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Measurement and Evaluation of Greenhouse Gases with Cloud Based Logging

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Abstract: Robust measurements of natural Greenhouse Gases emissions are vital for evaluating regional to global carbon budgets and for assessing climate feedbacks on natural emissions to improve climate models. To capture and analyze the high temporal variability of these fluxes in a well-defined footprint, we designed and developed an inexpensive device. In addition to automatically collect gas samples from footprint for subsequent various analyses in the laboratory, this device also utilizes a low cost carbon dioxide sensor, Temperature and Humidity Sensor, GPS sensor to measure Greenhouse Gases (GHG). Each of the devices modules were equipped with an ESP32 Wi-Fi, NodeMCU and Transceiver module to enable a local radio communication with the ground receiving Station for onward processing to cloud. This study shows the potential of a low cost and low instrument, open source software for devices development as automatic sensor network system to study GHG fluxes. Results obtained from research is shown as follows: CO2 (360 to 455 ppm), Temperature (26.9 ^{O}C to 30.9^{O}C) and Humidity (35.5% to 36.5%) which is good for human health. However, this research proves human capacity building and promotion of open data access for research.
Keywords: Greenhouse Gases; MQ 135, BMP280; DHT11; ESP 32 WiFi Modules; NodeMCU; Cloud.

I. INTRODUCTION

Atmospheric Greenhouse Gas (GHG) concentrations increases by human activities which result in global warming and climate change (IPCC, 2014). Measuring Greenhouse Gas (GHG) emissions is of paramount importance to understanding the emissions trends of companies, vehicular movement, facilities and human activities so that targeted and effective mitigation strategies can be developed. However, this prompt research on GHG emissions which is critical to understanding of the consequences of rapidly increasing atmospheric GHG concentrations. This research should be carried out globally, in both developed and developing countries, since both have different sources and sinks of GHGs, different climate-change vulnerabilities, and different capacities for mitigation and adaptation (López-Ballesteros et al., 2018; Ogle et al., 2014), GHG research has not been widely conducted globally especially developing countries. Recently, GHG research adopting appropriate technology and approach (Murphy et al., 2009) has been proposed and carried out. This uses low-cost and low-technology instruments, open source software and data, and participatory approaches, and in many cases has resulted in valuable research results accepted by International Scientific Communities (Choi, 2019; Shames et al., 2016; DeVries et al., 2016; Bastviken et al., 2015). High frequency measurements over long periods with broad spatial coverage of studied areas could reduce this uncertainty and result in more representative gas emission estimates. Some recent studies using low cost CH_4 (Eugster and Kling, 2012) and CO_2 sensors (Bastviken et al., 2015) could however be coupled to simultaneously study CH_4 and CO_2 flux across the air-water interface. It is a high sensitivity CH_4 gas sensor made for air contaminants and gas leak detection. Eugster and Kling (2012) showed that this sensor has potential to measure CH_4 at ambient air concentrations. The sensor has a high sensitivity to relative humidity and temperature, but these responses can be corrected for to yield a realistic CH_4 signal. To increase the quality and quantity of observations of GHG emission, we developed a low-cost, simple, robust and portable device with a well-defined footprint for investigating gas flux at with a defined location as reference point. Here, we tested three commercial sensors including: MQ135, DHT 11 and BMP 280. The $C0_2$ sensor used here is MQ135, which is low power modules that measures $CO_{2;}$ DHT 11 modules is a temperature and humidity sensor features a temperature sensor complex with a calibrated digital signal output and BMP280 modules measures humidity and pressure.

A. Observation of GHG Fluxes

It was reported in 2000, soil CO_2 flux measurements had been conducted at 1815 sites in only 42 countries; this had increased to 6625 sites in 75 countries by 2016 (Jian et al., 2021 and Dung-Gill et al., 2021) (Fig. 1 and 2). The exponential increases in measurements could be attributed to increased interest in the research area, and quickly-developing, highly advanced instruments using relevant technologies.

In terms of continental scale, measurements in Europe, North America and Asia cover around 90% of the global observations, while Africa and South America remain critically underrepresented (Dung-Gill et al.2021; Jian et al., 2021; Épule, 2015; Kim et al., 2013) compared to their importance in global GHG budgets (Fig. 3).

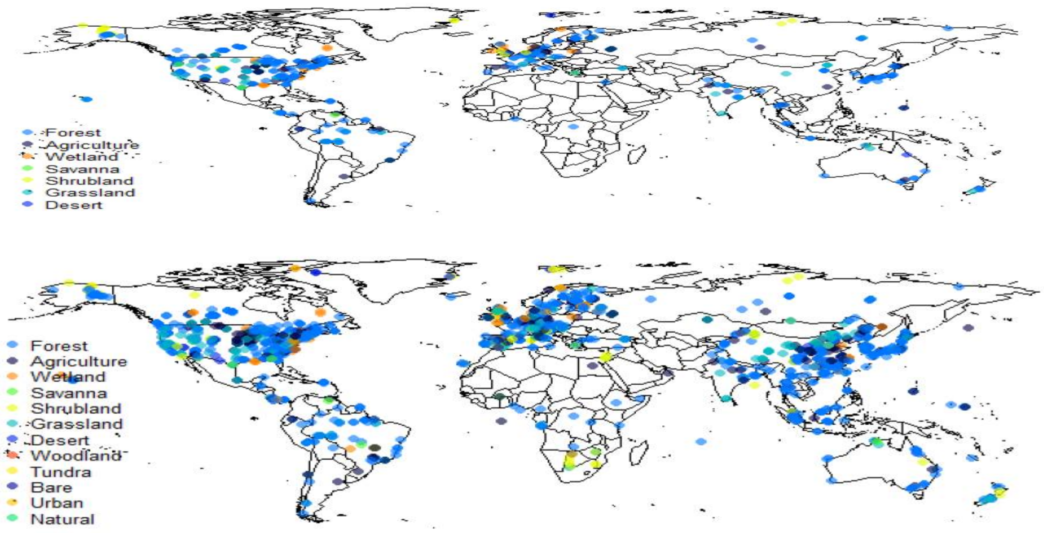


Figure 1: Global distribution of observed soil carbon dioxide fluxes by 2000 (above) and 2016 (below). Data Source: (Dung-Gill et al. 2021., Jian et al. 2021). Created by Giacomo Nicolini.

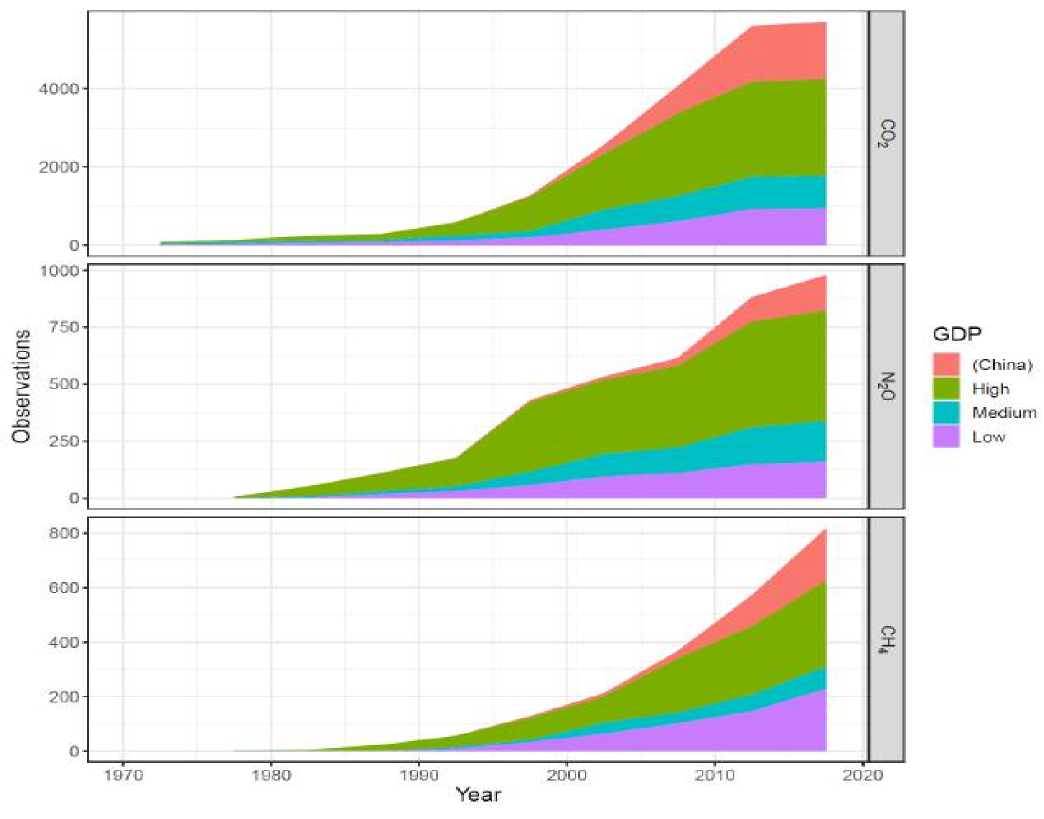


Figure 2: Cumulative observations of annual soil-to-atmosphere flux of greenhouse gases (CO2, N2O, and CH4) over time. An observation indicates a set of measurements that resulted in an annual flux estimate. Data source: CO2 – Jian et al. (2021); Dung-Gill et al. (2021) ; N2O – Global N2O Database (https://ecoapps.nrel.colostate.edu/global_n2o/) and CH4 – Al-Haj et al. (2020),

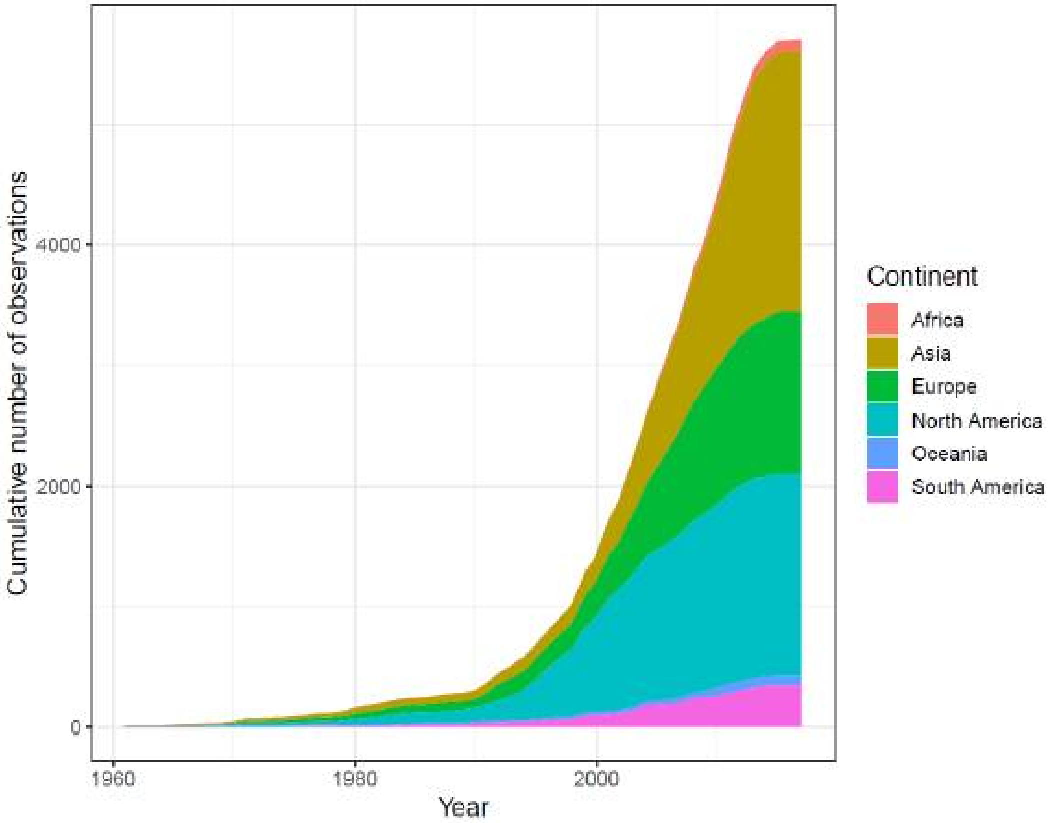


Figure 3: Number of published soil carbon dioxide flux observations in each region. An observation indicates a set of measurements conducted in a site during a certain period. Data source: Dung-Gill et al. (2021) and Jian et al. (2021)

B. Greenhouse Gas Flux

Low-cost technology has also been adopted in GHG research. Studies have utilized low-cost sensors to monitor atmospheric concentrations of CO_2 (Shusterman et al., 2018). Some studies have also demonstrated how to build low-cost gas sampling and analysis instruments (Carbone et al., 2019; Martinsen et al., 2018; Bastviken et al., 2015). For instance, Bastviken et al. (2015) utilized a low-cost CO_2 logger to measure CO_2 fluxes in terrestrial and aquatic environments. They replaced an expensive and high precision CO_2 analyzer and data logging system with a low-cost CO_2 logger which was originally produced for industrial uses, and with careful practices, bias and accuracy remain good enough for many carbon-cycle applications.

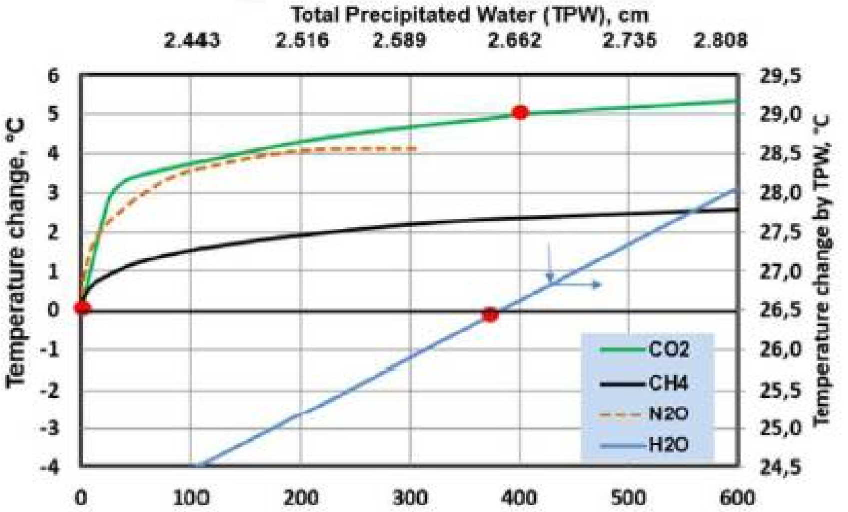
Antero Ollila (2017) reported the Warming Impacts of Greenhouse Gases in the Clear Sky using Average Global Atmosphere Model, AGA15 atmospheric profile, the absorption values of GHG can be calculated changing the concentration of each GHG starting from zero level in clear sky condition. The warming effects can be then calculated by using equation (1).

$T = -274.3249 + 50.7558 * \ln(E)$ ………………………………. ……………………(1)

The relationship between the temperatures (T, °C) and absorption energies (E, Wm-2) is logarithmic. The results are depicted in Fig. 4. And Fig. 5. Represent the absorption band Graphs of GHG in the AGA05 atmosphere. The warming effect of CO2 is highly nonlinear in the present atmosphere but the effect of H2O is practically linear around the average TPW value of 2.6 cm. Also, the concentrations of CH_4 and N_2O are so low that they are still in the region of Beer-Lambert law, where the absorption is almost linearly dependent on the gas concentration. The warming impacts of CO_2 can be fitted with the logarithmic equation:

$T = -1.01403 + 0.988487 * \ln(CO_2)$…………………………………… (2)

where T is the temperature impact (°C) and CO2 is the concentration of CO2 (ppm). The coefficient of determination R^2 is 0.999, the standard error is 0.02°C. This formula is valid in the concentration range from 200 ppm to 800 ppm. This formula gives the temperature change 0.6°C for the CO_2 concentration from 280 ppm to 560 ppm.



CO_2 CH_4 and N_20 concentration in troposphere, PPM

Fig. 4. The warming impacts of GH gases in the clear sky conditions. The red dots represent the concentrations and warming impacts of the year 2015

Data Source: Antero Ollila (2017)

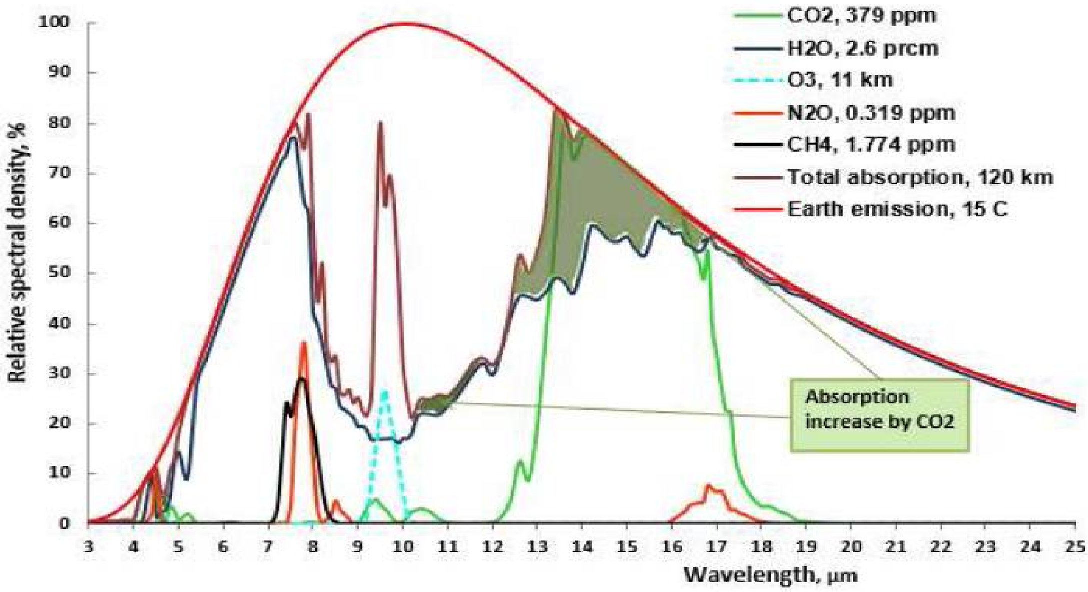


Fig. 5 The absorption band Graphs of GHG in the AGA05 atmosphere. The green shaded areas indicate a total warming impact of CO_2 of concentration of 379 ppm

Data Source: Antero Ollila (2017)

II. METHOD

This section, describe the technical details of our device that simultaneously measures CO_2 flux, temperature, altitude and equipped with a radio transmitter module as shown in figure 6 for wireless data transfer and monitor. The concept of the Cloud Based System for Greenhouse measurement is to demonstrate proof of concept of a satellite mission by measuring Greenhouses Gases (GHG) at selected altitude from the earth by utilizing greenhouse sensors as stated above and delivering data from such sensors to cloud at real time. This project will use the "ThingSpeak" server platform to output the data to the cloud, and the "ThingShow" mobile App as users' access terminal. Interested users of the data can download the app, and, with granted access, view the data as shown in figure 7.

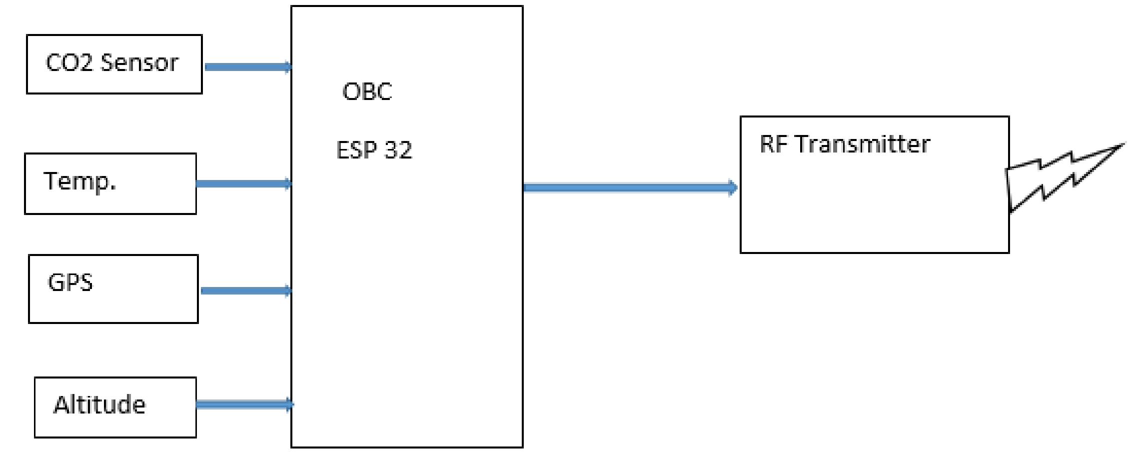


Fig 6: Remote Transmitter Unit

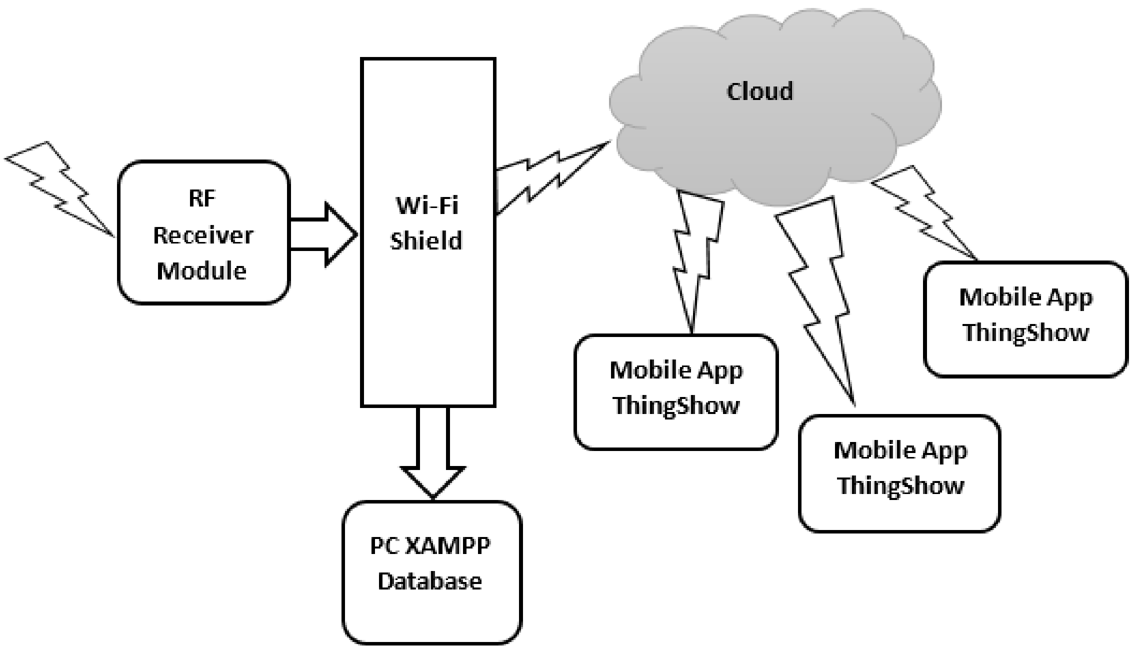


Fig. 7 Remote Receiver Unit

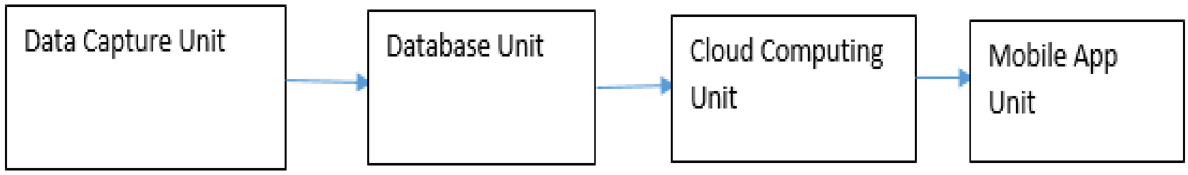


Fig. 8 Block Diagram for System Level Requirement

Figure 8 above show high level requirements specifications at stage level.

1) *Data Capture Unit:* Its main components are MQ-135, BMP280, and DHT11. Also, other components such as ESP32 Wi-Fi, NodeMCU, breadboard, and jumper wires will be integrated together to enable the sensors to detect any kind of gases along with dust, temperature and humidity.
2) *Database Unit:* The sensed data will be stored to be used by the XAMPP website and display the results immediately through using different display modules. Captured data will be sent through using IoT gateway to record collected data in a database using web services developed in Hypertext Pre-processor (PHP).
3) *Cloud Computing Unit:* ESP32 Wi-Fi module will send the sensed data from the sensors into the ThingSpeak cloud computing platform which will process faster and make it ready for use in our web application.
4) *Mobile App Unit:* ThingSpeak's web application needs a database to save and make the visualization of data easier, faster, and more accessible. The database will record information like for example user's personal information, sensing data, and user request information. The basic structure of this database is made of a set of graphs where information about a particular entity is graphically represented. Displayed information has many features and acts as interface for the user and administrator.

III. RESULT

Result of this research were calculated from the measured data of the cloud computing unit and information about a particular entity is graphically represented.

IV. DISCUSSION

Figure 9 presents the relationship of Carbon dioxide ($C0_2$) parts per million with Time, as it can be clearly seen from graphical representation Carbon dioxide (PPM) is within the recommended and accepted level for good health and human activities and in agreement with standard (https://www.CO2.earth >daily – CO_2). Carbon dioxide emission largely come from human activities such as burning fossils fuels and deforestation and are primary driver of climate change. Figure 10. Presents the relationship of Temperature (^{O}C) with Time at define footprint and result from graphical representation shown normal Temperature for human. Figure 11 presents the relationship between Humidity and Time, from the graph it shows a level between 35.5% to 36.5% humidity which is typically ideal for keeping home warm and comfortable for human existence.

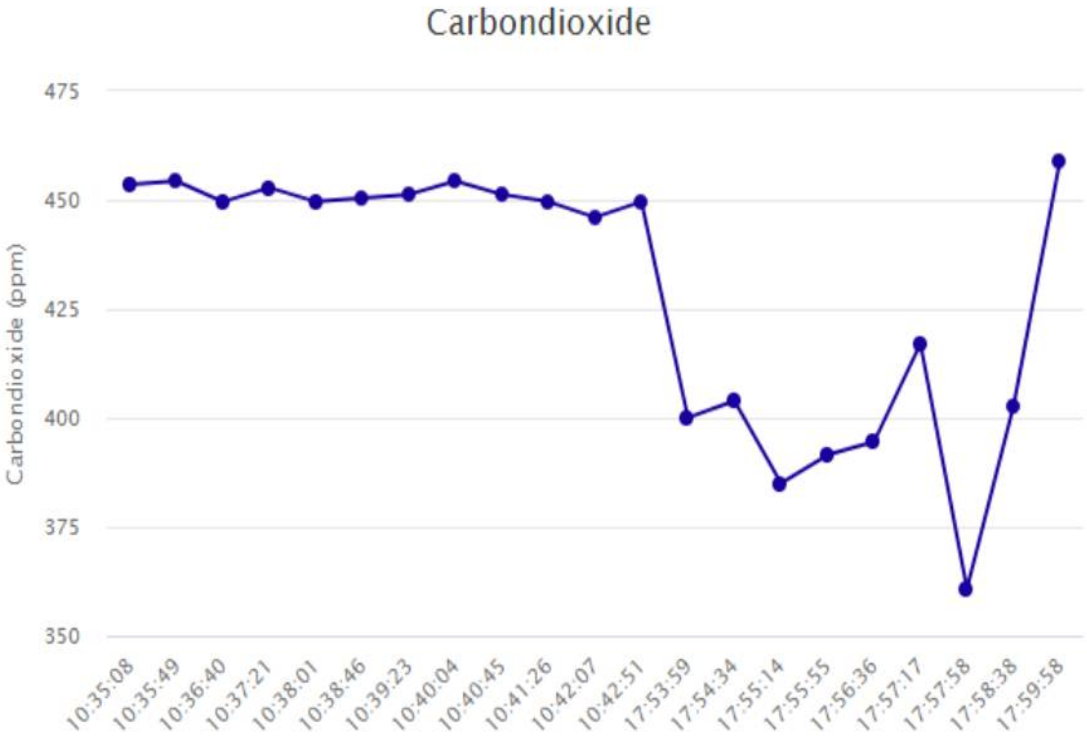


Fig. 9: Relationship between Carbon dioxide and Time

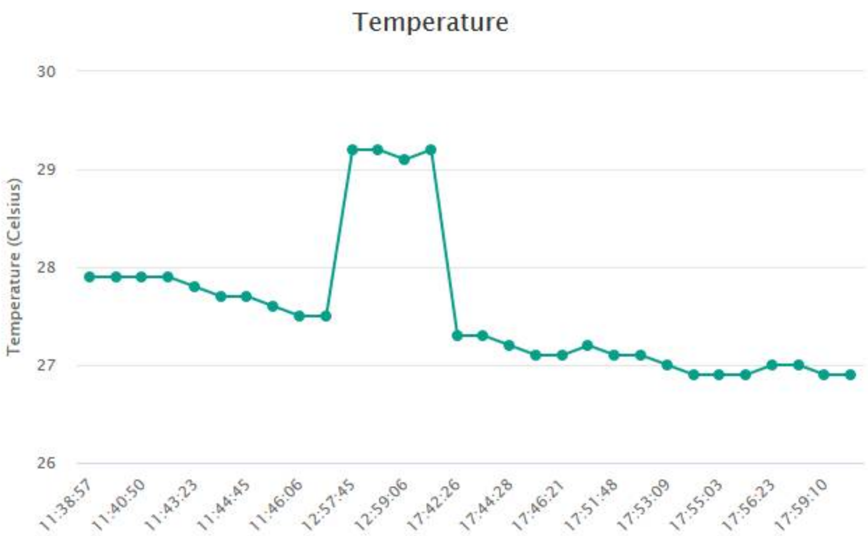


Fig. 10: Relationship between Temperature and Time

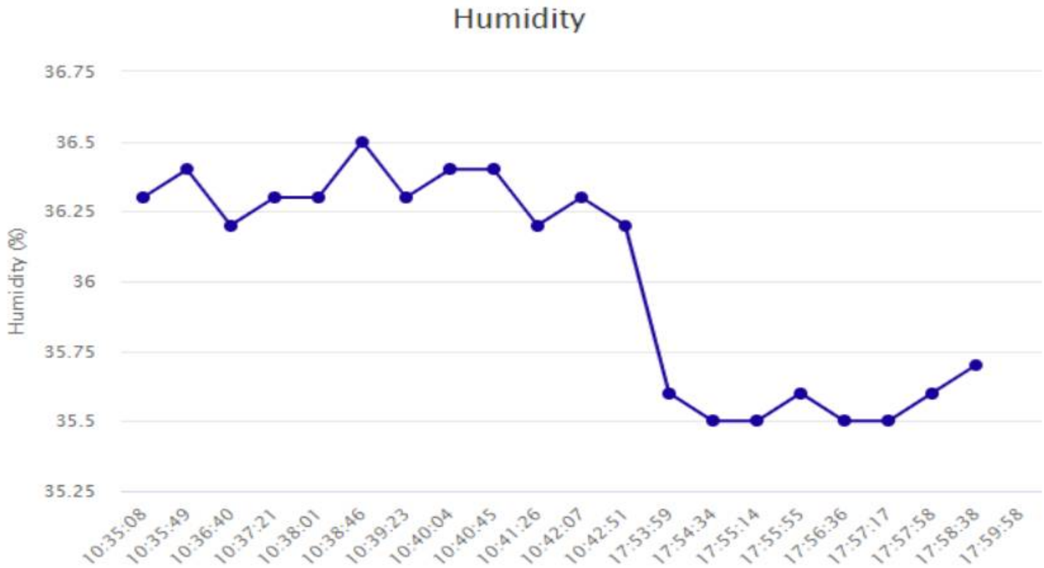


Fig. 11: Relationship between Humidity and Time

V. CONCLUSION

Measurement and Evaluation of Greenhouse Gases with Cloud Based Logging research has adopted a highly advanced technological with low-cost and low instrument, open source software for development. Results obtained as follows: CO_2 (360 to 455 ppm), Temperature (26.9 ^{O}C to 230.9^{O}C) and Humidity (35.5% to 36.5%) which is good for human health. However, this research proves human capacity building and promotion of open data access which is crucial for scientific information dissemination and training model for future generation of science community in the developing countries.

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