Prepare now for climate change, scientists warn

Scientists have been talking for many years about the possibility of global climate change wrought by the warming effects of extra carbon dioxide and other 'greenhouse-effect' gases. But, until recently, they have heavily qualified their predictions by statements about the uncertainties in forecasting future atmospheric composition, and about how inadequately computers could model the effects on the earth's climate.

Now, however, a general warming trend has been firmly established, and laboratories around the world have become more confident about the reliability of their predictions of associated climatic changes. It has become a matter of how to predict the regional details of these changes, rather than determining whether or not they will occur.

We are now certain that fossil fuel combustion is the prime cause of the carbon dioxide increase, while the destruction of forest is, at most, a secondary contributor.

Each year, combustion of gas, oil, and coal releases 18 billion tonnes of carbon dioxide directly into the atmosphere. About 58% of this remains in the atmosphere and most of the rest dissolves in the oceans. Carbon dioxide concentration is now rising at the rate of about 0·4% a year throughout the atmosphere.

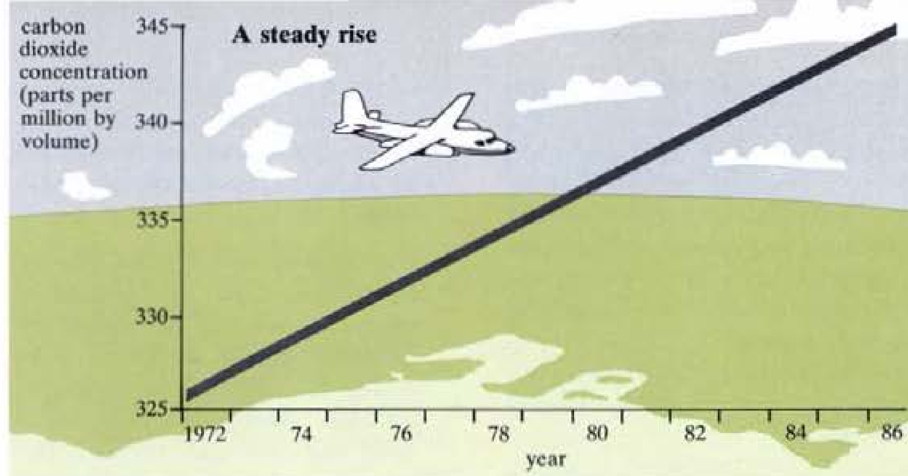
Moreover, high-precision measurements of atmospheric constituents from a global network of observatories (including the Australian Baseline Monitoring Station at Cape Grim, Tas.) have identified increasing concentrations of a variety of other trace gases — methane, nitrous oxide, ozone (in the lower part of the atmosphere), and chlorofluorocarbons — that also behave as greenhouse gases. Scientists working at Cape Grim (from CSIRO and the Department of Science) are continuing their watch on these gases. At present it appears that, taken together, these trace substances will have an effect on climate of about the same magnitude as that of carbon dioxide alone.

Significant climatic change now appears inevitable within 30–50 years, well within the time-scale of current planning and the working lives of present structures and undertakings.

The most advanced experiments with computer models of the earth's climatic system suggest a doubling of atmospheric carbon dioxide (or its equivalent for greenhouse gases in general) will raise the globe's mean surface temperature by 1·5–4·5°C. This is expected to occur within about 50 years, despite the 'thermal lag' of one or two decades resulting from the enormous heat-storing capacity of the oceans.

A rise of, at most, a few degrees may not sound much, but it will bring about substantial changes in regional climate, and will, through thermal expansion, increase sea levels by 20–140 cm, according to oceanographers. There is little doubt that the climate changes will profoundly affect ecosystems, agriculture, water resources and sea ice. The expected sea-level rises, although they appear small, are of major concern.

The head of the United Nations Environment Program's centre for oceans and coastal areas, Dr Stjepan Keckes, warns that rising seas could threaten the Sydney Opera House within 30 years. Kiribati, a nation occupying low Pacific islands, could disappear entirely, and in Bangladesh 15



Samples of air collected by aircraft flying high over south-eastern Australia show a steady rise in the amount of carbon dioxide in the troposphere.

million people may be forced to move inland.

A message to planners

Dr Graeme Pearman and Dr Barrie Pittock, of the CSIRO Division of Atmospheric Research, are two scientists long involved in studies of the greenhouse effect, and they are urging planners and design engineers to take heed of the forecast changes. They have organised a forthcoming conference, supported by the Commission for the Future, to acquaint these people with many of the ramifications of a warmer planet (see the box). The urgency of the matter relates to the long lead times required for planning appropriate social, economic, and environmental responses; and, as the scientists remind us, overcoming human inertia requires much dedicated work.

The promptings of Dr Pearman and Dr Pittock echo those made in October 1985, when more than 100 scientists from all over the world gathered in Villach, Austria, to assess the role of greenhouse gases in influencing future climate. In their consensus statement (known as the Villach statement), the participants urged that decision-makers review their planning processes to take account of the expected changes, and to develop firm policies aimed at decreasing the emission of greenhouse gases.

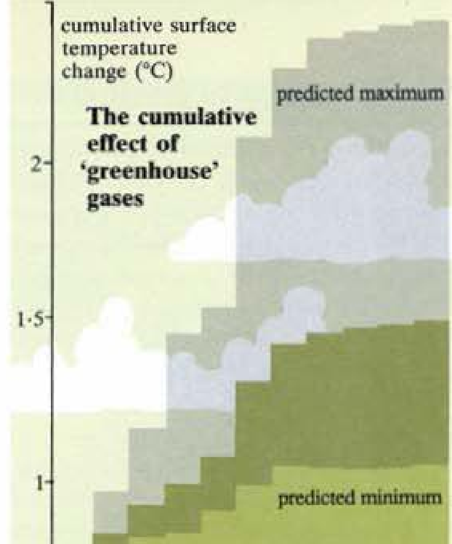
They wrote: 'As a result of the increasing concentrations of greenhouse gases, it is now believed that in the first half of the next century a rise of global mean temperature could occur which is greater than any in man's history... Many important economic and social decisions are being made today on long-term projects — major water resource management activities such as irrigation and hydro-power, drought relief, agricultural land use, structural designs and coastal engineering projects, and energy planning — all based on the assumption that past climatic data, without modification, are a reliable guide to the future. This is no longer a good assumption...'

Participants accepted the estimate of 1·5–4·5°C for the magnitude of the global warming over the next 30–50 years. The range of uncertainty reflects the complexity of the climatic system and imperfections in computer models, particularly in details of ocean-atmosphere interactions and the dynamics of clouds.

Nevertheless, a warming within the range quoted must be regarded as highly probable. Two recent experimental findings give added credence to the prediction.

Firstly, delicate techniques have been developed for recovering the air trapped as bubbles in polar ice and analysing its carbon dioxide content. Ice cores drilled to hundreds of metres below the surface provide a record of atmospheric constituents extending back hundreds of years, and show that the rising trend in carbon dioxide concentration began with the beginning of large-scale industrialisation last century (see *Ecos* 47).

These findings confirm the dominant role of fossil fuel combustion in raising carbon dioxide levels. The analysis also shows that another greenhouse gas, methane, has doubled over the same period.

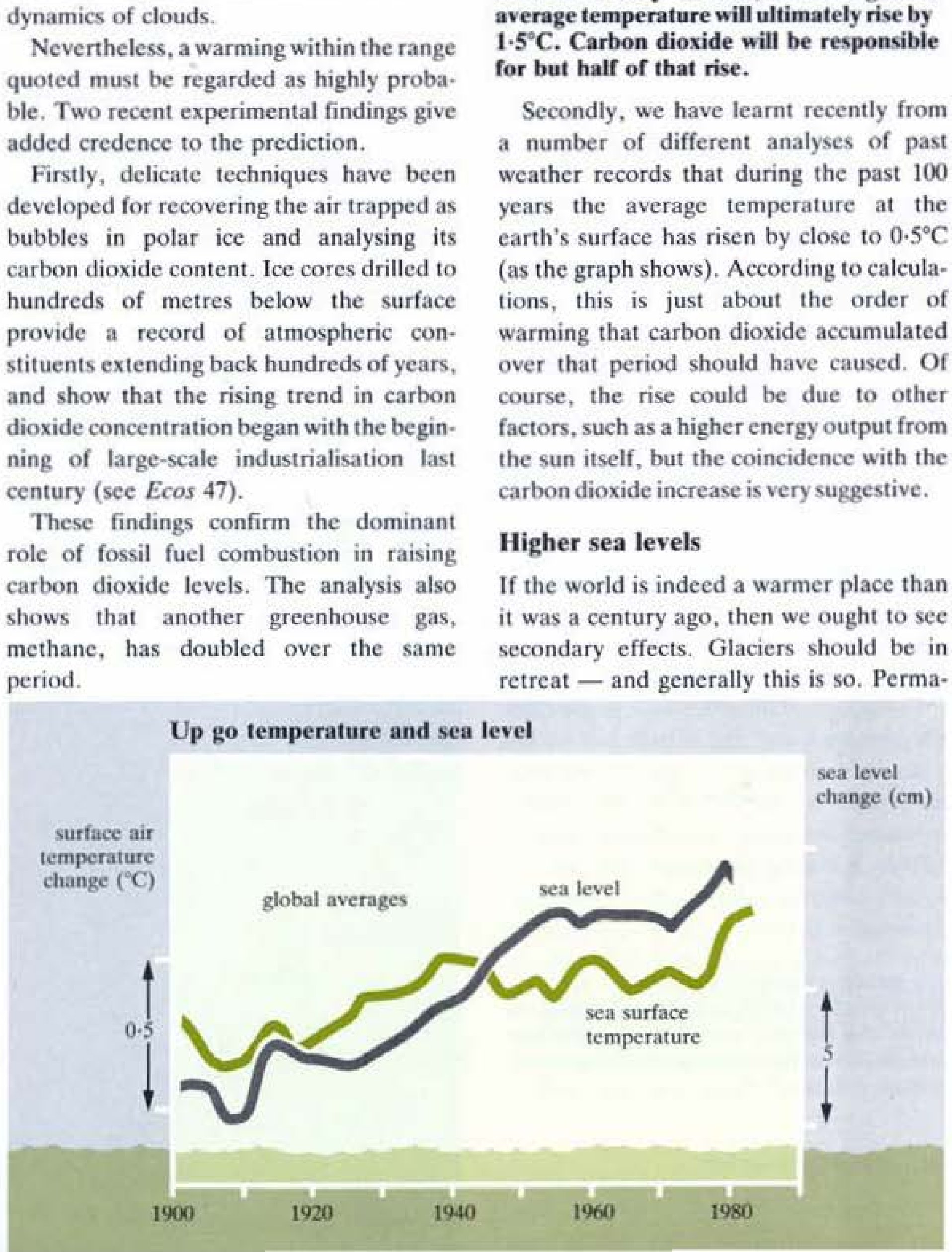


One computer model predicts that, if concentrations of carbon dioxide and other greenhouse gases keep rising at present rates until the year 2030, then the globe's average temperature will ultimately rise by 1·5°C. Carbon dioxide will be responsible for but half of that rise.

Secondly, we have learnt recently from a number of different analyses of past weather records that during the past 100 years the average temperature at the earth's surface has risen by close to 0·5°C (as the graph shows). According to calculations, this is just about the order of warming that carbon dioxide accumulated over that period should have caused. Of course, the rise could be due to other factors, such as a higher energy output from the sun itself, but the coincidence with the carbon dioxide increase is very suggestive.

Higher sea levels

If the world is indeed a warmer place than it was a century ago, then we ought to see secondary effects. Glaciers should be in retreat — and generally this is so. Perma-



As the oceans warm up, their waters expand, and sea levels rise. A further warming of 3°C should be accompanied by a rise of about 80 cm.

The greenhouse project

Faced with a rising tide of carbon dioxide of our own making, we can either sit back and wait to see what happens — and react as best we can — or we can try to anticipate the effects and plan our best strategy. Ideally, we want to minimise losses and capitalise on the gains. We should also seek to slow down the changes by trying to limit emissions of carbon dioxide and the other greenhouse gases.

To anticipate well, we will need reliable and detailed forecasts of regional climate changes and their ramifications. Scientists in CSIRO are planning research programs aimed at helping to answer this need. A wide range of engineers, planners, and other experts will, in turn, need to apply their skills to assess what these changes will mean in their own areas of expertise.

The Commission for the Future and CSIRO have commenced a program — the Greenhouse Project — to inform policy-makers and the general public of the social and environmental impacts that climate change may induce.

The Project began in mid 1987, when 40 or so specialists encompassing eight different fields got together at a workshop. The fields were primary industry; manufacturing industry; service industries (including insurance and transport); public works and services (including coastal management and irrigation); government, policy, and law; conservation and environment; education; and the economy.

Following on from this launch, two national conferences are planned for this year and next.

The first, GREENHOUSE 87, organised by the CSIRO Division of Atmospheric Research, will be held at Monash University, Melbourne, from November 30 to December 4, 1987. It has the following aims:

- ▷ to encourage research into the impact of climate and sea-level changes (of the sort expected over the next 30–50 years) on specific aspects of the Australian environment, community activities, and economy
- ▷ to establish a basis for a rational Australian research and development program designed to minimise the undesirable impacts of climate change on the Australian environment, community, and economy, and to take full advantage of the benefits that may ensue
- ▷ to communicate the scientific developments concerning the greenhouse effect (and the type of impacts and research techniques required to make reliable estimates of those impacts) to the wider community — especially to those engineers and planners who have a responsibility for the planning and construction of systems and structures to be used in the future

People interested in attending should contact: Ms Val Jemmeson, CSIRO Division of Atmospheric Research, Private Bag No. 1, Mordialloc, Vic. 3195 (telephone 03-586 7666).

The second conference, this time with a much broader scope, is planned for June next year. Called GREENHOUSE 88, and organised by the Commission for the Future, it will bring together scientists and community leaders in an attempt to disseminate to the community at large the message of impending climate change due to the greenhouse effect.

frost should be warmer, and measurements recently made in old oil exploration wells drilled on the Alaskan North Slope show temperature rises of 2·5°C or more since the wells were drilled in the 1950s. The oceans should be warmer and, through thermal expansion of sea water, sea levels should be higher. Observations do show that sea levels have risen, on average, by about 10 cm over the past 100 years.

Scientists generally agree that only over time-scales of hundreds of years will melting of polar ice caps contribute significantly to sea-level rises. In 500 years it is possible that sea levels will be 5–7 m higher following the melting of the West Antarctic ice sheet. (Over thousands of years, the melting of the East Antarctic ice sheet could raise sea levels by 55 m.)

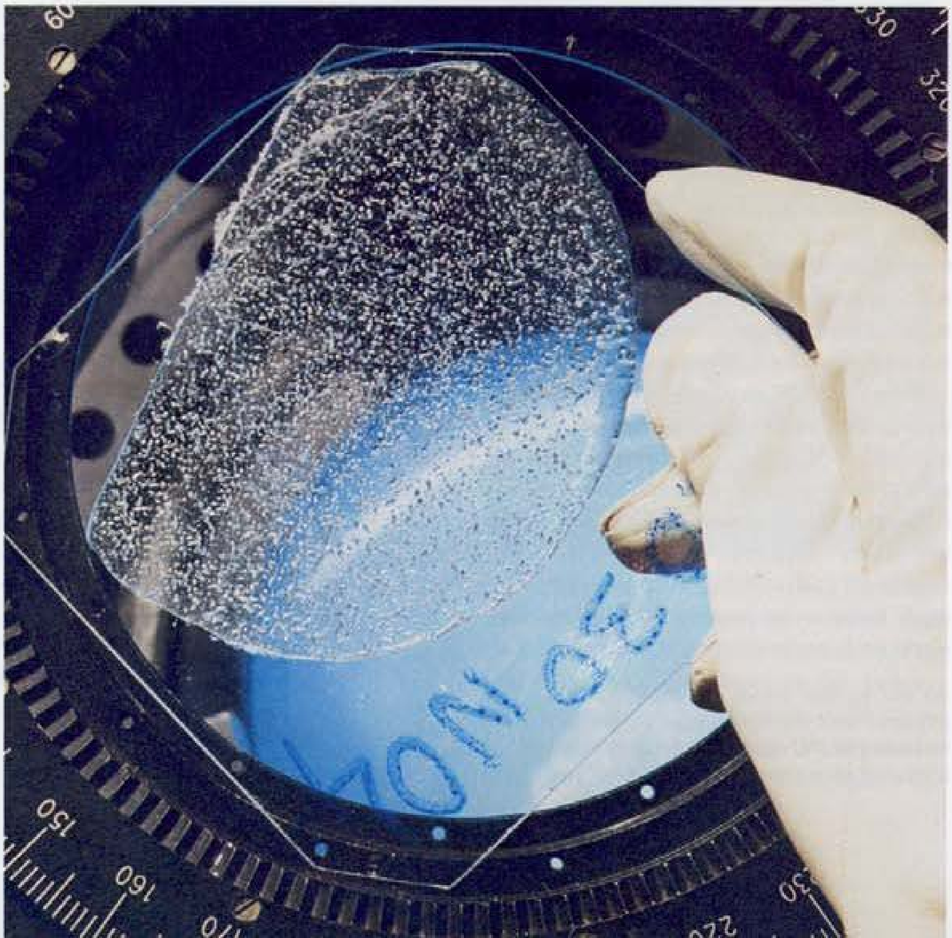
Consistent with observations over the last 100 years that the earth's surface has warmed by about 0·5°C, and that sea levels have risen by about 10 cm, the Villach statement supports calculations that a further warming of about 3°C will be accompanied by a sea-level rise of somewhere near 80 cm.

Air bubbles trapped in Antarctic ice, recovered from drilling hundreds of metres below the surface, record the progressive increase over the centuries of atmospheric carbon dioxide.

Inundation of the land by the sea will have far-reaching effects; some dramatic possibilities were noted earlier. Because the effects will be specific to the sites concerned, considerable study will be needed to make reliable predictions in each case. Rises in sea level will not be globally uniform because the warming of the oceans will vary from place to place.

Regional effects

The warming of the atmosphere brought about by the greenhouse gases is strongest in winter, and near the Poles. At the



Equator the temperature rise due to doubling of carbon dioxide may be only 2°C, but at high latitudes the winter-time increase could be as much as 8–12°C. The unevenness of future warming will bring about geographic shifts in the earth's major climatic zones, causing highly regional climate disturbances.

For example, it appears likely that the Australian summer-rainfall region will push further south, as will the influence of tropical monsoons. Together, these shifts would bring more rain to the middle latitudes of Australia, such as central New South Wales.

Indeed, recent studies by Dr Pittock suggest that such a trend in summer rain has already commenced. He has found that, from the Hunter Valley west to beyond Dubbo, average spring, summer, and autumn rainfall during the period 1946 to 1978 increased by 30–40% in some months compared with that for the period 1913 to 1945.

In contrast, Dr Pittock expects that rain-bearing fronts embedded in mid-latitude winter westerlies will move south and be off-shore more frequently than at present. Less rain will result over land, especially in the south-west of Western Australia. Again comparing rainfall records for 1913–45 with those for 1946–78, Dr Pittock finds that this region has already suffered a 10–20% reduction in winter rainfall, and the trend can only be expected to continue as the greenhouse effect becomes more noticeable.

On the basis of computer model conclusions, Dr Pittock predicts that, for doubled carbon dioxide, average temperatures will rise by about 2°C over inland areas of northern Australia, and by up to 3 or 4°C further south. Near the coast, increases will probably be moderated by lagging sea-surface temperatures. Minimum temperatures — overnight and in winter — are likely to be more affected than daily maximum and summer temperatures.

Higher temperatures cause increased evaporation — leading, on average, to greater precipitation. Computer models suggest global average rainfall figures 7–11% higher than at present for a doubling of the atmospheric blanket.

And higher temperatures give air a bigger capacity to hold water vapour; consequently we face the likelihood that figures for maximum rainfall intensity will also increase. Such figures are critical in assessing the risk of flash floods, and in the design of dam spillways and the like.

Soil moisture and water run-off exist in delicate balance between rainfall and evaporation. With marked regional and seasonal changes in the last two, the outcome for the other factors is far from clear. Research by Dr Pittock and Mr Henry Nix, head of the Centre for Resource and Environmental Studies at the Australian National University, is attempting to estimate expected changes in water balance resulting from likely climate shifts.

Australian snowfields could be practically eliminated if the warming trend continues.

Changes in water balance will affect the level of water tables. Rising water tables could exacerbate problems of soil salinity in some inland river basins.

Tropical cyclones are born and sustained only where the sea-surface temperature exceeds about 27°C. An increase in water temperature by 2–3°C would allow tropical cyclones to be set loose some 200–400 km further south. In the year 2030, therefore, a cyclone could strike Brisbane. Moreover, warmer oceans are expected to produce more violent cyclones.

Snow enthusiasts may also suffer. The snow-line is sensitive to average temperature, with every 1°C increase capable of raising the altitude of permanent snow-lines by 100 m. Australia's snowfields don't exist year-round, but if a similar relationship applies to them they could be practically eliminated if the warming trend continues.

Finally, increased carbon dioxide concentrations would directly affect plant growth. Laboratory and glasshouse experiments indicate that a doubling of carbon dioxide levels leads to a 0–10% increase in the growth and yield of plants such as corn, sorghum, and sugar-cane (which employ a C-4 photosynthetic pathway), and a 10–50% increase for plants (the majority) that utilise a C-3 pathway — including wheat, rice, barley, and most fruits and vegetables.

However, it's not clear that all of this increase, registered with individual plants, will occur in whole crops or forests, since canopy interactions and other growth-limiting factors blur the picture. Other complications include competition with weeds of promoted vigour, and the apportioning of increased growth between edible and inedible fractions, or between protein and carbohydrate content.

Dr Roger Gifford of the CSIRO Division of Plant Industry has undertaken experiments to try to clarify the probable outcome, and these are continuing. One thing is already clear: plants growing under high carbon dioxide conditions demonstrate a pronounced improvement in efficiency of water use, and this factor alone will certainly promote higher rates of plant productivity, and will extend growing regions into more arid environments.

Among natural vegetation, carbon dioxide's 'fertiliser effect' could change species composition. On farms, extra carbon dioxide and the associated climatic change may dictate a switch from one crop to another, and a change in weed-control strategy. The incidence of various plant diseases, notably rust and other fungal diseases, will probably alter, as will the abundance of insect pests like locusts and aphids.

Clearly, the world will be a very different place when human influence pushes carbon dioxide concentrations above 700 p.p.m. some time next century. The planet will, so far as we can tell, exist in a state of warmth not experienced for at least a million years.

Andrew Bell

More about the topic

Climatic changes and coastal management. G.I. Pearman. *Planner*, 1986, **2**, 11–13.

The greenhouse effect. A.B. Pittock. *Engineers Australia*, 1987, **59**, 40–3.

Exploiting the 'fertilizing' effect of higher levels of atmospheric carbon dioxide. R.M. Gifford. *Proceedings, International Symposium on Climate and Food Security, New Delhi, February 1987.*