

**Note to readers with disabilities:** *EHP* strives to ensure that all journal content is accessible to all readers. However, some figures and Supplemental Material published in *EHP* articles may not conform to [508 standards](#) due to the complexity of the information being presented. If you need assistance accessing journal content, please contact [ehp508@niehs.nih.gov](mailto:ehp508@niehs.nih.gov). Our staff will work with you to assess and meet your accessibility needs within 3 working days.

### **Supplemental Material**

#### **Preterm Birth among Infants Exposed to *in Utero* Ultrafine Particles from Aircraft Emissions**

Sam E. Wing, Timothy V. Larson, Neelakshi Hudda, Sarunporn Boonyarattaphan, Scott Fruin, and Beate Ritz

#### **Table of Contents**

**Table S1.** Maternal and Infant Demographics by Quartiles of UFP Exposure.

**Table S2.** Adjusted logistic regression results, stratified by race/ethnicity and maternal Nativity.

**Table S3.** Count of preterm (PTB) and term births by UFP exposure quartile, stratified by race/ethnicity and maternal Nativity.

**Table S4.** Pearson correlation coefficients ( $r$ ) between UFP exposures by trimester, NO<sub>2</sub>, and airport noise.

**Table S5.** Adjusted logistic regression results according to different categories of UFP exposure.

**Table S6.** Adjusted ORs (95% CIs) of preterm birth by pregnancy trimester-specific exposures to UFP.

**Table S7.** Adjusted logistic regression results of preterm birth with modified elliptical exposure buffers, quartiles of UFP exposure.

**Table S8.** Adjusted logistic regression result of preterm birth stratified by quintile of nSES Index.

**Table S9.** Percent of mothers in quartiles of UFP exposure stratified by quintile of nSES index.

**Table S10.** Adjusted ORs (95% CIs) of preterm birth stratified by educational attainment.

**Table S11.** Adjusted ORs (95% CIs) of very preterm birth ( $n = 2,085$ ) exposure.

**Table S12.** Adjusted ORs (95% CIs) of preterm birth, excluding births within 2 km and 5 km of SMO airport.

**Figure S1.** Hourly wind rose at LAX for the period January 2008 through December 2016 (Station #23174, anemometer height 30 ft, base elevation 108 ft).

**Figure S2.** Schematic side view of tilted volume line source. Mixing depth can vary with hour of the day. Emissions from above the mixing depth will not impact the surface.

**Figure S3.** Diurnal flight activity at LAX by hour.

**Figure S4.** Mobile monitoring transects.

**Figure S5.** Transect Average Particle Number Concentration (#/cc). The numbers refer to the averages of the transect shown in figure S-4. The 1:1 line and the 95% confidence interval of the slope are also shown.

**Figure S6.** AERMOD Model Monthly Average Prediction Locations. Base layers obtained from USGS.gov.

**Figure S7.** Monthly average total flight activity over the study period.

**Figure S8.** Areas above an annual average of 65 dB CNEL. Base layers obtained from USGS.gov.

**Table S1. Maternal and Infant Demographics by Quartiles of UFP Exposure**

Total N = 174,186	Quartile 1 (< 5340 particles/cc)	Quartile 2 (5340 – 8600 particles/cc)	Quartile 3 (8600 – 14600 particles/cc)	Quartile 4 (>14600 particles/cc)
Gestational Age, mean weeks (sd), missing = 0	39.4 (2.0)	39.3 (2.1)	39.2 (2.2)	39.1 (2.2)
Birth Weight, mean grams (sd), missing = 6	3299 (503)	3288 (524)	3275 (530)	3269 (535)
Parity, mean children (sd), missing = 0	1.9 (2.2)	2.1 (2.6)	2.2 (2.4)	2.2 (2.1)
Quintile of nSES Index, mean (sd), missing = 0	2.8 (1.6)	2.1 (1.3)	1.8 (1.2)	1.8 (1.2)
<b>Infant Sex</b>				
Male, No. (%)	22707 (51.5)	21970 (51.2)	21841 (50.9)	22538 (51.0)
Female, No. (%)	21415 (48.6)	20972 (48.8)	21077 (49.1)	21664 (49.0)
Missing, No.	0	1	0	1
<b>Maternal Age</b>				
<20, No. (%)	2092 (4.7)	3043 (7.1)	3999 (9.3)	3846 (8.7)
20-24, No. (%)	5560 (12.6)	8130 (18.9)	9880 (23.0)	10141 (22.9)
25-29, No. (%)	9573 (21.7)	10190 (23.7)	10684 (24.9)	11332 (25.6)
30-34, No. (%)	14424 (32.7)	11725 (27.3)	10202 (23.7)	10723 (24.3)
35+, No. (%)	12473 (28.3)	9855 (22.9)	8153 (19.0)	8161 (18.5)
Missing, No.	0	1	1	1
<b>Maternal Race</b>				
White, No. (%)	14949 (33.9)	7785 (18.1)	4582 (10.7)	4275 (9.7)
Black, No. (%)	2389 (5.4)	6216 (14.5)	7253 (16.9)	9656 (21.8)
Hispanic, No. (%)	18497 (41.9)	24201 (56.4)	28537 (66.5)	27354 (61.9)
Asian, No. (%)	7337 (16.6)	3724 (8.7)	1662 (3.9)	1863 (4.2)
Others, No. (%)	950 (2.1)	1017 (2.4)	884 (2.1)	1055 (2.4)
Missing, No.	606	651	799	686
<b>Maternal Education</b>				
High School Graduate or Less, No. (%)	16415 (37.2)	21709 (50.6)	26590 (62.0)	25737 (58.2)
Some College to Bachelor's Degree, No. (%)	18585 (42.1)	15502 (36.1)	13385 (31.2)	15339 (34.7)
More than a Bachelor's Degree, No. (%)	9122 (20.7)	5732 (13.3)	2943 (6.9)	3127 (7.1)
Missing, No.	807	1254	2958	2176
<b>Maternal Nativity</b>				
US-Born, No. (%)	30493 (69.1)	29885 (69.6)	29758 (69.3)	31753 (71.8)

Foreign-Born, No. (%)	13629 (30.9)	13058 (30.4)	13160 (30.7)	12450 (28.2)
Nitrogen Dioxide, mean (sd), missing = 0	24.6 (2.7)	24.2 (2.5)	23.7 (2.5)	22.5 (2.5)
High Airport Noise at Residence, > 65 dB CNEL, No. (%)				
≥ 65 dB	0 (0.0)	0 (0.0)	33 (0.1)	7431 (16.8)
< 65	444122 (100)	42943 (100)	42885 (99.9)	36772 (83.2)
Cigarette Smoking, ever during pregnancy, No. (%)				
Ever	219 (0.5)	272 (0.6)	294 (0.7)	296 (0.7)
Never	44189 (99.5)	42912 (99.4)	42810 (99.3)	44061 (99.3)
Missing, No.	2697	3922	4001	2747

Data are complete unless otherwise indicated.

<sup>a</sup>SES measured as a composite index of seven indicator variables based on US Census Data at the census tract level. 5 = high nSES, 1 = low nSES.

<sup>b</sup>CNEL: Community Noise Equivalent Level

**Table S2. Adjusted logistic regression results<sup>a</sup>, stratified by race/ethnicity and maternal Nativity**

Race/ Ethnicity	Maternal Nativity	4 <sup>th</sup> vs 1 <sup>st</sup> Quartile OR (95% CI)	3 <sup>rd</sup> vs 1 <sup>st</sup> Quartile OR (95% CI)	2 <sup>nd</sup> vs 1 <sup>st</sup> Quartile OR (95% CI)	UFP x Nativity P value <sup>b</sup>
All	Foreign-born	1.27 (1.15 – 1.41)	1.15 (1.04 – 1.26)	1.01 (0.98 – 1.18)	0.17
	US-born	1.08 (1.01 – 1.16)	1.05 (0.98 – 1.11)	1.01 (0.95 – 1.11)	-
White	Foreign-born	1.36 (0.90 – 2.03)	1.05 (0.73 – 1.50)	0.95 (0.72 – 1.25)	0.48
	US-born	0.90 (0.75 – 1.08)	1.01 (0.86 – 1.19)	0.82 (0.71 – 0.94)	-
Black	Foreign-born	0.90 (0.53 – 1.54)	1.17 (0.69 – 1.97)	0.86 (0.51 – 1.47)	0.24
	US-born	1.20 (1.02 – 1.40)	1.06 (0.90 – 1.24)	1.09 (0.92 – 1.27)	-
Hispanic	Foreign-born	1.21 (1.07 – 1.36)	1.06 (0.96 – 1.19)	1.01 (0.90 – 1.14)	0.23
	US-born	1.12 (1.02 – 1.23)	1.09 (1.00 – 1.18)	1.08 (0.99 – 1.18)	-
Asian	Foreign-born	1.61 (1.18 – 2.19)	1.75 (1.29 – 2.37)	1.35 (1.06 – 1.72)	0.12
	US-born	1.09 (0.79 – 1.49)	1.28 (0.97 – 1.71)	0.95 (0.75 – 1.21)	-
Other	Foreign-born	1.07 (0.39 – 2.94)	1.52 (0.55 – 4.25)	1.75 (0.69 – 4.45)	0.35
	US-born	0.53 (0.42 – 0.94)	0.94 (0.65 – 1.34)	0.78 (0.55 – 1.12)	-

<sup>a</sup>Adjusted for NO<sub>2</sub>, Maternal Age, Maternal Educational Attainment, nSES Index, Maternal Race, Airport Noise and Cigarette Smoking.

<sup>b</sup>Joint p value testing the relationship between nativity and UFP exposure within strata of race/ethnicity

**Table S3. Count of preterm (PTB) and term births by UFP exposure quartile, stratified by race/ethnicity and maternal Nativity**

Race/ Ethnicity	Maternal Nativity	4 <sup>th</sup> Quartile		3 <sup>rd</sup> Quartile		2 <sup>nd</sup> Quartile		1 <sup>st</sup> Quartile	
		Term	PTB	Term	PTB	Term	PTB	Term	PTB
White	Foreign-born	3,028	191	1,334	86	702	42	464	34
	US-born	11,021	709	6,032	333	3,599	239	3,569	208
Black	Foreign-born	229	24	490	49	428	59	535	59
	US-born	1,896	240	5,002	675	5,980	786	7,927	1,135
Hispanic	Foreign-born	5,786	537	8,167	763	10,075	984	9,221	1,015
	US-born	11,110	1,064	13,871	1,400	15,869	1,609	15,493	1,625
Asian	Foreign-born	3,505	176	1,887	125	707	64	880	72
	US-born	3,423	233	1,608	104	815	76	845	66
Other	Foreign-born	145	8	139	18	88	11	155	15
	US-born	726	71	788	72	699	86	814	71

**Table S4. Pearson correlation coefficients (r) between UFP exposures by trimester, NO<sub>2</sub>, and airport noise**

	UFP (Preg. Total)	UFP (Tri. 1)	UFP (Tri. 2)	UFP (Tri. 3)	NO <sub>2</sub>	Airport Noise
UFP (Preg. Total)	1.00	0.97	0.98	0.97	-0.18	0.56
UFP (Tri. 1)	0.97	1.00	0.94	0.89	-0.17	0.54
UFP (Tri. 2)	0.98	0.94	1.00	0.94	-0.17	0.54
UFP (Tri. 3)	0.97	0.89	0.94	1.00	-0.17	0.54
NO <sub>2</sub>	-0.18	-0.17	-0.17	-0.17	1.00	-0.14
Airport Noise	0.56	0.54	0.54	0.54	-0.14	1.00

**Table S5. Adjusted logistic regression results<sup>a</sup> according to different categories of UFP exposure**

	Deciles OR (95% CI)	Quintiles OR (95% CI)	Quartiles OR (95% CI)	Tertiles OR (95% CI)
2nd vs 1st Quantile	1.03 (0.95 - 1.12)	1.00 (0.94 - 1.06)	1.03 (0.98 - 1.08)	1.05 (1.01 - 1.10)
3rd vs 1st Quantile	1.01 (0.93 - 1.09)	1.05 (0.99 - 1.11)	1.08 (1.02 - 1.13)	1.12 (1.07 - 1.17)
4th vs 1st Quantile	1.02 (0.94 - 1.10)	1.10 (1.04 - 1.17)	1.14 (1.08 - 1.20)	-
5th vs 1st Quantile	1.07 (0.99 - 1.16)	1.14 (1.07 - 1.22)	-	-
6th vs 1st Quantile	1.06 (0.97 - 1.14)	-	-	-
7th vs 1st Quantile	1.13 (1.04 - 1.22)	-	-	-
8th vs 1st Quantile	1.11 (1.03 - 1.21)	-	-	-
9th vs 1st Quantile	1.15 (1.06 - 1.25)	-	-	-
10th vs 1st Quantile	1.17 (1.08 - 1.28)	-	-	-

<sup>a</sup>Adjusted for NO<sub>2</sub>, Maternal Age, Maternal Educational Attainment, nSES Index, Maternal Race, Airport Noise and Cigarette Smoking.

**Table S6. Adjusted ORs<sup>a</sup> (95% CIs) of preterm birth by pregnancy trimester-specific exposures to UFP**

Variable	Trimester 1	Trimester 2	Trimester 3
UFP			
Quartile 1	Ref.	Ref.	Ref.
Quartile 2	1.03 (0.98 – 1.08)	1.04 (0.99 – 1.10)	1.03 (0.99 – 1.09)
Quartile 3	1.06 (1.00 – 1.11)	1.08 (1.02 – 1.14)	1.10 (1.04 – 1.16)
Quartile 4	1.13 (1.07 – 1.19)	1.15 (1.09 – 1.21)	1.14 (1.08 – 1.21)
NO <sub>2</sub>			
Quartile 1 (< 21.8 ppb)	Ref.	Ref.	Ref.
Quartile 2 (21.8 – 23.8 ppb)	1.10 (1.05 – 1.15)	1.10 (1.05 – 1.16)	1.10 (1.05 – 1.16)
Quartile 3 (23.9 – 25.5 ppb)	1.10 (1.05 – 1.16)	1.10 (1.05 – 1.16)	1.10 (1.05 – 1.16)
Quartile 4 (> 25.5 ppb)	1.14 (1.08 – 1.21)	1.15 (1.09 – 1.22)	1.15 (1.09 – 1.22)
Exposed to airport noise > 65 dB			
CNEL	1.10 (1.01 – 1.19)	1.10 (1.01 – 1.19)	1.10 (1.02 – 1.20)

<sup>a</sup>Adjusted for Maternal Age, Maternal Educational Attainment, nSES, Maternal Race, and Cigarette Smoking, NO<sub>2</sub>, and Airport Noise

<sup>b</sup>Educational attainment was recorded in 9 ordinal categories: No formal education, 8<sup>th</sup> grade or less, 9<sup>th</sup> grade through 12<sup>th</sup> grade with no diploma, High school graduate or GED, Some college credit with no degree, Associates degree, Bachelor's degree, Master's degree, Doctorate or professional degree

**Table S7. Adjusted logistic regression results<sup>a</sup> of preterm birth with modified elliptical exposure buffers, quartiles of UFP exposure**

	Ellipse semi-axes		
	14 km x 16.1 km	12 km x 18.8 km	10 km x 22.5 km
4th vs 1st Quartile (95% CI)	1.14 (1.08 - 1.21)	1.12 (1.06 - 1.18)	1.11 (1.05 - 1.17)
3rd vs 1st Quartile (95% CI)	1.08 (1.03 - 1.14)	1.07 (1.02 - 1.13)	1.07 (1.02 - 1.13)
2nd vs 1st Quartile (95% CI)	1.04 (0.98 - 1.09)	1.02 (0.97 - 1.08)	1.03 (0.98 - 1.08)

<sup>a</sup>Adjusted for NO<sub>2</sub>, Maternal Age, Maternal Educational Attainment, nSES Index, Maternal Race, Airport Noise and Cigarette Smoking.



**Table S8. Adjusted logistic regression result<sup>a</sup> of preterm birth stratified by quintile of nSES Index**

	Quintile of nSES									
	5 (high)		4		3		2		1 (low)	
	PTB	Term	PTB	Term	PTB	Term	PTB	Term	PTB	Term
N	1,022	15,602	1546	23,090	1,299	14,752	2,323	22,951	8,933	82,521
(%)	(6%)	(94%)	(6%)	(94%)	(8%)	(92%)	(9%)	(91%)	(10%)	(90%)
4th vs 1st Quartile OR	0.92		1.03		1.22		1.02		1.26	
(95% CI)	(0.74 – 1.14)		(0.86 – 1.23)		(1.00 – 1.49)		(0.89 – 1.17)		(1.16 – 1.36)	
3rd vs 1st Quartile OR	0.95		1.07		1.20		0.99		1.16	
(95% CI)	(0.79 – 1.15)		(0.90 – 1.26)		(0.99 – 1.47)		(0.86 – 1.14)		(1.08 – 1.24)	
2nd vs 1st Quartile OR	0.75		0.96		1.03		1.00		1.13	
(95% CI)	(0.59 – 0.94)		(0.85 – 1.09)		(0.87 – 1.22)		(0.87 – 1.15)		(1.05 – 1.21)	

<sup>a</sup>Adjusted for NO<sub>2</sub>, Maternal Age, Maternal Educational Attainment, SES, Maternal Race, Airport Noise and Cigarette Smoking.

**Table S9. Percent of mothers in quartiles of UFP exposure stratified by quintile of nSES index<sup>a</sup>**

	Quintile of nSES Index						Total
	1st (Low)		2nd	3rd	4th	5th (High)	
	1st	2nd	3rd	4th	5th		
Quartile of UFP exposure	1st	36%	11%	8%	21%	23%	100%
	2nd	51%	13%	12%	19%	4%	100%
	3rd	66%	13%	7%	8%	6%	100%
	4th	57%	20%	10%	8%	5%	100%

<sup>a</sup>Pearson Correlation coefficient: -.27, p<.0001

**Table S10. Adjusted ORs<sup>a</sup> (95% CIs) of preterm birth stratified by educational attainment**

Variable	High School Degree or Less OR (95% CI)	Some College to College Degree OR (95% CI)	More than a College Degree OR (95% CI)
UFP			
Quartile 1	Ref.	Ref.	Ref.
Quartile 2	1.09 (1.01 – 1.17)	0.99 (0.90 – 1.08)	0.98 (0.78 – 1.04)
Quartile 3	1.08 (1.01 – 1.16)	1.10 (1.01 – 1.21)	1.11 (0.93 – 1.32)
Quartile 4	1.19 (1.10 – 1.28)	1.10 (1.00 – 1.21)	1.03 (0.85 – 1.24)
NO <sub>2</sub>			
Quartile 1 (< 21.8 ppb)	Ref.	Ref.	Ref.
Quartile 2 (21.8 – 23.8 ppb)	1.08 (1.01 – 1.16)	1.13 (1.04 – 1.22)	1.12 (0.97 – 1.29)
Quartile 3 (23.9 – 25.5 ppb)	1.09 (1.01 – 1.17)	1.14 (1.05 – 1.24)	1.15 (0.98 – 1.35)
Quartile 4 (> 25.5 ppb)	1.16 (1.08 – 1.24)	1.18 (1.07 – 1.30)	1.19 (0.98 – 1.44)
Exposed to airport noise > 65 dB CNEL	1.08 (0.98 – 1.20)	1.14 (0.99 – 1.33)	0.99 (0.36 – 2.73)

<sup>a</sup>Adjusted for Maternal Age, nSES, Maternal Race, and Cigarette Smoking, NO<sub>2</sub>, and airport noise

**Table S11. Adjusted ORs<sup>a</sup> (95% CIs) of very preterm birth (n = 2,085) exposure**

Variable	OR (95% CI)
UFP	
Quartile 1	Ref.
Quartile 2	0.98 (0.91 – 1.05)
Quartile 3	1.03 (0.97 – 1.11)
Quartile 4	1.13 (1.05 – 1.22)
NO <sub>2</sub>	
Quartile 1 (< 21.8 ppb)	Ref.
Quartile 2 (21.8 – 23.8 ppb)	1.04 (0.97 – 1.11)
Quartile 3 (23.9 – 25.5 ppb)	1.03 (0.97 – 1.10)
Quartile 4 (> 25.5 ppb)	1.14 (1.06 – 1.22)
Exposed to airport noise > 65 dB CNEL	1.02 (0.92 – 1.14)

<sup>a</sup>Adjusted for Maternal Age, Maternal Educational Attainment, nSES, Maternal Race, and Cigarette Smoking, NO<sub>2</sub>, and airport noise

<sup>b</sup>Educational attainment was recorded in 9 ordinal categories: No formal education, 8<sup>th</sup> grade or less, 9<sup>th</sup> grade through 12<sup>th</sup> grade with no diploma, High school graduate or GED, Some college credit with no degree, Associates degree, Bachelor's degree, Master's degree, Doctorate or professional degree

**Table S12. Adjusted ORs<sup>a</sup> (95% CIs) of preterm birth, excluding births within 2 km and 5 km of SMO airport**

Variable	Excluding < 2 km OR (95% CI)	Excluding < 5 km OR (95%)
UFP		
Quartile 1	Ref.	Ref.
Quartile 2	1.05 (0.99 – 1.10)	1.11 (1.04 – 1.17)
Quartile 3	1.09 (1.03 – 1.15)	1.11 (1.05 – 1.18)
Quartile 4	1.15 (1.09 – 1.21)	1.18 (1.11 – 1.25)
NO <sub>2</sub>		
Quartile 1 (< 21.8 ppb)	Ref.	Ref.
Quartile 2 (21.8 – 23.8 ppb)	1.10 (1.05 – 1.16)	1.09 (1.04 – 1.15)
Quartile 3 (23.9 – 25.5 ppb)	1.12 (1.06 – 1.18)	1.11 (1.05 – 1.17)
Quartile 4 (> 25.5 ppb)	1.17 (1.10 – 1.23)	1.16 (1.09 – 1.23)
Exposed to airport noise > 65 dB	1.10 (1.01 – 1.19)	1.09 (1.01 – 1.19)
CNEL		

<sup>a</sup>Adjusted for Maternal Age, Maternal Educational Attainment, nSES, Maternal Race, and Cigarette Smoking, NO<sub>2</sub>, and airport noise

<sup>b</sup>Educational attainment was recorded as 9 ordinal categories: No formal education, 8<sup>th</sup> grade or less, 9<sup>th</sup> grade through 12<sup>th</sup> grade with no diploma, High school graduate or GED, Some college credit with no degree, Associates degree, Bachelor's degree, Master's degree, Doctorate or professional degree

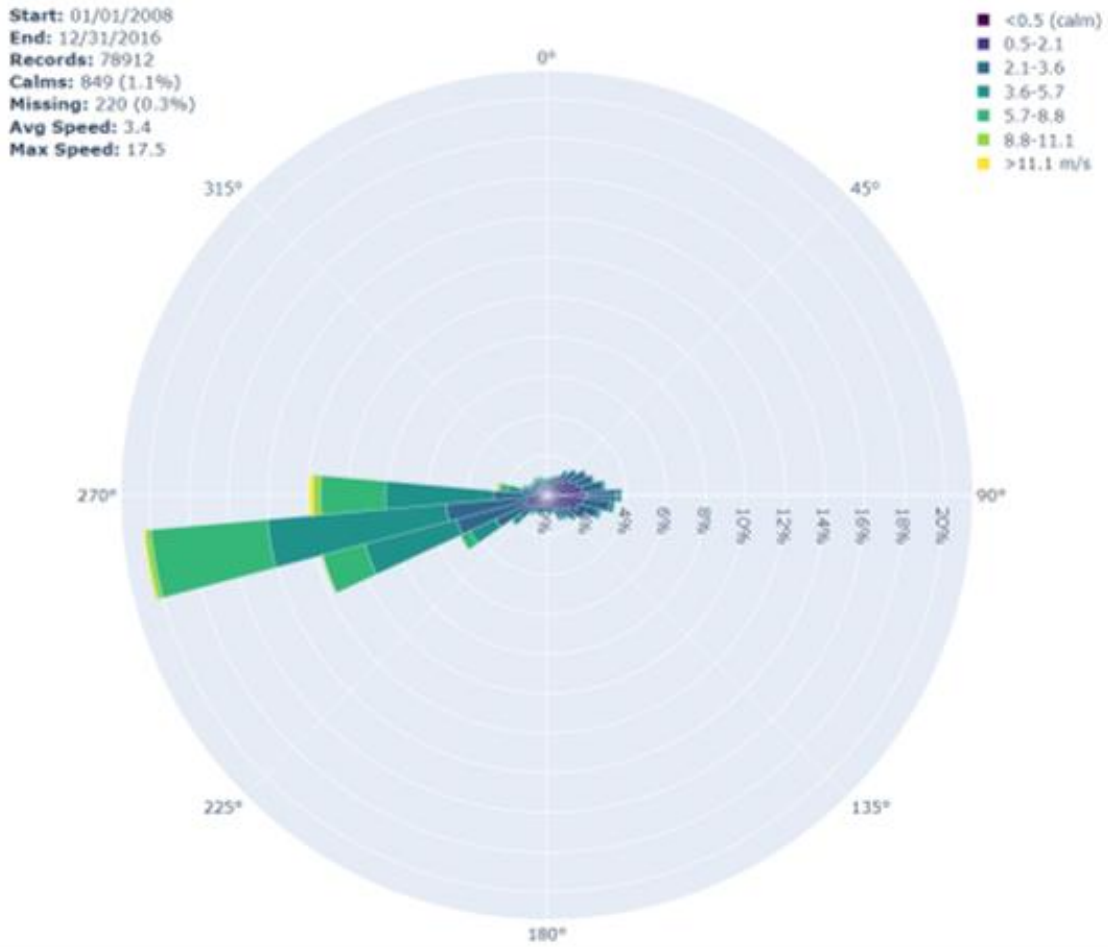


Figure S1. Hourly wind rose at LAX for the period January 2008 through December 2016 (Station #23174, anemometer height 30 ft, base elevation 108 ft)

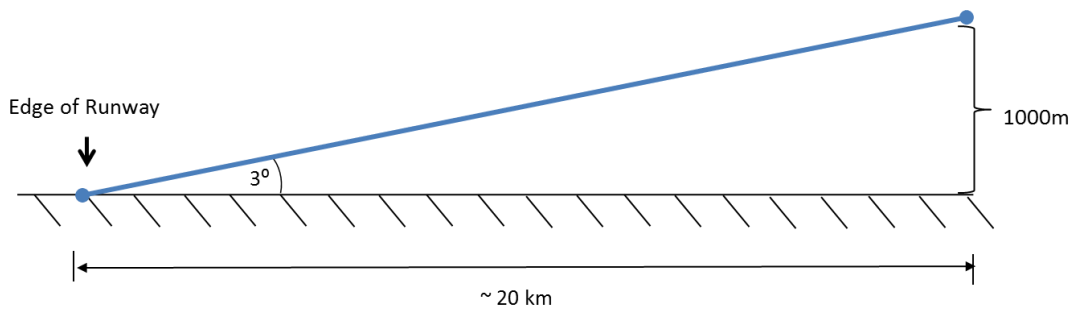


Figure S2. Schematic side view of tilted volume line source. Mixing depth can vary with hour of the day. Emissions from above the mixing depth will not impact the surface.

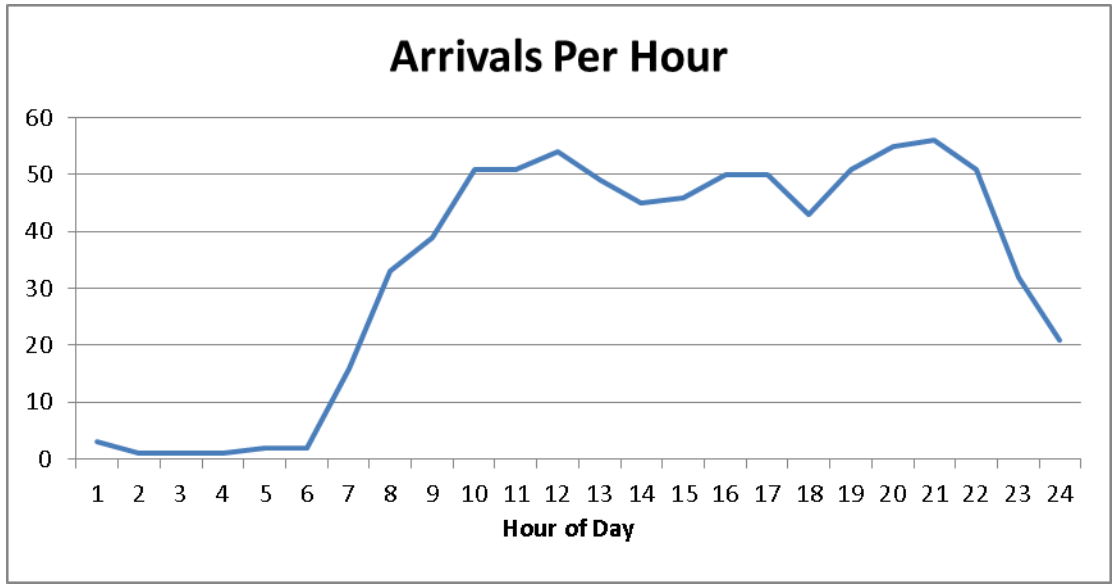


Figure S3. Diurnal flight activity at LAX by hour.

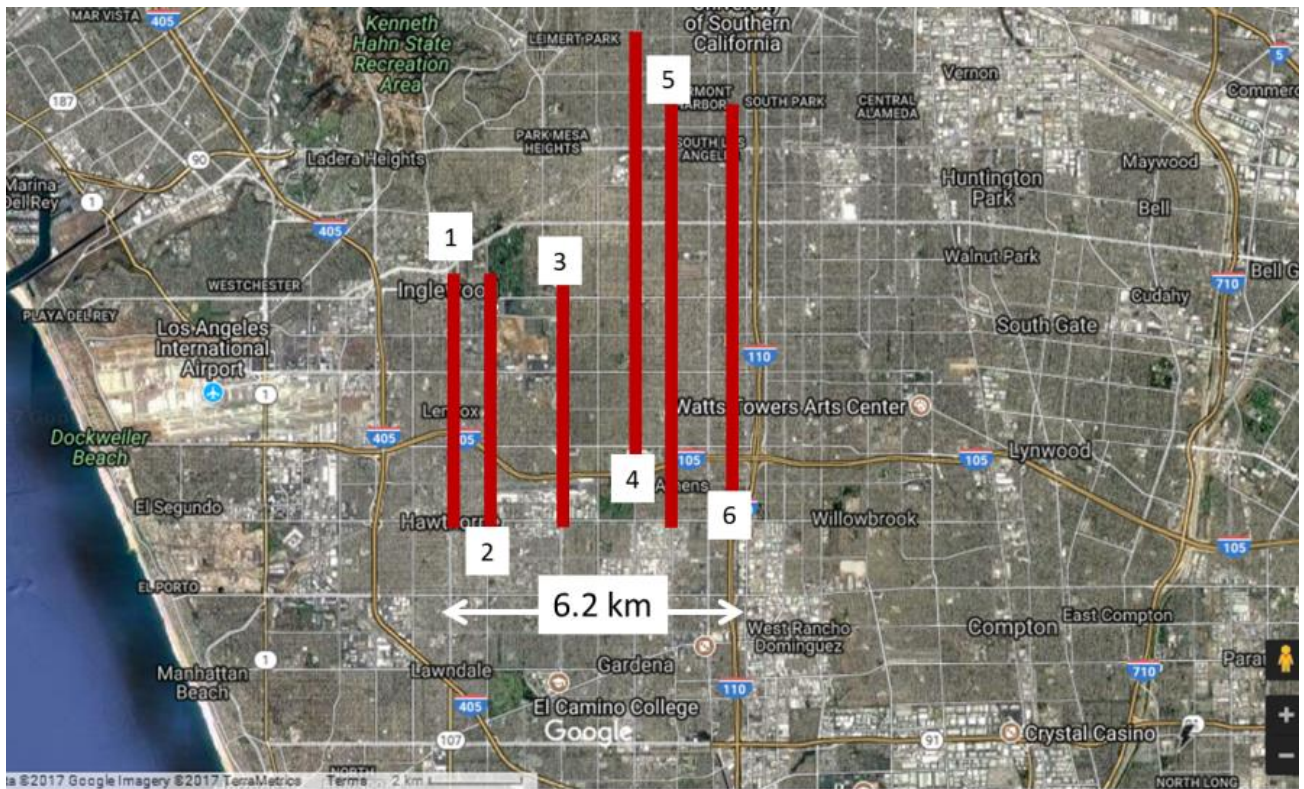


Figure S4. Mobile monitoring transects.

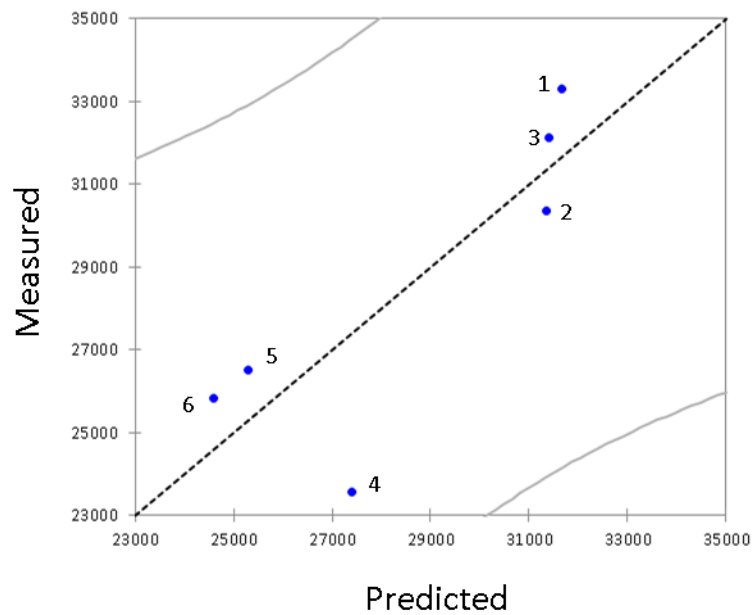


Figure S5. Transect Average Particle Number Concentration (#/cc). The numbers refer to the averages of the transect shown in figure S-4. The 1:1 line and the 95% confidence interval of the slope are also shown.

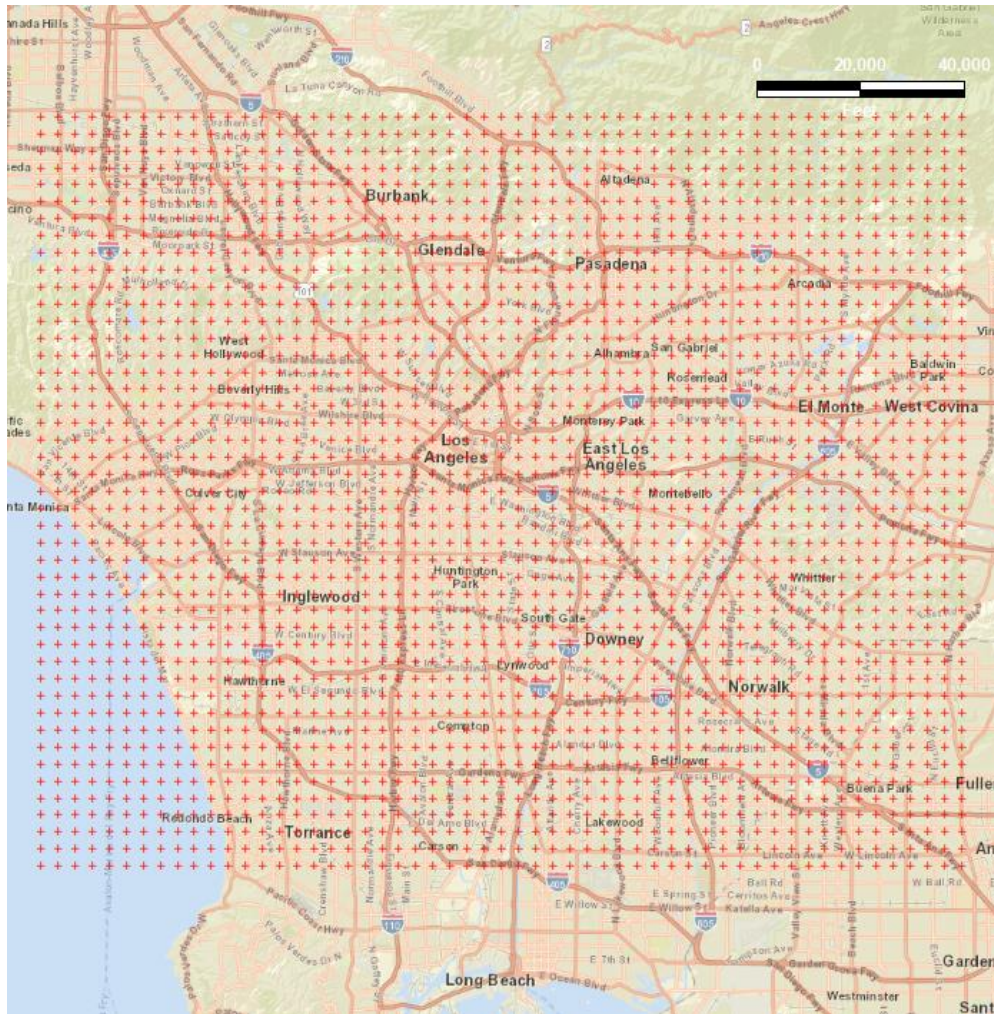


Figure S6. AERMOD Model Monthly Average Prediction Locations. Base layers obtained from USGS.gov.

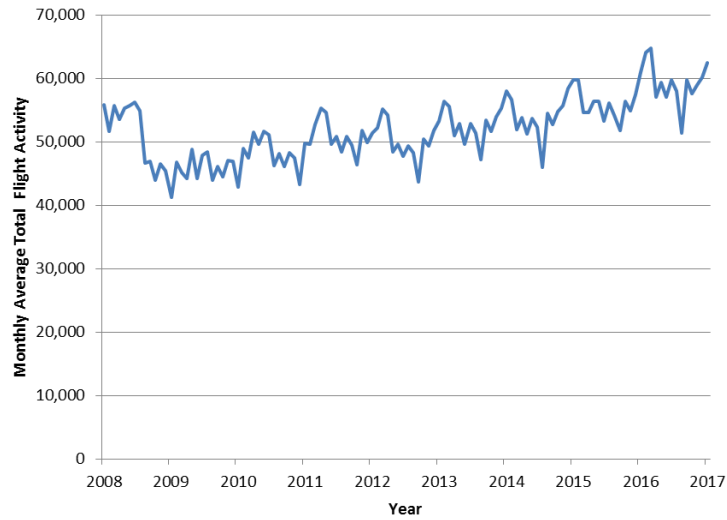


Figure S7. Monthly average total flight activity over the study period

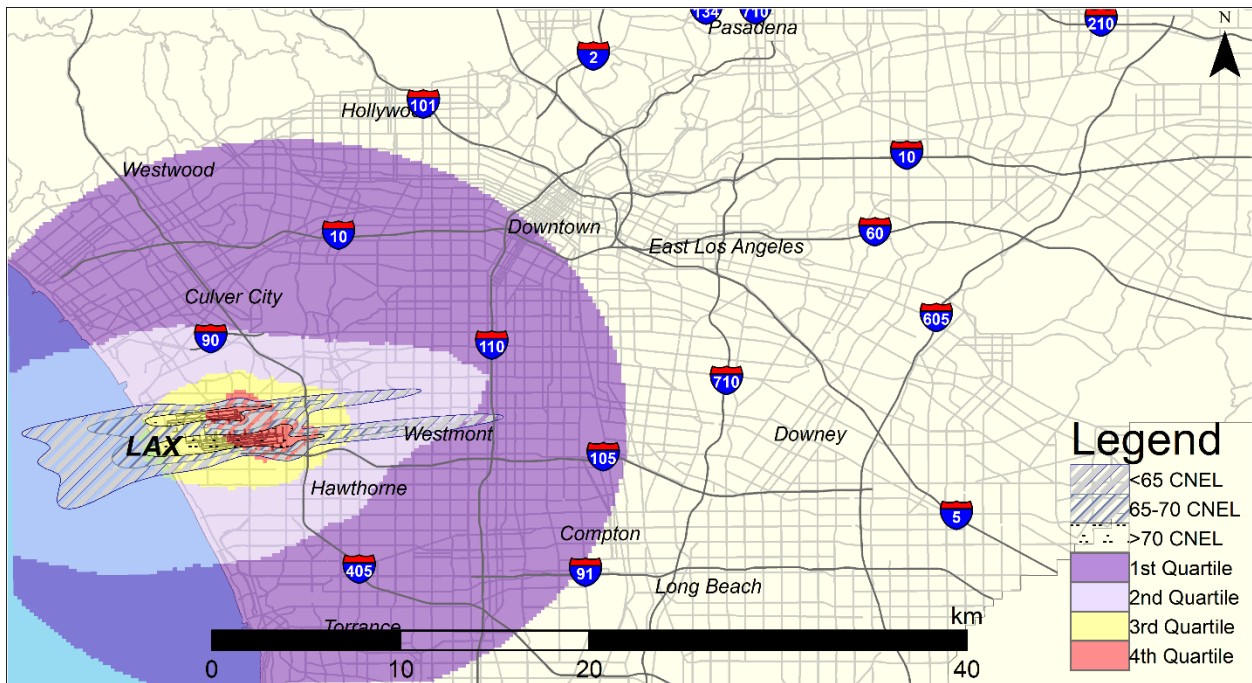


Figure S8. Areas above an annual average of 65 dB CNEL. Base layers obtained from USGS.gov.