Analysis of Significant Weather Event - Inversion, Dust, Wildfire Smoke - Impact on Indoor and Outdoor $PM_{2.5}$ Levels Measured Using a Network of Low-Cost Air Quality Sensors

Tristalee Mangin[1], Dillon Tang[1], Zachary Palmer[2], Darrah Sleeth[2], Kerry Kelly[1]
[1]University of Utah Department of Chemical Engineering, [2]University of Utah Department of Family & Preventive Medicine

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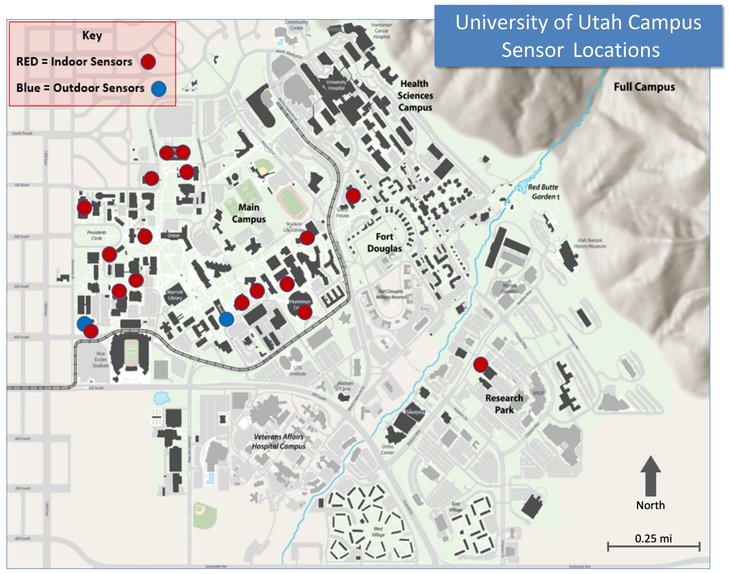
Introduction

- Individuals typically spend more than 80% of their time indoors, and Indoor air quality (IAQ) is critical for human health and worker productivity. The World Health Organization's (WHO) 24-hour guideline for indoor $PM_{2.5}$ is 15 $\mu g/m^3$ [1].
- Low-cost sensor technology can screen for IAQ problems, increase the spatial resolution of IAQ measurements, assist building managers, and engage the local community.

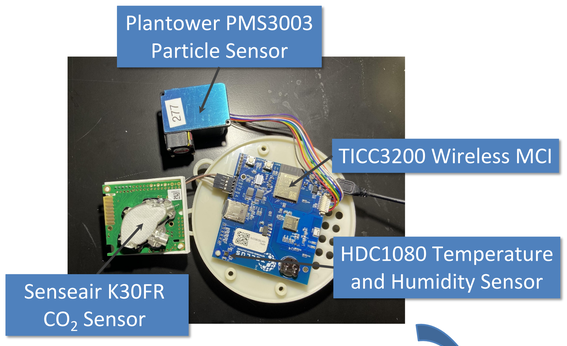
Objectives

- Utilize low-cost sensor measurements to determine if IAQ is impacted during pollution events – inversion, dust, and wildfire smoke.
- Communicate real-time IAQ measurements with facility management.
- Analyze HVAC performance, particularly during these pollution events.
- Develop HVAC operation recommendations for these pollution events – inversion, dust, and wildfire smoke – if HVAC operations negatively affect IAQ.

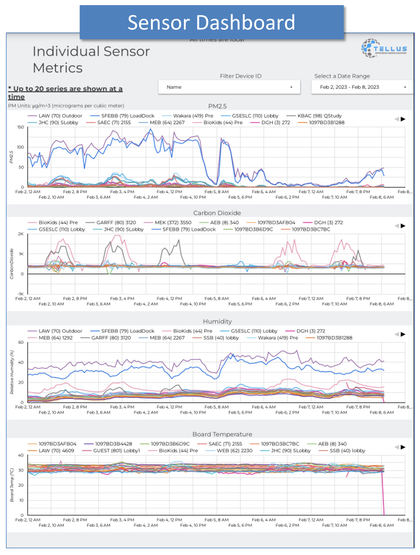
University of Utah Campus Sensor Locations



Methods



Sensor Dashboard

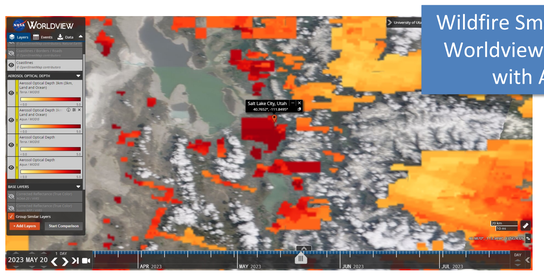


- Since November 2022, 21 sensors deployed across the University of Utah campus.
  - 17 indoor locations
  - 2 outdoor locations (2 sensor nodes collocated at each)
- The sensor nodes measure:
  - Particulate matter (PM)
  - Carbon dioxide (CO_2)
  - Temperature
  - Relative humidity
- Hourly averaged measurements are communicated wirelessly to an online dashboard that facility managers can access in real-time.
- Raw PM measurements corrected using a U.S. wide correction [2][3].

Pollution Event Identification

- Inversion event identification
  - Three or more consecutive daily valley heat deficit values > 4.04 MJ/m^2 [4].
- Dust event identification
  - Utah Division of Air Quality PM_{10} > 100 $\mu g/m^3$ and wind speeds > 5 m/s [5].
- Wildfire smoke event identification
  - NASA WorldView satellite images of the smoke plume and the aerosol optical depth (AOD) [6].

Wildfire Smoke Event NASA Worldview Satellite Photo with AOD Layer



Inversion Results

- Four inversion events identified between November 2022 and February 2023, lasting an average of 3.5 days.
- WHO indoor 24-hour guideline exceedances:
  - 110 hours from 7 indoor locations over 15 $\mu g/m^3$ hourly average.
  - 4 days from 3 indoor locations over 15 $\mu g/m^3$ daily average.
- Low correlation (R2) of 0.32 averaged across indoor locations.

Dust Results

- Eleven dust events identified between November 2022 and August 2023, lasting an average of 5.8 hours.
- WHO indoor 24-hour guideline exceedances:
  - 7 hours from 4 indoor locations over 15 $\mu g/m^3$ hourly average.
  - No indoor locations over the daily average.
- Low-moderate correlation (R2) of 0.44 averaged across indoor locations.

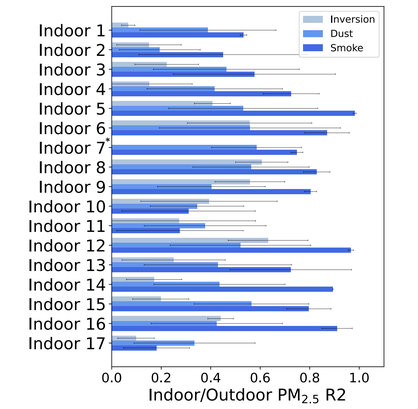
Wildfire Smoke Results

- Two wildfire smoke events occurred between November 2022 and August 2023, lasting an average of 3.5 days.
- WHO indoor 24-hour guideline exceedances:
  - 353 hours from 12 indoor locations over 15 $\mu g/m^3$ hourly average.
  - 13 days from 9 indoor locations over 15 $\mu g/m^3$ daily average.
- Moderate correlation (R2) of 0.68 averaged across indoor locations.
- Highest maximum $PM_{2.5}$ concentration averages for 13 of the 17 indoor locations.

Conclusion

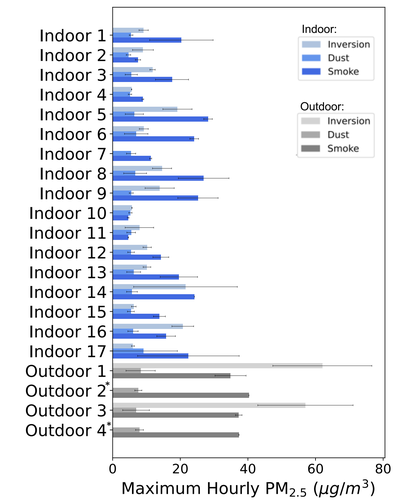
Wildfire smoke had the biggest impact on IAQ of the three pollution events. Wildfire smoke had the highest indoor/outdoor correlation, the most indoor locations with the highest maximum $PM_{2.5}$ concentration, and the most hourly and daily average $PM_{2.5}$ measurements that exceeded the WHO indoor 24-hour guideline.

Indoor/Outdoor $PM_{2.5}$ Correlation Average for each Pollution Event



* Indoor 7 was not in place during inversion dates.

Maximum $PM_{2.5}$ Levels Average for each Pollution Event

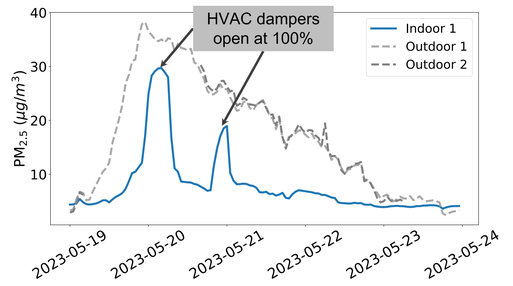


* Outdoor 2 and Outdoor 4 were not in place during inversion dates.

Future Work

- Compare differences in $PM_{2.5}$ levels between HVAC system types (specifically DOAS and VAV systems) during pollution events.
- Utilize building management software to obtain historical air handler unit information to determine if PM anomalies are due to HVAC changes.
- Determine a correction factor for PM measurements from indoor sensors.

Wildfire Smoke Event Showing Possible HVAC Impact on Indoor PM concentration (Preliminary Results)



Acknowledgments

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Dr. Kerry Kelly has an interest in the company Tetrad: Sensor Network Solutions, LCC, which commercializes solutions for environmental monitoring.

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SUSTAINABILITY, THE UNIVERSITY OF UTAH
THE WILKES CENTER FOR CLIMATE SCIENCE & POLICY

[1] WHO Guidelines for Indoor Air Quality 2010
[2] Barkjohn 2020, https://doi.org/10.5194/amt-14-4617-2021
[3] Barkjohn 2022, https://doi.org/10.3390/s22249669
[4] Whiteman 2014, https://doi.org/10.1016/j.atmosenv.2014.06.012
[5] Whiteman 2014 https://doi.org/10.1016/j.atmosenv.2014.06.012
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