

“The Great Global Warming Swindle”: a critique.

David Jones, Andrew Watkins, Karl Braganza and Michael Coughlan

National Climate Centre, Bureau of Meteorology

Background

The Great Global Warming Swindle (GGWS) is a controversial documentary on climate change by British television producer Martin Durkin. This documentary argues against conventional scientific understanding of the degree and cause of recent, observed climate change. The overwhelming view amongst climate scientists is that twentieth century global warming is largely due to an increase in atmospheric greenhouse gases resulting from increased industrialization during the last 100-150 years. Durkin presents an alternative view that recent global warming is neither significant nor due to human activity. The documentary does not attempt to argue the latter view through any critical deconstruction of climate science orthodoxies. Rather, it contends that modern climate scientists are at best seriously misguided in their collective opinion on the nature and causes of global warming, or are at worst guilty of lying to the rest of the community. Publicity for the documentary leans heavily towards the latter, stating that global warming is “the biggest scam of modern times”.

There are at least three versions of this documentary currently in circulation. The first was shown on Channel 4 in the UK on 8 March 2007. A revised version was then shown on Channel “More 4” in the UK on 12 March, which corrected a number of obvious errors. A shortened (approximately 60 minute) version was due to air on Australian ABC Channel 2 on 12 July 2007.

The documentary uses a series of techniques, as listed below, to shake the viewer’s belief in current orthodox understanding and to present an amenable contrary viewpoint.

- Several experts, labelled as ‘authoritative’, are interviewed to lend credibility to the documentary.
- These commentators are presented as ‘insiders’ who cast doubt on the integrity of climate change science and the IPCC assessment process that

has led to current orthodox understanding.

- Alternate scientific contentions are presented in a credible way by selectively presenting facts and heightening uncertainties without context or by specious reference to the actual published science.
- The motivation and morality of scientists driving current orthodox understanding is questioned through aspersions that are conspiratorial in nature.

Most of the expert commentators appearing in the documentary are well known ‘climate sceptics’. One of the key scientists interviewed for the original documentary, Professor Carl Wunsch, Chair of Physical Oceanography at the Massachusetts Institute of Technology, has publicly stated¹ that he was completely misrepresented in the documentary. Indeed, much of the documentary’s shortening to 60 minutes for the ABC (about 15 minutes shorter than the original) is a result of heavy editing of Professor Wunsch’s contribution to the original version. His removal leaves the documentary with four climate experts: Richard Lindzen, Patrick Michaels, Roy Spencer and John Christy. To the best of our knowledge, none of these interviewees has published a credible alternative to the scientific consensus on global warming provided in the IPCC reports. They present intentionally or otherwise through selective editing, grossly simplified and often disingenuous and counterfactual arguments and quotes.

In summary the documentary is not scientifically sound and presents a flawed and very misleading interpretation of the science. While giving the impression of being based on peer-reviewed science, much of the material presented is either out-of-date, already discredited or of uncertain origin. A number of the graphs and figures used in the documentary

¹

<http://ocean.mit.edu/~cwunsch/papersonline/channel4response>

are not based on any known or published climate data, while others are presented schematically, and hence may confuse and mislead the viewer.

Detailed Overview of Errors

Since its first screening in the UK, errors in the claims made in the programme have been well documented. This critique draws upon two sources^{2,3} that have provided detailed discussions of factual errors in the GGWS. It also draws upon the IPCC reports and relevant literature to clearly outline the current state of knowledge in relation to issues that the programme presents as scientifically contentious.

ASSERTION: Global average temperature today is not as high as it was during other times in recent history, such as the Medieval Warm Period, indicating that the recent warming trend is a natural phenomenon.

The documentary attempts to support the claim that temperatures were higher in the recent past with the graph shown below ‘Temp – 1000 Years’ – attributed to the “IPCC”. This graph purports to show global average temperature between AD 900 and “now”, with the highest values recorded between about 1100 and 1300 (labelled as “Medieval Warm Period”).

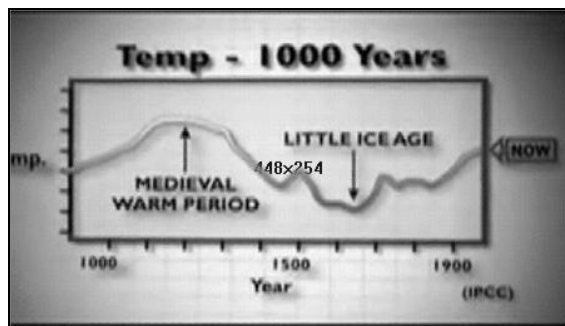


Figure 1. GGWS historical temperature graph adapted from the IPCC (1990) First Assessment Report.

The graph is actually a reproduction of a schematic diagram published by the Intergovernmental Panel on Climate Change (IPCC) in its First Assessment Report in 1990 (Figure 2). It is important to note that this schematic is largely based upon early reconstructions of European temperature

changes such as that of Lamb (1988). Critically, the 1990 IPCC Report cautioned that “it is still not clear whether all the fluctuations indicated were truly global”, underlying the fact that neither regional temperature averages nor temperature records from single locations can be used as proxies for global temperature.

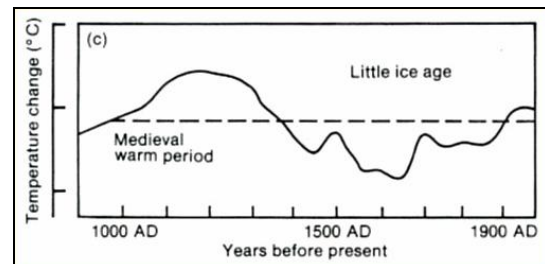


Figure 2. The temperature reconstruction shown in IPCC (1990) (largely based on European temperature series).

This 17 year-old graph has been superseded by numerous more recent studies, with the IPCC successively publishing updated records of “near global” temperature in its Second Assessment Report in 1995, its Third Assessment Report in 2001, and its Fourth Assessment Report in 2007. The most up-to-date figure for the Northern Hemisphere, from IPCC (2007), is reproduced in Figure 3 which shows 12 different reconstructions. These consistently show that, for the Northern Hemisphere, the past century is exceptionally warm, and that the warmth of recent decades clearly exceeds that of the Medieval Warm Period in all cases.

The United States National Academies published a report in 2006 (NAS 2006) that reviewed the published scientific evidence on surface temperature reconstructions for the last 2000 years. It found that “[e]vidence for regional warmth during medieval times [centred around AD 1000] can be found in a diverse but more limited set of records including ice cores, tree rings, marine sediments, and historical sources from Europe and Asia, but the exact timing and duration of warm periods may have varied from region to region, and the magnitude and geographic extent of the warmth are uncertain”. Based on a review of the scientific literature, the report concluded that “none of the large-scale surface temperature reconstructions show medieval temperatures as warm as the last few decades of the 20th century.”

Very clearly, the documentary has misrepresented the early IPCC figure, and ignored all IPCC updates to this figure. The

² [Bob Ward, Global Science Networks, http://www.climateofdenial.net/?q=node/4.](http://www.climateofdenial.net/?q=node/4)
³ Real Climate <http://www.realclimate.org/>

analyses published by the IPCC strongly contradict the documentary.

in temperature between about 1940 and 1980 (Figure 4).

ASSERTION: Global average temperature decreased between 1940 and 1980, and so could not depend on atmospheric concentrations of greenhouse gases, which increased over this period.

The programme broadcast on 8 March on UK Channel 4 presented a graph, attributed to NASA, purporting to show “World Temperature – 120 Years” between about 1878 and 2002, plotted against temperature change ranging in value from about -0.05 to 0.70 (presumably °C). The graph, a heavily smoothed representation of temperature change, shows an almost continuous decrease

In the subsequent broadcast on More 4 on 12 March, the programme presented a slightly different version of the graph, with the title “World temperature – 110 Years”. The attribution to NASA was now omitted (but not replaced with any other attribution), and the scale of the x-axis was altered such that the graph covered the years from 1880 to about 1990. Despite this change in the x-axis scale, the shape of the plot remained the same as originally broadcast, such that the apparent decline in “World Temperature” was this time shown to occur between about 1940 and 1967.

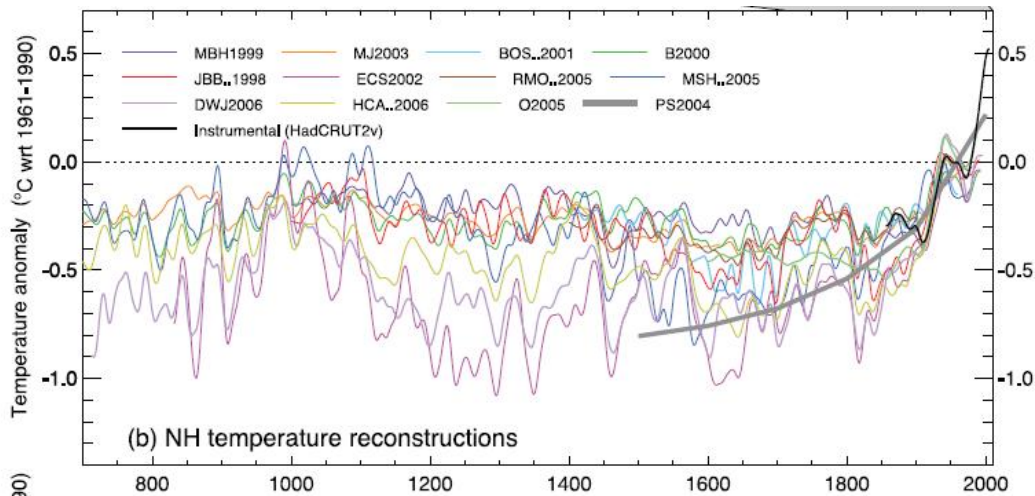


Figure 3: Northern Hemisphere temperature reconstruction (from IPCC 2007).

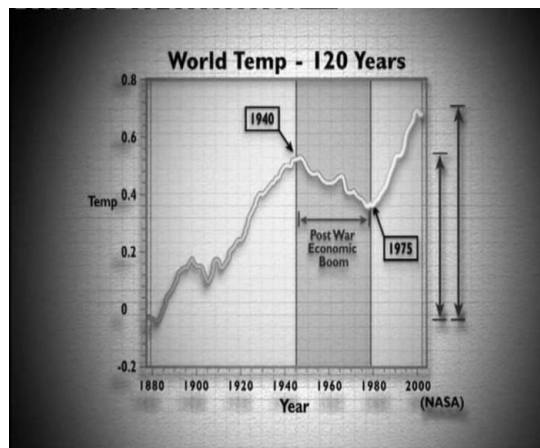


Figure 4: The temperature series shown in the original GGWS. The producers in the follow-up broadcast showed a different graph that implicitly ‘admitted’ the data actually ended in 1988, rather than around 2005-06 as suggested here.

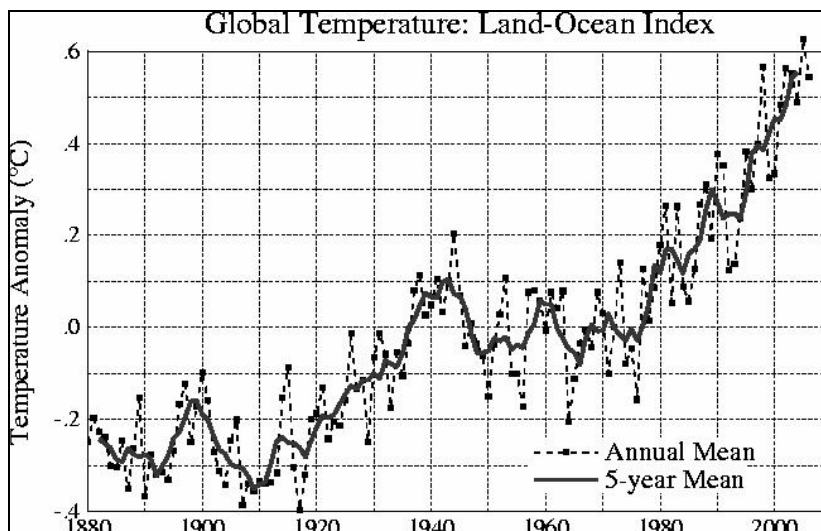


Figure 5. Global average temperatures based on NASA GISS analyses (available from <http://data.giss.nasa.gov/gistemp/graphs/>).

The origin of Figure 4 is obscure. The original graph corresponds very closely to Figure 12 of a paper by Arthur Robinson and Zachary Robinson of the Oregon Institute of Science and Medicine, with co-authors Sallie Baliunas and Willie Soon of the George C. Marshall Institute. This paper appeared in the September/October 1998 issue of 'Medical Sentinel'.

Measurements from meteorological stations that have been published by NASA and other agencies show that there was an overall *slight* decline in global temperature between about 1940 and 1976, but this decline was far less than that shown on the graph presented in the documentary (the decline seems to be around half that shown, but the actual value is uncertain as the program shows a highly smoothed graph). A copy of the most recent global temperature series from NASA's GISS is shown in Figure 5. The data used in this figure is widely available and is peer reviewed. Further, updates of these data to May 2007 show that global temperatures for 2007 are currently running at warmest on record.

The documentary's use of out-dated datasets also allows it to make the clearly incorrect statement that most global warming occurred prior to 1950. This central claim is clearly false, particularly when data from the last 10 years are included in the assessment.

In the Australian release of the film (made available to the authors by the ABC), the "NASA" curve is replaced by one from the IPCC (2001) report. This curve is not the most recent available and does not include the years 2001 to 2006 which include the globe's second, third, fourth, fifth, sixth and seventh warmest years on record (1998 and 2005 are generally accepted as being equal warmest). With the film's original point no longer valid, a five year old figure for Arctic temperature is shown in tandem with global carbon dioxide. It is quite meaningless to compare a regional temperature series to global levels of carbon dioxide.

Further, it is disingenuous to expect that a monotonic increase in carbon dioxide will lead to monotonic increases in temperatures. The anthropogenic greenhouse effect overlays other natural climate changes such as those associated with volcanic activity and the El Niño-Southern Oscillation, as well as other human induced climate changes (such as the "dimming" or cooling effect of aerosols released by industry during and after WWII, and subsequently reduced in the 1970s amidst concerns about acid rain). Numerous scientific papers have shown that the global temperature trend of the last century is entirely consistent with climate model simulations, which consider all such climate change mechanisms. This point is well made in the Third (2001) and Fourth (2007) IPCC Assessment Reports.

The fact that this stalling of the global temperature rise is well understood and reproducible in climate models further strengthens the confidence in the science of global warming.

ASSERTION: Climate models suggest that greenhouse gases should warm the troposphere faster than the surface, but observed data show that the surface is warming more quickly, indicating that any climate change that is occurring is not due to human activities.

For the most part, public dissemination of the science of climate change relies on the concept of global mean surface temperature. This concept is useful for the good and simple reason that it is a relatively easy way to describe global climate change. However, climate science uses many different climate parameters and lines of evidence to attribute recent global warming to the enhanced greenhouse effect. These lines of evidence include spatial patterns of temperature change, also known as climate 'fingerprints'. Use of the climatic fingerprinting technique has consistently shown that recent warming is largely due to greenhouse gas increases.

The pattern of temperature change through the vertical column of the atmosphere is one such spatial 'fingerprint' used by climate scientists to assess what has caused recent warming. Over the years, inconsistencies between climate models and observations meant that climate scientists had a difficult time explaining exactly what they were seeing. These issues have been addressed over the last five years, principally through increased understanding of satellite and balloon-borne radiosonde data. From these investigations there is now even firmer evidence for the enhanced greenhouse effect. The vertical structure of warming in the atmosphere, with large warming at the surface and cooling in the stratosphere, implicates greenhouse gases as the main cause.

The GGWS introduces only a very small piece of this puzzle to the viewer, viz. the apparent inconsistency between the way climate models and observations have characterized the vertical structure of the atmosphere. As mentioned above, this problem has been dealt with in a number of peer reviewed publications and is now satisfactorily understood. The science is clear, that there is no significant difference between modelled and observed vertical temperature profiles. From the outset, this issue was never large enough to outweigh all other evidence for the enhanced greenhouse effect, yet the assertion of some ongoing controversy in this area continues to be put forward by climate change sceptics. The documentary provides a simplistic and misleading interpretation of a very complicated concept that few viewers would be capable of properly comprehending.

ASSERTION: Volcanoes produce far more carbon dioxide than human activities, so anthropogenic greenhouse gases cannot be having a significant effect on global average temperature.

The documentary's claim that volcanoes produce more carbon dioxide than human activities is incorrect. It is difficult to know on what basis this claim is made, as the producers did not cite a source. However, a paper by Nils-Axel Morner and Giuseppe Etiope, published in the journal 'Global and Planetary Change' in 2002, estimated that the lower limit for global volcanic degassing of carbon dioxide at around 300 million tonnes per year. By comparison, Gregg Marland and his colleagues at the U.S Dept. of Energy's Carbon Dioxide Information Analysis Center have estimated that 26,778 million tonnes of carbon dioxide were emitted by human use of fossil fuels in 2003. Therefore, although Morner and Etiope did describe their estimate of carbon dioxide emissions from volcanoes as "conservative", it is less than 2 per cent of the annual emissions of carbon dioxide from human use of fossil fuels.

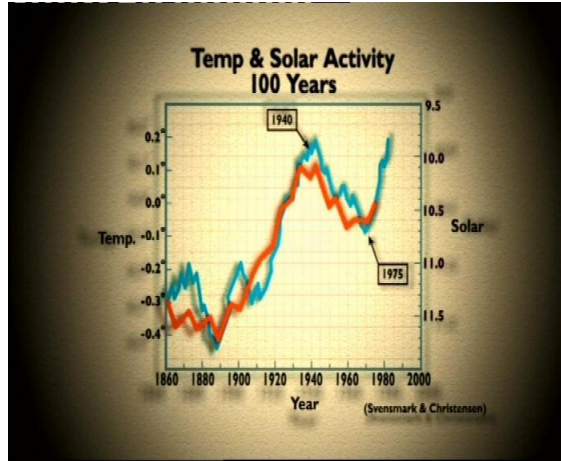


Figure 7. The temperature series shown in the original GGWS with an overlaid series of the “solar activity” (length of the solar cycle).

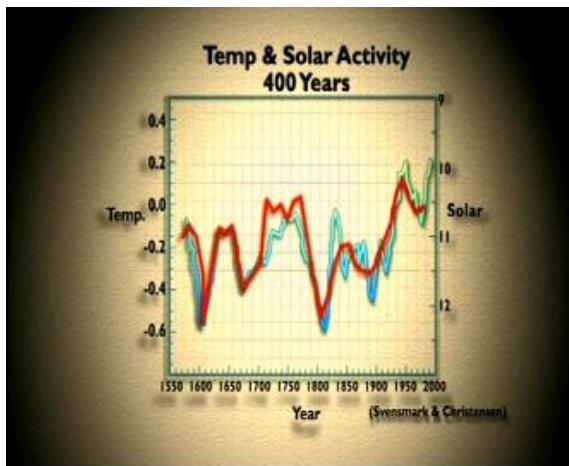


Figure 8. Extended temperature series shown in the original GGWS with an overlaid series of the “solar activity” (length of the solar cycle). The original figure on which this is based is shown in the right.

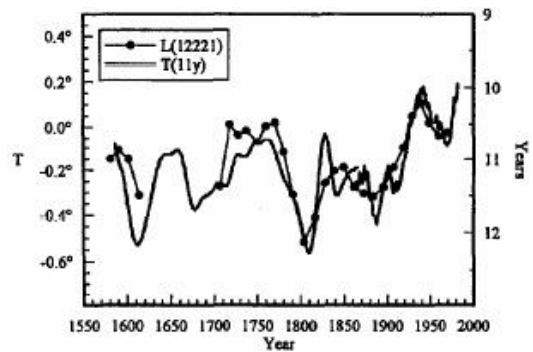


Fig. 6. Eleven-year running average of annual mean values of the northern hemisphere land air temperature 1579–1860 relative to the average temperature 1881–1975, reconstructed by Grovman and Landsberg (1979) together with corresponding values for 1851–1987 relative to 1951–1980 from Jones *et al.* (1986) and Jones (1988). Also plotted is the filtered value (1-2-2-2-1 filter) of the sunspot cycle length.

ASSERTION: Ice cores show that, during earlier periods in the Earth's history, rises in carbon dioxide followed increases in temperature, and therefore by implication the current rise in greenhouse gas concentrations has not caused the recent increase in global average temperature.

Research using ice cores from Antarctica show that *local* temperature rises during the very long periods of transition from glacial (cold) to interglacial (warm) periods are the result of the slow, regular and largely predictable changes in the Earth's orbit. The same research also indicates that these temperature changes occurred prior to associated increases in the local average concentration of atmospheric carbon dioxide. In other words, in the past, warming episodes initially led increases in greenhouse gases. The conclusion drawn in the documentary is that, since carbon dioxide increases in the past (approximately 1 million years ago) occurred after global temperature increases commenced, current global warming cannot be *caused* by greenhouse gases. This is a simplistic and piece-meal presentation of a complex issue.

Again, this issue is not an ongoing controversy in climate science. Research suggests that the fluctuations in global temperature associated with the glacial cycle (ice ages) are associated with the Earth's orbital changes. These changes occur on timescales ranging from around five thousand years to tens to hundreds of thousands of years. Inter-glacial warming or deglaciation (the period of warming coming out of an ice-age) is also triggered by changes in the Earth's orbit. The steady rise in temperature (but very slow compared to 20th Century warming) is then the product of a complex feedback between the warming and changes in atmospheric greenhouse gas concentrations. Simply put, the gradual warming of the oceans leads to a release of more greenhouse gases, which in turn causes more warming. As such, there is a positive feedback between warming and greenhouse gases (carbon dioxide in particular). The ice-core temperature record does not indicate that carbon dioxide does not cause warming. It indicates that warming in interglacial periods is not instigated by carbon dioxide, but is carried on or enhanced through its agency. This evidence, rather than refuting evidence for the enhanced greenhouse effect, suggests that injection of carbon dioxide into the atmosphere by artificial means *is* likely to cause warming in the atmosphere. The

paleoclimate science is very clear on the substantial role that historical carbon dioxide concentrations have played in climate variability, and this role is not a significant matter of debate or uncertainty.

The GGWS producers misrepresent the contents of a paper by Nicolas Caillon and co-authors (published in the journal 'Science' in 2003) in relation to this issue. The work of these authors, in showing the sequence of warming and carbon dioxide increase in the past, never concluded that carbon dioxide could not lead temperature increases. The programme fails to point out that the Caillon *et. al.* record of temperature increases, followed by rises in carbon dioxide concentration, all relate to episodes of *deglaciation*. The last deglaciation on Earth occurred 12,000 years ago. The current rise in carbon dioxide and other greenhouse gases, such as methane and nitrous oxide, started during the Industrial Revolution in the 18th century, more than 11,000 years after the last deglaciation.

As the IPCC Third Assessment Report in 2001 points out, the atmospheric concentration of carbon dioxide prior to the Industrial Revolution was 280±10 parts per million. Levels have risen continuously ever since, reaching 377 parts per million in 2006. The atmospheric concentration of carbon dioxide today is 25 per cent higher than the maximum level recorded at any time during (at least) the 650,000 years prior to the Industrial Revolution.

ASSERTION: The variation in global average temperature over the last couple of centuries can be explained by the effect of solar activity instead of the rise in greenhouse gas concentrations since the Industrial Revolution.

There is no evidence that warming over the 20th century can be substantially explained by solar radiation changes, particularly warming in the latter half of the twentieth century, which has been strongly attributed to increases in greenhouse gases. Indeed, since around 1950 the combination of solar and volcanic activity changes has likely acted to *cool* the globe. Several studies claiming a strong link between solar changes and global warming have been published in the grey literature or in non-climate related journals. These studies have generally been examined and subsequently refuted by peer-reviewed

research. In most cases, the basic methodologies of these studies were shown to be in error or to have lacked rigour. We outline some examples below.

The documentary presents a graph, attributed to Svensmark and Christensen, purporting to show variations in temperature and solar activity (in unspecified units) for “100 Years”. The record of temperature on the graph extends from 1860 to about 1982, while the record of solar activity only extends to about 1975. The solar activity curve shown is not a conventional one, but rather based on the so-called “solar cycle length”.

Damon and Laut (2004) and others have shown that when analysed correctly, there is little if any relationship between the solar cycle length and global temperatures from 1700 to around 1950, and since 1950 the changes show no relationship at all. These analyses are well known and accepted.

The best record of solar changes exists from the 1970s to present. Climate researchers have reconstructed a number of likely past solar radiation changes to assess the influence that such changes may have had on global climate. These studies all show that the magnitude of solar radiation changes over the 20th century has been far too small to be the cause of the observed global warming. This consistent finding has been omitted by the producers of GGWS, and the absence of sensible units in their graphic (Figure 7) obscures this fact from the viewer. In addition, the figure does not show temperature or solar radiation changes over the last twenty five years. This is the period of highest quality data and a period where basic data show little or no relationship between solar radiation and global temperature.

An extended time series included by the producers deserves special consideration (Figure 8: left panel). This diagram as shown is based on a paper by Lassen and FriisChristensen (1995) with the original figure shown on the right. The curve in the documentary contains solar data from 1610-1710, a period in the 1995 paper without data. It is unclear from where this added data has been derived, though the striking match with temperatures seems physically implausible.

In addition, the underlying temperature series are not the same as others shown in the program. They are a very early (more than 30 years old) temperature series for the Northern Hemisphere. The striking correspondence between the temperature data and solar data in this curve is very surprising, as modern day temperature reconstructions based on much more data and improved techniques are very different to those shown in the graph.

There are numerous other errors in the programme’s solar radiation thesis. For instance, the programme fails to point out that the length of a sunspot cycle is not a good indication of the sun’s energy output. A recent review of the scientific literature by Peter Foukal and co-authors, published in the journal *Nature* in 2006, drew attention to the fact that the proper measure of the Sun’s total contribution to the temperature on Earth is “the wavelength-integrated radiation flux illuminating the Earth at its average distance from the Sun, called the total solar irradiance (TSI)”. The authors of this paper stress that observations of sunspot cycle length “lack a demonstrated connection to TSI variation”. Precise measurements of TSI have been possible through satellite-borne radiometry since the 1970s and, as the paper by Foukal and his co-authors makes clear, “the variations [in TSI] measured from spacecraft since 1978 are too small to have contributed appreciably to accelerated global warming over the past 30 years”.

Finally, the programme fails to point out that in order to reproduce the various decadal and century scale changes in global mean temperature since the Industrial Revolution, models need to take into account all major natural and man-made factors that influence climate. This point is clearly outlined in the latest IPCC scientific assessment report. Meehl *et al.* (2004) for instance, confirmed previous studies which showed that changes in solar and volcanic forcing contributed to increases in global average temperature during the first forty years of the twentieth century, and that the increase in temperature since the late 1960s was mostly caused by the increase of greenhouse gases, partially offset by aerosol cooling.

Summary

The *Great Global Warming Swindle* does not represent the current state of knowledge in climate science. Scepticism in science is a healthy thing, and the presence of orthodox scientific scepticism in climate change is ubiquitous. Many of the hypotheses presented in the *Great Global Warming Swindle* have been considered and rejected by due scientific process. This documentary is far from an objective, critical examination of climate science. Instead the *Great Global Warming Swindle* goes to great lengths to present outdated, incorrect or ambiguous data in such a way as to grossly distort the true understanding of climate change science, and to support a set of extremely controversial views.

References

- Alley, R., Berntsen, T., Bindoff, N.L., Chen, Z., Chidthaisong, A., Friedlingstein, P., Gregory, J., Hegerl, G., Heimann, M., Hewitson, B., Hoskins, B., Joos, F., Jouzel, J., Kattsov, V., Lohmann, U., Manning, M., Matsuno, T., Molina, M., Nicholls, N., Overpeck, J., Qin, D., Raga, G., Ramaswamy, V., Ren, J., Rusticucci, M., Solomon, S., Somerville, R., Stocker, T.F., Stott, P., Stouffer, R.J., Whetton, P., Wood, R.A. and Wratt, D. (Drafting Authors) 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Summary for Policymakers. IPCC Secretariat, Geneva, Switzerland. 21p.
- Caillon, N., Severinghaus, J.P., Jouzel, J., Barnola, J.-M., Kang, J. and Lipenkov, V.Y. 2003. Timing of atmospheric CO₂ and Antarctic temperature changes across Termination III. *Science*, volume 299, p.1728-1731.
- Committee on Surface Temperature Reconstructions for the Last 2,000 Years. 2006. Surface Temperature Reconstructions for the Last 2,000 Years. National Research Council. National Academies Press, Washington DC, USA, 160p.
- Damon, P.E. and Peristykh, A.N. 2005. Solar forcing of global temperature since AD 1400. *Climatic Change*, volume 68, p. 101-111.
- Damon, P.E. and Laut, P. 2004. Pattern of Strange Errors Plagues Solar Activity and Terrestrial Climate Data. *Eos*, Vol. 85, No. 39, p. 370-374.
- Foukal, P., Frohlich, C., Spruit, H. And Wigley, T.M.L. 2006. Variations in solar luminosity and their effect on the Earth's climate. *Nature*, volume 443, p.161-166.
- Friis-Christensen, E. and Lassen, K. 1991. length of the solar cycle: an indicator of solar activity closely associated with climate. *Science*, volume 254, p. 698-700.
- Houghton, J.T., Jenkins, G.J. and Ephraums, J.J. (Eds) 1990. Scientific Assessment of Climate Change – Report of Working Group I. Intergovernmental Panel on Climate Change. Cambridge University Press, UK. 365p.
- Houghton J.T., Meira Filho, L.G., Callender, B.A., Harris, N., Kattenberg, A. and Maskell, K. (Eds) 1995. Climate Change 1995: The Science of Climate Change. Contribution of Working Group I to the Second Assessment of the Intergovernmental Panel on Climate Change. Cambridge University Press, UK. 572p.
- Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J. and Xiaosu, D. (Eds) 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, UK. 944p.
- IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996p.
- Kiehl, J.T. and Shields, C.A., 2004. Climate simulation of the last Permian: Implications for mass extinction. *Geology*, volume 33, p. 757-760.
- Lamb, H.H., 1988. Climate and life during the Middle Ages, studied especially in the mountains of Europe. In: *Weather, Climate and Human Affairs*. Routledge, London, 40-74.
- Lassen, K. and Friis-Christensen, E. 1995. Variability of the solar cycle length during the past five centuries and the apparent association with terrestrial climate. *Journal of Atmospheric and Terrestrial Physics*, volume 57, number 8, p. 835-845.
- Marland, G., Boden, T.A. and Andres, R.J. 2006. Global, regional, and national CO₂

emissions. In: Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US Department of Energy, Oak Ridge, Tenn., USA.

Meehl, G.A., Washington, W.M., Ammann, C.M., Arblaster, J.M., Wigley, T.M.L. and Tebaldi, C. 2004. Combinations of natural and anthropogenic forcings in twentieth-century climate. *Journal of Climate*, volume 17, p.3721-3727.

Morner, N.-A. and Etiope, G. 2002. Carbon degassing from the lithosphere. *Global and Planetary Change*, volume 33, issues 1-2, p.185-203.

National Academies (2006). Surface Temperature Reconstructions for the last 2,000 years. National Research Council, The National Academies Press, Washington DC. Available from <http://www.nap.edu/catalog/11676.html>.

Robinson, A.B., Baliunas, S.L., Soon, W. and Robinson, Z.W. 1998. Environmental effects of increased atmospheric carbon dioxide. *Medical Sentinel*, volume 3, number 5.

Siegenthaler, U., Stocker, T.F., Monnin, E., Lüthi, D., Schwander, J., Stauffer, B., Raynaud, D., Barnola, J.-M., Fischer, H., Masson-Delmotte, V. and Jouzel, J. 2005. Stable carbon cycle-climate relationship during the Late Pleistocene. *Science*, volume 310, p.1313-1317.

Stern, D. 2005. Global sulfur emissions from 1850 to 2000. *Chemosphere*, volume 58, p.163-175.

Svensmark, H. and Friis-Christensen, E. 1997. Variation of cosmic ray flux and global cloud coverage – a missing link in solar-climate relationships. *Journal of Atmospheric and Solar-Terrestrial Physics*, volume 59, number 11, p. 1225-1232.

Wigley, T.M., Ramaswamy, V., Christy, J.R., Lanzante, J.R., Mears, C.A., Santer, B.D. and Folland, C.K. 2006. Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences. Executive Summary. US Climate Change Science Program, Synthesis and Assessment Product 1.1, 14p.

h's rotation on ocean currents', *Arkiv foer Matematik, Astronomi och Fysik*, Vol 2(11), 1-53, (1905).