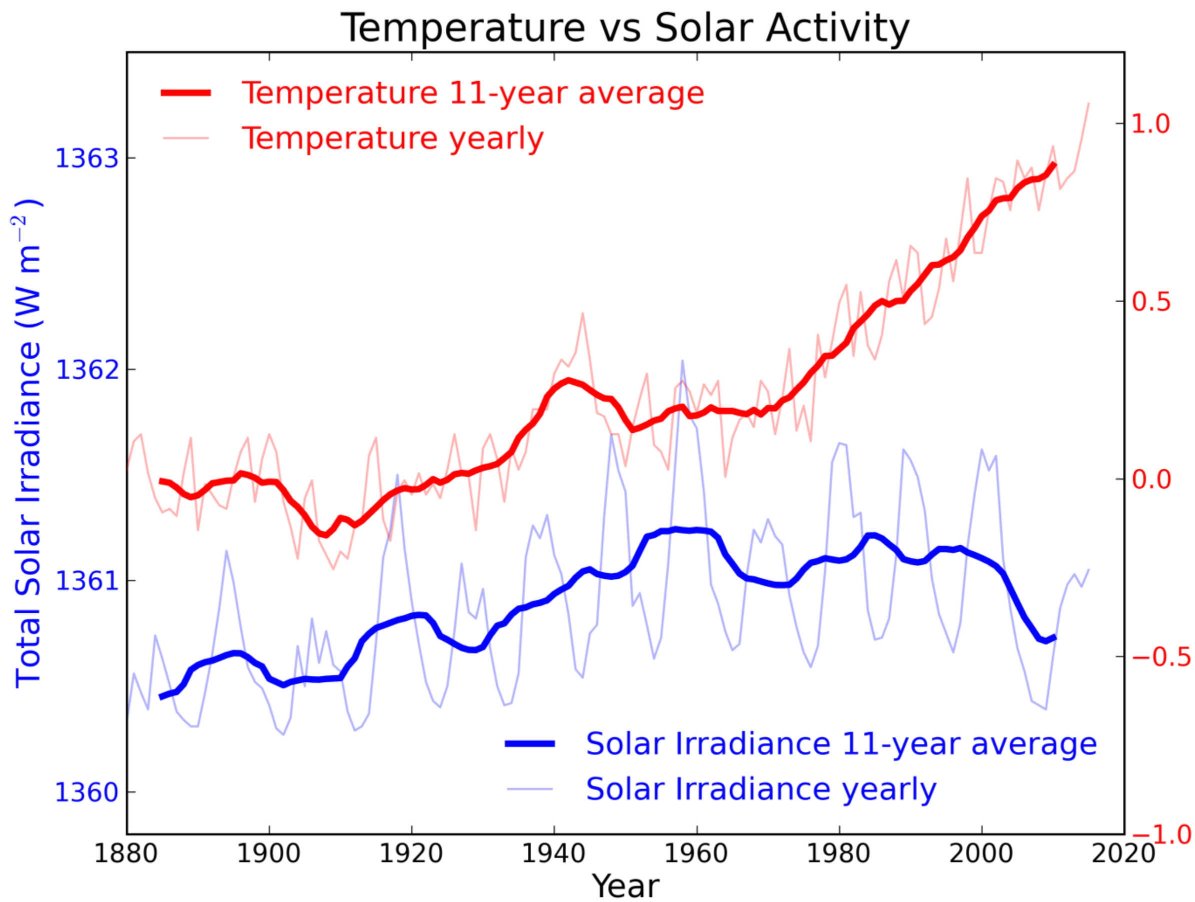
Let's Get Skeptical About Global Warming Skepticism

The Climate Has Changed Before	Climate is always changing. We have had ice ages and warmer periods when alligators were found in Spitzbergen. Ice ages have occurred in a hundred thousand year cycle for the last 700 thousand years, and there have been previous periods that appear to have been warmer than the present despite CO2 levels being lower than they are now. More recently, we have had the medieval warm period and the little ice age. (Richard Lindzen, atmospheric physicist)
See XKCD for Perspective	Greenhouse gasses – mainly CO_2, but also methane – were involved in most of the climate changes in Earth's past. When they were reduced, the global climate became colder. When they were increased, the global climate became warmer. When CO_2 levels jumped rapidly, the global warming that resulted was highly disruptive and sometimes caused mass extinctions. Humans today are emitting prodigious quantities of CO_2, at a rate faster than even the most destructive climate changes in earth's past. **Abrupt vs slow change.** Life flourished in the Eocene, the Cretaceous and other times of high CO_2 in the atmosphere because the greenhouse gasses were ***in balance*** with the carbon in the oceans and the weathering of rocks. Life, ocean chemistry, and atmospheric gasses ***had millions of years to adjust*** to those levels. But there have been several times in Earth's past when Earth's temperature jumped abruptly, in much the same way as they are doing today. Those times were caused by large and rapid greenhouse gas emissions, just like humans are causing today. Those abrupt global warming events were almost always highly destructive for life, causing mass extinctions such as at the end of the Permian, Triassic, or even mid-Cambrian periods. The symptoms from those events (a big, rapid jump in global temperatures, rising sea levels, and ocean acidification) are all happening today with human-caused climate change. So yes, the climate has changed before humans, and in most cases scientists know why. In all cases we see the same association between CO_2 levels and global temperatures. And past examples of ***rapid*** carbon emissions (just like today) were generally highly destructive to life on Earth.
It's the Sun	"Over the past few hundred years, there has been a steady increase in the numbers of sunspots, at the time when the Earth has been getting warmer. The data suggests solar activity is influencing the global climate causing the world to get warmer." (BBC)
But Mostly Humans	Over the last 35 years the sun has shown a cooling trend. However global temperatures continue to increase. If the sun's energy is decreasing while the Earth is warming, then the sun can't be the main control of the temperature. The figure on the next page shows the trend in global temperature compared to changes in the amount of solar energy that hits the Earth. The sun's energy fluctuates on a cycle that's about 11 years long. The energy changes by about 0.1% on each cycle. If the Earth's temperature was controlled mainly by the sun, then it should have cooled between 2000 and 2008.



Annual global temperature change (thin light red) with 11 year moving average of temperature (thick dark red). Temperature from NASA GISS. Annual Total Solar Irradiance (thin light blue) with 11 year moving average of TSI (thick dark blue). TSI from 1880 to 1978 from Krivova et al 2007. TSI from 1979 to 2015 from the World Radiation Center (see their PMOD index page for data updates). Plots of the most recent solar irradiance can be found at the Laboratory for Atmospheric and Space Physics LISIRD site.

The solar fluctuations since 1870 have contributed a maximum of 0.1 °C to temperature changes. In recent times the biggest solar fluctuation happened around 1960. But the fastest global warming started in 1980.

The next figure shows how much different factors have contributed recent warming. It compares the contributions from the sun, volcanoes, El Niño and greenhouse gases. The sun adds 0.02 to 0.1 °C. Volcanoes cool the Earth by 0.1-0.2 °C. Natural variability (like El Niño) heats or cools by about 0.1-0.2 °C. Greenhouse gases have heated the climate by over 0.8 °C.

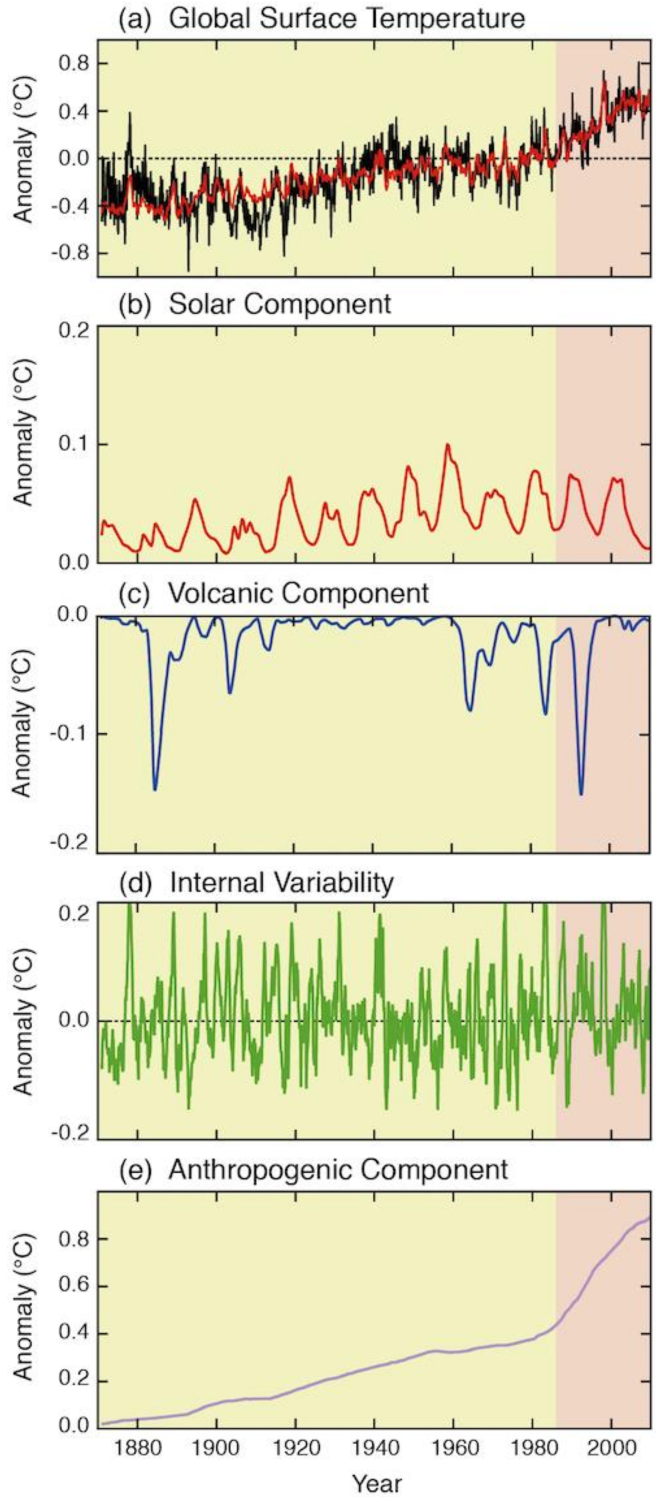


Figure 2 Global surface temperature anomalies from 1870 to 2010, and the natural (solar, volcanic, and internal) and anthropogenic factors that influence them. (a) Global surface temperature record (1870–2010) relative to the average global surface temperature for 1961–1990 (black line). A model of global surface temperature change (a: red line) produced using the sum of the impacts on temperature of natural (b, c, d) and anthropogenic factors (e). (b) Estimated temperature response to solar forcing. (c)

Estimated temperature response to volcanic eruptions. (d) Estimated temperature variability due to internal variability, here related to the El Niño-Southern Oscillation. (e) Estimated temperature response to anthropogenic forcing, consisting of a warming component from greenhouse gases, and a cooling component from most aerosols. (IPCC AR5, Chap 5)

Some people try to blame the sun for the current rise in temperatures by cherry picking the data. They only show data from periods when sun and climate data track together. They draw a false conclusion by ignoring the last few decades when the data shows the opposite result.

It's Not That Bad

"Two thousand years of published human histories say that warm periods were good for people. It was the harsh, unstable Dark Ages and Little Ice Age that brought bigger storms, untimely frost, widespread famine and plagues of disease." (Dennis Avery, director of Center for Global Food Issues at the Hudson Institute, financially backed by agricultural companies and pesticide manufacturers like Monsanto Company and DuPont)

Except It Totally Is

Negative impacts of global warming on agriculture, health & environment far outweigh any positives. Here’s a list of cause and effect relationships, showing that most climate change impacts will confer few or no benefits, but may do great harm at considerable cost.

Agriculture
While CO_2 is essential for plant growth, all agriculture depends also on steady water supplies, and climate change is likely to disrupt those supplies through floods and droughts. It has been suggested that higher latitudes – Siberia, for example – may become productive due to global warming, but the soil in Arctic and bordering territories is very poor, and the amount of sunlight reaching the ground in summer will not change because it is governed by the tilt of the earth. Agriculture can also be disrupted by wildfires and changes in seasonal periodicity, which is already taking place, and changes to grasslands and water supplies could impact grazing and welfare of domestic livestock. Increased warming may also have a greater effect on countries whose climate is already near or at a temperature limit over which yields reduce or crops fail – in the tropics or sub-Sahara, for example.

Health
Warmer winters would mean fewer deaths, particularly among vulnerable groups like the aged. However, the same groups are also vulnerable to additional heat, and deaths attributable to heatwaves are expected to be approximately five times as great as winter deaths prevented. It is widely believed that warmer climes will encourage migration of disease-bearing insects like mosquitoes and malaria is already appearing in places it hasn’t been seen before.

Polar Melting
While the opening of a year-round ice free Arctic passage between the Atlantic and Pacific oceans would confer some commercial benefits, these are considerably outweighed by the negatives. Detrimental effects include loss of polar bear habitat and increased mobile ice hazards to shipping. The loss of ice albedo (the reflection of heat), causing the ocean to absorb more heat, is also a positive feedback; the warming waters increase glacier and Greenland ice cap melt, as well as raising the temperature of Arctic tundra, which then releases methane, a very potent greenhouse gas (methane is also released from the sea-bed, where it is trapped in ice-crystals called clathrates). Melting of the Antarctic ice shelves is predicted to add further to sea-level rise with no benefits accruing.

Ocean Acidification
A cause for considerable concern, there appear to be no benefits to the change in pH of the oceans. This process is caused by additional CO_2 being absorbed in the water, and may have severe destabilizing effects on the entire oceanic food-chain.

Melting Glaciers
The effects of glaciers melting are largely detrimental, the principle impact being that many

millions of people (one-sixth of the world's population) depend on fresh water supplied each year by natural spring melt and regrowth cycles and those water supplies – drinking water, agriculture – may fail.

Sea Level Rise
Many parts of the world are low-lying and will be severely affected by modest sea rises. Rice paddies are being inundated with salt water, which destroys the crops. Seawater is contaminating rivers as it mixes with fresh water further upstream, and aquifers are becoming polluted. Given that the IPCC did not include melt-water from the Greenland and Antarctic ice-caps due to uncertainties at that time, estimates of sea-level rise are feared to considerably underestimate the scale of the problem. There are no proposed benefits to sea-level rise.

Environmental
Positive effects of climate change may include greener rainforests and enhanced plant growth in the Amazon, increased vegetation in northern latitudes and possible increases in plankton biomass in some parts of the ocean. Negative responses may include further growth of oxygen poor ocean zones, contamination or exhaustion of fresh water, increased incidence of natural fires, extensive vegetation die-off due to droughts, increased risk of coral extinction, decline in global phytoplankton, changes in migration patterns of birds and animals, changes in seasonal periodicity, disruption to food chains and species loss.

Economic
The economic impacts of climate change may be catastrophic, while there have been very few benefits projected at all. The Stern report made clear the overall pattern of economic distress, and while the specific numbers may be contested, the costs of climate change were far in excess of the costs of preventing it. Certain scenarios projected in the IPCC AR4 report would witness massive migration as low-lying countries were flooded. Disruptions to global trade, transport, energy supplies and labor markets, banking and finance, investment, and insurance, would all wreak havoc on the stability of both developed and developing nations. Markets would endure increased volatility and institutional investors such as pension funds and insurance companies would experience considerable difficulty.

Geopolitical
Developing countries, some of which are already embroiled in military conflict, may be drawn into larger and more protracted disputes over water, energy supplies or food, all of which may disrupt economic growth at a time when developing countries are beset by more egregious manifestations of climate change. It is widely accepted that the detrimental effects of climate change will be visited largely on the countries least equipped to adapt, socially or economically.

There is No Consensus	The Petition Project features over 31,000 scientists signing the petition stating, "There is no convincing scientific evidence that human release of carbon dioxide will, in the foreseeable future, cause catastrophic heating of the Earth's atmosphere ...". (Petition Project, a group focused on disproving climate change evidence)
If by "No Consensus" You Mean Overwhelming Consensus	97% of climate experts agree humans are causing global warming. Science achieves a consensus when scientists stop arguing. When a question is first asked – like 'what would happen if we put a load more CO2 in the atmosphere?' – there may be many hypotheses about cause and effect. Over a period of time, each idea is tested and retested – the processes of the scientific method – because all scientists know that reputation and kudos go to those who find the right answer (and everyone else becomes an irrelevant footnote in the history of science). Nearly all hypotheses will fall by the wayside during this

testing period, because only one is going to answer the question properly, without leaving all kinds of odd dangling bits that don't quite add up. Bad theories are usually rather untidy.

But the testing period must come to an end. Gradually, the focus of investigation narrows down to those avenues that continue to make sense, that still add up, and quite often a good theory will reveal additional answers, or make powerful predictions, that add substance to the theory.

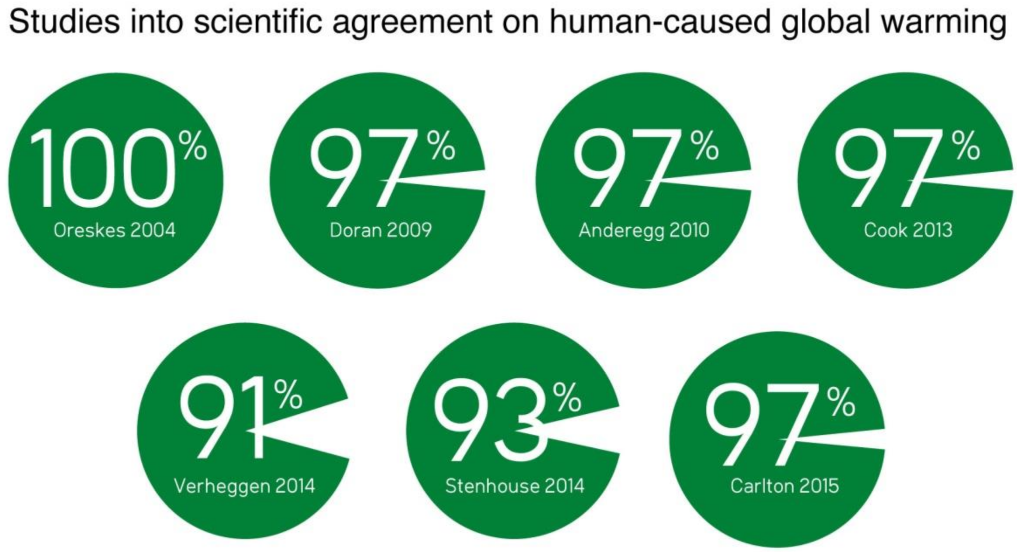
So a consensus in science is different from a political one. There is no vote. Scientists just give up arguing because the sheer weight of consistent evidence is too compelling, the tide too strong to swim against any longer. *Scientists change their minds on the basis of the evidence, and a consensus emerges over time.* Not only do scientists stop arguing, they also start relying on each other's work. All science depends on that which precedes it, and when one scientist builds on the work of another, he acknowledges the work of others through *citations*. The work that forms the foundation of climate change science is cited with great frequency by many other scientists, demonstrating that the theory is widely accepted - and relied upon.

In the scientific field of climate studies – which is informed by many different disciplines – the consensus is demonstrated by the number of scientists who have stopped arguing about what is causing climate change – and that's nearly all of them.

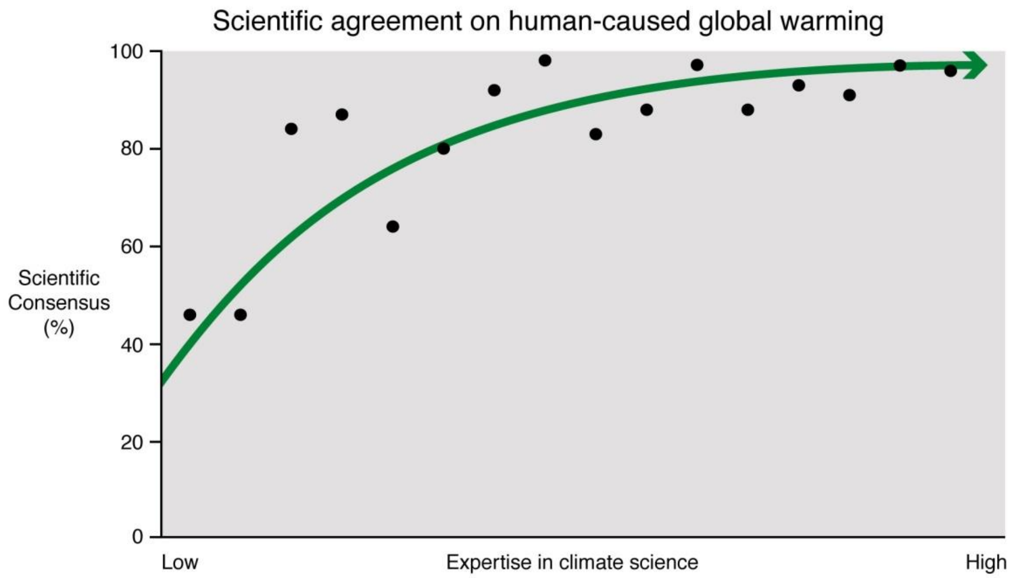
Authors of seven climate consensus studies — including Naomi Oreskes, Peter Doran, William Anderegg, Bart Verheggen, Ed Maibach, J. Stuart Carlton, and John Cook — co-authored a paper that should settle this question once and for all. The two key conclusions from the paper are:

1) Depending on exactly how you measure the expert consensus, it's somewhere between 90% and 100% that agree humans are responsible for climate change, with most of our studies finding 97% consensus among publishing climate scientists.

2) The greater the climate expertise among those surveyed, the higher the consensus on human-caused global warming.



Expert consensus results on the question of human-caused global warming among the previous studies published by the co-authors of Cook et al. (2016). Illustration: John Cook.



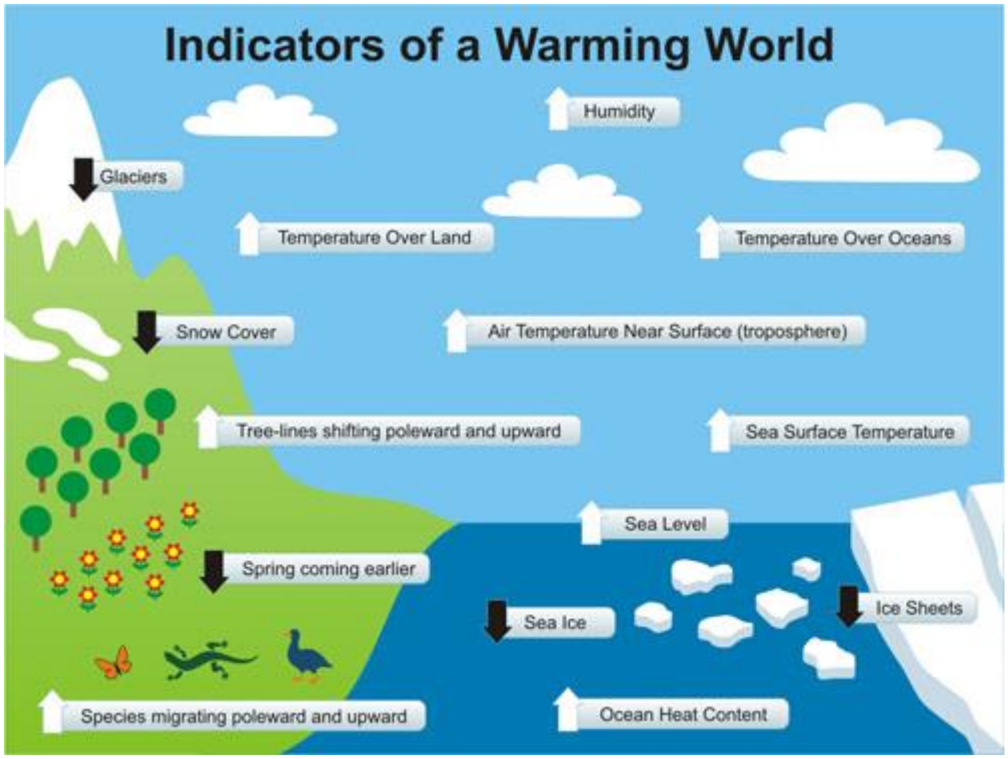
Scientific consensus on human-caused global warming as compared to the expertise of the surveyed sample. There's a strong correlation between consensus and climate science expertise. Illustration: John Cook.

Expert consensus is a powerful thing. People know we don't have the time or capacity to learn about everything, and so we frequently defer to the conclusions of experts. It's why we visit doctors when we're ill. The same is true of climate change: most people defer to the expert consensus of climate scientists. Crucially,

Public perception of the scientific consensus has been found to be a gateway belief, affecting other climate beliefs and attitudes including policy support.

That's why those who oppose taking action to curb climate change have engaged in a misinformation campaign to deny the existence of the expert consensus. They've been largely successful, as the public badly underestimate the expert consensus, in what we call the "consensus gap." Only 16% of Americans realize that the consensus is above 90%.

It's Cooling	"In fact global warming has stopped and a cooling is beginning. No climate model has predicted a cooling of the Earth – quite the contrary. And this means that the projections of future climate are unreliable." (source: Henrik Svensmark, controversial physicist)
Only If You Have the A/C On	When looking for evidence of global warming, there are many different indicators that we should look for. Whilst it's natural to start with air temperatures, a more thorough examination should be as inclusive as possible; snow cover, ice melt, air temperatures over land and sea, even the sea temperatures themselves. The key indicators of global warming shown below are all moving in the direction expected of a warming globe.



Indicators of a warming world based on surface, satellite, and ocean temperature measurements, satellite measurements of energy imbalance (the difference between incoming and outgoing energy at the top of the atmosphere), and of receding glaciers, sea ice, and ice sheets, rising sea level, and shifting seasons.

The question of global warming stopping is often raised in the light of a recent weather event - a big snowfall or drought breaking rain. Global warming is entirely compatible with these events; after all they are just weather. For climate change, it is the long term trends that are important; measured over decades or more, and those long term trends show that the globe is still, unfortunately, warming.

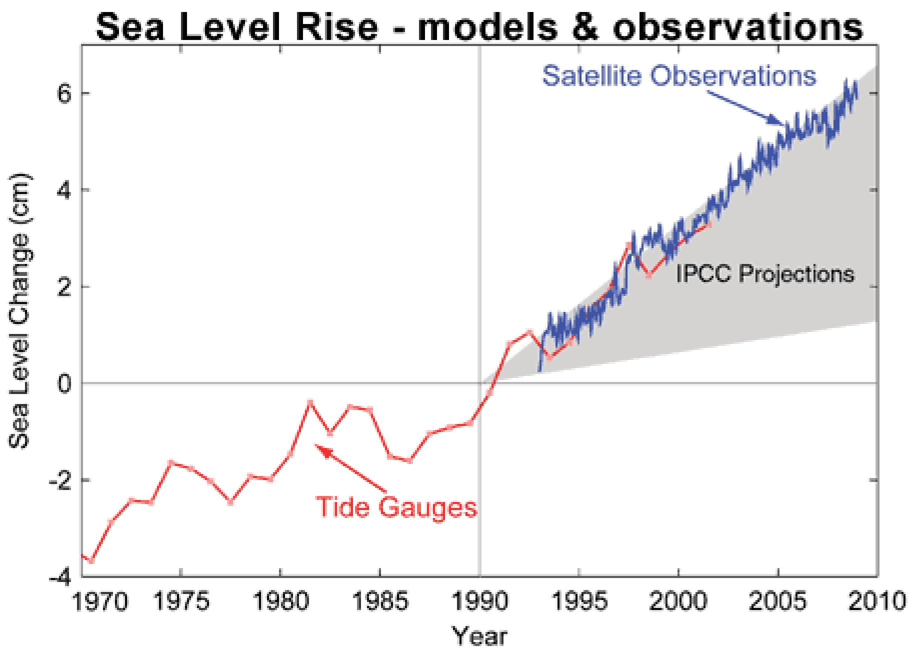
Models are Unreliable	"[Models] are full of fudge factors that are fitted to the existing climate, so the models more or less agree with the observed data. But there is no reason to believe that the same fudge factors would give the right behavior in a world with different chemistry, for example in a world with increased CO_2 in the atmosphere." (Freeman Dyson, theoretical physicist)
Models are More Than A Geek Pastime	Climate models are mathematical representations of the interactions between the atmosphere, oceans, land surface, ice – and the sun. This is clearly a very complex task, so models are built to estimate *trends* rather than events. For example, a climate model can tell you it will be cold in winter, but it can't tell you what the temperature will be on a specific day – that's weather forecasting. Climate *trends* are weather, averaged out over time - usually 30 years. Trends are important because they eliminate - or "smooth out" - single events that may be extreme, but quite rare. Climate models have to be tested to find out if they work. We can't wait for 30 years to see if a model is any good or not; models are tested against the past, against what we know happened. If a model can correctly predict trends from a starting point somewhere in the past, we could expect it to predict with reasonable certainty what might happen in the future. So all models are first tested in a process called *Hindcasting*. The models used to predict future global warming can accurately map past climate changes. If they get the past right, there is a high confidence that future predictions would be correct. Testing models against the existing instrumental record suggested CO_2 must cause global warming, because the

models could not simulate what had already happened *unless* the extra CO2 was added to the model.

All other known forcings are adequate in explaining temperature variations prior to the rise in temperature over the last thirty years, while none of them can explain the rise in the past thirty years. CO_2 does explain that rise, and explains it completely without any need for additional, as yet unknown forcing.

Where models have been running for sufficient time, they have also been proved to make accurate predictions. For example, the eruption of Mt. Pinatubo allowed modelers to test the accuracy of models by feeding in the data about the eruption. The models successfully predicted the climatic response after the eruption. Models also correctly predicted other effects subsequently confirmed by observation, including greater warming in the Arctic and over land, greater warming at night, and stratospheric cooling.

The climate models, far from being melodramatic, may be conservative in the predictions they produce. For example, here's a graph of sea level rise:

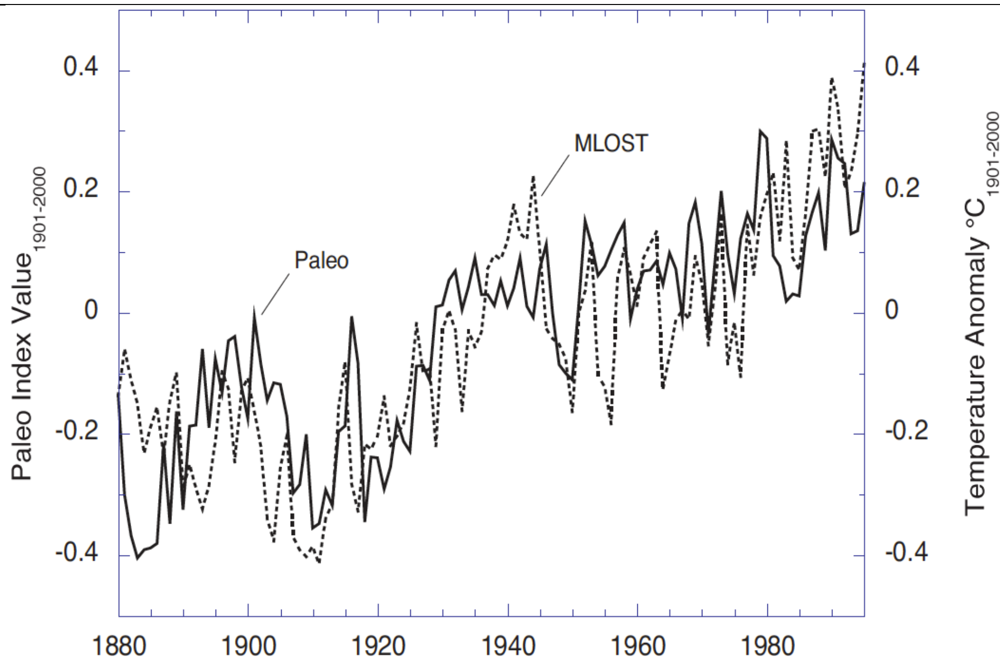


Observed sea level rise since 1970 from tide gauge data (red) and satellite measurements (blue) compared to model projections for 1990-2010 from the IPCC Third Assessment Report (grey band). (Source: The Copenhagen Diagnosis, 2009)

Here, the models have understated the problem. In reality, observed sea level is tracking at the upper range of the model projections. There are other examples of models being too conservative, rather than alarmist as some portray them. All models have limits - uncertainties - for they are modelling complex systems. However, all models improve over time, and with increasing sources of real-world information such as satellites, the output of climate models can be constantly refined to increase their power and usefulness.

Climate models have already predicted many of the phenomena for which we now have empirical evidence. Climate models form a reliable guide to potential climate change. Mainstream climate models have also accurately projected global surface temperature changes. Climate contrarians have not.

Temperature Records Are Unreliable	"We found [U.S. weather] stations located next to the exhaust fans of air conditioning units, surrounded by asphalt parking lots and roads, on blistering-hot rooftops, and near sidewalks and buildings that absorb and radiate heat. We found 68 stations located at wastewater treatment plants, where the process of waste digestion causes temperatures to be higher than in surrounding areas. In fact, we found that 89 percent of the stations – nearly 9 of every 10 – fail to meet the National Weather Service's own siting requirements that stations must be 30 meters (about 100 feet) or more away from an artificial heating or radiating/reflecting heat source." (Watts 2009) – Anthony Watts is a meteorologist and blogger who runs *Watts Up With That?*, a climate change denial blog.
It's Hard to Argue with 10 Million Thermometers	The warming trend is the same in rural and urban areas, measured by thermometers and satellites, and by natural thermometers. Surveys of weather stations in the USA have indicated that some of them are not sited as well as they could be. This calls into question the quality of their readings. However, when processing their data, the organizations which collect the readings consider any local heating or cooling effects, such as might be caused by a weather station being located near buildings or large areas of tarmac. This is done, for instance, by weighting (adjusting) readings after comparing them against those from more rural weather stations nearby. More importantly, for the purpose of establishing a temperature trend, the relative level of single readings is less important than whether the pattern of all readings from all stations taken together is increasing, decreasing or staying the same from year to year. Furthermore, since this question was first raised, research has established that any error that can be attributed to poor siting of weather stations is not enough to produce a significant variation in the overall warming trend being observed. It's also vital to realize that warnings of a warming trend — and hence Climate Change — are not based simply on ground level temperature records. Other completely independent temperature data compiled from weather balloons, satellite measurements, and from sea and ocean temperature records, also tell a remarkably similar warming story. For example, a study by Anderson et al. (2012) created a new global surface temperature record reconstruction using 173 records with some type of physical or biological link to global surface temperatures (corals, ice cores, speleothems, lake and ocean sediments, and historical documents). The study compared their reconstruction to the instrumental temperature record and found a strong correlation between the two:



Temperature reconstruction based on natural physical and biological measurements (Paleo, solid) and the instrumental temperature record (MLOST, dashed) relative to 1901-2000. The range of the paleo trends index values is coincidentally nearly the same as the GST although the quantities are different (index values versus temperature anomalies °C).
Confidence in climate science depends on the correlation of many sets of these data from many different sources in order to produce conclusive evidence of a global trend.

Animals and Plants can Adapt	[C]orals, trees, birds, mammals, and butterflies are adapting well to the routine reality of changing climate." (source: Hudson Institute) –a conservative think tank
But Most Likely They'll Go Extinct	A large number of ancient mass extinction events have been strongly linked to global climate change. Because current climate change is so rapid, the way species typically adapt (e.g. - migration) is, in most cases, simply not be possible. Global change is simply too pervasive and occurring too rapidly. Humans are transforming the global environment. Great swathes of temperate forest in Europe, Asia and North America have been cleared over the past few centuries for agriculture, timber and urban development. Tropical forests are now on the front line. Human-assisted species invasions of pests, competitors and predators are rising exponentially, and over-exploitation of fisheries, and forest animals for bush meat, to the point of collapse, continues to be the rule rather than the exception. Driving this has been a six-fold expansion of the human population since 1800 and a 50-fold increase in the size of the global economy. The great modern human enterprise was built on exploitation of the natural environment. Today, up to 83% of the Earth's land area is under direct human influence and we entirely dominate 36% of the bioproductive surface. Up to half the world's freshwater runoff is now captured for human use. More nitrogen is now converted into reactive forms by industry than all by all the planet's natural processes and our industrial and agricultural processes are causing a continual build-up of long-lived greenhouse gases to levels unprecedented in at least the last 800,000 years and possibly much longer. Clearly, this planet-wide domination by human society will have implications for biological diversity. Indeed, a recent review on the topic, the 2005 Millennium Ecosystem Assessment report (an environmental report of similar scale to the Intergovernmental Panel on Climate

Change Assessment Reports), drew some bleak conclusions – 60% of the world's ecosystems are now degraded and the extinction rate is now 100 to 1000 times higher than the "background" rate of long spans of geological time. For instance, a study I conducted in 2003 showed that up to 42% of species in the Southeast Asian region could be consigned to extinction by the year 2100 due to deforestation and habitat fragmentation alone.

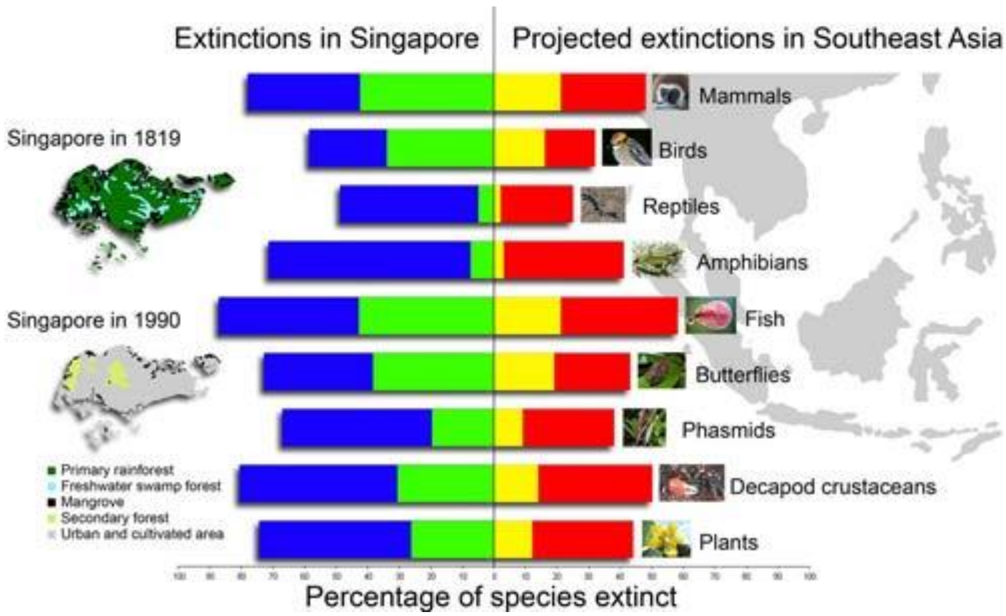


Figure 1: Southeast Asian extinctions projected due to habitat loss (source: Sodhi, N. S., Koh, L. P., Brook, B. W. & Ng, P. K. L. 2004)

Given these existing pressures and upheavals, it is a reasonable question to ask whether global warming will make any further meaningful contribution to this mess. Some, such as the skeptics S. Fred Singer and Dennis Avery, see no danger at all, maintaining that a warmer planet will be beneficial for mankind and other species on the planet and that "corals, trees, birds, mammals, and butterflies are adapting well to the routine reality of changing climate". Also, although climate change is a concern for conservation biologists, it is not the focus for most researchers (at present), largely I think because of the severity and immediacy of the damage caused by other threats.

Global warming to date has certainly affected species' geographical distributional ranges and the timing of breeding, migration, flowering, and so on. But extrapolating these observed impacts to predictions of future extinction risk is challenging. The most well-known study to date, by a team from the UK, estimated that 18 and 35% of plant and animal species will be committed to extinction by 2050 due to climate change. This study, which used a simple approach of estimating changes in species geographical ranges after fitting to current bioclimatic conditions, caused a flurry of debate. Some argued that it was overly optimistic or too uncertain because it left out most ecological detail, while others said it was possibly overly pessimistic, based on what we know from species responses and apparent resilience to previous climate change in the fossil record – see below.

Many ancient mass extinction events have indeed been strongly linked to global climate change, including the most sweeping die-off that ended the Paleozoic Era, 250 million years ago and the somewhat less cataclysmic, but still damaging, Paleocene–Eocene Thermal Maximum, 55 million years ago. Yet in the more recent past, during the Quaternary glacial cycles spanning the last million years, there were apparently few climate-related extinctions. This curious paradox of few ice age extinctions even has a name – it is called 'the Quaternary Conundrum'.

Over that time, the globally averaged temperature difference between the depth of an ice age and a warm interglacial period was 4 to 6°C – comparable to that predicted for the coming century due to anthropogenic global warming under the fossil-fuel-intensive, business-as-usual scenario. Most species appear to have persisted across these multiple glacial–interglacial cycles. This can be inferred from the fossil record, and from genetic evidence in modern species. In Europe and North America, populations shifted ranges southwards as the great northern hemisphere ice sheets advanced, and reinvaded northern realms when the glaciers retreated. Some species may have also persisted in locally favorable regions that were otherwise isolated within the tundra and ice-strewn landscapes. In Australia, a recently discovered cave site has shown that large-bodied mammals ('megafauna') were able to persist even in the arid landscape of the Nullarbor in conditions similar to now.

However, although the geological record is essential for understanding how species respond to natural climate change, there are a number of reasons why future impacts on biodiversity will be particularly severe:

A) Human-induced warming is already rapid and is expected to further accelerate. The IPCC storyline scenarios such as A1FI and A2 imply a rate of warming of 0.2 to 0.6°C per decade. By comparison, the average change from 15 to 7 thousand years ago was ~0.005°C per decade, although this was occasionally punctuated by short-lived (and possibly regional-scale) abrupt climatic jolts, such as the Younger Dryas, Dansgaard-Oeschger and Heinrich events.

B) A low-range optimistic estimate of 2°C of 21st century warming will shift the Earth's global mean surface temperature into conditions which have not existed since the middle Pliocene, 3 million years ago. More than 4°C of atmospheric heating will take the planet's climate back, within a century, to the largely ice-free world that existed prior to about 35 million years ago. The average 'species' lifetime' is only 1 to 3 million years. So it is quite possible that in the comparative geological instant of a century, planetary conditions will be transformed to a state unlike anything that most of the world's modern species have encountered.

C) As noted above, it is critical to understand that ecosystems in the 21st century start from an already massively 'shifted baseline' and so have lost resilience. Most habitats are already degraded and their populations depleted, to a lesser or greater extent, by past human activities. For millennia, our impacts have been localized although often severe, but during the last few centuries we have unleashed physical and biological transformations on a global scale. In this context, synergies (positive or self-reinforcing feedbacks) from global warming, ocean acidification, habitat loss, habitat fragmentation, invasive species, chemical pollution (Figure 2) are likely lead to cascading extinctions. For instance, over-harvest, habitat loss and changed fire regimes will likely enhance the direct impacts of climate change and make it difficult for species to move to undamaged areas or to maintain a 'buffer' population size. One threat reinforces the other, or multiple impacts play off on each other, which makes the overall impact far greater than if each individual threats occurred in isolation (Brook et al 2008).

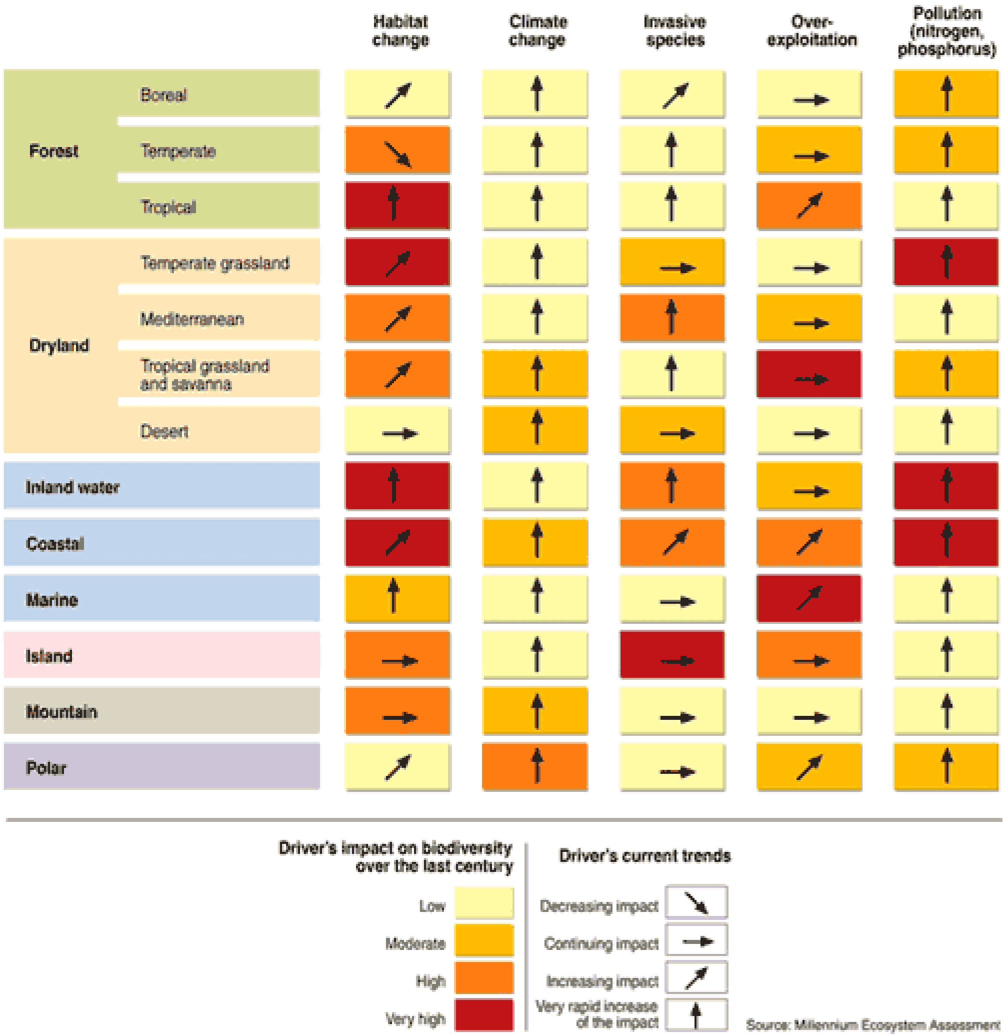
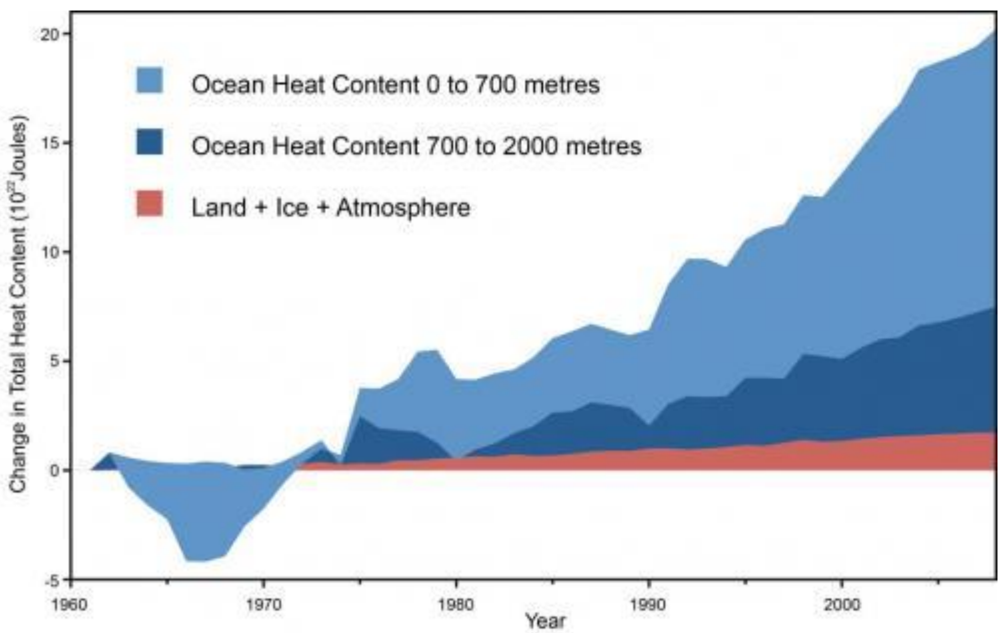


Figure 2: Figure from the Millennium Ecosystem Assessment

D) Past adaptation to climate change by species was mainly through shifting their geographic range to higher or lower latitudes (depending on whether the climate was warming or cooling), or up and down mountain slopes. There were also evolutionary responses – individuals that were most tolerant to new conditions survived and so made future generations more intrinsically resilient. Now, because of points A to C described above, this type of adaptation will, in most cases, simply not be possible or will be inadequate to cope. Global change is simply too pervasive and occurring too rapidly. Time's up and there is nowhere for species to run or hide.

It Hasn't Warmed Since 1998	“For the years 1998-2005, temperature did not increase. This period coincides with society's continued pumping of more CO2 into the atmosphere.” (Bob Carter – paleontologist, stratigrapher, and marine geologist. Telegraph 2006, April 9)
This is Why Multiple Measurements Are Used	Every part of the Earth's climate system has continued warming since 1998, with 2015 shattering temperature records. Even if we ignore long term trends and just look at the record-breakers, 2015, 2014, 2010, and 2005 were hotter than 1998. The myth of no warming since 1998 was based on the satellite record estimates of the temperature of the atmosphere. However, even that argument is no longer accurate. Satellites show warming since 1998 too. There's also a tendency for some people just to concentrate on atmospheric or surface air temperatures when there are other, more useful, indicators that can give us a better idea how rapidly the world is warming. More than 90% of global warming heat goes into warming the oceans, while less than 3% goes into increasing the atmospheric and surface air temperature. Records show that the Earth has been warming at a steady rate before and since 1998 and there is no sign of it slowing any time soon (Figure 1).  *Figure 1: Land, atmosphere, and ice heating (red), 0-700 meter ocean heat content (OHC) increase (light blue), 700-2,000 meter OHC increase (dark blue). From Nuccitelli et al. (2012).* Even if we focus exclusively on global surface temperatures, Cowtan & Way (2013) shows that when we account for temperatures across the entire globe (including the Arctic, which is the part of the planet warming fastest), the global surface warming trend for 1997–2015 is approximately 0.14°C per decade. Ultimately, every part of the Earth's climate system is warming, and has continued warming since 1998.

Antarctica is Gaining Ice	"[Ice] is expanding in much of Antarctica, contrary to the widespread public belief that global warming is melting the continental ice cap." (Greg Roberts, *The Australian*)
Not All Ice is Ice, Ice, Baby	Skeptic arguments that Antarctica is gaining ice frequently hinge on an error of omission, namely ignoring the **difference between land ice and sea ice**. In glaciology and particularly with respect to Antarctic ice, *not all things are created equal*. Let us consider the following differences. **Antarctic land ice** is the ice which has accumulated over thousands of years on the Antarctica landmass itself through snowfall. This land ice therefore is actually stored ocean water that once fell as precipitation. *Sea ice in Antarctica is quite different* as it is ice which forms in salt water primarily during the winter months. When land ice melts and flows into the oceans global sea levels rise on average; when sea ice melts sea levels do not change measurably. In Antarctica, sea ice grows quite extensively during winter but nearly completely melts away during the summer (Figure 1). That is where the important difference between Antarctic and Arctic sea ice exists as much of the Arctic's sea ice lasts all the year round. During the winter months it increases and before decreasing during the summer months, but an ice cover does in fact remain in the North which includes quite a bit of ice from previous years (Figure 1). Essentially Arctic sea ice is more important for the earth's energy balance because *when it increasingly melts, more sunlight is absorbed by the oceans* whereas Antarctic sea ice normally melts each summer leaving the earth's energy balance largely unchanged.

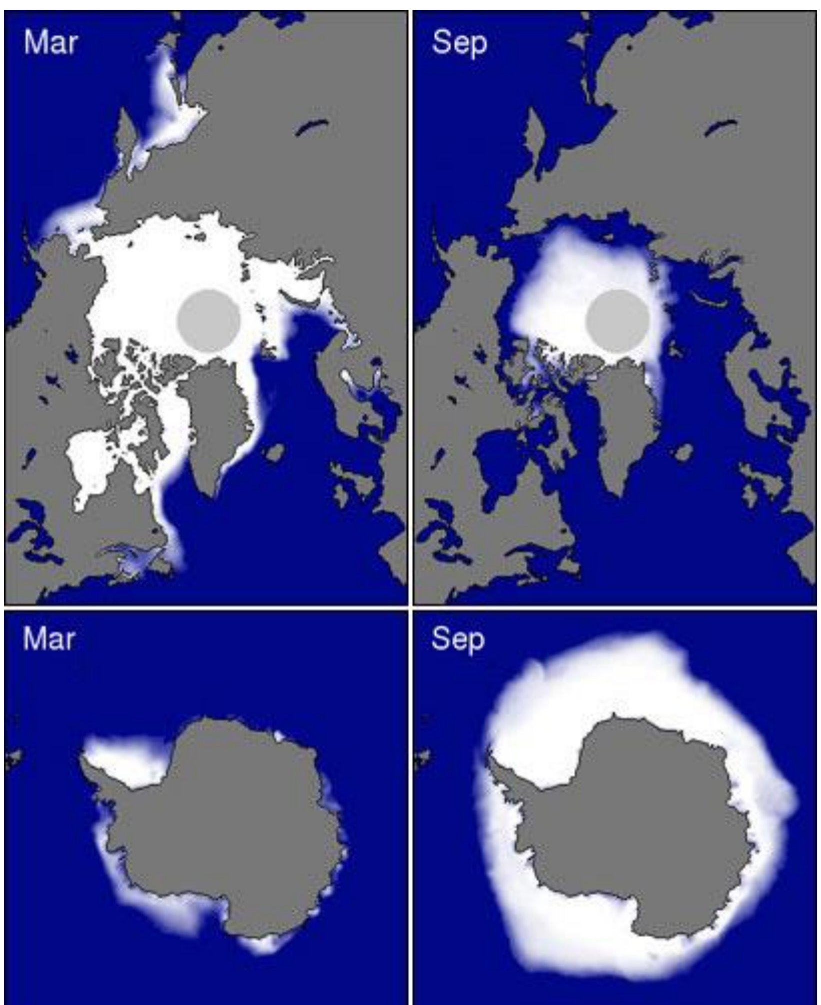


Figure 1: Coverage of sea ice in both the Arctic (Top) and Antarctica (Bottom) for both

summer minimums and winter maximums
Source: National Snow and Ice Data Center

One must also be careful how you interpret trends in Antarctic sea ice. Currently this ice is increasing overall and has been for years but *is this the smoking gun against climate change?* **Not quite**. Antarctic sea ice is gaining because of many different reasons but the most accepted recent explanations are listed below:

1. Ozone levels over Antarctica have dropped causing stratospheric cooling and increasing winds which lead to more areas of open water that can be frozen (Gillet 2003, Thompson 2002, Turner 2009).

2. The Southern Ocean is freshening because of increased rain and snowfall as well as an increase in meltwater coming from the edges of Antarctica's land ice (Zhang 2007, Bintanga et al. 2013). Together, these change the composition of the different layers in the ocean there causing less mixing between warm and cold layers and thus less melted sea and coastal land ice.

All the sea ice talk aside, it is quite clear that really when it comes to Antarctic ice and sea levels, sea ice is not the most important thing to measure. In Antarctica, the largest and most important ice mass is the land ice of the West Antarctic and East Antarctic ice sheets.

Therefore, how is Antarctic land ice doing?

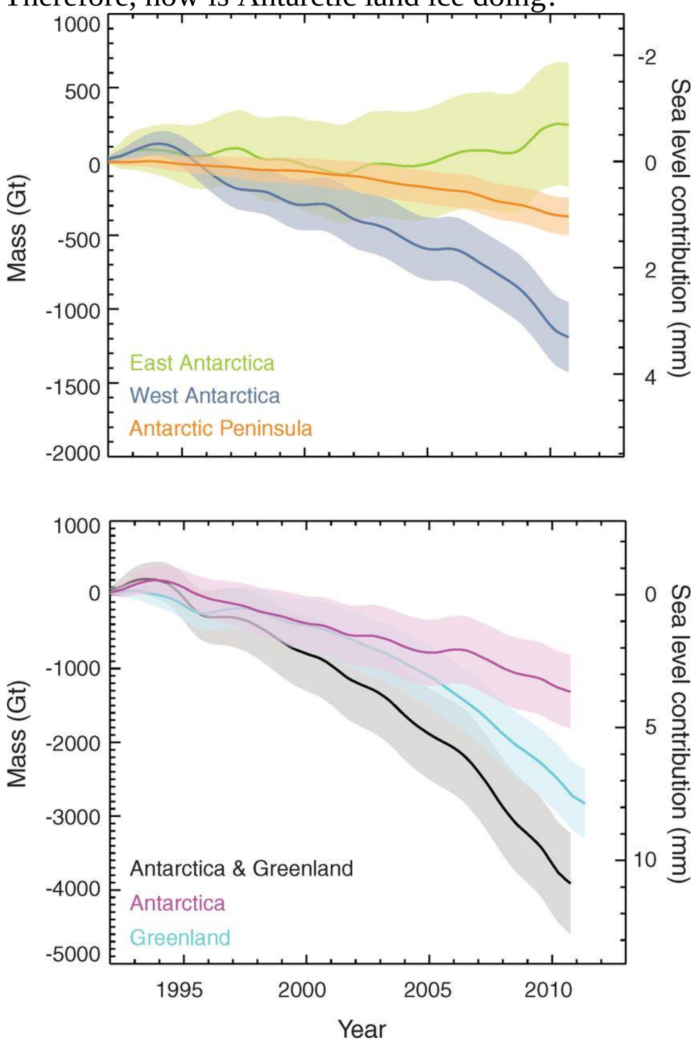


Figure 2: Estimates of total Antarctic land ice changes and approximate sea level contributions using a combination of different measurement techniques (Shepherd, 2012).

Shaded areas represent the estimate uncertainty (1-sigma).

Estimates of recent changes in Antarctic land ice (Figure 2, bottom panel) show an *increasing contribution to sea level with time*, although not as fast a rate or acceleration as Greenland. Between 1992 and 2011, the Antarctic Ice Sheets overall lost 1350 giga-tons (Gt) or 1,350,000,000,000 tons into the oceans, at an average rate of 70 Gt per year (Gt/yr). Because a reduction in mass of 360 Gt/year represents an annual global-average sea level rise of 1 mm, these estimates equate to an increase in global-average sea levels by 0.19 mm/yr.

There is variation between regions within Antarctica (Figure 2, top panel), with the West Antarctic Ice Sheet and the Antarctic Peninsula Ice Sheet losing ice mass, and with an increasing rate. The East Antarctic Ice Sheet is growing slightly over this period but not enough to offset the other losses. There are of course uncertainties in the estimation methods but independent data from multiple measurement techniques all show the same thing, Antarctica is losing land ice as a whole, and these losses are accelerating quickly.

Climategate CRU Emails Suggest Conspiracy	“[T]he 1079 emails and 72 documents seem indeed evidence of a scandal involving most of the most prominent scientists pushing the man-made warming theory - a scandal that is one of the greatest in modern science. […] emails suggesting conspiracy, collusion in exaggerating warming data, possibly illegal destruction of embarrassing information, organized resistance to disclosure, manipulation of data, private admissions of flaws in their public claims and much more.” (Andrew Bolt, Herald Sun) – a conservative social and political commentator
When the Conspiracy is the Conspiracy	A number of independent investigations from different countries, universities, and government bodies have investigated the stolen emails and found no evidence of wrong doing. Focusing on a few suggestive emails, taken out of context, merely serves to distract from the wealth of empirical evidence for man-made global warming.

In November 2009, the servers at the University of East Anglia in Britain were illegally hacked and emails were stolen. When a selection of emails between climate scientists were published on the internet, a few suggestive quotes were seized upon by many claiming global warming was all just a conspiracy.

1. In February 2010, the Pennsylvania State University released an Inquiry Report that investigated any 'Climategate' emails involving Dr. Michael Mann, a Professor of Penn State's Department of Meteorology. They found that *"there exists no credible evidence that Dr. Mann had or has ever engaged in, or participated in, directly or indirectly, any actions with an intent to suppress or to falsify data"*. On "Mike's Nature trick", they concluded *"The so-called “trick”1 was nothing more than a statistical method used to bring two or more different kinds of data sets together in a legitimate fashion by a technique that has been reviewed by a broad array of peers in the field."*
2. In March 2010, the UK government's House of Commons Science and Technology Committee published a report finding that the criticisms of the Climate Research Unit (CRU) were misplaced and that CRU’s *"Professor Jones’s actions were in line with common practice in the climate science community"*.
3. In April 2010, the University of East Anglia set up an international Scientific Assessment Panel, in consultation with the Royal Society and chaired by Professor Ron Oxburgh. The Report of the International Panel assessed the integrity of the research published by the CRU and found *"no evidence of any deliberate scientific malpractice in any of the work of the Climatic Research Unit"*.
4. In June 2010, the Pennsylvania State University published their Final Investigation

Report, said, *"there is no substance to the allegation against Dr. Michael E. Mann"*.

5. In July 2010, the University of East Anglia published the Independent Climate Change Email Review report concluding, *"we find that their rigour and honesty as scientists are not in doubt."*
6. In July 2010, the US Environmental Protection Agency investigated the emails and *"found this was simply a candid discussion of scientists working through issues that arise in compiling and presenting large complex data sets."*
7. In September 2010, the UK Government responded to the House of Commons Science and Technology Committee report, chaired by Sir Muir Russell. On the issue of releasing data, they found *"In the instance of the CRU, the scientists were not legally allowed to give out the data"*. On the issue of attempting to corrupt the peer-review process, they found *"The evidence that we have seen does not suggest that Professor Jones was trying to subvert the peer review process. Academics should not be criticised for making informal comments on academic papers"*.
8. In February 2011, the Department of Commerce Inspector General conducted an independent review of the emails and found *"no evidence in the CRU emails that NOAA inappropriately manipulated data"*.
9. In August 2011, the National Science Foundation concluded *"Finding no research misconduct or other matter raised by the various regulations and laws discussed above, this case is closed".*

Just as there are many independent lines of evidence that humans are causing global warming, similarly a number of independent investigations have found no evidence of falsification or conspiracy by climate scientists.

"Mike's Nature trick" and "hide the decline"

The most quoted email is from Phil Jones discussing paleo-data used to reconstruct past temperatures (emphasis mine):

"I've just completed **Mike's Nature trick** of adding in the real temps to each series for the last 20 years (i.e. from 1981 onwards) and from 1961 for Keith's to **hide the decline**."

"Mike's Nature trick" refers to a technique (aka "trick of the trade") used in a paper published in Nature by lead author Michael Mann (Mann 1998). The "trick" is the technique of plotting recent instrumental data along with the reconstructed data. This places recent global warming trends in the context of temperature changes over longer time scales.

The most common misconception regarding this email is the assumption that "decline" refers to declining temperatures. It actually refers to a decline in the reliability of tree rings to reflect temperatures after 1960. This is known as the "divergence problem" where tree ring proxies diverge from modern instrumental temperature records after 1960. The divergence problem is discussed in the peer reviewed literature as early as 1995, suggesting a change in the sensitivity of tree growth to temperature in recent decades (Briffa 1998), and examined recently in Wilmking 2008, which explores techniques in eliminating the divergence problem. So, when you look at Phil Jone's email in the context of the science discussed, it is not the scheming's of a climate conspiracy but technical discussions of data handling techniques available in the peer reviewed literature.

Trenberth's "travesty we can't account for the lack of warming"

The second most cited email is from climate scientist and IPCC lead author Kevin Trenberth. The highlighted quote is this: ***"The fact is that we can't account for the lack of warming at the moment and it is a travesty that we can't."*** This has been most commonly interpreted (among skeptics) as climate scientists secretly admitting amongst themselves that global warming really has stopped. Trenberth is actually discussing a paper he'd recently published that discusses the planet's energy budget - how much net energy is flowing into our climate and where it's going (Trenberth 2009).

Trenberth's paper discusses how we know the planet is continually heating due to increasing carbon dioxide. Nevertheless, surface temperature sometimes shows short term cooling periods. This is due to internal variability and Trenberth was lamenting that our observation systems can't comprehensively track all the energy flow through the climate system.

The full body of evidence for man-made global warming

An important point to realize is that the emails involve a handful of scientists discussing a few pieces of climate data. Even without this data, there is still an overwhelming and consistent body of evidence, painstakingly compiled by independent scientific teams from institutions across the world.

The findings conclude the planet is steadily accumulating heat. When you add up all the heat building in the oceans, land and atmosphere plus the energy required to melt glaciers and ice sheets, the planet has been accumulating heat at a rate of 190,260 Gigawatts over the past 40 years (Murphy 2009). Considering a typical nuclear power plant has an output of 1 Gigawatt, imagine over 190,000 power plants pouring their energy output directly into heating our land and oceans, melting ice and warming the air.

This build-up of heat is causing ice loss across the globe, from the Arctic to the Antarctic. Both Greenland and Antarctica are losing ice at an accelerated rate (Velicogna 2009). Even East Antarctica, previously thought to be too cold and stable, is now losing ice mass (Chen 2009). Glacier shrinkage is accelerating. Arctic sea ice has fallen so sharply, observations exceed even the IPCC worst case scenario. The combination of warming oceans and melting ice has resulted in sea level rise tracking the upper limit of IPCC predictions.

Rising temperatures have impacted animal and plant species worldwide. The distribution of tree lines, plants and many species of animals are moving into cooler regions towards the poles. As the onset of spring is happening earlier each year, animal and plant species are responding to the shift in seasons. Scientists observe that frog breeding, bird nesting, flowering and migration patterns are all occurring earlier in the year (Parmeson 2003). There are many other physical signs of widespread warming. The height of the tropopause, a layer in our atmosphere, is rising (Santer 2003). Arctic permafrost, covering about 25% of Northern Hemisphere land, is warming and degrading (Walsh 2009). The tropical belt is widening (Seidel 2007). These results are all consistent with global warming.

Humans are emitting huge amounts of carbon dioxide into the atmosphere - 29 billion tons in 2009 (CDIAC). Greenhouse theory predicts that more carbon dioxide in the atmosphere will trap heat energy as it escapes out to space. What do we observe? Carbon dioxide absorbs heat at certain wavelengths. Satellites over the past 40 years find less heat escaping to space at these wavelengths (Harries 2001, Griggs 2004, Chen 2007). Where does the heat go? Surface measurements find more heat returning back to the Earth's surface (Philipona 2004). Tellingly, the increase occurs at those same carbon dioxide absorption wavelengths (Evans 2006). This is the human fingerprint in global warming.

There are multiple lines of empirical evidence that global warming is happening and human activity is the cause. A few suggestive emails may serve as a useful distraction for those wishing to avoid the physical realities of climate change. But they change nothing about our scientific understanding of humanity’s role in global warming.