Supporting Information for

Emissions from an international airport increase particle number concentrations fourfold at 10 kilometers downwind

N. Hudda\textsuperscript{1}, T. Gould\textsuperscript{2}, K. Hartin\textsuperscript{3}, T. Larson\textsuperscript{2}, and S.A. Fruin\textsuperscript{1*†}

\textsuperscript{1}Keck School of Medicine, Department of Preventive Medicine, University of Southern California, Los Angeles, CA 90089, United States
\textsuperscript{2}Department of Civil and Environmental Engineering, University of Washington, Seattle, WA 98195, United States
\textsuperscript{3}Department of Environmental and Occupational Health Sciences, University of Washington, Seattle, WA 98195, United States

Corresponding Author
*Telephone: 323-442-2870. Fax: 323-442-3272. E-mail: fruin@usc.edu.

Present Address
†S. A. Fruin: Department of Preventive Medicine, University of Southern California, 2001 North Soto Street, Los Angeles, CA 90089-9013, United States

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### INSTRUMENTS

**Table S.1: Instruments used in University of Southern California Mobile Monitoring Platform**

| Instrument | Parameter measured | Instrument Flow Rate (L min⁻¹) | Response Time (s) | Accuracy, Resolution, Sensitivity | Detection Limit |
|------------|---------------------|-------------------------------|-------------------|-----------------------------------|----------------|
| TSI portable CPC (ethanol-based) model 3007 | Particle number (PN) conc., 10 nm–1 μm | 0.8 | <9 sec for 95% response | 20%, 1 particle/cm³ | 10 nm, <0.01 particles/cm³ |
| Aeth Labs MicroAeth AE 51 Model Year 2010 | Black carbon (BC) | 0.15 | ~5 | ±0.1 μg BC/m³, 0.001 μg BC/m³ | ±0.1 μg BC/m³ at 1 min avg |
| EcoChem PAH analyzer, model PAS 2000 | Particle-bound polycyclic aromatic hydrocarbons (PB-PAH) and elemental carbon | 2 | <10 | 0.3–1 ng/m³ PB-PAH per picoamp | 3 ng/m³ |
| Garmin GPSMAP 76CSx | Location, speed | N/A | 1 | 3 meters | - |
| 2-B Technology Model 401-410 | NOₓ | 1 | 8 | Higher of 1.5 ppb or 2% of reading | - |

**Table S.2: Instruments used in University of Washington Mobile Monitoring Platform**

| Instrument | Parameter measured | Instrument Flow Rate (L min⁻¹) | Response Time (s) | Accuracy, Resolution, Sensitivity | Detection Limit |
|------------|---------------------|-------------------------------|-------------------|-----------------------------------|----------------|
| TSI portable CPC (Ethanol-based) model 3007 | Particle number (PN) conc., 10 nm–1 μm | 0.8 | <9 sec for 95% response | 20%, 1 particle/cm³ | 10 nm, <0.01 particles/cm³ |
| Aeth Labs MicroAeth AE 52 | Black carbon (BC) | 0.20 | ~5 | ±0.1 μg BC/m³, 0.001 μg BC/m³ | ±0.1 μg BC/m³ at 1 min avg |
| Aerodyne CAPS NO₂ monitor | NO₂ | 0.85 | ~8 | 0.01 ppb | < 0.1 ppb |
| US GlobalSat BU-353 GPS | Location, speed | N/A | 0.1 | Location: 5 m | - |
WIND ROSES

The following wind roses describe the distribution of wind speed and direction for the results shown in Figure 2–3. The wind roses were based on data collected by Automated Surface Observing Systems monitor operated by National Weather Service at site KLAX located at LAX and reported as 2 minute averages at 1 minute resolution. (The wind speed summary in Table 1 of the manuscript is based on hourly data.)

Figure S.2 (a): Wind rose for 1300–1459 hours, Sep 29, 2012.

Figure S.2 (b): Wind rose for 1500–1730 hours, Sep 29, 2012.

Figure S.2 (c): Wind rose for 1630–1820 hours, Sep 30, 2012.
Figure S.2 (d): Wind rose for 1200–1830, Jun 22, 2013.

Figure S.2 (f): Wind rose for 0931–1559, Jul 01, 2013.

Figure S.2 (e): Wind rose for 1200–1615, Jun 27, 2013.
Figure S.2 (g): Wind rose for 0850–1450, Aug 15, 2013.

Figure S.2 (h): Wind rose for 1100–1759, Aug 23, 2013.

Figure S.2 (i): Wind rose for 1923–2359, Aug 23, 2013.
Wind Roses for spring-winter sampling data presented in Figure S.8 and S.9 in this Supporting Information are presented in Figures S.3 (a)–(g).

Figure S.3 (a): Wind rose for 1830–2100 hours on Dec 10, 2013.

Figure S.3 (c): Wind rose for 1500–2000 hours on Dec 23, 2013.

Figure 3 (b): Wind rose for 1645–1845 hours Dec 18, 2013.

WIND SPEED (m/s)

- >= 11.1
- 8.8 - 11.1
- 5.7 - 8.8
- 3.6 - 5.7
- 2.1 - 3.6
- 0.5 - 2.1
Figure S.3 (d): Wind rose for the sampling duration on Apr 10, 2011

Figure S.3 (f): Wind rose for the sampling duration on May 27, 2011

Figure S.3 (d): Wind rose for the sampling duration on Jan 26, 2012

WIND SPEED (m/s)

- >= 11.1
- 8.8 - 11.1
- 5.7 - 8.8
- 3.6 - 5.7
- 2.1 - 3.6
- 0.5 - 2.1
DATA PROCESSING

Figure S.4 shows the raw data that include a localized traffic emissions signal representing microscale (10–100m) and middle scale variations (100 – 500m) and the underlying “baseline” pollutant concentration that only varied gradually over the neighborhood scale (500 m–4 km). Local traffic emissions were excluded by taking a rolling 30-second 5th percentile value of the 1-second concentration time series, and assigning that value to the measured location, resulting in a smoothed data series of 1 s data which we referred to as “baseline.” The figure illustrates that this data smoothing process successfully captures the broader spatial-scale changes while removing the transitory and localized impacts of specific vehicles on the roadways sampled. Occasionally, individual spikes/plumes lasted longer than 30 seconds. In those rare instances, the spikes were excluded manually if confirmed to be a specific vehicle by video or field-notes.

Figure S.4: Illustration of data before and after smoothing

The following figures illustrate that the smoothed data series retained the neighborhood-scale changes in baseline PN concentrations occurring over several kilometers as shown in Figure S.5. Figure S.6 shows PN concentration versus distance from the start of the transects labeled in Figure S.5. Figure S.7 shows same PN concentration profile plotted versus monitoring time. These PN concentration profiles for selected transects from monitoring from 17:30 on 08/24/2013 to 01:00 on 08/25/2013 show that this increase in PN baseline concentration occurred over a scale of kilometers. The longer duration spikes that weren’t manually removed do not obscure the spatial pattern. Even as far downwind as 10–16 km, the increase was easily discernible in real time at arterial road driving speeds (e.g., over 5–10 minutes per transect at 32–56 km/h speeds).
Figure S.5: Spatial pattern of the PN concentration monitoring from 17:30 08/24/2013 to 01:00 08/25/2013 including the transects shown below.

Figure S.6: Raw data (black line) and smoothed data (red line) for transects on Western (10 km east of LAX), Vermont (11.75 km east of LAX), Main (13.5 km east of LAX) and Central Av. (16 km east of LAX). These transects have been identified with street name labels in Figure S.5.
Figure S.7: Raw data (black line) and smoothed data (red line) time-series for transects on Western (10 km east of LAX), Vermont (11.75 km east of LAX), Main (13.5 km east of LAX) and Central Av. (16 km east of LAX). These transects have been identified with street name labels in Figure S.5.

**Traffic Volumes**

A major thoroughfare in Los Angeles, Freeway I-405, runs N-S at the eastern edge of LAX. Freeway 105 runs E-W at the southern edge of LAX but traffic volumes are smaller on I-105 than on I-405. Where I-105 crosses I-405, the annual average daily traffic count (AADT) in 2012 for I-105 was 177,500 vehicles per day (both directions) with a truck fraction of 4.8%, and for I-405, 274,000 vehicles per day with a truck fraction of 3.3 %. Where I-105 crosses I-110, which runs N-S about 12 km east of LAX and closer to the eastern extent of the study area, the AADT increases to 231,000 vehicles per day with a truck fraction of 5.2% for I-105 and an AADT of 269,500 and 4.3%, respectively, for I-110.
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SPATIAL PATTERN OF PN ELEVATION ON ADDITIONAL WINTER DAYS

Figure S.8 shows the pattern during additional winter days with different prevailing wind directions. For the corresponding wind roses see Figures S.3 (a)–(c). The prevailing wind direction was northerly on 12/10/2013, southwesterly on 12/18/2013 and westerly on 12/23/2013. The impacted locations corresponded to the wind direction but impacted PN concentrations were comparable, except for the baseline that was higher under northerly wind because it was influenced by urban air and not the usual marine air associated with westerly/southwesterly wind.

Figure S.8: Spatial pattern of impact during monitoring in December 2013. PN concentrations are colored by deciles and plotted in units of 1000 particles/cm$^3$. 
**Spatial Pattern of PN Elevation in Previous Years**

Archived records from previous years were re-examined to uncover similar impacts from LAX. Figure S.9 shows the spatial pattern of PN concentration increase on two transects Western Av which is 10 km east of LAX and Avalon Av. which is 14 km east of LAX. These runs were conducted in winter and spring time of 2011 and 2012.

![Spatial Pattern of PN Elevation](image)

| Percentile | 4/10/2011 | 5/27/2011 | 1/26/2012 |
|------------|-----------|-----------|-----------|
| 10         | 7750      | 10000     | 18200     |
| 20         | 8980      | 11400     | 20400     |
| 30         | 10600     | 13600     | 22300     |
| 40         | 11600     | 15500     | 23900     |
| 50         | 13300     | 18800     | 25600     |
| 60         | 14600     | 25800     | 29600     |
| 70         | 17800     | 28000     | 36800     |
| 80         | 22900     | 31400     | 43000     |
| 90         | 35000     | 39500     | 53500     |
| 100        | 55500     | 53900     | 137700    |

**Figure S.9**: Spatial pattern of PN concentration during monitoring in 2011 observed on Western Av (10 km east of LAX) and Avalon Av. (14 km east of LAX).
CONCURRENT SAMPLING

The use of two mobile platforms allowed us to measure the pollutant concentrations at two locations concurrently and further verified the high temporal and spatial consistency of the impacts. During these runs, the USC MMP monitored within 7.5 km of LAX and the UW MMP monitored 9.5–12 km from LAX.

To ensure neither mobile platform was affected by its own emissions, the USC MMP hybrid vehicle engine turned off when the car was not moving. For the UW MMP, a regular gasoline powered van, the sampling inlet location was located at about five feet high through the second row passenger window behind the driver, away from the tailpipe location at the other side of the vehicle under the rear. This orientation prevented the tailpipe from being upwind of the sampling inlet during the north and south transects. They were driven at similar speeds to cover the same N-S distance within the same time via synchronous crossing of major E-W cross streets. During this dual mobile platform monitoring, transects were sampled multiple times within a short span of time. No direct comparisons were made between the data from two platforms and this sampling was conducted only to measure the consistency in spatial patterns. (The two CPC agreed within 10% during collocated sampling before and after the run.)

The profiles shown in Figure S.10 (a), (c) and (d) for a given transect were remarkably consistent over the duration of one to two hours. The overall spatial pattern is illustrated in Figure S.10 where successive loops on the monitoring route are staggered in the northeast direction. The pattern between measured by two MMPs but at different locations aligned well with the prevailing winds for that day, which is shown in Figure S.11.

Figure S.10: PN concentrations on multiple consecutive transects.
Figure S.11: Spatial pattern (staggered for visibility) for PN concentrations on concurrent sampling runs of June 22 and June 27. Western loops were sampled with the USC MMP and eastern loops with the UW MMP.
CALCULATIONS FOR COMPARING FREEWAY IMPACTS

The following tables present the detailed calculations used to calculate the length of freeway necessary to produce the equivalent area-weighted increases in PN concentration produced by LAX. Table S.3(a) gives the area-weighted PN concentration increases for each 10,000/cm³ step in PN concentration for each of the three days. Table S.3(b) gives the area-weighted PN concentration increases for each 10 meter interval downwind of a typical freeway in Los Angeles. Table S.3(c) gives the figures used to calculate the equivalent freeway distances.

Table S.3(a): Average LAX-related particle number increase and corresponding impact areas

| Area (km²) | 4 | 9 | 14 | 27 | 44 | 65* |
|------------|---|---|----|----|----|-----|
| 8/15/2013  |   |   |    |    |    |     |
| Baseline PN Conc. = 20000/cm³ |   |   |    |    |    |     |
| Minimum PN conc. increase in area over baseline (particles/cm³) | 70000 | 60000 | 50000 | 40000 | 30000 | 20000 |
| Average conc. increase in area over baseline (particles/cm³) | 78700 | 69100 | 623000 | 51300 | 43200 | 35600 |
| Impact (Avg. conc. increase X area), [particles/cm³ x km²] | 3.15E+05 | 6.22E+05 | 8.72E+05 | 1.39E+06 | 1.90E+06 | 2.31E+06* |

| Area (km²) | 0.1 | 0.5 | 7 | 22 | 36 | 47* |
|------------|-----|-----|---|----|----|-----|
| 8/23/2013  |   |   |   |    |    |     |
| Baseline PN Conc. = 20000/cm³ |   |   |   |    |    |     |
| Minimum PN conc. increase in area over baseline (particles/cm³) | 70000 | 60000 | 50000 | 40000 | 30000 | 20000 |
| Average conc. increase in area over baseline (particles/cm³) | 70000 | 61400 | 50700 | 43600 | 38200 | 33700 |
| Impact (Avg. conc. increase X area), [particles/cm³ x km²] | 7.00E+03 | 3.07E+04 | 3.55E+05 | 9.58E+05 | 1.38E+06 | 1.58E+06* |

| Area (km²) | 0.5 | 1.4 | 4 | 12 | 17 | 30* |
|------------|-----|-----|---|----|----|-----|
| 8/24/2013  |   |   |   |    |    |     |
| Baseline PN Conc. = 15000/cm³ |   |   |   |    |    |     |
| Minimum PN conc. increase in area over baseline (particles/cm³) | 70000 | 60000 | 50000 | 40000 | 30000 | 20000 |
| Average conc. increase in area over baseline (particles/cm³) | 75800 | 69200 | 60200 | 49800 | 45100 | 36500 |
| Impact (Avg. conc. increase X area), [particles/cm³ x km²] | 3.79E+04 | 9.68E+04 | 2.41E+05 | 5.97E+05 | 7.67E+05 | 1.10E+06* |

*Values reported in the research article.
### Table S.3(b): Calculations showing increase in particle number concentration from freeways as a function of downwind distance

| Distance from freeway (X) (m) | °Conc. increase at distance X for background = 15,000 (particles/cm³) | Cumulative impact (avg. conc. increase X area) for 1 km of freeway length (particles/cm³× km²) | °Conc. increase at distance X for background = 20,000 (particles/cm³) | Cumulative impact (avg. conc. increase X area) for 1 km of freeway length (particles/cm³× km²) |
|-------------------------------|-------------------------------------------------|---------------------------------|-------------------------------------------------|---------------------------------|
| 0-10                          | 56000°                                          | 560°                            | 51000°                                          | 510°                            |
| 10-20                         | 48200°                                          | 1040°                           | 43900°                                          | 950°                            |
| 20-30                         | 43600°                                          | 1480°                           | 39700°                                          | 1350°                           |
| 30-40                         | 39500°                                          | 1870°                           | 36000°                                          | 1710°                           |
| 40-50                         | 35700°                                          | 2230°                           | 32500°                                          | 2030°                           |
| 50-60                         | 32300°                                          | 2553°                           | 29400°                                          | 2330°                           |
| 60-70                         | 29200°                                          | 2850°                           | 26600°                                          | 2590°                           |
| 70-80                         | 26500°                                          | 3110°                           | 24100°                                          | 2830°                           |
| 80-90*                        | 23900°                                          | 3350°                           | 21800°                                          | 3050°                           |
| 90-100                        | 21700°                                          | 3570°                           | 19700°                                          | 3250°                           |
| 100-110                       | 195600°                                         | 3760°                           | 17800°                                          | 3420°                           |
| 110-120                       | 17700°                                          | 3940°                           | 16100°                                          | 3590°                           |
| 120-130*                      | 16000°                                          | 4100°                           | 14600°                                          | 3730°                           |
| 130-140                       | 14500°                                          | 4250°                           | 13200°                                          | 3870°                           |
| 140-150                       | 13100°                                          | 4380°                           | 12000°                                          | 3990°                           |
| 150-160                       | 11900°                                          | 4500°                           | 10800°                                          | 4090°                           |
| 160-170                       | 10800°                                          | 4600°                           | 9800°                                           | 4190°                           |
| 170-180                       | 9700°                                           | 4700°                           | 8900°                                           | 4280°                           |
| 180-190                       | 8800°                                           | 4790°                           | 8000°                                           | 4360°                           |
| 190-200                       | 8000°                                           | 4870°                           | 7300°                                           | 4430°                           |

† For the first 10 m, it is assumed that concentration equals freeway concentration. For distance intervals the values have been reported at the mid-point to nearest 100 particles/cm³.

*Values reported in the research article

<sup>a</sup>Zhu et al. 2008 (a) regression fit: Particle conc. increase at distance X = (Particle conc. increase on-freeway) × exp (-0.01*X)

<sup>b</sup>Li et al. 2013 Average particle concentration on Los Angeles freeways, i.e., 71,000 particles/cm³ minus background

### Table S.3(c): Calculations showing equivalent freeway lengths

| Date  | Urban Background | LAX-related impact | Freeway-related Impact, per km of freeway | Equivalent Freeway Length |
|-------|------------------|--------------------|------------------------------------------|---------------------------|
|       | (particles/cm³)  | Area (km²)         | Average PN Increase (particles/cm³)       | Impact (particles/cm³× km²)|                       |                       |                       |
|       |                  |                    |                                          | Area (km²)                | Average PN Increase (particles/cm³) | Impact (particles/cm³× km²) |                       |                       |
| 8/15/13 | 20000            | 65*                | 35600*                                   | 2.31E+06*                 | 0.090                          | 32500*                    | 2930*                  | 790*                  |
| 8/23/13 | 20000            | 47                 | 33700*                                   | 1.58E+06*                 | 0.090                          | 32500*                    | 2930*                  | 540                   |
| 8/24/13 | 15000            | 30*                | 36500*                                   | 1.10E+06*                 | 0.130                          | 30200*                    | 3930*                  | 280*                  |

*Values reported in the research article