Student reading: A brief history of climate science

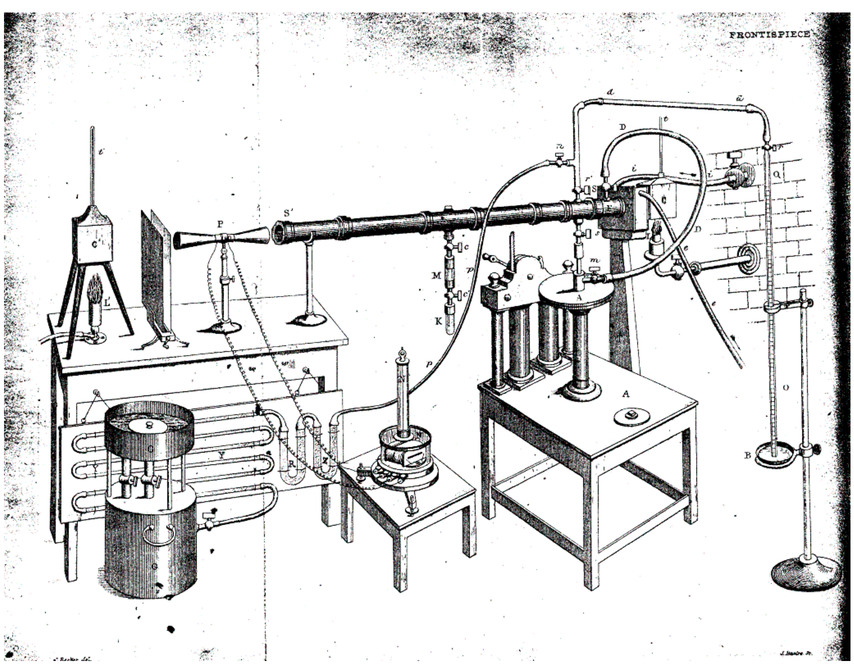
In 1820, scientists were making significant advances in chemistry and biology. The science we now call physics was emerging from “natural philosophy.” However, people were just beginning to understand the how the whole planet worked as a system. Charles Darwin was 11 years old. Napoleon Bonaparte was one year away from death. Jean-Baptiste Joseph Fourier, who worked for Napoleon, was doing investigations in physics. His work showed the nature and behavior of heat energy that is still vital today. A little over 100 years earlier, astronomers had calculated the distance between Earth and the sun. Fourier used that knowledge to calculate that the Earth is warmer than it would be if radiation from the sun were the only factor. He calculated that Earth should be too cold for any liquid water to exist, given our distance from the sun.

Fourier never discovered *why* Earth’s temperature is above freezing. However, he published two hypotheses in 1824 and 1827. The first, which he favored, was that Earth was also being warmed by radiation coming from the other stars. We now know that is not the case.

His second hypothesis was that Earth’s atmosphere might act as a sort of blanket, trapping some of the energy that came from the sun.

In the late 1850s, the American physicist John Tyndall measured the properties of the invisible gases in our atmosphere in his lab. By 1860, he had shown that molecules of several of the gases absorbed energy. He also showed that they emitted energy again as heat, which radiated out in all directions. This evidence supported Fourier’s second hypothesis. It showed that Earth’s temperature resulted from solar radiation plus an insulating effect in Earth’s atmosphere. Gases in the atmosphere could absorb radiation from the sun, and emit it back into the atmosphere.

This effect was called the “Greenhouse Effect.” While this may be a catchy title, it is inaccurate. The atmosphere is less like a greenhouse and more like a blanket. The gases in the atmosphere absorb the energy being released by Earth’s surface as the sun warms it. The atmosphere then radiates some of that heat back to Earth, while some of it escapes back into space. The insulating gases – known as



"greenhouse gases" – make up a fairly small part of our atmosphere but have a large effect. They are like long underwear - thin compared to our bodies but able to keep us warm. Greenhouse gases are the reason that Earth is not a frozen, lifeless ball of rock and ice. Important greenhouse gases, from most to least plentiful, are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2), ozone (O_3), and a group of complex gases known as chlorofluorocarbons (CFCs).

In the 1890s, a Swedish scientist named Svante Arrhenius built on the discoveries of Tyndall, Fourier, and other scientists before them. Arrhenius recognized that the amount of water vapor in the atmosphere changed a huge amount daily. This made him realize that it probably did not play a key part in how stable Earth's climate was in the long term. Instead, he focused on carbon dioxide, the second most common greenhouse gas.

Arrhenius concluded from his calculations that Earth's temperature would drop enough to go into an ice age if CO_2 levels were cut in half. At the same time, other scientists including Arvid Högbom, were investigating past CO_2 levels. They discovered that CO_2 levels had likely changed in the past. They also discovered that increasing coal use was changing CO_2 levels in the present. As one scientist put it, we were "evaporating" our coalmines into the atmosphere[1].

When he learned that human activities were causing CO_2 levels to increase, Arrhenius calculated what effect a doubling of CO_2 would have. He calculated that Earth's average temperature would rise by 5-6ºC if CO_2 levels doubled from the 1890 level of around 290 parts per million (ppm) to 580ppm. His calculations have been confirmed many times since then.

Arrhenius also thought that it would take about three THOUSAND years for CO_2 levels to rise that much. Högbom thought it would never happen, because of the ocean's ability to absorb CO_2. Living in Sweden, Arrhenius didn't see warming as alarming. Rather, he thought that it would make life better for those in the cold north.

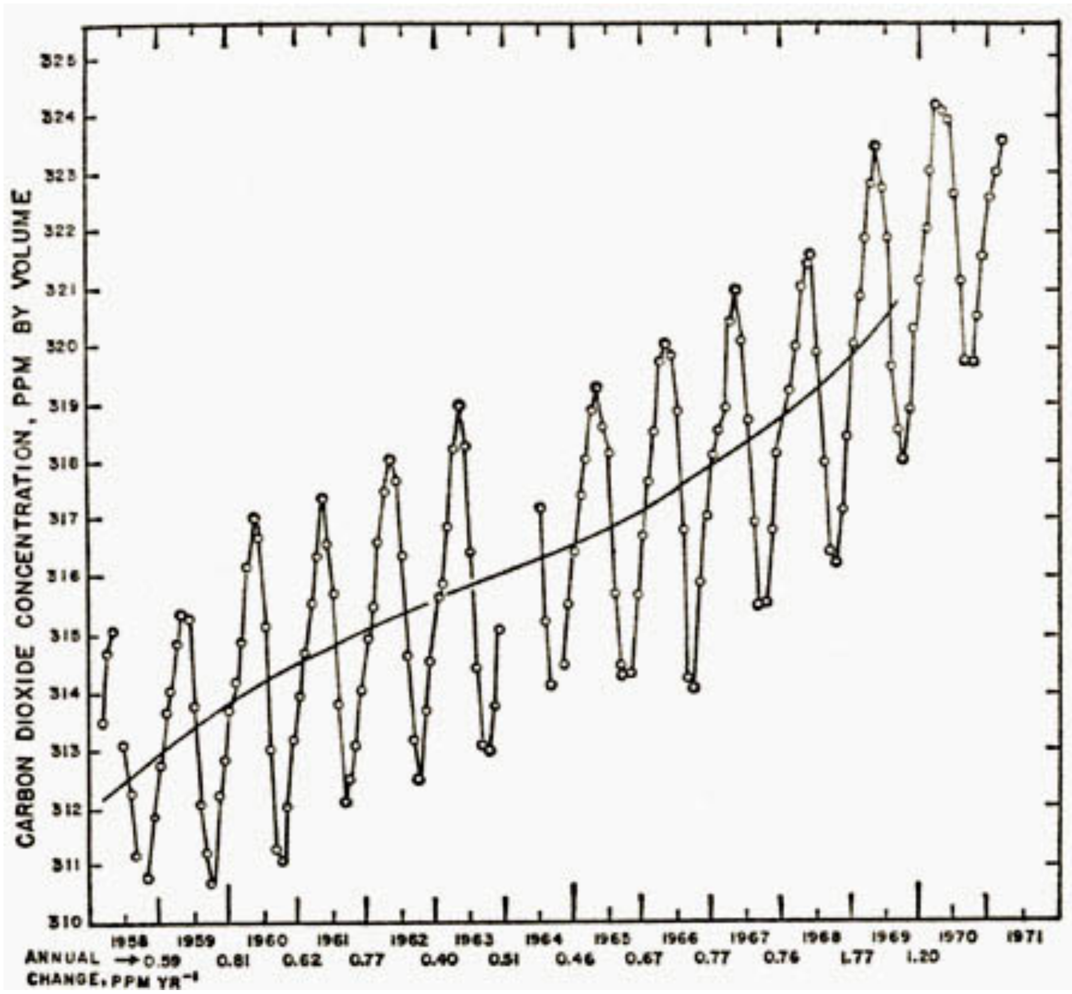
In 1908, he published a book about ice ages that mentioned the possibility of future warming. By that time, coal burning had increased so much that he revised his estimate from 3,000 years down to a few hundred.

Scientists debated the topic over the next 50 years. They gathered new data as new technology became available. In 1956, a physicist named Gilbert Plass was doing calculations for weapon engineers. He decided to calculate the movement of energy through the atmosphere in his spare time. He showed that a doubling of CO_2 would result in an approximate rise of 3-4ºC. It would rise at a rate of about 1.1ºC per century if emissions continued at the same rate as in the 1950s.

Until this point, CO_2 levels had mostly been estimated, rather than measured. However, scientists now discovered that the rate at which the ocean absorbed CO_2 had been over-estimated. This increased the likelihood of an increase in atmospheric levels. Suddenly, the need to get an accurate measurement became more urgent.

Advances in technology allowed a scientist named Charles David Keeling to make precise measurements of atmospheric CO_2 levels over time. He was able to show that the

[1] http://www.aip.org/history/climate/co2.htm



planet's CO_2 levels had an annual pattern, going up over the course of the winter in the Northern Hemisphere, and down during the summer.

After a couple of years of measurement, it became clear that CO_2 levels were rising fast enough to be visible year to year. Within a few years, the increase became shockingly obvious. It can be seen clearly in the graph he published, now known as the Keeling Curve:

In the 1970s climate scientists began to actively search for other factors that might influence greenhouse gas levels. They also began to look into the potential results of increasing temperatures. Over the past fifty years, scientists have ruled out solar cycles, changes in Earth's orbital cycles, and other natural cycles as possible causes of the temperature rise or the rise in CO_2 levels.

In the 1990's, a climatologist named Michael Mann was looking for evidence of a natural cycle that might explain the warming trend. His research involved using tree rings, ice cores, sediment cores, and corals. All of these provide evidence of conditions in the past. Mann showed that present temperatures are higher than at any point in the last thousand years. Since then, Mann and his team have redone their calculations, and have added in new data. They and other teams all over the world have now shown that today's temperatures *and* today's CO_2 levels are almost certainly higher than at any point in the last million years.