THE GEOLOGICAL PERSPECTIVE OF GLOBAL WARMING

A DEBATE

Dr Colin P. Summerhayes
Professor Robert Carter
Professor Vincent Courtillot

The Global Warming Policy Foundation
GWPF Note 6

GWPF REPORTS

THE GLOBAL WARMING POLICY FOUNDATION

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The Geological Perspective Of Global Warming - A Debate

Dr Colin P. Summerhayes, Vice-President of the Geological Society of London

Dear Dr Peiser,

In the interest of contributing to the evidence-based debate on climate change I thought it would be constructive to draw to your attention the geological evidence regarding climate change, and what it means for the future. This evidence was published in November 2010 by the Geological Society of London in a document entitled 'Climate Change: Evidence from the Geological Record', which can be found on the Society's web page.[1]

A variety of techniques is now available to document past levels of CO_2 in the atmosphere, past global temperatures, past sea levels, and past levels of acidity in the ocean. What the record shows is this. The Earth's climate has been cooling for the past 50 million years from 6-7°C above today's global average temperatures to what we see now. That cooling led to the formation of ice caps on Antarctica 34 million years ago and in the northern hemisphere around 2.6 million years ago. The cooling was directly associated with a decline in the amount of CO_2 in the atmosphere. In effect we moved from a warm 'greenhouse climate' when CO_2, temperature and sea level were high, and there were no ice caps, to an 'icehouse climate' in which CO2, temperature and sea level are low, and there are ice caps. The driver of that change is the balance between the emission of CO_2 into the atmosphere from volcanoes, and the mopping up of CO2 from the atmosphere by the weathering of rocks, especially in mountains. There was more volcanic activity in the past and there are more mountains now.

Superimposed on this broad decline in CO_2 and temperature are certain events. Around 55 million years ago there was a massive additional input of carbon into the atmosphere – about 4 times what humans have put there. It caused temperatures to rise by a further 6°C globally and 10°C at the poles. Sea level rose by some 15 metres. Deep ocean bottom waters became acid enough to dissolve carbonate sediments and kill off calcareous bottom dwelling organisms. It took over 100,000 years for the Earth to recover from this event. More recently, during the Pliocene, around 3 million years ago, CO_2 rose to levels a little higher than today's, global temperature rose to 2-3°C above today's level, Antarctica's Ross Ice Shelf melted, and sea level rose by 10-25 metres.

The icehouse climate that characterised the past 2.6 million years averaged 9°C colder in the polar regions and 5°C colder globally. It was punctuated by short warm interglacial periods. We are living in one of these warm periods now – the Holocene – which started around 11,000 years ago. The glacial to interglacial variations are responses to slight changes in solar energy meeting the Earth's surface with changes in: our planet's orbit from circular to elliptical and back; the position of the Earth relative to the sun around the Earth's orbit; and the tilt of the Earth's axis. These changes recur on time scales of tens to hundreds of thousands of years. CO_2 plays a key role in these changes. As the Earth begins to warm after a cold period, sea ice melts

1 http://www.geolsoc.org.uk/en/Policy%20and%20Media/Policy%20and%20Position%20Statements/Climate%20change%20evidence%20from%20the%20geological%20record

allowing CO_2 to emerge from the ocean into the atmosphere. There it acts to further warm the planet through a process known as positive feedback. The same goes for another greenhouse gas, methane, which is given off from wetlands that grow as the world warms. As a result the Earth moves much more rapidly from cold to warm than it does from warm to cold. We are currently in a cooling phase of this cycle, so the Earth should be cooling slightly. Evidently it is not.

The Geological Society deduced that by adding CO_2 to the atmosphere as we are now doing, we would be likely to replicate the conditions of those past times when natural emissions of CO_2 warmed the world, melted ice in the polar regions, and caused sea level to rise and the oceans to become more acid. The numerical models of the climate system that are used by the meteorological community to predict the future give much the same result by considering modern climate variation alone. Thus we arrive at the same solution by two entirely independent methods. Under the circumstances the Society concluded that 'emitting further large amounts of CO_2 into the atmosphere over time is likely to be unwise, uncomfortable though that fact may be.'

Yours sincerely,

Dr Colin P. Summerhayes

Vice-President, Geological Society of London and Emeritus Associate, Scott Polar Research Institute, Cambridge.

8 February 2013

Professor Robert Carter and Professor Vincent Courtillot respond:

Dear Dr Peiser,

Thank you for your invitation on behalf of the [Global Warming Policy] Foundation to reply to Dr Summerhayes' letter about geological evidence in relation to the hypothesis of dangerous anthropogenic global warming (DAGW) that is favoured by the Intergovernmental Panel on Climate Change (IPCC).

We are in agreement with many of Dr Summerhayes' preliminary remarks about the geological context of climate change. This reflects that a large measure of scientific agreement and shared interpretation exists amongst most scientists who consider the global warming issue.

Points of commonality in the climate discussion include:

* that climate has always changed and always will,

* that Earth has often been warmer than it is today, and that its present climatic condition is that of a warm interglacial during a punctuated icehouse world,

* that carbon dioxide is a greenhouse gas and warms the lower atmosphere (though debate remains as to the magnitude and timescale of the warming),

* that a portion of human emissions are accumulating in the atmosphere,

* that a global warming of around 0.5°C occurred in the 20th century, but that there has been no global temperature rise over the last 16 years.

The first two points are rooted in geological evidence (as discussed in more detail by Dr Summerhayes), the third is based upon physical principle and the last three are mostly matters of instrumental measurement (i.e. observation). Despite the disparate scientific disciplines involved, all these points are relevant to achieving a quantitative understanding of climate change, together with several other disputed scientific matters such as those that we discuss below.

One of the disputed scientific matters is represented by Dr Summerhayes' assertion that cooling over the last 34 million years 'was directly associated with a decline in the amount of CO2 in the atmosphere'.

The word 'associated' is ambiguous. It may simply mean that temperature and CO_2 were correlated, in the sense that their trends were parallel. But as everyone knows correlation is not causality and whether one drives the other, or the two are driven by a third forcing factor, or the correlation is the result of chance, requires careful analysis and argument. Though it may be true that a broad correlation exists between atmospheric CO_2 content and global temperature, at least on some time-scales, it remains unclear whether the primary effect is one of increasing CO_2 causing warming (via the greenhouse effect) or of warming causing CO_2 increase (via outgassing from the ocean). We are familiar with the argument that the currently decreasing carbon isotope ratio in the atmosphere is consistent with a fossil fuel source for incremental CO_2 increases, and therefore with the first of these two possibilities, but do not find it compelling because other natural sources (soil carbon, vegetation) also contribute isotopically negative carbon to the atmosphere.

A second area of uncertainty, related to the point just discussed, is the rate, scope and direction of the various feedbacks that apply during a natural glacial-interglacial climatic cycle. Dr Summerhayes provides a confident, and perhaps plausible, account as to how changing insolation (controlled by orbital change), melting sea-ice and increasing CO_2 and CH_4 jointly drive the asymmetrical glacial-interglacial cycles that have characterised recent planetary history. However, our knowledge of the climate system and its history currently remains incomplete; some of the forcing mechanisms and feedbacks may not be known accurately, or even at all. For example, we do not yet know whether clouds exert a net warming or cooling effect on the climate. Similarly, variations in ultraviolet radiation and high-energy particle emission from the Sun, in atmospheric electricity and in galactic cosmic rays may all play larger roles in controlling climate change than is currently assumed, yet these effects are absent from most of the current generation of deterministic computer models of the future climate. The temperature projections made by these models may well be affected by our ignorance of the magnitude, the sign, or even the existence of some of the forcings and feedbacks that are actually involved.

Thirdly, Dr Summerhayes also briefly discusses the issue of sea level change. He quotes an estimated increase of 15 m in sea level associated with a temperature increase of 6–10°C 55 million years ago. He then quotes a range of 10–25 m rise for a 2–3°C warming 3 million years ago. To this we might add the further examples of the 125 m sea level rise that has accompanied the 6°C temperature rise since the last glacial maximum, and the 0.2 m rise associated with the ~0.5°C 20th century warming. It appears from these examples that a 1°C temperature rise can be associated with a sea level rise of as little as 0.4 m or as much as 8 m, and all values in between! This indicates an uncertainty in our understanding of the temperature/CO2/sea-level connection that surely lessens its value for contributing to policy formulation.

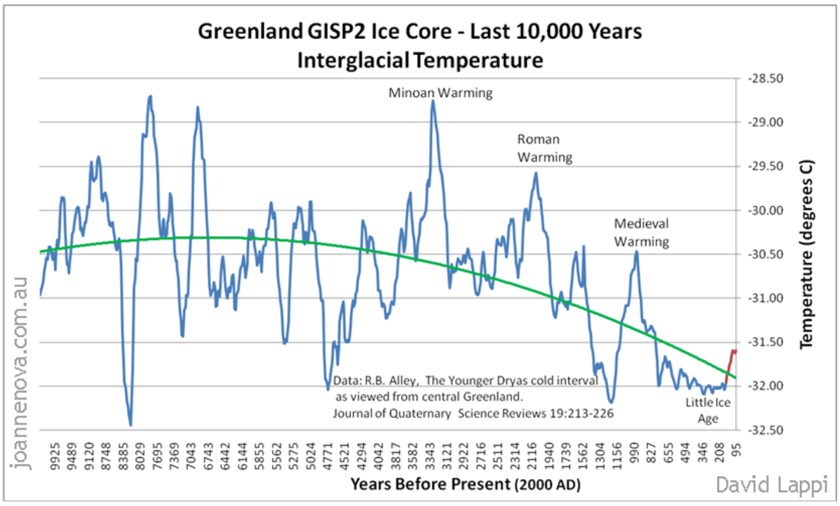

Figure 1. Temperature curve reconstructed from oxygen isotope measurements in a Greenland ice core over the last 10,000 years. *Lappi* (2010) after *Alley* (2000).

Fourth, and last, Dr Summerhayes says that because orbitally-forced climate periodicity is currently in a cooling phase 'the Earth should be cooling slightly. Evidently it is not'. The statement is tendentious, because whether Earth is seen to be cooling or warming depends upon the length of climate record that is considered. Trends over 1, 10, 100 or 1000 years are not the same thing, and their differences must be taken into account carefully. We reproduce two figures that may be used to demonstrate that Earth is currently not warming on either the longer-term millennial timescale (Figure 1) or the short-term decadal/meteorological timescale (Figure 2). We note also that on the intermediate centennial timescale (1850–2010) the temperature trend has been one of a slight (0.5°C) rise. In assessing which of these timescales is the 'proper' one to consider in formulating climate policy, we observe that the results conveyed in Figure 2 have little scientific (and therefore policy) meaning unless they are assessed in the context of the data in Figure 1.

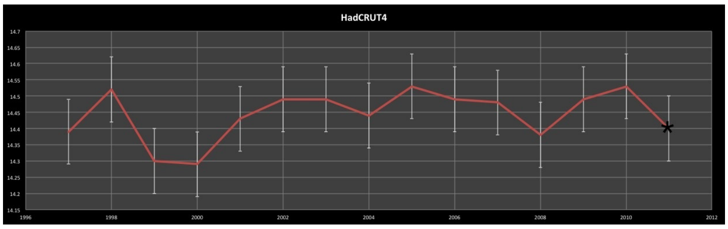

Figure 2. Mean temperature of lower atmosphere: HadCRUT4 annual means 1997-2011

We acknowledge that the data in Figure 1, which are drawn from a Greenland ice core, represent regional rather than global climate. But a similar pattern of Holocene long-term cooling is seen in many other records from around the world, including from Antarctic ice cores. Also, evidence for a millenial solar cycle has been accumulating over the past years, and, representing that rhythm, the Medieval Warming (also called Medieval Climatic Optimum) appears to have been both global and also warmer than today's climate.

Regarding Figure 2, the data demonstrate that no warming has occurred since 1997. In response, some leading IPCC scientists have already acknowledged that should the temperature plateau continue, or turn into a statistically significant cooling trend, then the mainstream IPCC view will need revision. It is noteworthy, too, that over the 16 years during which global temperature has remained unchanged (1997-2012), atmospheric carbon dioxide levels have increased by 8%, from 364 ppm to c.394 ppm. Given a mixing time for the atmosphere of about 1 year, these data would invalidate the hypothesis that human-related carbon dioxide emissions are causing dangerous global warming. In any case, observed global temperatures are currently more remote than ever from the most recent predictions set out in IPCC AR4.

The areas of uncertainty in the prevailing argument over DAGW are therefore not only geological but also instrumental and physical. Current debate, which needs to be resolved before climate policy is set, centres on the following three issues:

* whether any definite evidence exists for dangerous warming of human causation over the last 50 years,

* the amount of net warming that is, or will be, produced by human-related emissions (the climate sensitivity issue), and

* whether the IPCC's computer models can provide accurate climate predictions 100 years into the future.

In assessing these issues, our null hypothesis is that the global climate changes that have occurred over the last 150 years (and continue to occur today) are mainly natural in origin. As summarised in the reports of the Nongovernmental International Panel on Climate Change (NIPCC[2]), literally thousands of papers published in refereed journals contain facts or writings consistent with this null hypothesis, and plausible natural explanations exist for all the post-1850 global climatic changes that have been described so far. In contrast, no direct evidence exists, and nor does the Geological Society point to any, that a measurable part of the mild late 20th century warming was definitely caused by human-related carbon dioxide emissions.

The possibility of human-caused global warming nonetheless remains, because carbon dioxide is indubitably a greenhouse gas. The major unknown is the actual value of climate sensitivity, i.e. the amount of temperature increase that would result from doubling the atmospheric concentration of CO2 compared to pre-industrial levels. IPCC models estimate that water vapour increases the 1°C effect that would be seen in a dry atmosphere to 2.5-4.5°C, whereas widely cited papers by *Lindzen & Choi* (2011) and *Spencer & Braswell* (2010) both describe empirical data that is consistent with negative feedback, i.e. sensitivity less than 1°C. The conclusion that climate sensitivity is significantly less than argued by the IPCC is also supported by a range of other empirical or semi-empirical studies (e.g. F*orster & Gregory* (2006); *Aldrin et al.* (2012); *Ring et al.* (2012)).

Conclusions

Gathering these various thoughts together, we conclude that the risk of occurrence of damaging human-caused global warming is but a small one within the much greater and proven risks of dangerous natural climate-related events (not to mention earthquakes, volcanic eruptions, tsunamis and landslides, since we are dealing here with geological topics). Moreover, the property damage and loss of life that occurred in the floods in the UK in 2007; in the 2005 Katrina and 2012 Sandy storms in the USA; and in deadly bushfires in Australia in 2009 and 2013 all attest that even wealthy and technologically sophisticated nations are often inadequately prepared to deal with climate-related hazard.

The appropriate response to climate hazard is to treat it in the same way as other geological hazards. Which is to say that national policies are needed that are based on preparing for and adapting to all climate events as and when they happen, and irrespective of their presumed cause. Every country needs to develop its own understanding of, and plans to cope with, the unique combination of climate hazards that apply within its own boundaries. The planned responses should be based upon adaptation, with mitigation where appropriate to cushion citizens who are affected in an undesirable way.

The idea that there can be a one-size-fits-all global solution to deal with just one possible aspect of future climate hazard, as recommended by the IPCC, and apparently supported by Dr Summerhayes on behalf of the Geological Society, fails to deal with the real climate and climate-related hazards to which all parts of the world are episodically exposed.

Yours sincerely,

Professor Robert (Bob) Carter and Professor Vincent Courtillot, 14 February 2013

2 http://www.nipccreport.org/reports/reports.html

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Spencer R. W. & Braswell, W.D. 2010. 'On the diagnosis of radiative feedback in the presence of unknown radiative forcing.' *Journal of Geophysical Research* 115, D16109.

3 http://joannenova.com.au/2010/02/the-big-picture-65-million-years-of-temperature-swings/

Dr Colin P. Summerhayes, Scott Polar Research Institute, Cambridge

Dear Dr Peiser,

Thank you for the opportunity to respond to the critique by Drs Carter and Courtillot of my note of 14/2/13 on "The Geological Perspective of Global Warming". I initially wrote to you to draw attention to Geological Society of London's statement on this topic, because the geological perspective is usually overlooked in discussions about climate change, and it should not be. But, because Drs Carter and Courtillot moved the debate out of just the geological arena, I am responding in my own capacity, not as a representative of the GSL.

Drs Carter and Courtillot took exception to my use of the phrase

> The cooling [of the past 50 million years] was directly associated with a decline in the amount of CO_2 in the atmosphere,

saying that correlation was not causation. True. What I should have said was

> The cooling of the past 50 million years was driven by a decline in CO_2 in the atmosphere'

Prior to the Ice Age of the last 2.6 million years the amount of CO_2 in the atmosphere resulted from the interplay between the emission of CO_2 by volcanoes and its absorption by the weathering of rocks, especially in mountainous areas, as well as by sequestration in sediments. Methods to determine the likely concentration of CO_2 in the atmosphere in the geological past have improved in recent years. They include the numbers of pores (stomata) on leaves, the abundance of the mineral nahcolite (stable above concentrations of 1000 ppm CO_2), and the carbon isotopic composition of alkenones from marine plankton. Methods for determining global temperature through time have also improved. We now know that the Eocene was a time of greater volcanic output of CO_2, and that the rise of major mountain chains after that time pulled CO_2 out of the atmosphere. Geochemical models of the carbon cycle simulate the decline in CO_2 after the middle Eocene. Convergence between the CO_2 data and the output from those models provide confidence that we understand the process. There is no geologically plausible alternative. We are not talking about a loose association where there is uncertainty about cause as Drs Carter and Courtillot imply. Indeed, even Drs Carter and Courtillot accept that CO_2 is a greenhouse gas, and that accumulation of greenhouse gas in the atmosphere warms it. Likewise, its loss will cool the atmosphere.

Besides that, the GSL statement regards the massive injection of carbon into the atmosphere that took place over a short period 55 million years ago, raising temperature, raising sea level, and causing ocean acidity, as a case history that we can draw upon to tell us what may happen in the future if we continue to pump CO_2 into the atmosphere at rapid rates. It was not alone; there was another such event in the Toarcian, for example, some 180 million years ago.

Moving on to the Ice Age of the past 2.6 million years, by this time the levels of CO_2 in the atmosphere were so low that other drivers of the climate system had more effect. The primary drivers of change in the Ice Age were the tiny changes in solar radiation received at the Earth's surface due to regular and predictable changes in the Earth-Sun distance and in the tilt of the Earth's axis. These made the climate of the Ice Age fluctuate between cold periods – glacials- and warm ones – interglacials – in one of which we now live. The role of CO_2 in this system was to provide positive feedback to the rises in temperature that took us from glacials into interglacials. In this narrow context, Drs Carter and Courtillot are correct – CO_2 increased during the interglacials mainly by outgassing from the ocean. But that was not the main source of CO_2 during the Cenozoic era.

We should all reflect on the fact that the past 4 interglacials were warmer than today, and sea levels then were higher than today. Drs Carter and Courtillot wonder if we know enough about the behaviour of the climate system during the Ice Age to be confident in our analysis. Yes we do. The uncertainties are minor. Given what we know from the link between CO_2 and temperature with time from the geological record, it would be foolish to imagine that if we warm our planet to the same extent as it warmed in previous interglacials, we will not also see similar rises in sea level to those that occurred in them. In any case, waiting until all small uncertainties are resolved is not a reasonable option.

Our geological knowledge of past climate change is independent of the numerical models used by climatologists to tell us what may happen if we add more CO_2 to the atmosphere. The geological data, recalibrated in 2012 by the PALAEOSENS team led by Eelco Rohling (*Nature* 491, 683-691, 29 November 2012), tell us that the sensitivity of the climate in the past to a doubling of CO_2 was 2.2-4.8°C, about the same as calculated for the modern climate by the climate modellers who feed data to the IPCC. This match is unlikely to be a coincidence. Indeed, it suggests that the climate modellers may well be on the right track, and that Dr Lindzen and others may be wrong in suggesting that the sensitivity is 1°C or less. However, Drs Carter and Courtillot are right to point out that some recent studies suggest that the climate sensitivity to a doubling of CO2 may be closer to the low than to the high end of the IPCC range. While that may appear comforting, it only postpones the inevitable.

Drs Carter and Courtillot took me to task over the relationship between CO_2, temperature and sea level. However, their sea level calculations are simplistic. The 20 cm rise that we have seen since 1900 is not an equilibrium response – it is instead a transient response to a rise in temperature of 0.8°C occasioned by a rise in CO_2 of 40%, or 100 ppm. The sea level will go on rising even if we stop putting CO_2 into the atmosphere, as the ocean equilibrates with the atmosphere over decades to centuries, and as ice sheets slowly decay. Models suggest that the equilibrium position may be 0.5m/1°C due to thermal expansion alone. Currently thermal expansion accounts for around 1/3 of sea level rise, and glaciers and ice sheets for another 1/3 each. It is not difficult to see how a further rise in CO_2 could by 2100 lead to a rise in sea level of perhaps as much as 1.4 m as estimated by Stefan Rahmstorf and colleagues.

Drs Carter and Courtillot took exception to my statement that the Earth should have been cooling over the past 10,000 years. Indeed it should because that is what we calculate from known phenomena like changes in the Earth-Sun distance and tilt of the Earth's axis. Other shorter-term changes will of course be superimposed upon that trend. Drs Carter and Courtillot emphasize them by providing a graph of Greenland temperatures, but as they point out those were regional. Even so, that graph too shows underlying cooling for the past 5000 years. The small divergences from the mean on the Greenland graph were caused by short term climate changes like those of the Medieval Warm Period and the cooling of the Little Ice Age, which coincided with the Maunder Minimum in sunspot activity between around 1645 and 1715. Both events seem to have been most intense in the North Atlantic and European region, not globally. There is no evidence that the Medieval Warm Period was warmer than today globally. Nor is there any evidence to suggest that we are now living through a similar event.

Drs Carter and Courtillot would like us to believe that the current rapid global warming event is purely natural. This seems odd given that they also accept that carbon dioxide is a greenhouse gas that warms the lower atmosphere and that a portion of human emissions of CO_2 is now accumulating in the atmosphere. Moreover one of their key references (*Ring et al* 2012) makes it clear that human activity has caused the warming since 1900. All our attempts to relate the post 1970 warming to natural sources of heat have failed. Our burning of fossil fuels is detectable in the atmosphere from a reduction in oxygen as well as from an increase in CO_2 and from the carbon isotopic signature typical of the burning source materials. Since the 1970s, warming has been taking place while the suns output has not been increasing. Nobody has yet come up with a better explanation of this recent warming than that it is caused by the known increases in CO_2 and related greenhouse gases, much as we might expect from what we know of the effect of CO_2 in the climates of the past, and from the basic physics of radiation.

The warming of the recent past up to and including 2012 is shown in the attached graph by *Hansen, J., Sato M., and Ruedy, R.,* 2013 'Global Temperature Update Through 2012' [4]. The reader will notice that the rise has not proceeded smoothly, but in a series of steps like the one that started in 2002. It was inaccurate of Drs Carter and Courtillot to suggest that this flat spot started in 1998, which was a prominent El Niño year. During El Niño years, shown in the lower graph, the emission of heat from the Pacific Ocean warms the world. Temperatures drop during the subsequent cool La Niña events. They also drop during volcanic eruptions large enough to eject fine particulates and acid gases into the stratosphere. Thus the 1998 El Niño effect visible in the graph was not the start of a flat step; it was followed by a cooling due to a large La Niña. Other large-scale oscillations within the climate system will also have had an effect, one such being the Interdecadal Pacific Oscillation, which shifted to a positive phase in the 1970s and led to a warmer Pacific. In the 2000s that Oscillation reversed, cooling the Pacific and likely thereby contributing to masking the rise in global temperature (EOS, v.94, No.6, 5 February 2013).

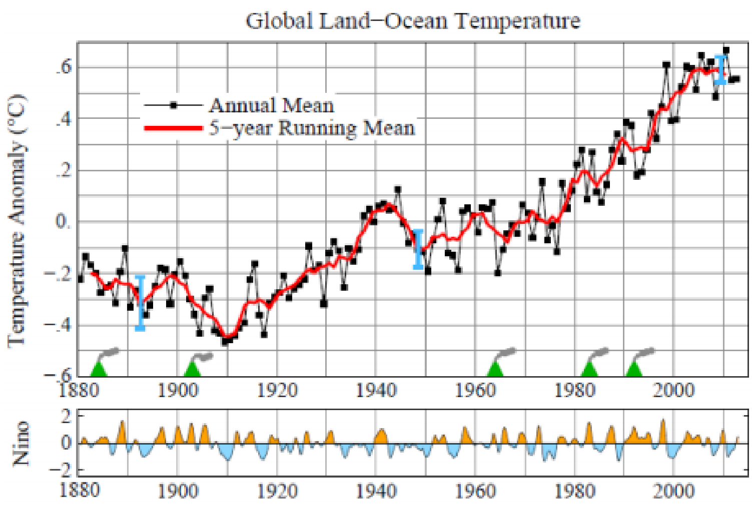

Figure 1. From *Hansen, Sato and Ruedy*, 2013. Global surface temperature anomalies relative to 1951-1980. The Nino index is based on the detrended temperature in the Nino 3.4 area in the eastern tropical Pacific. Green triangles mark volcanic eruptions that produced an extensive stratospheric aerosol layer. Blue vertical bars are estimates of the 95% confidence interval for comparisons of nearby years.

4 http://www.columbia.edu/~jeh1

In conclusion, I consider that the data from the geological record are consistent with the data from the modern environment, and with projections made on the basis of those modern data as to how our climate may change in the future. Anyone who accepts that CO_2 is a greenhouse gas, as Drs Carter and Courtillot do, must expect that a large increase in its concentration is bound to have a warming effect, and observations show a warming that is consistent with this effect. Remarkably few climate scientists dispute that fact. The world is indeed exposed to real short-term climate related events, as Drs Carter and Courtillot point out, but what we face in human-made global warming is an insidious underlying upward trend that will exacerbate those short term events unless action is taken to deal now with the causes of that trend.

C. P. Summerhayes, Scott Polar Research Institute, Cambridge

Revised 3 March 2013

Professor Robert Carter and Professor Vincent Courtillot respond:

We thank Dr Summerhayes for his further comments, and agree with him that the geological perspective on climate change is an important one that is often underappreciated.

However, the science of geology is a holistic one, and includes an understanding of modern earth processes such as those involved in meteorology and climatology. We therefore do not see that we have moved the debate out of the geological arena. Rather, our approach to the global warming issue is to undertake an assessment of all the major and relevant scientific considerations within proper geological context.

Turning to the main points made by Dr Summerhayes, we are aware of the Eocene as a time of great output of CO_2. One of us (VC) has worked for the past decade on geological evidence of huge and rapid volcanic pulses in large igneous provinces (the Deccan traps at the KT boundary and the Karoo traps at the Toarcian extinction), and has suggested that the Late Paleocene Thermal Maximum could have been caused by one phase of the eruption of the Greenland traps. Volcanic flows exceeding 10,000 km^3 in volume and erupted in less than a century have been documented, and their climatic consequences, due to release of SO_2 and CO_2, have been studied and modelled. We are therefore alert to the fact that the release of CO_2 by volcanism, and its subsequent withdrawal by alteration and sequestration in sediments, have played roles in influencing ancient climate.

Nonetheless, and as we stated in our earlier letter, the key questions that remain concern:

(i) the accuracy (or uncertainties) of the quantitative estimates of climate sensitivity to CO2 increase; and

(ii) the precise, quantitative nature of important processes of cloud microphysics and solar forcings.

For example, though total solar irradiance (TSI) varies by only 0.1 percent over the decadal time scale of instrumental observations, ultra-violet (UV) and extreme ultra-violet (EUV) radiation varies by tens of percent. Depending on whether the forcing mechanism depends only on TSI or also on UV and EUV (through atmospheric electricity and induced cloud cover variations), the climate response will be totally different. And the degree to which such variations occur also on longer, geological timescales remains unknown.

For these reasons, applying what is seen on geological time scales to the present, or vice versa, remains fraught with uncertainty. It is these uncertainties that are often forgotten, that remain as topics for much further research, and that we wish to emphasize.

As Dr Summerhayes recalls, some past interglacials were warmer and sea levels higher than today due to the Sun and not CO_2. Nonetheless, the unattentive reader here may be led to forget that the warming that caused these earlier sea level rises was due to the Sun, through Milankovic orbital changes.

Further on sea level rise: the steady 20th century increase in sea level displayed by the tide gauge record starts around 1900, when the flat slope in previous decades changes to a linear, regular increase of about 20 cm/century. This slope was established before the major post-WWII CO_2 increases, and continues unchanged after them. How then can it be considered as a transient response to CO_2 rise?

The last sentence of Dr Summerhayes' comments on sea level concludes that

> In any case, waiting until all small uncertainties are resolved is not a reasonable option.

This is an affirmation of the 'precautionary principle', which is a sociological and not a scientific concept. Apart from the fact that the remaining uncertainties in climate science are not small but large and many, the doctrinaire application of the precautionary principle often leads to expensive or unreasonable consequences, to the degree that a 2006 report by the House of Commons Select Committee on Science and Technology recommended against the use of the concept in public policy formulation.[5]

On climate sensitivity, Dr Summerhayes acknowledges that some recent studies suggest that climate sensitivity is significantly smaller than previously emphasized in many reports, and by the IPCC. Dr Lindzen indeed 'may be wrong' in suggesting that sensitivity is less than 1°C; alternatively, he may be right. The key point is that the debate is clearly not over and therefore the situation cannot be considered as being scientifically settled to the degree that public policy formulation requires. Most climate modellers, who have achieved significant advances over the past decades, acknowledge that a number of ill-understood physical processes that bear on climate sensitivity remain to be modelled accurately, such as details of water phase changes and cloud microphysics.

Dr Summerhayes asserts that we took exception to his statement that the Earth should have been cooling over the past 10,000 years. In fact, we queried the comment that

> the Earth should be cooling slightly. Evidently it is not,

and gave reasons why the statement is, at best, ambiguous. We also made the specific point that the Earth had indeed cooled through the Holocene, consistent with a Milankovic control.

On the Medieval Warm Period (MWP) being global and warmer than today, there are many papers arguing for that and the debate is certainly not closed. Whether the MWP was more intense in some locations than others, as claimed by Dr Summerhayes, is largely irrelevant for the same reason that it is irrelevant that the climatic signature of the last glaciation was much reduced in lower, and enhanced in higher, latitudes. 'Global climate' is an abstraction within which great local and regional variation can and does occur. In any case, an excellent and comprehensive database of papers on the MWP from locations around the world has been compiled by Dr Craig Idso.[6]

On the temperature rise of just under a degree Celsius that has occurred over the past 150 years, the idea that it reflects a millennial cycle of solar activity remains as valid as (and we believe more likely than) the idea that CO_2 rise is responsible. Again, the issue is one of climate sensitivity and the disentanglement of the solar and CO_2 responses, all of which are topics of ongoing research.

On the global temperature plateau since 1997, this has now been acknowledged by even

5 'We can confirm our initial view that the term "precautionary principle" should not be used, and recommend that it cease to be included in policy guidance…In our view, the terms "precautionary principle" and "precautionary approach" in isolation from any such clarification have been the subject of such confusion and different interpretations as to be devalued and of little practical help, particularly in public debate.' House of Commons Science and Technology Committee, 2006 'Scientific Advice, Risk and Evidence Based Policy Making.' Seventh Report of Session 2005-06.
http://www.publications.parliament.uk/pa/cm200506/cmselect/cmsctech/900/900-i.pdf

6 http://www.co2science.org/data/mwp/mwpp.php

the head of the IPCC, Dr Rajendra Pachauri, who has previously strongly denied its reality. However, the temperature pause is a short-term feature, and its significance within any longer-term trends or multi-decadal rhythms that may be present remains a challenge, not a settled point.

Dr Summerhayes asserts that we wish people to believe 'that the current rapid global warming event is purely natural'. In actuality, we wrote regarding the mild, not rapid, 20th century warming that 'our null hypothesis is that the global climate changes that have occurred over the last 150 years (and continue to occur today) are mainly natural in origin', and pointed to the abundant evidence that favours this hypothesis. Given that the warming response to increasing carbon dioxide decreases at a logarithmic rate, the facts that CO_2 is a greenhouse gas and is accumulating in the atmosphere do not necessarily imply that dangerous or even measurable warming will occur – as may already be indicated by the lack of warming over the last 17 years in face of an 8% increase in carbon dioxide.

In conclusion, climate change is as much a geological matter as it is a meteorological one. For that reason we agree with Dr Summerhayes that studying the geological past, trying to make observations at always increasing time resolution and extracting constraints on past climate behaviour can greatly enlighten our understanding of recent and current climate change.

Yet all of that accepted, the most important point to be reiterated here is that many disputed scientific matters need to be better understood before climate science can be viewed as mature enough to be used to inform public policy.

Vincent Courtillot

Bob Carter

4 March 2013

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Our main focus is to analyse global warming policies and their economic and other implications. Our aim is to provide the most robust and reliable economic analysis and advice.

Above all we seek to inform the media, politicians and the public, in a newsworthy way, on the subject in general and on the misinformation to which they are all too frequently being subjected at the present time.

The key to the success of the GWPF is the trust and credibility that we have earned in the eyes of a growing number of policymakers, journalists and the interested public.

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Published by the Global Warming Policy Foundation, December 2013

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