RADIATIVE FORCING BY CARBON DIOXIDE IN SOUTH AFRICA†

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Abstract

The radiative forcing by carbon dioxide one of the long living green house gases has been evaluated for South Africa. It is found that the mean value of CO₂ for the fourteen year period is 370ppm with a radiative forcing of 1.53 Wm⁻². The radiative forcing is found to be increasing at a rate of 0.027 Wm⁻² per year over a fourteen year period. This positive radiative forcing indicates warming which corresponds with the International Panel on Climate Change (IPCC) Fourth assessment report in Africa.

Key words: Green house gases, Carbon dioxide, Radiative Forcing, Atmosphere, South Africa

1. INTRODUCTION

The Inter-governmental Panel on Climate Change (IPCC) reported that the global average surface temperature of the earth has increased by between 0.6 ± 0.2°C over the 20th century, they further predicted that the global average temperature will rise by about 1.4°C–5.8°C by the year 2100 IPCC(2001). This global temperature increase is assumed to arise from an increase in atmospheric concentration of greenhouse gases and is termed Global warming. A number of studies have explored the potential changes in the climate system associated with this global warming (Mahlman, 1997, Kattenberg et al., 1996; Warrick et al., 1996, and Santer et al., 1996, Hinzman et al. 2005). The observed warming of 0.6 ± 0.2°C is modest and, in itself is unlikely to lead to a substantial global impact. The prediction by the year 2100 creates concern on the future global warming. It is obvious that when compared to natural variability over the past 1000 years an additional 1.4–5.8°C change in the next 90 years would be very significant.

It seems likely that most of the warming observed to date is associated with human activities releasing greenhouse gases into the atmosphere thereby altering the natural green house effect with the atmosphere having excess green house gases. When greenhouse gases increase in the atmosphere on account of human activities, the radiative balance of the Earth is altered. The greenhouse gases absorb the long wave radiation emitted by the Earth but are transparent to the radiation coming from the sun. Hence the increase in greenhouse gases causes an increase in the net radiation at the top of the atmosphere thereby warming the earth. The change in net radiation at the tropopause caused by changes in greenhouse gas or aerosol concentrations is called radiative forcing. Thus increased radiative forcing is the change in the rate at which additional energy is made available to the earth-atmosphere system over an "average" square meter of the earth’s surface due to increased concentration of a greenhouse gas, or group of gases, with reference to the unperturbed time (1750). A positive radiative value indicates warming while negative value indicates cooling effect on the climate. Radiative forcing is measured in Watts/m². Projections from the latest generation of climate models (Kattenberg et al., 1996) suggest that global surface air temperature will increase substantially in the future due to the radiative effects of enhanced atmospheric concentrations of greenhouse gases. Thus, if the temperature profile and the concentration of the greenhouse gases in the atmosphere are known, Radiative forcing can be calculated accurately. Radiative forcing depends upon how strongly a greenhouse gas absorbs radiation and the atmospheric life time of the gas.
In light of the long atmospheric lifetime of carbon dioxide over (100 years), substantial increases in its emission during the past century, and expected increases in future emissions, the atmospheric concentration of carbon dioxide in the year 2100 will almost certainly be substantially greater than that today and the climate will continue to warm. Carbon dioxide Information Analysis Center (CDIAC) based on 2007 fossil-fuel CO₂ emissions reported that South Africa is the 13th largest emitting country in the world and the largest emitting country on the continent of Africa.

IPCC fourth assessment report on Africa (IPCC, 2007) reported that central Southern Africa will be more vulnerable to the future warming. This implies greater competition for scarce land and water resources, frequently recurring extreme weather events, notably prolonged droughts and sudden flooding and more humanitarian emergencies resulting from food insecurity, natural disasters and local conflicts. Global greenhouse gas emissions is found to be continually on the increase and evidence is mounting that even the daunting findings of the Intergovernmental Panel on Climate Change (IPCC)’s Fourth Assessment Report (IPCC, 2008) underestimate both the pace and the intensity of climate change dynamics (Levin and Tirpak, 2009).

Observations of radiative forcings are critical for improving understanding of the climate drivers, how they varied in the past, and how they might change in the future. Hence, this work aims at evaluating the radiative forcing due to carbon dioxide in South Africa thus giving an insight on the contribution of carbon dioxide to Radiative forcing and possibly guide policy decisions makers on the need to reduce emission by suggesting methods of emission reduction.

2. DATA AND METHOD OF ANALYSIS

The data set used in this analysis is carbon dioxide values emitted from different sources in South Africa for fourteen years (1995-2008) collected by the South African Weather services (SAWS) in Cape point South Africa, Latitude 34°21' S, and Longitude 18°29' E and hosted by the World Data Center for Green House Gases (WDCGHG).

To determine the total radiative forcing of the greenhouse gases, The IPCC [IPCC 2001] recommended expressions to convert greenhouse gas changes, relative to 1750, to instantaneous radiative forcing were used.

The empirical expression used for radiative forcing is seen below

\[ \Delta F = \alpha \ln \left( \frac{C}{C_0} \right) \] (1)

Where \( C_0 \) is the value of CO₂ during the unperturbed condition (1750) = 278ppm
and \( \alpha = 5.35 \) which is a constant.

### 1. RESULTS AND DISCUSSION

![Yearly variation of CO\(_2\) in South Africa](image)

Fig. 1 displays the Variation of CO\(_2\) in South Africa with respect to years. It can be seen from Fig. 1 that the average value of CO\(_2\) over the fourteen year period is 370ppm. When compared with the unperturbed global average value of CO\(_2\) (1750 Value, 278ppm) it gives a 33\% increase in the quantity of CO\(_2\) in the atmosphere which creates a lot of concern. Comparing the values obtained here with global average values obtained from the Green House Gas Bulletin (GHGB), 2008, it is found that the CO\(_2\) global average value for 2008 is 385.2ppm and 383.1ppm for 2007, the results obtained here indicates that the CO\(_2\) South African average value for 2008 is 382.6ppm, and 380.5ppm for 2007, this trend continues over the 14 year period harmonizing with CDIAC, (2007) and disagreeing with the report by Bauer and Scholz, (2010) who claimed that the green house emission in this region is only a minuscule fraction of the global total. Although the average value for the entire Africa might be small, it is understood that since these amount of CO\(_2\) is in the atmosphere in South Africa any heating occurring from this quantity will be felt more by South Africans and their surroundings more than the rest of the word as such there should be more of
a regional warming than global warming experienced more by South Africans and their surrounding countries.

Fig. 2 displays the Variation in the Radiative Forcing of CO\textsubscript{2} from 1995-2008. The mean radiative forcing of 1.53Wm\textsuperscript{-2} is found for the fourteen year period. This forcing is found to be increasing at a rate of 0.027 Wm\textsuperscript{-2} per year over a fourteen year period. This positive radiative forcing indicates warming. The global average for the fourteen years is 1.56Wm\textsuperscript{-2} (AGGI, 2010), comparing with the result obtained here, it shows that South Africa contribute meaningfully to Global warming contradicting Bauer and Scholz, (2010) and harmonizing with the report of CDIAC, (2007).

The GHGB, 2008 reports that CO\textsubscript{2} in the atmosphere contributes about 63.5% to the overall global radiative forcing and it is responsible for 85% of the increase in radiative forcing over the past decade. Thus since the forcing by CO\textsubscript{2} in South Africa is close to the Global average a lot is to be done in reducing the quantity of CO\textsubscript{2} that is being emitted in South Africa. This IPCC has evaluated and found that the consequences at present and in future will be very disastrous. Its regional consequences are already observable and exacerbate the trends of desertification and biodiversity loss that are by themselves diluting vital ecosystem services and thereby adverse to sustainable human development. Collier et al., 2008 reported that projected climatic trends will force much of rural agriculture out of production and make maize production in many parts of Zimbabwe and South Africa very difficult if not impossible. Chipanshi et al., 2003 noted that Maize and sorghum yields in Botswana could decrease by roughly one third as a result of declining rainfall in an already dry environment.
Thus this calls for serious emission reduction strategies and implementation by policy makers such strategy must include; Substitution away from greenhouse-gas intensive forms of energy production - for example, from brown and black coal to solar and natural gas. Natural gas releases less carbon dioxide per unit of energy than coal or oil. Hence, switching to natural gas is a quick way to cut emissions. There would be substitution of currently available capital for fossil fuels, through say, the construction of hydro and nuclear plants and through the installations of emissions control equipment. Nuclear energy produces virtually no greenhouse gases, but public concern over safety, transport and disposal of radioactive wastes -- not to mention weapons proliferation -- means that the responsible employment of nuclear power will likely remain limited. There would be change in the composition of production away from energy intensive items, that is, items which consume relatively large amounts of energy, to less energy intensive ones. Technical change would be stimulated to produce new kinds of capital equipment, energy and other products with lower emissions level. The pace of substitution will be governed by the relative cost of these different sources and the delay inherent in making new sources of power available. It takes several years to build a replacement power station but the end result should be worth the time taken.

2. CONCLUSION

The results obtained here reveal that Carbon dioxide in South Africa has increased up to 33% from the unperturbed (1750) value. The radiative forcing due to this carbon dioxide is found to be increasing at a rate of 0.027 Wm$^{-2}$ per year over a fourteen year period. This positive radiative forcing indicates warming which is seen to be more of a regional warming than global which is to be experienced more by South Africans and their surrounding countries.

It is concluded that serious CO$_2$ emission reduction strategies and implementation by policy makers should be sought.

Consequently, it is suggested that substitution away from greenhouse-gas intensive forms of energy production could be a better strategy. This includes the use of renewable energy and nuclear energy forms.

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