Journal of Special Topics

P2_6 The influence of agricultural emissions on global warming

J. Anand, A. Buccheri, M. Gorley, I. Weaver

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH.

October 30, 2009

Abstract

Current estimates on the influence anthropogenic greenhouse gas emissions on global warming may have neglected the influence the agricultural emissions have, especially given the attempts to phase in biofuels in the transport industry. This paper investigates the effect emissions of nitrous oxide (N_2O) may have by calculating its Global Warming Potential (GWP) over the next 100 years. It is concluded whilst over this period 1kg of N2O would have the same impact as 300kg of CO2, due to a lack of data a final judgment on the effect growing more biofuels would have on climate change could not be made.

P2_1 Climate Change

Introduction

Whilst the effects of anthropogenic CO_2 emissions on the Earth's climate have been well publicised and analysed there is growing concern that the effect of both natural and anthropogenic emissions of other greenhouse gases may have been neglected in current studies. One such claim is by P. Crutzen et al [1], who suggest that emissions of nitrous oxide (N_2O) by agricultural processes such as pesticide and fertiliser use may even negate any gains made by phasing out fossil fuel use. In particular, the increase in agriculture to produce biofuels to phase out conventional petrol and diesel is of particular concern, as this is linked with the already increasing emissions from the transport sector. Using biofuels could therefore possibly exacerbate this effect.

N_2O is produced from microbial activity in the soil, as part of the nitrogen cycle [2]. Like CO_2 this occurs as a result of natural processes, but the use of nitrogen-based fertilisers & pesticides upsets this balance, so an excess is produced.

Model: Global Warming Potential

The main issue when discerning the effect greenhouse gases have on global warming is that different gases have different lifetimes in the atmosphere before decaying, whilst also varying in efficiently absorbing and radiating energy. For instance, despite carbon dioxide being the most abundant greenhouse gas in the atmosphere its ability to absorb radiation is much less than other gases such as methane.

A solution to this is to calculate the "Global Warming Potential" (GWB) for a gas, as first put forward by D. Lashof and D. Ahuja [3]. defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kg of a trace substance relative to that of 1 kg of a CO_2 (used as a reference), given as:

$$GWP(x) = \frac{\int_0^T a_x[x(t)]dt}{\int_0^T a_{CO_2}[CO_2(t)]dt} \quad (1)$$

where a is the radiative efficiency of the gas (i.e. its capacity to absorb and transmit radiation) and [x (t)] is the concentration of the gas as a function of time. The entire ratio is subject to the time period T, which is arbitrarily chosen depending on the window of observation required. In this case, this will be 100 years, as the main focus of research undertaken by the IPCC is the effects of climate change in the next century.

The concentration of the gas against time can be shown to be an exponential decay [3]:

$$[x(t)] = e^{-t/\lambda_t} \quad (2)$$

where λ_x is the mean lifetime of a gas, measured in years.

A further complication arises when the lifetime of CO_2 is considered. As well as decaying CO_2 can also be absorbed by other systems, such as the ocean and biosphere, from which it can also return to the atmosphere. To rectify this, the Bern carbon cycle model is used [4], where the decay of CO_2 is instead given as:

$$[CO_2] = a_0 + \sum_{i=0}^{3} a_i e^{-t/\tau_i} \quad (3)$$

where a_0 = 0.217, a_1 = 0.259, a_2 = 0.338, a_3 = 0.186, τ_1 = 172.9 years, τ_2 = 18.51 years, and τ_3 = 1.186 years.

Substituting expressions (2) and (3) into (1) and integrating accordingly therefore gives:

$$GWP(N_2O) = \frac{a_{N_2O}\lambda_{N_2O}\left[1-\exp\left(-T/\lambda_{N_2O}\right)\right]}{\sum_{i=0}^{3} a_{N_2O}\lambda_{N_2O}\left[1-\exp\left(-T/\lambda_{CO_2}\right)\right]} \quad (4)$$

Substituting the appropriate values for the constants defined earlier [4] over a 100 year period therefore gives the GWP of N_2O as approximately 300. That is, 1 kg of N_2O is equivalent to approximately 300 kg of CO_2.

Discussion

It is estimated that 5.6 – 6.5 Tg of N_2O is emitted by agricultural processes each year [1]. Using the previously calculated GWP value this is approximately equivalent to 1680 – 1950 Tg of CO_2 in terms of contribution to the greenhouse effect.

By comparison, global emissions of CO_2 are approximately 26400 Tg per year [5]. Whist this does appear to dwarf the contribution made by agriculture it must be noted that the reason for growing biofuels is to cut down vehicular CO_2 emissions. However, data pertaining to how much transportation contributes to total CO_2 emissions, and indeed how much of this is expected to be offset by widespread use of biofuels, is scarce. Further data would be required in order to properly make a judgment on the exact effect this would have on any emissions offset by biofuels.

There are further complications to this method, as it neglects the impact the change in land use to accommodate growing the crops required would have on CO_2 emissions from this sector. Similarly, other factors such as the amount of fossil fuels used to manufacture and transport the biofuels has not been considered, along with the effect other processes such as growing crops for animal feed would have on N_2O emissions.

Conclusion

Whilst it has been established that current N_2O emissions are approximately equivalent to 7% of global CO_2 emissions, not enough data is available to ascertain the effect reducing CO_2 emissions by biofuel use would have on global warming.

References

[1] P. Crutzen et al, *N_2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels*, Atmos. Chem. Phys., **8**, 389–395, 2008

[2] Nitrous oxide Sources (GHGOnline), *http://www.ghgonline.org/nitrousagri.htm*

[3] D. Lashof, D. Ahuja, *Relative contributions of greenhouse gas emissions to global warming*, Nature, **344**, 529-531, 1990

[4] IPCC Fourth Assessment Report (**AR4**), 2007, Ch 2, p. 212-213

[5] IPCC Fourth Assessment Report (**AR4**), 2007, Summary for Policymakers, p. 2