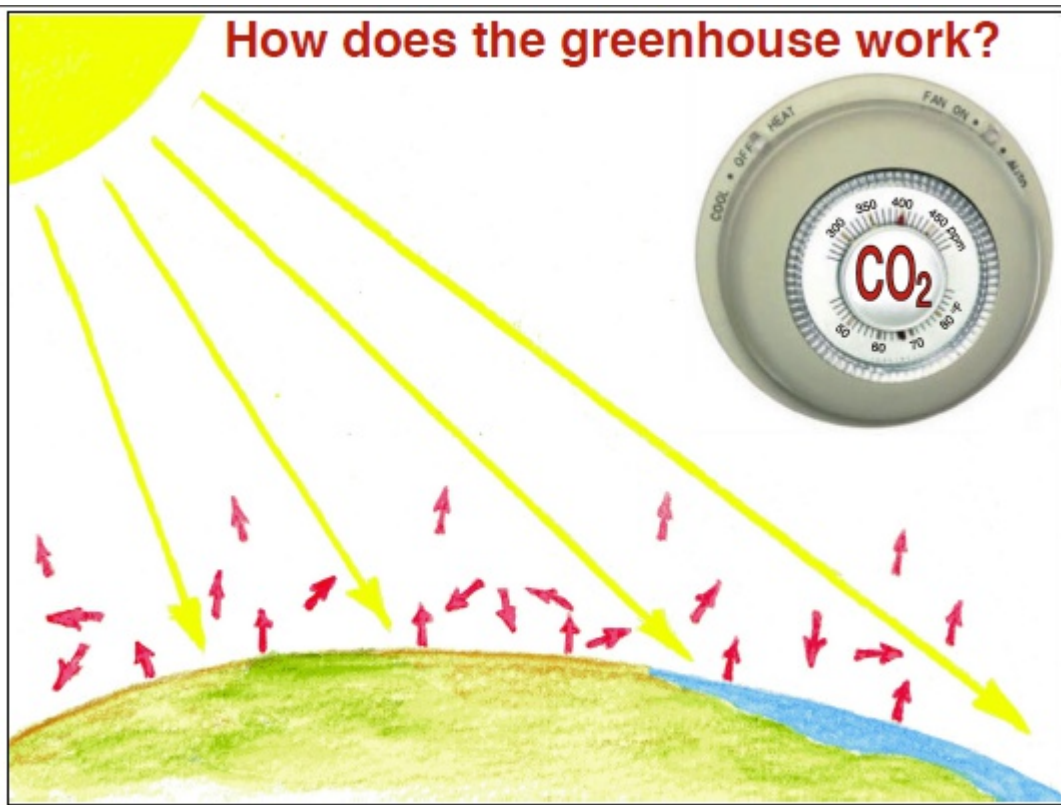
Post-war research pinned down nearly all remaining details



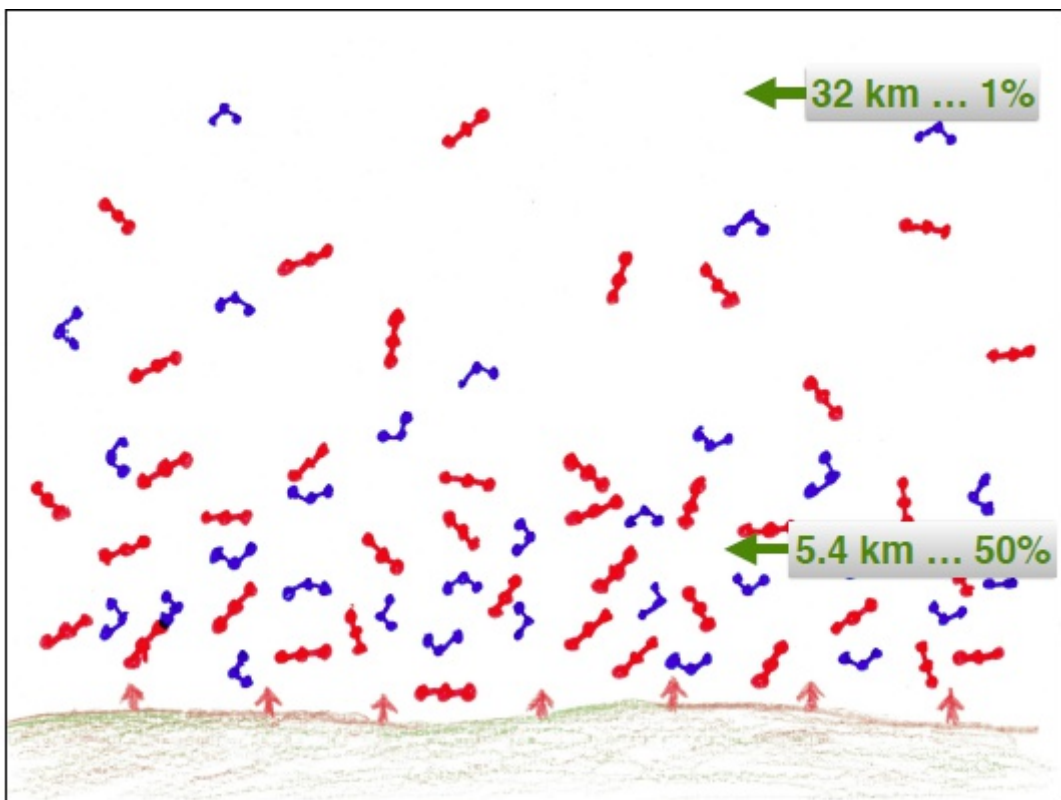
No climate on the Moon and no greenhouse.  
Hence diurnal extremes



Not just on Earth  
carbon cycle makes Earth different



Photons

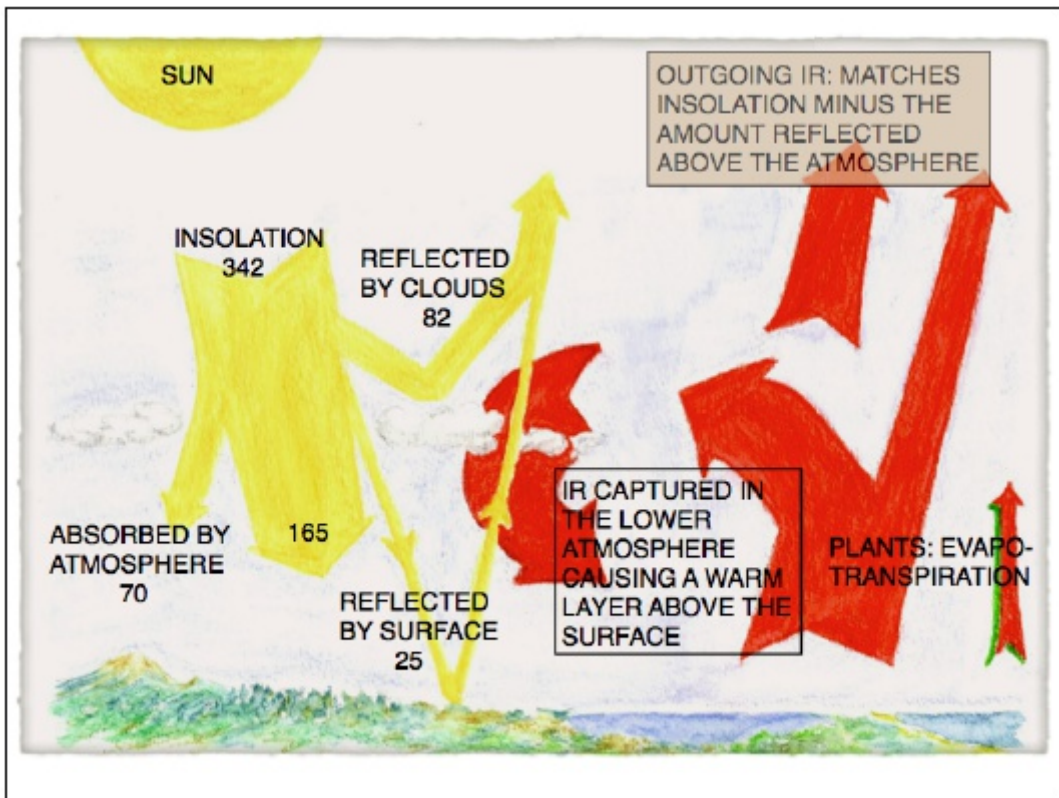


Greenhouse gas molecules

Q: desert

Martian - Earth radiates from the top of atmosphere



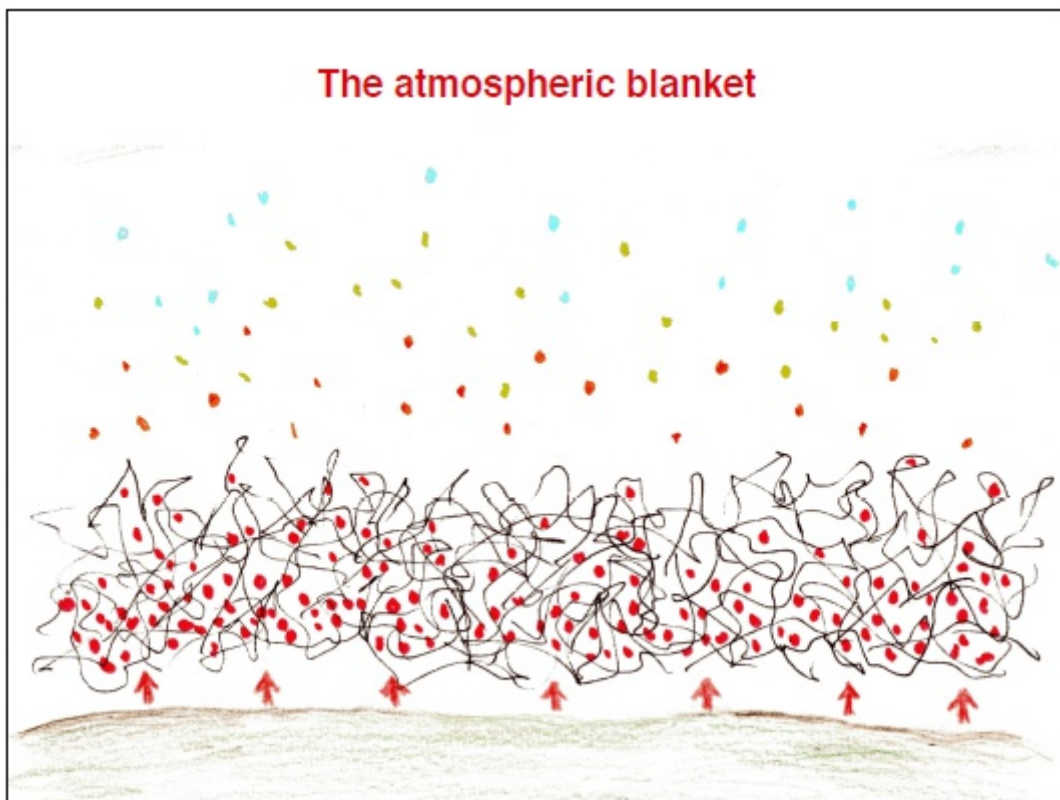


As a diagram, greenhouse warming is represented as a “circulation” of infrared (I-R) photons in the lower troposphere, causing the net back-radiation that warms the surface

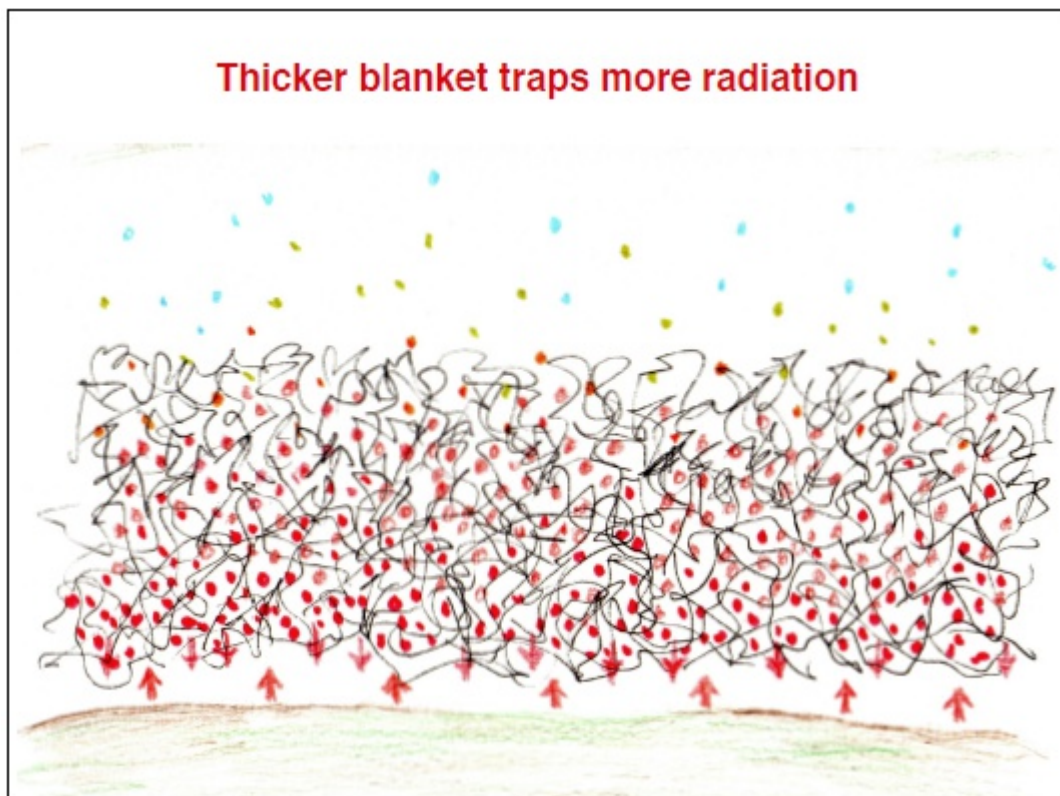


I-R photograph is like seeing the greenhouse working

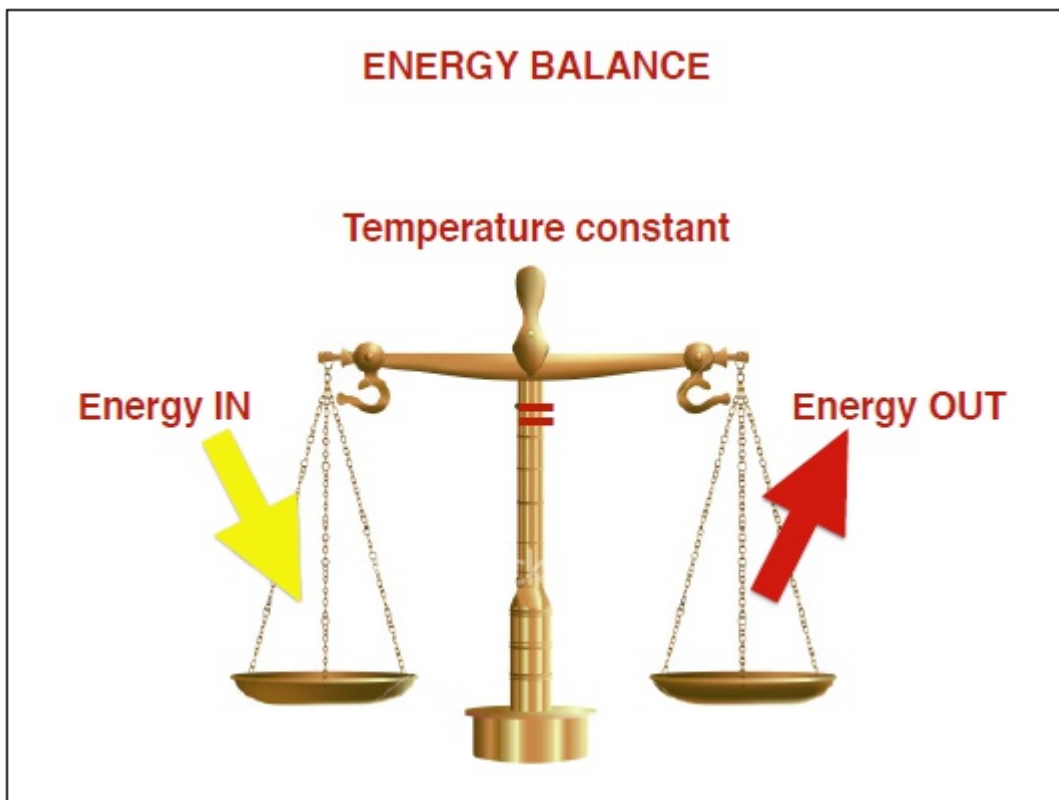




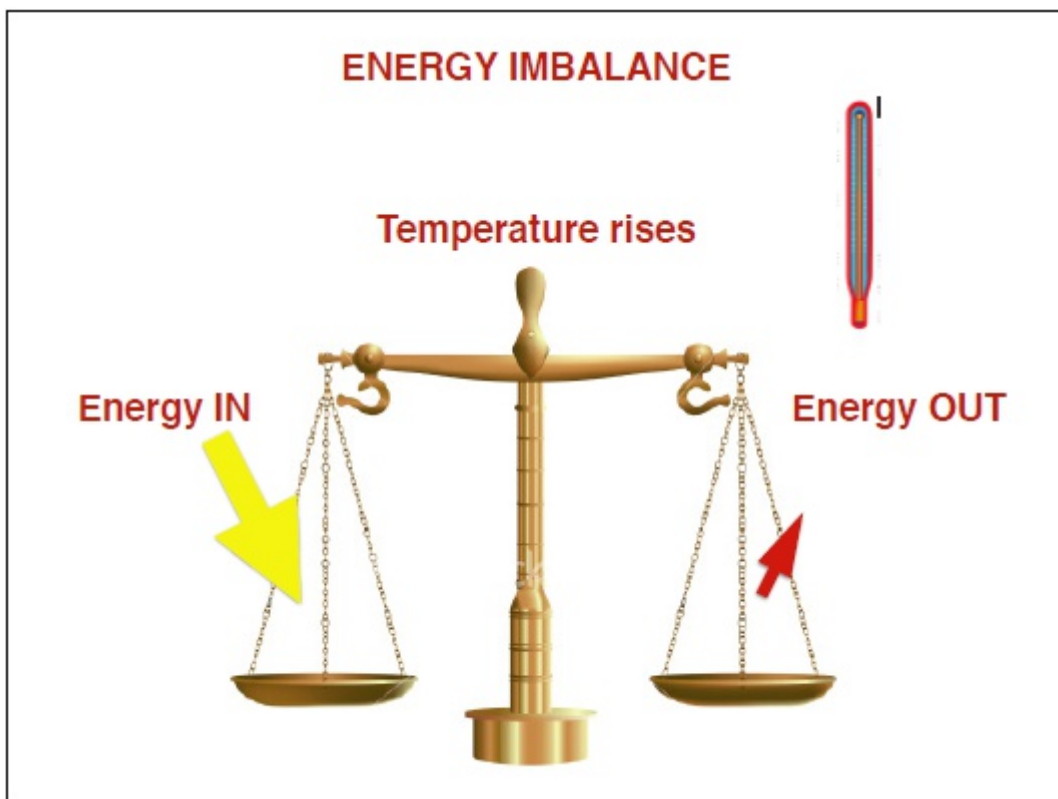
Why does a second blanket make you warmer?



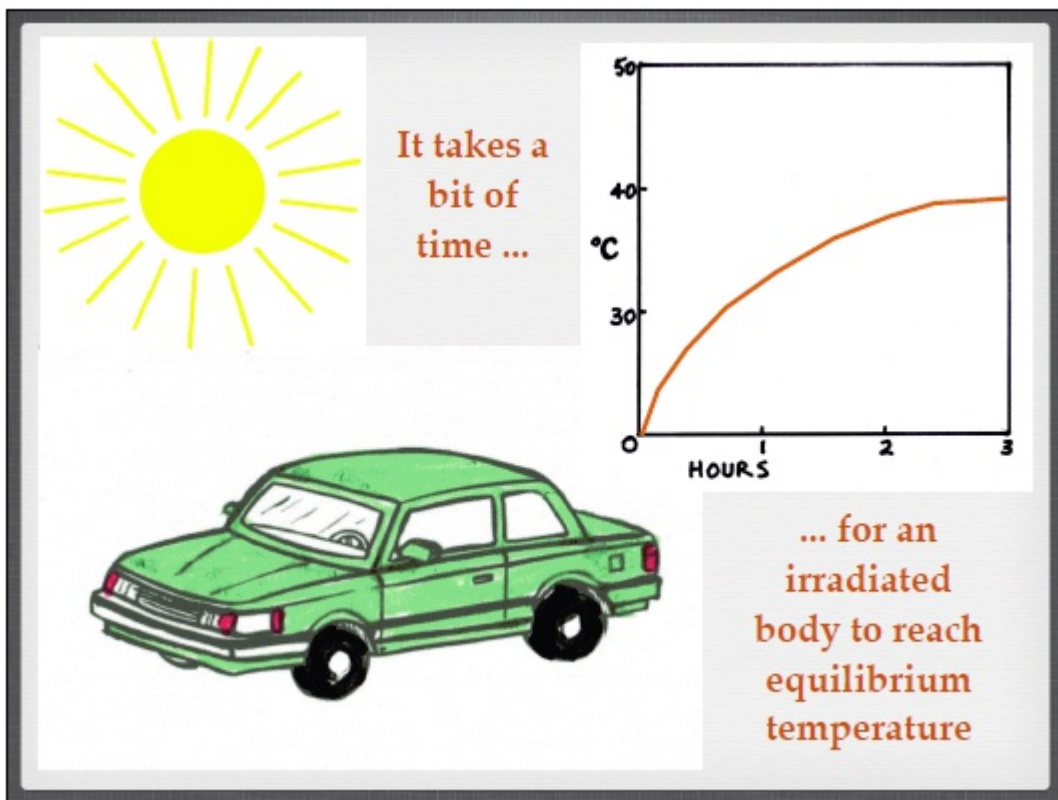
Increasing the population of energised molecules increases back-radiation



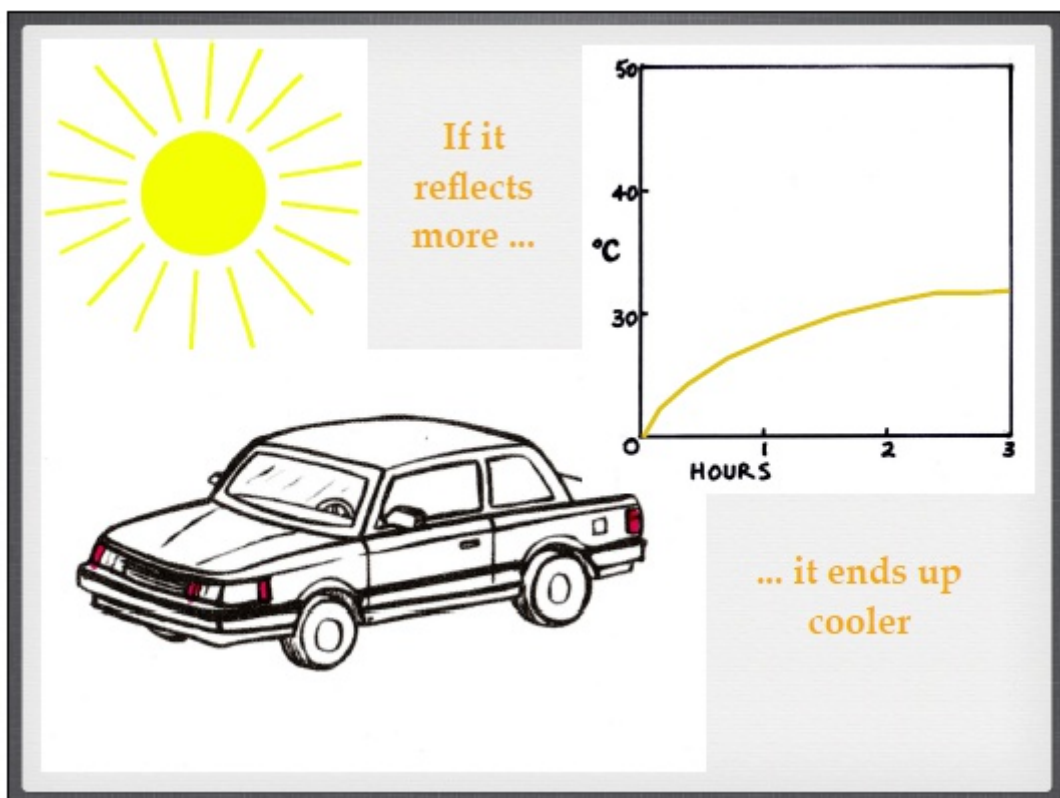
An irradiated body at thermal equilibrium



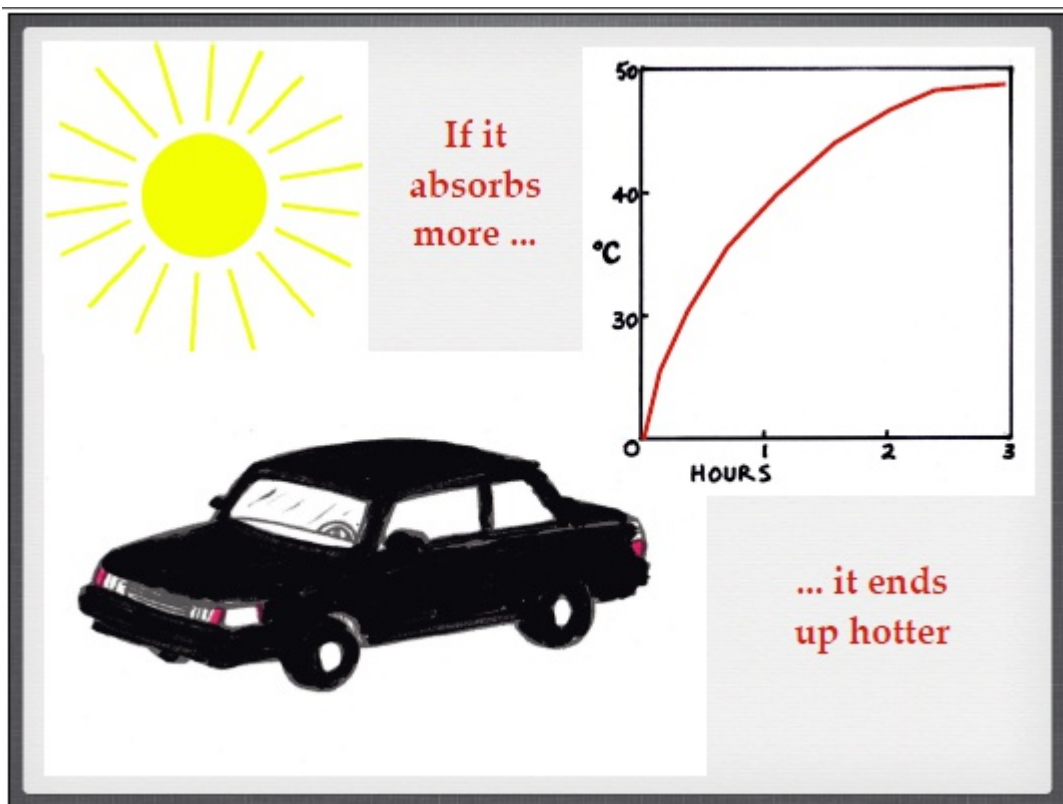
Diminish energy outflow, and:  
temperature must rise;  
out-going radiation begins to increase ...  
until new equilibrium at higher temperature



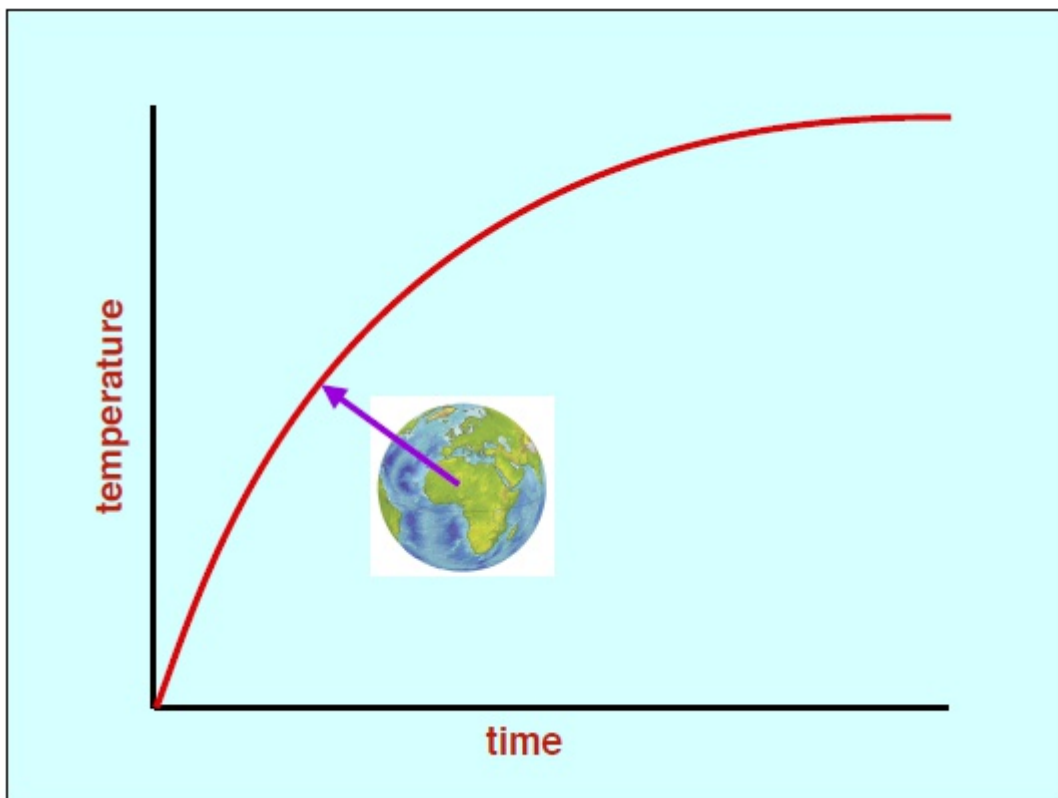
Positive energy balance  
 In Earth's case, the time lag is measured in centuries



higher albedo = lower equilibrium temp



As things warm up they approach a balance, when the temperature stays the same  
 This is some of the puzzle, but not all ...  
 Venus is a white shiny planet, but very hot ...



Earth, too is somewhere on a graph like this  
 We don't know the numbers ...



## Earth's calorie problem



Gaining energy at  $8 \times 10^{21}$  Joules a year

or

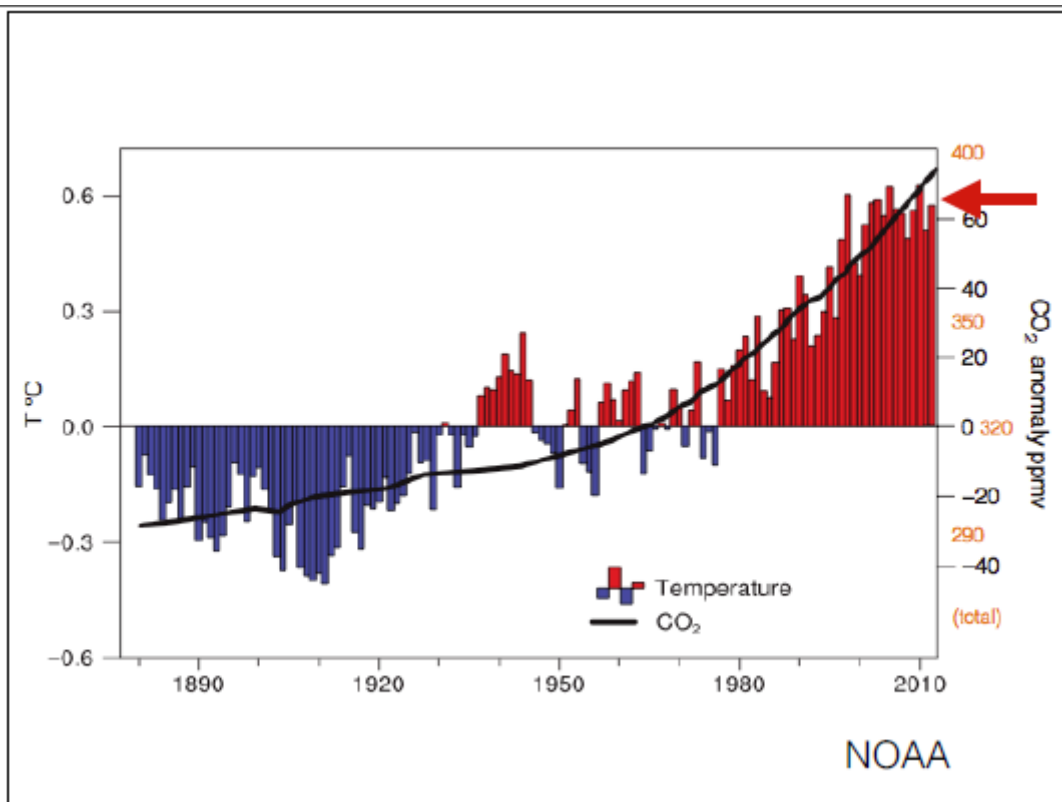
**400,000 Hiroshima bombs a day**

Defined this way, the remedy is like obesity ...  
Not brief campaigns, but sustained behaviour change

**Warming hasn't  
stopped ...**

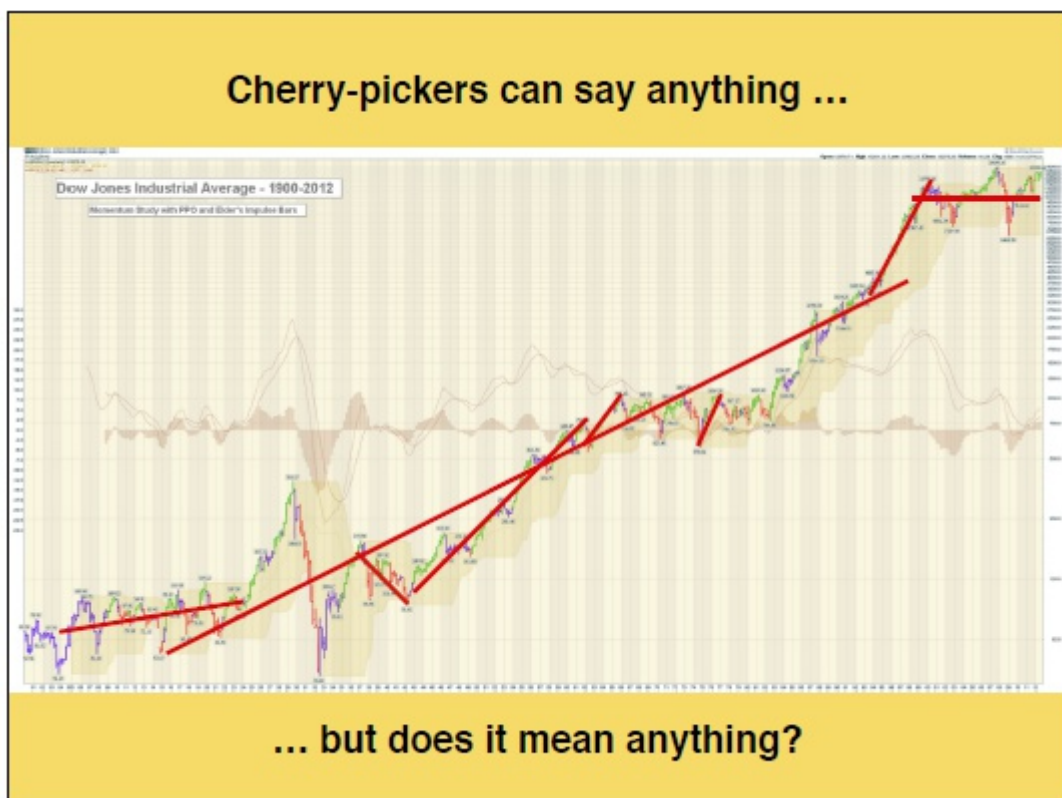
**it's slowed down**

This a common theme of deniers, due either to ignorance or deception

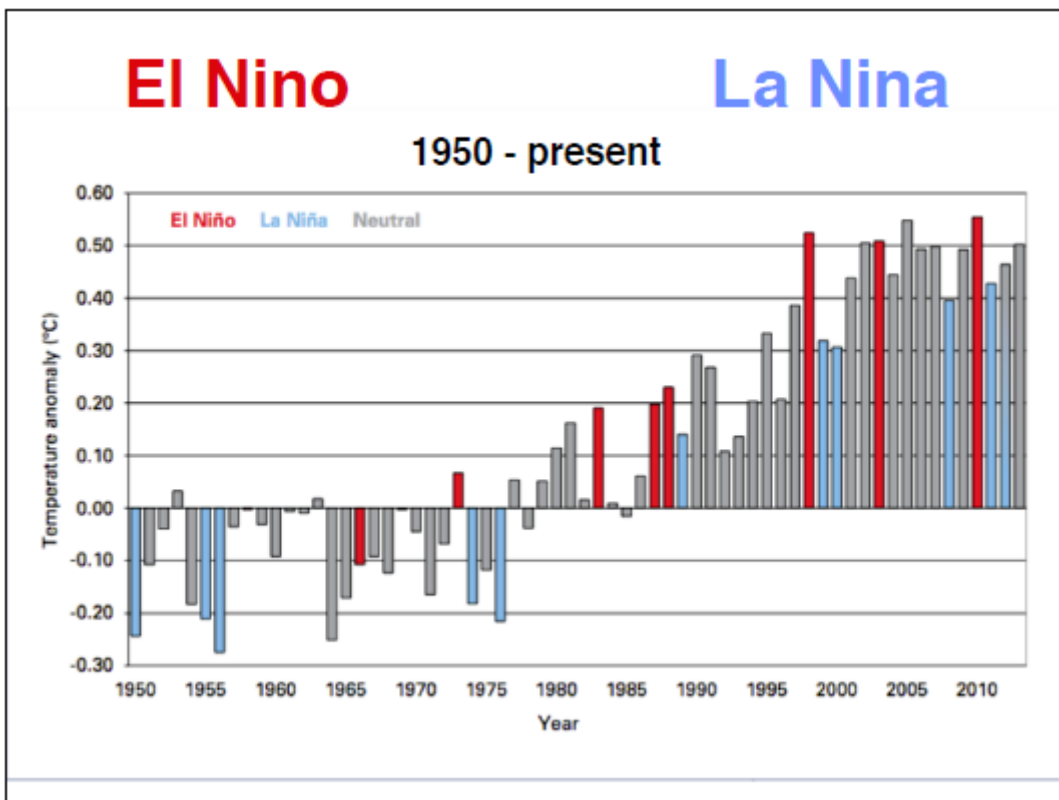


Anomalies.

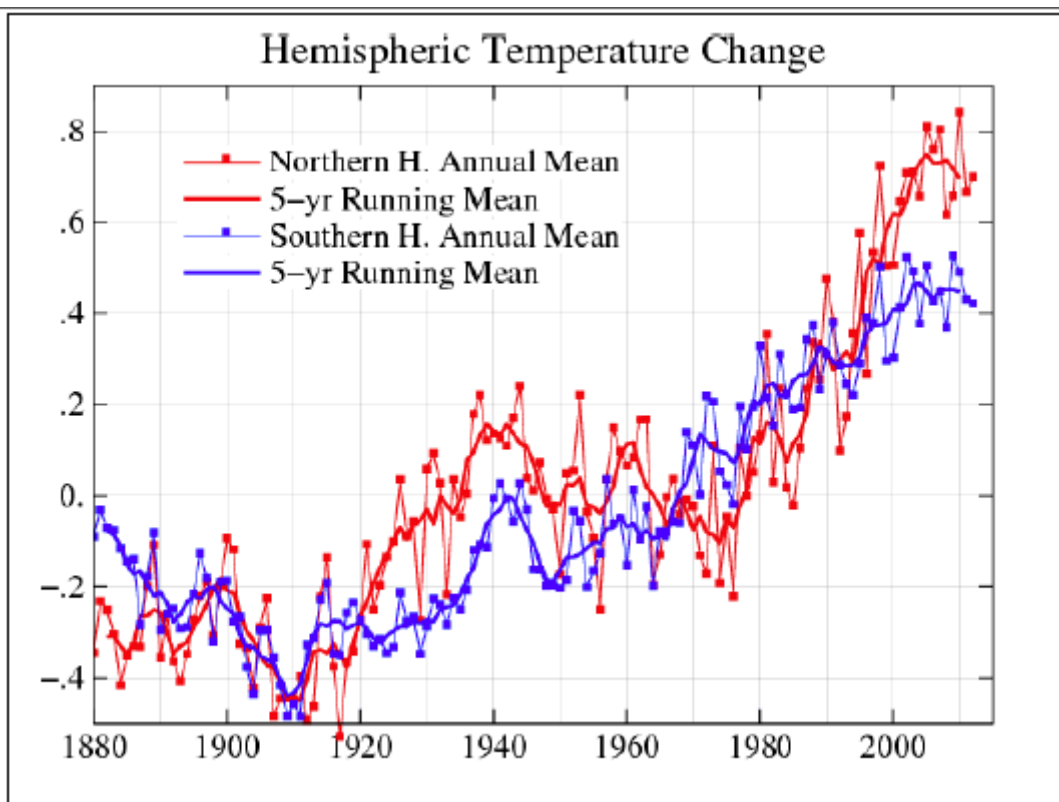
You can't just stick a trend line on a graph like this and claim it means something  
no year cooler than 20C mean for 35 years



Meaning depends on the actual behaviour of the system represented.  
An infinite number of trends can be superimposed on this data

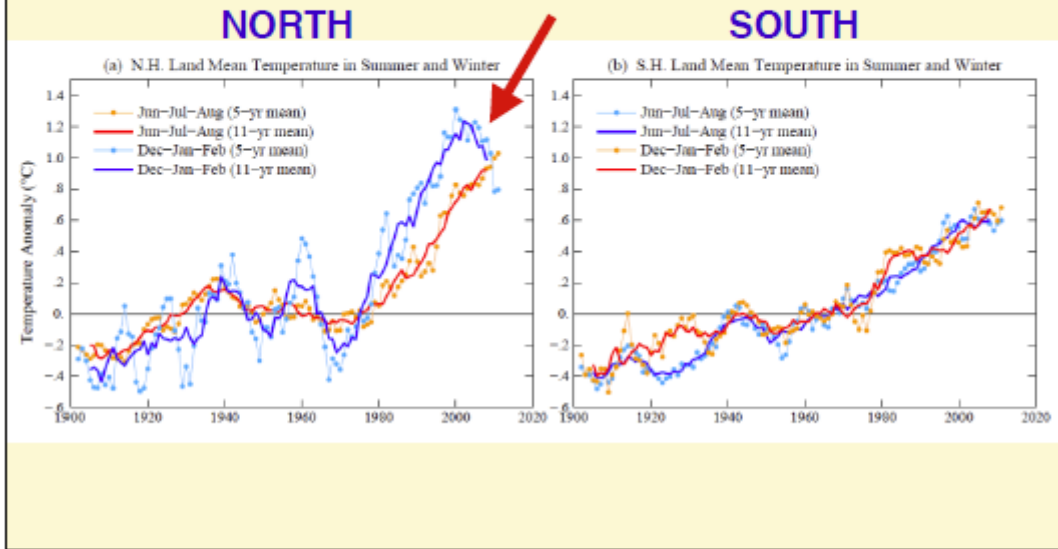


Clue# 1 ... distribution of extremes of this cycle will affect the shape of the graph

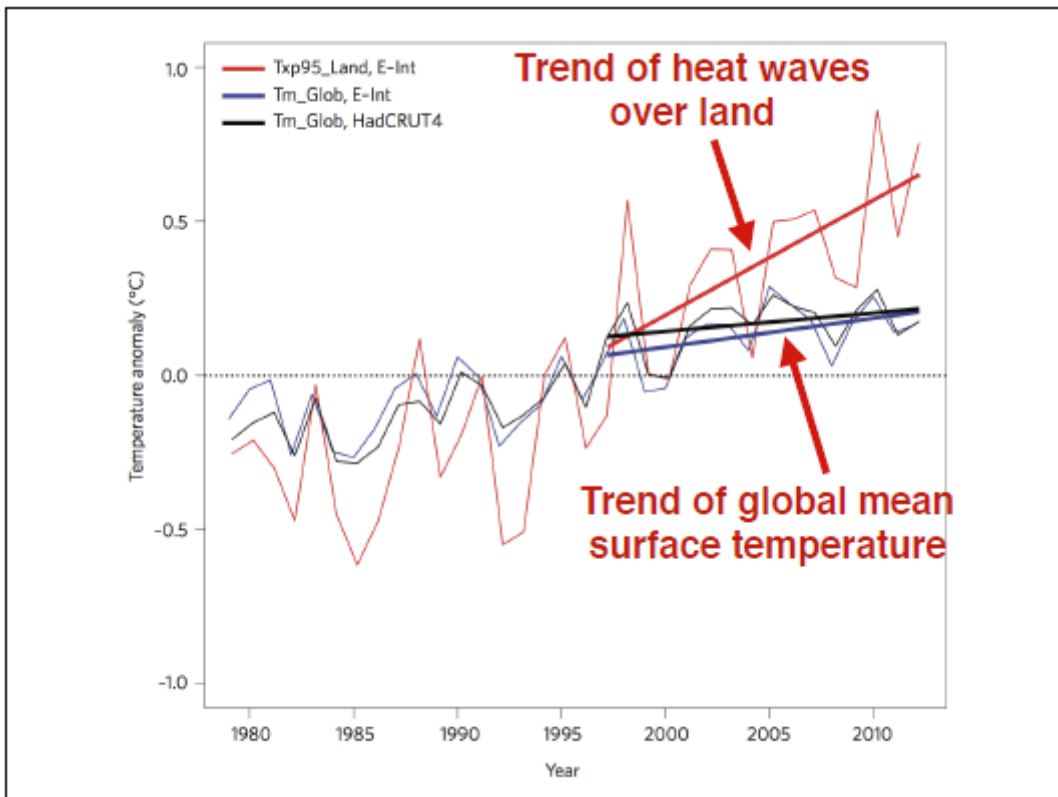


Twice as much land in NH  
Lots of natural variability  
mid-century pause

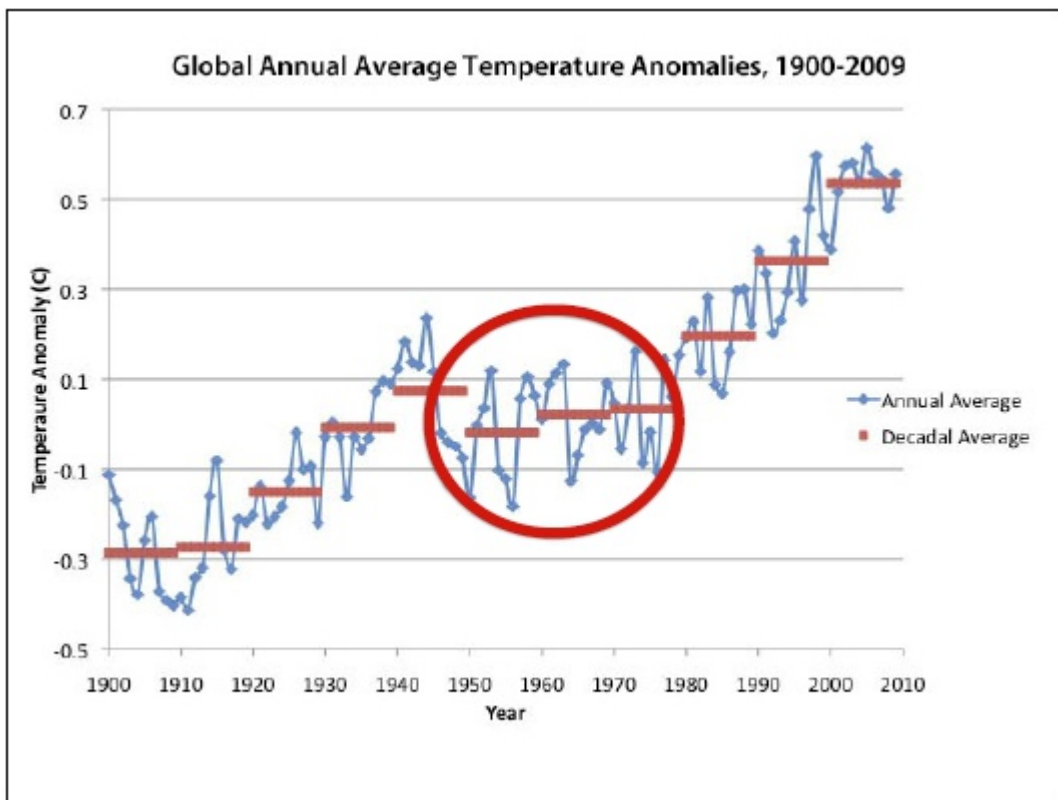
# Summer (orange) & winter (blue) in both hemispheres



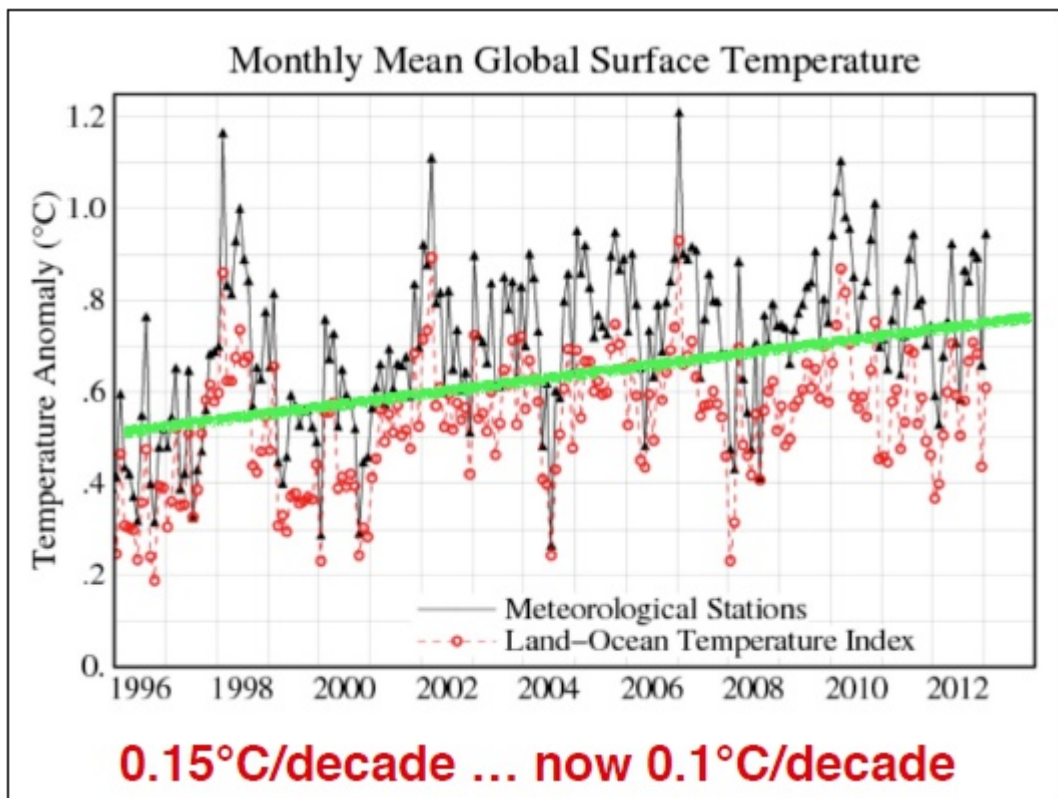
Anomalous NH winter trend ... ? cause



Unchanged trend of heat extremes over land



Unchanged decadal trend  
 Thirteen of the 14 hottest years on record have occurred since 2001  
 decades are not long enough



Plot of monthly means reveals the actual trend



## **But wait!**

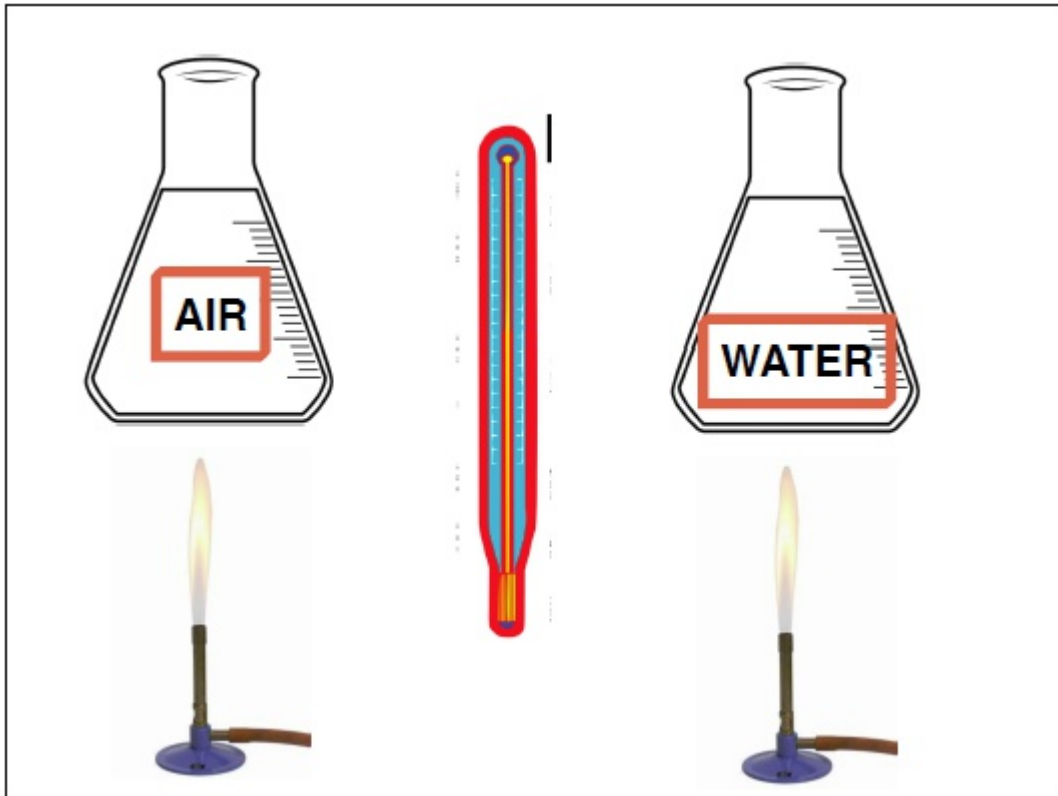
If 400,000 bombs  
is added to the  
energy budget daily,  
it must get hotter.

**So where's the heat?**

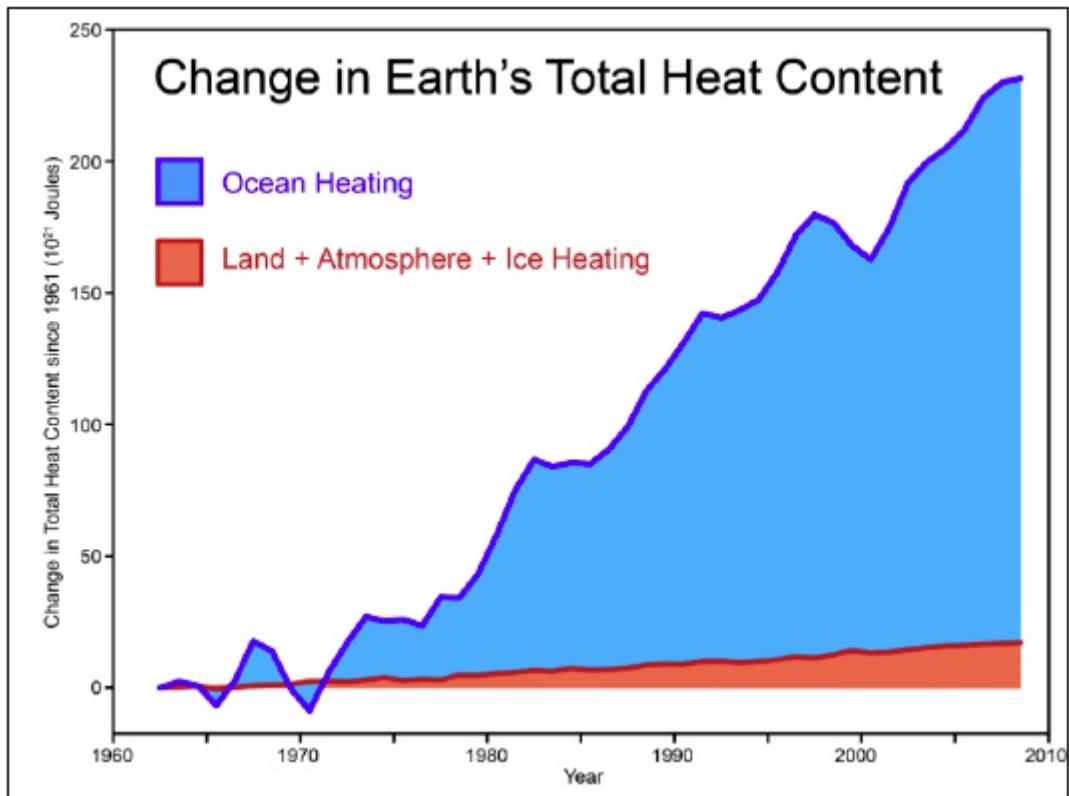
Puzzle is: if the heat isn't going into the air at the former rate, where is it going?

- Clouds?
- Aerosols?
- Volcanoes?
- The Sun?
- Wrong theory?
- Bad measurements?

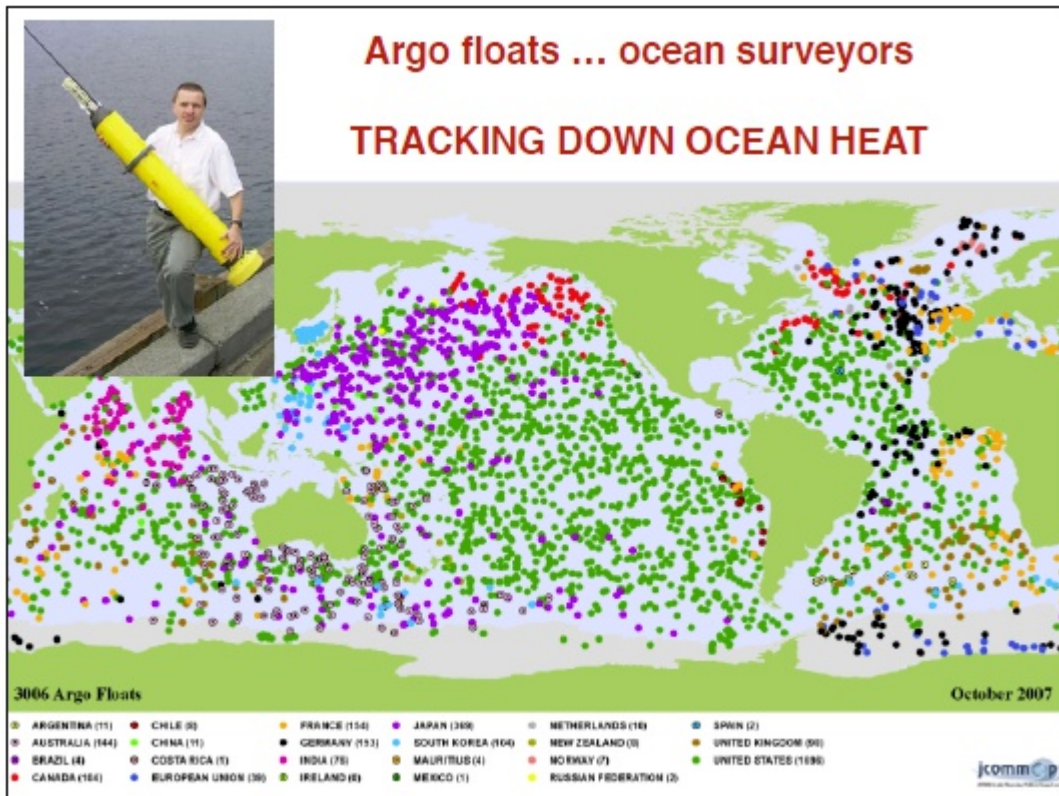
All suggestions tested and refuted



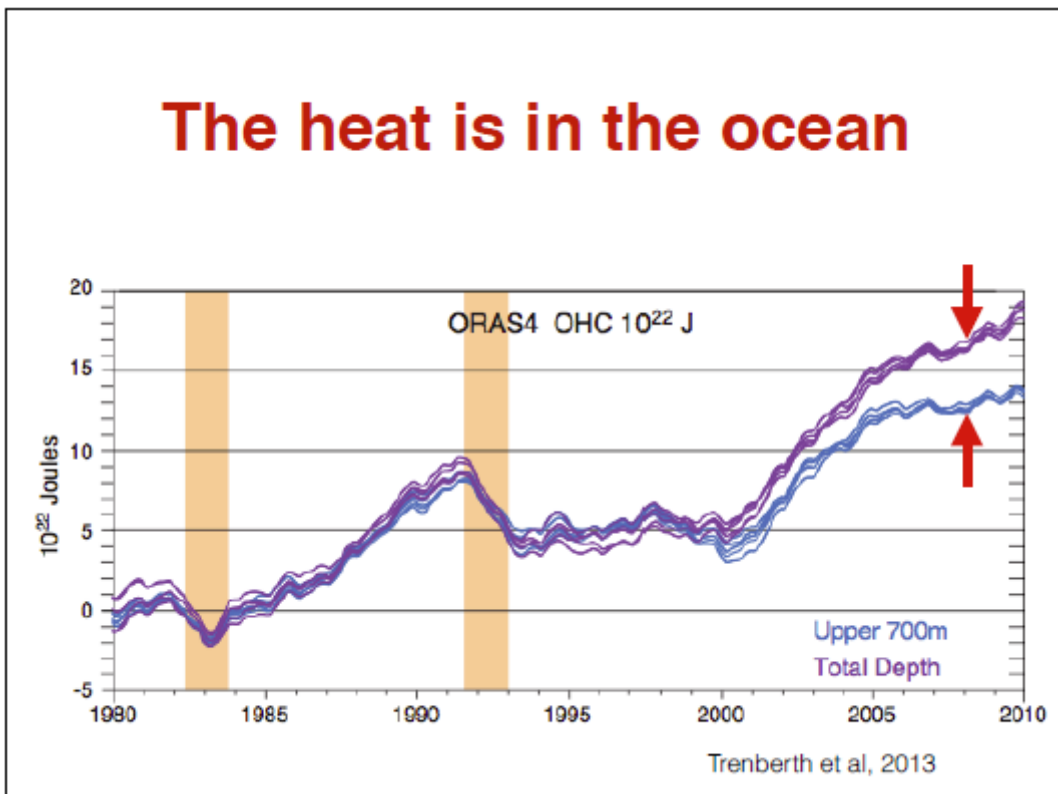
Heat capacity of water is 3,000 times that of air



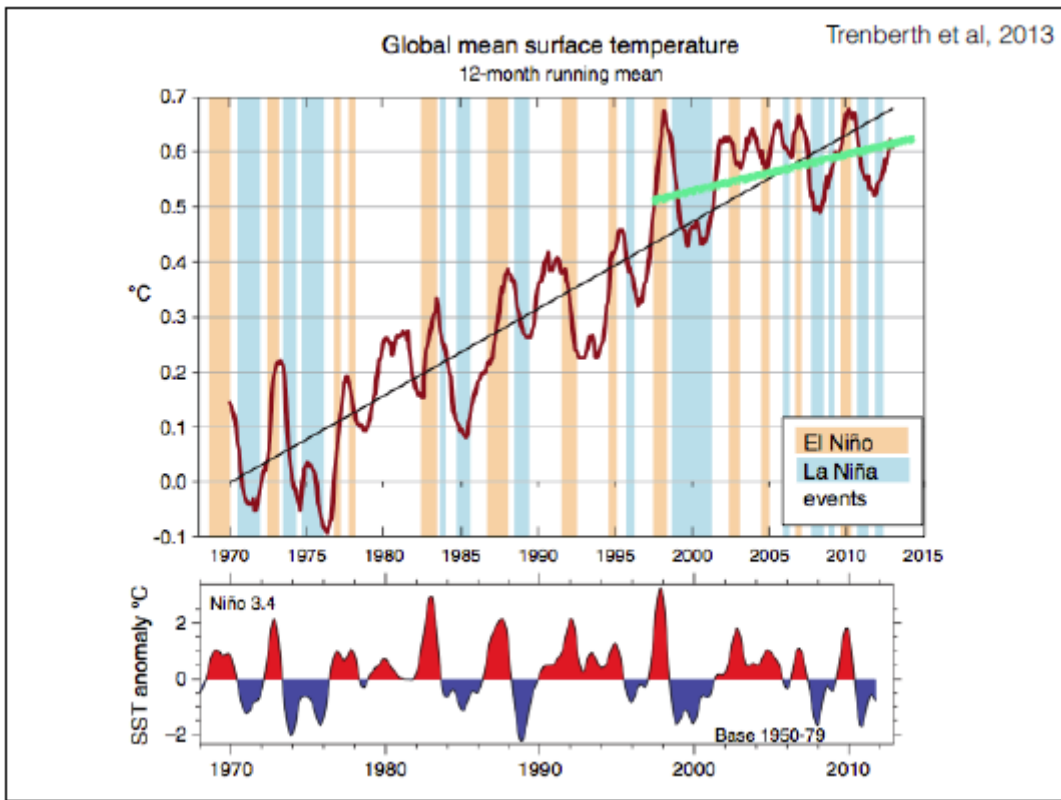
Ocean is Earth's great heat reservoir ... about 93% of all the added energy goes there  
 surface exchanges with air  
 deep sequester



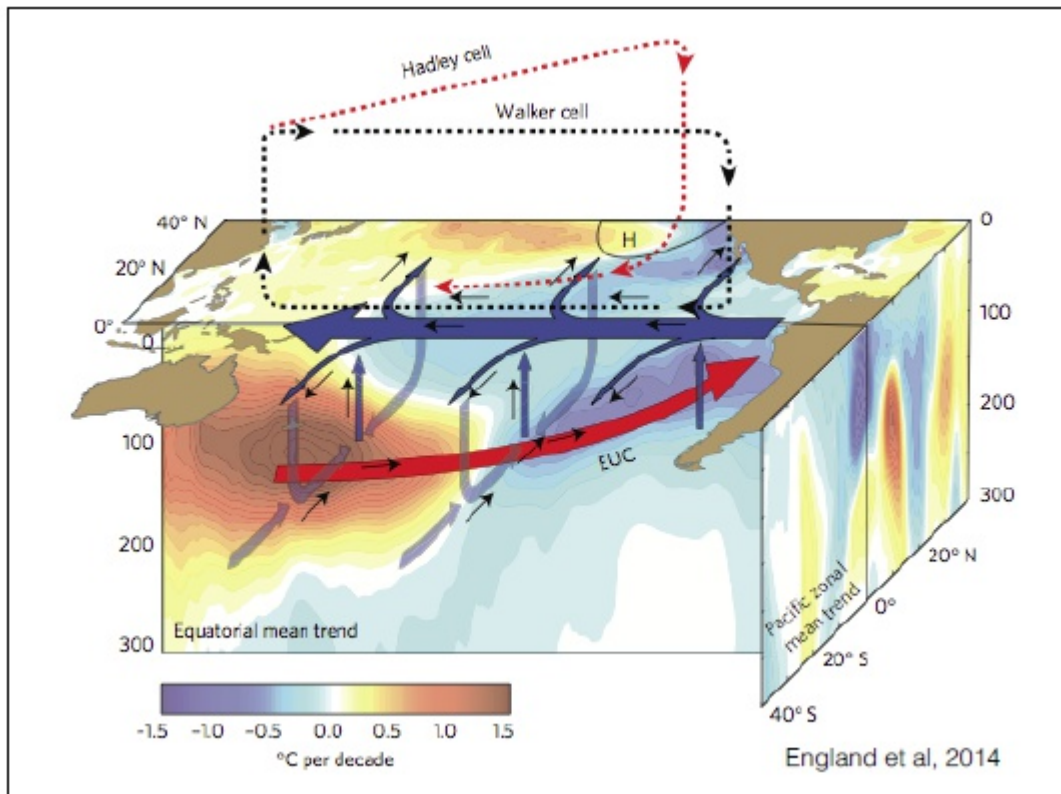
Investigating ocean heat content with Argo floats over the last decade or two



Heat entering the deep ocean cannot warm the air ...  
 but sooner or later it will surface and then redistribute  
 This is our best record of the energy imbalance

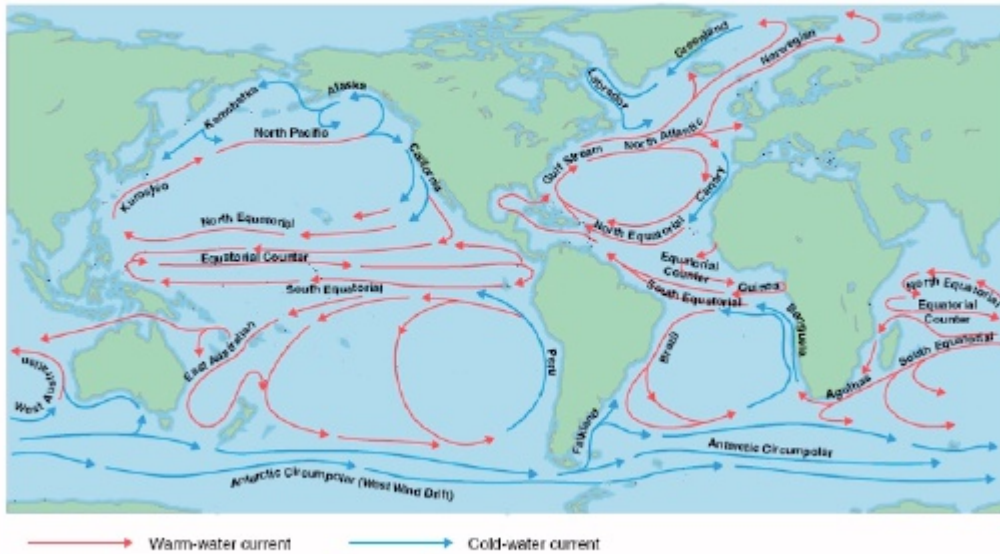


Underlying reason is the big Pacific warm surface water anomaly



Trade wind anomaly may continue ... no one knows  
When it ceases, warming resumes  
Matthew England UNSW, 2014

## Global ocean heat transport system

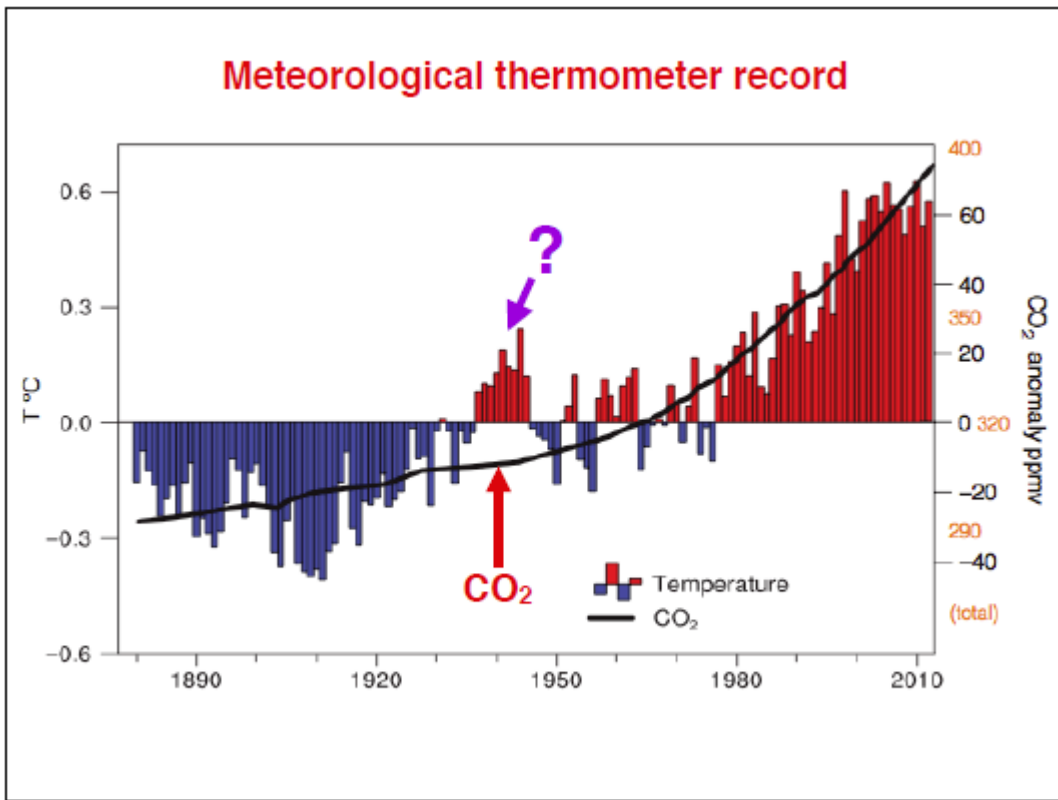


Ocean heat transport

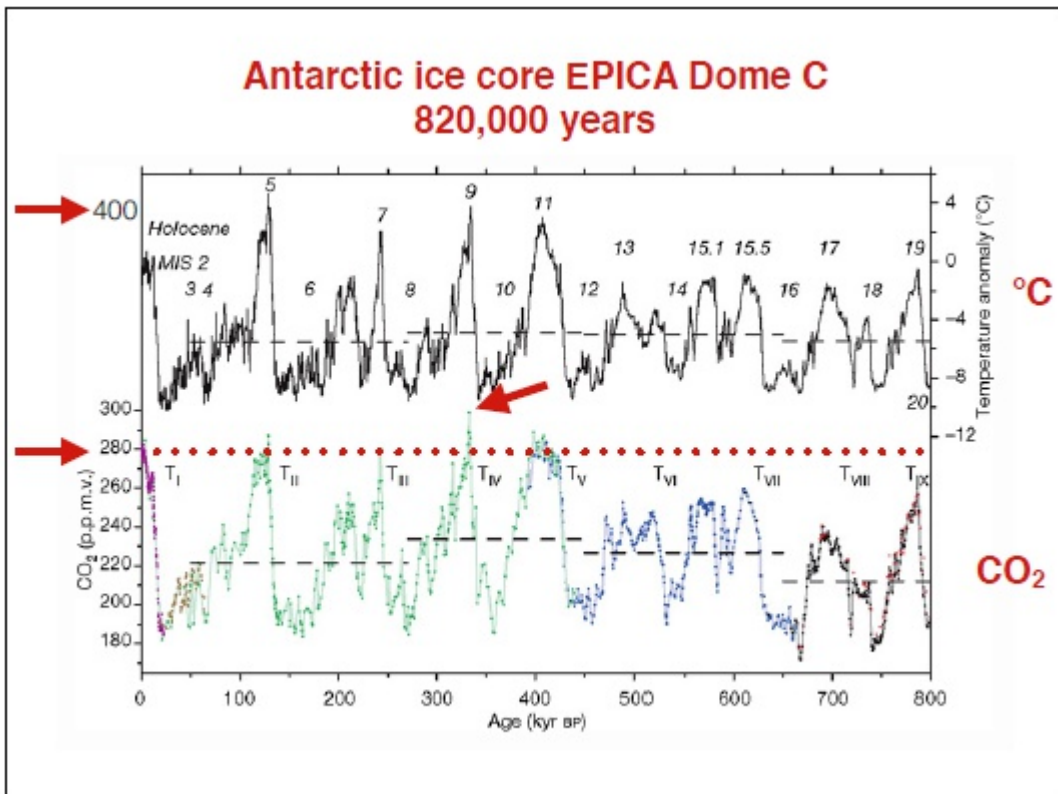
**Study of Earth's  
climate history  
shows very clearly  
the relation between  
greenhouse gases  
and climate**

Newman has this exactly wrong. Paleoclimatology is the most productive and vigorous research field at present growing our understanding. It show very clearly how the atmosphere affects climate on Earth - not by simple linear causes, but by complex causal networks.

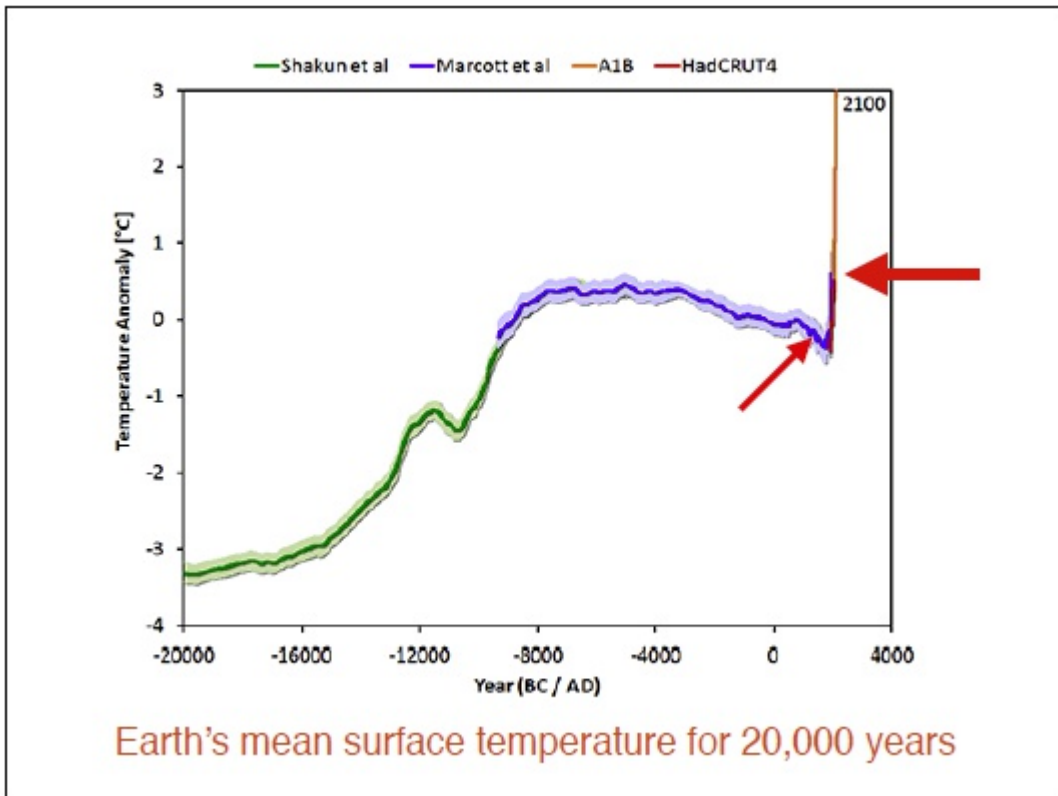




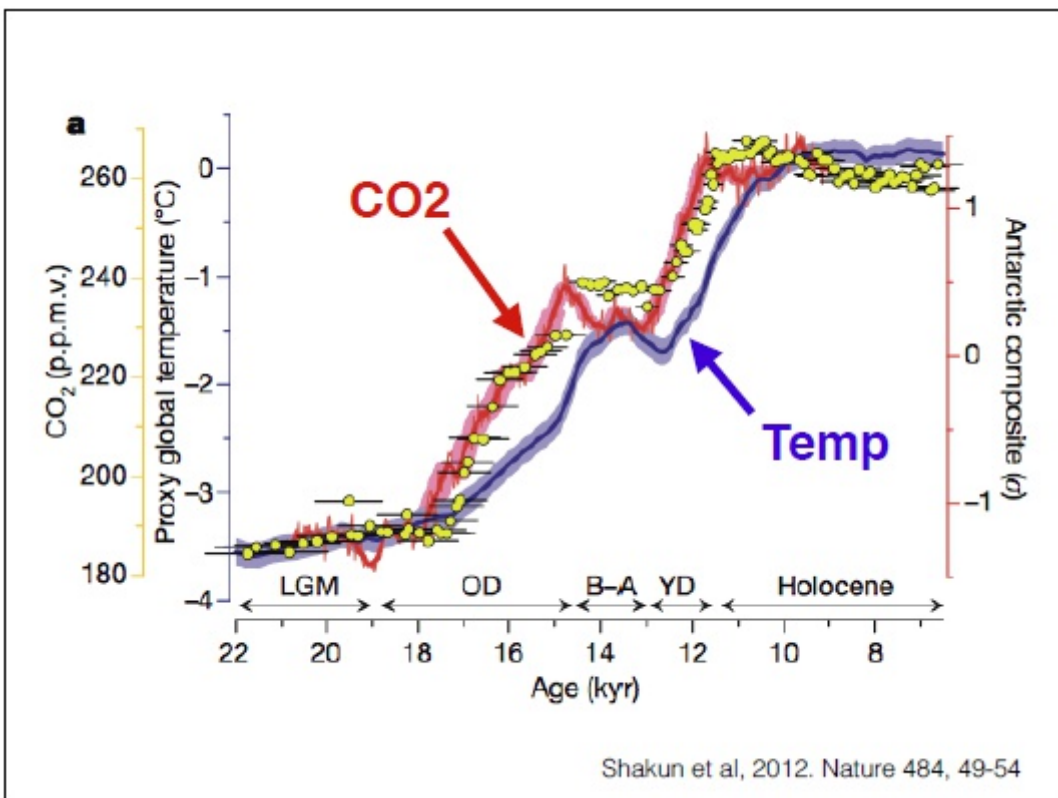
Anomalies  
 no year cooler than 20C mean for 35 years  
 Newman's CO<sub>2</sub> worry



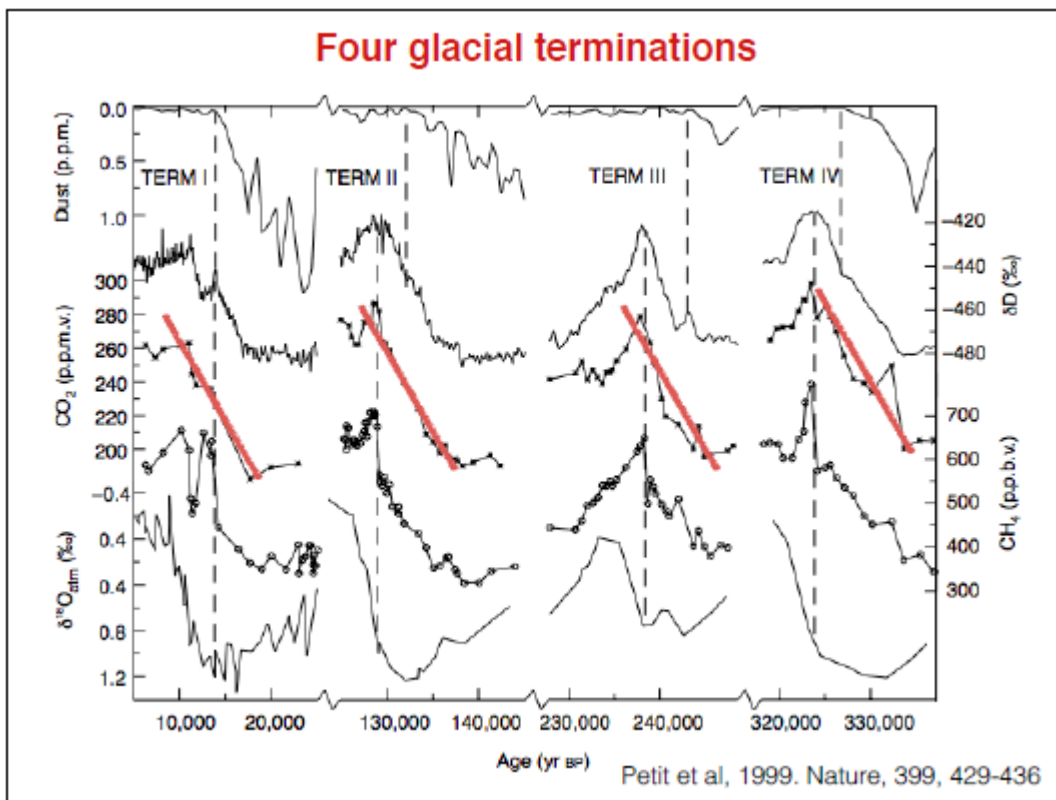
Longest ice core so far completed. Miraculous detail for 820,000 years  
 CO<sub>2</sub> never above 300 ppm; typical interglacial 280 ppm



Earth's temperature profile since the last glacial maximum. Holocene cooling since 5,000 years ago, suddenly reversed in a century. MWP barely registers



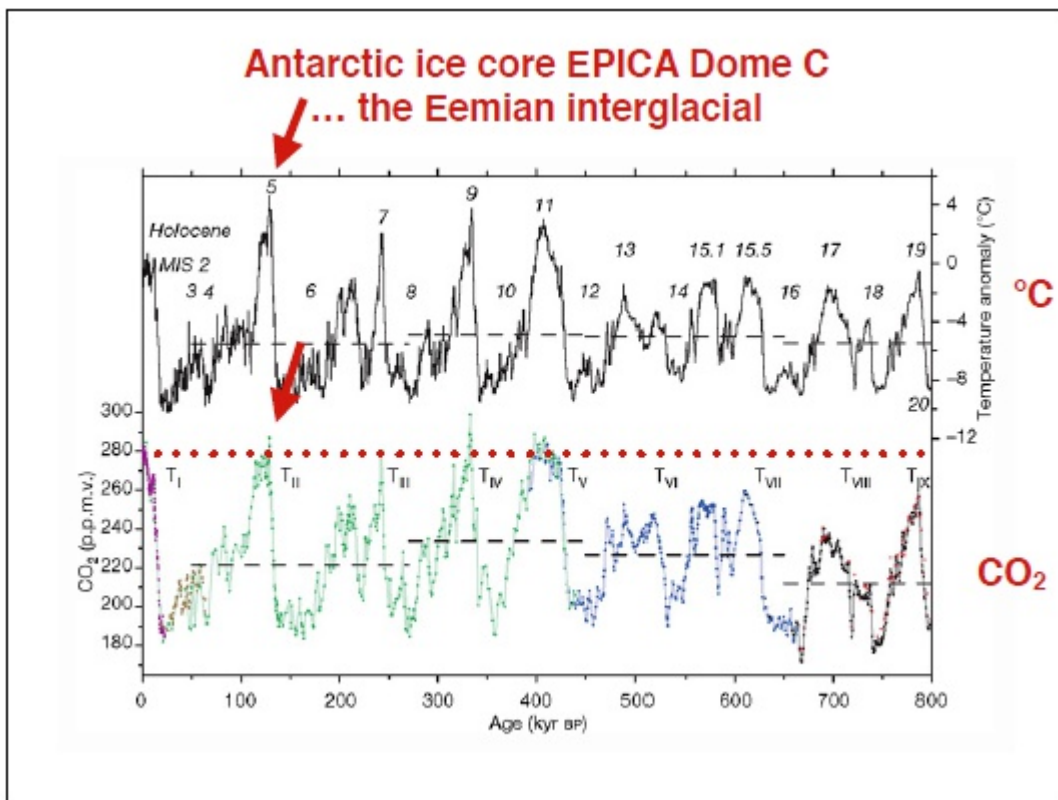
Relation between CO<sub>2</sub> & temp is not linear, but compounded by numerous feedbacks. The time interval between the two curves does not refute the theory, but invites explanation of these interesting geophysical processes



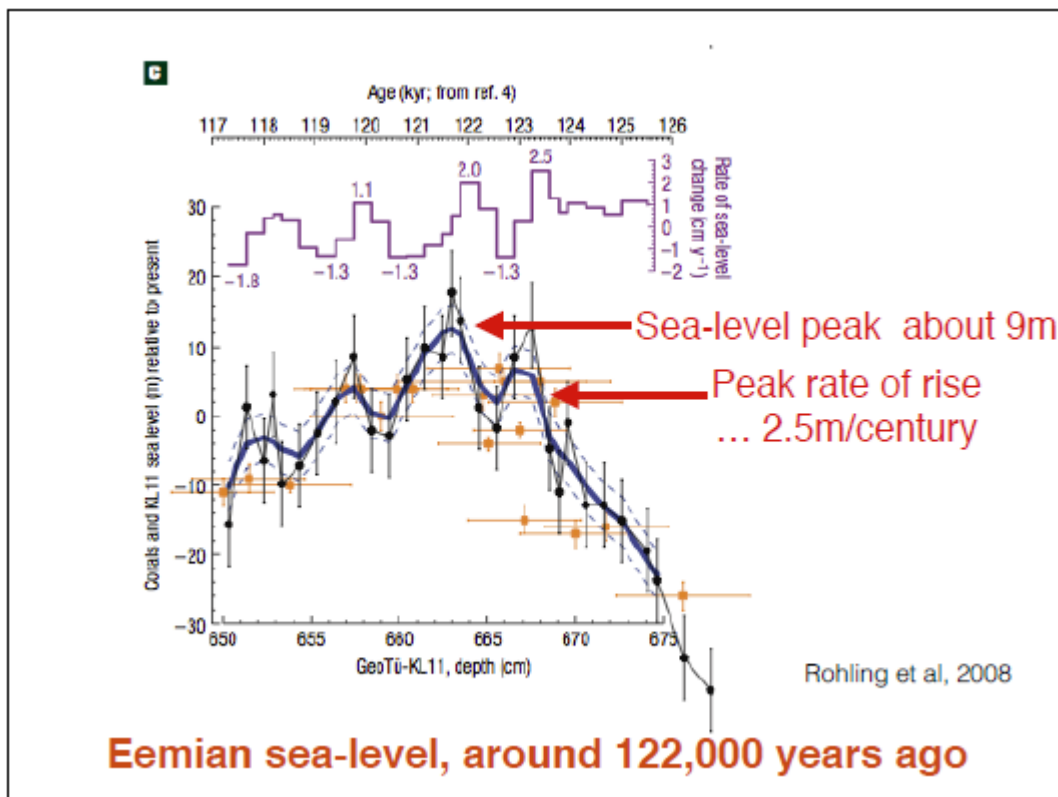
Vostok core, 1999 ... four glacial terminations  
 Modern CO<sub>2</sub> rise is 200 times faster than typical post-glacial rise

**Currently CO<sub>2</sub> is rising  
 just over 2 ppmv each year**

**200 times faster  
 than the fastest natural rise  
 we know of**



The Eemian ... 1-2 degrees warmer at peak; CO<sub>2</sub> 290. What about the sea?

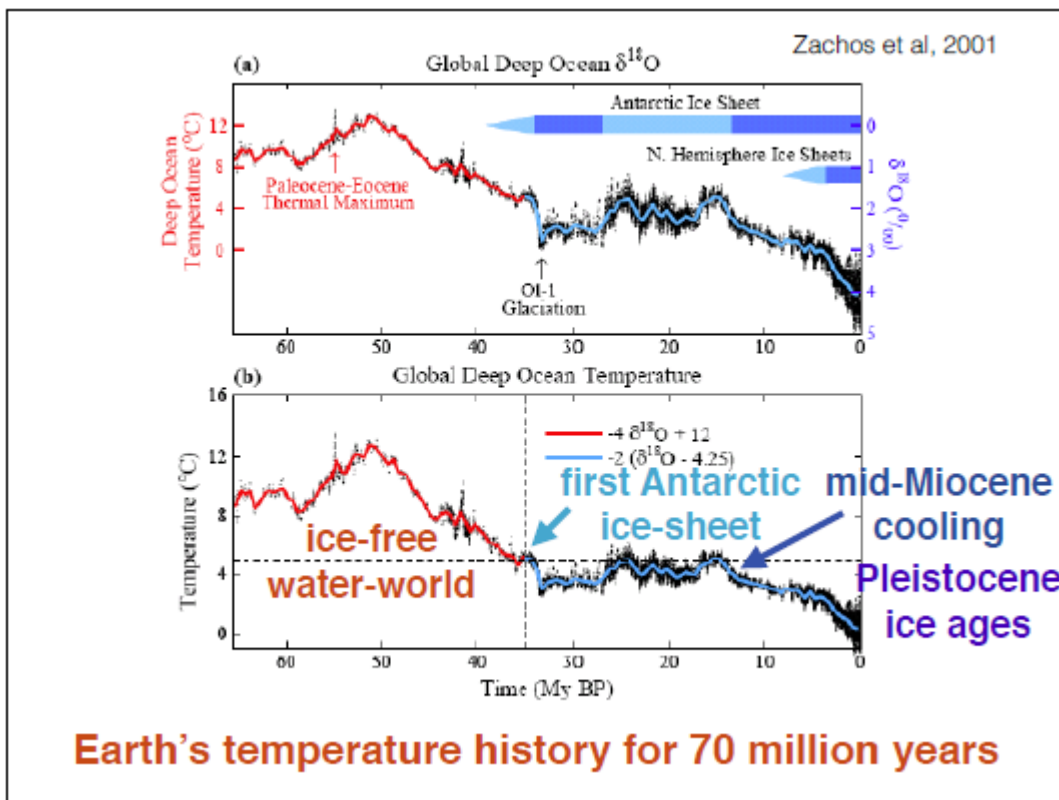


Peak Eemian sea-level 9m higher

Peak rate of rise 2.5m/century

All that melt-water came from the same vulnerable ice sheets we are watching now.

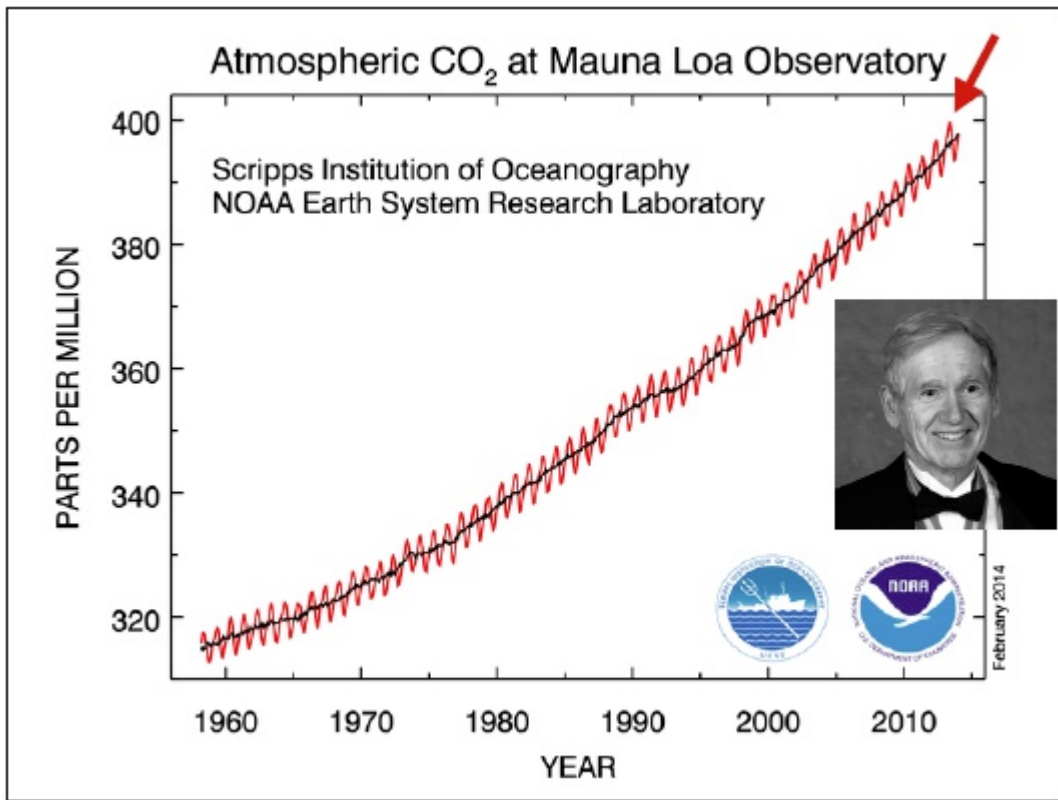




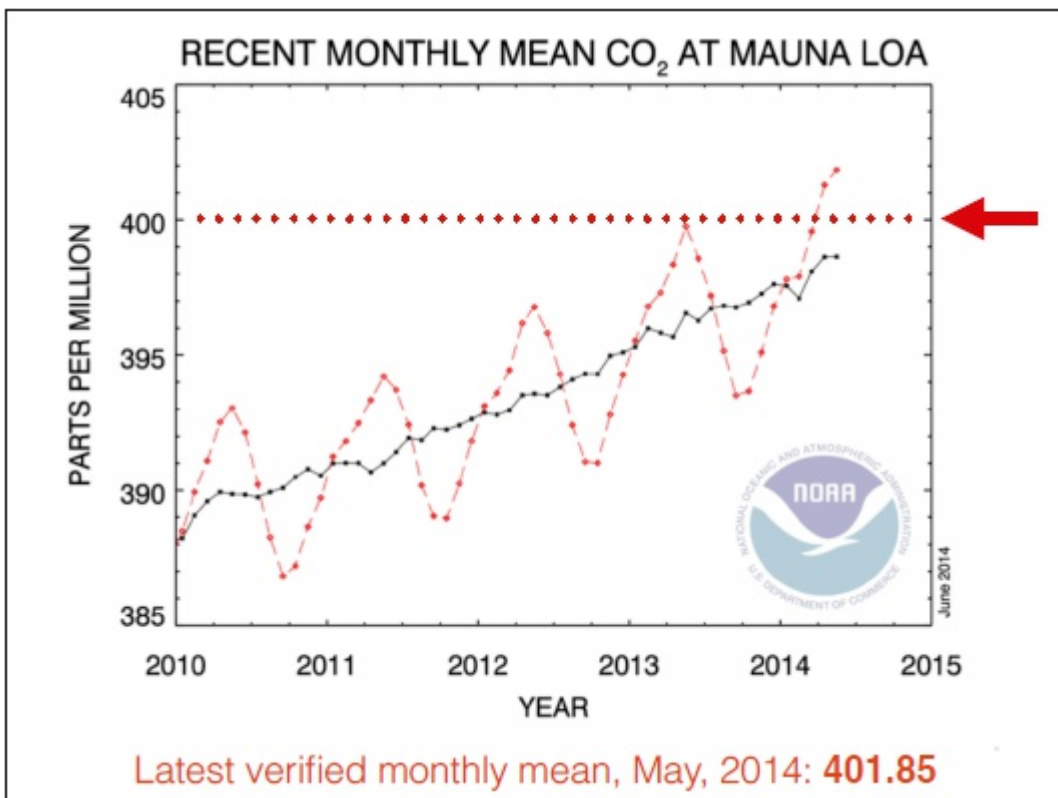
Jim Zachos wonderful Cenozoic temperature reconstruction. Each and every one of the features in this record invites further research to provide geophysical accounts of their causes. Much work is currently underway

**It's not all about models ... it's mostly about observations**

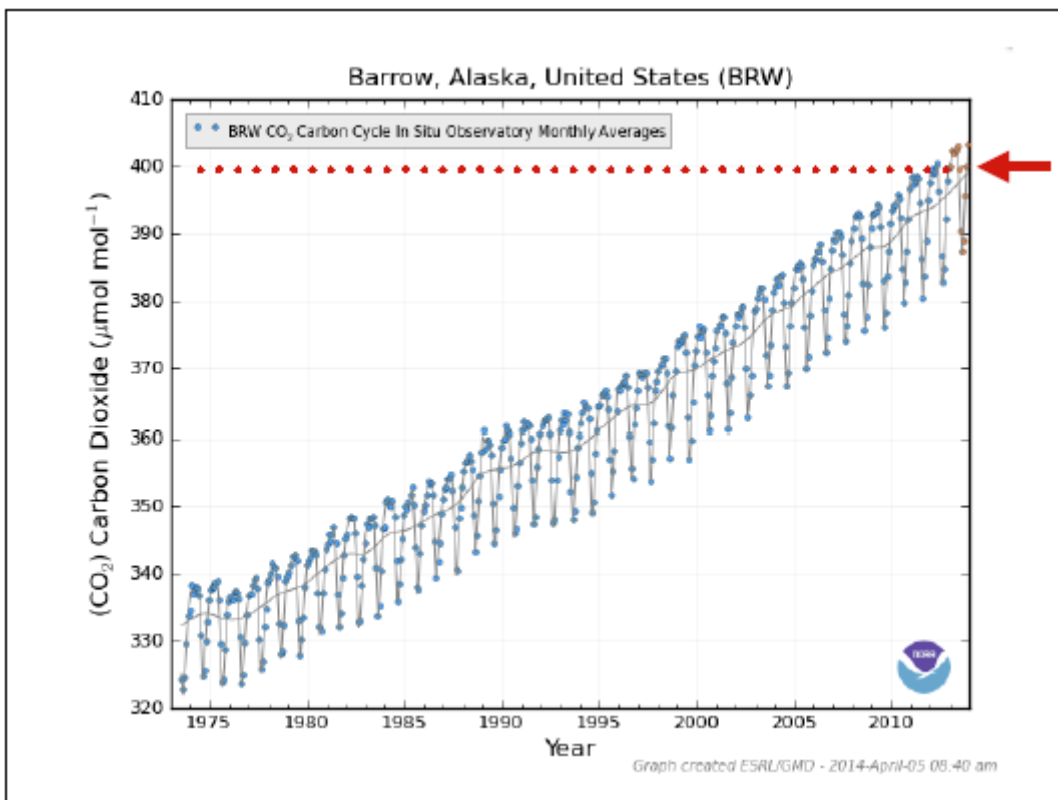
Animus for models is standard contrarian fare - mostly ignorant rubbish. Discovery in climate science is due to the normal methods - observing, measuring, figuring & testing. Models play their part, and are regulated by peer review, like everything else.



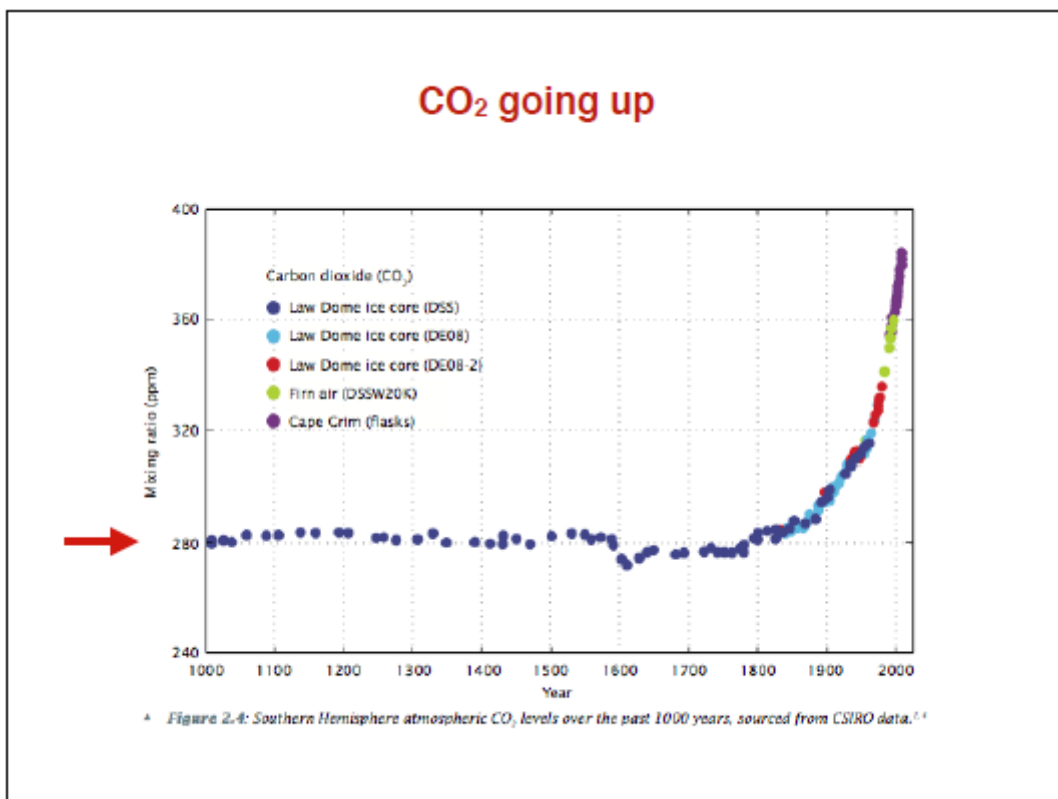
Observational record ... Keeling 1958 ... 0.7  
400 in May 2013  
Annual mean in 2016



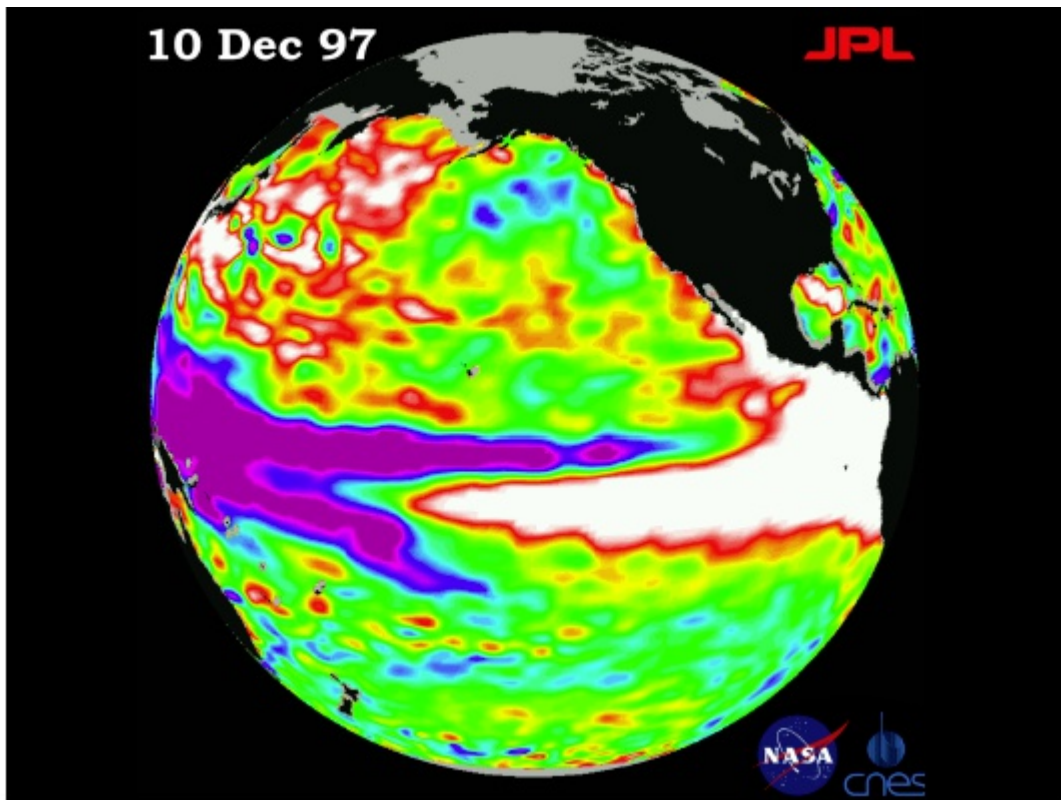
Mauna Loa monthly



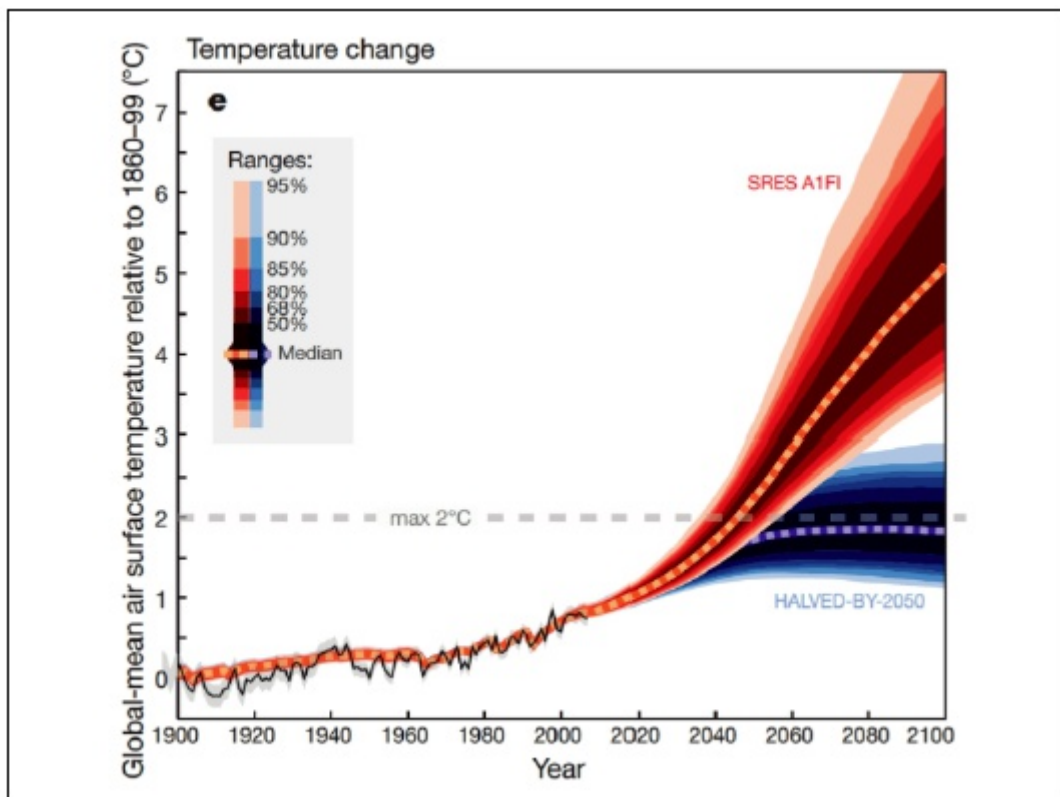
Barrow monthly



Ice cores  
\* 280 interglacial

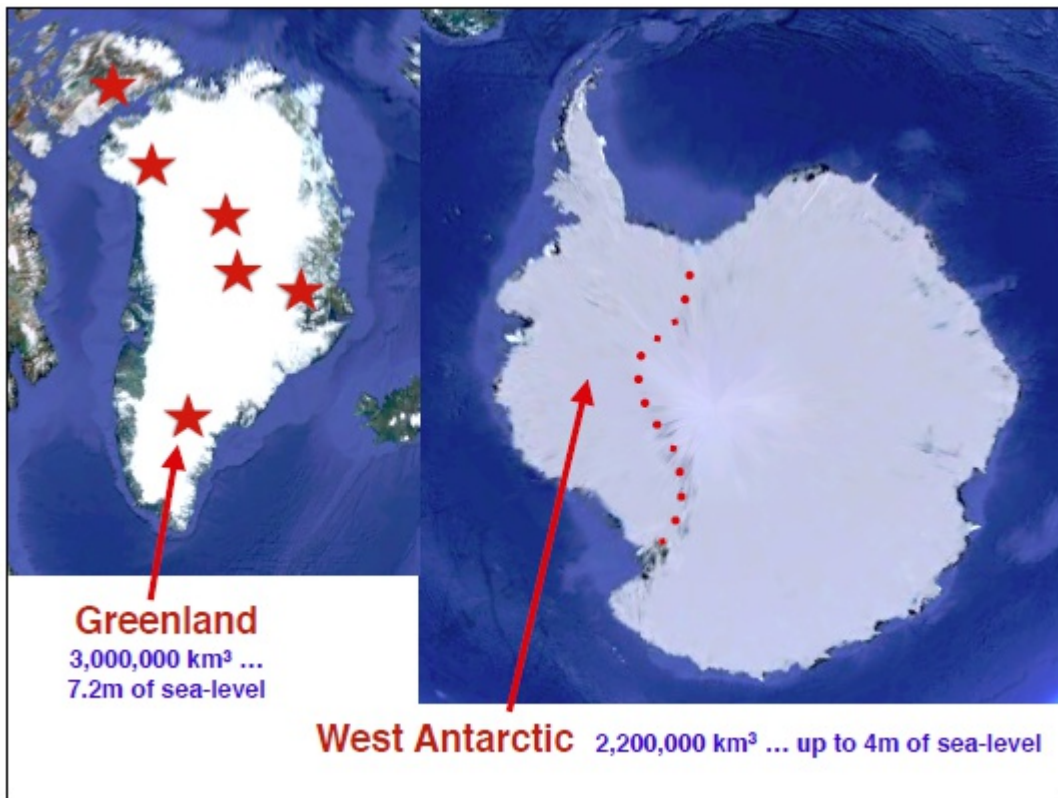


Sea-surface topography with satellite-borne altimeters of wonderful precision

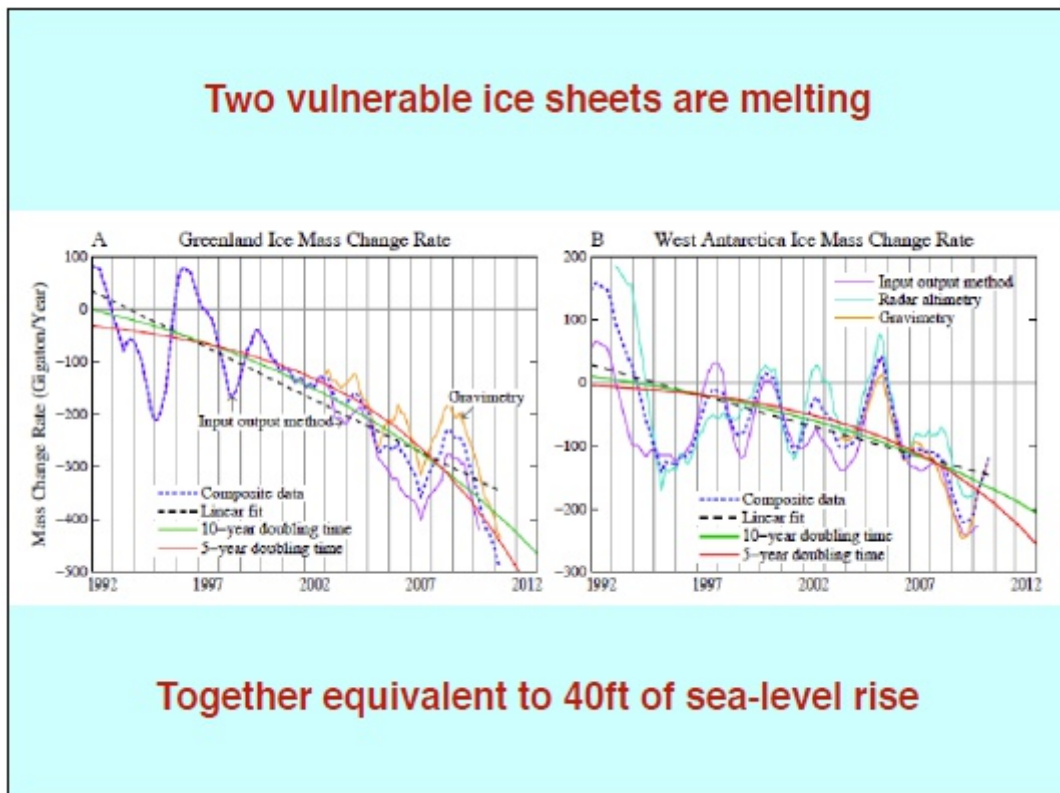


Model studies, such as this - of temperature projections, come with expressly quantified confidence limits, which should match the competence of underlying theory

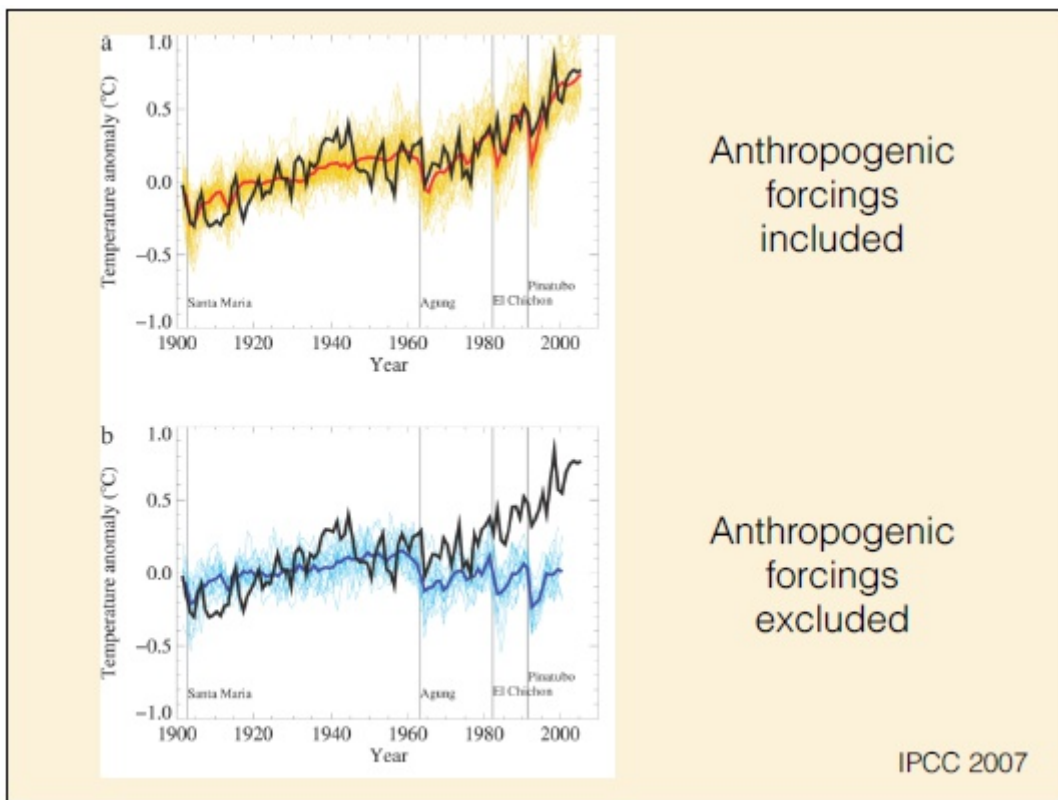




An instance of a prediction problem where we don't have theory good enough to give useful model results; instead, these vulnerable ice sheets are investigated by very clever observational techniques



Latest summary of observational record for the two ice-sheets. Further observation will show which mathematical trend best fits the data



An example of a pure model study - an attribution experiment from IPCC 2007

**In science,  
mavericks have  
their work checked,  
just like  
everyone else**

Loners in science should expect the same scrutiny as everyone else. Science is a community enterprise and peer review is a necessary corrective to wayward individuals, blind spots, prejudices and eccentricities



**Dr Roy Spencer,**  
principal research scientist,  
University of Alabama, Huntsville

- Warming has stopped
- More CO<sub>2</sub> is good
- Most warming is natural
- The climate is not sensitive to additions of greenhouse gases
- All policies designed to reduce emissions are a bad idea and far too costly
- There will be very little future warming
- CO<sub>2</sub> from joggers is 10% of the problem

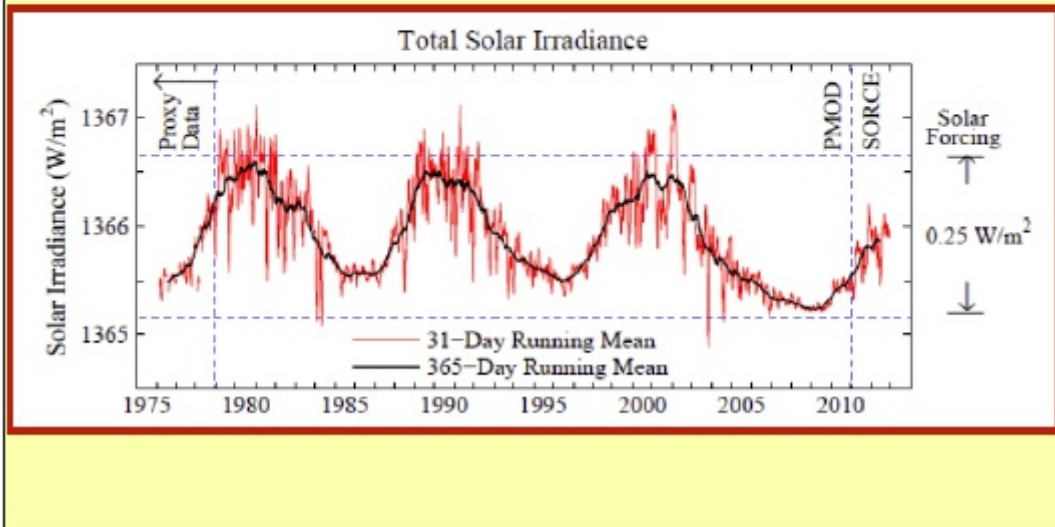
Roy Spencer's peculiar record of dissident opinions - all refuted.  
The man himself takes no notice

**It's not the Sun**

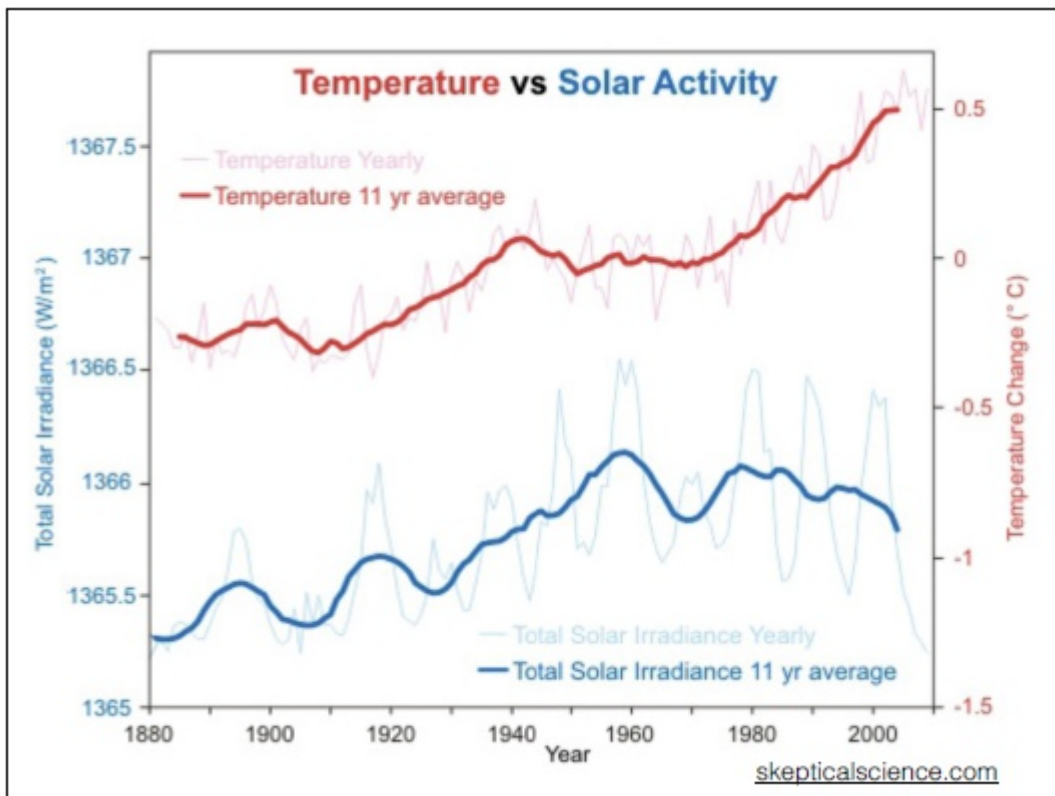
Common contrarian myth.

Role of the Sun has been exhaustively investigated - both direct and indirect effects.

## The Sun? ... No



The precise instrumental record of solar irradiance



Solar irradiance 0.02% variance over 11 year cycles  
No evidence of causation

# **Climate science**

**is difficult,  
complicated,  
and very technical ...**

***no place for amateurs***

The tacit assumption that anyone at all can have a worthwhile opinion is probably only found in a few other places where scientific findings conflict with touchy traditional values - evolution and a few ecological issues.

Many people who would not dream to claim they understand how antibiotics, microprocessors or immunisations work seem happy to wax lyrical on their views on climate change.

Prof Andrew Pitman, UNSW



## Evidence ...

**Preachers and lawyers  
use it to get to their goal;**

**but scientists' goal is to  
follow wherever it leads**

Mr Newman appears to understand by “evidence” something quite different from what scientists do.

Propagandists use it advance their case; scientists to guide their search



The case of Richard Muller, who challenged the orthodox global temperature record, and found it to be sound, and, like a good scientist, didn't mind admitting his error.



**Anthony Watts**

[whattsupwiththat.com](http://whattsupwiththat.com)

I'm prepared to accept whatever result they produce, even if it proves my premise wrong.

The study's methodology is flawed

And the case of Anthony Watts, who couldn't bring himself to admit anything, despite his scientific training.

It doesn't matter how beautiful your theory is, it doesn't matter how smart you are. If it doesn't agree with experiment, it's wrong.

Richard Feynman

The first principle is that  
you must not fool  
yourself and you are the  
easiest person to fool.

Richard Feynman


**What must we do?**

Change lightbulbs?

Prius?

Despair?

Need a diagnosis  
like aspirin for fever ... economic framing  
prescription before diagnosis



**What's the diagnosis?**

then ...

**What's the remedy ?**

Clinical analogy  
surface air temp is not diagnostic ... ocean reservoir  
Not theory ... historical precedent

## **Symptoms**

- Global surface warming (0.15°C/decade)
- Arctic sea-ice shrinking (80% volume reduction)
- Global average sea-level rising 3.4mm/yr
- Trend in more severe heat waves
- Greenland & West Antarctic ice sheets melting
- Disappearing mountain glaciers
- Increasing ocean acidity
- More powerful tropical storms
- More heavy rain events and flooding
- Expanding sub-tropical arid zones

Multiple geophysical effects can be read as “symptoms”

## **We know why**

### **Earth's energy imbalance**

Energy equivalent to  
400,000 Hiroshima bombs daily  
added to surface systems ...  
mostly the ocean

If all accumulated heat had been retained in the air ...  
36°C warmer & life extinguished

## **We know the source of the extra energy**

Enhanced atmospheric greenhouse

## **We know what it would take to restore energy balance**

Reducing the amount of CO<sub>2</sub> in the air

***What about the cost of the remedy?***

2 questions: can we do it;  
what cost?  
Garnaut; Stern ... economists question



“What good is it to save the planet  
if humanity suffers?”

Rex Tillerson,  
CEO, ExxonMobil



Question of cost causes confusion ... why?

Man inhabits two worlds. One is the natural world of plants and animals, of soils and airs and waters which preceded him by billions of years and of which he is a part. The other is the world of social institutions and artefacts he builds for himself, using his tools and engines, his science and his dreams to fashion an environment obedient to human purpose and direction. *Rene Dubos, 1972*

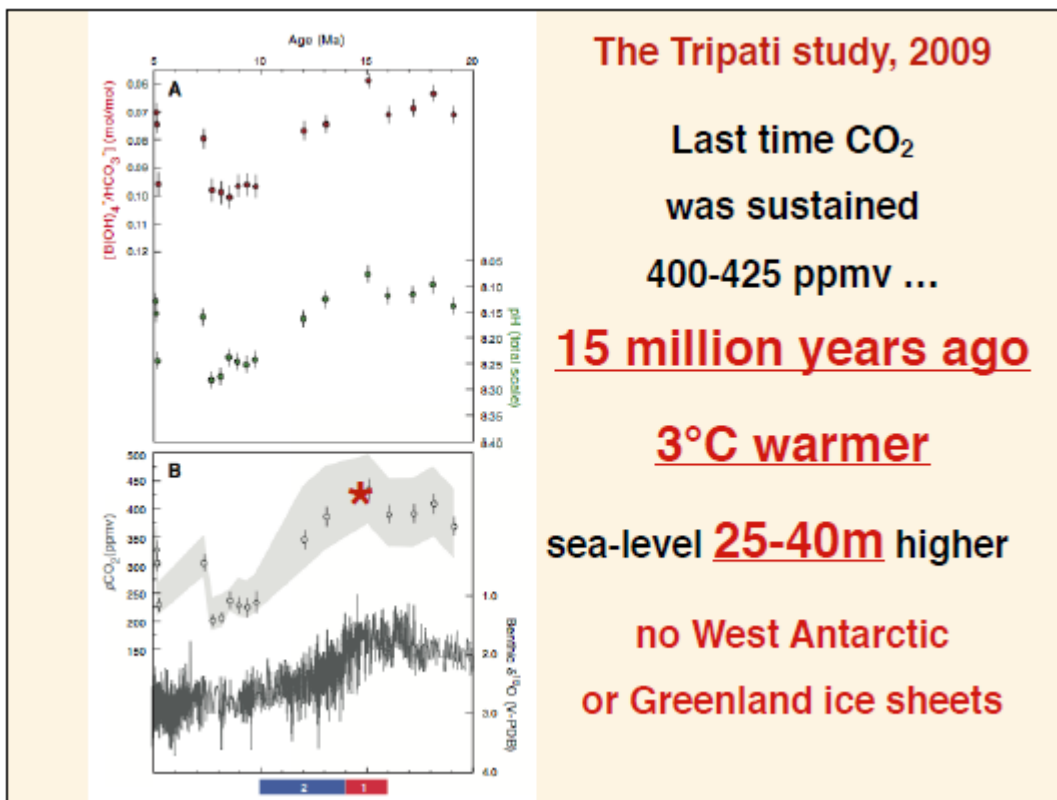
Primacy of the human world

**The economy is not autonomous  
It is not even a human artefact;  
it is a sub-system  
of the dynamic planetary surface**

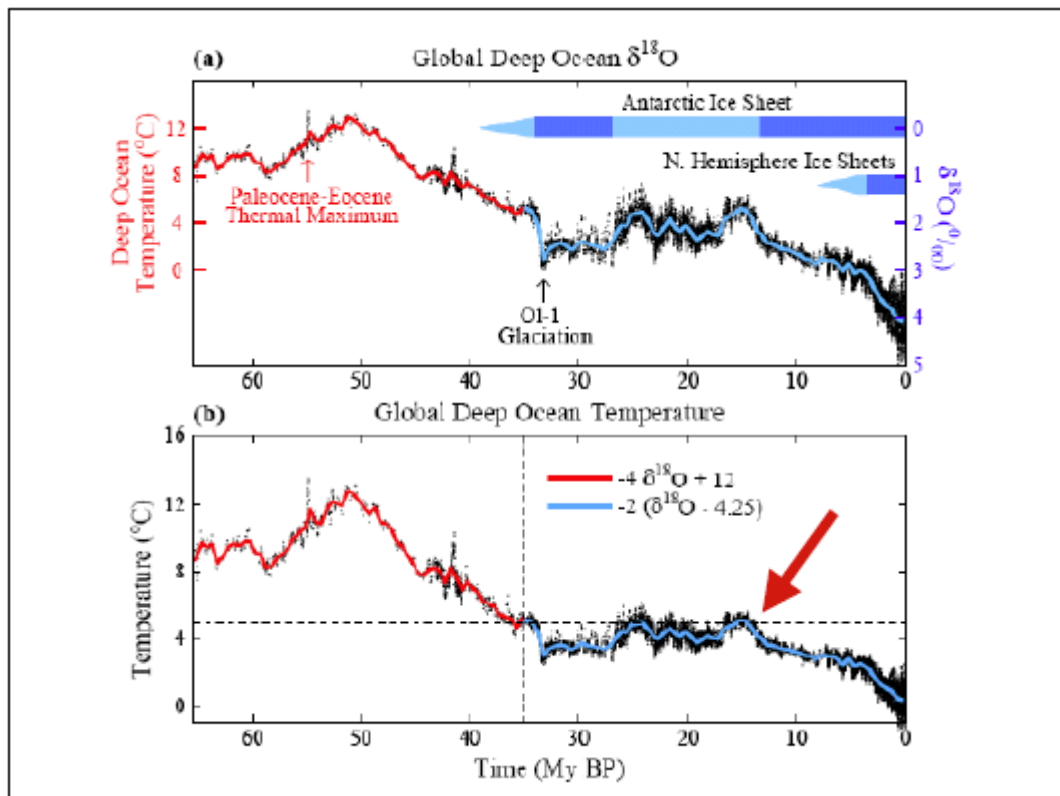
**CO<sub>2</sub> @ 400 ppmv**

**what does it mean?**

Climate scientist's question is a good way of stating the diagnosis



Tripati, the best empirical answer to this vital question: what changes could we expect in a world at thermal equilibrium with 400-425 ppmv?



This is where we would be

Jim Hansen

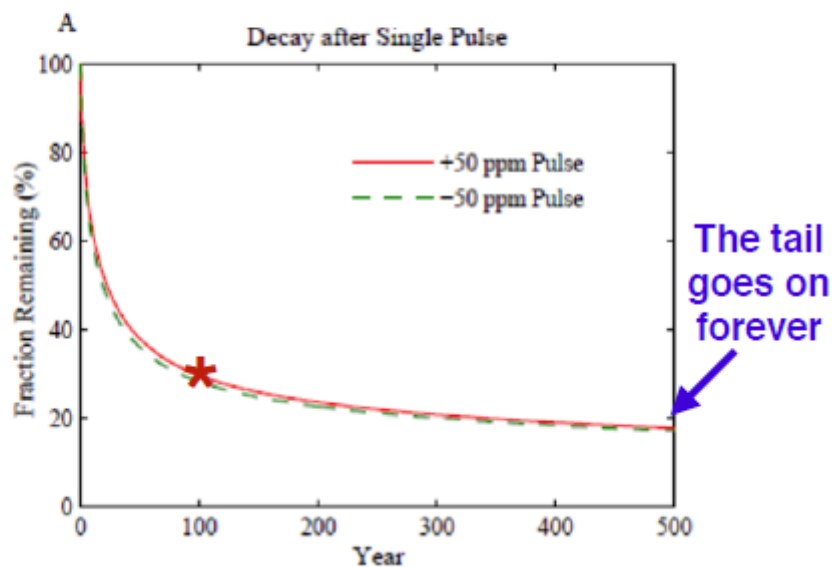


**CO<sub>2</sub> down to 350 ppm**

Hansen says we could be close to energy balance around 350 ppm ... although the number might need to be revised by and by.

**A bit of atmospheric physics ...**

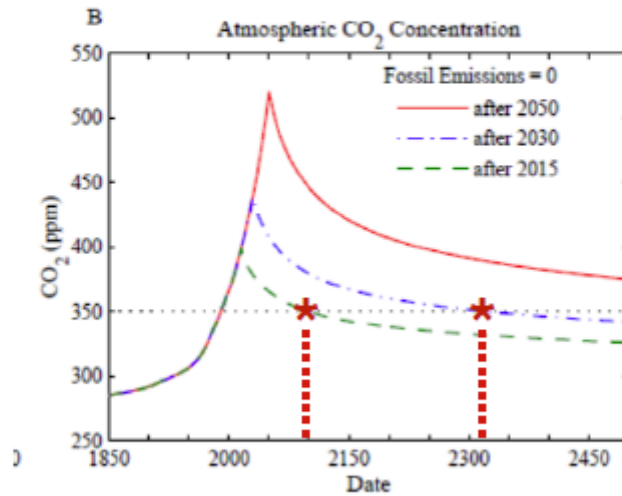
## CO<sub>2</sub> lasts a long time



Three-quarters gone in a century ... the rest for ever.

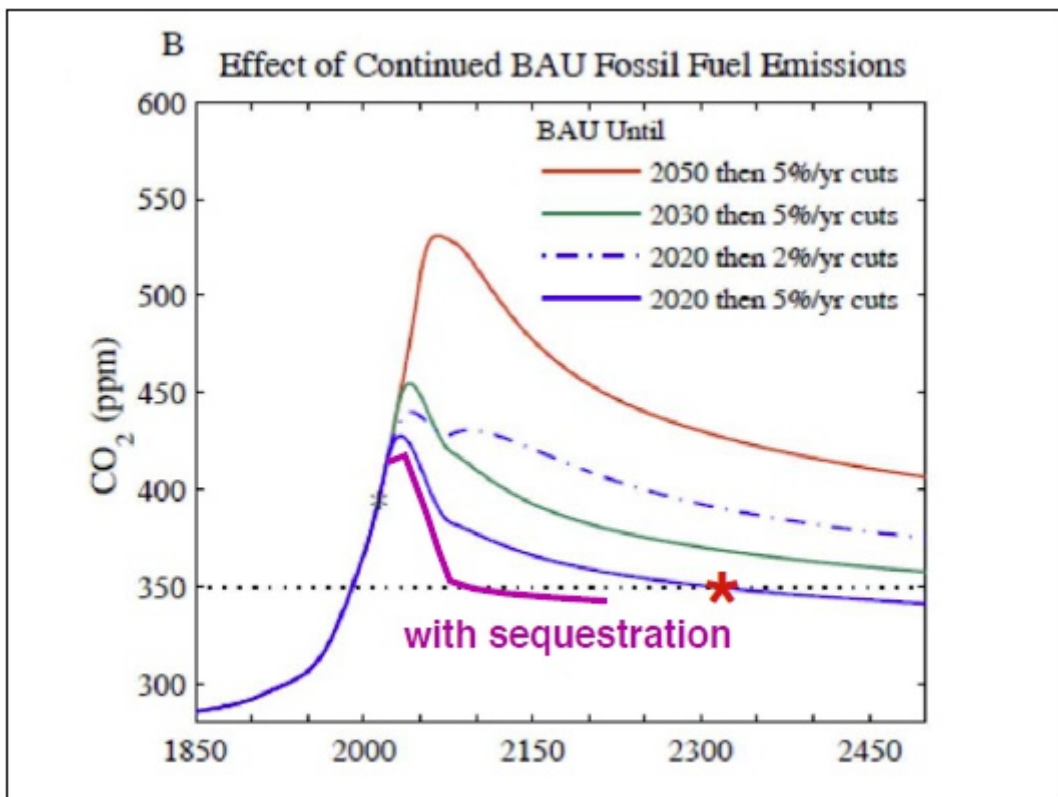
A bit more atmospheric physics ...

## Delay makes a big difference



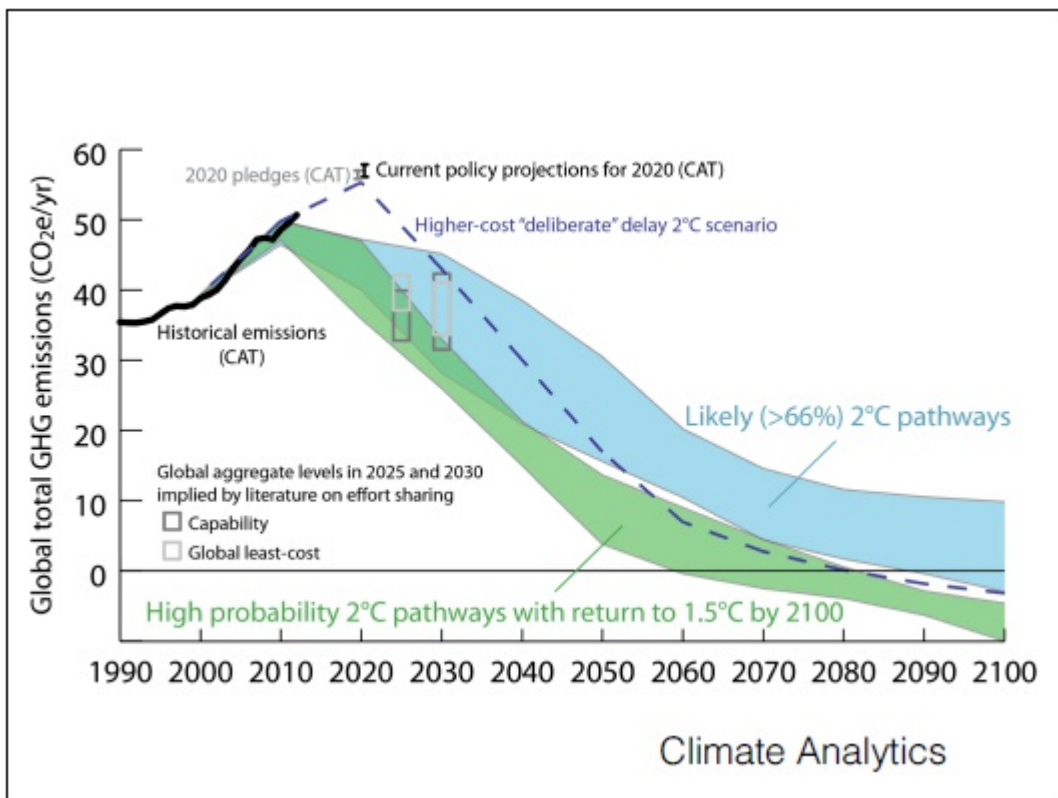
**350 ppm is our target**

Delay is not an option  
CO<sub>2</sub> above 350 ... 100y; 300y; 1000'sy



350 by century's end is still possible providing we get serious about withdrawing 100 Gt over the remainder of the century by bio-sequestration. Further work needed, but we know enough to make a start





Independent confirmation

- ### Hansen's program
- ★ Phase out coal over 30 years
  - ★ Big energy efficiency program
  - ★ Transition to zero-carbon electricity & transport
  - ★ Fee & dividend costing for carbon emissions
  - ★ Invest in technology - including nuclear
  - ★ Leave all "unconventional" fossil fuels in the ground
  - ★ Stop tropical deforestation
  - ★ Big reforestation program
  - ★ Sequester carbon in agricultural soils & rangelands
  - ★ ? CCS

Coal has to go - abundant and cheap ... until it pays for messing up the air  
 Efficiency - 30% gain almost no cost; up to 60% possible  
 Unconventional fuels cannot be exploited

# Policy #1 ...

## CARBON FEE & DIVIDEND

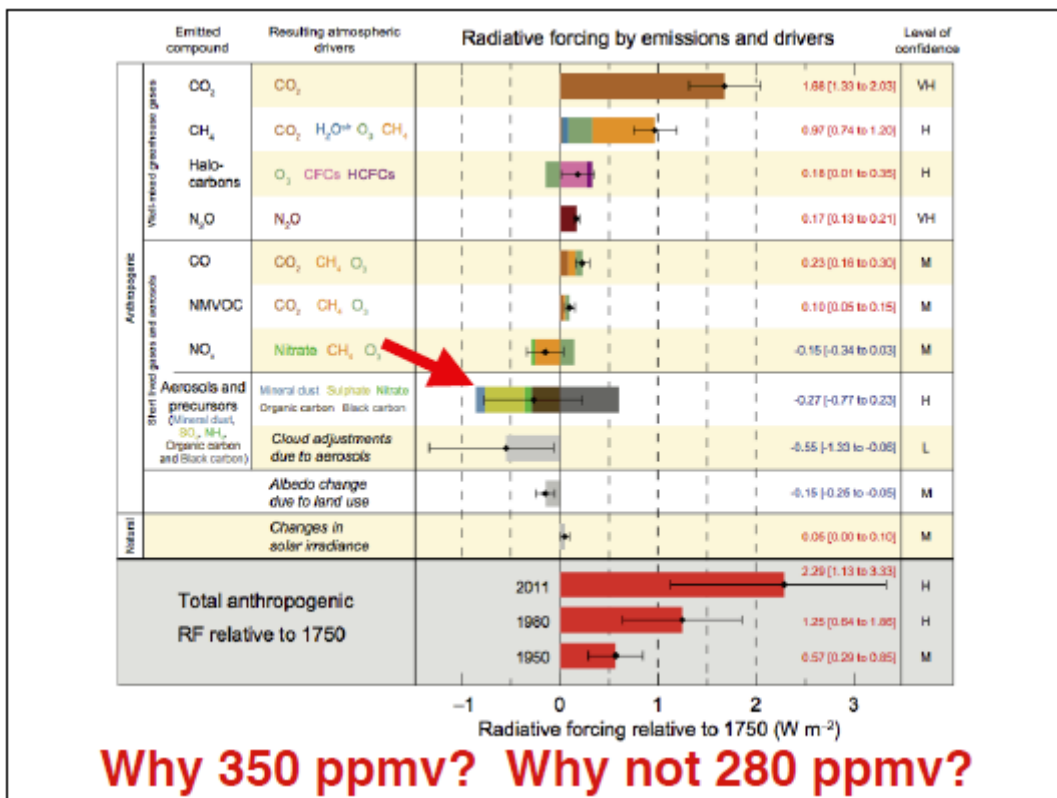
All else will fail without this measure - to end free dumping of GHGs. Start at \$10-20/tonne; increase \$10/tonne annually until zero emissions (expected by mid-century); every cent of revenue returned to citizens equally as monthly dividend. Correct incentives.

**Five ways to price CARBON**

**Carbon Pricing Primer**  
Carbon emissions carry hidden costs  
THESE ARE THE 5 WAYS WE CAN PAY...

- The Status Quo**  
Whole society finances fossil fuels  
Most expensive option, by far
- Regulation**  
Boots on the ground, eyes on emissions  
Dependent on budget for enforcement
- Cap & Trade**  
Regulatory solution, artificial market  
Narrow focus, requires enforcement
- Carbon Tax**  
'Sin tax', pressure on consumers  
Highly effective, can slow GDP
- Carbon Fee & Dividend**  
100% returned to households  
Revenue-neutral, grows economy

No action is not free; it simply defers the cost to our descendants



Big negative forcings - opaque aerosols. If these remain, 350 ppm will be close to energy balance' if they decline, the target must be lower.

**Can this be done?**

**Wrong question**

**Better question ...**

**Do we want it enough?**



Citizens Climate Lobby - Political Will for a Livable World - Climate Hope

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Political Will for a Livable World

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So we can turn up the heat on Congress to deal off the world

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CCL media packet: Dire warning from latest IPCC report shows need for Congress to come together on sensible solution of a revenue-neutral carbon tax

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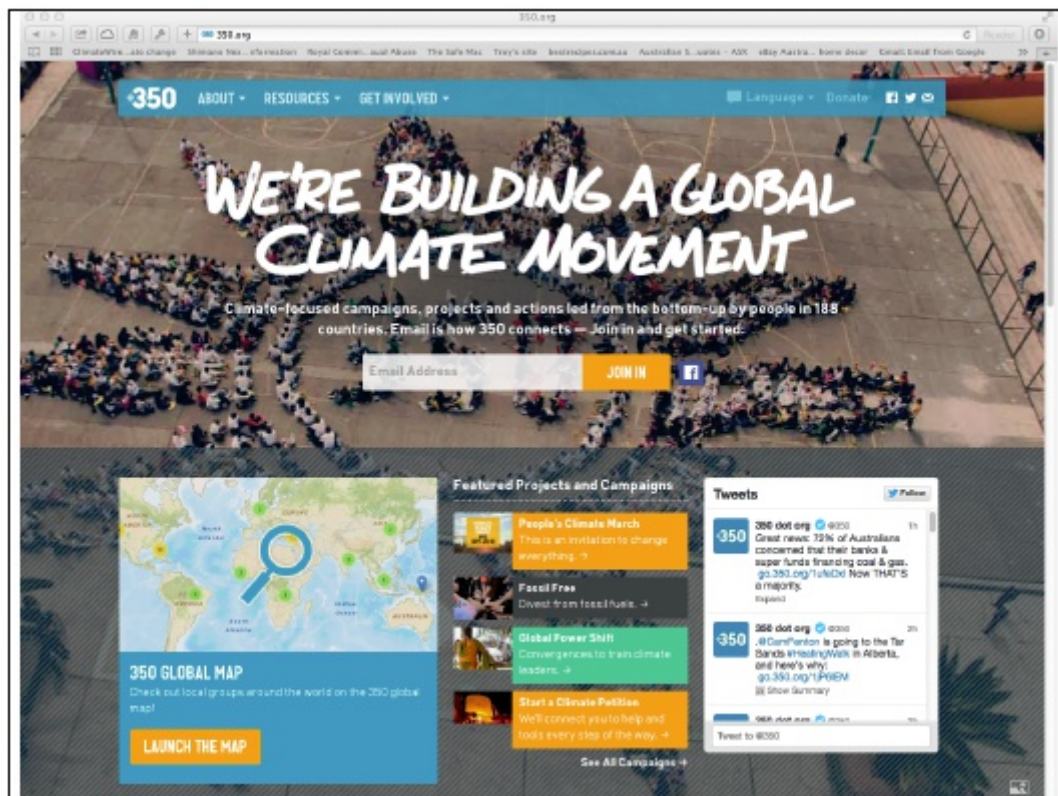
LTE of the Day  
Want to learn more about  
f

CCL  
[citizensclimatelobby.org](http://citizensclimatelobby.org)





BZE, Australia's premier community based research group on renewable energy transition. World-class work [bze.org.au](http://bze.org.au)



Bill McKibben's popular movement [350.org](http://350.org)

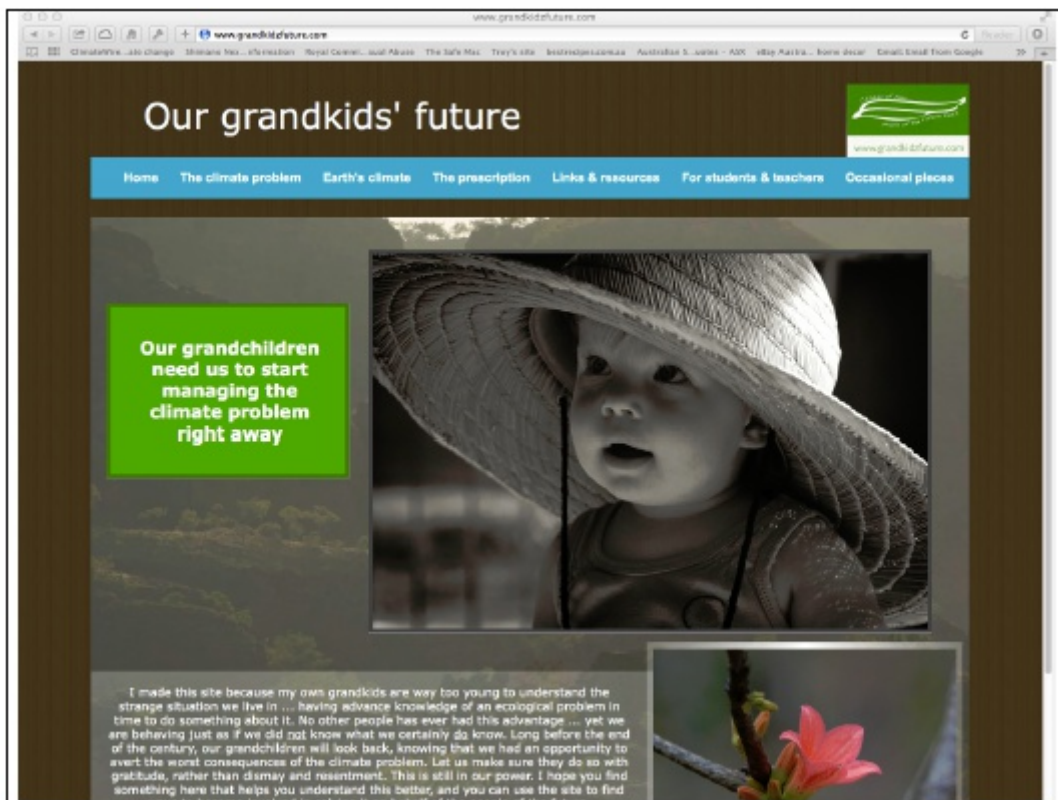




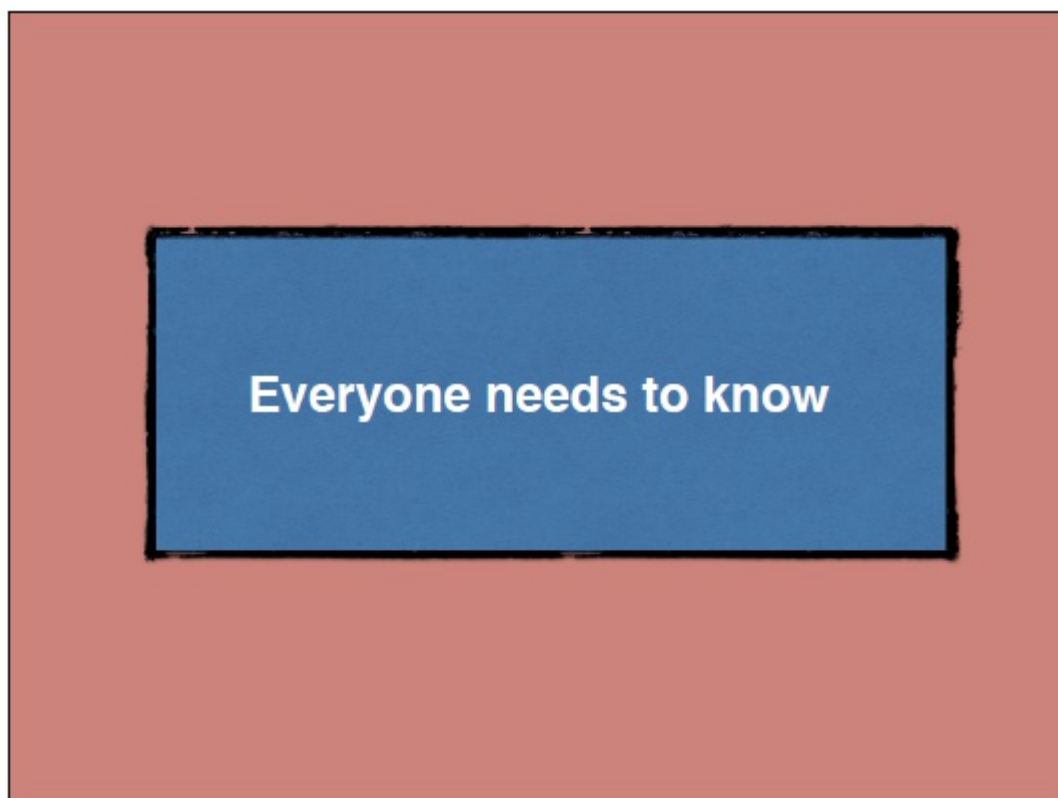
Tim Flannery's community-funded successor to the Climate Commission  
[www.climatecouncil.org.au](http://www.climatecouncil.org.au)



The best place to answer questions



The author's site of general information about the climate problem  
[www.grandkidzfuture.com](http://www.grandkidzfuture.com)



*Because if we don't know  
we can't choose*