Great greenhouse in the sky?

The latest report on the carbon dioxide problem deserves careful reading but does not settle the question whether there will be calamity. But its proposals for research should be taken up.

WHAT is to be made of the problem of accumulating carbon dioxide in the atmosphere? The latest opinion on the subject, the report of Dr William Nierenberg's committee of the National Research Council of the US National Academy of Sciences, *Changing Climate*, published last month (see *Nature*, 27 October, p.751) can be read in two ways. Either, innocent readers may conclude, the problem is even more complicated than had been thought, or the new document serves chiefly to confirm the suspicion that there will at some stage be a pronounced alteration of the Earth's climate caused by the greenhouse effect. Especially because the document says nothing new about the climatic models used to predict the changes that may occur, but instead endorses the conclusions of a report published last year under the same auspices by a panel headed by Joseph Smagorinski (*Carbon Dioxide and Climate: A Second Assessment*, Washington DC, 1982), some readers will conclude that the only certainty is that the carbon dioxide problem, whatever it is, is one year nearer than it was a year ago.

That would do the Nierenberg document an injustice. The outstanding issues about the climatic models will not in any case be quickly cleared up. One of these is the difficulty of including realistic clouds in climate models even though it is accepted that clouds must to some extent work towards climatic stability, with higher surface temperatures implying more atmospheric moisture, more cloudines and thus less radiation reaching the surface of the Earth. Another is the persisting uncertainty about what happens to the carbon dioxide added annually to the atmosphere by the discharge of combustion gases. The Nierenberg report shows more precisely than its predecessors that only a proportion, perhaps 60 per cent, of the annual load of carbon dioxide remains in the atmosphere, so that the rest must disappear either into the oceans or into vegetation. The snag is that there is still no conclusive evidence of how this fraction is related to the total concentration in the atmosphere and so no certain way of moderating future estimates of carbon dioxide concentration by a realistic estimate of the rate at which it will be naturally removed. (If anthropogenic emissions were to cease, the atmospheric concentration would presumably begin to edge back to what it used to be in the early nineteenth century.) On the third major uncertainty in the climatic models, the still imprecisely known effect of heat (and gas) transfer between the atmosphere and the oceans, however, the new report is informative.

What follows is a miscellaneous selection of some of the data buried in the Nierenberg report, not the least arresting of which is still the direct demonstration, by means of infrared observations of the Sahara Desert from the Nimbus 4 satellite, that carbon dioxide does virtually block out transmission of infrared radiation in the wide band around a wavelength of 15 μm (Hanel, R.A. *et al. J. geophys. Res.* **11**, 2629–2641; 1972). Second, there is now ample evidence not merely of the increase of the average annual concentration of carbon dioxide at stations such as Mauna Loa in Hawaii but of the slow increase in the amplitude of seasonal fluctuations of carbon dioxide concentrations (probably caused by the annual growth of vegetation in the spring and summer in the Northern Hemisphere) of about 10 per cent per decade. The accumulation of further data from several stations throughout the world should make it possible to disentangle the causes of the well-known annual fluctuations of carbon dioxide concentration, not nearly as well linked with the calculated emission of carbon dioxide as might be hoped. In his contribution to the Nierenberg report, Lester Mechta even invokes the El Niño phenomenon, the geophysicists' equivalent of the universal solvent, as a possible explanation.

The prediction of future carbon dioxide emissions is probably the best-known part of the whole enterprise, but involves assumptions of two kinds — estimates of future energy consumption, which in turn entails estimating the total level of economic activity, and estimates of the extent to which this will be partitioned between the consumption of fuels releasing carbon dioxide to the atmosphere and other sources of energy, of which nuclear and solar energy are the only significant candidates. The data given in the Nierenberg report argue for the emission of some 10 gigatonnes of carbon dioxide a year by the end of the century (with a factor of two covering the spread of the various estimates). The uncertainties beyond that are, however, so great that a greenhouse effect expected, on present trends, to become apparent only halfway through the next century might in fact not become apparent for a century after that. But provided that the greenhouse effect is not largely cancelled out by some hitherto unknown negative feedback, continued accumulation of carbon dioxide must make the effect apparent later if not sooner.

This is why attention necessarily centres on the oceans, and on the exchange of heat and gases at the interface. The Nierenberg report includes a clear summary by P. G. Brewer of the chemistry of carbon dioxide in seawater, in particular of the mechanism by which it is expected that continuing solution of carbon dioxide, by decreasing the normal alkalinity of saline seawater, will decrease the solubility of carbon dioxide at the surface. This is without question a positive (or destabilizing) feedback, but too little is known of the variations of carbon dioxide removal at various parts of the ocean surface for accurate predictions of the future course of events to be possible. But Brewer does quote evidence to show that the partial pressure of seawater in the Sargasso Sea has been increasing during the past quarter of a century.

Heat removal is a more difficult problem, at least while so little is known of the stability of the oceanic surface layer in conditions very different from the present (such as would obtain if the thermocline were uniformly deeper). But Roger Revell raises in the Nierenberg document a scary possibility — that increased oceanic temperatures might release large quantities of methane from the hydrous clathrates in which it is supposed to be combined in oceanic sediments at great pressure. Methane is, of course, another potential cause of greenhouse warming.

In the most provoking section of the Nierenberg report, G. Weller *et al.* consider the problem of detection. Trends of mean air temperature are shown to be poor indicators of climatic change but also essential — they are the only variables for which long records are available. Sensibly, the group argues for a more comprehensive programme of climatic monitoring if only so that those concerned can evaluate claims to have detected warming. Other possible causes of climatic fluctuation than carbon dioxide, such as other greenhouse gases, volcanic aerosols and changes of solar output, need careful watching, while the group gives priority among climatic variables to the measurement of sea surface temperatures, stratospheric temperatures, variables that might throw light on the radiation balance at the surface of the Earth and the water content of the atmosphere.

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