MODELING THE SPATIAL DISTRIBUTION OF GREENHOUSE GAS EMISSIONS IN URBAN AREAS OF SRI LANKA

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ABSTRACT

Greenhouse gases (GHG) are gases in the atmosphere that absorb and emit radiation within the thermal infrared range. Urban areas are the main sources of GHG emissions. Globally, almost 80% of GHG emissions come from the burning of fossil fuels and industrial processes. Since many of the major GHGs stay in the atmosphere for tens to hundreds of years after being released, their warming effects on the climate persist over a long time and can therefore affect both present and future generations having an impact on environment, human health and economy. Recent studies have shown that the surface air temperature over Sri Lanka has been rising and that the annual rainfall and the number of rainy days per year have been decreasing at most places. However, little research has focused on monitoring and modeling of greenhouse gas concentrations in Sri Lanka. Hence, modeling the spatial distribution of GHG emissions in urban areas is essential to monitor the air quality, evaluate the health effects and initiate various policy level decisions on mitigating adverse climate related effects. Carbon dioxide (CO_2) is the second most abundant GHG and it remains in the atmosphere longer than the other GHGs. Moreover, CO_2 and temperature are closely correlated, which means they rise and fall together. Hence, in this research, a Remote Sensing based model was developed to estimate the GHG emissions, especially the CO_2, based on the temperature levels. This research allows various climate related organizations in Sri Lanka to use the proposed modeling approach for any urban area of Sri Lanka to monitor the GHG levels in a more cost effective manner.

***Key words*:** Greenhouse Gases, Modeling, Remote Sensing, CO_2, Temperature

1. INTRODUCTION

Earth is the only one planet in solar system which is suitable for life because of its perfect location in the solar system and its unique atmosphere which is composed of unique combination of gases. This unique atmosphere plays a vital role to keep optimum levels of planets temperate to sustain life by absorbing heat of solar energy. To sustain this temperature earth's atmosphere has unique combination of gases such as 78% Nitrogen, 20% Oxygen, 1% of Argon, and 1% of GHGs (Water vapor, Carbon dioxide, Methane, Nitrous oxide, Ozone and Chlorofluorocarbons. Especially Carbon Dioxide (CO_2) and Methane (CH_4) is very important to keep heat of the atmosphere. Therefore when the amount of these gases goes up, atmospheric heat also goes up. Contradicting to this statement, some studies have shown the temperature rise has caused the CO_2 increase, not the other way around [1].

However, one of the most remarkable aspects of the paleoclimate record is the strong correspondence between temperature and the concentration of CO_2 in the atmosphere observed during the glacial cycles of the past several hundred thousand years. When the CO_2 concentration goes up, temperature goes up. When the CO_2 concentration goes down, temperature goes down (Figure 1).

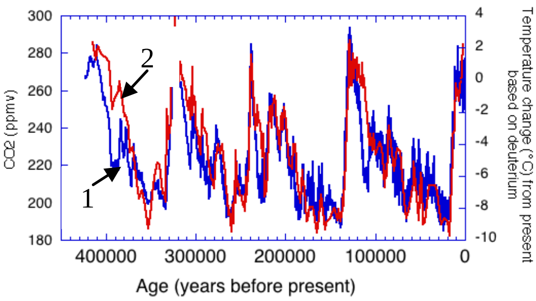

Figure 1: Temperature change (1) and carbon dioxide change (2) observed in ice core records

Compared to rural areas, urban areas emit more GHGs due to substantial usage of fossil fuel by industries and vehicles. Especially, vehicles in traffic jams emit large volumes of CO_2, compared to freely moving vehicles. Extreme weather incidents such as drought & flooding, melting of ice & snow and sea level rise are the major consequences associated with high concentration of GHG emissions.

2. METHODOLOGY

2.1. Case Study

GHG emissions can be estimated using either ground based testing methods or Remote sensing methods. Soil gas surveys and ambient sampling are commonly used ground based testing methods.

Under the soil gas surveys, gas samples from soil are collected and laboratory test is performed to measure the amount of GHGs. Ambient samplingmethod is similar to the soil gas surveys, but this method estimates GHG emissions in larger areas by assuming that most of the emissions remain near to emitting source due to its high density. Thus this method collects samples from nearby sources and estimates amount of GHGs from laboratory tests.

However, these methods are more time consuming and more labor intensive. Satellite remote sensing of air quality applications has advanced over the past decade. Many methods, data, and tools have been developed by various groups around the world to convert satellite retrieved information for air quality monitoring

Remote sensing is a technique for collecting information about the earth without taking a physical sample of the earth's surface or touching the surface using sensors placed on a platform at a distance from it. A sensor is used to measure the energy reflected from the earth. This information can be displayed as a digital image or as a photograph. Sensors can be mounted on a satellite orbiting the earth, or on a plane or other airborne structure.

In remote sensing, there are several methods of estimating GHG emissions. One of the direct method is use of special ground based sensors such as field spectrometers to extract relevant gases. This method is bit expensive and more time consuming. The second method is use of Light Detection and Ranging (LIDAR) surveying to extract GHG emissions. This method is more accurate, but very expensive. Therefore, in this research an alternative model has been developed to quantify the GHG emissions, especially the CO_2. The model uses Thermal Infrared bands (bands 10 & 11) of Landsat 8 satellite images to model the CO_2 emissions based on the surface temperature and atmospheric radiation. Part of the Colombo core area (Figure 2) of Sri Lanka has been selected as the case study area.

Figure 2: Case Study Area

3. RESULTS

Initially, the bit values in the thermal bands were converted into radiance using eq. (01).

$$R = (ML) \times DN + AL \qquad (01)$$

Where;
ML-Band specific multiplicative Rescaling Facto
AL-Band specific Additive Rescaling Factor
R-Radiance
DN- Digital Number or Brightness value of pixel

Rescaling Factor	Band 10	Band 11
ML	0.000 342	0.000 342
AL	0.1	0.1

Then, the pixel based radiance values were converted into temperature using eq. (02)

$$T = \frac{K1}{\ln\left\{\frac{K*0.95}{R}+1\right\}} \qquad (02)$$

Where;
T-Temperature

K, K1 –Thermal conservation Constant (K= 1321, K1= 777)
R-Radiance value

The output received from eq. (2) includes atmospheric temperature too. Hence, to get an atmospherically corrected temperature, eq. (03) was applied.

$$CV2 = \left\{\frac{(CV1-Lh)}{0.95}\right\} - \left\{\frac{1-t}{t}\right\} Ld \qquad (03)$$

Where;
CV2-atmospherically corrected cell value as radiance
CV1-cell value of Heat signature
Lh-Upwelling Radiance
Ld- Down welling Radiance
T-transmittance

Finally, to get the real atmospheric temperature (Figure 3), output received from eq. (02) was subtracted from the eq. (03) output. Hence, using this final output, it is possible to identify the areas with heated air packets which comprise of GHGs, especially the CO_2.

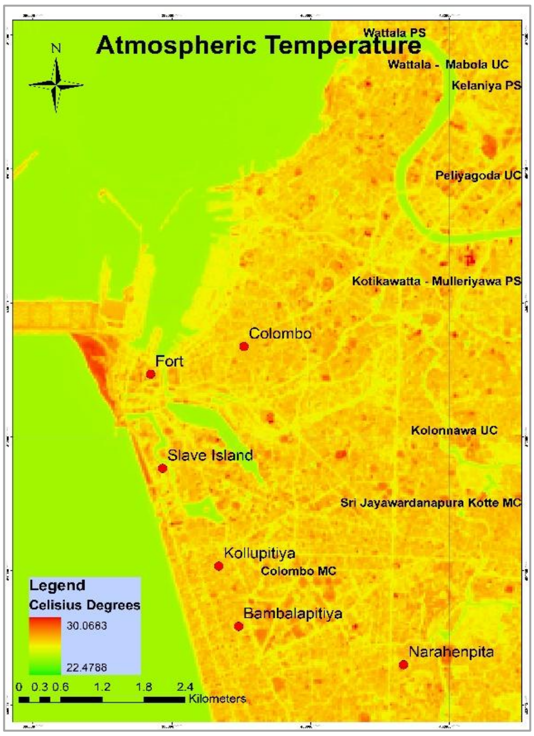

Figure 3: Atmospheric temperature as at 27th January 2016.

The accuracy of the model was tested by comparing the high heat emission places illustrated in Figure 3 with its associated land uses. Accordingly, high GHG emission places such as Kelanitissa power plant, Maradana, Armor Street and Pettah have been highlighted in the map as areas with high temperature and high GHG emissions Further, the atmospheric temperature at Pettah area was substituted to ideal gas equation [eq. (4)] to calculate the no of air mols present in the atmosphere in $1m^3$

$$PV = nRT \qquad (04)$$

Where;
P- Pressure (Pa)
V- Volume measure (m^3)
n- Amount of particles (No. of moles)
R - Universal gas constant (8.314 J/K mol)
T - Absolute temperature measure in Kelvins

Then, considering that an average mass of an atmospheric mol is 28g, the atmospheric density at Pettah area was calculated as $1.142kg/m^3$. Since this value has little deviation with the real atmospheric density of $1.125kg/m^3$, the validity of the model is satisfactory.

From eq. (04), the total no of mols in the atmosphere was received as 40.76. The average mass of a CO_2 mol is 44g. If M_o, C & O are the mass of other gases in the atmosphere except CO_2, no of CO_2 mols and no of other gas mols respectively, three equations can be built as follows:

$$(44 + M_0)/2 = 28 \qquad (05)$$
$$C + O = 40.76 \qquad (06)$$
$$44C + M_0 O = 1142 \qquad (07)$$

Solving the eq.(05), (06) & (07), mass of CO_2 in $1m^3$ can be obtained. Accordingly, CO_2 density at Pettah & Kelanitissa power plant area was received as $898.04g/m^3$& $644.6g/m^3$ respectively

4. CONCLUSION

This study indicates the potential application of digital satellite data for air-quality studies. The time required for traditional sampling methods for environmental monitoring can be reduced by using remote sensing. Thus, using the above Remote Sensing based model, it is possible to visualize and quantify the CO_2 emissions at any urban area of Sri Lanka in a more cost effective manner.

5. REFERENCES

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