# eAppendix

## Indoor Exposure to Outdoor $PM_{10}$: Assessing its Influence on the Relationship between $PM_{10}$ and Short-term Mortality in U.S. Cities

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## Table of Contents

## $PM_{10}$ penetration factor ($P$) and surface removal rate constant ($k_{sr}$)

The city-specific mean concentrations of $PM_{10}$ ([$PM_{10}$]) and $PM_{2.5}$ ([$PM_{2.5}$]) are available at the website of the Internet-based Health & Air Pollution Surveillance System (iHAPSS). Given this information, the mass fractions of both $PM_{2.5}$ (mf $OutdrPM_{2.5}$) and $PM_{10\text{-}2.5}$ (mf $OutdrPM_{10\text{-}2.5}$) in outdoor $PM_{10}$ can be obtained by:

$$\text{mf } OutdrPM_{2.5} = [PM_{2.5}] / [PM_{10}] \quad \text{(S1)}$$

$$\text{mf } OutdrPM_{10\text{-}2.5} = ([PM_{10}] - [PM_{2.5}]) / [PM_{10}] \quad \text{(S2)}$$

Based on the mass fractions and the penetration factors for both modes of outdoor $PM_{10}$ (($P_{2.5}$) and ($P_{2.5\text{-}10}$)), the city-specific overall penetration factor of $PM_{10}$ has been calculated as:

$$P = (P_{2.5}) (\text{mf } OutdrPM_{2.5}) + (P_{2.5\text{-}10}) (\text{mf } OutdrPM_{10\text{-}2.5}) \quad \text{(S3)}$$

The penetration factor of $PM_{2.5}$ particles was assumed to be 0.8 (Meng et al., 2009; Chen and Zhao, 2011), while the penetration factor of ($PM_{2.5}$ - $PM_{10}$) particles was assumed to be 0.3 (Chen and Zhao, 2011). Based on the mass fractions of outdoor $PM_{10}$ in the $PM_{2.5}$ and $PM_{2.5}$ - $PM_{10}$ modes, an overall $PM_{10}$ penetration factor was calculated for each city using equations (S1-S3).

Based on the mass fraction and penetration factors of $PM_{2.5}$ and $PM_{10\text{-}2.5}$ in outdoor $PM_{10}$, the mass fraction of both $PM_{2.5}$ (mf $IndrPM_{2.5}$) and $PM_{10\text{-}2.5}$ (mf $IndrPM_{10\text{-}2.5}$) that constitute indoor $PM_{10}$ of outdoor origin can be estimated:

$$\text{mf } IndrPM_{2.5} = (P_{2.5}) (\text{mf } OutdrPM_{2.5}) / P \quad \text{(S4)}$$

$$\text{mf } IndrPM_{10\text{-}2.5} = (P_{2.5\text{-}10}) (\text{mf } OutdrPM_{10\text{-}2.5}) / P \quad \text{(S5)}$$

Riley et al. (2002) report a modeled surface removal rate constant for $PM_{2.5}$ of 0.09 $h^{-1}$. Meng et al. (2009) report a measured value of 0.06 $h^{-1}$, while Sinclair et al. (1990) report measured values

0.1 to 0.2 $h^{-1}$ (product of deposition velocities for fine mode sulfate in Table 9 of citation and surface-to-volume ratio of 1 $m^{-1}$). Given these modeled and measured values, we judge that 0.09 $h^{-1}$ is a reasonable value for the surface removal rate constant of $PM_{2.5}$ ($k_{sr,2.5}$). Based on the modeled results by Riley et al. (2002) and measured results by Sinclair et al. (1990), the surface removal rate constant of $PM_{10\text{-}2.5}$ ($k_{sr,10\text{-}2.5}$) was assumed to be 4 $h^{-1}$. With estimates of the mass fractions and the surface removal rate constants for both modes of indoor $PM_{10}$, the city-specific surface removal rate constant of $PM_{10}$ when windows are closed ($k_{sr,infilt}$) can be estimated as:

$$k_{sr,infilt} = (k_{sr,2.5})\,(\text{mf } IndrPM_{2.5}) + (k_{sr,10\text{-}2.5})\,(\text{mf } IndrPM_{10\text{-}2.5}) \quad \text{(S6)}$$

When windows are open, the mass fractions of both modes of indoor $PM_{10}$ are the same as those of outdoor $PM_{10}$. Hence, the city-specific surface removal rate constant of $PM_{10}$ when windows are open ($k_{sr,open}$) can be estimated as:

$$k_{sr,open} = (k_{sr,2.5})\,(\text{mf } OutdrPM_{2.5}) + (k_{sr,2.5\text{-}10})\,(\text{mf } OutdrPM_{10\text{-}2.5}) \quad \text{(S7)}$$

## Fraction of time windows were open in mild weather ($z$)

The average annual fraction of time that windows were open in mild weather ($z$) was estimated to be 0.23, based on the fraction of time that windows were open during mild weather in a residential study by Wallace et al. (2002), and supported by several office studies (Rijia et al. 2007; Yun and Steemers 2008; Herkel et al. 2008; Haldi and Robinson 2009). Wallace et al. (2002) present data for the monthly fraction of time that windows were open in a house in Virginia (Figure 10 in their paper). Based on outdoor temperature data from NOAA (2002), in this location mild weather (15 to 24 $^{o}$C) occurs from April to October. However, window-opening when the temperature was higher than 24 $^{o}$C was included in Wallace et al.'s data. To correct for this, we first estimated the fraction of time that windows were open during mild weather in a given month, $z_{monthly}$:

$$z_{monthly} = (\text{FTWO} \times \text{FTMW}) / (\text{FTMW} + \text{FTS}) \quad \text{(S8)}$$

where FTWO is the total fraction of time that windows were open in a given month (Wallace et al. 2002), FTMW is the fraction of time in a month that the weather was mild (15 to 24 $^{o}$C; NOAA), and FTS is the fraction of time in a month that the temperature was higher than 24 $^{o}$C; NOAA). For example, in July FTWO was 0.58; FTMW was 0.44, and FTS was 0.56; hence in July $z_{monthly}$ equaled 0.26. The average annual fraction of time that windows were open in mild weather ($z$) was obtained by FTMW-weight averaging the values for "$z_{monthly}$".

## $PM_{10}$ exposure coefficient

The change in outdoor $PM_{10}$ exposure that results from a change in outdoor $PM_{10}$ concentration, $\Delta(outdr\ PM_{10}\text{-}expos)$, is given by:

$$\Delta(outdr\ PM_{10}\text{-}expos) = t_{out}\ (\Delta[PM_{10}]_{out}) \quad \text{(S9)}$$

where $t_{out}$ is the time outdoors.

The *change* in indoor $PM_{10}$ exposure, $\Delta(indr\ PM_{10}\text{-}expos)$, for the same change in outdoor $PM_{10}$ concentration is given by:

$$\Delta(indr\ PM_{10}\text{-}expos) = t_{in}\ (\Delta[PM_{10}]_{in}) \quad \text{(S10)}$$

where $t_{in}$ is the time indoors. From Equation 4:

$$\begin{aligned}\Delta[PM_{10}]_{in} = {} & \{(x_{cool})(y)\ [P\lambda_{infilt}/(\lambda_{infilt} + k_{sr,infilt} + \eta\lambda_{recirc})] + \\ & [(x_{cool})(1\text{-}y) + (x_{mild})(z)]\ [\lambda_{win\_open}/(\lambda_{win\_open} + k_{sr,open})] + \\ & [(x_{mild})(1\text{-}z) + x_{heat}]\ [P\lambda_{infilt}/(\lambda_{infilt} + k_{sr,infilt})]\}\ \Delta[PM_{10}]_{out}\end{aligned} \quad \text{(4a)}$$

Or, more simply:

$$\Delta[PM_{10}]_{in} = (\beta)\ \Delta[PM_{10}]_{out} \quad \text{(S11)}$$

where $$\begin{aligned}(\beta) = {} & \{(x_{cool})(y)\ [P\lambda_{infilt}/(\lambda_{infilt} + k_{sr,infilt} + \eta\lambda_{recirc})] + \\ & [(x_{cool})(1\text{-}y) + (x_{mild})(z)]\ [\lambda_{win\_open}/(\lambda_{win\_open} + k_{sr,open})] + \\ & [(x_{mild})(1\text{-}z) + x_{heat}]\ [P\lambda_{infilt}/(\lambda_{infilt} + k_{sr,infilt})]\}\end{aligned} \quad \text{(S12)}$$

Hence,

$$\Delta(indr\ PM_{10}\text{-}expos) = t_{in}\,(\beta)\,\Delta[PM_{10}]_{out} \qquad \text{(S13)}$$

If we consider only "outdoor" and "indoor" environments, then the change in *total* $PM_{10}$ exposure that results from a given change in outdoor $PM_{10}$ concentration, $\Delta(total\ PM_{10}\text{-}expos)$, is the sum of the resulting changes in outdoor and indoor exposures:

$$\Delta(total\ PM_{10}\text{-}expos) = t_{out}\,(\Delta[PM_{10}]_{out}) + t_{in}\,(\beta)\,\Delta[PM_{10}]_{out} \qquad \text{(S14)}$$

Expressed slightly differently, the change in total $PM_{10}$ exposure per change in outdoor $PM_{10}$ exposure is:

$$PM_{10}\text{ exposure coefficient} = \Delta(total\ PM_{10}\text{-}expos)/\Delta(outdr\ PM_{10}\text{-}expos) = \{t_{out}\,(\Delta[PM_{10}]_{out}) + t_{in}\,(\beta)\,\Delta[PM_{10}]_{out}\} / t_{out}\,(\Delta[PM_{10}]_{out}) \qquad \text{(S15)}$$

Which simplifies to:

$$PM_{10}\text{ exposure coefficient} = 1 + (t_{in}/t_{out})\,\beta \qquad (5)$$

where "β" has been defined in Equation (S15).

**eTable 1.** Seasonal $PM_{10}$ mortality coefficients for the 7 U.S. regions. Values have been taken from the plots in Figure 3 of Peng et al. (2005).

| **Region** | **$PM_{10}$ mortality coefficients** (%) | | | |
|---|---|---|---|---|
| | **Spring** | **Summer** | **Fall** | **Winter** |
| Northeast | 0.50 | 0.88 | 0.52 | 0.14 |
| Industrial Midwest | 0.21 | 0.37 | 0.18 | 0.02 |
| Southeast | 0.12 | 0.19 | 0.15 | 0.08 |
| Upper Midwest | 0.17 | 0.00 | -0.18 | 0.00 |
| Southwest | 0.00 | -0.01 | -0.02 | 0.00 |
| Northwest | 0.25 | 0.32 | 0.14 | 0.07 |
| Southern California | 0.32 | 0.32 | 0.41 | 0.40 |
| All regions | 0.22 | 0.28 | 0.16 | 0.10 |

## Sensitivity analysis

### *Lower and upper bounds*

We have examined the sensitivity of our results to city-to-city values for fraction of time that cooling occurs ($x_{cool}$), air change rate when windows are open ($\lambda_{window\_open}$), air recirculation rate provided by central AC ($\lambda_{recirc}$), filtration efficiency ($\eta$) of the filter installed in the central AC system, and fraction of time that windows are open in mild weather ($z$). This has been done by examining correlations between "$PM_{10}$ exposure coefficients" and "$PM_{10}$ mortality coefficients" when the former are calculated with what we judge to be reasonable lower and upper limits for these four parameters. The rationales behind the values selected for the lower and upper limits are presented in the following paragraphs.

For $x_{cool}$, the lower bound estimates were calculated by an approach analogous to that described in the *Methods* section to calculate the favored value of $x_{cool}$, but rather than assuming that cooling occurred at temperatures higher than 24 $^{o}$C, we assumed that cooling occurred at temperatures higher than 26 $^{o}$C. This method likely results in an under-prediction, since most people operate AC systems when the temperatures are between 24 and 26 $^{o}$C. For the upper bound, the cutoff temperature was set at 18.3 $^{o}$C; this is the base temperature used by NOAA in their calculation of cooling degree days (CDDs). This method likely results in an over-prediction, since few people operate AC systems when the temperatures are between 18.3 and 24 $^{o}$C.

To bound the air change rate when windows are open ($\lambda_{window\_open}$), we have chosen 1.0 $h^{-1}$ as a lower estimate and 5.0 $h^{-1}$ as an upper estimate. These selected lower and upper limit estimates are based on a study of window opening and measured air change rates by Alevantis and Girman (1989). Alevantis and Girman (1989) suggested that when more than one window is open, "$\lambda_{window\_open}/\lambda_{infilt}$" is roughly 5. "$\lambda_{window\_open}/\lambda_{infilt}$" is the ratio of the air change rate with windows open to the air change rate with windows closed and fans off (for the same wind conditions). We estimated $\lambda_{infilt}$ to be in the range of 0.42 to 0.70 $h^{-1}$. It follows that a reasonable estimate for $\lambda_{window\_open}$ is in the range of 2.1 to 3.5 $h^{-1}$. To further examine the sensitivity of this parameter, we extended the range to 1.0 to 5.0 $h^{-1}$.

To bound the air recirculation rate provided by central AC ($\lambda_{recirc}$) we have chosen 2.0 $h^{-1}$ as a lower estimate and 6.0 $h^{-1}$ as an upper estimate. These bounds are based on the authors' professional judgment.

The lower estimate for the filtration efficiency ($\eta$) was determined as 0%, corresponding to no filter in the central AC system. Lennox Inc. (2011) indicated that the majority of U.S. homes probably use one inch thick "disposable" filters; such filters remove less than 20% of the 3-10 μm particles and an even smaller percentage of particles in the 0.1-3.0 μm size range. Therefore, the upper estimate for the filtration efficiency was set at 20%.

The lower estimate for the fraction of time that windows were open in mild weather ($z$) was set at 0, corresponding to the extreme situation where residents do not open their windows in mild weather. The monthly fraction of time that windows were open in the study conducted by Wallace et al. (2002) included window-opening during hot weather (the summer). In estimating our default value for $z$, we tried to correct for window opening during hot weather. The uncorrected estimate (0.4) is what we are using for the upper estimate of the fraction of time that windows are open in mild weather.

**eTable 2.** Key input parameters for the initially targeted 19 cities. (a) Penetration factor ($P$), surface removal rate constant when windows are open ($k_{sr,open}$), surface removal rate constant when windows are closed ($k_{sr,infilt}$), average infiltration rate when windows are closed ($\lambda_{infilt}$); fraction of residences with central AC ($y$) and ratio of time indoors to time outdoors ($t_{in}/t_{out}$); (b) Monthly fraction of time that cooling occurs ($x_{cool}$); (c) Monthly fraction of time that heating occurs ($x_{heat}$); (d) Monthly fraction of time that the weather is mild ($x_{mild}$).

(a) Penetration factor ($P$), surface removal rate constant when windows are open ($k_{sr,open}$), surface removal rate constant when windows are closed ($k_{sr,infilt}$), average infiltration rate when windows are closed ($\lambda_{infilt}$); fraction of residences with central AC ($y$) and ratio of time indoors to time outdoors ($t_{in}/t_{out}$).

| **City** | $\boldsymbol{P}$ (unitless) | $\boldsymbol{k_{sr,open}}$ $(h^{-1})$ | $\boldsymbol{k_{sr,infilt}}$ $(h^{-1})$ | $\boldsymbol{\lambda_{infilt}}$ $(h^{-1})$ | $\boldsymbol{Y}$ (unitless) | $\boldsymbol{t_{in}/t_{out}}$ (unitless) |
|---|---|---|---|---|---|---|
| Boston | 0.58 | 1.81 | 0.98 | 0.68 | 0.18 | 7.58 |
| New York | 0.59 | 1.76 | 0.94 | 0.62 | 0.10 | 6.74 |
| Washington | 0.58 | 1.78 | 0.96 | 0.54 | 0.82 | 6.66 |
| Worcester | 0.58 | 1.85 | 1.01 | 0.60 | 0.10 | 7.58 |
| Buffalo | 0.64 | 1.35 | 0.68 | 0.70 | 0.43 | 6.74 |
| Chicago | 0.56 | 1.98 | 1.10 | 0.61 | 0.51 | 6.83 |
| Cincinnati | 0.57 | 1.88 | 1.03 | 0.52 | 0.57 | 6.83 |
| St. Louis | 0.57 | 1.91 | 1.05 | 0.58 | 0.80 | 6.27 |
| Atlanta | 0.60 | 1.65 | 0.87 | 0.43 | 0.86 | 6.47 |
| Birmingham | 0.59 | 1.73 | 0.92 | 0.43 | 0.80 | 6.47 |
| Dallas/Ft. W | 0.55 | 2.08 | 1.19 | 0.50 | 0.89 | 6.58 |
| Miami | 0.50 | 2.41 | 1.47 | 0.35 | 0.80 | 6.47 |
| Nashville | 0.57 | 1.88 | 1.03 | 0.51 | 0.83 | 6.47 |
| Minneapolis | 0.54 | 2.14 | 1.23 | 0.60 | 0.80 | 6.83 |
| Corp Chrsti | 0.49 | 2.51 | 1.57 | 0.48 | 0.78 | 6.58 |
| Phoenix | 0.43 | 2.95 | 2.07 | 0.42 | 0.92 | 6.46 |
| Denver | 0.48 | 2.59 | 1.65 | 0.49 | 0.32 | 6.54 |
| Seattle | 0.49 | 2.52 | 1.58 | 0.62 | 0.06 | 5.61 |
| Los Angeles | 0.57 | 1.92 | 1.06 | 0.42 | 0.34 | 6.46 |

(b) Monthly fraction of time that cooling occurs ($x_{cool}$)

| City | $x_{cool}$ (unitless) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| Boston, MA | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.42 | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 |
| New York City, NY | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.58 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 |
| Washington, DC | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.34 | 0.56 | 0.49 | 0.14 | 0.00 | 0.00 | 0.00 |
| Worcester, MA | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 0.38 | 0.00 | 0.00 | 0.00 | 0.00 |
| Buffalo, NY | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 |
| Chicago, IL | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 0.39 | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cincinnati, OH | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.28 | 0.48 | 0.66 | 0.14 | 0.00 | 0.00 | 0.00 |
| St. Louis, MO | 0.00 | 0.00 | 0.00 | 0.00 | 0.31 | 1.00 | 0.76 | 0.31 | 0.25 | 0.00 | 0.00 | 0.00 |
| Atlanta, GA | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 | 0.58 | 0.76 | 0.70 | 0.39 | 0.00 | 0.00 | 0.00 |
| Birmingham, AL | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.56 | 0.74 | 0.94 | 0.44 | 0.00 | 0.00 | 0.00 |
| Dallas/Ft. Wrth, TX | 0.00 | 0.00 | 0.00 | 0.03 | 0.40 | 0.78 | 0.97 | 1.00 | 0.61 | 0.13 | 0.00 | 0.00 |
| Miami, FL | 0.08 | 0.15 | 0.33 | 0.53 | 0.79 | 1.00 | 1.00 | 0.64 | 1.00 | 0.77 | 0.44 | 0.15 |
| Nashville, TN | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.49 | 0.70 | 0.96 | 0.30 | 0.00 | 0.00 | 0.00 |
| Minneapolis, MN | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 | 0.40 | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 |
| Corpus Christi, TX | 0.00 | 0.00 | 0.03 | 0.30 | 0.65 | 0.90 | 0.96 | 1.00 | 0.80 | 0.43 | 0.00 | 0.00 |
| Phoenix, AZ | 0.00 | 0.00 | 0.00 | 0.31 | 0.65 | 1.00 | 1.00 | 0.27 | 0.97 | 0.48 | 0.00 | 0.00 |
| Denver, CO | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.24 | 0.44 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 |
| Seattle, WA | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 |
| Los Angeles, CA | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.71 | 0.10 | 0.00 | 0.00 | 0.00 |

(c) Monthly fraction of time that heating occurs ($x_{heat}$)

| City | $x_{heat}$ (unitless) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| Boston, MA | 1.00 | 1.00 | 1.00 | 1.00 | 0.53 | 0.00 | 0.00 | 0.00 | 0.14 | 0.82 | 1.00 | 1.00 |
| New York City, NY | 1.00 | 1.00 | 1.00 | 0.90 | 0.29 | 0.19 | 0.00 | 0.00 | 0.00 | 0.68 | 1.00 | 1.00 |
| Washington, DC | 1.00 | 1.00 | 1.00 | 0.76 | 0.33 | 0.00 | 0.00 | 0.00 | 0.11 | 0.66 | 1.00 | 1.00 |
| Worcester, MA | 1.00 | 1.00 | 1.00 | 1.00 | 0.64 | 0.21 | 0.00 | 0.00 | 0.44 | 1.00 | 1.00 | 1.00 |
| Buffalo, NY | 1.00 | 1.00 | 1.00 | 1.00 | 0.60 | 0.12 | 0.00 | 0.00 | 0.35 | 1.00 | 1.00 | 1.00 |
| Chicago, IL | 1.00 | 1.00 | 1.00 | 1.00 | 0.59 | 0.14 | 0.00 | 0.00 | 0.26 | 0.81 | 1.00 | 1.00 |
| Cincinnati, OH | 1.00 | 1.00 | 1.00 | 0.79 | 0.41 | 0.03 | 0.00 | 0.00 | 0.19 | 0.65 | 1.00 | 1.00 |
| St. Louis, MO | 1.00 | 1.00 | 1.00 | 0.62 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.54 | 1.00 | 1.00 |
| Atlanta, GA | 1.00 | 1.00 | 0.72 | 0.38 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.31 | 0.78 | 1.00 |
| Birmingham, AL | 1.00 | 1.00 | 0.69 | 0.41 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.34 | 0.76 | 1.00 |
| Dallas/Ft. Wrth, TX | 1.00 | 0.95 | 0.58 | 0.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 0.70 | 1.00 |
| Miami, FL | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Nashville, TN | 1.00 | 1.00 | 0.92 | 0.52 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.46 | 1.00 | 1.00 |
| Minneapolis, MN | 1.00 | 1.00 | 1.00 | 1.00 | 0.49 | 0.06 | 0.00 | 0.00 | 0.40 | 1.00 | 1.00 | 1.00 |
| Corpus Christi, TX | 0.65 | 0.48 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 | 0.55 |
| Phoenix, AZ | 0.72 | 0.54 | 0.34 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.39 | 0.72 |
| Denver, CO | 1.00 | 1.00 | 1.00 | 0.93 | 0.57 | 0.21 | 0.01 | 0.06 | 0.39 | 0.77 | 1.00 | 1.00 |
| Seattle, WA | 1.00 | 1.00 | 1.00 | 0.98 | 0.65 | 0.38 | 0.14 | 0.11 | 0.37 | 0.91 | 1.00 | 1.00 |
| Los Angeles, CA | 0.61 | 0.57 | 0.55 | 0.38 | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.58 |

(d) Monthly fraction of time that the weather is mild ($x_{mild}$)

| City | $x_{mild}$ (unitless) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| Boston, MA | 0.00 | 0.00 | 0.00 | 0.00 | 0.47 | 0.92 | 0.58 | 0.69 | 0.86 | 0.18 | 0.00 | 0.00 |
| New York City, NY | 0.00 | 0.00 | 0.00 | 0.10 | 0.71 | 0.66 | 0.42 | 0.51 | 1.00 | 0.32 | 0.00 | 0.00 |
| Washington, DC | 0.00 | 0.00 | 0.00 | 0.24 | 0.67 | 0.66 | 0.44 | 0.53 | 0.75 | 0.34 | 0.00 | 0.00 |
| Worcester, MA | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.79 | 0.78 | 0.89 | 0.56 | 0.00 | 0.00 | 0.00 |
| Buffalo, NY | 0.00 | 0.00 | 0.00 | 0.00 | 0.40 | 0.88 | 0.75 | 0.85 | 0.65 | 0.00 | 0.00 | 0.00 |
| Chicago, IL | 0.00 | 0.00 | 0.00 | 0.00 | 0.41 | 0.74 | 0.61 | 0.69 | 0.74 | 0.19 | 0.00 | 0.00 |
| Cincinnati, OH | 0.00 | 0.00 | 0.00 | 0.21 | 0.59 | 0.69 | 0.52 | 0.58 | 0.67 | 0.35 | 0.00 | 0.00 |
| St. Louis, MO | 0.00 | 0.00 | 0.00 | 0.38 | 0.69 | 0.00 | 0.24 | 0.34 | 0.75 | 0.46 | 0.00 | 0.00 |
| Atlanta, GA | 0.00 | 0.00 | 0.28 | 0.62 | 0.77 | 0.42 | 0.24 | 0.29 | 0.61 | 0.69 | 0.22 | 0.00 |
| Birmingham, AL | 0.00 | 0.00 | 0.31 | 0.59 | 0.69 | 0.44 | 0.26 | 0.30 | 0.56 | 0.66 | 0.24 | 0.00 |
| Dallas/Ft. Wrth, TX | 0.00 | 0.05 | 0.42 | 0.74 | 0.60 | 0.22 | 0.03 | 0.06 | 0.39 | 0.75 | 0.31 | 0.00 |
| Miami, FL | 0.92 | 0.85 | 0.67 | 0.47 | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 | 0.56 | 0.85 |
| Nashville, TN | 0.00 | 0.00 | 0.08 | 0.48 | 0.78 | 0.51 | 0.30 | 0.36 | 0.70 | 0.54 | 0.00 | 0.00 |
| Minneapolis, MN | 0.00 | 0.00 | 0.00 | 0.00 | 0.51 | 0.76 | 0.60 | 0.73 | 0.60 | 0.00 | 0.00 | 0.00 |
| Corpus Christi, TX | 0.35 | 0.52 | 0.83 | 0.70 | 0.35 | 0.10 | 0.04 | 0.04 | 0.20 | 0.57 | 0.82 | 0.45 |
| Phoenix, AZ | 0.28 | 0.46 | 0.66 | 0.63 | 0.35 | 0.00 | 0.00 | 0.00 | 0.03 | 0.52 | 0.61 | 0.28 |
| Denver, CO | 0.00 | 0.00 | 0.00 | 0.07 | 0.43 | 0.55 | 0.55 | 0.56 | 0.54 | 0.23 | 0.00 | 0.00 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Seattle, WA | 0.00 | 0.00 | 0.00 | 0.02 | 0.35 | 0.63 | 0.86 | 0.89 | 0.63 | 0.09 | 0.00 | 0.00 |
| Los Angeles, CA | 0.39 | 0.43 | 0.45 | 0.63 | 0.83 | 1.00 | 0.99 | 0.87 | 0.90 | 1.00 | 0.64 | 0.42 |

**eTable 3.** Monthly average values of $\Delta[PM_{10}]_{in}/\Delta[PM_{10}]_{out}$ for residences in the 19 initially targeted cities.

| City | $\Delta[PM_{10}]_{in}/\Delta[PM_{10}]_{out}$ (unitless) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| Boston, MA | 0.24 | 0.24 | 0.24 | 0.24 | 0.27 | 0.33 | 0.39 | 0.37 | 0.30 | 0.25 | 0.24 | 0.24 |
| New York City, NY | 0.23 | 0.23 | 0.23 | 0.24 | 0.29 | 0.33 | 0.44 | 0.42 | 0.31 | 0.26 | 0.23 | 0.23 |
| Washington, DC | 0.21 | 0.21 | 0.21 | 0.23 | 0.26 | 0.27 | 0.26 | 0.27 | 0.27 | 0.24 | 0.21 | 0.21 |
| Worcester, MA | 0.22 | 0.22 | 0.22 | 0.22 | 0.24 | 0.28 | 0.34 | 0.32 | 0.26 | 0.22 | 0.22 | 0.22 |
| Buffalo, NY | 0.32 | 0.32 | 0.32 | 0.32 | 0.35 | 0.39 | 0.41 | 0.40 | 0.37 | 0.32 | 0.32 | 0.32 |
| Chicago, IL | 0.20 | 0.20 | 0.20 | 0.20 | 0.23 | 0.27 | 0.30 | 0.30 | 0.26 | 0.21 | 0.20 | 0.20 |
| Cincinnati, OH | 0.19 | 0.19 | 0.19 | 0.21 | 0.24 | 0.29 | 0.30 | 0.30 | 0.27 | 0.22 | 0.19 | 0.19 |
| St. Louis, MO | 0.20 | 0.20 | 0.20 | 0.23 | 0.27 | 0.24 | 0.25 | 0.25 | 0.27 | 0.24 | 0.20 | 0.20 |
| Atlanta, GA | 0.20 | 0.20 | 0.22 | 0.25 | 0.27 | 0.24 | 0.23 | 0.23 | 0.26 | 0.26 | 0.22 | 0.20 |
| Birmingham, AL | 0.19 | 0.19 | 0.21 | 0.24 | 0.26 | 0.25 | 0.24 | 0.24 | 0.26 | 0.25 | 0.21 | 0.19 |
| Dallas/Ft. Wrth, TX | 0.16 | 0.17 | 0.20 | 0.22 | 0.22 | 0.19 | 0.18 | 0.18 | 0.20 | 0.23 | 0.19 | 0.16 |
| Miami, FL | 0.18 | 0.18 | 0.18 | 0.17 | 0.17 | 0.16 | 0.16 | 0.16 | 0.16 | 0.17 | 0.18 | 0.18 |
| Nashville, TN | 0.19 | 0.19 | 0.20 | 0.23 | 0.26 | 0.25 | 0.23 | 0.24 | 0.26 | 0.23 | 0.19 | 0.19 |
| Minneapolis, MN | 0.18 | 0.18 | 0.18 | 0.18 | 0.22 | 0.24 | 0.24 | 0.25 | 0.22 | 0.18 | 0.18 | 0.18 |
| Corpus Christi, TX | 0.14 | 0.16 | 0.19 | 0.19 | 0.19 | 0.18 | 0.18 | 0.18 | 0.19 | 0.19 | 0.18 | 0.15 |
| Phoenix, AZ | 0.10 | 0.11 | 0.13 | 0.13 | 0.12 | 0.09 | 0.09 | 0.09 | 0.10 | 0.13 | 0.12 | 0.10 |
| Denver, CO | 0.11 | 0.11 | 0.11 | 0.12 | 0.15 | 0.21 | 0.26 | 0.25 | 0.17 | 0.13 | 0.11 | 0.11 |
| Seattle, WA | 0.14 | 0.14 | 0.14 | 0.14 | 0.17 | 0.19 | 0.20 | 0.21 | 0.19 | 0.14 | 0.14 | 0.14 |
| Los Angeles, CA | 0.19 | 0.20 | 0.20 | 0.22 | 0.23 | 0.25 | 0.25 | 0.27 | 0.26 | 0.25 | 0.22 | 0.20 |

**eTable 4.** Monthly $PM_{10}$ exposure coefficients for residences in the 19 initially targeted cities.

| City | **$PM_{10}$ exposure coefficients** (unitless) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| Boston, MA | 2.80 | 2.80 | 2.80 | 2.80 | 3.06 | 3.47 | 3.94 | 3.79 | 3.28 | 2.90 | 2.80 | 2.80 |
| New York City, NY | 2.57 | 2.57 | 2.57 | 2.62 | 2.94 | 3.21 | 3.94 | 3.81 | 3.09 | 2.74 | 2.57 | 2.57 |
| Washington, DC | 2.40 | 2.40 | 2.40 | 2.53 | 2.76 | 2.82 | 2.74 | 2.77 | 2.83 | 2.58 | 2.40 | 2.40 |
| Worcester, MA | 2.63 | 2.63 | 2.63 | 2.63 | 2.84 | 3.10 | 3.60 | 3.41 | 2.96 | 2.63 | 2.63 | 2.63 |
| Buffalo, NY | 3.18 | 3.18 | 3.18 | 3.18 | 3.37 | 3.60 | 3.78 | 3.73 | 3.49 | 3.18 | 3.18 | 3.18 |
| Chicago, IL | 2.36 | 2.36 | 2.36 | 2.36 | 2.57 | 2.87 | 3.07 | 3.04 | 2.75 | 2.46 | 2.36 | 2.36 |
| Cincinnati, OH | 2.31 | 2.31 | 2.31 | 2.43 | 2.64 | 2.95 | 3.04 | 3.02 | 2.81 | 2.50 | 2.31 | 2.31 |
| St. Louis, MO | 2.26 | 2.26 | 2.26 | 2.45 | 2.68 | 2.50 | 2.57 | 2.59 | 2.70 | 2.49 | 2.26 | 2.26 |
| Atlanta, GA | 2.29 | 2.29 | 2.45 | 2.64 | 2.75 | 2.58 | 2.49 | 2.51 | 2.67 | 2.68 | 2.41 | 2.29 |
| Birmingham, AL | 2.21 | 2.21 | 2.39 | 2.55 | 2.68 | 2.62 | 2.57 | 2.58 | 2.66 | 2.59 | 2.35 | 2.21 |
| Dallas/Ft. Wrth, TX | 2.07 | 2.09 | 2.30 | 2.48 | 2.43 | 2.26 | 2.17 | 2.19 | 2.34 | 2.49 | 2.23 | 2.07 |
| Miami, FL | 2.19 | 2.18 | 2.15 | 2.12 | 2.07 | 2.04 | 2.04 | 2.04 | 2.04 | 2.08 | 2.13 | 2.18 |
| Nashville, TN | 2.22 | 2.22 | 2.26 | 2.48 | 2.66 | 2.59 | 2.51 | 2.53 | 2.65 | 2.51 | 2.22 | 2.22 |
| Minneapolis, MN | 2.20 | 2.20 | 2.20 | 2.20 | 2.48 | 2.66 | 2.64 | 2.67 | 2.52 | 2.20 | 2.20 | 2.20 |
| Corpus Christi, TX | 1.95 | 2.05 | 2.23 | 2.27 | 2.24 | 2.21 | 2.20 | 2.20 | 2.22 | 2.26 | 2.21 | 2.01 |
| Phoenix, AZ | 1.62 | 1.72 | 1.83 | 1.86 | 1.75 | 1.60 | 1.60 | 1.60 | 1.62 | 1.82 | 1.81 | 1.62 |
| Denver, CO | 1.72 | 1.72 | 1.72 | 1.76 | 1.95 | 2.40 | 2.71 | 2.62 | 2.12 | 1.85 | 1.72 | 1.72 |
| Seattle, WA | 1.77 | 1.77 | 1.77 | 1.78 | 1.93 | 2.04 | 2.15 | 2.16 | 2.05 | 1.81 | 1.77 | 1.77 |
| Los Angeles, CA | 2.26 | 2.28 | 2.29 | 2.39 | 2.51 | 2.61 | 2.62 | 2.73 | 2.70 | 2.61 | 2.40 | 2.28 |

**eTable 5.** Monthly $PM_{10}$ exposure coefficients for residences in the 7 U.S. regions represented by the 19 targeted cities.

| **Regions** | **$PM_{10}$ exposure coefficients** (unitless) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| Northeast | 2.58 | 2.58 | 2.58 | 2.64 | 2.93 | 3.18 | 3.72 | 3.61 | 3.07 | 2.73 | 2.58 | 2.58 |
| Industrial Midwest | 2.40 | 2.40 | 2.40 | 2.45 | 2.66 | 2.87 | 3.03 | 3.00 | 2.80 | 2.52 | 2.40 | 2.40 |
| Southeast | 2.18 | 2.19 | 2.30 | 2.42 | 2.44 | 2.32 | 2.26 | 2.28 | 2.38 | 2.43 | 2.26 | 2.18 |
| Upper Midwest | 2.20 | 2.20 | 2.20 | 2.20 | 2.48 | 2.66 | 2.64 | 2.67 | 2.52 | 2.20 | 2.20 | 2.20 |
| Southwest | 1.66 | 1.76 | 1.87 | 1.90 | 1.80 | 1.66 | 1.66 | 1.66 | 1.68 | 1.86 | 1.85 | 1.66 |
| Northwest | 1.75 | 1.75 | 1.75 | 1.77 | 1.94 | 2.19 | 2.39 | 2.36 | 2.08 | 1.83 | 1.75 | 1.75 |
| Southern California | 2.26 | 2.28 | 2.29 | 2.39 | 2.51 | 2.61 | 2.62 | 2.73 | 2.70 | 2.61 | 2.40 | 2.28 |
| All regions | 2.31 | 2.32 | 2.35 | 2.42 | 2.59 | 2.71 | 2.92 | 2.90 | 2.68 | 2.50 | 2.35 | 2.31 |

**eTable 6.** Key input parameters and calculated results for 83 cities. (a) Key input parameters; (b) Monthly fraction of time that cooling occurs ($x_{cool}$); (c) Monthly fraction of time that heating occurs ($x_{heat}$); (d) Monthly fraction of time that the weather is mild ($x_{mild}$); (e) Monthly average values of $\Delta[PM_{10}]_{in}/\Delta[PM_{10}]_{out}$ (f) Monthly $PM_{10}$ exposure coefficients; (g) Monthly $PM_{10}$ exposure coefficients for 7 regions represented by 83 NMMAPS cities.

(a) Key input parameters: infiltration rates ($\lambda_{infilt}$), penetration factor ($P$), surface removal rate constant when windows are open ($k_{sr,open}$), surface removal rate constant when windows are closed ($k_{sr,infilt}$), cooling degree days ($CDD$), and fraction of residences with central AC ( $y$).

| **City** | $\lambda_{infilt}$ ($h^{-1}$) | ***P*** *(unitless)* | $k_{sr,open}$ ($h^{-1}$) | $k_{sr,infilt}$ ($h^{-1}$) | ***CDD*** *(day $^{o}$C)* | ***y*** *(unitless)* | ***Population*** |
|---|---|---|---|---|---|---|---|
| **Northeast** | | | | | | | |
| Arlington | 0.54 | 0.63 | 1.39 | 0.70 | 1560 | 0.64 | 207,627 |
| Baltimore | 0.54 | 0.57 | 1.90 | 1.05 | 1220 | 0.64 | 2,639,213 |
| Boston | 0.68 | 0.58 | 1.81 | 0.98 | 777 | 0.18 | 4,424,649 |
| Washington | 0.54 | 0.58 | 1.78 | 0.96 | 1560 | 0.82 | 5,139,549 |
| Jersey City | 0.62 | 0.60 | 1.69 | 0.90 | 882 | 0.14 | 247,597 |
| Kingston | 0.62 | 0.59 | 1.76 | 0.94 | 220 | 0.20 | 177,749 |
| New York | 0.62 | 0.59 | 1.76 | 0.94 | 1160 | 0.10 | 18,709,802 |
| Newark | 0.62 | 0.55 | 2.07 | 1.18 | 1220 | 0.25 | 277,140 |
| Norfolk | 0.54 | 0.59 | 1.77 | 0.95 | 1560 | 0.54 | 242,803 |
| Philadelphia | 0.62 | 0.51 | 2.37 | 1.43 | 1235 | 0.47 | 5,800,614 |
| Providence | 0.68 | 0.51 | 2.35 | 1.42 | 714 | 0.19 | 1,628,808 |
| Richmond | 0.54 | 0.61 | 1.56 | 0.81 | 1466 | 0.82 | 1,154,317 |
| Rochester | 0.70 | 0.60 | 1.65 | 0.87 | 577 | 0.35 | 1,041,499 |
| Syracuse | 0.70 | 0.53 | 2.24 | 1.31 | 551 | 0.20 | 653,988 |
| Worcester | 0.60 | 0.58 | 1.85 | 1.01 | 371 | 0.10 | 779,488 |
| **Industrial Midwest** | | | | | | | |
| Akron | 0.61 | 0.60 | 1.64 | 0.86 | 679 | 0.38 | 702,078 |
| Buffalo | 0.70 | 0.64 | 1.35 | 0.68 | 548 | 0.43 | 1,154,378 |
| Chicago | 0.61 | 0.56 | 1.98 | 1.10 | 835 | 0.51 | 9,391,515 |
| Cincinnati | 0.52 | 0.57 | 1.88 | 1.03 | 1210 | 0.57 | 2,058,221 |
| Cleveland | 0.61 | 0.53 | 2.18 | 1.27 | 712 | 0.43 | 2,137,073 |
| Columbus | 0.61 | 0.60 | 1.68 | 0.89 | 2297 | 0.86 | 1,693,906 |
| Dayton | 0.61 | 0.60 | 1.67 | 0.88 | 935 | 0.38 | 845,646 |
| Detroit | 0.61 | 0.55 | 2.07 | 1.17 | 695 | 0.57 | 4,493,165 |
| Evansville | 0.52 | 0.57 | 1.91 | 1.06 | 1422 | 0.79 | 348,454 |
| Fort Wayne | 0.61 | 0.62 | 1.48 | 0.76 | 830 | 0.52 | 253,691 |
| Grand Rapids | 0.61 | 0.59 | 1.76 | 0.94 | 613 | 0.52 | 767,539 |
| Indianapolis | 0.52 | 0.58 | 1.83 | 0.99 | 1042 | 0.78 | 1,621,613 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Lexington | 0.51 | 0.64 | 1.32 | 0.66 | 1154 | 0.68 | 424,661 |
| Louisville | 0.51 | 0.58 | 1.79 | 0.96 | 1443 | 0.68 | 1,200,847 |
| Madison | 0.61 | 0.58 | 1.79 | 0.96 | 582 | 0.45 | 531,766 |
| Pittsburgh | 0.70 | 0.56 | 1.93 | 1.07 | 726 | 0.48 | 2,401,575 |
| St. Louis | 0.58 | 0.57 | 1.91 | 1.05 | 1561 | 0.80 | 2,764,054 |
| Toledo | 0.61 | 0.58 | 1.79 | 0.97 | 715 | 0.50 | 658,236 |
| **Southeast** | | | | | | | |
| Atlanta | 0.43 | 0.60 | 1.65 | 0.87 | 1810 | 0.86 | 4,708,297 |
| Baton Rouge | 0.50 | 0.57 | 1.88 | 1.03 | 2652 | 0.77 | 728,731 |
| Birmingham | 0.43 | 0.59 | 1.73 | 0.92 | 1881 | 0.80 | 1,082,193 |
| Charlotte | 0.54 | 0.60 | 1.65 | 0.87 | 1644 | 0.79 | 1,474,734 |
| Dallas/Ft. Wrth | 0.50 | 0.55 | 2.08 | 1.19 | 2571 | 0.89 | 5,700,256 |
| Greensboro | 0.54 | 0.61 | 1.56 | 0.81 | 1332 | 0.79 | 667,542 |
| Houston | 0.50 | 0.55 | 2.08 | 1.18 | 2893 | 0.84 | 5,180,443 |
| Huntsville | 0.51 | 0.64 | 1.36 | 0.69 | 1671 | 0.80 | 362,459 |
| Jackson | 0.43 | 0.61 | 1.56 | 0.81 | 2290 | 0.65 | 517,275 |
| Jacksonville | 0.43 | 0.51 | 2.32 | 1.39 | 2636 | 0.84 | 1,225,381 |
| Knoxville | 0.51 | 0.59 | 1.73 | 0.92 | 1450 | 0.81 | 647,170 |
| Little Rock | 0.50 | 0.58 | 1.84 | 1.00 | 2086 | 0.86 | 636,636 |
| Memphis | 0.51 | 0.57 | 1.88 | 1.03 | 2190 | 0.78 | 1,250,293 |
| Miami | 0.35 | 0.50 | 2.41 | 1.47 | 4383 | 0.80 | 5,361,723 |
| Nashville | 0.51 | 0.57 | 1.88 | 1.03 | 1656 | 0.83 | 1,395,879 |
| New Orleans | 0.48 | 0.59 | 1.71 | 0.91 | 2776 | 0.70 | 1,319,589 |
| Orlando | 0.35 | 0.58 | 1.81 | 0.98 | 3457 | 0.93 | 1,861,707 |
| Raleigh | 0.54 | 0.63 | 1.42 | 0.72 | 1521 | 0.85 | 914,680 |
| Shreveport | 0.50 | 0.58 | 1.78 | 0.96 | 2396 | 0.65 | 381,817 |
| St. Petersburg | 0.35 | 0.55 | 2.05 | 1.16 | 3718 | 0.87 | 2,733,761 |
| Tampa | 0.35 | 0.55 | 2.07 | 1.18 | 3481 | 0.87 | 2,587,967 |
| Tulsa | 0.50 | 0.54 | 2.09 | 1.19 | 2049 | 0.82 | 881,815 |
| **Upper Midwest** | | | | | | | |
| Minneapolis | 0.60 | 0.54 | 2.14 | 1.23 | 699 | 0.80 | 3,116,206 |
| **Southwest** | | | | | | | |
| Albuquerque | 0.49 | 0.42 | 3.04 | 2.19 | 1290 | 0.54 | 781,447 |
| Austin | 0.50 | 0.53 | 2.16 | 1.25 | 2974 | 0.91 | 1,412,271 |
| Corpus Christi | 0.48 | 0.49 | 2.51 | 1.57 | 3498 | 0.78 | 409,741 |
| El Paso | 0.50 | 0.42 | 3.03 | 2.17 | 2165 | 0.81 | 713,126 |
| Lubbock | 0.50 | 0.44 | 2.87 | 1.96 | 1777 | 0.89 | 257,663 |
| Oklahoma City | 0.50 | 0.51 | 2.37 | 1.44 | 1907 | 0.81 | 1,144,327 |
| Phoenix | 0.42 | 0.43 | 2.95 | 2.07 | 4189 | 0.92 | 3,715,360 |
| San Antonio | 0.48 | 0.53 | 2.23 | 1.31 | 3038 | 0.69 | 1,854,050 |
| **Northwest** | | | | | | | |
| Colorado Sprg | 0.49 | 0.45 | 2.85 | 1.94 | 443 | 0.18 | 576,251 |
| Denver | 0.49 | 0.48 | 2.59 | 1.65 | 695 | 0.32 | 2,330,146 |
| Modesto | 0.42 | 0.53 | 2.17 | 1.26 | 1570 | 0.90 | 498,355 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Oakland | 0.42 | 0.56 | 1.98 | 1.10 | 530 | 0.27 | 390,724 |
| Olympia | 0.62 | 0.50 | 2.42 | 1.49 | 192 | 0.06 | 46,478 |
| Sacramento | 0.42 | 0.63 | 1.39 | 0.70 | 1248 | 0.80 | 2,016,702 |
| Salt Lake City | 0.49 | 0.46 | 2.73 | 1.81 | 1089 | 0.38 | 1,018,826 |
| San Jose | 0.42 | 0.58 | 1.81 | 0.98 | 811 | 0.31 | 1,741,431 |
| Seattle | 0.62 | 0.49 | 2.52 | 1.58 | 192 | 0.06 | 3,166,828 |
| Spokane | 0.62 | 0.44 | 2.88 | 1.98 | 394 | 0.37 | 435,644 |
| Stockton | 0.42 | 0.54 | 2.08 | 1.19 | 1456 | 0.71 | 649,868 |
| Tacoma | 0.62 | 0.52 | 2.30 | 1.38 | 167 | 0.07 | 3,500,900 |
| **Southern California** | | | | | | | |
| Bakersfield | 0.42 | 0.54 | 2.08 | 1.19 | 2304 | 0.73 | 734,846 |
| Fresno | 0.42 | 0.51 | 2.34 | 1.40 | 1991 | 0.80 | 866,772 |
| Los Angeles | 0.42 | 0.57 | 1.92 | 1.06 | 1506 | 0.34 | 12,925,330 |
| Riverside | 0.42 | 0.54 | 2.10 | 1.20 | 1697 | 0.73 | 3,793,081 |
| San Bernardino | 0.42 | 0.45 | 2.86 | 1.95 | 1937 | 0.73 | 4,026,135 |
| San Diego | 0.42 | 0.55 | 2.03 | 1.14 | 866 | 0.30 | 2,931,714 |
| Santa Anaheim | 0.42 | 0.53 | 2.22 | 1.30 | 1294 | 0.34 | 717,914 |

(b) Monthly fraction of time that cooling occurs ($x_{cool}$).

| **City** | $x_{cool}$ (unitless) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| **Northeast** | | | | | | | | | | | | |
| Arlington | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.38 | 0.56 | 0.49 | 0.22 | 0.00 | 0.00 | 0.00 |
| Baltimore | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.59 | 0.86 | 0.75 | 0.33 | 0.00 | 0.00 | 0.00 |
| Boston | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.42 | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 |
| Washington | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.34 | 0.56 | 0.47 | 0.14 | 0.00 | 0.00 | 0.00 |
| Jersey City | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 | 0.50 | 0.39 | 0.00 | 0.00 | 0.00 | 0.00 |
| Kingston | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 |
| New York | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.58 | 0.49 | 0.00 | 0.00 | 0.00 | 0.00 |
| Newark | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.30 | 0.62 | 0.52 | 0.03 | 0.00 | 0.00 | 0.00 |
| Norfolk | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.46 | 0.75 | 0.65 | 0.29 | 0.00 | 0.00 | 0.00 |
| Philadelphia | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.65 | 0.57 | 0.09 | 0.00 | 0.00 | 0.00 |
| Providence | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.40 | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 |
| Richmond | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.41 | 0.64 | 0.56 | 0.23 | 0.00 | 0.00 | 0.00 |
| Rochester | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.29 | 0.19 | 0.00 | 0.00 | 0.00 | 0.00 |
| Syracuse | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.30 | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 |
| Worcester | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Industrial Midwest** | | | | | | | | | | | | |
| Akron | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 | 0.44 | 0.34 | 0.00 | 0.00 | 0.00 | 0.00 |
| Buffalo | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 |
| Chicago | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 0.39 | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cincinnati | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.28 | 0.48 | 0.42 | 0.14 | 0.00 | 0.00 | 0.00 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cleveland | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.32 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 |
| Columbus | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.31 | 0.50 | 0.42 | 0.09 | 0.00 | 0.00 | 0.00 |
| Dayton | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.45 | 0.35 | 0.02 | 0.00 | 0.00 | 0.00 |
| Detroit | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.49 | 0.39 | 0.00 | 0.00 | 0.00 | 0.00 |
| Evansville | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.48 | 0.66 | 0.56 | 0.25 | 0.00 | 0.00 | 0.00 |
| Fort Wayne | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.42 | 0.31 | 0.01 | 0.00 | 0.00 | 0.00 |
| Grand Rapids | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 | 0.33 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 |
| Indianapolis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.51 | 0.42 | 0.10 | 0.00 | 0.00 | 0.00 |
| Lexington | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.35 | 0.55 | 0.48 | 0.14 | 0.00 | 0.00 | 0.00 |
| Louisville | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.45 | 0.69 | 0.60 | 0.23 | 0.00 | 0.00 | 0.00 |
| Madison | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 | 0.33 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pittsburgh | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 | 0.37 | 0.29 | 0.00 | 0.00 | 0.00 | 0.00 |
| St. Louis | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 1.00 | 0.76 | 0.66 | 0.25 | 0.00 | 0.00 | 0.00 |
| Toledo | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.39 | 0.29 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Southeast** | | | | | | | | | | | | |
| Atlanta | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 | 0.58 | 0.76 | 0.71 | 0.39 | 0.00 | 0.00 | 0.00 |
| Baton Rouge | 0.00 | 0.00 | 0.00 | 0.10 | 0.44 | 0.74 | 0.86 | 0.83 | 0.61 | 0.19 | 0.00 | 0.00 |
| Birmingham | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.56 | 0.74 | 0.70 | 0.44 | 0.00 | 0.00 | 0.00 |
| Charlotte | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.57 | 0.76 | 0.69 | 0.37 | 0.00 | 0.00 | 0.00 |
| Dallas/Ft. Wrth | 0.00 | 0.00 | 0.00 | 0.03 | 0.40 | 0.78 | 0.97 | 0.94 | 0.61 | 0.13 | 0.00 | 0.00 |
| Greensboro | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.42 | 0.64 | 0.56 | 0.22 | 0.00 | 0.00 | 0.00 |
| Houston | 0.00 | 0.00 | 0.00 | 0.18 | 0.53 | 0.82 | 0.92 | 0.89 | 0.67 | 0.29 | 0.00 | 0.00 |
| Huntsville | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.54 | 0.71 | 0.66 | 0.37 | 0.00 | 0.00 | 0.00 |
| Jackson | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.66 | 0.77 | 0.77 | 0.51 | 0.06 | 0.00 | 0.00 |
| Jacksonville | 0.00 | 0.00 | 0.00 | 0.14 | 0.42 | 0.70 | 0.85 | 0.83 | 0.65 | 0.20 | 0.00 | 0.00 |
| Knoxville | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.43 | 0.64 | 0.59 | 0.28 | 0.00 | 0.00 | 0.00 |
| Little Rock | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 | 0.65 | 0.85 | 0.78 | 0.46 | 0.00 | 0.00 | 0.00 |
| Memphis | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 | 0.68 | 0.88 | 0.80 | 0.48 | 0.00 | 0.00 | 0.00 |
| Miami | 0.08 | 0.15 | 0.33 | 0.53 | 0.79 | 1.00 | 1.00 | 1.00 | 1.00 | 0.77 | 0.44 | 0.15 |
| Nashville | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.49 | 0.70 | 0.64 | 0.31 | 0.00 | 0.00 | 0.00 |
| New Orleans | 0.00 | 0.00 | 0.00 | 0.14 | 0.52 | 0.82 | 0.94 | 0.92 | 0.72 | 0.23 | 0.00 | 0.00 |
| Orlando | 0.00 | 0.00 | 0.16 | 0.34 | 0.58 | 0.80 | 0.87 | 0.88 | 0.82 | 0.50 | 0.18 | 0.00 |
| Raleigh | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.47 | 0.67 | 0.60 | 0.30 | 0.00 | 0.00 | 0.00 |
| Shreveport | 0.00 | 0.00 | 0.00 | 0.06 | 0.39 | 0.73 | 0.91 | 0.86 | 0.58 | 0.13 | 0.00 | 0.00 |
| St. Petersburg | 0.00 | 0.00 | 0.00 | 0.31 | 0.71 | 1.00 | 1.00 | 1.00 | 1.00 | 0.60 | 0.10 | 0.00 |
| Tampa | 0.00 | 0.00 | 0.06 | 0.30 | 0.64 | 0.92 | 1.00 | 1.00 | 0.94 | 0.54 | 0.16 | 0.00 |
| Tulsa | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.64 | 0.90 | 0.82 | 0.42 | 0.00 | 0.00 | 0.00 |
| **Upper Midwest** | | | | | | | | | | | | |
| Minneapolis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 | 0.40 | 0.27 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Southwest** | | | | | | | | | | | | |
| Albuquerque | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.49 | 0.62 | 0.53 | 0.27 | 0.00 | 0.00 | 0.00 |
| Austin | 0.00 | 0.00 | 0.00 | 0.17 | 0.49 | 0.79 | 0.92 | 0.91 | 0.70 | 0.29 | 0.00 | 0.00 |
| Corpus Christi | 0.00 | 0.00 | 0.03 | 0.30 | 0.65 | 0.90 | 0.96 | 0.96 | 0.80 | 0.43 | 0.00 | 0.00 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| El Paso | 0.00 | 0.00 | 0.00 | 0.11 | 0.44 | 0.76 | 0.86 | 0.77 | 0.51 | 0.10 | 0.00 | 0.00 |
| Lubbock | 0.00 | 0.00 | 0.00 | 0.00 | 0.28 | 0.57 | 0.69 | 0.62 | 0.33 | 0.00 | 0.00 | 0.00 |
| Oklahoma City | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 | 0.58 | 0.80 | 0.76 | 0.41 | 0.00 | 0.00 | 0.00 |
| Phoenix | 0.00 | 0.00 | 0.00 | 0.31 | 0.65 | 1.00 | 1.00 | 1.00 | 0.97 | 0.48 | 0.00 | 0.00 |
| San Antonio | 0.00 | 0.00 | 0.00 | 0.22 | 0.53 | 0.82 | 0.94 | 0.92 | 0.70 | 0.30 | 0.00 | 0.00 |
| **Northwest** | | | | | | | | | | | | |
| Colorado Spg | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.31 | 0.23 | 0.00 | 0.00 | 0.00 | 0.00 |
| Denver | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.24 | 0.44 | 0.38 | 0.07 | 0.00 | 0.00 | 0.00 |
| Modesto | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 | 0.45 | 0.58 | 0.55 | 0.43 | 0.12 | 0.00 | 0.00 |
| Oakland | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.15 | 0.17 | 0.14 | 0.00 | 0.00 | 0.00 |
| Olympia | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sacramento | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.38 | 0.50 | 0.49 | 0.39 | 0.11 | 0.00 | 0.00 |
| Salt Lake City | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 | 0.57 | 0.51 | 0.10 | 0.00 | 0.00 | 0.00 |
| San Jose | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.25 | 0.34 | 0.33 | 0.27 | 0.03 | 0.00 | 0.00 |
| Seattle | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Spokane | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.26 | 0.26 | 0.00 | 0.00 | 0.00 | 0.00 |
| Stockton | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.44 | 0.56 | 0.54 | 0.42 | 0.12 | 0.00 | 0.00 |
| Tacoma | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Southern California** | | | | | | | | | | | | |
| Bakersfield | 0.00 | 0.00 | 0.00 | 0.02 | 0.32 | 0.59 | 0.78 | 0.75 | 0.56 | 0.17 | 0.00 | 0.00 |
| Fresno | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 | 0.53 | 0.70 | 0.66 | 0.48 | 0.11 | 0.00 | 0.00 |
| Los Angeles | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.13 | 0.10 | 0.00 | 0.00 | 0.00 |
| Riverside | 0.00 | 0.00 | 0.00 | 0.04 | 0.19 | 0.43 | 0.61 | 0.64 | 0.53 | 0.27 | 0.00 | 0.00 |
| San Bernardino | 0.00 | 0.00 | 0.00 | 0.05 | 0.22 | 0.46 | 0.63 | 0.65 | 0.53 | 0.27 | 0.00 | 0.00 |
| San Diego | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.28 | 0.35 | 0.28 | 0.09 | 0.00 | 0.00 |
| Santa Anaheim | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.19 | 0.38 | 0.45 | 0.40 | 0.21 | 0.00 | 0.00 |

(c) Monthly fraction of time that heating occurs ($x_{heat}$)

| **City** | $x_{heat}$ (unitless) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| **Northeast** | | | | | | | | | | | | |
| Arlington | 1.00 | 1.00 | 1.00 | 0.65 | 0.32 | 0.00 | 0.00 | 0.00 | 0.17 | 0.60 | 1.00 | 1.00 |
| Baltimore | 1.00 | 1.00 | 1.00 | 0.55 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.41 | 1.00 | 1.00 |
| Boston | 1.00 | 1.00 | 1.00 | 1.00 | 0.53 | 0.00 | 0.00 | 0.00 | 0.14 | 0.82 | 1.00 | 1.00 |
| Washington | 1.00 | 1.00 | 1.00 | 0.76 | 0.33 | 0.00 | 0.00 | 0.00 | 0.11 | 0.66 | 1.00 | 1.00 |
| Jersey City | 1.00 | 1.00 | 1.00 | 1.00 | 0.40 | 0.00 | 0.00 | 0.00 | 0.06 | 0.76 | 1.00 | 1.00 |
| Kingston | 1.00 | 1.00 | 1.00 | 1.00 | 0.68 | 0.34 | 0.18 | 0.23 | 0.54 | 0.98 | 1.00 | 1.00 |
| New York | 1.00 | 1.00 | 1.00 | 0.90 | 0.29 | 0.19 | 0.00 | 0.00 | 0.00 | 0.68 | 1.00 | 1.00 |
| Newark | 1.00 | 1.00 | 1.00 | 0.89 | 0.28 | 0.00 | 0.00 | 0.00 | 0.00 | 0.65 | 1.00 | 1.00 |
| Norfolk | 1.00 | 1.00 | 1.00 | 0.58 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.37 | 0.89 | 1.00 |
| Philadelphia | 1.00 | 1.00 | 1.00 | 0.83 | 0.24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.61 | 1.00 | 1.00 |
| Providence | 1.00 | 1.00 | 1.00 | 1.00 | 0.52 | 0.06 | 0.00 | 0.00 | 0.24 | 0.80 | 1.00 | 1.00 |
| Richmond | 1.00 | 1.00 | 1.00 | 0.58 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.53 | 0.97 | 1.00 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rochester | 1.00 | 1.00 | 1.00 | 1.00 | 0.59 | 0.19 | 0.00 | 0.01 | 0.39 | 0.96 | 1.00 | 1.00 |
| Syracuse | 1.00 | 1.00 | 1.00 | 1.00 | 0.58 | 0.20 | 0.00 | 0.01 | 0.39 | 0.96 | 1.00 | 1.00 |
| Worcester | 1.00 | 1.00 | 1.00 | 1.00 | 0.64 | 0.21 | 0.00 | 0.00 | 0.44 | 1.00 | 1.00 | 1.00 |
| **Industrial Midwest** | | | | | | | | | | | | |
| Akron | 1.00 | 1.00 | 1.00 | 0.95 | 0.39 | 0.00 | 0.00 | 0.00 | 0.16 | 0.82 | 1.00 | 1.00 |
| Buffalo | 1.00 | 1.00 | 1.00 | 1.00 | 0.60 | 0.12 | 0.00 | 0.00 | 0.35 | 1.00 | 1.00 | 1.00 |
| Chicago | 1.00 | 1.00 | 1.00 | 1.00 | 0.59 | 0.14 | 0.00 | 0.00 | 0.26 | 0.81 | 1.00 | 1.00 |
| Cincinnati | 1.00 | 1.00 | 1.00 | 0.79 | 0.41 | 0.03 | 0.00 | 0.00 | 0.19 | 0.65 | 1.00 | 1.00 |
| Cleveland | 1.00 | 1.00 | 1.00 | 1.00 | 0.53 | 0.07 | 0.00 | 0.00 | 0.26 | 0.89 | 1.00 | 1.00 |
| Columbus | 1.00 | 1.00 | 1.00 | 0.82 | 0.33 | 0.00 | 0.00 | 0.00 | 0.15 | 0.70 | 1.00 | 1.00 |
| Dayton | 1.00 | 1.00 | 1.00 | 0.92 | 0.39 | 0.00 | 0.00 | 0.00 | 0.21 | 0.78 | 1.00 | 1.00 |
| Detroit | 1.00 | 1.00 | 1.00 | 1.00 | 0.40 | 0.00 | 0.00 | 0.00 | 0.15 | 0.81 | 1.00 | 1.00 |
| Evansville | 1.00 | 1.00 | 1.00 | 0.65 | 0.22 | 0.00 | 0.00 | 0.00 | 0.08 | 0.57 | 1.00 | 1.00 |
| Fort Wayne | 1.00 | 1.00 | 1.00 | 0.96 | 0.44 | 0.01 | 0.00 | 0.00 | 0.27 | 0.81 | 1.00 | 1.00 |
| Grand Rapids | 1.00 | 1.00 | 1.00 | 1.00 | 0.54 | 0.14 | 0.00 | 0.00 | 0.39 | 0.97 | 1.00 | 1.00 |
| Indianapolis | 1.00 | 1.00 | 1.00 | 0.82 | 0.33 | 0.00 | 0.00 | 0.00 | 0.17 | 0.70 | 1.00 | 1.00 |
| Lexington | 1.00 | 1.00 | 1.00 | 0.71 | 0.26 | 0.00 | 0.00 | 0.00 | 0.05 | 0.61 | 1.00 | 1.00 |
| Louisville | 1.00 | 1.00 | 1.00 | 0.63 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.53 | 1.00 | 1.00 |
| Madison | 1.00 | 1.00 | 1.00 | 1.00 | 0.56 | 0.15 | 0.00 | 0.01 | 0.42 | 0.97 | 1.00 | 1.00 |
| Pittsburgh | 1.00 | 1.00 | 1.00 | 0.92 | 0.45 | 0.06 | 0.00 | 0.00 | 0.25 | 0.83 | 1.00 | 1.00 |
| St. Louis | 1.00 | 1.00 | 1.00 | 0.62 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.54 | 1.00 | 1.00 |
| Toledo | 1.00 | 1.00 | 1.00 | 1.00 | 0.47 | 0.04 | 0.00 | 0.00 | 0.29 | 0.85 | 1.00 | 1.00 |
| **Southeast** | | | | | | | | | | | | |
| Atlanta | 1.00 | 1.00 | 0.72 | 0.38 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.31 | 0.78 | 1.00 |
| Baton Rouge | 0.95 | 0.76 | 0.44 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.50 | 0.82 |
| Birmingham | 1.00 | 1.00 | 0.69 | 0.41 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.34 | 0.76 | 1.00 |
| Charlotte | 1.00 | 1.00 | 0.77 | 0.42 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.37 | 0.82 | 1.00 |
| Dallas/Ft. Wrth | 1.00 | 0.95 | 0.58 | 0.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 0.70 | 1.00 |
| Greensboro | 1.00 | 1.00 | 0.94 | 0.56 | 0.19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.52 | 0.96 | 1.00 |
| Houston | 0.84 | 0.66 | 0.35 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.41 | 0.74 |
| Huntsville | 1.00 | 1.00 | 0.80 | 0.44 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.40 | 0.88 | 1.00 |
| Jackson | 1.00 | 0.94 | 0.60 | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.28 | 0.68 | 1.00 |
| Jacksonville | 0.77 | 0.64 | 0.39 | 0.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.38 | 0.69 |
| Knoxville | 1.00 | 1.00 | 0.94 | 0.55 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.51 | 1.00 | 1.00 |
| Little Rock | 1.00 | 1.00 | 0.76 | 0.39 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.32 | 0.85 | 1.00 |
| Memphis | 1.00 | 1.00 | 0.78 | 0.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.29 | 0.84 | 1.00 |
| Miami | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Nashville | 1.00 | 1.00 | 0.92 | 0.52 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.46 | 1.00 | 1.00 |
| New Orleans | 0.85 | 0.67 | 0.32 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.38 | 0.71 |
| Orlando | 0.42 | 0.34 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.31 |
| Raleigh | 1.00 | 1.00 | 0.85 | 0.50 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.46 | 0.85 | 1.00 |
| Shreveport | 1.00 | 0.86 | 0.52 | 0.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.64 | 1.00 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| St. Petersburg | 0.33 | 0.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 |
| Tampa | 0.37 | 0.29 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 |
| Tulsa | 1.00 | 1.00 | 0.85 | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.34 | 0.95 | 1.00 |
| **Upper Midwest** | | | | | | | | | | | | |
| Minneapolis | 1.00 | 1.00 | 1.00 | 1.00 | 0.49 | 0.06 | 0.00 | 0.00 | 0.40 | 1.00 | 1.00 | 1.00 |
| **Southwest** | | | | | | | | | | | | |
| Albuquerque | 1.00 | 1.00 | 0.88 | 0.61 | 0.31 | 0.00 | 0.00 | 0.00 | 0.11 | 0.57 | 1.00 | 1.00 |
| Austin | 0.94 | 0.71 | 0.38 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.47 | 0.84 |
| Corpus Christi | 0.65 | 0.48 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 | 0.55 |
| El Paso | 1.00 | 0.83 | 0.58 | 0.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.28 | 0.75 | 1.00 |
| Lubbock | 1.00 | 1.00 | 0.76 | 0.46 | 0.13 | 0.00 | 0.00 | 0.00 | 0.02 | 0.44 | 0.90 | 1.00 |
| Oklahoma City | 1.00 | 1.00 | 0.85 | 0.47 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.37 | 0.97 | 1.00 |
| Phoenix | 0.72 | 0.54 | 0.34 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.39 | 0.72 |
| San Antonio | 0.87 | 0.67 | 0.37 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.46 | 0.78 |
| **Northwest** | | | | | | | | | | | | |
| Colorado Spg | 1.00 | 1.00 | 1.00 | 0.99 | 0.66 | 0.32 | 0.14 | 0.19 | 0.47 | 0.85 | 1.00 | 1.00 |
| Denver | 1.00 | 1.00 | 1.00 | 0.93 | 0.57 | 0.21 | 0.01 | 0.06 | 0.39 | 0.77 | 1.00 | 1.00 |
| Modesto | 1.00 | 0.83 | 0.60 | 0.39 | 0.19 | 0.01 | 0.00 | 0.00 | 0.03 | 0.26 | 0.74 | 1.00 |
| Oakland | 1.00 | 0.85 | 0.69 | 0.50 | 0.33 | 0.16 | 0.06 | 0.03 | 0.07 | 0.26 | 0.69 | 1.00 |
| Olympia | 1.00 | 1.00 | 1.00 | 1.00 | 0.75 | 0.53 | 0.35 | 0.35 | 0.53 | 0.93 | 1.00 | 1.00 |
| Sacramento | 1.00 | 0.92 | 0.72 | 0.51 | 0.28 | 0.11 | 0.02 | 0.03 | 0.10 | 0.30 | 0.78 | 1.00 |
| Salt Lake City | 1.00 | 1.00 | 1.00 | 0.91 | 0.51 | 0.12 | 0.00 | 0.00 | 0.26 | 0.78 | 1.00 | 1.00 |
| San Jose | 0.98 | 0.77 | 0.61 | 0.45 | 0.29 | 0.14 | 0.06 | 0.05 | 0.09 | 0.28 | 0.68 | 1.00 |
| Seattle | 1.00 | 1.00 | 1.00 | 0.98 | 0.65 | 0.38 | 0.14 | 0.11 | 0.37 | 0.91 | 1.00 | 1.00 |
| Spokane | 1.00 | 1.00 | 1.00 | 1.00 | 0.69 | 0.40 | 0.16 | 0.16 | 0.49 | 1.00 | 1.00 | 1.00 |
| Stockton | 1.00 | 0.89 | 0.68 | 0.46 | 0.24 | 0.05 | 0.00 | 0.00 | 0.05 | 0.30 | 0.77 | 1.00 |
| Tacoma | 1.00 | 1.00 | 1.00 | 0.93 | 0.63 | 0.38 | 0.19 | 0.19 | 0.40 | 0.86 | 1.00 | 1.00 |
| **Southern California** | | | | | | | | | | | | |
| Bakersfield | 1.00 | 0.78 | 0.58 | 0.36 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.70 | 1.00 |
| Fresno | 1.00 | 0.88 | 0.67 | 0.41 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 | 0.81 | 1.00 |
| Los Angeles | 0.61 | 0.57 | 0.55 | 0.38 | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.58 |
| Riverside | 0.65 | 0.58 | 0.52 | 0.36 | 0.18 | 0.01 | 0.00 | 0.00 | 0.00 | 0.16 | 0.46 | 0.64 |
| San Bernardino | 0.68 | 0.61 | 0.54 | 0.37 | 0.19 | 0.03 | 0.00 | 0.00 | 0.00 | 0.18 | 0.49 | 0.67 |
| San Diego | 0.66 | 0.63 | 0.62 | 0.48 | 0.31 | 0.10 | 0.00 | 0.00 | 0.00 | 0.17 | 0.46 | 0.64 |
| Santa Anaheim | 0.54 | 0.50 | 0.45 | 0.31 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.36 | 0.55 |

(d) Monthly fraction of time that the weather is mild ($x_{mild}$)

| **City** | $x_{mild}$ (unitless) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| **Northeast** | | | | | | | | | | | | |
| Arlington | 0.00 | 0.00 | 0.00 | 0.35 | 0.63 | 0.62 | 0.44 | 0.51 | 0.61 | 0.40 | 0.00 | 0.00 |
| Baltimore | 0.00 | 0.00 | 0.00 | 0.45 | 0.85 | 0.41 | 0.14 | 0.25 | 0.67 | 0.59 | 0.00 | 0.00 |
| Boston | 0.00 | 0.00 | 0.00 | 0.00 | 0.47 | 0.92 | 0.58 | 0.69 | 0.86 | 0.18 | 0.00 | 0.00 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Washington | 0.00 | 0.00 | 0.00 | 0.24 | 0.67 | 0.66 | 0.44 | 0.53 | 0.75 | 0.34 | 0.00 | 0.00 |
| Jersey City | 0.00 | 0.00 | 0.00 | 0.00 | 0.60 | 0.86 | 0.50 | 0.61 | 0.94 | 0.24 | 0.00 | 0.00 |
| Kingston | 0.00 | 0.00 | 0.00 | 0.00 | 0.32 | 0.66 | 0.64 | 0.65 | 0.46 | 0.02 | 0.00 | 0.00 |
| New York | 0.00 | 0.00 | 0.00 | 0.10 | 0.71 | 0.65 | 0.42 | 0.51 | 1.00 | 0.32 | 0.00 | 0.00 |
| Newark | 0.00 | 0.00 | 0.00 | 0.11 | 0.72 | 0.70 | 0.38 | 0.48 | 0.97 | 0.35 | 0.00 | 0.00 |
| Norfolk | 0.00 | 0.00 | 0.00 | 0.42 | 0.92 | 0.54 | 0.25 | 0.35 | 0.71 | 0.63 | 0.11 | 0.00 |
| Philadelphia | 0.00 | 0.00 | 0.00 | 0.17 | 0.76 | 0.67 | 0.35 | 0.43 | 0.91 | 0.39 | 0.00 | 0.00 |
| Providence | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.84 | 0.60 | 0.69 | 0.76 | 0.20 | 0.00 | 0.00 |
| Richmond | 0.00 | 0.00 | 0.00 | 0.42 | 0.75 | 0.59 | 0.36 | 0.44 | 0.77 | 0.47 | 0.03 | 0.00 |
| Rochester | 0.00 | 0.00 | 0.00 | 0.00 | 0.41 | 0.75 | 0.71 | 0.79 | 0.61 | 0.04 | 0.00 | 0.00 |
| Syracuse | 0.00 | 0.00 | 0.00 | 0.00 | 0.42 | 0.72 | 0.70 | 0.78 | 0.61 | 0.04 | 0.00 | 0.00 |
| Worcester | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.79 | 0.78 | 0.89 | 0.56 | 0.00 | 0.00 | 0.00 |
| **Industrial Midwest** | | | | | | | | | | | | |
| Akron | 0.00 | 0.00 | 0.00 | 0.06 | 0.61 | 0.77 | 0.56 | 0.66 | 0.84 | 0.18 | 0.00 | 0.00 |
| Buffalo | 0.00 | 0.00 | 0.00 | 0.00 | 0.40 | 0.88 | 0.75 | 0.85 | 0.65 | 0.00 | 0.00 | 0.00 |
| Chicago | 0.00 | 0.00 | 0.00 | 0.00 | 0.41 | 0.74 | 0.61 | 0.69 | 0.74 | 0.19 | 0.00 | 0.00 |
| Cincinnati | 0.00 | 0.00 | 0.00 | 0.21 | 0.59 | 0.69 | 0.52 | 0.58 | 0.67 | 0.35 | 0.00 | 0.00 |
| Cleveland | 0.00 | 0.00 | 0.00 | 0.00 | 0.47 | 0.82 | 0.68 | 0.78 | 0.74 | 0.11 | 0.00 | 0.00 |
| Columbus | 0.00 | 0.00 | 0.00 | 0.18 | 0.67 | 0.69 | 0.50 | 0.58 | 0.76 | 0.30 | 0.00 | 0.00 |
| Dayton | 0.00 | 0.00 | 0.00 | 0.08 | 0.61 | 0.75 | 0.55 | 0.65 | 0.77 | 0.23 | 0.00 | 0.00 |
| Detroit | 0.00 | 0.00 | 0.00 | 0.00 | 0.60 | 0.75 | 0.51 | 0.61 | 0.85 | 0.19 | 0.00 | 0.00 |
| Evansville | 0.00 | 0.00 | 0.00 | 0.35 | 0.70 | 0.52 | 0.34 | 0.44 | 0.67 | 0.43 | 0.00 | 0.00 |
| Fort Wayne | 0.00 | 0.00 | 0.00 | 0.04 | 0.56 | 0.74 | 0.58 | 0.69 | 0.72 | 0.19 | 0.00 | 0.00 |
| Grand Rapids | 0.00 | 0.00 | 0.00 | 0.00 | 0.46 | 0.72 | 0.67 | 0.78 | 0.61 | 0.03 | 0.00 | 0.00 |
| Indianapolis | 0.00 | 0.00 | 0.00 | 0.18 | 0.67 | 0.67 | 0.49 | 0.58 | 0.73 | 0.30 | 0.00 | 0.00 |
| Lexington | 0.00 | 0.00 | 0.00 | 0.29 | 0.74 | 0.65 | 0.45 | 0.52 | 0.80 | 0.39 | 0.00 | 0.00 |
| Louisville | 0.00 | 0.00 | 0.00 | 0.38 | 0.84 | 0.55 | 0.31 | 0.40 | 0.77 | 0.47 | 0.00 | 0.00 |
| Madison | 0.00 | 0.00 | 0.00 | 0.00 | 0.44 | 0.72 | 0.67 | 0.78 | 0.58 | 0.03 | 0.00 | 0.00 |
| Pittsburgh | 0.00 | 0.00 | 0.00 | 0.08 | 0.55 | 0.76 | 0.63 | 0.71 | 0.75 | 0.18 | 0.00 | 0.00 |
| St. Louis | 0.00 | 0.00 | 0.00 | 0.38 | 0.87 | 0.00 | 0.24 | 0.34 | 0.75 | 0.46 | 0.00 | 0.00 |
| Toledo | 0.00 | 0.00 | 0.00 | 0.00 | 0.53 | 0.76 | 0.61 | 0.71 | 0.71 | 0.15 | 0.00 | 0.00 |
| **Southeast** | | | | | | | | | | | | |
| Atlanta | 0.00 | 0.00 | 0.28 | 0.62 | 0.77 | 0.42 | 0.24 | 0.29 | 0.61 | 0.69 | 0.22 | 0.00 |
| Baton Rouge | 0.05 | 0.24 | 0.56 | 0.75 | 0.56 | 0.26 | 0.14 | 0.17 | 0.39 | 0.70 | 0.50 | 0.18 |
| Birmingham | 0.00 | 0.00 | 0.31 | 0.59 | 0.69 | 0.44 | 0.26 | 0.30 | 0.56 | 0.66 | 0.24 | 0.00 |
| Charlotte | 0.00 | 0.00 | 0.23 | 0.58 | 0.75 | 0.43 | 0.24 | 0.31 | 0.63 | 0.63 | 0.18 | 0.00 |
| Dallas/Ft. Wrth | 0.00 | 0.05 | 0.42 | 0.74 | 0.60 | 0.22 | 0.03 | 0.06 | 0.39 | 0.75 | 0.31 | 0.00 |
| Greensboro | 0.00 | 0.00 | 0.06 | 0.44 | 0.73 | 0.58 | 0.36 | 0.44 | 0.78 | 0.48 | 0.04 | 0.00 |
| Houston | 0.16 | 0.34 | 0.65 | 0.76 | 0.47 | 0.18 | 0.08 | 0.11 | 0.33 | 0.70 | 0.59 | 0.26 |
| Huntsville | 0.00 | 0.00 | 0.20 | 0.56 | 0.73 | 0.46 | 0.29 | 0.34 | 0.63 | 0.60 | 0.12 | 0.00 |
| Jackson | 0.00 | 0.06 | 0.40 | 0.69 | 0.67 | 0.34 | 0.23 | 0.23 | 0.49 | 0.65 | 0.32 | 0.00 |
| Jacksonville | 0.23 | 0.36 | 0.61 | 0.68 | 0.58 | 0.30 | 0.15 | 0.17 | 0.35 | 0.80 | 0.62 | 0.31 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Knoxville | 0.00 | 0.00 | 0.06 | 0.45 | 0.78 | 0.57 | 0.36 | 0.41 | 0.72 | 0.49 | 0.00 | 0.00 |
| Little Rock | 0.00 | 0.00 | 0.24 | 0.61 | 0.73 | 0.35 | 0.15 | 0.22 | 0.54 | 0.68 | 0.15 | 0.00 |
| Memphis | 0.00 | 0.00 | 0.22 | 0.65 | 0.73 | 0.32 | 0.12 | 0.20 | 0.52 | 0.71 | 0.16 | 0.00 |
| Miami | 0.92 | 0.85 | 0.67 | 0.47 | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 | 0.56 | 0.85 |
| Nashville | 0.00 | 0.00 | 0.08 | 0.48 | 0.78 | 0.51 | 0.30 | 0.36 | 0.69 | 0.54 | 0.00 | 0.00 |
| New Orleans | 0.15 | 0.33 | 0.68 | 0.83 | 0.48 | 0.18 | 0.06 | 0.08 | 0.28 | 0.77 | 0.63 | 0.29 |
| Orlando | 0.58 | 0.66 | 0.71 | 0.66 | 0.42 | 0.20 | 0.13 | 0.12 | 0.18 | 0.50 | 0.80 | 0.69 |
| Raleigh | 0.00 | 0.00 | 0.15 | 0.50 | 0.69 | 0.53 | 0.33 | 0.40 | 0.70 | 0.54 | 0.15 | 0.00 |
| Shreveport | 0.00 | 0.14 | 0.48 | 0.71 | 0.61 | 0.27 | 0.09 | 0.14 | 0.42 | 0.70 | 0.36 | 0.00 |
| St. Petersburg | 0.67 | 0.75 | 1.00 | 0.69 | 0.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.40 | 0.90 | 0.82 |
| Tampa | 0.63 | 0.71 | 0.91 | 0.70 | 0.36 | 0.08 | 0.00 | 0.00 | 0.06 | 0.46 | 0.84 | 0.75 |
| Tulsa | 0.00 | 0.00 | 0.15 | 0.58 | 0.79 | 0.36 | 0.10 | 0.18 | 0.58 | 0.66 | 0.05 | 0.00 |
| **Upper Midwest** | | | | | | | | | | | | |
| Minneapolis | 0.00 | 0.00 | 0.00 | 0.00 | 0.51 | 0.76 | 0.60 | 0.73 | 0.60 | 0.00 | 0.00 | 0.00 |
| **Southwest** | | | | | | | | | | | | |
| Albuquerque | 0.00 | 0.00 | 0.12 | 0.39 | 0.54 | 0.51 | 0.38 | 0.47 | 0.62 | 0.43 | 0.00 | 0.00 |
| Austin | 0.06 | 0.29 | 0.63 | 0.76 | 0.51 | 0.21 | 0.08 | 0.09 | 0.30 | 0.71 | 0.53 | 0.16 |
| Corpus Christi | 0.35 | 0.52 | 0.83 | 0.70 | 0.35 | 0.10 | 0.04 | 0.04 | 0.20 | 0.57 | 0.82 | 0.45 |
| El Paso | 0.00 | 0.17 | 0.42 | 0.60 | 0.56 | 0.24 | 0.14 | 0.23 | 0.49 | 0.62 | 0.25 | 0.00 |
| Lubbock | 0.00 | 0.00 | 0.24 | 0.54 | 0.60 | 0.43 | 0.31 | 0.38 | 0.65 | 0.56 | 0.10 | 0.00 |
| Oklahoma City | 0.00 | 0.00 | 0.15 | 0.53 | 0.77 | 0.42 | 0.20 | 0.24 | 0.59 | 0.63 | 0.03 | 0.00 |
| Phoenix | 0.28 | 0.46 | 0.66 | 0.64 | 0.35 | 0.00 | 0.00 | 0.00 | 0.03 | 0.52 | 0.61 | 0.28 |
| San Antonio | 0.13 | 0.33 | 0.63 | 0.69 | 0.47 | 0.18 | 0.06 | 0.08 | 0.30 | 0.70 | 0.54 | 0.22 |
| **Northwest** | | | | | | | | | | | | |
| Colorado Spg | 0.00 | 0.00 | 0.00 | 0.01 | 0.34 | 0.55 | 0.55 | 0.58 | 0.53 | 0.15 | 0.00 | 0.00 |
| Denver | 0.00 | 0.00 | 0.00 | 0.07 | 0.43 | 0.56 | 0.55 | 0.57 | 0.54 | 0.23 | 0.00 | 0.00 |
| Modesto | 0.00 | 0.17 | 0.40 | 0.61 | 0.58 | 0.54 | 0.42 | 0.45 | 0.55 | 0.62 | 0.26 | 0.00 |
| Oakland | 0.00 | 0.15 | 0.31 | 0.50 | 0.67 | 0.81 | 0.79 | 0.80 | 0.79 | 0.74 | 0.31 | 0.00 |
| Olympia | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.47 | 0.61 | 0.59 | 0.47 | 0.07 | 0.00 | 0.00 |
| Sacramento | 0.00 | 0.08 | 0.28 | 0.49 | 0.56 | 0.51 | 0.48 | 0.49 | 0.51 | 0.59 | 0.22 | 0.00 |
| Salt Lake City | 0.00 | 0.00 | 0.00 | 0.09 | 0.49 | 0.61 | 0.43 | 0.49 | 0.64 | 0.22 | 0.00 | 0.00 |
| San Jose | 0.02 | 0.23 | 0.39 | 0.55 | 0.65 | 0.61 | 0.60 | 0.62 | 0.64 | 0.69 | 0.32 | 0.00 |
| Seattle | 0.00 | 0.00 | 0.00 | 0.02 | 0.35 | 0.63 | 0.86 | 0.89 | 0.63 | 0.09 | 0.00 | 0.00 |
| Spokane | 0.00 | 0.00 | 0.00 | 0.00 | 0.31 | 0.60 | 0.58 | 0.58 | 0.51 | 0.00 | 0.00 | 0.00 |
| Stockton | 0.00 | 0.11 | 0.32 | 0.54 | 0.55 | 0.52 | 0.44 | 0.46 | 0.53 | 0.58 | 0.23 | 0.00 |
| Tacoma | 0.00 | 0.00 | 0.00 | 0.07 | 0.37 | 0.62 | 0.77 | 0.74 | 0.60 | 0.14 | 0.00 | 0.00 |
| **Southern California** | | | | | | | | | | | | |
| Bakersfield | 0.00 | 0.22 | 0.42 | 0.62 | 0.60 | 0.41 | 0.22 | 0.25 | 0.44 | 0.66 | 0.30 | 0.00 |
| Fresno | 0.00 | 0.12 | 0.33 | 0.59 | 0.58 | 0.47 | 0.30 | 0.34 | 0.52 | 0.62 | 0.19 | 0.00 |
| Los Angeles | 0.39 | 0.43 | 0.45 | 0.63 | 0.83 | 1.00 | 0.99 | 0.87 | 0.90 | 1.00 | 0.64 | 0.42 |
| Riverside | 0.35 | 0.42 | 0.48 | 0.60 | 0.63 | 0.56 | 0.39 | 0.36 | 0.47 | 0.56 | 0.54 | 0.36 |
| San Bernardino | 0.32 | 0.39 | 0.46 | 0.58 | 0.58 | 0.52 | 0.37 | 0.35 | 0.47 | 0.55 | 0.51 | 0.33 |
| San Diego | 0.34 | 0.37 | 0.38 | 0.52 | 0.69 | 0.84 | 0.72 | 0.65 | 0.72 | 0.74 | 0.54 | 0.36 |
| Santa Anaheim | 0.46 | 0.50 | 0.55 | 0.69 | 0.86 | 0.81 | 0.62 | 0.55 | 0.60 | 0.75 | 0.64 | 0.45 |

(e) Monthly average values of $\Delta[PM_{10}]_{in}/\Delta[PM_{10}]_{out}$.

| City | $\Delta[PM_{10}]_{in}/\Delta[PM_{10}]_{out}$ (unitless) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| **Northeast** | | | | | | | | | | | | |
| Arlington | 0.27 | 0.27 | 0.27 | 0.30 | 0.33 | 0.36 | 0.36 | 0.36 | 0.34 | 0.31 | 0.27 | 0.27 |
| Baltimore | 0.19 | 0.19 | 0.19 | 0.23 | 0.27 | 0.29 | 0.29 | 0.29 | 0.28 | 0.24 | 0.19 | 0.19 |
| Boston | 0.24 | 0.24 | 0.24 | 0.24 | 0.27 | 0.33 | 0.39 | 0.37 | 0.30 | 0.25 | 0.24 | 0.24 |
| Washington | 0.21 | 0.21 | 0.21 | 0.23 | 0.26 | 0.27 | 0.26 | 0.27 | 0.27 | 0.24 | 0.21 | 0.21 |
| Jersey City | 0.24 | 0.24 | 0.24 | 0.24 | 0.29 | 0.35 | 0.42 | 0.40 | 0.32 | 0.26 | 0.24 | 0.24 |
| Kingston | 0.23 | 0.23 | 0.23 | 0.23 | 0.26 | 0.28 | 0.33 | 0.31 | 0.27 | 0.23 | 0.23 | 0.23 |
| New York | 0.23 | 0.23 | 0.23 | 0.24 | 0.29 | 0.33 | 0.44 | 0.42 | 0.31 | 0.26 | 0.23 | 0.23 |
| Newark | 0.19 | 0.19 | 0.19 | 0.20 | 0.24 | 0.32 | 0.37 | 0.35 | 0.27 | 0.22 | 0.19 | 0.19 |
| Norfolk | 0.21 | 0.21 | 0.21 | 0.25 | 0.29 | 0.32 | 0.34 | 0.33 | 0.31 | 0.26 | 0.22 | 0.21 |
| Philadelphia | 0.15 | 0.15 | 0.15 | 0.17 | 0.21 | 0.26 | 0.29 | 0.28 | 0.24 | 0.18 | 0.15 | 0.15 |
| Providence | 0.17 | 0.17 | 0.17 | 0.17 | 0.20 | 0.26 | 0.32 | 0.30 | 0.22 | 0.18 | 0.17 | 0.17 |
| Richmond | 0.25 | 0.25 | 0.25 | 0.28 | 0.31 | 0.30 | 0.29 | 0.29 | 0.31 | 0.28 | 0.25 | 0.25 |
| Rochester | 0.27 | 0.27 | 0.27 | 0.27 | 0.30 | 0.33 | 0.37 | 0.36 | 0.31 | 0.27 | 0.27 | 0.27 |
| Syracuse | 0.18 | 0.18 | 0.18 | 0.18 | 0.21 | 0.26 | 0.31 | 0.29 | 0.23 | 0.19 | 0.18 | 0.18 |
| Worcester | 0.22 | 0.22 | 0.22 | 0.22 | 0.24 | 0.28 | 0.34 | 0.32 | 0.26 | 0.22 | 0.22 | 0.22 |
| **Industrial Midwest** | | | | | | | | | | | | |
| Akron | 0.25 | 0.25 | 0.25 | 0.25 | 0.30 | 0.35 | 0.38 | 0.36 | 0.31 | 0.26 | 0.25 | 0.25 |
| Buffalo | 0.32 | 0.32 | 0.32 | 0.32 | 0.35 | 0.39 | 0.41 | 0.40 | 0.37 | 0.32 | 0.32 | 0.32 |
| Chicago | 0.20 | 0.20 | 0.20 | 0.20 | 0.23 | 0.27 | 0.30 | 0.30 | 0.26 | 0.21 | 0.20 | 0.20 |
| Cincinnati | 0.19 | 0.19 | 0.19 | 0.21 | 0.24 | 0.29 | 0.30 | 0.30 | 0.27 | 0.22 | 0.19 | 0.19 |
| Cleveland | 0.17 | 0.17 | 0.17 | 0.17 | 0.21 | 0.26 | 0.28 | 0.27 | 0.23 | 0.18 | 0.17 | 0.17 |
| Columbus | 0.24 | 0.24 | 0.24 | 0.26 | 0.29 | 0.30 | 0.28 | 0.29 | 0.30 | 0.27 | 0.24 | 0.24 |
| Dayton | 0.24 | 0.24 | 0.24 | 0.25 | 0.29 | 0.35 | 0.37 | 0.36 | 0.31 | 0.26 | 0.24 | 0.24 |
| Detroit | 0.19 | 0.19 | 0.19 | 0.19 | 0.23 | 0.28 | 0.29 | 0.28 | 0.25 | 0.20 | 0.19 | 0.19 |
| Evansville | 0.19 | 0.19 | 0.19 | 0.22 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.22 | 0.19 | 0.19 |
| Fort Wayne | 0.28 | 0.28 | 0.28 | 0.28 | 0.32 | 0.36 | 0.37 | 0.37 | 0.33 | 0.29 | 0.28 | 0.28 |
| Grand Rapids | 0.23 | 0.23 | 0.23 | 0.23 | 0.27 | 0.31 | 0.33 | 0.32 | 0.28 | 0.23 | 0.23 | 0.23 |
| Indianapolis | 0.20 | 0.20 | 0.20 | 0.21 | 0.25 | 0.27 | 0.26 | 0.27 | 0.26 | 0.22 | 0.20 | 0.20 |
| Lexington | 0.28 | 0.28 | 0.28 | 0.30 | 0.34 | 0.36 | 0.35 | 0.35 | 0.35 | 0.31 | 0.28 | 0.28 |
| Louisville | 0.20 | 0.20 | 0.20 | 0.23 | 0.27 | 0.29 | 0.29 | 0.29 | 0.29 | 0.24 | 0.20 | 0.20 |
| Madison | 0.23 | 0.23 | 0.23 | 0.23 | 0.26 | 0.30 | 0.33 | 0.32 | 0.27 | 0.23 | 0.23 | 0.23 |
| Pittsburgh | 0.22 | 0.22 | 0.22 | 0.23 | 0.26 | 0.31 | 0.32 | 0.32 | 0.28 | 0.24 | 0.22 | 0.22 |
| St. Louis | 0.20 | 0.20 | 0.20 | 0.23 | 0.28 | 0.24 | 0.25 | 0.25 | 0.27 | 0.24 | 0.20 | 0.20 |
| Toledo | 0.22 | 0.22 | 0.22 | 0.22 | 0.27 | 0.31 | 0.33 | 0.32 | 0.28 | 0.24 | 0.22 | 0.22 |
| **Southeast** | | | | | | | | | | | | |
| Atlanta | 0.20 | 0.20 | 0.22 | 0.25 | 0.27 | 0.24 | 0.23 | 0.23 | 0.26 | 0.26 | 0.22 | 0.20 |
| Baton Rouge | 0.19 | 0.21 | 0.23 | 0.26 | 0.26 | 0.25 | 0.24 | 0.25 | 0.25 | 0.26 | 0.23 | 0.20 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Birmingham | 0.19 | 0.19 | 0.21 | 0.24 | 0.26 | 0.25 | 0.24 | 0.24 | 0.26 | 0.25 | 0.21 | 0.19 |
| Charlotte | 0.23 | 0.23 | 0.25 | 0.28 | 0.30 | 0.28 | 0.27 | 0.28 | 0.29 | 0.28 | 0.25 | 0.23 |
| Dallas/Ft. Wrth | 0.16 | 0.17 | 0.20 | 0.22 | 0.22 | 0.19 | 0.18 | 0.18 | 0.20 | 0.23 | 0.19 | 0.16 |
| Greensboro | 0.24 | 0.24 | 0.25 | 0.28 | 0.31 | 0.30 | 0.29 | 0.30 | 0.31 | 0.28 | 0.25 | 0.24 |
| Houston | 0.18 | 0.19 | 0.22 | 0.23 | 0.22 | 0.20 | 0.20 | 0.20 | 0.21 | 0.23 | 0.21 | 0.18 |
| Huntsville | 0.27 | 0.27 | 0.29 | 0.32 | 0.34 | 0.32 | 0.31 | 0.31 | 0.33 | 0.32 | 0.28 | 0.27 |
| Jackson | 0.21 | 0.22 | 0.25 | 0.27 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.28 | 0.24 | 0.21 |
| Jacksonville | 0.14 | 0.15 | 0.17 | 0.19 | 0.19 | 0.18 | 0.17 | 0.17 | 0.18 | 0.20 | 0.18 | 0.15 |
| Knoxville | 0.21 | 0.21 | 0.22 | 0.25 | 0.28 | 0.27 | 0.26 | 0.26 | 0.28 | 0.25 | 0.21 | 0.21 |
| Little Rock | 0.19 | 0.19 | 0.21 | 0.24 | 0.26 | 0.23 | 0.22 | 0.22 | 0.25 | 0.25 | 0.20 | 0.19 |
| Memphis | 0.19 | 0.19 | 0.21 | 0.24 | 0.26 | 0.25 | 0.24 | 0.25 | 0.26 | 0.25 | 0.20 | 0.19 |
| Miami | 0.18 | 0.18 | 0.18 | 0.17 | 0.17 | 0.16 | 0.16 | 0.16 | 0.16 | 0.17 | 0.18 | 0.18 |
| Nashville | 0.19 | 0.19 | 0.20 | 0.23 | 0.26 | 0.25 | 0.23 | 0.24 | 0.26 | 0.23 | 0.19 | 0.19 |
| New Orleans | 0.22 | 0.23 | 0.26 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.26 | 0.23 |
| Orlando | 0.21 | 0.21 | 0.22 | 0.21 | 0.19 | 0.17 | 0.16 | 0.16 | 0.17 | 0.20 | 0.23 | 0.22 |
| Raleigh | 0.27 | 0.27 | 0.28 | 0.31 | 0.32 | 0.31 | 0.29 | 0.30 | 0.32 | 0.31 | 0.28 | 0.27 |
| Shreveport | 0.20 | 0.21 | 0.24 | 0.27 | 0.29 | 0.30 | 0.30 | 0.30 | 0.29 | 0.27 | 0.23 | 0.20 |
| St. Petersburg | 0.19 | 0.20 | 0.22 | 0.20 | 0.18 | 0.16 | 0.16 | 0.16 | 0.16 | 0.18 | 0.21 | 0.20 |
| Tampa | 0.18 | 0.19 | 0.21 | 0.20 | 0.18 | 0.16 | 0.16 | 0.16 | 0.16 | 0.18 | 0.21 | 0.19 |
| Tulsa | 0.16 | 0.16 | 0.17 | 0.21 | 0.24 | 0.22 | 0.21 | 0.21 | 0.23 | 0.22 | 0.16 | 0.16 |
| **Upper Midwest** | | | | | | | | | | | | |
| Minneapolis | 0.18 | 0.18 | 0.18 | 0.18 | 0.22 | 0.24 | 0.24 | 0.25 | 0.22 | 0.18 | 0.18 | 0.18 |
| **Southwest** | | | | | | | | | | | | |
| Albuquerque | 0.08 | 0.08 | 0.09 | 0.11 | 0.14 | 0.20 | 0.21 | 0.20 | 0.17 | 0.11 | 0.08 | 0.08 |
| Austin | 0.16 | 0.18 | 0.20 | 0.22 | 0.20 | 0.18 | 0.17 | 0.17 | 0.18 | 0.21 | 0.20 | 0.17 |
| Corpus Christi | 0.14 | 0.16 | 0.19 | 0.19 | 0.19 | 0.18 | 0.18 | 0.18 | 0.19 | 0.19 | 0.18 | 0.15 |
| El Paso | 0.08 | 0.09 | 0.11 | 0.13 | 0.15 | 0.14 | 0.14 | 0.14 | 0.15 | 0.14 | 0.10 | 0.08 |
| Lubbock | 0.09 | 0.09 | 0.11 | 0.13 | 0.15 | 0.14 | 0.14 | 0.14 | 0.15 | 0.14 | 0.10 | 0.09 |
| Oklahoma City | 0.13 | 0.13 | 0.14 | 0.17 | 0.20 | 0.19 | 0.19 | 0.19 | 0.20 | 0.18 | 0.13 | 0.13 |
| Phoenix | 0.10 | 0.11 | 0.13 | 0.13 | 0.12 | 0.09 | 0.09 | 0.09 | 0.10 | 0.13 | 0.12 | 0.10 |
| San Antonio | 0.15 | 0.17 | 0.19 | 0.22 | 0.23 | 0.23 | 0.24 | 0.24 | 0.23 | 0.23 | 0.19 | 0.16 |
| **Northwest** | | | | | | | | | | | | |
| Colorado Spg | 0.09 | 0.09 | 0.09 | 0.09 | 0.12 | 0.17 | 0.23 | 0.20 | 0.13 | 0.10 | 0.09 | 0.09 |
| Denver | 0.11 | 0.11 | 0.11 | 0.12 | 0.15 | 0.21 | 0.26 | 0.25 | 0.17 | 0.13 | 0.11 | 0.11 |
| Modesto | 0.13 | 0.15 | 0.17 | 0.19 | 0.19 | 0.19 | 0.18 | 0.18 | 0.19 | 0.19 | 0.16 | 0.13 |
| Oakland | 0.15 | 0.17 | 0.18 | 0.20 | 0.21 | 0.24 | 0.26 | 0.27 | 0.26 | 0.22 | 0.18 | 0.15 |
| Olympia | 0.15 | 0.15 | 0.15 | 0.15 | 0.17 | 0.18 | 0.21 | 0.21 | 0.18 | 0.15 | 0.15 | 0.15 |
| Sacramento | 0.24 | 0.24 | 0.26 | 0.28 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.26 | 0.24 |
| Salt Lake City | 0.10 | 0.10 | 0.10 | 0.11 | 0.14 | 0.21 | 0.26 | 0.25 | 0.17 | 0.12 | 0.10 | 0.10 |
| San Jose | 0.18 | 0.19 | 0.21 | 0.22 | 0.25 | 0.29 | 0.31 | 0.31 | 0.30 | 0.24 | 0.20 | 0.17 |
| Seattle | 0.14 | 0.14 | 0.14 | 0.14 | 0.17 | 0.19 | 0.20 | 0.21 | 0.19 | 0.14 | 0.14 | 0.14 |
| Spokane | 0.11 | 0.11 | 0.11 | 0.11 | 0.13 | 0.15 | 0.21 | 0.21 | 0.15 | 0.11 | 0.11 | 0.11 |
| Stockton | 0.14 | 0.15 | 0.17 | 0.19 | 0.21 | 0.23 | 0.23 | 0.23 | 0.23 | 0.20 | 0.16 | 0.14 |
| Tacoma | 0.16 | 0.16 | 0.16 | 0.17 | 0.19 | 0.21 | 0.23 | 0.24 | 0.21 | 0.17 | 0.16 | 0.16 |
| **Southern California** | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bakersfield | 0.14 | 0.16 | 0.18 | 0.20 | 0.22 | 0.23 | 0.23 | 0.23 | 0.23 | 0.21 | 0.17 | 0.14 |
| Fresno | 0.12 | 0.13 | 0.15 | 0.17 | 0.18 | 0.19 | 0.18 | 0.19 | 0.19 | 0.18 | 0.13 | 0.12 |
| Los Angeles | 0.19 | 0.20 | 0.20 | 0.22 | 0.23 | 0.25 | 0.25 | 0.27 | 0.26 | 0.25 | 0.22 | 0.20 |
| Riverside | 0.17 | 0.18 | 0.18 | 0.20 | 0.21 | 0.23 | 0.23 | 0.23 | 0.23 | 0.21 | 0.19 | 0.17 |
| San Bernardino | 0.11 | 0.11 | 0.12 | 0.13 | 0.15 | 0.16 | 0.17 | 0.17 | 0.17 | 0.15 | 0.12 | 0.11 |
| San Diego | 0.18 | 0.18 | 0.18 | 0.19 | 0.21 | 0.24 | 0.29 | 0.30 | 0.29 | 0.24 | 0.20 | 0.18 |
| Santa Anaheim | 0.17 | 0.17 | 0.18 | 0.19 | 0.20 | 0.24 | 0.27 | 0.29 | 0.28 | 0.24 | 0.18 | 0.17 |

(f) Monthly $PM_{10}$ exposure coefficients.

| **City** | **$PM_{10}$ exposure coefficients** (unitless) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| **Northeast** | | | | | | | | | | | | |
| Arlington | 2.83 | 2.83 | 2.83 | 3.02 | 3.20 | 3.37 | 3.37 | 3.37 | 3.28 | 3.05 | 2.83 | 2.83 |
| Baltimore | 2.29 | 2.29 | 2.29 | 2.53 | 2.82 | 2.91 | 2.95 | 2.94 | 2.88 | 2.61 | 2.29 | 2.29 |
| Boston | 2.80 | 2.80 | 2.80 | 2.80 | 3.06 | 3.47 | 3.94 | 3.79 | 3.28 | 2.90 | 2.80 | 2.80 |
| Washington | 2.40 | 2.40 | 2.40 | 2.53 | 2.76 | 2.82 | 2.74 | 2.77 | 2.83 | 2.58 | 2.40 | 2.40 |
| Jersey City | 2.64 | 2.64 | 2.64 | 2.64 | 2.95 | 3.34 | 3.85 | 3.70 | 3.13 | 2.76 | 2.64 | 2.64 |
| Kingston | 2.57 | 2.57 | 2.57 | 2.57 | 2.74 | 2.91 | 3.21 | 3.12 | 2.81 | 2.58 | 2.57 | 2.57 |
| New York | 2.57 | 2.57 | 2.57 | 2.62 | 2.94 | 3.21 | 3.95 | 3.81 | 3.09 | 2.74 | 2.57 | 2.57 |
| Newark | 2.27 | 2.27 | 2.27 | 2.33 | 2.65 | 3.13 | 3.50 | 3.38 | 2.83 | 2.45 | 2.27 | 2.27 |
| Norfolk | 2.41 | 2.41 | 2.41 | 2.64 | 2.91 | 3.13 | 3.24 | 3.20 | 3.06 | 2.75 | 2.47 | 2.41 |
| Philadelphia | 2.02 | 2.02 | 2.02 | 2.11 | 2.42 | 2.74 | 2.93 | 2.88 | 2.60 | 2.23 | 2.02 | 2.02 |
| Providence | 2.26 | 2.26 | 2.26 | 2.26 | 2.53 | 2.95 | 3.39 | 3.27 | 2.69 | 2.37 | 2.26 | 2.26 |
| Richmond | 2.63 | 2.63 | 2.63 | 2.86 | 3.04 | 3.00 | 2.90 | 2.94 | 3.08 | 2.88 | 2.65 | 2.63 |
| Rochester | 2.80 | 2.80 | 2.80 | 2.80 | 3.00 | 3.25 | 3.51 | 3.43 | 3.10 | 2.82 | 2.80 | 2.80 |
| Syracuse | 2.23 | 2.23 | 2.23 | 2.23 | 2.44 | 2.73 | 3.10 | 2.98 | 2.54 | 2.25 | 2.23 | 2.23 |
| Worcester | 2.63 | 2.63 | 2.63 | 2.63 | 2.84 | 3.10 | 3.60 | 3.41 | 2.96 | 2.63 | 2.63 | 2.63 |
| **Industrial Midwest** | | | | | | | | | | | | |
| Akron | 2.70 | 2.70 | 2.70 | 2.73 | 3.02 | 3.40 | 3.56 | 3.48 | 3.14 | 2.79 | 2.70 | 2.70 |
| Buffalo | 3.18 | 3.18 | 3.18 | 3.18 | 3.37 | 3.60 | 3.78 | 3.73 | 3.49 | 3.18 | 3.18 | 3.18 |
| Chicago | 2.36 | 2.36 | 2.36 | 2.36 | 2.57 | 2.87 | 3.07 | 3.04 | 2.75 | 2.46 | 2.36 | 2.36 |
| Cincinnati | 2.31 | 2.31 | 2.31 | 2.43 | 2.64 | 2.95 | 3.03 | 3.02 | 2.81 | 2.50 | 2.31 | 2.31 |
| Cleveland | 2.18 | 2.18 | 2.18 | 2.18 | 2.43 | 2.76 | 2.94 | 2.87 | 2.57 | 2.24 | 2.18 | 2.18 |
| Columbus | 2.65 | 2.65 | 2.65 | 2.75 | 3.00 | 3.02 | 2.93 | 2.97 | 3.06 | 2.81 | 2.65 | 2.65 |
| Dayton | 2.67 | 2.67 | 2.67 | 2.72 | 2.99 | 3.38 | 3.54 | 3.46 | 3.10 | 2.79 | 2.67 | 2.67 |
| Detroit | 2.28 | 2.28 | 2.28 | 2.28 | 2.60 | 2.89 | 2.98 | 2.94 | 2.73 | 2.38 | 2.28 | 2.28 |
| Evansville | 2.28 | 2.28 | 2.28 | 2.47 | 2.70 | 2.72 | 2.68 | 2.70 | 2.73 | 2.52 | 2.28 | 2.28 |
| Fort Wayne | 2.89 | 2.89 | 2.89 | 2.90 | 3.18 | 3.49 | 3.55 | 3.51 | 3.27 | 2.98 | 2.89 | 2.89 |
| Grand Rapids | 2.57 | 2.57 | 2.57 | 2.57 | 2.82 | 3.08 | 3.23 | 3.19 | 2.90 | 2.59 | 2.57 | 2.57 |
| Indianapolis | 2.35 | 2.35 | 2.35 | 2.46 | 2.73 | 2.83 | 2.79 | 2.81 | 2.80 | 2.52 | 2.35 | 2.35 |
| Lexington | 2.81 | 2.81 | 2.81 | 2.96 | 3.20 | 3.30 | 3.28 | 3.29 | 3.29 | 3.01 | 2.81 | 2.81 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Louisville | 2.30 | 2.30 | 2.30 | 2.50 | 2.76 | 2.85 | 2.85 | 2.85 | 2.84 | 2.56 | 2.30 | 2.30 |
| Madison | 2.54 | 2.54 | 2.54 | 2.54 | 2.78 | 3.08 | 3.27 | 3.19 | 2.85 | 2.56 | 2.54 | 2.54 |
| Pittsburgh | 2.49 | 2.49 | 2.49 | 2.53 | 2.75 | 3.04 | 3.16 | 3.12 | 2.85 | 2.57 | 2.49 | 2.49 |
| St. Louis | 2.26 | 2.26 | 2.26 | 2.45 | 2.73 | 2.50 | 2.57 | 2.59 | 2.70 | 2.49 | 2.26 | 2.26 |
| Toledo | 2.54 | 2.54 | 2.54 | 2.54 | 2.82 | 3.14 | 3.25 | 3.20 | 2.91 | 2.62 | 2.54 | 2.54 |
| **Southeast** | | | | | | | | | | | | |
| Atlanta | 2.29 | 2.29 | 2.45 | 2.64 | 2.74 | 2.57 | 2.49 | 2.51 | 2.67 | 2.68 | 2.41 | 2.29 |
| Baton Rouge | 2.26 | 2.36 | 2.54 | 2.68 | 2.70 | 2.64 | 2.61 | 2.62 | 2.66 | 2.68 | 2.51 | 2.33 |
| Birmingham | 2.21 | 2.21 | 2.39 | 2.55 | 2.68 | 2.62 | 2.57 | 2.58 | 2.66 | 2.59 | 2.35 | 2.21 |
| Charlotte | 2.49 | 2.49 | 2.61 | 2.79 | 2.93 | 2.84 | 2.77 | 2.80 | 2.90 | 2.82 | 2.58 | 2.49 |
| Dallas/Ft. Wrth | 2.07 | 2.09 | 2.30 | 2.48 | 2.43 | 2.26 | 2.17 | 2.19 | 2.34 | 2.49 | 2.23 | 2.07 |
| Greensboro | 2.58 | 2.58 | 2.61 | 2.81 | 2.98 | 2.96 | 2.89 | 2.92 | 3.03 | 2.83 | 2.60 | 2.58 |
| Houston | 2.15 | 2.25 | 2.43 | 2.53 | 2.44 | 2.34 | 2.30 | 2.31 | 2.39 | 2.51 | 2.39 | 2.21 |
| Huntsville | 2.75 | 2.75 | 2.86 | 3.05 | 3.17 | 3.07 | 2.99 | 3.01 | 3.13 | 3.07 | 2.82 | 2.75 |
| Jackson | 2.38 | 2.41 | 2.60 | 2.77 | 2.98 | 3.01 | 3.02 | 3.02 | 2.99 | 2.79 | 2.56 | 2.38 |
| Jacksonville | 1.92 | 1.99 | 2.13 | 2.20 | 2.22 | 2.14 | 2.09 | 2.10 | 2.15 | 2.29 | 2.14 | 1.96 |
| Knoxville | 2.36 | 2.36 | 2.39 | 2.60 | 2.79 | 2.75 | 2.68 | 2.70 | 2.80 | 2.63 | 2.36 | 2.36 |
| Little Rock | 2.27 | 2.27 | 2.40 | 2.60 | 2.70 | 2.53 | 2.44 | 2.47 | 2.61 | 2.64 | 2.35 | 2.27 |
| Memphis | 2.22 | 2.22 | 2.34 | 2.57 | 2.70 | 2.62 | 2.57 | 2.59 | 2.66 | 2.60 | 2.31 | 2.22 |
| Miami | 2.19 | 2.18 | 2.15 | 2.12 | 2.07 | 2.04 | 2.04 | 2.04 | 2.04 | 2.08 | 2.13 | 2.18 |
| Nashville | 2.22 | 2.22 | 2.26 | 2.48 | 2.66 | 2.59 | 2.51 | 2.54 | 2.65 | 2.51 | 2.22 | 2.22 |
| New Orleans | 2.44 | 2.54 | 2.73 | 2.89 | 2.89 | 2.88 | 2.88 | 2.88 | 2.88 | 2.90 | 2.70 | 2.52 |
| Orlando | 2.34 | 2.39 | 2.41 | 2.38 | 2.23 | 2.10 | 2.05 | 2.04 | 2.08 | 2.28 | 2.47 | 2.41 |
| Raleigh | 2.74 | 2.74 | 2.82 | 3.01 | 3.10 | 3.00 | 2.89 | 2.93 | 3.10 | 3.03 | 2.82 | 2.74 |
| Shreveport | 2.32 | 2.40 | 2.58 | 2.75 | 2.91 | 2.94 | 2.96 | 2.96 | 2.93 | 2.79 | 2.52 | 2.32 |
| St. Petersburg | 2.23 | 2.28 | 2.42 | 2.30 | 2.14 | 2.03 | 2.03 | 2.03 | 2.03 | 2.19 | 2.38 | 2.31 |
| Tampa | 2.18 | 2.23 | 2.36 | 2.29 | 2.15 | 2.04 | 2.01 | 2.01 | 2.04 | 2.19 | 2.34 | 2.26 |
| Tulsa | 2.06 | 2.06 | 2.14 | 2.38 | 2.55 | 2.43 | 2.36 | 2.38 | 2.49 | 2.42 | 2.08 | 2.06 |
| **Upper Midwest** | | | | | | | | | | | | |
| Minneapolis | 2.20 | 2.20 | 2.20 | 2.20 | 2.48 | 2.66 | 2.64 | 2.68 | 2.52 | 2.20 | 2.20 | 2.20 |
| **Southwest** | | | | | | | | | | | | |
| Albuquerque | 1.51 | 1.51 | 1.57 | 1.72 | 1.95 | 2.29 | 2.35 | 2.31 | 2.12 | 1.74 | 1.51 | 1.51 |
| Austin | 2.04 | 2.16 | 2.35 | 2.43 | 2.31 | 2.16 | 2.10 | 2.10 | 2.21 | 2.41 | 2.30 | 2.09 |
| Corpus Christi | 1.95 | 2.05 | 2.23 | 2.27 | 2.24 | 2.21 | 2.20 | 2.20 | 2.22 | 2.26 | 2.21 | 2.01 |
| El Paso | 1.52 | 1.61 | 1.75 | 1.88 | 1.99 | 1.95 | 1.94 | 1.95 | 1.99 | 1.89 | 1.66 | 1.52 |
| Lubbock | 1.59 | 1.59 | 1.72 | 1.88 | 1.97 | 1.94 | 1.90 | 1.92 | 2.01 | 1.90 | 1.65 | 1.59 |
| Oklahoma City | 1.86 | 1.86 | 1.95 | 2.15 | 2.34 | 2.28 | 2.23 | 2.24 | 2.32 | 2.21 | 1.88 | 1.86 |
| Phoenix | 1.62 | 1.72 | 1.83 | 1.86 | 1.75 | 1.60 | 1.60 | 1.60 | 1.62 | 1.82 | 1.81 | 1.62 |
| San Antonio | 2.00 | 2.11 | 2.27 | 2.45 | 2.52 | 2.54 | 2.55 | 2.55 | 2.54 | 2.50 | 2.23 | 2.05 |
| **Northwest** | | | | | | | | | | | | |
| Colorado Spg | 1.59 | 1.59 | 1.59 | 1.59 | 1.77 | 2.14 | 2.48 | 2.34 | 1.87 | 1.67 | 1.59 | 1.59 |
| Denver | 1.72 | 1.72 | 1.72 | 1.76 | 1.95 | 2.40 | 2.71 | 2.62 | 2.13 | 1.85 | 1.72 | 1.72 |
| Modesto | 1.86 | 1.96 | 2.09 | 2.20 | 2.21 | 2.21 | 2.16 | 2.17 | 2.21 | 2.22 | 2.01 | 1.86 |
| Oakland | 2.00 | 2.08 | 2.17 | 2.28 | 2.38 | 2.52 | 2.71 | 2.75 | 2.69 | 2.42 | 2.17 | 2.00 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Olympia | 1.83 | 1.83 | 1.83 | 1.83 | 1.94 | 2.03 | 2.16 | 2.20 | 2.04 | 1.86 | 1.83 | 1.83 |
| Sacramento | 2.53 | 2.58 | 2.69 | 2.82 | 2.88 | 2.90 | 2.90 | 2.91 | 2.90 | 2.89 | 2.66 | 2.53 |
| Salt Lake City | 1.64 | 1.64 | 1.64 | 1.69 | 1.91 | 2.35 | 2.68 | 2.63 | 2.13 | 1.76 | 1.64 | 1.64 |
| San Jose | 2.14 | 2.26 | 2.35 | 2.44 | 2.60 | 2.89 | 3.03 | 3.03 | 2.94 | 2.57 | 2.31 | 2.13 |
| Seattle | 1.77 | 1.77 | 1.77 | 1.78 | 1.93 | 2.04 | 2.15 | 2.16 | 2.05 | 1.81 | 1.77 | 1.77 |
| Spokane | 1.59 | 1.59 | 1.59 | 1.59 | 1.72 | 1.85 | 2.15 | 2.15 | 1.81 | 1.59 | 1.59 | 1.59 |
| Stockton | 1.92 | 1.98 | 2.10 | 2.23 | 2.36 | 2.47 | 2.51 | 2.50 | 2.47 | 2.32 | 2.05 | 1.92 |
| Tacoma | 1.90 | 1.90 | 1.90 | 1.93 | 2.06 | 2.17 | 2.31 | 2.34 | 2.16 | 1.96 | 1.90 | 1.90 |
| **Southern California** | | | | | | | | | | | | |
| Bakersfield | 1.92 | 2.04 | 2.16 | 2.28 | 2.43 | 2.47 | 2.46 | 2.47 | 2.47 | 2.39 | 2.09 | 1.92 |
| Fresno | 1.76 | 1.83 | 1.95 | 2.09 | 2.19 | 2.22 | 2.19 | 2.20 | 2.23 | 2.15 | 1.87 | 1.76 |
| Los Angeles | 2.26 | 2.28 | 2.29 | 2.39 | 2.51 | 2.61 | 2.61 | 2.73 | 2.70 | 2.61 | 2.40 | 2.28 |
| Riverside | 2.11 | 2.15 | 2.18 | 2.27 | 2.37 | 2.46 | 2.46 | 2.45 | 2.46 | 2.37 | 2.21 | 2.11 |
| San Bernardino | 1.68 | 1.72 | 1.76 | 1.86 | 1.96 | 2.06 | 2.08 | 2.08 | 2.08 | 1.97 | 1.79 | 1.69 |
| San Diego | 2.15 | 2.17 | 2.17 | 2.26 | 2.35 | 2.53 | 2.84 | 2.92 | 2.85 | 2.53 | 2.27 | 2.16 |
| Santa Anaheim | 2.09 | 2.11 | 2.14 | 2.22 | 2.32 | 2.58 | 2.78 | 2.84 | 2.79 | 2.58 | 2.19 | 2.09 |

(g) Monthly $PM_{10}$ exposure coefficients for 7 regions represented by 83 NMMAPS cities.

| **Regions** | **$PM_{10}$ exposure coefficients** (unitless) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| Northeast | 2.47 | 2.47 | 2.47 | 2.55 | 2.83 | 3.09 | 3.51 | 3.42 | 2.97 | 2.64 | 2.47 | 2.47 |
| Industrial Midwest | 2.41 | 2.41 | 2.41 | 2.46 | 2.71 | 2.93 | 3.04 | 3.02 | 2.83 | 2.53 | 2.41 | 2.41 |
| Southeast | 2.23 | 2.26 | 2.38 | 2.48 | 2.48 | 2.38 | 2.33 | 2.34 | 2.42 | 2.47 | 2.35 | 2.25 |
| Upper Midwest | 2.20 | 2.20 | 2.20 | 2.20 | 2.48 | 2.66 | 2.64 | 2.68 | 2.52 | 2.20 | 2.20 | 2.20 |
| Southwest | 1.77 | 1.85 | 1.98 | 2.08 | 2.09 | 2.03 | 2.02 | 2.02 | 2.04 | 2.09 | 1.94 | 1.79 |
| Northwest | 1.92 | 1.95 | 1.98 | 2.03 | 2.17 | 2.37 | 2.52 | 2.51 | 2.31 | 2.10 | 1.97 | 1.92 |
| Southern California | 2.10 | 2.14 | 2.16 | 2.26 | 2.37 | 2.47 | 2.52 | 2.59 | 2.57 | 2.44 | 2.23 | 2.12 |
| All regions | 2.25 | 2.27 | 2.31 | 2.39 | 2.54 | 2.66 | 2.80 | 2.78 | 2.63 | 2.46 | 2.31 | 2.26 |

## Effect modification of indoor temperature

***Fraction of residences with AC (y') and heating system ($y^*$).*** The estimates for the fraction of residences with AC (central AC + window AC) were based on values provided by R. L. Smith and colleagues from their study of the relationship between ozone and short-term mortality in US urban communities (Smith et al. 2009). Details of how these estimates were obtained are provided in their paper. Estimates for the fraction of residences with a heating system ($y^*$) were based on the information regarding heating system use in various standard metropolitan statistical areas (SMSAs) from national American Housing Survey (U.S. Census Bureau). The survey includes information on the number of total housing units as well as the number of "main heating equipment". The "main heating equipment" accounted for in the present analysis includes: warm-air furnace; steam or hot water system; electric heat pump; built-in electric heating units; floor, wall or other built-in hot air units without ducts; and room heaters with a flue. The fraction of residences with some type of heating system ($y^*$) was calculated as the sum of these heating systems divided by the total number of housing units.

***Indoor temperature.*** For homes with AC, when the outdoor temperature is higher than $T_{cutoff,1}$ (24 $^{o}$C), we have assumed that the AC is on and that the average indoor temperature is 24 $^{o}$C (based on the Residential Buildings Energy Consumption Survey (RECS) by the U.S. EIA (2005)). For homes without AC, the average indoor temperature is calculated to be $(T_{max} + T_{cutoff,1})/2 + \Delta T_1$.

In mild weather, when the outdoor temperature is between $T_{cutoff,1}$ and $T_{cutoff,2}$, we have assumed that both the AC and the heating system are off, and the average indoor temperature is calculated to be $(T_{cutoff,1} + T_{cutoff,2})/2 + \Delta T_2$.

For homes with heating system, when the outdoor temperature is lower than $T_{cutoff,2}$ (15 $^{o}$C), we have assumed that the heating system is on and that the average indoor temperature is 21 $^{o}$C (based on the Residential Buildings Energy Consumption Survey (RECS) by the U.S. EIA(2005)). For homes without a heating system, the average indoor temperature is calculated by $(T_{cutoff,2} + T_{min})/2 + \Delta T_3$.

All the ΔTs represent the temperature differences between indoors and outdoors due to indoor heat sources and the thermal capacity of building envelopes. As a rough approximation, we have assumed that $\Delta T_1 = 1\ ^oC$, $\Delta T_2 = 3\ ^oC$, $\Delta T_3 = 5\ ^oC$. The sensitivity of our results to these parameters ($T_{cutoff,1}$, $T_{cutoff,2}$, $\Delta T_1$, $\Delta T_2$, $\Delta T_3$) is examined in the following table:

**eTable 7.** Sensitivity of the association between "average indoor temperature" and "$PM_{10}$ mortality coefficients" to calculation method for $T_{cutoff,1}$, $T_{cutoff,2}$, $\Delta T_1$, $\Delta T_2$ and $\Delta T_3$.

| | **r** |
|---|---|
| $\boldsymbol{T_{cutoff,1}}$ – 24 $^o$C (favored value) | 0.15 |
| $\boldsymbol{T_{cutoff,1}}$ – 18.3 $^o$C (lower estimate) | 0.08 |
| $\boldsymbol{T_{cutoff,1}}$ – 26 $^o$C (upper estimate) | 0.26 |
| $\boldsymbol{T_{cutoff,2}}$ – 15 $^o$C (favored value) | 0.15 |
| $\boldsymbol{T_{cutoff,2}}$ – 12 $^o$C (lower value) | -0.00 |
| $\boldsymbol{T_{cutoff,2}}$ – 18.3 $^o$C (upper estimate) | 0.21 |
| $\Delta T_1$ – 1 $^o$C (favored value) | 0.15 |
| $\Delta T_1$ – 0 $^o$C (lower value) | 0.18 |
| $\Delta T_1$ – 3 $^o$C (upper value) | 0.07 |
| $\Delta T_2$ – 3 $^o$C (favored value) | 0.15 |
| $\Delta T_2$ – 0 $^o$C (lower value) | -0.18 |
| $\Delta T_2$ – 5 $^o$C (upper value) | 0.21 |
| $\Delta T_3$ – 5 $^o$C (favored value) | 0.15 |
| $\Delta T_3$ – 3 $^o$C (lower value) | 0.13 |
| $\Delta T_3$ – 10 $^o$C (upper value) | 0.13 |

***Monthly average indoor temperature in a given city.***

When the outdoor temperature is higher than $T_{cutoff,1}$, the average indoor temperature can be approximated using Eq. S16:

$$T_{in,summer} = (y')\ (24\ ^oC) + (1- y')\ [(T_{max} + T_{cutoff,1})/2 + \Delta T_1] \quad \text{(S16)}$$

When the outdoor temperature is between $T_{cutoff,1}$ and $T_{cutoff,2}$, the average indoor temperature can be approximated using Eq. S17:

$$T_{in,mild} = (T_{cutoff,1} + T_{cutoff,2})/2 + \Delta T_2 \quad \text{(S17)}$$

When outdoor temperature is lower than $T_{cutoff,2}$, the average indoor temperature can be approximated using Eq. S18:

$$T_{in,winter} = (y^*)\,(21\ ^{o}\mathrm{C}) + (1-y^*)\,[(T_{cutoff,2} + T_{min})/2 + \Delta T_3] \quad \text{(S18)}$$

Therefore, for a given city, the average indoor temperature can be approximated using Eq. S19:

$$T_{in} = (x_{cool})(T_{in,summer}) + (x_{mild})(T_{in,mild}) + (x_{heat})(T_{in,winter}) \quad \text{(S19)}$$

## Other limitations.

The following limitations were presented in our companion paper, which assesses the influence of indoor exposure to ozone of outdoor origin on the relationship between ozone and short term mortality in U.S. cities (Chen et al. 2012). We repeat them here since these same limitations apply to the present analysis of PM10 exposure and mortality coefficients.

When estimating normalized total $PM_{10}$ exposure, there is no well-matched "representative city" for NMMAPS cities located in the middle of the U.S. These cities tend to have low $PM_{10}$ mortality coefficients in summer and, based on the present analysis, would be anticipated to have low normalized total $PM_{10}$ exposure. We do know that the fraction of residences with central AC is high in these cities (e.g., Kansas City KS, 0.84; Kansas City MO, 0.84; Omaha NE, 0.83; Wichita KS, 0.80), consistent with a low normalized total $PM_{10}$ exposure.

The infiltration rates used in the present analysis are for single family homes (Table 8, Persily et al., 2010). More assumptions are required to calculate infiltration rates for apartment buildings, and there are few measurements of airtightness and ventilation system performance in such buildings (Persily et al., 2010). Hence, we have not attempted to include estimates of infiltration rates for apartment buildings. Yet we recognize that the fraction of a city's residents who live in apartment buildings varies from city-to-city. This is a factor that might be considered in future analysis, as infiltration data becomes available for apartment buildings in different geographic regions. Furthermore, the infiltration rates used in this study are not anticipated to apply to non-residential indoor locations. NHAPS indicates that, on average, the U.S. population spends 69%

of their time in residences, 5.4% in offices or factories, and 12.8% in other indoor locations (Klepeis et al. 2001).

We neglected the resuspension of indoor $PM_{10}$ of outdoor origin when estimating the average change in indoor $PM_{10}$ concentration per change in outdoor $PM_{10}$. The resuspension of particles is a complicated phenomenon influenced by multiple factors including: the degree of human activity and other disturbances indoors, cleanliness of the surfaces, and the nature of the deposited particles. Regional and seasonal differences in the resuspension of indoor $PM_{10}$ of outdoor origin require further examination.

## References


Alevantis L. E., Girman J. R., "The effects of window-opening on residential ventilation," *IAQ'89,* American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta, 1989.

Chen C, Zhao B. 2011. Review of relationship between indoor and outdoor particles: I/O ratio, infiltration factor and penetration factor. Atmos Environ 45: 275-288.

Chen C, Zhao B, Weschler CJ. 2012. Assessing the influence of indoor exposure to "outdoor ozone" on the relationship between ozone and short-term mortality in U.S. communities Environ Health Perspect. 2012; 120:235-240.

Haldi F, Robinson D. 2009. Interactions with window openings by office occupants. Build Environ 44: 2378-2395.

Herkel S, Knapp U, Pfafferott. 2008. Towards a model of user behaviour regarding the manual control of windows in office buildings. Build Environ 43: 588-600.

Klepeis NE, Nelson WC, Ott WR, Robinson JP, Tsang AM, Switzer P, et al. 2001. The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. J Expo Anal Environ Epidemiol 11:231-252.

Lennox Inc. 2011. 2011 Product Manual for IAQ Systems and Home Comfort Controls. www.DaveNet.com.

Meng QY, Spector D, Colome S, Turpin B. 2009. Determinants of indoor and personal exposure to PM2.5 of indoor and outdoor origin during the RIOPA study. Atmos Environ 43: 5750-5758.

NOAA 2002. "United States Climate Normals 1971-2000. Annual Degree Days to Selected Bases."Climatography of the United States No. 81. Supplement No. 2. National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, an Information Service, National Climatic Data Center. Asheville, NC.

Peng RD, Dominici F, Pastor-Barriuso R, Zeger SL, Samet JM. 2005. Seasonal analyses of air pollution and mortality in 100 U.S. cities. Am J Epidemiol 161: 585-94.

Persily A, Musser A, Emmerich SJ. 2010. Modeled infiltration rate distributions for U.S. housing. Indoor Air 20:473-485.

Rijia HB, Tuohy P, Humphreys MA, Nicol JF, Samuel A, Clarke J. 2007. Using results from field surveys to predict the effect of open windows on thermal comfort and energy use in buildings. Energy Build 39: 823-836.

Riley WJ, McKone TE, Lai AK, Nazaroff WW. 2002. Indoor particulate matter of outdoor origin: importance of size-dependent removal mechanisms. Environ Sci Technol 36: 200-207.

Sinclair JD, Psota-Kelty LA, Weschler CJ, Shields HC. 1990. Measurement and modeling of airborne concentrations and indoor surface accumulation rates of ionic substances at Neenah, Wisconsin. Atmos Environ 24A: 627-638.

Smith RL, Xu BW, Switzer P. 2009. Reassessing the relationship between ozone and short-term mortality in US urban communities. Inhal Toxicol 21:37-61.

U.S. Census Bureau. American FactFinder and American Housing Surveys. (Available: http://factfinder.census.gov/home/saff/main.html?_lang=en) 2006.

U.S. Energy Information Administration (EIA) 2005.Residential Buildings Energy Consumption Survey (RECS) Public Use Data.(http://www.eia.doe.gov/emeu/cbecs/public_use.html)

Wallace LA, Emmerich SJ, Howard-Reed C. 2002. Continuous measurements of air change rates in an occupied house for 1 year: The effect of temperature, wind, fans, and windows. J Expos Anal Environ Epidemiol. 12: 296-306.

Yun GY, Steemers K. 2008. Time-dependent occupant behaviour models of window control in summer. Build Environ 43: 1471-1482.