



ABOUT THIS COURSE

In public discussions, climate change is a highly controversial topic. However, in the scientific community, there is little controversy with [97% of climate scientists concluding humans are causing global warming](#).

- Why the gap between the public and scientists?
- What are the psychological and social drivers of the rejection of the scientific consensus?
- How has climate denial influenced public perceptions and attitudes towards climate change?

[This course examines the science of climate science denial.](#)

We will look at the most common climate myths from “global warming stopped in 1998” to “global warming is caused by the sun” to “climate impacts are nothing to worry about.”

We’ll find out what lessons are to be learnt from past climate change as well as better understand how climate models predict future climate impacts.

[You’ll learn both the science of climate change and the techniques used to distort the science.](#)

With every myth we debunk, you’ll learn the critical thinking needed to identify the fallacies associated with the myth. Finally, armed with all this knowledge, you’ll learn the psychology of misinformation. This will equip you to effectively respond to climate misinformation and debunk myths.

THIS ISN'T JUST A CLIMATE MOOC:
IT'S A MOOC ABOUT HOW PEOPLE THINK ABOUT CLIMATE CHANGE.

WHAT YOU'LL LEARN

- How to recognise the social and psychological drivers of climate science denial
- How to better understand climate change:
the evidence that it is happening, that humans are causing it and the potential impacts
- How to identify the techniques and fallacies that climate myths employ to distort climate science
- How to effectively debunk climate misinformation

MEET THE INSTRUCTORS

SCIENTISTS, RESEARCHERS, PROFESSORS & EXPERTS WHO ARE PASSIONATE ABOUT CLIMATE SCIENCE



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WEEK 1-1: OVERVIEW

WHY IS CLIMATE CHANGE SO CONTROVERSIAL TO THE GENERAL PUBLIC
WHEN THERE'S NO CONTROVERSY AMONG CLIMATE SCIENTISTS?

Among climate scientists, 97% agree that humans are causing global warming.
But if you ask the average person off the street, they think there's a 50:50 debate.

WEEK 1-2: CONSENSUS

1. CONSENSUS OF EVIDENCE

Science is based on evidence

- when we burn fossil fuels like oil & coal, we send **carbon dioxide** into the atmosphere and oceans
 - carbon dioxide is a **heat-trapping gas**
 - this process of trapping heat = **greenhouse effect**
 - as we emit more greenhouse gases, more heat is being trapped = **increase greenhouse effect**
 - this is making the world warmer = **global warming**
 - warming from increased greenhouse effect is proven by **a number of different patterns**
- = **human fingerprints** (human-caused warming)

		Climate Drivers			
		Greenhouse Gases	Sun	Volcanoes	Internal Variability
Climate Patterns	Cooling upper atmosphere	✓	✗	✗	✗
	Less heat to space	✓	✗	✗	✗
	Rising tropopause	✓	✓	✓	✗
	Annual cycle	✓	✗	✗	✗
	Daily cycle	✓	✗	✗	✗
	Ocean warming	✓	✗	✗	✗
	More heat back to Earth	✓	✗	✗	✗
Land warming faster than oceans		✓	✓	✗	✗
		✓ Consistent with Climate Driver	✗ Rules out Climate Driver		

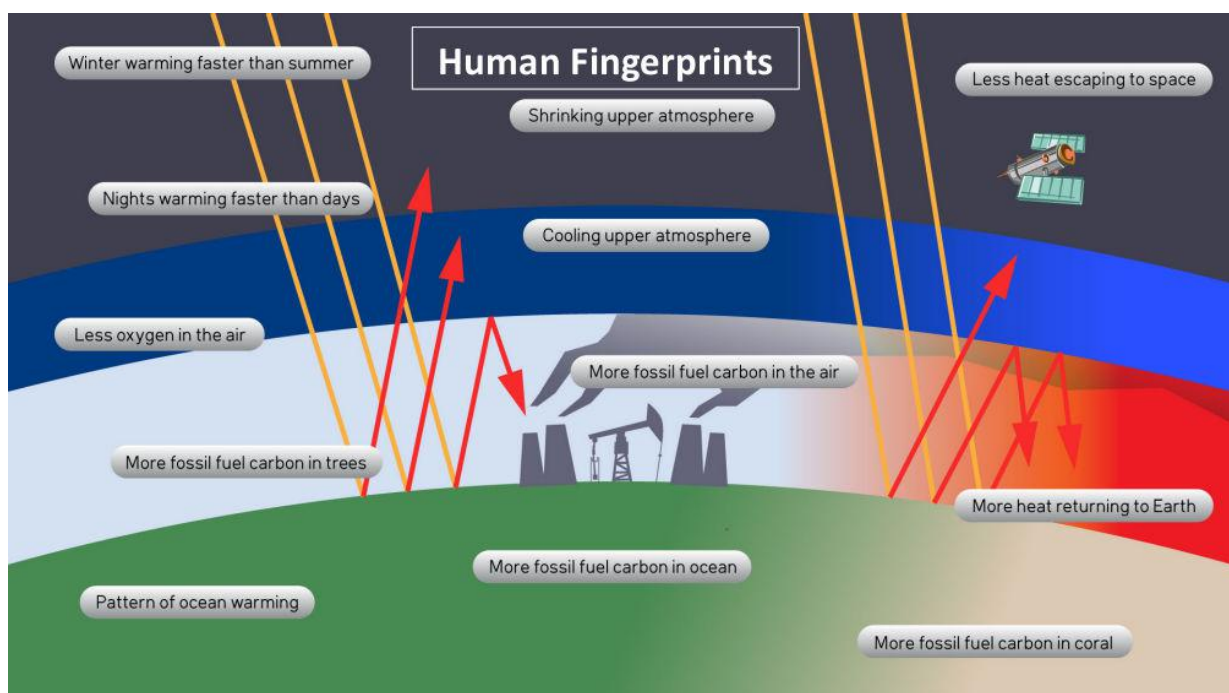
Human fingerprints give evidence that we are causing climate change AND rule out other possible natural causes



Warming from increased greenhouse effect is proven by a number of different patterns.

Evidence of distinct human fingerprints

- a series of different satellites have measured **less heat escaping to space** for over 40 years
 - measurement at the Earth's surface find **more infrared radiations (heat) radiating back to Earth**
 - cooling in the upper atmosphere** because heat is being trapped in the lower atmosphere
 - because of this cooling, the **upper atmosphere is shrinking**, we are changing the structure of our planet's atmosphere
 - other fingerprints** measured by many different independent sources conclude human-caused GW
 - cross-checking all other natural possibilities (volcanoes, sun, ocean cycles) with the climate patterns do not match, **only the human fingerprints match all the patterns**
- = **consilience of evidence or consensus of evidence**
- myth that climate science relies only on models is wrong: misrepresentation as **climate science is based on physics and confirmed over and over again by many lines of evidence**



WEEK 1: BONUS MATERIALS

BONUS 1. THE SCIENTIFIC METHOD

Deductive method

- coming up with a **hypothesis first**, a possible explanation of how the world works
- **then scientists collect observation to see whether that prediction comes true**
- **example:** in 1859, John Tyndall predicted that if greenhouse gases were causing warming, **nights should warm faster than days and winter warming faster than summers**: 150 years later, data confirm his hypothesis and is one piece of evidence of GW
- **counter-example:** some early 20th scientists thought oceans could soak up all our CO₂ so in the 1950s, Charles Keeling made measurements year after year that refuted this theory (CO₂ increase)

Inductive method

- **collecting the data first then analysing it** to look for possible patterns

Peer review

- whether deductive or inductive, **research gets scrutinised by other experts before publication** to weed out errors and make sure the research is rigorous and evidence-based
- despite this, **mistakes** gets published sometimes
- but because of the level of scrutiny, it can be argued that peer-reviewed research is the highest quality source of scientific information available

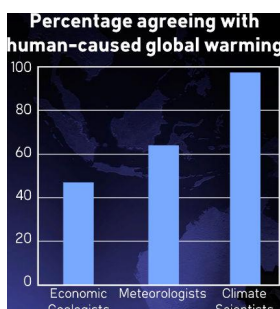
Checking the results

- **other scientists then check the results**
- they run their own experiments or take their own measurement to see if they obtain the same result
- when a result is replicated independently, there is more confidence that it is accurate
- if replicated with different types of measurement, confidence is even stronger

Many independent lines of evidence point to the same consistent conclusion that humans are causing global warming.



This is a consilience of evidence that leads to a consensus amongst scientists.



- American Association for the Advancement of Science
- American Astronomical Society
- American Chemical Society
- American Geophysical Union
- American Institute of Physics
- American Meteorological Society
- American Physical Society
- Australian Meteorological and Oceanographic Society
- Australian Bureau of Meteorology
- British Antarctic Survey
- Canadian Foundation for Climate and Atmospheric Sciences
- Canadian Meteorological and Oceanographic Society
- CSIRO
- Environmental Protection Agency



- European Federation of Geologists
- European Geosciences Union
- European Physical Society
- Federation of American Scientists and Technological Societies
- Geological Society of America
- Geological Society of Australia
- Geological Society of London
- International Union for Quaternary Research
- International Union of Geodesy and Geophysics
- National Center for Atmospheric Research
- National Oceanic and Atmospheric Administration
- Royal Meteorological Society
- Royal Society of the UK

80 National Academies of Science Endorse Human-Caused Global Warming



WEEK 1-2: CONSENSUS

2. CONSENSUS OF SCIENTISTS

How do we know there is a consensus?

- **2009 survey** Peter Doran & Maggie Kendall found that the higher level of expertise in climate science, the stronger the agreement about GW
 - = **97.4% of climate scientists actively publishing research agree about human-caused GW**
- **2010 study** William Anderegg & co collected a number of public statements from climate scientists published in scientific journals
 - = **same result: 97-98% of agreement**
- **2013 Cook & co** analysed over 12 000 climate research papers from 1991 to 2011
 - = **same result: 97.1% affirmed the consensus**



- **the consensus has been endorsed by**
 1. the academies of science from 80 countries (*not a single academy of science in the world rejected it*)
 2. virtually every scientific organisation that has made a statement about climate change
- many lines of empirical evidence tell us that humans are causing GW
- a number of independent sources find overwhelming agreement amongst scientists

Climate change myth about the consensus

- argues that there is no consensus
- based on a petition signed by 31 000 fake experts on the *Global warming petition project* website
- **the only requirement to be listed in the petition is an undergraduate degree in any kind of science**
- yet 10 millions people earned such a degree between 1971 and 2008
- so 31 000 people is only 0.3% of Americans with science degrees = magnified minority
- only 0.1% of those 31 000 are climate scientists
- as the general public relies on experts about complex issues such as CC, it is crucial to tell when fake experts are used to confuse them

WEEK 1-2: CONSENSUS

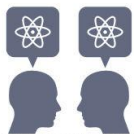
3. CONSENSUS OF PAPERS

Social calibration

- scientific research is based on common standards of evidence + test of time: scientists scrutinise each other's research over time: **peer-review**
- 2004, Naomi Oreskes examined ≈1000 peer-reviews papers from 1993 to 2003 on global change
- = 0/1000 rejected human-caused GW
- = so rejection has a negligible presence in papers
- 2011, Cook & co analysed more than 12000 scientific papers on global climate change and GW
- = 97.1% of the 4000 papers which stated a position in human-caused GW endorsed the consensus
- = other papers took it as granted
- = they asked peers to check their result so 1200 scientists rated 2000 papers & found 97.2%
- the dissenting views are negligible
- another study shows the scientific consensus has already formed in the 1990s
- in 1995, IPCC report found a "discernible human influence on global climate"
- 2013 IPCC report states it is more than 95% likely that human has been the most dominant cause of the observed GW since the mid-20th century

PEER-REVIEW

- Experts in the field scrutinize research before publication
- Ensure science is rigorous and evidence-based



SOCIAL CALIBRATION

IPCC STATEMENTS

- IPCC 1995
"The balance of evidence suggests a **discernible human influence on global climate.**"
- IPCC 2013
"It is extremely likely (**more than 95%**) that **human influence has been the dominant cause of the observed warming** since the mid-20th century."

97% of climate scientists agree that humans are causing global warming.



This is a strong knowledge-based consensus: based on a strong set of evidence, analysed by a social diversity of scientists with social calibration.

WEEK 1-2: CONSENSUS

4. KNOWLEDGE-BASED CONSENSUS

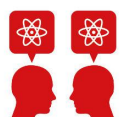
Ingredients of knowledge-based scientific consensus

- consilience of evidence:** many lines of evidence from independent sources all point to the same conclusion
- social calibration:** standards for that evidence
- social diversity:** agreement from ≠ groups & backgrounds

Consilience of Evidence



Social Calibration

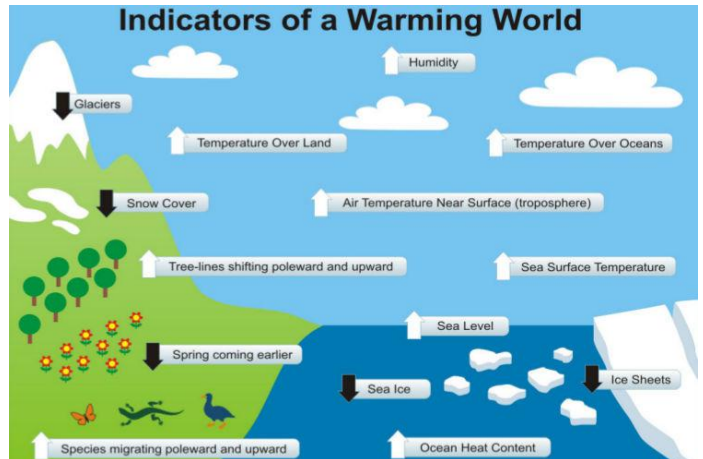


Social Diversity



Consilience of evidence of global warming

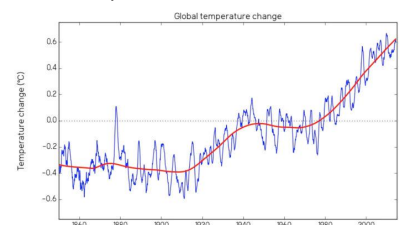
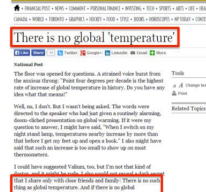
- thermometers on the ground, on ships (ocean) and on balloons (air) all show an increase in temperature
- glaciers around the world are melting
- sea level is rising
- moisture in the air is increasing
- = all of these indicators tell us the world is getting hotter



Social calibration for global warming

- to be able to address the question of whether the world is warming, you have to agree on some basic concepts
- = such as global temperature that can be measured across the planet to get an average (*yet some deniers deny the concept of global temperature*)
- scientists need to agree on rigorous standards of scientific enquiry to answer questions

NATIONAL POST



Social diversity for global warming

- a lack of social diversity can lead to wrong conclusions
- = avoids statistical flukes, contaminated materials, interference of the location of the scientists performing the experiment, groupthink, cultural bias, frauds etc.
- groupthink:** a desire for harmony within the group can promote conformity to avoid disagreement
- cultural bias:** scientists are products of their cultures and ≠ cultures have ≠ world views
- = so having social diversity helps ensure agreement isn't the product of values rather than evidence
- over 80 national science academies around the world agree humans are causing GW. None disagree.
- those with no stake or those who lose from an outcome, reaching the same conclusion as those who benefit, increases confidence that the conclusion is correct
- = clear social diversity on the consensus on climate

Myth against the knowledge-based consensus

- deniers argue that consensus, such as continental drift, have been wrong before but these did not meet all 3 requirements of knowledge-based consensus

WEEK 1-2: CONSENSUS

5. EXPERT INTERVIEWS: SCIENTIFIC CONSENSUS

Consilience of evidence (Santer)

- scientists have interrogated many ≠ aspects of climate, not just the average temperature, but looking at complex patterns of change in hard observations, using the latest technologies
- = natural causation alone can't explain observed changes
- into the stratosphere: complex pattern of warming low down & cooling up high
- = distinctive human fingerprint (greenhouse gases)
- human fingerprint in both size & timing of the seasonal cycle too (affected by changes in sea ice etc.)

Climate change consensus (Oreski)

- the IPCC reports and the National Academy's reports are accurate reflections of what working scientists actually think
- = they all agree climate change is underway and is mostly caused by human activities
- underlining the scientific consensus is important because a lot of people don't know about it as the media is presenting it as a great big debate

More on consensus:

- *Consensus on consensus* study - 2016:
<http://iopscience.iop.org/article/10.1088/1748-9326/11/4/048002>

WEEK 1-2: CONSENSUS

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Knowledge-based consensus

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WEEK 1-3: PSYCHOLOGY OF DENIAL

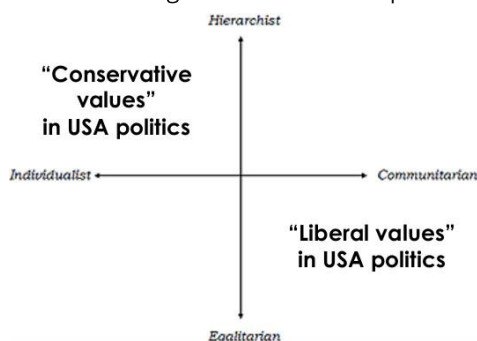
1. IDEOLOGICAL BIAS

Principal of evidence

- scientific method is founded on the principle that evidence determines what is considered factual
- multiple lines of objective, scientific evidence prove that humans are causing global warming
- this understanding is as strong as the settled fact that smoking increases the risk of lung cancer

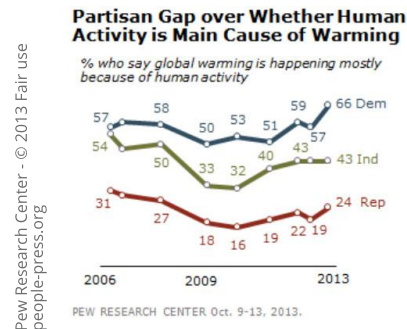


- a person's political persuasion influences their acceptance of facts
- people use motivated reasoning when they choose which facts they will accept and which they will deny
- 2013 US survey: only 24% of Republican voters believe GW is caused by humans compared to 66% Democrats
- = overall, political conservatism is associated with greater rejection of climate science
- education (unless climate-science specific) does not remove political bias
- = research shows a basic grasp of math & science translates to less acceptance of human-caused GW
- = but another research shows that specific understanding about climate science does translate to higher acceptance, even amongst Conservatives
- Dan Kahan's 2007 study: 4 categories to see how these shape understanding of controversial topics

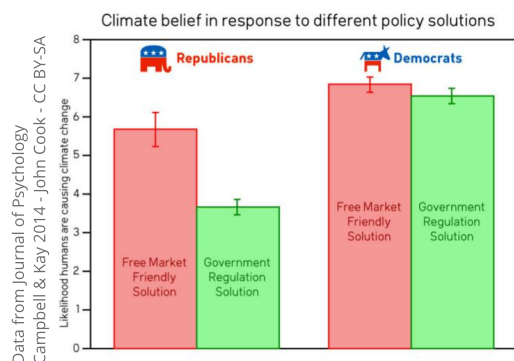


- hierarchical:** rights, duties & goods distribution based on defined & stable characteristics (wealth, gender etc.)
 - egalitarian:** distribution should be equal without regards to such characteristics
 - communitarian:** society should look after its individuals & society more important than individual needs
 - individualistic:** individuals should look after themselves without collecting interference or assistance
- = hierarchical+individualistic: usually conservative
= egalitarian+communitarian: usually liberal

- same study shows conservatives and libertarians rejected the same science about GW depending on the suggested solutions: if more anti pollution rules, they denied the science, if more nuclear, they were ok with it
- = people resist subconsciously factual information that do not fit with their values



- 2014 Campbell & Kay study: when the policy solution to GW was free-market friendly, conservatives reported much higher belief in human-caused GW than when the policy was increased governmental regulations - whilst liberals tended to accept the science in both cases
- = concerns that reducing GW will require government action can override scientific information because the implications are unacceptable to a person's ideology
- worldview backfire effect & social groups: if people belong to a group denying human-caused GW, facts alone won't convince them, they may even backfire



Political ideology creates a mental block, preventing some people from accepting the scientific evidence because of its implications.

Yet most people, regardless of political ideologies, accept the science when explained the greenhouse effect, the 97% scientific consensus & presented with free market solutions

Loyalty to social groups affects the way we learn new information

By using social science techniques like 'gateway information' we can learn to effectively communicate factual information to a broad range of audiences

WEEK 1-3: PSYCHOLOGY OF DENIAL

2. EXPERT INTERVIEWS

Climate change & politics

- climate change in the US is almost entirely motivated by politics, not by lack of access to information
- people not wanting to believe climate science because of its implications: that something must be done about it: personal or/and governmental measures and for individualistic worldviews, governmental interference is problematic and for conservatives, constraint on capitalism (even to reduce CO₂) is wrong
- data shows the strongest correlation between CC denial is with conservatives, not race, gender or religion
- people don't have the brain power to understand every single issue in the world so they go to the people they trust for information and for conservatives, that is conservative media and politicians who maintain CC is not a real problem
- there should not be a serious role for politics in science
- people must be aware that there is a small but vocal minority denying CC for personal ideological reasons
- this is not a scientific debate, it is a political debate made to look like a scientific debate

One of the most important driver to acceptance of scientific findings is a person's worldview.



People can reject the science because of its implications: climate governmental measures etc.

5 CHARACTERISTICS OF SCIENCE DENIAL



WEEK 1-3: PSYCHOLOGY OF DENIAL

3. 5 CHARACTERISTICS OF SCIENCE DENIAL

Skepticism vs denial

- **skepticism**: considers the evidence then come to a conclusion based on that evidence
- **denial**: comes to a conclusion first then rejects any evidence that conflict with their beliefs

Scientific consensus that face(d) denial:

- smoking link to cancer
- biological evolution
- human-caused global warming

5 characteristics of science denial (Diethelm & McKee)

1. Fake experts:

- foster the fake impression of an ongoing scientific debate which casts doubt about the science for the public, who rely on experts
- fake experts appear highly qualified but don't have expertise in the relevant scientific field
- people tend to attribute more expertise to those who agree with their beliefs & values, so the more they disagree with a consensus, the lower they think it is -> **magnified minority**: emphasise the few remaining scientists that reject a consensus, for instance some still refuse that HIV causes AIDS & though their views have lost respectability in the scientific community, they continue to cast doubt in the public's mind

2. Logical fallacies: distorts the science by drawing incorrect conclusions from the data

- can arise from **confirmation bias**, a tendency to favour evidence that confirm our beliefs
- **strawman argument**: focusing on an opponent's weaker argument while ignoring their strong ones -> **red herring**: distract with irrelevant info -> **misrepresentation**: oversimplification -> **jumping to conclusion**: faulty leaps of logic -> **false dichotomy**: presenting only 2 choices when others are available

3. Impossible expectations: demands standards of evidence that is impossible to achieve

- can rise from **disconfirmation bias**, when threatening evidence is vigorously resisted
- strategy pioneered by the tobacco industry which claimed insufficient evidence about smoking/cancer

4. Cherry picking: using small, select pieces of data, often out of context, while ignoring any inconvenient data

- putting more weight on agreeable information = breakdown at a nuclear power plant: pro-nuclear focused on the fact that safeguards worked whilst opponents focused on the breakdown itself so same event but ≠ conclusions & no change in their belief

5. Conspiracy theories: frequent among groups who disagree with an overwhelming consensus

- 20% US citizen, 15% UK think climate change is a hoax

= these bias are not always deliberately deceptive, they can be unconscious so best to address the techniques of denial than try to discern the motives of an individual, which could be counterproductive as it can provide them with opportunity to evade the scientific arguments

WEEK 1-3: PSYCHOLOGY OF DENIAL

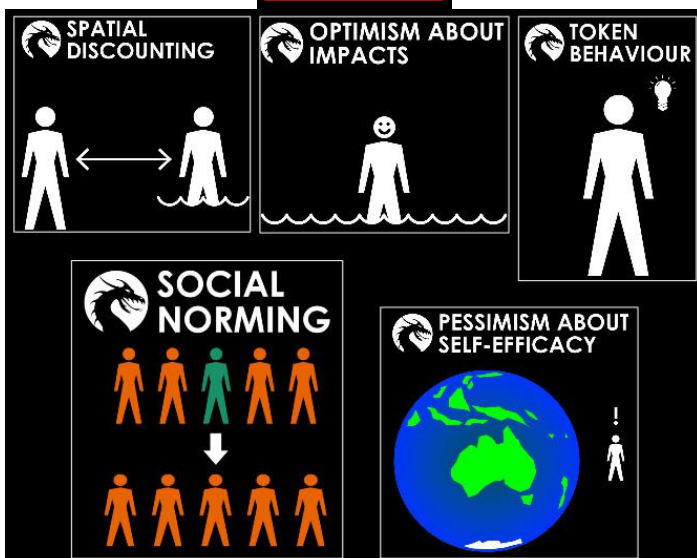
4. DRAGONS OF INACTION

Climate change (CC)'s threat

- unlike any threat humanity as ever encountered: involves gradual changes across the whole planet over decades rather than immediate dangers from predators
- people think of CC as affecting other people in far away parts of the world or not affecting people at all
- = of course the reality of CC is affecting all parts of the world right now but people don't think about it that way

Dragons of inaction - Robert Gifford

- = psychological barriers preventing people from acting to prevent climate change
- 1. **Spatial discounting**: when events seem far away, people tend to discount them: study shows people think environmental conditions are worse in other countries
- 2. **Over-optimism about impacts**: people systematically underestimate the risks they face from CC hazards
- 3. **Pessimism about self-efficacy**: feeling of helplessness and inability to solve the problem alone
- 4. **Social norming**: if people see others around them are not doing their part, they're more likely not to theirs either, thinking "if they don't bother, why should I?"
- 5. **Token behaviour**: doing easy actions (*changing light bulbs or recycling for instance*) that don't really have much impact unlike long-term behaviour changes and thinking it is enough "I've done my bit."
- 6. **Consensus gap**: gaping chasm between public perception of the CC scientific consensus and reality
 - = problematic because consensus is a gateway belief that induce more support for CC action
 - = arises from misinformation or lack of information

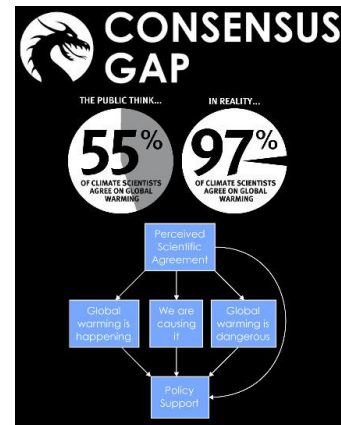


WEEK 1-3: PSYCHOLOGY OF DENIAL

5. EXPERT INTERVIEWS

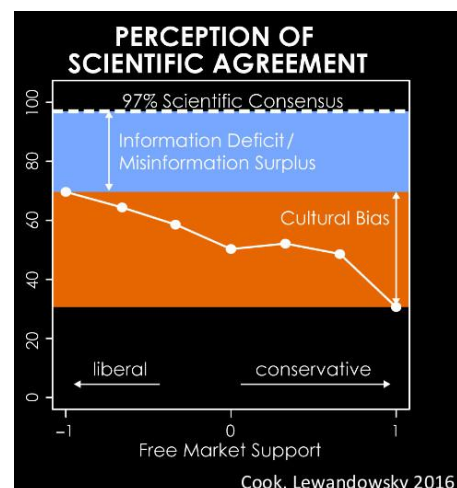
Skepticism vs denial

- **skepticism is the underlying principle of science**
- = scientists try to see what's wrong with others' theories, +they subject their own work to skeptical peer's review
- ignoring all of the evidence that refutes your explanation is not doing science, but pseudo science
- **deniers have no real interest in better understanding** what's going on in the world
- **deniers claim to be skeptic about climate science yet they easily accept any false information** about it, even if it is incoherent
- science denial cherry pick one scientist or a sentence out of context to make it seems there is still a debate
- **the use of scientists with credentials is absolutely critical to the strategy (of merchants of doubt) because people trust scientists much more than industry executives**
- to answer denial, it is essential to be driven by data, by research, by empirical findings (& psychology)



Psychological barriers prevent people from accepting the reality of climate change.

Explain to people why they should not believe misinformation and explain what is true instead.



WEEK 1-3: PSYCHOLOGY OF DENIAL

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PSYCHOLOGY OF DENIAL

- Psychology tells us that anti-science arguments can arise from unconscious psychological processes
- Misinformation can be indistinguishable from disinformation
- Address techniques of denial rather than motives

SKEPTICISM DENIAL



WEEK 1-4: SPREAD OF DENIAL

1. MANUFACTURING DOUBT

Confusing the public

- "Doubt is our product since it is the best means of competing with the 'body of fact' that exists in the mind of the general public. It is also the means of establishing controversy." 1970's Tobacco Industry memo
- the most effective way to neutralise scientific evidence is to raise doubt about the science in 3 ways:

1. cast doubt on scientific evidence:

- misrepresenting scientific papers
- cherry picking data
- conspiracy theories

2. attack the scientists themselves:

- abusive emails, intimidation of scientists
- excessive freedom of information act requests
- online attacks in blogs & discussion
- hacked private correspondence
- pressure on academic journals & universities with complaints that interfere with academic freedom
- scientists, including IPCC, consequently tend to underestimate the impacts of CC to avoid hostility

3. cast doubt on the scientific consensus:

- for over 20 years doubt has been manufactured to confuse the public

Tracking the money funding denialist media often lead to coal & oil industries.



These "merchants of doubt" help reluctant people to justify their rejection of the accepted science, by providing misleading arguments that look credible.

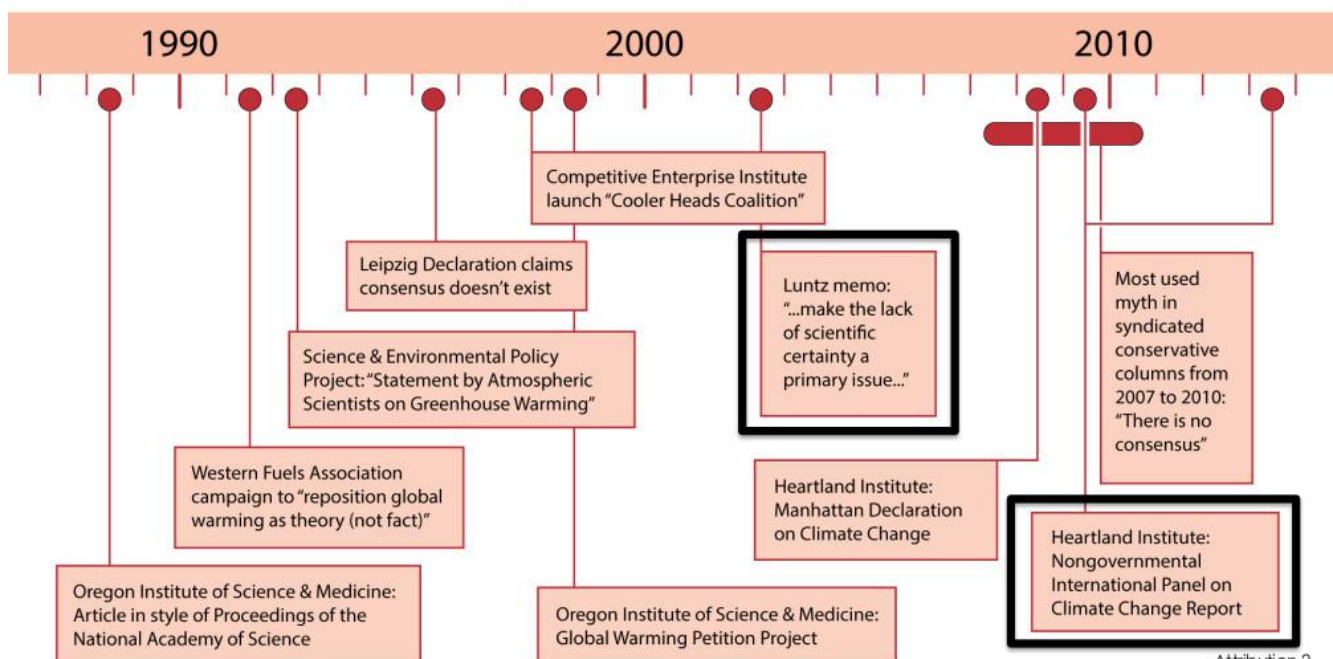
WEEK 1-4: SPREAD OF DENIAL

2. VESTED INTERESTS

Selling opinions

- advertising & media have a **vested interest** concerning the products so they sell opinions that favour them
- **coal & oil industries spread confusion**, a technique pioneered by the tobacco industry to confuse people about the dangers of smoking, long after its connection to cancer was established by science
- Union of Concerned Scientists listed some of the ways that the oil company **ExxonMobil waged a most successful science denial campaign using:**
 - = **information laundering:** seemingly independent front groups that pretend to be doing science but are conducting public relations for the company instead
 - = virtually all of these front groups publicize the misleading work of the same small number of board members or scientific advisors
 - = creates the illusion that many organizations & people have doubts about GW, which confuses people
 - **a few fossil fuel interests have funded the campaign to manufacture doubt about human-caused GW**
 - from 2005 to 2008, ExxonMobil spent \$8.9 million to fund climate misinformation groups & Koch Industries, also heavily invested in fossil fuels, \$24.9 million
 - **most oil companies adopt public statements accepting CC science but still fund groups that lobby against CC governmental policies & spread disinformation**
 - some people are instinctively unwilling to accept the CC science, because they don't like the proposed solutions
 - yet, surveys show that scientists are still the most widely trusted groups whatever people's political convictions
 - = **the overwhelming opinion of genuine experts cannot forever be brushed aside by campaigns of false experts manufacturing doubt where none exists**

Manufacturing Doubt about Scientific Consensus



Attribution 2

WEEK 1-4: SPREAD OF DENIAL

3. MEDIA BALANCE AS BIAS

Inaccurate reflection of the science

- media try to give both sides of an issue equal voice, to give a 50/50 balanced non biased coverage
- appropriate for matters of opinions but not for scientific facts, especially not when 97% agree and only 3% deny
- = **does not accurately reflect the consensus but amplifies a small vocal minority of deniers**
- manufacturers of doubt exploit this journalistic norm of balance to spread doubt effectively **because many people get their information from mainstream media**
- study shows 1 group only CC science coverage and another group mixed media coverage (CC+denier)
- = 1st group had low perceived agreement (48%) but mixed media group even lower (36%)

Mixed media coverage lowers acceptance of the reality of climate change and subsequently, of the necessity to support climate action.



Communicate about the 97% scientific consensus can help neutralising mixed media coverage, as well as an effective debunking of denial.

- Cook's similar research & results with written coverage
- media coverage has great influence on CC perception
- 1988-2002: half of leading US newspapers gave deniers equal weight with climate scientists
- = **false perception of a divided scientific community**
- 2003-2006: US prestige press coverage improved with nearly 97% of coverage was accurate
- but US network television 70% mixed coverage 50-50
- to **neutralise mixed coverage influence**:
 1. explain the misleading influence of mixed coverage
 2. communicate about the 97% consensus
- = more context helps people more accurately understand

WEEK 1-4: SPREAD OF DENIAL

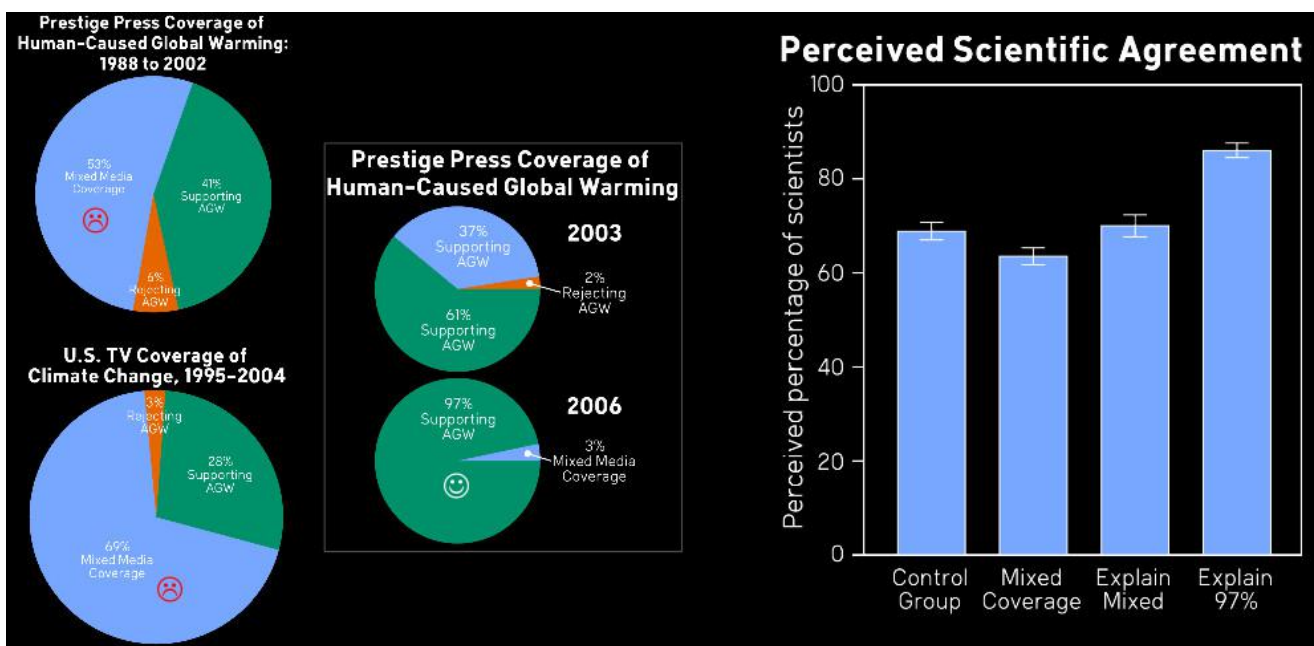
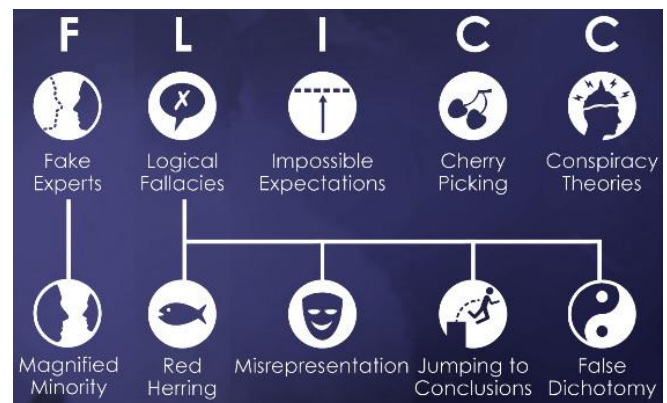
4. STRUCTURE OF AN EFFECTIVE DEBUNKING

Psychology of debunking

- present both the correct information and the myth BUT explain why the misinformation is incorrect**
- don't give the myth too much attention** as it could end up reinforcing the myth rather than refuting it
- warn people before presenting a myth** so they are less likely to be influenced by it

Structure of debunking

- FACT
- MYTH
- FALLACY
- GO TO WEEK 6 for more info on debunking**
- use FLICC to explain the fallacy
 - > 5 characteristics of science denial
 1. fake experts
 2. logical fallacies
 3. impossible expectations
 4. cherry picking
 5. conspiracy theories



WEEK 1-4: SPREAD OF DENIAL

5.1. EXPERT INTERVIEWS: SPREAD OF DENIAL

Vested interests & political networks

- Robert Brulle's research:
 - = analysed tax returns filed by a huge number of so-called US think tanks & lobbying outfits
 - = concluded up to a billion dollars a year go into a propaganda machine, part of which is used to deny CC
- vested interests also include people who don't want government's interference in industry

Blogs & medias

- most people, politicians included, get information not directly from scientific reports, but from blogs & media who may give it an ideological spin & repackage
- Union of Concerned Scientists
 - = CNN: 30% false information on CC year before study
 - = Fox News: 70% false year before & 90% that year
- CC denialism misrepresents or cherry pick CC science

Fake experts

- the use of scientists with credentials is essential to the strategy of manufacturing doubt because people trust scientists more than industry executives
 - = since 1950s, recruitment of scientists as a keypoint strategy for industries to spread denial

Climate science denial is motivated by vested interests, politics, ideology & other psychological factors.

Deniers put pressure on scientists & editors, misrepresent the science, make science denial look like a scientific debate whereas it is a political one.

Media balance as bias

- gives false impression that there are 2 possibilities, 2 interpretations of the science whilst there is really just 1
- gives equal time to wrong ideas = misinformation

Nothing scientific in denial

- none of the opposition to climate science is scientific
- a lot of denial is motivated by money, vested interests, politics, ideology & other psychological factors

WEEK 1-4: SPREAD OF DENIAL

5.2. EXPERT INTERVIEWS: ATTACK ON SCIENCE

Deniers put pressure on scientists

- talking about CC off a campus, even just in a church or school, can cause harassment such as:
 1. hate mails & letters
 2. complaints to the scientists's university
 3. requests for e-mails, hacking & releasing e-mails
 4. routine online attacks
 5. threats on scientists' funding
 6. attacks on scientists' integrity & person
 7. Freedom of information act abusive request used to intimidate, threaten, take up scientists' time
 8. conspiracy theories, cf Naomi Oreskes accused of being part of a scientific conspiracy to bring down capitalism
- the attack on science is a proxy to discredit science that may prove inconvenient for certain interests
- internet enables denials to harness their supporters to go after individual scientists

Denial is misrepresenting science

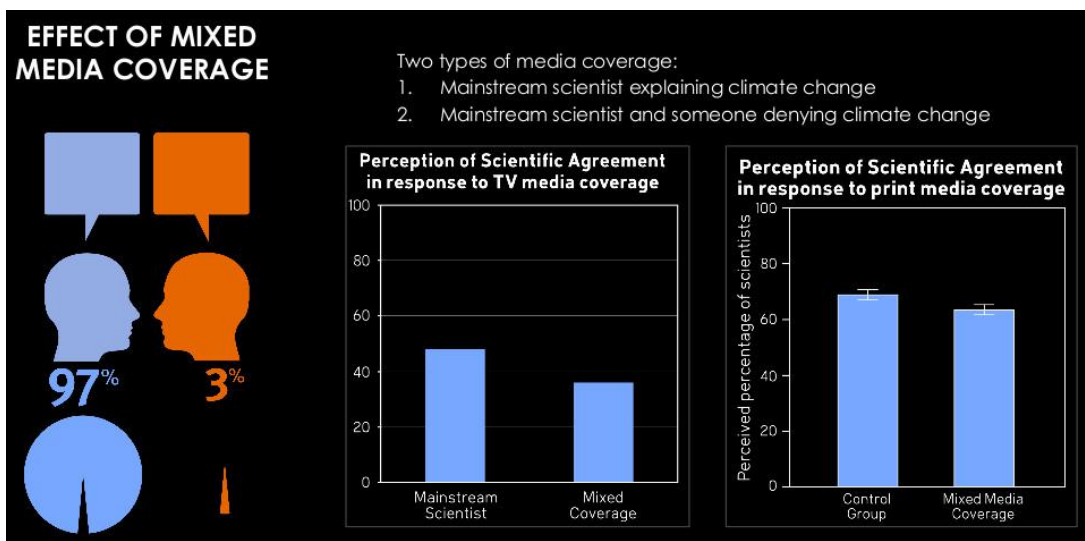
- cherry picking & distorting the science
 - = early work by Jim Hansen taken out of context to argue that CC is caused by the sun when in fact his paper argues exactly the opposite

Deniers put pressure on editors

- bullying editors to try to get them to retract articles saying that CC is real because threatening to their case

Denial is not focusing on the science

- no interest in understanding, contributing but only in tearing down & destroying science inconvenient to them
- important to maintain high standards of documentation to inform people, institutions etc about this problem



WEEK 1-3: SPREAD OF DENIAL

6. REFERENCES

Manufacturing doubt

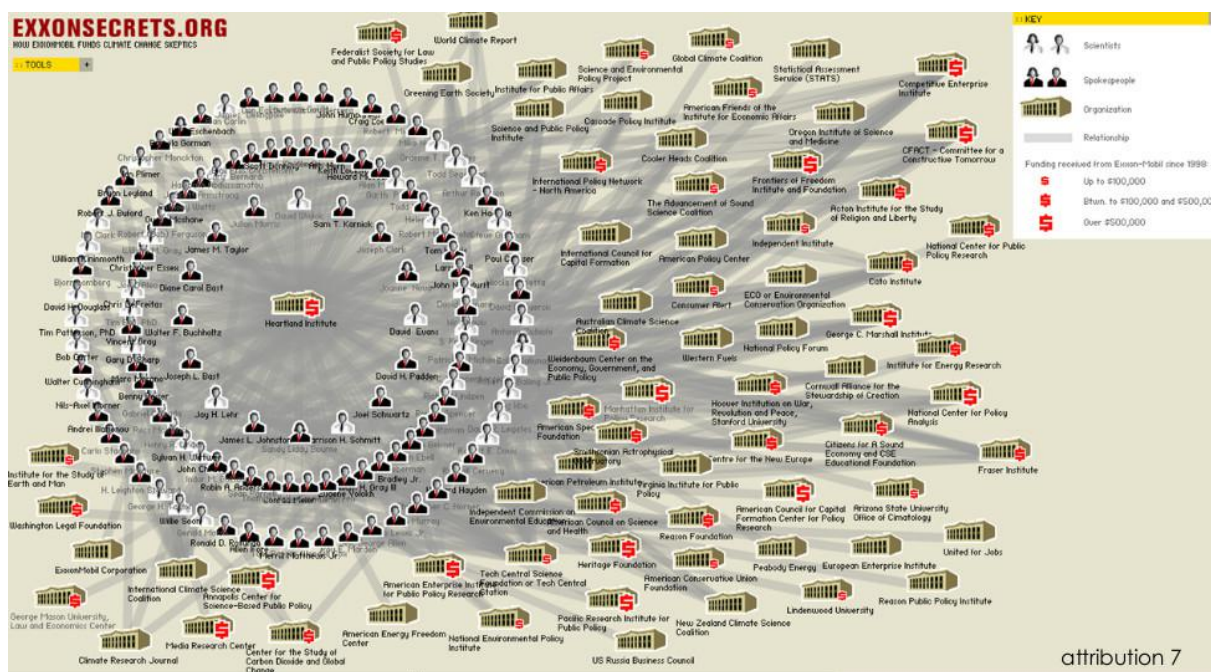
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WEEK 2-1: OVERVIEW

- BACK TO BASICS: EXAMINING THE MANY DIFFERENT INDICATORS THAT OUR PLANET IS WARMING
- CHALLENGING MYTHS CASTING DOUBTS ON THE BASIC REALITY OF GLOBAL WARMING

Global warming is about the temperature averaged over the whole planet.

Even while the planet continues to build up heat, some places will still experience cold, even record cold, at times.

We'll look at the heat building in our climate system and how that affects heat records and sea level rise.

WEEK 2-2: WARMING INDICATORS

1. HEAT BUILD UP

Heat-trapping gases

- over the past century, humans have released huge quantities of heat trapping gases into the atmosphere
- = this has **caused the earth to warm on a global scale**

Global air temperature

- misunderstanding arise from looking at just one place or just one time period because of weather variation
- but there is a **general pattern of warming if we combine weather records from many locations over the world**

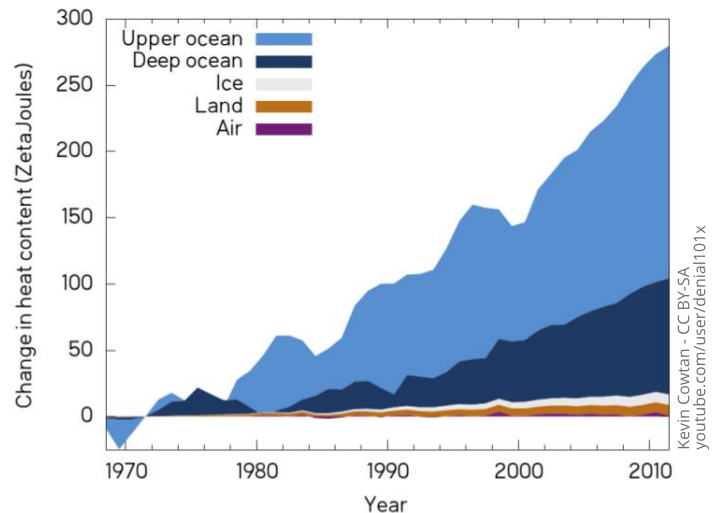
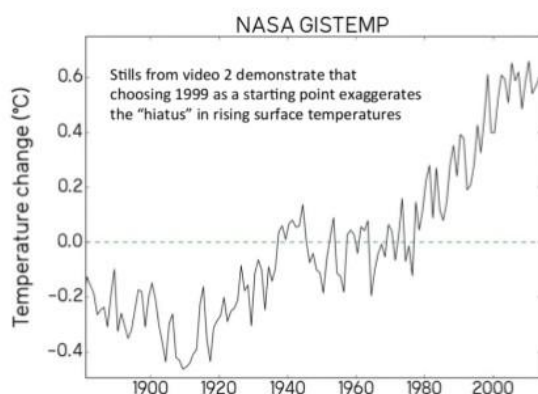
Myth about global warming having stopped

- pretends that GW stopped in 1998 because of air temperature is cherry picking because this was a hot year compared to many in the last two decades and it ignores other warming factors such as:
- most of the Earth is covered by water
- water can hold a lot more heat than air
- = **more than 90% of the extra heat trapped by greenhouse gases goes into warming the oceans**
- = some of what's left warms the land, or melts ice
- = only about 2% ends up in the atmosphere

Heat-trapping gases released by humans have caused the Earth to warm on a global scale.

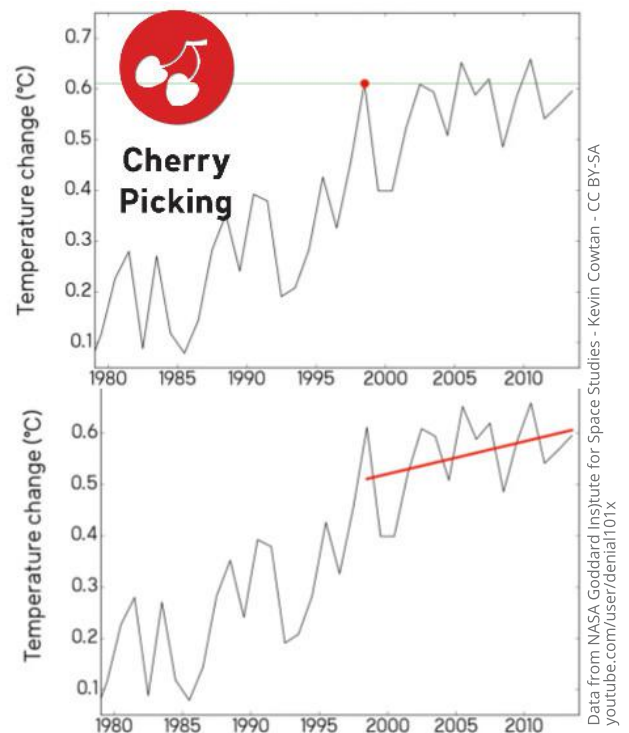


More than 90% of this trapped extra heat goes into warming the oceans, which causes sea-level rise, because of thermal expansion.



Identifying cherry picking

- when you see a claim based on data from just one country, or one or two decades, ask yourself "why did they chose that data"? What happens if you look at the bigger picture?
- = if we look at the heat in the whole climate system including the oceans, not just in the atmosphere, we can see that the heat in the system has continued to increase since 1998



WEEK 2-2: WARMING INDICATORS

2. HOT RECORDS

Weather against climate

- weather changes all of the time, so variations are observed day to day. Climate only changes when something makes it change and changes can only be observed over long time periods such as decades
- GW does not stop cold weather from happening

Weather stations

- more than 10 000 weather stations over the world
- just counting temperature records is misleading but instead we can count the number of hot & cold records and compare it in any decade
- = we see more hot records than cold, so GW is happening
- = this is a very simple but efficient way to analyse data but scientists have even better ways of detecting warming

What is climate?

- climate is how likely you are to get \neq kinds of weather
- \neq parts of the planet have \neq climates: colder
- normally, there is one mix of weather is likely to happen at one place, for instance Alaska is cold and Arizona hot

Climate change

- if the climate changes, different kinds of weather happen more or less frequently
- = if the climate gets warmer, you are more likely to get exceptionally hot days and less likely cold ones BUT you'll still get cold records
- GW is like rigging the climate "dice" (see video)

Confusing weather & climate myth

- fallacy of false expectations to think that because GW is happening there should be no cold days

Impacts of climate change

- climate change is gradual: most noticeable impacts will be on water supply, extreme weather & agriculture

WEEK 2-2: WARMING INDICATORS

3. SEA LEVEL RISE

Why is sea level rising?

1. Thermal expansion

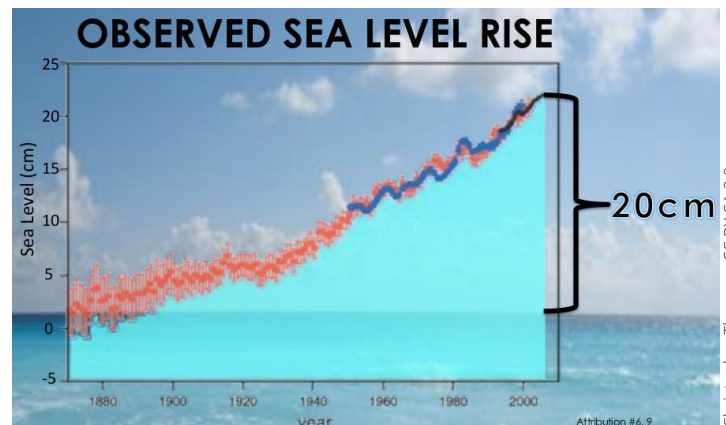
- this is an indicator of GW
- = thermal expansion of seawater as oceans get warmer
- = warm water expands, takes more place than cold water
- this effect alone has been responsible for a lot of the sea level rise observed so far
- thermal expansion is straightforward basic physics

2- Melting of land ice

- glaciers & the 2 ice sheets (Greenland & Antarctica)
- when sea ice melts, it does not add to sea level (just like ice cubes melting in a glass don't make its water go up)

How much is sea level rising?

- stitching tide gauge record with satellite's, scientists have found sea level rose about 20cm since 1880
- rate of sea level rise is increasing: rising more quickly now than over the past century
- how much sea level rise will rise in the future depends on how much CO_2 we'll emit
- IPCC report estimates about half a meter by the end of the century whilst other reports expect twice as much
- difficult to know for sure how much but scientists expect more sea level rise in the 21st than in the 20th century



A myth about sea level rise

- pretends it is exaggerated & is slowing down
- = cherry picking a short term change in sea level (in a particular year) while ignoring the long term trend

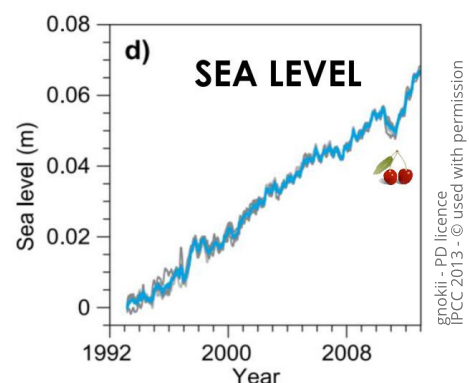
Consequences of sea level rise

- can displace populations
- allows storm surges from tropical storm system to penetrate further inland to places previously untouched

Sea level rose about 20cm since 1880 and the rate of sea level rise is increasing much more rapidly now than over the past century.



Global warming means that it is most likely to get hot records than cold ones but it does not mean there will never be cold records at all.



WEEK 2-2: WARMING INDICATORS

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WEEK 2-3: CRYOSPHERE

1. SHRINKING GLACIERS

What are glaciers?

- they are not rigid: they act like a soft plastic, which can bend & flow downhill like slow-motion rivers of ice
- not only on mountains: any mass of ice which remain year round is also a glacier
- glaciers gain ice from snowfall & loses ice through flowing into lakes or ocean or melting in the summer
- act like water towers in some areas for cities downriver: they store water in winter & release it during summer

Glaciers are shrinking

- most glaciers expanded until late 19th & began retreating after, even more rapidly in the last 2 decades
- retreat has accelerated particularly in the Polar regions
- rapid warming has disintegrated some small glaciers
- many of the smallest mountain glaciers in the Alps & other mid-latitude locations will eventually disappear

MUIR GLACIER



William Osgood Field - Bruce Molnia; USGS - CC BY

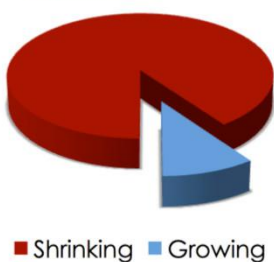
QORI KALIS GLACIER



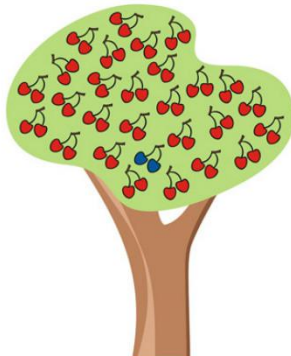
Lonnie Thompson; Ohio State University- CC BY

Excluding the polar ice sheets, glaciers are losing about 150 billions tonnes of ice each year.

Proportions of Growing and Shrinking Glaciers



Keah Schuenemann - CC BY-SA



How do we know glaciers are shrinking?

- satellites measured gravity feeling weaker & weaker over glaciers as they melt
- sample cores taken from ice in the Canadian Arctic show recent melt is the greatest in 4000 years
- moraines: ridges of sediment remaining long after a glacier has retreated, useful to estimate its previous size



Wilson44691 - PD licence - Wikipedia

- ancient vegetation preserved under ice is thawing out and dating them shows that they had been covered by ice for thousand of years



Photo credit: Matthew Kennedy, Earth Vision Trust, and INSTAAR's Baffin Island research team, on behalf of INSTAAR, University of Colorado Boulder

Matthew Kennedy, Earth Vision Trust, INSTAAR's Baffin Island research team, on behalf of INSTAAR, University of Colorado Boulder - © used with permission

- = some glaciers are now smaller than during anytime in the past several thousand years

Glaciers & climate

- glaciers are very sensitive to climate: need low summer air temperature & high winter snowfall to form
- changes in air temperature therefore affect them

A cherry picking myth about glaciers

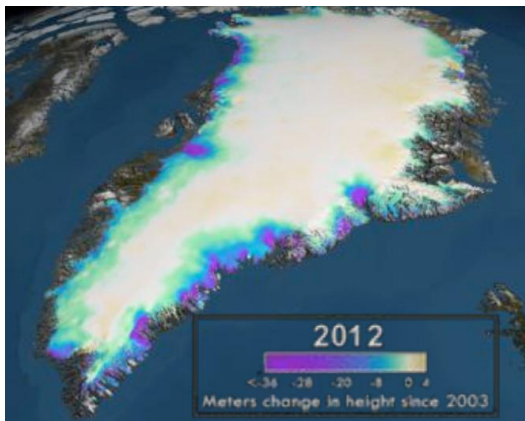
- over 100 000 glaciers in the world so even though most are shrinking, you can find a few that aren't
- annual mass balance: the difference between the total gain and losses of an ice mass measured over a year
- because some glaciers's mass balance are more affected by snowfall than temperature & warmer air holds more moisture so can cause more snow
- a warmer regional climate may cause glacier to temporarily grow, but overall, most glaciers worldwide are now shrinking and will continue to do so as it warms

WEEK 2-3: CRYOSPHERE

2. GREENLAND ICE LOSS

How much is the Greenland ice sheet losing ice?

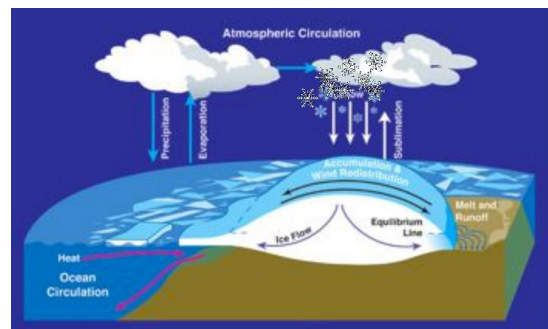
- currently losing over 300 billion tonnes of ice every year
- = more than the entire weight of Mount Everest
- its total melting would cause sea level to rise >6 metres
- very sensitive to climate change: around 400 000 years ago, when global temperature was 3°C warmer than now, its melting caused sea level to rise by 4.5 metres
- Greenland is now the largest individual contributor to global sea level rise and its ice loss is on the increase



How can an ice sheet lose that much ice?

- ice sheets are the largest physical features on Earth
- they rise kilometres up in the air
- Greenland loses ice in a few ways:
 1. icebergs break off the end of glaciers
 2. ice melts at the surface then runs off into the ocean=> some of this melt water drains into deep channels in the ice called "moulins" which can act as lubricant if it reaches the base of glaciers & speed up their flow into the ocean
- 3. floating ice at the edges of ice sheet act as a cork, holding back ice sheets & preventing them from melting into the ocean but warmer air & oceans "pops the cork" and let the outlet glacier fall faster into the ocean

- Greenland also gains ice in its interior: when snow falls in winter or when summer meltwater refreezes
- so we must look at the total mass of Greenland's ice to see if it is increasing or decreasing
- temperatures in Greenland have increased by nearly 2°C over the last 150 years
- satellites data show the surface area of ice melt on Greenland has doubled over the past decade
- satellites also show that most of Greenland's largest outlet glaciers are speeding up and losing more ice
- = Greenland has been losing ice at an accelerated rate



A cherry pick about Greenland

- looking only at the ice build up in its interior & not considering the rest of Greenland ice
- = myth that Greenland is gaining ice
- in the 1990s, warmer air meant more snow which led to a temporarily balance between loss & gain
- but since early 2000s, the amount of ice being lost in coastal areas began to exceed ice gains in the interior and this process is accelerating

What about other ice sheets?

- 3 major ice sheets: Greenland, East & West Antarctica
- if all 3 melted, sea level would rise by nearly 80 metres

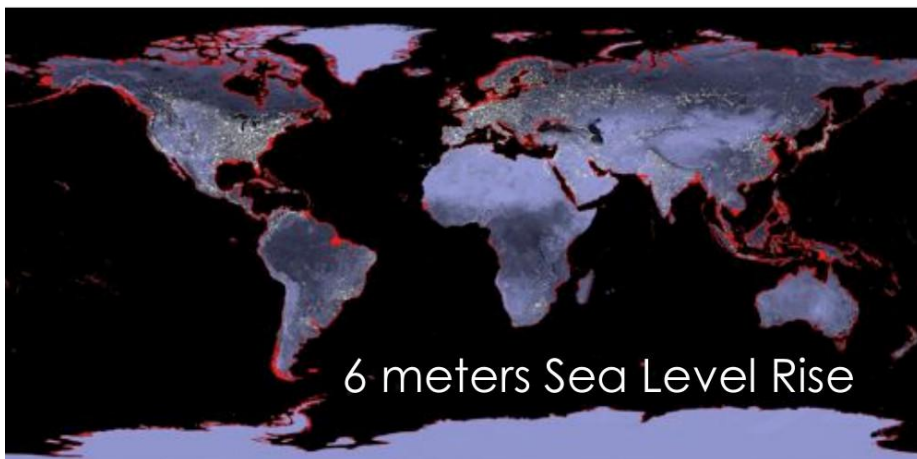


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Greenland is currently losing over 300 billion tonnes of ice every year, making it the largest individual contributor to global sea level rise.

☀️
if all 3 major ice sheets were to melt, sea level would rise by 80 metres.

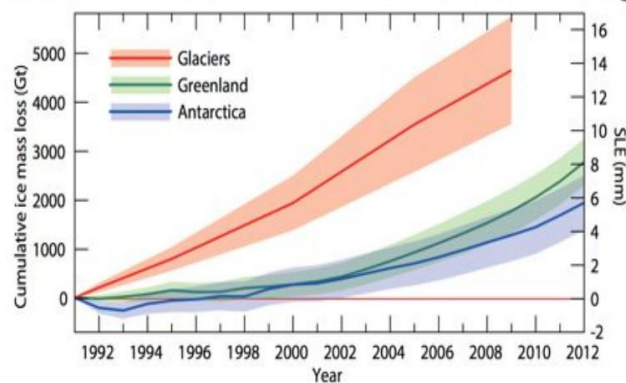
WEEK 2-3: CRYOSPHERE

3. ANTARTIC LAND ICE VS SEA ICE

How much land ice is Antarctica losing?

- West Antarctica: losing >100 billion tonnes of ice/year
- = is a large contributor to sea level rise
- East Antarctica: is relatively stable since the 1990s
- Antarctica contains 18% more ice than Greenland, its entire melting would cause sea level to rise by 7 metres
- East Antarctica ≈ 32 million years old
- West Antarctica formed millions of years later
- East Antarctica Sheet is the largest ice mass in the world
- = roughly the size of the United States
- if both melted, global sea level rise would rise 72 metres

Contribution of Glaciers and Ice Sheets to Sea Level Change

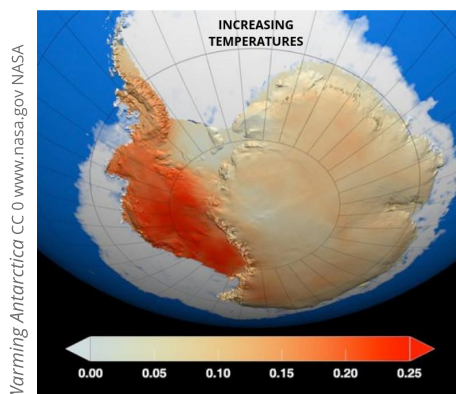


Contributions to sea level change
© with permission IPCC AR5 Fig 4.25 IPCC

How can an ice sheet lose that much ice?

- Antarctica is made almost entirely of ice and snow
- satellite data show both the Antarctic Peninsula & West Antarctic Ice Sheet are losing ice
- in both regions, ice loss has accelerated since 1990s

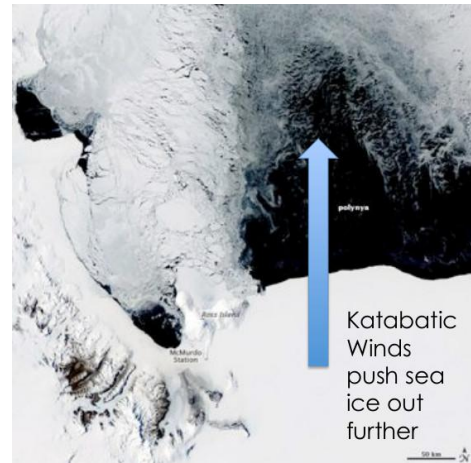
West Antarctica is currently losing over 100 billion tonnes of ice/year and its ice loss has accelerated since the 1990s, making it a large contributor to global sea level rise.



Warming Antarctica CC 0 www.nasa.gov NASA

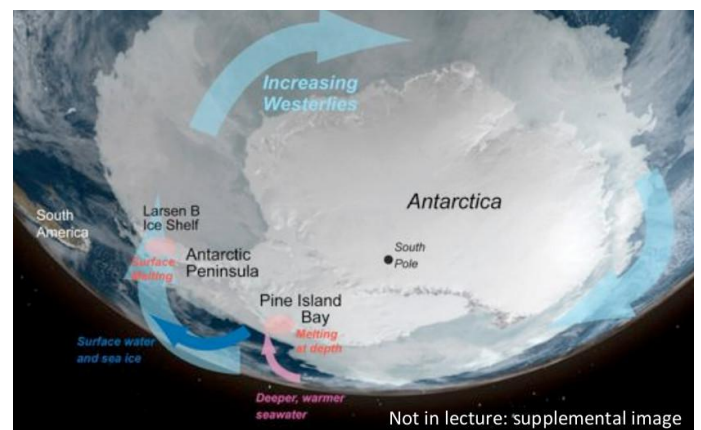
What about sea ice in Antarctica?

- Antarctica sea ice forms in the ocean waters around the continent each winter then it melts
- = Antarctic sea ice is mostly seasonal so does not affect global climate as much as Arctic sea ice
- the area of sea ice around Antarctica has been increasing over the last few decades, despite warming of the ocean



Polynya CC 0 earthobservatory.nasa.gov
NASA Earth Observatory

1. winds have been increasing & carry more cold air to the ocean where sea ice forms & blow sea ice away from coastline = more sea ice form from extra open water
2. increasing melt water from coastal glaciers because fresh water is easier to freeze than salt water
3. Antarctica's climate change increases snow fall
4. even though Antarctica has a whole has warmed, there are also regional differences with some areas cooling



<http://www.nasa.gov/topics/earth/features/unstable-antarctica.html> NASA/NSIDC

What about Antarctica gaining ice

- this myth relies on an error of omission, it ignores the difference between sea and land ice
- also cherry picking: focusing on one small part of Antarctica's cryosphere whilst ignoring the full picture
- scientists are confident that both changes in sea ice & land ice are linked to climate change

WEEK 2-3: CRYOSPHERE

4. FROM THE EXPERTS: CRYOSPHERE

What is the cryosphere?

- cryosphere means the cold environment, the cold / frozen component of the Earth
- = seasonal snow cover, sea ice, glaciers, ice caps, ice sheets & permafrost

How do we measure ice mass etc?

- satellite technology have revolutionised the way scientists can look at polar region, making it accessible
- they measure changes in the gravity field of the earth: as mass goes from land into the ocean
- laser & radar altimeters measure very accurately changes to a few millimeters/year of ice sheet surface
- altimetry & gravity measurements can be taken over all Greenland and most of Antarctica

What do scientists observe with this measurements?

- Greenland is losing ice faster: small amount of increase in the interior but big losses around the margin
- there are ≈ 210 outlet glaciers in Greenland: 99% of them are retreating & 90% has accelerated
- Antarctica's mass loss is increasing & West Antarctica's accelerating with time
- Antarctica's ice is up to 5km thick (3.5 miles) so if that goes into the ocean, its level goes up

- West Antarctica may have already contributed more than 3 metres of sea level rise
- geometry of West Antarctica is in a potential unstable configuration: a little change can trigger rapid mass loss and that cannot be easily reversed
- ice decay is going faster than predicted by models
- a pretty continuous decline in Arctic's sea ice since mid 1970s & it's unequivocal
- for 24 consecutive years, alpine glaciers around the world on every continent have lost mass globally

What are the consequences of ice loss?

- glaciers act like an insurance policy: they hold the snow in winter then release it in summer dry's months
- = they even out annual precipitations
- but as they are getting smaller & smaller, their ability to provide water when needed is getting smaller
- = this has tremendous consequences for people who live in areas that depend on those water sources

Ice loss has big impacts on agriculture & dangerous consequences in sea level rise.



Humans are very vulnerable to sea level rise: if sea level goes up by just 1 metre, it could displace up to 200 million people

WEEK 2-3: CRYOSPHERE

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WEEK 2-4: TEMPERATURE

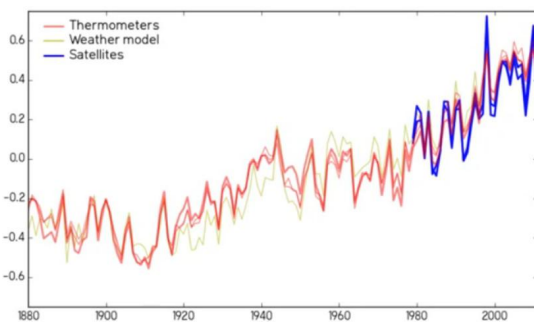
1. BUILDING A ROBUST TEMPERATURE RECORD

How do we measure global warming?

- **thermometer records**, maintained & checked by a number of groups tell us the planet is warming
- **weather forecasting software** estimate air temperature using ship data & air pressure observations
- **satellites** measure air temperature from the radio noise coming from different layers of the atmosphere
- **tree-rings & ice cores**: natural thermometers that can give temperature records over much longer periods

Myths about thermometer records

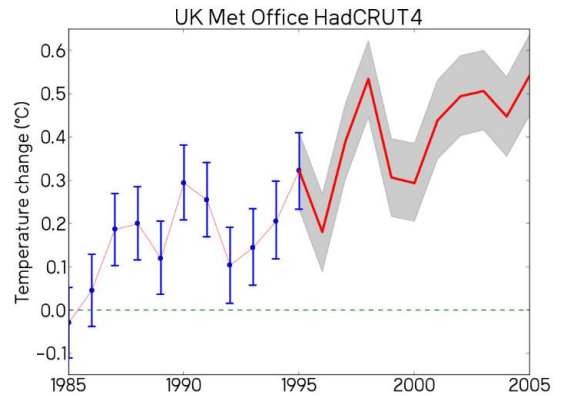
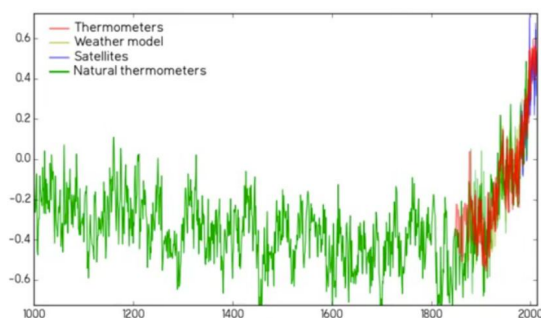
- claim they are unreliable to calculate global temperature
 1. claim early thermometer readings not precise enough
 2. claim there aren't enough weather stations worldwide
- **jumping to conclusion: estimated measurement errors are much smaller than the warming observed**
- thermometer is reliable because the data tell us so
 - + it agrees with all the other sources of temperature data



Thermometer records, satellites & weather forecasting software all confirm the planet has been warming over recent decades.

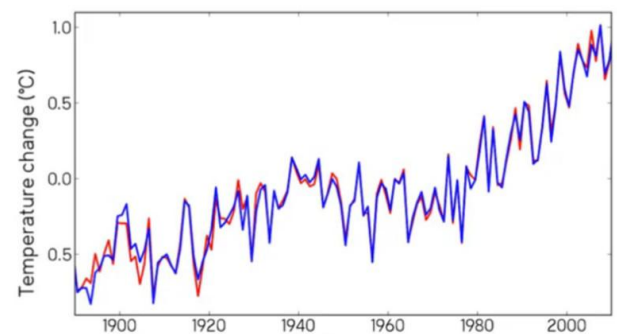
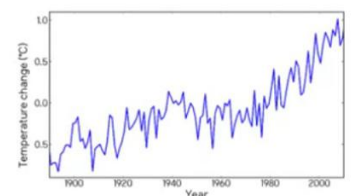
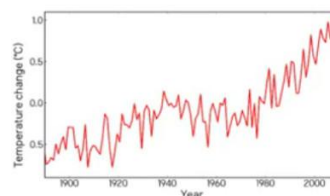
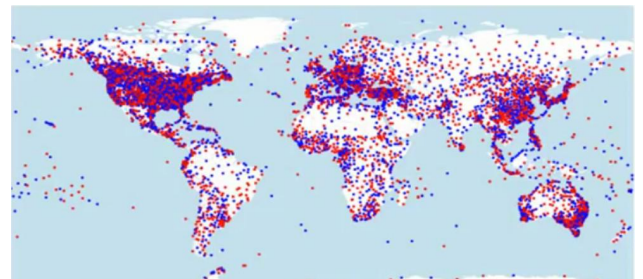


Tree-rings & ice cores show that recent warming is very different from natural climate change



How do we know measurements are accurate?

- **uncertainty of measurement**: scientists work out how "accurate" their measurements are by estimating how far off it might be
 - in a graph it is shown by errors bars or by shading
 - 2 weather stations close together should have similar records, if their thermometers are accurate
- = thus we can check global temperature, by dividing the world's stations by half & comparing the results
- => both graphs are very similar, the small difference between them give us the accuracy of the record

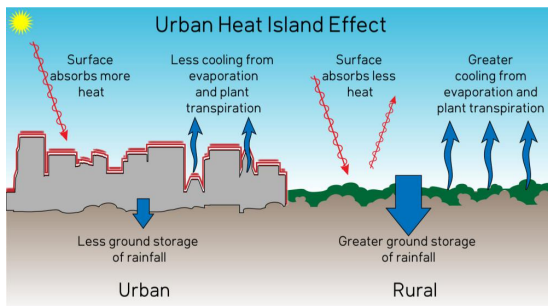


WEEK 2-4: TEMPERATURE

2. HEAT IN THE CITY

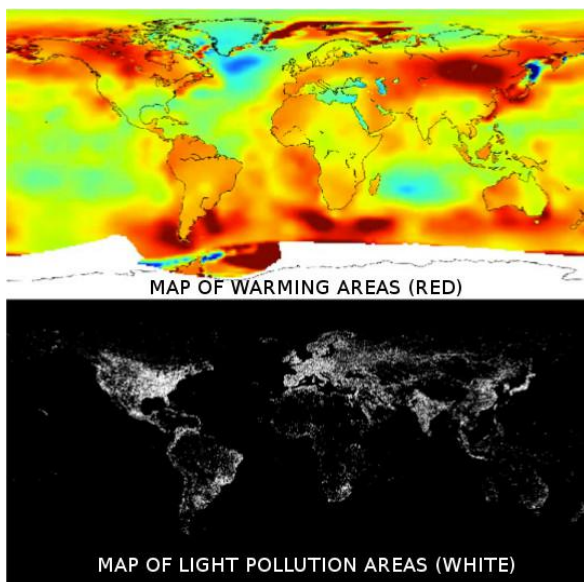
Data collection

- fundamental to every branch of science
- to construct a reliable record of climate spanning a century or more, we need to understand how the observations are influenced by **non-climate factors**, such as changes in the instrument & their environment
- **Urban Heat Island effect**: on hot summer days, urban areas are noticeably warmer than rural areas because
 - => urbanisation creates darker surface which absorb light rather than reflecting it
 - => urban areas also have less moisture to cool the air
 - => of other factors, like waste heat from human activities



Urban heat does not affect GW measurements

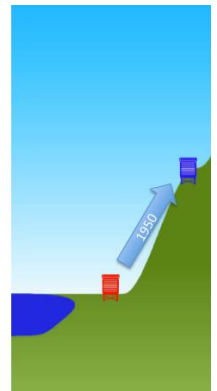
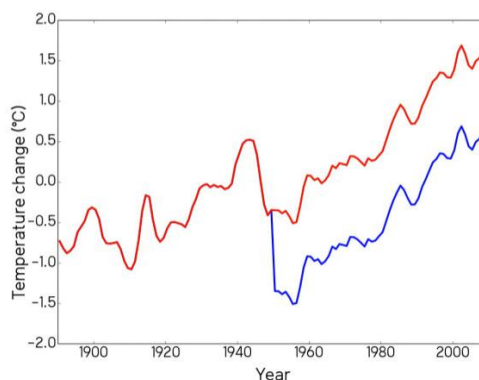
- **Bekerley Earth project**: comparing maps of the areas that have most warmed with maps of human development shown by light pollution does not match
 - = some areas warming have little human development: oceans, Amazon basin, Mongolia, American Arctic
 - = some highly developed countries show little warming: China, south-eastern US
- NASA adjusted urban stations to match the nearest rural station and the results are almost identical
- UK Met Office compared temperature trends for still & windy days: found no significant difference
 - = these studies + other evidence all tell us that urban heat has islands have a minimal effect on global warming



Kevin Cowtan - CC BY-SA
youtube.com/user/denial101xData from Global Historical Climatology Network

Myth about urbanization

- **jumping to conclusion**: saying that urbanization, and not the greenhouse effect, is responsible for GW
- saying that something could affect data does not mean that it truly does: this myth is rejected by data
- another (jumping to) confusion arises from the fact that **scientists make correction to weather station data** & some people wrongly claimed that data is incorrect
 - = **adjustments are necessary to avoid mistakes in case of changes** in station location, instrumentation etc.
 - => if a station is moved up a hill, it may record cooler temperatures than before the move, so scientists adjust data otherwise it may result in a false cooling effect

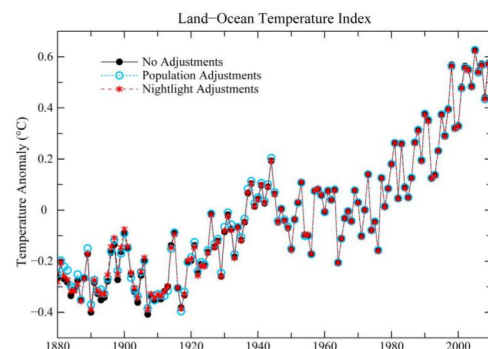


- checking temperature records with & without adjustments show the difference is not significant

Urbanization has no significant impact on global warming.



Adjustments made to weather stations have a very small impact on data.

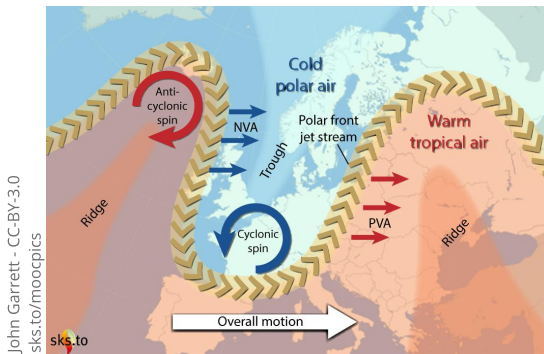


WEEK 2-4: TEMPERATURE

3. WAVY JET STREAMS

The jet stream

- is a narrow band of strong winds near the top of the troposphere, about 10km above the Earth's surface
- is like a fast moving river of air
- its wavy shape & location changes with the weather
- under the ridges¹ formed by the jetstream are warm & dry conditions
- ridges can sometimes open a door to the poles & allow for cold Arctic air to blow down through the trough²
- this cold air was sitting over traditionally cold areas but this weather pattern, also known as blocking pattern, brings it down to lower latitudes so the poles are getting warmer & lower altitudes colder
- = like a balancing act, warm air does not disappear, it moves to other places



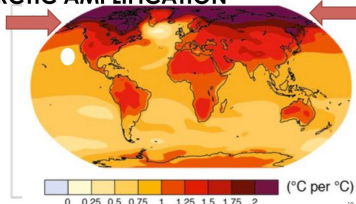
Myth about cold weather & global warming

- = cherry picking a local region instead of looking at the global picture
- cold weather events mean that cold air leaked down from the poles to a region: an exchange of air masses
- = does not disprove global warming
- global warming is the average global temperature change, not the temperature you feel at your local area

Hypothesis about climate change & jet stream

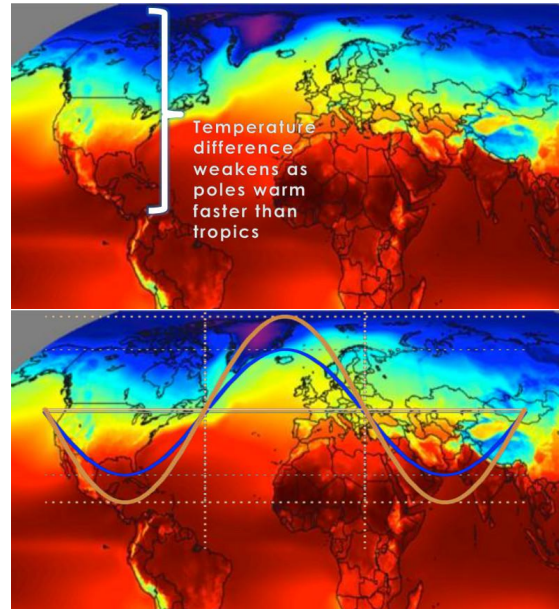
- CC might be creating conditions for a slower wavier JS
- the strength of the JS is based on the pressure gradient force which depends on the Δ in temperature across the polar front: between warm tropical vs cold polar air
- Arctic amplification: Arctic is warming faster than any other region on Earth, twice as fast as global average
- => self-reinforcing cycle caused by GW: ice melts, revealing dark surfaces underneath which absorb more sunlight & so gets warmer, which melts more ice etc.

ARCTIC AMPLIFICATION



Keah Schuenemann modified from IPCC 5th assessment report © used with permission

- as Arctic gets warmer, the cold side of the JS is a few degrees warmer than usual so the Δ is less important so the JS can be slowing & taking on a large amplitude pattern, which could lead to more blocking patterns
- CC could thus lead to more cold events



Robert A. Rohde for Global Warming Art - CC-BY-SA commons.wikimedia.org

Example of blocking pattern in the jet stream

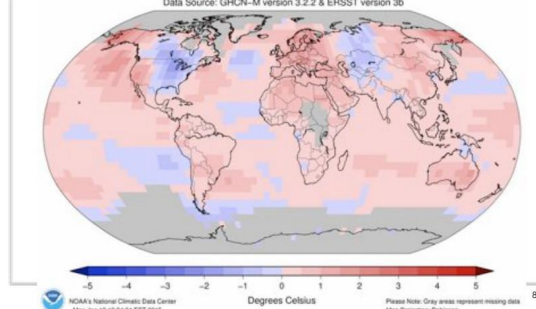
- 2013-14 winter in the US: Eastern half experienced one of the harshest coldest winter on records whilst western US experienced one of the warmest & driest on record, leading to an extensive drought in California
- meanwhile, 2014 was globally the warmest year on record, which can be confusing for people who experienced so much cold in the Eastern US

Cold weather events do NOT disprove global warming.



They can even result from exchanges of air masses as the Arctic warms. Looking at local events instead of global average temperature is cherry picking

Land & Ocean Temperature Departure from Average Jan-Dec 2014 (with respect to a 1981-2010 base period)
Data Source: GHCN-M version 3.2.2 & ERSST version 3b



NOAA National Climatic Data Center - CC 0
ncdc.noaa.gov/isotc/global/2014/12

From Oxford's online learner's dictionaries:

1. ridge: a long narrow area of high pressure in the atmosphere
2. trough: a long, narrow region of low air pressure between 2 regions of higher pressure

WEEK 2-4: TEMPERATURE

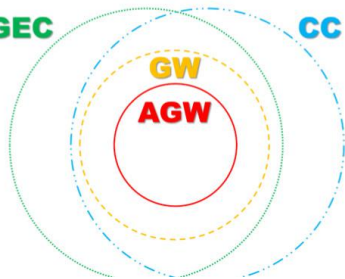
4. CLIMATE CHANGE VS GLOBAL WARMING

Labels matter

1. **GEC: Global Environmental Change**
 2. **CC: Climate Change**: a change in statistics of a climatic variable over a given area (precipitation, wind speed...)
 3. **GW: Global Warming**: an increase in the average surface temperature of a planet
- = can all refer to:
- AGW: Anthropogenic (human-caused) Global Warming
 - = but can also refer to specific aspects of environmental changes that other terminologies may not
- => climate change can be neither global nor warming, such as a regional drought
- => global warming has been natural in the past
- => human-made global environmental change can be neither warming nor climatic (*worldwide loss of wildlife*)
- => global warming is a kind of climate change but not all CC have to do with GW

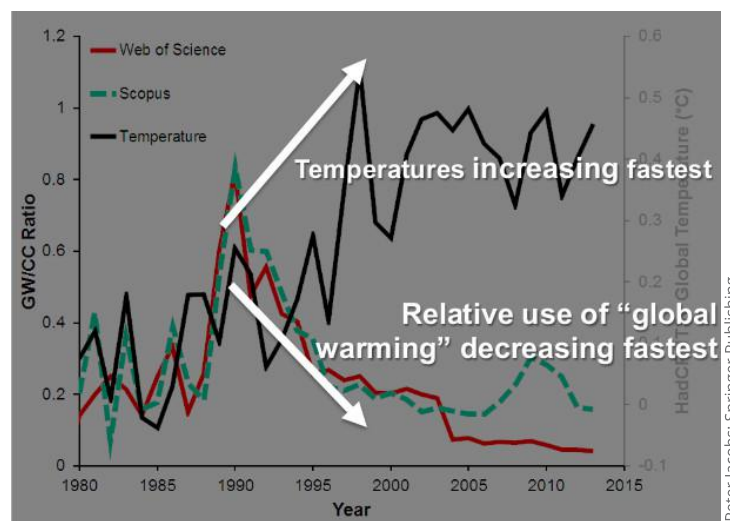
TERMINOLOGY

- Global Environmental Change: **GEC**
- Climate Change: **CC**
- Global Warming: **GW**
- Anthropogenic AGW (i.e. Man-Made) Global Warming:



Myth about scientists' use of terminology

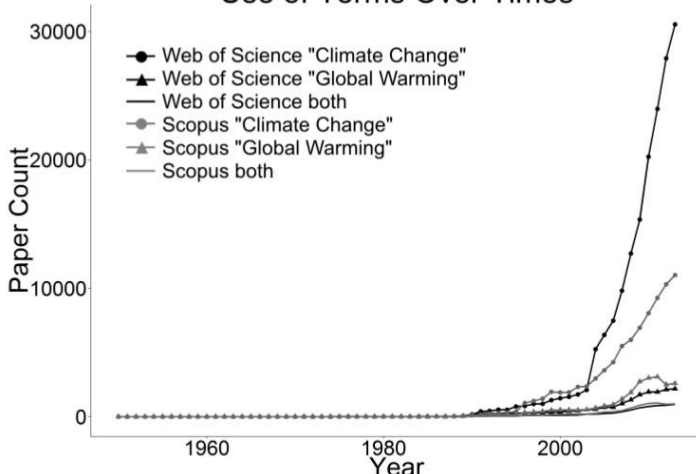
- denialists claim scientists stopped using GW & started using CC recently for the Earth has stopped warming up but it is **false because**:
 1. Earth is continuing to heat up globally
 2. there is no correlate between a preference for GW during times of hotter temperatures, on the contrary
- = conspiracy theory is successful because it oversimplifies a complex reality into a simple falsehood
- = a common characteristic of science denial: believing incorrect information because it is easier to understand than a complex reality



History of terms

- climate change's usage goes back to the 1920s and climatic change to the 1850s
 - global warming is more recent: 1960s and less frequently used by scientists than CC
- => 1992: UNFCCC (United Nations Framework Convention on CC)
- => 1988: IPCC (Intergovernmental Panel on CC)

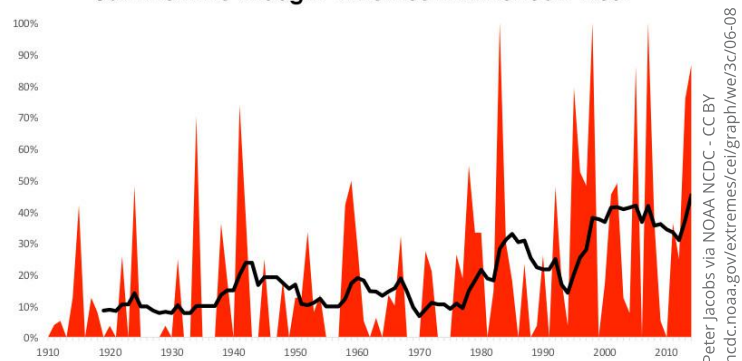
Use of Terms Over Times



Scientists have always used climate change more often whatever the global temperature trends were.

Climatic change was even coined back in the 1850s. Different terminologies (GW, CC, GEC, AGW) are useful to describe different aspects of environmental changes.

Summertime Drought Extremes in American West



a local drought is an example of non-global climate change so global warming would not be fit to describe that event

WEEK 2-4: TEMPERATURE

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WEEK 3-1: OVERVIEW

- WHAT'S CAUSING GLOBAL WARMING?

- EXPLORING THE BALANCE OF EVIDENCE SUGGESTING A DISCERNIBLE HUMAN INFLUENCE ON GLOBAL CLIMATE

Understanding the carbon cycle.

Explaining the effect of adding carbon dioxide to the atmosphere

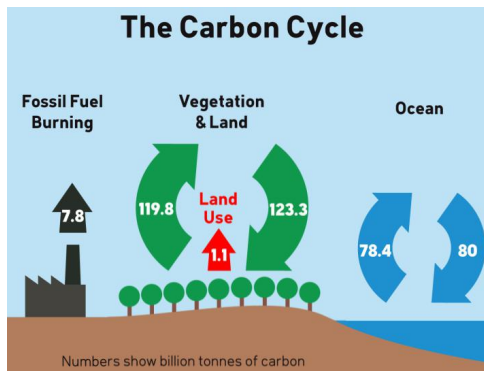
Looking for human fingerprints that indicate human-caused global warming

WEEK 3-2: CARBON CYCLE

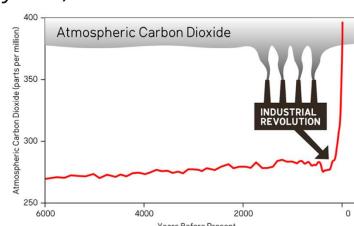
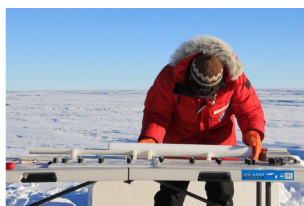
1. UPSETTING THE NATURAL BALANCE

How does the carbon cycle works

- 40% rise of CO_2 over the last few centuries
- carbon cycle: flows of carbon between the atmosphere, the oceans & the biosphere
- => carbon sources release CO_2 in the atmosphere
- => carbon sinks absorb CO_2 out of the atmosphere
- some of these flows are the result of natural processes such as plant growth (sink) + decay (source)



- some of them are human-made: burning fossil fuels, land use change such as deforestation release CO_2
- ice cores provide information on how atmospheric CO_2 has changed over time (small bubbles of air trapped in the ice for thousands of years)



- cores drilled deep in the ice show that prior to IR (Industrial Revolution), atmospheric CO_2 had been fairly stable & balanced for several thousand years

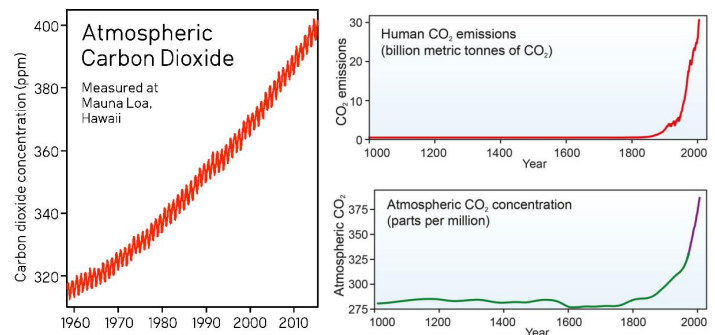
=> in a state of natural balance: sinks & sources \approx matched

Human activity's influence on the carbon cycle

=> human activity has upset this natural balance

- when plants die, their carbon is taken out of the system: burning fossil fuels releases it back into the atmosphere
- => as a result CO_2 levels have been rising
- accurate measurements of CO_2 concentrations made in 1958 (at the Mauna Lao observatory) confirm CO_2 levels began to grow rapidly after the IR

- the increase in atmospheric CO_2 has closely tracked the amount of CO_2 we have been releasing
- => clear evidence that humans are rising CO_2 levels



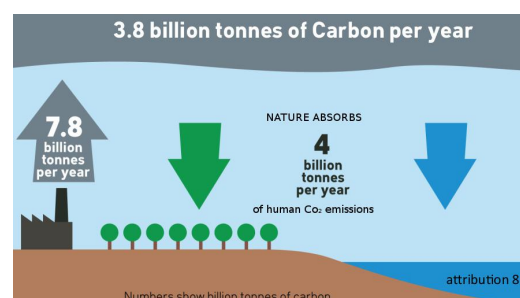
Myth about nature's influence on CO_2

- think because humans release is small compared to the CO_2 released by nature, its influence must be negligible
- fails to consider nature's sinks which absorbs its sources
- = over simplification : difference between total sinks & total sources governs the rise in atmospheric CO_2
- carbon cycle obeys the principle of conservation of mass, the CO_2 we release does not disappear:
 1. either it is removed by natural sinks
 2. or it ends up in the atmosphere
- CO_2 levels are rising more slowly than we are releasing because nature absorbs some of human emissions

Nature has been acting as a net carbon sink: taking out more CO_2 out of the atmosphere than it is putting in for at least 50 years. So humans are responsible for the rise in CO_2 .



Nature has been resisting the rise in CO_2 which proves that this rise is not a natural phenomenon.

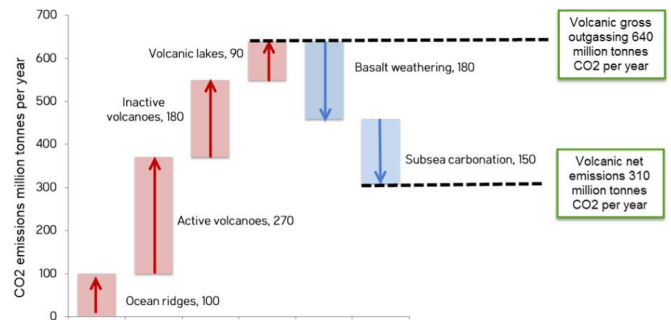
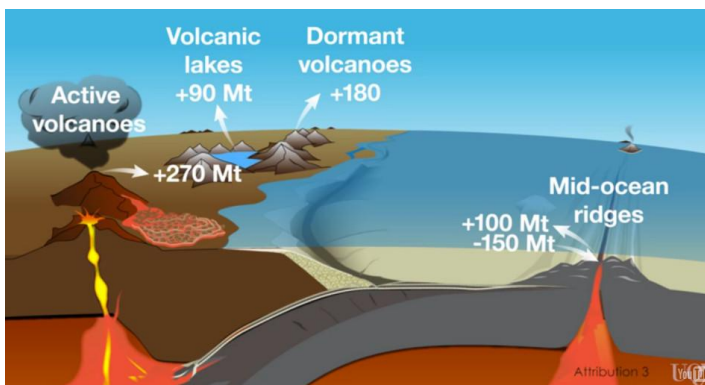


WEEK 3-2: CARBON CYCLE

2. HUMAN CO₂ TRUMP VOLCANOES'

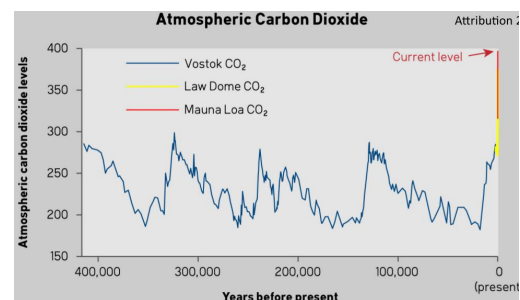
2 main classes of volcanoes

- undersea:** 90% of the world volcanoes:
 - > they erupt under the ocean & produce only: ≈ 100 million tonnes CO₂ /year
 - \approx same amount as an average US state emits
 - ≈ 350 times less CO₂ than humans emit
 - > they also absorb ≈ 150 million tonnes CO₂ /year
- air:** produce ≈ 5 *more CO₂ than underseas
 - > Mount Etna produces ≈ 13 million tonnes/year
 - \approx half as much as what Sicily's people emit
 - > dormant volcanoes & volcanic lakes emit as much as actively erupting volcanoes
 - > volcanic rocks absorbs ≈ 180 million tonnes/year



CO₂ rise is caused by human, not volcanoes

- the carbon dioxide composition of the air started to change rapidly after the 1950s:
 - > fossil fuels' consumption greatly increased at that time
 - > whilst all volcanoes did not started to erupt faster then
- jumping to conclusion: saying volcanoes produce CO₂ so it must account for the rise without checking the data

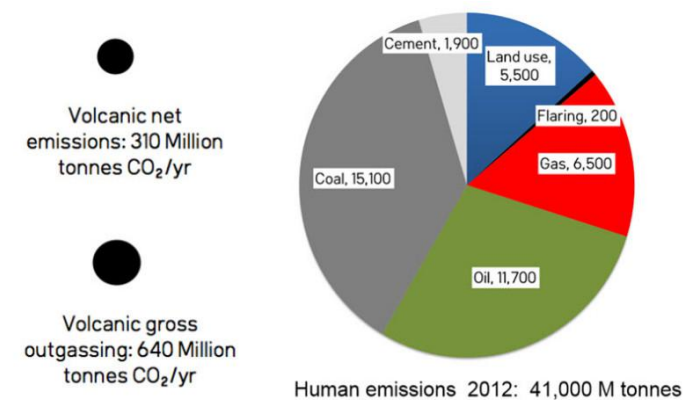


All volcanoes produce

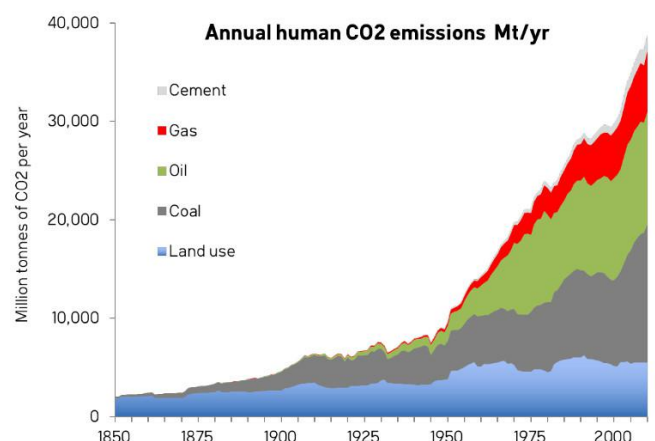
- > all volcano sources produce ≈ 640 million tonnes/year
- > all volcano sinks absorb ≈ 330 millions tonnes/year
- => which leaves 310 million tonnes/year
- \approx human emissions from the country of Turkey
- < 1% of all human emissions
- human emissions in 2012 = 60 to 120 times > than volcanoes & cement-making alone > 3 to 6 times more

Concentration of CO₂ now is:
 ≈ 400 parts per million
 $\approx 40\%$ higher than at anytime during the last 400 000 years

Volcanoes' emissions are too small to make such a significant change in just a couple of hundred years



Recent human emissions are 60-120 times bigger than those from volcanoes.

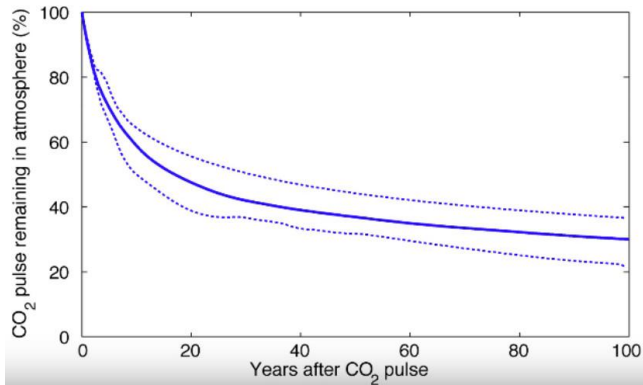


WEEK 3-2: CARBON CYCLE

3. TAKING UP RESIDENCE

Adjustment time vs residence time

- if we stopped all CO_2 human emissions tomorrow:
 - > most of the excess would be gone in 50-200 years
 - > but it would take many thousand of years to return to pre-industrial levels



- oceans absorb 80 billion tonnes of CO_2 /year & release 78
- plants absorb 123 billion T/year & release 119
- = nature removes ≈ 6 billion T/year
- > but an enormous amount of CO_2 is constantly moving back & forth between the various part of this cycle
 - = does not affect the total amount left but has consequences in rise & fall of atmospheric CO_2
- an individual molecule of CO_2 only remain in the air a short time before exchanged with one from nature
 - = straight swap that does not affect atmospheric CO_2 levels
 - > **residence time** = number of molecules / flow out
 - ≈ 4 years
- adjustment time** = how long will it take to return to normal if we add lots of molecules of CO_2 in the air
 - = 50-200 years
 - \neq between total uptakes & total emissions
- myth about CO_2 adjustment time: red herring looking only at residence time instead of adjustment time

It will take the atmosphere between hundreds to thousands of years to return back to normal after we stop human emissions.

An individual molecule has a short residence time, but it is the adjustment time of all the molecules that governs the fall of atmospheric CO_2 .

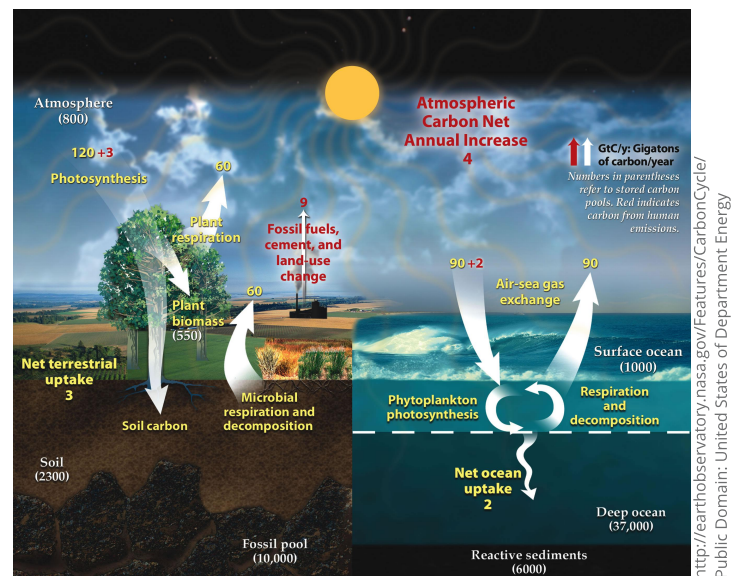
- = human newly-added CO_2 is not part of the natural cycle
- = puts the natural system out of balance because human emissions are very rapid and the natural systems don't have time to respond to them
- it's unequivocal that amount of CO_2 is increasing, increasing fast and faster than ever

Rate of human emissions CO_2 increase

- in the Earth's past (\approx Ice Ages), it took thousands of years for concentration of CO_2 in the atmosphere to range between 180-280 parts per million
 - \neq now it's gone to 350-400 parts/million on a single day basis over only a couple hundreds years
- every single generation is emitting more than the previous one:
 - > since 1750, humans emitted ≈ 2000 gigatons of CO_2
 - > more than half of this amount over the last 50 years

Adjustment time

- scientists know that excess CO_2 is coming from fossil fuels because they do isotopes of the carbon
- CO_2 dissolves in the ocean's surface but it takes hundreds of thousands of years to completely dissolve in it, because there are \neq adjustment times
- about 1/3 of human CO_2 will stay for millenia before being removed by natural processes



WEEK 3-2: CARBON CYCLE

4. EXPERT INTERVIEWS: CARBON CYCLE

Human influence on the carbon cycle

- continuous massive exchange of CO_2 between the atmosphere on land & the atmosphere in the ocean roughly in balance until we introduce human change
- human are moving huge volumes of carbon from stores underground in the form of fossil fuels and adding it to the atmosphere by burning them

The rate of atmospheric change in CO_2 now is incredibly rapid & humans have pushed it higher than ever before in 800 000 years of history.

Humans can't change the chemistry of the atmosphere with one of the main constituents CO_2 by 25% and expect nothing to happen.

WEEK 3-2: CARBON CYCLE

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WEEK 3-3: GREENHOUSE EFFECT

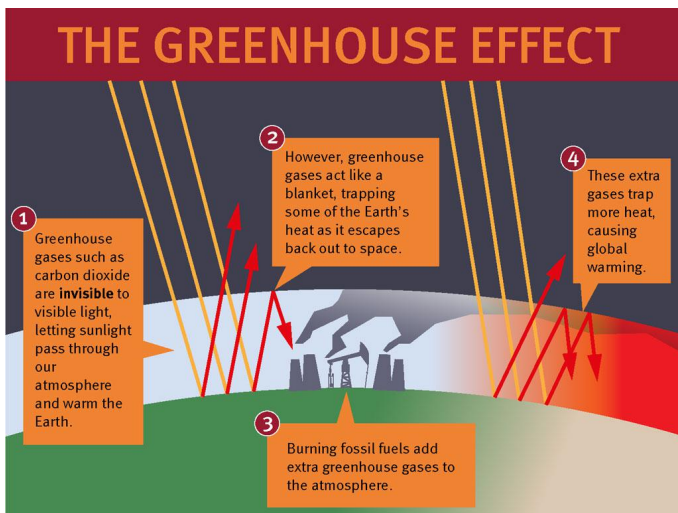
1. WHAT IS THE GREENHOUSE EFFECT (GE)?

How can a single gas like CO₂ be so powerful?

- Venus has thick big clouds so less sunlight reaches its surface but its atmosphere is 95% CO₂
= superpowered greenhouse effect
= surface hot enough to melt lead
- the Sun's rays get to Earth's surface & warm us up because light is a form of heat
- Earth's surface warmed by sunlight glows upwards with infrared: a form of light invisible to the human eye
- greenhouse gases let through sunlight but absorb this infrared & slow down its escape
= keeps Earth warmer, like blankets keep humans warm
=> blankets don't give off heat yet they keep us warm

How can we see infrared if it is invisible?

- pyrometers measure the greenhouse effect daily: they only let infrared light through to be measured
- = measure the constant, warming, greenhouse glow
- infrared can be seen with infrared cameras
- they see the glow of infrared from Earth's surface goes upward then GE absorb some of the heat which they glow in every direction, including down towards us
- = this recycled heat is how the GE warms us



A common myth denying the greenhouse effect

- myth claims GE does not exist is a misinterpretation of the 2nd law of thermodynamics
= heat flows from hot to cold and not from cold to hot
= myth says GE effect would require heat going from the cooler sky to the warmer surface
= misinterpretation because GE does obeys the law:
-> 1 meter² of Earth sends 500 Watts of heat upwards
-> GE sends back down 330 Watts of heat
-> in total, 170 Watts goes from the surface to the sky
=> overall, heat does go from hot to cold but the greenhouse effect send some heat back
- similarly, outer space is very cold: about 270°C below freezing yet a tiny part of noise on a TV screen is the remains of electronic noise from the Big Bang, which contains energy (heat), so despite being cold, some heat flows from frigid outer space to a balmy living room

WEEK 3-3: GREENHOUSE EFFECT

2. INCREASING THE GREENHOUSE EFFECT (GE)?

Think of the atmosphere as layers

- greenhouse gases absorb some of Earth's surface infrared & at the same time, they glow with their own infrared in all directions including down & up
-> the part of infrared that goes up can be absorbed by greenhouse gases further up in the atmosphere
-> think of the atmosphere as layers:
-> each layer has a greenhouse glow in every directions + each layer absorbs infrared from layers above&below
-> the air is thicker low down than higher up
=> low down, each layer has enough greenhouse gas to absorb much of the infrared going through it
=> higher up, the air gets thinner & layers don't have enough gas to fully trap passing infrared
- burning fossil fuels releases CO₂, which, stirred by the wind, mixes through the atmosphere
=> the biggest effect is high up where the air is thinner, where infrared previously escaped to space but is now trapped by the captured greenhouse gases & recycled back into the Earth's atmosphere
- this is how adding more G. gases makes Earth warmer

Myth pretending GE is saturated

- distorts science by ignoring last century of research
-> based on 1900 Knut Ångström experiment: shone infrared light through a tube filled with CO₂, which was much more concentrated than in the atmosphere
-> they changed the amount of CO₂ a bit and found the amount of infrared absorbed stayed the same
-> thought it proved that adding more CO₂ to the atmosphere won't cause warming
≠ but the atmosphere isn't like a tube in a lab: the concentration is a lot less than in the tube
- scientists use computers to calculate the GE & applied the laws of physics in their calculations
-> in the early 2000s, aircrafts measured infrared off the eastern USA and near Ascension Island
=> the match between both measurements was excellent
- satellites & observatories also confirm that the GE is getting stronger because of human-added CO₂

Greenhouse gases let sunlight pass through the atmosphere but absorb infrared radiation.



The Earth warmed by sunlight releases heat in the form of infrared radiation, which is then trapped by greenhouse gases as it goes up.

- the extra heat greenhouse gases trap is staggering: hundreds of times more powerful than the whole world's electricity grid

WEEK 3-3: GREENHOUSE EFFECT

3. REINFORCING FEEDBACK

Reinforcing feedback loop

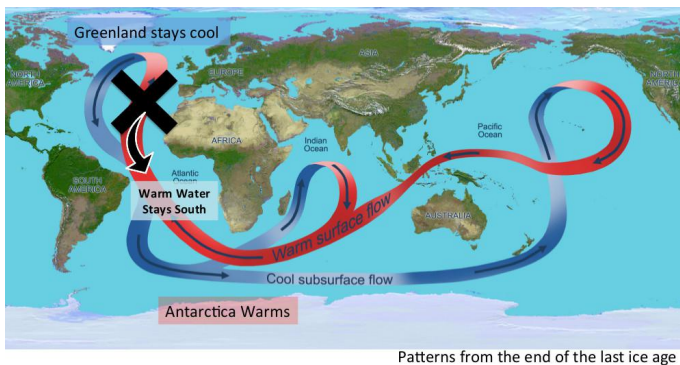
- in order to understand major climate changes, scientists study past climates through the ice core record
- the most famous one is from Vostok Station in East Antarctica, goes back 400 thousand years
- another one called Epica goes back ≈ 800 thousand years
- > in looking at the core data, scientists see that temperature and CO₂ have similar patterns
- => when CO₂ are high, the Earth is warmer
- => when CO₂ are low, the Earth gets colder
- => but correlation is not causation: does CO₂ cause warming or does warming cause CO₂?
- = both statements are true
- = reinforcing feedback loop: warming caused CO₂ to increase, which in turn caused more warming

Myth about CO₂

- > myth that because warming caused CO₂ then CO₂ can't cause warming: false dichotomy
- => false dilemma pretend there is only 2 options and that one negates the other
- => but science reveals a 3rd option that allows for both statements to be true: an increase in CO₂ caused warming AND warming causes an increase in CO₂

How does GW leads to increased CO₂ levels?

- when water is heated, gases, such as CO₂, are driven out because water can't hold as much gas when it's warm
- when opened, a warm soda fizzes more than a cold one
- a warmer ocean also releases much more CO₂ in the air and oceans hold a lot of CO₂ so this increases GW
- after the Ice Age, the Earth took 7-8 thousand years to



Patterns from the end of the last ice age

warm to our current temperature

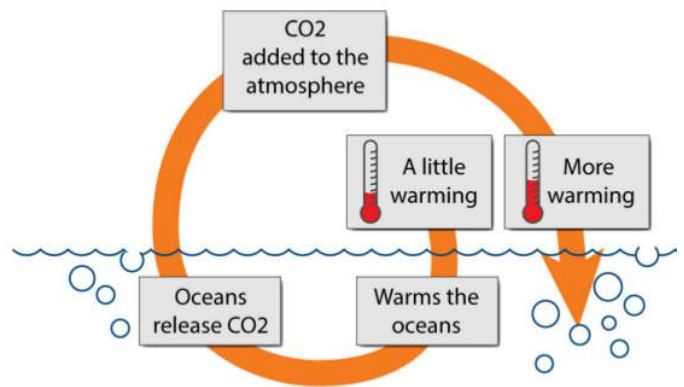
- Antarctica started warming before CO₂ increased because warming was not even over the whole globe: changes in the Earth's orbit triggered warming that started the feedback loop
- but data from other sites prove that globally CO₂ increased before most of the warming
- = proves CO₂ is the primary cause of GW

WEEK 3-3: GREENHOUSE EFFECT

4. EXPERT INTERVIEWS: GREENHOUSE EFFECT

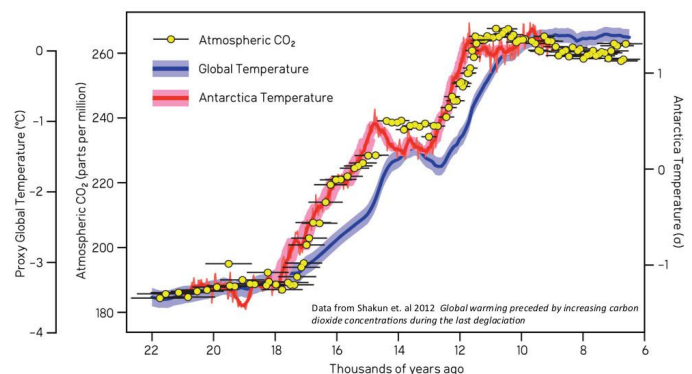
History of climate science

- greenhouse effect is based on basic physics & chemistry known since the 19th century
- => light comes in, heat gets trapped: if CO₂ is added to the atmosphere, more heat gets trapped, Earth warms up
- climate science' history is old, not new & controversial: it started back in the 18th century with Joseph Fourier (law of heat conduction, he understood the GE)
- John Tyndall's experiments in the 1860s measuring how various greenhouse gases absorb infrared radiation
- 1890s, Svante Arrhenius realised human activity's CO₂ emissions could be affecting Earth's atmosphere, did the first estimates of GW's temperature if CO₂ rised
- 1930s: Guy Stewart Callendar: worked out the global average temperature & saw Earth was warming, also linked it to measurements of human emissions of CO₂



A reinforcing feedback loop causes more warming as warming causes CO₂ increase which in turn causes more warming.

Strong evidence based on physics & chemistry prove humans are causing global warming.



WEEK 3-3: GREENHOUSE EFFECT

5. REFERENCES

The greenhouse effect

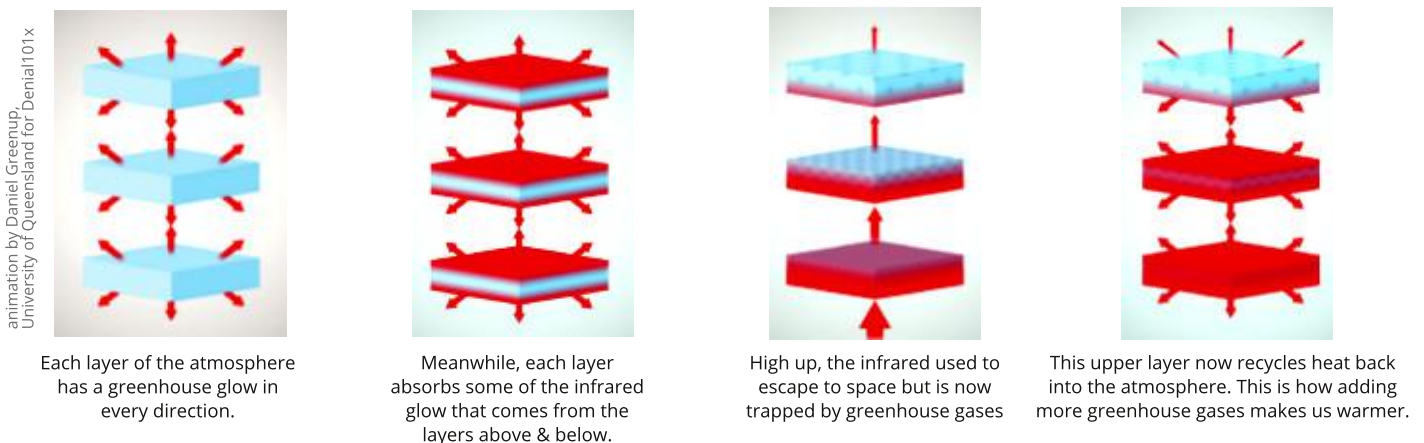
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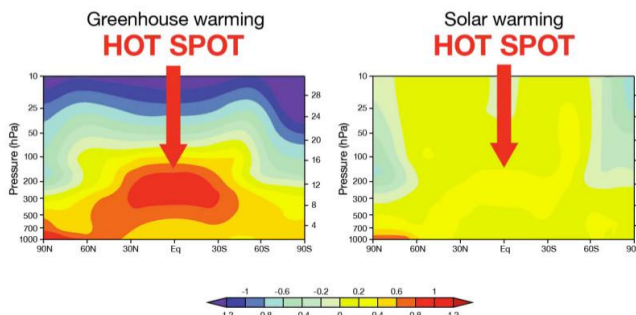


WEEK 3-4: FINGERPRINTS

1. STRUCTURE OF THE ATMOSPHERE

Changing the structure of the atmosphere

- climate scientists have found human fingerprints all over the climate, causing global warming
- human fingerprints on climate: unique pattern of climate changes linked to human activities
- near Earth's surface, greenhouse gases absorb more of the infrared and send some of the trapped heat back to the surface where it is absorbed again
- = heat cycles between the surface and the atmosphere and temperatures rise
- high up in the atmosphere, about 20km & above, outer space barely absorbs or emits infrared so basically no heat is coming from above, so adding greenhouse gases cools the sky while the lower atmosphere warms
- = pattern predicted by scientists before 1970s and now confirmed by satellite measurements
- = unique human fingerprint, because a solar pattern would be uniformly warm through the atmosphere



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ipcc.ch/publications_and_data/ar4/wg1/en/ch9s9-2-2.html

Red herring about the tropical hotspot

- red herring myth focusing on tropical's hotspot
- > simulations expect this hot spot to warm faster but real-world measurements have not confirmed that yet
- > myth says this lack of confirmation disprove GW
- > but this hotspot is irrelevant to GW

Warming near the Earth's surface while the atmosphere is cooling at the top is a distinctive human fingerprint on climate.



The cooling upper atmosphere has contracted like a balloon in a freezer. Satellites have literally felt it falling away.

- Earth's surface can cool by sweating: water evaporates & carries heat with it
- > as it rises, air cools = lapse rate & some of its water condenses out, sometimes enough to fall (=rain)
- > when it condenses, it dumps the heat that had been carried up by evaporation
- > warming means more heat & more evaporation & more rising vapour
- > this has the largest effect above the tropics, where scientists expect to see the hot spot
- > if it is not there, scientists will have to explain why but it is a red herring to use this to cast doubt on GW because it is a sign of moisture change, not of greenhouse gas

WEEK 3-4: FINGERPRINTS

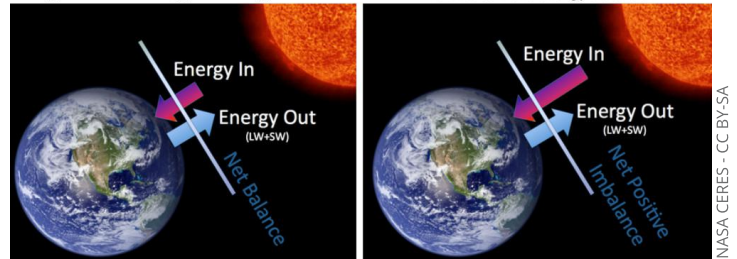
2. MEASURING FROM SPACE

Balance of energy

- one of the strongest piece of evidence of GW is the balance of energy of the planet
- temperature: result of the amount of energy going into an object and leaving it
- when incoming & outgoing energies are in balance, the object reaches a constant temperature
- > if more energy is added, the object heats up & emits more heat until it reaches a new, warmer balance
- satellites show more energy is coming in than going out of the planet

Energy balance = energy in – energy out

Earth's current energy balance :



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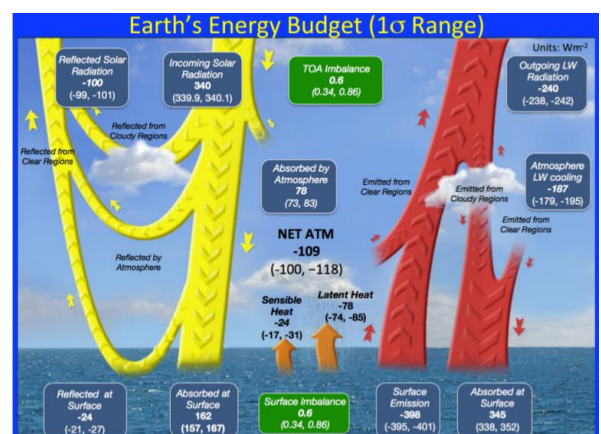
Myth about CO2 being just a trace gas

- jumping to conclusion: a small amount of something can have a big impact, also a red herring
- = a tiny amount of arsenic can be a health hazard
- > show average energy input to the Earth is 340W/m²
- > energy is divided into:
 - shortwave radiation, Sun's rays (visible UV light)
 - > ≈ 30% is reflected directly back to space from the atmosphere, clouds & the Earth's surface
 - longwave radiation (invisible, heat)
- => NASA measurements show 0.6W per m² extra heat coming in that is not going out = GW

Even though each extra molecule of CO₂ contributes a tiny amount of warming, its effects add up globally & grow each year



Satellites data since 1978 prove CO₂ emissions are changing the energy balance of the Earth & that more heat is coming in than leaving it.



Norman G Loeb, NASA Langley research Center
PD licence

WEEK 3-4: FINGERPRINTS

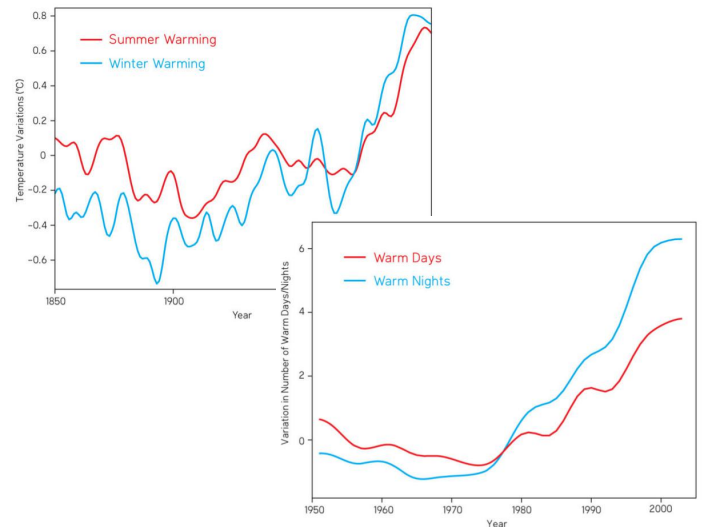
3. DAILY AND YEARLY CYCLE

Human fingerprint pattern of warming

- scientists predicted that human-caused GW should result in certain specific patterns of warming
- = fingerprints of human influence on Earth's climate
- 1865: John Tyndall predicted warming caused by increased greenhouse effect (GE) should cause nights to warm faster than days & winters faster than summers
- = because the Sun doesn't work 24/7 but GE does
- > Moon has no atmosphere nor GE: as a result the \neq between night & daily temperatures is extreme:
 - > 120°C daytime vs -200°C at night
- > vs Venus has a GE bigger than Earth so it has no seasons & its temperature is 460°C day & night, all year long
- = the bigger the GE the smaller \neq between day/night temp.

Myth that the Sun, not humans, is responsible for GW

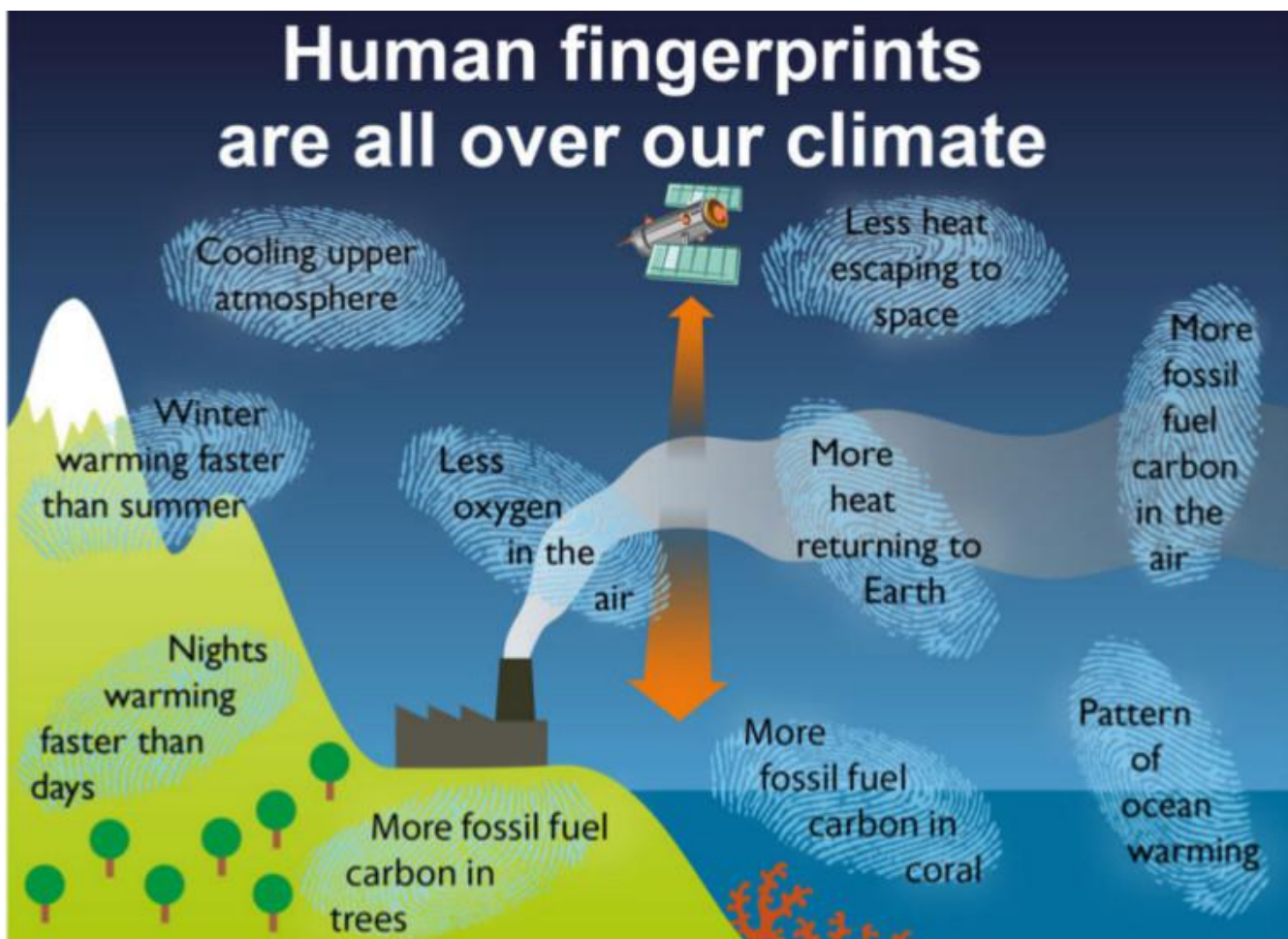
- > fails to account for the available evidence
- > if the Sun was responsible, the Earth would warm most when sunlight is bombarding the surface the most: during daytime & summer but we have the opposite
- over the last few decades, surface measurements have confirmed Tyndall's predictions: nights are warming faster than days & winters than summers



Graph created using data from HadCRUT3 global monthly surface air temperatures since 1850
<http://hadobs.metoffice.com/hadcrut3/index.html>

Humans, and not the Sun, are responsible for global warming over the past century

☀️
Measurements have confirmed that nights are warming faster than days & winters than summers: a distinctive human fingerprint.



WEEK 3-4: FINGERPRINTS

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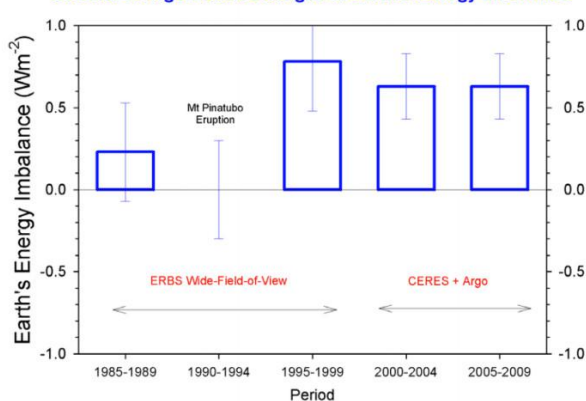
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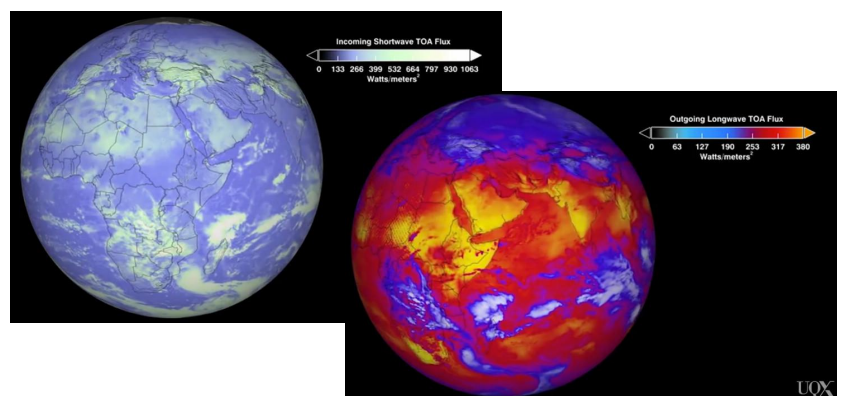
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Satellite & Argo Based Changes in Earth's Energy Imbalance



- The planet's EEI imbalance has been fairly stable since 1995.



Lori Perkins, NASA Goddard Space Flight Center
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WEEK 4-1: OVERVIEW

- LOOKING AT PAST CLIMATE CHANGE PROVIDE INSIGHTS INTO FUTURE CLIMATE CHANGE
- EXPLAINING HOW CLIMATE MODELS WORK, BASED ON FUNDAMENTAL PHYSICAL PRINCIPLES

Learning about the medieval warm period & the little ice age

Understanding the difference between climate and weather

Examine how & why scientists have a tendency to underestimate climate impacts

WEEK 4-2: PAST

1. MODERN VS PAST CLIMATE CHANGE

Ruling out natural causes

- in the past, **changes in the Earth's position relative to the Sun** has caused CC, but these changes are far too slow to be the present cause of GW + their current positions would result in cooling, not warming
- **the Sun's intensity** changes over time but instruments show that solar energy reaching the Earth has been decreasing for the past several decades
- **volcanic activities** release a tiny fraction of greenhouse gases compared to human activity + their CO₂ has a ≠ chemical composition to the ones building up in the atmosphere, which come from fossil fuels burning

human fingerprint:

ATMOSPHERIC CO₂ SOURCE

- Different sources of carbon have different isotopic ratios
- Fossil fuels are depleted in ¹³C
- Burning fossil fuels has decreased the relative amount of ¹³C in the atmosphere
- CO₂ from volcanoes would not cause this
- Known as the Suess Effect



- so **natural factors** don't fit but many **human fingerprints** all over the climate do fit the current pattern of CC

Myth about natural causes

- **myth claims that because CC has happened naturally in the past, means it must be natural now also**
- => like claiming a murder client whose fingerprints were all over a crime scene is innocent because people have died of natural causes for 200 000 years
- => **over simplification, faulty reasoning leading to jumping to conclusion by focusing on the past and ignoring all the other new possibilities**

Analyzing the ways in which natural forces have changed climate in the past rule out natural factors from being responsible for current CC.



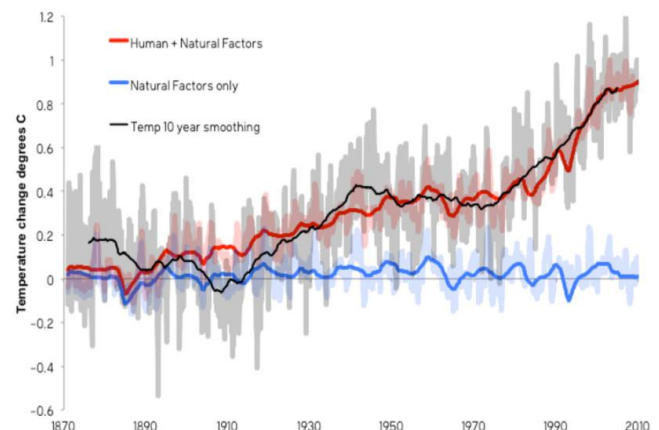
Claiming that because CC happened in the past naturally, is must be natural now too is an over simplification ignoring all other possibilities.

WEEK 4-2: PAST

2. THE LITTLE ICE AGE (LIA)

Myth regarding the Little Ice Age

- **claims recent warming is just a continuation of the natural processes that ended the LIA**
 - these factors were indeed dominant at the beginning but since 1950, human influence has become dominant
 - **LIA lasted from ≈ 1450 (or earlier) -1850**
 - **temperatures were globally lower than now:** in Europe, Central Asia & North America: 1°C lower
- => this warming might seem small but was enough to cause the majority of the world's glaciers to shrink
- glaciers advanced during the LIA but as the cool period ended, glaciers nearly everywhere started to retreat
 - **LIA had historical impacts in Europe: bitterly cold winters, very wet years that led to crop failures & famine**
- > the river Thames froze over 21 times in 300 years



Andy Skuce modified from IPCC AR5 WG1 Ch5 fig 5-08 - © used with permission

What caused the LIA

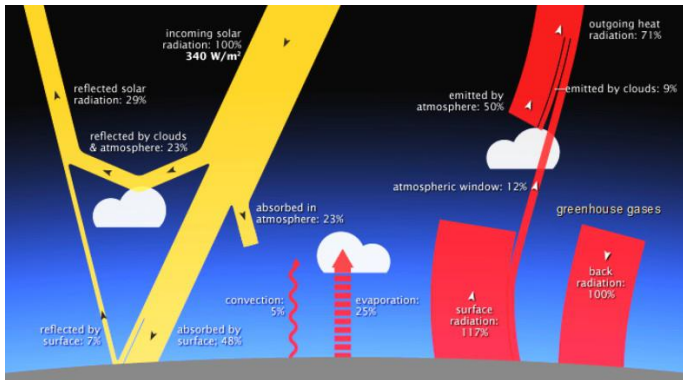
1. **small changes in the tilt of the Earth** helped cause a decreasing trend in temperature over 5000 years
-> rate of cooling: 1/5 of 1°C per thousand years
-> LIA occurred towards the end of this slow decline & ended when temperatures went up sharply after 1850
 2. **at least 2 large lows in the output of the Sun:** the Spörer & the Maunder minima
 3. **an unusual number of big volcanic eruptions** threw small particles into the atmosphere that acted like little mirrors reflecting sunlight back into space
-> Mount Tambora's eruption in 1815
- **researchers estimate past temperatures by analyzing records like tree rings, ice cores, stalactites' growth**
 - volcanic eruptions continued after the LIA but were generally smaller & dwarfed by human influence
-> since 1850, more people & more industries produced more & more greenhouse emissions

WEEK 4-2: PAST

3. ANCIENT CO₂ LEVELS

Paleoclimatology

- "The climate system is an angry beast and we are poking at it with sticks." Wally Broecker
- paleoclimatology**: studying the Earth's past climate, before records were kept, before instruments
-> using techniques from chemistry to infer what temperatures, sea levels & atmosphere were like then
-> going back hundreds of millions of years
=> conclusion of data: **significant changes occur when the amount of energy changes in the climate system**
=> like adding CO₂ unbalance the energy of the system
= similar data to modern climate models' predictions



Reinforcing feedbacks & other factors

- reinforcing feedbacks** amplify any initial change in temperature: the total amount of temperature change triggered by a change in energy is several times greater than it would be without these feedbacks
- the Sun is getting hotter and brighter over time, which means in the past, CO₂ levels could be higher with less consequences, because the Sun was less hot
- Earth's continents' position** changed a lot over time & lands are more reflective to sunlight than oceans & the Sun is much more intense near the equator
=> current position helps reflecting more light as continents are more clustered towards the Equator
- plants & ice sheets** also play a role in sunlight reflection

When CO₂ levels changed rapidly in the Earth's past history, this caused big impacts on life, including most of the worst mass extinctions.

Current changes are faster and bigger than any that occurred in the last 2 million years: the rate & scale are unprecedented.

Myth about CO₂'s past levels

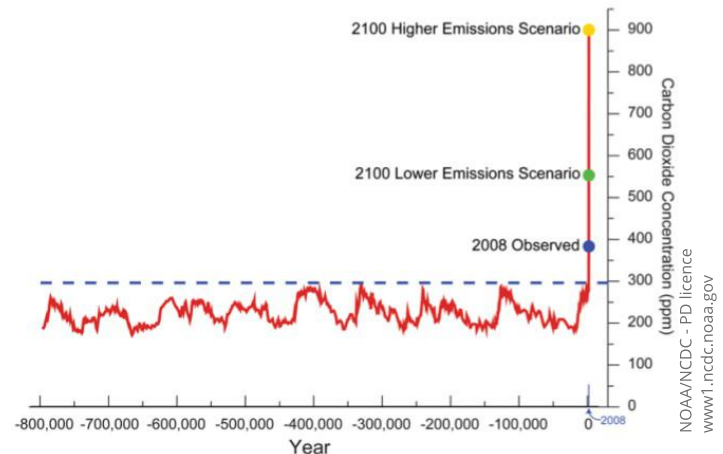
- myth claims because CO₂ levels got so high in the past without climate becoming too hot then CO₂ warming effect cannot be that strong now either
=> **faulty reasoning + cherry picking**: disregarding other aforementioned factors & jumping to conclusion
=> & ignoring historical proofs about CO₂ levels causing climate change in the past

WEEK 4-2: PAST

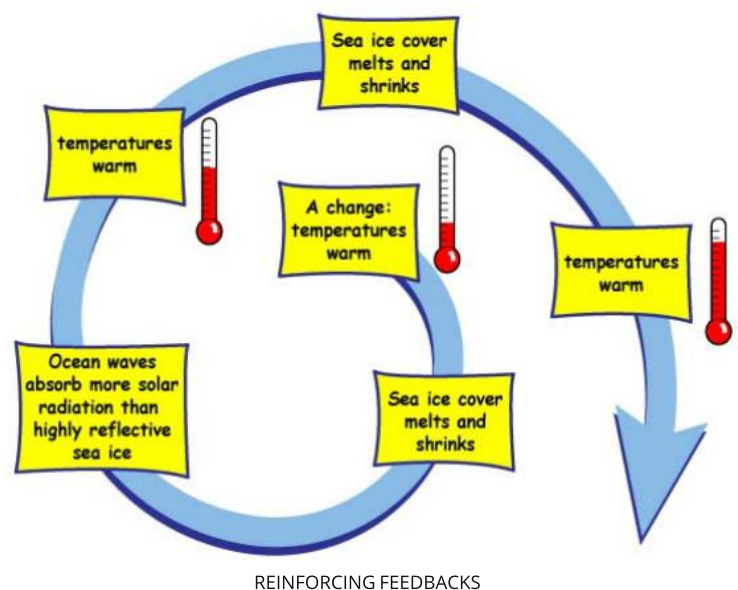
4. EXPERTS INTERVIEWS: THE PAST

Unprecedented rate & amount of CO₂ rise

- the modern warming spike (warming curve) is unprecedented as far back as a thousand years
- evidence prove that **temperature back at the Medieval warm period were not globally warmer than today**, some regions were, but most of the globe was substantially cooler: averaged over the globe, temperatures then were not nearly as high as now
- ≠ studies have ≠ conclusions about the details, but all agree that recent warming is unprecedented**



- an event 55 million years back resulted in high CO₂ levels but at a much slower rate than now
- Pliocene time period**: 3 million years ago, CO₂ was about 400 ppm: sea level was ≈ about 10 meters higher than today: this would result now in inundation in many of the world's major cities, of much of the crop land



WEEK 4-2: PAST

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Ancient CO₂ Levels

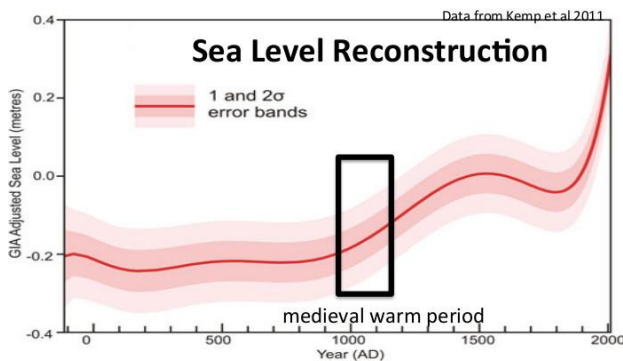
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WEEK 4-3: HOCKEY STICK

1. MEDIEVAL WARM PERIOD (MWP)

Global temperature over the MWP

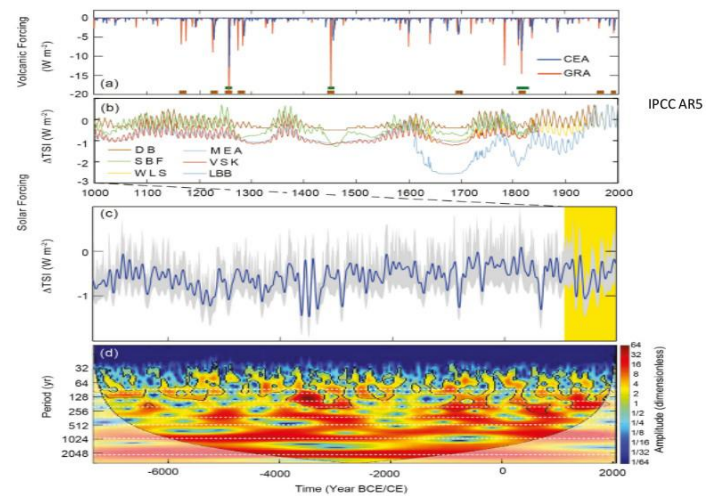
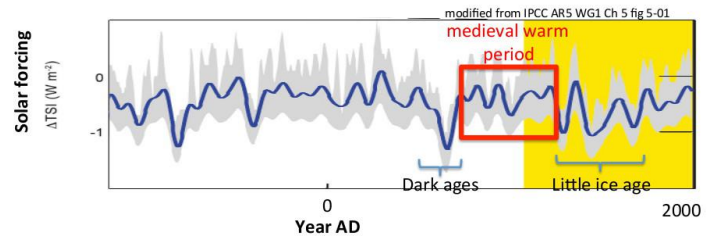
- 900-1150 AD: warmer climate than the Dark Ages before it or the Little Ice Age (LIA) that followed
- averaged over the whole globe, paleoclimatologists estimate temperatures were similar to mid-20th century, but less than those seen over the last decade
- so the myth that MWP was warmer than present is false = cherry picking some locations that were warmer but you need to average the global, not local, temperature + sea levels then were not as high as now



- like today, certain regions warmed more than others: the North Atlantic warmed more than the tropics -> mega-droughts occurred in the southwestern US

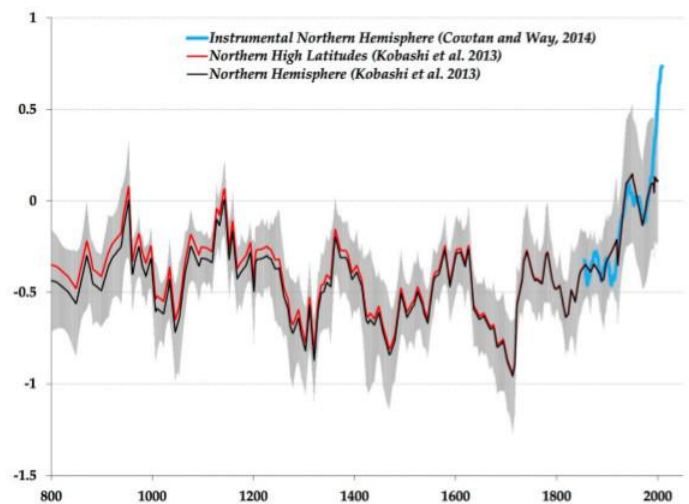
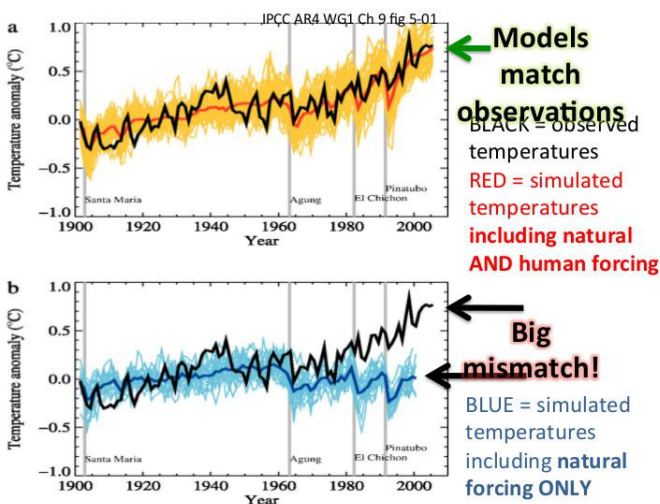
Natural factors: MWP vs now

- a combination of the same natural factors that caused the LIA led to the MWP's beginning and end
 - solar activity was greater
 - low volcanic activity during the MPW but increasing at the end, causing cooling
 - Earth's orbit was different
- studies with climate models can reproduce air & ocean temperatures during MWP by including these 3 factors
- myth argues modern warming could be caused by the same 3 factors that caused MWP = jumping to conclusion -> these 3 factors nowadays actually cause cooling



Current warming cannot be caused by natural factors. The only way to account for recent GW is to include human CO₂ emissions.

Natural factors actually have a cooling influence these last decades. They did cause warming in the past, but much less important than the current one.

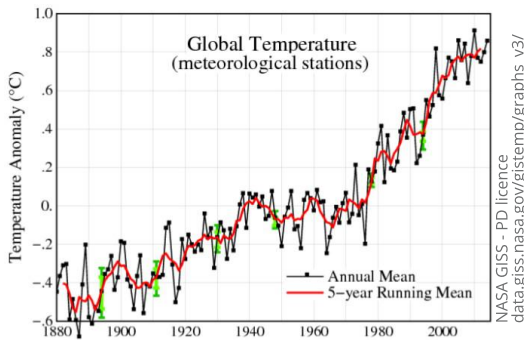


WEEK 4-3: HOCKEY STICK

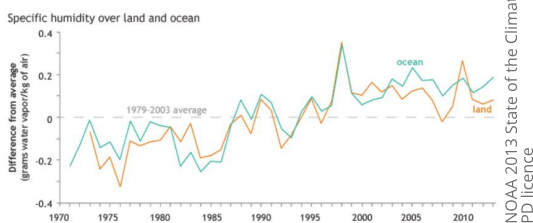
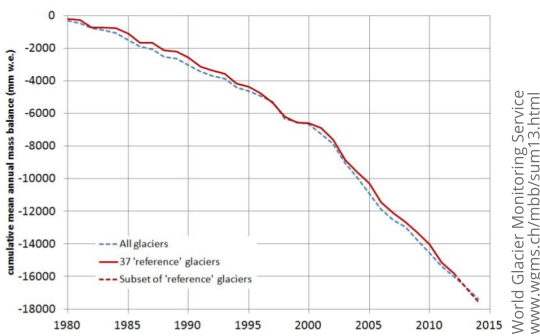
2. CONFUSED DECLINE

Indicators of warming

- land, ocean (surface & below) + air temperatures are rising: these are measured by weather stations, buoys from ships, network of floats, satellites, balloons etc.



- sea level rise, glaciers shrinking, increased humidity



Conspiracy theory & diverging data

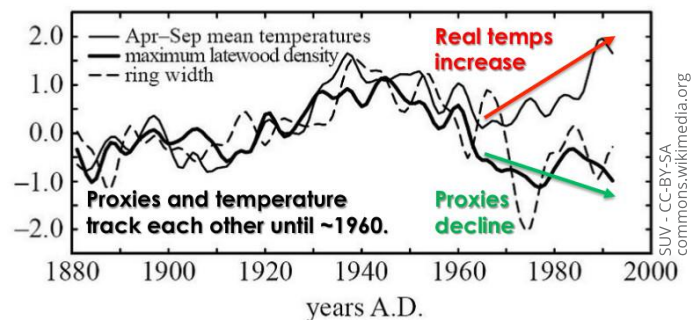
- conspiracy theory + quote-mining (out of context) = claim scientists are hiding a decline in temperature from mine-quoting stolen e-mails
- > the mail was referring to an unreliable climate proxy (paleoclimatologists use them to estimate temperature when no records are available: tree rings, corals etc.)
- > around 1960, some temperature proxies from tree rings stopped tracking temperature and went down, when all the aforementioned lines of evidence went up = divergence problem yet no other proxy showed decline (glacier length, borehole temperatures etc.) = scientists identify misleading data (like these tree rings or malfunction on a satellite), cross-checked with earlier data against overlapping records & stop using it
- some proxy (tree rings) did stop recording temperature rise, but all major lines of evidence, from satellites to sensors in the deep ocean show the planet is heating up

WEEK 4-3: HOCKEY STICK

3. EXPERT INTERVIEWS: THE DECLINE

Stolen e-mail & conspiracy theory

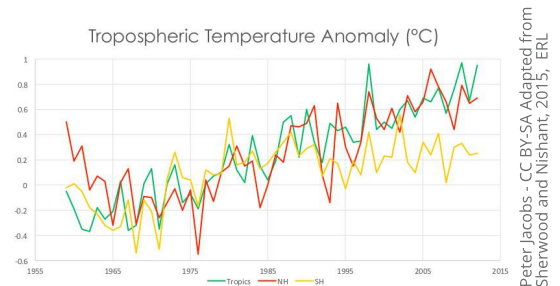
- 2009 Copenhagen Summit: to discredit climate science & sabotage CC negotiations, deniers stole e-mails from a scientist (Phil Jones) & took words that out of context to spread doubt by pretending scientists were deceitful
- => deniers took 2 different phrases from the same e-mail that appear at the opposite ends of a very long sentence & splice them together then claimed that the scientists talked about a trick to hide the decline in temperature
- => the e-mail says nothing of the sort: just talks about a failing proxy (tree-rings) that hide the decline since 1960 & therefore should not be used anymore as unreliable
- trees respond to climate: density is linked to summer temperatures even more strongly than the rings' width = warmer summers: wider rings & denser woods vs colder summers: thinner, less dense
- but tree rings stopped working from the 1960s and diverging from all the other sources of data: anthropogenic pollution could be an explanation
- before that e-mail, these scientists had talked publicly in a paper in 1998 about this divergence problem and that they had stopped using tree rings: it was no secret



Scientists do not hide facts, on the contrary: when they run erroneous data, they stop using it, to avoid drawing misleading conclusions.



Deniers quote out of context to spread doubt. One myth distorts a sentence in an e-mail about a decline in a proxy to accuse scientists of conspiracy.



WEEK 4-3: HOCKEY STICK

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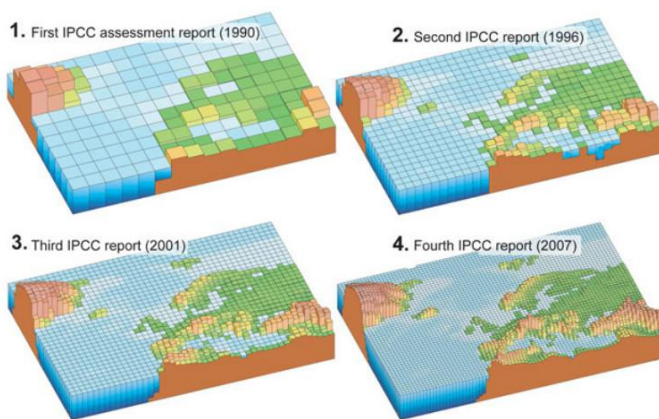
WEEK 4-4: MODELS

1. PRINCIPLES THAT MODELS ARE BUILT ON

How do climate models work?

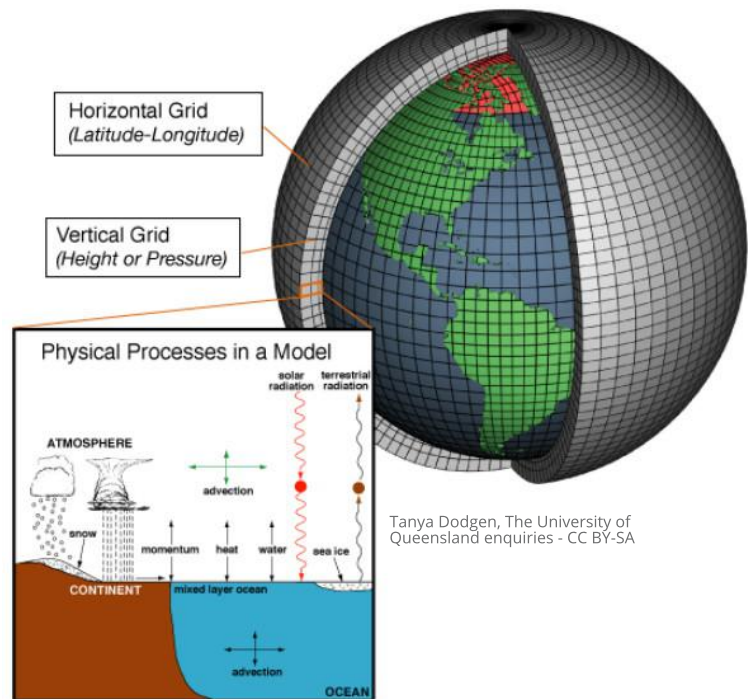
- climate models use the laws of physics to simulate our planet's climate & run on computers that work out mathematical representations of the Earth's climate
- it can take months to make a single calculation
- their results are checked by a large worldwide community of climate modelers & researchers
- divide the Earth, its oceans & atmosphere into a 3D grid
- factors like temperature, wind, rainfall etc. are calculated at each grid point to predict their future CC

The resolution of global climate models has improved



-> as computers improved, grids size got smaller & models much more detailed

- 1st computer climate models developed in the 1950-60s
- modern models include components representing oceans, land surface, sea ice, the atmosphere and simulate greenhouse gases, clouds, aerosols
- aerosols: tiny particles released by volcanic eruptions & fossil fuel burning which deflect sunlight & influence cloud formation
- land surface component simulates vegetation, snow cover, soil moisture, rivers & carbon storage
- the ocean component simulates the movement & mixing of currents, a critical component for accuracy => the ocean is the main reservoir for heat & carbon
- sea ice component plays a big role in the amount of heat absorbed or reflected by the ice
- climate models compute how all these variables change over time & interact with one another

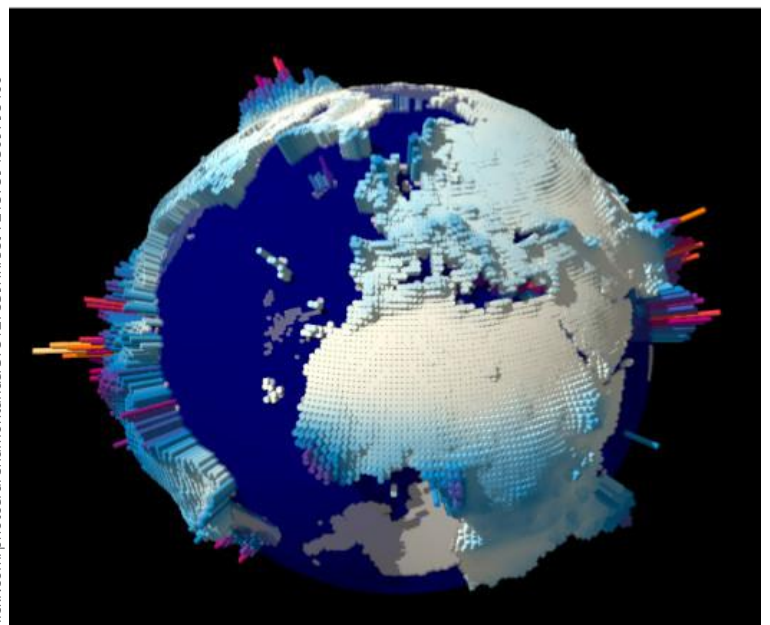


Models represent sophisticated simulations of the Earth's climate, based on the laws of physics, & complex calculations including many factors.

☼

Climate models include components representing the atmosphere, ocean, land surface & sea ice, plus various factors like wind, rainfall, temperature etc.

World rainfall visualization



WEEK 4-4: MODELS

2. CLIMATE MODEL SUCCESS STORIES

Accurate predictions

- late 1800s: 1st numerical model of the Earth (pen & paper) -> created by **Svante Arrhenius**
=> estimated if amount of CO₂ in the atmosphere doubled, global temperature would go up 5-6°C
=> close to modern day models: estimate +2-4.5°C
- Arrhenius also predicted that if the amount of CO₂ rose in the atmosphere, there would be more water vapor, which is a greenhouse gas too and amplifies GW
- 1967: 3D model of the Earth's atmosphere
-> created by **Manabe & Wetherald**
=> doubling CO₂ => +1.3°C warming => increases the amount of water vapour in the air => +1.1°C
=> they also predicted
 - the Arctic would warm faster than the rest of the planet because of decreased reflectivity due to melting ice
 - warming of lower atmosphere / cooling of upper
- 1989: **Stouffer, Manabe & Bryan** predicted land surface would warm faster than ocean surface

Accurate global temperature changes estimations

- models also predicted well global temperature changes
- > **J.S. Sawyer** projected humans would increase CO₂ levels 25% above 1850 levels by the year 200
=> which would increase global temp +0.6°C
= both projections were almost spot on
- 1975: "global warming" coined by **Wallace Broecker**
-> predicted +1°C global temp between 1975-2015 and was only 0.3% too high though he was using a simple model
- 1981: **James Hansen** developed a more detailed model
-> 1981-2015: projected +0.5°C vs +0.6°C in reality
-> 1988-2018: new model +0.67°C vs 0.5°
=> this new model was too sensitive to GE
- 1990-2014: **IPCC's** models projections have been remarkably accurate

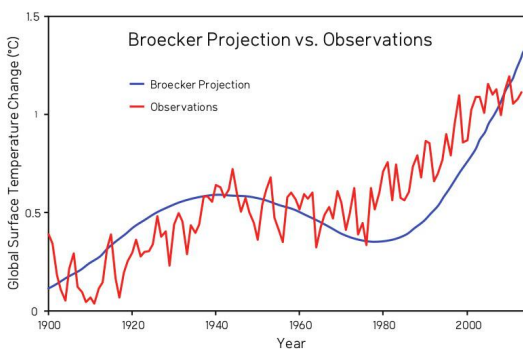
Myth about climate models

- myth relying on the fallacy of impossible expectations
- > models can't make perfect short term predictions, so myth say they are also unreliable for long terms ones
- > but climate models are better for long-term predictions because unpredictable factors like ocean & solar cycles have less influence in the long term than the short one
- > in the long term, natural effects average out whilst the long term effects like greenhouse effect dominate

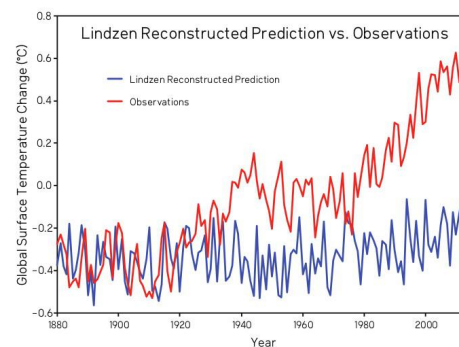
Models predicted well geographic pattern & temperatures of GW, loss of Arctic sea ice & the rising of sea levels.



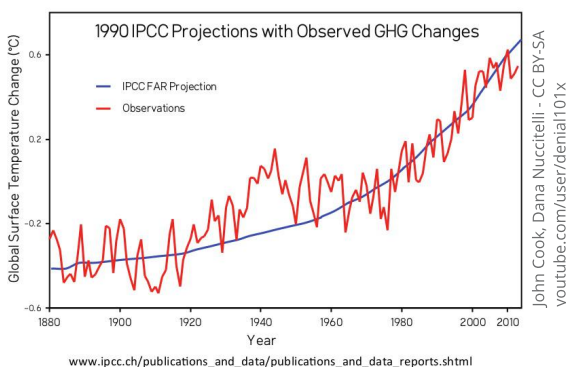
Climate models are not perfect, but they have consistently made pretty accurate predictions, much more accurate than deniers' ones.



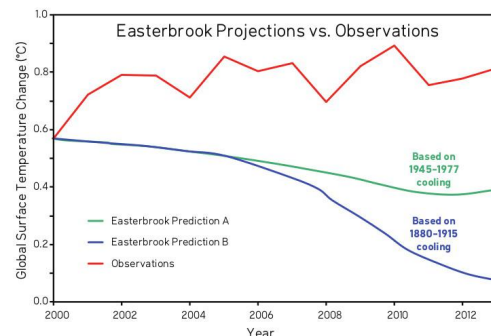
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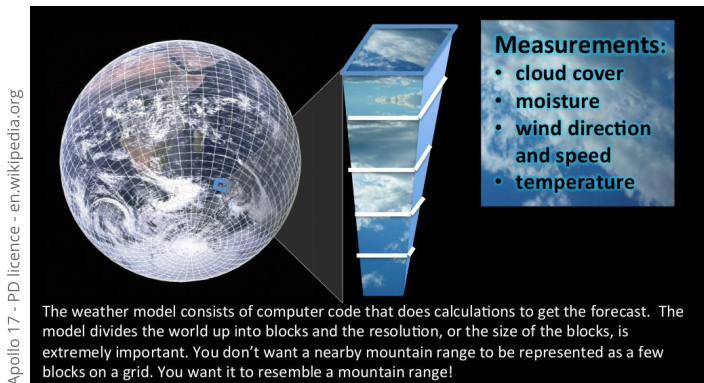
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WEEK 4-4: MODELS

3. WEATHER VS CLIMATE

Difference between weather & climate

- **weather**: state of the atmosphere at a given point in time: what's the current temperature, cloud cover, wind direction & speed, is it raining or snowing etc.
- **climate**: average weather over a long period of time:
 - > long-term factors for a given date at a given location
 - > average high & low temperature, records highs & lows, precipitation amount & types, seasonal variation
- **weather models**: tell temperature, precipitation & cloud cover for an exact position at an exact time in the future
 - > using a variety of data: weather balloons & stations, satellite that are put into weather models which divide the world into blocks with hourly forecasts
- **climate models**: are built differently, to get long-ranged projections: take into accounts many different factors, like the carbon cycle, on a global scale

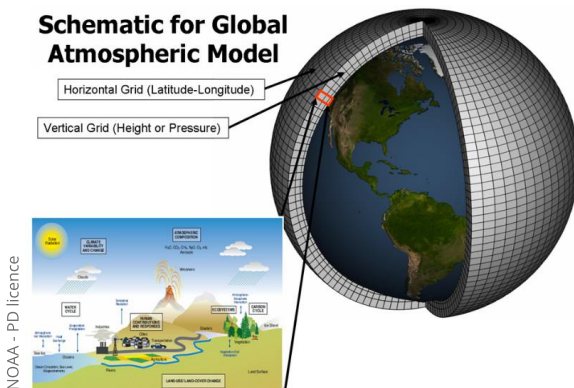


- **myth**: since models can't predict the weather 2 weeks from now, they can't predict weather in 200 years
 - > confuses weather with climate: use the emotion of a failed weather forecast to cast doubt on climate change

Climate is the average weather over a long period of time for a given date/location VS weather is the state of the atmosphere at a given point in time.



Myth claiming that global cooling is happening misrepresent a study from the 1970s which expected cooling IF sulfate pollution dominated CO₂



WEEK 4-4: MODELS

4. CLIMATE SCIENCE IN THE 1970S

Most research expected warming

- in the 1970s, global temperature hadn't changed much for the last decades, it had even cooled slightly
- yet **most research at that time expected that global temperature should soon start to increase, because of the huge amount of human CO₂ emissions**

A few research considered another scenario

- but a small number of papers in the 1970s speculated that **under certain conditions, global cooling might occur**, maybe even a new ice age

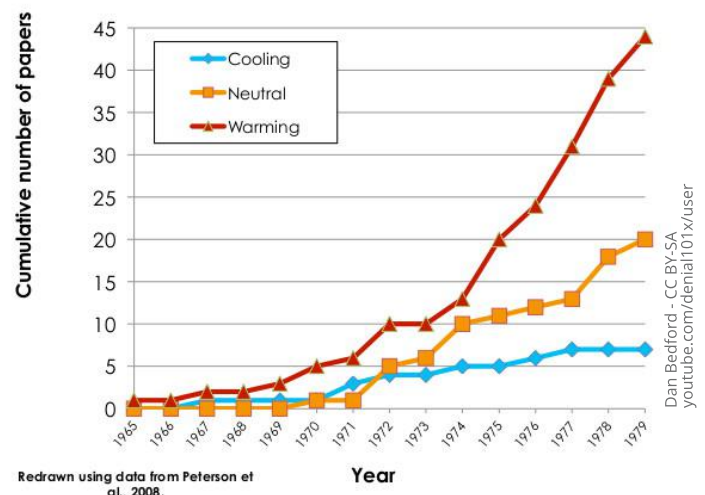
Myth exploiting those researches

- > **myth misrepresents these studies** to cast doubt on CC
- > the research was based on the fact that **burning fossil fuels also release sulfate aerosols, which have the opposite effects of CO₂: they reflect sunlight**



- > scientists could not know at that time which of CO₂ or aerosol emission would dominate later on, so they provided estimates for both scenarios: CO₂ & aerosol
- => estimated that **IF sulfate aerosol quadrupled due to fossil fuel burning, this would cool temperature by 3.5°C**
- => **but the opposite happened**, a number of countries enacted regulations to reduce sulfate aerosol pollution
- > **newspapers Times & Newsweek distorted this study by warning of a possible oncoming ice age which is a sensationalized simplification of the study whilst scientific newspapers took a more reasoned, evidence-based approach & indicated oncoming warming**

Cumulative number of papers published per year predicting warming, cooling or neutral.

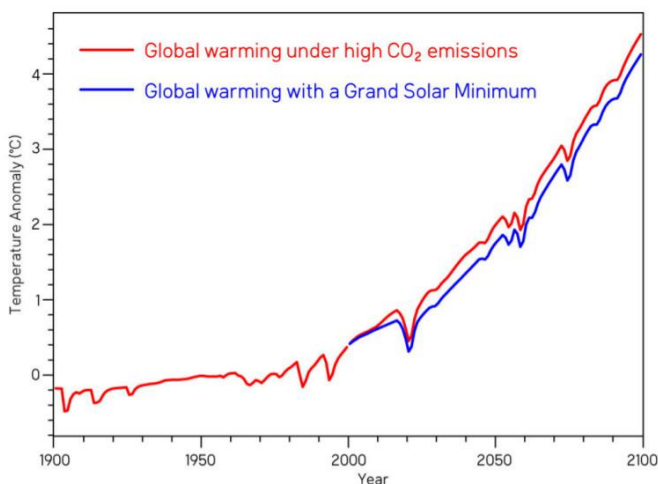


WEEK 4-4: MODELS

5. FUTURE ICE AGE

Solar activity during little ice age (LIA) & modern CC

- scientists predict that if we continue on our current path, global temperature will reach +4°C by 2100
- but over the last few decades, the Sun has been getting cooler: what if it kept getting cooler, like during LIA during the Maunder & Dalton minimum?
- sunspots are a good indicator of how active & energetic the Sun is at any given time:
 - > if lots of sunspot, lots of sunlight is reaching the Earth
 - > fewer sunspot observed during both minima
- scientists agree that even if the Sun now entered another quiet period like during LIA, it would not be enough to stop GW, at best offset it about a decade
- temperatures now are already +1-2°C than during LIA and still increasing
- that slight solar cooling would only be temporary, as the Sun would eventually enter a more active period again
- solar activity: a minor blip compared to human influence



The Sun's influence on climate change is quite small now and even during the Little Ice Age. Human influence is much more predominant.



Myth claims IPCC Reports are alarmist but in reality, it is the opposite: these reports often underestimate the impacts of climate change.

Myth about solar activity

- myth argues the cooling sun will soon trigger a new LIA
 - > misrepresents the role of the Sun in CC
 - > volcanic eruptions & changes in CO₂ have been the main drivers of LIA, not the sun
 - > LIA was little: the planet was not that cool apart from Europe & North America: only 0.5-1° higher than MWP and that took several centuries to happen
 - > human GW took only 40 years to cause >+0.5°C

WEEK 4-4: MODELS

6. TENDENCY TO UNDERESTIMATE CLIMATE IMPACTS

How the reports are written

- IPCC (Intergovernmental Panel on CC): organized by the UN, have produced 5 reports since 1990
 - > each report is a series of books, each almost 1000 pages, covering physical science, impacts adaptation & vulnerability & the mitigation of CC
 - > includes climate models from >20 worldwide climate laboratories, all written independently
 - > assess the science on CC & produce summary reports

Underestimated impacts

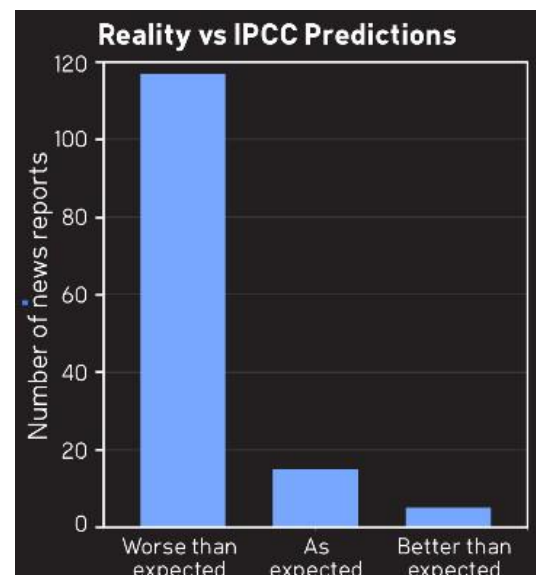
- reports go through rigorous review process: each sentence is scrutinised & all authors + governments of the member countries must agree on the report
 - => so the reports tend to be conservative & show a tendency to underestimate climate impacts like
 1. the amount of greenhouse gases human will emit
 - > IPCC adjusted its scenarios to give a better sample of future CO₂ emissions on its recent report
 2. Arctic sea ice decline: much faster than any prediction
 3. sea-level rise: 60% below the observed trend
 4. ice loss: data not included in the 4th report

Scientific findings vs IPCC predictions

- findings after IPCC reports come out are overall 20 times likely to be worse than IPCC predictions in the report
- there are a few examples where the IPCC overestimated CC impacts but overall IPCC often underestimates climate impacts because of their cautious approach
 - => scientists tend to be cautious & conservative because they are worried about being accused of alarmism

Myth about the IPCC reports

- myth distorts evidence from IPCC reports: pretends they are alarmist, exaggerating the danger of GW & cause needless worry + cherry picking isolated examples when IPCC overestimated impacts whilst globally they always underestimate those impacts, they are the polar opposite of being alarmist



WEEK 4-4: MODELS

7. FROM THE EXPERTS: CLIMATE MODELS

More info on how climate models work

- the basic underpinning laws that climate are build from include basic chemistry, biology & physical principles like **Newton's law of motion**, **conservation of energy & mass** + applied mathematics: their core is sound
- a climate model is a **million lines of computer code running on a really big computer system**
- climate models are a bit like **Lego**, they divide the world up into a **serie of boxes**:
 - > each box has a value for temperature, for how fast the amount of air & water is moving, how much moisture is contained in the atmosphere etc.
 - > they are surrounded by a "matrix" that goes up into the atmosphere, down in the ocean
- highest resolution models "boxes" are about 10km but most are 100 and in reality lots of processes occur on a smaller scale so scientists make approximations**

New climate models vs old ones

- 1970s: the 1st computer that did weather forecast was $\approx 30\,000\times$ slower than a mobile phone but new climate models computers are $\approx 30\,000\times$ faster than a mobile => **great improvement in climate models** in just 40 years
- new climate models resolution has passed from 500 to 100km, everything has been improved
- climate models struggle with the detail of cloud fields, methane release, permafrost melt but they estimate temperature rise very well in response to increasing CO_2
- climate models are tested for efficiency & accuracy** by comparing their average simulations with climate of the real world nowadays and in the past as well
=> **multiple lines of evidence that models are reliable**

The Physical Science Basis

Working Group I Fact Sheet

The Working Group I contribution to the IPCC Fifth Assessment Report (WG1 AR5) provides a comprehensive assessment of the physical science basis of climate change. The report was developed by an international team of scientists who were selected in May 2010. It went through a multi-stage review process involving expert reviewers and governments. It was presented to the IPCC member governments for approval and acceptance in September 2013.

The Report

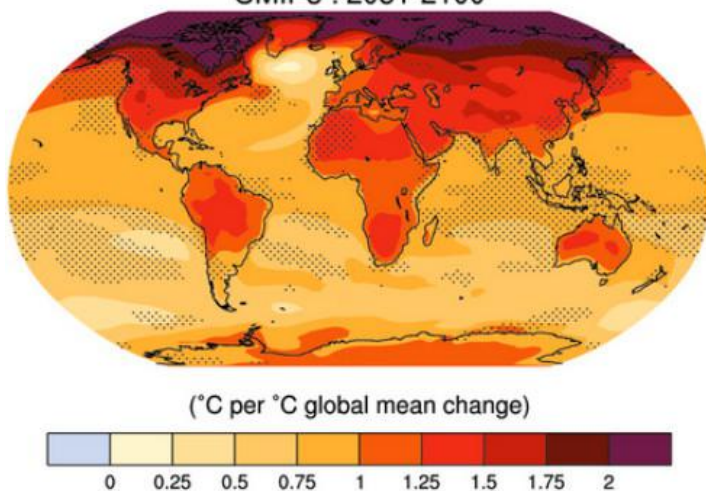
• **1** Scoping Meeting to outline **14** Chapters • Over **1000** nominations from **63** countries • **209** Lead Authors and **50** Review Editors from **39** countries • Over **600** Contributing Authors from **32** countries • Over **2 million** gigabytes of numerical data from climate model simulations • Over **9200** scientific publications cited •

Models are based on basic scientific principles, tested for reliability in many ways and multiple lines of evidence show they are reliable.

Even without climate models, there are still many lines of evidence pointing at human-caused GW and its important impacts on climate

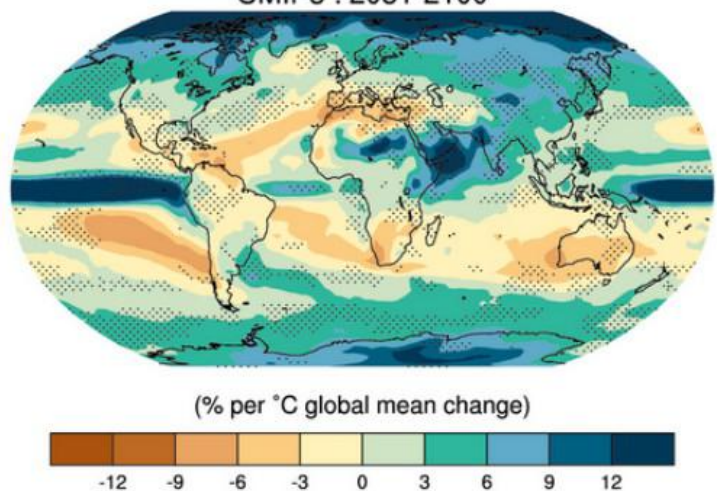
TEMPERATURE

CMIP5 : 2081-2100



PRECIPITATION

CMIP5 : 2081-2100



WEEK 4-4: MODELS

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Success stories

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WEEK 5-1: OVERVIEW

- HOW IS THE CLIMATE AFFECTING HUMAN SOCIETIES, NATURAL ENVIRONMENT & OTHER SPECIES?
- WHY IS THERE ACIDIFICATION OF THE OCEANS?

Debunking myths that try to minimise the impacts of climate change

Understanding the impacts of longer & hotter heatwaves, more intense rainfall & other forms of extreme weather

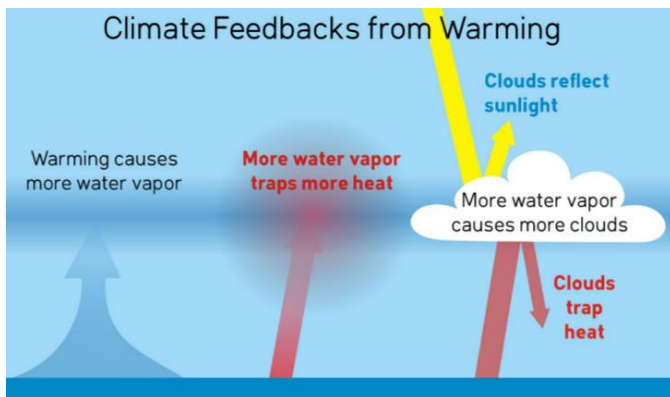
Examine the combined effect of global warming & ocean acidification coral reefs

WEEK 5-2: CLIMATE FEEDBACKS

1. CLIMATE IS SENSITIVE

Amplifying vs dampening feedbacks

- Some feedbacks **amplify global warming**
 - > **ice melt** makes Earth's surface less reflective
 - > warmer atmosphere holds more **water vapor**, which is a greenhouse gas
- => some feedbacks can **amplify or dampen GW**
 - > **clouds** can either reflect light or trap more heat
- => **climate sensitivity**: total effect on climate when adding up all the feedbacks



Methods to estimate climate sensitivity

- to estimate climate sensitivity, scientists:
 1. look at how Earth climate has behaved in the **past**
 2. use **complex climate model** to simulate all the feedbacks
 3. combine **modern measurements** with simpler mathematical models
- => all these methods find a fairly consistent answer:
 - = if human double the amount of CO₂ in the atmosphere, the heat trapped will cause +1.2°C direct warming
 - + **reinforcing feedbacks** ≈ +3°C
- 3°C seem small but a small temperature change make a big difference when talking about the whole planet

Myth about climate sensitivity

- **myth argues that climate sensitivity is low** so there is no reason to worry about GW
 - > **cherry picks**: only look at modern measurements & ignores estimates using past CC & climate models
 - > each method has its strengths & weaknesses: only by combining them can we get accurate estimations
- => **the full body of evidence & research conclude that we are on track to experience warming at dangerous levels**
- > even the most optimistic ones using modern measurements: they just estimate it will happen 2 decades later than other methods

WEEK 5-2: CLIMATE FEEDBACKS

2. WATER VAPOR AMPLIFIES WARMING

Water vapor self-reinforcing loop

- **water vapor is a greenhouse gas**: it amplifies a small amount of warming and makes it a big warming
- > water vapor (like CO₂) absorbs the Earth's outgoing heat, raising average GW temperature through a blanketing effect called the greenhouse effect
- water vapor comes from the evaporation of liquid water, mainly the oceans: the warmer it gets, the more water vapor rise into the atmosphere
- warmer air can hold more water than cold air
 - + warm temperatures cause more water to evaporate
 - + water vapor being a greenhouse gas
 - = even further warming
 - = **self-reinforcing loop or reinforcing feedback**
 - = plays an important part in climate sensitivity

Water vapor & CO₂

- the water vapor feedback occurs because of the **increasing warming caused by CO₂ & amplifies it**
- humans can't control how much water vapor is in the atmosphere but can control the amount of CO₂ responsible for triggering the water vapor feedback

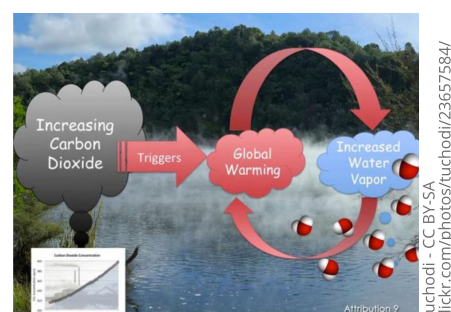
Myth about water vapor

- **myth claims water vapor is responsible for GW, not CO₂**
 - > **jumping to conclusion**: oversimplifies the science
 - > **water vapor does not control the Earth's temperature but is controlled by it and CO₂ acts like the Earth's thermostat by raising temperature**

The full body of evidence & research on climate sensitivity conclude that we are on track to experience warming at dangerous levels.



Adding CO₂ in the atmosphere warms the planet, which triggers the major feedback of water vapour, also a greenhouse gas, which amplifies warming.



WEEK 5-2: CLIMATE FEEDBACKS

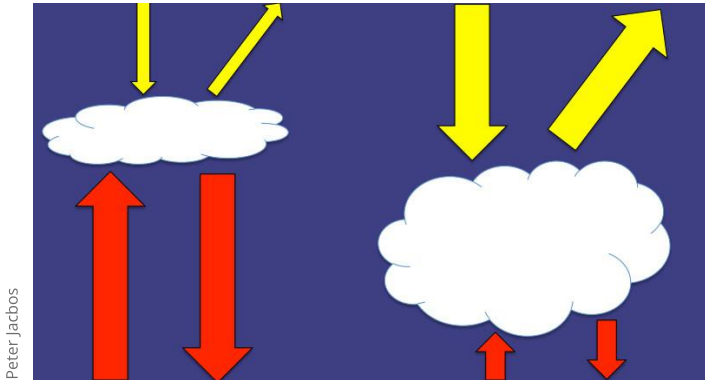
3. THE ROLE OF CLOUDS IN CLIMATE CHANGE

Albedo & greenhouse effects

- clouds affect the Earth's climate in many ways but the 2 most important are
 1. **the albedo effect**: how much a surface either reflects or absorbs light
 - > low thick clouds have a high albedo effect: they reflect a lot of sunlight => cooling effect
 - > higher thin clouds: low: don't reflect a lot of sunlight & trap heat through greenhouse effect => warming
 2. **the greenhouse effect**
- => both cloud types have both effects but for low clouds, cooling is more important VS warming for high clouds

Low impact of clouds on climate

- now, low clouds are more important, but this may change as we warm the planet
- over the past 10-15 years, evidence gathered allowed scientists to see how clouds respond to climate change,



Peter Jacobus

at least over the short term & with some caution
= **should be a small warming effect, but cooling can't be ruled out: either way, small influence of clouds on CC**

- climate models overall predict a reduction in low clouds that will lead to a modest amount of warming

Myth about clouds

- myth say clouds can act as a thermostat to cool the planet and limit the amount of warming
=> **oversimplification**: clouds can have a cooling effect, but the myth ignores their warming effect
+ large increases in temperature linked to CO₂ have repeatedly occurred in the past, despite clouds
+ clouds have a minor influence on CC

The assumption that clouds will save us from GW is not supported by the balance of evidence their impact on future warming will be modest



Methane clathrates are not an imminent threat yet, but there are many other sources of methane & CO₂ in the Arctic that are active today & increasing with GW.

WEEK 5-2: CLIMATE FEEDBACKS

4. METHANE CLATHRATE FEEDBACK

What are methane clathrates?

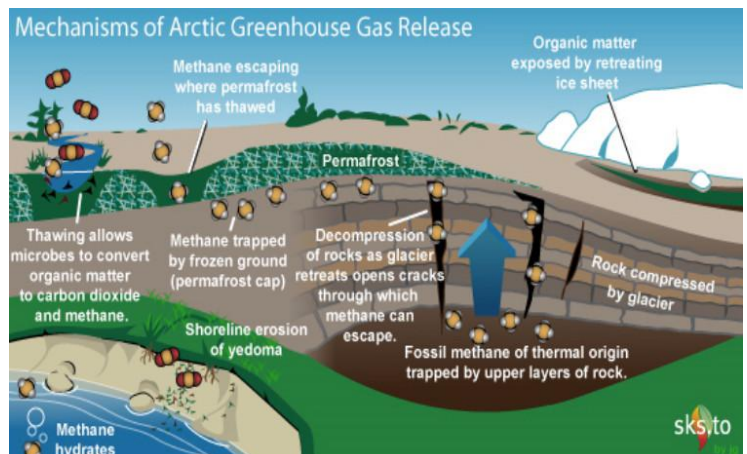
- methane clathrate (or hydrates)**: ice-like substances that trap methane gas in a cage of water molecules
 - > they form where there is a combination of **high pressures & low temperatures**
 - > can be found at or just below the seabed, usually in **ocean depths** of greater than 500m
 - > can also be found in places **in the Arctic**, in places where there are thick sections of **permafrost** at ~200m below the surface, either on land or under an ocean shelf
 - > **clathrates become unstable as soon as the temperature goes up or the pressure goes down**

Why should we care about clathrates?

1. they **contain more carbon than the entire atmosphere**
2. a release of 1% of the world's clathrates would double the amount of methane in the atmosphere
3. Arctic clathrates are the most vulnerable to CC

Why not to worry... YET ?

- for the majority of clathrates in deep oceans or permafrost, it will take millenia to become a threat
- when deep sea clathrates are destabilised, most of the methane gets consumed in the sediment of the seabed
 - > much of the remaining methane will be absorbed by the ocean but will worsen ocean acidification
 - > what is left will be released as CO₂ in the atmosphere
- some clathrates located on continental margins have emitting methane in sea waters so deep it does not reach the atmosphere + been doing so for millenia
- no evidence in the past of massive & sustained methane release even when temperatures were warmer
- no data corroborate the myth that clathrates are an imminent threat to climate yet**
- BUT** if we continue to fail to limit emitting CO₂ from fossil fuels, clathrates will become a problem
- AND** there other potential sources of CO₂ & methane in the Arctic and some of these sources are active today & will grow in importance over the next decades with GW



WEEK 5-2: CLIMATE FEEDBACKS

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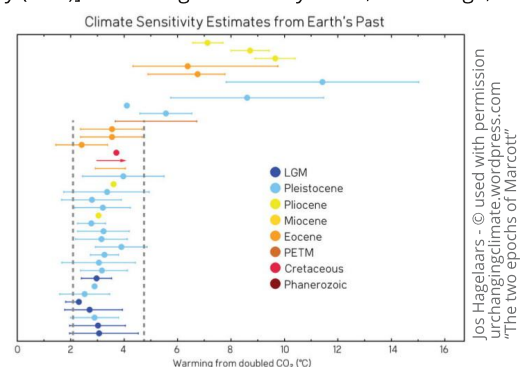
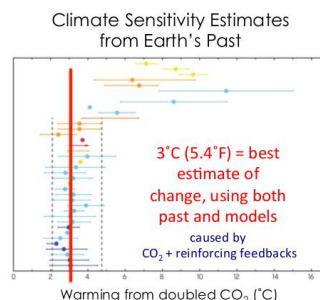
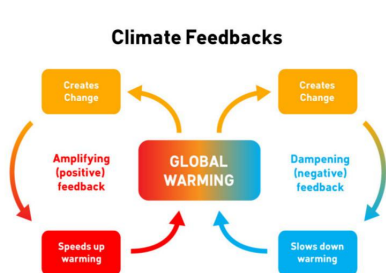
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WEEK 5-3: ENVIRONMENT

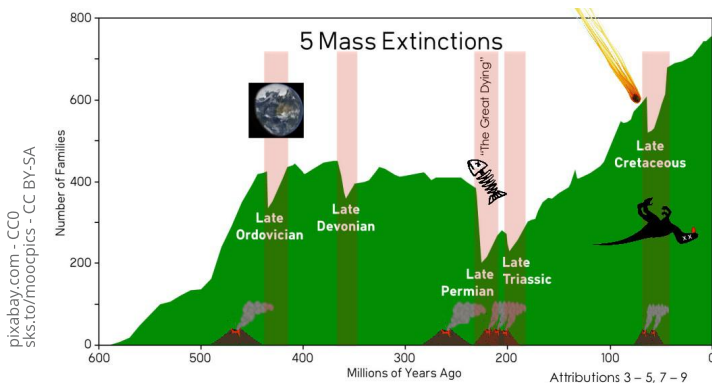
1. ADAPTATION TAKES TIME

Natural selection

- **species evolution:**
 - > members of the species that are the best adapted to threats pass on their genes to the next generation
 - > but this is a **slow process**
 - => thousands of years
 - > whilst **humans are causing climate to change rapidly**
 - => over a few decades

Mass Extinction Events (MEE)

- = **catastrophic events where most species weren't able to adapt fast enough to survive**
 - > most of them were triggered by huge volcanic eruptions:
 - => particles blocked sunlight & caused sharp cooling
 - => CO2 caused long-term warming (greenhouse effect)
- 1. end of Ordovician Period: 445 million years ago
 - => 86% of species went extinct: intense ice age (volcanoes particles) followed by a warm period
- 2. end of Devonian Period: 360 million y/a
 - => 75% because of relatively rapid climate changes
- 3. end of Permian Period: 250 million y/a
 - => 85% - volcano: global cooling - acid rain - then GW
 - = "The Great Dying": nearly all marine species went extinct
- 4. End of Triassic Period: 200 million y/a
 - => 80% (volcanic activities)
- 5. End of the Cretaceous Period: 65 million y/a
 - => 76% (volcanic eruptions + large meteor impact)
 - = when dinosaurs went extinct



6. NOW?

- => **scientists are concerned we may be entering the 6th**
- => over the past 1000 years, the average extinction rate has been 24 times > than natural rate
- => **over the past 500 years, extinction rate is at least as fast as the rate that triggered the 5 mass extinctions**
- => mass extinctions usually takes hundreds of thousands of years BUT if we lose all currently threatened species, we'll be on course for a record MEE in just 500 years

Myth about species evolution

- think humans & other species will be able to adapt to climate change to survive so nothing to worry about:
 - => **jumping to conclusion: just because adaptation exists does not mean species can adjust to any new situation**
 - => many species have gone extinct in previous MEE and humans are changing climate faster than ever before
 - => **if humans continue burning fossil fuels, 40% of species could be at risk of extinction by the end of the century**
 - => it would take millions of years for the planet to recover from such a human-caused MEE
 - => but we're still relatively early in the process: **although it will be difficult, there is still time to change course & prevent a huge loss in Earth's biodiversity**

WEEK 5-3: ENVIRONMENT

2. EXPERT INTERVIEWS: ECOLOGICAL IMPACTS

Extreme weather events

- **overwhelming evidence that humans are having a very damaging effect on the climate system**
- **CC is increasing the probability of extreme weather events** which are very damaging for the environment
- **many species are suffering from & threatened by CC**
 - = cf, koalas can't thermoregulate, hundreds of species are moving, even butterflies, the ultimate in mobile species, can't keep up with the rapidity of CC
 - + **species can't move far from their source of food** so as flowers & plants can't move with them
 - + **vegetals are affected by weather extremes** & dying so animals that depend on them can't feed anymore

Seasonal overlap & other problems

- **species depend upon one another: necessary interactions that depend on seasons & the environment**
 - = pollinators & flowers's timing is getting ripped apart because of CC: overlap problem, emerging at ≠ times

Being a CC biologist feels like you are studying a global catastrophe unfolding in slow motion: we are losing species at the same rate than at the end of the age of the dinosaurs.



Mass extinctions events usually takes hundreds of thousands of years BUT we may be on course for a record "500 years only" mass extinction event.

- **species use environmental cues tell species when they can hibernate, so they can survive winters but with CC, those cues are no longer as coordinated as they were so organisms may start to make mistake which endangers them & the species that depend on them**

WEEK 5-3: ENVIRONMENT

3. POLAR BEARS

Types of Arctic sea ice

- polar bear need platforms of ice floating on the sea to reach their preys but due to GW because of melting ice
- some **seasonal sea ice**: melts each summer, re-freezes in the fall but ice-free seasons have gotten longer & longer because of GW = endangers polar bears there
- some other regions have more **persistent sea ice** & so bear polulation are not threatened yet there
- in "**divergent ice regions**", sea ice retreats from the shore during the summer but due to GW, there regions have retreated further & further, forcing bears to
 - come ashore & forego hunting until ice returns in fall => risk of starvation
 - swim longer distances to reach remaining ice pack, where there may be a few seals to hunt: => risk drowning
- in **convergent ice regions**, where sea ice forms along the shore, bears continue hunting successfully but may still be gone by the end of the century if ice melts there
- same problem with **archipelago ice regions**
- 19 ≠ polar bear populations in the Arctic
 - > 4 groups are declining, 5 are stable, 1 is increasing & other 9 groups: not enough data to tell

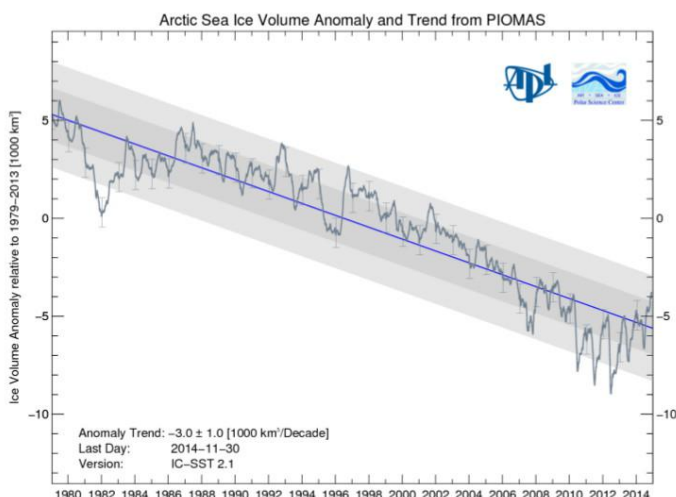
About 70% Arctic sea ice has disappeared these last 35 years.



Polar bear need sea ice to hunt & warming melts ice so the connection between GW & the endangerment of bears is crystal clear.

Myth about polar bears

- argues that their number is greater now than in the 1970s so pretend bears are not endangered now
- = oversimplification: melting sea ice is not the only factor affecting polar bears: **hunting** was widespread then
 - > over 1000 bears were killed each year
 - > hunting regulation laws helped polar bear recovery
- = **the threat of hunting has been replaced by a new threat of human-caused GW melting the ice they need to hunt**



Arctic Sea ice volume - ©FairUse-
h5p://psc.apl.uw.edu/-1 PIOMAS, Zhang and Rothrock, 2003

Polar bear



Conservation status

Extinct Threatened Least Concern

EX EW CR EN **VU** NT LC

Vulnerable (IUCN 3.1)^[1]

Scientific classification

Kingdom: **Animalia**

Phylum: **Chordata**

Class: **Mammalia**

Order: **Carnivora**

Family: **Ursidae**

Genus: **Ursus**

Species: **U. maritimus**

Attribution-Share Alike 3.0 Unported - Alan Wilson - http://www.naturespicsonline.com/https://en.wikipedia.org/wiki/Polar_bear



Polar bear on Svalbard, starving due to the ice around the islands melting earlier than before



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WEEK 5-3: ENVIRONMENT

4. OCEAN ACIDIFICATION

Coral reefs

- = <1% of the Earth's surface but
- = 29.8 billion\$ of global net benefits
- coral reefs support ≈ 850 million people who depend on reef organisms for their daily protein
- **depend on the temperature and concentration of CO₂**
-> even small changes can have large impacts on them

Ocean acidification

- 70% Earth covered by oceans
- goods & services provided by oceans >\$20Trillion/year
- 30% of human-emitted CO₂ has been absorbed by surface ocean which has caused acidification
- once CO₂ dissolve in the ocean, a number of chemical reactions take place:
 1. increase in hydrogen ions, which lowers ocean's pH
 2. some hydrogen ions react with bicarbonate ions
-> reduces the quantity of carbonate ions
-> which are essential for calcification, which allows marine animals/plants to build their skeleton/shell
- = so **adding CO₂ to the atmosphere decreases the pH & concentration of carbonate ions, leading to a decrease in calcification & a range of other negative effects**
- it takes **thousands of years to reverse acidification**: the ocean become less acidic from materials being washed gradually away into it from rocks on land
- the bad decisions we are making today will have **consequences for the next 300 generations of humans**

How do we know the ocean is acidifying?

- chemistry behind this acidification known for 150 years
- since the pre industrial period, ocean pH should have decreased by 0.1 units, based on CO₂ levels
- **pH scale is exponential: 0.1 pH decrease = 26% decrease in carbonate ions concentration**
- ocean acidification has been confirmed by measurements taken by oceanographers
- ocean pH has been stable for a long time, but there have been periods when it was lower than today & it corresponded with CO₂ increase in the atmosphere
- UQX research: coral reefs exposed to levels of CO₂ we will reach if we don't reduce emissions do not survive

Myth denying the danger for marine life

- myth saying coral reefs have survived periods of history when conditions were warmer & more acidic than today
- BUT **recovery after a mass extinction event (MEE) takes a very long time, it took coral reef ecosystem about 10 million years to recover last MEE=40 times longer than human species have been on the planet**
- many scientists believe humans are driving another MEE from which it will take millions of years to recover
=> problem for people&organism who depend on them

Myth denying ocean acidification

- myth claims because oceans are not acidic, acidification is a lie = misrepresentation: **oceans are alkaline but their pH is decreasing**, moving in the direction of acidity, like cooling a hot bath by adding add cold water (still warm but colder than before)

WEEK 5-3: ENVIRONMENT

5. EXPERTS INTERVIEWS:

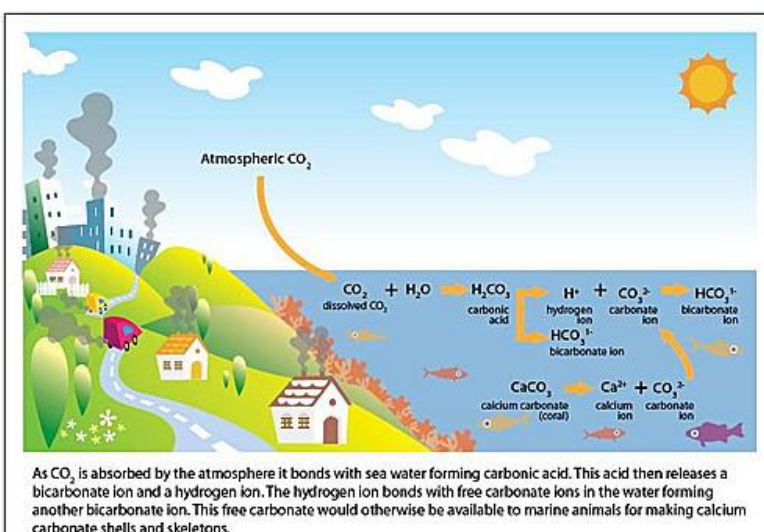
CORAL BLEACHING & OCEAN ACIDIFICATION

CC & marine life

- **2 effects of CC we can absolutely be certain about it that the temperature & acidity of the ocean is rising**
- **bleaching**: large amounts of coral have gone white
- Veron took part in 66 expeditions, 6000 hours of scuba diving studying corals: witnessed drastic deterioration in coral reefs in just 20 years
- **humans have stressed the ecosystem from a temperature point of view & a rapid change in a chemistry which is fundamental to most organisms**
- a third of all marine species have some part of their life cycle in coral reefs so if they gone down, all these species are going down with them
- it's not so much the amount of CO₂ but the rate at which it is building up: much of life in the ocean is not genetically equipped to accomodate such rapid changes
- **coral over the Great Barrier Reed has dropped about a half since the early 80s** = adaptation clearly not effective enough to drop that decline
- we are at ≈ one thousand times the natural rate of extinction, we are at a rate of massive mass extension such as there was at the end of the dinosaur
- **myth that nothing can be done: but it will be worse if we do nothing, we can at least slow it down and we will be really culpable if we don't**

850 million people & 1/3 of all marine species depend on reef organisms, which are greatly endangered by climate change.

The current rate of acidification is faster than any other time in the past 65 million years: a serious challenge to the biology of life in the ocean.



https://adairhagarresearch.wikispaces.com/file/view/Ocean_Acidification.jpg/212120364/Ocean_Acidification.jpg

WEEK 5-3: ENVIRONMENT

6. REFERENCES

Adaptation takes time

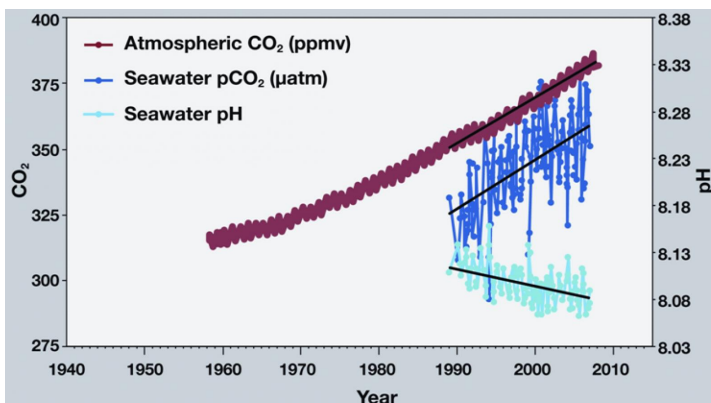
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Ocean Acidification

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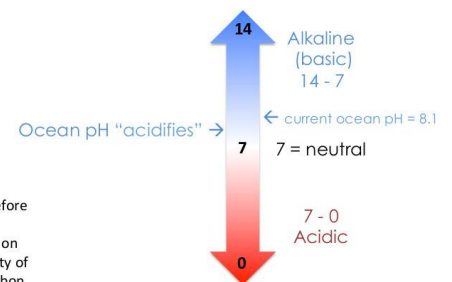
Mattie Mylonas - wikipedia - ocean acidification (visual for next chapter)
<https://wiki.seg.org/wiki/File:Hitimeseries.jpg#filelinks>

MISREPRESENTATION



Saying that the ocean is basic and therefore "ocean acidification" is a lie is a MISREPRESENTATION that is focusing on semantics rather than the physical reality of our ocean becoming more acidic as carbon dioxide floods into it.

Ocean Acidification



WEEK 5-4: SOCIETY

1. OVERALL IMPACTS

CC is a risk management issue

- the more GW human cause, the greater the chance that some damaging consequences will occur
 - > those consequences are estimated based on past climate
 - > **pumping CO₂ in the atmosphere is a risk management issue, the more human release, the greater the risks**, like smoking: more cigarettes = greater risk of cancer
- myth pretending climate change is not so bad**
 - > **cherry pick a few beneficial CC impacts & ignore others**
- humans are unlikely to be able to move to a new planet by the end of the century so they must mitigate the risks of the Earth's CC & reduce their CO₂ consumption
- Earth's surface temperature now +1°C since Indust. Rev.

Expected impacts at +1.5° GW

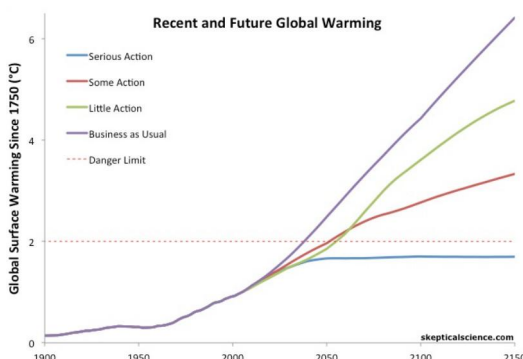
- significant adverse impacts are expected:
 - > widespread coral mortality will worsen
 - > increased water stress for hundreds of millions of people
 - > more damage from droughts, heat waves & floods
 - > increased species extinction rates
- => **humans should be able to adapt to these impacts, with difficulty but without disastrous consequences**

Expected impacts at +2° GW

- worse actual impacts + new impacts triggered
 - > coastal flooding will impact millions of people
 - > most coral reefs may not survive
 - > decline in global food crop production = major famines
 - > sea levels will rise by ≈1m by 2100
 - > up to 30% of global species will be at risk of extinction
- => **"danger limit" used in international climate negotiations**
- => **guardrail from more dangerous potential consequences**

Expected impacts at +3-4° GW

- corals will disappear
- damage to aquatic ecosystem will deplete fisheries
- 40-70% of global species at risk of extinction
- glaciers retreat will threaten water supplies in Central Asia & South America
- possibility of significant releases of CO₂ & methane from ocean hydrates & permafrost amplifying GW
- sea level rise >1m by 2100 & much more afterwards
- Greenland & West Antarctic ice sheets melting will become a major risk or more sea level rise & flooding
- => **far down the path to the 6th Mass Extinction Event**
- => **societal problems: food & water scarcity & floodings can lead to economic damages, mass migrations & conflicts**



WEEK 5-4: SOCIETY

2. CARBON DIOXIDE IS A POLLUTANT

Poisonous vs harmful

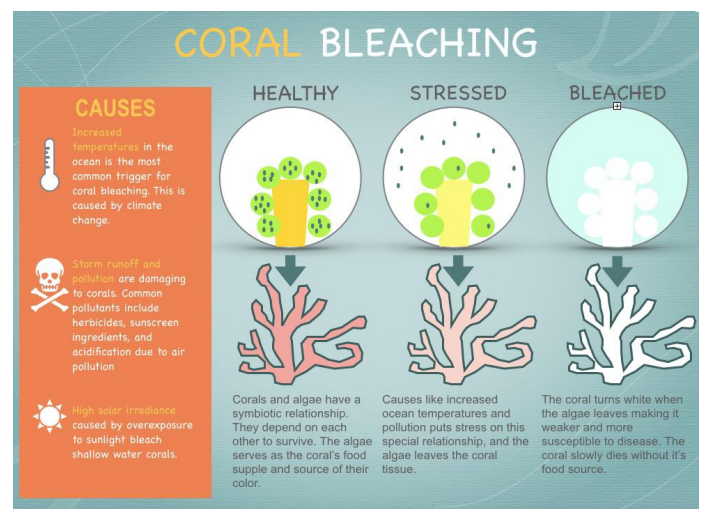
- pollutant**: any substance, chemical or natural, that has harmful or/and poisonous effects
 - => chemicals like DDT are both harmful & poisonous
 - => excess phosphate is very harmful to the environment & so is plastic but they are not considered poisonous
 - => **CO₂ is a naturally occurring, not poisonous, gas, however it is harmful to the environment on a global scale: GW, causing sea level rise & ocean acidification**
- 2007: US supreme court defined CO₂ as a pollutant
- US Environmental Protection Agency decided CO₂ should be regulated as a pollutant because its climate effects pose a clear **danger to public health & welfare**

Myth about CO₂ not being a pollutant

- myth claims CO₂ is not a pollutant because not a poison but this is a **red herring about word-use, distracting from the real issue: that CO₂ is affecting the climate**

Climate change can lead to societal problems:
food & water scarcity + floodings can lead to
economic damages, mass migrations & conflicts

☀
CO₂ is harmful to the environment & the public
on a global scale and its effects last for millennia,
much longer than most other pollutants



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wikipedia: https://en.wikipedia.org/wiki/File:Coral_Bleaching.jpg

WEEK 5-4: SOCIETY

3. AGRICULTURAL IMPACTS

4 ingredients for plant growth

- plants need the right balance of this 4 ingredients:
 - > light, water, CO₂ & fertilizer
- of these 4 factors, light will change the least but water is a big concern because of CC
 - > CC affects where, how much & when rain falls:
 - => some areas may become wetter & others dryer
 - => rain may come too soon or too late
 - => floods & heavy pouring rain wash away seeds & plants, as well as fertilisers out of fields into rivers

Pests and GW

- plants also need also to be safe from dangers
 - > as temperatures go up, crop yields go down
 - > plants are especially sensitive to extremely hot days
 - > pests grow best on hot weather & affect plants
 - => Colorado potato beetle, European grapevine moth...
 - > some pests prefer plants grown with more CO₂
 - => like wheat blight called FHB (fusarium head blight)
 - > many pests are migrating north as the climate warms

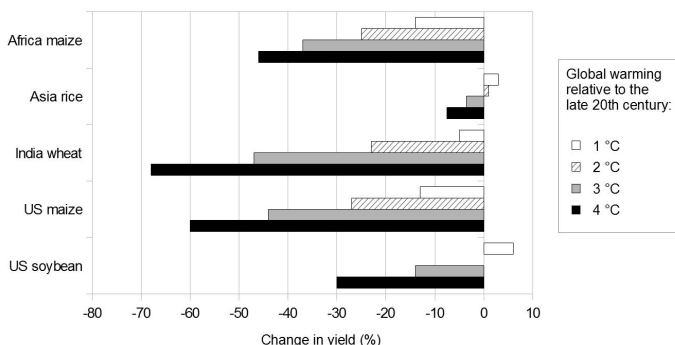
Myth about CC agricultural impacts

- myth claim CO₂ is a plant food so ok for plants
 - > oversimplification, ignores other plant needs
 - > like saying humans need calcium so all they need to live is ice-cream

Scientific consensus: the negative impacts of CC (droughts, extreme weather events, pest increase) far outweigh the positive effect of CO₂ on plants



Every passing day that we don't begin to address CC, the impacts get worse, more expensive & immediate, and have a death toll for human & other species.



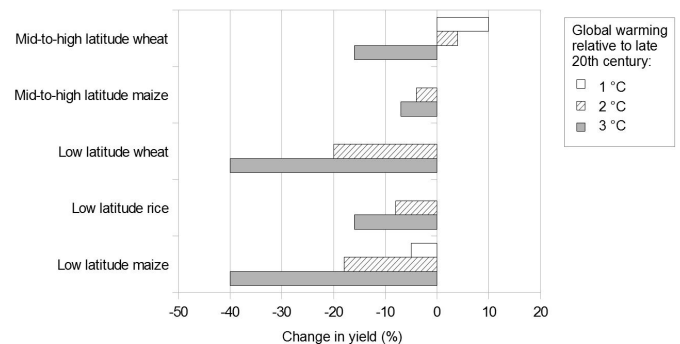
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https://en.wikipedia.org/wiki/File:Projected_changes_in_yields_of_selected_crops_with_global_warming.png

WEEK 5-4: SOCIETY

4. EXPERT INTERVIEWS: IMPACTS ON SOCIETY

Myth about CC being a far away problem

- myth that CC is distant in time & place but CC impacts are happening now and everywhere around the world
- all the systems in place: agriculture, urban environment, everything human have set up has been predicated on a stable climate which they are making uncontrollable
 - > many things humans have built hit sudden thresholds
- => cf, little climate changes can make a big difference to whether your city is livable or not after a storm, flood...
- impacts on climate & humans: food production, biodiversity, sea level rise, precipitation



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https://en.wikipedia.org/wiki/File:Projected_changes_in_crop_yields_at_different_latitudes_with_global_warming.png

Inequalities about CC

- developing regions will be most affected by the pollution of other countries, the highest emitters of CO₂
 - => Kirabati is having saltwater intrusion inundation & sea level rise yet they are not emitting any CO₂
- to some islands, Cf Pacific islands, a small amount of sea level makes a massive difference to your livelihood
 - > sometimes combined with high tide or storm surge
- countries like Bangladesh & the Netherlands would be completely devastated by a sea level rise >1m
- millions & millions of people are set to be displaced with scientists' even low end projections of sea level rise
- in the tropics, people are depending on the glaciers
 - > like in Peru: 34 million people, >50% live in the desert depending on rivers that come from glaciers
 - > 75% of their electricity also depend on these rivers
 - > Tibet glaciers provide water for China, India, Pakistan
- biggest CC impacts could be on agriculture
 - > problems with water supplies or floodings
 - > problems with heat thresholds (wheat etc.)
- people who don't have access to air conditioning or inadequate public infrastructures can be sick & even die because of heat waves
 - => 2003: 35000-50000 deaths in Europe
- spread of diseases such as malaria in East Africa as GW allows more pests like mosquitoes to expand

Importance to tackle CC now

- CC is expensive: each degree of warming cost more than the previous one: the price, the damages go up
- no time to muck about, it's happening, it's serious but we can solve it and we must because it's the planet we live on and its people that are affected

WEEK 5-4: SOCIETY

5. REFERENCES

Overall impacts

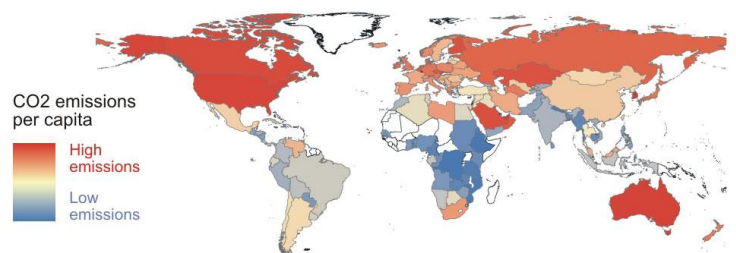
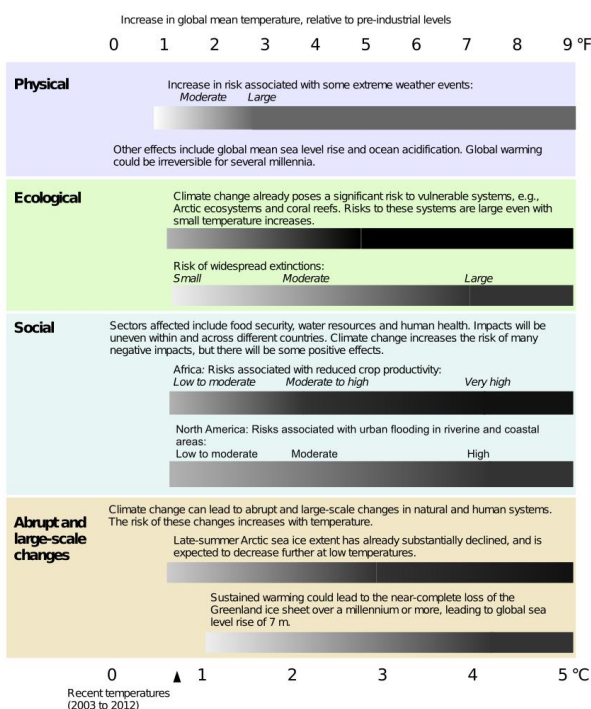
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Carbon dioxide is a pollutant

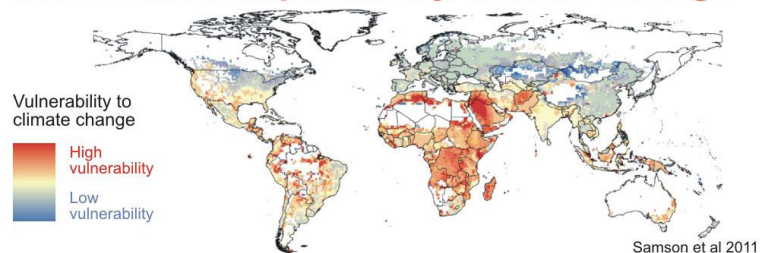
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Agricultural impact

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Those who contribute the least greenhouse gases will be most impacted by climate change



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WEEK 5-4: EXTREME WEATHER

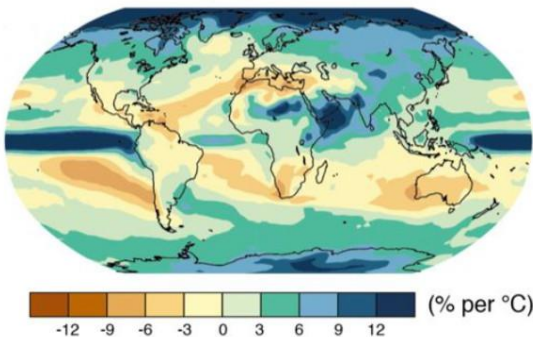
1. EXTREME WEATHER

Heat is a type of energy

- the simplest way to think of GW is to say we are "adding energy" to the climate system
- > creates a warmer, moister atmosphere
- all weather will be affected in some way by the new, more energetic climate we are creating
- scientists cannot tell if a specific weather event was caused by CC but they can say that GW amplifies the risk of extreme weather events in several ways:
 - warmer ocean temperature can feed heat & moisture to storms and change the places where they develop
 - warmer atmosphere holds more moisture: so rain & snow are likely to fall more heavily
 - moisture is also the key to some precipitation events such as flash flooding from a big rain storm

How can moisture power storms?

- warm air cools as it rises & water vapour condensed into liquid cloud droplets= condensation releases heat
- > causes the air to rise further & the heat released when the water condenses feeds more energy into the storm
- scientists expect some overall changes caused by GW
 - more rain & snow at mid to high latitudes of the Northern Hemisphere because of the extra moisture
 - wet areas are getting wetter VS dry areas getting drier
 - > floods VS droughts
 - > projected to increase by 5-20% this century



IPCC, AR5, Ch.14: Precipitation Change-FigFAQ14.2-1 - Skeptical Science use with permission [ipcc.ch/pdf/assessment-report/ar5/wg1/wg1AR5_Chapter14_FINAL.pdf](https://www.skepticalscience.com/ipcc/ar5/wg1/wg1AR5_Chapter14_FINAL.pdf)

Myth about extreme weather & GW

- > says because extreme weather has happened naturally before, it must be natural today to
- => jumping to conclusions: just because extreme weather events happened naturally before does not mean humans can't affect them too
- => GW is affecting all weather but that does not time every single extreme weather event is caused by CC
- > scientists have observed more frequent occurrences of certain types of weather events now and there is more & more evidence that these changes are caused by GW
- statistics & computer simulations can help determine if an event would have been likely to occur without GW
- > 2013: heavy precipitation caused landslides, debris flow & flooding (5800 deaths): scientists found out these kind of events happen more often now than 100 years ago
- => pointing to GW amplifying the risk of extreme weather
- => fossil fuels are fuel for extreme weather

WEEK 5-4: EXTREME WEATHER

2. HEAT WAVES

Consequences & increased frequency of heatwaves

- Europe, Asia & Australia are already seeing more frequent heat waves because of GW
- => 2003 European heatwave killed >50 000 people
- => human-induced greenhouse effect made it 4x more likely that such an event would occur

Why are heatwaves increasing?

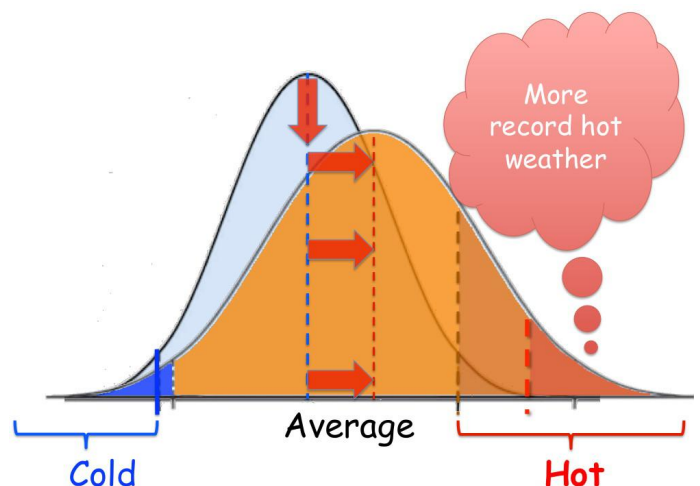
- increasing global temperature changes the average temperature, pushing it towards warmer territory
- > more frequent + more intense + longer heatwaves
- CC may have already doubled the occurrence of heat waves in some regions
- => amplified by the fact that heat can't escape to space because of greenhouse gases, not even at night when we should be able to get some coolness otherwise
- => amplified by the moisture in the air which intensifies discomfort and danger of heat waves

Myth about heatwaves

- > heat waves have happened naturally before so must be happening naturally now
- => logical fallacy called sequitur "does not follow"
- = jumping to false conclusions
- => like saying people died of cancer long before cigarettes were invented so smoking does not cause cancer

Extreme weather events have always happened but in the warmer moister climate we are creating, they are likely to be more severe & frequent.

Heat waves can cause droughts, which can lead to wildfires & crop failures, as well as death: >50 000 deaths in Europe in 2003.



Keah Schuenemann - Weather bell curve - CC BY-SA
[youtube.com/user/denial101x](https://www.youtube.com/user/denial101x)

WEEK 5-4: EXTREME WEATHER

3. HURRICANES

Storm surge

- = one of the most damaging effect of hurricanes
 - > hurricanes powerful winds pile up enormous volumes of water & the low pressure at their center lets ocean level rise higher
 - => creates a towering supply of water
 - => waves ride on top of this surge
- GW causes sea levels to rise & increasing the underlying sea level makes the storm surge even larger
 - = storms surges do more damage over the same areas
 - + reach areas even further inland than before
- Lloyd's of London's report, an insurance firm estimates that current sea level rise has increased Hurricane Sandy's damage by 30% = \$8 billion in NY alone



(UCAR) COMET Program; NOAA- Surge bulge -
Skeptical Science use with permission - www.nhc.noaa.gov/surge/

Torrential rain

- hurricanes also produce torrential rains:
 - the warm moist air they pull up from the ocean cools & condenses as it rises, causing massive rainfall
 - => these rains are expected to get heavier with GW
 - => storm surges + rain cause massive flooding

Winds

- hurricanes can also be destructive because of their fierce winds, which speed increases with GW
- wind shear: ≠ in wind speed at ≠ heights in the atmosp.
 - > high wind shears rip apart hurricanes & some places may get higher wind shears with GW
- = a warming world will have fewer but stronger storms
- hurricanes can also be pushed around the oceans by prevailing winds so for some areas this may mean less storm (pushed away) but more to others (pushed in)

Myth doubting link between GW & hurricanes

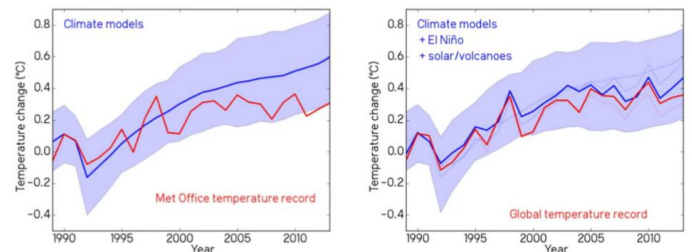
- > oversimplification: hurricanes have happened before but that does not mean CC does not affect them now
- > hurricanes are influenced by a lot of environmental factors, the main one being hot ocean temperature
- > hurricanes have always gotten stronger in response to natural increases in ocean temperature in the past too
- => strengthens confidence they will do so in a human-caused increase in ocean temperature too now
- cherry picking North Atlantic in recent years, because it has not had storms as dramatic as in the mid-2000s
- > yet the overall picture from accurate observations point to increased hurricane activity tied to ocean warming

WEEK 5-4: EXTREME WEATHER

4. MAKING SENSE OF THE SLOWDOWN

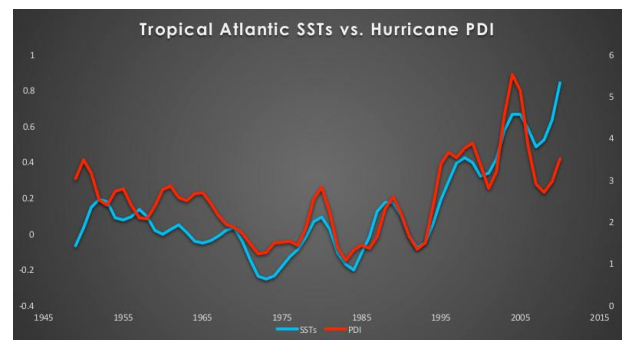
Myth claims GW has stopped

- inspired by evidence that warming of the atmosphere has been slower over the past one and a half decades = the hiatus (slowdown)
 - => cherry picking because ocean heat measurements show that the planet is indeed absorbing heat
- + other factors affect the atmosphere over short periods
 1. El Nino cycle: phenomena storing heat in the Western Pacific Ocean then releasing it to the atmosphere in the Eastern Pacific over the course of a few years
 - => recent years have been dominated by the cool phase of this cycle but this does not explain all the slowdown
 2. cooler periods in the early 80-90s were caused by 2 major volcanic eruptions, which dust spread in the atmosphere, cooling the surface + smaller eruptions
 3. solar cycle: last cycle was particularly weak so it offset a bit of the warming too
 4. rapid industrialisation in Asia has led to more particulate pollution in the atmosphere: cooling effect
 5. 2 of the major data providers (UK Met Office & NOAA) don't include the Arctic in their global temp' calculation
 - > because there are not weather stations there
 - > but the Arctic has been warming faster than anywhere else on the planet
- => the hiatus does not change scientists' understanding of human-caused GW



As humans warm the planet, rising sea levels, heavier rains, stronger winds & warmer ocean water will increase the destructive potential of hurricanes.

Hiatus: greenhouse gases have continued to build up but other natural temporary factors (El Nino etc.) have had a short-termed cooling effect.



Peter Jacobs - Tropical Atlantic SeaSurfaceTempearatures vs. PDI -
CC BY-SA - Adapted from doi: 10.1038/nclimate1452 Fig. 3

WEEK 5-4: EXTREME WEATHER

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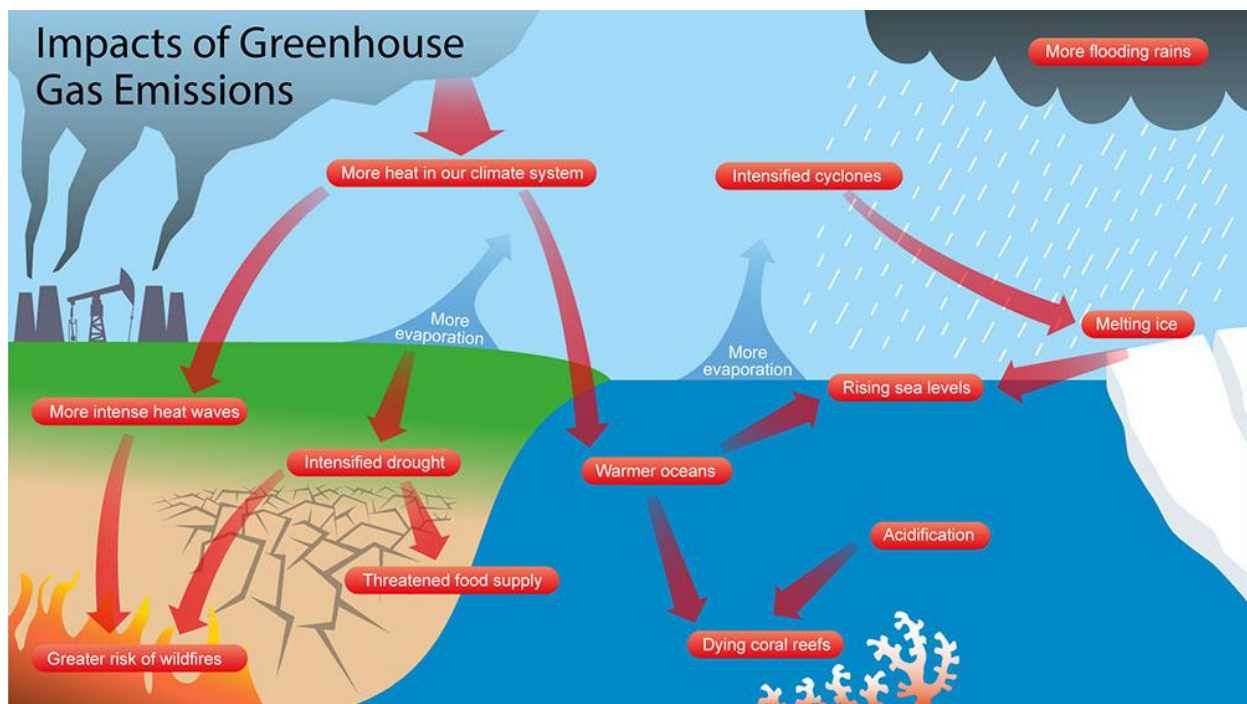
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WEEK 6-1: OVERVIEW

HOW DO WE RESPOND TO SCIENCE DENIAL?

What is the most effective approach in reducing the influence of misconceptions?

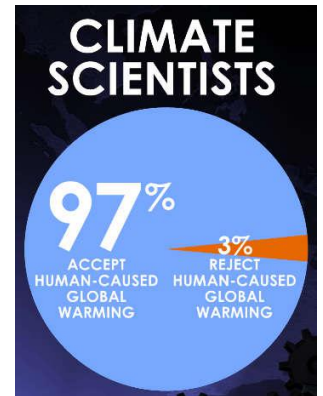
Given the complexities of how the human brain works, what's the best way to debunk a myth?

WEEK 6-2: BARRIERS TO CHANGE

1. VOCAL MINORITY

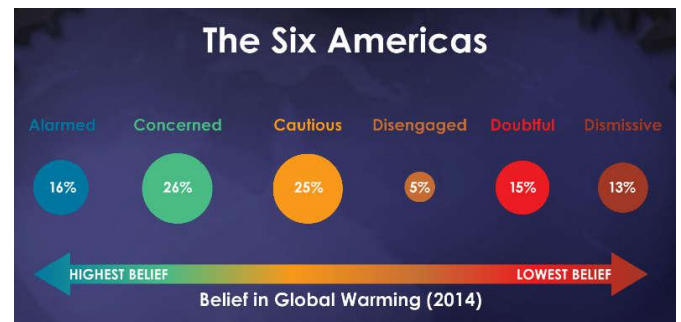
US Senate voted on whether "human activity significantly contributes to climate change" (2015)

- half of them voted no
- whilst 97% of climate scientist agree yes
- huge gap between what the scientific community and the country leaders think



What the public think

- the Six Americas' reports (2014 survey)
 1. dismissive of climate science=13%
 2. doubtful=15%
 3. disengaged=5%
 4. cautious=25%
 5. concerned=26%
 6. alarmed=16%



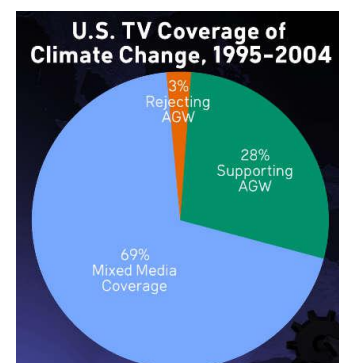
Australia : survey by Zoe Leviston&co

1. think GW caused by humans 45% but think they are only 40%
2. think GW natural
4. don't know
3. think GW not happening 7% but think they are 49%
= false consensus effect
They are less likely to change their opinions
The rest of the public think deniers are 23%
= pluralistic ignorance
These 7% deniers are a vocal minority
= they have a disproportionate influence on the rest of the public



Media

- only 28% of media coverage paints a realistic picture of climate science
- studies show climate denial gets a disproportionately high amount of coverage
- John Cook study shows a great influence of media coverage on people's beliefs about climate change
- just reading 1 article with false balance reduces public's perception of scientific consensus
- so the small vocal minority of deniers cannot be ignored because they have a large influence
- this means it is necessary to respond to denial



WEEK 6-2: BARRIERS TO CHANGE

2. WORLDVIEW BACKFIRE EFFECT

Daniel Batson religious belief experiment (1975)

- shows (false) evidence that JC did not rise from the dead to a group of young Christians in Kansas
- yet after being shown evidence that ran counter to their belief, their faith got stronger
- = **worldview backfire effect: evidence can backfire if it threatens someone's worldview** because they expect their beliefs to be challenged & distrust evidence that go against it

Brendan Nyhan & co (recent study on vaccins)

- test people who deny the importance of vaccins
- showing them articles about the risks of the diseases preventable by vaccin did not help
- debunking the autism myth actually even lowered their intent to vaccinate
- = **no message could change their mind because their worldview predisposed them to oppose vaccination**

Weapons of mass destruction in Irak & climate change

- American Conservatives were more likely to believe that there were weapons despite proofs
- same problem with climate: news stories about the health impacts of climate change of climate change backfired amongst political conservatives
- = **worldview influences how people respond to evidence about climate change, whether they update or not their beliefs**

N.Smith & A.Leiserowitz (response to global warming)

- asked climate change deniers the first words that came to their mind about global warming
- most common response by far: conspiracy theory
- = **most deniers think the science is a hoax, so any more scientific proof will be seen as part of the hoax, as more proof of the "conspiracy"**

TO AVOID WORLDVIEW BACKFIRE EFFECT:

Study by David Hardisty & co

- talking about *offset* instead of *tax* increases acceptance of price increase by conservatives
- = **language not threatening to conservatives neutralized the biasing influence of ideology**

3 different reasons for action (Queensland Uni)

1. avoid environmental & health risks
 2. improve economy & scientific development
 3. help people be more caring & friendly
- = the 3rd reason worked best on deniers
 - = the 2nd ranked just behind
 - = the 1st ranked lowest

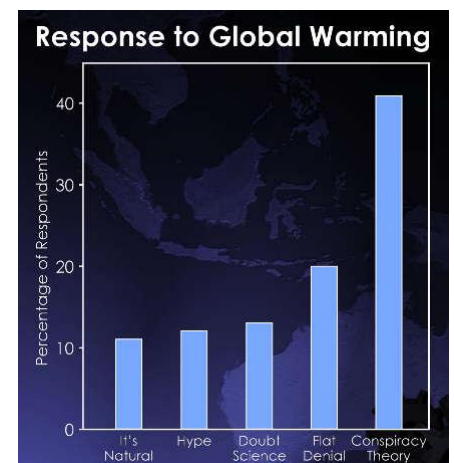
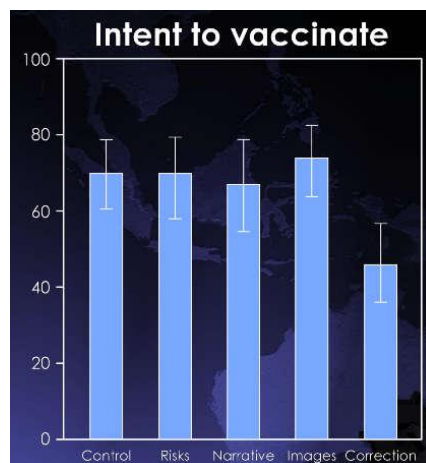
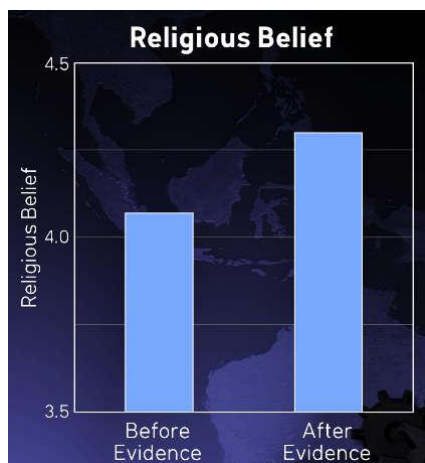
Conclusion

- engaging with deniers can result in counterproductive, backfire effects, or at best, a small positive effects if their ideology is spared
- yet misconceptions originating from deniers confuse the rest of the public and erode their support for climate action
- = **it is better to engage with the vast undecided majority of the public, who are more open to evidence, than deniers, who aren't**

Evidence can backfire
if it threatens someone's worldview.



There is a huge gap
between what the scientific community
and the country leaders think



WEEK 6-2: BARRIERS TO CHANGE

3. FROM THE EXPERTS:

MOVING PAST BARRIERS TO CHANGE

How to deal with denial? (S. Lewandowsky)

- be driven by data, research, empirical findings
- look at the data in cognitive science & psychology
- = difficult to change people's mind who are committed to reject the science because **trying to change their beliefs about climate change challenges their world-views & risk backfire effect**
- = so engagement with deniers is inadvisable since it can strengthen their beliefs (counterproductive)
- = **waste of time & resources to talk to deniers since they are not evaluating the evidence rationally but are motivated by ideology, politics etc.**
- they mostly fear interference with the free market

Unreliable sources (L. Hamilton)

- if you contradict things people cherish, they will type you as an unreliable source

Ideology (Kerr)

- **ideological or psychological barrier:** when people are not interested in either evidence or reason

Identity (S. Sherwood)

- some people have already made up their mind as almost part of their identity (*almost impossible to change their mind*)

Disbelief in science (Sir Attenborough)

- what can you say to people who reject the science?

Impossible conversation (L. Alexander)

- some people, the more you give them facts, the more they hold on to their beliefs

Strong belief (U. Ecker)

- **people defend beliefs central to their identity, they can become even more extreme if challenged**
- a minority of people will never change their mind, no matter how much evidence you give them but most other people might listen and change

Teaching the next generation (M. England)

- can't convince deniers but can teach the next generation how the physics works

Climate change swing-voter (S. Donner)

- undecided people who will change their views according to the media & current events
- usually people politically in the middle

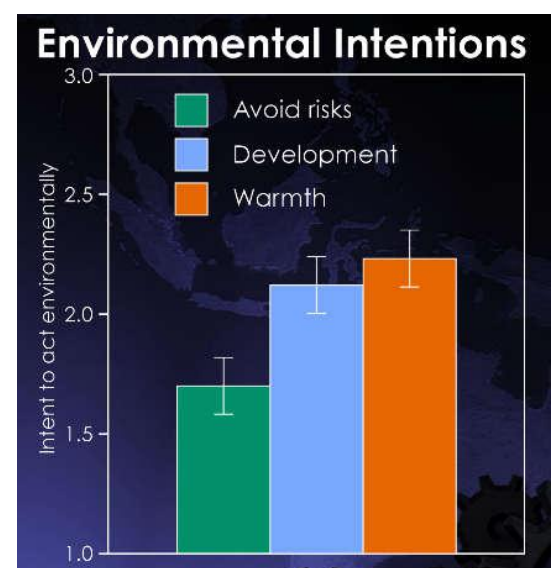
Engage with open-minded people (experts)

- **tell about the scientific consensus**
- **explain that deniers are just a vocal minority**



People defend beliefs central to their identity, they can become even more extreme if their values are challenged.

Deniers are not evaluating the evidence rationally but are motivated by ideology.



WEEK 6-2: BARRIERS TO CHANGE

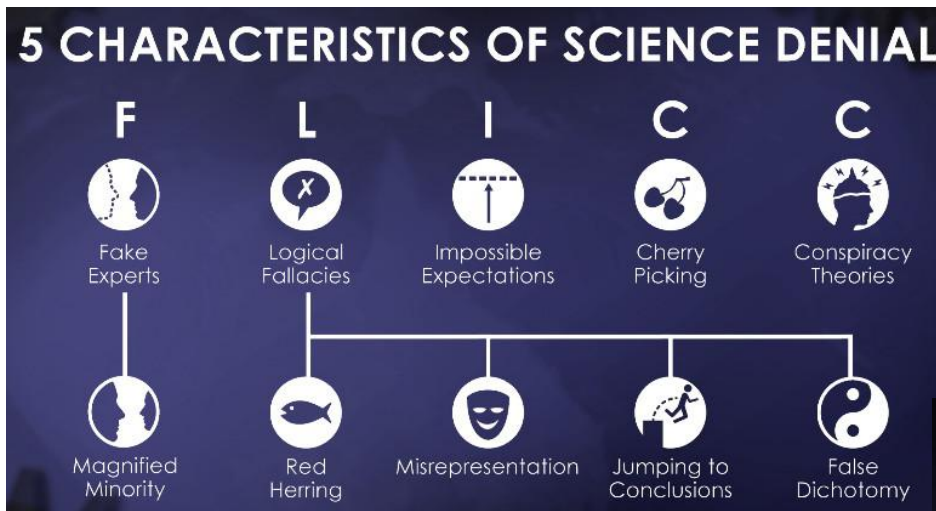
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"Comprehending why ideas are wrong matters just as much as understanding why some ideas may be right."

JONATHAN OSBORNE

WEEK 6-3: DEBUNKING

1. INOCULATION THEORY

How to deal with denial?

- only 14% of U.S. public dismiss climate change science but their misconceptions lower the rest of the public's understanding of & trust in CC science

Inoculation theory

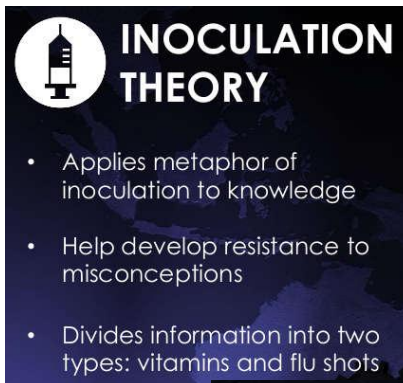
- psychological study over 50 years apply the metaphor of inoculation to knowledge
- help people develop resistance to misconceptions
- divides information into vitamins & flu shots
- = vitamins alone may not give you immunity, just like a scientific explanation may not help you to identify a misconception or myth
- = flu shot is a weak version of the virus, just like in inoculation theory, a weak version of a misconception is given, so that when people encounter it later on, they are better able to fight it
- = must expose people to myths to help them build resistance to them, identify them etc.

"Comprehending why ideas are wrong matters just as much as understanding why some ideas may be right." (Jonathan Osborne)

- Education is not just about adding new information but also about correcting misconceptions.

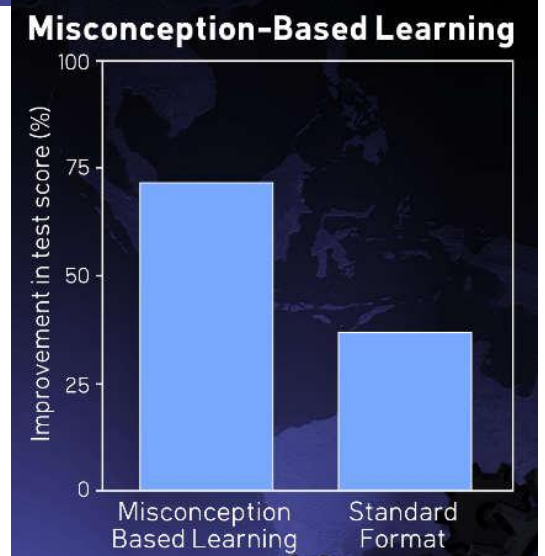
Misconception-based learning

- mention myths then debunk them is important otherwise just adding new facts, as standard lectures do, won't erase misconceptions
- debunking lectures twice more efficient than standard ones to reduce misconceptions
- need to directly challenge false ideas to get people to examine how their preconceptions are wrong
- debunking lecture lower confidence but boost genuine understanding & humility whilst standard lectures instill false confidence



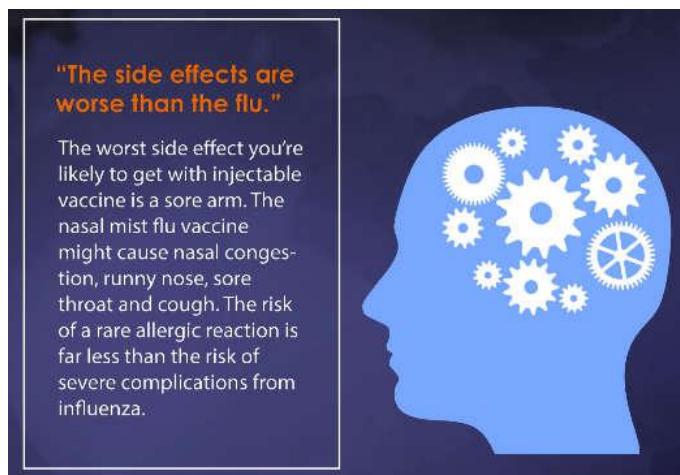
INOCULATION THEORY

- Applies metaphor of inoculation to knowledge
- Help develop resistance to misconceptions
- Divides information into two types: vitamins and flu shots



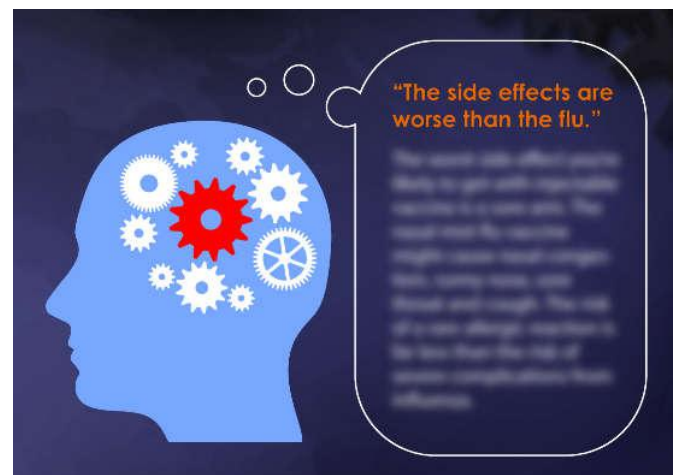
"Of course, we need to teach the science. But that's only half the picture. We also need to explain how that science can be distorted. By teaching the fallacies of science denial, we neutralise its influence"

John Cook



"The side effects are worse than the flu."

The worst side effect you're likely to get with injectable vaccine is a sore arm. The nasal mist flu vaccine might cause nasal congestion, runny nose, sore throat and cough. The risk of a rare allergic reaction is far less than the risk of severe complications from influenza.



"The side effects are worse than the flu."

The worst side effect you're likely to get with injectable vaccine is a sore arm. The nasal mist flu vaccine might cause nasal congestion, runny nose, sore throat and cough. The risk of a rare allergic reaction is far less than the risk of severe complications from influenza.

WEEK 6-3: DEBUNKING

2. STICKY SCIENCE

The psychology of debunking (Norbert Schwarz)

- if you debunk myth in the **wrong way** (*making the myth more prominent than the fact, for instance using it as a title*), you risk **reinforcing** it

How people think - mental models

- as we learn new information, we build mental models of how the world works
 - because we think inside our heads whilst the world is outside of our heads
 - having a complete working mental model means we understand something (*or think we do*)
 - all the parts fit like cogs if the model is complete
 - **debunking a myth plucks out a part of people's mental model and that leaves an uncomfortable gap**
 - when a mental model is incomplete, people don't understand anymore so **they prefer a false complete model than an accurate incomplete one**
 - that is why a myth can come back into people's mind even after debunking, to fill the gap
- = **CONTINUED INFLUENCE EFFECT OF MISINFORMATION**

How to debunk myths without leaving gaps

- **when you debunk a myth, you must fill the gap by providing a fact** to complete the mental model
- = like in a murder case, people will continue to suspect someone even if proven innocent until the real culprit is found
- **alternative fact needs to be plausible** and must fit all the casual links left by the myth's gap: people should understand the world better afterwards
 - **emphasise the facts, not the myths**, for people forget details so if you repeated the myth or put it into a headline, they may remember only the myth

Debunking a myth is like reaching into someone's mind to **pluck out a part of their mental model** and that leaves an uncomfortable gap.



To debunk a myth without leaving a gap, you must explain the science effectively.

Sticky science

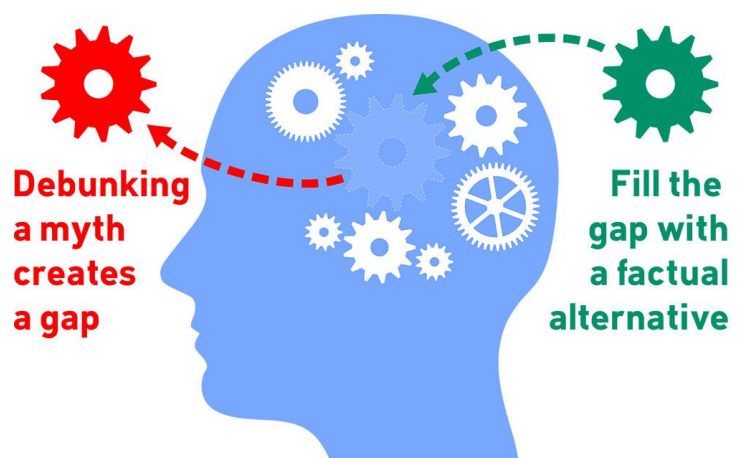
- *Made to stick* - a book by Chip & Dan Heath
 - fight sticky myths with stickier facts
- = communicate the science in a compelling manner
- **SUCCES method**:
 - 1. **simple** (*avoid unnecessary complexities*)
 - 2. **unexpected** (*take people by surprise*)
 - 3. **credible** (*reliable sources*)
 - 4. **concrete** (*visuals & metaphors*)
 - 5. **emotional** (*easier to remember & share*)
 - 6. **stories** (*better than numbers & abstract concepts*)

WEEK 6-3: DEBUNKING

3. EXPERT INTERVIEWS: CLIMATE METAPHORS

Common basis metaphors

- choose analogies that your audience understands
- examples:
- 1. **sponges**: glaciers act like sponges, they hold the fallen snow in winter then release it in summer
- 2. **drugs**: comparing an athlete's extreme performance on drugs with climate change's extreme weathers's "drug" (Co2)
- 3. **disease**: what's the prognosis of this disease (climate change) based on what we know?
- 4. **burglary**: rates of biodiversity going down is like getting burgled repeatedly and losing more and more furniture until nothing's left but unwanted stuff that is hard to get rid of
- 5. **insurance policy**: glaciers are like it, they accumulate water during wet periods then melt & release it during drought and dry seasons
- 6. **Lego**: climate models are like Lego, each block represents a box in which the climate model has a value for temperature etc.
- 7. **cork**: ice sheet works like a bottle's cork, if you break the ice, the water flows faster in the ocean
- 8. **cars**: comparing new climate models to old ones is like comparing a 2014's F1 gd prix car to a 1970's
- 9. **business**: any business running as badly as glaciers would be bankrupt (*since they have mostly bad years/negative balance*)
- 10. **lemon vs sugar**: scientists have lemon but industries have sugar, so people prefer listening to the sweet talk than to the "crazy" scientists
- 11. **physicians of the planet**: climate scientists are like doctors who tell a patient that he has terminal cancer but the patient don't believe it, climate scientists have done a scan of the planet, saw that it is running a fever, looked at all the other symptoms around the world resulting from it



WEEK 6-3: DEBUNKING

4. FLU SHOTS:

How to speak about myths / give flu shots

- "A lie gets halfway around the world before the truth has a chance to get its pants on." Churchill
- myths spread quickly with social media and don't disappear easily, on the contrary, they go viral
- **always warn people before stating a myth that it is one:** "a common myth is ..." puts them on guard so they're less likely to be influenced by the myth
- then explain why the myth is wrong, how it distorts the science, using which fallacy

Don't put too much emphasis on a myth but don't ignore it either: it's a balancing act.

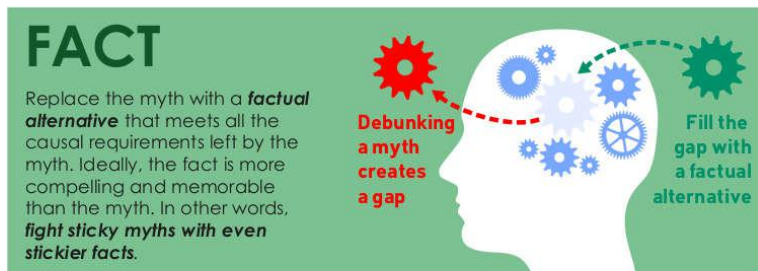


Explaining the fallacy behind a myth neutralise it and can even make it backfire

5 characteristics of science denial (Diethelm & McKee)

1. **Fake experts:** foster the fake impression of an ongoing scientific debate, denies consensus
-> **magnified minority**
 2. **Logical fallacies:** distorts the science by drawing incorrect conclusions from the data
-> **red herring:** distract with irrelevant info
-> **misrepresentation:** oversimplification
-> **jumping to conclusion:** faulty leaps of logic
-> **false dichotomy:** presenting only 2 choices when others are available
 3. **Impossible expectations:** demands standards of evidence that is impossible to achieve
 4. **Cherry picking:** using small, select pieces of data, while ignoring any inconvenient data
 5. **Conspiracy theories:** frequent among groups who disagree with an overwhelming consensus
- = **response to misinformation study:** people informed about a fallacy before reading a denial myth using it, did not fall for it, they even believed more in climate change's consensus after reading

An effective debunking of a myth requires three elements: Fact, Myth and Fallacy:



MYTH/MISCONCEPTION

Mentioning the myth makes people more familiar with the myth, which risks a **familiarity backfire effect**. Nevertheless, you need to mention the myth to debunk it. Here are 3 techniques to reduce the risk of a backfire effect:

- Emphasise the fact rather than the myth.
- Warn people before mentioning the myth. This puts them cognitively on guard so they're less likely to be influenced by the misinformation. This can be as simple as "A common myth is..."
- Immediately explain the fallacy - the technique used to distort the fact.

FALLACY

Explain the technique used by the myth to distort the fact. This enables people to reconcile the fact with the myth. Common fallacies include:



DEBUNKING

Structure of an effective debunking

FACT

MYTH

FALLACY

WEEK 6-3: DEBUNKING

5. REFERENCES

Inoculation theory

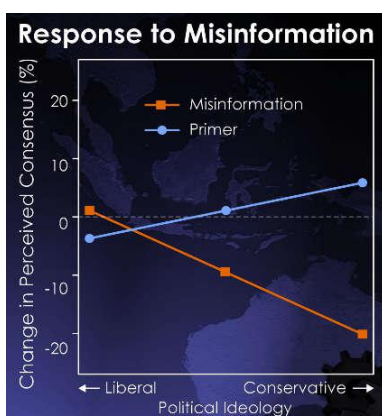
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Flu shots

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INOCULATION THEORY

- Applies metaphor of inoculation to knowledge
- Explaining the science isn't enough
- We need to specify the myth

FLU SHOT

- Flu shot: a weak form of the myth
- Warning before specifying the myth
- Explain the fallacy that the myth uses to distort the science



ABOUT THE MOOC'S TEAM

The DENIAL101x team is made up of [scientists, researchers, professors and experts](#) from Australia, the United Kingdom, Europe, the United States and Canada who are passionate about climate science. In a truly collaborative effort, they have developed lectures & activities to engage students with the science and enable them to respond to climate myths using evidence.

They have also conducted & included [over 75 interviews with notable experts in climate science](#) to add even more depth to the course. Their team contributes to the Skeptical Science website at skepticalscience.com.

The DENIAL101x team is led by [John Cook](#), a research assistant professor at the Center for Climate Change Communication at George Mason University. When this course was developed, he served as a Climate Communication Fellow for the Global Change Institute at The University of Queensland in Brisbane, Australia.

THIS DOCUMENT IS A STUDENT'S UNOFFICIAL SUMMARY OF THE MOOC:
THE DENIAL 101X TEAM CANNOT BE HELD RESPONSIBLE
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MORE ABOUT CLIMATE CHANGE & THE MOOC'S TEAM

- Skeptical Science website: <https://www.skepticalscience.com>
- Denial101X videos: <https://www.youtube.com/user/denial101x>
- MOOC: <https://www.edx.org/course/making-sense-climate-science-denial-uqx-denial101x-6>