Catching "Cooties" with Carbon Dioxide

Modeling Carbon Dioxide Buildup as an Indicator for Increased Risk of Disease Transmission

Andrew Baugher - Dr. Shelly Miller

Hypothesis: Carbon Dioxide (CO_2) concentrations in high occupancy spaces can be accurately modeled based on the occupancy of the space. CO_2 concentrations may be correlated to the probability of disease transmission.

Background

- Disease transmission in high occupancy spaces is not easily modeled
  - Risk of infection is affected by occupant density, concentration of infectious aerosol, and air exchange rates
  - CO_2 is believed to be an indicator for probability of disease transmission
- Currently, only approximate mathematical models exist for Carbon Dioxide concentrations
  - These models cannot account for disturbances such as windows or doors opening and closing

Experimental Design

- Enclosed high occupancy spaces to be studied
  - School bus, infectious disease ward, mock airplane, college dorm rooms
  - This study models a school bus
- Electronic sensors used to collect Carbon Dioxide concentrations over time
  - Sensors evenly spaced throughout the bus
  - School bus occupancy over time is recorded to correlate occupancy to concentration

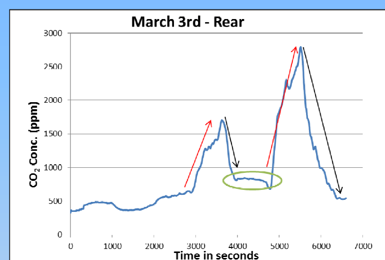
Model Assumptions

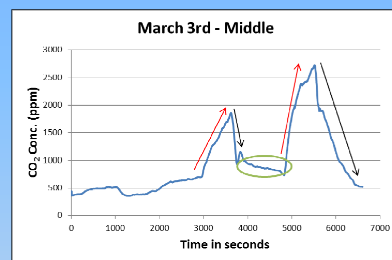
- Boulder Valley School District route was monitored with high occupancy density
- Model assumes that the windows and doors remain closed during concentration buildup time
- Model assumes constant air exchange rate and constant Carbon Dioxide generation rate per person

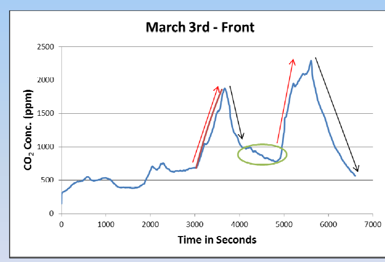
The Model

$$C(t) = C_0 e^{-\lambda t} + \frac{\left(\frac{E}{V} + \lambda * C_{OA}\right)}{\lambda} * [1 - e^{-\lambda t}]$$

- Model depends on:
  - Initial concentration of Carbon Dioxide, Air Exchange Rate (λ), Outdoor air concentration C_{OA}, Volume V, CO_2 generation rate per person E, and time t
  - Concentration is expected to increase exponentially





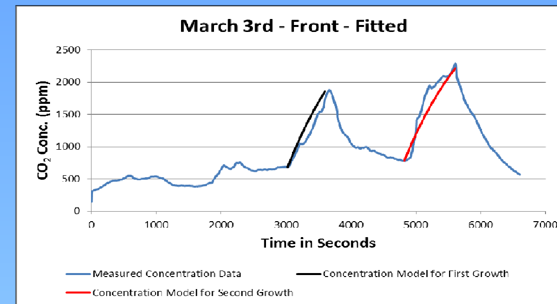


Legend

- Red Arrows – Concentration spikes due to high occupancy
- **Black Arrows** – Concentration loss due to occupants leaving bus
- Green Circles – Concentration decay-area of interest

Data of Interest

- Data collected over multiple days
- The front of the bus had the steepest decay area and smallest peak concentrations
  - The rear had the flattest decay and largest concentrations
- Indicates that the rear of the bus is not exchanging as much air as the front



Conclusions

- Model fit well with physical data
  - Model was tested against multiple samples and fit as desired
  - Fit parameters include: ACH of 3, generation rate of 2.803 ppm per second, fixed occupancy of 29
- Model does not account for disturbance effects
  - Windows opening, traffic, mixing that may occur

Future Work

- Correlate $C0_2$ concentrations to probability of disease transmission and occupancy density
- Add correction factors to account for disturbances
  - Doors/windows opening
  - Occupancy density changing with time
- Tracer gas decay test to better determine the ACH

Acknowledgements

Graduate Student Advisor – Julia Luongo
DLA Coordinator – Dan Watson and Sharon Anderson
Boulder Valley Transit Coordinator – Mark Levinson