OPINION

A general linear model to describe observed global warming as a function of the atmospheric surface concentrations of greenhouse gases and greenhouse constants

Rasmus Friberg

Friberg R. A general linear model to describe observed global warming as a function of the atmospheric surface concentrations of greenhouse gases and greenhouse constants. J Pure Appl math.2024; 8(5):1-4

ABSTRACT

This is the first paper in a series of papers with the overall aim of analyzing and deriving theoretical models to indirectly measure and test the root cause of observed Global Warming (GW) and the Greenhouse Effect (GHE) at the earth's surface due to the atmospheric concentration of Greenhouse Gases (GHGs) in general and the Mass of Anthropogenic CO_2 Emissions (MACE) in particular. The objective of this specific paper is to present a new theoretical model, which are the framework theory and the starting point for explaining the relationship between observed Global Warming (GW) and the atmospheric concentrations of Greenhouse Gases (GHGs). It is derived from the theory of Lambert–Beer–Bouger's law, Planck's law and the heat balance over the atmospheric surface layer, where the GW is measured. The result is called the general linear model of GW (GLMGW). Consequently, the GLMGW indicates that there is a linear relationship between the observed GW (and GAST-global atmospheric surface temperature) and the GHG atmospheric surface concentrations. The characteristic constants of the GLMGW are the greenhouse constants for each GHG, which is a measure of how much the temperature rises per atmospheric concentration of a given greenhouse gas. The claims originating from the GLMGW were tested directly or indirectly in subsequent papers (Evidences I-V) based on the global data series of temperature and atmospheric GHG concentrations obtained from NOAA, ECMWF and GCP. Several new practical validated measurement models are available for calculating and forecasting GW as a function of the dominant GHGs. The different models can be used with high measurement certainty and forecasting capability to estimate several different quantities in the context of the GW; for example, the Global Atmospheric Surface Temperature Anomaly (GASTA) can be used as a function of the atmospheric CO_2 concentration, and the remaining time and remaining MACE can be used to breach the 1.5K and 2.0K limits.

Key Words: *Global warming; Greenhouse effect; Keeling curve; Greenhouse gases; climate sensitivity*

INTRODUCTION

This paper presents a new theoretical model, which is the core theoretical result of comprehensive research carried out by this author during the 2020-2023 time period, with respect to observed Global Warming (GW) and the Greenhouse Effect (GHE). The complete work on GW and GHE by this author is presented in a series of papers with the main objective of testing and quantifying the main hypothesis that Anthropogenic CO_2 Emissions (ACE) are the root cause of observed global warming. In other words, is it possible to distinguish CO_2 as a single dominant Greenhouse Gas (GHG) among the many claimed GHGs, such as methane, nitrous oxide, and chlorinated hydrocarbons? This first paper derives the overarching theoretical framework, which subsequent papers use to directly or indirectly derive partial hypotheses to be tested against empirical evidence.

Furthermore, the theoretical model derived herein is based on the classical radiation absorption theory applied to gases, namely, the Lambert–Beer–Bouguer law (LBBL), for an optically thin Atmospheric Surface Layer (ASL). The resulting model is referred to as the General Linear Model of Global Warming (GLMGW). The model describes the observed Global Atmospheric Surface Temperature (GAST) as a function of the observed atmospheric Greenhouse Gas Concentration (GHG) via a linear model (Figure 1). The GLMGW was initially developed since simple theoretical models for describing GW and the GHE are rare in the literature.

Bircham International University, United States

Correspondence: Rasmus Friberg, Independent Researcher, Stockholm, Sweden, e-mail: rasfri.rf@gmail.com

Received: 3 Sep, 2024, Manuscript No. puljpam-24-7203, Editor Assigned: 5 Sep, 2024, PreQC No. puljpam-24-7203(PQ), Reviewed: 8 Sep, 2024, QC No. puljpam-24-7203(Q), Revised: 13 Sep,2024, Manuscript No. puljpam-24-7203(R), Published: 30 Sep, 2024, DOI:-10.37532/2752-8081.24.8(5).01-04

This author initiated this research effort on the basis that several basic questions are still unsatisfactorily resolved and associated with unreasonably high uncertainties in the scientific literature regarding claims about GHE and GW. The following are a few examples of basic questions:

1. Is there a linear, logarithmic, polynomial or exponential relationship between the observed GW and the GHG concentrations at the surface of earth?
2. How much does the atmospheric surface temperature increase as a function of the atmospheric CO_2 concentration [K/ppm CO_2].
3. Are there any dominant GHGs and can some of the claimed GHGs (forcing agents) be neglected because of their small contribution to the GHE? and
4. to what degree are the mass of anthropogenic CO_2 emissions responsible for the observed GW? The questions above and several other related topics are derived, tested and proven in this work by the combination of theory and empirical evidence.

Furthermore, there is no doubt among researchers about the existence of GW and its magnitude at the surface of the earth; see Figure 1. However, how to mathematically describe the GW curve in terms of the GHE, that is, the GHGs and their atmospheric concentrations, is still highly uncertain. The latter fact is directly correlated with the uncertainties reflected in the four questions above. In conclusion, in the scientific literature in general and in the IPCC reports in particular, this author has not been able to find any basic or unequivocal engineering model with a reliable measurement uncertainty describing the relationship between the observed GW data series and the observed concentration of GHGs (Figure 1).

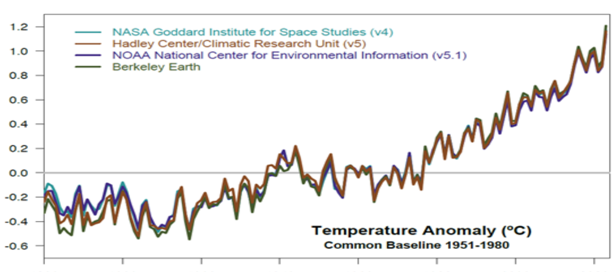

Figure 1) *There is high agreement between some of the most well-known data measurement series of the global atmospheric surface temperature anomaly (GASTA). Records are rebaselined to a common 1951–1980 reference period.*

Therefore, the main objective of this author's research has been to develop simplified, robust and unequivocal engineering models relating the observed GW and observed atmospheric concentrations of GHGs. The main requirement with respect to model development has been that the model be developed based on classical physics in combination with the validated global measurement data series (Figure 1). Furthermore, the developed measurement model should be able to indirectly measure the observed GW datasets for a defined operating range of GHG concentrations, with an acceptable measurement uncertainty.

This paper comprises a summary of the main part of the work, a literature review, and the derivation of the theoretical model, that is, the GLMGW. For the reader to have an overview of the work, a summary is made of the most important results of the first six articles, including this paper. The literature review briefly reviews the historical developments within the theory of absorption spectroscopy, which is the theoretical branch that explains the physics behind the GHE, which is IR absorption by GHGs. Finally, the GLMGW is mathematically derived based on a physical model that defines the important premises and assumptions constituting the theory.

Finally, the lack of simple and unequivocal measurement models based on validated measurement data series might be part of the fact that there has been such high protest and skepticism among the public. There is still significant denial regarding the GHE and the GW among scientists, politicians, business leaders and layman. They dismiss the claimed theory and evidence that anthropogenic emissions of CO_2 and greenhouse gases cause the observed GW. This author believes that, not until we have developed reliable, simplified and validated measurement models that concretely connect the observed GW curve (recall Figure 1) with atmospheric concentrations of GHGs, we can confidently and effectively argue for a global phase out of fossil fuels among all nations. This work presents a solution to the addressed problem.

Because of the extensive work by Dr Friberg on the GW and the GHE, it needed to be broken down into parts. The entire work consists of more than six papers presenting several groundbreaking results and findings obtained during the research work on the GW and GHE. However, only six of these studies are summarized below since they cover more than enough of the most important results and conclusions, resolving the main problems defined above and below.

Furthermore, a logical red line delineates the entire work, starting from the derivation of the GLMGW herein. At least seven major linked research topics, to finally arrive at a complete picture of the GW and GHE, were identified and resolved during this work. Here, evidence is defined as at least one piece of empirical evidence tested on the theory (hypothesis), which is the basis of each paper. Each piece of evidence tests the claims that directly or indirectly emanates from the GLMGW derived herein by means of global datasets, such as temperature, atmospheric concentrations of CO_2 and H_2O, and mass of anthropogenic CO_2 emissions. Consequently, to fully comprehend and appreciate the results and logic of each separate piece of evidence, the entire work needs to be studied. Therefore, in addition to this paper, each piece of paper is referred to Evidence X and may include references to other papers (evidence) of the series. The datasets used to test the theories are presented and appended in each paper for the sake of reproduction.

The first paper in the series of papers starts by deriving a new hypothetical model (theory) to explain the GHE and GW. It expresses the relationship between the observed GW (GAST) based on classical physical laws and atmospheric greenhouse gases (GHGs). The derived theory is defined for the surface of earth, which is the so-called Atmospheric Surface Layer (ASL). This model is referred to as the General Linear Model of GW (GLMGW) and describes GAST as a linear combination of all GHG atmospheric surface concentrations. The characteristic constants of GLMGW are the individual

Greenhouse Temperature Constants of each GHC. The GLMGW is directly or indirectly the theoretical basis for all the other papers in the series.

The second paper tests the hypothesis that the supposedly strongest GHG, carbon dioxide (CO_2), and its dataset of the global Atmospheric Surface Concentrations of CO_2 (GACC, Keeling Curve) drive the observed GW; recall figure 1. The theory behind the hypothesis is based on the GLMGW. This model is called the Simple Model of GW 1 (SMGW1) because the average GW (average GAST) can be described as a function of CO_2 alone. It has the second highest atmospheric concentration of all GHGs. Consequently, the GACC for the time period 1959-2022 is tested separately according to SMGW1, assuming that the GHG with the highest atmospheric concentration of all GHGs, that is, H_2O, is linearly dependent on CO_2 and feedback only in the GW regime. Simply put, all the other potential GHGs, according to the GLMGW, are assumed to have neglectable GW effects. As a result, the empirical correlations between GAST and GACC exhibited strong linear behavior throughout the entire period, which is the first strong indication that GLMGW is correct and that the atmospheric concentration of CO_2 is the root cause of the observed GW. The characteristic constants of SMGW1 are quantified as the global effective linear CO_2 greenhouse (temperature) constant (effective CO_2 greenhouse constant) and the Fundamental Global Atmospheric Surface Temperature (FGAST). The effective CO_2 greenhouse constant is indirectly measured to be 0.010 K per ppm CO_2. The greenhouse constant is a measure of how much the atmospheric surface temperature changes based on a change in the atmospheric CO_2 concentration. FGAST is defined as GAST for a CO_2-free atmosphere, and moisture is the only existing GHG in the atmosphere. FGAST is estimated to be 283.8K. By means of SMGW1, the average GASTA (global atmospheric surface temperature anomaly) can be estimated with high measurement certainty. The indirect measurements show that GASTA≈1.39 K at the beginning of 2023, assuming a preindustrial CO_2 concentration of 280 ppmv. In other words, the GASTA is only 0.11 K below the 1.5 K limit. Preliminary results applying SMGW1 predict that the 1.5K limit will be breached by the mid-2027±0.5 years, which is verified.

The third paper analyses the question of whether the recorded datasets of Mass Anthropogenic CO_2 Emissions (MACE-Gton of CO_2) are the root cause of the observed increase in the GACC. A new and simplified linear theory to describe the GACC as a function of the cumulative MACE (cMACE) based on classical chemical laws is derived and tested in Evidence II. The theory derived in Evidence II is called the Simple Model Of Global Atmospheric Concentration of CO_2 2 (SMGACC2), where the GACC is described as a linear function of cMACE. The results of the empirical correlations between GACC and cMACE are nearly perfectly linear in the range of 0-1,800 Gton of ACE, which strongly indicates that MACE is the root cause of the observed increase in GACCs. The characteristic constant of SMGACC2 is quantified and called the effective linear CO_2 emission transfer constant. The transfer constant estimates the fraction of cMACE that stays in the atmosphere. By means of SMGACC2, the total mass of atmospheric CO_2 and the total mass of the atmosphere can be indirectly measured.

The fourth paper is the final test of the hypothesis that the anthropogenic emissions of CO_2 are the single dominant driver of the observed GW. The theory derived is the combination of SMGW1 (Evidence I) and SMGACC2, which results in the Simple Model of GW 2 (SMGW2). GAST is a linear function of cMACE. The empirical correlation test between the GAST and cMACE data series revealed undoubtly linear features, in addition to some minor interannual variability, in the range of 0-1,800 Gton in the ACE. The characteristic constant of SMGW2 is quantified and called the effective CO_2 emission temperature constant. In conclusion, unequivocally shows that anthropogenic CO_2 emissions are the driver and the root cause of the observed GW, and this finding point indirectly to the fact that no other GHGs besides CO_2 and H_2O have a significant GHE. By means of SMGW2, the remaining time and remaining cMACE required to breach the 1.5K and 2.0K limits can be calculated. Estimations confirm that the 1.5K limit is breached around mid-2027±0.5 years. The estimated remaining cMACE to breach the 1.5K limit is 197 ± 26 Gton ACE.

The fifth paper tests the hypothesis that the observed GW curve is completely described by the GLMGW and the atmospheric surface concentrations of the two most dominant GHGs, that is, carbon dioxide (CO_2) and water vapor (H_2O) (Figure 1). The theory derived from the GLMGW is called the Special Linear Model of GW (SLMGW). The empirical correlation tests and multiple regression between the XAST, GACC and XASCM (domain atmospheric surface concentration of moisture) data series show good agreement between the XAST and the SLMGW for all three domains (X=global, sea and land). The agreement for the global and sea domains is high. The characteristic constants of the SLMGW are quantified. These parameters include the FXGBT (fundamental domain grey-body temperature) and the individual linear greenhouse constants of CO_2 and H_2O for each domain. The Fundamental Global Grey-Body Temperature (FGGBT) is indirectly measured to be 274.8 K, which explains why the earth is only partially an ice ball. The FGGBT=274.8K contradicts the present theory, which claims that the blackbody temperature is approximately 255 K. The higher ground temperature of the earth discovered in this work is explained by the fact that both the SWR and LWR strike the earth constantly, not only the SWR. This is derived and tested in a subsequent paper not yet published. Furthermore, the theory and empirical evidence of show that CO_2 explains the upward trend and that H_2O describes the interannual variability of the GW curve. By means of the SLMGW, the GAST(A) can be indirectly measured as a function of the atmospheric concentrations of CO_2 and H_2O and compared with the direct temperature measurements of the GAST(A). The absolute measurement uncertainty (2σ) of the SLMGW for the global domain is ±0.067 K for the entire time period from 1959–2022. In conclusion, the results of Evidence IV show that no GHGs other than CO_2 or H_2O are required to explain the observed GW.

Finally, the sixth paper tests the hypothesis that FGAST=283.8 K is indirectly linked to FGGBT=274.8 K (Evidence IV) via the Fundamental Global Atmospheric Surface Greenhouse Temperature (FGASGHT=FGAST-FGGBT=9K). The latter quantity is caused by the fundamental GHE due to the fundamental atmospheric surface concentration of moisture, which is a result of the FGGBT and the evaporation of GHG water vapor from the giant oceans of the earth. A theory (iterative algorithm) for calculating the equilibrium FGAST is derived. It is based on the Clausius–Clapeyron equation and the GHE described by the SLMGW. The results of the algorithm show very good agreement with the indirectly measured FGGBT and FGAST results. This result eventually shows that the SLMGW accurately describes the GHE at the surface of earth and that the greenhouse constants of the most dominant GHGs can be quantified and used to determine the GW at the Earth's surface. The results also prove that the Clausius–Clapeyron equation controls the fundamental atmospheric moisture concentration and, in turn, the fundamental GHE, FGASGHT and FGAST. Consequently, the scientific certainty about the cause and effect of GW and GHE according to the GLMGW in general and the SMGW1 and SLMGW in particular reaches a climax. The remaining quantity to theoretically derive and explain is the origin of the FGGBT=274.8K, which will be presented in a subsequent paper.

This will focus on the classical work of radiation absorption theory, which has led to the development of mathematical tools to describe IR absorption by IR-absorbing gases (greenhouse gases). IR-absorption is the primary cause of GHE and is also referred to as the IR-Thermal Effect (IRTE) hereafter. The reader should be acquainted with the early discoveries of the GHE by Fourier, Tyndall, Arrhenius and Callendar. A number of reviews on the early scientific discoveries of the GHE, the early developments of absorption spectroscopy theories, and climate and GW modeling exist for the reader who wants to dwell more on the scientific history.

Radiation absorption theory for gases in the context of GW at the surface of earth

Here, is a brief review of the development of the radiation absorption theory for gases, which mathematically and quantitatively describes IR absorption by certain gases. The Irish scientist John Tyndall first discovered this natural phenomenon in 1861. IR absorption is the main mechanism behind IRTE (GHE) and is also believed to dominate the observed GW due to GHGs. The scientific history of the radiation absorption theory for gases is central to the scientific history of GW and the GHE, but strangely, it is often neglected.

The first three scientists mentioned, who directly or indirectly made important contributions to the theoretical understanding of the absorption and emission of light by gases, are the three German scientists Gustav Kirchoff, Robert Bunsen and Joseph von Fraunhofer, who were the first to establish the theory of spectrum analysis with respect to gases. Fraunhofer invented the first spectrometer. Notably, Kirchoff also made important contributions to the understanding of black-body radiation.

The first documented attempts to mathematically analyze and describe the relationship between the transmission of radiative flux (electromagnetic radiation, irradiance, light intensity, radiation flux) and its attenuation, due to absorption through a medium (gas, liquid, solid), were made by the French astronomer Pierre Bouguer (1729). He realized that the loss in irradiance $(d\dot{E}''_{tr})$ when light travels through a medium is directly proportional to its radiant flux and path length. By this discovery, he laid the first foundation and one of the most important theoretical laws in the field of spectroscopy, namely, the Lambert–Beer-Bouguer's Law (LBBL). The latter have many names, such as Bouguer-Beer–Lambert's Law, Lambert–Beer's Law, Beer–Lambert's Law and Lambert's equation.

However, LBBL was initially attributed to Johann Heinrich Lambert because he was the first to mathematically formulate the overall relationship between irradiance and transmission through a body of a given thickness in his Photometria (1760). Lambert assumed that the attenuated light intensity could be described by a differential equation according to Bouguer's original ideas, which Lambert was well aware of,

$$d\dot{E}''_{tr}(\lambda) = -\mu\dot{E}''_{tr}(\lambda)dx \quad (1)$$

The proportionality factor (μ) is defined in modern and general terms as the absorption coefficient (absorptivity) and has units (m^{-1}). $\dot{E}''_{tr}(\lambda)$ is the monochromatic irradiance (spectral intensity, radiation flux) transmitted (*tr*) through the absorbing gas medium. The quantity of spectral intensity is commonly denoted by I_λ or P in modern scientific literature. $\dot{E}''_{tr}(\lambda)$ is used to denote the transmitted radiation flux herein to harmonize it with other energy-related quantities that are used in the heat balance derivations below. Lambert's integration of Eq 1, under the assumption of a homogenous absorbing body, resulted in the exponential attenuation law; see Eq 2, which is called Bouguer–Lambert's Law.

$$\dot{E}''_{tr}(\lambda) = \dot{E}''_{tr,0}(\lambda) \cdot e^{-\mu \cdot \Delta x} = \dot{E}''_{tr,0}(\lambda) \cdot e^{-a} \quad (2)$$

In 1852, the German scientist August Beer presented his great research efforts to understand the nature of the exponent of Bouguer–Lambert's law obtained from experiments on different liquids. He proved that if he varied the volume fraction of a certain dye and the light path length but kept the product of the two quantities constant, the irradiance transmitted was also constant. His work led to a deeper understanding of absorptivity (μ_i). Owing to Beer's work, among other factors, the absorption coefficient could later be further resolved into the molar absorption coefficient (α_i) and the molar concentration (C_i) of the absorbing species (i). The molar absorption coefficient is also called the molar absorptivity and has units (m^2/mol i). The exponent Eq 2 was termed the absorbance (a) and is expressed in modern terms.

$$a_i = \alpha_i C_i \Delta x \quad (3)$$

Eq 3 describes the absorbance of one of the absorbing species of the absorbing medium, and the name Beer's law was subsequently used to indicate August Beer. The molar absorption coefficient is commonly denoted by the Greek letter ε (epsilon). Instead, this author used the Greek letter α to distinguish it from emissivity, which is used in the context of the Stefan–Boltzmann law and is also commonly designated epsilon. Sometimes, the total magnitude of the absorbance by the absorbing gas medium is so small (<0.2) that the absorptance, below can be approximated by Beer's law. The absorbing gas is referred to as "optical thin" or a "diluted gas". This approximation is derived below and applied herein with respect to the atmospheric surface layer described below.

Combining the works of Bouguer, Lambert and Beer results in the most basic form of the LBBL describing the relationship of transmitted radiation flux as a function of the concentration of the i:th attenuating species at a specific monochromatic wavelength. A constant concentration is assumed for the whole light path of the absorbing gas medium.