

What is driving the present climate change?

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 May 20, 2011

The climate of the Earth depends on the *energy balance of the Earth*. The Earth is heated by energy coming from the sun (part of the sun's energy is reflected back into space by clouds, ice and deserts). The Earth cools to space by thermal (infrared) radiation, but the greenhouse gases in the atmosphere absorb most of this and radiate some back down, increasing the Earth's average temperature. Over millions of years, the climate of the Earth has varied a lot. The ice-caps formed about 30 million years ago as the greenhouse gases (GHGs) in the atmosphere fell and the earth cooled. Then in the past half million years, through the *ice-age period*, the temperature of the Earth has swung every 100,000 years between a very cold state with large ice-caps, and the more familiar warmer Earth of the last ten thousand years.

The primary driver of the ice-ages were slow variations in the Earth's orbit around the sun, which change the amount of energy falling on the earth; but these small changes in solar heating were amplified in the cold periods by more ice reflecting more sunlight and less GHGs trapping less heat. At the coldest point of the last ice-age, the Earth was 5°C (9°F) cooler at the equator and 10°C (18°F) cooler at the poles; and atmospheric CO₂ fell to 180 parts per million (ppm).

During the past thousand years there have been small variations of climate: a warm medieval period and a cooler 'little ice-age' in the 1600s, when the Pilgrim Fathers settled in America. But the fluctuations of temperature have been small: only a degree or so; and CO₂ in the atmosphere remained around 280 ppm.

But the energy balance of the Earth started to change with the industrial revolution, which was powered by burning fossil fuels. A few centuries ago in Britain the industrial revolution started with the burning of coal to drive steam engines to pump water out of the coal mines, and provide power for factories and trains. This was followed later by the discovery of oil and gas, and the fossil fuels have powered all the technological advances that have transformed our world and our lives this past century: electric power, automobiles, appliances and computers. The pace has been so breath-taking that it has been impossible to stop and take stock of where we are going, and how we are getting there. But we must, because our present industrial society is having a global impact on the Earth.



Figure 1. Steam and invisible CO₂ coming from industrial plant

All our fossil fuels contain carbon, which was taken out of the air by plants by photosynthesis, millions of years ago, and buried and stored in the earth. Plants use sunlight to make carbohydrates and woody trees from carbon dioxide and water. That is where all our food comes from, today and for all of human history; and most our energy, except for nuclear power. So think of fossil fuels as stored

energy, concentrated sunlight. When humanity found the fossil fuels, it gave us a huge energy source, and the industrial revolution took off. Our economy, if it continues with business-as-usual, is on a path to burn all our fossil fuel reserves in a few centuries. This will return fossil carbon to the atmosphere that has been locked in the earth for hundreds of millions of years from a time when the earth was much warmer and had no icecaps. The forests and oceans are taking up CO₂ as fast as they can (about half of what we are burning), but we are burning fossil fuels so fast that CO₂ in the atmosphere has risen by 40%, from 280ppm to currently about 391ppm (rising at 2 ppm per year).

Along with water vapor and other greenhouse gases, CO₂ blankets the earth and regulates the earth's temperature by trapping the heat radiated from the earth. These greenhouse gases keep the earth warm (in fact they heat the earth about 30°C (54°F), so the oceans don't freeze and life on this glorious earth is possible). But burning so much fossil carbon so fast is changing the Earth's atmosphere. This has upset the energy balance of the earth, and is propelling us to a much warmer planet.

The last few summers, about 30% of the Arctic ice-cap melted. Even the scientific community was stunned; we thought we would not see such melt for another 20 years. As the summer icecap melts, the warming of the north accelerates for two reasons: less ice means less sunlight is reflected, and more open water means more evaporation – and water vapor is a powerful GHG. As the north warms, the melt of Greenland is accelerating, and sea-level will rise for centuries, eventually flooding our coastal cities and plains.

A sense of time is very helpful. When my grand-parents were children, it was the end of the 19th century. Houses in England were heated with coal fires and electric light was just beginning to replace gas lights. The motor-car was new and noisy; and shared the road with horse and carriage. In less than a century, just four generations, our human industrial society has become the major driver determining the future of the Earth: its fauna, forests and its very climate. This is new, and for the Earth ecosystem the change is very rapid. We didn't start down this path consciously, but now we have a sense of where it leads. So we must take stock of our responsibilities, because our technology is no longer a small part of a vast natural world: its impact has become global.

Explore deeper:

The Climate Energy Balance.

The Earth's Water Cycle.

Our Responsibilities to the earth.