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Capturing, Calculating, and Disseminating Real-Time CO_2 Emissions and CO_2 Flux Measurements via Twitter in a Smart City

Laurie Butgereit
CSIR Meraka Institute
Pretoria, South Africa
lbutgereit@meraka.org.za

Alecia Nickless
CSIR NRE
Pretoria, South Africa
anickless@csir.co.za

***Abstract*—Carbon Dioxide levels in South Africa's Cape area have shown a steady increase from 355.6 ppm in 1983 to approximately 383 ppm in 2008 with current values being approximately 387. These values, however, are not necessarily communicated to the general public in a way that is understandable. This paper describes a project in which carbon dioxide levels are measured at three stations surrounding the Cape Town metropolitan area in South Africa. The wind direction and wind speed are also obtained from various sensors within the metroploitan area. From these measurements, it is possible to determine the changes in the carbon dioxide levels and determine if the Cape Town metropolitan area is emitting or absorbing carbon dioxide. These values are then published on Twitter and Facebook for easy access by the public.**

Keywords – Twitter, Picarro, Carbon, CO_2

I. INTRODUCTION

The relationship between atmospheric CO_2 (carbon dioxide) and climate change has been investigated since the 1800s [1]. The CO_2 levels at South Africa's Cape Point have shown a steady increase from 355.6 ppm in 1983 to approximately 383 ppm in 2008 [2, 3] with current baseline measurements being approximately 387 ppm. The projected climatic impacts of these changes have led to calls for reductions in emissions [4]. It has been argued that climate change which takes place specifically due to increases in CO_2 concentration is largely irreversible for one thousand years after emissions stop [5].

Measuring CO_2 levels and calculating CO_2 emissions and CO_2 flux is important. However, in order to change the public's habits with respect to CO_2, these measurements must be presented to the public in a manner which is easy to obtain and understand.

This paper presents work on monitoring the CO_2 levels around Cape Town in South Africa. Three sensors are situated around the perimeter of Cape Town: one sensor is to the south and is positioned at Cape Point and is maintained by the South African Weather Service, one sensor is to the north and is positioned on Robben Island, and the third sensor is to the east and is positioned in Hangklip. The latter two instruments were installed by the CSIR (Council for Science and Industrial Research) specifically to monitor emissions from the City of Cape Town. A collection of wind sensors in the greater Cape Town area record the wind direction and wind speed. A combination of this data can be used to calculated the CO_2 flux levels. These levels are then communicated with the public using popular social media such as Twitter and Facebook.

II. RELATED WORK

The carbon fluxes of various geographic areas have been calculated using a number of different techniques.

The carbon flux of the city of Baltimore, Maryland, in the United States was calculated for period 2002-2006. One 37.2m tower was erected and hourly measurements were made over the course of the study and combined with wind information and knowledge of the land cover (paved, water, treed, bare soil, etc) [6].

The carbon flux of the city of Indianapolis, Indiana, in the United States was calculated by collecting data via aircraft which flew over the city. Eight flights were taken during the period 2008/2009. Measurements of CO_2 were conducted in flight. Emissions were calculated using the wind speed and the difference between the CO_2 concentration in the plume and the background concentration [7].

In 2012, the city of Davos, Switzerland, published CO_2 emissions (but not flux values) on a webpage with visualisations of the movement of CO_2 [8]. Also in 2012, Tasmania installed its first carbon flux tower which is 80m tall and takes measurements every 30 minutes [9].

The related work, thus far however, does not involve any social media.

III. RESEARCH QUESTION, OBJECTIVES, AND METHODOLOGY

The research question for this study was “Can CO_2 levels, emissions and flux values be presented in a timely manner to the general public using social media”.

The research objectives for this study was to

1. Collect CO_2 levels at three different points around the perimeter of Cape Town, South Africa

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2. Collect wind speed and wind direction measurements at various positions within Cape Town, South Africa
3. Calculate the CO_2 emissions and flux values from the data collected
4. Publish this information so that it is easy accessible by the public

In order to satisfy these research objectives, a Design and Creation Research Methodology as defined by Oates [10] was followed. According to Oates, the Design and Creation Research Methodology is an iterative process consisting of five steps:

1. Awareness – the recognition and statement of the problem.
2. Suggestions - tentative ideas about how this problem might be addressed.
3. Development – implementation of the tentative ideas
4. Evaluation – assessment of the development items
5. Conclusion – consolidation of the results.

These five steps were iterated over for a number of cycles in order to satisfy the research objectives and answer the research question.

IV. Carbon Dioxide and Picarro Sensors

The concentrations of atmospheric carbon dioxide (in ppm) at the three sites are measured using a Picarro Cavity Ring-Down Spectroscopy Analyzer (model G2301 at Robben Island and Hangklip and a G2302 at Cape Point). These measurements occur every second and are stored in files which contain approximately an hour's worth of data. The analyzer is connected to the Internet through a 3G Internet connection which is managed through a DLink router, and the hourly data files are submitted to an email account through the use of a batch script which runs once an hour.

In order to obtain the emission or flux estimates in manner which is computationally fast, not data intensive and easily compatible with social media platforms, such as Twitter and Facebook, a "back-of-the-envelope" approach is used. Firstly, the CO_2 concentration is determine from the emailed data files. The wind speed and direction are obtained from the South African Weather Service, and if the wind is blowing from the North West or the South East, and assuming that the wind is blowing in a straight line, then the air should pass over a measurement station, then over the city, and then over the next measurement station, in the case of Robben Island and Hangklip stations (Figure 1).

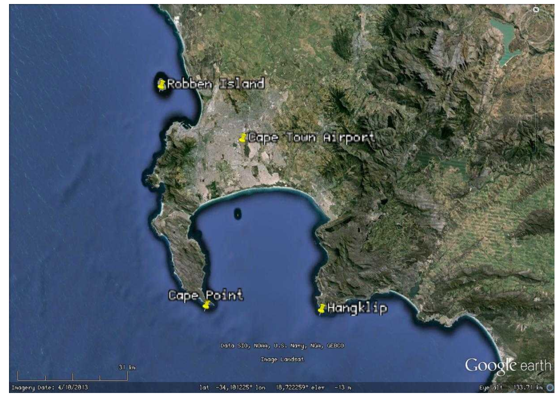

Figure 1: Map of 3 Picarro sensors and one wind sensor

First the difference in the CO_2 concentrations between the two sites is calculated. The difference is then converted into mg CO_2 per m^3 using the ideal gas law:

$$\text{mg } CO_2 \text{ per } m^3 = CO_2 \text{ ppm} \times 44.01/(8.3145 \times \text{Temperature/Pressure})$$

The first assumption is that the wind is traveling in a straight line (as per the direction measurement) from one station to another station. The second assumption is that the wind speed is constant across the area of interest.

Using the wind speed from the Cape Town International Airport, and assuming a planetary boundary layer height of 1000m, and that the distance between the Robben Island and Hangklip stations is 77.4km, an approximate CO_2 flux can be calculated:

$$CO_2 \text{ flux} = \Delta CO_2 \times \text{wind speed} \times 1000 / 77400$$

This method of calculation is derived using a depiction of the surface atmosphere as a tall cylinder, with a base of area $1m^2$, which gets pushed from station A to station B at the speed of the wind. This cylinder of air is assumed to be perfectly mixed, and that CO_2 can only be added or removed at the base of the cylinder (the surface). This will be affected by how much time the cylinder spends on each piece of surface, which is determined by the windspeed, and how far the cylinder has to travel, which would be the distance between the two stations. The CO_2 which is being added or removed from the cylinder will get mixed inside the cylinder, and the cylinders of air which surround are exactly the same. The height of the cylinder is the planetary boundary layer height.

This is a crude method of flux calculation, but the results are comparable to what is obtained from eddy covariance flux measurement stations, and the main purpose is not to obtain scientifically referenceable quantities, but to obtain instantaneous measurements which would be of interest to those following climate change mitigation efforts. A more rigorous method for determining the fluxes is through inverse modeling [11]. This allows the determination of whether the flux is positive (emission) or negative (uptake), and how the quantity changes from time to time.

V. ARCHITECTURE

The architecture is based on Beachcomber [12]. Beachcomber is a JEE (Java Enterprise Edition) application based on the Mobicents communication platform [13]. Beachcomber (via Mobicents) supports resource adaptors (RAs) which communicate with external objects and service building blocks (SBBs) which manipulate the data.

An overview of the architecture can be seen in Figure 2. The three CO_2 analyzers communicate via POP3 email. The wind sensors are accessed via HTTP as explained in Section VI. The values are forwarded to the Service Building Block which calculates the emission and flux values. The resulting calculations are then forwarded to Twitter using the Twitter resource adaptor based on the Twitter4j library.

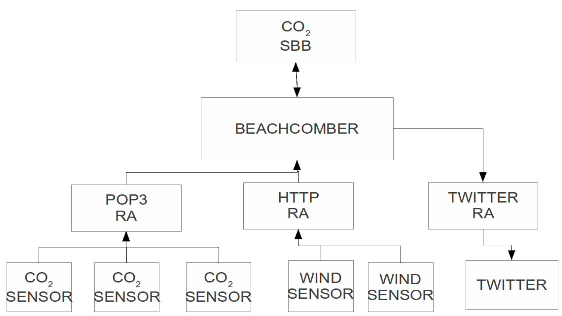

Figure 2: General architecture

Messages containing the CO_2 levels are sent from the three Picarro sensors periodically. These messages are received by Beachcomber and forwarded to the CO_2 monitoring Service Building Block. The CO_2 SBB also initiates HTTP requests to find the wind direction and wind speeds at various locations around Cape Town. With this information, the CO_2 SBB can calculate the emissions values and flux values. These are formatted into the size of a Tweet and forwarded to Twitter.

VI. WIND SENSORS

The South African weather service maintains approximately 18 wind sensors which supply wind direction and wind speed at various locations around Cape Town [14]. These values are updated periodically by the South African Weather Service. As can be seen in Figure 1, there are wind sensors (such as Cape Town International Airport) which are on the straight line vector between pairs of CO_2 monitors (in this case between Hangklip CO_2 monitor and Robben Island CO_2 monitor).

VII. TWEETS

The platform produced a number of different outputs.

The CO_2 levels measured in PPM (parts per million) were posted on Twitter as they were received as can be seen in Figure 3

Figure 3: Sample post of CO2 levels measured in PPM

Wind speed and wind direction were also posted with a link back to the original data as can be seen in Figure 4

Figure 4: Sample post of wind speed and direction

When it was appropriate, the carbon emissions, flux, or absorption was also posted as can be seen in Figure 5

Figure 5: Sample post when nature is absorbing CO2

When appropriate, the posts would also indicate if Cape Town emitting carbon or whether it was carbon neutral as can be seen in Figure 6.

Figure 6: Sample post when Cape Town is relatively carbon neutral

VIII. CHALLENGES

There were a number of challenges on this project.

One of the challenges was that some of the sensors were positioned in remote areas (specifically the CO_2 sensors in Robben Island and Hangklip). These two sensors run unattended and communicate with the various servers using the cell phone network. If and when networking problems arose, it was problematic because both authors were located over one thousand kilometers away in the Pretoria area.

Another challenge was that not all the sensors were operated by the authors. Two of the CO_2 sensors were maintained by the second author of this paper. One of the CO_2 sensors was maintained by the South African Weather

Service. Data from the three sensors were in slightly different format and the CO_2 SBB needed to cater for this.

A third challenge was that the wind sensors data was not always available. Different calculations needed to be used if a wind sensor which was on the straight line vector between two CO_2 sensors was not online and if a different wind sensor needed to be accessed which was not on the straight line vector.

IX. Results

The research question, "Can CO_2 levels, emissions and flux values be presented in a timely manner to the general public using social media", can be answered positively. It is possible to post these CO_2 measurements on social media in a timely manner.

The four research objectives have been satisfied:

1. CO_2 levels are obtained from various sensors
2. Wind speed and direction measurements are obtained from various sensors
3. CO2 levels, flux, and emissions are calculated from these measurements
4. The resulting values are published on Twitter and Facebook and included in blogs about the project.

The five steps of the Design and Creation Research Methodology were iterated a number of times.

1. Awareness – The authors recognised that informing the public of CO_2 levels, emissions, and flux values could assist in reducing the carbon footprint of an area.
2. Suggestions – It was proposed that CO_2 values and wind values be monitored, flux values calculated, and disseminated on Twitter and Facebook.
3. Development – Communication between the Picarro sensors, the wind sensors, and server was established. The flux levels were calculated and disseminated.
4. Evaluation – The platform was evaluated in terms of Information Technology but was not evaluated in terms of climate change or social engineering.
5. Conclusion – Conclusions were drawn from the results in terms of Information Technology and suggestions for future research were created.

X. Carbon Literacy, numeracy, and Capability

In the financial world, one can speak of the terms *financial literacy*, *financial numeracy*, and *financial capability*. The term *financial literacy* refers to a person's ability to understand how the financial world operates. The term *financial numeracy* refers to a person's ability to do calculations (such as tax and interest calculations) on monetary values. The term *financial capability* refers to a person's capability to operate in the financial world by opening a bank account, earning money, and purchasing goods.

Similar terms can be used when dealing with carbon and researchers have used the terms *carbon literacy, carbon numeracy,* and *carbon capability. Carbon literacy* can be defined as the general knowledge or awareness of the concepts, causes, and effects of greenhouse gases [15]. *Carbon numeracy* can be defined as the knowledge and skills to calculate carbon related values whether in scientific terms or in financial terms [15]. *Carbon capability* refers to a person's capability to actually make choices which can affect real carbon measurements in the person's life [16].

Whitmarsh *et al* identify three dimensions to *carbon capability.* The first dimension is a cognitive dimension where people talk about carbon in abstract terms and blame others for climate change. The second dimension is individual behaviour where people take steps to lead a low-carbon lifestyle or purchase carbon-offsets. The third dimension is broader public engagement including contacting government representatives, joining organisations, and campaigning for lower carbon levels [16].

The authors believe that this project can help at all three dimensions of *carbon capability* by providing the public with information about carbon (the first dimension), by specifically giving information about high and low carbon flux levels which could influence their behaviour (the second dimension), and by providing specific information which could be forwarded to governing authorities or be part of a public campaign (the third dimension).

XI. Future Research

This research dealt primarily with obtaining the CO_2 levels and wind information, calculating the CO_2 flux levels and the disseminating the information on Twitter and Facebook. The research showed that this level of connectivity was possible.

The current research did not attempt to measure the human reaction to this information or whether more people could be reached using different communication channels.

Future research could include the following:

1. More widely disseminating the CO_2 values by SMS, audio radio, and XMPP.
2. Increase the number of followers on Twitter and Facebook.
3. Attempt to use these CO_2 values to influence the cost of public transportation, parking, etc.

Research and collaboration is invited in these areas.

XII. Conclusions

This research has shown that is is possible to disseminate information about CO_2 levels, flux, and emissions using social media in a timely manner. The platform developed for this project received timely information about the CO_2 levels from three monitoring stations surround the City of Cape Town in South Africa. In addition, wind information was obtained from independent sensors stationed around the City. From these values, one could calculate whether CO_2 was being emitted by the City, absorbed by the City, or whether the City was Carbon Neutral. This information was then successfully posted on Twitter and Facebook.

In a smart city, however, this information should be used to influence other domains such as the cost of public transportation or the cost of parking personal vehicles in the city centre. Research and collaboration is invited in this area.

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