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Assessment of air quality benefits from national air pollution control policies in China. Part I: Background, emission scenarios and evaluation of meteorological predictions

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ABSTRACT

Under the 11th Five Year Plan (FYP, 2006–2010) for national environmental protection by the Chinese government, the overarching goal for sulfur dioxide (SO_2) controls is to achieve a total national emissions level of SO_2 in 2010 10% lower than the level in 2005. A similar nitrogen oxides (NO_x) emissions control plan is currently under development and could be enforced during the 12th FYP (2011–2015). In this study, the U.S. Environmental Protection Agency (U.S.EPA)'s Community Multi-Scale Air Quality (Models-3/CMAQ) modeling system was applied to assess the air quality improvement that would result from the targeted SO_2 and NO_x emission controls in China. Four emission scenarios — the base year 2005, the 2010 Business-As-Usual (BAU) scenario, the 2010 SO_2 control scenario, and the 2010 NO_x control scenario—were constructed and simulated to assess the air quality change from the national control plan. The Fifth-Generation NCAR/Penn State Mesoscale Model (MM5) was applied to generate the meteorological fields for the CMAQ simulations. In this Part I paper, the model performance for the simulated meteorology was evaluated against observations for the base case in terms of temperature, wind speed, wind direction, and precipitation. It is shown that MM5 model gives an overall good performance for these meteorological variables. The generated meteorological fields are acceptable for using in the CMAQ modeling.

1. Introduction

During the 10th Five Year Plan (FYP, 2001–2005) period, China maintained 9.48% annual average growth rate of the national economy. The primary energy consumption increased by 62% from 1.38 G tons of standard coal equivalent (tce) in 2000 to 2.24 G tce in 2005 (NBS, 2007). The Chinese government implemented several new policies during the 10th and 11th FYP to improve environmental pollution control efforts and reduce energy consumption. These polices were designed to prevent emission increases during a time of rapid growth in the economy and energy demand. During the 10th FYP period, environmental investment in China was double the investment during the 9th FYP (1995–2000) (SCPRC, 2007). Local governments placed more emphasis on environmental improvement for key areas, cities, and rivers; many inefficient and polluting industries were shut down or renovated; and investment in environmental infrastructure was accelerated. As a result, the air quality in most Chinese cities did not deteriorate despite the rapid economic growth. In 2000, the concentrations of the key air pollutants (coarse particulate matter (PM_{10}, particles with aerodiameter less than or equal to 10 μm), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2)) in 36.5% of 338 monitored cities reached the China National Ambient Air Quality Standards (CNAAQS) while 33.1% of monitored cities suffered severe air

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pollution, exceeding the Grade III air quality standards (MEP, 2000, 2001–2006). By 2005, the number of monitored cities increased to 522 with the addition of smaller cities with relatively better air quality. In 2005, 60.2% of the monitored cities reached CNAAQS and the number of highly-polluted cities declined to 10.6% (MEP, 2001–2006), demonstrating an evident improvement in air quality.

Despite progress, several goals of the 10th FYP were not achieved. The national SO_2 and dust emission targets were set at levels 10% below 2000 levels. However, the total emissions of SO_2 during the five years increased by 27.8% from 19.95 Mt to 25.49 Mt. Moreover, soot and industrial dust emissions increased by 1.5% and 16.6%, respectively (SCPRC, 2007).

In an attempt to address these challenges, the Chinese government published the 11th FYP for national environment protection in 2007. The 11th FYP included five major goals including a goal to reduce SO_2 emissions in 2010 by 10% from the 2005 level, primarily targeting emissions from the power sector. In addition, many large point sources in heavily-polluted regions are required to accelerate deployment of combustion modifications for NO_x emission control (SCPRC, 2007).

The purpose of this study is to assess the air quality benefits that would result from the planned SO_2 and NO_x emission control efforts during the 11th FYP. The U.S.EPA's CMAQ modeling system is applied to simulate air quality in China. The CMAQ modeling system, available publicly, is an air quality modeling system that has been broadly used to study the formation and transport of multiple air pollutants and assess the air quality benefits resulting from emissions control (Byun and Schere, 2006). The CMAQ modeling system has been extensively evaluated by several modeling studies in Asia by Zhang et al. (2006a), Uno et al. (2007), Fu et al. (2008), Wang et al. (2008a,b) and Liu et al. (2010, in press). A number of recent studies have employed CMAQ to estimate air quality changes in China and the East Asia region, e.g., Zhang (2004, 2005), Zhang et al. (2004, 2007c) applied CMAQ to simulate SO_2, sulfate, nitrate, ammonia, organic carbon and total aerosols in East Asia. Quan and Zhang (2008) and Quan et al. (2008) used CMAQ to assess the impact of ammonia and sulfate emissions on sulfur transport and deposition in China. Several studies estimated the NO_2 column to evaluate recent NO_2 emission trends (He et al., 2007; Shi et al., 2008). CMAQ has not, however, been used to assess emission control policy at the national level. Several regional scale modeling studies have used CMAQ to evaluate pollution control efforts and transboundary air pollution over the Beijing area for the 2008 Olympics (Chen et al., 2007; Cheng et al., 2007; Streets et al., 2007; Wang et al., 2008a,b), in the Yangtze River Delta (Li et al., 2008), in Pearl River Delta (Feng et al., 2007; Wei et al., 2007), and, under different control scenarios, in Shangdong province (Wang et al., 2005). Wang et al. (2005) had a similar methodology to our study, but they assessed only provincial level air quality changes.

In this study, the base case of CMAQ simulation is evaluated using available observations and the control case simulations are then used to assess the benefit of emission controls. Multi-pollutant assessment of key air quality issues, including particulate matter, ozone (O_3), visibility, acid rain, and nitrogen deposition is conducted for a base year (2005) and a future projected year (2010). Three scenarios are constructed: the 2010 BAU scenario using the predicted economic growth and no additional controls from 2005, the 2010 SO_2 control scenario using the national SO_2 emission control plans for 11th FYP, and the 2010 NO_x control scenario with 10% NO_x emission reduction from the 2005 level. CMAQ simulations for the three emission scenarios are conducted to evaluate the air quality changes from the planned national SO_2 controls and NO_x controls. It should be noted that the 10% reduction in NO_x emission is not required by the 11th FYP but potentially may be included in the 12th FYP. The objective of modeling this scenario is to assess the air quality benefits from NO_x controls to provide policy guidance for the 12th FYP.

2. Model configurations and inputs

2.1. Domain and episode

The modeling domain covers most of China and part of East Asia with a 36 × 36 km grid resolution, as shown in Fig. 1. A Lambert projection with the two true latitudes of 25°N and 40°N is used. The domain origin is (34°N, 110°E), and the coordinates of the southwest corner are ($x = -2934$ km, $y = -1728$ km). The selected model simulation periods include January, April, July and October, 2005, representing the four seasons in 2005. The year 2005 was selected mainly because it is the end year of the 10th FYP and the start year of the 11th FYP. According to the statistics of the China Ministry of

Fig. 1. The Models-3/CMAQ modeling domain at a horizontal grid resolution of 36-km (164 × 97 cells). The MM5 modeling domain is three grid cells broader on each side of the CMAQ domain. The diamond indicates the location of the continuous $PM_{2.5}$ monitoring site located in the campus of Tsinghua University (THU).

Environmental Protection (MEP, 2001–2006), the national emissions of SO_2 and fly ash maintained a relatively stable annual growth rate from the year 2002–2005. Then the emission trends began to change since the year 2006 as a result of the new emission controls planned in the 11th FYP. Therefore, 2005 is an appropriate baseline to reflect air quality and pollution control during the 11th FYP. The meteorological conditions in 2005 were slightly different than the historical average, with higher than normal average temperatures across China in 2005 and higher than average precipitations (Xiao and Xu, 2005).

2.2. Configurations and inputs

MM5 Version 3.7 is applied to generate the meteorological fields needed for the Models-3/CMAQ simulations. In the MM5 simulations, 23 sigma levels are selected for the vertical grid structure with the model top pressure of 100 mb at approximately 15 km. The height of the first 12 levels extends up to 2 km from the surface with the lowest level at approximately 40 m.

The MM5 data come from a number of sources. Terrain and land use data are from the U.S. Geological Survey (USGS) database (ftp://ftp.ucar.edu/mesouser/MM5V3/TERRAIN_DATA/). First-guess fields and the initial conditions for MM5 are from the National Center for Environmental Prediction (NCEP) final analysis datasets. The data for the objective analysis, using a four dimensional data assimilation (FFDA) technique, are from NCEP Automated Data Processing (ADP) data. The major physics options used in the MM5 simulations include the Kain-Fritsch 2 cumulus scheme (Kain and Fritsch, 1993; Kain, 2002), the high resolution Blackadar PBL scheme (Zhang and Anthes, 1982), the NCEP/Oregon State University/Air Force/Hydrologic Research Lab (NOAH) land surface model, the mixed phase (Reisner 1) explicit moisture scheme for cloud microphysics (Reisner et al., 1998), the cloud-radiation shortwave radiation scheme, the Rapid Radiative Transfer Model (RRTM) longwave radiation scheme (Mlawer et al., 1997) and the force/restore (Blackadar) surface scheme (Blackadar, 1976; Deardorff, 1978). The Meteorology-Chemistry Interface Processor (MCIP) version 3.2 is applied to process the meteorological data in a format required by CMAQ. The same meteorological field generated by MM5 for the base year 2005 is used for all the 2010 scenarios. Future climate change is not considered in this study.

Models-3/CMAQ is a three-dimensional Eulerian atmospheric chemistry and transport modeling system, which can simulate multiple air pollution issues and their interactions simultaneously, such as ozone, acid deposition, visibility, and fine particulate matter throughout the troposphere. It can simulate spatial scales from local to hemispheric. The detailed information on chemical and transport processes in CMAQ is described in Byun and Ching (1999). CMAQ version 4.6 officially released in September 2007 is applied in this study to simulate the air quality under each emission scenario. The vertical resolution of CMAQ includes fourteen layers from the surface to the tropopause with denser layers at lower altitudes to resolve the planetary boundary layer (PBL). The corresponding sigma levels are 1.000, 0.995, 0.988, 0.980, 0.970, 0.956, 0.938, 0.893, 0.839, 0.777, 0.702, 0.582, 0.400, 0.200 and 0.000. These sigma levels are a subset of the original MM5 vertical structure and are interpolated through the MCIP. The 2005 Carbon Bond Mechanism (CB05) with aqueous and aerosol extensions and the Aero 4 model derived from the Regional Particulate Model (RPM) (Binkowski and Shankar, 1995) are chosen for the gas-phase chemistry and aerosol modules, respectively. Particulates are represented using a modal approach with two modes: fine and coarse particles (e.g., $PM_{2.5}$ and $PM_{10\text{-}2.5}$). The aqueous/cloud chemical mechanism, which is adapted from the Regional Acid Deposition Model (RADM), is applied in the modeling.

A spin-up period of six days is used for all model simulations to reduce the influence of initial conditions on model results. The initial conditions (ICON) and boundary conditions (BCON) are extracted from the global GEOS-CHEM (GEOS–CHEM model (http://acmg.seas.harvard.edu/geos/)). The total ozone column data from the Total Ozone Mapping Spectrometer (TOMS) are used in the photolysis rates processor (JPROC) to calculate the photolysis rate for various altitudes, latitudes, and zenith angles.

3. Emission scenarios

3.1. Base year 2005

The general methodology used to develop the China regional emission inventory is described in Streets et al. (2003, 2006) and Zhang et al. (2007a). Using the same general approach, we implemented an improved technology-based methodology to include the types of technology currently operated in China. We also implemented a new anthropogenic particulate matter (PM) emission model of Zhang et al. (2007b) to calculate primary PM emissions, including PM_{10} and $PM_{2.5}$. Activity data, such as energy consumption, industrial production and population, are from statistics published by a variety of local and regional governmental agencies of China (NBS, 2002a,b, 2004, 2005a–c; AISIC, 2002, 2006). Fuel consumption by sector and by province is derived from the China Energy Statistical Yearbook (NBS, 2005b). Technology distribution within each sector is obtained from a wide variety of Chinese technology reports (Zhou, 2003; MMBI, 2000) and an energy demand modeling approach (SEI, 2001). Emission factors are based primarily on measurements in China with estimates based on real-world technology deployment and practices. In some cases, where local data and information are lacking, we use adjusted emission factors for similar activities from international databases, such as the U.S. EPA's AP-42 Database (U.S. EPA, 1996). In general, the methodology is similar to that used in the emission inventory for the Intercontinental Chemical Transport Experiment-Phase B (INTEX-B) mission. The detailed description of this methodology system is described in Zhang et al. (2009).

With the updated methodology, we have constructed a new emission inventory for China for the year 2004 based on official governmental statistics. The new inventory includes the four major gaseous species (SO_2, NO_x, carbon monoxide (CO), and non-methane volatile organic compounds (NMVOCs)) and four primary aerosol species (PM_{10}, $PM_{2.5}$, black carbon (BC) and organic carbon (OC)). When this inventory was developed in 2006, most of the available statistics for Chinese provinces were for 2004.We therefore developed a new set of growth algorithms based on the increase of total energy consumption to extrapolate the statistics-based 2004 inventory to 2005. The projected emissions in China in 2005 are 28.3 Tg SO_2, 19.8 Tg NO_x, 163.7 Tg CO, 22.4 Tg NMVOCs, 18.3 Tg PM_{10}, 13.4 Tg $PM_{2.5}$, 1.8 Tg BC, and 3.2 Tg OC. In INTEX-B, the 2006 national emissions are 31.0 Tg SO_2, 20.8 Tg NO_x, 166.9 Tg CO, 23.2 Tg NMVOCs, 18.2 Tg PM_{10}, 13.3 Tg $PM_{2.5}$, 1.8 Tg BC, and 3.2 Tg OC (Zhang et al., 2009), in which the SO_2 and NO_x emissions are 9.5% and 5.1% higher, respectively, relative to the 2005 level in this study. Emissions of other pollutants are close in these two years.

To support CMAQ modeling, emissions are distributed into the 36 km × 36 km grid cells using various spatial proxies at a grid resolution of 1 km × 1 km using the methodology described in Streets et al. (2003) and Woo et al. (2003). NMVOC emissions are further disaggregated into 17 chemical species based on the 2005 CB05 chemical mechanism that is used in the CMAQ simulations. The NMVOC emissions are speciated into about a total of 500 species by using VOC source profiles (U.S. EPA's Database of Speciated Emission Profiles, SPECIATE, http://www.epa.gov/ttn/

chief/software/speciate/) and each of the species is mapped to the CB05 species based on a very detailed chemical reaction mapping table.

3.2. 2010 Scenarios

The 2010 BAU scenario is used as a baseline for the evaluation of the air quality benefits from SO_2 and NO_x controls. While the 2010 SO_2 control scenario is based on the planned emission reduction in the 11th FYP, the 2010 NO_x control scenario is designed to address additional NO_x controls needed to bring key air pollutants such as O_3 and $PM_{2.5}$ into attainment by 2010, as NO_x is an important precursor for both O_3 and secondary particulate nitrate.

During the 10th FYP period, consumption of coal and petroleum in China increased by about 63.7% and 45.8%, respectively (NBS, 2007; Jiang, 2008). In the 2010 BAU scenario, the growth rate and emission factors for coal and petroleum are assumed to be the same as the measured growth rate and emission factors during the 10th FYP. In China, coal is a major energy source for power plant, industry, commercial, and residential sources, the emissions from these sectors are assumed to increase by 63.7% in 2010 relative to the 2005 level. The emissions growth from transportation in 2010 is assumed to be 45.8%, consistent with the growth rate of petroleum consumption between 2001 and 2005.

In the 2010 SO_2 control scenario, the SO_2 emission inventory is based on the objectives of the national 11th FYP for environmental protection. Its objective is to reduce SO_2 emissions by 10% relative to the 2005 level. This goal requires significant SO_2 emission reductions from power plants through the installation of desulfurization equipment. Emissions from other sources, such as industry, commercial, residential, and transportation, are required to remain at the 2005 level through the use of fuel modifications and emission control technologies. MEP provided the 2010 projected emission inventory for power plants, including planned power plants. Other pollutant emissions are assumed to be the same as the 2010 BAU scenario.

The objective of the 2010 NO_x control scenario is to provide scientific information to policymakers about the benefits of NO_x emission control. Although the 11th FYP does not currently have a NO_x objective, the government is in the process of developing a national plan for NO_x emission control. In the 2010 NO_x control scenario, NO_x emissions are assumed to decrease by 10% from the 2005 level, equal to the SO_2 reduction target of the 11th FYP. Other pollutant emissions are assumed to be the same as the 2010 BAU scenario.

Fig. 2 summarizes the national anthropogenic emissions of SO_2 and NO_x for each scenario. If the national SO_2 control policy is implemented successfully, the total SO_2 emissions in 2010 will decline by as much as 21% from the 2005 level and 52% from the 2010 BAU scenario. This number is higher than the 10% overarching goal because the MEP set up a very strict and detailed control plan for power sector to guarantee the reduction in the national SO_2 emissions in 2010. The 10% NO_x emission reduction in 2010 from the 2005 level requires a 43% reduction from the 2010 BAU scenario. The substantial reduction in both SO_2 and NO_x emissions poses a significant challenge in the development of control policies, deployment of control technologies, and enforcement of emission control regulations.

Fig. 2 also illustrates the relative contributions of each sector to total SO_2 and NO_x emissions in 2005 and 2010 are different. The relative contributions change between the base year and projections. For example, SO_2 emissions from power plants decrease from approximately 60% of total SO_2 emissions in 2005 to below 50% in 2010, while industrial SO_2 emissions increase from 31% of total SO_2 emissions to 40%.

4. Evaluation of meteorological predictions

The air quality predictions rely on the accuracy of the meteorological predictions. However, at present, there are no strict guidelines describing how to systematically and objectively evaluate the performance of the MM5 model at present (Johnson, 2003). Due to the limited observational data available for China, the MM5 evaluation is restricted to the following parameters: temperature at 2-m (T2), wind speed and wind direction at 10-m (WS10 and WD10, respectively), and daily precipitation. These parameters are the key attributes of the meteorological modeling performance (Miao et al., 2007). All the observational data are obtained from the National Climatic Data Center (NCDC), where hourly or every third hour observations are available. The geospatial distribution of the site locations is shown in Fig. 3. All the meteorological evaluations are conducted in terms of temporal variations at 12 major Chinese cities and domain-wide statistical analysis over all the monitoring stations. The 12 cities include Beijing, Shanghai, Guangzhou, Changsha, Hangzhou, Wuhan, Guilin, Najing, Xi'an, Xining, Hohhot and Shenyang. Domain-wide analysis is performed to evaluate model results. The detailed analysis of the temporal variations at the 12 cities can be found in the report of Fu et al. (2007).

For the domain-wide analysis, the MM5 model predictions are extracted to compare with observations at the closest monitoring station using the METSTAT tool (Environ, 2004). The statistical parameters employed include the mean observation (Mean OBS), the mean prediction (Mean PRD), the bias, gross error, the root mean square error (RMSE), and the index of agreement (IOA). RMSE provides the information of overall model performance from both

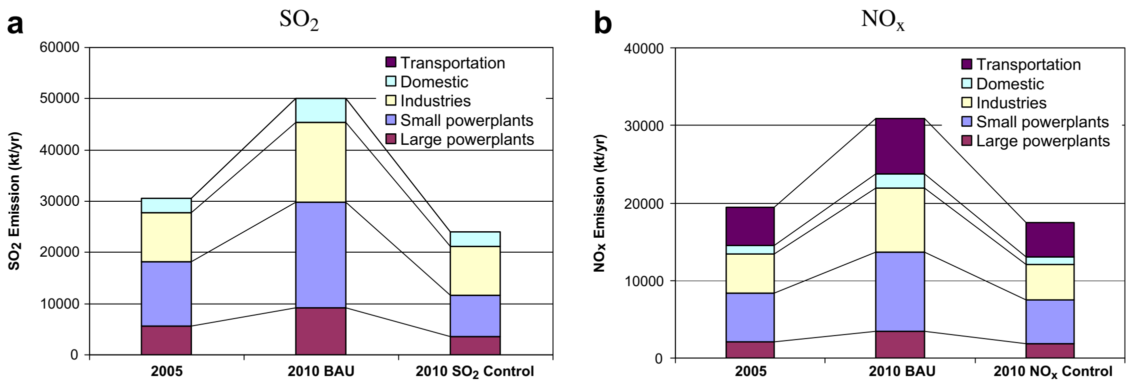

Fig. 2. SO_2 and NO_x emissions in China under the base year 2005 emission scenario, the 2010 Business-As-Usual (BAU) scenario, and SO_2 and NO_x control scenarios.

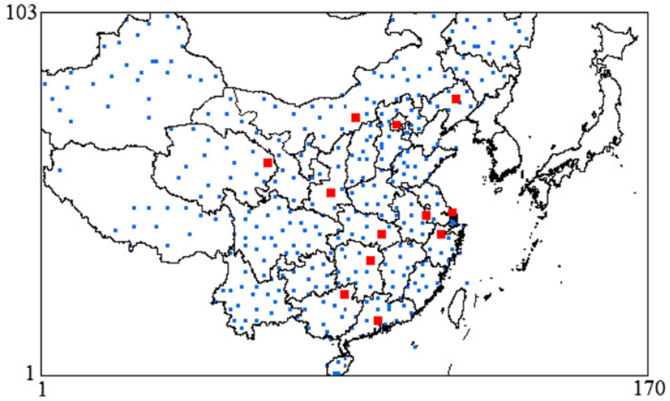

Fig. 3. Location of NCDC observational sites and 12 selected sites in China.

the systematic and the unsystematic root mean square errors (Sys RMSE and Unsys RMSE). Sys RMSE estimates the linear error of the model, while Unsys RMSE informs the error of random processes or influence beyond the legitimate range of the model. In general, a small value of Sys RMSE indicates a good model performance. When Sys RMSE approaches zero, Unsys RMSE becomes the RMSE. The IOA provides information on whether the predictions are error-free. The closer the IOA value is to one, the better the agreement between the simulated and observed values (Baker, 2004).

Table 1 lists the model performance statistics and the benchmarks suggested by Emery et al. (2001). These benchmark values are derived based on performance statistics of MM5 from a number of studies over the U.S. domain (mostly at a horizontal grid resolution of 4 and 12 km). While these values take into account the quality of the observational data available in the U.S., they may not be directly applicable to China where observational data are sparse. In addition, the use of a grid resolution of 12-km or finer generally gives more accurate meteorological predictions than that at 36-km. This may not, however, always be true and may vary from episode to episode (Queen and Zhang, 2008). To reflect these differences and apply the benchmark values for a 36 km horizontal resolution over China, an uncertainty factor of 20% is used to adjust the original temperature benchmark values of Emery et al. (2001) (except for IOA) for MM5 evaluation in this study (Emery et al., 2001; Kim et al., 2010).

Table 1
Performance statistics for meteorological variables.

			January	April	July	October	Benchmark
Temperature	Mean OBS	(°C)	−1.0	15.0	25.0	13.0	
	Mean PRD	(°C)	−1.9	13.9	24.3	11.6	
	Bias	(°C)	−1.0	−1.1	−0.6	−1.3	≤±0.6[a]
	Gross Error	(°C)	2.4	2.4	2.2	2.3	≤2.4[a]
	RMSE	(°C)	3.3	3.4	3.0	3.1	
	Sys RMSE	(°C)	1.2	1.2	0.7	1.4	
	Unsys RMSE	(°C)	3.0	3.2	3.0	2.8	
	IOA		0.9	0.9	0.9	0.9	≥0.8
Wind speed	Mean OBS	($m\,s^{-1}$)	2.5	3.2	2.6	2.7	
	Mean PRD	($m\,s^{-1}$)	3.2	3.6	3.1	3.2	
	Bias	($m\,s^{-1}$)	0.7	0.4	0.4	0.5	≤±0.5
	Gross Error	($m\,s^{-1}$)	1.5	1.6	1.4	1.4	≤2.0
	RMSE	($m\,s^{-1}$)	2.0	2.0	1.9	1.8	≤2.0
	Sys RMSE	($m\,s^{-1}$)	1.2	1.2	1.2	1.1	
	Unsys RMSE	($m\,s^{-1}$)	1.7	1.7	1.4	1.5	
	IOA		0.7	0.8	0.7	0.8	≥0.6
Wind direction	Mean OBS	(deg)	285	231	153	214	
	Mean PRD	(deg)	304	233	154	224	
	Bias	(deg)	5	5	5	4	≤10
	Gross Error	(deg)	48	46	47	44	≤30
Precipitation	Mean OBS	(mm)	24	84	221	22	
	Mean PRD	(mm)	15	72	204	25	
	Bias	(mm)	−9	−12	−18	3	
	Gross Error	(mm)	19	26	30	7	

[a] 20% increased from the actual benchmark values used in the U.S. recommended by Emery et al. (2001).

As shown in Table 1, the observed temperatures at 2-m are reproduced reasonably well by MM5 with moderate Sys RMSEs and relatively large Unsys RMSEs. The large Unsys RMSEs indicate that most of the errors are random errors. The IOA values for all four months are very close to one, indicating an overall good model performance. MM5, however, tends to underpredict T2, with cold biases of 0.63 to −1.32 °C. For WS10, the gross errors and RMSEs for all the four months are below the benchmark value of 2.0 $m\,s^{-1}$. The corresponding IOA values are above 0.6. The biases for April, July, and October are equal to or below the benchmark value of 0.5 $m\,s^{-1}$, and is slightly above this benchmark value for January. These statistics indicate an overall satisfactory performance in terms of wind speed. For wind direction, No RMSE and the IOA are available in METSTAT. While the WD10 bias is below the 10 degrees benchmark value, the gross errors range from 43 to 47 degrees—13 to 17 degrees larger than the 30 degrees benchmark value. The high gross errors may result from a caveat in treating the wind direction vector as a scalar in METSTAT, as indicated in Zhang et al. (2006b), where error calculations are performed inconsistently when determining the differences between simulated and observed values. On a wind rose plot, both 0 and 360 degrees represent the direction of north. Therefore, for instance, if the observed wind is in the north direction and the predicted value is 190 degrees, the actual difference can be $190-0=190$ degrees or $360-190=170$ degrees. If the first value (i.e., 190) is selected in calculating the gross errors, this increases the actual difference in the gross errors by 20 degrees. For monthly total precipitation, the statistical values are calculated based on observations from two hundred national meteorological stations. The statistical results show that the precipitation in January, April and July is underpredicted and the precipitation in October is slightly overpredicted. Overall, no extreme precipitation disagreement is found between the observations and predictions.

5. Conclusions

Due to rapid economic and energy demand growth, China currently experiences severe air pollution. Air quality will continue to decline without policies to control emissions. In this study, the U.S. EPA's CMAQ air quality modeling system is applied to simulate air quality over China to assess the air quality benefits that would result from the SO_2 emission controls planned by the Chinese government through the 11th FYP and, separately, NO_x emission controls assumed during the same period.

In this Part I paper, four emission scenarios were constructed: the base year 2005, the 2010 BAU scenario with the assumption that the growth rate and emission factors for coal and petroleum are the same as those during the 10th FYP, the 2010 SO_2 control scenario based on a detailed projected emission inventory for power sector by MEP, and the 2010 NO_x control scenario with 10% NO_x emission reduction relative to the 2005 level. The results shows that in 2010 SO_2 control scenario the national total SO_2 emissions will decline by 21% from the 2005 level and 52% from the 2010 BAU scenario. The 10% NO_x emission reduction in 2010 from the 2005 level requires a 43% reduction from the 2010 BAU scenario.

The model performance for the base year 2005 is statistically evaluated. In this Part I paper, the meteorological predictions of

MM5 are evaluated against observations in terms of the four key parameters, temperature, wind speed, wind directions and precipitations. The result shows that MM5 performed reasonably well for all the four simulation months in the base year 2005. The MM5 outputs are acceptable for use in the CMAQ modeling.

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