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# FUTURE GLOBAL – MEAN TEMPERATURE CHANGES

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## ABSTRACT

The green house problem, global-mean temperature charge. As this variable changes, all other climate variables will change in concert. At the regional level, large changes in temperature are expected. This will vary according to season. At present, however, models are unable to predict the details of future climatic change at the regional level. Sea level will almost certainly rise due to thermal expansion of the oceans and melting of land-based ice.

**KEYWORDS:** Global , Mean temperature changes, greenhouse gases.

## INTRODUCTION

In order to estimate future global-mean temperature changes, we must consider the transient response and somehow account for the damping effect of oceanic thermal inertia. A variety of models is potentially available for this purpose but, to date, only relatively simple models have been used in any systematic way. These simple models describe vertical heat transport in the oceans as a diffusion process, often including, in a simplified way, the effects of vertical advection [1, 2]. The results described below are based on the model of this type developed by Wrigley and Rapper [2]. The main model parameters that determine its response are the climate sensitivity and, to a lesser degree, the vertical diffusion coefficient. As noted above, climate sensitivity determines not only the equilibrium response, but how rapidly equilibrium is approached. For any given forcing, the damping or lag is greater for higher climate sensitivity.

Future warming must, of course, depend on future forcing; i.e. on future greenhouse gas concentrations. These are subject to considerable uncertainty. The present (1988) level of the most important greenhouse gas, carbon dioxide, is just over 350 ppmv. This is some 25% more than the pre-industrial (late eighteenth century) level, which was around 279 ppmv. In projecting future changes, the overall effect of changes in carbon dioxide, methane, CFCs, etc., is often expressed in terms of an equivalent carbon dioxide concentration. Using a base level of 279 ppmv in the late eighteenth century, the present equivalent carbon dioxide level is just over 400 ppmv. This is some 50 ppmv above the actual carbon dioxide level, indicating that the other greenhouse gases have, in terms of their radioactive forcing, effectively added 50 to the carbon dioxide level. The overall radiative forcing change since the late 1700s is more than 2 $W/m^2$, equivalent to increasing solar irradiance by about 1% [3,4].

For the future, the best estimate is that the equivalent carbon dioxide level will reach 558 ppmv (double the pre-industrial level) by the late 2020s. Projected changes, together with an estimate of the uncertainty.

In Figure (1), the projected changes have been made after consideration of the Montreal Protocol for reducing CFC production. CFCs are estimated to have contributed approximately 20% to total greenhouse forcing over the period 1950-85 (compared with 22% due to methane, 6% due to nitrous oxide and 52% due to carbon dioxide), and, before the Montreal Protocol, they were expected to contribute even more in percentage terms in the future.

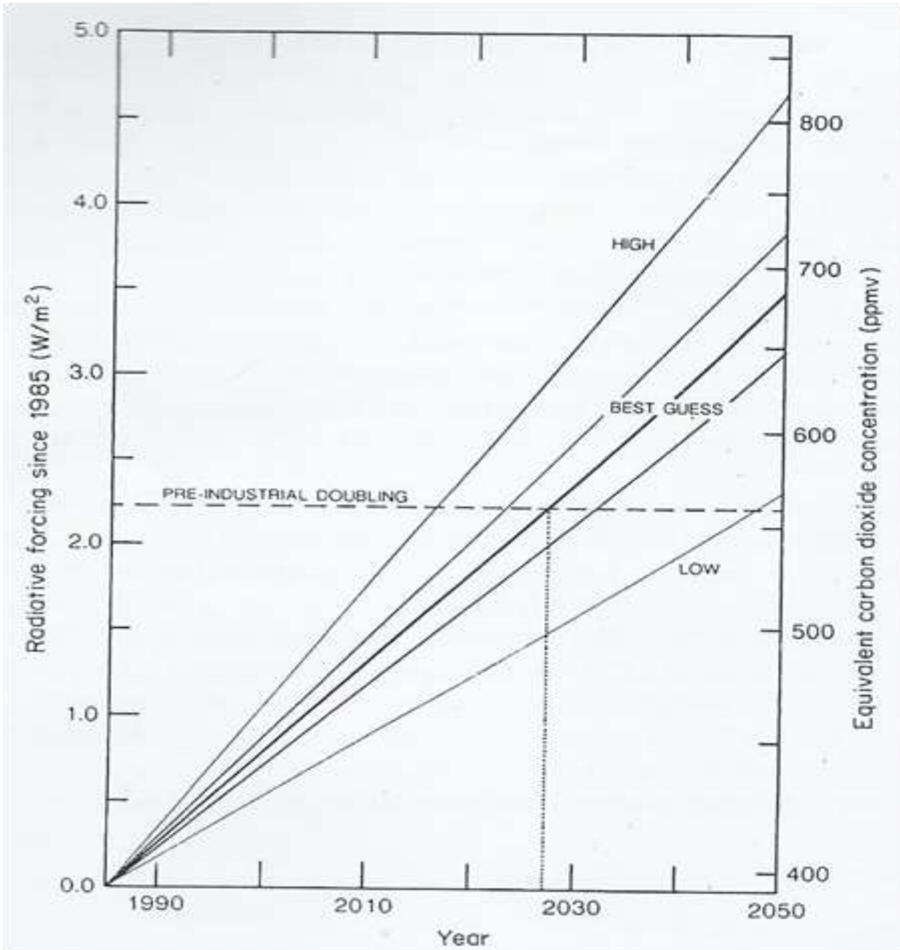
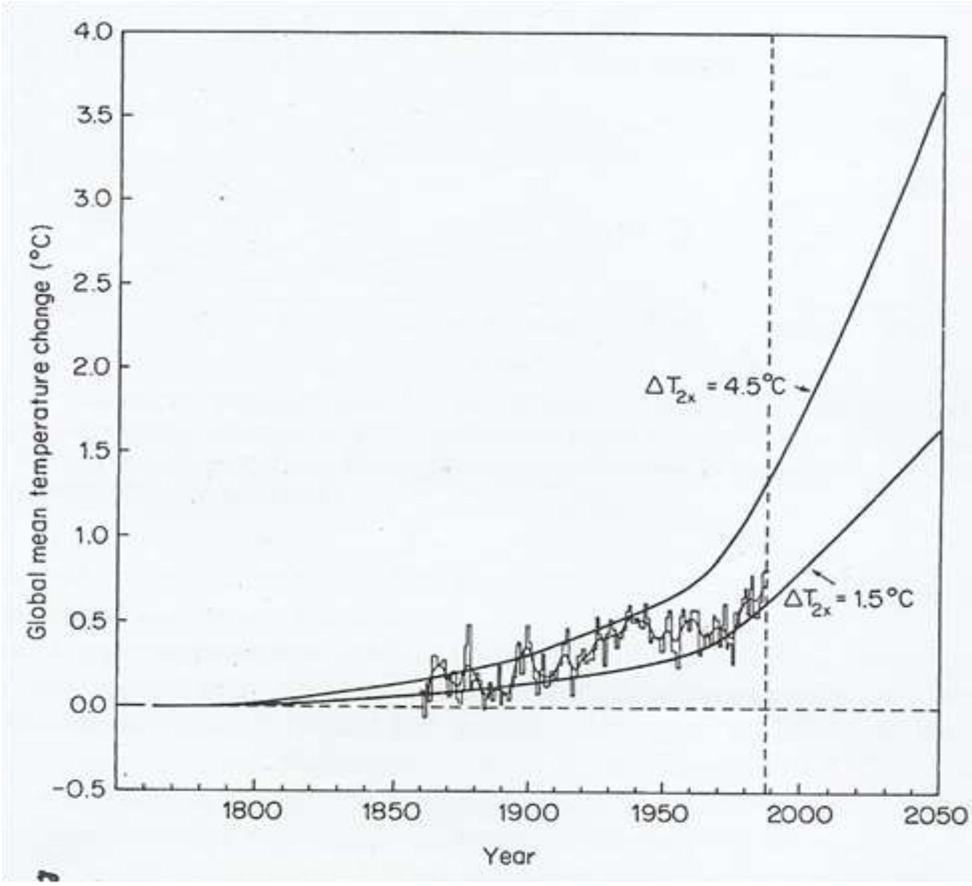



***Fig. (1) Projected greenhouse forcing, 1985-2050. The values are expressed in terms of radiative forcing and the equivalent $CO_2$ concentration. To give some idea of the magnitude of the radiative changes, a 1% increase in solar irradiance corresponds to about 2.4 $W/m^2$.***

However, if the protocol is rigidly adhered to, if all countries (including India and China) eventually sign the Protocol, and if the level of substitution by other related chemicals is relatively small, the future greenhouse contribution from CFCs will be much less. This is an optimistic viewpoint, especially since some proposed substitutes are strong greenhouse gases, but the protocol will probably be strengthened in the future so the net effect on greenhouse forcing is likely to be one of considerable benefit.

Past and projected forcing can be used as input to a climate model to estimate global-mean temperature changes. In figure (2) the forcing used is a observed up to 1988, together with the best estimate of future forcing from Figure 1 subsequently. Figure (2) also shows the observed global-mean temperature changes. The only uncertainty accounted for in figure (2) is that due to uncertainty in the climate sensitivity, which produces a band of model-based estimates of global warming. Other model uncertainties would make this band a little wider.

It can be seen immediately that the observations are consistent with the hypothesis of a long-term, greenhouse-gas-induced warming. However, it is not possible to say whether the observations fit the lower curve (low sensitivity) or upper curve (high sensitivity) better; the choice would depend on whether one concentrates on the earlier or later part of the record[5].




***Figure( 2) Comparison of observed and modeled global-mean temperature changes. The modeled data (smooth curves) correspond to observed forcing prior to 1986 and 'best guess' projected forcing after that. The two model curves show results for extreme values of the climate sensitivity, namely equilibrium 2 X $CO_2$ warmings of 1.5 ℃ and 4.5 ° C. The model runs begin in 1765.***

In spite of the overall consistency, there are important aspects of the observed record which differ from model expectations. The most obvious is the lack of observed change between 1940 and the mid- 1970s, which is at odds with the model-predicted warming. If we were certain of the magnitude of the greenhouse effect, these discrepancies would be clear indications of the magnitude of natural climatic variability; either internally generated and/or externally forced variability. Independent calculations show that natural variability of this magnitude is to be expected. However, since we cannot quantify this natural variability, we are unable to quantify the residual greenhouse component of the record. Indeed, it is still possible that none of the observed warming is the result of an increased greenhouse effect, although this is unlikely. Most scientists, therefore, say that the climatic consequences of increasing greenhouse gas concentrations have not yet been proved beyond doubt 5 but they also point out that there is no evidence that the models are seriously wrong. Furthermore, just as it is possible that much of the observed long-term warming trend is a natural phenomenon, it is also possible that there has been a strong greenhouse warming which has been partially offset by natural variability (namely, a long-term natural cooling) [6].

Figure (2) gives projections into the future, but these projections do not account for all possible sources of uncertainty. These are accounted for which is based on the extremes of forcing shown in Figure 1, together with a range of climate sensitivities ($\Delta T_{2x} = 1.5 – 4.5$°C) and a range of ocean diffusivities ($K = 0.5 – 2.0$ $cm^2/s$). Global-mean warming over the next 40 years or so is expected to be between 0.5 and 2.5°C, with a best estimate of 1.5°C. Even at the low end of this range, the rate of warming would be almost three times the average rate over the past century. At the high end, the warming rate would exceed anything observed in the past record: it would be about twice as rapid as the warming that has occurred over the past 15 years, but sustained for many decades – perhaps a century or more.

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