Global Warming:

a Field Guide for Everyday People

by

John F. Weaver, Jeff Braun

Cooperative Institute for Research in the Atmosphere

Colorado State University

and

William J. Szlemko

Department of Psychology

Colorado State University

Ft. Collins, CO 80523

Introduction

This book is written from the perspective of those of us who question the role of human activity in global warming – not to emphatically deny its role, but simply to question its contribution. Our primary goal is to simply present the facts in a logical and rational manner. We have tried not so much to argue *beliefs*, but rather to present information and allow it to speak for itself. We are scientists and, as such, have tried to stick mostly to facts. Occasionally, we may make a comment that reflects our true feelings, but we try not to do it very often.

There is another purpose to this book which will probably be at least as useful as that of the first. Typically, whenever one searches for material on the topic of global warming – whether on the worldwide web, the book store, or the local library – it is difficult to find a single source for charts, graphs and explanations of what one might call the Big Picture. We have tried to provide a large sampling of this information (much of it in illustrated format), along with documentation of sources and brief explanations of how some of the measurements are obtained. You will not find them rigorously detailed, but the information is accurate, and should be easy to follow for those with a basic knowledge of how science works. We also try to provide enough in the way of source referencing such that the reader who wants to pursue individual topics in even more detail can follow the trail markers.

A few words on the concept of "global mean temperature." In this book, we will use the most common meaning; that is, the average, near-ground temperature for the entire year, over the entire earth – as measured by existing sensors. For the most recent century-and-a-half, it is pretty much all of the temperatures, from all of the days and nights, and from thermometers at many sites around the earth, all averaged together. This "global mean temperature" concept can be somewhat tricky to interpret. There is seldom a year when there aren't a lot of places around the world that have had an unusually cold, or unusually warm year. In a globally colder year, some locations might experience an exceptionally long, hot summer and residents there question how the experts can call it a cooler year. Or when experts announce that a given year was warmer than the previous, many people who have suffered a cold and snowy winter might not believe it. But the global mean temperature is an average, and one tenth of a degree cooler globally could accompany a broiling hot summer in New York. Remember that the global mean temperature is supposed to represent a compilation of everywhere. That's the key. An average represents a collection of differences. Almost no one experiences the actual average. It only gives us an idea of the Big Picture, and that's what we plan to talk about in this book.

Chapter 1

Global Mean Temperature

The Big Picture

Long Term Trends

Mother Earth is cooling. In the very beginning, a cloud of gaseous matter condensed and formed this great planet; the third-closest satellite of the Sun. At first, the earth was nothing more than a red-hot, molten blob of matter. But, of course, that couldn't last. Traveling along through the near absolute zero temperature of outer space, and following the so-called zeroth law of thermodynamics[1], our planet began losing heat to its icy cold environment from the moment of its birth. That was, and remains, the undeniable truth – thermodynamics rules. At least for now. On its long journey through time and space, the earth finally managed to develop an atmosphere that could sustain life. However, thermodynamics says that one day – in the absence of other forces – the earth will be so cold, that even this miraculous, life-sustaining atmosphere will become unsustainable. Still, that's a problem for generations in the far, far future. For now, we need only recognize that Planet Earth is gradually cooling[2].

The general downward cooling trend can be seen in any reliable, long-term chart of global temperature, though the trends in those charts are typically heavily masked by the noisy spikes that we scientists call "other factors." To the non-scientist, it may seem a bit confusing, but we will deal with the confusion by beginning with the larger picture,

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[1] The zeroth law of thermodynamics states that when two systems of differing temperature come into direct contact with one another, there will be a net exchange of energy between the two until they are in thermal equilibrium. Put a pot of boiling water outside on a freezing cold day, and it will cool off.

[2] So far, even the daily radiation received from the sun hasn't been enough to counteract the long term trend. The sun shining on our little planet will not be quite enough, in the long run.

and gradually working our way down into the details. Let's start with a chart that covers a pretty long period of time. Figure 1.1 is a graph of global temperatures from the 5.5 million years in the past (on the left), to the present time (on the right). Even the briefest of glances makes it clear that, in times long past, global temperatures were quite a bit warmer (somewhere around 10^{o}C warmer 5.5 million years ago, according to the temperature scale on the right in Figure 1.1). It may seem a little hard to sort out the specific nature of the temperature drop, because there have been so many little temperature spikes over the millennia. We'll talk about these spikes in a minute, because some of the most severe are an important part of what might happen during our geologically minuscule lifetimes.

The main thing to notice right now is that Mother Earth has been cooling.

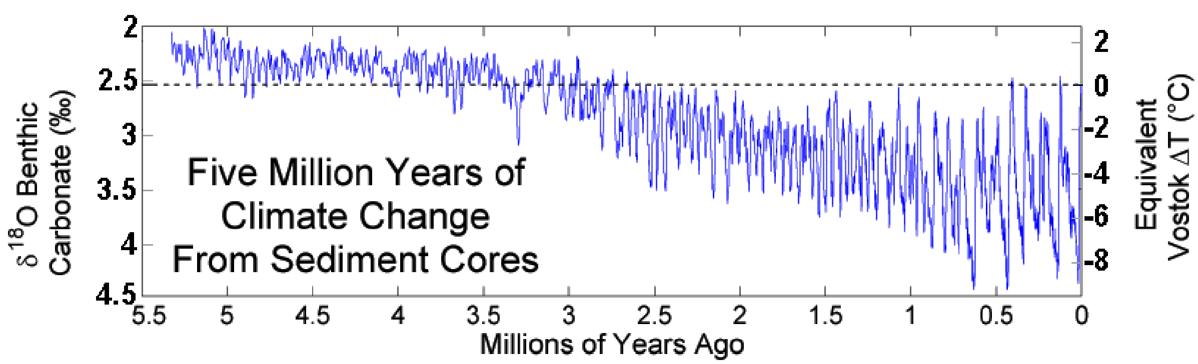

Figure 1.1. Plot of global climate changes over the past 5.5 million years as presented by Lisiecki and *Raymo*[3] *from oceanic sediment cores. Observations are calibrated to Vostok ice core temperature data (refer to scale on the right), and are plotted relative to the mean global temperature in 1950 (dashed line). The data illustrate that, overall, the mean global temperature is decreasing over the long haul. It also shows that temperature decrease is not smooth, but replete with fluctuations nearly as great as the magnitude of the overall trend (see also, Muller and MacDonald, 2002)*[4]*. For an explanation of* δ^{18}O*, refer to Appendix I. This version of graph prepared by* Global Warming Art *and was copied from their website at:* http://www.globalwarmingart.com/wiki/Image:Five_Myr_Climate_Change_Rev_png

[3] Lisiecki, L. E., and M. E. Raymo (2005), A Pliocene-Pleistocene stack of 57 globally distributed benthic δ^{18}O records, *Paleoceanography*, 20, PA1003, doi:10.1029/2004PA001071

[4] Muller, R.A. & MacDonald, G.J. (2002). *Ice Ages and Astronomical Causes*. (2nd ed.) New York: Springer Verlag

Looking a Little More Closely

The problem with most things in nature (in terms of understanding what the heck is going on) is that there is never just one thing going on. Probably nobody reading this is really surprised by that. One natural force may be trying to warm the atmosphere, while another is working, simultaneously, to cool it off. Indeed, there are many different temperature cycles – many factors acting at the same time – that (as noted earlier) make our temperature graphs look pretty noisy. These smaller, secondary cycles all occur for a variety of reasons – reasons that have to do with things like astronomy, the oceans, or the atmosphere itself. We'll be talking about those things in later chapters.

One of the most important of the shorter cycles is one that we'll take a quick look at right now. It lasts a little over 100,000 years – at least on average. (We'll be using the phrase "on average" *a lot*). So let's zoom in on the most recent 410,000 years of that 5.5 million year graph we just talked about, and look at another chart (Figure 1.2) which shows us a little more detail. Here, the present time is on the right again. These data come from ice core samples and give us an added bonus in that when you sample deep ice cores from glaciers, we not only get a measurement of the historical temperature (the *lower graph* in Figure 1.2), but we can also obtain a record of atmospheric carbon dioxide (CO_2) content at the same time (upper graph). We'll talk about CO_2 and other greenhouse gases later in the book.

The important thing to notice in the lower chart in Figure 1.2 (which is global mean temperature) is that over the past 410,000 years the earth has been mostly cold. In fact, there have been pretty long periods that, on average, were downright frigid. These cold periods (called ice ages) have each lasted roughly 85,000 - 90,000 years each, but were broken up by brief periods of 12,000 - 18,000 years that were about 8 ^{o}C warmer at their peak. We're in one of these relatively brief warm periods at the present time (at the right side of the lower graph). Remember, the big cycles in this graph were actually some of those tiny spikes we saw in Figure 1.1. However, notice that that there seem to be a lot of tiny spikes superimposed on this graph, as well. As we said, the true answer is never really simple when it comes to the real world. The important thing is that we are currently in one of those little warm periods right now.

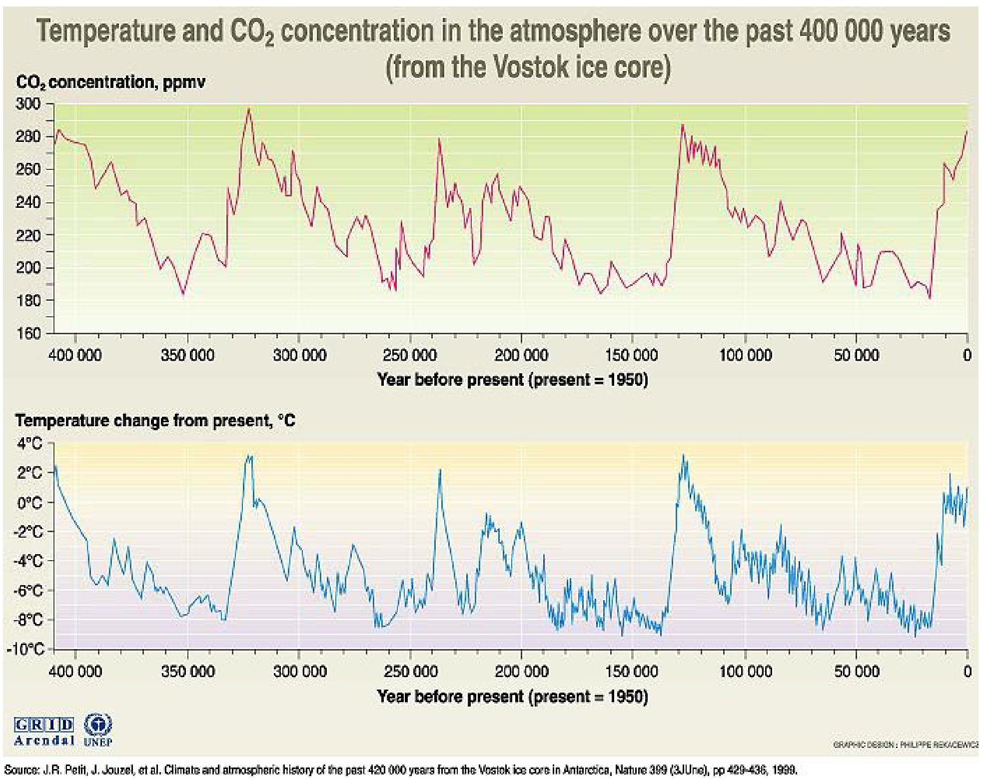

Figure 1.2. Data calculated from Vostok Ice core samples. Graphs as presented by Pettit et al. (1999)[5]*. Top – CO_2 concentration in parts per million (by volume) from 410,000 years ago (lt.) to the present (rt.). Bottom – Temperature change from 410,000 years ago to the present in degrees Celsius for the same time period as shown in top portion of figure. The time axis represents number of years before the present ending in 1950. Extensions to the year 2000 are available at http://www.geocraft.com/WVFossils/last_400k_yrs.html .*

[5] Petit, J.R., Jouzel, J., Raynaud, D., Barkov, N. I., Barnola, J. M., Basile, I., Benders, M., Chappellaz, J., Davis, M., Delaygue, G., Delmotte, M., Kotlyakov, V. M., Legrand, M., Lipenkov, V. Y., Lorius, C., Pépin, L., Ritz, C., Saltzman, E., & Stievenard, M. (1999). Climate and Atmospheric History of the past 410,000 years from the Vostok Ice Core, Antarctica. *Nature, 399*, 429-436

Closer Still

The flat, wiggly little plateau on the far right side of the temperature graph shown in Figure 1.2 represents the era that most of us humans so proudly call “civilization.” The time period covers from around 12,000 years ago to the present. It is during this period that modern civilization developed – the recent averages represent the temperature range where we live right now. Let’s look at these last 12,000 years a little more closely. Near the beginning of this period (from about 10,000 BC to about 8,000 BC), Mother Earth had finally begun to come out of her most recent ice age. Prior to this warm-up, huge glaciers covered very large portions of North America, Europe and Asia (gray areas in Figure 1.3). Many of these glaciers were 3 – 4 km thick. All around these glaciers either Polar and Alpine desert, sub-Artic coniferous forest, or Steppe-tundra dominated the landscape. Most of the water was locked up in glaciers. It was definitely not a place fit for humans.

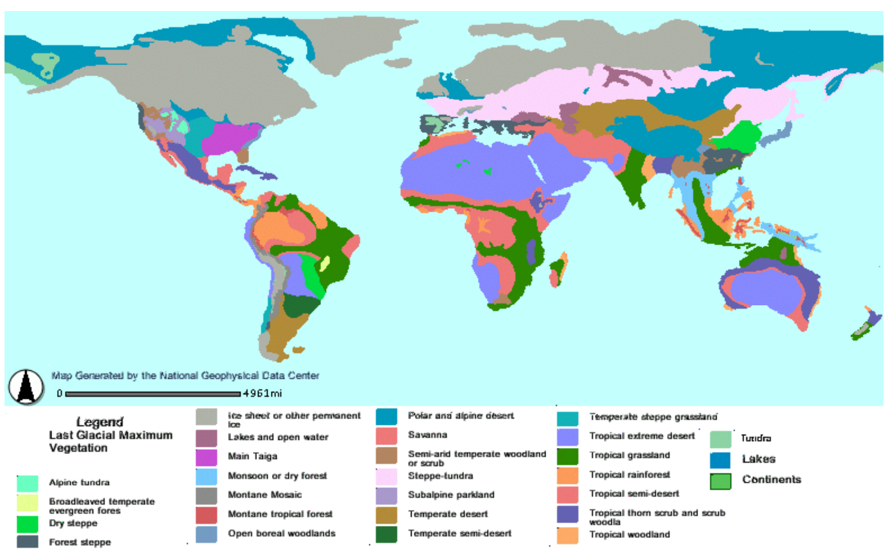

Figure 1.3. Vegetation and glaciers during the last ice age[6]. See Figure 1.2 for time frame.

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[6] Ray, N. and J. M. Adams. 2001. A GIS-based Vegetation Map of the World at the Last Glacial Maximum (25,000-15,000 BP). Internet Archaeology 11.

About 7,500 BC, the earth had finally warmed up enough (Figure 1.4) that those massive, continent-sized, mile-deep glaciers began to melt. The melting that occurred accelerated, and somewhere around 6,500 – 7,000 BC, there began a series of major worldwide storms and floods. The excessive water over this several hundred year period caused sea level to eventually rise by about 110 meters, on average. The abundant water also brought massive rainstorms the likes of which the earth hasn't seen since. Many cultures have permanent societal memories of these floods (e.g., the story of Noah in the Bible, Mayan legends, etc.).

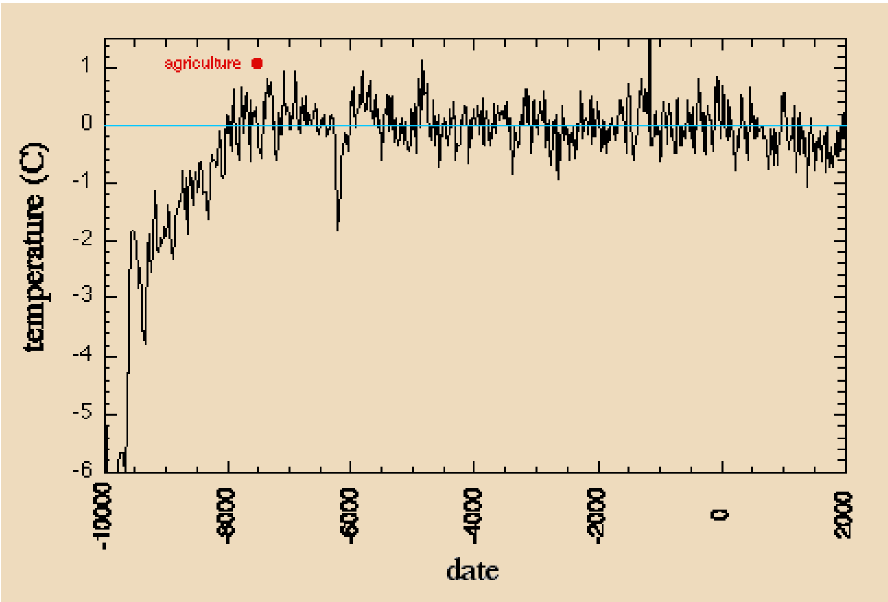

Figure 1.4. Plot of global temperature deviations from the 1961–1990 average (~14C) for the years 9,800 BC through 2,000 AD plotted in degrees C. Data from Muller & MacDonald, (2002)[7].

As the glaciers retreated and the water receded, huge areas of remnant damage were left behind. We're all familiar with at least a few of them – five of the better known

[7] Muller, R. A. & MacDonald, G. J., (2002). *Ice Ages and Astronomical Causes: data, spectral analysis, and mechanisms.* Springer-Verlag New York

of such areas we now call the Great Lakes. It was around this time, too, that agriculture began to develop and flourish in places like the fertile valleys of the Middle East, particularly around the Tigris and Euphrates Rivers, as well as along the Nile in Egypt. The red dot in Figures 1.4 represents the approximate time when modern agriculture began. It was the pivotal point in history when humankind could finally focus a little less on its incessant search for food on the arctic tundra, and focus a little on more interesting pursuits. That is to say, as soon as the most of the massive glaciers had melted and the great storms had ended, things began to get pretty rosy for the human race. We weren't completely free of climate's more unpleasant effects, of course, because there were still a few little glitches to come. But most of our recent history (i.e., the last few millennia) has been relatively pleasant – relative to what came before, that is. Next, we'll look at the most recent 2,400 years of climate, and discuss how even those the little blips in recent times have affected human civilization.

The last 2,400 years

Now, at last, we're getting down to some of the finer detail that might seem more real to us poor mortals – the last few thousand years. By about 1,000 BC, ninety percent of the glacial mass from the last ice age had melted. Europe, Asia and North America had all warmed, and agriculture-based societies had begun to flourish. Figure 1.4 showed that the most radical temperature variations had pretty much settled down by this time – being limited to about plus-or-minus one degree Celsius. But even these minor changes managed to cause more than a few unpleasant consequences. Let's zoom in again, this time on the past 2,400 years (Figure 1.5).

Generally, the global warm-up was good news, since it allowed for a little more stability in the way of food production. There were still some hard times, though – for example, the so-called Little Ice Age during which mostly cooler years, including a few that were extremely cold, began around 1,000 – 1,200 AD and continued for about the next seven hundred and fifty years.

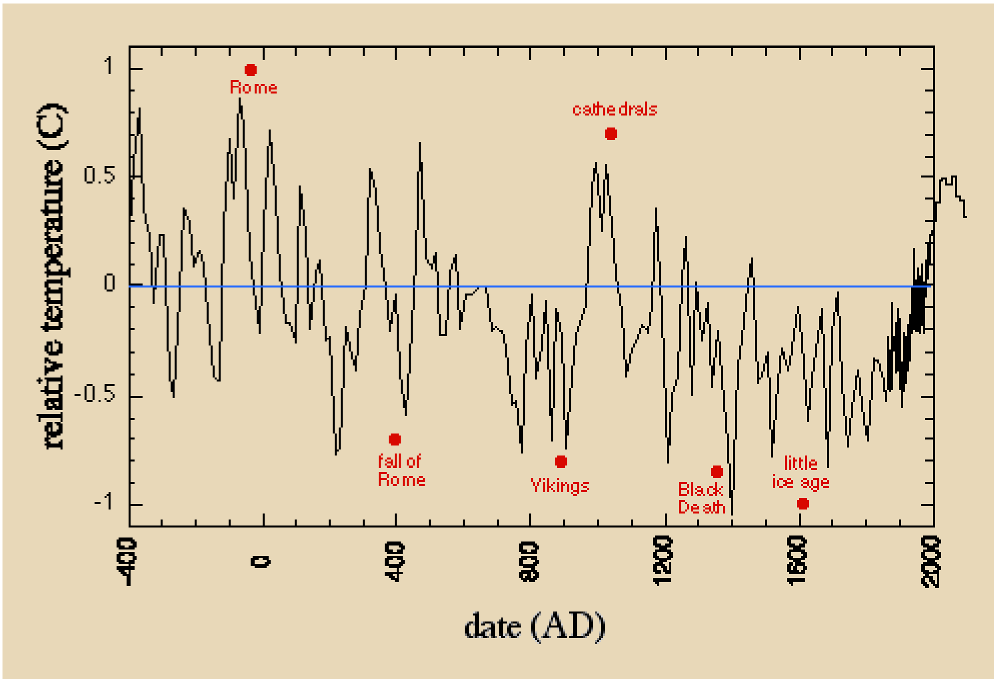

Figure 1.5. Same as in Figure 4, except data covers the period over the last 2,400 years. Extension beyond chart represents data added from IPCC records for the most recent years.

The worst part of the Little Ice Age was that it brought with it a number of years with bitterly cold winters. The cold periods were mixed with a few warmer years as you can see from Figure 1.5, but there were a lot more cold winters than warm. During these colder years (and sometimes cold decades), crops failed and famine spread across Europe, as did epidemic disease. During these frigid decades, snowfall records were set that still stand today. Snow stayed on the ground in some locations well into summer.

Shallow glaciers re-developed in many parts of the northern hemisphere during the more extreme downward "spikes," sometimes engulfing whole villages. For example, growing glaciers wiped out the entire Viking settlement effort in Greenland, and several villages in the Alps. Plus, there was great variability from year-to-year, and decade-to-decade, making it nearly impossible to plan for farming[8]. Indeed, the French Revolution – which began in July of 1789 – has been blamed by historians, at least in part, on a string of cold years, culminating in an exceptionally long and cold winter. The result was record crop failures and famine across much of Europe.

Recent History

Around 1850 the coldest of the fluctuations ended, and the forces affecting climate started a process that would eventually move temperatures out of that frigid range. The global mean temperature leveled off, then slowly began to rise again from around 1910 until around 1945, though something happened to make the temperature curve dip slightly for about the next 25 to 30 years (Figure 1.6). It was during this tepid period that some climatologists began to worry that the long-anticipated, next major ice age might be beginning. Scientific articles, and books such as "Climates of Hunger[9]" among others, warned of this potentially devastating disaster, and even suggested that human activity might be playing a contributing role by introducing pollution in the form of particulate matter into the stratosphere which would reflect incoming solar radiation and add to the cooling. This was the beginning of the recent fascination with the concept of anthropogenic (human-generated) climate change.

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[8] Fagan, B., 2000: The Little Ice Age. Basic Books, New York, 246 pp.
[9] Bryson, R. A., & Murray, T. J., (1977). Climates of Hunger. The University of Wisconsin Press, Madison, WI, 171 pp.

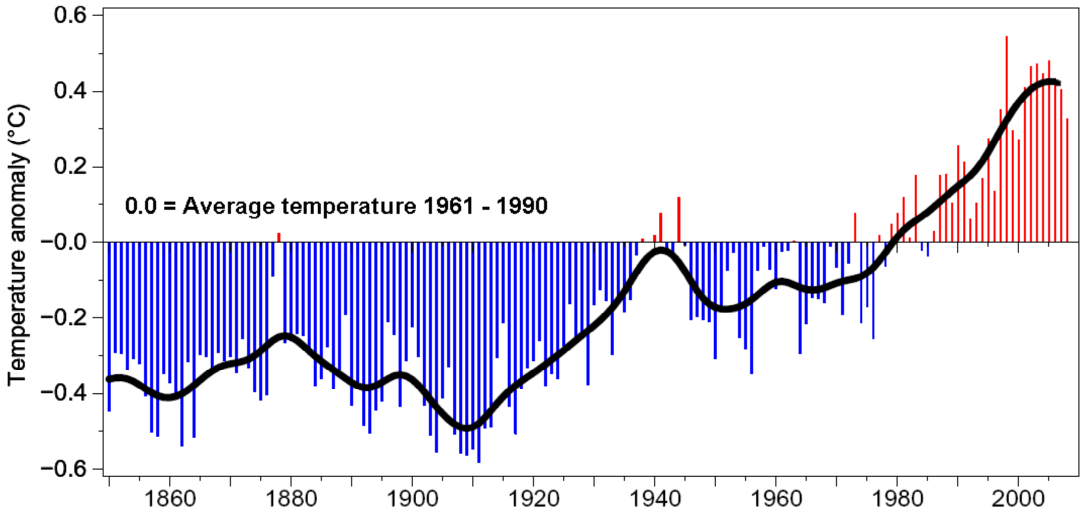

Figure 1.6. Average global temperature as measured in-situ at weather/climate stations around the world for the period 1850 – 2008 (IPCC, 2001).[10] The lowest temperatures during the Little Ice Age would all be below the lowest level shown on this chart. The black line represents a "smoothed" curve, made by averaging the surrounding years with the current year (called a five-point running mean) to remove some of the "spikiness," and reveal the general trend.

For several years there was an ongoing controversy over whether we should be worried about global cooling, or global warming. Both sides of the debate offered their own evidence, and both sides blamed a lot of it on human activity. The global warming advocates talked about greenhouse gases, while the global cooling community pointed to particulate matter. When the temperature finally started to rise steadily again in the 1970s, the global warming community claimed victory and almost immediately began to try to organize a human response to somehow mitigate the warming trend. They pointed to data, such as that presented in Figure 1.6 as evidence that immediate action was required. Anthropogenic global warming advocates frequently state that the recent global temperature measurements presented in this chart portray the warmest temperatures ever measured during the so-called "period of record." In a way, this statement is the "truth,"

[10] IPCC, 2001. *Climate Change 2001: The Scientific Basis,* Intergovernmental Panel on Climate Change, Working Group 3, third assessment report (editor: J T Houghton). Global temperatures after the year 2000 were added to the 2001 graph from yearly IPCC reports.

though it is not the whole truth. The period of record to which they refer to is the period of recorded *thermometer measurements* from sites that have been in place since the early part of the nineteenth century. Another chart they sometimes use to add weight to their argument is one generated from recent ice core data which begins around 1600 AD, during the middle of the Little Ice Age. However, when we compare these geologically brief periods with longer term data, we can see that right now, at this point in history, we are privileged to be living in an era where humans can live comfortably over a very large portion of the land mass found on our little planet.

To those familiar with the long term climate record, and the forces of nature that drive the trends in global temperature, it is clear that we can't stay warm forever. At some point in the future (probably quite soon in geological terms) we will find ourselves living in a major ice box (Figures 1.2 and 1.3) that represents what is more the normal for Planet Earth. And when the mean global temperature falls, it's important for the reader to know that ninety percent of the global temperature changes take place outside of the tropics, so the brunt of the cold will be on us. The winters of 2006-07 and 2007-08 were unusually cold, and people across the country were remarking on how long the snow stayed on the ground in many places, and longed aloud for the coming spring. But those winters were – on average – just *tenths* of a degree Celsius cooler than those in recent years. The major ice ages, *in the middle latitudes*, were likely to have been 10 – 15 ^{o}C colder, on average. There was even a major volcanic eruption[11] during the last ice age that filled the upper atmosphere with sun-reflecting particulates and triggered an "ice-

[11] Mount Toba in northwest Sumatra. It sent over 2,000 times as much ash into the atmosphere as did Mt. St. Helens and triggered a six-year nuclear winter, followed by centuries of temperatures even colder than the "normal" ice age devastating chill.

age-within-an-ice-age, that lasted over a thousand years. Anthropologists report that the human race was nearly wiped-out at that time.

How will we live when New York, London or Rome, experience winters worse than those that extreme northern Canada and the arctic suffer now? How will the human race be able to fight the formation of continent-sized, mile-deep glaciers? Worse yet, as the centuries crank along the colder times will probably get colder still and the fluctuations more dramatic. We (the authors) are glad to be living in one of earth's geologically brief warm spells. We would like it to go on this way. But the harsh reality of nature, if the past geological record is any indication, seems to answer with an emphatic "no." Sometime in the distant future – in a hundred years, or a thousand – the best of times will likely end, and those of us who chose to stay in the mid-latitudes will be fighting for our very survival.