Building and Testing a Low-Cost CO_2 Sensor

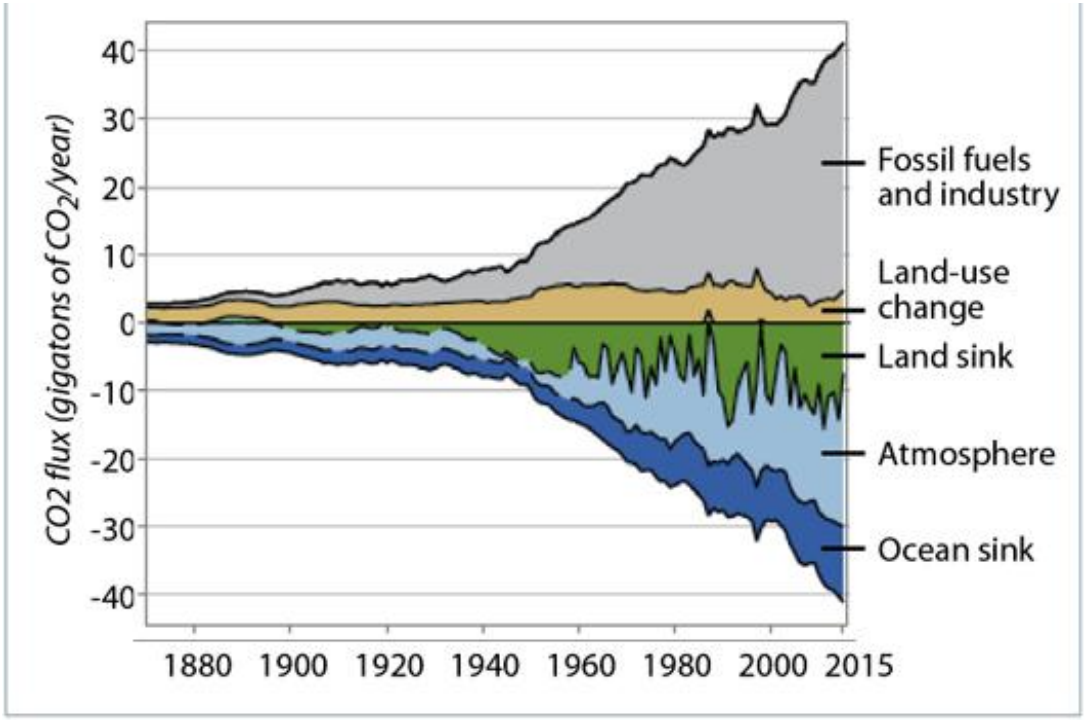
Benjamin Yang

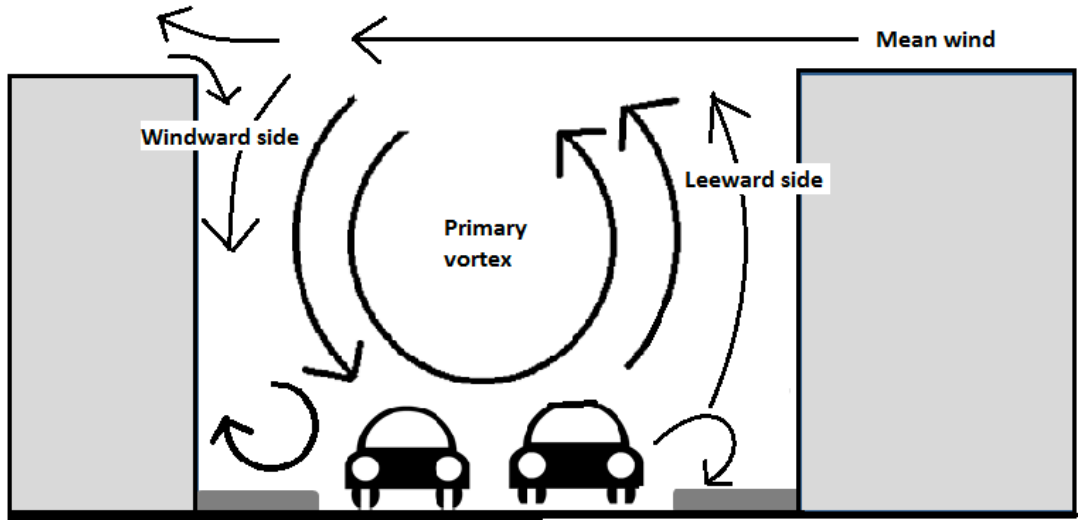
EESC GR6935

Fall 2021

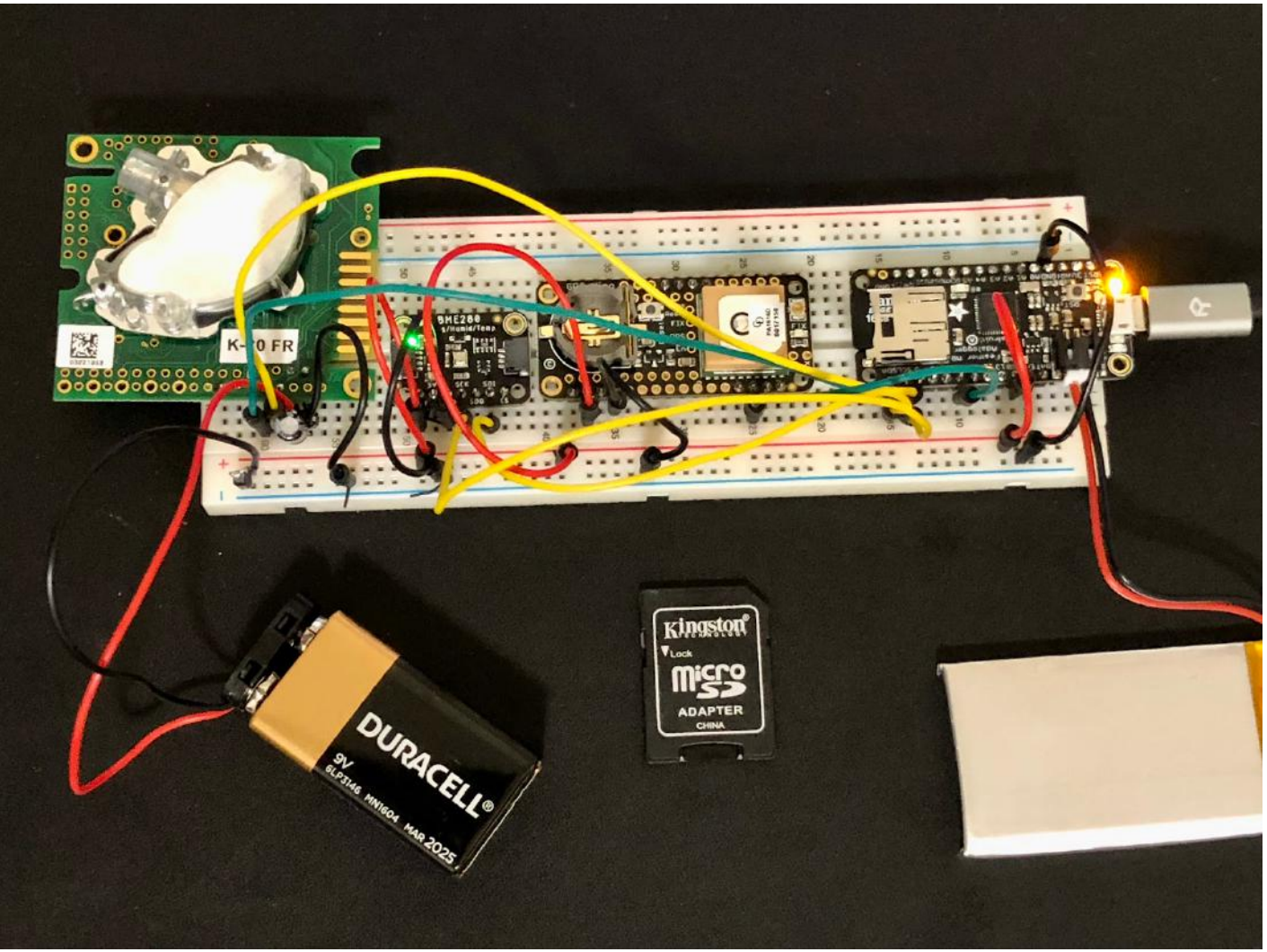
Indoor vs. outdoor CO2

- CO2 = important long-lived greenhouse gas
- Typically, indoor CO2 > outdoor CO2
- We tend to spend time indoors
- Ventilation is key
  - Air exchange rate (ACH = ppm h^{-1})
- CO2 = proxy for air pollution (e.g. PM)
- Urban CO2
  - Power plants, buildings, vehicles, people
  - Street canyons
  - NYC = highest population density in U.S.



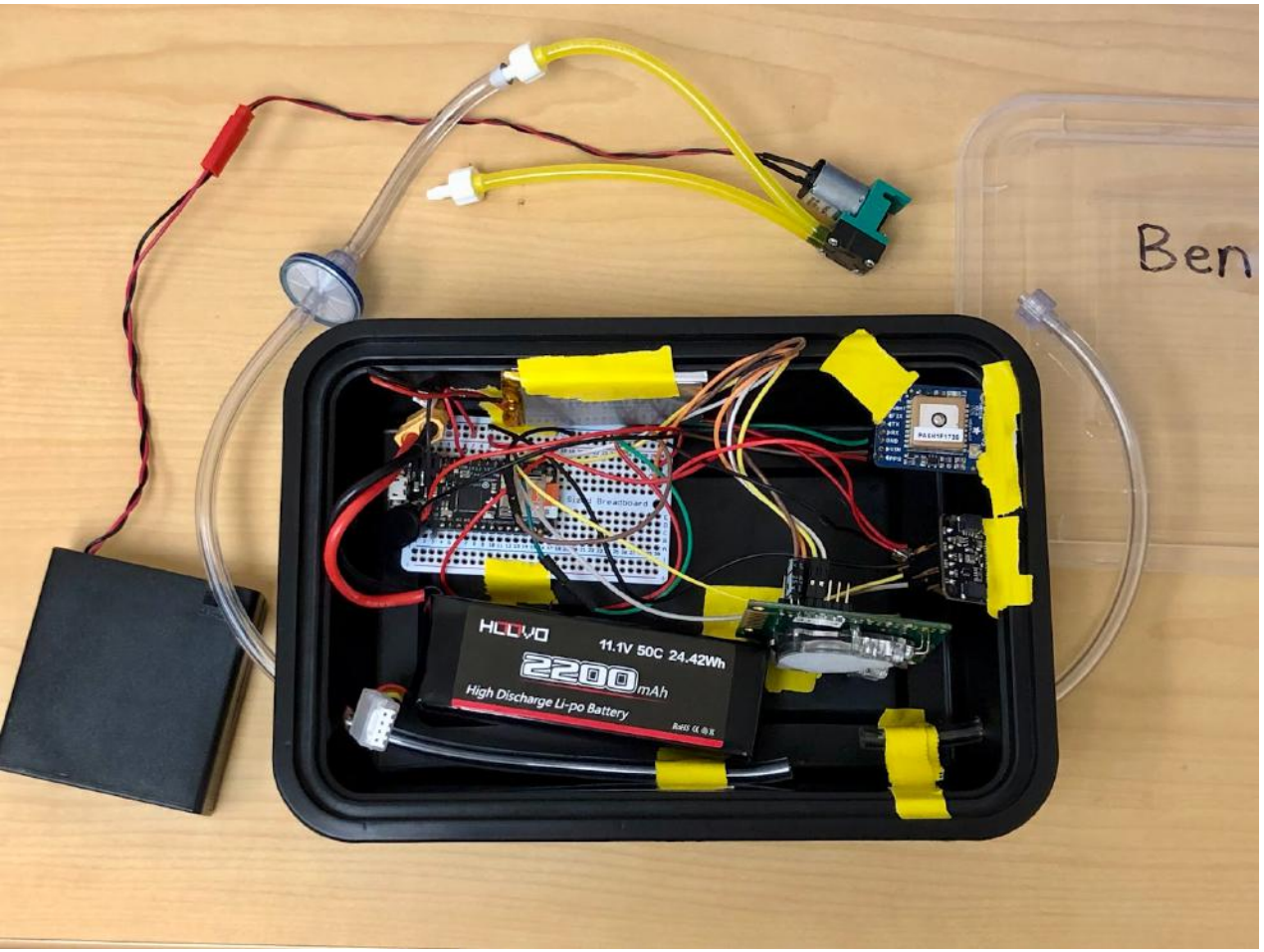


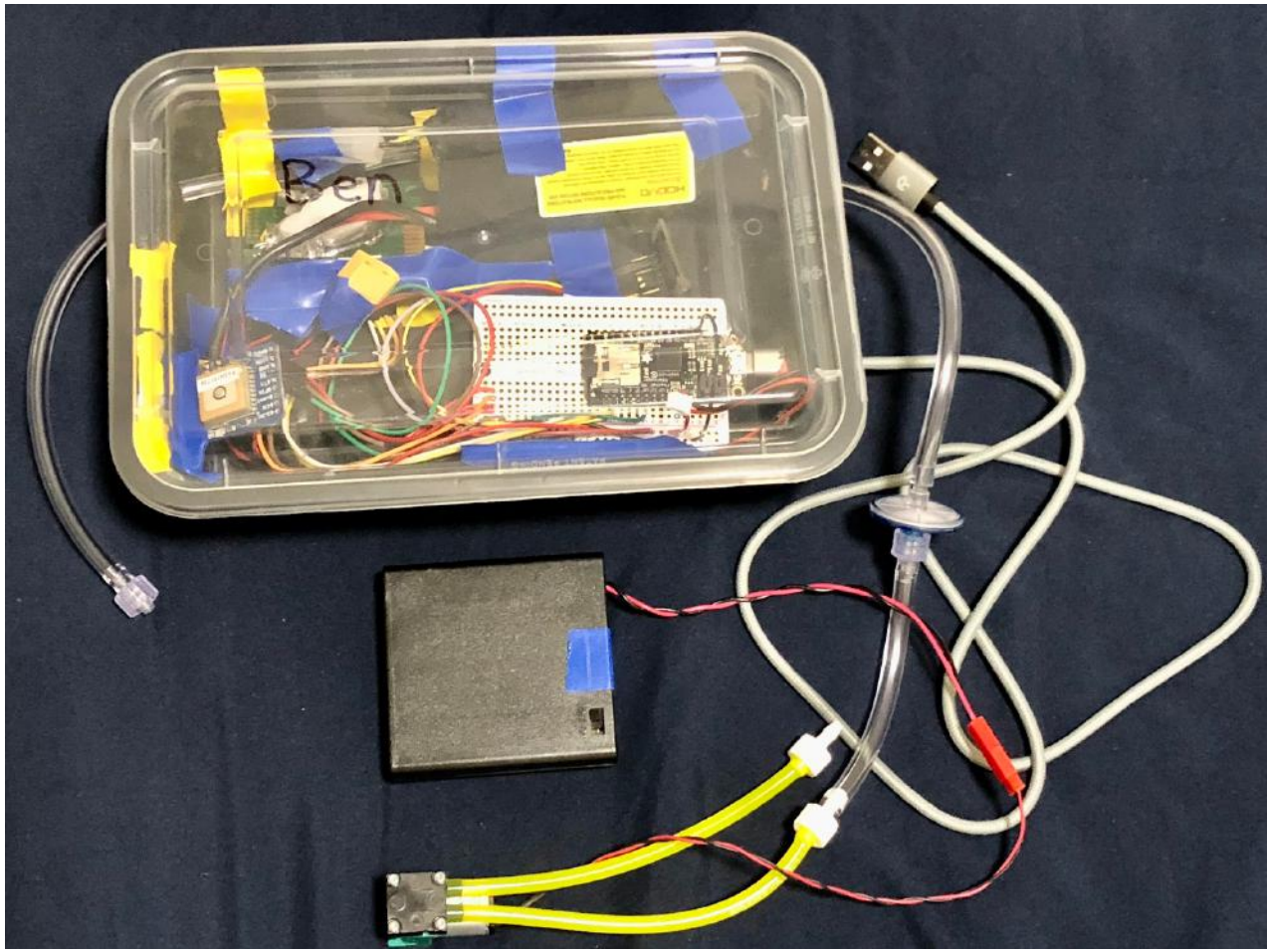
Initial K30 sensor setup + Arduino



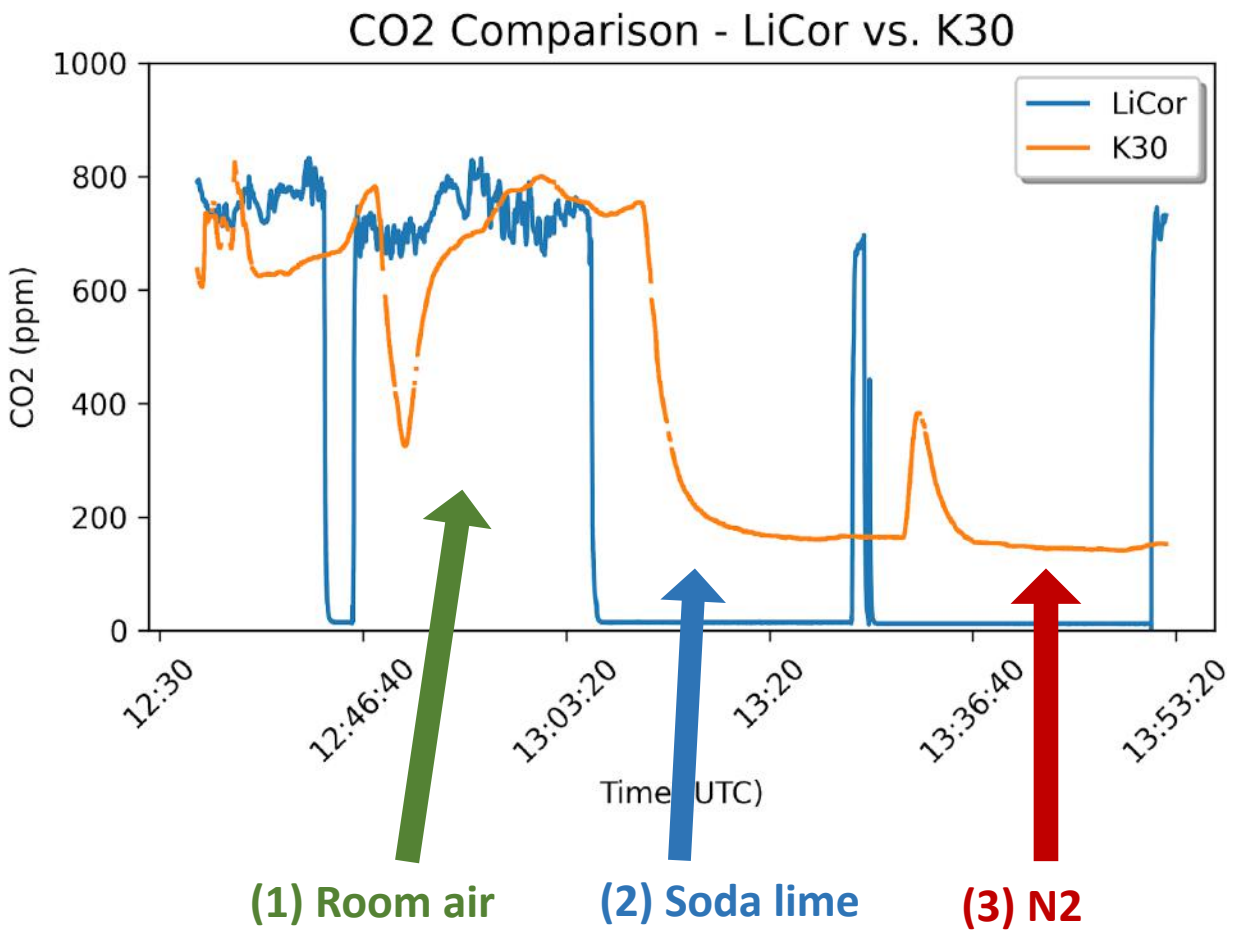

```
Done uploading.

Sketch uses 54744 bytes (20%) of program storage space. Maximum is 262144 bytes.
Atmel SMART device 0x10010005 found
Device        : ATSAMD21G18A
Chip ID       : 10010005
Version       : v1.1 [Arduino:XYZ] Oct 27 2020 20:25:30
Address       : 8192
Pages         : 3968
Page Size     : 64 bytes
Total Size    : 248KB
Planes        : 1
Lock Regions  : 16
Locked        : none
Security      : false
Boot Flash    : true
BOD           : true
BOR           : true
Arduino       : FAST_CHIP_ERASE
Arduino       : FAST_MULTI_PAGE_WRITE
Arduino       : CAN_CHECKSUM_MEMORY_BUFFER
Erase flash
done in 0.898 seconds

Write 55408 bytes to flash (866 pages)
[==============================] 100% (866/866 pages)
done in 0.348 seconds

Verify 55408 bytes of flash with checksum.
Verify successful
done in 0.095 seconds
CPU reset.
```

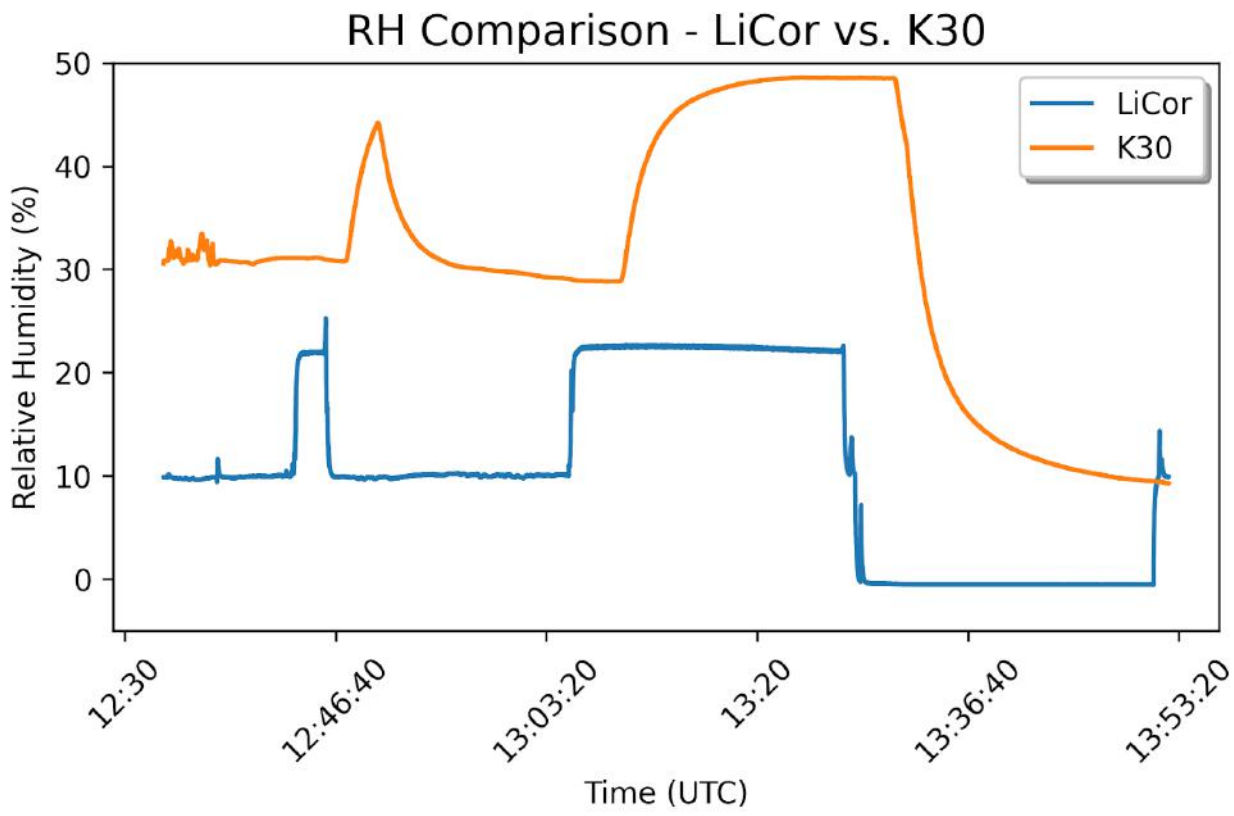
Sensor v2 and v3 (easy to break)



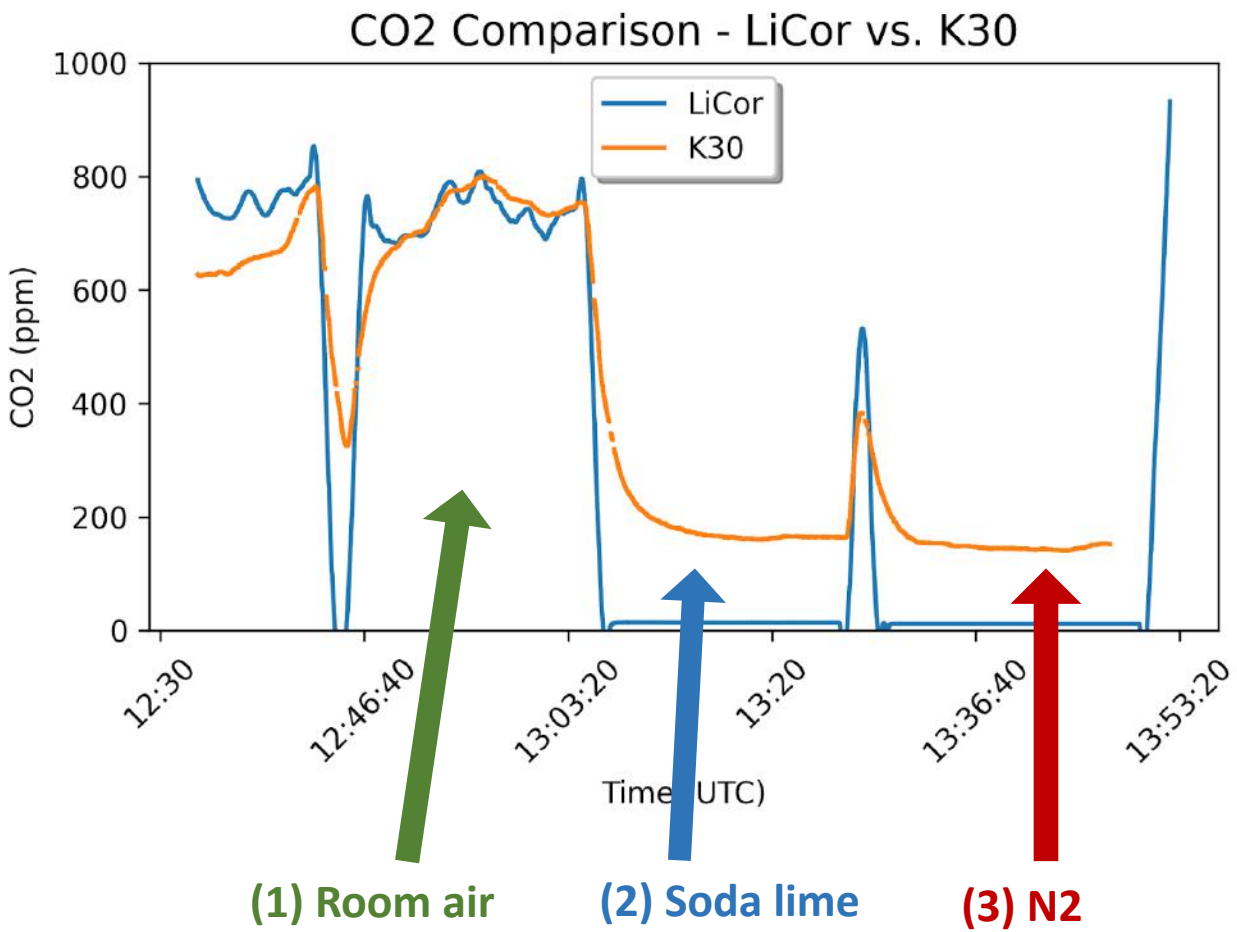


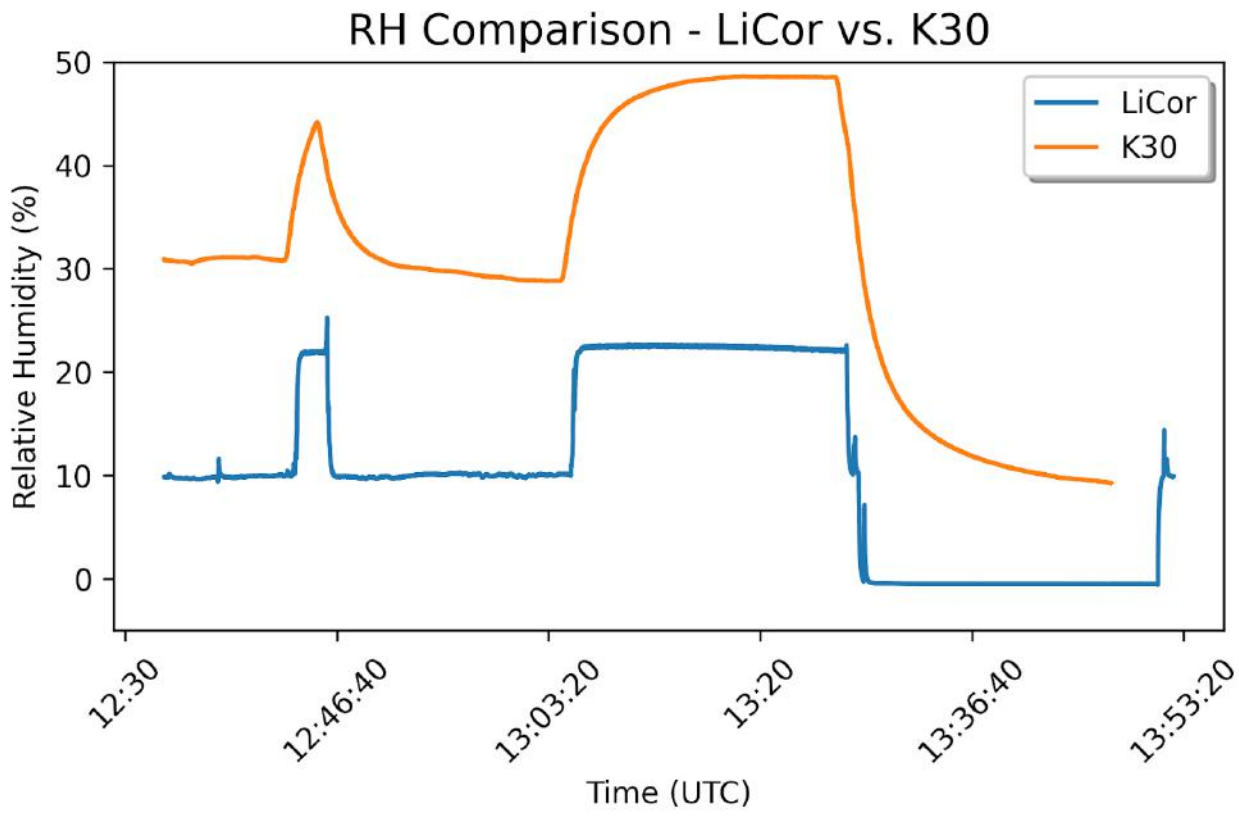
K30 Sensor (w/ BME280) vs. LI-850 Trace Gas Analyzer



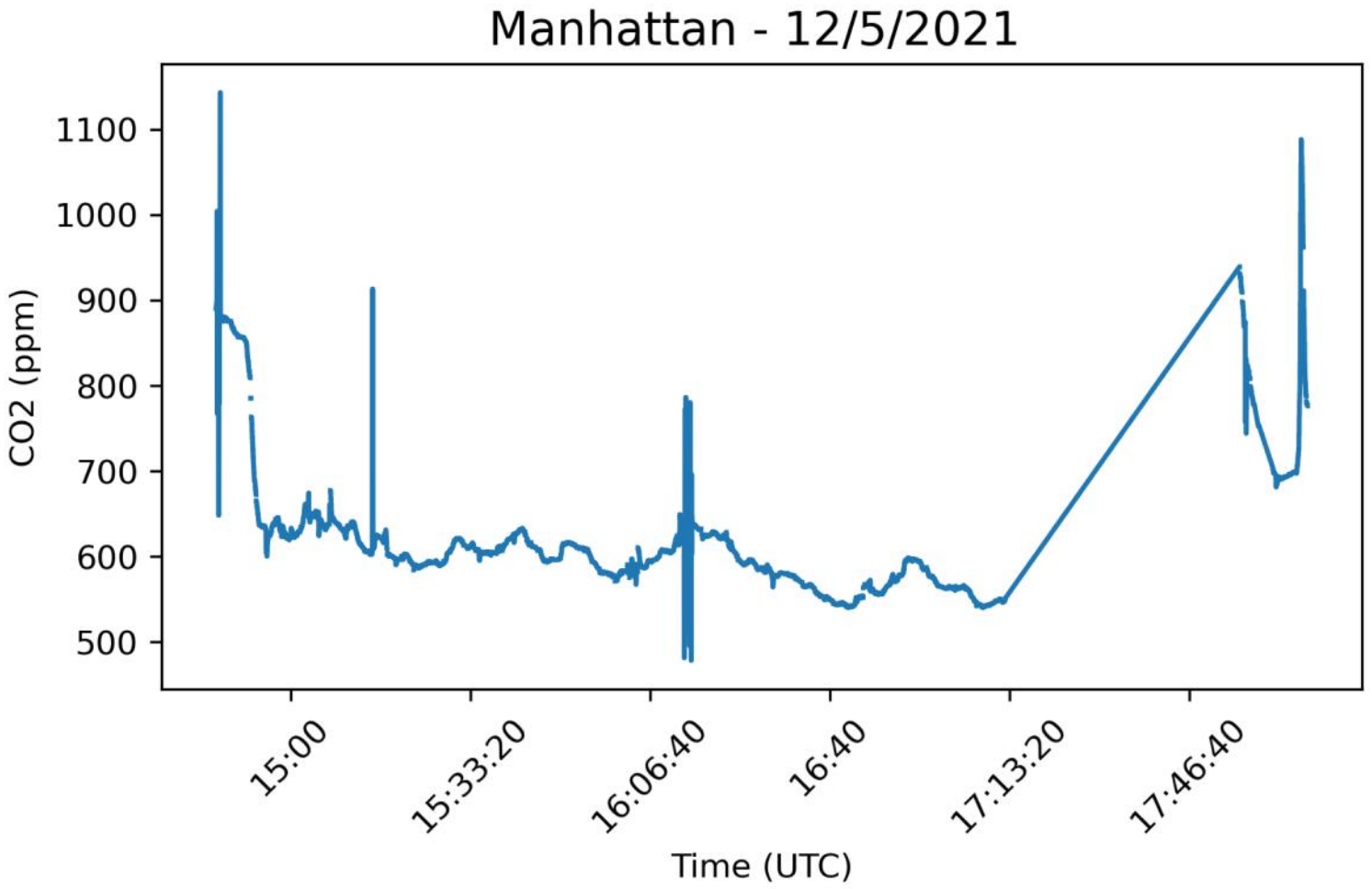


Smoothed LiCor data + time-shifted K30 (-4.9 min) to match LiCor





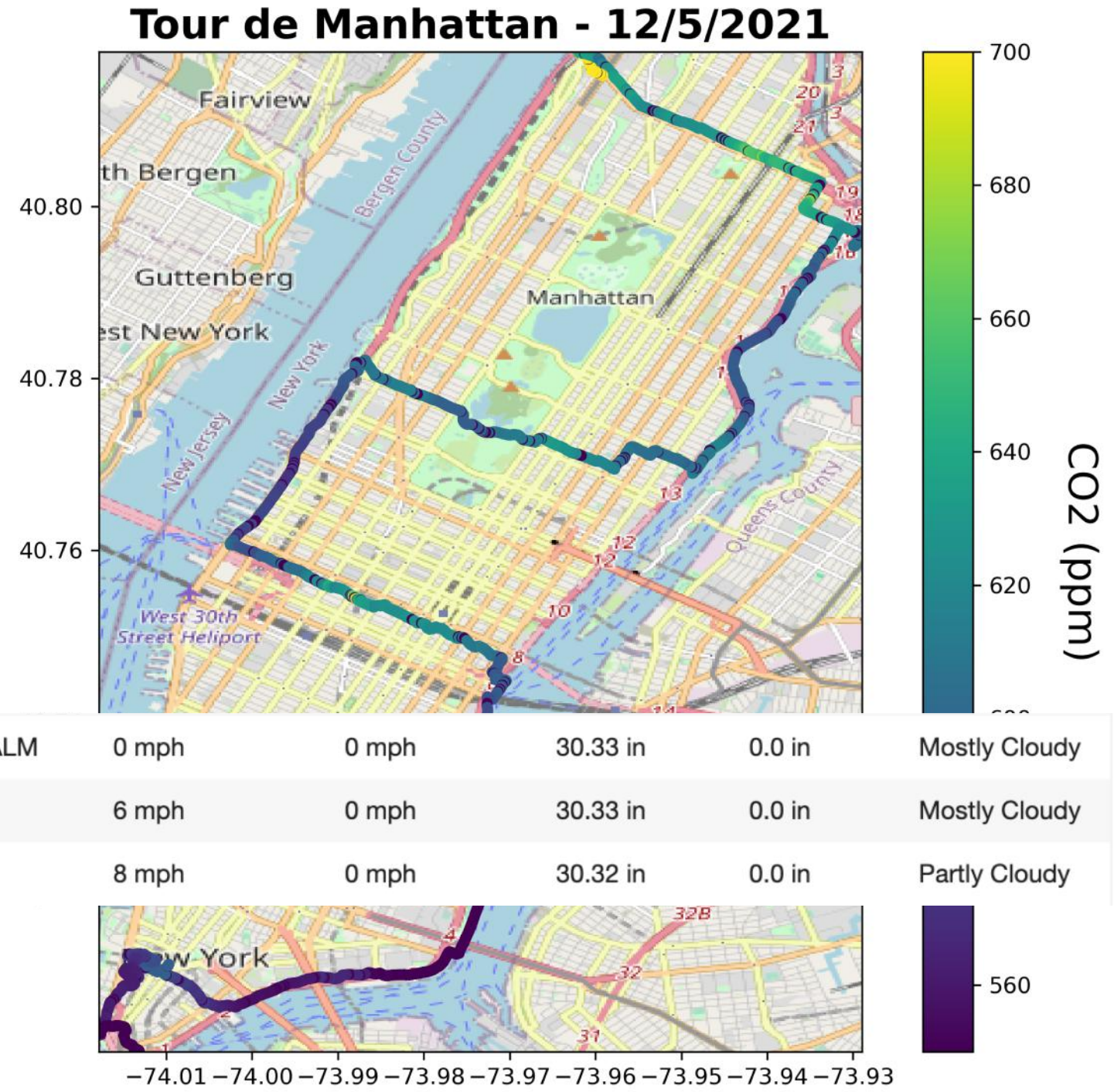
Biking around Manhattan



2:50-3:00 – Harlem
3:00-3:15 – Detour
3:15-3:30 – Trail by Harlem/East Rivers
3:30-3:40 – Upper East Side
3:40-3:45 – Central Park
3:45-3:50 – Upper West Side
3:50-4:00 – Trail by Hudson River
4:00-4:20 – Midtown
4:20-4:45 – Trail by East River
4:45-4:55 – Financial District
4:55-5:00 – Trail to The Battery
5:10-5:50 – Subway (1 Train Line)

Bike Route

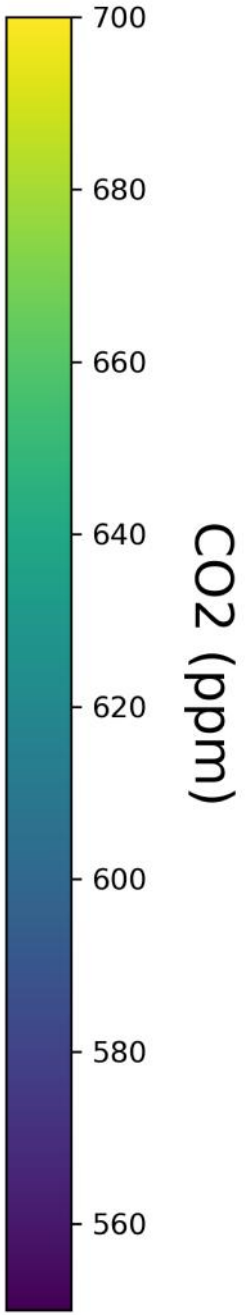
- CO2 (or pollution) hotspots
  - Indoors (apartment + subway)
  - Harlem
  - Midtown
  - Upper East/West Side?
- Lower CO2 levels by rivers



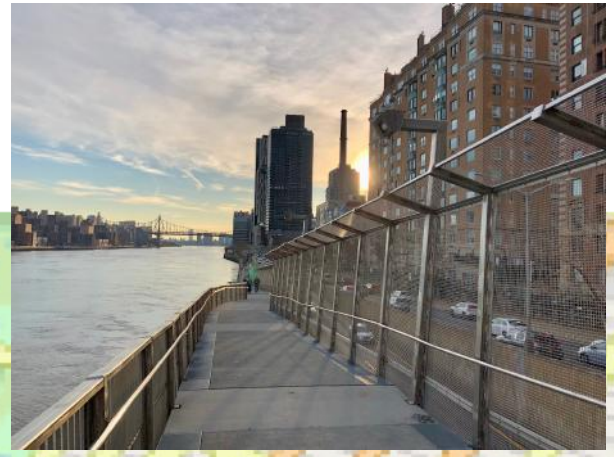
2:51 PM	49 °F	18 °F	29 %	CALM	0 mph	0 mph	30.33 in	0.0 in	Mostly Cloudy
3:51 PM	48 °F	19 °F	32 %	S	6 mph	0 mph	30.33 in	0.0 in	Mostly Cloudy
4:51 PM	47 °F	19 °F	33 %	S	8 mph	0 mph	30.32 in	0.0 in	Partly Cloudy

Upper

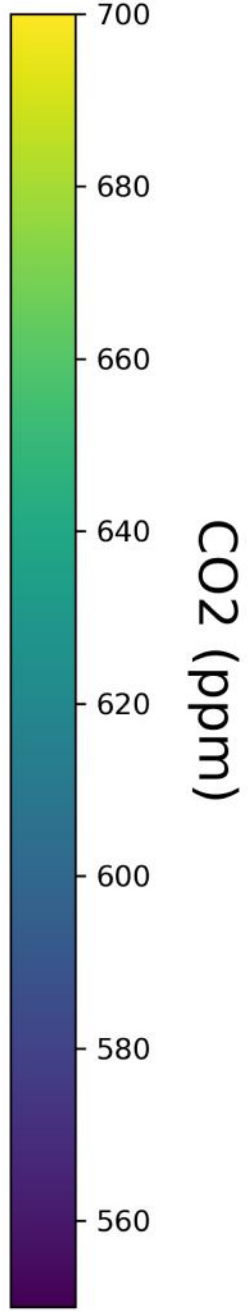
Manhattan
3
20
3
21
19
18
1b
1
1
1


700
680
660
640
620
600
580
560
CO2 (ppm)

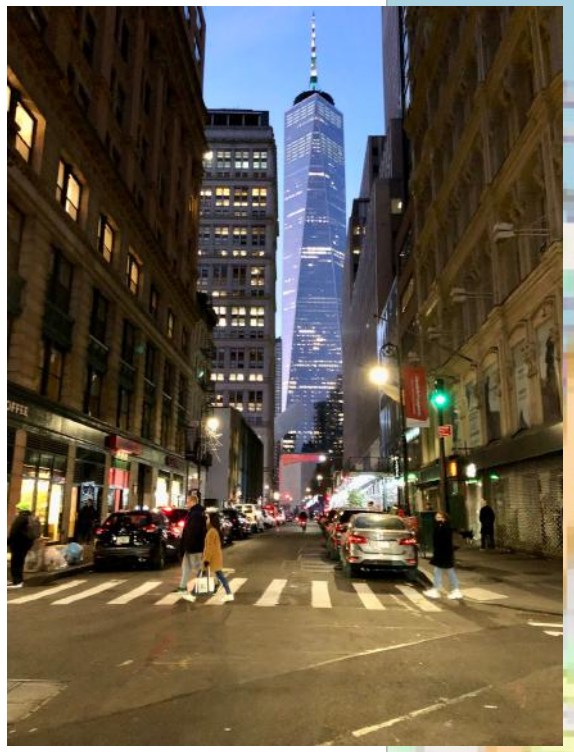
Middle



New Jersey
13
12
12
10
8
14


700
680
660
640
620
600
580
560
CO2 (ppm)

Lower



Conclusions

- Low-cost CO2 sensors can sample air reasonably well in cities
  - Fill in data gaps in remote areas
- Useful for estimating sources/sinks of CO2 (or pollution)
- Many limitations/challenges though
  - Soldering cables properly
  - Hardware prone to failure
  - Multiple batteries with short lives
  - Adjusting C++ code
  - Pump is loud
  - Use of uSD card
  - Port connection
  - Sensor calibration
  - Influence of water vapor (NDIR)
- Lower CO2 levels in summer? (future studies)

Thank you!

Questions?