The Kyoto Protocol:
Don’t Forget the Science

by Bob Foster

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by RJ Foster

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ABSTRACT

Observed warming of the earth's surface during the 20th century was in two roughly-equal tranches (each of about 0.35 ^{0}C) in 1925-44 and 1978 to its end. In the belief that:

- Global warming over the past century resulted from the human-caused emission of greenhouse gases, particularly CO_2 from the burning of fossil fuels,

and that:

- If the nations of the world were to control anthropogenic greenhouse gas emissions strictly enough in the future, we could 'stabilise' the climate,

Australia joined in negotiating the 1997 Kyoto Protocol. The sole objective of this treaty is limitation of GHG emissions—and *both its under-pinning beliefs are probably wrong*.

The scientific basis for the Kyoto Protocol is *Climate change 1995: the science of climate change* from the IPCC's Second Assessment Report published in 1996. Even now, the Australian Government accepts the IPCC Report "as the most authoritative source of information on the science of global climate change". Misleadingly, the Report treats climate science and climate-change science as the same thing; and it ignores powerful contrary evidence from the geosciences. This self-serving study promotes meteorology, not protection of the environment; and it is itself an environmental threat, because its message has the effect of diverting money and zeal from better-founded and more-pressing environmental needs, including those right here in Australia.

Greenhouse is a phenomenon of the lower atmosphere. Theory has it that an increasing concentration of GHGs will cause the *atmosphere* to heat up, in the first instance, with subsequent re-distribution of this increased warmth upward to Space, and downward to Earth with consequent warming at its surface. It is this resultant *surface* warming which we call the 'greenhouse effect'.

However, if there is no warming of the lower atmosphere, that warming can't then cause warming at the surface; *ie* no atmospheric warming means no 'greenhouse warming'. We now have a global coverage of satellite-derived temperatures for the lower atmosphere which extends for 21 years—and there is little or no warming trend!

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A Panel of the US National Research Council was formed to examine this remarkable observation; and it accepts that surface warming over the period has not been matched by concomitant warming of the atmosphere; but the NRC urges that any inference await a longer run of measurements—it suggests 40 years—to ensure that conclusions drawn are statistically robust. However, a 42-year run of relevant data is already available. A less globally-complete coverage by balloon-mounted thermometers extends back to 1958; and, in the period of overlap from 1979, agrees closely with temperatures derived from satellites. Except for an abrupt upward step of 0.35 ^{0}C at 1976/7, the balloon record is flat from 1958 to 1999; and there is strong circumstantial evidence that the jump reflects a major contemporaneous re-ordering of oceanic circulation, rather than the gradually-changing composition of the atmosphere arising from GHG emissions. Therefore, the more-recent (1978-99) tranche of observed 20th century surface warming is unlikely to be *greenhouse* warming.

Our Ice Age climate shows natural variability, globally and regionally, at many time-scales—from long Glacials and short Interglacials on a 100,000-year cycle, down to El Niño warm events at an irregular frequency of less than a decade. In the Interglacial we now enjoy, the most prominent is the *ca* 1500-year warm/cold/warm cycle in the North Atlantic Basin mega-region of which the Dark Ages, Mediaeval Warm Period and Little Ice Age are all part. At least at this scale, cyclicity correlates with the quantity of warm equatorial water entering the Nordic seas, and in turn with the episodic launching of iceberg armadas. Climate-change is driven by ice/ocean-related inertial effects.

The earlier tranche of observed 20th century surface warming (1925-44) appears to have been dominated by rebound from the Northern Hemisphere's last cyclic cold period, the Little ice Age. Also important, was the increase of solar output over the AD1800-1950 period. Atmospheric temperatures for this interval are unknown; but because the main growth in anthropogenic GHG emissions came only later, the first tranche of observed global warming is unlikely to be *greenhouse* warming.

IPCC's hypothesis that 20th C warming is all or largely the result of human-caused GHG emissions, is almost certainly wrong. The sensitivity of global climate to GHG emissions appears to be much less than has been factored into IPCC's climate models. Its over-predicting models fail the test of reconciliation with an under-warming world during the past century, even when IPCC arrogates to its validation *all* of the observed warming for the period—irrespective of likely cause. Therefore, the model-based predictions of future GHG warming, already reduced in steps from 0.8 ^{0}C per decade in 1988 to 0.2 ^{0}C/decade in the current IPCC Report, are probably still too high.

In conclusion, reciting the mantra 'we accept the science' would be a poor substitute for consideration by Government of the full range of relevant scientific input *before* Australia ratifies the Kyoto Protocol. Ratification on the basis of the 'precautionary principle' alone would be a mistake, because more-important environmental needs would be starved of funds as a consequence—for no known countervailing benefit.

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1. INTRODUCTION

1.1 Big picture, big questions

Climate has changed much in the past—that we all know; and it will change much in the future—of that we can be certain. Let me put it another way: we humans can't ensure that climate stays as it is now—any more than we can command the seas to keep their present station. 'Stabilising the global climate' is a chimera.

Furthermore, we don't yet even know whether sky-rocketing carbon dioxide emissions from the burning of fossil fuels are, directionally, good or bad for the future of humanity—and of the biodiversity for which we are sole custodians. However, we *do* know that the money and zeal being diverted now to the greenhouse issue subtracts from that available for meeting Australia's many better-founded, and obviously much more pressing, environmental needs. Some preventable harm will be irreversible.

Indeed, time is not of the essence when considering greenhouse response measures. The 1988 Toronto Conference was spurred on by predicted global warming of an almost-incredible 0.8 ^{0}C per decade because of greenhouse gas emissions. This prediction had been reduced to 0.3 ^{0}C per decade by the time of the Rio Conference in 1992, and to 0.2 ^{0}C per decade by Kyoto in 1997. The analysis below suggests that even this last is an over-estimate.

But what caused the warming, averaging some 0.7 ^{0}C across the Globe, which we experienced during the twentieth century? The answer to this question bears crucially on an important matter of policy:

Whether or not Australia should ratify the Kyoto Protocol.

1.2 How it all began

1.2.1 North American origins

Back in the 70s the greater concern, particularly in the United States, was the possibility of global *cooling*. However, it was also in the United States during the latter part of that decade, that the attention of scientists was drawn to predictions by primitive numerical climate-models that increasing emissions of CO2 (arising from the combustion of fossil fuels) would cause global warming.

This concern was picked up by the World Meteorological Organisation (WMO) and the United Nations Environment Program (UNEP). Together with the International Council of Scientific Unions (ICSU), these organisations met at Villach (Austria) in October 1985 to discuss this newly-discovered threat to mankind. Seldom has a scientific meeting had such an influence on policy-making.

Villach led on to a meeting which was far from scientific—albeit jet-propelled by new modelling results from climate scientists which predicted global greenhouse warming of 0.8 0C per decade. This was the Toronto Conference of June 1988: *The changing atmosphere: implications for global security*.

Although sponsored by the Canadian Government, the Conference was not officially government-sanctioned. Therefore, the drafting committee was comprised largely of environmentalists; and for the first time in the global warming sage, activists dominated.

Hyperbole also dominated. The Toronto Conference statement began:

> Humanity is conducting and unintended, uncontrolled, globally pervasive experiment whose ultimate consequence could be second only to a global nuclear war. It is imperative to act now.

And recommended a target as follows:

> An initial global goal should be to reduce CO2 emissions by approximately 20 percent of 1988 levels by the year 2005. Clearly, the industrialised nations have a responsibility to lead the way, both through their national energy policies and their bilateral and multilateral assistance arrangements.

The impetus which Toronto gave to greenhouse concerns has never waned. The fact that the 0.8 had become 0.2^{0}C per decade by the time of Kyoto hasn't made any difference.

1.2.2 Meanwhile, back at the farm …

Australia played a significant role at Villach; and it continues to play an important role in scientific research on the climate-change issue. CSIRO's Cape grim atmospheric base station supplies a crucial real-time input for the data-short Southern Hemisphere. In addition, individual Australian scientists from the CSIRO, the Met Bureau, and more recently academia, play a prominent part in the activities of the Intergovernmental Panel on Climate Change's Working Group I (dealing with climate change science, see below).

During the time of Minister Barry Jones, the Melbourne-based but Federally-funded Commission for the Future made the early running on publicising the greenhouse issue to the Australian community. This work culminated in *Greenhouse 88* at Dallas Brookes Hall on 3/11/1988—with a video link to audiences at venues in other states.

The program offered an address by "new generation greenhouse campaigner" Stephen H Schneider, brought to Australia for the purpose by CSIRO and the Commission. He and James Hansen (of both, there will be more later) were the two main greenhouse activists in the US science community of the time. The evening was padded out with four local speakers, including Yours Truly. In those, days, I was the green face of capitalism.

The event filled a need, of that there be no doubt, attracting as it did 800 paying customers in Melbourne and smaller, but not insignificant, audiences interstate. A part of the well-educated segment of the community had found a new cause. The event had the opposite effect on me. Schneider's address, supposedly on the science, was advocacy—with but a tenuous and selective scientific basis. In particular, he told us that "the atmosphere will warm as much in the next 50 years as it did in the past 15,000", i.e., since before the Glacial/Interglacial transition. That evening was my Road to Damascus.

1.3 The IPCC Report is advocacy not science

1.3.1Second Assessment Report of Working Group I

The Second Assessment Report of IPCC's Working Group 1—*Climate Change 1995: the science of climate change*—was the scientific under-pinning of the Kyoto Conference (Houghton *et al* Eds 1996). I must make it clear at the outset, that when I talk below of the 'IPCC Report' or the 'Report', I mean its first 50 pages comprising *Preface*, *Summary for Policymakers* and *Technical Summary*. I doubt whether Australia's 'policymakers', be they politicians or public servants, would have time to read the whole 572 pages. Neither should they need to.

My paper disagrees with the fundamental thesis of the IPCC Report that the observed warming trend at the Earth's surface during the 20th century was wholly or largely the result of anthropogenic changes to the composition of the atmosphere.

Perhaps, the Report's wrong analysis can be explained by the dominance of meteorologists in the deliberations of Working Group I—or at least in the preparation of the summaries at the Report's head (*ie* its first 50 pages, see above). The Report is advocacy, not science, and it advocates the self-interested thesis that climate science and climate-change science are the same thing.

The Report is said to be "the consensus of 2500 of the world's top climate scientists"; but the evolution of scientific understanding is not a matter of voting. However in science, the dominant paradigm dominates—and the advancement of science is slowed as a consequence. Nevertheless, it must be conceded that IPCC has received much seemingly-authoritative support[2] since the Report's publication in 1996.

The Australian environmental bureaucracy champions with vigour the dominant paradigm as espoused by IPCC, as apparently do those Canberra policymakers with carriage in the climate-change area (see below).

1.3.2 Letter to Canberra and its response

I wrote a letter to Prime Minister Howard in the naive hope that someone not in the Canberra environmental bureaucracy might read it.

My concerns were that:

2 The most recent is from a 22/6/2000 news item in *Nature* (v 405 pp 873,4) *UK panel calls for more cuts to carbon dioxide emissions* which announces the findings of a "key independent report to the UK government". The Royal Commission on Environmental Pollution is an independent body which reports to parliament on the crucial environmental issues facing Britain; and the commission's chairman is Tom Blundell, head of the department of biochemistry at the University of Cambridge. The Royal Commission's new report, *Energy—The changing climate*, says the UK has a "moral imperative" to act now to curb emissions. Britain should reduce its emissions of carbon dioxide by 60% over the next 50 years, and set an international model for tackling climate change. Altruism lives.

- Australia's policymakers are not being properly informed, and the IPCC Report—the scientific rationale for the Kyoto negotiations—is advocacy not science.
- Given current knowledge, the wise course for Australia would be to defer ratification of the Protocol.
- Reciting the mantra 'we accept the science' would be a poor substitute for considering the full range of relevant scientific input *before* making a decision on ratification.
- Government needs advice on climate-change which is countervailing to the advocacy of IPCC—and of those in Australia, including the environmental bureaucracy, who support IPCC's narrow and self-serving line.

But the dominant paradigm continues its domination. As I had feared, the response came from the Australian Greenhouse Office, saying:

> Thank you for your letter of 4 February 2000 concerning the science of climate change and ratification of the Kyoto Protocol.

and

> The Australian Government recognises the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) as the most authoritative source of information on the science of global climate change.

1.4 Why is it me writing this?

1.4.1 IPCC's self-confessed perfection

The introduction to the *Technical Summary* of the IPCC Report asserts that:

> ... the summary presents a comprehensive, objective and balanced view of the subject matter.

In my opinion, the *Technical Summary* (of 35 pages) does nothing of the sort—and neither do the two shorter summaries which precede it. Hence, Canberra policymakers hear only one side of the very complex story which is climate-change science.

Individuals who press a view countervailing to the dominant paradigm are not heard. Furthermore, those in Australia who rely on Government funding for their research in the area of observed changes in climate at time-scales relevant to humans, simply don't get money if their studies are seen to lie outside the paradigm. Until you start working in this area, you don't appreciate the practical difficulties involved in swimming against the greenhouse tide.

1.4.2 Who will put the countervailing view?

To whom might our policymakers turn for views on climate-change science which are countervailing to those promulgated by IPCC, and by its adherents here in the Australia?

I doubt if it would be the Bureau of Meteorology, because it seems hardly realistic to expect that this organisation might espouse a line which diminishes the perceived role of the atmosphere.

We had better look elsewhere.

I doubt also if the large resource companies will help—scarred as they are by the *Brent Spar* debacle. Sadly, being ostentatiously better 'good citizens' (and sooner) than their direct competitors is seen by many large companies as the preferred way forward, irrespective of the science. A 'green' image and, hopefully, a larger proportion of the shrinking economic pie as a consequence, is seen as preferable to giving intellectual leadership in such a controversial area. There will be little from this quarter.

However, Australia has at its disposition a long-established research body in our well-respected Commonwealth Scientific and Industrial Research Organization. Furthermore, CSIRO encompasses people with a wide range of talents in various aspects of the natural sciences—precisely what is needed if Government is to be provided with disinterested and authoritative advice in such an extensively multi-disciplinary field.

But for reasons unknown to me, CSIRO appears to have hitched—sometimes it seems more like welded—its star to the IPCC. The atmosphere rules, OK?

In terms of its scientific input to Australia's policy-making on climate change, I tend to think of CSIRO, not as the knowledgable guardian of our national scientific interest, but as somewhat like an 'IPCC-in-Australia'.[3]

Hence, here I am, writing what should be a superfluous paper. I am not claiming that my effort herein is devoid of advocacy—far from it. I have not written, and indeed cannot write, the knowledgeable and disinterested review of **all** the relevant science that, collectively, CSIRO's array of experts *could* have written.

In particular, my paper advocates the view that the IPCC Report—on which Australia relies for the scientific under-pinning of its climate-change policy—is also advocacy. If you read on, you will find there is much more to climate change at a time-scale relevant to humans than human-caused alteration to the composition of the atmosphere.

Finally, a disclaimer. The atmosphere is not my field; I am not a meteorologist. I am an engineer by qualification, and my relevant experience is in the geosciences. The atmospheric science part of my paper relies heavily on *World Climate Report*, a contrarian newsletter from

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3 CSIRO remains rigidly 'on-message'. Under the heading "Kyoto treaty not enough to stop global warming", *Reuters* reports Graeme Pearman, CSIRO's division chief of Atmospheric Research, as saying in his address to the National Press Club in Canberra on 13/9/2000, that:

> ... even stopping the growth of greenhouse gas emissions will not be enough to prevent climate change.

Thus, CSIRO is expounding—instead of exposing—IPCC's implausible contention that if human-caused GHG emissions were to be reduced 'enough', future climate change would be prevented.

the United States whose Chief Editor is Patrick J Michaels. I also draw on two recent paperback books[4] of similarly-contrarian sentiment.

4 Published in 1999: *Climate policy after Kyoto* edited by Tor Ragnar Gerholm; and published in 2000: *The Satanic Gases: clearing the air about global warming* by Patrick J. Michaels and Robert C. Balling Jr.

2. WE LIVE IN AN ICE AGE

2.1 Long, long ago

A journey of ten thousand miles begins with a single step, said the Great Helmsman. Understanding global climate-change is a long journey too, because climate has a past as well as a future. What happened to the warm, wet, Earthly Paradise of Cretaceous times? Why is our home planet so cold and dry now? (This section follows Foster, 2000). Solar radiation is the key determinant of variation in the Earth's warmth at several time-scales; but the Sun appears to have played no crucial role here.

At around the Palaeocene/Eocene boundary, 55 million years before the present (MyBP) in the early Cainozoic, the atmospheric carbon dioxide concentration was more than 2,000 ppmv, as shown in **Figure 1(a)** from Pearson and Palmer, 2000. By 20 MyBP, CO_2 content had declined to roughly its current level, and there is some evidence for it (temporarily) falling as low as 140 ppm at about 16-14 MyBP; the immediate pre-industrial level was about 280 ppm. Also shown in Figure 1(a), is an estimate of the reduced radiative forcing (greenhouse warming) caused by the CO_2 decline. Here is one obvious reason why the Earth has cooled, but what was the *underlying* cause?

Tectonics took the lead in Cainozoic climate change. Over the past 50 My and more, the northward march of the Indian subcontinent (see LH map in **Figure 1(b)** for the relationship of the Australian and Indian tectonic plates in mid-Cretaceous times) and resulting uplift of the Tibetan Plateau have been influential (Raymo and Ruddiman 1992). Continual rejuvenation and weathering of high-relief terrain, consequent enrichment of oceanic waters with the calcium and silica from which organisms build their hard-parts, and subsequent sequestering of carbon *via* the accelerated deposition of their remains in marine sediments, are likely to have been the major cause of reduced atmospheric CO_2 since the end of the Cretaceous (counterbalanced to some extent by the emission of CO_2 from volcanoes). A lesser greenhouse effect means a cooler Globe.

Figure 2 is from Lear *et al* (2000). The time of the Palaeocene/Eocene deep-sea temperature peak (graph A), coincides with the high CO_2 level shown in Figure 1(a). But notably, graph B also shows a series of steps and still-stands in the growth of global ice volume[5]—uncharacteristic of slowly-changing atmospheric composition, acting alone.

I correlated (Foster 1974) the sharp temperature drop, at about 41-36 MyBP, in the still-narrow seaway between Antarctica and Australia with the opening of Drake Passage between Antarctica and South America, and the concomitant inception of the mighty Antarctic Circumpolar Current—compare Australia/Antarctica positions in Figure 1(b).

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5 Ice freezes with a different ratio of the oxygen isotopes to that in its parent water-body. Variations in the ^{18}O content of the world's oceans ($\delta^{18}O$, as enshrined in the tests [*ie* shells] of foraminifera contained in deep-sea sediments recovered in cores), in relation to the common ^{16}O isotope, is a proxy for the volume of ice existing globally at that time. Lesser and shorter-term deviations in the $^{18}O/^{16}O$ ratio in the fossil tests of surface-dwelling [*ie* planktonic] or bottom-dwelling [benthic] forams, are a proxy for fluctuating surface or deep-sea temperatures. Here, Laird *et al* have used an independent proxy of Mg/Ca ratio in foram tests.

My new evidence was the abrupt change in the shallow-water echinoid (sea urchin) fauna on the southern coast of Australia at that time, from neo-tropical to neo-arctic in its aspect. As was the Tibetan uplift, the breaching of the Andean/Antarctic cordillera was a tectonic driver. It appears that there was a sharp increase of ice volume at about the same time as the opening of Drake Passage. Indeed, it is very likely that this tectonic event marks the beginning of the global accumulation of continental ice on any significant scale; and early accumulation was on the continent of East Antarctica.

Lear *et al* have built up a global deep-ocean temperature record across the Cainozoic, based on the magnesium/calcium ratio in the carbonate skeletons of benthic foraminifera (graph A in Figure 2), showing a cooling of some 12 ^{0}C in steps which parallel those of global ice accumulation. However, they conclude that the deep-ocean cooling was more gradual than was the ice accumulation in the vicinity of the Eocene /Oligocene boundary (graph B)—and continued well beyond the time of rapid ice build-up, rather than running ahead of it. Ocean cooling did not create the East Antarctic Ice Sheet.

Preservation of the continental ice sheet on East Antarctica (whose initial accumulation Lear *et al* place at about 34 MyBP) albeit with some subsequent variability in its volume, and the continued deep-ocean cooling thereafter, are consistent with its becoming the world's 'refrigerator'. There is little doubt that this ice sheet post-dates the creation of Drake Passage, and that the ice-refrigerator owes its durability to the existence by then of the giant Circumpolar Current. But could breaching of the Andean-West Antarctic Cordillera, on its own, have been enough to switch the refrigerator on—particularly in such emphatic fashion?

The Fohn-1 offshore exploration well in the Bonaparte Basin, drilled in the Zone of Co-operation between Australia and (then) Indonesia, might have uncovered the switch when it encountered a buried impact crater formed in a late Eocene erosional surface (Gorter 1999). The well found a 350 metre breccia lens displaying high platinum-group-element abundances, including iridium, and PGE ratios indicative of an extra-terrestrial origin.

Seismic profiling shows a possible rim anticline to the Fohn crater with a diameter of some 3 kilometres, and a field of around 30 smaller depressions spread over an axial length of more than 100 km at the same horizon. According to Gorter, the stratigraphic relationship and the limited palaeontological evidence place the bombardment at 38-34 MyBP; and he suggests that it could be contemporaneous with the Popigai (Siberia, 100 km diameter crater) and Chesapeake Bay (USA, 90 km) impacts. New information from Farley[6] makes it likely that the Timor Sea impacts are indeed part of the same series of events as those in Russia (35.8+/-0.8 MyBP) and the United States (35.5+/-0.3 MyBP). These latter are by far the largest known impacts during the Cainozoic.

Using the helium isotope ^{3}He (otherwise extremely depleted on Earth) contained in seafloor sediments, Farley's group has built up a record of the delivery rate of cosmic dust (tiny fragments of asteroids or comets) over the past 100 My. Abundance of extra-terrestrial

6 New to me, anyway. On 16 March 2000, I attended a Geological Society of Australia lecture by Professor Kenneth A. Farley, a noble-gas geochemist from the Division of Geological & Planetary Sciences at Caltech, in which he gave details of the work of his research group.

material increases by 8 or 9 orders of magnitude for a period of a million years or more at about 36-35 MyBP—and this is the only very pronounced peak in the Cainozoic.

Uplifted marine sediments in the Umbrian Apennines of Italy provide the type locality for the Late Eocene. Here, falling within the period of increased ^3He concentration, are twin peaks of Ir and shocked quartz abundance—compelling evidence of comet or asteroid arrivals.

Farley speculates that these events are cometary impacts, and are the result of galactic tidal perturbation of the Oort Cloud—presumably by a passing star (I think I will just take him at his word here); and that the lasting outcome on Earth was the extinctions which mark the Eocene/Oligocene boundary. The lesser impacts in the Timor Sea are almost certainly part of the same million years or so of bombardment. Even if the larger individual impacts were separated by a few hundred thousand years, episodes of 'nuclear winter' would be their result.

For the purposes of a paper on climate change, the important point is that these impacts could well have had a *cumulative* effect. Any of these coolings might have been severe enough to frost-over the Antarctic continent, and thus get the giant East Antarctic Ice Sheet started. The cold Circumpolar Current would have served to preserve the nascent covering of snow and ice (and its crucial albedo change[7]) between impacts. Accumulation of a substantial ice sheet was the end result of the bombardment. Enter catastrophism.

However, there is another problem to be resolved; and it is well displayed in Figure 2. The events prior to the beginning of the Oligocene, as summarised above, might well explain both the abrupt cooling at around 35 MyBP, and the absence of subsequent rebound to the previous (Upper Eocene) level of warmth. But what caused the further rapid growth of the East Antarctic Ice Sheet at around 14 MyBP?

This surge of renewed accumulation appears to have brought the Ice Sheet to about its present volume (some 80% of today's total ice quantity, and equivalent to about 50 metres on global sea level). Again, catastrophism might have been the key.

There is a well-known example (Rampino and Self 1992) of another sort of catastrophic and climate-influencing phenomenon in the volcanic winter, and the subsequent accelerated glaciation following the Toba (Sumatra) super-eruption of about 70-75 thousand years (ky) BP. It was this event which tipped an already-cooling Earth into the depths of the last (Würm) Glacial, with massive ice sheets (reducing sea level by about 100 m) forming on northern North America and northern Eurasia. More of this later.

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7 The 'albedo' is the proportion of incoming solar radiation which is reflected away, and hence not absorbed at the Earth's surface; 'reflectivity' would do just as well. According to Michaels and Balling (see Footnote 4 for the reference) the average albedo of the Earth is around 28%, meaning that it reflects about a quarter of the solar heat it receives. Neither tectonic movements on Earth, nor extra-planetary bombardment, can alter the output of our heat-source—the sun. Therefore, these events must trigger associated feedbacks on Earth, if they are to have any lasting impact on global climate. But frosting of the Antarctic continent might increase its albedo to 80/90%, and thus dramatically reduce the absorption of solar radiation; climate change is under way. Furthermore, as ice accumulates on Antarctica, sea level drops as a consequence. Thus, shelf seas with an albedo of 10/20% are replaced by emergent land with an albedo of perhaps 20/40%. As a result, cooling continues.

Cas (1999) explains how the 'aerosol' gas SO_2, emitted in volcanic eruptions, readily combines with H_2O to produce H_2SO_4 vapour droplets. These droplets, dispersed in the atmosphere, would significantly increase planetary albedo and hence the proportion of incoming solar warmth reflected to space. Global cooling would be the result. He reminds us of the Mount Pinatubo eruption in 1991 (30 million tonnes H_2SO_4 entering the atmosphere), which caused a temporary global cooling of some 0.5 ^{0}C; but Toba (see above) with at least 1,000 Mt H_2SO_4 formed, caused a cooling of some 3-5 ^{0}C; and much further into the past at some 14.7 MyBP, the Roza flood basalt (USA) with some 12,000 Mt of H_2SO_4 entering the atmosphere at the time of its out-pouring, caused a cooling of 5-15 ^{0}C over a period of a decade or so.

In the Roza out-pouring, we have a plausible trigger for the growth of the East Antarctic Ice Sheet to its modern dimensions.

The *coup de grace* was the sealing about 3.5 MyBP (by the emergent Isthmus of Panama) of the seaway which had linked the equatorial Pacific and Atlantic. This prevented the continuation of a warm, globe-circling, surface current; and the consequent changes in circulation patterns led ultimately to the accumulation of continental ice on Greenland. By some 2.5 MyBP, the Ice Age was with us.

Ours is not a uniformitarian world, and extreme events have played a prominent part. The East Antarctic Ice Sheet is the Globe's refrigerator; and it is maintained by the giant circum-south-polar cold current. The on-switch was a shower of comets.

At very long time-scales, we can say with a high degree of confidence that there are factors—both terrestrial and celestial—other than changes in the composition of the atmosphere, which are major drivers of climate change. It is a good conceptual foundation on which to build our understanding of near-term climate change.

Another concept, equally crucial to our topic, also emerges above—that of feedback. Without it, extreme events would have no long-term impact on climate.

2.2 A time of Glacials and Interglacials

Enter the Sun. Orbital factors influence the way the Sun strikes the Earth; and although the variations are not themselves large in proportional terms, fortuitous triggers and crucial feedbacks (see above) dictate quite dramatic changes in global climate. For about the last million years or more, pronounced variations at a period of 100 ky (see **Figure 3** from Clark, Alley and Pollard, 1999) have dominated our climate.

As suggested by Milankovitch early last century, the eccentricity of the Earth's orbit appears to be the factor which sets this period. This is the Glacial/Interglacial cyclicity which we still enjoy today.

There are variations at shorter periods which also play a part (variation of the Earth's axial tilt has a 41 ky cycle; and precession due to the Earth's axial wobble has a 19-23 ky cycle[8]). When these various influences are combined (see **Figure 4** from Broecker 1984 for the long term, and **Figure 5** from Ruddiman and Wright 1987 for the impact across the last Glacial/Interglacial transition) there is a convincing correlation between summer insolation in the northern Northern Hemisphere and global ice volume. But there are dissenters (Karner and Muller, 2000).

There appears to be an important unifying factor at work here (Flohn 1978). The hemispheres respond in concert to orbital forcing—not, as one might expect, in opposite senses. This conjunction appears to be because the Arctic Ocean is covered with sea-ice every winter, and summer insolation determines the proportion which melts annually. On the other hand, most of the Antarctic sea-ice melts each summer, and its annual variation in extent therefore depends on the level of winter insolation. The maps in **Figure 6** show what I mean.[9]

A record of the last 400,000 thousand years (400 ky) of the current ice age have been captured in ice cores from Vostok in Antarctica (see **Figure 7** from Petit et al 1999). The Figure shows a temperature proxy based on deuterium isotopes compared to a proxy for global ice volume based on oxygen isotopes. There is a prominent 100 ky climate cycle of long Glacial and short Interglacials.

In their duration, Glacials predominate; and 10 ky appears to be about the normal length of the much-more-benign Interglacials. We live in an Interglacial.

2.3 The last Glacial period

2.3.1 The Heinrich events

Figure 8 (Williams *et al* 1998) isolates the last Glacial and its two adjacent Interglacials—the Eemian (shown as '5e' on the Figure) and the present interglaciation known as the Holocene.

The last Glacial is divided at about 74 kyBP into earlier and milder, and later and harsher, phases; and the division coincides with the Toba super-eruption.[10] At least at longer time-

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8 Summarised in many places, including Hewitt 2000.

9 The N/S contrast (and hence the differing albedo changes) is illustrated by the areas currently involved. In the north, the coverage of sea ice at the end of summer and winter is 9 and 12×10^6 km^2 respectively. In the south, the equivalent figures are 4 and 20×10^6 km^2.

10 Here is an interesting aside which underlines the significance of Toba. Professor Martin Williams, in his presidential address to the Royal Society of South Australia on 8/6/2000, tells us:

> Genetic evidence suggests that the human population nearly became extinct towards 100-50 ka (ie kyBP), being reduced to about 10-20,000 breeding pairs, most of whom probably lived in Africa. The eruption of Toba volcano in northern Sumatra 74,000 years ago may have been the cause of this near demise of the human species. The Toba eruption was the biggest eruption in at least the last 65 Ma, and was followed by prolonged and severe global cooling. All of peninsula India was covered in Toba ash. Toba ash has recently been recovered from marine cores in the China Sea and as far south as latitude 12 ^{0}S. The survival of humans in Africa after the 74 ka Toba eruption was probably related to the richness, diversity, and resilience of the African Rift ecosystems, but this remains speculative until sites of this age have been investigated using fine resolution methods of microfossil analysis and dating.

scales, climate change is a matter of extreme events (triggers) and their associated feedbacks overprinting variations in the availability of solar heat.

Figure 9 (from Jouzel 1999) shows the fluctuations in northern North Atlantic climate during the colder part of the last Glacial, as derived from an oxygen-isotope proxy recorded in a Greenland ice core. During the Glacial there were a series of gradual coolings and subsequent prominent warmings in the Atlantic Basin on two time-scales. I have discussed these fluctuations in more detail elsewhere (Foster 1999).

The larger 'Heinrich events', at a variable frequency averaging roughly 7 ky, were associated with the surging of continental ice into the sea, mostly from the Baffin Island region of the North American ice-sheet. The last four Heinrich events (H1 to H4) can be correlated with cold intervals in the ice-core record of Figure 9 at 14.6, 21, 27 and 35 kyBP respectively. These are radiocarbon years, depending on variations in the proportion of the ^{14}C isotope cf the common ^{16}C. 'Carbon years' are usually a little different from calendar years (a ^{14}C age of 21 ky is about 23 kyBP, for instance).

Figure 10 (from Grousset et al 1993) shows the trajectory of the layers of ice-rafted detritus dropped on the North Atlantic sea floor as each of the iceberg armadas melted. The cross in Figure 10 at about 20 ^{0}W marks the position of the Dreizack submarine seamount on top of which Heinrich (1988) recognised the layers of ice-rafted sediment.

The Heinrich events were each associated with subsequent warmings which were large and abrupt—5 ^{0}C or more in a few decades or less. These surges of continental ice into the sea were themselves almost certainly not caused by contemporaneous changes in the local climate (ice is a very good insulator).

Instead, they were related to the physical characteristics of ice; and thus, almost certainly, they were internally not externally triggered. Ice is a rock; and surging ice-sheets are rock-mechanics in action. Like volcanic eruptions, iceberg outbursts are extreme events.

2.3.2 IPCC's explanation is wrong

IPCC could hardly ignore the dramatic climate shifts in the North Atlantic during the last Glacial. Yet, to acknowledge any substantial role for ice-surges in past climate-change, would risk diminishing the claimed dominance in observed 20th century climate-change of anthropogenic variations in atmospheric composition. Its dissembling on this issue does IPCC's credibility much harm.

It is not until the last page of text in its *Technical Summary* (p 46) that the IPCC Report grasps this nettle:

> Both the study of palaeoclimate from sediment records and ice cores and modelling studies ... can be interpreted to suggest that the ocean circulation has been very different in the past.

So far, so good; but then the Report loses its way:

> Both in these observations and in the ocean models, transitions between different types of circulation seem to occur on a time-scale of a few decades, so relatively sudden changes in the regional (North Atlantic, Western Europe) climate could occur, *presumably mainly in response to precipitation and runoff changes ...*

Attribution of these remarkably-abrupt warmings in the North Atlantic Basin to 'precipitation and runoff changes' does indeed maintain the primacy of the atmosphere in the IPCC Report. Expediency has vanquished science here.

But it is relatively simple to distinguish fluvial sediments from those of glacial origin—which were rafted to their place of deposition, and then dropped to the sea-bed (without having been sorted by moving water) as their supporting icebergs melted. Furthermore, there is no known way that 'precipitation and runoff' could place layers of terriginous sediment (*ie* originating on land) on the top of a North Atlantic seamount. The trillion-tonne layers of ice-rafted detritus spread across the North Atlantic from Labrador to Ireland are the end-point of surging continental ice sheets—of that there is no doubt.

No trace of a "comprehensive, objective and balanced view of the subject matter" appears in this self-serving—and wrong—piece of work. If the explanation quoted above really does represent the 'consensus of 2500 of the world's top climate scientists', we live in a strange world indeed.

2.3.3 The Last Glacial Maximum

The LGM is identified at 21 kyBP in Figure 9, based on evidence from Greenland where average near-surface air temperatures at the time were some 20 ^{0}C lower than now. Even in and near the tropics, on-land temperatures were substantially lower then. Based on the evidence of noble gas concentrations in groundwater (Aeschbach-Hertig 2000), and confirming less-precise work going back many years, there was glacial-era cooling of 5.3, 5.4 and 6.5 ^{0}C in Namibia, Brazil and Oman, respectively.

For reasons unknown to me, IPCC has tended to belittle the extent of cooling during the last Glacial.[11] The world was spectacularly different then—cold and dry, and with sea level 120 metres lower than today.

Figure 11 (Hewitt 2000) shows the extent of continental ice sheets, permafrost, and both perennial and seasonal sea-ice at the LGM, some 20 kyBP. Continental North America and Eurasia were ice-bound to about 40-50 ^{0}N, and well beyond 40 ^{0}N on the Tibetan plateau; and

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11 At a conference organised by the Royal Geographical Society, and held in London on 31/5/94, "Sir John Houghton, Chair of the Intergovernmental Panel on Climate Change" spoke:

> The IPCC's third report (ie the Report discussed herein), he said, would reaffirm the position of the world's leading climate scientists that emissions of Carbon Dioxide are having a profound impact on the world's climate. In the last ice age, average temperatures were only 5 ^{0}C lower than today. Those who differed from this view, he added, were not top climate scientists and he questioned their position and the quality of their work.

My quotes are from "Implementing the Climate Change Convention: conference reviews challenges and opportunities" in the June-July 1994 edition of *The Network*, p 5. (Actually, Professor Bert Bolin was chairman at the time; Sir John chaired IPCC's Working Group I on the science of climate change.)

Northern Hemisphere seasonal sea-ice extended beyond 50 ^{0}N in most oceanic areas. The southern continents were generally very dry and, although also cold, escaped extensive glaciation; sea-ice was largely restricted to south of 50 ^{0}S. Tropical rain forest retreated to the equatorial regions.

The LGM coincided with a period of minimum solar input (see Figure 5) and attendant albedo-related feedbacks (see Figure 11); and the average global cooling, *cf* today, was certainly well beyond 5 ^{0}C—despite Sir John's churlish-sounding strictures (as reported in Footnote 11).

But drastic cooling was only the half of it. In southeastern Australia, for instance, live desert dunes extended south to the vicinity of Melbourne (Cranbourne), to Gippsland, and across an emergent Bass Strait to NE Tasmania.

2.3.4 The transition to the current Intergalcial

Figure 12 from Rühlemann *et al* (1999) contrasts the transition from the last (Würm) Glacial to the current (Holocene) Interglacial in the Northern (evidence from the GRIP icecore, Greenland) and Southern (Byrd icecore, Antarctica) Hemispheres. (The third curve, at the top, is vital to my later argument; it will be saved until then).

In the south, as one might expect from the simple geometry of that hemisphere, the change is gradual—in line with increasing solar warmth (see Figures 4, 5) and feedbacks from reduced (winter) sea-ice coverage. In the north however, things are much more complicated (as can be better seen in Figure 9), probably for reasons of geometry again. Here, factors are involved which are much more influential than the potential feedbacks evident in Figure 6 and discussed in Footnote 9.

The north/south difference is manifested by the abrupt change from Glacial to Interglacial conditions in the north (which Figure 9 puts at 14.6 kyBP). The important point here is that the jump immediately follows the latest of the Heinrich events (H1 in **Figure 13** from Chapman and Maslin 1999). This Figure shows a series of direct and proxy measurements derived from two cores of sea-bed sediments, one from offshore Ireland and the other from further south in the central North Atlantic.

Of most importance for the current discussion is the record of peaks in the deposition of ice-rafted detritus on the North Atlantic sea-bed during the past Glacial. These peaks represent the last four major launchings of iceberg armadas into the North Atlantic (coinciding with Heinrich events H1 to H4). The pattern of deposition associated with these events is shown in Figure 10.

These extreme events are typically associated with contemporaneous cooling, followed by abrupt warming, as is illustrated in the Greenland ice-core record of Figure 9. Event H1 is especially significant because, this time, the abrupt warming was not succeeded by a slow return to fully-glacial conditions. Clearly, increased solar heat (and associated feedbacks) allowed establishment of the Interglacial, or at least of its harbinger the Bølling-Allerød period (see figures 9 and 12).

Also shown in Figure 13, is an estimate of summer sea-surface temperature based on changes in planktonic foraminiferal assemblages; the Glacial/Interglacial difference is about 10 ^{0}C in the more-northerly core. Oxygen isotope records from the tests of forams have been corrected for global ice-volume history and temperature effects to yield an estimate of variations in salinity at the ocean surface. Event H1 displays a prominent drop in salinity.

But why are the warmings related to Heinrich's iceberg outbursts so abrupt? I develop this topic below.

2.4 Inertia takes the lead

2.4.1 Ice-sheet surge means sea-level change

Figure 14 (originally from Bond *et al* 1997, but here taken from the expanded version in Thomas 2000) correlates the surface-air temperature proxy from a Greenland ice-core (LH graph) with the layers of ice-rafted sediment (RH graph) in the North Atlantic. It also can be seen here that Heinrich event H1 relates to a particularly prominent layer of ice-rafted detritus.

As an aside in the context of this discussion, although of much interest for later parts of my paper, note the presence of more frequently-occurring layers of sediment on the Atlantic seabed, smaller than the Heinrich layers, and known as the Dansgaard-Oeschger layers (also of glacial origin). Their sources are more diverse than those of the Heinrich iceberg armadas, which mostly enter the North Atlantic *via* the Labrador Sea.

The Dansgaard-Oeschger events appear with a frequency of some 1500 +/- 500 years during the last Glacial, and are still substantial enough to have a discernible impact on climate (as shown in Figure 9). Particularly important is the report by Bond *et al* (RH graph in Figure 14) that similar, but even yet smaller, layers of ice-rafted detritus continue to occur beyond the end of the Glacial, and right through the current Interglacial—at an unchanged pacing. Their discovery is crucial to an understanding of climate change at time-scales relevant to humans.

The LH graph in **Figure 15** (from McGuire *et al* 1997) shows the 120 metre rise in sea level since the LGM, most of which originated in the melting of the great continental ice-sheets of North America and Eurasia (see Figure 11). The RH graph shows the widely-varying rate of change in sea level during the last Glacial. There is little doubt that all or most of the rapid sea-level rises (by as much as 10 metres per millennium) occurring during the last Glacial represent the launching of iceberg armadas, particularly those of the Heinrich events memorialised in the North Atlantic sea-bed as layers of ice-rafted sediment (see Figures 13 and 14).

2.4.2 Oceanic transportation of heat

Figure 16 (from Williams *et al* 1998) illustrates the 'thermohaline conveyor' which carries equatorial heat, *via* the North Atlantic, to high northern latitudes, and hence keeps Western Europe much warmer than would otherwise be the case.

Very briefly, deep oceanic water upwells in the eastern Pacific and drifts westward on the surface, under the inertial influence of a Globe spinning from west to east. By the time it strikes against the Americas, this equatorial current has picked up much heat. It then turns north into the Atlantic (the sea-way between North and South America now being closed), losing heat by evaporation as it goes and becoming more saline as a consequence. The water of the North Atlantic Current, on penetrating between Scotland and Iceland, is now saltier than resident Arctic water. It gives up further warmth to the atmosphere—which then ameliorates the climate of the adjacent continental areas by distributing that heat—and sinks preferentially *cf* the less-salty Arctic water.

Once this newly-formed deep water spills over the sill between Scotland and Iceland into the Atlantic (it is now called North Atlantic Deep Water), it returns at depth to the Southern Hemisphere before completing the circuit by again upwelling in the Pacific.

Inertial effects relating to the Earth's rotation, density effects relating to salinity differences, and deep-ocean tidal energy all help to drive this crucial circulation.

But there are intermittent drivers also, which, when operating, over-ride these uniformitarian influences. Our old friend 'extreme events' returns.

2.4.3 Mörner, and the preservation of angular momentum

A decade-long series of papers by Nils-Axel Mörner, culminating in 1996, provide an entirely different way of looking at abrupt and short-term changes of climate in the northern North Atlantic Basin.

Mörner's inertia-based concept has not yet found its way into the numerical models IPCC uses to predict climate change. One reason might be that the timing of occurrence for future extreme events is unpredictable. Projections of a uniformitarian world are easier.

Mörner calculates that the Earth's rate of rotation has slowed since the LGM and, correspondingly, the length of day has increased. Melting of the continental ice-sheets has led to a rise in global sea-level of some 120 metres. In effect, ice at high latitudes has become water in equatorial seas, and the Earth's radius of gyration has increased as a consequence. Preservation of angular momentum *requires* that LOD increase in response—by about 2000 milliseconds.

There is nothing controversial here; and there should be no detectable climatic impacts so long as the deceleration is slow enough. This is another way of saying: 'provided the rise in sea-level is gradual enough'.

But we know the sea level rise associated with the ice-related Heinrich events was not gradual (see figure 15). Furthermore, that associated with the termination of the Younger Dryas cold event early in the present Interglacial (shown on Figures 9, 12, and 14) was not gradual either. The Younger Dryas may be related to breaching of the Kara ice-dam on the Russian north coast (Grosswald 1993), and the consequent release of melt-water into the Arctic ocean.

Mörner reasoned that these extreme events, and consequent abrupt sea-level rises, caused a sharp deceleration of the rotating Earth. This is preservation of *angular* momentum.

But the oceans are not glued to the stony Earth; and the linear momentum of oceanic currents must also be preserved. In the Southern Hemisphere, the necessary adjustments will have little effect on climate, because of the open geometry of the oceanic areas. But things are very different in the Northern Hemisphere. In the northern North Atlantic Basin, Scotland and Iceland provide a choke-point, restricting the access of warm Atlantic water to the Arctic (see Foster 1999 for a reproduction of his series of illustrative diagrams). This is preservation of *linear* momentum.

During the peak of the last glaciation, Mörner envisaged substantially less warm Atlantic water penetrating into the Nordic seas than now, with more instead returning south on the surface along the Iberian and NW African coasts. The thermohaline conveyor would have been much weaker than is the case today; and the Atlantic's cover of seasonal sea-ice would have extended beyond 50 ^{0}S (as illustrated in Figure 11).

However, a decelerating Globe would have caused the North Atlantic Current to push further west than was normal at that time—with a greater quantity if warm water entering the Nordic seas, and resultant abrupt warming of NW Europe and Greenland.

The thermohaline circulation would have received a major boost; but cold conditions (related to low solar insolation) would have led to its gradual and inevitable weakening thereafter, and a subsequent return to full glacial conditions.

Indirect corroboration for Mörner's hypothesis of sea-level-triggered, and inertia-driven, diversion of oceanic warm currents is provided by McGuire *et al* (1999). These authors found that, in the Mediterranean region, increased vulcanism (marked by the crosses at the top of Figure 15) was associated with abrupt changes in global sea-level. Liquid magma or liquid ocean, both are affected by the decelerating Earth; and both these mobile components of the global whole are required to preserve their linear momentum as best they can.

Heinrich event H1 differed from its earlier equivalents in that increased solar insolation at the time allowed the stronger thermohaline circulation to persist for much longer—in fact for sufficiently long that palaeoclimatologists have deemed the warming it caused (see Figure 9) to be the start of the current Interglacial.

All in all, though, it may have been more realistic to acknowledge the end of the Younger Dryas as the real start of the Interglacial. From here on, right up to the present day, the thermohaline conveyor has been able to perpetuate its strength at above its 'normal' Glacial level. Hence, from this time on, a greater amount of the heat from the surface waters of the tropical oceans is being distributed to the temperate and far-northern North Atlantic Basin mega-region.

2.4.4 Do we have the answer now?

The new thinking was crystallised by Heinrich in 1988, when he recognised a series of ice-rafted detritus layers in the sediments preserved on the tops of 'deep-sea hills' in the North Atlantic.

However it was Hughes, in a series of papers culminating in 1992, who emphasised the significance of continental ice-sheet dynamics, and the likely role of surging ice sheets and consequent iceberg outbursts in climate change, saying:

> ... a new paradigm is emerging for linking ice sheets with the full spectrum of Quaternary[12] climatic changes.

It is Hughes' view that the flow of continental ice streams:

> can change rapidly ... and may be inherently unstable, with unstable behaviour in the timeframe for abrupt climate changes ...

Climate change tended to be abrupt because ice-stream life cycles began and ended abruptly.

His series of papers (1996, and earlier references given in Foster 1999) added a crucial extension to the ice-surge/climate-change hypothesis by recognising a role for the preservation of momentum (first angular, and then linear) in the face of changes in the Globe's radius of gyration.

Based on the work of Hughes and Mörner, the hypothesis outlined above makes a plausible story indeed, and it is a step forward in our understanding of what drives climate-change. But it is not by any means the *whole* story:

> First, it only explains big climate changes of long ago, unlike the lesser changes and shorter time-scales which demand our attention today;

and

> Second, it ignores likely North Atlantic Basin choke-points other than that between Scotland and Iceland.

These deficiencies are redressed below.

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12 The Quaternary is the ~2 million years of the current Ice Age, comprising Pleistocene and Holocene.

3. INTERGLACIAL WARMTH: AND A CONTINENT DOUBLY-BLESSED

3.1 Arrival of the Holocene

Europe's first blessing is shared by the world. After some 100 ky of glacial conditions (see Figures 4, 5), it and the world in general are now enjoying the benevolence of the Holocene interglaciation.

Figures 9 and 12 show the Glacial/Interglacial transition in the northern North Atlantic Basin, highlighting particularly the abrupt advent of the Interglacial, and the abrupt resumption of interglacial conditions (put at 14.6 and 11.6 kyBP, respectively, in Figure 9) after the temporary reversion to a near-glacial state during the Younger Dryas. (There is much good evidence that the Greenland isotope-proxy climate record, as invoked in these two Figures, is representative of the direction in which temperatures move throughout the northern North Atlantic Basin.)

Figure 12 also shows that at the times of both the latest Heinrich event and the Younger Dryas (H1 and YD in the Figure), Caribbean sea-surface temperatures moved in the *opposite* direction to northern near-surface air temperature derived from Greenland ice-cores. The map (**Figure 17**) shows with a **+** the location of this surprising Caribbean record. I will return to this crucial clue later.

Figure 18(a) (from deMenocal *et al* 2000) sets the Holocene climatic period in context Obviously of crucial importance is the rise and subsequent fall of Northern Hemisphere insolation shown in the left-hand column of the graph (replicating Figure 5). The peak insolation at about 10 kyBP coincides with the advent of full (Holocene) Interglacial conditions in the North Atlantic, as portrayed if the right-hand column.

The proxy used here for northern North Atlantic Basin climate is not oxygen isotope variation in Greenland ice-cores (Figures 9, 13), but the abundance of lithic (*ie* ice-rafted, in this context) grains in North Atlantic sea-bed sediments. One important point to note here is that the declining insolation has not been matched by a cooling climate. The thermohaline conveyor, and the feedbacks established during the time of increased insolation, are maintaining the warm interglacial climate in the face of now-declining solar input. **It can't last**.

The other important point is that a cyclic variation in the abundance of ice-rafted grains in North Atlantic sea-bed sediments persists right through the Holocene (as also shown in Figure 14). Although not shown in Figure 18, this cyclic variation is now known to have continued into the Little Ice Age during the millennium just past.

Although the scale is much reduced, the intermittent surging of continental ice continues to dominate northern North Atlantic Basin climate—irrespective of the change from Glacial to Interglacial conditions, and of the subsequent melting of the continental ice-sheet which covered NE North America.

The second column from the left in Figure 18(a) introduces data from a sea-bed core offshore West Africa (near Cap Blanc, at about 20 ^{0}N). This oxygen isotope record suggests a major change in the global ice volume roughly concurrent with the end of the Younger Dryas cold period, and the start of the Holocene which followed it.

The third column records the proportion of terrigenous sediment (in this context, aeolian), *cf* biogenic sediment of marine origin, in the West African core. The observed variation in the deposition of wind-borne sediment is consistent with other evidence that NW Africa was nearly-completely vegetated (under monsoonal influence) during the warmest part of the Holocene. It was not until about 5.5 kyBP that declining insolation caused reversion to a climatic regime like that during the last glacial—and that of today.

The fourth column shows sea-surface temperatures in the region, including the variation between the cold and warm seasons. Again, it is about 5.5 kyBP that the current climate regime becomes established. During this latter period climate was by no means uniform, however, with cool events (of 2 to 4 ^{0}C amplitude) at about 6.0, 4.6, 3.0 and 1.9 kyBP.

Subsequent to an intervening Mediaeval Warm Period, this series of cold intervals was followed by “two closely spaced but discrete events in the most recent part of the record at 0.80 and 0.35” kyBP. These last are the twin troughs of the Little Ice Age (marked ‘LIA’ in the Figure).

3.2 The Little Ice Age, AD 1300-1900

Europe’s second blessing is widely shared in the North Atlantic Basin mega-region: the Little Ice Age is over. Why the IPCC Report did not mention this pronounced cold period, and the subsequent rebound, is an abiding mystery. If this were politics not science, one might be tempted to call it a cover-up. (I define the Report as its first 50 pages, remember.)

Modern understanding of the Little Ice Age stems from the 1973 paper by Denton and Karlén. They recognised a cyclic, and contemporaneous, advance and retreat of mountain glaciers (and rise and fall of the tree-line) in Europe and North America. Thus, the cold period just ended, and so well known from the European historical record, was part of a longer cold/warm/cold cyclicity which extended far beyond NW Europe.

Figure 19 (from Stuiver, Grootes and Braziunas 1995) shows a northern North Atlantic Basin climate proxy for the past 1200 years, derived from Greenland ice-cores. The method of display (20-year rests and no longer-term smoothing) yields a highly variable record. However, it is still easy to distinguish the Mediaeval Warm Period from the succeeding Little Ice Age. The abrupt warming during the first half of the 20th century can also be seen (toward the right end of the graph). The Norse settling of Greenland in *ca* AD 975, and the extinction of their settlements in the 14th century, both look quite consistent with the evidence presented here.

Perhaps a little surprising is the very similar record shown in **Figure 20** (Keigwin and Pickart 1999) from the Sargasso Sea. Here the 20th century is toward the left end of the graph, and substantial smoothing is present. Sea-surface temperature estimates, based on a foraminiferal proxy, reveal a prominent Mediaeval Warm Period flanked by a twin-troughed Little Ice Age and the Dark Ages cold period.

Perhaps even more surprising, is the strong development of the twin-troughed Little Ice Age as far south as 20 ^{0}N, off the coast of West Africa (see right column of Figure 18(b) from deMenocal *et al*) where sub-tropical sea-surface temperatures were reduced by as much as 3 to 4 ^{0}C (again based on a foraminiferal proxy).

The centre column in the graph replicates Figure 20 (discussed above). The right column records temperatures measured in the holes left by the extraction of Greenland ice-cores. Ice is an extremely good insulator, and the profile of a twin-troughed Little Ice Age and preceding Mediaeval warm Period is still quite clear.

Existence for a Little Ice Age in the North Atlantic Basin is supported by much more than the 'anecdotal' evidence of history (as canvassed extensively in Foster 1999).

Indeed, the last paragraph of deMenocal *et al*, in which they discuss the implications of the sea-surface temperature (SST) record derived from their borehole 658C offshore West Africa, is worth quoting in full:

> Whatever their ultimate cause, these millennial-scale Holocene SST variations appear to have involved the entire North Atlantic basin, recurred with a ~1500 +/- 500 year period throughout glacial and interglacial intervals, were accompanied by terrestrial climate changes, and involved large-scale ocean and atmosphere reorganizations that were completed within decades or centuries, perhaps less. These climate perturbations continue to persist during 'our time'. The most recent of these, the LIA, ended in the late 19th century, and some of the warming since that time may be related to the present warming phase of this millennial-scale climate oscillation, although the warming in recent decades is unprecedented relative to the past millennium (36).[13] The Hole 658C SST record also supports the view that Holocene climate variability has been increasing in recent millennia, with the LIA representing the largest-amplitude event of the last 20 ky.[14] These results underscore the need to understand anthropogenic warming within the context of rates and amplitudes of natural late Holocene climate variability.

But the IPCC Report deals with the Little Ice Age by ignoring it.

3.3 Explaining Holocene climate-change

3.3.1 The Caribbean pond—warm and warmer

As mentioned above, Figure 12 shows that at the times of both the latest of the Heinrich events and the somewhat-later Younger Dryas, Caribbean sea-surface temperatures moved in the opposite direction to surface air temperatures in the northern North Atlantic Basin. Furthermore, and much nearer our own day, **Figure 21** (from Black *et al* 1999) shows a similar reversal, based on a foraminiferal proxy.

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13 The reference '36' comes out garbled in the list of deMenocal *et al* references at the end of their paper; however, it doubtless refers to Mann, Bradley and Hughes (1998). I believe this paper to be seriously flawed, and I discuss the reasons why later. These authors 'count apples with the oranges'.

14 The authors are referring here to the fourth column from the left in Figure 18(a). This reports the evidence of a sea-bed core from near the coast of West Africa—not from the northern North Atlantic.

The Little Ice Age began at about AD 1300 and continued until, say, 1900. This twin-troughed cold period began abruptly; and written records tell us that, at its beginning, the Baltic froze over in AD 1303 and again in 1306-7. However, Figure 21 shows that, in the Caribbean, a *warm* period of about a century duration also began abruptly at that time (Figure 17 marks with an **X** the position of this core-based record).

Why is this? It obviously can't be variations in the sun's output. Part of the likely answer is available in Figure 14. The Dansgaard-Oeschger ice-rafting events in the northern North Atlantic Basin continue, but in lesser form, right through the present Interglacial (the Holocene) at a similar 1500 +/- 500 year periodicity. These periodic incursions of ice-rafted detritus, persisting up until almost the present day,[15] are well illustrated in Figures 14 and 18(a).

By about 6000 years BP, the continental ice-sheets on North America and Eurasia had melted, and their melt-water had drained to the sea. Interglacial conditions, such as we now enjoy, were in full force by then. When Figure 14 is compared to Figures 9 and 13, it can be seen that, during the last Glacial, ice-rafting events in the North Atlantic Basin coincided with immediately colder conditions, and subsequent abrupt warming. Although the climate fluctuations are now of a lesser amplitude, the same has applied during the last 6 ky of 'normal' Holocene conditions.

The question is: can surging ice-sheets still be invoked as driver of the cyclic cold/warm/cold North Atlantic Basin climate fluctuations since the great continental ice-sheets finished melting some 6,000 years ago

Figure 22 (from Bianchi and McCave 1999) is important. It shows variations of particle size in sea-bed sediment just south of the sill between Scotland and Iceland. It is this sill which separates the Arctic from the North Atlantic at depth; and the velocity of flow of deep water

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15 A highly-relevant recent *PNAS Perspective* article (Broecker 2000) says of the Little Ice Age:

> Based on studies of ice-rafted debris in northern Atlantic sediments, a strong case has been made that a cycle averaging about 1,500 years in duration punctuated the climate in this region ... during the Holocene ... (The) LIA, well recorded in the region around the Northern Atlantic, was the most recent of this series of cold pulses.

and:

> ... by the late 1800s, geologists and geographers had reached even the most remote parts of the world and mapped the extent of mountain glaciers. The bottom line is that, in both the north and the south temperate zones of our planet, snowlines were about 100 m lower than they were in 1975. The difference is comparable to a snowline lowering of 900 to 950 m during the full glacial time ...

and also:

> In addition to the snowline record, there is historical evidence, which extends back to about A.D. 1600, that the Northern Atlantic had greater ice cover during the LIA. This record shows that from 1650 to 1890 Iceland was surrounded by sea ice for an average of two months per year. During the present century, a dramatic decrease in sea ice occurred. By 1920, the waters around Iceland were free of sea ice for the entire year. Of course the finding that the deposition of ice-rafted debris in the region west of Iceland was greater during the LIA is consistent with these historic records.

across the sill into the Atlantic is a proxy for the quantity of warm Atlantic surface water entering the Nordic seas.

It is variations in this importation of equatorial heat (*via* the thermohaline conveyor, see Figure 16) which is the main control on climate in NW Europe and adjacent regions. (In fact, NW Europe appears to be particularly prone to abrupt climate-change.)

In Figure 22, faster flow coincides with the Roman Empire period of warmer climate (when, it is said, the Romans made wine in Britain), the Mediaeval Warm Period (when the Norsemen settled Greenland), and today.

Slower flow indicates the Dark Ages (a time of migrating peoples and sparse written records, during which Europe is thought to have become a quite brutish place in which to live) and, in the last millennium, a twin-troughed Little Ice Age (a time of intermittent, and well-documented, misery).

At crucial times, sea-surface temperatures in the Caribbean were the reverse of those in the northern North Atlantic. Herein lies the key to the larger fluctuations of North Atlantic Basin climate during the past ‘stable’ 6000 years of the Holocene.

3.3.2 A plausible hypothesis

According to Karl Popper, a hypothesis is only ‘scientific’ if, at least in theory, it is subject to the law of empirical disproof. An event such as Christ’s rising on the third day is now outside the realm of science, for instance, because it can no longer be subject to such a law. But my hypothesis as to what drives climate-change on time-scales relevant to humans, can be subject to several such tests—if we care to seek them out.

The development of my ice-driven and inertia-based hypothesis, here following Mörner, began above when discussing the Heinrich events. Here, I strike out on my own for a period when considering smaller, but apparently still ice-related, variations in the oceanic transport of heat. Then below, I rejoin the majority of contrarians by acknowledging an important role for the sun.

The likely explanation for climate fluctuations in the North Atlantic Basin during the past 6000 years is, in sequence:

Surging of continental ice from Greenland.

> These ice surges are confirmed by the layers of ice-rafted detritus found on the North Atlantic sea-bed. During the latest 6000 years of the current (Holocene) Interglacial, the surges must have originated from Greenland, because there was no other plausible source. Ice is a very good insulator, and thus it is most unlikely that contemporaneous local climate change caused the surging. Instead, surging is almost certainly the result of internal changes of a mechanical nature within the ice sheet (Foster 1999 discusses surging). Ice is a rock; and ice-sheet surging is rock mechanics.

Consequent cooling in the North Atlantic.

> One obvious reason is the loss of latent heat as each iceberg armada melts, and another is the replacement on the Atlantic surface of low-albedo ocean by high-albedo ice. A third, and perhaps more important is the interference of the iceberg melt-water (see Figure 13) with northerly heat-transport by thermohaline conveyor. But these are all second-order factors. Much more important is the inertial effect. As the Earth decelerates after the iceberg launching (the outcome of preserving angular momentum), the ocean current bringing equatorial heat into the Atlantic is diverted from its previous course (preservation of linear momentum), and it temporarily fails to exit the Caribbean via the Yucatan Channel (Figure 17).
>
> Thus the Caribbean countercyclically stores warm water (see figure 21 for the AD 1300-1400 period, at the start of the Little Ice Age), and the thermohaline conveyor is starved as a consequence The Caribbean is the choke which acts while inertial effects remain relatively small, as they have during the latter part of the Holocene.

Subsequent return of full Interglacial conditions.

> While solar warmth remains strong enough, once deceleration ceases and after a likely period of almost-random instability (hunting), the steady supply of warm water to the far north will resume. The thermohaline conveyor is then fully reinstated.

There will become a time however, when the weakening Sun, as portrayed in the LH column of Figure 18(a), and the consequences of warming feedbacks lost during the cold period, will prevent full recovery of the conveyor. Once this happens, the cooling processes which will lead ultimately the next Glacial, will begin. Now that solar input is so far past its maximum, the next major change in global climate is likely to be in the colder direction.

A surge of continental ice from Greenland or Antarctica would offer a plausible trigger.

3.3.3 Bigger and longer ice-sheet surges

It is worth adding here that if the surge is of longer duration, as would certainly have been the case with launching of the Heinrich armadas (which may have lasted 500-1000 years), the outcome would be somewhat different.

Ponding of warm water in the Caribbean could have interrupted only temporarily the flow of equatorial heat into the North Atlantic.

If deceleration continued, the equatorial current would have ultimately by-passed the Caribbean, entering the western North Atlantic to the north of the Antilles. But continuing deceleration would force the warm northerly flow to keep west (left) so that more of the flow would enter the Nordic seas—rather than return south via the Iberian coast. This could help explain the initial cooling and subsequent abrupt warming associated with each Heinrich event.

3.4 A place in the Sun

3.4.1 IPCC view of the Sun's long-term role

The IPCC Report pays little attention to the Sun. But considering the Report's track record on the surging of ice-sheets, and on rebound from the Little Ice Age, I don't think we should give up without a fight.

In Box 1 entitled "What drives changes in climate?" (p 14), the Report says:

> The Sun's output of energy varies by small amounts (0.1%) over an 11-year cycle, and variations over longer periods occur. On time-scales of tens to thousands of years, slow variations in the Earth's orbit, which are well understood, have led to changes in the seasonal and latitudinal distribution of solar radiation; these changes have played an important part in controlling the variations of climate in the distant past, such as the glacial cycles.

But it is almost certain that the Sun has also played a key role much closer to the present day.

3.4.2 Evidence from productivity of Greenland lakes

A good place from which to start testing the IPCC view is **Figure 23** from Willemse and Törnqvist (1999).

The bottom two graphs are climate proxies during the current Interglacial, derived from two cores of the Greenland ice-cap. The advent of the Holocene warm period at 10 kyBP coincides with the peak of (orbitally-controlled) solar insolation as shown in Figures 5 and 18(a). Insolation has been in slow decline ever since, albeit with second-order fluctuations at several time-scales; nevertheless, the Interglacial continues.

These climate proxies contain three significant features.

One is an intense cold snap at about 8 kyBP which is thought to represent the breaching of a North American ice-dam and the rapid escape of a large volume of melt-water into the North Atlantic.

The second is the rapid small-scale climate variability throughout the Holocene: climate has never been 'stable'.

The third, and perhaps most important, is the pronounced general cooling over past 3000 years. This cooling is not related to any obvious long-term weakening of the thermohaline conveyor over that time (confirmed by Figure 22); rather it appears that the feedbacks which were developed at the zenith of interglacial insolation, and are now preserving the Holocene warm period, are beginning to loose the battle. This is further evidence that the next *major* climate-change is likely to be in the colder direction.

The top two graphs of Figure 23 are a measure of variations in biological productivity, as recorded in lake-bed sediment cores from two SW Greenland lakes (the ROI and LOI scales on the graphs mean 'remainder on ignition' and 'loss on ignition') situated almost on the Arctic Circle. Prominent in these lake-bed records are the Mediaeval Warm Period and a twin troughed Little Ice Age. But what caused the short-term fluctuations which seem to continuously overprint the cyclic longer-term record? Could the Sun be involved?

3.4.3 Solar influence during the Little Ice Age

Direct measurements of short-term variation in solar output are unreliable, because our notoriously inhomogenious atmosphere makes it almost impossible to measure small fluctuations of in-coming solar heat.

But all is not lost. Variations in the Sun's magnetosphere correlate with variations of its heat output. Furthermore, a strengthening solar magnetic field increases Earth's shielding from cosmic rays, and reduces isotopic transmutations as a consequence. Thus, **Figure 24** (from Baliunas[16] and Soon 1996) yields a history of fluctuations in isotopic proportions which provides an inverse proxy for solar output. The timing of a twin-troughed Little Ice Age, with a separation at about AD 1600, plus the short-lived last cold period at about 1800-1820, are all embedded in the isotopic record.

An example of solar influence on a regional basis is provided in **Figure 25** from Verschuren, Laird & Cumming 2000. As a proxy for solar output they use a generalised record of ^{14}C isotope variation (see figure 24); and as a proxy for regional climate-change they use variations of the salinity and level of East African lakes.

Figure 25 provides evidence of severe drought in East Africa contemporaneous with Europe's Mediaeval Warm Period; although this great drought does not appear to correlate with solar variability. However, within the time of the Little Ice Age, the correlation is good—and here, at least, lesser droughts tie directly to phases of increased solar radiation. The evidence from lake-levels is reinforced by oral history (here assuming 25 years to a generation).

We know from the records of the Paris observatory, that the period from about 1640 to 1710 was a time of few sunspots; and it didn't take observers long to correlate a paucity of sunspots with bad times in Europe. (It now appears that bad times in Europe were good times in East Africa.)

There can be little doubt that short-term variations in the activity of the Sun have a significant impact on climate. Solar variability is another driver of climate change, overprinting the larger orbital and inertial influences.

3.4.4 Solar feedbacks

The 100,000-year variation of insolation (solar heat reaching the earth's surface) at higher northern latitudes in summer, which drives the Glacial/Interglacial cycle, is only a few percent (assuming that solar *output* is unchanged). As discussed earlier, this orbital effect on climate is enhanced by feedbacks.

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16 Ms Baliunas is an astrophysicist; and has been variously described as 'senior scientist at the George C. Marshall Institute' in Washington DC, 'deputy director of the Mount Wilson Observatory' and as working at the 'Harvard-Smithsonian Centre for Astrophysics'.

Shorter-term variations in solar output are also thought to be minor. However, **Figure 26** (from Baliunas and Soon 2000) suggests that variations in solar output also engender positive feedback. Each of the three graphs in the Figure compares cloudiness with variations of solar output[17] during the Sun's 11-year sunspot cycle. High clouds (above 8 km) and middle clouds show no correlation with solar output. However, low clouds (below 3 to 4 km) show a strong relationship; and they tend to cool the Earth.[18]

Thus the supposed 0.1% reduction of peak-to-trough solar output during the sun-spot cycle (I am quoting here the estimate in the IPCC report) is accompanied by a 2% increase in the coverage of (cooling) low clouds. This is a significant (positive) feedback.

3.4.5 Solar activity increased into the 20th century

Figure 27 is crucial to an understanding of the transition (in the North Atlantic Basin mega-region) from the Little Ice Age to the current warm period—which is the (as yet un-named, so far as I know) modern counterpart of the Mediaeval Warm Period. The Figure (from Robinson *et al* 1998) plots Northern Hemisphere on-land temperatures (the heavier line) across the transition against a proxy for solar output.[19] The correlation is remarkable.

Another proxy for solar output is intercyclic variation in sunspot numbers, as shown in **Figure 28** (Bryant 1997). It too is a compelling graph, showing so clearly the Maunder Minimum which coincided with a period of great suffering in Europe, as well as the period of increasing solar output in the first half of the 20th century.

Thus the cold/warm transition over the past one and a half centuries is related both to increasing flow of equatorial water into the Nordic seas (see Figure 22) *and* increasing solar warmth.

3.4.6 IPCC's view of the Sun's 20th century role

The IPCC Report gives the Sun short shrift as a significant factor in recent changes of climate but, unlike its treatment of the Little Ice Age,[20] without ignoring it.

Its parsimonious genuflection to the sun says (p 4):

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17 The variations in solar heat are derived from the neutron count. This is an inverse relationship: the greater the neutron flux (measured here at an altitude of 3,400 metres at Climax, Colorado) the greater must be the incidence of cosmic rays, and hence the lesser the solar magnetism protecting Earth; magnetic activity correlates with solar heat output. Cloudiness is from the International Cloud Climatology Project.

18 First, they reflect some sunlight; and second, they emit infrared radiation to higher altitudes from where it can escape to space.

19 Solar magnetic cycle length is a proxy for solar output. The shorter the magnetic cycle length, the more active (and hence brighter) the Sun.

20 The Report does refer to the Little Ice Age *en passant*, but without invoking its name and in a deprecatory way. For instance (p 15), it says: "... over the past 1000 years, a period when climate was relatively stable ..." 'Relatively stable' might be an adequate account of global averages over the period, but this term does not convey the intermittent horrors experienced in NW Europe—or the demise of the Norse settlements on Greenland. For some unknown reason, IPCC doesn't like the Little Ice Age.

> Any human-induced effect on climate will be superimposed on the background ‘noise’ of natural climate variability, which results both from internal fluctuations and from external causes such as solar variability or volcanic eruptions.

On p 21 it quantifies the warming impact of the Sun since 1850 as less than that for tropospheric ozone—and less in magnitude than the cooling impact of aerosols[21] (though opposite in sign).

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21 The natural warming of the Sun since 1850 is put by IPCC at +0.3 (range +0.1 to +0.5) Wm^{-2} , compared to anthropogenic forcings by greenhouse gases of +2.45 (+2.1 to +2.8) Wm^{-2}, by tropospheric ozone of +0.4 (+0.2 to 0.6) Wm^{-2} and by aerosols of -0.5 (-0.25 to -1.0) Wm^{-2} .

4. THE 20TH CENTURY INSTRUMENTAL RECORD

4.1 Measurements replace proxies

The instrumental record of near-surface air temperatures is surprisingly long. The oldest, the Central England Record, begins in about 1660; and as shown in **Figure 29** (here reproduced from Karlén 1999), it captures at its beginning the nadir of the Little Ice Age. In Central England, it has not been as cold since for any lengthy period.

Two continental records begin shortly after 1700 (Uppsala and De Bilt, also shown in Figure 29), and they confirm the last incidence of prolonged severe cold around 1820 (although there have been other cold periods since). Prominent cold intervals are described in European written records as extending intermittently as far back as the beginning of the 14th century. However anecdotal accounts, even when supplemented by thermometer measurements in later years, comprise a very sparse record indeed, and for Europe only. Of necessity, in the earlier sections of this paper, proxy records have been used right through the Little Ice Age.

In the 20th century, there are three quite-differently-derived instrumental climate records available, as shown in **Figure 30** (Michaels 2000). The first is the combined sea-surface, and near-surface-air, record which is available over the entire century and well back into the mid 1800s, as shown in more detail[22] in **Figure 31** going back to 1856. The trouble with this surface record (aside from imperfections in data collection, and likely inclusion of non-greenhouse anthropogenic impacts such as land-use changes and heat-island effects) is the lack of a complete global coverage. This is particularly so poleward of 50 ^{0}S and 70 ^{0}N, as illustrated in **Figure 32** from the report of the Panel on Reconciling Temperature Observations (2000).

However, for the purposes of this paper, the surface record is accepted at face value: *ie* it is here treated as an adequate record of global near-surface temperature variations over the past century and more.

On inspection, this record is seen to comprise two (roughly-equal) periods of warming at about 1910-45 and 1975 to the present. However, depending on how gaps in the data-coverage are treated, different authorities come to slightly different results. Jones *et al* (1999) describe the warming as two tranches of 0.37 ^{0}C in 1925-44, and 0.32 ^{0}C in 1978-97, with warming continuing thereafter. The (US) National Research Council (Panel on Reconciling Temperature Observations, 2000) puts it a little differently; it sees a warming of 0.053 to 0.059 ^{0}C/decade for the period 1890-1998, including an accelerated warming of 0.13 to 0.19 ^{0}C/decade for the 20-years 1979-98. However, both sources find warming in the 20th century; much as that shown in Figure 30.

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22 The version shown here is reproduced from the CSIRO submission (March 2000) to the *Inquiry into Global Warming* by the Senate Environment, Communications, Information Technology and the Arts Reference Committee. This data had already been compiled by the Climatic Research Unit at the University of East Anglia for other purposes.

4.2 First half of the 20th century

What caused the first tranche of 20th century warming in the period 1910 to 1945? **Figure 33**, from Michaels and Balling (2000), puts the global record in a somewhat different light. It appears that 1915-35 was a period of relatively stable average surface temperature in the Southern Hemisphere, but this was certainly not the case in the north. In the south, warming in the first half of the 20th century was confined to two short periods—1910-15 and 1935-45. Both hemispheres display cooling in the decade 1900-10.

Therefore, in the first half of the century, there were at least two major drivers of climate-change at work (ignoring land-use changes, and setting aside greenhouse for the moment). It appears that only one had a world-wide reach; the other was confined to the Northern Hemisphere.

Part of the explanation might be provided by the model illustrated in Figure 21. The pronounced warming of the Caribbean in 1300-1400 (discussed above) is an inertial effect, countercyclic to cooling in the North Atlantic Basin at that time. On the other hand, the Caribbean appears colder at about 1820, in phase with the Atlantic. Obviously, the latter change is not inertially driven. Another part of the explanation is provided by Figures 27 and 28, which show *reduced* solar output in the 1800-20 period.

I hypothesise that a generally-increasing flow of equatorial water into the Nordic seas (see Figure 22), plus the impact on this flow of continued minor surging of ice-sheets into the sea (from West Antarctica and/or Greenland), is the likely cause of climate fluctuations around a warming trend in the North Atlantic Basin in the first half of the century. Overprinted on these mega-regional influences, is the (global) impact of strengthening solar output.

In **Figure 34**, I have juxtaposed two graphs from the IPCC Report. That on the left (from p 26) shows the rise in global surface temperature, and that on the right (from p 16) shows the growth in emissions of carbon dioxide, the dominant anthropogenic greenhouse gas. Across the latter graph, I have drawn a line at the emission rate of 1950. Global warming is in two equal tranches before and after 1950; but either global temperature rose in *anticipation* of the CO_2 emissions, or we must look elsewhere for an explanation of the pre-1950 warming—because most of the growth in emissions post-dates that time.

Rebound from the Little Ice Age (related to increasing flow of warm water into northern seas) and increasing solar output, provide together a more plausible explanation of observed climate change in the first half of the century than does IPCC’s reliance on human-caused changes in the composition of the atmosphere.

4.3 The last 50 years

4.3.1 The surface record

Figure 35 from World Climate Report in 1998 provides a generalised depiction of global temperature changes during the past 50 years.

I have already noted the greater warming in the Northern Hemisphere, as depicted in Figure 33. Furthermore, Michaels and Balling (2000) show in the LH graph of **Figure 36** that two-thirds of this northern warming takes place in winter.

More remarkable though is the distribution of the winter warming. It is mostly in the intensely cold (and very dry) high pressure systems of Siberia and, to a lesser extent, Alaska/Yukon (see RH graph in Figure 36). In these very cold/dry regions, winter half-year warming is 0.21 ^{0}C/decade *cf* an average of only 0.02 ^{0}C/decade for the greater part of the Hemisphere.

Michaels and Balling put it as follows:

> Obviously, a warming of the very cold and deadly winter air masses is a pretty good thing; after all, winter temperatures are so far below freezing that a few degrees of warming could not possibly melt polar ice. ... How much of the warming of the last 50 years is in this exceedingly cold air? Do the math: 69 percent of total warming is in the winter; 78 percent of that warming is in the deadliest air masses. That means that more than half of the warming is occurring in these air masses. They only cover, on a seasonally adjusted basis,[23] 12 percent of the area. So (Northern Hemisphere) warming is compressed—by a factor of four—into the most obnoxious air masses we know of, mitigating their deadly frigidity.

As shown in Figure 32, the region with most warming suffers from a paucity of measuring stations. Despite this apparent short-coming in the record, Rind’s 1999 review article accepts a similar distribution for the areas with greatest warming, as shown in **Figure 37**. (The chart is reproduced here from a colour original; note that the dark patch in Antarctica denotes the area of greatest cooling.)

4.3.2 Balloon-borne thermometers

Radiosondes (weather balloons) provide a continuous record of temperatures in the lower atmosphere back to 1958 (see Figure 30). However, **Figure 38** (from Panel on Reconciling Temperature Observations, 2000) shows that their coverage is almost entirely restricted to land areas, and also excludes the polar regions.

There is a mystery apparent in the balloon record, as shown in **Figure 39** from Michaels and Balling (2000). There appears to be no warming trend in atmospheric temperatures prior to 1976, and none thereafter; and all the (substantial) temperature jump of about 0.35 ^{0}C occurs in a single year!

The rate of greenhouse warming predicted by climate models tends to be fairly constant. Hence whatever its cause, this 1976/77 step-change is unlikely to be the result of human interference with the composition of the atmosphere. I return to this interesting and important question later.

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23 What is meant here by ‘seasonally adjusted’ is that more than half of the Northern Hemisphere warming at the surface in the past half-century occurred in the winter half-year on a quarter of its area. Thus on an annualised basis, half the warming occurred on an eighth of the total (*ie* winter plus summer) area.

Despite its less-than-perfect coverage, the radiosonde (weather balloon) record appears to acknowledge the known major short-term influences on global climate. In particular, it appears responsive to the El Niño/Southern Oscillation (ENSO) fluctuations,[24] centred in the Eastern Pacific, as shown in **Figure 40** (reproduced from the "La Niña 1998/99" pamphlet by Mark Saunders from the Benfield Greig Hazard Research Centre, University of London). In addition, the balloon record in Figure 39 shows a marked cooling in the years immediately following the 1993 Mt Agung eruption in Indonesia. All this circumstantial evidence suggests that the balloons are providing valid information on atmospheric temperatures.

Returning now to Figure 40, there appears to be a change in the character of the ENSO record at about 1976/77—coincident with the step-change in the balloon record. More of this intriguing correlation later.

4.3.3 Satellite-borne microwave sounding units

A world-wide coverage of temperature in the lower atmosphere has been available since 1979. This record is derived from microwave sounding units borne by polar-orbiting weather satellites, and is shown in the top graph of **Figure 41** (from Michaels and Balling, 2000).

Comparison with the ENSO index in Figure 40 shows a tight correlation between global atmospheric temperature and fluctuations in sea-surface temperature in the equatorial eastern Pacific. This surprising nexus is discussed later.

Figure 42 reproduces the top graph of Figure 41. On it I have marked the start of the El Chichón (3/82) and Mt Pinatubo (6/91) volcanic eruptions; and it can be seen that each had a cooling influence over several years. Of particular interest is the weak expression of the strong El Niño event of 1982/3 (*cf* that of 1997/8); it appears to have been largely counterbalanced by El Chichón cooling.

All or most of the fluctuation in globally-averaged temperature for the lower atmosphere over the past 21 years (the duration of the MSU record) can be explained in terms of volcanic cooling and variations in Pacific sea-surface temperatures. There is little evidence of a global trend for the temperature of the lower atmosphere. The lower pair of graphs in Figure 41 (this information is regularly updated in *World Climate Report*) separate out the Northern and Southern Hemisphere records, and update them to mid 2000. Clearly the two Hemispheres are subject to the same drivers.

However, there are differences. For instance, the impact on atmospheric temperature of the 1980 El Niño appears to have been suppressed in the north, but not the south, by the Mt St Helens eruption (5/80, 46 ^{0}N). Even cooling events originating much nearer the equator, such as that at Mt Pinatubo on Luzon or El Chichón in southern Mexico (say, 15-20 ^{0}N), are more strongly expressed in the Northern Hemisphere.

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24 The term 'El Niño' refers to events where the 'normal' upwelling of cold water in the eastern Pacific is suppressed. One outcome of the resulting warmer ocean surface is rain in the deserts of western South America, leading to a carpet of white flowers in December—hence El Niño, the Christ-Child. On the other hand periods of enhanced upwelling, and thus of a much cooler sea-surface in the equatorial eastern Pacific, are often now called 'La Niña' events.

Despite an obviously-lesser volcanic cooling influence in the Southern Hemisphere, it still displays a slight cooling trend in the lower atmosphere over the duration of the (21-year) record, which almost entirely cancels the slight warming trend observed in the Northern Hemisphere.

The unexpected direction of the divergence in this inter-hemispheric trend (illustrated in **Figure 43** from *World Climate Report*, 2000 5/24) has important implications, as will be discussed later. The IPCC's purported validation against the past, of the models used to project future climate change, invokes cooling by anthropogenic aerosols. IPCC *needs* aerosol cooling!

4.3.4 Atmospheric temperature trends confirmed

There are not two, but three, independently-derived measures available of temperature variation in the lower atmosphere. One is that from radiosonde (balloon-borne) thermometers (Figure 39) back to 1958; and another is from satellite-borne microwave sounding units (Figure 41) back to 1979.

The third is derived from the PVT relationship—if any two of pressure, volume and temperature are known, the other can be calculated. Thus, if the height at which an ascending weather balloon encounters an atmospheric pressure half that at the surface is recorded, then P and V are known and T can be calculated. **Figure 44** (Michaels and Balling, 2000) plots annual temperatures thus derived (for 1979-89) with a comparison of MSU and radiosonde-thermometer records.

There is good agreement between all three, and thus the satellite-derived temperature record receives a substantial validation. Furthermore, it suggests that it is reasonable to assume the balloon record back to 1958 is a valid account of temperature fluctuations in the lower atmosphere from that time. Therefore, the available atmospheric record is not 21, but 42 years.

4.3.5 Surface-atmosphere comparisons

As can be seen in the top graph of Figure 41, there is much fluctuation but little trend in the global temperature of the lower atmosphere. But **Figures 45 and 46** (from *World Climate Report*) shows that, although both are responding to the same influences, there is an underlying warming trend at the surface *which is not present in the atmospheric record.*

This remarkable dichotomy is crucial to any plausible hypothesis as to what is driving climate-change. It is discussed in detail later.

4.3.6 An oscillation in surface temperatures?

Schlesinger and Ramankutty (1994) recognise oscillations on a 50-to-88-year period for 11 geographical regions of the world, using the available instrumental record from the 1850s to 1992. They derive an overall statistical result of 65-70 years (see Figure 31, where this cyclicity is quite easy to see).

Kerr (2000) has revisited this topic, but without referring to the earlier findings of Schlesinger and Ramankutty. He reports a roughly 60-year climate oscillation (which he suggests be called the *Atlantic Multidecadal Oscillation* or *AMO*) in and around the North Atlantic within a "total global warming from 1860 to the present of about 0.6 ^{0}C".

What is its cause? Schlesinger and Ramankutty suggest that:

> ... the oscillation arises from predictable internal variability of the ocean-atmosphere system.

Kerr canvasses several possible explanations, for instance:

> Some researchers, particularly climate modellers, suspect that oscillations in the heat-carrying currents of the North Atlantic are to blame for this natural mode.

He also refers to the view of other researchers that a self-perpetuating oscillation of the Thermohaline Conveyor is involved. This reasoning has it that a strong (warm) surface current in the North Atlantic engenders increased evaporation, thus increasing salinity of the current as it moves north, and hence enhanced sinking of this heavier water when it arrives in the Arctic to create an increased quantity of (returning) North Atlantic Deep Water. At the same time, the warmer northerly current will draw in cool westerlies from northern North America, thus in turn cooling the surface water and reducing evaporation. A cooler surface means less inflowing wind, and so on.

I am with the modellers. An oscillation with such a long period and such a pronounced amplitude must surely be ocean-related. It could well represent hunting/resonance effects persisting in the aftermath of an earlier extreme event which caused inertial changes on a global scale. The reason that the present climate impact is most obvious in the northern North Atlantic Basin relates to basinal geometry.

5. THE ‘GREENHOUSE EFFECT’ HYPOTHESIS

5.1 Unavoidable technicalities

The anthropogenic (*ie* enhanced) greenhouse effect is fundamental to the Kyoto Protocol; and it certainly needs to be discussed in a paper which purports to deal with climate-change science.

5.1 1 IPCC’s definition of the ‘enhanced greenhouse effect’

Back in 1996, the *Technical Summary* of the Report explained it (in the box *What drives changes in climate?* on p 14) as follows:

> The Earth absorbs radiation from the Sun, mainly at the surface. This energy is then redistributed by the atmosphere and oceanic circulation and radiated to space at longer (“terrestrial” or “infrared”) wavelengths. On average, for the Earth as a whole, the incoming solar energy is balanced by outgoing terrestrial radiation.
>
> Any factor which alters the radiation received from the Sun or lost to space, or which alters the redistribution of energy within the atmosphere, and between the atmosphere, land and ocean, can affect climate. A change in the energy available to the global Earth/atmosphere system is termed here ... a *radiative forcing*.
>
> Increases in the concentrations of greenhouse gases will reduce the efficiency with which the Earth cools to space. More of the outgoing terrestrial radiation from the surface is absorbed by the atmosphere and emitted at higher altitudes and colder temperatures. This results in a positive radiative forcing which tends to warm the lower atmosphere and surface. This is the enhanced greenhouse effect—an enhancement of an effect which has operated in the Earth’s atmosphere for billions of years due to the naturally occurring greenhouse gases: water vapour, carbon dioxide, ozone, methane and nitrous oxide. The amount of warming depends on the size of the increase in concentration of each greenhouse gas, the radiative properties of the gases involved, and the concentrations of other greenhouse gases already present in the atmosphere.

This explanation doesn’t quite hit the spot, in the area crucial to IPCC’s climate-change hypothesis, when it says: “This (*ie emission of anthropogenic greenhouse gases*) results in a positive radiative forcing which tends to warm the lower atmosphere *and surface*”.

Alert readers will recognise IPCC’s problem: human-caused greenhouse emissions cannot *directly* warm the surface. Instead, they cause warming in the lower atmosphere; and surface warming is a consequence of *that* warming.

But the satellites find little or no atmospheric warming!

5.1.2 Trying to make it clearer

More recently (Pearman 2000, in a paper originating at CSIRO, and relying “heavily” on the IPCC Report) a discussion of the science begins with a section headed *Climate Processes*. This first describes the role of the atmosphere (including the greenhouse effect, but without referring to it by name), saying:

> These processes include the radiative absorption process that causes energy from sunlight to be absorbed or trapped in the atmosphere or at the earth's surface and that influence the exchanges of thermal long-wave radiation.

This really doesn't add much to our understanding, either. I think it imperative that we spend a little more time on greenhouse fundamentals before proceeding.

Figure 47 from Lindzen[25] (1999) provides an illustration of the natural greenhouse effect. As implied by his top graph, if average global temperature is to remain unchanged, incoming solar heat must match outgoing terrestrial radiation.

The lower two graphs show relatively free access to incoming short-wavelength radiation (in the visible part of the spectrum, 0.4 to 0.7 microns) from the Sun. They also show the natural absorption of outgoing radiation at longer wavelengths (in the infra-red range, more than 10 microns), particularly in the lower atmosphere, and particularly by the dominant greenhouse gas—water vapour. It is this capture of outgoing radiation which keeps the earth at a habitable temperature. **Figure 48** (from Bryant 1997) shows the tropopause at an altitude of about 11 km separating the troposphere from the stratosphere; and Lindzen distinguishes his absorption diagrams at this level.

Human-caused emissions of greenhouse gases (CO_2 from the combustion of fossil fuels is the most important) accumulate in the atmosphere. Because these GHGs are transparent to incoming radiation, they do not reduce the incidence of the sun's heat at the Earth's surface. However, when the Earth radiates back to Space an equivalent quantity of heat at longer wavelengths, an increased proportion is absorbed in the lower atmosphere—because the additional (anthropogenic) GHGs are not transparent to this returning lower-temperature terrestrial radiation.

Figure 47 shows on the horizontal axis of the middle graph (at about 12-15 microns) where most of the CO_2 absorption in the troposphere will take place—adding to the effect of CO_2 already present in the atmosphere.

The lower graph shows a prominent absorption peak for naturally-occurring stratospheric ozone at a nearby wave-length

Thus, more out-going heat is trapped in the lower atmosphere than previously, because of increasing absorbtion by anthropogenic GHGs. The lower atmosphere, as a consequence, becomes warmer. Some of this extra warmth is then reradiated to space, and some is redistributed in a manner which returns it to the Earth's surface. The subsequent warming of the Earth's surface is the "greenhouse effect"—whose amelioration is the sole objective of the Kyoto Protocol.

The most fundamental point to make when discussing "the underpinning science of 'greenhouse' " is that greenhouse is a phenomenon of the atmosphere. Put another way, if

25 Richard S. Lindzen is a long-standing critic of IPCC's greenhouse science. He has been Alfred Sloan Professor in Meteorology at MIT since 1983; and his particular interest is the dynamics of atmospheric circulation.

human-caused GHG emissions are not warming the atmosphere, obviously the atmosphere can't then cause 'greenhouse' warming at the surface.

Remember, it is this *resultant* surface warming which we call the 'greenhouse effect'.

5.2 The atmosphere/surface mis-match

5.2.1 The NRC study

Without revealing the remarkable extent of the mis-match of trends (illustrated in Figures 45 and 46),—nor even its sign—the Pearman (2000) paper tells us that the recent satellite debate:

> ... has had to do with whether satellite measurements in the micro-wavelengths are showing a different trend from that observed at the surface.

Nevertheless, it is an exceedingly relevant debate, both topical and vital. In fact, the (US) National Research Council released a study in January which attempted to resolve the issue. It was prepared by a panel of eleven scientists with a variety of skills (Panel on reconciling temperature observations, 2000)—and outlooks ranging from greenhouse booster to greenhouse sceptic. 'Boosters' could include James E Hansen and Benjamin D Santer; and John R Christy and Roy W Spencer (long-time proponents of the relevance of satellite-derived atmospheric temperature measurements) could qualify as 'sceptics'.

Before reading on, there are several points to remember here:

First, greenhouse is a phenomenon of the atmosphere. If the lower atmosphere doesn't warm, none of that extra warmth can be redistributed to the surface.

Second, the surface *is* warming.

Third, if the very warm 1998 El Niño year is excluded, there is no warming trend in the lower atmosphere over the 20 years studied by the NRC Panel. Indeed, the 21st year (1999) is now in (see Figure 41), and there is still no significant warming trend in the satellite-derived data. There are 12 warmer and eight cooler years than 1999 in this history.

Fourth, balloon data is available back to 1958. Long-run coverage is relatively sparse except over land areas of the temperate Northern Hemisphere but, where there is overlap, balloon and satellite data are in extremely good agreement. For 15 years the balloon-based lower atmosphere temperatures were warmer, and for 27 cooler, than 1999. As mentioned earlier, the balloon record (see Figure 39) contains an as-yet-unexplained step-change of some 0.35 ^{0}C between 1976 and 1977.

The Panel states at the beginning of the Executive Summary:

> The global-mean temperature at the earth's surface is estimated to have risen by 0.25 to 0.4 ^{0}C during the past 20 years. On the other hand, satellite measurements of radiances indicate that the temperature of the lower to mid-troposphere (the atmospheric layer extending from the earth's surface up to about 8 km) has exhibited a smaller rise of approximately 0.0 to 0.2 ^{0}C Estimates of the temperature trends of the same atmospheric layer based on balloon-borne observations (i.e., radiosondes) tend to agree with those inferred from the satellite observations.

and

> The panel was asked to assess whether these apparently conflicting surface and upper air temperature trends lie within the range of uncertainty inherent in the measurements and, if they are judged to lie outside that range, to identify the most probable reason(s) for the differences.

The conclusions in the Executive Summary are:

> ... the warming trend in global-mean surface temperature observations during the past 20 years is undoubtedly real and substantially greater than the average rate of warming during the twentieth century.

and

> The various kinds of evidence examined by the panel suggest that the troposphere actually may have warmed much less rapidly than the surface from 1979 into the late 1990s, due both to natural causes and human activities. Regardless of whether the disparity is real, the panel cautions that temperature trends based on data for such short periods of record, with arbitary start and end points, are not necessarily indicitave of the long-term behavior of the climate system.

The Executive Summary doesn't concede much; but it is better than would be the continuation of a decade of denial! Also, the text goes considerably further than does the Executive Summary. Three points are of particular relevance to the hypothesis being developed herein:

First, on pp 62,3:

> Surface temperature has been increasing at a rate of about 0.1-0.2 ^{0}C/decade, whereas tropospheric temperature has changed so little that a different sign for the trend is obtained, depending on whether or not the final year of the record is included—a year that was extraordinarily warm in the wake of the exceptionally strong 1997-98 El Niño.

Second, on p 63:

> Direct comparison of surface and tropospheric temperature changes is feasible with radiosonde observations, because they include both surface and upper-air data. ... Using longer radiosonde data records extending back approximately 40 years, Angell (1999) found less pronounced (but still noticeable) differences between surface and tropospheric temperature trends than during the satellite period ...

Third, on p 69:

> ... it is highly unlikely that a differential trend as large as the one observed during the past 20 years could be entirely due to the internal variabiliy of the climate system.

The satellite observations to date certainly don't *hurt* the view that most of the global surface warming observed over the past 100 years is **not** caused by anthropogenic changes in the composition of the atmosphere.

However, the greenhouse issue is not yet resolved in the negative.

The NRC Panel urges that, to ensure the differential between surface and atmosphere trends is statistically robust, we wait until we have 40 years of global coverage for temperatures in the lower atmosphere. Including 1999 and the first half of 2000, there are still $18^1/_2$ years to go!

Although, I should point out, the Panel has confidence to spare when discussing a pronounced *surface* warming trend which only began with the jump in 1977, as shown in Figures 30 and 31; the 77-98 period of virtually-uninterrupted surface warming is not 40, but 22 years. One law for the rich, and another ...

But, have we not already served our time? Including 1999, we now have radiosonde balloon coverage for 42 years, and the correspondence of balloon and satellite-derived temperatures in the period of overlap (see Figure 44) is accepted by all.

Furthermore, the Angell (1999) finding (mentioned in the second quote above) that the radiosonde data in pre-satellite days showed a less pronounced but still noticeable difference between surface and tropospheric temperature trends is just as we would expect. Figure 39 shows no trend in radiosonde measurements of atmospheric temperature prior to the jump in 1977; likewise, Figures 30 and 31 shows not much happening at the surface in those years either.

Popper's Law of Empirical Disproof—20 yrs or 40—is already weaving its magic spell.[26]

5.2 2 Explaining or dissembling?

Damage control is in full swing. Santer *et al* (2000) published a paper in *Science* of 18 February explaining the divergence in temperature trends at the surface and in the lower troposphere "by up to 0.14 ^{0}C per decade".

They begin by pointing out that satellites have a global coverage but, as shown in **Figure 49** reproduced from a coloured original in their paper, surface observations do not. That part of the surface for which we have no record, might of course be behaving just like the atmosphere. Who can say this presumption is wrong? Thus we have reduced the known divergence, right there, to "a statistically significant residual of roughly 0.1 ^{0}C/decade".

Santer *et al* conclude that natural variability cannot explain the rest of the difference; although, they say that "coverage differences ... and the effects of natural climate variability ... may make substantial contributions to the observed trend difference".

Therefore, they invoke:

> ... a recent model result that suggests that the observed warming of the surface relative to the lower troposphere may be a response to combined forcing by well-mixed greenhouse gases, sulfate aerosols, stratospheric ozone, and the effects of the Pinatubo eruption in June 1991.

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26 However, it would be difficult to draw this sense from accounts of the NRC Report in the scientific press. For instance, *Nature* of 20 January 2000 covered its release (v 403 p 233) in its *news* section under the headline "Global-warming sceptics left out in the cold". Science can be *very* political these days.

I smell a rat here. What about the El Chichón eruption which began in March 1982?

As shown in Figure 42, without the impact of the Mt Pinatubo eruption, the later years would be warmer—giving a warming trend in the atmosphere over the 20 years of the NRC study. However, if the impact of El Chichón is also removed, the early and late impacts (as shown in **Figure 50** from Bryant, 1999) tend to cancel each other out in terms of their influence on the trend. What is more, the El Chichón eruption masks the prominent El Niño in 1982/3 (see Figure 40). If this warm event had been allowed full expression, the trend in the atmosphere over the 20 years may well have been down.

These authors' reliance on 'sulfate aerosals' to help fix their problem could be just as insupportable as that on volcanoes, as discussed later.

But enough of smoke and mirrors. All parties agree that the surface and atmosphere trends diverged over the period (see Figure 46). It doesn't matter what caused the divergence, regardless of how interesting it would be to know. If the atmosphere is not warming, a warming atmosphere can't explain the surface warming over that period.

Hence over the period 1979-99, or even 1958-99 if we accept the balloon data, the available evidence suggests that the observed surface warming (particularly pronounced since 1976) is not greenhouse warming.

5.3 Spurious validation of IPCC's models

5.3.1 Credibility—and changing forecasts

The numerical models used to predict future global warming[27] have proved to be a problem in the past, and predictions have required substantial reduction over time. At the 1988 Toronto Conference a warming of 0.8 ^{0}C/decade was invoked, reducing to 0.3 ^{0}C/decade for Rio in 1992, and 0.2 ^{0}C/decade for Kyoto in 1997.

But reducing the predicted sensitivity of the globe to human-caused greenhouse emissions brings with it not one, but two, credibility problems. The other is that of a lower sensitivity to emission *reductions*. Thus Wigley (1998) estimates that, if fully implimented and maintained by all Annex B nations (*ie* those with a commiment to reduce their emissions), the Kyoto Protocol would reduce the projected warming 0.07 ^{0}C by 2050 and 0.2 ^{0}C by 2100. Reductions of this magnitude would be lost in the 'noise' of natural variability.

There are also credibility problems closer to home. Under the heading "To what degree are we warming?", *Ecos* says:[28]

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27 Because of the sort of equations involved, numerical climate models convert the assumed exponential increase of anthropogenic greenhouse gas emissions into a predicted straight-line increase in global temperature. Hence, the common use of degrees (or parts thereof) per decade when talking of global warming predictions

28 Summer 1996/7, p 4. *Ecos* is "a CSIRO magazine reporting on scientific research related to the environment".

> Australia is likely to be 0.3-1.4 ^{0}C warmer by 2030 ...

and

> CSIRO's previous climate-change scenarios were issued in 1992. The revised scenarios draw on seven climate models from around the world, including those developed by CSIRO and the Australian Bureau of Meteorology. They also reflect changes to global-warming estimates contained in the Second Assessment Report of the Intergovernmental Panel on Climate Change, released earlier this year (1996).

But what do these new numbers mean? Why weren't they put in a relevant context? Our understanding of their significance would have been greatly helped had the CSIRO reminded us that those forecasts "issued in 1992" were for an Australian warming of between 2 and 4 ^{0}C by 2030—more than double the newly-predicted increase!

5.3.2 Sulphate aerosols: *another* credibility problem

If IPCC's model-based projections of future climate-change are to be believed, the successful hindcasting of their models against past climate must be demonstrated. Validation is crucial.

However, the IPCC continues to suffer from the same old problem: over-predicting models and an under-warming world.

Figure 51 is from the IPCC Report,which says (p 33):

> Currently available model simulations of global mean surface temperature trend over the past half century show closer agreement with observations when the simulations include the likely effect of aerosol in addition to greenhouse gases.

Misleadingly, the Report also says (p 34) of its models:

> They have been tested with a good degree of success against known climate variations ... This provides some confidence in their use for future climate perturbations caused by human activities.

As can be seen in Figure 51, the use of GHGs alone cannot validate the IPCC models. What then of the "closer agreement" achieved by invoking aerosols? The inclusion of both greenhouse warming and aerosol cooling certainly turns a mis-match into a match. However, there is more to aerosols than meets the eye.

The Box in the Report "What drives changes in climate?" (p 14) says of this topic:

> Anthropogenic aerosols (small particles) in the troposphere, derived mainly from the emission of sulphur dioxide from fossil fuel burning, and derived from other sources such as biomass burning, can absorb and reflect solar radiation. In addition, changes in aerosol concentrations can alter cloud amount and cloud reflectivity through their effect on cloud properties. In most cases tropospheric aerosols tend to produce a negative radiative forcing and cool climate. They have a much shorter lifetime (days to weeks) than most greenhouse gases (decades to centuries) so their concentrations respond much more quickly to changes in emissions.

So far so good. But let's look at the distribution of aerosols. **Figure 52** from Capaldo *et al* (1999) shows the total surface concentrations for July, including ship, land-based anthropogenic and biogenic, of sulphate emissions. The figure reproduces a coloured original; but it is possible still to see that the great majority of these short-lived emissions is in the Northern Hemisphere. In fact, the obvious mis-match would be still greater in the northern winter because of space heating, particularly in China.

Figure 53 excludes biogenic aerosols, and gives an estimate of average radiative forcing (in Watts/square metre), and of resultant cooling. As is already suggested by Figure 52, the main cooling impact is in the Northern Hemisphere, with only modest additional cooling in southern Africa and western South America. Still no surprises.

Reality is the problem (Popper would doubtless talk of empirical disproof). Obviously, if the aerosols invoked by IPCC are indeed coolants, then the Southern Hemisphere (few coolants) will warm relative to the Northern Hemisphere (abundant coolants). An examination of hemispheric temperatures (surface in Figure 33, and atmospheric in Figures 41, 43) show the opposite to be the case. With aerosols, theory and practice are in opposition. IPCC's supposed model validation is worthless.

5.3.3 Forget the present, because the future will be hotter

The present impasse of overwarming models and underwarming world (as shown in Figure 51) doesn't really matter, it seems. The globe *will* warm more in due course—once sulphate aerosols stop cooling it! Pearman (2000) puts it this way:

> The Intergovernmental Panel on Climate Change Third Assessment Report, due to be published next year, is likely to include a number of significant revisions to estimates of future climatic changes.

and

> One revision is likely to relate to the role of aerosol. Atmospheric aerosol, which is prevalent in industrial regions of the northern hemisphere, limits the extent of localised global warming by scattering incoming solar radiation. Previous estimates have directly linked aerosol emissions with fossil fuel projections. However, it is now believed that efforts to limit aerosol emissions during fuel combustion is likely to result in a much smaller future growth rate in aerosol emissions than previously thought. As a result, masking of global warming by aerosol is likely to be less effective than previously supposed, leading to a slightly greater rate of predicted warming.

An even more authoritative source, the new Chairman of the IPCC Working Group 1 on the science of climate change, Robert Watson (from NASA, replacing Sir John Houghton), provides confirmation. He said much the same in his evidence to the (Australian) Senate Environment, Communications, Information Technology and The Arts References Committee inquiry into global warming on 9 March 2000:

> There is no doubt we are increasing the atmospheric concentration of sulfate aerosols primarily again due to the combustion of fossil fuels. The greenhouse gases, as you know, warm the atmosphere. Sulfate aerosols on the other hand can cool the atmosphere—firstly, by directly reflecting incoming solar radiation back to space and, secondly, by changing the optical properties of clouds.

Later in his evidence, he returns to this story:

> The role of sulfur is a very simple one. Sulfur actually offsets part of global warming. ... But the sulfur effects are very localised. Whereas carbon dioxide, methane and nitrous oxide, the major greenhouse gases, spread throughout the globe fairly uniformly, sulfur has a very short atmospheric lifetime—a few days, the maximum is a few weeks—so it stays very localised.

and

> What we are projecting ... is that we believe the emissions of sulfur will probably go up for a period of time, ... but then they will start to decrease. ... But even when they grow over the next few decades, largely because of the energy needs in India, China and a few other developing countries, they will not grow at the same rate as the emissions of CO_2 and methane. So, over time, they will be less and less of a cooling offset to the greenhouse gases.

But, as demonstrated above for both surface and atmosphere, anthropogenic aerosol emissions are at present simply not doing the cooling job which IPCC has ascribed to them. How does IPCC know they will do it in the future? Both experts remained silent on this crucial point; and until IPCC explains the apparent contradictions, it would seem prudent to assume that variations in aerosol concentrations will continue to have little or no impact on climate.

5.4 Duelling hypotheses

5.4.1 IPCC's greenhouse hypothesis

First some recapitulation. According to Jones *et al* (1999) the Earth's surface warmed during the 20th century in two tranches, of 0.37 ^{0}C in 1925-44 and 0.32 ^{0}C in 1978-97. The latter period of warming has continued through 1998 and 1999.

Figure 51 from the IPCC report, in effect, arrogates to greenhouse all the observed surface warming during the century. I say this because it seeks to validate its numerical models against the entire climate record without first removing from the comparison that part of the record which relates to other causes of warming—either natural or non-greenhouse anthropogenic (such as might be caused by land-use changes). The IPCC hypothesis is that the observed surface warming during the 20th century is greenhouse warming, *ie* it arises from human-caused changes to the composition of the atmosphere.

5.4.2 First half of the 20th century

At least in the 1925-44 period, the IPCC hypothesis is on shaky ground, because:

- The large majority of the anthropogenic GHG emissions up to today had not yet taken place, as shown in Figure 34.

- In the North Atlantic Basin mega-region, where climate is known to be particularly variable, this is a time of rebound from the Little Ice Age as illustrated in Figures 18(b), 19, 20 and 23.

- As shown in **Figure 54** (from *World Climate Report* 5/21, see also Figure 16) Northern Europe and adjacent regions are dependent, for the maintenance of an equable climate, on oceanic transport of equatorial heat into high latitudes. Figure 22 indicates that the quantity of this flow increased at the end of the Little Ice Age.

- There was a notable increase in solar heat output in the first half of the 20th century, as shown in Figures 27, 28

A far more likely hypothesis, than that of IPCC, is that the 1925-44 warming was ocean-heat-transport [29]and insolation related, and had little to do with greenhouse.

5.4.3 Second half of the 20th century

What caused the observed surface warming beween 1978 and the end of the 20th century?

Firstly, how do those who espouse the IPCC line cope with the lack of warming in the lower atmosphere since global records began in 1979?

A key figure is Dr Geoff Jenkins, Director of the Hadley Centre for Climate Prediction and Research, UK Met Office. In his evidence on 9 March 2000 to the committee of the Australian Senate handling the global warming reference, he said:

> We have also looked at observations in the atmosphere. You may be aware that particularly in America there has been some controversy as to the extent to which changes in global warming at the surface disagree with measurements of warming made by satellites higher in the atmosphere at about a height of maybe three or five kilometres. What we have done is not to use satellite measurements but measurements from weather balloons and look at the trends in temperature that have occurred since about 1960 to the present day in the atmosphere. That has shown us that the overall trends in temperature in the atmosphere have not been very much different from those at the surface which sees quite a clear warming in the atmosphere reasonably similar to that at the surface overall over that period.
>
> What we however see is that there are differences between the atmosphere warming and the surface warming in periods of a few years or a decade long which we do not understand. ... There is an issue there that still has to be resolved, but it does not negate the fact that the warming at the surface is very robust and that we believe the warming of the atmosphere is quite substantial as well.

Jenkins is maintaining the IPCC tradition when he treats the inconvenience of the satellite-derived global atmospheric temperatures (showing little or no warming over the 21-year period of record) by ignoring them. This is how IPCC treated the impact of ice surges on North Atlantic Basin climate during the last Glacial, and how it treated the Little Ice Age (both omissions are discussed above).

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29 Support for this view comes from an article in the *Editor's Choice* section in *Science* of 4 August 2000 (v 289 p 697) which reports recent work by Broecker and Sutherland concluding that:

> ... deep-water formation in the Southern Ocean was much stronger during the Little Ice Age (~1350 to 1880 A.D.) than it is now ...

This quote is consistent with my hypothesis (supported by Figure 22) that formation of North Atlantic Deep Water in the Arctic was *less* during the Little Ice Age, and that its increase during the first half of the 20th century (with concomitant northerly flow of warm surface water) was a major factor in the observed Northern Hemisphere warming which IPCC wrongly ascribed to greenhouse.

But in my opinion, what he *does* say is less easy to forgive than that he has chosen to ignore. Here, we enter the murky world of the half truth.

Indeed, a comparison of the three graphs of Figure 30 does provide a modicum of support for his view. The top graph of surface temperature measurements shows a warming trend from 1960, and so does the middle graph of balloon measurements of atmospheric temperature. The odd man out is the bottom graph which shows the 21 years of global satellite records now available. But there is more to these records than Jenkins chooses to bring out.

First, some recapitulation. Heat is transported around the globe by the oceans, as is illustrated in Figure 54. Past changes in ocean circulation are known to have changed climate abruptly, and often by large amounts.

Now look at **Figure 55**, also from World Climate Report. The top graph is that in the middle of Figure 30, also reproduced in Figure 39; however, this time, the step-change of some 0.35 C in 1976/77 has been emphasised. As pointed out above, this step is quite uncharacteristic of expected greenhouse warming, as portrayed in Figure 51. The lower graph in Figure 55 shows a less abrupt, but rather similar, step in world ocean temperatures at about the same time. Could the two steps be related?

Figure 56, from Levitus *et al* (2000) provides more detail, showing that all of the Atlantic, Indian and Pacific oceans display similar abrupt warming[30]at about the same time. Surely, gradually-changing atmospheric composition is not the cause of this jump.

A plausible answer to the puzzle is provided by **Figure 57** from Guilderson and Schrag (1998). It shows a similar step-change in sea-surface temperatures (SSTs) in the tropical Pacific at the same time as that observed in atmospheric temperatures (see top graph in Figure 55). These authors introduce their paper by saying:

> Several studies have noted that the pattern of El Niño-Southern Oscillation (ENSO) variability changed in 1976, with warm (El Niño) events becoming more frequent and more intense. This “1976 Pacific climate shift” has been characterized as a warming in SSTs through much of the eastern tropical Pacific.

At this stage, it is worth turning to Figure 40 which shows the ENSO Index for the second half of the 20th century, There is indeed a significant change in its character at about 1976/77.

Guilderson and Schrag continue:

> Maximum temperatures (January to March) increased slightly after 1976 as a result of more frequent ENSO warm phases, with no change occurring in non-El Niño years.

They then contrast this lack of any significant change in surface temperatures during the warm season with conditions during July to September, when the thermocline is higher, as follows:

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30 Levitus *et al* elaborate on their graph as follows:

> Time series for the period 1948 to 1998 of ocean heat content (10^{22} J) in the upper 300 m for the Atlantic, Indian, Pacific, and world oceans. Note that 1.5 x 10^{22} J equals 1 W.year.m^{-2} (averaged over the entire surface of Earth).

> ... the persistence of warmer SSTs during upwelling seasons since 1976, even during cold phase (La Niña) conditions, suggests that a change in the ocean, independent from wind forcing, might be involved.

They then conclude by suggesting that:

> Additional radiocarbon data on Galapagos corals from times in the past 100 years when the frequency of El Niño is known to have waxed and waned could be used to determine whether similar shifts in thermocline structure occurred at these intervals and whether the “1976 climate shift” was unusual.

By his selective silence, Jenkins has allowed us to assume that the balloon record supports IPCC’s hypothesis that the atmosphere rules. It doesn’t.

A *NEWS FOCUS* article (Kerr 1998), in the same issue of *Science* as the paper by Guilderson and Schrag, ties things together as shown in **Figure 58**. In 1997, meteorologist Nathan Mantua and quantitative biologist Steven Hare dubbed a slow (20-30 year) swing in North Pacific temperatures the ‘Pacific Decadal Oscillation’. Kerr reports that “in 1997, the North Pacific seemed to flip to a whole new mode of operation” and “evidence that shifts also occurred around 1947 and 1925”.

Something similar applies in the Atlantic. Uppenbrink (1999) discusses the North Atlantic Oscillation, saying:

> The NAO may be more influential than ENSO in regions surrounding the North Atlantic ... since the mid-1970s, the NAO index has generally been very high. During this time, winters have been relatively warm in Europe and cold in the northwest Atlantic, and the Mediterranean has been particularly dry.

and

> significant changes in convective activity in the Arctic Seas have been shown to correlate with long-term NAO trends.

There is abundant and compelling circumstantial evidence that the observed step-change in atmospheric temperatures at 1976/77 is ocean—not greenhouse-related. Once this single (warming) step of some 0.35 ^{0}C is removed from the record, we have a sequence of atmospheric temperatures from 1958 to 1999 which display no warming trend.

Thus, there is good evidence that greenhouse has *not* been the cause of the observed surface warming during this extended period of 42 years. Thus, the direct evidence from the satellite record, of 21 years duration so far, is notably supplemented. Has Jenkins misled us?

But what about 1947 and 1925?

Compare Figure 30 with Figure 58. There *are* breaks in global surface temperature trend approximating each of those two times—a warming after 1925, followed by a cooling from about 1947. This circumstantial evidence supports my hypothesis that the oceans were a far more dominant driver of 20th century climate than were human-caused changes in the composition of the atmosphere.

Does Figure 58 provide the smoking gun? Does it *prove* that changes in oceanic heat transportation were the key factor in 20th century climate-change? Obviously not; but it does serve to keep my hypothesis well clear of that nemesis of paradigms—the law of empirical disproof.

It will be a sysyphean task for IPCC to bring the evidence for human-caused changes in atmospheric composition as *the* major driver of 20th century climate-change up to a similar level of intellectual probity.

Nevertheless, there are those still willing to try; for instance those at the Hadley Centre for Climate Prediction and Research of the UK Met Office—the chief source of intellectual back-bone for IPCC's climate-change science. Tett *et al* (1999) don't feel the need to invoke changes in oceanic heat transportation, saying:

> The warming peak around 1940 is accounted for by a combination of internal variability and a steadily increasing temperature due to anthropogenic forcings. ... from 1946 sulphate aerosols balance the effect of greenhouse gases giving little warming until the mid-1970s when the warming due to increasing greenhouse gases predominates.

This is the IPCC line at its hardest. In the opinion of Tett *et al*, the Emperor has clothes enough; but in my opinion, this line accords with the available evidence neither in regard to GHG warming nor to aerosol cooling. I conclude that global climate is in reality much less sensitive to warming from anthropgenic GHG emissions, or to cooling from aerosols, than is the inherent assumption of IPCC's climate models.

Instead, it is my hypothesis that the main driver of 20th century climate-change was changes in oceanic heat transportation, supplemented by changes in solar output. These are non-atmospheric factors; and the atmospheric-science community in general, and IPCC in particular, are ignoring them.

In summary, changes in location and quantity of oceanic upwelling, surface-water flow, and downwelling are inertially triggered:

- These inertial changes are the result of individual extreme events, most probably episodes of surging in the continental ice-streams of Antarctica and Greenland.
- The launching of ice into the sea at high latitudes raises sea-level in equatorial regions, reduces the Globe's radius of gyration, and consequently increases length of day as the Earth decelerates to preserve angular momentum.
- These inertial effects cause an abrupt re-ordering of oceanic heat transportation, plus subsequent resonance and hunting effects as ocean-flows over-shoot and over-correct in an endeavour to preserve their linear momentum.

Even quite small ice-sheet surges are likely to produce these effects, albeit of a very-much-reduced magnitude to those provoked by the Heinrich events discussed earlier in this paper.

5.4.4 Is there more?

Are there factors other than Sun and oceans involved in 20th century climate change?

Probably yes, is the answer. For instance, there are substantial anthropogenic, but non-greenhouse, influences including heat-island effects related to urbanisation and industrial activity. However, these are rather limited in their proportionate global coverage.

More important in their impact on global average temperature, are land use changes. These include albedo effects, and reductions in respirational cooling by plants, relating to land clearing and over-grazing. Of particular interest in the Australian context, is the likely warming impact outside the settled areas of our furry friend, the rabbit.

But why are the intensely-cold high pressure cells over Siberia and far-northern North America in winter (see Figures 35, 37) the focus of the observed near-surface warming over the past half-century?

Those noted greenhouse sceptics Michaels and Balling (2000) have a hypothesis. About 98% of the natural greenhouse effect is from water vapour; but the air in these high pressure systems is bone-dry. Perhaps anthropogenic increases in (non-water-vapour) GHG concentrations in the atmosphere are relatively more efficacious, in their prevention of heat-loss to Space, in the absence of dominant water vapour. Perhaps also, therefore, these winter highs are a place where IPCC has underestimated, rather than overestimated, the atmosphere's sensitivity to human-caused GHG emissions.

But does it matter? Even after the warming, the near-surface air temperature in these winter high pressure cells remains well below freezing point. Surely, this is not a top-order environmental concern. Let's not throw money at it.

In summary, the 'greenhouse effect' hypothesis, which IPCC invokes to explain all or most of the observed 20th century surface warming, is not supported by the available evidence. Indeed, IPCC asserts that global warming because of human-caused changes in the composition of the atmosphere would have been *even more*, if it were not for the countervailing effect of cooling by human-caused aerosol emissions. Obviously, no conclusion could be drawn from a run of a few years in which the Earth's surface warms on average, while the atmosphere does not; after all, natural systems are variable. But we now have a run of 42 years (1958-99) with no detectable greenhouse-related warming in the lower atmosphere! Can the dominant paradigm for 20th century global warming—that anthropogenic GHG emissions were the cause—survive the winds of change?

6. WOLF! WOLF!

6.1 Hansen and the 1988 heatwave

6.1.1 How to capture public attention

An article in Harvard Business Review (Packard and Reinhardt, 2000) begins its first paragraph as follows:

> The possibility that the Earth's surface temperature is rising—permanently and significantly—caught the public's attention during the brutal summer of 1988.

I think this paper is mostly misinformation and scare-mongering; anyway, it ends:

> The ability to think steadily and consistently about a topic as complicated as climate change is a tough test of management acumen. Some executives are meeting it head-on. Those who are not should wonder why they aren't—and so should their shareholders.

Figure 33 does indeed show 1988 as part of a warming trend in surface temperatures, particularly in the Northern Hemisphere; but why single it out? However, *HBR* is a US publication; and obviously, Packard and Reinhardt mean a brutal *US* summer. **Figure 59**, from *World Climate Report*, shows summer temperatures in the contiguous United States for the period 1895-1998. The summer of 1988 stands out—like a dinosaur in a swamp of 'normal' years—until you look back to the 1930s.

Politically, even if not statistically, the 1988 heatwave was crucial; and Packard and Reinhardt were right to give it prominence. The following extract from an excellent review article by Sarewitz and Pielke (2000) tells us why:

> In the early 1980s the CO_2 problem received its first sustained attention in the US Congress, in the form of hearings organised by Representative Al Gore ... In 1983 the US Environmental Protection Agency released a report detailing some of the possible threats posed by the anthropogenic ... emission of CO_2, but the Reagan administration decisively downplayed the document. [Three years later], at a US Senate fact-finding hearing ..., Robert Watson, a climate scientist at NASA testified, "Global warming is inevitable. It is only a question of the magnitude and the timing.
>
> At that point global warming was only beginning to insinuate itself into the public consciousness. The defining event came in June of 1988, when another NASA climate scientist, James Hansen, told Congress with "99 per cent confidence" that "the greenhouse effect has been detected, and it is changing our climate now". Hansen's proclamation made the front pages of major newspapers, ignited a firestorm of public debate and elevated the CO_2 problem to pre-eminence on the environmental agenda, where it remains to this day.

How could an experienced climate scientist mistake the 1988 US heatwave for proof that human-caused greenhouse warming is now with us? Was Hansen's testimony of 23/6/88 a genuine mistake, or a beat-up?

Moberg (1999) looks at the incentive for scientists to dramatise areas of uncertainty:

> Political science has given increasing prominence to the idea that politicians are not just governed by considerations of the public good but are also affected by motives of self-interest. ... It could be equally well argued that the same also applies to research and researchers. ...

And Böttcher (1999) provides the real-life example:

> In the summer of 1988 the US suffered from a heatwave. The testimony of James Hansen, a NASA climate modeller, to the Senate Energy Committee that “the greenhouse effect has been detected and it is changing our climate now” made front page news, coming as it did at the height of the heatwave. ... James Hansen should have known better because every meteorologist knows that regional heatwaves have nothing to do with climate change.

6.1.2 More publicity!

Recently, Hansen has confused those who follow his work, supporters and detractors alike, by down-playing for the first time the relative importance of CO_2 in anthropogenic warming (Hansen *et al*, 2000). I have not yet seen this new paper, but the *New York Times* puts it as follows:

> An influential expert on global warming, who for nearly 20 years has pressed countries to cut emissions of carbon dioxide and other heat-trapping greenhouse gases, now says the emphasis on carbon dioxide may be displaced.
>
> He and a team of scientists have concluded that the quickest way to slow warming is to cut other heat-trapping greenhouse gases first.

One of the difficulties under which we contrarians labour, is the selective nature of main-stream science; the health of the paradigm comes first. The masking by (cooling) anthropogenic aerosols of (warming) GHG emissions is a key tenet of the IPCC Report, because aerosol cooling is invoked to bring IPCC’s over-predicting models back into line with the under-warming 20th century (see Figure 51). Yet neither the Report nor, it now appears, Hansen mention that this appealing concept is fatally flawed.

Under the heading *Climate change expert stirs new controversy*, in its *news* section of 7/9/2000 (v 407 p 7), *Nature* staffer Paul Smaglik says:

> Hansen’s modelling assumes that levels of CO_2 in the atmosphere will continue to increase at a rate of 1.5 parts per million per year. He also calculates that tiny particles entering the atmosphere as a result of fossil-fuel burning—in particular aerosols of sulphates—have a cooling effect that is largely counterbalancing the warming caused by CO_2. Given this, Hansen argues that measures to limit global warming should focus on pollutants giving rise to ozone in the atmosphere.

The same issue of *Nature*, in a three-page *news feature* (Schrope 2000) explaining the role of aerosols, provides this distinction:

> One of the main complicating factors in modelling the effect of aerosols is their short residence times in the atmosphere. Typically, particles remain aloft for a week or less, being either dragged down by their weight or removed by rain. In contrast, molecules of carbon dioxide persist for about a century, and other greenhouse gases also have long residence times. So although greenhouse gases become well mixed on a global scale, levels of aerosols can vary widely on scales of less than one kilometre.

and this warning:

> Although the uncertainties remain large, some modellers predict that indirect cooling effects could be similar in size to the warming effects of greenhouse gases. If so, that raises the troubling possibility that aerosols could be counteracting the full effect of greenhouse warming. This could mean that the coming decades will see even more calamitous climate change than current models suggest—particularly if clean-air controls result in a reduction in anthropogenic aerosols.

Next day's *Science*, in *Editors' Choice* (v 289 p 1655), says:

> Although carbon dioxide has received the most attention, an equal amount of heat is trapped in the atmosphere by the combined effect of the other four principal trace greenhouse gases: methane, chlorofluorocarbons (CFCs), tropospheric ozone, and nitrous oxide. Hansen et al argue that instead of constructing strategies for mitigating global warming that rely mostly on reducing carbon dioxide emissions, a more expedient approach would be to reduce emissions of the other greenhouse gases and black soot (a product of coal and diesel fuel combustion).

'Forget US car-drivers, concentrate on Third World rice-growers' might be great politics, but is it good science? None of the written works quoted above point out the obvious: the aerosol-cooling hypothesis is starving for lack of factual support.

Most of today's aerosol emissions are in the Northern Hemisphere (Figure 52), and hence most of their supposed cooling effect is calculated to be in that hemisphere (Figure 53). But the greater observed warming at the surface is also in the Northern Hemisphere, which the models say is the one which should be enjoying aerosol cooling (Figures 33, 35, 37).

Much the same is the case for the lower atmosphere (Figures 41, 43), where the Northern Hemisphere is again the one which is warming; in fact, the Southern hemisphere is *cooling* slightly.

Is this what they call a 'conspiracy of silence'?

6.2 Santer and a 'discernible human influence'

6.2.1 IPCC Report's 'key finding'

The *Preface* to the IPCC Report, signed by IPCC chairman Bert Bolin and WG 1 Co-chairs John Houghton and L. Gilvan Meira Filho, is only just over one page in length. But it contains a revelation which was exceedingly influential at Kyoto, saying that:

> ...the underlying aim of this report is to provide objective information on which to base global climate change policies ...

and then:

> ...observations suggest "a discernible human influence on global climate" ...

and describes it as:

> ...one of the key findings of this report ...

This message was repeated in the 5-page long *Summary for Policymakers* (on p 5), and in the 35-page *Technical Summary* (p 39)—both in the words:

> ...the balance of evidence suggests that there is a discernible human influence on global climate.

But the body of the 572-page Report is a let-down. The relevant chapter (8) of the Report (*Detection of climate change and attribution of causes*, Santer *et al* 1996) provides no specific justification for this 'key finding', and is much more circumspect in its manner of expression. Santer *et al* (p 439) say:

> Finally, we come to the difficult question of when the detection and attribution of human-induced climate change is likely to occur.

and

> The body of statistical evidence ... when examined in the context of our physical understanding of the climate system, now points towards a discernible human influence on global climate. Our ability to quantify the magnitude of this effect is currently limited by uncertainties in key factors, including the magnitude and patterns of longer-term natural variability and the time-evolving patterns of forcing by (and response to) greenhouse gases and aerosols.

The spectacular assertion in the *Preface* is not justified in the text. It isn't science *sensu stricto*, but it is brilliant politics.

After release of the Report, the man who became the principal representative of the United States Administration at Kyoto, Timothy Wirth the Under-Secretary of State for Global Affairs, is reported[31] in a *Nature* news item on 25/7/96 as follows:

> Wirth described as a 'remarkable statement' the conclusion of the IPCC's latest report on climate change, that 'the balance of evidence suggests that there is a discernible human influence on global climate'. He said the administration took the report 'very seriously'.

and, as a stark reminder of the intellectual climate prevailing at that time:

> Wirth described the IPCC's critics as 'naysayers and special interest groups bent on belittling, attacking and obfuscating climate change science'.

Already, it is easy to see in the minds of policymakers a distinction between the exponents of the dominant paradigm (white-hats) and of the countervailing view (black-hats). Sadly, the same applies to the scientific establishment. In the lead-up to the Kyoto Conference, the Editorial in *Nature* of 12/6/97 "Seizing global warming as an opportunity" (v 387 p 637) was unequivocal:

> If agreement is reached, as hoped, at Kyoto on relatively ambitious targets for reducing greenhouse gas emissions, much of the credit must go to the work of the ... IPCC. The panel's hard-fought consensus, published in 1995, that 'the balance of

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31 According to a 1996 news item by staffer Ehsan Masood, "United States backs climate panel findings", *Nature* v 382 p 287.

> evidence suggests that there is a discernible human influence on global climate', has established a clear reality that cannot be wished away, as even lobby groups representing the fossil-fuel industries have now, reluctantly, come to admit.

To policymakers and scientists, must be added opinion-formers in the lay community. For instance, an Editorial in the *International Herald Tribune* of 23/6/97 (picked up from *The New York Times),* and entitled "Take warming seriously", said:

> One reason why the industrialized nations opted for voluntary targets at Rio (in 1992) was that main-stream scientists simply could not agree whether man-made emissions had contributed to the small rise in global temperatures that began late in the 19th century. In 1995, however, the UN Intergovernmental Panel on Climate Change, consisting of about 2,500 scientists, concluded that they had. ... Despite challenges from businesses, which have attacked the science in tobacco-industry fashion, the UN panel has not retreated from its basic findings.

6.2.2 The Santer paper—a matter of timing

The scientific justification for the IPCC's 'key finding' was published, after the event, in *Nature* (Santer *et al*, 1996) on 4/7/96.

These authors present their case in **Figure 60** (reproduced from a coloured original). All the graphs in the figure show latitude (N or S) on the x axis, and atmospheric pressure (in hectopascals) on the y axis. A pressure-to-altitude conversion is available in Figure 48. Change of temperature over time (*ie* the temperature trend in terms of latitude and altitude) is shown on the original graphs using colour.

The first point to make here, is that we will have to suspend disbelief while we go through these graphs. There are several wrong or misleading assumptions inherent in the graphs as presented.

Graph a shows the distribution of warming in the atmosphere from an increase in CO_2 from a pre-industrial 275 ppm to a near-present-day 345 ppm; but it yields less warming than do most models employed by IPCC, which incorporate all the anthropogenic GHGs accumulating in the troposphere—not CO_2 alone. Black on my reproduction of this graph means warm; and as might be expected of well-mixed gases, the warming is roughly symmetrical about the equator.

But graph b is definitely not hemispherically symmetric. This graph shows the response of the model to sulphate aerosols (black is cool, here), with increased cooling in the Northern Hemisphere "where anthropogenic sulphate aerosol forcing is largest". We know that a global coverage of atmospheric temperatures over the past 21 years reveals no such aerosol cooling—but no matter.

Graph c combines these two above—CO_2 warming and aerosol cooling—predicting pronounced warming in the lower atmosphere of the Southern Hemisphere. North of the equator warming and cooling tend to cancel, so there is little calculated change in the northern temperate latitudes (30-60 ^{0}N). It also predicts stratospheric cooling in both hemispheres—but that is not an environmental threat *per se*.

Graph j shows observed temperature changes recorded by weather balloons over 1963-87, expressed as linear trends. The authors explain these trends as follows:

> The observations show two prominent features: stratospheric cooling and tropospheric warming, and reduced warming in the Northern Hemisphere between 850 and 300 hPa. ... In the lower atmosphere, it is clear that the observations are in better accord with the combined greenhouse-gas and aerosol signals than with CO_2-only signals.

This last remark means that, even with an atypically-cool model, aerosol cooling is also needed to bring its calculated warming down to proximity with the observed lower atmosphere trend.

Of crucial importance to the veracity of IPCC's 'key finding' is the conclusion:

> Our results suggest that the similarities between observed and model-predicted changes in the zonal-mean vertical patterns of temperature change over 1963-87 are unlikely to have resulted from natural internally generated variability of the climate system. This conclusion holds for pattern comparisons over 50-850 hPa, which focus on the large-amplitude signal of stratospheric cooling and tropospheric warming, and for comparisons over 500-850 hPa, which emphasize hemispheric-scale temperature asymmetries in the lower atmosphere.

In the similarity of graphs c and j (which the authors call pattern-matching) we have the basis for IPCC's assertion, as well-ventilated in the *Preface* of the Report, that:

> ... observations suggest "a discernible human influence on global climate", one of the key findings of this report ...

6.2.3 Sprung!

The *denouement* is in **Figure 61** from Michaels and Balling (2000).

Graph (a) in this Figure is an enlargement of the Santer *et al* graph j, as reproduced in Figure 60; and graph (b) is their graph c. This comparison shows the pattern-matching (stratospheric cooling and tropospheric warming) which provides the *Nature* paper's *ex-post* support for the IPCC Report's assertion.

The next thing is to look more closely at the actual (measured) data in Figure 61 (a), which is compared by Santer *et al* to the model-based distribution of atmospheric temperature change predicted in (b). *The observed 1963-87 warming trend is in the lower atmosphere (500-850 hPa), and is concentrated in the 30-60 ^{0}S latitudinal band*. The distribution of the actual warming is indeed similar to that in the prediction.

I have already mentioned above a couple of concerns about the data:

- Use of an atypical model (which understates the known human-caused GHG emissions) is one; leading to a much lower predicted warming than would the models in, for instance, Figure 51 or in IPCC's prediction of future human-caused global warming.

- Acceptance of 'IPCC-style' sulphate-aerosol cooling.

These artefacts lead to a warming trend which is much lower than otherwise would have been predicted—although still higher than the actuals with which they are compared.

Two new carps follow:

- One is that the weather balloon data, as shown in the graph of actuals, is rather sparse in the 30-60 ^{0}S band (see Figure 38); and yet it is data from this region of rather imperfect coverage which gave such an impetus to the Kyoto Conference.

- The other is that Santer *et al* based their influential conclusions on a relatively short (25-year) run of measurements.

These concerns are positively picayune compared to that which follows.

Stratospheric cooling is no problem;[32] models and actuals both have it; but in terms of its impact on either human well-being or biodiversity, cooling of the stratosphere is not an attention-grabbing event.

But why did Santer *et al* only take advantage of the balloon data for 1963-87, and ignore the 5 earlier and 8 later years also then available? Michaels and Knappenberger (1996) provide the answer. If *all* the data (*ie* 1958-95) for the atmospheric temperature in the 30-60 ^{0}S band were taken into account, as can be seen from graph (c) in Figure 61, the outcome would be very different.

News-worthy pattern-matching with model-based predictions of warming, even using an atypical model predicting less warming, and even including spurious aerosol cooling, **required** a warming trend in the actuals.

How can you squeeze a warming trend out of the thoroughly unpromising data in graph (c) of Figure 61? Where there's a will, there's a way, it seems. A good place to start is with cooling from the (1963) Mt Agung eruption in Indonesia. And where to finish? Why not try an El Niño year (see Figure 40)?

But once a hare like this is set running, it becomes devilish hard to catch.[33]

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32 Santer *et al* show two main sources of stratospheric cooling: one as part of the aerosol cooling predicted throughout the atmosphere (figure b); the other largely confined to the stratosphere (with its maximum at high latitudes in both hemispheres, see figure f) as a result of stratospheric ozone reduction. Thus, even if the modelled representation of aerosol cooling in figure b is found to be spurious, the observed stratospheric cooling (shown in figure j) could be as well explained by the depletion of stratospheric ozone. Neither of the main potential sources of stratospheric cooling identified by Santer *et al* has any close relation to the build-up of anthropogenic GHGs in the troposphere.

33 IPCC's siren song is still leading unwary sailors onto the rocks. Ian Lowe is Honorary Professor of Science, Technology and Society at Griffith University in Queensland; and in his December 1999 paper "From the century of achievement to the century of change: the energy industry at the turning point" (*Energy Journal* v 17 no 4 pp 79-81), he said:

> The main environmental problem associated with energy use is global climate change. It is now accepted that there is a discernible human influence on the global climate, mainly due to the level of use of carbon fuels.

In *The Age* of Melbourne on 26/8/2000 was an advertisement for the *Victorian Greenhouse Strategy* discussion paper. I quote here the first paragraph of the *Summary*:

> Climate change is one of the most important environmental challenges confronting the world today. In 1995, the second report of the Intergovernmental Panel on Climate Change concluded that "the balance of evidence suggests a discernible human influence on global climate".

What can I say?

6.3 Mann and the millennium hockey-stick

6.3.1 Don't mention the War

The IPCC Report (here defined as its first 50 pages, containing the summaries) ignores the Little Ice Age. And yet, as discussed above, recognition of the *ca* 1500-year cold/warm/cold climate cycle centred on the northern North Atlantic Basin is crucial to an understanding of climate-change during the current Interglacial. At least in the first half of the 20th century, rebound from the Little Ice Age—in the form of increased flow of equatorial water into northern seas (Figure 22), together with increased solar isolation since the Dalton (sunspot) Minimum (Figure 28)—is the likely cause of the observed surface warming.

Why doesn't IPCC want to know? It is hard to think of a reason; however, those who espouse the IPCC line are still of that mind. The War isn't mentioned.

For instance, Pearman (2000) says in reference to Mann *et al* (1999):

> ... there appears to have been a small general cooling of the surface of the planet up until a century or so ago, with a warming that has vastly exceeded any natural fluctuation.

Jenkins (from the UK Met Office's Hadley Centre) says much the same in his evidence on 9/3/2000 to the (Australian) Senate References Committee:

> ... a very strong pointer is the work done by Michael Mann at the University of Massachusetts. There is also some work from Keith Briffa and Phil Jones at the University of East Anglia in England. What they have done is to reconstruct paleo records going back over the last thousand years, largely in the Northern Hemisphere.

and

> When they put these paleo records from tree rings, ice cores, corals and so on all together to look at the temperature change over the past thousand years, despite the very large uncertainties in the measurements, you can see a reasonably clear trend of very little change or perhaps a small decrease in temperature over that period.

Here we have it. In the Northern Hemisphere over the past thousand years, there was "very little change or perhaps a small decrease in temperature". After this act of denial, Jenkins draws attention to the new party-line—Mann's 'hockey stick':

> That is until the last 100 years or so, when there is a very significant upward trend over that period, both in the proxy data and in, obviously, the instrumental records

> that we all know about. ... what is happening over the last 50 or 100 years is unusual in the context of the last thousand years or so.

Both Pearman and Jenkins are referring to work reported in two papers by Mann, Bradley and Hughes (1998 and 1999). This new and apparently-compelling story is represented in the next two Figures.

Figure 62 (a*)* shows[34] the graph from Mann *et al* (1998) which reconstructs Northern Hemisphere climate from AD 1400 using the proxies already available, particularly multiple relatively-short runs of tree-ring width and density data from high latitude and altitude regions of Eurasia and North America. To this derived composite record are appended thermometer measurements from 1902-97. Figure 62 (b) from their 1999 paper extends the proxy record back to AD 1000, and updates the instrumental record to include 1998.

It appears that Mann's "the last 100 years is unusual" will, in the IPCC's Third Assessment Report due out next year, replace "a discernible human influence on global climate" of Santer *et al* as chief attention-getter. Staffer Richard A. Kerr, in a *News of the Week* piece in *Science* of 28/4/2000 (v 288 pp 589-90) entitled *Draft Report affirms human influence* says adjacent to a reproduction of the Mann hockey-stick (as shown in Figure 62 (b):

> The confident recognition of an anthropogenic climate effect—which could bolster calls for action to curb global warming—is the draft report's only major shift since 1995, when the IPCC found that "the balance of evidence suggests a discernible human influence".

The earlier (1998) paper appears to have been 'launched' by some Guiding Hand. In the same issue of *Nature* (23/4/88) is a *news and views* article by Gabriele Hegerl discussing the new paper, which tells us:

> ... it seems that increases in greenhouse gases have been the main forcing in the twentieth century, whereas natural climate forcing by changes in solar irradiance and vulcanism dominate the early part of the record.

This statement is 'very IPCC'. In particular, there is no mention of variation in oceanic heat transportation—let alone of what might cause such variation.

In the next day's *Science* was another review article, and the process was repeated in the *New York Times* four days later. In a remarkable example of mass imagination block, all four articles see anthropogenic GHG emissions as the cause of the spectacular 20th century warming; and **none** mention the Little Ice Age, nor the probability (dare I say, 'near-certainty'?) that a significant part of the observed Northern Hemisphere surface warming was rebound from that ice/ocean-related cyclic cold period.

Many graphs and charts from earlier in this paper illustrate aspects of the Little Ice Age (see Figures 18-23, 25, 27, 28). In order to demonstrate that this period of intermittent severe cold

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34 Figure 62 (a) is a copy of the cleaned-up version of Figure 5b of Mann *et al*, as published in *The New York Times* on 28 April 1998.

is more than an abstract concept lacking human relevance, I give below two quotes based on the anecdotal records of the time. One is by Tuchman (1979):

> The Baltic sea froze over twice, in 1303 and 1306-7; years followed of unseasonable cold, storms and rains ... Contemporaries could not know it was the onset of the ... Little Ice Age. Nor were they yet aware that ... communication with Greenland was gradually being lost, that the Norse settlements there were being extinguished, that cultivation of grain was disappearing from Iceland and being severely reduced in Scandinavia. But they could feel the colder weather, and mark with fear its result: a shorter growing season.

The other is by Mitford (1969). She wrote of 1709, during the Maunder Minimum:

> [This year] was perhaps the most terrible that France has ever known. On 12 January the cold came down. In four days the Seine, all the rivers and the sea on the Atlantic coast were frozen solid. The frost lasted for two months; then there was a complete thaw; as soon as the snow which had hitherto afforded some protection to the land, melted away, the frost came again, as hard as ever. The winter wheat of course was killed as were the fruit, olive and walnut trees; and nearly all the vines; the rabbits froze in their burrows; the beasts of the field died like flies.

At least in NW Europe, these were hard times; and there is archaeological evidence that the same may have been the case in North America. In contrast, the sunspot minima, associated with the coldest periods in Europe, denoted particularly good times in East Africa (see Figure 25).

6.3.2 Counting apples with the oranges

Figure 63 includes palaeotemperatures derived from 616 on-land bore-holes from all continents except Antarctica (heavy band on all three graphs, from Huang *et al*, 2000).

The top graph is a global comparison with instrumental surface records extending back into the mid-1800s; and in the middle is a comparison for the Northern Hemisphere with Mann, Bradley and Hughes' climate reconstruction. Also included is a reconstruction for the Arctic (Overpeck *et al*, 1997) back to 1600. Obviously, Mann *et al* have failed to capture the full extent of the temperature contrast between the 20th century and the depths of the Little Ice Age.

But my disquiet runs deeper. Figures 35-37 show that measured Northern Hemisphere surface-warming over the past half-century (*ie* during the time of rapidly-accelerating anthropogenic GHG emissions) has been mostly in Siberia, in *winter*.

We all know that trees grow in the growing-season; and that tree rings can tell us little about temperature variations in the depths of winter. Indeed, the message of **Figure 64** (from Vaganov *et al* 1999) is that, in subarctic Eurasia, trees experience their growth in only 3-5 weeks of June and July (data above the horizontal line in these graphs is statistically significant). Hence, Figure 62 (a) plots 500 years of apples with 100 years of oranges.

In fact, if it *were* necessary to plot apples and oranges on the same graph, **Figure 65** (from Serreze *et al* 2000) offers a more appropriate temperature record. Here, in graph (a), the temperatures shown are those from 55 ^{0}N and higher. Particularly the middle (summer) line on this graph would be the least misleading—and certainly much less so than the broader record chosen by Mann *et al*.

When apples are plotted with apples (an idea by no means new to science) the outcome looks very different. **Figure 66** (from Naurzbaev and Vaganov 2000, as reprinted in *World Climate Report*) shows a long run of tree-ring data from the Russian Arctic. This record would be best compared with the high-arctic temperatures in Figure 65 (b) from Pryzbylak (2000); although, even more appropriate would be summer-only temperatures. Naurzbaev and Vaganov say of their 2000-year-long record:

> The warming in the middle of the 20th century ... has analogs in the past. So the warming at the border of the millennia [ie at about AD 1000] shows a close amplitude and was longer. Historical evidence on the climate of this Medieval Warm Period says it was a larger climate warming than the present one [and that] temperature variations in high latitudes for the instrumental record (1850-1990) do not go far beyond limits of natural variations revealed during two millennia.

How different their record looks to that of Mann *et al*!

6.3.3 A thousand years of spurious comparisons

But it is Figure 62 (b) which is the current weapon of those who promulgate the dominant paradigm. I concede that I am not an atmospheric scientist; and confess that when an opponent put this graph up immediately after my presentation in a lunch-time debate at Monash University, I was brought down in flames—as adjudged by the measurement of applause. But to my eye, the graph is outside the great scientific tradition.

The evidence is there for all to see. A downward-trending line has been drawn through the proxy temperatures from AD 1000 to 1900, contrasting sharply with the rise in measured temperatures during the 20th century.

This sloping straight line gives short shrift to the well-known climate cyclicity in the temperate and northern latitudes of the Northern Hemisphere. As can be seen[35] from **Figure 67** (from Dahl-Jensen *et al* 1998), and from earlier figures in this paper, the ‘trend’ is an artefact of the years chosen. Starting in AD 1000, and ending in 1990, gives the best down-trend money can buy. Is this the way to advance science?

In Figure 62 (b), the measured surface temperature for 1998 is marked with a cross, and emphasised with a horizontal line at that level running across the whole 1000 years—inviting comparison with the 900 years of proxies below it. (These are dubious proxies at best, remember. Winter warming has exceeded summer warming in the Northern Hemisphere over the past half-century by more than two to one.)

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35 Figure 67 is a record of temperature measurements taken on re-entry to a borehole on the Greenland ice-cap from which cores had been previously extracted. Ice is such a good insulator that quite a long record of near-surface air temperatures still can be derived. A twin-troughed Little Ice Age and the preceding Mediaeval Warm Period can be seen, although detail becomes lost as the record extends further into the past. I have drawn the same trend-line on this record as Mann et al have in Figure 62 (b), in order to show how misleading it is.

The middle graph in Figure 41 sets 1998 in context. This was the time of the particularly strong 1997/98 El Niño (there was in fact another in 1982/83, see **Figure 68** from Federov and Philander 2000, whose impact was largely suppressed by the El Chichón eruption as illustrated in Figures 42 and 50).

But one El Niño does not a climate make.

This much-publicised phenomenon has appeared in its modern form in the lake-sediment-derived record of climate in western South America for the past 5,000 years (Rodbell *et al* 1999). It is in the first instance a warming of the sea-surface in the tropical eastern Pacific, appearing at an irregular sub-decadal frequency. It is associated with much-reduced upwelling of cold, deep, water off the coast of South America, although its transient influence is widely spread (*eg* mild winters in North America are often attributed to it).

At the time of the big 1997/98 El Niño, sea-surface temperature in the equatorial eastern Pacific rose to nearly 4 ^{o}C above normal in first half 1998, only to drop back sharply once upwelling resumed in mid year. Because of the very large area of warm surface water involved, a strong El Niño has a big influence on global average (particularly atmospheric) temperature at the time.[36] But it has little relevance to the 900-year proxy record graphed by Mann *et al*. El Niño wasn't the main driver of tree-growth in boreal forests—apples and oranges again.

The graphs reproduced here as Figure 62 look more like weapons developed for the hearts and minds battle than they do an attempt at rigorous and disinterested science. What do you think? I don't blame the authors, or the journals; they can write or publish whatever they like. But how did the graphs in Figure 62 get through peer-review?

Not all scientists support Mann *et al*. Briffa and Osborne 2000 (these authors are from the distinctly main-stream Climatic Research Unit at the University of East Anglia) chip away at the assumptions underlying the hockey-stick. For instance:

> An uninformed reader would be forgiven for interpreting the similarity between the 1000-year temperature curve of Mann et al and a variety of others also representing either temperature change over the NH as a whole or a large part of it as strong corroboration of their general validity, and to some extent this may well be so. Unfortunately, very few of the series are truly independent: There is a degree of common input to virtually every one, because there are still only a small number of long, well-dated, high-resolution proxy records.

and:

> ... the production of a long tree-ring chronology normally involves some degree of detrending (known as "standardization") to reduce bias in the final chronology resulting from temporal changes in the average age of the samples (young trees have wider and more dense rings than older ones). As a result of standardization, many long

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36 Federov and Philander (2000) explain why El Niño events have such a pronounced impact on global average atmospheric temperature at that time (as illustrated in Figure 41):

> The expanse of warm waters in the Pacific during El Niño is so vast and causes such a huge increase in evaporation from the ocean (and hence in the release of latent heat in the atmosphere when the water vapor condenses to form clouds) that weather patterns are affected globally.

> tree-ring chronologies may not represent all of the long-term climate variability that influenced tree growth in their region.

and

> Mann *et al* state that ... a group of high-elevation tree-ring chronolgies in the western United States, is essential before A.D. 1400 for a verifiable NH reconstruction. Unfortunately, these trees display a progressive increase in growth from the middle of the 19th century, which may be wholly or partly due to rising atmospheric CO_2 levels.

and later:

> Mann et al adjust the time series of these crucial high-elevation U.S. trees by comparing it with a separate record of growth at the northern North American tree line and assuming that the trend in the residuals is nonclimatic. They state that "there is no a priori reason to expect the CO_2 effect ... to apply to the northern tree line series". However, there is accumulating evidence of enhanced growth of trees

and finally:

> A number of tree-ring chronologies have displayed anomalous growth or changed responses to climate forcing on different time scales in very recent decades.

It appears that, in their Northern Hemisphere climate reconstruction for the last 1000 years, Mann *et al* have ignored the impact which the increasing concentration of atmospheric CO_2 over recent decades has had on the growth-rate of trees—the well-known 'plant fertilisation effect'. This means that an assumption of a similar response to temperature variation in ancient growth rates to that observed today, can lead to a serious under-estimation of past climate variability in the growing-season. The hockey-stick has already outgrown it meagre scientific underpinnings.

6.3.4 The Sun: Mann's forgotten man

As mentioned before in this paper, there appear to be two main drivers of intra-Holocene climate fluctuations (*ie* during the 10,000 years of the current Interglacial). One is, of course, inertially-driven variations in oceanic heat transportation. The other is variations in the heat output of the Sun.

Parker (1999) discusses the latter in some depth:

> We begin with the fact that the total brightness of the Sun has been monitored by radiometers on NASA spacecraft since 1978, which discovered that, astonishingly, the brightness of the Sun varies by an amount ~0.15%, in step with the 11-year magnetic cycle. Monitoring other solar-type stars shows that this is normal behaviour, along with occasional shutdowns of activity for a century at a time (as during the Maunder Minimum of 1645-1715) or jumps to extraordinary levels of activity (as during the twelfth century Mediaeval Maximum). It is estimated that [the output of the Sun varies by] ~0.5% during these abnormal centuries, the Sun being abnormally bright in the twelfth century and abnormally faint in the seventeenth.

and

> Seawater temperatures have risen since 1900, with most of the warming of the atmosphere and oceans occurring before 1950 and most of the fossil-fuel burning after 1950. We know that sea-surface temperatures are influenced by the brightness of the Sun, so one wonders to what extent the solar brightening has contributed to the increase in atmospheric temperature and CO_2. [warmer seas mean less CO_2 can be absorbed or retained].

Parker continues with a discussion of the cloud feedback[37] which significantly enhances the impact on climate of fluctuations in solar output (see also Figure 26, and its attendant explanation).

If you are beginning to think that Mann's hockey stick is a rather selective representation of what we know about how climate has changed over the past millennium, read on.

6.3.5 What of the future?

Mann's "the last 100 years is unusual" statement has been challenged. Karlén is one of the palaeoclimatologists (see Denton and Karlén, 1973) who identified the *ca* 1500-year cyclic variation of climate in the North Atlantic Basin mega-region. He (1999) says:

> The temperature changes that have occurred during this [20th] century do not appear to be unique.

Perhaps on this issue, 'where you stand depends on where you sit'. Bradley (2000) is one of the Mann, Bradley and Hughes team of authors; and he has no doubts. Referring to the concept of a Mediaeval Warm Period, (which he sees as based on 'highly anecdotal and largely qualitative' evidence) he says:

> ... a few years ago ... the available evidence allowed nothing more significant to be concluded 'than the fact that in some areas of the globe, for some part of the year, relatively warm conditions may have prevailed'. Subsequent research has not altered that conclusion.

and continues:

> One fact stands out as indisputable: Temperatures rose in the 20th century at a rate unprecedented in the last millennium. Further research is unlikely to shake that conclusion.

But what of the future? If you *are* satisfied with the supposed validation of climate models against observed changes in surface temperature during the 20th century (see Figure 51), then models provide a ready means of projecting future climate. Crowley (2000) is satisfied and has done so, as shown in **Figure 69**.

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37 Parker (1999) says:

> Finally, it has come to light that cloud cover follows the cosmic-ray intensity closer than any direct index of solar activity. We know that the condensation of water vapour to form ice crystals and water drops is nucleated by ions in the atmosphere, and cosmic rays are the principal source of atmospheric ions. The intensity of cosmic rays is strongly suppressed by solar activity, so an increase in activity means reduced nucleation opportunities for cloud formation and an associated increase in sunlight reaching the surface of the Earth.

About the past, Crowley has no doubts whatever:

> Here I show that the agreement between model results and observations for the past 1000 years is sufficiently compelling to allow one to conclude that natural variability plays only a subsidiary role in the 20th-century warming and that the most parsimonious explanation for most of the warming is that it is due to the anthropogenic increase in GHG.

But he appears to mis-read the past in the most fundamental way; and understanding the drivers of past climate-change is crucial to any projection of the future. In his abstract, he summarises his conclusion on the past as follows:

> Comparisons of observations with simulations from an energy balance climate model indicate that as much as 41 to 64% of preanthropogenic (pre-1850) decadal-scale temperature variations was due to changes in solar irradiance and volcanism.

This conclusion leaves out more than half the story. To the extent that solar variations and/or vulcanism have a world-wide impact, that impact will be of the same sign throughout. The Sun doesn't vary in a way that makes it simultaneously shine hotter on some parts of the Globe and cooler on others.

The biggest transition in Northern Hemisphere climate over the AD1000-1850 period was that from the Mediaeval Warm Period to the Little Ice Age (see Figures 18-20 and 22-25). But, at the same time as North Atlantic sea-surface temperatures fell (after about AD 1300), Caribbean temperatures did the opposite—they clearly rose (see Figure 21).

The major change in the period was *not* related to solar fluctuations or vulcanism. It was an inertial effect which re-directed the carriage of oceanic heat; and was probably caused by the sudden surging of continental ice (from Greenland) into the North Atlantic.

Nevertheless, Crowley still feels able to extrapolate:

> Projection of the "Business as Usual" scenario [of IPCC] into the next century using the same model sensitivity of 2.0 ^{0}C [for an atmospheric GHG concentration of twice the pre-industrial level] indicates that, when placed in the perspective of the past 1000 years, the warming will reach extraordinary levels. The temperature estimates for 2100 also exceed the most comprehensive estimates of global temperature change during the last interglacial (~ 120,000 to 130,000 years ago)—the warmest interval in the past 400,000 years.

One of the main considerations upon which Crowley's apocalyptic vision stands or falls is whether or not most of the warming in the 20th century really "is due to the anthropogenic increase in GHG", rather than to changes in oceanic heat transportation (see Figure 22). In my opinion, the weight of available evidence is against him—in his interpretation of the past and, therefore, in his projection of the future.

6.4 *Scylla* and *Charybdis*

The Dominant Paradigm, with all who sail in her, is caught between two rocks. These are: *over-predicting models*, and an *under-warming world*. Sections 6.2 and 6.3 of Wolf! Wolf! (see above) illustrate the increasingly ornate—and increasingly implausible—explanations being produced in support of a paradigm under threat. The biggest threat IPCC faces today is from the oceans; if you will forgive the introduction of another allusion to the Ancients, the oceans are *Pandora's Box*.

If IPCC acknowledges the warm/cold *ca* 1500-year climate cyclicity, as manifested by the Mediaeval Warm Period and Little Ice Age, variations in oceanic heat transportation must be accepted.[38] (The same could be said for known cyclicities of lesser duration.) Once this happens, anthropogenic changes to the composition of the atmosphere and 'good' natural influences, such as vulcanism and variable solar output, must make room for the impact of circulation changes in the oceans. Already, there is not enough observed 20th century surface warming to go around.

But there is more. The models on which IPCC relies do not include the inertial impact of extreme events, such as surges of continental ice-sheets, on oceanic heat transportation. Hence inertial effects resulting from observed present-day surging (of up to 2 km/yr) in West Antarctic ice-streams (not discussed in this paper) are just ignored.

Worse still, greenhouse is a phenomenon of the lower atmosphere. No warming of the lower atmosphere means no resultant 'greenhouse effect' warming at the Earth's surface. We now have 42 years of temperatures for the lower atmosphere, and there appears to have been little or no *greenhouse-related* atmospheric warming during that time!

IPCC is under siege—by facts.

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38 There are others thinking along similar lines, it seems. Broecker (2000) says:

> One aspect of the debate with regard to the extent of global warming generated by the ongoing buildup of greenhouse gases has to do with the contribution of natural climate change. Those opposed to emission restrictions are quick to conclude that the warming during the past century may be dominated by the relaxation of LIA conditions. Although we are still a long way from being able to assess whether or not this interpretation is correct, were thermohaline circulation to be implicated, a step toward this goal would be taken.

7. CONCLUSIONS

7.1 The main points

- *Observed warming of the Earth's surface during the 20th century* was in two roughly-equal tranches (each of about 0.35 ^{0}C) in 1925-44 and from 1978 to its end.

- *In the case of the first tranche*, where direct evidence is sparse, there is no easy route to a firm conclusion about its cause. However, we do know that pre-1945 observed warming *anticipated* the bulk of anthropogenic GHG emissions.

- A more plausible explanation of the 1925-44 warming is the combined effect of increased flow of (warm) equatorial surface water into the Nordic seas *via* the North Atlantic, and increased output of solar warmth. There is considerable circumstantial evidence supporting this hypothesis.

- *Greenhouse is a phenomenon of the atmosphere*. Human-caused GHG emissions result in the increased capture of radiant heat from the Earth by the lower atmosphere, which warms as a consequence. Part of this extra warmth is then lost to Space, and part is redistributed back to the surface. It is this *resultant* warming of the Earth's surface which we call the 'greenhouse effect'.

- This leads to the conclusion that no prior warming of the atmosphere means no 'greenhouse warming'. Popper's law of empirical disproof can be applied here—provided the period of observation is long enough to allow for the inherent complexities of the climate system. Just a few years, won't do.

- *We now have a record of temperature trends in the atmosphere*. Since a satellite-derived global record of atmospheric temperatures became available in 1979, there has been little or no warming of the lower atmosphere. Therefore the observed warming at the surface, during this 21-year period at least, is unlikely to be greenhouse warming.

- A longer balloon-sourced record of atmospheric temperatures is available back to 1958, but with a less-comprehensive coverage. However, during the period of overlap from 1979, it shows excellent agreement with the complete global coverage of the satellite-derived record.

- With the exception of a single step-jump of 0.35 ^{0}C at 1976/7, the entire 42-year atmospheric record is without any significant warming trend. Thus, there is no significant trend in atmospheric temperatures for 1958-76 and 1977-99.

- The 1976/77 jump is probably a direct response to a contemporary re-ordering of oceanic circulation, for which there is much available evidence. This jump appears to be unrelated to human-caused change in the composition of the atmosphere.

- *In the case of the second tranche of observed warming at the surface*, the evidence against the IPCC hypothesis is much more direct, and is quite compelling.

- The 1978-99 warming at the surface is not *greenhouse* warming. Instead, it is closely related to changes in oceanic heat transportation; and there is a large amount of circumstantial evidence supporting this hypothesis.

- *The IPCC hypothesis (and the dominant paradigm in climate-change science)* that all or most of the observed 20th century surface warming is the result of human-caused changes to the composition of the atmosphere, runs counter to the weight of evidence. As more evidence becomes available, the dominant paradigm is coming under increasing pressure from the Law of Empirical Disproof.

- *Model-based projections of climate-change over the next century* rely for their credibility on the veracity of IPCC's models.

- The test of reconciliation with observed movements in climate during the 20th century shows that IPCC's models over-predict greenhouse warming.

- It is only when aerosol cooling is also included in the model-based analysis, that models and actuals yield similar global warming during the 20th century.

- The (short-lived) anthropogenic aerosols are emitted largely in the Northern Hemisphere, which should be the cooler as a consequence.

- However, both at the surface and in the lower atmosphere, it is the *Northern* Hemisphere which has the stronger warming trend—thus providing empirical disproof of IPCC's hypothesis of aerosol cooling.

- Without the ability to invoke aerosol cooling, there is no reconciliation between IPCC's models and observed climate change over the past century.

- Without a successful reconciliation, there can be no justification for using these models to project climate-change in the century ahead.

7.2 Three conclusions—and an unanswered question

I draw three conclusions:

1). The idea that humans can stabilise global climate by 'doing the right thing' regarding GHG emissions is mistaken.

Climate demonstrates cyclicity at many time-scales; and past (natural) climate changes were often both large and abrupt, at least at the regional scale. This is bound to continue.

There is much climate-related human misery to come in countries less fortunate than Australia, and it cannot be prevented by the limitation of GHG emissions. This misery will need to be alleviated; and thus mitigation is a more realistic, and much more humane, approach than is the *chimera* of prevention.

2). The greenhouse issue is itself an environmental threat.

There is only so much zeal, and so much money, available for the environment in all its facets. By presently concentrating both to such a degree on greenhouse, Australia is neglecting better-substantiated, and more-pressing, environmental needs.

3). Australia should not ratify the Kyoto Protocol before it has considered *all* the relevant science relating to climate-change.

IPCC is not a disinterested guide to climate-change science. On the contrary, it is a partisan for a self-serving cause: that climate science and climate-change science are the same thing. It is an advocate for the atmospheric sciences *vis a vis* the broader range of geosciences.

There is abundant evidence, ignored or down-played by IPCC, that observed warming during the 20th century was not caused solely or largely by anthropogenic changes to the composition of the atmosphere. On the contrary, changes in oceanic heat transportation and solar output are likely to be the dominant factors in 20th century surface warming.

Lastly, there is a question which needs answering, and for which I have no answer:

Are increased emissions of CO_2 to the atmosphere, on balance, good or bad for the future of humanity, and of the biodiversity for which we are custodians?

Consider what we know:

First, CO_2 is an essential plant food, not a pollutant. Elevated concentrations of this gas in the atmosphere promote in plants both growth and more efficient use of available water; enhanced growth of trees, increased production of food, and (if the human propensity for land-clearing will allow it) improved protection of biodiversity would be the outcome.

Second, orbital factors are already moving against us, and the Holocene Climate Optimum is long gone. The world has been cooling for the past three or four thousand years. Overprinted on this threatening trend is the well-known *ca* 1500-year warm/cold cyclicity. Will it be the next ‘Little Ice Age’ in which the resultant feedback changes tip us over into an irreversible decline toward the next Glacial? Remember, Armageddon will be cold not hot, when it comes.

We have here an important question, too often dismissed without thought.

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The Kyoto Protocol: Don't Forget the Science—Figures

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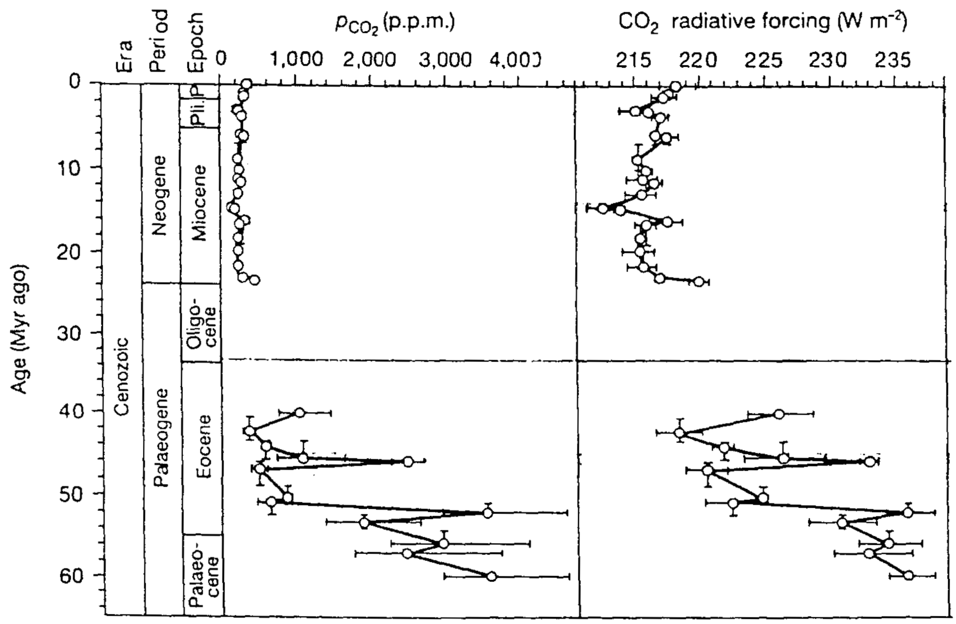
FIGURE 1A: DECLINE IN ATMOSPHERIC CO_2 CONCENTRATION



Carbon dioxide levels and Cenozoic climate change. The p_{CO_2} record is converted to radiative forcing (a measure of global warming).

Pearson and Palmer 2000, *Nature* v 406

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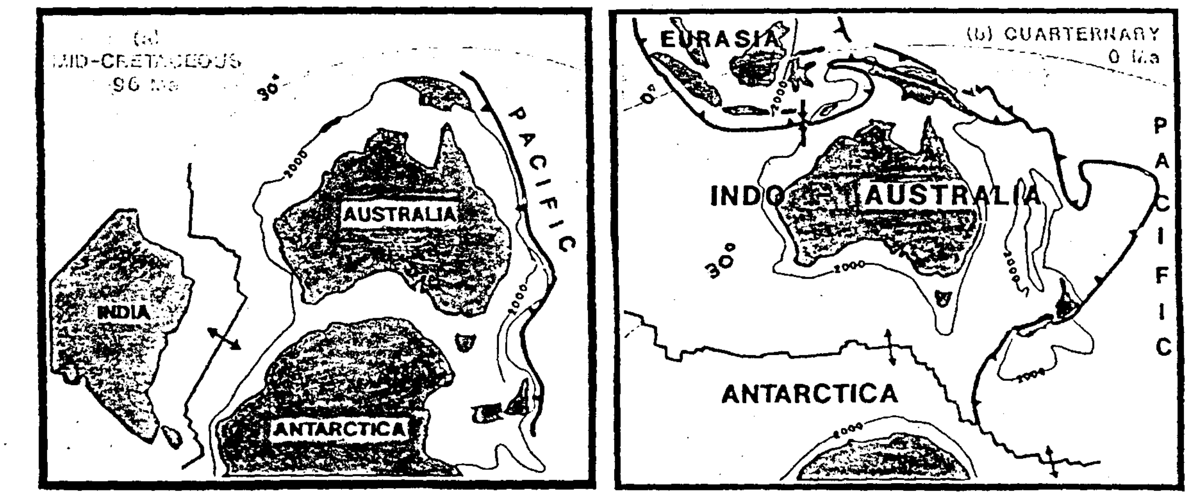
FIGURE 1B: TECTONIC PLATES IN MID-CRETACEOUS (96 MyBP) AND TODAY



BHP Petroleum

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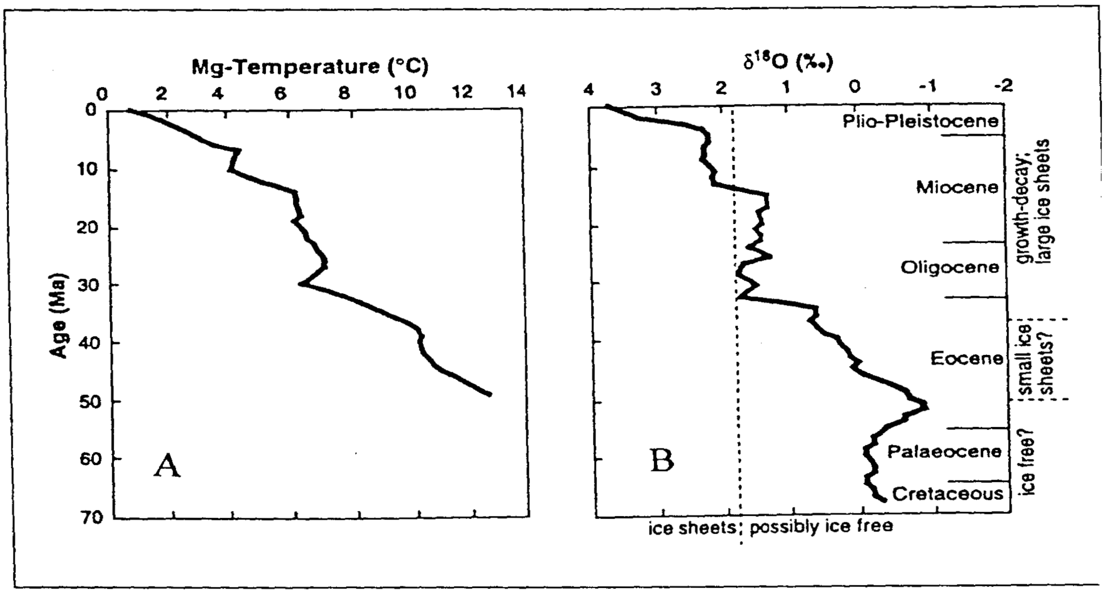
FIGURE 2: CAINOZOIC DEEP-SEA TEMPERATURES



(A) Magnesium-based temperature record obtained from composite Mg/Ca data for benthic foraminifera from deep-sea sites. (B) Cainozoic composite benthic foraminiferal record of oxygen-isotope differences from Atlantic cores.

Lear, Elderfield & Wilson 2000, *Science* v 287

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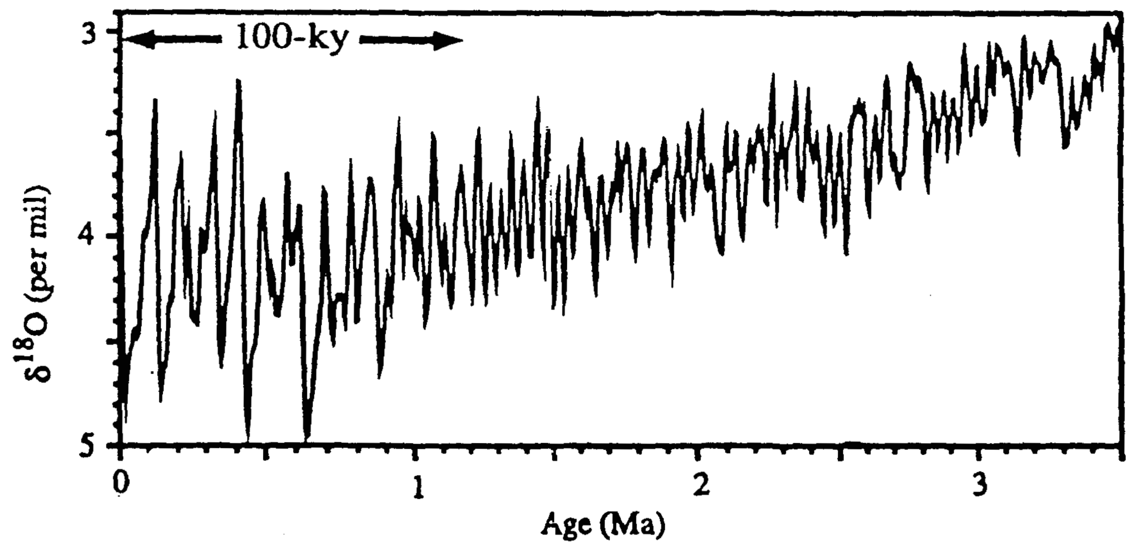
FIGURE 3: ISOTOPE PROXY FOR GLOBAL ICE VOLUME



Clark, Alley & Pollard 1999, *Science* v 286

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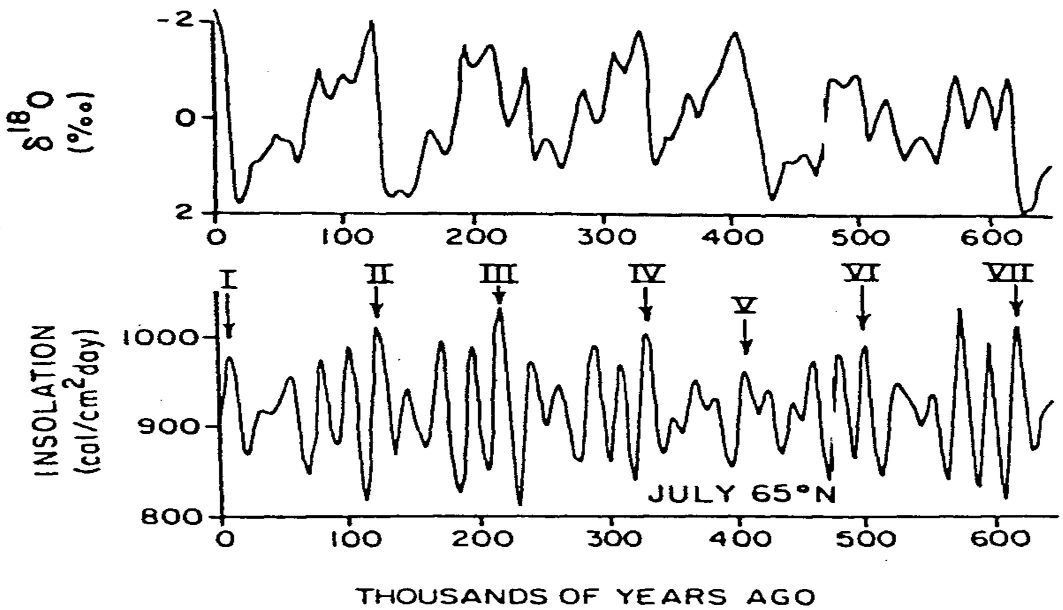
FIGURE 4: RELATIONSHIP BETWEEN GLOBAL ICE VOLUME AND SUMMER INSOLATION AT 65°N



Wallace S Broecker, 1984, in *Milankovitch and climate*, D Reidel

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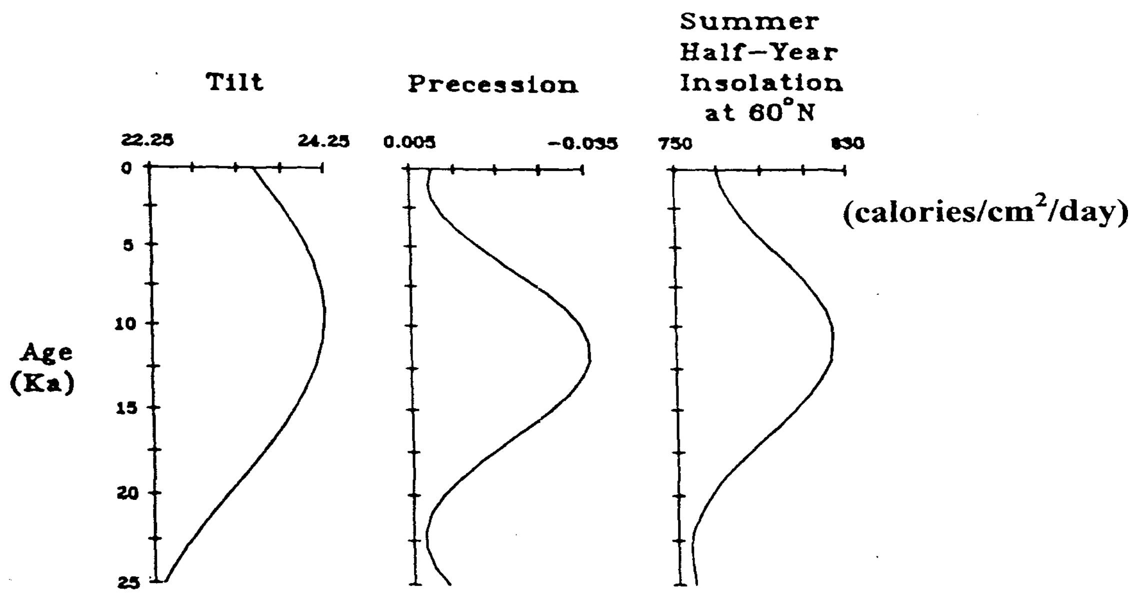
FIGURE 5: ORBITALINFLUENCE ON INSOLATION AT 60°N



Ruddiman & Wright (Eds) 1987, *The Geology of North America* v K

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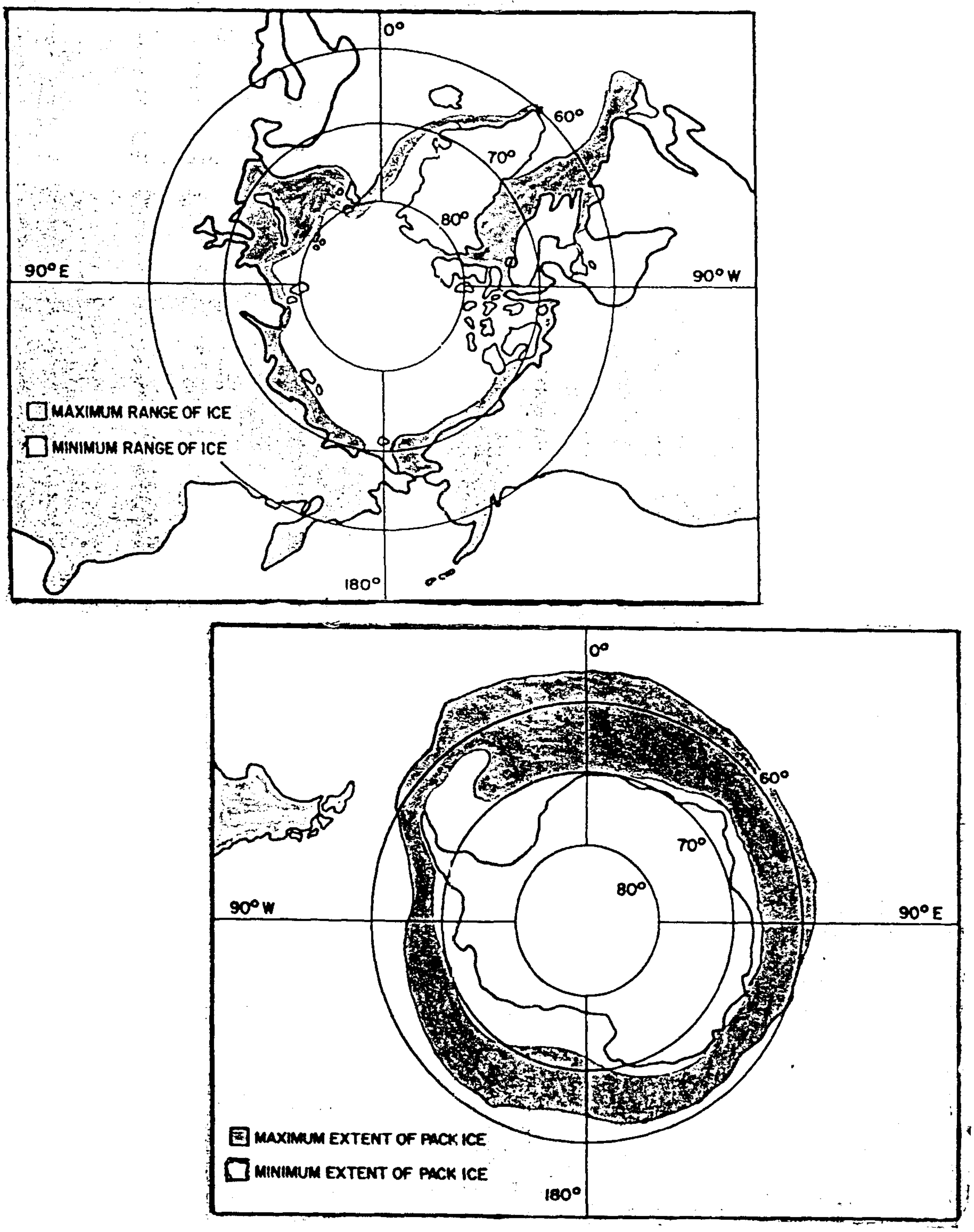
FIGURE 6: EXTENT OF SEA ICE IN AUTUMN AND SPRING



Prepared for BHP and Esso by Roy G. Scarfo Inc, Thorndale PA

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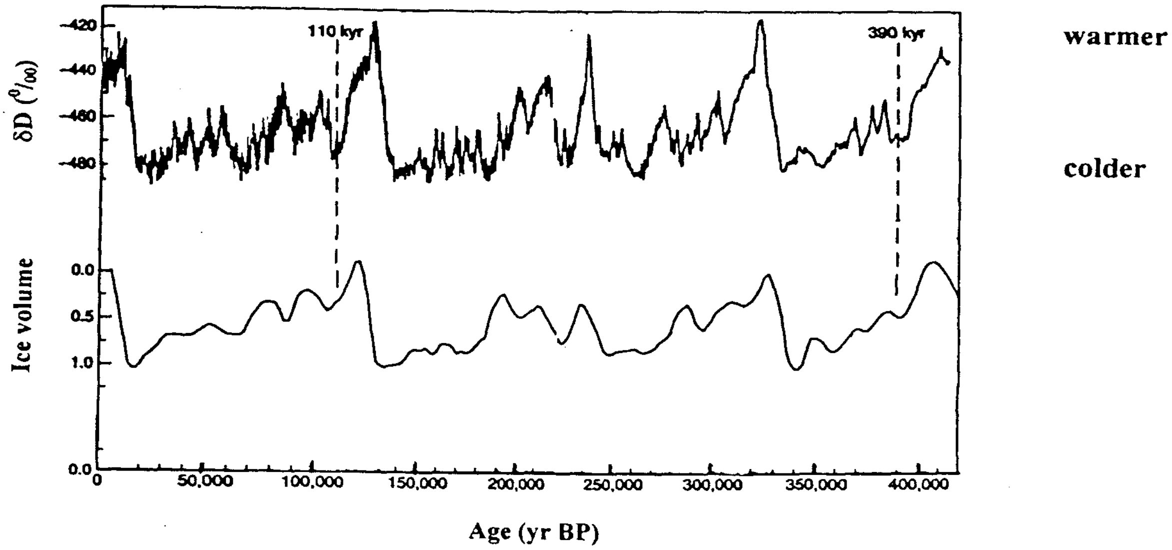
FIGURE 7: GLACIAL/INTERGLACIAL CLIMATE PROXY



Vostok ice-core

Petit *et al* 1999, *Nature* v 399

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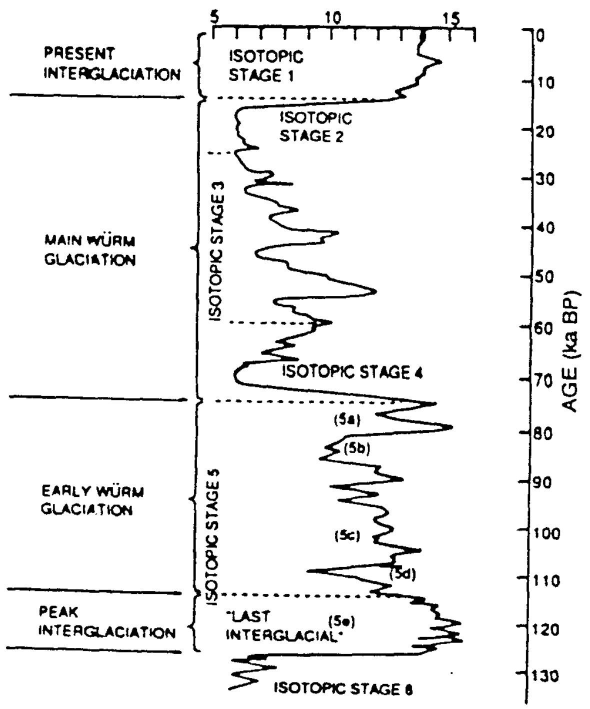
FIGURE 8: NW ATLANTIC SUMMER SEA-SURFACE TEMPERATURE (ºC)



Williams, Dunkerly, De Decker, Kershaw & Chapple 1998, *Quaternary Environments*

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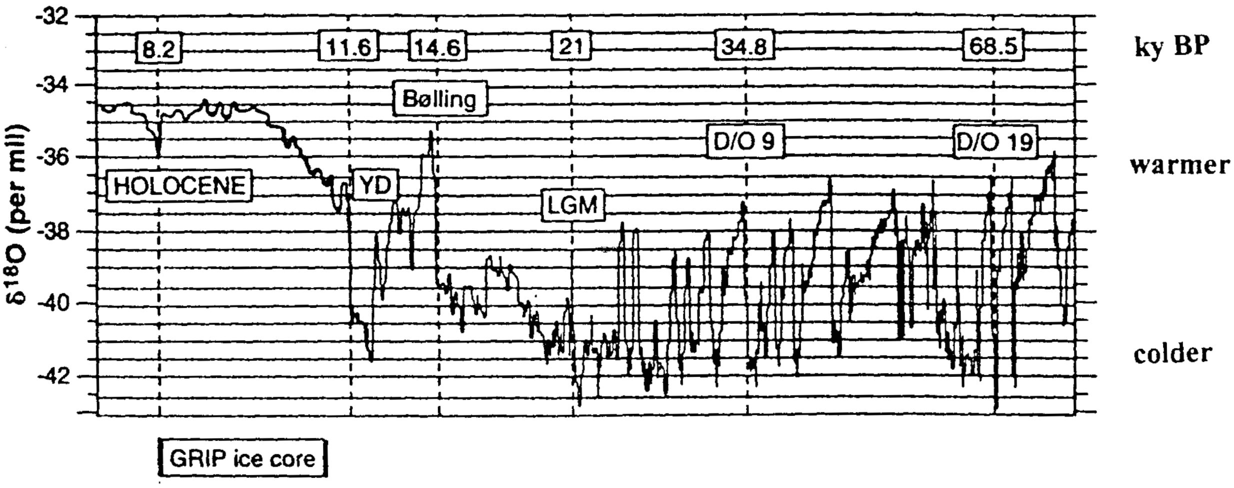
FIGURE 9: GREENLAND GLACIAL/INTERGLACIAL TRANSITION



Jouzel 1999, *Science* v 286

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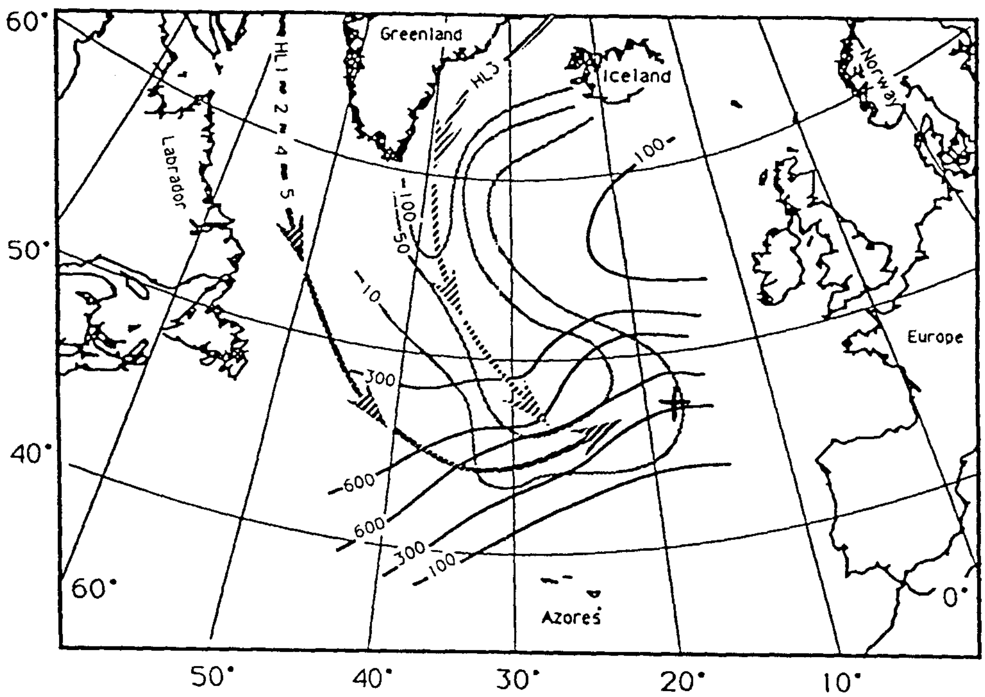
FIGURE 10: ORIGIN OF NORTH ATLANTIC HEINRICH LAYERS



Grousset, FE *et al* 1993, *Paleoceanography* v 8

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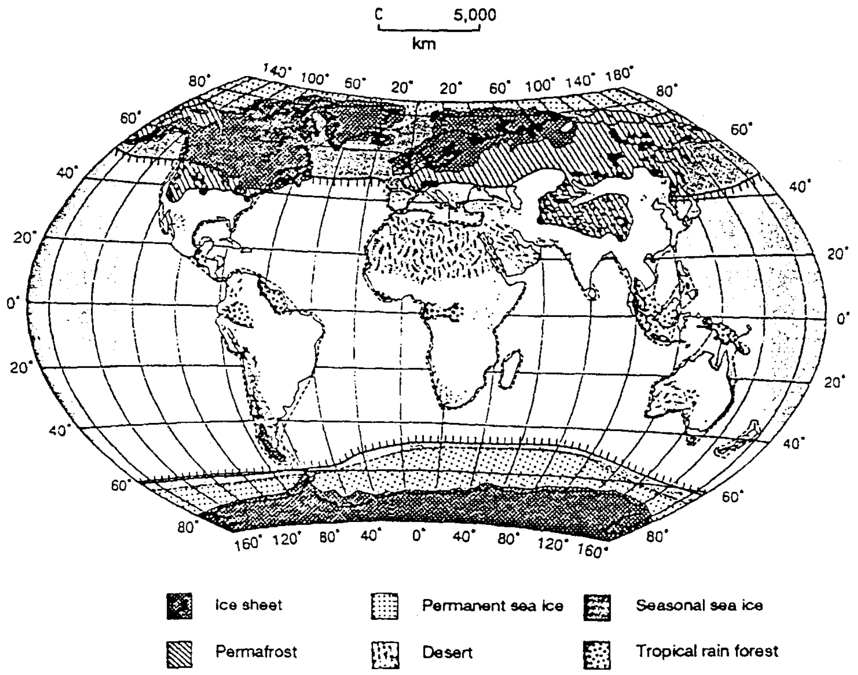
FIGURE 11: EXTENT OF ICE/PERMAFROST AT THE LAST GLACIAL MAXIMUM



Godfrey Hewitt 2000, Nature v 405

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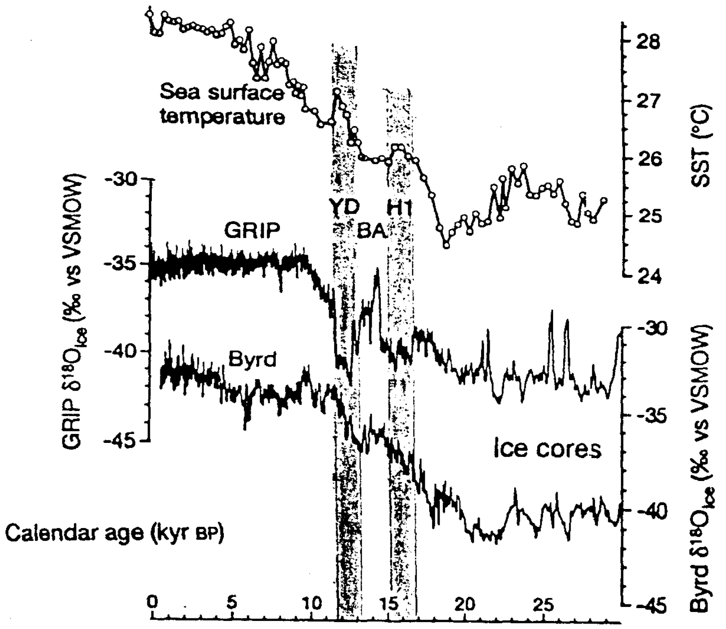
FIGURE 12: LAST GLACIAL /INTERGLACIAL TRANSITION AND CONTRAST-



H1, BA and YD denote Heinrich event H1 (16,900 – 15,400 cal. yr BP), the Bølling–Allerød period (15,400 – 12,900 cal. yr BP), and the Younger Dryas period (12,900 – 11,600 cal. yr BP), respectively.

Rühlemann *et al* 1999, *Nature* v 402

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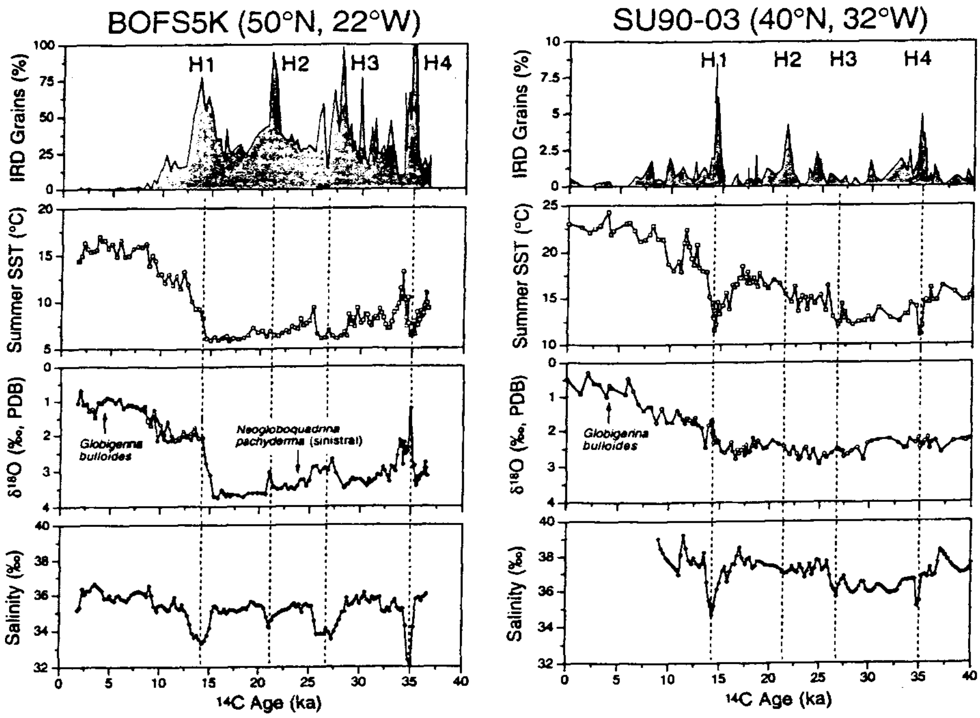
FIGURE 13: ICE-RAFTED DETRITUSIN GLACIAL TIMES NORTH ATLANTIC CORES



Comparison of surface ocean proxy records from North Atlantic cores BOFS5K and SU90-03. Time series records of ice-rafted detritus (IRD), summer sea-surface temperatures (SST), planktonic $\delta^{18}O$, and sea-surface salinity vs. ^{14}C age.

Chapman & Maslin 1999, *Geology* v 27 no 10

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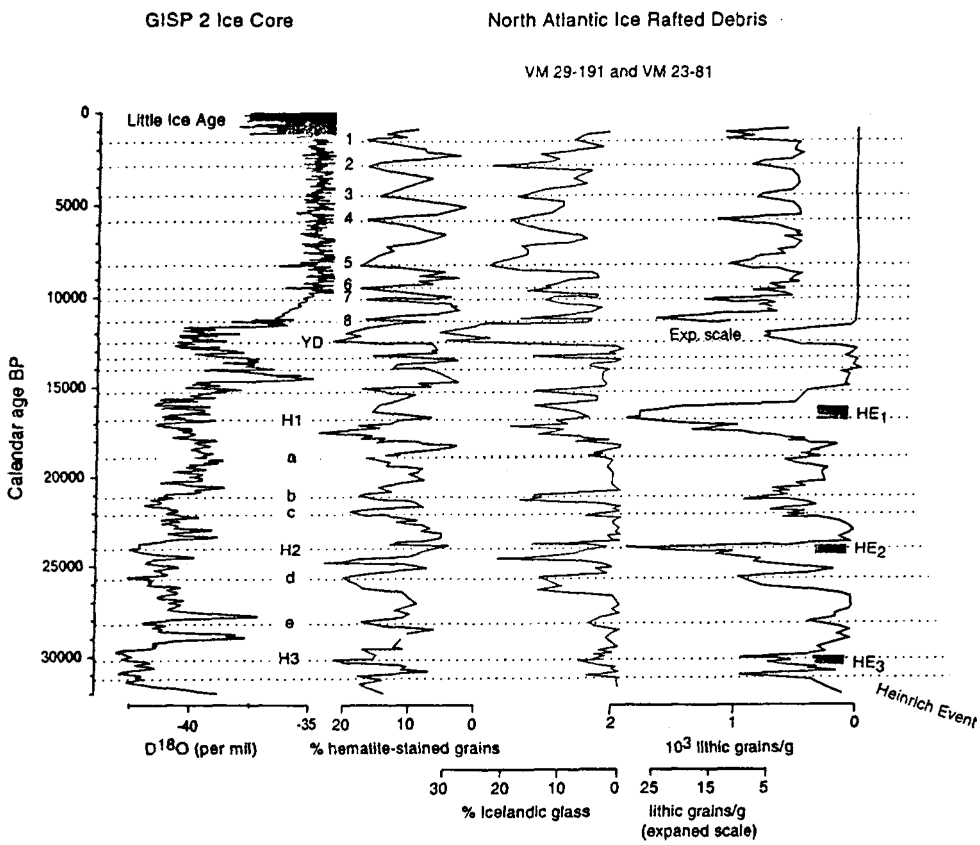
FIGURE 14: IRD IN GLACIAL AND INTERGLACIAL NORTH ATLANTIC CORES



Thomas V. Lowell 2000, PNAS v 97 no 4
(after Bond *et al* 1997, *Science* v 278)

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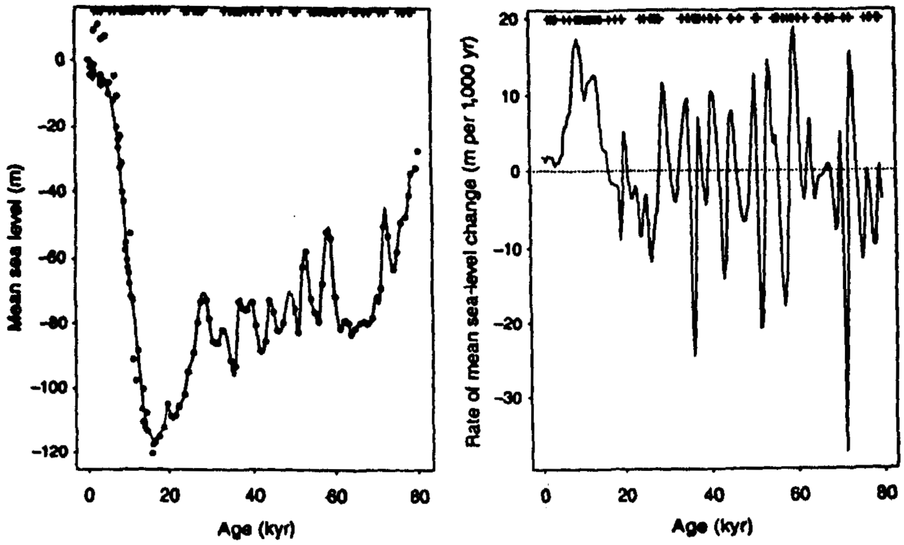
FIGURE 15: GLOBAL SEA-LEVEL FLUCTUATIONS



McGuire, WJ *et al* 1997, *Nature* v 389

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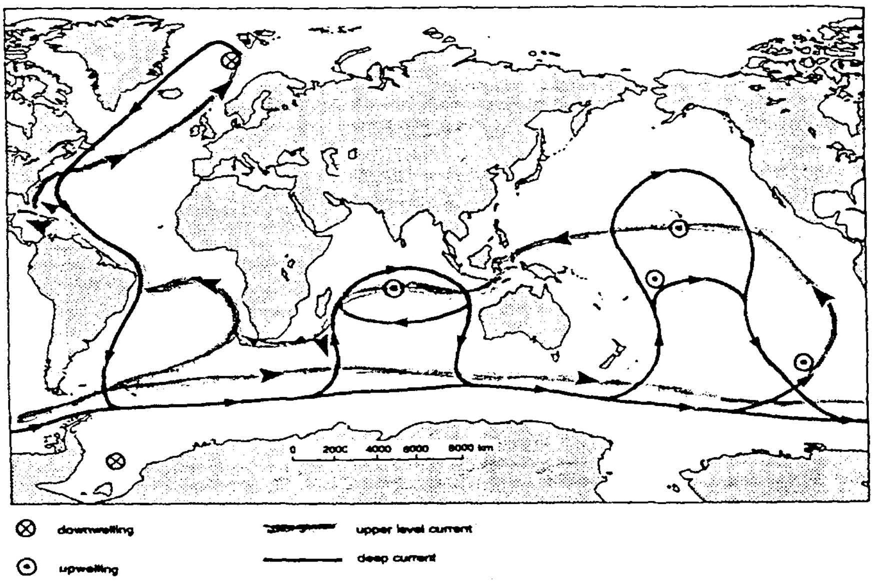
FIGURE 16: GLOBAL OCEANIC CIRCULATION



Williams, Dunkerley, de Dekker, Kershaw & Chappell 1998,
Quaternary Environments

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FIGURE 17: CARIBBEAN AND ANTILLES

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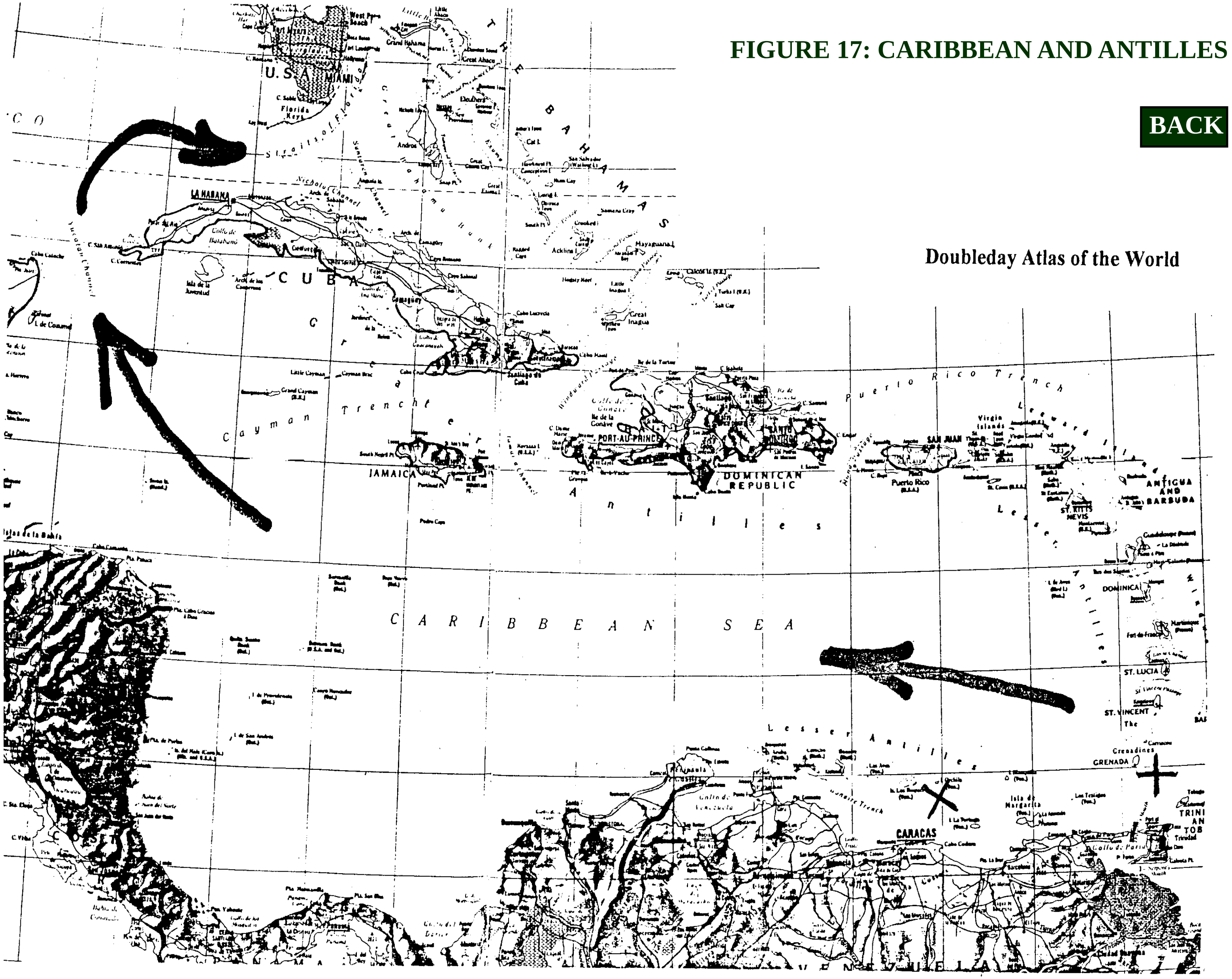

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FIGURE 18A: NW AFRICAN CLIMATE IN THE HOLOCENE

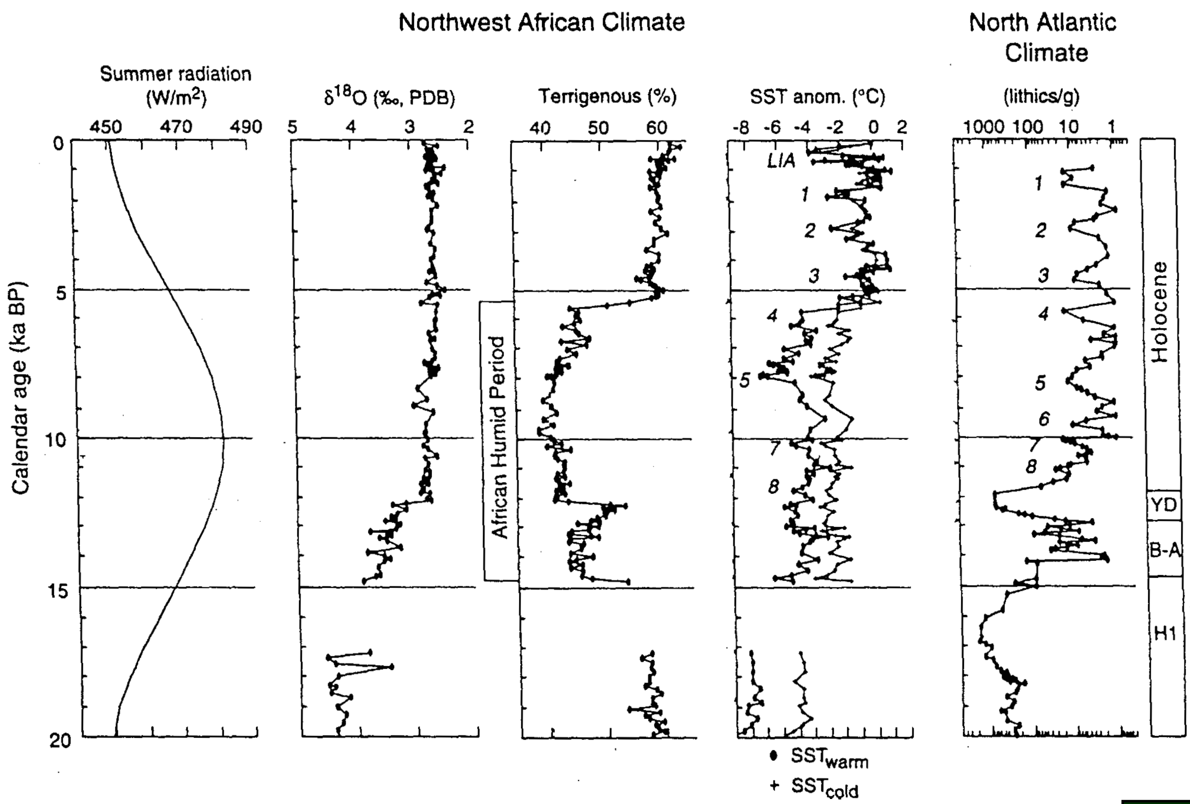

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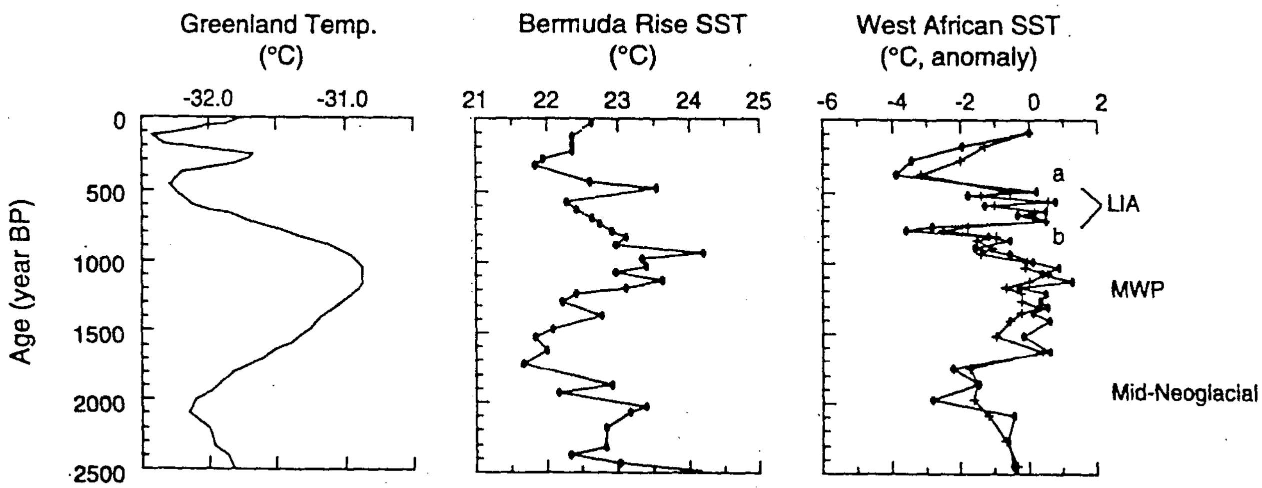
FIGURE 18B: LITTLE ICE AGE OFFSHORE WEST AFRICA



deMenocal *et al* 2000, *Science* v 288

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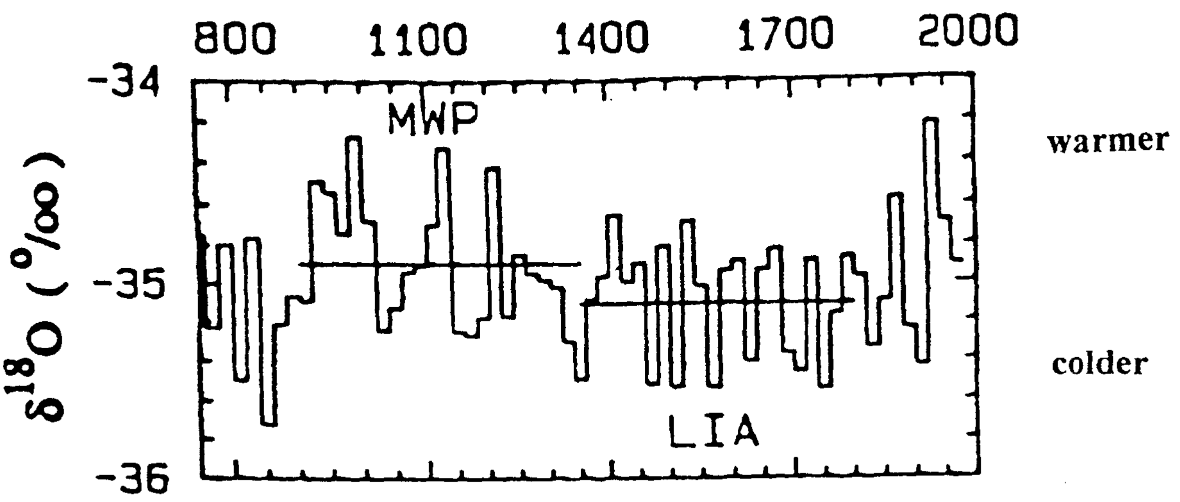
FIGURE 19: CLIMATE PROXY IN GREENLAND ICE CORES



Stuiver, Grootes & Braziunas 1995, *Quaternary Research* v 44

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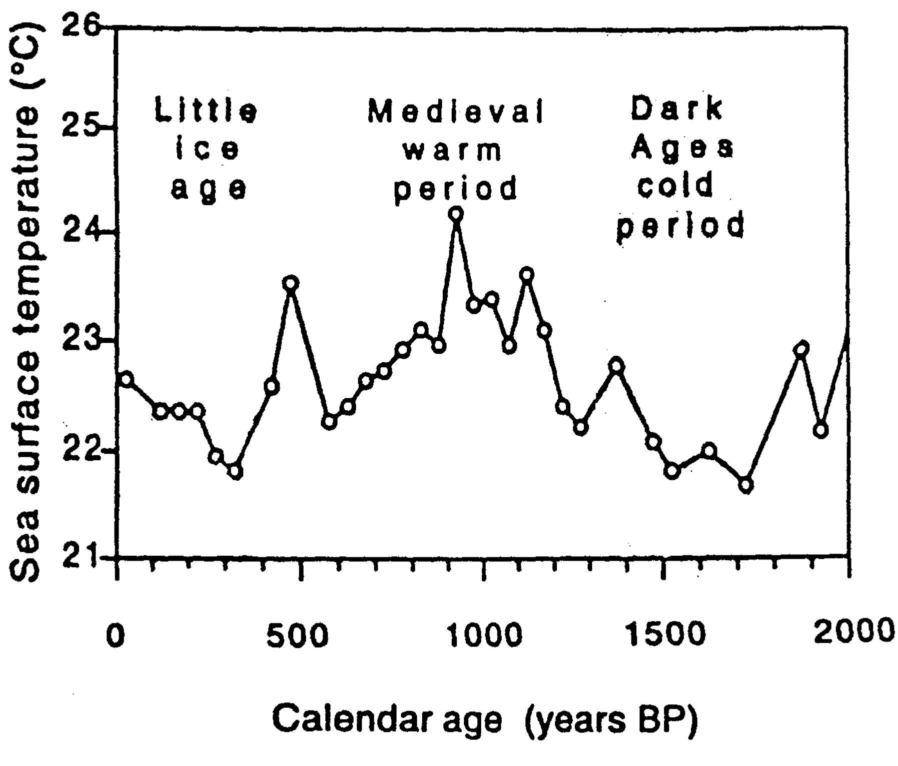
FIGURE 20: ATLANTIC SURFACE TEMPERATURE AT 30°N



Keigwin & Pickart 1999, *Science* v 286

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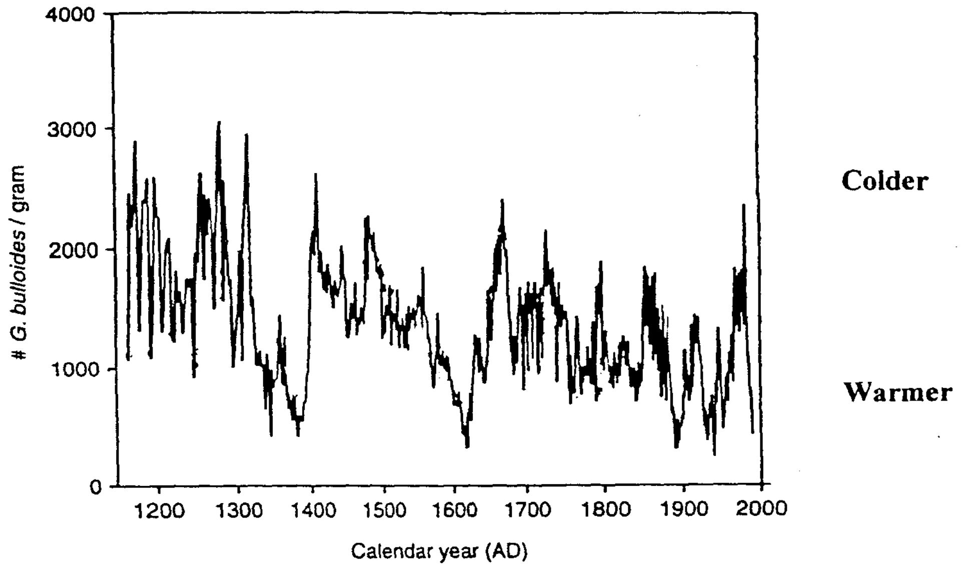
FIGURE 21: PROXY FOR CARIBBEAN SEA-SURFACE TEMPERATURE



Black *et al* 1999, *Science* v286

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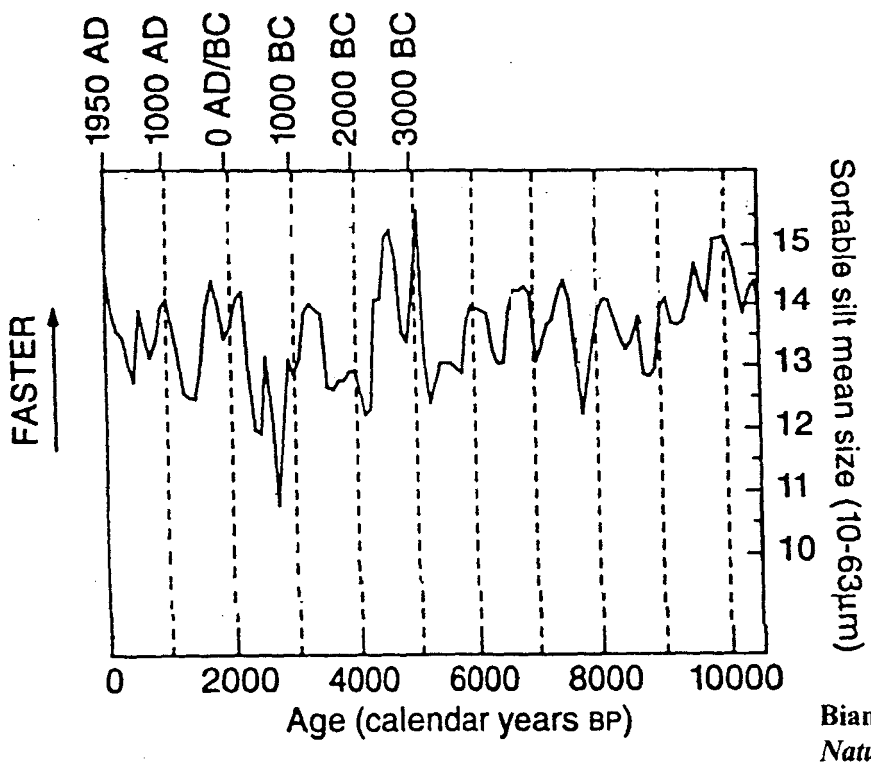
FIGURE 22: PROXY FOR WARM ATLANTIC FLOW INTO THE ARCTIC



Bianchi & McCave 1999, *Nature* v 397

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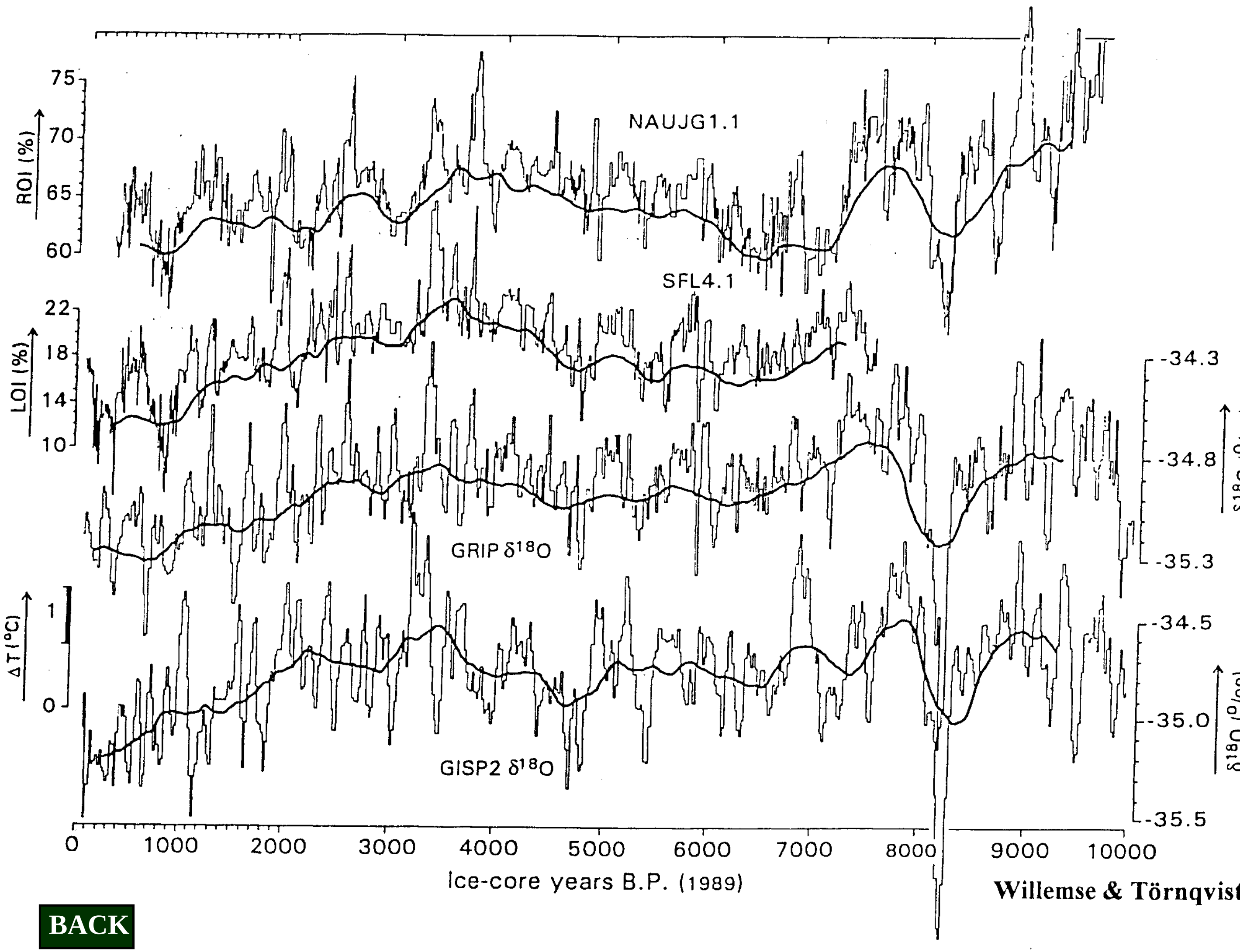
FIGURE 23: BIOLOGICAL PRODUCTIVITY IN SOUTH GREENLAND LAKES COMPARED WITH GREENLAND ICE-SHEET CLIMATE PROXIES



Willemse & Törnqvist 1999, *Geology* v 27 no 7

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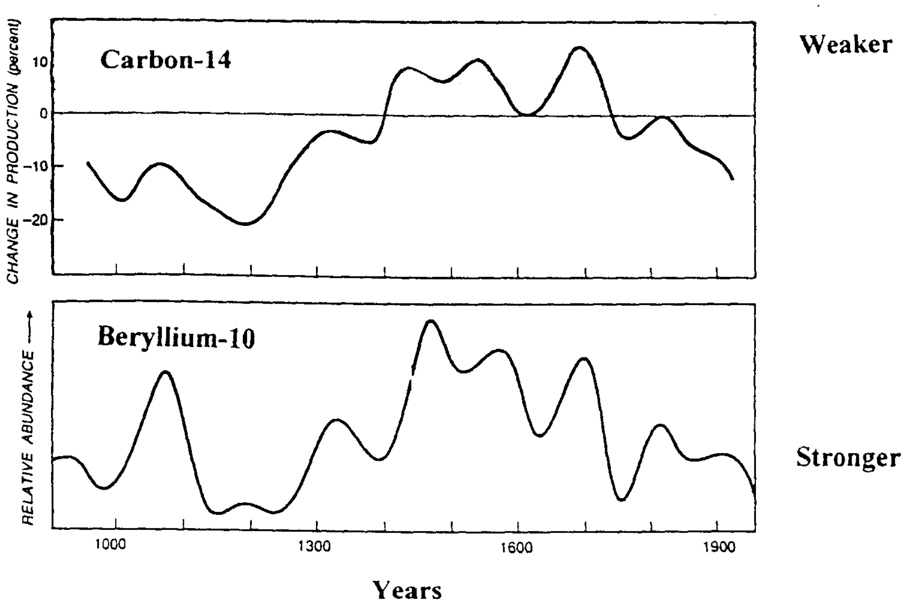
FIGURE 24: RADIOISOTOPE PROXY FOR SOLAR OUTPUT



Baliunas & Soon, *Sky & Telescope* December 1996

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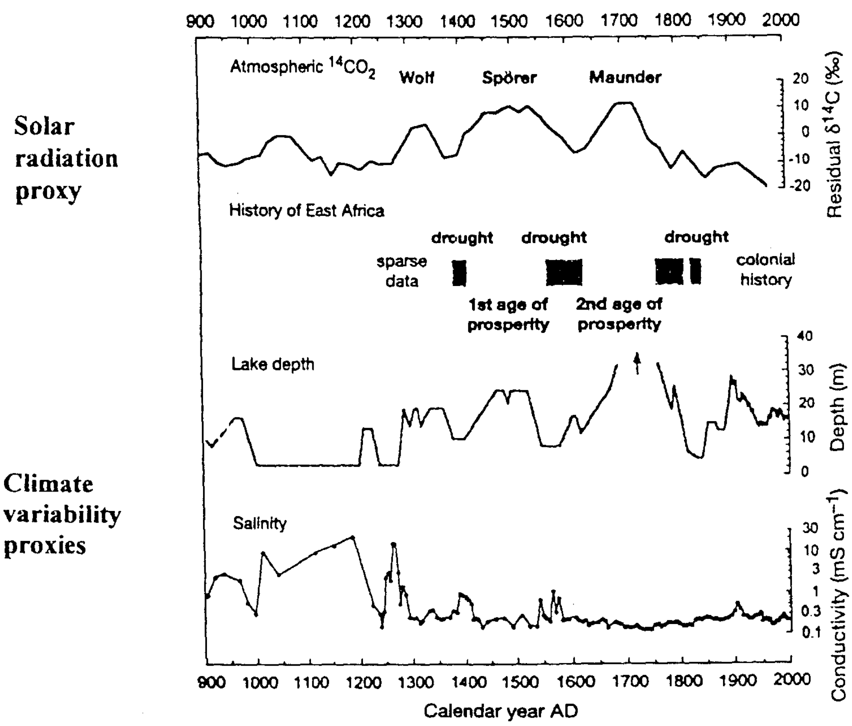
FIGURE 25: EASTAFRICAN CLIMATE VARIABILITY



Verschuren, Laird & Cumming 2000, *Nature* v 403

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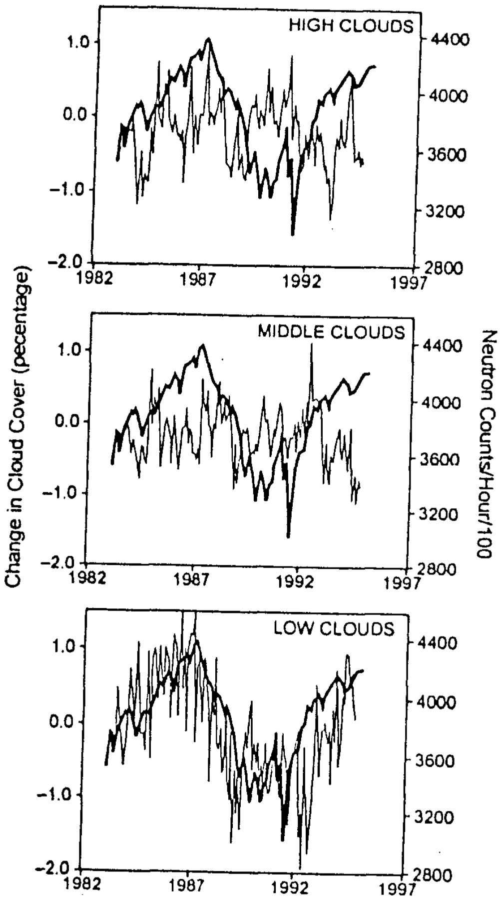
FIGURE 27: SOLAR ACTIVITY vs SURFACE TEMPERATURE



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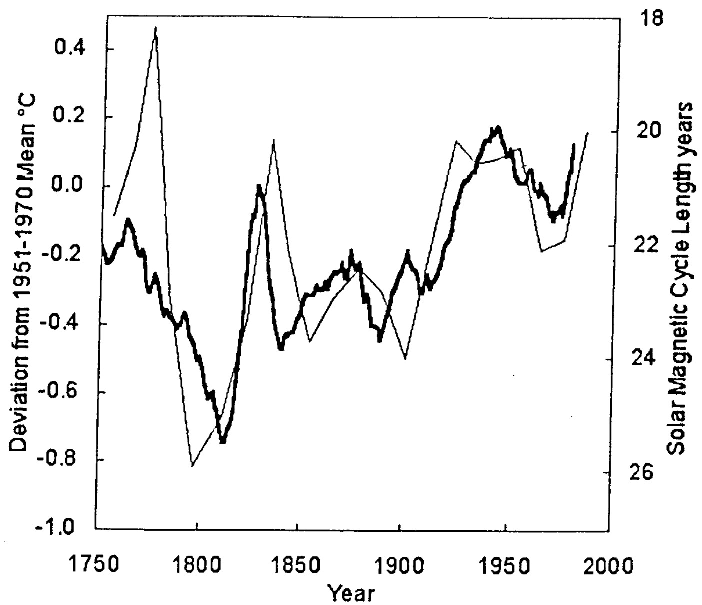
Baliunas & Soon 2000, *World Climate Report* v 5/19

FIGURE 26: SOLAR ACTIVITY vs CLOUD COVERAGE

Heavy line:
Terrestrial Northern Hemisphere temperature

Light line:
Magnetic cycle proxy for solar activity



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Robinson, Baliunas, Soon & Robinson 1998, *Petition Project* document

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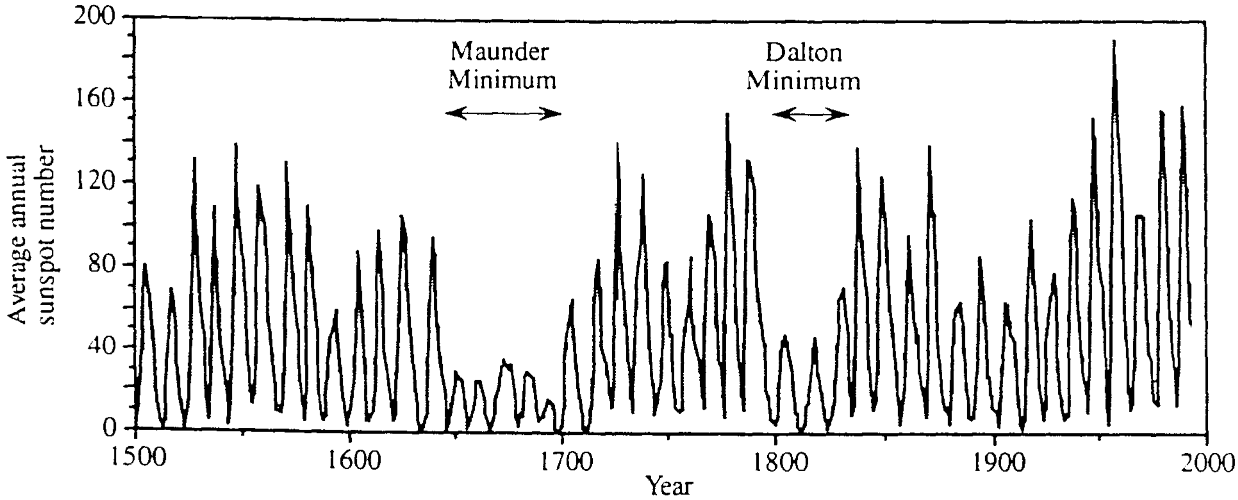
FIGURE 28: VARIATION IN SUNSPOT NUMBERS, 1500-1993



Edward Bryant 1997, *Climate process & change* CU Press

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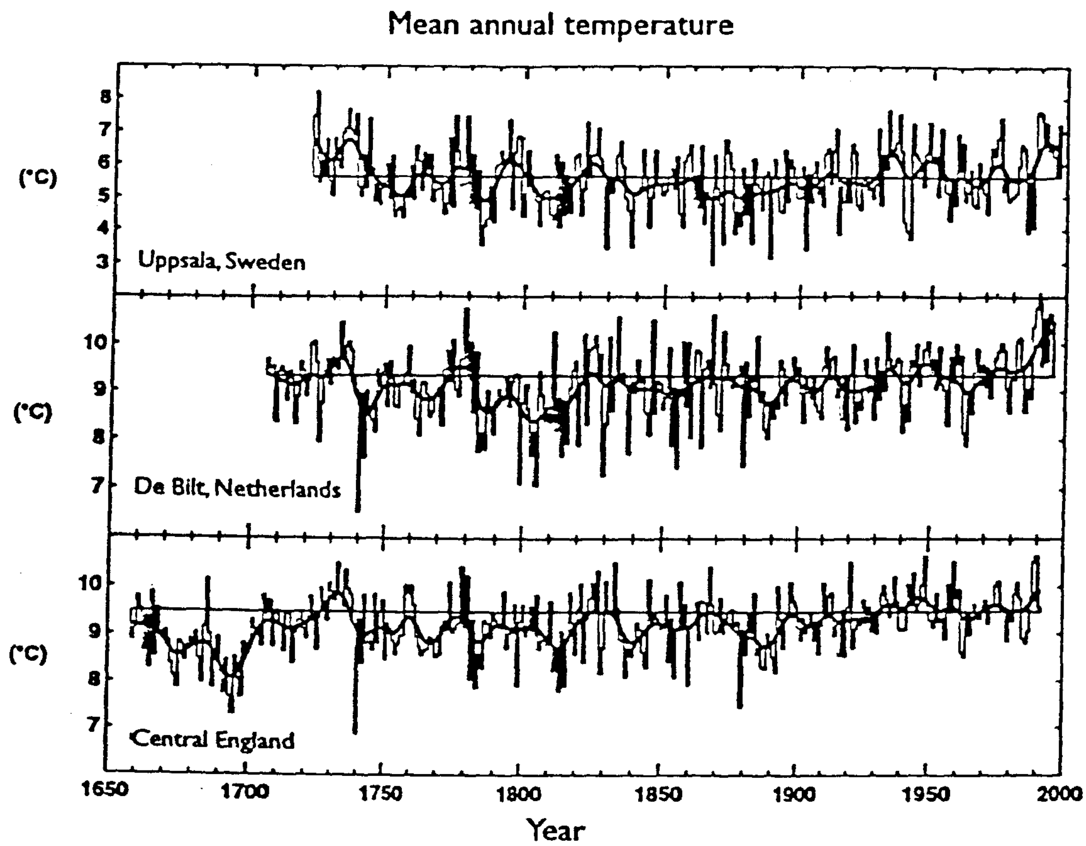
FIGURE 29: WORLD'S THREE LONGEST OBSERVATION SERIES



Karlén 1999, <u>in</u> *Climate policy after Kyoto*

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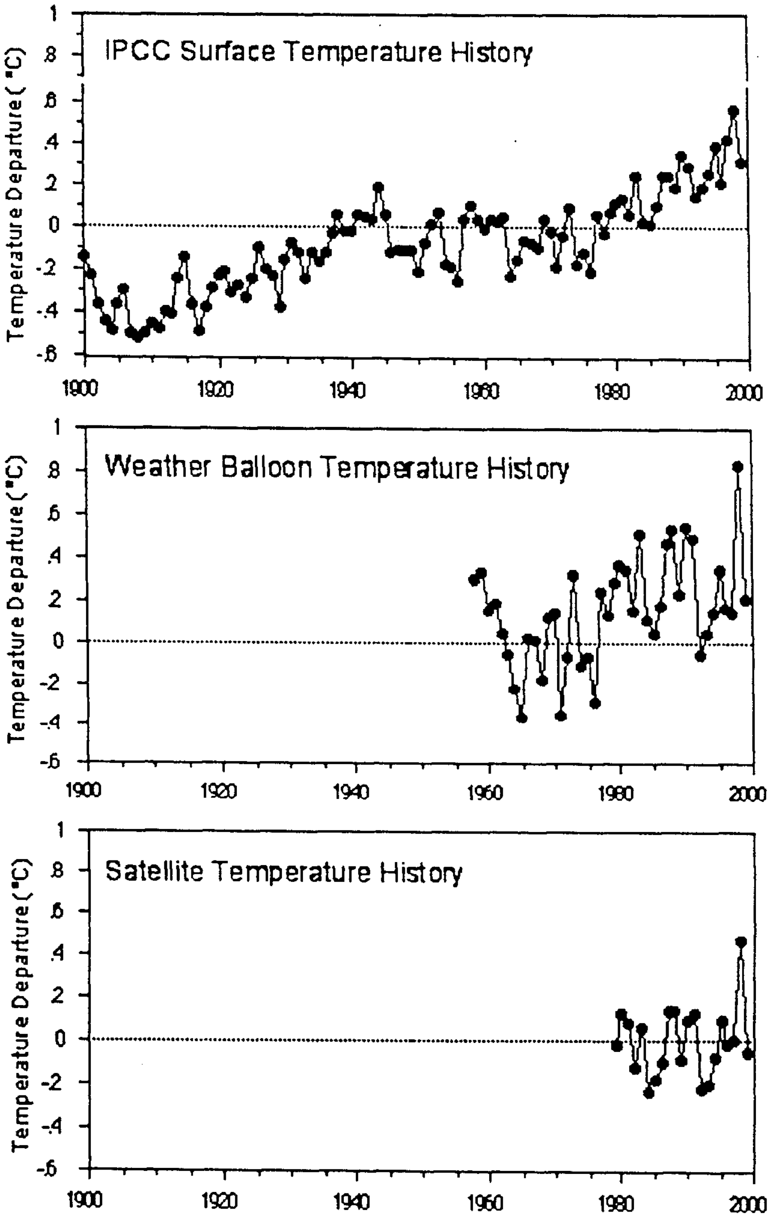
FIGURE 30: GLOBAL TEMPERATURE RECORD



Various versions of the global temperature record: Surface (top) and lower atmosphere records, from weather balloons (middle) and as derived from satellites (bottom).

World Climate Report v 5 no 9, 2000

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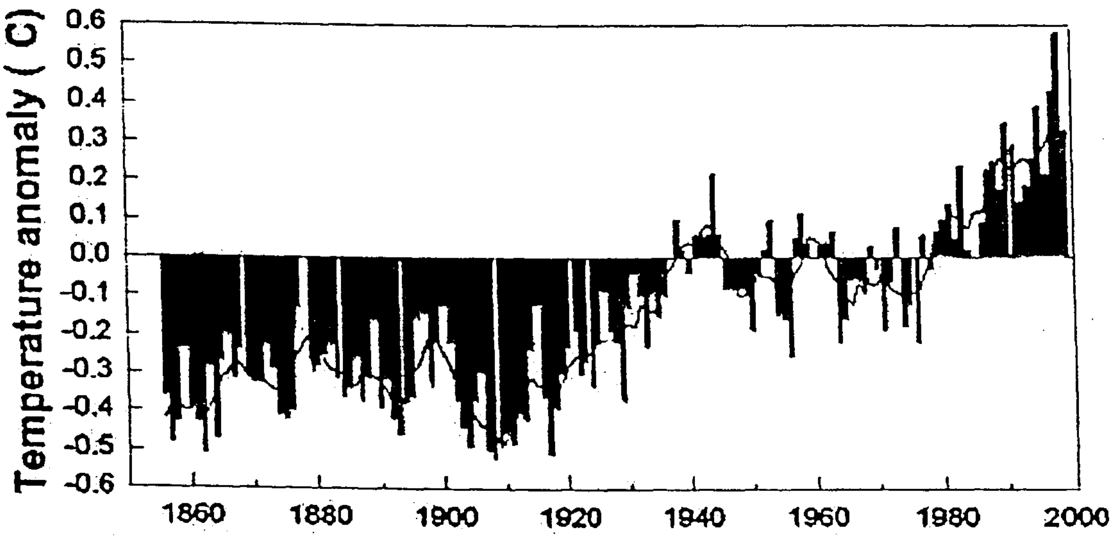
FIGURE 31: GLOBAL MEAN TEMPERATURE (LAND + SEA) 1856-1999 (relative to 1961-1990)



Climatic Research Unit, University of East Anglia

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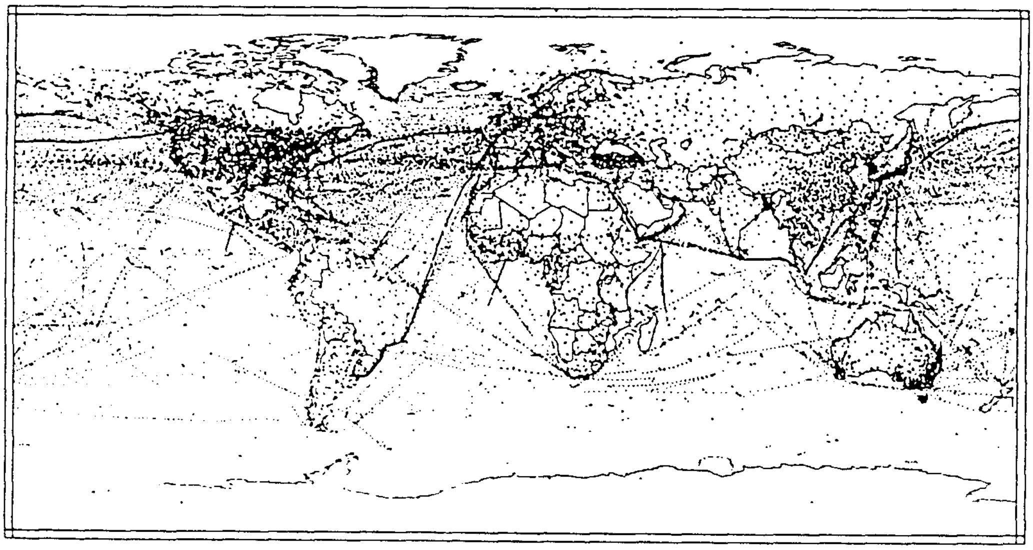
FIGURE 32: LOCATION OF SURFACE-TEMPERATURE OBSERVATIONS



Panel on Reconciling Temperature Observations 2000, *National Research Council*, Washington DC

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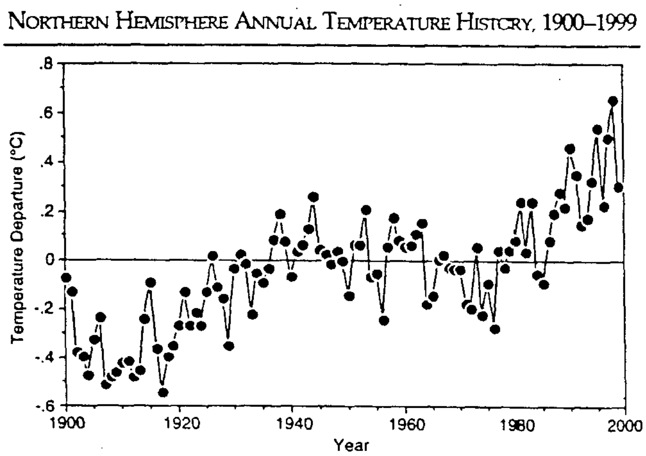
FIGURE 33: 20TH CENTURY HEMISPERIC SURFACE TEMPERATURES



Michaels & Balling 2000,
The Satanic Gases,
Cato Inst. Washington DC

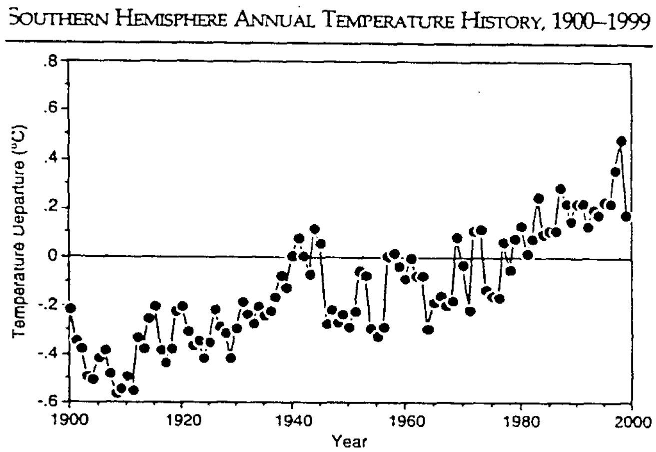


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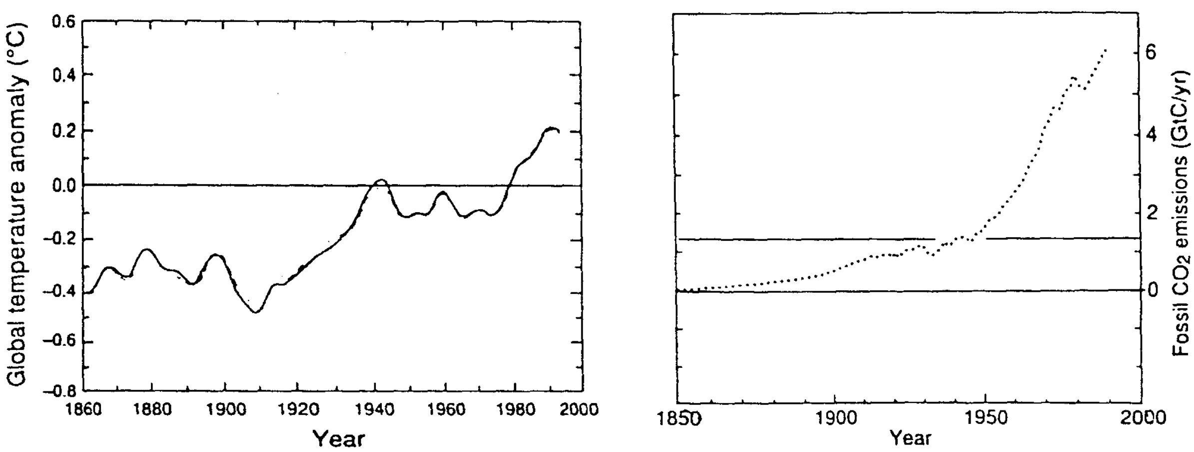
FIGURE 34: GLOBAL TEMPERATURES *vs* CO_2 EMISSIONS



Houghton, JT *et al* Eds 1996
Climate change 1995: the science of climate change

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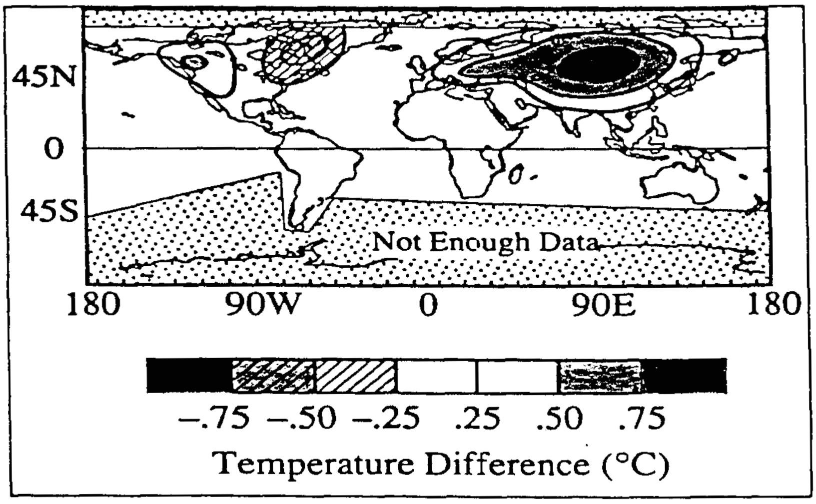
FIGURE 35: TRENDS IN SEASONAL TEMPERATURE DIFFERENCE



World Climate Report
v 3 no 9, 1998

For the last 50 years, winter temperature trends minus summer temperature trends shows that the greenhouse effect is really the Siberian effect.

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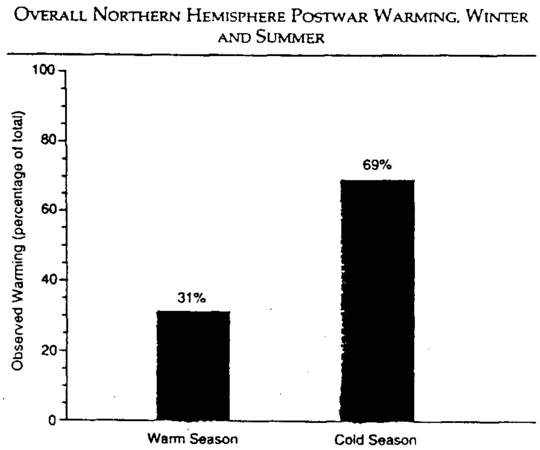
FIGURE 36: DISTRIBUTION OF NORTHERN HEMISPHERE SURFACE WARMING OVER THE PAST 50 YEARS



Michaels & Balling 2000,
***The Satanic Gases*,**
Cato Inst. Washington DC

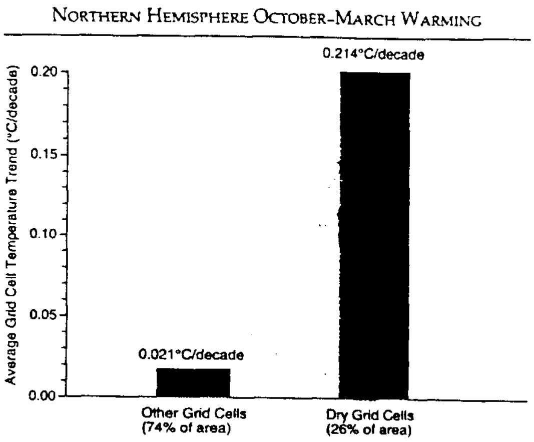


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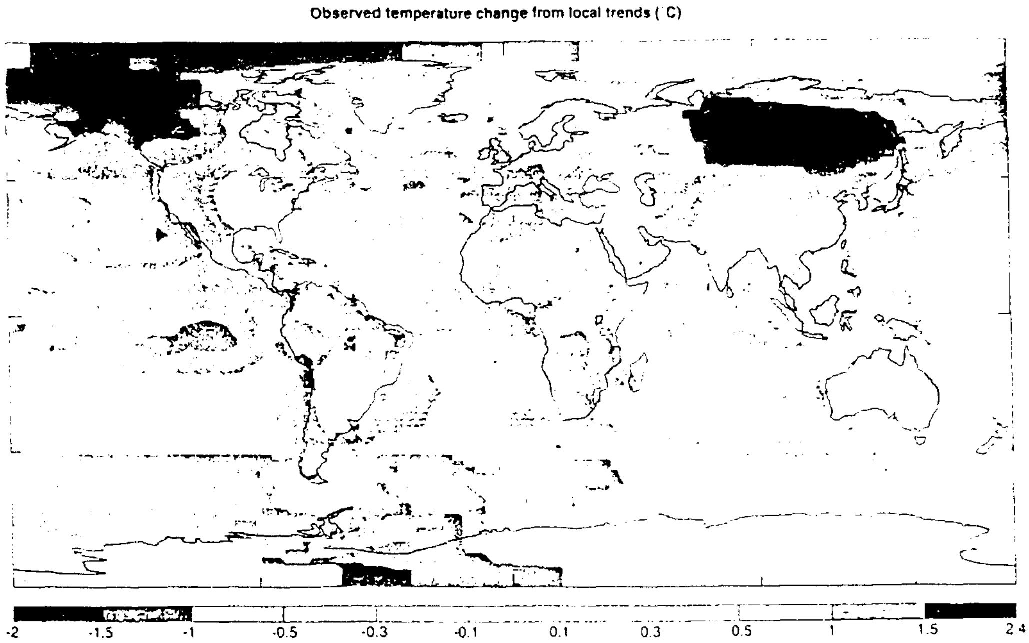
FIGURE 37: SURFACE TEMPERATURE CHANGE 1969-1998



Surface air temperature change between 1969 and 1998 based on land data from the Global Historical Climate Network (GHCN) and ocean temperature data.

Rind 1999, *Science* v 284

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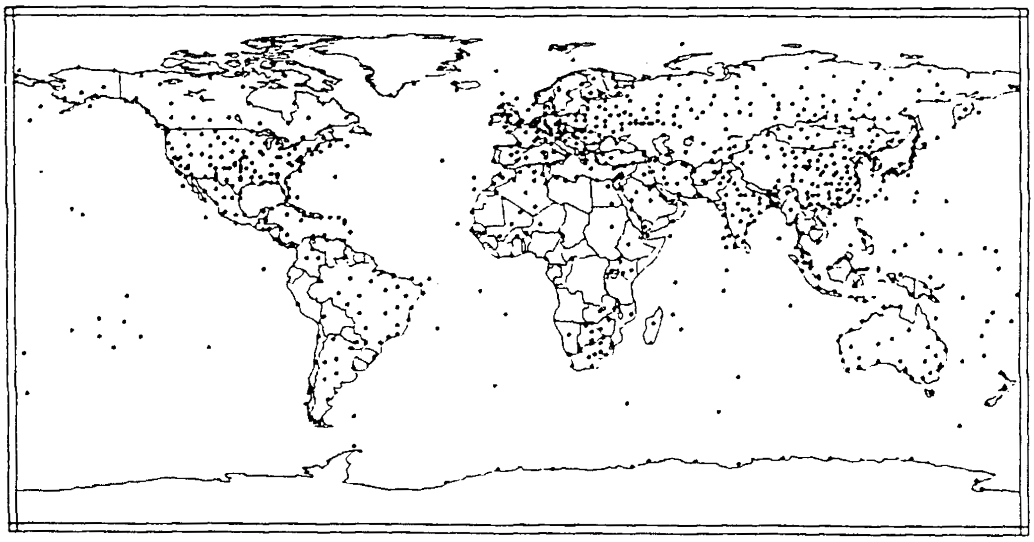
FIGURE 38: LOCATION OF BALLOON-BORNE RADIOSONDE OBSERVATIONS



Panel on Reconciling Temperature Observations 2000, National Research Council, Washington DC

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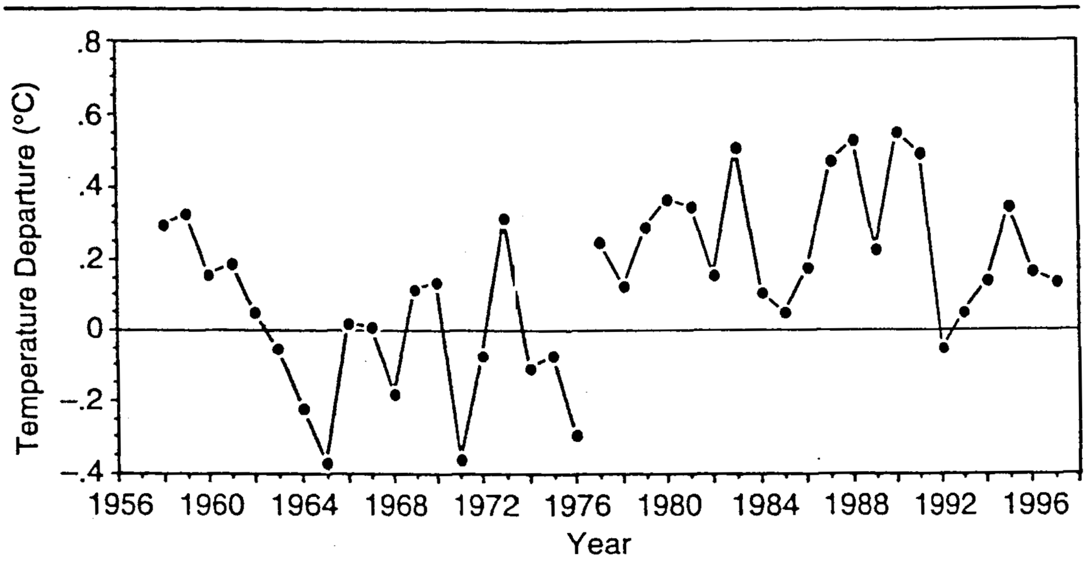
FIGURE 39: BALLOON RECORD OF 5,000–30,000 FT TEMPERATURES



An examination of the entire history reveals a distinct jump in 1976–77 that explains all the warming trend in the entire record.

Michaels & Balling 2000, *The Satanic Gases*, Cato Inst. Washington DC

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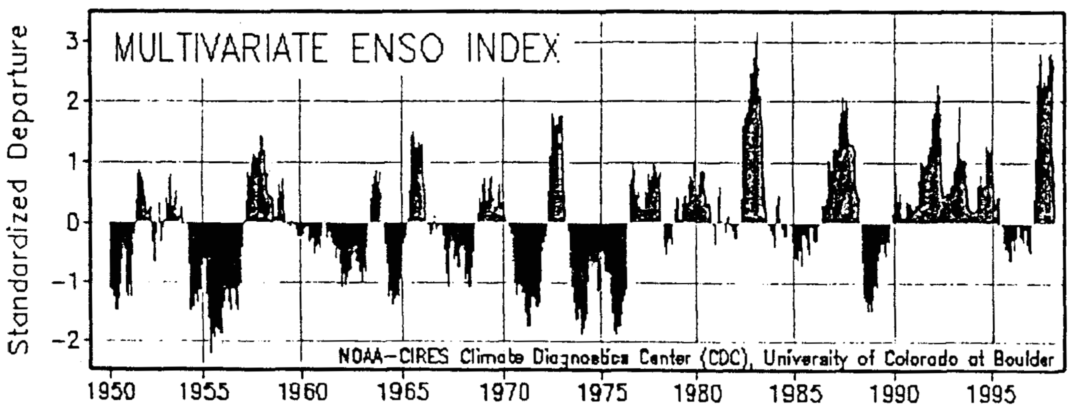
FIGURE 40: EL NINO/SOUTHERN OSCILLATION INDEX



Warmer

Colder

Benfield Greig Hazard Research Centre

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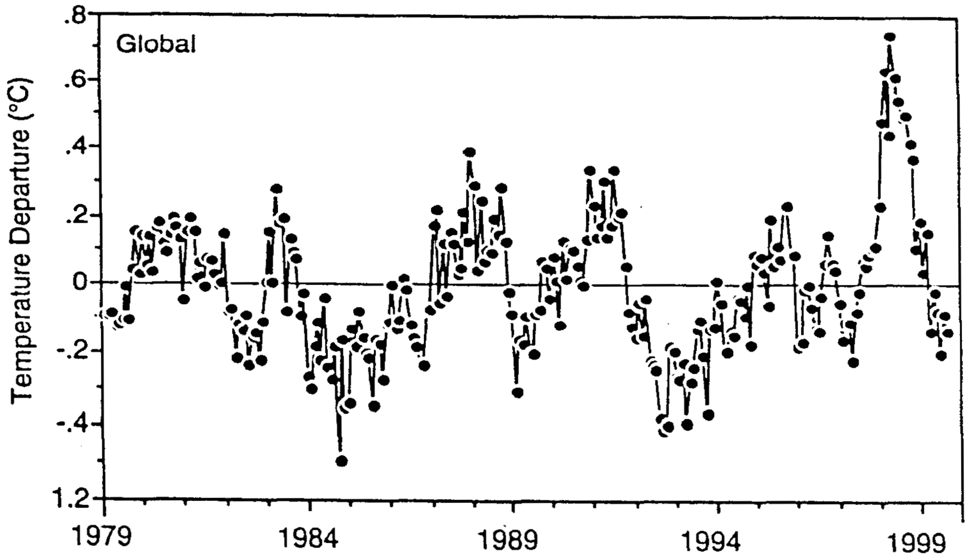
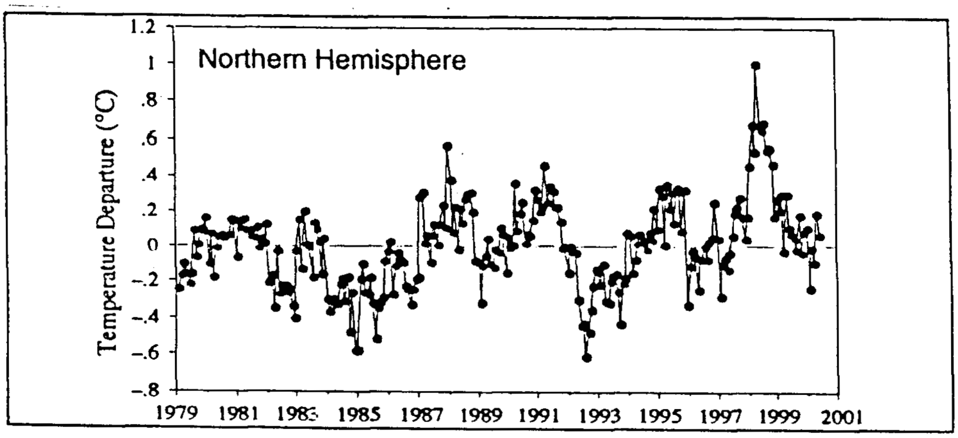
FIGURE 41: MONTHLY TEMPERATURES FROM MSU SATELLITE SENSORS



Michaels & Balling 2000, *The Satanic Gases*, Cato Inst. Washington DC



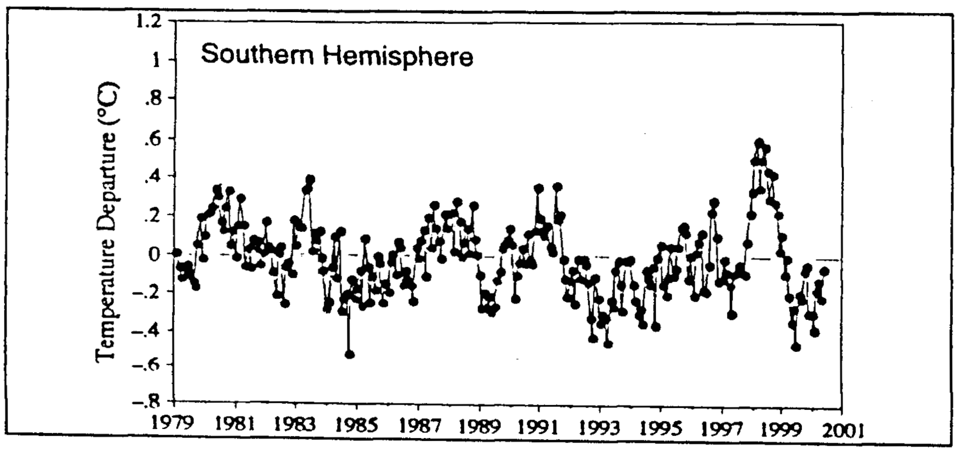


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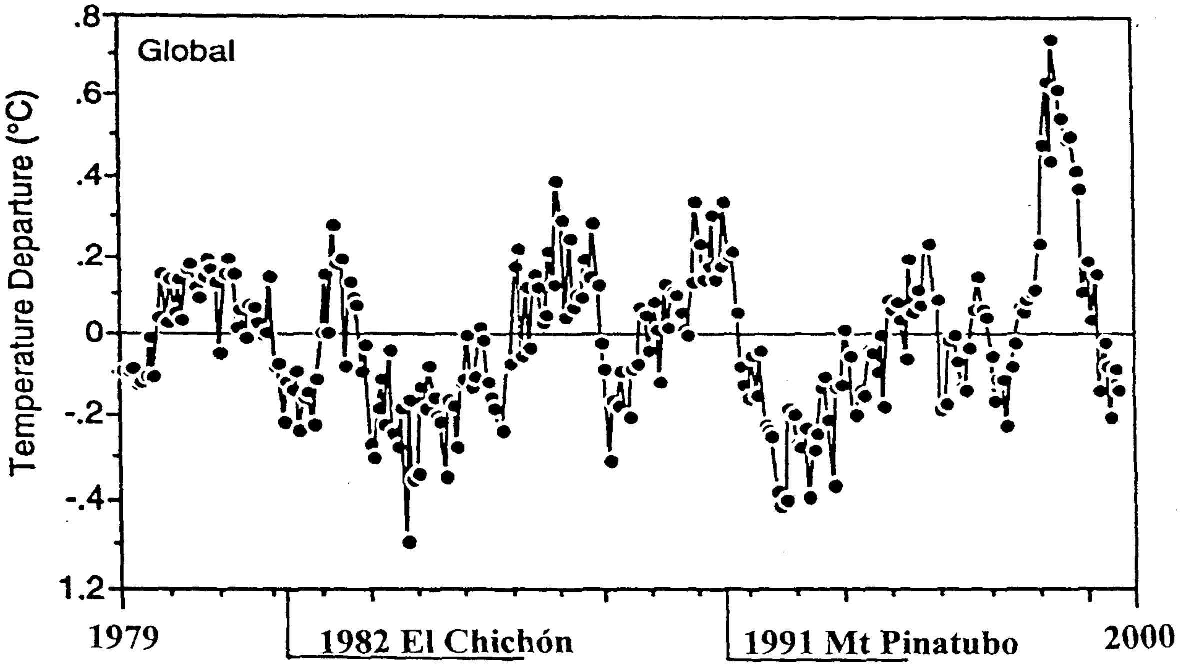
FIGURE 42: VOLCANIC INFLUENCE ON SATELLITE MSU TEMPERATURES



Michaels & Balling 2000, *The Satanic Gases*, Cato Inst. Washington DC

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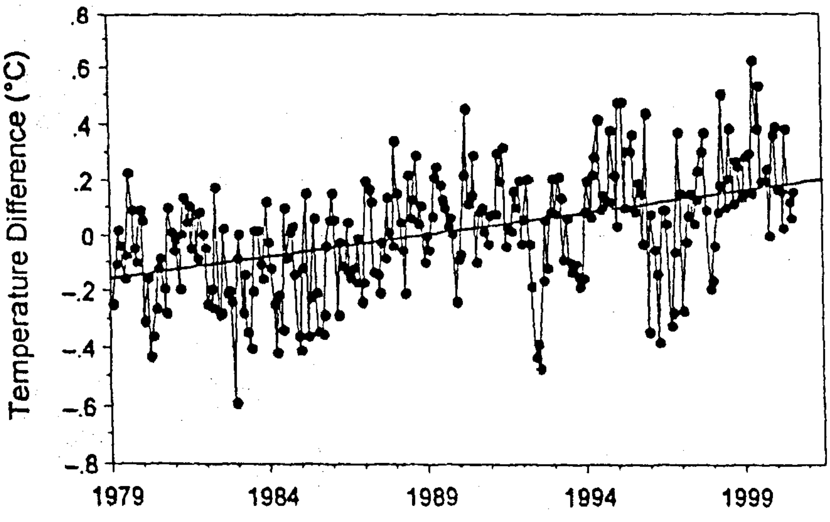
FIGURE 43: SATELLITE-DERIVED LOWER-ATMOSPHERE RECORD



World Climate Report 2000, v 5 no 24

Northern Hemispheric satellite-measured temperatures minus Southern Hemispheric satellite-measured temperatures. If the aerosol cooling effect were as strong as hypothesized, the Northern Hemisphere warming would be lower than in the Southern, where there are very few sulfates to mitigate heating. That would manifest itself as a negative trend. Instead, just the opposite is occurring.

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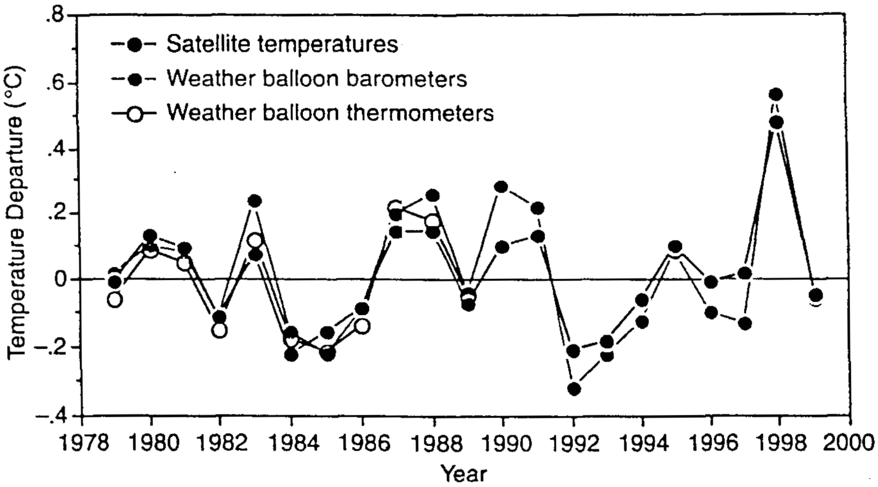
FIGURE 44: SATELLITE-MSU-DERIVED TEMPERATURES COMPARED TO BALLOON-BORNE THERMOMETERS AND BAROMETERS



NOTE: These three independent measures all show the same year-to-year variation and have no warming trend (except the now-departed El Niño spike of 1998).

Michaels & Balling 2000, *The Satanic Gases*, Cato Inst. Washington DC

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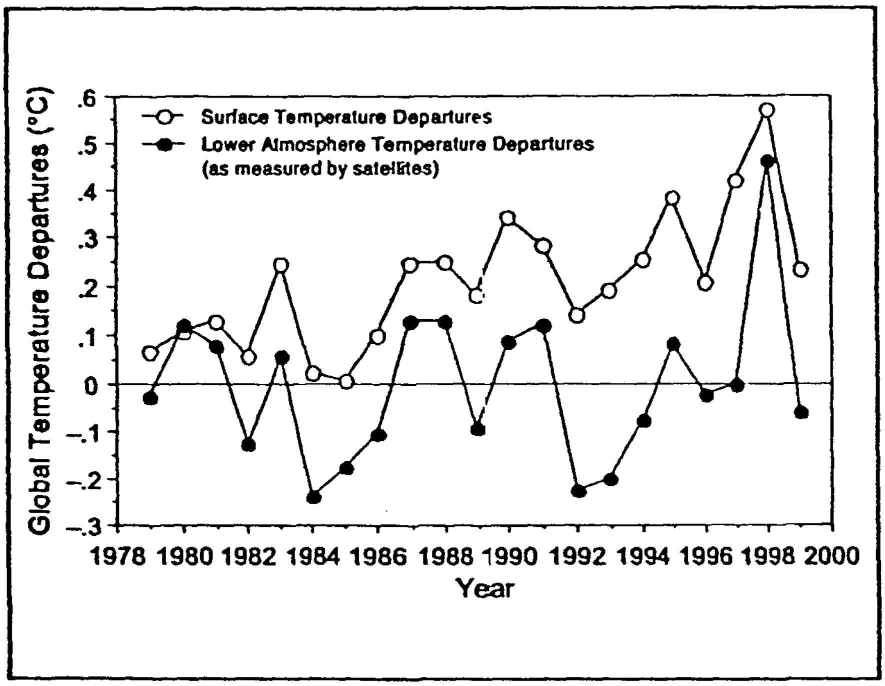
FIGURE 45: SURFACE AND ATMOSPHERE TEMPERATURE TRENDS



***World Climate Report* 2000, v 5 no 10**

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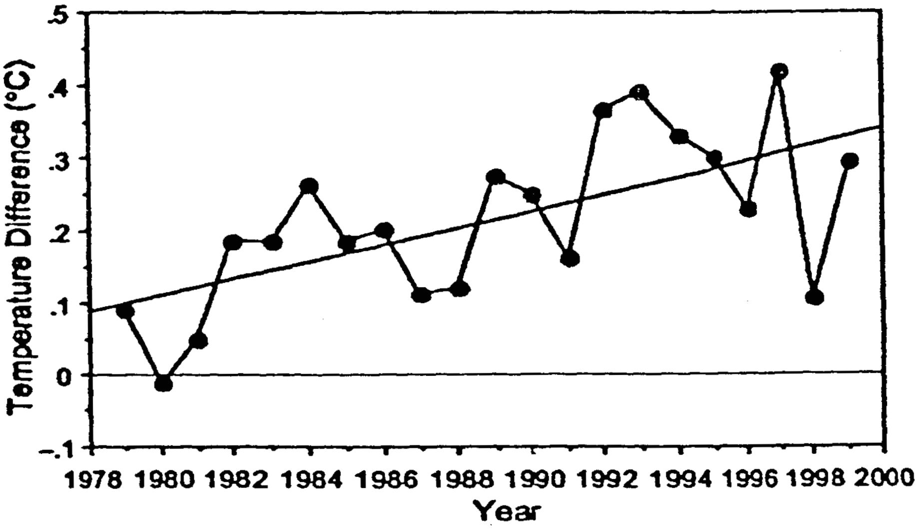
FIGURE 46: GROUND/SATELLITE TEMPERATURE DIFFERENCE



World Climate Report 2000, v 5 no 10

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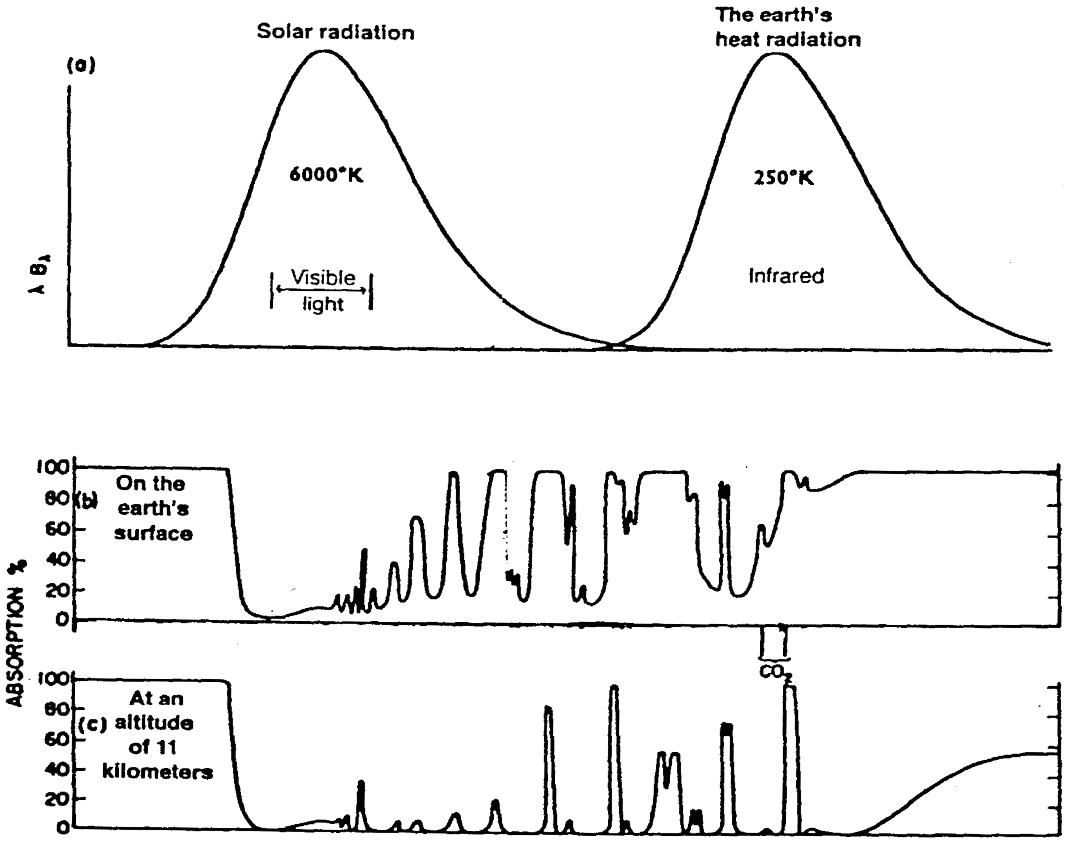
FIGURE 47: ATMOSPHERIC ABSORPTION OF RADIANT ENERGY



Lindzen 1999, <u>in</u> *Climate policy after Kyoto*

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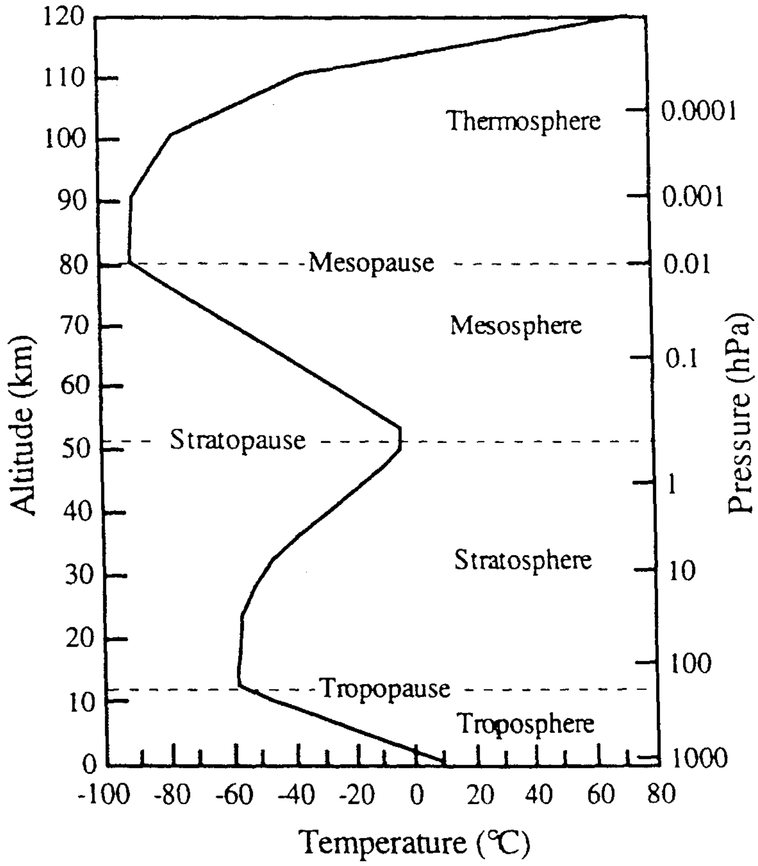
FIGURE 48: TEMPERATURE STRUCTURE OF THE ATMOSPHERE



Edward Bryant 1997, *Climate process & change* CU Press

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FIGURE 49: IPCC SURFACE TEMPERATURE COVERAGE FOR 1998

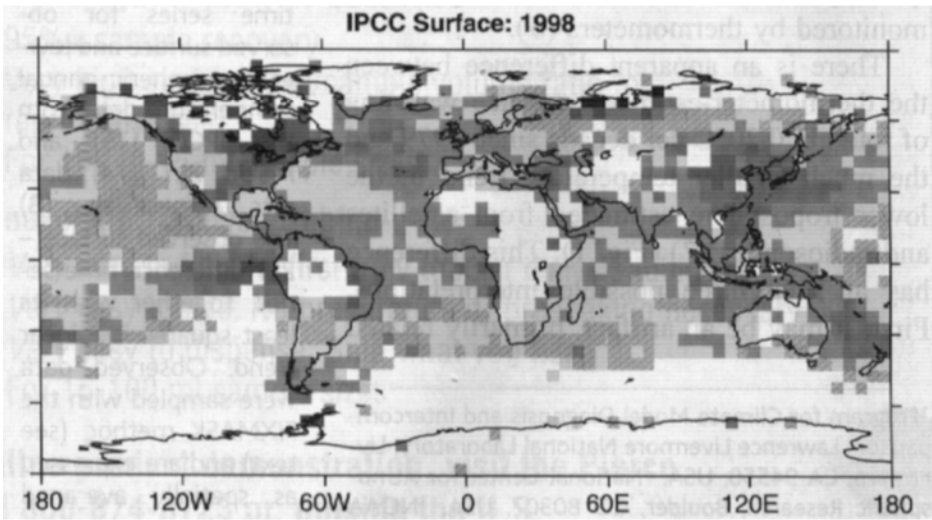

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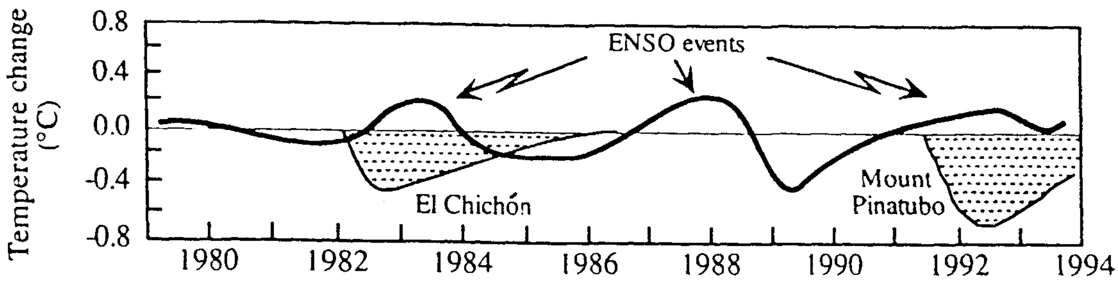
FIGURE 50: IMPACT OF ERUPTIONS ON ATMOSPHERIC TEMPERATURE



Edward Bryant 1997, *Climate process & change* CU Press

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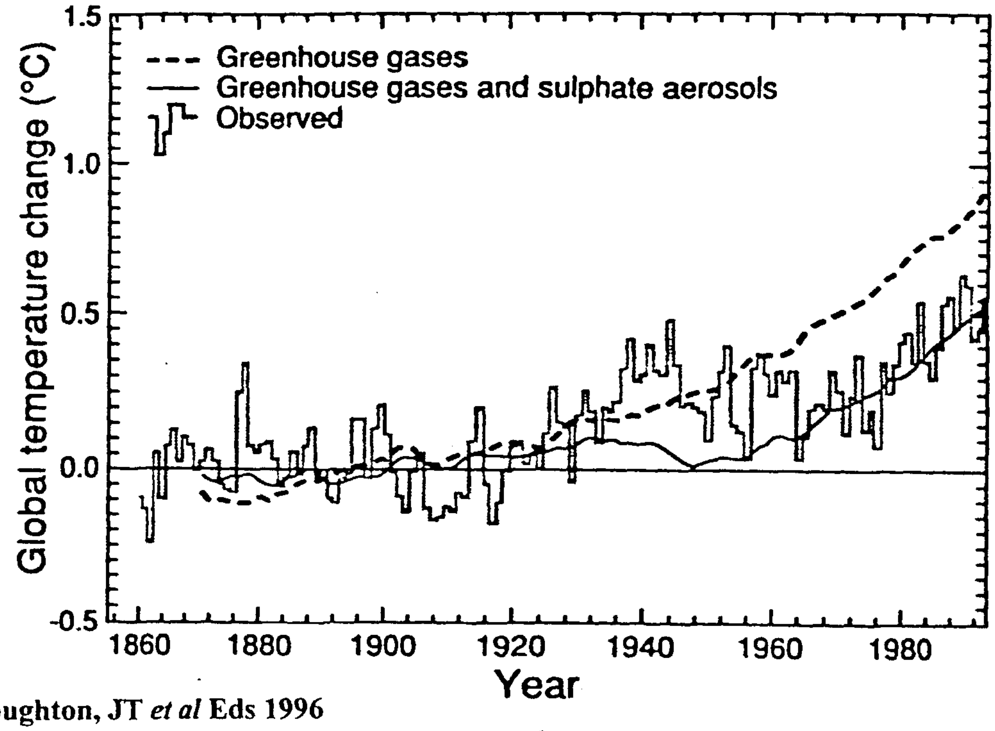
FIGURE 51: OBSERVED *vs* SIMULATED GLOBAL WARMING



Houghton, JT *et al* Eds 1996
Climate change 1995: the science of climate change

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FIGURE 52: ANTHROPOGENIC/BIOGENIC SULPHUR EMISSIONS (JULY)

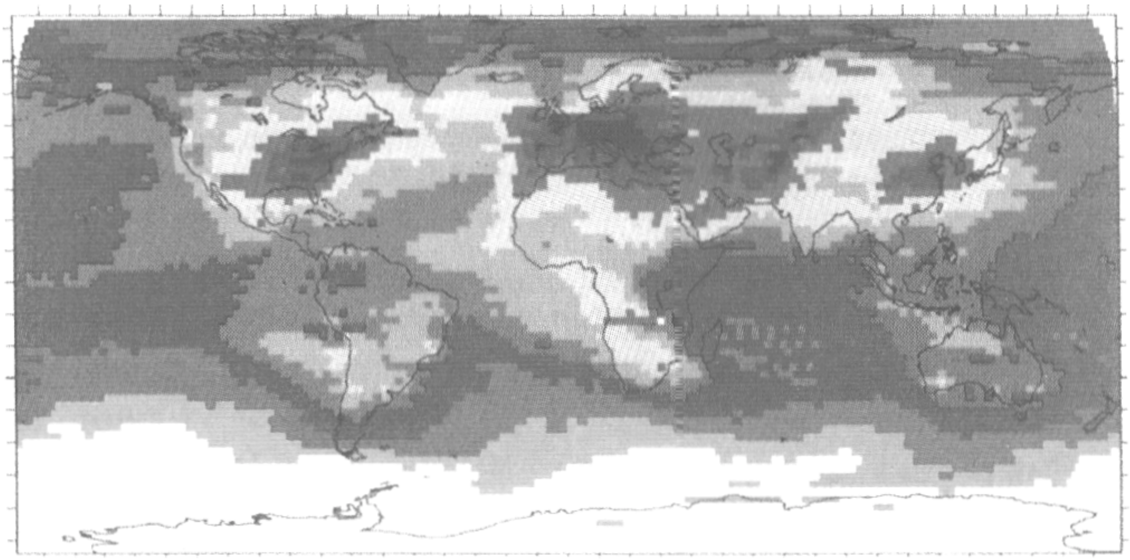

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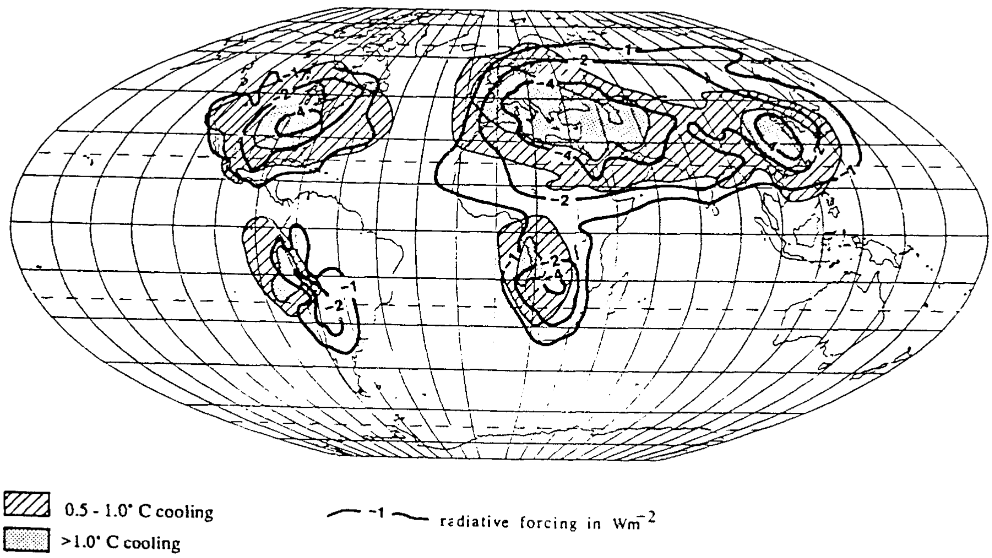
FIGURE 53: COOLING EFFECT OF ANTHROPOGENIC SULPHATES



Global distribution of radiative forcing by anthropogenic sulphates, averaged over the period 1970–1990, and the magnitude of resulting cooling effect in °C (based on Hadley Centre, 1995 and Houghton et al., 1995).

Edward Bryant 1997, *Climate process & change* CU Press

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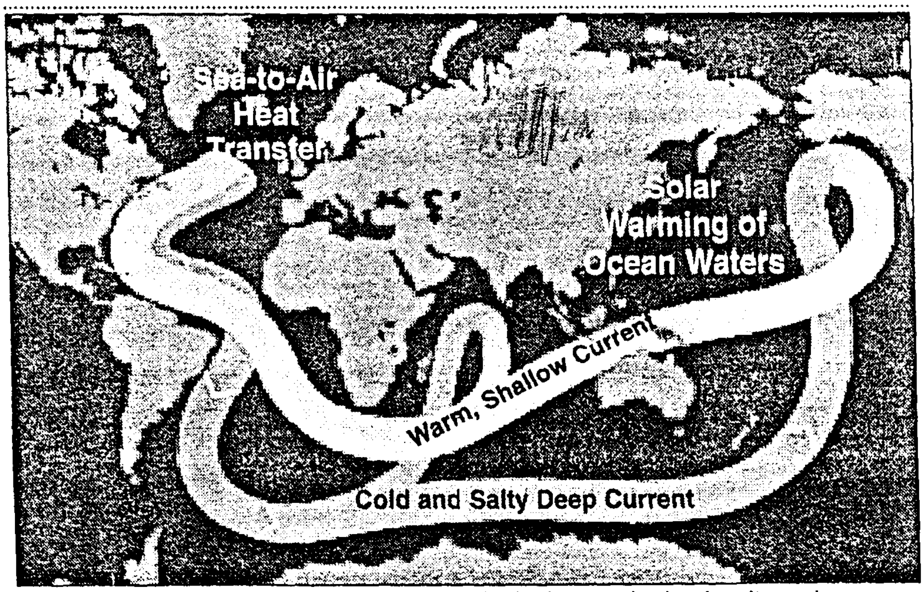
FIGURE 54: THE THERMOHALINE CONVEYOR



The thermohaline circulation, by which changes in the density and saltiness of ocean waters link the world's oceans (and climates) via a global ocean current.

World Cimate Report 2000, v 5 no 21

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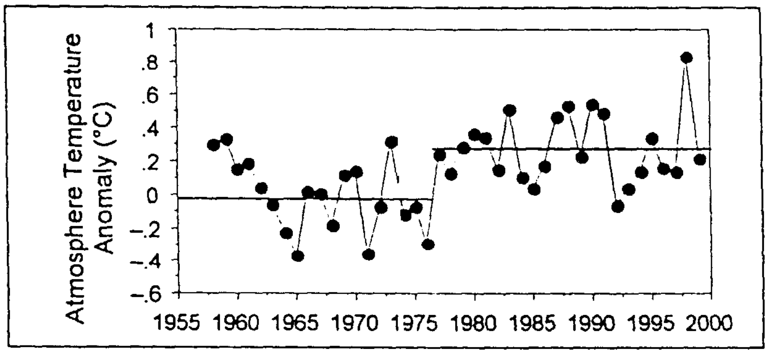
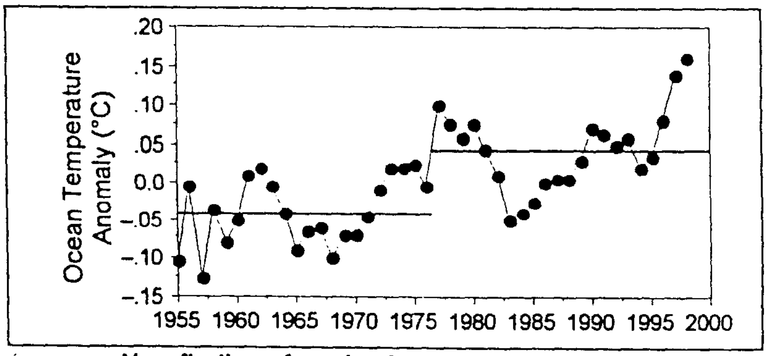
FIGURE 55: COMPARISON OF OCEAN AND ATMOSPHERE TEMPERATURES



Weather balloon measurements of temperatures in the lower atmosphere show a jump in about 1976.

Figure 55



New findings from Levitus, who measured ocean temperatures, also reveal this shift.

World Cimate Report 2000, v 5 no 14

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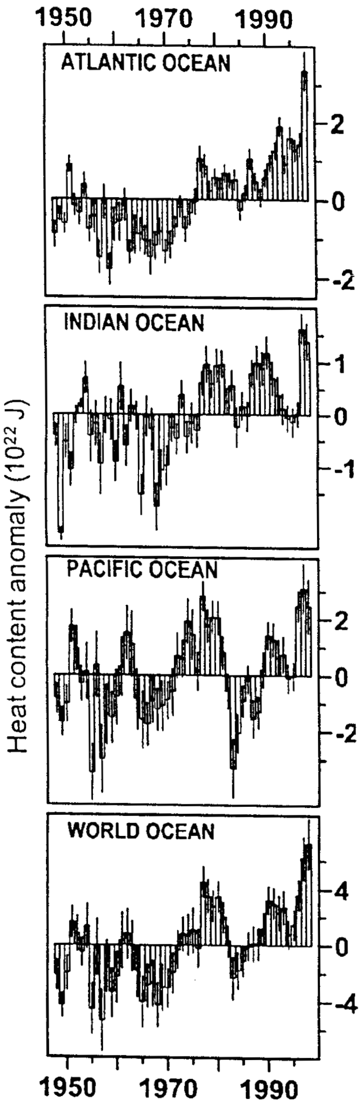

FIGURE 56: OCEAN HEAT CONTENT

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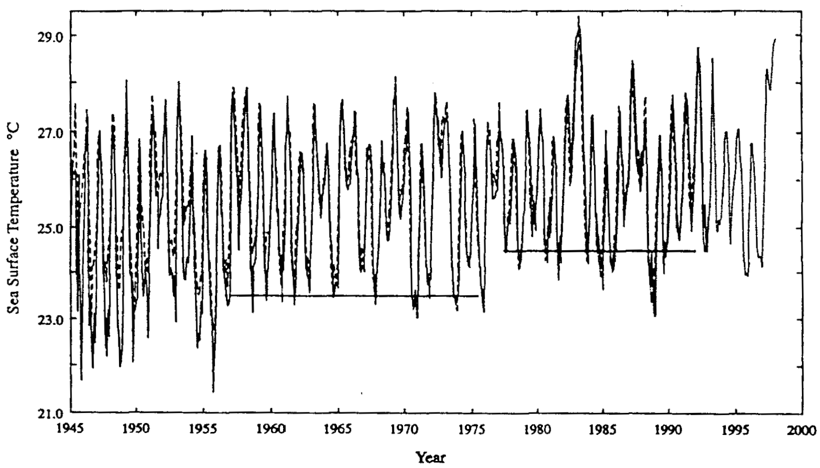
Levitus *et al* 2000, *Nature* v 287

FIGURE 57: TROPICAL PACIFIC TEMPERATURES

Guilderson & Schrag 1998, *Science* v 281



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SSTs in the Niño-3 region (90° to 150°W, ±5°) as observed in COADS (solid line), GOSTA (dashed line), and NMC/IGOSS (dotted line) databases. Warm season SSTs have remained relatively invariant, whereas upwelling season SSTs underwent a step-like warming in 1976.

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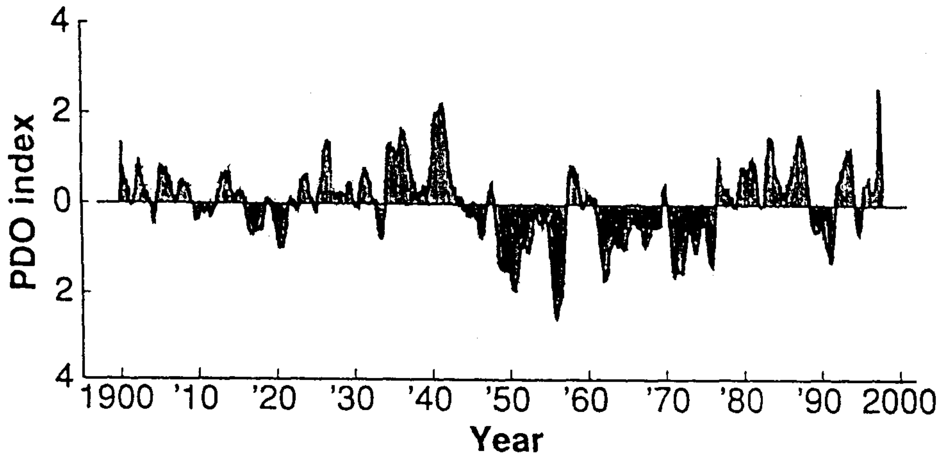
FIGURE 58: PACIFIC DECADAL OSCILLATION



Richard A. Kerr 1998, *Science* v 281

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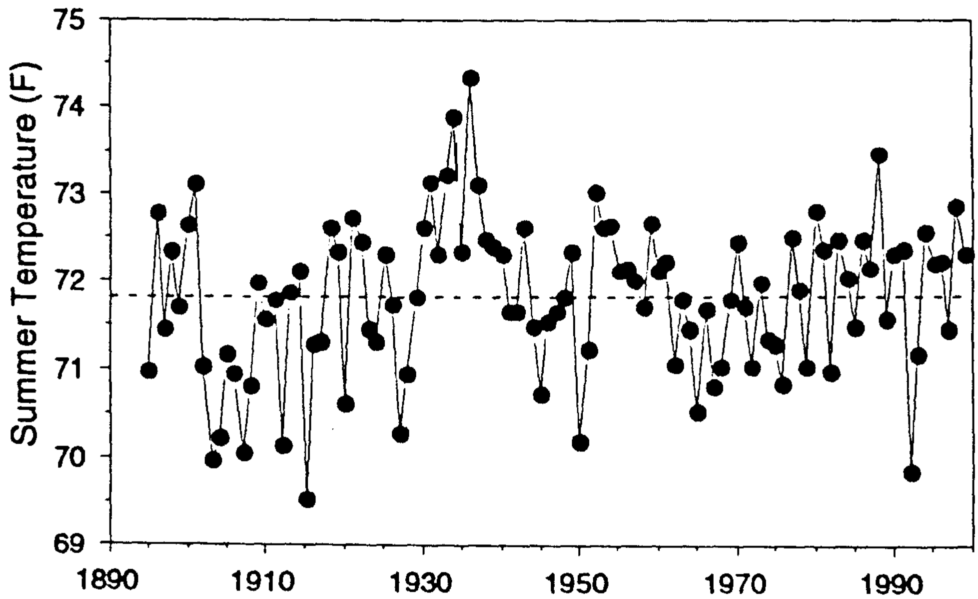
FIGURE 59: SUMMER SURFACE TEMPERATURES: US LOWER-48



Summer temperatures, 1895 to present. No warming trend exists for U.S. summer temperatures

Patrick J Michaels 1999, *World Climate Report* v 5/4

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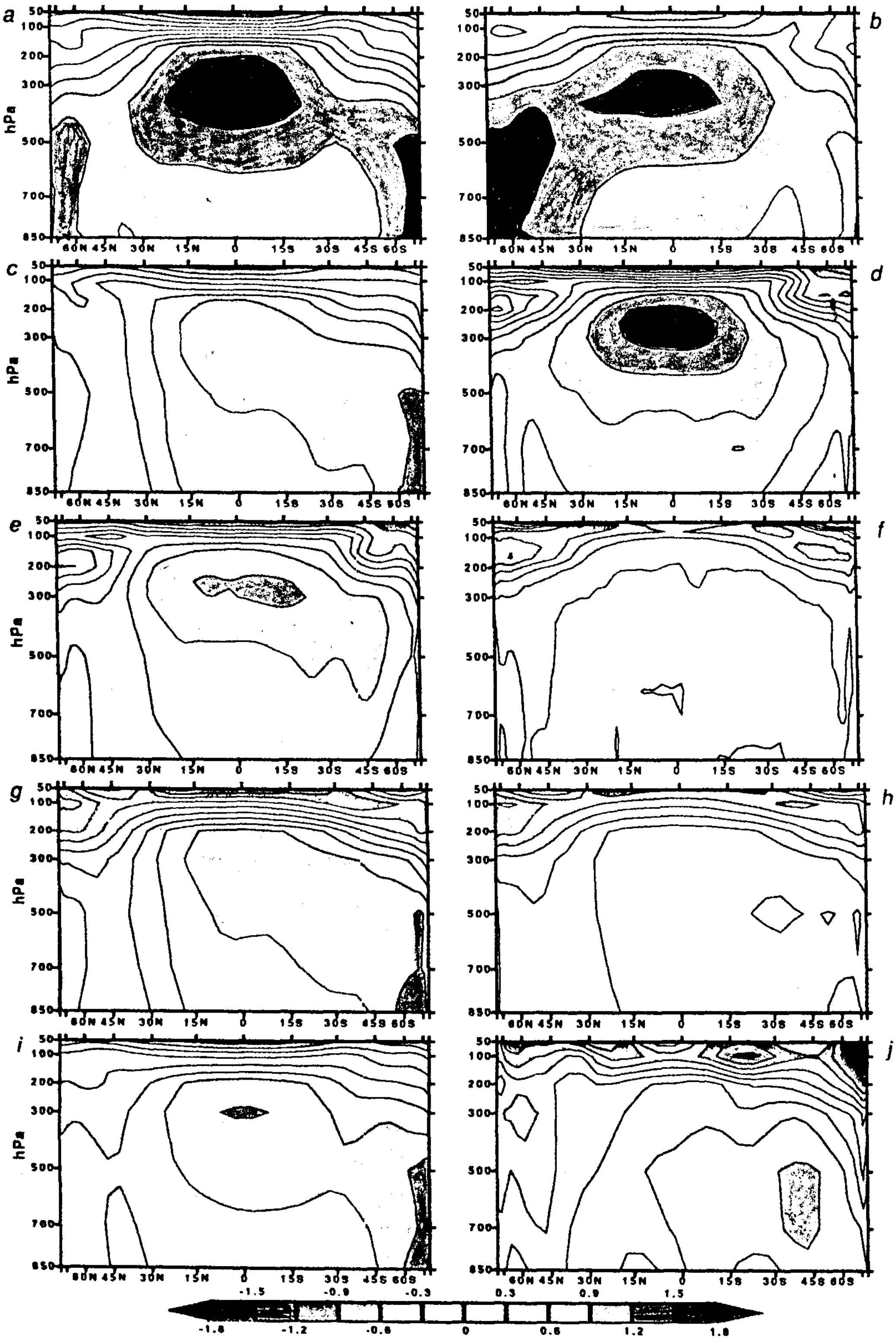
FIGURE 60: THERMAL STRUCTURE OF THE ATMOSPHERE



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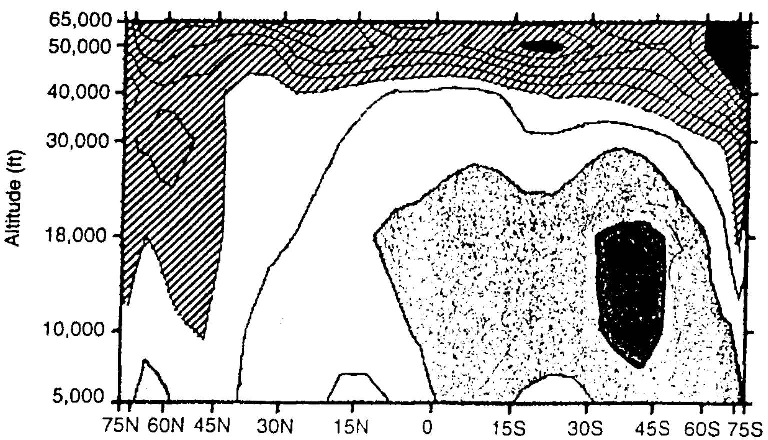
Santer *et al* 1996, *Nature* v 382

FIGURE 61: HUMAN EFFECT ON GLOBAL CLIMATE?

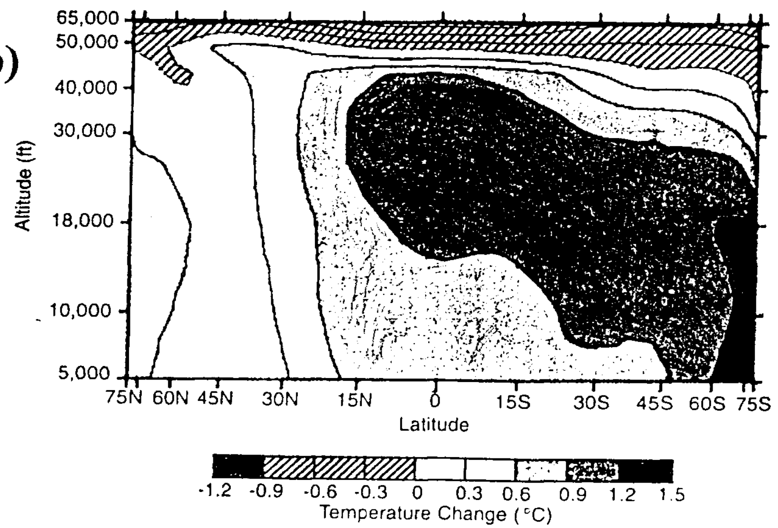
OBSERVED TEMPERATURE CHANGES ON THE LOWER ATMOSPHERE AS PUBLISHED BY SANTER ET AL., 1996

(a)



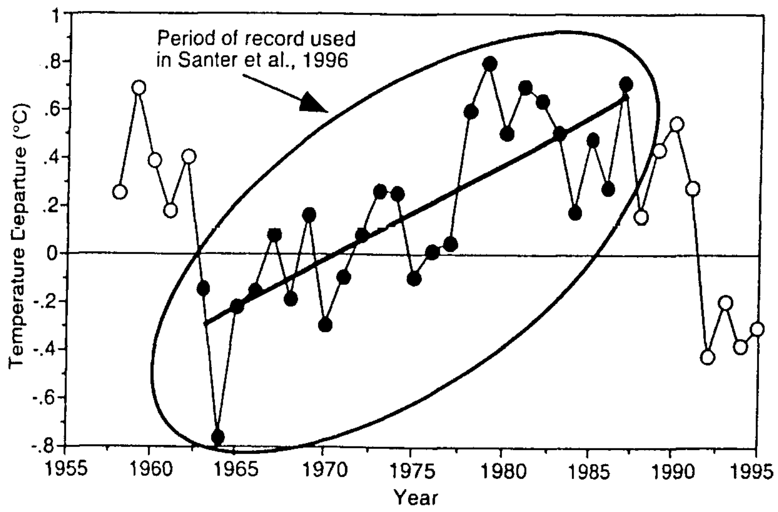
TEMPERATURE CHANGES PROJECTED BY THE TAYLOR AND PENNER MODEL WITH SULFATE AND GREENHOUSE GASES

(b)



(c)

WARM REGION TEMPERATURE HISTORY, 1958–95



SOURCE: Michaels and Knappenberger, 1996.

NOTE: The closed circles represent the data used in the study, compared with the data excluded (open circles). The "human fingerprint" Santer et al. claimed in their study was largely a result of the years chosen.

BACK

Michaels and Balling 2000,
***The Satanic Gases*, Cato Inst. Washington DC**

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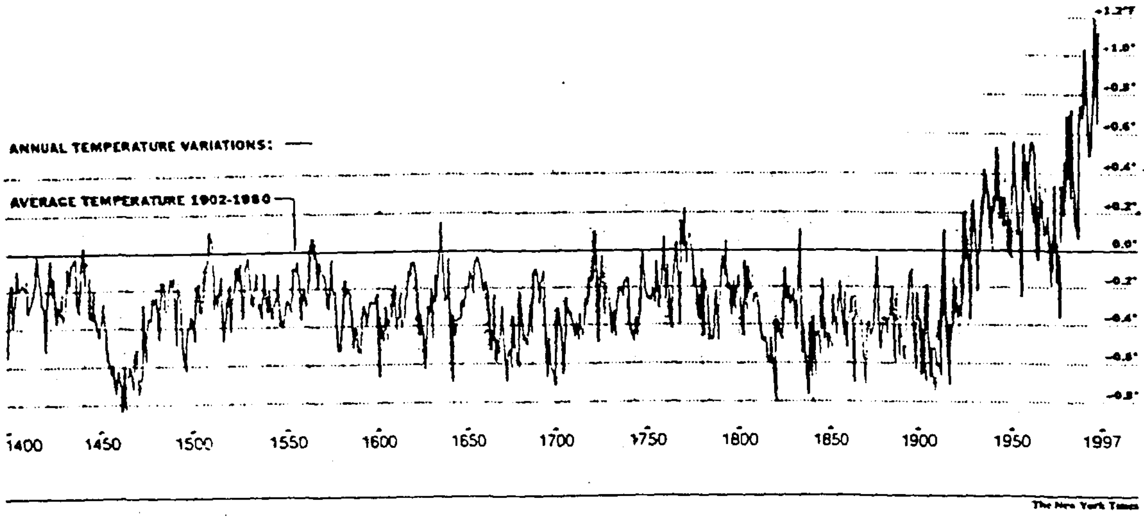
FIGURE 62A: WARMER WEATHER, RECENTLY, IN NORTHERN HEMISPHERE



The New York Times
(adapted from Mann, Bradley & Hughes 1998, *Nature* v 392)

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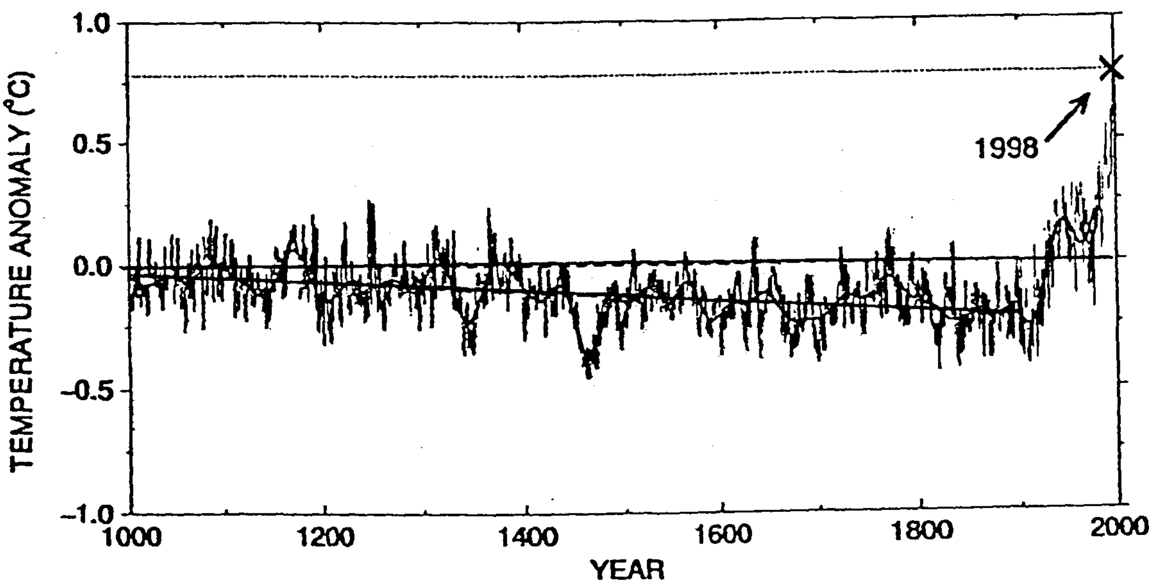
FIGURE 62B: RECONSTRUCTED NORTHERN HEMISPHERE TREND



Mann, Bradley & Hughes 1999, *Geophysical Research Letters* v 26

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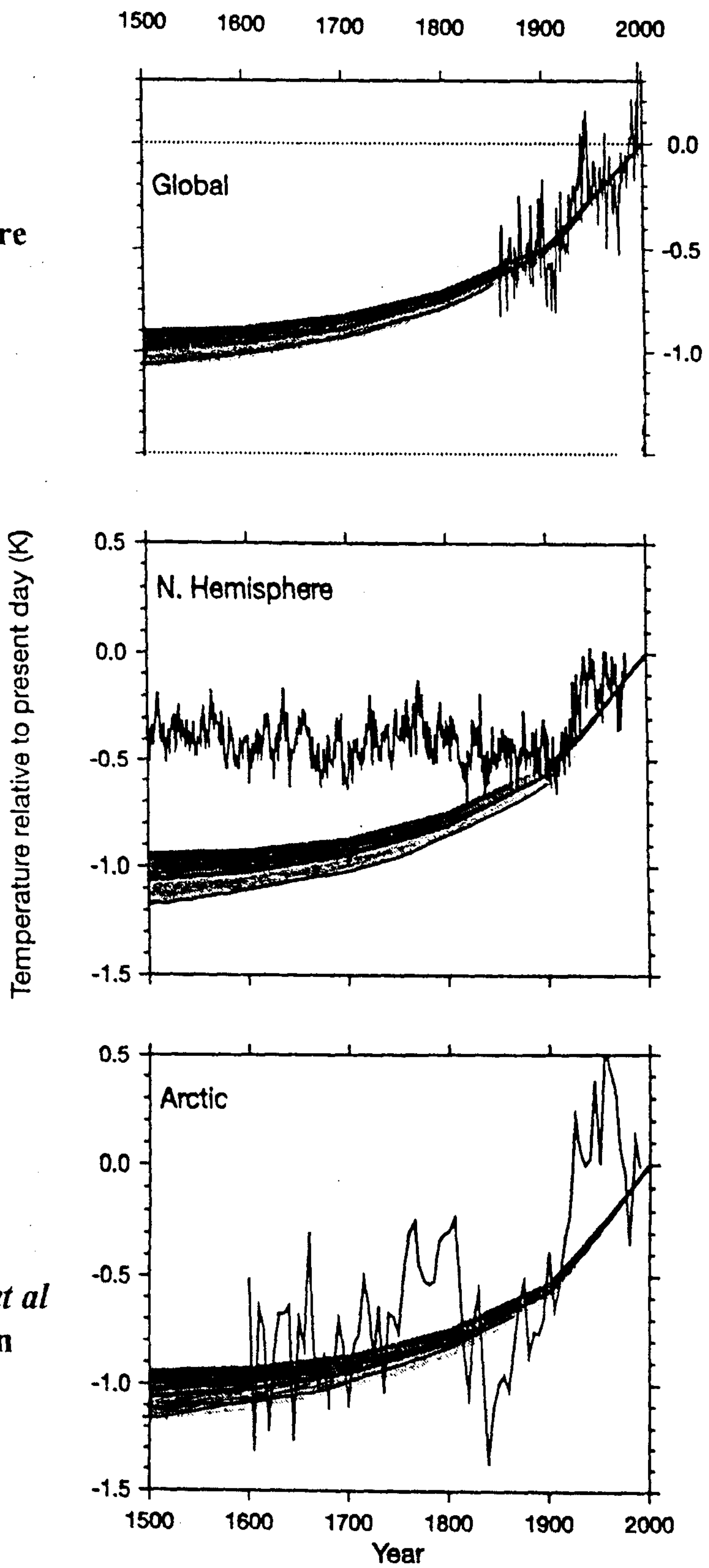
FIGURE 63: TEMPERATURE TREND FROM BOREHOLES

cf Surface air temperature



cf Mann *et al* reconstruction

cf Overpeck *et al* reconstruction

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Huang, Pollack & Shen 2000, *Nature* v 403

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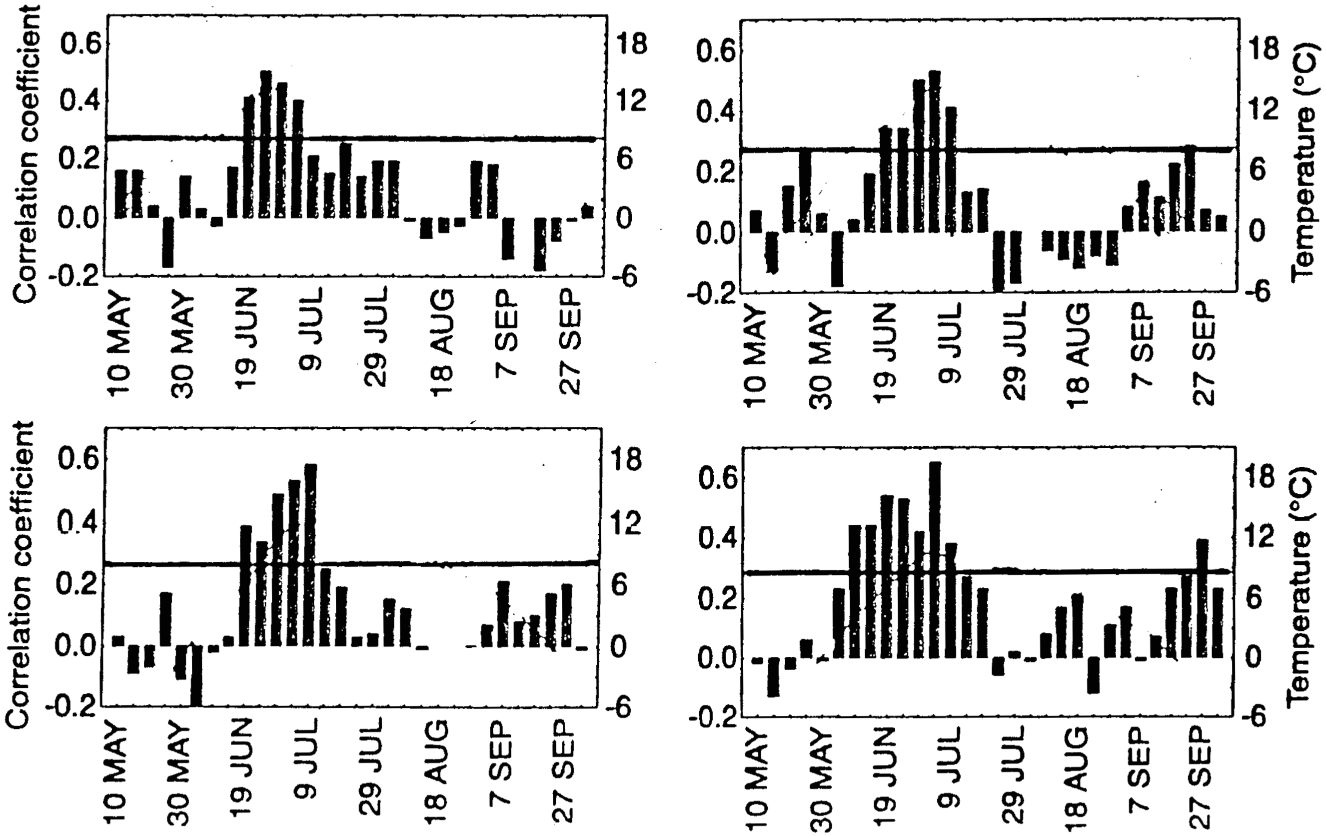
FIGURE 64: TREE GROWTH IN SUBARCTIC EURASIA

Vaganov *et al*,

***Nature* 1999**



Correlation of the mean temperature of five consecutive days with tree-ring width indices

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FIGURE 65A: ARCTIC NEAR-SURFACE TEMPERATURES

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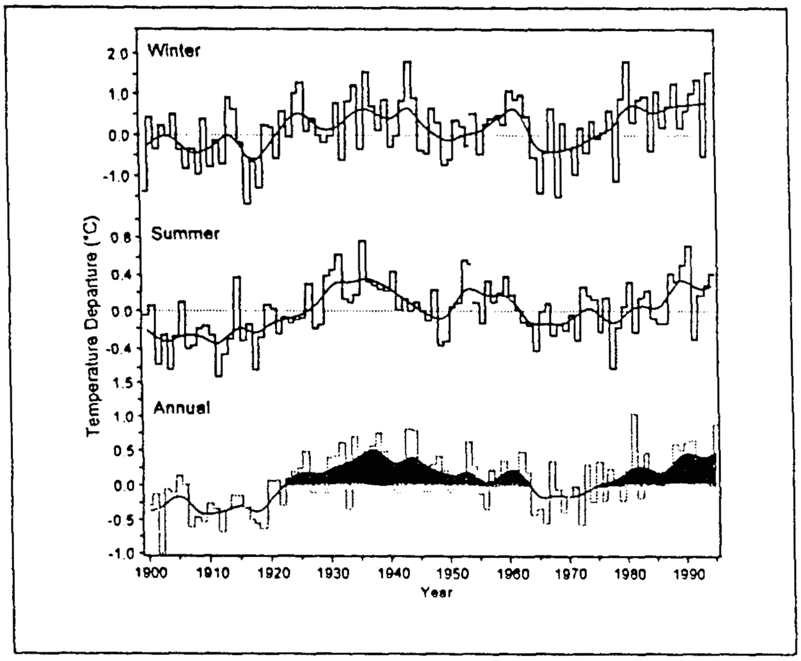

Winter, summer, and annual temperatures from the United Nations' Intergovernmental Panel on Climate Change for the North polar region (latitude 55°N or higher) from Serreze and colleagues (2000). The integrated warming early in the last century—before humans could change the climate very much—is larger than the current warming.

FIGURE 65B: ARCTIC NEAR-SURFACE TEMPERATURES

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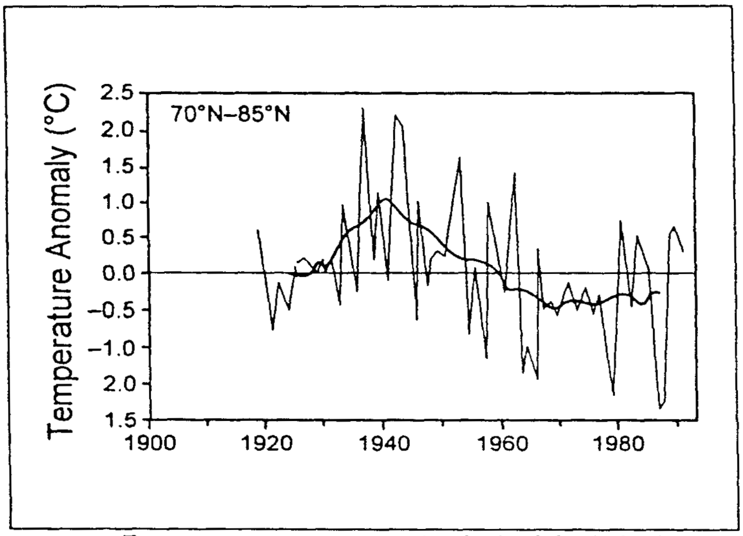

Temperature records starting in 1920 for latitude 70°N and higher, published by Pryzbylak (2000), show a decline since 1940.

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FIGURE 66: RUSSIAN HIGH ARCTIC TREE-RING RECORD

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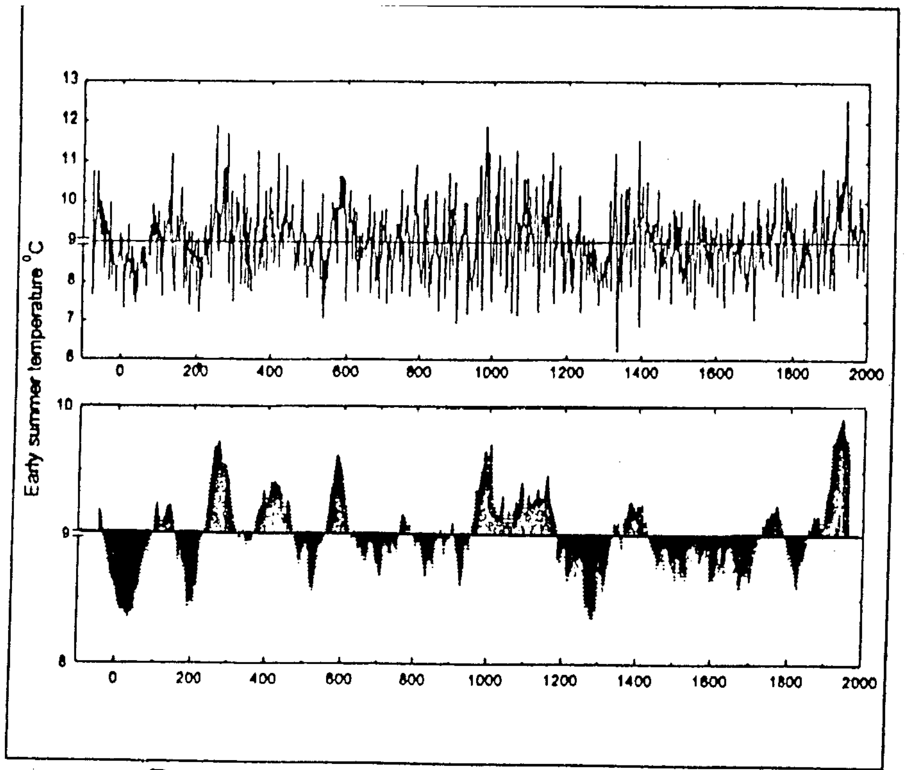

Reconstructed early summer temperature history in northern Siberia (top) and a 57-year smoothed version of the same data (bottom) show the warming in the first half of the 20th century is not unprecedented: In fact, it has natural counterparts in past centuries.

Naurzbaev and Vaganov 2000, *Jour Geophys Res* v 105 D6

FIGURE 67: PAST GREENLAND SURFACE TEMPERATURE

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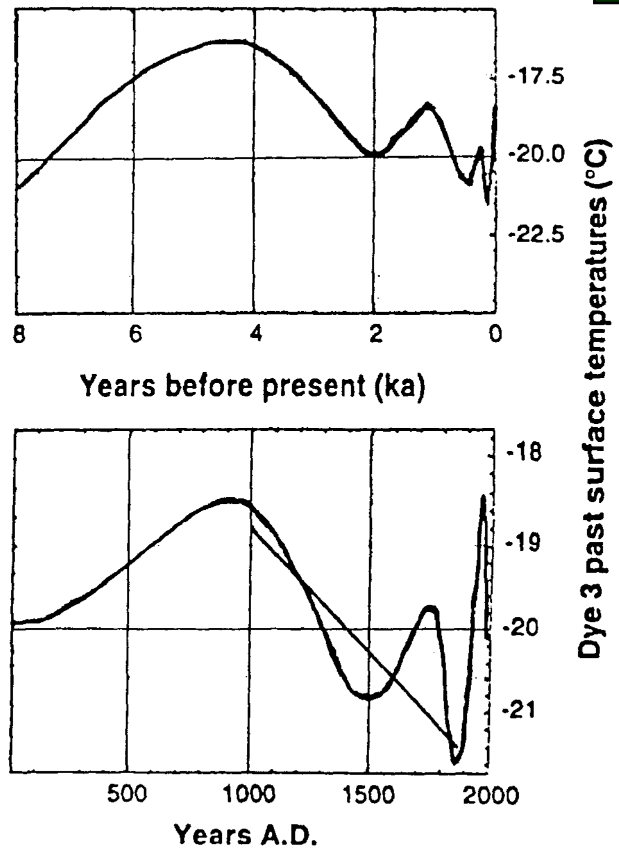

Dahl-Jensen, D *et al* 1998, *Science* v 282

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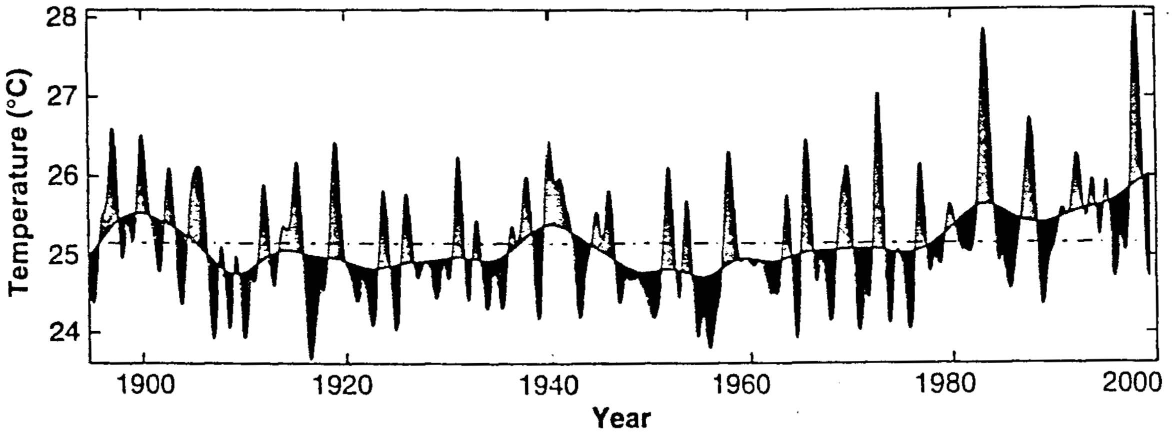
FIGURE 68: EQUATORIAL EASTERN PACIFIC SEA-SURFACE TEMPERATURE



The interannual oscillations in sea surface temperature (SST) at the equator in the eastern Pacific (averaged over the area 5°S to 5°N, 80° to 120°W) shown on the background of the decadal fluctuation (obtained by means of a low-pass filter) after removal of the annual cycle and higher frequency variability. The horizontal dot-dashed line is the time average for the record.

Federov and Philander 2000, *Science* v 288

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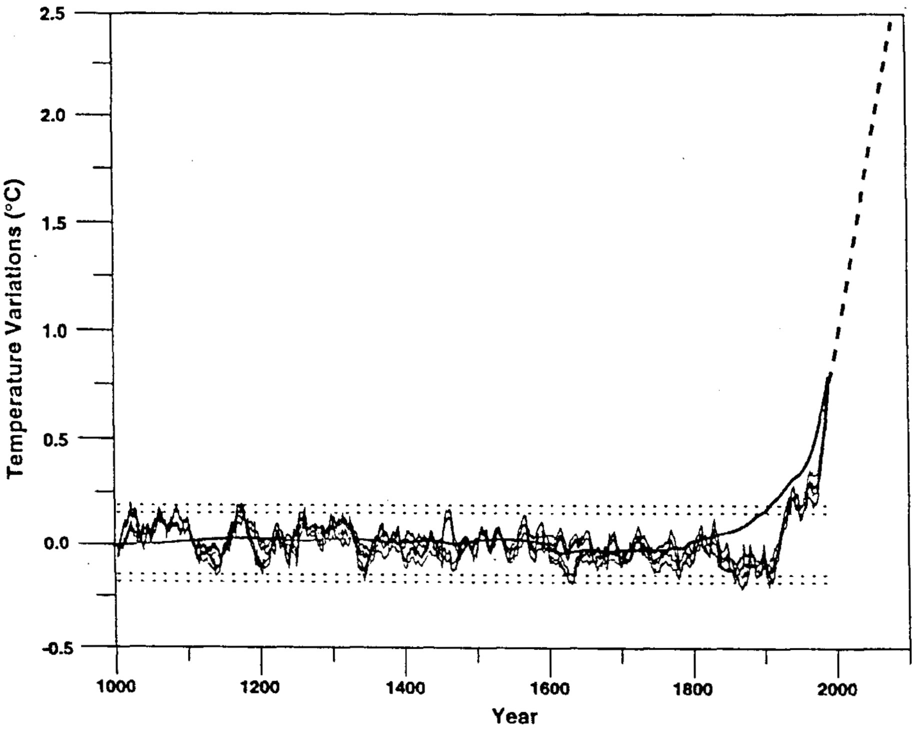
FIGURE 69: MODEL SIMULATION OF 21ST CENTURY TEMPERATURE



Thomas J. Crowley 2000, *Science* v 289

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