THE EFFECTS OF CARBON CYCLE MODEL ERROR IN CALCULATING FUTURE ATMOSPHERIC CARBON DIOXIDE LEVELS

J. A. LAURMANN* and J. R. SPREITER
Division of Applied Mechanics, Stanford University, CA 94305, U.S.A.

Abstract. Empirical investigations have indicated that projections of future atmospheric carbon dioxide concentrations of a quality quite adequate for practical questions regarding the environmental threat of anthropogenic carbon dioxide emissions and its relationship to energy use policy could be made with the simple assumption that a constant fraction of these emissions would be retained by the atmosphere. By analysis of the structural behavior of equations describing the transfer of carbon and carbon dioxide between their several reservoirs we have been able to demonstrate that this characteristic can be explained to result from approximately linear behavior and exponentially growing carbon dioxide release rates, combined with fitting of carbon cycle model parameters to the last twenty years of observed atmospheric carbon dioxide growth.

These conclusions are independent of the details of carbon cycle model structure for projections up to 100 years into the future as long as the growth in atmospheric carbon dioxide release rates is sufficiently high, of the order of 1.5% per annum or more, as referenced to pre-industrial (steady state) conditions. At low rates of growth, when the longer response times of the carbon cycling system become important, for most energy use projections the resultant CO2 induced climate changes are small and the uncertainties in predicted atmospheric carbon dioxide level are thus not important. A possible exception to this condition occurs for scenarios of future fossil fuel use rates designed to avoid atmospheric CO2 levels exceeding a chosen threshold. In this instance details of carbon cycle model structure could significantly affect conclusions that might be drawn concerning future energy use policies; however, it is possible that such a result stems from inappropriate specification of a criterion for an environmental threat, rather than from inherent inadequacy of current carbon cycle models.

Recent carbon cycle model developments postulate transfer processes of carbon into the deep ocean, large carbon storage reservoir at rates much higher than in the models we have analysed. If the existence of such mechanisms is confirmed, and they are found to be sufficiently rapid and large, some of our conclusions regarding the use of the constant fractional retention assumption may have to be modified.

1. Background

In a series of research recommendations concerning the fossil fuel induced threat of global climatic change from CO2 emissions, we ranked study of carbon cycle models low on the list of priorities (Laurmann, 1978, 1980), basing this conclusion on an inter-comparison of predictions made by a large number of carbon cycle models of future increases in atmospheric CO2 levels. Figure 1 shows the results we obtained and Figure 2 is an alternative representation of the same information designed to collapse the data

* Currently at the Gas Research Institute, 8600 West Bryn, Mawr Ave., Chicago, IL 60631, U.S.A.
Fig. 1. Fractional growth $G$ of atmospheric CO$_2$ concentration relative to pre-industrial value according to several models of the carbon cycle that assume varying fossil fuel depletion conditions. The dashed lines correspond to the fixed exponentially growing CO$_2$ atmospheric release at the rates indicated in the figure, assuming 56% atmospheric retention.

Fig. 2. Carbon cycle model predictions compared with a constant fractional retention assumption. Increments $\Delta$ are relative to 1975 conditions; $\Delta t_D$ is the CO$_2$ doubling date. The 45° straight line corresponds to 56% retention of atmospherically released CO$_2$. 