Supplemental Information for:

Variability in observation-based onroad emission constraints from a near-road environment

Heather Simon[1], Barron Henderson[1], R. Chris Owen[1], Kristen Foley[2], Michelle G. Snyder[3], Sue Kimbrough[2],

[1]Office of Air Quality Planning and Standards, US EPA, RTP, NC

[2]Center for Environmental Measurement and Modeling, US EPA, RTP, NC

[3]Wood Environment and Infrastructure Solutions, Inc., Durham, NC

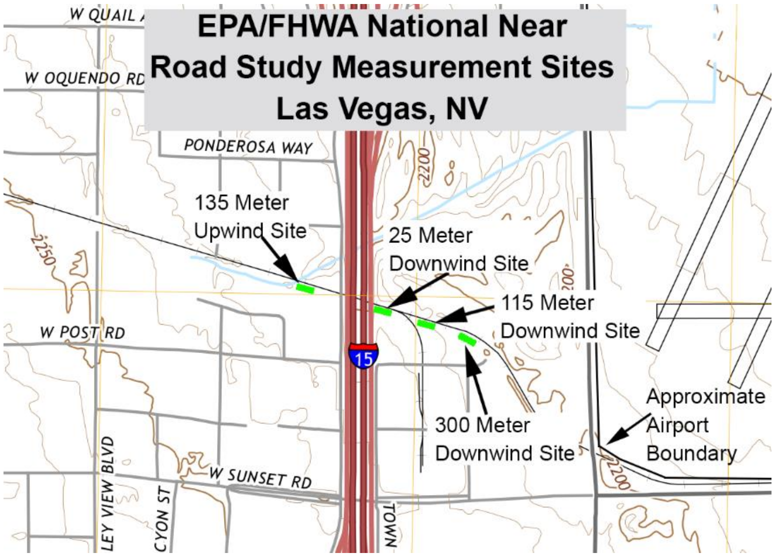

Figure S1. Map of Las Vegas Study Sites

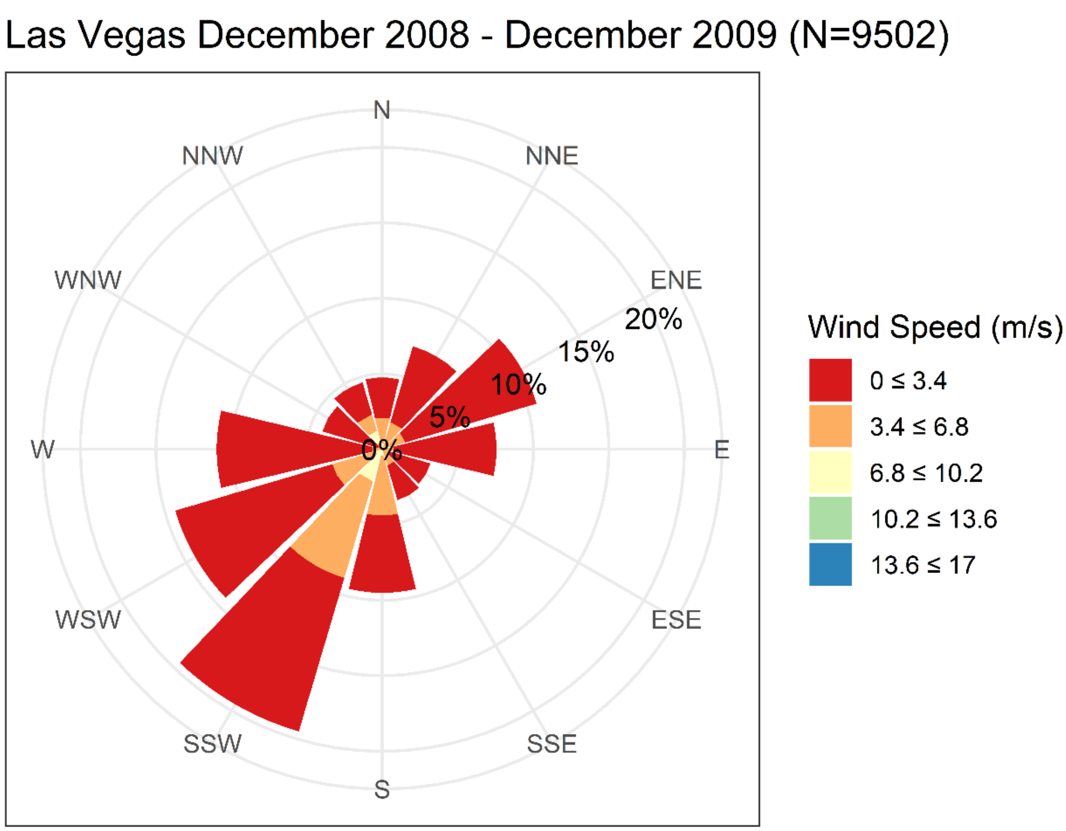

Figure S2. Wind rose for Las Vegas study site from Dec 2008-December 2009.

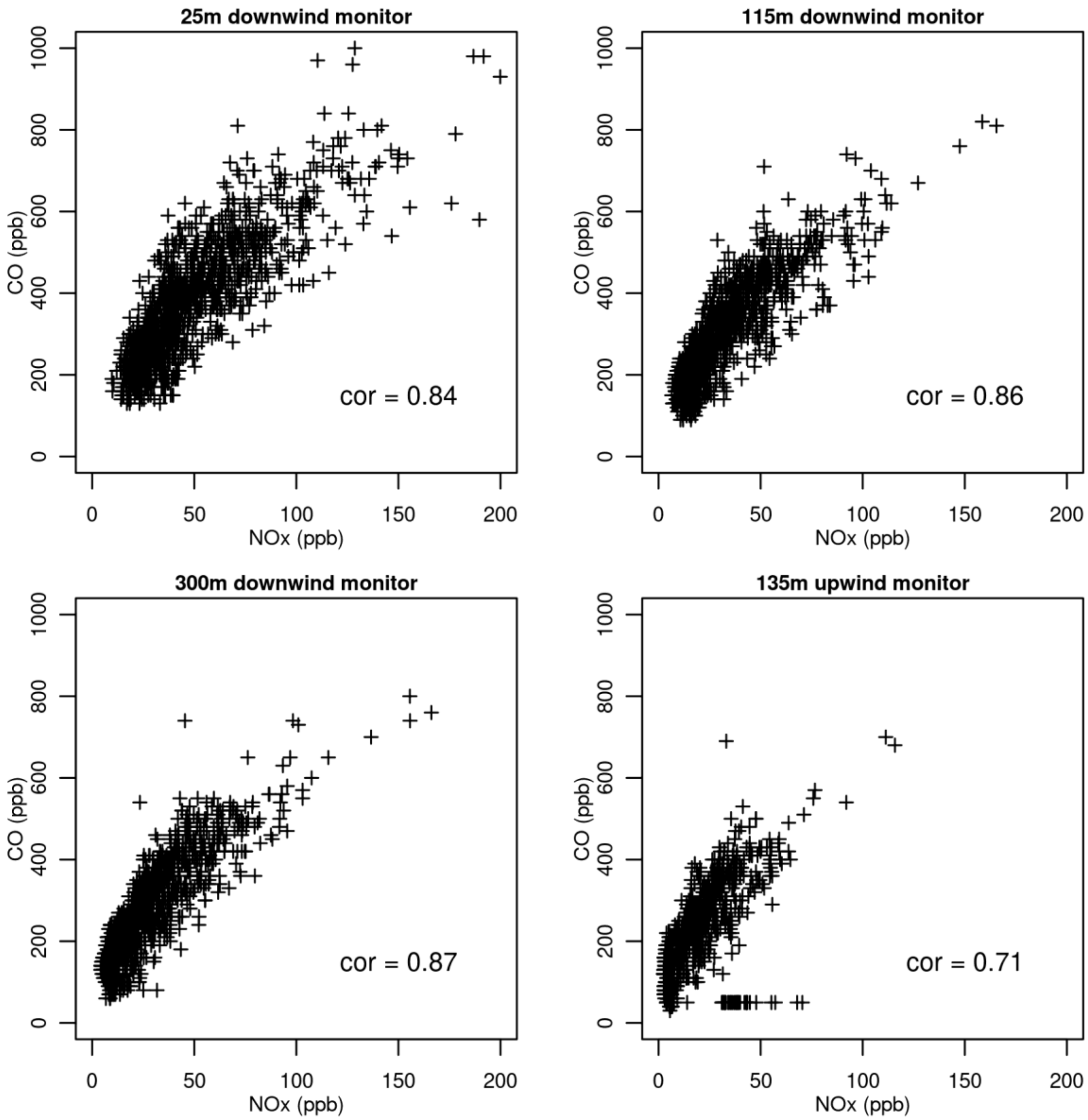

Figure S3. Comparison of 5-minute CO and NO_x data for all 168 hours included in this analysis at each monitor location.

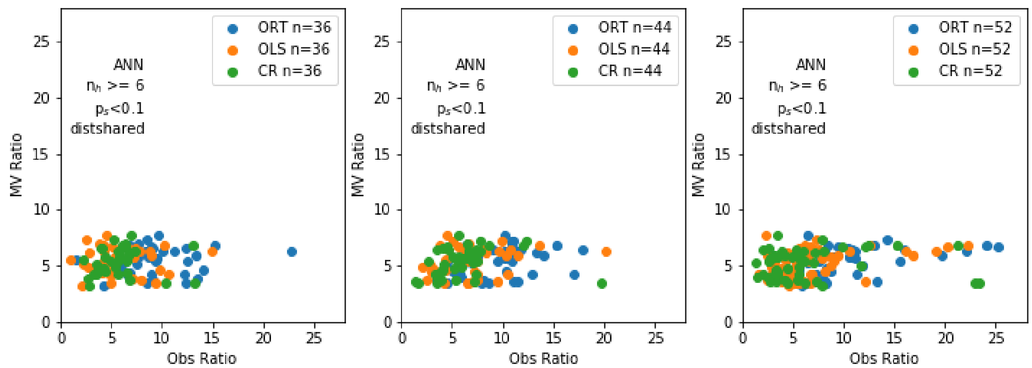

Figure S4. Data from Figure 2 of main paper shown as a scatterplot. Comparison of emitted CO:NOx from MOVES with ΔCO:ΔNOx values from 3 ambient-based methods. Distribution of emitted CO:NOx from MOVES ("MV"), from the cross-road gradient method ("CR"), from OLS regressions and from orthogonal regressions ("ORT") at the 25m downwind monitor (left), the 115m downwind monitor (center) and the 300m downwind monitor (right). Note that there are 3 outlier points off the scale in the plot: ORT at 115m with a CO:NOx of 30.5; CR at 300m with a CO:NOx of 44.4; ORT at 300m with a CO:NOx of 37.3.

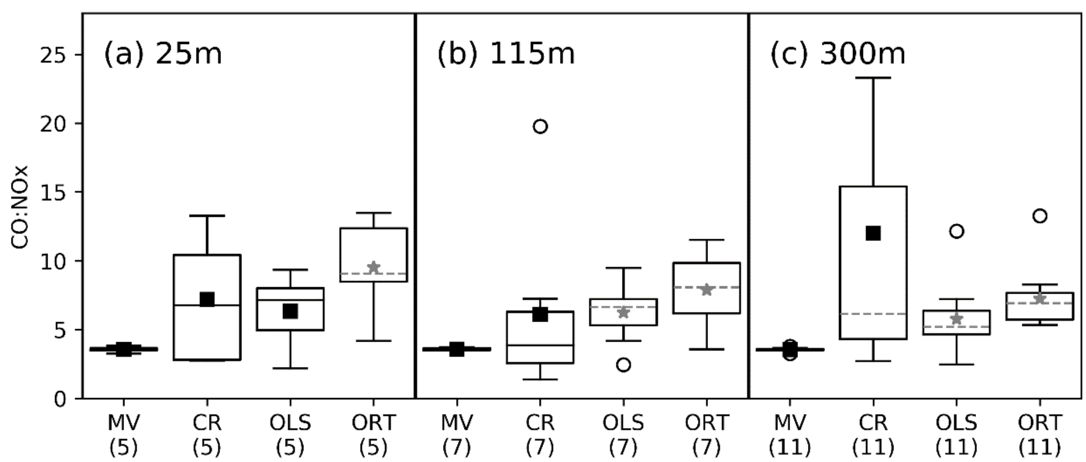

Figure S5. Winter (December, January, February) comparison of ΔCO:ΔNOx values from MOVES and 3 ambient-based methods. Distribution of emitted CO:NOx from MOVES ("MV"), (a); Distribution of ΔCO:ΔNOx values from the cross-road gradient method ("CR"), at different distances from the roadway (b). Distribution of ΔCO:ΔNOx values from OLS regressions and at different distances from the roadway (c). Distribution of ΔCO:ΔNOx values from orthogonal regressions ("ORT") at the 25m downwind monitor (a), the 115m downwind monitor (b) and the 300m downwind monitor (c). different distances from the roadway (d). Numbers below each boxplot represent (n, max value). Sample size excludes outlier values and insignificant regression slopes. Boxes represent interquartile range; mid-lines represent median values; and symbols represent mean values. When the Mann Whitney test is statistically different from MOVES, the median line is grey and dashed. When the Welch's t-test is statistically different from MOVES, the mean is a star and grey.

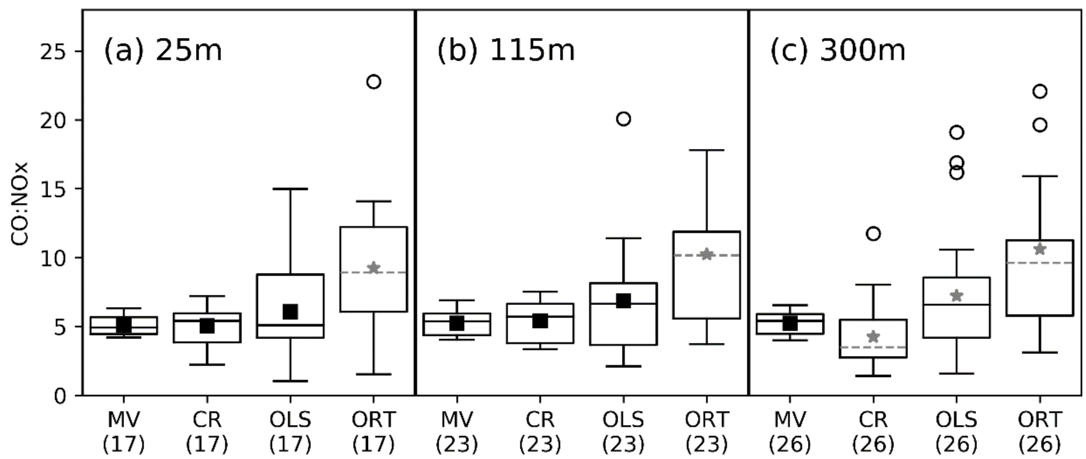

Figure S6. Spring (March, April May) comparison of ΔCO:ΔNOx values from MOVES and 3 ambient-based methods. Distribution of emitted CO:NOx from MOVES ("MV"), (a); Distribution of ΔCO:ΔNOx values from the cross-road gradient method ("CR"), at different distances from the roadway (b). Distribution of ΔCO:ΔNOx values from OLS regressions and at different distances from the roadway (c). Distribution of ΔCO:ΔNOx values from orthogonal regressions ("ORT") at the 25m downwind monitor (a), the 115m downwind monitor (b) and the 300m downwind monitor (c). different distances from the roadway (d). Numbers below each boxplot represent (n, max value). Sample size excludes outlier values and insignificant regression slopes. Boxes represent interquartile range; mid-lines represent median values; and symbols represent mean values. When the Mann Whitney test is statistically different from MOVES, the median line is grey and dashed. When the Welch's t-test is statistically different from MOVES, the mean is a star and grey.

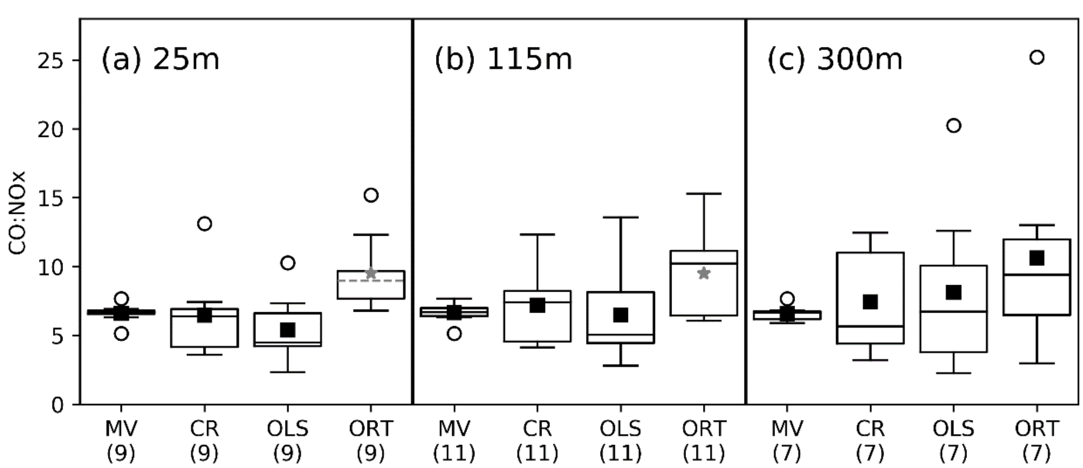

Figure S7. Summer (June, July, August) comparison of ΔCO:ΔNOx values from MOVES and 3 ambient-based methods. Distribution of emitted CO:NOx from MOVES ("MV"), (a); Distribution of ΔCO:ΔNOx values from the cross-road gradient method ("CR"), at different distances from the roadway (b). Distribution of ΔCO:ΔNOx values from OLS regressions and at different distances from the roadway (c). Distribution of ΔCO:ΔNOx values from orthogonal regressions ("ORT") at the 25m downwind monitor (a), the 115m downwind monitor (b) and the 300m downwind monitor (c). different distances from the roadway (d). Numbers below each boxplot represent (n, max value). Sample size excludes outlier values and insignificant regression slopes. Boxes represent interquartile range; mid-lines represent median values; and symbols represent mean values. When the Mann Whitney test is statistically different from MOVES, the median line is grey and dashed. When the Welch's t-test is statistically different from MOVES, the mean is a star and grey.

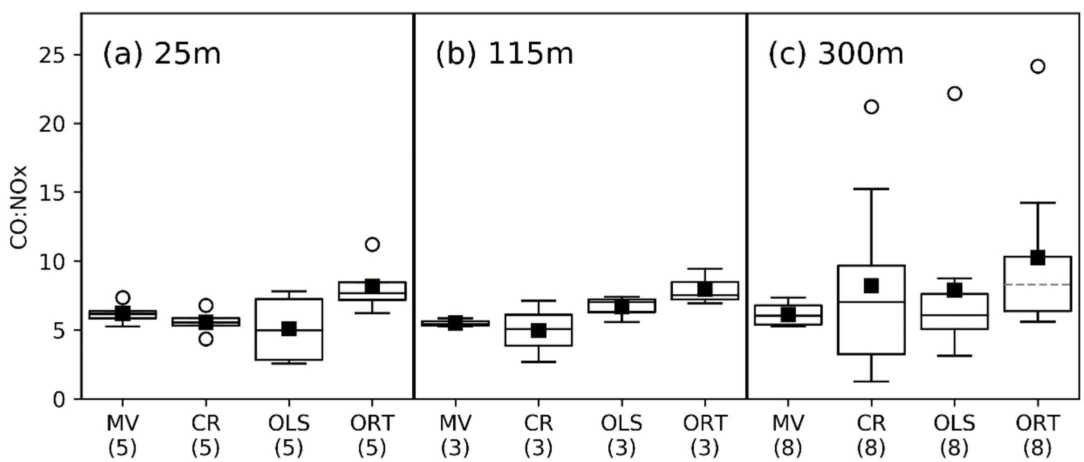

Figure S8. Autumn (September, October, November) comparison of ΔCO:ΔNOx values from MOVES and 3 ambient-based methods. Distribution of emitted CO:NOx from MOVES ("MV"), (a); Distribution of ΔCO:ΔNOx values from the cross-road gradient method ("CR"), at different distances from the roadway (b). Distribution of ΔCO:ΔNOx values from OLS regressions and at different distances from the roadway (c). Distribution of ΔCO:ΔNOx values from orthogonal regressions ("ORT") at the 25m downwind monitor (a), the 115m downwind monitor (b) and the 300m downwind monitor (c). different distances from the roadway (d). Numbers below each boxplot represent (n, max value). Sample size excludes outlier values and insignificant regression slopes. Boxes represent interquartile range; mid-lines represent median values; and symbols represent mean values. When the Mann Whitney test is statistically different from MOVES, the median line is grey and dashed. When the Welch's t-test is statistically different from MOVES, the mean is a star and grey.

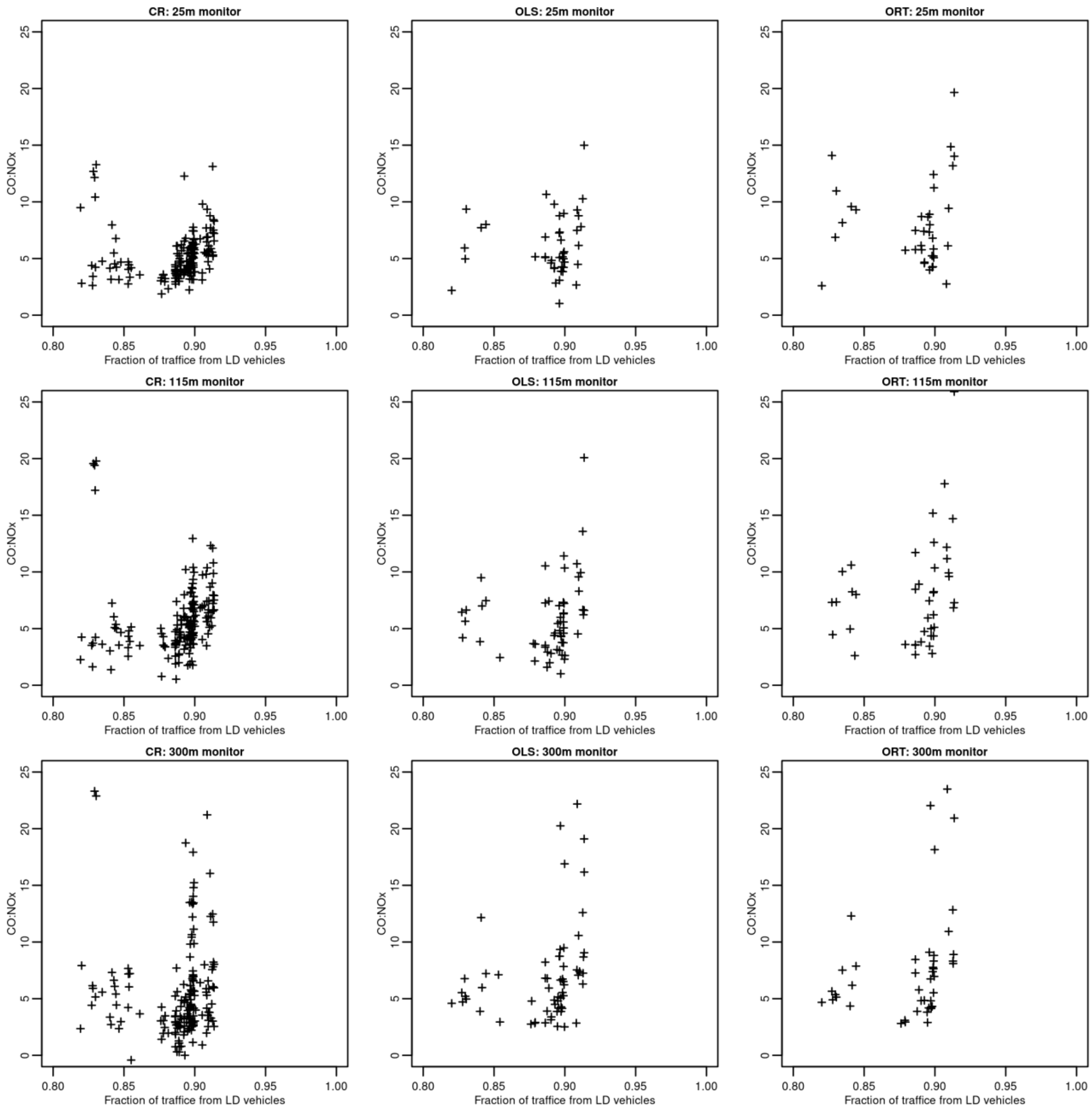

Figure S9.Comparison of ΔCO:ΔNOx from all nine ambient datasets (3 methods and 3 downwind monitors) with the fraction of light-duty vehicles estimated on I-15 for the hour of each estimate.

Table S1. Instrument summary and manufacturer specifications

Measurement Parameter	Sampling Approach	Monitoring sites outfitted with instrument	Instrument Data			
			Make/Model	Accuracy	Precision	Detection Limit
Gas Analyzers						
Carbon Monoxide	continuous monitoring (NDIR FRM CO analyzer)	100m upwind; 20m downwind; 100m downwind; 300m downwind	EC 9830T	± 5% 0-1000ppb	0.5% of reading	25 ppb
Oxides of nitrogen	Chemilluminescence (FRM analyzer)	100m upwind; 20m downwind; 100m downwind; 300m downwind	EC 9841B	< 1%	0.5 ppb	0.5 ppb
Meteorological Instruments						
Wind Speed	Sonic anemometer	100m upwind; 20m downwind; 100m downwind; 300m downwind	Young Model 81000	±0.05 m/s	std. dev. 0.05 m/s at 12 m/s	0.01 m/s
Wind Speed				± 5°	± 10°	0.1°
Air Temperature	Temperature probe	100m downwind	Vaisala HMP45D Vaisala HMP45A	±0.2°C at 20° C	0.1 ° C	0.1 ° C
% Relative Humidity	Relative humidity sensor	100m downwind		±2%RH from 0…90% RH)	1% RH	1% RH
Solar Radiation	solar radiation	100m downwind	MetOne 394 Pyranometer	±5% from 0…2800 watts meter^2	±1% constancy from -20°C to +40°C	9 mV/kwatt meter-2, approx
Traffic Data						
Vehicle Counts Vehicle Speed Vehicle Length Bin	side-fire radar		Wavetronix SmartSensor HD			

Table S2. Sample size (number of hours) grouped by time of day and season

Time of Day			
Morning (6am-9am)	Day (10am-4pm)	Evening (5pm-7pm)	Night (8pm-5am)
4	16	51	74
Season			
Spring (Mar/Apr/May)	Summer (Jun/Jul/Aug)	Fall (Sep/Oct/Nov)	Winter (Dec/Jan/Feb)
74	32	14	25

Table S3. Percentage of regressions with statistically significant slopes

	DW Monitor Distance (m)	% of regression fits with a significant slope
Ordinary Least Squares	20	40%
	100	46%
	300	55%
Orthogonal	20	29%
	100	32%
	300	38%

Table S4. Mean and median ΔCO:ΔNOx derived in this study

Method	Distance from roadway (m)	Sample Size	Mean ΔCO:ΔNOx	Median ΔCO:ΔNOx	Mean emitted CO (mol/m^2-s)	Mean emitted NOx (mol/m^2-s)
MOVES (field site specific inputs)	25	36	5.4	5.5	1339.7	248.7
	115	44	5.4	5.5	1275.7	236.9
	300	52	5.2	5.4	1216.0	235.2
MOVES (county default inputs)	25	36	6.5	6.5	2169.0	333.2
	115	44	6.4	6.5	2070.8	318.3
	300	52	6.3	6.4	1968.6	313.4
Cross-road	25	36	5.8	5.7	N/A	N/A
	115	44	5.9	5.5	N/A	N/A
	300	52	6.9	4.7	N/A	N/A
OLS regression	25	36	5.8	5.0	N/A	N/A
	115	44	6.7	6.5	N/A	N/A
	300	52	7.1	6.0	N/A	N/A

Orthogonal regression	25	36	9.2	8.8	N/A	N/A
	115	44	9.5	9.8	N/A	N/A
	300	52	9.8	8.1	N/A	N/A

Table S5. Regression-based ΔCO:ΔNOx from studies in the literature

Study	Regression Method	Location	Year	ΔCO:ΔNOx
Studies conducted in the United States				
Harley et al. (1997) [23]	Unknown – CO as explanatory variable	Southern California	1987	16.8*
Marr et al. (2002) [25]	OLS - CO as explanatory variable	San Francisco	1990	14.5*
Parish et al. (2006) [26]	Orthogonal Regression using known uncertainty for each instrument	Nashville	1994	10.2 ±1.5
			1995	8.5±1.3
			1999	6.3±0.9
		Boulder	1989	18.9±2.7
			1991	15.7±2.3
			1996	12.7±2.0
			1998	8.9±1.3
		Los Angeles	1987	18.9±2.1
Luke et al. (2010) [30]	Ordinary Least Squares	Houston	2006	6.81±0.94
Wallace et al. (2012) [29]	Unknown	Boise	2008-2009	5.2±0.5
Anderson et al. (2014) [21]	Orthogonal	Baltimore	2011	11.2±1.2
Studies conducted outside the United States				
Kourtidis et al. (1999) [24]	Unknown – CO as explanatory variable	Athens	1994	25.2
Ariaga-Colina et al. (2004) [22]	Unknown	Mexico City	1996-2000	34.9-42.9
Vivanco et al. (2006) [28]	Unknown – CO as explanatory variable	Sao Paulo	1999	14.6*

*These studies used CO as the explanatory variable and consequently reported ΔNO_x:ΔCO ratios. Values in Table S4 were converted to ΔCO:ΔNOx.