

1 Supporting Information for  
2 Source attribution of black carbon and its direct radiative forcing  
3 in China  
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19 **Table S1.** Comparisons of observed and modeled seasonal mean near-surface  
 20 concentrations (units:  $\mu\text{g m}^{-3}$ ) of BC in China corresponding to Fig. 3a. Numbers in  
 21 bold represent sites with observed concentration lower than modeled concentration,  
 22 otherwise the observation higher than modeled concentration.  
 23

Sites	DJF		MAM		JJA		SON		
	Obs.	Model	Obs.	Model	Obs.	Model	Obs.	Model	
NC	Gucheng	1.687E+01	6.332E+00	6.939E+00	3.597E+00	7.038E+00	3.089E+00	1.155E+01	4.606E+00
	Linan	<b>4.831E+00</b>	<b>5.830E+00</b>	4.167E+00	2.629E+00	3.735E+00	1.993E+00	4.133E+00	2.829E+00
	Zhengzhou	1.270E+01	9.171E+00	8.034E+00	3.974E+00	6.939E+00	3.404E+00	9.894E+00	5.173E+00
SC	Jinsha	<b>3.436E+00</b>	<b>6.708E+00</b>	<b>2.241E+00</b>	<b>3.016E+00</b>	<b>1.892E+00</b>	<b>2.252E+00</b>	4.283E+00	3.446E+00
	Panyu	9.628E+00	5.080E+00	8.134E+00	2.928E+00	4.847E+00	1.864E+00	7.437E+00	3.646E+00
	Taiyangshan	<b>2.623E+00</b>	<b>7.346E+00</b>	<b>2.042E+00</b>	<b>3.410E+00</b>	<b>2.092E+00</b>	<b>2.408E+00</b>	<b>3.652E+00</b>	<b>4.038E+00</b>
SW	Chengdu	1.147E+01	6.828E+00	1.072E+01	2.831E+00	9.728E+00	2.509E+00	1.106E+01	3.617E+00
	Nanning	4.980E+00	3.074E+00	2.623E+00	1.579E+00	2.722E+00	8.660E-01	4.980E+00	1.926E+00
CW	Gaolanshan	5.279E+00	2.211E+00	2.789E+00	9.690E-01	2.872E+00	9.000E-01	4.050E+00	1.302E+00
	Xian	1.853E+01	6.465E+00	1.145E+01	2.664E+00	7.570E+00	2.173E+00	1.077E+01	3.360E+00
NE	Dalian	7.520E+00	2.093E+00	4.548E+00	1.525E+00	3.519E+00	9.770E-01	5.428E+00	1.277E+00
	TYS	3.818E+00	2.636E+00	1.527E+00	1.440E+00	1.112E+00	9.790E-01	2.507E+00	1.698E+00
NW	Dunhuang	5.760E+00	2.090E-01	2.556E+00	1.340E-01	3.436E+00	1.220E-01	4.548E+00	1.550E-01
TP	Lhasa	5.428E+00	1.840E-01	3.021E+00	2.420E-01	3.469E+00	7.100E-02	3.486E+00	1.300E-01

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27 **Table S2.** Comparisons of observed and modeled seasonal mean aerosol absorption  
 28 optical depth (AAOD) of BC in China corresponding to Fig. 3b. Numbers in bold  
 29 represent sites with observed concentration lower than modeled concentration,  
 30 otherwise the observation higher than modeled concentration. Lack data show in  
 31 blank.  
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Sites	DJF		MAM		JJA		SON		
	Obs.	Model	Obs.	Model	Obs.	Model	Obs.	Model	
Beijing	6.430E-02	2.986E-02	5.568E-02	3.699E-02	4.286E-02	4.182E-02	5.303E-02	3.361E-02	
Xianghe	6.658E-02	2.986E-02	5.646E-02	3.699E-02	<b>3.480E-02</b>	<b>4.182E-02</b>	6.412E-02	3.361E-02	
NC	Xinglong	3.535E-02	2.986E-02	<b>3.249E-02</b>	<b>3.699E-02</b>	<b>2.612E-02</b>	<b>4.182E-02</b>	<b>2.531E-02</b>	<b>3.361E-02</b>
	Taihu	<b>4.684E-02</b>	<b>6.860E-02</b>	<b>4.122E-02</b>	<b>4.683E-02</b>	<b>3.581E-02</b>	<b>3.754E-02</b>	4.073E-02	4.020E-02
	Hefei	<b>6.600E-02</b>	<b>7.464E-02</b>	<b>3.700E-02</b>	<b>4.926E-02</b>			<b>4.050E-02</b>	<b>4.406E-02</b>
	Shouxian	<b>6.400E-02</b>	<b>8.011E-02</b>	<b>2.700E-02</b>	<b>5.215E-02</b>	<b>2.300E-02</b>	<b>4.263E-02</b>	4.967E-02	4.844E-02
Chen-Kung U.	<b>1.468E-02</b>	<b>2.437E-02</b>	1.903E-02	1.835E-02	<b>7.186E-03</b>	<b>8.903E-03</b>	<b>8.059E-03</b>	<b>1.098E-02</b>	
SC	Polytechnic U.	3.642E-02	2.735E-02	3.790E-02	1.987E-02	5.125E-02	9.388E-03	3.863E-02	1.637E-02
	Hok Tsui	3.733E-02	2.735E-02	4.733E-02	1.987E-02	4.500E-02	9.388E-03	2.500E-02	1.637E-02
CW	SACOL	3.047E-02	1.925E-02	3.171E-02	1.794E-02	2.459E-02	1.950E-02	2.288E-02	1.828E-02

33 **Table S3.** Contributions from tagged source regions (S, column) to regional mean  
 34 surface concentrations of BC ( $\mu\text{g m}^{-3}$ ) over the seven receptor regions in China and  
 35 China (R, row) in December-January-February (DJF), March-April-May (MAM),  
 36 June-July-August (JJA), and September-October-November (SON).  
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		DJF							
S \ R	NC	SC	SW	CW	NE	NW	TP	CN	
NC	5.793E+00	1.289E+00	5.014E-01	2.135E-01	1.453E-01	6.057E-04	8.484E-03	1.115E+00	
SC	1.497E-01	2.740E+00	6.591E-01	5.026E-02	5.030E-04	1.717E-04	1.391E-02	4.001E-01	
SW	6.907E-02	7.979E-02	2.106E+00	2.189E-01	1.014E-03	3.279E-04	2.224E-02	2.359E-01	
CW	1.247E-01	5.615E-02	8.148E-02	1.028E+00	7.969E-03	2.548E-03	1.905E-03	1.184E-01	
NE	5.103E-02	7.271E-03	1.610E-03	3.652E-04	1.020E+00	1.324E-05	3.031E-05	1.539E-01	
NW	1.570E-02	7.569E-03	5.851E-03	3.849E-02	5.227E-03	2.967E-01	5.280E-04	7.559E-02	
TP	2.647E-03	5.986E-03	3.483E-02	6.624E-03	6.045E-05	2.153E-03	8.348E-02	2.121E-02	
RW	4.759E-02	1.229E-01	1.641E-01	4.306E-02	2.991E-02	8.403E-02	1.737E-01	9.626E-02	
		MAM							
NC	2.631E+00	2.837E-01	1.058E-01	1.154E-01	1.930E-01	1.100E-03	2.014E-03	4.804E-01	
SC	1.556E-01	1.614E+00	2.161E-01	2.255E-02	4.397E-03	3.414E-04	3.331E-03	2.292E-01	
SW	3.816E-02	3.322E-02	9.988E-01	1.345E-01	3.407E-03	5.673E-04	4.062E-03	1.139E-01	
CW	2.990E-02	6.613E-03	1.579E-02	3.894E-01	7.070E-03	3.688E-03	6.514E-04	4.036E-02	
NE	3.649E-02	7.578E-03	1.230E-03	1.495E-03	5.124E-01	1.122E-04	2.338E-05	7.963E-02	
NW	3.874E-03	1.469E-03	1.488E-03	1.373E-02	2.766E-03	9.793E-02	1.329E-03	2.505E-02	
TP	1.995E-03	4.814E-03	2.748E-02	2.616E-03	1.380E-04	4.511E-04	5.312E-02	1.382E-02	
RW	9.188E-02	1.884E-01	2.730E-01	4.523E-02	6.837E-02	7.014E-02	2.054E-01	1.290E-01	
		JJA							
NC	2.004E+00	4.844E-02	2.846E-02	1.215E-01	2.503E-01	3.223E-03	5.409E-04	3.600E-01	
SC	2.736E-01	1.234E+00	1.108E-01	5.379E-02	2.797E-02	1.112E-03	2.229E-03	2.004E-01	
SW	2.692E-02	1.967E-02	8.639E-01	2.194E-01	6.650E-03	5.495E-03	8.326E-03	1.075E-01	
CW	1.022E-02	2.836E-04	4.260E-03	2.769E-01	4.605E-03	9.085E-03	1.659E-03	2.752E-02	
NE	1.035E-02	2.630E-04	6.470E-05	9.615E-04	3.480E-01	1.288E-04	1.354E-05	5.125E-02	
NW	1.001E-03	1.649E-04	5.722E-04	6.316E-03	1.150E-03	7.543E-02	5.272E-03	1.915E-02	
TP	7.957E-04	8.475E-04	1.749E-02	2.431E-03	1.415E-04	2.908E-04	3.105E-02	8.020E-03	
RW	8.071E-02	1.210E-01	7.176E-02	2.047E-02	6.054E-02	4.822E-02	4.372E-02	6.221E-02	
		SON							
NC	3.239E+00	4.962E-01	2.577E-01	1.680E-01	2.060E-01	1.405E-03	7.070E-03	6.182E-01	
SC	1.300E-01	1.739E+00	3.896E-01	4.141E-02	2.950E-03	2.873E-04	1.014E-02	2.580E-01	
SW	3.083E-02	1.919E-02	1.217E+00	1.826E-01	3.085E-03	1.156E-03	2.309E-02	1.390E-01	
CW	4.234E-02	1.015E-02	2.033E-02	5.113E-01	1.035E-02	4.947E-03	8.765E-04	5.377E-02	
NE	4.230E-02	1.230E-02	4.253E-03	1.685E-03	6.537E-01	6.916E-05	1.502E-04	1.015E-01	
NW	6.967E-03	2.650E-03	2.562E-03	2.018E-02	4.738E-03	1.549E-01	1.782E-03	3.968E-02	
TP	1.139E-03	1.127E-03	1.748E-02	3.623E-03	9.359E-05	5.573E-04	6.368E-02	1.446E-02	
RW	6.893E-02	1.185E-01	5.844E-02	2.435E-02	3.891E-02	6.036E-02	8.202E-02	6.620E-02	

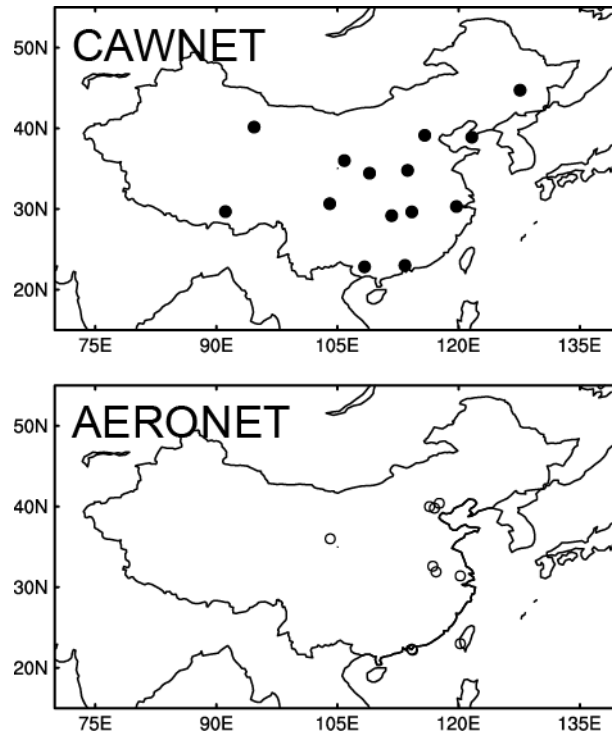
39 **Table S4.** Seasonal and annual direct radiative effect (DRF) efficiency of BC ( $W m^{-2}$ )  
 40 for each of the tagged source regions over China and globally, respectively. The  
 41 efficiency is defined as the DRF divided by the corresponding scaled annual emission  
 42 (seasonal emission multiplied by 4).  
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China	DJF	MAM	JJA	SON	ANN
NC	3.571E-01	5.491E-01	7.189E-01	5.204E-01	5.126E-01
SC	3.644E-01	5.563E-01	7.596E-01	5.928E-01	5.574E-01
SW	6.950E-01	8.289E-01	8.660E-01	7.377E-01	7.714E-01
CW	6.433E-01	9.416E-01	1.106E+00	6.780E-01	8.034E-01
NE	2.562E-01	3.530E-01	4.673E-01	2.453E-01	3.154E-01
NW	9.674E-01	1.652E+00	3.174E+00	1.556E+00	1.670E+00
TP	9.499E-01	1.182E+00	9.443E-01	9.421E-01	1.015E+00
Global	DJF	MAM	JJA	SON	ANN
NC	1.701E-02	4.056E-02	3.537E-02	2.253E-02	2.741E-02
SC	2.081E-02	3.241E-02	3.080E-02	2.878E-02	2.784E-02
SW	3.436E-02	4.387E-02	3.434E-02	3.493E-02	3.672E-02
CW	2.492E-02	5.780E-02	5.070E-02	2.758E-02	3.778E-02
NE	1.078E-02	4.483E-02	3.562E-02	1.790E-02	2.575E-02
NW	2.863E-02	9.540E-02	1.567E-01	6.668E-02	7.661E-02
TP	4.681E-02	7.488E-02	4.435E-02	4.937E-02	5.564E-02
RW	1.701E-02	4.056E-02	3.537E-02	2.253E-02	2.741E-02

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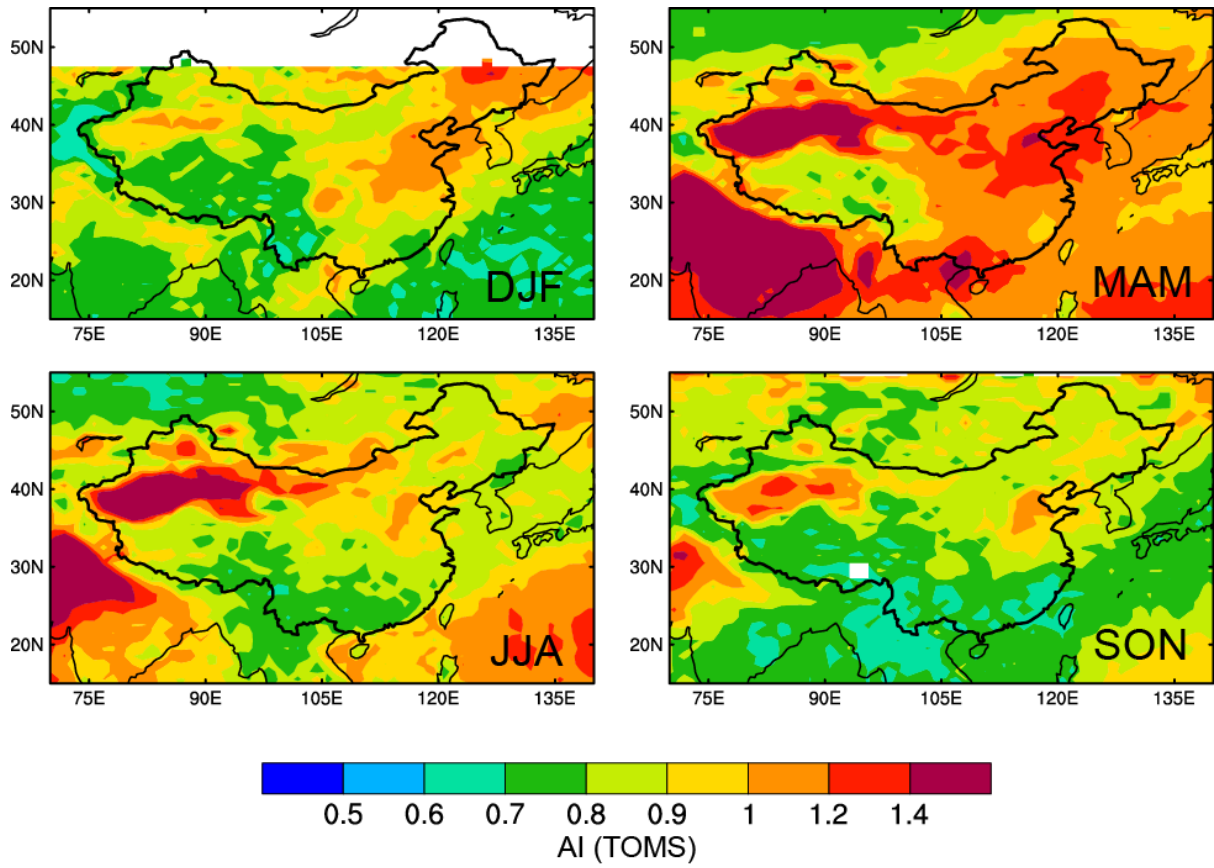
46 **Table S5.** Seasonal and annual near-surface concentration ( $\mu\text{g m}^{-3}$ ) and column  
 47 burden ( $\text{mg m}^{-2}$ ) efficiency of BC for each of the tagged source regions over China  
 48 and globally, respectively.  
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Near-Surface Concentration Efficiency					
China	DJF	MAM	JJA	SON	ANN
NC	7.457E-01	4.917E-01	3.961E-01	6.345E-01	5.922E-01
SC	5.989E-01	4.096E-01	3.605E-01	4.701E-01	4.652E-01
SW	5.010E-01	3.000E-01	2.894E-01	3.727E-01	3.726E-01
CW	7.485E-01	4.036E-01	3.256E-01	5.108E-01	5.376E-01
NE	5.812E-01	3.683E-01	3.522E-01	4.828E-01	4.603E-01
NW	9.715E-01	4.918E-01	4.702E-01	7.397E-01	7.109E-01
TP	4.009E-01	2.266E-01	1.967E-01	3.307E-01	2.898E-01
Global	DJF	MAM	JJA	SON	ANN
NC	1.876E-02	1.229E-02	8.863E-03	1.502E-02	1.445E-02
SC	1.688E-02	1.006E-02	7.981E-03	1.281E-02	1.213E-02
SW	1.324E-02	6.939E-03	6.081E-03	9.305E-03	9.129E-03
CW	1.775E-02	9.510E-03	7.178E-03	1.149E-02	1.247E-02
NE	1.579E-02	1.191E-02	9.091E-03	1.396E-02	1.316E-02
NW	2.498E-02	1.337E-02	1.103E-02	1.872E-02	1.822E-02
TP	1.222E-02	6.117E-03	4.477E-03	8.917E-03	8.031E-03
RW	1.490E-02	1.226E-02	1.213E-02	1.346E-02	1.317E-02
Column Burden Efficiency					
China	DJF	MAM	JJA	SON	ANN
NC	5.460E-01	4.588E-01	4.007E-01	5.345E-01	4.948E-01
SC	4.960E-01	4.099E-01	4.665E-01	4.726E-01	4.623E-01
SW	5.927E-01	3.825E-01	3.865E-01	4.421E-01	4.575E-01
CW	7.089E-01	5.172E-01	4.507E-01	5.175E-01	5.729E-01
NE	2.477E-01	2.665E-01	2.736E-01	2.906E-01	2.676E-01
NW	5.982E-01	6.861E-01	1.023E+00	8.382E-01	7.527E-01
TP	5.506E-01	4.055E-01	3.213E-01	4.270E-01	4.312E-01
Global	DJF	MAM	JJA	SON	ANN
NC	1.875E-02	1.865E-02	1.308E-02	1.750E-02	1.732E-02
SC	1.935E-02	1.548E-02	1.390E-02	1.814E-02	1.682E-02
SW	2.288E-02	1.533E-02	1.163E-02	1.708E-02	1.710E-02
CW	2.313E-02	2.143E-02	1.585E-02	1.690E-02	1.992E-02
NE	1.129E-02	1.905E-02	1.313E-02	1.555E-02	1.473E-02
NW	1.925E-02	3.080E-02	4.100E-02	3.187E-02	2.892E-02
TP	2.713E-02	2.282E-02	1.393E-02	2.051E-02	2.166E-02
RW	2.509E-02	2.609E-02	2.681E-02	2.722E-02	2.633E-02



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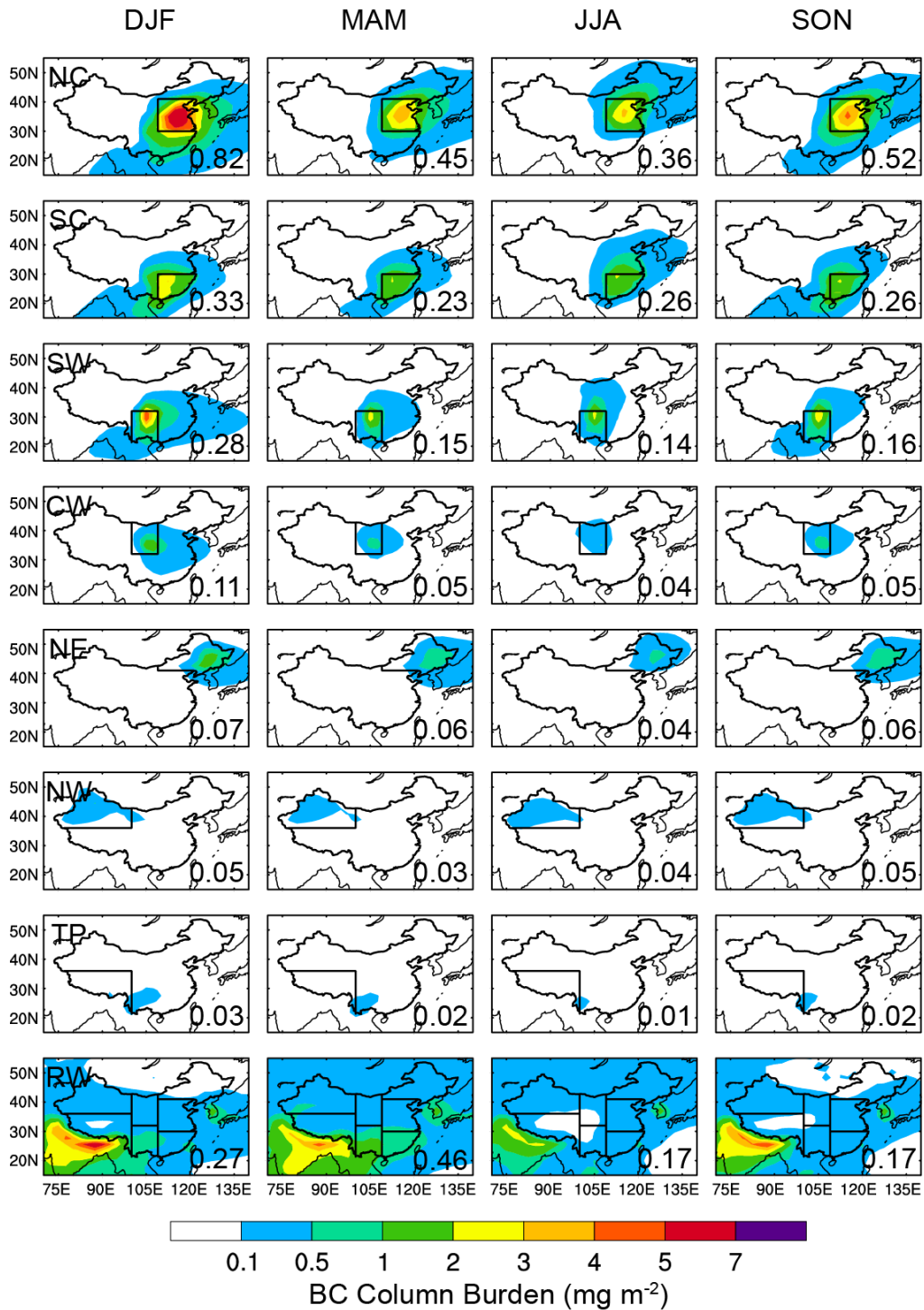
**Figure S1.** Locations of 14 sites of the China Meteorological Administration (CMA) Atmosphere Watch Network (CAWNET, top) (Zhang et al., 2012) and 10 sites of the Aerosol Robotic Network (AERONET, bottom) (Holben et al., 2001).



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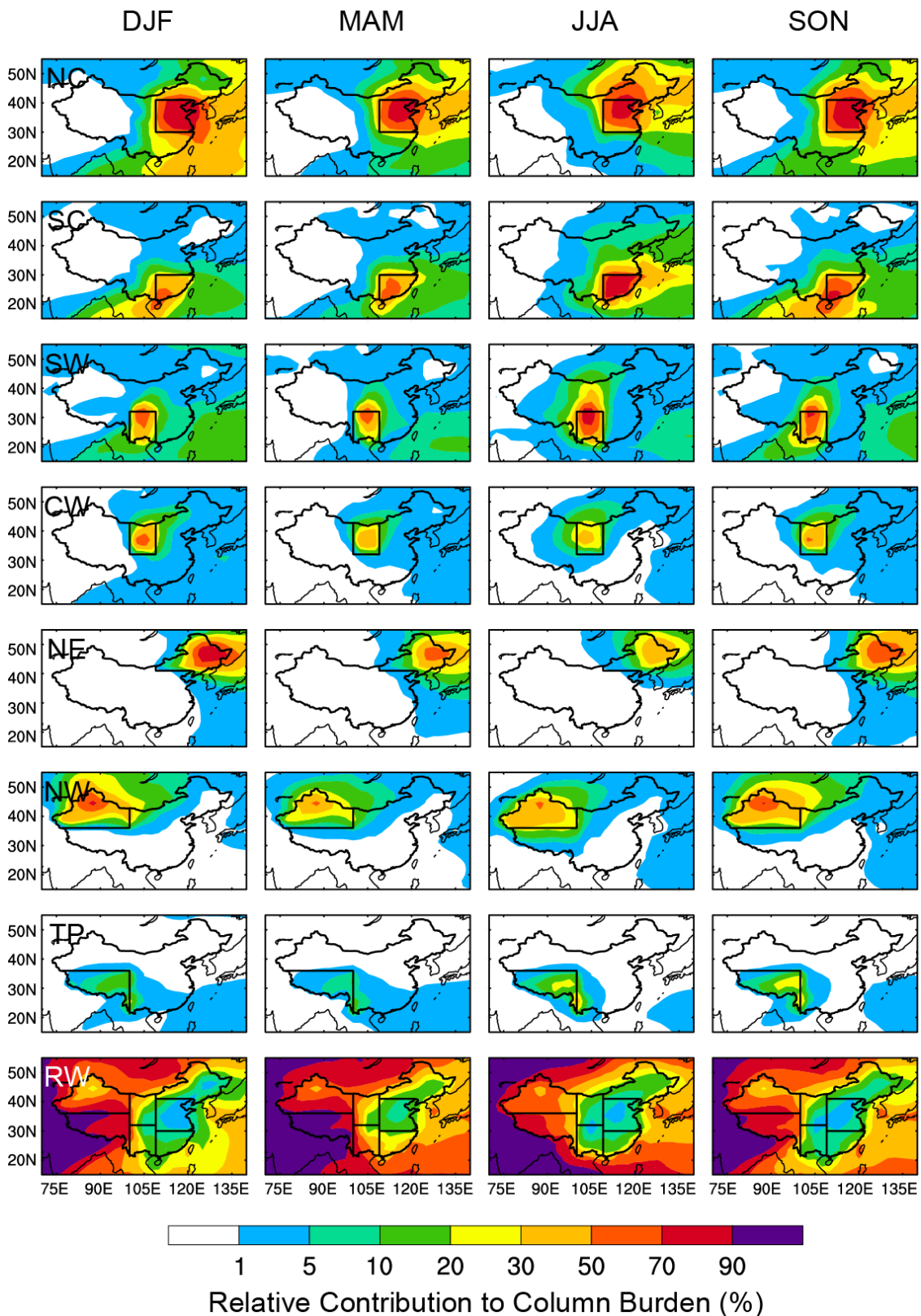
**Figure S2.** Spatial distribution of seasonal mean Aerosol Index (AI) derived from Total Ozone Mapping Spectrometer (TOMS) measurements over years of 1997–2004.





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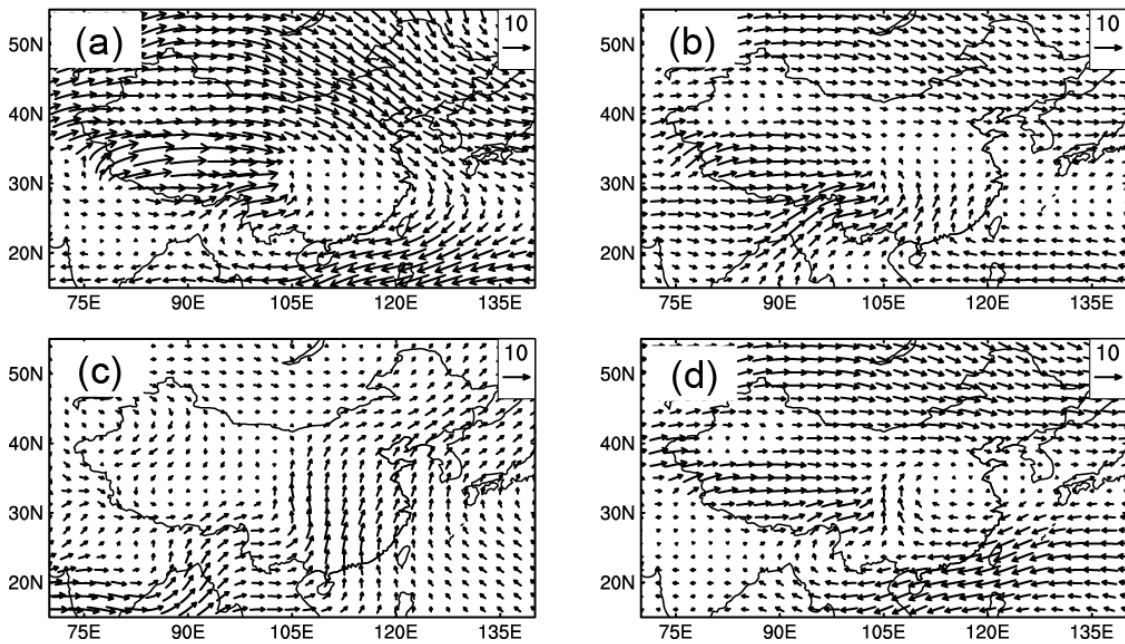
**Figure S3.** Spatial distribution of seasonal mean BC column burden ( $\text{mg m}^{-2}$ ) originating from the seven source regions in China (NC, SC, SW, CW, NE, NW, and TP), marked with black outlines, and sources outside China (RW). Regionally averaged BC in China contributed by individual source regions is shown at the bottom right of each panel.



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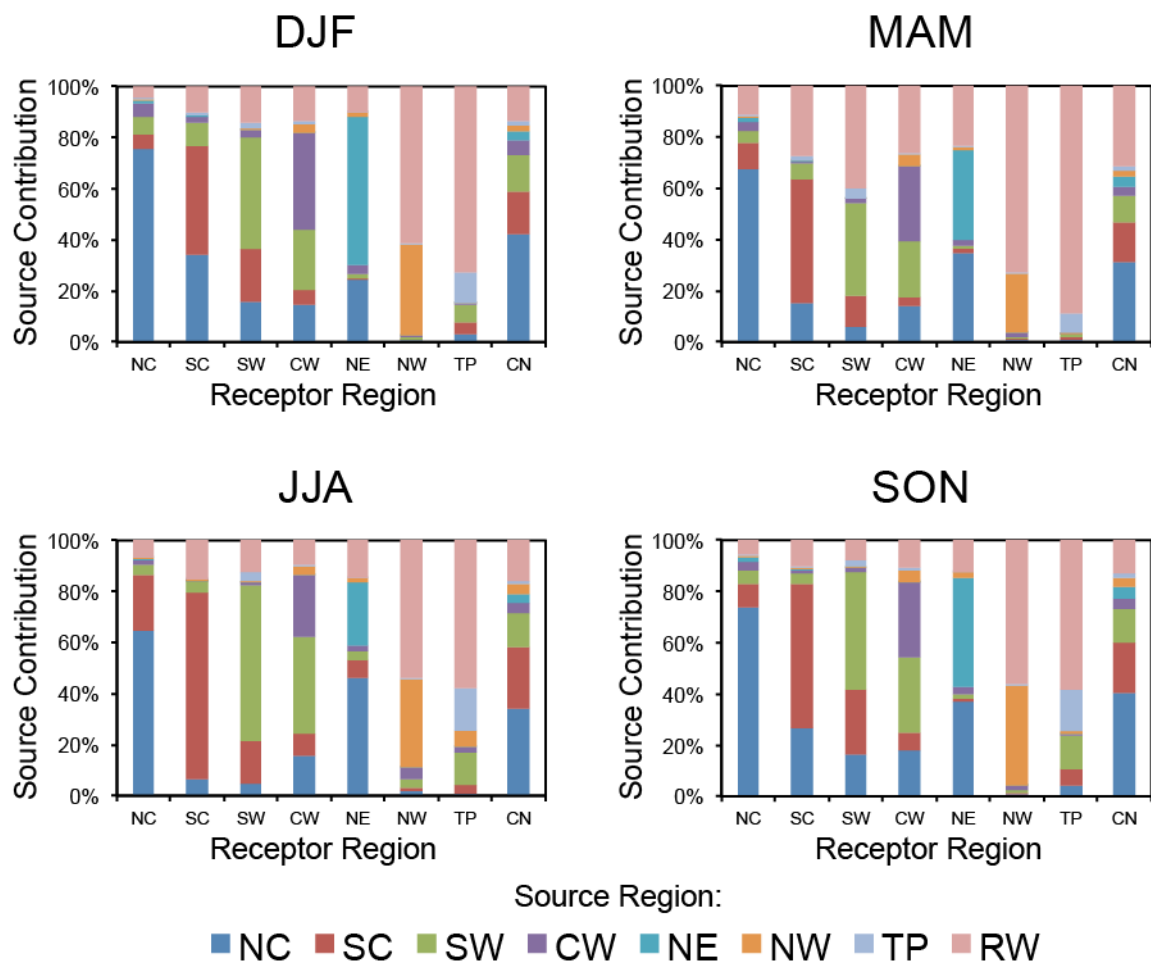
**Figure S4.** Spatial distribution of relative contributions (%) to seasonal mean BC column burden from each of the tagged source regions.

## Wind fields at 850 hPa



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76 **Figure S5.** Simulated seasonal mean winds at 850 hPa ( $\text{m s}^{-1}$ ) in (a)  
77 December-January-February (DJF), (b) March-April-May (MAM), (c)  
78 June-July-August (JJA), and (d) September-October-November (SON).

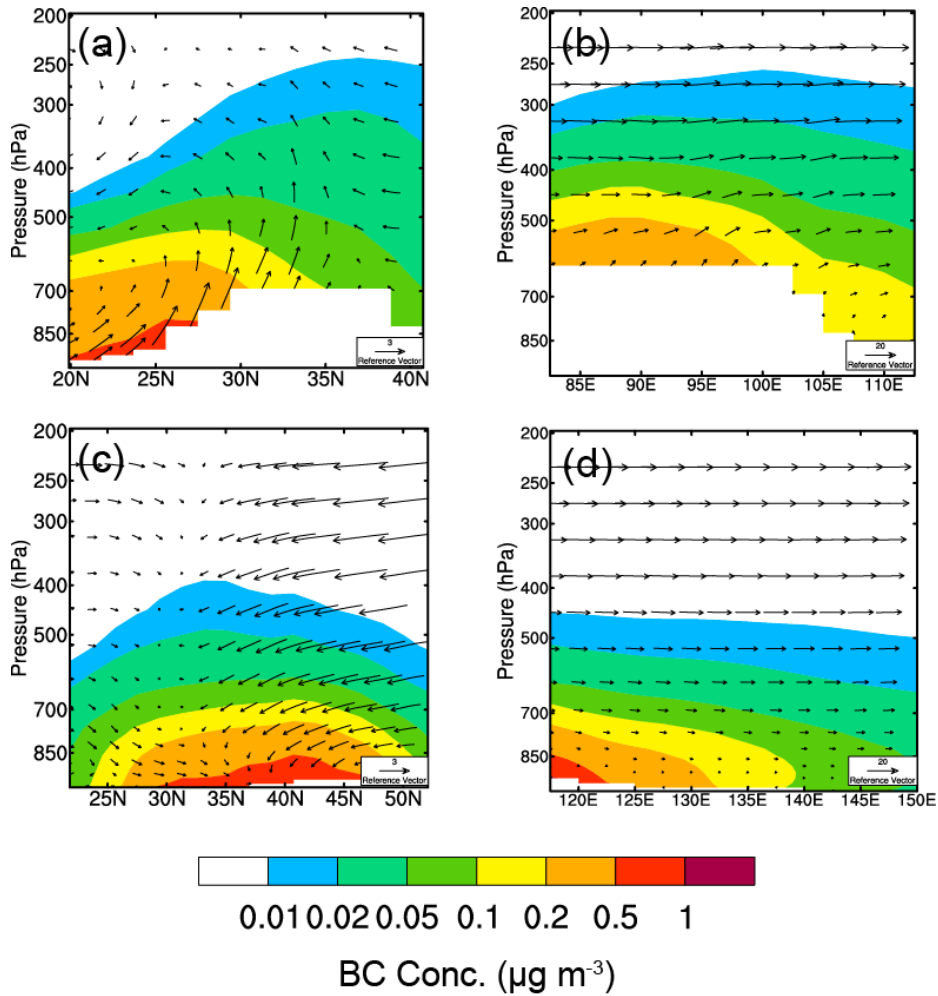


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81 **Figure S6.** Relative contributions (%) from the tagged source regions (denoted by  
 82 colors) to regional mean BC column burden over seven receptor regions in China  
 83 (NC, SC, SW, CW, NE, NW, and TP) and all of China (CN) in different seasons. The  
 84 receptor regions are marked on the horizontal axis in each panel.

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**Figure S7.** Vertical distributions of BC concentrations ( $\mu\text{g m}^{-3}$ ), originating from emissions outside China, averaged over (a)  $75^{\circ}$ – $120^{\circ}$ E and (b)  $25^{\circ}$ – $35^{\circ}$ N, respectively, near the south boundary of China, and BC originating from total emissions in China averaged over (c)  $120^{\circ}$ – $135^{\circ}$ E and (d)  $20^{\circ}$ – $50^{\circ}$ N, respectively, near the east boundary of China.