

Investigating Indoor Air Quality in On-Campus Residences Using Low-Cost Air Sensor Network

Ran Zhao*, Mst Rowshon Afroz, Xinyang Guo, Ariel Delorme,
Chu-Wen Cheng, and Ryan Duruisseau-Kuntz

* Assistant professor of chemistry

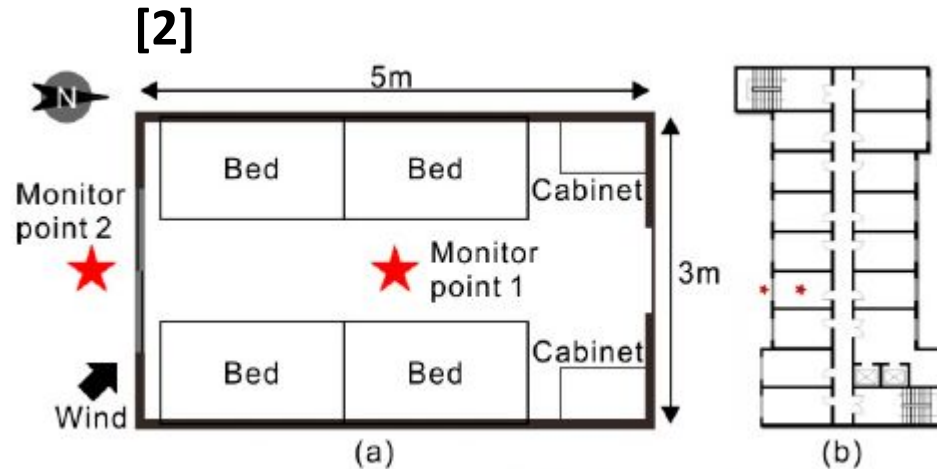
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Motivation of Study

- 22% of university students in US live in on-campus residences.[1]
- Very few studies have focused on indoor air quality (IAQ) in student residences.
- Limitation in using research-grade instruments[2].
 - Usually new or unoccupied units.
 - Short-term or occasional.
 - Variability in IAQ.



Objectives

- A case study of IAQ using low-cost sensor network (29 sensors).
- Assist the university's Residence Service to identify potential issues in IAQ and ventilation.
- Continuous monitoring in occupied units.
- Elucidating factors affecting IAQ: ventilation, cooking, etc.
- Student community engagement.

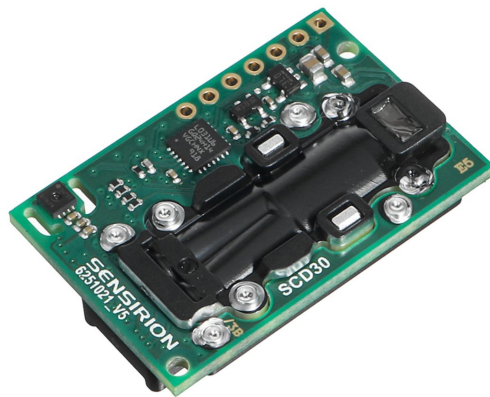


Our sensor

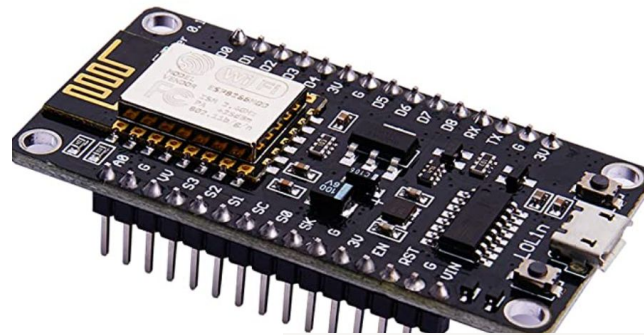
- Custom-assembled (\$150 CAD ea.)



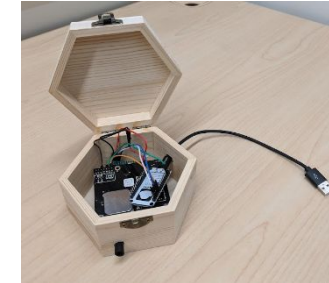
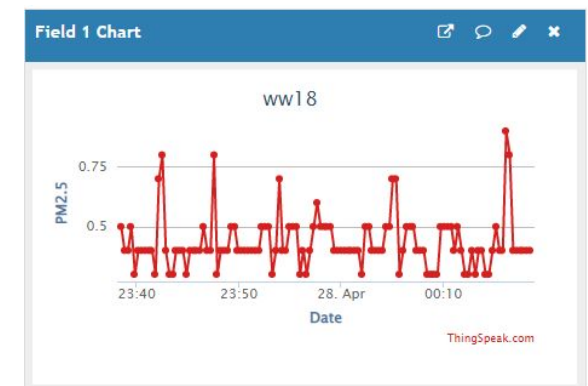
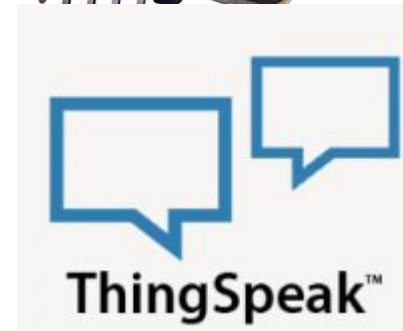
PM_{2.5}/PM₁₀
Nova SDS011[1,2]



CO₂/Temp/RH
Sensirion SCD30
*NDIR detector



ESP8266 Nodemcu
Sending real-time data to
ThingSpeak.
Participants can view.



Target Buildings

U of A has over 10 student residences. We made choices strategically.

Total # of sensor: $n = 29$



Two towers.
One tower with in-suite HRV (A1) Another without (A2).

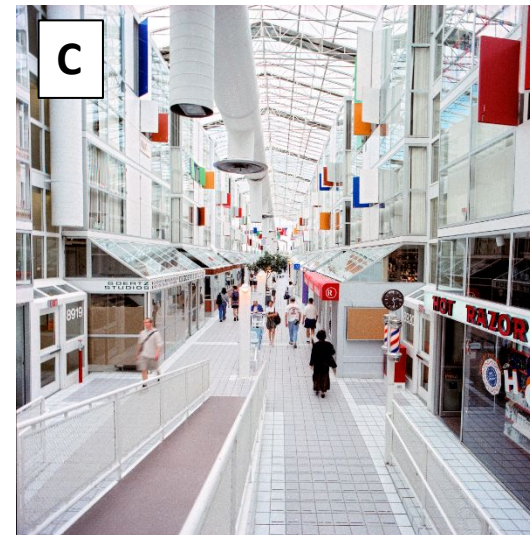
No cooking allowed

$n = 8$ each tower



Private room with shared kitchens

Cooking allowed
 $n = 8$



Private room with shared kitchens
Cooking allowed.
Inside a mall with restaurants and shops

$n = 5$

Recruitment

- Sensors were setup in actual living space (private rooms).
- Our project was approved by U of A Human Research Ethics.
- Ethics ID#: Pro00112541
- Recruitment was done through classroom visit and newsletters.
- Measurement was conducted from Dec 2021 to April 2022.
- Two questionnaires were sent to participants to gauge their indoor activities.
- A \$100 gift card was sent to each individual as an incentive.

We need your help to understand the cleanness of air we breathe!

We spend so much time in our residences, but how clean is the air?

What we will learn:
Indoor air quality in student residences



How often did you cook inside your residence over the past two months? *

- Never
- A couple of times a week
- Cook most of my meals
- Every day, every meal

Did any of the following activities happen inside your residence over the past two month? - Your answer will only be used for our study *

- Cleaning with vacuum machine
- Use of humidifier
- Use of diffuser
- Use of candle
- Use of incense
- Smoking (including cigarette and cannabis)
- E-cigarette smoking or vaping
- Gathering or Party (4 people or more)
- Use of dry ice

Benefits and Challenges Experienced

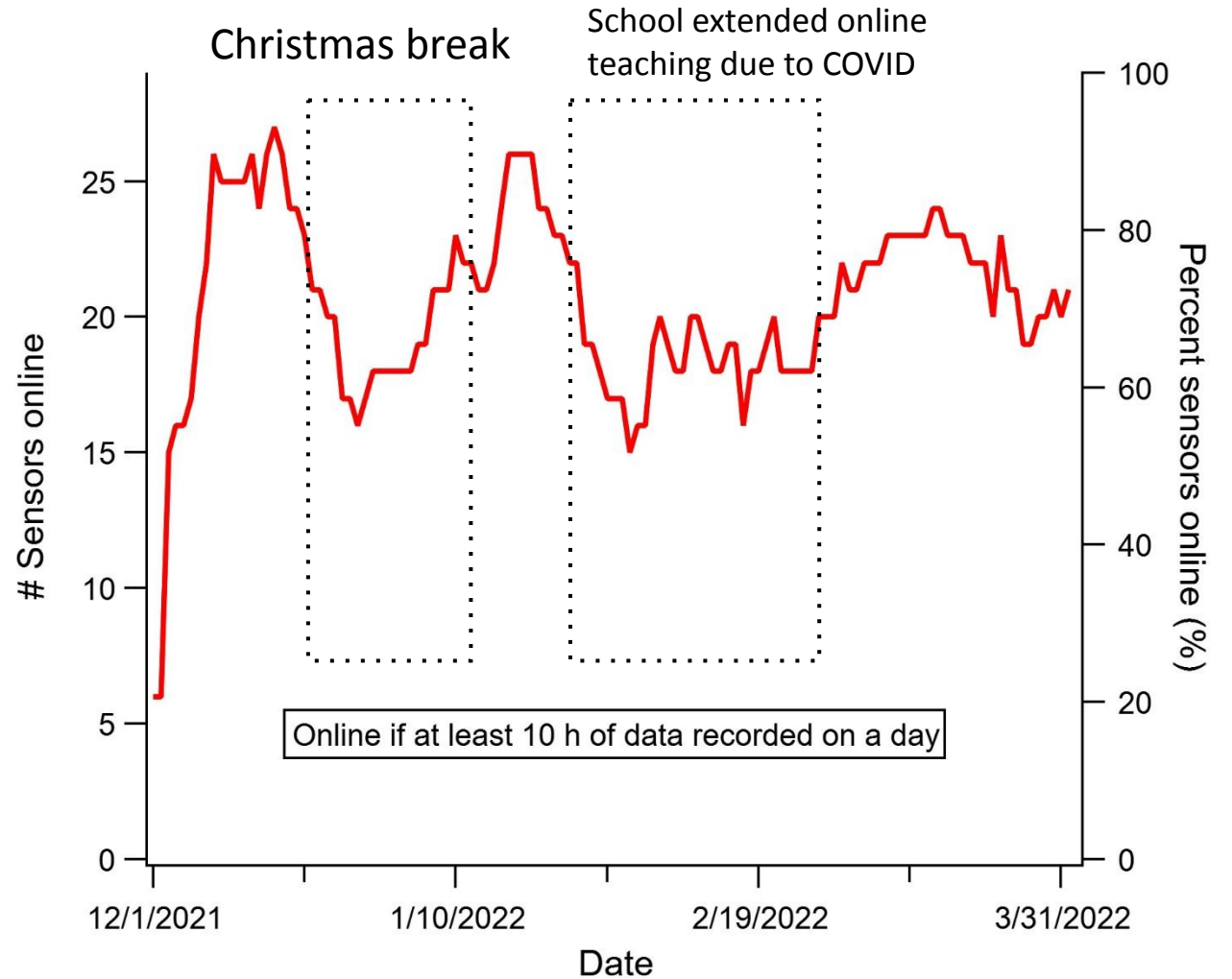
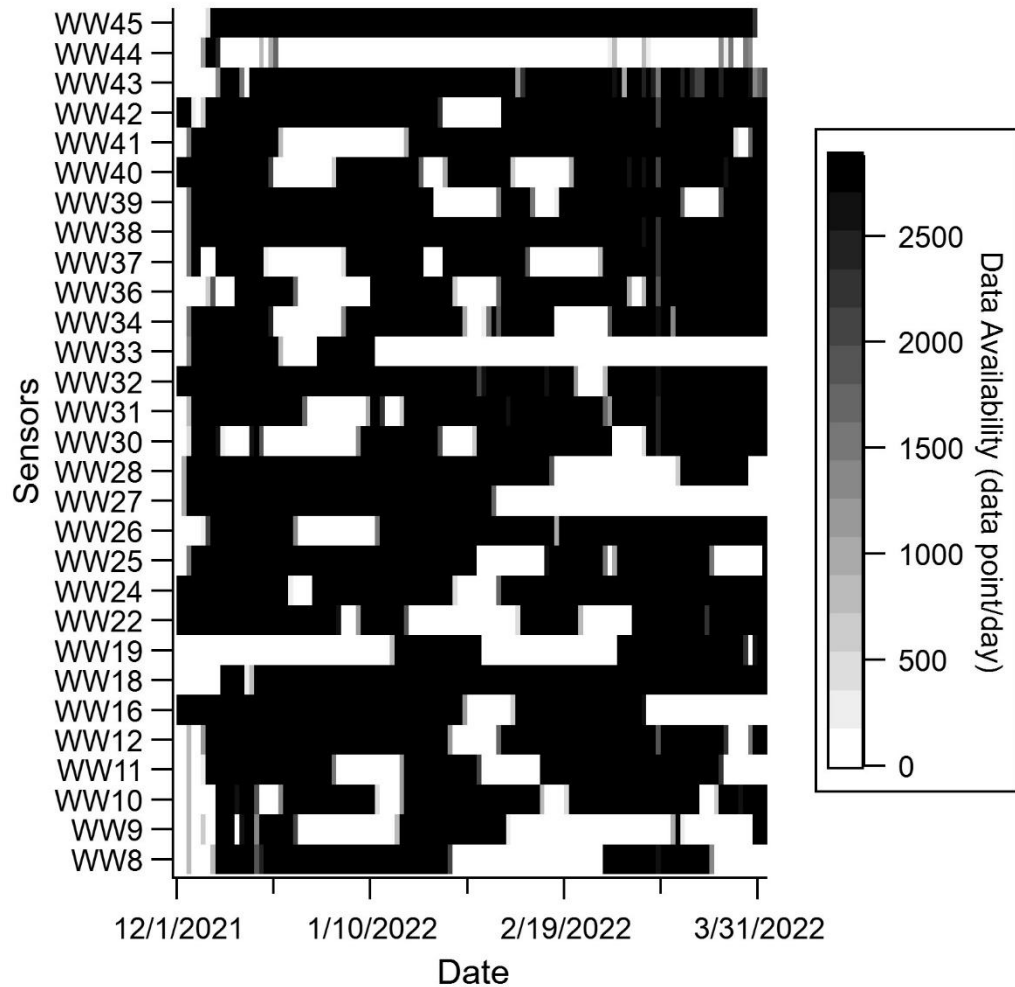
- Benefits

- Well-organized and maintained buildings by Residence Services.
- Collaborative and eager student participants (over 200 applicants).
- *Universal* Wi-Fi available.

- Challenges

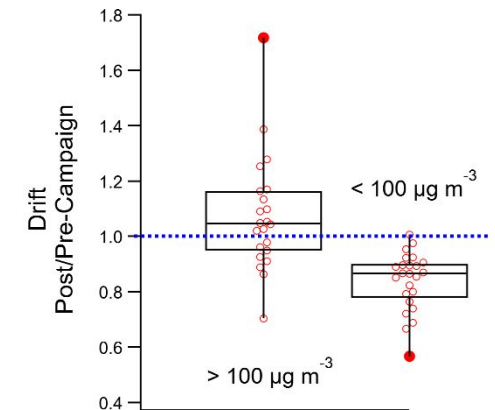
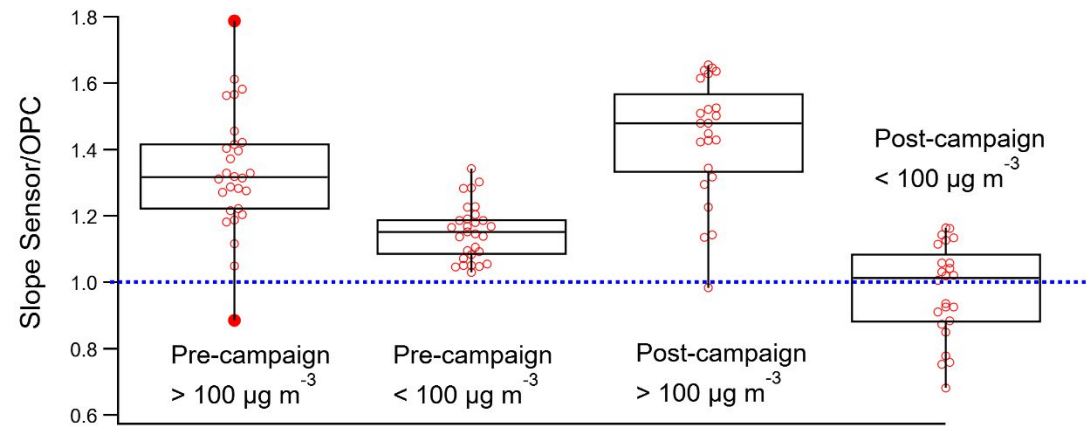
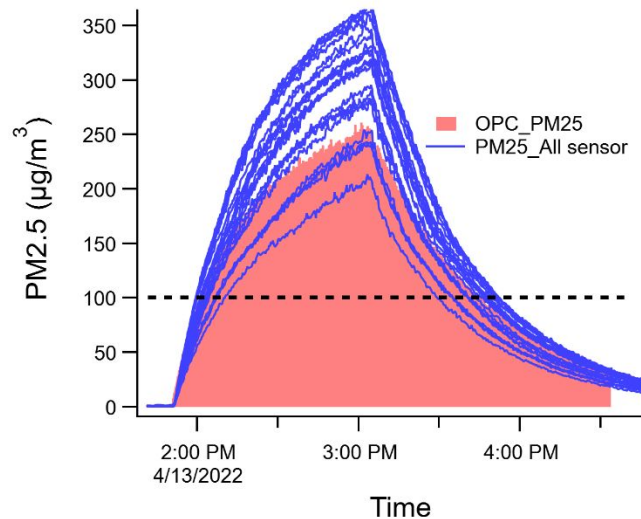
- Researchers do not have access to private living spaces.
- University Wi-Fi 'kicks-out' IoT devices randomly.
- University switched to online teaching due to COVID.
- Data availability

Data Availability

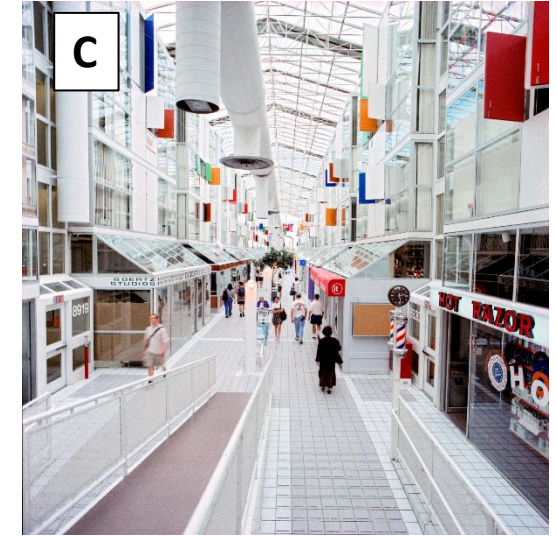
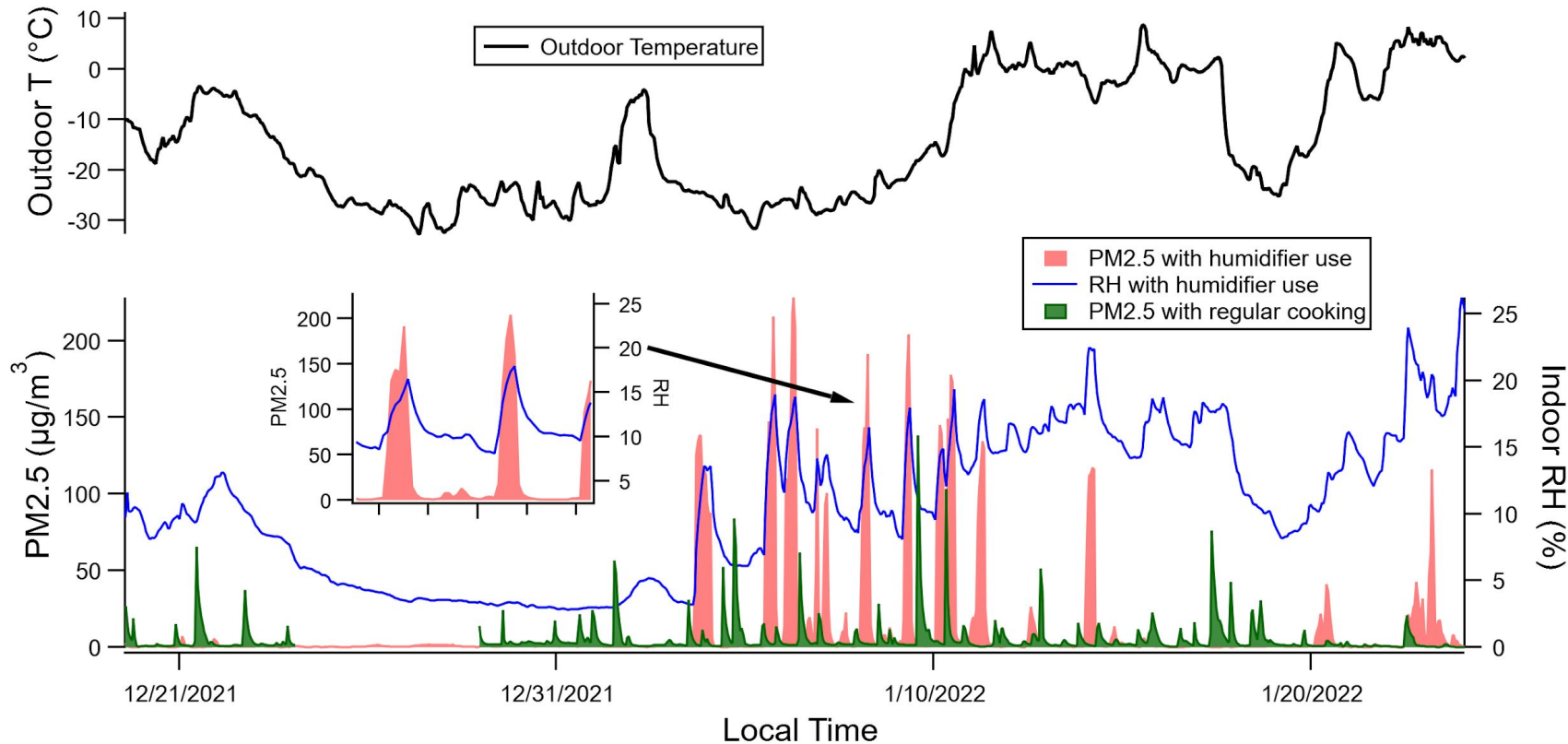


Calibration of PM_{2.5}

- Calibrated all sensors against an optical particle counter (OPC) in an empty office using humidifier particles.
- Separate calibration for PM_{2.5} above and below 100 $\mu\text{g m}^{-3}$. (Raw Data shown Today)
- Pre- and post campaign calibrations for potential drifting.
- For CO₂, RH, and Temp, we ensured consistency between sensors but did not calibrate.
- Not intended to use PM₁₀ due to deviations between sensors and OPC.



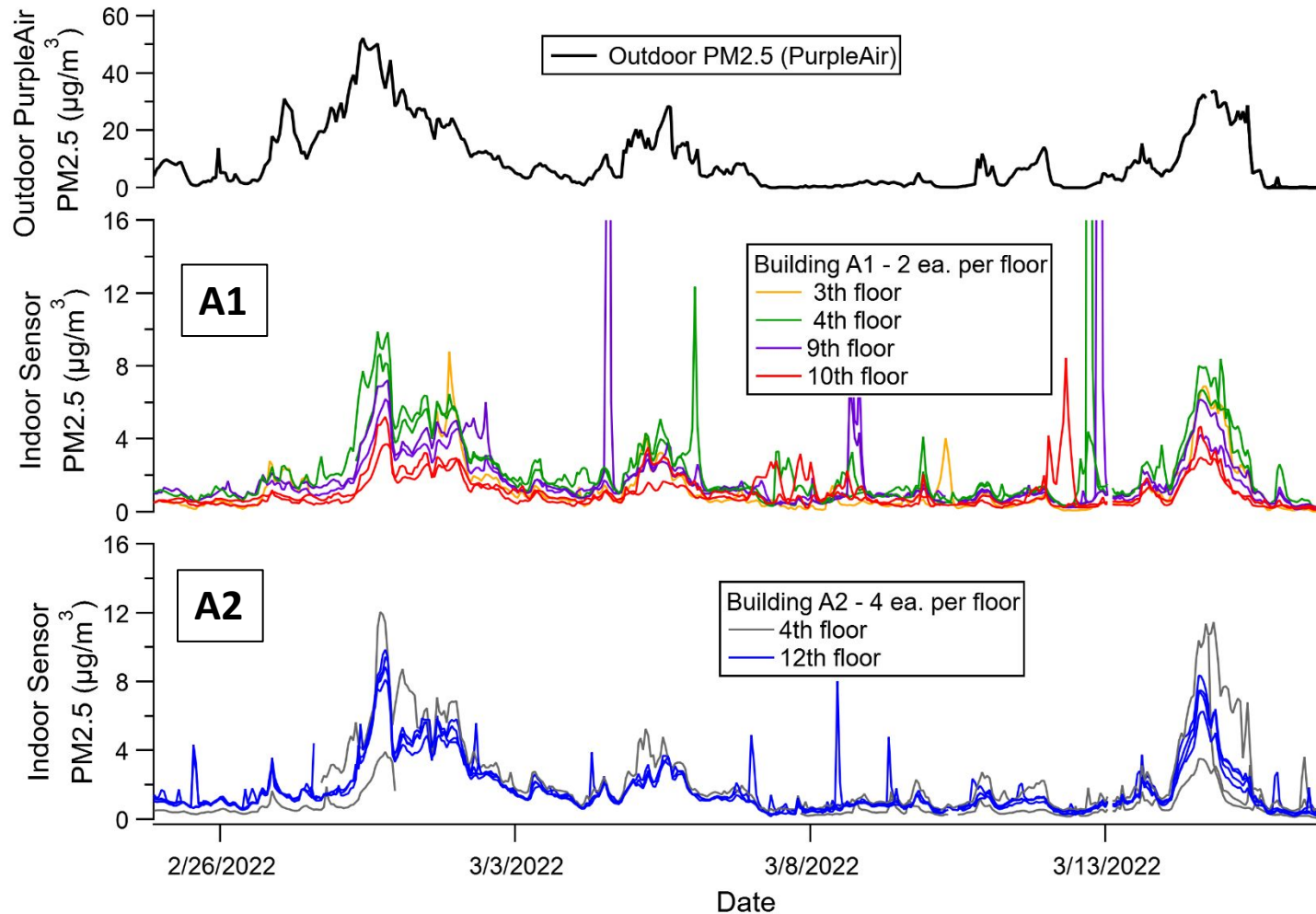
Impact of Indoor Sources



Inside a mall, cooking allowed

- Cooking and humidifier use are major source of $PM_{2.5}$.
- Ultrasonic humidifier generates indoor $PM_{2.5}$ [1].
- Indoor RH correlates with outdoor temperature – very dry (5% RH)!

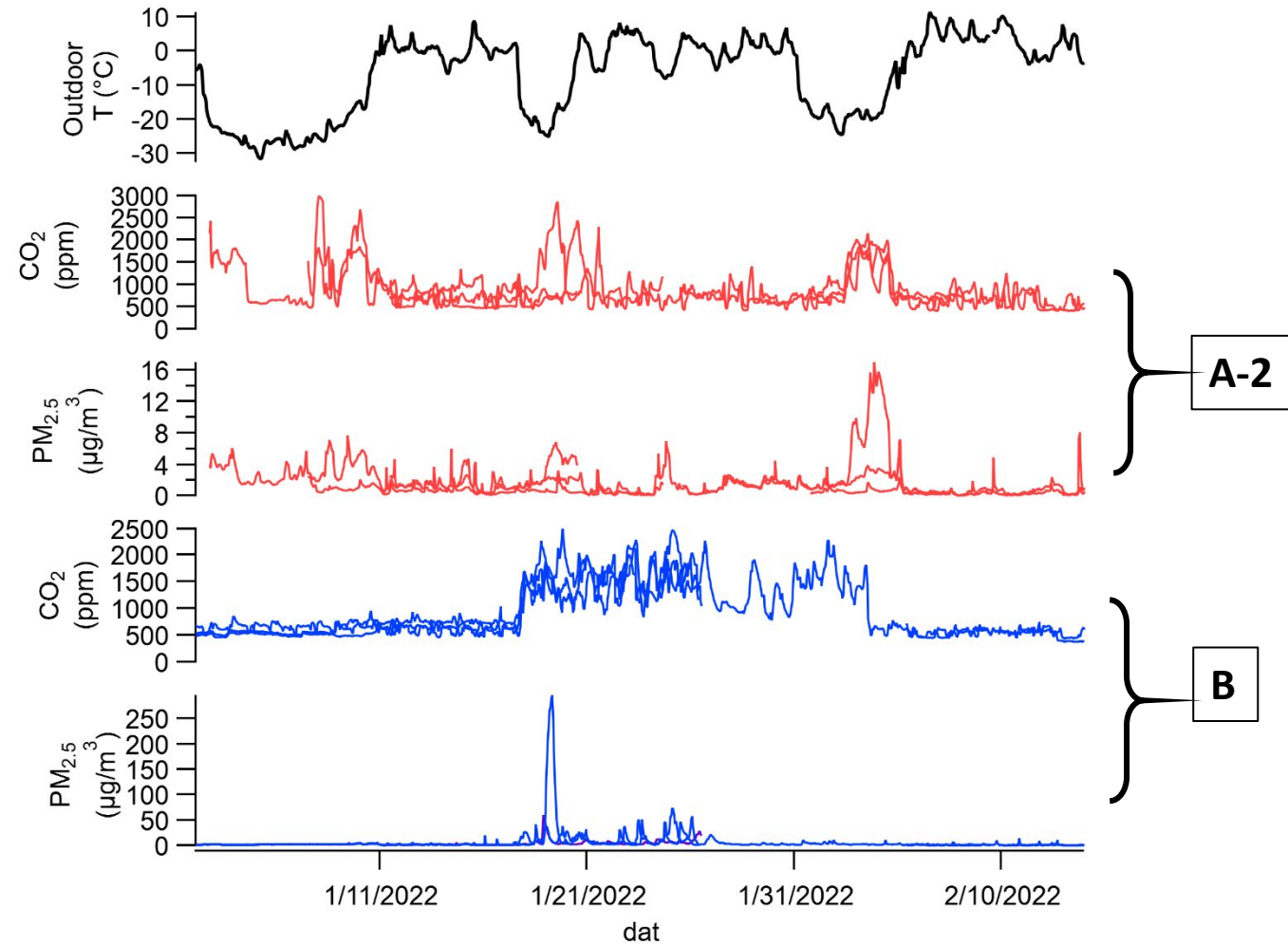
Impact of outdoor source



Two towers;
No cooking allowed

- Strong correlation between indoor and outdoor $\text{PM}_{2.5}$.

Cold Snaps and Ventilation



- Multiple building's ventilation systems were affected by cold weather.
- “Fan stopped working”
- Study participant sent emergency request.

Summary

- IAQ in student residences is highly variable and is affected by:
 - Indoor sources (cooking, humidifier)
 - Outdoor air quality
 - Ventilation
- Extremely cold weather poses a unique and significant challenge for ventilation and air quality control in residences.
- These challenges may have been overlooked without air quality monitoring.