Guide to the Science of Climate Change in the 21st Century

Chapter 2
History of the Scientific Study of Climate Change

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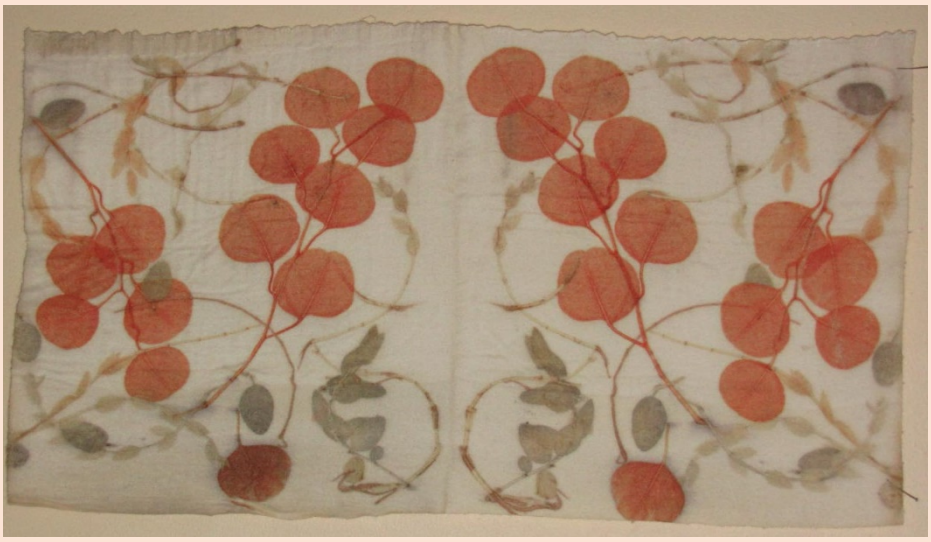

Eco-print, "Rabbit Dance", Nora Manz 2020

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2. History of the Scientific Study of Climate Change

The science of climate change, climatology, is the study of weather conditions over long periods of time. It has developed over the past two hundred years or so, most of it since the 1950's. Today, Earth's climate, its regional and seasonal variability and the identification and interaction of most of the forces that determine it are known. The scientific study of climate change has not only enabled the understanding of our present climate but also how human activity might affect it. The same science has provided insight into how climate has varied over the history of our planet (billions of years), a field of study known as paleoclimatology.

The early development of the science of climate change as presently understood benefitted from those scientists who participated in the discovery that climate did in fact change (discovery of the ice ages and explanation) and those who pursued physical-chemical studies of the properties of Earth's atmosphere. The scientists of the day built on the theories and observations of those before them and the availability of new observation technologies – like the present.

Human interest in climate is ancient. Climate and climate change have had profound impacts on society.

Humans evolved and survived by adapting to the changing seasons to allow for gathering and production of food, security and obtaining the necessary shelter.

With the end of the ice age, approximately 12,000 years ago, and the advent of agriculture as a main food provider the importance of knowing when and how climate varies from season to season became critical as ancient monuments around the world, whose purpose was to predict the seasons, will testify. Stonehenge in England and the ancient Maya observatory in Chichen-Itza, Mexico were constructed using knowledge that had been acquired long before and used to guide their construction. It was important to know when to plant crops, when they must be harvested and how they must be stored. Animal husbandry would have similar needs. The role of priesthood and leadership was to reliably predict the changing of the seasons and take responsibility for the consequences of their variation. A stable predictable climate was very important to maintain a thriving society.

Civilization has evolved rapidly over the ten to twelve thousand years after the end of the last ice age also known as the Holocene period. During this time regions of the Earth have experienced very significant climate changes due to a variety of naturally occurring phenomena such as changes in ocean currents, rising sea levels and volcanic activity. Great civilisations formed during periods of relative stable climate and are believed to have disappeared when the regional climate changed.

It is now believed that several complex, sophisticated societies developed as long ago as ten thousand years (e. g. Gobekli Tepe in Turkey). Several agrarian based civilizations developed in the Middle East, Northeast Africa, Asia and the Indian subcontinent. The rise of these civilisations depended on stable climatic conditions and several disappeared when climate change that resulted in decreasing precipitation caused the collapse of the agrarian economy.

The science of climate change began with scientific observation. A very good review of the history of climate change science may be found in one of the Wikipedia sites; https://en.wikipedia.org/wiki/History_of_climate_change_science#:~:text=The%20history%20of%20the%20scientific,natural%20greenhouse%20effect%20first%20identified .

At the beginning of the nineteenth century geographers observed that surficial topography in Northern Europe were distinctly similar to formations associated with existing glaciers in the Alps. It was from these studies that Louis Agassiz, geologist and zoologist, proposed that at least the northern regions of Europe were periodically covered with glaciers which then receded, advanced and receded over time. He concluded that Earth, at least in these regions, had experienced very large changes in climate which had resulted in development of glaciers which caused massive reshaping of the landscape. This period of Earth's geologic history became known as the 'Ice Ages'. Later in the century his theories that climate had indeed changed several times over Earth's past were supported by sampling and analysis of sediment cores taken from the ocean bottom. The occurrence and cause of the ice ages were just beginning to be understood.

At approximately the same time Joseph Fourier, a prominent physicist and mathematician, proposed that the Earth was warmed by the atmosphere 'trapping' heat similar to a greenhouse – origin of the so-called 'greenhouse effect'.

John Tyndall, an Irish physicist and a contemporary of Fourier, described the physics behind the greenhouse effect by identifying the various gases in the atmosphere and how they would transmit (pass) short wave radiation and absorb and reemit infrared radiation (heat) back to the Earth's surface and outer space.

Svante Arrhenius, a prominent Swedish physicist, in the process of attempting to find an explanation to the occurrence of the ice ages, established the importance of the role of carbon dioxide in Earth's atmosphere as the principal gas that was responsible for the greenhouse effect that resulted in Earth warming.

It was the work of the Serbian geophysicist and astronomer, Milutin Melankovic, in the early 20th century that identified the correlation of the cyclical variations of Earth's orbit and the tilting of its axis to the occurrence and disappearance of the ice ages (http://en.wikipedia.org/wiki/Milankovitch_cycles). He explained why this phenomenon would occur over land in the northern latitudes. He introduced a very important concept known as

'forcing' which explained how climate, regionally and globally, could be impacted by changes in any of the elements in the systems that determine what the climate might be.

It is now known that changes in climate can occur very slowly over hundreds, thousands, tens of thousands or even millions of years, or very abruptly over days, months, years or decades. The changes which occur slowly might allow for adaptation to the environment while abrupt changes could be catastrophic to the affected biosystems that may be entirely destroyed and ultimately replaced (e. g. the extinction of dinosaurs). Changes in climate may occur over the entire globe or over specific regions. Affected regions may vary in size from a few hundred square kilometres to many thousands or millions of square kilometres in scale. Adjacent regions may not experience climate change at all.

Historic climate changes were the result of natural phenomena. With the spread of modern agriculture, the industrial revolution and resource exploitation it is now believed that human activities that produce carbon dioxide and other gases (collectively known as greenhouse gases, GHG) are causing rapid global warming that may result in an abrupt change in global climate. (Recall the work of Arrhenius). This period, which can't be much older than a few hundred years (still a debate), has become known as the 'Anthropocene period'. During this same period there have also been notable and documented naturally occurring phenomena, volcanic activity in particular, that have also affected global climate but never to same extent as human activities.

The impacts of rapid climate change can be very significant and destructive to the biosphere. It is important to understand what causes it so questions such as: 'Can climate change be predicted? Where will it occur? When will it occur? What will the changes actually be? How long will the changes last? Can we do anything about it?' are important.

It wasn't until the 1950's when it was observed how rapidly the concentration of carbon dioxide was increasing in the atmosphere. It was then that many scientists from around the world, determined that human activity would likely result in rapid changes to Earth's climate with many profound negative impacts.

The use of computers to simulate global climate change and natural climate variations was pioneered by Syukuro Manabe in the mid 1960's https://en.wikipedia.org/wiki/Syukuro_Manabe for which he was awarded a Nobel Prize in Physics in 2021 which he shared jointly with two others who actually were not working on computer simulation of global climate change https://www.nobelprize.org/prizes/physics/2021/manabe/facts/ .

As early as 1981 James Hansen and others published a study, '*Climate impact of increasing atmospheric carbon dioxide*' (https://pubs.giss.nasa.gov/abs/ha04600x.html) which noted, 'It is

shown that the anthropogenic carbon dioxide warming should emerge from the noise level of natural climate variability by the end of the century, and there is a high probability of warming in the 1980s. Potential effects on climate in the 21st century include the creation of drought-prone regions in North America and central Asia as part of a shifting of climatic zones, erosion of the West Antarctic ice sheet with a consequent worldwide rise in sea level, and opening of the fabled Northwest Passage.' In 1988 James Hansen reported to the Congress of the United States his assessment that human-caused warming was affecting the global climate.

The threat of rapid climate change motivated the founding of the United Nations Framework Convention on Climate Change (UNFCCC) secretariat in 1992, https://unfccc.int/ which was tasked with supporting the global response to the threat of climate change. The United Nations Intergovernmental Panel on Climate Change (IPCC) was created by the United Nations Environmental Program (UNEP) and World Meteorological Organization (WMO) in 1988 to assess the science related to climate change and report this to world governments including the UNFCC (https://www.ipcc.ch/about/history/). The Intergovernmental Panel on Climate Change provides a detailed perspective on how the individual elements of the science of climate change were identified and understood. This information is made available through assessment reports the most recent complete report being the Sixth Assessment Report published August 9 2021 titled AR6 Climate Change: The Physical Science Basis, (https://www.ipcc.ch/report/ar6/wg1/#FullReport). Working Group II, Impacts, Adaptation and Vulnerability, and Working Group III, Mitigation of Climate Change, contributions were released in 2022, https://www.ipcc.ch/assessment-report/ar6/ . These assessments form the basis for various international agreements coordinated by the UNFCC to limit the impact of global warming on climate change.

The IPCC assessment reports are a synthesis of peer reviewed scientific articles by many reputable scientists reporting their research on global warming and climate change, the factors contributing to the phenomena, the impacts, potential to adapt and opportunities to mitigate. The greatest concern is that if humans do not take drastic measures to mitigate global warming by limiting its causes the earth will inevitably become a victim of their activities without any possibility of mitigation by the year 2100. It is urgent that these measures start to be implemented now.

Despite these warnings those societies contributing most to the problem of global warming and climate change appear reluctant to start mitigation activities of any impactful nature.

The message from the IPCC is clear. Net emissions of greenhouse gases of any type must be reduced to zero to avoid the serious effects of global warming and associated climate change.

Efforts by the UNFCC to gain the commitment and cooperation from the nations of the world to act have only been partially successful. This is most likely a result of the 'push-back' the governing leadership receives from their citizenry when the mitigative measures are proposed.

It is my belief that if the citizenry actually understood the science, they would accept the conclusions of the IPCC and certainly dismiss the self-serving misinformation so prevalent on the internet.

There is no question that the science is complicated and the IPCC reports difficult for the non-scientific community to understand. That said, the citizenry, including governing individuals are concerned and willing to learn. There is an urgent need to provide them the opportunity to begin to understand the science of global warming and climate change, the actual science and not a dumbed down version, and empower them to continue a self-guided learning process. This would enable those concerned to participate in the solution forming process.

The science of climate change continues to rapidly evolve with ever improving theories, the ability to collect more and better-quality data (particularly using satellite technology) and the development of faster computers able to exploit the developing theory and synthesize ever increasing amounts of information. The history of climate change modelling is described in detail in a paper published in the newsletter Carbon Brief 16.01.2018 titled Timeline: The history of climate change modelling https://www.carbonbrief.org/timeline-history-climate-modelling.

One of the unfortunate and surprising outcomes of the successful study of the science of climate change is the evolution of what are known as 'climate change deniers. They accept that climate has changed over Earth's history and that the climate will continue to change – naturally. To them the Anthropocene period doesn't exist. The 'experts' in this field have quite a following and are sometimes organized into like-minded groups to raise funds to spread the word.

There are several books and countless web sites, blogs and other types of information available on the internet. There is 'real science' and 'bogus science'. Those knowing little of the subject can easily be misguided and spend their energies reviewing 'trash' and accepting, or worse engaging in bizarre conspiracy theories.

The purpose of this book is to provide the reader a guide to the 'real science' as it is presently understood by virtually all reputable scientists in a manner and language most of the global population can understand.

The Sixth Assessment Report includes what is called an Interactive Atlas in the report, IPCC WG1 Climate Change 2021: The Physical Science Basis

https://www.ipcc.ch/report/ar6/wg1/#FullReport.. This feature facilitates the examination of the impacts of global warming of the entire globe or specific regions. It is discussed in Chapter 21.

The timeline for the study and reporting of the science of climate change is summarized in Figure 2.1.

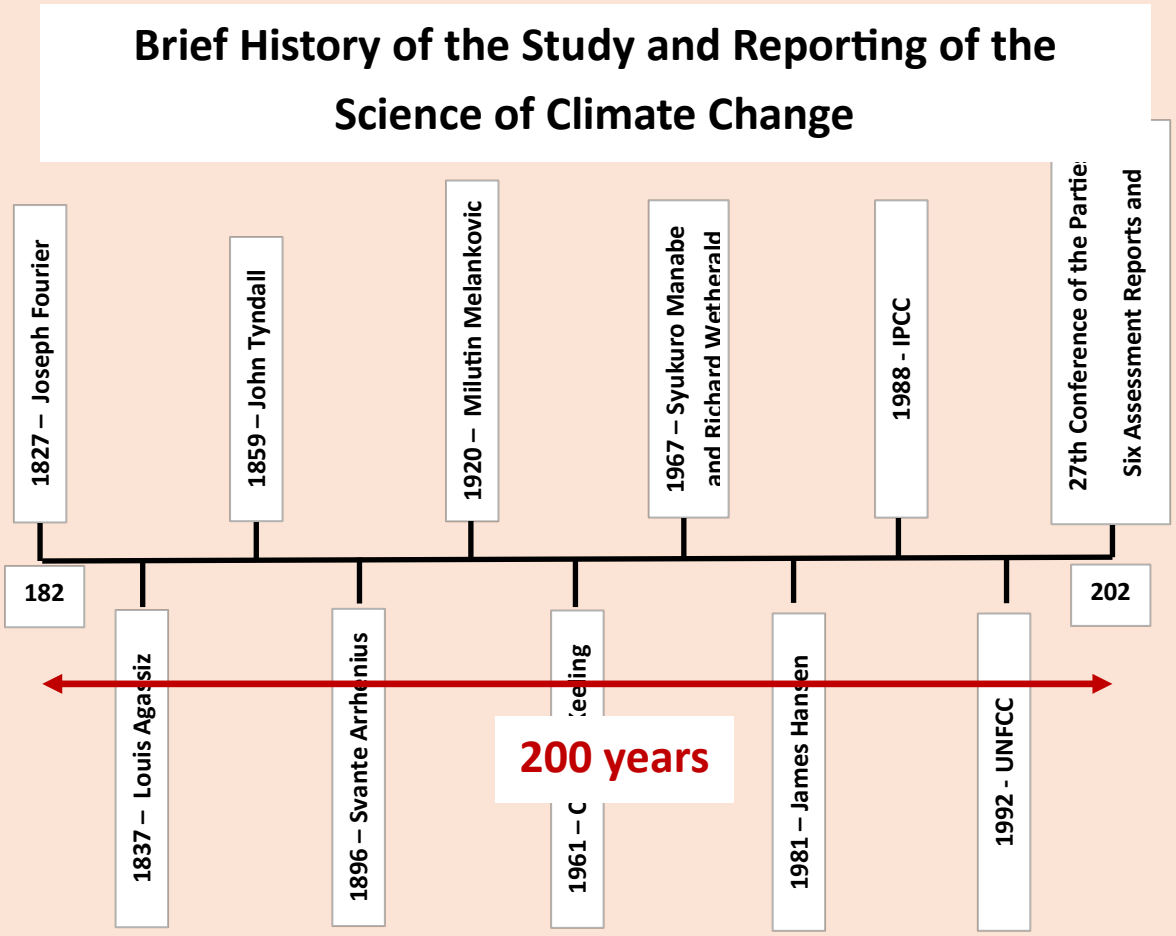

Figure 2.1 Timeline of the study and reporting of the science of climate change.

2.1 Information support

Key web sites:

1. IPCC History. https://www.ipcc.ch/about/history/

2. Discovery of Global Warming. http://www.aip.org/history/climate/

3. History of climate change science. https://en.wikipedia.org/wiki/History_of_climate_change_science#:~:text=The%20history%20of%20the%20scientific,natural%20greenhouse%20effect%20first%20identified.

4. Milankovitch. http://en.wikipedia.org/wiki/Milankovitch_cycles

5. Hansen et al. 1981, Climate impact of increasing atmospheric carbon dioxide. https://pubs.giss.nasa.gov/abs/ha04600x.html

6. United Nations Framework Convention on Climate Change 1992. https://unfccc.int/

7. IPCC Sixth Assessment Report, WG1 Climate Change: The Physical Science Basis, https://www.ipcc.ch/report/ar6/wg1/#FullReport

8. Timeline: The history of climate modelling, Carbon Brief 16.91.2018. https://www.carbonbrief.org/timeline-history-climate-modelling.

9. Syukuro Manabe, pioneer work on the use of computers to simulate global climate change and natural climate variations. https://www.nobelprize.org/prizes/physics/2021/manabe/facts/ and https://en.wikipedia.org/wiki/Syukuro_Manabe

10. IPCC AR6 assessment reports, https://www.ipcc.ch/assessment-report/ar6/ .

Other references:

1. Hansen, J.; et al. (1981). "Climate impact of increasing atmospheric carbon dioxide". Science. **231** (4511): 957–966. Bibcode:1981Sci... 213..957H. doi:10.1126/science.213.4511.957. PMID 17789014