ATMOSPHERIC HEAT FLUXES AND RESTORATION OF THE CIRCUMGLOBAL EQUATORIAL CURRENT

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ABSTRACT

An analytical model is developed for estimating the heat fluxes in the lower and upper parts of the atmosphere that would result from possible 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 troposphere where weather phenomena are initiated.

As a contingency measure in case efforts to reduce emissions are unsuccessful, a geoengineering project is considered to mitigate the effects of a possible runaway global change. The goal is the restoration of the ancient circumglobal equatorial current by digging a trans-isthmian sea level canal through the Isthmus of Panama using conventional and nuclear civil engineering methods. This would restore the temperate climatic conditions that existed 3 million years ago.

Other alternatives involving ocean iron seeding, atmospheric injection of sulfates to increase reflectivity to solar radiation and shading the Earth with Mylar disc reflectors, are discussed.

1. INTRODUCTION

A delicately balanced mild greenhouse effect has kept the Earth's climate within the livability zone of the sun. At a distance of 93 million miles, 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 degree 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 situation 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 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. 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 alter at their own peril

2. EARTH GREAT CONVEYOR BELT

The ocean water 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 (Fig. 1).

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.

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. The conveyor belt has shut down in the past with dramatic results.

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 takes about 1,000 years for a parcel of water to complete the journey along the global conveyor belt.

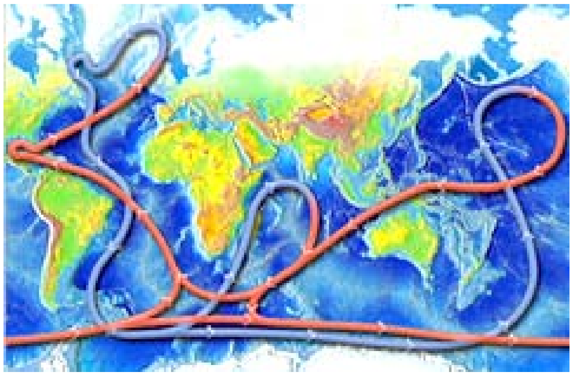

Figure 1. Contemporary great Earth ocean conveyor belt. Source: NOAA.

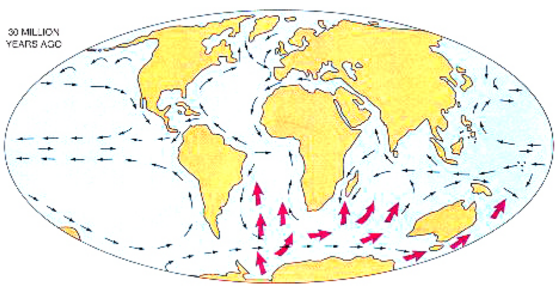

Figure 2. Global ocean currents 30 million years before present. Source: NOAA.

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 [1].

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 an example that suggests that global warming can lead in unpredictable ways to an opposite effect of climate cooling [2].

3. 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.

Considering the tropical region, since the lower atmosphere traps more heat than the upper atmosphere as a result of increased CO_2 concentrations, its temperature will increase relatively more than the upper atmosphere, whose temperature will decrease [1].

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 3 displays this 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.

Analytical Model

We consider the geometry shown in Fig. 4, 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:

$$\nabla^2[t(z)] = 0 \tag{1}$$

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

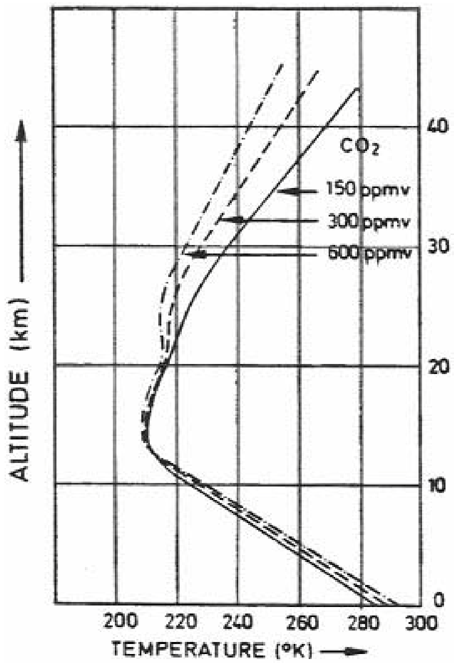

Figure. 3. The variation of temperature as a function of height depending on the CO2 concentration. Source: IAEA Bulletin, 1979.

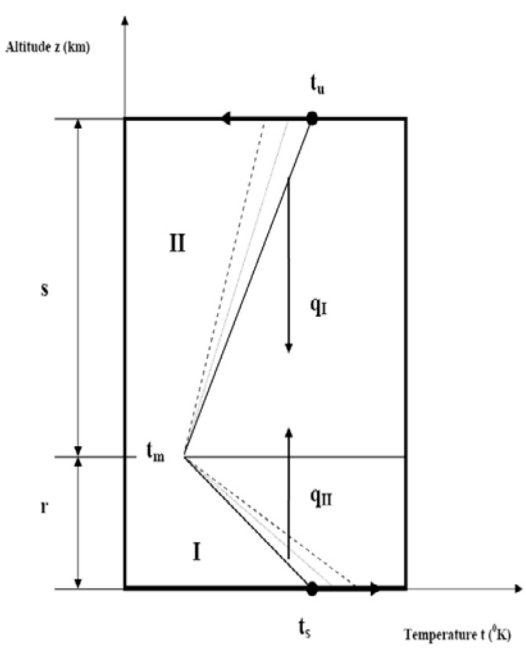

Figure 4. Geometrical model of heat fluxes flows in the atmosphere.

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

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

$$\begin{aligned} At: z &= r \quad , \quad t(r) = t_m \\ z &= 0 \quad , \quad t(0) = t_s \\ z &= r+s \quad , \quad t(r+s) = t_u \end{aligned} \tag{3}$$

Temperature distributions

In region I of the lower atmosphere, we can integrate Eqn. 2 to get:

$$\begin{aligned} &\frac{d^2 t_I(z)}{dz^2} = 0 \\ &\frac{d}{dz}\left(\frac{dt_I(z)}{dz}\right) = 0 \\ &\frac{dt_I(z)}{dz} = C_1 \end{aligned} \tag{4}$$

Integrating a second time yields:

$$\begin{aligned} &\int dt_I(z) = \int C_1 dz \\ &t_I(z) = C_1 z + C_2 \end{aligned} \tag{5}$$

To determine the constants of integration C_1 and C_2, we apply the boundary conditions 3:

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

From which we can rewrite Eqn. 5 as:

$$t_I(z) = C_1 z + t_s \tag{6}$$

Applying the boundary conditions to Eqn. 6 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:

$$t_I(z) = \frac{(t_m - t_s)}{r} z + t_s \tag{7}$$

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:

$$\int dt_{II}(z) = \int C_3 dz$$
$$t_{II}(z) = C_3 z + C_4 \tag{8}$$

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

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

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:

$$t_{II}(z) = \frac{(t_u - t_m)}{s} z + t_m - (t_u - t_m)\frac{r}{s} \tag{9}$$

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:

$$\overline{q} = -kA\nabla t(z) \tag{10}$$

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

From Eqn. 10, the heat flux in region I of the lower atmosphere becomes:

$$\begin{aligned} q_I &= -kA\frac{dt(z)}{dz} \\ &= -kA\frac{(t_m - t_s)}{r} \\ &= +kA\frac{(t_s - t_m)}{r}, \text{ since } t_s > t_m \end{aligned} \tag{11}$$

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. 11 becomes:

$$\begin{aligned} q_{II} &= -kA\frac{dt(z)}{dz} \\ &= -kA\frac{(t_u - t_m)}{r}, \text{ since } t_u > t_m \end{aligned} \tag{12}$$

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

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

$$\begin{aligned} q_{net} &= q_I - q_{II} \\ &= +kA\frac{(t_s - t_m)}{r} - kA\frac{(t_u - t_m)}{s} \\ &= +kA\left[\frac{(t_s - t_m)}{r} - \frac{(t_u - t_m)}{s}\right] \end{aligned} \tag{13}$$

Numerical values

For illustration of the applicability of the derived equations, 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. 3 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. 4). This creates a higher temperature drop resulting in higher net heat fluxes to the troposphere (Fig. 5). The percent relative increase in the net heat fluxes can be defined as:

$$PRI = \left|\frac{q_{net} - q_{ref}}{q_{ref}}\right| x100 \tag{14}$$

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

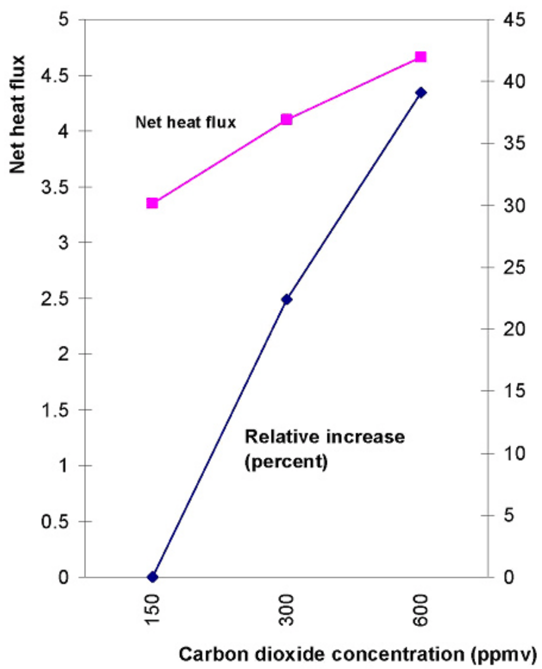

Figure 5. Temperature effect of carbon dioxide concentration.

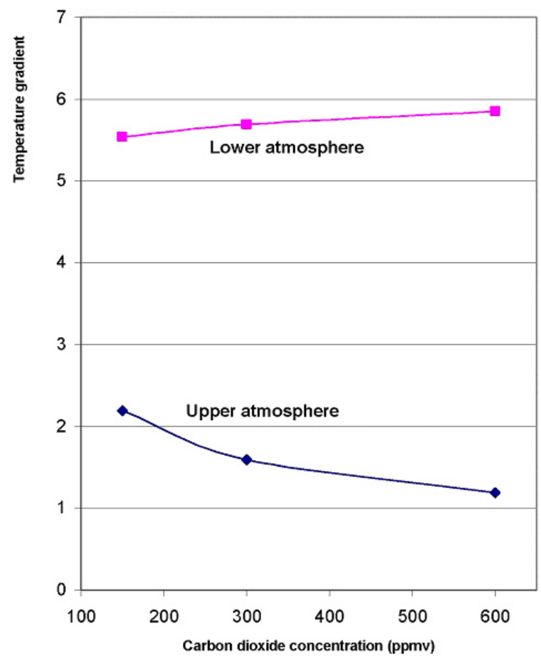

Figure 6. Temperature gradients as a function of carbon dioxide concentration.

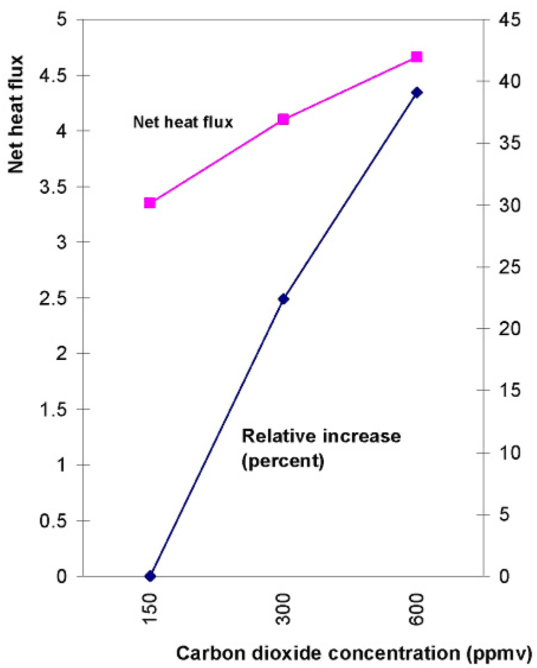

Figure 7. Net heat flux as a function of carbon dioxide concentration.

4. 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 Climates

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 reentrant 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 ginkgos.

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 [2].

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 circumglobal 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.

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 [2].

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 including large tankers cross it daily carrying 300 million tons of freight per year.

The Isthmus of Panama

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.

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, social unrest 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. 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. Control of the canal was turned over to Panama on December 31, 1999.

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 contiued 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.

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.

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. 8.

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 economical means of achieving such an ambitious project as shown in Fig. 9. In all cases important environmental considerations will have to be addressed.

Table 2. 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

Figure 8. The locations of Trans-Ithsmian possible routes. The routes through Mexico and Columbia are the best choices for a sea level connection. Google Earth satellite photograph.

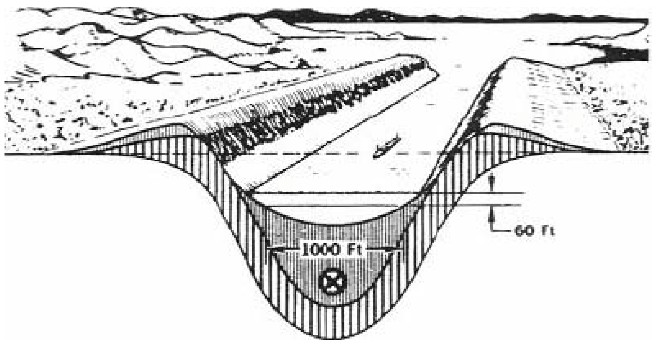

Figure 9. Peaceful clean thermonuclear cratering devices releasing megatons equivalent of TNT can excavate a sea level canal using nuclear civil engineering methodologies. Source: LLNL.

An alternate sea level canal through Panama, Southern Mexico or northern Columbia, restoring the old ocean currents intercepted by Central American Land Bridge, may become an international global geoengineering project.

Five different Trans-Isthmian routes for a sea level canal are possible as shown in Table 2. The cost figures include the operating facilities.

5. ALTERNATE APPROACHES

Iron Dust Seeding

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 [3].

It is not yet known how much CO_2 is ingested by the plankton per ton of seeded iron. 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.

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 set 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 anthropogenic 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 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. The scheme is controversial since environmentalists fear such geo engineering could knock the ecosystem out of balance. 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

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 [4].

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.

A recent suggestion involves cloud generation through the generation of ocean water spray. It must be noticed that even though clouds can shield the Earth's surface, they are effective infrared radiation absorbers which they later radiate [4].

6. DISCUSSION

An analytical model is developed for estimating the heat fluxes in the lower and upper atmospheres that would result from increases in the 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.

In case efforts to reduce CO_2 emissions and carbon sequestration are unsuccessful, a planetary engineering or geoengineering project can be considered to mitigate the effects of a possible runaway global change. The goal is the restoration of the ancient global equatorial current. By digging a trans-isthmian sea level canal through the Isthmus of Panama using conventional and nuclear civil engineering methods, the temperate climatic conditions that existed 30 million years ago could be restored.

Other alternatives involving ocean iron seeding, atmospheric injection of sulfates to increase reflectivity to solar radiation and shading the Earth with Mylar disc reflectors, have been proposed [3,4].

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.

7. REFERENCES

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