Appendix B: Data Sets Provided

Prescribed data files

The following files were made available to participating modellers via internet, as specified in the instructions (Part 5 of Appendix A of this report).

address.txt: Addresses of participants (and some potential participants).

calcs.txt: Summary of instructions, specifying cases and constraints.

calcs.tex: LaTeX source file for the full instructions.

co2spl.dat: Spline fit to Mauna Loa plus ice core data. Standard case, growth rate of 1.7 ppmv/yr for 1990.5. Columns are time, CO2, d/dt of CO2. Time intervals 0.5 years 1765.0 to 1990.5

co2-sens.dat: 3 cubic spline fits to Mauna Loa plus ice core data. First is standard case. The other 2 are for sensitivity studies. Growth rates of 1.7, 1.6 and 1.8 ppmv/yr for 1990.5. Columns are time, CO2, d/dt of CO2, CO2, d/dt of CO2, CO2, d/dt of CO2. Time intervals 0.5 years 1765.0 to 1990.5 The curves are plotted in Figures B.1 and B.2.

deforest.dat: Net carbon emissions from land-use change. Annual totals in Gt C. As estimated by R.A. Houghton. Linear extrapolation from 1850 back to 1765. Used for all forward initialisations.

deforest.all: Net carbon flux from land-use change 1765 to 2100. Combination of **deforest.dat** up to 1990 and IS92a modified to go to zero in 2100 and linearly matched to Houghton over 1990 to 2000. Standard series for all stabilisation cases and all cases with fixed percentage reductions in industrial emissions. The data are plotted in Figure B.4.

foss91.dat: Fossil carbon emissions 1765 to 1989. Annual totals in Gt C. From *Trends '91* (CDIAC, 1991), extended back from 1860 as described in instructions.

fossil.dat: Fossil carbon emissions 1765 to 1990. Annual totals in Gt C. From *Trends '91* (CDIAC, 1991), extended back from 1860 as described in instructions. New values for 1985 to 1990 from Marland.

stab.dat: Prescribed CO_2 concentrations for the 7 stabilisation scenarios. Half-year intervals.

c14sth.dat, c14equ.dat, c14nth.dat: Atmospheric ^{14}C levels for southern hemisphere (extra-tropical), equatorial and northern hemisphere (extra-tropical) regions. Supplied by M. Heimann. These data are plotted in Figure B.5.

Further details

The requirements specified by Wigley and Enting (1993) (i.e., Appendix A of the present report) included the absence of any oddities or characteristics that are unobtainable in terms of practical policies (such as very rapid emissions changes). In particular, they wished to ensure that there is no marked emissions discontinuity at the starting year for the main inverse calculations (viz. 1990). To do this requires $\frac{dC}{dt}$ to be continuous in the year 1990. This, in turn, requires $\frac{dC}{dt}$ at the start of each future $C(t)$ scenario to be equal to that at the end of the observational record.

The standard values for 1990.5 are C = 354.17 ppmv and $\frac{dC}{dt}$ = 1.7 ppmv y^{-1}. These were prescribed for all cases except those designed for explicit exploration of the sensitivity to these choices.

To ensure smoothness at all times, the pre-1990 and post-1990 segments of the CO_2 history were represented by differentiable functions: smoothing splines pre-1990 and Padé approximants (ratios of polynomials) post-1990.

Past

The CO_2 concentrations for the period 1765 to 1990 were specified as values every six months. These values were a smoothed representation of the combination of direct observations from Mauna Loa (Keeling et al., 1989) and ice-core data from Neftel et al. (1985) and Friedli et al. (1986).

The fits were defined as the functions $f(t)$ that minimised

$$\sum_{j=1}^{N}[f(t_j) - c_j]^2/w_j^2 + \lambda \int_{t_1}^{t_N} [\frac{d^2}{dt^2} f(t)]^2 \, dt \qquad (B.1)$$

where c_j is the observed concentration at time t_j and λ determines the degree of smoothing.

The solution, $f(t)$, is a piecewise cubic polynomial with nodes (discontinuous third derivative) at each data point t_j, i.e., a cubic spline commonly termed a smoothing spline. These approximations have been comprehensively studied. Some of the key results are reviewed by Enting (1987). The main result is that the smoothing spline acts as a low-pass filter with response of $1/[1 + (\omega/\omega_{1/2})^4]$ at frequency ω.

By adjusting the weights, w_j, and/or the smoothing parameter, λ, the degree of smoothing (expressed in terms of $\omega_{1/2}$) can be adjusted.

We have used three differing cases of smoothing to give our preferred reference case (with growth rate of 1.7 ppmv y^{-1}) and two other cases (with growth rates of 1.6 and 1.8 ppmv y^{-1}) for use in the sensitivity studies.

The specifications used for each are:

- Ice-core data with $w_j = 3.0$, Mauna Loa data with $w_j = 0.5$ and $\lambda = 100$ leads to a gradient of 1.7 ppmv y^{-1} at end of the record and $C(1990.5) = 354.17$.
- Tighten fit to Mauna Loa data, using $w_j = 0.29$ but relax fit to 1990 value, using $w_j = 1.74$. This leads to gradient of 1.8 ppmv y^{-1} at end of record and concentration of 354.50.
- Relax fit to Mauna Loa, using $w_j = 1.8$. This leads to a growth rate of 1.6 ppmv y^{-1} and $C(1990.5) = 353.77$.

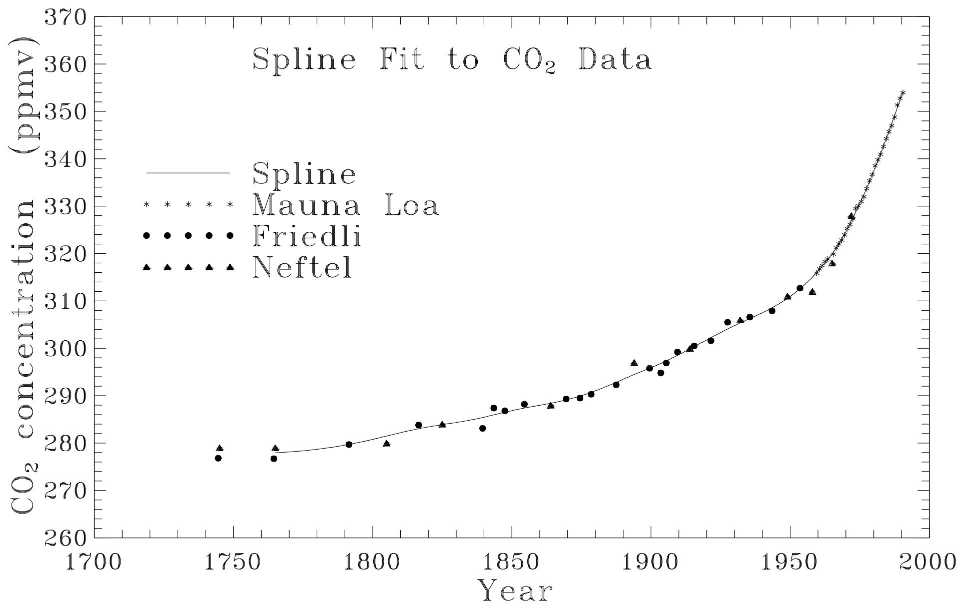

Figure B.1. Spline fit defining prescribed CO_2 concentrations from pre-industrial times to the present, compared to observed concentrations from ice-cores and direct atmospheric measurements.

Figure B.1 shows the preferred spline fit over the period 1765 to 1990. The alternatives are barely distinguishable on this scale. Figure B.2 shows the three splines over the period 1975 to 1990 compared to the data. The question of which curve is the best fit depends on the interpretation that is placed on the CO_2 data. We regard 1988 and 1989 as being anomalously high in CO_2 concentration. The atmospheric δ^{13}C for this period is also anomalous (R. Francey, personal communication). The alternative would be to regard 1990 as anomalously low. There is scope for using later data to resolve the question.

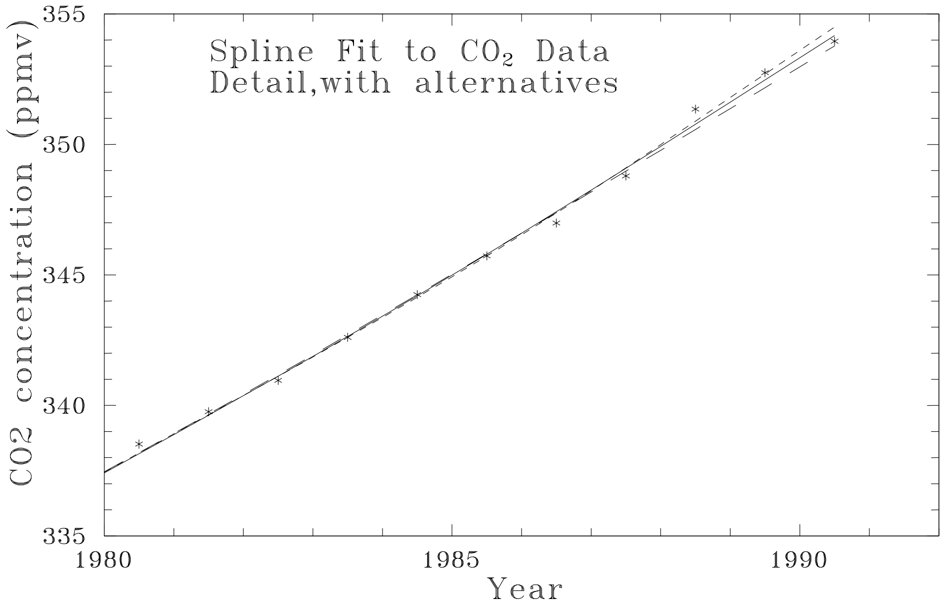

Figure B.2. Prescribed spline fits to CO_2 data showing detail of the period immediately prior to 1990. The standard case is the solid line. The other cases are those defined for sensitivity studies.

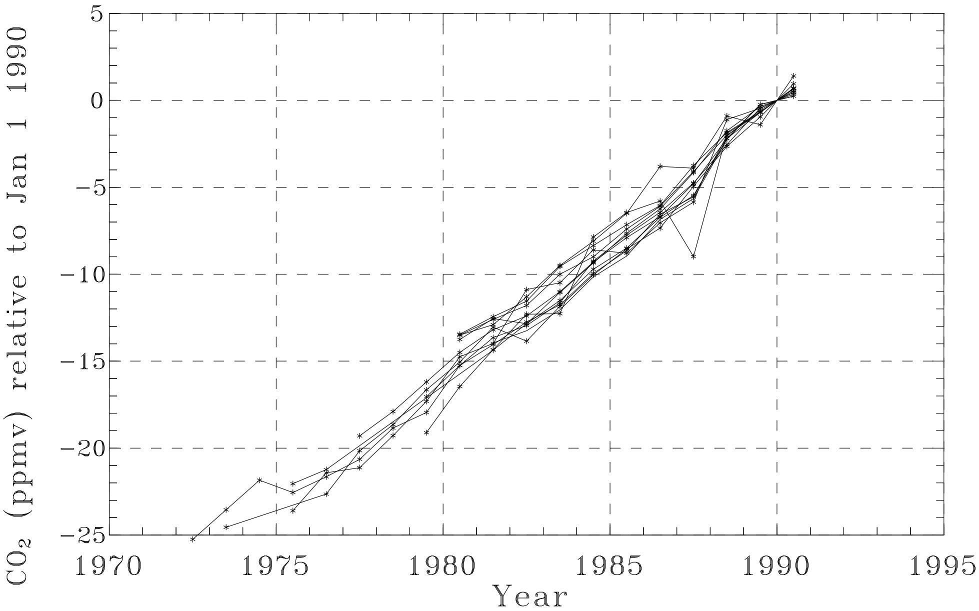

Figure B.3. Growth in atmospheric CO_2 over the 1980s. Annual means of data from CDIAC (1991), normalised to 1989–90 mean.

In view of the importance of the rate of growth in atmospheric CO_2, we show additional data to justify our use of the Mauna Loa record for defining the specified atmospheric CO_2 concentration prior to 1990. Figure B.3 shows data from CDIAC (1991) demonstrating the rate of increase over the 1980s. The data plotted are annual means, normalised to a common 1989–90 mean of zero. It will be seen that the range 1.6 ± 0.1 ppmv y^{-1} is representative of this data set which includes all stations for which data were available over all or most of the decade. As noted in Section 3, a more recent analysis by the NOAA group suggests 1.53 ppmv y^{-1} as the best estimate of the mean rate of increase over the 1980s. The NOAA estimate effectively weights the data set to take account of the fact that tropical sites are under-represented (as a proportion of the earth's area) in the NOAA network.

Future

For the 'stabilisation' cases, we required a smoothly changing set of values with a regular progression between cases. In order to achieve this, Wigley and Enting began with a set of plausible but ad hoc concentration histories and refined them, firstly by an iterative adjustment to remove rapid changes in the releases and then finally by fitting the curves with smooth functions.

The functions chosen to represent the concentration were Padé approximants, i.e. the ratios of polynomials in time. These were specified as

$$C(x) = \frac{a + bx + cx^2 + dx^3}{1 + ex + fx^2} \qquad (B.2)$$

with

$$x = \frac{t - t_0}{t_s - t_0} \qquad (B.3)$$

where $t_0 = 1990$ (except in the delayed cases) and t_s is the time of stabilisation.

Three distinct cases were used:

- The basic case, with $d = 0$, had the approximants fitted to specified values at $x = 0$, $x = 1$ and at one other x value ($t = t'$ in Table B.1), together with the constraints in the gradients at $x = 0$ (to match observations) and $x = 1$ (zero gradient).
- The 'overshoot' case was specified from values and trends at $x = 0$ and $x = 1$ and the value and trend of zero at a specified time where the concentration peaks. This was only used for S350.
- The delayed cases. These use two approximants to represent the concentrations over the periods 1990–2010 and 2010 to stabilisation. The 1990 to 2010 approximant is one of the basic cases. The second approximant has $t_0 = 2010$ and takes the value and gradient from the first approximant.

	S350	S450	S550	S650	S750	DS450	DS550
t_0	1990.5	1990.5	1990.5	1990.5	1990.5	2011	2011
$c(t_0)$	354.17	354.17	354.17	354.17	354.17	$c_{S550}(2011)$	$c_{S650}(2011)$
$d(t_0)$	1.7	1.7	1.7	1.7	1.7	$d_{S550}(2011)$	$d_{S650}(2011)$
t_s	2150.5	2100.5	2150.5	2200.5	2250.5	2100.5	2150.5
$c(t_s)$	350	450	550	650	750	450	550
$d(t_s)$	0	0	0	0	0	0	0
t'	—	2031	2031	2031	2051	2051	2061
$c(t')$	—	411.91	420.78	429.23	489.17	436.28	474.70
t_m	2041	—	—	—	—	—	—
$c(t_m)$	396.5	—	—	—	—	—	—
$d(t_m)$	0	—	—	—	—	—	—

Table B.1. Specification of Padé approximants used to define the CO_2 concentration histories prior to stabilisation. Here $c(t)$ is the concentration and $d(t)$ is the trend.

The curves defined in this way are plotted in Figure 8.1.

For the future net flux from land-use change, we used a modification of that from IS92a, as described in Appendix A. Figure B.4 shows this specified flux for the future and the specified land-use flux for the past, based on the work of R.A. Houghton.

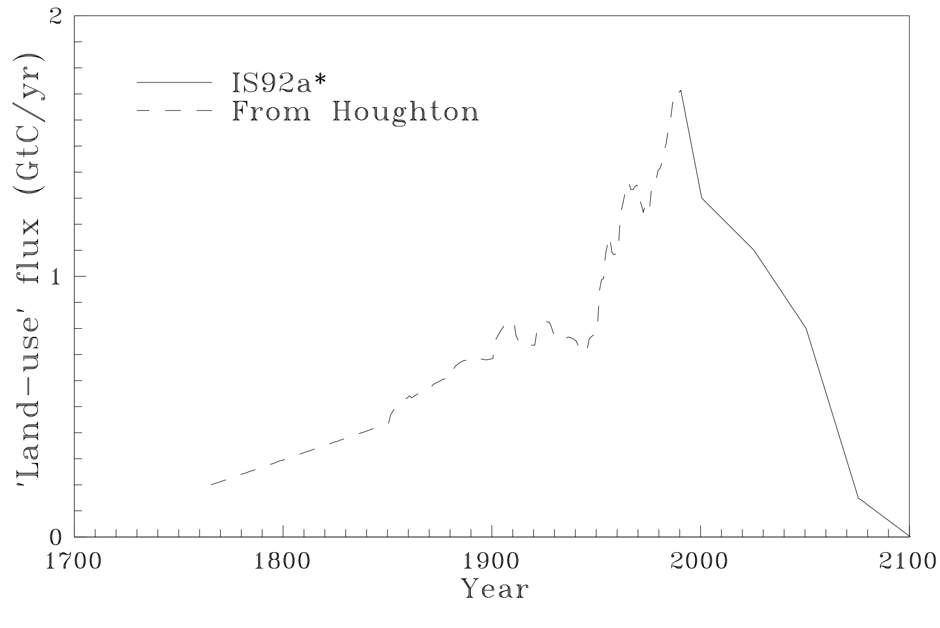

Figure B.4. Prescribed net carbon flux from 'land-use' changes.

Radiocarbon data for validation

Figure B.5 shows the ^{14}C data set provided for model validation studies.

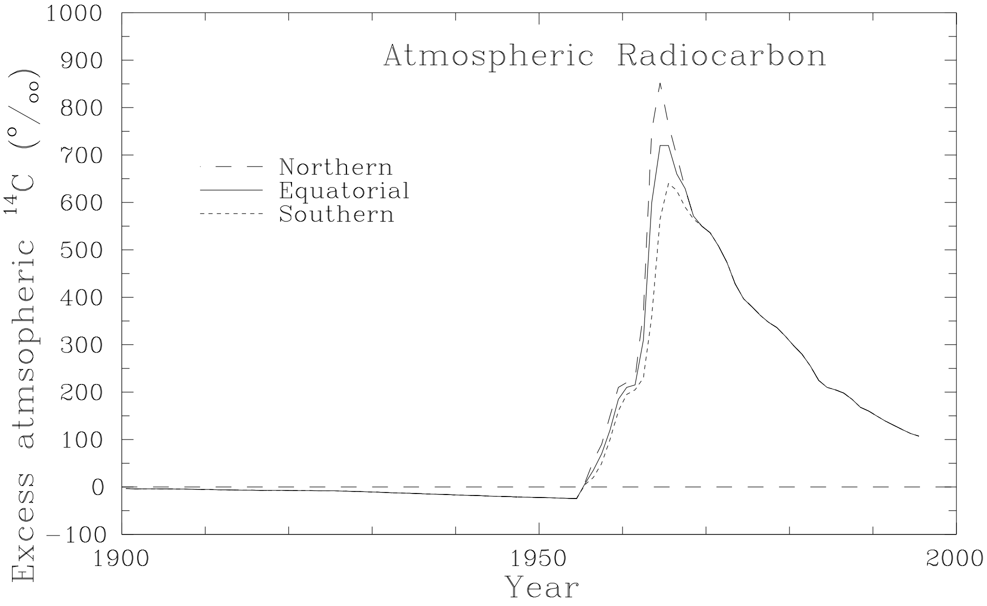

Figure B.5. Atmospheric ^{14}C levels prescribed for validation calculations.

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