Ozone calibration model developed for a low-cost metal oxide sensor during a wildfire smoke event

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Introduction

- Wildfire smoke contains large quantities of ozone precursors which can react to produce high ozone concentrations.
- This work utilizes the University of Utah's network of low-cost air quality sensors (AirU) to predict spatial ozone concentration gradients across the Salt Lake Valley.

Utah State Capital Building during Wildfire Smoke Event

Walker, N; Heleah, J; Aug 6, 2021; *Wildfire smoke blankets northern Utah, darkens sky*; Fox13 Salt Lake City; https://www.fox13now.com/news/local-news/hazy-wildfire-smoke-expected-friday-coming-into-the-valley-for-everyone

Objectives

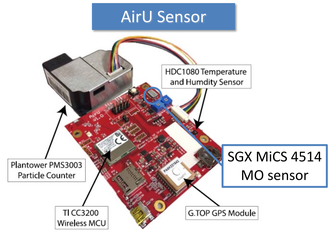
- Develop a smoke event ozone calibration model using the AirU sensors co-located with the Hawthorne Division of Air Quality (DAQ) station.
- Predict ozone concentrations during a wildfire smoke event using the AirU sensor network and the ozone calibration model.

$$\underbrace{NO_x + VOC}_{\text{Wildfire smoke contains ozone precursors.}} + Heat/Sunlight = O_3$$

Methods

- AirU sensors contain a metal oxide sensor that can detect ozone as an oxidizing agent.
- Multiple linear regression (MLR) calibration model developed using three variables against DAQ ozone concentration as the standard:
  1. AirU sensor temperature
  2. AirU sensor oxidizing species signal
  3. DAQ solar radiation

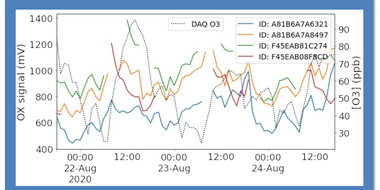
AirU Sensor



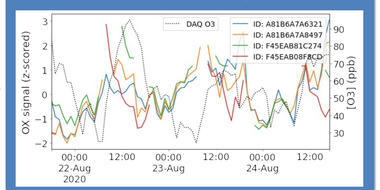
T. Becnel et al., "A Distributed Low-Cost Pollution Monitoring Platform," in IEEE Internet of Things Journal, vol. 6, no. 6, pp. 10738-10748, Dec. 2019, doi: 10.1109/JIOT.2019.2941374.

- Low-cost sensor baseline differences addressed using a z-score normalization process on the variables prior to calculation of the MLR calibration model.

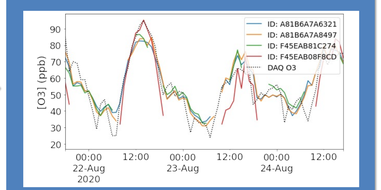
Raw sensor signals



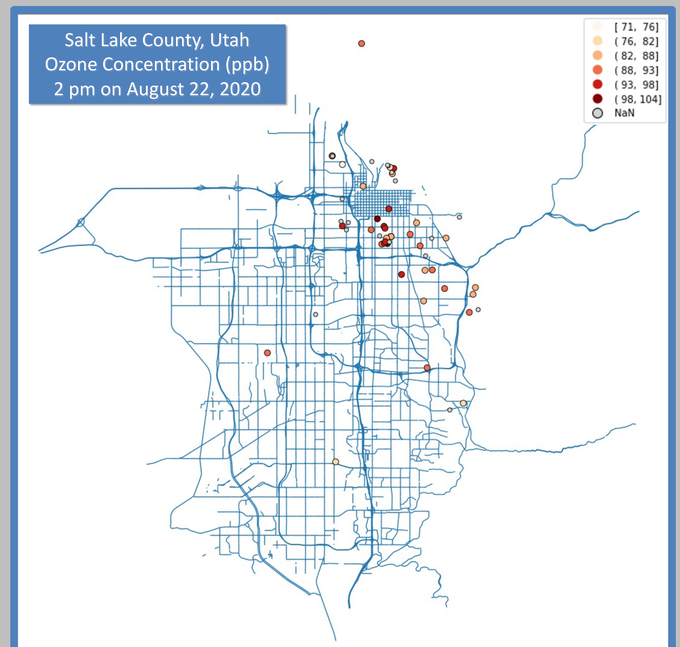
z-scored sensor signals



MLR calibration model



Salt Lake County, Utah Ozone Concentration (ppb) 2 pm on August 22, 2020



Results

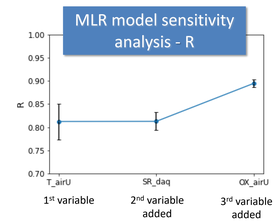
$$O_{3,pred} = 56.42 + 13.39\,T_{AirU} - 7.36\,OX_{AirU} + 6.49\,SR_{DAQ}$$

T_{airU}	**z-scored** AirU temperature (C)
OX_{airU}	**z-scored** AirU MO oxidation species signal (mV)
SR_{daq}	**z-scored** DAQ solar radiation (Langley/min)
$O_{3_{pred}}$	Predicted ozone concentration (ppb)

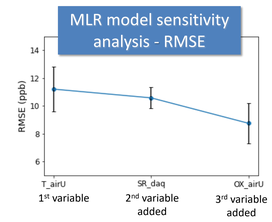
Calibration Model Performance Measures	
MSE (ppb^2)	72.16
RMSE (ppb)	8.49
Bias (%)	2.41
Precision (%)	21.94

- Salt Lake Valley spatially resolved ozone concentrations predicted using the AirU network during the wildfire smoke event from August 21-24, 2020.
- Ozone concentrations at 2 pm shown overlayed on a Salt Lake County street map.
- Variable sensitivity was determined by sequentially adding the variables to the MLR model and analyzing changes to the Pearson correlation coefficient and the root mean square error.

MLR model sensitivity analysis - R



MLR model sensitivity analysis - RMSE



Key Findings

- Spatial resolution of ozone concentration was improved using the the AirU sensor network.
- AirU temperature measurements showed the highest correlation to ozone concentration.
- AirU oxidizing species signals and DAQ solar radiation measurements improved the RMSE by 18.9% and 5.8% respectively.

Future Work

- Use the spatially resolved ozone concentrations predicted with the AirU sensor network to assist in validation of models targeted at predicting ozone concentration during wildfire events.
- Explore spatial ozone concentration gradients during smoke events in urban environments.

Acknowledgements

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

Further Information

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