The Science of Climate Change: A Consideration of the IPCC Assessment Reports

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Since the 17th century, science has been characterized by a scientific method in which researchers propose hypotheses to explain observed phenomena and design experimental studies to test those hypotheses. Fundamental to this method is the principle of full disclosure, which requires full documentation, archiving, and the sharing of data and methodology so that the results can be verified and reproduced by other scientists independently.

In general, full disclosure has not been the practice of the United Nations Intergovernmental Panel on Climate Change (IPCC), which has been reluctant to provide its data archives or to reveal or discuss its methodology. Moreover, its practice has been to ignore lines of evidence that do not support its hypothesis about the human impact on climate change—evidence such as Earth's climatic history or global temperatures determined from proxies other than tree rings. Finally, it is dismaying to find that the IPCC's analysis of climate dismisses the sun as a natural agent of climate variability, even though there is a 400-year history of sunspot cycles that correlate closely with climate.

Although the body of evidence for warming as a result of human activities has not changed materially since the IPCC's First Assessment Report (FAR) in 1990, the conclusions of subsequent assessments have become increasingly emphatic, even with the declining evidence for warming as the result of the human release of carbon dioxide (CO_2).

In FAR, the conclusion was as follows: "The fact that we are unable to reliably detect the predicted [CO_2] signals today does not mean that the greenhouse theory is wrong or that it will not be a serious problem for mankind in the decades ahead" (IPCC 1990, 243).

The Second Assessment Report (SAR) concluded that "the balance of evidence suggests that there is a discernible human influence on global climate" (IPCC 1996, 5). This statement was controversial because it was added after the draft scientific report had been approved by the authors. The conclusion was based on a then unpublished study by Santer et al (1996). When the study appeared in *Nature* in July 1996, it presented the evidence for human influence from upper troposphere temperatures measured by radiosonde balloons. In Figure 1, the time period selected appears to show a distinct warming trend. However, as was subsequently shown by Michaels and Knappenberger (1996), the warming trend was simply an artifact of the chosen time frame. Figure 2 clearly shows that when the full data suite is added to Figure 1, the trend no longer exists.

Figure 1
Based on data from Santer et al (1996).

In the Third Assessment Report (TAR) in 2001, the conclusion in the scientific report was as follows:

> The fact that the global mean temperature has increased since the late 19th century and that other trends have been observed does not necessarily mean that an anthropogenic effect on the climate system has been identified. Climate has always varied on all time-scales, so the observed change may be natural. (IPCC 2001, 97)

This objective view of participating scientists was never publicized because it was contradicted in the report's "Summary for Policymakers," which states, "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities" (p 10). Nevertheless, the conclusion in the scientific report demonstrates a lack of consensus among IPCC scientists; furthermore, in the intervening decade, no evidence has been presented that would contradict this conclusion.

The rather surprising contradiction in TAR was brought about by the introduction of the Mann, Bradley and Hughes (1998, 1999) millennial northern hemisphere temperature reconstruction, which is often referred to as the MBH hockey stick and which was reproduced as Figure 5 in TAR (IPCC 2001, 29). The reconstruction has a number of fundamental problems and should never have attained successful peer review. It contradicts entirely well-established climate variability over the last millennium, which was documented in detail by Hubert Lamb (1965), founder of the Climate Research Unit at the University of East Anglia. Figure 3 is based on a figure published without attribution in the First Assessment Report as Figure 7.1(c) (IPCC 1990, 202), but it is clear that it is based on the work of Lamb.[1] This climate variability was subsequently substantiated in hundreds of peer-reviewed articles. When his conclusions were challenged, Mann refused to release his data but was eventually required to do so under the terms of his research grant.

In their review of the data in Mann, Bradley and Hughes (1998), McIntyre and McKitrick (2003) found that the millennial northern hemisphere temperature reconstruction was without merit. They concluded that

Figure 2
Based on data from Michaels and Knappenberger (1996).

Figure 3
Adapted from Figure 7.1(c), IPCC (1990, 202).

the hockey stick graph was an artifact of poor data handling, obsolete data and incorrect handling of principal components. Nevertheless, the diagram continued to be used for promotional purposes in the media, by the US National Academy of Sciences and by the Government of Canada to demonstrate the human influence on climate.

In 2006, a special committee of the United States Congress, led by Edward Wegman, was established to investigate the scientific merits of the MBH hockey stick. The Wegman commission's conclusions (Wegman, Scott and Said 2006) were as devastating as those of McIntyre and McKitrick (2003). The statistical handling of the data was such that the hockey stick curve would be produced from random data; therefore, the claim by Mann, Bradley and Hughes (1999) that the 1990s was the hottest decade and 1998 the hottest year in the millennium could not be supported. Thus, the so-called compelling evidence for unusual and unprecedented late 20th-century warming was gone, and it could no longer be claimed that the 20th-century warming differed from historical climatic variability.

The IPCC's Fourth Assessment Report (AR4) concluded that "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level" (IPCC 2007a, 2). The report went on to say that "most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic GHG [greenhouse gas] concentrations" (p 5). This is an advance since the conclusion in TAR that "most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations" (IPCC 2001, 699).

What the IPCC assessment reports give us is a series of assertions about warming of the climate with no proof that it is linked to human-released CO_2. Warming in itself does not indicate human causation, and as indicated in TAR, "climate has always varied on all time-scales, so the observed change may be natural" (IPCC 2001, 97).

To date, no evidence has been presented to indicate that the observed warming is not the result of natural variability. Where do we stand now? The IPCC's Fourth Assessment Report presents the forecasts of warming from previous assessment reports (FAR, SAR and TAR) in its Figure 1.1 (IPCC 2007b, 98). These forecasts are shown together with a forecast of temperature increase, given no further additions of CO_2.

The current global average temperature lies below the zero emissions forecast, as is shown in Figure 4. The figure illustrates the profound difference between projections made by the Goddard Institute for Space Studies (GISS) (squares) and actual observations and measurements from University of Alabama at Huntsville (UAH) global satellite measurements (solid lines). The GISS model's curves represent modest and restricted CO_2 emissions, yet they lie far above actual observed measurements. However, current UAH global satellite measurements in the troposphere lie even below the zero emissions curve marked by open squares. The UAH satellite measurements have a very high degree of accuracy and have been carefully benchmarked against measurements from radiosonde balloons in the troposphere. The UAH satellite measurements show that the global temperature has been stable and has probably been cooling for the last 15 years.

Figure 4

Adapted from Figure 2.1 in Christy[2].

However, we know that CO_2 emissions are actually increasing, from 26.3 gt/year in 2002 to 34 gt/year in 2011, yet no corresponding temperature response is shown in the atmosphere. The lack of temperature response in the atmosphere over the last 20 years is undeniable evidence that the climate sensitivity projected by the IPCC is wrong, and that the catastrophic projections for the doubling of CO_2 cannot be correct.

The major thrust in each IPCC assessment report has been to show strong late 20th-century warming exceeding any previous historic high, and apparently driven by the strong rise of CO_2. The evidence for this conclusion—Santer et al (1996) in SAR; Mann, Bradley and Hughes (1998) in TAR; and the multiproxy studies from the Arctic Urals in the Fourth Assessment Report—has been shown to have used inappropriate scientific methods in order to emphasize warming over the last 50 years while de-emphasizing the climate variations over the last millennium, such as the Little Ice Age and the Medieval Warm Period.

The second graph of Figure 6.10 in the Fourth Assessment Report (IPCC 2007b, 467) purports to represent 10 independent reconstructions. However, this is not the case on two counts. The same proxies are used over and over again, as indicated by McIntyre on many occasions[3] and confirmed by Wegman, Scott and Said (2006). Thus, when problems arise, multiple studies will be affected. In addition, there are not really 10 independent groups, at least not in the way *independence* is understood in the real world. Mann and Jones (2003) are not independent of Mann, Bradley and Hughes (1998) or Jones et al (1998) or Rutherford et al (2005). The 10 multiproxy curves have little in common except the addition of the instrumental temperature to emphasize late 20th-century warming. This has not been recognized in any of the hundreds of other proxy reconstructions, in which the Medieval Warm Period (MWP) is up to 1°C warmer than current warming (see Figures 16–18).

Now the support for significant warming in the last 50 years rests with global average temperatures derived from land-based thermometers. There are numerous reasons to question the accuracy of these global temperature curves—the first of which is the fact that the land-based thermometers account for only 30 per cent of the world's surface and there are significant gaps in coverage, especially in Asia and Africa. The crucial 70 per cent of historic ocean temperature measurements are bedevilled by different measurement techniques and standards that prevent an appropriate standardization.

The problem with the surface database is that the thermometer stations were not designed for research purposes. The US National Oceanic and Atmospheric Administration (NOAA) criteria state that thermometers must be placed on level ground with less than 10 centimetres of vegetation. The sensors must be placed 100 metres from all sources of heat or reflecting surfaces; buildings, concrete surfaces and parking lots; and large bodies of water. They must also be in a position where they will not be shaded for sun elevations greater than 3°. Although these guidelines appear straightforward, a remarkable 89 per cent of the United States Historical Climatology Network (USHCN) surface stations are located such that they will have error ranges in the order of 1–5°C (total warming in the last century is only 0.8°C).[4]

Figure 5

Distribution of surveyed surface temperature stations in the Continental United States. Only CRN-1 and CRN-2 meet acceptable site standards.

Figure 5 shows the poor coverage of quality stations in the USHCN. In practice, the stations were sited where they could be manned 24/7, at airports, radio stations, fire stations (Figure 6) and water treatment plants (Figures 7 and 8). NOAA has released an account indicating that its processing of the data is reliable and its algorithms correct for siting errors. This hardly seems feasible, and the United States Government Accountability Office (GAO 2011) found in its survey of weather forecast offices that about 42 per cent of the active stations in 2010 did not meet one or more of the siting criteria. GAO recommended that NOAA enhance its information systems to centrally capture information useful in managing the USHCN and develop a policy on how to address stations that do not meet its siting standards. NOAA agreed with GAO's recommendations and has established a new network, the US Climate Reference Network (USCRN).

In addition to the problems with inadequate thermometer sites, there is a fundamental problem resulting from increased urbanization and more housing, factories, parking lots, shopping centres and associated infrastructure. Figure 9 compares average temperature with population growth in Phoenix, Arizona. What is being measured is not warming per se but, rather, the increase in population with its required infrastructure. This is known as the urban heat island (UHI) effect, and it is present even in modest-sized towns. In Figure 10, the data from 93 climate stations in California has been stratified according to county population. Note that with a population of over 1 million, the warming recorded is 3°F, but in counties with a population between 1 million and 100,000, the warming is now only 1.4°F. It drops to only 0.25°F in more rural settings with a population below 100,000. Rural settings should yield the most accurate values but, as we have seen, poor thermometer sites can still give spurious indications of warming.

Figure 6

Temperature station at the Marysville, California, fire department surrounded by heat sources. Why site a modern maximum/minimum temperature sensor (MMTS) in the middle of a parking lot?

Figure 7

An MMTS located adjacent to wastewater treatment tanks in Ontario, Oregon. The thermal output from the tanks is shown in infrared view in Figure 8.

Figure 8

Infrared view indicating thermal output from wastewater treatment tanks in Ontario, Oregon.

The IPCC claims that the UHI effects have been adequately corrected for in its global average temperature curves, although it has never released the processing algorithms. McKitrick and Michaels (2007) studied the effects of extraneous factors on global average temperatures and concluded that up to 50 per cent of the signal from 1980 to 2002 could be attributed to anthropogenic land-use processes (UHI) and inhomogeneities (station-siting errors). De Laat and Maurellis (2006) similarly concluded that most of the warming was not the result of CO_2 forcing but, rather, that it originated from anthropogenic surface-heating processes (UHI). Watts et al (2012), using a new siting classification system developed by Michael Leroy for Météo-France in 1999 and substantially improved in 2010, concluded that siting problems and inappropriate corrections led to a spurious doubling of US mean temperature trends in the 30-year data period (1979–2008) covered by their study.

Figure 9
Mean annual air temperature in Phoenix, Arizona, from 1931 to 1990, and population growth for the Phoenix metropolitan area. Adapted from Balling (1992).

Figure 10
Average annual air temperatures at 93 California climate stations, stratified by 1990 county population: over 1 million (top), between 1 million and 100,000 (middle), and below 100,000 (bottom). Source: Goodridge (1996).

Figure 11
Source: Hansen et al (1999).

Are the surface global average temperature curves reliable? In 1999, Hansen et al presented a revised temperature history for the United States in a science brief, after McIntyre uncovered an error in the data. This is presented in Figure 11, which shows that the hottest decade was not the 1990s but the 1930s, with 1934 the hottest year by 0.6°C. This is not entirely surprising, given the drought and dustbowl conditions in the mid-continent during the dirty '30s; nothing remotely similar was seen in the '90s. Nevertheless, the intervening period has seen a series of upward corrections (such as the mysterious adjustment shown in Figure 12) to bring the '90s back to the dominant position. The embarrassing initial error and the subsequent adjustments do not instill a high degree of confidence in the GISS data. This is reinforced by the fact that the temperature history in Canada also shows the '30s as the hottest decade (Khandekar 2004), and a similar history is present in the Arctic of Canada and Alaska (Polyakov et al 2002), as shown in Figure 13.

The fact that North America and the Arctic experienced their hottest years in the 1930s (as fully supported by published records) raises fundamental issues regarding CO_2 as the climate driver. Since CO_2 is uniformly distributed in the atmosphere, its warming effects should be uniformly expressed in each hemisphere.

Why is the thermal history of North America significantly different from the global temperature history? There are two possible conclusions, and probably both apply. First, the global temperature history is contaminated by the UHI effect and by thermometer-station-siting errors. Second, the sensitivity of Earth's climate to CO_2 in the atmosphere has been significantly overestimated, as is demonstrated in Figure 14, in which the modelled greenhouse warming of up to 1.2°C has never been observed over a period of 30 years. This demonstrates that the atmosphere does not react to CO_2 in the manner supposed and that climate sensitivity is substantially less than has been claimed by the IPCC.

The thrust of the IPCC assessment reports has been to show that the 20th-century warming is unique and unprecedented; however, the evidence provided has proven to be manipulated and unreliable (for example, Santer et al [1996], the MBH hockey stick [Mann, Bradley and Hughes 1998,

Figure 12

Source: http://data.giss.nasa.gov/gistemp/graphs_v3/.

Figure 13

Showing significant warming of Arctic temperatures and a maximum in 1934 in excess of the 1990s. Historical documents show that there was a significant meltback of the Arctic ice pack in the 1920s and '30s. Adapted from Polyakov et al (2002).

1999] and the northern hemisphere multiproxy graph in Figure 6.10 of the Fourth Assessment Report [IPCC 2007b, 467]).

At the same time, there is a substantial body of peer-reviewed data, using proxies other than tree rings, that demonstrates the cyclical nature of Earth's climate over the past 15,000 years, since the Pleistocene glaciation. As shown in Figure 15, there have been eight warm oscillations in which, in most cases, the warm maxima exceeded our current warming. The cycles are well defined by geology, history, archaeology and numerous proxy temperature studies of global coverage. The literature on these climate cycles is extensive, with more than 600 citations for the Little Ice Age and more than 1,000 for the Medieval Warm Period.

The approaches to developing thermal histories are diverse and include terrestrial heat flow (Huang, Pollack and Shen 1997), oxygen isotopes in foraminifera (Keigwin 1996), marine bivalves (Dietrich 2007), ostracodes (Filippi et al 1999), midge assemblages (Clegg et al 2010), and diatom distribution and oxygen isotopes (Jiang et al 2007), as well as multiproxy studies of ice cores, tree rings and lake sediments (Yang et al 2009) and studies of British Columbia lake sediment (Patterson, Prokoph and Chang 2004). The geographical range of these studies is worldwide.

Space does not permit a complete review of these studies, but some outstanding examples are presented here. Figure 16 is a synthesis of several papers, covering a vast area of Central Asia, and the temperature history shows distinctly the oscillations of climate over a period of two millennia, with a well-defined Little Ice Age (LIA) and Medieval Warm Period (MWP) and extending back to the Dark Ages Cold Period (DACP) and the

Figure 14

On the left are actual observations in the tropical mid-troposphere, showing no warming but slight cooling (derived from radiosonde balloon data from the Hadley Centre Climatic Research Unit). In contrast, in the diagram on the right (IPCC 2007b, 675), a greenhouse-model-predicted temperature trend shows an increase of 1.2°C in the tropical mid-troposphere. In 30 years of observation, this has never been seen.

Figure 15

Post-Pleistocene climate cycles since the end of the last glaciation. There are 16 oscillations, with the warm cycles shaded with light grey and the cold cycles shaded with dark grey.

Post Pleistocene Climate Cycles		
Name	**From**	**To**
Pleistocene Ice Age	110,000	14,700
Rolling	14,700	13,900
Older Dryas	13,900	13,600
Allered	13,600	12,900
Younger Dryas	12,900	11,600
Holocene Warming	11,600	8,300
Egyptian Cooling	8,300	8,000
Holocene Warming	8,000	5,600
Akkadian Cooling	5,600	3,500
Minoan Warming	3,500	3,200
Bronze Age	3,200	2,500 BC
Roman Warm Period	500 BC	535 AD
Dark Ages	535 AD	900
Medieval Warm Period	900	1300
Little Ice Age	1300	1850
Modern Warm Period	1850	present

Roman Warm Period (RWP). The Current Warm Period (CWP) is comparable to or cooler than both the MWP and the RWP. This pattern of cyclical climate is also well expressed in Figure 17, which shows sea surface temperature from Iceland's north coast developed from proxies derived from coccolithophores, and continues in Alaska in Figure 18, confirming an unequivocal cyclical climate system during the Holocene.

Figure 16

Standardized representations of various reconstructions of the temperature history of arid Central Asia, with clearly defined climate cycles defining the Roman Warm Period (RWP) to the Current Warm Period (CWP), and cold cycles of the Dark Ages Cold Period (DACP) and the Little Ice Age (LIA). The CWP does not show any unusual warmth relative to either the RWP or the MWP. Adapted from Yang et al (2009).

Figure 17

A unique 2,000-year summer sea surface temperature (SST) record with unprecedented temporal resolution (two to five years) from a sediment core retrieved off North Iceland, based on analyses of alkenones synthesized primarily in the summer by the marine alga Emiliania huxleyi, *which grew in the overlying ocean's surface waters.*

Even with the help of the supposedly unprecedented anthropogenic-induced increase in the atmosphere's CO_2 concentration that occurred over the course of the 20th century, the CWP has not achieved anywhere near the warmth of the MWP or the RWP, which suggests that the climatic impact of the CO_2 has been negligible.

The presence of the eight warm and eight cold cycles in the Holocene is clear evidence that climate is controlled naturally by a cause other than anthropogenic CO_2. The most probable source is the sun, as has been indicated by many solar scientists and astrophysicists. However, the IPCC has chosen to ignore the solar influence by arguing that changes in solar irradiance are insufficient to account for climatic variation. This is done largely to evade the rather obvious correlation of solar activity with climate.

Solar activity and the strength of the sun's magnetic field are indicated by sunspots (Figure 19). Sunspots were first observed by Galileo in 1612, and since 1749 they have been systematically observed and counted so that now there is a 400-year history. The sun is made of a viscous material in which the poles rotate at a different rate than the equator. This disrupts the magnetic field, and sunspots erupt at the surface. The intense magnetic activity inhibits normal convection, thus the dark spots are up to 1,000°C cooler than the background. Sunspots occur cyclically on the sun's surface, with an average 11-year cycle, in which the maxima achieve a sunspot number of up to 200, dropping to 15–20 during the minimum. The cycle length varies with the level of activity in the cycle so that in a very active cycle, the length may be as short as 9.5 years, while weaker cycles may last up to 14 years.

In 1991, the correlation of sunspot cycle length with average temperature was noted by Friis-Christensen and Lassen, confirming a strong link between the sun and climate over the last 130 years, as shown in Figure 20. On average, sunspot cycles are 11 years, but the cycles are shorter when activity is strong and longer when activity is weak. Although this correlation convincingly indicates a sun–climate link, it has been systematically ignored by the IPCC.

Similarly, the 400-year history of sunspot cycles is highly correlated with observed climate during that period. The Maunder Minimum, a period of approximately 75 years during which there were very few sunspots and the usual 11-year sunspot cycle was absent, correlates with the coldest and most intense part of the Little Ice Age. In Figure 21, the heavy line shows the 11-year mean of the monthly sunspot averages, and it shows that the climate's recovery from the cold

Figure 18

The authors conducted a high-resolution analysis of midge assemblages found in the sediments of Moose Lake, in the Wrangell–St Elias National Park and Preserve of south-central Alaska, based on data obtained from cores removed from the lake bottom in the summer of 2000 and a midge-to-temperature transfer function that yielded mean July temperatures (TJuly) for the past 6,000 years. The study confirmed that there is a clear multicentennial oscillation about the declining trend line, with its peaks and valleys defining the temporal locations of the RWP, the DACP, the MWP, the LIA (during which the coldest temperatures of the entire interglacial period, or the Holocene, were reached) and, finally, the start of the CWP, which is still not expressed to any significant degree compared with the MWP and the RWP. Based on Clegg et al (2010).

Figure 19
The Earth in scale relative to a typical large sunspot.
Source: www.norcalblogs.com/watts/climate_change.

Figure 20
A plot of the sunspot cycle length versus the northern hemisphere land temperature shows a remarkably good correlation over the last 130 years.
Source: Friis-Christensen and Lassen (1991).

of the Little Ice Age is related to the recovery of solar activity, which cannot be attributed to CO_2 in the pre-industrial period. Furthermore, it can be seen that the maximum solar activity occurs from 1950 onward, the exact period for which the IPCC claims that warming is human-induced, while in reality the modern warming is solar in origin. The strongly active solar cycles in the last half of the 20th century show that the modern warming is an integral part of the climate oscillation observed throughout the Holocene (see Figure 17).

The most convincing evidence for the sun's role in 20th-century warming is that the decline in temperature recorded between 1950 and 1975, in the global average surface temperature, is also reflected in the sunspot cycle averages (Figure 22). Further evidence that this is the result of a decline in solar activity is provided by the decline in sunspot cycle 20 (SSC20) with a sunspot number of only 105, a drop from over 200 in SSC19 and 165 in SSC21. The change in sunspot number coincides with a significant drop in the sun's magnetic field. The Ap index, a measure of the sun's magnetic field, drops from 23 to 13 Ap units, and there is a corresponding increase in the solar cycle length from 9 to 13 years. The strong correlation of the cooling of the atmosphere with the decline in solar activity negates the claim of the role of CO_2 because, during the three-decade decline in temperature, atmospheric CO_2

Figure 21

Four hundred years of sunspot numbers, with the 11-year mean of the monthly averages (heavy black line) showing that the modern maximum activity is higher than any time in the past 400 years shown on the chart. Source: Hoyt and Schatten (1998a, 1998b).

Figure 22

A presentation of the solar Ap index, a measure of the sun's magnetic field. The arrows running across the bottom indicate the sunspot minima, and high Ap index readings occur at the sunspot maxima. The cycles have been numbered since the 18th century and start with cycle 17 on the left and end with 23 on the right. Note the sharp drop in the Ap index at cycle 20, centred on 1970, from 23 Ap units to 13 Ap units during the 1970s cooling.

When the 10 Ap unit variations are multiplied by the 0.05 scale factor, it suggests about a 0.5 W per sq. meter modulation of global reflected sunlight during the 11 year solar cycle (as well as monthly and yearly variations of geomagnetic activity). I calculate that this is a factor of 10 greater than the change in reflected sunlight that results from the 0.1% modulation of the total solar

content increased from about 310 to 330 parts/million by volume (ppmv). According to IPCC forecasts of 0.016°C/ppmv for doubling of CO_2, the temperature should have risen by 0.32°C, but it actually dropped by a similar amount.

The decline in solar activity through sunspot cycles 21–24 is shown in Figure 23. This progressive drop is consistent with the lack of warming over the last 15 years. A weakening cycle 23 lasted for 12.4 years and recorded 821 sunspot-free days, a number not seen since the 19th century. A sunspot number of less than 70 has not been observed since 1795 during the Dalton Minimum, an extremely cold period of the Little Ice Age. The strong decline in sunspot numbers in cycle 24 suggests that we are now entering a solar minimum, indicating that the Modern Warm Period has reached its climax and that cooling in the next decade is probable.

There is considerably more evidence, both observational and experimental, that confirms the sun's role in determining climate. Henrik Svensmark has been a leading proponent of the solar influence on climate, and in 1998 he published an article showing that Earth's temperature follows more closely decadal variations in galactic cosmic ray flux and solar cycle length than other solar activity parameters. He then demonstrated a close relationship between cosmic ray flux and the development of low cloud (Marsh and Svensmark 2000). Figure 24 shows a remarkable correlation of cosmic ray flux with low cloud development. Svensmark then demonstrated in his laboratory (the SKY experiment) that incoming cosmic rays entering a simulated atmosphere caused the growth of clusters of molecules of the kind that build cloud condensation nuclei. These are specks of sulphuric acid on which cloud droplets form (Svensmark et al 2007).

To confirm these observations, a much more sophisticated experiment was undertaken at the European Organization for Nuclear Research (CERN). The results, released in 2011, have fully substantiated Svensmark's hypothesis that incoming cosmic ray flux results in a steady production of new ionized particles (molecular clusters) that induce the nucleation of clouds (Kirkby et al 2011). Therefore, in an exceptional demonstration of scientific method in climate science

Figure 23

A graphical comparison of sunspot cycles 21–24, showing a progressive drop in the daily average sunspot number.

through observation, measurement and experiment, Svensmark has shown that Earth's climate results in large part from an interplay of the sun's activity and the incoming flux of cosmic rays from space, primarily the Milky Way galaxy. When the solar flux is weak, cosmic bombardment is strong and low cloud is propagated, causing cooling. With an active sun, as we have had for most of the last century, the increased solar flux deflects and reduces the cosmic ray influx. The weaker cosmic ray flux results in less cloud and a warmer climate. This hypothesis explains in detail the climatic history of Earth for the last 550 million years without resort to CO_2 forcing.

In 2012, Svensmark presented a brilliant paper to the Royal Astronomical Society. It is, if I may say so, a stellar investigation, a Nobel-worthy contribution to science, with 22 figures, 30 equations and some 15,000 words, in which he has calculated the variation in cosmic rays over the past 500 million years and, with that astronomical history, has elucidated the histories of climate and life on Earth. No CO_2 required!

Figure 25 displays several studies of CO_2 content in the ancient atmosphere, indicating that CO_2 content in the modern atmosphere is at the lowest level in geological history. The Cambrian (Cm) CO_2 content was between 18 and 22 times the current level (Berner and Kothavala 2001). According to IPCC climate-sensitivity calculations, this should result in global average temperatures exceeding 100°C, leading to conditions inimical to life—a conclusion that is obviously incorrect. Berner and Kothavala's study is cited in the IPCC's (2007b) Fourth Assessment Report, in Figure 6.1, but its implications are not discussed.

The IPCC was formed in a rush to judgment to determine that 20th-century warming was caused by CO_2 released into the atmosphere by human activities. The result has been a concerted effort to subvert or ignore critical evidence in order to characterize the late 20th-century warming as uniquely rapid, dangerous and unprecedented. In fact, the evidence indicates that 20th-century warming is perfectly consistent with the seven previous Holocene warming cycles, only cooler.

Although the surface thermometer record has been presented as key evidence for late 20th-century warming, it has been shown to be unreliable, with a potential error range as high as 50 per cent.

It is clear that there is a correspondence of global average temperatures with variations in solar energy. In contrast, contradictory temperature trends occur in relationship to CO_2. With rising CO_2 from 1950 to 1975, the temperature dropped. For the last 15 years, with greater annual atmospheric CO_2 levels, there has been no statistically significant warming, according to the British Meteorological Office (Met Office).[5]

The current solar cycle progression has characteristics comparable to the Dalton Minimum of 1790–1830 and would indicate a return to a cooling cycle but of lesser magnitude because of the greater heat capacity of the oceans after 150 years of warming.

Figure 24

This diagram was developed by observing the changes in cloudiness (as observed by geostationary satellites) and comparing them with the variations in cosmic radiation. The coincidence of the changes in the cloud cover with the changes in cosmic radiation intensity is remarkable and provides compelling evidence of the sun's role in the cosmic ray cloud feedback system. Source: Marsh and Svensmark (2000).

Notes

1. See McIntyre (2008) for more on the source of Figure 7.1(c).

2. *Testimony of John R. Christy Before the Senate Committee on Environment and Public Works* (August 1, 2012) (testimony of John R Christy, Alabama state climatologist, University of Alabama in Huntsville). Summary available at http://nsstc.uah.edu/aosc/docs/ChristyJR_SenateEPW_120801.pdf (accessed March 4, 2014).

3. See McIntyre's blog, *Climate Audit* (http://climateaudit.org).

4. See www.surfacestations.org.

5. See www.metoffice.gov.uk/research/news/recent-pause-in-warming (accessed March 5, 2014).

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Figure 25

The level of atmospheric CO_2 over geologic time can be estimated by constructing mass balance expressions for all the processes that bring about inputs and outputs of CO_2 to and from the atmosphere. This is a daunting task at any time scale. However, repeated studies have yielded similar results that have been successfully benchmarked against other proxies, especially palaeosol horizons. Also, the very high CO_2 content is consistent with the extensive carbonate platforms flooding the continents during the Silurian (S), Ordovician (O) and Cambrian (Cm) periods. Major drawdown of CO_2 occurs concurrent with the development of land plants culminating in the Carboniferous (C) period, while rebound of CO_2 is associated with volcanism during the opening of the Atlantic Ocean.

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