



Supplement of

Emission inventory of air pollutants and chemical speciation for specific anthropogenic sources based on local measurements in the Yangtze River Delta region, China

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27 **1. Sources classification**

28 Table S1 shows the source classification in different levels in the Yangtze River
29 Delta (YRD) region. In the first level, the sources are classified into ten categories,
30 including stationary combustion source, industrial process source, industrial solvent-
31 use source, mobile source, dust source, oil storage and transportation source, residential
32 source, waste treatment and disposal source, and agricultural source. The second-level
33 categories of stationary combustion source include power plants and boilers. The three-
34 level classification is based on fuel type, which mainly includes coal, natural gas, fuel
35 oil, diesel, and biomass, etc. The fourth level is classified according to the combustion
36 method, such as grate-fired boilers, pulverized coal boilers, and fluidized bed
37 combustion (FBC) boilers, etc. Industrial process and solvent-use sources are divided
38 into second- and third-level according to their industrial sectors and product or material
39 types. Some sources are further subdivided into the fourth-level based on their detailed
40 product types or emission segments. For example, in the coating production industry,
41 solvent- and water-based coatings are further separated. In the ironmaking industry,
42 organized emission segments including sintering and blast furnaces, and fugitive
43 emission segments are further separated. The second-level classification of mobile
44 source includes motor vehicles, ships, non-road machinery, and civil aviation aircraft.
45 The third-level is divided according to their detailed types. Motor vehicles include light-
46 duty passenger cars, light-duty trucks, heavy-duty passenger vehicles, heavy-duty
47 trucks, and motorcycles, etc. Non-road machinery is divided into construction
48 machinery, port machinery, factory machinery, agricultural machinery, and airport
49 ground handling equipment (GHE) according to their purpose. The fourth-level
50 classification mainly considers their fuel type. The motor vehicles and non-road
51 machinery are further classified into the fifth-level according to their emission levels.
52 The dust source is mainly divided into two categories: construction dust and road dust.
53 The oil storage and transportation sources mainly include oil and gas volatilization
54 sources such as gas stations, storage tanks and loading and unloading operations. The

55 residential source includes residential combustion, residential solvent-use, catering, and
56 human excretion. The residential solvent-use source is further divided into architectural
57 coatings, consumer products, auto repair, dry cleaning, and hospital solvent-use. The
58 waste treatment and disposal sources include sewage treatment and waste treatment.
59 The waste treatment source is further divided into landfill and compost, while the
60 incineration is included in the boiler source. The agricultural source includes livestock
61 and poultry breeding, N-fertilizer application, and biomass burning. The livestock and
62 poultry breeding and biomass burning sources are further divided into the third-level
63 based on the species of livestock and poultry and crop residue types, respectively.
64 Biomass burning includes two categories of field burning and household stoves, and
65 then the fourth level according to different straw types, such as soybean, rape, rice,
66 wheat, corn, etc.

67 **2. Activity data sources**

68 Table S2 shows the emission estimation methods and activity data sources for
69 various sources and their reliability levels. The activity data for stationary combustion
70 source, industrial process source and industrial solvent-use source are mainly derived
71 from 2017 environmental statistics, covering nearly 30,000 major point sources in the
72 YRD region. The data used in this study mainly includes fuel consumption, sulfur and
73 ash content, product output, raw material consumption, solvent usage, and pollutant
74 removal method and its efficiency, etc. However, the environmental statistics cannot
75 include all industrial sources. The difference between the total fuel consumption and
76 product output in the statistical yearbook and the sum of environmental statistics for
77 each city is taken as an area source.

78 For motor vehicles, the number of various vehicle types come from the statistical
79 yearbook of each city. To prepare the fleet composition data, detailed information about
80 vehicle technology, fuel type, emission standard, and vehicle age was surveyed in the
81 representative cities like Nanjing, Hangzhou, and Shanghai. The annual average VMT
82 of each vehicle type is simultaneously obtained from local survey in these cities. The

total VMT is then allocated into four road types, including highways, elevated roads, arterial roads, and residential roads, based on their traffic flows and road length. The average speeds and driving cycles for different road types were obtained from previous studies (Huang et al., 2015; Tang et al., 2018). Since there are no ready-made statistics for other machines besides agricultural machinery, the numbers of non-road machinery are calculated based on local survey data from Shanghai and Hangzhou. The number of construction machinery is calculated by the construction area; the number of port machinery is calculated according to the cargo throughput for each port; the number of factory machinery is estimated according to the total output value of the heavy industry; the number of GHE is estimated according to the passenger volume of the civil aviation. The working hours of various non-road machinery types come from local survey results in Shanghai and Hangzhou (Lu et al., 2017). The activity data of ships come from the AIS data for the East China Sea in 2017. The number of takeoffs and landings of civil aviation aircrafts at each airport are obtained based on the flight information survey on the Internet. The engine type for each aircraft can be determined based on the engine database released by ICAO.

The activity data of other sources is mainly from statistical yearbooks. The construction dust emissions are estimated based on the construction area of each city. The dust control measures during construction period are from the surveys of typical cities such as Hangzhou and Shanghai. The activity data of road dust is basically the same as that of motor vehicle emissions. NMVOC emissions from oil and gas storage and transportation sources are related with the transfer of oil products from various cities and the consumption of gas stations. All of the storage tanks and gas stations have been equipped with oil and gas recovery facilities. The activity data of residential combustion sources are derived from fuel statistics including coal, natural gas (NG), and liquefied petroleum gas (LPG), etc., used by residents of various cities. The activity data for architectural coatings is calculated based on the newly built and built-up housing area of each city, combined with the solvent consumption used per unit area

111 from survey. The activity data for catering, human excretion, consumer products, auto
112 repair, and waste treatment and disposal sources are derived from statistics on
113 population, vehicle ownership, and sewage and solid waste disposal. The activity data
114 of agricultural sources comes from the statistics livestock and poultry farming in
115 different species and nitrogen fertilizer application in each city. The activity data of
116 Biomass burning is estimated based on the yield of different crops multiplied by the
117 ratio of straw and then minus the recovery of straw.

118 **3. Emission factors determination**

119 Table S1 lists the emission factors (EFs) for various emission sources and their
120 references. The EFs of coal-fired power plants mainly come from domestic
121 measurement results (Liu, 2008; Yao et al., 2009; Zhao et al., 2010; Wang et al., 2011;
122 Sun, 2015). The EFs of coal-fired boilers are determined by our local measurements in
123 the YRD region (Lou, 2014; Xu et al., 2018). For other fuels and non-criteria pollutants
124 (such as NMVOCs, NH₃, etc.), the EFs mainly refer to the USEPA's AP-42 (USEPA,
125 2002) and European's EMEP datasets (EEA, 2013). The EFs for industrial process
126 sources are mainly derived from the datasets provided by AP-42, EMEP and domestic
127 emission inventory (EI) guidebook of China (MEP, 2014). VOC content of coatings,
128 inks and adhesives from industrial solvent-use sources are determined by local surveys
129 in Shanghai and Hangzhou.

130 The EFs of motor vehicles are calculated by the International Vehicle Emissions
131 (IVE) model and then corrected based on the local measurements of 102 light-duty
132 gasoline vehicles (LDGVs) with Euro 2–5 standards and 33 heavy-duty diesel vehicles
133 (HDDVs) with Euro 3–5 standards (Huang et al., 2016; Huang et al., 2017; Huang et
134 al., 2018a; Huang et al., 2018b). The EFs for non-road machinery are referenced from
135 the NONROAD model (USEPA, 2010) and domestic EI guidebook of China (MEP,
136 2014), and then corrected based on local measurements in previous studies in China
137 (Fu et al., 2012; Fu et al., 2013; Ge et al., 2013; Qu et al., 2015; Li et al., 2016). The
138 NO_x EFs from local measurements are generally higher than those recommended by the

139 model and guidebook, while other pollutants are relatively close. The EFs of ships are
140 strongly related with the quality of fuel oils. China has executed the legislation that
141 requires ships to use LSF (<0.5 wt% S) when at berth beginning from January 1, 2017.
142 Therefore, the EFs were corrected based on the fuel quality in this study. Detailed
143 information is provided in a previous study (Fan et al., 2016). The NO_x, CO, and
144 NMVOC EFs of civil aircraft engines in each mode of operation are taken from the
145 Aircraft Engine Emissions Database from ICAO (ICAO, 2014). The SO₂ and PM
146 emissions are estimated using the mass balance and FOA3.0 methods, respectively.

147 The EFs of dust sources are mainly derived from the EI guidebook of China (MEP,
148 2014). Those of oil storage and transportation sources are determined from local
149 surveys of the storage and transportation process of oil depots and gas stations. A total
150 of 294 storage tanks for different oil types and more than 400 gas stations were surveyed
151 in Shanghai and Hangzhou. Then the NMVOC EFs for per unit turnover for the storage
152 and transportation process of oil depots and gas stations were determined based on the
153 method recommended by USEPA (USEPA, 2015). Besides of the oil storage and
154 transportation sources, the EFs of residential solvent-use sources, like architectural
155 coatings, auto repair, dry cleaning, and hospital solvent-use, are also estimated based
156 on the local surveys of typical sources in the YRD region. The EFs of catering and
157 biomass burning are both determined based on the local measurements (Tang et al.,
158 2014; Wang et al., 2018; Gao et al., 2019). For agricultural sources, the NH₃ emission
159 factors of swine and dairy cow breeding, and fertilization in paddy and wheat fields are
160 localized base on the measurements in Shanghai (Chen, 2017a; Chen et al., 2017b; Xia
161 et al., 2018; Zhou, 2019). For the other area sources, the EFs are mainly referred to the
162 EI guidebook of China (MEP, 2014).

163 **4. PM_{2.5} and NMVOC speciation**

164 PM_{2.5} and NMVOC speciation profiles of each source were determined based on
165 local measurements in this and previous studies and the USEPA's SPECIATE4.4
166 database (Hsu et al., 2014). Table S3 shows the references, samples, and sampling and

analytical methods of different sources in this study. A total of 34 PM_{2.5} sources and 64 NMVOC sources were localized in the YRD region. The speciation of PM_{2.5} included carbonaceous, ionic, and elemental components, which were analyzed by a thermal/optical carbon analyzer (Model 2001, DRI, USA), an ion chromatography (Model 940, Metrohm, Switzerland), and an energy-dispersive X-ray fluorescence spectrometer (ED-XRF, Epsilon 5, PANalytical, Finland) or an inductively coupled plasma direct reading spectroscopy (ICP-AES, JOBIN-YVON, France), respectively. VOC species were analyzed by a gas chromatograph with a mass spectrometer and flame ionization detector (GC-MS/FID, TH_PKU-300, China).

5. Emissions for different cities and sources

Annual air pollutant emissions from each city in the YRD region is shown in Table S4. SO₂ emissions mainly came from Suzhou, Xuzhou and Changzhou in Jiangsu Province. The cities with the largest NO_x emissions were Shanghai, Suzhou and Xuzhou, followed by Ningbo and Hangzhou in Zhejiang Province. CO emissions from Suzhou and Nanjing were relatively higher, followed by Shanghai. VOC emissions came from Shanghai, Suzhou and Ningbo in turn. Xuzhou in Jiangsu Province had the largest PM₁₀ and PM_{2.5} emissions, followed by Hefei in Anhui Province. NH₃ emission distribution was quite different from the pollutants mentioned above. Yancheng, Xuzhou, and Nantong in Jiangsu Province had the largest emissions, followed by Fuyang and Suzhou in Anhui Province. Table S5 shows the air pollutant emissions from 10 major source categories and 55 subcategories. Among them, industrial process and solvent-use sources include 13 and 12 major sectors, respectively. The mobile sources include 14 categories, including 7 types of vehicles and 5 types of non-road machinery.

6. Model evaluation

We used the Community Modeling and Analysis System (CMAQ version 5.3) to simulate the concentrations of SO₂, NO₂, PM_{2.5}, PM₁₀, O₃, and CO in the YRD region in January and July 2017, then compared with the observation data in each city of the region. Figure S2 shows the model domain and the locations of observation data for

195 meteorology and PM_{2.5} chemical composition. Simulations were conducted for three
196 nested grids with horizontal resolution of 36 km (D1), 12km (D2) and 4km(D3),
197 respectively. D1 covers most of China and the surrounding countries including Japan
198 and South Korea; D2 covers eastern China and D3 covers the entire YRD region and
199 its surrounding land and waters. Meteorological fields were provided by the Weather
200 Research and Forecasting (WRF version 3.7) model with 27 vertical layers extending
201 to the tropopause (100hpa). WRF initial and boundary conditions (ICs, BCs) are based
202 on the 1° × 1° reanalysis data from the National Centers for Environmental Prediction
203 Final Analysis (NCEP-FNL). Physical options used in the WRF simulation are listed in
204 Table S1. The emission inventory developed in this study was used to produce the
205 emission system in the YRD region while emission beyond YRD was supplied by
206 Multiresolution Emission Inventory for China (MEIC-2016) (<http://www.meicmodel.org>) and the Model Inter-Comparison Study (MIX) emission inventory for
207 2010 (Li et al., 2017). Biogenic emissions are estimated by Model of Emissions of
208 Gases and Aerosols from Nature (MEGAN) v2.1 using WRF meteorology predictions.
209 The Sparse Matrix Operator Kernel Emissions (SMOKE,
210 <https://www.cmascenter.org/smoke>) model is applied to process emissions for input to
211 CMAQ. CMAQ version 5.3.0 (<https://www.cmascenter.org/cmaq/>) was used to
212 simulate atmospheric pollutants concentrations. ICs and BCs of D1 domain are based
213 on a Model For Ozone And Related Chemical Tracers (MOZART) global simulation
214 (<https://www.acom.ucar.edu/wrf-chem/mozart.shtml>). For the inner D2 and D3 domain,
215 ICs and BCs are extracted from the simulation results of the outer domains. Options
216 selected for the CMAQ simulations include the CB6r3 gas phase chemistry, the AERO6
217 aerosol scheme, the Regional Acid Deposition Model (RADM) model aqueous phase
218 chemistry, ISORROPIA inorganic particulate thermodynamics, and SOAP secondary
219 organic aerosol scheme.

221 Table S7 compares the average concentration of observation and simulation data
222 in each city of the YRD region in January and July 2017 and shows the statistical results

223 of model performance. We used Normalized Mean Bias (NMB), Normalized Mean
224 Error (NME), Mean Fractional Bias (MFB) and Mean Fractional Error (MFE) to
225 characterize the deviation of simulation concentrations from measured results. For
226 NMB and MFB, negative numbers indicate that the simulation result is lower, while
227 positive numbers are the opposite. The smaller the absolute value of these four statistics,
228 the higher the accuracy.

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233 **Table S1.** Source classification and emission factors.

Source classification				Units	Emission factors						References	
1st level	2nd level	3rd level	4th level		SO ₂	NO _x	CO	NMVOCS	PM ₁₀	PM _{2.5}		
Stationary combustion sources	Power plants	Coal	Grate-fired boilers	g·kg ⁻¹ -fuel	2×S×Cs	3.88	2.50	0.03	26×A	10×A	0.03	Local measurements (Yao et al., 2009; Zhao et al., 2010; Wang et al., 2011; Sun, 2015); USEPA, 2002; EEA, 2013
			Pulverized coal boilers	g·kg ⁻¹ -fuel	2×S×Cs	6.28	0.25	0.03	201×A	25×A	0.03	USEPA, 2002; EEA, 2013
			FBC boilers	g·kg ⁻¹ -fuel	2×S×Cs	2.00	0.27	0.03	154×A	45×A	0.03	USEPA, 2002; EEA, 2013
		Natural gas	—	g·m ⁻³ -fuel	2×S×Cs	4.48	1.34	0.09	0.03	0.03	—	USEPA, 2002
	Boilers	Solid waste	—	g·kg ⁻¹ -fuel	2×S×Cs	1.07	0.04	0.01	1.50	1.00	—	EEA, 2013
		Coal	Grate-fired boilers	g·kg ⁻¹ -fuel	2×S×Cs	2.17	7.63	0.03	3.88×A	1.60×A	0.01	Local measurements (Lou, 2014; Xu et al., 2018); Zhao et al., 2010; USEPA, 2002; EEA, 2013
		Pulverized coal boilers	g·kg ⁻¹ -fuel	2×S×Cs	6.54	0.25	0.03	129×A	19×A	0.01	Xu et al., 2018; Zhao et al., 2010; USEPA, 2002; EEA, 2013	
		FBC boilers	g·kg ⁻¹ -fuel	2×S×Cs	2.00	0.27	0.03	154×A	45×A	0.01	USEPA, 2002; EEA, 2013	
Industrial process sources	Mining	Fuel oil	—	g·kg ⁻¹ -fuel	2×S×Cs	2.47	0.62	0.04	0.74	0.48	0.13	USEPA, 2002; EEA, 2013
		Diesel	—	g·kg ⁻¹ -fuel	2×S×Cs	2.82	0.71	0.04	0.14	0.04	—	USEPA, 2002
		Natural gas	—	g·m ⁻³ -fuel	2×S×Cs	1.60	1.34	0.09	0.03	0.03	—	USEPA, 2002
		Biomass	—	g·kg ⁻¹ -fuel	2×S×Cs	3.52	4.32	0.12	3.07	2.59	0.15	USEPA, 2002
		Coal mining	—	g·kg ⁻¹ -products	—	—	—	—	0.24	0.09	—	USEPA, 2002
		Oil and gas extraction	Oil	g·kg ⁻¹ -products	—	—	—	1.42	—	—	—	MEP, 2014
			Natural gas	g·kg ⁻¹ -products	—	—	—	0.50	—	—	—	MEP, 2014
		Metal mining	—	g·kg ⁻¹ -products	—	—	—	—	2.23	1.11	—	USEPA, 2002
Agricultural products processing		Non-metallic mining	—	g·kg ⁻¹ -products	—	—	—	—	0.09	0.02	—	USEPA, 2002
		Grain grinding	—	g·kg ⁻¹ -products	—	—	—	—	0.13	0.06	—	USEPA, 2002
		Feed processing	—	g·kg ⁻¹ -products	—	—	—	1.00	0.93	0.47	—	USEPA, 2002; EEA, 2013
		Vegetable oil processing	—	g·kg ⁻¹ -products	—	—	—	4.00	—	—	—	USEPA, 2002

Source classification				Units	Emission factors						References
1st level	2nd level	3rd level	4th level		SO ₂	NO _x	CO	NMVOCS	PM ₁₀	PM _{2,5}	
		Sugar production	—	g·kg ⁻¹ -products	—	—	—	0.20	0.52	0.26	— EEA, 2013
		Meat processing	—	g·kg ⁻¹ -products	—	—	—	0.52	—	—	— EEA, 2013
		Nut processing	—	g·kg ⁻¹ -products	—	—	—	—	0.53	0.26	— USEPA, 2002
Food manufacturing	Baked goods manufacturing	Bread	—	g·kg ⁻¹ -products	—	—	—	4.71	—	—	— EEA, 2013
		Biscuits	—	g·kg ⁻¹ -products	—	—	—	1.00	—	—	— MEP, 2014
Beverage manufacturing	Alcohol	—	—	g·kg ⁻¹ -products	—	—	—	32.11	—	—	— USEPA, 2002
	Liquor	—	—	g·kg ⁻¹ -products	—	—	—	14.45	—	—	— USEPA, 2002
	Red wine	—	—	g·kg ⁻¹ -products	—	—	—	3.85	—	—	— USEPA, 2002
	Beer	—	—	g·kg ⁻¹ -products	—	—	—	0.25	—	—	— MEP, 2014
Tobacco manufacturing	Tobacco	—	—	g·kg ⁻¹ -products	—	—	—	0.17	—	—	— USEPA, 2002
Wood processing	Plywood	—	—	g·m ⁻³ -products	—	—	—	0.25	0.03	0.02	— USEPA, 2002
	Oriented strand board	—	—	g·kg ⁻¹ -products	—	—	—	0.26	0.04	0.02	— USEPA, 2002
	Particleboard	—	—	g·kg ⁻¹ -products	—	—	—	0.92	0.05	0.02	— USEPA, 2002
	Fiberboard	—	—	g·kg ⁻¹ -products	—	—	—	1.02	0.05	0.02	— USEPA, 2002
	Other wood products	—	—	g·kg ⁻¹ -products	—	—	—	0.10	0.01	0.00	— USEPA, 2002
Papermaking	Pulp manufacturing	—	—	g·kg ⁻¹ -products	11.38	—	5.55	0.66	3.14	2.44	— USEPA, 2002
Petroleum refining	Process devices	—	—	g·kg ⁻¹ -materials	—	—	—	0.44	—	—	— Local surveys
	Equipment leak	—	—	g·kg ⁻¹ -materials	—	—	—	0.48	—	—	— Local surveys
	Storage tanks	—	—	g·kg ⁻¹ -materials	—	—	—	0.45	—	—	— Local surveys
	Bulk loading	—	—	g·kg ⁻¹ -materials	—	—	—	0.13	—	—	— Local surveys
	Flares	—	—	g·kg ⁻¹ -materials	—	—	—	0.001	—	—	— EEA, 2013
	Wastewater treatment	—	—	g·kg ⁻¹ -materials	—	—	—	0.25	—	—	— Local surveys

Source classification				Units	Emission factors							References
1st level	2nd level	3rd level	4th level		SO ₂	NO _x	CO	NMVOCS	PM ₁₀	PM _{2,5}	NH ₃	
Coking	Cooling Tower	—	g·kg ⁻¹ -materials	—	—	—	0.02	—	—	—	—	Local surveys
		Petrochemical furnace	Refinery dry gas	g·kg ⁻¹ -fuel	—	7.78	1.01	0.37	0.04	0.04	—	USEPA, 2002
	Coke production	Coke oven	g·kg ⁻¹ -materials	1.47	0.82	0.34	0.05	0.14	0.14	—	—	USEPA, 2002
		Fugitive emission	g·kg ⁻¹ -materials	0.12	0.01	15.04	0.04	2.94	1.86	—	—	USEPA, 2002
Chemical manufacturing	Organic chemical manufacturing	Overall	g·kg ⁻¹ -products	—	—	—	17.61	—	—	—	—	USEPA, 2002
	Inorganic chemical manufacturing	Sulfuric acid	g·kg ⁻¹ -products	15.28	—	—	—	—	—	—	—	USEPA, 2002
		Nitric acid	g·kg ⁻¹ -products	—	4.71	—	—	—	—	—	—	USEPA, 2002
		Calcium carbide	g·kg ⁻¹ -materials	3.00	—	—	—	5.82	2.91	—	—	USEPA, 2002
	Fertilizer	Synthetic ammonia	g·kg ⁻¹ -products	0.03	—	7.90	4.72	—	—	2.10	—	USEPA, 2002
		Urea	g·kg ⁻¹ -products	—	—	—	—	1.31	0.81	10.51	—	USEPA, 2002
		NPK Fertilizer	g·kg ⁻¹ -products	—	—	—	—	0.29	0.20	1.89	—	EEA, 2013
	Pesticide	—	g·m ⁻³ -products	—	—	—	0.001	—	—	—	—	USEPA, 2002
	Coating production	Solvent-based coating	g·kg ⁻¹ -products	—	—	—	15.00	—	—	—	—	USEPA, 2002
		Waterborne coating	g·kg ⁻¹ -products	—	—	—	3.00	—	—	—	—	Local surveys
		Varnish	g·kg ⁻¹ -products	—	—	—	46.25	—	—	—	—	USEPA, 2002
Ink production	Oily ink	Oily ink	g·kg ⁻¹ -products	—	—	—	75.00	—	—	—	—	USEPA, 2002
		Water-based ink	g·kg ⁻¹ -products	—	—	—	15.00	—	—	—	—	Local surveys
		Mineral ink	g·kg ⁻¹ -products	—	—	—	20.00	—	—	—	—	USEPA, 2002
	Synthetic resin	Overall	g·kg ⁻¹ -products	—	—	—	5.77	—	—	—	—	USEPA, 2002; EEA, 2013
	Synthetic rubber	Overall	g·kg ⁻¹ -products	—	—	—	4.18	—	—	—	—	USEPA, 2002
Synthetic fiber monomer	Overall	g·kg ⁻¹ -products	—	—	—	48.79	—	—	—	—	—	USEPA, 2002; MEP, 2014
	Specialty chemicals	Adhesive	g·kg ⁻¹ -products	—	—	—	227.00	—	—	—	—	USEPA, 2002

Source classification				Units	Emission factors							References
1st level	2nd level	3rd level	4th level		SO ₂	NO _x	CO	NMVOCS	PM ₁₀	PM _{2.5}	NH ₃	
Manufacturing	Chemical manufacturing	Household chemicals	Accelerator	g·kg ⁻¹ -products	—	—	—	1.87	—	—	—	USEPA, 2002
			Carbon black	g·kg ⁻¹ -products	7.13	1.08	720.49	26.20	1.31	0.65	—	USEPA, 2002
			Charcoal	g·kg ⁻¹ -products	—	12.00	145.00	135.00	12.80	6.40	—	USEPA, 2002
	Explosive	Overall	g·kg ⁻¹ -products	22.94	30.58	—	—	0.72	0.36	—	—	USEPA, 2002
	Food and beverage manufacturing	Household chemicals	Active agent	g·kg ⁻¹ -products	—	—	—	0.98	—	—	—	USEPA, 2002
		Spices	g·kg ⁻¹ -products	—	—	—	22.89	—	—	—	—	Local surveys
	Textile, apparel, and leather goods manufacturing	Chemical fiber	Synthetic fiber manufacturing	g·kg ⁻¹ -products	—	—	—	42.31	—	—	—	USEPA, 2002
		Chemical fiber	Synthetic fiber processing	g·kg ⁻¹ -products	—	—	—	0.36	—	—	—	USEPA, 2002
Pharmaceutical manufacturing	Chemical drug	—	g·kg ⁻¹ -products	—	—	—	260.00	—	—	—	—	MEP, 2014
Manufacturing	Plastic and rubber manufacturing	Rubber products	Tire	g·tire ⁻¹	—	—	—	329.60	—	—	—	USEPA, 2002
			General rubber products	g·kg ⁻¹ -products	—	—	—	6.64	—	—	—	USEPA, 2002
		Plastic products	General plastic products	g·kg ⁻¹ -materials	—	—	—	0.54	—	—	—	USEPA, 2002
			Foam plastic	g·kg ⁻¹ -products	—	—	—	0.77	—	—	—	MEP, 2014
			Poly urethane	g·kg ⁻¹ -products	—	—	—	147.00	—	—	—	USEPA, 2002
			Polyvinyl chloride	g·kg ⁻¹ -products	—	—	—	10.20	—	—	—	USEPA, 2002
			Plastic tape	g·m ⁻² -products	—	—	—	9.00	—	—	—	USEPA, 2002
	Non-metallic mineral manufacturing	Cement manufacturing	Cement kiln	g·kg ⁻¹ -products	0.11	2.10	1.80	0.06	3.81	1.17	—	USEPA, 2002
			Fugitive emission	g·kg ⁻¹ -products	—	—	—	—	0.24	0.05	—	USEPA, 2002
		Lime manufacturing	Lime kiln	g·kg ⁻¹ -products	2.70	1.60	0.74	—	22.00	2.52	—	USEPA, 2002
			Fugitive emission	g·kg ⁻¹ -products	—	—	—	—	11.54	1.33	—	USEPA, 2002
		Plaster manufacturing	—	g·kg ⁻¹ -products	—	—	—	—	8.22	1.78	—	USEPA, 2002
	Gypsum board	—	g·m ⁻² -products	—	—	—	—	8.76	4.38	—	—	USEPA, 2002

Source classification				Units	Emission factors						References
1st level	2nd level	3rd level	4th level		SO ₂	NO _x	CO	NMVOCS	PM ₁₀	PM _{2.5}	
Non-metallic mineral processing	Concrete products	Commodity concrete	—	g·kg ⁻¹ -products	—	—	—	—	1.13	0.56	— USEPA, 2002
		Brick and tile products	Brick kiln	g·kg ⁻¹ -products	0.60	0.26	0.40	0.01	0.38	0.14	— USEPA, 2002
			Fugitive emission	g·kg ⁻¹ -products	—	—	—	0.02	0.43	0.21	— USEPA, 2002
		Crushed Stone processing	—	g·kg ⁻¹ -products	—	—	—	—	0.05	0.02	— USEPA, 2002
		Abrasive processing	—	g·kg ⁻¹ -materials	—	—	—	—	0.03	0.01	— USEPA, 2002
	Glass products	Asphalt products	—	g·kg ⁻¹ -products	0.03	0.03	0.13	0.01	0.91	0.16	— USEPA, 2002
		Glass products	Container glass	g·kg ⁻¹ -products	—	—	8.70	4.40	0.53	0.37	— USEPA, 2002
			Plate glass	g·kg ⁻¹ -products	—	—	—	—	0.75	0.53	— USEPA, 2002
			Glass fiber	g·kg ⁻¹ -materials	—	—	—	0.15	1.33	0.66	— USEPA, 2002
		Ceramic products	—	g·kg ⁻¹ -products	—	—	—	29.00	5.41	2.71	— USEPA, 2002
Ferrous metal manufacturing	Iron making	Refractory products	—	g·kg ⁻¹ -materials	—	—	—	—	22.10	5.10	— USEPA, 2002
		Raw material yard	—	g·kg ⁻¹ -materials	—	—	—	—	0.71	0.11	— Local measurements
		Iron making	Sintering	g·kg ⁻¹ -sinter	1.05	0.97	22.00	0.07	2.44	1.05	— Local measurements (Guo et al., 2017)
			Pellet	g·kg ⁻¹ -pellet	0.90	0.03	0.06	0.01	0.75	0.32	— Local measurements (Guo et al., 2017)
			Blast furnace	g·kg ⁻¹ -iron	—	—	—	—	1.96	1.06	— Local measurements (Guo et al., 2017)
	Steel making	Steel making	Converter	g·kg ⁻¹ -steel	—	—	—	—	1.63	1.13	— Local measurements (Guo et al., 2017)
			Electric furnace	g·kg ⁻¹ -steel	—	—	—	—	0.18	0.09	— Local measurements (Guo et al., 2017)
		Casing steel	—	g·kg ⁻¹ -products	—	—	—	—	6.58	3.29	— USEPA, 2002
		Rolling steel	—	g·kg ⁻¹ -products	—	—	—	0.25	0.05	0.02	— USEPA, 2002
		Ferroalloy production	—	g·kg ⁻¹ -products	—	—	—	—	99.29	84.72	— USEPA, 2002
Non-ferrous metal manufacturing	Primary copper	—	g·kg ⁻¹ -products	0.67	—	—	—	2.81	1.71	—	USEPA, 2002
	Primary aluminum	—	g·kg ⁻¹ -products	—	—	—	—	2.75	2.13	—	USEPA, 2002

Source classification				Units	Emission factors							References
1st level	2nd level	3rd level	4th level		SO ₂	NO _x	CO	NMVOCS	PM ₁₀	PM _{2.5}	NH ₃	
Non-road mobile sources	Metallurgical processes	Primary lead	—	g·kg ⁻¹ -products	—	—	—	—	1.25	0.63	—	EEA, 2013
		Primary zinc	—	g·kg ⁻¹ -products	—	—	—	—	0.40	0.30	—	EEA, 2013
		Secondary copper	—	g·kg ⁻¹ -materials	—	—	—	—	60.41	30.20	—	USEPA, 2002
		Secondary aluminum	—	g·kg ⁻¹ -products	—	—	—	—	6.97	5.20	—	USEPA, 2002
		Secondary lead	—	g·kg ⁻¹ -materials	—	—	—	—	4.75	2.38	—	USEPA, 2002
		Secondary zinc	—	g·kg ⁻¹ -products	—	—	—	—	23.89	11.94	—	USEPA, 2002
	Other miscellaneous sources	Explosives detonation	—	g·kg ⁻¹ -materials	1.00	17.00	114.11	—	—	—	12.43	USEPA, 2002
		Abrasive blasting	—	g·kg ⁻¹ -products	—	—	—	—	13.00	1.30	—	USEPA, 2002
		Electric arc welding	—	g·kg ⁻¹ -materials	—	—	—	—	12.46	6.23	—	USEPA, 2002
Industrial solvent-use sources	—	—	—	—	Calculated based on solvent consumption							
Road transport	Motor vehicles	Light-duty gasoline vehicles	Euro 0	g·km ⁻¹	—	2.80	28.68	6.53	0.12	0.12	0.00	
			Euro 1	g·km ⁻¹	—	1.23	13.52	3.59	0.14	0.14	0.08	Local measurements (Huang et al., 2017; Huang et al., 2018a; Huang et al., 2018b)
			Euro 2	g·km ⁻¹	—	0.93	10.28	2.37	0.14	0.14	0.07	
			Euro 3	g·km ⁻¹	—	0.52	7.11	0.85	0.03	0.03	0.04	
			Euro 4	g·km ⁻¹	—	0.20	2.36	0.28	0.01	0.01	0.03	
			Euro 5	g·km ⁻¹	—	0.16	2.01	0.26	0.01	0.01	0.02	
	Light-duty diesel vehicles	Light-duty diesel vehicles	Euro 0	g·km ⁻¹	—	1.99	10.05	2.36	1.19	1.07	—	
			Euro 1	g·km ⁻¹	—	1.46	2.70	0.43	0.42	0.38	—	Estimated based on the International Vehicle Emission (IVE) Model (Huang et al., 2015)
			Euro 2	g·km ⁻¹	—	1.46	3.38	0.28	0.35	0.31	—	
			Euro 3	g·km ⁻¹	—	1.26	1.05	0.14	0.22	0.19	—	
			Euro 4	g·km ⁻¹	—	1.02	0.98	0.10	0.20	0.19	—	
			Euro 5	g·km ⁻¹	—	1.02	0.98	0.10	0.20	0.19	—	

Source classification				Units	Emission factors						References
1st level	2nd level	3rd level	4th level		SO ₂	NO _x	CO	NMVOCS	PM ₁₀	PM _{2.5}	
Heavy-duty gasoline vehicles		Euro 0	g·km ⁻¹	—	5.16	100.74	16.29	0.65	0.59	0.00	Estimated based on the International Vehicle Emission (IVE) Model (Huang et al., 2015)
		Euro 1	g·km ⁻¹	—	2.65	62.09	11.37	0.35	0.32	0.08	
		Euro 2	g·km ⁻¹	—	2.56	33.28	6.80	0.16	0.14	0.07	
		Euro 3	g·km ⁻¹	—	1.52	16.50	4.34	0.10	0.09	0.04	
		Euro 4	g·km ⁻¹	—	0.78	7.54	2.53	0.10	0.09	0.03	
		Euro 5	g·km ⁻¹	—	0.58	7.54	2.53	0.10	0.09	0.02	
Heavy-duty diesel vehicles		Euro 0	g·km ⁻¹	—	12.42	26.33	5.34	3.22	2.89	—	Estimated based on the International Vehicle Emission (IVE) Model (Huang et al., 2015)
		Euro 1	g·km ⁻¹	—	11.16	24.65	4.61	2.46	2.21	—	
		Euro 2	g·km ⁻¹	—	9.89	21.70	2.81	2.21	1.98	—	
		Euro 3	g·km ⁻¹	—	9.89	16.85	1.13	0.99	0.89	—	
		Euro 4	g·km ⁻¹	—	9.89	8.13	0.86	0.63	0.57	—	
		Euro 5	g·km ⁻¹	—	8.64	4.05	0.86	0.32	0.28	—	
Heavy-duty gasoline truck		Euro 0	g·km ⁻¹	—	7.26	153.91	18.07	0.82	0.73	0.00	Estimated based on the International Vehicle Emission (IVE) Model (Huang et al., 2015)
		Euro 1	g·km ⁻¹	—	3.72	94.74	17.80	0.44	0.40	0.08	
		Euro 2	g·km ⁻¹	—	3.63	36.44	8.42	0.20	0.18	0.07	
		Euro 3	g·km ⁻¹	—	2.14	16.73	4.29	0.12	0.11	0.04	
		Euro 4	g·km ⁻¹	—	1.13	7.03	2.29	0.12	0.11	0.03	
		Euro 5	g·km ⁻¹	—	0.85	7.03	2.29	0.12	0.11	0.02	
Heavy-duty diesel truck		Euro 0	g·km ⁻¹	—	16.75	10.54	8.46	2.24	2.04	—	Estimated based on the International Vehicle Emission (IVE) Model (Huang et al., 2015)
		Euro 1	g·km ⁻¹	—	11.62	6.73	3.72	1.60	1.44	—	
		Euro 2	g·km ⁻¹	—	9.61	3.58	2.16	1.29	1.16	—	
		Euro 3	g·km ⁻¹	—	9.61	3.24	1.06	0.88	0.79	—	
		Euro 4	g·km ⁻¹	—	8.41	2.56	0.67	0.47	0.43	—	

Source classification				Units	Emission factors						References
1st level	2nd level	3rd level	4th level		SO ₂	NO _x	CO	NMVOCS	PM ₁₀	PM _{2.5}	
Road transport	Passenger vehicles	Cars	Euro 5	g·km ⁻¹	—	7.15	2.56	0.67	0.30	0.27	—
			Taxi	g·km ⁻¹	—	2.80	43.03	7.74	0.18	0.18	0.00
			Euro 0	g·km ⁻¹	—	2.46	20.28	4.21	0.21	0.21	0.08
			Euro 1	g·km ⁻¹	—	2.32	15.42	2.76	0.21	0.21	0.07
			Euro 2	g·km ⁻¹	—	1.55	10.67	1.95	0.05	0.05	0.04
			Euro 3	g·km ⁻¹	—	0.44	3.54	0.91	0.02	0.02	0.03
			Euro 4	g·km ⁻¹	—	0.41	3.01	0.84	0.01	0.01	0.02
			Euro 5	g·km ⁻¹	—	22.26	20.18	7.39	2.79	2.51	—
			Bus	g·km ⁻¹	—	19.99	18.90	3.19	2.13	1.92	—
			Euro 0	g·km ⁻¹	—	17.73	16.64	1.95	1.91	1.72	—
			Euro 1	g·km ⁻¹	—	17.73	12.92	1.57	0.86	0.77	—
			Euro 2	g·km ⁻¹	—	16.65	9.58	1.01	0.65	0.59	—
			Euro 3	g·km ⁻¹	—	14.54	5.25	0.57	0.45	0.41	—
			Euro 4	g·km ⁻¹	—	0.13	21.30	4.47	0.07	0.06	—
			Euro 5	g·km ⁻¹	—	0.14	13.44	2.43	0.04	0.04	—
			Motorcycles	g·km ⁻¹	—	0.15	3.87	1.51	0.02	0.02	—
			Euro 0	g·km ⁻¹	—	0.10	1.67	0.87	0.01	0.01	—
			Euro 1	g·km ⁻¹	—	0.10	1.67	0.87	0.01	0.01	—
			Euro 2	g·km ⁻¹	—	0.10	1.67	0.87	0.01	0.01	—
			Euro 3	g·km ⁻¹	—	0.10	1.67	0.87	0.01	0.01	—
Non-road machinery	Construction machinery	Euro 0	g·kg ⁻¹ -fuel	0.61	61.82	20.75	6.64	3.85	3.65	—	Estimated based on the
		Euro 1	g·kg ⁻¹ -fuel	0.61	49.81	14.03	3.85	2.63	2.50	—	NONROAD Model and local
		Euro 2	g·kg ⁻¹ -fuel	0.61	37.47	11.93	2.95	1.69	1.60	—	measurements (Lu et al., 2017)
		Euro 3	g·kg ⁻¹ -fuel	0.61	25.60	11.41	2.44	1.27	1.20	—	
Port machinery	Port machinery	Euro 0	g·kg ⁻¹ -fuel	0.55	44.17	16.10	5.10	3.30	3.14	—	
		Euro 1	g·kg ⁻¹ -fuel	0.55	36.10	10.74	2.84	2.28	2.17	—	

Source classification				Units	Emission factors							References
1st level	2nd level	3rd level	4th level		SO ₂	NO _x	CO	NMVOCS	PM ₁₀	PM _{2.5}	NH ₃	
Road transport	Road vehicles	Passenger vehicles	Euro 2	g·kg ⁻¹ ·fuel	0.55	27.42	9.47	2.47	1.36	1.29	—	Estimated based on the NONROAD Model and local measurements (Lu et al., 2017)
			Euro 3	g·kg ⁻¹ ·fuel	0.55	17.68	8.95	1.88	1.02	0.97	—	
		Commercial vehicles	Euro 0	g·kg ⁻¹ ·fuel	0.45	61.82	20.75	6.64	3.85	3.65	—	Estimated based on the NONROAD Model and local measurements (Lu et al., 2017)
			Euro 1	g·kg ⁻¹ ·fuel	0.45	49.81	14.03	3.85	2.63	2.50	—	
			Euro 2	g·kg ⁻¹ ·fuel	0.45	37.47	11.93	2.95	1.69	1.60	—	
			Euro 3	g·kg ⁻¹ ·fuel	0.45	25.60	11.41	2.44	1.27	1.20	—	
		Agricultural machinery	Euro 0	g·kg ⁻¹ ·fuel	0.52	56.63	39.43	11.86	5.12	4.86	—	Estimated based on the NONROAD Model and local measurements (Lu et al., 2017)
			Euro 1	g·kg ⁻¹ ·fuel	0.52	45.46	25.81	6.47	3.49	3.32	—	
			Euro 2	g·kg ⁻¹ ·fuel	0.52	35.89	21.07	4.85	2.50	2.38	—	
			Euro 3	g·kg ⁻¹ ·fuel	0.52	25.35	17.10	3.23	2.21	2.10	—	
Non-road mobile sources	Garden equipment	Lawn mowers	Euro 0	g·kg ⁻¹ ·fuel	—	5.54	787.07	118.15	1.84	1.84	—	Estimated based on the NONROAD Model and local measurements (Lu et al., 2017)
			Euro 1	g·kg ⁻¹ ·fuel	—	6.77	802.04	75.16	1.34	1.34	—	
		Garden tractors	Euro 2	g·kg ⁻¹ ·fuel	—	4.77	703.52	64.46	0.76	0.76	—	
			Euro 3	g·kg ⁻¹ ·fuel	—	3.57	641.19	51.61	0.58	0.58	—	
		Ground handling equipment	Euro 0	g·kg ⁻¹ ·fuel	0.70	61.82	20.75	6.64	3.85	3.65	—	Estimated based on the NONROAD Model and local measurements (Lu et al., 2017)
			Euro 1	g·kg ⁻¹ ·fuel	0.70	49.81	14.03	3.85	2.63	2.50	—	
			Euro 2	g·kg ⁻¹ ·fuel	0.70	37.47	11.93	2.95	1.69	1.60	—	
			Euro 3	g·kg ⁻¹ ·fuel	0.70	25.60	11.41	2.44	1.27	1.20	—	
Other sources	Marine	—	—	—	Detailed emission factors can be referred to Fan et al., 2016							
	Aviation aircraft	—	—	—	Detailed emission factors can be referred to ICAO, 2014							
	Construction dust	—	—	g·m ⁻² ·month ⁻¹	—	—	—	—	78.03	19.36	—	MEP, 2014
	Road dust	highways	—	g·km ⁻¹	—	—	—	—	0.51	0.12	—	MEP, 2014

Source classification				Units	Emission factors						References	
1st level	2nd level	3rd level	4th level		SO ₂	NO _x	CO	NMVOCS	PM ₁₀	PM _{2,5}		
Oil storage and transportation	Oil depot	Storage and transportation process	Elevated roads	—	g·km ⁻¹	—	—	—	1.53	0.37	—	MEP, 2014
			Arterial roads	—	g·km ⁻¹	—	—	—	0.94	0.23	—	MEP, 2014
			Residential roads	—	g·km ⁻¹	—	—	—	0.82	0.20	—	MEP, 2014
			Crude oil	g·kg ⁻¹ -turnover	—	—	—	0.44	—	—	—	
			Gasoline	g·kg ⁻¹ -turnover	—	—	—	1.69	—	—	—	
			Diesel	g·kg ⁻¹ -turnover	—	—	—	0.65	—	—	Local surveys	
			Heavy oil	g·kg ⁻¹ -turnover	—	—	—	0.13	—	—	—	
			Chemicals	g·kg ⁻¹ -turnover	—	—	—	0.84	—	—	—	
	Gas station	Storage and transportation process	Gasoline	g·kg ⁻¹ -fuel	—	—	—	1.43	—	—	Local surveys	
Residential sources	Residential combustion	Bituminous coal	—	g·kg ⁻¹ -fuel	2×S×Cs	1.57	125.45	4.18	15.89	14.22	1.01	
		Anthracite coal	—	g·kg ⁻¹ -fuel	2×S×Cs	1.50	125.45	4.18	7.53	2.64	1.01	MEP, 2014; Li et al., 2016;
		Coal gas	—	g·m ⁻³ -fuel	—	1.50	1.34	0.09	0.05	0.05	—	USEPA, 2002; EEA, 2013
		Natural gas	—	g·m ⁻³ -fuel	—	1.60	1.34	0.09	0.03	0.03	—	
		Biogas	—	g·m ⁻³ -fuel	—	0.59	0.75	0.05	0.03	0.03	—	
	Residential solvent-use	Architectural coating	Solvent-based coating	g·kg ⁻¹ -coatings	—	—	—	600.00	—	—	—	Local surveys
			Waterborne coating	g·kg ⁻¹ -coatings	—	—	—	65.00	—	—	—	Local surveys
		Consumer products	—	g·capita ⁻¹	—	—	—	100.00	—	—	—	MEP, 2014
		Solvent degreasing	—	g·capita ⁻¹	—	—	—	44.00	—	—	—	MEP, 2014
		Auto repair	—	g·vehicle ⁻¹	—	—	—	20.02	—	—	—	Local surveys
		Dry cleaning	—	g·capita ⁻¹	—	—	—	24.36	—	—	—	Local surveys
		Hospital solvent	—	g·outpatient ⁻¹	—	—	—	16.00	—	—	—	Local surveys

Source classification				Units	Emission factors						References
1st level	2nd level	3rd level	4th level		SO ₂	NO _x	CO	NMVOCS	PM ₁₀	PM _{2.5}	
Catering	—	—	kg·restaurant ⁻¹	—	—	—	—	95.34	41.30	33.04	— Local measurements (Wang et al., 2018; Gao et al., 2019)
Waste treatment and disposal	Human excretion	—	—	kg·capita ⁻¹	—	—	—	—	—	—	0.79 MEP, 2014
	Sewage treatment	—	—	g·t ⁻¹ -wastewater	—	—	—	1.10	—	—	3.20 MEP, 2014
	Waste treatment	Landfill	—	g·kg ⁻¹ -refuse	—	—	—	0.23	—	—	0.56 MEP, 2014
Agricultural sources		Composting	—	g·kg ⁻¹ -refuse	—	—	—	0.74	—	—	1.28 MEP, 2014
Livestock and poultry breeding	Swine breeding	Shed	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	7.97	
	Manure fertilizing	—	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	1.80 Local measurements (Chen, 2017a)	
	Sewage storage	—	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	1.68	
	Apply fertilizer	—	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	1.80	
Dairy cow breeding	Shed	—	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	33.80	
	Manure fertilizing	—	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	17.40 Local measurements (Zhou, 2019)	
	Sewage storage	—	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	25.70	
	Apply fertilizer	—	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	93.80	
Beef cattle	Shed	—	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	43.00	
	Manure fertilizing	—	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	20.00 MEP, 2014	
	Sewage storage	—	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	20.00	
	Apply fertilizer	—	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	22.50	
Sheep	Shed	—	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	12.10	
	Manure fertilizing	—	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	5.60 MEP, 2014	
	Sewage storage	—	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	5.60	
	Apply fertilizer	—	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	6.30	

Source classification				Units	Emission factors						References
1st level	2nd level	3rd level	4th level		SO ₂	NO _x	CO	NMVOCS	PM ₁₀	PM _{2.5}	
N-fertilizer application	Broiler	Shed	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	—	0.10
			g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	—	0.10 MEP, 2014
			g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	—	0.03
	Egg-laying poultry	Shed	g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	—	1.40
			g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	—	0.90 MEP, 2014
			g·head ⁻¹ ·d ⁻¹	—	—	—	—	—	—	—	0.27
	Paddy field	—	g·kg ⁻¹ -fertilizer	—	—	—	—	—	—	—	243.40 Local measurements (Chen et al., 2017b)
	Wheat field	—	g·kg ⁻¹ -fertilizer	—	—	—	—	—	—	—	74.70 Local measurements (Xia et al., 2018)
Biomass burning	Field burning	Soybean	g·kg ⁻¹ -straw	0.53	1.08	32.30	8.45	1.98	1.84	0.53	
		Rape	g·kg ⁻¹ -straw	0.53	1.12	34.30	8.45	3.57	3.32	0.53	
		Rice stalk	g·kg ⁻¹ -straw	0.53	1.42	27.70	8.45	3.26	3.03	0.53	Local measurements (Tang et al., 2014); MEP, 2014
		Wheat stalk	g·kg ⁻¹ -straw	0.85	1.19	20.60	7.48	2.57	2.39	0.37	
		Corn stalk	g·kg ⁻¹ -straw	0.44	4.30	53.00	10.00	12.58	11.70	0.68	
	Household stove	Soybean	g·kg ⁻¹ -straw	1.36	2.19	80.70	7.97	8.29	7.71	0.52	
		Rape	g·kg ⁻¹ -straw	1.36	1.65	133.50	7.97	13.73	12.77	0.52	
		Rice stalk	g·kg ⁻¹ -straw	0.48	2.02	82.00	7.36	9.83	9.14	0.52	Local measurements (Tang et al., 2014); MEP, 2014
		Straw	g·kg ⁻¹ -straw	2.36	0.86	191.55	13.74	7.40	6.88	0.37	
		Corn stalk	g·kg ⁻¹ -straw	1.33	1.16	108.90	5.46	6.17	5.74	0.68	
		Firewood	g·kg ⁻¹ -straw	0.40	1.28	67.53	1.73	4.68	4.36	1.30	

235 **Table S2.** Emission estimation methods and activity data sources.

No.	Sources		Estimation methods	Activity data source	Reliability level
	1st level	2nd level			
1	Stationary combustion sources	–	SO ₂ , PM ₁₀ , and PM _{2.5} : mass balance method; Other pollutants: emission factor method	2017 environmental statistics	A
2	Industrial process sources	–	Emission factor method	2017 environmental statistics	B
3	Industrial solvent-use sources	–	Mass balance method	2017 environmental statistics	C
4	Mobile sources	Motor vehicles Non-road machinery Ships Aviation aircraft	International Vehicle Emission (IVE) model Emission factor method Automatic Identification System (AIS) method Emission factor and FOA3.0 method (Wayson et al., 2009)	Local surveys Estimated based on local surveys 2017 AIS data Local flight information surveys	B D B B
5	Dust sources	Construction dust Road dust	Emission factor method Emission factor method	Estimated based on statistic yearbooks Local surveys	D B
6	Oil storage and transportation sources	–	Emission factor method	Statistic yearbooks	C
7	Residential sources	Residential combustion Residential solvent-use Catering Human excretion	Emission factor method Emission factor method Emission factor method Emission factor method	Statistic yearbooks Estimated based on statistic yearbooks Estimated based on statistic yearbooks Estimated based on statistic yearbooks	C D D D
8	Waste treatment and disposal sources	–	Emission factor method	Statistic yearbooks	C
9	Agricultural sources	Livestock and poultry breeding N-fertilizer application Biomass burning	Emission factor method Emission factor method Emission factor method	Statistic yearbooks Statistic yearbooks Estimated based on statistic yearbooks	C C D

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237 **Table S3.** Emission estimation methods and activity data sources.

Source classification			PM _{2.5} speciation			NMVOC speciation		
1st level	2nd level	3rd level	References	Samples	Analytical method	References	Samples	Methods
Stationary combustion sources	Power plants	Coal	Local measurements (Zheng et al., 2013)	2	CA; IC; ICPAES	Local measurements	2	GC-FID/MS
		Natural gas	SPECIATE 4.4			SPECIATE 4.4		
		Solid waste	SPECIATE 4.4			Reference to coal		
		Boilers	Coal	Local measurements (Xu et al., 2018)	7	CA; IC; ICPAES	SPECIATE 4.4	
		Fuel oil	SPECIATE 4.4			SPECIATE 4.4		
		Diesel	SPECIATE 4.4			SPECIATE 4.4		
		Natural gas	SPECIATE 4.4			SPECIATE 4.4		
		Biomass	Local measurements	2	CA; IC; XRF	Local measurements	7	GC-FID/MS
	Mining source	Coal mining	Local measurements	2	CA; IC; ICPAES	/		
		Oil and gas extraction	/			SPECIATE 4.4		
		Metal mining	SPECIATE 4.4			/		
		Non-metallic mining	Local measurements	2	CA; IC; ICPAES	/		
Industrial process	Agricultural products processing	–	SPECIATE 4.4			Local measurements (Gao et al., 2019)	27	GC-FID/MS
	Food manufacturing	–	/			Local measurements (Gao et al., 2019)	27	GC-FID/MS
	Beverage manufacturing	Alcohol	/			SPECIATE 4.4		
		Liquor	/			SPECIATE 4.4		
		Red wine	/			SPECIATE 4.4		
		Beer	/			SPECIATE 4.4		
	Tobacco manufacturing	Tobacco	/			SPECIATE 4.4		
	Wood processing	–	SPECIATE 4.4			SPECIATE 4.4		
	Papermaking	Pulp manufacturing	SPECIATE 4.4			Local measurements	2	GC-FID/MS

Petroleum refining	Process devices	/			Local measurements (Wang et al., 2017a)	21	GC-FID/MS
	Equipment leak	/			Local measurements (Wang et al., 2017a)	21	GC-FID/MS
	Storage tanks	/			Local measurements (Wang et al., 2017a)	8	GC-FID/MS
	Loading and unloading	/			Local measurements (Wang et al., 2017a)	8	GC-FID/MS
	Flares	/			SPECIATE 4.4		
	Wastewater treatment	/			Local measurements (Wang et al., 2017a)	6	GC-FID/MS
	Cooling Tower	/			SPECIATE 4.4		
	Petrochemical furnace	/			SPECIATE 4.4		
Coking	Coke production	Local measurements	2	CA; IC; ICPAES	Local measurements (Wang et al., 2017a; Jing et al., 2018)	4	GC-FID/MS
Chemical manufacturing	Organic chemical manufacturing	/			Local measurements (Wang et al., 2017a; Jing et al., 2018)	32	GC-FID/MS
	Inorganic chemical manufacturing	SPECIATE 4.4			/		
	Fertilizer	SPECIATE 4.4			/		
	Pesticide	/			SPECIATE 4.4		
	Coating production	/			Local measurements (Wang et al., 2017a; Jing et al., 2018)	10	GC-FID/MS
	Ink production	/			Local measurements (Wang et al., 2017a; Jing et al., 2018)	22	GC-FID/MS
	Synthetic resin	/			Local measurements (Wang et al., 2017a; Jing et al., 2018)	2	GC-FID/MS
	Synthetic rubber	/			Local measurements (Wang et al., 2017a; Jing et al., 2018)	6	GC-FID/MS
	Synthetic fiber monomer	/			Local measurements (Wang et al., 2017a; Jing et al., 2018)	2	GC-FID/MS
	Specialty chemicals	SPECIATE 4.4			SPECIATE 4.4		
	Household chemicals	/			SPECIATE 4.4		
	Chemical fiber	/			Local measurements (Wang et al., 2017a; Jing et al., 2018)	2	GC-FID/MS
Rubber and plastic manufacturing	Rubber products	/			Local measurements (Wang et al., 2017a; Jing et al., 2018)	6	GC-FID/MS
	Plastic products	/			Local measurements (Wang et al., 2017a; Jing et al., 2018)	2	GC-FID/MS
Non-metallic mineral manufacturing	Cement manufacturing	SPECIATE 4.4			/		
	Lime manufacturing	SPECIATE 4.4			/		

	Plaster manufacturing	SPECIATE 4.4		/	
	Gypsum board	SPECIATE 4.4		/	
	Commodity concrete	Local measurements	2	CA; IC; ICPAES	/
	Brick and tile products	SPECIATE 4.4		/	
	Crushed Stone processing	SPECIATE 4.4		/	
	Abrasive processing	SPECIATE 4.4		/	
	Asphalt products	SPECIATE 4.4		SPECIATE 4.4	
	Glass products	SPECIATE 4.4		/	
	Glass fiber	SPECIATE 4.4		/	
	Ceramic products	SPECIATE 4.4		SPECIATE 4.4	
	Refractory products	SPECIATE 4.4		/	
Ferrous metal manufacturing	Raw material yard	Local measurements	2	CA; IC; XRF	/
	Sintering	Local measurements	4	CA; IC; XRF	SPECIATE 4.4
	Pellet	Local measurements	2	CA; IC; XRF	SPECIATE 4.4
	Blast furnace	Local measurements	3	CA; IC; XRF	SPECIATE 4.4
	Converter	Local measurements	2	CA; IC; XRF	SPECIATE 4.4
	Electric furnace	SPECIATE 4.4		SPECIATE 4.4	
	Casing steel	SPECIATE 4.4		SPECIATE 4.4	
	Rolling steel	SPECIATE 4.4		SPECIATE 4.4	
	Ferroalloy production	SPECIATE 4.4		/	
Non-ferrous metal manufacturing	Primary copper	SPECIATE 4.4		/	
	Primary aluminum	SPECIATE 4.4		/	
	Primary lead	SPECIATE 4.4		/	
	Primary zinc	SPECIATE 4.4		/	
	Secondary copper	SPECIATE 4.4		/	

		Secondary aluminum	SPECIATE 4.4		SPECIATE 4.4			
		Secondary lead	SPECIATE 4.4		/			
		Secondary zinc	SPECIATE 4.4		/			
	Other miscellaneous sources	Abrasive blasting	SPECIATE 4.4		/			
		Electric arc welding	SPECIATE 4.4		/			
Industrial solvent-use source	Textile	–		Local measurements (Wang et al., 2017a; Jing et al., 2018)	14	GC-FID/MS		
	Leather tanning	–		SPECIATE 4.4				
	Furniture manufacturing	–		Local measurements (Wang et al., 2017a; Jing et al., 2018)	6	GC-FID/MS		
	Package and printing	–		Local measurements (Wang et al., 2017a; Jing et al., 2018)	8	GC-FID/MS		
	Pharmaceutical manufacturing	–		SPECIATE 4.4				
	Shoemaking	–		Local measurements (Wang et al., 2017a; Jing et al., 2018)	6	GC-FID/MS		
	Metal products	–		Local measurements (Wang et al., 2017a; Jing et al., 2018)	12	GC-FID/MS		
	Machinery manufacturing	–		Reference to Metal products				
	Railway equipment	–		SPECIATE 4.4				
	Auto manufacturing	–		Local measurements (Wang et al., 2017a; Jing et al., 2018)	25	GC-FID/MS		
	Shipbuilding	–		Local measurements (Wang et al., 2017a; Jing et al., 2018)	28	GC-FID/MS		
	Appliance manufacturing	–		SPECIATE 4.4				
	Electronic equipment	–		SPECIATE 4.4				
Mobile source	Motor vehicles	Light-duty gasoline vehicles (LDGV)	Local measurements	10	CA; IC; XRF	Local measurements (Wang et al., 2017b)	21	GC-FID/MS
		Light-duty diesel vehicles (LDDV)	Reference to HDDT			Reference to HDDT		
		Heavy-duty gasoline vehicles (HDGV)	Reference to LDGV			Reference to LDGV		
		Heavy-duty diesel vehicles (HDDV)	Reference to HDDT			Reference to HDDT		
		Heavy-duty gasoline truck (HDGT)	Reference to LDGV			Reference to LDGV		
		Heavy-duty diesel truck (HDDT)	Local measurements	15	CA; IC; XRF	Local measurements (Wang et al., 2017b)	16	GC-FID/MS
		Taxi	Reference to LDGV			Reference to LDGV		

	Bus	Reference to HDDT		Local measurements (Wang et al., 2017b)	6	GC-FID/MS	
	Motorcycles	Reference to LDGV		Local measurements (Wang et al., 2017b)	7	GC-FID/MS	
	Evaporative emission	/		Reference to Gas station			
Non-road machinery	Construction machinery	Local measurements	10	CA; IC; XRF	Local measurements	10	GC-FID/MS
	Port machinery	Local measurements	2	CA; IC; XRF	Local measurements	2	GC-FID/MS
	Factory machinery	Local measurements	2	CA; IC; XRF	Local measurements	2	GC-FID/MS
	Agricultural machinery	Local measurements	2	CA; IC; XRF	Local measurements	2	GC-FID/MS
	Garden equipment			Reference to LDGV			
	Ground handling equipment (GHE)	Local measurements	2	CA; IC; XRF	Local measurements	2	GC-FID/MS
Marine	Inland ship	Local measurements	2	CA; IC; XRF	Reference to non-road diesel machinery		
	Marine vessel	Local measurements	1	CA; IC; XRF	Local measurements (Huang et al., 2018c)	11	GC-FID/MS
Aviation aircraft	—	SPECIATE 4.4		SPECIATE 4.4			
Dust source	Construction dust	—	Local measurements	3	CA; IC; ICPAES	/	
	Road dust	—	Local measurements	4	CA; IC; ICPAES	/	
Oil storage and transportation source	Oil depot	Crude oil	/		Local measurements (Wang et al., 2017a)	4	GC-FID/MS
		Gasoline	/		Local measurements (Wang et al., 2017a)	2	GC-FID/MS
		Diesel	/		Local measurements (Wang et al., 2017a)	2	GC-FID/MS
		Heavy oil	/		Reference to Crude oil		
		Chemicals	/		SPECIATE 4.4		
Gas station	Gasoline	/		Local measurements (Wang et al., 2017a)	4	GC-FID/MS	
Residential source	Residential combustion	—	Local measurements	2	CA; IC; ICPAES	SPECIATE 4.4	
	Residential solvent-use	Architectural coating	/		Local measurements (Wang et al., 2014b; Wang et al., 2016)	4	GC-FID/MS
		Consumer products	/		SPECIATE 4.4		
		Solvent degreasing	/		SPECIATE 4.4		
		Auto repair	/		Local measurements	4	GC-FID/MS

		Dry cleaning	/			SPECIATE 4.4		
		Hospital solvent	/			Local measurements		
Catering		–	Local measurements	27	CA; IC; XRF	Local measurements (Gao et al., 2019)	27	GC-FID/MS
Waste treatment and disposal source	Waste treatment	–	/			SPECIATE 4.4		
	Waste treatment	Landfill	/			SPECIATE 4.4		
		Composting	/			SPECIATE 4.4		
Agricultural source	Biomass burning	Field burning-Soybean	Local measurements (Tang et al., 2014)	1	CA; IC; ICPAES	Local measurements (Wang et al., 2014a)	1	GC-FID/MS
		Field burning-Rape	Local measurements (Tang et al., 2014)	2	CA; IC; ICPAES	Local measurements (Wang et al., 2014a)	2	GC-FID/MS
		Field burning-Rice stalk	Local measurements (Tang et al., 2014)	2	CA; IC; ICPAES	Local measurements (Wang et al., 2014a)	2	GC-FID/MS
		Field burning-Wheat stalk	Local measurements (Tang et al., 2014)	2	CA; IC; ICPAES	Local measurements (Wang et al., 2014a)	2	GC-FID/MS
		Field burning-Corn stalk	Local measurements (Tang et al., 2014)	2	CA; IC; ICPAES	Local measurements (Wang et al., 2014a)	2	GC-FID/MS
		Household stove-Soybean	Local measurements (Tang et al., 2014)	2	CA; IC; ICPAES	Local measurements (Wang et al., 2014a)	2	GC-FID/MS
		Household stove-Rape	Local measurements (Tang et al., 2014)	2	CA; IC; ICPAES	Local measurements (Wang et al., 2014a)	2	GC-FID/MS
		Household stove-Rice stalk	Local measurements (Tang et al., 2014)	2	CA; IC; ICPAES	Local measurements (Wang et al., 2014a)	2	GC-FID/MS
		Household stove-Straw	Local measurements (Tang et al., 2014)	2	CA; IC; ICPAES	Local measurements (Wang et al., 2014a)	2	GC-FID/MS
		Household stove-Corn stalk	Local measurements (Tang et al., 2014)	2	CA; IC; ICPAES	Local measurements (Wang et al., 2014a)	2	GC-FID/MS
		Household stove-Firewood	Local measurements (Tang et al., 2014)	1	CA; IC; ICPAES	Local measurements (Wang et al., 2014a)	1	GC-FID/MS

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Table S4. Annual air pollutant emissions in each city of the YRD region in 2017.

Province	City	Annual air pollutant emissions (Gg/year)						
		SO ₂	NO _x	CO	NMVOCs	PM ₁₀	PM _{2.5}	NH ₃
Shanghai	Shanghai	57.2	224.7	1392.9	418.2	123.7	56.2	54.4
	Nanjing	51.7	131.2	1445.6	223.3	90.8	39.7	29.1
	Wuxi	42.0	94.6	1141.4	198.4	92.0	43.2	27.2
	Xuzhou	94.7	148.5	1683.2	148.8	207.0	94.1	164.3
	Changzhou	58.0	86.8	1313.7	153.1	118.9	44.8	26.7
	Suzhou	105.4	183.4	2257.3	263.5	149.7	77.3	34.5
	Nantong	40.4	81.2	2308.1	209.1	106.7	40.4	145.7
Jiangsu	Lianyungang	25.2	72.2	826.3	117.6	87.6	33.6	96.4
	Huaian	43.0	76.5	1978.3	105.9	109.7	34.5	104.1
	Yancheng	42.5	77.3	1094.7	132.6	127.8	47.6	214.3
	Yangzhou	24.8	52.1	930.1	139.5	104.8	34.2	51.6
	Zhenjiang	42.7	55.2	1004.8	119.8	71.5	30.1	23.0
	Taizhou	22.0	55.0	835.4	152.8	114.2	37.3	68.8
	Suqian	26.6	51.4	490.4	91.6	59.5	20.5	107.1
Zhejiang	Hangzhou	39.0	110.7	1204.2	177.7	99.4	39.5	56.1
	Ningbo	61.5	136.9	1546.4	347.9	124.8	57.7	35.5
	Wenzhou	14.8	62.9	465.1	124.0	62.4	20.0	38.6
	Jiaxing	33.4	68.9	1055.0	190.0	84.1	30.8	26.1
	Huzhou	52.5	46.1	466.7	120.6	69.0	31.2	27.0
	Shaoxing	27.1	56.8	646.9	148.3	67.4	24.6	42.1
	Jinhua	27.8	59.2	498.7	100.6	70.5	28.5	38.9
Anhui	Quzhou	41.0	46.2	534.5	60.4	50.5	24.8	42.1
	Zhoushan	5.5	15.8	97.6	47.6	21.8	8.6	3.1
	Taizhou	22.2	55.2	412.0	129.5	84.9	29.6	31.6
	Lishui	13.8	17.9	109.0	36.9	40.5	12.3	21.6
	Hefei	21.5	98.7	907.1	149.1	135.0	55.1	73.1
	Wuhu	39.4	85.2	815.3	82.9	99.0	43.5	34.3
	Bengbu	15.8	40.3	599.4	63.5	116.1	40.7	79.2
	Huainan	19.6	48.6	848.3	27.2	74.3	41.5	61.9
	Ma'anshan	26.5	42.9	599.5	28.8	75.8	36.7	15.7
	Huaibei	36.9	45.2	4437.3	37.5	74.3	44.1	21.0
	Tongling	44.3	58.3	598.8	26.2	72.1	40.8	14.9
	Anqing	41.7	48.0	671.1	78.5	86.9	37.0	62.4
	Huangshan	6.5	8.7	134.8	17.1	22.8	7.0	21.5
	Chuzhou	19.3	58.8	590.3	81.1	107.2	46.4	90.5
	Fuyang	33.8	78.1	524.2	77.0	133.0	63.1	145.7

Suzhou	35.2	75.1	594.9	71.5	106.2	53.4	132.3
Lu'an	18.0	54.0	323.2	51.2	81.9	35.5	73.8
Bozhou	16.4	48.6	318.8	49.6	75.6	35.5	80.5
Chizhou	19.9	32.0	338.8	22.4	73.3	28.0	17.5
Xuancheng	27.4	46.7	446.1	45.9	81.8	33.3	32.9

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242 **Table S5.** Annual air pollutant emissions from different source in the YRD region in 2017.

1 st level	2 nd level	SO ₂	NO _x	CO	NMVOCS	PM ₁₀	PM _{2.5}	NH ₃
Power plants	Power plants	247.3	446.5	1444.0	12.1	156.0	105.5	11.4
Boilers	Boilers	756.1	418.0	28259.7	9.5	62.5	36.6	1.5
	Mining	14.5	18.9	72.8	1.8	111.2	65.2	0.5
	Agricultural products processing	0.3	0.1	0.3	62.7	97.7	70.5	-
	Food manufacturing	0.1	-	0.1	0.6	5.6	3.9	-
	Beverage manufacturing	0.1	-	0.1	104.1	0.1	-	-
	Papermaking	17.7	0.4	30.7	8.7	10.0	8.0	-
Industrial process sources	Petroleum refining	9.7	4.5	629.8	156.4	23.1	22.3	2.0
	Coking	34.7	17.6	241.3	1.3	17.6	13.2	0.1
	Chemical manufacturing	93.6	39.6	474.1	801.2	21.1	15.2	45.0
	Rubber and plastic manufacturing	0.6	0.4	1.0	254.7	0.1	0.1	-
	Non-metallic mineral manufacturing	69.6	240.5	506.4	191.4	606.5	338.2	-
	Ferrous metal manufacturing	77.5	105.2	383.5	32.6	91.2	69.9	0.3
	Non-ferrous metal manufacturing	20.7	0.8	0.9	1.6	107.3	77.2	-
	Other miscellaneous sources	6.7	4.0	19.2	55.4	4.4	2.8	-
	Textile	1.5	1.0	2.1	102.4	0.3	0.2	-
	Leather tanning	-	-	-	0.9	-	-	-
Industrial solvent-use sources	Furniture and wood manufacturing	-	-	-	363.4	-	-	-
	Package and printing	-	-	-	51.0	-	-	-
	Pharmaceutical manufacturing	-	-	0.1	103.2	-	-	-
	Shoemaking	-	-	-	15.8	-	-	-
	Metal products	0.2	0.1	0.1	77.6	40.7	24.4	-
	Machinery manufacturing	0.3	0.8	1.0	135.5	19.4	13.2	-
	Railway equipment	0.1	0.1	0.1	5.1	0.2	0.1	-
	Auto manufacturing	0.2	-	-	71.0	1.0	0.6	-
	Shipbuilding	-	-	-	20.8	0.2	0.2	-
	Appliance manufacturing	-	-	-	272.2	-	-	-
	Electronic equipment	0.3	0.1	0.2	100.8	0.1	-	-
Mobile sources	Light-duty vehicles	0.0	216.0	2694.3	434.9	17.7	17.4	28.2
	Light-duty trucks	0.0	48.7	134.3	19.4	8.5	7.7	0.8
	Heavy-duty vehicles	0.0	103.5	189.8	32.5	9.8	8.8	0.3
	Heavy-duty trucks	0.0	571.7	201.4	63.3	49.8	44.9	0.0
	Taxi	0.0	10.3	85.1	24.6	0.3	0.3	0.8
	Bus	0.0	92.9	111.0	26.7	4.1	3.7	0.1
	Motorcycle	0.0	5.4	175.0	228.9	0.8	0.8	1.1
	Construction machinery	3.0	248.4	70.5	20.0	10.7	10.2	0.0
	Port machinery	0.2	13.7	6.3	1.3	0.6	0.5	0.0
	Factory machinery	0.5	48.8	19.6	4.7	2.7	2.5	0.0
	Agricultural machinery	2.3	186.0	693.3	85.4	15.0	14.3	0.0

	Ground handling equipment	0.1	3.7	2.4	0.4	0.1	0.1	0.0
	Marine	114.9	298.8	21.3	7.8	15.9	14.6	0.1
	Aviation aircraft	0.8	11.9	7.3	1.3	0.1	0.1	0.0
Dust sources	Construction dust	-	-	-	-	1480.8	302.2	-
	Road dust	-	-	-	-	607.1	146.9	-
Oil storage and transportation sources	Oil depot	-	-	-	251.1	-	-	-
	Gas station	-	-	-	44.5	-	-	-
Residential sources	Human excretion	58.9	28.1	438.8	15.1	54.0	48.3	3.4
	Residential combustion	-	-	-	435.2	-	-	-
	Residential solvent-use	-	-	-	20.5	10.2	8.2	-
	Catering	-	-	-	-	-	-	82.2
Waste treatment and disposal sources	Sewage treatment	-	-	-	13.0	-	-	37.7
	Waste treatment	3.4	30.1	1.2	8.7	1.4	1.4	17.3
Agricultural sources	Biomass burning	16.6	17.7	1587.9	122.1	104.6	97.3	5.4
	Fertilizer application	-	-	-	-	-	-	32.5
	Soil background	-	-	-	-	-	-	728.6
	Livestock and poultry breeding	-	-	-	-	-	-	1467.6
	Total	1552.5	3234.5	38507.1	4875.2	3770.5	1597.5	2466.7

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245 **Table S6.** Parameterization scheme and inputs for the WRF and CMAQ model.

Model	Option	Configuration/Data source	Reference
WRF	Version	WRF-v3.9.1	https://www2.mmm.ucar.edu/wrf/
	IC/BC condition	NCEP FNL1°×1°	https://rda.ucar.edu/datasets/ds083.2/
	Microphysical Process	Purdue Lin Scheme	Lin, 1983
	Cumulus Convective Scheme	Grell-3 Scheme	Grell and Dévényi, 2002
	Road Process Scheme	Noah Scheme	Ek, 2003
	Boundary Layer Scheme	Yonsei University (YSU) Scheme	Hong, 2006
	Long-wave and Short-wave radiation scheme	RRTM and Goddard radiation Scheme	Mlawer et al., 1997; Chou and Suarez, 1999
CMAQ	Version	CMAQ-v5.3.0	https://www.cmascenter.org/cmaq/
	Domain	Three nested grid(36/12/4km)	-
	Gas Chemical Mechanism	CB6r3	http://www.camx.com/files/udaq_snowchem_final_6aug15.pdf
	Aerosol Chemical Mechanism	AERO6	https://github.com/USEPA/CMAQ/blob/master/CCTM/src/MECHS/READ_ME.md
	Anthropogenic emission inventory	MIX(2010) and MEIC(2016) emissions for 36km,12km and area around the YRD in 4km domain	Li et al., 2017 http://www.meicmodel.org/
	Biogenic emission inventory	MEGAN-v2.10	https://bai.ess.uci.edu/megan/ ; Liu et al., 2018
	Emission processor	SMOKE-v46	https://www.cmascenter.org/smoke/

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247 **Table S7.** The statistical results of model performance for the hourly concentrations in each city of
 248 the YRD region in January and July 2017.

249 (a) SO₂

Province	City	Jan.										Jul.															
		Data pairs	Obs. (µg/m ³)	Sim. (µg/m ³)	NMB (%)		NME (%)		MFB (%)		MFE (%)		IOA	R	Data pairs	Obs. (µg/m ³)	Sim. (µg/m ³)	NMB (%)		NME (%)		MFB (%)		MFE (%)		IOA	R
					NMB (%)	NME (%)	MFB (%)	MFE (%)	NMB (%)	NME (%)	MFB (%)	MFE (%)						NMB (%)	NME (%)	MFB (%)	MFE (%)						
Shanghai	Shanghai	624	18.0	10.2	-43.5	51.2	-69.0	74.3	0.6	0.5	741	11.3	7.0	-37.6	60.1	-65.3	83.7	0.4	0.1								
	Nanjing	613	16.8	16.5	-1.8	41.2	-8.6	42.8	0.6	0.4	722	6.0	5.2	-13.1	93.5	-39.0	100.8	0.2	-0.2								
	Wuxi	618	15.4	15.5	0.8	38.4	-5.4	39.1	0.7	0.5	740	8.0	5.9	-26.5	73.8	-50.6	87.9	0.2	-0.3								
	Xuzhou	606	33.9	36.9	8.9	47.8	-2.4	44.1	0.6	0.4	740	13.0	16.0	23.4	76.5	-8.5	67.9	0.3	0.1								
	Changzhou	622	16.3	18.8	15.5	44.9	7.3	40.7	0.6	0.4	701	16.2	7.6	-53.0	61.4	-86.2	93.1	0.5	0.2								
	Suzhou	623	17.1	14.2	-17.0	37.7	-29.7	46.8	0.7	0.6	618	8.5	7.9	-7.2	58.4	-23.6	63.7	0.4	0.1								
	Nantong	619	13.1	12.7	-3.4	44.3	-13.6	44.7	0.8	0.6	679	16.6	14.7	-11.3	54.0	-30.2	64.0	0.6	0.4								
Jiangsu	Lianyungang	601	31.3	12.5	-60.2	61.3	-92.4	93.7	0.5	0.5	741	5.5	3.0	-45.5	65.6	-79.6	96.1	0.3	-0.1								
	Huaian	617	17.4	17.0	-2.1	58.7	-11.3	59.3	0.5	0.3	737	9.6	11.9	24.4	86.3	-9.0	78.3	0.4	0.2								
	Yancheng	617	17.2	9.9	-42.2	51.1	-67.4	74.5	0.6	0.5	738	8.0	5.2	-35.4	53.1	-63.5	76.9	0.4	0.3								
	Yangzhou	624	14.9	14.0	-6.0	41.6	-16.3	44.6	0.7	0.5	691	18.1	8.1	-54.9	62.1	-89.4	96.0	0.5	0.3								
	Zhenjiang	621	12.0	19.9	65.9	83.3	43.9	57.7	0.6	0.5	741	16.9	12.7	-25.1	58.2	-38.4	70.2	0.5	0.1								
	Taizhou	500	14.4	10.8	-24.9	47.7	-45.1	61.7	0.6	0.4	740	12.4	8.9	-28.2	72.6	-28.8	94.0	0.4	0.1								
	Suqian	622	20.1	14.8	-26.4	44.4	-40.3	56.2	0.6	0.3	66	8.1	3.9	-51.9	54.4	-73.3	76.9	0.3	0.2								
Zhejiang	Hangzhou	624	13.0	12.4	-4.3	39.5	-11.9	42.5	0.6	0.4	740	8.3	4.4	-46.9	55.6	-72.0	77.8	0.5	0.4								
	Ningbo	623	11.5	16.2	41.0	71.3	8.9	47.4	0.4	0.4	740	8.3	8.4	0.9	64.2	-29.9	62.5	0.2	0.3								
	Wenzhou	575	6.6	8.0	21.6	65.6	24.9	64.3	0.6	0.4	741	10.4	6.0	-42.7	52.9	-67.8	77.7	0.5	0.4								
	Jiaxing	597	11.1	14.3	28.2	49.5	14.2	43.2	0.7	0.6	704	7.8	8.0	2.2	50.8	-7.0	57.2	0.7	0.5								
	Huzhou	621	14.2	12.5	-12.2	44.6	-25.0	51.4	0.6	0.4	731	7.1	3.6	-49.8	65.6	-93.2	104.2	0.5	0.4								
	Shaoxing	623	12.1	15.1	24.5	56.7	15.2	49.7	0.5	0.3	678	12.1	8.1	-32.8	52.1	-43.2	66.2	0.5	0.2								
	Jinhua	623	12.4	9.5	-23.3	46.7	-25.3	58.7	0.6	0.4	734	7.4	3.7	-50.0	60.5	-76.2	85.9	0.5	0.3								
Anhui	Quzhou	622	12.0	21.0	75.8	108.0	45.7	68.4	0.3	0.1	722	15.5	27.4	76.9	132.5	29.2	90.2	0.4	0.2								
	Zhoushan	614	11.3	5.8	-48.2	53.5	-80.7	84.5	0.6	0.7	741	7.6	5.0	-33.7	48.9	-55.5	65.3	0.6	0.5								
	Taizhou	622	8.5	8.5	0.7	57.2	5.1	59.9	0.6	0.3	741	5.6	4.6	-18.5	44.5	-24.7	54.4	0.7	0.5								
	Lishui	621	9.3	6.2	-32.9	50.4	-54.2	69.3	0.5	0.3	712	7.0	1.5	-78.1	78.3	-136.3	136.4	0.4	0.3								
	Hefei	624	18.1	14.8	-18.2	41.7	-21.7	46.5	0.6	0.3	732	5.1	4.3	-15.6	53.9	-24.7	61.8	0.5	0.2								
	Wuhu	614	20.6	15.4	-25.3	48.6	-35.4	56.0	0.4	0.1	737	11.5	9.4	-18.2	60.1	-25.7	71.0	0.6	0.3								
	Bengbu	618	17.4	14.5	-16.8	55.7	-19.8	58.5	0.5	0.1	739	8.5	4.5	-47.3	56.3	-74.4	84.4	0.5	0.2								
	Huainan	619	22.3	20.3	-9.1	39.8	-12.4	42.6	0.6	0.3	739	7.0	5.5	-21.5	48.7	-37.8	58.6	0.5	0.3								
Anhui	Maanshan	616	17.7	23.2	31.2	72.3	27.5	60.3	0.4	0.1	733	9.8	10.3	5.5	79.7	9.9	82.6	0.5	0.3								
	Huaibei	614	24.6	23.1	-6.1	39.5	-9.3	41.2	0.7	0.5	737	7.8	9.2	18.3	68.2	-7.6	68.3	0.5	0.3								
	Tongling	564	23.5	23.2	-1.3	62.1	0.9	60.2	0.5	0.2	731	19.2	9.6	-49.9	63.3	-72.4	87.3	0.5	0.2								
Anhui	Anqing	610	20.7	23.6	13.8	60.8	9.9	53.9	0.4	0.1	739	13.0	12.8	-1.7	71.8	-19.5	71.6	0.2	-0.2								

Huangshan	619	11.7	9.8	-16.4	56.6	-16.5	59.9	0.4	0.0	739	18.3	2.0	-89.1	89.1	-159.5	159.5	0.3	0.0
Chuzhou	621	14.7	14.3	-2.7	55.5	-14.8	57.5	0.5	0.2	737	12.3	5.0	-59.2	67.5	-87.4	97.0	0.4	0.0
Fuyang	603	15.0	27.2	81.4	101.1	45.6	63.3	0.3	0.2	739	13.4	12.0	-10.6	72.1	-31.9	79.5	0.4	0.0
Suzhou	591	24.9	19.9	-20.4	52.5	-15.6	57.4	0.6	0.3	703	14.8	4.7	-68.3	71.8	-98.2	104.0	0.4	0.1
Lu'an	622	16.5	13.5	-18.2	46.9	-27.2	54.5	0.5	0.2	738	8.4	3.2	-62.0	64.4	-93.5	96.2	0.4	0.0
Bozhou	615	29.8	19.1	-35.8	51.4	-48.3	64.8	0.5	0.2	723	9.4	4.0	-57.3	59.7	-89.4	91.8	0.4	0.2
Chizhou	604	23.8	19.6	-17.7	50.6	-23.8	54.6	0.5	0.2	739	18.9	3.8	-79.8	81.3	-129.6	131.6	0.4	-0.1
Xuancheng	612	21.0	16.0	-24.0	46.3	-34.9	56.1	0.3	-0.1	741	14.1	2.9	-79.5	80.4	-130.7	132.2	0.4	0.2

250 (b) NO₂

Province	City	Jan										Jul									
		Data pairs	Obs. (µg/m ³)	Sim. (µg/m ³)	NMB (%)	NME (%)	MFB (%)	MFE (%)	IOA	R	Data pairs	Obs. (µg/m ³)	Sim. (µg/m ³)	NMB (%)	NME (%)	MFB (%)	MFE (%)	IOA	R		
Shanghai	Shanghai	624	44.7	50.6	13.2	38.1	11.9	35.8	0.7	0.5	738	30.1	42.7	41.7	63.7	24.9	47.1	0.6	0.5		
	Nanjing	613	36.5	45.6	25.0	48.6	19.7	45.4	0.7	0.5	723	25.7	24.6	-4.2	62.1	-18.2	64.8	0.6	0.3		
	Wuxi	615	58.5	51.6	-11.8	31.3	-9.1	34.6	0.7	0.6	740	26.7	31.4	17.7	56.6	6.5	45.9	0.6	0.4		
	Xuzhou	620	54.2	49.8	-8.1	28.5	-7.3	31.2	0.8	0.6	740	22.0	24.6	11.7	46.8	15.1	44.1	0.7	0.5		
	Changzhou	622	42.5	50.9	19.7	41.6	19.2	42.3	0.7	0.5	704	26.3	29.7	13.1	59.5	2.1	52.2	0.6	0.3		
	Suzhou	623	50.3	50.6	0.6	31.6	0.8	33.6	0.8	0.6	618	30.3	33.4	10.5	56.1	-1.5	51.5	0.5	0.2		
Jiangsu	Nantong	619	32.2	36.2	12.5	43.5	9.7	42.4	0.8	0.6	678	45.5	43.5	-4.4	51.5	-9.0	55.5	0.6	0.4		
	Lianyungang	621	39.7	34.0	-14.4	41.4	-8.7	46.1	0.7	0.5	741	17.4	18.2	4.5	50.5	-4.9	46.8	0.5	0.3		
	Huaian	620	29.8	31.9	6.9	45.4	2.2	42.0	0.7	0.5	738	23.3	33.0	41.6	66.7	29.8	53.0	0.5	0.3		
	Yancheng	617	32.8	20.8	-36.7	50.6	-48.2	66.4	0.7	0.5	739	21.7	16.9	-22.0	48.9	-42.6	62.1	0.6	0.4		
	Yangzhou	619	43.8	34.2	-22.0	38.4	-28.5	43.9	0.7	0.6	689	29.1	28.1	-3.5	49.5	-19.6	53.5	0.7	0.5		
	Zhenjiang	621	42.6	38.4	-9.9	35.3	-14.6	39.4	0.8	0.6	740	29.3	30.5	4.2	52.2	4.6	52.5	0.6	0.4		
Zhejiang	Taizhou	500	27.1	28.5	5.2	43.9	-0.3	40.2	0.7	0.5	740	24.8	29.4	18.7	67.4	5.0	58.6	0.5	0.3		
	Suqian	622	39.1	36.0	-8.1	36.8	-11.6	39.8	0.7	0.5	66	25.5	20.8	-18.2	46.2	-29.0	54.9	0.6	0.4		
	Hangzhou	624	44.6	47.5	6.7	38.1	9.3	39.8	0.7	0.5	740	26.6	32.5	22.1	56.4	14.8	46.7	0.6	0.3		
	Ningbo	623	41.8	40.5	-3.2	37.5	-3.5	40.5	0.8	0.6	740	31.3	34.8	11.1	43.1	11.4	38.3	0.7	0.6		
	Wenzhou	574	31.1	30.9	-0.7	42.8	-1.1	42.5	0.6	0.4	741	25.9	29.5	14.3	44.4	3.8	38.2	0.6	0.5		
	Jiaxing	597	35.8	38.0	6.3	43.8	11.6	44.1	0.7	0.4	704	26.4	26.0	-1.8	48.6	-8.7	48.5	0.7	0.5		
Anhui	Huzhou	621	37.1	29.7	-20.0	46.2	-22.4	52.4	0.6	0.4	731	27.4	10.7	-61.0	70.4	-92.1	103.8	0.4	0.1		
	Shaoxing	623	45.7	36.9	-19.2	36.7	-20.3	42.9	0.7	0.5	670	19.2	16.9	-12.0	40.0	-17.9	41.3	0.6	0.4		
	Jinhua	623	32.8	29.7	-9.2	37.2	-8.1	41.4	0.7	0.5	732	19.0	13.5	-29.1	52.0	-45.0	61.9	0.5	0.3		
	Quzhou	623	34.7	46.6	34.2	66.2	21.2	52.6	0.3	0.1	730	23.9	45.2	89.1	116.9	51.7	76.3	0.3	-0.1		
	Zhoushan	614	13.0	15.7	20.7	54.3	14.5	48.6	0.7	0.6	741	15.4	18.6	21.1	51.3	12.2	43.0	0.7	0.5		
	Taizhou	622	24.9	27.2	9.5	45.5	11.0	42.7	0.6	0.4	741	11.9	17.3	45.2	66.4	30.9	47.2	0.7	0.6		
Anhui	Lishui	621	21.0	13.7	-34.6	46.7	-36.8	57.7	0.6	0.5	712	14.6	7.5	-48.5	51.7	-60.7	65.4	0.6	0.4		
	Hefei	624	44.8	48.0	7.3	35.0	11.4	35.6	0.7	0.6	732	30.2	32.4	7.1	39.3	3.6	36.1	0.7	0.5		
Anhui	Wuhu	613	42.6	32.7	-23.3	44.2	-19.8	48.4	0.7	0.5	740	31.4	23.1	-26.5	49.7	-23.9	57.2	0.7	0.5		

Bengbu	621	34.6	31.5	-8.9	45.7	-0.5	52.4	0.7	0.5	739	20.7	15.7	-24.3	46.9	-30.6	56.8	0.7	0.5
Huainan	622	25.8	40.0	54.6	70.0	46.9	57.9	0.6	0.4	739	17.6	17.3	-1.9	52.9	-8.4	50.1	0.4	0.2
Maanshan	616	36.0	44.8	24.5	49.4	25.0	46.8	0.6	0.4	737	23.5	23.4	-0.5	53.3	-1.8	51.9	0.6	0.3
Huaibei	616	57.9	42.0	-27.4	40.0	-29.9	51.6	0.6	0.5	737	23.1	22.0	-5.0	43.1	-5.7	42.4	0.6	0.4
Tongling	624	40.0	35.4	-11.5	42.6	-10.1	47.4	0.7	0.4	741	31.1	14.2	-54.4	60.0	-70.1	77.6	0.6	0.5
Anqing	619	40.8	30.1	-26.2	41.4	-24.1	44.6	0.6	0.4	741	29.3	16.4	-43.9	56.8	-40.4	62.2	0.5	0.3
Huangshan	622	18.0	13.0	-28.0	43.2	-33.4	49.2	0.5	0.3	739	20.7	6.9	-66.5	66.7	-103.9	104.1	0.4	0.3
Chuzhou	619	38.5	32.5	-15.6	41.7	-21.9	47.2	0.7	0.5	739	23.4	15.3	-34.6	54.8	-45.5	62.3	0.5	0.3
Fuyang	603	40.1	42.1	5.2	33.8	2.7	33.4	0.7	0.5	739	21.3	18.0	-15.4	39.5	-21.1	43.1	0.6	0.3
Suzhou	622	43.9	41.4	-5.8	35.9	0.0	38.7	0.8	0.6	718	23.9	22.6	-5.3	39.6	-5.4	40.5	0.7	0.5
Liuan	623	39.7	28.2	-28.9	40.9	-37.1	50.7	0.6	0.5	737	22.1	14.4	-34.7	49.8	-50.9	66.9	0.5	0.3
Bozhou	618	30.6	37.3	21.9	47.1	25.8	47.6	0.7	0.6	723	12.0	13.3	10.1	50.7	4.9	47.2	0.6	0.3
Chizhou	622	39.2	27.1	-30.7	44.8	-39.3	53.9	0.6	0.4	739	21.9	8.5	-61.1	62.7	-88.1	89.9	0.4	0.3
Xuancheng	612	22.8	26.8	17.7	60.9	12.8	54.1	0.6	0.3	741	25.7	11.8	-54.3	63.8	-74.0	91.0	0.4	0.0

251 (c) O₃

Province	City	Jan							Jul										
		Data pairs	Obs. (µg/m³)	Sim. (µg/m³)	NMB (%)	NME (%)	MFB (%)	MFE (%)	IOA	R	Data pairs	Obs. (µg/m³)	Sim. (µg/m³)	NMB (%)	NME (%)	MFB (%)	MFE (%)	IOA	R
Shanghai	Shanghai	624	61.4	45.6	-25.7	37.4	-46.5	61.7	0.7	0.6	677	90.5	62.4	-31.0	40.4	-57.3	71.3	0.8	0.8
	Nanjing	613	63.3	40.9	-35.4	49.7	-55.3	76.5	0.6	0.4	713	85.5	81.8	-4.3	43.4	-10.1	53.1	0.8	0.6
	Wuxi	618	39.6	39.3	-0.8	46.1	-21.8	66.6	0.8	0.6	729	87.8	72.7	-17.1	34.1	-25.9	52.0	0.9	0.8
	Xuzhou	622	30.0	33.1	10.4	51.6	-13.0	75.6	0.8	0.7	740	84.9	93.8	10.5	35.0	18.1	40.0	0.8	0.7
	Changzhou	622	40.9	39.8	-2.6	52.1	-30.2	73.9	0.7	0.5	699	81.1	71.3	-12.0	38.4	-20.6	56.3	0.8	0.7
	Suzhou	623	41.8	41.5	-0.6	47.4	-29.5	64.2	0.7	0.6	616	85.4	74.6	-12.6	38.3	-30.1	55.5	0.8	0.7
	Nantong	619	62.4	53.7	-13.9	30.8	-28.0	46.5	0.7	0.6	657	85.1	72.7	-14.6	37.0	-33.4	62.1	0.9	0.8
Jiangsu	Lianyungang	620	47.0	49.7	5.9	38.9	12.0	52.8	0.8	0.6	736	65.9	94.1	42.8	53.4	36.3	47.6	0.7	0.6
	Huaian	621	46.9	52.7	12.3	38.9	8.4	48.5	0.7	0.6	717	72.2	73.7	2.1	40.1	10.8	49.2	0.8	0.6
	Yancheng	611	57.2	64.8	13.4	34.5	12.5	41.5	0.7	0.5	739	60.0	81.5	36.0	52.5	32.5	50.4	0.7	0.6
	Yangzhou	624	49.7	52.7	6.0	35.8	-2.9	51.1	0.8	0.6	646	82.1	72.4	-11.8	42.0	-13.2	61.6	0.8	0.7
	Zhenjiang	621	49.8	49.8	0.0	36.6	-15.0	54.1	0.8	0.6	738	64.9	70.5	8.6	41.6	8.5	59.1	0.9	0.8
	Taizhou	499	51.1	59.1	15.6	35.5	4.6	40.0	0.7	0.5	728	77.4	73.8	-4.7	39.9	-14.4	57.2	0.9	0.7
	Suqian	612	42.7	47.6	11.4	45.0	1.7	56.7	0.7	0.6	66	66.3	71.6	8.0	30.8	13.1	34.6	0.9	0.7
Zhejiang	Hangzhou	624	38.2	48.7	27.5	63.9	15.0	73.1	0.7	0.6	700	70.1	62.1	-11.4	45.8	-5.5	61.9	0.8	0.7
	Ningbo	623	50.6	60.4	19.3	40.6	19.6	51.8	0.8	0.6	717	69.7	59.6	-14.4	34.0	-16.3	48.0	0.9	0.8
	Wenzhou	575	49.1	69.2	41.0	56.9	39.9	57.4	0.7	0.6	725	61.3	53.1	-13.4	36.8	-12.9	47.4	0.9	0.8
	Jiaxing	574	43.9	55.2	25.8	52.8	24.2	58.7	0.7	0.5	689	91.0	79.1	-13.2	29.7	-12.9	46.8	0.9	0.8
	Huzhou	621	45.4	61.1	34.7	59.8	38.1	64.3	0.7	0.4	717	68.6	78.8	14.8	49.6	42.6	67.0	0.8	0.8
	Shaoxing	623	37.8	58.2	54.1	71.7	43.1	71.1	0.7	0.6	649	90.5	76.0	-16.0	28.3	-18.0	35.3	0.9	0.8
	Jinhua	614	36.0	65.6	82.1	92.4	64.0	76.5	0.6	0.6	722	73.9	64.4	-12.8	32.8	-4.8	42.3	0.9	0.8

	Quzhou	623	39.3	51.6	31.5	64.2	28.2	67.4	0.7	0.4	726	60.1	34.7	-42.2	59.4	-31.0	80.5	0.6	0.6
	Zhoushan	614	76.4	84.6	10.8	23.7	11.3	25.7	0.7	0.6	739	61.9	51.8	-16.2	33.9	-23.2	43.4	0.8	0.7
	Taizhou	622	58.5	70.6	20.7	42.2	22.8	45.5	0.7	0.5	741	63.6	59.0	-7.3	32.0	-14.8	41.1	0.9	0.8
	Lishui	621	53.8	84.9	57.7	70.2	54.3	63.7	0.6	0.5	712	65.8	69.3	5.4	36.9	24.7	47.8	0.8	0.8
Anhui	Hefei	624	39.3	38.1	-3.0	48.0	-19.2	66.0	0.8	0.6	719	86.3	75.4	-12.6	37.5	-10.9	48.3	0.8	0.7
	Wuhu	616	54.3	53.5	-1.3	45.2	-16.1	55.2	0.5	0.3	667	76.9	72.2	-6.1	45.2	17.0	61.1	0.8	0.7
	Bengbu	621	46.9	52.2	11.3	44.7	7.7	56.9	0.8	0.6	739	76.9	89.4	16.3	33.9	20.2	37.4	0.9	0.8
	Huainan	622	44.5	44.8	0.6	46.4	0.0	60.2	0.7	0.5	736	74.4	84.0	12.9	36.7	18.5	41.2	0.8	0.6
	Maanshan	604	39.1	42.7	9.1	52.8	-4.7	64.9	0.7	0.5	715	79.3	79.7	0.5	39.3	14.5	51.9	0.9	0.8
	Huaibei	618	35.0	39.9	14.2	52.9	4.0	67.1	0.8	0.6	737	78.5	95.3	21.4	40.1	27.1	43.7	0.8	0.7
	Tongling	624	48.1	53.9	12.1	56.3	4.0	63.8	0.6	0.4	741	67.4	82.5	22.4	44.9	27.6	46.5	0.8	0.6
	Anqing	618	54.2	60.7	12.0	49.6	13.5	52.3	0.6	0.3	737	68.1	80.7	18.6	36.7	20.9	38.2	0.8	0.7
	Huangshan	621	62.9	85.8	36.3	50.1	31.3	44.3	0.6	0.4	739	52.8	69.6	31.8	42.9	34.7	41.7	0.8	0.7
	Chuzhou	621	72.6	52.3	-27.9	40.7	-42.2	58.7	0.6	0.4	739	88.0	89.5	1.7	28.7	-3.9	35.1	0.8	0.7
	Fuyang	602	34.5	40.9	18.4	55.2	4.7	66.1	0.8	0.6	739	59.4	84.4	42.0	47.8	40.0	46.3	0.8	0.7
	Suzhou	622	38.8	40.7	4.8	42.7	-11.5	59.9	0.8	0.7	731	85.8	86.0	0.2	31.3	5.6	36.6	0.8	0.7
	Liuan	624	49.3	55.2	12.1	49.1	11.1	55.7	0.7	0.5	736	70.1	83.7	19.3	38.7	23.7	40.7	0.8	0.6
	Bozhou	618	42.9	43.0	0.3	38.8	-13.2	51.6	0.8	0.7	722	88.8	97.6	9.9	31.0	14.0	33.4	0.8	0.6
	Chizhou	621	40.6	63.1	55.3	72.2	40.7	63.7	0.6	0.4	739	79.9	80.3	0.5	24.5	0.4	26.4	0.8	0.7
	Xuancheng	612	37.6	62.7	66.6	92.8	37.0	67.8	0.3	0.0	741	64.8	71.1	9.6	33.4	13.6	37.0	0.8	0.7

252 (d) PM_{2.5}

Province	City	Jan								Jul									
		Data pairs	Obs. (µg/m³)	Sim. (µg/m³)	NMB (%)	NME (%)	MFB (%)	MFE (%)	IOA	R	Data pairs	Obs. (µg/m³)	Sim. (µg/m³)	NMB (%)	NME (%)	MFB (%)	MFE (%)	IOA	R
Jiangsu	Shanghai	616	41.6	36.6	-12.0	37.7	-4.7	37.8	0.8	0.6	732	30.7	30.2	-1.8	40.5	-10.2	40.9	0.7	0.6
		611	46.4	46.3	-0.2	43.2	4.3	47.7	0.7	0.5	628	18.8	22.8	21.5	54.5	17.6	54.1	0.7	0.6
		617	48.2	44.5	-7.7	40.0	-6.5	42.1	0.7	0.5	734	25.0	24.9	-0.4	51.8	-9.6	51.6	0.7	0.5
		597	83.4	61.7	-26.0	35.6	-29.2	40.5	0.7	0.6	735	34.3	27.1	-21.0	45.1	-21.8	51.9	0.6	0.4
		620	58.0	48.2	-17.0	37.6	-16.4	42.8	0.7	0.5	704	28.3	24.7	-12.8	42.3	-18.5	48.4	0.8	0.6
		622	53.2	45.2	-15.0	36.7	-9.1	39.2	0.8	0.6	617	23.7	30.3	28.0	57.9	10.6	43.5	0.5	0.5
	Lianyungang	618	53.4	38.3	-28.3	38.7	-27.8	45.7	0.8	0.7	681	34.8	30.4	-12.7	38.6	-15.6	43.4	0.7	0.5
		618	52.8	41.8	-20.8	41.6	-23.3	48.2	0.7	0.6	741	33.5	17.7	-47.2	54.9	-59.3	70.5	0.5	0.3
		621	58.6	48.3	-17.6	44.3	-13.4	51.1	0.7	0.5	737	33.9	24.6	-27.5	40.0	-38.9	50.8	0.5	0.3
		612	45.8	34.5	-24.6	47.1	-18.1	53.4	0.7	0.6	730	28.0	23.2	-17.2	50.1	-25.0	57.5	0.6	0.4
	Hangzhou	612	63.4	49.0	-22.8	39.2	-19.8	46.6	0.7	0.6	691	34.7	26.7	-23.2	39.3	-33.1	47.5	0.7	0.6
		621	58.2	43.5	-25.3	35.1	-30.1	41.3	0.7	0.6	741	36.2	24.3	-32.7	44.1	-47.1	58.5	0.7	0.5
		494	53.0	37.8	-28.8	42.2	-29.7	48.2	0.7	0.5	736	32.7	28.9	-11.6	43.1	-16.9	47.1	0.6	0.4
		622	60.5	47.5	-21.4	37.5	-22.0	44.4	0.8	0.7	65	28.4	16.1	-43.4	48.0	-51.0	57.5	0.4	0.0
Zhejiang	Hangzhou	624	51.5	43.4	-15.7	39.3	-16.8	43.4	0.7	0.5	740	26.3	19.7	-25.2	33.8	-33.1	42.6	0.8	0.8

	Ningbo	623	40.0	36.6	-8.5	45.9	-9.3	49.7	0.7	0.6	740	26.2	21.9	-16.6	52.3	-31.3	55.9	0.7	0.5
	Wenzhou	575	33.1	29.4	-11.1	50.5	-1.4	56.7	0.6	0.4	741	23.2	22.4	-3.4	45.8	-20.1	48.7	0.7	0.6
	Jiaxing	597	47.5	42.0	-11.7	38.3	-9.0	41.7	0.8	0.6	705	32.1	25.1	-21.6	35.4	-31.4	43.3	0.8	0.7
	Huzhou	621	47.6	44.0	-7.5	38.5	-8.4	40.7	0.7	0.5	731	21.6	16.0	-26.1	51.8	-45.0	65.6	0.8	0.7
	Shaoxing	621	50.9	41.0	-19.5	41.2	-22.5	45.6	0.7	0.5	678	26.6	17.6	-33.8	39.8	-40.4	51.6	0.8	0.8
	Jinhua	622	47.7	37.1	-22.1	39.5	-20.4	43.1	0.6	0.5	730	26.2	12.0	-54.3	58.9	-74.6	82.2	0.5	0.5
	Quzhou	617	41.2	40.1	-2.9	42.5	6.6	42.9	0.7	0.5	731	26.3	18.3	-30.3	48.8	-37.9	57.2	0.5	0.3
	Zhoushan	614	29.1	21.9	-24.7	42.5	-33.8	52.8	0.8	0.7	741	16.3	11.8	-27.7	40.9	-46.7	55.4	0.8	0.7
	Taizhou	618	38.7	28.9	-25.2	48.0	-17.6	53.7	0.6	0.5	723	22.2	17.9	-19.2	37.6	-26.2	44.7	0.8	0.7
	Lishui	617	32.5	30.3	-6.7	49.8	-3.5	53.4	0.6	0.3	710	18.4	13.1	-28.8	43.4	-22.0	48.8	0.7	0.6
Anhui	Hefei	624	75.0	69.5	-7.4	33.7	-5.5	35.0	0.7	0.5	726	34.3	28.5	-16.8	39.7	-21.6	47.5	0.7	0.5
	Wuhu	616	47.9	56.5	18.0	42.3	17.0	39.5	0.7	0.6	741	30.3	28.5	-6.1	32.2	-6.4	38.3	0.9	0.8
	Bengbu	622	72.0	61.5	-14.6	37.3	-14.6	40.9	0.7	0.5	725	27.3	24.6	-9.7	49.2	-12.2	55.5	0.6	0.4
	Huainan	620	85.3	62.4	-26.9	35.6	-32.2	42.1	0.7	0.6	739	28.8	18.2	-36.7	49.5	-49.1	67.7	0.7	0.6
	Maanshan	616	59.5	55.4	-6.9	35.6	-3.9	38.5	0.7	0.6	738	24.8	33.6	35.3	64.2	27.7	53.5	0.6	0.4
	Huabei	615	84.9	59.6	-29.9	36.5	-36.1	43.0	0.7	0.5	734	30.4	27.7	-8.8	42.4	-13.0	43.3	0.5	0.3
	Tongling	621	74.6	73.6	-1.3	36.3	-6.6	36.9	0.7	0.5	741	29.3	24.9	-15.0	40.1	-22.2	50.0	0.8	0.6
	Anqing	616	75.7	65.9	-12.9	34.2	-10.7	38.4	0.7	0.5	740	19.8	27.5	39.2	68.4	40.5	64.2	0.6	0.5
	Huangshan	614	43.4	38.3	-11.6	52.8	-2.3	56.1	0.5	0.2	737	14.1	12.6	-10.9	51.4	-2.1	56.2	0.7	0.5
	Chuzhou	621	66.9	51.7	-22.7	37.5	-24.2	44.1	0.7	0.6	741	33.5	24.9	-25.6	37.0	-36.2	46.7	0.8	0.7
	Fuyang	597	96.2	67.9	-29.4	40.7	-34.7	48.6	0.7	0.5	738	28.3	21.1	-25.6	51.6	-21.5	58.9	0.6	0.3
	Suzhou	615	104.2	68.2	-34.5	38.5	-40.7	46.4	0.7	0.6	736	40.0	38.3	-4.3	38.4	-6.7	37.9	0.6	0.4
	Liuan	619	55.2	60.9	10.5	45.6	12.3	44.3	0.6	0.4	738	19.3	19.2	-0.5	48.3	9.0	52.6	0.7	0.5
	Bozhou	595	93.7	62.7	-33.0	41.0	-36.1	46.9	0.7	0.5	718	30.2	21.8	-27.7	49.9	-22.1	54.0	0.5	0.4
	Chizhou	612	81.5	74.6	-8.5	36.0	-13.6	39.0	0.6	0.4	723	24.3	25.3	4.4	48.0	3.0	54.7	0.8	0.6
	Xuancheng	612	63.7	54.5	-14.4	40.7	-17.2	44.4	0.7	0.4	741	22.3	19.6	-12.0	40.4	-12.2	45.8	0.8	0.7

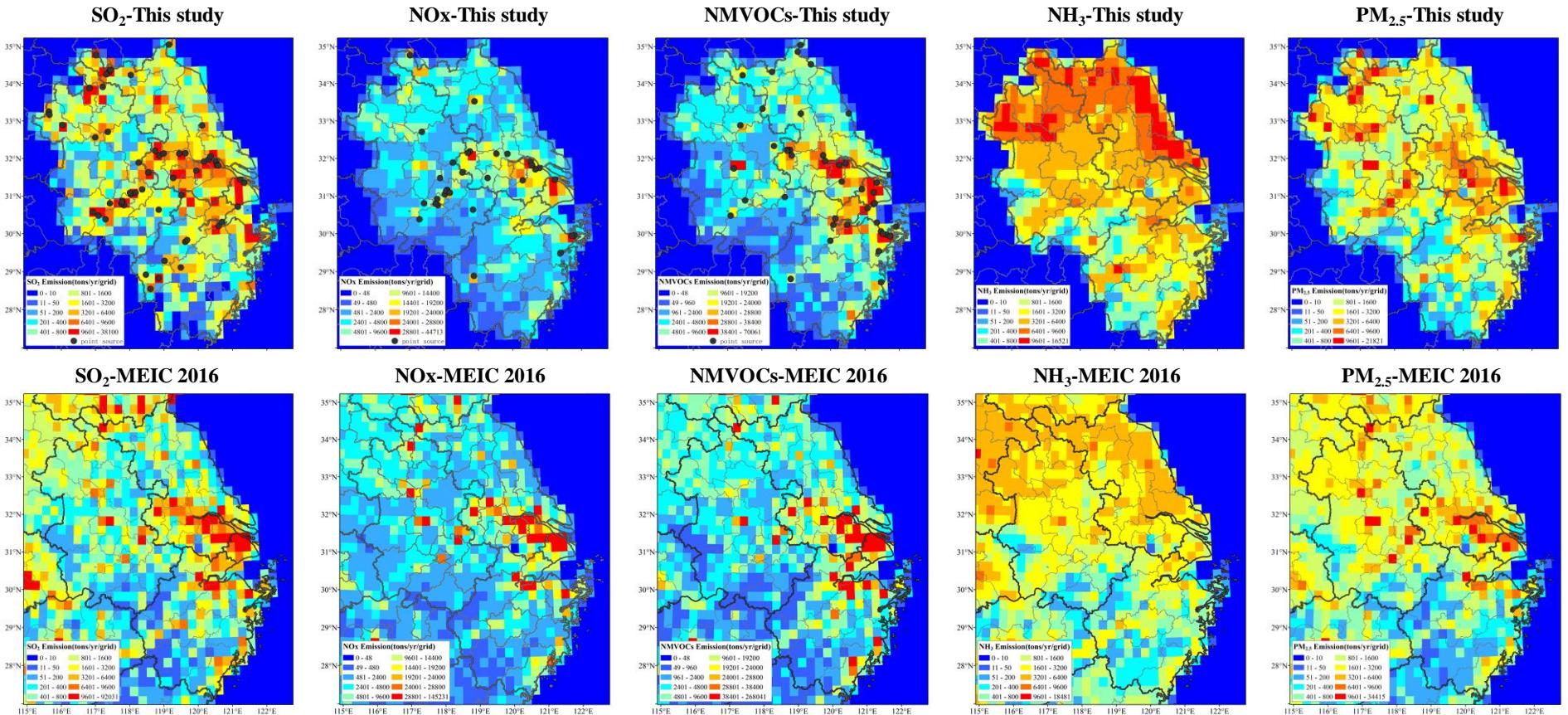
253 (e) PM₁₀

Province	City	Jan										Jul									
		Data pairs	Obs. (µg/m³)	Sim. (µg/m³)	NMB (%)	NME (%)	MFB (%)	MFE (%)	IOA	R	Data pairs	Obs. (µg/m³)	Sim. (µg/m³)	NMB (%)	NME (%)	MFB (%)	MFE (%)	IOA	R		
Jiangsu	Shanghai	530	52.3	49.9	-4.5	36.6	-4.3	34.7	0.7	0.5	714	53.2	50.4	-5.3	36.1	-11.5	37.0	0.7	0.5		
	Nanjing	593	72.7	61.7	-15.1	40.1	-15.5	45.2	0.6	0.4	428	29.7	33.4	12.5	49.9	10.7	51.4	0.8	0.7		
	Wuxi	615	79.3	63.0	-20.6	37.0	-24.2	41.7	0.7	0.5	736	48.5	40.2	-17.1	49.1	-30.5	54.2	0.6	0.4		
	Xuzhou	566	147.7	80.9	-45.2	47.6	-60.1	63.1	0.6	0.5	696	64.8	39.3	-39.4	46.2	-49.1	58.3	0.6	0.5		
	Changzhou	612	82.9	69.0	-16.7	36.1	-17.6	40.4	0.7	0.5	702	44.6	40.5	-9.2	39.0	-21.9	43.2	0.7	0.6		
	Suzhou	430	64.2	58.3	-9.2	38.0	-4.3	39.0	0.7	0.5	611	53.4	48.6	-9.1	47.9	-18.1	49.0	0.6	0.4		
	Nantong	421	61.2	50.7	-17.3	36.7	-14.1	37.6	0.7	0.5	652	66.1	49.1	-25.7	39.6	-31.2	47.9	0.6	0.4		
	Lianyungang	581	85.4	58.0	-32.1	45.6	-34.9	53.5	0.6	0.5	632	51.5	28.3	-44.9	53.1	-57.4	69.8	0.5	0.2		
	Huaian	603	101.5	71.9	-29.2	46.2	-34.9	53.5	0.6	0.4	693	58.7	43.2	-26.3	40.1	-33.4	48.8	0.6	0.4		

		Yancheng	572	70.6	46.8	-33.7	47.6	-39.5	55.7	0.7	0.5	738	76.2	35.9	-52.8	56.1	-76.6	81.5	0.5	0.4
		Yangzhou	578	92.4	74.9	-18.9	37.7	-20.2	43.9	0.7	0.5	675	64.0	46.1	-28.0	41.8	-38.5	50.8	0.6	0.5
		Zhenjiang	598	95.9	59.4	-38.1	42.8	-50.5	55.9	0.6	0.5	675	65.6	39.7	-39.4	48.8	-52.8	63.5	0.6	0.5
		Taizhou	438	70.0	59.8	-14.7	41.7	-13.7	43.6	0.7	0.4	734	56.0	49.4	-11.8	40.0	-16.7	43.6	0.6	0.4
		Suqian	541	75.4	64.3	-14.7	39.8	-16.5	44.0	0.7	0.5	64	73.0	26.1	-64.2	64.5	-85.2	85.8	0.4	0.1
		Hangzhou	624	74.5	62.1	-16.6	37.9	-18.6	41.6	0.7	0.5	738	42.8	34.2	-20.1	32.1	-26.9	38.4	0.8	0.7
		Ningbo	622	55.4	51.9	-6.4	41.9	-12.7	43.6	0.7	0.5	736	43.6	40.4	-7.4	37.8	-14.2	38.6	0.8	0.6
		Wenzhou	573	66.0	44.4	-32.7	48.4	-35.2	58.7	0.5	0.4	721	51.6	51.6	-0.1	38.9	-11.7	40.5	0.7	0.5
		Jiaxing	593	64.1	60.4	-5.8	34.2	-6.3	35.7	0.7	0.5	704	51.6	43.6	-15.4	33.9	-24.5	40.2	0.8	0.7
		Huzhou	514	64.5	61.3	-5.0	38.2	-5.9	40.4	0.7	0.4	710	41.8	25.6	-38.7	59.5	-63.6	79.8	0.6	0.4
Zhejiang		Shaoxing	617	80.9	57.6	-28.7	41.8	-31.0	47.4	0.6	0.4	677	43.7	30.9	-29.4	37.3	-36.0	46.0	0.8	0.7
		Jinhua	507	62.8	50.7	-19.3	32.5	-19.5	36.4	0.7	0.5	684	43.2	21.4	-50.5	55.7	-67.3	74.4	0.5	0.3
		Quzhou	583	70.8	54.9	-22.4	39.2	-19.2	42.6	0.6	0.5	710	50.9	29.2	-42.6	50.9	-53.2	63.3	0.5	0.2
		Zhoushan	612	44.7	36.4	-18.5	36.6	-19.9	40.6	0.8	0.7	741	30.1	40.7	35.2	44.8	21.7	36.7	0.7	0.8
		Taizhou	613	52.3	43.0	-17.8	40.0	-12.4	43.7	0.7	0.6	723	40.4	44.7	10.9	33.7	5.5	32.6	0.8	0.7
		Lishui	515	43.8	46.5	6.0	47.9	8.0	48.9	0.6	0.3	651	38.9	28.1	-27.9	48.3	-23.7	52.2	0.5	0.2
		Hefei	389	94.2	93.4	-0.8	35.9	-0.8	34.2	0.6	0.4	622	51.2	48.8	-4.7	35.2	-7.0	37.4	0.8	0.6
		Wuhu	597	76.6	76.8	0.4	37.3	-1.1	37.4	0.7	0.5	727	52.0	46.5	-10.6	31.7	-9.7	36.2	0.8	0.7
		Bengbu	604	104.8	87.1	-16.8	41.1	-18.6	44.8	0.6	0.4	721	51.1	38.1	-25.4	49.5	-29.9	59.2	0.6	0.4
		Huainan	573	109.4	77.9	-28.8	38.9	-37.7	47.5	0.6	0.5	736	68.6	26.1	-61.9	63.3	-95.3	97.1	0.5	0.5
		Maanshan	536	81.3	76.0	-6.5	38.5	-6.9	40.7	0.6	0.4	699	48.9	53.8	10.1	40.4	7.5	40.3	0.7	0.6
		Huabei	578	127.6	74.4	-41.7	44.1	-54.1	56.7	0.6	0.4	669	60.3	37.4	-38.0	47.3	-46.3	57.7	0.5	0.3
		Tongling	605	100.5	96.5	-4.0	36.6	-9.4	37.2	0.6	0.4	668	45.1	35.8	-20.7	40.2	-33.0	50.4	0.7	0.6
Anhui		Anqing	566	98.9	88.5	-10.5	34.8	-10.9	38.5	0.7	0.4	730	43.1	42.7	-0.9	43.0	-8.2	43.8	0.6	0.5
		Huangshan	509	55.8	52.8	-5.4	50.1	-3.3	49.7	0.4	0.0	735	43.3	23.5	-45.8	51.6	-65.4	70.9	0.5	0.4
		Chuzhou	599	105.9	74.3	-29.9	40.2	-35.4	48.5	0.6	0.4	683	54.0	43.0	-20.5	35.5	-27.2	42.9	0.8	0.6
		Fuyang	564	148.3	87.2	-41.2	46.9	-53.6	60.5	0.6	0.4	733	60.1	30.3	-49.5	55.7	-62.1	70.0	0.5	0.3
		Suzhou	497	145.6	84.5	-42.0	44.0	-52.6	55.2	0.6	0.4	637	53.7	52.9	-1.7	34.6	-5.4	33.0	0.6	0.4
		Liuan	507	77.5	81.2	4.8	45.8	5.9	45.3	0.5	0.3	729	47.0	31.2	-33.7	45.0	-36.6	51.1	0.5	0.4
		Bozhou	550	133.0	78.2	-41.2	47.0	-52.8	59.3	0.5	0.3	696	63.0	31.0	-50.9	56.6	-55.5	66.3	0.4	0.4
		Chizhou	561	118.6	108.7	-8.4	38.0	-12.3	39.7	0.6	0.3	731	55.4	50.0	-9.9	42.1	-19.0	48.6	0.7	0.5
		Xuancheng	507	88.0	75.1	-14.7	40.2	-18.0	43.5	0.6	0.3	728	41.9	36.4	-13.3	42.1	-14.9	46.0	0.7	0.6

254 (f) CO

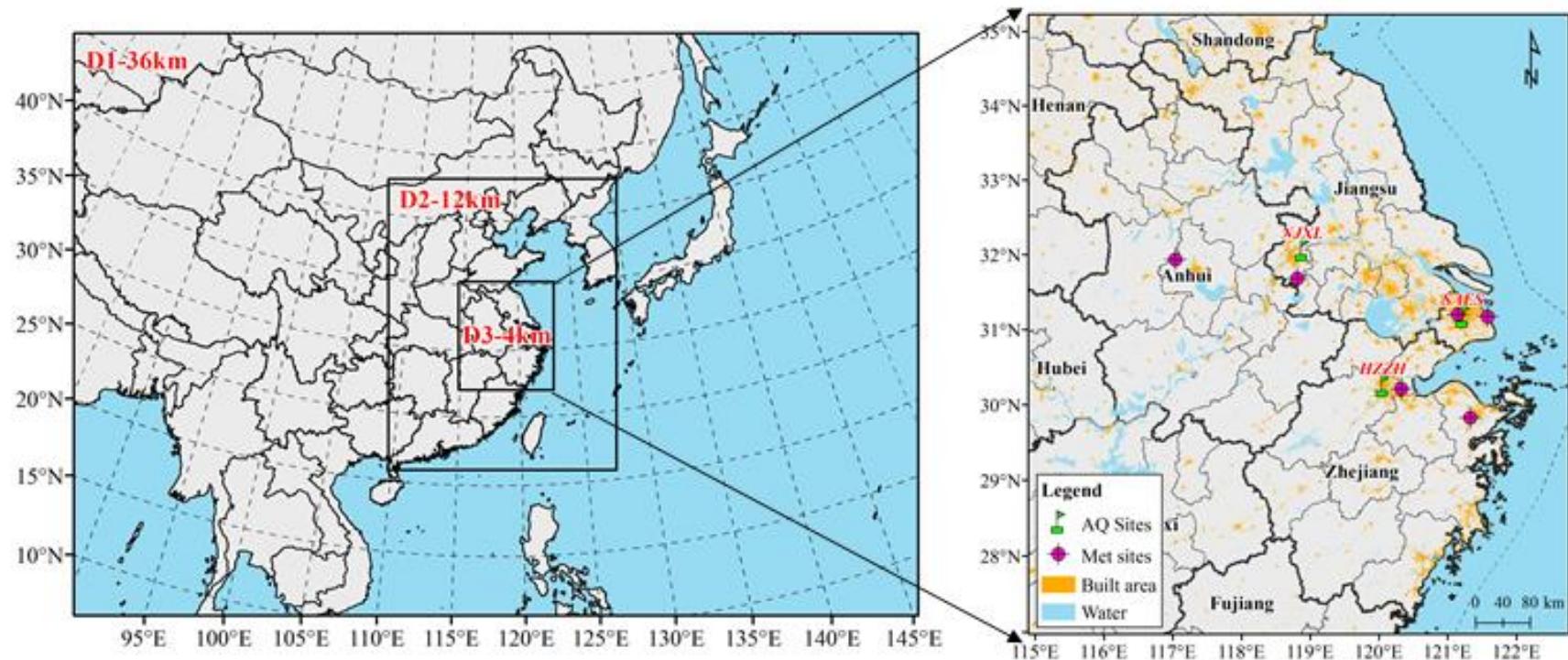
Province	City	Jan							Jul										
		Data pairs	Obs. (µg/m³)	Sim. (µg/m³)	NMB (%)	NME (%)	MFB (%)	MFE (%)	IOA	R	Data pairs	Obs. (µg/m³)	Sim. (µg/m³)	NMB (%)	NME (%)	MFB (%)	MFE (%)	IOA	R
Shanghai	Shanghai	624	0.9	0.6	-35.6	38.6	-42.4	46.1	0.7	0.7	741	0.5	0.4	-22.0	36.1	-31.2	42.5	0.6	0.4
Jiangsu	Nanjing	606	1.0	0.7	-26.2	36.3	-26.4	41.3	0.6	0.4	709	1.0	0.4	-62.4	63.3	-90.4	92.4	0.4	0.2
	Wuxi	618	1.1	0.8	-30.0	37.2	-33.1	41.8	0.6	0.4	740	0.7	0.4	-44.3	48.3	-60.2	64.0	0.4	0.1



256

257 **Figure S1.** Comparisons of spatial distributions of SO₂, NO_x, NMVOCs, NH₃, and PM_{2.5} emissions between this study and the MEIC. The black dots represent for
258 large point sources.

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261 **Figure S2.** Nested Modeling domain (left) and observation sites (right) for model validation.

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