



Characterizing Urban GHG Emissions: Results from São Paulo's Atmospheric Observing Network

Maria de Fatima Andrade¹, Marcia Talita Marques¹, Jose Agostinho Gonçalves de Medeiros², Marco Aurélio Menezes Franco¹, and Eduardo Landulfo²

¹Universidade de São Paulo, Instituto de Astronomia, Geofísica e Ciências Atmosféricas, Ciências Atmosféricas, São Paulo, Brazil

²IPEN, Instituto de Pesquisas Energéticas e Nucleares, São Paulo, Brazil

Since 2020, the **METROCLIMA Network** (www.metroclima.iag.usp.br) has been monitoring greenhouse gases (GHGs) across São Paulo, Brazil, with five strategically located stations: **Pico do Jaraguá (-23.46, -46.77)**, **IAG-USP (-23.56, -46.73)**, **UNICID (-23.54, -46.56)**, and **ICESP (-23.56, -46.67)**, measuring CO₂ and CH₄ via CRDS analyzers, and a flux tower at **Cientec (-23.65, -46.62)** equipped with an IRGASON system. The network aims to assess São Paulo's role as a major emission source impacting regional air quality and climate. Each monitoring station is equipped with two calibration gas cylinders: one containing a natural air standard (traceable to NOAA/ESRL references) and one containing a target gas mixture for routine instrument calibration. Stable carbon isotope analysis ($\delta^{13}\text{C-CO}_2$) at IAG-USP has revealed shifts in dominant CO₂ sources during extreme events, such as reduced vehicular emissions during the 2020 COVID-19 lockdown and increased contributions from Amazonian and Pantanal wildfires in the spring period. The data highlight the dual influence of anthropogenic and biogenic sources, with urban vegetation significantly modulating CO₂ concentrations despite strong emissions from transportation.

From 2019–2024, CO₂ concentrations in São Paulo increased at rates of **3.64 ppm/year (UNICID)**, **3.69 ppm/year (IAG-USP)**, and **1.73 ppm/year (Pico do Jaraguá)** — significantly higher than the **2.4 ppm/year** global average (WMO, 2023). Similarly, **CH₄ levels** rose by **42 ppb/year** in the urban station. These discrepancies highlight São Paulo's strong anthropogenic influence, with traffic and waste emissions as likely drivers. Isotopic data revealed shifts in CO₂ sources, such as reduced fossil fuel combustion during the 2020 lockdown and increased biomass burning influence from Amazonian wildfires.

Methane variability was particularly pronounced in densely populated areas, suggesting contributions from **vehicular emissions, landfills, and natural gas leaks**. In São Paulo, the main source of methane is the landfills, responsible for 98.7% of emissions, including those with biogas production. While urban emissions dominate, vegetation partially offsets CO₂ levels at greener sites, demonstrating the complex interplay between urbanization and local biogenic processes. These findings underscore the need for expanded GHG monitoring in cities, where localized trends often surpass global averages, and stress the importance of **international collaboration** to refine emission inventories and mitigation strategies.