# Climate Sensitivity and Carbon Footprint

*François Gervais*[AB]

*Faculty of Sciences and Techniques, University of Tours, France*

*Dedicated to the memory of Professor Nils-Axel Mörner*[C]

*francois.gervais@univ-tours.fr*

## Abstract

A simple formula is suggested to policy makers to evaluate the impact on Earth's temperature of fossil fuel emissions or reductions. It is illustrated for main emitters, country by country. Two lists of estimates are compared.

One is based on the last report of the Intergovernmental Panel on Climate Change (IPCC AR5 2013) which retained a range of 1–2.5 °C for the Transient Climate Response (TCR) in case of atmospheric $CO_2$ doubling, a metric that is more relevant than the Equilibrium Climate Sensitivity (ECS) to estimate warming in the next few decades. At the rate of increase of 0.5 % per year since the beginning of this century, a $CO_2$ doubling in the atmosphere will hardly be reached before the end of the century.

The second estimate is based on infrared thermal emission spectra of atmospheric $CO_2$ near the tropopause that constrain the climate sensitivity below 1°C in the absence of feedbacks consistent with 109 studies concluding to low climate sensitivity. An increasing number of their publications is reported during both last decades. They are also confirmed by a plateau observed since 1994 for the temperature of the low stratosphere measured by the Earth System Science Center, University of Alabama in Huntsville (UAH), over a period corresponding to 42 % of the increase of $CO_2$ in the atmosphere since the beginning of the industrial era.

A tendency of "cooling" of climate sensitivity versus year of publication is confirmed for studies based on instrumental records of ocean and surface temperature, whereas CMIP6 climate models are running hotter. The correlation of (i) monthly temperature fluctuations measured by UAH at the Earth's surface and (ii) $CO_2$ increases in the atmosphere that lag temperature fluctuations instead of driving them, is updated and discussed.

Keywords: *TCR*, *ECS*, *infrared*, *fossil fuel emissions*, *carbon footprint*

## Introduction

In 2020, the concentration of carbon dioxide in the atmosphere measured by NOAA at the observatory of Mauna Loa, detrended from seasonal oscillations, reached 414 parts per million (ppm). 1 ppm corresponds to 7.8 Gigatons of $CO_2$ ($GtCO_2$). The atmosphere, therefore, was composed in 2020 of $3.2\ 10^{12}$ tons of $CO_2$. The transient climate response (TCR) is defined as the increase of average Earth's temperature when the atmospheric $CO_2$ concentration would double. At the average rate of increase of 2.2 ppm per year observed since two decades as is detailed in Figure 6 of Section 4, viz. 2.2/414 = 0.5 %/year, doubling will hardly be achieved during this century.

---

[A] Submitted 2021-03-25. Accepted 2021-04-17. Reviewed by J.-E. Solheim. https://doi.org/10.53234/scc202106/23

[B] The author acted as expert reviewer of IPCC AR5 and AR6. [C] The work is dedicated to the memory of Professor Nils-Axel Mörner who encouraged the author to publish this study as proceedings of the Conference "Basic Science of a Changing Climate", University of Porto (2018) – www.portoconference2018.org – that Professor Mörner co-organized. The author was fascinated by the energy of Professor Mörner and his outstanding knowledge of oceans and sea level rise.

Section 1 complements the Summary for policymakers of IPCC AR5 (2013) by evaluating a key point that is missing, viz. the impact of the emission (or of reduction of emission) of one ton of $CO_2$ on the Earth's temperature, a metric that is more relevant than the carbon footprint in terms of climate. Results for largest emitter countries will illustrate their own climatic impact at their rate of emissions during 2019.

Section 2 is a review of published values of climate sensitivity lower than 1 °C that have not been considered in IPCC AR5 (2013) which retained for the TCR the interval from 1°C to 2.5 °C only.

In Section 3, the infrared thermal emission spectrum of atmospheric $CO_2$ near the tropopause – not shown in IPCC AR5 (2013) – is scrutinized. A TCR lower than 1 °C is deduced, confirming data of Section 2. Results of Section 1 are complemented with this value for comparison.

Section 4 updates the correlation of Earth's temperature measured by satellites and the yearly increase of $CO_2$, discuss them and focus on specific points.

## 1 Impact of one ton of $CO_2$ on Earth's temperature and contribution country by country

The Transient climate response (TCR) to $CO_2$ doubling is more relevant than Equilibrium climate sensitivity (ECS) to warming in the next few decades because to reach equilibrium would need several centuries while the present work focuses on next decades with the target of net zero emissions by 2050 announced by policy makers. Nijsse *et al.* 2020 report that the Coupled Model Intercomparison Project Phase 6 (CMIP6) models, the results of which are expected to be included in the IPCC Assessment Report AR6, constrain the likely range of TCR to 1.3–2.1°C, with a central estimate of 1.68 °C. This is near the medium value 1.75 °C of the TCR interval of 1 °C–2.5 °C of IPCC AR5 (2013).

In a first estimate, by considering

- an additional temperature of the Earth of 1.68 °C that would tentatively be reached if doubling, i.e. 3.2 $10^{12}$ $tCO_2$ would be added to the 3.2 $10^{12}$ $tCO_2$ already present in 2020 in the atmosphere,
- an airborne fraction of 44 % provided by IPCC AR5 (2013), the fraction of the $CO_2$ emissions that remains in the atmosphere at least several years (the number of years is still controversial and discussed in Section 4), a fraction found nearly constant for several decades, implying that to double atmospheric $CO_2$, the human activities should emit 3.2 $10^{12}$ $tCO_2$/44 % = 7.3 $10^{12}$ $tCO_2$,

then emitting one ton of $CO_2$ would warm the Earth by

$$(1/7.3\ 10^{12}\ tCO_2) \text{ x } 1.68\ °C = 2.3\ 10^{-13} °C/tCO_2 \qquad (1)$$

Thus, evaluated with the data of IPCC AR5 and CMIP6 models, the yearly emissions of 36 $GtCO_2$ warms the Earth by 0.008 °C. Although simple and useful, this fundamental evaluation is missing in IPCC AR5 (2013). Another fraction of emissions, ~ 1/3, enriches the vegetal biomass and nutritive plants by photosynthesis. The third smaller fraction is captured by the oceans (Section 4).

By replacing the molar weight of $CO_2$, 12 + 2 x 16 = 44, by that of carbon, 12, Eq. (1) provides

$$(1/7.3\ 10^{12}\ tCO_2) \text{ x } 1.68°C \text{ x } 44/12 = 8.4\ 10^{-13} °C/tC \qquad (2)$$

Equation (2) is the equivalent of Eq. (1) in terms of carbon footprint. It can be approximated as almost ~ 1 picodegree C/tC. To keep them as simple as possible, Equations (1) and (2) imply a linear interpolation. Section 3 considers the more relevant logarithmic law.

To illustrate the impact of Eq. (1), Table 1 lists the countries the largest emitters of $CO_2$ in 2019, as reported by *www.globalcarbonatlas.org.* The yearly impact of their emissions is evaluated with the central estimate of TCR of 1.68 °C of CMIP6 climate models.

Table 1. List of countries the most $CO_2$ emitters in 2019, as reported by *www.globalcarbonatlas.org*. The emissions per inhabitant per year listed in column 5 and compared with the world 5 tons average, changes the ranking of countries. Column 6 provides the contribution to the Earth warming per year calculated with Eq. (1) and a TCR of 1.68 °C (central estimate of CMIP6, Nijsse *et al* 2020). By considering that the accuracy generally admitted for the Earth's average temperature is 0.07°C, column 7 indicates how many years such warmings by each country will remain below the threshold of measurability. Values in excess of a century are omitted because they are beyond the limits of the method. Columns 8 and 9 indicate the results with a TCR of 0.78 °C deduced from the $CO_2$ infrared thermal emission spectrum as discussed in Section 3 and calculated by Eq. (7). Although a medium emitter with a $tCO_2$/inh/yr equal to the average for the world, France is added by reference to the COP21 Paris agreement.

| Country | $MtCO_2$ /yr | % of emiss. | Popul. million | $tCO_2$/inh /yr | °C/yr (TCR CMIP6 1.68°C) | Years below +0.06°C (TCR 1.68°C) | °C/yr (TCR 0.78°C) | Warming until 2050 (TCR 0.78°C) |
|---|---|---|---|---|---|---|---|---|
| China | 10175 | 28 | 1434 | 7 | 0.0023°C | 30 | 0.0011°C | 0.030°C |
| USA | 5285 | 15 | 329 | 16 | 0.0012°C | 58 | 0.0006°C | 0.016°C |
| India | 2616 | 7 | 1366 | 2 | 0.0006°C | > 100 | 0.0003°C | 0.008°C |
| Russia | 1678 | 5 | 146 | 11 | 0.0004°C | > 100 | 0.0002°C | 0.005°C |
| Japan | 1107 | 3 | 127 | 9 | 0.00025°C | > 100 | 0.0001°C | 0.003°C |
| Iran | 780 | 2 | 83 | 9 | 0.0002°C | > 100 | 0.0001°C | 0.002°C |
| Germany | 702 | 1.9 | 83 | 8 | 0.0002°C | > 100 | 0.0001°C | 0.002°C |
| Indonesia | 618 | 1.7 | 271 | 2 | 0.00014°C | > 100 | 0.00007°C | 0.002°C |
| South Corea | 611 | 1.7 | 51 | 12 | 0.00014°C | > 100 | 0.00007°C | 0.002°C |
| | | | | | | | | |
| France | 324 | 0.9 | 65 | 5 | 0.00007°C | > 100 | 0.00003°C | 0.001°C |
| | | | | | | | | |
| World | 36441 | | 7594 | 5 | | | | |

Lovejoy (2017) reports that the uncertainty on series of Earth's temperature is about 0.1°C. *berkeleyearth.org* rather considers an uncertainty of 0.045 °C. We therefore adopt an intermediate threshold of measurability of the Earth's average temperature of 0.07 °C. Column 7 of Table 1 indicates how many years the warmings with "business as usual" for each country according to the 2019 data of column 2 will remain below the threshold of measurability.

As seen in Table 1, the policy of any country, either "business as usual" or reduction of emissions, cannot significantly change the Earth's temperature since it remains below the threshold of measurability, at least on the term of several decades for two of them and above a century for the others. Column 9 focuses on the year target of "net zero" policies considering reaching zero fossil fuels emission by 2050. The values have to be multiplied by about 2 with a TCR of 1.78 °C. Again results are below the threshold of measurability of the Earth's temperature.

## 2 A brief review of studies concluding to low climate sensitivity

Table 2 lists 109 studies that conclude to climate sensitivity either low or negligible, below or equal to 1°C. They are listed per year of publication.

Table 2. 109 studies concluding to low climate sensitivity listed by year of publication. A number of them correspond to the list updated by P. Gosselin at *notrickszone.com/50-papers-low-sensitivity*. When a climate sensitivity per $CO_2$ doubling is indicated in the study, the value is reproduced in the Table. When indicated, radiative forcing is converted to climate sensitivity with Eq. (4). In their absence, key conclusion or keywords are briefly reproduced.

| | |
|---|---|
| Rasool and Schneider 1971 | 0.8°C |
| Weare and Snell 1974 | 0.7°C |
| Willett 1974 | ~ 0° |
| Zdunkowski *et al* 1975 | < 0.5°C |
| Oliver 1976 | negligible |
| Bryson and Dittberner 1976 | $\Delta T = 3.346 \ln(CO_2)$, corresponding to 0.7°C (Eqs. 4 and 5) |
| Dyson 1977 | « great uncertainty” |
| Newell and Dopplick 1979 | < 0.25°C |
| Robock 1979 | “no significant effect” |
| Choudhury and Kukla 1979 | “cooling rather than warming effect of $CO_2$” |
| Idso 1980 | < 0.26°C |
| Ramanathan 1981 | 0.5°C |
| Gates *et al* 1981 | 0.3°C |
| Schuurmans 1983 | 0.2 to 0.4°C at present concentration |
| Idso 1984 | inverse greenhouse effect |
| Balling 1994 | < 1°C |
| Lindzen 1994 | 2 W/m$^2$, hence 0.66°C |
| Idso 1998 | 0.4°C |
| Hug 2000 | “Resonance collisions reduce effect” (below 1°C) |
| Khilyuk and Chilingar 2003 | < 0.01°C |
| Jelbring 2003 | ~ 0° |
| Cess and Udelhofen 2003 | “effect temporally decreasing” |
| Khilyuk and Chilingar 2006 | 0.01°C |
| Barrett *et al* 2006 | 3.1 W/m$^2$, hence 0.9°C |
| Bellamy and Barrett 2007 | < 1°C |
| Miskolczi 2007 | 0.24°C |
| Chillingar et al 2009 | negligible |
| Florides and Christodoulides 2009 | 0.01–0.03°C |
| Gerlich and Tscheuschner 2009 | “atmospheric greenhouse conjecture falsified” |
| Lindzen and Choi 2009 | 0.5°C |
| Miskolczi 2010 | negligible |
| Soares 2010 | negligible |
| Clark 2010 | Cannot cause climate change |
| Wagoner *et al* 2010 | “very small” |
| Gerlich and Tscheuschner 2010 | “non-existing influence” |
| Lindzen and Choi 2011 | 0.7°C |
| Nahle 2011 | negligible |
| Arrak 2011 | Arctic warming: not greenhouse effect |
| Fang *et al* 2011 | “large uncertainties” |
| Zhao 2011 | “little evidence” |
| Kramm and Dugli 2011 | « meritless conjectures » |
| Ollila 2013 | 0.51°C |
| Clark 2013 | negligible |
| Singer 2013 | ~ 0° |
| Avakyan 2013 | “insignificant” |
| Harde 2013 | 2.6 W/m$^2$, hence 0.78°C |
| Laubereau and Iglev 2013 | ~ 1°C |

| | |
|---|---|
| Choi *et al* 2014 | 0.5–1.2°C |
| Gervais 2014 | 2.2 W/m$^2$, hence 0.66°C |
| Ollila 2014 | 0.6°C |
| Chilingar *et al* 2014 | “no essential effect” |
| Lightfoot and Mamer 2014 | 2.8 % of water vapor warming ~ 30° x 0.028 = 0.84°C |
| Miskolczi 2014 | “effect impossible” |
| Harde 2014 | 0.6°C |
| Kauppinen et al 2014 | “Less than 10 % of the temperature change” |
| Reynen 2014 | 0.03°C |
| Soon et al 2015 | 0.44°C |
| Kimoto 2015 | 0.14–0.17°C |
| Kissin 2015 | 0.6°C |
| Schmithüsen *et al* 2015 | “cooling effect” |
| Monckton *et al* 2015 | 1°C |
| Ollila 2016 | 1°C |
| Smirnov 2016 | 0.4°C |
| Bates 2016 | ~ 1°C |
| Evans 2016 | < 0.5°C |
| Gervais 2016 | < 0.6°C |
| Haine 2016 | negligible |
| Manheimer 2016 | negligible |
| Vares *et al* 2016 | negligible |
| Easterbrook 2016 | negligible |
| Allmendinger 2016 | negligible |
| Ellis and Palmer 2016 | “play little or no part” |
| Specht *et al* 2016 | 0.4°C |
| Hertzberg and Schreuder 2016 | “nothing supports” |
| Song *et al* 2016 | “no significant change of OLR” |
| Harde 2017a | 0.7°C |
| Ollila 2017 | 0.6°C |
| Abbot and Marohasy 2017 | < 0.6°C |
| Scafetta *et al* 2017 | < 1°C |
| Smirnov 2017 | 0.4°C |
| Kramm *et al* 2017 | negligible |
| Lightfoot and Mamer 2017 | negligible |
| Robertson and Chilingar 2017 | negligible |
| Hertzberg *et al* 2017 | “none of greenhouse description withstand scrutiny” |
| Davis 2017 | no effect |
| Allmendinger 2017 | negligible |
| Holmes 2017 | negligible |
| Harde 2017b | 0.7°C |
| Nikolov and Zeller 2017 | Solar irradiance and atmospheric pressure only |
| Wong and Minnett 2018 | negligible |
| Smirnov 2018 | 0.4°C |
| Lightfoot and Mamer 2018 | negligible |
| Stallinga 2018 | 0.5°C |
| Davis *et al* 2018 | weak at most |
| Allmendinger 2018 | no effect |
| Fleming 2018 | “no role” |
| Swift 2018 | “increase of absorbed solar radiation by 3 W/m$^2$” |
| Kato *et al* 2018 | “decrease of LW irradiance” |
| Sejas *et al* 2018 | negative $CO_2$ effect |
| Ollila 2019 | 0.6°C |
| Holmes 2019 | negligible |
| Krainov and Smirnov 2019 | 0.4°C |
| Kim and Lee 2019 | 1 W/m$^2$, hence 0.3°C |
| Varotsos and Efstathiou 2019 | negligible |
| Kennedy and Hodzic 2019 | negligible |
| Fleming 2020 | negligible |
| Drotos *et al* 2020 | negligible |

| | |
|---|---|
| Stallinga 2020 | < 0.5°C |
| Schildknecht 2020 | 0.5°C |

Figure 1 plots the climate sensitivity reported in the studies listed in Table 2 versus the year of publication. They are compared with the range of TCR, 1–2.5 °C, of IPCC AR5 (full lines) and with the range of equilibrium climate sensitivity, 1.5–4.5 °C (dotted lines).

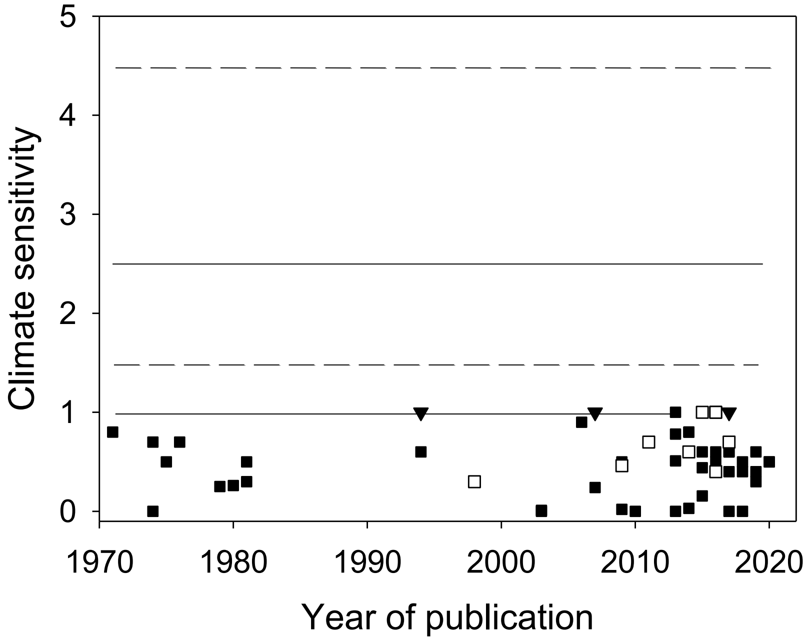

*Figure 1. A plot of the data of Table 2 versus year of publication. White symbols correspond to the studies cited in the review of Knutti et al (2017) in which conversely studies corresponding to black symbols are ignored. Triangles correspond to the upper limit of the conclusions of the study. The full horizontal lines correspond to the limits of TCR in IPCC AR5 (2013) while the dotted lines correspond to the limits of ECS.*

Figure 2 plots the number of studies of Table 2 published each year.

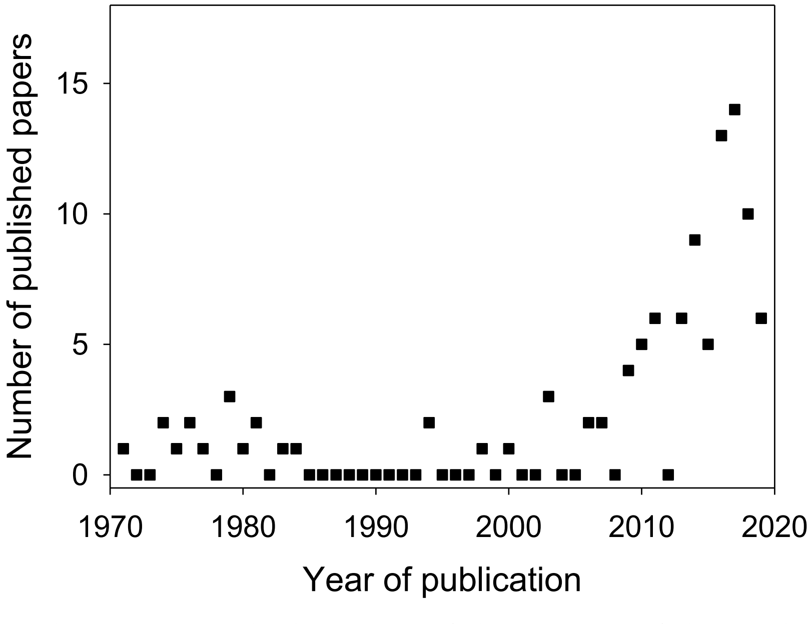

*Figure 2. Acceleration since the beginning of this century, of the number of studies focusing on low climate sensitivity (equal or lower than 1 °C) as shown in Table 2 and Figure 1.*

A tendency at acceleration emerges since the beginning of this century. The 108 studies of Table 2 may be compared to those reviewed by Knutti *et al* (2017) where 47 TCR or intervals of TCR are cited. Among them, only one study reports 1°C and only another one reports less than 1°C (Ollila 2014). 78 ECS or intervals of ECS are also reviewed. Among them, only 7 studies report 1°C or below (Idso 1998, Lindzen and Choi 2009, 2011, Monckton *et al* 2015, Bates 2016, Specht *et al* 2016, Harde 2017).

Figure 3 updates Figure 1 of Gervais (2016). It adds to the results plotted in Figure 1 the climate sensitivity estimated from instrumental records of surface temperature and ocean heat content as reported by Hausfather (2018), taken from the review of Knutti *et al* (2017), complemented by more recent results.

Figure 3 confirms that there is no consensus about the climate sensitivity. Each result appears disproved by a number of the others by as much as several degrees for some of them. A linear regression of results of Figure 3 indicates a "cooling" due to the tendency of decrease with year of publication of data deduced from instrumental records, a phenomenon which is amplified by the acceleration of results equal or below 1°C published recently as shown in Figures 1 and 2.

Conversely, no "cooling" is observed for ECS climate sensitivity of climate models, in particular CMIP5 and CMIP6, which remains essentially in the range from 1.5°C to 4.5°C without decrease of the uncertainty since the Charney report published in 1979. They are not shown in Figure 3 due to the deep uncertainty that persists to appear much too large.

Some CMIP6 models correspond to even larger climate sensitivity, with 5 of 34 models with TCR values above 2.5°C. Conversely, the lowest value of the range, 1.3°C, is the TCR reported by the INM-CM4-8 model (Volodin *et al* 2019). 12 of 34 models show an ECS value above 4.5°C (Nijsse *et al* 2020, McKitrick and Christy 2020). Figure TS.14(a) and Figure 1(a) of Box TS.3 of the IPCC AR5 (2013) show (i) that CMIP5 models do not agree between themselves while the IPCC AR5 (2013) does not make any choice between them, (ii) they run too "hot" to be validated by the observations from 1998 to 2014, a period that the AR5 designated as "hiatus".

Spencer (2021) has published an update with latest observations compared with CMIP6 models. Except INM-CM4-8, models persist to run hotter than observations.

The spread in estimated ECS has increased further in CMIP6 models. It reaches an uncertainty of 3.7 K as compared with 2.7 K in the previous CMIP5. McKitrick and Christy (2020) question pervasive warming bias in CMIP6 tropospheric layers. In addition, Zhu *et al* (2020, 2021) show that high climate sensitivity in CMIP6 models are not supported by paleoclimate. They find that the ECS is too large because of an incorrect treatment of clouds in the models. Wild (2020) shows that the inter-model spread amongst the magnitudes of the global energy balance components in the individual CMIP6 models is still unsatisfactorily large, typically of the order of 10–20 $W/m^2$. The inter-model spread in the simulated global mean surface latent heat flux reaches 18 $W/m^2$. These discrepancies have generally not decreased from the previous model generation CMIP5 to the latest model generation CMIP6, and the inter-model spreads and standard deviations remain similar.

Section 3 shows that in case of $CO_2$ doubling, the lack of flux at the TOA found from infrared thermal emission spectra could reaches 2.6 $W/m^2$. At the average rate of increase of $CO_2$ of 22 ppm/decade as shown in Figure 6, its contribution is of the order of (22/414) x 2.6 = 0.14 $Wm^{-2}$/ decade. The inter-model spread, therefore, appears more than 100 times larger, illustrating how much they are hardly convincing in the representation of the global energy imbalance.

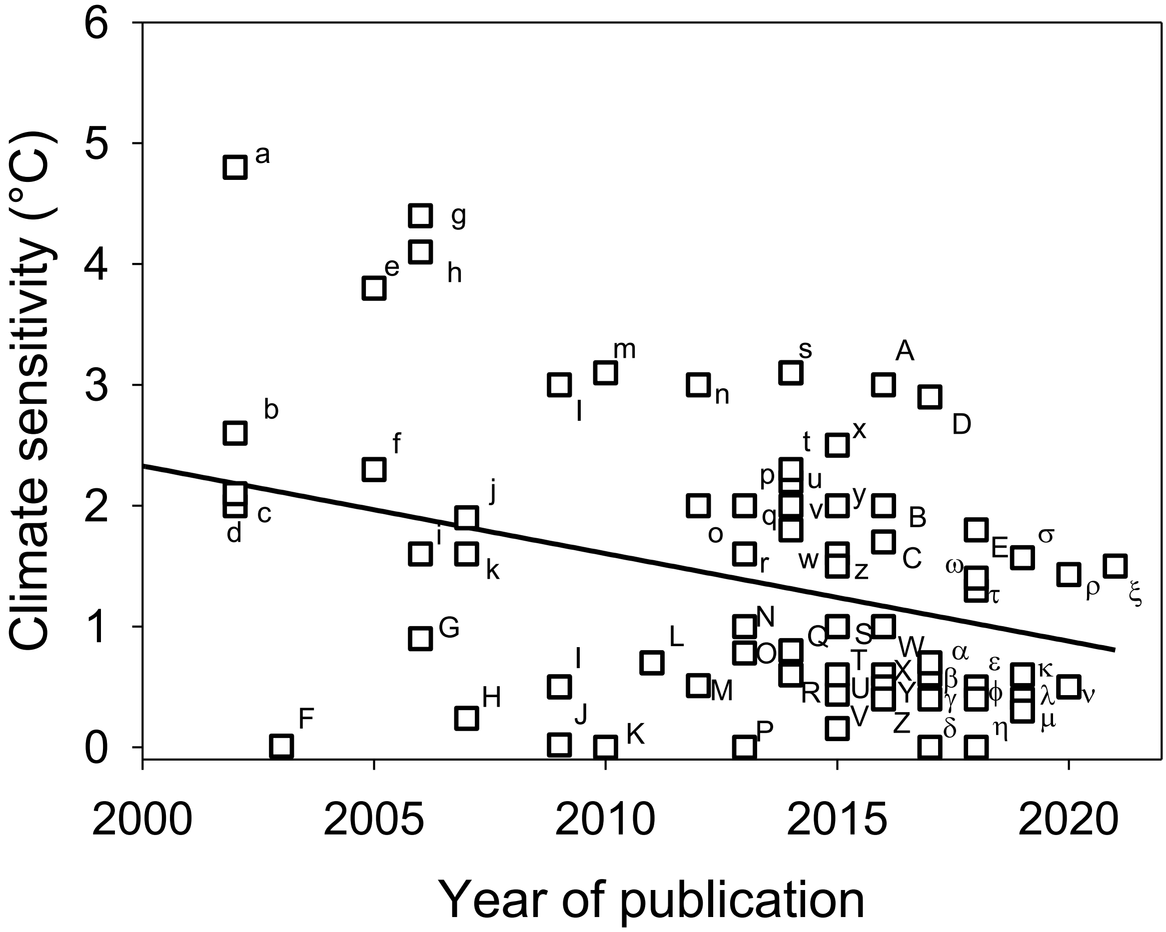

*Figure 3. Climate sensitivity from instrumental records as listed by Hausfather (2018) taken from the review of Knutti et al (2017), complemented by more recent results, plotted together with data of Figure 1. ECS of CMIP5 and CMIP6 models that remains essentially in the range from 1.5 °C to 4.5 °C are not shown here due to the deep uncertainty that persists to appear much too large as discussed in the text. a: Knutti et al 2002; b: Kaufmann and Stern 2002; c: Gregory et al 2002; d: Harvey and Kaufmann 2002; e: Tsushima et al 2005; f: Frame et al 2005; g: Stern 2006; h: Forest et al 2006; i: Forster and Gregory 2006; j: Schwartz 2007; k: Chylek 2007; l: Murphy et al 2009; m: Lin et al 2010; n: Schwartz 2012; o: Aldrin et al 2012; p: Bengtsson and Schwartz 2013; q: Otto et al 2013; r: Lewis 2013; s: Urban et al 2014; Donohoe et al 2014; Lovejoy 2014; t: Kummer and Dessler 2014; u: Lewis 2014; v: Loehle 2014; w: Skeie et al 2014; x: Johansson et al 2015; y: Cawley et al 2015; z: Lewis and Curry 2015; Loehle 2015; A: Forster 2016; B: Loeb et al 2016; C: Lewis 2016; D: Armour 2017; E: Lewis and Curry 2018; F: Jelbring 2003; G: Barrett et al 2006; H: Miskolczi 2007; I: Lindzen and Choi 2009; J: Florides and Christodoulides 2009; K: Clark 2010; L: Lindzen and Choi 2011; M: Ollila 2013; N: Laubereau and Iglev 2013; O: Harde 2013; P: Singer 2013; Q: Lindzen 2014, Lightfoot and Mamer 2014; R: Gervais 2014; S: Monckton et al 2015; T: Kissin 2015; U: Soon et al 2015; V: Kimoto 2015; W: Bates 2016; X: Gervais 2016; Y: Evans 2016; Z: Smirnov 2016; α: Scafetta et al 2017; β: Abbot and Marohasy 2017, Ollila 2017; γ: Smirnov 2017; δ: Holmes 2017; ε: Stallinga 2018; ϕ: Smirnov 2018; η: Fleming 2018; κ: Ollila 2019; λ: Krainov and Smirnov 2019; μ: Kim and Lee 2019; ν: Stallinga 2020, Schildknecht 2020; ρ: Myrvoll-Nielsen et al 2020; σ: Haustein et al 2019; τ: Booth 2018; ω: Skeie et al 2018; ξ: Scafetta 2021a.*

## 3 Infrared thermal flux towards space and climate sensitivity

Depending on the electromagnetic flux $I_s$ received from the sun, the Boltzmann equation allows the evaluation of the temperature of the Earth via

$$(1 - a)I_s/4 = \varepsilon\sigma T^4 \tag{3}$$

$a$ is the Earth albedo, $\varepsilon$ is the Earth emissivity and $\sigma$ the Boltzmann constant. The derivation of this equation reads

$$\Delta F/F = 4\ \Delta T/T \tag{4}$$

$F = 240\ W/m^2$ is the average thermal flux received from the sun and reemitted by the Earth towards space, averaged over day and night, latitude and seasons. To deduce the climate sensitivity $\Delta T$ to $CO_2$ doubling, a direct evaluation of $\Delta F$ can be deduced from the evolution of the infrared spectrum of the main $CO_2$ band that peaks near the maximum of the Planck thermal emission of the Earth, in case of doubling of its concentration, as shown in Figure 4.

The superposition of both curves – one for the $CO_2$ concentration observed at the observatory of Mauna Loa in 2005, the other in case of hypothetical doubling – in the immediate vicinity of the bending vibration mode of $CO_2$ of wavenumber 670 $cm^{-1}$ (corresponding to a wavelength of 15 micrometers) illustrates the almost saturation of its emission towards space.

Rasool and Schneider (1971) already mentioned the almost saturation: « as more $CO_2$ is added to the atmosphere, the rate of temperature increase is proportionally less and less, and the increase eventually levels off. The runaway greenhouse effect does not occur because the 15 µm $CO_2$ band which is the main source of absorption *saturates*, and the addition of more $CO_2$ does not substantially increase the infrared opacity of the atmosphere.» The almost saturation is confirmed by Schildknecht (2020).

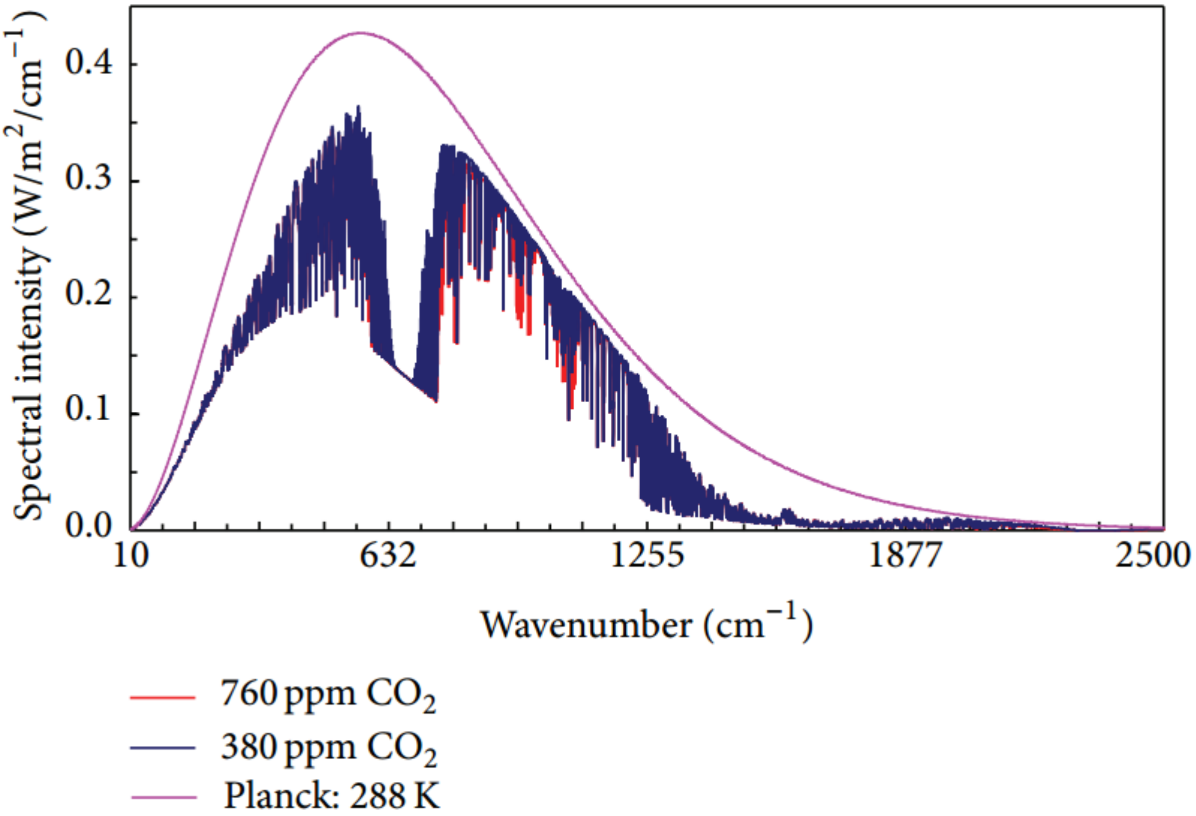

*Figure 4. An illustration of the little change of atmospheric $CO_2$ emission towards space, here at an altitude of 12.5 km, in case of doubling of its concentration, reproduced from the open access paper of Harde (2013).*

Figure 4 shows that at high $CO_2$ concentrations, adding more $CO_2$ does little due to the logarithmic law as shown by Myhre et al (1998). In addition, the $CO_2$ infrared linewidth is broadened by atmospheric pressure in the low troposphere. Conversely, the infrared absorption peaks become sharper with decreasing pressure, what happens with increasing altitude. As a result, there is no Earth radiation left for the wings of narrower lines at the top of the atmosphere where the pressure is lower, because the broader absorptions below mask it.

Harde (2014) evaluates a climate sensitivity of 0.6° ± 0.1°C. Such a tiny anthropogenic warming is consistent with the 108 other studies of Table 2. Besides, Figure 8.1b of Salby (2012) shows that the absorptivity of the infrared $CO_2$ band at 15 µm measured between the tropopause around 11 km and the top of the atmosphere is near 100 %. Above 11 km, the temperature does no longer decrease with altitude. As a result, the emission is no longer weakened – according to the key point of the definition of greenhouse effect in the glossary of the IPCC AR5 (2013) – with increasing concentration of $CO_2$. It could be weakened but only below the tropopause where the temperature decreases with altitude following to the atmospheric lapse rate.

Taking account of the shielding by cloudiness not shown in Figure 4, Harde (2013) evaluates that the difference of both spectra results in $\Delta F = 2.6\ W/m^2$. This is the flux that might be lacking in the energy balance at the top of the atmosphere (TOA) in case of $CO_2$ doubling, viz. a lack of 2.6/240 = 1.1 %. Other line by line radiative transfer model calculations confirm with a similar difference of $2.9\ W/m^2$ near the TOA in case of $CO_2$ doubling (Sherwood *et al* 2020). Ollila (2017a) reports $\Delta F = 2.2\ W/m^2$. With the intermediate value of $2.6\ W/m^2$ deduced from infrared spectra in Figure 4, the anthropogenic contribution to the Earth warming then would be

$$\Delta T_{CO2\,x\,2} = T/4 \text{ x } \Delta F/F = 288/4 \text{ x } 2.6/240 = 0.78\ °C \tag{5}$$

consistent with values lower than 1°C in Table 2 and in Figures 1 to 3. Rewritten in terms of concentration $C$ of $CO_2$ in the Earth atmosphere, Eq. (5) becomes

$$\Delta T = 288/4 \text{ x } 2{,}6\ \ln(C/C_0)/240\ \ln(2) = 1{,}1°C\ \ln(C/C_0) \tag{6}$$

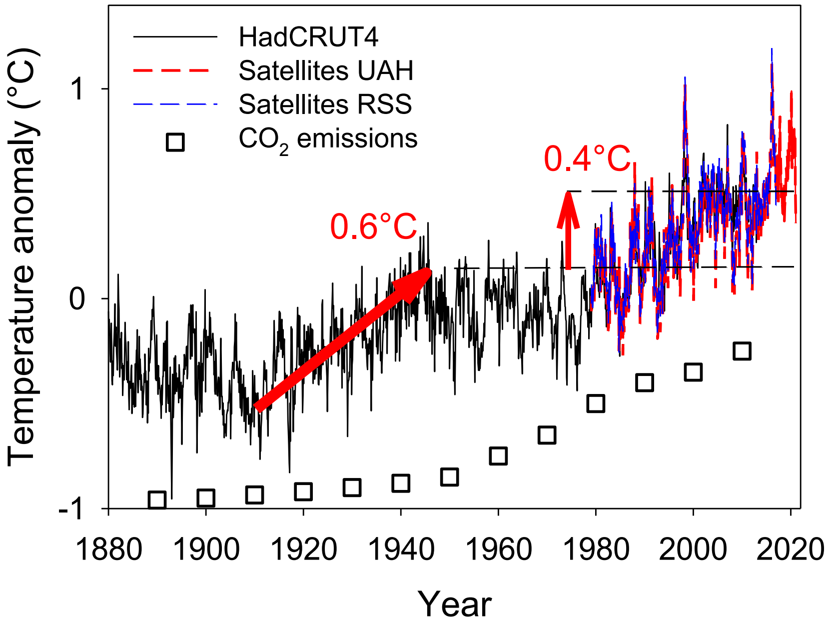

*Figure 5. Temperature anomaly observed by the British Hadley Center HadCRUT4 (2021), satellites UAH TLT (2021) and RSS (2021), compared to the relative increase of $CO_2$ in the atmosphere.*

Applied to the increase of $CO_2$ in the atmosphere since the beginning of acceleration of emissions in 1945, Eq. (6) provides *1,1°C ln(414 ppm/310 ppm) = 0.3°C*. Since 1945, HadCRUT4 data show a warming of about 0.4 °C if fluctuations like El Niño peaks that are natural phenomena related to the intensity of the dominant winds in the Pacific Ocean, are set aside to focus on the baseline as shown in Figure 5. The UAH satellite data indeed show that while a warming trend of 0.12 °C per decade is observed from 2000 to 2020, the trend is limited to only 0.01°C per decade from 2000 to 2015 before the onset of the strong El Niño peak of 2016 and replica afterwards.

Data are monthly. A warming of about 0.6 °C has been observed from 1910 to 1945 when $CO_2$ emissions were too low to explain it (Ring *et al* 2012), illustrating a contribution of the natural variability of climate. Since 1945, an anthropogenic contribution of 0.3°C evaluated above matches the observation of 0.4 °C, validating a climate sensitivity lower than 1°C, whereas higher values are not validated by observations in Figure 5.

With a climate sensitivity of 0.78 °C, Eq. 1 becomes

$$(1/7.3\ 10^{12}\ tCO_2) \times 0.78°C = 1.06\ 10^{-13}°C/tCO_2 \qquad (7)$$

This equation is applied in both right columns of Table 1. In terms of carbon footprint, the result reads 3.9 $10^{-13}$°C/tC.

A climate sensitivity higher than 1°C assumes positive feedbacks that might increase the climate sensitivity $\Delta T_{CO2 \times 2}$ in the form

$$\Delta T_f = \Delta T_{CO2 \times 2}/(1 - f) \qquad (8)$$

if $f$ is positive and lower than 1. The main supposed positive feedback is water vapor, considered to increase the $CO_2$ greenhouse effect in a warming world. A large fraction of emissions of infrared output longwave radiation (OLR) to space from the troposphere indeed is from water vapor. The radiation occurs at an average altitude of ~ 5 km that corresponds to the temperature of 255 K (– 18 °C) assuming an emissivity of 1, as given by Eq. (3). The difference of 33 K with the average surface Earth's temperature of 288 K is the warming attributed to greenhouse gases. This is essentially the greenhouse effect of the main one, water vapor (Ollila 2017a). Above the tropopause where the air is dryer, a fraction of OLR emissions is from $CO_2$ (Figure 4). Van Brunt (2020) has shown that changes in the concentration of water vapor and changes in water vapor heating are not a feedback response to changes in the concentration of $CO_2$.

Positive feedbacks due to water vapor were supposed to generate « hot spots », but none is found in the high troposphere in subtropical regions (Douglass *et al* 2004, 2008, Christy *et al* 2010, Fu *et al* 2011). Even more intricate in the context of such a hypothesis, at the altitude around 9 km where the hot spots are expected and where $CO_2$ emits heat towards colder space (Figure 4), the specific humidity that was supposed to increase actually has decreased. The decrease is from 0.28 g/kg in 1948 down to 0.25 g/kg these 15 last years as measured by NOAA (Humlum 2021). The supposed positive feedback of water vapor, therefore, is unsupported by observations and, therefore, not demonstrated.

Clouds may cool or warm the planet. If precipitating convective clouds cluster in larger clouds as temperature rise, negative feedbacks are expected (Mauritsen and Stevens 2015). Lindzen and Choi (2009, 2011) considered a negative feedback, the "iris" effect, which decreases the climate sensitivity down to 0.5–0.7 °C. Paltridge *et al* (2009), Spencer and Braswell (2010) also focus on negative feedbacks. Low-level clouds may be thick enough to reflect a part of the sun's radiation and increase the albedo (Loeb *et al* 2018, Delgado-Bonal *et al* 2020, Ollila 2020, Sfica *et al* 2021). More generally, cloud tuning (Golaz *et al* 2013) to achieve the desired radiation balance is a complementary cause of the scatter of climate sensitivity.

When Earth was cooling from 1945 to 1975 in spite of the acceleration of $CO_2$ emissions (Figure 5), Rasool and Schneider (1971) predicted even more cooling by introducing a strong concentration of aerosols known to have a cooling effect as confirmed by the momentary Earth's cooling of 0.5 °C in 1992 after the eruption of the Mount Pinatubo volcano. The cooling offsets a warming related to a weak climate sensitivity of 0.8 °C (Rasool and Schneider 1971). Wang *et al* (2021) confirms this concept by reporting that highest ECS climate sensitivity in CMIP6 models are offset by highest cooling by aerosol-cloud interaction.

However, over the 20th century, changes in anthropogenic aerosols were mostly concentrated in the Northern Hemisphere. Consequently, models with strong or weak aerosol-cloud interactions produce different warming asymmetry over the historical period.

The observed warming asymmetry is more consistent with the models that have weak aerosol cloud interactions and, therefore, less positive cloud feedback. This asymmetry appears not considered in recent studies based on CMIP6 models (Gillett *et al* 2021).

Besides, Scafetta (2021b) reports that Urban Heat Island effects raise city temperatures above the temperatures in surrounding rural areas. These significant biases alter instrumental records. Sea surface temperatures and land temperatures showed matching variations and amplitudes from 1900 to 1980. After 1980, the land surface temperatures rose substantially more, suggesting nearly half of the land temperature increase is non-climatic. Both asymmetry of warming and urban heat island effects tend to disprove the highest climate sensitivity of CMIP6 models.

The low stratosphere (altitude of ~17 km) displays a long plateau of temperature since 1994 as shown in Figure 6.

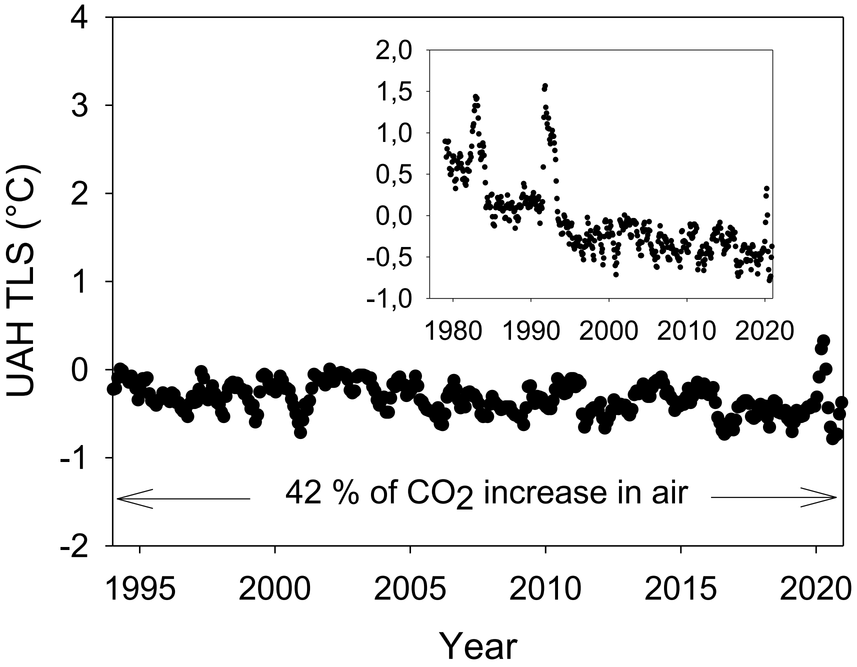

*Figure 6. Plateau of anomaly of temperature in the low stratosphere (TLS) measured by satellite in the low stratosphere as reported by the Earth System Science Center, University of Alabama in Huntsville (UAH) (Spencer et al 2017, here updated), at the altitude of ~ 17 km from 1994 to 2020. A flatness emerges in a period corresponding to not less than ~ 42 % of all the increase of* $CO_2$ *in the atmosphere since the beginning of the industrial era. The inset shows all available data. Both peaks in the inset corresponds to aerosols emitted by volcanic eruptions. The smaller peak in 2020 could be due to the Tall volcano eruption.*

## 4 Atmospheric $CO_2$ yearly increases mirror but lag surface temperature fluctuations

Figure 7 is an update of Figure 4 of Gervais (2014).

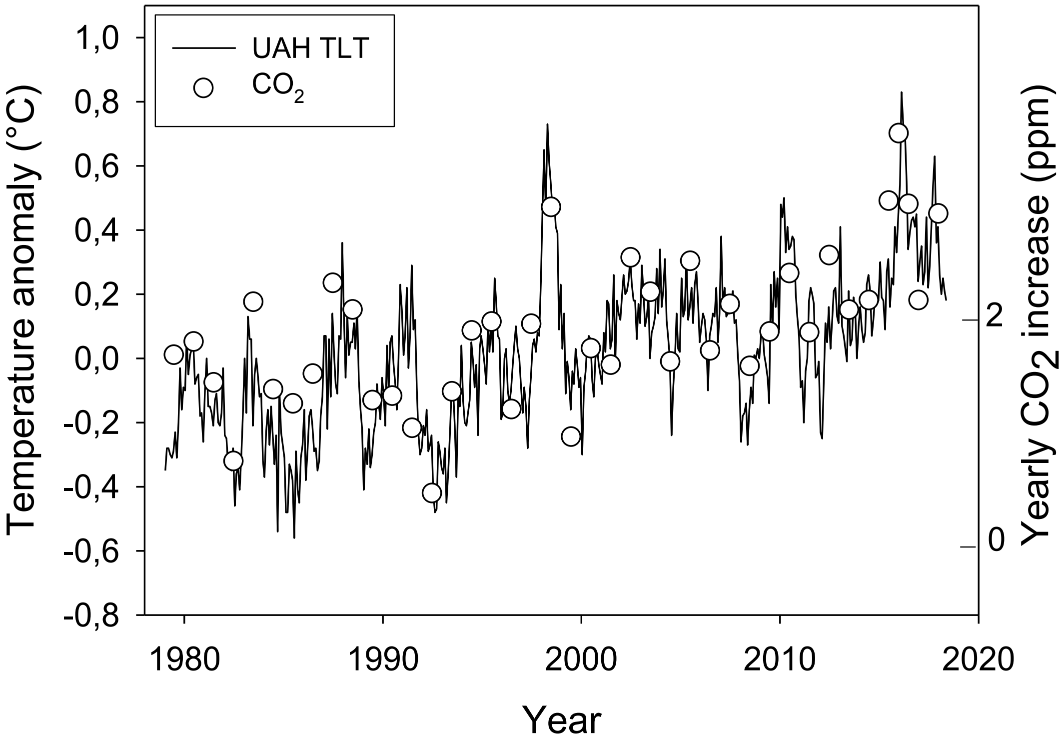

*Figure 7. UAH temperature in the low troposphere (TLT), i.e. surface satellite measurements (Spencer et al 2017, updated) compared with yearly increases of $CO_2$ measured at Mauna Loa (NOAA 2020) shifted left by 6 months, showing the fit. The shift focus on a lag of $CO_2$ increases with respect to temperature fluctuations. The lowest $CO_2$ increase follows the cold year 1992 and the highest follow the hot El Niño years 1998 and 2016.*

The yearly $CO_2$ increase in the atmosphere measured at the observatory of Mauna Loa is confirmed to be far from being a constant. The year 1992 was a cold year due to the aerosols emitted by the eruption of the Pinatubo volcano (see inset of Figure 6) in spite of the $CO_2$ emissions of the volcano itself and in spite of a warm El Niño which peaked at an excess of 2°C in the NINO3.4 Pacific region. The yearly increase of $CO_2$ in 1992 was 0.47 ppm only. The $CO_2$ increase since 12 months peaked at 4.6 ppm in the warm year 2016 related to a strong El Niño fluctuation as shown in Figure 8.

The increase of amplitude from 0.47 to 4.6 ppm is too large for mirroring changes in $CO_2$ anthropogenic emissions. These fluctuations show an amplitude larger than that related to the drop of $CO_2$ emissions related to the industrial slowdown and the lockdown due to the Covid-19 pandemic (NOAA 2020). The fluctuations of $CO_2$ correlated to temperature, therefore, appear mainly related to natural effects.

Kuo *et al* (1990) discussed the correlation temperature/$CO_2$. The changes in carbon dioxide content were reported to *lag* the temperature fluctuations by 5 months. The solubility of $CO_2$ in water increases with decreasing temperature. The correlation of Figure 7 may be interpreted, at least partly, by outgassing of $CO_2$ from the oceans that contains 60 times more $CO_2$ than the atmosphere (IPCC AR5 2013), during warmer years especially under the tropics (Park 2009, Quirk 2009, Beenstock *et al* 2012, Salby 2012, Humlum *et al* 2013, Gervais 2014, Harde 2017a, 2019, Berry 2019, Stallinga 2020).

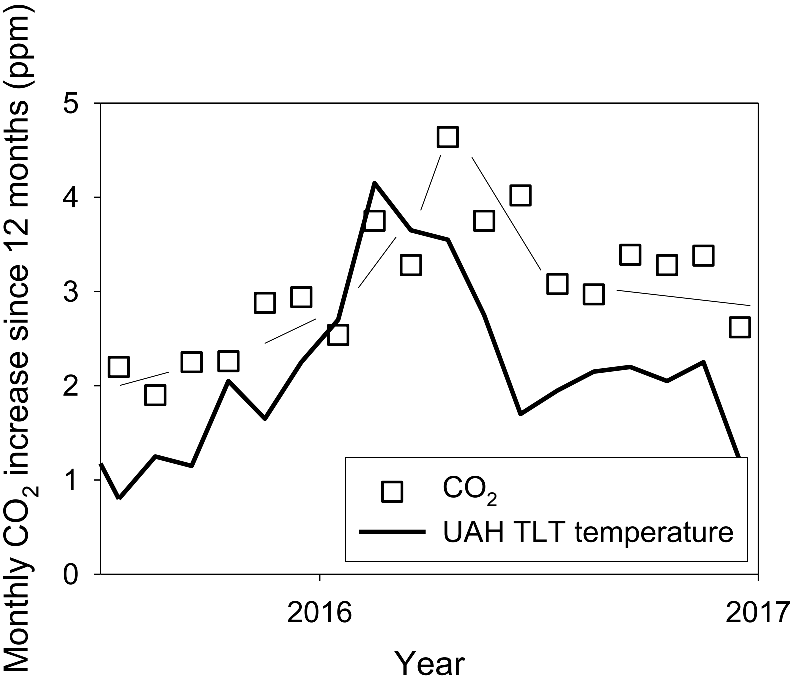

*Figure 8. Lag of monthly $CO_2$ increase with respect to UAH TLT temperature.*

Humlum *et al* (2013) concluded: « changes in ocean temperatures appear to explain a substantial part of the observed changes in atmospheric $CO_2$ since January 1980. $CO_2$ released from anthropogenic sources apparently have little influence on the observed changes in atmospheric $CO_2$. »

It is fair to concede that a convincing anthropogenic carbon budget does not seem to be settled. Many different models of carbon budget have been published (Friedlingstein *et al* 2006). Contemporary land uptakes show differences as large as 4 GtC per year, viz. nearly half the anthropogenic emissions, from a model to another. The difference is even larger in the projection to 2100 since it reaches 17 GtC per year, a level higher than contemporary emissions.

El Niño Southern Oscillation ENSO contributes to global temperature (Zeng *et al* 2005). However, (i) the lag of several months of $CO_2$ fluctuations that follows temperature fluctuations in general and (ii) the low increase of 1992 in spite of an El Niño fluctuation that year, contradict the hypothesis that ENSO would be the *driver* of the temperature-dependent fraction of the fluctuations of $CO_2$ addition in the atmosphere. The role of driver appears rather played by the temperature of oceans. It might appear counterintuitive that oceans that capture 23 % of anthropogenic $CO_2$ emissions might release it during warmest years. However (i) upwelling of 275 $GtC.yr^{-1}$ (corresponding to 130 $ppm.yr^{-1}$), larger than downwelling of 264 $GtC.yr^{-1}$ (corresponding to 125 $ppm.yr^{-1}$) reported by Levy *et al* (2013), permits within uncertainties a possibility of $CO_2$ release from oceans during warmest years. (ii) $CO_2$ may precipitate in the solid form of $CaCO_3$ because oceans contain calcium. (iii) Oceans appear as a biological carbon pump more efficient than previously considered (Buesseler *et al* 2020).

Lands and vegetation capture 1/3 of $CO_2$ emissions. To evaluate it, one method is linked to the amplitude of the seasonal drop of $CO_2$ concentration in the atmosphere in spring and summer due to enhanced uptake of carbon by photosynthesis also favored by longer days, in the northern hemisphere that shows a larger surface of vegetation than the southern hemisphere. The amplitude is nearly zero in Antarctica for lack of surrounding vegetation. Conversely, the amplitude of the drop has been found to increase 71 % more rapidly than the $CO_2$ concentration at La Jolla (California) between 1969 and 2013 (Gervais 2016). Does the amplitude of $CO_2$ fluctuations of

Figure 7 manifest themselves by fluctuations of seasonal amplitudes related to temperature? The cold year 1992 together with the warm year 1998 are compared in Figure 9.

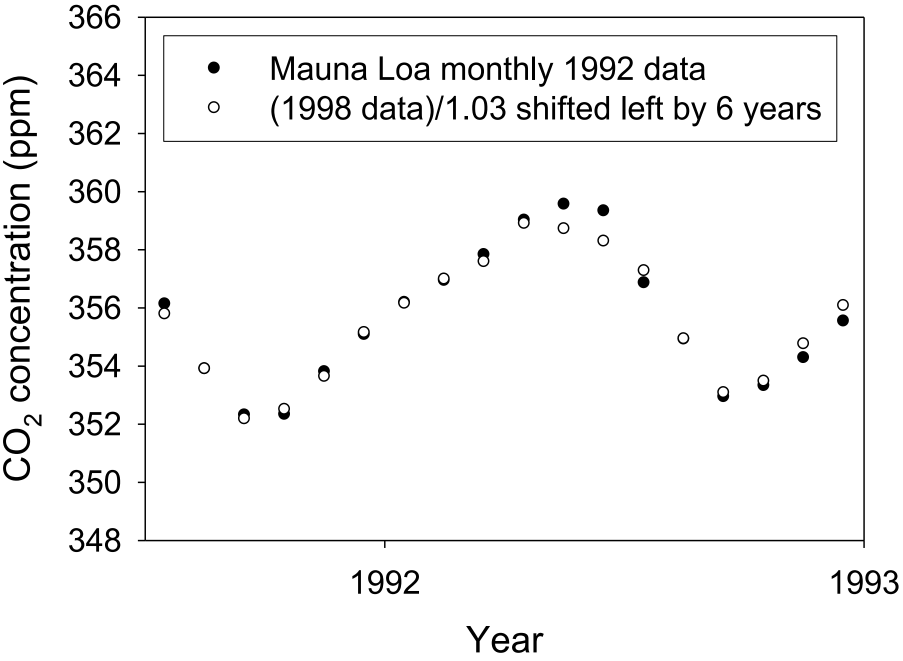

*Figure 9. Seasonal oscillation of $CO_2$ concentration measured at the Observatory of Mauna Loa (NOAA 2020) from 1991 to 1993. It is compared with the oscillation from 1997 to 1999 shifted left by 6 years. Data of the latest have been divided by 1.03, the ratio of $CO_2$ concentration in autumn 1997 and autumn 1991 to start both curves with a same origin for accurate comparison.*

Both seasonal oscillations of Figure 9 appear essentially superposed. This near superposition hardly supports Figure TS.4 of IPCC AR5 (2013) where it is seen that land sink would have been unable to absorb any anthropogenic emission in 1998, whereas land sink would have absorbed 4 GtC in 1992.

The yearly fraction of anthropogenic $CO_2$ added to the atmosphere may be estimated from the ratio $^{13}C/^{12}C$ (Segalstad 1998). The result is consistent with the low level of increase of $CO_2$ in 1992. This is confirmed by Harde (2017a, 2019) and Berry (2019).

Koutsoyiannis and Zbigniew (2020) raises the question of the correlation of Figure 7 in terms of hen-or-egg causality. They conclude: “the results of our study support the hypothesis that the dominant direction is $T \rightarrow CO_2$. Changes in $CO_2$ follow changes in T by about six months on a monthly scale.”

The correlation of Figure 7 possibly might be transient. But if it persists at least on the short term and if, for natural reasons (combination of lower solar activity, aerosols emitted by volcanic eruption, strong La Niña fluctuation), the surface temperature would drop down to –0.6°C in the left vertical scale of Figure 7 corresponding to 0 ppm in the right scale, then the increase of $CO_2$ in the atmosphere would cease, independent of anthropogenic emissions. With a yearly $CO_2$ increase of only 0.47 ppm compared to the peak at 4.6 ppm in 2016 in Figure 8, this situation almost happened in 1992 for a single natural reason, viz. aerosols emitted by the Pinatubo volcano that partially and momentarily attenuated the solar flux.

## 5 Discussion

The airborne fraction is the ratio of the annual increase of atmospheric $CO_2$ to the emissions from fossil sources. IPCC AR5 (2013) reports a value of 0.44 ± 0.06 % for the airborne fraction. Surprisingly, the airborne fraction has not much changed during the past 50 years. At least, the change seems not exceeding the uncertainty. Since fossil fuels emissions have about tripled during half a century, this means that the carbon sinks, lands and oceans, became about triply more efficient. In particular, the yearly growth of atmospheric $CO_2$ half a century ago was about only 1/3 of what it is nowadays. Harde (2017a) confirms that the uptake of $CO_2$ by natural sinks scales proportional with its atmospheric concentration.

It is instructive to compare 1/3 of 9.9 GtC emitted in 2019 with 450 GtC, the total vegetal biomass (Bar-On *et al* 2018). 3.3/450 = 0.73 %. During the 33 years of the Earth's greening observed by satellites (Zhu *et al* 2016), the enrichment of the vegetal biomass has been, therefore, of the order of 33 years x 0,73 % = 24 %. The global warming shown in Figure 5 seems to have not prevented this estimated increase. It is beyond the scope of this study to discuss whether it has favored it. Nevertheless, the increase of biomass could reach 174 GtC until the end of the century (Haverd *et al* 2020), viz. 174/450 = 39 %.

There are some parallel arguments. Greening is observed in particular in arid areas (Metcalfe 2014), thanks to additional photosynthesis of increased $CO_2$ levels. Additional carbon dioxide causes plants to produce less water loss due to evaporation, less hydric stress, lower sensitivity to pollution, and more resistance to heat and cold. The rising carbon dioxide concentration in the atmosphere is a primary cause of observed recent greening of the Earth. Newly grown rainforests can absorb eleven times as much carbon from the atmosphere as old-growth forests (Poorter *et al* 2016), confirming by direct measurements enhanced carbon land uptake in tropical latitudes of Latin America. This is also true for the increased efficiency of the biological carbon pump of the oceans (Buesseler *et al* 2020). Note that the anthropogenic contribution to the pH of the oceans remains small, –0.0017 per year (Byrne *et al* 2010).

Summarizing, there are benefits of $CO_2$ emissions for the fertilization of oceans, lands, forests, grasslands and nutritive plants (Donohue *et al* 2013, Idso 2013, Kaptué *et al* 2015, Rivero-Calle *et al* 2015, Lu *et al* 2016, Cheng *et al*, 2017, Gao *et al* 2019, Winkler *et al* 2019, Bastin *et al* 2020, Sswat *et al* 2018, Clark *et al* 2020). By contrast, mitigation policies of $CO_2$ emissions will have little effect on Earth's temperature as shown country by country in Table 1 even in terms of policies of largest emitters, especially with a TCR climate sensitivity equal or lower than 1°C, constrained by atmospheric $CO_2$ infrared spectrum. Values lower than 1°C are consistent with the near saturation observed in Figure 4, the plateau of TLS temperature in Figure 6 and the studies listed in Table 2. The natural variability of climate should be better taken into account (Scafetta *et al* 2020).

Frederikse *et al* (2020) report an average trend of 1.52 ± 0.33 mm per year for the sea level rise from 1900 to 2018. Such a rise do not show anything catastrophic. By considering 2,133 tide gauges, Parker and Ollier (2015) report an even lower average rise of 1.04 mm per year. By scrutinizing advection and subduction phenomena, Mörner (2016) confirms low sea level rise. In addition, Donchyts *et al* (2016) and Luijendijk *et al* (2018) report an average increase of continental surface with respect to sea surface and an average increase of the area of beaches in spite of erosion of several shores.

The highest biomass and biodiversity is present in tropical rainforests, and the least in cold polar regions (Brown 2013, Kraft *et al* 2011). Thus, higher temperatures than currently existing on Earth seem to be more favorable. Schulze-Makuch *et al* (2020) suggest "a slightly higher temperature, perhaps by 5 °C, similar to that of the early Carboniferous time period, would provide more habitable conditions until some optimum is reached". This recommendation questions the COP21 Paris agreement that pretends to limit the warming to 2 °C or even to 1.5 °C with respect to the preindustrial period. This means an increase of only 1 °C or 0.5 °C with respect to the beginning of this century since a warming of ~ 1 °C already occurred (Figure 2.5). Actually, it will be a benefit for the vegetal biomass as suggested by Schulze-Makuch *et al* (2020).

According to Kramm *et al* (2020), the average temperature of the Earth is 14.5 °C. Lindzen and Christy (2020) consider the average temperature as misleading because it is at any place on Earth almost as likely, at any given time, to be warmer or cooler than average. The temperature anomaly is much smaller than the temperature variations that all life on Earth regularly experiences, reason for which it appears questionable. As long as an additional average warning would not exceed 1.1 °C, it could remain beneficial to mankind in terms of global wealth (Tol 2009). In view of Table 1 and Eq. 6, an anthropogenic warning of 1.1 °C would hardly be reached until the end of this century at the present rate of $CO_2$ increase of 0.5 % per year even by retaining the CMIP6 TCR of 1.68 °C. The minor warming, therefore, remains beneficial to humanity in terms of global wealth (Tol 2009) and to vegetation (Schulze-Makuch *et al* 2020).

The origin of atmospheric $CO_2$, natural or anthropogenic, has no impact on the climate sensitivity. Conversely, the balance between natural and anthropogenic fractions as well as anthropogenic or natural origin of Earth's climate change, might have a decisive impact on policies of reduction of emissions if the anthropogenic fraction would appear minor. Since these policies have no impact on the natural fraction, massive expenditures might be useless or at least might have little efficiency.

**Conflict of Interests:** The author has no conflict of interests to declare. The study has been performed without external funding.

**Acknowledgement** – The author is indebted and expresses his thanks to the NOAA and UAH teams which provide online the data used in this study. The author thanks the referees for valuable comments.

## References

Abbot, J., Marohasy, J., 2017. The application of machine learning for evaluating anthropogenic versus natural climate change. *Geo. Res. J.* **14**, 36-46.

Aldrin, M., Holden, M., Guttorp, P., Skeie, R.B., Myhre, G., Berntsen, T.K., 2012. Bayesian estimation of climate sensitivity based on a simple climate model fitted to observations of hemispheric temperatures and global ocean heat content. *Environmetrics* **23**, 253–271.

Allmendinger, T., 2016. The thermal behavior of gases under the influence of infrared radiation. *Int. J. Phys. Sci.* **11**, 183-206.

Allmendinger, T., 2017. A novel investigation about the thermal behavior of gases under the influence of IR-radition: a further argument against the greenhouse thesis. *J. Earth Science & Climatic Change* **8**, 1000393.

Allmendinger, T., 2018. The thermal radiation of the atmosphere and its role in the so-called greenhouse effect. *Atmospheric and Climate Sciences* **8**, 212-234.

AR5, 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Armour, K. C. Energy budget constraints on climate sensitivity in light of inconstant climate feedbacks. *Nat. Clim. Change* **7,** 331–335 (2017).

Arrak, A., 2011. Arctic warming is not greenhouse warming. *Energy & Environment* doi.org/10.1260/0958-305X.22.8.1069

Avakyan, S.V., 2013. The role of solar activity in global warming. *Herald of the Russian Academy of Sciences* 83, 275-285.

Balling, R.C., 1994. Interpreting the global temperature record. *Economic Affairs* **14**, 18-21.

Bar-On, Y.M., Phillips, R., Milo, R., 2018. The biomass distribution on Earth. *PNAS* doi.org/10.1073/pnas.1711842115

Barrett, J., Bellamy, D., Hug, H., 2006. On the sensitivity of the atmosphere to the doubling of the carbon dioxide concentration and on water vapor feedback. *Energy & Environment* **17**, 603.

Bellamy, D., Barrett, J., 2007. Climate stability: an inconvenient proof. *Civil Engineering* **160**, 66-72.

Bastin, J.F., *et al*, 2020. The extent of forest in dryland biomes. *Science* **356**, 635-638.

Bates, J.R., 2016. Estimating climate sensitivity using two-zone energy balance model. *Earth and Space Science* **3**, 207–225.

Beenstock, M., Reingewertz, Y., Paldor, N., 2012. Polynomial cointegration tests of anthropogenic impact on global warming. *Earth Syst. Dynam.* **3**, 173-188.

Bengtsson, L. & Schwartz, S. E. Determination of a lower bound on Earth's climate sensitivity. *Tellus B* **65,** 21533 (2013)

Berry, E.X., 2019. Human $CO_2$ emissions have little effect on atmospheric $CO_2$. *Int. J. Atmospheric & Oceanic Sci.* **3**, 13-26.

Booth, R.J., 2018. On the influence of solar cycle lengths and carbon dioxide on global temperatures. *J. Atm. & Solar-Terrestrial Phys.* **173**, 96-108.

Brown, J.H., (2013). Why are there so many species in the tropics. *J. Biogeogr.* **41**, 8–22.

Bryson, R.A., Dittberner, G.J., 1976. A non-equilibrium model of hemispheric mean surface temperature. *J. Atmospheric Sci.* **33**, 2094-2106.

Buesseler, K.O., Boyd, P.W., Black, E.E., Siegel, D.A., 2020. Metrics that matter for assessing the ocean biological carbon pump. *PNAS* **18**, 9679-9687.

Byrne, R.H., Mecking, S., Feely, R.A., Liu, X.W., 2010. Direct observations of basin-wide acidification of the North Atlantic Pacific ocean. *Geophys. Res. Lett.* **37**, L02601.

Cess, R.D., Udelhofen, P.M., 2003. Climate change during 1985-1999: cloud interactions determined from satellite measurements. *Geophys. Res. Lett.* doi.org/10.1029/2002GL016128

Cheng, L., *et al* 2017. Recent increases in terrestrial carbon uptake at little cost to the water cycle. *Nature Comm.* DOI:10.1038/s41467-017-00114-5

Chilingar, G.V., Sorokhtin, O.G., Khilyuk, L., Gorfunkel, M.V., 2008. Greenhouse gases and greenhouse effect. *Environmental Geology* **58**, 1207-1213.

Chilingar, G., Sorokhtin, O., Khilyuk, L., Liu, M., 2014. Do Increasing Contents of Methane and Carbon Dioxide in the Atmosphere Cause Global Warming? *Atmospheric and Climate Sciences*, **4**, 819-827.

Choi, Y.S., Cho, H., Ho, C. H., *et al* 2014. Influence of non-feedback variations of radiation on the determination of climate feedback. *Theor Appl Climatol* **115,** 355–364.

Choudhury, B., Kukla, G., 1979. Impact of $CO_2$ on cooling of snow and water surfaces. *Nature* **280**, 668-671.

Christy, J.R., Herman, B., Pielke Sr, R., Klotzback, P., McNider, R.T., Hnilo, J.J., Spencer, R.W., Chase, T., Douglass, D., 2010. What do observational datasets say about modeled tropospheric temperature trends since 1979? *Remote Sensing* **2**, 2148.

Chylek, P. *et al.* 2007. Limits on climate sensitivity derived from recent satellite and surface observations. *J. Geophys. Res.* **112,** D24S04.

Clark, R., 2010. A null hypothesis for $CO_2$. *Energy Environ.* doi.org/10.1260/0958-305X.21.4.171

Clark, R., 2013. A dynamic, coupled thermal reservoir approach to atmospheric energy transfer. Part I: Concepts. *Energy & Environment* **24**, 319-340.

Clark, T.D., *et al*, 2020. Ocean acidification does not impair the behaviour of caral reef fishes. *Nature* **577**, 3706375.

Davis, W.J., 2017. The relationship between atmospheric carbon dioxide concentration and global temperature for the last 425 million years. *Climate* **5**, 76.

Davis, W.J., Taylor, P.J., Davis B., 2018. The Antarctic centennial oscillation: a natural paleoclimate cycle in the southern hemisphere that influences global temperature. *Climate* **6**, 3.

Donchyts, G. *et al*, 2016. Earth surface water change over the past 30 years. *Nature Climate Change* **6**, 810-813

Donohoe, A., Armour, K. C., Pendergrass, A. G. & Battisti, 2014. D. S. Shortwave and longwave radiative contributions to global warming under increasing $CO_2$. *Proc. Natl. Acad. Sci. USA* **111,** 16700–16705.

Donohue, R.J., *et al* 2013. Impact of $CO_2$ fertilization on maximum foliage cover across the globe's warm, arid environments. *Geophys. Res. Lett.* **40** 3031-3035.

Douglass, D.H., Pearson, B.D., Singer, S.F., 2004. Altitude dependence of atmospheric temperature trends: Climate models versus observation. *Geophys. Res. Lett.* **31**, L13208.

Douglass, D.H., Christy, J.R., Pearson, B.D., Singer, S.F., 2008. A comparison of tropical temperature trends with model predictions. *Int. J. Climatology* **28**, 1693.

Drotos, G., Becker, T., Mauritsen, T., Stevens, B. 2020. Global variability in radiative-convective equilibrium with a slab ocean under a wide range of $CO_2$ concentrations. *Tellus* A doi.org/10.1080/16000870.2019.1699387

Dyson, F.J., 1977. Can we control the carbon dioxide in the atmosphere? *Energy* **2**, 287-291.

Easterbrook, D.J., 2016. Evidence-based Climate Science Ed. Elsevier. doi.org/10.1016/B978-0-12-804588-6.00009-4

Ellis, R., Palmer, M., 2016. Modulation of ice ages via precession and dust-albedo feedbacks. *Geoscience Frontiers* **7**, 891-909.

Evans, D.M.W., 2016. Correcting problems with the conventional basic calculation of climate sensitivity. Evidence-based climate science, Ed. Elsevier doi.org/10.1016/B978-0-12-804588-6.00020-3

Fang, J-Y., Zhu, J-L., Wang, S-P., Yue, C., Shen, H-H., 2011. Global warming, human-induced carbon emissions, and their uncertainties. *Science China Earth Sciences* **54**, 1458.

Fleming, R.J., 2018. An updated review about carbon dioxide and climate change. *Environmental Earth Sciences* DOI: 10.1007/s12665-018-7438-y

Fleming, R.J., 2020. The Rise and Fall of the Carbon Dioxide Theory of Climate Change, Ed. Springer Nature, doi.org/10.1007/978-3-030-16990-3_15

Florides, G.A., Christodoulides, P., 2009. Global warming and carbon dioxide through sciences. *Environment International* **35**, 390-401.

Forest, C.E., Stone, P.H., Sokolov, A.P., 2006. Estimated PDFs of climate system properties including natural and anthropogenic forcings. *Geophys. Res. Lett.* 10.1029/2005GL023977

Forster, P. M. D. F. & Gregory, J. M. The climate sensitivity and its components diagnosed from Earth radiation budget data. *J. Clim.* **19,** 39–52 (2006).

Forster, P. M. *et al.* Recommendations for diagnosing effective radiative forcing from climate models for CMIP6. *J. Geophys. Res. Atmos.* **121,** 460–475 (2016).

Frame, D.J., Booth, B.B.B., Kettleborough, J.A., Stainforth, D.A., Gregory, J.M., Collins, M. Allen, M.R., 2005. Constrained climate forecasts: the role of prior assumptions. *Geophys. Res. Lett.* DOI: 10.1029/2004GL022241

Frederikse, T., *et al*, 2020. The causes of sea-level rise since 1900. *Nature* **584**, 393-397.

Friedlingstein, P., *et al*, 2006. Climate–Carbon Cycle Feedback Analysis: Results from the $C^4$MIP Model Intercomparison, *J. Climate* **19**, 3337-3353

Fu, Q., Manabe, S., Johanson, C.M., 2011. On the warming in the tropical upper troposphere: Models versus observations. *Geophys. Res. Lett.* **38**, L15704.

Gao, X. *et al*, 2019. Detected global agricultural greening from satellite data. *Agricultural & Forest Meteorology* **276**, 107652.

Gates, W.L., Cook, K.H., Schlesinger, M.E., 1981. Preliminary analysis of experiments on the climatic effects of increased $CO_2$ with an atmospheric general circulation model and a climatological ocean. *J. Geophys. Res.* **86**, 6385-6393.

Gerlich, G., Tscheuschner, R.D., 2009. Falsification of the atmospheric $CO_2$ greenhouse effect within the frame of physics. *Int. J. Modern Phys.* B **3**, 275-364

Gerlich, G., Tscheuschner, R.D., 2010. Reply to “Comment on falsification of the atmospheric $CO_2$ greenhouse effect within the frame of physics” by Halpern et al. *Int J. Modern Phys.* B **24**, 1333-1359.

Gervais, F., 2014. Tiny warming of residual anthropogenic $CO_2$. *Int. J. Modern Phys.* B 28, 1450095.

Gervais, F., 2016. Anthropogenic $CO_2$ warming challenged by 60-year cycle. *Earth-Science Reviews* **155**, 129-135.

Gillett, N.P., *et al,* 2021. Constraining human contributions to observed warming since the pre-industrial period. *Nat. Clim. Chang.* **11,** 207–212.

Golaz, J.-C., Horowitz, L.W., Levy, H., 2013. Cloud tuning in a coupled climate model: Impact on 20th century warming. *Geophys. Res. Lett.* **40**, 2246

Gregory, J.M., Stouffer, R.J., Raper, S.C.B., Stott, P.A., Rayner, N.A., 2002. An observationally based estimate of the climate sensitivity. *J. Climate* **15**, 3117-3121.

HadCRUT4, 2021. crudata.uea.ac.uk/cru/data/temperature

Haine, T.W.N., 2016. Vagaries of Atlantic overturning. *Nature Geoscience* **9**, 479-480.

Harde, H., 2013. Radiation and heat transfer in the atmosphere: a comprehensive approach on a molecular basis. *Int. J. Atmospheric Sci.* doi.org/10.1155/2013/503727

Harde, H., 2014. Advanced two-layer climate model for the assessment of global warming by $CO_2$. *Open J. Atm. Climate Change* DOI: 10.15764/ACC.2014.03001

Harde, H., 2017a. Scrutinizing the carbon cycle and the $CO_2$ residence time in the atmosphere. *Global and Planetary Change* DOI: org/10.1016/j.gloplacha.2017.02.009

Harde, H., 2017b. Radiation transfer calculations and assessment of global warming by $CO_2$. *Int. J. Atmos. Sci.* doi.org/10.1155/2017/925103

Harde, H., 2019. What humans contribute to atmospheric $CO_2$: comparison of carbon cycle models with observations. *Earth Sciences* **8**, 139-159.

Harvey, L. D. D. & Kaufmann, R. K., 2002. Simultaneously constraining climate sensitivity and aerosol radiative forcing. *J. Clim.* **15,** 2837–2861.

Hausfather, Z., 2018. www.carbonbrief.org/explainer-how-scientists-estimate-climate-sensitivity

Haustein, K., *et al*, 2019. A Limited Role for Unforced Internal Variability in Twentieth-Century

Warming. *J. Climate* DOI: 10.1175/JCLI-D-18-0555.1

Haverd, V., *et al*, 2020. Higher than expected $CO_2$ fertilization inferred from leaf to global observations. *Global Change Biology* **26**, 2390-2402.

Hertzberg, M., Schreuder, H., 2016. Role of atmospheric carbon dioxide in climate change. *Energy & Environment* DOI: 10.1177/0958305X16674637

Hertzberg, M., Siddons, A., Schreuder, H., 2017. Role of greenhouse gases in climate change. *Energy & Environment* doi.org/10.1177/0958305X17706177

Holmes, R.I., 2017. Molar Mass Version of the Ideal Gas Law Points to a Very Low Climate Sensitivity. *Earth Sciences* **6**, 157-163.

Holmes, R.I., 2019. On the apparent relationship between total solar irradiance and the atmospheric temperature at 1 bar on three terrestrial-type bodies. *Earth Sciences* **8**, 346-351.

Hug, H., 2000. A critical review of the hypothesis that climate change is caused by carbon dioxide. *Energy & Environment* **11**, 631.

Humlum, O., Stordahl, K., Solheim, J.E., 2013. The phase relation between atmospheric carbon dioxide and global temperature. *Global & Planetary Change* **100**, 51.

Humlum, O, 2020. www.climate4you.com

Idso, S.B., 1980. The climatological significance of a doubling of Earth's atmospheric carbon dioxide concentration. *Science* **207**, 1462-1463.

Idso, S.B., 1984. What if increases in atmospheric $CO_2$ have an inverse greenhouse effect? I. Energy balance considerations related to surface albedo. *J. Climatology* doi.org/10.1002/joc.3370040405

Idso, C.D., 2013. www.co2science.org/education/reports/co2benefits/
MonetaryBenefitsofRisingCO2onGlobalFoodProduction.pdf

Idso, S.B., 1998. $CO_2$-induced climate change: a skeptic's view of potential climate change. *Clim Res.* **10**, 69-82.

Jelbring, H., 2003. The "greenhouse effect" as a function of atmospheric mass. *Energy & Environment* DOI: 10.1260/095830503765184655

Johansson, D. J. A., O'Neill, B. C., Tebaldi, C. & Häggström, O. Equilibrium climate sensitivity in light of observations over the warming hiatus. *Nat. Clim. Change* **5,** 449–453 (2015).

Kaptué, A.T., Prihodko, L., Hanan, N.P., 2015. On regreening and degradation in Sahelian watersheds. *PNAS* **112**, 12133-12138.

Kato, S. et al, 2018. Surface irradiance of edition 4.0 Clouds and Earth's Radiant Energy System (CERES) Energy Balanced and Filled (EBAF) data product. *J. Climate* **31**, 4501-4527.

Kaufmann, R. K. & Stern, D. I. Cointegration analysis of hemispheric temperature relations. *J. Geophys. Res.* **107,** D000174 (2002).

Kauppinen, J., Heinonen, J., Malmi, P., 2014. Influence of relative humidity and clouds on the global mean surface temperature. *Energy & Environment* doi.org/10.1260/0958-305X.25.2.389

Kennedy, I.R., Hodzic, M., 2019. Testing the hypothesis that variations in atmospheric water vapour are the main cause of fluctuations in global temperature. *Periodical of Engineering & Natural Sciences* **7**, 870-880.

Khilyuk, L.F., Chilingar,G.V., 2006. On global forces of nature driving the Earth's climate. Are humans involved? *Environmental Geology* **50**, 899-910.

Khilyuk, L.F., Chilingar, G.V., 2003. Global warming: are we confusing cause and effect? *Energy sources* **25**, 357-370.

Kim, B-Y., Lee, K-T., 2019. Using the Himawari-8 AHI multi-channel to improve the calculation accuracy of outgoing longwave radiation at the top of the atmosphere. *Remote Sensing* **11**, 589.

Kimoto, K., 2015. Will coal save Japan and the world? *Energy & Environment* doi.org/10.1260/0958-305X.26.6-7.1055

Kissin, Y.V., 2015. A simple alternative model for the estimation of the carbon dioxide effect on the Earth's energy inbalance. *Energy & Environment* **26**, 1319-1333.

Knutti, R., Stocker, T.F., Joos, F., Plattner, G.K., 2002. Constraint on radiative forcing and future climate change from observations and climate model ensembles. *Nature* **416**, 719-723.

Knutti, R., Rugenstein, M., Hegerl, G., 2017. Beyond equilibrium climate sensitivity. *Nature Geoscience* **10,** 727–736.

Koutsoyiannis, D., Zbigniew, W.K., 2020. Atmospheric temperature and $CO_2$: hen-or-egg causality? *Sci* **2**, 83.

Krainov, V., Smirnov, B.M., 2019. Greenhouse effect in atmospheres of Earth and Venus doi.org/10.1007/978-3-030-21955-0_7

Kraft, N.J., *et al*, (2011). Disentangling the drivers of ß diversity along latitudinal and elevational gradients. *Science* **333**, 1755–1758.

Kramm, G., Dlugi, R., 2011. Scrutinizing the atmospheric greenhouse effect and its climatic impact. *Natural Science* **3**, 971.

Kramm, G., Dlugi, R., Mölder, N., 2017. Using Earth's moon as a testbed for quantifying the effect of the terrest atmosphere. *Natural Science* **9**, 78836.

Kramm, G., Berger, M., Dlugi, R., Mölders, N., 2020. Meridional Distributions of Historical Zonal Averages and Their Use to Quantify the Global and Spheroidal Mean Near-Surface Temperature of the Terrestrial Atmosphere. *Natural Sci.* **12**, 80-124.

Kuo, C., *et al.,* 1990. Coherence established between atmospheric carbon dioxide and global temperature. *Nature* **343**, 709-714.

Kummer, J. R. & Dessler, A. E., 2014. The impact of forcing efficacy on the equilibrium climate sensitivity. *Geophys. Res. Lett.* **41,** 3565–3568.

Laubereau, A., Iglev, H., 2013. On the direct impact of the $CO_2$ concenration rise to the global warning. *Europhysics Letters* **104**, 29001.

Levy, M., *et al,* 2013. Physical pathways for carbon transfers between the surface mixed layer and the ocean interior. *Global Biogeochem. Cycles* **27**, 1001–1012.

Lewis, N., 2013. An objective Bayesian, improved approach for applying optimal fingerprint techniques to estimate climate sensitivity. *J. Clim.* **26**, 7414–7429.

Lewis, N., 2016. Implications of recent multimodel attribution studies for climate sensitivity. *Climate Dynamics* **46,** 1387–1396.

Lewis, N., Curry, J.A., 2014. The implications for climate sensitivity of AR5 forcing and heat uptake estimates. *Climate Dynamics* doi:10.1007/s00382-014-2342-y.

Lewis, N. & Curry, J. A., 2015. The implications for climate sensitivity of AR5 forcing and heat uptake estimates. *Climate Dynamics* **45,** 1009–1023.

Lewis, N., Curry, J.A., 2018. The impact of recent forcing and ocean heat uptake data on estimates of climate sensitivity. *J. Climate* **31**, 6051-6071.

Lightfoot, H.D., Mamer, O.A., 2014. Calculation of atmospheric radiative forcing (warming effect) of carbon dioxide at any concentration. *Energy & Environment* doi.org/10.1260/0958-305X.25.8.1439

Lightfoot, H.D., Mamer, O.A., 2017. Back radiation versus $CO_2$ as a cause of climate change. *Energy & Environment* doi.org/10.1177/0958305X17722790

Lightfoot, H.D., Mamer, O.A., 2018. Carbon dioxide: sometimes it is a cooling gas, sometimes a warming gas. *Forestry Res. & Engineering* **2**, 169-174.

Lightfoot, H.D., 2020. The IPCC made three fatal errors in assumptions about $CO_2$. *J. Basic & Applied Sci.* **16***,* 94-104.

Lin, B. *et al*, 2010. Estimation of climate sensitivity based on top-of-atmosphere radiation imbalance. *Atmos. Chem. Phys.* **10**, 1923–1930.

Lindzen, R.S., 1994. On the scientific basis for global warming scenarios. *Environmental Pollution* **83**, 125-134.

Lindzen, R.S., Choi, Y.S., 2009. On the determination of climate feedbacks from ERBE data. *Geophys. Res. Lett.* **36**, L16705

Lindzen, R.S., Choi, Y.S., 2011. On the observational determination of climate sensitivity and its implications. *Asia-Pacific J. Atmos Sci.* **47**, 377.

Lindzen, R.S., Christy, J.R., 2020. The global mean temperature record: how it works and why it is misleading. co2coalition.org/publications/the-global-mean-temperature-anomaly-record

Loeb, N. G., Su, W., Kato, S., 2016. Understanding climate feedbacks and sensitivity using observations of Earth's energy budget. *Curr. Clim. Change Rep.* **2,** 170–178.

Loeb, N.G., *et al*, 2018. Changes in Earth's energy budget during and after the « pause » in global warming. *Climate* **6**, 62.

Loehle, C., 2014. A minimal model for estimating climate sensitivity. *Ecol. Modell.* **276,** 80–84.

Loehle, C., 2015. Global temperature trends adjusted for unforced variability. *Univers. J. Geosci.* **3,** 183–187.

Lovejoy, S., 2014. Return period of global climate fluctuations and the pause. *Geophys. Res. Lett.* doi.org/10.1002/2014GL060478

Lovejoy, S., 2017. How accurately do we know the temperature of the surface of the Earth? *Climate Dynamics* **49**, 4089-4106.

Lu, X., Wang, L., McCabe, M.F., 2016. Elevated $CO_2$ as a driver of global dryland greening. *Scientific Reports* doi:10.1038/srep20716

Luijendijk, A., *et al*, 2018. The state of the world's beaches. *Nature Sci. Rep.* DOI: 10.1038/s41598-018-24630-6

Manheimer, W., 2016. Two heretical thoughts on fusion and climate. *Energy & Environment* DOI: 10.1177/0958305X166746

Mauritsen, T., Stevens, B., 2015. Missing iris effect as a possible cause of muted hydrological change and high climate sensitivity in models. *Nature Geoscience* DOI: 10.1038/NGEO2414

McKitrick, R., Christy, J., (2020). Pervasive warming bias in CMIP6 tropospheric layers. *Earth and Space Science*, **7**, e2020EA001281.

Metcalfe, D.B., 2014. Climate science: a sink down under. *Nature* DOI: 10.1038/nature13341

Miskolczi, F., 2007. Greenhouse effect in semi-transparent planetary atmospheres. *Quarterly Journal of the Hungarian Meteorological Service* **111**, 1.

Miskolczi, F., 2010. Greenhouse effect and the IR radiative structure of the Earth's atmosphere. *Int. J. Environ. Res. Public Health* doi: 10.3390/ijerph70x000x

Miskolczi, F.M., 2014. The greenhouse effect and the infrared radiative structure of the Earth's atmosphere. *Dev. in Earth Science* **2**, 31-52.

Monckton, C., Soon, W., Legates, D.R., Briggs, W.M., 2015. Why models run hot: results from an irreducibly simple climate model. *Sci. Bull.* **60,** 122–135.

Mörner, N.A., 2016. Rates of sea level changes – A clarifying note. *Int. J. Geosciences* **7**, 1318-1322

Murphy, D. M. *et al.* An observationally based energy balance for the Earth since 1950. *J. Geophys. Res.* **114,** D012105 (2009).

Myrhe, G., Highwood, E.J., Shine, K.P., Stordal, F., 1998. New estimates of radiative forcing due to well mixed greenhouse gases. *Geophys. Res. Lett.* **25**, 2715.

Myrvoll-Nielsen, E., *et al*, 2020. Statistical estimation of global surface temperature response to forcing under the assumption of temporal scaling. *Earth Syst. Dynam.* **11**, 329-345.

Nahle, N.S., 2011. Determination of Mean Free Path of Quantum/Waves and Total Emissivity of the Carbon Dioxide Considering the Molecular Cross Section. *Biology Cabinet* www.biocab.org/Mean_Free_Path_Length_Photons.html

Newell, R.E., Dopplick, T.G., 1979. Concerning the possible influence of anthropogenic $CO_2$ on atmospheric temperature. *J. Appl. Meteorology* **18**, 822-825.

Nikolov, N., Zeller, K., 2017. New Insights on the Physical Nature of the Atmospheric Greenhouse Effect Deduced from an Empirical Planetary Temperature Model. *Environ. Pollut. Climate Change* **1**, 112.

Nijsse, F. J. M. M., Cox, P. M., and Williamson, M. S., 2020. Emergent constraints on transient climate response (TCR) and equilibrium climate sensitivity (ECS) from historical warming in CMIP5 and CMIP6 models, *Earth Syst. Dynam.* **11**, 737–750

NOAA, 2020. www.esrl.noaa.gov/gmd/ccgg/trends/

Oliver, R.C., 1976. On the response of hemispheric mean temperature to stratospheric dust: an empirical approach. *J. Applied Meteorology* **15**, 933-950.

Ollila, A.V.E., 2013. The roles of greenhouse gases in global warming. *Energy & Environment* doi.org/10.1260/0958-305X.23.5.781

Ollila, A.V.E., 2014. The potency of carbon dioxide ($CO_2$) as a greenhouse gas. *Development in Earth Science* **2**, 20-30.

Ollila, A.V.E., 2016. Climate sensitivity parameter in the test of the Mount Pinatubo eruption. *Phys. Sci. Int. J.* **9,** 1-14.

Ollila, A.V.E., 2017. Warming effect reanalysis of greenhouse gases and clouds. *Ph. Sc. Int. J.* **13**, 1-13.

Ollila, A., 2019. Challenging the greenhouse effect specification and the climate sensitivity of the IPCC. *Phys. Sci. Int. J.* **22**, 1-19.

Ollila, A., 2020. The pause end and major temperature impacts during super El Niños are due to shortwave radiation anomalies. *Phys. Sci. Int. J.* **24**, 55149.

Otto, A., *et al*, 2013. Energy budget constrains on climate response. *Nature Geosciences* **6**, 415-416.

Paltridge, G., Arking, A., Pook, M., 2009. Trends in middle- and upper-level tropospheric humidity from NCEP reanalysis data. *Theoretical & Applied Climatology* **98**, 351.

Park, J., 2009. A re-evaluation of the coherence between global-average atmospheric $CO_2$ and temperatures at interannual time scales, *Geophys. Res. Lett.* 36, L22704.

Parker, A., Ollier, C.D., 2015. Analysis of sea level time series. *Phys. Sci. Int. J.* **6**, 119-130

Poorter, L., Bongers, F., Rozendaal, D.M.A., 2016. Biomass resilience of neotropical secondary forests. *Nature* **530**, 211-214.

Quirk, T., 2009. Sources and sinks of carbon dioxide. *Energy & Environment* **20**, 103-119.

Ramanathan, V., 1981. The role of ocean-atmosphere interactions in the $CO_2$ climate problem. *J. Atmospheric Sci.* **38**, 918-930.

Rasool S.I., Schneider S.H., 1971, Atmospheric carbon dioxide and aerosols: effects of large increases on global climate. *Science* **173**, 138.

Reynen, J., 2014. Finite element model for atmospheric IR absorption. principia-scientific.com/publications/Reynen-Finite.pdf

Ring, M.J., Lindner, D., Cross, E.F., Schlesinger, M.E., 2012. Causes of the global warming observed since the 19th century. *Atmos. Clim. Sci.* **2**, 401-415.

Rivero-Calle, S., Gnanadesikan, A., Del Castillo, C.E., Balch, W., Guidema, S.D., 2015. Multidecadal increase in North Atlantic coccolithophores and the potential role of rising $CO_2$. *Science* DOI: 10.1126/science.aaa8026

Robertson, J.O., Chilingar, G.V., 2017. Effect of emission of $CO_2$ and $CH_4$ into the atmosphere. *Env. Aspects of Oil & Gas Production* doi.org/10.1002/9781119117421.ch4

Robock, A., 1979. "The little ice age": northern hemisphere average observations and model calculations. *Science* **206**, 1402-1404.

RSS 2021. www.remss.com/research/climate

Salby, M.L., 2012. *Physics of the Atmosphere and Climate,* 2nd Edition, Cambridge: Cambridge University Press.

Scafetta, N., Mirandola, A., Bianchini, A., 2017. Natural climate variability, part 2 : interpretation of the post 2000 temperature standstill. *Int. J. of Heat and Technology* **35**, S18-S26.

Scafetta, N., Milani, F., Bianchini, A., 2020. A 60-year cycle in the meteorite fall frequency suggests a possible interplanetary dust forcing of the Earth's climate driven by planetary oscillations. *Geophys. Res. Lett.* **47**, e2020GL089954.

Scafetta, N., 2021a. Reconstruction of the Interannual to Millennial Scale Patterns of the Global Surface Temperature. *Atmosphere* **12**, 147.

Scafetta, N., 2021b. Detection of non-climatic biases in land surface temperature records by comparing climatic data and their model simulations. *Climate Dynamics* doi.org/10.1007/s00382-021-05626-x

Schildknecht 2020. Saturation of the infrared absorption by carbon dioxide in the atmosphere. *Int. J. Modern Phys.* B doi.org/10.1142/S0217979220502938

Schmithüsen, H., *et al*, 2015. How increasing $CO_2$ leads to an increased negative greenhouse effect in Antarctica. *Geophys. Res. Lett.* doi.org/10.1002/2015GL066749

Schuurmans C.J.E. 1983. On the Detection of $CO_2$-Induced Climatic Change. In: Bach W., Crane A.J., Berger A.L., Longhetto A. (eds) Carbon Dioxide. Springer, Dordrecht. doi.org/10.1007/978-94-009-6998-8_12

Schwartz, S. E. 2007. Heat capacity, time constant, and sensitivity of Earth's climate system. *J. Geophys. Res.* **112,** D24S05.

Schwartz, S.E., 2012. Determination of Earth's transient and equilibrium climate sensitivities from observations over the twentieth century: strong dependence on assumed forcing. *Surveys in Geophysics* **33**, 745-777.

Segalstad T., 1998. *in* Global warming: the continuing debate ed. R. Bate, ESEF, Cambridge, U.K.

Sejas, S.A., Taylor, P.C., Cai, M., 2018. Unmasking the negative greenhouse effect over the Antarctic plateau. *npj Climate & Atmospheric Sci.* **1**, 17.

Singer, S.F., 2013. Inconsistency of modeled and observed tropical temperature trends. *Energy & Environment* **24**, 405-413 – Overcoming chaotic behavior of climate models. *Energy & Environment* **24**, 397-403.

Sfica, L., Beck, C., Nita, A-I., Voiculescu, M., Birsan, M-V., Philipp, A., 2021. Cloud cover changes driven by atmospheric circulation in Europe during the last decades. *Int. J. Climatology* **41**, E2211-E2230.

Sherwood, S.C. et al, 2020. An assessment of Earth's climate sensitivity using multiple lines of evidence. *Reviews of Geophysics* **58**, e2019RG000678.

Skeie, R.B., Berntsen, T., Aldrin, M., Holdren, M., Myhre, G., 2014. A lower and more constrained estimate of climate sensitivity using updated observations and detailed radiative forcing time series. *Earth Syst. Dynam.* **5**, 139.

Skeie, R.B., Berntsen, T., Aldrin, M., Holden, M., Myrhe, G., 2018. Climate sensitivity estimates – sensitivity to radiative forcing time series and observational data. *Earth Syst. Dynam.* **9**, 879–894.

Smirnov, B.M., 2016. Greenhouse effect in the atmosphere. *Europhysics Lett.* **114**, 24005.

Smirnov, B.M., 2017. Infrared atmospheric emission. *In*: Microphysics of Atmospheric Phenomena. Ed. Springer doi.org/10.1007/978-3-319-30813-5_10

Smirnov, B.M., 2018. Collision and radiative processes in emission of atmospheric carbon dioxide. *J. Phys. D: Appl. Phys.* **51,** 214004.

Soares, P.C., 2010. Warming power of $CO_2$ and $H_2O$: correlations with temperature changes. *Int. J. Geosciences* **1**, 102-112.

Song, J., Wang, Y., Tang, J., 2016. A hiatus of the greenhouse effect. *Scientific Reports* **6**, 33315.

Soon, W., Connolly, R., Connolly, M., 2015. Re-evaluating the role of solar variability on Northern Hemisphere temperature trends since the 19th century. *Earth-System Reviews* **150**, 409-452.

Specht, E., Redemann, T., Lorenz, N., 2016. Simplified mathematical model for calculating global warming through anthropogenic $CO_2$. *Int. J. Therm. Sci.* **102,** 1-8.

Spencer, R.W., Braswell, W.D., 2010. On the diagnosis of radiative feedback in the presence of unknown radiative forcing. *J. Geophys. Res.* **115**, D16109.

Spencer, R.W., Christy, J.R., Braswell, W.D., 2017. UAH version 6 global satellite temperature product: methodology and results. *Asia-Pacific J. Atmospheric Sci.* **53**, 121. DOI: 10.1007/s13143-017-0010-y – http://vortex.nsstc.uah.edu/data/msu/v6.0/tlt/uahncdc_lt_6.0.txt

Spencer, R.W., 2021. www.drroyspencer.com/wp-content/uploads/68-models-vs-obs-1979-2021-oceans-Fig01.jpg

Sswat, M., et al 2018. Growth performance and survival of larval Atlantic herring, under the combined effects of elevated temperatures and $CO_2$. *PLoS ONE* 13, e0191947.

Stern, D. I. 2006. An atmosphere–ocean time series model of global climate change. *Comput. Stat. Data Anal.* **51,** 1330–1346.

Stallinga, P., 2018. Signal analysis of the climate: correlation, delay and feedback. *J. Data Analysis & Information Processing* **6**, 30-45.

Stallinga, P., 2020. Comprehensive analytical study of the greenhouse effect in the atmosphere. *Atmospheric and Climate Sciences* **10**, 40-80

Swift, L., 2018. A new radiative model derived from solar insolation, albedo, and bulk atmospheric emissivity: application to Earth and other planets. *Climate* **6**, 52.

Urban, N. M., Holden, P. B., Edwards, N. R., Sriver, R. L. & Keller, K. 2014. Historical and future learning about climate sensitivity. *Geophys. Res. Lett.* **41,** 2543–2552.

Tol, R.S.J., 2009. The economic effect of climate change. *J. Economic Perspectives* **23**, 29-51.

Tsushima, Y., Abe-Ouchi, A. & Manabe, S. Radiative damping of annual variation in global mean surface temperature: comparison between observed and simulated feedback. *Clim. Dyn.* **24,** 591–597 (2005).

UAH 2021. vortex.nsstc.uah.edu/data/msu/v6.0/tlt/uahncdc_lt_6.0.txt

Van Brunt, W.A., 2020. Autonomous changes in the concentration of water vapor drive climate change. *Atmospheric & Climate Change* **10**, 443-508.

Vares, D.A.E., Carniello, T.N., Persinger, M.A., 2016. Quantification of the diminishing Earth's magnetic dipole intensity and geomagnetic activity as the causal source for global warming within the oceans and atmosphere. *Int. J. Geosciences* **7**, 63199.

Varotsos, C.A., Efstathiou, M.N., 2019. Has global warming already arrived? *J. Atmospheric & Solar-Terrestrial Physics* **182**, 31-38.

Volodin, E., *et al*, 2019. *INM-CM4-8 model output prepared for CMIP6* doi.org/10.22033/ESGF/CMIP6.5080

Wagoner, P., Liu, C., Tobin, R.G., 2010. Climate change in a shoebox: right result, wrong physics. *Am. J. Phys.* DOI: 10.1119/1.3322738

Wang, C., Soden, B.J., Yang, W., Vecchi, C.A., 2021. Compensation between cloud feedback and aerosol-cloud interaction in CMIP6 models. *Geophys. Res. Lett.* DOI: 10.1029/2020GL091024

Weare, B., Snell, F.M., 1974. A diffuse thin cloud atmospheric structure as a feedback mechanism in global climatic modelling. *J. Atmospheric Sci.* **31**, 1725-1734.

Wild, M., 2020. The global energy balance as represented in CMIP6 climate models. *Climate Dynamics* **55**, 553-577.

Willett, H.C., 1974. Do recent climatic fluctuations portend an imminent ice age? *Geofisica International* **14**, 265-302.

Winkler, A.J., *et al*, 2019. Earth system models underestimate carbon fixation by plants in the high latitudes. *Nature Comm.* doi.org/10.1038/s41467-019-08633-z

Wong, E. W., Minnett, P. J. (2018). The response of the ocean thermal skin layer to variations in incident infrared radiation. J. Geophys. Res.: Oceans **123**, 2475–2493.

Zdunkowski, W.G., Paegle, J., Fye, F.K., 1975. The short-term influence of various concentrations of atmospheric carbon dioxide on the temperature profile in the boundary layer. *Pure and Applied Geophysics* **113**, 331-353.

Zeng, N., Mariotti, A., Wetzel, P., 2005. Terrestrial mechanisms of interannual $CO_2$ variability. *Global Biogeochemical Cycles* **19**, GB1016.

Zhao, X. 2011. Is global warming mainly due to anthropogenic greenhouse gas emissions? *Energy Sources* A **33**, 2011.

Zhu, J., Poulsen, C. J., Otto-Bliesner, B. L., (2020). High climate sensitivity in CMIP6 model not supported by paleoclimate. *Nature Climate Change* **10**, 378–379.

Zhu, Z., *et al*., 2016. Greening of the Earth and its Drivers. *Nature Climate Change.*
DOI: 10.1038/nclimate3004