

## **Looking Backward, Looking Forward – Reflections on “Energy, Climate, People, Conservation And National Parks And Related Reserves”**

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### **Abstract:**

This paper reexamines issues and concerns expressed in the author's paper presented to the 1978 *Canadian National Parks: Today and Tomorrow, Conference II, Ten Years Later*. His predictions regarding the impending global crisis to anthropogenic induced climate change were prescient. It discusses what has been and has not been learned during the intervening three decades by scientists, politicians and society at large about the development of public policy on scientific issues such as the climate change crisis. The role played by vested interests in seeking to convince politicians and the general public that no problem exists is considered, as is the role of the media in provoking controversy. The paper examines the challenges now faced in our national parks and in our daily lives in adapting to a new environmental reality. The economic, social and environmental challenges that global climate change will create are discussed using ethical analysis.

### **INTRODUCTION.**

My 1978 parks conference paper (Buckmaster 1979) concerning the impending global climate change crisis due to the anthropogenic generation of carbon dioxide and other greenhouse gases may have been extremely audacious. I was convinced that it was timely to air these ideas because the scientific papers on the subject had received little publicity outside of a narrow scientific circle and deserved wider dissemination to promote healthy discussion and further studies. The amount of carbon dioxide being released into the atmosphere had increased from its estimated pre-industrial value of 280 ppm in the mid 19<sup>th</sup> century to 330 ppm in 1978 was one concern. Estimates of the annual average global temperature were inconclusive as it had flattened during the 1960's and 70's after increasing during the first half of the 20<sup>th</sup> century. The unanswered question was not whether but rather when would the role played by anthropogenic generated carbon dioxide and other green house gases become dominant in determining the mean global temperature. It could not be answered by atmospheric scientists because climate modeling studies lacked the necessary computational power. During the 1970's, global mean temperatures had been declining slightly and some scientists had suggested that another small ice age may be starting. It is legitimate to question why anyone would predict that global warming was imminent. The reasons were based on the available information. An increasing global population, increased industrialization in less developed countries, an increasing gross domestic product in many countries and its relationship to energy consumption made it is obvious that the amount of atmospheric carbon dioxide would continue to increase. These factors were sufficient to ensure that the forcing due to the increasing atmospheric concentration of carbon dioxide would eventually become the dominant factor determining the mean global temperature. There was no indication that any of the above factors would decrease rather than continue to increase so simple risk assessment demanded that aversive action should be taken.

## GLOBAL WARMING AND CARBON DIOXIDE DATA 1978-2008.

The author's concerns became justified when new global annual temperatures were reported. By 1990, the so-called "*hockey stick*" shape (Mann 2008) of the graph of the mean annual global temperature as a function of time had become well defined and eight of the warmest ten years in the past hundred years had occurred since 1980. The Mount Pinatubo volcanic eruption in 1991 gave scientists the opportunity to test their global climate change models. The mean global temperature declined during the next several years and these models made remarkably accurate predictions about the observed decline and recovery of mean global temperatures. The mean global temperature then continued to rise and the warmest twenty years in the past century have all occurred in the past twenty five years! These increases are much more pronounced at mid-latitudes in the northern hemisphere than in the southern hemisphere because the land mass is larger and a large fraction of the earth's population lives there including most of the developed countries in the world. It is also greater over land masses than over the oceans. There is no doubt about the reality of anthropogenic induced global warming and the correlation with the increasing amount of carbon dioxide in the atmosphere is evident. However, this warming is not uniform on a regional basis. The Mackenzie Basin in the western Arctic started to show evidence of warming long before the eastern Arctic. Figure 1a is a graph of the mean annual global temperature back to 1880 when systematic instrumental records started to become available (Hansen 2007). The "*hockey stick*" shape is very clear in this figure. Figure 1b is the same graph that includes temperatures reconstructed from various data sources back to 1000 AD (Houghton 2004). Note that the El Nino/ La Nina Southern Oscillation cycle of ocean warming and cooling in the Pacific basin plays a significant role in modulating this increase particularly in North America. The Arctic Oscillation affects North America and Europe and the Antarctic Oscillation affects the Antarctica (Cowie 2007, p.191). Figure 2a is a graph of the amount of atmospheric carbon dioxide at Mauna Loa as a function of time since measurements were initiated there in 1958. Figure 2b gives the same graph on a larger scale plotted on a monthly basis from 2003 until early 2008 (NOAA 2008). The slope exceeds 2 ppm/year as the "business as usual" fossil fuel energy consumption scenario continues unabated. By 1990, the atmosphere contained 354 ppm, 368 ppm in 2000 and by 2005, it had over 380 ppm of carbon dioxide. There are many other forms of supportive proxy evidence such as the dates on which northern lakes freeze in the fall and thaw in the spring (Cohen 1997).

Any discussion of global warming should take account of the fact that about 20% of the earth's population live in the so called developed countries and consume about 80% of the available resources. Two countries, China (20%) and India (17%), with another 37% of the population are in the process of emerging as developed countries. It is alarming that the global consumption of its resources already exceeds that of two planets. This consumption rate is doomed to increase rapidly in the next decade or two if this trend continues. The cost of food is already rising at a dramatic rate as emerging nations acquire the consumption and eating habits of the developed countries. The growing interest in biofuels is discouraging the production of food grains so their price is rising dramatically. This will result in a significant increase in the death rate amongst the poor particularly in Africa and other underdeveloped areas of the world and global warming will aggravate this problem. Drought is already a fact in many equatorial parts of the planet. Global warming is responsible for the increasing number of extreme weather events. The frequency of class four and five hurricanes has increased causing the death rate due to these events to increase as well as the cost of repairing and replacing damaged housing and commercial buildings. Insurance claims have soared as have the rates. Similarly, the frequency of heat waves has increased and the death rate due to these events has also

increased by an estimated 5%. The World Health Organization has estimated that over a hundred thousand people die annually of malaria and other insect transmitted diseases such as dengue and global warming will increase this number. (Hranski 2008)

## **ETHICAL ANALYSIS.**

Ethical analysis provides a very useful tool to assess multifaceted problems particularly where a range of potential solutions exist depending upon the weight given to economic, social and environmental considerations (Hurka 1993). The approach is to determine who has standing. The “Here and now” scenario, justifies those actions which benefit adults alive today. Most business decisions are made on this basis for obvious reasons. Expanding the group with standing to include everyone alive implies that the actions taken should be beneficial for a much longer period of time. Including grandchildren continues to increase the time scale under consideration and this group can be extended indefinitely. Should only humans have standing? If it is agreed that all mammals should have standing then the actions must be beneficial in a much larger group and extending this group to include all animate objects introduces an even more complex number of impacts to assess. Most environmental conflicts arise because the various groups involved assume that all the groups share the same ethical stance. Persons concerned about the impact of developments on the environment find it very difficult to accept that there are many people and businesses believe in the “Here and now” approach. The latter often assume that future technology will solve outstanding problems. Religious belief may help some people to make the “correct” ethical decisions about the environment but the concept of “Man having dominion over the earth” has many interpretations and has led some groups to take environmentally disastrous actions.

The application of ethical analysis to the problems presented by anthropogenic global warming should take account of the following factors. Rachel Carson first reminded us that the earth’s biotic system is incredibly complex and that minor interference in one area may cause serious effects in other apparently unrelated areas (Carson 1962). Each ecosystem consists of thousands of forms of life and each of them must coexist in its own ecological niche in precarious balance with its neighbours. This theme of balance was emphasized by Gore in his book (Gore 1992) and expanded upon later (Gore 2006). The present warming trend is occurring at a rate that is unprecedented in human history let alone global history. The earth has been much warmer in the past but rarely during the past few hundred thousand years when humans have existed. Humans may have a much greater chance of adapting and surviving than animals, birds and fish because of the technological resources they can develop. The latter must adapt to the impacts of rising temperatures on the biota that sustains them by altering their ecological niches. Their reproductive behaviour is timed by temperature and temperature changes. For example, during the past thousand years, the hardwoods in Appalachia have slowly extended their range northward from Florida until they reached their present range as far north as southern Ontario. Polar bears are now an endangered species because the Arctic ice melts earlier depriving them of access to their traditional spring feasts of baby seals to feed their offspring. The migration habits of many bird species that spend part of their life cycle in one hemisphere yet migrate to the Arctic to nest and reproduce is being upset by rising temperatures. Many biologists have lists of species trying to survive and adapt to these rapid changes. It is the unprecedented rate at which these changes are occurring that is the source of the problem of survival by adaptation for most biota.

It is noteworthy that the dedication in the legislation creating our national parks (Canada National Parks Act 2000) includes a definition of who has standing in our national parks. This shows that this concept is not new and has been used informally in many diverse situations.

My analysis is based upon giving standing to all future generations of humans as well as all biota but it is impossible to assign weights to the level of standing afforded different groups as the totality of the environment is too complex and interwoven. The living human members of this biotic assemble need to undertake serious lifestyle changes and receive immediate support in the form of dramatic action by all levels of government to initiate the reduction of the emission of greenhouse gases by industrial and personal activity. This implies that our economic system will need to be retooled so as to function effectively in a world where energy efficiency and resource conservation have a high priority. It is only through such drastic measures that I believe sustainable societies can be created that will be able to survive in the future. I am less confident about the number of species that will survive if the predicted upper limits to the temperature increase occur and landscape changes are beyond my imagination (Cowie, 2007 p. 466).

## **FACTORS THAT HAVE CREATED THE PRESENT POLIITICAL PROBLEMS.**

There are complex reasons why global society, and particularly those living in the developed countries, has been unable to take any effective action to move away from the “*Business as usual*” emission scenario. Sir Crispin Tickell has stated “*Mostly we know what to do, but we lack the will to do it. Be afraid, be very afraid*” (Tickell 1986). Four groups bear collective primary responsibility for this inaction; scientists, businesses, the media and politicians. The population of a country looks to its experts for advice on such issues and they have been left confused because of the wide discrepancy between the opinions espoused by various people representative of these four groups.

### **1. Scientists.**

Scientists have unwittingly played an unfortunate role that has confused the public. There is a vast difference between being able to prove a scientific prediction and the creation of science policy based upon the existing scientific evidence. My major criticism of the four Intergovernmental Panel on Climate Change (IPCC) reports is their focus on the need to predict the global climate future using climate models and to downplay the observed atmospheric carbon dioxide and global mean temperature data trends. This is a subject where traditional scientific proof is difficult to obtain since the issues involved are too complex. Most scientists have believed that it was their responsibility to “prove” the existence of global warming before they felt comfortable making recommendations because global warming is an unusual and complex scientific problem. Causal proof is not accepted as legal proof in British common law. This defense was used by the tobacco industry for years to claim that the relationship between lung cancer and smoking could not be proven. There is already sufficient evidence to justify serious action based upon risk assessment of the existing causal relationship between the rate of increase of carbon dioxide in the atmosphere and the rising global temperatures. This approach was used to justify the swift and decisive action concerning the emission of chlorofluorocarbons (CFC’s) into the atmosphere that resulted in the Montreal Convention in 1987 with the 1991 London and 1992 Copenhagen Amendments (Houghton 2004, pp. 45 – 47).

Some climate scientists persuaded the UN to create the World Climate Program (WCP) in 1979 and this eventually led the United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO) to create the IPCC in 1988. This panel was chaired initially by Professor Bolin of Sweden and had four working subcommittees involving scientists from many countries in the world. Unfortunately, many were also civil servants which may have

constrained their objectivity. The IPCC has now produced four reports in 1990, 1995, 2001 and 2007. Working Group 1 was responsible for assessing the available scientific climate change information. It best estimates for the mean global temperature in 2100 were 3.5°C (1.8 – 5.25°C) in 1990 and 3.4°C (1.1 – 6.4°C) in 2007. The mean value has not changed significantly in the four reports but the range has. These reports were responsible for the sequence of framework conventions that were signed by most countries in the world leading to the Kyoto Accord in 1997 which came into force on February 16, 2005 after Canada and Russia became signatories. Currently, new Conferences of Parties (COP) have been held in Bali in 2007 and Bangkok in 2008 with the hope that a new convention would be signed in Copenhagen in 2009. The USA and Canada are the most conspicuous countries who have failed to sign these new COP's accords. These accords included 27 principles, one of which affirmed "*Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature*" (Houghton 2004)

Thompson and coworkers have shown using statistical techniques that the increases in the average global temperature and the atmospheric carbon dioxide concentration have been strongly correlated since about 1980 (Kuo et al 1990) and that at least 75% of the temperature increase is correlated with the increase in atmospheric carbon dioxide and 25% with fluctuations in the solar radiation level (Thompson 1997). This causal relationship does not prove that it will continue into the future but in the absence of any decrease in the carbon dioxide emission rates it is reasonable to assume this relationship will continue. A risk assessment based on this correlation is sufficient justification for policy decisions because rigorous scientific proof is unnecessary before taking political and economic action on any environmental issue. It is foolhardy to take a small sailing craft out when a storm is forecast to become a hurricane regardless of the uncertainty associated with this forecast. For this reason, risk assessment is a powerful analytical tool in the creation of environmental policy.

## 2. Business.

Until recently, most business leaders were hostile to any proposal to decrease the consumption of fossil fuels based upon the arguments that the economy would be adversely affected because alternative sources of energy were too expensive. Energy efficiency was discounted and Amory Lovins' soft energy paths were considered impractical. Some international fossil fuel companies funded intensive media campaigns to discredit the theory of global warming and were successful in enlisting a few scientists who were willing to criticize global warming by making suggestions about factors that they claimed climate change models either ignored or did not take into account. Most of these suggestions had already been studied and those that had not were studied and found to be either small or insignificant. However, careful scientific studies never stopped them from repeating the same arguments over and over again. They knew that the public lacked the expertise to critique their claims and if these claims were repeated sufficiently frequently then they might become accepted as factual. The media played an important role in this process. There was a serious but unsuccessful attempt to derail the IPCC SAR Working Group 1 report in 1996 by some of these scientists aided and abetted by some OPEC IPCC representatives (Edwards and Schneider 1997).

## 3. Media.

The media, loving controversy and operating on the assumption that public debate deserves equal weight be given to each side gave those who debunked the existence of global warming or that it was likely to occur in the near future a great deal of free publicity. The media continue to refer to global warming as an unproven theory and ignore the four IPCC reports that have established the existence of global warming beyond any doubt and its known existence in

the Mackenzie basin for at least thirty years as its residents can affirm (Cohen 1997). It is reasonable to question whether this is responsible unbiased reporting. Unfortunately, there are very few reporters with a scientific background particularly in an era when technology is a dominant factor in our lives. Canadians are fortunate to have some extremely knowledgeable scientists who have become media personalities and communicate clearly.

#### 4. Politicians.

Politicians seldom have the time to become knowledgeable about many of the subjects that they create policy about and they rarely have scientific backgrounds to help them understand complex issues such as global warming. They prefer to rely on public opinion rather than the advice of knowledgeable civil servants on any subject that involves science. The advice of large corporations plays an important role in influencing politicians and they frequently use the media to further their objectives. The hostile response by many business leaders in both Canada and the United States to global warming makes it understandable that these two countries have not introduced any effective measures to reduce their emissions. There is already a growing backlash to the very modest but cost neutral proposal of the BC government concerning the reduction of greenhouse gases. The rising cost of automotive fuels is alarming the populace and the cost of importing food stuffs into Canada is rising. The loss of high quality arable land in Canada to urban sprawl has made us more dependent on food imports. These price increases have been buffered temporarily by the strength of the Canadian dollar but this strength has battered the industrial sector. It is amazing that there has not been a Royal Commission about any of these topics in Canada!

The UK is exceptional because a succession of its recent governments have chosen to take the advice of their senior scientific advisors, John Houghton (2004) and David King (2004), a former UK UN ambassador, Crispin Tickell (2006), and their economic advisor, Nicholas Stern (2007), and embark on an extremely aggressive program to reduce the nation's carbon dioxide emissions.

### **SCIENCE AND BELIEF.**

Some comments about the way science functions are pertinent. The media have emphasized the concept of whether someone "believes" in global warming. Belief plays no role in science. The dispassionate assembly of evidence by many researchers using vastly different measurement techniques that is consistent with a scientific model does not prove that a theory is correct but one piece of negative evidence is sufficient to disprove a theory. However, this negative evidence must also be verified independently by a number of researchers before it is acceptable evidence. One may question a theory if it has not been tested thoroughly but that is not a question of belief. This misunderstanding in the media about the methodology of science arises to a large extent because there are few science writers who are trained scientists and most people live in a world dominated by various economic, social and political beliefs. They are primarily concerned with economic survival and improving their lives. Politics influences the doctrines they believe play a major role in shaping their economic survival. Since a large fraction of the public are scientific illiterates and lack the background to know how to assess the validity of statements made about science in the media, it is not surprising that they fall back on the concept of belief. Unfortunately, scientists have been ineffective in countering this misunderstanding about how science functions.

## **PARKS CANADA.**

The six questions that I raised in 1978 remain valid today. It is ironic that the mission statement for the national parks is consistent with the ethical analysis I have used to justify extreme actions to avert global climate change since it gives standing to both present and future generations of Canadians and to the biota and landscape in our parks. Parks Canada has had the justification for undertaking an educational program for park visitors about the potential impact of global warming on our national parks. However, it is unreasonable to expect any government agency, in the absence of strong political direction, to provide such leadership even if Parks Canada personnel were convinced that their mandate justified such an interpretation. For example, would a parking lot have been built near the Sunshine Village turnoff or the parking lot at Lake Louise near the Chateau expanded if it had been government policy to limit the use of private vehicles in our national parks in order to decrease carbon dioxide emissions by park visitors? The answer is, of course, that the outcry by various vested interests and the public would have scuttled any suggestion as Canadians as well as visitors from most countries are wed to the use of their automobiles even in such special places. Parks Canada deserve credit for undertaking the many small steps which appear innocuous but all help make our parks more environmentally friendly and some decrease the amount of carbon dioxide emitted in our parks. The headquarters building for the Gulf Islands National Park in Sidney, BC meets the LEED Platinum standard (Parks Canada 2006). This building is a showcase for how modern buildings can be built to have minimum environmental impact. Modern sewage treatment facilities are another example. More such initiatives will help demonstrate to Canadians that Parks Canada is very concerned about global warming. A major source of greenhouse gas emissions in our parks comes from the vehicles that the visitors drive. The challenge is to get park visitors to accept the use of public transportation to reach many park destinations by restricting the use of the roads to these destinations. Parks Canada should replace its fleet of vehicles with more fuel efficient versions including electric and hybrid cars and trucks. I hope that the day will never come when it is necessary to have displays with photographs showing the impact of global warming on some of the famous places in our parks. It will, by that time, probably be too late to save these places from significant changes. Just imagine the view at Lake Louise when the glacier has disappeared.

## **FINAL COMMENTS.**

Revelle and Suess (1957) were the first to express their concerns about the inadvertent experiment upon which all humankind has embarked. *“Human beings are now carrying out a large-scale geophysical experiment of a kind that could not have happened in the past nor repeated in the future. Within a few centuries, we are returning to the atmosphere and oceans the concentrated carbon stored in the sedimentary rocks over hundreds of millions of years. This experiment, if adequately documented, may yield a far-reaching insight into the processes determining weather and climate.”* It is a monumental tragedy that the implications of this experiment are far too serious for us to continue yet the governments in the developed countries and those emerging as developed countries (China and India) have failed to take any significant action to stop and it has already continued for far too long. There is no serious indication that we, either as individuals or collectively, are prepared to take serious steps necessary to arrest it. I hope that Parks Canada will set an example to parks visitors about how to live in an energy efficient, low carbon emission, sustainable society without compromising their ability to enjoy their visitation experiences.

## ACKNOWLEDGEMENTS.

I would like to acknowledge the enormous intellectual debt that I owe Dr. Gordon Nelson who has been my colleague and friend for many years. It was his belief that physical scientists and, in particular physicists, should be involved in environmental issues. He challenged me to look at energy issues in our national parks thirty plus years ago and I have never looked back. The quality and clarity of this manuscript has benefited greatly from the insightful critiques provided by my wife, Margaret.

## BIBLIOGRAPHY.

- Buckmaster, H. A., "Energy, Climate, Conservation And National Parks And Related Reserves", The Canadian National Parks: today and tomorrow. Conference II: Ten Years Later. J.G. Nelson. R.D. Needham, S.H. Nelson, R.C. Scace, Proc. of the Canadian National Parks: Today And Tomorrow. Conference II, Oct. 8-13, 1978, Banff, AB. University of Waterloo, Waterloo, ON. Vol II, pp. 573 – 591, 1979.
- Carson, R. "Silent Spring", Houghton Mifflin, New York, NY, USA 1962. 462 pp.
- Cohen, S.J., Ed. Final Report: Mackenzie Basin Impact Study 1990 – 1997. Environment Canada, Downsview, ON. 1997. 372 pp.
- Cowie, J., "Climate Change - Biological and Human Aspects", Cambridge University Press, Cambridge, UK. 2007. xvi + 487 pp.
- Edwards, P.N. and Schneider, S.H., "Broad Consensus or "Scientific Cleansing"?", Ecofable/Ecoscience, Vol. 1, pp. 3 – 9, 1997.
- Gore, A., "Earth In Balance", Rodale Press, New York, NY, USA. 1990. 328pp.
- Gore, A., "An Inconvenient Truth", Houghton Mifflin, New York, NY, USA. 2006. 416pp.
- Hansen, J., "Global Warming: Connecting The Dots From Causes To Solutions", Speech given February 2007 to National Press Club and American University", ([dots\\_feb2007 James Hansen Power Point Slide 8](#))
- Hranjski, H., "WHO: Climate Change Threatens Millions." April 7, 2008. My Way. (<http://apnews.myway.com/article/20080407/D8VT8OQG0.html>)
- Houghton, J., "Global Warming – The Complete Briefing", 3<sup>rd</sup> Edition., Cambridge University Press, Cambridge, UK. 2004. xxx + 351 pp.
- Hurka, T., "Ethical Principles", Chapter 2 in Ethics & Climate Change: The Greenhouse Effect, Eds. H. Coward and T. Hurka. Wilfrid Laurier University Press, Waterloo, ON, 1993. pp. 23 – 38.
- King, D.A., "Climate Change Science: Adapt, Mitigate or Ignore?", Science, Vol. 303, No. 5655, 9 January, pp. 176 – 177, 2004.
- Kuo, C., Lindberg, C., and Thompson, D.J., "Coherence established between atmospheric carbon dioxide and global temperature", Nature, Vol. 343, No. 6260, pp. 709 – 714, 1990.
- Mann, M., Michael Mann (scientist). ([http://en.wikipedia.org/wiki/Michael\\_Mann\\_scientist](http://en.wikipedia.org/wiki/Michael_Mann_scientist))
- National Oceans and Atmospheric Research (NOAA), "Current Trends In Carbon Dioxide", US Dept. Of Commerce/National Oceans and Atmospheric Administration website 2008.
- Parks Canada, "Gulf Islands National Park Reserve of Canada – Operations Centre Sustainable Design Features". Folder Brochure, 2006, 6 pp.
- Revelle, R. and H. Suess, "Carbon Dioxide Exchange Between the Atmosphere and Ocean and the Question of an Increase of Atmospheric Carbon Dioxide During the Past Decades", Tellus Vol. 9, pp. 18 – 27, 1957.
- Statutes of Canada, "Canada National Parks, Act 2000, c.32", (<http://laws.justice.gc.ca/en/N->



[1401/index.html](#))

Stern, N., "The Economics of Climate Change: The Stern Report", Cambridge University Press, Cambridge, UK. 2007. 692pp.

Thompson, D.J., "Dependence of global temperature on atmospheric CO<sub>2</sub> and solar irradiance", Proc. Natl. Acad. Sci. USA, Vol. **94**, pp. 8370 – 8377, 1997.

Tickell, C., "Climate Change and World Affairs", 2<sup>nd</sup> Ed. 1986.

Tickell, C., "Vulnerable Earth", Robert C. Barnard Environmental Lecture, AAAS, Washington, DC, USA. Sept. 18, 2006. (<http://www.aaas.org/news/releases/2006/1002tickellspeech20060918.shtm>)

Figure 1a.

Graph showing the global mean temperature: land- ocean index anomaly obtained from instrumental records from 1880 to 2006 AD (Hansen 2007).

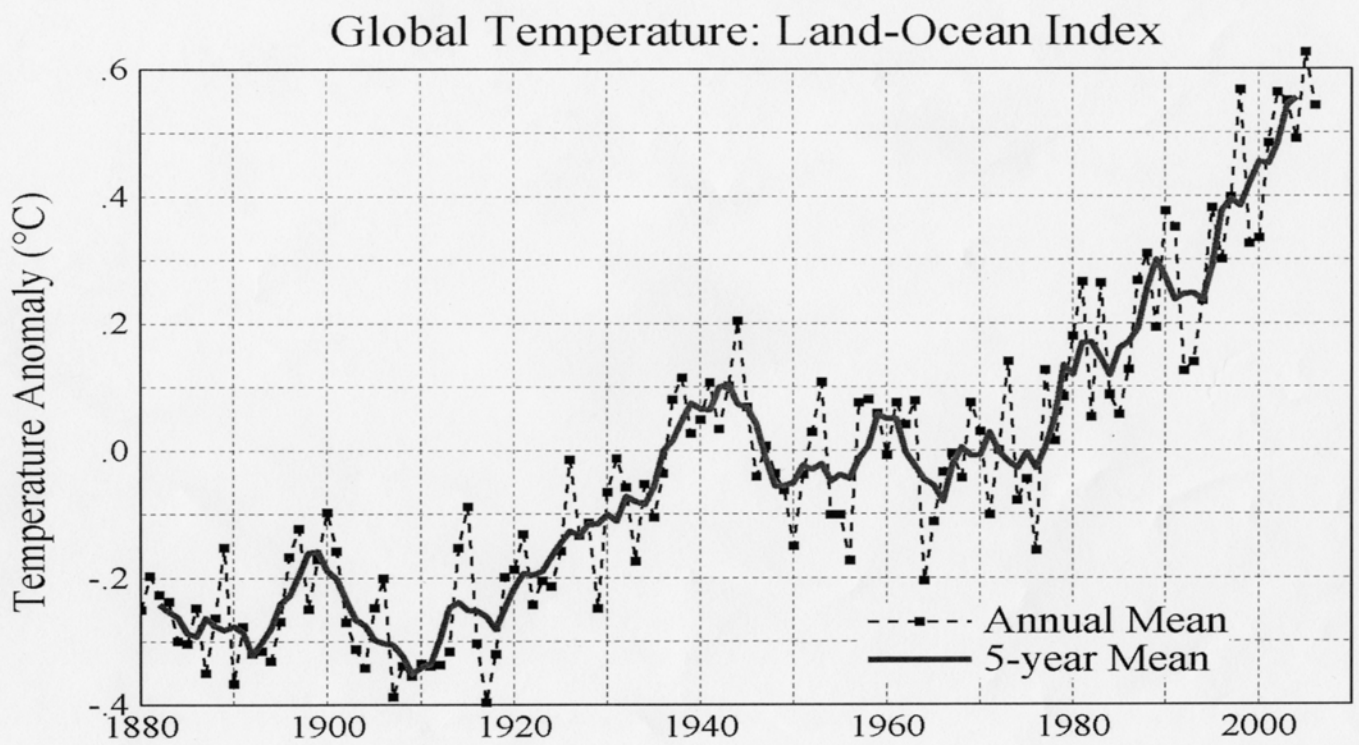


Figure 1b.

Graph showing the mean temperature for the northern hemisphere reconstructed from tree ring, coral, ice cores, and historical records for the period from 1000 to 1980 AD and from instrumental data from 1902 to 1999 AD. A smoothed version of the proxy record is also shown as are the 95% confidence limits (grey shaded) (Houghton 2004, p. 65).

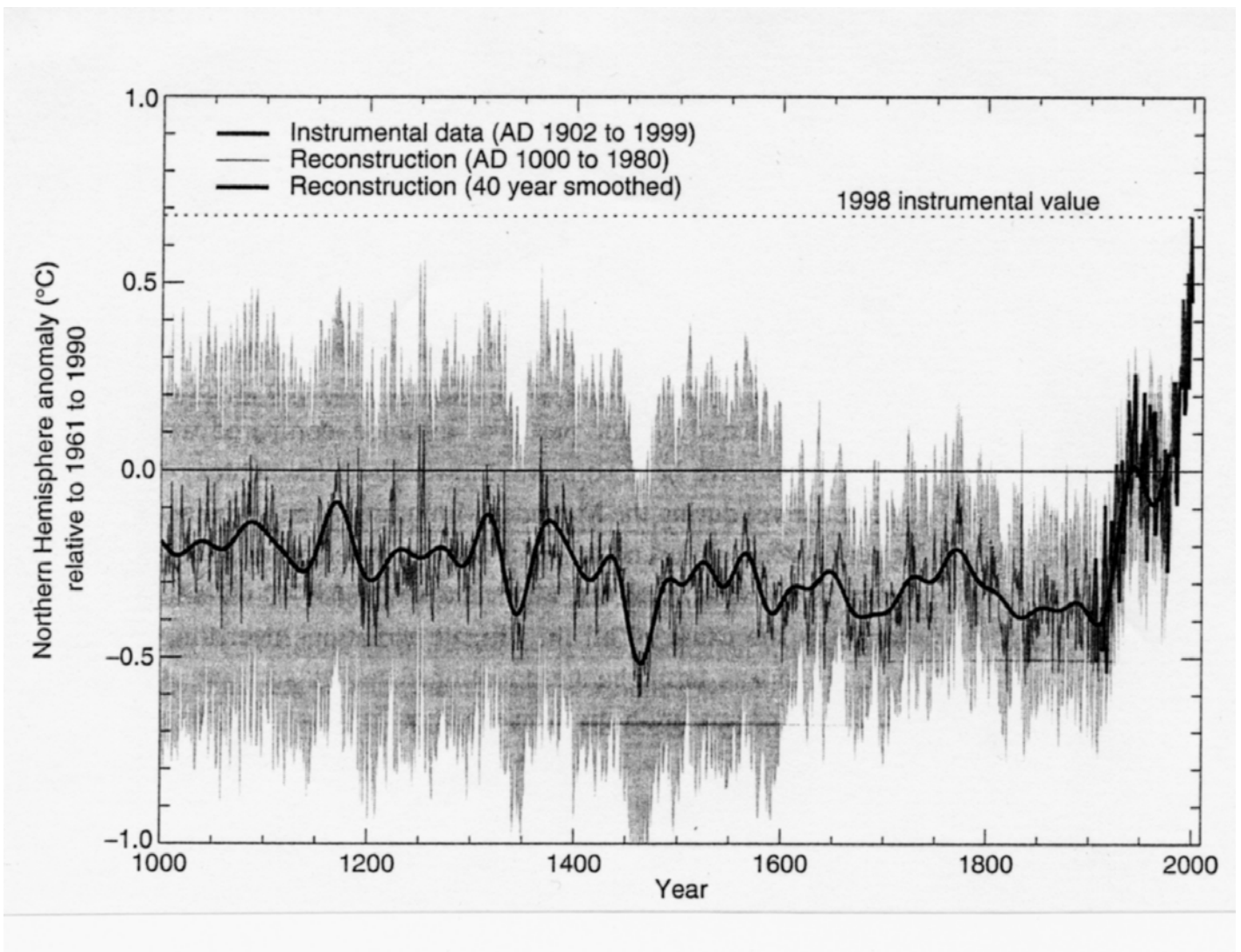


Figure 2a.

Graph showing the atmospheric carbon dioxide concentration measured at the Mauna Loa Observatory, Hawaii as a function of time from 1958 to 2008 (NOAA 2008).

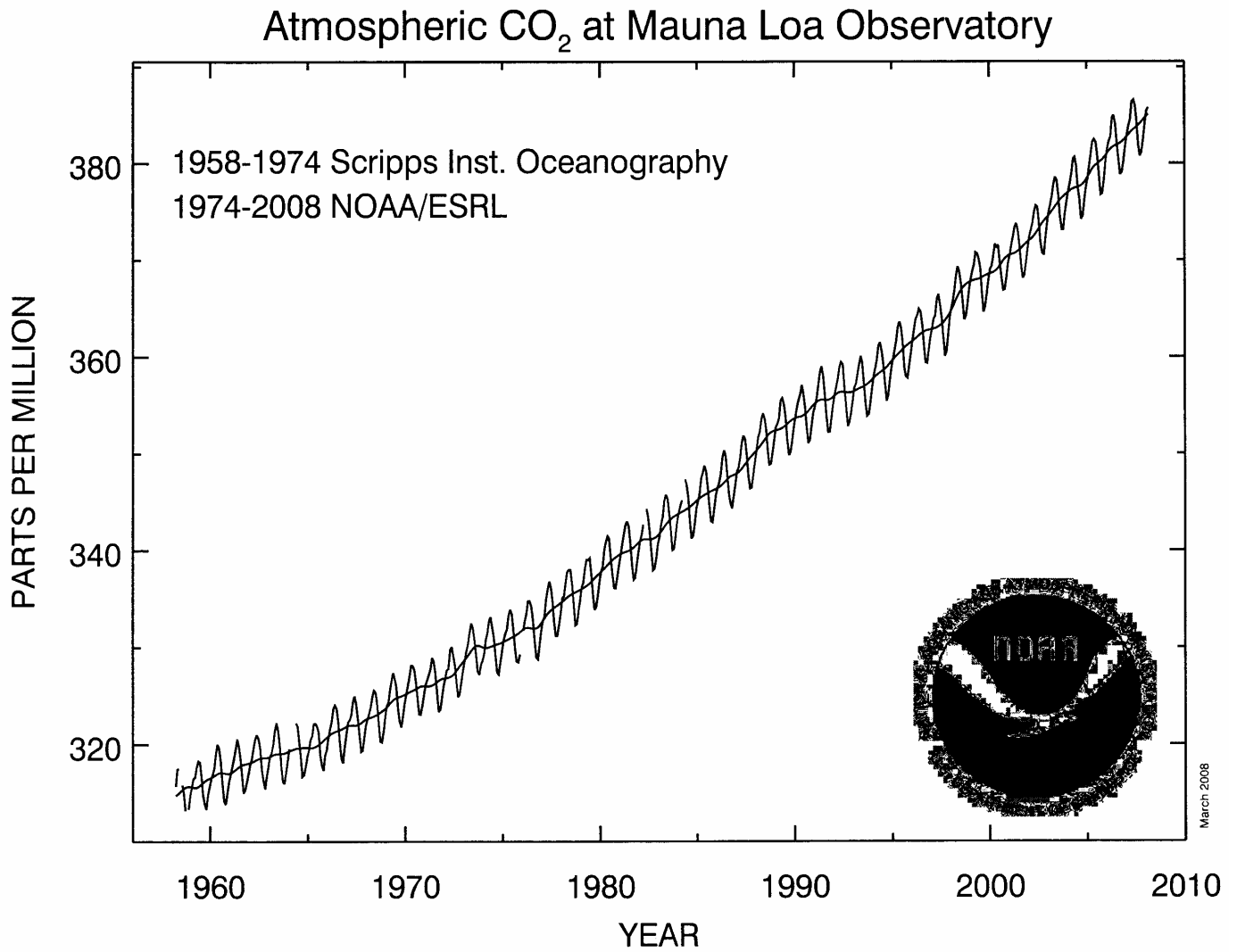


Figure 2b. Graph showing the monthly mean atmospheric carbon dioxide concentration measured at Mauna Loa, Hawaii as a function of time from 2004 to 2008 (NOAA 2008).

