8. Summary of Results for Stabilisation Calculations

Model	S350	S450	S550	S650	S750	DS450	DS550
A_1	-1.41	6.75	7.38	9.55	11.68	7.26	8.05
	2105	2001	2033	2076	2075	2011	2020
B_3	0.38	6.37	7.74	9.66	11.53	6.90	7.76
	2098	2002	2075	2077	2075	2011	2066
E	-1.26	6.92	8.42	10.71	12.94	7.57	8.69
	2111	2007	2075	2075	2075	2013	2039
F_2	-0.54	7.40	10.45	13.43	16.35	8.08	10.66
	2116	2021	2078	2092	2094	2018	2075
H		6.57		9.04			
		2000		2075			
J	-1.12	6.66	8.27	10.59	12.85	7.31	8.43
	2109	2005	2075	2075	2075	2011	2039
L	-1.48	6.82	8.02	10.35	12.64	7.45	8.43
	2108	2005	2075	2075	2075	2012	2033
M		6.26		9.43			
		2000		2076			
Q	-1.06	7.89	9.17	11.54	13.86	8.59	9.72
	2112	2010	2071	2075	2075	2013	2024
R	-0.26	7.15	8.99	10.77	12.69	7.38	9.37
	2100	2040	2056	2058	2059	2037	2043
W	0.03	6.78	9.16	11.44	13.68	7.41	9.26
	2112	2012	2075	2079	2077	2013	2073
T	-1.43	6.82	8.13	10.62	13.13	7.45	8.40
	2106	2005	2075	2079	2081	2012	2029
O		4.77		8.51			
		2007		2079			
P		6.10		7.83			
		1990		2075			
Z	1.05	7.90	11.29	13.66	16.04	8.40	11.45
	2125	2030	2080	2100	2085	2025	2075
B_1	-0.12	5.65	7.99	9.98	11.70	6.03	7.62
	2076	1998	2104	2104	2104	2008	2104
B_2	0.52	5.47	8.34	10.33	11.99	5.89	8.01
	2074	2001	2104	2104	2104	2011	2104
C		7.10		16.15			
		2000		2075			
G	0.00	7.10		13.70			
	2020	2000		2050			
V_A		6.90		16.93			
		2002		2047			
V_B		7.48					
		2010					

Table 8.1. Stabilisation cases. Maximum fossil emissions (minimum for S350), in Gt C y^{-1}, and year. The horizontal lines separate groups that are not directly comparable with the top group: the feedback case (T), ocean-only (O, P, Z), and those that fail to fit the specifications (see Section 5). The fossil (industrial) curves can be converted to total anthropogenic emissions by adding the land-use flux specified in Figure B.4. This will shift the positions of the maxima.

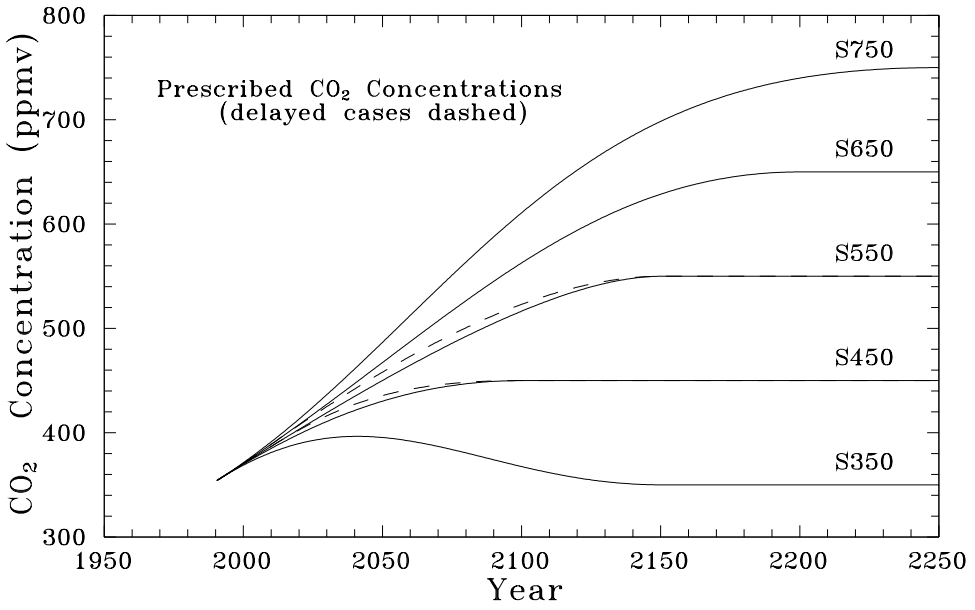

Figure 8.1. Prescribed CO_2 concentrations for stabilisation studies. The dashed curves are the 'delayed' cases DS450 and DS550.

This section describes the results of 'inverse' calculations which calculated the emissions required to achieve stabilisation of atmospheric CO_2 concentrations via specified concentration profiles. Seven sets of stabilisation profiles were prescribed, with stabilisation at 350, 450, 550, 650 and 750 ppmv. For the 450 and 550 stabilisation cases two concentration pathways were defined: a standard case, and a delayed case in which the concentrations initially followed a higher pathway and were subsequently modified to produce the lower stabilisation level. Figure 8.1 shows the seven prescribed concentration functions. The 'delayed' cases are shown as dashed.

Figures 8.2 and 8.3 show the calculated industrial emissions for various models for the S450 and S650 scenarios. Selected values for these cases are tabulated in Appendix D. The results from the two models that included climatic feedbacks are shown with short dashes. The results for the other scenarios are plotted in Appendix E. Tables 8.1 and 8.2 list some key characteristics of the results for all seven scenarios and for all models. These tables include (in their lower sections) results that are not strictly comparable in terms of the specification in Appendix A. Three models are 'ocean-only', two include climatic feedbacks, two produced poor fits to the specified concentration histories and one did not 'balance the current carbon budget', i.e., an unidentified residual sink was required for balance.

Model	S350	S450	S550	S650	S750	DS450	DS550
A	0.40	1.36	2.14	3.03	4.71	1.35	2.10
B_3	1.80	2.81	3.59	4.35	5.94	2.80	3.57
E	0.25	1.53	2.57	3.68	5.46	1.51	2.51
F_2	0.46	2.73	4.96	7.49	10.68	2.70	4.87
H		1.89		3.16			
J	0.34	1.64	2.73	3.88	5.81	1.63	2.67
L	0.31	1.39	2.27	3.33	5.20	1.37	2.22
M		1.55		2.88			
Q	0.60	2.14	3.28	4.49	6.39	2.12	3.22
W	1.02	2.73	4.16	5.58	7.57	2.71	4.10
T	0.21	1.53	2.85	4.51	7.01	1.51	2.80
O		1.95					
P		1.32		2.65			
Z	1.20	4.21	6.28	7.92	9.91	4.18	5.66
B_1	2.50	3.54	4.40	5.18	6.83	3.53	4.37
B_2	3.07	4.08	4.87	5.62	7.22	4.07	4.84
C		2.03		2.94			
G	0.00	1.49		1.50			
V_A		2.82		0.37			
V_B		5.55					

Table 8.2. Anthropogenic emissions, in Gt C y^{-1}, for 2200 (equal to calculated fossil, since prescribed land-use flux is zero) for stabilisation cases. The horizontal lines separate groups that are not directly comparable with the top group: the feedback case (T), ocean-only (O, P, Z), and those that fail to fit the specifications (see Section 5).

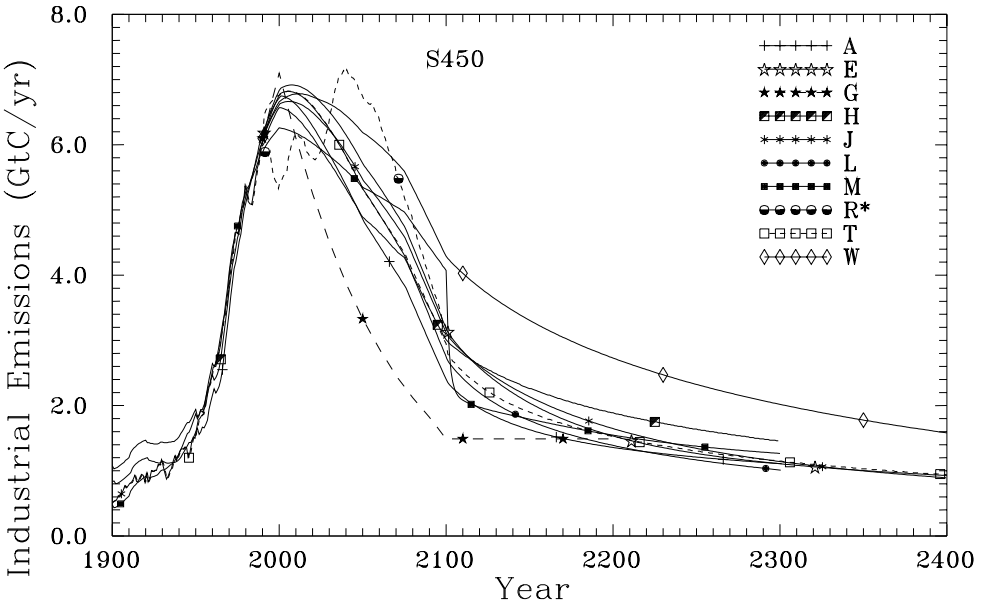

Figure 8.2. Calculated industrial (i.e., fossil) emissions for S450. Model T (short dashes) had temperature feedbacks included. Model G (longer dashes) used a different concentration profile.

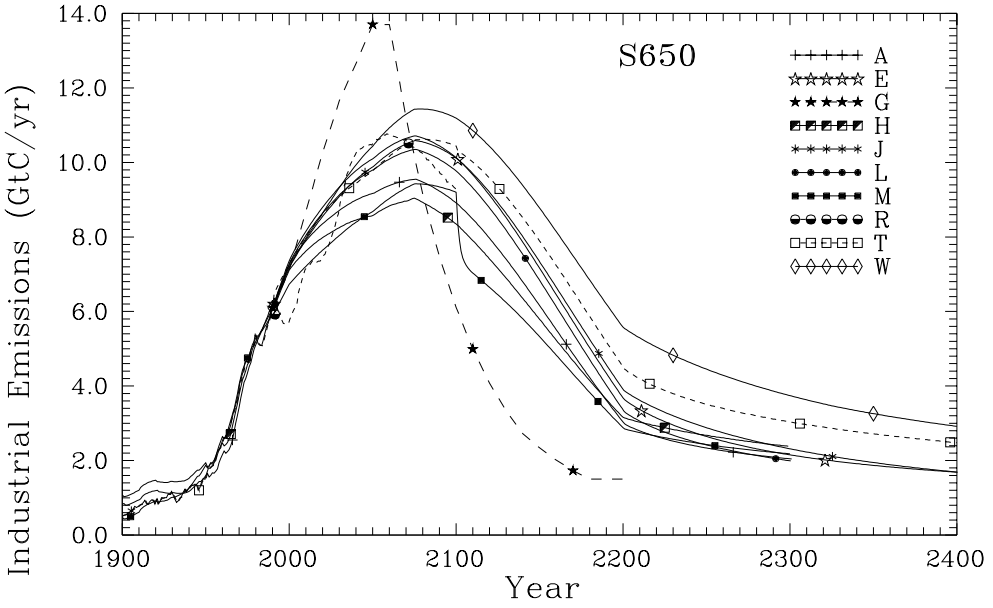

Figure 8.3. Calculated industrial (i.e., fossil) emissions for S650. Model T (short dashes) had temperature feedbacks included. Model G (longer dashes) used a different concentration profile.

For the S650 case, fluxes between the atmosphere and oceans are given in Table 8.3 and fertilisation fluxes are given in Table 8.4.

Model	1990	2000	2050	2100	2200	2300
A	2.25	2.59	3.54	3.65	2.53	1.89
B	2.74	3.15	4.26	4.39	3.07	2.30
E	2.30	2.70	3.70	3.80	2.60	2.00
F_2	2.27	2.74	4.76	6.02	5.03	3.70
H	1.63	1.87	2.55	2.72	2.18	1.85
J	2.41	2.75	3.68	3.76	2.52	1.84
L	2.38	2.65	3.27	3.22	1.90	1.35
M	1.90	2.18	3.16	3.46	2.70	2.12
O	2.36	2.76	4.18	4.71		
P	2.43	2.78	3.73	3.82	2.63	1.96
Q	2.98	3.46	4.19	3.85	2.13	1.30
R	1.63	1.69	2.57	2.85		
W	2.24	2.59	3.98	4.52	3.55	2.57
Z	4.20	5.09	8.65	10.56	7.92	4.89
T	1.98	2.30	3.20	3.95	3.54	2.80
V_A	4.22	5.35	10.26	7.08	2.80	

Table 8.3. Air-sea fluxes, in Gt C y^{-1}, for S650. All versions of Model B have the same ocean and thus the same air-sea flux in inverse calculations.

Model	1990	2000	2050	2100	2200	2300
A	2.04	2.25	2.19	1.66	0.47	0.15
J		1.97	2.74	2.74	1.36	0.47
T	2.21	2.63	3.31	3.01	1.20	0.50
W	1.85	2.12	2.98	3.07	2.03	1.17

Table 8.4. Fertilisation fluxes for S650.

Figures 8.4 and 8.5 show the effect (in emission terms) of delaying reductions in CO_2 emissions, or more specifically, choosing a higher target and then revising the target downwards. The higher emissions that are allowed in the 'pre-revision' period are largely offset by the requirements for greater reductions later. However the integrated emissions allowed in the delayed cases remain slightly higher (by less than 1 years current releases) for an indefinite future period. The real penalty for delay is that the future reductions, implied when the curves in Figures 8.4 and 8.5 go negative, are relative to the reduced emissions shown after 2050 and 2100 in Figures 8.2 and 8.3. In these cases, the marginal cost of achieving greater reductions may be greater. It appears that the result from Model G, which suggests a large penalty in total emissions if reductions are delayed (see dashed curve in Figure 8.6 a), is not representative of the set of model calculations.

Since the prescribed 'land-use' flux is the same in all cases, these curves represent the penalty in terms of both total anthropogenic emissions and in terms of calculated fossil emissions.

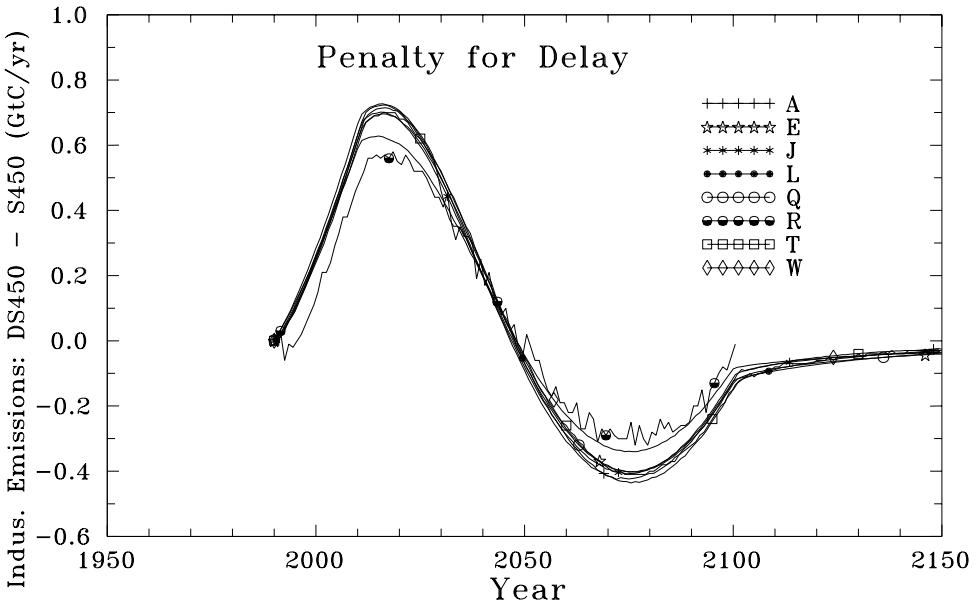

Figure 8.4. Effect of initial delay in moving to stabilisation at 450 ppmv: difference in emissions (DS450 minus S450). Model T was calculated with temperature feedbacks included.

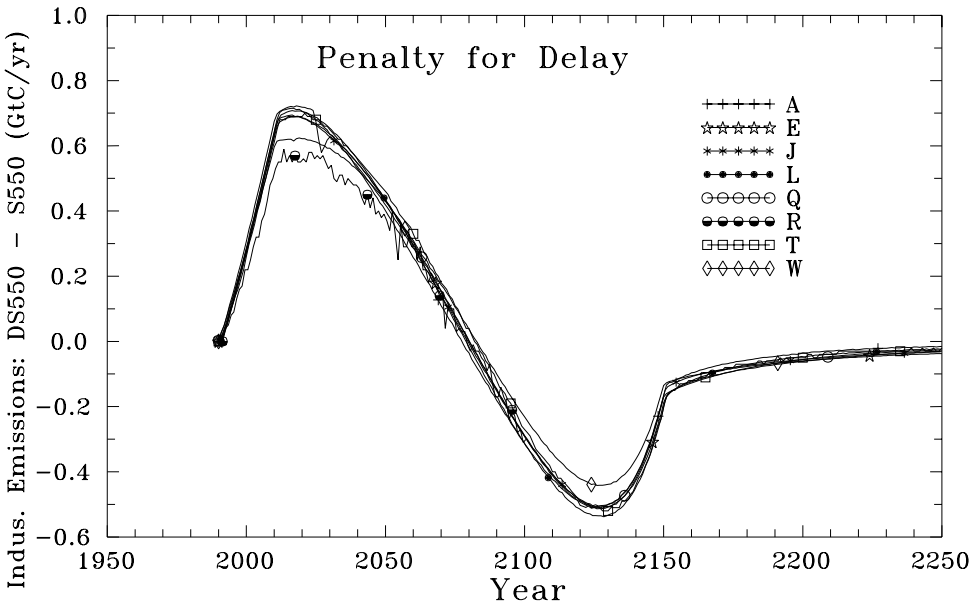

Figure 8.5. Effect of initial delay in moving to stabilisation at 550 ppmv: difference in emissions (DS550 minus S550). The curve with short dashes Model T was calculated with temperature feedbacks included.

An alternative way of characterising the results of these calculations is in terms of cumulative emissions. Table 8.5 shows the cumulative emissions from 1990 to the respective times of stabilisation for the 7 stabilisation profiles.

The two parts of Figure 8.6 present this information over the full time history for the S650 case. Part a shows the integrated emissions from 1990 onwards. Part b (with a factor of 2 change in scale) shows the integrated oceanic uptake from 1990 onwards. Also shown in part b (as the dashed curve) is the atmospheric increase (the prescribed profile, converted to GtC above the 1990 level). For the other stabilisation profiles, the corresponding pairs of plots are included in Appendix E. These are presented as fossil/industrial emissions. The conversion to total anthropogenic emissions involves a small change (82 GtC after 2100, less earlier) that is less than the spread of the results.

A common feature of these results is that, while CO_2 is increasing, the amount of extra CO_2 in the atmosphere, $N_{\rm a}(t) - N_{\rm a}(1990) = 2.123[C(t) - C(1990)]$ in GtC, is about half of the integrated anthropogenic emissions. (The land-use component is a small addition to the fossil component shown in the figures). This type of result is often described in terms of an 'airborne fraction', r, of CO_2. This is usually expressed in terms of rates:

$$r = \dot{N}_{\rm a}(t)/Q(t) \tag{8.1}$$

but it can also be expressed in integral form as

$$\bar{r} = \Delta N_{\rm a} / \int Q dt = [N_{\rm a}(t_2) - N_{\rm a}(t_1)] / \int_{t_1}^{t_2} Q(t)\, dt \tag{8.2}$$

The two expressions will be equivalent if $N(t)$ and $Q(t)$ increase exponentially, in which case r will be constant in time. Assuming a constant airborne fraction, r, can be a reasonable approximation so long as emissions are increasing, but it starts to break down as emissions decline. As shown in the figures, the integral form, $\bar{r}$ is more nearly constant until stabilisation is reached, at which point $r \equiv 0$.

	S350	S450	S550	S650	S750	DS450	DS550
t_s	2150	2100	2150	2200	2250	2100	2150
A	165.1	551.5	1052.6	1566.2	2078.6	558.3	1063.6
H		561.9		1484.7			
J	210.9	599.8	1158.3	1743.4	2331.5	607.0	1171.0
L	182.8	588.9	1128.7	1686.7	2243.1	595.7	1139.9
Q	301.5	711.9	1309.6	1931.6	2552.3	720.3	1323.3
R		623.8				631.2	
T	192.4	593.7	1159.6	1799.1	2503.4	601.4	1173.9
W	345.7	666.2	1277.6	1937.4	2618.7	674.8	1293.3

Table 8.5. Cumulative fossil emissions from 1990 to the time of stabilisation, t_s. Cumulative anthropogenic emissions are greater by 82 GtC.

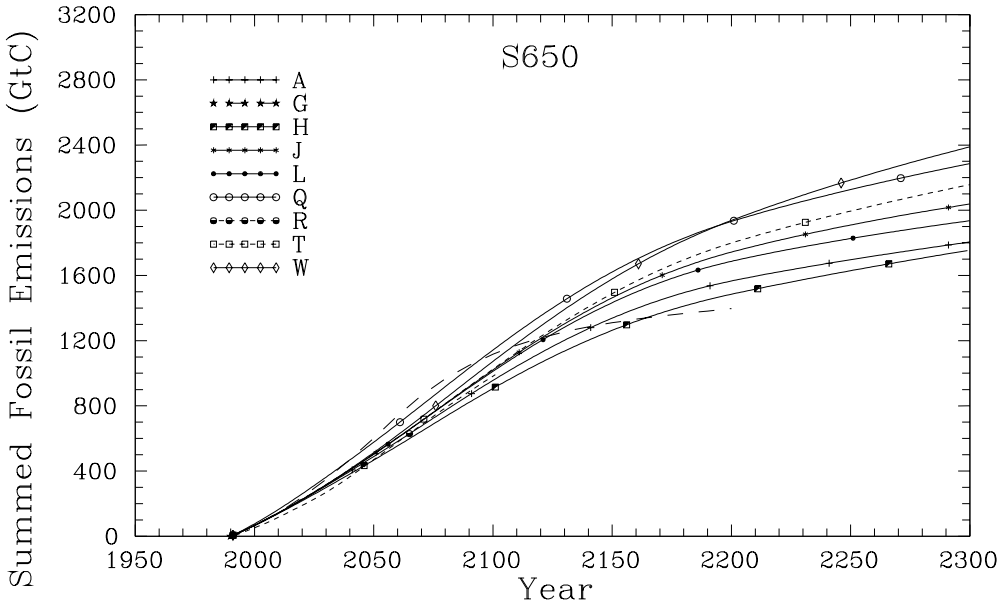

Figure 8.6a. Cumulative fossil emissions after 1990, for S650. Long-dashed curve is from Model G using alternative stabilisation profile (Appendix F). Integrated anthropogenic emissions are higher by 82 GtC after 2100 and by smaller amounts between 1990 and 2100.

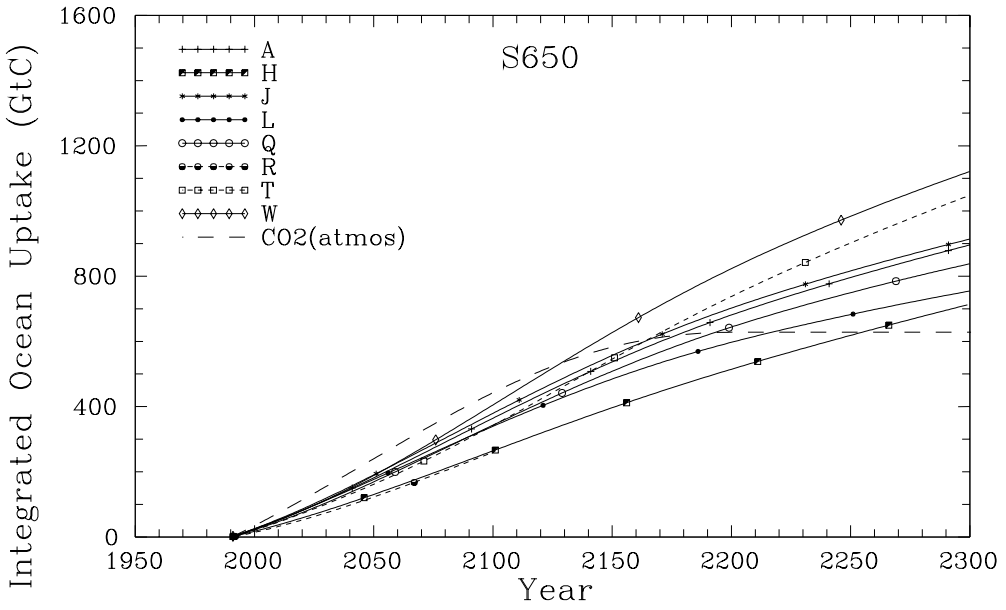

Figure 8.6b. Cumulative oceanic uptake after 1990 for S650. Long-dashed curve is atmospheric increase from 1990, from S650 curve in Figure 8.1.

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