Did Humans Cause the Little Ice Age?

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When climate change is discussed in the media, it is normally presented as something that is happening because of today's human activity (Ruddiman 2003:272, Cowey 2007:121). However, this is not a complete picture. In addition to a wide variety of natural causes of climate change, there is growing evidence that humans have been influencing climate in a major way for eight thousand years.

Starting 350 000 years ago, global climate followed a consistent pattern. During that time, the Earth has been in an ice age, which alternates between glacials and interglacials. In the glacials, large ice caps covered northern North America and Eurasia, the same way ice caps cover Greenland and Antarctica today. These glacials lasted about 100 000 years each. Between them are warm periods called interglacials. These lasted between 10 000 and 25 000 years. During this time, there has been a general cooling trend. Each glacial and interglacial has been colder than the one before. The last glacial was from 115 000 years ago to 11 500 years ago, and it was at its coldest in a period called the Last Glacial Maximum, 18 000 years ago (Cowey 2007:126).

The current interglacial, which is also the period called the Holocene Epoch, began 11 500 years ago, when the Earth warmed up enough to melt the ice caps that covered northern North America and Eurasia (Cowey 2007:159), with the exception of Greenland. The warmest period of the Holocene was from 8000 to 5000 years ago, when the Earth was warmer than it is today (Cowey 2007:162). This was followed by the Iron Age Neoglaciation, a cold period from 4500 to 2500 years ago. The global climate warmed up around the beginning of the Roman Empire, in the Roman Warm Period. Then, during the early Middle Ages, there was a cool period called the Antique Little Ice Age. At the height of the Middle Ages, the Earth became very warm in a period called the Medieval Warm Period. From 1300 to 1850, the global climate cooled down in the Little Ice Age. Since 1850, there was been a sharp warming trend.

There are many kinds of evidence for past climate, but the two most important for this part of the essay are methane and carbon dioxide levels. They are measured using ice cores from Greenland and Antarctica. Ice cores are long cylinders of ice that are drilled out of glaciers. Tiny air bubbles inside the ice preserve samples of the atmosphere from the time the ice was laid down. The ice at the top is the most recent, and the ice at the bottom is the oldest, so a scientist can follow the composition of the atmosphere backwards through time by going down an ice core.

Over the last 350 000 years, the amount of carbon dioxide in the atmosphere has followed a pattern. Carbon dioxide levels reach their peak just before the end of a glacial, and then they go down over the course of the next interglacial. At the beginning of the Holocene, carbon dioxide peaked and then started to go down, as it had in the previous interglacials. This pattern was broken eight thousand years ago, when there was an increase in carbon dioxide which has no equivalent in previous interglacials (Ruddiman 2003:265). The pattern of the last 350 000 years predicts that carbon dioxide levels should have been decreasing from the beginning of the Holocene to the present day. This means that, had the usual pattern continued, the Earth's climate today would be much colder than it is now. Ruddiman ruled out natural causes. He argues that it can't have been caused by a change in the amount of vegetation in the world, and that there is no difference in the amount of heat coming from the Sun between this interglaciation and previous ones, so that can't explain it (Ruddiman 2003:268-271).

Instead, he argues that forest clearing for agriculture can explain why carbon dioxide has been increasing when it should have been decreasing. People started clearing forests for agriculture 8000 years ago (Ruddiman 2003:274). They also used a lot of wood for heating and cooking, and shepherds burned forests to make pasture, and as a result of this most agricultural areas were deforested by 2000 years ago (Ruddiman 2003:276). In 1086, William the Conqueror ordered a survey of England, which found that only 15% of its natural forest remained (Ruddiman 2003:278). An important source of evidence for this is the pollen left by ancient plants (Ruddiman 2003:276). Archaeologists, biologists and geographers can recover pollen from the past, and use it as evidence of what flowering plants lived in an area at what time. They construct pollen sequences that show how plants changes through time in a given area, based on changes in the pollen they find. In total, worldwide deforestation accounts for 85-95% of all carbon produced by humans before 1850 (Ruddiman 2003:277).

For hundreds of thousands of years, methane levels and the amount of heat coming from the Sun matched perfectly. This is because an increase in heat increased the amount of rain. This rain floods wetlands, and flooded land is an important source of methane in the atmosphere. An increase in heat will also warm wetlands at higher latitudes, and again increase the amount of methane that goes into the atmosphere. In this interglaciation, methane levels peaked 11 000 years ago, when heat from the Sun also peaked, and when the last glaciation ended. After that, methane levels and the amount of heat coming from the Sun dropped in sync. This pattern was broken 5000 years ago, when methane levels started to rise again (Ruddiman 2003:264). Differences in methane levels in ice cores from Greenland and Antarctica indicate that the extra methane was coming from the northern hemisphere and not the southern hemisphere (Ruddiman 2003:262). Ruddiman argues that there could not have been an increase in monsoons during this time, because there was actually an overall drying trend (Ruddiman 2003:264). He argues that this extra methane comes from irrigated rice paddies in China and India, who began to irrigate rice fields around 5000 years ago (Ruddiman 2003:265).

In general, the amount of carbon dioxide in the atmosphere has increased over the last eight thousand years. However, there have been a few interruptions, where carbon dioxide goes down temporarily (Ruddiman 2003:279). Ruddiman argues that only large scale epidemics can account for this (Ruddiman 2003:280). They kill large numbers of people, leaving their villages and farms abandoned. Then, forests regrow to reclaim these abandoned farms, and the growing trees remove carbon dioxide from the atmosphere (Ruddiman 2003:282). Ruddiman argues that the Black Death correlates with a 5-10 billion ton drop in carbon in the atmosphere from 1347-1352 (Ruddiman 2003:283). He also argues that the same thing happened when European explorers introduced new diseases to the native peoples of the New World, new diseases which resulted in devastating epidemics (Ruddiman 2003:284). In 2005, D. M. Ferretti and others presented evidence that methane levels dropped from AD 1000 to 1700 from ice cores (Ferretti et al 2005). They argued that this reflects natural climate changes from 1000 to 1500, but from 1500 to 1700, they argue that it was caused by changes in forest burning that were caused by changes in human population in the Western Hemisphere.

Further research in the Western Hemisphere has lent considerable support to the above proposal. First, in 2006, Franz Faust and others made an argument similar to Ruddiman's except that they argue that Ruddiman actually underestimated the impact of reforestation in the Western Hemisphere on global climate (Faust 2006). In 2008, 2010 and 2011, Richard Nevle, Dennis Bird, William Ruddiman and Robert Dull presented evidence from the tropical lowlands of Mexico, Central America and South America as evidence that, after the arrival of Europeans, settlements and farms were abandoned and forests regrew (Nevle and Bird 2008, Dull et al 2010, Nevle et al 2011). Previously, this area was adding carbon dioxide to the air as people burned forests, but the new tree growth then removed 2-5 trillion kilograms

of carbon from the air. Their evidence for this consists of changes in the amount of charcoal from various points in time, collected in geographical fieldwork. Natural factors can only explain a small portion of the observed change in carbon. Most of it can only be explained by large scale abandonment of cultivated land.

In addition to the argument that humans caused the Little Ice Age, several scientists argue that it had natural causes, related to volcanic eruptions and changes in the circulation of water around the oceans. When volcanoes erupt, they release large amounts of dust and ash into the atmosphere. This blocks heat from the Sun, which can noticeably lower the average temperature of the world. Mount Tambora in Indonesia erupted in 1815, and 1816 was so cold it was called "The Year Without a Summer", because there was frost in July. In 1883, Krakatoa (also in Indonesia) erupted, and lowered the temperature of the Earth. In both cases, the effect only lasted a few years. The course of climate change quickly returned to normal.

Water has the ability to hold a lot of heat, and moving water carries the heat it is holding. The world's oceans have a current that goes through the Atlantic, Indian and Pacific Oceans, and carries heat around the world (Cowey 2007:134). This is a major factor in global climate, and if the movement of water and heat around the oceans is disrupted, major changes in global climate will result. In the North Atlantic, warm water flows north in the Gulf Stream, a current that starts on the north side of the Carribean islands, passes the east coast of the United States and Canada, and ends between Iceland and western Europe. There, it sinks to the bottom of the ocean, and becomes a cold current that moves back south. If the climate of the north Atlantic cools down enough, it will cause the Gulf Stream to sink farther south. Without this stream of heat flowing into the North Atlantic, the climate will cool down considerably (Cowey 2007:136).

In 2012, Gifford Miller and others presented evidence that four large volcanic eruptions from 1275 to 1300 cooled the climate, and four eruptions in rapid succession kept the climate cool long enough for the circulation of heat and water around the North Atlantic to change in way that sustained the Little Ice Age until 1500 (Miller et al 2012). In 2013, Flavio Lehner and others also presented evidence that the Little Ice Age was caused by changes in ocean circulation in the late 13th century (Lehner et al 2013).

So what caused the Little Ice Age? I believe that it is not one event, but a series of events, each with a different cause. First, volcanic eruptions and changes in ocean circulation cooled the climate around the North Atlantic in the late 13th century. Then, a series of epidemics caused reforestation on a scale sufficient to remove carbon from the atmosphere and cool the global climate. This started with the Black Death in 1347-52 and ended with the last epidemics in North America, on the Pacific coast of Canada in the 1860s. Therefore, the Little Ice Age was a mix of human and natural causes. There is considerable potential for further research that would determine the exact contributions of different causes, the effect of humans on the climate, and the effect of the climate on humans.

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