

A Waning Warming! What's Up with That?

Southern Oregon Climate Action Now

SOCAN

Confronting Climate Change

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Atmospheric Warming:

What Are the Temperature patterns 1880 – 2012 and 1998 – 2012?

What Other Factors Might Be Influencing Global Temperature?

Milankovitch Cycle

Solar Irradiance

Other Interstellar Radiation

Volcanoes

Regional Oscillations

The Rest of the Story:

Pollution.

What is driving the climate problem?

What is the carbon dioxide concentration history in our atmosphere?

What relevant properties are exhibited by water?

What is the Role of Water in Concealing the Warming Trend?

Are Atmospheric and Oceanic Warming the Only Problems?

Closing Notes and Conclusion

Looking at global atmospheric temperature trends since 1998 once again climate science deniers are claiming that global warming has slowed or stopped so we no longer need to worry about its consequences or address its symptoms. Here, I explore the claim.

Atmospheric Warming

What Are The Temperature Patterns 1880 – 2012 and 1998 – 2012?

It is difficult to look at the NASA Goddard Institute for Space Studies data reporting global temperature at meteorological stations around the world since 1880 (Figure 1) and not conclude that there is an overall pattern.

What the objective viewer will see is rising temperature (except for a period from

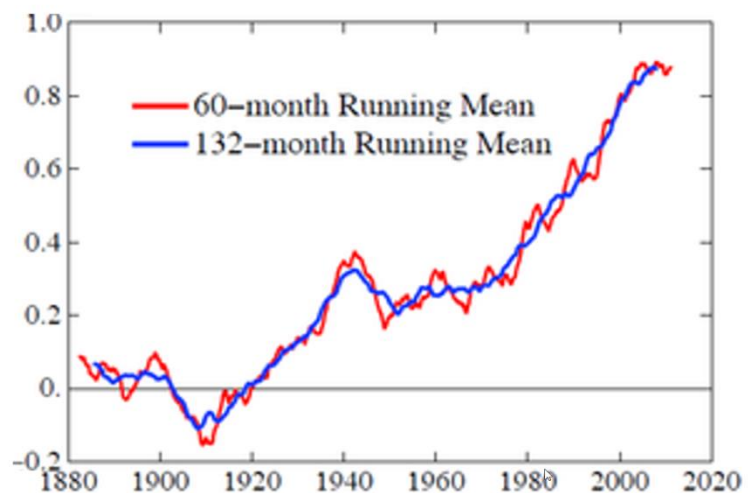


Figure 1. NASA – GISS data on the temperature trend since 1880; baseline 1880-1920. Hansen J, et al (2013) Assessing “Dangerous Climate Change”: Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature. <http://www.plosone.org/article/info:doi/10.1371/journal.pone.0081648>

about 1940 until the early 1970s). The most dramatic rise has occurred since about 1980. Indeed, the decade of the 1980s was the hottest decade on record, and subsequently, each decade has been hotter than the one before. Notable is the year 1998 which clocked in substantially above even the rising trend of the decade. Subsequently, while some years were cooler than 1998, globally the years 2005, 2007, and 2010 exceeded even that peak.

A similar representation of data from the United States (Figure 2) reveals a parallel pattern.

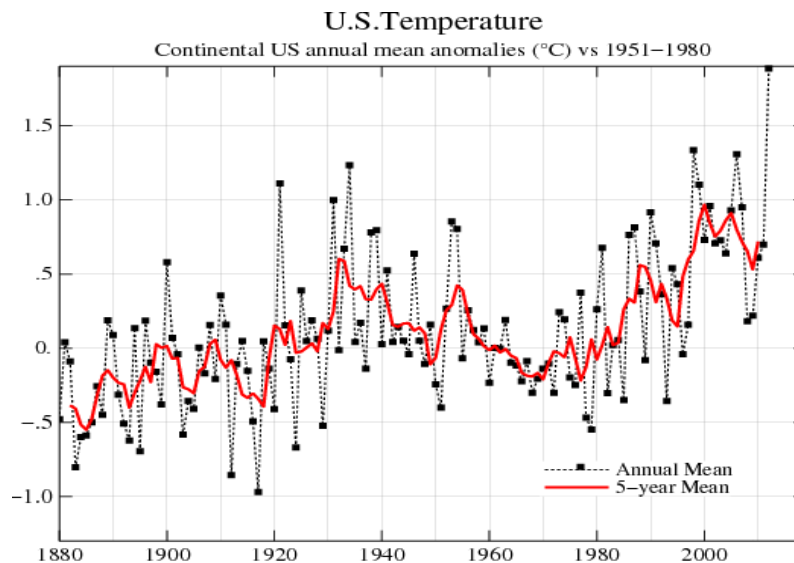


Figure 2. NASA – GISS data on the U.S. temperature trend since 1880; baseline 1951 – 1980.

http://data.giss.nasa.gov/qistemp/graphs_v3/fig.D.gif

Even though 2012 was globally only about the 8th or 9th hottest year on record (Figure 1), in the contiguous U.S. 2012 was fully 1.03°F above the previous record (1998). Historically, when records such as this are broken, the new record is a tenth of a degree or so above the previous record, not a full degree ('off the charts' would describe this phenomenon).

One statistical way to represent the pattern is via a regression line, which identifies the general trend (Figure 3) which represents a conventional scientific graphic summary of the data. The equation for the line is given as $\text{Temperature} = 0.055 \text{ Year} + 56.164$. The last value represents the point at which the line intercepts the vertical axis at the origin of the graph. The P value (> 99.9%) represents the probability that there is a relationship.

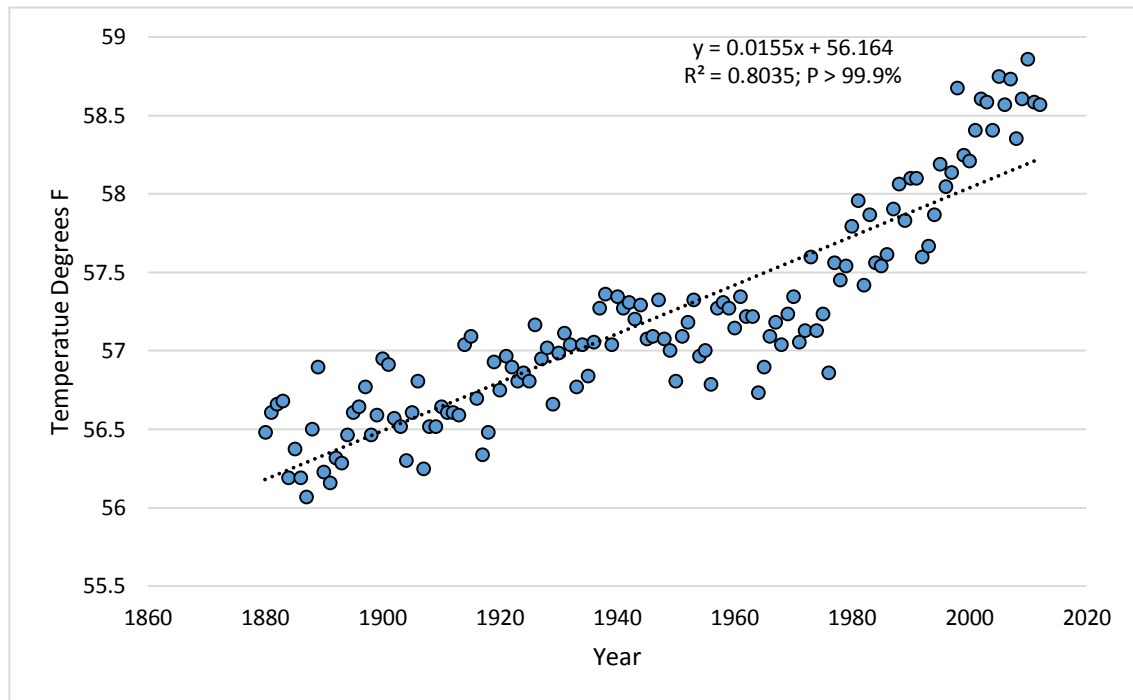


Figure 3. Regression analysis on the NASA - GISS global meteorological station data 1880 – 2012. (Journet)

There are, however, others who have looked at data such as those from NAASA's GISS and produced a different depiction of the pattern (Fig 4). What can be seen here is the selection of subsets of the data. Anywhere there appears to be a levelling or downward trend over a few adjacent years a regression analysis is conducted to suggest the warming trend has ended. A moment's reflection will reveal that cherry-picking the data in this manner will inevitably lead to a distorted view of the overall trend. As depicted here, time and again (on every occasion it has been trotted out to deny the general pattern) this distorted view has been negated as subsequent data return to the general upward trend. Many of those wishing to deny the overall trend have employed this technique repeatedly and apparently still do without acknowledging its fallacy.

However, it is important to appreciate that nowhere in the climate science literature is it suggested that every year should

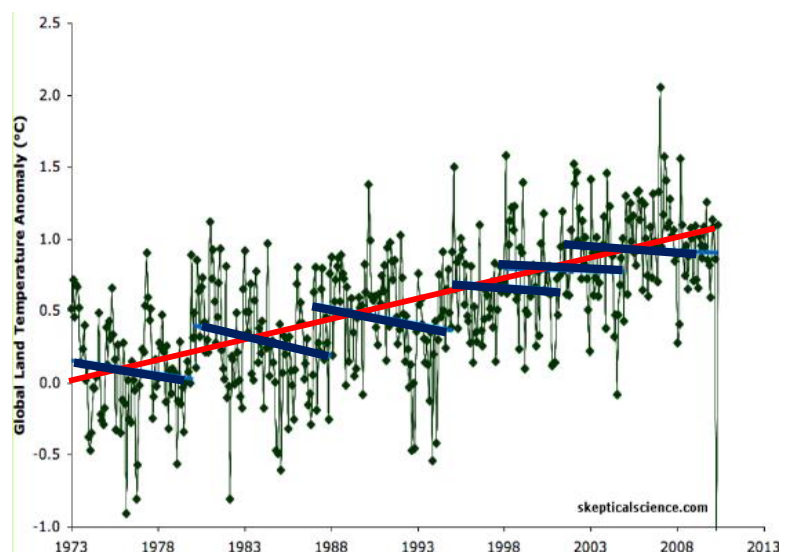


Figure 4. Selecting subsets (blue) from the overall pattern (red) produces a distorted relationship.

<http://skepticalscience.com/news.php?f=big-picture>

be warmer than the year before. The variability in all natural systems results in year to year fluctuations. The long term trend is what is important. As the 2013 Intergovernmental Panel on Climate Change 5th Assessment Report notes, anything less than a 30 year period is probably insufficient to indicate a meaningful pattern.

Over the last few months, the same deniers have returned yet again to argue that the general warming trend evident in Figures 1, 2, and 3 has been negated. They use the cherry-picked data subset of 1998 – 2012. These data deserve an inspection (Figure 5).

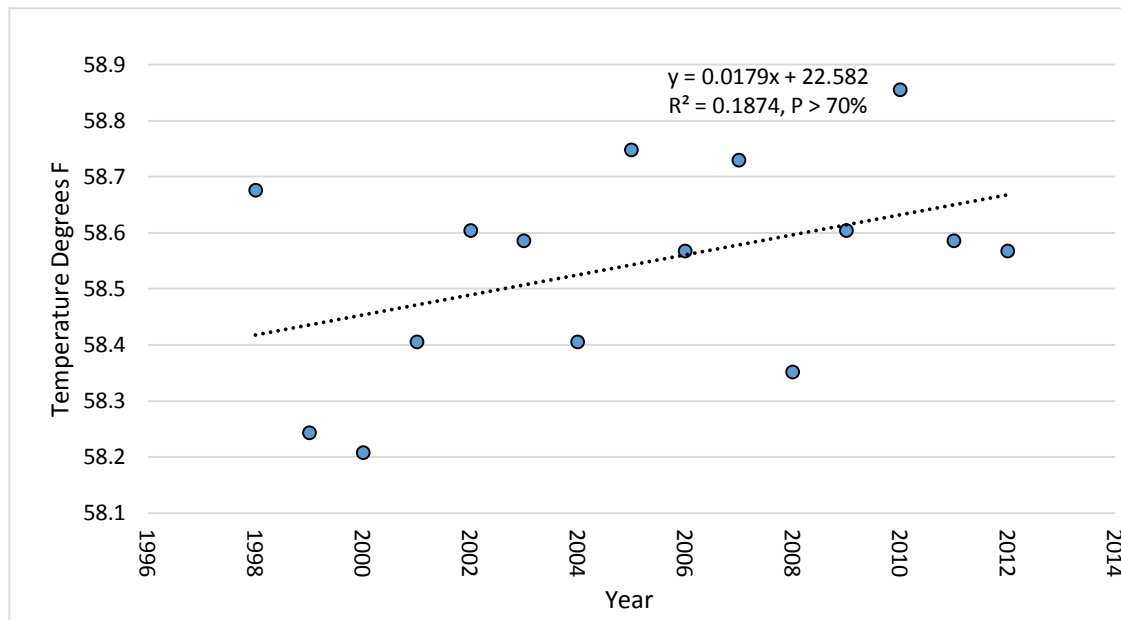


Figure 5. NASA – GISS global temperature data from Meteorological stations 1998 – 2012. Regression analysis by Journet 2013.

These data suggest that there is an increase, though it may be less remarkable than was evident from 1980 to 1998. However, the trend remains positive even if the probability, though still above 70%, is much lower.

Two points are worth making here:

- 1) The basic scientific criterion required to reject the null hypothesis of no relationship is 95% confidence that a relationship exists. Given the long term trend, and the risk associated with delaying action on the basis of an apparent slowing, it seems unreasonable to use this analysis (where there is still greater than a 70% probability of warming 1998-2012) to conclude we should deny the long term trend and postpone action. If the weather forecast were a 70% chance of rain, would you take an umbrella?
- 2) If it is reasonable to cherry-pick a sub-set of the entire data set, it is equally reasonable to ask more detailed questions of the data. Since 1998 was a record-breaker, and way above the trend of the decade, let's ask what the trend would be had 1998 been more typical (Figure 1). As we know, 1998 was an El Niño year – an event that increases global temperature about 0.1 – 0.15°C

(0.18 – 0.27°F). Though statistically questionable, some analysts reject outlier values precisely because they have a profound impact on analytical conclusions. I was curious, however, to see what the impact of the outlier El Niño year is. This can be assessed by replacing the actual value with the average of the two preceding and succeeding years (Figure 6).

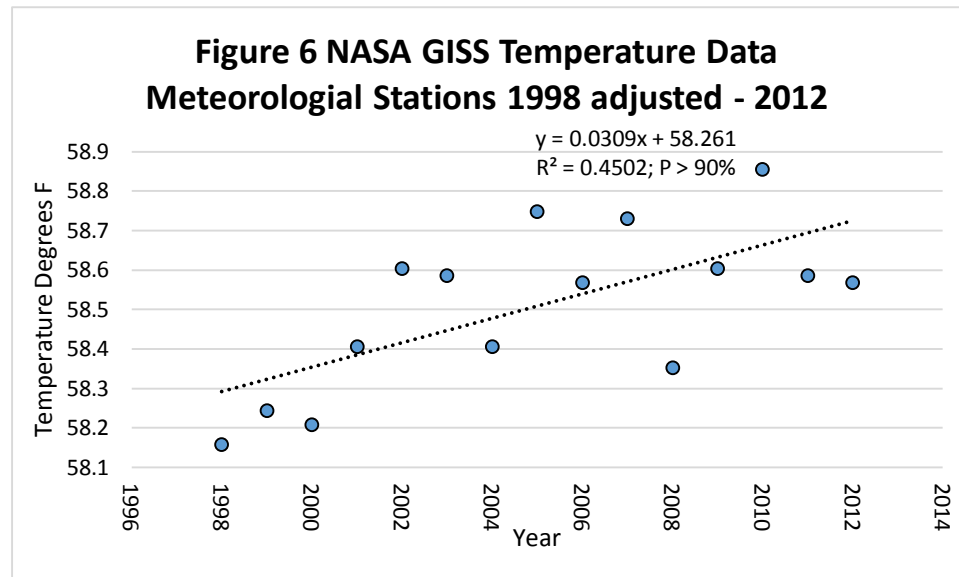


Figure 6. NASA – GISS Global Temperature Data from Meteorological Stations with 1998 adjusted as average of two preceding and succeeding years. Regression by Journet 2013.

What we now find is that the upward trend is again steep, with a probability of over 90%. The 1998 outlier seems to have a great impact; it confuses the trend. No wonder climate deniers select 1998 to start their calculations. The apparent slowing of warming is a function of cherry-picking a subset of the total data set available, and further carefully cherry-picking the year when that re-analysis starts. If 1998 had not been an exceptionally hot year, we would not now be debating whether atmospheric warming has slowed.

Again, nowhere in the climate science discussion has it been suggested that each year will be hotter than the previous year. It is well understood that other factors besides greenhouse gases influence global climate and warming. The combination of influential factors will inevitably lead to fluctuations such that periods of levelling or even decline will appear as is evident in Figure 4. However, a basic principle of honest science is to use all the data available – not cherry-pick subsets that seem to support an obscure and generally rejected preconception. Surely we have enough experience in recent years, where cherry-picking data has led to horrendously inaccurate conclusions, not to allow it again to influence national and international debate and policy.

What Other Factors Might Be Influencing Global Temperature?

Our understanding of other factors potentially influencing climate and likely to contribute to the temperature patterns we have witnessed since 1880 has grown substantially over the last decade. The main factors that have been suggested are the Milankovitch Cycle, Solar Irradiance, Cosmic Radiation, Volcanic activity, Atmospheric aerosols, The El Niño Southern Oscillation, the Pacific Decadal Oscillation, and The Atlantic Multi-decadal Oscillation.

The Quaternary Period			
10,000	Holocene	The Present Interglacial	
20,000 – 18,000	Pleistocene	WISCONSIN	Glacial
		Sangamon	Interglacial
170,000 – 120,000		ILLINOIAN	Glacial
		Yarmouth	Interglacial
480,000 – 230,000		KANSAN	Glacial
		Altonian	Interglacial
800,000 – 600,000		NEBRASKAN	Glacial
			Interglacial
		Pre-Glacial	

Table 1. Glacial periods during the last two million years.

The Milankovitch Cycle is a pattern comprising three sub-cycles that was first proposed in the 1930s but

finally accepted in the 1970s as explaining the sequence of four major ice ages through which our planet has passed over the last two million years (Table 1).

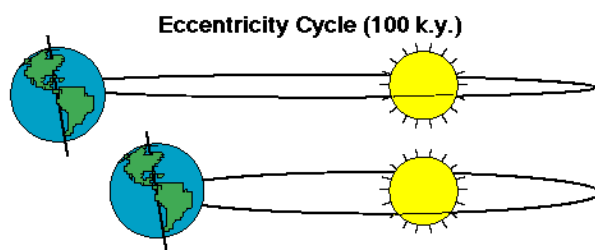


Figure 7. Milankovitch I - Eccentricity in the earth's Orbit of the Sun.

<http://deschutes.qso.uri.edu/~rutherford/milankovitch.qif>

(Fig 7)

The second component, termed the *Obliquity of the Ecliptic* is a 41,000 year cycle in the tilt of the Earth – from one extreme of 24.5° through its current 23.5° to the opposite extreme of 22.1° and back (Figure 8).

The third component, the Precession of the Equinoxes, results from the tilt itself rotating on a 21,000 year cycle such that solstices and equinoxes shift backwards through the year (Figure 9).

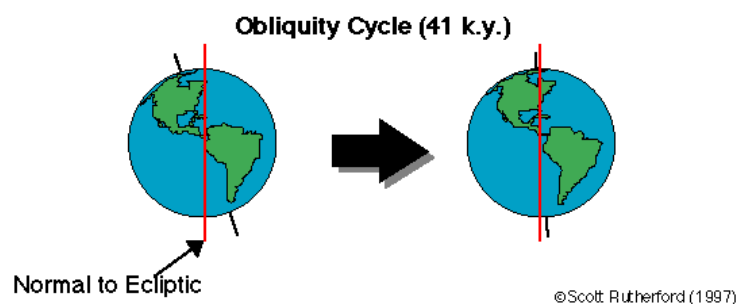


Figure 8. Milankovitch II – Obliquity in the Ecliptic of the Earth's tilt.

<http://deschutes.qso.uri.edu/~rutherford/milankovitch.qif>

The combined result of these cycles is depicted in Figure 10 (note the time line runs right to left) This indicates that the current trend in all three cycles is one of cooling.

Precession of the Equinoxes (19 and 23 k.y.)

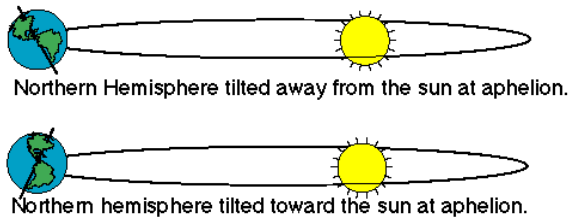


Figure 9. Milankovitch III – Precession of the Equinoxes of the Earth's tilt.

<http://deschutes.gso.uri.edu/~rutherfo/milankovitch>.

Solar Irradiance is the most common cause for the recent warming upon which climate change skeptics call to reject carbon pollution as the cause. Since over 99% of the energy driving our planet comes from the sun, this makes sense. If we compare recent temperature trends from 1880 with solar irradiance (Figure 11) we find the solar irradiance explanation was reasonable until about 1980 when the two trajectories diverged substantially. A note of importance is that while the planet has been warming since then, total solar irradiance has been dropping.

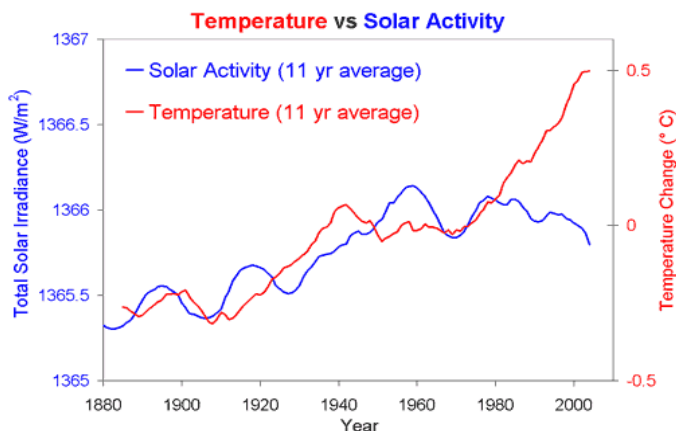


Figure 11. A comparison of solar irradiance and temperature trends since 1880.

The overall impact of the Milankovitch Cycles is not a substantial change in total irradiation but a cycle in the severity of the seasons from warm summer - cold winters to cool summers - mild winters. Glaciation occurs when summer is not warm enough to melt winter snow; thus snow and ice accumulate.

Clearly this cycle is not responsible for recent planetary warming. Quite the contrary, we should be cooling!

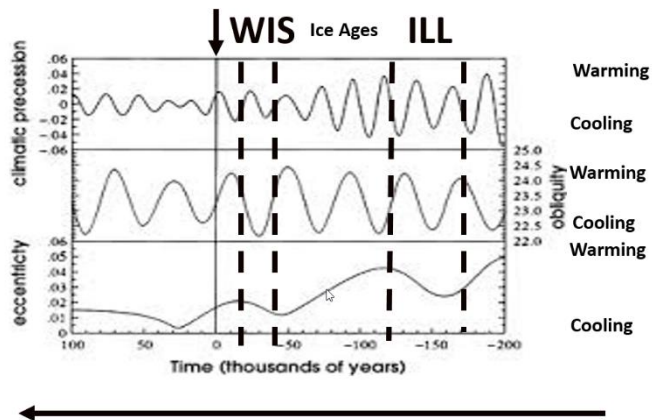


Figure 10. The combined warming – cooling impacts of the three Milankovitch Cycles (time runs left to right; we are at the intersection of the white and gray areas).

<http://academic.emporia.edu/aberjame/student/howar>

A curious feature of the sun is its production of sun spots. Counter-intuitively, maybe, the more spots the greater the irradiance. These have only been measured directly for fewer than 40 years during which the pattern in sunspots has been tracked (Figure 12), though proxy data allow estimates back beyond that. Sunspots frequency exhibits an approximately eleven year cycle.

Although the difference in sunspot number seems large, the actual range in irradiation from peak to trough is only

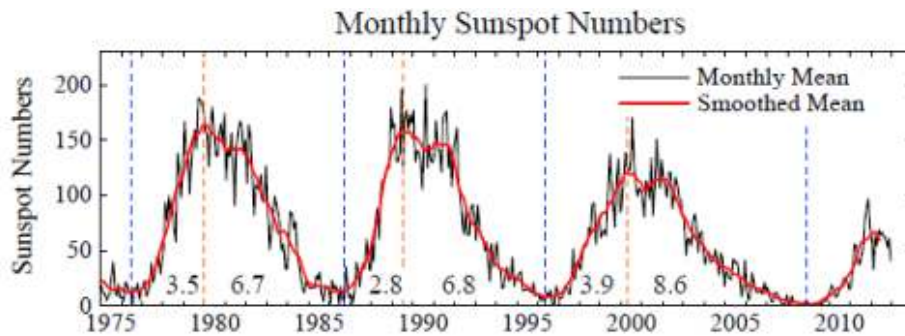


Figure 12. Sunspot activity from 1975.

http://www.nasa.gov/pdf/719139main_2012_GISTEMP_summary

0.2% of the total. Additionally, note that the period from about 2000 to 2008 exhibited a long downward trend with the 2008 trough reaching lower than any previous trough. Noteworthy is how this pattern in irradiance coincided

with a potential slowing of warming, but despite the trend of decreasing irradiance, global average temperature for that decade was still the highest on record.

If we examine the historic pattern in solar irradiance over the last millennium (Figure 13) we find a probable cause for both the Medieval Warm Period and Maximum (around 1200 AD), and the Little Ice Age (extending from the mid-16th to mid-19th centuries). Solar radiation is not claimed to be irrelevant as a driver of global temperature, but seems not to be a driver of the pattern experienced over the last few decades.

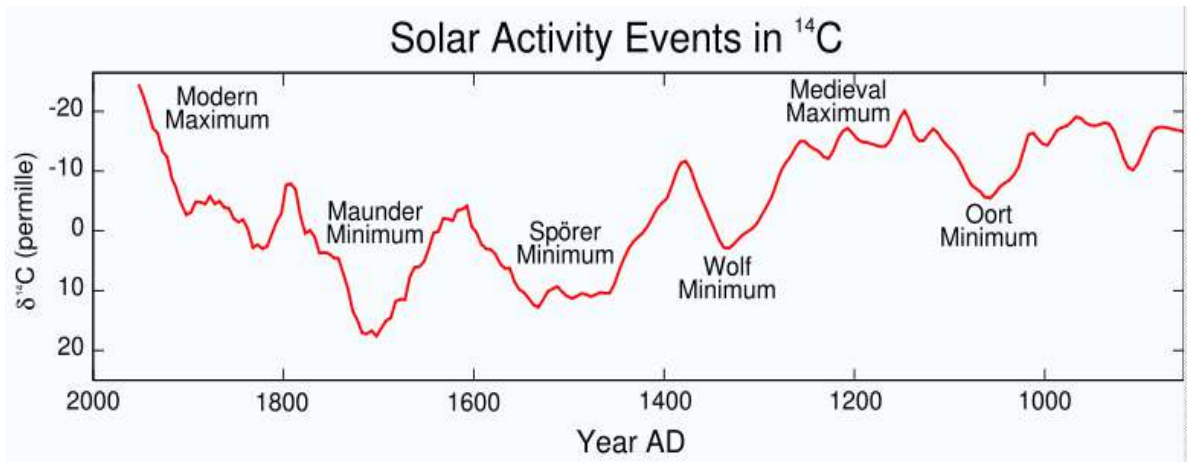


Figure 13. Solar activity during the last two millennia.

Other Interstellar Radiation have also been suggested to influence our temperature particularly radio waves and cosmic ray intensity. However, variability in these factors (Figure 14) completely fails to suggest they might have induced the pattern of temperature increase experienced over the last three decades. Note particularly the dropping values during the first decade of this century for three of the four.

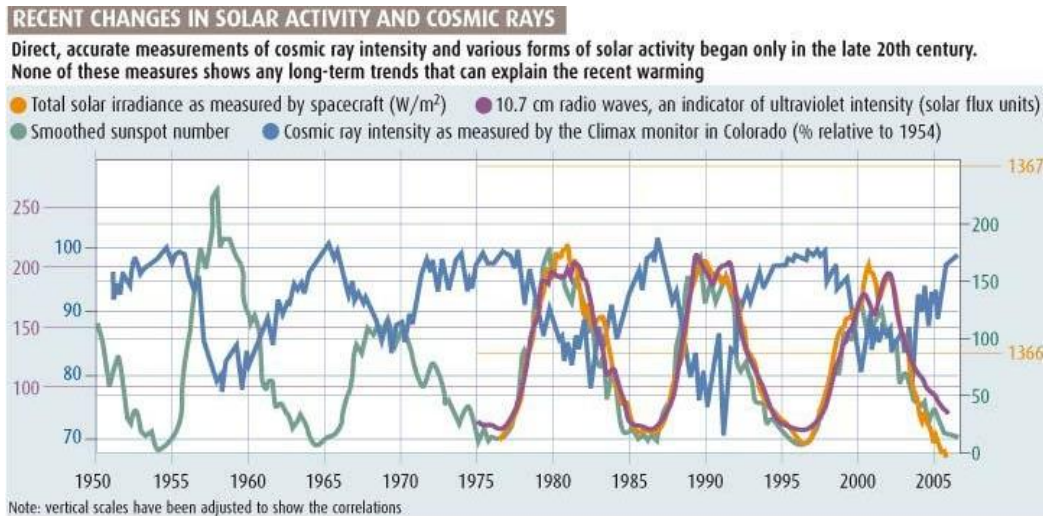


Figure 14. Patterns in total solar irradiance, radio waves, sunspot number and cosmic ray intensity from 1950 to about 2005.

http://www.newscientist.com/data/images/ns/cms/dn11650/dn11650-3_738.jpg

Volcanoes have been summoned as causal agents for warming by a few skeptic since they releases many substances that have climate impacts. Having positive impacts are water vapor and carbon dioxide while negative impacts are imposed by ash and sulfur gases - aerosols (small particles of dust and liquids). Water vapor, however, is very short-lived in the atmosphere, dissipating quickly. It is therefore not considered a long term temperature forcing agent. Land and sea volcanoes emit on average some 200 million tons of carbon dioxide annually, which seems substantial until we compare it to the 24 billion tons of carbon dioxide emitted by human activities. Overall volcano impact is negative; years of serious eruptions are regionally or globally cooler – not warmer.

Regional Oscillations in climate changing factors (El Niño Southern Oscillation; Pacific Decadal Oscillation; Atlantic Multi-decadal Oscillation) often been suggested to exert a more powerful global impact than the evidence indicates.

The *El Niño Southern Oscillation (ENSO)*, primarily influencing the central (equatorial) Pacific, seems to have a global impact that results in El Niño years being some 0.1 to 0.15°C (< 0.2 - $< 0.3^\circ\text{F}$) warmer than La Niña years. However, the pattern is one of cycling back and forth (Figure 15) not of increasing warming. Of particular interest is the year 1998 which exhibited a remarkable El Niño influence. This coincided with the globally unusually hot year from which climate change deniers always now calculate the apparent slowing of the warming trend

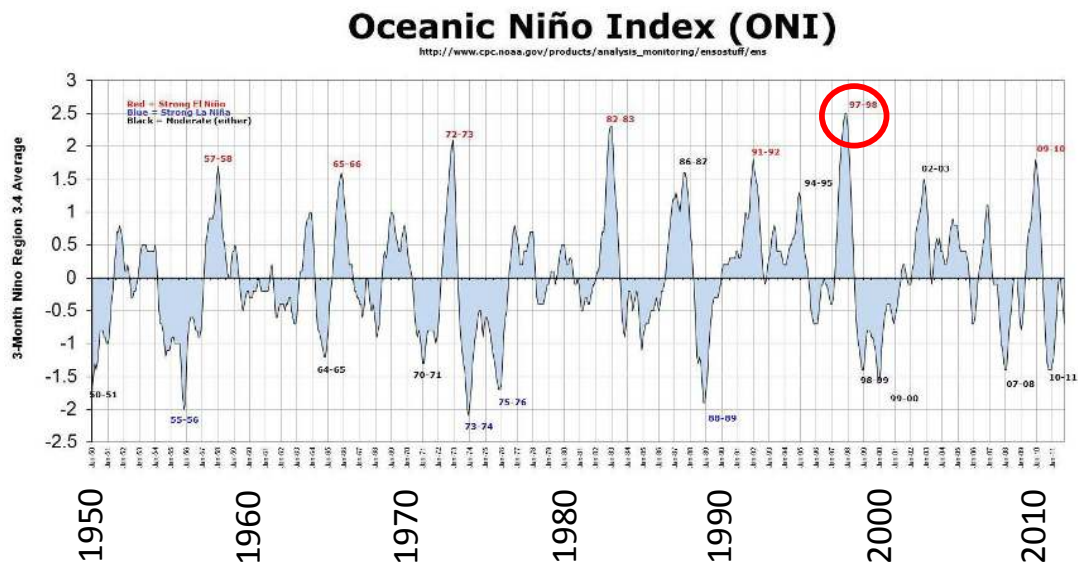


Fig 15. El Niño Southern Oscillation patterns from 1950 to 2012.

<http://ggweather.com/enso/oni.htm>

The *Pacific Decadal Oscillation* (PDO), paradoxically lasting some 30 years fluctuates between a warming and cooling extreme but primarily influences the Northern Pacific rim region. The historic and projected pattern in PDO is depicted in Figure 16 which clearly shows no general warming influence consistent with the global temperature increase of the last few decades. Although the period 1980 to about 2000 was a PDO warming period, this was equivalent to about 1940, but the global temperature in 1940 was far below that of 2000.

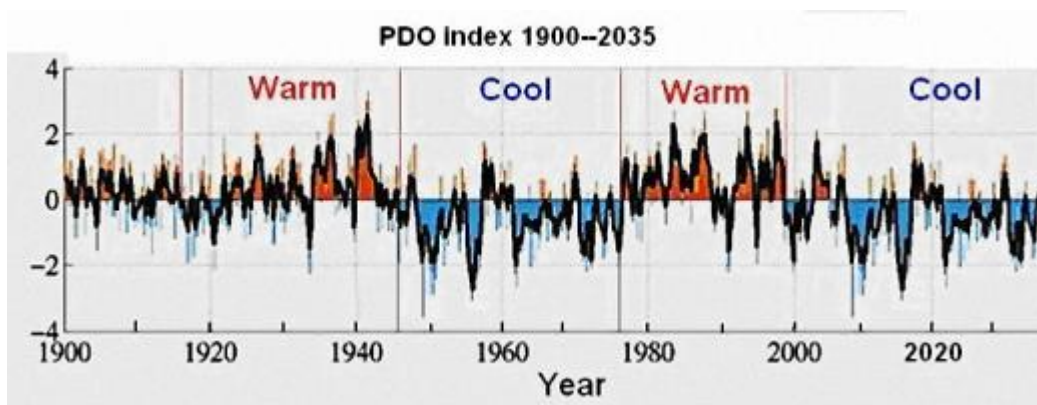


Figure 16. Cycles of the Pacific Decadal Oscillation indicating the warming and cooling periods.

<http://www.dailykos.com/story/2011/12/08/1043534/-eSci-Global-Cooling-Assured-for-the-Next-3-Decades>

The *Atlantic Multi-decadal Oscillation* (AMO) exhibits a 20 to 40 year cycle of warming and cooling (Figure 17) primarily influencing the Atlantic rim. Note that the 1930 – 1970 AMO influence was greater than that during the 1980 – 2000 period. If AMO were having a substantial effect on global temperature, 1930-1970 should have been as hot as the early years of this century. Additionally, while there appears to have been a positive AMO influence from 1980 through the early 2000s, the more recent AMO decrease should have resulted in a cooling back to the temperature experienced around 1990, but such a cooling has not been evident. Furthermore, it is also evident that the potential impact of AMO fluctuating 0.4°C around the baseline is insufficient to explain the global rise of 0.8°C over the last four decades. This suggests that AMO is not a candidate explaining the pattern.

Since the impact of these factors on global climate has been developing and is now relatively well understood, several researchers have explored how variations in these factors might influence global temperatures.

In 2004, Meehl, *et al* reported the global actual temperature pattern since 1900 along with what General Circulation Models incorporating human influences suggest the temperature should have been during that period (Figure 18). The graph also displays patterns for solar

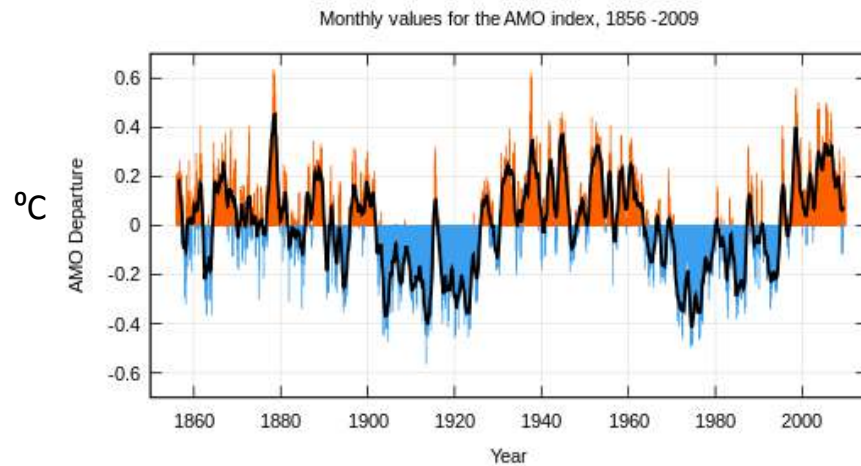


Figure 17. The Atlantic Multi-decadal Oscillation cycle from 1956 to 2009.

<http://www.azimuthproject.org/azimuth/show/Atlantic+multideca>

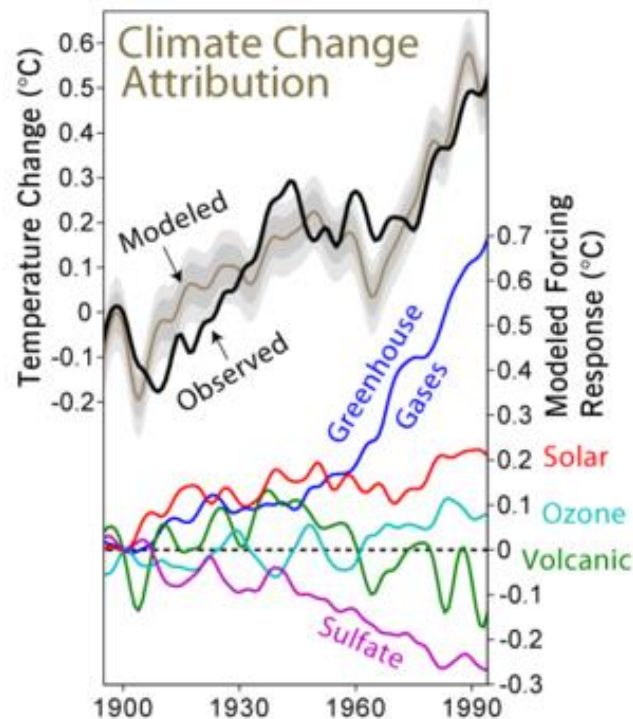


Figure 18. Comparison of actual temperature patterns, modeled patterns and several potential climate factors

http://en.wikipedia.org/wiki/List_of_scientists_opposing_the_mainstream

irradiance, ozone, volcanic input, and sulfate aerosols plus greenhouse gas concentration including their temperature impact. It is evident: (1) Running the models over our known temperature history reveals they are very close to actual values, a good test of model accuracy, and (2) the only variable exhibiting a trend that might stimulate the global increase we have witnessed is that collectively titled 'greenhouse gases.'

Foster and Rhamstorf (2011) explored how variables influenced global climate. They noted that several of these were exhibiting a depressing effect since 2000. Based on models from five sources, and employing a mathematical adjustment, they assessed what the global temperature probably would have been had El Niño, volcanic eruptions, and solar irradiance not been exhibiting a negative impact. The 1980 to 2010 pattern that would have resulted, absent these negative impacts, is depicted in Figure 19.

These data clearly suggest that global temperature would probably have continued to climb consistent with the previous pattern had these natural factors not been depressing it.

Even more recently, (2013) Cowtan and Way reported an adjustment undertaken to correct for the fact that some data sets contain relatively few collection stations in certain critical areas, especially the Arctic where recent warming has been far greater than the general global pattern. Using satellite data

correction techniques to remedy for these omissions, they report that the warming from 1998 to 2012 appears to be identical to the overall pattern from 1950 to 2012 (i.e. 0.12°C per decade (Figure 20). This analysis indicates that warming has not slowed over recent years.

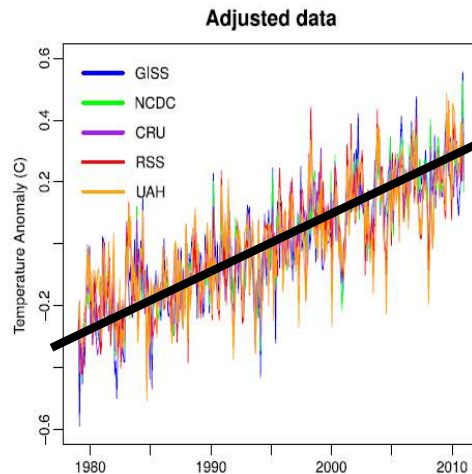


Figure 19. Data from the Foster and Rhamstorf study depicting the probable global temperature pattern from 1980 – 2011 had El Niño, volcanic eruptions, and solar irradiance not been decreasing.

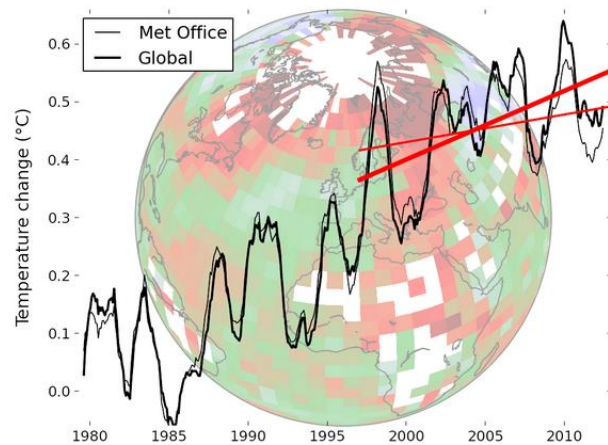


Figure 20. Cowtan and Way correction (thick red line) of data lacking representation from areas where warming has been most pronounced <http://www-users.york.ac.uk/~kdc3/papers/coverage2013/background.html>

An additional measure of current patterns concerns the incidence of record hot versus record cold

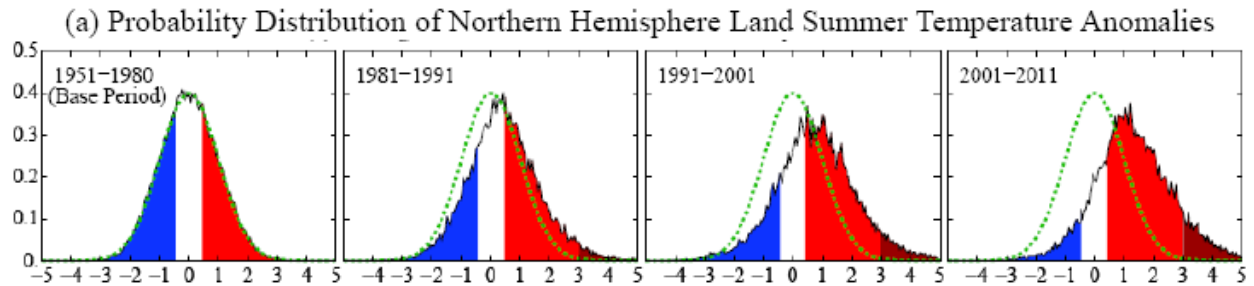


Figure 21. Patterns in record hot (red) versus cold (blue) events since 1951 – 1980

SOURCE: Hansen, Sato & Ruedy 2012 *Increasing Climate extremes and the New Climate Dice*.

events. All other things being equal, had there been no warming trend, it would be expected that the number of instances of record breaking hot events would be about equal to the number of such record-breaking cold events. In a cooling world, the number of record-breaking cold events would be greater, whereas in a warming world, the number of record-breaking hot events would be greater. The pattern that is evident is seen in Figure 21. The data show quite convincingly that hot records have exceeded cold records throughout the decades of the 1980s, 1990s and 2000s. Contrary to the pattern that would exist if warming had ceased or slowed (closer to equal hot and cold records), the pattern of many more record hot events continues.

To the extent that there has been a slowing of atmospheric warming, itself a questionable claim at best, the factors responsible are understood. Furthermore, recent analyses have revealed, as will be explored below, the trapped heat has been absorbed elsewhere. On a global scale, looking at all locations where heat is stored, there is no slowdown in warming.

The Rest of the Story

The discussion above focused solely on evaluating the claim of a slowing in the atmospheric warming trend. I will now explore a different, but equally important area by way of response to the claim that we should stop or postpone concern about the emissions of greenhouse gases. This deals with the vast array of other consequences of the carbon pollution that we have practiced unabated since the industrial revolution.

The issue is **Pollution**. Pollution occurs when we release an environmentally hazardous substance into a location where it has never before existed (the pesticide contaminant dioxin, for example, which has negative environmental and human health consequences) or releasing a substance where it has existed before - but in lower concentrations (salt added to freshwater would be an example since we can easily exceed the normal low salt concentration and thus compromise the health of the entire water body). Releasing carbon dioxide into our atmosphere is the second kind of pollution.

What is driving the climate problem?

First, it is beneficial to understand the mechanism by which our planet traps heat energy.

It all starts with incoming solar radiation (Figure 22). Hot bodies such as the sun, emit most of their energy as short waves ranging from gamma & cosmic rays, through UV and visible light to near infra-red radiation (wavelength 0.1 – 4 μm). Upon colliding with cooler bodies – such as our planet, the short wave radiation is absorbed and transformed (Figure 23) into longer wave infra-red and thermal radiation (wavelength 4 – 30 μm). This is re-radiated back out towards space. Cool bodies, such as planets, emit this longer wave heat radiation. Atmospheric gas molecules with three or more atoms have the capacity to absorb this re-radiating heat and thus warm. These atmospheric gases are called greenhouse gases. They include carbon dioxide (CO_2), methane (CH_4), oxides of nitrogen N_2O , Ozone (O_3) water vapor (H_2O), and such man-made molecules as chlorofluorocarbons (CF_2Cl_2).

In addition to warming the atmosphere, this heat energy can go elsewhere (see below). The concentration of heat-trapping gases may be low (total only about 0.04% which is almost all carbon dioxide) not including water vapor at 1 – 4%, but their influence is profound. Without them, our planet would be 35 -55°F cooler, and would probably neither have afforded conditions where life could

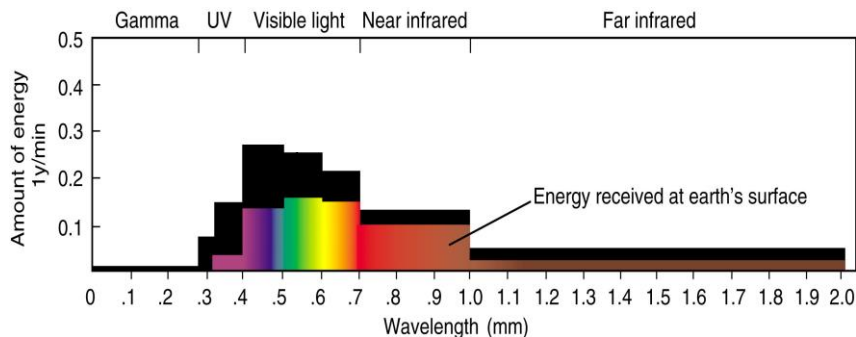


Figure 22. The majority of incoming solar radiation arrives in the short wave range (gamma, UV and visible radiation). Black represents proportion not reaching the Earth's surface.

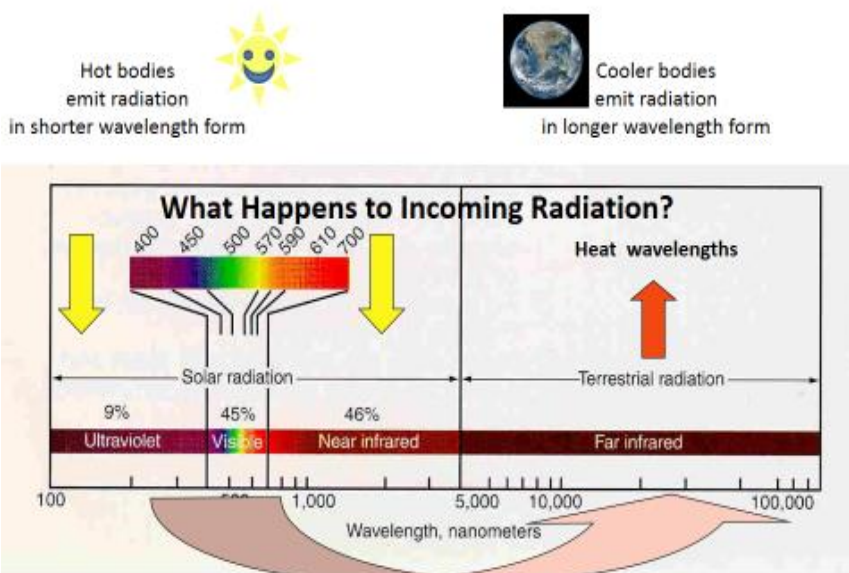


Figure 23. Incoming short wave solar radiation from the sun is transformed into longer wave heat radiation and re-radiates back out into space

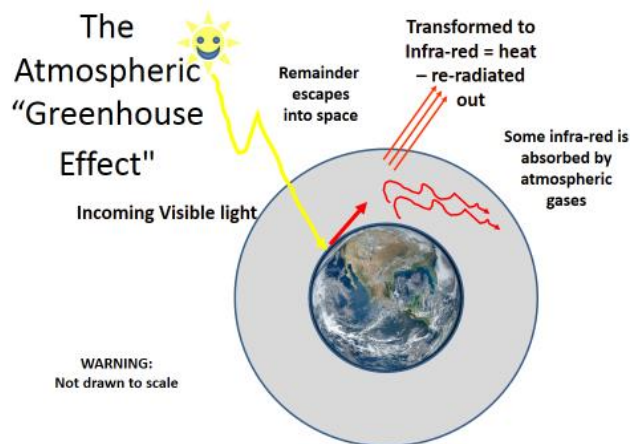


Figure 24. Incoming solar radiation passes through the atmosphere to reach the Earth's surface, transform into longer wavelength heat and radiate out, being trapped by greenhouse gases in the atmosphere – which then warm. *Journet 2013.*

the first suggestions about the warming influence of some were offered as long ago as the 1820s by Joseph Fourier, amplified by John Tyndall in the mid 19thC, and further by Svante Arrhenius in 1896. It was back in the early 1800s that the term 'greenhouse effect' was first used to describe the atmospheric warming process.). During the first decades of the 20th Century, long before the serious warmings of the late 20th Century was evident, atmospheric scientists (eg: Callendar) warned of a pending problem. Since then, studies have confirmed beyond question that gases in our atmosphere trap heat energy radiating from the Earth's surface (Figure 24). From 1958 (notably Keeling), measurements of atmospheric carbon dioxide have been undertaken. Concern about warming effects of these gases long pre-date actual warming. While molecules of carbon dioxide, methane, and oxides of nitrogen trap the radiating energy in their bonds, oxygen and nitrogen lack this property. This phenomenon is well understood and is completely non-controversial.

The remarkable global temperature increase (Figures 1, 2 above - often termed global warming) evident since the 1750s but particularly witnessed since the 1970s/1980s) is the most obvious consequence of our use of the atmosphere as a free

originate or evolve, nor support it currently. These gases are not equivalent in terms of their heating contribution. Methane is 23 times as effective as CO₂ while N₂O is 295 times as effective, and CF₂Cl₂ is some 10,000 – 15,000 times as effective.

Because of its higher concentration and greater longevity in the atmosphere, we focus most of our attention on carbon dioxide, but methane (= natural gas) should not be ignored because of its impact is 23 times as great. Water vapor, though a greenhouse gas, rises and falls in response to temperature and has a very short lifespan. While water vapor can become involved in short term positive warming feedback loops, it is discounted as a major forcing agent because of its short life span.

Our understanding about the properties of atmospheric gases has been developing since

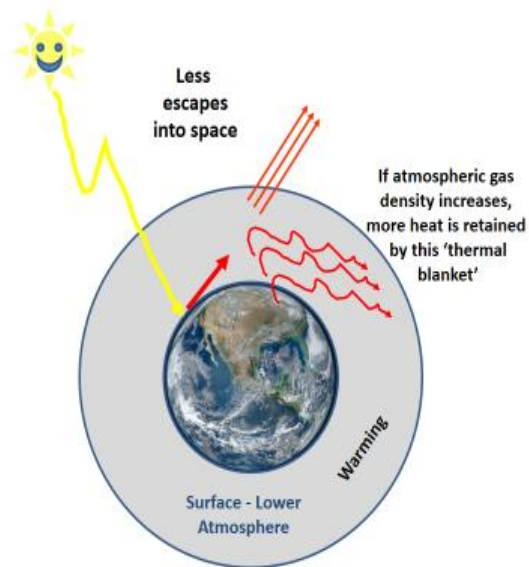


Figure 25. As the heat-absorbing gases build up in our atmosphere, they absorb more of the outgoing heat radiation, and thus warm. *Journet*

dumping place for the gaseous bi-products of our activities. During this period, carbon dioxide has increased from about 285 parts per million (ppm) to 400 ppm a result of which is that more or the re-radiating heat becomes trapped (Figure 25).

Without this thermal blanket of greenhouse gases, the Earth would be 35 - 55°F cooler. Life would probably not have originated and would certainly not resemble anything we see today.

In turn, because heat is retained in the atmosphere, less escapes back out into space (Figure 26).

Carbon dioxide (and other greenhouse gases) may be in a very low concentration, but their impact is profound. However, as mentioned above, warming is only one of the manifestations of our polluting behavior (see 'What is the role of water in concealing the warming trend?' below).

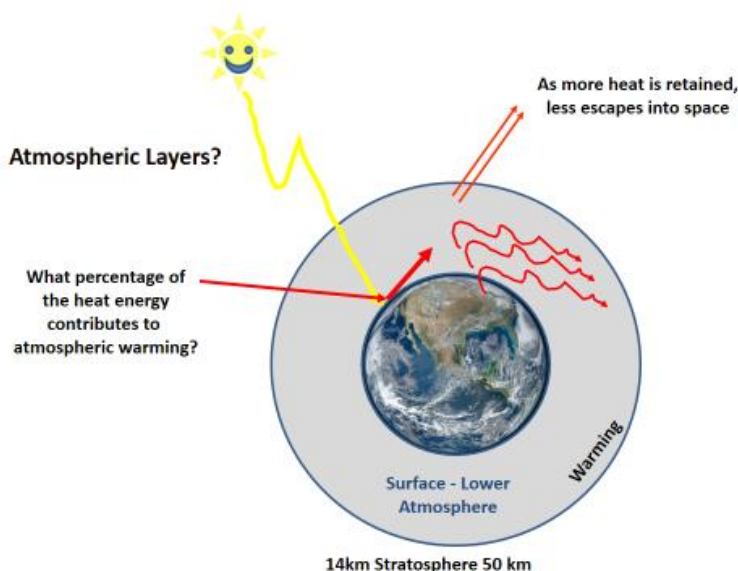


Figure 26. As more heat is retained less heat radiation escapes to space (Journet 2013).

What is the carbon dioxide concentration history in our atmosphere?

Monitoring of the concentration of carbon dioxide in our atmosphere has been undertaken directly since the late 1950s though we have records dating back to the 19th Century (Figure 27). Meanwhile, studying the air bubbles in ice cores, trapped at the time the ice was formed, allows us to track carbon dioxide concentration in the atmosphere back some 800,000 years in Antarctic Ice cores (Figure 28). Cores from Greenland in the Arctic offer similar data but not such extensive records. Note that for 800,000 years carbon dioxide has not been above 300ppm. Indeed, we can go back about 2 million years before CO₂ rises substantially above 300ppm, essentially the period humans have roamed the planet.

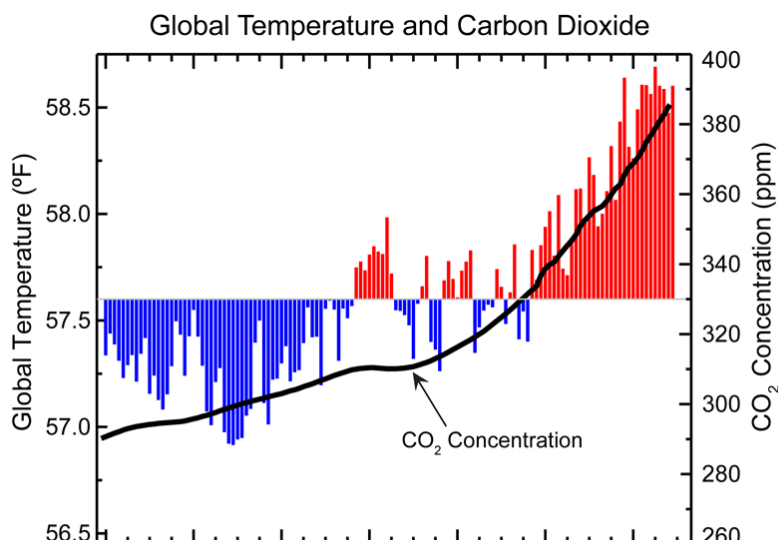


Figure 27. Trend in global carbon dioxide and temperature since 1880. Note similarity.

<http://www1.ncdc.noaa.gov/pub/data/cmb/images/indicator/s/global-temp-and-co2-1880-2009.gif>

As a result, we can track the parallel patterns in carbon dioxide concentration and temperature. The relationship is a little more complex than the graphs indicate, but the close relationship is clearly evident.

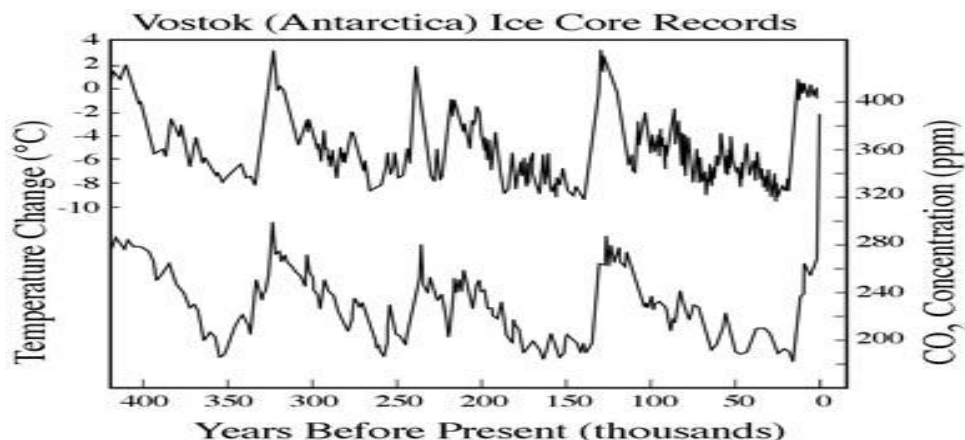


Figure 28. 800,000 years of carbon dioxide and temperature from the Antarctic Vostok Ice Core.

<http://michigantoday.umich.edu/2009/11/vostok-graph.jpg>

Other techniques allow assessments of temperature and carbon dioxide back through geologic time. Using isotopic carbon concentration in phytoplankton shells, for example, atmospheric concentrations can be determined over hundreds of millions of years. Such techniques provide what are called *Proxy Data* meaning values that allow inference of what the temperature was at the time.

What relevant properties are exhibited by water?

In addition to heating the atmosphere, much of this heat energy actually goes elsewhere than the atmosphere. To understand where, it is necessary to appreciate two critical properties of water.

Specific Heat deals with the amount of energy required to raise the temperature of a substance. Having high specific heat, water requires considerable energy (heat) input to raise its temperature especially compared to air. Place a thermometer in a jar of water and another in a jar of air, and apply heat; you'll see which warms faster. Heat and temperature are often confused, but heat energy (measured in Joules) is different from temperature (measured in degrees)

Latent Heat deals with the energetics of changing state. When ice melts to water, and water evaporates to vapor, considerable heat (energy) is consumed from the surrounding system – without a change in the temperature of the water. This is why sweating works – the evaporating sweat consumes heat from, and thus cools, our body. The reverse transition releases heat (energy) without a temperature change occurring. Thus when water vapor condenses into rain in the atmosphere, energy is released (this process increases the energy content of, and severity of, storms). Similarly energy is released as water forms into ice (a process that results in the water body itself gaining heat energy and thus resisting further ice formation).

These two properties result in water, our lakes and oceans, serving as vast heat sinks that suck up the heat energy resulting from the transformation of visible wavelengths of radiation into heat. If it weren't for the oceans absorbing this heat, our atmosphere would undoubtedly be warming much faster. In fact some 90% of the increase in trapped heat energy is actually being absorbed by our oceans.

Another interesting feature of water is that the maximum density is at about 4°C. If cooled below this water expands – and especially so when it freezes – hence ice floats. Above 4°C water also expands. Thus, one consequence of a body of water (ocean) heating is that it increases in volume - a process known as thermal expansion.

Thus, in addition to looking solely at air temperature as a measure of continued trapping of heat energy we must look at other locations where the heat energy might go and assess their trends. One line of evidence suggesting that the oceans are retaining heat and warming is that the sea level is continuing to rise, and at an accelerated rate. An additional consequence of warming oceans is thinning ice packs at the poles; this has not slowed.

What is the role of water in concealing the warming trend?

Figure 29 depicts the heat content of the upper ocean over the last 6 decades. From this graph, measuring ocean heat content in Joules not temperature, it is evident that our oceans have been absorbing vast amounts of the heat energy. While oceans have also been warming, because of the properties of water identified above, the warming is less pronounced than is the increasing heat content.

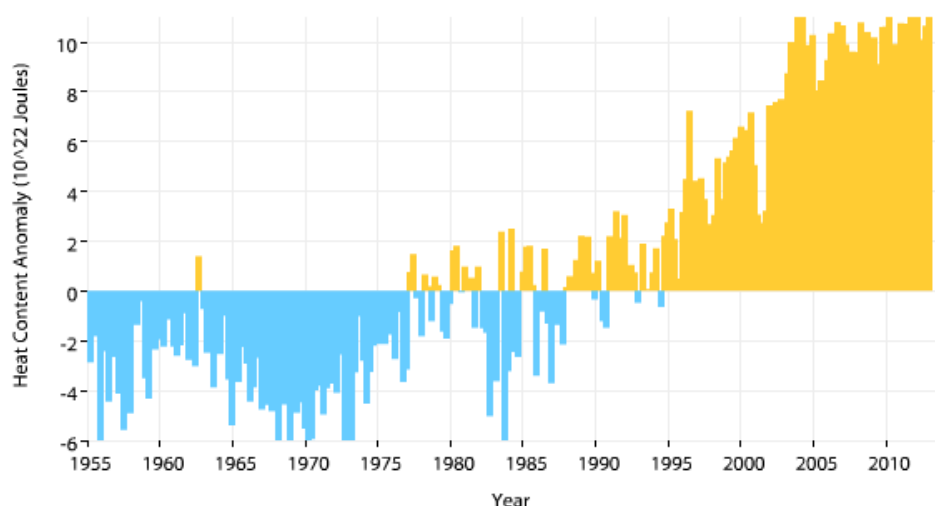


Figure 29 Heat content of the top 700 meters of ocean from 1955- 2006.
Source: NOAA - <http://www.climate.gov/news-features/understanding-climate/climate-change-ocean-heat-content>

Our oceans are tremendous heat sinks (Figure 30), storing energy that will be released for decades. Indeed, it is estimated that over 90% of the trapped heat energy is consumed by oceans. Focusing on atmospheric warming misses nearly 98% of the heating effect since 93.4% of trapped energy heats oceans; 2.1% heats continents, 0.9% glaciers and ice caps, 0.8% Arctic sea ice, 0.2% the Greenland ice sheet and 0.2% the Antarctic Ice Sheet. Only 2.3% contributes to atmospheric warming. It is evident that even if atmospheric warming has slowed (questionable, as argued above) global heating has not slowed during the first decade of this century.

In a reconstruction of Pacific Ocean temperatures over the last 10,000 years, Rosenthal, Linsley and Oppo reported (2013, *Science*) that middle depths have warmed 15 times faster in the last 60 years than they did during apparent natural warming cycles in the previous 10,000 years.

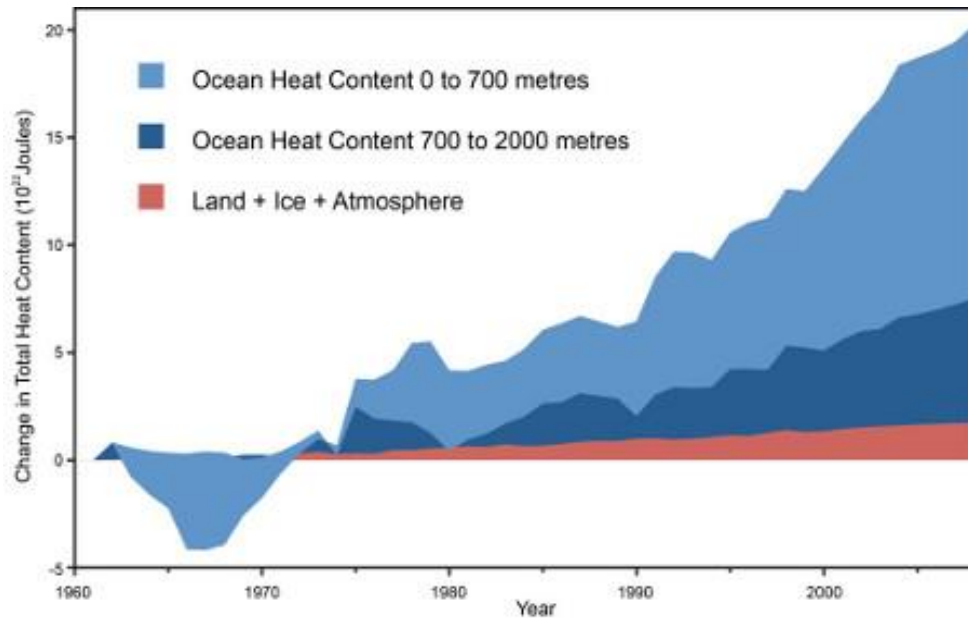


Figure 30. Heat content of upper and mid-level ocean depths.
 Nucitelli D, Way R, Painting R, Church J, Cook J. 2012 Comment on Ocean heat content and Earth's radiation imbalance. II. Relation to climate shifts
http://www.skepticalscience.com/docs/Comment_on_DK12.pdf

The impact of the Gulf Stream on the climate of Western Europe is evidence of the impact of warm oceans. Without the Gulf Stream carrying warm waters from the tropics across the Atlantic Ocean, Europe would be considerably colder. Comparing coastal seasonal and daily temperature fluctuations with those inland will indicate the profound stabilizing impact that oceans and local humidity have on local climate: winters are warmer, summers are cooler and daily fluctuations less pronounced.

Are Atmospheric and Oceanic Warming the Only Problems?

Our focus on the temperature of the atmosphere around us is understandable since we are land-dwelling creatures and it's the most immediate effect evident to us. However, it misses an array of other effects (Figure 31) identifying a series of measurable consequences of warming atmosphere that have shown no sign of abating. Indeed, sea level rise has actually accelerated over recent decades.

Particularly worth noting here is the impact of atmospheric carbon pollution on the oceans. Because carbon dioxide is absorbed by the oceans, much of the gas we have emitted over the last 250+ years has left the atmosphere. While this slows atmospheric warming it causes other problems. The carbon dioxide forms carbonate ions which result in carbonic acid formation → thus making our ocean more acidic. While this may not seem very serious, for the success of aquatic life and systems the acid composition of the oceans is critical. The first problem is that marine organisms producing calcium shells are compromised because the carbonate is unavailable. This prevents shell formations and results in shell reduction of organisms already possessing shells. In addition, fish and marine mammals suffer from an overly acidic environment with a build-up of acid in the tissues – inducing acidosis which compromises respiration, growth, development, reproduction, and healthy viable populations.

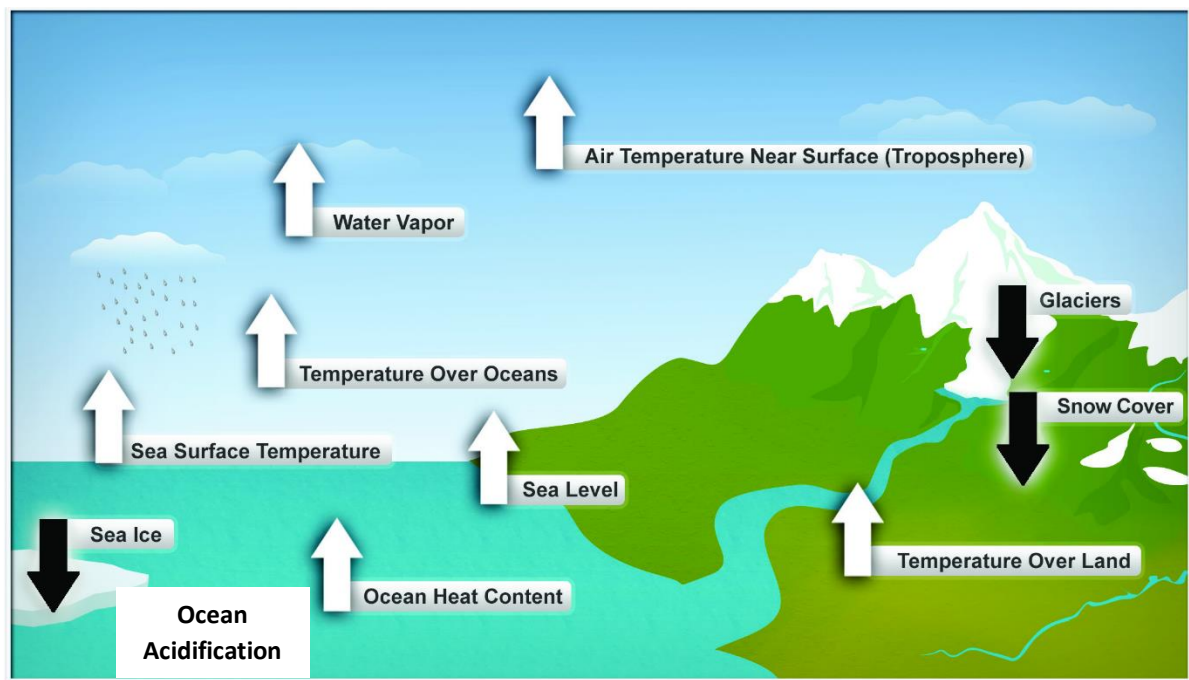


Figure 31 Eleven Indicators of a carbon polluted planet. Modified from:
<http://www.globalchange.gov/what-we-do/assessment> p. 30

Closing Notes and Conclusion:

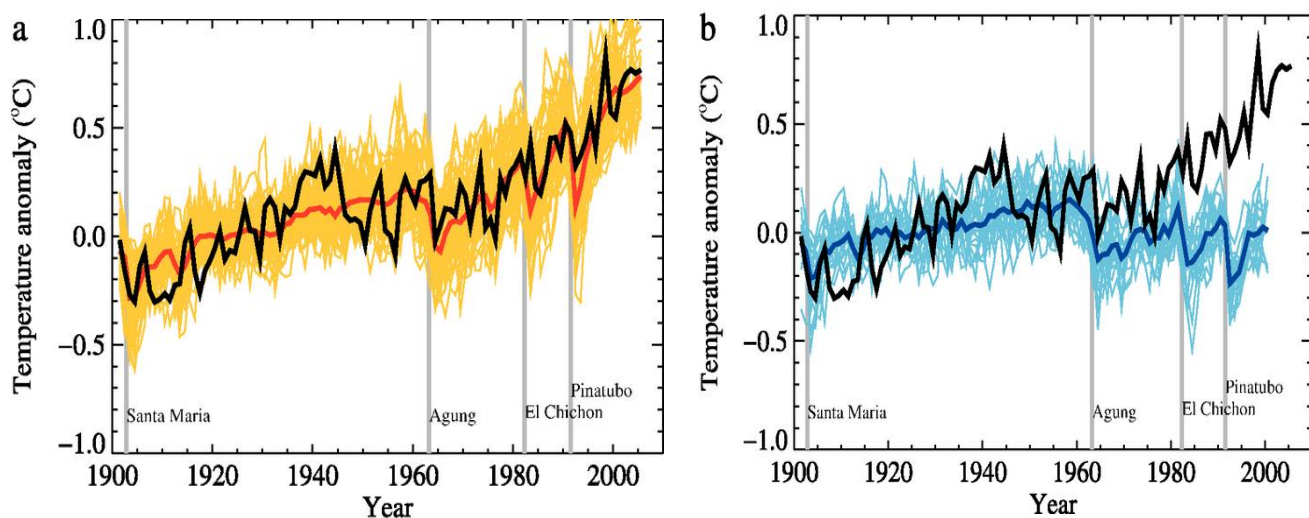


Figure 32. Climate Models are tested by comparing simulations with meteorological station data. 32a) presents actual historic data (black) and models that include human activities (red-orange) while 32b) presents actual data (black) compared with models lacking human influences (blue). From IPCC AR 4 2007. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/figure-9-5.html

One of the frequent criticisms of climate science is that the models are inaccurate and overestimate future atmospheric consequences. The reality, however, is that General Circulation Models (also known as Global Climate Models) actually track historic temperature patterns of the last century very well if human influences are included (Figure 32a). On the other hand, when human influences are excluded the models totally fail to simulate past temperature patterns – completely failing to track the increase that we have experienced (Figure 32b). It is evident that models excluding human influences totally fail to simulate the historic temperature pattern while those including human influence simulate actual data very accurately.

Another oft-repeated criticism is that if one ‘follows the money’ one will find that climate scientists are reaping huge

personal financial rewards for promoting climate alarmism. A comparison of the salaries of fossil fuel corporate CEOs, the profits of their corporations and salaries of climate scientists (Tables 2 and 3) reveals the absurdity of this argument; it’s clear where the financial resources and incentives are sufficient to drive biased opinions.

Risk is a function of the probability of an event happening multiplied by its severity should it happen.

Even if one thinks the probability of human induced climate change is low, the severity, were it to occur, is sufficient to warrant our action. To reject the evidence and demand ever more

CEO	Company	Salary	2012 Profit (billions)	5 year profits (millions)
Tillerson	Exxon-Mobil	\$40,266,501	\$44.9	
	Shell		\$26.6	
Watson	Chevron	\$32,277,122	\$26.2	
Heminger	Marathon	\$17,932,895		
	BP		\$12.2	
	Conoco-Phillips		\$8.4	
Bruce	Peabody Energy	\$9,491,405		\$3,396
	Consol			\$2,229
	Alliance Resource Partners			\$1,207
Leer	Arch Coal Corp.	\$5,094,248		\$871
	Cloud Peak Energy			\$704
Crutchfield	Alpha Natural Resources	\$1,879,875		
Total US Fossil Fuel Corporate Profits (2012)			\$271	
Total US Fossil Fuel Subsidies (2010)			\$66	
Total Global Fossil Fuel Subsidies (2010)			\$775 – 1,000	
Table 2. Fossil Fuel CEO Salaries and Corporate Profits. Data from various sources.				

Climate Scientists Opportunities	Salaries (actual)
Berkeley Senior Climate Scientist (2012)	\$119,000
Penn State Senior Climate Scientist (2012)	\$120,000
UNH Assistant Professor (2013)	\$52,860 - \$81,470
Berkeley Senior Climate Scientist (2013)	\$117,000
Average Climate Scientist (Nov 2013)	\$74,000
Table 3. Salaries of Climate Scientists – data from various sources.	

data is potentially to consign future generations to an unlivable planet; at least a planet that is able support life as we know it will be profoundly compromised.

Fully ninety seven percent of practicing climate scientists have independently reached similar conclusions to the 2007 Intergovernmental Panel on Climate Change (IPCC AR4) that: Warming of the Earth is unequivocal, and most of the observed increase in globally averaged temperatures since the mid-20th Century is very likely (defined as greater than 90% probability) due to the increase in anthropogenic [human released] greenhouse gas concentrations.

Subsequently, the 2013 IPCC report (AR5) has concluded that: the atmospheric concentrations of carbon dioxide (CO₂), methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years; human influence on the climate system is clear as is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system; it is extremely likely (greater than 95%) that human influence has been the dominant cause of the observed warming since the mid-20th century; most aspects of climate change will persist for many centuries even if emissions of CO₂ are stopped today.

There remains, however, a small number of climate scientists who reject this conclusion, but the question to ask is whether one would trust the judgment of 97 Physicians concurring on a diagnosis or rely on the three who disagreed.

Many of us are happy to pay insurance to protect ourselves against severe but unlikely events – and when we are required to buy insurance to undertake activities such as driving we do not rise up in opposition to reasonable state or federal requirements. Should not the same principle hold for a threat as serious as climate change? The ‘no regrets’ approach promoted by such as George Schultz (Reagan’s Secretary of State) is to place a fee on carbon to reduce its emissions, and use that fee to offset other taxes.

The conclusions suggested by this analysis are:

- 1) If the atmospheric warming trend has slowed, neither is it sufficient nor for long enough that we should reasonably reduce our level of concern. More likely, global warming as a whole, has accelerated while the apparent atmospheric hiatus has been in evidence.
- 2) The concentration of atmospheric greenhouse gases, particularly carbon dioxide, have a demonstrated impact on atmospheric temperature and exhibit a pattern consistent with the warming we have seen since 1880. Meanwhile, none of the other possible influences on global temperature exhibits a pattern consistent with that trend. If a natural phenomenon is responsible for global warming since the 1880s it is one unknown by science to have such an effect.
- 3) The overall heat balance of the warming we have experienced indicates that, even though there may have been a slowing of atmospheric warming, the global system is still heating.

For further discussion, visit: <http://www.realclimate.org/index.php?p=16547>