

# ROYAL METEOROLOGICAL SOCIETY: AUSTRALIAN BRANCH

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## THE FEAR OF CLIMATIC CHANGE

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'The Clymat's delicate, the Ayre most sweet'

*The Winter's Tale* Cleomines III i 1

### INTRODUCTION

Is our climate changing? If so, why - and to what extent? Man is conscious of his environment as never before. He is aware that he cannot continue indefinitely to plunder and despoil the planet on which he lives. He suspects, for the first time in history, that he might have the power to alter the global climate, albeit inadvertently, but perhaps irreversibly. Some of his experts have speculated that the world is heading for a climatic disaster in which the polar ice would melt and drown many of the world's major cities; or alternatively, instead of a man-made deluge, a man-made ice age. It would be nice to know which fate, if either, is in store, and what options are open to man to minimise the consequences.

What, then, do we mean by climate? Paradoxically, it may be less confusing not to attempt a precise definition, beyond saying that we are referring broadly to that intangible and complex combination of temperature, wind, rain, sunshine, snow, *etc* which makes up the physical environment in which we live.

Our climate has always been changing. No one year is identical with the one before, or the one after. Each decade is different, each century is different, each millenium is different, each epoch is different. From the practical point of view we are more vitally concerned with the decades just ahead. If our climate is really on the move, it is this immediate time scale that calls for action now. When we look ahead for centuries, and think of the well-being of the generations that are to follow us, we may feel we can proceed more leisurely in the business of acquiring better knowledge of prediction, of planning to move living communities, or of coping with agricultural difficulties. This could be a false sense of security, in that the climatic change that could occur over centuries is potentially more severe than that over decades. Certainly, our ability to adjust to a climatic change is strongly dependent on the rate at which the change occurs.

### CLIMATIC CHANGES IN THE PAST

To a certain extent we can infer some idea of the possibilities for the future from a knowledge of what has happened in the past. This knowledge is made of scientific evidence of various disciplines, of writings of peoples and places, and even of myths and legends. Just as our ability to forecast the weather becomes more uncertain the further ahead we try to forecast, so our level of confidence is weakened the further back we try to project.

Even with such a simple, but important, matter as temperature we must remember that the thermometer was not invented by Galileo until the sixteenth century A.D., and complete global measurements are still not available today, despite the substantial contribution by remote sensing satellites. Thus our knowledge of temperature in past ages must be derived by other means, often ingenious, but with attendant uncertainty and speculation.

### Climate in geological times

There is no doubt that the planet has suffered a number of ice ages, but precisely when is still a matter of controversy. The classic viewpoint is that the earth has been free of ice for 90% of the past 1000 million years, but it has been argued very recently (1970) that ice ages upon the earth are much more common. Our knowledge rests on such things as fossils, geological formations and glacial moraines (*ie*, debris deposited by glaciers).

We are equally unsure as to the cause of the ice ages. It seems not impossible that the glaciation itself is apt to obscure the cause. Two components of change have been identified. The primary changes, whatever they may be, initiate ice sheet development, whilst the secondary changes, arising from the ice sheet behaviour itself, operate through a complex process of positive feedback with the atmosphere to accelerate the change. So complex are these considerations that it is difficult to disentangle them with confidence. A quotation by Dutton is appropriate. 'While it cannot be doubted that the climate of the Glacial period was in some important respects different from the present climates the moment any attempt is made to ascertain what would be the effect, if any one of the determinants of climate were to undergo a marked variation, it is found to be so intricately interwoven with many other conditions and determinants that the ingenuity of the investigator is generally baffled in his endeavours to assign a just and proper weight to them all.' This was written in 1884 but is equally true today.

It seems that all we can be sure of is that, inasmuch as ice ages have occurred in the past, they will surely occur again, but when, and with what severity, is a matter of considerable speculation. We are, of course, currently in an ice age, but the time scale is such that we may not have any real problem, if at all, for thousands or even millions of years.

### Climate in historical times

The climate for the last two thousand years is reasonably well known in many parts of the world from a variety of sources. Historical records of settlements, and their success or failure is a typical example. We know, for example, that the Viking Eric the Red settled in Greenland about 986 A.D., and that eventually a population of 3000 was self-supporting with pasturage for sheep and cattle, and hunting for fish, seal and whale. By 1500 A.D. the Norse had virtually disappeared, partly as a result of raids by the Eskimos from the north, and partly from the deterioration of the favourable climate.

Science provides us with corroborative evidence such as the variation of the isotope  $O^{18}$  in deep ice cores, the concentration of this isotope being largely determined by the temperature at which precipitation condensed.

Other evidence comes to us from such things as the wine harvests in France, the cherry blossoms in Japan, tree rings using radiocarbon dating in America and elsewhere, so that, at least for those places where this information is available, we are almost in a position to put precise figures on the average temperature. However, some uncertainties must exist in the interpretation such as a possible variation in the French taste for wines over the centuries, whether the tree ring growth was limited by water availability or by sunshine, and so on.

We are thus able to assess the climate in historical times with some precision, and whilst the extremes do not compare with the glaciation of geological times, we must note the extreme variability which is still of sufficient intensity to place severe hardship on living man.

### The present climate

Meteorological records, as we now know them, have existed in one form or another for several hundred years; and we have some confidence that greater precision is available and we can draw more subtle conclusions from the available evidence.

Again, looking at temperature as a typical indicator, we can see that the average temperature of the northern hemisphere increased by about  $0.6^{\circ}\text{C}$  between 1890 and 1940 and that there has been a decrease of about  $0.4^{\circ}\text{C}$  between 1940 to 1970.

These changes may not sound like very much, but it may be useful to remember that a temperature change of  $6^{\circ}\text{C}$  is believed to have characterised the glacial and interglacial periods of the ice ages.

The temperature changes observed over the last eighty years serve to introduce another aspect, one which probably initiated the current speculation in climate, namely that man himself might have brought about these temperature changes. This thought is probably engendered by increasing public concern for the environment, and the very visible evidence that many of our rivers, lakes and harbours are already unpleasantly polluted.

It is man's rapidly increasing consumption of his fossil fuels which has been most suspect as the cause of the observed rise and fall in temperatures. We know that  $\text{CO}_2$  in the atmosphere is increasing, and that only half of man's input into the atmosphere is required to explain the observed increase.

We can make a guess at the increase in temperature (through the greenhouse effect) that will follow from the observed increase in  $\text{CO}_2$ , and can find tolerable agreement.

At the same time that man has been putting  $\text{CO}_2$  into the atmosphere he has also been putting in a considerable amount of particulate matter. Whilst the particulates enter only the lower atmosphere, and have a residence time of only several weeks, it has been argued that sufficient particulate matter has been injected to produce a cooling effect over the whole globe, by virtue of the particulates reducing the solar energy input to earth. Certainly, we again have the very visible evidence of atmospheric pollution in our large cities and industrial zones. However, the interaction of radiation with particulate matter is a very complex business, and we are not yet in a position to offer precise theoretical estimates of a cooling effect. Indeed, some studies have indicated a heating or cooling effect, according to the height of the particulates.

Mitchell has attempted an empirical estimate, by observing cooling trends after major volcanic eruptions, and concludes that it is not impossible that the cooling observed over the last thirty years is due to man.

There is also evidence that not all the globe has been cooling. For example, a recent examination of Indonesian glaciers has shown that over this period the glaciers have been retreating, and this is believed to be typical of tropical glaciers.

Furthermore, radiation studies here at Aspendale, using radiation data from all over the world, have indicated that whilst the Agung eruption of 1963 introduced a considerable amount of volcanic dust into the stratosphere, this has now virtually disappeared. The atmosphere has thus returned to its pre-Agung condition, and shows no significant evidence of a trend over the last decade.

The same analysis applied to a long series of radiation data from Nebraska also shows no evidence of a long-term trend.

There are thus many reasons for questioning whether there is any real possibility that we are on the brink of a climatic disaster as has been suggested by some.

At the same time we must note that our colleagues in the Australian Bureau of Meteorology in their most recent Annual Report have stated that 'The 1973-74 year was one of unusual weather occurrences . . . the chief of [which] produced the most extraordinary set of weather conditions to affect Australia in this century.' These are fairly strong words from a hard-headed group of professional meteorologists. Some reassurance is provided by their further comment that statistical analysis of long-period records do not support the contention that the climate of this continent is changing.

Overall, I believe their comment on the present climate is most apt. 'Long-period climatic changes [have clearly been] demonstrated by palaeoclimatologists. Such changes may take place [in the] future and may be taking place very slowly now, but . . . they cannot be identified with certainty.'

## FORECASTING THE FUTURE

From our knowledge of the past we are broadly aware of what sort of things might happen, but what we need is a means of forecasting the future climate so that some measure of planning can be introduced into man's thinking. This is particularly true since we must be concerned with whether man himself might inadvertently cause such a change, and therefore need to know the result of his activities.

A number of possibilities are open to us. We may look for naturally occurring events and seek to establish a cause-result relationship. This has the apparent advantage that we do not need to understand all the intermediate workings of the atmosphere in precise physical terms. The hazards of this approach are (a) we may relate an observed result to the wrong cause, and (b) the natural variability of the atmosphere will tend to conceal the effect we are looking for.

Alternatively, using our existing knowledge of physics as it relates to such things as the thermodynamics and radiation properties of gases, and the energetics and dynamics of fluid motion, we can attempt to calculate the final effect *ab initio*. The difficulties here lie not so much in a lack of knowledge of the basic science, but in the enormous complexity and interaction of the various physical components that defy even the capacity of the most modern computer. The reader will not be unaware that day-to-day meteorological forecasting is not without the occasional minor error.

There are a number of ways in which our science can be applied to the problem.

### Short-cut models

By short-cut models, I am referring to those which do not attempt to draw on the full power available from science but attempt to describe the atmosphere and some of its processes with a few relatively simple equations. In setting up these equations we employ analogy with known processes in classic physics, at the same time trying to ensure that we introduce in a realistic way those parameters which we know from qualitative considerations are essential ingredients of the system.

For example, the transport of heat is usually described by a transfer coefficient multiplied by a temperature difference by analogy with conduction, and we choose the value of the transfer coefficient somewhat broadly in the range that applies to current data. We recognise various time scales as being important. We know that the atmosphere has a response time of several weeks, as for example, a temperature change caused by a shift in the level of solar radiation. The upper mixed layer of the ocean interacts with the atmosphere over months to years, while the deeper waters have thermal adjustment times of the order of centuries. The ice and snow masses respond

much more slowly, apart from seasonal variation, with significant changes over hundreds to thousands of years. Thus, according to whether we are attempting a forecast for the next decade, or century, or millenium, so must we introduce certain components into the set of equations.

One example of the style of prediction which can be offered is taken from the work of Sellers.

Sellers proceeds to calculate the temperature rise that would occur if the polar ice caps were totally or partially removed. The model predicts a 7 to 11°C temperature rise in the arctic, and 13 to 17°C in the antarctic. These are enormous temperature changes but two things should be noted.

Firstly, the calculation assumes an equilibrium state, and this condition may take many years to attain, since the large heat-storage capacity of the oceans is almost certain to be involved.

Secondly, Sellers linked the albedo with the temperature in one empiric equation in such a way that an increase in temperature produces a decrease in albedo. This is positive feedback, or a destabilising mechanism. Other types of equation could easily be conceived involving a stabilising mechanism, or negative feedback; and here-in lies one of the difficulties of this style of modelling. This type of consideration is the point of entry of some very significant physics, and whether one gets it right or wrong will decide which way the forecast will go.

It is largely for this reason that Robinson referred to these models as useful toys in which one could think about the problem and generate some useful ideas, but he questioned the confidence which could be placed on the forecasting ability.

#### Dynamical circulation models

Most authorities agree that the most promising approach to the question of climatic change lies in the use of complex mathematical models using the full force which meteorological knowledge can bring to the subject. But the computing task is enormous, requiring the full resources of the most modern computers, and even greater capacity computers would be employed if they were available. The components recognised as being essential to the treatment include such things as ocean circulations, transfer of energy and momentum, evaporation, cloud cover, solar radiation, aerosol loading, CO<sub>2</sub>, water vapour, ozone concentrations, artificial heating by man and so on. As a preliminary step it is contemplated that the sensitivity of the models to such components should be tested in a series of reconnoitering experiments with a view to simplification and reduction in the computing demand.

It is not expected that the prediction of climatic events for an individual year is a likely outcome of the approach, but information would be obtained in a statistical form. For example, we would not forecast the year in which drought will occur but we could estimate the number of droughts per century.

There is a danger that we could mislead society by giving the impression that our forecasting skill in this context is greater than it really is. Much improvement in our knowledge needs to be made before we can display a satisfactory level of confidence.

#### A new scientific approach

Some recent research by one of my colleagues, Dr G. Paltridge, offers the chance of a new look at the possibilities that science has to offer, in such a way that the enormous computing task of the brute force method could be eliminated, and yet the inherent weaknesses of the empirical short-cut methods previously described might be avoided.

The essential idea involves the search for a convenient minimisation principle that would cut the Gordian knot of the complex approach. Physics abounds in the use of such principles, but we do not understand how or why they work, and it is a matter of trial and error to find which is the appropriate parameter to minimise.

In a preliminary paper, Paltridge has produced some most encouraging results. The minimised quantity is related to the global net rate of production of entropy. Specifically, it is the sum over all latitude zones of the ratio of net radiant energy input to the effective temperature of the zone. As with all minimisation principles, the test is whether it works or not. In this case, the beauty of the result is that the mean meridional distribution of temperature, cloud cover and meridional energy flux is predicted with extraordinary accuracy.

The technique contains no direct specification of the system dynamics, and to those steeped in the use of primitive equations who might feel some objection to this philosophy, I would remind them that the primitive equations themselves are indeed based on minimisation principles which we do not fully understand. The sole scientific test is that they work over a very wide range of situations.

It may also be relevant to remember that the gas and refrigeration engineer is perfectly able to predict the performance of his system by reference to the science offered by Boyle's and Charles's laws, without the need to refer to the detailed description of molecular behaviour provided by the kinetic theory of gases.

The approach being offered is scientifically sound, in my view, and could conceivably usher in a new wave of thinking about our means of describing the atmosphere.

## THE NEED FOR MORE DATA

This is the perennial cry of the meteorologist, but it is a very real need. Fairly detailed information is available for the northern hemisphere for the last twenty years. In the case of the southern hemisphere this lack severely limits our knowledge of how the atmospheric circulation takes place. The deficiency is being alleviated by the use of satellites and balloon-borne sondes, but the situation is even worse in the oceans, where little information is available about currents and the ocean heat flux.

There is a similar lack of information on the concentration of atmospheric constituents which might affect climate, such as  $\text{CO}_2$ , and the baseline station concept has grown to meet this need. The USA has already shown considerable initiative in this regard, having baseline stations established in Barrow, Alaska; Mauna Loa, Hawaii; the South Pole; and one projected for American Samoa. Australia has taken the decision in principle to establish a baseline station, but the process of putting this decision into effect is not yet completed.

## SCIENCE AND GOVERNMENT

A number of government initiatives that are lingering on the point of decision are very relevant to the matters raised. These are:

- (i) the possibility of Australian participation in GARP, and involvement in the Japanese geostationary satellite;
- (ii) the establishment of an Australian baseline station;
- (iii) the continuance of high altitude balloon facilities, provided generously at Mildura for so long by the US Atomic Energy Commission.

In none of these areas do we have a good record for the ability to make decisions. As an example, the initiatives towards an Australian baseline station were taken within the CSIRO Division of Atmospheric Physics as early as June 1971, but three and a half years later, despite a Government decision in principle, and numerous meetings of the appropriate inter-departmental committee, we do not yet have a submission prepared for Cabinet consideration. The ponderous machinery which seems almost inevitable with our style of government does not engender a favourable climate for scientific initiative.

I am aware that all governments have difficulty in coping with the numerous competitive demands put before them in the name of science, but it would be nice to think that judgments were made on the basis of respect for the value of science to our community, rather than the ability of science to catch votes, which must be almost non-existent.

Some of us will probably remember with nostalgia the role of (Lord) Casey as the Minister representing science, and the feeling he inspired that, whatever his colleagues thought, he himself possessed a deep, inner conviction that the world would be a better place if our society maintained a substantial investment in scientific endeavour.

### CONCLUDING REMARKS

The net result of our deliberations regarding the fear of climate change is that we must return a Scottish verdict of not proven.

We do not know that the climate is changing, either naturally or due to man, although there is ample evidence that severe climatic changes have occurred in the past.

We are not able to predict with certainty what the future climate will be.

These deficiencies in the current state of meteorological science mean that, if we are to provide the answers that society, quite rightly, is demanding of us, we must initiate and continue global monitoring programs relevant to climate, and we must seek to improve our theoretical understanding of the atmosphere so that we may advance our predictions with greater confidence. This cannot be done by waving a magic wand. If it is to be done at all, it can only be done by the provision of the appropriate facilities. This costs money, and society must take the decision as to whether the matter is of sufficient importance for public money to be spend in this way.

The meteorological community of the world is made of up all kinds of personalities. Naturally there are some, who, having assembled a model which happens to predict an ice age, are unusually ready to announce their finding with much publicity. When their results are repeatedly quoted by non-meteorologists, often with eloquence and persuasiveness, but neglecting the subtle though important weaknesses which exist in the basic formulation, speculation becomes probability, and probability becomes certainty. Scientists themselves are not always aware of their own frailty in focusing on a particular result which supports their preconceived notions, and neglecting all evidence to the contrary. There is much of this in popular writings on climatic change, as indeed in many subjects where conservation is invoked with religious fervour.

I would like to conclude with an apt quotation from one authority.

'There is probably nothing more important to man's future on this planet than an understanding of the long-range effect of his activities. The history of earth gives abundant evidence of cataclysmic happenings. The possibility that we might inadvertently set off an irreversible reaction must be constantly kept in mind.

'At the same time, we should be careful not to cry "wolf" needlessly or too often. The public and media give special weight to anybody who is a scientist, provided they make news. Scientific credibility can easily be lost by exaggerated claims and extravagant statements. We need to provide a voice of reason, not just of alarm. As scientists, we have the responsibility to speak up, but we must also know when to stop talking.'