Derivation of equations and example calculations of the components of CO_2
by
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Revision of May 11, 2022 based on a “No bombs” scenario

INTRODUCTION

This document is a revision of our previous version based on a “No bombs” scenario as explained in the first paragraph of the discussion. It is a supporting document for our paper titled, “World atmospheric CO_2, its ^{14}C specific activity, non-fossil component, anthropogenic fossil component, and emissions (1750 - 2018)” (Skrable et al. February 2022). The methodology we use to estimate the annual mean values for the anthropogenic fossil component, $C_F(t)$, and the non-fossil component, $C_{NF}(t)$, requires starting in 1750, the assumed onset of the industrial revolution and burning of fossil fuels. The letters “F” and “NF” in the subscripts of the symbols, $C_F(t)$ and $C_{NF}(t)$, represent respectively the anthropogenic fossil and non-fossil components. The anthropogenic component, $C_F(t)$, includes that from the burning of fossil fuels and that from cement production. The annual mean total CO_2 concentration in 1750, $C(0)$, and its ^{14}C specific activity, $S(0)$, are compared to values $C(t)$ and $S(t)$ in calculating annual mean values for the two components at *t* years after 1750. Values of $C(t)$ used in this revised document and our paper are those reported by the Energy Information Administration (EIA 2021). The initial values of $C(0)$ and $S(0)$ represent constant standards of reference. By definition, no anthropogenic fossil CO_2 is present in $C(0)$. Although $C(0)$ in 1750 has an unspecified, natural background fossil component, such as emissions from volcanos, it is small in comparison to the more recent anthropogenic fossil component, $C_F(t)$. The anthropogenic fossil emissions of CO_2 increased in 1950 to 2010 from 30 times to 135 times that from volcanos (Gerlach 2011), which are the major source of natural fossil CO_2. This natural background fossil component is not considered directly in the derivation of the equation for $C_F(t)$. Thus, $C(0)$ is considered not to have anthropogenic fossil CO_2, and it also could be designated by the symbol $C_{NF}(0)$. Likewise, the symbol for the initial specific activity in 1750, $S(0)$, could be designated by the symbol $S_{NF}(0)$. After 1750, the specific activities, $S(t)$, of CO_2 in the atmosphere decrease as emissions of anthropogenic fossil CO_2 increase and as exchanges of CO_2 occur among the reservoirs in each year. The symbol $S_{NF}(t)$ instead of $S(t)$ also could be used to represent the annual specific activity of both $C(t)$ and $C_{NF}(t)$. For consistency, this revised document uses the same symbols as those in the previous document and our paper. The brackets, < >, surrounding a symbol represent a quantity estimated from an algebraic equation that has no random variables, for example, the expected specific activity, $<S(t)>$. To be consistent with symbols used in our paper, its initial value in 1750 is represented by the symbol $S(0)$ instead of by $<S(0)>$.

Equations in either of two logic pathways can be used to estimate the two components of CO_2. Our paper uses equations in Pathway 2, which provides a more concise but complete presentation of the basis of our methodology and calculation of all CO_2 quantities of interest. The derivation of equations for Pathway 1 and example calculations below are used to provide additional clarification of the assumptions and methodology used in our paper. Both pathways and their equations are summarized later in this document. Quantities are calculated at *t* years after 1750, the assumed start of the industrial revolution. These calculated quantities are compared to values in the attached revised Table 2a calculated by equations in Pathway 2.

DISCUSSION

For consistency with our paper and previous version of this document, all CO_2 quantities calculated in the examples below and in our revised Table 2 and Table 2a are assumed to represent annual mean quantities in the atmosphere that automatically account for transfer of all isotopic forms of CO_2 among its reservoirs, including $<C_F(t)>$, and $C_{NF}(t)$. They rely on estimates of the expected specific activity, $<S(t)>$, calculated from our approximation fitting function of a curve of specific activities in

1750 through 2015. The curve is contained within a figure in a letter submitted to the Health Physics Journal (Schwartz et al. June 2022) that indicated our paper did not adequately account for the perturbation due to nuclear weapons testing. Our response to this letter and others is included in the June issue (Skrable et al. June 2022). Values for $<S(t)>$ are calculated by our equation expressed: $<S(t)> = 14 - [(10^{-14.309})t^6]$, which is estimated from the curve modeled in the absence of the perturbation due to nuclear weapons testing. The curve in the figure is labeled and designated here as a “No bombs” scenario.

Annual mean CO_2 concentrations, $C(t)$, in our paper, are used along with our revised expected specific activities, $<S(t)>$, to calculate values of CO_2 quantities in a revised Table 2a and a revised Table 2. The revised expected specific activities, $<S(t)>$, cause changes from values of some CO_2 quantities in our paper.

Major assumptions used to derive equations for CO_2 annual mean quantities

The major assumptions used to derive the equations for the CO_2 quantities present each year in the atmosphere are summarized as follows. The total CO_2 concentration, $C(t)$, has had an essentially constant value of 280 ppm for several thousand years prior to 1750 (Prentice et al. 2018). It is assumed that the production rate of ^{14}C in the atmosphere from the interaction of cosmic rays has been essentially constant for at least fifteen thousand years, and the world total activity of ^{14}C has maintained a steady state value (Eisenbud et al. 1997). Except for the variation of the annual change, $DC_{NF}(t)$, in the concentration of the non-fossil component from one year to the next due to the redistribution of CO_2 in its reservoirs and changes in land use, the activity of ^{14}C per unit volume of the atmosphere then would be constant. The initial ^{14}C activity per unit volume of air in 1750 is proportional to $C(0)S(0)$. The product of $C(t)<S(t)>$ is directly proportional to the activity of ^{14}C per unit volume at time t years after 1750. Therefore, the activity per unit volume of air would be constant except for the annual increase or decrease of the product of $DC_{NF}(t)<S(t)>$. The $<S(t)>$ value equals the specific activity of ^{14}C in $DC_{NF}(t)$ as well as in $C(t)$. The annual change, $DC_F(t)$, in the concentration, $<C_F(t)>$, of the anthropogenic fossil component from the value of zero in 1750 is the same as its annual value, $<C_F(t)>$, present at time t years after 1750. The symbol $DC_F(t)$ used in our paper should have been expressed by the symbol, $<DC_F(t)>$. For consistency with our paper, the symbol $DC_F(t)$ also is used here and in the tables and figures. The annual change, $DC(t)$ in $C(t)$ is given by the sum: $DC(t) = DC_{NF}(t) + DC_F(t)$. The annual mean total concentration, $C(t)$, can be expressed: $C(t) = C(0) + DC_{NF}(t) + DC_F(t)$ or by: $C(t) = C_{NF}(t) + <C_F(t)>$.

Derivation of equations for Pathway 1

The major assumptions above are used for the derivation of the equation for the $DC_{NF}(t)$ value in 2018 ($t = 268$ y) in relation to the initial non-fossil concentration, $C_{NF}(0)$, i.e., $C(0)$ of 276.44 ppm in 1750. The sign of $DC_{NF}(t)$ can be positive or negative depending on whether or not there is a net change in the activity per unit volume of the atmosphere in any year since 1750, which is proportional to the product $C(t)<S(t)>$. The non-fossil concentration, $C(0)$, of 276.44 ppm and its specific activity, $<S(0)>$, of 14 $dpm(gC)^{-1}$ in Table 2a are the values in 1750. In 2018, the total CO_2 concentration, $C(t)$, is 405.40 ppm, and its specific activity, $<S(t)>$, is 12.18 $dpm(gC)^{-1}$. These values are used below to calculate values for other CO_2 quantities in 2018 by the equations for Pathway 1. Values of CO_2 quantities listed in Table 2a were calculated by the equations in Pathway 2, and they would be the same as those in Pathway 1 except for roundoff errors. For ease of reference, equation numbers listed below are the same as the numbers listed for each section below and not the numbers listed at the head of columns of Table 2a.

(1) The statement for the annual change of the ^{14}C activity per unit volume of air in units of $(dpm)m^{-3}$ from that in 1750 is expressed based on a conversion factor K in units of $gCm^{-3}(ppm)^{-1}$:

$$KDC_{NF}(t)\langle S(t)\rangle \;=\; KC(t)\langle S(t)\rangle \;-\; KC(0)S(0),\ \textit{which yields}:$$

$$DC_{NF}(t) \;=\; \left(\frac{C(t)\langle S(t)\rangle \;-\; C(0)S(0)}{\langle S(t)\rangle}\right) \;=\; \left(\frac{(405.40)(12.18) \;-\; (276.44)(14)}{(12.18)}\right)\ ppm \;=\; 87.65\ ppm, \tag{1}$$

which differs slightly from the value of 87.68 ppm in Table 2a because not all of the digits in the value of *<S(t)>* in Table 2a have been used in the calculation above. The annual emission, *DE(t)*, of anthropogenic fossil CO_2 increases each year after 1750, and the equation for the expected specific activity, *<S(t)>*, yields decreasing values that are ≤ S(0). When $C(t)<S(t)>$ exceeds $C(0)S(0)$, then $DC_{NF}(t)$ is positive. When $C(t)<S(t)>$ is less than $C(0)S(0)$, then $DC_{NF}(t)$ is negative. When $C(t)<S(t)>$ equals $C(0)S(0)$, $DC_{NF}(t)$ is zero, and $C_{NF}(t)$ equals $C(0)$. The specific activity then is given by the equation: $<S(t)> = C(0)S(0)C(t)^{-1} = C(0)S(0)[C(0) + <C_F(t)>]^{-1}$, which as demonstrated later applies regardless of the sign or magnitude of $DC_{NF}(t)$. This equation for *<S(t)>* represents the dilution of the initial ^{14}C activity per unit volume in the atmosphere, *KC(0)S(0)*, because of the addition of the anthropogenic fossil component, $<C_F(t)>$. It is our fundamental equation used to quantify the Suess effect (Suess et al. 1967). The quantity, $<C_F(t)>$, is not included in the equation for $DC_{NF}(t)$ because its presence in the atmosphere does not add any activity of ^{14}C per unit volume of the atmosphere.

(2) The 2018 non-fossil concentration, $C_{NF}(t)$, at time *t* of 268 years is calculated:

$$C_{NF}(t) \;=\; C(0) \;+\; DC_{NF}(t) \;=\; (276.44 \;+\; 87.65)\ ppm \;=\; 364.09\ ppm, \tag{2}$$

which differs slightly from the value of 364.12 ppm in Table 2a calculated by equation in Pathway 2.

(3) The 2018 anthropogenic fossil concentration, $<C_F(t)>$, at time *t* of 268 years is calculated:

$$\langle C_F(t)\rangle \;=\; C(t) \;-\; C_{NF}(t) \;=\; (405.40 \;-\; 364.09)\ ppm \;=\; 41.31\ ppm, \tag{3}$$

which differs slightly from the value of 41.28 ppm in Table 2a calculated by equation in Pathway 2.

(4) The 2018 fraction, $f_F(t)$, of anthropogenic fossil CO_2 in *C(t)* at time *t* of 268 years is calculated:

$$f_F(t) \;\equiv\; \frac{\langle C_F(t)\rangle}{C(t)} \;=\; \frac{41.31}{405.40} \;=\; 0.102\ \textit{or}\ 10.2\%. \tag{4}$$

(5) The 2018 fraction, $f_{NF}(t)$, of non-fossil CO_2 in *C(t)* at time *t* of 268 y is calculated:

$$f_{NF}(t) \;\equiv\; \frac{C_{NF}(t)}{C(t)} \;=\; 1 \;-\; f_F(t) \;=\; 1 \;-\; 0.102 \;=\; 0.898,\ \textit{or}\ 89.8\%. \tag{5}$$

(6) To provide further insight about the relationships among quantities underlying the first three equations above, they are derived or expressed as follows. The algebraic expression for $DC_{NF}(t)$ in Equation (1) is key to the derivation and calculation of all quantities listed in the equations. The expression for $DC_{NF}(t)$ is derived alternatively using a thought experiment. Assume all of the carbon in the samples used to obtain the annual mean concentration *C(t)* of 405.40 ppm in 2018 is later used to measure its 2018 specific activity *<S(t)>* of 12.18 $dpm(gC)^{-1}$. Assume that the volume of all the air samples is *V* cubic meters. Based on a conversion factor *K* in the units of $gCm^{-3}(ppm)^{-1}$, the following relationships can be established for the expected specific activity, *<S(t)>*:

$$<S(t)> \;=\; \left(\frac{KVC(0)S(0) \;+\; KVDC_{NF}(t)<S(t)>}{KVC(t)} \right) \;=\; \left(\frac{C(0)S(0) \;+\; DC_{NF}(t)<S(t)>}{C(t)} \right), \; thus: \tag{6}$$

$$DC_{NF}(t) \;=\; \left(\frac{C(t)<S(t)> \;-\; C(0)S(0)}{<S(t)>} \right),$$

which is the same expression as that in Equation (1). The terms in the first equality represent:

$K\,V\,C(0)\,S(0)$ ≡ activity of ^{14}C in air volume V in 1750;
$K\,V\,DC_{NF}(t)\,<S(t)>$ ≡ activity of ^{14}C lost or added to air volume V from 1750 to 2018.
$K\,V\,C(t)$ ≡ total mass in grams of carbon in the air volume V in 2018.

(7) An expression for the expected specific activity, $<S(t)>$, can be obtained from the last expression in Equation (6), which yields the value of 12.18 dpm(gC)$^{-1}$ for $<S(268\ y)>$ in Table 2a:

$$<S(t)> \;=\; \frac{C(0)S(0)}{C(t) \;-\; DC_{NF}(t)} \;=\; \frac{(276.44\ ppm)(14\ dpm(gC)^{-1}}{405.40\ ppm \;-\; 87.65\ ppm)} \;=\; 12.18\ dpm(gC)^{-1}. \tag{7}$$

(8) It can be shown that the algebraic expression in Equation (7) for the expected specific activity, $<S(t)>$, can be reduced to an expression which also yields the value, $<S(268\ y)>$ of 12.18 dpm(gC)$^{-1}$:

$$<S(t)> \;=\; \frac{C(0)S(0)}{C(t) \;-\; DC_{NF}(t)} \;=\; \frac{C(0)S(0)}{C(t) \;-\; [C_{NF}(t) \;-\; C(0)]} \;=\; \frac{C(0)S(0)}{C(t) \;-\; [(C(t) \;-\; <C_F(t)>) \;-\; C(0)]}, \; or \tag{8}$$

$$<S(t)> \;=\; \frac{C(0)S(0)}{C(0) \;+\; <C_F(t)>} \;=\; \frac{(276.44\ ppm)(14.00\ dpm(gC)^{-1})}{276.44\ ppm \;+\; 41.31\ ppm} \;=\; 12.18\ dpm(gC)^{-1}.$$

(9) When the expression for $DC_{NF}(t)$ in Equation (1) is substituted in Equation (2), the non-fossil component, $C_{NF}(t)$, also can be expressed:

$$C_{NF}(t) \;=\; C(0) \;+\; \left(\frac{C(t)<S(t)> \;-\; C(0)S(0)}{<S(t)>} \right) \;=\; C(t) \;-\; \left(\frac{S(0)}{<S(t)>} \;-\; 1 \right) C(0), \tag{9}$$

which indicates that $C_{NF}(t)$ is larger for either larger values of $C(t)$ or of $<S(t)>$. When $<S(t)>$ equals $S(0)$, then $C_{NF}(t)$ equals $C(t)$. If a value larger than the chosen value of $C(0)$ of 276.44 ppm or of the expected value of $S(0)$ of 14.00 (gC)$^{-1}$ is selected later, then the calculated value of $C_{NF}(t)$ will be less, and the fossil component, $<C_F(t)>$, will be more.

(10) By Equation (8), the expected anthropogenic fossil component, $<C_F(t)>$, can be expressed:

$$<C_F(t)> \;=\; \frac{C(0)S(0)}{<S(t)>} \;-\; C(0) \;=\; \left(\frac{S(0)}{<S(t)>} \;-\; 1 \right) C(0), \; for \; <S(t)> \;\leq\; S(0), \tag{10}$$

which equals zero when $<S(t)>$ equals $S(0)$ and increases as $<S(t)>$ decreases. Thus, it varies each year only with the expected specific activity, $<S(t)>$, of the total concentration, $C(t)$. It is noted that this expression for calculating $<C_F(t)>$ could have been the starting point for calculating all other quantities of interest as indicated by the equations in Pathway 2. Equation (10) only requires knowledge of the initial concentration, $C(0)$, in 1750 and the specific activities, $S(0)$ and $<S(t)>$, of ^{14}C in, respectively, $C(0)$ and $C(t)$. A smaller estimate of either $S(0)$ or $C(0)$ would yield smaller values of $<C_F(t)>$ and larger values of $C_{NF}(t)$.

SUMMARY and CONCLUSIONS

(1) All calculated CO_2 quantities are assumed to represent annual mean values present at time t after 1750 and/or annual changes from values in 1750, and they automatically account for the redistribution of all isotopic forms of CO_2 among its reservoirs and changes in land use.

(2) The product $C(0)S(0)$ is directly proportional to the ^{14}C activity per unit volume of air in 1750. In subsequent years, the activity per unit volume is proportional to $C(t)<S(t)>$ regardless of the amount of the anthropogenic fossil component, $<C_F(t)>$, but varying with the value of the annual change, $DC_{NF}(t)$, of the non-fossil component each year.

(3) The annual change, $DC_F(t)$, in the anthropogenic fossil component from the value of zero in 1750 is the same as the concentration, $<C_F(t)>$, present, which varies only with the ^{14}C activity per gram of carbon, i.e., the expected specific activity, $<S(t)>$, of $C(t)$.

(4) The annual changes in the non-fossil component, $DC_{NF}(t)$, and anthropogenic fossil component, $DC_F(t)$, are independent processes whose sum is the annual change, $DC(t)$, in $C(t)$ since 1750.

(5) As indicated in our paper, the initial value of $C(0)$ of CO_2 and its specific activity, $S(0)$, may be somewhat overestimated, which would cause overestimates of $<C_F(t)>$ and underestimates of $C_{NF}(t)$. The specific activity, $S(0)$, of 16.33 dpm $(gC)^{-1}$ in 1750 in our paper is reduced to 14 dpm $(gC)^{-1}$ in this document based on the " No bombs" scenario.

(6) The values of all CO_2 quantities can be calculated by equations in Pathway 1 or Pathway 2.

(7) Pathway 1 begins with the equation for calculating the annual change, $DC_{NF}(t)$, in the non-fossil component. Pathway 2 begins with the equation for calculating the value of the anthropogenic fossil component, $<C_F(t)>$, present at the time t relative to its initial value of zero in 1750.

(8) Pathway 1 is expressed:
$\boldsymbol{DC_{NF}(t)} = [C(t) <S(t)> - C(0)\, S(0)] <S(t)>^{-1} \rightarrow \boldsymbol{C_{NF}(t)} = C(0) + DC_{NF}(t) \rightarrow \boldsymbol{C_F(t)} = C(t) - C_{NF}(t)$.

(9) Pathway (2) is expressed:
$\boldsymbol{<C_F(t)>} = [S(0)<S(t)>^{-1} - 1]C(0) \rightarrow \boldsymbol{C_{NF}(t)} = C(t) - <C_F(t)> \rightarrow \boldsymbol{DC_{NF}(t)} = C_{NF}(t) - C(0)$.

(10) Results highlighted in blue for the CO_2 components in Table 2a below negate claims of the dominance of the anthropogenic component, $C_F(t)$, in the increase of the total concentration, $C(t)$, that began in about 1800 at a value of 281.86 ppm. Significant annual emissions of anthropogenic fossil CO_2, $DE(t)$, greater than 2 GT y^{-1}, occurred after 1900, which is 100 years after the start of the increase in $C(t)$ in 1800. This observation suggests that the increase in $C(t)$ from 1800 to 1900, is due mostly to the increase in the value of the non-fossil component, $C_{NF}(t)$. This conclusion is verified by values of the annual increases: $DC_F(t)$ in column (3) and $DC_{NF}(t)$ in column (5) whose sum is the total increase, $DC(t)$, in column (6) of the CO_2 concentration.

(11) The anthropogenic fossil component, $<C_F(t)>$, percent of the total concentration, $C(t)$, increased from 0% in 1750 to 10% in 2018, much too low to be the cause of global warming.

(12) The assumption that the increase in CO_2 since 1800 is dominated by or equal to the increase in the anthropogenic fossil component is not settled science. Unsupported conclusions of the dominance of the anthropogenic fossil component and concerns of its effect on climate change and global warming have severe potential societal implications that press the need for very costly remedial actions that are misdirected, unnecessary, and ineffective in curbing global warming.

The tables, figures, and their discussion on the following pages give further evidence supporting the summary and conclusions above. The revised Table 2 is attached at the end of this document.

Table 2a. Partial world atmospheric CO_2, its ^{14}C specific activity, anthropogenic fossil and non fossil components, and emissions (1750 - 2018)

Year	Time t (years)	(1) C(t) (ppm)	(2) <S(t)> (dpm $(gC)^{-1}$)	(3) $<C_F(t)>$ (ppm)	(4) $C_{NF}(t)$ (ppm)	(5) $DC_{NF}(t)$ (ppm)	(6) DC(t) (ppm)	(7) DE(t) (bill. met. tons)
1750	**0**	**276.44**	**14.00**	**0.00**	**276.44**	**0.00**	**0.00**	**0.00**
1751	1	276.40	14.00	0.00	276.40	-0.04	-0.04	0.01
1800	50	281.86	14.00	0.00	281.86	5.42	5.42	0.03
1850	100	287.06	14.00	0.10	286.96	10.52	10.62	0.20
1900	150	296.03	13.94	1.11	294.92	18.48	19.59	1.96
1950	200	311.54	13.69	6.35	305.19	28.75	35.10	5.83
2000	250	367.43	12.80	25.88	341.55	65.11	90.99	24.53
2018	268	405.40	12.18	41.28	364.12	87.68	128.96	36.22
2018*	268	405.40	**13.96**	**46.84**	**358.6**	**82.12**	128.96	36.22

Discussion of revised Table 2a for the "No bombs" scenario

This partial table of CO_2 quantities in 1750 through 2018 includes those in columns headed by numbers (1) through (7); it is a partial listing of those in the revised Table 2. In 1750 ($t = 0$), the initial value of 276.44 ppm listed for both *C(0)* and $C_{NF}(0)$ in Table 2a has been estimated from the Table 2 values of *C(t)* in 1751 and in 1752 of respectively 276.40 ppm and 276.36 ppm.*The values in the last row are those in our paper and previous version of this document. The sum of *DE(t)* values each year in our previous and revised Table 2 through 2018 is 1.59×10^{18} g. In 2018, the $<C_F(t)>$ value of 41.28 ppm present in the atmosphere corresponds to a mass of 3.23×10^{17} g or about 20% of the total emissions. This value is likely an overestimate based on the assumption that $<C_F(t)>$ is uniform throughout the entire atmosphere. Thus in 2018, 80% of the total emissions is estimated to be in the atmosphere's exchange reservoirs, which is likely an underestimate (See text in paper.). The percent values in this revised Table 2a of 20% and 80% compare to values of 23% and 77% in our paper based on the value for $<C_F(t)>$ of 46.84 ppm in column (3) of the last row in the table.

The last row of data in this revised Table 2a contains values of CO_2 quantities in 2018* reported in our paper and previous version of this document. Quantities bolded and highlighted in yellow are the only quantities having values in 2018* that are significantly different from those in the current version of this document. Values for *C(t)*, *DC(t)*, and *DE(t)* are the same as those in our paper and previous version of this document. Values of expected specific activity, *<S(t)>*, in column (2) for the "No bombs" scenario are calculated by the equation, $<S(t)> = 14 - [(10^{-14.309})t^6]$, whose calculated values are 14 dpm $(gC)^{-1}$ in years 1750 through 1850. In 1900, values for *<S(t)>* then start to decrease slowly until 1950 when they begin to decrease more rapidly to 12.18 dpm $(gC)^{-1}$ in 2018. Values in column (3) of the anthropogenic fossil component, $<C_F(t)>$, are calculated by the equation, $<C_F(t)> = [S(0)<S(t)>^{-1} - 1]C(0)$. Calculated values of $<C_F(t)>$ are zero in1750 through 1800 when they begin to slowly increase until 1950, the year when they increase more rapidly from a value of 6.35 ppm in 1950 to a value of 41.28 ppm in 2018. Values of the non-fossil component, $C_{NF}(t)$, in column (4) are calculated by the difference of *C(t)* and $<C_F(t)>$. The value of 276.40 ppm for both $C_{NF}(t)$ and *C(t)* in 1751 is 0.04 ppm less than their initial value of 276.44 ppm in 1750. This decrease in 1751 is due to changes in both $DC_{NF}(t)$ and *DC(t)* of -0.04 ppm in respectively columns (5) and (6). In the revised Table 2, similar negative changes occur until 1962 that are likely associated with the decrease in temperatures, increased solubility of CO_2 in the oceans, and a resulting net flow of CO_2 from the atmosphere into the oceans during the Little Ice Age. From 1750 through 1800, the changes, $DC_{NF}(t)$ and $DC(t)$, are equal, and the concentrations, $C_{NF}(t)$ and $C(t)$ also are equal. In 1850 through 2018, the total concentration, $C(t)$, exceeds the concentration, $C_{NF}(t)$, by the concentration of the anthropogenic fossil component, $<C_F(t)>$, present in the atmosphere. It is noted that the annual change, $DC(t)$, in column (6), equals the sum of the change, $DC_F(t)$, in column (3) and the change, $DC_{NF}(t)$, in column (5). In 2018, the annual change, $DC_F(t)$, of 41.28 ppm is 47% of the annual change, $DC_{NF}(t)$, of 87.68 ppm, and 32% of the change, $DC(t)$, of 128.96 ppm. These percent increases for the anthropogenic fossil component increase each year from zero in 1750 as more anthropogenic fossil CO_2 is emitted into the atmosphere.

In 2018, the revised value for the expected specific activity, $<S(t)>$, of 12.18 dpm(gC)$^{-1}$, based on the " No bombs" scenario is considerably less than the value of 13.96 dpm(gC)$^{-1}$ in our paper, which presumably did not adequately account for the $^{14}CO_2$ contribution from bomb tests. In 2018, the revised $<C_F(t)>$ value of 41.28 ppm is 5.56 ppm less than the value of 46.84 ppm in our paper, and the revised $C_{NF}(t)$ value of 364.12 ppm is 5.56 ppm more than the value of 358.56 ppm in our paper. Thus, it appears that the revised value in 2018 for the anthropogenic fossil component, $<C_F(t)>$, is significantly less than that in our paper, and the non-fossil component is significantly more.

Values of $*S(t)$ and $*D14C$ statistics required to support claims of the dominance of $<C_F(t)>$

Larger reductions in values of the $<S(t)>$ and $D14C$ statistics are required to support claims that the increase, $DC(t)$, in 2018 (t = 268 y) above $C(0)$ in 1750 (t = 0) has been dominated by or equal to the anthropogenic fossil component, $<C_F(t)>$, in 2018. Quantities of CO_2 in1750 include: $C(0)$ of 276.44 ppm, and $S(0)$ of 14.00 dpm (gC)$^{-1}$. Quantities in 2018 include: $C(t)$ of 405.40 ppm; $DC(t)$ of 128.96 ppm; $<S(t)>$ of 12.18 dpm (gC)$^{-1}$; $<C_F(t)>$ of 41.28 ppm, which is a fraction F of 0.32 of $DC(t)$; and $D14C$ of -128.8‰ based on a ^{14}C decay factor F_d of 0.9918, fractionation factor F_{13} of 0.9671, the $<S(t)>$ value of 12.18 dpm (gC)$^{-1}$, and the ^{14}C standard specific activity S_{std14} of 13.41 dpm (gC)$^{-1}$. The specific activity based on the Suess effect is expressed: $<S(t)> = S(0)\,[1 + <C_F(t)>\,C(0)^{-1}]^{-1}$. Equations for calculating $*S(t)$ and $*D14C$ values required for $<C_F(t)>$ in 2018 to equal a given fraction, F, of $DC(t)$ are expressed:

$$*S(t) = \frac{S(0)}{1 + \left(\frac{F\,DC(t)}{C(0)}\right)}, \textit{ whose value gives: } *D14C = \left(\frac{*S(t)\,F_d\,F_{13}}{S_{std14}} - 1\right) 1{,}000\text{‰}.$$

To achieve an F value of 0.5, $*S(t)$ would have to be 11.35dpm(gC)$^{-1}$ instead of 12.18 dpm(gC)$^{-1}$, and $*D14C$ would have to be -188.2‰ instead of -128.8‰. Also, $C_F(t)$, $DC_{NF}(t)$, and $C_{NF}(t)$ would have values respectively of 64.48, 64.48, and 340.92 ppm. To achieve an F value of 1, $*S(t)$ would have to be 9.55 dpm (gC)$^{-1}$ instead of 12.18 dpm (gC)$^{-1}$, and $*D14C$ would have to be -316.9‰ instead of -128.8‰. Also, $C_F(t)$ then equals $DC(t)$ of 128.96 ppm; $DC_{NF}(t)$ is zero; and $C_{NF}(t)$ equals $C(0)$ of 276.44 ppm.

Description of revised Table 2 and figures

The revised eight page Table 2 contains values of all the same CO_2 quantities as those in Table 2a. Both tables contain annual values of seven CO_2 quantities in 1750 through 2018. The numbers (1) through (7) heading the columns are used as labels for the plots of values of all CO_2 quantities in Figure (3) and (4) on the next two pages. The column numbers are placed before the symbols in legends, equations, and at the end of a line for a plot in each figure. Equations listed in the figures are used to calculate the values of quantities in columns (2) through (6) of each table. Values for the total CO_2 concentration, $C(t)$, in column (1) and values of the annual anthropogenic fossil emissions, $DE(t)$, in column (7) are those provided by the Energy Information Administration (EIA 2021). Values of all seven CO_2 quantities in Table 2 are plotted in the figures versus the time t since 1750, and they are discussed below each figure.

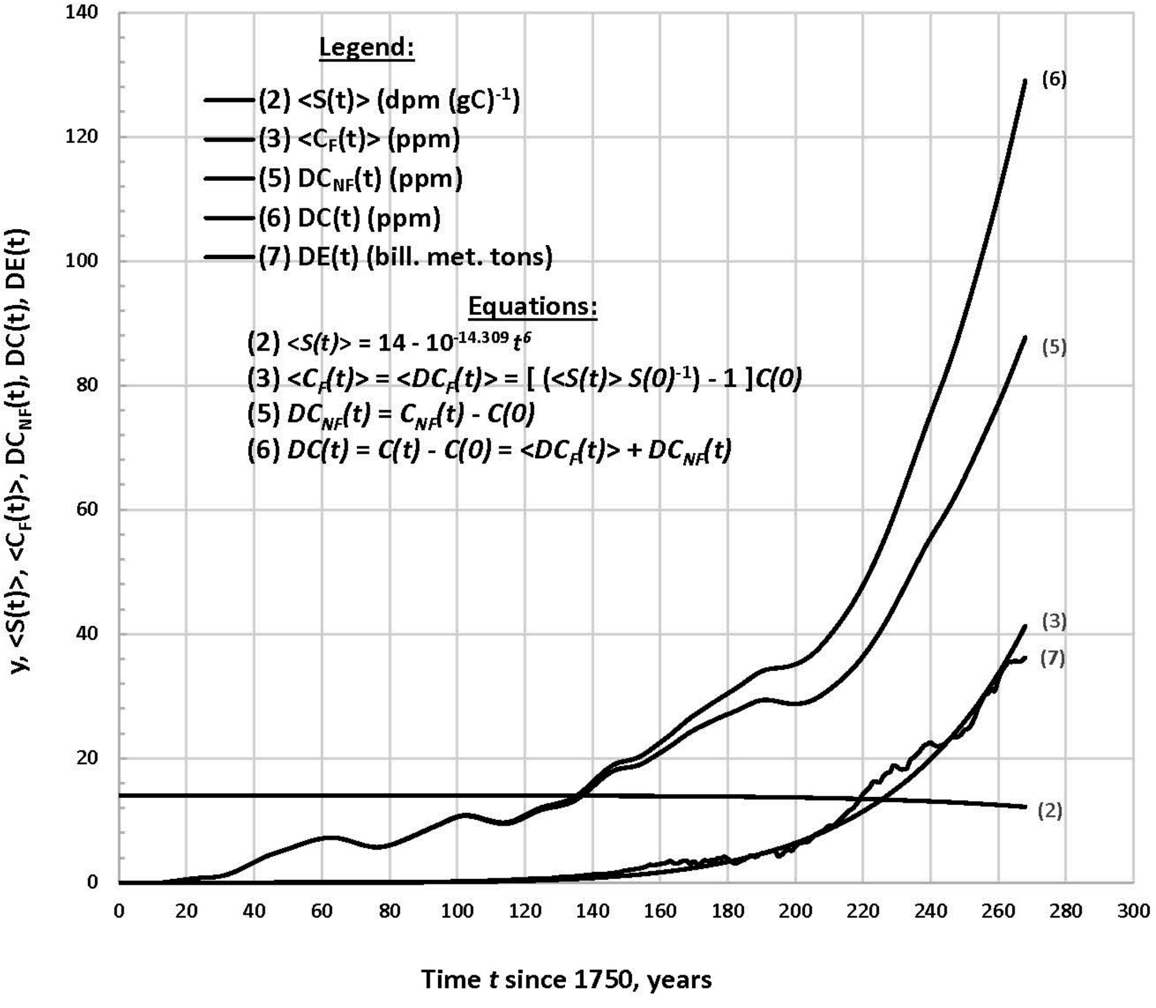


Fig. 3. DC(t), <S(t)>, <DC$_F$(t)>, DC$_{NF}$(t) and DE(t) versus t.

This figure provides numbered plots: (2) <*S(t)*> and annual changes in CO_2 quantities relative to their initial values in 1750: (3) <$DC_F(t)$>, (5) $DC_{NF}(t)$, (6) *DC(t),* and (7) *DE(t).* Values in 1750 through 1850 ($t = 100$ y) for <*S(t)*> in plot (2) do not change from the initial value of 14 dpm(gC)$^{-1}$; consequently, values for <$C_F(t)$> for the same time interval in plot (3) are not significantly different from zero. Values from Table 2 for the annual change *DC(t)* in plot (6), equal the sum of the those for the change, $DC_F(t)$ in plot (3) of the anthropogenic fossil component, <$C_F(t)$>, and those in plot (5) for the change, $DC_{NF}(t)$, for the non-fossil component, $C_{NF}(t)$. From 1750 through 1850 ($t = 100$ y), plot (6) for *DC(t)* and plot (5) for $DC_{NF}(t)$ appear to overlap each other as can be confirmed from values in Table 2. Thus, the change each year for this period appears to be due only to the changes, $DC_{NF}(t)$, in the non fossil component. From 1850 through 1950 ($t = 200$ y), plot (6) of *DC(t)* values begin to increase more and more than those in plot (5) for $DC_{NF}(t)$. The increasing spread in values for *DC(t)* and $DC_{NF}(t)$ equals the increasing values in plot (3) for <$C_F(t)$>. After 1950, plots of *DC(t)* and $DC_{NF}(t)$ increase more rapidly, and their separation becomes greater each year due to the increasing values in plot (3) of <$C_F(t)$>. Values in Plot 3 for <$C_F(t)$> of the anthropogenic fossil component begin to increase each year after 1850 as the expected specific activity, <*S(t)*>, begins to decrease from its value of 14 dpm(gC)$^{-1}$. After 1950, values of <$DC_F(t)$>, $DC_{NF}(t)$, and *DC(t)* begin to increase more rapidly. Coincidentally, for the units used, the <$C_F(t)$> values in plot (3) from 1750 through 2018 appear to overlay those for the annual emissions, *DE(t)*.

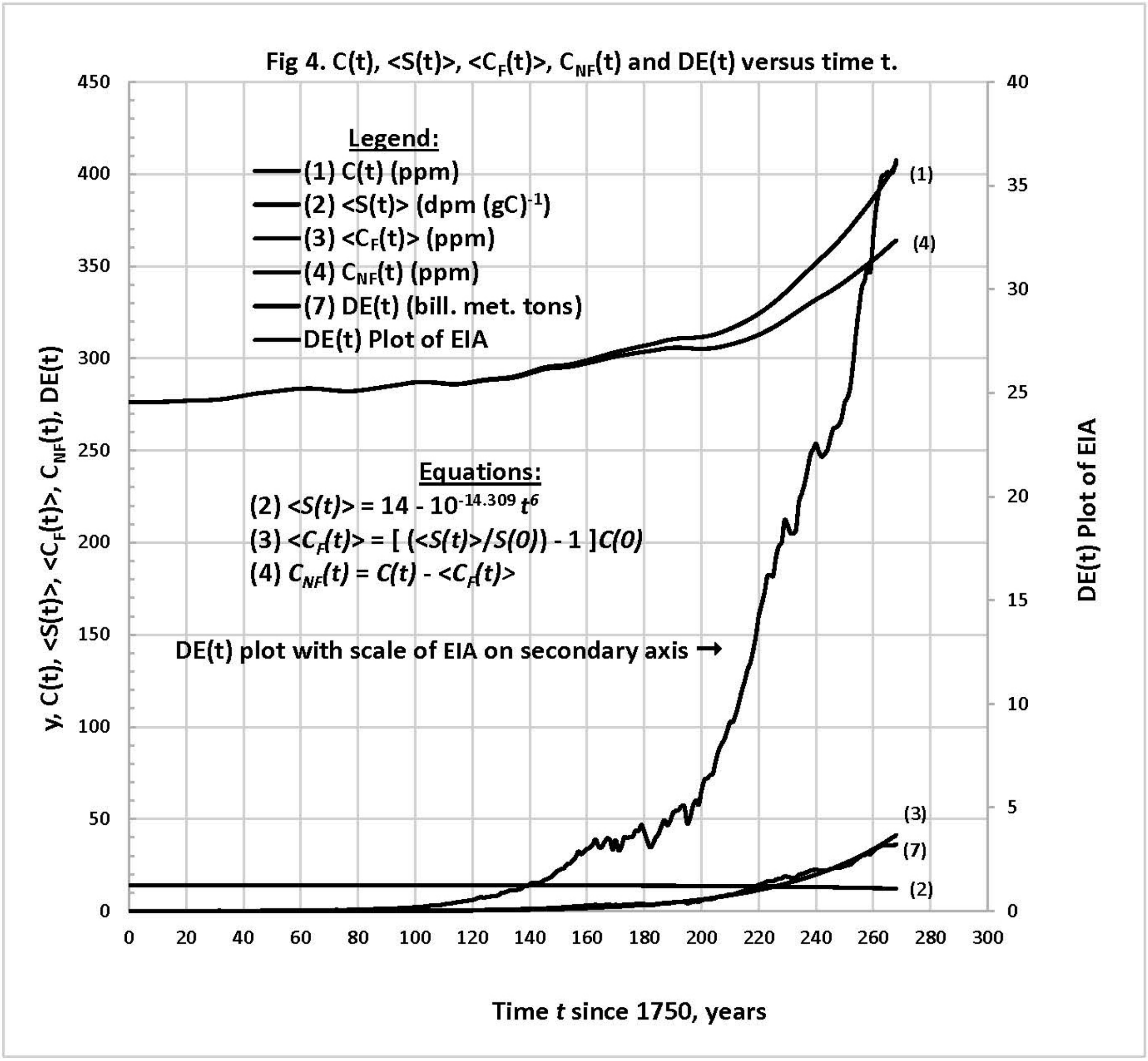


Fig 4. C(t), <S(t)>, $<C_F(t)>$, $C_{NF}(t)$ and DE(t) versus time t.

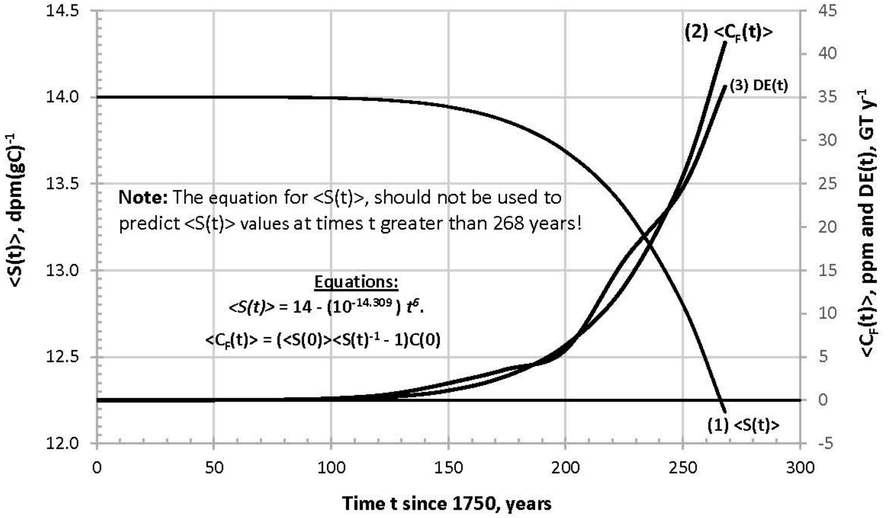
This figure contains numbered plots: (1) *C(t)*, (2) *<S(t)>*, (3) $<C_F(t)>$, (4) $C_{NF}(t)$, (7) *DE(t)*, on the primary vertical axis whose scale is from 0 to 450. The unnumbered plot, *DE(t)*, of the EIA uses the secondary vertical axis whose scale is 0 to 40, like that in the figure of plots of CO_2 concentrations and emissions in an article of the *Environmental Information Administration* (EIA 2021). The article is available in a link in the cited reference. The values of *C(t)*, in plot (1) equal the sum of the values in plot (3) for $<C_F(t)>$ and plot (4) for $C_{NF}(t$. From 1750 through 1850 (t = 100 y), values of *<S(t)>* in plot (2) do not change significantly from that in 1750; values of $<C_F(t)>$ in plot (3) are zero; and values of *C(t)* in plot (1) and $C_{NF}(t)$ in plot (4) are equal. Two plots are provided for *DE(t)*. Plot 7 for *DE(t)* uses the scale of the primary vertical axis on the left, and the unnumbered plot of *DE(t)* of the EIA uses the scale on the secondary vertical axis on the right. This same scale is used for the EIA plot of "CO2 emissions" in the figure provided in the EIA reference. Consequently, the plot of *DE(t)* values using the EIA scale of the secondary vertical axis appear in the figure above to be (450/40) or 11.5 times the values in plot (7) for *DE(t)*. Also, the slopes of the *DE(t)* plot of EIA appear in the figure to be 11.5 times those in plot (7). Absent plot (3) for $<C_F(t)>$ and plot (4) for $C_{NF}(t)$, and others except for plot (1) for *C(t)* and the unnumbered plot, *DE(t)*, of the EIA, one might falsely conclude that the increase in *C(t)*, in plot (1) after 1850 is due entirely to the increase in $<C_F(t)>$, which is more than implied in the EIA article.

Table 5. Expected specific activity, <S(t)>, anthropogenic fossil CO_2, <C_F(t)>, and emissions, DE(t), for No Bombs scenario.

Year	Time, *t*, Since 1750 (years)	(1) <S(t)> Specific Activity (dpm $(gC)^{-1}$)	(2) <C_F(t)> Anthropogenic Fossil CO_2 (ppm)	(3) DE(t) Annual Emissions (GT y^{-1})
1750	0	14.00	0.00	0.00
1775	25	14.00	0.00	0.01
1800	50	14.00	0.00	0.03
1825	75	14.00	0.02	0.06
1850	100	14.00	0.10	0.20
1875	125	13.98	0.37	0.69
1900	150	13.94	1.11	1.96
1925	175	13.86	2.81	3.58
1950	200	13.69	6.35	5.83
1975	225	13.36	13.18	16.17
2000	250	12.80	25.88	24.53
2018	268	12.18	41.28	36.22

C(0) = 276.44 ppm

Fig. 5. Expected specific activity, <S(t)>, anthropogenic fossil CO_2, <C_F(t)>, and emissions, DE(t), for No Bombs scenario.



Note: The equation for <S(t)>, should not be used to predict <S(t)> values at times t greater than 268 years!

<u>Equations:</u>

$\langle S(t)\rangle = 14 - (10^{-14.309})\, t^6.$

$\langle C_F(t)\rangle = (\langle S(0)\rangle\langle S(t)^{-1} - 1)C(0)$

Discussion for Table 5 and Fig. 5

The above table and figure provide, respectively, numerical and graphical comparisons of three numbered CO_2 quantities: (1) expected specific activity, *<S(t)>*, of *C(t)*, (2) expected anthropogenic fossil component, *<C_F(t)>*, and (3) annual emissions, *DE(t)*, of the anthropogenic fossil component in units of GT y^{-1}. The initial value of the CO_2 concentration in 1750, *C(0)* of 276.44 ppm, is listed below the table and used in the equation for *<C_F(t)>* shown in the figure. Values of *<S(t)>* are plotted on the primary vertical axis from 12 to 14.5 dpm$(gC)^{-1}$. Values of *<C_F(t)>* in units of ppm, and values of *DE(t)* in units of GT y^{-1} are plotted on the secondary vertical axis from 0 to 45. Values of *<S(t)>* and *<C_F(t)>* are calculated and correlated as indicated by the equations in the figure. As already indicated in this document, our equation for $<S(t)>$ has been estimated from the "No bombs" curve of specific activities in a figure provided in a letter to the Health Physics Journal (Schwartz et al. 2022). The values of annual emissions, $DE(t)$, have no direct mathematical correlations with either $<S(t)>$ or $<C_F(t)>$. The close numerical values of $DE(t)$ and $<C_F(t)>$ are coincidental with their chosen units. As indicated in the table and plots, values of all three quantities in 1750 (t = 0) through 1850 (t = 100 y) are not much different from their initial values in 1750. From 1850 through 1950 (t = 200 y), values for (1) $<S(t)>$ begin to slowly decrease while values of (2) $<C_F(t)>$ and (3) $DE(t)$ begin to slowly increase. From 1950 to 2018 (t = 268 y), values for all three quantities more rapidly change. It is noted that $<C_F(t)>$ only varies with the expected specific activity, $<S(t)>$, of $C(t)$, but not $C(t)$ itself, except for its initial value in 1750, C(0) of 276.44 ppm.

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Table 2. World atmospheric CO_2, its C-14 specific activity, anthropogenic-fossil component, non fossil component, and emissions (1750 - 2018) - no bombs.

Year	Time t (years)	(1) $C(t)$ (ppm)	(2) $\langle S(t) \rangle$ (dpm (gC)$^{-1}$)	(3) $\langle C_F(t) \rangle$ (ppm)	(4) $C_{NF}(t)$ (ppm)	(5) $DC_{NF}(t)$ (ppm)	(6) $DC(t)$ (ppm)	(7) $DE(t)$ (bill. met. tons)
1750	**0**	**276.44**	**14.00**	**0**	**276.44**	**0**	**0**	**0**
1751	1	276.40	14.00	0.00	276.40	-0.04	-0.04	0.01
1752	2	276.36	14.00	0.00	276.36	-0.08	-0.08	0.01
1753	3	276.33	14.00	0.00	276.33	-0.11	-0.11	0.01
1754	4	276.31	14.00	0.00	276.31	-0.13	-0.13	*0.01*
1755	5	276.29	14.00	0.00	276.29	-0.15	-0.15	0.01
1756	6	276.28	14.00	0.00	276.28	-0.16	-0.16	0.01
1757	7	276.28	14.00	0.00	276.28	-0.16	-0.16	0.01
1758	8	276.29	14.00	0.00	276.29	-0.15	-0.15	0.01
1759	9	276.30	14.00	0.00	276.30	-0.14	-0.14	0.01
1760	10	276.32	14.00	0.00	276.32	-0.12	-0.12	0.01
1761	11	276.36	14.00	0.00	276.36	-0.08	-0.08	0.01
1762	12	276.40	14.00	0.00	276.40	-0.04	-0.04	0.01
1763	13	276.45	14.00	0.00	276.45	0.01	0.01	0.01
1764	14	276.51	14.00	0.00	276.51	0.07	0.07	0.01
1765	15	276.58	14.00	0.00	276.58	0.14	0.14	0.01
1766	16	276.65	14.00	0.00	276.65	0.21	0.21	0.01
1767	17	276.73	14.00	0.00	276.73	0.29	0.29	0.01
1768	18	276.81	14.00	0.00	276.81	0.37	0.37	0.01
1769	19	276.88	14.00	0.00	276.88	0.44	0.44	0.01
1770	20	276.96	14.00	0.00	276.96	0.52	0.52	0.01
1771	21	277.03	14.00	0.00	277.03	0.59	0.59	0.01
1772	22	277.09	14.00	0.00	277.09	0.65	0.65	0.01
1773	23	277.15	14.00	0.00	277.15	0.71	0.71	0.01
1774	24	277.19	14.00	0.00	277.19	0.75	0.75	0.01
1775	25	277.22	14.00	0.00	277.22	0.78	0.78	0.01
1776	26	277.24	14.00	0.00	277.24	0.80	0.80	0.01
1777	27	277.27	14.00	0.00	277.27	0.83	0.83	0.01
1778	28	277.31	14.00	0.00	277.31	0.87	0.87	0.01
1779	29	277.37	14.00	0.00	277.37	0.93	0.93	0.01
1780	30	277.46	14.00	0.00	277.46	1.02	1.02	0.01
1781	31	277.58	14.00	0.00	277.58	1.14	1.14	0.02
1782	32	277.73	14.00	0.00	277.73	1.29	1.29	0.02

Table 2. World atmospheric CO_2, its C-14 specific activity, anthropogenic-fossil component, non fossil component, and emissions (1750 - 2018) - no bombs.

Year	Time *t* (years)	(1) *C(t)* (ppm)	(2) $\langle S(t) \rangle$ (dpm (gC)$^{-1}$)	(3) $\langle C_F(t) \rangle$ (ppm)	(4) $C_{NF}(t)$ (ppm)	(5) $DC_{NF}(t)$ (ppm)	(6) *DC(t)* (ppm)	(7) *DE(t)* (bill. met. tons)
1783	33	277.92	14.00	0.00	277.92	1.48	1.48	0.02
1784	34	278.13	14.00	0.00	278.13	1.69	1.69	0.02
1785	35	278.36	14.00	0.00	278.36	1.92	1.92	0.02
1786	36	278.62	14.00	0.00	278.62	2.18	2.18	0.02
1787	37	278.89	14.00	0.00	278.89	2.45	2.45	0.02
1788	38	279.16	14.00	0.00	279.16	2.72	2.72	0.02
1789	39	279.44	14.00	0.00	279.44	3.00	3.00	0.02
1790	40	279.72	14.00	0.00	279.72	3.28	3.28	0.02
1791	41	280.00	14.00	0.00	280.00	3.56	3.56	0.02
1792	42	280.27	14.00	0.00	280.27	3.83	3.83	0.02
1793	43	280.52	14.00	0.00	280.52	4.08	4.08	0.02
1794	44	280.76	14.00	0.00	280.76	4.32	4.32	0.02
1795	45	280.97	14.00	0.00	280.97	4.53	4.53	0.02
1796	46	281.16	14.00	0.00	281.16	4.72	4.72	0.02
1797	47	281.34	14.00	0.00	281.34	4.90	4.90	0.03
1798	48	281.51	14.00	0.00	281.51	5.07	5.07	0.03
1799	49	281.69	14.00	0.00	281.69	5.25	5.25	0.03
1800	50	281.86	14.00	0.00	281.86	5.42	5.42	0.03
1801	51	282.05	14.00	0.00	282.05	5.61	5.61	0.03
1802	52	282.24	14.00	0.00	282.24	5.80	5.80	0.04
1803	53	282.44	14.00	0.00	282.44	6.00	6.00	0.03
1804	54	282.63	14.00	0.00	282.63	6.19	6.19	0.03
1805	55	282.81	14.00	0.00	282.81	6.37	6.37	0.03
1806	56	282.99	14.00	0.00	282.99	6.55	6.55	0.04
1807	57	283.16	14.00	0.00	283.16	6.72	6.72	0.04
1808	58	283.30	14.00	0.00	283.30	6.86	6.86	0.04
1809	59	283.43	14.00	0.00	283.43	6.99	6.99	0.04
1810	60	283.53	14.00	0.00	283.53	7.09	7.09	0.04
1811	61	283.61	14.00	0.00	283.61	7.17	7.17	0.04
1812	62	283.66	14.00	0.01	283.65	7.21	7.22	0.04
1813	63	283.67	14.00	0.01	283.66	7.22	7.23	0.04
1814	64	283.64	14.00	0.01	283.63	7.19	7.20	0.04
1815	65	283.57	14.00	0.01	283.56	7.12	7.13	0.04
1816	66	283.46	14.00	0.01	283.45	7.01	7.02	0.05

Table 2. World atmospheric CO_2, its C-14 specific activity, anthropogenic-fossil component, non fossil component, and emissions (1750 - 2018) - no bombs.

	Time	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Year	t	$C(t)$	$<S(t)>$	$<C_F(t)>$	$C_{NF}(t)$	$DC_{NF}(t)$	$DC(t)$	$DE(t)$
	(years)	(ppm)	(dpm (gC)$^{-1}$)	(ppm)	(ppm)	(ppm)	(ppm)	(bill. met. tons)
1817	67	283.33	14.00	0.01	283.32	6.88	6.89	0.05
1818	68	283.17	14.00	0.01	283.16	6.72	6.73	0.05
1819	69	283.00	14.00	0.01	282.99	6.55	6.56	0.05
1820	70	282.83	14.00	0.01	282.82	6.38	6.39	0.05
1821	71	282.66	14.00	0.01	282.65	6.21	6.22	0.05
1822	72	282.50	14.00	0.01	282.49	6.05	6.06	0.06
1823	73	282.36	14.00	0.01	282.35	5.91	5.92	0.06
1824	74	282.25	14.00	0.02	282.23	5.79	5.81	0.06
1825	75	282.17	14.00	0.02	282.15	5.71	5.73	0.06
1826	76	282.13	14.00	0.02	282.11	5.67	5.69	0.06
1827	77	282.15	14.00	0.02	282.13	5.69	5.71	0.07
1828	78	282.21	14.00	0.02	282.19	5.75	5.77	0.07
1829	79	282.31	14.00	0.02	282.29	5.85	5.87	0.07
1830	80	282.45	14.00	0.03	282.42	5.98	6.01	0.09
1831	81	282.62	14.00	0.03	282.59	6.15	6.18	0.08
1832	82	282.81	14.00	0.03	282.78	6.34	6.37	0.08
1833	83	283.02	14.00	0.03	282.99	6.55	6.58	0.09
1834	84	283.24	14.00	0.03	283.21	6.77	6.80	0.09
1835	85	283.47	14.00	0.04	283.43	6.99	7.03	0.09
1836	86	283.71	14.00	0.04	283.67	7.23	7.27	0.11
1837	87	283.95	14.00	0.04	283.91	7.47	7.51	0.11
1838	88	284.19	14.00	0.05	284.14	7.70	7.75	0.11
1839	89	284.43	14.00	0.05	284.38	7.94	7.99	0.11
1840	90	284.68	14.00	0.05	284.63	8.19	8.24	0.12
1841	91	284.93	14.00	0.06	284.87	8.43	8.49	0.12
1842	92	285.18	14.00	0.06	285.12	8.68	8.74	0.13
1843	93	285.42	14.00	0.06	285.36	8.92	8.98	0.14
1844	94	285.66	14.00	0.07	285.59	9.15	9.22	0.14
1845	95	285.90	14.00	0.07	285.83	9.39	9.46	0.16
1846	96	286.14	14.00	0.08	286.06	9.62	9.70	0.16
1847	97	286.40	14.00	0.08	286.32	9.88	9.96	0.17
1848	98	286.65	14.00	0.09	286.56	10.12	10.21	0.17
1849	99	286.87	14.00	0.09	286.78	10.34	10.43	0.18
1850	100	287.06	14.00	0.10	286.96	10.52	10.62	0.20

Table 2. World atmospheric CO$_2$, its C-14 specific activity, anthropogenic-fossil component, non fossil component, and emissions (1750 - 2018) - no bombs.

Year	Time t (years)	(1) $C(t)$ (ppm)	(2) $\langle S(t) \rangle$ (dpm (gC)$^{-1}$)	(3) $\langle C_F(t) \rangle$ (ppm)	(4) $C_{NF}(t)$ (ppm)	(5) $DC_{NF}(t)$ (ppm)	(6) $DC(t)$ (ppm)	(7) $DE(t)$ (bill. met. tons)
1851	101	287.19	13.99	0.10	287.09	10.65	10.75	0.20
1852	102	287.26	13.99	0.11	287.15	10.71	10.82	0.21
1853	103	287.27	13.99	0.12	287.15	10.71	10.83	0.22
1854	104	287.22	13.99	0.12	287.10	10.66	10.78	0.25
1855	105	287.13	13.99	0.13	287.00	10.56	10.69	0.26
1856	106	287.00	13.99	0.14	286.86	10.42	10.56	0.28
1857	107	286.85	13.99	0.15	286.70	10.26	10.41	0.28
1858	108	286.69	13.99	0.15	286.54	10.10	10.25	0.29
1859	109	286.53	13.99	0.16	286.37	9.93	10.09	0.30
1860	110	286.39	13.99	0.17	286.22	9.78	9.95	0.33
1861	111	286.26	13.99	0.18	286.08	9.64	9.82	0.35
1862	112	286.16	13.99	0.19	285.97	9.53	9.72	0.35
1863	113	286.11	13.99	0.20	285.91	9.47	9.67	0.38
1864	114	286.10	13.99	0.21	285.89	9.45	9.66	0.41
1865	115	286.16	13.99	0.22	285.94	9.50	9.72	0.44
1866	116	286.28	13.99	0.24	286.04	9.60	9.84	0.45
1867	117	286.45	13.99	0.25	286.20	9.76	10.01	0.48
1868	118	286.69	13.99	0.26	286.43	9.99	10.25	0.49
1869	119	286.95	13.99	0.28	286.67	10.23	10.51	0.52
1870	120	287.24	13.99	0.29	286.95	10.51	10.80	0.54
1871	121	287.53	13.98	0.30	287.23	10.79	11.09	0.58
1872	122	287.82	13.98	0.32	287.50	11.06	11.38	0.64
1873	123	288.09	13.98	0.34	287.75	11.31	11.65	0.67
1874	124	288.33	13.98	0.35	287.98	11.54	11.89	0.64
1875	125	288.53	13.98	0.37	288.16	11.72	12.09	0.69
1876	126	288.70	13.98	0.39	288.31	11.87	12.26	0.70
1877	127	288.84	13.98	0.41	288.43	11.99	12.40	0.71
1878	128	288.96	13.98	0.43	288.53	12.09	12.52	0.72
1879	129	289.08	13.98	0.45	288.63	12.19	12.64	0.77
1880	130	289.20	13.98	0.47	288.73	12.29	12.76	0.87
1881	131	289.34	13.98	0.49	288.85	12.41	12.90	0.89
1882	132	289.51	13.97	0.51	289.00	12.56	13.07	0.94
1883	133	289.72	13.97	0.54	289.18	12.74	13.28	1.00
1884	134	289.97	13.97	0.56	289.41	12.97	13.53	1.01

Table 2. World atmospheric CO_2, its C-14 specific activity, anthropogenic-fossil component, non fossil component, and emissions (1750 - 2018) - no bombs.

Year	Time t (years)	(1) $C(t)$ (ppm)	(2) $\langle S(t) \rangle$ (dpm $(\text{gC})^{-1}$)	(3) $\langle C_F(t) \rangle$ (ppm)	(4) $C_{NF}(t)$ (ppm)	(5) $DC_{NF}(t)$ (ppm)	(6) $DC(t)$ (ppm)	(7) $DE(t)$ (bill. met. tons)
1885	135	290.29	13.97	0.59	289.70	13.26	13.85	1.02
1886	136	290.66	13.97	0.61	290.05	13.61	14.22	1.03
1887	137	291.09	13.97	0.64	290.45	14.01	14.65	1.08
1888	138	291.55	13.97	0.67	290.88	14.44	15.11	1.20
1889	139	292.05	13.96	0.70	291.35	14.91	15.61	1.20
1890	140	292.56	13.96	0.73	291.83	15.39	16.12	1.31
1891	141	293.08	13.96	0.76	292.32	15.88	16.64	1.36
1892	142	293.59	13.96	0.80	292.79	16.35	17.15	1.37
1893	143	294.09	13.96	0.83	293.26	16.82	17.65	1.36
1894	144	294.55	13.96	0.87	293.68	17.24	18.11	1.40
1895	145	294.96	13.95	0.90	294.06	17.62	18.52	1.49
1896	146	295.31	13.95	0.94	294.37	17.93	18.87	1.54
1897	147	295.58	13.95	0.98	294.60	18.16	19.14	1.61
1898	148	295.77	13.95	1.02	294.75	18.31	19.33	1.70
1899	149	295.91	13.95	1.06	294.85	18.41	19.47	1.86
1900	150	296.03	13.94	1.11	294.92	18.48	19.59	1.96
1901	151	296.14	13.94	1.15	294.99	18.55	19.70	2.03
1902	152	296.28	13.94	1.20	295.08	18.64	19.84	2.08
1903	153	296.46	13.94	1.25	295.21	18.77	20.02	2.26
1904	154	296.70	13.93	1.30	295.40	18.96	20.26	2.29
1905	155	297.00	13.93	1.35	295.65	19.21	20.56	2.43
1906	156	297.35	13.93	1.40	295.95	19.51	20.91	2.60
1907	157	297.74	13.93	1.46	296.28	19.84	21.30	2.87
1908	158	298.14	13.92	1.52	296.62	20.18	21.70	2.75
1909	159	298.55	13.92	1.58	296.97	20.53	22.11	2.88
1910	160	298.95	13.92	1.64	297.31	20.87	22.51	3.00
1911	161	299.35	13.91	1.70	297.65	21.21	22.91	3.06
1912	162	299.77	13.91	1.76	298.01	21.57	23.33	3.22
1913	163	300.21	13.91	1.83	298.38	21.94	23.77	3.46
1914	164	300.66	13.90	1.90	298.76	22.32	24.22	3.12
1915	165	301.13	13.90	1.97	299.16	22.72	24.69	3.07
1916	166	301.60	13.90	2.04	299.56	23.12	25.16	3.30
1917	167	302.06	13.89	2.12	299.94	23.50	25.62	3.51
1918	168	302.51	13.89	2.20	300.31	23.87	26.07	3.43

Table 2. World atmospheric CO_2, its C-14 specific activity, anthropogenic-fossil component, non fossil component, and emissions (1750 - 2018) - no bombs.

Year	Time *t* (years)	(1) *C(t)* (ppm)	(2) $<S(t)>$ (dpm $(gC)^{-1}$)	(3) $<C_F(t)>$ (ppm)	(4) $C_{NF}(t)$ (ppm)	(5) $DC_{NF}(t)$ (ppm)	(6) *DC(t)* (ppm)	(7) *DE(t)* (bill. met. tons)
1919	169	302.93	13.89	2.28	300.65	24.21	26.49	2.96
1920	170	303.33	13.88	2.36	300.97	24.53	26.89	3.42
1921	171	303.70	13.88	2.44	301.26	24.82	27.26	2.94
1922	172	304.06	13.87	2.53	301.53	25.09	27.62	3.10
1923	173	304.42	13.87	2.62	301.80	25.36	27.98	3.56
1924	174	304.78	13.86	2.72	302.06	25.62	28.34	3.53
1925	175	305.14	13.86	2.81	302.33	25.89	28.70	3.58
1926	176	305.49	13.85	2.91	302.58	26.14	29.05	3.61
1927	177	305.84	13.85	3.01	302.83	26.39	29.40	3.89
1928	178	306.19	13.84	3.12	303.07	26.63	29.75	3.87
1929	179	306.52	13.84	3.23	303.29	26.85	30.08	4.16
1930	180	306.85	13.83	3.34	303.51	27.07	30.41	3.82
1931	181	307.19	13.83	3.45	303.74	27.30	30.75	3.41
1932	182	307.53	13.82	3.57	303.96	27.52	31.09	3.08
1933	183	307.88	13.82	3.69	304.19	27.75	31.44	3.25
1934	184	308.26	13.81	3.81	304.45	28.01	31.82	3.54
1935	185	308.65	13.80	3.94	304.71	28.27	32.21	3.73
1936	186	309.05	13.80	4.07	304.98	28.54	32.61	4.10
1937	187	309.45	13.79	4.21	305.24	28.80	33.01	4.39
1938	188	309.82	13.78	4.35	305.47	29.03	33.38	4.15
1939	189	310.15	13.78	4.49	305.66	29.22	33.71	4.32
1940	190	310.42	13.77	4.64	305.78	29.34	33.98	4.72
1941	191	310.62	13.76	4.79	305.83	29.39	34.18	4.84
1942	192	310.76	13.75	4.94	305.82	29.38	34.32	4.88
1943	193	310.85	13.75	5.10	305.75	29.31	34.41	5.06
1944	194	310.92	13.74	5.27	305.65	29.21	34.48	5.05
1945	195	310.97	13.73	5.43	305.54	29.10	34.53	4.23
1946	196	311.02	13.72	5.61	305.41	28.97	34.58	4.50
1947	197	311.10	13.71	5.78	305.32	28.88	34.66	5.06
1948	198	311.21	13.70	5.97	305.24	28.80	34.77	5.34
1949	199	311.36	13.70	6.15	305.21	28.77	34.92	5.14
1950	200	311.54	13.69	6.35	305.19	28.75	35.10	5.83
1951	201	311.76	13.68	6.54	305.22	28.78	35.32	6.32
1952	202	312.03	13.67	6.75	305.28	28.84	35.59	6.41

Table 2. World atmospheric CO_2, its C-14 specific activity, anthropogenic-fossil component, non fossil component, and emissions (1750 - 2018) - no bombs.

Year	Time *t* (years)	(1) *C(t)* (ppm)	(2) $\langle S(t)\rangle$ (dpm (gC)$^{-1}$)	(3) $\langle C_F(t)\rangle$ (ppm)	(4) $C_{NF}(t)$ (ppm)	(5) $DC_{NF}(t)$ (ppm)	(6) *DC(t)* (ppm)	(7) *DE(t)* (bill. met. tons)
1953	203	312.34	13.66	6.95	305.39	28.95	35.90	6.56
1954	204	312.71	13.65	7.17	305.54	29.10	36.27	6.64
1955	205	313.14	13.64	7.39	305.75	29.31	36.70	7.27
1956	206	313.63	13.62	7.61	306.02	29.58	37.19	7.75
1957	207	314.17	13.61	7.84	306.33	29.89	37.73	8.07
1958	208	314.76	13.60	8.08	306.68	30.24	38.32	8.28
1959	209	315.38	13.59	8.32	307.06	30.62	38.94	8.72
1960	210	316.04	13.58	8.57	307.47	31.03	39.60	9.12
1961	211	316.72	13.57	8.83	307.89	31.45	40.28	9.14
1962	212	317.43	13.55	9.09	308.34	31.90	40.99	9.51
1963	213	318.15	13.54	9.36	308.79	32.35	41.71	10.02
1964	214	318.90	13.53	9.63	309.27	32.83	42.46	10.59
1965	215	319.68	13.52	9.92	309.76	33.32	43.24	11.06
1966	216	320.51	13.50	10.21	310.30	33.86	44.07	11.61
1967	217	321.38	13.49	10.51	310.87	34.43	44.94	11.96
1968	218	322.29	13.47	10.81	311.48	35.04	45.85	12.55
1969	219	323.25	13.46	11.12	312.13	35.69	46.81	13.30
1970	220	324.26	13.44	11.45	312.81	36.37	47.82	14.26
1971	221	325.31	13.43	11.77	313.54	37.10	48.87	14.80
1972	222	326.40	13.41	12.11	314.29	37.85	49.96	15.37
1973	223	327.53	13.40	12.46	315.07	38.63	51.09	16.17
1974	224	328.71	13.38	12.81	315.90	39.46	52.27	16.21
1975	225	329.93	13.36	13.18	316.75	40.31	53.49	16.17
1976	226	331.20	13.35	13.55	317.65	41.21	54.76	17.06
1977	227	332.51	13.33	13.93	318.58	42.14	56.07	17.61
1978	228	333.88	13.31	14.32	319.56	43.12	57.44	17.79
1979	229	335.29	13.29	14.72	320.57	44.13	58.85	18.85
1980	230	336.74	13.27	15.14	321.60	45.16	60.30	18.63
1981	231	338.20	13.25	15.56	322.64	46.20	61.76	18.26
1982	232	339.69	13.23	15.99	323.70	47.26	63.25	18.21
1983	233	341.19	13.21	16.43	324.76	48.32	64.75	18.39
1984	234	342.71	13.19	16.89	325.82	49.38	66.27	19.73
1985	235	344.24	13.17	17.35	326.89	50.45	67.80	20.14
1986	236	345.77	13.15	17.83	327.94	51.50	69.33	20.63

Table 2. World atmospheric CO_2, its C-14 specific activity, anthropogenic-fossil component, non fossil component, and emissions (1750 - 2018) - no bombs.

Year	Time t (years)	(1) $C(t)$ (ppm)	(2) $<S(t)>$ (dpm $(gC)^{-1}$)	(3) $<C_F(t)>$ (ppm)	(4) $C_{NF}(t)$ (ppm)	(5) $DC_{NF}(t)$ (ppm)	(6) $DC(t)$ (ppm)	(7) $DE(t)$ (bill. met. tons)
1987	237	347.29	13.13	18.32	328.97	52.53	70.85	21.29
1988	238	348.81	13.11	18.82	329.99	53.55	72.37	21.99
1989	239	350.31	13.09	19.33	330.98	54.54	73.87	22.28
1990	240	351.77	13.06	19.85	331.92	55.48	75.33	22.53
1991	241	353.21	13.04	20.39	332.82	56.38	76.77	22.13
1992	242	354.64	13.01	20.95	333.69	57.25	78.20	21.92
1993	243	356.07	12.99	21.51	334.56	58.12	79.63	22.06
1994	244	357.53	12.96	22.09	335.44	59.00	81.09	22.26
1995	245	359.05	12.94	22.68	336.37	59.93	82.61	22.79
1996	246	360.62	12.91	23.29	337.33	60.89	84.18	23.27
1997	247	362.24	12.89	23.92	338.32	61.88	85.80	23.34
1998	248	363.92	12.86	24.56	339.36	62.92	87.48	23.46
1999	249	365.66	12.83	25.21	340.45	64.01	89.22	23.81
2000	250	367.43	12.80	25.88	341.55	65.11	90.99	24.53
2001	251	369.25	12.77	26.57	342.68	66.24	92.81	24.77
2002	252	371.10	12.74	27.27	343.83	67.39	94.66	25.33
2003	253	373.00	12.71	28.00	345.00	68.56	96.56	26.49
2004	254	374.92	12.68	28.74	346.18	69.74	98.48	27.94
2005	255	376.87	12.65	29.49	347.38	70.94	100.43	29.07
2006	256	378.84	12.62	30.27	348.57	72.13	102.40	30.09
2007	257	380.83	12.59	31.07	349.76	73.32	104.39	30.44
2008	258	382.85	12.55	31.89	350.96	74.52	106.41	31.16
2009	259	384.89	12.52	32.72	352.17	75.73	108.45	30.84
2010	260	386.97	12.48	33.58	353.39	76.95	110.53	32.60
2011	261	389.11	12.45	34.46	354.65	78.21	112.67	33.92
2012	262	391.30	12.41	35.36	355.94	79.50	114.86	34.75
2013	263	393.56	12.38	36.29	357.27	80.83	117.12	35.45
2014	264	395.86	12.34	37.24	358.62	82.18	119.42	35.51
2015	265	398.21	12.30	38.21	360.00	83.56	121.77	35.65
2016	266	400.60	12.26	39.21	361.39	84.95	124.16	35.58
2017	267	403.00	12.22	40.23	362.77	86.33	126.56	35.70
2018	268	405.40	12.18	41.28	364.12	87.68	128.96	36.22
							Sum =	1589.86