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SÃO PAULO URBAN GREENHOUSE GAS NETWORK – METROCLIMA PRELIMINARY RESULTS AND PROCESSES

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INTRODUCTION

Cities cover only ~3% of the world's surface yet originate 70% to 80% of global CO2 emissions[1,2] and are expected to continue growing as urban migration continues and intensifies. Cities are projected to shelter ~70% of world's population by 2050[3]. Managing urban emissions is vital to address the climate crisis and meet the objectives established by the United Nations Framework Convention on Climate Change and the Paris Agreement. To achieve this, we need to not only quantify and monitor emissions[4], but most importantly, attribute them to specific sources[5-10].

The current state-of-art-method uses "inverse modelling"[11] to infer emissions through a combination of bottom-up emission inventories[12-14] and a small number of strategically placed high-precision direct atmospheric measurements[15-17].

There are several different approaches for top-down methods. Some of these methods include aircraft mass balance, in situ tower networks, and remote sensing. Each method presents its own strengths, weaknesses, and level of repeatability to other urban areas. The main strength that top-down methods have is measuring the concentrations directly, so it is getting an accurate level of concentrations. However, depending on the method, it can be hard to assign which sources are contributing to the overall emissions and by what magnitude.

The cavity ring-down spectroscopy (CRDS) appeared in the late 1890's and is a well stablished technique used for the high precision trace gas measurements. It consists in a laser-based technique which is used to excite a ring-down cavity, in which the infrared absorption loss caused by a gas in the sample cell is measured to quantify the gas mole fraction[18,19]. It generates a quasi-real-time data set, performing measurements from different species every approximately 2 seconds. This generates large data sets and to extract the best information from it, scripts from programs as R a Python must be used. In the program development, it also must be taken in account the packages and tools to applied due to the computing time.

In terms of comparability, The World Meteorological Organization (WMO) has stablished a high accuracy and compatibility goals for atmospheric CO_2 and CH4 measurements to ±0.1 ppm for CO_2 (±0.05 ppm in the southern hemisphere) and ±2 ppb for CH_4[20]. Achieving WMO goals is not a trivial task. Atmospheric water vapor must be taking in account due to its large variability, which can cover any signal in the trace gases. There are several methods to reach the desired dryness as cooling or streaming the sampling air but the limitations and specifications of the sites conditions must be considered and meticulously evaluated.

Different urban networks have developed their own method to continuously measure greenhouse gas mole fractions across the city, including the background mole fraction measurements from all wind directions and resolving spatial patterns[21]. The same logic follows the calibration method to be applied relying on optimizing the measurement equipment to its best response.

A recent study comparing the combination of measurements and modelling with inventories result, showed that cities using only bottom-up emission inventories are under-reporting emissions on an average of 18,3% ranging from -145,5% to +63,5%[22]. São Paulo city is among the biggest cities in the world and it can not rely only on bottom-up estimations to report and understand its emissions.

Here we present the network structure, the implemented modifications along with the calibration plan and primary results from the first urban greenhouse gas in Latin America.

METHODS

The METROCLIMA-GHG Network commenced its operations in early January 2020, initially setting up stations at UNICID (UND) and Pico do Jaraguá (PDJ). Subsequently, in April 2020, instruments for measuring CO_2 and CH_4 concentrations, along with carbon isotopes in both gases, were added at IAG. It's worth noting that prior measurements of CO_2 and CH_4 (2019) existed at PDJ and IAG stations; however, these lacked calibration gas checks. In August 2020, the ICESP station (ICP) was successfully installed (Figure 1).

Since November 2022, modifications have been carried out in the greenhouse gas monitoring systems aimed at increasing the reliability of measurements. These monitors are sensitive to the material applied to the system during sample injection and also to the amount of water contained in the samples.

To enhance measurement reliability, physical modifications are being made to the measurement systems, primarily concerning the previously installed tubes and connections. Additionally, a drying system is being added to reduce water content in the samples. Given that these are continuous monitoring stations, methodologies are being developed for automatic calibration and continuous verification of data quality. Figure 2 presents the scheme applied for the stations application.

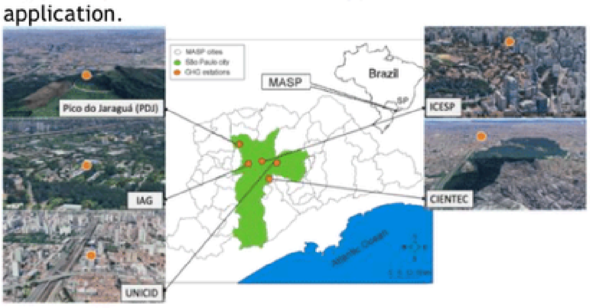

Figure 1. METROCLIMA-GHG Network sites overview. 4 greenhouse gas monitoring stations distributed throughout the city of São Paulo.

Figure 2. General scheme for the new configuration of the sampling sites.

FINDINGS AND ARGUMENT

The diurnal cycle of CO_2 is a widely utilized method for studying the variability of gas concentrations throughout the day. It helps to understand the main factors affecting these concentrations, such as sources, sinks, and atmospheric dynamics like the planetary boundary layer [19]. Consequently, the diurnal CO_2 cycle is influenced by local, regional, and seasonal characteristics, making it a crucial record of gas dynamics in a specific area.

Figure 3 presents the annual diurnal cycles of the PDJ, IAG, and UND stations. These cycles showed characteristic and distinct distributions for each station, mainly related to amplitudes (peak-trough), periods of maximum concentrations, and variations in the annual mean cycles. The maximum hourly concentrations were observed during the night and early morning hours at all stations. However, at UND, a characteristic peak (Fig. 3C) was observed during the morning rush hour (7-9 AM), associated with the source of heavy vehicular traffic on avenues near the station, characteristic of this station (Fig. 1). At the PDJ station, the smallest amplitude and the lowest values of maximum concentrations were observed compared to the others (Fig. 3A, D).

At the IAG station, the highest amplitude and maximum values were observed during the night. This station is located in a suburban area within the University of São Paulo (USP), which includes a semi-vegetated area with heavy vehicular traffic approximately 2 km away, exhibiting characteristics intermediate to the other two stations. Therefore, the peak concentrations at night may indicate the combined contributions of vegetation and vehicles. Meanwhile, the minimum concentrations, with values similar to those at the PDJ station, observed in the early afternoon (1-3 PM), are possibly due to more intense photosynthetic activity compared to the UND station (Fig. 3D).

The differences in average hourly values for each station between 2020 and 2021 were considerable at PDJ, with a slight increase from 2020 to 2021, possibly indicating a greater influence of global fluxes at this station. For the IAG and UND stations, there was no significant difference over the last two years (Fig. 3D). This may indicate that vehicular sources are the main contributors to CO2 at these stations.

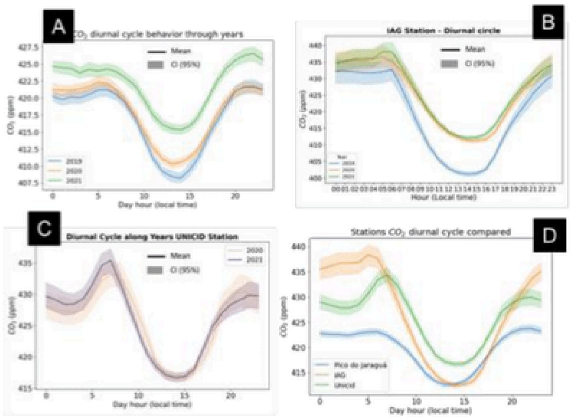

Figure 3. Annual diurnal cycle of CO_2 for the PDJ (A), IAG (B), and UND (C) stations. Comparison of the three stations for the period.

CONCLUSIONS

Significant adjustments have been made to the stations to enhance their accuracy. However, further critical adjustments are necessary. Implementing a calibration method and routine is crucial to achieve a more precise representation of the city's emissions. Clearly, important challenges still need to be pursued for the improvement of the network and understanding of the results. This includes evaluating other potential sites that may represent the CO2 background for the RMSP, assessing the dynamics of CH4, and identifying the main sources of the gas for the RMSP, among other important aspects. Additionally, publishing in indexed international journals and disseminating the results to the scientific community are continuous goals of the project.

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