11.3 ASSESSMENT OF REGIONAL CONTRIBUTIONS TO PAST AND FUTURE ATHROPOGENIC CLIMATE CHANGE

Gregory Bodeker and Martin Manning*
National Institute of Water and Atmospheric Research, New Zealand

1. INTRODUCTION

During the negotiations for the Kyoto Protocol, a proposal was made by Brazil to distribute the burden of emissions reductions among Annex I countries based on the effect of their cumulative historical emissions on the global average surface temperature (T_{mean}). To investigate the scientific issues associated with such a proposal, a simple climate model has been applied to calculate regional contributions to past and future anthropogenic climate change for the following four country groups:

1. OECD90 (countries that were members of the OECD in 1990): Canada, USA, OECD Europe, Oceania and Japan
2. REF: Eastern Europe and the former Soviet Union
3. ASIA: India, China and Southeast Asia
4. ALM: Latin America, Africa and the Middle East

Annex I countries are a subset of OECD90 and REF. The model uses prescribed emissions of CO_2, CH_4 and N_2O (section 2), calculates the resultant changes in their atmospheric concentrations (section 3), changes in global radiative forcing (section 4), and finally the resultant changes in T_{mean} (section 5).

2. EMISSIONS

Past emissions are taken from the EDGAR data base (see ref list) which provides anthropogenic CO_2, CH_4 and N_2O emissions, from 1890 to 1995, for the 13 regions listed above and total bunker fuel emissions (resulting from international air and ship transport) which were attributed on a pro-rata basis to each region. Emissions were then summed for each of the 4 country groups. Anthropogenic emissions in 1750 were assumed to be zero and were scaled linearly between 1750 and 1890. These pre-1890 emissions were not attributed to any of the country groups and, together with effects of sulfate aerosol forcing (section 4), were treated as unattributed. Future emissions data for 2000 to 2100 were taken from the IPCC SRES (Special Report on Emissions Scenarios) A2 ASF scenario (see ref list). This scenario describes “a future world of very rapid economic growth, low population growth and rapid introduction of new and more efficient technology. Major underlying themes are economic and cultural convergence and capacity building, with a substantial reduction in regional differences in per capita income. In this world, people pursue personal wealth rather than environmental quality”. The resultant past and future emissions time series are shown in Figure 1. The discontinuities in 1995 result from the switch from the historical emissions data to the future emissions scenarios which do not necessarily match. These discrepancies have not yet been resolved.

* *Corresponding author address:* G. Bodeker, NIWA, Private Bag 50061, Omakau, Central Otago, New Zealand; e-mail: g.bodeker@niwa.co.nz

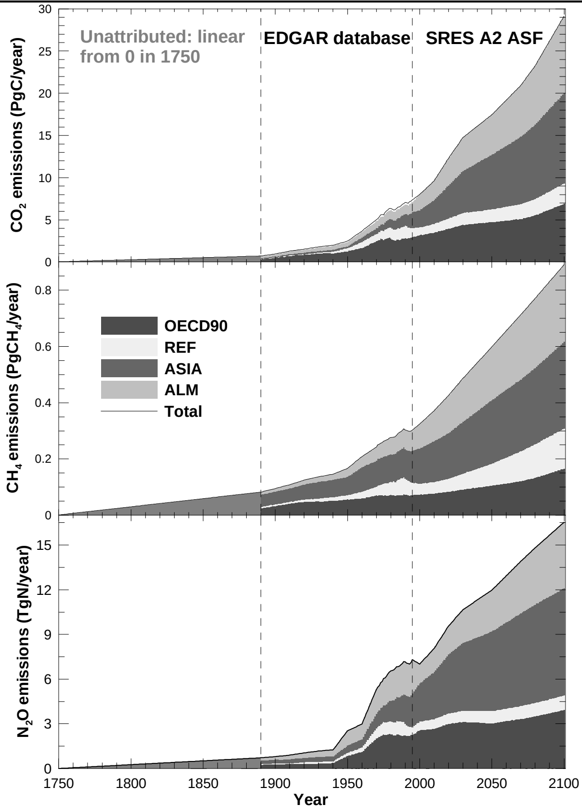

Figure 1: Emissions of CO_2, CH_4 and N_2O for the four different country groups.

3. EMISSIONS TO CONCENTRATIONS

A simple carbon cycle model was used to convert CO_2 emissions to CO_2 concentrations. The model used is the impulse response model of Joos et al. (1996) with separate response functions to describe ocean and biosphere uptake processes. To minimize non-linearities, feedbacks were neglected (e.g. the effect of temperature changes on biosphere uptake of CO_2, and temperature feedbacks on sea water CO_2 solubility). However, the model includes a number of non-linear processes. This non-linearity means that if each country group is treated individually, the total response exceeds the response if all country groups are treated as one. The ‘differential method’ (see

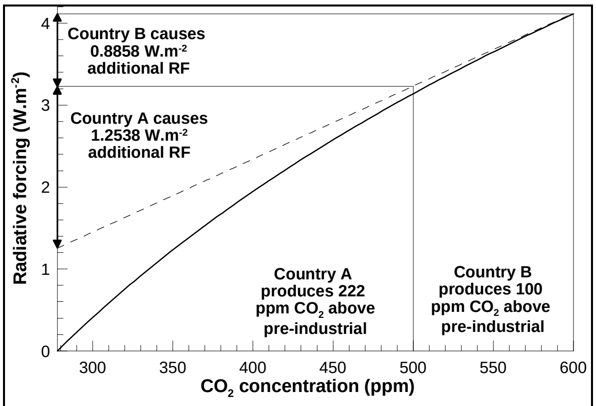

Figure 2: The differential approach to attribution in the presence of non-linear processes.

Figure 2) was used to attribute the *change* each year in the response (e.g. change in concentration) according to the attributed *change* in the driving factors (e.g. change in emissions). The separate responses are then scaled so that their sum equals the response associated with the total of the driving factors. The only parameter adjusted in the carbon cycle model was the effective air-sea exchange coefficient which was set at 0.07/year.

CH_4 and N_2O emissions were converted to concentrations by integrating the ordinary differential equations describing their budgets, using fixed life-times of 10 years and 114 years respectively.

4. CONCENTRATIONS TO RADIATIVE FORCING

The radiative forcing was calculated as the sum of the radiative forcing from CO_2, CH_4, N_2O and sulfate aerosol, with the first three of these being attributed to an emission region and the sulfate forcing being included in the unattributed class. The standard logarithmic formula for CO_2 radiative forcing given in the IPCC third assessment report (TAR) was used. Since this is a non-linear relationship, the differential method was again used to calculate the attribution. The standard square root formulae for radiative forcing for CH_4 and N_2O as given in the TAR were used. Non-linearities were treated as for CO_2. Estimates of direct and indirect aerosol radiative forcing from the UKMO HadCM3 model were used to determine factors relating sulfate emissions in the EDGAR data base to radiative forcing. Past and future forcing for each region was assumed to be proportional to the instantaneous emissions.

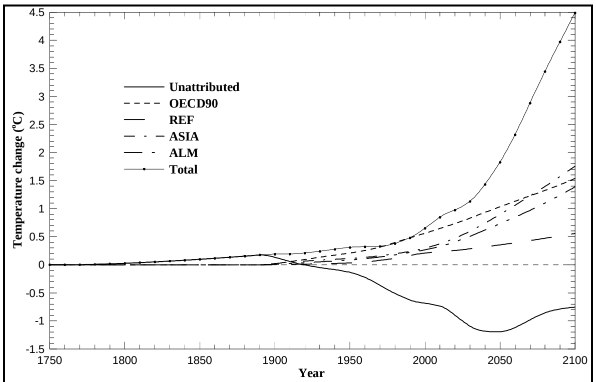

Figure 3: Calculated contributions to temperature changes as a result of the emissions shown in Figure 1 and sulfate aerosol forcing (included in the 'unattributed' class).

5. RADIATIVE FORCING TO CHANGES IN T_{mean}

An impulse response model was used to determine T_{mean} increases in response to radiative forcing changes. Because the radiative forcing used was incomplete (does not include ozone or CFCs), the climate sensitivity parameter was adjusted to 1.1°C so that the model gave a reasonable simulation of recent temperature changes. Resultant contributions to T_{mean} are shown in Figure 3. The unattributed temperature changes are largely negative as a result of the sulfate aerosol forcing being included in this class. The relative contribution of the four different regions to the attributed temperature changes are shown in Figure 4.

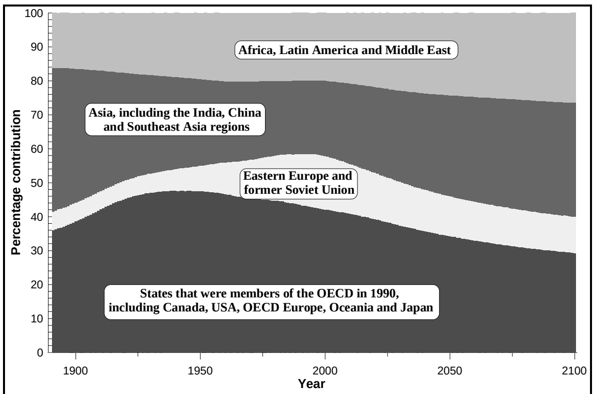

Figure 4: Percentage contribution of CO_2, CH_4 and N_2O emissions to changes in T_{mean}.

The contribution of OECD90 countries to T_{mean} maximizes at 47.6% in 1942, but this decreases to less than 30% by 2100. The contribution of Annex I countries (essentially OECD90+REF) maximizes at 58.5% in 1992, and this decreases to less than 40% by 2100.

References

EDGAR data base: http://arch.rivm.nl/env/int/coredata/edgar/

Joos, F., M. Bruno, R. Fink, U. Siegenthaler, T. F. Stocker, C. le Quéré, and J. L. Sarmiento, 1996: An efficient and accurate representation of complex oceanic and biospheric models of anthropogenic carbon uptake. *Tellus*, **48B,** 397-417.

SRES emission scenarios: http://www.grida.no/climate/ipcc/emission/index.htm