GLOBAL CLIMATIC VARIATION, CHANGE AND ENERGY USE

11/5/2016

"You cannot escape the responsibility of tomorrow by evading it today."
Abraham Lincoln

"Whenever you find that you are on the side of the majority, it is time to pause and reflect."
Mark Twain

"If we do not change direction, we shall end up where we are going."
Chinese proverb

"The whole aim of practical politics is to keep the populace alarmed; and hence clamorous to be led to safety, by menacing it with an endless series of hobgoblins, all of them imaginary."
H. L. Menken

INTRODUCTION

It is being increasingly realized that "climatic variation" is associated with inevitable long term natural cyclic phenomena, whereas "climatic change" is associated with short term controllable anthropogenic or human effects. Humanity is destined to gradually adjust to the natural variation as well as the anthropogenic or human-caused change. Otherwise, the Earth's feedback mechanisms would predominate, causing global economic, social and political dislocations, even threatening humanity as the dominant biological species on Earth.

It is unfortunate that climatic change is debated as if it were a policy issue like the death penalty or budgets where rational arguments can be made one way or the other on the merits and demerits. Climatic change is nothing of the sort, it is basic science. According to the Pew Research Center, only 27 percent of Americans agree that "almost all" climate scientists say that human behavior is mostly responsible for climate change, while 35 percent say that "more than half" of climate scientists agree on this. An additional 35 percent of those surveyed say that fewer than half at 20 % or almost no (15 %) climate scientists believe that human behavior is the main contributing factor in climate change. The Pew Research Center contrasted this to the United Nations' Intergovernmental Panel on Climate Change (IPCC), which "stated in the forward to its 2013 report, 'the science now shows with 95 percent certainty that human activity is the dominant cause of observed warming since the mid-20th century.'"

The Intergovernmental Panel on Climate Change (IPCC), a United Nations (UN) group, reported on September 27, 2013 that the three main gases blamed for global warming: CO_2, CH_4 and N_2O (nitrous oxide, laughing gas), are at their highest level in at least 800,000 years. An increase of 2 degrees Celsius (^oC) or 3.6 degrees Fahrenheit (^oF) is expected by the end of the present century. According to most climate models, an expected temperatures rise by around 0.25 ^oC or 0.45 ^oF over 10 years did not materialize. The observed increase over 15 years was just 0.06 ^oC or 0.11 ^oF. Secondary concerns are arising such as the rising sea levels and the potential acidification of the oceans due to CO_2

being introduced into their food chain from the atmosphere.

It is a misconception that global variation involves only higher temperatures. What is happening is a higher energy input into the climatic system and hence larger energy fluxes, which stimulates chaotic and more extreme weather phenomena such as heat waves, droughts, and floods caused by the altered air and ocean currents.

The entire Northern Hemisphere was warmer than average during 2012. Drought affected agricultural regions in North America, Europe, eastern Russia, the Ukraine, and Kazakhstan. These warm conditions impacted grain yields, water supplies, and heat-related illness. Global food prices rose by 10 percent during July 2012. The USA Department of Agriculture (USDA) estimates that that wheat production in the Great Plains will drop by 6 percent by 2050, and corn yields will fall by 4 percent due to expected extreme weather conditions. A shift in the existing locations of major crop production is observed. For instance, the center of the wheat production belt in the USA has migrated 173 miles to the northwest in the last 50 years. A similar trend exists for corn which has shifted 100 miles in the same direction.

CO_2 concentration averaged 400.03 parts per million (ppm) at the USA National Oceanic and Atmospheric Administration's Mauna Loa monitoring station in Hawaii on May 9, 2013. The last time that CO_2 concentration reached that level was 3 million years ago. The temperatures than were 2 to 3 degrees Celsius higher than pre-industrial times, the polar ice caps were much smaller, and sea levels were about 20 meters (66 feet) higher than today. CO_2 can linger in the atmosphere for a century, so present levels may cause warming for decades to come. The present concentration is 40 percent higher than the pre-industrial age level of 280 ppm.

The United Nations (UN) in 2007 set a goal of stabilizing the CO_2 concentration at 400 - 440 ppm, which would cause a temperature rise of 2.8 degrees Celsius or 5 degrees Fahrenheit. This could lead to a sea level rise of 1.7 meters that would threaten the coastal cities and the river deltas of the world. On the other hand, climate treaty negotiators from 190 nations wish to limit g the temperature increase to 2 degrees Celsius. The global average rose by about 0.8 degree Celsius since the pre-industrial age.

The oceans and terrestrial biosphere exchange about 160 Giga tons (Gt) of C according to the IIRC with the atmosphere each year. This is about one fifth of the atmospheric reservoir. So the residence time or the amount of time a molecule of CO_2 remains in the atmosphere before being taken up by the oceans and biota is about five years.

About 29 Gt per year are added to the Earth's atmosphere from different anthropogenic and natural sources, but only 15 Gt/year are staying in the atmosphere, indicating that nature acts as a sink for the additional about one half of the total amount of 14 Gt/year in the oceans and biota. Since nature absorbs about 1/2 of our annual CO_2 emissions, one can say that the rise in CO_2 concentration is caused by the lack of nature's ability to absorb all of human emissions. Part of the lack is due to the warming oceans. An interesting observation is that the addition of CO_2 to the Earth's atmosphere is depleting twice as much oxygen (O_2) as the carbon added (C), an important effect that also merits attention.

Ice-core isotopic measurements in central Greenland and Antarctica reveal that the Earth's climate is dynamic and has been varying over geological times from cooling periods to warming periods. The Earth currently undergoes a warm period of the climatic variation primarily caused by natural factors that existed before human ascendance. They reach beyond humans' control such as orbital perturbations, solar luminosity, tectonic plate movements, ocean and air currents, comet or asteroid astral assailants, volcanic activity and galactic cosmic rays irradiation affecting cloud formation.

Nitrogen constitutes 78 percent of the Earth's atmosphere, whereas oxygen only constitutes 21 percent of it. Neither one of them constitutes a significant concern. Water vapor is the most significant greenhouse gas. The current concern about climatic change is the rise in atmospheric carbon CO_2 concentration and other greenhouse gases such as methane (CH_4), nitrous oxide (N_2O), ozone and the halocarbons group of gases containing fluorine, chlorine, and bromine (e. g. the chlorofluorocarbons CFC-11 and CFC-12); which is very unusual for the Quaternary geologic period of the last 2 million years.

The concentration of CO_2 is known for the past 650,000 years from Antarctic ice cores where it varied between a low of 180 parts per million (ppm) during cold glacial times and a high of 300 ppm during warm interglacial periods. However, over the past century, it rapidly increased to 379 ppm. In comparison, the 80 ppm rise in CO_2 concentration at the end of the past ice age generally took over 5,000 years to occur. The higher values than at present have only occurred several million years ago.

Human activities starting 1750, since the beginning of the industrial revolution, have added CO_2 into the atmosphere through the burning of fossil fuels and deforestation. Positive reinforcing feedback effects occur. As warming occurs, more water vapor in the atmosphere intensifies the process and possibly doubling it. The Clausius-Clayperon relation determines that the water holding capacity of the atmosphere increases 7 percent for every 1 degree Celsius increase in temperature. The sea level currently rises by about 3 mm or 0.1 in per year on average.

High clouds are effective at absorbing infrared radiation then reradiating it, further heating the Earth. On the other hand, low lying stratocumulus clouds reflect some radiation back to space. Ice melting decreases the albedo of the Earth, or its reflectivity, further adding a positive feedback effect.

Charles Keeling [19] started measurements of atmospheric CO_2 at the Mauna Loa observatory in Hawaii in 1958. In June 1958, the value was 317.27 parts per million (ppm). The Kyoto climate treaty was available for signature in June 1992 when the CO_2 concentration had become 358.79 ppm and rising at a rate of 1.22 ppm per year. By June 2006, the value was 384.21 and rising at the larger rate of 1.92 ppm per year. Pledges by countries is to reduce the predicted emissions in 2020 to 52 gigatons / year from the present 58 gigatons / year. The emission rate consistent with 2 degrees of warming is 44 gigatons / year.

The best estimate is that 50 percent of the global change is due to greenhouse gas increases. Because of a time lag, even if humans were fully responsible for global change, there may not be any direct recourse available.

As the long running debate about whether global climate change is anthropogenic as human-caused from greenhouse gases emission, or caused by natural causes, rages; logic demands that the attention of sober minds should shift into identifying and anticipating the expected changes, adapting to them, and optimistically stabilize or even reverse them.

An analytical model is here developed for estimating the heat fluxes in the lower and upper atmospheres that would result from increases in the carbon dioxide (CO_2) concentrations and the ensuing temperature changes. For a doubling of the CO_2 concentration by volume, the net heat flux to the troposphere is estimated to increase by 22 percent and for a quadrupling of the concentration, the net heat flux increases by 39 percent, implying an enhanced energy input to the region of the atmosphere where weather phenomena are initiated.

Average USA temperatures could jump as much as 4 degrees Fahrenheit or 2.2 Celsius within a few decades according to a 2013 USA Global Change Research Program 60-member panel suggesting that many USA coastal areas face “potentially irreversible impacts” as warmer temperatures lead to flooding, storm surges and water shortages. The chances of record-breaking, high-temperature extremes will continue to increase as the climate continues to change [29]. Reports in 2000 and 2009 by the USA Global Change Research Program concluded that CO_2 emissions since the Industrial Revolution have led to a warming of the Earth’s temperature, which threatens to cause extreme weather, drought and floods.

Average USA temperatures are up 1.5 degrees Fahrenheit since 1895, with most of the increase occurring in the past three decades. The year 2012 was the warmest on record going back to 1895 for the 48 contiguous USA states and the second-worst for weather extremes including arid conditions, hurricanes and wildfires, according to the National Oceanic and Atmospheric Administration (NOAA).

The possible impact of the increased temperatures includes more intense heat waves, reduced water quality, increased risk of coastal erosion and stronger storm surges along the coasts. Beyond the next few decades, the amount of climate change will still largely be determined by choices society makes about emissions.

From a different perspective, warming will mean a longer growing season in the USA Midwest and Northeast, and farmers should be able to adapt to warmer seasons for the next 25 years.

In case efforts to reduce emissions are unsuccessful, a planetary engineering or geo-engineering project is proposed to mitigate the effects of a possible runaway global change. The goal is the restoration of the ancient circumglobal equatorial current. By excavating a trans-isthmian sea-level canal through the Isthmus of Panama using conventional and nuclear civil engineering methods, the temperate climatic conditions that existed 3 million years ago could be restored. Other alternatives involving ocean iron seeding, atmospheric injection of sulfates and cloud seeding to increase the reflectivity to solar radiation and shading the Earth with Mylar disc reflectors, are discussed.

DYNAMIC EARTH CLIMATE

The climate of the Earth has been always dynamic. To our best knowledge, when the solar system was formed 4.2 billion years ago and the sun ignited, warm periods have alternated with cold periods. The first period of glaciation is thought to have occurred 2.3 billion years ago during the early Proterozoic period after the appearance of oxygen in the atmosphere. The Cryogenian glaciation lasted 200 million years over the period of 850-630 million years ago with the ice caps meeting at the equator and covering the whole planet. Geologists consider that the Earth is in an interglacial period of the most recent Quaternary glaciation which started during the late Pleiocene 2.6 million years ago. The ice sheets advanced and retreated in 40,000-100,000 years cycles. The last glacial period which ended just 18,000 years ago covered North America and Europe with glaciers thousands of feet in depth.

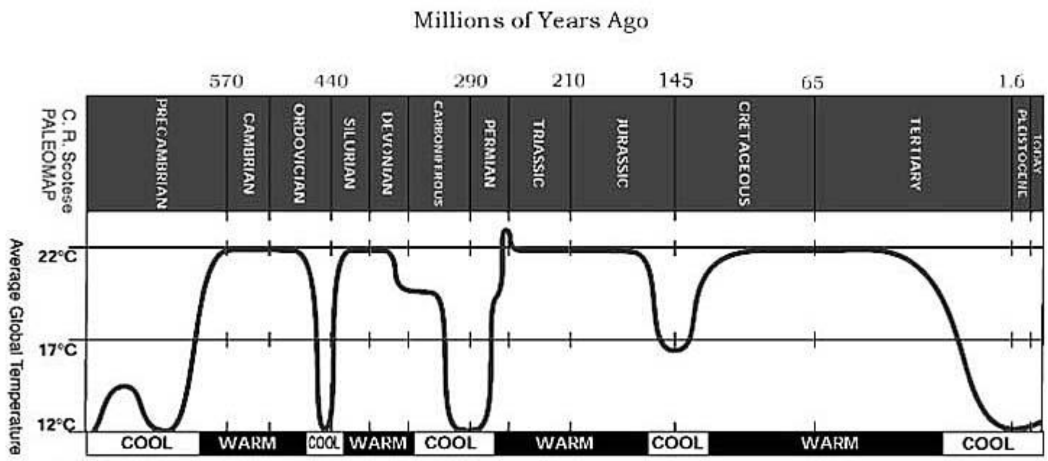


Figure 1. Temperature variation over the geological ages. The Earth emerged from the most recent glaciation period 18,000 years before present.

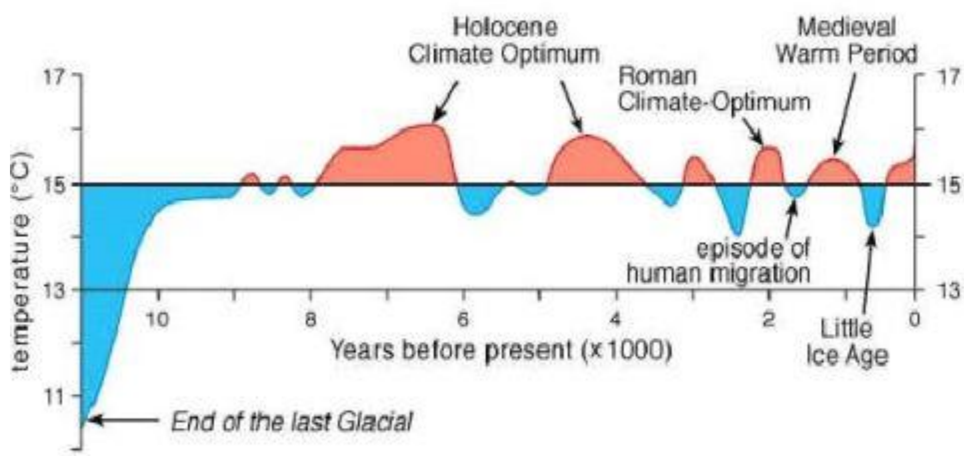


Figure 2. Exit from the last glaciation period.

Natural causes of climate change, like the sun activity and oscillating ocean currents challenge the dominance of CO_2 which could cause a warming of about 2 degrees Celsius or 3.6 degrees Fahrenheit by the end of the century. Amplification effects such as water vapor, can lead to a higher value. The fluctuations in ocean currents, such as the 60-year Pacific oscillation, which was in a positive warm phase from 1977 to 2000 and, since 2000, may have led to cooling as a result of its decline. Black soot creates 55 percent of the warming effect of CO_2, but it could be filtered out with little effort in the emerging and developing countries with large benefits to human health.

Cyclical climatic temperature variations have occurred over the last 7,000 years, long before humans began emitting CO_2 into the atmosphere. There exist warming phases with a 1,000 years period, including the Roman, the Medieval and the current warm periods. All of these warm periods consistently coincide with strong solar activity. In addition to this solar cycle, there is also a 210-year and an 87-year natural cycle of the sun. It is thought that the temperature changes by more than 1 degree Celsius for the 1,000-year cycle and by up to 0.7 degrees Celsius for the smaller cycles.

In the second half of the 20th century, the sun was more active than it had been in more than 2,000 years. This “large solar maximum”, as named by astronomers, may have contributed at least as much to global warming as the greenhouse gas CO_2. The sun has been getting weaker since 2005, and it is expected to do so in the next few decades possibly causing a cooling effect. An unusually long solar minimum, evidenced by the very small number of sunspots at the time, is thought to have led to the “Little Ice Age” that began in 1645.

The sun's magnetic field has weakened since 2000. This weakening magnetic field is thought to shield the Earth less against cosmic radiation. This in turn leads to enhanced cloud formation, shielding the Earth against solar radiation and hence cooling. The Cloud Experiment, headed by physicist Jasper Kirkby at the CERN particle research center near Geneva, Switzerland, has been testing this hypothesis since 2006. Tests were conducted in a chamber in which the Earth's atmosphere was simulated showed that cosmic particles do indeed lead to the formation of aerosol particles for clouds. The aerosols demonstrated in the Cloud Experiment are however too small, and would have to grow substantially before they could actually serve as condensation sites for cloud formation.

The Earth and its inhabitants are currently enjoying the benefit of an interglacial warm period. Modern civilization has emerged only 10,000-5,000 years ago during that warm period. During the Roman Climate Optimum, Egypt was considered the “cellar of the Roman Empire,” with wheat grown in what is now the Western Egyptian desert. The collapse of the Han Dynasty in China and the Roman Empire seem to coincide with a period of global cooling, resulting in what is called the Dark Ages. This was followed by the Medieval warm period when grapes for wine were grown in England and crops in Greenland; hence the “Green” part in the name. This period ended with the Renaissance period. Humanity using modern technology kept advancing through the Little Ice Age, which ended just about 150 years ago.

Solar cycles and changes in the Earth’s orbital movement affect the climate. Cloud formation is thought affected by galactic cosmic ray radiation that is isotropically irradiating the Earth and originating from the rest of the Milky Way Galaxy.

Changes in the oceans and their currents have an impact on the climate because of the large heat capacity of the water as a solar heat sink. Ocean currents are affected by tides, winds, and thermohaline circulation. Thermohaline circulation is a process driven by density differences in water due to temperature (thermo) and salinity (haline) in the oceans. This also applies to the atmospheric air currents.

Volcanism affects the Earth climate. As an example, the historically most energetic eruption of Mount Tambora in April 1815 killed thousands directly and tens of thousands indirectly from starvation. The year 1816 was named “the year without a summer,” as crops failed and livestock died causing mass starvation. The contemporary eruption of Mount Saint-Helens blew 0.7 cubic kilometer of ash and dust into the atmosphere covering the state of Washington in the USA with 4 inches of ash. This can be compared with an earlier Yellowstone eruption which ejected 1,000 cubic kilometers covering most of the North American continent.

Astral assailants as comets or asteroids caused giant tsunamis, global cooling and mass species extinctions. The latest Tunguska meteoric event occurred in 1908 leveled a thousand square miles of trees in Siberia.

Paleontological data suggest that a 100 ppm reduction in CO_2 during the last glacial period was accompanied by 3 degrees Celsius of cooling in the western tropical oceans; and larger changes occurred at the higher latitudes. Other changes included the growth of large ice sheets, lower sea levels, lower snow lines, and altered patterns of circulation.

NEGATIVE FEEDBACK EFFECTS

The atmospheric CO_2 levels in the Arctic have passed the 400 ppm for the first time in 2012. Yet, a vast CO_2-sucking phytoplankton bloom has been discovered beneath the Arctic ice. Research conducted in the Chukchi Sea in 2011 as part of NASA's Icescape Arctic-research expedition. This massive under-ice bloom discovered during Icescape was thoroughly unexpected. The meager amount of phytoplankton in that area's open waters had led scientists to believe that under-ice phytoplankton would be even rare. However, due to the recent thinning of the Arctic ice sheets, enough light is now able to penetrate below the ice, enabling phytoplankton to thrive.

Ponds of melt water form on the surface of the ice sheet, act as “skylights” that let light reach the phytoplankton below. These skylights do not have to let the light travel far: since satellite observations began in 1979, summer ice has declined by about 45 per cent due to global warming, wind patterns, and pollution. Much of the melt-season sea ice is now no more than around six feet thick, and has little or no snow cover. Without snow cover, more melting occurs; more melt ponds form, more skylights; and more sunlight reaches the phytoplankton.

The amount of phytoplankton blooming beneath the ice is so great that it contributes to the lack of blooms in open water as the under-ice blooms simply uses up all the available nutrients before they have a chance to make it out to the open ocean. The large amount of CO_2 photosynthesized by the phytoplankton may help explain why the ocean is absorbing more of that greenhouse gas than calculations would otherwise indicate: even though the amount of dissolved CO_2 in Arctic waters is below predicted levels, that carbon is finding another home in the photosynthetic systems of the phytoplankton.

As with most environmental effects, however, there is a possible downside to this CO_2 absorbing effect since the blooms change the timing of the nutrient chain, their effect on the rest of the food web is currently unknown. It is possible that it would be a disaster, and also possible that marine flora and fauna could adapt to this change fairly well.

The oceans and land have more than doubled the amount of greenhouse gases they absorb since 1960 in a negative feedback effect braking global warming. Carbon soaked up from the atmosphere by the seas and by plants and soil on land rose to an estimated 5 billion metric tons (1.1023 tons) in 2010 from 2.4 billion in 1960. Over the 50-year period, nature had soaked up 55 percent of mankind's greenhouse gas emissions that totaled 350 billion metric tons, mostly as CO_2 from burning fossil fuels.

The figures were in line with data by the Global Carbon Project, grouping scientists around the world, which put nature's rising absorption at 5 billion metric tons of carbon in 2010, according to Corinne Le Quere, co-chair of the project. Plants, both on land and in the seas, use carbon to grow. Ocean waters also absorb carbon dioxide.

While the uptake by the oceans and land has doubled, human emissions have quadrupled in the past 50 years. China, the USA, the European Union and India are top emitters. Le Quere, director of the Tyndall Center in Britain, said the main point of controversy was how far nature's “sinks”, like the oceans and forests, would keep on soaking up carbon. In a warmer world, changes in ocean chemistry or faster rotting of plants might stop overall carbon absorption. When that happens, heat-trapping emissions of CO_2 to the atmosphere would stay there, accelerating warming.

The average world temperatures have risen by 0.8 degree Celsius (1.4 F) since the Industrial Revolution. The warmest 13 years since records began in the mid-19th century have been in the past 15, according to United Nations data.

Other recent studies suggest that sinks will become saturated within the coming century, maybe in the next 30 to 50 years. And there were signs of big oscillations in carbon uptake by nature in the past 20 years, perhaps linked to an eruption of Mount Pinatubo in the Philippines in 1991 and a strong El Nino warming in the Pacific Ocean in 1998.

It is suggested the continued high rate of absorption could be a sign that some areas yet to be studied in detail, such as the Arctic, may be taking up more carbon. In the Arctic, summer sea ice is shrinking and permafrost is thawing. Yet, the Earth is pretty resilient. If the Earth was not taking up all that CO_2 it would be experiencing much more warming over the last 50 years than is observed."

SHORT TERM CYCLES, EL NINO, LA NINA

La Niña or “little girl” in Spanish, is associated with cooler than normal water temperatures in the Equatorial Pacific Ocean. This is unlike El Niño, meaning “the little child” in Spanish, referring to “baby Jesus” since it occurs around Christmas time, which is associated with warmer than normal water temperatures. Anchovies’ fisherman coined the names when observing lower fish catches during the warming episodes resulting from a lack of plankton presence, associated with oceanic cold water upwellings as feed to the anchovies. Both of these climate phenomena, which typically occur every 2-5 years, influence weather patterns throughout the world and often lead to extreme weather events.

When El Niño is present, warmer ocean water in the equatorial Pacific shifts the patterns of tropical rainfall that in turn influence the strength and position of the jet stream and storms over the Pacific Ocean and the USA. El Niño contributes to record-breaking rain and snowfall leading to severe flooding in some parts of North America, with record heat and drought in other parts of the country. Although La Niña is the opposite of El Niño, it also has the potential to bring weather extremes to parts of North America.

NORTH ATLANTIC OSCILLATION, NAO

Other climate factors play a role in the winter weather at times across the country such as the North Atlantic Oscillation (NAO) are difficult to predict more than one to two weeks in advance. The NAO adds uncertainty to the winter weather forecast in the Northeast and Mid-Atlantic portions of the USA.

PALEONTOLOGICAL ICE CORE CLIMATIC DATA

SOLAR CYCLE EFFECT, MINI ICE AGE 1347-1351

There exists a positive correlation between global temperature and solar activity. It follows an 11 years cycle, passed its peak in the early 1990s and is expected to decline to a minimum around 2030.

Cooling in the 1940s-1970s inspired global cooling scare stories about an impending new Little Ice Age, with its attendant crop failures and famines. Inspiring the tale of Hansel and Gretel, the Little Ice Age forced families facing starvation to choose which of their children to abandon in the forest in order to stretch the food supply far enough for the rest of the family to survive the winter until spring.

The bad weather confined weakened and malnourished families indoors in close quarters and increased the rodent's population as disease vectors harboring fleas and setting up the conditions for the Black Bubonic Plague pandemic to ravage Europe over the period of 1347-1351.

VOSTOK, ANTARTICA ICE CORES

Records of past temperature, precipitation, atmospheric trace gases, and other aspects of climate and environment derived were generated from ice cores drilled on glaciers and ice caps around the world.

The parameters measured are delta stable Oxygen^{18} isotope $\delta^{18}O$ ‰ (per mille or per thousand); temperature; deuterium (per mille or one-thousand's); methane concentration (parts per million by volume, ppmv); sodium ion concentration (micrograms / kilogram); age of gas (years before 1950); carbon dioxide concentration (parts per million by volume); and particle concentration (number per milliliter). The temperature difference in degrees C for the Vostok, Antartica, Ice Core Data for 420,000 years [1] is plotted in Fig. 3.

The Deuterium content in ‰ Vienna Standard Mean Ocean Sea Water (SMOW) measurements has been performed on three adjacent cores 3G, 4G and 5G. The values have been measured on ice samples of length comprised between 0.5 and 2 m down to 2080 m, then every 1 m. Data was re-interpolated on 1 m intervals afterwards. The ice recovery is 85 percent or higher. Measurement accuracy is of ± 0.5‰ SMOW (1 s). From the surface down to 7 m a constant value (derived from surface and pits samples) of -438.0 ‰ is reported [2].

The temperature change indicated (temperature above the inversion) is calculated using a deuterium/temperature gradient of 9‰ / °C after accounting for the isotopic change of sea-water. No correction for the influence of the geographical position of the ice was applied.

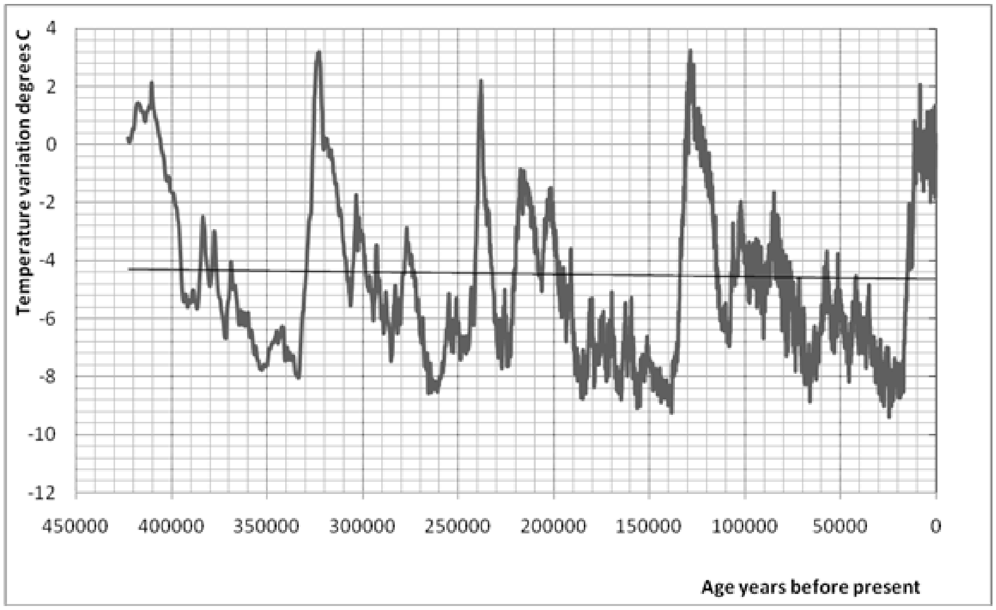


Figure 3. Temperature difference in degrees C with respect to mean of recent time value, from deuterium data over a 420,000 years period from ice core data at Vostok, Antartica. Steep sudden increases by about 10 degrees are followed by gradual decreases to about 8 degrees below the recent time mean. A linear least-squares curve-fit identifies a long term decrease in the average global temperature. Plot from data from: [1, 2].

CENTRAL GREENLAND ICE CORES

Temperature interpretation based on stable isotope analysis, and ice accumulation data, from the GISP2 ice core, central Greenland are plotted in Figs 4 and 5.

Greenland ice-core records provide an exceptionally clear picture of many aspects of abrupt climate changes, and particularly of those associated with the Younger Dryas event. Well-preserved annual layers can be counted confidently, with only 1 percent errors for the age of the end of the Younger Dryas 11,500 years before present (bp) [3].

Ice-flow corrections allow reconstruction of snow accumulation rates over tens of thousands of years with little additional uncertainty. Glacio-chemical and particulate data record atmospheric-loading changes with little uncertainty introduced by changes in snow accumulation [4].

Confident paleo-thermometry is provided by site-specific calibrations using ice-isotopic ratios, borehole temperatures, and gas-isotopic ratios. Near-simultaneous changes in ice-core paleo-climatic indicators of local, regional, and more-widespread climate conditions demonstrate that much of the Earth experienced abrupt climate changes synchronous with Greenland within thirty years or less. Post-Younger Dryas changes have not duplicated the size, extent and rapidity of these paleo-climatic changes [5].

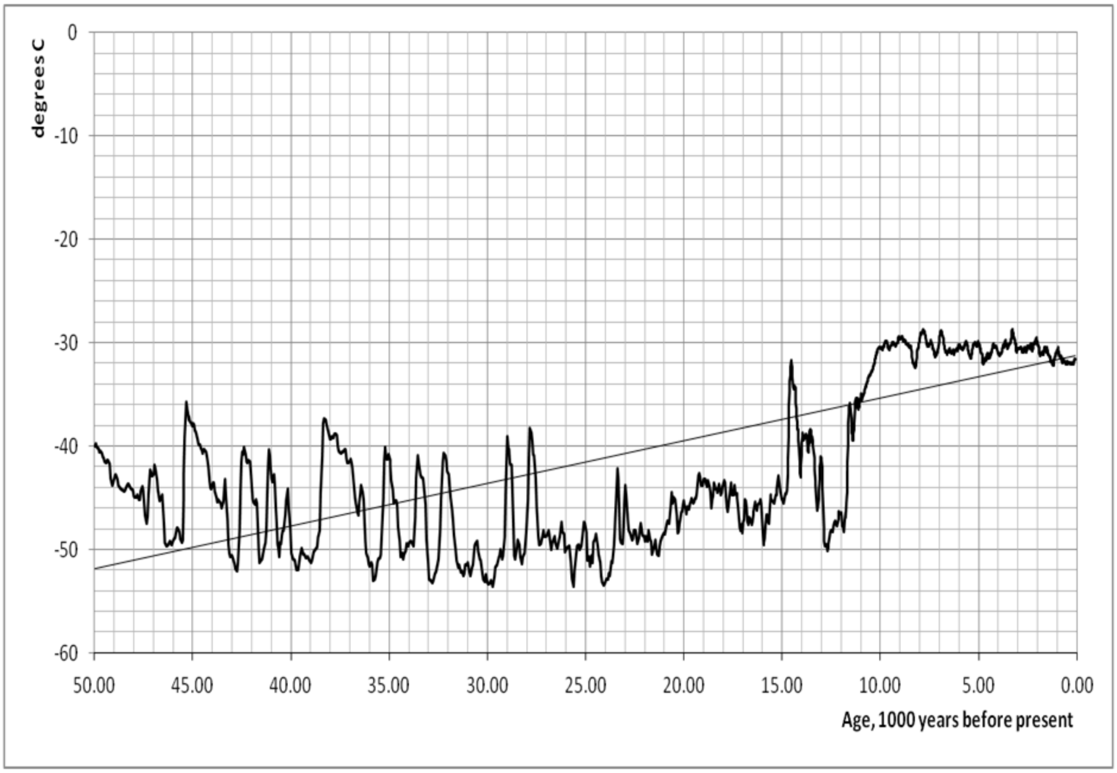


Figure 4. Temperature variation in central Greenland in the last 50,000 years up to the year 2000. Linear least squares interpolation shows a range of increase of about 22 degrees Celsius to the current warm period that seems to be cooling down over the last 10,000 years. Plot from data from [3, 4].

Figure 5. Temperature in central Greenland from isotopic deuterium content. A cooling trend over a 5,000 years period has been interrupted by a warming trend starting 165 years ago. Least squares linear interpolation shows about 0.2 degrees C increase The generated graph displays what is refrred to as the Mann's "hockey stick curve." Data from [3, 4].

MILANKOVITCH EARTH'S ORBITAL CYCLES

Global climate is determined by the energy radiation balance of the Earth. There are three ways the Earth's radiation energy balance can change, thus causing a climate variation:

1. A change in the incoming solar radiation through changes in the Earth's orbit or in the sun itself undergoing its own cycles.
2. A change in the fraction of solar radiation that is reflected or albedo; affected by the cloud cover, small particles or aerosols or land cover.
3. An alteration of the long wave energy radiated back to space by changes in the greenhouse gas concentrations.
4. Local climate also depends on how heat is distributed by winds and ocean currents.

The astrophysicist Milutin Milankovitch is best known for developing one of the most significant theories relating to Earths motions and long term climate change. Milutin Milankovitch developed a mathematical theory of climate change based on the seasonal and latitudinal variations in the solar radiation received by the Earth from the sun. This was the first truly plausible theory for how minor shifts of sunlight could make the entire planet's temperature swing back and forth from cold to warm.

Milutin Milankovitch's theory states that as the Earth travels through space around the sun, cyclical variations in three elements of Earth and sun geometry combine to produce variations in the amount of solar energy that reaches the Earth. The three components are:

1. Eccentricity cycle: Variations in the Earth's orbital eccentricity or the shape of the orbit around the sun, leading to a 100,000 year period.
2. Obliquity cycle: Changes in obliquity or tilt of the Earth's axis or changes in the angle that Earth's axis makes with the plane of Earth's orbit, leading to a 41,000 year period.
3. Precession of the equinoxes cycle: Or the change in the direction of the Earth's axis of rotation, leading to a 19,000 to 23,000 year period.

These orbital processes are thought to be the most significant drivers of the ice ages and, when combined, are known as the Milankovitch Cycles.

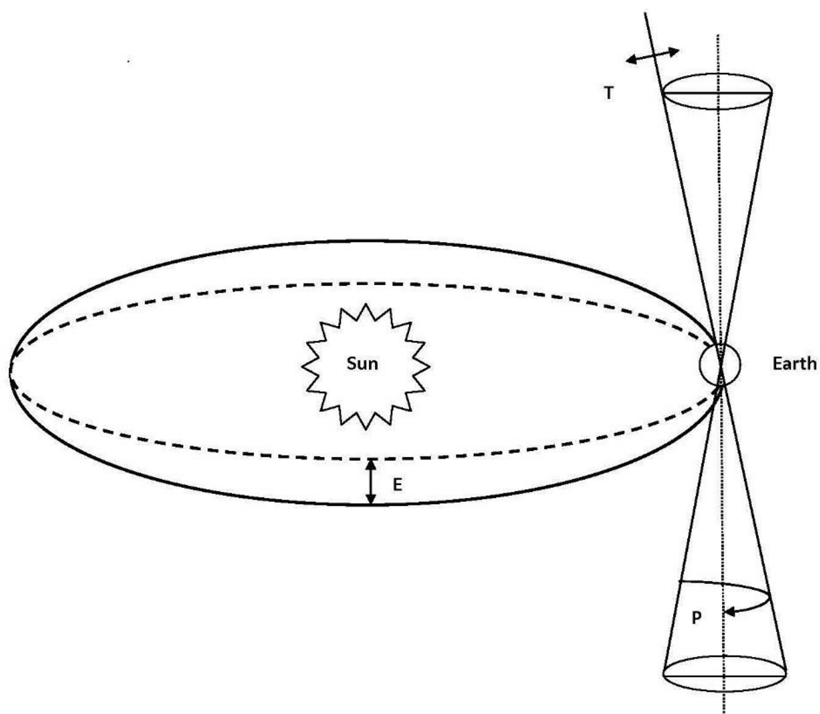


Figure 6. Milankovitch cycles in the Earth's orbital changes driving the ice ages. T denotes changes in the tilt or obliquity of the Earth's axis. E denotes changes in the eccentricity of the orbit due to variations in the minor axis of the ellipse. P denotes precession or changes in the direction of the axis tilt at a given point of the orbit [8].

The ice ages cycles in the past nearly 3 million years are linked to regular variations in the Earth's orbit around the sun, or the Milankovitch cycles. They change the amount of solar radiation received at different latitudes in each season, but do not affect the global annual mean.

The cycles interact with each other. Due to the interactions with other planets, the eccentricity of the Earth's orbit, the tilt of its axis, and the direction of that tilt relative to its place on the orbit all change over periods of 19,000 to 100,000 years. For instance, at some times the northern hemisphere has summer when it is closest to the sun because of the elliptic nature of the orbit, and if the tilt of the axis is also at a maximum, all the effects that make the summers hot add up. At other times, the northern summer can be when the Earth is farthest from the sun on the orbit and the eccentricity of the orbit can be large, making summers cooler.

If the amount of summer sunshine on the northern continents drops below a critical value, snow from the past winter does not melt away in the summer and an ice sheet starts to grow as more and more snow accumulates. The next large reduction in northern summer insolation, similar to those that started past Ice Ages, is expected to begin within 30,000 years.

OTHER CLIMATIC VARIATION DRIVERS

Changes occurring within the sun affect the intensity of sunlight that reaches the Earth's surface. These changes in intensity can cause either warming through a stronger solar intensity or cooling when the solar intensity is weaker.

Volcanoes often affect the climate by emitting aerosols and carbon dioxide into the atmosphere. Aerosols block sunlight and contribute to short term cooling, but do not stay in the atmosphere long enough to produce long term change. CO_2 has a warming effect. For about two-thirds of the last 400 million years, geologic evidence suggests that the CO_2 levels and temperatures were considerably higher than at present. Each year 186 billion tons of carbon from CO_2 enters the Earth's atmosphere, of which six billion tons are from human activity, approximately 90 billion tons come from biologic activity in the Earth's oceans and another 90 billion tons from such sources as volcanoes and decaying land plants.

These climate variation “drivers” often trigger additional changes or “feedbacks” within the climate system that can amplify or dampen the climate's initial response to them: The heating or cooling of the Earth's surface can cause changes in the greenhouse gas concentrations. When the global temperatures become warmer, CO_2 is released from the oceans and when temperatures become cooler, CO_2 enters the ocean and contributes to additional cooling.

During at least the last 650,000 years, CO_2 levels have tracked the glacial cycles. During the warm interglacial periods, the CO_2 levels have been high and during cool glacial periods, the CO_2 levels have been low.

The heating or cooling of the Earth's surface can cause changes in the ocean currents. The ocean currents play a significant role in distributing heat around the Earth so changes in these currents can bring about significant changes in climate from region to region.

In 1985, the Russian Vostok Antarctic drill team pulled up cores of ice that stretched through a complete glacial cycle. During the cold period of the cycle, CO_2 levels were much lower than during the warm periods before and after. When plotted on a chart the curves of CO_2 levels and temperature tracked one another very closely. Methane, CH_4 an even more potent greenhouse gas, showed a similar rise and fall to that of CO_2.

Small rises or falls in temperature, more, or less sunlight, seemed to cause a rise, or fall, in gas levels. Changing atmospheric CO_2 and methane levels physically linked the

Northern and Southern hemispheres, warming or cooling the planet as a whole. In the 1980s the consensus was that Milankovitch's Cycles would bring a steady cooling over the next few thousand years.

As studies of past ice ages continued and climate models were improved, worries about a near term re-entry into an interglacial period died away, and the models now predict that the next ice age would not come within the next ten thousand years.

The orbital changes, as explained by Milankovitch's Theory, initiate a powerful positive feedback loop. The close of a glacial era comes when a shift in sunlight causes a slight rise in temperature, this raises the greenhouse gases levels over the next few hundred years and the resultant greenhouse effect drives the planet's temperature higher, which drives a further rise in the gas levels and so on.

ROLE OF ATMOSPHERIC CO_2

Atmospheric CO_2 correlates with the occurrence of the ice ages. Antarctic ice core data show that CO_2 concentration is low during the cold glacial times at about 190 ppm, and high in the warm interglacial periods at about 280 ppm. Atmospheric CO_2 follows temperature changes in Antarctica with a lag of some hundreds of years.

Because the climate changes at the beginning and end of ice ages take several thousand years, most of these changes are affected by a reinforcing positive CO_2 feedback mechanism. A small initial cooling due to the Milankovitch cycles is subsequently amplified as the CO_2 concentration falls.

During the last ice age, over 20 abrupt climate shifts occurred around the northern Atlantic. These differ from the glacial-interglacial cycles in that they do not involve large changes in global mean temperature since changes are not synchronous in Greenland and Antarctica, and they are in the opposite direction in the South and North Atlantic. This implies that a major change in global radiation balance would not have been needed to cause these shifts. A redistribution of heat within the climate system would have sufficed. Changes in ocean circulation and heat transport can explain many features of these abrupt events. Sediment data show that some of these changes could have been triggered by instabilities in the ice sheets surrounding the Atlantic Ocean, and the associated freshwater releases into the ocean.

Warmer times have also occurred. During most of the past 500 million years, the Earth was probably completely free of ice sheets. As geologists report marks that ice leaves on rock, analysis of geological samples suggests that the warm ice-free periods coincide with high atmospheric CO_2 levels. On million-year time scales, CO_2 levels change due to tectonic activity, which affects the rates of CO_2 exchange of ocean and atmosphere with the solid Earth.

SOLAR ENERGY OUTPUT

A cause of past climatic changes is variations in the energy output of the sun. Measurements over recent decades show that the solar output varies slightly by about 0.1 percent in an 11-year cycle. Sunspot observations going back to the 17th century, as well as data from isotopes generated by cosmic radiation, provide evidence for longer-term changes in solar activity.

Solar variability and volcanic activity are likely to be leading reasons for climate variations during the past millennium, before the start of the industrial era.

The fact that natural factors caused climate changes in the past does not mean that the current climate change is only caused by natural causes.

SOLAR MAGNETIC ACTIVITY, COSMIC RAYS AND CLOUD FORMATION

The current understanding of climate change in the industrial age is that it is predominantly caused by anthropogenic greenhouse gases, with relatively small natural contributions due to solar irradiance and volcanoes. Palaeoclimatic reconstructions show that the climate has frequently varied on 100 year time scales during the Holocene climate optimum period of the last 10,000 years, by amounts comparable to the present warming. Some reconstructions show associations with solar variability recorded in the light radioisotopes C^{14} in tree rings, and Be^{10} measurements that measure past variations of cosmic ray intensity.

The isotope Be^{10} with a half-life of 1.51×10^6 years results from the spallation reactions caused by neutrons from galactic cosmic rays interactions in the Earth's atmosphere with nitrogen:

$$ {}_0n^1 + {}_7N^{14} \rightarrow {}_1H^1 + {}_2He^4 + {}_4Be^{10} \qquad (1) $$

as well as with oxygen:

$$ {}_0n^1 + {}_8O^{16} \rightarrow {}_1H^1 + {}_1D^2 + {}_2He^4 + {}_4Be^{10} \qquad (2) $$

It is used and its decay product B^{10} as proxies for measuring soil erosion, soil formation from regolith, the formation of lateric soils and the age of ice cores.

It also results from a reaction of fast neutrons with C^{13} in the atmosphere:

$$ {}_0n^1 + {}_6C^{13} \rightarrow {}_2He^4 + {}_4Be^{10} \qquad (3) $$

and is used for the detection of past nuclear tests.

The isotope C^{14} with a half-life of 5,730 years also occurs from cosmic rays neutrons interactions:

$$ {}_0n^1 + {}_7N^{14} \rightarrow {}_1H^1 + {}_6C^{14} \qquad (4) $$

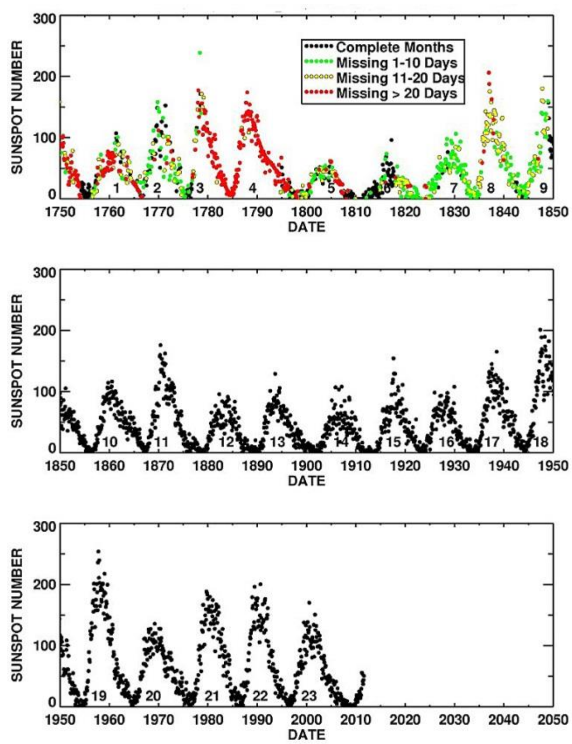
and is used as a proxy for measurements from tree rings.

Some other cosmogenic isotopes and their mode of formation are:

$$
\begin{aligned}
&{}_0n^1 + {}_7N^{14} \rightarrow {}_1T^{13} + {}_6C^{12} \\
&{}_1H^1 + {}_8O^{18} \rightarrow {}_0n^1 + {}_9F^{18} \\
&{}_0n^1 + {}_{17}Cl^{35} \rightarrow \gamma + {}_{17}Cl^{36} \\
&{}_1H^1 + {}_{17}Cl^{37} \rightarrow {}_0n^1 + {}_{18}Ar^{37} \\
&{}_0n^1 + {}_{18}Ar^{38} \rightarrow \gamma + {}_{18}Ar^{39} \\
&{}_0n^1 + {}_{18}Ar^{40} \rightarrow {}_0n^1 + {}_1H^1 + {}_{17}Cl^{39} \\
&{}_0n^1 + {}_{18}Ar^{40} \rightarrow \gamma + {}_{18}Ar^{41} \\
&{}_0n^1 + {}_{36}Kr^{80} \rightarrow \gamma + {}_{36}Kr^{81}
\end{aligned}
$$

Other isotopes generated by neutrons from cosmic rays spallation with O and Ar are:

$$
\begin{aligned}
&{}_4Be^7, {}_4Be^{10}, {}_6C^{11}, {}_9F^{18}, {}_{11}Na^{22}, {}_{11}Na^{24}, {}_{12}Mg^{28}, \\
&{}_{14}Si^{31}, {}_{14}Si^{32}, {}_{15}P^{32}, {}_{16}S^{35}, {}_{17}Cl^{34m}, {}_{17}Cl^{38}, {}_{17}Cl^{39}
\end{aligned}
$$



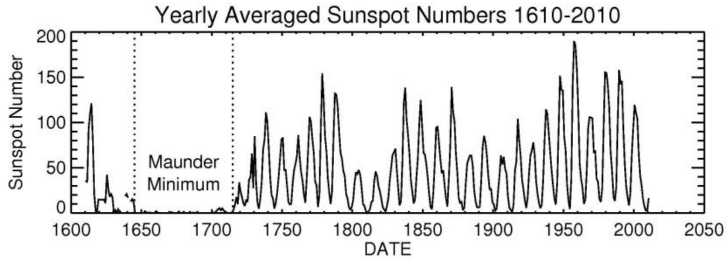


Figure 7. Monthly averaged sunspot number. Sun spot cycles since the use of telescopes. The Little Ice Age occurred during a period of low sunspots activity Maunder Minimum from 1640 to 1700. Source: NOAA, NASA.

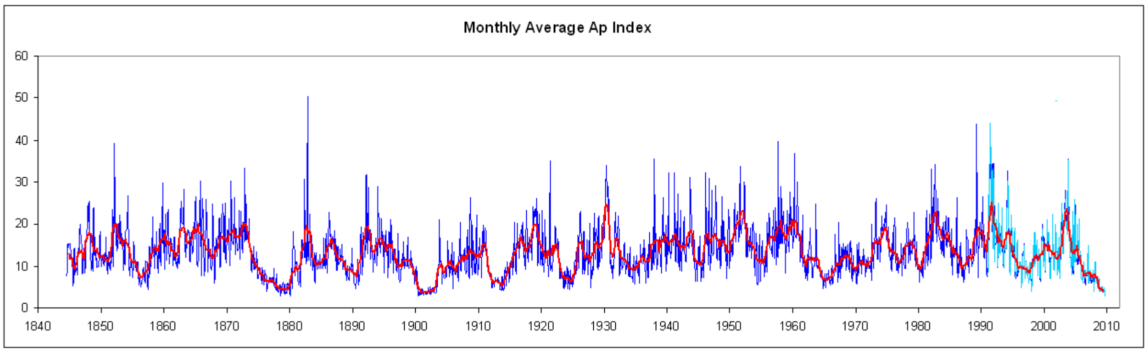


Figure 8. Monthly average Ap Geomagnetic Index since 1844. Recent values imply a dimming rather than a warming trend. Source NOAA.

Estimated changes of solar irradiance on these time scales appear to be too small to account for the climate observations. This raises the question of whether galactic cosmic rays may directly affect the climate, providing an effective indirect solar forcing mechanism. Recent satellite observations, suggest that cosmic rays may affect clouds formation.

Other people theorize that, with less Ultra Violet (UV) radiation being emitted by the sun during the Maunder Minimum of the Small Ice Age period, less would have hit the atmosphere and reacted with the oxygen there to form ozone, which is a potent greenhouse gas.

The magnetic activity of the sun forms the basis of a theory of Galactic Cosmic Ray (GCR) Modulation advanced by Henrik Svensmark and Friis-Christensen at the Danish National Space Center in Copenhagen, Denmark in 1997. The argument is that lower magnetic activity by the sun allows more galactic cosmic rays, which permeate the universe and bombard the galaxy isotropically from all directions, to penetrate the solar system. Consequently, they can produce microscopic cloud seed trails in the Earth's atmosphere such as occurs in a Wilson Cloud Chamber. This would result in more cloud cover and a cooler planet. Sun spots activity is just a manifestation of a stronger solar magnetic field. In 2005, an experiment in an air box showed that electrons were set free by galactic cosmic rays interactions and they formed droplets of water and sulfuric acid. These would act as nuclei for condensation and cloud formation.

The theorized link is tested by the Cosmics Leaving OUdoor Droplets (CLOUD) experiment at the CERN research center in Switzerland. It studies the microphysical interactions of cosmic rays with aerosols, cloud droplets and ice particles. This is a possible mechanism of solar and climate variability since the solar wind varies over time and affects the intensity of the cosmic rays reaching the Earth. A beam from the Proton Synchrotron is used to generate a beam of artificial cosmic rays for the experiment.

A plot since 1844 by Leif Svalgaard [11] of the monthly average value of the Ap geomagnetic index imply lower solar magnetic activity and hence a cooling rather than a warming trend.

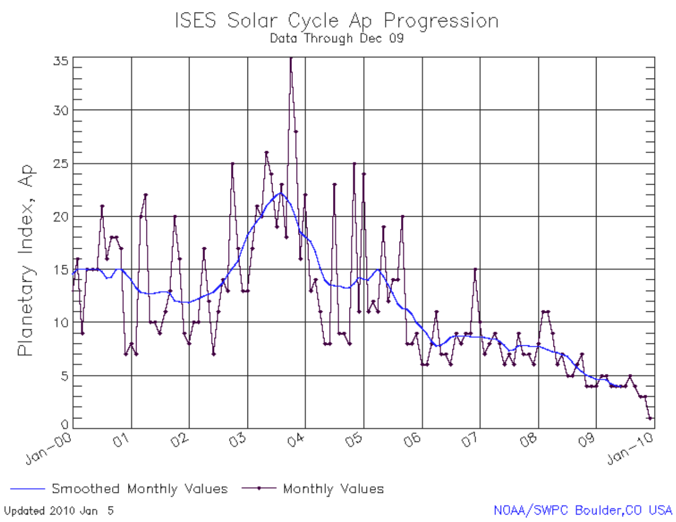


Figure 9. Space Weather Prediction Center (SWPC) Ap geomagnetic index. December 2009. Source: NOAA.

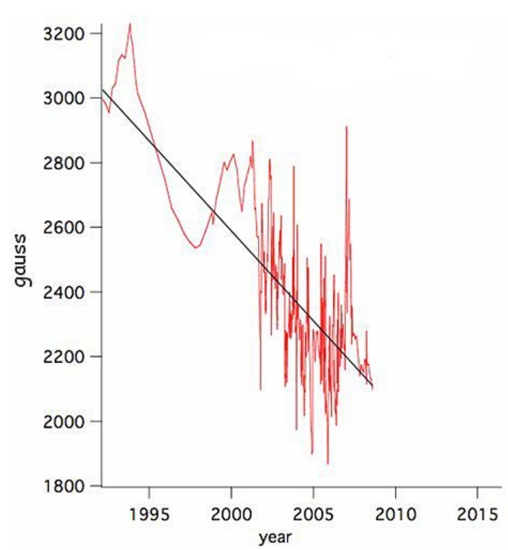
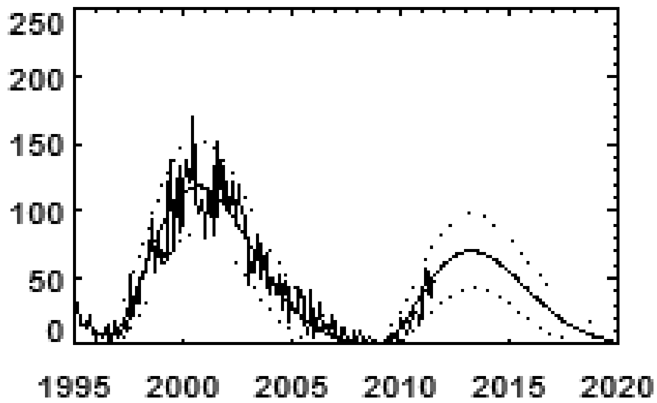


Figure 10. Sunspot maximum magnetic field strength decline independent of the solar cycle, 1992-2009. Source: Bill Livingston and Matt Penn, National Solar Observatory, NSO.



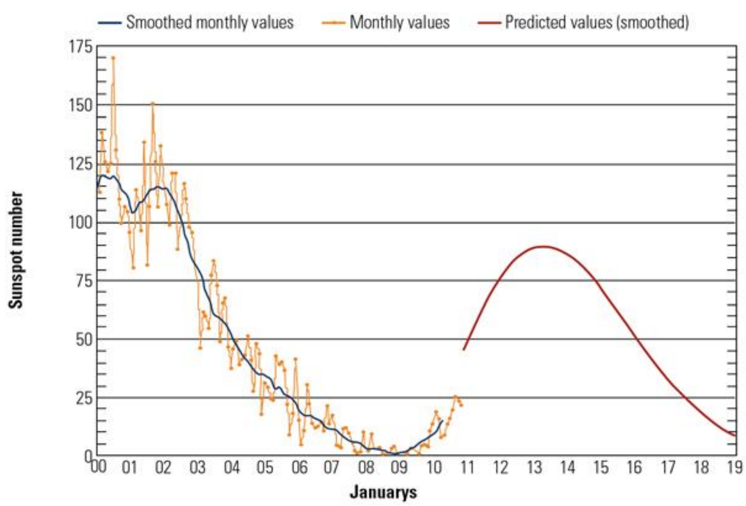


Figure 11. Sunspot activity measurements and predicted activity according to the 11 years solar cycle. Solar Cycle 24 Prediction Panel. The solar minimum of the current cycle occurred in December 2008. Source: NOAA.

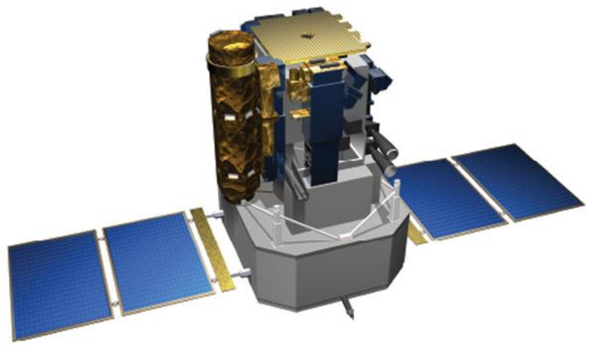


Figure 12. The SOHO satellite studies the sun from its deep core to the outer corona and the solar wind. It is 25 feet in width, weighs 2 tons and was launched in 1995. Source: NASA.

Sun spots magnetism has been on the decline at the rate of 50 Gauss / year over the period 1992 – 2009. It was measured using an infrared Zeeman splitting telescope [10]. If the year 2009 is considered as a minimum of the 11 years sunspot cycle; which is in fact a 22 years solar magnetic field cycle, the 24th cycle is due to peak again around 2015. The sunspots show the same hemispheric magnetic polarity on alternate 11 year cycles, meaning that the sun's magnetic field flips its polarity every 11 years.

Sunspots seem to form only when the magnetic field is stronger than 1,500 gauss. The last solar maximum occurred in 2001 producing powerful magnetic disturbances to some space based satellites. The solar wind follows in its energy intensity the solar sunspot cycle.

THE MAUNDER MINIMUM

The "Maunder Minimum" over the period 1645-1715 corresponds to the period known in Europe as the "Little Ice Age." Early records of sunspots indicate that the sun went through a period of inactivity in the late 17th century. Very few sunspots were seen on the sun from about 1645 to 1715. Although the observations were not as extensive as in later years, the sun was in fact well observed during this time and this lack of sunspots is well documented.

As NASA reports:

> "Although the observations were not as extensive as in later years, the sun was in fact well observed during this time and this lack of sunspots is well documented. This period of solar inactivity also corresponds to a climatic period called the "Little Ice Age" when rivers that are normally ice-free froze and snow fields remained year-round at lower altitudes. There is evidence that the sun has had similar periods of inactivity in the more distant past. The connection between solar activity and terrestrial climate is an area of ongoing research."

The latest SDO results would seem to indicate a greater cooling effect from a calming sun than would previously have been expected by physicists.

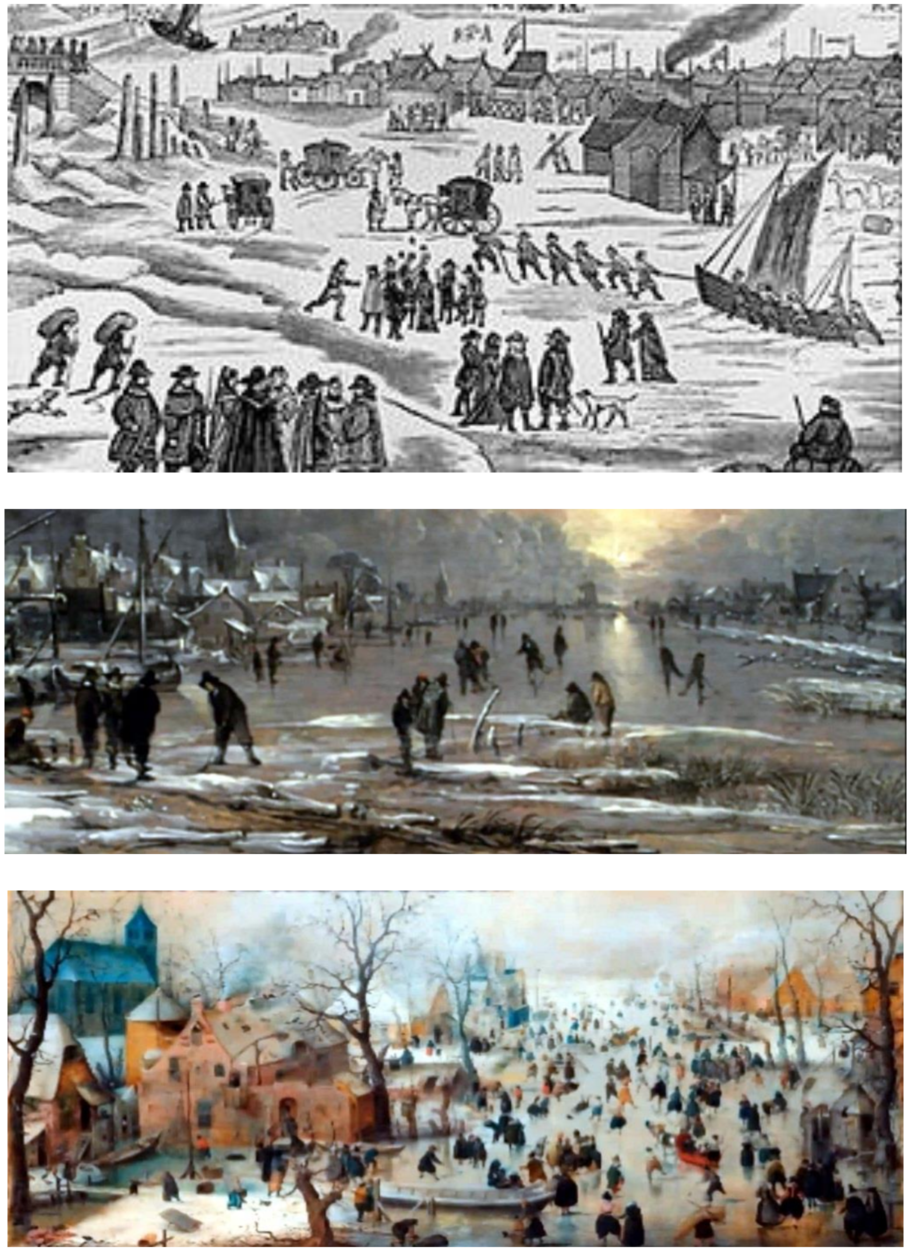


Figure 13. Little Ice Age in Europe saw the River Thames in England freeze over..

VOLCANIC INTERPRETATION OF THE LITTLE ICE AGE

The Little Ice Age may have been caused by the cooling effect of massive volcanic eruptions, and sustained by changes in the Arctic ice cover. Studies of ancient glacier plants from Iceland and Canada, and sediments carried by glaciers suggest that there was a series of volcanic eruptions just before 1300 that lowered Arctic temperatures enough for the ice sheets to expand.

While some studies suggest temperatures fell globally in the 1500s, others suggest the Arctic and sub-Arctic began cooling several centuries previously. The global dip in temperatures was less than 1 ^oC, but parts of Europe cooled more, particularly in winter, with the River Thames in London iced thickly enough to be traversable on foot.

A link is established back to a series of four explosive volcanic eruptions between the years 1250 and 1300 in the tropics, which would have blasted clouds of sulfate particles into the upper atmosphere. These aerosol particles are known to cool the globe by reflecting solar energy back into space.

Figure 14. Volcanic eruption release of sulfur dioxide and ash.

Studies of sites in north-eastern Canada and in Iceland where small icecaps have expanded and contracted over the centuries reveal that when the ice spreads, plants underneath are killed and entombed in the ice. Carbon-dating can determine how long ago this happened. the plants provide a record of the icecaps' sizes at various times and indirectly.

The records show that cooling began fairly abruptly at some point between 1250 and 1300. Temperatures fell another notch between 1430 and 1455. The first of these periods saw four large volcanic eruptions beginning in 1256, probably from the tropics sources, although the exact locations have not been determined. The later period incorporated the major Kuwae eruption in Vanuatu.

The short but intense burst of cooling was enough to initiate growth of summer ice sheets around the Arctic Ocean, as well as glaciers. The extra ice in turn reflected more solar radiation back into space, and weakened the Atlantic Ocean circulation commonly known as the Gulf Stream. Sea ice exports into the North Atlantic set up a self-sustaining feedback process, showing that a perturbation of decades can result in a climate shift of centuries.

THE SUN ULTRA VIOLET SPECTRUM CONNECTION

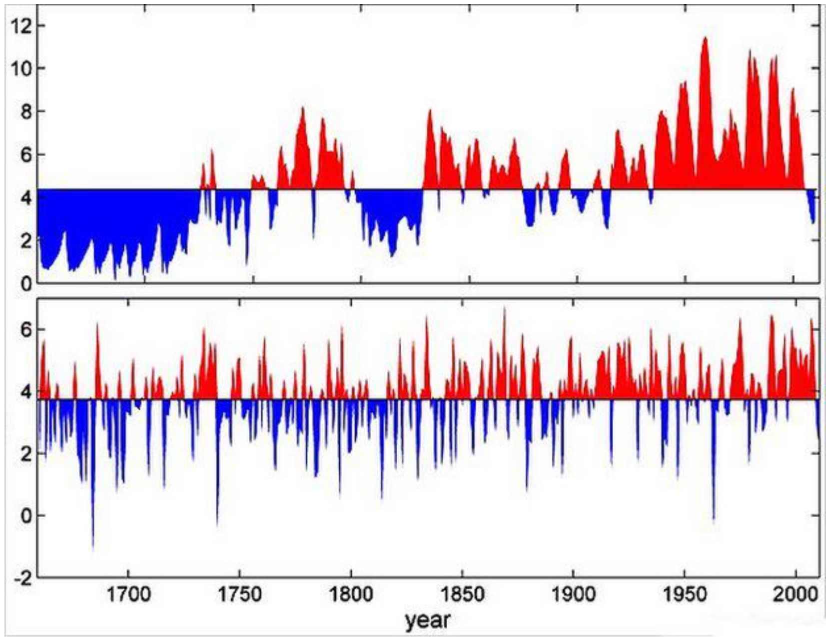


Figure 15. Correlation between the sun’s magnetic flux (top) and the temperature in central England (bottom).

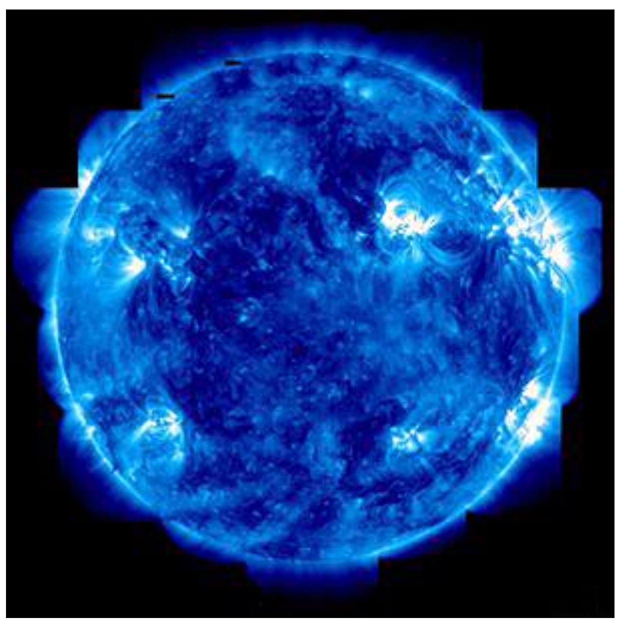


Figure 16. Ultraviolet spectrum of the sun. Source: NASA.

Cold winters in the UK and northern Europe may correlate with the sun's varying Ultra Violet (UV) spectrum. This does not imply an impact on global warming. The sun's ultraviolet variability come from a NASA satellite designated as the SOlar Radiation and Climate Experiment (SORCE), launched in 2003. Among its instruments is the Spectral Irradiance Monitor (SIM), which analyses the sun's output at frequencies in the infrared, visible and ultraviolet parts of the spectrum.

SIM gave scientists a picture of how the sun's ultraviolet emissions vary over its regular 11-year cycle and suggests the UV variation is about five times larger than had been inferred from previous observations. The results reinforce the idea that the UV variations affect winter weather across the European region.

The UV radiation is absorbed in the stratosphere, the upper atmosphere, by ozone. In the quiet part of the solar cycle, when there is less UV to absorb, the stratosphere is relatively cooler. The effects of this percolate down through the atmosphere, changing wind speeds, including the jet stream that circles the globe above Europe, North America and Russia. The net change is a reduced air flow from west to east, which brings colder air to the UK and northern Europe and re-distributes temperatures across the region.

As well as the 11-year cycle, the sun's output also varies on longer timescales. Its intensity has increased since the 1600s when the Maunder Minimum began, with astronomers documenting a dearth of sunspots over many decades. The Maunder Minimum coincided with part of a period that has come to be known as the Little Ice Age, when winter weather overall grew colder in parts of Europe.

An explanation of why the Little Ice Age occurred has nothing to do with Global Warming, but can be explained in terms of temperature re-distribution around the north Atlantic as a result of the solar cycle.

GLOBAL WARMING AND COOLING TRENDS

The 10 warmest years in the past 150 years have all been since 1990 and a United Nations (UN) climate panel, drawing on the work of 2,500 scientists, reached a consensus in 2007 that it was “very likely” that human activities were the main cause. The panel gave a best estimate that temperatures would raise by 1.8 - 4.0 degrees Celsius or 3.2 - 7.8 Fahrenheit this century. The drastic and immediate reduction in the emissions of carbon dioxide (CO_2), methane (CH_4) and other greenhouse gases into the atmosphere is impossible and would continue increasing in the coming decades.

The Earth's temperature curve rose sharply for almost 30 years, as global temperatures increased by an average of 0.7 degrees Celsius or 1.25 degrees Fahrenheit, from the 1970s to the late 1990s. However, Britain's Hadley Centre for Climate Prediction and Research suggests figures that the world grew warmer by 0.07 degrees Celsius from 1999 to 2008 and not by the 0.2 degrees Celsius assumed by the United Nations Intergovernmental Panel on Climate Change. When their figure is adjusted for two naturally occurring climate phenomena, El Niño and La Niña, the resulting temperature trend is reduced to 0.0 degrees Celsius or a standstill.

The differences among individual regions of the world are noticeable. In the Arctic, temperatures rose by almost 3 degrees Celsius, which led to a dramatic melting of sea ice. Temperatures declined in large areas of North America, the western Pacific and the Arabian Peninsula. Europe, including Germany, remains slightly in a positive warming territory.

Climatologists’ computer models predict that the average global temperature will increase by about three degrees Celsius or 5.4 degrees Fahrenheit by the end of the century, unless humanity manages to drastically reduce greenhouse gas emissions. However, they are puzzled as to why average global temperatures have stopped rising over the last 10 years. Some attribute the trend to a lack of sunspots, while others explain it through ocean currents. The fact is that the sun is weakening slightly. Its radiation activity is currently at a minimum, as evidenced by the small number of sunspots on its surface. Others attribute the stagnation to the Pacific Decadal Oscillation (PDO). This phenomenon in the Pacific Ocean allows a larger volume of cold deep-sea water to rise to the surface at the equator.

The concentration of greenhouse gases was 460 parts per million (ppm) of CO_2 equivalents in 2007. At 450 ppm there is a 50 percent chance that the temperature rise would stay below 2 degrees Celsius.

The global average temperature rose 0.8 degrees Celsius from 1850 to 2005. The current warming trend is 0.13 to 0.16 degrees per decade. In 2007, the UN Intergovernmental Panel on Climate change (IPCC) assumed that the Earth's average temperature could increase anywhere from 1.8 to 4.0 degrees Celsius by the end of this century, depending on which strategy the international community adopts and by how much greenhouse gas emissions are reduced.

Dirt particles from pollution in the atmosphere; particularly sulfate aerosols, have created a cooling effect and has prevented a larger temperature increase. If sulfur filters were installed all over the world, then it would already have seen at 2.5 degree Celsius warming. Rising sea levels caused by rapidly melting polar ice caps and severe weather phenomena are expected to last for centuries. The changes current generations initiate in the climate will directly influence future ones long into the future. Global average surface temperature will hardly drop in the first thousand years after greenhouse gas emissions are even cut to zero.

Geologically, the Earth has been in a warming cycle since the end of the last ice age; 18,000 years ago. Through its 4-5 billion years of geological time, the Earth's climate has been changing going through natural cycles of cooling and warming and dry and wet conditions. Humans may have had no impact on the 11,500 years of this trend, but have been dramatically influencing it in the last few centuries.

The most recent research shows that the sea level is rising at a rate of 3 mm/year since 1993. This is a rate above the 20th century average. Accordingly, the sea level would rise by 0.9-1.2 meters by 2100, well above the estimate earlier given as 59 cms by the 2007 Fourth Assessment Report of the United Nation's Intergovernmental Panel on Climate Change (IPCC). The implications for the millions of people constituting the 10 percent of the world population that is living in low lying areas would cause severe social dislocations. The ice sheets in Greenland and Antarctica are contributing to a faster rise of sea level than anticipated,

The Royal Society, one of the world's oldest scientific academies, founded in 1660, issued a statement in July 2007: "At present there is a small minority which is seeking to deliberately confuse the public on the causes of climate change. They are often misrepresenting the science, when the reality is that the evidence is getting stronger every day."

The USA West is expected to see devastating droughts as global climatic change reduces the amount of mountain snowpack and causes the snow that does fall to melt earlier in the year. By storing moisture in the form of snow, mountains act as huge natural reservoirs, releasing water into rivers long into the summer dry season. The changes currently affecting the USA West have less than a one percent chance of being due to natural variability. They are caused by global climatic change and will continue setting the stage for a dramatic water crisis.

Mountain snow melts earlier, and winter storms arrive later, extending the fire season in the Western USA by several weeks. Vast tracts of drought weakened trees have succumbed to insect attacks and disease turning them into tinder. As a result, in 2006, wildfires started by lightning or by humans burned 15,000 square miles across the country, with 2/3 of the acreage out in the West.

Solar variability has influenced the Earth's climate in the past and may well have been a factor in the first half of the last century, but British and Swiss researchers concluded in the Proceedings of the Royal Society that it could not explain recent warming: "Over the past 20 years, all the trends in the sun that could have had an influence on Earth's climate have been in the opposite direction to that required to explain the observed rise in global mean temperatures." Mike Lockwood of Britain's Rutherford Appleton Laboratory and Claus Froehlich of the World Radiation Centre in Davos, Switzerland, studied factors that could have forced climate change in recent decades, including variations in total solar irradiance and cosmic rays. The data was smoothed to take into account the 11 year sun spot cycle, which affects the amount of heat the sun emits but does not impact the Earth's surface air temperature, due to the way the oceans absorb and retain heat. They concluded that the rapid rise in global mean temperatures seen since the late 1980s could not be ascribed to solar variability, whatever mechanism was invoked.

BALANCED PARTIAL GREENHOUSE EFFECT

A delicately balanced mild greenhouse effect has kept the Earth's climate like Baby Bear's porridge in the Goldilocks and the Three Bears story; neither too hot nor too cold, within the livability zone from the sun. At 93 million miles from the sun or one astronautical unit (au), the Earth receives a flux of solar energy that, averaged over the face of the planet at the top of the atmosphere is 343 W/m^2. A part of this energy is reflected back into space, and the rest is absorbed and then reradiated back into space as infrared radiation.

If Earth were to radiate back an amount of energy equal to what it absorbs as a blackbody radiator, its surface temperature would settle around zero degrees Fahrenheit. At this temperature, its surface water would freeze, reflecting more of the sun's light, and making Earth an even colder and lifeless planet.

The fortunate thing for life on Earth is that the atmospheric trace gases: water vapor, methane, carbon dioxide, and other greenhouse gases absorb the infrared radiation that would otherwise escape into space and reradiate it both out to space and back to Earth, warming the planet's surface overall to its comfortable 57 degrees Fahrenheit, as a mean surface temperature. At that temperature life evolved and thrives on Earth.

In the preindustrial age, the Earth's atmosphere absorbed 88 percent of the infrared radiation that would otherwise have been reradiated away. In the last 150 years, that balance has been altered by humans' growing reliance on fossil fuels and the ensuing increased amount of carbon dioxide in the atmosphere by about 30 percent.

The planet Venus is a little closer to the sun than Earth, and the laws of physics should permit Venus to be earthlike in temperature. However, Venus undergoes a runaway greenhouse effect caused by its carbon dioxide atmosphere leading to a surface temperature higher than molten lead. This suggests that distance from the sun is only one of several variables that determine the possibility of life on Earth including its molten outer core and magnetic field and its mild well balanced greenhouse environment. At 93 million miles from the sun, the Earth could be a frozen Martian wasteland, or it could be a Venus inferno. Fortunately for life, Earth enjoys a delicately balanced partial greenhouse effect that humans can only mess with at their own peril

Figure 17. Emissions from coal power plant and a chemical plant in Tianjin, Northern China and the eruption of the Mayon volcano at Legazpi City in the Alpay Province, south of Manila, Philippines, August 7, 2006.

ANALOGY TO VENUS

Other than the hellish heat, a crushing carbon dioxide atmosphere and corrosive clouds of sulfuric acid, Venus is a lot like Earth. The European Space Agency's Venus Express mission showed signs of lightning, surprising swings of temperature and additional evidence that Venus could have once had oceans the size of Earth's.

The Earth and Venus are considered as twins who separated at birth. Venus is about the same size and mass as Earth, and of roughly the same composition. Before the space age, planetary scientists imagined an Earth-like environment, perhaps even tropical jungles, obscured by Venus's perpetual cloud cover. In 1958, when astronomers measured intense microwaves emanating from the planet, they realized that it was not as lush as they had imagined.

Visits by spacecraft confirmed that the surface temperatures exceed 800 degrees Fahrenheit, hot enough to melt tin and lead. Although Venus is closer to the sun than is

Earth, the clouds reflect much of the sunlight, and the high temperatures largely result from the heat trapping effects of an atmosphere that is almost pure carbon dioxide and about 100 times as dense as the Earth's atmosphere.

Venus may have formed with much liquid water, just like Earth, but that because it is closer to the sun, with sunlight twice as intense as on Earth, the water began to evaporate. Water vapor, a greenhouse gas, trapped heat, heated up the surface and lead to more evaporation in a positive feedback effect.

The evaporation accelerated until all the liquid water had turned into a thick atmosphere of water vapor. As the water molecules floated in the air, ultraviolet radiation from the sun broke them apart into hydrogen and oxygen atoms. Chemical reactions with minerals in the rocks transformed the oxygen into carbon dioxide. The hydrogen, the lightest of atoms, escaped into outer space.

Measurements from the Venus Express probe support that hypothesis, looking at amounts of hydrogen remaining in the atmosphere compared with concentrations of deuterium, the heavier isotope of hydrogen. The heavier deuterium would escape more slowly into space, and Venus Express detected a D/H ratio 150 times as high as on Earth, a finding that agreed with earlier measurements. What was surprising was that the deuterium concentration turned out to be 2.5 times as high in the upper atmosphere as near the ground.

Venus Express detected bursts of radio waves known as "whistlers," which on Earth are generated by lightning, and also found large temperature swings, up to 70 degrees Fahrenheit, between the daytime and nighttime sides of Venus. The much thicker atmosphere would have been expected to minimize the temperature differences. The clouds of Venus are much different from those that produce thunderstorms on Earth and are more like smog or a haze of sulfuric acid which does not produce electrical charges making it puzzling to detect lightning.

RUNAWAY GREENHOUSE, VENUS SYNDROME

In the book: "Storms of my Grandchildren," climate scientist James Hansen issued the following warning: "If we burn all reserves of oil, gas, and coal, there is a substantial chance we will initiate the runaway greenhouse. If we also burn the tar sands and tar shale, I believe the Venus syndrome is a dead certainty. [33]"

Venus has a thick atmosphere that is 96.5 percent CO_2, which keeps its surface at 900 °F or 482 °C. The planet's water boiled off to space long ago. This could happen on Earth, which is farther from the sun, and where the CO_2 level is just now rising past 400 parts per million (ppm)

A positive feedback loop is at stake. As CO_2 warms the planet through the greenhouse effect, more water evaporates from the ocean, and amplifies the warming, since water vapor is a greenhouse gas. That positive feedback is happening now. James Hansen argues that fossil-fuel burning could cause the process to run out of control, vaporizing the entire ocean and sterilizing the planet.

However, a counter argument is advanced by Raymond Pierrehumbert of the University of Chicago, that during the Paleocene-Eocene Thermal Maximum (PETM), 56 million years ago, a huge natural spike in CO_2 sent temperatures on Earth soaring, but life went on and the ocean remained intact.

Physicists have been using supercomputers on the water molecule, calculating its properties from first principles, and finding that it absorbs more radiation at more wavelengths than they had realized before. In a paper published by Colin Goldblatt of the University of Victoria in British Columbia in Nature Geosciences, those calculations have rippled into a simple climate model. The paper's conclusion contains this sentence: "The runaway greenhouse may be much easier to initiate than previously thought." It used to be thought that a runaway greenhouse was not theoretically possible for Earth with its present amount of sunlight. To the contrary, it is theoretically possible. That does not mean it is going to happen, but it is theoretically possible [33]. The earlier models were underestimating the amount of radiation that would be absorbed in a water-vapor-rich atmosphere.

The explanation is that the surface of the Earth emits radiation, and some of that radiation gets absorbed in the atmosphere by gases like CO_2, CH_4 and water vapor. This means less radiation can get out to space than if there were no greenhouse atmosphere. Or conversely, to get the same amount of radiation out to space to balance the energy you are getting from the sun, the surface needs to be hotter. That is what is happening now: Because we are making the greenhouse effect stronger, the Earth is heating up so it will come back into balance. If enough water vapor is added to the atmosphere, any radiation from the surface will get absorbed before it gets out to space. Only the upper part of the atmosphere can emit radiation to space. So it turns out that there is a fixed amount of radiation you can emit to space once you have enough water vapor.

An analogy is that if one takes a single layer of tinted glass, one is able to see through. But one stacks up 10, 20, or 100 layers, one cannot see through it. Thus, the runaway greenhouse effect happens when the amount of incoming solar radiation exceeds a fixed limit. This happens if the Earth absorbs more sunlight than it can emit thermal radiation. The limit on how much radiation Earth can get out to space is smaller than previously thought. The amount of sunlight that will be absorbed in a water-vapor-rich atmosphere is bigger than previously thought. The implication for the Earth is that it is possible to absorb more sunlight than it could emit to space from a water-vapor-rich atmosphere [33].

This model ignores the moderating effects of clouds which would shield the Earth by reflecting the incoming solar radiation. But if they are high enough in the atmosphere, they will also have a greenhouse effect. On Earth today, the reflection effect dominates with clouds overall have a cooling effect.

If about ten times as much carbon dioxide is added to the atmosphere as one would get from burning all the coal, oil, and gas to about 30,000 parts per million (ppm), then one could cause a runaway greenhouse today. So burning all the fossil fuels would not give us a runaway greenhouse. “However, the consequences will still be dire. It won't sterilize the planet, but it might topple Western civilization. There are no theoretical obstacles to that. [33]”

Because Venus is nearer the sun, it gets more energy from the sun than we do, Venus experienced this runaway greenhouse early in its history. Venus's past is Earth's future. The sun increases its luminosity slowly with time. At the beginning of the solar system, the sun was only 70 percent as bright as it is now. It is going to keep getting brighter. Given that the runaway greenhouse happens when there is more solar radiation absorbed than we can emit thermal radiation, it is just going to happen within half a billion and a billion years.

Don Korycansky, an astronomer proposed that one could move the Earth out away from the sun with gravity assists from asteroids. “As a species we are technologically adolescent at the moment. If we get through adolescence, if we get through the next couple of hundred years alive, as a mature species who is not screwing up the planet that we live on, and then if you are talking about on timescales of hundreds of millions of years, how are we going to keep our planet alive? Then I think that is the kind of thing you might start to think about [33].”

MAYRE’S RADIATIVE FORCING FORMULA, CLIMATE SENSITIVITY

The Infrared (IR) forcing, or power flux formula for CO_2 attributed to Mayre is:

$$F = 5.35 \ln \frac{\text{ending}\, CO_2 \text{ concentration(ppm)}}{\text{starting}\, CO_2 \text{ concentration(ppm)}} [\frac{Watts}{m^2}]$$

For a doubling of the CO_2 concentration,

$$F = 5.35 \ln 2 = 5.35 \times 0.6931 = 3.71 \frac{Watts}{m^2}$$

Assuming that the preindustrial CO_2 concentration was 280 ppm and considering that the present CO_2 concentration is 400 ppm, yields:

$$F = 5.35 \ln \frac{400}{280} = 5.35 \ln 1.42857 = 5.35 \times 0.35667 = 1.91 \frac{Watts}{m^2}$$

This suggests that 1.91 / 3.71 = 0.51, or about ½ of the forcing towards a CO_2 doubling from the pre-industrial age levels has been achieved today.

Using the Intergovernmental Panel on Climate Change (IPCC) AR4 estimate of temperature increase over the same period of:

$$0.6 \pm 0.2 ^{o}C ,$$

The implied climate sensitivity can be estimated as:

$$(0.6 \pm 0.2 ^{o}C) \times \frac{1}{0.51} = (1.2 \pm 0.4)\ ^{o}\text{C}$$

GLOBAL DIMMING AND WARMING

Global dimming and global warming are happening at the same time. A global tug of war is occurring between two man-made pollutants causing a forcing effect on the

Earth's energy budget. Global warming adds a power flux of 2.6 Watts/m^2 on the Earth's surface, whereas global dimming subtracts 1.5 Watts/cm^2. About one half of the effect of the heating by greenhouse gases is masked by global dimming caused by particles pollutants. A double whammy is occurring as the trend of decreasing air pollution is pursued for human health considerations, while greenhouse gases continue to be emitted.

Figure 18. The eruption of Mount Pinatubo in the Philippines in 1991 sent 20 million tons of volcanic ash 20 kilometers high into the atmosphere and contributed to global dimming to a level of -0.5 degree F.

Figure 19. Mount Aetna volcano eruption, Sicily, Italy, July 16, 2006.

Figure 20. Eyjafjallajokul volcano eruption, Iceland, April 16, 2010. Source: AP.

The global dimming is caused by air pollution in the form of particulates, soot and sulfates release, and even condensation trails or contrails from aircraft, turning the cloud system into a mirror reflecting back solar radiation into space. The global warming is caused by the release of greenhouse gases such as CO_2 and methane (CH_4).

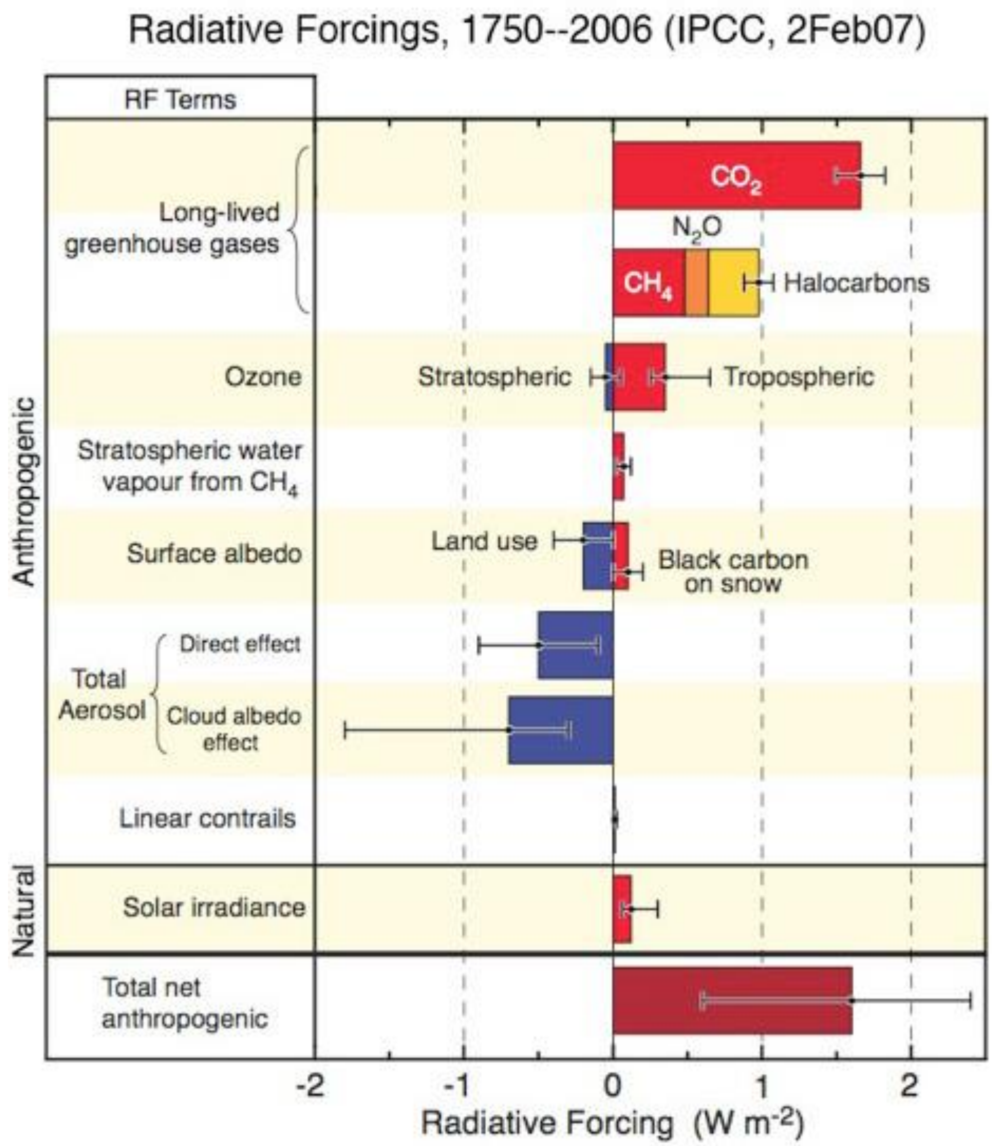


Figure 21. Climate positive and negative forcings in Watts/m^2 over the period 1750-2006 [8].

Both processes are combining to modify the climatic patterns, causing droughts and starvation in some parts and excessive precipitation and flooding in others. One effect is that the tropical rain regions are moving northward denying the Sahel region in Africa its rain and causing drought, starvation and social dislocation. The USA southwest is expected to also move into a perennial drought. The Monsoon pattern affecting 3.6 billion people of about half the world population has been altered.

The paradoxical effect is that global dimming is accelerating the global warming effect. The temperature difference swing between day and night has increased. If a predicted 25 meters water level rise in the oceans were to occur, the state of Florida would cease to exist, and cities like Venice, Alexandria, New York, Washington DC and New Orleans would be under water. The low lands of Holland would be reclaimed back by the sea. Trees would die, droughts and famine would prevail and a catastrophic release of the frozen methane at the bottom of the oceans could lead according to a model to a runaway temperature increase of 25 ^oC.

Figure 22. Dust storm and drought during the Dust Bowl climatic period at Stratford, Texas, April 18, 1935 in the USA Great Plains.

Figure 23. Dust storm in Australia, 2009.

The World Meteorological Organization (WMO) reports that rising temperatures had made ice caps melt faster. It also reported that more extreme weather conditions, ranging from droughts to heavy rainstorms, were observed worldwide. The Arctic ice cap had melted to its smallest area since satellite observations begun. Surface melting of the ice cap in Greenland was also reported to be greater than in previous known records. Since 1976, global surface temperatures have been rising at three times the average rate recorded during the past century.

POSSIBLE CONSEQUENCES

Global warming is closely associated with the process of energy production and usage. However, it is not global warming per se that we should be concerned about, but the possible climatic shifts that it could lead to. Some of these shifts may become long, lasting for centuries, or irreversible over human lifetimes. In addition, paradoxical unexpected results can occur. For instance periods of cold weather lasting centuries can result as an effect of global warming if large quantities of frigid and fresh water are suddenly melted and added to the North Atlantic drift of the Gulf Stream.

Some of the postulated immediate effects of global warming include:

1. Species extinctions: Some are already migrating to cooler regions, but some are failing to adjust.
2. Reduced food production as the temperature increase in some agricultural production regions is leading to a drop in crop yields. An average increase of a couple degrees in temperature would lead to a decrease on crop yields of 2 percent. The reduced yield would likely occur in the low latitude regions where hunger is already a problem such as at Sub-Saharan Africa and South Asia. Wheat yield in South Asia would decrease by 12 percent over the first half of the 20st century. Within 30 years later, the decrease could reach 29 percent.
3. Higher food prices becoming a security issue resulting in civil unrest such as the Arab Spring in the Middle East associated with a rise to the 40 percent level of households income spent on food. During the 2008 food price spike, 30 countries experienced increased social tensions.
4. Modified storms patterns: Warming will cause more violent and unpredictable climatic events.
5. Oceanic disruptions: Coral reefs are under pressure and bleaching from the rising water level and its increased temperature. With more dissolution of carbon dioxide in the water, plankton could suffer affecting species higher up on the food chain.
6. Flooding of low lying areas: In this century a one meter rise in the sea level would lead to the submersion of islands and coastal areas that already experience seasonal flooding.

The process is so real and hard to stop that humanity must learn to adapt to it. This includes coping with a different lifestyle in coming generations. The American Southwest and West's dwindling water supply will have to be managed more efficiently. Public health programs will have to be beefed up. Massive environmental restoration projects like the restoration of the Florida Everglades will have to be rethought. The methods of transportation and energy production will have to be shifted from reliance on fossil fuels to an electrical and hydrogen economy depending initially on methane gas then wind, nuclear and solar processes.

The Southeast USA will have to manage its forests differently, cutting down trees to keep them from dying out. Massive floods in some areas, which occurred once every 100 years, are expected to occur once every 20 years. Both the Atlantic Ocean and the Gulf of Mexico will continue rising 1 to 2 millimeters per year. At some barrier islands like Miami or Hatteras, the rise in the sea interacts with the slope of sand to yield a change in sea level of as much as 4.5 feet a year. This could lead to population shifts and relocation, not just in the USA, but all over the Globe.

Human activities currently release as much CO_2 in a year as a small volcano. However, it is a continuously erupting volcano. The process of global warming seems to be occurring, as a result of the continuous release of 20 billion tons of CO_2 per year. For a world population of about 6 billion people, about 3 metric tonnes of carbon dioxide are discharged into the atmosphere per human per year.

Extreme and passionate views abound about what is a real effect. Some scientists suggest that humanity has a decade to act before reaching a tipping point sliding towards destruction of human civilization and the demise of most other species on the planet. Upon reaching this tipping point, it would be too late for any action. The UK ecologist Sir James Lovelock who proposed the Gaia hypothesis about the Earth functioning as a living organism, even published a book suggesting that in 100 years mankind would be reduced to: “A few breeding couples at the poles.” On the other hand, Senator James Inhofe of the State of Oklahoma, who chaired the USA’s Senate Environment Committee is of the opinion that: “Global warming is the greatest hoax ever perpetrated on the American people.”

CLIMATIC OBSERVATIONS

A National Academy of Science report suggests that ground monitors have shown a distinct increase in the Earth's temperature. This warming which has been under way for a century has accelerated in the last 20 years. Satellite and weather balloon observations, on the other hand, have shown little or no warming.

Researchers at the Universities of Arizona and Massachusetts reported on their reconstruction of a thousand years record of the Earth’s average temperature. They report that a 900 hundred years trend has been suddenly and decisively reversed in the past fifty years.

The Intergovernmental Panel on Climate Change (IPCC), suggested earlier in 1995 that: “ … the balance of the evidence suggests a human influence on global climate.” Scientific findings since that time still suggest a human influence on climate.

Figure 24. From 1932 to 1988 an ice cave vanished completely within 56 years in the USA's Glacier National Park in the state of Montana.

Computer models predict an Arctic Ocean that would be free of ice by the summer of 2050. Current trends suggest that ice is melting faster than the computer models predictions. According to the National Snow and Ice Data Center in Boulder, Colorado, in 2012 the ice cap at the North Pole extends over 1.32 million miles; 18 percent smaller than a record of 1.61 million square miles recorded in 2007. This is based on a record of satellite data extending back to 1979. Sea ice shrank in 2007 to levels that are 22 percent below a previous record in 2005. Ice in the Arctic melts in the summer and grows in extent in the winter months. In the 1980s, the summer sea ice would cover an area slightly smaller than the continental USA; now it covers half that extent.

Arctic ice is a sensitive gauge of climatic change, and it affects climate over the rest of the globe. The ice in the Arctic keeps the rest of the globe cooler, and as it melts out it ceases to reflect 90 percent of the incident solar radiation and absorbs more of it, to the extent of 50 percent in its darker water state.

USA Navy submarines cruising below the Arctic ice pack reported that the average thickness of Arctic ice has declined by 4.3 feet over the last decade. Measurements of the thickness were routinely conducted from 1958 to 1976. The Scientific Ice Expeditions program, a series of cruises covering the Arctic basin, compared the earlier measurements to new measurements in the 1990s. The comparison shows that in all of 29 sites studied, the perennial cover, averaging 3 to 9 feet, is about 40 percent thinner in the new measurements.

The Surface Heat Budget of the Arctic (SHEBA) project involving 170 scientists on board the Canadian Icebreaker Des Groseillers, reported that the North Polar cap was melting with unexpected speed, and even faster than what is happening in the Antarctic. They report that in the 1970s, the thickness of the ice in the Arctic was 3 meters, but that in 1997 they found the thickest ice to be 1.5 to 2 meters. In twenty years, the ice has lost half of its thickness. Scientists are convinced that most of the Arctic will soon be an open ocean over the summer in a few years. The Arctic Ocean is shallow, and apt to change rapidly if it is flooded with fresh water compared to what it was 22 years ago.

At the lower end of the Earth, the massive West Antarctica ice sheet is shrinking steadily. Polar ice forms and melts in periods lasting thousand of years. As of 1988, huge icebergs began to carve off the Larsen Ice Shelf on the western side of the Antarctic continent, close to the tip of South America. By 1998, half of the shelf had broken up, and the other half is in danger of melting. In 1994, a large section measuring 22 by 48 miles broke off the Larsen Ice Shelf. In 1998 another 160 square mile piece broke off the Larsen-B Ice Shelf. The British Antarctic Survey reported in January of 1995 that the entire Larsen-A Ice Shelf had disintegrated. Since 1940, the Antarctic's average annual temperature has increased by about 6 degrees F. The Arctic increase was a larger 8 degrees F. The reduction of salinity is an important factor, in addition to temperature differentials in the world ocean's currents.

In July of 1998 the Pine Island Glacier flowing into the Amundsen Sea has been reported to have been retreating for the past four years. The hinge line of this glacier where the ice ceases to be attached to the continent retreated by ¾ of a mile between 1992 and 1996. If the West Antarctic Ice sheet were to melt, coastal areas of the world containing two-dozen of the world largest cities would be flooded displacing a billion persons.

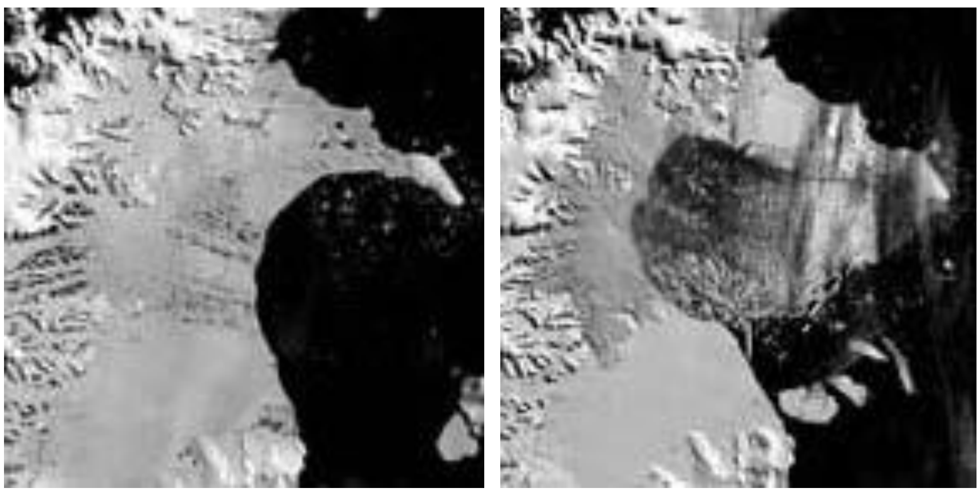


Figure 25. Shattering of 1,300 square miles of Antartica's ice shelf within 30 days in 2000. Source: NASA.

The Greenland ice sheet, which is on land, has been thinning by about eight inches per year. Close to the coast the thinning is taking place at the rate of 36 inches per year. Greenland's glaciers are flowing faster into the sea, and may possibly surge into the ocean.

Figure 26. Greenland glaciers in retreat.

The two most important factors preserving our current climate are:

1. The stability of the North Atlantic current.
2. The temperature of the upper atmosphere.

The greater the temperature differential between the upper and lower atmosphere, the more violent our weather is expected be. Upper atmosphere temperatures are presently dropping with the greenhouse gases trapping more heat closer to the ground. Human activities seem to be accelerating the warming of the atmosphere and the oceans.

Human society is conducting the largest experiment to its living environment in history. Such an experiment is being conducted without a clear knowledge of its ultimate results. It may be that this experiment would have never been started if the potential outcome were known. In addition, it is not clear that if the results of the experiment are deemed unacceptable in the future, that the effects of the experiment are reversible.

Energy sources other than fossil fuel, including solar, wind and nuclear power possess an important role in providing electrical energy for the present and possible fresh water supplies in the future to an increasing world population. Nuclear power has to be viewed from the perspective of its relative benefits and risks compared with its alternatives. One of the issues is the risk of long-term global effect of the emission of greenhouse gases, particularly Carbon Dioxide (CO_2) from fossil fuel burning in power production and transportation.

EARTH GREAT CONVEYOR BELT

The ocean waters circulation pattern known as the “Great Conveyor Belt,” is expected to be affected by global climatic shifts. The conveyor belt transports heat around the globe. It starts in the Arctic Ocean and the North Atlantic Ocean where the water surrounding the ice is cold and salty, hence denser than the warm water. The higher density causes it to sink down. As a river, it flows thousands of miles to the south then turns east to the Indian and Pacific Oceans.

Replacing the dense sinking water, less dense warm water flows up from the tropics partially forming the Gulf Stream. Without the Gulf Stream, the North Eastern USA as well as Europe would become far colder than they currently are.

The largest pump of the ocean conveyor belt is where the cooled super-salty evaporated water from the Gulf Stream Current winds its way south again, through the strait of Denmark and plummets down to the bottom of the ocean just off the tip of Greenland. It is so strong that it use to cause an observable depression where it sank. It has a trough just before the strait that was a reserve of the super dense water. This trough has been emptying for decades. The saltiness is diluted by Greenland fresh melt water runoff. The trough has been empty for a few years. The cool water is pooling on the surface where it is causing a temperature anomaly.

It must be emphasized that the ocean conveyor belt conveys one thousand times more thermal energy between the equator and the poles than the atmosphere. If it stops, this will result in:

1. An increased thermal gradient between the equator and poles,
2. Stronger winds to compensate for the thermal transfer.

This is a recipe for a "global dehydrator" where the increased temperature at the equator evaporates moisture at a higher rate, and the decreased temperature at the poles locks up that moisture, and increased convection winds drive the process at an accelerated rate.

The global ocean conveyor belt is a strong, but easily disrupted process. The conveyor belt may be affected by climate change if global warming results in increased rainfall in the North Atlantic, and the melting of glaciers and sea ice. Under this circumstance, the influx of warm freshwater onto the sea surface could block the formation of sea ice, disrupting the sinking of cold, salty water. This sequence of events could slow or even stop the conveyor belt, which could result in potentially drastic temperature changes in the European continent.

The cold and salty and hence dense water sinks at the Earth's northern polar region and heads south along the western Atlantic basin. The current is recharged as it travels along the coast of Antarctica and picks up more cold salty dense water. The current splits into two sections, one traveling northward into the Indian Ocean, while the other heads up into the western Pacific Ocean. The two branches of the current warm and hence rise as they travel northward, then loop back around southward and westward. The now-warmed surface waters continue circulating around the globe. They eventually return to the North Atlantic where the cycle begins again. It can take 1,000 years for a parcel of water to complete the journey along the global conveyor belt.

If the Arctic ice melts and the North Atlantic waters grow warmer and less salty, they would no longer sink to the ocean's depths. The whole conveyor belt would shut down. Without the Gulf Stream, the North Eastern USA and Europe will be deprived of heat. The conveyor belt has shut down in the past with dramatic results.

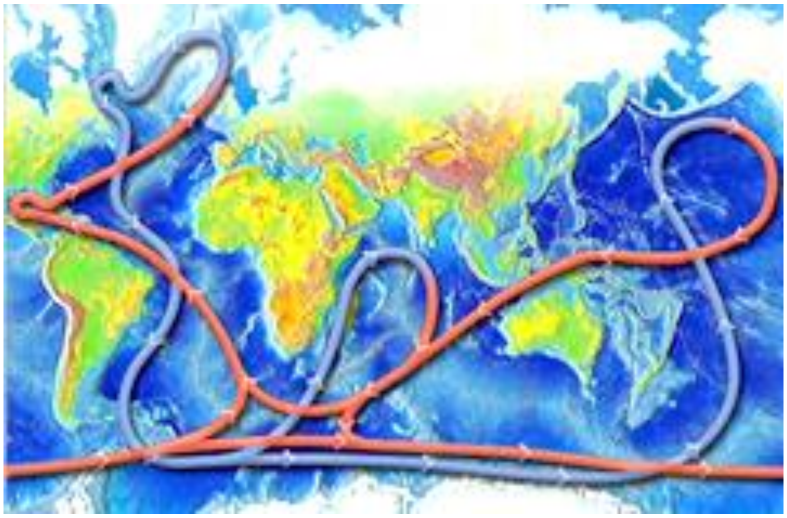


Figure 27. Contemporary great Earth ocean conveyor belt. Warm water flow in the Atlantic Ocean is diverted to the North at the joining point of North and South America, warming Europe. Source: NOAA.

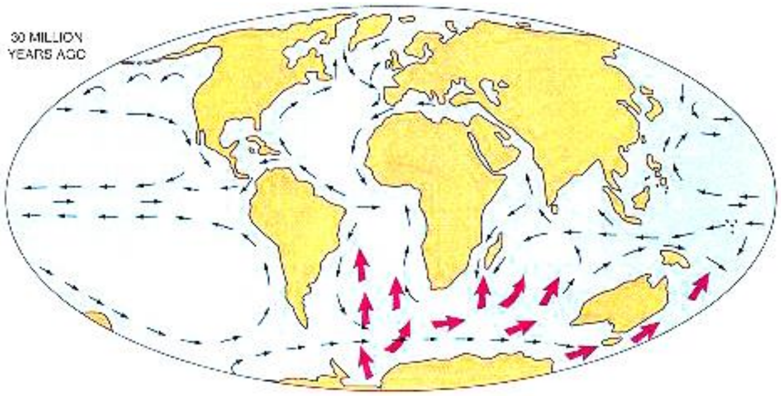


Figure 28. Global ocean currents 30 million years before present. Notice the flows from the Atlantic Ocean to the Pacific Ocean, and from the Pacific Ocean to the Mediterranean Sea then to the Atlantic Ocean. The Arctic Ocean had then open waters. Source: NOAA.

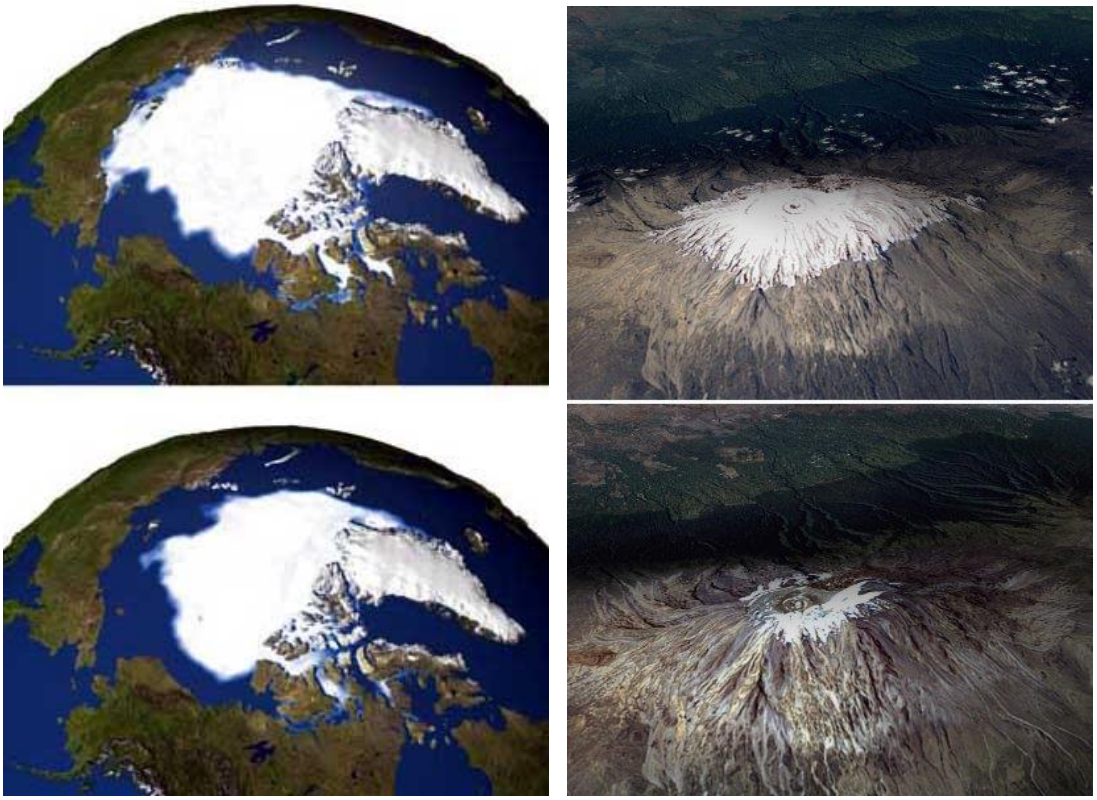


Figure 29. Left: The retreat of the ice in the Arctic Ocean from September 1979 to September 2005. Source: NASA. Right: Mount Kilimanjaro, Tanzania February 1993 and February 2000. Source: AFP.

PREVIOUS CLIMATIC SHIFTS

About 20,000 years before present (bp) glaciation had reached its maximum extent covering the Great Lakes region in North America and Northern Europe and Asia. A warming period occurred in which the glaciers started 18,000 years bp retreating to north of the Great Lakes. By about 8,200 years bp, the leading edge of the ice had moved so far north that an ice dam blocking Lakes Agassiz and Ojibway in northern Canada started melting. It eventually collapsed initiating a massive flood of a 100 trillion cubic meters of frigid fresh water into the Labrador Sea and into the Atlantic Ocean.

By affecting both the temperature and the salinity of the North Atlantic Drift of the Gulf Stream, the warming trend paradoxically led to a cooling trend that lasted for two centuries. In this cooling trend, the warm Gulf Stream was so much affected as to reduce the temperature by as much as 15 degrees F in Greenland, and 6 degrees F in continental Europe. The temperature stayed down for about two centuries. Don Barber of the University of Colorado and his coworkers identified and carefully dated a reddish layer of sediment that stretches 800 miles from the northern Hudson Bay in Canada into the Atlantic that was associated with this event. This is a documented scientific example that suggests that global warming can lead in unpredictable ways to an opposite effect of climate cooling.

ATMOSPHERIC CO_2 CONCENTRATION

A steady increase in the atmospheric concentration of CO_2 has been observed worldwide. This effect started being measured since the year 1958, and shows a steady and relentless increase. The observations at the South Pole in Antarctica, at the Mauna Moa volcano site in Hawaii, at Point Barrow, Alaska, and Swedish airplane high atmosphere sampling flights, all agree that the atmospheric CO_2 level has been increasing steadily. Figure 30 shows the steady increase of CO_2 concentration in the atmosphere in parts per million in volume (ppmv) from different observations.

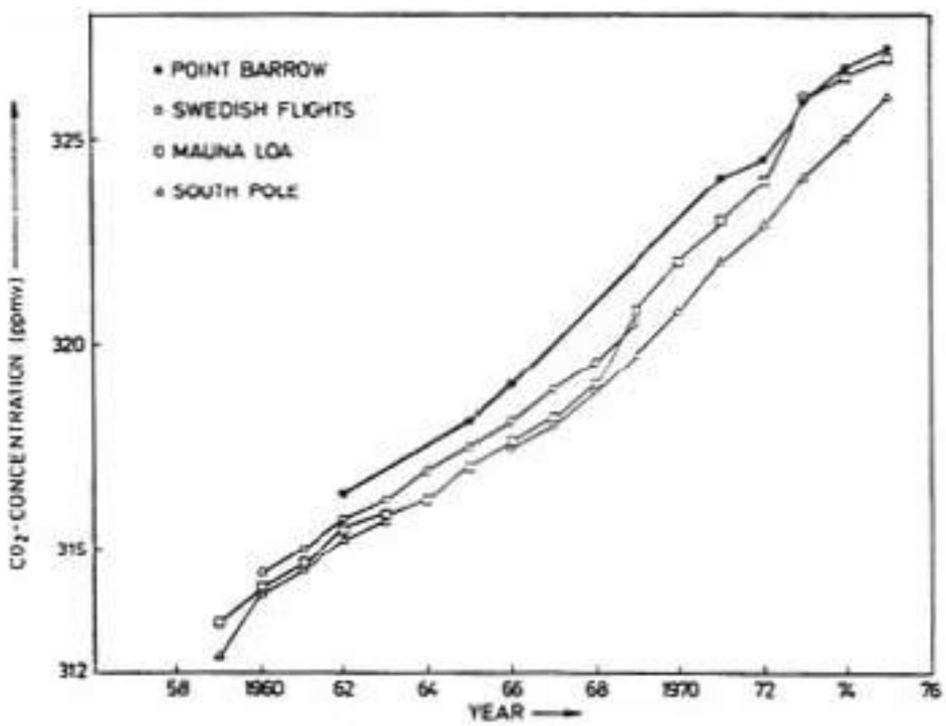
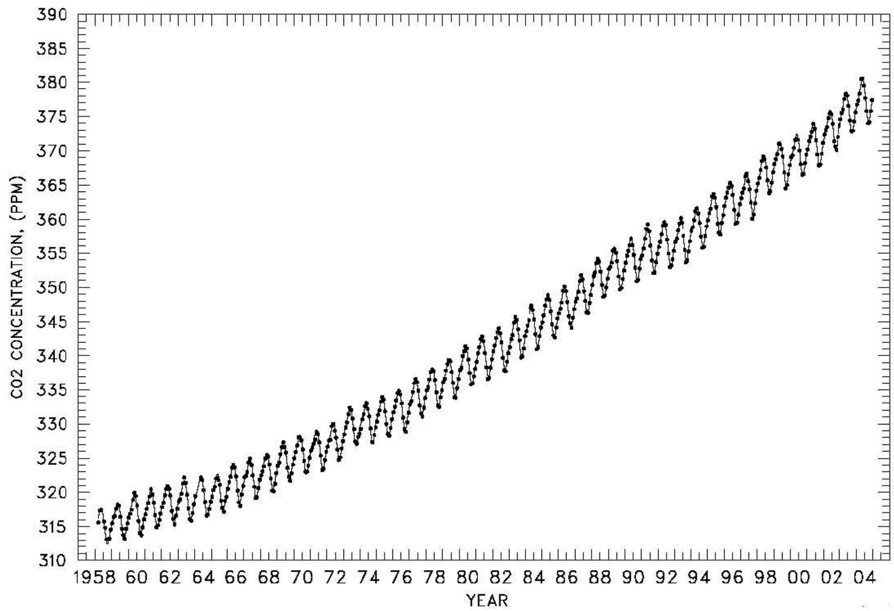


Figure 30. The steady increase in parts per million in volume from different observations.

There are seasonable variations caused by several natural cycles involving:

1. Plant growth in the spring decreases the CO_2 concentration, and plant decay in the fall increases it.
2. Variations in the solubility of CO_2 in the surface ocean water. Higher temperatures are associated with higher solubility.
3. Variations in emissions in energy production from fossil fuels from summer to winter.



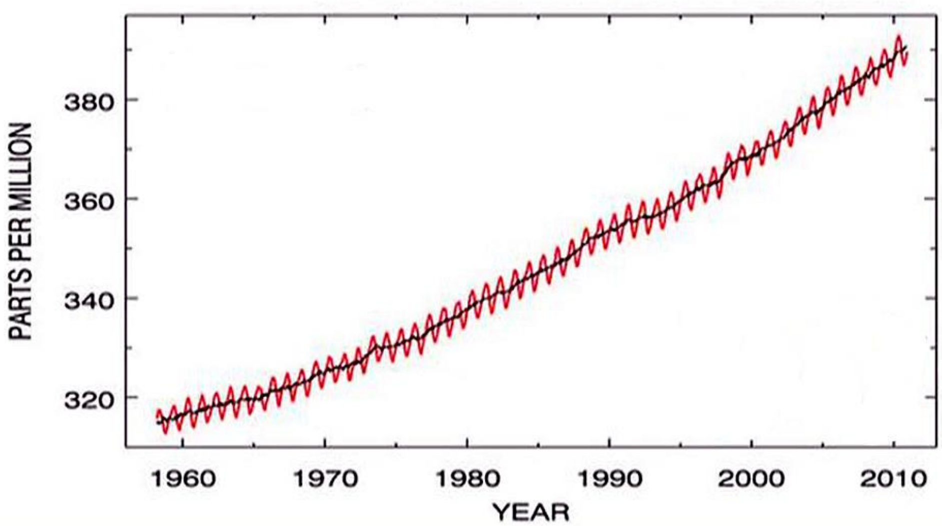


Figure 31. Keeling curve for the seasonal monthly average CO_2 concentration taken at the Mauna Loa observatory, Hawaii, as of May 19, 2005 (top) and as of January 2011. An increase from 380 ppm to 390 ppm can be noticed within the 6 years period. Source: NOAA.

The concentration maxima occur during springtime. The variations decrease with altitude and increase with northern latitude. The increase in the southern-hemisphere lags behind the northern atmosphere increases by about two years.

The pre-industrial concentration of CO_2 is estimated at about 295 $\pm$ 5 parts per million (ppm) by volume. In 1958 it had reached the value of about 312 ppm. In 1975, it was 327 ppm. Thus the relative increase in concentration from 1958 to 1975 is:

$$\frac{\Delta C}{C} = \frac{(327\text{-}312)}{312} = \frac{25}{312} = 0.0801 \qquad (5)$$

or 8 percent. The relative yearly increase would be:

$$\frac{0.0801}{(1975\text{-}1958)} = \frac{0.0801}{17} = 0.0047,$$

or a percentage yearly increase of 0.5 percent.

The relative increase in concentration from the pre-industrial stage to 1975 is:

$$\frac{\Delta C}{C} = \frac{(327\text{-}295)}{295} = \frac{32}{295} = 0.1085 \qquad (6)$$

or about 11 percent.

EFFECTS OF THE INCREASE IN CO_2 AND CH_4 CONCENTRATIONS

At the present concentrations, CO_2 is not toxic, and is necessary for plant life growth through photosynthesis. The risk from an increase in CO_2 concentration is due to the "greenhouse effect."

In a plant greenhouse, glass is transparent to solar radiation or to the visible range of the electromagnetic spectrum. It acts as an insulator and is opaque to the infrared or heat part of the electromagnetic spectrum. Visible solar radiation penetrates the transparent glass, hits objects inside the greenhouse, is absorbed and then re-emitted primarily in the infrared part of the spectrum. Since glass is an insulator to the infrared radiation, this re-emitted radiation cannot escape from the greenhouse, and is trapped in it with a subsequent increase in temperature. Carbon dioxide in the Earth's atmosphere acts as glass in a greenhouse.

The Earth's atmosphere provides a window that is 48 percent transparent to the incoming solar radiation. However, it only absorbs, with a 20 percent transparency, the infrared radiation emitted from the Earth's surface. It acts as a blanket to keep the Earth warm. The reflectivity of the atmosphere is 29 percent, leading to an equilibrium temperature of –19 ^oC. The observed difference between this figure and the observed average of +15 ^oC can be attributed to the greenhouse effect. This effect is caused by CO_2 as well as by water vapor in the atmosphere. Such delicate balance sustains biological life on the planet Earth.

If the concentration of CO_2 increases, this is expected to lead to a temperature increase in the atmosphere depending on the fixed cloud tops altitudes and temperatures. If we consider the 15 μm and the weak absorption bands for CO_2, a doubling of the CO_2 concentration from 320 ppm to 640 ppm, leads to a temperature increase of 1.98 ^oC. This would apply to the low and middle latitudes. At the polar and sub-polar regions, the existing more stable conditions would add an amplifying factor of about 3.

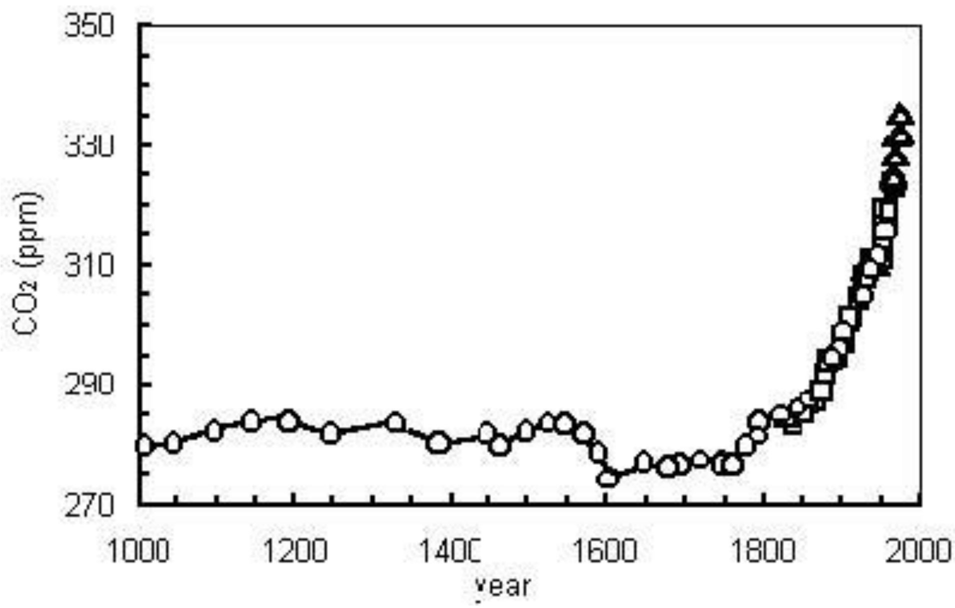


Figure 32. Increase of CO_2 concentration in the last thousand years from Antarctic ice core measurements.

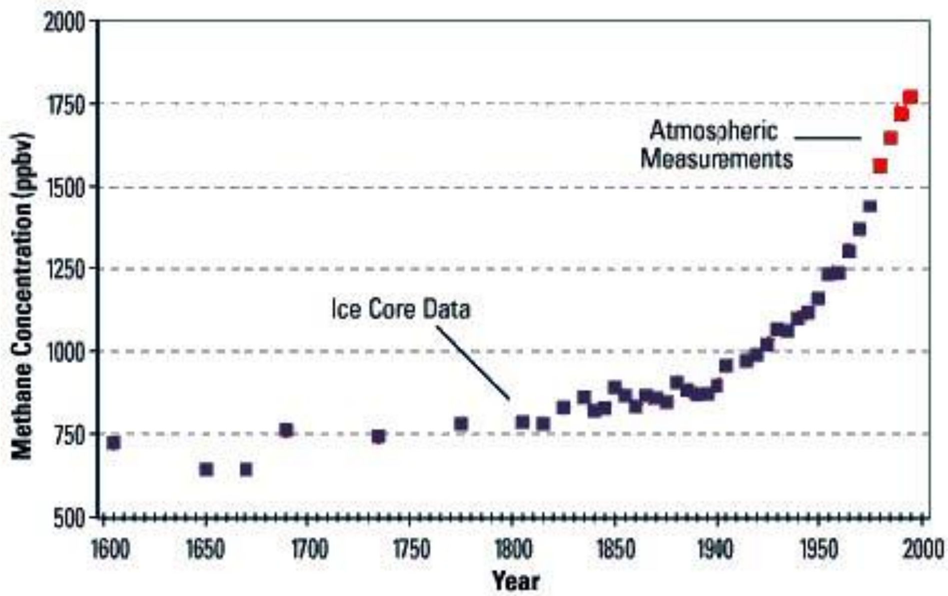


Figure 33. Increase in the CH_4 concentration from ice core and atmospheric measurements.

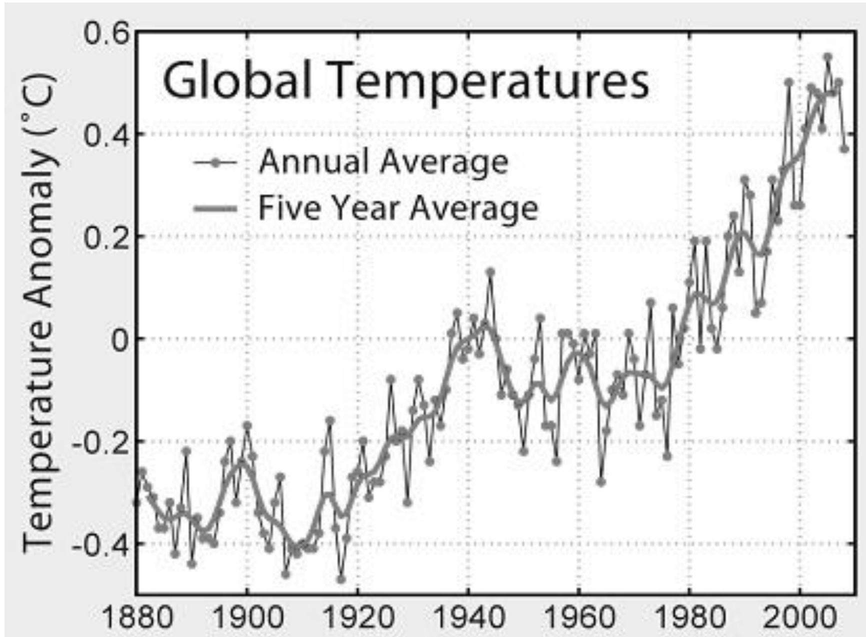


Figure 34. Global temperature trend. Source: Intergovernmental Panel on Climate Change, IPCC.

THE GLOBAL CARBON CYCLE

The combustion of fossil fuels releases:

3.4 tonnes of CO_2 per tonne of lignite coal, or,

1.9 tonnes of CO_2 per tonne of natural gas.

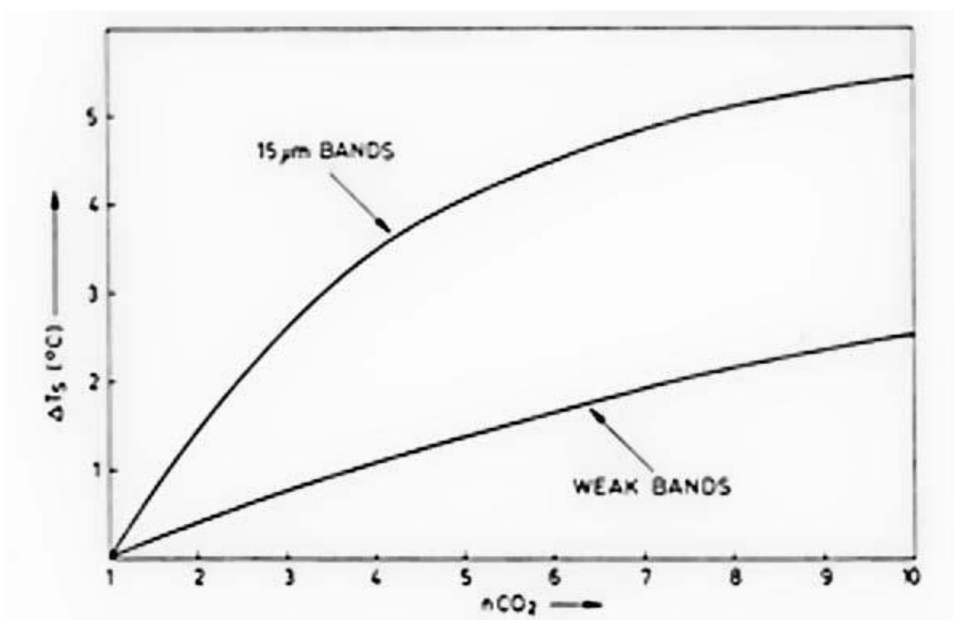


Figure 35. The 15 µm and the weak absorption bands for CO_2, a doubling of the CO_2 concentration from 320 ppm to 640 ppm, leads to a temperature increase of 1.98 ^oC.

The atmospheric emission is currently about $20x10^9$ tonnes of CO_2 per year. The amount emitted since 1850 is about $500x10^9$ tonnes. The $2,600x10^9$ tonnes of CO_2 in the atmosphere are in continuous exchange with the carbon stored in the ocean's water. The 10 meters surface layer stores $840x10^9$ tonnes of carbon, and the deep layer stores $36,000x10^9$ tonnes of carbon and $830x10^9$ tonnes in organic matter. The carbon in the biomass on land is $1,500x10^9$ tonnes. On a molecular weight basis, 12 tonnes of carbon are equivalent to 44 tonnes of CO_2. Since about 50 percent of the emitted CO_2 remains in the atmosphere, it can be assumed that what remains is absorbed by the oceans. Higher temperatures of the oceans water would be associated with higher absorption rates.

In addition to CO_2 emissions from fossil fuels, an extra amount could have been caused by deforestation on a large scale, as normal crops are not as efficient as trees in their uptake of atmospheric CO_2. Tillage methods for crops that expose the carbon in the topsoil to oxygenation through fungal and bacterial action could also be contributing to increased CO_2 concentration in the atmosphere.

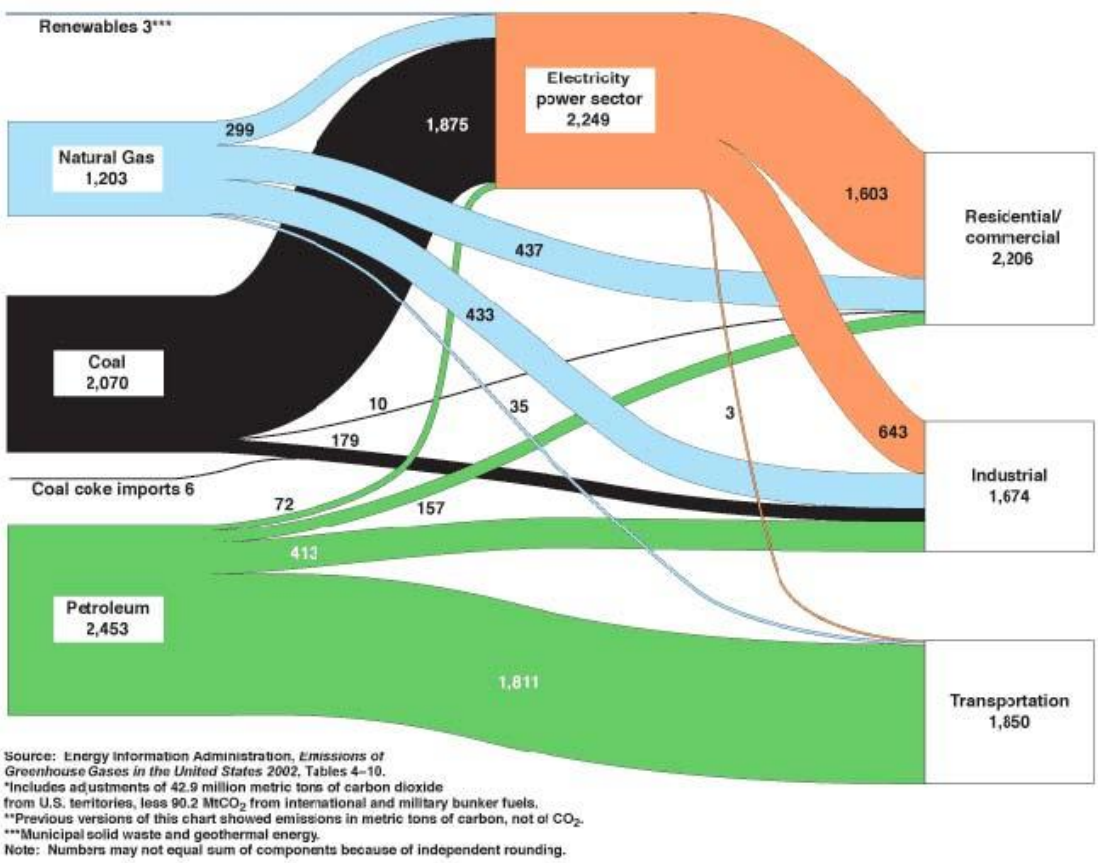


Figure 36. Breakup of CO_2 emissions of 5,682 million metric tonnes in the USA from energy consumption in 2002.

FUTURE LEVELS OF CO_2

Presently, the world's primary energy consumption is about 8 TeraWatts (TW). If we take the future world population at 10 billion persons, and consider them as using the present per capita energy consumption level, one can envision a future scenario of primary energy consumption based on natural gas, oil and coal with a consumption level of 50 TW.

Such a scenario would consume all coal reserves at $4,300 \times 10^9$ metric tonnes of coal equivalent. The maximum CO_2 emission would be 40×10^9 tonnes of carbon per year, and the CO_2 concentration should increase to 5 times the pre-industrial value. The corresponding temperature increase would be about 5 ^oC. Figure 37 shows the ensuing carbon dioxide concentration increase, and the associated temperature increase.

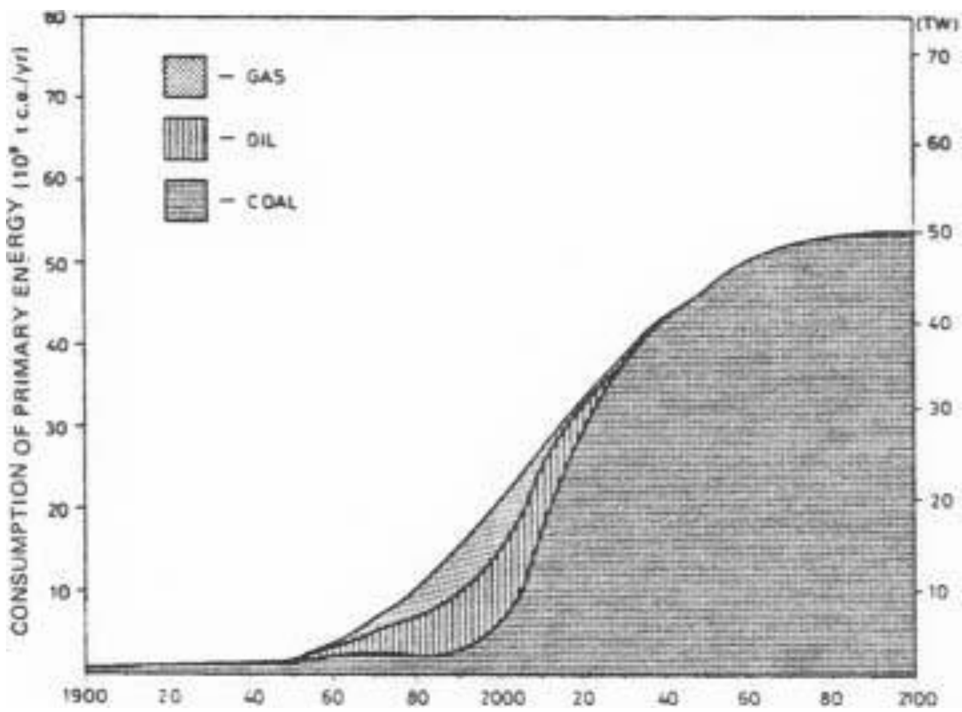


Figure 37. A 50 TW of fossil fuel energy scenario consisting of coal, oil and natural gas.

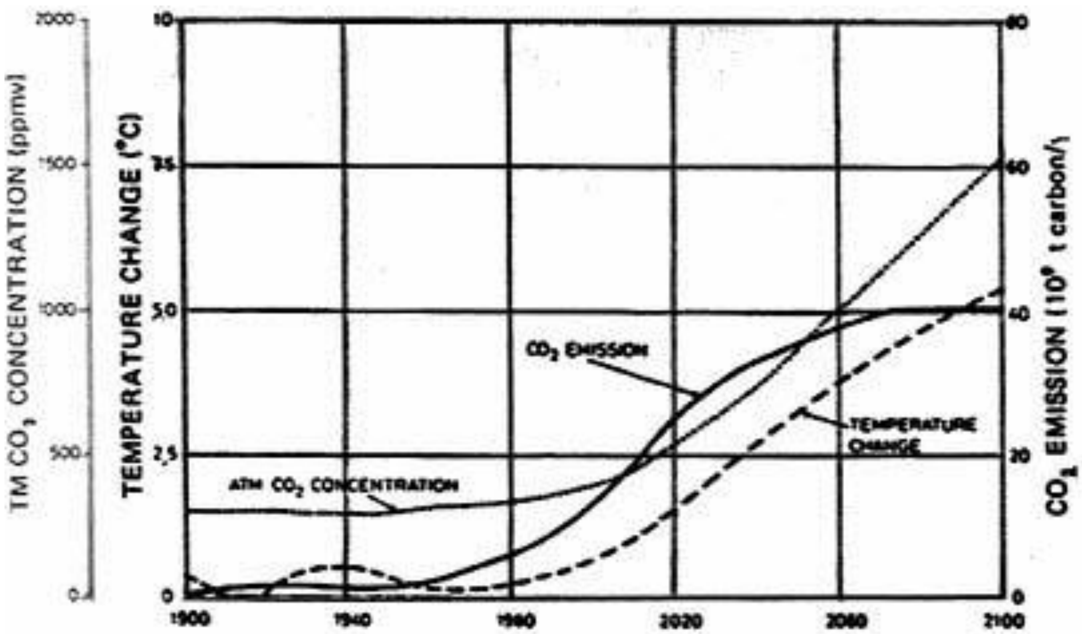


Figure 38. Carbon dioxide concentration increase for a 50 TW fossil fuel energy scenario and the associated temperature increase.

If the total consumption is at a lower level of 30 TW, the concentration increase would still be 4 times today's concentration, and the increase in the global temperature would be about 4 ^oC.

Assuming a decision were taken soon enough to reduce CO_2 emissions, according, for instance to the Kyoto agreement, with wind, solar and nuclear energy replacing the fossil fuels energy consumption, an alternate scenario could be considered. Figure 39 shows a 50 TW energy consumption scenario where fossil fuels are replaced by solar and nuclear energy.

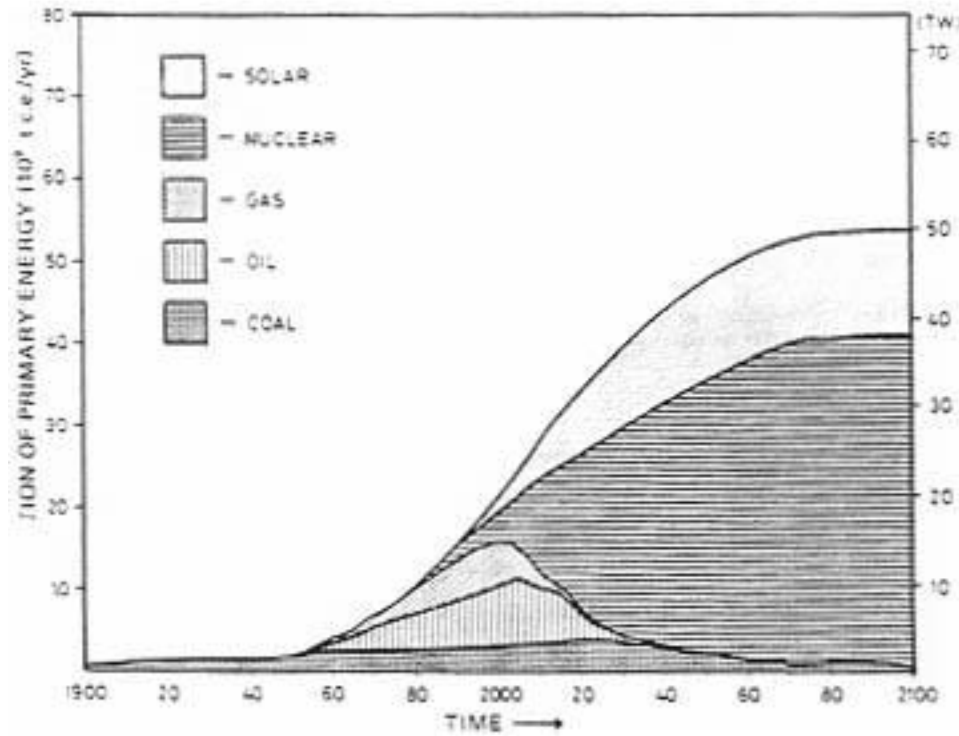


Figure 39. A 50 TW energy consumption scenario where fossil fuels are replaced by solar and nuclear energy.

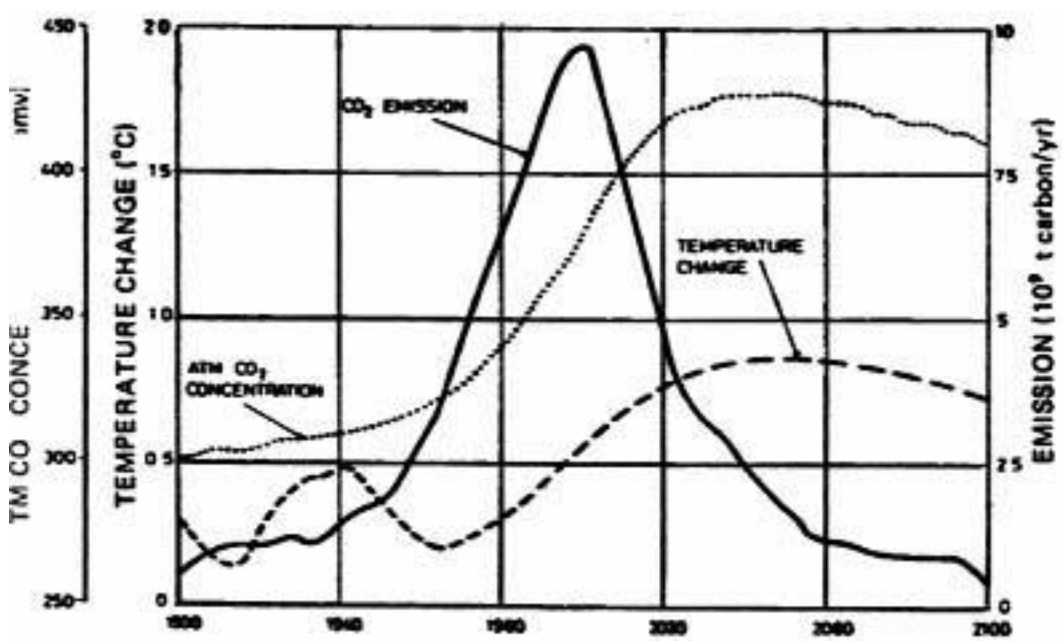


Figure 40. The increase then decrease of the arbon dioxide concentration and the ensuing maximum temperature increase.

In this case, maximum emissions of about 10×10^9 tonnes of carbon per year would be emitted. The CO_2 concentration would reach 430 ppm by 2050 and would then slowly decrease. The maximum temperature change would be 0.6 ^oC above today's level. Figure 40 shows the increase then decrease of the carbon dioxide concentration and the ensuing maximum temperature increase.

POTENTIAL CLIMATIC EFFECTS OF THE CO_2 GREENHOUSE EFFECT

Ice cores sampling in the Arctic allows evaluation of previous temperature levels. This shows that in the past climatic changes occurred very rapidly on short time scales. The changes are connected to temperature changes in the range of 2-4 ^oC, and occurred with time constants of a few decades, with stabilization at different levels than the original one. Small changes triggered off large effects.

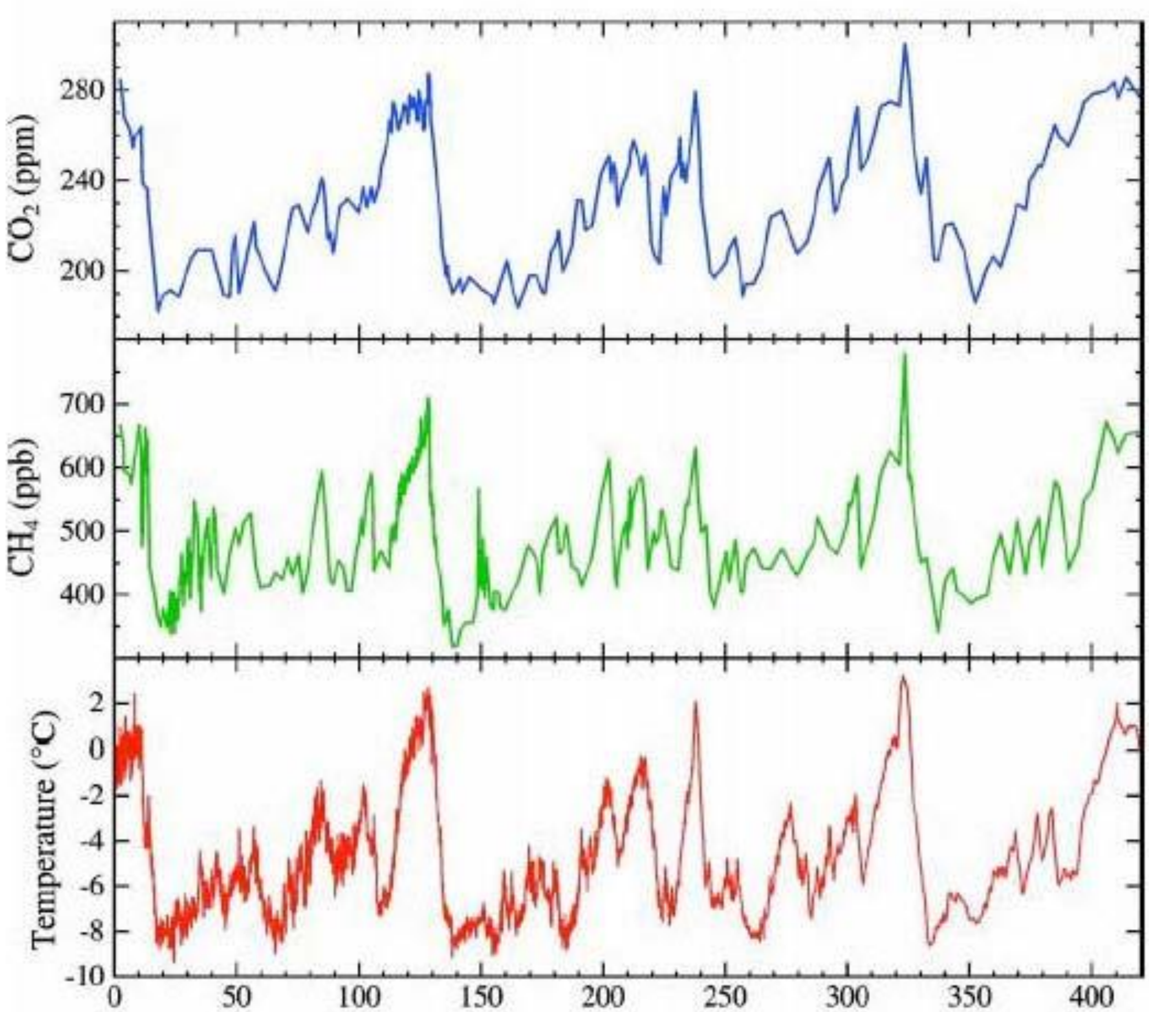


Figure 41. Antarctic ice cores show a positive correlation between past temperatures variations and the CO_2 and CH_4 concentrations [1, 2]. In statistics, however, correlation does not imply causation.

An increase in the average temperature of the Earth could have unforeseen consequence. There are uncertainties in the possible results of the global greenhouse effect, since they depend on the atmosphere's radiation balance. There exists limited knowledge on the pressure zones, cloudiness and precipitation possible changes. Considering these uncertainties, several possible risks can be associated with a potential; temperature increase:

1. Melting of the polar ice caps, ozone depletion, bromide explosions

This would raise the sea level by 60 meters, drowning low-lying islands, coastal cities and submerging river deltas, with a time constant of 10,000 years.

A study by NASA's Goddard Space Flight Center in Greenbelt, Maryland reports that the oldest and thickest multiyear arctic sea ice is disappearing faster than younger and thinner ice at the edges. At the same time, the surface temperature in the arctic is going up, which results in a shorter ice-forming season. The extent of perennial ice that has survived at least one summer is shrinking at a rate of 12.2 percent per decade, while its area is declining at a rate of 13.5 percent per decade. Older sea ice is more vulnerable than new sea ice. Older sea ice usually survives the summer, rebuilding on itself as winter arrives.

Reductions in the arctic sea ice is intensifying the chemical release of chemicals such as bromine into the atmosphere, resulting in ground-level ozone depletion and the deposit of toxic mercury in the Arctic, said NASA researchers. As the thick, perennial arctic sea ice is being replaced by a thinner and saltier ice, bromine is released into the air when it interacts with sunlight and cold. That in turn triggers a chemical reaction called a "bromine explosion" that turns gaseous mercury in the atmosphere into a toxic pollutant that falls on snow, land and ice and can accumulate in fish.

In March 2008, the extent of year-round perennial sea ice eclipsed the 50-year record low set in March 2007, shrinking by 386,100 square miles; an area the size of the USA states of Texas and Arizona combined. Seasonal ice, which forms over the winter when seawater freezes, now occupies the space of the lost perennial ice. This younger ice is much saltier than its older counterpart because it has not had time to undergo processes that drain its sea salts. It also contains more frost flowers which are clumps of ice crystals up to four times saltier than ocean waters, providing more salt sources to fuel bromine releases.

The shrinking summer sea ice has drawn attention to the possible exploitation of the arctic resources such as petroleum and natural gas and improving maritime trading routes. But the change in sea ice composition has impacts on the environment. The region north of the Arctic Circle is most susceptible to global climate change.

2. Disintegration of the West Antarctica ice sheet

About 1/10 of the land area on Earth is covered with ice and snow. The ice sheet over Antarctica is nearly 3 miles thick in some areas and contains nearly 90 percent of the ice cover on Earth. It takes more than 2,000 years for snow to be converted to glacial ice. In a warmer climate it is about 5 years. The Lambert Glacier in Antartica is over 200 miles long and 40 miles wide. The melting of the West Antarctica Ice Sheet would raise the level of the oceans by about 4 meters, with a time constant of 1,000 years.

Figure 42. Antarctic glaciers retreat.

3. Melting of the North Atlantic ice cover

Being thin, this ice cover could melt within decades turning the Arctic Ocean into open waters. Polar Regions would be more sensitive than the rest of the planet to changes in atmospheric CO_2. This melting would change the albedo or reflectivity of the Earth's surface, cause a positive feedback effect and lead to a northern shift of the climatic zones.

4. Change in the world food production patterns

This would be the most immediate effect. A temperature change of 1 ^{o}C can lead to a 1 to 3 percent decrease in the world's food production. Some parts would be much better off, and some other parts would suffer. This would be a problem of adjustment, since the detection would be slow, and new agricultural patterns must be adopted. For instance, the corn belt in the North American continent would be moved north. Illinois, at the center of agricultural production in the USA, would exhibit, by the end of the next century a climate similar to Northern Texas.

5. Increased biomass

Increased levels of carbon dioxide in the atmosphere will increase photosynthesis and alter the nitrogen to carbohydrate ratio in the plants. Crop yields in above and below ground level biomass production would be enhanced; an effect designated as the carbon dioxide fertilization process.

6. Decreased soil organic matter and fertility

The increased biomass production is associated with decreased soil organic matter resulting from increased microbial activity from both increased temperatures and increased soil moisture from rain that both favor microbial activity in the soil profile. Average annual and soil temperatures are increasing while winters are getting shorter. By the end of the century the maximum daily temperature could rise by 5-12 ^oF in the winter and 5-20 ^oF in the summer. There is a tendency towards shifts in rainfall distribution favoring increased rain in the winter and spring and drier summers. Dry conditions constrain plant growth and microbial decay rates. Plants exposed to higher carbon dioxide concentrations become more water efficient opening their stomata favoring the transport of both carbon dioxide and water through their pores. When plants satisfy their need they close the stomata to conserve water.

This is an effect negating the hoped for process of carbon segregation in soil organic matter. It is an undesirable effect from a soil quality and climate perspective since the degradation of organic stocks releases carbon as well as nitrogen into the atmosphere. Over the long term this reduces soil productivity and its ability to resist wind and water erosion.

7. Increased pest and disease pressure

Enhanced carbon dioxide levels are associated with increased damage in plants from insects that would live longer and reproduce more often. Plants lose their ability to produce jasmonic acid, a hormone which starts a chain of chemical reactions in the plant leaves leading to the production of a protease inhibitor; an enzyme protein that plants use to protect themselves against pests. When insects ingest the enzyme they are unable to digest the leaves properly, they stop eating, shortening their life expectancy. Absent the protease inhibitor, insects eat more, live longer and produce a larger number of offspring further damaging the plants. Caterpillars and insect larvae need nitrogen to grow and would eat more to get it. At the same time the sugary carbohydrates would encourage them to further attack the plants causing more damage.

Soybean plants exposed to high levels of CO_2 in a test plot at the University of Illinois at Urbana-Champaign attracted more adult Japanese beetles, Western corn root worms and aphids and exhibited more significant insect damage than control plots.

8. Increased incidence of severe weather events

Temperature in the atmosphere varies at different altitudes and it depends on latitude and time. Ascending into the lower atmosphere from the surface of the Earth, the temperature of the air falls steadily, in general toward a minimum value. The region of decreasing value is designated as the “troposphere.” The top of the troposphere, where the temperature ceases to decrease, is called as the “tropopause.” Above the tropopause lies the “stratosphere.” There the temperature remains more or less constant in the isothermal region with increasing altitude in the temperate and polar regions. However, in the tropical region, the temperature increases with altitude within the stratosphere. This inversion occurs at the higher altitudes in the temperate and polar regions. The temperature behavior in the different regions of the atmosphere is shown in Fig. 43.

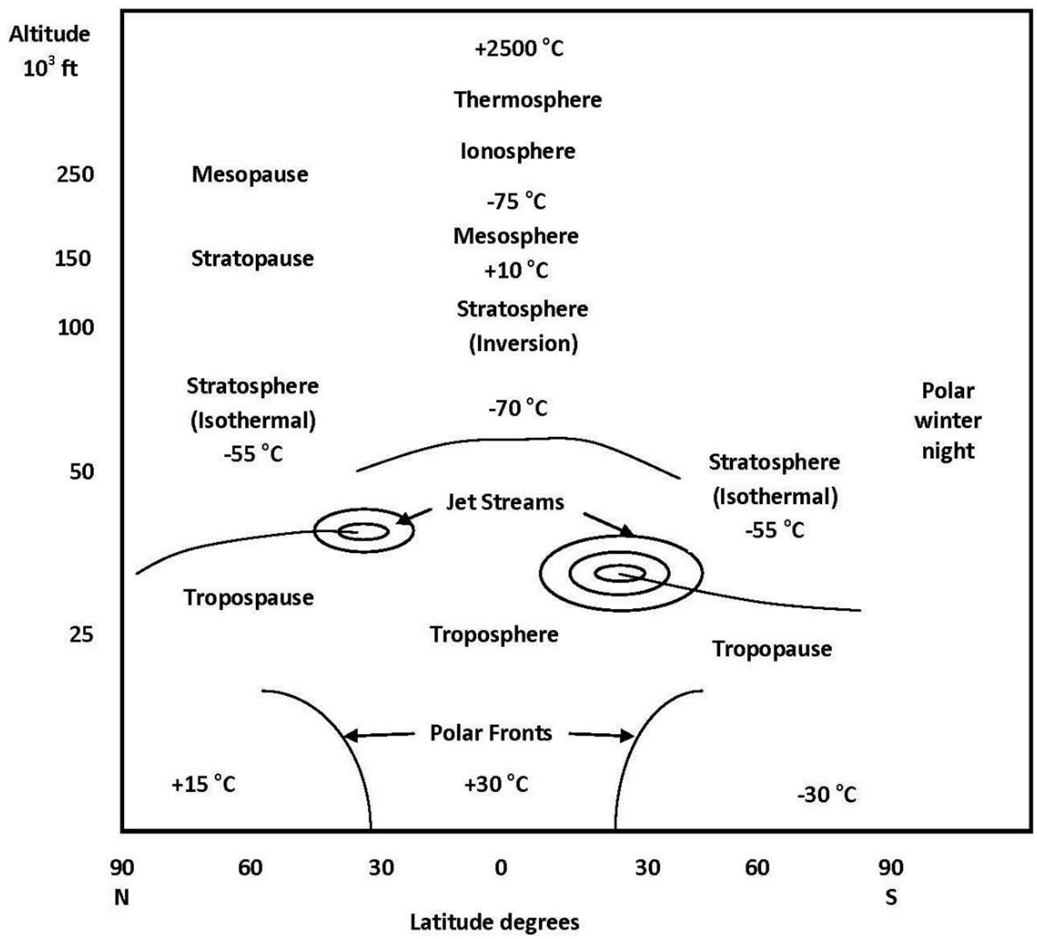


Figure 43. The temperature behavior in the different regions of the atmosphere.

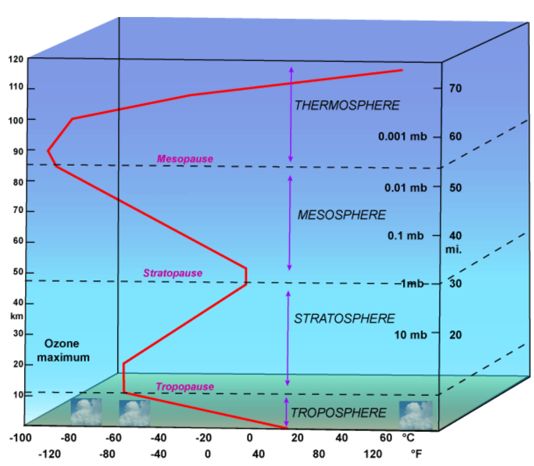


Figure 44. Vertical atmospheric temperature distribution. Source: Atkins, 2008.

In the mesosphere, the temperature decreases back again with increasing height. At still higher heights, the temperature rises rapidly with height in the thermosphere. Most of the visible weather phenomena occur in the troposphere. The high moisture content, the relatively high temperature at the Earth's surface, and the convective movement or instability of the air arising from temperature differences, promotes the formation of clouds and rainfall. At 45 degrees in the summer and 30 degrees in the winter in the temperate latitudes, where the cold polar air meets the warm air of the tropics, there are formed meandering, wavelike bands of storm fronts called polar fronts. In these regions there is significant rainfall.

The tropopause, or the top of the atmosphere, is lower in the Polar Regions than in the tropics. Its height varies from 25,000 to 45,000 feet in the Polar Regions, depending on latitude, time of the year, and particular conditions of the day. The tropopause can completely disappear in the polar winter night. In the tropical regions, the tropopause occurs at 55,000 feet at all seasons. Its boundary is more sharply defined than in the temperate and polar regions. This is so since the temperature in the tropics increases above the tropopause instead of remaining constant. There exists a distinct gap in the tropopause in each temperate zone that constitutes a region of marked turbulence. The gaps move north and south seasonally, following the sun, and are normally located near the polar fronts. The gaps are a region where interchange of air between the troposphere and stratosphere takes place. A jet stream circulates the air at high speed around the Earth, and is located at the tropical edge of the polar tropopause in each hemisphere.

9. Allergies incidence

Over the past few decades, more and more humans have started suffering from seasonal allergies and asthma. Though lifestyle changes and pollution ultimately leave people more vulnerable to the airborne allergens they breathe in, research has shown that the higher CO_2 levels and warmer temperatures associated with global warming are also playing a role by prodding plants to bloom earlier and produce more pollen. With more allergens produced earlier, allergy season can last longer.

10. Habitat alterations

Starting in the early 1900s, it is observed that rodents such as chipmunks, mice and squirrels have moved to slightly higher ground. Many of these animals have moved to greater elevations, possibly due to changes in their habitat caused by global warming. Similar changes to habitats are also threatening Arctic species like polar bears, as the sea ice they dwell on gradually melts away.

11. Early arctic bloom

Arctic plants usually remain trapped in ice for most of the year. As the ice melts earlier in the spring, the plants seem to be eager to start growing. Higher levels of a certain type of the pigment chlorophyll, which is a sign of photosynthesis, were found in modern soils than in ancient soils, showing a biological boom in the Arctic in recent decades. In the Baffin Sea, southwest of Greenland, the peak bloom moved from September to early

July.

Phytoplankton is crucial to the marine ecosystem, because it forms the base of the food chain. The creatures that eat the tiny plants, including fish and tiny animals called zooplankton, have adapted to make the most of these blooms. It is not clear if they are able to synchronize up with the earlier blooms and avoid disruptions to critical life stages, such as egg hatching and larvae development. The spring bloom provides a major source of food for zooplankton, fish and bottom-dwelling animals. The advancement of the bloom time may have consequences for the Arctic ecosystem.

12. Permafrost melting

The planet's rising temperature thawing out the layer of permanently frozen soil below the ground's surface. This thawing causes the ground to shrink and occurs unevenly, so it could lead to sinkholes and damage to structures such as railroad tracks, highways and houses. The destabilizing effects of melting permafrost at high altitudes, for example on mountains, could even cause rockslides and mudslides.

Recent discoveries reveal the possibility of long-dormant diseases like smallpox could re-emerge as the ancient dead, their corpses thawing along with the tundra, get discovered by modern man.

Permafrost stores methane gas CH_4 in the Arctic regions and Siberia. These regions are releasing 50 million tons / year of methane; equivalent to 1 billion tons of CO_2 / year. The process is accelerating since the average temperature has already reached 32 ^oF. The entire region is on the verge of melting. If the whole permafrost region melted or rapidly collapsed, this would be equivalent to adding 500 billion tons of carbon to the atmosphere and would add 30 ^oF to the average Earth temperature.

13. Genetic profile changes

As global warming brings an earlier start to spring, the early bird might not just get the worm, but also get its genes passed on to the next generation. Because plants bloom earlier in the year, animals that wait until their usual time to migrate might miss out on all the food. Those who can reset their internal clocks and set out earlier stand a better chance at having offspring that survive and thus pass on their genetic information, thereby ultimately changing the genetic profile of their entire population.

14. Upper atmosphere thinning

Air in the Earth’s atmosphere outermost layer is very thin, but air molecules still create drag that slows down satellites, requiring engineers to periodically boost them back into their proper orbits. The amount of CO_2 up there is increasing. And while the CO_2 molecules in the lower atmosphere release energy as heat when they collide, thereby warming the air, the sparser molecules in the upper atmosphere collide less frequently and tend to radiate their energy away, cooling the air around them. With more CO_2 in the upper atmosphere, more cooling occurs, causing the air to settle. So the atmosphere is less dense and creates less drag on satellites.

15. Higher mountain chains

The Alps and other mountain chains have experienced a gradual growth spurt over the past century or so thanks to the melting of the glaciers atop them. For thousands of years, the weight of these glaciers has pushed against the Earth's surface, causing it to depress. As the glaciers melt, this weight is lifting, and the surface slowly is springing back. Because global warming speeds up the melting of these glaciers, the mountains are rebounding faster.

16. Archaeological Effects

Ancient structures, temples, settlements and other artifacts stand as monuments to civilization’s past, which until now have withstood the test of time. The immediate effects of global warming are affecting them. Rising seas and more extreme weather have the potential to damage irreplaceable sites. Floods attributed to global warming have damaged the 600-year-old site of Sukhothai, which was once the capital of a Thai kingdom.

17. Forest fires incidence

Global warming seems to be increasing the frequency of forest fires in the USA. In the western states over the past few decades, more wildfires have blazed across the countryside, burning more area for longer periods of time. The rampant blazes positively correlate with the warmer temperature and earlier snowmelt. When spring arrives early and triggers an earlier snowmelt, forest areas become drier and stay so for longer, increasing the chance that they might ignite.

18. Cloud height shrinking

Over the last 10 years, the height of clouds has been shrinking. The time frame is short, but if future observations show that clouds are truly getting lower, it could have an important effect on global climate change. Clouds that are lower in the atmosphere would allow the Earth to cool more efficiently, potentially offsetting some of the warming caused by greenhouse gases.

The decreased cloud height may be caused by a change in the circulation patterns that give rise to cloud formation at high altitude. The Multi-angle Imaging Spectro Radiometer on NASA's Terra spacecraft has been watching Earth's clouds. From March 2000 to February 2010, the global average cloud height decreased by around 1 percent over the decade, a distance of 100 to 130 feet (30 to 40 meters). Most of the reduction stemmed from fewer clouds forming at very high altitudes.

19. Ocean’s acidification, mass extinctions

The Earth’s oceans are acidifying faster than at any point during the last 300 million years due to industrial emissions. The increasing levels of CO_2 in the atmosphere reduced the pH of the ocean by 0.1 unit in the last century, 10 times faster than the closest historical comparison from 56 million years ago. The seas absorb CO_2 from the atmosphere, forming carbonic acid.

Past instances of ocean acidification have been linked with mass extinctions of coral reefs and marine creatures. The UN's Intergovernmental Panel on Climate Change (IPCC) suggests that ocean pH may fall another 0.3 units this century. The closest change to the current pace occurred during the Paleocene-Eocene Thermal Maximum about 56 million years ago, when a doubling of the atmospheric concentration of carbon dioxide may have pushed pH levels down by 0.45 units over 20,000 years. Then, fossil records indicate as many as half of all species of seabed-dwelling single-celled creatures called benthic foraminifers went extinct, suggesting species higher up the food chain may also have died out.

The evidence comes from fossil records including the preservation of calcium carbonate in ocean sediments and the concentrations of various elements that are used to reconstruct past ocean conditions. Two other mass extinctions about 200 million years and 252 million years ago may also be linked to acidification.

EFFECT ON FOOD PRODUCTION

By 2050, the world's population is expected to reach around 9 billion, with the minimum and maximum projections ranging from 7.4 billion to 10.6 billion. The Green Revolutions high yield growth is tapering off and in some cases declining. So far this is mostly because of an increase in the price of fertilizers, other chemicals and fossil fuels, but also because the overuse of chemicals has exhausted the soil and irrigation has depleted the water aquifers.

A study "Climate Trends and Global Crop Production Since 1980" compared yield figures from the Food and Agriculture Organization (FAO) with average temperatures and precipitation in the major growing regions. The results indicated that the average global yields for several of the crops studied responded negatively to warmer temperatures. From 1981 to 2002, warming reduced the combined production of wheat, corn, and barley, which are cereal grains that form the foundation of much of the world's diet, by 40 million metric tons per year.

Though the impacts are relatively small compared to the technological yield gains over the same period, the results demonstrate that negative impacts are already occurring. Other researchers who focused on wheat, rice, corn, soybeans, barley and sorghum, with these crops accounting for 55 percent of non-meat calories consumed by humans and contributing more than 70 percent of the world's animal feed, reported that each had a critical temperature threshold above which yields started plummeting, for instance, 29 °C for corn and 30 °C for soybeans. At the International Rice Research Institute in the Philippines scientists have found that the fertilization of rice seeds falls from 100 per cent at 34 degrees to near zero at 40 degrees. On the other hand, crop losses due to plant diseases could decline by as much as 30 percent with warmer and drier conditions.

According to Norman Borlaug, the father of the Green revolution:

> "Future food-production increases will have to come from higher yields. And though I have no doubt yields will keep going up, whether they can go up enough to feed the population monster is another matter. Unless progress with agricultural yields remains very strong, the next century will experience sheer human misery that, on a numerical scale, will exceed the

worst of everything that has come before."

If the average global temperatures rise just over 1/2 degree Centigrade the frost-free growing season in the USA's corn-belt would be lengthened by two weeks. But if temperatures increase beyond a specific threshold, fertilization is affected, thus reducing the plants growing season and reducing yield.

Carbon dioxide affects plants in two ways:

1. It is an essential compound in photosynthesis and it increases water use efficiency in plants. A doubling of the pre-industrial carbon-dioxide levels, such as we have seen, should increase crop yields significantly. The fact is, in laboratory tests yields do increase tremendously, but in real life field conditions other atmospheric gases surrounding the plant diminish the carbon dioxide's photosynthesis enhancement and the yield levels reached in the lab are cut drastically by as much as 75 percent. All of the positive effects of carbon dioxide increases may be negated by the stress caused by low rainfall and high temperatures. Increased cloud cover due to higher global temperatures might limit photosynthesis and result in reduced crop production.
2. Higher levels of carbon dioxide help some plants tolerate less water and limited amounts of soil nitrogen but do not compensate for reduced levels of phosphorus or potassium.

If global warming raises the temperature just 2 degrees Celsius, insects' numbers will increase becoming a major nuisance. Some insects will be able to extend their range as a result of the warming. Farmers in the USA, depending on the crop, can expect a 25 to 100 percent increase in crop losses.

The heating and cooling of the Earth coincides with the activity of the sun. The sun determines the Earth's temperature. Since man-made carbon dioxide emissions started in the 1850's, the CO_2 level has only risen 11 percent, which is a very small rise with a nearly negligible effect.

HADLEY CELL, DROUGHT IN THE USA'S SOUTHWEST

Human induced change in the Earth's atmosphere is expected to leave the American Southwest in a perpetual drought for the next 90 years. Conditions in the southwestern states and portions of northern Mexico will be similar to those seen during a severe multiyear drought in the Southwest during the 1950s, as well as the drought that turned the Great Plains into the Dust Bowl in the 1930s.

The southern USA lies in a climatic region called the subtropics, which is dry because the atmosphere moves water out of those regions with the moist air transported to temperate regions at higher latitudes.

As greenhouse gases warm the air, it can hold more moisture, so the atmospheric flow moves more water vapor out of subtropical zones and into the higher latitudes. The dry areas then become drier, and the wet become wetter. This air flow which is known as the Hadley cell, features rising air over the equator and descending air over the subtropics which suppresses precipitation. In a warming world, it expands towards the pole, bringing the USA Southwest more under the influence of the descending air.

Similar changes in the atmosphere produced past droughts and conditions such as the Dust Bowl, but the ultimate cause of historic droughts was natural, unlike this projected drought which is manmade. During those natural droughts, La Niña, and El Niño's cool water counterpart, brought cooler ocean temperatures to the equatorial Pacific, which resulted in drier conditions over North America.

The level of drought is calculated based on the amount of evaporation at the ground subtracted from the amount of precipitation that falls at the surface. The balance between these two processes is what maintains rivers and groundwater flow. As less water is available, water resources become jeopardized. In fact, by 2007, the lifeline of the Colorado River and other rivers were already stressed by 10 years of drought in the USA Southwest. As populations in the Southwest increase, local governments are making adjustments to reduce water usage.

HEAT FLUX FLOWS IN THE ATMOSPHERE

INTRODUCTION

Because of its temperature structure, there is very little convective motion in the stratosphere, and the air there is quite stable. This is particularly true in the tropics where the vertical movement of the radioactive cloud from nuclear explosions in the atmosphere was noticed to be less than 2 miles in three trips around the globe or 70,000 miles. This stable behavior continues up to the mesosphere where marked turbulence is again noticed. The polar stratosphere is less stable than in the tropical zones: during the polar winter night the temperature structure changes so much that the inversion could disappear. When this occurs convection mixing of the air can occur to great heights.

While CO_2 contributes to global warming near the Earth's surface, it causes cooling in the stratosphere. The CO_2 molecules generated at ground level can eventually migrate to the less-dense upper layers of the atmosphere, where they collide with oxygen atoms. During the collision, the colliding atoms lose energy and consequently cool, while the CO_2 is transferred to an internal excited state. The excited CO_2 then radiates, causing a net cooling of the upper atmosphere.

This is the opposite effect to the response of the dense lower atmosphere. The reason for this apparent paradox is that CO_2 and other multi-atom molecules such as methane (CH_4) can emit infrared radiation as well as absorb it. In the lower atmosphere, especially in the troposphere below 15 km, CO_2 absorbs radiation coming from the Earth, which excites it to higher vibrational states. Before it can reemit the radiation, it undergoes collisions with other atmospheric gases, transferring the vibrational energy into heat.

Incidentally, in the stratosphere this cooling contributes to the enhanced formation of polar stratospheric clouds, leading to greater ozone depletion. Models suggest that the doubling of CO_2 in the atmosphere, as is predicted to occur over the next century, will result in significant amounts of cooling in the upper atmosphere and, in turn, more ozone O_3 depletion, playing a role in the formation of ozone holes. Although ozone near the surface of Earth is a pollutant and contributes to global warming, O_3 in the stratosphere screens the Earth from harmful ultraviolet sunlight. Ozone is produced naturally in the stratosphere and is destroyed by a complex series of chemical reactions, some of which are fueled by man-made chemicals.

Considering the tropical region, since the lower atmosphere traps more heat than the upper atmosphere as a result of increased carbon dioxide concentrations, its temperature will increase relatively more than the upper atmosphere, whose temperature will decrease.

The expected temperature change varies with the altitude. It even becomes negative at higher altitudes beyond 10 km. However, a warming occurs in the lower troposphere because, for a doubling of CO_2 concentration, only half the path length is required for the same absorption. The result is a larger temperature drop between the upper and the lower atmospheres. Figure 45 displays his variation of temperature as a function of height depending on the CO_2 concentration in the tropical region.

The larger temperature drop, in addition to higher stored energy in general, is expected to lead to an increased incidence of severe weather events. These include heat waves, droughts, and floods. We attempt an exact analytical solution for the estimation of the magnitudes of the heat fluxes that would result from such temperature changes.

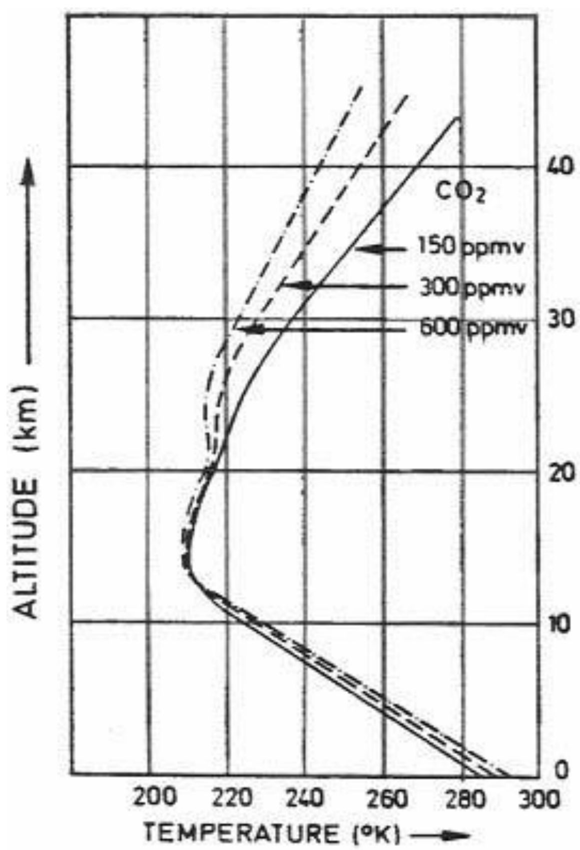


Figure 45. The variation of temperature as a function of height depending on the CO_2 concentration. Source: IAEA Bulletin.

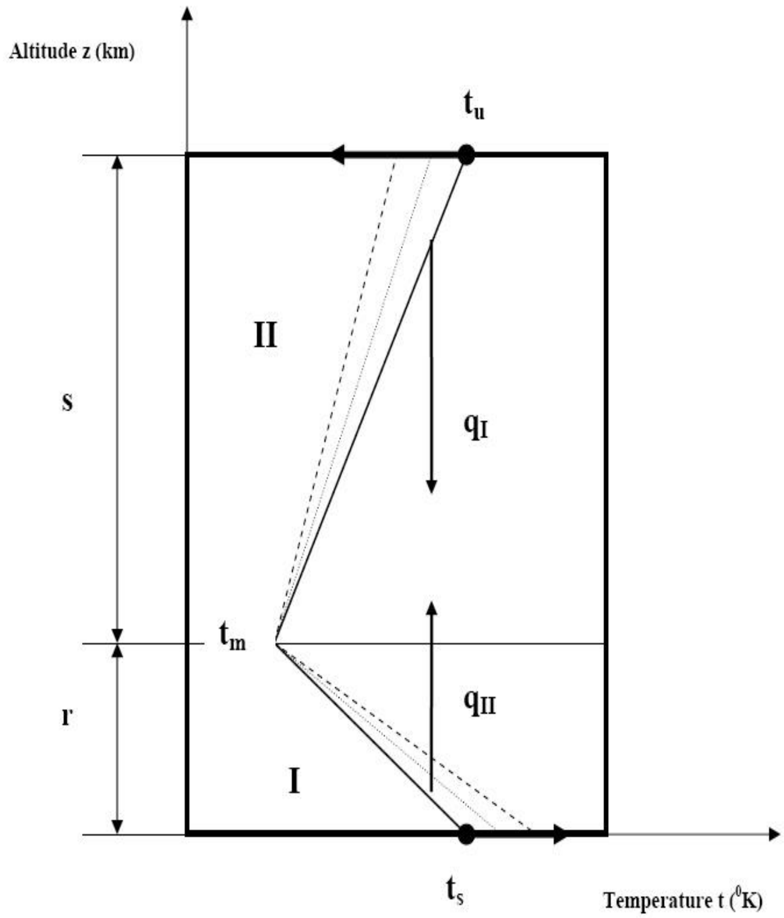


Figure 46. Geometrical model of heat fluxes flows in the atmosphere.

ANALYTICAL MODEL

We consider the geometrical model shown in Fig. 46, where region I represents the lower atmosphere, and region II represents the upper atmosphere. The surface temperature is designated as t_s, the troposphere temperature as t_m, and the upper atmosphere temperature as t_u.

The height of the troposphere is considered as r in the z direction and the total height of the atmosphere is taken as: r + s.

We consider the governing equation for the heat flow as the steady state heat conduction equation:

$$\nabla^2[t(z)] = 0 \quad (7)$$

Substituting for the one dimensional Laplacian operator ∇^2 in cartesian coordinates in the z direction, we can write:

$$\frac{d^2 t(z)}{dz^2} = 0 \tag{8}$$

This equation applies in the lower atmosphere region I, as well as in the upper atmosphere region II, subject to the temperature boundary conditions:

$$\begin{aligned} At: z = r \quad &, \quad t(r) = t_m \\ z = 0 \quad &, \quad t(0) = t_s \\ z = r + s \quad &, \quad t(r+s) = t_u \end{aligned} \tag{9}$$

TEMPERATURE DISTRIBUTIONS

In region I of the lower atmosphere, we can integrate Eqn. 4 to get:

$$\begin{aligned} &\frac{d^2 t_I(z)}{dz^2} = 0 \\ &\frac{d}{dz}\left(\frac{dt_I(z)}{dz}\right) = 0 \\ &\frac{dt_I(z)}{dz} = C_1 \end{aligned} \tag{10}$$

Integrating a second time yields:

$$\begin{aligned} &\int dt_I(z) = \int C_1 dz \\ &t_I(z) = C_1 z + C_2 \end{aligned} \tag{11}$$

To determine the constants of integration C_1 and C_2, we apply the boundary conditions 9:

$$t_I(0) = t_s = C_1.0 + C_2 \Rightarrow C_2 = t_s$$

From which we can rewrite Eqn. 7 as:

$$t_I(z) = C_1 z + t_s \tag{12}$$

Applying the boundary conditions to Eqn. 8 again yields:

$$t_I(r) = t_m = C_1 r + t_s \Rightarrow C_1 = \frac{t_m - t_s}{r}$$

From which the temperature distribution in the lower atmosphere follows the straight line:

$$t_I(z) = \frac{(t_m - t_s)}{r} z + t_s \qquad (13)$$

This describes the situation of the temperature decreasing as a function of height from the surface temperature t_s to the troposphere temperature t_m.

In region II of the upper atmosphere, the same procedure can be followed as:

$$\begin{aligned} &\int dt_{II}(z) = \int C_3 dz \\ &t_{II}(z) = C_3 z + C_4 \end{aligned} \qquad (14)$$

$$t_{II}(r) = t_m = C_3 r + C_4$$

$$t_{II}(r+s) = t_u = C_3(r+s) + C_4$$

Subtracting the two last equations yields:

$$(t_u - t_m) = C_3 s \Rightarrow C_3 = \frac{(t_u - t_m)}{s}$$

From which:

$$\begin{aligned} C_4 &= t_m - C_3 r \\ &= t_m - \frac{(t_u - t_m)}{s} r \end{aligned}$$

Thus the temperature distribution in the upper atmosphere region II becomes:

$$t_{II}(z) = \frac{(t_u - t_m)}{s} z + t_m - (t_u - t_m)\frac{r}{s} \qquad (15)$$

This describes the situation of the temperature increasing in the upper atmosphere as a function of the height z.

HEAT FLUX VECTORS

The temperature gradients in the upper and lower atmospheres will result in heat flux vectors that will depend on the temperature drops according to Fourier's law:

$$\overline{q} = -kA\nabla t(z) \qquad (16)$$

where: k is the atmosphere's thermal conductivity, A is the heat flow cross sectional area.

From Eqn. 1, the heat flux in region I of the lower atmosphere becomes:

$$\begin{aligned} q_I &= -kA\frac{dt(z)}{dz} \\ &= -kA\frac{(t_m - t_s)}{r} \\ &= +kA\frac{(t_s - t_m)}{r}, \text{ since } t_s > t_m \end{aligned} \tag{17}$$

This implies a constant heat flux at any height z flowing upwards in the positive z direction.

In region II of the upper atmosphere, the heat flux from Eqn. 15 becomes:

$$\begin{aligned} q_{II} &= -kA\frac{dt(z)}{dz} \\ &= -kA\frac{(t_u - t_m)}{r}, \text{ since } t_u > t_m \end{aligned} \tag{18}$$

This implies a constant heat flux flowing downwards in the negative z direction.

Since the heat flux is a vectorial quantity, the heat fluxes must be summed vectorially. The net heat flux becomes a constant at any given height as:

$$\begin{aligned} q_{net} &= q_I - q_{II} \\ &= +kA\frac{(t_s - t_m)}{r} - kA\frac{(t_u - t_m)}{s} \\ &= +kA\left[\frac{(t_s - t_m)}{r} - \frac{(t_u - t_m)}{s}\right] \end{aligned} \tag{19}$$

NUMERICAL VALUES

For numerical estimates, we adopt the following values for the parameters:

$$\begin{aligned} r &= 13 \ km \\ s &= 40 - 13 = 27 \ km \\ t_m &= 210 \ K \end{aligned}$$

In addition we adopt the values of t_s and t_u from Fig. 46 as shown. The calculational results are shown in Table 1.

It can be observed that as the CO_2 concentration doubles then quadruples, the temperature at the surface of the Earth increases, but the temperature in the upper atmosphere decreases (Fig. 46). This creates a higher temperature drop resulting in higher net heat fluxes to the troposphere (Fig. 47). The percent relative increase in the net heat fluxes can be defined as:

$$PRI = \left| \frac{q_{net} - q_{ref}}{q_{ref}} \right| x100 \qquad (20)$$

where q_{ref} is the reference heat flux.

As Table 1 shows, for a doubling of the CO_2 concentration by volume, the net heat flux to the troposphere is estimated to increase by 22.4 percent and for a quadrupling of the concentration, the net heat flux increases by 39.1 percent, implying increased energy input to the region of the atmosphere where weather phenomena are initiated.

Table 1. Effect of carbon dioxide concentration on temperature gradients and atmospheric heat fluxes.

Carbon dioxide concentration (ppmv)	Surface temperature (t_s)	Upper level temperature (t_u)	Temperature gradient, lower atmosphere (K/km)	Temperature gradient, upper atmosphere (K/km)	Net heat flux (x kA)	Relative increase (percent)
150	282	269	5.54	2.19	3.35	-
300	284	253	5.69	1.59	4.10	22.4
600	286	242	5.85	1.19	4.66	39.1

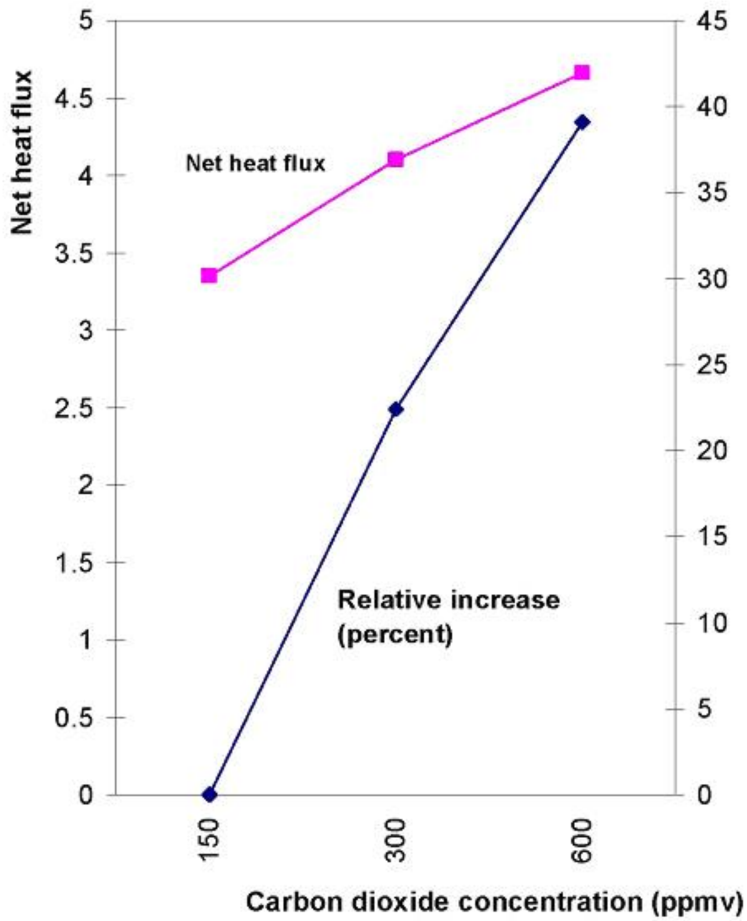


Figure 48. Temperature effect of carbon dioxide concentration.

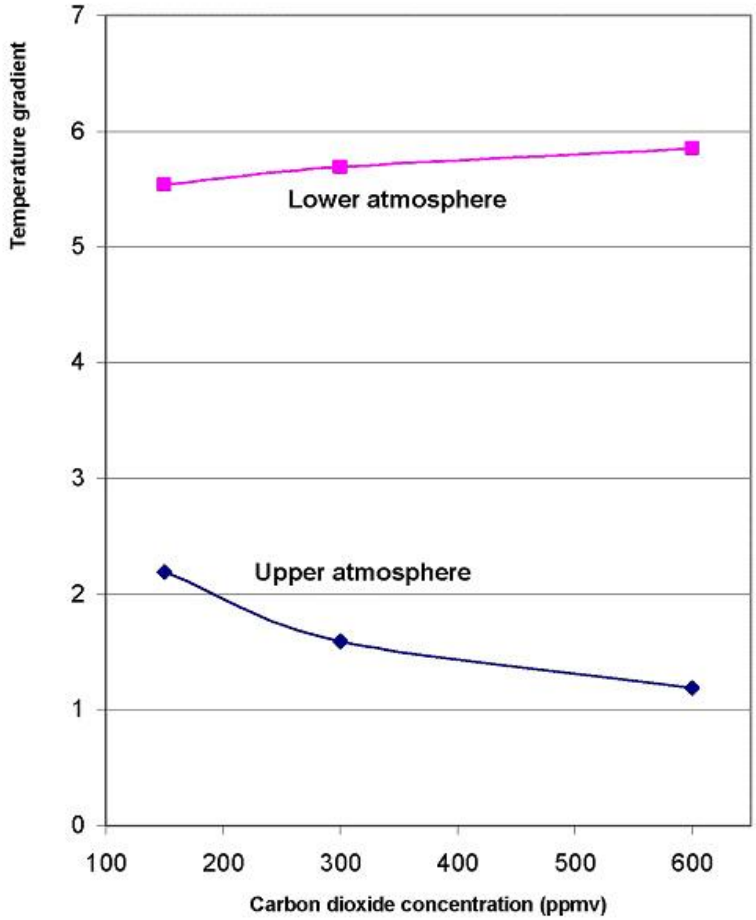


Figure 49. Temperature gradients as a function of carbon dioxide concentration.

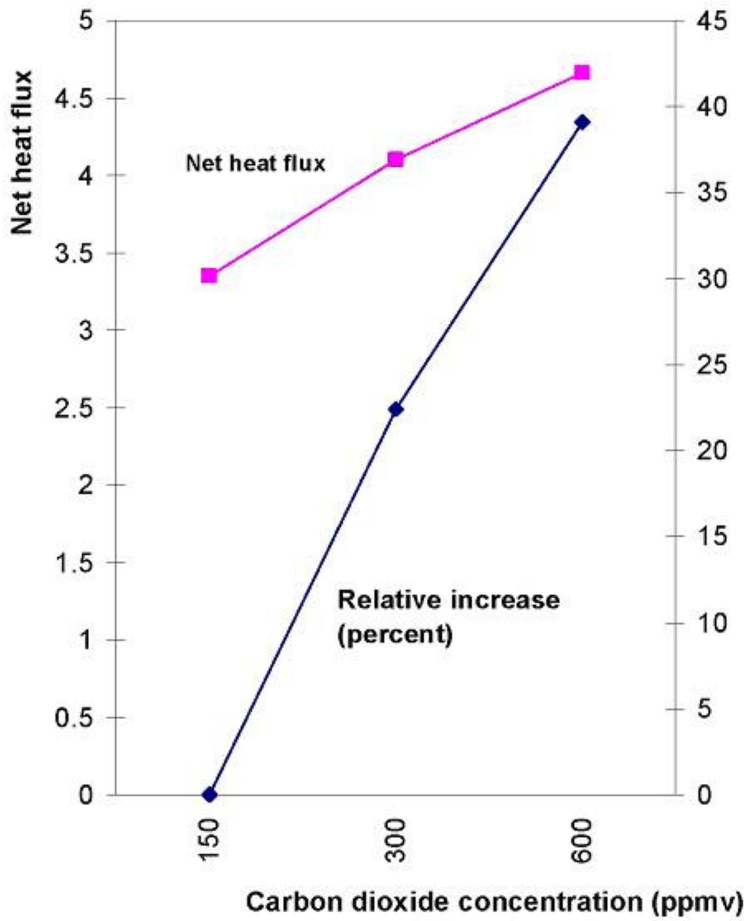


Figure 50. Net heat flux as a function of carbon dioxide concentration.

INCREASED SURFACE TEMPERATURE AND HURRICANE FREQUENCY AND INTENSITY

A statistical analysis by Greg Holland of the National Center for Atmospheric Research, (NCAR), and Peter Webster of Georgia Institute of Technology was published in July 2007 by the Royal Society of London reported that twice as many Atlantic hurricanes formed each year from 1995 to 2005, on average, than formed during parallel years a century ago.

The researchers concluded that warmer sea surface temperatures and altered wind patterns associated with global climate change are responsible for the increase. The increases over the last century correlate closely with sea surface temperatures, which have risen by about 1.3 degrees Fahrenheit in the last 100 years. The changes in sea surface temperatures took place in the years before to the sharp increases in storm frequency; with a sea surface temperature rise of 0.7 degrees Fahrenheit leading up to 1930 and a similar rise leading up to 1995 and continuing ever after.

The analysis identified three periods since 1900, separated by sharp transitions, during which the average number of hurricanes and tropical storms increased and then remained elevated and relatively steady:

1. The first period, between 1900 and 1930, saw an average of six Atlantic tropical cyclones each year, of which four were hurricanes and two were tropical storms.
2. From 1930 to 1940, the annual average increased to 10, consisting of five hurricanes and five tropical storms.
3. In the third period, from 1995 to 2005, the average reached 15, of which eight were hurricanes and seven were tropical storms. This last period has not yet stabilized, which means that the average hurricane season may be even more active in the future.

For comparison, for the 2007 Atlantic hurricane season, the NOAA scientists predicted 13 to 17 named storms, with seven to 10 becoming hurricanes, of which three to five could become major hurricanes of Category 3 strength or higher. An average Atlantic hurricane season brings 11 named storms, with six becoming hurricanes, including two major hurricanes.

According to the 2007 assessment report of the Intergovernmental Panel on Climate Change (IPCC), on a global scale, there has been an increase in hurricanes and tropical storms intensity and it is "more likely than not" that there is a human contribution to the observed trend of hurricane intensification since the 1970s.

Future hurricanes will be even more intense, the IPCC predicted, suggesting: "It is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation" associated with ongoing increases of tropical sea surface temperatures.

Figure 51. Hurricane Mitch resulted in 11,000 deaths and 8,000 persons missing in South America, October 26, 1998. NOAA photograph.

Figure 52. Damage to housing at Pensacola Beach, Florida from hurricane Dennis, July 16, 2005. FEMA photograph.

PARADOXICAL HIGHER ANTARCTIC WINDS AND INCREASED ICE COVER

Attention is paid to melting sea ice in the Arctic. But less clear is the situation on the other side of the planet. Despite warmer air and oceans, there is more sea ice in Antarctica than in the 1970s; a fact often pounced on by global warming skeptics. Changes in winds have apparently led to the more general upward sea ice trend during the past few decades, according to University of Washington (UW) research. A new modeling study to be published in the Journal of Climate shows that stronger polar winds lead to an increase in Antarctic sea ice, even in a warming climate.

“The overwhelming evidence is that the Southern Ocean is warming,” said author Jinlun Zhang, an oceanographer at the UW Applied Physics Laboratory. “Why would sea ice be increasing? Although the rate of increase is small, it is a puzzle to scientists.” His study shows that stronger westerly winds swirling around the South Pole can explain 80 percent of the increase in Antarctic sea ice volume in the past three decades.

The polar vortex that swirls around the South Pole is not just stronger than it was when satellite records began in the 1970s, it has more convergence, meaning it shoves the sea ice together to cause ridging. Stronger winds also drive ice faster, which leads to still more deformation and ridging. This creates thicker, longer-lasting ice, while exposing surrounding water and thin ice to the blistering cold winds that cause more ice growth.

In a computer simulation that includes detailed interactions between wind and sea, thick ice — more than 6 feet deep — increased by about 1 percent per year from 1979 to 2010, while the amount of thin ice stayed fairly constant. The end result is a thicker, slightly larger ice pack that lasts longer into the summer.

When the model held the polar winds at a constant level, the sea ice increased only 20 percent as much. A previous study by Zhang showed that changes in water density could explain the remaining increase.

Differences between the two poles could explain why they are not behaving in the same way. Surface air warming in the Arctic appears to be greater and more uniform, Zhang said. Another difference is that northern water is in a fairly protected basin, while the Antarctic sea ice floats in open oceans where it expands freely in winter and melts almost completely in summer. The sea ice uptick in Antarctica is small compared with the amount being lost in the Arctic, meaning there is an overall decrease in sea ice worldwide. Eventually, Zhang anticipates that if warmer temperatures come to dominate they will resolve the apparent contradiction. “If the warming continues, at some point the trend will reverse,” Zhang said.

SUDDEN CLIMATIC SHIFTS: GLOBAL SEVERE WEATHER EVENTS

Any sudden change in climate could cause irreversible consequences. Some theoretical work suggests that the Earth climate acts like a rubber band getting stretched, storing energy in potential form, then, once a certain threshold is reached, this potential energy is suddenly released in the form of kinetic energy. For years, the stresses slowly build up as the chemistry and thermodynamics of the air change, and then, once the threshold is reached, in a period of months or years, a vast shift can occur.

Another analogy is advanced comparing the Earth’ climate to a light switch being thrown, a little pressure may not cause things to change in a hurry, but when the pressure reaches a threshold value, the switch flips suddenly.

Evidence in the fossil record suggests that the Earth has a regulatory mechanism where heat builds up to a certain point, and then a massive release of energy would occur in the form of super storms, as the Earth’s climate seeks to reorganize itself. The paradoxical effect is that global warming could eventually lead to a new ice age. Over the last three million years the Earth’s climate warmed up, until suddenly the glaciers reappeared and covered ¼ of the planet for hundreds of thousands of years. One effect of global warming is increased precipitation in the lower latitudes. This in turn could change the warm ocean currents flowing north, precipitating drastic cooling in the higher latitudes.

A 1998 study of ice cores from Greenland suggested a rapid increase in temperature around 10,000 BC. In the Antarctic, temperatures rose 20 degrees F over a short period of time. This increase in temperature occurred during a period when the Arctic's temperature had risen an even higher 59 degrees F.

It is also suggested that about 22,000 years ago, at the peak of the last ice age, an underwater slide in the Mediterranean caused ½ billion tons of methane gas, that was trapped in the undersea sediment, to be released. This event would have doubled the amount of methane in the atmosphere. Temperatures warmed abruptly, melting the permafrost. This resulted in the release of even more methane. The result was that a period of 120,000 years of cold was broken. At the end of the Pleiocene, 8,000 years ago, methane levels in the atmosphere came down suddenly by 20 percent. Cooling of the atmosphere followed. Thus we know from ice core studies that abrupt climate change is a reality of life on Earth.

About 8,000 years ago, Egypt and the Middle East were temperate zones, with a much larger rainfall than at present. Glaciers stretched as far as northern Canada. African animals such as lions roamed the Mediterranean area. At that time, a drastic decrease in the methane content of the atmosphere of twenty percent occurred. Temperatures plummeted for a short period, but long enough for the world to be devastated. A suggestion is that a severe weather event had occurred. The last of the mammoths and mastodons died during this period with a large extinction of large animals that had followed their range north during the warming.

A possible scenario for a sudden climatic shift has been suggested to follow the following steps:

1. Greenhouse warming could reach such an extent that the Arctic begins to melt.
2. The Arctic Ocean gets flooded with enough freshwater from that melt and from increased precipitation so that its temperature and level of salinity are modified.
3. Since Fick's law of diffusion suggests that water will flow from regions of higher salinity to regions of lower salinity, equalizing the temperature and salinity differential between polar and tropical waters could weaken the warm ocean currents flowing north.
4. The warm ocean currents would stop to flow and mix with Arctic waters, leading to the Arctic water’s temperature to drop. Possibly, the North Atlantic current would, temporarily at least, reverse its flow to the south.
5. This would cause the tropical air flowing to the north to be reduced, and will result in cold air held in the high Arctic to plunge southward.
6. This cold air plunging south would collide with the hot air trapped south.
7. Global warming causes the air in lower parts of the atmosphere to heat up, while the air in the stratosphere to cool down. The cold air in the stratosphere could plunge down, intensifying the violence of the ensuing storms.
8. Storms can intensify into severe weather events lasting 4 to 6 weeks. These storms would be self perpetuating, in the sense that they develop such a large circulation in the atmosphere that they are directly fed by arctic cold and tropical heat.
9. The Northern Hemisphere would become half covered with billions of tons of snow most of it packed into ice and hard frozen.
10. The snow cover could increase the Earth’s albedo or reflectivity to solar radiation, causing a dramatic drop in temperature.
11. Depending on the depth of the snow cover and on the season where this happens, the ice would become the basis for a long period of glaciations, or it would melt resulting in large floods caused by the runoff.
12. Ocean currents in the Southern Hemisphere will also be altered, engulfing Australia and New Zealand. Summer conditions would resemble winter, and winter would be harsh. Heavy seas and Typhoons would blow in the southern seas affecting the Philippines, Japan, and the Pacific Islands.
13. Food production zones like the American Midwest would be under a sheet of ice, extending across Siberia and Northern Europe.
14. Massive population movements from northern Asia, Europe and America would be moving south, with mass disruptions.

About 18,000 years ago, the last ice age was at its maximum, with glaciers stretching across Central North America. Winter temperatures in Texas were like those in Canada nowadays. Sea levels were lower than now with ocean shores several miles ahead of present shores. Animal species like the mastodon and mammoth, the cave bear, dire wolf, giant beaver populated the Earth. For 8 thousand years the ice retreated, with apparent warming. Warming was caused by the increase of methane, a potent greenhouse gas, in the atmosphere, possibly caused by volcanic activity in the Pacific ring of fire or the North American west. This was followed, 8,200 years ago by a sharp cooling lasting 200 years, apparently caused by a rush of fresh water into the Arctic Ocean, and possibly a reversal of the flow of the North Atlantic current. Large animals disappeared, 8 genera of mammals became extinct in North America, and 27 genera worldwide.

The Adams Mammoth discovered in 1789, was well fed, and the Berezoka Mammoth from Northern Siberia discovered in 1901 and displayed at the Zoological Museum in Saint Petersburg, Russia, had fragments of flowers in its stomach. Remains of mammoths are found in this period around the Arctic Circle with food in their mouths and stomachs, indicating:

1. They were grazing in a temperate climate when they died, and
2. Their death was sudden.

Trees have been found that were frozen solid while in blossom, suggesting a major event occurring on a spring or summer day, which suddenly turned much colder. A whole set of flora and fauna died with them including fruit trees and plants associated with warmer climates. The surrounding area went into a frozen state that remains until today as permafrost. It is thought that a sudden cooling to around –150 degrees F, from a starting temperature of +80 degrees F occurred. About 116 specific concentrations of animals dying under these circumstances were found.

A possible explanation of what has happened is that the climate went into a state of greenhouse warming caused by methane gas, and that these animals died suddenly in some violent weather when a snap back to the cooling trend occurred. This severe weather event would have occurred in the spring or summer, so that it did not initiate an extended icy period, but may have possibly caused massive flooding.

Methane is generated in the atmosphere from human activity, volcanoes, decomposing vegetation in marshes, permafrost, and rice fields, animal digestion and chemical reactions at the bottom of lakes and seas. Methane dissipates if its source is removed. It is hard to explain why the previously mentioned increase in methane levels remained high, since there is no definite evidence of volcanic activity that would have sustained it. Its decrease is also hard to explain. A possible explanation is that the precipitation in the severe weather event itself may have caused it to drop. Some volcanic or solar phenomena or comet or asteroid encounters with the Earth may have contributed to it. This is left to scientific investigations, but the decrease and increase of methane levels remain as empirical observations.

The evidence in the fossil record from 8,000 years ago suggests that global warming reached an extreme similar to what is occurring now. There was a sudden flood of fresh water into the oceans, like today where the Arctic is losing an average 26,000 square miles of ice a year. It is possible that we are reaching a moment of crisis in global warming that we could precipitate and accelerate, through human tampering with the green-house gases, with CO_2 rather than methane.

DEMISE OF THE MAMMOTHS

Previous theories about the extinction of the woolly mammoths blamed one cause or another: hunting, climatic change, disease or a meteor impact. The latest view is that it was a combination of causes. Using radiocarbon dating, researchers traced the changing locations of peat lands, forests, plant species, mammoth populations and human settlements, and cross-referenced this information with climatic change data.

Humans hunted the mammoths in Siberia for millennia. At the last ice age, humans crossed the Bering Strait and began hunting them in Alaska and the Yukon. Following a harsh, 1,500-year cold period called the Younger Dryas about 13,000 years ago, the climate began to get warmer. This led to a decline in the woolly mammoths' favored foods, such as grasses and willows. It encouraged the growth of low-nutrient conifers and potentially toxic birch species. Marshy peat lands took shape, forcing the mam moths to struggle through tough and nutritionally poor terrain. Forests be came widespread, squeezing the mam moths out of their former territory.

Human hunt-ing expanded at the same time that the habitat became less amenable. Most of the woolly mammoths disappeared about 10,000 years ago, with small populations living on islands lingering until about 4,000 years ago.

LOCAL CLIMATIC CHANGE

With global warming global models assuming a doubling of the current level of CO_2 concentration, the continental USA would experience extreme temperatures for the next century throughout the country and more extreme precipitation along the Gulf Coast, the Pacific North West and East of the Mississippi River.

An Iowa State University (ISU) research team has looked at Iowa climate data from 1975 to 2000 and observed some trends:

1. Annual precipitation has increased by about an inch over the past 30 years. More of that precipitation is happening in extreme weather events. There are more 3-inch rain events than there were 30 years ago.
2. Winter low temperatures are not as cold as earlier. There are about eight more frost-free days than there were in the 1950s, making for a longer growing season.
3. Summer heat is not as intense as it was 30 years ago, but the humidity is rising.

If those trends continue, climate change in the American Midwest could be favorable for agriculture over the next 10 to 20 years.

In the northeastern USA east of Illinois and north of Kentucky, summers would be longer and hotter.

The desert Southwest would experience more heat waves of greater intensity combined with less summer precipitation.

The Gulf Coast would be hotter and receive more precipitation in greater volumes in shorter periods of time. It would experience more dry spells punctuated by heavier rainfall, maybe associated with tropical cyclone activity.

The continental USA would experience an overall warming trend. Temperatures now experienced during the coldest two weeks of the year will pass into memory. The winter's season duration will be shortened.

One can gain some insight by looking at past events to try to anticipate future ones. The warmest summers ever recorded in Illinois were in the years 1934 and 1936. The temperature then was 5 to 6 degrees Fahrenheit higher than average normal temperatures at present. This is the magnitude of change predicted for the next century, if global warming continues.

Illinois experiences nowadays 1 day per year on average of a temperature 100 degrees or higher. In the 1930s, heat waves occurred with temperatures above 100 degrees lasting 10 to 15 days at a time. The city of Chicago, in Illinois, experiences an average of 191 heat related deaths each summer. It has been suggested that this number would triple in the next 50 years.

Considering droughts in the Northern American Midwest, severe to extreme events occur during the summer months once 10 years. In the 1930s, the incidence of severe droughts was once every 2 years.

SHIFT IN AGRICULTURAL PRODUCTION

Donald Wuebbles from the Department of Atmospheric Sciences at the University of Illinois and George Kling from the Department of Ecology and Biology at the University of Michigan coauthored a report with experts from the Union of Concerned Scientists issued in April 2006: "Confronting Climate Change in the Great Lakes Region." The report predicted that global warming is likely to intensify floods and extreme weather in the USA's great Lakes region.

An increase in the frequency of storms and floods during the planting season could hurt crop yields. A longer and warmer growing season may lead to more pests and crop losses in Illinois, Indiana, Michigan, Minnesota, Ohio and Wisconsin.

Extreme heat events are observed to be occurring more frequently, as are heavy precipitation events. The combination of high heat and flooding is considered especially lethal to the corn and soybean crops grown in these states, with soybeans being the most vulnerable to climate variability.

Michelle Wander from the University of Illinois observed that the greatest damage to these crops could result in mid-summer when peak accumulated ozone concentration level coincide with peak crop productivity.

Perennial crops such as fruit trees are even more vulnerable than row crops to storms and floods because adjustments cannot be made to them easily, placing long term investments at risk.

EFFECT ON RICE AS A GLOBAL FOOD STAPLE

Rising temperatures within a 25 years period cut the rice yield growth rate by 10-20 percent in several parts of Asia. Such a decline means that more people would suffer from hunger and poverty.

Around 3 billion people eat rice everyday and 60 percent of the world's 1 billion poorest and undernourished people who live in Asia depend on rice as their food staple.

Higher daylight temperatures can increase rice yields, but higher nighttime temperatures have a negative effect on yields, according to research at the Philippines International Rice Research Institute. The nighttime temperatures are rising faster than the daytime temperatures and are expected to cause a net loss in productivity. The studies covered 6 years of real-world data from 227 irrigated rice farms, supporting earlier results from laboratory controlled experiments.

The rice production methods need to adapt to the new conditions and new strains of rice need to be developed to cope with the new temperatures.

The suggestion is that the average rise in temperature needs to be contained below 3.6 degrees Fahrenheit above the levels that predominated before the start on industrialization in the 18th century.

MASS EXTINCTIONS

Global warming and not a giant asteroid may have nearly wiped out life on Earth some 250 million years ago. The mass extinction, known as the “Great Dying,” extinguished 90 percent of sea life and nearly 3/4 of land-based plants and animals.

Most experts agree there is a great deal of evidence to show an asteroid wiped out the dinosaurs 65 million years ago, forming what is now the Chicxulub crater off Mexico's Yucatan Peninsula.

There has been recent evidence that another big asteroid or meteor hit the Earth 250 million years ago and triggered the catastrophe, but researchers say they now have evidence that something much more long-term, global warming, was the culprit.

Kliti Grice of Curtin University of Technology in Perth, Australia, and colleagues studied sediment cores drilled off the coasts of Australia and China and found evidence the ocean was lacking oxygen and full of sulfur loving bacteria at that time.

This finding would be consistent with an atmosphere low in oxygen and poisoned by hot, sulfurous, volcanic emissions.

A second team led by Peter Ward at the University of Washington looked at fossil evidence in South Africa and found little evidence of a catastrophe and instead signs of a gradual die off. They examined 126 reptile and amphibian skulls from the Karoo Basin in South Africa, where there is an exposed piece of dried sediment from the end of the Permian Era and the beginning of the Triassic, 250 million years ago. They found two patterns, one showing gradual extinction over about 10 million years leading up to the time of the extinction, and then a spike in extinction rates that lasted another 5 million years. Animals and plants both on land and in the sea were dying at the same time, and apparently from the same causes: too much heat and too little oxygen.

Volcanic eruptions may have pumped greenhouse gases into the air, which would have trapped heat in the atmosphere and raised temperatures. Temperatures rose to a critical point. It got hotter and hotter until it reached a critical point and everything died. It was a double-whammy of warmer temperatures and low oxygen, and most life could not deal with it.

Researchers said they found evidence of a giant asteroid striking Earth off the coast of what is now Australia 251 million years ago. But others have disputed their conclusions.

SEASONAL CHANGES

In one of the most comprehensive studies that plants in the Northeast are responding to the global warming trend, Cornell scientists and their colleagues at the University of Wisconsin found lilacs are blooming about four days earlier than they did in 1965.

David Wolfe, a plant ecology professor at Cornell University suggested that nature's calendar is changing due to an increase in greenhouse gases. It is not just the weather data telling us there is a warming trend going on; we are now seeing the living world responding to the climate change as well.

The Cornell University study is consistent with other examinations involving the biological impact of rising temperatures, but those studies have been much more limited in geographic scope.

Harvard University scientists also reported finding evidence of earlier flowering in specimens at the Arnold Arboretum in Boston, while botanists at the Smithsonian Institution in Washington, D.C. found the city's Japanese cherry trees are blooming about a week earlier than they were 30 years earlier.

According to the Northeast Regional Climate Center at Cornell, the average annual temperature in the Northeast has increased by 1.8 degrees Fahrenheit since 1900, which is slightly higher than the global average of 1.1 degrees Fahrenheit.

The greatest rate of warming, though, has occurred during the winter months from December to February, with an average increase of almost 3 degrees Fahrenheit over the past 100 years. This rate has accelerated over the past 30 years to 4.4 degrees Fahrenheit.

Cornell researchers analyzed data from 72 locations throughout the Northeast where genetically identical lilacs were planted during the 1960s and 1970s as part of a joint USA Department of Agriculture-funded project involving Cornell and the University of Vermont. The lilacs were planted to help farmers predict planting and harvest dates, but have now provided scientists with a historical record of bloom dates.

The Cornell study also included apples and grapes at four sites in New York, which Wolfe said were blooming six to eight days earlier than in 1965.

The warming trend has many implications. It could favor some invasive species and alter important interactions between plants and pollinators, insect pests, diseases and weeds. If the interdependence and synchrony between animals and plants are disrupted, the very survival of some species could be threatened.

Climate change also could affect plant and bird migration patterns, animals' hibernation patterns, reproductive cycles, woodland composition, plant pathogens and the availability of plant food for insects and animals.

On the positive side, the warming trend is extending the growing season in the Northeast by several days, although hotter summers can negatively affect some crops, such as apples and grapes.

PLANETARY ENGINEERING, RESTORING THE CIRCUMGLOBAL EQUATORIAL CURRENT

INTRODUCTION

Before the last 3 million years, the Earth’s climate enjoyed a steady state situation with the ocean currents rotating around the globe. In the past, whenever there has been a return to ice conditions, this was preceded by a rise in greenhouse gases, followed by a sudden drop. For the past 3 million years, the CO_2 levels in the atmosphere have been low. However, tectonic Earth movements caused the Central American Land Bridge to develop, blocking the flow of ocean currents that had stabilized the Earth’s climate for millions of years. This land bridge forced the ocean currents into a north-south flow. It may have caused a die-off of forests, and a CO_2 level decrease. The diverted oceans currents lead to a more variable climate, with dramatic differences between the seasons.

The temperate forests reaching into the Arctic were replaced by a taiga or sub arctic forests characterized by pine trees. Winters became longer and the north and south ice caps formed. The recurrent periods of glaciation and thawing in the last three million years, and the rising of the Central American land bridge may have forced the Earth's climate into a long cycle involving long ice ages followed by short warm periods. Every glaciation period has been accompanied with large species extinctions.

JURASSIC AND LATE JURASSIC CLIMATE

During the Jurassic period, the latitudinal extension of the continents from pole to pole blocked circumglobal oceanic circulation at high southern latitudes. The ancient Tethys ocean was a large triangular re-entrant of the global ocean Penthalassa into the eastern continents from the east.

There exists evidence of distinct temperature-linked gradients during the Jurassic period. Floral evidence suggests the existence of a tropical belt with cycad-like plants and ferns which can be distinguished from temperate belts with conifers and gingkoes.

The primarily latitudinal circulation pattern that deflected into higher latitudes around the polar extremities of Pangaea, appears to have contributed to the equitable climate of the Jurassic.

A significant circulation event occurred during the late Jurassic about 140 million years ago: the opening or extension of a seaway through Central America, linking the Atlantic and Pacific Oceans for the first time in the equatorial region through the straits of Panama. Coupled with the gradual opening of the North Atlantic by seafloor spreading, this allowed the development of a circum-global equatorial current system, which has continued, essentially unabated, until relatively recent time about 3 million years ago (Ma). This expanded the tropics to the northern latitudes.

The Pliocene was a time 5.3-1.8 mya of global cooling after the warmer Miocene. The cooling and drying of the global environment may have contributed to the enormous spread of grasslands and savannas during this time. The change in vegetation was a major factor in the rise of long-legged grazers who came to live in these areas.

The Panamanian land-bridge between North and South America appeared during the Pliocene, allowing migrations of plants and animals into new habitats. Of even greater impact was the accumulation of ice at the poles, which would lead to the extinction of most species living there, as well as the advance of glaciers and ice ages of the Late Pliocene and the following Pleistocene.

Three million years ago during the Pliocene period, the elevation of the isthmus of Panama eliminated the straits of Panama. The result was an interruption of the Pacific and Atlantic faunal exchange followed by a latitudinal displacement of the Floral and faunal provinces. Increased seasonality ensued with initiation of the northern hemisphere continental glaciations and the Labrador current.

RESTORING THE CIRCUMGLOBAL EQUATORIAL CURRENT SYSTEM

It is thought that the ice ages were initially spawned by massive volcanic eruptions in Central America that created a land bridge at the Isthmus of Panama. The separation of the Atlantic and Pacific Oceans altered the global ocean currents, and resulted in rapid cooling of the Earth. The Quaternary period coincide with the appearance of the first hominid ancestors.

A scientific engineering project worth investigation that would lead to a more stable climate for the Earth, would be to restore the previous stable condition in the Earth's climate where the ancient equatorial ocean currents circulated freely across the Central American Land Bridge.

A shallow sea level canal can be deepened over time allowing larger water flow. As an example, the Suez Canal was inaugurated on November 17, 1869, connecting the Mediterranean and the Red seas. Initially, it was only 25 feet deep, but with improvements and deepening, about 50 ships cross it daily carrying 300 million tons of freight per year.

THE PANAMA CANAL

The Isthmus of Panama is a land bridge arched between the North and South American continents. With 12 distinct ecosystems between mountains, rainforests, cloud forests and beaches, it is home to orchids, jaguars and an astounding biodiversity.

In the 16th century, Spanish mariners dreamed of a shortcut waterway through the Isthmus of Panama. Balboa conceived the notion in 1513, but the daunting idea was forgotten. Ferdinand de Lesseps, 367 years later tried to build a sea level canal like the Suez Canal between the Mediterranean and the Red Sea. Disease, scandal, rain, corruption and the jungle claimed the lives of 16,000-20,000 workers, and the effort was discontinued.

By 1900, the USA had the engineering resources to take on the challenge. President Theodore Roosevelt committed himself to the project, signed a treaty with Panama, and the project started with 35,000 persons work force.

Construction started in 1904 creating one of the world's largest artificial lakes: Lake Gatun, as well as an 8 miles winding channel called the Gaillard Cut. Six massive locks were built to raise or lower the giant sea going vessels to a height of 85 feet. More than 52 million gallons of fresh water are used for each ship which transits the Panama Canal.

Completed in 1914, the Panama Canal cost over $336 million and 5,600 lives lost to tropical diseases such as yellow fever, temperatures reaching 130 ^{0}F, and accidents. It has saved every ship passing through it a 7,872 miles trip around South America. Now, each ship takes a 51 miles journey through an intricate system of gates, locks, and drains, including dredged approach channels at each end. A single trip through the canal requires 52 million gallons of water, and busy days can see up to 40 trips. For the water it needs, the canal depends on one of the world's biggest artificial lakes: Gatún Lake. For its water supply, Gatún Lake depends on the health of the surrounding rain forest.

The canal consists of artificially created lakes, channels, and a series of locks, or water filled chambers, that raise and lower ships through the mountainous terrain of central Panama. Built by the USA from 1904 to 1914, the Panama Canal posed major engineering challenges, such as damming a major river and digging a channel through a mountain ridge. It was the largest and most complex project of this kind ever undertaken at that time, employing tens of thousands of workers and costing $350 million.

Figure 53. Panama Canal locks.

Figure 54. Panama Canal map.

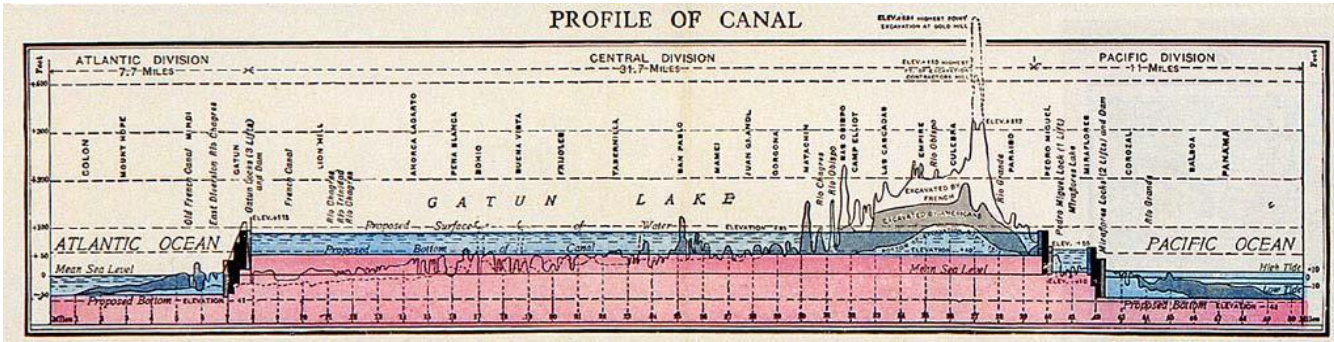


Figure 55. Elevation cut of the Panama Canal, showing the mountainous areas excavated by the French and the Americans.

The Panama Canal system is composed of three major locks, one on the Atlantic side: the Gatun locks, and two on the Pacific side: the Pedro Miguel and Miraflores locks. The Gailard cut represents the line of continental divide. To supply this system of locks a large amount of water is required, a goal fulfilled by the artificially created Gatun Lake. Running parallel to the canal is the Panama Canal Railway designed to absorb the extra shipping traffic generated by ships too large to use the facilities.

The canal cuts through the central and most populated region of Panama, and it has been a point of dispute between the governments of Panama and the USA through most of its existence. Under a 1903 treaty, the USA controlled both the waterway and a large section of the surrounding land, known as the Panama Canal Zone, considered as a USA territory.

The Panamanians resented this arrangement and argued that their country was unfairly denied benefits from the canal. Eventually, riots and international pressure led the USA to negotiate two new treaties, which were signed in 1977 and took effect in 1979. The treaties recognized Panama's ultimate ownership of the canal and all the surrounding lands. More than half of the former Canal Zone came under Panamanian control shortly after the treaties were ratified. Control of the canal was turned over to Panama on December 31, 1999. In December of 1989, the USA invaded Panama, ostensibly in order to capture Noriega, who languished in a Florida prison serving a 40 year sentence for alleged drug trafficking. .

Article XII of the Panama Canal Treaty provides for a joint study of "the feasibility of a sea-level canal in the Republic of Panama." In 1981 Panama formally suggested beginning such a study. After some discussion, a Preparative Committee on the Panama Canal Alternatives Study was established in 1982, and Japan was invited to join the USA and Panama on this committee. The committee's final report called for the creation of a formal Commission for the Study of Alternatives to the Panama Canal, which was set up in 1986. Although there was a general perception that the costs of such a canal would outweigh benefits, the commission is still studying the problem with no further action.

The French Ferdinand de Lesseps attempted digging a canal at sea level around 1884, in the same way as the Suez Canal between the Mediterranean and the Red Sea. Even though he succeeded with the Suez Canal Company, he ended his life bankrupt and confined in jail for fraud following the failure of his Panama Canal Company. The present Panama Canal was started in 1904 and finished in 1914 using the labor of a ½ million men.

Table 2. Characteristics of the Panama Canal.

Dimension	feet
Length of each lock chamber	1,000
Width of lock chamber	110
Depth of lock chamber	70
Minimum depth of water in each lock	40
Width of each lock gate leaf	60
Height of lock gates	47-82
Thickness of lock gate leaf	7
Diameter of main culvert for filling locks	18
Weight	tons
Towing locomotive	55
Lock gate leaves	390-730
Distance	miles
Length of canal, deep water to deep water	50
Shoreline, Gatun Lake	1,100
Distance saved by ships, San Francisco to New York	7,873

After debating on the most appropriate place for the canal, the USA Congress authorized President Theodore Roosevelt to purchase the French assets and take over the Panama project. Panama, where the isthmus was located, was part of Colombia. Negotiators from both countries agreed upon terms, but Colombia rejected the treaty, holding out for more money. Angered, President Roosevelt stopped negotiations and found another way to get the isthmus. He supported the Panamanian rebels in their fight for independence from Colombia. An American fleet was dispatched to both sides of the isthmus, blocking its sea approaches. Colombian forces were forced into a land approach through the dense Darien jungle, and were forced to turn back. Panama achieved its independence. The USA acquired the lease to build the Panama Canal on very favorable terms with the newly independent country. The new country could not survive without USA support.

The Panama Canal is a major maritime route slashing 8,000 miles off the shipping distance between the east and west coasts of the American continent. The Panama Canal does not slice through the mountainous backbone of Panama. It is constructed as a series of locks interconnecting artificial lakes constructed by damming rivers in the mountains, and feeding the canal through gravity. About 52 million gallons of fresh water are flushed into the sea every time a ship passes through the canal. Since about a couple of decades ago, scientists are noticing that Panama's climate is slowly becoming drier, possibly caused by the clearing of the forests along the canal's watershed: 2/3 of the forests in the hills have been cut out. Silting and mudslides in 1970 and 1984 are affecting the one way traffic of ships. Modern super tankers and large bulk carriers are too large to go through the canal.

A time may come to consider the possibility of a new sea level canal of the order of a mile or more in width in the isthmus area to restore the ancient equatorial ocean current.

Control of the canal changed hands from the USA to Panama on December 31, 1999.

NUCLEAR CIVIL ENGINEERING

An alternate sea level canal through South Mexico or Northern Columbia, restoring the old ocean currents intercepted by Central American Land Bridge, may become an international global planetary engineering project.

As part of the Plowshare program in the USA over the period 1958-1970, the possibility of excavating a sea-level canal across the Americal isthmus was studied was conducted by the Atlantic-Pacific Canal Study Commission.

Five different Trans-Isthmian routes for a sea level canal are possible as shown in Table 3. The cost figures include the operating facilities.

Table 3. Different Trans-Isthmian routes for a sea level canal across the Central American Isthmus.

Location	Length (miles)	Maximum Elevation of divide (feet)	Relative Cost, Conventional excavation	Relative Cost, Nuclear excavation
Tehuantepec, Mexico	125	810	21.00	3.71
Greystown-Salinas Bay, Nicaragua-Costa Rica	140	760	6.61	3.06
San Blas, Panama	37	1,000	10.00	1.00
Sasardi-Morti, Panama	46	1,100	8.28	1.16
Atrato-Truando, Columbia	102	950	8.49	1.94

Table 4. Canister diameters as a function of yield.

Canister diameter m	Yield kT TNT
0.30	30
0.45	45
0.60	60
0.90	90

Some previous studies considered canals that were 600 feet wide and 60 feet deep, and canals which were 1,000 feet wide and 280 feet deep. The locations of these possible routes are shown in Fig. 57.

A sea level canal construction would require the use of massive amounts of energy carving hills and mountain ranges. Peaceful clean thermonuclear cratering devices releasing megatons equivalent of TNT may be an economic means of achieving such an ambitious project as shown in Fig. 58. As an example, Nicaragua could be an alternate sea level canal route, where a 140 miles sea level canal would connect the Pacific to the volcanic Lake Nicaragua, to the San Juan River. In all cases important environmental considerations will have to be addressed.

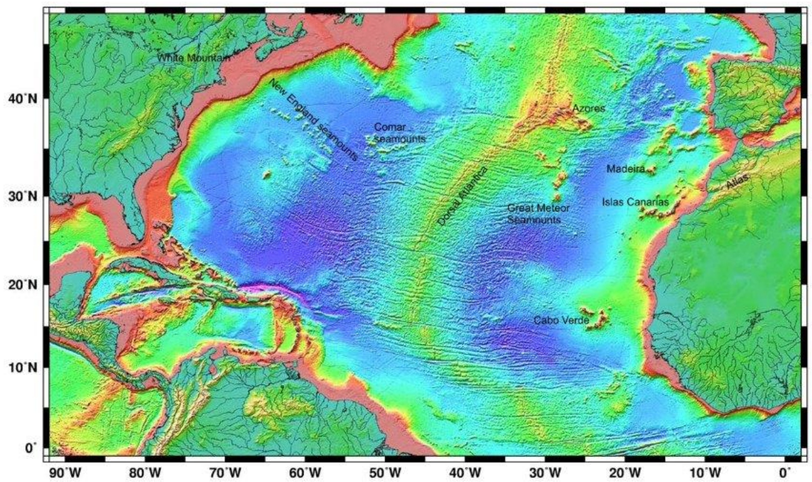


Figure 56. Atlantic Ocean relief.

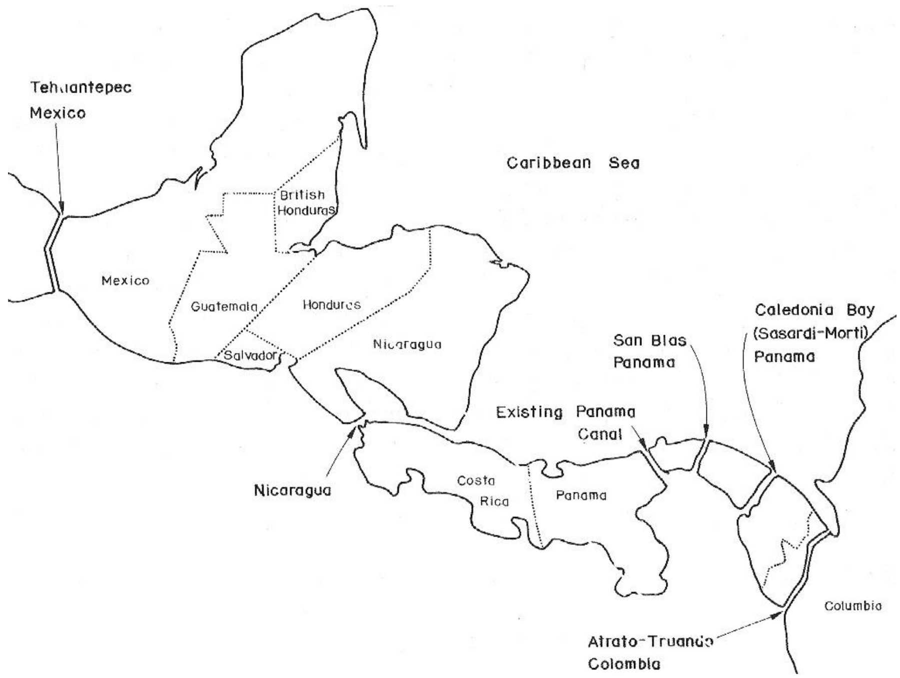


Figure 57. The locations of Trans-Isthmian possible routes. The routes through Mexico and Columbia are the best choices for a sea level connection. Sea level varies and during the Great Ice Age 18,000 years ago, the sea level was 130 meters lower. Today, large areas are under water that during the Great Ice Age were well above sea level. It is also likely that long ago and far into the future, plate tectonics may produce higher mountains and deeper trenches and depressions than we have today. Google Earth satellite photograph.

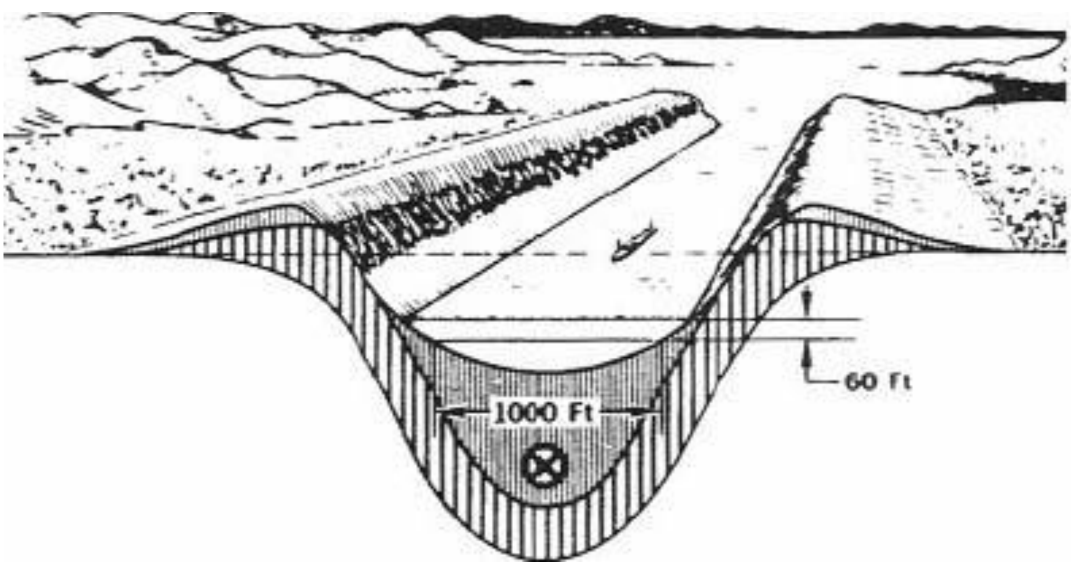


Figure 58. Peaceful clean thermonuclear cratering devices releasing megatons equivalent of TNT can excavate a sea level canal using nuclear civil engineering methodologies.

EXCAVATION EXPERIENCE

The Plowshare program commited an important part of its effort toward minimizing the ensuing fallout in a series of cratering experiments.

Two single charge experiments were conducted in basalt as a representative hard rock:

1. Cabriolet, 2.3 kT TNT,
2. Schooner, 35 kT TNT.

This was followed by a row of 5 charges at the Buggy experiment that resulted in digging a ditch. This followed the earlier Danny Boy experiment with a single chemical explosive charge of 0.42 kT.

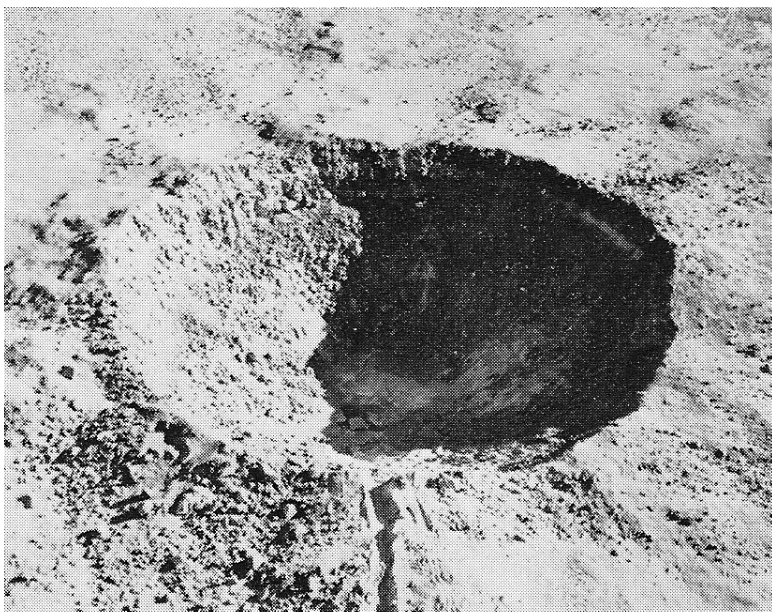


Figure 59. Single cratering 35 kT TNT charge in basalt hard rock, Schooner experiment. Source: LLNL.

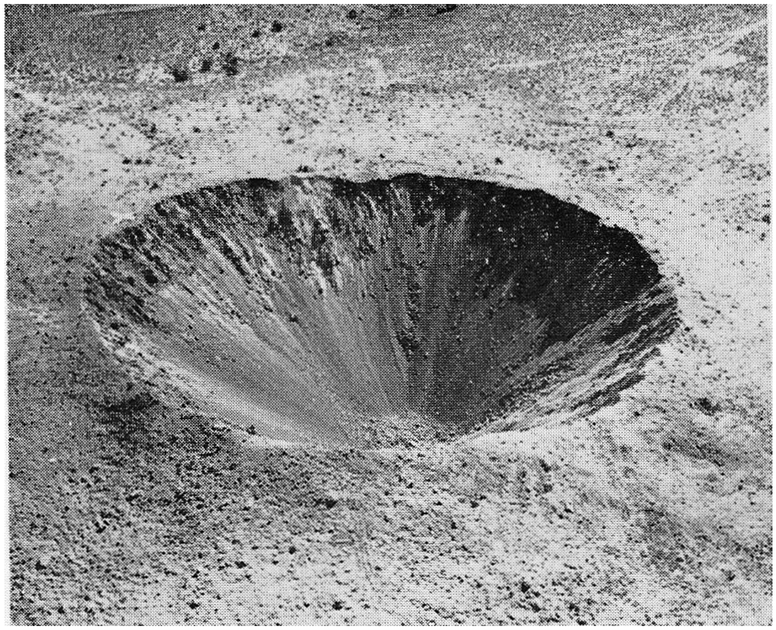


Figure 60. Cabriolet 2.3 kT TNT single shot experiment in basalt. Source: LLNL.

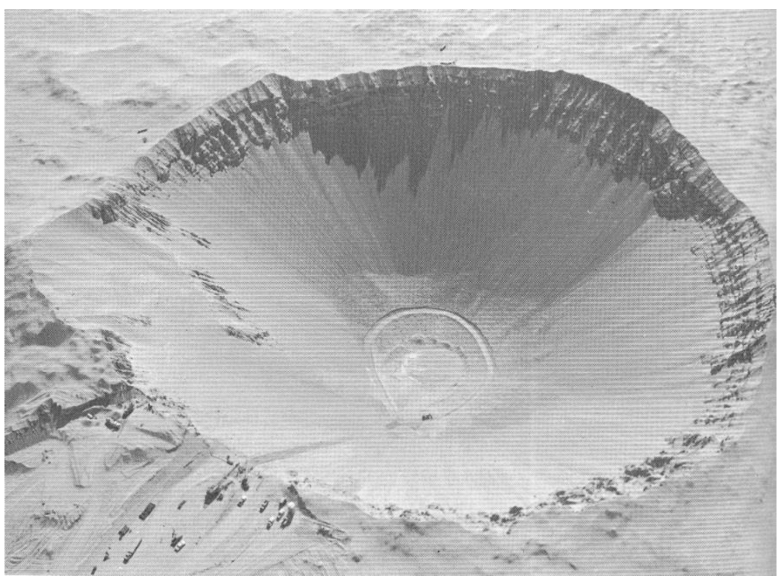


Figure 61. Single cratering experiment in alluvium. Sedan 100 kT TNT experiment.
Source: LLNL.

Figure 62. Multiple five-row 1.1 kT TNT charges Buggy channel cutting experiment in basalt hard rock. Source: LLNL.

The largest experiment was the Sedan event in alluvium using a 100 kT TNT charge placed at a depth of 194 m on July 6, 1962, and resulted in a crater 183 m in radius and 96 m in depth.

In the row charge experiment, 5 charges of 1.1 kT TNT each were exploded in basalt. The simultaneous explosion of the charges resulted in a ditch 260 meters in length, 77.5 meters in width, and 20 meters in depth. The crater sides reached 12.5 m in height and the ends were 4.3 m high.

Table 5. Dimensions and yield of cratering experiments.

Experiment	Yield kT TNT	Emplacement depth m	Crater radius m	Crater depth m
Danny Boy (Chemical)	0.42	33.6	32.6	18.9
Cabriolet	2.30	51.8	55.2	35.6
Schooner	35.00	108.0	130.0	63.5
Sedan	100.00	194.0	183,0	96.0

The dimensions of the craters are a function of the yield and follow an empirical scaling law that was developed with chemical explosives:

$$L = CY^{\frac{1}{3.4}} \tag{21}$$

where: Y is the yield in kT TNT,
C is a constant.

The dimensions for another yield can thus be obtained from:

$$L = L_{ex}\left(\frac{Y}{Y_{ex}}\right)^{\frac{1}{3.4}} \tag{22}$$

Example 1

The crater's radius and depth for a 1 kT TNT device taking the Schooner event as a reference are:

$$R = 130\left(\frac{1}{35}\right)^{\frac{1}{3.4}} = 45.7\,m$$

$$d = 63.5\left(\frac{1}{35}\right)^{\frac{1}{3.4}} = 22.3\,m$$

Example 2

The crater's radius and depth for a 1 MT TNT device taking the Schooner event as a reference are:

$$R = 130\left(\frac{1,000}{35}\right)^{\frac{1}{3.4}} = 348.5\,m$$

$$d = 63.5\left(\frac{1,000}{35}\right)^{\frac{1}{3.4}} = 170.2\,m$$

MINIMIZING THE ACTIVATION FALLOUT PRODUCTS

The two main considerations with nuclear cratering are the slope stability and the radionuclides production.

The activation products can be minimized by:

1. Using fusion devices with a minimum fission component.
2. Use low activation materials in the structure of the device such as tungsten and lead.
3. Use of appropriate shielding materials such as lead.
4. Use neutron absorbing materials such as boron.

By appropriate choice of the materials, the activation of the device structure and the surrounding medium can be brought to remarkably low values and short half lives. The produced radionuclides can be made to have short half lives in the hours and days range with Fe^{55} from the steel components being the longest with a 2.7 years half life.

Table 6. Upper limit values of total radionuclides production in cloud and fallout at detonation time for different device yields in kilocuries.

Radioactive nuclide	Half life	Decay radiation	Yield 100 kT TNT	Yield 1 MT TNT	Yield 10 MT TNT
$_{11}Na^{24}$	15.02 h	β^-, γ	200.00	800.00	2,000.00
$_{15}P^{32}$	14.28 d	β^-, no γ	0.10	0.40	0.80
$_{20}Ca^{45}$	163 d	β^-, γ	0.01	0.03	0.06
$_{25}Mn^{54}$	312.5 d	ε, γ	0.10	0.30	0.70
$_{25}Mn^{56}$	2.58 h	β^-, γ	600.00	2,000.00	5,000.00
$_{26}Fe^{55}$	2.7 a	ε, no γ	0.04	0.15	0.30
$_{26}Fe^{59}$	44.6 d	β^-, γ	0.04	1.15	0.30
$_{74}W^{185}$	75.1 d	β^-, γ	6.00	10.00	14.00
$_{74}W^{187}$	23.9 h	β^-, γ	300.00	500.00	700.00
$_{82}Pb^{203}$	52.1 h	ε, γ	1,000.00	7,000.00	20,000.00
other	-	-	15.00	25.00	40.00

ε refers to electron capture

The activation products occur in the device components, the casing, shielding and surrounding soil from neutron interactions. Some of these activation reactions are:

$$_0n^1 + {}_{11}Na^{23} \rightarrow {}_{11}Na^{24} + \gamma$$
$$_0n^1 + {}_{15}P^{31} \rightarrow {}_{15}P^{32} + \gamma$$
$$_0n^1 + {}_{20}Ca^{44} \rightarrow {}_{20}Ca^{45} + \gamma$$
$$_0n^1 + {}_{25}Mn^{55} \rightarrow {}_{25}Mn^{54} + 2\,{}_0n^1$$
$$_0n^1 + {}_{25}Mn^{55} \rightarrow {}_{25}Mn^{56} + \gamma$$
$$_0n^1 + {}_{26}Fe^{54} \rightarrow {}_{26}Fe^{55} + \gamma$$
$$_0n^1 + {}_{26}Fe^{58} \rightarrow {}_{26}Fe^{59} + \gamma$$
$$_0n^1 + {}_{74}W^{184} \rightarrow {}_{74}W^{185} + \gamma$$
$$_0n^1 + {}_{74}W^{186} \rightarrow {}_{74}W^{187} + \gamma$$
$$_0n^1 + {}_{82}Pb^{204} \rightarrow {}_{82}Pb^{203} + 2\,{}_0n^1$$

The magnitude of airborne radioactivity in the cloud and in the fallout is minimized by scavenging during the venting process by special emplacement techniques, by using minimum fission explosives and by using extensive neutron shielding.

The amount of fission products such as Ruthenium^{206}, a pure beta emitter without gammas with a half life of 368 days, from the fission component airborne in the radioactive cloud and in the fallout can be expected to be as low as the equivalent of 20 tons per device exploded. Another fission product is Krypton^{85} a noble gas with a half life of 10.72 years leading to a whole body exposure.

The tritium with a half life of 12.34 years release from the fusion component is less than 20 kilocuries per kiloton of the total yield. It would result minimally from fission, the interaction with lithium in the device and primarily from trace lithium in the surrounding soil. Without neutron shielding, a lithium content in the soil of 10 ppm would lead to 1 nanocurie or 10^{-9} curies of tritium per gram of rubble.

The sum of the activation products that are airborne and in the fallout are shown in Table 6.

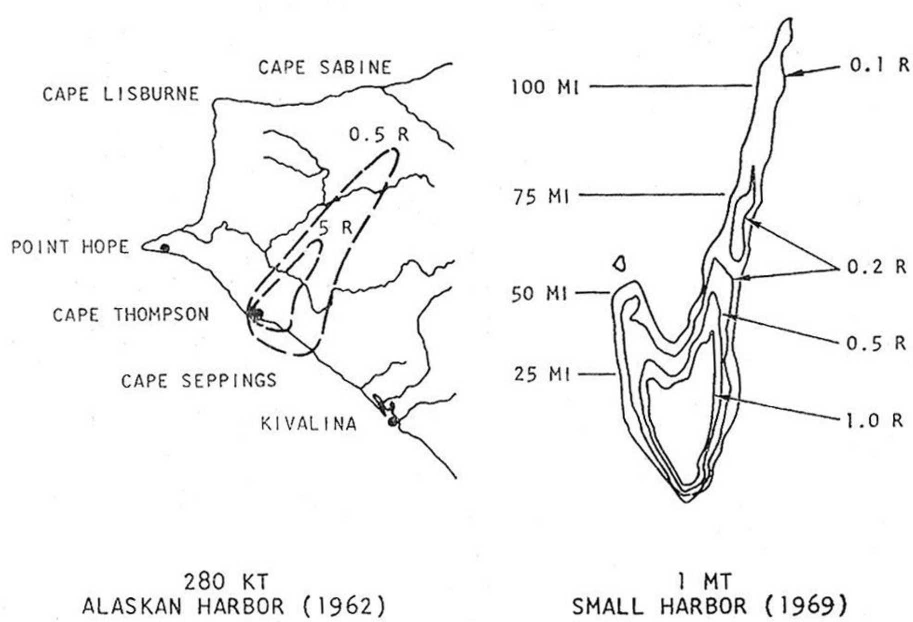


Figure 63. Contour lines for exposure in Roentgens (R) at different distances from fallout in two harbor construction studies.

The fallout patterns of gamma ray exposure calculated for hypothetical Alaskan harbor projects that would have involved the simultaneous firing of four 20 kT TNT and one 200 kT TNT, and for five 50 kT charges and four 200 kT charges, is shown in Fig. 63.

EFFECT OF DEPTH OF BURIAL

The explosive energy of a deeply buried device initially generates a high temperature bubble that later expands generating a crater or a ditch. The radius of the bubble depends on the yield and the depth of burial, as:

$$R = \frac{CY^{\frac{1}{3}}}{(\rho h)^{\frac{1}{4}}} \quad (23)$$

where:
R is cavity radius, m
Y is yield, kT TNT
C is an empirical constant dependent on the medium
ρ is the density of the medium, gm/cm^3
h is deoth of burial, m

Table 7. Empirical constant for different media.

Medium	Empirical constant C
Dolomite	51
Granite	59
Dome salt	63
Bedded salt	67
Volcanic tuff	77

COST ESTIMATES

Compared with chemical explosives, nuclear explosive possess the following advantages:

1. Compactness hence lower cost, particularly for thermonuclear devices.
2. Clean explosives with a minimum fission component can be used. Thermonuclear devices produce primarily x-rays with minimum neutrons that would cause activation of the surrounding materials and the device components.
3. A demonstrated experience of testing underground and in the atmosphere with measurable and predicted effects.
4. Demonstrated capability for underground explosions to reduce through shielding, choice of materials and optimal emplacement to greatly reduce the leakage of radioactivity to the environment.

The nuclear Non Proliferation Treaty (NPT) provides a promise to the non-weapon states to be provided by the weapon states with services for the peaceful applications of nuclear explosives under what became known as the Plowshare program in the USA.

The United States Atomic Energy Commission (USAEC) issued guidelines for cost estimates for explosives of different sizes. In 1964 dollars, the costs ranged from $350,000 for a 10 kT of TNT (Tri-Nitro-Toluene) equivalent to $600,000 at the 2 MT TNT level.

The associated diameters ranged from 0.91 m for yields up to 200 kT TNT and 1.22 m for yields in the range of 200 kT TNT to 2 MT TNT.

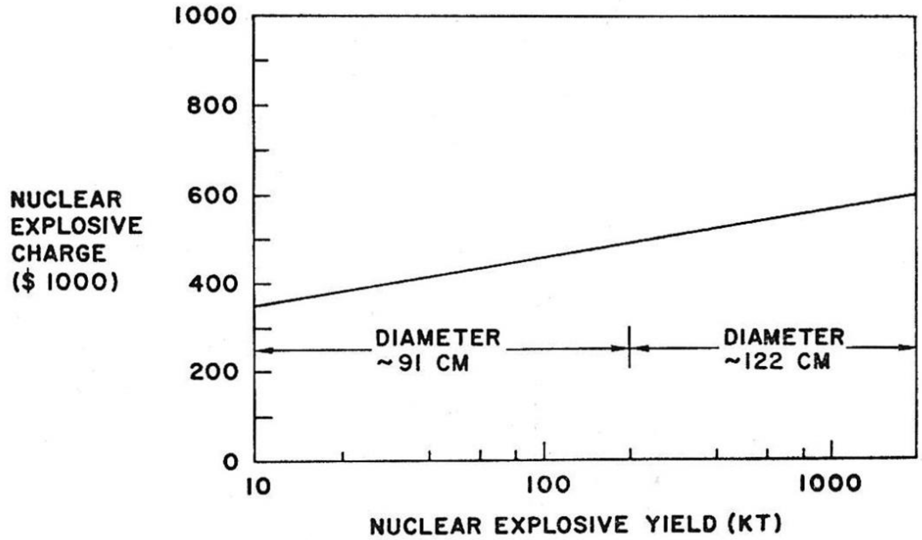


Figure 64. Charges for different yield charges in 1985 dollars. Source: USDOE.

ENVIRONMENTAL CARBON MANAGEMENT

There exist several basic strategies which can lead to reduced carbon emissions into the environment:

1. Improvement of energy efficiency.

This should include the different sectors of Carbon usage, including electrical utilities, transportation, industrial, residential, or commercial.

Considering the transportation sector, by applying new knowledge in combustion chemistry, non-thermal plasmas, and catalytic processes to the piston engine, one can reduce carbon emissions. The most viable technology for reducing the carbon dioxide emissions of light vehicles is the use of the Diesel engine, most probably in hybrid drive train configurations. Using light-weight materials, improved aerodynamics and lower rolling resistance and after-treatment technologies, diesel engine cars can reach the 70-mile per gallon efficiency level. After treatment technologies include catalytic converters that reduce pollution from the released hydrocarbons, oxides of nitrogen, carbon monoxide, and particulates. The new Homogeneous Charge Compression Ignition engine does not produce significant amounts of nitrogen oxides, and can replace the Diesel engine, if a control mechanism can be found for it. Careful choices of oxygenated and reformulated fuels such as cellulosic ethanol, sugar and other agricultural crops, avoiding the history of MTBE contamination of water supplies, can be considered.

2. Development of low cost carbon separation and sequestration technologies.

Soil tillage and the decay of plant residues release through microbial action significant amounts of carbon to the atmosphere. One simple application is in soil stabilization and carbon sequestration. This is the natural process by which the nation's prairies were formed

Carbon credit programs for farmers who would adopt no-till and other conservation tillage approaches such as strip-till in farming could enhance carbon sequestration in crops residue. The surface of no-till fields has higher amounts of crop residue, carbon, and microbial and fungal activity that can use much of the Nitrogen from applied fertilizer. Thus adoption of these practices may result in a larger level of use of fertilizers. A question arises about how farmers can maintain long term production levels if their fields become covered with a thick layer of crop residue on the surface.

The commercial application of carbon credits started in October of 1999. A consortium of Canadian utilities paid the state of Iowa's farmers in the USA $3 to $15 dollars per acre to no-till, replace commercial fertilizer with animal manure, and plant trees in an effort to obtain credit from the Canadian government for reduction of Carbon emissions.

About 100 Iowa farmers were the first to be paid to practice no-till or minimum till farming to lower carbon emissions. As part of an agreement with utility companies, IGF Insurance Company of DesMoines in collaboration with CQuest Ltd. of West DesMoines, Iowa, contacted its policy holders and other potential clients to ask if they would like to participate in the program. A modest 1.3 million tons of carbon credits for 2,000 and up to 6 million tons by 2,012 were contracted. The price paid is $0.50 to $2.50 per ton of carbon credits. Farmers should be able to deliver 4-5 tons of carbon credits per acre depending on their farming practices. This amounts to $10 to $15 per acre. USA farmers could sequester 300 million of carbon emissions annually.

Tillage is the enemy of carbon sequestering, so that the major method of carbon sequestration is through no-till and minimum-till farming. The difficulty is the need to maintain the soil's productivity. Research need to determine the optimum practices and locations and the carbon sequestering capacity of different soils.

Additional credits for sequestration are obtained through the saving of tractor fuel that otherwise would be used for tillage. A negative effect is the need to use more hydrocarbons for extra herbicides and fertilizers needed to maintain the soil's productivity.

Using livestock manure as fertilizer instead of commercial nitrogen fertilizer manufacture by natural gas would add more credits. If manure is injected into the soil instead of being stored in lagoons, less methane gas is released leading to further credits. Waterways, buffer strips and other conservation measures will also earn farmers carbon credits.

These programs are targeted to Canadian utilities, since there are not yet USA federal regulations requiring USA companies to reduce carbon emissions. Some companies are anticipating such regulations in the future.

3. Use of fuels containing less or no carbon.

Some fuels contain less carbon than coal, such as natural gas and hydrogen. Methods to manufacture low carbon fuels can be pursued such as methanol from natural gas, ethanol from agricultural crops such as sugar cane, liquefied natural gas, and hydrogen fuel. Trending toward hydrogenation and decarbonization will accelerate. Electricity production can be considered from sources that contain no carbon such as wind energy, solar energy, fission energy for the immediate future, and fusion energy for the long term.

THE DEFORESTATION FACTOR

Forests, particularly the tropical rain forests, are thought to play an important role in increased carbon dioxide concentrations. The reasoning is that trees are more efficient than grasses and crops in fixing carbon in their solid matter through the process of photosynthesis. Burning the tropical forests and converting them into crop lands is considered as adding to the greenhouse effect. Rain forests are considered to be the lungs of the Earth and the carbon sinks of the Earth. Rain forests are considered as maintaining the stability and balance of the Earth. Playing on this theme, power companies in North America, compensate for their burning high and low sulfur coal by countering it with a pollution credit, involving replanting forests in areas of South America such as Costa Rica.

It must be realized that the dry grasslands and deserts, both cold and hot, dominate the continents, and are only exceeded by the area occupied by the oceans. For instance, tropical savannahs, which are grasslands with woody shrubs and small trees cover about 1/3 of the Earth's land surface.

That the surface of the Earth must be covered with trees seems to be a romantic European and American concept that originated in the Wald of Germany's Black Forest and Walden Pond in Massachussets. The great 19th century American philosopher Henry David Thoreau wrote: "Nature endeavors to keep the Earth clothed with wood of some kind." When the European colonists noticed unforested lands in the tropics such as the veld of South Africa, the Mediterranean scrub of California, the Arabian Desert, or the Atacama Desert in Chile, they conveniently assumed that these lands were originally forested and cleared by fire, the ax, the plow, and the hoe.

In fact, as pointed out by Philip Stott at the University of London, and the editor of the Journal of Biogeography, these areas of the world have not carried any forests for millions of years. From 12,000 to 18,000 years ago, at the end of the last ice age, today's tropics were seasonal savannah grasslands. They were cooler and drier than today, with frequent fires, as attested by layers of ash in the soil, suggesting unforested areas. There were no forests then in most of Amazonia and the Malay Peninsula. There were then even less forests than exist today.

Ironically, the rain forests may in fact function as a lung which absorbs oxygen and releases carbon dioxide, and not vice versa. This is caused by the following two factors:

1. Rain forests are primarily composed of older trees, with minimal new growth. To trap carbon dioxide, old trees need to be replaced by new trees.
2. Rain forests contain heavy decomposition systems, further converting biomass into carbon dioxide through bacterial and fungal action.

Philip Stott goes on to suggest: "Certain good folk, particularly those living in the rich countries of the North, may indeed like rain forests. Others may psychologically need them as part of their own romantic New Age agendas. But the innate danger of the Great Green Anglo-Saxon Myth of the Rain Forest is that it has now burgeoned into a hegemonic myth. That is, a myth that excludes brutally all other myths from debate and discourse. In doing so, it not only denies the fundamental search for truth in science, but, more seriously, it warps policy-making that affects the poor of the developing world. It has become neo-colonial oppression."

Preserving old growth forests is unquestionably a worthwhile goal for both existing plant and animal diversity and other ethical and aesthetic considerations. The assumption that such preservation *alone* is sufficient to address the greenhouse effect would generate complacency, and would be a diversion from dealing with the real existing problems.

EFFECT OF NON-VASCULAR PLANTS ON CLIMATE CHANGE

Non-vascular land plants may have set off a series of ice ages on Earth. A study published in the journal Nature Geoscience entitled: "First plants cooled the Ordovician," suggests that land plants from more than 400 million years ago set off a series of ice ages on Earth by dramatically reducing the levels of carbon dioxide in the atmosphere.

This occurred during the Ordovician Period, which took place 488 million to 444 million years ago. The first land plants triggered a series of ice ages by removing minerals, like calcium, magnesium and others, from rocks in order to live. These first colonizers caused a substantial change in chemical weathering, with a significant impact on the global carbon cycle and climate.

The "chemical weathering" caused by the land plants' need to grow eliminated carbon dioxide from the atmosphere and lowered global temperatures by approximately 5 degrees Celsius. It is highly unlikely that plants will ever be able to trigger a series of ice ages again.

The researchers combined the moss "Physcomitrella patens" and rocks in incubators to recreate the "chemical weathering" effect the first land plants had on the ancient rocks. After three months, the researchers deployed an Earth system model to determine how the plants could have impacted the Earth's climate millions of years ago.

Much like humans, plants have a powerful effect on the climate. Although plants are still cooling the Earth's climate by reducing atmospheric carbon levels, they cannot keep up with the speed of today's human-induced climate change. It would take millions of years for plants to remove current carbon emissions from the atmosphere.

THE CARBON STORAGE FACTOR

In the Proceedings of the National Academy of Science in 2006, the agro ecologist Johan Six and other researchers at the University of California, Davis, Northern Arizona University and Wageningen University in the Netherlands defy the thoughts that the rise in the concentration of carbon dioxide would help plants fix more of it.

This challenges recent assessments and model projections from the Intergovernmental Panel on Climate Change which anticipated increases in soil carbon with rising carbon dioxide levels.

The new findings are that plants cannot keep up with increasing levels of carbon dioxide unless some essential nutrients such as potassium, phosphorus and molybdenum are added as fertilizers. In addition, the raising levels of carbon dioxide do not speed up the process of nitrogen fixation. Soils are limited in their impact on global warming because of their dependence on nitrogen and other nutrients. For soils to lock away more carbon dioxide as carbon, there has to be much more nitrogen than is normally available in most ecosystems.

Various plants such as legumes can pump nitrogen from the atmosphere into the soil by the process of nitrogen fixation. The process cannot keep up with increasing levels of carbon dioxide unless other essential nutrients are added.

Plants do play a role in mitigating global warming in that they store about ½ the carbon dioxide emitted into the atmosphere, temporarily until they decay, in land or marine ecosystems. However, the soils of unmanaged ecosystems have a limited and reduced capacity to clean up the excess carbon dioxide in the atmosphere.

This suggests that the ability of plants to counteract global warming by removing carbon dioxide from the atmosphere and storing it as carbon in the soil is limited. Future carbon storage by land ecosystems may be smaller than previously thought and is not a solution to global warming. Reducing the reliance on fossil fuels is more effective than expecting natural ecosystems to absorb the increasing levels of carbon dioxide.

PLANKTON CARBON FIXATION, OCEAN IRON DUST SEEDING, GERITOL EFFECT

In 2007, NASA reported that satellite data showed that ocean plant life is shrinking, and that a 6-9 percent loss in plankton production has occurred since the 1980s. Some regions, like the equator, have experienced a 50 percent drop. This can result in an imbalance in the oceans ecosystems.

By seeding the plankton deficient areas of the oceans with micron size iron dust particles in the form of ground iron ore as a catalyst, photo plankton growth can be stimulated leading to algal blooms that last 2-3 months. Through the process of photosynthesis it would fix atmospheric CO_2. About 50 percent of these algae would constitute food for sea life, the rest dies, bleaches and sinks down. As it reaches a depth of 1,000 feet it should be trapped for decades, at 1,500 feet, for centuries, and at 3,000 feet for millennia.

It is not yet known exactly how much CO_2 is ingested by the plankton per ton of seeded iron. Estimates are that every ton of iron ore dumped into the ocean would cause 100,000 tons of CO_2 to be absorbed by the resulting algae bloom.

Side effects of the process include the depletion of oxygen in the water by the algal bloom, the overproduction of nitrogen and of carbonic acid, and the ocean currents could carry the dead plankton back to the surface where it would release the trapped CO_2. The process could change the sea temperature which would affect local species and generate political implications in international waters.

Every ton of sequestered carbon corresponds to three tons of CO_2. Countries that signed the Kyoto Protocol such as Japan and Canada are already trading carbon credits. In the USA, which did not sign the protocol, the states of Texas and California were setting a certification process for carbon credits trading.

NEGATIVE FEEDBACK EFFECT

The ocean that surrounds the Antarctic continent is full of nutrients such as nitrogen. The only element lacking for plankton to be able to bloom there is iron. Wind was the only proven source of iron in the Southern Ocean, blowing much needed iron oxide and other metal oxides from the dusty deserts of the southern continents. The quantities moved by this method are miniscule.

A powerful mechanism has been operating under the waves for millions of years: icebergs fertilize the ocean around the South Pole with microscopic particles containing iron. Algae are then able to bloom, and they in turn absorb the greenhouse gas carbon dioxide from the Earth's atmosphere via photosynthesis. Some of the algae then sinks to the ocean floor. This helps to slow down global warming. Icebergs, dump around 120,000 tons of iron into the Southern Ocean, causing 2.6 billion tons of CO_2 to be removed from the atmosphere. This massive amount corresponds to the greenhouse gases emitted from power plant smokestacks, home chimneys and automobile exhaust pipes in India and Japan combined.

The Earth itself seems to want to save us through this self healing negative feedback process, although it is by no means sufficient to halt global warming. The effect will increase in the coming decades, as more and more ice breaks off from ice sheets due to rising temperatures. This is happening especially along the Antarctic Peninsula, which has seen a rapid temperature increase of 2.5 degrees Celsius or 4.5 degrees Fahrenheit in the last 50 years. Every percentage point increase in the amount of ice that breaks off, an additional 26 million tons of CO_2 is removed from the atmosphere.

Ice is moving out from the interior of the Antarctic continent faster than ever before, grinding across the rocky bedrock and releasing iron oxides such as schwertmannite. Iron from these minerals then allows algae in the ocean to bloom in greater quantities.

This naturally occurring iron fertilization does not come close to tapping the nutrient rich but iron poor Southern Ocean's full potential to act as a CO_2 sink. The iron-deficient area covers 50 million square kilometers or 20 million square miles. If this entire expanse were to be artificially fertilized with several million tons of iron oxide, the ocean could remove three and a half gigatons of carbon dioxide from the atmosphere. This amounts to an eighth of the yearly emissions created by burning oil, gas and coal.

IRON SULFATE, VOLCANIC DUST ATMOSPHERIC SEEDING

Among scientists and environmental entrepreneurs, a plan has long been in the works to fertilize the ocean around Antarctica with iron sulfate, using large tankers. Another suggestion is to use balloons, jet engines, rockets, and artillery shells to place millions of tons of sulfates in the stratosphere to mimic the cooling effect of volcanic eruptions.

The scheme is costly since tens of thousands of pounds are needed per month to generate enough cooling. It could cause a drying of the Mediterranean and the Middle East regions, without a reduction of the CO_2 levels.

Sulfur’s cooling effect is only temporary, while the CO_2 from hydrocarbons burning remains in the Earth’s atmosphere for an extended period of time. Sulfur quickly drops out of the air if it is not replenished.

The scheme is controversial since environmentalists fear such geoengineering could knock the ecosystem out of balance. The use of enough sulfur to reduce warming could wipe out the protective Arctic ozone layer and delay the recovery of the Antarctic ozone hole by about 70 years.

American oceanographer Mary Silver even predicts possible large-scale proliferation of poisonous algae. For this reason, the UN Convention on Biological Diversity in May 2008 called for a moratorium on such plans, at least until further scientific results is available.

A particular species of algae that grows along the coast is of interest. Spores of this species are enclosed by a silicon dioxide shell, and they also incorporate carbon dioxide into their organic inner parts. When the spores then sink through the water, even fish can hardly digest them. Then the greenhouse gas is sure to be out of the Earth's atmosphere for several hundred years.

An authority at the United Nations should oversee future iron fertilization projects undertaken to save the climate. This matter cannot be left in the hands of industry, allowing companies simply to buy their way out of other climate related obligations with a tanker full of iron sulfate.

EARTH SHADING, SOLAR UMBRELLA

If global climatic change results in runaway warming, directly shading the Earth from solar radiation is considered as an alternative. Ken Caldeira at the Carnegie Institution in the USA proposes seeding the stratosphere with millions of tons of reflective particles such as sulfates. Since they would fall back to Earth, the process would have to be continually delivered.

The use of sulfates as heat reflectors is confirmed from the observations from volcanic eruptions. The eruption of Mount Pinatubo in the Philippines in 1991 launched into the stratosphere about 10 million tons of sulfur resulting in a dimming haze around the Earth that dropped the average global temperature by about one degree Fahrenheit. The effect lasted over a one year period.

A similar suggestion is advanced by Roger Angel from the University of Arizona in launching thin silicon nitride discs that are two feet in diameter and weighing less than one gram into space between the sun and the Earth. Their number would reach into the trillions and the deployment would take decades and cost trillions of dollars.

The deployment of 16 trillion discs disks into orbit between the sun and Earth could block 1.8 percent of the solar flux. This would require 20 million launches over 30 years. The cost could reach $4 trilllion, without an effect on CO_2.

Unintended consequences and side effects could be met such as an effect on the ozone layer. It could be realized that weaning ourselves from fossil fuels is the cheapest alternative. If this is not realized on a timely basis, in the case of a global warming emergency what appears presently too costly may be perceived in the future as a necessity.

CARBON CATCHING, ARTIFICIAL TREES

Carbon dioxide contributes more to global warming than any other greenhouse gas, even though the concentration is a mere 0.04 percent.

There exist suggestions to build millions of CO_2 catchers. These would be devices the size of shipping containers fitted with chemical filters to pull greenhouse gases out of the air. A simple approach is to use sodium hydroxide liquid as a sorbent to catch the CO_2.

The devices, referred to as artificial trees, may be bulkier and less attractive than real trees, but they can be thousands of times more efficient.

The issue is how much energy it would take to extract CO_2 from the atmosphere. Energy expenditure rises as the concentration of CO_2 falls, but in logarithmic, not linear fashion suggesting that it remains low.

A material that binds CO_2 must be identified that can also release it again without requiring an excessive amount of energy input. Special synthetic alkaline resins with a property that they attract CO_2 strongly when dry, but releases it again easily when wet, has been identified. The resin gets fully saturated after one hour of exposure. An amount of 32,800 feet of resin would harvest a ton of CO_2 per day.

Figure 65. Artificial tree CO_2 catcher conceptual design.

A CO_2 catcher would include large synthetic resin surfaces protected from rain, turning in the wind like a carousel until filled with carbon dioxide, then drawn into a vacuum container and sprayed with water. The CO_2 released would then be pumped out and compressed then provided to industrial customers or disposed of at high pressure underground or deep in the oceans.

The cost of this method is estimated at about $150-300 per ton of carbon dioxide. In the long term the price could settle to to around $20-30 per ton. It would require 10 million CO_2 catchers to offset between 10 and 15 percent of the annual global emissions. The goal would be to filter 90,000 tons of CO_2 per year. Each artificial tree can filter 6.6 pounds per second.

The separation, transportation and disposal costs are high. Potential leaks would constitute a hazard to humans and ecosystems.

CLOUD SEEDING

Cloud seeding has been proposed around 1990 by John Latham, senior research associate at the National Center for Atmospheric Research and former head of the Atmospheric Physics Research Group at the University of Manchester. The method is not intended to make new clouds. It would make existing clouds whiter.

The concept involves seeding ocean clouds with tiny droplets of saltwater. In theory, the clouds should reflect more sunlight, possibly offsetting greenhouse warming for up to 100 years. In effect, the scientists propose speeding up the natural process of cloud formation over water much as cloud seeders do over land using dry ice and silver nitrate.

A fleet of 1500 300-ton ships powered by vertical spinning wind turbines called Flettner rotors is proposed. The rotors would both propel the ships and spray seawater into the atmosphere to promote cloud formation around salt nuclei. A ship powered by Anton Flettner's rotors crossed the Atlantic in 1926. German wind turbine manufacturer, Enercon, had plans to build a state-of-the-art ship based on similar technology.

Figure 66. Conceptual designs of cloud seeding towers on ship using Flettner rotors. The rotating towers use the Magnus effect to propel the ship. Source: John McNeil.

Sean Twomey reported that the reflectivity of clouds is set by their distribution of droplets size. A large number of small drops is capable of reflecting more solar radiation than the same amount of water in larger drops. In clean marine air masses there are fewer cloud condensation nuclei in the range of 10 – 100 droplets / cm^3 than over land masses. Thus the water is shared between droplets about 25 microns in diameter, larger than the average 15 microns over land. If the number of suitable nuclei could be increased, the same liquid water content would be shared over a large number of smaller droplets and so more of the incoming solar energy radiation would be reflected back to space. Doubling the drop number increases cloud albedo by about 5.6 percent.

It is recognized that micron sized droplets of salt water are ideal condensation nuclei. If they are sprayed into the marine boundary layer, turbulence will move some of them into the clouds. The suggested spraying could be done from a number of remotely navigated using the Global Positioning System (GPS), much like aerial drones, wind driven sailing vessels dragging water turbines to generate the energy for the spray. .

The solar-energy reflected to surface-tension energy needed to create the sub-micron seeds is several orders of magnitude. The technique does nothing for the chemical problems of CO_2 emissions and so is a contingency measure for use if CO_2 emissions cannot be reduced or if methane released from permafrost takes over as the main driver of climate change.

COOLING TOWERS CLOUD SEEDING

Instead of just making clouds whiter, we propose that the energy rejection from fossil and nuclear power generation can be used to generate new clouds. These could be made to offset at least a part of the CO_2 generated by the fossil power plants.

Figure 67. Cloud seeding from nuclear and fossil fuel power plants' cooling towers.

Cooling towers used in conjunction with fossil fuel and nuclear power plants can be used as effective cloud seeders, even though their contribution has not been estimated. At an overall thermal efficiency of 1/3, fully 2/3 of the produced energy is available for their formation and dissipation. It may be possible to modify their design features or rebuild them so as to optimize their contribution to cloud seeding by providing spry nozzles rather than just using a gravitational fall. The parameters affecting cloud seeding in this situation can be listed as:

1. The diameter of the droplets,
2. The reflection coefficient of water drops,
3. The initial concentration of the condensation nuclei,
4. The number, but not the mass or volume of the seeding drops,
5. The fraction of these that will reach the cloud top,
6. The effective half life of the drops that reach the cloud level,

7. The surface tension of water,
8. The velocity with which the drops leave the spray-generating mechanism,
9. The viscosity loss in any passages forming the nozzle system,
10. The height from which the drops are released,
11. The pressure drop across pipe-work and any pre-filtering system,
12. The energy of any electrostatic charge that could be used to encourage separation,
13. The kinetic energy of any airflow needed to aid initial dispersion.

Figure 68. Steam generation from the twin cooling towers of the Byron nuclear power plant, Illinois, USA. The two reactor units are the smaller circular structures at the far left. Photo: Microsoft Bing.

CARBON CAPTURE AND STORAGE, CCS

The process of Carbon Capture and Storage involves the injection of liquid CO_2 into the ground at a depth of 2,000 meters (6,560 feet) is being researched. The best bedrock for this storage technique is assumed to be porous sandstone with concentrated salt water. The research goal is to see how much salt water the CO_2 displaces, how it distributes itself and whether it would stay down there.

Water companies are afraid that the CO_2 could displace salt water and possibly contaminants to the surface and that the groundwater could become contaminated.

The benefits of this storage technology are as diffuse and abstract as the climate change it is supposed to be alleviating.

By 2040, in Germany there exists a goal of phasing out coal-fired electricity generation. CCS is one of the few options to minimize CO_2 emissions in the short term.

Scientists at the Geomar Institute in Kiel, Germany propose to inject CO_2 deep under the ocean floor while extracting methane (CH_4) at the same time.

METHANE PRODUCTION

Methane CH_4 is 20 times more potent as a greenhouse gas than CO_2. The main human activity producing methane is animal agriculture. An average cow releases 70 gallons of CH_4 per day. Cows that are fed grain produce 20-25 less methane than grazing cows. Adding tannin to the feed could lower it further.

The present contribution of extra methane to global warming is about 1/3 that of CO_2. However, measurements of the release from Siberian permafrost are about 5 times higher than expected. If the rate of methane release increases it could replace CO_2 as the main driver of global warming, making reductions in the use of fossil fuels less effective.

NITROUS OXIDE EFFECT

Nitrous Oxide N_2O, laughing gas or sweet air, is the third most abundant greenhouse gas in the earth's atmosphere. It should not be confused with nitric oxide NO or nitrogen dioxide NO_2. Nitrous oxide interacts with O_2 leading to NO:

$$2N_2O + O_2 \rightarrow 4NO ,$$

the NO in turn reacts with ozone, and is the main naturally occurring regulator of ozone in the stratosphere.

According to the Environmental Protection Agency, EPA, it has 310 times the heat trapping ability of CO_2 in part because of its longevity of 120 years in the Earth's atmosphere. From another perspective, over a 100 year period, it is 310 x (100 / 120) = 258.3 times more potent on a per weight basis than CO_2 as a greenhouse gas.

Using a no-till practice and a corn-soybean rotation reduces nitrous oxide emission by 57 percent over chisel plowing and 40 percent over moldboard plowing according to research by Tony Vyn, a Purdue University agronomist published in the "Soil Science Society of America Journal." The soil disturbance and plant residue placement modify the soil's physical and microbial environments affecting the nitrous oxide release.

Methods of reducing nitrous oxide emissions are important since food production accounts for 58 percent of all USA emissions and 38 percent of it originates from the soil. Agriculture releases more nitrous oxides than the tailpipes of transportation vehicles.

A corn-soybean rotation alone, instead of continuous corn decreased the nitrous oxide emissions by 20 percent since a rotation corn receives about 20 percent less nitrogen fertilizer application because of the contribution in fixing nitrogen from the air by the leguminous soybean plant.

This suggests that there is an added air quality advantage of the no-till practice other than its soil and water preservation aspects.

OPPOSING POINTS OF VIEW

Dennis Avery, a senior fellow and director of global issues with the Hudson Institute, a New York conservative think tank disputes the argument that man-made greenhouse gases are affecting global weather. He suggests that there have been 7 previous global warming periods since the last Ice Age, and that most were warmer than the present one. He points out that historical data show that the average global temperature rose 0.7 degrees Celsius from 1860 to 1940 but only 0.2 degrees since then. He adds that there has been no warming since 1990. He points out to studies of solar variations that suggest that the current warming period merely mirrors routine cyclical sunspot activity.

The Global Climate Coalition is a Washington based group composed of about 54 corporate members, including the major oil companies and General Motors, arguing the case that there is no sufficient evidence to confirm any serious warming of the Earth due to the greenhouse effect. The coalition opposes ratification of the Global Climate Treaty by the USA Senate on the basis that developing countries account for a significant proportion of the world's population, therefore its pollution, and they must also agree to emission cuts. Under environmental groups' pressure, major companies including British Petroleum, Shell Oil, Dow Chemical, Ford, and Chrysler have left the group.

The National Coal Association and the National Petroleum Institute in the USA oppose taxes on fossil fuels. A video film produced by the Western Fuels coal company suggests that carbon dioxide in the atmosphere enhances the process of photosynthesis as well as precipitation, and would help turn current desert areas into grass lands. This view does not consider that deserts are created by a complex process involving geographic conditions such as mountain ranges deflecting moist air currents, and soil conditions that prevent growth, rather than by the single factor of lack of plant growth.

The American Public, under the influence of opposing views, has understandably adopted a "wait and see" attitude by the politicization of what is otherwise a scientific issue to be raised above politics. Congressional conservative delegates consider the issue as a liberal posturing. Ratification of the Global Climate Treaty by the USA Congress is doubtful.

Scientific modeling of the process, such as the General Circulation Model, lacks in the capability of predicting the carbon dioxide exchange between the oceans and air. Narrow specialization of the scientific disciplines, makes it difficult to join the individual pieces of evidence in the puzzle to create an overall perspective.

INCREASING WIND SPEED, WARMING OF DEEP OCEAN WATER

For most of the 21st century, the average surface air temperature around the world did not increase as rapidly as predicted by climate computer models even though they are 1.53 degrees Fahrenheit or 0.85 degrees Celsius warmer than in 1880.

A reason could be attributed to the trade winds, which persistent surface winds that flow from East to West near the equator. Since late 1990s, abnormally strong winds blowing across the Pacific Ocean may have trapped heat from the air in the ocean's deep waters. This trapped heat slowed average global temperature increases over the past years. If the winds slow down to normal, the heat could escape quickly and cause rapid warming of the Earth's atmosphere.

Faster-than-normal trade winds may have been the previously unknown mechanism for hiding heat in the ocean. As the winds sped up over the Pacific Ocean in the 1990s, they forced warmer surface water down. Cooler, deeper water then flowed to the surface. We may be witnessing a pause in warming before the next rise in global temperatures."

EFFECT OF VOLCANIC ERUPTIONS

According to a study presented by Benjamin D. Santer and coworkers from the Lawrence Livermore National Laboratory (LLNL) published on February 24, 2014 in Nature Geoscience, an unusual swarm of 17 volcanic eruptions over the period 19989 - 2012 may be partially responsible for the slowing of global warming as they pumped SO_2 into the Earth's upper atmosphere, where it formed liquid particles that reflected more sunlight back to space, moderating the larger-scale warming of the planet surface

Adding the volcanic activity into calculations effectively reduced the discrepancy between observed temperature trends and the models that underpin the Intergovernmental Panel on Climate Change's (IPCC) reports on climate change attributable to human activity. Those models assumed that the additional aerosols pumped into the atmosphere by such events at the 1991 eruption of Mount Pinatubo in the Philippines would eventually subside to zero [37].

The research team looked at satellite readings of temperature in the lower Troposphere, the 11-mile-thick mass of air closest to Earth's surface, and compared them with 28 climate models. They factored out the natural effects of the El Niño Southern Oscillation, which causes varying cooling and heating of the eastern equatorial Pacific Ocean. The models proved accurate until the beginning of the current century, but the actual temperatures soon bucked the trend. That discrepancy set off a flurry of speculation among skeptics that the framework underlying climate change was fatally flawed.

Scientists are examining the moderation in the predicted warming rate, focusing on such phenomena as fluctuations in solar cycles, the absorption of heat by the oceans and an increase in sulfur dioxide emissions from coal burning in China and the cycling the heat from the troposphere to the ocean's water. Volcanic eruptions are thought to provide a temporary respite from the relentless warming pressure of continued increases in CO_2.

HAROLD LEWIS' PERSPECTIVE, CLIMATE-GATE, "THE GREATEST AND MOST SUCCESSFUL PSEUDOSCIENTIFIC FRAUD"

Harold Lewis is Emeritus Professor of Physics at the University of California, Santa Barbara. He is former Chairperson; Former member Defense Science Board, Chairperson of Technology Panel; Chairperson DSB study on Nuclear Winter; Former member Advisory Committee on Reactor Safeguards; Former member, President's Nuclear Safety Oversight Committee; Chairperson APS study on Nuclear Reactor Safety, Chairperson Risk Assessment Review Group; Co-founder and former Chairperson of JASON; Former member USAF Scientific Advisory Board; served in the USA Navy during WW II. He is author of the books: Technological Risk and Why Flip a Coin.

He submitted a letter of resignation to Curtis G. Callan Jr, Princeton University, President of the American Physical Society (APS):

> "Dear Curt:
>
> When I first joined the American Physical Society sixty-seven years ago it was much smaller, much gentler, and as yet uncorrupted by the money flood (a threat against which Dwight Eisenhower warned a half-century

ago). Indeed, the choice of physics as a profession was then a guarantor of a life of poverty and abstinence—it was World War II that changed all that. The prospect of worldly gain drove few physicists. As recently as thirty-five years ago, when I chaired the first APS study of a contentious social/scientific issue, The Reactor Safety Study, though there were zealots aplenty on the outside there was no hint of inordinate pressure on us as physicists. We were therefore able to produce what I believe was and is an honest appraisal of the situation at that time. We were further enabled by the presence of an oversight committee consisting of Pief Panofsky, Vicki Weisskopf, and Hans Bethe, all towering physicists beyond reproach. I was proud of what we did in a charged atmosphere. In the end the oversight committee, in its report to the APS President, noted the complete independence in which we did the job, and predicted that the report would be attacked from both sides. What greater tribute could there be?

How different it is now. The giants no longer walk the earth, and the money flood has become the raison d'être of much physics research, the vital sustenance of much more, and it provides the support for untold numbers of professional jobs. For reasons that will soon become clear my former pride at being an APS Fellow all these years has been turned into shame, and I am forced, with no pleasure at all, to offer you my resignation from the Society.

It is of course, the global warming scam, with the (literally) trillions of dollars driving it, that has corrupted so many scientists, and has carried APS before it like a rogue wave. It is the greatest and most successful pseudoscientific fraud I have seen in my long life as a physicist. Anyone who has the faintest doubt that this is so should force himself to read the ClimateGate documents, which lay it bare. (Montford's book organizes the facts very well.) I don't believe that any real physicist, nay scientist, can read that stuff without revulsion. I would almost make that revulsion a definition of the word scientist.

So what has the APS, as an organization, done in the face of this challenge? It has accepted the corruption as the norm, and gone along with it. For example:

1. About a year ago a few of us sent an e-mail on the subject to a fraction of the membership. APS ignored the issues, but the then President immediately launched a hostile investigation of where we got the e-mail addresses. In its better days, APS used to encourage discussion of important issues, and indeed the Constitution cites that as its principal purpose. No more. Everything that has been done in the last year has been designed to silence debate.

2. The appallingly tendentious APS statement on Climate Change was apparently written in a hurry by a few people over lunch, and is certainly not representative of the talents of APS members as I have long known them. So a few of us petitioned the Council to reconsider it. One of the outstanding marks of (in)distinction in the Statement was the poison word incontrovertible, which describes few items in physics, certainly not

this one. In response APS appointed a secret committee that never met, never troubled to speak to any skeptics, yet endorsed the Statement in its entirety. (They did admit that the tone was a bit strong, but amazingly kept the poison word incontrovertible to describe the evidence, a position supported by no one.) In the end, the Council kept the original statement, word for word, but approved a far longer "explanatory" screed, admitting that there were uncertainties, but brushing them aside to give blanket approval to the original. The original Statement, which still stands as the APS position, also contains what I consider pompous and asinine advice to all world governments, as if the APS were master of the universe. It is not, and I am embarrassed that our leaders seem to think it is. This is not fun and games, these are serious matters involving vast fractions of our national substance, and the reputation of the Society as a scientific society is at stake.

3. In the interim the ClimateGate scandal broke into the news, and the machinations of the principal alarmists were revealed to the world. It was a fraud on a scale I have never seen, and I lack the words to describe its enormity. Effect on the APS position: none. None at all. This is not science; other forces are at work.

4. So a few of us tried to bring science into the act (that is, after all, the alleged and historic purpose of APS), and collected the necessary 200+ signatures to bring to the Council a proposal for a Topical Group on Climate Science, thinking that open discussion of the scientific issues, in the best tradition of physics, would be beneficial to all, and also a contribution to the nation. I might note that it was not easy to collect the signatures, since you denied us the use of the APS membership list. We conformed in every way with the requirements of the APS Constitution, and described in great detail what we had in mind—simply to bring the subject into the open.

5. To our amazement, Constitution be damned, you declined to accept our petition, but instead used your own control of the mailing list to run a poll on the members' interest in a TG on Climate and the Environment. You did ask the members if they would sign a petition to form a TG on your yet-to-be-defined subject, but provided no petition, and got lots of affirmative responses. (If you had asked about sex you would have gotten more expressions of interest.) There was of course no such petition or proposal, and you have now dropped the Environment part, so the whole matter is moot. (Any lawyer will tell you that you cannot collect signatures on a vague petition, and then fill in whatever you like.) The entire purpose of this exercise was to avoid your constitutional responsibility to take our petition to the Council.

6. As of now you have formed still another secret and stacked committee to organize your own TG, simply ignoring our lawful petition.

APS management has gamed the problem from the beginning, to suppress serious conversation about the merits of the climate change claims. Do you wonder that I have lost confidence in the organization?

I do feel the need to add one note, and this is conjecture, since it is always risky to discuss other people's motives. This scheming at APS HQ is so bizarre that there cannot be a simple explanation for it. Some have held that the physicists of today are not as smart as they used to be, but I don't think that is an issue. I think it is the money, exactly what Eisenhower warned about a half-century ago. There are indeed trillions of dollars involved, to say nothing of the fame and glory (and frequent trips to exotic islands) that go with being a member of the club. Your own Physics Department (of which you are chairman) would lose millions a year if the global warming bubble burst. When Penn State absolved Mike Mann of wrongdoing, and the University of East Anglia did the same for Phil Jones, they cannot have been unaware of the financial penalty for doing otherwise. As the old saying goes, you don't have to be a weatherman to know which way the wind is blowing. Since I am no philosopher, I'm not going to explore at just which point enlightened self-interest crosses the line into corruption, but a careful reading of the ClimateGate releases makes it clear that this is not an academic question.

I want no part of it, so please accept my resignation. APS no longer represents me, but I hope we are still friends.

Hal"

COUNTER ARGUMENTS, NIPCC GROUP

On September 27, the United Nations climate change report entitled: "Working Group I: The Physical Science Basis," is issued. It is the fifth assessment report of the UN's Intergovernmental Panel on Climate Change (IPCC). The IPCC suggests that climate change activities must adhere to the doctrine laid down in Rio de Janeiro in 1992 by the UN Framework Convention on Climate Change (FCCC). At that summit, virtually all national leaders endorsed the FCCC's proclamation that humanity must work to accomplish "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." Today, no one knows what, if any, greenhouse gas level would cause climate problems is immaterial. "The climate change express left the station long ago" [35].

The UN, managing the developing nations $100-billion Green Fund convened international conferences in exotic locations to orchestrate climate treaties. They created global warming and alternative energy "road maps" for the world to follow. They designed strategies to monitor and enforce countries' compliances with treaty obligations [35].

An anti-IPCC movement has emerged as a formal group of independent experts who do not support the hypothesis that the greenhouse gas emissions, carbon dioxide in particular, are causing climate problems. There have been open letters and petitions signed by leading experts asserting that the IPCC is wrong. In addition, the Nongovernmental International Panel on Climate Change (NIPCC), a panel of scientists and scholars from across the globe, issued a report entitled: "Climate Change Reconsidered II: Physical Science." The NIPCC report suggests a scientific community deeply uncertain about the reliability of the computer models used by the IPCC to predict climate problems.

The NIPCC is not sponsored by the UN or member governments, and so is not politically motivated to come to any pre-ordained conclusion. It is co-authored and coedited by Craig Idso, chairman of the Center for the Study of Carbon Dioxide and Global Change; Professor Robert Carter, former head of the School of Earth Sciences, James Cook University, Australia; and S. Fred Singer, PhD, president of the Science and Environmental Policy Project and professor emeritus of environmental science at the University of Virginia. Forty-six other climate experts from 14 countries acted as authors and reviewers [35].

Climate Change Reconsidered II focuses especially on research papers that were either overlooked by the IPCC or that contain data, discussion or implications arguing against the dangerous global warming hypothesis. The report concludes that the IPCC has exaggerated the amount of warming likely to occur due to rising CO_2 concentrations and that whatever warming may occur will be harmless. Among the other conclusions of the NIPCC report [35]:

1. There has been no global warming for the past 16 years, even though CO_2 levels have risen eight per cent. Climate models clearly do not work.
2. We may soon experience global cooling due to changes in the brightness of the sun.
3. The global area of sea ice today is close to that first measured by satellites in 1979.
4. Sea-level rise is not accelerating.
5. There have been no significant changes in the magnitude or intensity of extreme weather events in the modern record.

The key question to be answered in the climate change debate is not whether climate change is real, or whether human activities have some impact. Both are obviously true. The real question is whether reputable science indicates that it is worth spending hundreds of billions of dollars to restructure our energy infrastructure to avoid a man-made climate catastrophe. Activists cite the reports of the IPCC to support an affirmative answer to this question. The new report of the NIPCC suggests the exact opposite is true [35].

GLOBAL CLIMATE KYOTO PROTOCOL

The Intergovernmental Panel on Climate Change, shared the 2007 Nobel Peace Prize with former USA Vice President Al Gore, The Kyoto Protocol expired by 2012. To state it in simple terms: “The world needs clean energy” for economical development. Thus action is needed because it is becoming increasingly convincing that we cannot exclusively depend on fossil fuels, because of their polluting effects, as well as their contributing to a possible ecological problem in terms of global warning caused by their carbon CO_2 emissions. Nowadays, fossil fuels provide an important 85 percent of all energy production worldwide. In addition, energy production powers economic growth.

Cutting down on fossil fuels usage will severely impair world economic growth. To discourage fossil fuels consumption, energy rationing administered by some international organization possessing inspection powers, or higher taxes, dubbed “carbon taxes” may have to be imposed.

Energy taxes high enough to stabilize the USA’s and other industrialized nations' fossil fuel consumption at the year 1990 level would raise gasoline prices by an average of 60 cents per gallon, and residential and commercial fuel prices by more than 50 percent.

This is called for by the Kyoto Global Climate Treaty, which was signed but not ratified by the USA in December of 1997. If ratified by a USA Senate vote, which seems doubtful, the USA would be obligated to cut greenhouse gas emissions by a factor of one third by the years 2008-2012, to below 1990 emission levels. The treaty would not impose limits on economically developing countries such as China and India.

The USA and other countries are not expected to be able to limit carbon emissions from fossil fuel plants as required by the Kyoto treaty. The energy related reductions by the USA required by the Kyoto agreement amount to 551 million metric tons of carbon. Electricity's share of the total is 37 percent or 219 million metric tons. This would require the unrealistic retirement of 150 base load fossil fuel power plants of 1,000 Megawatts Electric (MWe) each, operating at a capacity factor of 80 percent.

In the USA 25 cents per gallon gas tax hike is anticipated to force the green house emissions called for by the Kyoto Treaty. In energy intensive industries such as farming, incomes would be slashed by one quarter to one half as a result of expenses increasing by more than 10 billion dollars. Agricultural exports from the USA would suffer a 7 percent loss if the Kyoto protocol were implemented. Some alarming views even suggest that another half million people would be added to the unemployment and the food stamps rolls in the USA.

Consequently, there exists a staunch opposition in the USA against international bodies as exemplified by the rejection of global trade proposals at the World Trade Organization's (WTO) meeting in December of 1999 at Seattle, Washington in the USA. The opposition has brought together the normally opposing points of view groups of trade unions and environmental concerns.

CANCUN, MEXICO CLIMATE CONFERENCE

The Cancun climate conference attended by 194 countries, on December 10, 2010 reached a modest compromise preserving the UN's leadership in climate talks on a continuation of the 1997 Kyoto Protocol that expires in 2012, and on help to be paid by industrial nations to developing nations.

The countries most affected by global warming are to receive assistance from a "Green Climate Fund" agreed by nations in Cancun. Industrialized countries agreed to provide $30 billion by 2012, rising to $100 billion by 2020.

The Kyoto document explicitly refers to the calculations of the Intergovernmental Panel on Climate Change (IPCC) that calls on industrialized nations to reduce their CO_2 emissions by 25 to 40 percent. A decision on Kyoto can only be taken at the next climate conference at the end of 2011 in Durban, South Africa.

There will be a gap between the expiry of the first phase of the Kyoto Protocol at the end of 2012 and the start of the second phase, because it will take years for countries to ratify a successor treaty.

The USA and China, which top the list of the world's biggest CO_2 polluters, emerged as winners at the summit. If the Kyoto Protocol is extended at the Durban conference in 2011, China will continue to be spared from having to make binding commitments to cut its CO_2 emissions. The same applies to the USA, the only industrial country never to have ratified the Kyoto Protocol.

The Cancun deal includes a commitment to limit warming to less than 2 degrees Celsius or 3.6 Fahrenheit above pre-industrial times; a long-term goal that scientists have insisted is essential to avert the worst effects of climate change. That goal is not legally binding because nations only agreed to "take note" of it. The agreement contains no concrete targets for cuts in CO_2 emissions by 2050. There are no such goals for individual industrial sectors such as farming, aviation and maritime transport either.

The European Union, EU remains committed to cut its CO_2 emissions by 20 percent by 2020.

Figure 69. United Nations Climate Change Conference in Cancun, Mexico, December 10, 2010 was attended by 194 countries. Greenpeace' "Sinking Icons" dramatizes increased sea water levels. Photo: AFP.

CURRENT LEGAL FRAMEWORK

Regardless, a USA House of Representatives bill (H.R.2454), designated as "cap-and-trade," aims at reducing USA greenhouse gas emissions by 17 percent from 2005 levels by 2020 and by 83 percent by 2050. It allows the imposition of tariffs on carbon-intensive goods such as steel, cement, paper, and glass, if they are produced in countries the USA judges to be irresponsible in reducing greenhouse gas emissions. The large greenhouse gas emitters such as China, whose industrialization and growing use of coal recently pushed it to the top-spot in greenhouse emissions, and India catching up, are asked to curb their emissions. In doing so, they will be denied their aspirations to reach the same standard of living that the industrialized countries enjoy. The contradiction is noted by the developing nations, making the global accords on emissions unachievable.

On April 5, 2007, the USA Supreme Court ruled out that the USA Federal Government agencies such as the Environmental protection Agency (EPA) has the pervue to regulate CO_2 emissions which the court has officially deemed as a pollutant as a contributor to global warming. In the USA, by law, CO_2 emitting industries will be either forced to reduce their emissions, reducing their production and therefore income or offset them with certified carbon credits. A carbon credit or offset is a tradable permit providing a way to reduce greenhouse gas emissions by assigning them a monetary value. One credit or permit represents 1 ton of CO_2 removed from the atmosphere. A corporation purchasing carbon credits from other industries sequestering it on the open market for about $20 acquires the right to emit it.

The United Nations (UN) “Framework Convention on Climate Change” in Copenhagen, Denmark on December 7-18, 2009 ended with a non-binding accord limiting temperature rises to less than 2 degrees C, but no emission targets. It preserves the Kyoto Protocol. No details were given on how to provide funds to help affected developing nations in coping with the climate change: $30 billion from 2010-2012 and $100 billion per from 2020.

PARIS CLIMATE CHANGE AGREEMENT, 2016

The Paris climate change agreement was drawn up in December 2915, and was formally ratified by enough nation-states in October 2016. By November 4, 2016 it became binding for the countries that decided to sign up, which includes the USA, China, and the members of the European Union (EU). Those countries commit themselves to endeavor to reduce their fossil-fuel use in order to limit average global temperature rises to less than 2 °C above preindustrial levels.

Such a large-scale international agreement is difficult to engineer. The negotiations were difficult, but the agreement is considered as a beacon of hope for humankind, signaling that efforts will be made to mitigate the effects of climate change. Unprecedented reductions in greenhouse gas emissions and unequaled efforts to build societies that can resist rising climate impacts are expected.

A UN report warns that the emissions pledges put forward by the countries to date do not go far enough, suggesting that the emissions targets between now and 2030 will actually put the world on track to warm up by 3.4 °C by 2100. The report says that a further 25 percent reduction in emissions will be required to keep warming below the 2 °C limit.

A study published in Science magazine about the impact of the CO_2 gas on Arctic ice suggests that three square meters of ice are lost for every ton of carbon dioxide emitted. The addition of another 1,000 gigatons of carbon dioxide into the atmosphere—about the amount that can be emitted before temperature rises exceed 2 °C—would turn the Arctic ice-free during the summer. The Paris agreement is good news, but most scientists think that we are still a long way from where we need to be.

INSURANCE IMPLICATIONS

On October 17, 2012 the German reinsurance company Munich Re, which provides backup policies purchased by other insurance companies, issued a report titled: “Severe Weather in North America.” It asserts that, globally, the rate of extreme weather events is rising, and “nowhere in the world is the rising number of natural catastrophes more evident than in North America. From 1980 through 2011, weather disasters caused losses totaling $1.06 trillion.

Munich Re found: “A nearly quintupled number of weather-related loss events in North America for the past three decades.” By contrast, there was: “An increase factor of 4 in Asia, 2.5 in Africa, 2 in Europe, and 1.5 in South America.” Human-caused climate change “is believed to contribute to this trend, though it influences various perils in different ways.”

Global warming “particularly affects formation of heat waves, droughts, intense precipitation events, and in the long run most probably also tropical cyclone intensity.” July of 2012 was the hottest month recorded in the USA since record-keeping began in 1895, according to the National Oceanic and Atmospheric Administration. The USA Drought Monitor reported that two-thirds of the continental USA suffered drought conditions in the summer of 2012.

In the book: “The Conundrum,” David Owen, a staff writer at the New Yorker, contends that as long as the West places high and unquestioning value on economic growth and consumer gratification, with China and the rest of the developing world following right behind, the world will continue to burn the fossil fuels whose emissions trap heat in the atmosphere. According to David Owen, solutions such as fast trains, hybrid cars, compact fluorescent light bulbs, and carbon offsets are insufficient.

SENSITIVITY FACTOR AND FEEDBACK MECHANISMS

Climate models relate a “Forcing” or power flux in Watts/m^2 to an equilibrium temperature change, ΔT, through the relation:

$$\Delta T = S \times Forcing \ [Kelvin] \tag{25}$$

where: S is the sensitivity in Kelvin/(W/m^2).

The amount of CO_2 in the atmosphere is easily measured and well understood. The forcing that results from this through the greenhouse effect is also well understood.

What is not fully understood is the sensitivity factor S. It requires a lot of complex modeling of the response of Earth including the feedback mechanisms.

Some positive feedbacks increase the value of S and some negative feedbacks decrease S.

A positive feedback example is that a warmer Earth leads to less ice formation, hence more sunlight absorbed and consequently a warmer Earth.

The negative feedbacks include the complicated water system, since H_2O is a potent greenhouse gas, but also causes clouds formation reflecting sunlight.

The increase in the Earth's temperature is simply lower than that predicted by the known CO_2 increases and the IPCC estimates of the sensitivity factor S. The “best value” from the IPCC shows a sensitivity that is just short of 3 times more sensitive than simple black-body radiation would indicate. The Earth has actually acted close to a simple black-body radiator; suggesting that the assumption of the existence of positive feedbacks may be inaccurate.

SEA LEVEL RISE AND DECREASE

The sea level currently rises globally by about 3 mm or 0.1 inch per year on average. A number of factors contribute to this rise, including water from melting glaciers and the constant increase in the amount of ground water used in agriculture. It is also partly due to a simple thermal effect: Because water expands as it gets warmer, rising temperatures cause the sea level to rise. All of this will accelerate even further by the end of the century, leading to a total increase of 1 meter, according to the current consensus among oceanographers.

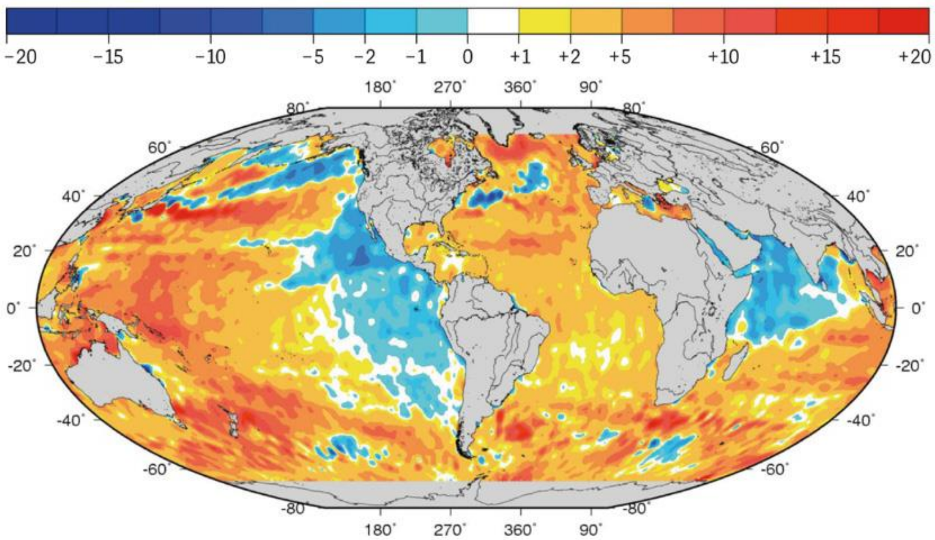


Figure 70. Average change in sea level over the period 1993-2005 in mm / year. Source: Laboratoire d’études en Géophysique et Océanographie Spatiales, LEGOS and Centre National d’études Spatiales, CNES.

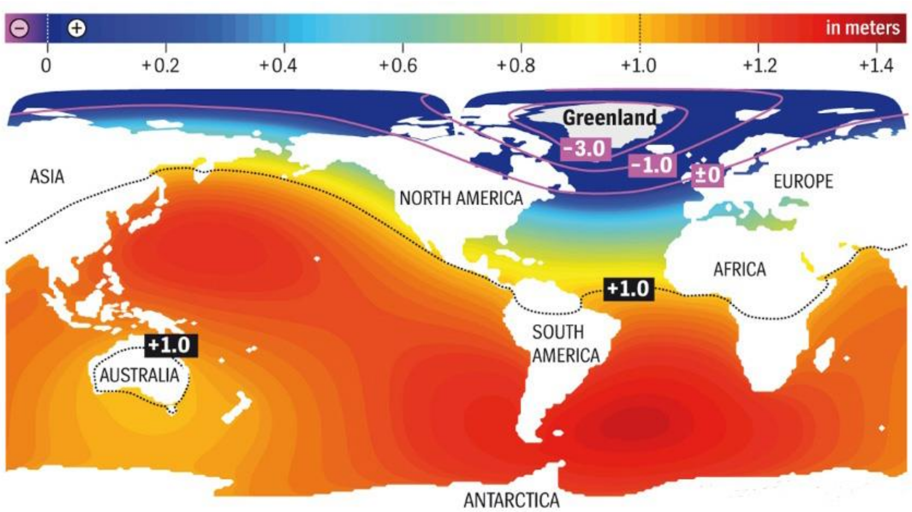


Figure 71. Simulation of a melting of the Greenland ice sheet reveals that an average rise in the global sea level would ensue in the next 100 years. Some regions would undergo a rise and other regions would see a decrease. Source: Climatic Change 103/2010, Der Spiegel.

Climate change is expected to cause sea levels to rise in some parts of the world. In other parts, the level of the ocean will fall.

The Earth is not round and smooth, the water in the oceans wobbles all over the place with large scale bulges and bumps in the sea level. In the Indian Ocean, the sea level is about 100 meters or 330 feet below the average, while the waters around Iceland are 60 meters above the average.

The rising sea level is widely viewed as the most threatening consequence of global warming. The sea level is expected to rise by about 1 meter or 3.28 feet on average in the next 100 years as revealed This is the number that will be mentioned again and again during negotiations at the United Nations Climate Change Conference in Cancun, Mexico in December 2010.

As the total amount of liquid in the oceans is increasing, the way water expands in ocean basins differs widely. There will be regions of the world where nothing much will change, while the sea level will rise by well over the 1-meter average in others.

The degree to which glaciers will melt as a result of rising temperatures is not exactly known. The most important consideration is the rate at which the Greenland and Antarctic ice sheets shrink. It appears that the net amount of melt water is still rising in Greenland. It is currently at 237 cubic kilometers or 57 cubic miles per year. The volume of ice at the South Pole seems to be generally stable. The ice is melting in western Antarctica, but in the larger eastern part, snow is actually building up.

Regional effects are partly influenced by winds and currents, with gravity and the laws of thermodynamics also playing an important role. Making sense of how all of these factors are interrelated requires a relatively solid understanding of the individual processes and a massive computing power to perform the calculations.

In late December 1992, a satellite was placed into Earth orbit that uses a radar altimeter to measure the sea level, to within a few centimeters, anywhere in the oceans. The data from the orbiting satellite produced surprises for scientists in recent years. For instance, while seas have risen by about 15 centimeters in the tropical Western Pacific, the ocean near San Francisco has fallen by about the same amount. On the German coast, on the other hand, the sea level today is a few centimeters higher than it was 15 years ago.

Such regional effects are the result of natural fluctuations that unfold over decades. The currents in the world's oceans are constantly shifting. This applies to the Gulf Stream, which provides Europe with warm water, just as it does to the Pacific circulation system, which reacts to the moods of El Niño.

If the Greenland ice sheet, which is 3 kilometers or 1.88 miles thick in some places, were to melt completely, sea levels would rise by 7 meters on average. It would take many centuries before the 3 million cubic kilometers of glaciers ended up in the ocean. Humans living near Germany's North Sea coast would hardly even notice, because the sea level there would remain virtually unchanged. The water would even subside off the coast of Norway. Theoretically, the sea level would actually fall by several meters off the coast of Greenland.

This striking effect is based on the law of gravity, which states that every mass attracts every other mass. Water levels are higher off the coast of Iceland for the same reason. Volcanic activity pushes heavy masses of rock out of the Earth's interior, and those masses attract water like magnets. By contrast, sea levels are lower in the Indian Ocean because, eons ago, a meteorite most probably knocked so much rock out of the Earth's crust there that the gravitational force attracting water was reduced.

If the Greenland ice sheet shrinks, the island will lose mass and, along with it, gravitational force. As a result, much less water will accumulate off the island's shores than today. To a lesser extent, the same effect is present in the oceans of almost the entire northern hemisphere, including the North Sea.

New York would also not get the full amount of the 7 meter sea level rise, but only half of it. North of a line that passes from Newfoundland through the Atlantic and the North Sea, the sea level would fall.

On the opposite side, the nations bordering the entire Indian Ocean and the Pacific, as well as the countries of South America and Africa, would be the true victims of a global rise in sea levels. In those regions, the oceans would not just rise by the average of 7 meters, but by as much as 8 or even 10 meters.

Conversely, if the Antarctic lost ice mass, the effects would be felt more strongly by coastal residents in the northern hemisphere. To a certain extent, the two effects in the far north and the far south could offset each other. If the Arctic and the Antarctic thawed at the same rate, the region in the middle would be the most severely affected.

Scientists at Princeton University recently published a model-based calculation of rising sea levels in the journal Climate Change. The model also includes effects that result from geophysical force, namely the effect that the Earth's rotation has on sea levels.

Sea levels are also affected by winds and currents, which are themselves changing as a result of anthropogenic climate change. This is the real challenge for oceanographers.

In Serious Trouble

Or the atolls in the tropical Pacific, which are barely a meter above sea level, everything depends on the future development of the El Niño phenomenon. Polynesia had to cope with a sea-level rise of up to 15 centimeters in only four years, from 1996 to 2000. This exceeds the rise caused by global warming by almost a factor of 10. If El Niño gets stronger, the Pacific islands could be submerged.

The critical phenomenon for Western Europe is the Gulf Stream, which is part of the massive trans-Atlantic circulation system. Like a pump, it pushes masses of water northward, where they sink into the depths of the northern ocean. This is why the sea level is a meter lower in the northern part of the Gulf Stream than in the south.

This gradient shifts when the Gulf Stream changes its position, which it does as part of a completely natural cycle. This explains why the sea level in the Labrador Sea off the eastern coast of Canada rose by 8 centimeters between 1993 and 1998. Then the rising trend stopped and was reversed.

There is a fear that this delicate balance could tip during a warmer future on Earth. The computer models predict that the Gulf Stream will weaken by about 25 percent. This could cause the sea level to rise by about 20 centimeters in the North Sea.

Europeans need to keep an eye on the possibility of a significant shift in the prevailing wind directions which could mean low-pressure troughs over the North Atlantic.

This is where the precision of the climate predictions model reaches its limits. Any risk estimate is associated with uncertainty which also applies to the rise in sea levels models.

According to the principle of foresight humanity should prepare itself for unpleasant surprises. Despite the many unanswered questions, there is one thing scientists know for certain: The land along the German Bight is sinking by a millimeter a year. That effectively means a 1-millimeter increase in sea level along the coast every year. This phenomenon is also attributable to climate change, but in this case humans are not at fault. Because the massive weight of the Ice Age glaciers is no longer pushing down on

Scandinavia, the land there is rising. Farther south, just like on the opposite end of a seesaw, the land is sinking.

WARMING AND INCREASED ACIDITY OF THE OCEANS, MARINE LIFE

The global emissions of CO_2 affect the temperature and acidity of the oceans, possibly affecting marine life. According to a report by the UN Environmental Program (UNEP), the chemistry of the oceans is changing at a rate unseen for 65 million years. Should the rate of change continue unaltered, our oceans could be 150 percent more acidic by the end of this century.

Oceans absorb 1/4 percent of global CO_2 emissions, but once they do so, the carbon dioxide is transformed into carbonic acid, which accounts for a precipitous fall in the pH or acidity levels. The change may harm many shell-building organisms at the bottom of the food chain such as crabs and oysters.

The impact of the oceans' acidification affects organisms and on some key ecosystems that help provide food for billions of humans. An increase in acidification could have a significant effect on coral reefs, which provide a home for 1/4 of all marine species and provide food and jobs to some 500 million people around the world.

It is not just global warming that is damaging fish stocks in the oceans. The total global catch quintupled between 1950 and 1987, primarily the result of a rapid and expansive increase in fishing grounds. Even though the expansion has slowed and the total catch has leveled off, and even dropped slightly from the peak of 90 million tons per year.

One third of the world's oceans and 2/3 of coastal waters are presently exploited, with the only frontiers left being relatively unproductive waters on the high seas and the coastal regions of the Arctic and Antarctic; both difficult to access. If fish is going to remain a major part of the global diet, sustainable methods must be rapidly introduced to counteract the natural limits that may now have been reached.

The observed decline in spatial expansion since the mid-1990s is not a reflection of successful conservation efforts but rather an indication that humanity has run out of room to expand fisheries.

The era of expansion has ended, and to maintain the current supply of wild fish is not sustainable.

Figure 72. Warming coastal waters could be harmful to coral reefs. The rising acidity could affect the creatures that build the reefs. Photo: Reuters.

CIRCADIAN CYCLES OF PLANTS AND ANIMALS

Plants and animals may have to reset their circadian clocks to keep up with climate change. Organisms that rely on several cues besides daylight to regulate their behavior will have the advantage. For mammals in the wild, daylight appears to be a stronger regulator than previously thought.

Day length regulates many behaviors such as breeding and migration. This enables animals' circadian rhythms to match up with the long-term patterns of the Earth's ecosystems. Evolutionarily, this helped species to survive through erratic weather patterns, as they would avoid deadly mistakes like migrating north during a warm spell in January, only to find no food and die when the weather turns cold again.

With global climate change rapidly impacting seasonal plant growth, now the evolutionary benefits of relying on day-length cycles may backfire.

Animals may miss events such as the peak growing season of important foods. Animal's response to day length may be hard-wired as part of their nature, making it more difficult to adapt to changes in the growing seasons.

Hormones influence yearly behavior changes, and the exact chemical pathways involved are triggered by day length. A molecular pathway links the circadian clock to the evolution of seasonal timing in mammals. This means global warming may have dire effects on animals that evolved around certain yearly cycles.

Research focused on the chemical signals that trigger mating behavior in Soay sheep living wild on Saint Kilda Island in the north Atlantic. The changes in the expression of the genes coding for a hormone, thyrotrophin β, in the sheep's pituitary gland as day length changed were monitored. The production of thyrotrophin β was regulated by two other chemicals, “eyes absent 3” (Eya 3) and thyrotroph embryonic factor.

Day length affected the production of those two chemicals because their production was regulated by the secretion of melatonin from the pineal gland, which was regulated by exposure to sunlight. Melatonin levels caused the production of Eya3 to peak 12 hours after nightfall.

The effect was a strong peak in Eya3 levels in the morning during times of the year with long days. This then served as the trigger for thyrotrophin β and the behaviors associated with it.

Many mammals and birds use similar chemicals to perform similar functions, and hence may have the same interaction with seasonal day length changes.

CLIMATE CHANGE JURISPRUDENCE, TUVALU ISLAND DISSAPPEARANCE

Figure 73. Main Island of Funafati, Tuvalu.

International legal experts are discovering climate change law, and the Pacific island nation of Tuvalu which has 11,000 inhabitants is a case in point: The Polynesian archipelago is doomed to disappear beneath the ocean. Lawyers are asking what sort of rights citizens have when their homeland no longer exists.

The group of islands lies just 10 centimeters or 4 inches above sea level; if the average sea level continues to rise, in just 50 years there will be nothing here but waves.

Some of the islands are already uninhabitable; the ocean nibbles at the narrow landmass from all sides. Nine islands totaling just 26 square kilometers or 10 square miles in area make up the 4th smallest country in the world.

Environmentalists have long worried about the fate of this tiny Pacific state. Now, however, international legal experts have also taken up the topic of its imminent demise. A nation's “territorial integrity” is one of the paramount legal principles. It is unprecedented, however, for a country to completely lose its territory without the use of military force.

Over 3,000 Tuvaluans have already left their homeland; the largest exile community is in Auckland, New Zealand. In the meantime, however, refugees are increasingly knocking on locked doors, particularly in nearby Australia, where immigration has long been an election issue.

A gradual withdrawal of the ocean refugees via a special certification scheme as proposed by the German federal government is hardly feasible. The term climate refugee is itself full of inconsistencies. Under the Geneva Convention, climate damage is not a basis for humanitarian asylum. The United Nations Declaration of Human Rights does not guarantee a basic right to a sound environment.

For a long time legal academics had categorically rejected the notion that a country like Tuvalu could claim damages for its devastated environment; it would be impossible to name the guilty party.

A growing number of lawyers have come to consider such claims legitimate. The State of California initiated a case against major automakers is an indication of the future of climate change in jurisprudence, even though that case only deals with national, as opposed to international, law.

Some experts now believe changes will have to be made to international law to deal with the impact of climate change. Other small island nations like Kirabati, the Marshall Islands and the Maldives are also concerned about their future.

PERMAFROST RELEASE OF CARBON

About one quarter of the Northern Hemisphere's landmass is frozen as “permafrost,” holding 1,700 giga (10^9) tonnes of carbon. This results from generations of flora and fauna that lived then died in the area over millions of years. A portion of those dead plants and animals were not decomposed by microorganisms because it was too cold for the decomposition process to occur. This permafrost is slowly melting. If large areas of permafrost were to thaw one day, the bacterial decomposition process would pick up where it left off, releasing substantial amounts of greenhouse gases. Permafrost contains twice as much carbon as what is currently released into the Earth's atmosphere. As a result of such release, the world's climate would suffer serious consequences. The question of just how strongly global warming affects the permafrost areas is being asked.

Figure 74. Thawing permafrost at Alaska’s Noatak National Preserve. Photo: Edward

Schuur, University of Florida.

A study published in the Science journal suggests that it is possible that even slightly higher temperatures could thaw out significant portions of the global permafrost areas. Researchers led by Anton Vaks at the University of Oxford examined calcareous deposits from a total of six Siberian caves. They looked at “speleothems,” which are mineral deposits including stalactites and stalagmites that form in limestone and other caves. Speleothems only grow when rain and melt water can seep through cracks into the caves. This process only occurs when temperatures are above the freezing point. Since water from the frozen Earth cannot reach cracks deep within the caves, the mineral deposits constitute a precise records of the climate. In the warmer times of interglacial periods, stalactites and stalagmites form. In the colder phases of glacial periods, they do not. This results in a pattern similar to how tree rings can be used to tell their age.

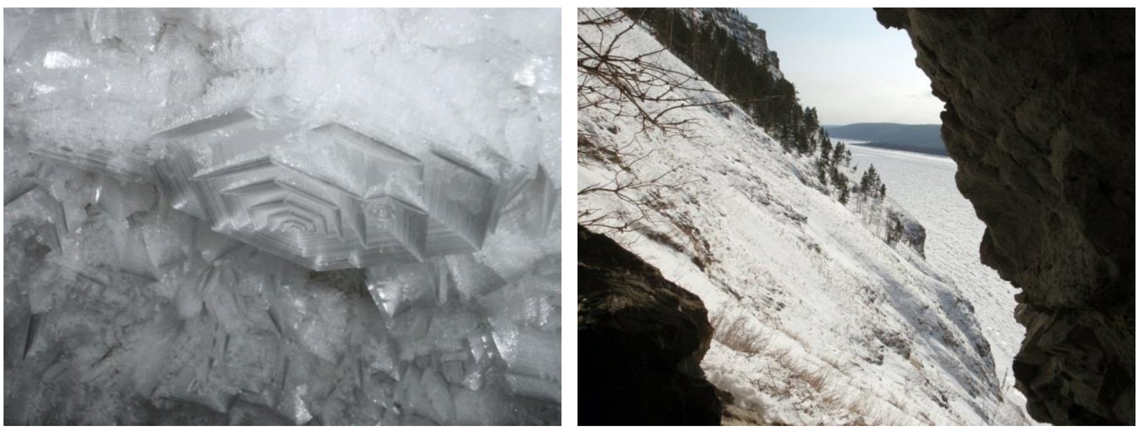


Figure 75. Speleothems frost crystals in the Lenskaya Ledyanya Cave on the Lena River, Siberia. Photos: Anton Vaks

A total of 36 speleothems were dated using the uranium-thorium radioactive dating method. Over time, uranium decays into thorium. The uranium isotopes dissolve in water that penetrates into the speleothems, while thorium does not, and thus remains in the deposits. The dating process can look back about 500,000 years into the past. Speleothems in today's permafrost areas must have come from a significantly warmer period in which water was flowing. Stalactites in the northern latitude Lenskaya Ledyanaya Cave only grew in a very warm part of an interglacial period about 400,000 years ago. At that time, the average temperatures were about 1.5 degrees Celsius higher than they are today. Traces of this particularly warm period were also proven with pollen deposits and residue of algae found in the sediment of the Elgygytgyn Lake, in northeastern Siberia, as well as from other sources. During this time, there were probably even numerous trees in southern Greenland.

In periods with higher temperatures, the permafrost retreated farther north. The Lenskaya Ledyanaya Cave lies at a 40 degrees north in latitude, in an area currently on the border of the continuous permafrost. If the temperatures rise another one or two degrees, to approach something like what they were in the interglacial period 400,000 years ago, the situation could reach the threshold where the continuous permafrost becomes vulnerable.

The frozen permafrost varies in thickness from a few of meters to 1.5 kilometers, depending on the area. A large portion of the permafrost areas lie farther north than was studied so far, with parts on the oceans' floor.

AN INCONVENIENT TRUTH

Previous USA vice president Al Gore presented in 2006 a documentary based on a speech that he developed over six years: "An Inconvenient Truth," in which he made the following points:

1. Global warming is real,
2. It is caused by human activity,
3. Mankind and its governments must begin immediate action to halt and reverse it.

He was granted a Nobel Prize in 2007 for this effort.

He contends that if nothing is done, in about 10 years the planet may reach a tipping point after which it would be too late for any action and begin to slide toward destruction of civilization and most of the other species on the planet.

He presents as evidence statistics suggesting that the 10 warmest years in history were in the last 14 years. In 2005 South America experienced its first hurricane. Japan and the Pacific were setting new records for typhoons. Hurricane Katrina in 2005 passed over Florida, doubled back over the Gulf of Mexico, picked up strength from unusually warm waters, and increased in strength from a category 1 hurricane to a category 5 one causing extensive damage. Changes were occurring to the Gulf Stream and in the jet stream.

Polar ice cores were showing that the CO_2 concentration is now much larger than in the last 250,000 years. He suggested that in the past this happened in cycles, but that today it is increasing exponentially.

He accuses the energy industry of launching a disinformation campaign since the 1990s to "reposition global warming as a debate," the same strategy used for years by the defenders of tobacco use. Al Gore asserts: "The world won't end overnight in 10 years. But a point will have been passed, and there will be an irreversible slide into destruction."

ECONOMIC IMPACT OF METHANE RELEASE FROM THAWING PERMAFROST AND OCEAN CLATHRATES

Permafrost is melting in Antarctica where ground ice in the McMurdo Dry Valley Regions has accelerated consistently between 2001 and 2012, rising to about ten times the historical average. Rising temperatures do not account for this increased melting but they can be attributed to an increase in sunlight caused by changes in weather patterns [31].

Using an economic model similar to one used by Lord Stern in his 2006 review of the economics of climate change, Prof. Gail Whiteman at Erasmus University in the Netherlands and coworkers examined the impact of the release of 50 giga-tonnes of methane over a decade to the atmosphere. The release of large amounts of methane from thawing permafrost in the Arctic could have a large economic impact of about $60 trillion or £39 trillion, roughly the size of the global economy in 2012. This would be caused by the increased climate impacts such as flooding, sea level rise, damage to agriculture and human health, primarily affecting developing regions of the world [31].

Large amounts of methane are concentrated in the frozen Arctic tundra but are also found as semi-solid gas hydrates under the sea. Hydrates or clathrates are a frozen mixture of water and gas, primarily methane accumulated under the high pressure of the bottom of the oceans. The CH_4 molecules reside inside a water molecule lattice. The methane will ignite in ice form, suggesting the "fire ice" moniker. They are a potential source of energy since they burn if extracted to atmospheric pressure. If released uncontrollably, their methane addition to the atmosphere is a potential greenhouse gas. Methane is a powerful greenhouse gas, but lasts less than a decade in the Earth's atmosphere.

Figure 76. Clathrates or methane hydrates from the bottom of the oceans. The methane will ignite in ice form, hence the "fire ice" moniker. Source: USGS.

A diminishing ice cover in the East Siberian Sea is allowing the waters to warm and the methane to leach out. Plumes of the gas up to a kilometer in diameter were observed rising from these waters. Up to 30 percent of the world's undiscovered gas and 13 percent of undiscovered petroleum lie under the oceans. Transport companies are looking to send increasing numbers of ships through the fast melting seas. According to Lloyds of London, investment in the Arctic could reach $100 billion within ten years.

The benefits would be a fraction of the likely costs of a large scale methane emission. The release of methane on this scale could bring forward the date when global temperatures increase by 2 degrees C by between 15 and 35 years. In fact, the Metop satellite, suggests that methane in the atmosphere has gone up significantly and the place where the increase is happening most is over the Arctic Ocean [31].

CLIMATE SHIFT RELATION TO HUMAN VIOLENCE

In a review of 60 studies on how climate change helps spark conflict throughout the world, the researchers found a surprisingly close link between climate change and civil wars, riots, invasions and even personal violence such as murder, assault and rape. Rising temperatures are especially provocative. A shift toward greater warmth of one standard deviation caused personal violence to increase by 2.5 percent and intergroup conflict by 24 percent.

One can consider how subsistence farmers could come into greater conflict with one another as their croplands become less productive. In the face of rising sea levels, coastal dwellers could come to blows over shrinking habitable land. Many psychological and economic studies show that people behave more aggressively or violently when temperatures are higher.

Small changes in temperature or rainfall may correlate with a rise in assaults, rapes and murders, as well as group conflicts and war. In a study published in Science, Marshall Burke, from the University of California, Berkeley, said: "This is a relationship we observe across time and across all major continents around the world. The relationship we find between these climate variables and conflict outcomes are often very large."

The researchers looked at 60 studies from around the world, with data spanning hundreds of years. They report a "substantial" correlation between climate and conflict. Their examples include an increase in domestic violence in India during recent droughts, and a spike in assaults, rapes and murders during heat waves in the USA.

The report also suggests rising temperatures correlated with larger conflicts, including ethnic clashes in Europe and civil wars in Africa. "One of the main mechanisms that seems to be at play is changes in economic conditions. We know that climate affects economic conditions around the world, particularly agrarian parts of the world. "There is lots of evidence that changes in economic conditions affect people's decisions about whether or not to join a rebellion, for example."

There could also be a physiological basis, because some studies suggest that heat causes people to be prone to aggression. "It is a major priority for future research to distinguish between what is going on in each particular situation." The scientists say that with the current projected levels of climate change the world is likely to become a more violent place. They estimate that a 2 ^{o}C (3.6 ^{o}F) rise in global temperature could see personal crimes increase by about 15 percent, and group conflicts rise by more than 50 percent in some regions.

Commenting on the research, Dr Stephan Harrison from the University of Exeter said it was a "timely study". "What they have found is entirely plausible... For example, we already know that hotter and drier weather causes an increase in urban violence. Likewise, during cooler and wetter weather people tend to stay indoors, and the threat diminishes."

However, other researchers have questioned whether climate breeds conflict. Work published in the Proceedings of the National Academy of Sciences suggested that this environmental factor was not to blame for civil war in Africa. Instead, Dr Halvard Buhaug, from the Peace Research Institute Oslo, Norway, concluded that the conflict was linked to other factors such as high infant mortality, proximity to international borders and high local population density. Commenting on the latest research, he said: "I disagree with the sweeping conclusion (the authors) draw and believe that their strong statement about a general causal link between climate and conflict is unwarranted by the empirical analysis that they provide. "I was surprised to see not a single reference to a real-world conflict that plausibly would not have occurred in the absence of observed climatic extremes. If the authors wish to claim a strong causal link, providing some form of case validation is critical."

TROPICAL CYCLONES SHIFT

A paper: “The Poleward Migration of the Location of Tropical Cyclone Maximum Intensity,” co-authored by Emanuel, James P. Kossin of the University of Wisconsin, and Gabriel A. Vecchi of the National Oceanic and Atmospheric Administration (NOAA), published in the journal Nature shows that tropical cyclones, also referred to as hurricanes or typhoons, are moving poleward at a rate of about 33 miles per decade in the Northern Hemisphere and 38 miles per decade in the Southern Hemisphere. They are reaching their peak intensity farther from the equator and closer to the poles. The trend is statistically significant at a high level [38].

The thermodynamically favorable conditions for these storms are migrating poleward. Since the movement of peak intensity means regions further north and south of the equator, which have not previously had to face many landfalls by violent cyclones, may now have greater exposure to these extreme weather events.

The scientists used international data from 1982 to 2012, collected by NOAA's National Climactic Data Center. They used the location of peak intensity of cyclones as a benchmark because it is a more consistent metric than statistics such as storm duration. The duration can be harder to estimate because of difficulties in establishing precisely when a storm should first be considered a tropical cyclone.

There are regional differences in the poleward movement of cyclones. Every ocean basin other than the northern Indian Ocean has experienced this change leads the researchers to suggest, in the paper, that this "migration away from the tropics is a global phenomenon."

It is possible that this is connected to independently observed poleward expansion of the Hadley circulation; a large-scale pattern of global winds, which in recent years has also moved further poleward. The paper notes the potential impact of vertical wind shear, which inhibits cyclone formation; data suggests a decrease in wind shear in the tropics and an increase at higher latitudes.

The incidence of cyclones in the tropics has actually diminished because while tropical cyclones may become more intense in a warmer climate, it is actually more difficult to generate them. Ocean temperatures between 82 and 86 degrees Fahrenheit seem to be ideal for the genesis of tropical cyclones. This belt migrates poleward as the whole ocean warms, the tropical cyclone genesis regions might just move with it.

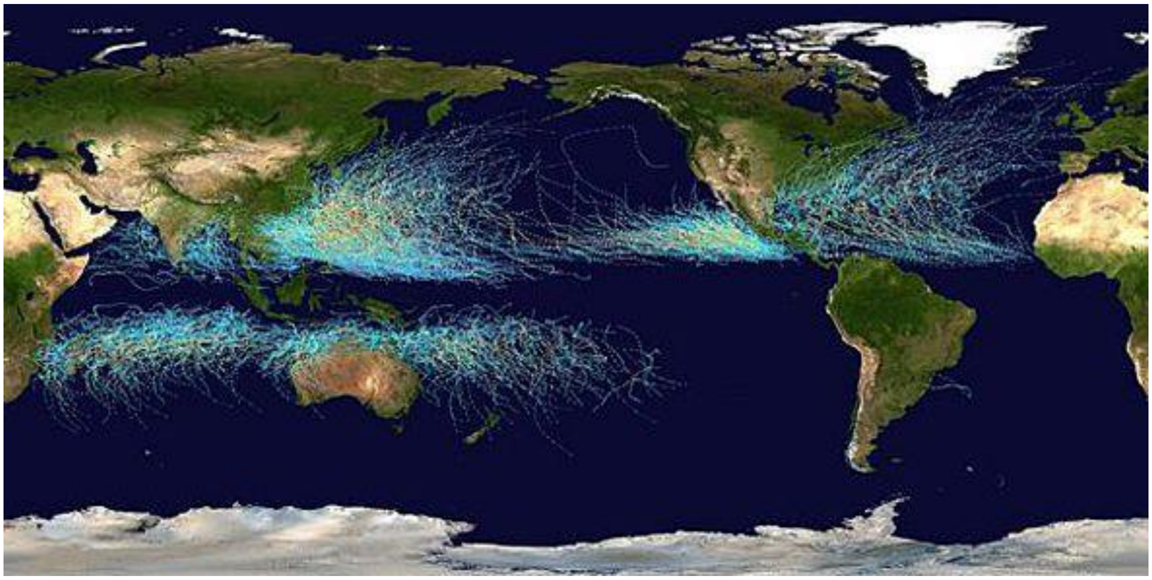


Figure 77. Tropical cyclones, the broader name for hurricanes, typhoons and tropical storms tracks 1985-2005. Source: NASA.

MICROBIAL MASS EXTINCTION, 250 MILLION YEARS BEFORE PRESENT

A study by Geophysics professors Daniel Rothman and Gregory Fournier of Massachusetts Institute of Technology (MIT) and five other researchers at MIT and in China published in the Journal Proceedings of the National Academy of Science suggests that it was neither asteroids impacts nor volcanic eruptions, but methane-producing microbes that were the perpetrators of the largest of the Earth's five known mass extinctions. Microbes were one of the biggest events in the history of Earth as they wiped out 90 per cent of the planet's species 252 million years ago [37].

The methane CH_4-producing microbes called Methanosarcina bloomed explosively in the oceans and churned out heavy amounts of methane into the atmosphere and dramatically changed the chemical composition of the oceans. This is attributed to their ability to use a rich source of organic carbon required for their growth. Three sets of evidence are advanced [37]:

1. Geochemical evidence shows an exponential rise of CO_2 in the oceans at the time of the mass extinction event.
2. Genetic evidence shows a change in the Methanosarcina bacteria at that time. This allowed it to become a major producer of methane from an accumulation of organic carbon in the water.
3. Sediments show a sudden increase in the amount of nickel deposited at exactly this time.

The carbon deposits show that something caused a significant uptick in the amount of the carbon-containing gases CO_2 and CH_4 produced at the time of the mass extinction. A rapid initial injection of CO_2 from a volcano would be followed by a gradual decrease. Instead, the opposite is observed: a rapid, continuing increase that suggests a microbial expansion. The growth of microbial populations is among the few phenomena capable of increasing carbon production exponentially [37].

AREAS MOST SUSCEPTIBLE TO CLIMATE CHANGE

The Wildlife Conservation Society (WCS), the University of Queensland, and Stanford University have come up with a world map that classifies the planet's countries based on how vulnerable they are to climate change. The new world map is part of a study that appeared in the journal Nature Climate Change. It shows that South and southeastern Asia, western and central Europe, eastern South America and southern Australia are the most vulnerable regions in the world. On the other hand, North and south-western Africa, Northern Australia and Southern South America are shown to be the least vulnerable regions in the world [34].

The map is created using data from the world's ecosystems and predictions of how climate change will impact them, is expected to help governments, environmental agencies and donors identify regions that would be best served by investments in programs such as the creation of protected areas, restoration efforts and other conservation activities.

Climate change is going to impact ecosystems both directly and indirectly in a variety of ways and we cannot keep on assuming that all adaptation actions are suitable everywhere. Ecosystems with highly intact vegetation and high relative climate stability are the best locations for future protected areas, as these regions have the best chance of retaining species. In contrast, ecosystems with low levels of vegetation and high relative climate stability could merit efforts at habitat restoration. Ecosystems with low levels of vegetation and low climate stability would be the areas most susceptible to climate change. These regions would require significant levels of investment to achieve the desired results from conservation efforts. Effective conservation strategies must anticipate not only how species and habitats will cope with future climate change, but how humans will respond to these challenges.

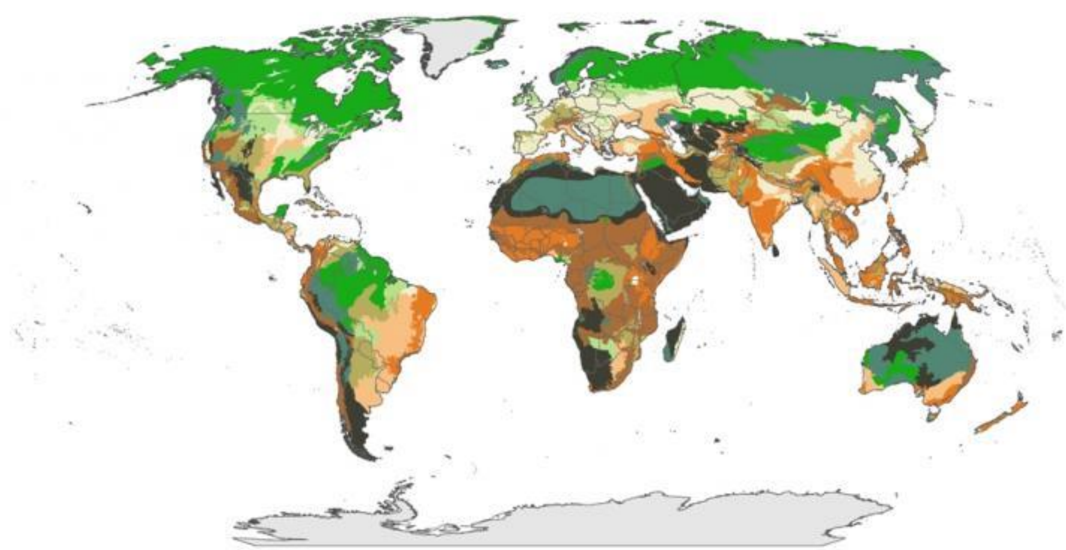


Figure 78. Ecoregions with both high climate stability and vegetation intactness are dark

grey. Ecoregions with high climate stability but low levels of vegetation intactness are dark orange. Ecoregions with low climate stability but high vegetation intactness are dark green. Ecoregions that have both low climate stability and low levels of vegetation intactness are pale cream. Source: Wildlife Conservation Society (WCS).

DISINTEGRATION OF WESTERN ANTARTICA'S ICE SHELF

The floating ice that dot the coast of Antarctica have been thinning and doing so at an increasing rate, in part because of global climatic change with implications for significant sea level rise:

The ice shelves which may be larger in extent than the state of California in the USA, and tens to hundreds of yards thick, are the linchpins of the Antarctic ice sheet system, holding back the millions of cubic miles of ice contained in the glaciers that flow into them, like doorstops. As the ice sheets thin, the massive rivers of ice behind them can surge forward into the sea [39].

"Antarctica holds enough ice, if it all melted, to raise sea levels more than 200 feet. That would take hundreds to thousands of years, but the recent thinning of the ice shelves means that there has already been an increase in the rate of Antarctica's contribution to sea level rise, and it is accelerating" [39].

The melting of ice shelves or the breaking off of icebergs aren't themselves signs of climate change. They're natural processes that help keep the mass of a glacier in balance: Snow that falls in the continent's interior adds ice to the glacier, while ice shelf melt and iceberg calving keep the glacier in balance by losing about the same amount of ice that is added. The problem comes when the ice shelves lose more mass than the glaciers are gaining. The massive ice shelves were losing, on the whole, about 30 to 50 cubic miles of ice per year over that span. And in that period, the rate of ice loss accelerated by an average of 7 cubic miles per year [39].

Much more ice loss in West Antarctica than East Antarctica and for particular glaciers in the west. West Antarctica has been a major focus of south polar climate research, in part because of the clear signs of melt there as well as some spectacular ice shelf collapses in recent decades [39].

Half of the continent has seen a 70 percent increase in its average rate of loss from ice shelves from 1994 to 2012 according to satellites data. The Amundsen and Bellingshausen sea areas had particularly high rates of loss; while the two regions account for less than 20 percent of West Antarctica's ice shelf area, they contributed more than 85 percent of the volume lost there over the study period. One particular glacier in the Amundsen embayment lost 18 percent of its thickness over the 18 years of study [39].

East Antarctica has until recently been thought to be more stable, as its glaciers rest on land that is above sea level and the waters surrounding it are thought to be cooler. Recent research has showed that there is still much to learn about the susceptibility of the glaciers in East Antarctica, which holds much more ice than the west. Totten Glacier was recently shown to have channels in the seabed beneath it that would make it much more vulnerable to an influx of warm water than previously thought, though such warm water has not yet been detected there [39].

In West Antarctica, it is thought that most of the thinning is caused by warm waters that are eating away at the ice shelves from below, a consequence of changes in prevailing winds that is potentially linked to global warming. The characteristic signature of this kind of melt, which happens at what is called the grounding line, or the point where the glacier last touches land and the ice shelf begins. Other recent studies examining glaciers have also bolstered this idea, and have even suggested that some glaciers in West Antarctica have reached a point where their retreat and melt is now irreversible [39].

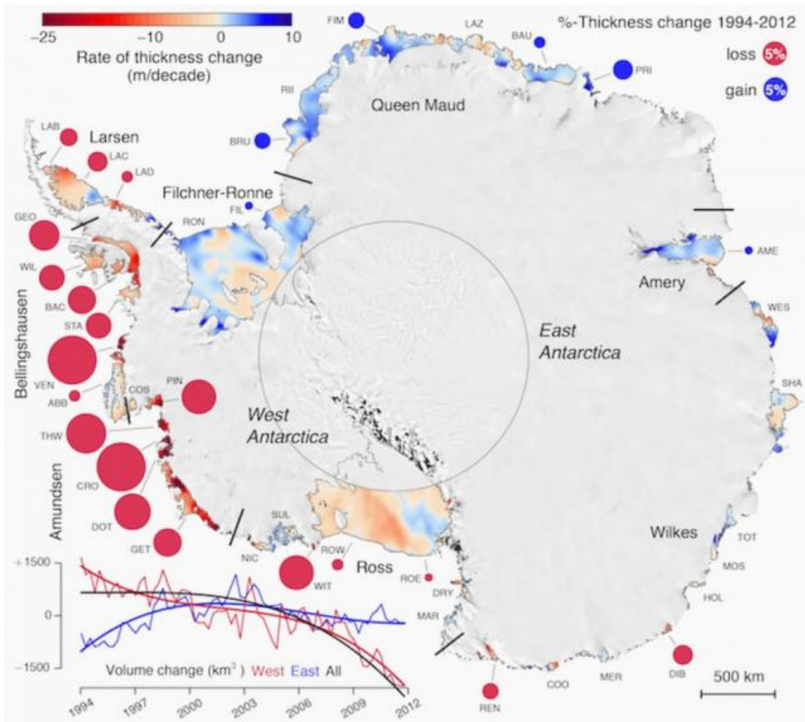


Figure 79. Loss of Western Antartica's ice shelf from 1994-2012. Paolo and Fricker, Science, March 27, 2015 [39].

EFFECT ON JET STREAM

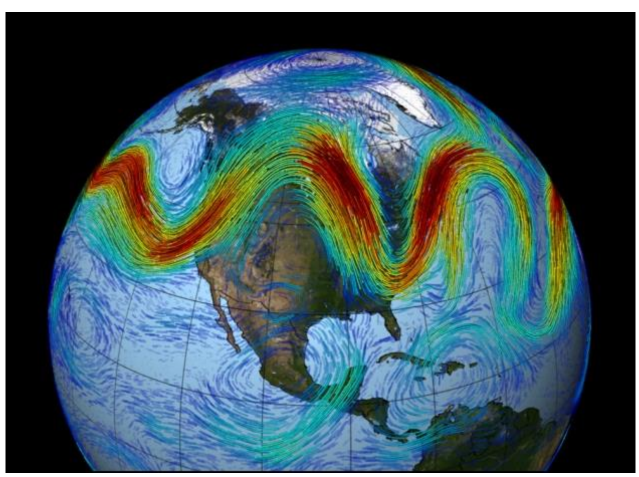


Figure 80. Effect of Arctic warming on looping of the jet stream. Source: NASA.

The jet stream is a powerful, high-altitude circulation system that carries weather around the Northern Hemisphere. The main fuel behind it is the difference in temperature between the Arctic and the warmer regions to the south. Rutgers University climate scientist Jennifer Francis suggests that the warming Arctic is causing the jet stream to slow down, gets loopier, which causes large masses of frigid air slip south. When the Arctic is warming fast, that means there is less fuel driving the jet stream. When the jet stream has less fuel it flows more slowly, and it tends to take these big north-south dips.

When the northeastern USA happens to be in the path of one of those big dips, we get cold winters. A northward swing over the western USA causes drought and heat waves in California. As the Arctic is warming fast, this is making it more likely that these kinds of patterns will happen more often.

The Atlantic Ocean off the east coast has been warming, creating more evaporation and putting more moisture in the air. That moisture is fuel for storms. A shift in those jet stream dips could push the cold part of the loop elsewhere and bring more winters like 2012 when there were already crocuses and mosquitos in Boston by early March.

WARMER OR COLDER FUTURE

The United Nations Framework Convention on Climate Change represents an international evidence of anthropomorphic (human caused), climate change. It originally aimed to have an accord setting firm greenhouse-gas-reduction targets for all countries by 2009. It is now hoping to accomplish this task by 2015. In the USA, President Barack Obama has been forced to act outside Congress, through the Environmental Protection Agency, to limit CO_2 pollution from coal-fired power plants.

On the other hand, Republican members in the USA House of Representatives have introduced legislation to forbid any such action, based on economic considerations. Delaying the start of action by five years, say from 2020 to 2025, would drastically dim the hope of limiting the rise in global mean temperature to 3.6 ^oF or 2 ^oC long considered the point at which it becomes significantly more difficult to adapt. Chances of success would fall to just 34 percent from 56 percent. On the other hand, starting to take action in 2015 would improve humanity's chances to 60 percent.

Even if the temperature target is met, the ocean will still grow more acidic (actually less basic), cropland will become less productive, and sea levels will gradually rise by 4.8 meters or 15.7 feet, which is twice the height of Hurricane Sandy's peak storm surge at Battery Park in New York City in October-November 2012. As the USA and the world continue emitting greenhouse gases, an underwater future for hundreds of world and USA cities and towns is being written.

A bathtub analogy is used to describe the problem. Greenhouse gases are like water flowing from a faucet into a tub with a limited drain represented by the trees, plants and oceans that soak up the gases. If the faucet is wide open, the tub quickly fills to the point at which the concentration of carbon in the atmosphere reaches 450 parts per million (ppm), and the only way to prevent overflow is to shut the tap entirely. By slowing the stream now, we would allow ourselves the relative luxury of reducing emissions gradually. Turning the tap slowly can be achieved by increasing energy efficiency, developing renewable energy sources, nuclear energy and subjecting CO_2 to the same kind of limits that are placed on mercury, arsenic and other pollutants. The unacceptable alternative is to let the tap run and leave the overflow for the next generations to deal with.

An interesting observation is the fact that global warming seems to be taking a break. The average global temperature has not risen for 15 years, a deviation from the climatologists' computer-simulated predictions, despite a forecast that coastal waters may rise by between 29 and 82 centimeters (11 and 32 inches) by the end of the century. The climate models should have been able to predict the sudden flattening in the temperature curve.

Scientists have discovered some possible explanations as to why temperatures are not currently rising. One explanation involves the Pacific Ocean, which, calculations indicate, has absorbed an unusually large amount of heat from the Earth's atmosphere in recent years. If this proves to be true, then the warnings are still in effect and it would mean the greenhouse effect is adding more and more energy into the climate system, exactly as the simulations predict, just with a larger portion of that energy than expected disappearing temporarily into the ocean.

Another advanced possible explanation is that the large quantity of soot emitted into the atmosphere by cars and factory smokestacks in Asia has had a cooling effect on the atmosphere. A decrease in air pollution would allow global warming to proceed unchecked and the stagnation in temperature does not negate the physical evidence of global warming.

DISCUSSION

Adaptation to the realities of global climatic change needs to consider adaptation to the newly created environment. This could use chemical and physical interventions.

In 1947, the USA Corps of Engineers considered Project Cirrus to weaken devastating Caribbean Hurricanes by seeding their clouds with silver iodide crystals. In 1960, architects Buckminster Fuller and Shoji Sadao proposed a utopian " Dome over Manhattan" project of covering downtown Manhattan with a 2 miles diameter glass geodesic dome that would control its climate in both summer and winter. In 2010, architect Vincent Callebut proposed a plan of an ocean floating city called "Lilypad" as a haven to climate refugees.

Figure 81. Architect Vincent Callebaut concept of Lilypad; an ocean floating city for climate refugees. Vincent Callebaut Architectures.

Some people consider global climatic change or anthropogenic global warming as mass hysteria raging across the world. School children are taught how to decrease their "carbon footprint." They refer to it as the "one of the greatest swindles in world history," and consider it as a political scam with little scientific basis. They attribute it to a class of hysterics in the world reminiscent of the fear-mongering about the year 2000 (y2k) and the danger of national and international terrorism. They compare them to people who walked around in the Middle Ages dressed in sack-cloth, threw ashes on their bodies, proclaiming that the world is coming to an end; which will eventually come true when the sun dies out in about 5 billion years. They point out that there are factors that have orders of magnitude higher impacts on the climate that humans can do.

The current consensus is that global climatic change caused by increased CO_2 emissions, and other greenhouse gases such as methane, could warm the Earth's atmosphere by about 5-6 degrees Fahrenheit in the next century. The climate data from the 1930s could be used as a predictor of the future effects. However, the heat waves of the thirties did not last for long, and temperatures returned to the average levels. This may not be the case in the future, since it would take 50 to 100 years for some greenhouse gases to be dissipated in the atmosphere, or be absorbed by the ocean waters or biomass.

Once injected in the atmosphere, it would be impossible to significantly decrease the CO_2 concentration by other than the natural means. If the concentration would double then quadruple to the 600 ppm level, decreasing it by 100 ppm would be a monumental task. In principle, this would require 1,000 chemical plants, with air intake speed of 30 km/hr, each 100 m high and 1 km long, to operate for 30 years, to recycle 1/6 th of the atmosphere.

Adjustments to the new reality are already occurring. Increased rainfall, longer growing seasons, warmer winters and higher dew points in the summer are already being observed in the American plains. Plant disease pressures have increased in many areas due to increased moisture and higher dew points, which requires different variety selection and disease management strategies. Farmers are already responding with more pattern tile drainage, split applications of fertilizer to reduce the risk of leaching and runoff losses during downpours. The earlier arrival of spring weather has shifted events such as egg laying, the end of hibernation and flower blooming ahead about five days per decade for temperature zones species.

Humanity has one to two decades or so at hand to plan on how to cope with the problem before the consequences would become irreversible. The future course of action should be based on a comparison of the risks and benefits of different energy sources, but it appears that enhancement of fossil fuels usage should not be encouraged, unless compelling reasons arise. New agricultural tillage and forestry management practices would have to be developed.

As the long running debate about whether global climate change is anthropogenic or human-caused from greenhouse gases emission, or caused by natural causes, rages; logic demands that the attention of sober minds should shift into identifying and anticipating the expected changes, and adapting to them. The best estimate is that 50 percent of the global change is due to greenhouse gas increases. Because of a time lag, even if humans were fully responsible for global change, there may not be any direct recourse available.

To most of us who feel uneasy about altering the natural order of things, planetary engineering or geoengineering may be a cause of concern. But the fact is that humans have altered nature over the course of history, for instance by inventing agriculture and strive to make it stably coexist with nature. They must be equally wise enough to restore nature to its best stable state. Humanity has greatly influenced the present geological age Holocene environment. Whereas all organisms influence their environments to a degree, few organisms have ever changed the globe as much or as fast as the human species. Habitat destruction, pollution, and other factors are causing an ongoing mass extinction of plant and animal species. According to some projections, 20 percent of all plant and animal species on Earth will be extinct within 25 years.

Yet the present Holocene geological age is witnessing unprecedented growth in the development of human knowledge, science and technology, which can be used to understand the changes, to predict their effects, and to stop, mitigate or even ameliorate the damage they may do to life on Earth.

Those who believe that the wider use of renewable energy sources is the ideal solution, also would agree that it is prudent to investigate contingency measures to slow down, stabilize, or even reverse the increases of global temperatures and have them ready as a contingency for deployment if necessary.

As climatic change is becoming recognized as a major threat, more research will be initiated as human society attempts geoengineering solutions. If the possibility of severe weather events becomes more of a possibility, planetary engineering or geoengineering projects restoring more stable climatic states, such as restoring the ancient global equatorial current across the Central American Land Bridge, may provide survival for the existing Human Civilization as well as life on Earth.

REFERENCES

1. J. R. Petit, et al., 2001, “Vostok Ice Core Data for 420,000 Years,” IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series #2001-076, NOAA/NGDC Paleoclimatology Program, Boulder CO, USA, 2001.

2. J. R. Petit, Jouzel J., Raynaud D., Barkov N.I., Barnola J.M., Basile I., Bender M., Chappellaz J., Davis J., Delaygue G., Delmotte M., Kotlyakov V.M., Legrand M., Lipenkov V., Lorius C., Pépin L., Ritz C., Saltzman E., Stievenard M., Climate and Atmospheric History of the Past 420,000 years from the Vostok Ice Core, Antarctica, Nature, 399, pp.429-436, 1999.

3. R. B. Alley, “GISP2 Ice Core Temperature and Accumulation Data,” IGBP PAGES/World Data Center for Paleoclimatology, Data Contribution Series #2004-013, NOAA/NGDC Paleoclimatology Program, Boulder CO, USA, 2004.

4. R. B. Alley, R.B, “The Younger Dryas cold interval as viewed from Central Greenland,” Quaternary Science Reviews 19:213-226, 2000.

5. Robert Kunzig, “Shading the Earth” National Geographic, Vol. 216, No. 2, pp. 24-27, August 2009.

6. C. Lorius, J. Jouzel and D. Raynaud, “The Ice Core Record: Past Archive of the Climate and Signpost to the Future.” In: Antarctica and Environmental Change. Oxford Science Publications, pp. 27-34, 1993.

7. D. M. Etheridge, L.P. Steele, R.L. Langenfelds and R.J. Francey, “Natural and anthropogenic changes in atmospheric CO_2 over the last 1000 years from air in Arctic ice and fern,” J. Geophys. Res., Vol. 101, pp. 4115-28, 1996.

8. Neil Shea and Mark Thiessen, “Under Fire,” National Geographic, Vol. 214, No. 1, pp. 116-143, July 2008.

8. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H.L. Miller (eds.). “Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,” Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, IPCC, 2007.

9. Gerald W. Johnson, “Peaceful Nuclear Explosions,” in: Progress in High Temperature Physics and Chemistry, Carl A. Rouse, ed., Vol. 4, Pergamon Press, 1971.

10. W. Livingston and M. Penn, “Are Sunspots Different During This Solar Minimum?” National Solar Observatory, EOS, Transactions American Geophysical Union, Vol. 90, No. 30, pp. 257-264,July 28, 2009.

11. L. Svalgaard, E. Cliver and Y. Kamide, Geophysical Research Letters, Vol. 32, 01 104, 2005.

12. M. Milankovitch, “Théorie Mathématique des Phénomènes Thermiques produits par la Radiation Solaire,” Gauthier-Villars Paris, 1920.

13. Stephen H. Salter and John Latham, “The Reversal of Global Warming by the Increase of the Albedo of Marine Stratocumulus Cloud,” http://www.mmm.ucar.edu/people/latham/files/cloud_albedo_spray_quantity_paper.pdf

14. R. Angel, “Feasibility of cooling the Earth with a cloud of small spacecraft near the inner Lagrange point.,” Proceedings National Academy of Sciences, vol. 103, pp 17184-17189 2006. From: http://www.pnas.org/cgi/reprint/103/46/17184

15. R. Bennartz, "Global assessment of marine boundary layer cloud droplet number concentration from satellite," Journal of Geophysical Research, vol. 112, 12, D02201, doi:10.1029/2006JD007547, 2007, From:
http://www.agu.org/pubs/crossref/2007/2006JD007547.shtml
16. K. Bower, T. Choularton, J. Latham , J. Sahraei , S. Salter, "Computational assessment of a proposed technique for global warming mitigation via albedo-enhancement of marine stratocumulus clouds," Atmospheric Research, vol. 82, pp 328-336, 2006.
17. P. Crutzen, "Albedo enhancement by stratospheric sulfur injections: a contribution to resolve a policy dilemma," Climatic Change, vol. 77, pp.211-219, 2006. From
http://www.springerlink.com/content/t1vn75m458373h63/
18. J. Hansen, "Efficacy of climate forcings," Journal of Geophysical Research 110(d18): D18104, 2005. http://www.columbia.edu/~jeh1/
19. C. D. Keeling, S. C. Piper, R. B. Bacastow, M. Wahlen, T. P. Whorf, M. Heimann, and H. A. Meijer, "Atmospheric CO_2 and $^{13}CO_2$ exchange with the terrestrial biosphere and oceans from 1978 to 2000: observations and carbon cycle implications," pages 83-113, in: "A History of Atmospheric CO_2 and its effects on Plants, Animals, and Ecosystems," editors, J. R. Ehleringer, T. E. Cerling, M. D. Dearing, Springer Verlag, New York, 2005.
20. J. Latham, "Control of global warming?" Nature, vol. 347, pp 339-340, 1990.
21. S. E. Schwartz, A. Slingo, "Enhanced shortwave cloud radiative forcing due to anthropgenic aerosols," in: "Clouds, Chemistry and Climate," pp. 191-236, Crutzen and Ramanathan, eds, Springer Heidelberg, 1996. From
http://www.ecd.bnl.gov/steve/pubs/Enhanced_Shortwave.pdf
22. G. N. Sortino, "A data resource for cloud cover simulations," Master of Science thesis, School of Informatics University of Edinburgh, 2006.
23. Stephen Salter, Graham Sortino and John Latham, "Sea-going hardware for the cloud albedo method of reversing global warming," Phil. Trans. R. Soc. A 2008 366, 3989-4006, From rsta.royalsocietypublishing.org
24. S. Twomey, "The influence of pollution on the shortwave albedo of clouds," Journal of Atmospheric Sciences, vol. 34, pp1149-1152, July 1977. From:
http://ams.allenpress.com/archive/1520-0469/34/7/pdf/i1520-0469-34-7-1149.pdf
25. K. M. Walter, S. A. Zimov, J. P. Chanton, D. Verbyla, F. S. Chapin, "Methane bubbling from Siberian thaw lakes as a positive feedback to climate warming," Nature vol. 443, pp 71-75, September 2006.
26. E. Teller, K. Wilson Talley, Gary H. Higgins, and Gerald W. Johnson, "The Constructive Uses of Nuclear Explosives," McGrawHill, New York, 1968.
27. Gerald W. Jonson, "Excavation with Nuclear Explosives: Promise and Problems," Physics Today, Vol. 16, pp. 38-44, November 1963.
28. Rik Myslewski, "Global Warming helps Arctic Algae suck CO_2. Massive phytoplankton Bloom Solves Missing Carbon Mystery," Biology, June 6, 2012.
29. Mark Drajem, "Climate Panel says Coast, Midwest at Risk of Extreme Weather," Bloomberg, January 11, 2013.
30. Christoph Seidler, "Melting Permafrost: Scientists Warn of Dangers of Trapped Carbon," Der Spiegel, February 22, 2013.
31. Matt McGrath, "Arctic Methane 'time bomb' Could Have Huge Economic Costs,"

BBC News, Science and Environment, July 24, 2013.
32. Rebecca Morelle, "Rise in Violence 'Linked to Climate Change," BBC World Service, August 2, 2013.
33. Robert Kunzig, "Will Earth's Ocean Boil Away?," National Geographic, July 29, 2013.
34. Kukil Bora, "Scientists Produce New World Map, Identifying Areas Most Susceptible to Climate Change," International Business Times, September 17, 2013.
35. Tom Harris, "New Report Counters Climate Change Scare," Calgary Herald, September 16, 2013.
36. Geoffrey Mohan, "Volcanoes Slowed Global Warming, Report says; It Won't Last," Science Now, February 25, 2014.
37. Amanda Pierce, "Methane-producing microbes were perpetrators of mass extinction 252 million years ago: Study," Utah People's Post, April 1st, 2014.
38. Peter Dizikes, "Dangerous storms: Hurricanes peaking further north, typhoons further south, than in past," Science Daily, 14 May 14, 2014.
39. Andrea Thompson, "Antartica's Icy 'Doorstops' Thin; Rising Seas At Risk," Climate Central, March 26, 2015.

APPENDIX I

GEOLOGIC TIME SCALE

The recent Holocene Epoch starting 10,000 years ago, marks the beginnings of modern man and the spread of human civilizations. The age of the Earth is considered as 4.6 billion years.

Table I: Geological Time Scale, million years ago (mya).

Eon	Era	Period	Epoch	Age [mya]
Phanerozoic (Visible Life)	Cenozoic (Recent Life) (Age of mammals)	Quaternary	Holocene	0.01
			Pleistocene	1.8
		Tertiary	Pliocene	5.3
			Miocene	23.8
			Oligocene	33.7
			Eocene	54.8
			Paleocene	65
	Mesozoic (Middle Life) (Age of Reptiles)	Cretaceous		144
		Jurassic		206
		Triassic		248
	Paleozoic (Ancient Life)	Permian		290
		Carboniferous	Pennsylvanian	323
			Mississippian	354
		Devonian		417
		Silurian		443

		Ordovician		490
		Cambrian	Tommotian	527
				530
				543
Precambrian Time	Proterozoic (Early life) (Oldest known life)	Neoproterozoic	Vendian	650
		Mesoproterozoic		900
		Paleoproterozoic		2,500
	Archaean (Oldest) known rocks)			3,800
	Hadean (Age of Earth)			4,600

APPENDIX II

SEA LEVEL DIFFERENCE BETWEEN THE PACIFIC AND ATLANTIC OCEANS [1]

An intriguing question is whether electrical power can be produced if the Atlantic and Pacific Oceans were reconnected as a terra-forming project. The hydraulic head is small, but the flow rate may be large enough to justify it. If this were possible, then a question arises whether such oceanic water current flows could be beneficially used. The Gulf Stream, Tidal currents across the Gibraltar and the Bosphorus straits and even the Suez Canal may be considered for electrical power generation.

The potential energy of a mass of fluid at a constant height h is given by:

$$E = mgh[Joule] \tag{1}$$

where:

m is mass [kg]

g is the gravity acceleration constant $= 9.81[\frac{m}{\sec^2}]$

h is height or water head difference [m]

The theoretical hydroelectric power can be estimated from:

$$P = \frac{dE}{dt} = \frac{d}{dt}(mgh) = \frac{dm}{dt}gh = \dot{m}gh[\frac{Joule}{\sec}], [Watt] \tag{2}$$

where:

$\dot{m}$ is the mass flow rate $[\frac{kg}{\sec}]$

The mass flow rate can be expressed as:

$$\dot{m} = \rho \dot{V} \, [\frac{kg}{\sec}] \quad (3)$$

where:

ρ is the water density $[\frac{kg}{m^3}]$

$(\rho = [1.03 - 1.05] \times 10^3 [\frac{kg}{m^3}],$ for salt water)

$\dot{V}$ is the volumetric discharge rate $[\frac{m^3}{\sec}]$

Substituting from Eqn. 3 into Eqn. 2 yields:

$$P = \rho \dot{V} g h \, [Watt] \quad (4)$$

The electrical power production depends on the efficiency of the electrical conversion process as:

$$P_e = \eta \rho \dot{V} g h \times 10^{-6} \, [MWe] \quad (5)$$

where: η is the electrical conversion efficiency in the range of 0.30-0.50

Thus the hydraulic head h can be small, but a large volumetric mass flow rate $\dot{V}$ would allow appreciable power production.

According to the Permanent Service for Mean Sea Level, (PSMSL) [1]:

> "Sea level is about 20 cm higher on the Pacific side than the Atlantic due to the water being less dense on the Pacific side, on average, and due to the prevailing weather and ocean conditions. Such sea level differences are common across many short sections of land dividing ocean basins.
>
> The 20 cm difference is determined by geodetic levelling from one side to the other. This levelling follows a 'level' surface which will be parallel to the geoid. The 20 cm difference at Panama is not unique. There are similar 'jumps' elsewhere e.g. Skagerrak, Indonesian straits.
>
> If the canal was open sea and did not contain locks, i.e. if somehow a deep open cutting had been made rather than the canal system over the mountains, then there would be a current flowing from the Pacific to the Atlantic. An analogy, though imperfect because there are many other factors, is a comparison between Panama and the Drake Passage off the south tip of Chile, which has a west-east flow. (The flow in the Drake Passage is primarily wind-driven, but Pacific-Atlantic density must play some role.)
>
> Locks are needed in the Panama Canal because the canal climbs over

the hills and makes use of mountain lakes. Therefore, locks would be needed even if sea level was the same on the two sides. For example, there are also locks on canals here in England, which is much less mountainous than Panama.

Note also that the tides have opposite phases on the two sides of Panama, so, if there was a sea level canal, there would be major tidal currents through it."

APPENDIX III

THE ISTHMUS OF PANAMA [2]

Figure 1. "Scientists made this false-color image of Panama using data acquired in February 2000 by the Shuttle Radar Topography Mission (SRTM), flying aboard the Space Shuttle Endeavor. High-quality satellite imagery of Central America is generally difficult to obtain due to persistent cloud cover in the region. The ability of SRTM to penetrate clouds and make three-dimensional measurements has allowed scientists to produce the first complete high-resolution topographic map of all of Central America. Two visualizations were combined to produce this image of Panama: shading and color coding of topographic height. By computing the topographic slope in the north-south direction, scientists were able to make the shading that gives it its three-dimensional appearance. The colors directly relate to height. Green shows the lowest elevations, just above sea level. Yellows and then tans show progressively higher elevations, with white being the highest" [2]. Image: SRTM Team, NASA/JPL/NIMA.

"Twenty million years ago ocean covered the area where Panama is today. There was a gap between the continents of North and South America through which the waters of the Atlantic and Pacific Oceans flowed freely. Beneath the surface, two plates of the Earth's crust were slowly colliding into one another, forcing the

Pacific Plate to slide slowly under the Caribbean Plate. The pressure and heat caused by this collision led to the formation of underwater volcanoes, some of which grew tall enough to break the surface of the ocean and form islands as early as 15 million years ago. More and more volcanic islands filled in the area over the next several million years. Meanwhile, the movement of the two tectonic plates was also pushing up the sea floor, eventually forcing some areas above sea level.

Over time, massive amounts of sediment (sand, soil, and mud) were peeled away from North and South America by strong ocean currents and fed through the gaps between the newly forming islands. Little by little, over millions of years, the sediment deposits added to the islands until the gaps were completely filled. By about 3 million years ago, an isthmus had formed between North and South America. (An "isthmus" is a narrow strip of land, with water on either side, that connects two larger bodies of land.)

Scientists believe the formation of the Isthmus of Panama is one of the most important geologic events to happen on Earth in the last 60 million years. Even though it is only a tiny sliver of land, relative to the sizes of continents, the Isthmus of Panama had an enormous impact on Earth's climate and its environment. By shutting down the flow of water between the two oceans, the land bridge re-routed currents in both the Atlantic and Pacific Oceans. Atlantic currents were forced northward, and eventually settled into a new current pattern that we call the Gulf Stream today. With warm Caribbean waters flowing toward the northeast Atlantic, the climate of northwestern Europe grew warmer. (Winters there would be as much as 10 degrees C colder in winter without the transport of heat from the Gulf Stream.) The Atlantic, no longer mingling with the Pacific, also grew saltier. Each of these changes helped establish the global ocean circulation pattern we see today. In short, the Isthmus of Panama directly and indirectly influenced ocean and atmospheric circulation patterns, which regulated patterns of rainfall, which in turn sculpted landscapes.

The formation of the Isthmus of Panama also played a major role in biodiversity on our world. The bridge made it easier for animals and plants to migrate between the continents. For instance, in North America today, the opossum, armadillo, and porcupine all trace back to ancestors that came across the land bridge from South America. Likewise, the ancestors of bears, cats, dogs, horses, llamas, and raccoons all made the trek south across the isthmus."

REFERENCES

1. ___, "Sea Level: Frequently Asked Questions and Answers," Permanent Service for Mean Sea Level, PSMS," http://www.psmsl.org/train_and_info/faqs/

2. ___, "Panama: Isthmus that Changed the World," Earth Observatory, Images, NASA, December 31, 2003, http://earthobservatory.nasa.gov/IOTD/view.php?id=4073.