Supplemental Information

Seasonal and long-term trend of on-road gasoline and diesel vehicle emission factors measured in traffic tunnels

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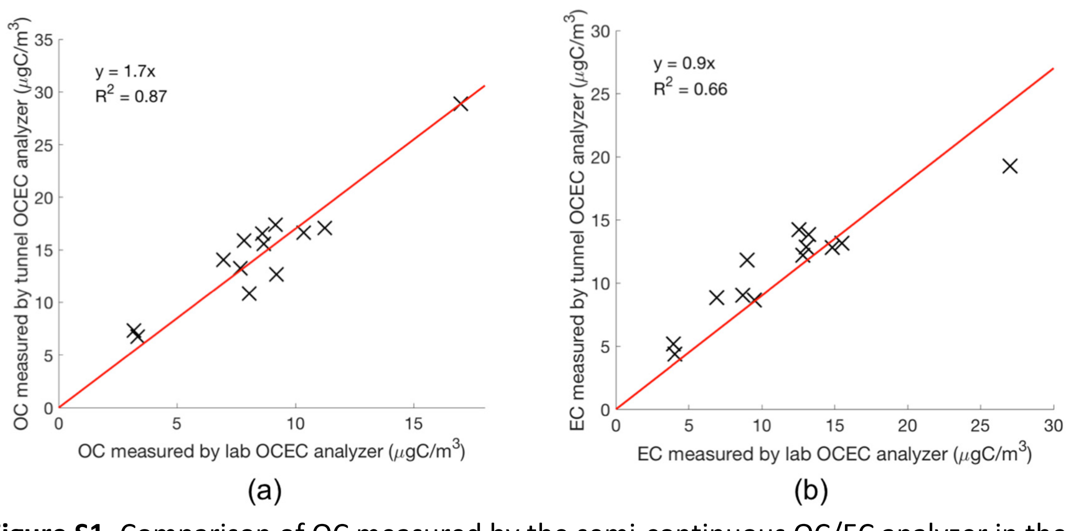

Figure S1. Comparison of OC measured by the semi-continuous OC/EC analyzer in the tunnel and the OC measured by the quartz filter sets and OC/EC analyzer in the lab. Red solid lines are the linear regression fitting of the data.

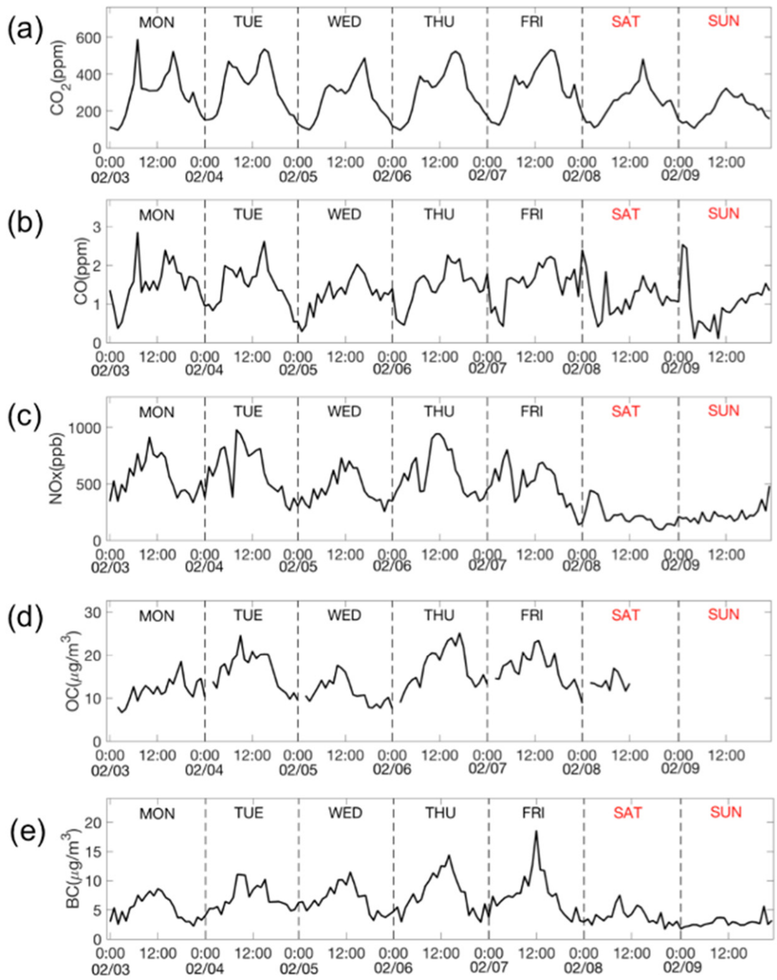

Figure S2 One-week time series of (a) CO_2, (b) CO, (c) NO_x, and (d) OC concentrations measured in the tunnel. All data presented in the figure are 1-h averaged data. Except PAH, all other pollutants are background corrected.

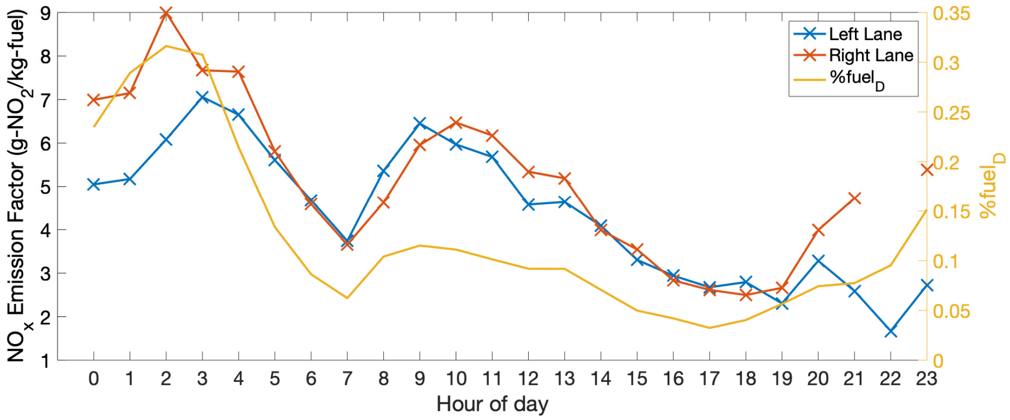

Figure S3. Diurnal pattern of NOx emission factors measured during weekdays of a single week in spring 2014 over left and right lanes of Fort Pitt Tunnel

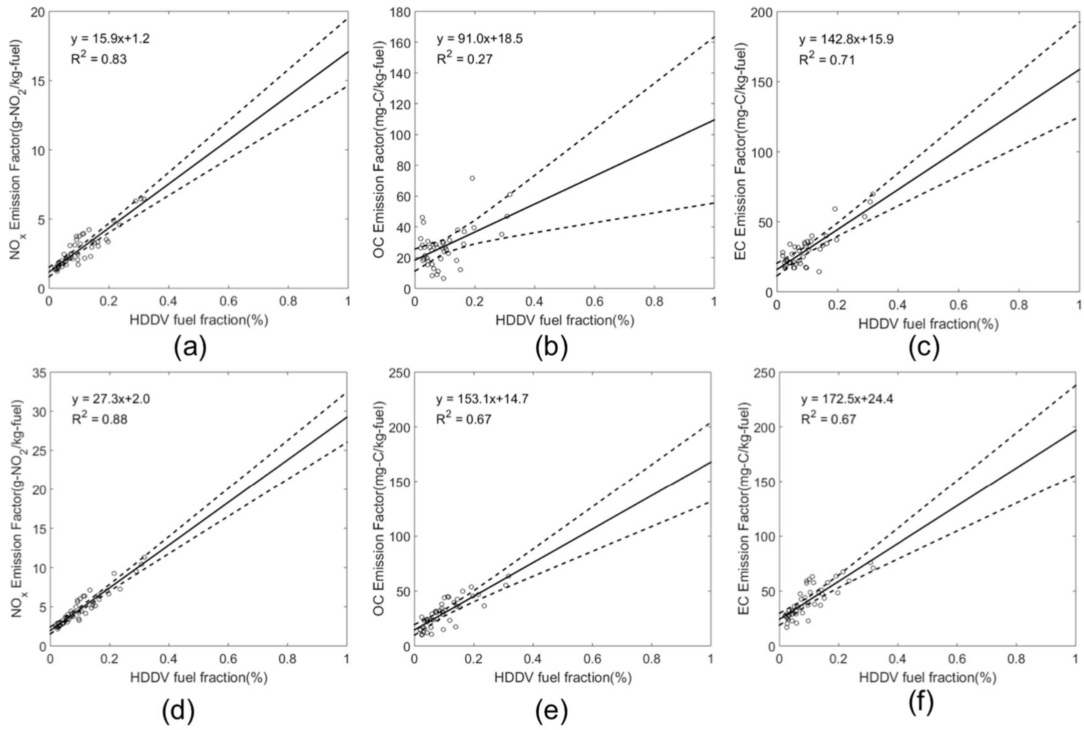

Figure S4. (a) NO_x, (b) OC, and (c) EC emission factors measured in the spring as a function of diesel fuel fractions in the tunnel and (d) NO_x, (e) OC, (f) EC emission factors measured in the winter as a function of diesel fuel fractions in the tunnel. Circles represent the measurement data. Solid lines are the linear regression fitting of the data, and the dashed lines are the 95% confidence bounds of the fitting.

Table S1. Emission factors of Light Duty Vehicle (LDV) measured in traffic tunnels over United States

References	Tunnel	Year of measurement	NO_x (g-NO_2/kg-fuel)	CO (g/kg-fuel)	OC (mg-C/kg-fuel)	EC (mg-C/kg-fuel)
Pierson et al.[1]	Fort McHenry Tunnel, MD, Downhill	1992	7.5 ± 0.7[a]	63.2 ± 3.2[a]	-	-
Pierson et al.[1]	Fort McHenry Tunnel, MD, uphill	1992	10.4 ± 1.4[a]	75 ± 8.6[a]	-	-
Pierson et al.[1]	Tuscarora Mountain Tunnel, PA, level	1992	5 ± 3.6[a]	64.6 ± 6.4[a]	-	-
Miguel et al.[2]	Caldecott Tunnel, CA	1996	-	-	-	-
Kirchstetter et al.[3]	Caldecott Tunnel, CA	1997	9 ± 0.4[b]	-	35.7 ± 7.1[bc]	35 ± 4[b]
Allen et al.[4]	Caldecott Tunnel, CA	1997	-	-	39.0 ± 22.0[d]	15.0 ± 71.0[d]
McGaughey et al.[5]	Washburn Tunnel, TX	2000	9.1 ± 14.9[e]	74.3 ± 6.8[e]	-	-
Gëller et al.[6]	Caldecott Tunnel, CA	2004	-	-	-	29.4 ± 4.3[f]
Grieshop et al.[7]	Squirrel Hill Tunnel, PA	2002 and 2004	3.3 ± 1.9	-	31.2 ± 32.4	26.6 ± 29.8
Ban-Weiss et al.[8]	Caldecott Tunnel, CA	2006	3.0 ± 0.2	-	22.1 ± 3.6[g]	22 ± 4
Dallmann et al.[9]	Caldecott Tunnel, CA	2010	1.9 ± 0.08[h]	14.3 ± 0.7[h]	16.8 ± 4.8[hi]	-
This work	Fort Pitt Tunnel, PA	2013 and 2014	2 ± 0.5[j]	11.5 ± 3.5[k]	14.7 ± 4.8[j]	24.4 ± 5.5[j]
Difference of this work with Grieshop et al.(%)			-39.4 ± 63.7	-	-52.9 ± 118.5	-8.3 ± 114.3

a. We assumed one gallon of gasoline weighs 2.80 kg and one gallon of diesel weighs 3.24 kg to convert unit.
b. Data calculated by Ban-Weiss et al.[8] using the revised regression method are reported here.
c. A factor of 1.4 is used to convert Organic Matter (OM) concentration to OC concentration.
d. Data reported here are for $PM_{1.9}$.
e. We assumed the density of gasoline equals to 0.74 kg/L to convert unit.
f. Data reported here are for $PM_{2.5}$.
g. A factor of 1.4 is used to convert OM concentration to OC concentration.
h. Data reported here are adjusted light-duty-vehicle emission factors reported in Dallmann et al.[9].
i. A factor of 1.25 is used to convert Organic Aerosol (OA) concentration to OC concentration.
j. Results from linear regression of winter data are reported here.

k. The averaged CO emission factor measured in winter 2014 is reported here.

Table S2. Emission factors of Heavy Duty Diesel Vehicle (HDDV) measured in traffic tunnels over United States

References	Tunnel	Year of measurement	NO_x (g-NO_2/kg-fuel)	CO (g/kg-fuel)	OC (mg-C/kg-fuel)	EC (mg-C/kg-fuel)
Pierson et al.[1]	Fort McHenry Tunnel, MD, Downhill	1992	29.9 ± 0.9[a]	21.0 ± 4.6[a]	-	-
Pierson et al.[1]	Fort McHenry Tunnel, MD, uphill	1992	33.0 ± 1.5[a]	21.0 ± 8.0[a]	-	-
Pierson et al.[1]	Tuscarora Mountain Tunnel, PA, level	1992	34.6 ± 1.5[a]	10.8 ± 2.8[a]	-	-
Miguel et al.[2]	Caldecott Tunnel, CA	1996	-	-	-	-
Kirchstetter et al.[3]	Caldecott Tunnel, CA	1997	57 ± 7[b]	-	421.4 ± 57.1[bc]	1400 ± 600[b]
Allen et al.[4]	Caldecott Tunnel, CA	1997	-	-	495.0 ± 105.0[d]	788.0 ± 332.0[d]
McGaughey et al.[5]	Washburn Tunnel, TX	2000	28.3 ± 4.4[e]	-	-	-
Gëller et al.[6]	Caldecott Tunnel, CA	2004	-	-	-	709 ± 76[f]
Grieshop et al.[7]	Squirrel Hill Tunnel, PA	2002 and 2004	43 ± 5.5	-	269 ± 118	439 ± 109
Ban-Weiss et al.[8]	Caldecott Tunnel, CA	2006	40 ± 3	-	292.9 ± 50[g]	860 ± 70
Dallmann et al.[10]	Caldecott Tunnel, CA	2010	28.0 ± 1.5	8.0 ± 1.2	-	-
This work	Fort Pitt Tunnel, PA	2013 and 2014	11.9 ± 15.7[h]		167.8 ± 36.3[h]	196.8 ± 41.0[h]
Difference with Grieshop et al.(%)			-72.3 ± 39.8	-	-37.6 ± 48.8	-55.2 ± 29.9

a. We assumed one gallon of gasoline weighs 2.80 kg and one gallon of diesel weighs 3.24 kg to convert unit.

b. Data calculated by Ban-Weiss et al.[8] using the revised regression method are reported here.

c. A factor of 1.4 is used to convert Organic Matter (OM) concentration to OC concentration.

d. Data reported here are for $PM_{1.9}$.

e. We assumed the carbon fraction of diesel equals to 0.87 to convert unit. The diesel vehicle emission factor reported here are calculated based on the linear regression results presented in Table 4 in McCaughey et al.[5]

f. Data reported here are for $PM_{2.5}$.

g. A factor of 1.4 is used to convert OM concentration to OC concentration.

h. Results from linear regression of winter data are reported here.

References

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