Future Emissions and Concentrations of Carbon Dioxide: Key Ocean/Atmosphere/Land Analyses

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Abstract

Various projections of the relation between future CO_2 concentrations and future emissions were undertaken as part of the scientific assessment for Working Group 1 of the Intergovernmental Panel on Climate Change. There were three types of calculation: (i) forward projections, calculating the atmospheric CO_2 concentrations resulting from specified emission scenarios, (ii) inverse calculations determining the emission rates that would be required to achieve stabilisation of CO_2 concentrations via specified pathways and (iii) impulse response function calculations required for determining Global Warming Potentials.
The use of a standardised set of conditions allows an intercomparison of models. Sensitivity studies explore other aspects of the uncertainties of such projections. This report documents the specifications, the models that were used and the results that were obtained. Some preliminary interpretations of the results are included.

1. Introduction

This report documents a set of calculations which relate future atmospheric CO_2 concentrations to industrial emissions. These calculations were performed in support of the report on *Radiative Forcing of Climate Change* of the Intergovernmental Panel on Climate Change (IPCC). Calculations were contributed by groups from a number of countries (a list is given as Table 5.1, and summary descriptions of models are given in Appendix C). The specifications for the calculations were prepared by Tom Wigley and Ian Enting who were charged with this duty at the IPCC WG1 Bureau and Ozone Assessment 'Experts' Meeting (Bath, UK, 18–19 February, 1993). These instructions are reproduced in this document as Appendix A.

In assessing these calculations it must be emphasised that they are not 'predictions' of a specific future. We prefer the term 'projections' — calculations of the possible consequences of prescribed courses of action. Similarly, these results do not constitute recommendations on the part of the contributors, the editors or the IPCC. In particular, the pathways to stabilisation are illustrative rather than prescriptive. The calculations are intended to present ranges of options that may be relevant to dealing with the problems arising from greenhouse gas emissions. The results also give an indication of the accuracy with which such calculations can be undertaken at the present time.

One aspect of the calculations that prevents them being regarded as predictions is the neglect of feedbacks between CO_2 and climate. The uncertainties in such feedbacks are too large to justify

defining any standard cases for comparitive studies at this time. A small number of calculations with feedbacks were contributed. These are discussed separately in Section 12.

The inputs for the various cases are specified in terms of future values of emissions or concentrations specified as functions of time. It is important to ensure that the definitions are both complete and consistent. These issues are discussed at greater length in Section 2b below.

The main calculations are those concerned with the stabilisation of atmospheric concentrations of CO_2. This emphasis is motivated by the provisions of the UN Framework Convention on Climate Change which has as its objective: *to achieve stabilization of greenhouse gas concentrations ... at a level that would prevent dangerous anthropogenic interference with the climate system ... within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner*. For the present modelling exercise, we have constructed a set of profiles [1], defining CO_2 concentrations as functions of time, that lead to constant CO_2 concentrations in the 21st or 22nd centuries.

Previously, projections of future CO_2 had been included in the IPCC reports (IPCC 1990, 1992). The update (IPCC, 1992) included few specific projections of CO_2. However, it did introduce new emission scenarios, IS92a–f, and included assessments of the climatic consequences using the STUGE system (Wigley et al., 1991). This integrated system included a carbon cycle model that was an earlier version of the Model W whose results are reported here.

Our objective has been to present options based on a credible scientific assessment. For this reason, an important part of our report is an analysis of the uncertainties. We have also reviewed the validation and calibration of the models in connection with this analysis.

However, scientific credibility is achieved as a result of critical examination. While the results in this report have been scrutinised during the process of compilation and the overall report has been subject to peer review, the ultimate assessment of its credibility will occur after the results are made freely available to the scientific community.

The modelling presented here is based on a large body of scientific knowledge and experience. While we do not attempt to review the carbon cycle modelling literature, we note a few key general references: Bolin et al. (1981), Bacastow and Bjorkstrom (1981), Broecker and Peng (1982), Emanuel et al. (1985), Sundquist (1985) and Bolin (1986). Other key references are noted in connection with particular topics. [2]

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[1] The preferred IPCC terminology is to reserve the term 'scenarios' for those cases that are determined from specific policies.

[2] *Footnote to electronic edition* Of course up-to-date assessments can be found in the IPCC reports and references there in.