An Independent Constraint on Climate Sensitivity

by Christopher Monckton of Brenchley

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ABSTRACT

Global CO_2 emissions per unit annual increase in atmospheric CO_2 concentration show no significant trend over the 49 year timescale of the available data (1960-2008). The mean emissions/concentration-growth ratio over the period was 15.5 Gte CO_2 $ppmv^{-1}$. Current central estimates are that CO_2 concentration will rise by 345 ppmv over the 21st century, during which CO_2-driven warming is projected to be 1.56 K, suggesting that, on a centennial scale, CO_2 concentration must rise by 223 ppmv, or 3450 Gte CO_2, to cause 1 K of warming. Since total global CO_2 emissions from 1960-2008 were 975 Gte CO_2, the CO_2-driven contribution to the 0.66 K measured global warming over the period was 0.28 K. However, on currently-accepted central estimates, the CO_2-driven warming over the period was almost two-thirds higher, at 0.46 K. The ratio of CO_2 emissions to concentration change – useful as an independent constraint on climate sensitivity – suggests that CO_2-driven warming in the 21st century may be little more than 1 K. In the short term and perhaps also in the long, climate sensitivity may lie below the values found in the general-circulation models.

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INTRODUCTION

NOAA (2008) reported that "The simulations rule out (at the 95% level) zero trends for intervals of 15 yr or more, suggesting that an observed absence of warming of this duration is needed to create a discrepancy with the expected present-day warming rate." There has now been no global warming for 15 years. Therefore, a method of verifying modeled projections of climate sensitivity that is, as far as possible, independent of the models themselves is desirable. The method demonstrated here relies upon the ratio of global CO_2 emissions to annual increases in atmospheric CO_2 concentration, which shows no trend over the 49 years of available data and may, on decadal to centennial timescales, be near-invariant.

BENCHMARKS

Central estimates are used throughout. Benchmarks for this analysis are the model-derived central estimates of the Inter-governmental Panel on Climate Change (IPCC) that during this century CO_2 concentration will rise by 345 ppmv, that consequent CO_2-driven warming will be 1.56 K, and that the centennial-scale climate-sensitivity parameter is 0.44 K W^{-1} m^2.

Projected CO_2 concentration C_{2100} in 2100, taken as the mean of the values on all six IPCC emissions scenarios, is 713 ppmv (Annex, Table 0), an increase over the 368 ppmv measured in 2000 (Conway & Tans, 2011) of 345 ppmv.

Projected 21st-century anthropogenic warming, as the mean of values on all six IPCC emissions scenarios, is 2.8 K (IPCC, 2007, table SPM.3: Annex, Table 0). The mean may legitimately be taken, since the IPCC is at pains to stress that all scenarios are of equal weight. Of this 2.8 K projected warming, 0.6 K is stated to be in the pipeline. Of the remaining 2.2 K, some 0.64 K is attributable to non-CO_2 forcings, since the CO_2 fraction of anthropogenic warming is 71% (the Annex explains the derivation). Thus the IPCC's current implicit central estimate of the warming by 2100 that will be attributable solely to the CO_2 we emit this century is 1.56 K.

The IPCC (2001, p. 358, Table 6.2), citing Myhre *et al.* (1998), takes the CO_2 forcing ΔF as 5.35 times the logarithm of a proportionate change C_b/C_a in CO_2 concentration, where C_a is the unperturbed value. Warming ΔT is simply ΔF multiplied by some climate sensitivity parameter λ. Therefore, the IPCC's implicit climate-sensitivity parameter for the 21st century is 1.56 / [5.35 ln(713/368)], or 0.44 K W^{-1} m^2. This centennial-scale value, adopted in (1), is half of the IPCC's implicit equilibrium value 0.88 K W^{-1} m^2 (derived in the Annex).

Global warming during the period of study

The IPCC's implicit central estimate of CO_2-driven warming from 1960-2008 is at (1):

$$\Delta T = \lambda \, \Delta F = 0.44 \left[5.35 \ln \left(\frac{385.6}{316.9} \right) \right] = 0.46 \text{ K.} \qquad (1)$$

The CO_2 forcing coefficient 5.35 was given in Myhre *et al.* (1998). Initial and final CO_2 concentrations were 316.9 and 385.6 ppmv respectively (Tans, 2012). Since the 0.46 K warming driven by the CO_2 fraction is 71% of anthropogenic warming, use of the IPCC's methods implies that, as a central estimate, all of the 0.66 K observed warming from 1960-2008 (the linear trend on the data over the period in HadCRUt3, 2011) was anthropogenic.

Since few non-linearities will obtrude over time-scales as short as a century, current central estimates imply that to warm the Earth's surface by 1 K the CO_2 concentration in the atmosphere must increase by approximately the ratio of the 345 ppmv projected additional CO_2 concentration in the 21st century to the 1.56 K projected warming: i.e. 223 ppmv K^{-1}.

The ratio of CO_2 emissions to concentration change

The trend in the ratios of annual global CO_2 emissions to annual increases in atmospheric CO_2 concentrations over the 49-year period of available data, from 1960-2008, does not differ significantly from zero (Fig. 1). The mean emissions/concentration-change ratio was 15.5 Gte CO_2 ppmv^{-1}. Multiplying this value by 223 ppmv K^{-1} gives the quantum of CO_2 emissions currently necessary to raise global temperature by 1 K: i.e. 3450 GTe CO_2 K^{-1}.

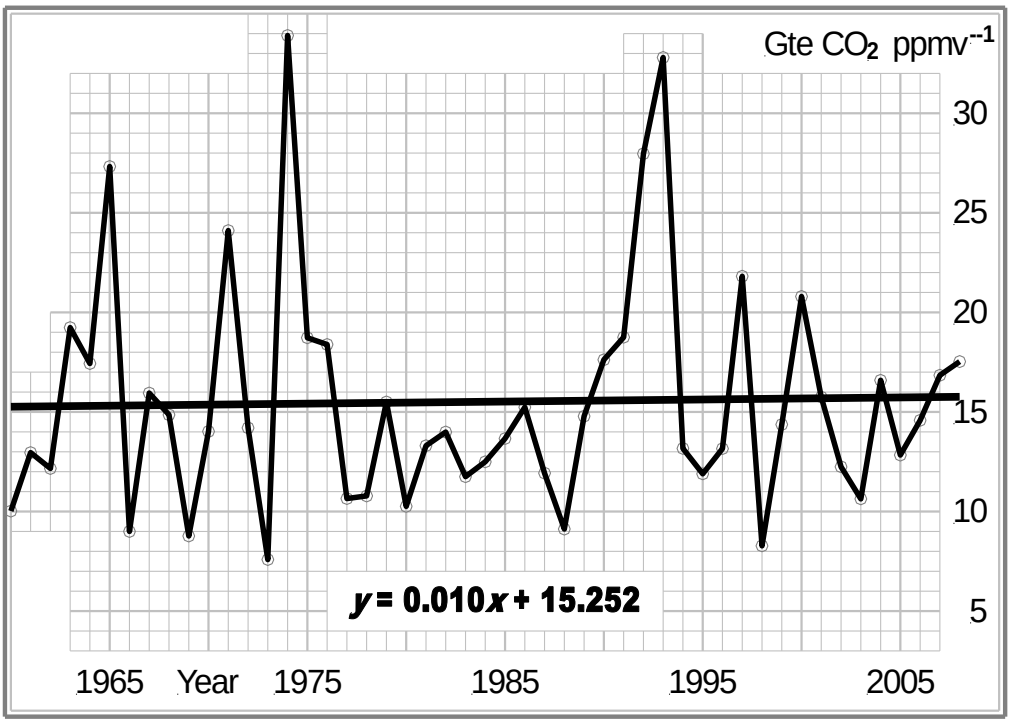

Figure 1. The near-zero trend in annual emissions/concentration-growth ratios (global annual CO_2 emissions in gigatonnes per part per million by volume annual increase in CO_2 concentration), 1960-2008. Source data and methods are set out in the Annex. Spikes caused by volcanic eruptions are visible: however, excluding effects of major eruptions makes little difference to the outcome.

Total global CO_2 emissions from 1960-2008 were 975 Gte CO_2 (Boden *et al.*, 2011). Accordingly, the CO_2-driven contribution to warming over the period, by the present method, was 975 divided by 3450, or 0.28 K. Allowing for the non-CO_2 fraction, some 0.40 K warming over the period (equivalent to 61% of observed warming), was anthropogenic, not inconsistent with the estimate in IPCC (2007) that at least 50% of observed warming from 1950-2005 was anthropogenic. However, inconsistently with (1), this method yields a CO_2-driven warming that is only 61% of the current central estimate from the models relied upon by the IPCC.

IMPLICATIONS

On the assumption that the coefficient in the CO_2 forcing function, cut from 6.3 to 5.35 in Myhre *et al.* (1998), is now correct, one implication of the finding that CO_2-driven warming from 1960-2008 was not 0.46 K but 0.28 K is that the centennial-scale climate-sensitivity parameter λ is not 0.44 K W^{-1} m^2, as the models suggest, but 0.27 K W^{-1} m^2.

In that event, it is likely that CO_2-driven warming to 2100 will be <1 K and that warming from all anthropogenic sources will be <1.4 K. Since 0.27 K W^{-1} m^2 is below the 0.31 K W^{-1} m^2 value of the instantaneous or Planck sensitivity parameter λ_0 (IPCC, 2007, p. 631 fn.), temperature feedbacks operating during the period of study may have been somewhat net-negative, rather than appreciably net-positive as implied by (1), whereupon little or none of the projected positive-feedback-dependent warming in the pipeline from past emissions is to be expected. Furthermore, supra-centennial-scale as well as centennial-scale warming may also turn out significantly less than currently projected. If so, all attempts at mitigation will prove cost-ineffective, and the cost of adaptation to future warming will be well below current estimates.

Supra-centennial-scale as well as centennial-scale warming may also turn out significantly less than currently projected.

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ANNEX: SUPPLEMENTARY MATERIAL

Values of the climate sensitivity parameter λ

If net temperature feedbacks exceed zero, the climate sensitivity parameter λ is not constant: as longer- and longer-acting feedbacks begin to act, it will tend to increase between the time of a forcing to the time when equilibrium is restored to the climate 1000-3000 years after the forcing that perturbed it (Solomon *et al.*, 2009). Illustrative values of λ are given below.

The sensitivity parameter derived from the present result and applicable to the 49 years 1960-2008 is 0.44 K W^{-1} m^2 times 0.28 K divided by 0.46 K: i.e. **0.27 K W^{-1} m^2.**

Where temperature feedbacks sum to zero, the instantaneous value λ_0 is **0.31 K W^{-1} m^2** (derived from IPCC (2007, p. 631 fn.: see also Soden & Held, 2006).

Garnaut (2008) talks of keeping greenhouse-gas rises to 450 ppmv CO_2-equivalent above the 280 ppmv prevalent in 1750, so as to hold 21st-century global warming since then to 2 K, implying λ_{262} = 2 / [5.35 ln{(280 + 450) / 280}] = **0.39 K W^{-1} m^2.**

As explained in the text, the IPCC's implicit climate-sensitivity parameter for the 21st century is λ_{100} = 1.56 / [5.35 ln(713/368)] = **0.44 K W^{-1} m^2.**

On each emissions scenario, the IPCC's estimate of the bicentennial-scale transient-sensitivity parameter λ_{200} is **0.49 K W^{-1} m^2** (derived in Table 0 below), a value supported by IPCC (2001, p. 354, citing Ramanathan, 1985).

The implicit central estimate of the equilibrium-sensitivity parameter λ_{equ} is the warming currently predicted at a CO_2 doubling, i.e. 3.26 K (IPCC, 2007, p. 798, Box 10.2), divided by the forcing of 5.35 ln 2 = 3.71 W m^{-2} at that doubling. Thus, λ_{equ} = **0.88 K W^{-1} m^2.**

The bicentennial climate-sensitivity parameter and the CO_2 fraction

Table 0	ΔT_{C21}	ΔT_{200}	ΔF_{200}	C_{2100}	λ_{200}	$\Delta F_{200,CO2}$	q
A1B	2.8 K	3.0 K	6.2 W m^{-2}	708 ppmv	0.48 K W^{-1} m^2	4.6 W m^{-2}	0.74
A1F1	4.0 K	4.5 K	9.1 W m^{-2}	985 ppmv	0.50 K W^{-1} m^2	6.4 W m^{-2}	0.70
A1T	2.4 K	2.5 K	5.1 W m^{-2}	572 ppmv	0.49 K W^{-1} m^2	3.5 W m^{-2}	0.68
A2	3.4 K	3.8 K	8.0 W m^{-2}	858 ppmv	0.48 K W^{-1} m^2	5.6 W m^{-2}	0.70
B1	1.8 K	2.0 K	4.1 W m^{-2}	535 ppmv	0.49 K W^{-1} m^2	3.1 W m^{-2}	0.76
B2	2.4 K	2.7 K	5.6 W m^{-2}	617 ppmv	0.48 K W^{-1} m^2	3.9 W m^{-2}	0.69
Mean	2.8 K	3.1 K	6.3 W m^{-2}	713 ppmv	**0.49 K W^{-1} m^2**	4.5 W m^{-2}	**0.71**

Table 0 gives projected 21st-century anthropogenic warming ΔT_{C21} (IPCC, 2007, p. 13, Table SPM.3) and warming ΔT_{200} and total radiative forcings ΔF_{200} from all greenhouse gases for 1900-2100 on all emissions scenarios, and CO_2 concentration C_{2100} in 2100 (IPCC, 2007, p. 803, Fig. 10.26); and, derived from these, the 200-year transient-sensitivity parameter $\lambda_{200} = \Delta T_{200}/\Delta F_{200;}$ the CO_2 radiative forcing $\Delta F_{200,CO2} = 5.35 \ln(C_{2100}/C_{1900})$ from 1900-2100, taking C_{1900} as 300 ppmv; and the CO_2 fraction, which is the ratio $q = \Delta F_{200,CO2} / \Delta F_{200}$ of CO_2 forcing to total greenhouse-gas forcing over the 200-year period.

Determination of CO_2 emission/concentration-growth ratios (Fig. 1)

Table 2 is derived by multiplying each value in Table 1 by 3.667 to convert from Mte C to Mte CO_2. Table 4 is obtained by taking the differences between successive annual CO_2 concentrations in Table 3. Table 5, derived by dividing the values in Table 2 by those in Table 4, gives the annual CO_2 emission/concentration-growth ratios plotted in Fig. 1.

Mte C	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
1950								2330	2454	2569
1960	2580	2686	2833	2995	3130	3288	3393	3566	3780	4053
1970	4208	4376	4615	4623	4596	4864	5026	5087	5369	5316
1980	5152	5113	5095	5283	5441	5609	5755	5968	6088	6151
1990	6239	6178	6172	6284	6422	6550	6663	6638	6584	6750
2000	6916	6981	7397	7782	8086	8350	8543	8749		

Table 1. *Global anthropogenic emissions (Mte C), 1958-2008. Source: Boden et al., (2011).*

Mte CO_2	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
1950								8544	8999	9421
1960	9461	9850	10389	10983	11478	12057	12442	13077	13861	14862
1970	15431	16047	16923	16953	16854	17836	18430	18654	19688	19494
1980	18892	18749	18683	19373	19952	20568	21104	21885	22325	22556
1990	22878	22655	22633	23043	23549	24019	24433	24342	24144	24752
2000	25361	25599	27125	28537	29651	30619	31327	32083		

Table 2. *Global anthropogenic emissions (Mte CO_2), multiplying Table 1 by 3.667.*

ppmv	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
1950									315.97	316.91
1960	317.64	318.45	318.99	319.62	320.04	321.38	322.16	323.04	324.62	325.68
1970	326.32	327.45	329.68	330.18	331.08	332.05	333.78	335.51	336.78	338.68
1980	340.10	341.44	343.03	344.58	346.04	347.39	349.16	351.56	353.07	354.35
1990	355.57	356.38	357.07	358.82	360.80	362.59	363.71	366.65	368.33	369.52
2000	371.13	373.22	375.77	377.49	379.80	381.90	383.76	385.59	387.38	

Table 3. *Atmospheric CO_2 concentration (ppmv), Mauna Loa, Hawaii. Source: Tans (2012).*

ppmv	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
1950										0.94
1960	0.73	0.81	0.54	0.63	0.42	1.34	0.78	0.88	1.58	1.06
1970	0.64	1.13	2.23	0.50	0.90	0.97	1.73	1.73	1.27	1.90
1980	1.42	1.34	1.59	1.55	1.46	1.35	1.77	2.40	1.51	1.28
1990	1.22	0.81	0.69	1.75	1.98	1.79	1.12	2.94	1.68	1.19
2000	1.61	2.09	2.55	1.72	2.31	2.10	1.86	1.83		

Table 4. *Annual growth in CO_2 concentration (ppmv), as annual differences from Table 3.*

Mte CO_2 $ppmv^{-1}$	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
1950										10022
1960	12960	12160	19238	17433	27328	8998	15951	14860	8773	14021
1970	24111	14201	7589	33905	18726	18388	10653	10783	15502	10260
1980	13304	13992	11751	12499	13666	15236	11923	9119	14785	17622
1990	18753	27969	32801	13168	11894	13418	21815	8279	14371	20800
2000	15752	12248	10637	16591	12836	14581	16843	17531		

Table 5. *CO_2 emissions (Mte) per unit CO_2 concentration increase (ppmv).*
(Values in Table 2 divided by values in Table 4.)

Cover photo of the Karymsky Volcano in Russia provided by Microsoft.