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Intra-urban spatial variability of surface ozone in Riverside, CA: viability and validation of low-cost sensors

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Supplemental Material

Table S1: Field calibration results of different regression models showing R^2, RMSE for each sensor signal. Two entries mean there are two sensors in that U-Pod.

U-Pod ID	Linear 3 (conc., temp, abshum)	Linear 3T (conc., temp, abshum, temp|conc.*)	Linear 4 (conc., temp, abshum, time)	Linear 4T (conc., temp, abshum, time, temp|conc.*)
	O_3	O_3	O_3	O_3
D0	0.88, 7.2	0.98, 3.3	0.88, 7.0	0.97, 2.9
	0.86, 7.6	0.97, 3.4	0.87, 7.4	0.97, 3.0
D3	0.83, 7.1	0.98, 2.5	0.84, 7.4	0.97, 3.0
	0.85, 6.9	0.98, 2.7	0.85, 8.0	0.97, 3.0
D4	0.84, 4.9	0.96, 2.7	0.86, 5.2	0.97, 2.5
	0.83, 5.1	0.96, 2.2	0.84, 5.5	0.97, 2.7
D5	0.90, 5.9	0.98, 2.5	0.90, 5,6	0.98, 2.5
	0.87, 6.6	0.98, 2.9	0.87, 6.5	0.97, 2.8
D6	0.82, 7.3	0.98, 2.9	0.83, 7.6	0.95, 3.5
	0.90, 5.8	0.98, 2.4	0.90, 5.8	0.98, 2.4
D7	0.87, 4.9	0.96, 3.3	-	0.95, 3.0
	0.86, 5.0	0.94, 3.5	-	0.95, 3.2
D8	0.90, 6.2	0.98, 2.9	0.90, 6.2	0.97, 3.3
DA	0.82, 7.6	0.97, 4.3	0.82, 7.6	0.97, 3.0
	0.81, 7.6	0.97, 4.3	0.81, 7.6	0.97, 3.1
DB	0.57, 15	0.69, 17	0.61, 14	0.97, 2.8
DC	0.87, 6.6	0.98, 2.6	0.87, 6.6	0.97, 2.6
	0.89, 6.3	0.98, 2.8	0.89, 6.2	0.97, 2.7
DD	0.89, 4.6	-	0.91, 4.6	0.98, 1.8
	0.91, 4.4	-	0.93, 4.2	0.98, 1.6
DE	0.85, 7.3	0.97, 2.9	0.86, 7.4	0.96, 3.3
	0.91, 6.0	0.98, 2.7	0.91, 6.0	0.97, 2.6
DF	0.87, 6.5	0.98, 2.4	0.87, 6.6	0.97, 3.1
	0.90, 6.0	0.98, 2.5	0.90, 6.0	0.97, 3.0

***** temp|conc. is the interaction term between temperature and concentration, the second term in Eq. (1). U-Pod ozone measurements tend to have more error at higher temperatures, which usually corresponds with higher ground level ozone. For the 3T and 4T models, a temperature-concentration interaction term was included in the current calibration linear model to help account for this phenomenon but may not be addressing transient temperature effects on the ozone sensor or

temperature/humidity sensors on board. Also note that these R^2 values are between reference signal in ppb and the sensor signal ($S=R/R_o$), not between the reference concentration and the U-Pod, as they are in Table 1.

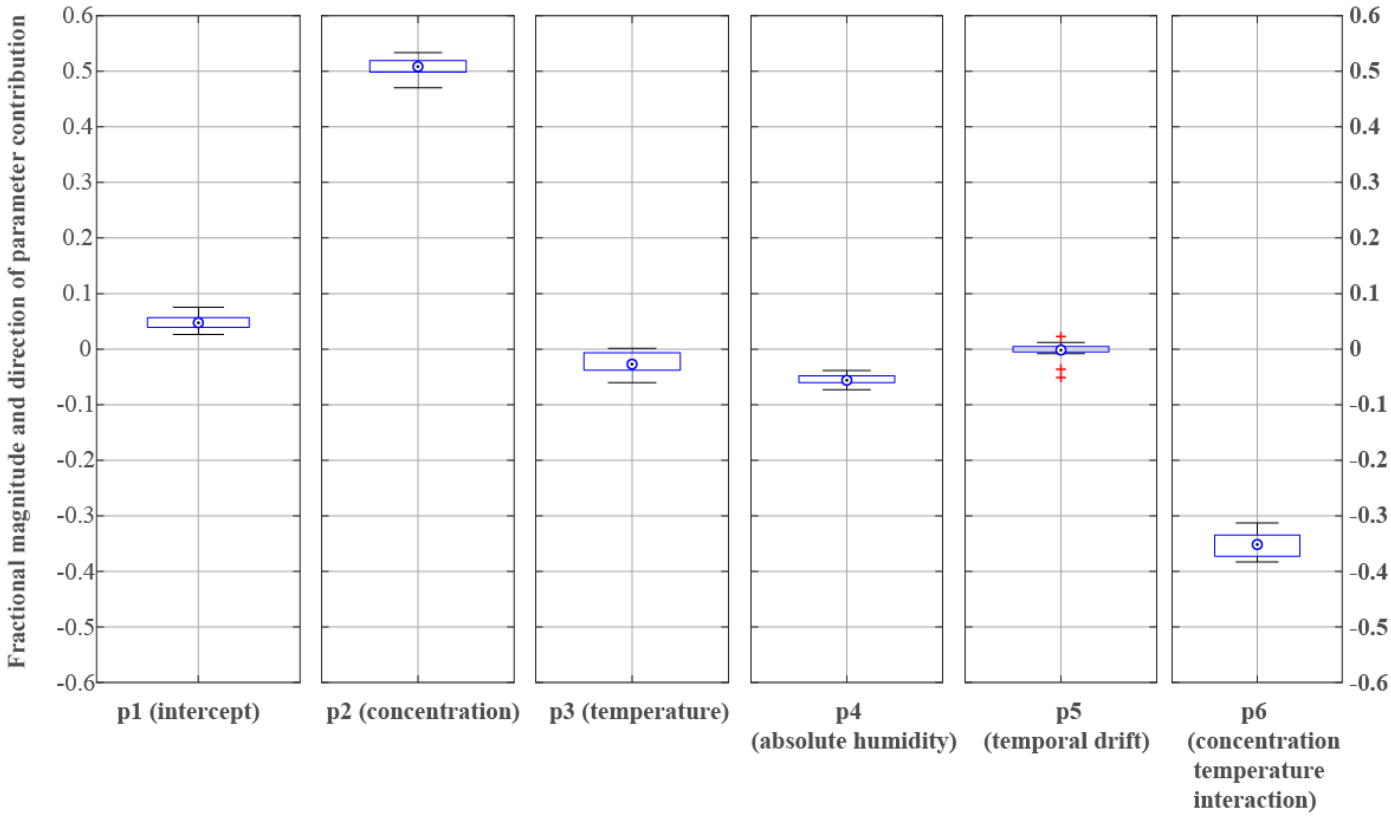

Figure S1: Distributions of relative effects sizing from standardized (dimensionless) regression model coefficients estimating sensor signal (S), see Eq. 1, using scaled input variables (0 to 1). The magnitude of the effect size (sum to unity) are shown along with the direction corresponding to the sign of the coefficient. The boxes show the interquartile range, the target marks the coefficient median and whiskers showing 1st and 99th percentiles with red "pluses" indicating values outside this range. Tight distributions indicate low inter-sensor signal variability as modeled by the various parameters.

Table S2. Percentage of original data lost from post-process filtering

U-Pod ID	O_3 sensor 1				O_3 sensor 2				Totals	
	M	CD	AH	T	M	CD	AH	T	Sen1	Sen2
D0	0.0	0.1	11.9	3.6	0.0	0.2	11.9	3.5	15.5	15.6
D3	0.0	0.2	8.5	2.5	0.0	0.2	8.5	2.5	11.2	11.2
D4	0.0	0.2	21.1	5.2	0.0	0.2	21.2	5.2	26.6	26.7
D5	0.0	0.1	13.4	4.4	0.0	0.2	13.5	4.4	17.9	18.1
D6	0.0	0.1	5.1	4.2	0.0	0.1	5.2	4.2	9.4	9.5
D7	0.01	0.0	1.3	5.2	0.01	0.0	1.3	5.3	6.7	6.7
D8	0.0	0.1	14.9	3.7	NaN	NaN	NaN	NaN	18.6	NaN
DA	0.0	0.0	20.8	4.6	0.0	0.1	20.8	4.6	25.4	25.4
DB	0.0	0.1	2.7	2.3	NaN	NaN	NaN	NaN	5.1	NaN
DC	0.01	0.0	2.8	8.3	0.09	0.2	2.5	8.0	11.1	11.6
DD	0.0	0.1	37.4	8.3	0.04	0.1	37.2	8.3	45.8	45.9

DE	0.0	0.1	9.6	2.7		0.0	0.0	9.7	2.7	12.4	12.4
DF	0.0	0.2	11.4	1.0		0.0	0.2	11.4	1.0	12.6	12.6

M stands for maximum filtering. CD stands for consecutive differences, which were filtered if they exceeded 8 standard deviations away from the mean. AH stands for absolute humidity, filtered if it the value was not observed during collocation. T stands for temperature, also filtered out if the value was not observed during collocation. Sen1 stands for ozone sensor 1, and sen2 stands for the second ozone sensor.

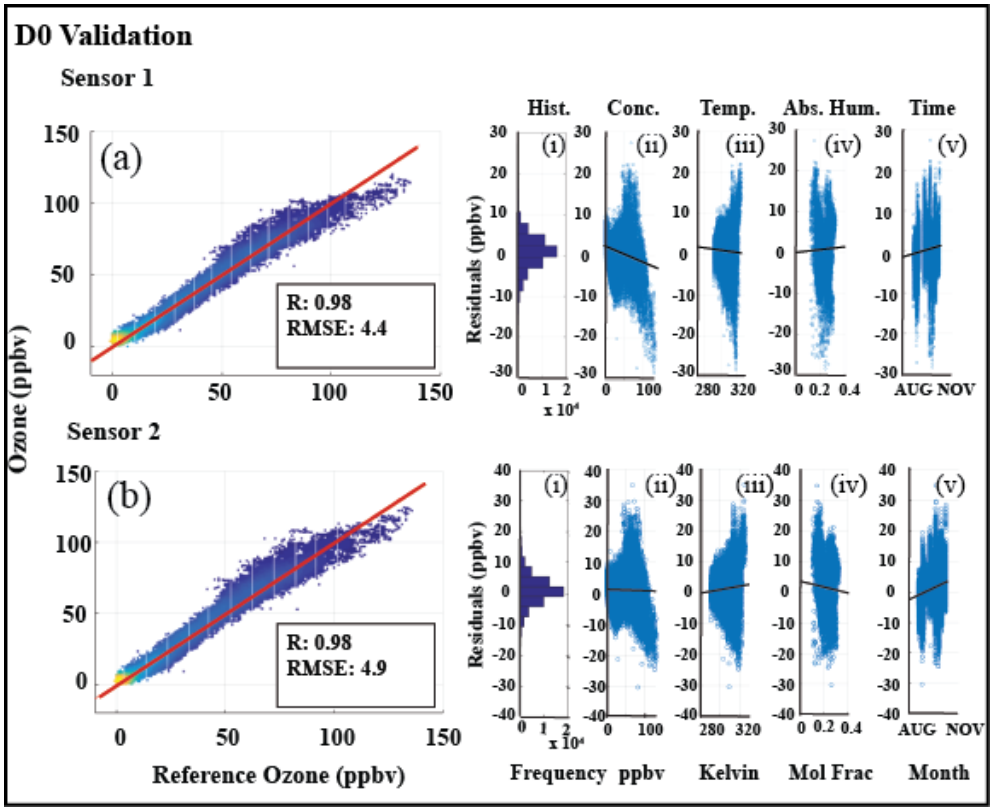

Figure S2. Panel (a) shows D0 sensor validation for the first sensor and (b) shows the same for the second sensor, with warmer shading showing a higher density of points. Then, from left to right for each sensor: a histogram of residuals (i), and then residuals against: concentration (ii), temperature (iii), absolute humidity (iv) and time (v). The red 1:1 line in panels (a) and (b) are not lines of best fit, and are for comparison purposes.

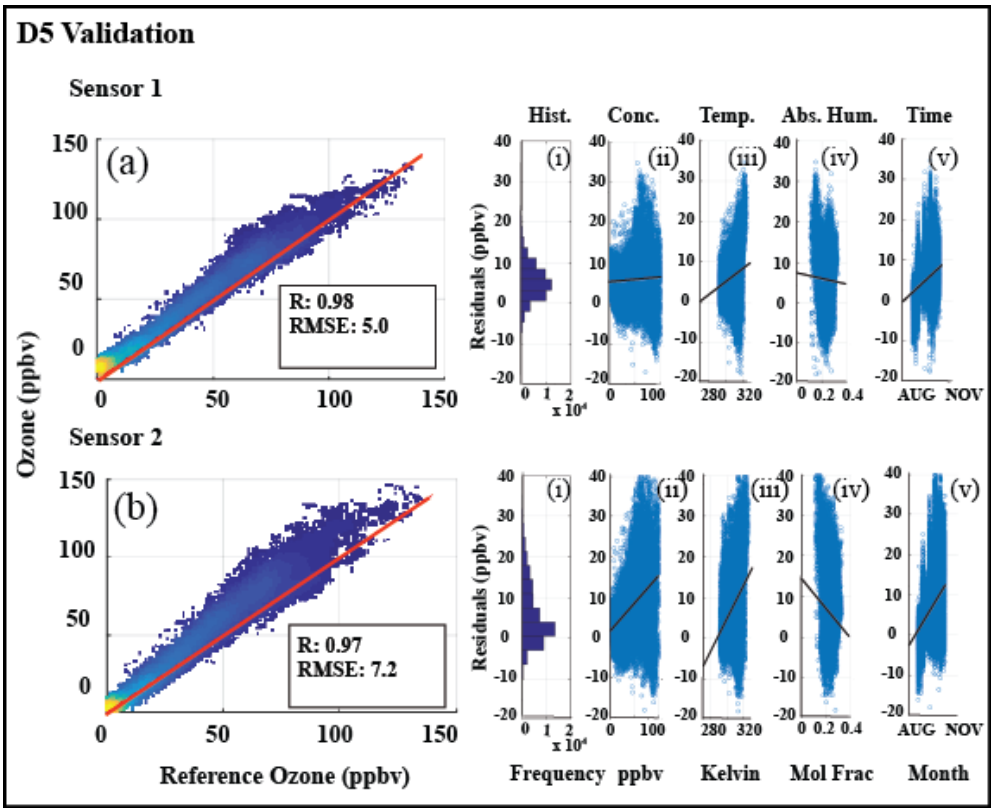

Figure S3. Panel (a) shows D5 sensor validation for the first sensor and (b) shows the same for the second sensor, with warmer shading showing a higher density of points. Then, from left to right for each sensor: a histogram of residuals (i), and then residuals against: concentration (ii), temperature (iii), absolute humidity (iv) and time (v). The red 1:1 line in panels (a) and (b) are not lines of best fit, and are for comparison purposes.

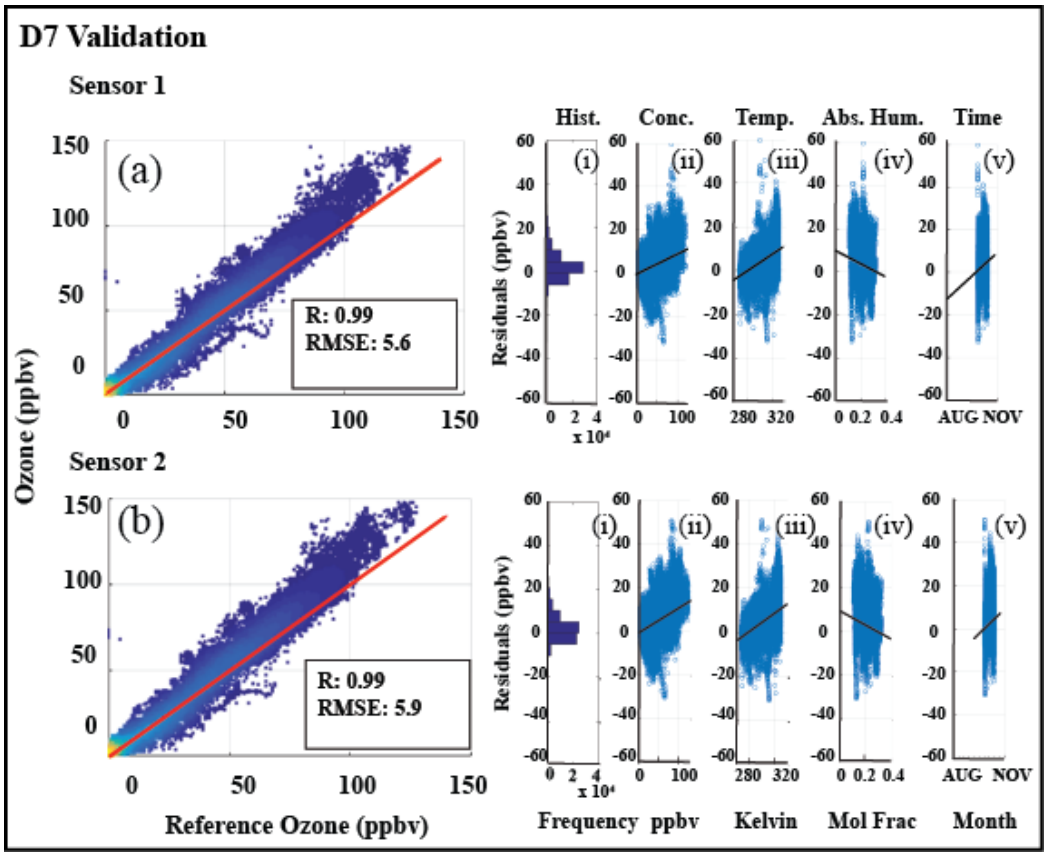

Figure S4. Panel (a) shows D7 sensor validation for the first sensor and (b) shows the same for the second sensor, with warmer shading showing a higher density of points. Then, from left to right for each sensor: a histogram of residuals (i), and then residuals against: concentration (ii), temperature (iii), absolute humidity (iv) and time (v). The red 1:1 line in panels (a) and (b) are not lines of best fit, and are for comparison purposes.

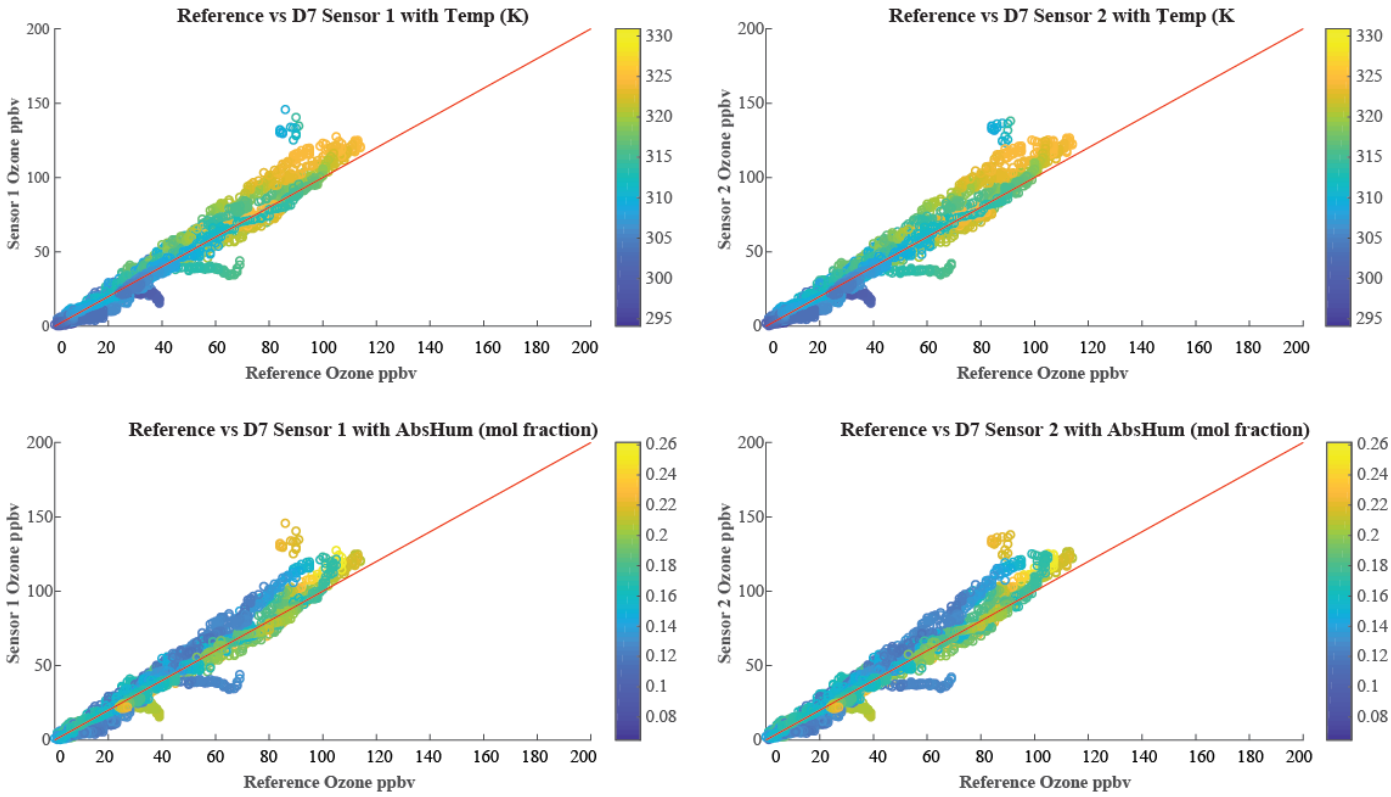

Figure S5. Scatterplots of D7 sensor measurements compared to Rubidoux reference measurements during the first week of validation (Aug 11-17). Upper plots are colored by temperature (Kelvin) while the lower plots are colored by absolute humidity (mol fraction). The "claw" features are sensor under predictions and occur both at high and low temperatures and humidity suggesting a separate confounding variable causing such deviations from the 1:1 line (red).

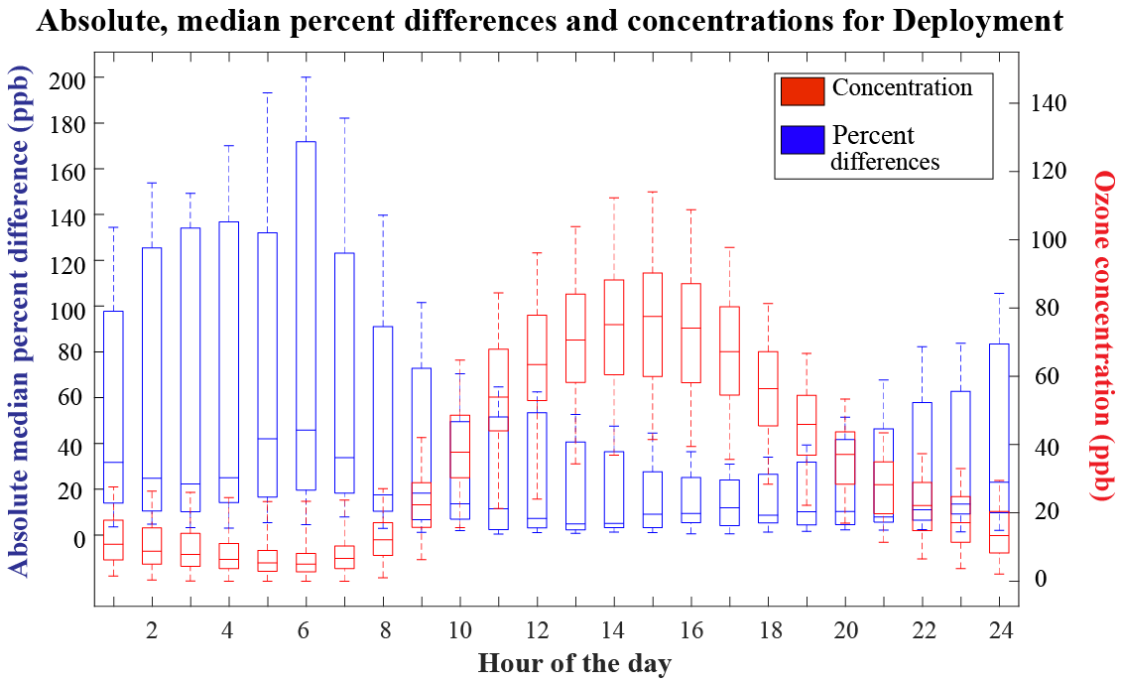

Figure S6. The right-hand axis shows the distribution of ozone concentrations from all U-Pods for each hour of the day over the deployment. The left-hand axis is the relative percent differences in concentration between all possible pod pairs. Percent difference is used here as the difference in concentration between two U-Pod pairs, normalized by their average. Whiskers indicate the 5th and 95th percentiles, values outside of this range are not shown. The box boundaries span the 25th to 75th percentiles.

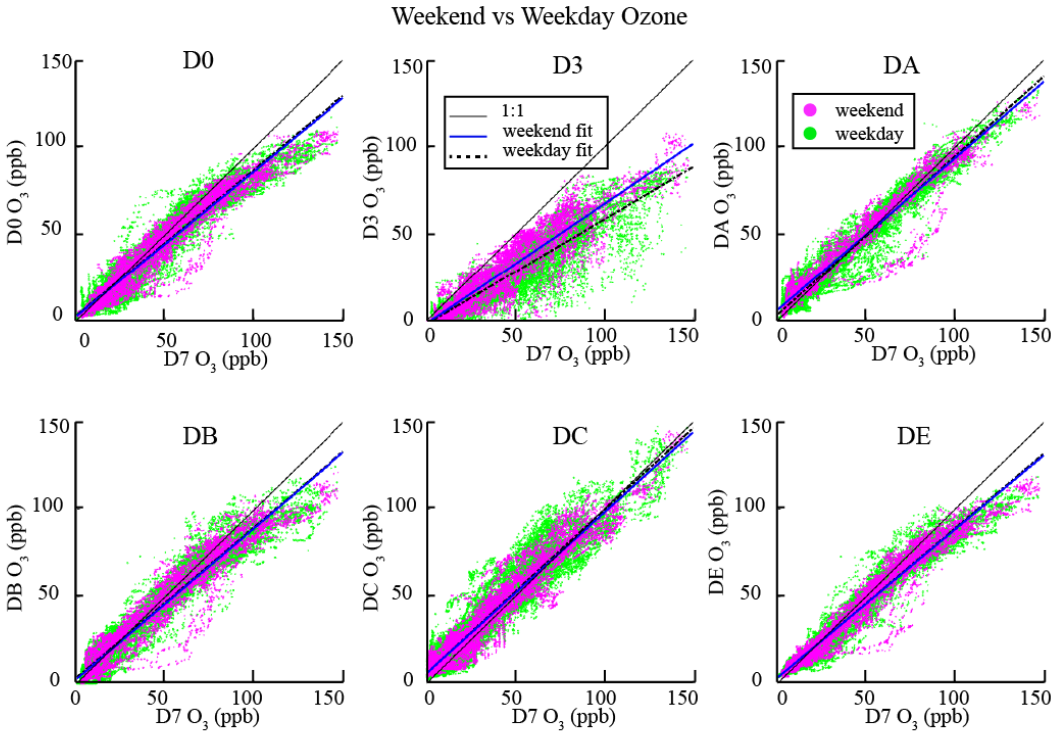

Figure S7. During the deployment period, the magenta data represents data points recorded on the weekend, while green data was recorded during the week. Each subplot is a different U-Pod compared to U-Pod D7 ozone.