Global Warming: Only Partially True

1.0 Introduction

That the Earth has been warming steadily for the past few centuries and intermittently for over 10,000 years is incontrovertible fact. However, there have been a number of assertions about global warming that are half-truths or outright falsehoods. This blog will focus on my problems with the current conventional wisdom about global warming.

Fifteen years ago I accepted the conventional wisdom about global warming. My background was in geology and computer science, and I had no reason to doubt what some climate scientists were saying about it. At that time I was engaged in an email discussion with an old college fraternity brother, and he happened to make an assertion about global warming that I knew was untrue because of my knowledge of the geologic record of the Earth.

By refuting what my friend had said, I precipitated a debate that went on until he died a couple of years ago. My friend kept citing things about global warming that were often scientific charlatanism or outright scientific fraud. To refute the things he said, I was forced to expand my own horizons in climate science, meteorology, biology, paleontology, oceanography, zoology, and even cosmology. As I did so, I found that the conventional wisdom about global warming had a rather large number of problems. Essentially this blog is a compendium of that research.

For the record, I regard myself as an environmentalist. I do not believe we should be burning fossil fuels for energy because our posterity is going to desperately need them in a few centuries. I do not believe we should be driving species to extinction in pursuit of aphrodisiacs, perfumes, and culinary delicacies. I certainly do not believe that we should trash our natural environment with unbridled human development. And I believe there are numerous organizations, such as the Nature Conservancy, that are pursuing rational environmental policies.

However, there are three environmental organizations that I have serious problems with: the International Panel on Climate Change (IPCC), the World Meteorological Organization (WMO), and the National Oceanic and Atmospheric Administration (NOAA). In my opinion these organizations have been advocating a view of global warming that is riddled with half-truths and falsehoods. I believe this is because these organizations are dominated by scientists who are mostly meteorologists that are now calling themselves climate scientists. For the rest of this blog I will refer to these people as the Global Warming Crowd, or GWC for short. But, I want to be clear that I am only talking about a very narrowly defined group of environmentalists that espouse the following message about global warming...

1. The Earth’s climate has been warming continuously throughout the Industrial Revolution.

2. Climate change is due to increasing carbon dioxide (CO_2) in the atmosphere.
3. The annual surplus of CO_2 is all Man's fault due to burning hydrocarbons for energy.
4. Global warming will continue so long as Man continues to burn fossil fuels.
5. Continued global warming will result in imminent economic catastrophes.
6. Continued global warming will result in imminent ecological catastrophes.
7. Venus once had permanent oceans but suffered a runaway greenhouse effect, which could also occur on Earth if Man continues to burn fossil fuels.

Of these statements, only the first statement is completely true. The second statement is only partially true. Atmospheric Methane has increased three-fold in the past two centuries. It now provides more that half of the greenhouse warming that CO_2 does.

The third statement is also a half-truth. Man is very likely fully responsible, directly or indirectly, for the current CO_2 surplus, but only about 25% of that surplus is due to the burning of hydrocarbons for energy. The fourth statement is highly unlikely to be true, because we are currently poised to return to a glacial phase of the Quaternary Ice Age.

The fifth statement depends on how we define "catastrophe". If the polar ice caps completely melt (the Earth has permanent polar ice caps only during ice ages), the area of the planet covered by water will increase from 70% to 75%. That will flood our coastal cities and inundate substantial areas currently employed for agriculture. However, there are some things the GWC neglects to mention. Sea level is rising at the rate of millimeters per year, so we will have a century or two to adjust. Sea levels have been rising intermittently for 10,000 years, so scuba divers in places in the Mediterranean Sea can view ancient cities that are now completely submerged. In other words, we have already been adjusting to rising sea levels. In addition, we have no reason to doubt that the huge advances in agricultural productivity seen in the past half-century will not continue or be supplemented with aquaculture. While the economic effects of adjusting to rising sea levels will be quite substantial over a century or more, I don't see anything approaching an imminent catastrophe.

For the sixth statement, IPCC provides a list of ecological catastrophes with the implication that they could all occur with a rise of only a few degrees C. In fact, most of them, such as turning the Amazon basin into a desert, are regional weather phenomenon, not global climate issues. Even then it is due more to clear cutting for homesteads by the Brazilian government than global warming. One of the disasters in IPCC's list, the sublimation of the methane clathrates in the continental shelves, is a true catastrophe, but has only occurred in the geologic record when the surface temperature of the Earth approaches 20°C warmer than present. Although such temperatures occur periodically, the forces driving them work very slowly, so we are tens of millions of years away from that sort of catastrophe.

One of the ecological catastrophes the IPCC cites, though, is happening right now. There is a much-publicized die-off of organisms in the shallow tropical seas, notably corals. What the GWC fails to mention is that this is the ninth such die-off in the past 800,000 years. In other words, it is a natural process that has operated since before Homo Sapiens existed, much less had kitchen matches. Another thing the GWC doesn't talk about is that evolution is already compensating. There are already corals taking over the abandoned reefs that have mutated to withstand warmer temperatures and more acidic oceans. I don't see that as a catastrophe and I certainly don't see it as being all Man's fault.

In fairness, I have to say that very few GWC scientists talk about the runaway greenhouse effect. That is because it is scientific nonsense. Venus has always been a hell-hole and never had liquid oceans. (I will explain why when I discuss extraterrestrial drivers of climate.) In addition, the Earth has long-term climate cycles that are self-correcting and make the possibility of a runaway greenhouse effect extremely remote (until the Sun becomes a Red Giant in a few billion years). It is far more likely that the Earth will become an ice ball, as happened 700m years ago, than that it will have a runaway greenhouse effect.

The criticisms of the GWC Message above are by no means the only problems with the message; they merely represent a sort of executive summary. One thread you may have noticed is that there are facts that the GWC doesn't like to talk about. This will be a recurring theme throughout the blog. One of the problems I have with the GWC is that they believe their message with religious fervor. This allows them to ignore contrarian data or dismiss it out of hand; they *know* they are right, so such data *must be wrong*. This is supported, in part, by the fact that many of them have devoted their entire careers to the notion of continued global warming and the catastrophes they associate with it.

Let me list just a few more facts that the GWC tends to ignore:

The average temperature of the Earth for the past 540 million years since multi-cellular life evolved is about 7°C warmer than present. That is because we are living *in* the Quaternary Ice Age. We don't see a lot of ice sheets because we are currently in an interglacial hiatus, a brief warming period. Though the hiatus is warmer than a glacial phase, it is still well below the norm for the Earth.

The average atmospheric CO_2 level for the past 540 million years is well above 3,000 ppm. This is more than eight times the current level.

The Earth's biosphere is most profuse and most diverse at the norms for temperature and atmospheric CO_2. That is, at those norms the tropical zone extends from the present 10° north and south latitude to as much as 60° north and south latitude.

The lowest level of atmospheric CO_2, about 200 ppm, in the entire 4.5 billion year history of the Earth was reached about 12,000 years ago. The long term trend for CO_2 is downwards; the present interglacial hiatus is merely a small, temporary reversal of that trend.

The minimum atmospheric CO_2 necessary support photosynthesis in plants is 185-225 ppm. In other words, 12,000 years ago we were on the verge of extinction, given that plants are the bottom of our food chain.

The first three facts tell us that IPCC's ecological catastrophes are not quite as imminent or catastrophic as they would have us believe. The last two facts tell us that we should be putting more CO_2 into the atmosphere rather than cutting it back. The present 400 ppm is far too close to the extinction level for my taste.

While this blog will be highly critical of IPCC, WMO, NOAA, and the GWC that controls those organizations, I must be clear that I do not believe there is any malevolent conspiracy. Nobody is calling a meeting on the first Monday of the quarter to decide how to hoodwink the public. These people really believe what they are saying. Nor were there any palace coups to take over these organizations. Such organizations are primarily populated by invitation, so it is quite natural to invite like-minded individuals to join. Unfortunately, *a few* members of the GWC feel it is imperative to raise public consciousness about the impending catastrophes they believe are imminent, so they embrace the notion that the end justifies the means and they step over the line into scientific charlatanism and scientific fraud.

The remainder of this blog is divided into four parts: (1) a discussion of the several mechanisms that actually control global climate; (2) a brief geologic history to demonstrate how these mechanisms interact with one another to drive the real climate of the Earth; (3) a description of the present interglacial hiatus, because its future is critically important to the survival of human civilization; and (4) a discussion of the deceptive ways the GWC promulgates their message.

2.0 Climate mechanisms

Though the GWC focuses almost exclusively on atmospheric CO_2, there are actually several other important mechanisms that drive global climate. These can be roughly characterized in five broad groups of processes: extraterrestrial; atmospheric; plate tectonic; biological; and oceanic.

2.1 Extraterrestrial climate drivers

The universe is a dangerous place. For example, a neutron star in the WR-104 system, 8,000 light years away, will generate a gamma ray burst sometime in the next 500,000 years or so that could sterilize life on the surface of the Earth and, perhaps, blow away most of our atmosphere. While that burst is likely to be a near miss of our solar system, another neutron star could target us at any time. Nearby novas and supernovas could produce similar results. Massive solar flares could also raise havoc with the Earth's climate. There have also been mass extinctions roughly every 30 million years that some attribute to intersections between Earth's orbit and a cluster of comets from the outer solar system in a highly eccentric orbit. While such events can cause climatic mass extinctions, they are quite rare so I won't deal with them specifically.

2.1.1 Our Warming Sun

One extraterrestrial event of interest, though, is that the Sun is warming. The Sun is currently providing about 30% more energy to the surface of the Earth than 4 billion years ago when life first appeared on Earth. That increase has been fairly steady, but the rate of increase has been so slow that it is unimportant at any time scale of interest to Man.

I only mention it because it supports the Gaia Hypothesis, which is a favorite of SciFi writers. Under the Gaia Hypothesis, a planet can act to control its own surface environment in an intelligent manner, much like a single, vast organism. I don't subscribe to the Gaia Hypothesis. However, it is a remarkable coincidence that the Earth's greenhouse effect, which is largely determined by highly diverse life on the surface, has decreased in lock-step with the Sun's increasing energy to maintain the very narrow climate band of 10-30°C necessary for carbon-based life as we know it. Maintaining that narrow band is a remarkable coincidence. In passing, I will point out a number of other, even more remarkable coincidences in the geologic record that seem to support the Gaia Hypothesis.

2.1.2 The Goldilocks Zone

Of greater relevance is the Goldilocks Zone. This is an orbital zone around a star where it is possible for planets orbiting in the zone to have permanent liquid water on their surfaces. Cosmologists have found evidence of water all over our solar system in the past few decades, but Earth is the only body with permanent liquid water on the surface. The Earth is just inside the Sun's Goldilocks Zone, about 0.1 astronomical unit (Earth's average orbital radius) inside the outer edge of the zone.

The operative word in the above definition is 'possible'. Earth is so near the outer edge of the Goldilocks Zone, that it would be frozen solid without a strong greenhouse effect. (In fact, about 700 million years ago the Earth was an ice ball with an average surface temperature of -15°C, but that is getting ahead of the story...). While the Goldilocks Zone has nothing to do with day-to-day climate change, it is important to the idea of a runaway greenhouse effect.

Venus is actually just outside the inner boundary of the Goldilocks Zone (though it was barely inside the zone during the first billion years of its existence). It receives about 42% more energy from the Sun than the Earth does. The Earth cooled enough for steam to condense from the atmosphere into our oceans about 4.1 billion years ago. But because Venus receives much more energy from the Sun, it would not have cooled enough to condense oceans until about 3.5 billion years ago. However, by that time Venus was dry as a bone due to its lack of a protective magnetic field. Without that field, Venus is bombarded by hard radiation from the Sun. That radiation disassociated the steam molecules into separate hydrogen and oxygen molecules. The hydrogen rose in the atmosphere and was swept away in the solar wind, leaving Venus completely dry.

The lack of water on Venus means that plate tectonics on Venus has no lubrication. Therefore the crustal rocks on Venus respond to the larger tidal forces there by breaking and sliding, generating massive friction heat. That is why Venus always has almost continuous volcanism, more than any other planet in our solar system. That volcanism has produced an atmosphere that is now 99% CO_2. Thus Venus has always been a hell-hole since it started to form 4.5 billion years ago.

The presence of large amounts of water on Earth and its position just inside the outer edge of the Goldilocks Zone pretty much precludes the Earth from ever having a runaway greenhouse effect. But to understand why, I need to discuss the roles of plate tectonics and biologic processes in determining the Earth's long-term climate later in the blog.

2.1.3 The Fulcrum Effect

There is one very important process for driving climate that is indirectly the result of extraterrestrial factors: the Fulcrum Effect. The Earth is far enough away from the Sun so that the photons striking the Earth's surface come from the Sun in essentially parallel streams. If we take a square meter of the Earth's surface, we can define the *energy density* of the Sun's warming energy as the number of photons striking that square meter in a unit time. However, because of the curvature of the Earth, the energy density is not the same at all places on the surface. Thus, if we looked at the same number of photon streams striking the Earth at the Equator and near one of the poles, the energy density would be different. That's because the streams impacting the Earth near the pole would land on a much larger area than they would land on at the Equator due to the curvature if the Earth.

Therefore, the Sun's energy density is always less at the poles than it is at the Equator. With less energy density to warm the Earth's surface at the poles, there will always be a temperature gradient between the Equator and each of the Earth's poles because of the differential warming among those locations. If there were no atmosphere or oceans, those gradients would be constant (subject to seasonal variations due to the Earth's orbit and axial tilt).

The Earth does have an atmosphere and oceans and those fluids can transfer heat laterally around the surface of the Earth via winds and currents. If there is a strong transfer of heat from Equator to poles, then the gradient will be reduced. If there is very little transfer of heat from Equator to poles, the temperature gradient will be steeper, approaching the maximum possible. To a first approximation, we can think of the gradient as a straight line from Equator to pole. That line pivots up an down from the Equator, depending on the amount of heat transferred from Equator to poles, hence the notion of a 'fulcrum' for the Northern and Southern Hemispheres of the Earth.

The average temperature of the Earth for a hemisphere will then be a point near the midpoint of the gradient line. Thus, as the temperature gradient fulcrum moves up and down, so does the average temperature of the surface of the Earth in that hemisphere. Note that transferring heat between Equator and pole via winds and currents has nothing whatsoever to do with CO_2. Yet the geologic record tells us that Fulfcrum Effect can change the average temperature of the Earth by several degrees C in a few centuries as prevailing winds and currents change. (In fact, the largest rapid climate change we know of in the geologic record, 14°C, was driven by a combination of plate tectonics, the Fulcrum Effect, and changes to ocean currents, but that is getting ahead of the story...)

At this point I need to make a digression to discuss how we describe global climate. Geologists have a number of qualitative descriptions of climate, such as arid, tropical, etc. However, there is only one quantitative metric for describing the Earth's overall *global* climate: the average temperature of the surface of the entire Earth. Though some members of the GWC would have you believe that atmospheric CO_2 is a metric for climate, that is not true because the geologic record tells us that atmospheric CO_2 does not match very well with historic climate conditions. For example, 700 million years ago the Earth was an ice ball while atmospheric CO_2 was roughly 20 times higher than present.

It is important to realize that when talking about the global climate of the Earth, people typically refer to simply "the temperature of the Earth", but technically they are referring to the *average* temperature of the *surface* of the *entire* Earth. Far too often some members of the GWC will make assertions about the 'temperature of the Earth' when they are actually referring to other definitions of 'temperature', such as peak value. As I will demonstrate later in the blog, this invites erroneous conclusions about changing climate.

An indirect implication of the Fulcrum Effect is that the Earth does not warm uniformly. For example, at present the Earth's poles are warming faster than any other region of the Earth while temperatures at the Equator are not warming significantly. When the slopes of the fulcrums in the northern and southern hemispheres decreases, the tropical zone expands. That, in turn, raises the *average* temperature of the surface of the Earth.

2.1.4 Orbital Changes

The last extraterrestrial process worth mentioning is related to changing the orbit of the Earth. Usually the Earth's orbit is nearly circular. However, roughly every 450,000 years the planets of the solar system align in a way that causes the Earth's orbit to become an elongated ellipse. That orbit carries the Earth outside the Goldilocks Zone for part of each year, resulting in abnormal cooling. As I shall demonstrate later, this can combine with plate tectonics and ocean currents to cause the entire surface of the Earth to freeze, as happened 700m years ago. While this special configuration of the planets every 450,000 years is a necessary condition for Snowball Earth, it is not a sufficient one, so freezing the Earth is a very rare event.

2.2 Atmospheric processes

There are a vast number of atmospheric processes that affect local climate, but local climate just represents variance for the global climate. There are only two major atmospheric processes -- the greenhouse effect and Hadley cells -- that drive global climate change in a major way, and a very few minor processes.

2.2.1 The Greenhouse Effect

The Earth is just a large rock orbiting the Sun. If it had no atmosphere or oceans, it would be trivial to compute the average temperature of the Earth's surface from a black body radiation model. We would have short-wave radiation (visible light) coming in from the

Sun to warm the surface and we would have long-wave (infrared) radiation outwards from the surface to cool it. Balancing the two would be simple. (The distinction between short-wave and long-wave is mostly a matter of convention because visible and infrared are essentially next to each other in the vastly larger electromagnetic spectrum.)

Our reality is not that simple because the Earth is not black, it has an atmosphere, and it has oceans. In addition, the atmosphere is comprised of several different components, some of which interact with long-wave radiation. Components that interact with long-wave radiation are known as *radiative* components. (All of the atmosphere's components are transparent to short-wave radiation.) Radiative components absorb long-wave radiation in the bonds that hold the atoms of the component molecule together (sometimes known as *vibration* of the bonds). However, there is a limit to how much radiation can be absorbed. When that limit is reached, the molecular bonds reach an unstable energy state and all the absorbed energy is released by radiating it outwards in all directions.

This re-radiation of the long-wave radiation is the source of the greenhouse effect. Because the atmosphere is very thin relative to the curvature of the Earth, almost half of the re-radiated energy goes back down to the surface of the Earth to provide additional warming.

Not all radiative components provide the same amount of warming on a molecule-by-molecule basis. The amount of re-radiation depends primarily on the number of atoms in the molecule and the kinds of atoms. CO_2 is a moderate greenhouse component with three atoms, one of which is different. Methane (CH_4) has five atoms, one of which is different, and a molecule of methane provides about 70 times as much warming as a CO_2 molecule. Nitrogen oxide (N_2O_3) has five atoms with two different and it is provides about 230 times as much warming as CO_2. Fortunately for global warming, nitrogen oxide is a trace element in the atmosphere compared to CO_2.

Water vapor (H_2O) is actually the dominant greenhouse component, contributing 60% of all greenhouse warming. Like CO_2, it has three atoms with one different, but CO_2 provides about 50 times more warming per molecule[1]. However, there is vastly more water vapor in the atmosphere than CO_2. The following table provides the relative contributions of the greenhouse components to the greenhouse effect at the present time.

Component	**% of Warming**
Water vapor	61%
Carbon dioxide	24%
Methane	14%
Ozone, Nitrogen oxide, other	1%

1. The reason is that CO_2 is a gas while atmospheric water vapor is actually a phase of liquid water in suspension. Generally gaseous phases absorb more long-wave radiation than liquid phases due to the larger sizes of the gas molecules.

This table introduces my first example of scientific charlatanism by IPCC. Very early in my email debate with my friend, I needed to crunch some numbers with the molar values of the greenhouse components, but I didn't know the values off the top of my head and had to look them up. I naively went to the IPCC website to get them. The website has a table of greenhouse gases with the information I needed. But imagine my surprise when that table did not include the 600 lb gorilla of global warming -- water vapor! When pressed, IPCC argues their table is for greenhouse gases, but water vapor is not a gas; it is a suspension of liquid water molecules.

Does it not seem somewhat misleading for IPCC to omit that dominant greenhouse component when talking about the greenhouse effect? If they are going to be that pedantic, then they should have renamed their table 'greenhouse components' and included water vapor to give a more fair picture of the greenhouse effect. With their table the naive viewer might believe that CO_2 contributes over 70% of greenhouse warming -- which is exactly what the GWC would like you to believe!

By the way, it would be almost as bad to denigrate the role of CO_2 in driving climate based on it contributing only 24% of greenhouse warming. CO_2 is very important because it provides long-term stability to climate. A molecule of CO_2 remains in the atmosphere for an average time of 800-1,000 years. Water vapor is ephemeral, changing every time it rains. Methane has a half-life on the order of a year (though it converts to CO_2 and H_2O). Most other trace components have a half-life of a few months or less. Thus changes in CO_2 tend to dominate long-term climate trends while other components are associated with variance or rapid climate change.

However, longevity introduces another example of scientific charlatanism on the part of the GWC. They have a metric to describe the greenhouse effect: the Global Warming Potential (GPW) index. This metric weights the potency of a component for warming (how much long wave radiation is absorbed and re-radiated by a molecule) by the longevity of the component in the atmosphere. This is a valid metric if one wants to evaluate the long-term effects of introducing N tons of one radiative component into the atmosphere, compared to N tons of a different radiative component.

The problem I have with the GWP index is the way it is commonly used. If you search for references to the GWP, you will find that 70-80% of the contexts where it occurs are a comparison of the *potency* of greenhouse components, rather than their long-term effects. The GWC does this to denigrate the other components compared to CO_2. Thus, the GWP index for methane is 4, not 70.

A few members of the GWC talk about the greenhouse effect as if it were something evil that needs to be eliminated. In fact, life as we know it on Earth needs a strong greenhouse effect. Without the present greenhouse warming, the Earth would by a permanent ice ball with an average surface temperature approaching -18°C.

2.2.2 Hadley cells

Hadley cells are large convection cells in the atmosphere. They do not directly affect the global temperature of the Earth, but they combine with plate tectonics, the greenhouse effect, and life on the Earth's surface to control long-term cycles in the Earth's average temperature. Those cycles produce temperature swings of roughly 20°C over each cycle. These cycles currently have a period on the order of 150 millions years. The Hadley cells are shown in Fig. 2.1.

There are three Hadley cells in each hemisphere. They are bounded roughly by the 0, 30, and 60 degree latitudes (subject to seasonal vaiations).The two nearest the Equator in each hemisphere operate in the same way, while the two polar cells operate somewhat differently. The four cells that are nearest the Equator in each hemisphere are the ones that are important to long-term climate cycles. Since these four cells all work the same way, I will only describe the one nearest the Equator in the Northern Hemisphere.

The cell is a large toroid that circumnavigates the Earth parallel to the Equator. The winds circulate around the surface of the toroid in a roughly north/south direction, as indicated by the arrows. They are not exactly north/south due primarily to Coriolis forces from the Earth's rotation. The Sun's maximum energy density is warming the land at the Equator. By conduction, convection, and radiation, much of that heat is transferred to the atmosphere and warms it. As the air warms, it expands and its density decreases. That causes the air to rise. As it rises, it mixes with much cooler air in the upper atmosphere and begins to cool. As it cools, the air is forced to drop much of the moisture that it acquired near the ground when it was warm. Cold, dry air in the upper atmosphere is displaced and flows across the top of the Hadley cell. Eventually, it cools enough so it is heavier than that the warmer air below it, even without water vapor, so it begins to sink on the northern side of the Hadley cell. As it falls, it mixes with warmer air and heats up. That heating makes it even easier to hold what little moisture it has left. So the winds that complete the loop on the underside of the Hadley cell are very dry.

Thus the Hadley cell has heavy rains on its southern side and very little rain on its northern side. It is this difference that is critical to long-term climate. We can see this today in Fig. 2.2, which is a topographical map of the world. On the map, areas of profuse plant growth are in various shades of green while arid areas with little rainfall are in light shades of brown. Looking at the map, we see the world's tropical rain forests along the Equator: Amazon; Congo; and Indonesia. We also see deciduous forest along the southern side of the second Hadley just above 30° latitude. There are also vast conifer forests in the polar Hadley cell just above 60° latitude.

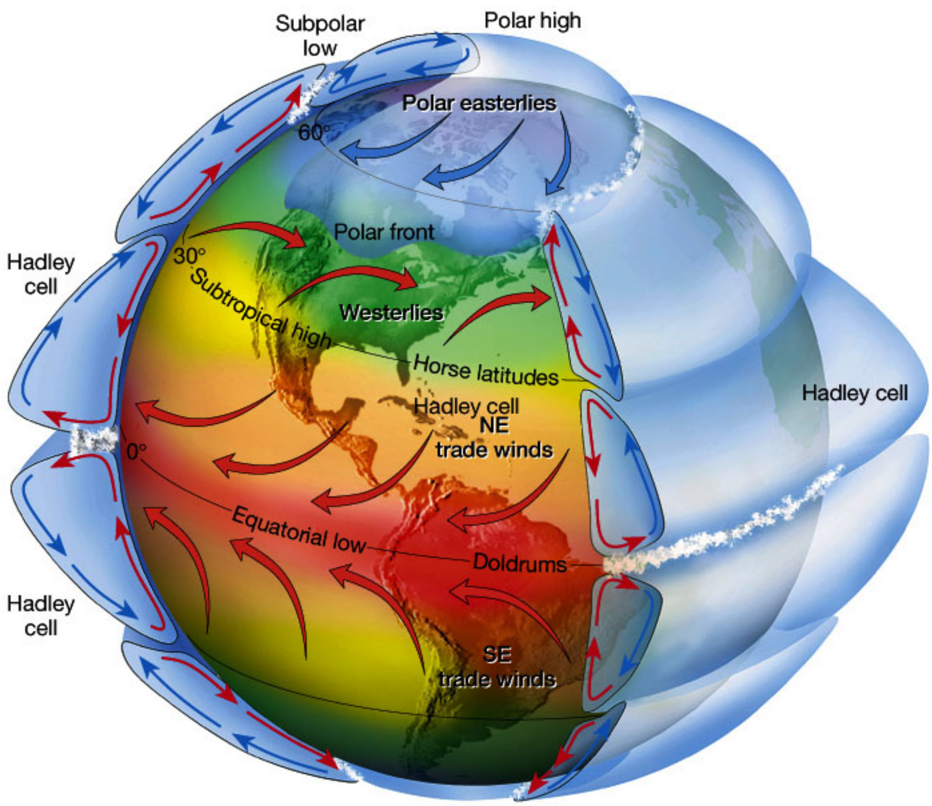

FIGURE 2-1. Hadley Cells.

On the north side of the cell, just below 30° latitude, we find deserts: Sahara; Empty Quarter; American Southwest; and Australian Outback. The world's largest desert, the Gobi, is just below 60° latitude in Asia. The driest place in the world, where rainfall is a few inches per century, is in the Andes mountains just below 60° latitude. Today, these deserts are relatively small. However, as the average temperature of the Earth rises, these deserts tend to expand and become harsher. The percentage of land area that is desert depends on where plate tectonics has moved the continents. If most of the continental land masses happen to be just under 30° or 60° latitude, the proportion of deserts will be greater than if the continental land masses are bunched along the Equator or along the polar side of the 30° and 60° boundaries. Thus geography will combine with the Earth's average temperature to determine whether life on the continents is profuse or is highly curtailed by deserts. As I shall show later, how much the Earth is warming or cooling in the long term depends on how much animal life there is on the continents.

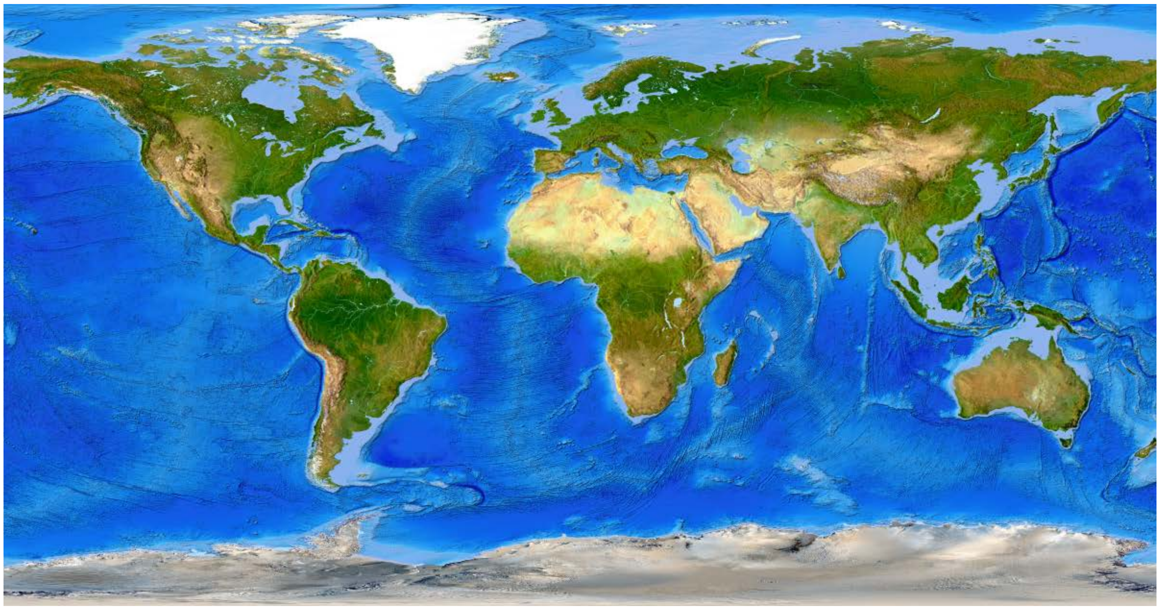

FIGURE 2-2. Topo map of Earth

2.2.3 Minor atmospheric processes

There are a lot of minor mechanisms related to climate in the atmosphere, such as evaporation cycles in tropical rain forests. However, these are mostly limited to affecting local climate conditions rather than global climate or they have very little affect on global climate. The two minor contributors to global climate are precipitation (immediately below) and oceanic evaporation (which I will defer until I talk about the role of the oceans in climate).

Whenever it rains, some greenhouse components will be caught is solution and carried back to the Earth's surface. This scrubbing is rather minor at time scales of interest to Man. It is one-way, so it can have a significant affect on global climate at time scales of millennia or greater. However, to be significant, precipitation must occur under conditions where animal life on continents is severely curtailed, such as during the glacial phases of ice ages. This is because animal respiration replaces CO_2 in the atmosphere at rates that can be more than an order of magnitude greater than the rate at which precipitation scrubs CO_2 from the atmosphere.

2.3 Plate tectonics.

Plate tectonics is responsible for *every natural thing we see* on the surface of the Earth, from a grain of beach sand to the highest mountain top. Even the atoms of our bodies have been reworked by plate tectonics many times, bringing new meaning to Wordsworth's line, "Dust thou art, to dust thou returnest". Plate tectonics is the prime driver of long-term climate cycles on a scale of hundreds of millions of years. Plate tectonics can also cause rapid climate change on scales of weeks to millennia. And it is responsible for enabling local climate conditions at intervals in between. The forces involved are far beyond anything that Man's vaunted technology could possibly bring to bear. Even granting that the current annual surplus of CO_2 is all Man's fault, it is nothing more than minor variance in the long-term climate change driven by plate tectonics. In other words, Man's contribution of CO_2 is merely a pimple on the posterior of long-term climate change.

2.3.1 Basic Mechanism

Plate tectonics involves a number of different mechanisms that can affect global and local climate. To explain how plate tectonics works, I need to start with the basic structure of the Earth, shown in Fig. 2.3. The Earth has several distinct layers. The Inner and outer core of the Earth is very hot, roughly 5,200°C, so the outer core is molten. But the pressure is so great on the inner core that it is compressed solid despite its temperature. The core is composed of iron and heavy elements, many of which are radioactive to provide the heat. Above the outer core is the mantle, composed primarily of ferromagnesian minerals.

The crust of the Earth, the lithosphere in the diagram, is of two types: oceanic crust and continental crust. The oceanic, or basaltic, crust is chemically the same as the mantle but forms different minerals due to being cooler and under much less pressure. Continental crust is made of primarily aluminum silicates and other light minerals. When the Earth formed, it was essentially molten due to constant high-energy bombardment by solar debris and underwent a process known as *gravitational differentiation*, which is just a fancy way of saying that heavy stuff sinks while light stuff floats. Thus the continents represent a sort of slag of "impurities" that formed when the Earth was molten.

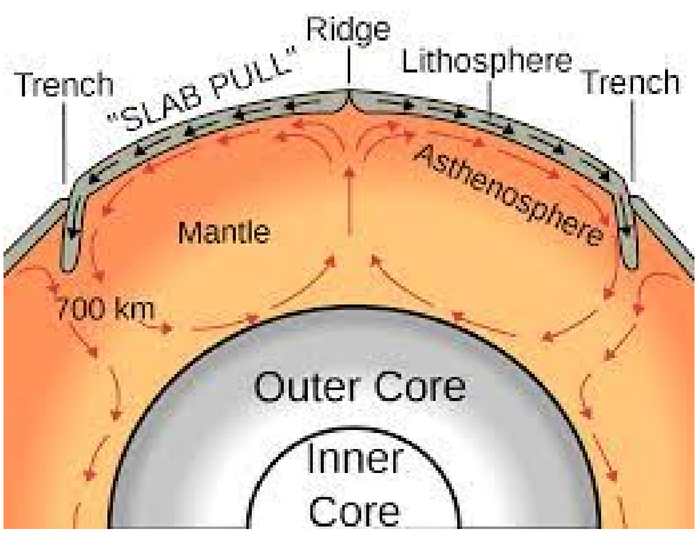

FIGURE 2-3. Overall structure of the Earth.

The crust is quite cold compared to the other layers, so the materials are hard and brittle. Higher temperatures at depth cause the materials to be more pliant, enabling convection currents through a process known as *plastic deformation*. The red arrows in the mantle in Fig. 2.3 indicate convection currents. These convection currents drag on the underside of the crust and provide friction. This moves large plates of the crust around on the surface of the Earth. The currents move very slowly, about a meter per year in the mantle compared to a few centimeters per year for the crustal plates. However, the energy involved is enormous so that there are profound effects on the Earth's surface. For example, Mt. Everest has grown 27 feet taller since it was first measured in 1859.

The diagram is somewhat misleading about the symmetry of the convection currents in the mantle. In practice they are far more irregular in size and shape. They also change direction over time and there are "hot spots" between the currents. If one stripped off the crust and looked down on the upper mantle it would look much like a pot of water at a rolling boil, albeit in super slow motion. This dynamic nature of the convection currents is what shapes the surface of the Earth and global climate over geologic time scales.

There are a number of different things that happen when crustal plates collide. Fig 2.4 shows a *subduction zone* where a continental plate and an oceanic plate collide. Because the aluminum silicates of the continent are lighter than the ferromagnesian minerals of the oceanic plate, the continent rides up over the oceanic crust, forcing it down into the mantle, where it is heated up and absorbed. In the ocean where they meet, a deep trench is formed. The deepest one is the Mindanao Trench off the Philippines, which is 7 miles deep.

Where the continent slides over the oceanic plate there is enormous friction, which causes the continental crust to melt, forming *magma*. When the magma finds a path of weakness to the surface, the result is volcanism. The legendary "Ring of Fire" around the northern Pacific Ocean is the result of the northern Pacific Ocean being closed on all sides as various continents are pushed into it.

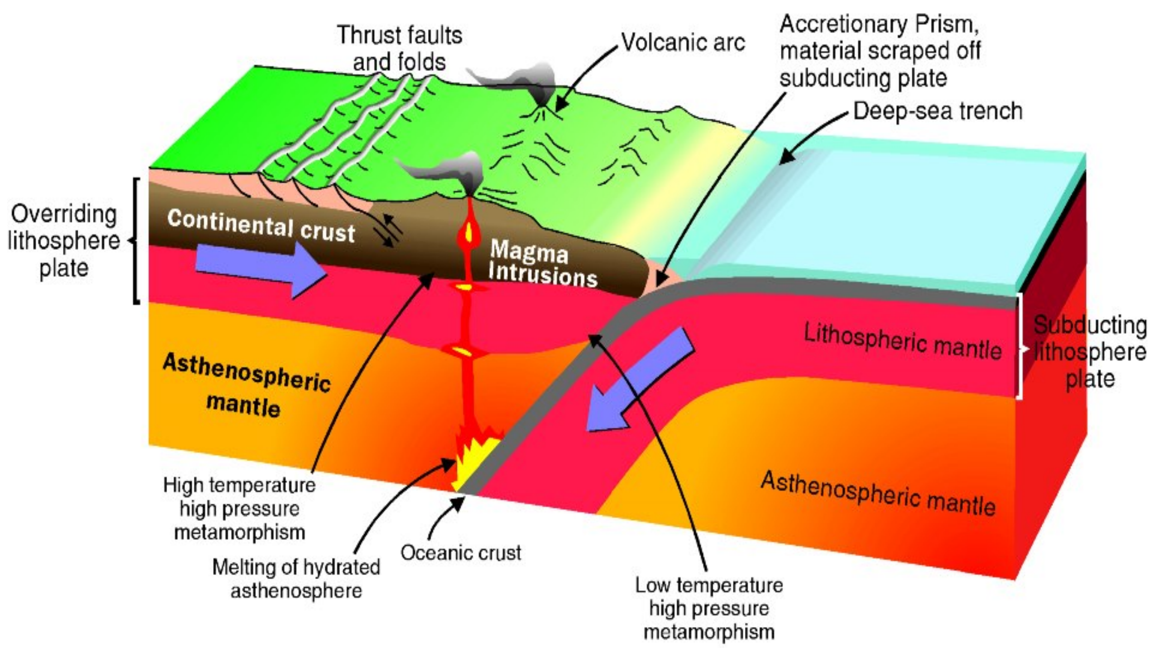

FIGURE 2-4. Subduction zone.

If the volcanoes are offshore on the continental shelf, which is formed by wave action eating into the continent, volcanic islands form *Island Arcs*. The Indonesian Archipelago is a modern example of a middle aged Island Arc where volcanoes have filled in between older volcanic islands to coalesce into larger islands, such as Sumatra. The islands of Japan represent an ancient Island Arc where all that is left is one very large island and three adjacent mid-sized islands. When there is no extensive continental shelf, the volcanoes will be inland as shown in Fig. 2.4.

In the diagram the continent is being pushed from the West at constant speed. But as it rises up over the oceanic crust on the East, there is great friction that slows the continent's progress. Something has to give and a mountain range is formed inland as the continental material crumples. When large mountains rise, an even larger root is driven down into the Upper Mantle, as shown in Fig. 2.5. This is sometimes called the *iceberg effect*. The continent is literally floating on the mantle. Because the continent is made of lighter material, it behaves much like an iceberg at sea. Because ice is only slightly less dense that liquid water, most of the iceberg is under water, leading to the phrase, "tip of the iceberg". If one were to place a Ping Pong ball on the water, it would make almost no indentation in the water because it is far less dense than water. For continents the density difference is somewhat greater than ice/water, so we get a root that is only a little larger than the mountains. Because the root is deep in the Earth, it is subjected to much higher temperature and pressure that can cause it to flow plastically or even melt into magma.

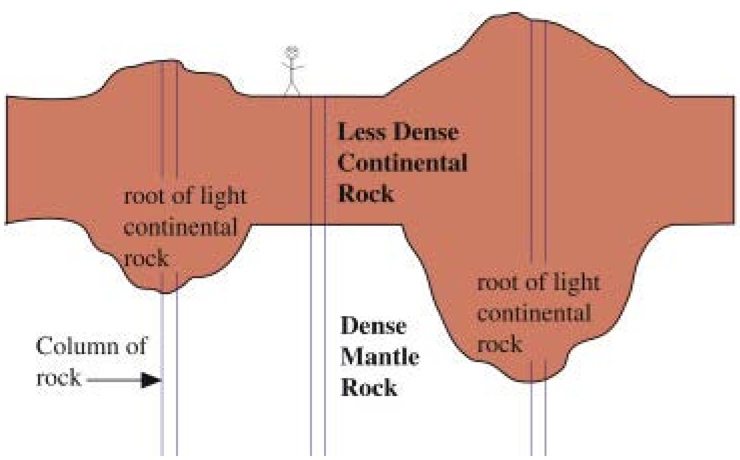

FIGURE 2-5. A Mountain root.

2.3.2 Isostatic Adjustment

Gravity wants the Earth to be a perfect sphere with the same gravity at every point on the surface. Thus gravity tries to get rid of mountains and their roots through a process known as *isostatic adjustment*. Erosion represents the primary agent for flattening mountains. Essentially erosion removes material from mountain tops and redistributes it, usually via flowing water, to alluvial plains and deltas. Today the Appalachian Mountains in eastern North American are little more than rolling hills, but a few hundred million years ago they were probably greater than the Himalayan Mountains today. Both the Rocky Mountains in the West and the Appalachian Mountains in the East, drain into the Mississippi River system in central North America. Where the Mississippi enters Caribbean Sea, the delta is about 7 miles deep with sediments carried off those mountains. This is another way that continents are reshaped by plate tectonics.

The root of the mountains is eliminated by buoyancy. As material is removed from the mountains and carried away, there is less weight bearing down on the root and it rises upwards in a process geologists call *uplift*. (A variation on this sort of isostatic adjustment may have been responsible for life as we know it on Earth. But that's getting ahead of the story again...)

When two continents collide, they have the same density and neither can rise up over the other. The result is massive crumpling that forms the largest mountain ranges. This is happening today as India is crashing into Asia, forming the world's largest mountain system, the Himalayas.

During all this incredible slow-motion violence of geology in action, the surface of the Earth is constantly changed. Material on the surface gets deeply buried in mountain roots and deltas. Isostatic adjustment then brings the material in mountain roots and deltas back up to the surface. This continuing cycle has been going on for 4 billion years and it has modified every atom of the things we see on the surface, including ourselves, many times.

2.3.3 Rock Transformations

Geologists classify rocks into a gazillion different types within three broad classes: *igneous*, which crystallize from a liquid magma as it cools; *sedimentary*, which are deposits of material eroded from elsewhere; and *metamorphic*, which are any materials (igenous or sedimentary) that are buried deeply enough for temperature and pressure to alter them chemically and/or physically. This is quaintly known as the Rock Cycle and it is shown in Fig. 2.6. The arrows between the groups represent the various processes that move material from one group to another. Plate tectonics is the driver that makes the Rock Cycle churn continuously.

2.3.4 The Long-Term Climate Cycle

So what does all this have to do with climate? It turns out that the changes in mantle convection currents are not entirely random, unlike boiling water. There are long-term patterns that repeat, where the continental land masses move from Equator to poles and back in well-defined cycles. When most of the continental masses are jammed together into a mega-continent near the Equator, the Earth warms up. The convection cells then change direction and that mega-continent breaks up. The continents then do a random walk towards the poles. When most of the continental land masses are at or near the poles, we have an Ice Age. The cooling depends on interactions with other mechanisms, like ocean currents, the Fulcrum Effect, and animal life on continents that I will deal with later. Because continents move so slowly, the current length of this cycle is about 150 million years.

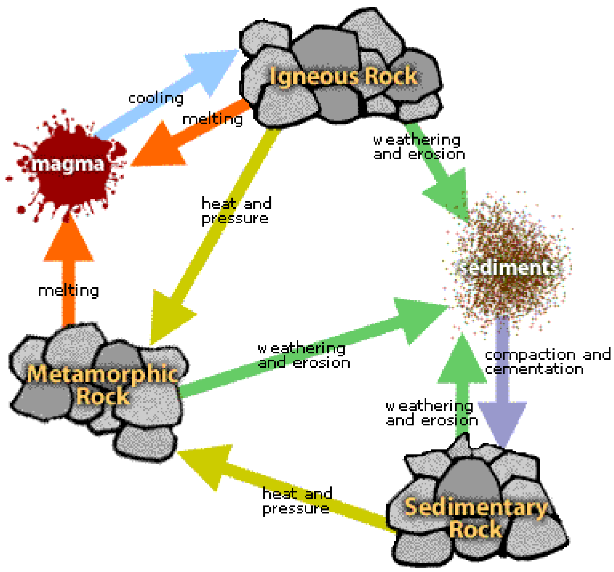

FIGURE 2-6. Rock cycle.

The alternation of mega-continent formation and ice ages is illustrated in table 1 below. The unshaded entries are major episodes of mega-continent formation on or near the Equator while the shaded entries are episodes of major glaciation, when most of the continental masses are on or near the poles.

While the table shows a clear pattern, in reality things are a bit more messy because of the

TABLE 1.

Name	Dates (my)
Cenozoic	34-present
Gondwannaland	180-80
Karoo	369-260
Pangaea	336-173
Andean-Saharan	450-420
Pannotia	633-573
Sturt-Marino	715-680
Rodina	1130-750
Columbia	1820-1350
Huron	2400-2100
Ur	2803-2408
Pongola	2900-2780

randomness of the continental paths. Thus, today we are in the Quaternary Ice Age but Africa and South America are still on the Equator while India is crashing into Asia.

The fact that some continents are still on the Equator while we are in an ice age is mostly an issue of map projection. The more commonly used Mercator projection tends to emphasize areas near the Equator. Fig. 2.7 is an equal-area projection of the world map where the size of any part of the map has the same ratio to the actual area as any other part of the map. If you count the squares in Fig 2.7, most of the continental mass is at or above 50° latitude north and south (Antarctica is the while blob at the bottom of the map). Also note that Africa and South America appear thinner in this projection.

As I indicated earlier, the present amplitude of this temperature cycle is about 20°C and we are currently near the low point of the cycle. This casts some doubt on the GWC perception that any rise in the Earth's temperature will be disastrous. In fact, increasing the Earth's temperature by several degrees C will actually be returning to normalcy. For example, the Earth only has permanent polar ice caps during Ice Ages. And this cycle is quite natural.

Plate tectonics also affects climate through geography at time scales from a few hundred thousand years to tens of millions of years. For example, moisture-laden trade winds blow off the Pacific Ocean onto Southeast Asia. As they climb in elevation towards the Himalayas across a broad coastal plain, they must drop their moisture. As a result, Southeast Asia has two monsoons a year, enabling the fabled "rice bowl" that feeds about 2 billion people.

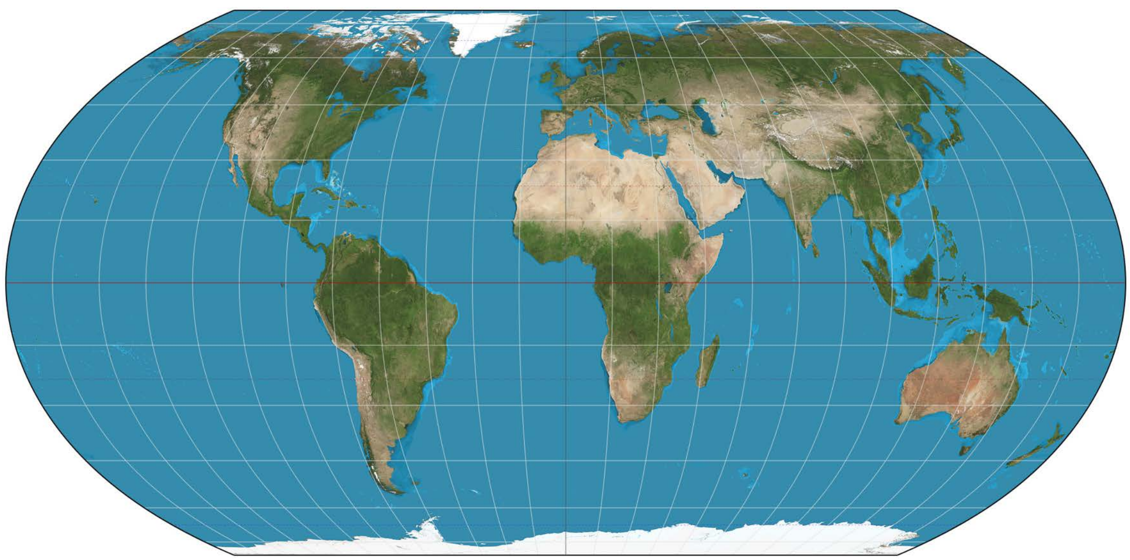

FIGURE 2-7. Equal area map of the Earth.

Another example is in northwestern North America. At the Pacific, the coastal plane is quite narrow, often less than 10 miles wide. If one drives due East for 100 miles from the shore of the Pacific, one encounters two dramatically different climate regimes. On the coast rainfall is more than 50 inches per year as moisture-laden trade winds from the Pacific make landfall and collide with the Cascade Mountains. Once past the Cascades, one enters a high plateau of the Rocky Mountains. However, the trade winds have already dropped all their moisture, so annual rainfall is less than 5 inches per year. In some places in the Rockies, there are even sand dunes while the coast is quite wet.

These two examples are about local weather rather than global weather. Nonetheless, they provide rather dramatic insight into the way geography can affect climate. Later I will have similarly dramatic examples of how geography can affect global climate. But to understand why, I need to talk about other mechanisms first.

2.3.5 Volcanism and Climate

Plate tectonics can affect global climate on a scale of weeks to a million years through volcanism. When volcanoes erupt they can release large amounts of gas into the atmosphere. Sulfur dioxide and hydrogen sulfide react in the upper atmosphere to produce sulfuric acid clouds that reflect sunlight back into space before it can warm the surface of the Earth. A supervolcano eruption can cause a “nuclear winter” cold spell this way that lasts for several years. The most common gas emitted by volcanoes, though, is carbon dioxide. All of these gases are radiative and can substantially raise the temperature of the Earth in the long term if the eruption is large enough.

Two different types of volcanism are relevant that depend on the type of magma involved. Oceanic volcanoes are formed from basaltic magmas of heavy, dark-colored ferromagnesian minerals. Continental volcanoes are formed from felsic magmas of light, light-colored aluminum silicates. Basaltic magmas have lower viscosity than felsic magmas (though these are relative terms since basaltic lava flows like molasses while felsic lava flows like tar). The viscosity is a major factor in how much gas a magma can have in solution; generally felsic magmas can hold much more gas that basaltic magmas.

This is reflected in the way basaltic and felsic volcanoes erupt. Basaltic volcanoes are usually quite well behaved. The lava simply flows out of the volcano. For example, there are hardly ever any fatalities from the almost constant eruptions of the volcanic vents on the Big Island of Hawaii because a brisk walk will keep one well ahead of the lava flow. Felsic volcanoes, on the other hand, usually erupt explosively. The analogy one might apply is the world’s largest artillery shell buried in the ground with only the tip visible. When the detonator is triggered, the powder burns and all the released gas propels the shell up into the atmosphere. Consequently, there are almost always fatalities associated with large felsic eruptions[1].

Geologists have a scale for measuring the explosive power of felsic eruptions, cleverly known as the Volcanic Explosivity Index (VEI). Like the Richter scale for earthquakes, it goes from 0 to 8 where each integer represents an order of magnitude increase in explosive power. Supervolcanoes are defined as having a power of VEI 7 or greater. The minimum criterion for VEI 7 is that 100 cubic kilometers of material is blown up into the upper atmosphere. I live near Boston, MA, USA which has a population of about five million. The area of metropolitan Boston is roughly 100 square kilometers. A minimum VEI 7

1. Volcanologists are all crazy people. There are usually a couple of volcanologist fatalities at every major felsic eruption because the best time to study a volcano is when an eruption is imminent. They also do things like walking on active lava flows (the top of the flow hardens in air and the lava flows out from the leading edge; but you still only have an inch or so of hard crust between you and flowing lava at 1800°). As a result vulcanologists need to breed like rabbits to keep up with demand.

eruption is equivalent to putting metropolitan Boston to a depth of 1 Km into the upper atmosphere. That's a pretty big explosion. There has only been one supervolcano eruption in all of Man's recorded history. That was in the early 19th century in Indonesia. That year was known in Europe as the "year with no summer" because the sun was so dimmed by particulate matter. That eruption was controversial as to whether it actually qualified as a VEI 7 eruption. A single VEI 7 eruption can put several integer factors more carbon dioxide into the atmosphere that Man's entire annual output.

To provide a scale, the largest active supervolcano is the one under Yellowstone Park in the northwestern USA. Geologists were aware that the region was volcanically active for a century, but no knew it was a single supervolcano until a geologist got declassified spy satellite photos of the region and put them up as a montage on a wall. There is an urban legend that he immortalized the discovery of the Yellowstone Supervolcano by shouting, "Holy S**t!" when he first looked at the montage as a whole.

The reason no one knew it was there was because it was so big. The caldera from the last eruption 640,000 years ago is 45+ miles long and 35+ miles wide. If one stands on one lip of the caldera and looks across to the other side, one can't see it because of the curvature of the Earth. The cliffs of the caldera are about 0.5 Km high. Roughly 3,000 cubic miles of material went into the sky with that eruption. It released something approaching 2 trillion tons of carbon dioxide into the atmosphere -- the equivalent of 180 ppm in a single eruption. The ash layer was six feet thick on the Atlantic coast, 1800 miles away. (Volcanic ash is heavy; a foot on the roof of a typical single family dwelling would flatten that dwelling like a pancake.) The particulate matter in the upper atmosphere would have dimmed the sun for years so that at high noon it would look like a full moon.

If Yellowstone were to erupt again today, it is estimated that the immediate death toll in the first three weeks would be 100 million in North America and the following nuclear winter and crop failures world wide would thin our herd by billions.

There are 26 active supervolcanoes worldwide. They are located above hot spots in the upper mantle. Each has a fixed eruption cycle in the range 400,000 to 800,000 years, depending on local geology. If you do the math you can expect a supervolcano eruption about every 23,000 years. Because they have different fixed cycles, they can bunch up with several eruptions in a few thousand years or go for a 100,000 years without an eruption.

Not all supervolcanos are as dangerous as Yellowstone. However, they can have a significant effect on global climate because of the carbon dioxide they release, especially if they bunch up. (In fact, human civilization was enabled by a bunching up of supervolcano eruptions 10,000 years ago; without them we would be hunter-gatherers leading a subsistence existence in a glacial phase of the Quaternary Ice Age today. But, I'm getting ahead of the story again...)

While felsic eruptions can be devastating and have profound effects on global climate for a few millennia, a certain type of basaltic eruption can have a major effect on global climate for as long as a million years. When a mega-continent breaks up, a major crack in the crust opens up that can extend all the way down to the Earth's Mantle. That allows the hot Mantle material to well up out of that crack onto the surface in massive flows known as *plateau basalts*. Such eruptions will continue so long as the continent is splitting apart, until the crack reaches the ocean so the sea water can quench it (at which time it goes under water as *sea floor spreading*). While the amount of gas in solution is less for basaltic magmas, these flows can be enormous. The largest individual flow found was 1000 feet thick and covered 300,000 square miles. More important, flows keep coming as the mega-continent continues to split apart. Thus a large plateau basalt can raise the temperature of the Earth by as much as 5°C over a million years.

When continents move apart, the ocean floor must spread in the same way. The Middle Atlantic Ridge, shown in Fig. 2.8, is an example. This crack has been opening for 80m years and some parts of it began opening about 130m years ago. An interesting question is: why hasn't there been a tremendous increase in atmospheric CO_2 because of this? The short answer is that life in the deep ocean eats it. The deep ocean is anaerobic and without sunlight, so the life that lives there has an entirely different chemistry than the carbon-based life we are used to on the surface of the Earth.

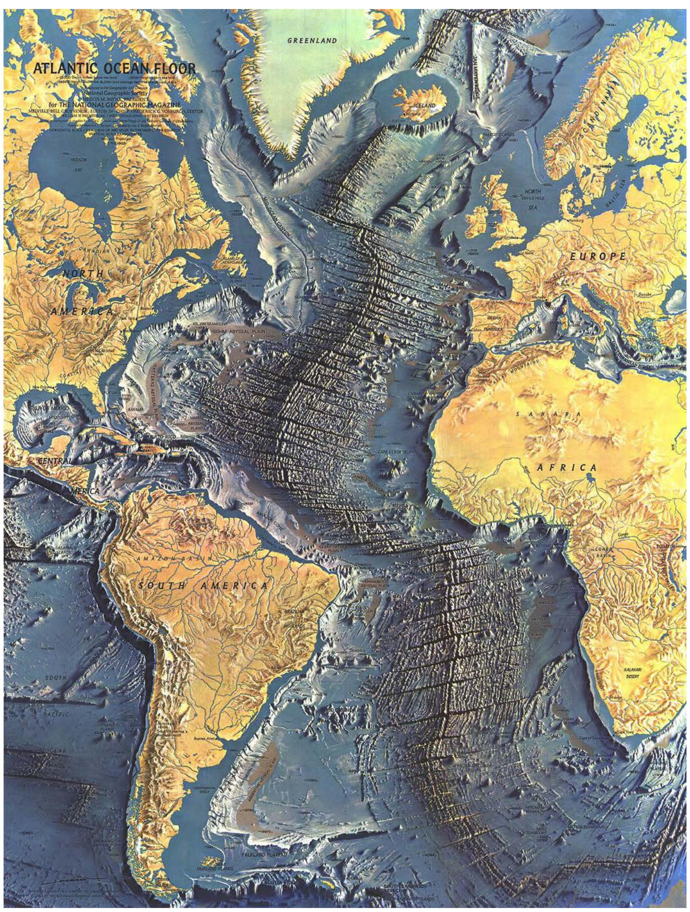

FIGURE 2-8. Topography of Middle Atlantic Ridge.

Volcanism is the *only* way to rapidly increase the amount of green house gases in the atmosphere in a very short period of time.

2.4 Biological Processes

Generally we refer to the life on the surface of the Earth and in shallow oceans as *carbon-based life*. However, this is something of a misnomer because all life on Earth is made of hydrocarbon molecules and shares DNA, even the life that exists 10,000 feet deep in the continents and in the deepest parts of the oceans. A more precise term would be life with *oxygen-based respiration.* Respiration is the process where organisms take in oxygen and that oxygen reacts with hydrocarbon molecules, like sugar, in the blood to provide energy for movement and some forms of reproduction. The waste products of the reaction are water and carbon dioxide. The word equation is

Oxygen + Hydrocarbon = Water + Carbon Dioxide + Energy.

All non-microscopic “carbon-based life” on the surface of the Earth employs this process in some form. This is the primary way that CO_2 is replenished in the atmosphere. There is very little hard data on exactly how much CO_2 is provided in this manner, but we do know that it is at least an order of magnitude more that Man’s activities provide.

The other major process for life on the surface of the Earth related to CO_2 is photosynthesis. Photosynthesis is the process where some simple microbes and all plants combine sunlight, water, and carbon dioxide to produce the hydrocarbon molecules needed for cell growth, like cellulose. The waste product of the reaction is oxygen. In other words, the word equation is:

Sunlight + Water + Carbon Dioxide = Hydrocarbon + Oxygen,

which is the mirror image of the equation for respiration. This is the primary way that CO_2 is scrubbed from the atmosphere.

Given that all carbon-based life does respiration, but only plants and some microbes do photosynthesis, there seems to be a conundrum: Why isn’t atmospheric CO_2 always increasing in a big way? The answer is that the plants and microbes doing photosynthesis do not move (with a very few exceptions, like Venus Fly Traps). So they only need respiration for reproduction, which in microbes is very simple. Thus plants and microbes do a lot of photosynthesis compared to their respiration. Since plants and microbes comprise most of the biomass, the respiration of animals fits into the gap.

This leads to another remarkable coincidence that supports the Gaia Hypothesis. There is great diversity among various types of microbes and plants. This means that the ratio of photosynthesis to respiration can vary greatly from one species to another. Similarly the demands for respiration among animals and insects can vary widely. Nonetheless, the amount of CO_2 replenished by respiration is usually almost equal to the amount of CO_2

scrubbed by photosynthesis and this has been true for at least 500m years, despite extraordinary evolution in that time.

When the GWC blames Man for all the global warming, they are making a fundamental assumption: if Man would stop burning fossil fuels for energy, all the natural processes would be in perfect balance, enabling the Earth to be a garden planet forevermore. In fact, the natural processes are almost never *exactly* in balance and the Earth is constantly warming or cooling. Though the rates that the CO_2 is replenished and scrubbed in the atmosphere are usually close to be equal, they are only exactly equal at major climate turning points as they pass each other switching from warming to cooling or cooling to warming.

Interestingly, at such major climate turning points, temperature usually leads CO_2 by roughly a thousand years. However, between turning points CO_2 does, indeed, drive long term temperature as it increases or decreases. The reason for this apparent contradiction is that other mechanisms come into play at major climate turning points.

While respiration and photosynthesis are the dominant mechanisms that determine how atmospheric CO_2 is replenished and scrubbed from the atmosphere, it is worthwhile to explain why Man is currently responsible for the warming. At the present time there is slightly more photosynthesis than respiration because we are in the Quaternary Ice Age, which restricts land animal habitats and, consequently, their populations and total respiration. Because of the warming of the interglacial hiatus, that difference is very small. In that situation Man becomes, in economic terms, the marginal supplier of CO_2. So, even though Man's contribution is tiny compared to the respiration of the biomass, that contribution is larger than the current difference between natural photosynthesis and respiration.

Currently about 25% of the warming is due to burning hydrocarbons for energy. Another 25% is due to other direct activities, such as cement manufacture and fertilization. The remaining 50% of the current CO_2 surplus is very likely due to deforestation. (I say 'very likely' because we simply don't have hard data on the effects of deforestation.) Trees do a lot more photosynthesis than they do respiration while agricultural plants have relatively high respiration for their bulk. Thus when we chop down trees to create farms, we are changing the natural balance between respiration and photosynthesis towards warming.

This is a major concern because today over 50% of the continents are used for farms, pastures, and urban development that support Man's seven-fold increase in population over the past two centuries. While it is hard to quantify this contribution, it certainly seems plausible that deforestation does account for 50% of the current warming.

At this point I can explain how the amplitude of the Earth's long-term temperature cycles is driven by the combination of plate tectonics, Hadley cells, and life. When there is a single mega-continent near the Equator, we have a tropical paradise that supports huge amounts of plant life. That plant life, in turn, supports huge numbers of animals that feed on those plants. All those animals cause respiration to replenish more carbon dioxide than photosynthesis scrubs out, so the planet warms.

However, when the mega-continent breaks up and pieces start moving to the poles, they pass through the Hadley desert zones. Those desert zones are larger than present because the temperature is higher, which considerably curtails animal habitats. As the habitats for land animals are curtailed, their numbers decline and respiration begins to decrease. This decrease grows as the continents near the poles, where animal habitats are further curtailed, Eventually photosynthesis wins and the planet cools, descending into a glacial phase of an ice age.

As it happens, there are more animals in the shallow oceans than there are on land, but they have a relatively small affect on climate. That's due, in part to the oceans being an enormous reservoir of heat, so it is difficult to change their environment. The big difference, though, is that sea animals have neutral buoyancy, so they only have to overcome the friction of water over their skins to move. In contrast, land animals need to fight gravity every waking moment, which demands much more respiration for movement. Thus land animals are the 'swing' variable in the range of temperature change during the long-term cycles driven by plate tectonics.

2.4.1 Methane and Climate

The other greenhouse gas that is controlled biologically is methane. Since animals and more complex microorganisms do not do photosynthesis, they must provide for cell growth in another way: digestion. Animals must eat to get the amino acids necessary for cell growth. The byproduct of that chemistry is methane, especially from herbivores and cyanobacteria. Fig. 2.9 shows the growth in atmospheric methane over the past ten centuries.

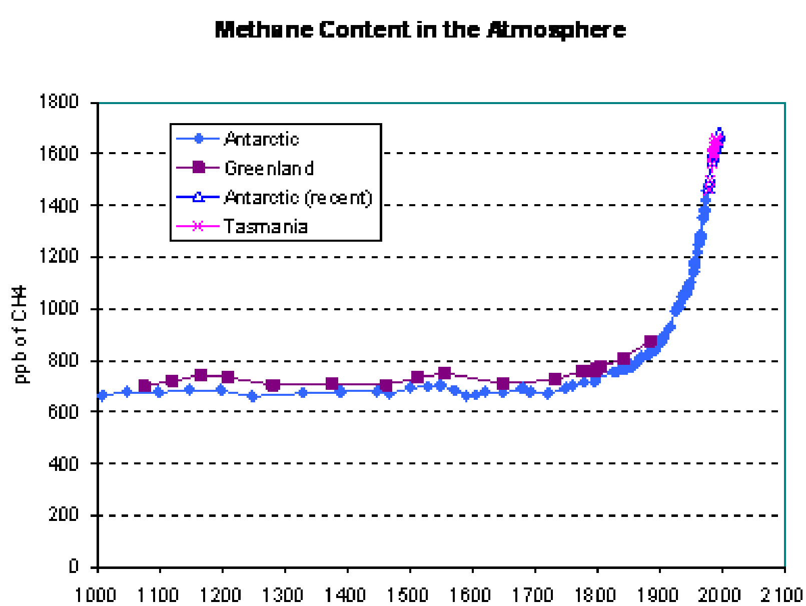

FIGURE 2-9. Cumulative atmospheric methane over the past ten centuries.

Note that there has been very close to a 300% increase during the past two centuries. During that same period CO_2 only increased by about 60%. During those two centuries the Earth's temperature rose slightly more than 1°C. The GWC would have us believe that rise was all do to increasing CO_2 because that is what IPCC's steady-state climate models predict. However, the three-fold increase in methane surely had something to do with that temperature rise. My assertion is that the atmospheric methane increase actually accounted for most of that temperature increase since methane is 70 times more potent as a greenhouse component than CO_2. That, in turn, casts some suspicion on the validity of IPCC's models.

The largest single source -- by far -- of atmospheric methane is domestic livestock. Livestock has increased in the past two centuries to keep pace with Man's seven-fold increase in population. (The increase in methane is less than seven-fold because most of the livestock has replaced large numbers of wild herbivores that were present before deforestation.) If one looks at populations of large herbivores (wildebeests, bison, reindeer, etc.) there appears to be a limit to each species' total population of around 10 million. Man's cattle number 1.5 billion.

There is another source of atmospheric methane: non-carbon-based microscopic organisms. These organisms live in anaerobic environments without sunlight, so their chemistry is very different than that of the organisms on the surface of the Earth. A waste product of many of these organisms is methane. Almost all natural gas comes from such organisms deep in the Earth. That methane rarely reaches the surface of the Earth naturally in significant quantities.

However, when such organisms live in the muck of continental shelves or in sub-polar regions, the methane they produce can reach the atmosphere. If one goes scuba diving in very shallow ocean waters with sandy bottoms, one can occasionally see streams of tiny bubbles rising out of the sand. Those bubbles are methane from such organisms that was trapped in the bottom muck until it was disturbed and the methane found a path up and out of the muck. In deeper water, 100m or more, though, that methane is often trapped in sedimentary deposits known as *methane clathrates*.

When we think of water, we usually just think of it as having three phases: steam, the gaseous phase; water, the liquid phase; and ice, the solid phase. That's because we only see water, steam, and ice at one atmosphere of pressure. In fact, there are many phases of ice that can form, depending on pressure and temperature. Some phases of ice can form at temperatures as high as +19°C if the pressure is great enough. On the outer continental shelves where the water is more than 100m deep and the water temperature is 5-10°C, ice can form and trap the methane molecules produced by the non-carbon-based organisms living in the muck of the shelves.

Methane clathrates have been forming on the world's continental shelves for about 200m years. It has been estimated that the total energy equivalent of the methane trapped in clathrates on continental shelves exceeds the total energy equivalent of all known reserves of oil, natural gas, and coal. That's a lot of methane when one considers our known coal reserves could satisfy our present energy needs for about 150 years if we burned them for energy.

The reason these clathrates are relevant to climate is that if the temperature of the shallow oceans were to rise enough, it would eventually warm the sediments on the continental shelves enough to cause the ice in the clathrates to sublimate. Instead of melting to normal liquid water, they produce water vapor, a less dense phase of water like that produced by evaporation. That can produce one of the ecological disasters on IPCC's list. Because they sublimate, the water vapor produced is less dense than the original ice. That expansion roils the sediments and allows warmer water to reach the deeper clathrates. The result is a sort of explosive chain reaction that can cause all of the methane trapped in a continental shelf to be released at once[1].

Fortunately, this is very rare because the oceans are an enormous reservoir of heat and it takes a very long time to warm them sufficiently to trigger sublimation of the shelf clathrates. It has only happened once that we know of in the geologic record, nearly 300m years ago. However, that event was the coup de gras for the worst mass extinction in the geologic record; nearly 95% of all carbon-based species on the surface went extinct and the average temperature of the surface of the Earth rose 5-8°C in a few years.

This brings me to another example of scientific charlatanism on the part of the GWC. To cause that sort of sublimation of the shelf clathrates requires the Earth's temperature to be more than 20°C greater than it is now for a sustained period of time. However, when the GWC talks about this, they talk about clathrates sublimating in permafrost areas, which is happening in a few places now. These are much easier to warm, so some are sublimating today. They then juxtapose that discussion with one about the offshore methane clathrates and what a catastrophe that would be, implying the catastrophe is imminent. In fact, the amount of clatrates in continental permafrost deposits is tiny compared to that in the continental shelves. In addition, the continental clathrate sediments are usually widely separated, so they do not sublimate all at once. Even if they did sublimate all together, the increase in greenhouse warming would be barely noticeable. By juxtaposing the ongoing permafrost sublimation with the continental shelf sublimation, they imply that a true catastrophe is imminent when it is actually tens of millions of years away.

1. This can happen in large, deep lakes in sub-polar regions. The lake bottoms are sunless and anaerobic, so the microroganisms living there produce methane. If the lake is deep enough and near enough to the pole, clathrates can form. When there is a prolonged period of warming, such as an interglacial hiatus, the lake eventually warms enough for the clathrates to sublimate, suddenly asphyxiating all the fish in the lake. In ancient times this was regarded as a supernatural event. This was actually observed happening a few decades ago. The observer described the entire central portion of the lake suddenly erupting in huge geyser about 100 feet high. The amount of clathrates in such a lake would be tiny compared to a continental shelf, so there is little effect on climate in such circumstances.

2.5 Oceanic Processes

There are two basic ways that the oceans can affect global climate: evaporation, which increases or decreases the greenhouse effect; and heat transfers, which drive the Fulcrum Effect.

2.5.1 The role of Oceanic Evaporation

Virtually all of the moisture in the atmosphere comes from evaporation of the oceans because they cover 70% of the Earth's surface. The rate of evaporation is not constant. A generalized graph for oceanic evaporation is shown in Fig. 2.10. As the figure indicates, the dominant variable is temperature. However, there are many other variables that affect the evaporation rate (e.g, wind velocity, current velocity, salinity, turbulence, atmospheric moisture saturation, etc.). Thus there are no numbers on the graph. (I once asked an oceanographer why there weren't. He smiled and told me that to accurately compute the evaporation over a square kilometer of ocean for an hour would require chaining together all the world's super computers for about a year.)

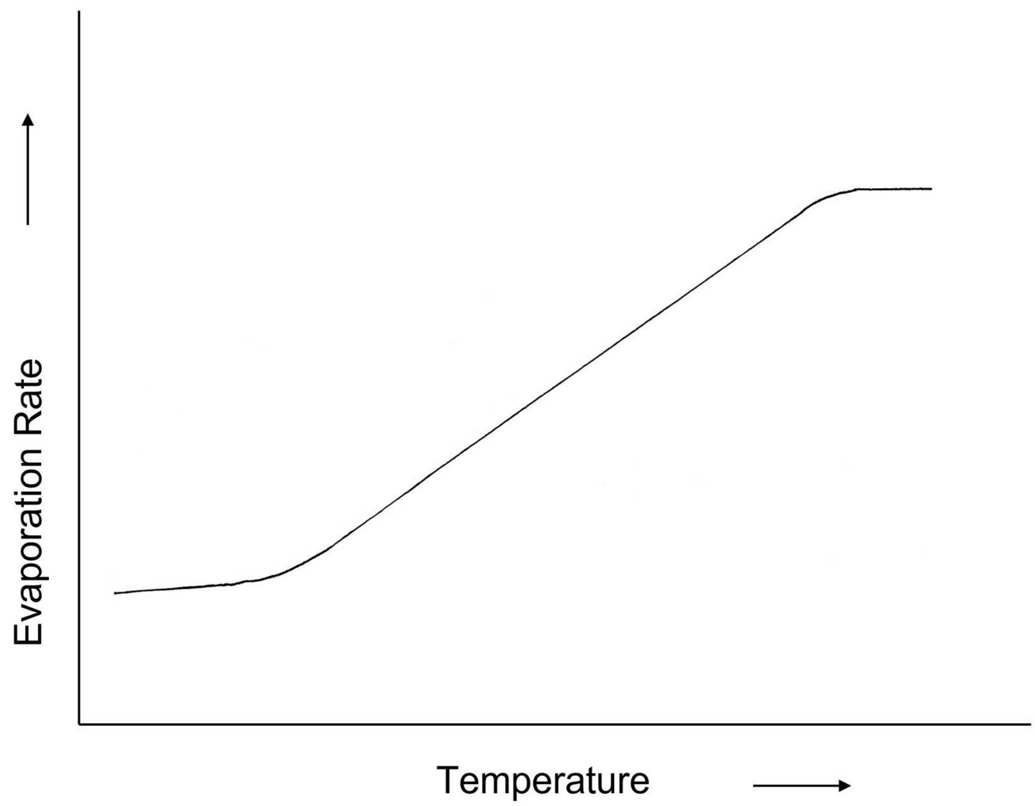

FIGURE 2-10. Generalized evaporation graph.

Nonetheless, the curve in Fig. 2.10 does enable a reasonable qualitative discussion of oceanic evaporation. It might seem counterintuitive that the curve does not continue rising steeply until the boiling point of water is reached. It doesn't because there is a limit to the amount of moisture the atmosphere can carry; once that saturation point is reached there can be no further evaporation. At higher temperatures, that atmospheric saturation point rises very slowly with temperature.

The present average temperature of the surface of the entire Earth is slightly over 15°C, which is on the steep portion of the curve somewhere near the lower inflexion point. This is because we are still in the Quaternary Ice Age, despite the interglacial hiatus. Being on the steep portion of the curve enables a process known as *positive feedback*. To demonstrate how this process works, I will conduct a thought experiment.

Fig. 2.11 shows just the steep portion of the evaporation curve. Imagine that we are at point A on the curve and there is a supervolcano eruption that dumps a few hundred billion tons of carbon dioxide into the atmosphere. That might suddenly increase the greenhouse effect, raising the temperature of the Earth by quarter degree or so. That sudden rise in temperature takes us to point B. However, at that point we have a new, higher evaporation equilibrium point at point C. So the oceans begin to suddenly evaporate faster. That puts more moisture into the atmosphere, causing additional warming.

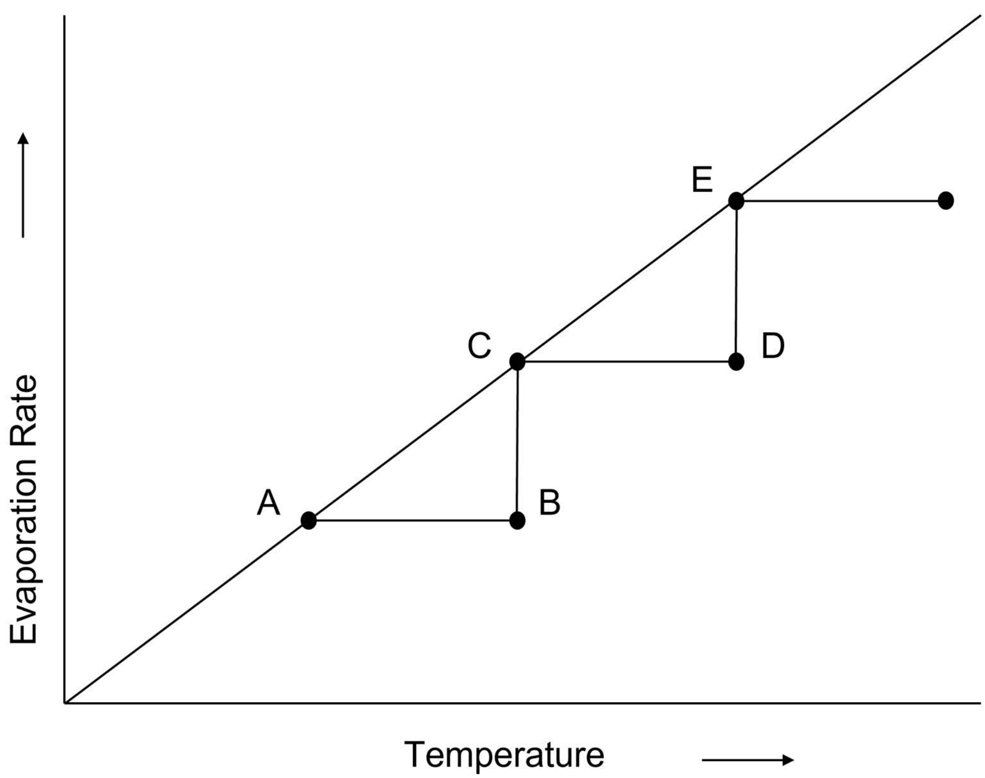

FIGURE 2-11. Positive feedback.

That additional warming now moves us to a higher temperature for the Earth at point D. But the equilibrium evaporation at that temperature is at point E. So that increase in temperature triggers a further increase in evaporation, causing another rise in temperature. This feedback of changing temperature and evaporation rate would continue to ‘walk up’ the curve indefinitely until the entire atmosphere was fully saturated. In practice, though, the process tends to peter out because the actual curve is not rising at 45° and the increase in evaporation is proportionately smaller for each iteration than the increase in temperature. (Note that one can walk down the curve in the same way if there is a sudden drop in temperature, which is relevant to terminating interglacial hiatuses.)

Nonetheless, this process is responsible for almost all rapid climate change where the Earth's temperature changes by several degrees in a very short time. Note that in this thought experiment, the introduction of carbon dioxide only contributed warming for the first step; in all the rest of the steps the rises in temperature were due solely to the changes in evaporation.

This thought experiment is actually the mechanism that initiates interglacial hiatuses. The rapid rise in temperature to initiate a hiatus is due almost entirely to positive feedback in oceanic evaporation. (One of the first hypotheses for how interglacial hiatuses were initiated attributed the rapid climate change to precession of the wobble of the Earth's axis of rotation, which changes how the Earth is warmed by the Sun. Precession is a necessary condition, but it is not sufficient to account for the hiatuses. For example, precession events occur about every 25,000 years but hiatuses are usually separated by 100,000 years or more. In fact, both precession and positive feedback are necessary.)

2.5.2 The Gyre Currents

There are large circular currents in each of the oceans, known as *gyres*, as shown in Fig. 2.11. The gyres flow clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere, though the direction has nothing to do with Coriolis forces due to the Earth's spin. These currents are purely wind-driven surface currents. Easterly trade winds circumnavigate the globe from East to West at the Equator while westerly trade winds circumnavigate the globe at higher latitudes from West to East. These winds drag on the surface of the ocean, driving the gyres, The directional shear from these winds determines the current direction in each hemisphere.

The gyre currents are substantial. The smallest gyre is in the North Atlantic and it has a volume flux (the amount of water moving across a cross section of the current per unit time) of 20 million tons of water *per second*, which is a lot of water. This is important to climate because this water movement also transfers heat from the Equator to the polar regions, which reduces the slope of the Fulcrum Effect gradient.

On the gyre's equatorial legs, the Sun beats down on them at maximum energy density and warms them. They carry this heat towards the poles. On the polar legs, trade winds pull heat off the currents and carry it to the continents to the East. They also mix with colder polar waters to raise the temperature of the surface layer of the oceans in polar regions.

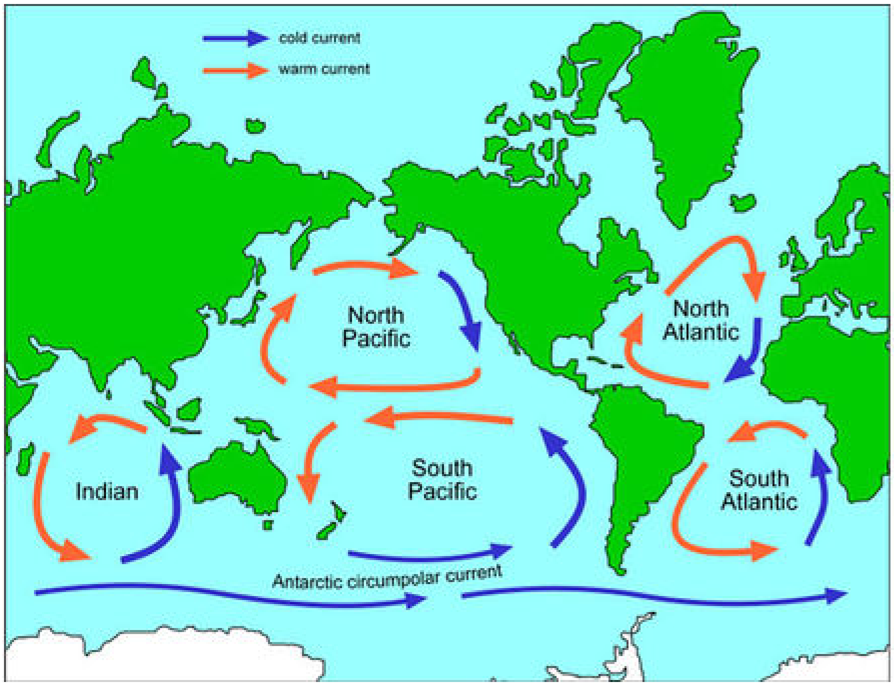

FIGURE 2-12. The Gyre currents]\.

The Quaternary Ice Age is one of the mildest in the geologic record because of the gyres. Major winds in the atmosphere of a planet tend to circumnavigate the planet parallel to the planet's equator, like trade winds on Earth. The drag of those winds would cause any ocean current to also circumnavigate the planet. However, a remarkable accident of plate movement yields a present geography for the Earth where there are contiguous land bridges almost pole-to-pole in both the Eastern and Western Hemispheres. These land bridges prevent circumnavigation of the ocean currents, forcing gyres to form in each ocean, The gyres are essentially a permanent heat conveyor from Equator to poles that mitigates the effects of the ice age.

2.5.3 The Thermo-Haline Circulation.

While the gyres are pure surface currents of the oceans, there is another system that transfers water back and forth between the surface of the ocean and the abyssal plain at the bottom of the oceans. This system is known as the Thermo-Haline Circulation (THC) and it is the largest current system on the planet. While the name accurately describes the driving mechanism, oceanographers originally called it the Great Ocean Conveyor because it also transfers enormous amounts of heat from the Equator to the poles. The THC is shown in Fig. 2.13.

The overall structure is defined by two major up-welling points, off the west coasts of South America and Africa at the Equator, where water rises from the abyssal plain to the surface, and two down-welling points, off Scandinavia and Antarctica, where water sinks from the surface to the abyssal plain. (There are much smaller upwelling points in the Indian and North Pacific oceans that are driven by deep sea volcanism.) The up-welling points are connected to the down-welling points by surface currents, shown in red in the diagram. The down-welling points are connected to the up-welling points in the abyssal layer of the oceans by the blue currents in the diagram. (See the infrared satellite view of the Peru upwelling point in Fig. 2.14.)

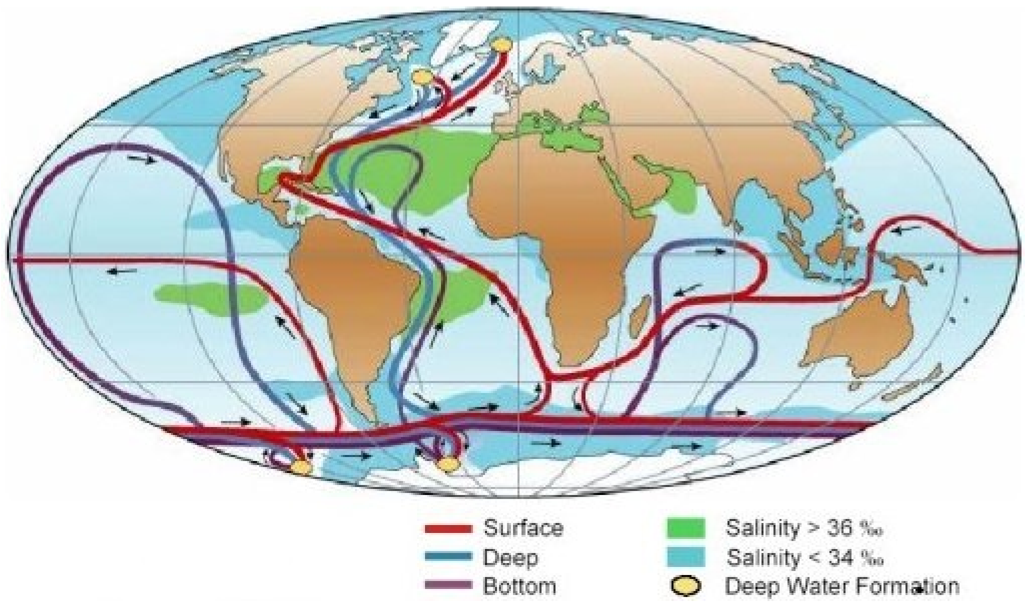

FIGURE 2-13. Thermo-Haline Circulation.

The THC is extremely important to the Earth for two reasons. The up-welling points provide critical nutrients -- mostly metallic ions such as phosphorous, iron, and calcium -- that are critical to cell building in more complex organisms. The locations of most of the world’s major fisheries are located along the paths of the two THC surface currents, the Gulf Stream in the Atlantic and the South Australia Current in the Pacific and Indian Oceans.

The second reason the THC is important is because of the enormous heat transfers the surface currents provide between Equator and poles. The Gulf Stream is the largest current on the planet: over 100 Km wide and 750 m deep. The volume flux of the Gulf Stream is 50 million tons of water per second, 2-1/2 times as great as the North Atlantic gyre. This heat transfer is enormously important to global climate.

For example, Madrid, Spain is on the same latitude as New York City in the USA. New York has a north temperate climate while Madrid has a subtropical climate. Central Europe, from the tip of France at the Atlantic to Moscow has a North Temperate climate. However, that latitude corresponds to the Northwest Territories in Canada. I spent a winter living in a plywood shack in the Northwest Territories. The average temperature was -30°F and it got to at least -70° (as low as our thermometer went). After using an outdoor latrine there, I can testify that climate is not a North Temperate climate. That warming of central Europe is due to the combined heat transfers of the Gulf Stream and the North Atlantic gyre as trade winds suck heat from those currents and carry it into Europe.

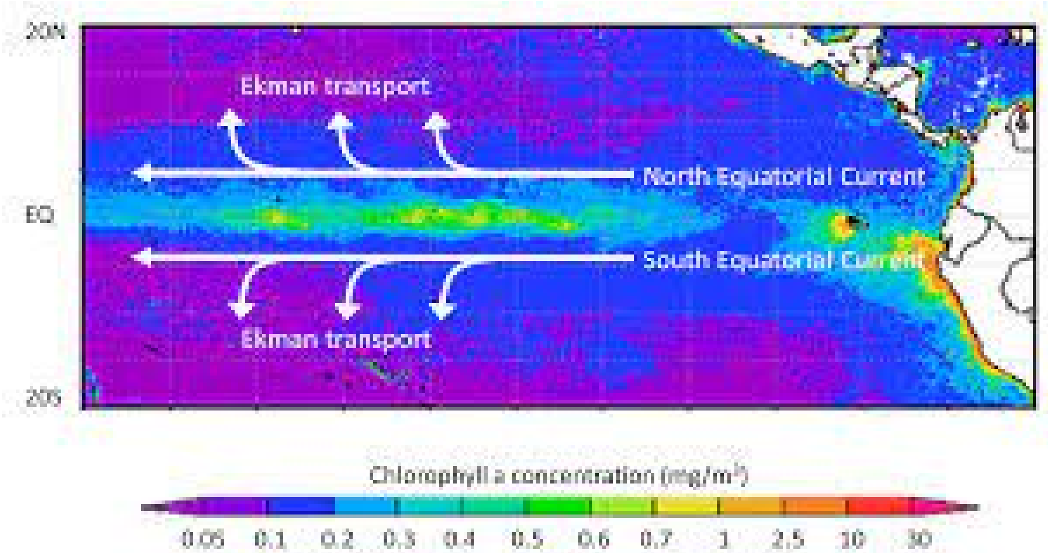

FIGURE 2-14. Upwelling point off Peru.

Most of the heat transfer, though, is manifested in warming the North Atlantic waters. That increases the surface temperature, which leads to higher evaporation and increased atmospheric moisture that increases greenhouse warming.

Alas, the THC is not always running. For the past 2.6 million years during the Quaternary Ice Age, it has only been running during interglacial hiatuses. In fact, the termination of interglacial hiatuses is due to a rapid catastrophic shutdown of the THC, where the temperature of the Earth drops 3-4°C in a matter of a few decades. To understand why, I need to explain the main driving force behind the THC. Since the mechanism is essentially the same for both down-welling points, I will just describe it for the Atlantic down-welling point.

As the Gulf Stream crosses the Atlantic at the Equator, the Sun beats down on it with maximum energy density. That warms the water, causing it to expand and reducing its density. That keeps the current on the surface all the way to Scandinavia. However, the higher surface temperature results in greater evaporation along the Equator, increasing the salinity and, consequentially, increasing the density. The thermal density decrease is great enough to dominate all the way to Scandinavia. In the North Atlantic trade winds suck heat away from the Gulf Stream, causing its thermal density to increase.

By the time the Gulf Stream reaches Scandinavia, the combination of reduced temperature and higher salinity makes the Gulf Stream more dense than the ocean layers[1] beneath it and it begins to sink. As it sinks, it mixes with colder waters below, so its density continues to increase. In addition, the lower layers of the oceans are less saline, so the salinity difference becomes increasingly important. The result is a sort of vast hydraulic piston that forces water all the way down to the abyssal plain, where it displaces water that moves towards the upwelling points. This hydraulic piston provides the power that drives the entire THC.

At this point I can describe how an interglacial hiatus is terminated. Note that in Fig. 2.13, the Gulf Stream passes just below the tip of Greenland. Greenland has been collecting ice sheets for 2.6 million years, throughout the Quaternary Ice Age. During an interglacial hiatus, summers get longer and warmer. Eventually, Greenland reaches a tipping point where it switches from net accumulation of ice each year to net melting of ice. That tipping point equates to an average surface temperature of the Earth of between 14-16°C. Once the tipping point is reached, the amount of fresh melt water each year increases rapidly. That fresh water goes into the Gulf Stream and dilutes the salinity.

In addition, the sea ice behind Greenland also starts melting. When sea ice melts on its surface, the melt water drains into cracks in the ice caused by tidal stresses. At the bottom of the cracks it re-freezes. Since ice expands, it forces the cracks further open. Eventually ice bergs spall off the ice packs and float south where they are caught by the Gulf Stream. Sea ice is actually fresh water because when sea water freezes the salts are squeezed out as a brine under the ice. So the fresh water ice bergs are grabbed by the Gulf Stream and carried to Scandinavia, melting all the way.

The bottom line is that the fresh water dilutes the salinity of the Gulf Stream, causing a catastrophic shutdown of the THC when the water at the down-welling point is no longer dense enough to force its way to the abyssal plain and the loop is broken. Essentially the same thing happens for the South Australia Current, but with a delay because, as any penguin can attest, winters in Antarctica are substantially harsher than at the North Pole, so it takes longer for the tipping point to kick in for that sea ice.

Several things happen as the THC heat flows collapses. The North Atlantic and Southern Oceans cool, causing less evaporation and less greenhouse warming. Winters in Europe are harsher with longer snow cover in winter. That snow cover raises the Earth’s albedo (its reflectivity) so more sunlight is reflected directly back into space without warming the Earth’s surface. That snow cover also holds moisture that would have been in the atmosphere, so the greenhouse warming is reduced. Also, sea ice expands with the cooling, further lowering the Earth’s albedo and capturing more water from the atmosphere.

When I discussed the Hadley cells, I mentioned that the polar cells work differently than the other cells. The polar cells have winds that circle the pole. During winter these cells extend down into the continents. This is why the central regions of North America and Eurasia have harsher winters than the coastal regions of those continents at the same lati-

1. Oceanographers identity seven major layers in the oceans, where density increases with depth as temperature decreases. For this discussion I simplify this to three layers: the surface layer, which is less than 1500m deep; the middle layer that extends to about 3000m; and the abyssal layer below 3000m.

tude. With the collapse of the THC, there is little to prevent the polar vortexes from descending to lower latitudes and spreading out into the North Atlantic and North Pacific. That cools those oceans further, reducing evaporation and positive feedback kicks in to cause rapid cooling. It also provides longer snow cover on the continents, raising the albedo and tying up more moisture on the ground.

In other words, the effects of the THC shutdown spreads out from the North Atlantic like a cancer, triggering a spiral back into a glacial phase of the Quaternary Ice Age. Oceanographers have been modeling the THC since the early ‘80s. Back then they predicted a catastrophic shutdown for 2150. Today they have better data and a clearer understanding of the THC and the date has been moved up considerably.

It is worth noting that the models predict that a catastrophic shutdown of the THC will be manifested by several things happening in a rough sequence:

- The salinity of the Gulf Stream off Scandinavia decreases at an increasing rate.
- World-wide weather becomes more erratic as the atmosphere adjusts to the changes in heat transfers. [95% of the heat in the Earth’s surface fluids is in the oceans while only 5% is in the atmosphere. Consequently, small changes in heat transfer from the ocean to the atmosphere can have an enormous effect on the atmosphere.]
- The volume flux of the Gulf Stream decreases.
- There is a temperature plateau as positive feedback in the North Atlantic compensates for increasing atmospheric carbon dioxide.
- The middle layers of the North Atlantic and Southern Oceans begin to warm up when the down-welling points are no longer capable of reaching the abyssal layer.
- The temperature of the Earth drops 3-4°C in the space of a few decades as positive feedback increases rapidly.

This all happens in about 40-60 years. I will revisit these predictions when I discuss the details of our present interglacial hiatus.

2.5.4 The Southern Oscillation

Before leaving the THC, I would like to present an example of how profoundly the THC can affect climate in the short-term. I mentioned that the Gulf Stream is the largest current in the oceans. This is counterintuitive because the width of the Pacific at the Equator is about twice as wide as the Atlantic. Since the South Australia Current travels twice as far under maximum energy density from the Sun, one would expect it to be saltier and, consequently, more powerful than the Gulf Stream at the down-welling point. However, it is actually significantly less powerful at the down-welling point.

The reason is that the eastern coast of North America has very little continental shelf. So the Gulf Stream can flow unimpeded in deep water up the coast when it hits the continent. In contrast, the South Australia Current encounters Asia in the South China Sea, which is the largest continental shelf in the world. To cross that shelf the South Australia Current has to spread out because the average depth is only 100m or so. There is also considerable drag against the bottom as the current moves through the South China Sea. The drag gets worse when the current passes through Indonesia as it has vertical friction against the volcanic islands.

Thus the South Australia Current slows down when it reaches the South China Sea. Since it is being pushed at a constant rate by the trade winds, there is a pile up of warm water in the South China Sea. Sea level is 2-3m higher in the South China Sea than it is off the coast of Peru. That pile of warm water, which is still being warmed by the Sun at maximum energy density, transfers heat to the atmosphere above it. That heat causes the air to expand, effectively producing a permanent high pressure zone in the atmosphere over the South China Sea that continues to grow in strength as more water piles up.

As the high pressure zone increases in size and power, the trade winds are forced to separate and go around it. About every seven years the zone gets so strong that a hot wind blows back across the Pacific between the trade winds to Peru. When that happens, gravity can even out the pile of water in the South China Sea and it flows back to Peru over the top of the South Australia Current. (The South Australia Current continues to flow via inertia as the gazillion pressure differentials that guide it take a decade or more to dissipate.)

The result is that Peru's economy takes a nose dive every seven years or so when this happens. That's because the warm water from the South China Sea kills the plankton bloom at the up-welling point. So the fish that feed on the plankton go away, shortly followed by the sea birds that feed on the fish. Peru's primary export is fish and its second most important export is fertilizer from the sea bird guano.

This cycle is technically known as the Southern Oscillation. More commonly, it is known as El Nino, for the hot westerly wind that hits Peru every seven years or so. El Nino affects more than Peru. In a mathematical sense, the atmosphere is a chaotic system. One property of chaotic systems is that sometimes you can tweak them a little bit over *here* and cause a large, seemingly unrelated effect over *there*. A number of unusual local weather events world-wide correlate strongly with El Nino years. A couple of examples are: an increase in drought conditions in the Sonoran desert of the southwestern US and northern Mexico and an increase in the number and intensity of hurricanes in the North Atlantic, nearly halfway around the world from the South Chine Sea.

My point here is that these climate effects are substantial and they are a direct result of the THC piling up water in the South China Sea. And that pile up is due to plate tectonics placing Southeast Asia in just the right place after leaving it undisturbed long enough for wave action to carve out an enormous continental shelf under the South China Sea. However, when you see descriptions of the Southern Oscillation, they rarely mention the role of the THC, plate tectonics, or, especially, convection currents in the upper mantle.

3.0 A Short Geologic History of the Earth

I have multiple reasons for providing a geologic history of the Earth. One is that there are climate events in the geologic record that do not agree with IPCC's CO_2 myopia about how climate works. A second reason is to show as dramatically as possible how the various climate mechanisms work. The most important reason, though, is to demonstrate how the various climate mechanisms interact with one another in complex ways to produce a global climate.

3.1 The Early Years

The first few hundred million years of the Earth's history were characterized by bombardment of solar debris that was growing in size just as the Earth was. The energy of those impacts was converted primarily to heat, so the Earth's surface was essentially molten. The atmosphere was well over 30% CO_2 (some estimates go as high as 60%), there was very little oxygen, and all of the Earth's water was in the form of steam.

By about 4.2b years ago, the rocky planets had swept out most of the solar debris, so the bombardment decreased and the planet cooled enough for the steam to condense out of the atmosphere to form our oceans. Within the accuracy we can measure such things, life appeared on Earth about 4.1b years ago. To identify life in the distant past, we need relatively undisturbed marine sediments formed at that time. I know of only two places on the entire Earth's surface where suitable sedimentary rocks about 4b years old exist. One is 4.1b years old and the other is 3.8b years old. Both have evidence of life. More interestingly, one suggests life that is typical of the carbon-based life we see today on the surface of the Earth while the other suggests life that is typical of the life we find today in the deep oceans. (As you might imagine, the evidence of this is controversial since there are no direct fossils, only chemical or physical traces that suggest life.)

From a statistical perspective, this indicates that the oceans must have already been teeming with life when those sediments were formed. This is one reason why many biologists and cosmologists argue that life appears wherever there is permanent liquid water. The life that lived 4.1b years ago, the Prokaryotes, consisted of extremely simple single-celled organisms.

The Prokaryotes ruled the Earth's oceans essentially unchanged for about 2b years. There is a theory in biology that there can be no evolution without stress in the environment. The idea behind this theory is that if an organism is perfectly suited to its environment, any mutation will be inferior and will not survive. The rule of the Prokaryotes gives credence to this theory because there was some sort of major stress in the Earth's environment about 2b years ago. About that time there was a significant change in atmospheric pressure. We don't know for certain what triggered that change (most likely a major solar flare), but whatever it was likely placed a lot of stress on the environment. The result was a new family of life, the Eukaryotes.

The Eukaryotes were still primitive single-celled organisms. However, their cells had a nucleus for their DNA that was covered by a protective membrane, making them much hardier than the Prokaryotes. The Euraryotes ruled the Earth's oceans for another billion years. During the reign of the Prokaryotes and Eukaryotes, the Earth's climate did not change a great deal. This was because the oceans were an enormous reservoir of heat so the environment was resistant to change. In addition, there was no life on the continents to change the ratio of photosynthesis and respiration with habitats as continents moved back and forth between Equator and poles, so the temperature amplitude of the long-term cycles was less than 5°C.

3.2 Snowball Earth.

About 1b years ago there was a rapid succession of glacial events, each more intense that the last. This culminated in an Earth whose surface was completely frozen 700m years ago. Every square meter of the continents was covered by ice sheets and the oceans were frozen to a depth of at least thousands of meters. The average temperature of the surface of the Earth was around -15°C.

At the same time, atmospheric CO_2 was in excess of 30,000ppm. IPCC's models indicate that the temperature of the Earth should rise about 3.5°C for every doubling of atmospheric CO_2. Starting at our present 400ppm, 30,000ppm should give us a temperature about 18°C higher than present. Clearly something else was going on 700m years ago to drive the Earth's climate.

The answer lies primarily in water vapor and sea ice. More precisely, the lack of water vapor in the atmosphere because it was all tied up in ice. Sea ice always grows to cover more of the Earth's oceans in an ice age. When sea ice grows, that changes the albedo of the Earth, causing more of the Sun's energy to be reflected back into space without warming anything. This can result in the same sort of feedback mechanism as positive feedback of oceanic evaporation. More ice -> higher average albedo -> less heat from the Sun -> cooling -> more sea ice. There is a tipping point in the area of the oceans covered by ice where cooling will continue until the entire ocean is iced over, regardless of atmospheric CO_2.

Fortunately, this is a rare phenomenon; it has only occurred once in the geologic record that I know of. The interesting question is: how was the tipping point in sea ice growth reached? The answer lies in ocean currents. As I indicated earlier, the paths taken by the continents between Equator and poles are random walks. I also talked about how the contiguous land bridges from pole-to-pole in both the Eastern and Western Hemispheres forces gyre currents that mitigate the present Quaternary Ice Age. To understand how Snowball Earth came about, imagine a different random walk that tipped that geography on its side so that the land bridges were parallel to the Equator. Further imagine that the continents were strung out in the middle of the Hadley cells so that there was little land exactly on the boundaries of the Hadley cells.

In that scenario the trade winds would drive ocean currents completely around the world parallel to the Equator. There would be no oceanic heat transfer between Equator and poles at all, so the Fulcrum Effect would have maximum gradient between Equator and poles. As the Earth cooled, more moisture would be tied up for longer periods in winter snow and ice on the surface. Finally, the Hadley desert zones expose the silicate rocks of the continents to greater erosion and that reaction extracts CO_2 from the atmosphere.

However, this was a necessary but not sufficient condition to create the tipping point. Recall that I talked about the Earth's orbit becoming an elongated ellipse that extended beyond the Goldilocks Zone every 450,000 years. That was also a necessary but not sufficient condition to reach the tipping point.

The combination of these effects, though, would cool the Earth enough for the sea ice growth to reach the tipping point -- even though CO_2 was still around 30,000ppm. This is my most dramatic example of where IPCC's steady state atmospheric models can go wrong, because they ignore several other climate mechanisms that are independent of atmospheric CO_2. To have Snowball Earth, both necessary conditions must prevail and neither condition has anything to do with atmospheric CO_2.

Another interesting question is: How did the Earth get out of the Snowball Earth mode? Because of the Earth's location at the outer edge of the Goldilocks Zone, it wants to stay Snowball Earth once it gets there, even after the orbit reverts to circular. One hypothesis is that a massive plateau basalt provided enough CO_2 to raise greenhouse heating enough to melt all the ice. While this is certainly plausible, and we do know there was a massive plateau basalt at that time, I can't buy this. The problem I have is that the largest plateau basalt we know that occurred in what is now Siberia a few hundred million years ago only raised the Earth's temperature about 5°C. If we are starting out at -15°C, that only gets us to -10°C and we know from the present Quaternary Ice Age that the ice melts only when we get above +5°C.

Thus, I prefer a different hypothesis that is a variation on how our moon formed. That happened in the Earth's very early history when the Earth was struck by a planetoid-sized body. That collision threw a massive amount of material into space and that material went into orbit around the Earth, eventually coalescing into our moon. The hypothesis I prefer here is far less grand in scale; it would require a collision with a body that was only a few hundred miles in diameter or so -- just enough to instantly melt all the ice in at least one hemisphere with substantial melting of the ice on the other hemisphere as the fireball circumnavigated the globe. If it landed in an area of carbonate rocks, tremendous amounts of CO_2 would have been released to enhance the greenhouse effect enough to melt the rest of the ice, along with the steam from super heating the oceans.

The reason I like this hypothesis is that it accounts for another epic event that occurred at the same time. If you talk to a paleontologist who specializes in fossils of microscopic life, you will be told that the greatest evolutionary explosion of life on Earth occurred just after Snowball Earth. By the beginning of the Cambrian period, 160m years later, multicellular life had evolved with great diversity. Several of the phylums in today's zoological taxonomy can be traced to microscopic organisms living in the oceans 540m years ago.

If one buys into the notion of evolution being driven by stress in the environment, then this hypothesis provides us with lots of ongoing stress. Such a collision would have put a pretty deep hole in the Earth. Gravity wants a perfectly spherical Earth, so isostatic adjustments would have been needed to fill in that hole. Isostatic adjustments are nothing, if not slow. Thus, there would have been an elevated level of earthquakes and volcanism that would have continued for 100m years or more, essentially continuously providing stress in the environment. While any evidence for such a hypothesis is long gone, killing two birds with one stone is compelling.

3.3 The Dawn of Modern Climate.

The start of the Cambrian period marks the start of the modern geologic record. The 4b years prior to that are known as the Precambrian. (The Precambrian is technically broken up into three eras, but each is on the order of a billion years long while the Cambrian and younger periods are typically only tens of millions of years long.) If you talk to paleontologists who deals with macro fossils that you can see with your unaided eye, they will tell you that the greatest explosion of life in the geologic record occurred in the Cambrian period. By the end of the Cambrian period, 485m years ago, the Earth's oceans were populated by creatures that were comparable in size and diversity to what we see today, though they tended to look very different because internal skeletons had not evolved yet.

This remarkable evolution can be accounted for by another form of stress in the environment: the predator/prey relationship that continues until the present. As multi-cellular life evolved, the more complex organisms that did not do photosynthesis began eating the less complex organisms. This drives the prey to evolve to evade predators and the predators to evolve to catch the prey.

The Cambrian period was followed by three rather short periods: the Ordovician, which was essentially an ice age; the Silurian, when plant life emerged from the tidal flats and began to take hold on the continents; and the Devonian, when amphibians crawled out of tidal pools and began to populate the continents with animals. By the end of the Devonian, all of the mechanisms that control modern climate were present on Earth, albeit in rather primitive form.

3.4 The Permian Cycle: Pangaea.

After the Devonian Period we have my favorite period: the Carboniferous Period. At this point a new mega-continent was beginning to form on the Equator called Pangaea. Life on the continents was fully established and now the modern climate mechanisms could interact.

The Carboniferous Period is known for three things. The name comes from the fact that the world's largest and highest quality coal beds were formed in the Carboniferous[1]. A major reason for the high quality of those coal beds is forest fires. The second thing that is unique to the Carboniferous is the oxygen levels, which were almost twice what they are today. If you struck a wooden kitchen match in the Carboniferous, it would literally explode in your fingers. This meant that droughts were not necessary for forest fires. A lightning strike could cause underbrush full of sap to burst into flame. Every time the brush was cleared by one of the incessant forest fires, another layer of almost pure carbon would be laid on the peat bogs.

The last thing the Carboniferous was famous for was insects, so much so that paleontologists refer to it as the Age of Insects. The insects were huge: dragonflies with one meter wingspans; beetles the size of German Shepherd dogs. Their size was due to the high levels of oxygen in the atmosphere. Insects breathe through their skins and, consequently, they are victims of the square-cube law of physics: as a body grows in size, its surface area increases as the square of the radius while the volume grows as the cube of the radius. Therefore, insects are limited in size by the amount of internal organs they can support with respiration through the area of their skins. In the Carboniferous, the higher oxygen content enabled more efficient respiration, hence large insects. (Larger animals today have lungs with fractal-like tissue whose total surface area is vastly larger than that of their surface skin.)

Another characteristic of insects is that they tend to have the highest metabolisms in the zoological taxonomy. That is, they do more respiration in proportion to body weight than other critters. You can verify this by observing an ant carry a leaf morsel back to the nest. That morsel may by five times the ant's body weight, but he moves right along over the five meters back to the nest. That is equivalent to a man carrying 500 kilograms at a sprint for a hundred meters; it just isn't happening.

As Pangaea formed near the Equator, it was a tropical paradise with lots of plants for the giant insects to eat. With their high respiration, the insects caused respiration to beat photosynthesis by a considerable margin and the planet warmed up rapidly. However, the forest fires and all that high respiration also scrubbed oxygen from the atmosphere. Towards the end of the Carboniferous the oxygen levels were dropping like a stone and the insects began to devolve back to sizes nearer to what we see today.

The Carboniferous Period was followed by the Permian Period. Early in the period, Pangaea finished forming near the Equator and a new group of critters took over the Earth from the shrinking insects. The Permian is known as the Age of Reptiles. The Permian was nature's first try at large land animals, and the reptiles were not very efficient in their movement. Though their respiration wasn't as great as the insects, it was still pretty high due to that inefficiency and the Permian continued to warm at a rapid rate.

1. Coal forms in cool, wet climates like present day Ireland. In such climates we have a lot of peat bogs. Peat is a soil that is very high in organic matter. When the peat is buried and subjected to high pressure and temperature, the water is squeezed out and the organic matter is "refined" to form coal. Even today some Irish farmers cut peat blocks out of the bogs in the spring and let then dry in the sun. Then they burn them as fuel in the winter.

By the Middle Permian, though, Pangaea began to break up and the continents started their random walk to the poles. As they moved, they passed through the Hadley desert zones, which were larger and harsher than today because of the increased temperature. This restricted the reptiles' habitats and reduced their population, which reduced their respiratory contribution to atmospheric CO_2.

By the Late Permian, the Earth was poised to start cooling as photosynthesis was about to lead respiration. Alas, a major plateau basalt formed in what is now Siberia and it erupted nearly continuously for about 1m years. That raised the temperature of the Earth by about 5°C. At this point the average temperature of the Earth was around 35°C and the Hadley desert zones were badly squeezing the reptiles. The result was a lengthy period of mass extinction.

But the worst was yet to come. Because of the elevated temperature driven by the high respiration of insects and reptiles, the shallow oceans warmed enough to warm the sediments of the outer continental shelves. That caused a catastrophic sublimation of the methane clathrates in those sediments. That released vast amounts of methane into the oceans and atmosphere. That asphyxiated the life in the shallow seas over continental shelves and raised the temperature of the Earth another 5-8°C. That was the culmination of the worst mass extinction in the geologic record where nearly 95% of carbon-based species went extinct. The cyanobacteria that replaced life in the oceans made the Earth look like a red planet from space, rather than blue, as red tides covered large areas of the oceans.

As an aside, I should point out that the Carboniferous and Permian periods support the Gaia Hypothesis, if one regards the huge insects and inefficient reptiles as nature's first tries at populating the continents with animals to replenish the dwindling atmospheric CO_2. In other words, it took the planet a couple of tries to get it right.

3.5 The Dinosaur Cycle

At the end of the Permian, there was no ice age as the continents reached the polar regions because the continental masses we know of today as South America, Antarctica, Australia, and India remained near the Equator as a small mega-continent known as Gondwanaland.

The Triassic Period that followed the Permian is notable for its reddish sedimentary rocks. With almost all the life on the surface of the continents gone, there was no protection for the soils and the iron in them oxidized to rust red. (It only takes tiny amounts of metals like iron and manganese to stain entire sedimentary beds.) By the end of the Triassic, though, life returned to the continents and a new group of critters came to dominate: the dinosaurs.

The dinosaurs were much more efficient in their movement than the reptiles, so when Gondwanaland was augmented by returning land masses from the poles and repopulated, the Earth's temperature did not rise as rapidly as it did in the Carboniferous and Permian periods. However, it did rise as the tropical zone spread into higher latitudes as dinosaur respiration exceeded photosynthesis scrubbing. The heyday of the dinosaurs was the

Jurassic Period, which followed the Triassic, and the Early Cretaceous Period that followed the Jurassic.

By the Middle Cretaceous, though, Gondwanaland broke up and the continents began to move towards the poles again, passing through the Hadley desert zones. This reduced the habitats for giant herbivores and the dinosaur population began to decline. Just as the temperature cycle was about to switch over from warming to cooling, another plateau basalt erupted in what is now India. This plateau basalt raised the Earth's temperature by another 3-4°C, expanding the deserts and making things even harder on the dinosaurs.

3.5.1 Dinosaur seppuku

The dinosaurs also contributed to their demise in a major way. To explain why, I need to talk about East African elephants today. If you fly over the savannas in East Africa in a light plane, you will see that they are criss-crossed with trails. The most permanent of these trails, lasting a decade or more, are made by elephants. I have observed an elephant herd on the move and they travel in roughly single file along a track about 10m wide. After the elephants pass, that track is complete devastation. Every blade of grass is broken off and trampled into the dust. Every tuft of grass that can be gripped by a trunk is uprooted. Every shrub is uprooted. Every young tree with a bole less than 15cm in diameter is either uprooted or head-butted until the bole snaps off so the elephants can reach the leaves.

If the track is made just at the end of the rainy season, the last rains will pack the dust down into mud. The ensuing dry season bakes that mud into a clay known as Caliche. Caliche is impermeable and rock hard. It can't be shoveled; a pick ax is necessary to break it up. So it takes a couple of decades before plants are able to reclaim the tracks. I cite this as an example of the devastation African elephants can create, but it isn't the real problem.

Any game warden at an African game preserve will tell you that the elephant herds must be culled every few years (that was in the '60s when I was there; poachers more than handle the culling now) or else they will devastate the game preserve. The reason is that East African elephants forage on the edge of forests because they need to eat about a quarter ton of vegetation per day. When they forage, they eat all the young trees. When the older trees die, they have no replacements at the edge of the forest, so the forest recedes. In other words, African elephants deforest the continent.

In contrast, this is not true for Asian elephants. Asian elephants live spread out within the forest. In Asia, the apex predators (tigers, leopards) capable of taking down an elephant calf are solitary hunters. A mother elephant can protect her calf in dense forest growth by simply keeping the calf behind her. So the Asian elephants can spread out their foraging through the forest so that the damage is minimized.

But in Africa, the apex predators, lions, are excellent pack hunters. I have seen a herd of African elephants under threat. They form a ring around the calves with tusks outward. They can do this quickly and easily in semi-open areas, but it is very difficult to do and maintain in dense forest. Thus the East African elephants are careful to forage only around the edges of the forest where their damage is concentrated. The African savannas are extensive and most of that area has been natural grassland for 10,000 years. Nonetheless, a substantial portion today was once virgin forest.

We know that the apex predators in the Jurassic and Cretaceous were mostly pack hunters (the legendary T-Rex being a notable exception that simply stole other predators' kills). Thus the huge dinosaur herbivores would have to forage around the edges of forests to enable forming defensive rings. Imagine what herbivores five times the size of today's elephants would do to the planet's forests over the roughly 100m years that they ruled the planet. In collaboration with expanding Hadley desert zones, they turned the entire planet into an Easter Island[1] and helped drive themselves to extinction.

The reason I spent time on the dinosaurs' role in their own extinction is because history is repeating itself today. We are the modern day dinosaurs as we deforest the planet to support farms, pastures, and urban sprawl. In so doing, we are changing the balance of photosynthesis and respiration to change the climate. If we were not in the trough of the long-term temperature cycle, we would be driving ourselves to extinction, just like the dinosaurs.

You will note that I made no mention any asteroids in this discussion of the extinction of the dinosaurs. A geochemist studying the K-P boundary with the Iridium layer indicting an asteroid collision, made an erroneous conclusion based upon two facts: (A) there are no land dinosaur fossils at all in rocks younger than the K-P boundary and (B) there are vast numbers of full dinosaur skeletons from the Triassic, Jurassic, and Cretaceous Periods older than the K-P boundary. Because he was not a paleontologist, he was unaware that there are no dinosaur skeletons in the rocks immediately beneath the K-P boundary either. Because the idea makes great copy, the media ran with it and has created an urban legend.

The paleontologists who do specialize in dinosaurs have three persuasive reasons for asserting the dinosaurs were already gone when the asteroid hit. The first is related to the fact that the K-P boundary is the most heavily investigated piece of geologic real estate on the planet. I recall a picture of a geologist hanging in a bosun's chair halfway down a 1000' cliff hammering away with his pick. He was looking at the K-P boundary. Geologists have hired bulldozers to peel away thousands of tons of overburden to get a look at the K-P boundary in the bedrock below. If the asteroid killed every dinosaurs where it stood, one might expect to find a complete dinosaur skeleton on the K-P boundary. To date, no continental dinosaur fossil of any kind (other than birds, today's descendants of dinosaurs) has been found on the K-P boundary.

1. For those not familiar with the story, Easter Island was a tropical paradise that supported a population of several thousand people at its peak. For religious reasons the people carved giant stone heads and planted them on the island's beaches. To get the heads from the quarry to the beaches, they had to be rolled on large logs. The logs would splinter and had to be replaced several times for each head. By the 19th century there were no trees left on the island and less than 1000 people remained, eking out a subsistence existing fishing. When the trees were gone, the ecology and the islander's civilization collapsed.

It turns out that lack of fossils on the boundary itself is not very compelling, statistically. When we look at the K-P boundary in a rock outcrop, all we see is a line; the actual boundary surface extends into the outcrop were we can't see it. Though the K-P boundary is exposed in a lot of places around the world, it is somewhat less than even money that a dinosaur was standing exactly on that line when the asteroid hit.

A much more compelling argument is that there have been no dinosaur skeletons found in the 3m of sediment *below* the K-P boundary. Only six dinosaur fossils have been found in those 3m anywhere in the world. Each of those was a fragment of a single dinosaur bone, indicating the dinosaur died elsewhere and then the skeleton was broken up and spread out by erosion.

The most compelling argument, though, is the nature of the rocks below the K-P boundary. The sedimentary rocks in the 3m below the K-P boundary represent a hot, dry climate almost everywhere in the world. A large fraction of the sediments are *loess* (sand dunes). There is no way dinosaurs that needed to eat two tons of food a day to live could survive in such climates. This argument is even more compelling because if you have three sites a few hundred miles apart with the same climate, it is very likely that everything between those sites had a similar climate.

Also note that the continents passing through the Hadley desert zones reduces habitats permanently, so far as reoccupation is concerned. Passing through the zone acts much like a windshield wiper across a windshield. Once a desert prevails coast-to-coast, there are no large animals left to repopulate it even if the continent moves into the wet zone of the next Hadley cell. This is the main reason why a new taxonomy of animals takes over at the beginning (mega-continent formation in the tropics) of each long-term temperature cycle. Between the Hadley desert zones and deforestation, there just weren't any dinosaurs left when the asteroid hit[1].

3.6 The Quaternary Ice Age

With no large land animals left, the planet cooled in the very short, modern geologic periods that followed the Cretaceous. That brings us to roughly 3m years ago. At that time it would have been possible to recognize all of today's continents. They would have been shaped somewhat differently and been in somewhat different positions, but recognizable nonetheless. However, there was one major difference compared to today's world map. The Americas were not linked through a contiguous land bridge. Instead, there was a maturing island arc located where Central America is today.

This drastically affected the THC. After crossing the Atlantic, the Gulf Stream was not blocked by land, forcing it to turn north. Instead, it could flow through the island arc and

1. This is, perhaps, not strictly true. Conceivably there could have been some isolated pockets of small dinosaurs in protected coastal zones that survived the climate disaster and geologists haven't found them because plate tectonics reworked them. But the large populations like the Jurassic and Early Cretaceous were simply not possible by the time the asteroid struck.

join the South Australia Current. This difference led to two dramatic climate effects. Today the South Pole has harsher winters than the North Pole, but 3m years ago the North Pole had much harsher winters than the South Pole because it was getting no heat transfer at all via the Gulf Stream and there was no Atlantic gyre. In contrast, the South Australia Current was augmented by the heat transfer of the Gulf stream. While Antarctica was not quite over the South Pole yet, it was mostly more than 60° south latitude. Yet Antarctica has tropical plant fossils from 3m years ago and the Earth's average temperature was about 7°C warmer than present (close to the mean temperature for the past 500m years).

This didn't last. Volcanoes were steadily filling in between the islands of the Central American island arc. 2.6m years ago the last passage was filled and the Gulf Stream was blocked from passage to the Pacific. The Gulf Stream leg of the THC was shut down and the heat transfer of the South Australia Current was drastically reduced. This resulted in the largest rapid[1] climate change in the known geologic record -- about 14°C as the planet dropped into the first glacial phase of the Quaternary Ice Age.

4.0 Our Interglacial Hiatus

We are presently living in the fifth interglacial hiatus during the past 800,000 years. I am devoting an entire section to it for two reasons. First, the four previous interglacial hiatuses were much shorter than this one, so I have to anticipate a GWC argument that the Quaternary Ice Age is over. (The GWC always refers to the last glacial phase as 'the last ice age' as if the Quaternary Ice Age was completely over.) The second reason is that the termination of this interglacial hiatus is extremely important to the future of human civilization and possibly the survival of the human species.

The temperature record for this hiatus is shown in Fig. 4.1. The first thing to note is that the hiatus actually started nearly 15,000 years ago. (The graph includes 2,000 years AD.) However, after several hundred years, the nascent hiatus suddenly terminated and dropped back into the deep freeze for nearly three thousand years.

The reason was that initially a large lake formed in northern Canada due to melting ice sheets as the climate warmed. That lake was far larger than the Great Lakes system and possibly as large as Hudson's Bay. It was blocked from the North Atlantic by ice dams. Eventually, though, the water began to flow over the top of the ice dams. Once the water began to flow, the ice dams gave way very quickly. The result was a flood of truly biblical proportions, moving boulders the size of small houses for tens of miles in the torrent. That torrent of fresh water flowed into the North Atlantic and immediately shut down the THC, which terminated the hiatus and drove the climate back into a glacial phase of the Quaternary Ice Age. The evidence of that flood is solid proof for the mechanism that terminates interglacial hiatuses due to the tangible evidence of the flood.

1. Rapid in a geologic sense. It actually took thousands of years for the island arc's volcanoes to completely separate the Atlantic from the Pacific.

It took about 3,000 years for the THC to start up again, where the second rapid warming begins, nearly 12,000 years ago. About 10,000 years ago the Earth's average surface temperature reached the tipping point and the THC shut down again. But the Earth did not plunge back into a glacial phase. Instead, the hiatus has endured for 10,000 years to the present. The reason this interglacial hiatus has lasted so long is due a remarkable set of coincidences related to supervolcano eruptions.

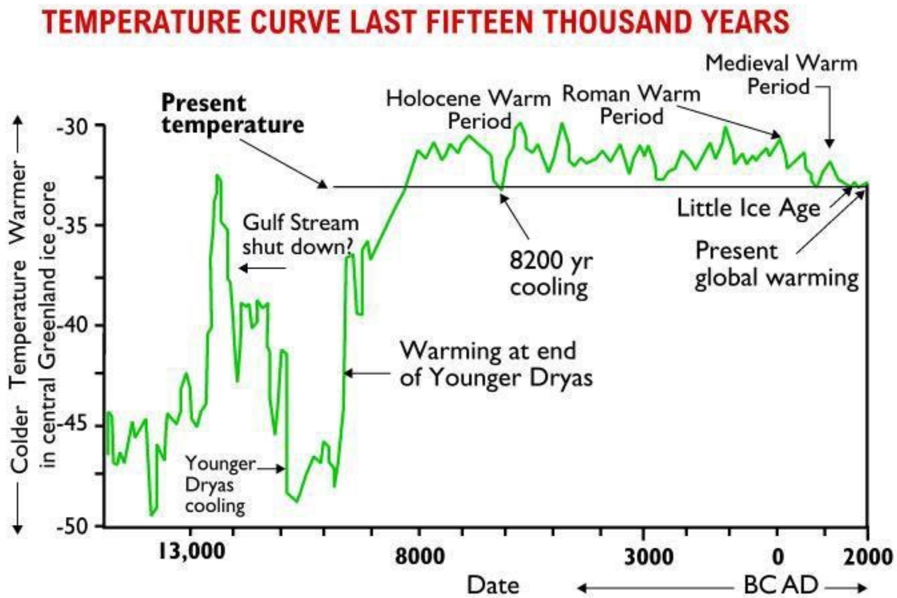

FIGURE 4-1. Temperature of the current Interglacial Hiatus.

The first cluster of supervolcano eruptions occurred 10,080, 10,115, and 10,957 years ago, just as the THC started to collapse. Another cluster occurred 7,177, 7,572, and 7,793 years ago to increase atmospheric CO_2 as the Earth began to cool again. Other, somewhat smaller eruptions occurred 1, 491, 2,376, and 4,860 years ago, adding more atmospheric CO_2. (These were not all supervolcanoes, but they were the eleven largest eruptions of the time.)

When the THC shut down at the tipping point, the supervolcano eruptions put enough CO_2 in to atmosphere to cause a standoff with the cooling of the North Atlantic and Southern Oceans that prevented the positive feedback collapse of oceanic evaporation. The subsequent eruptions replenished the CO_2 of previous eruptions to maintain the standoff. Thus these eruptions extended the present interglacial hiatus well beyond the usual time for such hiatuses. By about 1,000 years ago, the THC began to start up again and the eruptions ceased.

Extending the hiatus made it possible to develop the highly technical civilization we have today. It took 10,000 years for Man to work through the Stone, Copper, Bronze, and Iron

Ages. Without those eruptions the hiatus would have terminated 10,000 years ago and we would still be hunter gatherers. The most remarkable coincidence of all is that this all happened just after CO_2 levels fell to 200ppm, threatening all plant life on Earth -- especially when one considers that only a technical civilization has a chance of preventing a further long-term decline in CO_2 levels. In other words, this interglacial hiatus provides the strongest support yet for the Gaia Hypothesis.

We are now back at the tipping point. Will this hiatus terminate now, just like the previous ones? That is very likely. The only thing that could prevent it at this point is the eruption of the Yellowstone supervolcano, which would be a cure that is almost as bad as the disease. You will recall that the oceanographers' models predicted several things that would happen during a catastrophic shutdown of the THC. Let's look at whether any of these things have occurred yet:

1. ***A reduction in the salinity of the Gulf Stream***. The salinity near Scandinavia started to drop in the late '80s and the rate of decrease has steadily increased since.
2. ***World-wide erratic weather.*** An increase in erratic weather events began in the mid-'90s and weather has been becoming more erratic ever since.
3. ***The volume flux of the Gulf Stream decreases***. The volume flux of the Gulf Stream decreased by slightly more than 30% in the '00s decade (measured on the abyssal plain).
4. ***A plateau in the Earth's temperature despite rising atmospheric CO2***. The temperature plateaued in the mid-'90s. (There is a lot of variance, but the least squares fit is flat. I'll have a lot more to say later about NOAA's "reanalyisis" that made it go away.)
5. ***The middle layers of the North Atlantic and Southern Oceans begin to warm***. This warming was observed in 2014.
6. ***A sudden drop in the Earth's temperature of 3-4°C in a few decades***. This has not happened yet, but we are only 35 years into the 40-60 year cycle.

A return to a glacial phase of the Quaternary Ice Age could be disastrous. When the last hiatus terminated a little over 70,000 years ago, Man's population dropped from on the order of 10 million to a gene pool of about 5,000 -- and as hunter-gatherers, they were much better able to live off the land than we are. Civilization is likely to completely collapse, so the major technical capability carried into the glacial phase will be the ability to make crossbows rather than spears.

The collapse of civilization will be due primarily to the increase in erratic weather. The geologic record tells us that we have not seen the worst of it by a large margin. One example is ARkStorms. These are hurricanes (Atlantic) or cyclones (Pacific) that form so rapidly that they appear to be a single storm when they make landfall. The ARkStorm's landfall can last several weeks with 200mph winds and dumping hundreds of inches of rain. Another example is ice storms. These can be so severe that they break off all the limbs of all the trees in a forest (even conifers that are designed to bear ice weight), leaving nothing but telephone poles. In the past, such storms have devastated forests in temperate zones over areas of hundreds of square kilometers. Such storms would bring down every power transmission line and many of the towers in an entire transmission grid.

We simply do not have the resources, equipment, or experienced personnel to repair such damage in anything less than a decade. Most of the G7 nations are in north temperate zones. When the power goes off and the computers shut down, the infrastructure for moving goods, including food and medicines, around the world will collapse. As temperatures drop and growing seasons shrink in temperate zones, the people there will try to migrate to the tropics, which will result in warfare because the equatorial nations simply can't absorb such large populations.

Now you may begin to understand why I believe the GWC is worried about the wrong problems. The GWC is in complete denial about the termination of the present interglacial hiatus. As a segue to the next section of the blog, I would like to talk about how the GWC responds to the evidence of a catastrophic shutdown of the THC. They employ three basic tactics: they ignore the data; they co-opt it as being due to increasing atmosphere CO_2; and they simply "cook" the data to get the answers they want. Evidence of a return to a glacial phase of the Quaternary Ice Age, especially the temperature plateau, is in direct conflict with most of the GWC message. As a result, some members of the GWC resort to outright scientific fraud to refute it.

1. ***Gulf Stream salinity reduction***. The GWC simply ignores this data as irrelevant. For example, I could find no mention of it on the IPCC website.
2. ***Increase in erratic weather***. The GWC simply co-opts these data. In recent years you have seen many GWC statements that the erratic weather is evidence of climate change *due to global warming*. In fact, the increase in erratic weather has nothing to do with atmospheric CO_2; it is caused by disturbances in the planetary heat flows. Given that atmospheric CO_2 and the Earth's temperature have been steadily increasing for two hundred years, one should ask: why did weather only start becoming abnormally erratic in the mid-90s? Why not in 1950? Or 1850?
3. ***Reduction in Gulf Stream volume flux***. If you go to the IPCC website, you will find two papers about changes to the Gulf Stream cited. One measured the surface velocity of the Gulf Stream as a surrogate for the volume flux. The other did a statistical analysis of satellite radar scans to determine sea level (since the Gulf Stream is less dense, it should bulge upwards slightly compared to surrounding waters) as a surrogate for volume flux. Both papers concluded that variations in Gulf Stream volume flux "were within normal variance".

   The way oceanographers measure volume flux is by driving a boat across a current at right angles to it. They hang a long cable off the end of the boat with clusters of instruments to measure temperature, salinity, etc.. There is a flow meter in each cluster. This technique provides a direct in situ measurement of the actual volume flux[1]. Which do

1. Truth in advertising. The 30% reduction in the Gulf Stream volume flux I cited was not measured at the surface. It was measured on the abyssal plain at the Scandinavian down-welling point. It was an in situ measurement, but it was more complicated. The surface currents of the THC are not losing power as fast as at the abyssal plain currents. The water just can't sink as powerfully anymore.

you find more compelling: a direct in situ measurement of volume flux or surrogates based on surface velocity and sea level differences? By the way, I found no mention of the oceanographer's in situ measurement on the IPCC website. Another example of scientific charlatanism in only using the data that agrees with your position.

4. ***Warming of the middle layers of the North Atlantic and Southern Oceans***. The most comical reference to this warming was an early GWC response to the temperature plateau. The paper noted that the heat needed to raise the temperatures of those middle layers almost exactly equaled the heat that was added to the greenhouse via CO_2 growth in the same period. The conclusion was that global warming was continuing, but the heat was temporarily going into those middle layers of the oceans. There are so many things wrong with this that I got a stitch in my side from laughing. I checked to see whether the paper was published on April 1 (April Fools Day) or in the Journal of Irreproducible Results (the science humor journal). The first question one might ask is a variation of the one above: given continuous warming for the past two hundred years, why did the heat only start going into the middle layers in the 21st century? The second question one might ask is: the greenhouse effect is global, so why did the heat just go into the middle layers of two oceans? The third question to ask is: why is this a temporary effect? The last question one might ask is: what is the magical heat teleportation mechanism that transfers heat from the atmosphere to the middle layers of the ocean without changing the temperature of the surface layers?

5. ***The temperature plateau***. This plateau is an enormous problem for the global warming message. I will provide one response in the next section because it is mainly about the way data is presented. Another response came a few years ago as NOAA "reanalyzed" the temperature for the past three decades. They came up with the graph in Fig. 4.2. Quelle surprise! The plateau has disappeared!

   When I first saw this conclusion, I was highly suspicious. I assumed they had tinkered with the algorithms for the actual averaging. It turns out this is very complicated because of the distribution of weather stations. (Large areas of the world have no weather stations and in other places they are very densely packed, so a lot of interpolation and weighting is required.) In fact, NOAA hardly touched the algorithms. The main change of the "reanalysis" was to add weather stations.

   As soon as I saw this, the sampling alarm klaxons went off in the back of my brain. NOAA switched databases for the "reanalysis", moving from the GHCN (Global Historical Climatology Network) database to the ISTI (International Surface Temperature Initiative) database. The ISTI database is a superset of the GHCN database. So I went to the ISTI website to see where weather stations had been added.

   I found some very helpful diagrams. Each one was a small world map with colored dots. The colors indicated the source and the dots indicated the location of the stations. There was a map for each update of the database. I went through the maps in chronological order to see where stations were added. It only took a few diagrams for the pattern to become clear. The stations were added in areas of fastest warming (e.g., polar regions, where the Fulcrum Effect gradient is rising fastest, and desert areas). Interestingly, NOAA's own 1600 deep sea buoys were not included. That's because they were arrayed in two parallel lines along the Equator where the temperature is not changing at all.

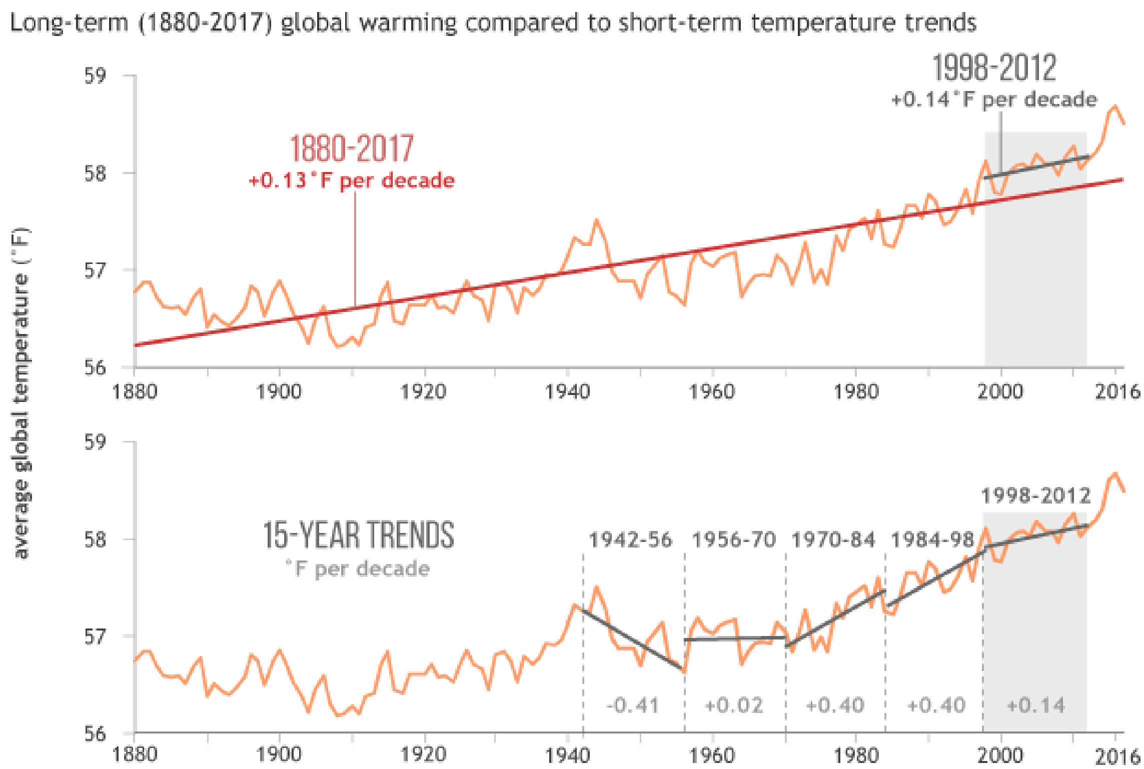

FIGURE 4-2. NOAA reanalysis curve.

In other words, NOAA cooked the data to get the answer they wanted (no plateau) via sampling that was weighted towards warming. But the story doesn't end with this outrageous scientific fraud. I talk to a number of people about global warming. One was an old friend who is currently using global warming to justify an economic policy he is advocating. He was very interested in what I had to say and did his due diligence by relaying my views to a climate scientist he knew. The climate scientist responded that there was no problem. Various climate scientists use the ISTI database for a wide variety of purposes and each one uses a *subset* of the data that is appropriate to their purpose. This did not give me a warm and fuzzy feeling because the most obvious purpose for NOAA would be to eliminate the plateau that contradicted their global warming message!

About a month later I referred someone else to the ISTI database to check the data themselves. They couldn't find the data. I went to the website and all those helpful little diagrams were gone. They were replaced by a single table with source, date, and number of stations, but no location data. They were in such a hurry to get rid of the location data that the table didn't fit in the web page frame and they forgot to put scroll bars on it, so the bottom of the table was not visible.

I went back to my friend and asked him if the climate scientist he talked to had any connection to NOAA and/or ISTI. It turned out he used ISTI extensively and was on a first name basis with several people there and at NOAA. Did ISTI remove the data from the website in response to my comments to my friend? I can't say for sure, but it seems like an amazing coincidence that the location data suddenly disappeared less than a month after my friend relayed my views to the climate scientist.

In other words, NOAA's "reanalysis" deliberately cooked the data to eliminate the temperature plateau and, when they were caught with their hand in the cookie jar, they scrambled to cover it up.

5.0 How the GWC Promulgates Their Message

The GWC has a wide variety of techniques that they use to spread their message in both the scientific and public domains. In this section I will discuss these in five broad categories: fundamental approaches; the scientific domain; the public domain; detailed examples; and control of research.

5.1 Fundamental Approaches

The most common approach to promulgating the GWC message is being highly selective of the data that they use to justify their positions. I won't belabor this because this presentation has been littered with examples of facts that the GWC doesn't like to talk about because they are contrary to the message.

The GWC employs three tactics to deal with contrarian facts. The first tactic is to simply ignore them, like the increase in salinity of the Gulf Stream. The second is to co-opt or recast them, such as associating increasing erratic weather with global warming rather than shifting THC heat transfers. The third is to provide research that refutes the inconvenient facts, which can involve scientific charlatanism or fraud.

All three approaches are justified by the GWC's almost religious belief in the message. Because of their faith in the message, they *know* the truth so any contrarian evidence is obviously wrong. That certainty of the imminent economic and ecological disasters associated with continued global warming allows the GWC to embrace the notion that the ends justify the means when trying to refute inconvenient facts.

Another fundamental characteristic is that the GWC is extremely myopic about carbon dioxide driving climate. This is probably because most of the GWC are meteorologists who are now calling themselves climate scientists and when the only tool you have is a hammer, the world appears full of nails. Of the tens of thousands of words on the IPCC, WMO, and NOAA web sites, there is hardly any mention of methane or water vapor affecting climate, much less the role of plate tectonics, Haldley cells, and oceanic heat transfers. Virtually the entire global warming message revolves around carbon dioxide as the sole driving force behind global climate.

5.2 Scientific Domain Approaches

The primary GWC approach to spreading their message in the scientific domain is a variation on the idea of *information cascade*. In this case dubious research, done by people with good credentials or working for organizations with good credentials, is accepted at face value by members of the scientific community in different disciplines. For example, I have seen two programs on TV edification channels where non-climate scienists stated that Venus was once a garden planet with permanent liquid oceans.

In fairness, I must be clear that this is not a problem that is unique to climate science. There is an important element of the scientific method that is largely ignored today: independent verification of the experimental results that justify converting hypotheses into accepted theories.

One reason for this is that experiments have become very expensive to reproduce. No one is going to fund building another Large Hadron Collider just to duplicate the work at CERN that found the Higgs Boson. (There is a new collider in the works that may eventually duplicate that experiment, but that isn't why the new collider will be built and at that price they probably have a long list of higher priority original experiments.)

A second reason for the lack of experimental validation is the notion of "publish or perish". One description of basic science is that there is no immediate financial gain from doing the research, so funding must come from governments and altruistic billionaires. Unfortunately, such funds are quite limited and there is fierce competition among the universities and nonprofit research corporations. Awarding the funds is based largely on the prestige of the research entity. Such entities gain prestige based on the original work of their researchers, not by having those researchers duplicate the original research done by other entities. Thus, there is a substantial disincentive for independent experimental validation.

Sadly, this has resulted in an increasing number of scandals related to irreproducible results from research in recent years all across the scientific community.

The GWC also uses peer pressure. You may have seen statements that 999 out of 1000 scientists support the global warming message. This is an old lobbyist trick. A lobbyist does a mass mailing to scientists with a questionnaire that has 3-4 questions. The questions are carefully worded so it is nearly impossible to say No. For example,

1. Do you agree the climate has been warming for two hundred years?

2. Do you agree that current global warming is due to Man's activities?

3. Do you agree that continued global warming could lead to serious economic and ecological problems?

Despite my rather contrarian views on the global warming message, even I would have to answer Yes to all three questions (with the caveat that it might takes tens of millions of years for the last point). If one returns the questionnaire, one gets counted in the 999 who agree with the entire message.

Another way for getting the message out is to control the research being done, but that is important enough for its own subsection later.

5.3 Public Domain Approaches

The GWC employs two basic approaches to the public domain: the media and the Internet. To understand how the GWC utilizes the media, I will do a thought experiment. Imagine you are a June Grad journalism graduate and you decide your first piece should be an article on global warming for your local newspaper's Sunday Supplement. For your article you need facts, but that presents a problem because your degree is in journalism, not climate science. Where do you get your facts?

You could spend three weeks in the library reading books on climate science, but that probably isn't a good use of your time -- especially when you are going be lucky to get a couple of hundred bucks for your piece. A more viable approach is to pick the brains of an expert in a one-on-one interview. Experts love to talk about their specialties and you can channel the conversation to focus it on things relevant to your article. So where do you find the expert? The obvious choice is in organizations whose charters say they know all things about climate change: IPCC, WMO, and NOAA.

Guess what message you are going to get from the people in those organizations. This why most media outlets have a pronounced editorial bias towards the global warming message.

A similar thing happens on the Internet. Bloggers provide a very useful service when they read arcane scientific papers and then translate them into language that lay people can understand. But where do climate science bloggers find the papers to read? The obvious place is from organizations whose charters indicate they know all things about climate science: IPCC, WMO, and NOAA.

If you search with a general query for anything related to climate change, the first few pages of listings your search engine provides will be for GWC bloggers who have thoroughly bought into the global warming message. That's because they cross reference each others' websites because that raises their priority with the search engines. So if you want to find any of the contrarian facts in this presentation you need to either be very specific in your query or skip past the first few pages to get to the academic websites.

5.4 Detailed Approaches

Perhaps the most ubiquitous technique used by GWC is the omission of contrarian facts. In the introduction I identified several things that the GWC simply doesn't talk about when promoting their message. Thus they talk stridently about how current CO_2 levels are the highest in 800,000 years without mentioning that we are living in an ice Age and atmospheric CO_2 reached the lowest point in the entire 4.6 billion year history of the Earth

12,000 years ago. Or IPCC waxes enthusiastically about the “man-made” die-off of shallow marine life without mentioning that the current die-off is the ninth such in the last 800,000 years, starting long before Man existed.

In my experience with the GWC literature, I find that whenever I encounter a surprising fact or assertion related to the message, I need to look for the back story to see what context information they are not telling me.

In print media or lectures, there are all sorts of tricks that can be used to wrap facts in ways that present a particular editorial viewpoint. Political writers on both the far right and far left are notorious for being short on facts, but very long on strident rhetoric and bombast. Much of the GWC literature, especially the bloggers, has similar stridency. Thus IPCC refers to *all* of the economic and ecological impacts of global warming as “catastrophes”, when only one of them qualifies for that designation and it can’t happen until tens of millions of years from now.

Discussions can be written in ways that invite the reader to erroneous conclusions that are not actually justified by the discussion. A common example is to introduce one fact in the first sentence of a paragraph and a second fact in the last sentence of the paragraph. The intervening sentences then imply a causal relationship between the facts when none actually exists. For example, IPCC talks about methane clathrates that are currently sublimating in some tundra areas due to melting of permafrost due to global warming. IPCC then talks about the enormous quantities of methane clathrates on the continental shelves and then the dire consequences of their sublimation. The connective context strongly implies that the clathrates on the continental shelves are very close to sublimating right now, rather then in tens of millions of years.

Another common technique is the presentation of data in ways that invite erroneous conclusions. Figure 5.1 is an example of this. This diagram is found on a number of GWC web sites. The diagram purports to describe the carbon cycle, which transfers carbon, usually in the form of CO_2, back and forth between the atmosphere and the surface of the Earth. I use the word ‘purports’ advisedly because the real purpose of the diagram is to present three elements of the GWC message: (1) global warming is all Man’s fault; (2) without Man’s actions the natural processes would be in prefect balance; and (3) there is great danger in what Man is doing.

The first thing to note about the diagram is that all the natural processes are in muted pastels, but the eye is drawn to the very bright red in the center of the diagram. Bright red conveys interpretative baggage like ‘Stop!” and ‘Danger!’ The red, of course, is Man’s activities. If one does the math, the red numbers exactly match the total annual surplus of CO_2. Thus, this diagram practically screams the various elements of the GWC message.

However, the numbers in the diagram are purely fictional and have nothing at all to do with how the carbon cycle works. For example, there are processes for plant respiration and microbial respiration, but no process for animal respiration. If animal respiration were presented without changing the rest of the numbers, the CO_2 surplus would be gigantic. The numbers that are present for the natural processes are essentially arbitrary because we do not have sufficient data for them. For example, to quantify plant respiration, we would need to identify every species of plant, test the respiration for every species in the lab, and estimate the proportion of the total plant biomass that each species represented. We simply don't have those numbers. Every time a botanist goes into a tropical rain forest, he comes out with a dozen new species of plants. If we put error envelopes on each of the natural processes, they would probably be something like -75/+300%.

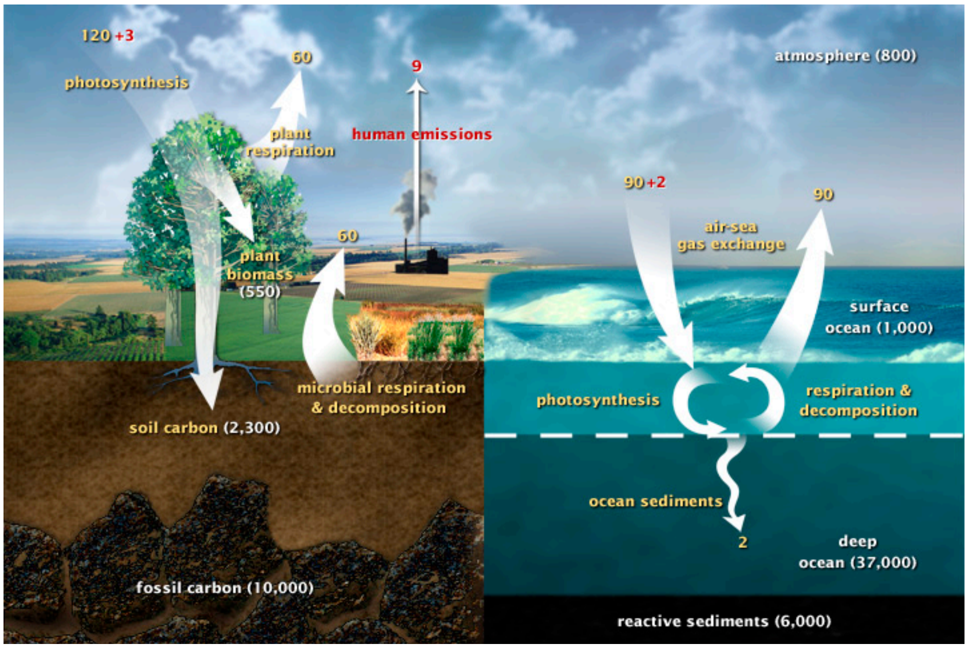

FIGURE 5-1. Carbon cycle.

We do know some numbers on the diagram fairly accurately. Currently Man produces slightly less than 15 billion tons of atmospheric CO_2 by burning fossil fuels for energy each year. (Every major intelligence agency has people pouring over satellite photos analyzing power plants, auto factories, and the like to determine other nation's capabilities.) The diagram understates that as 9 billion tons. We also know that the total atmospheric CO_2 is about 5.3 trillion tons. The diagram says it is 600 billion tons; an understatement of nearly an order of magnitude. The only possible reason for these discrepancies is that the numbers are completely fictional and the author simply made them up to deliver GWC messages.

In contrast to the Carbon Cycle diagram, the graph in Fig. 5.2 is accurate, as far as I know. An interesting thing about this graph is that the GWC would normally not have it on their web sites because the units are in parts per million. When talking about Man's production of CO2, the GWC prefers to talk about billions of tons per year, because that sounds like a lot more than five ppm.

Nonetheless this diagram does appear on GWC web sites because it very subtly conveys the GWC messages: it's all Man's fault; it's due to burning fossil fuels; and if it weren't for Man, the natural processes would be in perfect balance and Mother Nature would take care of us all.

Looking closely at the diagram, it seems strange that it includes the period 1750-1770 because the cumulative CO_2 was flat (i.e., everything was in balance so atmospheric CO_2 was not changing, which is exactly the point they are trying to make). In fact, CO_2 was increasing during those decades, just not as rapidly as during the Industrial Revolution. However, the scale used to emphasize the dramatic rise in CO_2 during the Industrial Revolution makes that smaller rate of increase seem flat.

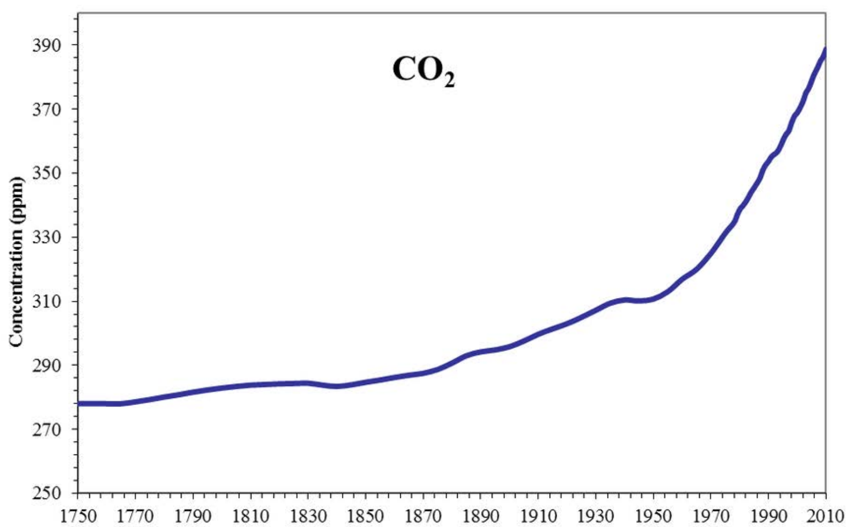

FIGURE 5-2. Cumulative atmospheric CO2.

The message that it is all Man's fault due to burning fossil fuels depends on the viewer not having slept through their high school history class. An obvious question is: why does CO_2 take off so dramatically at the beginning of the nineteenth century? Aha! That was the beginning of the Industrial Revolution! And to run all those factories, we needs lots more energy. So the sudden increase must have been due to burning fossil fuels for energy! Of course! And just in case you did sleep through the history class, the blogger will helpfully point out the start of the Industrial Revolution at the beginning of the nineteenth century.

The reality is that those conclusions are largely erroneous for the nineteenth century and only partially true for the twentieth century. During the nineteenth century, the only industrial energy derived from burning fossil fuels was steam and that was limited primarily to railroads. Factories were all located on rivers and they got their power from paddle wheels and delivered it to the machines on the factory floor via belts and spindles. It was not until the development of industrial strength electricity about 1890 that fossils fuels were used in substantial quantities for energy to run factories.

Even in the last and current centuries, burning fossil fuels for energy accounts for only about 25% of the annual CO_2 surplus. Another 25% is a direct result of other activities, such as cement manufacture and fertilization. As I pointed out earlier, the remaining 50% is probably due indirectly to Man's expansion via deforestation, but we don't have sufficient data to prove or disprove that.

Fig. 5.3 was an early attempt to refute the temperature plateau that began in the mid-90s. It was the centerpiece of a paper that argued that the Earth's temperature for the last three decades was rising sharply, rather than being plateaued. Nonetheless, I was very skeptical because by that time I did not trust anything the GWC says. So I went to the original article and read it carefully.

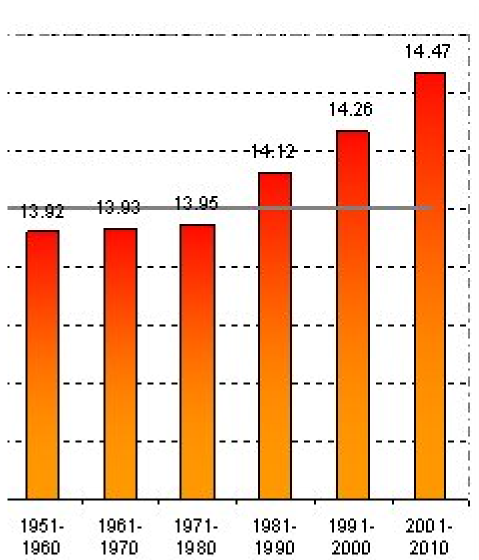

FIGURE 5-3. Wolrd temperature rise.

The first thing to note is that the numbers are off. At about 1990 the average temperature of the surface of the entire Earth reached +15°C, but none of the numbers are close to that high. The article only referred to the "temperature of the Earth". Clearly they had some other standard for the temperature of the Earth, which the article didn't clarify.

When I read the article I found a sentence about what the authors actually did. The temperature they are talking about is not the average temperature of the Earth. Instead, it is an average of peak values of whatever temperature they were using. Thus, what we are really looking at in the graph is an increase in erratic weather. In other words, if one averaged the minimum values, the bars would go down just as rapidly as the peak values go up.

I regard this as going beyond simple scientific charlatanism. I spent a good portion of my career modeling processes to understand how they work. There are a number of tools one uses in such modeling, such as sensitivity analysis where all inputs but one are held constant to understand how strongly a particular input affects the results. Another tool is examining boundary conditions. Peak values are a form of boundary conditions. I cannot imagine a competent researcher examining peak values without also examining minimum values. If one looks at both, it is obvious that the mean will be in the middle. So representing peak values as average values is not some simple typo; it is deliberate scientific fraud.

Unfortunately the GWC employs peak values all the time to support their position. We are bombarded with assertions about the hottest day, the hottest week, the hottest month, the hottest year, or the hottest decade on record to support the assertion of increasing global warming. Almost always these assertions are based on local weather and/or peak values rather than global average values. The GWC never talks about record breaking winters with so much snow cover that it results in record breaking floods the next Spring, such as 2020 in the central US.

Fig. 5.4 shows a pair of diagrams published monthly by NOAA. The top diagram displays the raw differences in temperature around the world for the given month compared to a datum in the past (identified in the diagram title). The differences are color coded so blue shades represent cooler temperatures at present than in the past and brown/red shades represent warmer present temperatures. The second diagram ostensibly takes those same differences and converts them to a percent change with the same color coding conventions.

As an exercise, take a look at these diagrams and see if you can identify an inconsistency between the diagrams.

The difference is that some blue areas in the top diagram are brown in the bottom diagram. If all you are doing is computing a percentage change from a difference value, the sign does not change. Areas that were cooling in the top diagram should still be cooling in the bottom diagram. All that might change is the shade of coloring as a percentage may provide a different emphasis.

I cannot be completely sure what NOAA did to change cooling to warming because NOAA would not give me the time of day unless I had a subpoena under the Freedom of Information Act. However, I can make an educated guess. Note that the bottom diagram does not identify the benchmark in its title bar, implying that it is the same. I would be willing to bet a substantial sum the bottom diagram benchmark is different than that of the top diagram.

When comparing to historical benchmarks, you want to use a benchmark that is representative of the years around it. The benchmark identified in the top diagram probably meets that criterion. However, if you choose a year for the second diagram that is an outlier (i.e., atypical of the time period), the differences may be quite different. I suspect the benchmark for the bottom diagram was an abnormally cool year, which would make the present year seem warmer than in the top diagram.

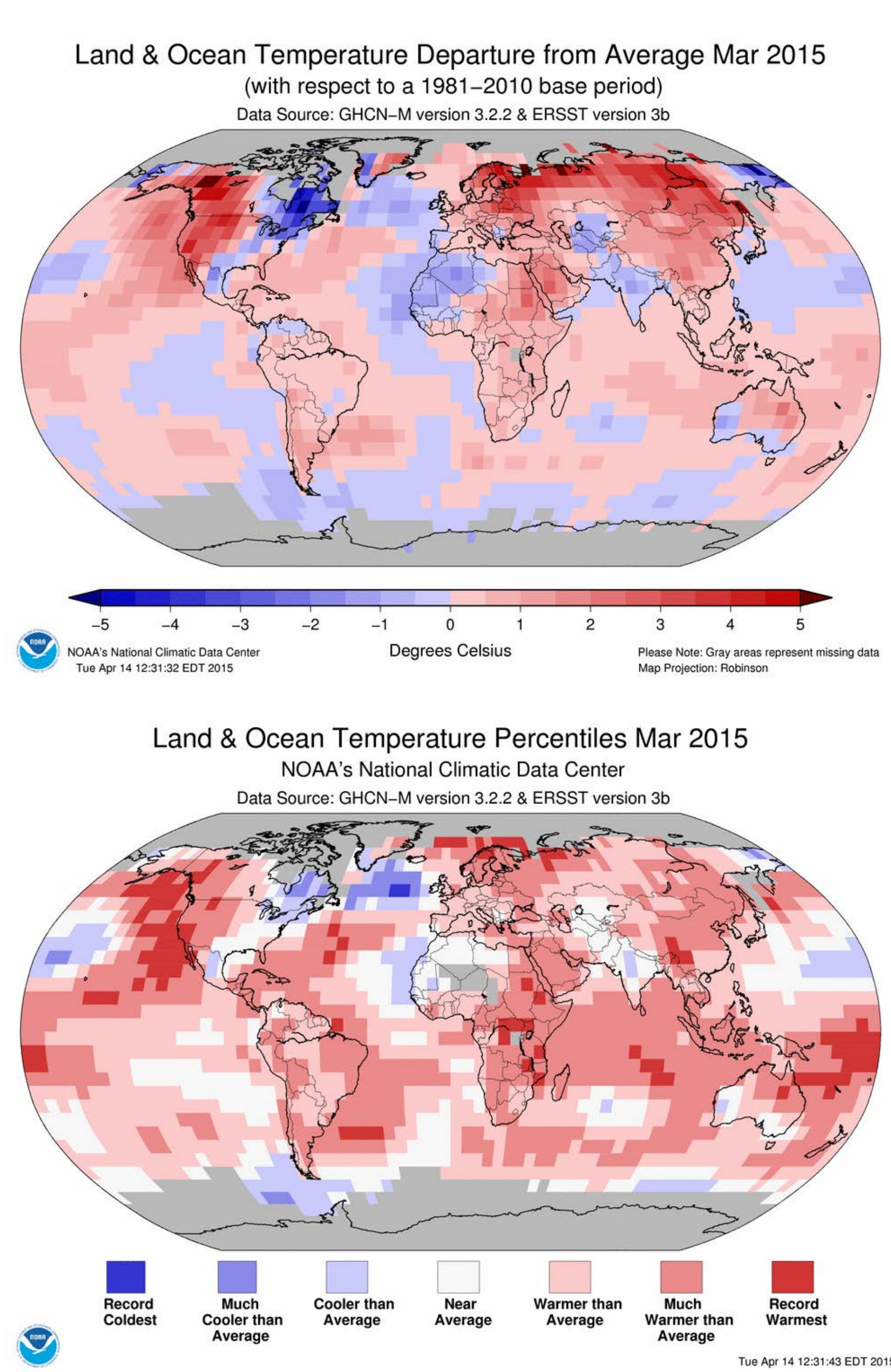

FIGURE 5-4. NOAA Monthly Temperature Change

The real question, though, is: why would NOAA do this? To produce one of these diagrams requires nontrivial processing of a vast pile of temperature data from around the world. That's a lot of trouble to go to just to have more brown on the diagram. (NOAA could not use the same outlier year for both diagrams because when it was identified in the top diagram, it would leave them open to criticism from anyone familiar enough with historical temperature data to recognize it as an outlier.) The only reason I can think of is that NOAA is trying to support GWC bloggers. It is quite common for bloggers to download diagrams and insert them into their blogs as talking points. In that case, the blogger will usually only need one of the diagrams to make their point. Which diagram is a GWC blogger going to download? It is going to be the diagram with the most brown/red on it because the blogger wants to emphasize the dangers of global warming. If that is the reason, then NOAA gets my award for the most subtle example of scientific charlatanism in spreading the GWC message.

5.5 Control of Research

I am going to close this presentation with what I consider to be the most insidious thing the GWC does to promote their view of climate. As I mentioned previously, climate science is basic research, which can be described as research than has no immediate financial gain. Thus climate research is done with the largess of governments and altruistic billionaires. More importantly, the research is done almost exclusively in universities.

Imagine you are a legislator on a committee that must allocate a very limited budget among a large number of candidate climate research projects. How do you decide where the money should go? You have a degree in Law, not Climate Science. So how do you make an informed decision? The most obvious way is to seek the advice of experts. So where do you find the experts? IPCC, WMO, and NOAA. Since these organizations are controlled by the GWC, what sort of advice are they likely to give? Support this controversial, radical, non-mainstream research that might produce results that contradict the GWC Message? Or support this mainstream, noncontroversial, non-radical research that will likely add to the body of the GWC Message?

Today the US government spends more on climate research than any other government. NOAA is an agency of the US government, part of whose charter is to advise Congress on where to spend the research budget. Talk about the fox guarding the hen house! I have an apocalyptic vision that the world's climate research is rapidly heading down the same rabbit hole as Soviet agricultural research in the mid-twentieth century.

There was a Russian biologist, Trofim Lysenko, who had good friends high in the Communist Party who allocated funds for agricultural research. The problem was that Lysenko did not believe in Mendelian genetics and had his own theory. For several decades Russian agricultural research was dominated by Lysenko's view. If you were an academic who disagreed with Lysenko, you could kiss your career goodbye. If you were too vociferous in your objections, you could get a one-way ticket to the Gulag. The result was a total disaster for Russian agriculture. By the late '80s Russian housewives waited in line all day for a loaf for bread and Russia had to go to its arch enemy, the USA, to buy wheat to stave off famine. That disaster played a significant part in the collapse of Soviet Communism. I am deeply concerned that climate research worldwide is being driven down the same road today by IPCC, WMO, and NOAA as they have far too much influence on where research funds are spent.

Alas, I suspect it may be worse than simply providing bad advice. (Truth in advertising: I have only two data points for the following scenario, both in the US and requesting anonymity.) Universities sometimes have discretionary research funds from their endowments that they can spend any way they want. If a university spends those discretionary funds on research that leads to opposing conclusions to the GWC Message, the department head may get a call from a lobbyist. That lobbyist will explain that such controversial, radical, non-mainstream research concerns the legislators because it suggests the university may not be using their money wisely. If that sort of bad judgment continues, the legislators may have to move their funds to another university. That's a pretty big stick to wave at a university department head.

As I indicated, I have very little to back up this scenario. If you are a journalist reading this blog, I strongly urge you to investigate this yourself. If the GWC is using such heavy-handed techniques extensively, that could be worth a Pulitzer. It is one thing for lobbyists to lobby legislators for their clients. It is quite another to use legislators to blackmail universities.

6.0 List of Figures