Online Supplemental Material

Estimating emissions and concentrations of road dust aerosol over China using the GEOS-Chem model

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Calculation of road dust emission

We use the Air Pollutant Emission Factors (AP-42) model developed by the U.S. Environmental Protection Agency (USEPA, 2011) to calculate road dust emissions from paved roads in China. The emission at grid cell \( j \), \( E_j \), is calculated by

\[
E_j = \sum_{i=1}^{n} A_j \times EF_{ij},
\]

where \( EF_{ij} \) (gram of road dust per vehicle kilometer traveled, g VKT\(^{-1}\)) is the emission factor for road type \( i \) in grid \( j \), and \( n \) is 6, which represents 6 road types including freeway, first-class highway, second-class highway, third-class highway, fourth-class highway, and other highway according to the national highway levels of China (CCOT, 2007–2012). \( A_j \) (VKT) represents traffic activity rate (vehicle mileage traveled) of road type \( i \) in grid \( j \).

The monthly emission factor \( EF_{ij} \) of paved road for road type \( i \) is calculated as

\[
EF_{ij} = k \times (sL_{ij})^{0.01} \times (W_{ij})^{0.02} \times (1 - Pr_j / 4N),
\]

where \( k \) is a constant (function of particle size) in g VKT\(^{-1}\), in this study, we use the AP-42 document-recommended value, \( k=0.62 \), for PM\(_{10}\); the value of \( sL_{ij} \) is the road surface silt loading for road type \( i \) in grid \( j \) (g m\(^{-2}\)); \( W_{ij} \) stands for the average weight (tons) of the vehicles traveling the road for road type \( i \) in grid \( j \); \( Pr_j \) is the number of “wet” days with at least 0.254mm (0.01 in) of precipitation during the averaging period in grid \( j \) which is calculated from the meteorological field; and \( N \) is the number of days in the averaging period (e.g., 365 for annual).

Once \( sL \) and \( W \) are determined, according to the formula above, paved road particulate emission factor \( EF \) can be estimated. However, the emission parameters above are almost changing with areas and require field experiments to determine, and we do not have enough experiments to determine them for every grid. Therefore, referring to previous studies, we obtain the values of \( sL_{ij} \) and \( W_{ij} \) from the studies for Pearl River Delta (PRD, 21°–23.5°N, 112°–116°E) (Peng et al., 2013), Beijing-Tianjin-Tanggu (BTT, 35°–40°N, 114°–120°E) (Shou-bin et al., 2009),
Yangtze River Delta (YRD, 29.5°–32.5°N, 118°–122°E) (Yanmin et al., 2006), and Sichuan Basin (SCB, 28°–31.5°N, 102.5°–107.5°E) (Yang et al., 2015). For other areas, we use the average values of $s_{L_{ij}}$ and $W_{ij}$ from four areas above.

The value of $A_{ij}$ (VKT) can be determined by traffic flow and road length (Peng et al., 2013):

$$A_{ij} = F_{ij} \times L_{ij} \times T,$$

where $F_{ij}$ (h$^{-1}$) is the traffic flow of road type $i$ in grid $j$; $L_{ij}$ (km) represents the length of road type $i$ in grid $j$, and $T$ (h) is the number of hours in the period (e.g., 24 for daily).

The data of $L_{ij}$ for each grid over China comes from WGS84 Datum (http://tapiquen-sig.jimdo.com/english-version/free-downloads/china/). However, there is a difference in the road lengths of WGS84 Datum and Year Book of China Transportation & Communication, thus we multiplied factors for correction due to the values in Year Book of China Transportation & Communication (CCOT, 2007–2012).

The transport emissions of HTAP_V2 data set and traffic flow information in previous studies are used to determine the monthly value of $F_{ij}$ of road type $i$ in grid $j$.

Firstly, we defined the traffic flow of road type $i$ in grid $j$, $F_{ij}$ as:

$$F_{ij} = \frac{F_{total}}{P_j} \times R_i,$$

where the value of $R_i$ represents the ratio of traffic flow for road type $i$ to the total traffic flow; and $P_j$ represents the ratio of traffic flow in grid $j$ to the total traffic flow in China; $\frac{F_{total}}{}$ (h$^{-1}$) represents total traffic flow of China.

$R_i$ can be calculated from:

$$R_i = \frac{1}{3} \left[ \left( \frac{F_{PROD}}{F_{PRD}} \right) + \left( \frac{F_{YRD}}{F_{YRD}} \right) + \left( \frac{F_{SCB}}{F_{SCB}} \right) \right],$$

where $F_{PRD}$, $F_{YRD}$, and $F_{SCB}$ represent the traffic flow in PRD, YRD, and SCB of road type $i$, and $F_{PRD}$, $F_{YRD}$, and $F_{SCB}$ represent the total traffic flow in PRD, YRD, and SCB by the sum of all road types. The values for the six variables describe above can be derived from previous studies (Yanmin et al., 2006; Peng et al., 2013; Yang et
The defined ratio $P_j$ is derived from HTAP_V2 dataset (http://edgar.jrc.ec.europa.eu/htap_v2/) which calculated the transport emission data for different pollutant species (such as SO$_2$, NO$_x$, and so on) by using traffic activity data and emission factors (Zheng et al., 2014). Here we assume that the ratio of transport emission in each grid to the total transport emission is equal to the ratio of traffic flow, which is described as $P_j$. So we can calculate $P_j$ from the formula as follows:

$$P_j = \frac{E_{HT_j}}{E_{HT_{total}}},$$

where $E_{HT_{total}}$ is the total transport emission from HTAP_V2 dataset for all grids in China, and $E_{HT_j}$ is the transport emission of grid $j$.

Next, the traffic flow for all grids is calculated by dividing traffic flow in PRD, YRD, and SCB by their related ratio $P_j$,

$$F_{total} = \frac{1}{3} \left( \frac{F_{PRD}}{P_{PRD}} + \frac{F_{YRD}}{P_{YRD}} + \frac{F_{SCB}}{P_{SCB}} \right),$$

where $F_{PRD}$, $F_{YRD}$, and $F_{SCB}$ represent the total traffic flow in PRD, YRD, and SCB; and $P_{PRD}$, $P_{YRD}$, and $P_{SCB}$ are the transport flow ratios over three areas. The total traffic flow over China is multiplied by factors according to the vehicle numbers in Year Book of China Transportation & Communication for each year (CCOT, 2007–2012).

Then, the monthly variation of $F_{ij}$ is multiplied by factors for correction due to transportation volume in Year Book of China Transportation & Communication (CCOT, 2007–2012).

In other word, $A_{ij}$ is dependent on road length and vehicle number that have yearly variations and are from Year Book of China Transportation & Communication. Lastly, we get the road dust emission at each grid cell.
References

CCOT. 2007–2012. Year Book of China Transportation & Communication. Beijing: Year Book House of China Transportation & Communications.

Peng, K., Y. Yang, J. Zheng, et al. 2013. "Emission factor and inventory of paved road fugitive dust sources in the Pearl River Delta region." Acta Scientiae Circumstantiae 33: 2657-2663.

Shou-bin, F., T. Gang, L. Gang, et al. 2009. "Road fugitive dust emission characteristics in Beijing during Olympics Game 2008 in Beijing, China." Atmospheric Environment 43: 6003-6010. doi:10.1016/j.atmosenv.2009.08.028.

USEPA. 2011. " Section 13.2.1: Paved Roads." In Emission factor documentation for AP-42, edited by United States Environmental Protection Agency. Kansas City: Midwest Research Institute.

Yang, D., Z. Ye, H. Yang, et al. 2015. "EMISSION INVENTORY AND SPATIAL DISTRIBUTION OF PAVED ROAD FUGITIVE DUST IN CHENGDU IN SICHUAN PROVINCE." Environment Engineering 33: 83-87.

Yanmin, H., S. H. U. Jiong, W. E. I. Haiping, et al. 2006. "Estimation of fugitive dust emission from paved roads in Wusong industrial estate based on GIS." Science of surveying and mapping 31: 133-136.

Zheng, B., H. Huo, Q. Zhang, et al. 2014. "High-resolution mapping of vehicle emissions in China in 2008." Atmospheric Chemistry and Physics 14: 9787-9805. doi:10.5194/acp-14-9787-2014.