## 1. Meteorological Approximation for dispersion model

The data required for the dispersion model can be divided into two main categories: the data describing atmospheric conditions and the data required for modeling the dispersion of pollutants. This approximation is advantageous because the dispersion model requiring input friction velocity and sensible heat flux can be estimated through the commonly available routine weather data, including temperature, wind speed, and wind direction.

The surface friction velocity (u*), which is also called shear velocity, describes the diffusion and dispersion of contaminants in the flow. It serves as a scaling parameter for the fluctuating component of velocity in turbulent flows [1]. The friction velocity would numerically determine the standard deviations of vertical and horizontal velocities $\sigma_v$ and $\sigma_w$, which further determine the pollution dispersion rate. An approximation proposed by Wang and Chen is used to calculate the u* [2,3]

$$u_* = ku\frac{1 + d_1 \ln(1 + d_2 d_3)}{\ln\left(\frac{1}{r_h}\right)}$$

where

$$r_h = \frac{z_0}{z_r - d_h}$$

$$d_1 = \begin{cases} 0.128 + 0.005\ln(r_h), & for\ r_h \le 0 \\ 0.107, & otherwise \end{cases}$$

$$d_2 = 1.95 + 32.6 r_h^{0.45}$$

$$d_3 = \frac{\frac{H_0}{\rho c_p} kg(z_r - d_h)}{T_0 \left\{ \frac{kU}{\ln\left[\frac{z_r - d_h}{z_0}\right]} \right\}^3}$$

where $Z_r$ is the receptor height in meters. $T_0$ is the surface temperature acquired through measurement, or from the nearby monitoring station; k is the von Karman constant = 0.4; U is the wind speed at receptor height in m/s; g is the gravitational acceleration = 9.8m/s$^2$; $c_p$ is the heat capacity of air = 1.004 KJ/kg˙K; and $z_0$ is roughness length. For the suburban study region, $z_o$ = 0.12 m, $d_h$ is the zero-plane displacement, and $d_h$=5$z_0$. $H_0$ is the sensible heat flux, for which the calculation is illustrated below.

The sensible heat flux is the energy flux that takes into account the temperature difference between the ground and the atmosphere. It is responsible for the thermal fluctuation and thus influences the velocity turbulence in the canyon. An empirical scheme proposed by Van Ulden is utilized to estimate the surface fluxes of heat and momentum from routine weather data during the daytime [4].

$$Q_* = \frac{\left((1 - A)K^+\right) + (c_1 T^6) + (\sigma T^4) + (c_2 N)}{(1 + c_3)}$$

$$K^+ = k_0(1 + b_1 N^{b_2})$$

$$K_0 = a_1 sin\alpha + a_2$$

The empirical constants are:

$$a_1 = 990, a_2 = -30, b_1 = -0.75, b_2 = 3.4, c_1 = 5.31 \times 10^{-13} W\ m^{-2} K^{-6}, c_2 = 60 W\ m^{-2},$$
$$c_3 = 0.12, \sigma = 5.67 \times 10^{-8} W\ m^{-2} K^{-4}$$

where $\alpha$ is the solar elevation, which changes with time and season.

Based on the net radiation, the sensible heat flux is estimated by the following empirical equation [3]:

$$H_0 = 0.9Q_* \frac{B_0}{1 + B_0}$$

where Bo is the Bowen ratio, which describes the type of heat transfer for a surface that contains moisture. Bo can be inferred, based on the terrain type. In the study case, the Bowen ratio is taken as 3.0, categorized based on semi-arid landscapes.

The approximation methodology is compared with the results of a field measurement study. A 3 m tower with a sonic anemometer was assembled near UC Riverside to measure the friction velocity and sensible heat flux. The measured parameters were averaged hourly and compared with the current meteorological approximation output. The estimates of u* compare well with observed values for this field measurement. Most of the model estimates are within a factor of two of the measurement, as shown in Figure S1.

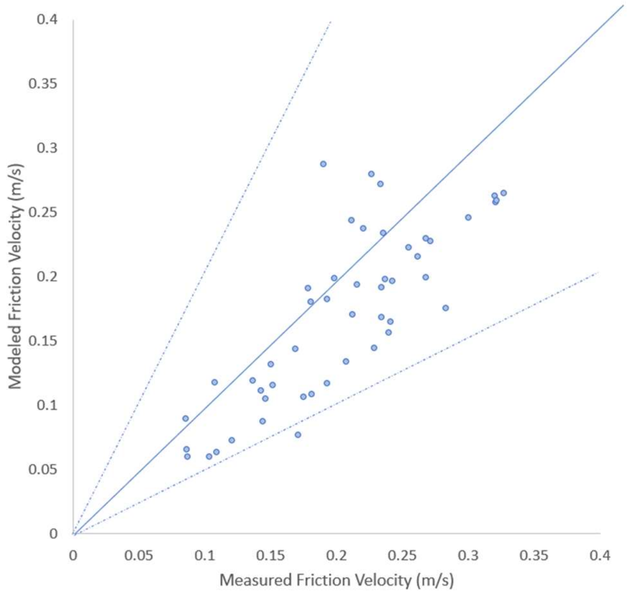


**Figure S1.** Comparison of meteorological approximation model output and a field measurement

## 2. Comparison of numerical models and experiment

The water channel is constructed to provide dispersion data under controllable and repeatable settings for verification purpose when field measurements are not available. One can control factors such as flow speed, source emission, and ground terrain. The flow

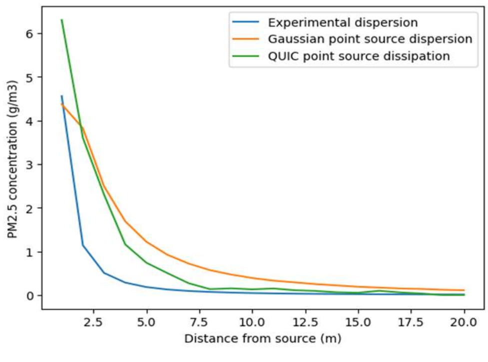


**Figure S2.** Comparison of point source dispersion among Gaussian, QUIC, and water channel behavior under steady state is recorded by a camera and post-processed through MATLAB. Fluorescence dye is used for concentration dispersion visualization.

During the experiment, the point source emission is 10 g/s with mean wind speed of 2 m/s at the roof level. The water tank experiment is scaled to the field size to compare with numerical models; the scaling procedure can be found in [5]. Figure S2 shows the comparison of point source dissipation rate between the QUIC output, the Gaussian output (AERMOD is a Gaussian-based model), and the water channel experiment. The variation in concentrations from the three simulations was similar. The pollutants dissipate exponentially along with distance, and the source impact diminished after 5 meters, based on the current study case. In addition, the cooking induced outdoor pollution dispersion for part of the village, as simulated by AERMOD and QUIC-PLUME, and the comparison is shown in Figure S3. The outputs from AERMOD and QUIC are in fairly close agreement, and the broad shape of the plume footprint is correctly matched.

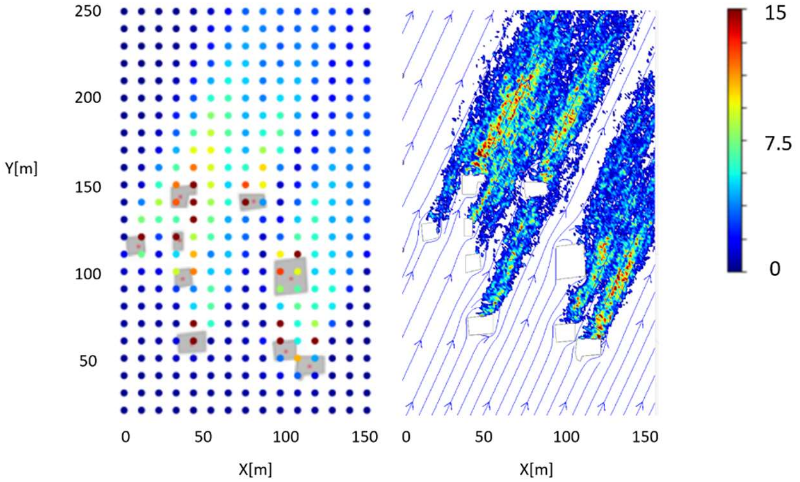


**Figure S3.** Comparison of (left) AERMOD output with (right) QUIC output for one-hour outdoor emission estimation

## References

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