Yale-NUIST Center on Atmospheric Environment

Simulation and evaluation of haze day in Jiangsu Province based on WRF/CMAQ model

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2017.4.28

Outline

- Introduction
- Data and Method
- Results
- Conclusion & Discussion

Introduction

- To our knowledge, haze is traditionally an atmospheric phenomenon where dust, smoke and other dry particles obscure the clarity of the sky, let visibility reduced to 10km below.

- Studies have indicated that haze weather are significantly related to climate background, local weather conditions, pollutant concentrations and its composition distribution. (Chang et al.,2009; Zhang et al.,2012; Liu et al.,2014; Wu et al.,2016; Yang et al.,2010; Huang et al.,2011)

Introduction

- Numerical simulation is an important method for the prediction and research of haze days and WRF/CMAQ is the most common numerical model. WRF/CMAQ is one of the most common numerical model. In China, CMAQ also has some of the related research, such as the emission reduction of air quality in Beijing (Xing et al.,2011; Lee et al., 2015).

- This paper evaluates the accuracy of the WRF / CMAQ numerical model for the 18-month haze simulation of Jiangsu Province from October 2014 to March 2016, and explores the possible causes of inaccuracies in haze forecast.

Data and Method

- **Time：** Oct 1st,2014 to Mar 31th,2016：

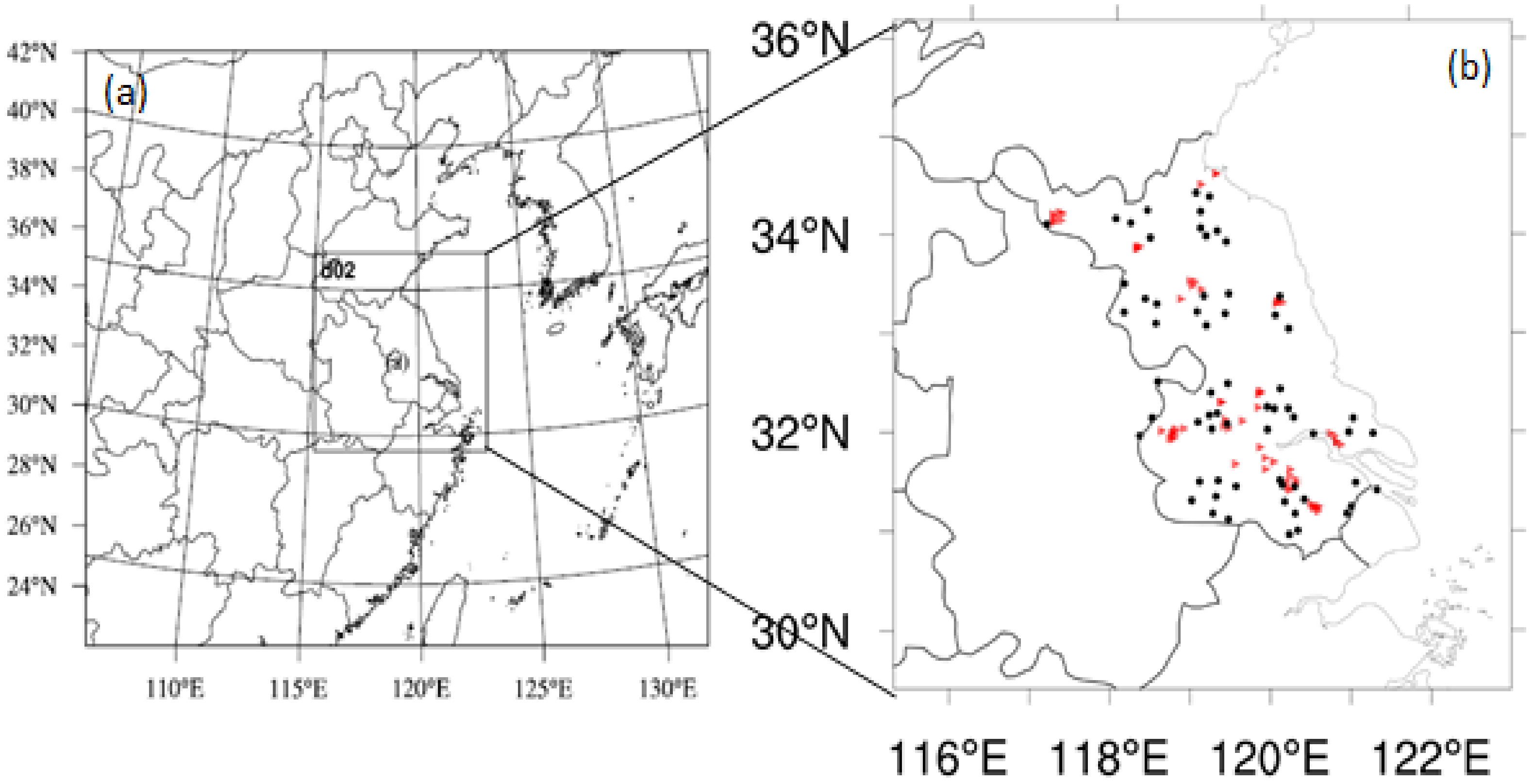

Fig.1 Two nested modeling domains(Meteorological stations are black spots, environment monitor stations are red spots).

Table. 1 Parameter settings

Domain		1	2
Time		Oct 1st,2014 to Mar 31th, 2016	
Initial meteorological field		Fnl(1° ×1°)	
Center		33.0° N, 119.0° E	
Vertical stratification		28 levels	
Horizontal grid point		WRF: 180 × 150 CMAQ: 160 × 130	WRF: 150 × 150 CMAQ: 130 × 130
Horizontal resolution		15km	5km
mp_physics		Lin et al. scheme	
ra_sw_physics		Goddard shortwave	
sf_surface_physics		Noah Land Surface Model	
CMAQ	The horizontal advection and vertical convection	PPM	
	The vertical diffusion	Crank-Nicholson	
	Chemical mechanism	CB05(CB05-AE6-AQ)	
	Emissions plume	Smoke	

- **Method :**

Atmospheric visibility is not a direct predictor of the pattern and needs to be diagnosed based on model predictions. Calculation of Atmospheric Visibility based on Koschmieder law.

$$V_R = 3.91/\beta_{ext}$$

V_R is the visibility; β is the overall extinction coefficient, which includes particle scattering extinction and absorption extinction, gas molecules scattered extinction and absorption extinction.

The method is explained by the American IMPROVE study program proposed by Malm et al. (1994), taking into account particulate matter extinction and extinction.

$$\beta_{ext}\left[\frac{1}{m}\right] = 3 \times f(rh) \times [(NH_4)_2SO_4 + NH_4NO_3] + 4 \times f(rh) \times [POM] + 10[LAC]$$
$$+1[\text{fine soil}] + 0.6[\text{coarse mass}] + 10$$

$(NH_4)_2SO_4$=1.37[SO_4^{2-}]; NH_4NO_3=1.29[NO_3^-]; POM=1.4[OC]; LAC=EC;

fine soil =2.2 [Al]+2.49 [Si]+1.63 [Ca]+2.42[Fe]+1.94[Ti] ;coarse mass=PM_{10}-$PM_{2.5}$;

The visibility calculated from the aerosol extinction coefficient obtained in the model is denoted as the parameterization scheme A(referred to as scheme A).

It is known from the present study that the contribution of [fine soil] and [coarse mass] to the aerosol extinction coefficient βext is small, and NO2 has the effect of light absorption ,Tao(2012) corrected formula and new visibility parameterization scheme is referred to as Scheme B.

$$\beta_{ext}\left[\frac{1}{m}\right] = 3 \times f(\mathrm{rh}) \times [(NH_4)_2SO_4 + NH_4NO_3] + 4 \times f(\mathrm{rh}) \times 1.4[OC] + 10[EC] + 161[NO_2]$$

Table. 2 *f*(rh) values under different relative humidity conditions

相对湿度（%）	40%-45%	45%-50%	50%-55%	55%-60%	60%-65%
f(rh)	1.22	1.27	1.33	1.38	1.45
65%-70%	70%-75%	75%-80%	80%-85%	85%-90%	>90%
1.55	1.65	1.83	2.1	2.46	3.17

Results

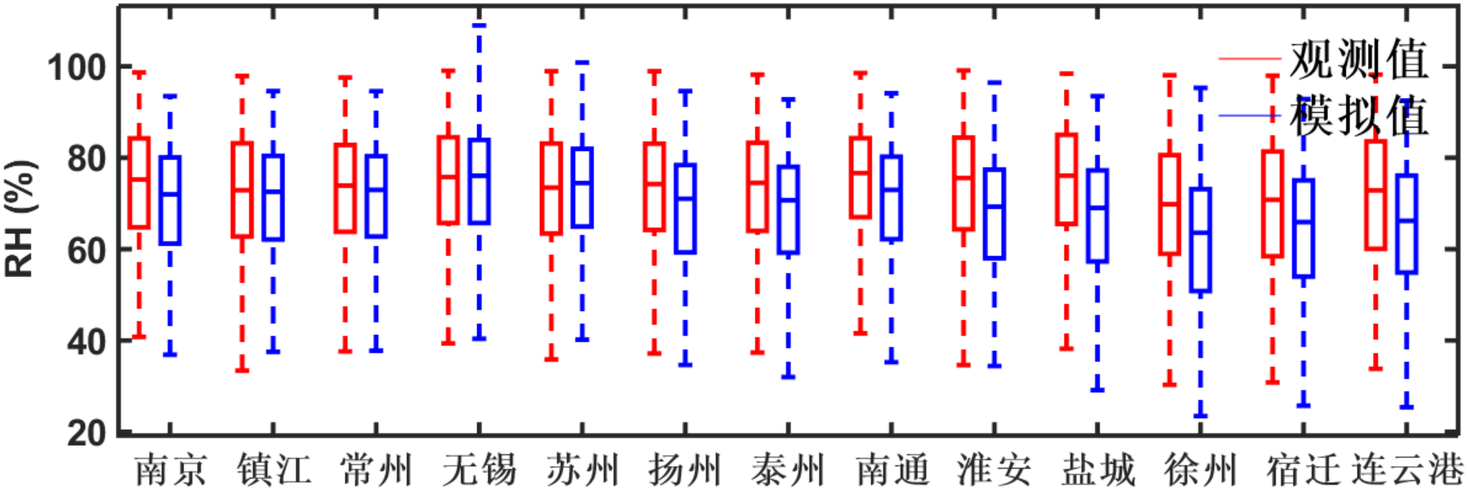

Fig. 2 Observations (blue) and simulations (red) of relative humidity boxplot at 13 cites in Jiangsu Province.

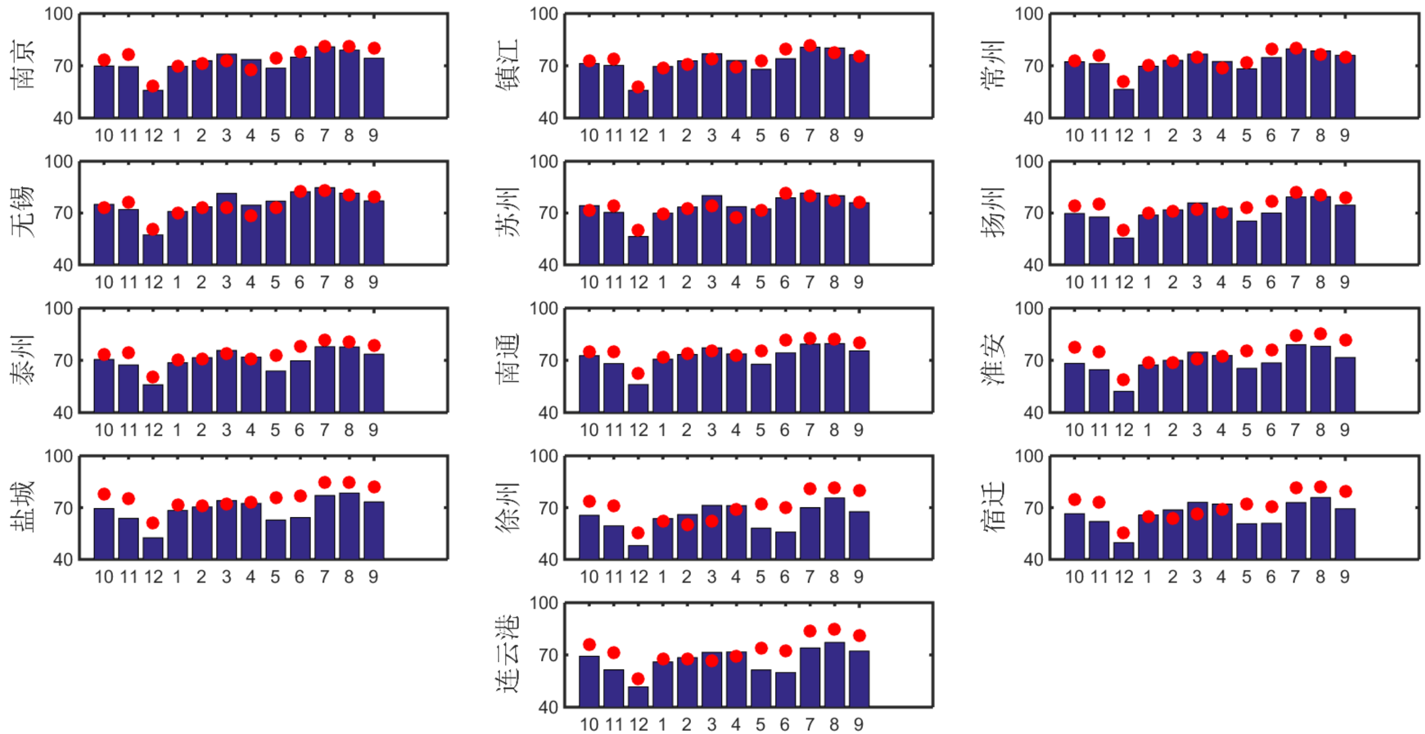

Fig. 3 Monthly variation of relative humidity in Jiangsu Province. (The histogram is the simulated value; the solid dot is the observed value)

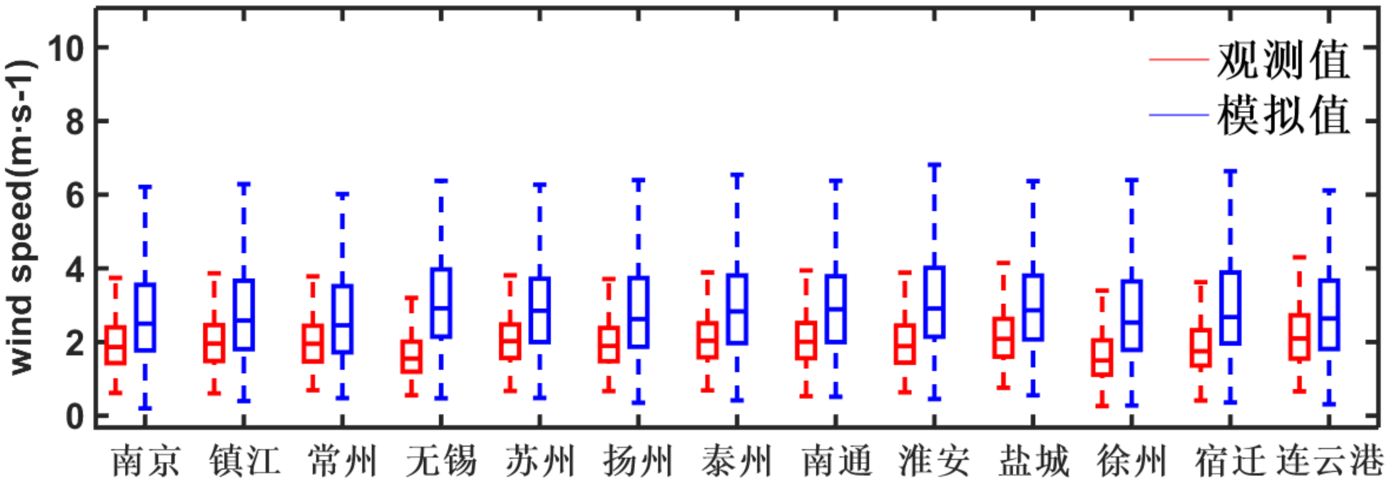

Fig. 4 Observations (blue) and simulations (red) of wind speed boxplot at 13 cites in Jiangsu Province.

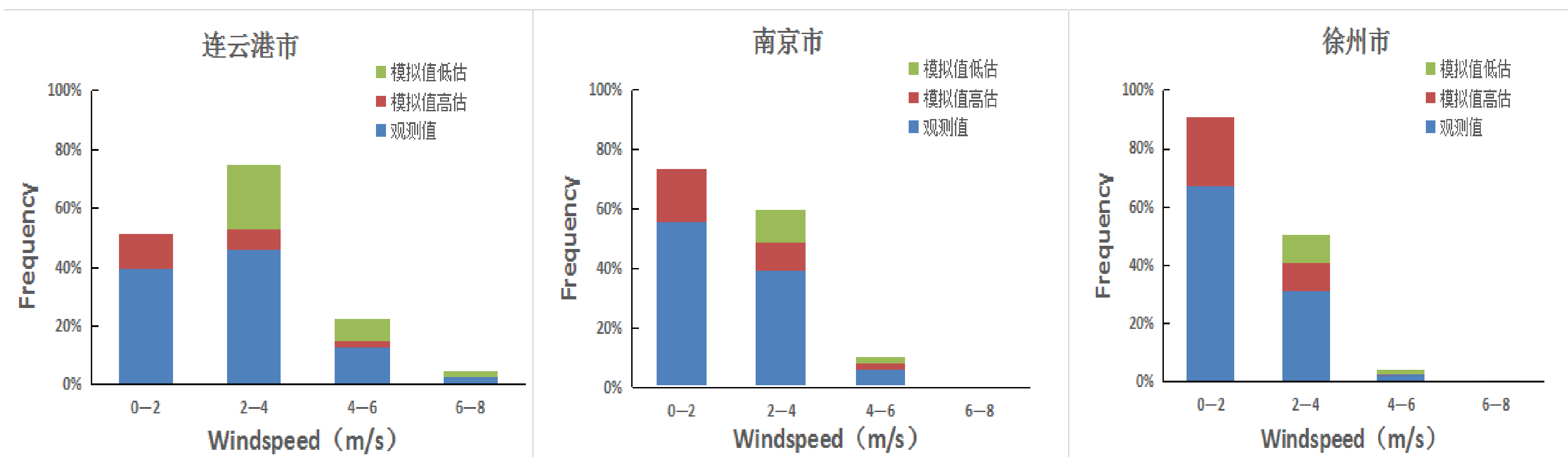

Fig. 5 The frequency of wind speed in three representative cities of Jiangsu Province

Table.3 Statistical characteristics of relative humidity and wind speed

City	relative humidity （%）				wind speed(m·s-1)			
	AVE_obs	AVE_sim	R	RMSE	AVE_obs	AVE_sim	R	RMSE
南京	74	70	0.55	13.1	2.00	2.80	0.70	1.22
镇江	72	70	0.57	13.3	2.03	2.82	0.75	1.17
常州	73	71	0.57	12.8	2.03	2.71	0.74	1.14
无锡	75	74	0.56	12.9	1.66	3.16	0.64	1.34
苏州	73	72	0.55	13.0	2.10	3.03	0.72	1.22
扬州	73	69	0.53	13.4	2.00	2.89	0.76	1.19
泰州	73	68	0.53	13.7	2.11	3.00	0.74	1.19
南通	75	71	0.42	12.8	2.10	3.08	0.65	1.25
淮安	73	68	0.55	14.1	2.02	3.19	0.70	1.33
盐城	74	67	0.55	14.3	2.22	3.04	0.68	1.23
徐州	69	62	0.48	15.3	1.62	2.77	0.67	1.23
宿迁	69	64	0.52	15.2	1.87	2.99	0.69	1.27
连云港	71	65	0.55	15.2	2.23	2.84	0.58	1.24

City	PM2.5（μg·m-3）			
	AVE_obs	AVE_sim	R	RMSE
南京	62	85	0.34	37.8
镇江	63	70	0.30	34.8
常州	64	78	0.33	36.4
无锡	65	80	0.36	34.9
苏州	61	70	0.35	33.2
扬州	56	64	0.33	33.2
泰州	66	57	0.33	34.6
南通	59	52	0.35	35.0
淮安	64	55	0.36	35.1
盐城	56	43	0.33	34.7
徐州	67	68	0.35	35.7
宿迁	64	54	0.28	34.5
连云港	59	43	0.40	37.2

Table.4 Statistical characteristics of PM2.5

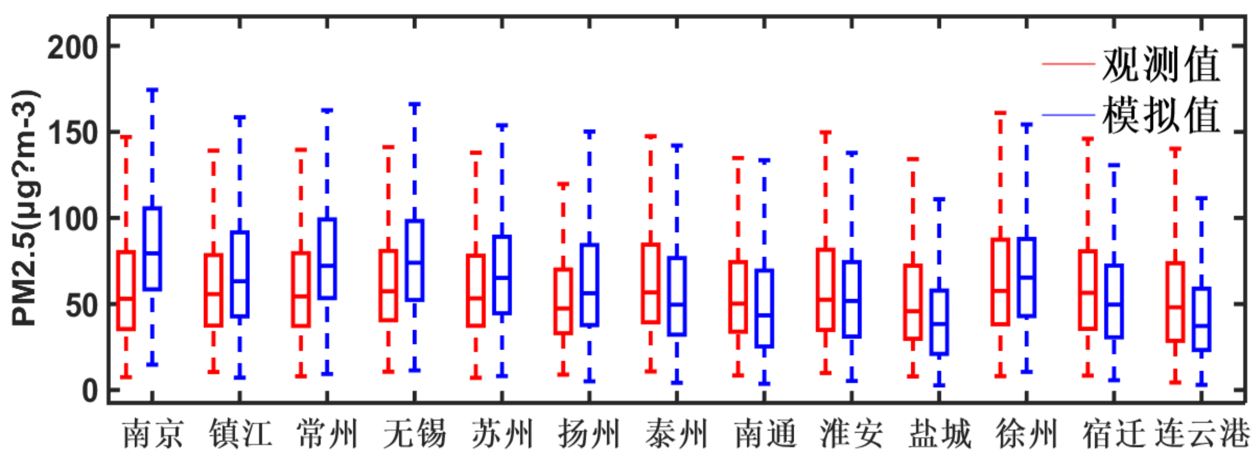

Fig. 6 Observations (blue) and simulations (red) of PM2.5 boxplot at 13 cites in Jiangsu Province.

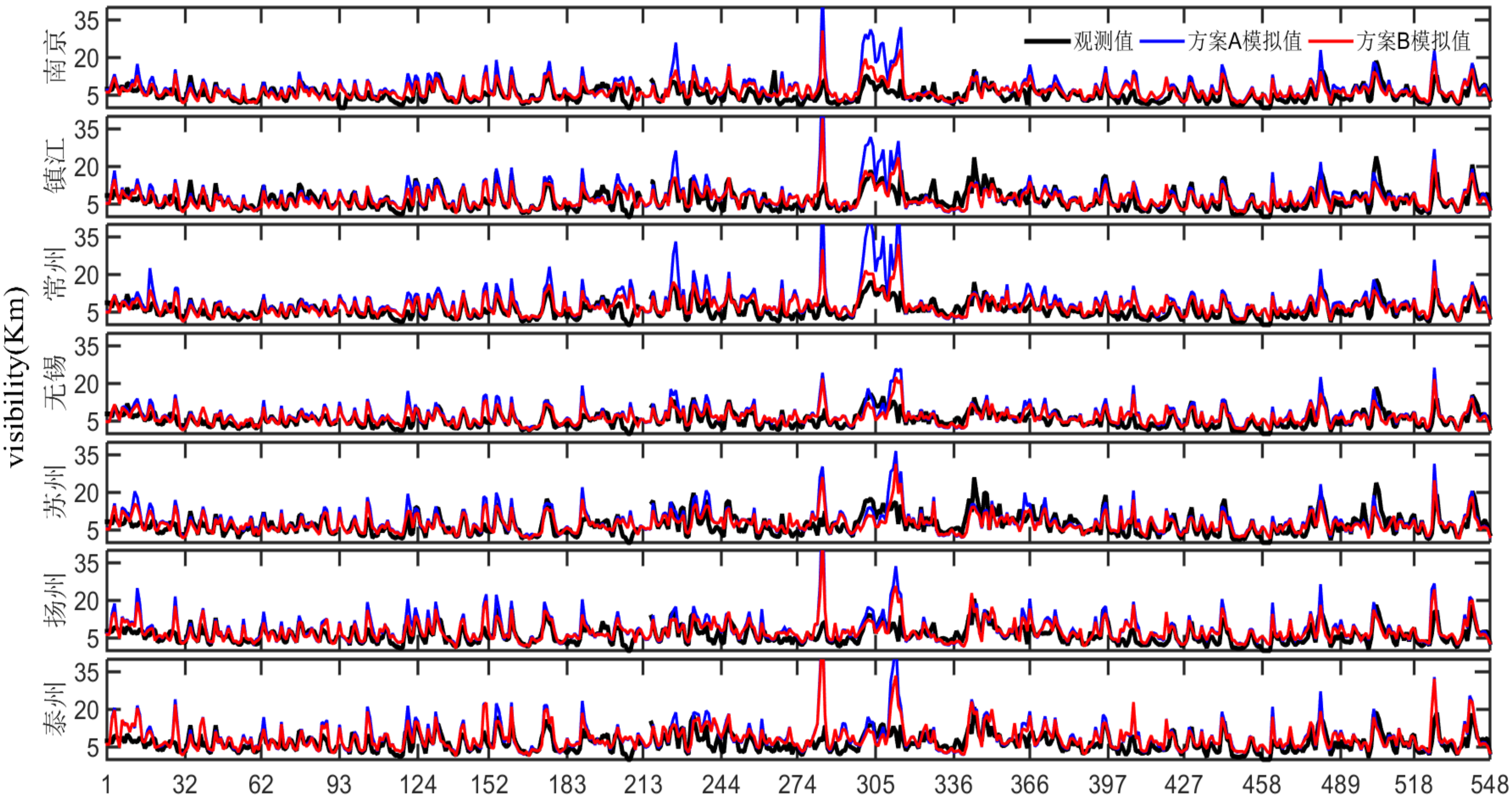

Fig. 7a Observations (black lines) and simulations (scheme A is blue lines; scheme B is red lines) of relative humidity at 13 cites in Jiangsu Province from Oct 2014 to Mar 2016.

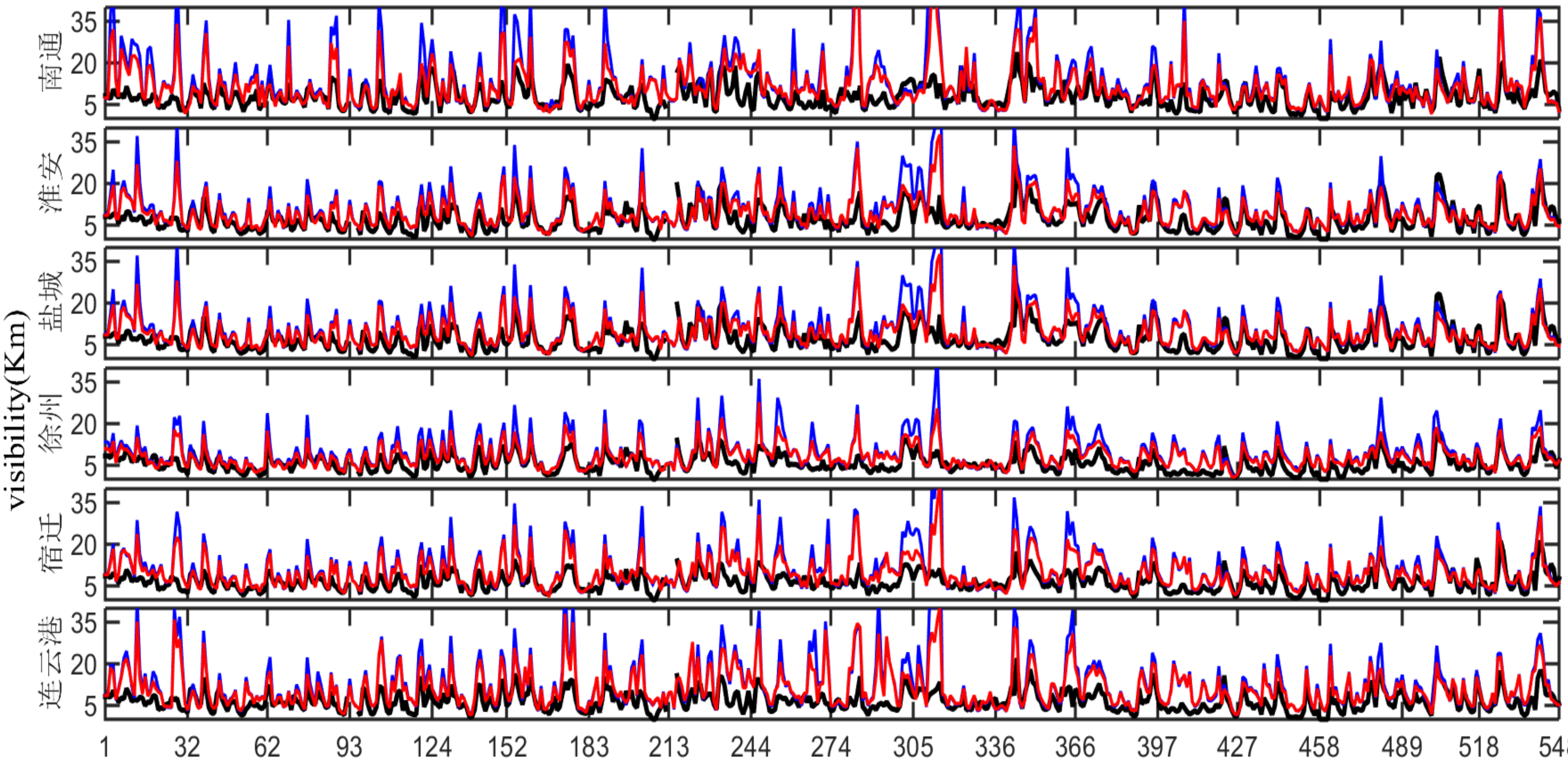

Fig. 7b Observations (black lines) and simulations (scheme A is blue lines; scheme B is red lines) of relative humidity at 13 cites in Jiangsu Province from Oct 2014 to Mar 2016.

Table.5 Statistical characteristics of different visibility parameterization schemes

City	Scheme A（km）			
	AVE_obs	AVE_sim	R	RMSE
南京	5.4	7.5	0.60	4.3
镇江	6.7	7.8	0.61	4.8
常州	6.0	8.5	0.63	5.1
无锡	5.6	7.1	0.65	3.7
苏州	7.1	8.2	0.63	4.6
扬州	6.3	8.3	0.64	4.8
泰州	6.8	9.0	0.61	5.2
南通	8.0	13.0	0.59	8.3
淮安	7.6	10.4	0.64	6.5
盐城	6.6	12.9	0.58	8.0
徐州	5.7	9.3	0.73	5.1
宿迁	6.5	10.8	0.60	14.2
连云港	6.7	12.4	0.63	7.6

	Scheme B（km）			
	AVE_obs	AVE_sim	R	RMSE
南京	5.4	6.6	0.62	3.3
镇江	6.7	7.1	0.63	3.9
常州	6.0	6.6	0.66	3.7
无锡	5.6	6.8	0.64	3.2
苏州	7.1	7.5	0.63	4.1
扬州	6.3	7.7	0.65	4.1
泰州	6.8	8.6	0.61	4.6
南通	8.0	11.6	0.60	6.6
淮安	7.6	9.4	0.67	5.2
盐城	6.6	12.1	0.61	6.8
徐州	5.7	8.2	0.74	4.0
宿迁	6.5	9.8	0.65	5.0
连云港	6.7	11.3	0.65	6.1

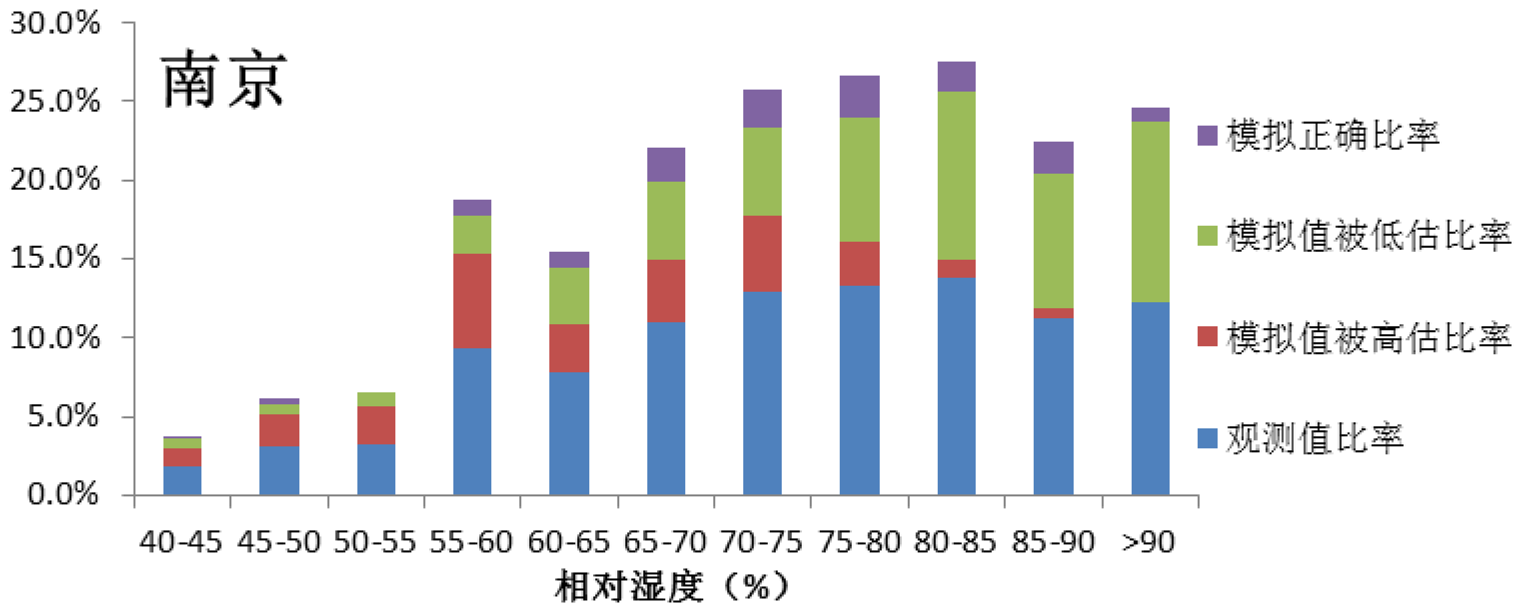

Fig. 8 Relative humidity segmentation of simulation in Nanjing.

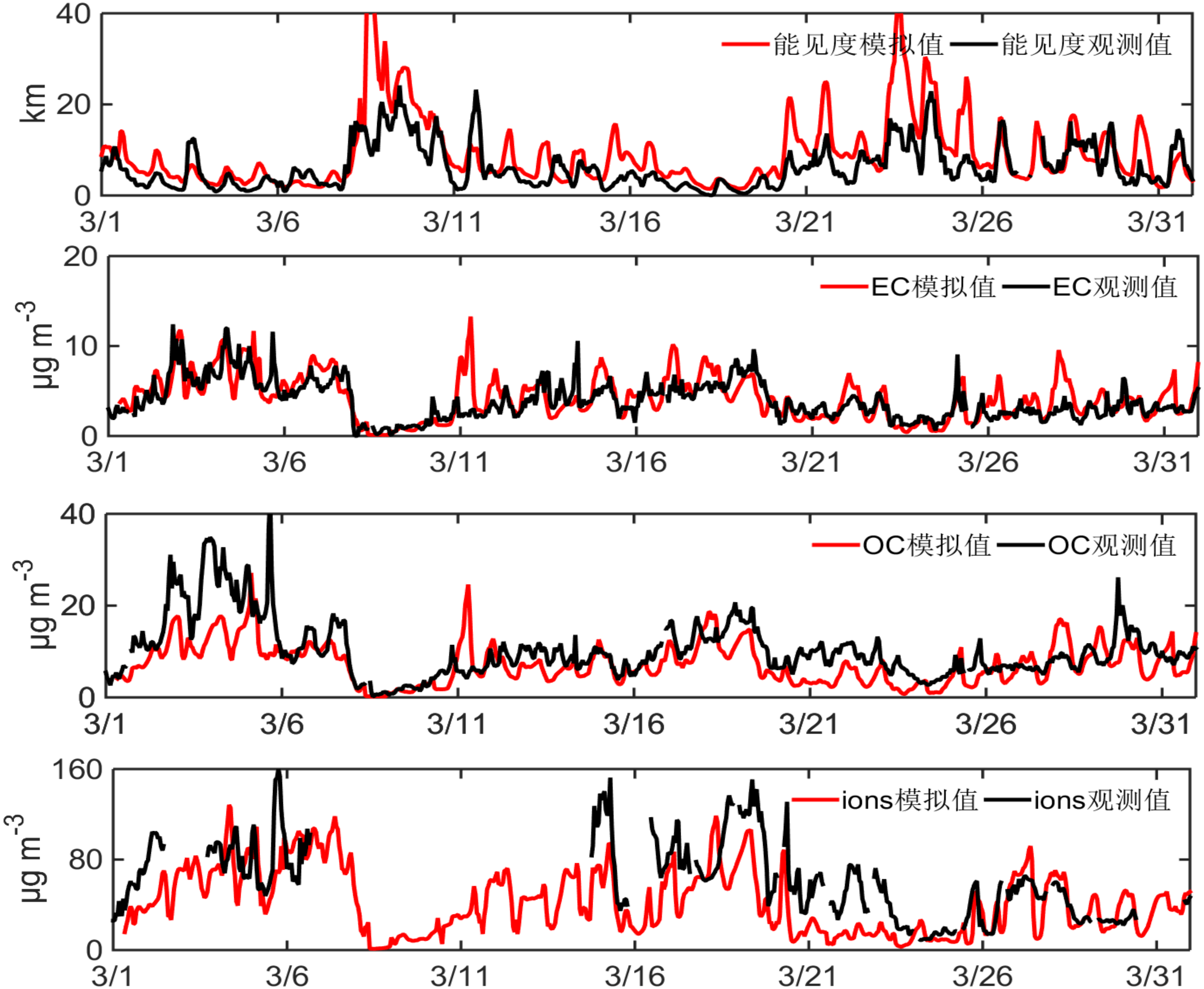

Fig. 9 Observations (black lines) and simulations (red lines) of visibility,EC,OC and ions at Nuist from Mar 1st to Mar 31th ,2016.

Table. 6 The statistics of haze days (the total period of 548 days)

City	南京	镇江	常州	无锡	苏州	扬州	泰州	南通	淮安	盐城	徐州	宿迁	连云港
Obs	341	321	338	329	301	308	302	249	277	292	371	326	290
Sim	415	367	373	373	343	355	331	235	304	233	370	315	264

Table. 7 The different levels of haze days (the total period of 548 days)

Level	轻微		轻度		中度		重度	
Visibility (km)	5.0≤V＜10.0		3.0≤V＜5.0		2.0≤V＜3.0		V＜2.0	
	Obs	Sim	Obs	Sim	Obs	Sim	Obs	Sim
南京	218	277	138	156	90	36	43	6
镇江	221	279	140	137	55	31	26	6
常州	224	293	147	118	62	25	33	5
无锡	218	281	148	150	76	33	39	8
苏州	234	285	124	118	53	22	21	8
扬州	220	266	145	128	63	25	27	5
泰州	233	264	143	104	43	21	20	4
南通	239	210	106	71	34	8	10	2
淮安	207	249	121	90	56	12	27	5
盐城	273	210	114	62	48	12	20	4
徐州	207	271	150	109	68	18	58	4
宿迁	244	258	132	76	48	15	21	3
连云港	221	220	135	76	42	9	32	6

Conclusion & Discussion

1) The WRF/CMAQ simulation showed coincidence with observation in relative humidity and $PM_{2.5}$. The average error is 2-5km between atmospheric visibility simulation values and observation values. In coastal and offshore cities, the simulated visibility is much greater than the observed, and root mean square error exceeds 10km.

2) With aerosol extinction coefficient obtained from IMPROVE program, visibility that calculated from parameterization scheme A is much larger than the observed value when the visibility of the visibility is much larger than 10 km. Given the effects of NO2 absorbance, visibility calculated from parameterization scheme B had a lower relative error compared to scheme A.

Conclusion & Discussion

3) Simulated haze days is far less than observed and the difference is within 60 days in Jiangsu area. The largest error of visibility can reach 10km and mostly happened in eastern coastal cities like Yancheng and Lianyungang which existed high simulated peaks. Simulated haze days in those cities are much less than observed days with an error of 30-60 days.

4) Preliminary discussions on possible causes of differences between observed and simulated atmospheric visibility are described in this paper. Relative humidity plays a crucial role in visibility prediction. Low proportions of EC and OC, underestimated water-soluble ions, underestimated relative humidity, large wind speed and so on caused low simulated values of aerosol extinction coefficient in some regions.

Thank you !