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Performance Comparison of Electrochemical Sensors across Six Cities of Continental United States

Presented by

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Background

- NO_2 is pre-cursor for O_3. NO_2 exposure reduce lung functions, increase airways inflammation & asthma. O_3 exposure results in more severe lung diseases like asthma, emphysema, and chronic bronchitis.

- For higher spatial density measurement of NO_2 and O_3, low cost electrochemical sensor is necessary.

- NO_2 and O_3 sensor calibration involves relating raw voltage data with target concentration (FRM/FEM).

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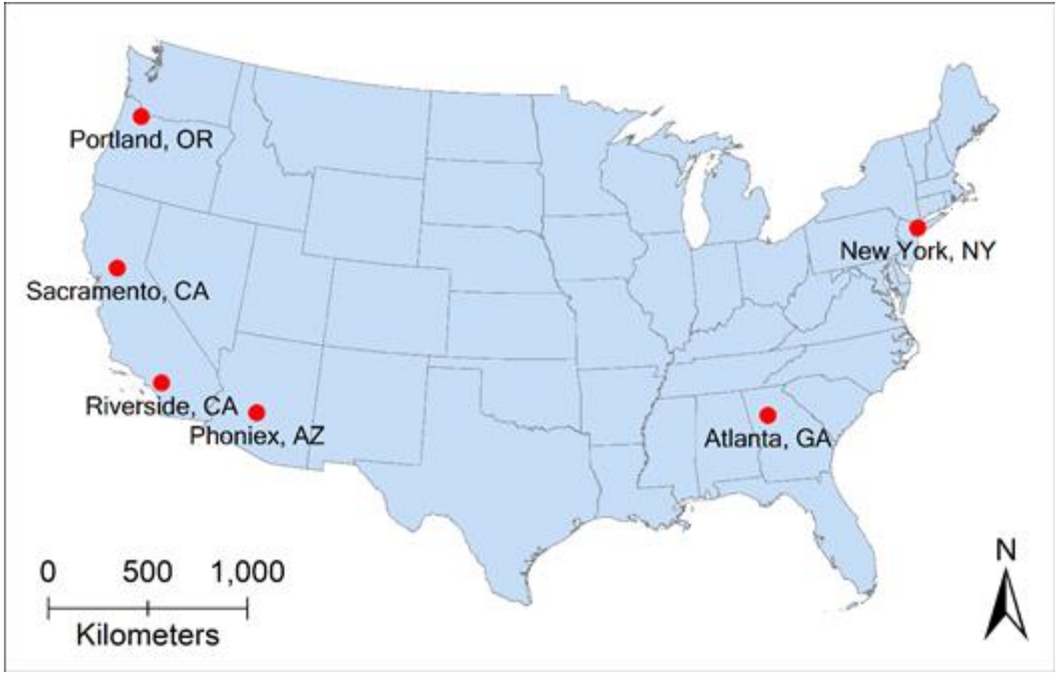
Location of Six Monitoring Sites



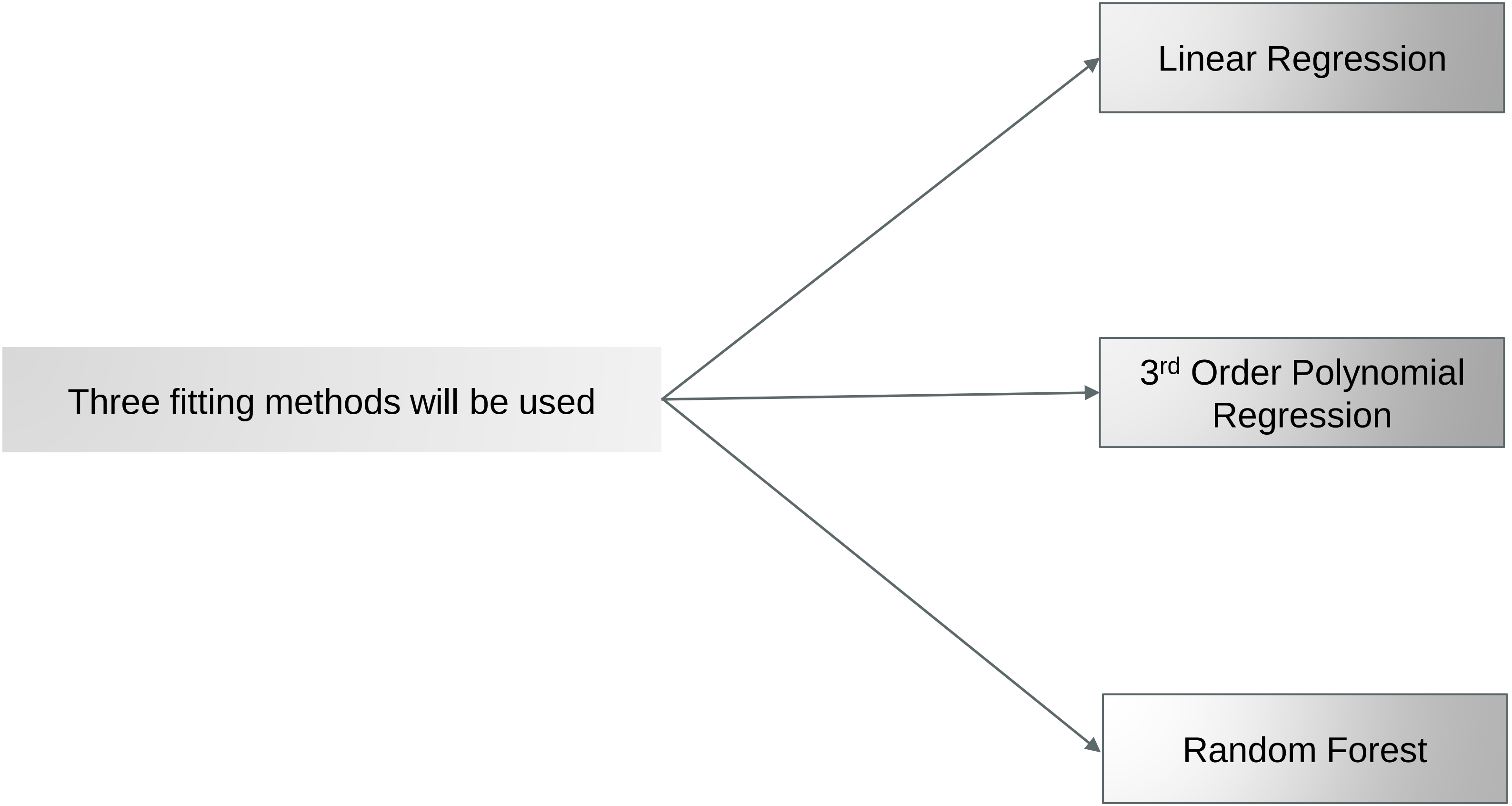
Location of Six Monitoring Sites

Site	Latitude(N)	Longitude(W)	Elevation(m)
Atlanta,GA	33.69	84.29	308
Riverside, CA	33.99	117.49	220
Sacramento,CA	38.57	121.49	30
New York, NY	40.74	73.82	25
Portland, OR	45.5	122.6	69
Phoenix, AZ	33.51	112.1	354

Research Questions

1. Performance comparison of low-cost NO_2 and O_3 sensors across the six cities
2. Are NO_2 and O_3 sensor performances affected by any other gaseous pollutants, and meteorological factors?
3. Are the machine learning calibration methods better than linear and polynomial regression?

Calibration Methods



Local Calibration Comparison

Ranges and Mean values of Temperature, RH, NO_2 and O_3 concentration(ppbv) across six cities

City	Start time	End time	Days	Temperature	RH	NO_2	O_3
ATL (Atlanta, GA)	6/28/2019	8/9/2019	42	28.3 (17-40.5)	72 (31.7-97.4)	7.4 (1-38)	28.5 (1-77)
NYC (New York City, NY)	1/28/2020	4/22/2020	85	7.5 (-9-23.9)	62.5 (22.2-101)	13.9 (1.1-53.7)	28.8 (1-58)
PHX (Phoenix, AZ)	12/11/2019	4/14/2020	125	15.7 (0-34.3)	52.3 (16.9-98.3)	15.5 (2-50)	20.6 (1-56)
PTL (Portland, OR)	1/4/2019	10/31/2019	301	14.7 (-4-40.2)	68.9 (17-103)	7.5 (1-42)	23.2 (1-77)
RAV (Riverside, CA)	8/2/2019	8/22/2019	20	26.9 (16.1-44.2)	54.8 (15.3-90.1)	10.2 (2-31)	42.1 (2-126)
SAC (Sacramento, CA)	9/27/2019	11/8/2019	43	17.6 (3-34.2)	48.1 (12-94.8)	17.1 (1-62)	23 (-2-66)

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Local Calibration Comparison

Sensor Performance (R^2) at corresponding cities

		PTL	ATL	RAV	SAC	NYC	PHX
NO_2	Linear	0.73	0.34	0.26	0.83	0.84	0.51
	Polynomial	0.83	0.37	0.20	0.88	0.88	0.62
	RF	0.84	0.65	0.48	0.93	0.9	0.74
O_3	Linear	0.63	0.81	0.97	0.59	0.23	0.58
	Polynomial	0.65	0.79	0.95	0.55	0.18	0.53
	RF	0.59	0.86	0.97	0.82	0.39	0.70

CO gas influences Sensor Performance?

Sensor Performance (R^2) at corresponding cities after incorporation of CO signal

		PTL	ATL	RAV	SAC	NYC	PHX
NO2	Linear	0.80(+0.07)	0.45(+0.11)	0.59(+0.33)	0.89(+0.06)	0.86(+0.02)	0.76(+0.25)
	Polynomial	0.84(+0.01)	0.45(+0.08)	0.48(+0.28)	0.89(+0.01)	0.85(-0.03)	0.72(+0.1)
	RF	0.86(+0.02)	0.74(+0.09)	0.68(+0.2)	0.97(+0.04)	0.92(+0.02)	0.90(+0.16)
O3	Linear	0.78(+0.15)	0.83(+0.02)	0.97(+0)	0.80(+0.21)	0.70(+0.47)	0.79(+0.21)
	Polynomial	0.77(+0.12)	0.77(-0.02)	0.95(+0)	0.76(+0.21)	0.60(+0.42)	0.73(+0.2)
	RF	0.69(+0.10)	0.89(+0.03)	0.97(+0)	0.94(+0.12)	0.81(+0.42)	0.91(+0.21)

- Electrochemical sensor performance is increased when we include raw CO signal due to the possible co-variation between CO and target gas.
- Correlation coefficient increases the most in those cities where R^2 were considerably lower before the inclusion of CO signal.

CO gas influences Sensor Performance?

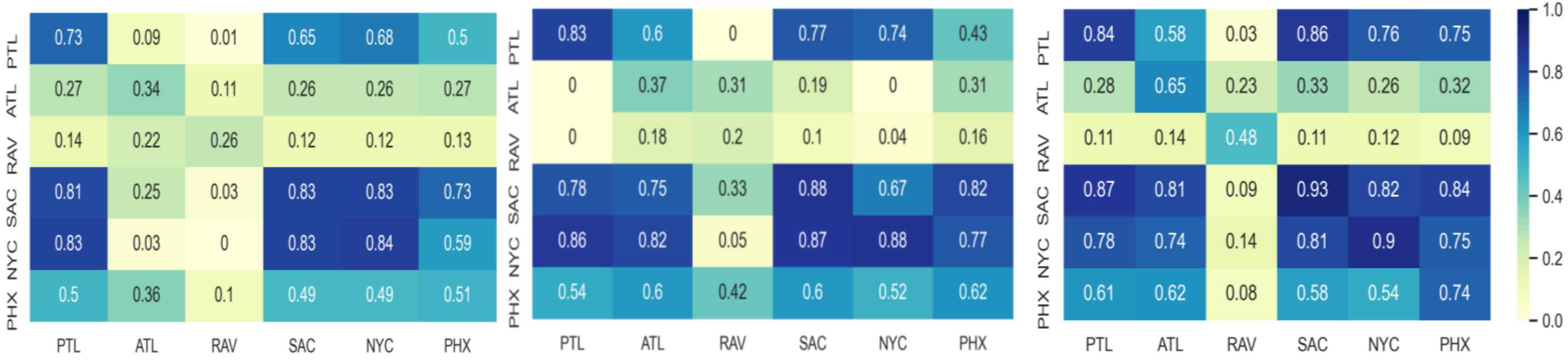
R^2 between CO and NO_2 and O_3 measured by FRM/FEM, and by low-cost sensors

		PTL	ATL	RAV	SAC[a]	NYC	PHX
CO & NO_2	Between FRM/FEM	0.45[b]	0.45	0.79	N/A	0.72	0.65
	Between low-cost sensor	0.22	0.37	0.26	N/A	0.57	0.41
CO & O_3	Between FRM/FEM	0.27[c]	0.07	0.11	N/A	0.56	0.56
	Between low-cost sensor	0.22	0.01	0.04	N/A	0.29	0.27

Machine Learning Algorithms Perform Better?

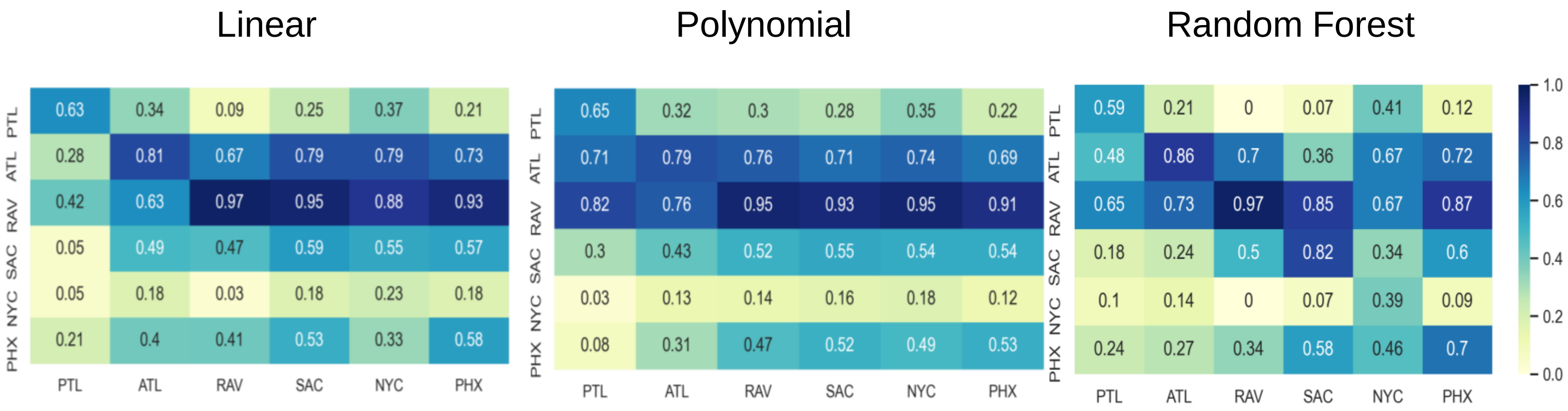
NO_2 Performance

Linear | Polynomial | Random Forest

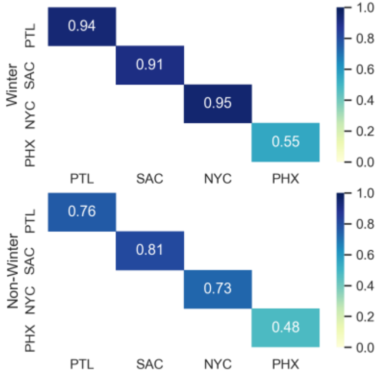


Machine Learning Algorithms Perform Better?

O_3 Performance

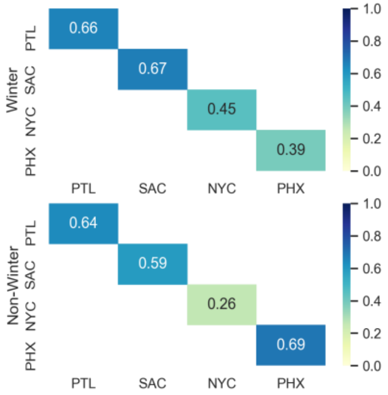


Seasonal Variation of Sensor Performance Exists?



NO_2 Performance

Both winter and non-winter data available at 4 cities



O_3 Performance

Findings

1. Local calibration models perform better in Portland, Sacramento and New York city for NO_2 and Atlanta and Riverside for O_3.
2. Incorporation of CO signal increases model performance of NO_2 and O_3
3. Random Forest method performs better than linear or polynomial regression.
4. Better winter performance of sensors observed

Thank You!

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