Indoor Climate Control: A Data-Driven Approach

Pavel Bozmarov

Content

Introduction

Data Overview

Methodologies, Results, and Suggestions

Introduction

- **Primary objective:** Our primary objective is to analyse indoor temperature, humidity, and CO2 levels using IoT sensor data. This analysis aims to ensure these elements align with our operational goals for indoor air quality.
- **Operational Goals:** Specifically, we are focused on maintaining indoor temperature at or above 21°C, humidity at or above 20%, and CO2 levels at or below 1000 ppm, as per our building operation guidelines.
- **Outcome**: Through this analysis, we expect to identify areas for improvement in our building's climate control systems and develop recommendations for efficient and effective facilities management.
- **Why is this important?** The quality of our indoor environments significantly impacts comfort, health, and productivity. By analysing data from various sensors, we aim to maintain optimal conditions and improve the overall building experience.

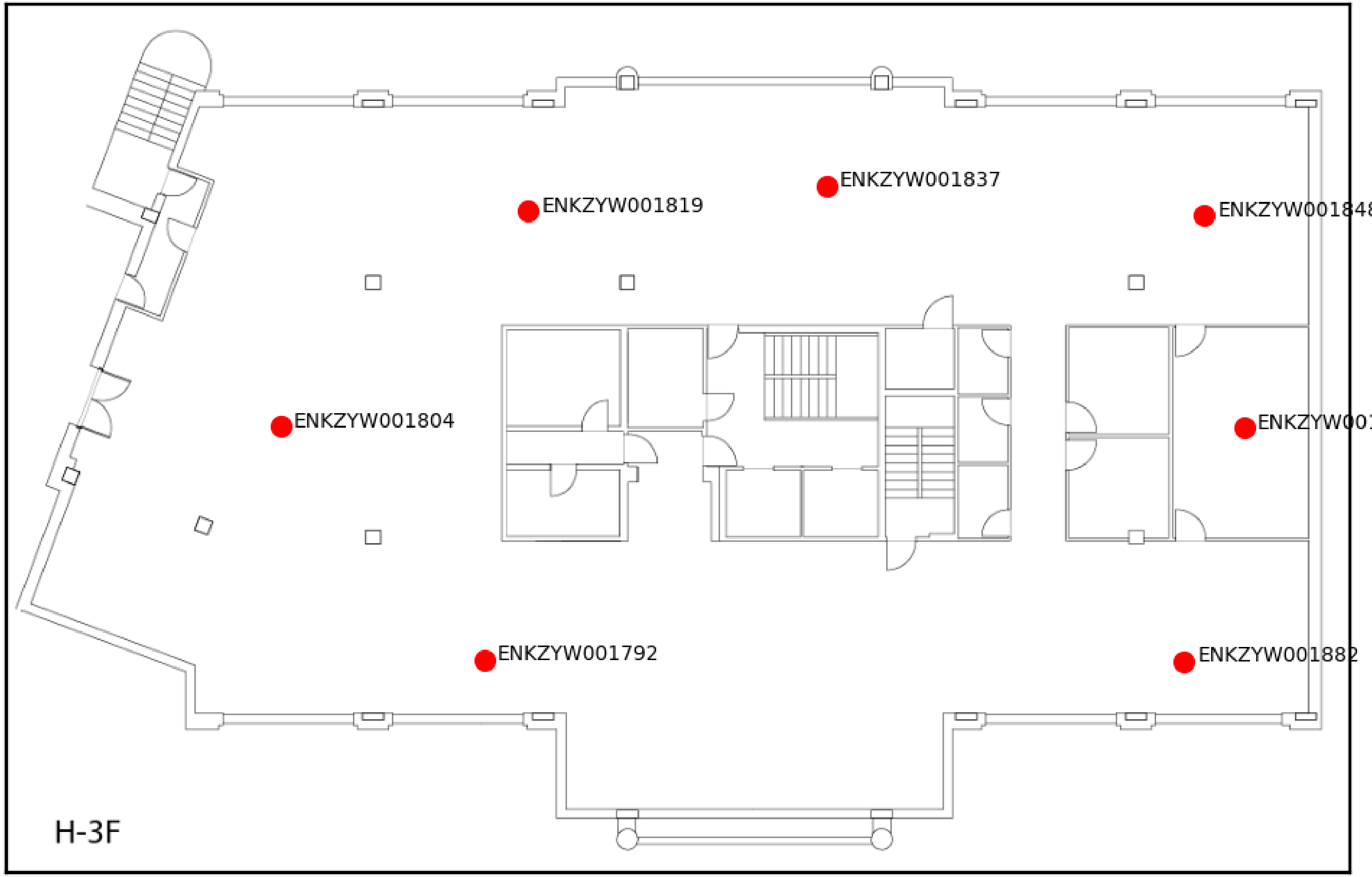
Data Overview

- **Indoor Air Quality (IAQ) Data:** Extracted from *iaq.json*, this dataset includes indoor temperature, humidity, and CO2 levels, recorded by sensors located across floors 3 and 4 of the building.
- **Outdoor Air Quality (OAQ) Data:** Sourced from *oaq.json*, comprising outdoor temperature, humidity, and wind speed data, essential for comparing and contrasting with indoor conditions.
- **Sensor Locations**: Information from *floors.json* details the position of each sensor within the floor plans, offering precise spatial context for our data.
- **Sensor Specificity:** Each sensor's data is identified by a unique sensor ID, allowing for accurate tracking and analysis of readings from specific locations.
- **Collection Time Frame:** The IAQ and the OAQ datasets span from 23 January 2023 to 19 February 2023, where the IAQ one is collected on a 5-minute interval basis and the OAQ dataset is sourced per hour.

Data Overview

- Image of Floor 3 with the sensors placed in their corresponding locations

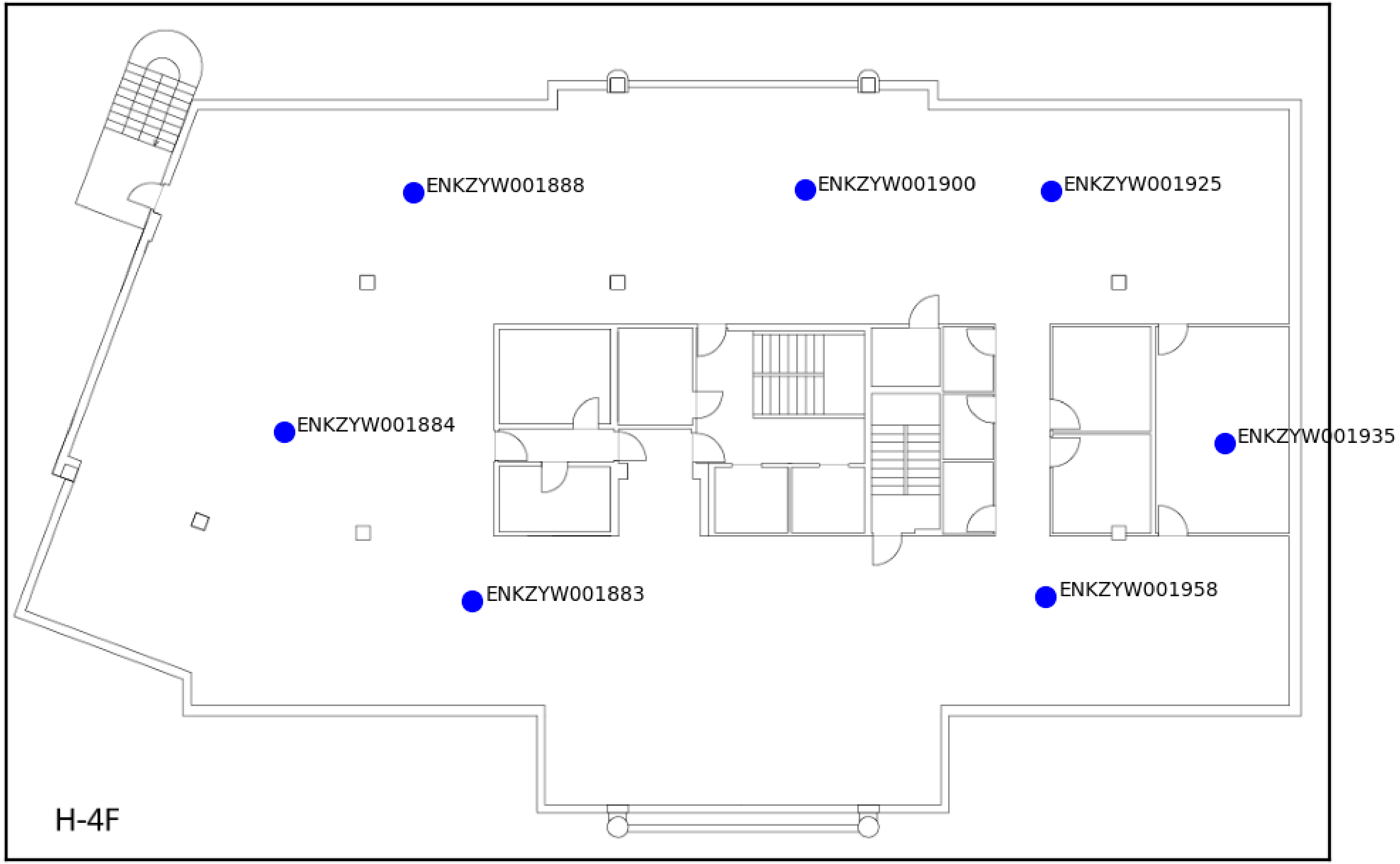
Floor 3



Data Overview

- Image of Floor 4 with the sensors placed in their corresponding locations

Floor 4



Methodologies, Results, and Suggestions (MRS)

- We have used Spearman correlation to estimate the relationships between the floor 3, floor 4, and the outdoor features.
- What is a Spearman Correlation?
- Measuring Relationships: Spearman Correlation helps us determine if two variables move together. It's especially useful for non-linear relationships where increases or decreases are not consistent.
- Value Range: The correlation coefficient ranges from -1 to +1.
  - Perfect Positive Correlation (+1): When one variable increases, the other also increases reliably. For instance, as the number of study hours goes up, so do the grades.
  - Perfect Negative Correlation (-1): An increase in one variable leads to a consistent decrease in the other. Imagine that as the speed of a car increases, the amount of gas in the tank decreases.
  - No Correlation (0): There's no discernible pattern. The amount of coffee someone drinks has no bearing on their shoe size.
- Strength of Relationship: Values near +1 or -1 indicate a strong relationship, meaning the movement of one variable is closely associated with the movement of the other. A correlation of 0.5 suggests a moderate positive relationship where the association is present but not exact.

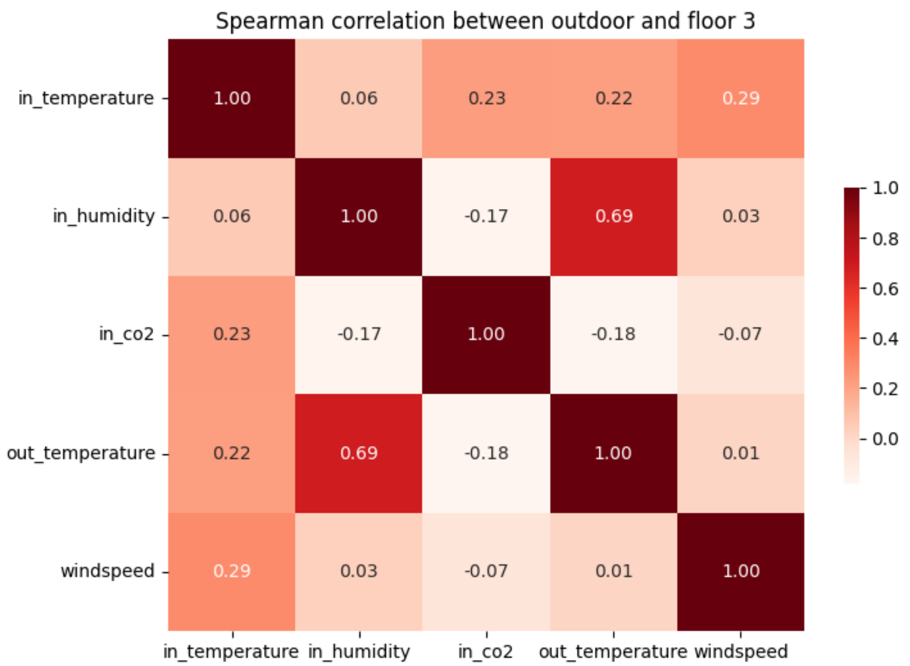
MRS

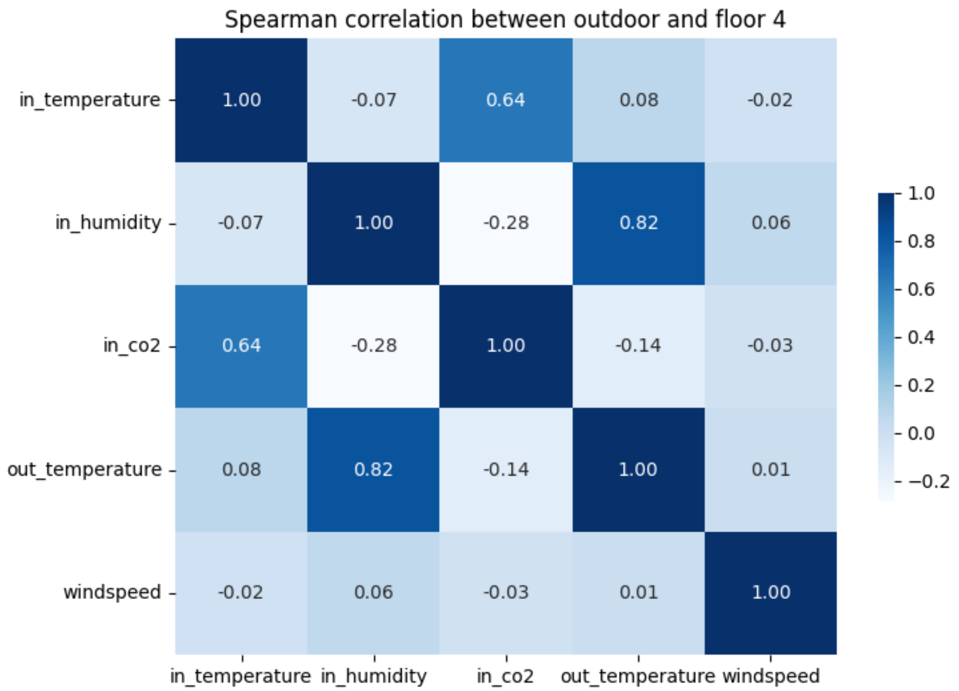
- **Floor 3**:

Indoor Temperature and Wind Speed: A mild correlation (0.29) suggests a slight influence of outdoor wind speed on indoor temperature.
Indoor Humidity and Outdoor Temperature: A moderate correlation (0.69) indicates that as outdoor temperature increases, indoor humidity tends to increase as well.
No Correlation Between Indoor and Outdoor Temperature

- **Floor 4**:

Indoor Temperature and CO2 Levels: A moderately strong correlation (0.64) suggests that higher indoor temperatures are associated with increased CO2 levels.
Indoor Humidity and Outdoor Temperature: A very strong correlation (0.82) implies a significant influence of outdoor temperature on indoor humidity.
No Correlation Between Indoor and Outdoor Temperature



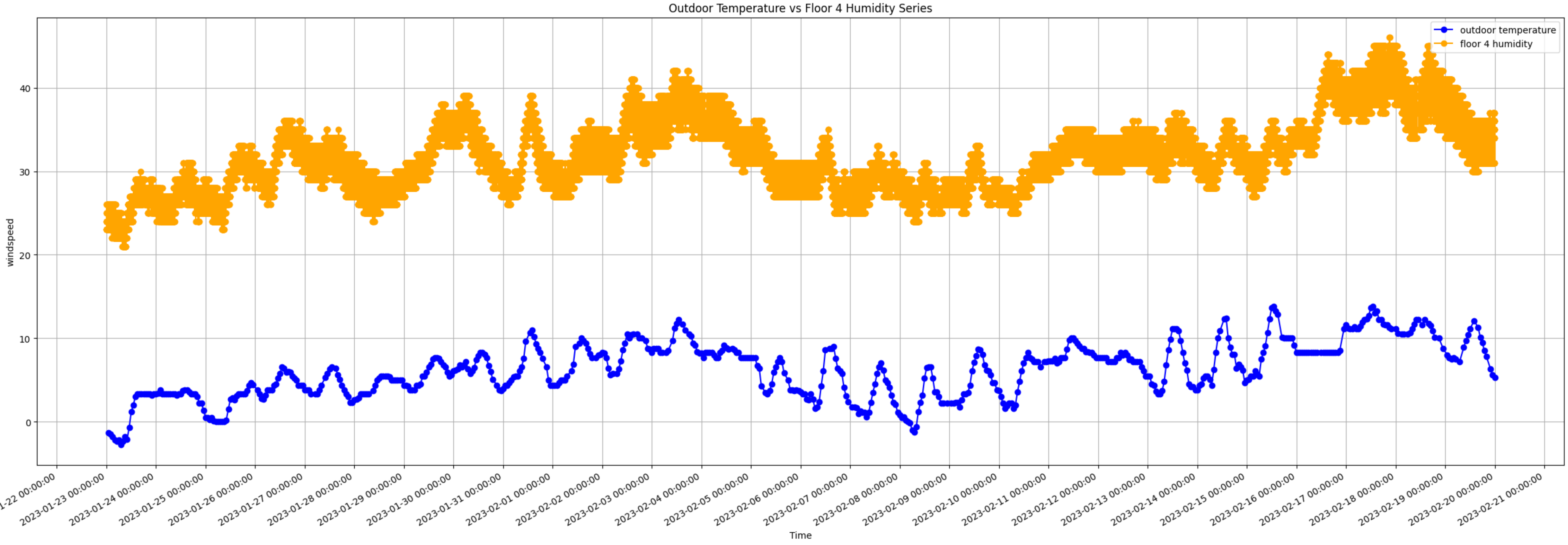


MRS

- **Suggestions**
- The lack of correlation between indoor and outdoor temperatures suggests that the building's insulation and climate control are effectively moderating indoor temperatures
- **Enhance Ventilation Systems**:
    - *For Floor 3*: Given the mild influence of wind speed on indoor temperature, improving ventilation systems could help in regulating temperature more effectively, especially on days with higher wind speeds.
    - *For Floor 4*: As indoor temperature correlates with CO2 levels, enhanced ventilation could help in reducing CO2 concentrations, particularly in areas with higher occupancy or activity.
- **Climate Control Adjustments**:
    - *Humidity Management*: Considering the strong correlation between outdoor and indoor humidity, implement responsive climate control systems that adjust humidity levels based on outdoor temperature changes. This is particularly important for Floor 4, where the correlation is very strong.

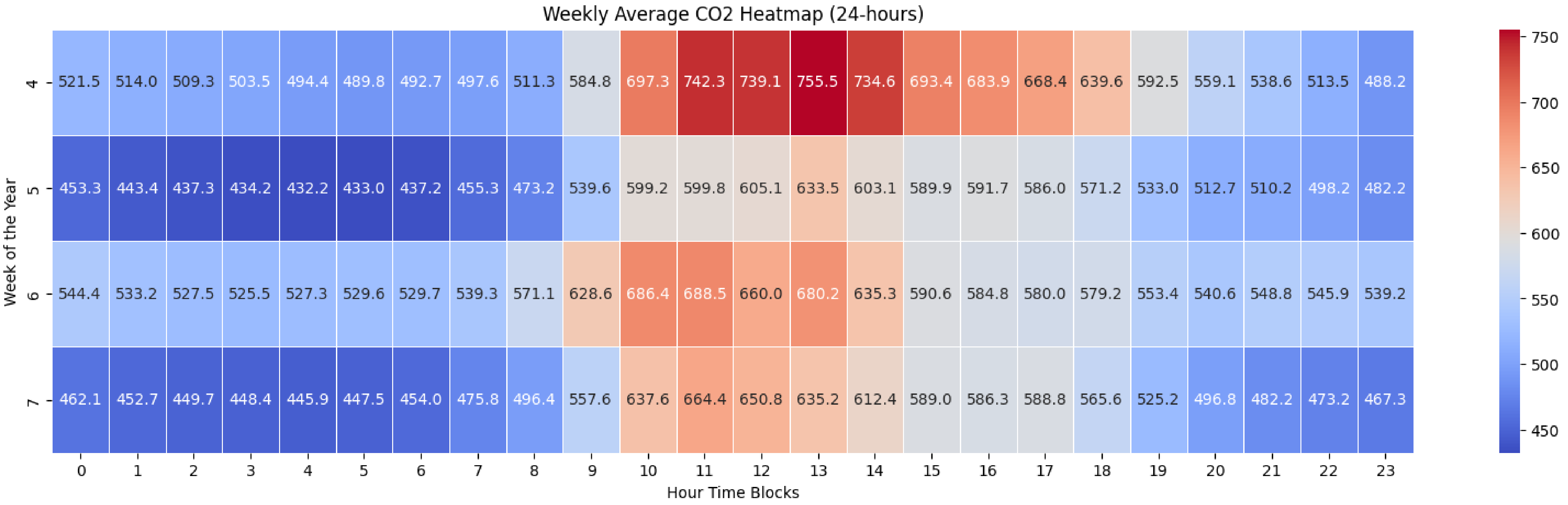
MRS

When we look at the changes in indoor humidity on Floor 4 alongside outdoor temperature, we see they often move together in a similar pattern, indicating a strong link between these two factors.



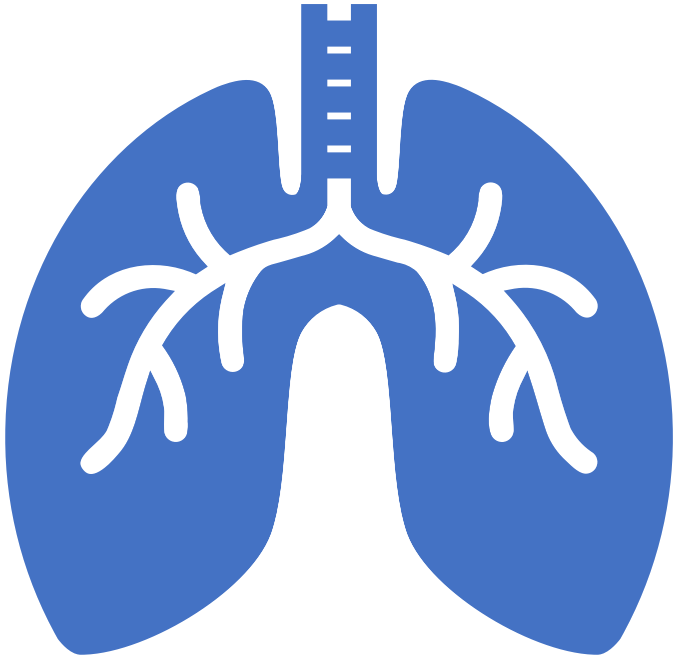
MRS

- Our analysis also involved creating weekly heatmaps for each floor, calculating average hourly humidity, temperature, and CO_2 levels throughout the week. These heatmaps revealed a consistent pattern: from 10:00 am to 6:00 pm, all these factors increase, followed by a decrease outside these hours. Notably, the CO_2 levels on both floors show this pattern most distinctly. The image below represents the CO_2 levels on Floor 4.



MRS

- **Suggestions**
- **Enhanced Ventilation During Peak Hours**: Increase the airflow through ventilation systems specifically during the peak hours of 10:00 am to 6:00 pm on Floor 4. This can help in reducing the elevated CO_2 levels observed during these times.
- **Occupancy Management**: Implement occupancy scheduling or management strategies to distribute the number of people more evenly throughout the day, if possible. This could help in mitigating the high CO_2 levels during peak hours.
- **Real-Time Monitoring Systems**: Install or enhance real-time monitoring systems for CO_2 levels. This would allow for immediate adjustments to ventilation or air filtering systems when CO_2 levels start to rise.



MRS

- In this analysis phase, we systematically examine each floor for key environmental factors: humidity, temperature, and CO_2 levels. Our focus is on identifying data points that fall outside our predefined acceptable ranges. This process involves several steps:
  - **Identification**: We pinpoint data points for each factor that deviate from our set thresholds.
  - **Organization**: The data is then organized by both the date and the unique ID of each sensor.
  - **Extreme Data Point Calculation**: For each sensor, we calculate the total number of these extreme data points daily.
  - **Average Calculation**: We compute the daily average of these extreme values for every sensor.
  - **Outlier Analysis**: To assess the accuracy of our sensors, we determine the percentage of these data points that are outliers.
- This methodical approach helps us ascertain the reliability of our sensors and potentially identify any that might be malfunctioning.

MRS. Extreme Data - Floor 3

- **CO2 Spike on January 23rd**:
  - Significant rise in CO2 levels detected by 6 out of 7 sensors.
  - Average readings above 1150 ppm, indicating potential air quality concerns.
- **Continuous High Readings from Sensor 1886**:
  - Consistently high CO2 readings, particularly on February 14th with extreme values.
- **Recommendations**:
  - **Ventilation Check**: Increase and optimize ventilation during peak CO2 times.
  - **Investigate External Factors**: Examine potential events or activities on January 23rd that could have impacted air quality.
- **Temperature Drops in Early February**:
  - Recorded lower temperatures on February 2nd, 3rd, and 5th
- **Humidity Consistency**:
  - Humidity levels remained within expected ranges, no discrepancies noted.
- **Recommendations**:
  - **Sensor Verification**: Check sensors, particularly Sensor 1882, for calibration due to unusually low temperature readings.
  - **Environmental Controls**: Review and adjust heating settings to maintain consistent indoor temperatures.

MRS. Extreme Data - Floor 4

- Extended Period of High CO_2:
  - We observed a significant increase in CO_2 levels from January 23rd to February 2nd, a continuous 10-day period.
  - This trend was most pronounced on January 23rd, where multiple sensors simultaneously reported CO_2 levels averaging above 1160 ppm.
- Recommendations:
  - Activity Review: To address these CO_2 spikes, we recommend conducting an in-depth review of specific areas or activities on Floor 4. Identifying peak times of occupancy can help us understand and mitigate factors contributing to the elevated CO_2 levels.
  - Long-Term Monitoring: The implementation of continuous CO_2 monitoring will enable us to quickly identify and respond to air quality issues, ensuring a healthier environment for building occupants.

- **Analysis of Temperature Fluctuations:**
  - **On January 29th, 30th, and 31st, we observed unusual temperature dips below our standard threshold of 21 degrees Celsius.**
  - **Notably, these lower temperatures were reported by multiple sensors with a low outlier rate, particularly on the 30th and 31st, suggesting a genuine drop in the indoor temperature.**
- Recommendations:
  - **In response to the observed temperature drops, we advise assessing and optimizing the heating systems on this floor. Ensuring they are responsive to changes in weather and occupancy can help maintain a stable and comfortable indoor environment.**
  - **Regular checks and maintenance of temperature sensors are crucial to ensure their accuracy and reliability, particularly during periods of environmental fluctuation.**
  - **Maintaining ongoing surveillance of both temperature and CO_2 levels will enable proactive adjustments, ensuring the comfort and safety of all occupants on Floor 4.**