Engineering the Global Thermostat! PART A – Humanitys' Dilemma

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ABSTRACT:

"Engineering the Global Thermostat!" is presented in two Parts: Part A and Part B. The complete paper involves itself in the emerging debate concerning engineering the global climate to counter global warming. Can we do it? Is it wise? What has happened in the past? Under what circumstances would we do it and what could go wrong? Part A, this paper, will review our knowledge of a changing climate over the ages and comment on the uniqueness of the last 10,000 years. Using the Milankovitch mechanism an attempt is made to forecast the future "predestined' climate change and then to predict a more complicated state by superimposing the anthropogenic effects on such global changes using the findings of the Intergovernmental Panel on Climate Change Assessment Report. Part B, "Creating a Permaclimate" deals with what temperature to set the 'Thermostat', considers the 'Double Threat' and what existing and proposed 'Geo-Engineering' are economically feasible and ethically possible.

1. INTRODUCTION

This paper is Part A of two parts: Part A and Part B. Part A considers the changing climate over the ages and the relevance of a stable climate, particularly over the last 1000 years, for the development of our current civilisation. The major factors forcing the climate on earth are used to understand future predictions with and without the anthropogenic effects. The second part, Part B, considers the need for the setting of a 'Thermostat' and the creation of a 'Permaclimate' for Earth and discusses how existing and proposed Geo-Engineering is now necessary to stabilise rising average global temperatures until greenhouse gas emissions are reduced.

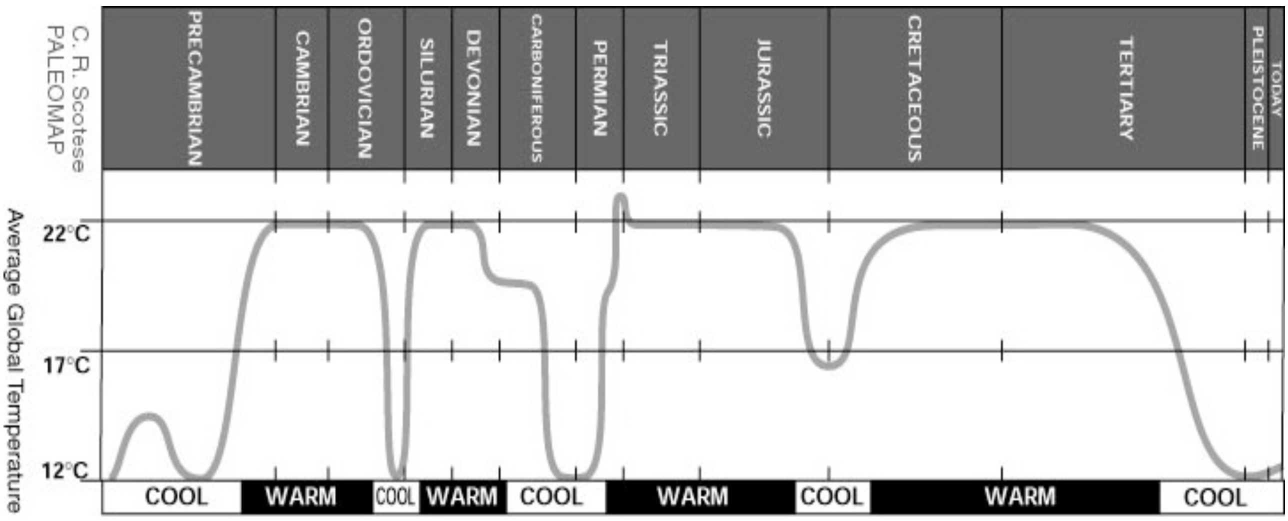


Figure 1. The global climate changing through time. (www.scotese.com/climate.htm) Note: The top right-hand corner of this figure in the 'Today' column depicts the Holocene (10,000 years) and the present which has an average global temperature of approximately 13°C. Note

the recent glacial periods are possibly 10^{0}C cooler and the abscissa is a logarithmic scale becoming larger to the left.

2. CHANGING CLIMATE OVER THE AGES

An appreciation of the rhythms of the weather generally depend on your age, what you have been told, what you have read how you have been educated and what you have personally researched. The changing of climates over the ages is 'the rule' and it is all a matter of what time frameworks you wish to consider. Obviously when you are young the timeframe is very short and as you become older that timeframe extends beyond your physical dimensions to possibly a very long time depending upon your curiosity and interests. It is now, in the 21st century that Homo sapiens are sharpening their awareness in the history of these timeframes and it would appear that in these we hope to find the answer to our survival as a species.

Geological time is measured in billions of years and over the most recent period, the last 600 million years, the estimated variation in average temperature on the earth has been between 12° and 22°C, referred to figure 1 above constructed by Christopher Scotese.

"During the last 2 billion years Earth's climate has altered between a frigid 'Ice House', like today's world, and a steaming 'Hot House' like the world of dinosaurs.". (Scotese, 2001)

Since the Cambrian (650 million years ago) there have been very few cool 'Ice House' periods. The remainder have been 'Hot House', very warm and active. E.g. during the Carboniferous (the coal age – 350 million years ago). Figure 2 depicts a record of climate change over the last 440,000 years as extracted from the Vostok ice cores which were drilled in Antarctica in the 1990s. (Petit et. al., 1999) This ice core requires its depths to be "tuned" to geological events (time) and it can be seen that for the last 400,000 years the interdependence of 'events' to temperature is truly remarkable.

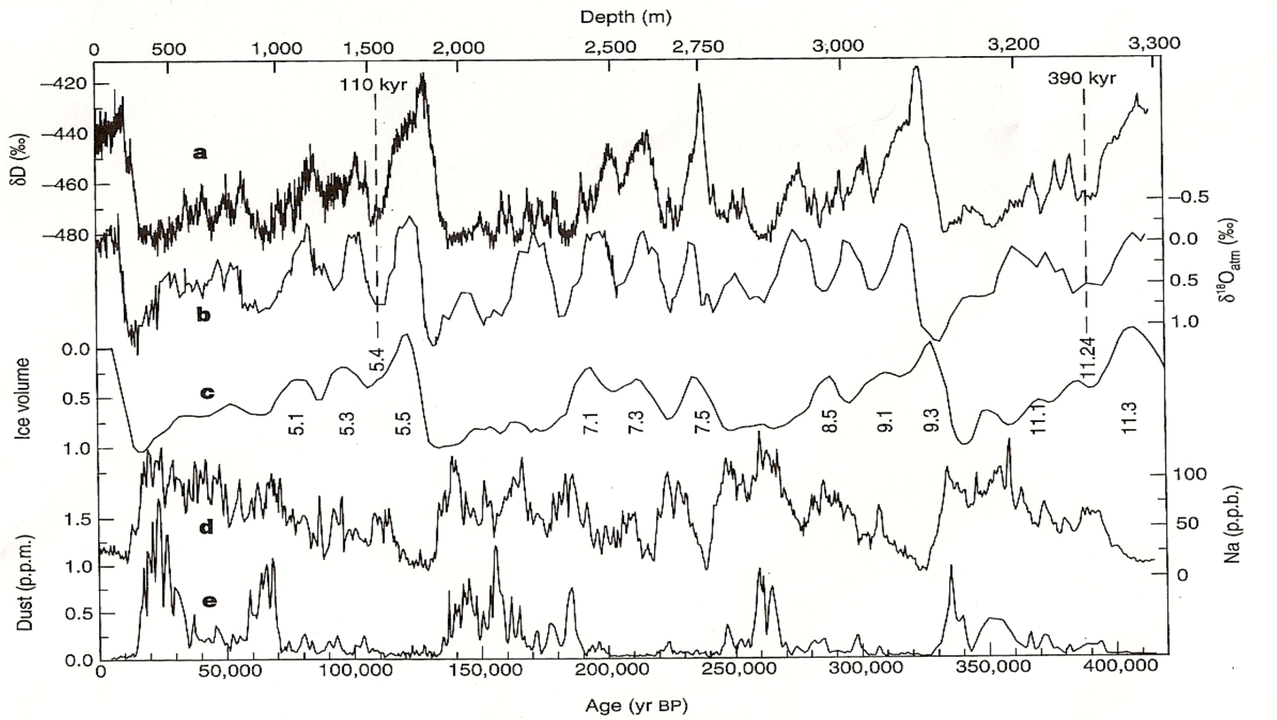
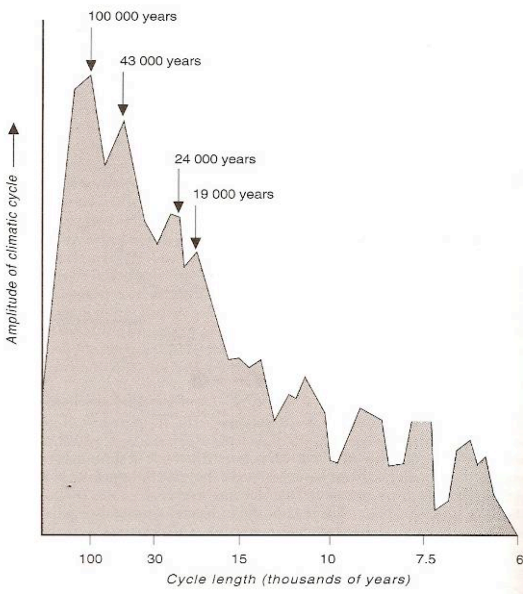


Figure 2 Vostok time series and ice volumes. It is of interest to note the correlation between the temperature proxies (a and b) and the ice volume and dust (c and e). Other figures in their paper broadly correlate the Insolation (Predicted by the Milankovitch mechanisms) with the other phenomena variations shown in the traces. Refer to figure 4 for trace (e) the Insolation trace. ("Insolation" = INcoming SOLar radiATION = INSOLATION)

The difference in temperature between the most recent glacial period and the present is approximately 10°C, this relates to approximately 1 mile of ice over Chicago on a spring day. The implication of such temperature variations for the survival of our ancestors (Homo erectus and maybe Neanderthal man) over this period are nearly beyond present day imagination. It is of importance to note that the average temperature gradient for the transition for the past four glacial and inter-glacial events is about 2°C per thousand years which meant that Homo sapiens and Neanderthal man had 5,000 years, perhaps 200 generations, to adjust to the extremes from cold to hot through migration and acclimatisation.

Figure 3 shows the departure of average global temperature from the current level and atmospheric carbon dioxide levels for one of the Milankovitch 100,000 year cycles. During the glacial periods when the seas were 100 metres lower than they are now, the migration in the lower latitudes both to the northern and southern hemispheres would have been towards more elevated lands. The most recent ten thousand years has offered a breathing space of relatively stable temperatures (plus or minus 2.0°C) and this has enabled multiple independent civilisations to develop and flourish. It is to be noted that for the last 1000 years Homo sapiens had 'never had it so good' since the temperature variation has been plus or minus 0.5°C. This could be termed a period of 'Permaclimate' for Homo sapiens, during the period of the 'Anthropocene'.



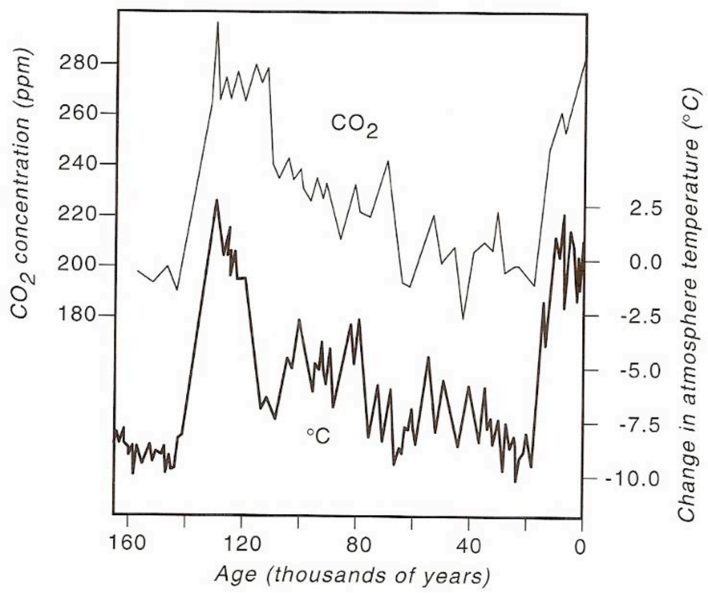


Figure 3a Shows the spectrum of cycle frequencies of 100,000; 43,000; 24,000 and 19,000 years.
Figure 3b Shows the change in both and Atmospheric Temperature and CO_2 for the 100,000 year Milankovitch Cycle. (After Manning 1990)

Note 1. **The relatively steady temperature of the last 10000 years corresponds to cultivation, farming settlements and later civilizations as we know them today.**

2. **The rise in CO_2 at the end of both Interglacial periods is after the temperatures initial rise, which is, in direct response to the Earth's elliptical eccentricity orbit around the Sun. i.e. There is an ecological response to the rise in temperature out of the glacial period.**

3. PREDICTING THE GLOBAL CLIMATE

3.1 Milutin Milankovitch and James Croll.

Both James Croll and Miluton Milankovitch are credited with developing a mathematical theory for climate over the last 500,000 years and more. Their theories predict the variable amounts of solar energy that arrive on the surface of the earth. These annual amounts depend upon the relative geometric position of the earth's axis and the relationship of its orbital position to the sun. There are three basic cyclic variations. (Earth Observatory, 2008)

1. "Variations in the Earth's orbital eccentricity - the shape of the orbit around the sun.
2. Changes in obliquity - changes in the angle that Earth's axis makes with the plane of the Earth's orbit.
3. Precession - the change in the direction of the earth's axis of rotation, I. E., the axis of rotation behaves like the spin axis of a top that is winding down; hence it traces a circle on the celestial sphere over a period of time."

In addition to the above three basic cycle variations, there are influences from all of the other 'heavenly bodies' upon the resultant radiation forcing received by earth. E.g. both Jupiter and Saturn influence the amount of radiation forcing that arrives on earth. In addition to the relative geometric orbits and motions of the 'heavenly bodies' there are other major factors like the composition of the earth's surface (sea, land, ice, forest, desert, cities, agriculture), greenhouse gases in the atmosphere, sun spot activity, aerosols, variations in the concentrations of interstellar dust, etc, which influenced the surface temperature of the earth. However, the mathematical modelling compared to the ice core climate records over the last 500,000 years indicate that eccentricity, obliquity and procession are the major influences of radiation forcing. The word which is used to describe this particular phenomenon is "Insolation". (INcoming SOLar radiATION = INSOLATION)

3.2 Predicting the "Future"

In 1976 Hays, Imbrie and Shackleton published in SCIENCE a paper entitled, "Variations in the Earth's Orbit: Pacemaker of the Ice Ages" (Hayes et. al.,1976) This was the first significant paper to correlate Milankovitch's theoretical mathematical model of orbital eccentricity, obliquity and precession to Insolation for past ocean floor sediments history obtained in the Southern Hemispheres' oceans. The spectral analysis of the climate variations over this period showed peaks at periods of 23,000, 42,000 and approximately 100,000 years and these correspond to the periodicity of the phenomena of precession, obliquity and orbital eccentricity respectively. Also it was found, "These peaks corresponded to the dominant periods of the Earth's solar orbit and contain respectively about 10, 25, and 50% of the climatic variance." This was a quite remarkable finding. From this the authors concluded that the earth's orbital geometry was the fundamental cause of the succession of glacial and interglacial periods during the Quaternary ice ages and in keeping with this finding "predicts that the long-term trend over the next several thousand years is towards extensive northern hemisphere glaciation.": this now is in total conflict with IPCC predictions of global warming.

In June 1999 Petit et. al. published in NATURE a paper entitled, "Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica". This paper extended the study of Hays et al. above and confirmed the significance of the findings from deposits below the sea floor in the Southern Hemisphere. Another example of their findings is reproduced below in figure 4.

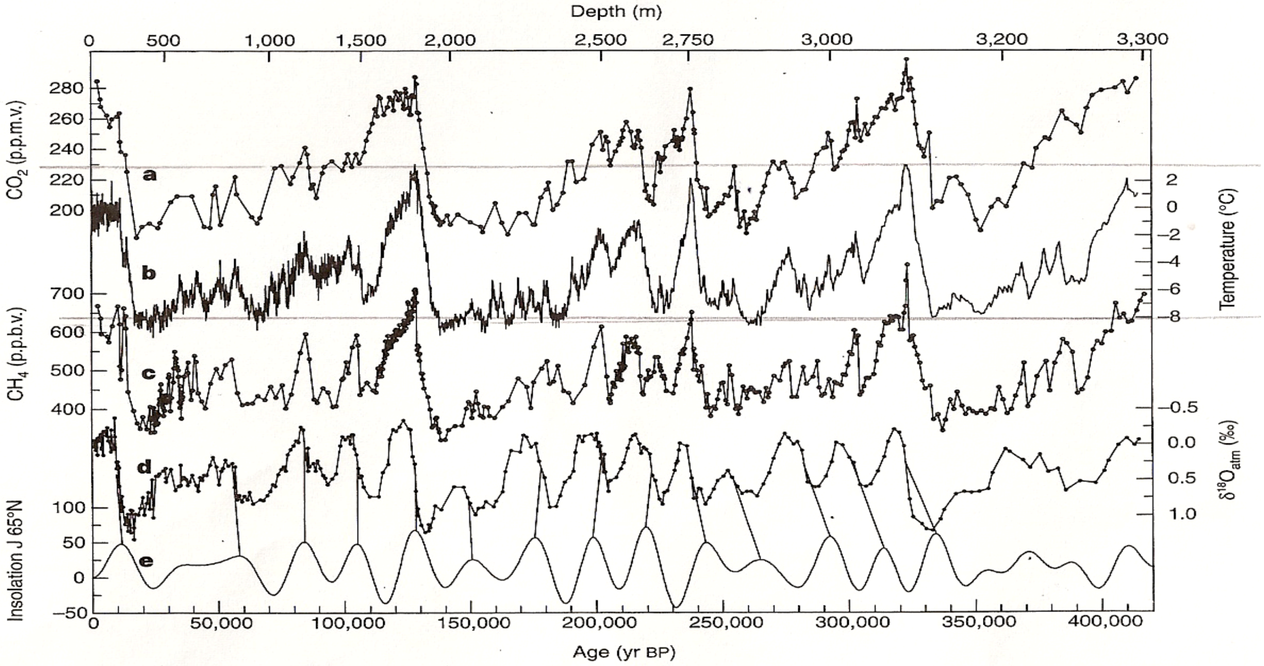


Figure 4 Vostok time series and Insolation (trace 'e') relationships to temperature methane (CH_4) and carbon dioxide (CO_2). (Showing Milanokovitch 100,000 year cycles)

The paper gives no projections of future climate possibilities apart from the statement that, "Finally, CO_2 and CH_4 concentrations are strongly correlated with Antarctic temperatures; this is because, overall our results support the idea that greenhouse gases have contributed significantly to the glacial-interglacial change. This correlation, together with the uniquely elevated concentrations of these gases today, is of relevance with respect to the continuing debate on the future of the Earth's climate."

3.2.1 Is it Global Warming or Cooling?

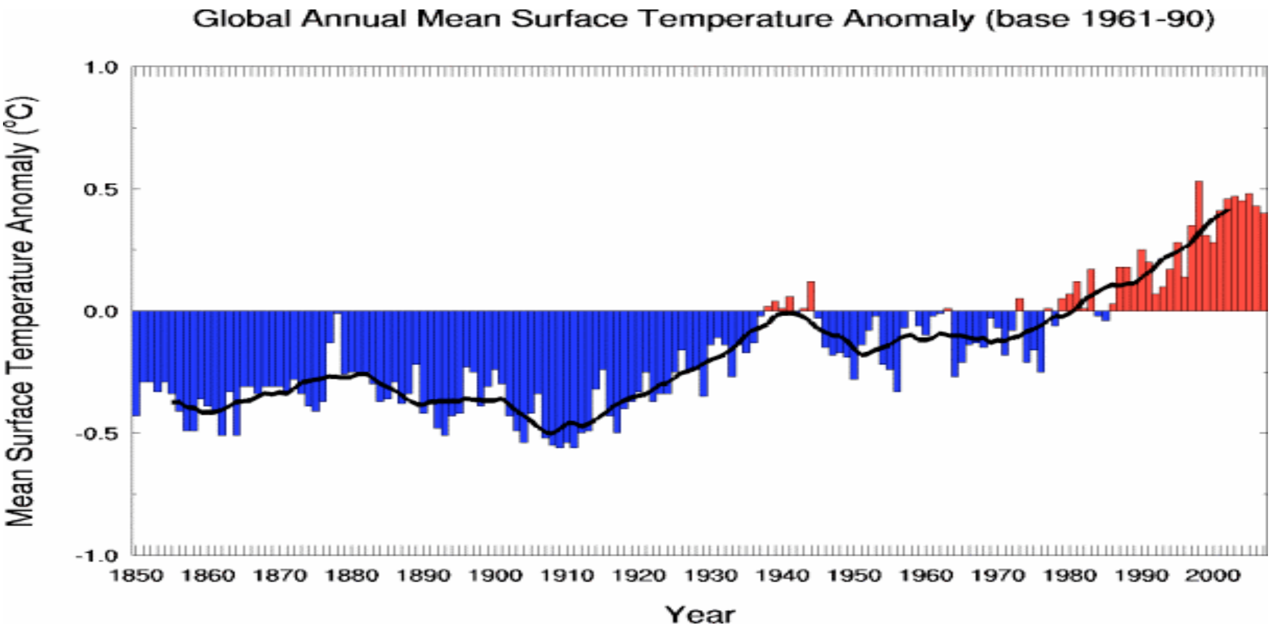


Figure 5 Depicts the increase global annual mean surface temperature since the onset of the industrial revolution. Note: After the Second World War the temperature dropped for approximately 36 years. This drop is attributed to global dimming attributed to the release of sulphur into the atmosphere from 'dirty coal' burning. (The acid rain phenomena.)

Figure 5 clearly shows that since the Industrial Revolution and the burning of fossil fuels the overall global average has increased approximately 0.7°C. In the last four years it can be seen that the temperature has marginally decreased from the average temperature projection and this is considered to be the usual variations on the increasing temperature signal. (The author sincerely hopes the opposite were the case.) It is important to remember that this average anomaly temperature is the average for both land and sea for both the Northern and Southern Hemispheres. Also, unfortunately, speculation concerning the commencement of an overdue glacial period is not supported by the recent studies as set out in the following section.

3.2.2 Or Is It the 'Heavenly Bodies' At Work?

In August 2002 Berger and Loutre published in SCIENCE a paper entitled, "An Exceptionally Long Interglacial Ahead?" The authors made a detailed study of past work and concluded that, "Most models studied to date confirm that the pattern and range of global climate conditions likely to be experienced in the future, would be close to those during the warmest phases of the last few tens of millions of years. We must use the reconstructed record of these past climates to test our understanding of the behaviour of the climate system and as a guide to future conditions." (Berger and Loutre, 2002) Reproduced below is their figure for 200,000 years before the present to 130,000 into the future describing the orbital eccentricity, insolation and ice volume.

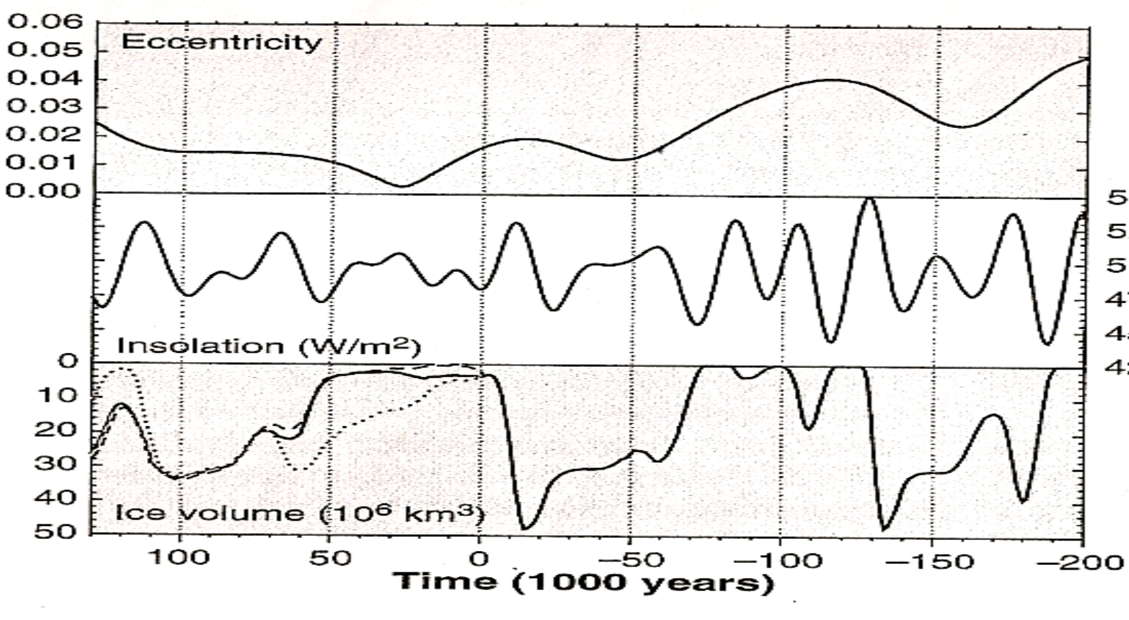


Figure 6. Orbiting the Sun. Long term variations of eccentricity (top), June insolation at 65° N (middle), and simulated Northern Hemisphere ice volume (increasing downward) (bottom) for 200,000 years before the present time to 130,000 from now.

Of particular relevance in this paper is the period from the present to 50,000 years in the future. Berger and Loutre have identified the insolation (middle) over this period of being uncommonly "average" the likes of which was last seen about 400,000 years ago where there was 50000 years of relative climate constancy, plus or minus 2^0C. They state that this isolation is the result of a particularly low eccentricity of the earth's movement around the sun (little heating or cooling variation from the 100,000 year cycle, only a variation of 25 Watts per metre squared) with the resultant effect of the ice volumes remaining basically unchanged, from what they are now, as can be seen in the bottom of the figure; the bold line.

Of particular relevance to this discussion is the dash and dotted lines which represent the 750 ppmv and 210 ppmv CO_2 scenario concentrations respectively. It becomes obvious that if the modelled levels of CO_2 rises to 750 ppmv ('Business as Usual' scenario) then we can anticipate the ice volume on earth to approach zero; this now is in agreement with IPCC predictions of global warming.

3.2.3 IPCC Assessment Report - A Summary

The chairman of the Intergovernmental Panel on Climate Change, Dr R K Pachauri, presented in Valencia, Spain on the 17th November 2007 a 'Synthesis Report' to the Press on the IPCC's Fourth Assessment Report.(IPCC,2007a) In this he stated the Vision of the UN Secretary-General on Climate Change:

- "Climate change is a serious threat to development everywhere"
- "Today, the time for doubt has passed. The IPCC has unequivocally affirmed the warming of our climate system, and linked it directly to human activity"
- "Slowing or even reversing the existing trends of global warming is a defining challenge of our ages"
- "Galvanizing international action on global warming is one of the main priorities as General Secretary"

The Fourth Assessment Report (AR4) was prepared by more than 2500 scientific expert reviewers, 150 leading authors from over 130 countries in the world. Their findings showed unequivocally that there was warming of the climate system: increasing global air and ocean temperatures, rising global average sea levels and reductions in snow and ice around the World. There was an increase in the frequency of extreme events and that anthropogenic warming could lead to some impacts that could be abrupt and/or irreversible. This consensus report presented a number of carbon dioxide mitigation models that could achieve particular stabilization levels. A number of models produced a range of outcomes. This is important because some of the models were conservative and others were extreme. Refer to table 1 for the relationship of a particular stabilization scenario, stabilization carbon level and corresponding temperature rise.

Table 1 IPCC Summary table showing mitigation categories, temperature rise, sea level rise and corresponding CO2 –equivalents.

Category	CO_2 concentration at stabilization (2005 = 379 ppm) [b]	CO_2-equivalent Concentration at stabilization including GHGs and aerosols (2005 = 375 ppm) [b]	Peaking year for CO_2 emissions [a, c]	Change in global CO_2 emissions in 2050 (% of 2000 emissions) [a, c]	Global average temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity [d], [e]	**Global average sea level rise above pre-industrial at equilibrium from thermal expansion only** [f]	Number of assessed scenarios
	ppm	ppm	Year	Percent	°C	**metres**	
I	350 – 400	445 – 490	2000 – 2015	-85 to -50	2.0 – 2.4	**0.4 – 1.4**	6
II	400 – 440	490 – 535	2000 – 2020	-60 to -30	2.4 – 2.8	**0.5 – 1.7**	18
III	440 – 485	535 – 590	2010 – 2030	-30 to +5	2.8 – 3.2	**0.6 – 1.9**	21
IV	485 – 570	590 – 710	2020 – 2060	+10 to +60	3.2 – 4.0	**0.6 – 2.4**	118
V	570 – 660	710 – 855	2050 – 2080	+25 to +85	4.0 – 4.9	**0.8 – 2.9**	9
VI	660 – 790	855 – 1130	2060 – 2090	+90 to +140	4.9 – 6.1	**1.0 – 3.7**	5

The IPCC AR4 suggested Solutions are as follows:

- A wide variety of policies and instruments are available to governments to create the incentives for mitigation action.
- Stabilisation levels assessed can be achieved by the deployment of a portfolio of technologies that are either currently available or expect to be commercialised in coming decades.

- An effective carbon-price signal could realise significant mitigation potential in all sectors.

Table 2 Shows the 'Key Finding' on the Pathways towards Stabilisation (IPCC, 2007b)

Characteristics of stabilization scenarios

Stabilization level (ppm CO_2-eq)	Global mean temp. increase at equilibrium (°C)	Year CO_2 needs to peak	Year CO_2 emissions back at 2000 level	Reduction in 2050 CO_2 emissions compared to 2000
445 – 490	2.0 – 2.4	2000 - 2015	2000- 2030	-85 to -50
490 – 535	2.4 – 2.8	2000 - 2020	2000- 2040	-60 to -30
535 – 590	2.8 – 3.2	2010 - 2030	2020- 2060	-30 to +5
590 – 710	3.2 – 4.0	2020 - 2060	2050- 2100	+10 to +60
710 – 855	4.0 – 4.9	2050 - 2080		+25 to +85
855 – 1130	4.9 – 6.1	2060 - 2090		+90 to +140

Mitigation efforts over the next two to three decades will have a large impact on opportunities to achieve lower stabilisation level. (IPCC, 2007b)

This table relates the particular stabilisation level, in ppm, that is required to meet a specific global mean temperature increase and as a consequence how this would relate to carbon dioxide levels. Further, the right-hand-side column shows the required reduction in 2050 of the carbon dioxide emissions compared to the year 2000 to meet the chosen temperature increase target. From this table it is clear what stabilisation actions need to be taken to bring carbon dioxide emissions back to the 2000 year level. E.g. if a stabilisation target was set at between 445 to 490 ppm of carbon dioxide equivalent then it would take until 2000 or to 2020 to bring those levels back to the 2000 emission level. It would be expected that as a consequence the global mean temperature increase would be between 2.4 and 2.8°C. In the next section we will see what each degree centigrade rise in average global temperature could mean.

3.2.4 What does 1^0C mean?

What does the actual increase in average global surface temperature of 1°C mean? (Russell, 2008) (The current increase in average global surface temperature is estimated to be 0.8°C since the beginning of the industrial revolution.) For that matter how does a rise of two, three, four, five or six degrees Celsius relate to living conditions on planet Earth? This question has been addressed by Mark Lynas in his recently published book, "SIX DEGRESS Our Future on a Hotter Planet". (Lynas, 2007) Mark Lynas reviewed tens of thousands of scientific papers and has done what no other journalist or scientist has achieved: presented all the available scientific information about incremental climate change and its implications in chapter by chapter format. I.e. chapter 1 is entitled, "1^0" and chapter six "6^0".

Chapter 1 and 2 acknowledges the commencement of the processes which are moving towards tipping points in various parts of the world. Chapter 3 acknowledges among other outcomes the destruction of the Amazonian forests; what can be expected when the temperature rise of up to 3^0C. The subheadings read, "What every Botswanan wants, Perils of the Pliocene, the Christ Child returns, The death of the Amazon, Australia's Ash Wednesday, Houston, we have a (hurricane) problem, Dawn over a new Arctic, Mysteries of the Maya, Mumbai's monsoon, Where the Indus once ran, The last drops of the Colorado, Sinking the Big Apple, Storms gather in Europe, Africa's fever, Paradise lost and Growing food in the greenhouse: fascinating subheadings with chilling predictions that are all the distillation of refereed research papers.

Chapter 6 postulates the extinction of most life on Earth with a temperature rise of up to 6^0 C. The subheadings read, The Cretaceous world, Oily oceans, The end - Permian wipe-out and Back to the future.

3.3.5 Recent Developments

At a recent conference in Canberra Australia, June 2008, "Imagining The Real-Life on the Greenhouse Earth" Professor Barry Pittcock, of the CSIRO, said in an interview with The Age "We are at or exceeding the fossil-fuel-intensity scenario, which the latest IPCC report didn't cover because they thought it was too much," and "… the amount of carbon dioxide going into the atmosphere had overtaken even the worst-case scenario included in last year's benchmark report by the Intergovernmental Panel on Climate Change. The article was entitled, "'No return' fears on climate change". (The Age, 2008). In the same article, climate change expert, Professor Barry Brook of the Adelaide University said, "We are seeing events predicted for the end of the 21st century happening already".

4.0 SUMMARY

1. The climate of the Earth has been changing over the ages.
2. Since the Cambrian (650 million years ago) the average global temperature has varied between 12° and 22°C
3. Today we are in an Ice- House which can get 10°C cooler during a glacial periods.
4. The Vostok ice core and other studies confirm that the incoming solar radiation (INSOLATION) is the driver for the Earth's climate in the current period.
5. The Insolation can be reliably modelled using the Milankovitch Mechanism theory of the orbital movement of the Earth around the Sun.
6. Future projections of the Milankovitch Mechanism indicate a very small variation in the Insolation in the next 50000 years due to be unusually small eccentricity in the Earth's orbit around the Sun.
7. The above projections indicate basically unchanged ice volumes over the next 50,000 years if the carbon dioxide concentrations replicate the carbon dioxide levels attributed to the last glacial/interglacial period.
8. Modelling of human induced carbon dioxide concentrations of 750 ppmv indicate that the Earth's ice volumes could approach zero.
9. Modelling of carbon dioxide concentrations of 210 ppmv would allow the Earth's ice volumes to gradually increase.
10. The IPCC's chosen stabilisation level scenario is 445 to 490 (ppmv CO2 – eq) which corresponds to a reduction in 2050 of CO2 emissions of -85 to -50% compared to 2000 levels and would result in a global mean temperature to increase an equilibrium of 2.0 to 2.4°C.
11. Recent developments indicate that the IPCC's worst-case scenario will be exceeded if current levels of CO2 emissions continue at their increasing rate.
12. The greatest average global temperature that the Earth can endure without the severe risk of irrevocable damage to our current ecological system is 2°C.

5. CONCLUSION

1. That unless there is a demonstrated WILL by the nations of the world to drastically reduce carbon dioxide emissions within a very short time-frame the world community will have to consider desperate measures if billions of people are not to perish and the species is to survive.

2. A two pronged approach will be essential to avoid this latter scenario. Both the carbon dioxide emissions must be reduced as quickly as possible and measures taken to reduce the Insolation particularly in the next 20 to 30 years.

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