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OPEC Meeting in Vienna - April

Global Warming: the Origin and Nature of Alleged Scientific Consensus

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Introduction

Most of the literate world today regards 'global warming' as both real and dangerous. Indeed, the diplomatic activity concerning this issue would have one believe that this is the major crisis confronting mankind. The forthcoming environmental conference (Earth Summit) in Rio will focus on international agreements to deal with this threat, and the heads of state from dozens of countries are scheduled to attend. I must state at the outset, that, as a scientist, I can find no substantive basis for the warming scenarios being popularly described. Moreover, according to many studies I have read by economists, agronomists, and hydrologists there would be little difficulty adapting to such warming if it were to occur. (Such was also the conclusion of a recent National Research Council report on adapting to global change.) Many aspects of the catastrophe scenario have already been largely discounted by the scientific community. For example, fears of massive sea level increases accompanied many of the early discussions of global warming, but these estimates have been steadily reduced by orders of magnitude, and now it is widely agreed that even the potential contribution of warming to sea level rise would be swamped by other more important factors.

How did this peculiar situation arise? Although my lecture will focus on global warming, where I have personally followed the phenomenon, what I will describe is similar to what is happening with respect to many other environmental 'crises' including ozone depletion, acid rain, diminishing species diversity and contamination by PCB's, dioxin, asbestos and lead. Nevertheless, there are differences as well — at least in scale.

Before I continue, it will be essential to briefly review the science associated with the prediction of global warming in order that you can understand why I state that there is no substantive basis for predictions of sizeable global warming due to observed increases in minor greenhouse gases like CO_2, methane, and chlorofluorocarbons.

Summary of Scientific Issues

Before even discussing 'greenhouse theory', it may be helpful to begin with the issue that is almost always taken as a given: namely, that CO_2 will inevitably increase to values double and even quadruple present values. Figure 1 shows the behaviour of CO_2 since about 1800. Before 1958, the record is based on the analysis of ice cores. After 1958, it is based on direct atmospheric sampling. Clearly, CO_2 has been increasing. Prior to 1800 the density was about 275 ppmv (parts per million by volume). Today it is about 355 ppmv. The increase is generally believed to be due to the combination of increased burning of fossil fuels and (before 1905) to deforestation. The total source is estimated to have been increasing exponentially with a characteristic time of 45 years — at least until 1973. From 1973 until 1990 the rate of increase has been much slower. About half the production of CO_2 has appeared in the atmosphere.

Predicting what will happen to CO_2 over the next century is a rather uncertain matter. By assuming a shift toward coal, substantial advances in the third world's standard of living, large population increases, and a reduction in use of nuclear and other non fossil fuels, one can generate an emissions scenario which will lead to a doubling of CO_2 by 2030—if one uses a particular model for the chemical response to CO_2 emissions. This was referred to as the 'business as usual' scenario by the Intergovernmental Panel on Climate Change Working Group I. As it turns out, the chemical model used was inconsistent with the past century's record; it would have predicted that we would already have over 400 ppmv. An improved model developed at the Max Planck Gesellschaft in Hamburg shows the so called 'business as usual' scenario does not even double CO_2 by the year 2100. As we see from Figure 2, their model shows that under other scenarios, we may not even get much more CO_2 than is already in the atmosphere. Personally speaking, it seems unlikely that the indefinite future of energy belongs to coal. I also find it difficult to believe that technology won't lead to improved nuclear reactors within 50 years.

Nevertheless, we have already seen a significant increase in CO_2 which has been accompanied by in-

creases in other minor greenhouse gases as well (methane, chlorofluorocarbons, etc.). Indeed, in terms of greenhouse potential, we have had the equivalent of a 50% increase in CO_2 over the past century. The effects of these increases are certainly worth studying—quite independent of any uncertain future scenarios.

Figure 3 shows the common popular presentation of the greenhouse effect. The crude idea is that the atmosphere is transparent to sunlight (apart from the very significant reflectivity of both clouds and the surface) which heats the Earth's surface. The surface attempts to balance this heating by radiating in the infrared. The infrared radiation increases with increasing surface temperature and the temperature adjusts until balance is achieved. If the atmosphere were also transparent to infrared radiation, then the infrared radiation produced by an average surface temperature of -18°C would balance the incoming solar radiation (less that amount reflected back to space by clouds, etc.). However, the atmosphere is not transparent in the infrared, and so the Earth must heat up somewhat more in order to deliver the same flux of infrared radiation to space. This is what is called the greenhouse effect. The fact that the earth's average surface temperature is 15°C rather than -18°C is attributed to this effect. The main absorbers of infrared in the atmosphere are water vapour and clouds. Even if all other greenhouse gases (like carbon dioxide and methane) were to disappear, we would still be left with over 98% of the current greenhouse effect. Nevertheless, it is presumed that increasing carbon dioxide and other minor greenhouse gases will lead to significant increases in temperature. As we have seen, CO_2 is increasing. So are other minor greenhouse gases. A widely held, but (as we have discussed) questionable, contention is that these increases will continue along the path they have followed for the past century.

Before continuing, it is worth noting that the simple picture of the greenhouse mechanism is seriously oversimplified. Many of us were taught in elementary school that heat is transported by radiation, convection, and conduction. The above picture only refers to radiative transport. As it turns out, if there were only radiative transport in the atmosphere, the greenhouse effect would warm the Earth's surface by about 77°C rather than by 15°C. In fact, the greenhouse effect is only about 25% of what it would be in the purely radiative situation. The reason for this is the presence of convection (heat transport by air motions), which cancels as much of the radiative absorption. What actually happens is schematically illustrated in Figure 4. Most of the Earth is cooled in large measure by clouds (in various forms including deep clouds) which transport heat upward and poleward. One consequence of this picture is that it is the greenhouse gases in the Earth's surface that are of primary importance in determining the temperature of the Earth. This is especially important for water vapour whose density decreases by about a factor of 1000 between the surface and 10 km. Another consequence is that one cannot even calculate the temperature of the Earth without models that accurately reproduce the motions of the atmosphere. Indeed, present models have large errors here (order 50%) and, not surprisingly, these models are unable to correctly calculate either the present average temperature of the Earth or the equator-pole temperature distribution. Rather, the models are adjusted (or 'tuned') to get these quantities approximately right.

Having said all this, it is still of interest to ask what we would expect a doubling of CO_2 to do. A large number of calculations show that if this is all that happened, we might expect a warming of from 0.5-1.2°C. The general consensus is that such warming would present few if any problems. However, even this prediction is subject to some uncertainty because of the complicated way the greenhouse effect actually operates. More important, the climate is a complex system where it is impossible for all other factors to remain constant.

In present models, these other factors (commonly referred to as feedbacks) act as destabilizing factors which amplify the effects of increasing CO_2, leading to predictions of warming in the neighborhood of 4-5°C. The most important of these factors in current climate models is due to water vapour. In all current models, upper tropospheric (5-12 km) water vapour, the major greenhouse gas, increases as surface temperatures increase. Without this feedback, no current model would predict warming in excess of 1.7°C—regardless of any other feedback. Unfortunately, the way these factors (like clouds and water vapour) are handled in present models is disturbingly arbitrary. In many instances the underlying physics is simply not known. In other instances there are identifiable errors. Even computational errors play a major role. For example, existing models have only 10-20 levels in the vertical, which is inadequate for predicting the behaviour of a substance like water vapour which varies immensely with height. The difficulty leads to model predictions of negative water vapour in some parts of the atmosphere. The arbitrary filling routines used to correct this obviously unrealistic behaviour play a major role in the model water vapour budgets. In fact, there compelling evidence for all the known destabilizing feedbacks in the models to actually be stabilizing (negative) feedbacks. In that case, we would expect the response to CO_2 doubling alone to be diminished.

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It is commonly suggested that society should not depend on negative feedbacks to spare us from a 'greenhouse catastrophe'. What is omitted from such suggestions is that current models depend heavily on artificial positive feedbacks to predict high levels of warming. The positive feedback from clouds has been

receiving the closest scrutiny. This is not unreasonable. Cloud cover in models is poorly treated and inaccurately predicted. Yet clouds reflect about 75 watts per square meter. Given that a doubling of CO_2 will change the surface flux by only 2 watts per square meter, it is evident that a small change in cloud cover can strongly effect the response to CO_2. The situation is complicated by the fact that clouds at high altitudes can also supplement the greenhouse effect. Indeed, the effects of clouds in reflecting light and in enhancing the greenhouse effect are roughly in balance. Their actual effect on climate depends both on the response of clouds to warming, and on the possible imbalance of their cooling and heating effects. Similarly, feedbacks involving the contribution of snow cover to reflectivity serve, in current models, to amplify warming due to increasing CO_2. What happens seems reasonable enough; warmer climates presumably are associated with less snow cover and less reflectivity — which, in turn, amplifies the warming. However, snow is associated with winter when incident sunlight is minimal. Moreover, clouds shield the sun from the surface and minimize the response to snow cover. Indeed, there is growing evidence that clouds accompany diminishing snow cover to such an extent as to turn this feedback negative. If, however, one asks why current models predict large warming will accompany increasing CO_2, the answer is mostly the water vapour feedback. Current models all predict that warmer climates will be accompanied by increasing humidity at all levels. As already noted, this behaviour is an artifact of the models since they have neither the physics nor the numerical accuracy to deal with water vapour. Recent studies of the physics of how deep clouds moisturize the atmosphere strongly suggest that this largest of the positive feedbacks is not only negative, but very large.

Not only are there major reasons to believe that models are exaggerating the response to increasing CO_2, but, perhaps even more significantly, the models' predictions for the past century incorrectly describe the pattern of warming and greatly overestimate its magnitude. Figure 5 shows the global average temperature record for the past century or so. The record is irregular and not without problems. However, it does show an average increase in temperature of about 0.45°C±0.15°C with most of the increase occurring before 1940, followed by some cooling through the early 70's, and a rapid (but modest) temperature increase in the late 70's. Now, as we have noted, we have already seen an increase in 'equivalent' CO_2 of 50%. Thus, on the basis of models which predict a 4°C warming for a doubling of CO_2 we might expect to have seen 2°C already. However, if the delay imposed by the oceans' heat capacity is included, the expectation is reduced to about 1°C. This is still twice what has been seen. Moreover, most of what has been seen occurred before the bulk of the minor greenhouse gases were added to the atmosphere. Figure 6 shows what might have been expected for models with differing sensitivities to a doubling of CO_2. What we see is that the past record is most consistent with an equilibrium to a doubling of about 1.3°C — assuming that all the observed warming was due to increasing CO_2. However, there is nothing in the record that can be distinguished from the natural variability of the climate. If one considers the tropics, the situation is even more disturbing. There is ample evidence that the average equatorial sea surface has remained within ±1°C of its present temperature for billions of years, yet current models predict average warming of from 2-4°C even at the equator. It should be noted that for much of the Earth's history, the atmosphere had much more CO_2 than is currently anticipated for centuries to come. One could, in fact, go on for some time listing the evidence for small responses to a doubling of CO_2; however, there is only limited time.

Summarizing the scientific situation,

i) The data provide no evidence of man induced global warming.

ii) The models (whatever their other strengths or weaknesses) are predicting large global warming for identifiably artificial reasons.

iii) There are substantial reasons for expecting the response to increased CO_2 will, in fact be small.

The increasing acceptance of the above facts has led to a peculiar emphasis on the issue of potential climate 'surprises'. Here, the claim is that since we do not understand the climate system, it is possible that it may respond in ways we currently have no knowledge of if we subject the system to stress. This is indeed an unanswerable argument. The point, quite simply, is that ignorance is ignorance. It is certainly not a basis for action. If it were, the only logical response would be total paralysis.

Consensus and the Current 'Popular Vision'

Many studies from the 19th Century onwards suggested that industrial and other contributions to increasing CO_2 might lead to global warming. Problems with such predictions were also long noted, and the general failure of such predictions to explain the observed record caused the field of climatology as a whole to regard the suggested mechanisms as suspect. Indeed: the global cooling trend of the 50's and 60's led to a minor global cooling hysteria in the 70's. All this was more or less normal scientific debate although the cooling hysteria had certain striking analogues to the present warming hysteria including books such as The Genesis Strategy by S. Schneider and Climate Change

and World Affairs by Crispin Tickell (both authors are prominent in support of the present concerns as well) 'explaining' the problem and promoting international regulation. There was also a book by the prominent science writer Lowell Ponte (The Cooling) deriding skeptics, and noting the importance of acting in the absence of firm scientific foundation. There was even a report by the National Research Council of the U.S. National Academy of Sciences reaching its usual ambiguous conclusions. However, the scientific community never took the issue to heart, governments ignored it, and with rising global temperatures in the late 70's the issue, more or less died.[1] In the meantime, model calculations — especially at the Geophysical Fluid Dynamics Laboratory at Princeton — continued to predict substantial warming due to increasing CO_2. These predictions were considered interesting, but largely academic, exercises — even by the scientists involved.

The present hysteria formally began in the summer of 1988, though preparations had been put in place at least three years earlier.[2] This was an especially warm summer in some regions — especially in the United States. As we noted in the discussion of observations, there was an abrupt increase in temperature in the late 70's — too abrupt to be associated with the smooth increase in CO_2. However, James Hansen (Director of the Goddard Institute for Space Studies), in testimony before Senator Gore's Committee on Science, Technology and Space, said, in effect, that he was 99% certain that temperature had increased, and that there was some greenhouse warming. No statement was made concerning the relation between the two.

Despite the fact that these remarks were virtually meaningless, they led to the immediate adoption of the issue by the environmental advocacy movement. The growth of environmental advocacy since the 70's has been phenomenal. In Europe, the movement centred on the formation of Green Parties; in the United States, the movement centreed on the development of large public interest advocacy groups. These lobbying groups have budgets in the hundreds of millions of dollars, and employ about 50,000 people; their support is highly valued by many political figures. As with any large group, self-perpetuation becomes a crucial concern. 'Global Warming' has become one of the major battle cries in their fund raising efforts. At the same time, the media unquestioningly accept the pronouncements of these groups as objective truth.

However, within the large scale climate modelling community (a small subset of the community interested in climate), the immediate response was to criticize Hansen for publicly promoting highly uncertain model results as relevant to public policy. Hansen's motivation was not totally obvious, but there was clear involvement of a Michael Oppenheimer (originally with the Environmental Protection Agency and now with the Environmental Defense Fund — an advocacy group) who specifically funded the work at Goddard Institute for Space Studies. Despite the criticism of Hansen, the modelling community quickly agreed that large warming was not impossible. This was still enough for both the politicians and advocates who have generally adopted the paradigm that any hint of environmental danger is sufficient basis for regulation unless the hint can be rigorously disproved. This is a particularly pernicious asymmetry given that rigor is generally impossible in environmental sciences.

Other scientists quickly agreed that with increasing CO_2 some warming might be expected, and with large enough concentrations of CO_2, the warming might be significant. Nevertheless, there was widespread scepticism. By early 1989, however, the popular media in Europe and the US were declaring that 'all scientists' agreed that warming was real and catastrophic in its potential.

Like most scientists concerned with climate, I was eager to stay out of what seemed like a public circus. However, in Summer 1988, Lester Lave, Professor of Economics at Carnegie-Mellon University, wrote to me about being dismissed from a Senate hearing for suggesting that the issue of global warming was scientifically controversial. I assured him that the issue was not only controversial but also unlikely. In Winter 1989, Reginald Newell (Professor of Meteorology at MIT) lost NSF funding for data analysee that were failing to show net warming over the past century. Reviewers suggested that results were dangerous to humanity. In Spring 1989, I was an invited participant at a global warming symposium at Tufts University. I was the only scientist among a panel of environmentalists. There were strident calls for immediate action, and ample expressions of impatience with science. Claudine Schneider (then a congresswoman from Rhode Island) acknowledged that 'Scientists may disagree, but we can hear Mother Earth, and she is crying.' It seemed clear to me that a very dangerous situation was arising, and the danger was not of 'global warming' itself.

In spring of 1989, I prepared a critique of global warming which I submitted to Science (a magazine of the American Association for the Advancement of Science). It was rejected without review as being of no interest to the readership. The paper was resubmitted to the Bulletin of the American Meteorological Society where it was accepted after review, re-reviewed and re-accepted (an unusual procedure to say the least). In the meantime, the paper was attacked in Science — prior to publication (in 1990). The paper circulated for about 6 months as Samizdat. It was delivered at a Humboldt Conference at MIT, and reprinted in the Frankfurter Allgemeine.

In the meantime, the global warming circus was in full swing. Meetings were going on non-stop. One of the

more striking of these meetings was hosted in Summer 1989 by Robert Redford at his ranch in Sundance, Utah. Redford proclaimed that it was time to stop research and begin acting. I suppose that this was a reasonable suggestion for an actor to make, but it is also indicative of the overall attitude to science. Barbara Streisand personally undertook to support the research of Michael Oppenheimer at the Environmental Defense Fund - even though he is a full-time advocate, and not a climatologist. Meryl Streep made a public appeal to stop warming on Public Television. A bill was even prepared to guarantee Americans a stable climate.

By autumn of 1988 some media were becoming aware that there was controversy (Forbes, and Readers Digest were notable in this regard). Cries followed from environmentalists that sceptics were receiving too much exposure. The publication of my paper was followed by a determined effort on the part of the editor of the Bulletin of the American Meteorological Society, Richard Hallgren, to solicit rebuttals. Such articles were prepared by Stephen Schneider, and Will Kellogg (a minor scientific administrator for the last 30 years), and these articles were followed by an active correspondence mostly supportive of the skeptical spectrum of views. Indeed, a recent Gallup Poll of climate scientists (in the American Meteorological Society and in the American Geophysical Union) shows that a vast majority doubt that there has been any identifiable man-caused warming to date (46% asserted no, 33% didn't know, 18% thought yes some has occurred; however, among those actively involved in research and publishing frequently in peer-reviewed research journals, 0% believe any man-caused global warming has occurred so far.). On the whole, the debate within the meteorological community has been relatively healthy and, in this regard, unusual.

Outside the world of meteorology, Jeremy Legett (a geologist by training) of Greenpeace published a book attacking critics of warming — especially me. Senator Mitchell (Senate majority leader, and father of a prominent environmental activist) also published a book urging acceptance of the warming problem (World on Fire: Saving an Endangered Earth). Senator Gore has just published a book (Earth in the Balance: Ecology and the Human Spin), and this barely scratches the surface of the rapidly growing publications on this topic. Rarely has such meagre science provoked such an outpouring of popularization by individuals who do not understand the subject in the first place.

The activities of a particular organization, the Union of Concerned Scientists, deserves special mention. This widely supported organization was originally devoted to nuclear disarmament. With the spindown of the Cold War, it began to actively oppose nuclear power generation. This position was unpopular with many physicists. Over the last few years, it has turned to the battle against global warming in a particularly hysterical manner. In 1989, it began to circulate a petition urging recognition of global warming as potentially the great danger to mankind. Most recipients who did not sign were solicited at least twice more. The petition was eventually signed by 700 scientists including a great many members of the National Academy of Sciences and Nobel Laureates. Only about 3 or 4 of the signers, however, had any involvement in climatology. Interestingly, the petition had two pages, and on the second page there was a call for renewed consideration of nuclear power. However, when the petition was published in the New York Times, the second page was omitted. In any event, this document helped solidify the public perception that 'all scientists' agreed with the disaster scenario. This disturbing abuse of scientific authority was not unnoticed. Frank Press (President of the National Academy of Sciences), at the 1990 annual meeting of the Academy, warned the membership against lending their credibility to issues about which they had no special knowledge. Special reference was made to the above petition. In my opinion, what the petition did show was that the need to fight 'global warming' has become part of the dogma of the liberal conscience — a dogma to which scientists are not immune.

At the same time, political pressures on dissidents from the 'popular vision' increased. Senator Gore publicly admonished 'sceptics' in a lengthy New York Times op-ed piece. (In a perverse example of double-speak, he associated the 'true believers' in warming with Galileo. He also referred, in another article, to the summer of 1988 as the Kristallnacht before the warming holocaust.)

The notion of 'scientific unanimity' is currently intimately tied to the Working Group I report of the Intergovernmental Panel on Climate Change issued in September 1990. This panel consists largely of scientists posted to it by government agencies. The panel has three working groups. Working Group I nominally deals with climate science. Approximately 150 scientists contributed to the report, but university representation from the US was relatively small. This is likely to remain so, since the funds and time needed for participation are not available to most university scientists. Many governments have agreed to use this report as the authoritative basis for climate policy. The report, as such, has both positive and negative features. Methodologically, the report is deeply committed to reliance on large models, and, within this report, models are largely verified by comparison with other models. Given that models are known to agree more with each other than with nature (even after 'tuning'), this approach does not seem promising. In addition, a number of the participants have testified to the pressures placed on them to emphasize results supportive of the current scenario and to suppress other results. This pressure was fre-

quently effective, and a survey of participants reveals substantial disagreement with the final report. Nonetheless, the body of the report is extremely ambiguous, and the caveats are numerous. However, the report is prefaced by a Policymakers Summary written by the editor, Sir John Houghton, Director of the United Kingdom Meteorological Office. This summary largely ignores the uncertainty in the report, and attempts to present the expectation of substantial warming as firmly based science.[3] The Summary is published as a separate document, and, it is safe to say, that policymakers are unlikely to read anything further. On the basis of the summary, one frequently hears that hundreds of the worlds greatest climate scientists from dozens of countries all agreed that .... It hardly matters what the agreement refers to, since whoever refers to the summary insists it agrees with the most extreme scenarios (which, in all fairness, it does not). It should be added that the climatology community, until the last few years, was quite small and heavily concentrated in the US and Europe.

While the IPCC reports were in preparation, the National Research Council in the United States was commissioned to prepare a synthesis of the current state of the global change situation. The panel chosen was hardly promising. It had no members of the National Academy expert in climate. Indeed it had only one scientist directly involved in climate, Stephen Schneider, who is an ardent advocate. It also included 3 professional environmental advocates, and it was headed by a former senator, Dan Evans. It should be added that the panel did include distinguished scientists and economists outside the area of climate, and, perhaps because of this, the report issued by the panel was by and large fair. Their report concluded that the scientific basis for costly action was absent, though prudence might indicate that actions that were cheap and/or worth doing anyway should be considered. A subcommittee of the panel issued a report on adaptation which argued that even with the more severe warming scenarios, the United States would have little difficulty adapting. Not surprisingly, the environmentalists on the panel not only strongly influenced the reports, but failing to completely have their way, they attempted to distance themselves from the reports by either resigning or by issuing minority dissents. Equally unsurprising is the fact that the reports of this panel were typically covered on page 48 of the New York Times, and never subsequently discussed in the popular media—except to claim that the reports support the catastrophic vision. Nevertheless, the reports of this panel were indicative of the growing scepticism concerning this issue.

Indeed, the growing scepticism is in many ways remarkable. One of the earliest protagonists of global warming, Roger Revelle (late Professor of Ocean Sciences at Scripps Institution of Oceanography), who initiated the direct monitoring of CO_2 during the International Geophysical Year (1958), coauthored (with S. Fred Singer and Chauncy Starr) a paper just before his death recommending that action concerning global warming be delayed insofar as current knowledge was totally inadequate. Another active advocate of global warming, Michael McElroy (Head of the Department of Earth and Planetary Sciences at Harvard) has recently written a paper acknowledging that existing models cannot be used to forecast climate.

One might think that this growing scepticism would have some influence on public debate, but the insistence on 'scientific unanimity' continues unabated. At times, this insistence takes some very strange forms. Over a year ago, Robert White (former head of the Weather Bureau in the United States, and currently president of the National Academy of Engineering) wrote an article for Scientific American pointing out that the questionable scientific basis for global warming predictions was totally inadequate to justify any costly actions. He did state that if one were to insist on doing something, one should only do things that one would do even if there were no warming threat. Immediately after this article appeared, Tom Wicker (a columnist for the New York Times, and a confidant of Senator Gore) wrote a piece in which he stated that White had called for immediate action on 'global warming'. My own experiences have been similar. Stephen Schneider, in an article in Audubon states that I have 'conceded that some warming now appears inevitable'. Differences between expectations of unmeasurable changes of a few tenths of a degree and warming of several degrees are conveniently ignored. Karen White in a lengthy and laudatory article on James Hansen which appeared in the New York Times Sunday Magazine reported that even I agreed that there would be warming, having 'reluctantly offered an estimate of 1.2 degrees'. This was, of course, untrue. Most recently, I testified at a Senate hearing conducted by Senator Gore. There was a rather arcane discussion of the water vapour budget of the upper troposphere ~5-12 km). Two years ago, I had pointed out that if the source of water vapour in this region in the tropics were detrained water vapour from deep clouds, then surface warming would be accompanied by reduced upper level water vapour. In subsequent research it has been established that there must be an additional source which is widely believed to be ice crystals thrown off by these deep clouds. I noted that this source too probably acts to produce less moisture in a warmer atmosphere. Both processes cause the major feedback process to become negative rather than positive. Senator Gore wanted to know if I now rejected my suggestion of 2 years ago as a major factor. I answered that I did.[4] Senator Gore then called for the recording secretary to note that I had retracted my objections to 'global warming'. There followed consider-

able argument (involving mostly other participants in the hearing) in which it was explained to the senator that he was confusing matters. However, shortly thereafter Tom Wicker published an article in the New York Times claiming that I had retracted my opposition to warming and that this warranted immediate action to curb the purported menace. I wrote a letter to the Times indicating that my position had been severely misrepresented, and, after a delay of over a month, my letter was published. Senator Gore, nonetheless claims in his book that I have indeed retracted my scientific objections to the catastrophic warming scenario, and also warns others who doubt the scenario that they are hurting humanity.

Why, one might wonder, is there such insistence on scientific unanimity on this issue. After all, unanimity in science is virtually non-existent on far less complex matters. Unanimity on an issue as uncertain as 'global warming' would be surprising and suspicious. Moreover, why are the opinions of scientists sought regardless of their field of expertise? Biologists and physicians are rarely asked to endorse some theory in high energy physics. Apparently when one comes to 'global warming' any scientist's agreement will do.[5]

The answer almost certainly lies in politics. For example, this coming June at the Earth Summit in Rio, attempts will be made to negotiate international carbon emission agreements. The potential costs and implications of such agreements are likely to be profound for both industrial and developing countries. Under the circumstances, it would be very risky for politicians to undertake such agreements unless scientists 'insisted'. Nevertheless, the situation is probably a good deal more complicated than this example suggests.

The Temptation and Problems of 'Global Warming'

As Aaron Wildavsky (Professor of Political Science at Berkeley) has quipped, 'global warming' is the mother of all environmental scares. Wildavsky's view is worth quoting. "Warming (and warming alone), through its primary antidote of withdrawing carbon from production and consumption, is capable of realizing the environmentalist's dream of an egalitarian society based on rejection of economic growth in favor of a smaller population eating lower on the food chain, consuming a lot less, and sharing a much lower level of resources much more equally". In many ways, Wildavsky's observation does not go far enough. The point is that carbon dioxide is vitally central to industry, transportation, modern life, and life in general. It has been joked that CO_2 controls will permit us to inhale as much as we wish; only exhaling will be controlled. The remarkable centrality of carbon dioxide, means that dealing with the threat of warming fits in with a great variety of pre-existing agendas — some legitimate, some less so: energy efficiency, reduced dependence on middle eastern oil, dissatisfaction with industrial society (neo-pastoralism), international competition, governmental desires for enhanced revenues (carbon taxes), bureaucratic desires for enhanced power.

The very scale of the problem as popularly portrayed and the massive scale of the suggested responses have their own appeal. The Working Group I report of the Intergovernmental Panel on Climate Change suggested, for example, that 60% reductions in CO_2 emissions might be needed. Such a reduction would call for measures that would be greater than those that have been devoted to war and defense. And just as defense has dealt with saving ones nation, curbing 'global warming' is identified with saving the whole planet! It may not be fortuitous that this issue is being promoted at just the moment in history when the Cold War is ending.

Major agencies in the United States, hitherto closely involved with traditional approaches to national security have appropriated the issue of climate change to support existing efforts. Notable among these agencies are NASA, the Department of Defense, and the Department of Energy. The Cold War helped spawn a large body of policy experts, diplomats, etc. specializing in issues like disarmament, alliance negotiations, etc. In addition, since the Yom Kippur War, energy has become a major component of national security with the concomitant creation of a large cadre of energy experts. Many of these individuals see in the global change issue an area in which to continue applying their skills. Many scientists also feel that national security concerns formed the foundation for the US government's generous support of science. As the urgency of national security, traditionally defined, diminishes, there is a common feeling that a substitute foundation must be established. 'Saving the Planet' has the right sort of sound to it. I have already mentioned the phenomenal growth of the environmental advocacy movement. It seems that fund raising has become central to their activities, and the message underlying some of their fund raising seems to be 'pay us or you'll fry'.

Clearly, 'global warming' is a tempting issue for many very important groups to exploit. Equally clearly, though far less frequently discussed, there are profound dangers in exploiting this issue. As we will also see, there are good reasons why there has been so little discussion of the downside of responding to 'global warming'.

Let me begin with a parochial issue: namely, the danger to the science of climatology. As far as I can tell, there has actually been reduced funding for existing climate research. This may seem paradoxical, but, at least in the US, the vastly increased number of scientists, etc. involving themselves in climate as well as the

gigantic programs attaching themselves to climate have substantially outstripped the increases in funding. Perhaps more important are the pressures being brought to bear on scientists to get the 'right' results. Such pressures are inevitable, given how far out on a limb much of the scientific community has gone. The situation is compounded by the fact that some of the strongest proponents of 'global warming' in congress are also among the major supporters of science (Senator Gore is notable among these). Finally, given the momentum that has been building up among so many interest groups to 'fight' 'global warming', it becomes downright embarrassing to support basic climate research. After all, one would hate to admit that one had mobilized so many resources without the basic science being in place. Nevertheless, given the large increase in the number of people associating themselves with climatology, and the dependence of much of this community on the perceived threat of warming, it seems unlikely that the scientific community will offer much resistance. It should be added that as ever greater numbers of individuals attach themselves to this problem, the pressures against solving the problem grow proportionally; too many individuals and groups depend on the problem remaining.

In addition to climatologists, are there other groups that are at risk? Here, one might expect that industry could be vulnerable, and, indeed, it may be. However, at least in the US, industries seem to be primarily concerned with improving their public image. One way they attempt to do this is by supporting environmental activists. Moreover, some industries have become successful at profiting from environmental regulation. The most obvious example is the waste management industry. However, even electric utility companies have been able to use environmental measures to increase the base on which their regulated profits are calculated. It is worth noting that about 1.7 trillion dollars have been spent on the environment over the past decade. The environment, itself, qualifies as one of our major industries.

If Wildavsky's scenario is correct, the major losers will be ordinary people. Wealth will be squandered that could have been used to raise living standards in much of the world. Living standards in the developed world will decrease. Regulatory apparatuses will restrict individual freedom on an unprecedented scale. Here too, however, one cannot expect much resistance to proposed actions — at least not initially. Public perceptions, under the influence of extensive, deceptive, and one-sided publicity, can become disconnected from reality.[5] For example, the state of Alabama has had a pronounced cooling trend since 1935. Nevertheless, a poll among professionals in Alabama found that about 95% of the participants believed it had been warming over the past 50 years, and that the warming was due to the greenhouse effect. Public misperceptions coupled with a sincere desire to 'save the planet' can force political action even when politicians are aware of the reality.

What the above amounts to is a societal instability. At a particular point in history, a relatively minor suggestion or event serves to mobilize massive interests. While the proposed measures may be detrimental, resistance is largely absent or coopted. In the case of climate change, the fact that the proposed actions will, for the most part, have little impact on climate regardless of the scenario chosen, appears to be of no consequence.

Such societal instabilities are, by no means, unheard of. Unfortunately, the best example, in my opinion, is rather extreme. It is the start of the First World War. Here too, a relatively minor incident in Sarajevo led to the coalescence of a variety of narrow interests of important groups. The momentum of the actions coupled with hysteria over national security and interests overwhelmed any rational opposition. A particularly poignant image is that of Socialist parliamentarians fervently voting war credits and rushing to the front — despite earlier protestations that the working people of the world were united in their opposition to war.

Modelling and Societal Instability

So far I have emphasized the political elements in the current climate hysteria. There can be no question, however, that scientists are abetting this situation. Concerns about funding have already been mentioned. There is, however, another, perhaps more important element, to the scientific support. The existence of modern computing power has led to innumerable modelling efforts in many fields. Supercomputers have allowed us to consider the behaviour of systems seemingly too complex for other approaches. One of these systems is climate. Not surprisingly, there are many problems involved in modelling climate (or the economy or society or energy, etc.). Among the problems facing climate modelers are the following:

1. Even supercomputers are inadequate to allow long term integrations of the relevant equations at adequate spatial resolutions. At presently available resolutions, it is unlikely that the computer solutions are close to the solutions of the underlying equations.

2. The physics of unresolved phenomena like clouds and other turbulent elements is not understood to the extent needed for incorporation into models.

In view of these problems, it is generally recognized that models are at present experimental tools whose relation to the real world is questionable. As we have already noted, no current large model can, from first

principles, account for the average temperature of the earth or its equator-pole temperature distribution without arbitrary adjustments referred to as 'tuning'.

While there is nothing wrong in playing with these models in an experimental mode, there is a real dilemma when such models predict potentially dangerous situations. Should scientists publicise such predictions since the models are almost certainly wrong? Is it proper to not publicize the predictions if the predicted danger is serious? How is the public to respond to such predictions? The difficulty would be diminished if the public understood how poor the models actually are. Unfortunately, there is a tendency to hold in awe anything which emerges from a sufficiently large computer. There is also a reluctance on the part of many modellers to admit to the experimental nature of their models lest public support for their efforts diminish. Nevertheless, with poor and uncertain models in wide use, predictions of ominous situations are virtually inevitable—regardless of reality.

Such weak predictions feed and contribute to what I have already described as a societal instability which can cascade the most questionable suggestions of danger into major political responses with massive economic and social consequences. I have already discussed some of the reasons for this instability: the existence of large cadres of professional planners looking for work, the existence of advocacy groups looking for profitable causes, the existence of agendas in search of saleable rationales, the ability of many industries to actually profit from regulation, etc., coupled with an effective neutralization of opposition. It goes almost without saying, that the dangers and costs of these economic and social consequences may be far greater than the original environmental danger. This becomes especially true when the benefits of additional knowledge are rejected, and when it is forgotten that improved technology and increased societal wealth are what allow society to deal with environmental threats most effectively. The control of this societal instability may very well be the real challenge facing us.

Footnotes

1 *It is nonetheless worth noting that the last 700,000 years have been characterized by lengthy periods of glaciation interspersed by relatively brief interglacials such as our present climate. Presumably, we will have another ice age in a few thousand years.*

2 *In a paper in Science in 1985, for example, Jim Hansen was already arguing that a 'wait and see' attitude concerning warming was inappropriate because of the ocean delay. He suggested that because of ocean delay, we were already 'committed' to substantial warming even though we might not see it for over a hundred years.*

3 *The recently released update to the IPCC report continues the tradition of sophistry. The updated summary begins "Findings of scientific research since 1990 do not affect our fundamental understanding of the science of the greenhouse effect and either confirm or do not justify alteration of the major conclusions of the first IPCC Scientific Assessment, in particular the following:". There then follows a list of the more innocuous conclusions of the first report ("the size of the warming is broadly (emphasis added) consistent withpredictions of climate models, but it is also of the same magnitude as natural climate variability", "there are many uncertainties in our predictions particularly with regard to the timing, magnitude, and regional patterns of climate change due to our incomplete understanding"), followed by the change of a major earlier 'certainty', the positive water vapour feedback, to a matter of uncertainty, and a number of other retractions as well.*

4 *The issue of deep clouds (cumulonimbus towers) and water vapour is, I have noted, rather technical. These towers are the main mechanism for surface air to communicate with the interior atmosphere. Moist air rises in these towers. As this air rises to levels of lower pressure, it expands and cools (as does refrigerator coolant). As air cools, its capacity to hold water vapour diminishes. The excess water vapour condenses into liquid water or ice (depending on the temperature). In the simplest models of cumulonimbus towers, all the condensed vapour falls out as rain. When the cloud reaches its top altitude (in this simple model), it merges into the atmosphere as saturated (100% relative humidity) air at the cloud top temperature. Our original point was that as the surface warmed, cloud air would be more buoyant, and would reach higher top levels where the air would be colder and thus hold less water vapour. Hence, the supply of water vapour to the interior atmosphere would be diminished in a warmer climate. However, since water vapour is the main greenhouse gas in the atmosphere, this reduction would act to restrain the warming — i.e., provide a negative feedback. We then undertook two studies to check these ideas. In the first, we used some data from the last major glacial period (18,000 years ago) to see whether the colder atmosphere of those times had more water vapour. Our study showed that almost certainly it did, thus confirming the notion of a negative feedback. Our first study did not, however, tell us what mechanism was actually responsible for the negative feedback. Our second study undertook to examine the*

atmosphere's water vapour budget in greater detail. Here we discovered that our original mechanism had a significant problem. Saturated air from cloud tops constituted too small a source to maintain present levels of humidity. The problem, it turned out, was our assumption that all condensed water vapour in the cloud fell out as rain. Significant amounts are, in fact, carried aloft in the cloud and thrown out into the atmosphere mainly as ice crystals (leading to extensive cirrus cloud cover). The main source of water vapour for the atmosphere proves to be falling droplets and ice crystals which re-evapourate intothe environment. What causes a cloud to loft more water substance is not totally well known, but it appears to be related (not surprisingly) to how fast cloud air is rising. Our first study did, in fact, show why cloud air would rise faster in a colder climate. The results of the first study will appear in the Journal of Climate. The results of the second study have been submitted for publication in the Journal of the Atmospheric Sciences. Both papers were coauthored with a student, De-Zheng Sun.

5 *In view of the previously mentioned Gallup Poll, perhaps the agreement of scientists outside of the atmospheric sciences is needed. Unfortunately, a number of studies show that scientists outside of a given discipline are (with respect to that discipline) more influenced by the media than by the scientific literature. This influence is particularly strong when the media proclaim that 'all scientists' agree. There is a natural inclination to support ones peers.*

6 *The flavor of much of the journalistic coverage of the environment is given by the following quote from Teya Ryan, senior producer of Turner television's "Network Earth" and vice president of the Society of Environmental Journalists: "I think the environment may be the one area where you can say advocacy journalism is appropriate, indeed vital....At some point balanced journalism simply does not give them the answers, it gives them issues....Now does seem to be the time for rethinking some of our journalistic canons. The 'balanced' report, in some cases, may no longer be the most effective, or even the most informative. Indeed, it can be debilitating. Can we afford to wait for our audience to come to its conclusions? I think not."*

Figure Legends

Figure 1. Atmospheric CO_2 increase in the past 250 years, as indicated by measurements on air trapped in ice from Siple Station, Antarctica (squares) and by direct atmospheric measurements at Mauna Loa, Hawaii (triangles). (From Climate Change, The IPCC Scientific Assessment, 1990.)

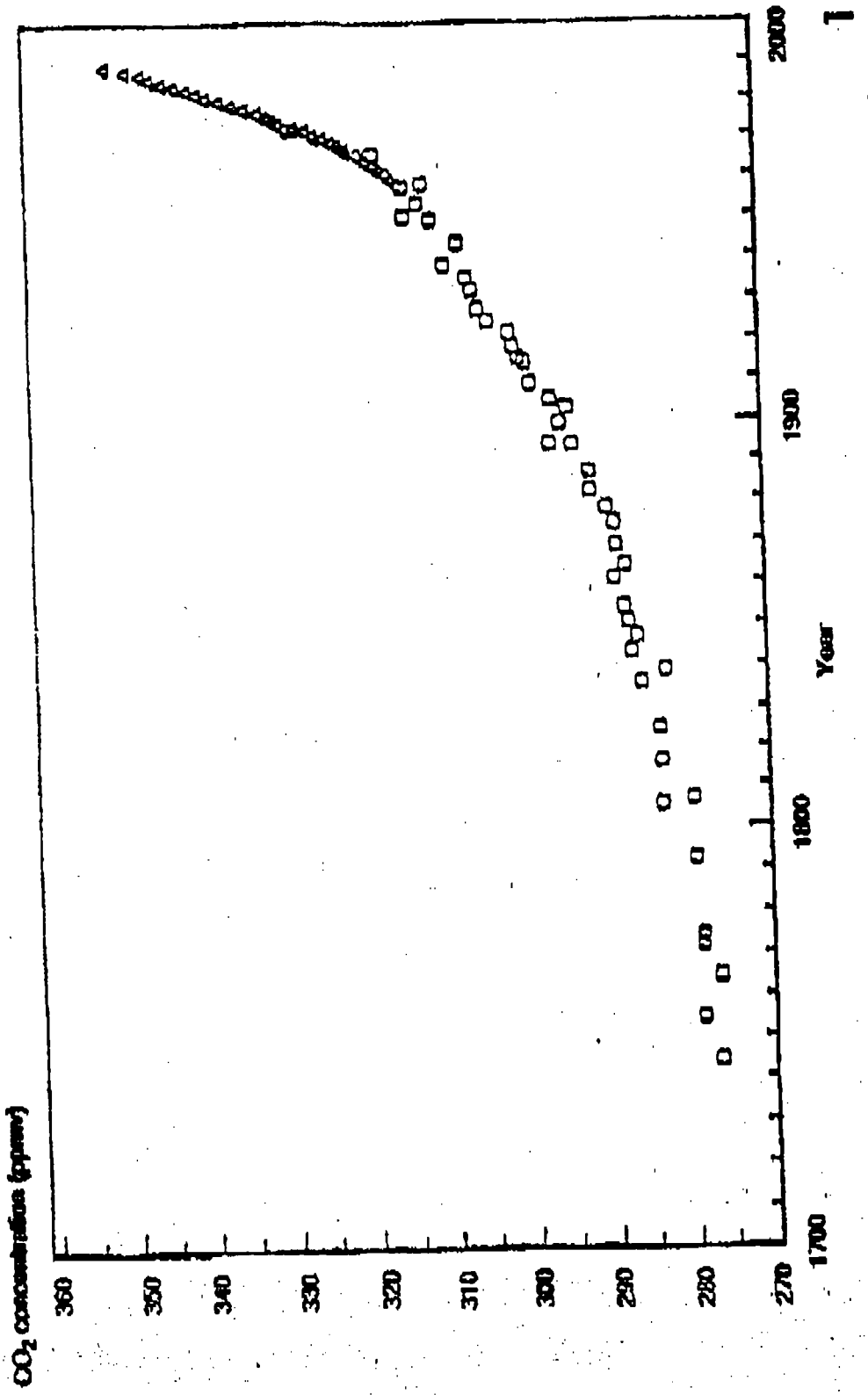
Figure 2. Expected CO_2 in the atmosphere according to various emissions scenarios. (From Max Planck Gesellschaft, Hamburg.)

Figure 3. Simplified schematic of the greenhouse warming process. (From Climate Change, The IPCC Scientific Assessment, 1990.)

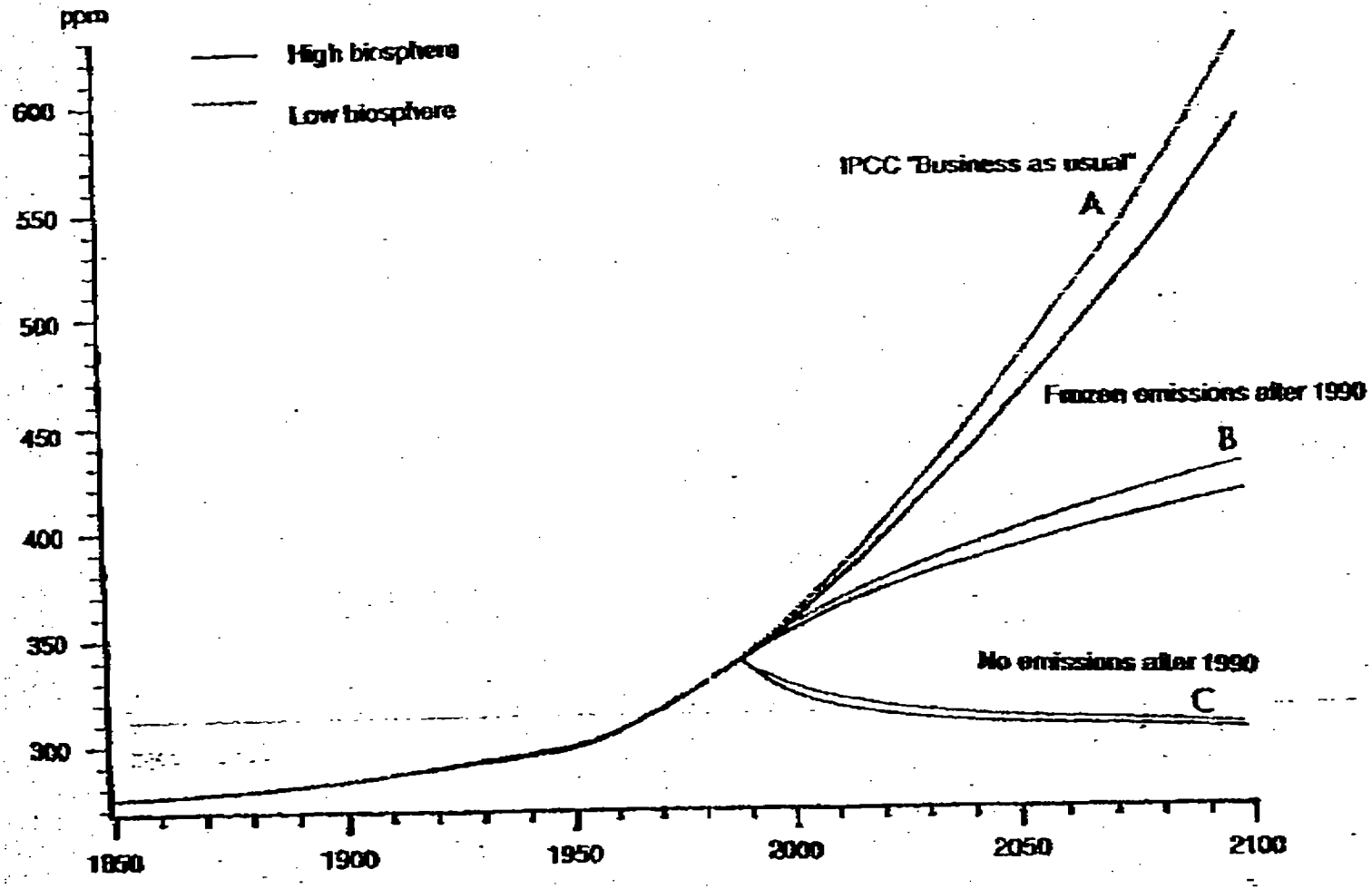
Figure 4. Schematic illustration of the role of dynamic heat transport in modifying greenhouse warming.

Figure 5. Combined land air and sea surface temperatures, 1861-1989, relative to 1951-1980. (a) Northern Hemisphere, (b) Southern Hemisphere, (c) Globe. (From Climate Change, The IPCC Scientific Assessment, 1990.)

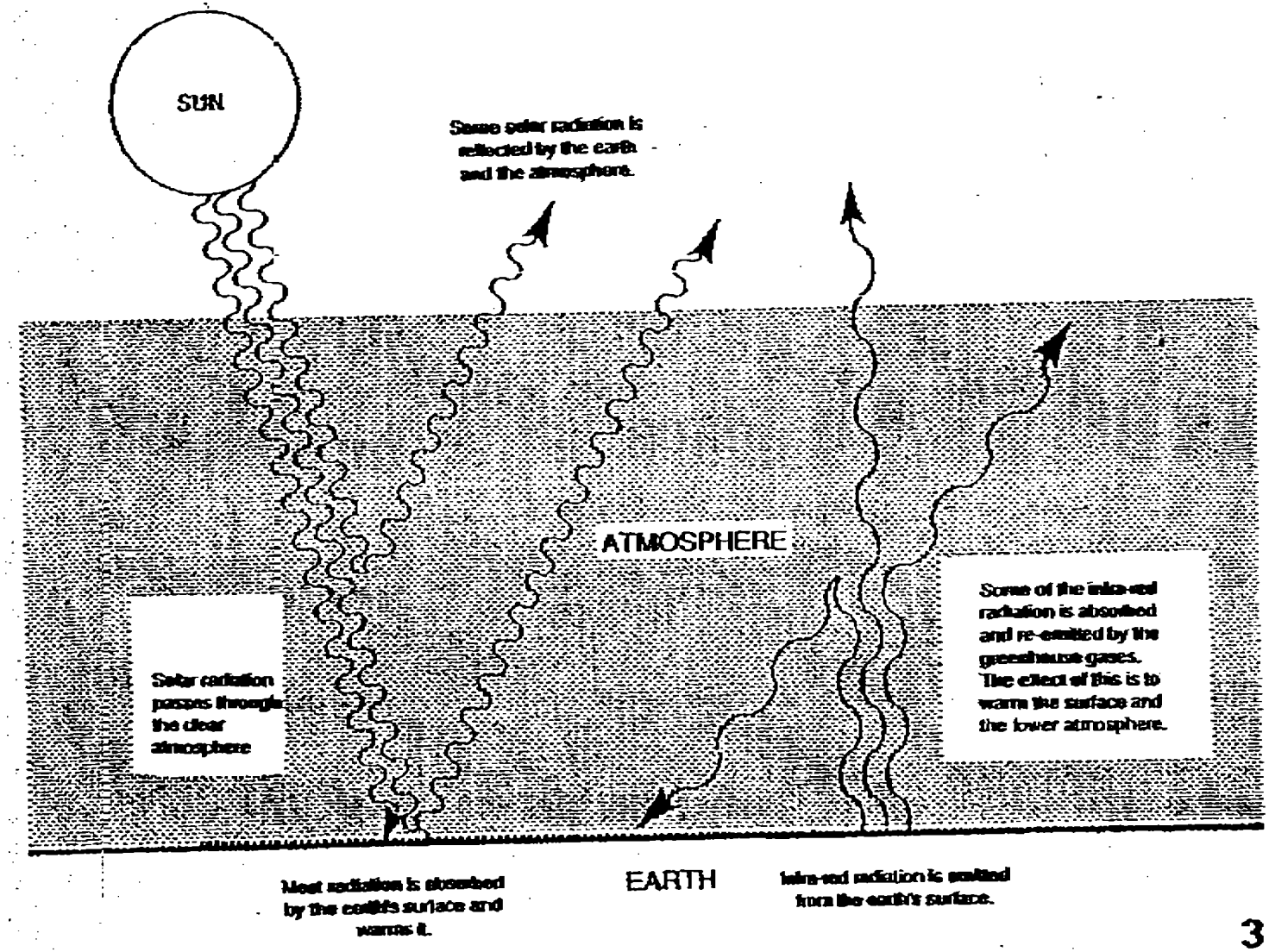
Figure 6. Observed behaviour of globally averaged temperatures since 1860, as well as expected behaviour from models whose equilibrium response to a doubling of CO_2 (ΔT_{2x}) is indicated on the curves. (From Climate Change, The IPCC Scientific Assessment, 1990.)


CO_2 concentration (ppmv)
360
350
340
330
320
310
300
290
280
270
1700
1800
1900
2000
Year

CO_2 Scenarios

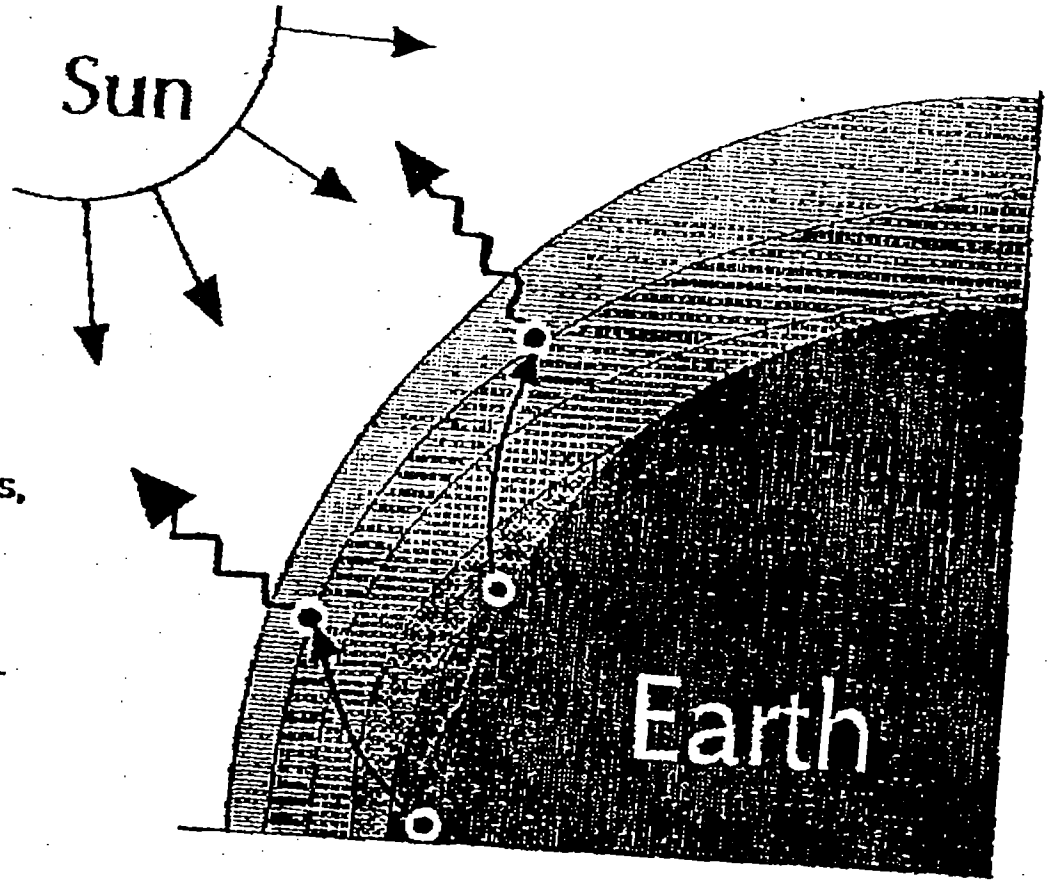


2

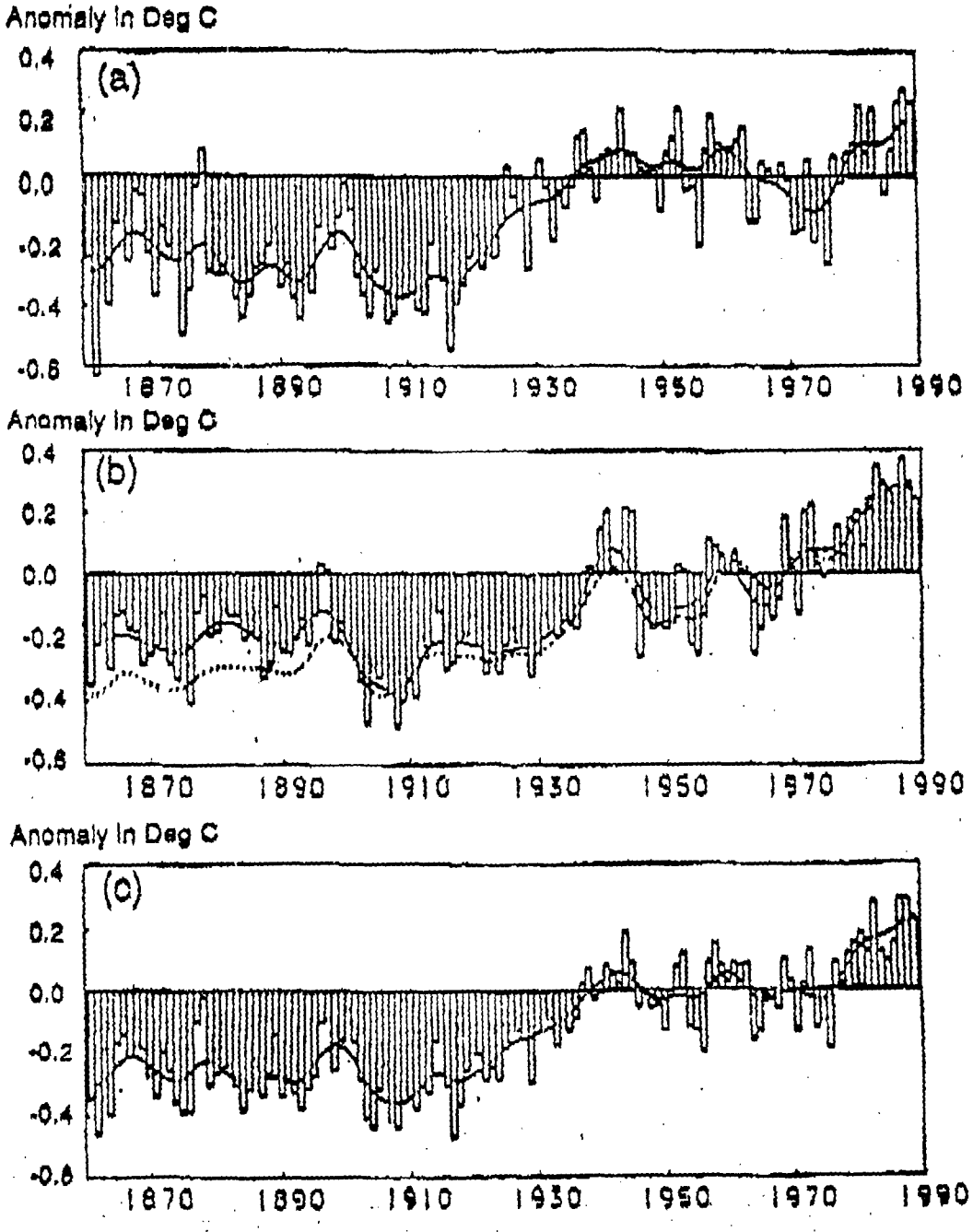


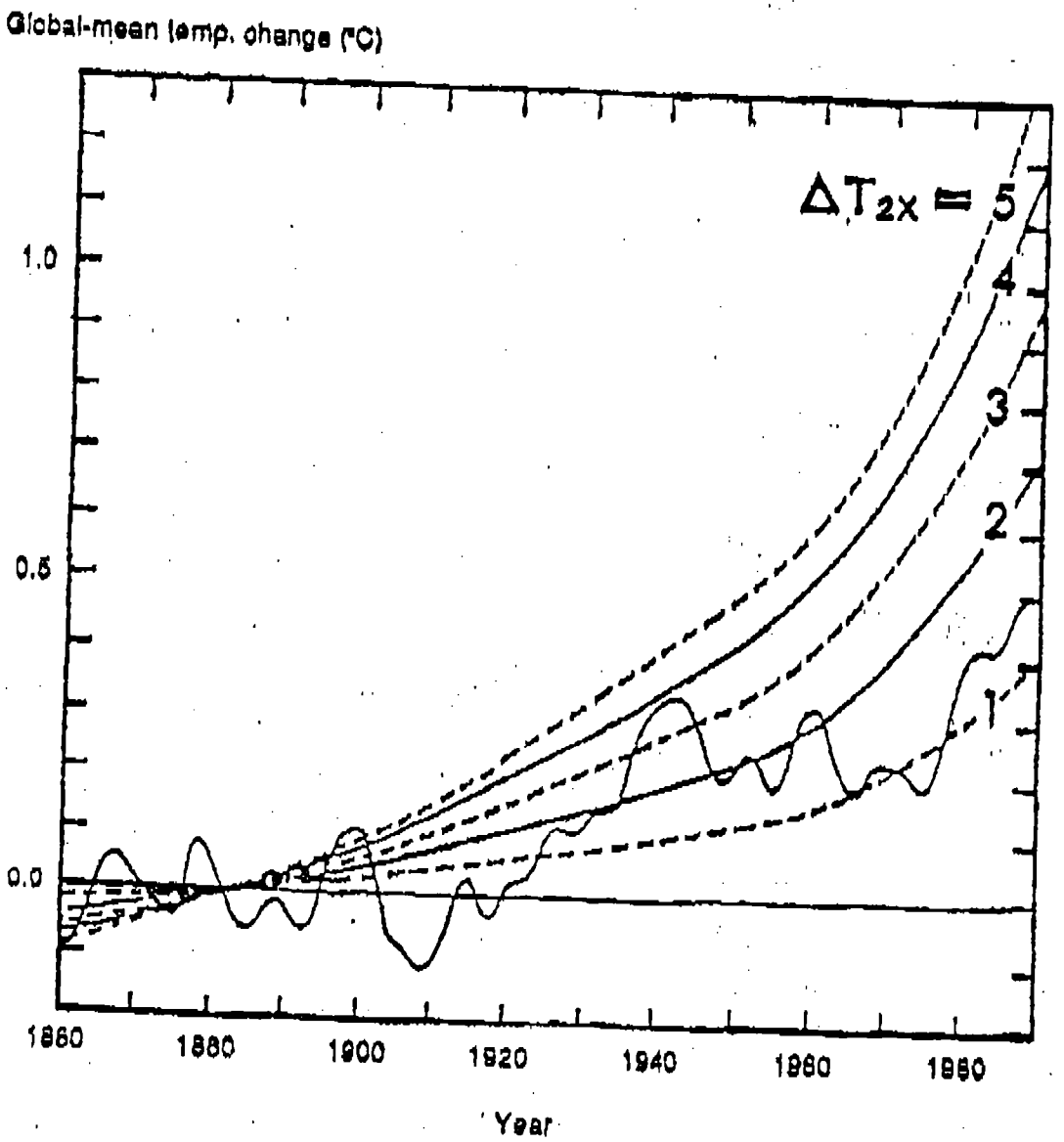
3

Infrared opacity is greatest at the ground over the tropics, and diminishes as one goes poleward and upward. Air currents bodily carry heat to regions of diminished infrared opacity where the heat is radiated to space - balancing absorbed sunlight.



Light shading schematically represents reduced opacity due to diminishing water vapor density.


Anomaly in Deg C
(a)
0.4
0.2
0.0
-0.2
-0.4
-0.6
1870
1890
1910
1930
1950
1970
1990
Anomaly in Deg C
(b)
0.4
0.2
0.0
-0.2
-0.4
-0.6
1870
1890
1910
1930
1950
1970
1990
Anomaly in Deg C
(c)
0.4
0.2
0.0
-0.2
-0.4
-0.6
1870
1890
1910
1930
1950
1970
1990


Global-mean temp. change (°C)
ΔT2x = 5
4
3
2
1
1.0
0.5
0.0
1860
1880
1900
1920
1940
1960
1980
Year

6

THE BOSTON GLOBE • WEDNESDAY, MAY 13, 1992

The Boston Globe

'Road to Rio'

The White House photo-opportunity staff fell down on the job yesterday by not having Bob Hope and Dorothy Lamour on hand when President Bush announced that he was going to Rio de Janeiro next month for the Earth Summit.

Hope and Lamour, along with Bing Crosby, starred in "Road to Rio," and the Earth Summit is certain to be no more substantial than that old-movie favorite in which plot (*i.e.*, substance) took a back seat to zany comedy and sunny romance.

In fact, Bush is only going to Rio because by his stubborn refusal to support legally-binding limits on emissions of global warming gases, he has ensured the world that the Earth Summit will be little more than a sun-filled photo-opportunity.

Up until last week, Bush's advisers had been concerned that he might have found himself at Rio in the embarrassing position of opposing an international global-warming treaty which the other heads of state were there to sign.

But by the use of still-unrevealed pressures, the US negotiators last week won approval from other industrial countries for an agreement which requires nations merely to "assess" their level of global-warming emissions. The accord they have agreed to does not require any specific action to curb those emissions.

The text of the accord is filled with "shoulds" and "woulds" which qualify virtually every statement about actions necessary to control global warming. In referring to an actual cap on emissions, the draft text proclaims that a cap "would be an appropriate signal by developed countries." A signal, apparently, that the developed countries, led by the US, are more interested in photo-ops in Rio than forceful actions at home.

Bush's pressure on other nations to accept the weak accord may stand as one of the most destructive acts of his presidency. His decision to go to the summit will stand as one of its most cynical acts.