Supplement of Atmos. Chem. Phys., 23, 4247–4269, 2023
https://doi.org/10.5194/acp-23-4247-2023-supplement

Supplement of

High-resolution regional emission inventory contributes to the evaluation of policy effectiveness: a case study in Jiangsu Province, China

Chen Gu et al.

Correspondence to: Yu Zhao (yuzhao@nju.edu.cn)

Supplement

Table List

Figure List

Figure S2 Summary of major air pollution control measures taken between 2015 and 2019. De-S, desulfurization; De-N, NO_X control; NG, natural gas.

Figure S3 The locations of key industries in Jiangsu. The blue line indicates the Yangtze River.

Figure S4 Spatial distribution of air pollutant emissions in 2019 at a horizontal resolution of 3km. The species include (a) SO_2, (b) NO_X, (c) CO, (d) AVOCs, (e) NH_3, (f) PM_{10}, (g) $PM_{2.5}$, (h) BC, and (i) OC.

Figure S5 The spatial distribution of BVOCs emissions from 2015 to 2019 at a horizontal resolution of 3 km.

Figure S6 Annual actual emissions reductions of SO_2, NO_X, AVOCs, NH_3, and $PM_{2.5}$ during 2015-2017 and 2017-2019.

Figure S7 Average pollutant removal efficiencies in the key industries including power, steel and cement production.

Figure S8 Spatial distribution of MDA8 O_3 from CMAQ simulation in January, April, July and October from 2015 to 2019 at a horizontal resolution of 3km ($\mu g \cdot m^{-3}$).

Figure S9 The same as Figure S8 but for $PM_{2.5}$.

Table S1 Source categories of the emission inventory for Jiangsu Province, China.

Sector (1st level)	Subsector(2nd level)	Fuel/product/process(3rd level)
Power sector	Power plant	Coal (8 categories)/ Fuel oil/ Natural gas/other 8 categories
Industry	Boilers	Coal (8 categories)/Fuel oil/Diesel/Natural gas/Biomass
	Mining	Coal mining
		Oil and gas extraction
		Metal mining
		Non-metalic mining
	Petroleum refining	Process devices
		Equipment leak
		Storage tanks
		Loading and unloading
		Flares
		Wastewater treatment
		Cooling Tower
		Petrochemical furnace
	Coking	Coke production
	Chemical manufacturing	Organic chemical manufacturing (18 categories)
		Inorganic chemical manufacturing (10 categories)
		Fertilizer (7 categories)
		Pesticide (8 categories)
		Coating production (16 categories)
		Ink production
		Synthetic resin/ Synthetic rubber (6 categories)
		Synthetic fiber monomer

	Specialty chemicals
	Household chemicals (11 categories)
	Chemical fiber (6 categories)
Rubber and plastic manufacturing	Rubber products/ Plastic products (30 categories)
Non-metallic mineral manufacturing	Cement manufacturing/ Lime manufacturing/ Plaster manufacturing
	Commodity concrete/ Brick and tile products/ Crushed Stone processing
	Abrasive processing/ Asphalt products /
	Glass products/ Glass fiber/ Gypsum board
	Ceramic products/ Refractory products
Ferrous metal manufacturing	Raw material yard
	Sintering
	Pellet
	Blast furnace
	Converter
	Electric furnace
	Casing steel
	Rolling steel
	Ferroalloy production
Non-ferrous metal manufacturing	Primary copper/ Primary aluminum/ Primary lead
	Primary zinc/ Secondary copper/ Secondary aluminum
Food manufacturing	
Tobacco manufacturing	
Wood processing	
Papermaking	Pulp manufacturing
Agricultural products processing	
Beverage manufacturing	Alcohol/ Liquor/ Red wine/ Beer

	Textile	
	Leather tanning	
	Furniture manufacturing	
	Package and printing	
	Pharmaceutical manufacturing	
	Shoemaking	
	Metal products	
	Machinery equipment manufacturing	
	Railway equipment	
	Auto manufacturing	
	Shipbuilding	
	Applicance manufacturing	
	Electronic equipment	
	Other industry	
Transportation	Motor vehicles	Light-duty gasoline vehicles
		Light-duty diesel vehicles
		Heavy-duty gasoline vehicles
		Heavy-duty diesel vehicles
		Heavy-duty gasoline truck
		Heavy-duty diesel truck
		Taxi/Bus/ Motorcycles
	Non-road machinery	Agricultural machinery
		Construction machinery
		Garden equipment
		Ground handling equipment
		Factory machinery

		Port machinery
	Marine	
	Aviation aircraft	
Residential	Residential combustion	
	Architectural coating	
	Housing retrofitting emissions	
	Ship fittings and repairs	
	Consumer products	
	Solvent degreasing	
	Auto repair	
	Dry cleaning	
	Hospital solvent	
	Catering	
	Sewage treatment	
	Waste treatment	Landfill/Composting
	Oil depot	Crude oil/Gasoline/Diesel/Heavy oil/ Chemicals
	Gas station	
Agriculture	Livestock	Cow/Horse/Donkey/Mule/Pig/Sheep/Rabbit/Poultry
	Nitrogen fertilizer application	Fertilizer-N/Fertilizer-P/Fertilizer-K
	Soil background	
	Nitrogen fixing plants	
	Biofuel	Rice straw/Wheat/Corn/Bean/Tuber/Cotton
	Human excrement	
Biogenic source	Biogenic volatile organic compounds emissions	

Table S2 Comparisons between observed and simulated meteorological parameters in D3 (OBS and SIM represent observation and simulation, respectively).

Meteorological parameters	Evaluation Indicators	2015	2016	2017	2018	2019	Recommended range
WS10	OBS (m/s)	2.91	2.63	2.88	2.37	2.55	
	SIM (m/s)	2.92	2.67	2.89	2.63	2.81	
	Bias (m/s)	0.01	0.04	0.04	0.27	0.26	≤±0.5
	RMSE (m/s)	0.27	0.29	0.33	0.27	0.3	≤2.0
	IOA	0.82	0.72	0.94	0.87	0.85	≥0.6
	R	0.89	0.82	0.82	0.89	0.75	
WD10	OBS (°)	184.29	163.29	169.28	174.34	151.75	
	SIM (°)	165.37	147.09	159.80	155.66	143.8	
	Bias	-18.92	-16.2	-9.48	-18.68	-7.95	≤±10
	R	0.69	0.74	0.8	0.71	0.66	
T2	OBS (℃)	15.96	16.02	16.54	16.85	15.78	
	SIM (℃)	16.19	15.73	16.33	16.35	15.45	
	Bias (℃)	0.23	-0.29	-0.21	-0.5	-0.33	≤±0.5
	RMSE (℃)	1.76	0.95	1.27	0.69	1.36	≤2.0
	IOA	0.95	0.98	0.95	0.99	0.91	≥0.8
	R	0.94	0.91	0.89	0.96	0.88	
RH2	OBS (%)	65.16	75.69	79.81	71.96	68.35	
	SIM (%)	61.87	76.21	82.24	70.80	63.91	
	Bias (%)	-3.29	0.52	2.43	-1.16	-4.44	
	RMSE (%)	6.61	3.86	4.24	4.07	5.18	
	IOA	0.97	0.98	0.95	0.98	0.83	≥0.7
	R	0.92	0.85	0.89	0.94	0.87	

Table S3 The meteorological variation (VMET) and emission variation scenarios (VEMIS) for evaluating the contributions of the two factors to changing air quality for 2015-2017 and 2017-2019.

	Contribution 2015-2017	Contribution 2017-2019
VMET	E2017M2017-E2017M2015	E2017M2019-E2017M2017
VEMIS	E2017M2017-E2015M2017	E2019M2017-E2017M2017

Note: VMET and VEMIS were simulated to estimate the contributions of changing meteorology and emissions, respectively. E2017M2017 means the simulation with emission inventory for 2017 and meteorological fields for 2017, and so on.

Table S4 Annual air pollutant emissions in Jiangsu from 2015 to 2019 (Gg·yr^{-1}).

Year	SO_2	NO_X	AVOCs	NH_3	CO	PM_{10}	$PM_{2.5}$	BC	OC
Power	222	351	29	0	607	71	46	0	0
Industry	325	465	854	14	4974	481	300	15	7
Transportation	35	546	195	6	1132	31	29	12	4
Residential	45	49	270	15	1022	128	116	7	33
Agriculture	0	0	0	433	0	0	0	0	0
2015 Total	627	1411	1348	468	7735	711	491	34	44
Power	191	282	28	0	549	51	35	0	0
Industry	305	450	838	14	4623	477	295	14	10
Transportation	39	613	208	7	1207	33	32	13	4
Residential	45	46	272	16	1018	126	113	7	29
Agriculture	0	0	0	415	0	0	0	0	0
2016 Total	580	1391	1347	452	7397	687	475	34	43
Power	123	263	26	0	493	54	36	0	0
Industry	207	359	837	14	4527	465	288	12	9
Transportation	41	664	209	8	1272	35	33	14	5
Residential	45	45	271	20	1013	122	111	7	27
Agriculture	0	0	0	392	0	0	0	0	0
2017 Total	416	1331	1343	434	7305	676	468	33	41
Power	128	251	26	0	490	51	32	0	0
Industry	158	184	848	14	4452	455	282	11	9
Transportation	43	717	163	7	1323	44	42	15	5
Residential	45	46	269	19	987	120	106	7	26
Agriculture	0	0	0	390	0	0	0	0	0
2018 Total	374	1198	1306	430	7252	670	462	33	40
Power	80	186	26	0	484	43	28	0	0
Industry	127	137	839	14	4349	374	240	10	7
Transportation	44	754	151	8	1356	45	43	15	5
Residential	45	45	255	17	974	103	100	7	24
Agriculture	0	0	0	383	0	0	0	0	0
2019 Total	296	1122	1271	422	7163	565	411	32	36

Table S5 The emission data of SO_2, NO_X, AVOCs, $PM_{2.5}$, and NH_3 by year and city for 2015 and 2019 ($Gg \cdot yr^{-1}$).

		SO_2	NO_X	$PM_{2.5}$	AVOCs	NH_3
Southern cities		334.5	684.1	229.1	602.8	81.4
	Nanjing	58.5	192.7	63.7	94.4	17.2
	Suzhou	150.8	205.5	55.0	237.2	25.1
	Wuxi	62.9	107.2	36.4	108.6	13.9
	Changzhou	39.0	111.9	48.4	92.0	13.7
	Zhenjiang	23.3	66.9	25.6	70.7	11.5
Northern cities		186.4	463.5	167.1	462.8	279.9
	Xuzhou	73.1	131.4	50.6	92.3	74.3
	Lianyungang	24.9	80.9	29.9	86.4	39.3
	Suqian	18.4	52.8	18.8	80.1	39.3
	Huaian	28.5	100.9	28.2	103.4	39.7
	Yancheng	41.4	97.5	39.7	100.7	87.3
Central cities		106.7	264.5	94.5	282.3	107.2
	Yangzhou	24.9	68.1	23.2	66.1	21.8
	Taizhou	32.5	69.1	37.3	99.7	27.2
	Nantong	49.3	127.3	34.0	116.4	58.3
2015 Total		627.6	1412.1	490.7	1347.9	468.5
Southern cities		136.3	524.5	174.9	665.0	73.2
	Nanjing	28.6	135.3	47.7	119.6	18.3
	Suzhou	43.7	145.4	39.4	284.3	19.8
	Wuxi	32.0	109.1	31.0	128.0	13.9
	Changzhou	23.7	70.9	35.8	83.8	12.2
	Zhenjiang	9.4	63.7	21.0	49.4	9.0
Northern cities		87.0	379.7	154.0	335.9	253.9
	Xuzhou	22.4	85.3	47.1	78.0	65.0
	Lianyungang	22.1	87.1	24.5	77.7	34.9
	Suqian	11.5	56.9	18.0	49.4	37.4
	Huaian	18.2	78.6	24.5	62.2	37.9
	Yancheng	12.7	71.8	40.0	68.7	78.7
Central cities		71.5	217.9	82.4	270.2	95.3
	Yangzhou	21.4	52.0	16.1	74.5	22.5
	Taizhou	20.4	48.8	36.3	92.0	25.9
	Nantong	29.7	117.1	30.0	103.7	46.9
2019 Total		295.8	1122.2	411.4	1271.1	422.5

Table S6 Comparison of observed and simulated hourly $PM_{2.5}$ concentrations by month in Jiangsu. In total, 110 state-operated observation sites were included in the comparison.

	Observation	Simulation ($\mu g \cdot m^{-3}$)		R		NMB (%)		NME (%)	
	($\mu g \cdot m^{-3}$)	This study[a]	MEIC[c]	This study	MEIC	This study	MEIC	This study	MEIC
2015/1	97.06	80.29	72.11	0.40	0.25	-10.47	-25.69	48.07	53.10
2015/4	54.31	42.42	41.14	0.26	0.24	-17.28	-19.79	49.83	48.84
2015/7	39.36	32.98	30.09	0.37	0.34	-8.58	-17.23	59.96	58.15
2015/10	56.55	42.33	39.66	0.44	0.29	-14.53	-30.27	50.15	52.58
2016/1	81.87	71.80	64.32	0.41	0.30	-12.29	-17.25	43.64	43.80
2016/4	50.42	49.03	41.34	0.24	0.20	-2.77	-15.33	56.48	49.15
2016/7	30.60	34.23	34.80	0.24	0.19	11.86	16.81	49.25	57.36
2016/10	28.93	26.44	24.33	0.31	0.30	-8.62	-14.65	36.79	51.98
2017/1	66.51	64.65	50.68	0.33	0.35	-19.71	-21.43	49.46	58.15
2017/4	49.09	46.59	40.81	0.27	0.15	-17.32	-15.39	54.50	58.69
2017/7	29.87	33.80	33.45	0.25	0.20	-9.13	11.57	28.82	35.89
2017/10	34.48	36.77	29.40	0.45	0.42	-7.29	-15.09	37.44	51.90
2018/1	83.95	61.24	53.66	0.57	0.40	-27.05	-33.49	49.50	58.57
2018/4	47.93	37.86	41.70	0.28	0.10	-23.67	-12.99	54.85	56.16
2018/7	24.42	23.03	28.63	0.37	0.24	-5.71	17.50	56.55	28.66
2018/10	38.97	20.01	11.16	0.20	0.17	-28.67	-43.36	41.21	43.34
2019/1	72.29	77.79	64.55	0.29	0.10	7.61	-11.53	38.72	52.74
2019/4	40.32	49.62	43.96	0.27	0.20	23.07	7.87	45.58	54.51
2019/7	25.20	26.86	27.35	0.19	0.10	6.58	21.45	42.08	53.40
2019/10	38.40	20.63	16.54	0.20	0.12	-29.32	-38.15	49.43	52.46

This study[a]: simulation with a horizontal resolution of 3 km (D3).

MEIC[c]: simulation with a horizontal resolution of 9 km (D2).

Table S7 The same as Table S6 but for MDA8 O_3.

	Observation ($\mu g\cdot m^{-3}$)	Simulation ($\mu g\cdot m^{-3}$)		R		NMB (%)		NME (%)	
		This study[a]	MEIC[c]	This study	MEIC	This study	MEIC	This study	MEIC
2015/1	50.93	35.83	39.54	0.25	0.17	-29.64	-25.20	47.13	42.58
2015/4	108.70	82.61	79.20	0.37	0.26	-24.01	-27.14	36.43	41.89
2015/7	107.18	85.58	86.53	0.48	0.41	-20.15	-19.85	36.74	41.82
2015/10	114.98	78.27	78.27	0.37	0.37	-31.93	-31.93	37.34	37.34
2016/1	60.19	40.62	38.52	0.29	0.32	-32.52	-36.00	41.43	42.69
2016/4	117.37	85.40	85.10	0.49	0.47	-27.24	-27.49	37.23	39.03
2016/7	118.38	95.91	110.76	0.58	0.50	-11.10	-6.44	31.68	31.61
2016/10	74.36	67.71	64.41	0.51	0.45	-8.94	-13.50	30.37	31.39
2017/1	66.37	44.2	42.70	0.43	0.44	-29.39	-35.67	38.71	41.95
2017/4	134.06	103.52	98.58	0.57	0.60	-17.48	-26.47	26.68	31.23
2017/7	134.59	116.08	145.43	0.44	0.37	-11.86	8.05	31.58	35.81
2017/10	91.28	85.92	81.97	0.57	0.37	-3.69	-10.20	24.93	26.75
2018/1	57.95	52.61	52.32	0.12	0.26	-9.21	42.04	38.74	66.28
2018/4	134.87	106.68	85.74	0.67	0.29	-20.90	-36.00	27.36	42.66
2018/7	118.01	117.53	114.78	0.45	0.43	-0.41	3.26	32.50	35.30
2018/10	108.75	79.42	70.85	0.33	0.31	-26.97	-34.66	34.99	39.03
2019/1	50.48	48.43	43.41	0.28	0.20	-9.99	-13.99	44.02	57.07
2019/4	112.93	101.95	94.46	0.50	0.41	-21.24	-16.35	31.71	39.57
2019/7	138.71	124.22	118.45	0.33	0.31	-12.65	-16.70	43.33	34.17
2019/10	109.55	88.26	80.72	0.28	0.20	-21.57	-24.10	43.93	35.89

This study[a]: simulation with a horizontal resolution of 3 km (D3).

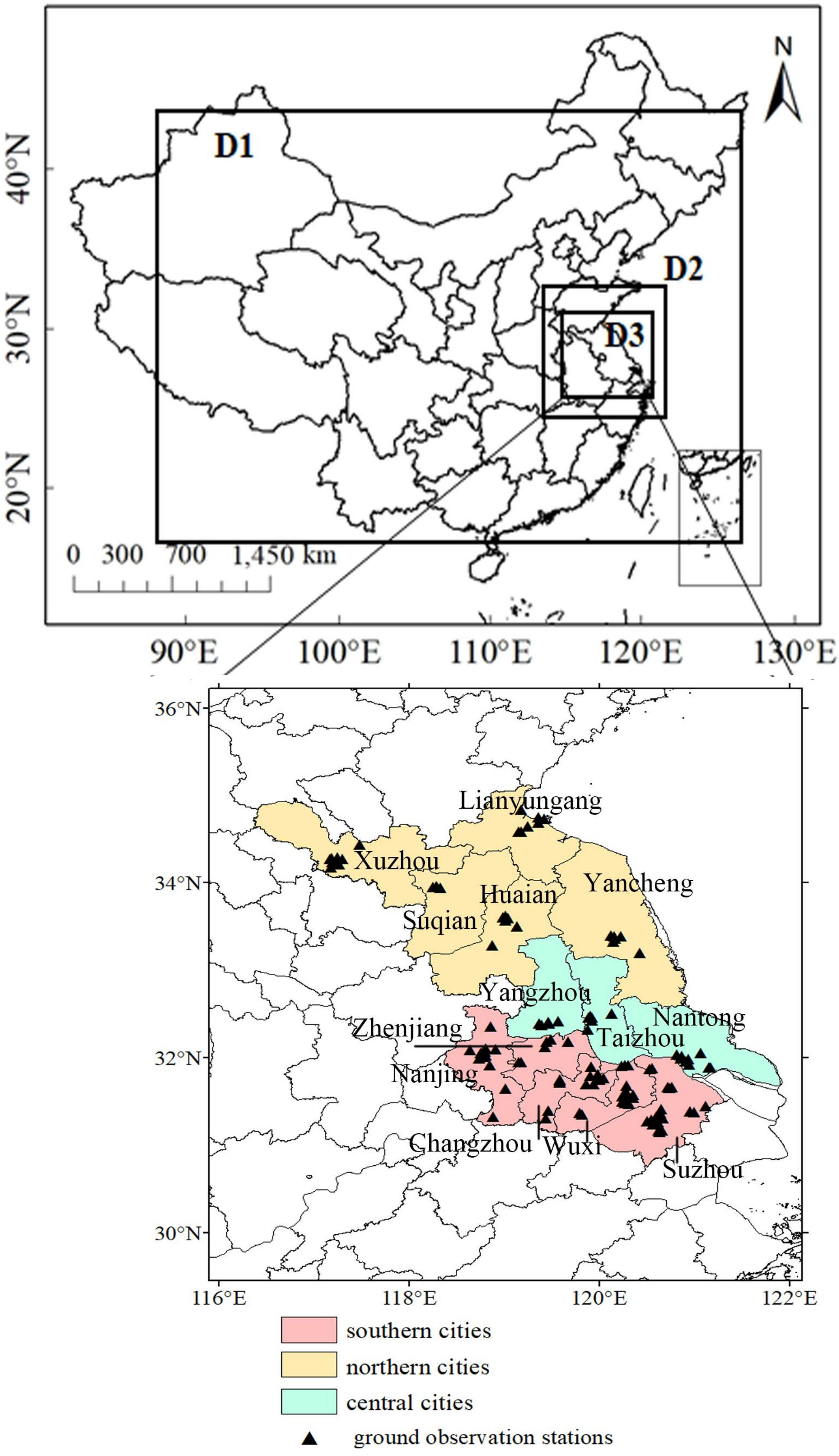
MEIC[c]: simulation with a horizontal resolution of 9 km (D2).

Table S8 Comparison of observed and simulated hourly SO_2 and NO_2 concentrations by month for 2017 in Jiangsu. In total, 110 state-operated observation sites were included in the comparison.

		Observation ($\mu g \cdot m^{-3}$)	Simulation ($\mu g \cdot m^{-3}$)	R	NMB (%)		NME (%)	
			This study[a]	This study	This study	MEIC[b]	This study	MEIC
SO_2	2017/1	19.73	14.68	0.36	-25.14	53.96	43.24	92.53
	2017/4	20.60	13.14	0.44	-27.57	35.03	53.17	83.59
	2017/7	14.06	8.82	0.42	-24.22	67.77	46.03	113.54
	2017/10	13.21	6.86	0.53	-38.01	58.70	51.85	110.01
NO_2	2017/1	42.68	51.23	0.44	29.25	58.69	47.22	73.45
	2017/4	38.24	47.58	0.40	26.01	51.47	47.19	65.46
	2017/7	25.77	42.08	0.32	21.88	133.05	37.85	138.17
	2017/10	30.46	42.34	0.31	40.17	50.02	61.31	71.08

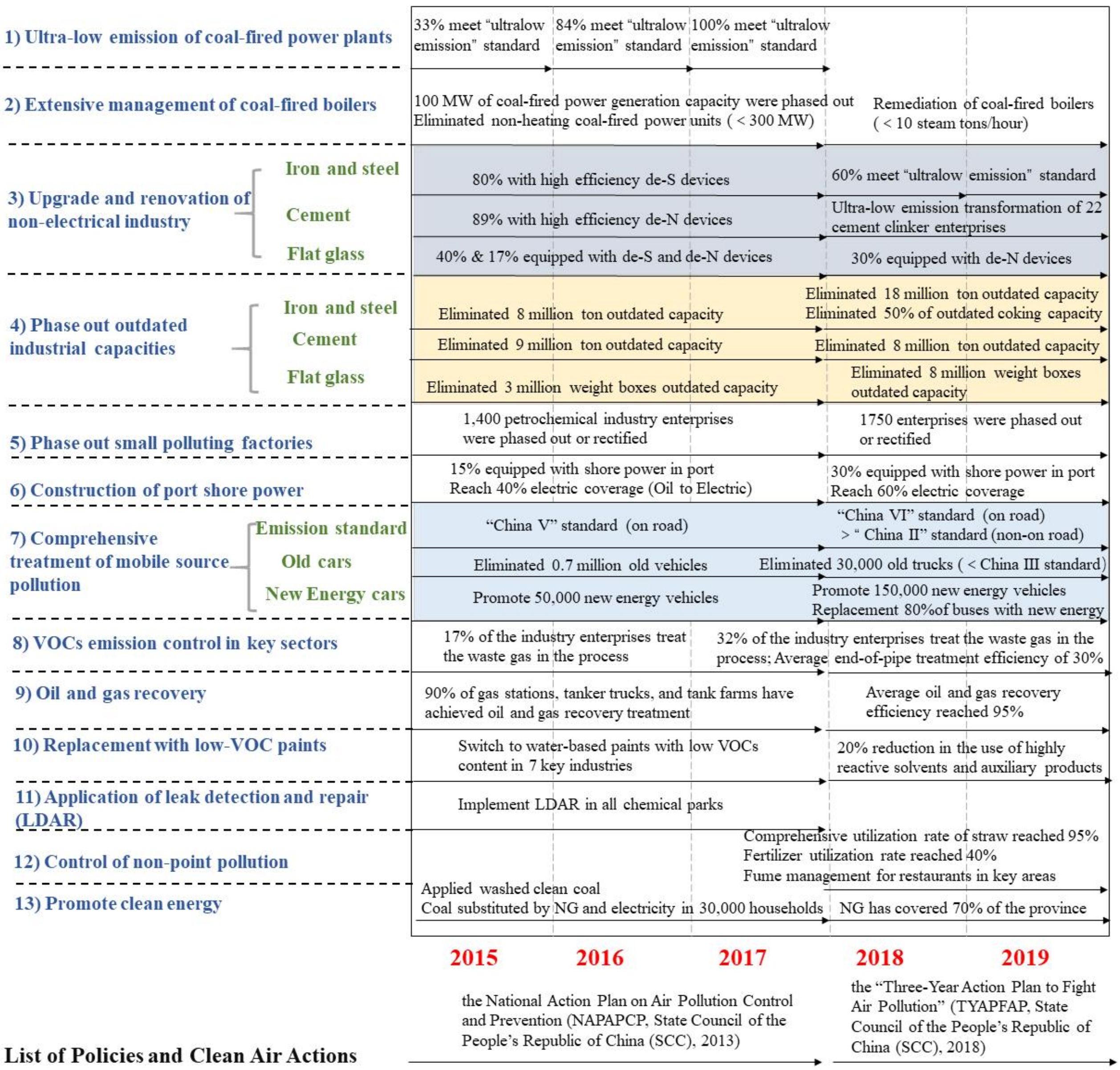
This study[a] : simulation with a horizontal resolution of 3 km (D3);
MEIC[b]: simulation with a horizontal resolution of 12 km (unpublished data, provided by the MEIC team, Tsinghua University).

Figure S1



N
D1
D2
D3
40°N
30°N
20°N
0 300 700 1,450 km
90°E
100°E
110°E
120°E
130°E
36°N
34°N
32°N
30°N
116°E
118°E
120°E
122°E
Lianyungang
Xuzhou
Huaian
Yancheng
Suqian
Yangzhou
Nantong
Zhenjiang
Taizhou
Nanjing
Changzhou
Wuxi
Suzhou
southern cities
northern cities
central cities
ground observation stations

Figure S2



Air Pollution Remediation Work Plan for Coal-fired Boilers in Jiangsu, (Department of ecological environment of Jiangsu, 2013)
VOCs Pollution Control Special Action Implementation Plan, (Department of ecological environment of Jiangsu, 2015)
Action Plan for Energy Saving, Emission Reduction and Renovation of Coal Power Units in Jiangsu (2014-2020), (The People's Government of Jiangsu, 2014)
The Implementation plan for Ultra-low Emission Transformation of Iron and Steel Enterprises in Jiangsu (2018), (Department of ecological environment of Jiangsu, 2018)

Figure S3

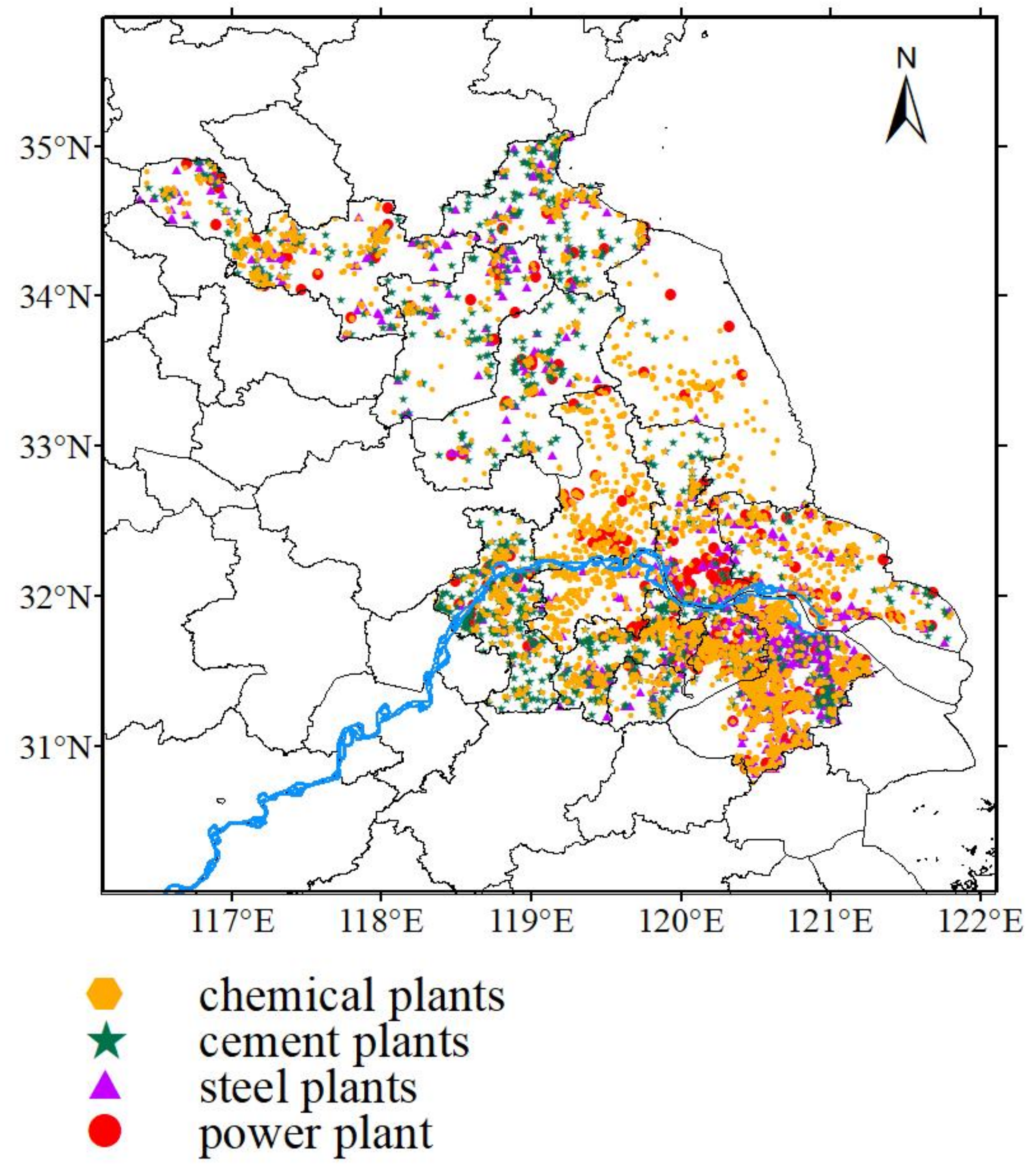

N
35°N
34°N
33°N
32°N
31°N
117°E
118°E
119°E
120°E
121°E
122°E
chemical plants
cement plants
steel plants
power plant

Figure S4

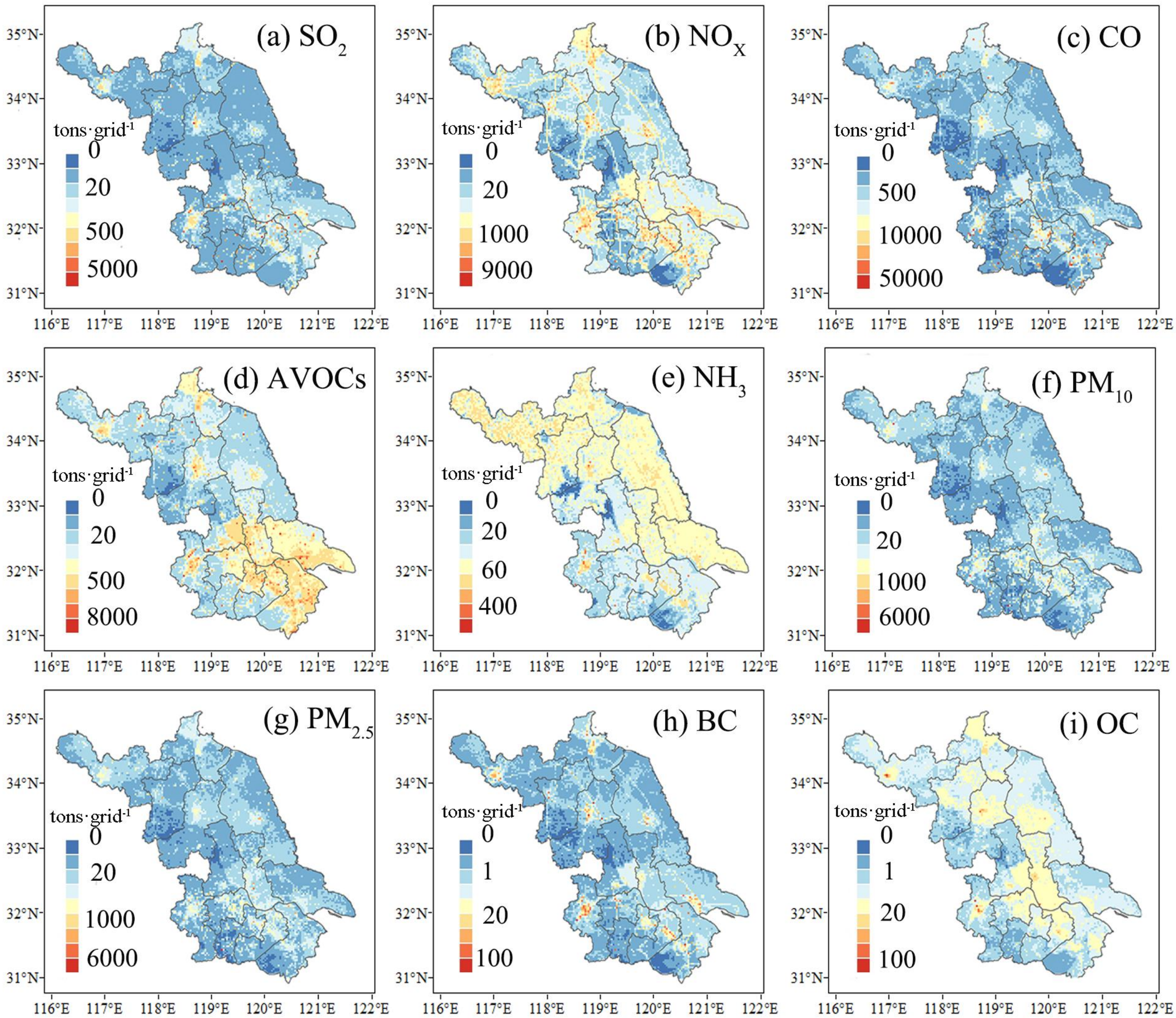

(a) SO_2
tons·grid^{-1}
0
20
500
5000
(b) NO_X
tons·grid^{-1}
0
20
1000
9000
(c) CO
tons·grid^{-1}
0
500
10000
50000
(d) AVOCs
tons·grid^{-1}
0
20
500
8000
(e) NH_3
tons·grid^{-1}
0
20
60
400
(f) PM_{10}
tons·grid^{-1}
0
20
1000
6000
(g) $PM_{2.5}$
tons·grid^{-1}
0
20
1000
6000
(h) BC
tons·grid^{-1}
0
1
20
100
(i) OC
tons·grid^{-1}
0
1
20
100
35°N
34°N
33°N
32°N
31°N
116°E
117°E
118°E
119°E
120°E
121°E
122°E

Figure S5

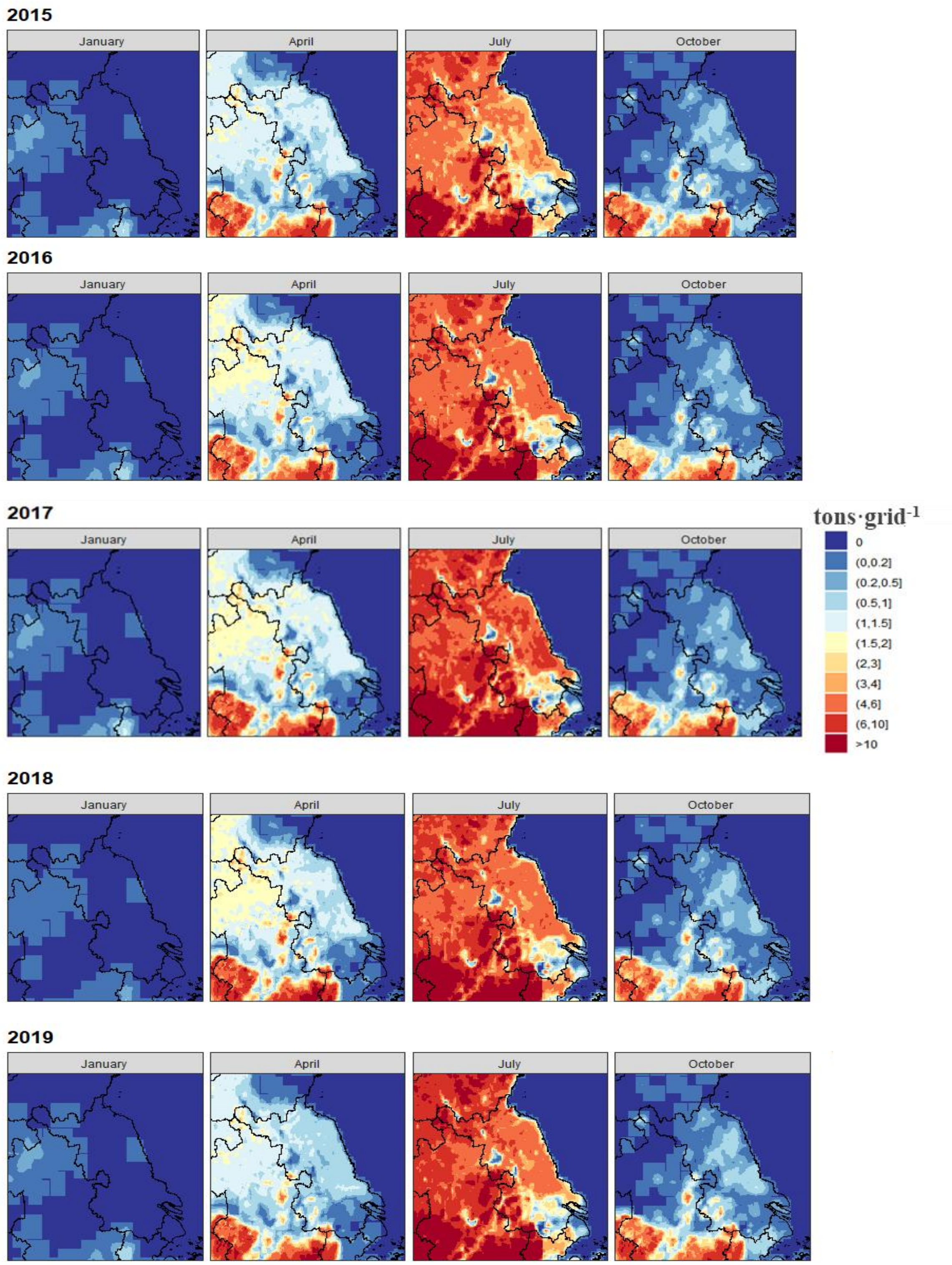
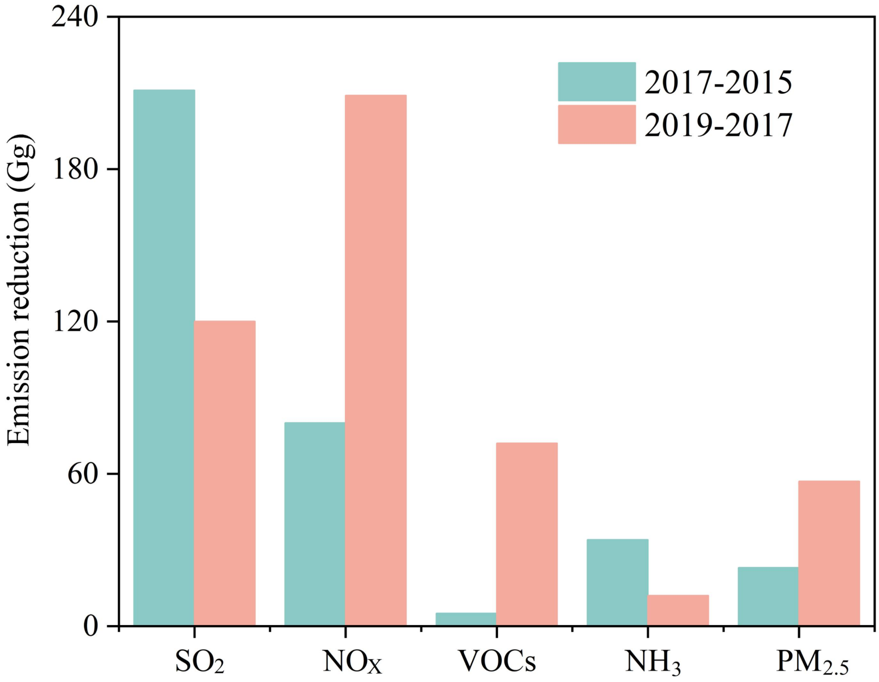
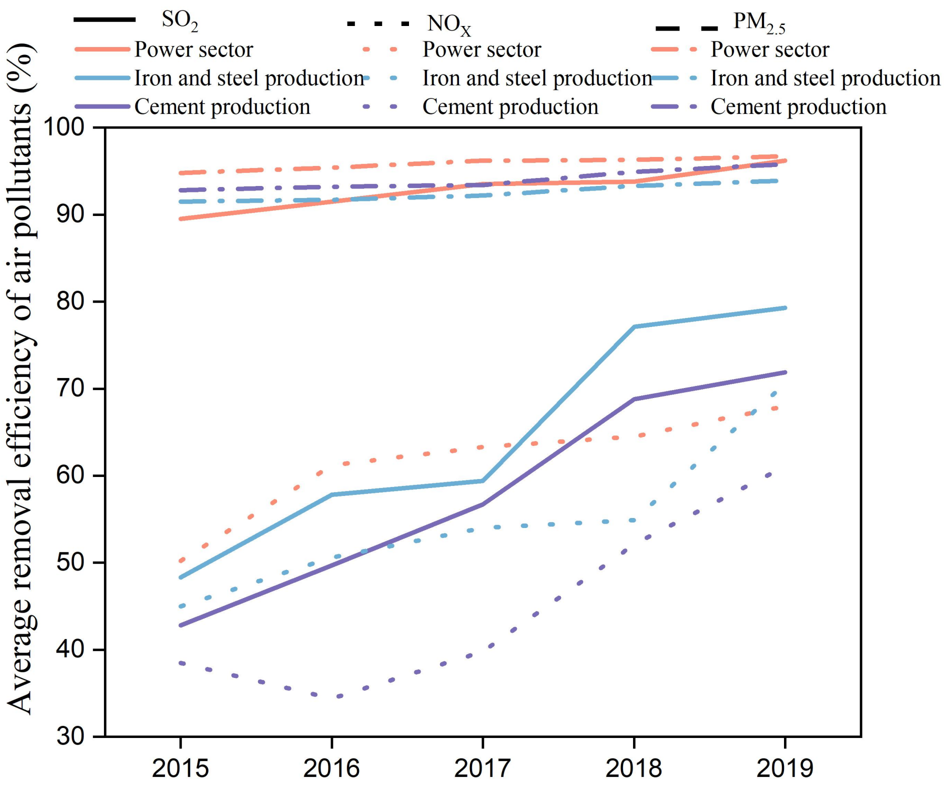

2015
January
April
July
October
2016
2017
2018
2019
tons·grid-1
0
(0,0.2]
(0.2,0.5]
(0.5,1]
(1,1.5]
(1.5,2]
(2,3]
(3,4]
(4,6]
(6,10]
>10

Figure S6



240
180
120
60
0
Emission reduction (Gg)
2017-2015
2019-2017
SO2
NOx
VOCs
NH3
PM2.5

Figure S7



SO2
NOX
PM2.5
Power sector
Iron and steel production
Cement production
Power sector
Iron and steel production
Cement production
Power sector
Iron and steel production
Cement production
Average removal efficiency of air pollutants (%)
100
90
80
70
60
50
40
30
2015
2016
2017
2018
2019

Figure S8

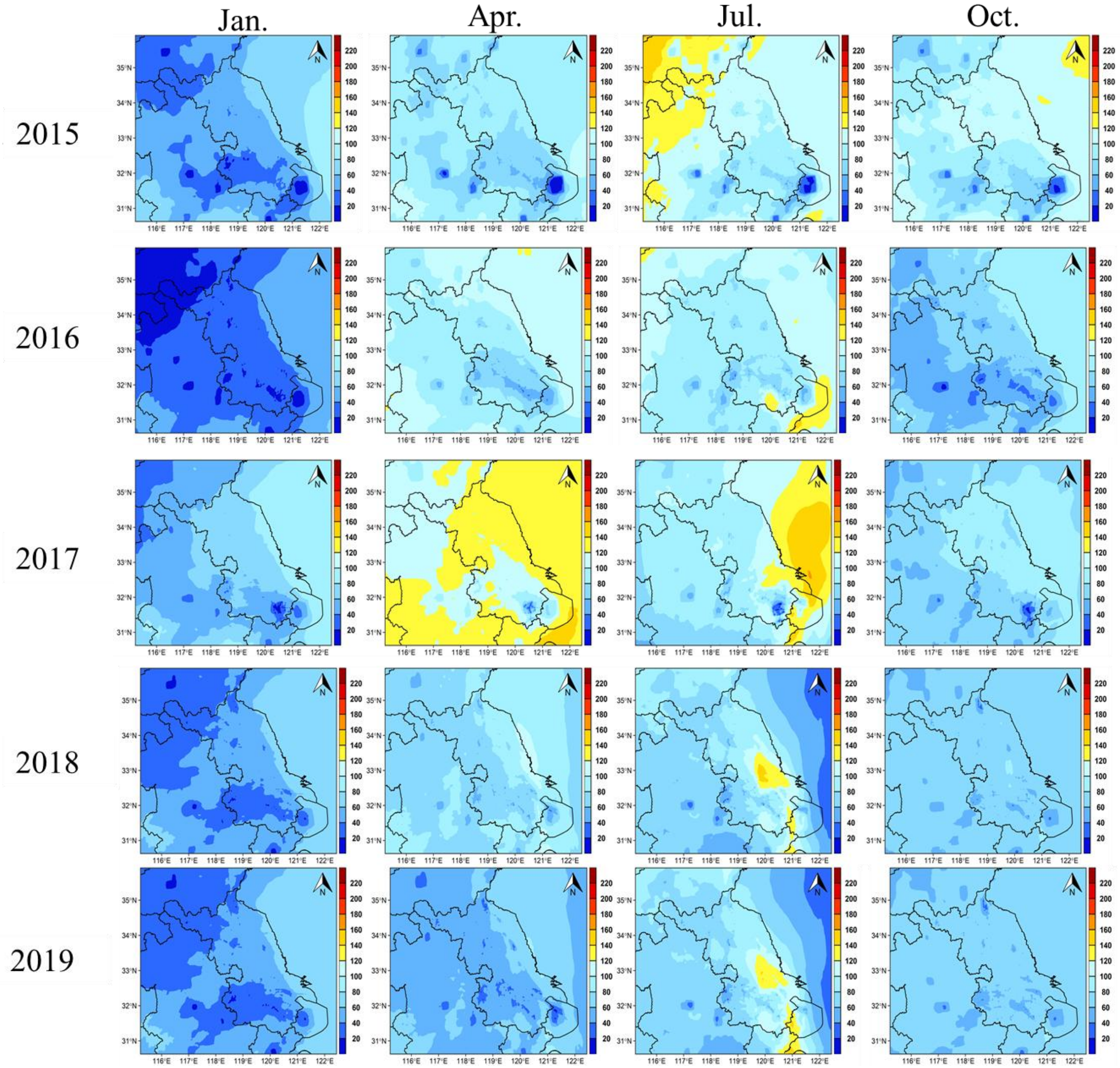
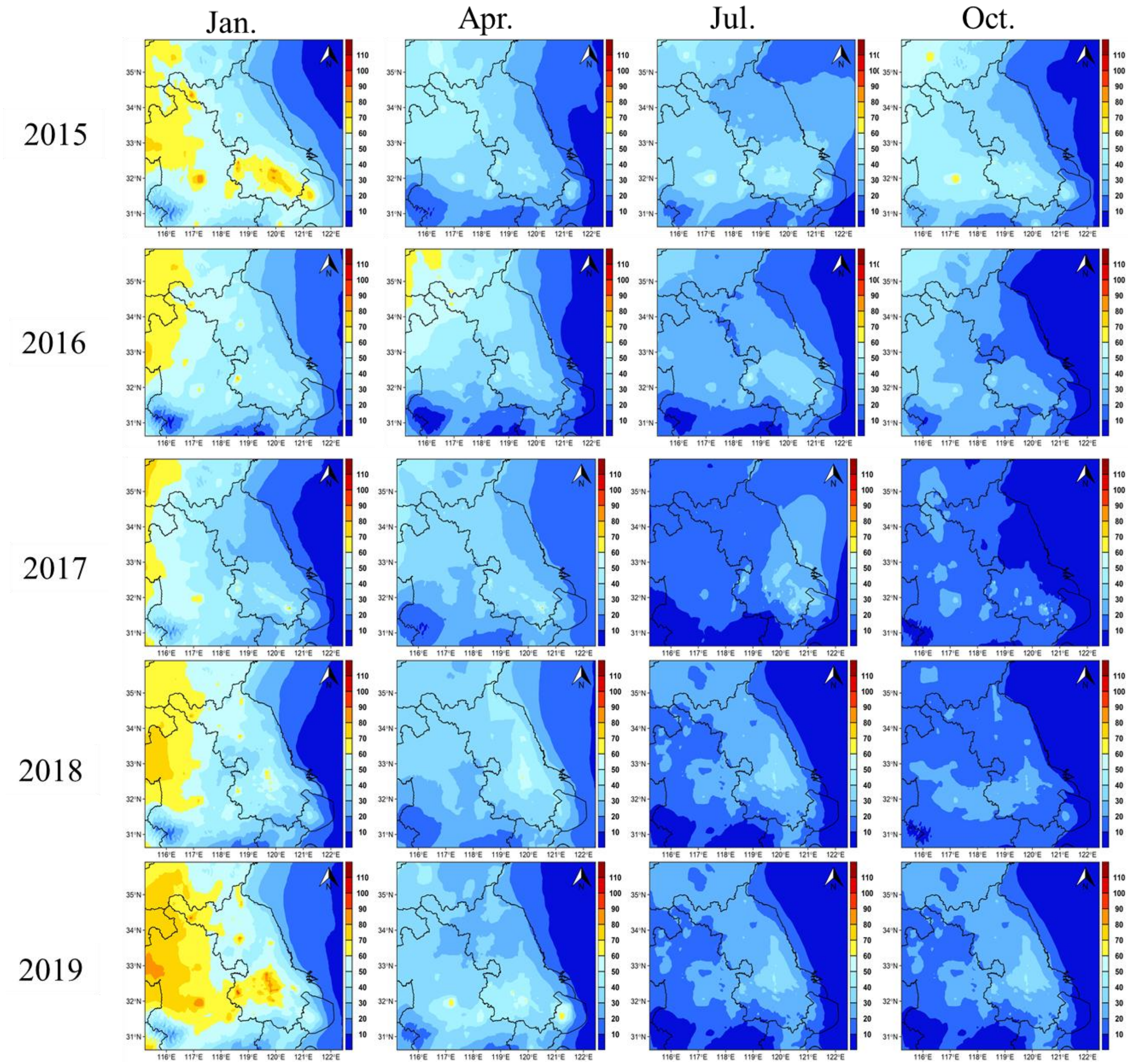

Jan.
Apr.
Jul.
Oct.
2015
2016
2017
2018
2019
220
200
180
160
140
120
100
80
60
40
20
35°N
34°N
33°N
32°N
31°N
116°E
117°E
118°E
119°E
120°E
121°E
122°E
N

Figure S9


Jan.
Apr.
Jul.
Oct.
2015
2016
2017
2018
2019
35°N
34°N
33°N
32°N
31°N
116°E
117°E
118°E
119°E
120°E
121°E
122°E
110
100
90
80
70
60
50
40
30
20
10
N

References

Department of ecological environment of Jiangsu, Notice of the Jiangsu Provincial Government on issuing the air pollution prevention and control action plan. http://www.jiangsu.gov.cn/art/2014/1/6/art_46690_2586827.html.

Department of ecological environment of Jiangsu, Air Pollution Remediation Work Plan for Coal-fired Boilers in Jiangsu. http://sthjt.jiangsu.gov.cn.

Department of ecological environment of Jiangsu, VOCs Pollution Control Special Action Implementation Plan in Jiangsu. http://www.jiangsu.gov.cn/art/2018/1/25/art_46143_7431312.html.

Department of ecological environment of Jiangsu, The Implementation plan for Ultra-low Emission Transformation of Iron and Steel Enterprises in Jiangsu (2018). http://sthjt.jiangsu.gov.cn/art/2019/5/22/art_83589_10046297.html.

Ministry of Ecology and Environment of the People's Republic of China, 2020 Report on the state of the ecology and environment in China. http://english.mee.gov.cn/Resources/Reports/soe/SOEE2019/202204/P020220407417638702591.pdf.

The People's Government of Jiangsu, Notice of the Jiangsu Provincial Government on issuing the Three-year Action Plan to fight Air Pollution. http://www.jiangsu.gov.cn/art/2018/10/17/art_64797_7842355.html.

The People's Government of Jiangsu, Action Plan for Energy Saving, Emission Reduction and Renovation of Coal Power Units in Jiangsu (2014-2020). http://www.jiangsu.gov.cn/art/2014/11/10/art_46144_2545297.html.