GLOBAL WARMING: REALITY OR BAD DREAM?

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INTRODUCTION

The last decade has seen a significant growth in interest in the effects of pollution on global environments, none more so than the enhancement of the greenhouse effect or 'global warming'. Indeed this problem has frequently acquired the status of front-page or special feature news. While it is heartening to see the human species recognising that it has inflicted damage on the natural environment, much of what is written betrays some degree of mis-understanding of the fundamental nature of the global warming problem and can, at times, be misleading. If indeed we are to expect some degree of change in the world's climates there is a real need to reassess the ability of human society to feed, water and shelter an expanding world population which continues to benefit from improved medical care but may at the same time falls victim to far-reaching changes in the distribution of risk from specific diseases. In order to secure the future it will be necessary to review the vital biochemical linkages between human society and the atmosphere.

GLOBAL WARMING

Expressed in its simplest form, global warming is a rise in the globally averaged near-surface (1.5-2.Om) air temperature resulting from changes in the gaseous composition of the lower atmosphere. In reality it is a complex network of cause-effect linkages involving, for example, the stability of global ice deposits such as the polar ice-caps, the temperature of the oceans, and the workings of what Nigel Calder (1974) has called 'The Weather Machine'. When we consider these more complex aspects of the problem we can begin to appreciate the full implications of global warming. Sea-level rises would offer a direct threat to coastal zone habitation and management; changes in the distribution of moisture lead to modified flood or drought risks; and shifts in global climatic zones can result in deleterious effect on food-production. The effects of global warming are, therefore, far-reaching but are far from adequately understood.

Responses to the perceived threat from predicted global warming have ranged from total rejection through to hysterical doom and gloom. The news media have used a range of headlines, from the baldly scientific to outrageous hyperbolae. While some reporting has been accurate and informative, much has concentrated on worthless sensationalism. The isolated individual who predicts the end of the world and the drowning of millions is thus as likely to reach the pages of the press as the more circumspect findings of a team of senior scientists. Political responses have been visible but are motivated as much by vote-catching as by a genuine concern for the global environment. The 1989 briefing called by Mrs Thatcher, her involvement in the 1990 Climatic Change conference in Geneva and the publication of the White Paper *This Common Inheritance* have been encouraging signs, but Governmental action has not always matched the rhetoric. A scientific community under financial siege has been all too eager to jump on a global warming bandwagon and there is a suspicion that objectivity has, in some cases, been sacrificed. Published conclusions have not always been supported by rigorous scientific arguments, but have degenerated into conjecture. The scientific community is now beginning to reappraise the evidence and we may be entering a period of more serious debate on the issue.

THE GREENHOUSE PROCESS

Global warming is a result of the enhanced absorption of the long-wave infra -red radiation emitted from the earth's surface by specific gases in the lower atmosphere. The fact that these gases absorb little, if any, of incoming short-wave solar radiation means that they are effectively retaining heat energy. The parallel with the action of a greenhouse is unfortunate as this acts to suppress heat loss by convection as much as by the retention of infra-red radiation. We are, however, stuck with the misnomer of the 'greenhouse effect' which is generated by 'greenhouse gases'. It is important to note that this greenhouse effect is not a recent man-made phenemenon but is vital to the development and survival of life on Earth. Without it the surface would not only experience huge swings of temperature between day and night and tropic and pole but would be as much as 30°C colder than at present. The principal greenhouse gases are water vapour and carbon dioxide, which absorb particular infra-red wavebands. The essential nature of the global warming problem is that we have increased the amount not only of carbon dioxide in the atmosphere but also of gases such as methane, nitrous oxide and ozone, all of which are powerful greenhouse agents. In addition to these, we have added a new agent in the form of chlorofluorocarbons (CFC's).

Carbon Dioxide forms an essential part of the carbon cycle or the constant exchange of carbon between living matter and the overlying atmosphere. Within this complex cycle there are huge stores of carbon in plants and animals, and in the oceans, in addition to longer term storage in fossil forms such as coal, oil and calcareous rocks. The combustion of coal and oil releases vast quantities of carbon in the form of carbon dioxide. The United Kingdom, for example, releases an average 509m tonnes of carbon dioxide into the atmosphere every year, of which 205m tonnes result from the generation of electricity (Association for the Conservation of Energy, 1989). The destruction of boimass such as tropical rainforests, and forests elsewhere in the world, not only reduces the amount of carbon held in the terrestrial store but also, when burned, releases carbon dioxide to the atmosphere. Measurements of the carbon dioxide content of the lower atmosphere during the 20th century have revealed a general increase.

Increases from the current level of 350ppm 1. Status of carbon dioxide emission controls Extract from *Independent* Monday 29th October, 1990

CARBON DIOXIDE TARGETS

Country	Target details	
NO *CONTROLS*		
US	Not in favour of emission controls despite a vague commitment by President Bush to stabilise at unspecified levels in Feb 1990	22.0
USSR	Not in favour of emission controls at present	18.4
STABILISERS		
JAPAN	Stabilise at 1990 levels by 2000	4.4
UK	Stabilise at 1990 levels by 2005	2.8
CANADA	Stabilise at 1990 levels by 2000 as a first step	2.0
ITALY	Stabilise at 1990 levels by 2000	
	Parliamentary resolution for 20% cut by 2005	1.8
BELGIUM	Stabilise at 1988 levels by 2000	0.5
AUSTRIA	Support stabilisation at 1990 levels by 2000.	
	20% cuts proposed by the environment minister	0.3
FINLAND	Stabilise at 1990 levels by 2000 at least	0.26
SWEDEN	Stabilise at 1988 levels by 2000	0.22
NORWAY	Stabilise at 1990 levels by 2000	0.22
SWITZERLAND	Has supported stabilisation at 1990 levels by 2000	0.2
IRELAND	Supported stabilisation at current levels by 2000	0.14
REDUCERS		
GERMANY	25% reduction on current levels by 2005. Agreed by cabinet but not yet ratified by parliament	3.2
AUSTRALIA	20% reduction by 2005	1.1
NETHERLANDS	Stabilise by 1995, 3% to 5% reduction by 2000	0.65
DENMARK	20% reduction by 2000, up to 50% by 2030	0.3
NEW ZEALAND	20% reduction by 2000	0.1

All EC member states excepf *UK* agreed overall Community stabilisation at current levels by 2000 at an informal meeting of Environment Council Ministers on September 23, under a formula which would allow Spain, Greece and Portugal initial CO_2 increases to a level in excess of 600ppm by AD2050 have been predicted.

However, our incomplete understanding of, for example, the role of the oceans, means that such a course of change is far from being a certainty. Of the observed increase, the majority can be attributed directly to the burning of fossil fuels and a relatively minor amount to deforestation (Rowntree, 1990). The analysis of Antarctic ice cores has suggested a strong correlation between air temperature and carbon dioxide so the implication is that current increases may lead to significant increases in temperature over the next 50-60 years (IPCC, 1990).

Methane is associated with the bacterial breakdown of organic matter and is temperature and moisture dependent. Typical natural sources include swamps and the digestive systems of animals. Anthropogenic sources include paddy fields and waste tips, which link methane production directly to the human population. These, in addition to inputs from cattle and leakage during fossil fuel extraction, have led to methane in the lower atmosphere increasing at a current rate of 1.0% per year. This gas is 30 times more effective than carbon dioxide as a greenhouse agent.

Anthropogenic *Nitrous Oxide* is a by-product of fertilizer manufacture and of fossil fuel and biomass burning. It is also emitted from vehicle exhausts. It is currently increasing at a rate of 0.4% per year.

Ozone in the lower atmosphere, as distinct from stratospheric ozone, results from the photochemical transformation of carbon monoxide, oxides of nitrogen, and hydrocarbons, which are emitted from vehicle exhausts. It is 2000 times more effective than carbon dioxide but has a relatively short lifespan in the atmosphere. The close association between road transport and economic development means that both ozone and nitrous oxides are likely to continue increasing, probably at accelerated rates.

CFC's 11 and 12 are essentially an industrial product, in the form of coolants in fridges and air conditioning systems, and propellants in aerosol cans, in addition to which they are used in the manufacture of plastic foams. Until recently there was an average 6.0% increase in atmospheric CFC's which are as much as 20,000 as effective as carbon dioxide as greenhouse agents.

The implication is that global temperatures will rise while the atmospheric content of greenhouse gases continues to increase. It is unlikely that the atmosphere has yet fully responded to current levels of these gases and their long lifespans means that even if their production were to cease tomorrow they would persist for many years to come. However, although we are aware of the physical properties of these gases, and of their proportional contribution to the gaseous mixture of the atmosphere, the link to global warming is not a matter of simply applying laboratory theory. The atmosphere and its interaction with the earth's surface are very complex and far from completely understood, added to which is the greenhouse effect of water vapour which can all too readily be understated. So, although there is obviously a bridge between the known behaviour of gases and the temperature of the lower atmosphere, it is by no means a firm structure and it should be crossed with care.

THE EVIDENCE FOR CLIMATIC CHANGE

There is no shortage of circumstantial evidence that changes in climate are taking place. The examples used here illustrate the broad nature of trends in climatological variables which have been identified. Global mean temperatures derived from a large number of locations throughout the world indicate that since the late 19th century there has been an increase of approximately 0.5°C in which there have been two periods of greater warming, between 1900 and 1940, and the more recent dramatic temperature rise during the 1980's (Jones et.al., 1988) culminating in the warmest year ever in 1990. Rainfall has followed trends which are regional, rather than global, in character. While annual rainfalls in subtropical latitudes have been decreasing since the 1950's, bringing drought to many areas, middle latitude locations such as the British Isles have experienced steady increases since the 1920's (Bradley et.al., 1987). In this latter case, annual rainfall in western Scotland has shown particularly remarkable increases, approaching 50%, since the drier years of the early 1970's. Analysis of snowfalls in temperate latitudes has revealed a decrease in recent years, which has created particular problems for the skiing industry in Scotland. There is a body of opinion that the frequency of extreme events such as flood, drought, and storms have increased but the evidence here is not convincing. Mean sea-levels have been rising steadily since the end of the 19th century (Doornkamp, 1989) alongside increases in air temperature.

At first glance the evidence would appear to provide adequate proof of the existence of real long-term climatic changes. This does not, of course, imply that these are directly attributable to an enhanced greenhouse effect. The difficulty lies in testing whether there is a real, and scientifically valid, link between available theory and a set of observations which appear to fit, in some respects, with theoretically determined outcomes of global warming. In assessing the evidence it is important to bear the following in mind:

(a) the observations from which conclusions are drawn are subject to error. Global mean temperature, for example, are derived from a scatter of land-based weather stations. At each of these stations there is a potentially large cumulative observation error resulting from the calibration of the thermometer shelter to approved standards, and the character of the recording site. In this last respect, local topography and proximity to surface features such as urban areas or open water exert influences on recorded temperature for which there are no means of correcting to an established standard. At the end of the day, temperatures registered at any individual station are, at best, to within ±0.5°C. This must be viewed alongside a trend in temperature which appears to suggest an increase of only 0.5°C over 100 years. Similar caution must be applied to sea-level data especially when one bears in mind that the relative levels of land and sea are subject to vertical movements in land masses.

(b) the span of the climatological record is very short. It is difficult to establish the nature of long-term changes in climate from less than 200 years of reliable records, bearing in mind that other forms of evidence for environmental change indicate change of the order of hundreds, if not thousands, of years.

(c) there is an ever-present and largely unknown background environmental variation. We don't know how climates would have evolved in the absence of human interference so it is impossible to gauge the magnitude of the anthropogenic component of change. For example, the observed warming could be simply a relaxation from the cold of the Litte Ice Age of the mid-15th century to mid-19th century. On the other hand, global warming may be disguising a general cooling trend relating to ice-age cycles or other human influences on climate such as atmospheric dust levels.

(d) relationships within the environment involve not simple cause-effect linkages but complex causal networks of which we have, as yet, a very incomplete understanding. Principal amongst these are feedbacks, in which small changes may be compensated for within the operation of the earth-atmosphere system (negative feedback) or may result in a disproportionately large change (positive feedback). It is, therefore, very difficult to identify exactly why, for example, temperature has increased or rainfall decreased.

PREDICTING FUTURE CLIMATIC CHANGES

On the assumption that there is a reasonable degree of confidence in our data and in our understanding of the behaviour of environmental systems, the future course of climatic change has been predicted using a range of different modelling techniques. In doing so it must be borne in mind that such models are very imperfect creations of the human mind and should not be seen as anything more than crude approximations. As predictions progress forward in time so the degree of confidence in them diminishes. Models tend to be based on either energy balance approaches or the more complex global climatic models. As far as Scotland is concerned the various models appear to be indicating that by 2050 there will be an increase in mean temperature of approximately 2.0°C, and generally wetter winters and drier summers. One of the biggest problems is to predict what will happen to sea-levels, which should rise due to thermal expansion, plus melt water inputs from alpine glaciers and snowfields, the Greenland ice-cap and the Antarctic ice-sheets. The range of predicated increases in global mean sea-level is, as expected, very large but is most likely to be between 24 and 38cms (Warrick et.al., 1989).

The implications of such changes are considerable. There could be major changes in the distribution of agriculturally the greatest and least productive lands, severe threats not only to coastal communities such as in Bangladesh but also to industrial and sewage disposal plants, and an increased incidence of disease. Before we become unduly pessimistic, it is prudent to be aware of the limitations of our predictive models : —

(a)Because of limitations in both our understandings of the functioning of environmental systems and the computers used to run the predictive models, it is obviously necessary to use some degree of simplification. Thus the true complexity of vertical structures of, for example, the oceans can not be fully represented so an approximation using slabs or layers of finite depth is used. A similar approximation is used for the atmosphere.

A corrollary of the above is that relatively coarse spatial resolutions are used, which are of the order of 1000km. This means that we can not differentiate between, for example, Scotland and southern England, or Argyll and East Lothian, despite the fact that we know these have markedly different climates.

There is, as yet, a very incomplete knowledge of the effect of oceans in climatic change. We know that they introduce a thermal lag because of their higher heat capacity, but insufficient is known of the exchanges of carbon dioxide across the air-sea interface. The role of marine biota is particularly problematical.

The response of polar ice-caps to changes in temperature remains uncertain. The simplistic statement that warmer air makes them melt is wholly inadequate, partly because of the exceptionally low temperatures, and partly because warmer air may result in more precipitation in the form of snow, thereby adding to the mass of ice.

Feedback processes are only partially understood and are certainly incompletely represented in predictive models.

However, although there remains much of uncertainty as to the exact course of future climatic changes, there is sufficient convergence in the models to suggest that global warming may be a reality and should be addressed as a potentially major environmental problem over the next few decades.

REDRESSING THE BALANCE

If we accept that the risks are real, there is clearly a need to engage in international dialogue to seek ways in which emissions of greenhouse gases can be reduced below critical environmental tolerance levels. For example, carbon dioxide emissions will have to be reduced by a little less than 60% to stabilise concentrations at present day levels (IPCC, 1990). A number of international conferences have taken place, best known of which have been the Montreal Protocol meetings and the 1990 Geneva conference on Climatic Change. At a second meeting of the Parties to the Montreal Protocol held in Britain in 1990 there was general agreement to phase out CFC's by 2000 with a cut of 50% by 1995 and 85% by 1997. Unfortunately agreement on other gases such as carbon dioxide is a more distant prospect. The uncertainties regarding the nature of feedback mechanisms in the carbon cycle and the role of the oceans, together with the close association between energy production and profitability in highly industrialised societies, have resulted in a wide range of responses to the perceived global warming problem (Table 1).

As far as the British public are concerned, there has been a noticeable increase in awareness of environmental problems and there has been a willingness to be more discerning in the choice of domestic products from the supermarket shelves; and the recycling of paper, glass and aluminium is now more widely accepted. However, the real problem of excessive energy use has not been addressed fully as this is perceived as having a direct impact on personal comfort and convenience. Energy conservation, including wider use of home insulation and more efficient use of the ubiquitous car go a long way towards reducing the amount of greenhouse gases in the atmosphere. Now is also the time to consider alternative energy sources such as wind power.

CONCLUSION

The not inconsiderable levels of uncertainty in the base data, the over-simplification of the complex environmental processes represented in predictive models, and the bandwagon element, together make it impossible to be certain about either the reality of ongoing global warming or climatic trends into the 21st century. We do not have to go too far back to recall an obsession with a forthcoming ice-age in the press of the 1970's. Perhaps global warming is just another passing fashion? To use a simple analogy, a sky full of clouds and a fresh westerly breeze in the morning are together sufficient indication that rainfall during the day is a real possibility, so we would be wise to take our umbrella with us. While we may return home at night with an unused umbrella we would also be protected should the rain materialise. Thus the signs are that real climatic changes may occur over the next few decades as a direct result of the addition of greenhouses gases to the atmosphere. We would be wise, therefore, to take steps to reduce emissions of these gases although at the end of the day the earth-atmosphere system may well be capable of absorbing them without generating major climatic changes.

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