1 **Quantifying sources of elemental carbon over the Guanzhong Basin of China:**
2 **A consistent network of measurements and WRF-Chem modeling**

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Abstract:

We conducted a year-long WRF-Chem (Weather Research and Forecasting Chemical) model simulation of elemental carbon (EC) aerosol and compared the modeling results to the surface EC measurements in the Guanzhong (GZ) Basin of China. The main goals of this study were to quantify the individual contributions of different EC sources to EC pollution, and to find the major cause of the EC pollution in this region. The EC measurements were simultaneously conducted at 10 urban, rural, and background sites over the GZ Basin from May 2013 to April 2014, and provided a good base against which to evaluate model simulation. The model evaluation showed that the calculated annual mean EC concentration was $5.1 \mu\text{gC m}^{-3}$, which was consistent with the observed value of $5.3 \mu\text{gC m}^{-3}$. Moreover, the model result also reproduced the magnitude of measured EC in all seasons (regression slope = 0.98-1.03), as well as the spatial and temporal variations ($r = 0.55$ -0.78). We conducted several sensitivity studies to quantify the individual contributions of EC sources to EC pollution. The sensitivity simulations showed that the local and outside sources contributed about 60% and 40% to the annual mean EC concentration, respectively, implying that local sources were the major EC pollution contributors in the GZ Basin. Among the local sources, residential sources contributed the most, followed by industry and transportation sources. A further analysis suggested that a 50% reduction of industry or transportation emissions only caused a 6% decrease in the annual mean EC concentration, while a 50% reduction of residential emissions reduced the winter surface EC concentration by up to 25%. In respect to the serious air pollution problems (including EC pollution) in the GZ Basin, our findings can provide an insightful view on local air pollution control strategies.

Main finding:

Local source is the major source of EC pollution in the GZ Basin and reduction of residential emissions is the most effective way to control the pollution.

Key words: Elemental carbon; Source apportionment; WRF-Chem; the Guanzhong Basin

1. Introduction

In recent years, China has exhibited severe air pollution in the form of fine particulate matter (PM_{2.5}) (Chan et al., 2008; Cao, 2014). Elemental carbon aerosol (EC), alternatively referred to as black carbon aerosol (BC) (Petzold et al., 2013), is an important component of PM_{2.5}, especially in the Guanzhong (GZ) Basin which is the most EC-polluted area in Western China (Cao et al., 2005, 2007, 2012a; Shen et al., 2011; Wang et al., 2015; Zhao et al., 2015a, b). EC is emitted directly from the incomplete combustion of fossil fuels (e.g. coal and diesel) and biomass (e.g. biofuel, agricultural and forest fires) (Cao et al., 2006; Zhang et al., 2009). EC considerably influences climate change by heating the atmosphere and cooling the land surface through its absorption of solar radiation (Jacobson, 2001; Ramanathan et al., 2001; Chung and Seinfeld, 2005; Ramanathan and Carmichael, 2008). EC also has adverse effects on air quality resulting from its contribution to regional haze and poor visibility (Cao et al., 2012b; Q. Zhang et al., 2015). Furthermore, EC has deleterious impacts on human health because of absorbing harmful gases, such as polycyclic aromatic hydrocarbons (PAHs) (Dachs and Eisenreich, 2000; Anenberg et al., 2011, 2012).

Many efforts have been made to estimate EC emissions in China (Streets et al., 2003a, b; Bond et al., 2004; Zhang et al., 2009; Lei et al., 2011; Lu et al., 2011; Kondo et al., 2011; Qin and Xie, 2012; Fu et al., 2012, Li et al., 2015). The annual mean Chinese EC emission estimated by previous studies for the year 2000-2010 varied from 1.0 to 2.9 TgC yr⁻¹, with strong regional and seasonal variations of the source proportion. For example, the major emission source of EC in large parts of China is residential sectors. This is particularly true in the winter in Northern China (residential sources contribute more than 60% to total EC emissions), a time and place in which home heating abound (Zhang et al., 2009; Li et al., 2015). However, when turning to the Yangtze River Delta region in Eastern China, we find the emissions from industries dominate in the spring, summer and autumn (~50%, Zhang et al., 2009; Li et al., 2015). In the Pearl River Delta region in Southern China, the transportation sectors play the most important roles (65%, Zheng et al., 2012).

Chemical transport models bridge the relations between the emission sources and ambient concentrations. However, we find limited studies on model-based characterizations of source contributions to EC pollutions (Chen et al., 2013; Liu et al., 2014; Kumar et al., 2015; R. Zhang et al., 2015; Zhao et al., 2015a). Kumar et al. (2015) used WRF-Chem to simulate surface black carbon (BC) aerosol over the Bay of Bengal and Arabian Sea. They suggested that residential sources were the major anthropogenic sources (61%) of BC concentration in South Asia and that regional-scale transport contributed up to 25% in Western and Eastern India. R. Zhang et al. (2015) used the CAM5 model to calculate the BC concentrations from various regions and sectors over the Himalayas and Tibetan Plateau. They pointed out that the largest contribution to the annual mean BC concentration in the Himalayas and Tibetan Plateau is from biofuel and biomass emissions from South Asia, followed by fossil fuel emissions from South Asia. Also focusing on the GZ Basin, Zhao et al. (2015a) used WRF-Chem to characterize fate of BC emitted from local and various neighboring areas. They found that the local and regional transport sources, respectively, contributed 60 and 40% to the annual mean BC concentration. They further pointed out that the regional transport was mostly from east of the GZ Basin (65%), but the sectorial contribution of the local GZ sources were not quantified.

In this study, we conducted a year-long simulation of EC concentrations in the GZ Basin. The simulation was driven by current best bottom-up estimate of EC emissions in this area. We compared the calculated results with the surface EC measurements in a network of 10 sites over the GZ Basin. Goals of the study were to analyze the temporal and spatial characteristics of EC pollution and then to identify the region- and sector-specific source contributions in the GZ Basin. This assessment result is expected to provide useful information for potential mitigation actions.

2. Model and Data

2.1 The WRF-Chem model

The regional chemical model WRF-Chem (Weather Research and Forecasting Chemical model, version 3.2) was applied to simulate the EC distributions in the GZ

Basin. The WRF model is a fully compressible, Euler non-hydrostatic model that simulates meteorological fields. Based upon WRF, the WRF-Chem model includes an online calculation of dynamical inputs (e.g., winds, temperature, boundary layer and clouds), transport (advection, convective and diffusive), dry and wet depositions, gas phase chemistry, as well as radiation and photolysis rates (Tie et al., 2003). A detailed description of WRF-Chem has been given by Grell et al. (2005), and some modifications in the chemical scheme have been introduced by Tie et al. (2007). The Yonsei University (YSU) PBL scheme is used in the model. This scheme uses counter-gradient terms to represent fluxes and explicitly considers the entrainment effect to calculate the PBL heights (Hong et al., 2006; Noh et al., 2001). Dry deposition is calculated as per Wesely (1989), with EC deposition velocity being 0.001 m s^{-1} . The Lin microphysics scheme (Lin et al., 1983), the Noah land-surface model (Chen and Dudhia, 2001), the longwave radiation parameterization (Mlawer et al., 1997) and the shortwave radiation parameterization (Dudhia, 1989) were used in this study.

The simulation domain (Fig. S1) centered on the GZ Basin, a region in China developing quickly but with high pollution levels (Shen et al., 2009, 2011; Wang et al., 2015). The GZ Basin, surrounded by the Qinling Mountains and the Loess Plateau, has a population of 22.4 million people. It is located in Western China and belongs to the mainland monsoon climate. We applied a study domain with a $3 \times 3 \text{ km}$ horizontal resolution and a 28-layer vertical structure. NCEP FNL Operational Global Analysis data provided the initial and boundary conditions for the meteorological fields. The initial and boundary conditions of EC were taken from monthly mean outputs from a global chemical transport model (Model for Ozone and Related chemical Tracers, MOZART) (Tie et al., 2005; Emmons et al., 2010). The initial EC was $1.5 \mu\text{g m}^{-3}$ as averaged for simulation domain, and the annual-mean boundary EC was $1.3 \mu\text{g m}^{-3}$ as averaged for the four laterals. The simulation was conducted for a period of one year, from May 2013 to April 2014. Considering the computational costs, we simplified the WRF-Chem model by reducing the complex chemical schemes of gases and aerosols. Only the modules related to the simulation of EC (emission, transport, and deposition)

were kept in our simulation (Zhao et al., 2015a, b).

2.2 Emissions

As a starting point for this study, we compiled the current best bottom-up EC emission inventories in the GZ Basin and the surrounding areas. These inventories included EC emissions from anthropogenic and open biomass burning sources. Table 1 summarizes the annual EC emission for the GZ Basin used in this study.

The anthropogenic EC emission was obtained from the Multi-resolution Emission Inventory for China (Li et al., 2015) for the year 2009, and included industry, power generation, transportation, as well as residential sources. Zhao et al. (2015a) applied this emission inventory to WRF-Chem and extensively compared the simulated EC concentration with surface measurements. The inventory had a 3×3 km spatial resolution, with a monthly temporal variation. The total annual anthropogenic EC emission for the GZ Basin was 28.5 GgC y⁻¹, including 13.9 GgC y⁻¹ from residential sources, 7.9 GgC y⁻¹ from industry, 6.7 GgC y⁻¹ from transportation, and less than 0.1 GgC y⁻¹ from power generation. The uncertainty (95% confidence interval, CI) for the anthropogenic EC emission in all of China was -50% to +100% but was not separately quantified in the GZ Basin. Although the date of this emission inventory did not match that of our simulation, the above emission data was taken as a reasonable choice for this study. To evaluate the rationality, we constrained this emission estimates with surface EC measurements in 2013-2014 using a top-down approach. Our results suggest that the top-down estimated EC emissions in 2013-2014 are no more than 5% higher than the original emissions in 2009. In addition, we compared the EC concentration data during 2009-2014 (Cao, 2014) observing at Institute of Earth Environment (an urban site in the GZ Basin, 34.23°N, 108.89°E). The small difference ($<\pm 5\%$) also implies no significant changes in emissions.

The open biomass burning EC emission was taken from the Fire Inventory from NCAR (FINN) (Wiedinmyer et al., 2011) for the year 2013-2014. This inventory provides high-resolved emission estimates both spatially (1×1 km) and temporally (daily) and includes wildfire, agricultural fires, and prescribed burning. The total

annual open biomass burning EC emission for the GZ Basin was 0.5 GgC y^{-1} , which was relatively small compared with the anthropogenic sources (28.5 GgC y^{-1}). The uncertainty of FINN was approximately a factor of two (Wiedinmyer et al., 2011).

Figure 1 shows the spatial distributions of the annual EC emissions in the GZ Basin from various sources. The industrial source had a strong spatial gradient, with the highest emissions centered in the city area. The residential source was evenly distributed in the GZ Basin, due to the dense farming activities in the region. The transportation brought on emissions mostly in urban areas, such as Xi'an, but rural areas also showed significant emissions, due to the dense roads and highway systems in these regions. In addition, as shown in Fig. S2, the areas outside the GZ Basin also experienced important EC emissions. One important outside source (Shanxi province) was located to east of the GZ Basin. That source's emissions could have been transported to the GZ Basin, affecting EC concentrations (Zhao et al., 2015a). Figure S3 shows the seasonal pattern of the EC emissions to be significantly higher in the winter (Dec., Jan. and Feb.) than in other seasons (i.e. spring, Mar-May; summer, Jun-Aug; and autumn, Sep-Nov). This strong seasonality was mainly caused by fossil-fuel and biofuel usage in residential winter heating (Zhang et al., 2009).

2.3 EC measurements in the GZ Basin

To better evaluate model performance, we needed representative EC measurements with sufficient spatial coverage and temporal resolution. In this study, a continuous high temporal resolution (daily) measurement of EC was conducted at 10 observation sites. This measurement allowed for the representation of different emission sources (urban residence, transport, rural area, etc.).

The 10 observation sites, 7 urban sites (BJ, CU, IEE, TC, WN, XJU, and XP), 2 rural sites (DL and HC), and 1 background site (QL), covered most regions of the GZ Basin (Fig. S1b). The sampling campaign was from May 2013 to April 2014 and provided the full information on the regional and seasonal characteristics of EC. Table 2 lists details for the 10 sites.

In each site, we collected 24-h $\text{PM}_{2.5}$ filter samples by mini-volume samplers

(Airmetrics, USA) at a flow rate of 5 L min^{-1} every 6 days. We used 47 mm Whatman quartz-fibre filters (QM/A Whatman Inc., UK), pre-heated to 900°C for at least 3 hours to remove adsorbed organic vapors. We analyzed a 0.5 cm^2 punch from the filter for EC concentration following the IMPROVE_A (Interagency Monitoring of Protected Visual Environments) thermal optical reflectance (TOR) protocol (Chow et al., 2007) using the DRI model 2001 Carbon Analyzer (Atmoslytic, Inc., USA).

The daily mean observed surface EC concentrations varied in the range of $0.4\text{--}23.1 \mu\text{gC m}^{-3}$, and showed a mean level of $5.3 \mu\text{gC m}^{-3}$. This value was similar to the seasonal means observed in the Pearl River Delta region ($1\text{--}13 \mu\text{gC m}^{-3}$), the Yangtze River Delta region ($1\text{--}33 \mu\text{gC m}^{-3}$) and the Beijing-Tianjin-Hebei region ($2\text{--}32 \mu\text{gC m}^{-3}$) (Cao, 2014). Table 2 shows the observed annual mean EC concentrations at the 10 sites, with the highest value at the urban sites in the Xi'an city (the IEE, XJU and CU sites) and the lowest at the rural and background sites (the HC and QL sites). As shown in Fig. S4, the observed EC exhibited clear seasonal variations. The highest EC occurred in winter ($7.7 \mu\text{gC m}^{-3}$), followed by autumn ($6.0 \mu\text{gC m}^{-3}$), spring ($4.3 \mu\text{gC m}^{-3}$) and summer ($3.3 \mu\text{gC m}^{-3}$).

3. Results and discussions

3.1 Model evaluation

We simulated EC concentrations over the GZ Basin using the emission estimates in Sect. 2.2 and compared the model results with the surface EC measurements in Sect. 2.3. Figure S5 shows the spatial distributions of the simulated and observed surface EC concentrations in different seasons. The spatial patterns of simulated EC were similar throughout the different seasons, with higher concentrations in the center of the GZ Basin. The patterns were mainly driven from the high EC emissions in the region (Fig. 1) and stable local meteorological conditions (Zhao et al., 2015a). We also found that outside transport from east of the GZ Basin was evident, especially during winter.

Figure S4 shows the simulated and observed surface EC concentrations at the 10 sites. The simulated annual mean EC concentration averaged for all sites was $5.1 \mu\text{gC}$

m^{-3} , only 4% lower than the observed $5.3 \mu\text{gC m}^{-3}$. Consistent with the observations, simulated seasonal EC concentration ranged from $0.7\text{--}13.8 \mu\text{gC m}^{-3}$ and was higher in winter ($8.0 \mu\text{gC m}^{-3}$) and autumn ($5.4 \mu\text{gC m}^{-3}$) than in spring ($3.9 \mu\text{gC m}^{-3}$) and summer ($3.1 \mu\text{gC m}^{-3}$). The simulated seasonal EC concentration agreed well with observations at most sites, with a normalized mean bias (NMB) of -3% for urban sites and -13% for rural and background sites.

We summarized the model performance via a statistical comparison between the measured and simulated daily mean EC concentrations at the 10 sites for each season (Fig. S6). We felt comfortable with the regression slopes in all seasons, in a range of 0.98-1.03, indicating that our model undoubtedly reproduced the magnitude of the measurements in all seasons. Additionally, the correlation coefficients between simulated and measured EC were in the range of 0.55-0.78, suggesting that our model satisfactorily captured the spatial and temporal variations of the observation in spring ($r=0.78$), winter ($r=0.74$), autumn ($r=0.70$) and summer ($r=0.55$).

3.2 EC contributions from different sources

The main objective of this study was to estimate the individual source contributions to EC pollution in the GZ Basin. Good model performance implies our model's capability of quantifying EC sources. We conducted a series of sensitivity simulations by turning off the emissions from each source (industry, power plant, residential, transportation and open biomass burning sources in the GZ Basin), in turn and all at once. This was done to evaluate the contributions to surface concentrations from each source sector and from outside transport.

Figure 2 shows the sectorial contributions to the simulated annual mean EC concentrations at the 10 GZ sites. At the urban sites, residential sources were the most important contributors of surface EC concentrations, contributing in the range of 36-44%. The outside transport, industry and transportation sources followed, contributing 25%, 20% and 16% on average, respectively. At the sites in the city of Xi'an (i.e., the IEE, XJU and CU sites), the EC was more influenced by local residential, industrial and transportation sources, than by outside transport. For the

rural sites (HC and DL), an important outside source exists to east of this region (Fig. S2), having strong effects on EC concentrations in these sites. As a result, the most important contributor for this region was transport from the outside sources (64-66%). For the background site QL (in the Qinling Mountain), most of the EC concentration was attributed to transport from outside sources (84%), suggesting that this location ideally serves as a remote background site. Open biomass burning (less than 2%) and power plants (less than 1%) played minor roles for the annual-mean EC concentration at all urban, rural and background sites.

Figure 3 shows the spatial distributions of the simulated annual mean EC concentrations from each individual source. The results suggest that the local and outside sources, respectively, contributed 59 and 41% to the simulated EC, averaged for the GZ Basin. This result is consistent with that of the previous modeling study (Zhao et al., 2015a). For the local sources, residential contributions were the largest ($1.2 \mu\text{gC m}^{-3}$ or 55% of local sources) and were widely spread in the region. These contributions were highest in the city of Xi'an. The next largest local sources were transportation and industrial sources, each contributing $0.5 \mu\text{gC m}^{-3}$ (22% of local sources) to the annual-mean EC concentration. The spatial distribution of transportation and industrial EC was higher in urban areas (including Xi'an and other small cities). Notably, residential sources contributed 55% to the local concentration but 48% to the emissions (see Table 1), while industry and transportation acted in the opposite manner. This is because on the regional scale the influences of industry (point source) and transportation (line source) emissions are relatively more local compared with residential sources (area source). For the outside sources, the contribution was $1.5 \mu\text{gC m}^{-3}$, composed of $1.1 \mu\text{gC m}^{-3}$ from nearby regions in our domain and $0.4 \mu\text{gC m}^{-3}$ from background concentrations. The transport was mainly from east of the GZ Basin and produced a significant spatial gradient from east to west.

Table 3 summarizes the seasonal variations of the simulated annual mean EC concentrations from each individual source, averaged for the GZ Basin. The seasonal variations of EC concentrations due to the industrial and transportation sources were

relatively small. However, the EC concentrations due to the residential and outside transport sources showed a noticeable peak in winter, mainly caused by fossil-fuel and biofuel usage for residential winter heating (Zhang et al., 2009). In terms of the relative contributions, the outside transport played a more important role in summer (50%) than in other seasons (37-43%). This is because the prevailing wind in the GZ Basin during summer is generally an east wind with a wind speed above 2 m s^{-1} (Zhao et al., 2015a), which can efficiently transport EC to the GZ Basin from the highly-polluted Shanxi province (as shown in Fig. S2).

Finally, we conducted a scenario study to see how the EC pollutions over the GZ Basin could be affected under various emission control strategies. We performed a series of sensitivity simulations, in which industry, residential, transportation EC emissions in the GZ Basin were decreased by 50%, in turn and all at once. Figure S7 compares the monthly mean EC concentrations averaged for the GZ Basin in the reference simulation with that in the scenario simulations. A 50% reduction of industry or transportation emissions in the GZ Basin only caused a 6% ($0.2 \mu\text{gC m}^{-3}$) annual decrease in the surface EC concentration. However, in winter a 50% reduction of GZ residential emissions reduced the surface EC concentration up to 25% ($1.7 \mu\text{gC m}^{-3}$), a fact again suggesting that residential sources were the most important local sources in the GZ Basin. Overall, when all the anthropogenic emissions in the GZ Basin were reduced by 50%, the annual mean surface EC concentration decreased by 30% ($1.1 \mu\text{gC m}^{-3}$). The moderate pollution mitigation demonstrates the important but incomprehensive role of local emission reduction. We encourage inter-regional cooperation for more effective pollution control strategies.

4 Conclusion

In this study, we used the WRF-Chem model to simulate surface EC concentrations in the GZ Basin from May 2013 to April 2014 and compared the results against the daily measurements, with the aim of quantifying the region- and sector-specific source contributions to EC pollution. We employed the current best bottom-up estimate of EC emission (29.0 GgC yr^{-1}) in the GZ Basin to drive our

simulation. Surface EC measurements were introduced from a consistent network of 10 sites, which were carefully selected to represent different emission sources.

The simulated annual mean EC concentration averaged for all sites was $5.1 \mu\text{gC m}^{-3}$, which is consistent to the observed value of $5.3 \mu\text{gC m}^{-3}$. Additionally, we successfully reproduced the magnitude of measured EC in all seasons (regression slope = 0.98-1.03), and the spatial and temporal variations ($r = 0.55$ -0.78). A good agreement between the modeled and measured results lent confidence to the characterization of the sources of EC pollution. Our finding suggests that local EC sources have larger contributions (~60%) than the outside sources (~40%) to the EC pollution in the GZ region. Among the local sources, the residential sources had the largest contributions and were followed by industry and transportation. The dominant contribution of residential sources was partly due to their abundant emissions, but was also affected by their relatively wider influence area. Further analysis suggests that a 50% reduction of industry or transportation emissions in the GZ Basin only causes a 6% decrease in the annual mean EC concentration, while a 50% reduction in the GZ residential emissions reduces the surface EC concentration in winter by up to 25%. Overall, when all the anthropogenic emissions in the GZ Basin are reduced by 50%, the annual mean surface EC concentration decreases by about 30%. This assessment result can provide useful information to local governments for use in air pollution strategies.

Acknowledgments

This research is supported by National Natural Science Foundation of China (Grant Nos. 41275186 and 41430424), the "Strategic Priority Research Program" of the Chinese Academy of Sciences (Grant No. XDB05060500), Shaanxi Government (2012KTZB03-01-01), and the Open Fund of the State Key Laboratory of Loess and Quaternary Geology (SKLLQG1221). The National Center for Atmospheric Research is sponsored by the National Science Foundation.

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Fig. 1. Annual mean EC emissions in the GZ Basin as estimated by MEIC and FINN. Figure includes EC emissions from (a) open biomass burning, (b) power generation, (c) industry, (d) residential, (e) transportation and (f) total sources. The annual emission summed over the GZ Basin are shown in red in the inset.

Fig. 2. Source contributions to the annual mean simulated EC concentrations at the 10 sites of the GZ Basin. Pie charts show the relative contributions of industry (blue), residential sources (brown), transportation (orange), open biomass burning (purple) and transport from outside of the GZ Basin (green). Also shown are the simulated (red) and observed (black) annual mean EC concentrations at the 10 sites.

Fig. 3. Simulated components of annual mean surface EC concentrations: (a) total simulated EC; (b) simulated EC from GZ industry; (c) simulated EC from GZ residential sources; (d) simulated EC from GZ transportation and (e) simulated EC from outside the GZ Basin. The regional annual mean simulated EC concentrations from each component are shown in red in the inset. Power plants and open biomass burning contribute less than 1% of the regional mean EC concentrations, so we do not show them here.

Table 1. EC emission estimates in the GZ Basin

Source sector	Emission (GgC y ⁻¹)
Anthropogenic ^a	28.5 (98%)
Industry	7.9 (27%)
Power generation	<0.1 (<1%)
Residential sources	13.9 (48%)
Transportation	6.7 (23%)
Open Biomass Burning ^b	0.5 (2%)
Total	29.0 (100%)

^a From Multi-resolution Emission Inventory for China (MEIC) for the GZ Basin.

^b From Fire Inventory from NCAR (FINN) for the GZ Basin.

Table 2. Observed and simulated surface annual mean EC concentrations at the 10 GZ sites ($\mu\text{gC m}^{-3}$)

Site name	Location	Site information	Observation	Simulation
<i>Urban</i>				
Baoji (BJ)	34.33°N, 107.11°E	Roof (10 m ^a) of a building at Baoji Meteorological Bureau	4.9	3.1
Chang'an University (CU)	34.37°N, 108.90°E	Roof (15 m) of a building at Chang'an University	7.4	6.9
Institute of Earth Environment (IEE)	34.23°N, 108.89°E	Roof (10 m) of a building at Institute of Earth Environment	8.7	8.9
Tongchuan (TC)	35.07°N, 109.08°E	Roof (12 m) of a building at Yifu primary school	4.7	4.4
Weinan (WN)	34.51°N, 109.45°E	Roof (12 m) of a building at Weinan Environmental Protection Bureau	5.4	5.2
Xi'an Jiaotong University (XJU)	34.24°N, 108.99°E	Roof (15 m) of a building at Xi'an Jiaotong University	7.5	9.0
Xingping (XP)	34.28°N, 108.48°E	A monitoring site (2 m) at Xingping Meteorological Bureau	5.8	5.3
<i>Rural</i>				
Dali (DL)	34.83°N, 110.05°E	Roof (10 m) of a building at Xiaqin village, Dali	5.0	3.2
Hancheng (HC)	35.42°N, 110.41°E	Roof (10 m) of a building at Beichen village, Hancheng	3.7	4.4
<i>Background</i>				
Qinling (QL)	33.83°N, 108.79°E	A monitoring site (2 m) in the Qinling Mountain	1.1	0.9
<i>Regional average</i>			5.3	5.1

^a Inlet height above ground level

Table 3. Simulated EC composition in the GZ Basin.

	Regional mean simulated surface EC concentrations [$\mu\text{gC m}^{-3}$] ^a				
	Industry	Residential sources	Transportation	Outside of the GZ Basin	Total
<i>Spring average</i>	0.4 (15%)	0.7 (26%)	0.4 (15%)	1.1 (43%)	2.5
Mar.	0.4	1.0	0.4	1.4	3.2
Apr.	0.4	0.5	0.4	1.0	2.3
May	0.4	0.5	0.3	0.9	2.1
<i>Summer average</i>	0.4 (17%)	0.4 (18%)	0.3 (14%)	1.2 (50%)	2.3
Jun.	0.4	0.3	0.3	1.0	2.0
Jul.	0.5	0.5	0.4	1.4	2.6
Aug.	0.3	0.4	0.3	1.1	2.2
<i>Autumn average</i>	0.8 (21%)	0.9 (25%)	0.5 (15%)	1.3 (38%)	3.5
Sep.	0.7	0.6	0.5	1.1	2.9
Oct.	0.8	0.6	0.5	1.3	3.3
Nov.	0.7	1.4	0.6	1.6	4.3
<i>Winter average</i>	0.5 (8%)	2.9 (46%)	0.6 (9%)	2.4 (37%)	6.4
Dec.	0.7	3.4	0.7	2.1	6.9
Jan.	0.4	2.8	0.6	2.4	6.2
Feb.	0.4	2.6	0.6	2.6	6.1
<i>Annual</i>	0.5 (14%)	1.2 (33%)	0.5 (13%)	1.5 (40%)	3.7

^a Power plants and open biomass burning contribute less than 1% of the regional mean EC concentrations, so we do not show them here.