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TITLE

Up to 80% of global carbon dioxide (CO2) emissions come from urban areas (CITE). This statistic makes sense: larger, denser populations mean more cars, more space heating, and more fossil fuels burning. But how exactly is this statistic calculated? And how useful is this statistic when attacking/investigating the drivers of climate change?

Cities do not produce CO2 evenly throughout. Emission point-sources like smoke stacks produce CO2 hotspots in the landscape, and small-scale landscape features like the urban canyon between skyscrapers may accumulate more CO2 than areas surrounding it.

When trying to quantify and map CO2 emissions, it is critical that environmental scientists and meteorologists choose what scale they’re working with.

**Meso-scale** measurements allow you to estimate emissions from a whole city. Specialized satellites can measure a column of air from the top down, through space, and estimate the amount of CO2 gas in that column. But the resolution is not great; we might only be able to estimate the amount of CO2 above a \_\_\_ square kilometer area. That’s larger than the city of \_\_.

**Local-scale** estimates aim to quantify CO2 flux in neighborhoods or zones of specific land use, like agricultural land. The most commonly-used method for CO2 mapping is the *eddy covariance method*, where instantaneous gas measurements atop a \_\_\_ foot tower are fed into an algorithm that can back-calculate the flux of gas from the \_\_\_km area surrounding it. However, eddy covariance towers are large, expensive, and rely upon assumptions that don’t hold true in cities (for instance, that all the air reaching the sensor blew there over flat ground). Lots of averaging.

What’s missing are robust, common-place ways of measuring and monitoring **micro-scale** CO2. The term “micro” refers not just to spatial scale (How do the CO2 concentrations differ between uptown and the projects?) but temporal scale as well (How do concentrations on this road differ from this road, during rush hour and noon?). Indeed, it’s the micro-scale measurements that are the future, and have the biggest implications or chances of making a difference in the lives of people who live in the city.

Micro-scale gas measurement is nothing new: arguably, weather stations and \_\_\_\_\_\_ have been monitoring the atmosphere immediately around them for decades. However, only Formal Real Scientists in a university or private research institutes have had the funding and the resources to set up sensors like these. They are costly, and if one is set up longitudinally it’s hard to say how representative that sensor is for the surrounding area.

A big shift has taken place over the last few years/decades… increasingly, low-cost {example cost) or off-the-shelf sensors are becoming incredibly affordable, for non-experts to build into platforms of their own. The science is simple: small CO2 monitor, lightweight, intakes air, analyzes it with near infrared light. When the sensor detects how much NIR light is absorbed by the air being flushed into the sensor, it can calculate a concentration of CO2. Either as part of a classroom, independent research, citizen science campaign where citizens monitor air quality and report their numbers to a nonprofit or government arm, who can use those numbers to make an argument or a difference. Criticisms or downsides of sensors like these: their errors are large, and measurements often are only taken haphazardly in certain locations

**Drones** help us address some of these criticisms. They are the next step into making these small affordable sensors just a hobby-est project and a one-off project into full fledged campaigns, with an argument, with a story. With a drone, we have the ability to take measurements of CO2 concentrations that take into account the *meters* surrounding the drone. This could reveal insights into very fine level differences, understanding the forcings of how CO2 accumulation works in cities. We can easily take multiple measurements in the same location at different times of day, or measurements at different sites within a relatively short time window. We can also take measurements at the same site, but at varying heights. A stable meteorological station cannot do that.

Obviously the first step of any new technology is “Can we build the platform, how precise/accurate is it?” But then we must ask, how accurate or precise does the platform NEED to be in order to be useful to certain audiences? Who ARE the target audiences?

For example, Climate modelers and scientists would require a certain level of precision in order to get published results, to add an in-situ measurement into a model and not fear that the error would propagate as they tried to scale it up. But a citizen flying a drone in their city to try and convince the city council of something may not need three decimal places. They might just need to see that a point source EXISTS.

How would the city of New Haven find that information useful? We can make some guesses.

* Identify point sources of CO2 outgassing that were well above others in the city, identify who the biggest contributors are
* Huge implications for environmental justice. New Haven is one of the most segregated cities in America and has a long history of environmental injustice, marginalizing certain populations. In-situ micro met measurements of CO2 emissions could give teeth to community or legislative measures, to identify whether Black or low income populations are living closer to high-polluting industries or buildings.
* Can better help us prep for future extreme climate events. Knowing about CO2 concentrations and how they are affected by micro-sources… like near certain roads, parks, urban canyons… can give us some idea of “if a heatwave were to strike the city, how might that heterogeneously affect the city?”
* Help us to answer the question: Are the biggest CO2 emitters the companies/businesses/people with a LOT of money, or a LITTLE money? Because that will affect how we might attempt to deal with the problem. If the institutions with money are the biggest emitters, maybe a solution is tighter regulations that those institutions must meet, better caps. If the institutions with little money are emitting a lot, maybe it’s because they lack sustainable or fuel-efficient infrastructure, and need capital/material support to reduce their carbon footprint.
* Natalie’s goals: understand the drivers of fine scale CO2 fluxes

The way to figure out what people’s needs are: talk to people. Combine the quantitative engineering in tandem with reading city records, talking to city officials of what changes or programs have already taken hold in the city, what’s succeeded and what’s failed.