Development in Air Pollution Measurement Technologies in Kenya

by

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Abstract

Air pollution monitoring is fast emerging as an area of research interest in different scientific institutions. Various environmental and health agencies consider clean air as a basic requirement for human health and environmental well-being. The increased concentration of greenhouse gasses (GHG) in the atmosphere is central to weather and climate sensitivity and ultimately climate change. It is against this background that Global Atmospheric Watch (GAW) runs environmental and pollution monitoring activities in Kenya through the Kenya Meteorological Service (KMS). This presentation traces the evolution of pollution monitoring instruments, since 1999 when vertical ozone measurement was first started, to the latest analysers for aerosols, carbon and particulates installed just last year. In addition, KMS has just recently acquired a Mobile Air Monitoring Laboratory (MAML) that has various analysers that can measure up to 17 different gases such as methane, sulphur dioxide, ozone, nitrogen oxide, benzene aerosols or different sizes of particulate matter and others. In the end, the presentation will examine the variation of Surface Ozone, over Dagoretti, Nairobi for a 12-month period ending July 2013, being exactly one year since the installation and acquisition of the data.

Introduction

Air pollution monitoring is fast emerging as an area of research interest in different scientific institutions. Various environmental and health agencies consider clean air as a basic requirement for human health and environmental well-being. Recently, March 2014, there were reports from Paris, France that the administrative authorities had to limit automobiles movement, encouraging public transport in the face of increasing air pollution levels in the city. Across from Beijing, China, pollution levels kept foreign nationals away and that many resident foreigners were leaving the city due to health concerns. As many countries develop and move up the socio-economic ladder, greenhouse gas (GHG) emissions will continue to increase, rising air pollution levels. At the same time, March 2014, the world Health Organisation (WHO) released a report that showed close to 7 million persons died in 2012 due to exposure to air pollution. In India, research by Ambient Air Quality ranked air pollution as the fifth largest killer.

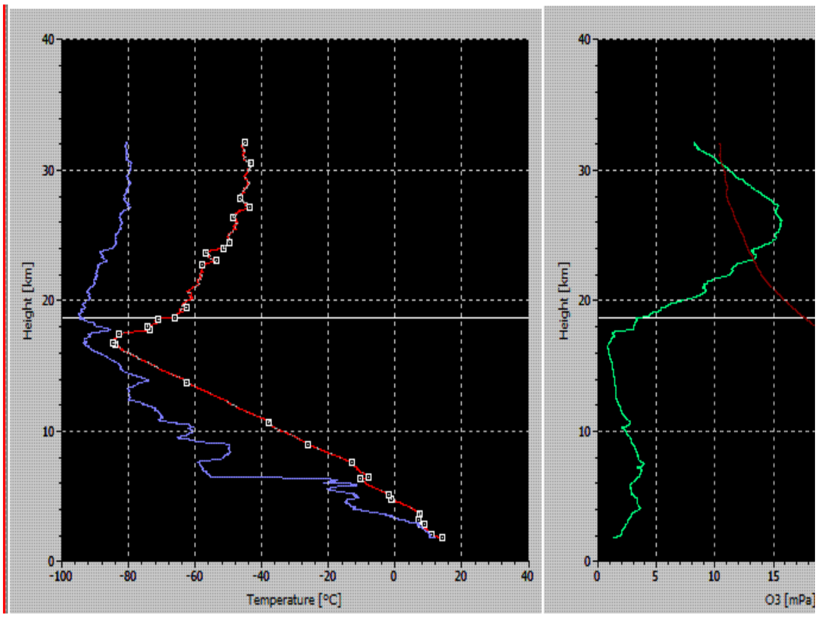
In the climate system, continued emission of GHG and aerosols in the atmosphere alters the weather, general system balance and circulation thereby causing climate oscillations, radiative forcing and feedback mechanism leading to, over time, a shift in the climate regime. Measurements therefore are of great importance in monitoring air pollution levels. In Kenya, pollution-monitoring efforts have sequentially improved with development in instruments and technologies used to measure various pollutants. Kenya, through the Kenya Meteorological Service (KMS), collaborating with partners such as World Meteorological Organisation (WMO), MeteoSwiss, Southern Hemisphere Additional OZonesondes (SHADOZ) and Swiss Federal Laboratories for Materials Science (EMPA) have improved over time. The instruments are located at the following sites; Dagoretti - Nairobi, Jomo Kenyatta International Airport, Chiromo campus - University of Nairobi, Mt Kenya GAW station and San Marco Equatorial Site. The later station is now not operational and has remained dormant for a long time. Another key installation is the state of the art Mobile Air Monitoring Laboratory (MAML).

Nairobi station

Nairobi station measures ground level ozone, vertical profile of ozone, total column ozone, and various weather parameters. It is also the head station of the MAML. Pollution monitoring activities started in earnest at Dagoretti in 1996 when KMS installed vertical ozonesonde sounding system at Dagorretti, Nairobi. Initially the system was run on a manual ozonizer test unit model KTU-2A (KTU) monitoring instrument. The KTU system operated based on the Vaisala RS80 radiosonde and the Electrochemical Cell (ECC) ozone sonde. In the year 2010, the Vaisala RS80 was upgraded to a new Vaisala RS92 that is now in operation. Two years later, in 2012, MeteoSwiss changed the entire KTU system to an automatic pre-flight calibrations and ozone conditioning system (Figure 1). This system is used in preparation of the ozonesonde on the day of launch and conditioning 7 days before the launch. The only other place with such system now is Payerne, Switzerland. It facilitates measuring; vertical profile ozone, upper air data, amount of voltage in the batteries and the electric current generated.

The vertical profile of ozone in Nairobi is measured with ozonesondes attached to radiosondes. Ozonesondes have been used record ozone levels in other places for longer periods. Measurement of the concentration of ozone gas as a function of height is done by sampling ambient air with a balloon‐borne ascent to an average altitude of 30-32 km. Ozonesondes utilize electrochemical detection methods, through the reaction of ozone in an aqueous potassium iodide solution in the cell. A typical ozonesonde used in Nairobi is a small, lightweight, detachable air balloon borne instrument, which is connected to a radiosonde for additional measurements of meteorological parameters - pressure, temperature, humidity, wind direction and speed. Sample flight data is shown in figure 2.

Figure 1; *Scientist preparing the ozonesonde (left) and ready for flight (right)*



On average the ascent;

Gets to30-32 Km high

Rises at 5-6 m/s

Ozone layer at 18 km

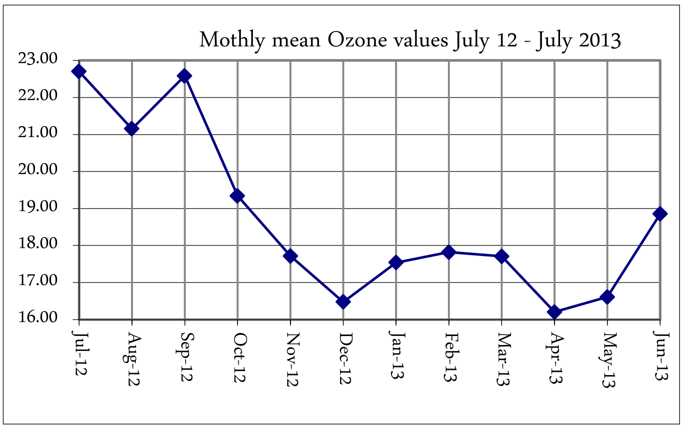
Tropause at 15-18 km

Figure 2*; generated data during flight*

Surface / ground ozone measurement

In the same year, 2012 MeteoSwiss also installed thermo-scientific surface ozone analyser Model 49i for sampling ground level ozone (Figure 3).The analyser utilizes ultraviolet radiation photometric technology to measure the amount of ozone in the sampled air in parts per billion (ppb). It is a dual photometer with both sampled and reference air flowing at the same time. Surface ozone data measurement, monitored continuously, is captured after every 5 minutes. The analyser in Nairobi, at Dagoretti, is in a laboratory room with a rain proof air inlet directed outside at a distance of 10m above the ground. An air-sucking pump draws in air to the analyser through a filter paper that removes any particles.

A)



B)

C)

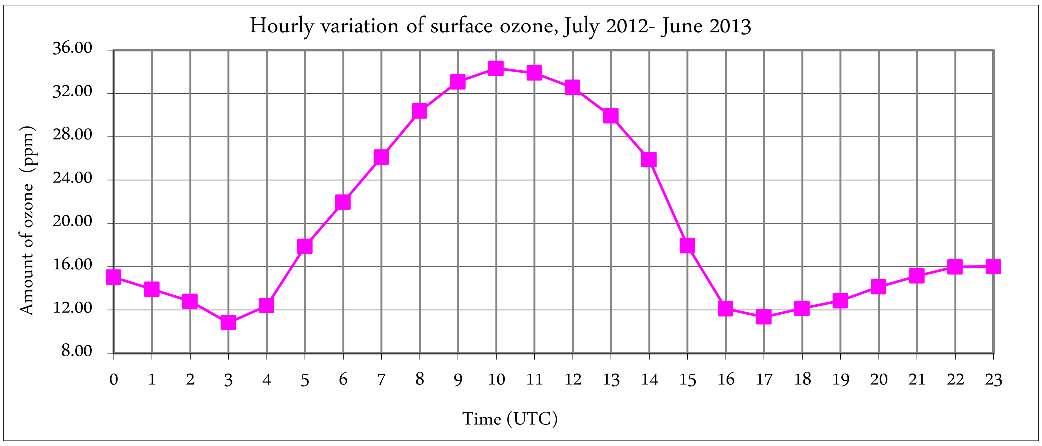


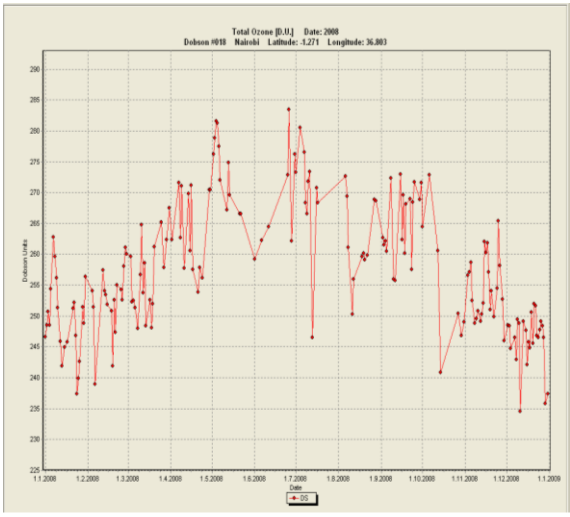
***Figure 3**; Surface ozone analyser, Model 49i and data generated;*

The 8-hour highest maximum mean concentration of surface ozone for year 2012 was 30.76ppm. This mean value is way below compared to the 50-ppm threshold considered by WHO to be harmful concentration (WHO, 2006) for human habitation.

Figure 3b shows seasonal variations with maximum values of 22.5 ppm recorded in the month of July 2012 while the least concentration recorded was 16.5 ppm in the month of December 2012. On the other hand, the low values were observed in December 2012, April 2013 and May 2013. These periods coincide with the rain season over the study region. However, it is noted that the ozone levels are at the lowest with one-month lag from the onset of long rains. The results agree with studies by Ayoma et al, (2004) and Muthama (1989). The observation could therefore be attributed to wet deposition of the ozone molecules. On diurnal variation, minimum ozone concentrations are recorded between 0300UTC and 1600 UTC. It increases from 0300 UTCat 11 ppm to 1000 UTCat 34 ppm (Figure 3c). A decrease in concentration is observedthereafter to 11 ppm at 1700 UTC. The observations imply that most of the ozone at Dagoretti is thermally generated. The observed ozone concentration can thus be attributed to the prevailing weather conditions on daily to seasonal timescales.

DOBSON SPECTROPHOTOMETER – Column Ozone

In the Nairobi, station there is installed the Dobson Spectrophotometer No. 18 column ozone-measuring instrument since 2005 (Figure 4). This instrument was initially at Chiromo campus at the University of Nairobi where WMO installed it in 1984 and was in operation until 1996. A ground-based instrumentthat measures the total ozone present in the atmospheric column by estimating the ultraviolet radiation (UV-B and UV-C) which calculate how much ozone is present in the entire atmospheric column.



***Fiugre4**; Dobson and its sample data set; Picture **Credit**; John Nguyo*

Jomo Kenya International Airport (JKIA)

***Fiugres5**; Set of analysers at JKIA*

At the airport the following analysers and instruments are installed; Ground ozone (O_3) – API 400E, Carbon Monoxide (CO) – TEI 48c, Sulphur Dioxide (SO_2) – API 100E, Particulate Matter (PM10) – BAM

1o20 and weather station for weather parameters

- Teflon air inlet sucks air from outside
- Each instrument has a data logger,
- Software to download the data available

Mt Kenya station

This station started in 2009. It is located at the top of Mt Kenya standing at a height of 3897m AMSL. It is considered a high altitude station in Africa standing close to the equator at a longitude of 37.18° E and latitude of 0° 3'S. It is vital as it monitors background air pollution around the equatorial belt. In addition, it provides a unique opportunity for research and assessment of long trajectory air transport within Africa and beyond. At the station the following instruments are installed; 1) surface ozone analyser (TEI 49c) – started in 2002 but have since stalled from 2006 due to various reasons including power cut out at the station. 2)analysers for CO_2 and CH_4.

Parameters measured include;

Ozone: Average values *20-50 ppb*

Carbon monoxide: Average values *50-150 ppb*

Carbon dioxide,

Methane

Aerosols

Weather parameters

Some of the analysers are not operational

Fiugre 6*; Outside View; Mt. Kenya Station*

Picture Credit, http://gaw.empa.ch/gawsis/reports.asp?StationID=57

Mobile Air Van

Van Laboratory provides quick access to any site including remote locations as well as easy maneuverability in urban. The system supports a wide variety of applications performed for environmental monitoring such as adjacent to mining operations, engineering and quality control personnel for road construction industry and environmental auditors. This compact mobile laboratory accommodates a small team of personnel who must gain access to sites quickly. The system is equipped to take measurements of the ambient lair concentrations of;

- Ozone (O_3),
- Carbon Monoxide (CO),
- Carbon Dioxide (CO_2),
- Nitrogen Oxides,

- Sulphur Dioxide (SO_2),
- Hydrogen Sulphide (H_2S),
- Black Carbon (soot),
- Ammonia (NH_3),
- Suspended Particulate Matter (Dust) and others

It has two furnaces running up to temperature of 710 ^{0}C that ensure the generation of hydrogen that is essential for the measurement of hydrocarbons and operation temperature of the instruments. There are 2 laptops in the MAML for downloading and analysing the data. Figure 7 shows the MAML station.

Figure 7*; Mobile air van outside and inside showing the analysers,*

Picture Credit*;* [*http://www.sianalytics.co.za*](http://www.sianalytics.co.za)

Legal tools for air pollution control in Kenya

There exists a fragmented legal framework for air pollution monitoring and control in Kenya. These can be placed in four legal documents; a) the constitution - 2010, b) statutoryprovisions specifically the Public Health Act, c) common law rules d) County council by-laws. However, ability to address issues of pollution is hindered by low levelpublic environmental awareness. This is despite the statutory National Environment Management Authority - NEMA- that supervises and regulates all matters relating to the environment.

Challenges

There are some limitations and challenges in air pollution monitoring activités in Kenya. Theyinclude ; fluctuation in electric power supply system that heavily rely on Hydro-generation ; lack of other sprcialised instruments to measure other GAW parameters and inadequate analysing facilities and softwares.

Conclusion and Recommendations

Although pollution-monitoring stations in Kenya are now becoming well equipped, the data volumes are in still in early stages (except vertical ozone profile). The data can give general the trends. It is recommended that there be continuous and accurate observation of pollution activities in Kenya. There is need to introduce air transport modelling and pollution products on the models already available in the department such as SYNERGIE. Proper training of the staff should be scaled up as there are very few officers who can run the machines.

Acknowledgement

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