What does past climate change tell us about global warming?

What The Science Says:
Scientific analysis of past climates shows that greenhouse gasses, principally CO_2, have controlled most ancient climate changes. The evidence for that is spread throughout the geological record. This makes it clear that this time around humans are the cause, mainly by our CO_2 emissions.

Climate Myth: Climate's 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)

Science has a good understanding of past climate changes and their causes, and that evidence makes the human cause of modern climate change all the more clear. Greenhouse gasses – mainly CO_2, but also methane – have been implicated 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 changes were big and rapid (as they are today), the consequences for life on Earth were often dire – in some cases causing mass extinctions.

So why is the myth wrong?

The myth is wrong for two reasons:

- First, to infer that humans can't be behind today's climate change because climate changed before humans is bad reasoning (a non-sequitur). Humans are changing the climate today mainly via greenhouse gas emissions, the same mechanism that caused climate change before humans.
- Second, to imply we have nothing to fear from today's climate change is not borne out by the lessons from *rapid* climate changes in Earth's past.

Third rock from the Sun – why we're not deep frozen.

A rocky planet this far from the sun should be frozen solid and lifeless at an average temperature of -18°C (0°F). The fact that it isn't is due to greenhouse gasses in the atmosphere, mainly CO_2. These atmospheric gasses have been in a delicate balance with the Earth's oceans, the biosphere, and even the geosphere (all the rocks and sediments). Whether it was frigid ice ages or the steamy climates of the Eocene and the age of the dinosaurs, every change in the Earth (like a decrease in the rate of tectonic plate subduction or an increase in the rate of mountain building) caused a proportional change in CO_2 in the atmosphere and in the oceans, and every change in atmospheric CO_2 caused a proportional reaction in global temperatures, climate and ocean chemistry.

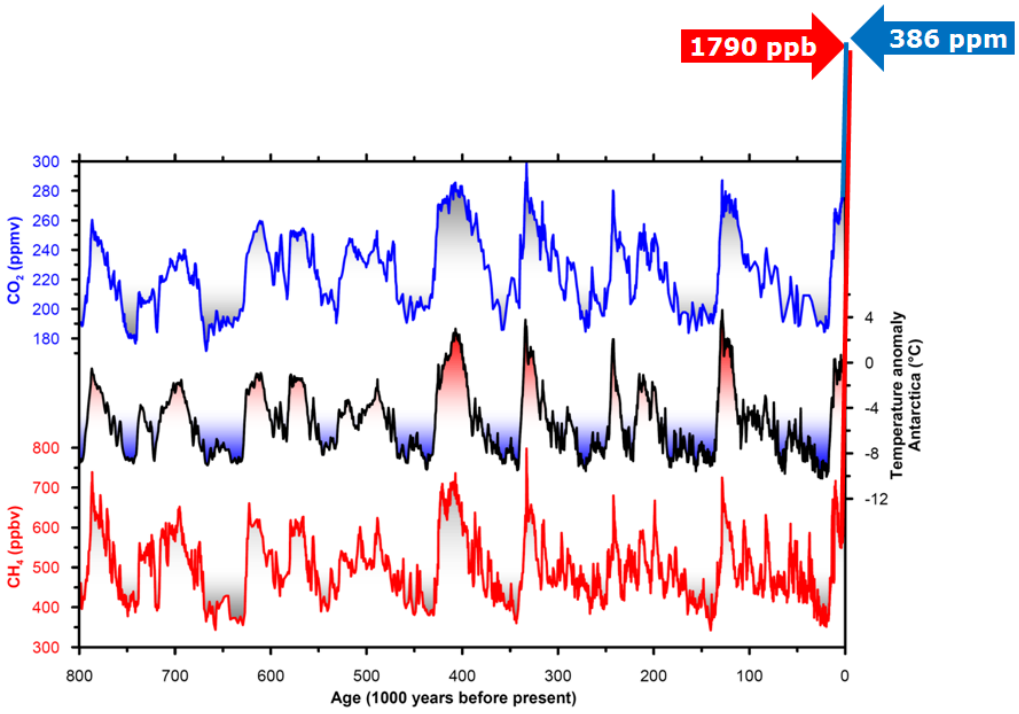
Ice ages

Scientists have shown that CO_2 and climate moved in lock-step throughout the Pleistocene ice ages. The ice ages were actually many pulses of cold glacial phases interspersed with warmer

interglacials. These pulses had a distinct regularity caused by wobbles in Earth's orbit around the Sun (Milankovitch cycles). When Earth's orbit reduced the intensity of sunlight in the northern hemisphere, the Earth went into a glacial phase. When the orbital cycle brought increased the intensity of insolation in the northern hemisphere, ice sheets melted and we went into a warm interglacial. Because warmer oceans can dissolve less CO_2, the CO_2 levels see-sawed extremely closely with Earth's temperature. It was a slow pace of change, taking tens to hundreds of thousands of years, and yes as the myth states, in the last million years the biggest orbit-induced cycles were every 100,000 years.

But we know these ***orbital changes are not behind today's global warming***. In fact our orbit dictates we should be cooling now, not warming.

The Earth was indeed cooling over the last 6,000 years due to Earth's orbit, heading into the next glacial phase scheduled for about the year 3500 AD. But all that changed when we got to the industrial era. Global temperatures departed from that cooling trend, and instead rose parallel with our greenhouse gas emissions.



Greenhouse gasses and Temperature moved in lock-step through the Pleistocene Ice Ages, controlled by Earth's orbit around the Sun (Centre for Ice and Climate, University of Copenhagen). Arrows show where levels were a few years ago, on the same scale.

CO2 doesn't lag behind temperature

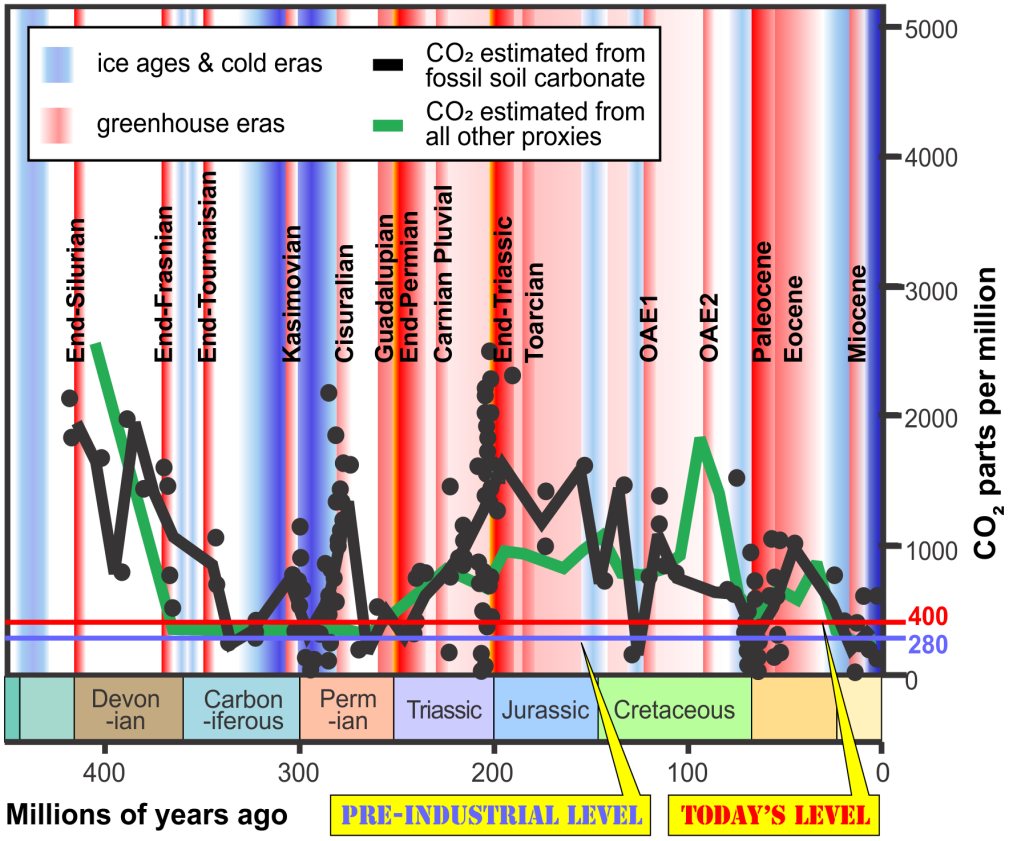
Until 2012, Antarctic ice core data suggested CO_2 may have lagged behind the warming trend by hundreds of years. This was used by skeptics to question the link between CO_2 and climate. More recent studies, with much more precise correlation between ice cores and global temperature records, have shown that temperature and CO_2 changed synchronously in Antarctica during the end of the last ice age, and ***globally*** CO2 rose slightly before global temperatures.

Palm-fringed Arctic and balmy dinosaurs

It's true that at times in Earth's past the climate has been as warm or even warmer than temperatures projected for the end of this century and beyond. Aside from some warm interglacials, the average climate was last as warm as we expect in 2100 during the Pliocene epoch – before the emergence of the genus Homo which includes you and me. In that time, summer Arctic temperatures were 3°C (5°F) warmer than today, with CO_2 levels similar to today's and sea levels were 15-25m (50-82ft) higher than today. Rain-drenched forests fringed

the Arctic Ocean at the time.

Going further back to the Eocene, the world then was very warm and humid – on average 10°C (18°F) warmer than today. Lush swamp forests fringed the Arctic, inhabited by turtles, alligators, primates, tapirs, and the hippo-like Coryphodon (just as the myth claims). Lowland Antarctica was warm and covered in near-tropical vegetation, and London was a mangrove swamp as rainforests spread across much of the planet. Going back even further to the age of the dinosaurs, life flourished in a time of high CO_2 and generally warm average temperatures with high sea levels. Even Antarctica was forested and supported a healthy population of dinosaurs.



CO2 and Climate Changes in the last 400+ million years (note all human existence fits under the right-hand vertical axis line). CO2 proxy data from Dan Breeker, U.Texas, originally published here. Greenhouse events in part from Kravchinsky 2012.

Sudden 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 rapidly, 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. In Earth's past the trigger for these greenhouse gas emissions was often unusually massive volcanic eruptions known as "Large Igneous Provinces," with knock-on effects that included huge releases of CO_2 and methane from organic-rich sediments. But there is no Large Igneous Province operating today, or anytime in the last 16 million years. Today's volcanoes, in comparison, don't even come close to emitting the levels of greenhouse gasses that humans do.

Those rapid 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 (huge and rapid carbon emissions, a big rapid jump in global temperatures, rising sea levels, ocean acidification, widespread oxygen-starved zones in the oceans) are all happening today with human-caused climate change. The outcomes for life on Earth were often dire. The end Permian extinction saw around 90% of species go extinct, and it left tropical regions on the planet lethally hot, too hot for complex life to survive. The Triassic extinction was another, one of the 5 biggest mass extinctions in the geological record. Even in the end Cretaceous extinction, in which dinosaurs were finally wiped out by an asteroid impact, a major global-warming extinction event was already underway causing a major extinction within 150,000 years of the impact. That global warming 66 million years ago was due to catastrophic eruptions in India, which emitted a pulse of CO_2 that sent global temperatures soaring by 7°C (13°F).

So yes, the climate has changed before, 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 offer no comfort at all for the likely outcome from today's climate change.

Intermediate rebuttal written by howardlee

Update July 2015:

Here is a related lecture-video from Denial101x - Making Sense of Climate Science Denial

Additional video from the MOOC

Dana Nuccitelli: Adaptation takes time.

Skeptical Science explains the science of global warming and examines climate misinformation through the lens of peer-reviewed research. The website won the Australian Museum 2011 Eureka Prize for the Advancement of Climate Change Knowledge. Members of the Skeptical Science team have authored peer-reviewed papers, a college textbook on climate change and the book Climate Change Denial: Heads in the Sand. Skeptical Science content has been used in university courses, textbooks, government reports on climate change, television documentaries and numerous books.