Global Warming as a Classroom Topic: Fresh Perspectives on the Climate Change Debate

Chris de Freitas

Chris de Freitas is an Associate Professor of Geography at the University of Auckland. He is also Editor of the international science journal "Climate Research". For the past four years he has been interim Pro Vice Chancellor of the University's new Tamaki Campus.

Introduction

Global warming issues are as emotionally charged as they are widely misunderstood. Despite this, calls for action have put enormous pressure on governments to formulate policies in response to the perceived threat of the human-caused climate change resulting from a build up greenhouse gases in the atmosphere. The Kyoto Protocol proposed by the United Nations in 1997 calls for an average cut in greenhouse gas emissions of 5.2 percent from 1990 levels by industrialised nations by the year 2010.

The New Zealand Government is in the early stages of exploring policy options to reduce greenhouse gas emissions. If New Zealand formally ratifies the Kyoto Protocol it would be obliged to stabilise its emissions at 1990 levels by 2010. Given current trends, emissions would be almost 40 percent higher than 1990 levels by 2010. Thus, to meet the requirements of the Kyoto Protocol, New Zealand must give up over one third of its energy use, or find some other way of meeting its commitment. A decrease of this magnitude can only be achieved by severe rationing of oil, coal and natural gas. Because the economic implications - in higher prices for transportation and energy used by industry and for manufacturing - would be immense, the question arises as to whether these harsh measures are justifiable. Clearly, without clear, accurate scientific information, it is impossible to determine what are the right policies to protect the environment.

The Kyoto Protocol aims to ratify the UN Framework Convention on Climate Change set out as long ago as 1992. The science surrounding global warming has come a long way since then. It is highly debatable now whether the known facts support the calls for major social and political action. And despite all that has been written, there is still confusion on the most basic science. This confusion leads to misunderstanding, some of which is perpetuated in teaching resource material and in school and university textbooks. The reasons for this are summarised below in what I call the 13 fallacies surrounding the global warming hypothesis.

1) The widespread belief that global warming is a major global environmental crisis is well founded.

There is probably no environmental issue that is as misunderstood as that of global warming. It is now common practice to teach in schools that carbon dioxide is a pollutant that is dramatically warming the Earth's climate with dire consequences such as rising sea levels and severe weather changes. We are lead to believe that the evidence is all around us. It is not uncommon to see reports of how cold spells, warm spells, floods, droughts, increased frequency of storms and even El Niño events are proof of global warming. Global warming has become the scapegoat for climate variability (de Freitas, 1991, 1994).

Why should this particular view prevail? What is behind it? It is difficult to say for certain, but one reason is that myths, although they give an incomplete understanding of environmental issues, are believed because they fit well with popular trends towards concern for the environment. Another reason is that no matter how outrageous the tale, it becomes the truth if it is told often enough. The view that global warming is both real and dangerous is now deeply entrenched in the minds of the public. Many are reluctant to challenge this, as it is politically incorrect to do so. It would be taken to imply a lack a concern for the environment.

Underlying the hype about global warming is the disproportionate influence of the reports of the United Nations Intergovernmental Panel on Climate Change (IPCC). The IPCC is seen by many governmental agencies and the media as the leading source of scientific information on climate change. The first IPCC report was published in 1990 (Houghton et al, 1990), the most recent in 1996 (Houghton et al, 1996). The dense 300-page IPCC Science reports themselves have by and large been good compilations of global warming science. But few people read these voluminous publications. Instead they read the brief, politically approved "Summaries for Policymakers"(SPM), which have become notorious for their bias, tendency to overstate problems and penchant for simplifying and dramatising scientific speculation.

A classic example is the claim in the 1996 SPM (Houghton et al, 1996, p. 4): "the balance of evidence suggest that there is a discernible human influence on global climate." The so called "evidence" cited in Chapter 8 of the main report was based on a key paper that at the time had not been published in the refereed scientific literature. Moreover, one of the authors of this paper was also the convening lead author of the Chapter 8 that supported the "human influence" claim. A hearing in August 1998 on the subject of global warming before the US House Committee on Small Business, Chaired by Republican James Talent, made public the following finding. It revealed that the 1995 IPCC scientific report (Houghton et al, 1996) was deceptively altered to convey the misleading impression to the public that there is a "discernible human influence on climate" which will lead to catastrophic warming. The background to this is as follows.

The "discernible influence" statement of the IPCC's 1995 report (Houghton et al, 1996) was based on what are called "fingerprinting" studies. A fingerprint study is one in which a geographical pattern of observed climate changes are compared with the patterns of climate changes predicted by global climate models (GCMs). The idea is that by finding a pattern in the observed data that matches the predicted data, a causal connection can be claimed. Following publication of 1995 IPCC scientific report and in the wake of mounting criticism of the "discernible evidence" claim, a paper by Santer et al (1996) was published that endeavoured to defend the claim. Subsequently, the results of a re-analysis of the data used in this work were published in *Nature* (Michaels and Knappenberger, 1996). It showed that the research on which the IPCC "discernible influence" statement is based had used only a portion of the available atmospheric temperature data, with no scientifically defensible reason for not using the entire data set. When the full data set was used, the previously identified warming trend disappeared. Clearly this is a serious matter given the widespread use of the "discernible influence" statement to imply that there is proof of global warming.

2) The earth's temperature increased over the last century in pace with increasing atmospheric carbon dioxide.

The average temperature of the globe has increased by about 0.5 °C over the past century. Most of this rise occurred before 1940, but over 80 percent of the carbon dioxide entered the atmosphere after 1940. In fact, from 1940 to 1970 the earth's atmosphere cooled despite increasing levels of carbon dioxide.

3) The earth's temperature has increased over the past two decades.

Detecting climate change is not a simple matter as modification of the surface by human activity can have a significant effect on climate near the ground. The best-documented example is the urban heat island effect. The official IPCC land-based record (of Phil Jones, University of East Anglia) is a supposedly "de-urbanised" record, but there is more contamination of the surface temperature record than many climatologists realised. Balling and Idso (1989) have demonstrated that only very small changes in population are enough to induce a statistically significant local warming. Also, there is the problem of uneven spatial sampling. Rural stations account for only 7% of the Earth's area (Peterson et al, 1999). There is another reason to doubt the reliability of the surface temperature record: poor coverage during the early part of the record, particularly in the Southern Hemisphere and Pacific Ocean generally.

The temperature record of the globe cannot be assembled simply by relying on a few thermometers on the ground, usually on the land and located in growing urban areas. The satellite temperature data set is the only one that is truly global, highly accurate (to 0.1 °C) and that uses a completely homogeneous measurement over the entire planet (Spencer and Christy, 1992; Christy, 1995). It also measures the part of the lower atmosphere that, according to the climate models, should be experiencing the greatest warming due to the enhanced greenhouse effect (Bengtsson et al, 1999). But satellite data since 1979 show no significant warming trend (Soon et al, 1999). These data are unpopular with the some climate scientists because they do not show the recent warming trend suggested by the surface temperature record. The reliability of the satellite data has been thoroughly critiqued and adjusted for influences such as orbital decay of the satellite, yet the results show that the overall temperature trend is essentially zero (Spencer and Christy, 1992; Christy, 1995; Christy *et al*, 1998; Christy *et al*, 2000). It is noteworthy that no mention is made of the satellite data in the IPCC's Summary for Policy Makers (SPM).

4) Computer models of the earth's climate are reliable.

The climate modellers themselves recognise how primitive their computer simulations of global climate are. They accept that the models (GCMs) do not adequately handle key aspects of the climate system, such as the feedback effect of clouds and aspects of heat transfer in ocean circulation (Cess et al, 1995; Charlock and Alberta, 1996; Lindzen, 1997). Earlier on some scientists argued that better models might actually show more warming. The opposite has proved to be the case. The fact is that, from their inception, global climate models have been predicting spuriously high values of global temperatures. Clearly, with time, warming projections are becoming smaller (Figure 1).

The results from global climate models are of little value until the reliability of their performance can be verified. According to Singer (1996, p. 581): "The gap between the satellite observations and existing theory is so large that it throws serious doubt on all computer-modelled predictions of future warming. Yet this discrepancy is never mentioned in the IPCC report's Summary [SPM] – nor does the SPM even admit the existence of satellites."

In contrast, a great deal of research on the theory relating the Sun's variability to climate change is now underway (Friis-Cristensen and Lassen, 1991; Lassen and Friis-Cristensen, 1995; Svensmark and Friis-Cristensen, 1997; Soon et al, 1996). The results of the work (Figure 2) show a close correlation with observed global temperature trends.

5) Human action is destabilising the carbon balance and causing concentrations of carbon dioxide in the atmosphere to rise at alarming rates.

The concentration of carbon dioxide in the atmosphere is rising and the hypothesis that humans are causing the rise is reasonable. However, the factors that influence the atmospheric CO_2 concentration are not fully understood. Each year, human activity (primarily the use of coal, oil, natural gas and production of cement) contributes about 6.5 Gt gross (about 3 Gt net) to the 750 Gt atmospheric reservoir of carbon. But despite this, the annual rate of increase of CO_2 in the atmosphere is highly variable, falling close to zero in some years (for example, in 1992) and declining in others (for example, in 1998). The reasons for this are not known. But whatever the explanation, the result should not be surprising, as humans are relatively small players in the global carbon cycle. Carbon dioxide emissions caused by human use of fossil fuels are small compared to the natural carbon exchange between the atmosphere on the one hand and the terrestrial system and oceans on the other. Anthropogenic CO_2 emissions are only about 3% on the natural carbon cycle. The magnitude of the natural reservoirs of carbon between ocean, atmosphere and land and the rates of exchange between them are so large that

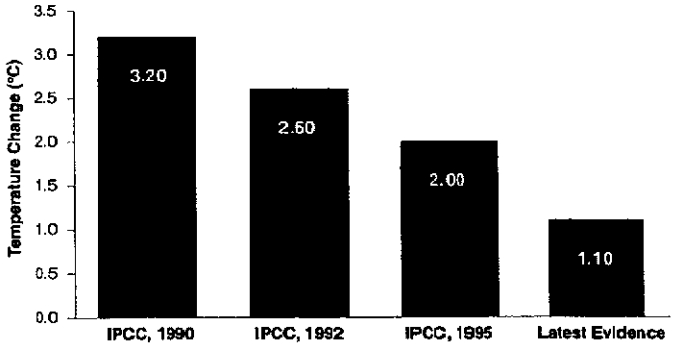

Figure 1: Changes in IPCC projections of global temperature rise to the year 2100 caused by increases in greenhouse gas concentrations in the atmosphere. The figure shows that, from their inception, global climate models have been predicting spuriously high values of global temperatures. Clearly, warming projections are becoming progressively smaller. The most recent projection is based on calculations by Michaels using current models and emission criteria (World Climate Report, 1998). It is noteworthy that the large projections of the earlier models are the basis for the UN Framework Convention on Climate Change (the Rio Treaty) and 1997 Kyoto Protocol.

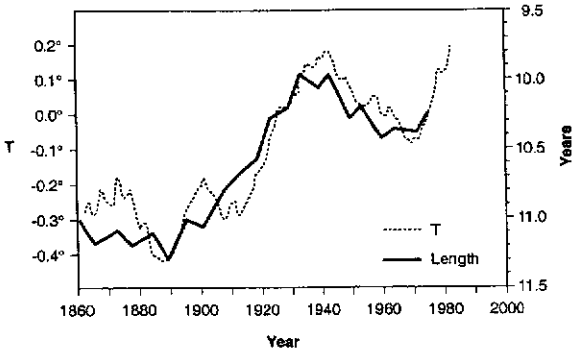

Figure 2: Eleven-year running means of solar activity, in terms of the sunspot cycle length (years), compared with global temperature (T) based on the work of Friis-Cristensen and Lassen (1991). The global temperature is the same as that used by IPCC (Jones, 1988; Jones et al 1986).

the role of humans in the natural carbon budget is unclear. In fact, so great are the difficulties quantifying the natural carbon budget and the uncertainties with which the numbers are estimated that the source of recent rise in atmospheric CO_2 has not been determined with certainty (Keeling, Piper and Heimann, 1996; Tans, Fung and Takahashi, 1990; Adger and Brown, 1995).

Atmospheric CO_2 concentrations have varied widely over geologic time, but we are unable to fully explain why. The atmosphere is a result of outgassing of the earth, and this outgassing was largely accomplished as volcanic activity. The rates of outgassing, however, are highly irregular. Mt Etna, for example, has emitted well over 25 millions tons of CO_2 into the atmosphere in one year (Gerlach, 1991a; Allard *et al*, 1991). This equals the output of four 1,000 MW coal-fired power stations. Scientists at Pennsylvania State University have recently discovered that geothermal activity at Yellowstone National Park currently emits 10 times the CO_2 of a typical mid-sized coal-fired power plant. The mid-ocean-ridge volcanic system emits 65 million tons of CO_2 annually (Gerlach, 1991a, 1991b).

There are many other factors that influence atmospheric CO_2 concentrations that are not fully understood. For example, the current increase in atmospheric CO_2 follows a 300-year warming trend, during which temperatures have been recovering from the global cool period known as the Little Ice Age Lamb, 1985). The observed increases in CO_2 are of a magnitude that can, for example, be explained by oceans giving off gases naturally as temperatures rise (Dettinger and Ghil, 1998; Segalstad, 1998). Indeed, changes in atmospheric CO_2 have shown a tendency to follow rather than lead global temperature increases (Kuo et al, 1990; Priem, 1997; Dettinger and Ghil, 1998; Fischer et al, 1999, Indermuhle at al, 1999).

It is known that the equatorial oceans are the dominant oceanic source of atmospheric CO_2. The net flow per year amounts to 0.7 to 1.5 Gigatons of carbon - about what is emitted in the United States - of which up to 72 percent emanates from the equatorial Pacific Ocean. Owing to changes in sea surface temperature during the 1991 to 1994 El Niño period, the annual flow of CO_2 was 30 to 80 percent of normal (Feebly et al, 1999). This has a significant effect on global CO_2 concentrations in the atmosphere.

6) The climate record shows a good relationship between changes in atmospheric carbon dioxide and global temperature.

A close association between paleo-temperatures and past CO_2 concentrations has long been used to support greenhouse warming theory. But recent research has challenged this as, for example, in the work of Pearson and Palmer (1999). CO_2 levels were about five times greater than present values some 200 million years ago. It is usually taken that a steady decrease since then accompanied by a general cooling proves a causal link. However, Pearson and Palmer (1999) show that the global cooling since the Eocene was not primarily due to decreases in CO2 levels, but to changes of ocean circulation resulting from the tectonic opening and closing of oceanic gateways, as continents move around.

Another example is the recent re-analysis the famous Vostok ice core (Fischer et al, 1999). This research shows CO_2 increases lagging about 600 years behind the temperature increases of the three significant deglaciations. Clearly, high CO_2 levels are not the primary cause of temperature rises signaling the end of an ice age. Other research on the long-term record also shows that sometimes temperatures were high when carbon dioxide concentrations were low, and vice versa (Indermühle et al, 1999).

7) Plants, especially trees, are often implicated in the global warming debate. But how plants fit in and the role they play are unimportant.

Carbon dioxide is food for plants. The more there is, the more they use. There are countless studies that show the effect of an increased concentration of carbon dioxide in the atmosphere is to increase the growth rates of most plants (Soon et al, 1999). There is also evidence that there may be a substantial global net absorption of the fossil fuel emissions of carbon dioxide by plants. This absorption is increasing each year, as

the absorption by the atmosphere remains constant and the fossil fuel emissions increase (Soon et al, 1999).

Not only do plants provide a substantial sink for atmospheric CO_2, but also plants under stress from less-than-ideal conditions – a common occurrence in nature – respond more to CO_2 fertilization. The significance of all this is that, assuming a doubling of CO_2 release as compared to current emissions, it has been estimated that atmospheric CO_2 levels will rise by about 300 ppm before leveling off (Idso, 1991). At that level, CO_2 absorption by increased terrestrial biomass may be able to absorb about 10 Gt C per year (Soon, et al, 1999). This is over three times the current net annual increase in atmospheric CO_2 from world fossil fuel combustion. These studies indicate that we are anticipating larger carbon dioxide concentrations in future than will actually occur. The research emphasizes the need to better understand the carbon cycle and the three important drivers of change in atmospheric CO_2, namely, changes in volcanic activity, terrestrial biomass and sea surface temperatures.

8) There is a consensus among climate scientists that greenhouse induced climate change is a major threat.

There is no consensus. Besides, science is not decided by ballot. It is decided by observations that support a theory or hypothesis. In 1990, the IPCC claimed their report represented the "consensus" view of science, and this was used by some as an excuse for discouraging debate. The views of scientists who objected to the IPCC stand were dismissed as "a small but vocal band of sceptics" and "pseudo-scientists." However, the sheer number of them and the presence of their opposing views in the peer reviewed scientific literature led to the IPCC authorship abandoning the "consensus" claim in their 1996 report.

9) Global warming will cause the spread of infectious disease.

Studies that speculate on relationships between climate and infectious diseases, such as malaria and yellow fever, are sometimes quite misleading. Malaria and yellow fever were once common in non-tropical regions. For example, during the Middle Ages malaria was still a major problem in Europe (Reiter, 1998, 2000). Earlier this century malaria was reported in both Alaska and Russia. Lifestyle, level of economic development and quality of medical care are the main determinants of the spread of infectious diseases (Gubler, 1998).

10) Global warming will produce a rise in sea levels.

There is now a substantive body of research reported in the peer reviewed scientific journal literature that suggests that sea levels, which have been rising since the end of the last ice age (long before industrialisation), are likely to stabilise or fall in a greenhouse warmed world. This is because empirical evidence indicates that a modest warming of the Earth could lower sea level by increasing evaporation from the oceans. The result is increased deposition and accumulation of snow on the polar ice caps, principally in the Antarctic, thereby transferring water from the oceans to the ice sheets (Bromwich, 1995; Thompson, and Pollard, 1995; Ohmura, Wild, and Bengtsson, 1996; Ye and Mather, 1997; Meese et al, 1994; Hogan, and Gow 1997). The reasoning here is that if the Antarctic air were to warm, it would still be below freezing, but its water holding capacity would increase as it warms. With more moisture in the atmosphere over the Antarctic snowfall would increase and ice sheets would grow locking up water that would otherwise be in the sea. It is noteworthy that historical records show no acceleration in sea level rise in the 20th century (Douglas, 1992).

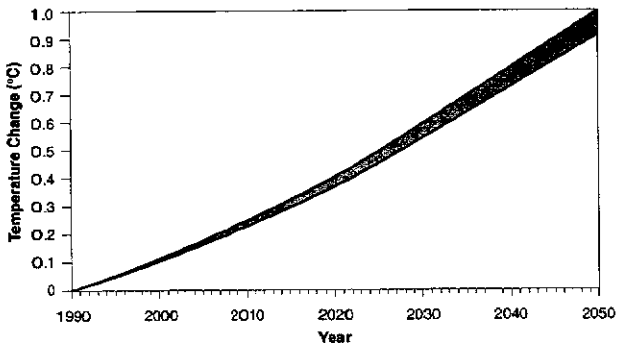

Figure 3: The effect on global temperature rise of cuts in greenhouse gas emissions proposed by the 1997 Kyoto Protocol (Wigley, 1998). The upper line is the projected global temperature rise based on the 1996 IPCC Report (Houghton et al, 1996, p. 39 of Technical Summary) that would occur if greenhouse gases were to continue to increase into the next century, labelled the "IS92e" scenario. The lower line is the temperature rise that would occur if emissions were stabilised at 1990 levels, as proposed by the 1997 Kyoto Protocol, labelled the "IS92d" scenario. The figure shows that, by the year 2050, the Kyoto stabilisation emission policy would have reduced temperature rises by less than 0.1°C.

11) Global warming will result in more extreme weather events.

According to the most recent IPCC report (Houghton *et al*, 1996, p. 173): "Overall, there is no evidence that extreme weather events, or climate variability, has increased, in a global sense, through the 20th century..." The increasing dollar cost of storm and other weather related events can be accounted for by a rise in the value of development and number of properties, especially in tropical cyclone prone areas (Changnon et al, 1997; Pielke and Lansea, 1998; Kunkel Pielke and Changnon, 1999). In the Atlantic region, the number of intense hurricanes declined during the 1970s and 1980s, and the period 1991-1994 experienced the smallest number of hurricanes of any four years over the last half century (Idso *et al*, 1990; Landsea *et al*, 1996; Bengtsson *et al*, 1996; Serreze et al, 1997; Zhang and Wang 1997; Murphy and Mitchell, 1995).

12) Global climate is changing.

Climate is naturally variable and always changing. The notion of constant climate is misleading. Climate is always either warming or cooling. Over the past 100 years, all changes in climate have been well within the range of the climate's natural variations (Mahlman, 1997).

13) The threat of human-caused climate change justifies taking the drastic action proposed in the Kyoto Protocol.

The Kyoto Protocol, while economically damaging, would be ineffective in reducing the calculated temperature increase. Research by Wigley (1998) shows that the 1997 Kyoto Protocol (calling for an average cut in greenhouse gas emissions of 5.2 percent from 1990 levels by industrialised nations by the year 2010) is not sufficient to reduce significantly the growth of greenhouse gases in the atmosphere; therefore, its effect on temperature would be imperceptible (Figure 3). The required emission cuts by OECD countries would, according to the climate models, reduce warming by as little as 0.07°C by 2050.

Climate models suggest that increases in greenhouse gases are likely to give rise to a warmer and wetter climate in most places, in particular, warmer nights and warmer winters (Houghton et al, 1996). Generally higher latitudes would warm more than lower (equatorial) latitudes. This is hardly a major threat. A more likely threat would be policies that endanger economic progress. The negative impact of these would be far greater than any change caused by global warming. Moreover, a warming, from whatever cause, is more likely to produce economic benefits than economic losses.

References

Adger, W. Neil and Brown, K. 1995: Policy implications of the missing global carbon sink. *Area*, 24(4), 311-317.

Allard, P., Carbonelle, J., Dajlevic, D., Le Bronec, J., Morel, P., Robe, M.C., Maurenas, J.M., Faivre-Pierret, R., Martin, D., Sabrouk, J.C., and Zeltwoag, P. 1991. Eruptive and diffuse emissions of CO2 from Mount Etna, *Nature*, 351, 387-391.

Balling, R.C. Jr. and Idso S.B. 1989: Historical temperature trends in the United States and the effect of urban population growth, *Journal of Geophysical Research*, 94, 3359-3363.

Bengtsson, L. et al, 1996. Will greenhouse gas-induced warming over the next 50 years lead to a higher frequency and greater intensity of hurricanes? *Tellus*, 48A, 57-73.

Bengtsson, L., Roeckner E. and Stendel M. 1999: Why is the global warming proceeding much slower than expected? *Journal of Geophysical Research*, 104, 3865.

Bromwich, D., 1995: Ice sheets and sea level, *Nature*, 373, 18.

Cess, R.D. et al 1995: Absorption of solar radiation by clouds: Observations versus models, *Science*, 276, 496.

Changnon, S. A. et al 1997: Effects of recent weather extremes on the insurance industry: Major implications for the atmospheric sciences, *Bulletin of the American Meteorological Society*, 78, 425.

Charlock, T. P. and Alberta T. L. 1996: The CERES/ARM/GEWEX Experiment (CAGEX) for the retrieval of radiative fluxes with satellite data, *Bulletin of the American Meteorological Society*, 77, 2673.

Christy, J.R., Spencer R.W. and Lobl E.S. 1998: Analysis of the merging procedure for the MSU daily temperature time series, *Journal of Climate*, 11, 2016.

Christy, J.R., Spencer R.W. and Braswell W.D. 2000: MSU tropospheric temperatures: dataset construction and radiosonde comparisons, *Journal of Atmospheric and Ocean Technology*, (in press).

de Freitas, C.R. 1991: The greenhouse crisis: myths and misconceptions. *Area* (Institute of British Geographers), 23(1), 11-19.

de Freitas, C.R. 1994: A critical appraisal of the global warming debate. *New Zealand Geographer*, 50 (1), 30-33.

Dettinger, D.M. and Ghil M. 1998: Seasonal and interannual variations of atmospheric CO_2 and climate, *Tellus*, 50B, 1-24.

Douglas, B.C. 1992: Global sea level acceleration, *Journal of Geophysical Research*, 97, 12699-12706.

Feebly, R., Wanninkhof R., Takahashi T. and Trans P. 1999: Influence of El Niño on the equatorial Pacific contribution to atmospheric CO_2 accumulation, *Nature*, 398, 597-600.

Fischer, H., Wahlen M, Smith J., Mastroianni D. and Deck B. 1999: Ice core records of atmospheric CO_2 around the last three glacial terminations, *Science*, 283, 1712-1714.

Friis-Cristensen, E. and Lassen K. 1991: Length of solar cycle: an indicator of solar activity closely associated with climate, *Science*, 254, 698-700.

Gerlach, T., 1991a: Etna's greenhouse pump. *Nature*, 351, 352-353.

Gerlach, T., 1991b: Present-day CO_2 emissions from volcanoes. *Eos, Transactions of the American Geophysical Union*, 72 (23), 254-255.

Gubler, D. J. 1998: Resurgent vector-borne diseases as a global health problem, *Emerging Infectious Diseases*, 4, 442.

Hansen, J. E. *et al*, 1998: A common-sense climate index; Is climate changing noticeably? *Proceedings of the National Academy of Sciences*, 95, 4113-4120.

Hogan, A. W. and Gow A. J. 1997: "Occurrence frequency of thickness of annual snow accumulation layers at South Pole, *Journal of Geophysical Research*, 102, 14, 021-14, 027.

Houghton, J. T., Callander B. A., S. K. Varny (eds) 1992: *Climate Change 1992: the Supplementary report to the IPCC Scientific Assessment*, Cambridge University Press, Cambridge.

Houghton, J. T., Jenkins G. J. and Ephraums J. J. (eds) 1990: *Climate Change, the IPCC Scientific Assessment*, Cambridge University Press, Cambridge.

Houghton, J. T., Meira Filho, L. G., Callander, B. A., Harris N., Katenberg A. and Maskell K. (eds) 1996: Climate Change 1995: the Science of Climate Change, Contribution to Working Group I to the *Second Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, 572 pp.

Idso, S. B. 1991a: The aerial fertilisation effect of CO2 and its implications for global carbon cycling and maximum greenhouse warming. *Bulletin of the American Meteorological Society*, 72, 962-965.

Idso, S. B. 1991b: Reply to comments of L. D. Danny Harvey, B. Bolin and P. Lehmann. *Bulletin of the American Meteorological Society*, 72, 1910-1914.

Idso, S. B., Balling, R. C. and Cerveny, R. S. 1990: Carbon Dioxide and Hurricanes: Implications of Northern Hemispheric Warming for Atlantic/ Caribbean storms, *Meteorology and Atmospheric Physics*, 42, 259-263.

Indermühle, A. *et al* 1999: Holocene carbon-cycle dynamics based on CO_2 trapped in ice at Taylor Dome, Antarctica, *Nature*, 398, 121-126.

Jones, P. D., Raper, S. C. B., Riley, R. S., Diaz, H. F., Kelly P. M. and Wrigley, T. M. L. 1986: Northern hemisphere surface air temperature variations: 1851-1984, *Journal of Applied Meteorology*, 25, 161-179.

Jones, P. D. 1988: Hemispheric temperature variations: Recent trends and an update to 1987, *Journal of Climate*, 1, 654-660.

Keeling, R. F., Piper S. C. and Heimann, M. 1996: Global and hemispheric CO2 sinks deduced from changes in atmospheric CO_2 concentration, *Nature*, 381, 150-1508.

Kunkel, K. E., Pielke R. A. and Changnon, S. A. 1999: Temporal fluctuations in weather and climate extremes that cause economic and human health impacts: A review, *Bulletin of the American Meteorological Society*, 80, 1077.

Kuo, C., Lindberg C. R. and Thomson, D. J. 1990: Coherence established between atmospheric carbon dioxide and global temperature, *Nature*, 343, 709-714.

Lamb, H. H. 1985: *Climate, History and the Modern World*, Methuen, 387 pp.

Landsea, C. W., Nicholls, N., Gray W. M. and Avila, L. A. 1996: Downward trends in the frequency of intense Atlantic hurricanes during the past five decades, *Geophysical Research Letters*, 23, 1697-1700.

Lassen K. and Friis-Cristensen, 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*, 57 (8), 835-845.

Lindzen, R. S. 1997: Can increasing carbon dioxide cause climate change? *Proceedings of the National Academy of Sciences USA*, 94, 8335.

Mahlman, J. D. 1997: Uncertainties in projections of human-caused climate warming, *Science*, 278, 1416.

Meese, D. A., Gow, A. J., Grootes, P., Mayewski, P. A., Ram, M., Stuiver, M., Taylor, K. C., Waddington, E. D. and Zielinski, G. A. 1994: The Accumulation Record from the GISP2 Core as an indicator of Climate Change throughout the Holocene, *Science*, 266, 1680-1682.

Michaels, P. J. and Knappenburger, P. C. 1996: Human effect on global climate, *Nature*, 384, 522-523.

Murphy, J. M. and Mitchell, J. F. B. 1995: Transient response of the Hadley Centre coupled ocean-atmosphere model to increasing carbon dioxide. Part II: Spatial and temporal structure of response, *Journal of Climate*, 8, 57-80.

Ohmura, A., Wild, M. and Bengtsson, L. 1996: A Possible Change in Mass Balance of Greenland and Antarctic Ice Sheets in the Coming Century, *Journal of Climate*, 9, 2124-2135.

Pearson, P., and Palmer. M. 1999: Middle Eocene seawater pH and atmospheric carbon dioxide concentrations, Science, 284, 1824.

Pielke, R. A. and Landsea, C. W. 1998: Normalized hurricane damages in the United States 1925-1995, *Weather Forecasting*, 13, 621.

Peterson, T. C. et al 1999: Global rural temperature trends, *Geophysical Research Letters*, 26, 329-332.

Priem, H. A. 1997: CO_2 and climate: a geologist's view, *Space Sciences Review*, 81, 173-198.

Reiter, P. 1998: Global warming and vector borne disease in temperate regions and at high latitude, *Lancet*, 351, 839.

Reiter, P. 2000: From Shakespeare to Defoe: Malaria in England in the Little Ice Age, *Emerging Infectious Diseases*, 6.

Santer, B. D. 1996: A search for human influences on the thermal structure of the atmosphere, *Nature*, 382, 39-46.

Segalstad, T. V. 1998: Carbon cycle modelling and the residence time of natural and anthropogenic atmospheric CO_2: on the construction of "greenhouse effect global warming" dogma, in Bate, R. (ed) *Global Warming the Continuing Debate*, Cambridge, UK. European Science and Environmental Forum, pp. 184-218.

Singer, S. F. 1996: Climate change and consensus, *Science*, 271, 581.

Soon, W., Baliunas, S. L., Robinson A. B. and Robinson, Z. W. 1999: Environmental effects of increased atmospheric carbon dioxide, *Climate Research*, 13 (2), 149-164.

Soon, W. H., Postmentier E. S. and Bauliunas, S. L. 1996: Inference of solar irradiance variability from terrestrial temperature changes, 1880-1993: an astrophysical application of the sun-climate connection, *Astrophysical Journal*, 472, 891.

Spencer, R. W. and Christy J. R. 1990: Precise monitoring of global temperature trends from satellites, *Science*, 1558-1562.

Spencer, R. W. and Christy, J. R. 1992: Precision and radiosonde validation of satellite gridpoint temperature anomalies, Part I: MSU channel 2 and Part II: a tropospheric retrieval and trends during 1979-1990, *Journal of Climatology*, 5, 847-866.

Spencer, R. W., Christy J. R. and Grody, N. C. 1990: Global atmospheric temperature monitoring with satellite microwave measurements: methods and results 1979-1984, *Journal of Climate*, 3, 1111-1128.

Svensmark, H. and Friis-Cristensen, E. 1997: Variation in cosmic ray flux and global cloud coverage- a missing link in solar-climate relationships, *Journal of Atmospheric and Terrestrial Physics*, 59 (11), 1225-1232.

Tans, P. P., Fung I. Y. and Takahashi, T. 1990: Observational constraints on the global atmospheric CO2 budget, Science, 247, 1431-1438.

Thompson, S. L., and Pollard, D. 1995: Greenland and Antarctic Mass Balances for Present and Doubled Atmospheric CO2 from the GENESIS Version-2 Global Climate Model, *Eos (Trans. AGU)* 76, No. 46 Supplement (meeting abstracts). Also: 1997, *Journal of Climatology*, 10, 871-900.

Wigley, T. M. L., 1998: The Kyoto Protocol: CO_2, CH_4 and climate implications, *Geophysical Research Letters*, 25 (13), 2285-2288.

World Climate Report, 1998: Global warming moderates nail extremists 8 ways, *World Climate Report*, 3 (23), 1.

Ye, H. and Mather, J. R. 1997: Polar snow cover changes and global warming, *International Journal of Climatology*, 17, 155-162.

Zhang Y. and Wang, W. C. 1997: Model simulated northern winter cyclone and anticyclone activity under a greenhouse warming scenario, *Journal of Climate*, 10, 1616-1634.