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Geoscientific
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Supplement of

Air quality forecast of PM₁₀ in Beijing with Community Multi-scale Air Quality Modeling (CMAQ) system: emission and improvement

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Figure 1: The location of Baoding, Tangshan and Xianghe stations are shown as “green tringle”. They are all in the Beijing’s surrounding areas, where more point sources have been added in this paper.

1 The model performance on the Beijing’s surrounding stations

In the section, the PM_{10} hourly concentration in Baoding, Tangshan and Xianghe stations are collected to illustrate the model performance in Beijing’s surrounding areas. The observation is from the Beijing-Tianjin-Hebei Atmospheric Environment Monitoring Network operated by the Institute of Atmospheric Physics, Chinese Academy of Sciences[1]. The location of the three stations are shown in Figure 1, Baoding and Tangshan stations are located at the urban of Baoding and Tangshan Municipality, and Xianghe station is located at one county of Langfang Municipality.

As described in the left figure of Fig.2 in the manuscript, the fourth domain(D4) in the forecast system just covers Beijing Municipality, that Baoding, Tangshan and Langfang station, is either outside or nearby the domain boundary. Therefore, the “New” expanded model domain is used to check if the “added” point and “updated” area sources emissions would improve the model performance on the surrounding areas. The model results “FEmis+NewDomain(CMAQ)” (short for “FEmis” in this section) driven by the forecast emission in the expanded domain have been compared to the final model results “New(CMAQ)”, which is driven by the updated point and area sources emssions in the “New” expanded domain in this section. With this set of comparison, we can get the model performance on Beijing’s surrounding areas, and get the model improvement due to the emissions updated.

Table 1: Statistical measures for PM10 hourly concentration in Baoding, Tangshan and Xianghe stations, which is located at Beijing’s surrounding areas. The “FEmis” is mark that the model results driven by the forecast emission and the “New” is mark the model results driven by the updated emissions.

	Baoding		Tangshan		Xianghe	
	FEmis	New	FEmis	New	FEmis	New
MB	-208.22	-182.95	-121.69	-111.52	-141.73	-103.68
ME	209.53	187.42	133.07	130.25	143.00	117.07
FAC2	16%	33%	38%	35%	23%	48%
NMSE	4.258	2.702	2.549	2.036	3.064	1.367

The scatter plot and quantile–quantile (Q–Q) plots are used to illustrate the model performance. The Q–Q plots are introduced by Chang et al.(2004) [2], and used to compare the concentration distributions between the simulations and observations, with the Q–Q plots, biases at low or high concentrations are quickly revealed, which is used in Wu et al.(2012)[3] for model evaluation.

As shown in Figure 2, the “New(CMAQ)”, which is driven by the updated point and area sources emissions, has obviously better model performance in Baoding and Xianghe station, and a little model improvement in Tangshan station than the “FEmis”: the pink simulated–observed points in Baoding and Xianghe stations are much closed to the red line “y=x” than the blue ones according the left scatter plots. With the Q–Q plots in Figure 2, we also can found that the “New(CMAQ)” has better performance in both the high and low concentration range, and get better distribution on PM10 hourly concentration.

The mean bias(MB), mean error(ME), FAC2 and normalized mean square error(NMSE) are calculated and shown in Table. 1. Consistent with the scatter plots and Q–Q plots, the statistical measures indicate the model performance improved obviously in Baoding and Xianghe stations, that their FAC2 increases from 16% and 23% to 33% and 48% respectively, while the NMSE decreases from 4.258 and 3.064 to 2.702 and 1.367.

As shown in the plots and statistical parameters, after the point and area sources emissions updated, the model performance improved obviously, especially in Baoding and Xianghe stations. But we also can found that even the model performance improved obviously in Beijing’s surrounding areas, their model performance of PM10 hourly concentration is poorer than the Beijing’s, which the FAC2 of the hourly concentration reach to 74% driven by the updated emissions in the “New” expanded domain. There may be two reasons that need more in-depth analysis. First, the emissions in the surrounding area maybe still underestimated, that the Q–Q plot shows that the model underestimates in both high and low concentration range in the three surrounding stations. Second, the model domain may need to be expanded much bigger if we want to get much better model performance in the surrounding area. In the other word,

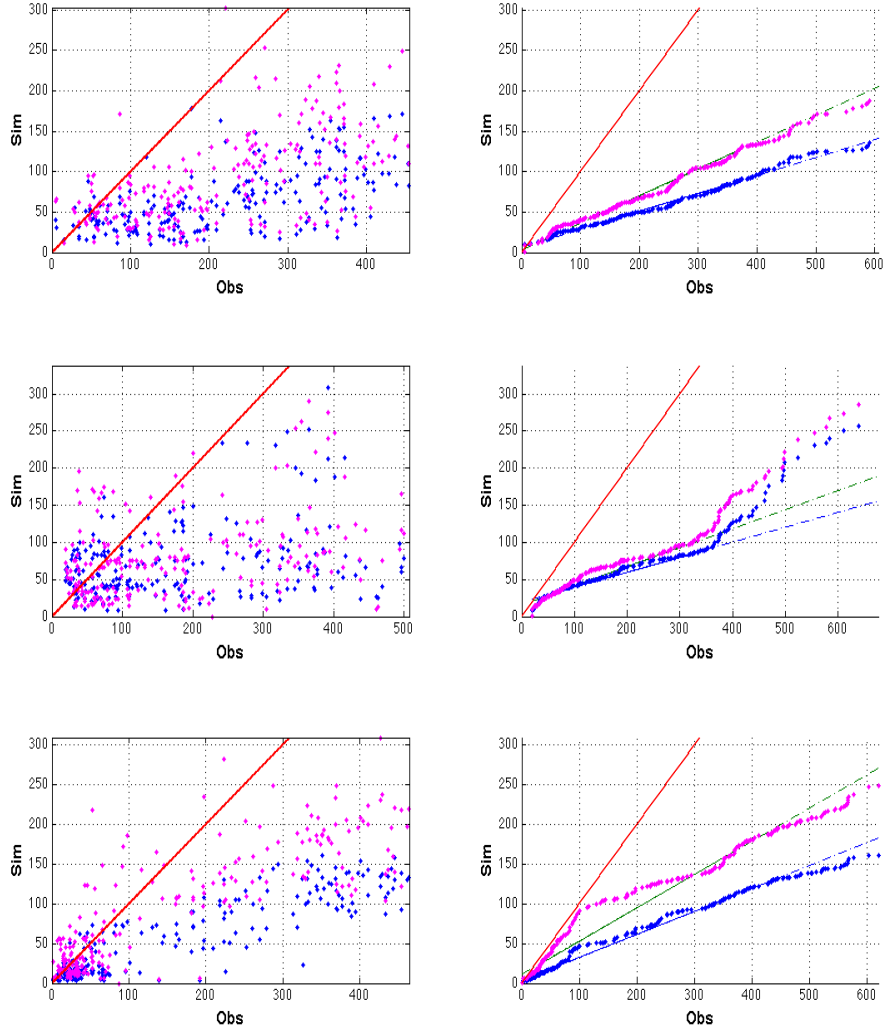


Figure 2: The scatter plot and quantile–quantile (Q–Q) plots of the observed and simulated PM10 hourly concentration in Baoding, Tangshan and Xianghe stations. The upper is Baoding stations, the middle is Tangshan station, the lower is Xianghe station. The “blue” points are driven by the forecast emission in the expanded domain, the “pink” points are driven by the updated emission in expanded domain, while the “Red” line is the model perfect line “ $y=x$ ”.

if we want to get much better model performance in Baoding Municipality, may we need to expand the model domain to cover Baoding’s surrounding areas, e.g. Shijiangzhuang Municipality.

2 Compared to the CAMx model

In the air quality Ensemble Air Quality Forecast System for Beijing (EMS-Beijing), there are another air quality model CAMx, which is developed by ENVIRON International Corporation[5]. In the section, we collected the forecast model results of CAMx model during the same air pollutant episode in January 2010, as the blue dashed line shown in Figure 3. The CAMx model also underestimated the PM10 concentration when the episode occurs, and the peak of PM10-API forecast by CAMx model is 113, a little better than CMAQ model but also underestimated much.

The same model sensitivity testing results by the CAMx model is present in Figure 3. The “NewEmis+FDomain(CAMx)” is driven by the updated emissions in the forecast original model domain without expanding, shown as “the blue points-line with triangle” in Figure 3. We can find that the model performance of the “NewEmis+FDomain(CAMx)” improves obviously, and the peak of PM10-API reaches to 170, much better than 113 in the “Forecast(CAMx)” results, and also much better than its brother model, CMAQ, with the same emissions and model domain.

The most possible reason is that the CMAQ v4.4 model uses one-way nested technology while the CAMx v4.4 model uses two-way nested. In this manuscript, the “New” updated emissions include the more regional point source emissions in Baoding, Tangshan and Langfang, and the increased area source emissions in Baoding and Tangshan according to the emissions report in CCCPSC(2011)[4], and most areas of Baoding, Tangshan and Langfang Municipality are outside of the original inner model domain D4 but in its mother model domain D3, in the CAMx model, the “added” emissions in the mother domain effect can transport through the boundary of the domain and improve the model performance in the inner model domain; but in the CMAQ v4.4 model, several variables have been chosen as the boundary condition that would underestimate something due to the transport of the boundary, thus, the added surrounding emissions of the CAMx model can affect the Beijing’s stations more effectively. This is a possible reason, to make sure this reason, more in-depth analysis should be taken in the future study.

Furthermore, we added another CAMx model simulation, drive the model with the updated emission in the “New” expand domain. As shown in Figure 3, the peak of PM10-API in the blue solid line with “New” emission and “New” domain would reach to 181, closer to the observation, that is better than the blue points-line, which driven by the “New” emission in the original forecast domain. That means the domain expanded would also improve the model performance of the CAMx model, although just a little.

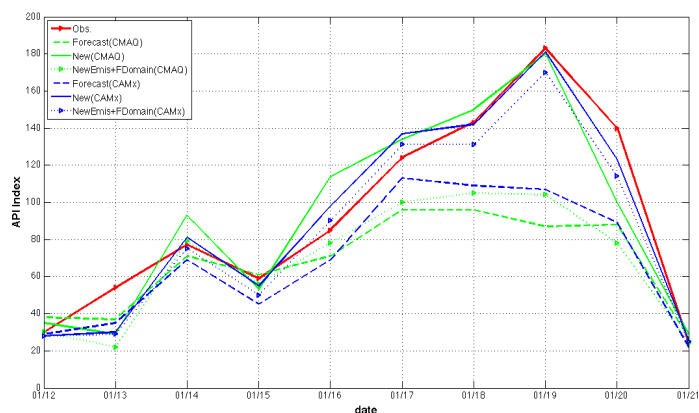


Figure 3: The time series of the averaged PM10-API in the NSAQ stations in Beijing urban area. The red solid line is the observation, the green lines are the CMAQ model results and the blue lines are the CAMx model results. The green dashed line is the CMAQ model results in the forecast system, and the green solid line is the CMAQ model results with the updated emission and expanded domain, and the green points-line with triangle is the CMAQ model results driven by the updated emissions in the original forecast domain. The blue dashed line is the CAMx model results in the forecast system, the blue solid line is the CAMx model results with the updated emissions and expanded model domain, and the blue points-line with triangle is the CAMx model results driven by the updated emission in the original forecast domain.

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