RESPONSIVENESS OF ATMOSPHERIC CO2 TO FOSSIL FUEL EMISSIONS: UPDATED

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ABSTRACT: The IPCC carbon budget concludes that changes in atmospheric CO2 are driven by fossil fuel emissions on a year by year basis. A testable implication of the validity of this carbon budget is that changes in atmospheric CO2 should be correlated with fossil fuel emissions at an annual time scale net of long term trends. A test of this relationship with insitu CO2 data from Mauna Loa 1958-2016 and flask CO2 data from twenty three stations around the world 1967-2015 is presented. The test fails to show that annual changes in atmospheric CO2 levels can be attributed to annual emissions. The finding is consistent with prior studies that found no evidence to relate the rate of warming to emissions and they imply that the IPCC carbon budget is flawed possibly because of insufficient attention to uncertainty, excessive reliance on net flows, and the use of circular reasoning that subsumes a role for fossil fuel emissions in the observed increase in atmospheric CO2.[1]

1. INTRODUCTION

The essence of the theory of anthropogenic global warming (AGW) is that fossil fuel emissions cause warming by increasing atmospheric CO2 levels and that therefore the amount of warming can be attenuated by reducing fossil fuel emissions (Hansen, 1981) (Meinshausen, 2009) (Stocker, 2013) (Callendar, 1938) (Revelle, 1957) (Lacis, 2010) (Hansen, 2016) (IPCC, 2000) (IPCC, 2014). At the root of the proposed AGW causation chain is the ability of fossil fuel emissions to cause measurable changes in atmospheric CO2 levels in excess of natural variability. Evidence for this relationship between emissions and atmospheric CO2 has been presented in terms of carbon dioxide flows derived from climate models (Sarmiento, 1998) (Canadell, 2007) (Bachelet, 2001) (Friedlingstein, 2006) (McGuire, 2001) (Bopp, 2002) (Chen, 2000) and also from global carbon budgets based on the assessment of “net flows”.

Net flows are differences between large uncertain flows but with the uncertainty removed by making certain assumptions. Net flows thus circumvent insurmountable measurement problems of large and uncertain gross flows (Massman, 2002) (Aubinet, 2012) (Rosón, 2003) (Giering, 2014) (Smith, 2001) (Lundberg, 1996) (Peltoniemi, 2006) (Ito, 2005) (Haverd, 2013) (Shvidenko, 1996) (Dufrêne, 2005). However, net flows and flow information derived from climate models may be a form of circular reasoning if they subsume AGW in the process of providing empirical evidence for AGW (Munshi, 2016) (Rodhe, 2000) (Edwards, 1999) and in particular if uncertainty is not given due consideration (Munshi, 2015a). A testable implication of the validity of a carbon budget constructed with net flow assumptions is its core AGW conclusion that changes in atmospheric CO2 are driven by fossil fuel emissions. Measurements of atmospheric CO2 at Mauna Loa 1958-2016 and worldwide 1967-2015 are used to carry out the test. In a prior study it was shown with Mauna Loa insitu CO2 data 1958-2011 that detrended correlation analysis does not provide evidence that changes in atmospheric CO2 are driven by fossil fuel emissions at an annual time scale (Munshi, 2015). This study is an update of the 2015 paper with extended data availability to 2016 as well as availability of global CO2 measurements.

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Key words: global warming, climate change, fossil fuel emissions, atmospheric carbon dioxide, detrended correlation analysis, AGW, anthropogenic global warming, natural variability, uncertainty, IPCC carbon budget, circular reasoning
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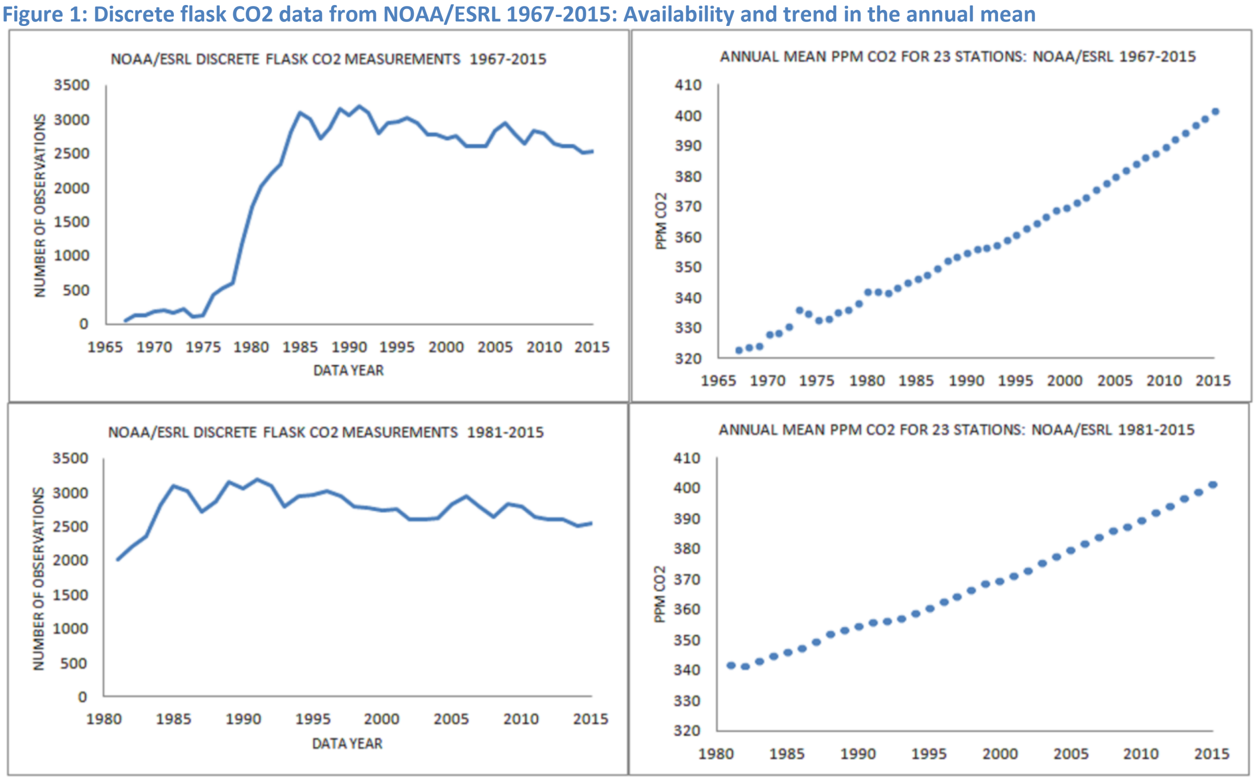
2. DATA AND METHODS

Weekly mean insitu atmospheric CO2 concentrations in parts per million measured at the Mauna Loa Observatory 1958-2016 are provided by the Scripps CO2 Program of UC San Diego (Scripps CO2 Program, 2017). Discrete flask measurements of atmospheric CO2 from 104 stations around the world are provided by the Earth System Research Laboratory of the NOAA for various sample periods within the range of 1967-2015 (ESRL, 2017). Twenty three of these stations are selected for this study using a criterion of at least 20 years of data availability. The selected stations, listed in Figure 2, provide a wide geographical distribution. They include Mauna Loa as well as stations in the South Pole, Australia, Canada, Alaska, the lower 48 states of the USA, the South Pacific, China, Central Asia, Europe, and Russia and provide more than 102,500 discrete flask atmospheric CO2 measurements for the period 1967-2015. Figure 1 shows that data availability is sparse prior to 1981 in the ESRL dataset and that atmospheric CO2 rose from about 320 ppm in 1967 to more than 400 ppm in 2015. Data availability is more uniform in the Scripps insitu weekly mean data and they also show rising CO2 levels in the atmosphere from less than 320 ppm in 1958 to more than 400 ppm in 2016.

Figure 1: Discrete flask CO2 data from NOAA/ESRL 1967-2015: Availability and trend in the annual mean



Because of the difference in data availability between the early years and later years in the ESRL data, and also because it is helpful to test the robustness of results with respect to sample period, both datasets are studied for different time spans. The full span of the data for both datasets and the period 1981 to 2015, a period with good data availability that is common to both datasets, are studied. An annual time scale is used as is usual in the study of the impact of emissions on atmospheric CO2 (Bousquet, 2000) (Canadell, 2007) (Gillett, 2013).

Figure 2: List of NOAA/ESRL/GMD CO2 measuring stations used in this study with approximate number of observations

SEQ	STATION	FROM	TO	YEARS	OBS*
1	Alert, Nunavut, Canada (ALT)	1985	2015	31	4029
2	Ascension Island, United Kingdom (ASC)	1979	2015	37	4810
3	Barrow, Alaska, United States (BRW)	1971	2015	45	5841
4	Cold Bay, Alaska, United States (CBA)	1978	2015	38	4940
5	Cape Grim, Tasmania, Australia (CGO)	1984	2015	32	4160
6	Cape Meares, Oregon, United States (CMO)	1982	1998	17	2210
7	Mariana Islands, Guam (GMI)	1978	2015	38	4940
8	Halley Station, Antarctica, United Kingdom (HBA)	1983	2015	33	4290
9	Key Biscayne, Florida, United States (KEY)	1972	2015	44	5719
10	Cape Kumukahi, Hawaii, United States (KUM)	1971	2015	45	5850
11	Mould Bay, Northwest Territories, Canada (MBC)	1980	1997	18	2340
12	Sand Island, Midway, United States (MID)	1985	2015	31	4030
13	Mauna Loa, Hawaii, United States (MLO)	1967	2015	49	6419
14	Niwot Ridge, Colorado, United States (NWR)	1967	2015	49	6411
15	Palmer Station, Antarctica, United States (PSA)	1978	2015	38	4940
16	Ragged Point, Barbados (RPB)	1987	2015	29	3770
17	Mahe Island, Seychelles (SEY)	1980	2015	36	4680
18	Shemya Island, Alaska, United States (SHM)	1985	2015	31	4030
19	South Pole, Antarctica, United States (SPO)	1975	2015	41	5330
20	Ocean Station M, Norway (STM)	1981	2015	35	4550
21	Summit, Greenland (SUM)	1997	2015	19	2470
22	Tae-ahn Peninsula, Republic of Korea (TAP)	1990	2015	26	3380
23	Mt. Waliguan, Peoples Republic of China (WLG)	1990	2015	26	3378

For the NOAA/ESRL data, a single amalgamated time series of all 102,517 measurements from all twenty three stations is created and the mean and standard deviation of atmospheric CO2 for each year of data are derived and used in a Monte Carlo procedure to simulate the uncertainty in the data. Annual changes in atmospheric CO2 are computed as the corresponding difference in parts per million reported by the measuring stations multiplied by 2.12 to convert ppm to gigatons of carbon equivalent (GTC).

Data for fossil fuel emissions in millions of tons of carbon equivalent are provided by the Carbon Dioxide Information Analysis Center of the Oak Ridge National Laboratories (CDIAC, 2017). Data are available from 1750 to 2013 provided as megatons of carbon equivalent per year. These values are divided by 1000 and reported in this work as gigatons of carbon equivalent per year (GTC). Emissions for later years are inferred from percentage changes reported by other sources (CarbonBrief, 2016) (The Conversation, 2016) (Netherlands Environmental Assessment Agency, 2016).

Correlation between annual changes in atmospheric CO2 and the corresponding fossil fuel emissions are computed both in the source time series and in the detrended series. Uncertainty in the data causes the computed correlations to be somewhat different from one simulation to the next. Ten consecutive simulations are used as a representative sample of the correlation. The standard deviation of correlation is estimated using Bowley's procedure (Bowley, 1928).

Correlation in the source time series can be spurious because it contains both the time scale effect being investigated and an effect of a common drift in time in the two series. For this reason both time series must be detrended to isolate the effect at any given time scale (Podobnik, 2008) (Hu, 2001) (Munshi, 2016). Both source data correlation and detrended correlation are reported and tested for statistical significance. There are three combinations of source and detrended correlations, viz, (1) the source data are correlated and the correlation survives into the detrended series, (2) the source data are correlated but the correlation does not survive into the detrended series, and (3) the source data are not correlated. Only case (1) provides evidence of correlation at the time scale being studied. Case (2) indicates that the correlation in the source data derive mostly from a shared long term drift in time and not at the time scale being studied.

Because a positive correlation is necessary to establish the causal relationship between changes in atmospheric CO2 and fossil fuel emissions described in the IPCC carbon budget, statistical significance is established with the one tailed hypothesis test H_0: $\rho \leq 0$ against H_A: $\rho > 0$. Here ρ represents the correlation in the underlying phenomenon that generated the sample data being studied.

The maximum false positive error rate is set to α=0.001, much lower than the usual values of α=0.01 to α=05, in accordance with Revised Standards for Statistical Significance (Johnson, 2013) published by the NAS to address an unacceptable rate of irreproducible results in published research (Siegfried, 2010). Since ten comparisons are made for the ten different simulation results for each correlation tested, the probability of finding at least one significant correlation in random data is increased by a factor of ten (Holm, 1979). The maximum false positive error rate is maintained by the requiring multiple rejections of H_0 in any given set of ten comparisons rather than applying the so called Bonferroni Adjustment (Armstrong, 2014) (Moran, 2003) (Garamszegi, 2006).

For the annual time scale, emissions is set to E_J for the J^{th} year and atmospheric accumulation is computed as $2.12*(C_J-C_{J-1})$. Here E_J is fossil fuel and cement emissions in gigatons of carbon equivalent in the J^{th} year and C_J is average atmospheric CO2 concentration for the J^{th} year denoted in parts per million.

This work represents an update and further study of the relationship between fossil fuel (and cement production) emissions and atmospheric accumulation of carbon dioxide presented in prior studies (Munshi, Responsiveness of Atmospheric CO2 to Anthropogenic Emissions: A Note , 2015) (Munshi, Responsiveness of Atmospheric CO2 to Fossil Fuel Emissions: Part 2, 2016) (Munshi, Some Methodological Issues in Climate Science, 2016). All data and computational details used in this study are available in an online data archive (Munshi, 2017 Atmospheric CO2 paper Data Archive, 2017).

3. DATA ANALYSIS

Figure 3: Annualized summary of Mauna Loa Insitu weekly mean CO2 data 1958-2016

MAUNA LOA INSITU CO2 1958-2016					SIM		SIM		
YEAR	MEAN	STDEV	N	SE	MEAN	EMISSIONS	INCREASE	DETEMIS	DETINCR
1958	315.47	1.48	25	0.295	315.12	2.33			
1959	315.95	1.62	48	0.234	316.22	2.45	2.328	0.041	0.774
1960	316.90	1.99	53	0.273	316.70	2.57	1.019	0.033	-0.595
1961	317.63	1.74	52	0.241	317.76	2.58	2.258	-0.079	0.584
1962	318.60	1.82	48	0.262	318.91	2.69	2.425	-0.097	0.691
1963	318.95	2.00	49	0.285	319.50	2.83	1.261	-0.073	-0.533
1964	318.62	1.66	31	0.299	318.51	3.00	-2.110	-0.034	-3.964
1965	320.03	1.66	52	0.231	320.14	3.13	3.474	-0.022	1.561
1966	321.36	1.98	49	0.283	321.50	3.29	2.864	0.013	0.892
1967	322.17	1.86	50	0.263	322.65	3.39	2.438	-0.005	0.406
1968	323.05	1.78	52	0.247	323.10	3.57	0.956	0.045	-1.136
1969	324.62	1.78	52	0.247	324.66	3.78	3.304	0.136	1.152
1970	325.68	1.74	52	0.241	325.99	4.05	2.838	0.286	0.626
1971	326.32	1.78	52	0.248	325.93	4.21	-0.141	0.318	-2.412
1972	327.46	1.62	53	0.223	327.51	4.38	3.361	0.363	1.030
1973	329.68	1.74	52	0.241	329.81	4.61	4.864	0.478	2.473
1974	330.25	1.89	52	0.262	330.40	4.62	1.249	0.364	-1.201
1975	331.14	1.85	52	0.257	331.09	4.60	1.473	0.214	-1.037
1976	332.11	1.95	51	0.273	331.97	4.86	1.858	0.359	-0.712
1977	333.91	1.80	53	0.247	333.92	5.02	4.143	0.388	1.513
1978	335.53	1.87	52	0.259	335.33	5.07	2.993	0.322	0.303
1979	336.86	1.90	52	0.263	337.19	5.36	3.930	0.482	1.181
1980	338.69	1.86	52	0.257	338.78	5.30	3.377	0.303	0.568
1981	339.91	2.07	52	0.286	340.01	5.14	2.606	0.017	-0.263
1982	341.11	2.09	52	0.290	340.90	5.09	1.898	-0.150	-1.031
1983	342.77	1.93	53	0.264	342.44	5.08	3.248	-0.292	0.260
1984	344.24	2.00	48	0.288	344.20	5.26	3.728	-0.232	0.680
1985	345.92	2.05	51	0.287	345.47	5.42	2.695	-0.196	-0.412
1986	347.13	1.89	52	0.263	347.11	5.58	3.493	-0.153	0.326
1987	348.93	1.75	52	0.242	349.11	5.73	4.222	-0.134	0.995
1988	351.48	1.80	53	0.247	351.89	5.94	5.908	-0.046	2.622
1989	352.92	1.96	52	0.272	353.01	6.07	2.365	-0.039	-0.981
1990	354.19	1.93	52	0.267	353.84	6.10	1.764	-0.132	-1.642
1991	355.61	2.34	52	0.324	355.53	6.17	3.588	-0.180	0.122
1992	356.38	2.24	52	0.311	356.53	6.11	2.122	-0.364	-1.404
1993	357.05	2.10	52	0.291	356.70	6.10	0.354	-0.493	-3.231
1994	358.90	1.89	53	0.259	359.09	6.21	5.056	-0.513	1.411
1995	360.89	1.98	52	0.275	361.03	6.34	4.132	-0.500	0.428
1996	362.65	1.98	52	0.274	363.06	6.49	4.288	-0.476	0.524
1997	363.77	2.00	52	0.277	364.21	6.59	2.434	-0.501	-1.390
1998	366.62	1.75	52	0.243	366.54	6.57	4.949	-0.642	1.065
1999	368.29	2.10	52	0.291	368.20	6.56	3.510	-0.777	-0.433
2000	369.48	1.76	53	0.241	369.42	6.73	2.601	-0.732	-1.402
2001	371.03	1.90	52	0.264	370.84	6.89	3.012	-0.696	-1.051
2002	373.08	1.75	52	0.242	372.98	6.95	4.523	-0.759	0.400
2003	375.68	1.73	49	0.248	375.74	7.37	5.858	-0.461	1.675
2004	377.36	2.14	52	0.297	377.15	7.74	2.986	-0.216	-1.256
2005	379.58	1.99	49	0.284	380.26	8.03	6.586	-0.049	2.284
2006	381.80	1.97	50	0.278	382.00	8.31	3.701	0.110	-0.661
2007	383.60	1.95	51	0.272	383.58	8.49	3.353	0.168	-1.068
2008	385.43	1.78	52	0.248	384.87	8.74	2.735	0.295	-1.746
2009	387.36	1.90	52	0.263	387.12	8.64	4.771	0.075	0.231
2010	389.88	2.03	52	0.282	390.04	9.14	6.183	0.447	1.582
2011	391.65	1.74	53	0.239	391.86	9.51	3.868	0.695	-0.792
2012	394.00	1.79	50	0.253	394.32	9.67	5.203	0.735	0.483
2013	396.56	1.95	52	0.270	396.53	9.78	4.694	0.717	-0.086
2014	398.61	2.08	52	0.289	398.92	9.84	5.056	0.663	0.216
2015	400.88	2.01	52	0.278	401.16	9.84	4.749	0.540	-0.151
2016	404.28	2.24	53	0.307	404.22	9.86	6.489	0.436	1.530

Annual means of the weekly mean insitu atmospheric CO_2 data provided by Scripps are tabulated in Figure 3. The listed variables are MEAN = annual mean of the reported atmospheric carbon dioxide values, STDEV = their standard deviation, N = number of values reported that year, SE = the standard error of the mean, SIM-MEAN = Monte Carlo simulation of the mean that captures uncertainty implied by the standard error, EMISSIONS = fossil fuel and cement carbon dioxide emissions reported as gigatons of carbon equivalent per year (GTC), SIM-INCREASE = annual accumulation of CO_2 in the atmosphere computed from the SIM-MEAN column as this year's CO_2 level minus previous year's CO_2 level and converted to GTC, DETEMIS = detrended emissions, and DETINCR = detrended annual CO_2 accumulation.

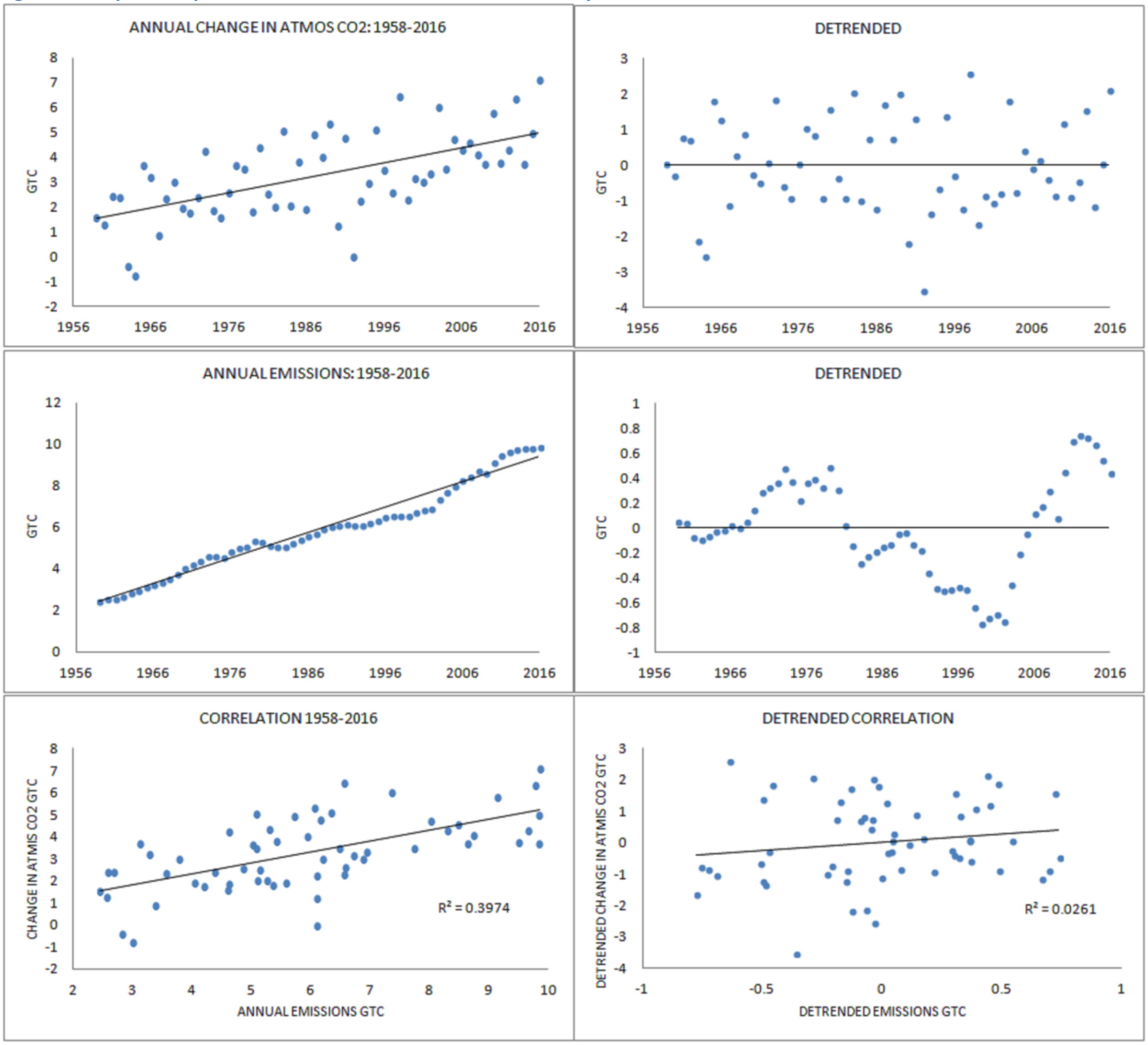
Values in the two SIM columns will be different for each simulation. Ten different Monte Carlo simulations are used and the correlation between SIM-INCR and EMISSIONS and that between DETINCR and DETEMIS are computed for each simulation and tested for statistical significance at $\alpha=0.001$ per comparison. Results for the time span of 1958-2016 and time scale of one year are tabulated in Figure 4 where CORR refers to the correlation between the source data (SIM-INCREASE and EMISSIONS) and DETCORR to the detrended correlation between DETINCR and DETEMIS. The eleven rows in the Table represent eleven different simulations.

Figure 4: Detrended correlation analysis of Mauna Loa insitu CO2 data 1958-2016 at an annual time scale

1958	2016	RSQRD		STDEV		TSTAT		PVALUE		DECISION	
CORR	DETCORR	CORR	DETCORR	CORR	DETCORR	CORR	DETCORR	CORR	DETCORR	CORR	DETCORR
0.6612	0.1400	0.4372	0.0196	0.0985	0.1300	6.71	1.08	0.0000	0.1431	REJECT	FAIL
0.6330	0.1397	0.4007	0.0195	0.1017	0.1300	6.23	1.07	0.0000	0.1436	REJECT	FAIL
0.6227	0.1482	0.3878	0.0220	0.1027	0.1299	6.06	1.14	0.0000	0.1293	REJECT	FAIL
0.5923	0.1259	0.3508	0.0159	0.1058	0.1303	5.60	0.97	0.0000	0.1689	REJECT	FAIL
0.6098	0.1113	0.3718	0.0124	0.1041	0.1305	5.86	0.85	0.0000	0.1987	REJECT	FAIL
0.6271	0.1463	0.3933	0.0214	0.1023	0.1299	6.13	1.13	0.0000	0.1324	REJECT	FAIL
0.5738	0.1139	0.3293	0.0130	0.1075	0.1305	5.34	0.87	0.0000	0.1933	REJECT	FAIL
0.6790	0.1421	0.4611	0.0202	0.0964	0.1300	7.04	1.09	0.0000	0.1395	REJECT	FAIL
0.6560	0.1095	0.4303	0.0120	0.0991	0.1305	6.62	0.84	0.0000	0.2025	REJECT	FAIL
0.6925	0.1281	0.4796	0.0164	0.0947	0.1302	7.31	0.98	0.0000	0.1647	REJECT	FAIL
0.6421	0.1377	0.4123	0.0190	0.1007	0.1301	6.38	1.06	0.0000	0.1472	REJECT	FAIL

The CORR columns in Figure 4 show strong statistically significant correlations for the source data in all eleven simulations. The simulations capture the uncertainty in annual mean CO_2 accumulation. The null hypothesis H_0: $\rho \leq 0$ is rejected in all eleven simulations. At the same time the DETCORR columns show a complete failure to reject H_0 for detrended correlations. A graphical representation of these results appears in Figure 5. The combination of a correlation in the source data and absence of correlation at a given time scale in the detrended series indicates that the correlation in the source data derives from a shared long term drift in time and not from a relationship between their annual fluctuations net of long term trend. These results show that the data do not provide evidence that EMISSIONS and SIM-INCREASE are related at an annual time scale. This result is consistent with the findings in prior works (Munshi, 2015) and inconsistent with the IPCC carbon budget and the AGW hypothesis which assume that observed increases in atmospheric CO_2 derive from fossil fuel emissions (Le Quéré, 2009) (Canadell, 2007) (Solomon, 2009) (Hansen, 1981) (IPCC, 2000) (IPCC, 2014).

Figure 5: Graphical representation of detrended correlation analysis of Mauna Loa data 1958-2016 at an annual time scale



We now look at the same data for two additional time spans for ease of comparison with the dataset of global flask CO2 measurements. Figures 6&7 summarize the results for the time span 1967-2015 and Figures 8&9 show results for the span 1981-2015. The time scale is annual in both cases. The time for emissions to become well mixed in the atmosphere is thought to be one year (Bousquet, 2000).

For the span 1967-2015 (Figures 6&7), strong evidence of correlation is found in the source data but no correlation can be detected in the detrended series. As we did for the full span 1958-2015, we conclude that correlation in the source data derives from long term trends and not from correspondence in year to year fluctuations. Somewhat different results are seen for the span 1981-2015 (Figures 8&9). No statistically significant correlation is found in the detrended series or in the source data. These data also fail to provide evidence in support of the IPCC carbon budget that relates changes in atmospheric CO2 to fossil fuel emissions at an annual time scale.

Figure 6: Detrended correlation analysis of Mauna Loa insitu CO2 data 1967-2015 at an annual time scale

1967	2015	RSQRD		STDEV		TSTAT		PVALUE		DECISION	
CORR	DETCORR	CORR	DETCORR	CORR	DETCORR	CORR	DETCORR	CORR	DETCORR	CORR	DETCORR
0.4831	0.0963	0.2334	0.0093	0.1264	0.1437	3.82	0.67	0.0002	0.2531	REJECT	FAIL
0.5166	0.0927	0.2669	0.0086	0.1236	0.1437	4.18	0.65	0.0001	0.2611	REJECT	FAIL
0.4687	0.0804	0.2197	0.0065	0.1275	0.1439	3.68	0.56	0.0003	0.2894	REJECT	FAIL
0.5445	0.0919	0.2964	0.0084	0.1211	0.1437	4.50	0.64	0.0000	0.2628	REJECT	FAIL
0.5522	0.1275	0.3049	0.0163	0.1203	0.1432	4.59	0.89	0.0000	0.1888	REJECT	FAIL
0.5395	0.1260	0.2911	0.0159	0.1215	0.1432	4.44	0.88	0.0000	0.1918	REJECT	FAIL
0.4771	0.0959	0.2276	0.0092	0.1269	0.1437	3.76	0.67	0.0002	0.2539	REJECT	FAIL
0.4678	0.0837	0.2189	0.0070	0.1276	0.1438	3.67	0.58	0.0003	0.2818	REJECT	FAIL
0.5868	0.1419	0.3444	0.0201	0.1169	0.1429	5.02	0.99	0.0000	0.1630	REJECT	FAIL
0.4946	0.0608	0.2447	0.0037	0.1254	0.1441	3.94	0.42	0.0001	0.3375	REJECT	FAIL
0.5541	0.1064	0.3070	0.0113	0.1202	0.1435	4.61	0.74	0.0000	0.2310	REJECT	FAIL

Figure 7: Graphical representation of detrended correlation analysis of Mauna Loa data 1967-2015 at an annual time scale

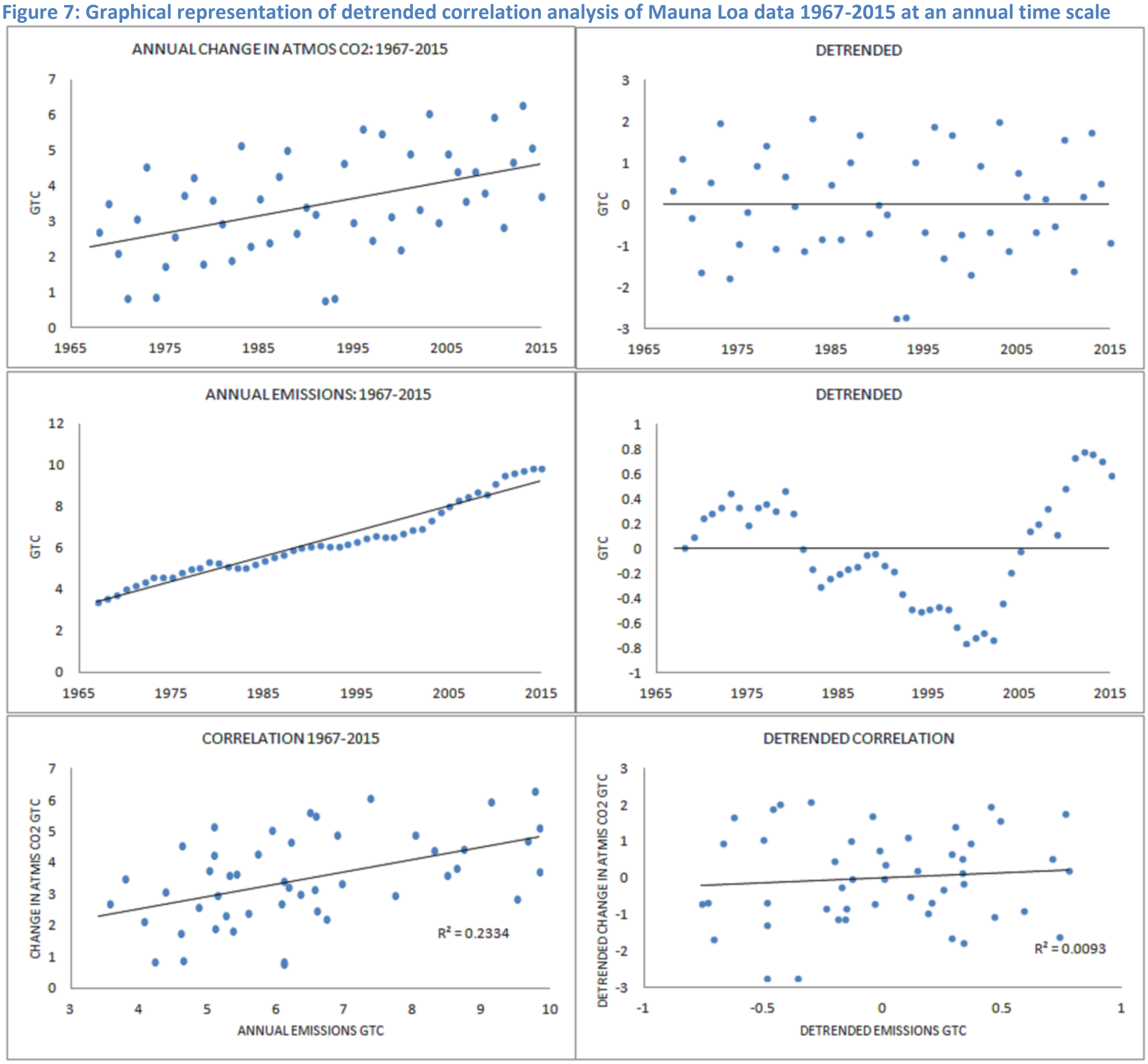


Figure 8: Detrended correlation analysis of Mauna Loa insitu CO2 data 1981-2015 at an annual time scale

1967	2015	RSQRD		STDEV		TSTAT		PVALUE		DECISION	
CORR	DETCORR	CORR	DETCORR	CORR	DETCORR	CORR	DETCORR	CORR	DETCORR	CORR	DETCORR
0.4325	0.1034	0.1871	0.0107	0.1546	0.1706	2.80	0.61	0.0043	0.2743	FAIL	FAIL
0.4039	0.0573	0.1632	0.0033	0.1569	0.1712	2.57	0.33	0.0074	0.3700	FAIL	FAIL
0.4113	0.0358	0.1692	0.0013	0.1563	0.1714	2.63	0.21	0.0065	0.4178	FAIL	FAIL
0.4099	0.1169	0.1680	0.0137	0.1564	0.1703	2.62	0.69	0.0067	0.2488	FAIL	FAIL
0.4861	0.0647	0.2363	0.0042	0.1499	0.1711	3.24	0.38	0.0014	0.3539	FAIL	FAIL
0.4202	0.0902	0.1766	0.0081	0.1556	0.1708	2.70	0.53	0.0055	0.3006	FAIL	FAIL
0.4103	0.0925	0.1683	0.0086	0.1564	0.1708	2.62	0.54	0.0066	0.2959	FAIL	FAIL
0.4486	0.0732	0.2012	0.0054	0.1533	0.1710	2.93	0.43	0.0031	0.3358	FAIL	FAIL
0.4453	0.0520	0.1983	0.0027	0.1536	0.1713	2.90	0.30	0.0033	0.3817	FAIL	FAIL
0.5194	0.1092	0.2698	0.0119	0.1465	0.1705	3.54	0.64	0.0006	0.2631	REJECT	FAIL
0.4351	0.0856	0.1894	0.0073	0.1544	0.1709	2.82	0.50	0.0041	0.3099	FAIL	FAIL

Figure 9: Graphical representation of detrended correlation analysis of Mauna Loa data 1981-2015 at an annual time scale

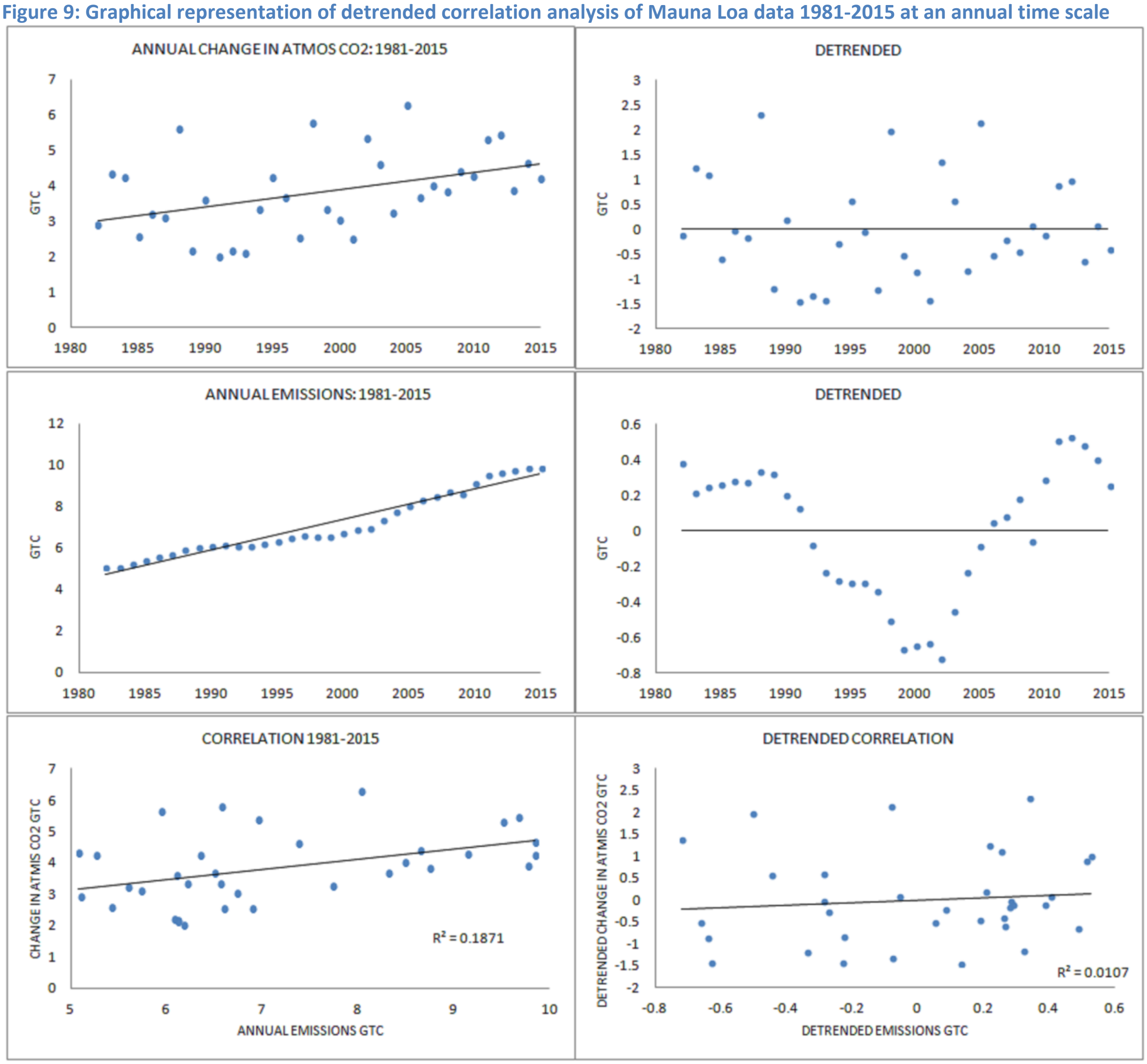


Figure 10: Annualized summary of 102,517 discrete flask measurements of atmospheric CO2 globally 1967-2015

GLOBAL DISCRETE FLASK MEASUREMENTS 1967-2015					SIM			SIM		
YEAR	MEAN	STDEV	N	SE	MEAN	YEAR	EMISSIONS	INCREASE	DETEMIS	DETINCR
1967	322.96	2.35	47	0.343	323.11	1967	3.39			
1968	323.68	1.94	117	0.179	323.63	1968	3.57	1.100	0.006	-1.250
1969	324.40	4.03	125	0.361	324.81	1969	3.78	2.501	0.099	0.103
1970	328.11	8.93	179	0.668	330.30	1970	4.05	11.640	0.251	9.196
1971	328.55	8.26	199	0.585	328.27	1971	4.21	-4.311	0.285	-6.803
1972	330.81	7.49	167	0.580	330.63	1972	4.38	5.000	0.331	2.462
1973	336.31	11.79	212	0.810	335.08	1973	4.61	9.444	0.448	6.859
1974	335.04	9.43	104	0.924	335.77	1974	4.62	1.463	0.336	-1.170
1975	332.86	5.49	120	0.501	333.55	1975	4.60	-4.710	0.188	-7.389
1976	333.20	5.47	430	0.264	332.99	1976	4.86	-1.185	0.335	-3.911
1977	335.23	4.84	523	0.212	335.33	1977	5.02	4.960	0.365	2.187
1978	336.37	4.90	593	0.201	336.15	1978	5.07	1.730	0.302	-1.090
1979	338.30	5.78	1158	0.170	338.39	1979	5.36	4.755	0.464	1.888
1980	342.08	5.73	1717	0.138	342.01	1980	5.30	7.680	0.287	4.766
1981	342.11	5.00	2015	0.111	342.34	1981	5.14	0.699	0.002	-2.262
1982	341.92	5.04	2206	0.107	341.99	1982	5.09	-0.741	-0.163	-3.749
1983	343.39	5.04	2347	0.104	343.45	1983	5.08	3.095	-0.303	0.039
1984	345.03	4.75	2818	0.089	345.19	1984	5.26	3.688	-0.241	0.585
1985	346.49	4.46	3094	0.080	346.53	1985	5.42	2.832	-0.203	-0.317
1986	347.90	4.63	3010	0.084	347.83	1986	5.58	2.754	-0.159	-0.442
1987	349.62	4.33	2725	0.083	349.51	1987	5.73	3.567	-0.138	0.324
1988	352.27	4.22	2876	0.079	352.18	1988	5.94	5.663	-0.048	2.373
1989	353.76	4.81	3156	0.086	353.86	1989	6.07	3.563	-0.039	0.226
1990	355.08	4.67	3053	0.085	355.07	1990	6.10	2.552	-0.131	-0.832
1991	356.36	4.60	3194	0.081	356.30	1991	6.17	2.611	-0.177	-0.820
1992	356.68	4.50	3100	0.081	356.68	1992	6.11	0.815	-0.359	-2.663
1993	357.52	4.61	2788	0.087	357.63	1993	6.10	2.000	-0.486	-1.525
1994	359.17	5.06	2940	0.093	359.18	1994	6.21	3.290	-0.503	-0.282
1995	361.01	5.58	2962	0.103	361.10	1995	6.34	4.081	-0.489	0.462
1996	362.97	5.39	3015	0.098	362.88	1996	6.49	3.777	-0.463	0.111
1997	364.68	7.61	2951	0.140	364.89	1997	6.59	4.262	-0.486	0.549
1998	366.98	5.56	2783	0.105	366.86	1998	6.57	4.165	-0.625	0.405
1999	368.75	6.12	2778	0.116	368.87	1999	6.56	4.253	-0.759	0.446
2000	369.95	5.54	2727	0.106	369.84	2000	6.73	2.055	-0.712	-1.799
2001	371.59	6.11	2762	0.116	371.61	2001	6.89	3.771	-0.674	-0.130
2002	373.08	6.30	2603	0.124	373.18	2002	6.95	3.321	-0.735	-0.628
2003	375.71	6.63	2600	0.130	375.72	2003	7.37	5.383	-0.435	1.388
2004	377.85	4.76	2612	0.093	377.81	2004	7.74	4.430	-0.189	0.388
2005	379.89	6.25	2828	0.118	380.00	2005	8.03	4.642	-0.020	0.553
2006	382.24	6.79	2938	0.125	382.24	2006	8.31	4.750	0.141	0.614
2007	384.11	6.15	2795	0.116	383.86	2007	8.49	3.430	0.201	-0.753
2008	386.34	6.10	2635	0.119	386.37	2008	8.74	5.335	0.329	1.105
2009	387.75	6.76	2830	0.127	387.91	2009	8.64	3.262	0.111	-1.015
2010	390.02	6.28	2797	0.119	389.96	2010	9.14	4.337	0.486	0.013
2011	392.21	5.72	2644	0.111	392.25	2011	9.51	4.861	0.736	0.490
2012	394.29	6.34	2598	0.124	394.42	2012	9.67	4.604	0.778	0.186
2013	396.98	6.83	2600	0.134	396.88	2013	9.78	5.205	0.761	0.740
2014	399.02	6.79	2509	0.135	398.95	2014	9.84	4.384	0.709	-0.128
2015	401.52	7.40	2537	0.147	401.33	2015	9.84	5.058	0.587	0.499

Atmospheric CO2 data from the twenty three stations listed in Figure 2 are summarized in Figure 10. These data are studied for detrended correlation with fossil fuel emissions for two different time spans. These are the full time-span in the data of 1967-2015 and a period of greater data availability in the time span 1981-2015. Data are sparse for the period prior to 1981. The difference in data availability may introduce heteroskedasticity into the full span time series (Baltagi, 1985).

Figure 11: Detrended correlation analysis of global flask CO2 data 1967-2015 at an annual time scale

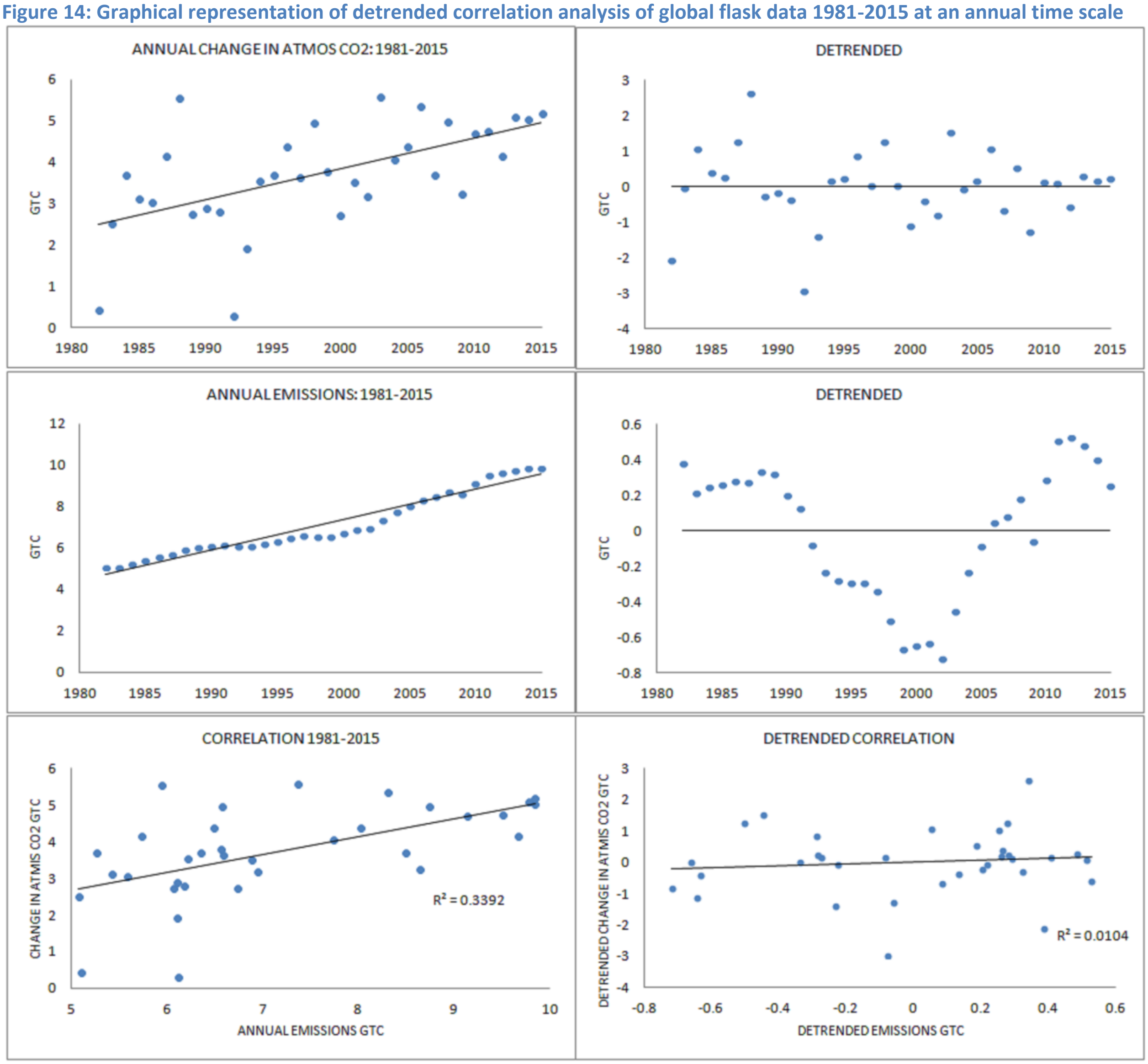
1967	2015	RSQRD		STDEV		TSTAT		PVALUE		DECISION	
CORR	DETCORR	CORR	DETCORR	CORR	DETCORR	CORR	DETCORR	CORR	DETCORR	CORR	DETCORR
0.3038	0.1737	0.0923	0.0302	0.1375	0.1421	2.21	1.22	0.0161	0.1140	FAIL	FAIL
0.2987	0.1744	0.0892	0.0304	0.1377	0.1421	2.17	1.23	0.0177	0.1131	FAIL	FAIL
0.3167	0.1858	0.1003	0.0345	0.1369	0.1418	2.31	1.31	0.0126	0.0984	FAIL	FAIL
0.3095	0.1785	0.0958	0.0319	0.1372	0.1420	2.26	1.26	0.0145	0.1076	FAIL	FAIL
0.2620	0.1583	0.0687	0.0251	0.1393	0.1425	1.88	1.11	0.0332	0.1362	FAIL	FAIL
0.2550	0.1520	0.0650	0.0231	0.1396	0.1427	1.83	1.07	0.0371	0.1461	FAIL	FAIL
0.2808	0.1648	0.0788	0.0271	0.1385	0.1424	2.03	1.16	0.0242	0.1266	FAIL	FAIL
0.2875	0.1593	0.0826	0.0254	0.1382	0.1425	2.08	1.12	0.0216	0.1348	FAIL	FAIL
0.2523	0.1632	0.0636	0.0266	0.1397	0.1424	1.81	1.15	0.0387	0.1289	FAIL	FAIL
0.2678	0.1469	0.0717	0.0216	0.1391	0.1428	1.93	1.03	0.0302	0.1545	FAIL	FAIL
0.2968	0.1718	0.0881	0.0295	0.1378	0.1422	2.15	1.21	0.0183	0.1165	FAIL	FAIL

Figure 12: Graphical representation of detrended correlation analysis of global flask data 1967-2015 at an annual time scale

Figure 13: Detrended correlation analysis of global flask CO2 data 1981-2015 at an annual time scale

1981	2015	RSQRD		STDEV		TSTAT		PVALUE		DECISION	
CORR	DETCORR	CORR	DETCORR	CORR	DETCORR	CORR	DETCORR	CORR	DETCORR	CORR	DETCORR
0.5703	0.1004	0.3253	0.0101	0.1409	0.1706	4.05	0.59	0.0002	0.2802	REJECT	FAIL
0.5738	0.1178	0.3292	0.0139	0.1405	0.1703	4.09	0.69	0.0001	0.2470	REJECT	FAIL
0.5880	0.1045	0.3457	0.0109	0.1387	0.1706	4.24	0.61	0.0001	0.2721	REJECT	FAIL
0.5371	0.0747	0.2884	0.0056	0.1447	0.1710	3.71	0.44	0.0004	0.3327	REJECT	FAIL
0.5937	0.0935	0.3525	0.0087	0.1380	0.1707	4.30	0.55	0.0001	0.2939	REJECT	FAIL
0.5704	0.0868	0.3254	0.0075	0.1409	0.1709	4.05	0.51	0.0002	0.3075	REJECT	FAIL
0.5556	0.0811	0.3087	0.0066	0.1426	0.1709	3.90	0.47	0.0002	0.3192	REJECT	FAIL
0.5586	0.0855	0.3120	0.0073	0.1423	0.1709	3.93	0.50	0.0002	0.3101	REJECT	FAIL
0.5723	0.0926	0.3275	0.0086	0.1406	0.1708	4.07	0.54	0.0001	0.2956	REJECT	FAIL
0.5620	0.0948	0.3158	0.0090	0.1419	0.1707	3.96	0.56	0.0002	0.2912	REJECT	FAIL
0.5676	0.0923	0.3221	0.0085	0.1412	0.1708	4.02	0.54	0.0002	0.2963	REJECT	FAIL

Figure 14: Graphical representation of detrended correlation analysis of global flask data 1981-2015 at an annual time scale



The results of detrended correlation analysis of global flask CO2 measurements for the full span of the data 1967-2015 are summarized in Figures 11&12. As in Figures 8&9, we find that although the correlation in the source data appears to be higher than that in the detrended series, no statistically significant correlation is found in either series at the maximum false positive error rate of $\alpha=0.001$ per comparison used in this study. However, for the shorter time span of 1981-2015 (Figures 13&14) where data availability is more uniform across the study period (Figure 1), the source data correlations are much higher and here we see the results similar to those depicted in Figures 4&5 (Mauna Loa 1958-2016) and Figures 6&7 (Mauna Loa 1967-2015) with a strong correlations in the source data that goes away when the data are detrended.

In all of the above cases, the absence of correlation in the detrended series fails to provide empirical support for the usual carbon budget hypothesis that emissions drive changes in atmospheric CO2. In cases where the a correlation is found in the source data, its absence in the detrended series indicates that the source data correlation derives from a shared drift in time and not from shared fluctuations at the specified time scale that is prerequisite to a causation hypothesis (Podobnik, 2008) (Chatfield, 1989). These results are consistent with findings in prior works that also found no empirical evidence that changes in atmospheric CO2 are driven by fossil fuel emissions at an annual time scale (Munshi, 2015) (Munshi, 2016). All data and computational details are available in a data archive (Munshi, 2017).

4. CONCLUSIONS

A key relationship in the theory of anthropogenic global warming (AGW) is that between annual fossil fuel emissions and annual changes in atmospheric CO2. The proposed causation sequence is that annual fossil fuel emissions cause annual changes in atmospheric CO2 which in turn intensifies the atmosphere's heat trapping property. It is concluded that global warming is due to changes in atmospheric composition attributed to human activity and is therefore a human creation and that therefore we must reduce or eliminate fossil fuel emissions to avoid climate catastrophe (Parmesan, 2003) (Stern, 2007) (IPCC, 2014) (Flannery, 2006) (Allen, 2009) (Gillett, 2013) (Meinshausen, 2009) (Canadell, 2007) (Solomon, 2009) (Stocker, 2013) (Rogelj, 2016).

A testable implication of the proposed causation sequence is that annual changes in atmospheric CO2 must be related to annual fossil fuel emissions at an annual time scale. This work is a test of this hypothesis. We find that detrended correlation analysis of annual emissions and annual changes in atmospheric CO2 does not support the anthropogenic global warming hypothesis because no evidence is found that changes in atmospheric CO2 are related to fossil fuel emissions at an annual time scale. These results are consistent with prior works that found no evidence to relate the rate of warming to the rate of emissions (Munshi, The Correlation between Emissions and Warming in the CET, 2017) (Munshi, Long Term Temperature Trends in Daily Station Data: Australia, 2017) (Munshi, Generational Fossil Fuel Emissions and Generational Warming: A Note, 2016) (Munshi, Decadal Fossil Fuel Emissions and Decadal Warming: A Note, 2015) (Munshi, Effective Sample Size of the Cumulative Values of a Time Series, 2016) (Munshi, The Spuriousness of Correlations between Cumulative Values, 2016).

The finding raises important questions about the validity of the IPCC carbon budget which apparently overcomes a great uncertainty in much larger natural flows to describe with great precision how flows of annual emissions are distributed to gains in atmospheric and oceanic carbon dioxide (Bopp, 2002) (Chen, 2000) (Davis, 2010) (IPCC, 2014) (McGuire, 2001). These carbon budget conclusions are inconsistent with the findings of this study and are the likely result of insufficient attention to uncertainty, excessive reliance on climate models, and the use of “net flows” (Plattner, 2002) that are likely to be subject to assumptions and circular reasoning (Edwards, 1999) (Ito, 2005) (Munshi, 2015a) (Munshi, 2016) (Munshi, An Empirical Study of Fossil Fuel Emissions and Ocean Acidification, 2015).

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