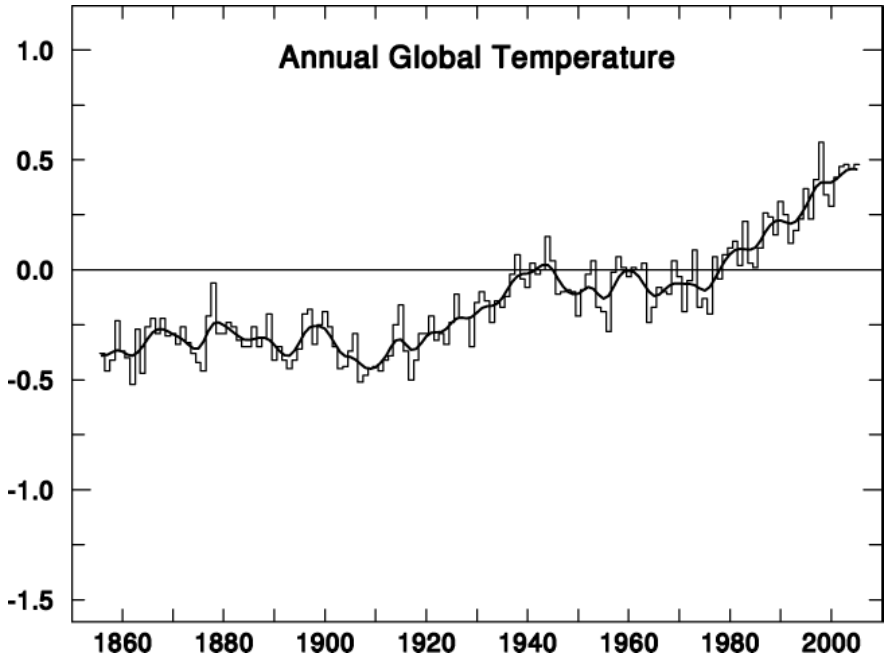
Climate Change

My interest in the topic of climate change began about 60 years ago when my parents, as educators, talked a lot about the International Geophysical Year (IGY) of 1957-58. A good part of the rational for the huge scientific effort that went in to IGY was to answer one question - *is the world getting warmer or colder*? We knew then that northern Europe, and all of what is now Canada, had spent the most of past million years under kilometers-deep ice sheets, with only brief interglacial periods of about 10,000 years - the same duration as the current interglacial had already run. So were we heading into another 100,000 years of ice age? On the other hand, the famous Swedish scientist Svante Arrhenius had predicted global warming as a result of the industrial revolution. In 1896, he calculated - by hand - that an increase of carbon dioxide by 50% (from burning of fossil fuels) would raise average temperatures at mid-latitudes by about 4 degrees Celsius - a result quite comparable to the elaborate climate models and best data of today.

International Geophysical Year left the fate of our climate unanswered. People knew that glaciers all over the world had mostly been shrinking for a century or two. Glaciers are good indicators of climate change, as they represent an accumulated "memory" of temperatures (but also of precipitation) over long time intervals. But the actual temperature records of the two decades previous to IGY just didn't show any warming. With all that carbon dioxide going into the atmosphere *why wasn't the world getting hotter?* Climate experts were just starting to understand the Earth's (and especially the ocean's) incredible capacity to absorb and sequester carbon dioxide. For example, CO2 dissolves well in water, and ocean chemistry turns much of it into carbonates. The biosphere's CO2 processing capacity is great, but it is not infinite!



The temperature graph shows why IGY didn't find global warming - there was a hiatus in the warming trend from 1940 to 1980. Just possibly this was due to other human activities: war and atmospheric nuclear testing lift dust high into the atmosphere, which has a cooling effect. Volcanic eruptions clearly indicate this effect.

Climate is inherently variable, and the on-again, off-again glacial cycles of the last million years tell us that with the current solar irradiation and overall atmospheric composition, climate is bi-stable. Any warming trend melts snow cover, causing more of the sun's energy to be absorbed, and driving temperatures upwards. On entering an ice age, the reverse is true.

Climate has always varied, so we cannot assert that all climate change is driven by human activity. Solar activity (on a timescale of decades to centuries) is believed to have a contributing effect.. Strong solar activity expands the heliosphere, which in turn shields out low energy cosmic rays that would seed cloud formation high in the Earth's atmosphere (by charging the seed nuclei that form cloud droplets), which results in less cloud cover and more sunlight reaching the Earth to warm its surface. In any case, high solar activity seems to contribute to a warmer Earth, low solar activity to a cooler Earth.

Unfortunately, the link between solar activity and climate change is little studied at this time, at least not in Canada. National Research Council of Canada disbanded its entire solar-terrestrial research group of several dozen scientists in the early 1990s, as part of the politicalization of the government's science agenda. The timing was and is unfortunate: the solar contribution to climate change was just becoming recognized, and those scientists aren't around now to clarify the trillion-dollar questions surrounding climate change. Alas, this is how governments often tend to deal with the issues of the day - by shutting them down.

On the timescales of decades and centuries, there is good reason to believe that solar activity does play a part in climate variability. The so-called Little Ice Age of the 17th and 18th centuries apparently was a time of very low solar activity: auroras were not observed, and such evidence as exists implies that sunspots were absent, or at the least there were no large sunspots. Besides the 11-year cycle of sunspot activity, solar activity varies on a timescale of a century or more, in a manner that we do not yet understand. The important point to remember when discussing climate variation: examine the data over a full decade or more, otherwise we may be looking at solar cycle effects, not long-term trends.

Temperatures derived from ice data show very long natural cycles of climate change, with a ~100,000 year period being dominant. It is believed but unproven that these long patterns in the occurrence of ice ages are due to Milankovitch cycles in the shape of the Earth's orbit.

Arguably, one of the greatest achievements of human civilization has been to prevent the recurrence of the next ice age! But we seem to have jumped out of the freezer into the fire. Earth's 2016 surface temperatures were the warmest since modern recordkeeping began in 1880, according to independent analyses by NASA and the National Oceanic and Atmospheric Administration (NOAA). A few decades ago, one could be forgiven for doubting that the dominant cause of climate change is anthropogenic (human caused). No informed person can hold such a position today.

Today the evidence is overwhelming that most of the current warming is anthropogenic, accelerating, and irreversible (at least within our lifetimes). Svante Arrhenius' prediction has been vindicated with a vengeance - we are simply overloading our atmosphere with CO2 faster than nature can recycle it.

Almost anyone can see global warming happening - in the seasonal onset of plant growth, the dates of animal migration and of freezing and thawing of lakes. I can see global climate change happening out my window. In the maritime climate where I live on Vancouver Island, the temperature at sea level for three winter months hovers very close to a few degrees above freezing. Twenty kilometers to the west of Courtenay, I see two ski areas on the mountains. One tops out at 1600 meters elevation, and it still receives 4 to 8 meters (or more) of snow a year, because it is below freezing during our season of high precipitation. The other slope, now closed, was used from the 1960s through the 1990s, but with its altitude of about 800 to 1200 meters, it no longer has a snow season sufficient for operation. In other words, the average freezing level from December through February has risen, and is now well above 800 meters most of the winter.

Although global warming is an intricate subject whose causes and effects are manifold and complicated, its bottom line is astonishingly simple: we are dumping carbon dioxide into the atmosphere much faster than nature can reprocess it. To mitigate the effects, we need only do one thing: reduce our use of fossil fuels drastically. Some, like George Monbiot in his book Heat: How to Stop the Planet from Burning, believe that we must reduce our consumption of fossil fuels by 90% in order to avoid catastrophic climate change. Currently humans release

about 36 Gigatons of CO2 per year into the atmosphere. The last time CO2 levels were stable (at around 312 ppm from 1940-1955), this figure was about one-quarter as much CO2. This simple argument suggests we must reduce CO2 emissions by at least 75% in order have any hope of returning to a stable climate.

So, let's just get a little perspective here. For most of geological history during which life emerged and proliferated on this planet, the Earth has been significantly warmer than it is today. For most of the life era, until about 30 million years ago, polar ice caps were largely absent. That's the good news - the Earth has been warm before, and things worked out pretty well, thank you very much.

The bad news is that humans haven't been there before. The last time CO2 levels were as high as they are today, and as warm as the world will likely be within this century, human beings were not even a gleam in our primate ancestors' eye. In 150 years of industrial burning, we have reversed *15 million years* of natural carbon sequestration. It's hard to think of that as a stable condition. In a world of 7.5 billion humans, divided by national boundaries where none once existed, we can do a lot a damage by changing planetary climate too quickly. War, famine and loss of biodiversity emerge as very real threats.

So here's the dilemma: Maybe the Industrial Revolution came along just in time, to prevent our descent into another ice age, thank goodness. But If we keep burning fossil fuels at anything like current rates, the world will keep getting hotter, and humanity and civilization will loose bigtime.

Geology gives us some other clues. Sudden temperature and composition changes of the atmosphere have wiped the biosphere clean in a least five times in earlier Earth history. This time it could take our civilization and much biodiversity on our planet along with it, into the dustbin of cosmic history...

...which is a place we do not wish to go.