Seasonal Variability of Nitrous Oxide (N_2O) in Rwanda

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Abstract: ***Nitrous oxide (N_2O) is one of the main three greenhouse gases, besides methane and carbon dioxide that are contributing to global warming. N_2O levels have risen approximately by 15% since the preindustrial times reaching 315ppb in 2000. The current estimate of lifetime of N_2O is 120 years. N_2O is of concern due to its critical contribution to global warming and to ozone layer depletion along with halogen containing compounds. The main objective of this research was to evaluate the seasonal variability of N_2O concentration in Rwanda. The N_2O data were obtained from Rwanda Climate Observatory by measurement using mid infrared analyser. The study results indicated that the annual N_2O average concentration is 329.5 ppb. The short dry season, the long rainy season, the long dry season and the short rainy season had concentrations of 329.79 ppb, 329.08 ppb, 329.30 ppb and 330.15 ppb respectively. The main reason for the disparity in concentration was the rainfall and temperature differences across the seasons, and regional and continental influences, like biomass burning. We suggest that policies be set to counteract the increase in N_2O emissions especially from anthropogenic sources in order to reduce the effects of global warming and ozone layer depletion.***

Keywords: Nitrous oxide, Greenhouse gas, Global warming, Ozone layer depletion, Seasonal variability

1.Introduction

Since the starting of the industrial age, dating around 1750s, there has occurred significant increase in atmospheric concentrations of several trace gases. Those trace gases have environmental impacts on regional and global scales. Three of these trace gases namely carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are considered as the main greenhouse gases (GHGs) and contribute to global warming [1]. N_2O levels have risen approximately 15% since the preindustrial times, reaching 315ppb in 2000[2] and 324 ± 0.1 ppb in 2011, with an increase of 5ppb since 2005[3].

International policy discussions have focused in the last two decades on emissions rather than CO_2. The reason is justified by the fact that emission such as N_2O are less expensive to mitigate than CO_2 emissions [4].

Nitrous oxide is a colorless gas of slightly sweet odor and taste under ambient conditions. It was discovered by Joseph Priestley in 1772 from the reduction of Nitric oxide (NO) with iron sulfur mixtures [1]. The gas is used as anesthetic and it is commonly referred to as "laughing gas" [2].

N_2O is present in the earth's atmosphere at a trace level. The concentration of Nitrous oxide has been increasing linearly over last few decades as a consequence of the introduction of N_2O into the atmosphere at a rate greater than its rate of removal by natural processes[5]. The current estimate for the lifetime of N_2O is 120 years [2].

Nitrous oxide is produced from a wide variety of natural and human sources. Natural sources are primarily bacterial decomposition of nitrogen in soils and the earth's oceans. Anthropogenic sources are agricultural activities, animal manure, sewage treatment, mobile and stationary combustion of fossil fuels and nitric acid production [6]. Besides the sources above mentioned, biomass burning also contributes to N_2O sources [7] , a small portion of N_2O may come from degassing of irrigation water[2].

Soils are the main contributor to nitrous oxide (N_2O) emission in the atmosphere, via the microbial processes of nitrification and denitrification [8].

Nitrous oxide becomes of environmental concern for two reasons. First its capacity to absorb infrared radiation, known as global warming potential[9] is 300 times greater than that of carbon dioxide although its mixing ratio is a thousand times less than that of CO_2[5]. Second reason that makes N_2O of environmental concern is that when it reaches the stratosphere along with some halogen containing compounds, contributes to ozone depletion [5].

N_2O has the third largest radiative forcing of the anthropogenic gases [3]. Anthropogenic contributions to atmospheric Nitrous oxide (N_2O) are now close to the natural contributions [7].

The reason for the closeness is the addition of reactive forms of nitrogen into the biosphere beyond the natural additions. Mainly the reactive forms come from the addition of synthetic nitrogenous fertilizers, animal manure to agricultural land and the creation of new arable areas (land) from forests and grasslands, which result in the release of nitrogen from relatively inert forms from the soil and therefore releasing reactive forms of nitrogen into the atmosphere[5].

Agriculture mainly relies on synthetic fertilizers; hence it enhances the processes of nitrification and denitrification. The latter two processes make the agro-ecosystems to contribute to more than a half of the global anthropogenic emissions of N_2O [8].

The main removal mechanism of nitrous oxide is through photolysis and oxidation reactions in the stratosphere [3].

In Rwanda we have two dry and two rainy seasons. Short dry season is from January to February (JF) and the long dry season is from June to September (JJAS). The short rainy season is the October-November-December season (OND) and the long rainy season is from March to May (MAM)[10].

This research aims at comparing the concentrations of N_2O for the dry season with those of rainy season; the scope extends to finding the possible correlation of nitrous oxide with weather temperature and weather relative humidity.

2 Methods

2.1 Site selection and description

Rwanda is a country located in central-east Africa at the coordinates 2°S and 30°E. It lies on an area of 26,338 square kilometers, and it is the 149th largest country in the world. The country is bordered by the Democratic Republic of Congo to the west, Burundi to the south, Tanzania to the east and Uganda to the north [11].

Rwanda is dominantly high altitude. The lowest altitude of 950 m above sea level is found in the south of the country and the highest point being at the top of volcano Karisimbi with an altitude of 4507m above sea level [12].

The daily average minimum temperature in Rwanda varies between 10°C and 16°C while the daily average maximum temperature varies between 20°C and 28°C. The country possesses an altitude-rainfall correlation, and the highest parts of the country receive most of rainfall. The highest point, Karimbi receives an annual average rainfall of 2,200 millimeter while Nyagatare receives the lowest rainfall, with an annual average of 850 millimeter [13].

The mole fraction data of N_2O used were recorded in Rwanda, Northern Province, and Musanze district. The site is called Rwanda Climate Observatory, built on Mount Mugogo.

Mount Mugogo is located at the coordinates of 1°35'02" South and 29°33'54" East and is at an altitude of 2590m above sea level [12].

2.2 Measurement of Nitrous Oxide concentration

The mole fraction data N_2O were measured with the mid infrared analyser, known as Picarro G5105. It is a high precision instrument that reliably measures nitrous oxide (N_2O) concentration and water from the air.

2.3 Statistical analysis

In order to get a clear picture of the behavior of N_2O concentration and its variability along the year 2017, statistics such as mean, standard deviation and coefficients of correlation are computed.

The annual and seasonal mean values of N_2O concentration are calculated, and they help in comparing the seasons. The correlation coefficients are calculated with respect to N_2O concentration. N_2O-relative humidity and N_2O- temperature correlation coefficients are evaluated to elucidate the interdependence between the variables.

3 Results and Discussion

The nitrous oxide annual mean concentration found was 329.5 ppb, while the seasonal concentration was 329.79, 329.08, 329.30 and 330.15 ppb for short dry season (JF), long rainy season (MAM), long dry season (JJAS) and short rainy season (OND) respectively. The annual daily standard deviation found for N_2O concentration was 0.5ppb, suggesting a weak variation in the daily concentration of the greenhouse gas. The coefficient of correlation between N_2O concentration and temperature was 0.29 while it was -0.21 between N_2O and relative humidity. N_2O concentration is positively correlated with weather temperature and negatively correlated with relative humidity. The mean seasonal values of temperature, relative humidity and N_2O concentration are shown in Table 1.

The N_2O's hourly, daily and annual mean concentration is depicted in Figure 1 below.

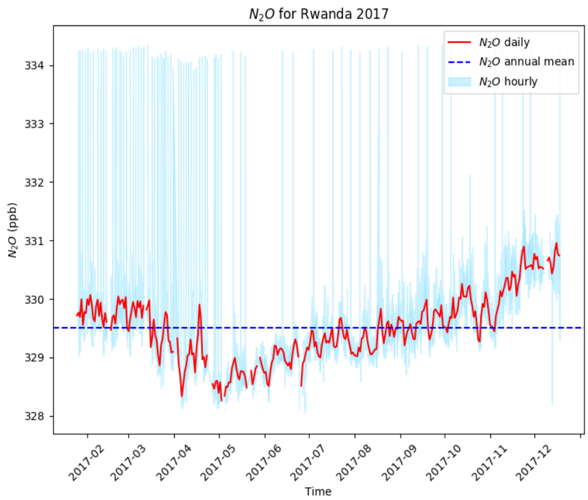

Figure 1: Plot of hourly, daily and annual mean N_2O concentration for the year 2017
Source: Figure drawn using N_2O data recorded at Rwanda climate observatory in 2017

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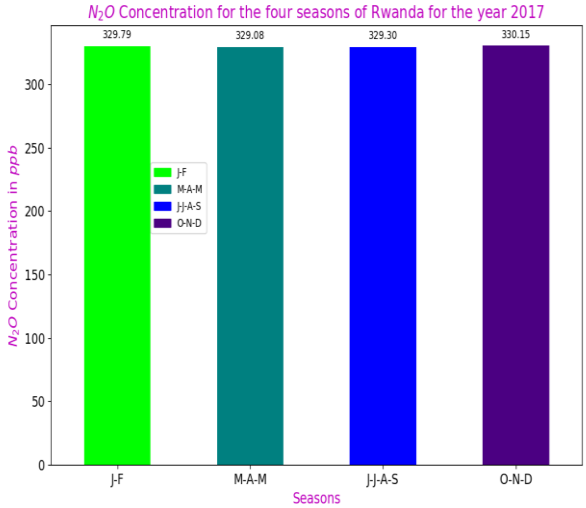

Figure 2 : Bar plot of N_2O annual mean and seasonal concentration for the year 2017

Source: The figure is drawn using N_2O data recorded by mid infrared analyser at Rwanda climate observatory.

Figure 1 and Figure 2 show that the concentration increases over time along the year from the month of April. From Figure 2, the short rainy season, October-November-December (OND) had the highest emission; that is its N_2O concentration was the highest. The reason for the yearly increase lies behind increase in activities that lead to N_2O emissions like agriculture development and fossil fuels combustion. The increase may also be attributed to biomass burning in the northern part of Africa which starts at around December [14],[12]. The same biomass burning extends to January and February, which may explain the closeness of emissions for JF season and OND season [12]. The oceanic sources may contribute to the local emissions through global transport [9]. The seasonal variation may be explained by the fact that the rainfall and temperature were not correlated; the latter variables are among the key factors influencing the N_2O emissions from the soil [15],[16].

The Figure 3 below shows a comparative temperature variation among the seasons during the year 2017.

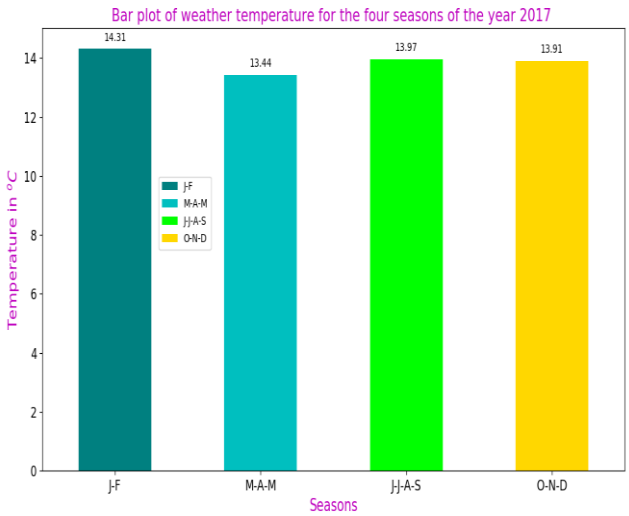

Figure 3 : Seasonal variation of weather temperature at data site during the year 2017

Source: this figure is drawn using Temperature data recorded at Rwanda Climate Observatory located at Mount Mugogo.

According to the research of [17], short rainy season is more likely to undergo more emission due to the possibility of availability of more water filled pore spaces and a temperature close to that of the two dry seasons. So the short dry season, although it has been the warmest season, it lacks correlation of rainfall therefore water filled pore spaces with its temperature. The long rainy season (MAM) has both the lowest N_2O concentration and the lowest temperature. Although it is the season which records the highest rainfall, the lowest emissions may be attributed to lack of rainfall and temperature correlation.

Table 1: Mean seasonal values for temperature, relative humidity and nitrous oxide concentration for the year 2017

Seasons	Mean seasonal value		
	Relative humidity (%)	Weather temperature (°C)	Nitrous oxide (N_2O) (ppb)
Short dry season (JF)	78.86	14.31	329.79
Long rainy season (MAM)	89.91	13.44	329.08
Long dry season (JJAS)	78.63	13.97	329.30
Short rainy season (OND)	82.96	13.91	330.15

Source: The table is generated using values calculated from N_2O data recorded at Rwanda Climate observatory.

4 Conclusion and Recommendation

The results show that the short rainy (OND) season has the greatest N_2O concentration and the long rainy season (MAM) has the lowest N_2O concentration. The same situation was observed for Australia using data available at [18]. Temperature and water availability in soil, interpreted as rainfall received, are the probable main factors contributing to N_2O concentration variability among seasons. It is difficult to point out the specific causes behind N_2O concentration disparity among seasons, especially the drop in concentration around March to May, that's why we recommend consistent and deep studies to elucidate the causes of N_2O seasonal variability in Rwanda. Due to continual increase in N_2O concentration as observed within this research, we urge policy makers to intervene in counteracting the N_2O emissions, especially those resulting from anthropogenic activities like agriculture and biomass burning. The overtime increase in concentration is an alarm to the community. We need policies that guarantee the recovery of ozone layer and decrease in global warming. Natural gas should be used instead of biomass in energy generation. The other way of reducing emissions from agricultural systems should be the application of fertilizer quantity that the plant will efficiently use, to avoid excess of fertilizer.

5 Future Scope

Future studies should focus on assessing the seasonal variability by using a larger data set recorded for at least two years to elucidate the seasonal nitrous oxide concentration behavior and finally study the main processes which may have effect on concentration of the greenhouse gas. The main limitation is a small data set, because the nitrous oxide has been recorded from Rwanda Climate Observatory since 2017.

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