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RADIATIVE FORCING DUE TO LONG-LIVING AND WELL-MIXED GREENHOUSE GASES - A CONTINENTAL VIEW

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ABSTRACT: *The radiative forcing due to the long-lived and well-mixed greenhouse gases (CO_2, CH_4 and N_2O) has been calculated for two countries in each of the world's continents for an eleven year period (2001-2011) except for Antarctica where no data was published. We found that for the countries under consideration the average values of radiative forcing by CO_2, CH_4 and N_2O were 1.6774Wm^{-2}, 0.5705 Wm^{-2} and 0.2094 Wm^{-2} respectively, increasing annually by 0.0255 Wm^{-2}, 0.0011 Wm^{-2} and 0.0025 Wm^{-2} also respectively. USA was the top on the list with radiative forcing value of 1.7157 Wm^{-2} by CO_2 increasing annually by 0.0278 Wm^{-2} while Australia was least with 1.6470 Wm^{-2} with an annual incremental trend of 0.0262 Wm^{-2}. This is largely believed to be due to heavy industrial activity in that region. We also found by calculation that if this present trend continues (as it is very likely to and even increase) that by the year 2101, the radiative forcing by CO_2 in a country like the USA would rise to 3.952 Wm^{-2} while globally, the value would rise to 3.834 Wm^{-2} with CO_2 emission rising up to 920ppm per year.*

KEYWORDS: Radiative Forcing, Greenhouse Gases, Global Warming, Atmosphere, Continent

INTRODUCTION

The global average surface temperature has increased approximately by 0.6 ± 0.2^{o}C over the 20th century (IPCC, 2001). In the same report, the Inter-governmental Panel on Climate Change predicted an alarming global temperature increase of 1.4 ^{o}C – 5.8 ^{o}C by the year 2100. It is the increase in the atmospheric concentration of greenhouse gases that result in global temperature rise; this is known as global warming.

Industrialization dated back to 1750 (the unperturbed era) and other human activities have continued to increase the concentration of greenhouse gases in the atmosphere thereby altering the earth's natural balance, thus; global warming (Hinzman et al, 2005). These greenhouse gases absorb long wave radiation emitted by the earth but are transparent to the radiations coming from the sun (Obiekezie, 2010). The net change in the balance between the incoming radiations from the sun and the out-going radiation from the earth at the tropopause is called radiative forcing. If the value of radiative forcing is positive it indicates warming, however, if the value is negative it implies cooling. Radiative forcing is measured in Watts/m^2. Radiative forcing is dependent on the absorptive power and the atmospheric lifetime of the greenhouse gases. Thus, knowledge of the temperature profile and the concentration of a greenhouse gas would enable us calculate radiative forcing accurately.

As warming (temperature) increases, certain alterations in the earth's natural balance are experienced. Various studies (Graf,1997, Ghan, 2000, IPCC, 2007) have shown the adverse effects this global warming will definitely have on man and his environment. These would

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include drought, extreme weather events, flooding, food scarcity, epidemics, and earthquakes among other natural disasters.

It is important that knowledge of radiative forcing is widened especially on a continental view which is what this study hopes to achieve. We aim to create a global awareness and further suggest to policy makers to come up with and implement greenhouse gas emission reduction strategies globally.

Data and method of analysis

The data set used for this analysis are those of carbon dioxide, methane and nitrous oxide values emitted from different sources all over the world for a period of eleven (11) years (2001-2011) at stipulated longitude and latitude hosted by the World Data Centre for Greenhouse Gases (WDCGG).

The expressions recommended by the IPCC (IPCC, 2001) to convert greenhouse gas changes relative to 1750 levels to instantaneous forcing were used to determine the radiative forcing of the greenhouse gases. The expressions are shown in equations 1 to 3

CO_2----------$\Delta F = \alpha \ln(C/C_o)$ ---------- (equ.1)

CH_4----------$\Delta F = \beta(M^{½} - M_o^{½}) - [f(M,N_o) - f(M_o,N_o)]$----------(equ.2)

N_2O----------$\Delta F = \varepsilon(N^{½} - N_o^{½}) - [f(M_o,N) - f(M_o,N_o)]$---------- (equ.3)

The subscript "o" denotes the unperturbed (1750) abundance

$f(M,N) = 0.47\ln[1 + 2.01x10^{-5} (MN)^{0.75} + 5.31x10^{-15}M(MN)^{1.52}]$

C is CO_2 in ppm, M is CH_4 in ppb
N is N_2O in ppb, X is CFC in ppb

C_o = 278 ppm, M_o = 700 ppb, N_o = 270 ppb, X_o = 0

α = 5.35, β = 0.036, ε = 0.12 are constants.

ΔF = Radiative forcing.

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RESULTS AND DISCUSSION.

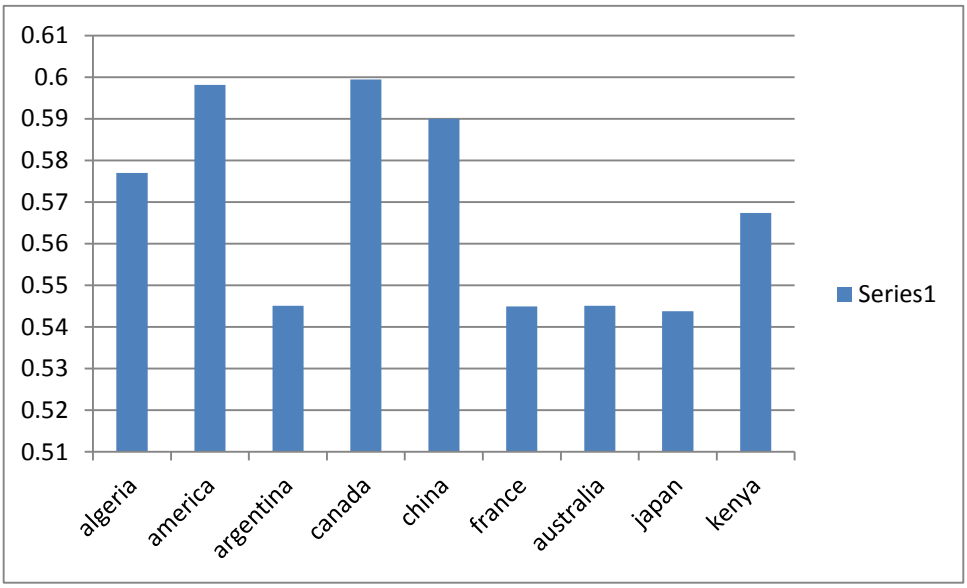

Fig.1 Radiative forcing due to CH_4 (2001-2011)

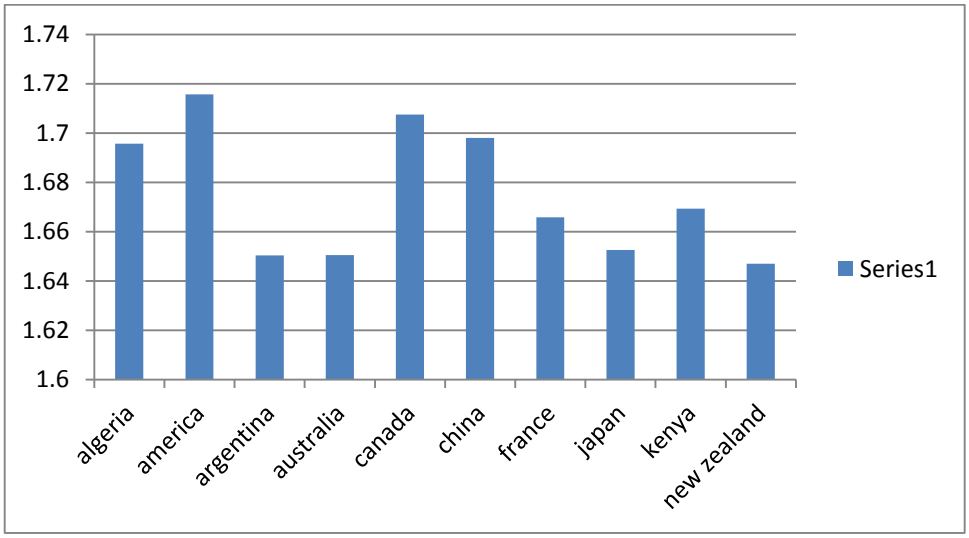

Fig.2 Radiative forcing due to CO_2 (2001-2011)

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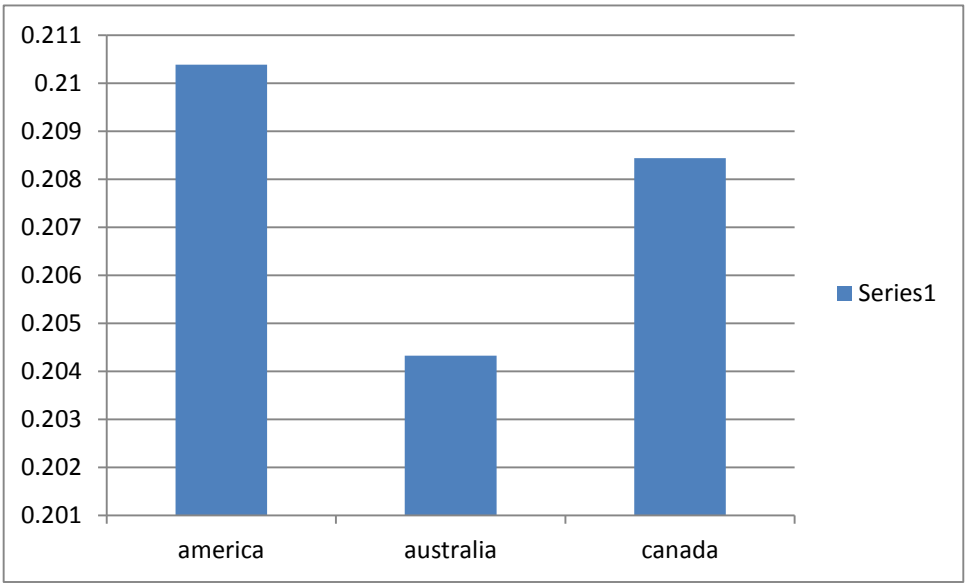

Fig.3 Radiative forcing due to N_2O (2001-2011)

From figure1, we observe two North American countries towering highest in the radiative forcing arising due to CH_4, while Canada was the highest with 0.5995Wm^{-2}, USA followed closely with a value of 0.5982 Wm^{-2}. Asia came behind North America with China having 0.5900 Wm^{-2}, Africa followed with Algeria and Kenya yielding 0.5770 Wm^{-2} and 0.5674 Wm^{-2} respectively. The radiative forcing due to CH_4 is seen increasing at 0.0012 Wm^{-2} annually.

Results arising from figure 2 are alarming, seeing that every continent contributes significantly to the global values. However, USA and Canada the two analysed North American countries once again contribute the most to the forcing arising due to CO_2. America was first on the list with a value 1.7157Wm^{-2} during the period (2001-2011) increasing at 0.0278 Wm^{-2} annually; Canada came directly behind USA with a high value of 1.7075Wm^{-2} with an annual increment of 0.0258Wm^{-2} during the same period. China, Algeria and Kenya had 1.6980 Wm^{-2}, 1.6957 Wm^{-2} and 1.6694 Wm^{-2} respectively increasing annually at 0.0230 Wm^{-2}. This result contradicts a publication by Audra 2007, that China was the top emitter of CO_2 in the world behind America, also from the analysis made, while China's radiative forcing in 2007 was 1.7309Wm^{-2} that of the USA was 1.7457 Wm^{-2} and it is clear that the value of radiative forcing due to a gas is a function of the emitted value of that gas. By emission also, America led China by 13.91ppm.

Figure 3 shows the result of radiative forcing through 2001-2011 due to N_2O, most countries do not have data available for N_2O. However, from the available data USA was the top on the chat before Canada and Australia.

The data collected for CH_4 in Germany, Brazil and New Zealand were incomplete for the years under consideration hence, their absence from the graph, however, the available data was analysed and the trend calculated. For CO_2, Brazil and Germany had incomplete data. Only America, Australia and Canada had complete data for N_2O hence the graph.

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From the results obtained from analyzing the world's continents it is clear that global warming is occurring since all the countries through the eleven year period gave positive results.

In North America, the USA and Canada were analyzed. For the calculated radiative forcing due to CO_2 an alarming future conditions were seen. The average value for the period (2001-2011) was found to be 1.7157Wm^{-2} and increases annually at trend of 0.0278 Wm^{-2}. Comparing these results with the global values an amazing result was obtained. According to AGGI, 2010 global values for radiative forcing due to CO_2, in 1981 was 1.075 Wm^{-2}, in 1991 it was 1.311 Wm^{-2} and in 2001 it came to 1.534 Wm^{-2}. The average of the difference between these eleven (10) year period is 0.230 Wm^{-2}. This means that every ten years, the value of radiative forcing due to CO_2 increases by a value of about 0.23 Wm^{-2}. Taking the global value at the year 2001 which was 1.534 Wm^{-2} we make certain projections. The year 2101 is 100 years away from 2001. Now, at 2101 the value of radiative forcing should have increased by 2.300 Wm^{-2} (i.e. 0.23 x 10). If we add this increment to 2001 value it shows that at the year 2101, the value of radiative forcing globally would go up to 4.064Wm^{-2} meaning that CO_2 emission by that time would be about 920ppm annually. The USA has a value above the global. At 2001 the radiative forcing due to CO_2 in USA was 1.5640 Wm^{-2} in 2011 it rose to 1.8028 Wm^{-2}, showing a difference of about 0.2388 Wm^{-2} for the eleven (11) year period. This implies that by 2101, the value would rise to 4.430Wm^{-2}. These findings show very strong positive forcing which agrees with the prediction of the IPCC of increment by the year 2100.

The results obtained when the radiative forcing values due to CH_4 from the USA is compared with the global values are similar. That from the USA constantly was more than the global average with some years varying by as much as 0.1012 Wm^{-2}. It is evident that United States of America and indeed North America as a whole is a major contributor to global warming. This goes on to show that the publication of Guardian 31, 2011 which states that the USA alone contributes 28.8% of global greenhouse emission is correct. The reason behind this occurrence is not hidden. There was a natural balance between the atmospheric greenhouse gases and their sinks such as the oceans and forests, however, industrialization and other anthropogenic factors have seriously altered and continues to alter this balance.

CONCLUSION

From the results obtained, it is clear that North America contributes the highest to radiative forcing with the United States of America leading in the trend. America and Canada have very high radiative forcing due to CO_2 and the incremental trend is continuous. Bearing in mind the report of the GHGB of 2008 that CO_2 alone contributes about 63% to the overall global radiative forcing and that it is responsible for up to 85% of the increase in radiative forcing over the past decade this result is a serious source of concern. The contributions of the other gases to radiative forcing are also significant as shown by the result.

It is therefore concluded that serious emission reduction policies be made about the greenhouse gases in order to preserve man's planet, the earth.

It is recommended that alternative sources of energy such as nuclear, solar, wind and other renewable forms of energy be used instead of greenhouse based forms of energy. If this is done, our planet may last longer and the adverse effects of warming on man, his environment and animals will be greatly reduced.

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