Reference: www.skepticalscience.com

Activity #1: Debunk the Myths

- Pick your favorite climate myth, and find out what the science says
- Go to www.skepticalscience.com (or use printouts in binder)
- Work in pairs/small groups

Myth #1: Mauna Loa is a volcano (CO2 record unreliable)

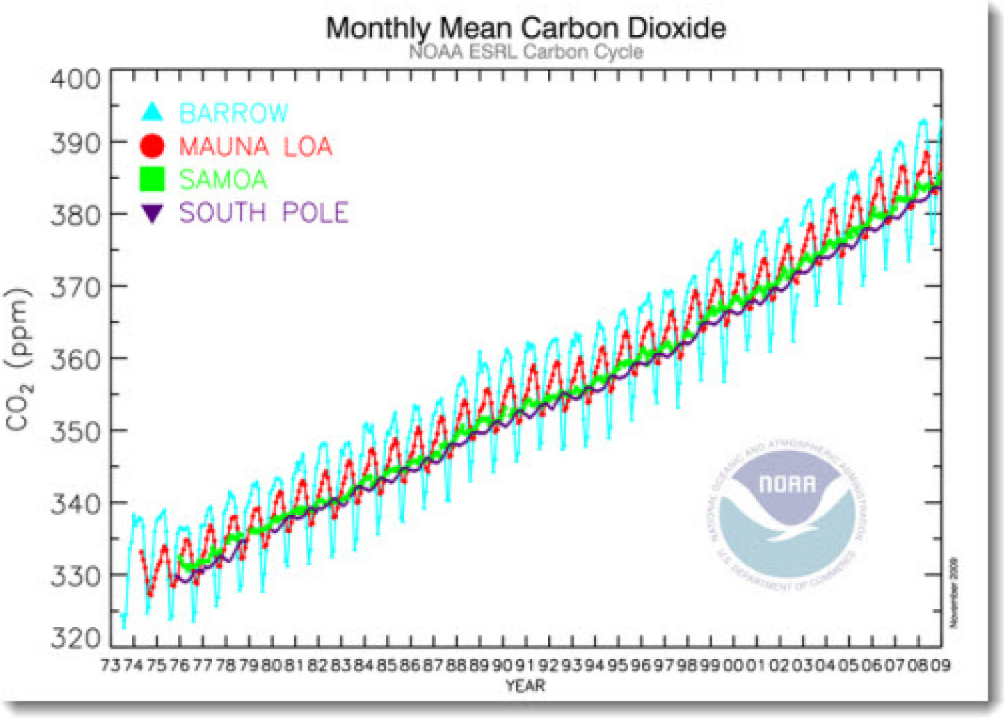
What The Science Says:
The measurements of the amount of CO2 made at the Mauna Loa Observatory are accurate and uncontaminated by any emissions from the volcano. The measurements show a steadily increasing tend of CO2 concentrations in the air, a trend that is confirmed by many measurements made elsewhere.

Climate Myth: Mauna Loa is a volcano
'Mauna Loa has been producing a readout which supports Manning's predetermined goal by showing steady growth in atmospheric CO2 concentrations since 1959. Just thirty miles from the observatory, Kilauea's Pu`u O`o vent sends 3.3 million metric tons of CO2 into the atmosphere every year. Pu`u O`o sends into "the undisturbed air" near "the remote location" the equivalent to yearly CO2 production from an average city of 660,000 people.' (Andrew Walden)

The observatory near the summit of the Mauna Loa volcano in Hawaii has been recording the amount of carbon dioxide in the air since 1958. This is the longest continuous record of direct measurements of CO2 and it shows a steadily increasing trend from year to year; combined with a saw-tooth effect that is caused by changes in the rate of plant growth through the seasons. This curve is commonly known as the Keeling Curve, named after Charles Keeling, the American scientist who started the project.

Why Mauna Loa? Early attempts to measure CO2 in the USA and Scandinavia found that the readings varied a lot due to the influence of growing plants and the exhaust from motors. Mauna Loa is ideal because it is so remote from big population centres. Also, on tropical islands at night, the prevailing winds blow from the land out to sea, which effect brings clean, well-mixed Central Pacific air from high in the atmosphere to the observatory. This removes any interference coming from the vegetation lower down on the island.

But how about gas from the volcano? It is true that volcanoes blow out CO2 from time to time and that this can interfere with the readings. Most of the time, though, the prevailing winds blow the volcanic gasses away from the observatory. But when the winds do sometimes blow from active vents towards the observatory, the influence from the volcano is obvious on the normally consistent records and any dubious readings can be easily spotted and edited out (Ryan, 1995).



Importantly, Mauna Loa is not the only atmospheric measuring station in the world. As the graph from NOAA shows, other stations show the same year-after-year increasing trend. The seasonal saw-tooth varies from place to place, of course, but the background trend remains steadily upwards. The Keeling Curve is one of the best-defined results in climatology and there really are no valid scientific reasons for doubting it.

Further reading: Spencer Weart's *The Discovery of Global Warming* describes Charles Keeling's research efforts in more detail. Weart also has a separate article on Keeling's struggle to fund his research.

Myth #2: It's the sun (not humans that causes global warming)

Sun & climate: moving in opposite directions

What The Science Says:
In the last 35 years of global warming, sun and climate have been going in opposite directions

Climate Myth: 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)

Over the last 35 years the sun has shown a slight cooling trend. However global temperatures have been increasing. Since the sun and climate are going in opposite directions scientists conclude the sun cannot be the cause of recent global warming.
The only way to blame the sun for the current rise in temperatures is by cherry picking the data. This is done by showing only past periods when sun and climate move together and ignoring the last few decades when the two are moving in opposite direction.

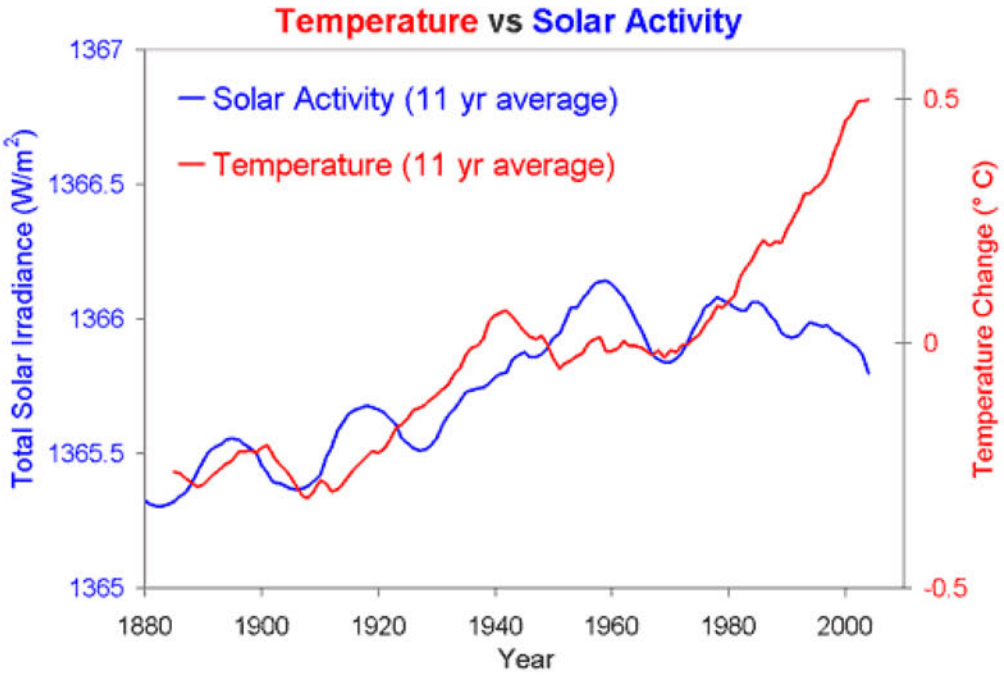


Figure 1: Global temperature (red, NASA GISS) and Total solar irradiance (blue, 1880 to 1978 from Solanki, 1979 to 2009 from PMOD).

Myth #3: It's not bad (warm periods are good for people)

Positives and negatives of global warming

What The Science Says:
Negative impacts of global warming on agriculture, health & environment far outweigh any positives.

Climate Myth: It's not 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)

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 CO2 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 CO2 being absorbed in the water, and may have severe destabilising 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 vegitation 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 photoplankton, 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 labour 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.

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.

Basic rebuttal written by GPWayne

Myth #4: CO2 lags temperature (so it can't cause warming)

CO2 lags temperature - what does it mean?

What The Science Says:
CO2 didn't initiate warming from past ice ages but it did amplify the warming. In fact, about 90% of the global warming *followed* the CO2 increase.

Climate Myth: CO2 lags temperature
"An article in *Science* magazine illustrated that a rise in carbon dioxide did not precede a rise in temperatures, but actually lagged behind temperature rises by 200 to 1000 years. A rise in carbon dioxide levels could not have caused a rise in temperature if it followed the temperature." (Joe Barton)

Earth's climate has varied widely over its history, from ice ages characterised by large ice sheets covering many land areas, to warm periods with no ice at the poles. Several factors have affected past climate change, including solar variability, volcanic activity and changes in the composition of the atmosphere. Data from Antarctic ice cores reveals an interesting story for the past 400,000 years. During this period, CO2 and temperatures are closely correlated, which means they rise and fall together. However, based on Antarctic ice core data, changes in CO2 follow changes in temperatures by about 600 to 1000 years, as illustrated in Figure 1 below. This has led some to conclude that CO2 simply cannot be responsible for current global warming.

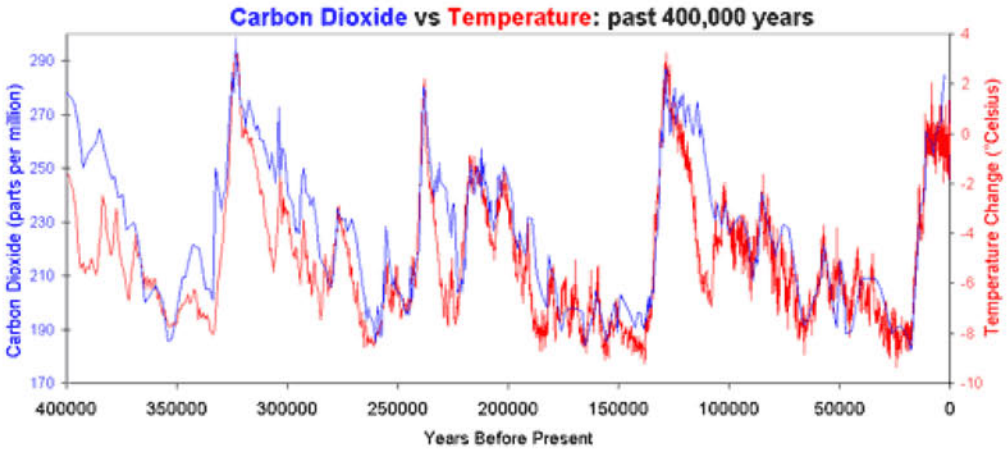


Figure 1: Vostok ice core records for carbon dioxide concentration and temperature change.

This statement does not tell the whole story. The initial changes in temperature during this period are explained by changes in the Earth's orbit around the sun, which affects the amount of seasonal sunlight reaching the Earth's surface. In the case of warming, the lag between temperature and CO2 is explained as follows: as ocean temperatures rise, oceans release CO2 into the atmosphere. In turn, this release amplifies the warming trend, leading to yet more CO2

being released. In other words, increasing CO2 levels become both the cause and effect of further warming. This positive feedback is necessary to trigger the shifts between glacials and interglacials as the effect of orbital changes is too weak to cause such variation. Additional positive feedbacks which play an important role in this process include other greenhouse gases, and changes in ice sheet cover and vegetation patterns.

A 2012 study by Shakun et al. looked at temperature changes 20,000 years ago (the last glacial-interglacial transition) from around the world and added more detail to our understanding of the CO2-temperature change relationship. They found that:

- The Earth's orbital cycles trigger the initial warming (starting approximately 19,000 years ago), which is first reflected in the the Arctic.
- This Arctic warming caused large amounts of ice to melt, causing large amounts of fresh water to flood into the oceans.
- This influx of fresh water then disrupted the Atlantic Ocean circulation, in turn causing a seesawing of heat between the hemispheres. The Southern Hemisphere and its oceans warmed first, starting about 18,000 years ago.
- The warming Southern Ocean then released CO2 into the atmosphere starting around 17,500 years ago, which in turn caused the entire planet to warm via the increased greenhouse effect.

Overall, about 90% of the global warming occurred ***after*** the CO2 increase (Figure 2).

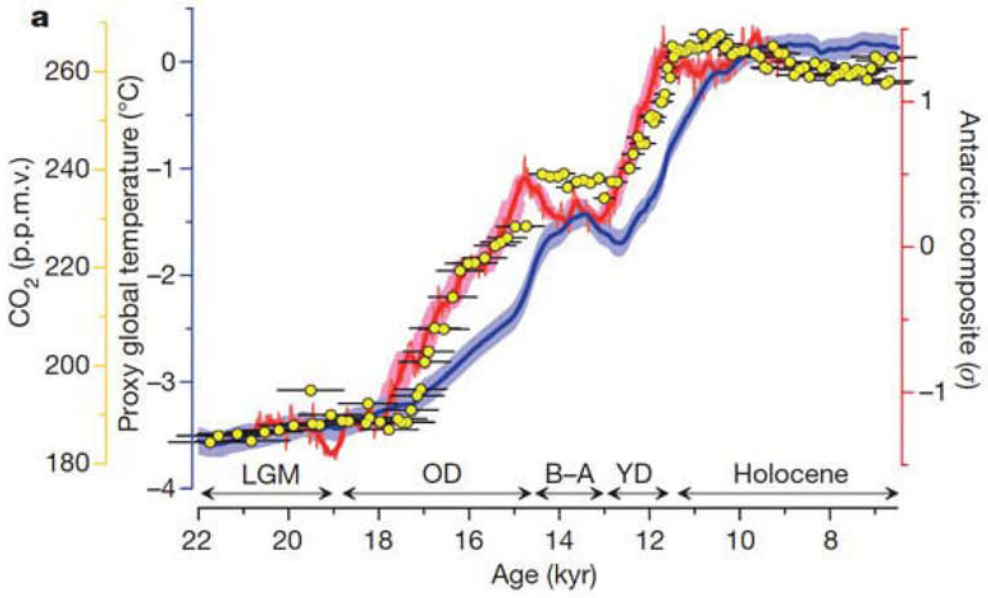


Figure 2: Average global temperature (blue), Antarctic temperature (red), and atmospheric CO2 concentration (yellow dots). Source.

Myth #5: It's freaking cold! (so Earth can't be warming)

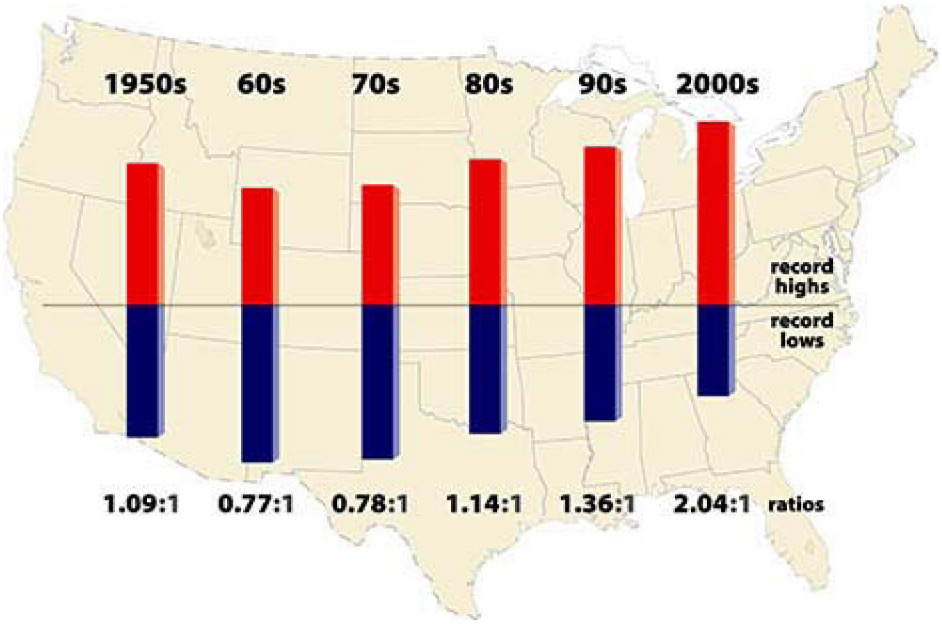
Does cold weather disprove global warming?

What The Science Says:
A local cold day has nothing to do with the long-term trend of increasing global temperatures.

Climate Myth: It's freaking cold!
"Austria is today seeing its earliest snowfall in history with 30 to 40 centimetres already predicted in the mountains. Such dramatic falls in temperatures provide superficial evidence for those who doubt that the world is threatened by climate change." (Mail Online)

It's easy to confuse current weather events with long-term climate trends, and hard to understand the difference between weather and climate. It's a bit like being at the beach, trying to figure out if the tide is rising or falling just by watching individual waves roll in and out. The slow change of the tide is masked by the constant churning of the waves.

In a similar way, the normal ups and downs of weather make it hard to see slow changes in climate. To find climate trends you need to look at how weather is changing over a longer time span. Looking at high and low temperature data from recent decades shows that new record highs occur nearly twice as often as new record lows.



New records for cold weather will continue to be set, but global warming's gradual influence will make them increasingly rare.

Myth #6: Climate change is just a theory (no consensus)

Is there a scientific consensus on global warming?

What The Science Says:
97% of climate experts agree humans are causing global warming.

Climate Myth: 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 forseeable future, cause catastrophic heating of the Earth's atmosphere ...". (Petition Project)

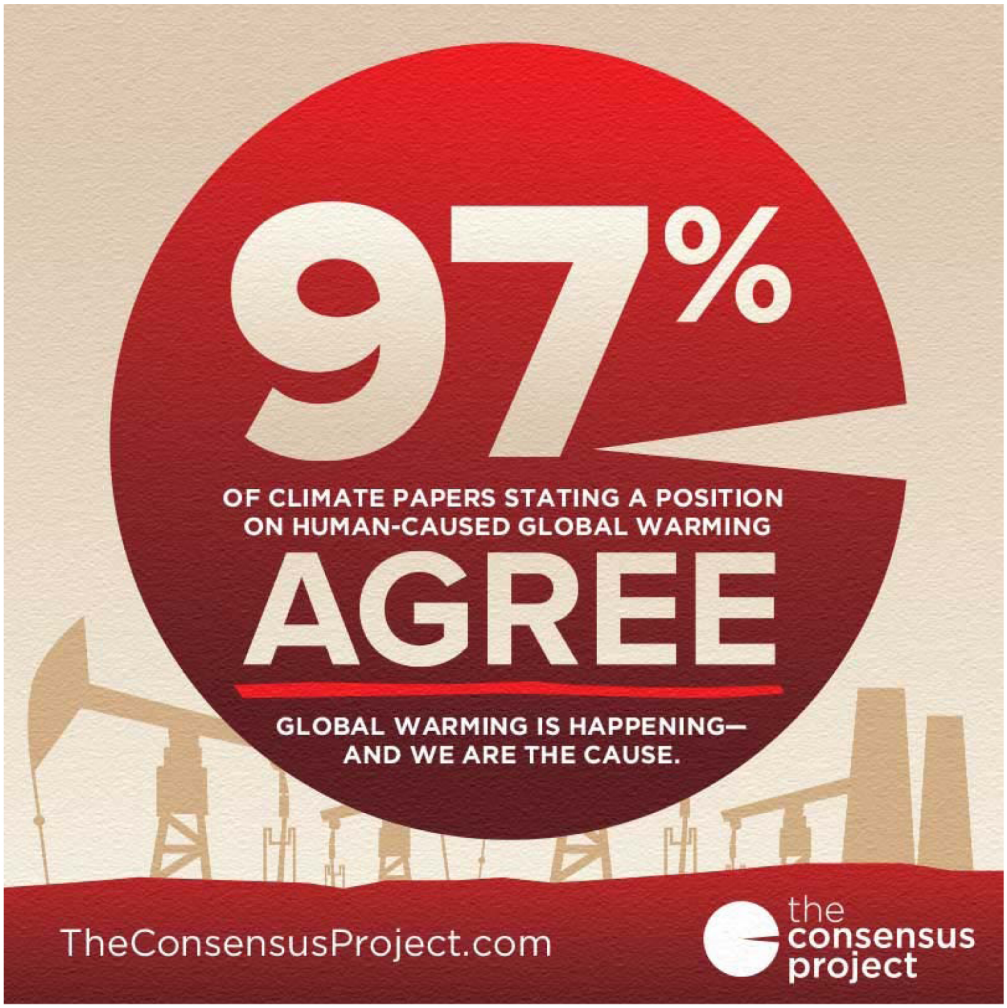
Science achieves a consensus when scientists stop arguing. When a question is first asked – like 'what would happen if we put a load more CO2 in the atmosphere?' – there may be many hypotheses about cause and effect. Over a period of time, each idea is tested and retested – the processes of the scientific 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. A survey of 928 peer-reviewed abstracts on the subject 'global climate change' published between 1993 and 2003 shows that not a single paper rejected the consensus position that global warming is man caused (Oreskes 2004).

A follow-up study by the Skeptical Science team of over 12,000 peer-reviewed abstracts on the subjects of 'global warming' and 'global climate change' published between 1991 and 2011 found that of the papers taking a position on the cause of global warming, over 97% agreed that humans are causing it (Cook 2013). The scientific authors of the papers were also contacted and asked to rate their own papers, and again over 97% whose papers took a position on the cause said humans are causing global warming.



Several studies have confirmed that "...*the debate on the authenticity of global warming and the role played by human activity is largely nonexistent among those who understand the nuances and scientific basis of long-term climate processes".* (Doran 2009). In other words, more than 97% of scientists working in the disciplines contributing to studies of our climate, accept that climate change is almost certainly being caused by human activities.

We should also consider official scientific bodies and what they think about climate change. *There are no national or major scientific institutions anywhere in the world that dispute the theory of anthropogenic climate change*. Not one.

In the field of climate science, the consensus is unequivocal: human activities are causing climate change.

Basic rebuttal written by GPWayne

SkepticalScience.com