United States District Court for the District of Vermont
Rebuttal Expert Report for the Plaintiffs' in
Green Mountain Chrysler Plymouth Dodge Jeep, et al. v. Crombie, et al.
Case No. 05-cv-302

Prepared by:

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At the request of counsel for plaintiffs in this action, I have prepared the following expert report, which provides estimates of the temperature and sea level impacts of the AB 1493 regulations.

Qualifications

I am a Professor of Atmospheric Science and Director of Earth System Science Center at the University of Alabama in Huntsville. I received a Ph.D. in Atmospheric Science from University of Illinois at Urbana-Champaign in 1987. I am member and fellow of the American Meteorological Society, a member of American Geophysical Union, and as the State Climatologist of Alabama I am a member of the American Association of State Climatologists. I have published more than 50 articles in peer-reviewed scientific journals and served as a lead author on the 2001 IPCC Scientific Assessment of Climate Change and was contributing author to the 2007 IPCC Scientific Assessment (Working Groups 1 & 2).

My curriculum vitae is attached as Appendix A.

Compensation

I am not receiving compensation for the preparation of this report nor will I receive any compensation for future testimony.

Previous Testimony By Trial or Deposition

I have not given testimony by trial or deposition in the preceding four years.

Summary of Opinions

My analysis suggests that in light of the amount of carbon dioxide in the environment, the reduction of carbon dioxide emissions due to AB 1493 will have a negligible, if not indiscernible, impact on temperature change and sea level rise. Additionally, tipping points are speculative and uncertain and thus it is highly unlikely that the impacts of such measures like AB 1493 would have any impact on their occurrence or duration.

Analysis

I. Analysis of Temperature and Sea Level Rise

The predictions of global temperature and sea level rise utilized here are determined from a coupled, gas-cycle/climate model known as MAGICC (v4.1). MAGICC has been the primary model used by the IPCC to produce projections of future global-mean temperature and sea level rise.

[From MAGICC/SCENGEN 4.1: Technical Manual]

> Information on earlier versions of MAGICC has been published in Wigley and Raper (1992) and Raper et al. (1996). The carbon cycle model is the model of Wigley (1993), with further details given in Wigley (2000). Modifications to MAGICC made for its use in the IPCC Third Assessment Report (TAR) are described in Wigley and Raper (2001,2002) and Wigley et al. (2002). Gas cycle models other than the carbon cycle model are described in the TAR atmospheric chemistry chapter and in Wigley et al. (2002).

For the purposes of this report, I will focus on results for model simulations which are characterized by a climate sensitivity of 2.6°C for a doubling of atmospheric CO_2. This is consistent with the “best guess” of the recently released IPCC 2007 AR4 Summary for Policymakers (SPM). Also for the purposes of this report, the only input variable that will be altered to generate experimental outcomes is the amount of CO2 production due to fossil fuel combustion. All other input variables will remain unchanged from the prescribed values in MAGICC. Listed in Table 1 and shown in Fig. 1 are the original input values of fossil fuel emissions of CO2 for the six scenarios.

Table 2 and Figure 2 display the global temperature responses generated by MAGICC based on the six IPCC scenarios in Table 1. The parameters for the model runs are (a) “mid”-level response for the carbon cycle model, (b) Carbon cycle climate feedbacks “on”, (c) “mid”-level response for aerosol forcing, (d) 2.6°C sensitivity for doubled CO2 (e) “variable” thermohaline circulation, (f) vertical oceanic diffusion coefficient “2.3 cm^2/s” and (g) ice melt “mid”-level response.

The IPCC AR4 SPM gives as a central value for the temperature rise of 2.8°C and for sea level rise of 21 to 48 cm by 2100 under the AIB scenario (Table 1-SPM) which is in the middle range of the scenarios assumed. With this as a base I shall limit the following results to scenario A1B, a future in which fossil fuels will continue to be consumed in a “business as usual” manner (”A1”), but with new sources of energy mixing in to supply a balance of non-carbon emitting sources (hence “A1B”). Note as well that in Fig. 2, the MAGICC projection for A1B is almost identical to the value put forth by the latest IPCC AR4 SPM A1B best guess for 2095 (2.8°C).

For the purposes of this report, I then executed MAGICC using revised input values of CO2 to calculate the impact of a prescribed reduction in CO2 emissions. These CO2 reduction values were supplied by Mr. Thomas C. Austin (Sierra Research) as those anticipated to occur should AB 1493 be enacted and fully complied with. As in Table 1, these values have been converted to GTn C for appropriate input into MAGICC.

Because the resulting temperature-response lines in Fig. 4 are indistinguishable I include below a table and graph of the differences of the three cases relative to the base (i.e. the base is without AB 1493). Vermont is excluded in the figure because the minimum unit for input into MAGICC is 0.001 GTn while the impact of AB 1493 on Vermont emissions never exceeded 0.0002 GTn.

Tables 5 and 6 and Figures 5 and 6 show the differential impact on temperature and sea level of AB 1493. Note that the temperature scale on Fig. 5 is 300 times what it is in Fig. 4 and the sea level scale on Fig. 6 is 600 times what it is in Fig. 3. Given these results we may estimate the impact of AB 1493 if Vermont alone implemented and complied. Vermont emits roughly 1/500 of the U.S. total. Thus for temperature, Vermont's impact would be about $1/500^{th}$ of -0.01°C or, -0.00002°C. And similarly for sea level the impact would be 0.0002 cm.

Conclusions from MAGICC results

The estimated impact of AB 1493 on global surface temperature is negligible, even if applied nationwide. If the U.S. as a whole implemented AB 1493 the net impact on global temperature would be about -0.01 °C by 2100. Today, global temperature varies by tenths of a degree from year to year, so such an impact over a century would be imperceptible. Indeed, our current measuring systems are estimated to achieve a precision of about 0.04 °C/decade, and by 2100 one might hope for a precision of 0.01 °C/decade. The impact shown here of AB 1493 of 0.01 *°C/century* is much smaller than our observational systems are able to measure, and thus the impact would be undetectable.

To put this in a different context, I calculated the exact date for which the global temperature under the A1B scenario in MAGICC would reach 2°C. This is 23 January 2065. If the entire country adhered to AB 1493, the new date of a 2°C value would be 3 April 2065, or a postponement of 10 weeks. Because monthly temperatures vary by tenths of a degree from one to the next, this variation would completely swamp any possible method designed to detect this minute change in temperature and/or timing.

II. Analysis of Tipping Points

Tipping points may be thought of as threshold events that lead to rapid and sometimes semi-permanent changes in the climate system. In other words the climate system may evolve into a new state from which it is unlikely to escape once a certain threshold is crossed, a “point of no return” if you will.

It has been proposed that the current ice sheets on Greenland and Antarctica are potential players in a tipping point event. Under this idea, the temperature rises with no significant consequences until a threshold is reached at which time major sections of one or both of these ice sheets begin a process of melting and collapse that continues rapidly until a significant portion melts and raises sea level by several meters. A several-meter rise in sea level would affect considerable human infrastructure. The proposed timing of such an event varies according to the opinions of the scientists questioned, but some have suggested up to as much as a meter per decade or so.

Evidence is available to indicate that relatively rapid rises in sea level (1m per century) did occur when the major ice sheets of the North American and Eurasian continents began to melt after the last glacial maximum (i.e. since 25,000 years ago). However, these ice sheets encompassed a large area, were at lower altitudes and at lower latitudes than the ice plateaus represented by Greenland and Antarctica today. Thus, processes which led to the demise of the continental ice sheets were likely quite different than those that would do the same for the current, more poleward, high plateaus of Greenland and Antarctica.

Ice sheet dynamics are highly complex, non-linear, and site-specific physical systems. Controversy about how ice sheets might collapse is complemented by the lack of long-term, highly detailed datasets for rigorous analysis. Some point to evidence today, mainly from satellites, of new melting around the edges of Greenland because of increasing summer temperatures. They assert that this is the start of the collapse, due to human increases in greenhouse gases. (If so, then this view implies we have already gone past the threshold event and nothing will stop it now.) However, these observations cover only the last few years.

As Fig. 7 below indicates, the latest effort to reconstruct Greenland summer temperatures indicates the current period is not the warmest in the relatively short 200+ year period of instrumental measurements. It is clear that from 1920 to 1950 summer temperatures in Greenland were warmer than today and had we had satellites back then, one would assume that we would see just as much if not more melting than is observed today. There is a direct relationship between these temperatures and melting, so one must assume this melting has occurred many times in the past without leading to a consequence massive collapse.

Note in Fig. 7 that the past few years do indeed display a summer warming trend, but this trend started only in 1995 after an irregular downward trend from about 1935, all the while greenhouse gases were accumulating. This implies that the high natural variability of Greenland's temperature may be confused with specific causes for its changes. I cannot emphasize enough the limited understanding of the ice, ocean and climate processes that exists today. This creates, in this situation, opportunities for speculation since testing proposed hypotheses in a scientific framework is enormously difficult and fraught with ambiguities. As realclimate.org states, "At this juncture, numerical modeling simply does not provide a credible basis for quantitative projection of ice sheet behavior in a warmer world."

There is further information of Greenland's temperatures from boreholes drilled in the ice left behind after the ice core is removed. These provide direct measurements which indicate how the surface temperature propagates down into the ice sheet. The basic idea is that as the thermometer is let down deeper into the hole, the further back in time the temperature is being measured.

The reconstruction of Greenland's temperature by Dahl-Jensen et al. (1998) indicates the temperature of the plateau was warmer than today for a thousand-year period between 200 and 1200 CE. (Fig. 8). Around 900 CE the medieval warmth averaged about 1°C warmer than today for a period of at least 100 years. Obviously, this exceptional, long-lived warmth did not initiate the tipping point mechanism in which the ice sheet collapsed.

Dahl-Jensen et al. also produced temperatures back through the last 10,000 years (Fig. 8). Clearly visible in their results is the Holocene warmth, commonly called the climatic optimum, of 8,000 to 4,000 years before present (6,000 to 2,000 BCE). This 4,000 year period was on average over 2.5°C warmer than at present, and it is very likely that century-long periods of above-the-present warmth of 3°C or more occurred. Again, this evidence is consistent with the idea that the current ice plateaus have withstood the tipping point scenario of rapid demise under conditions much warmer than are anticipated (by some) to be experienced in this coming century.

The IPCC 2007 AR4 has examined the issue of sea level rise and has concluded that rates of change observed over most of the 20th century are likely to increase a bit, but not extraordinarily. In particular, the SPM notes that uncertainty suggests the rate of the most recently-measured decade (1993-2003, 3.1 cm/decade) “could increase or decrease.” For the A1B scenario, (i.e. most likely) the range of sea level rise is calculated to be 21 to 48 cm by 2100, or an average rate of 2.1 to 4.8 cm/decade (Table SPM-3). These estimates “exclude future rapid dynamical changes in ice flow” because these are not understood well enough to determine their plausibility, are not modeled, and are not being presently observed. Thus, referring to the discussion earlier, the evidence of considerably warmer periods in the recent past indicates that Greenland and Antarctica are apparently resilient to major collapsing events even during temperatures predicted by models to come this century. Indeed there is evidence that a potential for greater accumulation of snow on the plateaus may even lead to a *decrease* in the current, slow rate of sea level rise, particularly in Antarctica.

References

Dahl-Jensen, D., K. Mosegaard, N. Gunderstrup, G.D. Clow, S.J. Johnsen, A.W. Hansen, and N. Balling, 1998: Past temperatures directly from the Greenland ice sheet. Science, 282, 268-271.

(SPM) Summary for Policymakers, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

Tables and Figures

Table 1. Projected fossil fuel emissions of CO_2 in units of metric GTn of carbon equivalent (the mass of the carbon portion of CO_2) for the six main scenarios of future emissions of CO_2. A1F1MI, A1BAIM and B1AIM, in color, are three often considered to be the upper, middle and lower scenarios respectively and follow the color rendering in Fig. 1.

	A1F1MI	A2AIM	A1BAIM	B2MES	A1TMES	B1AIM
1990	5.991	5.991	5.991	5.991	5.991	5.991
1995	6.444	6.444	6.444	6.444	6.444	6.444
2000	6.896	6.896	6.896	6.896	6.896	6.896
2005	7.774	8.097	8.288	7.443	7.615	7.681
2010	8.652	9.298	9.680	7.989	8.335	8.467
2015	9.920	10.293	10.901	8.503	9.167	9.260
2020	11.187	11.289	12.122	9.018	10.000	10.054
2025	12.900	12.493	13.066	9.583	11.129	10.778
2030	14.613	13.696	14.011	10.149	12.258	11.502
2035	16.639	14.374	14.478	10.540	12.429	11.750
2040	18.664	15.052	14.945	10.930	12.599	11.998
2045	20.882	15.823	15.477	11.083	12.442	12.295
2050	23.101	16.595	16.009	11.235	12.285	12.592
2055	24.122	17.663	15.853	11.486	11.846	11.854
2060	25.144	18.731	15.697	11.736	11.407	11.116
2065	26.133	19.964	15.561	11.804	10.657	10.489
2070	27.122	21.196	15.425	11.871	9.907	9.862
2075	28.079	22.801	15.129	12.167	8.977	9.073
2080	29.036	24.407	14.834	12.463	8.047	8.285
2085	29.340	26.483	14.386	12.831	7.159	7.777
2090	29.643	28.558	13.938	13.199	6.271	7.269
2095	29.981	30.997	13.517	13.512	5.293	6.837
2100	30.320	33.435	13.096	13.824	4.314	6.404

Fig. 1 Values of Table 1 plotted against time. Included are two other estimates through 2030, one being a steady growth of 1.5% per year and the other the estimate made in 2006 by the Energy Information Administration (EIA IEO2006).

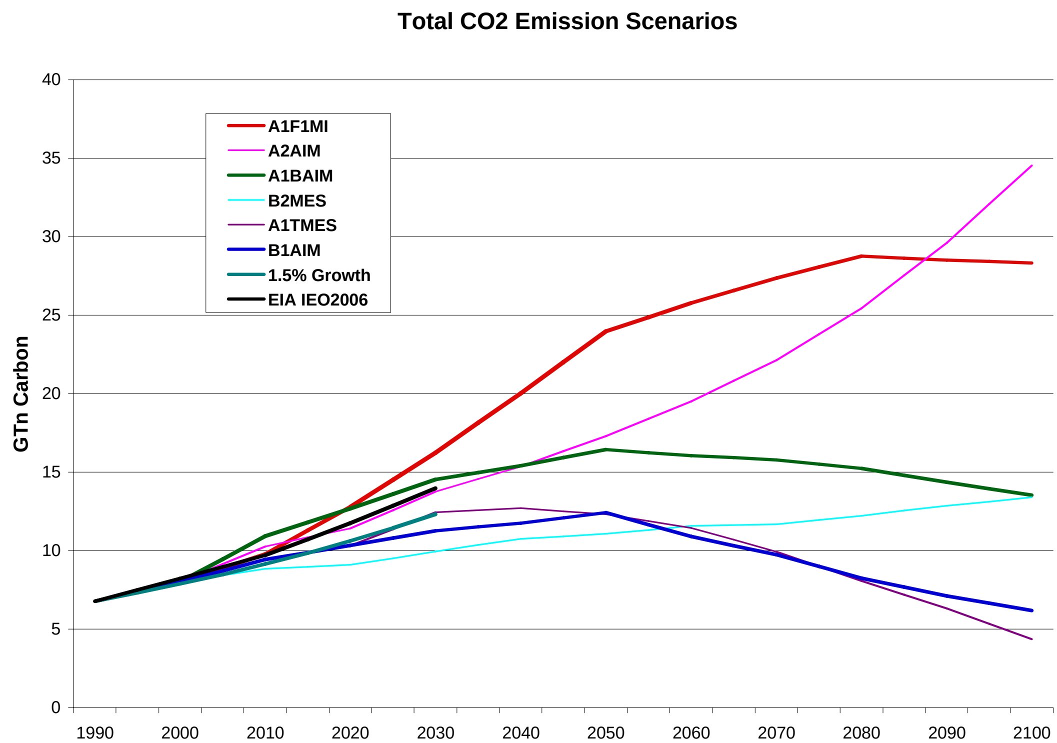

Table 2. Temperature response (°C) to the CO2 concentrations of Table 1 (i.e. base case input values) for the six IPCC scenarios.

	A1F1MI	A2AIM	A1BAIM	B2MES	A1TMES	B1AIM
1990	0	0	0	0	0	0
1995	0.0744	0.0744	0.0744	0.0744	0.0744	0.0744
2000	0.1511	0.1507	0.1506	0.1522	0.1523	0.1514
2005	0.2225	0.2106	0.2103	0.2514	0.2556	0.2281
2010	0.3021	0.2785	0.2799	0.3620	0.3740	0.3121
2015	0.3997	0.3553	0.3746	0.4858	0.5095	0.3946
2020	0.5085	0.4352	0.4823	0.6141	0.6545	0.4787
2025	0.6302	0.4979	0.6281	0.7337	0.7947	0.5792
2030	0.7683	0.5615	0.789	0.8525	0.9408	0.6880
2035	0.9466	0.6601	0.9743	0.9696	1.1122	0.8570
2040	1.1489	0.7676	1.1668	1.0872	1.2890	1.0465
2045	1.3958	0.8737	1.3291	1.2067	1.4487	1.2189
2050	1.6671	0.9812	1.4841	1.3264	1.6010	1.3904
2055	1.9561	1.0872	1.6599	1.4435	1.7417	1.5357
2060	2.2514	1.1978	1.8374	1.5596	1.8717	1.6661
2065	2.5311	1.3105	1.9981	1.6761	1.9808	1.7798
2070	2.8071	1.4293	2.1502	1.7920	2.0752	1.8824
2075	3.0601	1.5988	2.2803	1.9067	2.1573	1.9667
2080	3.3055	1.7900	2.3992	2.0216	2.2276	2.0370
2085	3.5257	2.0237	2.5022	2.1356	2.2789	2.0922
2090	3.7340	2.2802	2.5959	2.2495	2.3171	2.1361
2095	3.9292	2.5309	2.6824	2.3623	2.3477	2.1697
2100	4.1068	2.7892	2.7629	2.4753	2.3680	2.1953

Fig. 2 Temperature values of Table 2 plotted against time. The "x"s are the most recently released estimates from the IPCC AR4 Summary for Policy Makers (Table SPM-3)

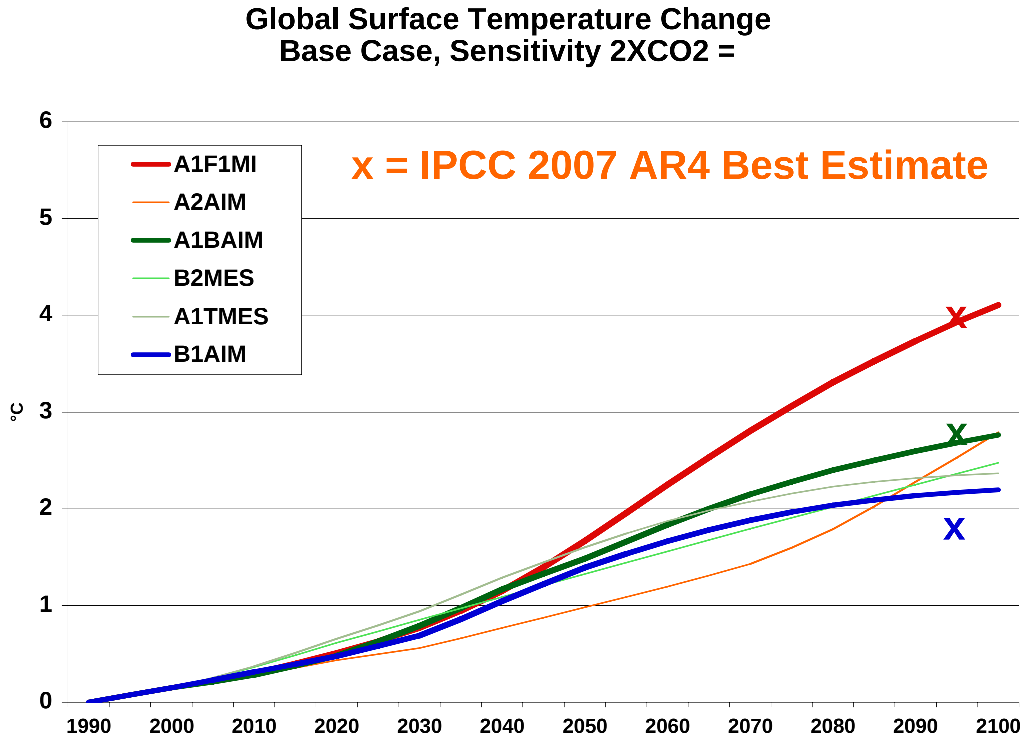

Table 3 Sea level rise (cm) associated with climate changes as produced from the six IPCC scenarios.

	A1F1MI	A2AIM	A1BAIM	B2MES	A1TMES	B1AIM
1990	0.00	0.00	0.00	0.00	0.00	0.00
1995	0.80	0.80	0.80	0.80	0.80	0.80
2000	1.65	1.65	1.65	1.65	1.65	1.65
2005	2.57	2.56	2.55	2.61	2.61	2.58
2010	3.56	3.52	3.52	3.68	3.70	3.59
2015	4.64	4.57	4.59	4.87	4.92	4.67
2020	5.83	5.70	5.79	6.17	6.29	5.82
2025	7.13	6.86	7.13	7.55	7.77	7.06
2030	8.57	8.04	8.63	9.00	9.34	8.37
2035	10.19	9.31	10.30	10.51	11.05	9.84
2040	12.03	10.67	12.13	12.08	12.90	11.50
2045	14.11	12.12	14.06	13.72	14.83	13.28
2050	16.45	13.63	16.05	15.41	16.83	15.16
2055	19.05	15.20	18.12	17.16	18.86	17.09
2060	21.86	16.85	20.30	18.95	20.91	19.05
2065	24.84	18.57	22.53	20.79	22.95	21.00
2070	27.95	20.36	24.78	22.67	24.96	22.93
2075	31.17	22.28	27.04	24.58	26.93	24.82
2080	34.46	24.38	29.28	26.54	28.84	26.67
2085	37.79	26.68	31.49	28.52	30.69	28.45
2090	41.15	29.20	33.67	30.54	32.45	30.16
2095	44.51	31.91	35.80	32.58	34.14	31.80
2100	47.82	34.77	37.90	34.65	35.74	33.36

Figure 3. Values of sea level rise from Table 3.

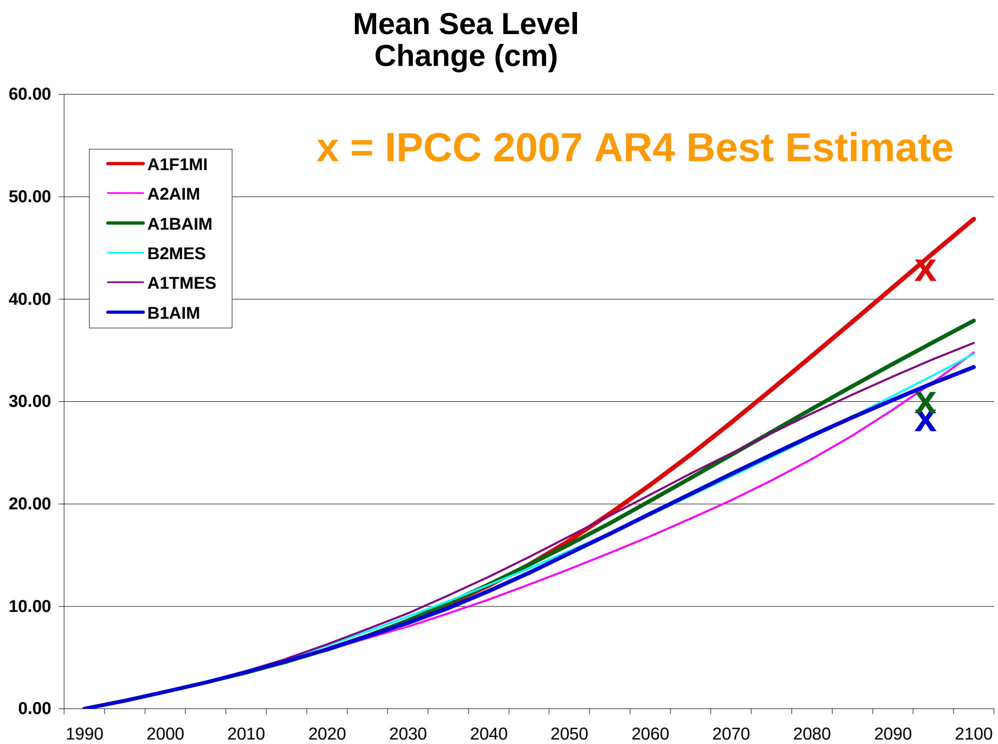

Table 4. Reductions in C (GTn) due to reductions in CO_2 to comply with AB 1493 for California (CA), Vermont (VT), the Northeast (NoEast) and the United States (US).

	CA	VT	NoEast	US
1990	0.0000	0.0000	0.0000	0.0000
2000	0.0000	0.0000	0.0000	0.0000
2010	0.0000	0.0000	0.0000	0.0000
2020	0.0055	0.0001	0.0071	0.0487
2030	0.0111	0.0002	0.0142	0.0973
2040	0.0111	0.0002	0.0142	0.0973
2050	0.0111	0.0002	0.0142	0.0973
2060	0.0115	0.0002	0.0147	0.1008
2070	0.0119	0.0002	0.0152	0.1042
2080	0.0123	0.0002	0.0157	0.1077
2090	0.0127	0.0002	0.0162	0.1111
2100	0.0131	0.0002	0.0167	0.1145

Figure 4. Temperature values for the base case and three experiments in which the input CO_2 emissions are reduced according to Table 4. I was unable to perform the calculation for Vermont because the smallest input value for MAGICC is a MTn (1/1000 of a GTn) and the projected reduction achieved by Vermont is estimated by Mr. Austin as only 0.2 MTn.

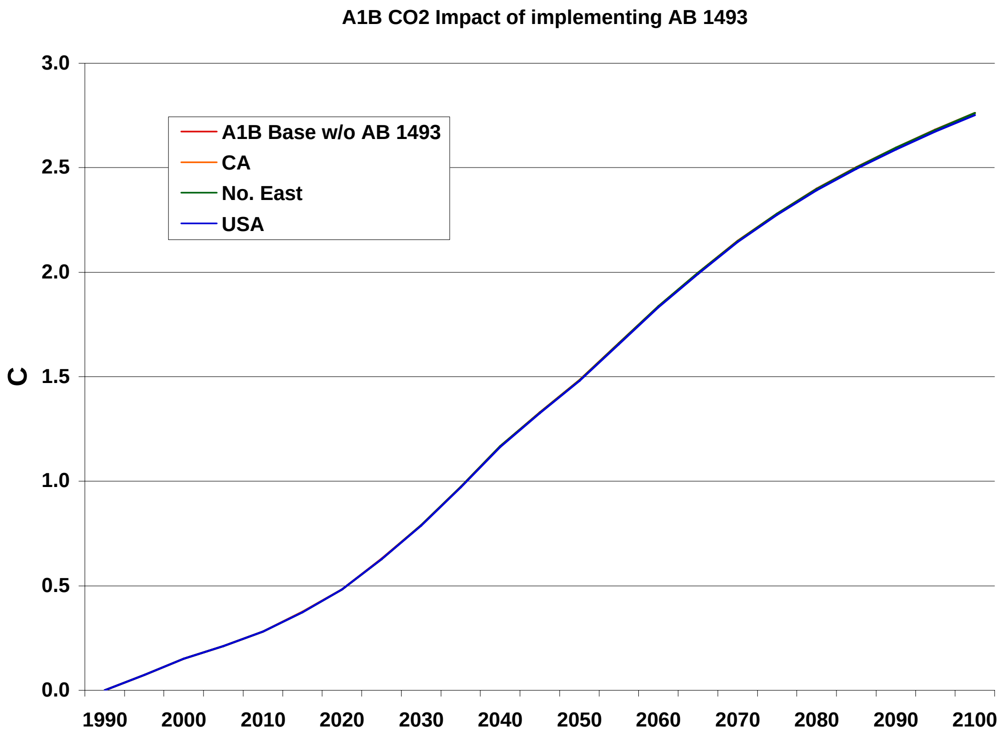

Table 5 Temperature reductions (°C) due to the implementation of AB 1493 in California, the Northeast and the U.S. as a whole.

	CA	No. East	USA
1990	0	0	0
1995	0	0	0
2000	0	0	0
2005	0	0	0
2010	0	0	0
2015	0.00000	-0.00010	-0.00010
2020	0.00000	0.00000	-0.00030
2025	-0.00010	-0.00010	-0.00080
2030	-0.00020	-0.00020	-0.00140
2035	-0.00020	-0.00030	-0.00210
2040	-0.00030	-0.00040	-0.00280
2045	-0.00040	-0.00050	-0.00340
2050	-0.00040	-0.00060	-0.00410
2055	-0.00050	-0.00070	-0.00470
2060	-0.00060	-0.00080	-0.00530
2065	-0.00070	-0.00080	-0.00580
2070	-0.00070	-0.00090	-0.00640
2075	-0.00080	-0.00100	-0.00690
2080	-0.00090	-0.00110	-0.00750
2085	-0.00090	-0.00120	-0.00810
2090	-0.00100	-0.00130	-0.00860
2095	-0.00110	-0.00140	-0.00920
2100	-0.00110	-0.00140	-0.00970

Fig. 5 Values of temperature reduction (°C) from Table 5. This represents a magnification of Fig. 4 by 300 times.

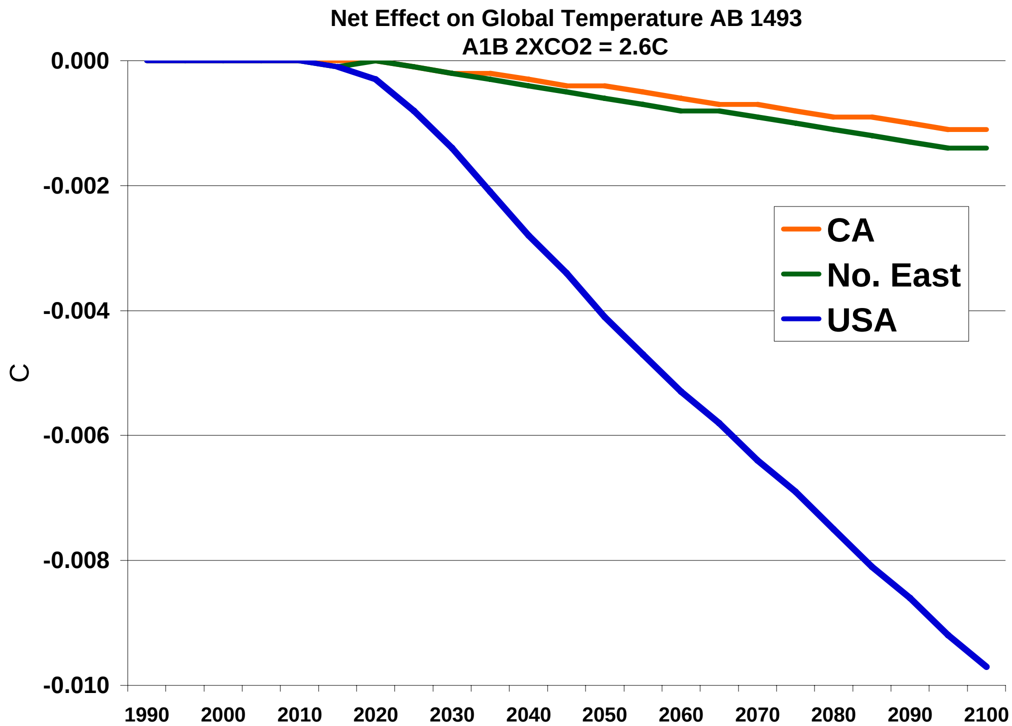

Table 6. Change in sea level due to the reduction of CO_2 emissions according to AB 1493 (cm).

	CA	No. East	USA
1990	0.00	0.00	0.00
1995	0.00	0.00	0.00
2000	0.00	0.00	0.00
2005	0.00	0.00	0.00
2010	0.00	0.00	0.00
2015	0.00	0.00	0.00
2020	0.00	0.00	0.00
2025	0.00	0.00	0.00
2030	0.00	0.00	0.00
2035	0.00	0.00	-0.01
2040	0.00	0.00	-0.01
2045	0.00	0.00	-0.02
2050	-0.01	-0.01	-0.03
2055	0.00	0.00	-0.03
2060	-0.01	-0.01	-0.04
2065	-0.01	-0.01	-0.05
2070	0.00	0.00	-0.05
2075	0.00	-0.01	-0.05
2080	0.00	-0.01	-0.06
2085	0.00	-0.01	-0.06
2090	-0.01	-0.01	-0.08
2095	-0.01	-0.01	-0.08
2100	-0.01	-0.02	-0.09

Figure 6. Values of sea level reduction listed in Table 6. This represents a magnification of Fig. 3 by 600 times.

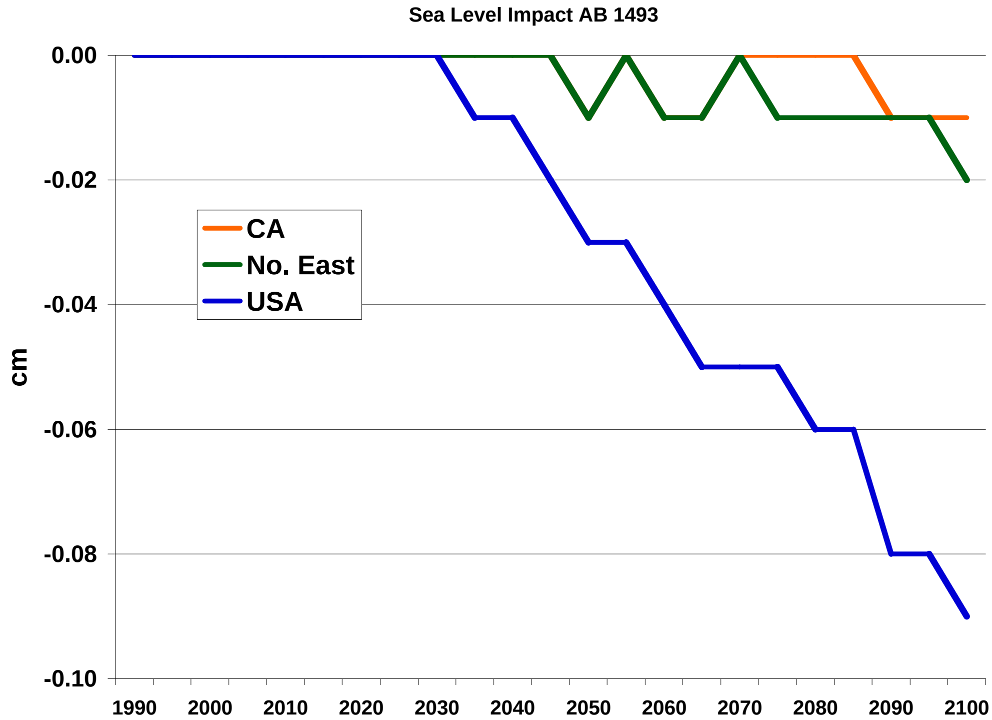

Figure 7. Reconstruction of summer (June, July, August) temperatures of Greenland coastal areas from Vinther et al. 2005, updated through 2005.

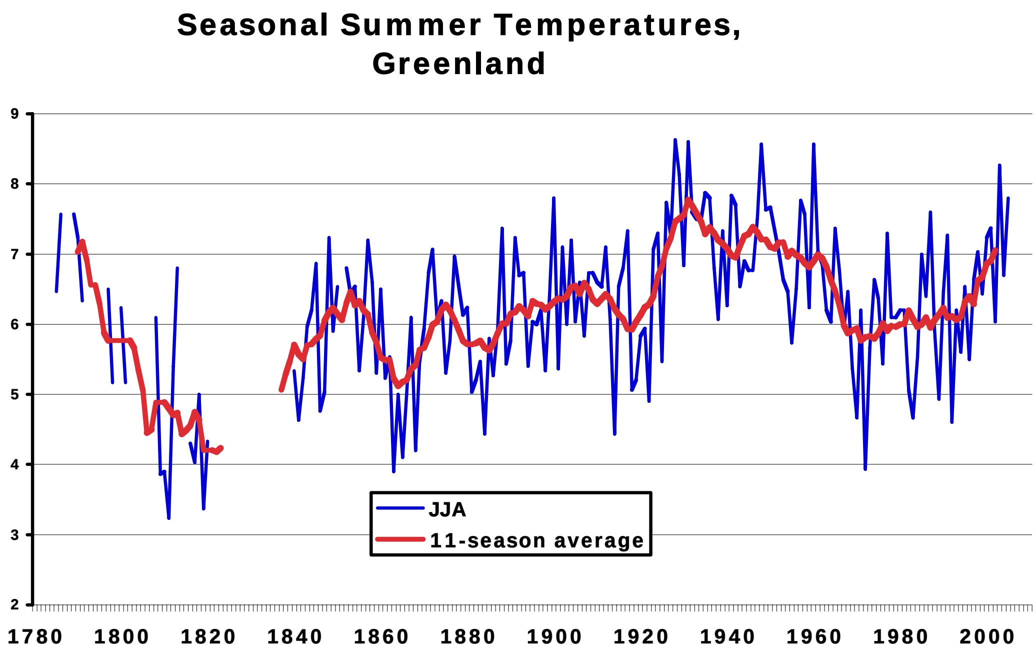

Figure 8. Reconstruction of Greenland temperatures from borehole methods.