

THE LONG TERM EVIDENCE FOR CLIMATE CHANGE

Robert B. Adams 11/12/13

A. INTRO

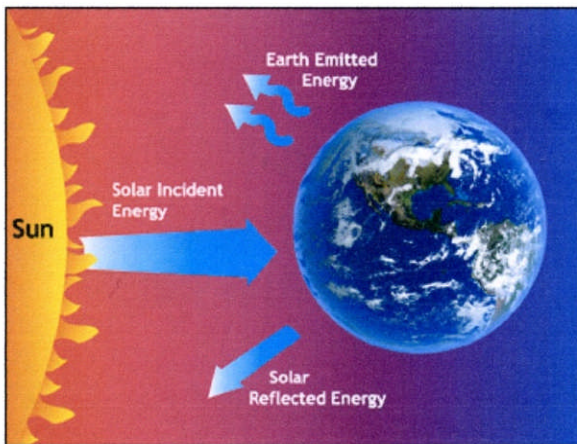
A.1. Today I'm going to talk about Climate Change and show you some of the evidence for the idea that the Earth's Climate may be changing. The word '**climate**' refers to long term trends in the properties and activities of the atmosphere. Climate is of interest because it appears that the long term stable local climate for any given area of the earth surface determine both the range of plants & animals that can live in comfort in the area, and the type of activities that the animals including people can undertake in the area. Climate determines sea levels, plant growth zones, and the location of habitats for animals like us. Humans can exist for short periods over a very wide range of climates but we can only live in regions with a very small range of climates that permit the growth of the plants & animals we need to sustain ourselves.

A.2. We live on the planet interface between the land surface and the atmosphere. The climate at this interface will be influenced primarily by the energy flow into and out of the surface-atmospheric system. This energy flow introduces temperature variations which influence many other things that happen in this surface-atmosphere system. The water in contact with the atmosphere is also a part of this critical system.

A.3. I hope to show you why most scientist who study these phenomena believe that Climate Change is happening and why they also believe that some of the change is caused by human activities.

B. First, lets look at what determines the CLIMATE in a given habitat.

B.1. Climate is determined by the energy balance for a given region. Energy balance is the result of the energy input which primarily increases system temperatures and energy losses which primarily decrease the system temperatures.



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B.2. The ENERGY SOURCES in this case are radiation energy from our sun, some energy from the space around us in the form of cosmic rays and asteroids, and some energy sources from inside the earth.

B.2.a. The sun is the current source of almost all the external energy falling on the earth with a very small contribution in the form of cosmic rays and of asteroids of various sizes. The intensity of the solar energy incident on the earth does vary and these variations have several identified causes. The most obvious variable is the variations in the output energy of the sun. The current estimate of the average solar energy incident on the upper edge of our atm is 1361 W/m^2 . In some local areas this current average intensity is known to vary about 6.5% on a seasonal basis which is the cause of our seasonal cycles. But these short term variations effect our local weather conditions but not the climate.

The evidence from several long term proxy indicators of incident solar intensity suggest that the long term solar output variation is at most about 0.2% over the last 400K yrs. This variation covers the sun spot cycle and several other long term astronomical factors involved which will be mentioned later.

B1b. Other sources in space.

There is also a very small energy input from cosmic rays and asteroids that strike the earth. This energy input is currently very insignificant compared to the

Solar energy input but a recent study suggest that variations in the cosmic ray flux into the upper atmosphere may influence some aspects of cloud formation which will, in turn, affect how much of the energy from the sun reaches the earth surface..

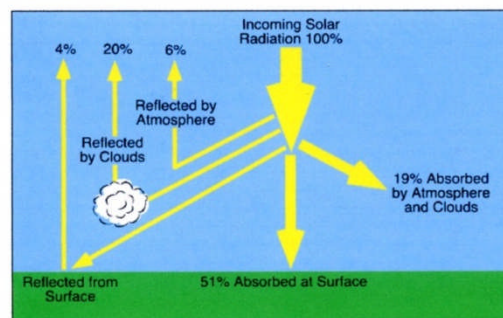
B1c. Internal energy sources.

Currently, at least 3 internal energy sources have been identified. The largest source is from the decay of radioactive material within the earth. The next is from the released heat of compaction as gravity continually works its way on all the matter of the earth, and third, the heat energy released as the iron core solidifies under the high pressure.

The decay of long lived radioactive materials within the earth is the most significant long term energy source keeping the inner regions of the earth hot enough to be molten. While this internal heat source does warm the earth surface from below, the heat flow rate to the surface is, except in the case of an active volcano, much too low, about 1/10,000 of the solar contribution, to make any significant contribution to the average climate at the surface.

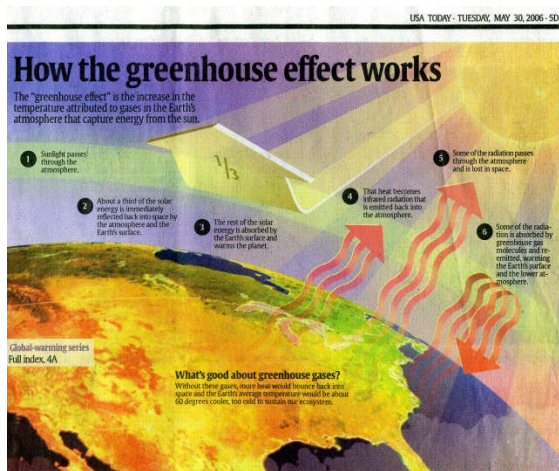
Active volcanoes do cause significant effects on world climates by injecting large amounts of dust particles and gasses into the atmosphere. And even then, it is not the heat released that has the major effect. Thus the one major energy source affecting our climate will be the sun.

C. How is the energy balance established. First there is the Distribution of Energy Input.



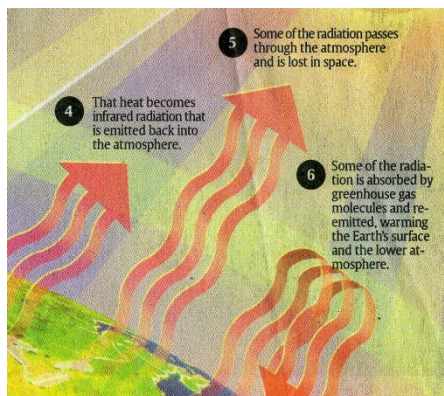
This slide shows a very simplified version of what happens to the solar energy incident on the upper atm. during a so-called standard day over vegetation covered land.

C.1. This next series of charts shows a more detailed view of what is happening to some of the incident energy.



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The solar energy absorbed by the atmosphere and the surface warms these materials so they will reradiate some of this energy in the form of longer wavelength IR radiation. If we look in detail at what happens to the reradiated long wavelength IR we see



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We have only been hearing about the problems with greenhouse gases the last few years but the phenomenon is a natural activity and is responsible for the very comfortable climate we developed in. This next slide shows why this is so.



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The good greenhouse gasses are the same ones we now hear about. CO₂, water vapor and Methane, when their respective concentrations in the atmosphere were at their pre-1700s levels.

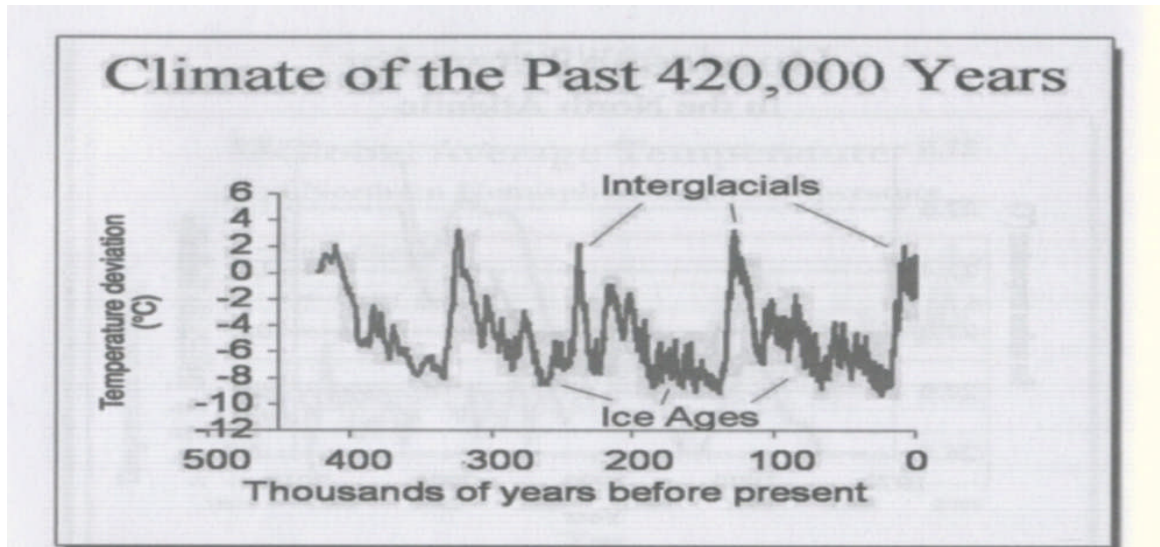
A recent report (Jan, 2013) in Geophysical Research suggest that black soot emitted from the burning of fossil fuels may have almost as much effect on global warming and Climate as CO₂. The mechanism seems to be that the soot emitted into the atmosphere rapidly settles on the ground level objects where it increases the fraction of the incident solar energy being directly absorbed. This increases the surface temperature which then also causes an increase in the re-emitted IR energy. Thus more of the total incident solar energy will be trapped by the existing greenhouse gases. (G W DARK SIDE From Earthweek 1/19/13;)

C.2. An energy balance is established.

So we have an energy balance established which has provided a useful worldwide climate for us for the last 2500 years. This balance depends on several critical factors like the solar input energy which is influenced by the orbital mechanics of the earth's motion around the sun, and the presence and concentration of certain gasses in the atmosphere.

D. But what is the history of this advantages state of affairs? Has this been the stable state for a long time? Well, no. We all have heard about the last glacial age. That was a significant climate change and it turns out that repeated glacial ages seem to have been occuring for a long time.

D.1. Using our current solar data, our current average earth temperature, and various earth temperature proxies, scientist have reconstructed this graph of the ave. earth temperature over the past 400K + yrs.



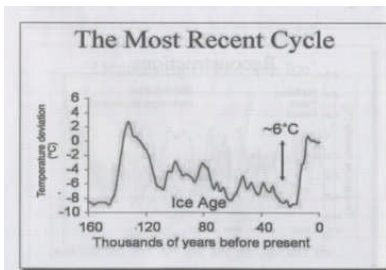
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This Fig. Shows a definite cyclic variation in the estimated ave. world temperature with a cycle period of about 130 K yrs. This cycle roughly correlates with the cycle of sun-earth distance variations due to the change in the Eccentricity of the orbit. The 4 important features to remember from this chart are: first, that the 0 on the temperature scale is set as the ave. current temp. Second, these temperature variations (about 11 C) seem to be due to small but repeated variations in distance from the sun. The rapid temperature increases occur when the orbit is circular and as the orbit becomes more of an ellipse the earth spends more time farther from the sun each year, so the earth slowly cools into another glacier age. Third, the last ice age ended about 13,000 yrs ago and the last 4000 yrs of civilization have occurred at this last temperature peak and the earth is slowly moving toward a more elliptical orbit. And forth, under normal conditions we should be looking at the beginning of a slow temperature decrease in the future.

My current understanding of the mechanisms driving these temp changes is as follows. As the earth's orbit slowly changes to its elliptical shape and the earth cools, the small amount of CO₂ in the atm. is, over about 100 K yrs, slowly dissolved into the oceans and other CO₂ traps, which further reduces the greenhouse heating effect.

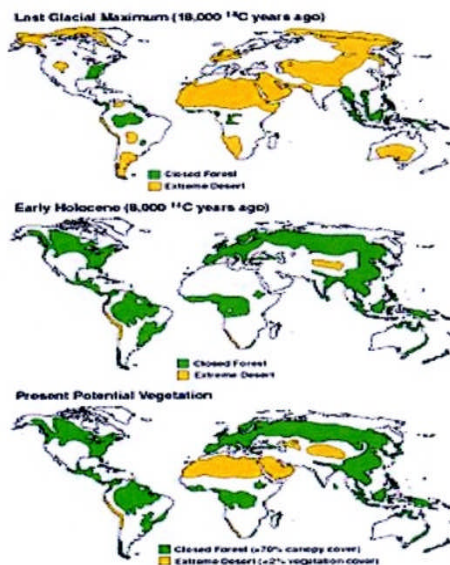
When the orbit returns to its circular phase, the increase in heat supplied causes a rapid and large greenhouse gas release which further increases the air temp causing more gas release. The result is a rapid-(over about 20,000 years)- temp increase. Then as the orbit starts changing towards its elliptical phase, the cycle repeats. As you can see, this cycle appears to have been stable for at least 420,000 yrs.

D.2. Looking at the last cycle in more detail we see



s-8

Again I remind you that the last 6000 years of recorded human history took place at this higher temperature. To give you a reference for the next slide, I will point out that 18,000 years ago the ave. temperature was about 9 deg. C below our current ave. temperature. and about 8,000 years ago the ave. temperature was about 2 deg. C below our current temp.



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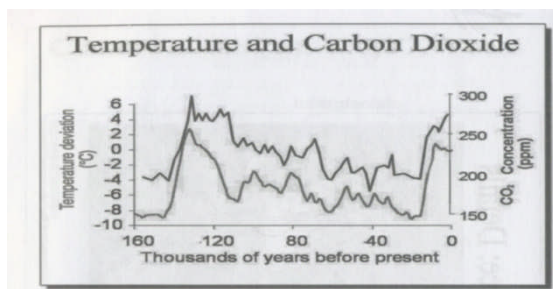
This slide, attempts to shows what the world looked like at two different times in the past. The orange areas represent extreme desert conditions. The green areas represent closed or dense forest areas. The white areas represent all the intermediate areas between these 2 extremes. I believe the features on the maps are based on the area distributions of plant materials found in excavations. The age of the materials was determined by measuring the carbon isotope ratios.

The top map shows the world about 18,000 years ago when the ave. temperature was 9 deg. C below our present ave.

The middle map shows the world about 8000 years ago when the ave. temperature was 2 deg. C below our present ave. value. You can see that over the intervening 10,000 yrs, the forest have spread in response to the warming and the desert areas have been much reduced.

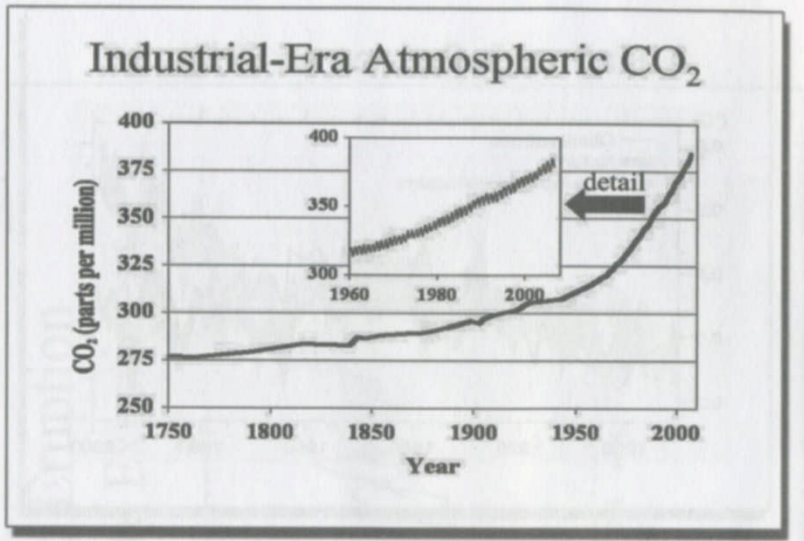
The bottom map shows our current world with much dense forest and some returning desert areas

D.3.



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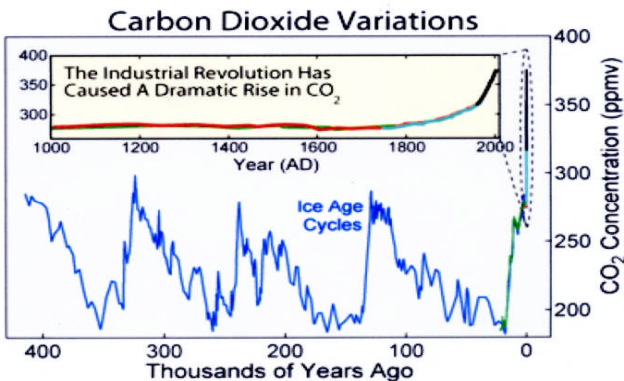
This shows the earlier last cycle graph again, the bottom line is the inferred temperatures with the variation scale on the left. The top line is the measured ice core CO₂ levels. The CO₂ scale is on the right side. Please note that the CO₂ and the temperature variations seem to be related, suggesting some relationship between them that has been in place for a very long time. Also note that when this graph was published in 1987, the ice core CO₂ level was already up to about 275 ppm.



s-11

D.4. This Fig. shows free air CO₂, estimated from 1750 to 1950 merged with the free air measurements started in the 1950s. According to other data, the estimated free CO₂ level had been in the neighborhood of 275 ppm for many years before the 1750 date shown here. After 1750 the level starts a slowly increasing rise to about 385 to 390 ppm in 2010. The value reported in April of this year was 400 ppm so the CO₂ concentration is still increasing.

D.5 If we superimpose this recent CO₂ data on the long term CO₂ record we see how extraordinary this recent increase has been.

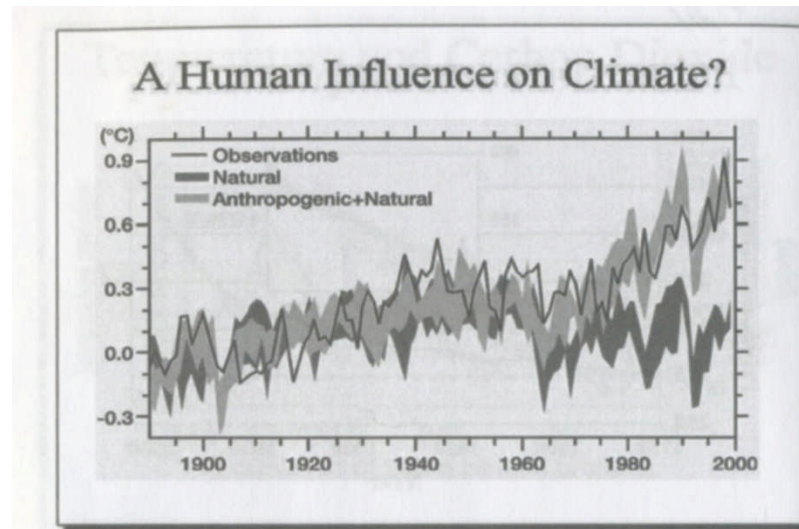


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D.6. As far as I have been able to discover while looking at this data for 2 years, the above evidence is the major long term evidence for what could be the cause of the climate change.

E. What caused the CO₂ increase.

The only change in any of the parameters we know about that might cause this large deviation from past history seems to be the advent of the industrial revolution and the activities that came with it.



s-13

This chart, based on modeling temperatures, shows the expected natural temperature deviations (the dark data) based on past history along with the actual measured temperature data for the past 100 years.

The differences seen in the last 40 years are currently attributed by many to warming caused by the activities of people since we have not found any other natural cause for the observed warming. But, regardless of the cause, the climate does seem to be changing in the direction of warmer weather.

F. Current evidence for climate change.

F.1. First we should look at what is happening on the land masses. The first change I remember reading about several years ago was the report that many trees in the northern forest were being killed by large infestations of beetles. The

widespread evidence of increased melting of ice since the mid 1990s." They also note that this melting is occurring at a higher rate than predicted in the IPCC AR4 report of 2007. This note also estimates that the total melting of glaciers & other mountain ice at the current melting rate, the sea level increase is about 1.2 mm/year.

In particular they mentioned the ice melt on Greenland and Antarctica and their contributions to sea level rise. These two land masses contain the largest ice reservoirs which if completely melted would raise the sea level about 62.5 meters.

The Copenhagen Diagnosis indicates that the ice cap over Greenland was melting back around the edges and showing considerable melting away from the shore line.

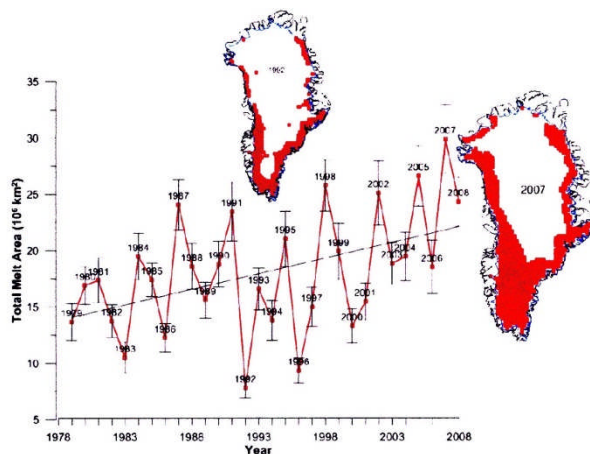
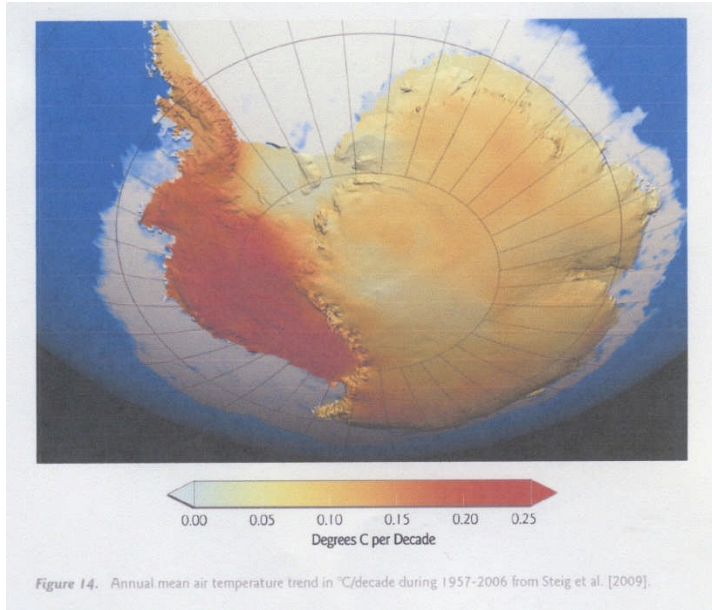


Fig. 9. The total melt area of the Greenland ice sheet increased by 30% between 1979 and 2008. About 55% of the total ice mass loss is caused by surface melt and runoff. The most extensive melt occurred in 2007 when about 50% of the ice area experienced some melt. The 1992 low melt area year was caused by the cooling caused by the aerosols in the air from the Mt. Pinatubo eruption.

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Recently I saw a video of a very large area (about the size of N Y city) of a Greenland glacier falling into the sea over a relatively short period of time.

Then there was the report that large chunks of the floating ice shelves around the large ice pack over Antarctica were breaking off. Between 2000 & 2006, the loss rate was determined to be about 104 Gt/year. In the 2006 to 2009 interval the loss rate has more than doubled to 246 Gt/year which alone produces a 0.7mm sea level increase per year.



s-15

A recent report in April of this year suggested that the melting of the Antarctic ice shelves was being slowed because the cold fresh water from the melting ice was floating on the warmer but denser ocean water and insulating the remaining floating ice from the warm ocean water.

F.2. This next set of reported effects deals with what is happening to the oceans. There are reports documenting the excessive melting of the arctic sea ice which was endangering the polar bears because they could not hunt food if the ice was gone.

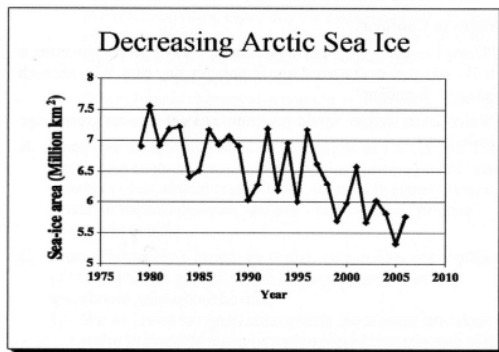
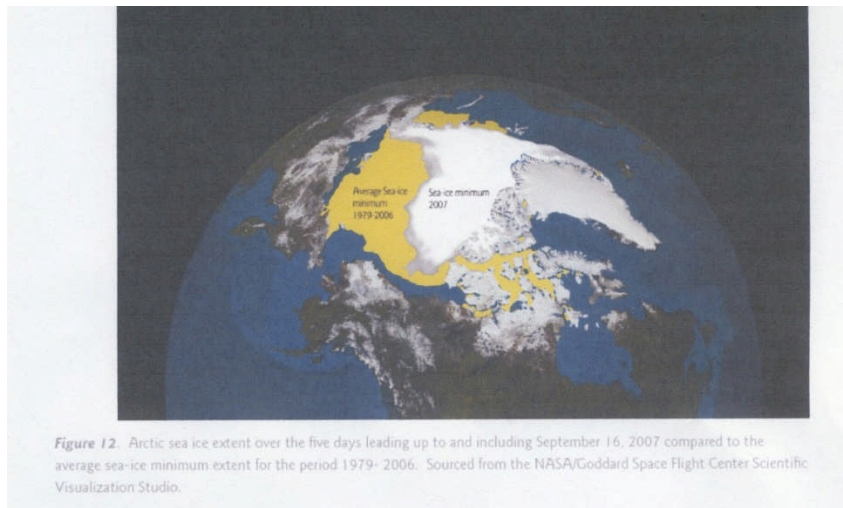


Figure 2

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Recent measurements show that this arctic sea ice is melting much faster than the IPCC AR4 modeling suggested so now there may be a possibility of an ice free Arctic ocean by the year 2100. The reduced ice cover in this area will increase the rate of energy input because the open sea water absorbes more of the incident energy than the reflecting ice. This positive feedback mechanism may account for some of the fast warming of the Arctic area.

Another result of the loss of Arctic ice cover is that the cool Arctic water is exposed to the high CO₂ in the atmosphere. Cold water absorbes CO₂ very easily, so the ph of the water has been dropping. The latest info is that the acidity of the Arctic water has increased about 30% since the start of the Industrial Age. (Earthweek, 5/11/13) This increased acidity effects both the animal and plant life that can grow in the water.

When ice fields on land melt and the melt water has a path to the sea, all the melt water will contribute to the sea level rise. When floating ice melts, very little of melt water contributes to higher sea levels, because the melt water fills in the hole in the water which was required to float the ice berg.

Conclusions

I could go on and on with current examples of changes in our environment that are reported and being attributed to climate change. But I have shown you what I found to be the historical evidence supporting the idea that the world climate is slowly changing. The signs are most visible in the Northern Hemisphere and around Antarctica at this time.

I have shown you evidence that the ave. surface temperature of the earth is increasing in a way that is consistent with the well established greenhouse effect of the measured increased CO₂ concentration and the increases in other greenhouse gases. While both parameters are increasing in ways that are consistent with the idea that one is the cause of the other, the current evidence does not prove in any absolute way that one is the cause of the other. It is just that no other reasonable cause for the current temperature increase has been found.

I have also shown you evidence that the CO₂ concentration in the atm has been increasing in an unaccustomed and increasing rate since about 1750. The current concentration of 400 ppm has not been present on earth for at least 420,000 years and very likely not seen since a million years ago. Thus the increase from 275 ppm to 400 ppm in 263 yrs. is an extraordinary increase. Again the association of this increased CO₂ level with the timing of the industrial age in human history cannot prove that the industrial activities were the direct cause of the increased CO₂ levels, but the known industrial age activities are consistent with the idea that the industrial age activities are responsible for the CO₂ increase. And , again, no other novel source for the CO₂ increases have been found.

The latest report I am aware of is from the Climate researchers at the Univ. of Hawaii. They published in Nature a prediction that we are approaching a point of no return that will occur in 2047. The coolest year from then on will be warmer than the hottest year so far which was 2005. The also named a number of cities around the world that would soon be very hot. Kingston, Jamaica by 2023, Singapore by 2928, Mexico City by 2031, Cairo by 2036, Phoenix & Honolulu by 2043, New York & Washington by 2046.

Many people ask for "proof" of 3 concepts of global warming.

The first demand is to prove that the increasing CO₂ concentrations are happening. Others demand proof that the ave, earth temperature is increasing. The method of validity of these two statements for the scientific community is to review the data collected by others we trust. If our evaluation of the data, usually presented as a series of repeated measurements collected over a determined period of time, agrees with the conclusions of the data presenter, we are inclined to accept the data set as valid. Of course, most of us trust the source of the data, especially if it has been evaluated by others we trust. So, if you do not trust the people presenting the data, there is no way to prove the statement based on the presented data. Note that I talked about validity of the date, not proof.

The next few demands for proof are of a different nature, they want proof that one phenomena is the cause of another. They are generally of the nature: prove to me that the increased CO₂ concentration is causing the ave. earth temperature to increase. The problem is that a direct & clear proof of causation is probably impossible because the experiment cannot be repeated or controlled. The only thing we can do is measure the two items, make displays of the two data sets which show the relative relationships between the 2 data sets, and then propose a mechanism that would explain how changes in the value of one variable would lead to the observed changes in the other.

The proposed mechanism, the so called greenhouse effect can be demonstrated in controlled conditions and each step in this process can be demonstrated. So the greenhouse mechanism can be considered an established or true mechanism.

If the world experiment could be repeated many times and the result were to be always the same, the validity of the proposal that the increased CO₂ levels are the cause of the increased temperatures would be greatly enhanced. Lacking this ability, all we can show is the determined association of the variables, that the proposed established mechanism relating them is reasonable , and that no other explanation fits the particular situation as well as the proposed relationship.

So we cannot prove, in the mathematical sense, that the increasing CO₂ level is

causing the increasing world temperature, but we can show the direct association, and we have a reasonable established mechanism by which one variable can be expected to affect the other. This is the best we can do.

Thank you for your attention.

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