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Observed surface ozone trend in the year 2012 over Nairobi, Kenya

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RESUMEN

El aire limpio es un requerimiento básico para la salud y el bienestar humanos. El Servicio Meteorológico de Kenia ha iniciado acciones de medición de contaminación del aire en varios sitios de Nairobi, en el Centro Meteorológico de Dagoretti Corner y en el monte Kenia. Se miden diversos contaminantes, incluyendo el ozono. La concentración ascendente de gases de efecto invernadero en la atmósfera ha influido en el clima y el tiempo atmosférico. En el presente estudio se analizaron las variaciones de ozono superficial en Dagoretti Corner, Nairobi, durante un periodo de 12 meses que finalizó en julio de 2013, exactamente un año después del inicio de la obtención de datos. Para estudiar la tendencia se analizaron series de tiempo horarias y mensuales de la concentración de ozono. Los datos de ozono se correlacionaron con datos meteorológicos y de temperatura. En términos generales, se encontró que la calidad del aire en Nairobi (representada por la estación meteorológica de Dagoretti Corner) es buena de acuerdo con los estándares de la Organización Meteorológica Mundial. La mayor concentración de ozono se observó durante la tarde y la mínima al amanecer. En una escala estacional, los niveles más altos se observaron en los meses fríos. Esta información ayuda a reducir la exposición al gas y por lo tanto a disminuir sus efectos sobre los seres vivos. Se recomienda la reducción de la exposición al ozono en los tiempos en que se han observado mayores concentraciones para minimizar su impacto.

ABSTRACT

Clean air is a basic requirement for human health and wellbeing. The Kenya Meteorological Department has established air pollution monitoring activities in various sites in Nairobi, at Dagoretti Corner meteorological station and at Mount Kenya. Different pollutants are measured including ozone. The increased concentration of greenhouse gases in the atmosphere has influenced the weather and climate. This study examined the variations of surface ozone over Dagoretti Corner, Nairobi for a 12-month period ending July 2013, exactly one year after the start of data acquisition. The trend was studied using time series analysis of ozone concentration on both an hourly and monthly basis. The ozone data was then combined with meteorological data and temperature to find correlations between the two. Overall, the air quality of Nairobi, represented by Dagoretti Corner meteorological station is good as compared to the World Meteorological Organization ozone standards. The highest concentration of ozone is observed in the afternoon and the minimum at dawn on a daily basis. On seasonal scale, the highest levels are recorded in the cold months. This information helps to reduce exposure to the gas and thus to reduce its impacts on living things. The study recommends the reduction of exposure to the gas during the times when it has been observed to be highest in order to minimize its impacts.

Keywords*:* Air pollution, greenhouse gas, ozone, climate, temperature, Nairobi.

1. Introduction

Ozone (O_3) is one of the most important global air pollutants in terms of impacts to human health, croplands and natural plant communities, and may become more important in the future. It is found in two primary layers in the atmosphere: in the upper stratosphere and the troposphere. In the upper stratosphere, it is a beneficial molecule that absorbs harmful ultra violet (UV) radiation from the sun before it reaches the Earth's surface (Crutzen, 1998). In the troposphere, ozone is a hazardous air pollutant which may cause damage to humans, animals, vegetation and materials under conditions of increasing surface ozone concentration because of smog photochemical reactions in the presence of growing atmospheric pollution (Kalabokas *et al.*, 2000). Ozone is not directly emitted into the atmosphere; it forms as a secondary pollutant from nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight. In urban areas on hot, sunny days ozone can reach very high concentration levels that can be unhealthy.

Following rapid technological and scientific advances in dynamic atmospheric chemistry processes in the recent past, air pollution monitoring has emerged as an area of research interest in different scientific institutions. This is evident in studies that have analyzed atmospheric chemicals, biogeochemical reactions (Carmichael *et al.*, 2003) and general global circulation effects on global air pollution (Henne *et al.*, 2008).

The increase in concentration of greenhouse gasses (GHG) in the atmosphere is central to weather and climate sensitivity and ultimately to climate change. Clean air and environment are basic requirements for human health and environmental wellbeing (WHO, 2006; NEMA, 2008). Air pollution poses an increasing threat to health and environment. According to an assessment by the World Health Organization (WHO) in 2012, over 4.3 million deaths annually are directly attributable to urban air pollution, with close 600 000 deaths in Africa (WHO, 2014).

Kenya Meteorological Department (KMD) monitors the concentration of greenhouse gases (GHG) at various sites in Kenya as one of its functions. The monitored GHGs include O_3, carbon dioxide (CO_2), carbon monoxide (CO), aerosols and particulate matter of different sizes. For almost six years, KMD only monitored vertical profiles and total column ozone using ozonesonde soundings and a Dobson spectrophotometer instrument. Since July 2012, KMD installed surface ozone analyzers specifically to measure ozone values at 10 m above the ground.

In general, ozone has not been much recorded or studied in tropical regions of the world, but it needs to be better understood since an increasing number of people around the world will be living in urban environments within the tropics. This paper examines hourly and monthly variations of surface ozone over the Dagoretti Corner meteorological station in Nairobi, for a 12-month period ending in July 2013.

Nairobi, Kenya's capital city, is located between 1º 9', 1º 28' S and 36º 4', 37º 10' E. It covers an area of 684 km^2 and has a population of 3.1 million people (KNBS, 2010). The predominant winds over the city are easterlies; they are associated with precipitation occasioned by moisture inflow into the country from the Indian Ocean (Opijah *et al.*, 2007; Ongoma *et al.*, 2013a). Nairobi has a bimodal rainfall regime with long and short rainy seasons in March-May (MAM) and October-December (OND), respectively (Okoola, 1996). Northeast monsoons are common during December to February, and southeast monsoons during June to August are associated to an extent with depressed rainfall conditions. Dagoretti Corner meteorological station is located at an elevation of 1795 masl, 10 km west of the central business district. Figure 1 shows the land use and location of the ozone measuring station with respect to Nairobi County.

The concentration of NO_x is the main factor that determines whether O_3 forms or dissociates in the atmosphere. Ozone concentration in the troposphere is highly variable, ranging from 10 ppb (parts per billion) over the tropical oceans to 100 ppb over land, and can even exceed this last value in polluted urban areas (Denman *et al.*, 2007). Its variability is dependent on available solar radiation, temperature fluctuations, winds, seasons and altitude, among other factors (IPCC, 2007). Atmospheric models that describe its chemistry and its coupling to transport are the best techniques currently applied to estimate current and future ozone levels.

Generally, temperature and long-term urban warming have a serious impact on urban pollution, resulting in higher ozone concentrations, since heat accelerates the chemical reactions in the atmosphere (Walcek and Yuan, 1999). Higher ozone concentration values in urban environments are mainly caused by solar radiation and pollutants. Urban areas accumulate greater amounts of heat than the surrounding rural