Supplement for manuscript

Effects of meteorology and emissions on urban air quality: a quantitative statistical approach to long-term records (1999–2016) in Seoul, South Korea

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Table S1. Degrees of freedom (dof) of each time series of short-term, baseline, and long-term components calculated based on Leith (1973).

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<th>NO$_2$</th>
<th>CO</th>
<th>O$_3$8h</th>
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<th>RH</th>
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Figure S1. (a) Numbers of available air quality monitoring sites in Seoul, of which missing data are less than 10% of the total. (b) Average and (c) standard deviation of PM$_{10}$ concentrations in Seoul. Asian dust events those were excluded from the PM$_{10}$ analysis are marked with orange color.
Figure S2. Number distribution of (a) daily average PM$_{10}$ concentration and (b) log-transformed daily average PM$_{10}$ concentration. The bell shaped curves show normal (Gaussian) distributions, and #, μ, and σ denote the total number of days, mean values, and standard deviation, respectively. Asian dust event days were excluded from the analysis.
Figure S3. Decompositions of (a) PM$_{10}$ and (b) O$_{3 \text{8h}}$ time series in Seoul for 1999–2016.
Figure S4. Power spectra of (a) log-transformed daily average PM$_{10}$ concentration time series (a black line) and its (b) short-term, (c) seasonal, and (d) long-term components (red lines). Effective filter widths for $KZ_{(15,5)}$ filter (33 days) and $KZ_{(365,3)}$ filter (632 days) are marked with blue vertical dashed lines.
Figure S5. An example of obtaining horizontal gradient of long-term component ($X_{LT}$) of PM$_{10}$ on 23 February 2014. (a) Locations of 70 air quality monitoring sites in Cartesian coordinates centered at the Seoul weather station (37.57° N, 126.97° E), of which data availability were more than 75% for the period of 1999–2016. (b) Meridional gradients of the baseline ($\frac{\partial X_{BL}}{\partial y}$) and seasonal component ($\frac{\partial X_{SN}}{\partial y}$) obtained by linear regressions. (c) Zonal gradients of the baseline ($\frac{\partial X_{BL}}{\partial x}$) and seasonal component ($\frac{\partial X_{SN}}{\partial x}$). Zonal and meridional gradient of the long-term component can be gained by subtracting the seasonal component gradients from the baseline gradients ($\frac{\partial X_{LT}}{\partial x} = \frac{\partial X_{BL}}{\partial x} - \frac{\partial X_{SN}}{\partial x}$, $\frac{\partial X_{LT}}{\partial y} = \frac{\partial X_{BL}}{\partial y} - \frac{\partial X_{SN}}{\partial y}$).
Figure S6. Long-term component of (a) zonal wind ($u_{LT}$) and (b) meridional wind ($v_{LT}$) at the Seoul weather station. Zonal gradient ($\partial X_{LT}/\partial x$, red lines) and meridional gradients ($\partial X_{LT}/\partial y$, blue lines) of the long-term components and transport term ($-\mathbf{V}_{LT} \cdot \nabla X_{LT}$, violet lines) by long-term components of horizontal winds ($\mathbf{V}_{LT} = (u_{LT}, v_{LT})$) for (c–d) PM$_{10}$, (e–f) CO, (g–h) SO$_2$, (i–j) NO$_2$, (k–l) O$_3$. 

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Figure S7. (a) Mean geopotential height (contours with interval of 20 gpm) and wind fields (arrows with reference scale of 3 m s\(^{-1}\)) at 850 hPa, and linear trends of (b) geopotential height (contours with interval of 0.5 gpm yr\(^{-1}\)) and wind (arrows with reference scale of 0.1 m s\(^{-1}\) yr\(^{-1}\)) at 850 hPa and (c) 10 m wind speed (contours with interval of 0.01 m s\(^{-1}\) yr\(^{-1}\)) for the period of 2000–2015. The trends statistically significant at 95% confidence level in (b) and (c) are represented as gray shaded areas and wind arrows. Seoul is marked by solid red circles.