

Future prediction of energy, CO₂, and surface ozone over South, East, and Southeast Asia in 2030

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Abstract:

Three future scenarios have been developed to evaluate the effects of economic growth in all of Asian countries and potential energy and environmental strategies implemented in China and India on surface ozone over South, East, and Southeast Asia as well as energy consumption and CO₂ emission. Three-dimensional regional air quality simulations using the emissions of nitrogen oxide (NO_x) and volatile organic compound (VOC) estimated in the scenarios imply that surface ozone basically increases due to future economic growth, and that the potential energy and environmental strategies assumed in the scenarios are effective to suppress surface ozone over China, India, and surrounding countries including Thailand. In addition, the potential energy strategies could realize co-benefits, which result in simultaneous reduction of energy consumption and CO₂ emission in China and India. More works are necessary to consider specific effective energy and environmental strategies to suppress energy consumption, CO₂ emission, and air pollution involving particulate matter (PM) as well as surface ozone in Thailand.

Keywords: Surface ozone; energy consumption; CO₂; air quality simulation; future scenario; effective strategies

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1. Introduction

Developing countries in Asia including Thailand as well as China and India are accomplishing rapid economic growth. On the other hand, expanding economic activities have caused significant increase of energy consumption and carbon dioxide (CO₂) emissions as well as heavy air pollution. One of key air pollutants is tropospheric ozone. Ozone has adverse effects on human health and vegetation. In addition, tropospheric ozone is getting more attentions as one of short-lived climate pollutants (SLCPs). Reduction of tropospheric ozone may achieve co-benefits which would save human health and vegetation, and simultaneously mitigate near-term climate change.

The purpose of this study is to predict anthropogenic energy consumption and emissions of CO₂ and precursors (nitrogen oxide (NO_x) and volatile organic compound (VOC)) which contribute to formation of tropospheric ozone in three future scenarios considering a business-as-usual (BAU) pathway and potential energy and environmental strategies. Then, three-dimensional regional air quality simulations were performed to evaluate effects of potential strategies on surface ozone over South and East Asia.

2. Methods

2.1 Prediction of energy consumption and emissions

We estimated anthropogenic energy consumption and emissions of CO₂, NO_x, and VOC for the current year (2010) referred as BASE and in the three future scenarios (BAU0, PC0, and PC1) for 2030 in 22 Asian countries including Thailand, China, and India. BAU0 assumed a business as usual pathway. PC0 assumed additional legislations and technological developments to suppress energy consumption and CO₂ emissions. PC1 assumed additional legislations and technological developments to reduce NO_x and VOC emissions besides PC0. It must be noted that potential energy and environmental strategies implemented only in China and India were currently reflected in PC0 and PC1. Potential strategies which would be implemented in Thailand will be considered in

the next step.

The anthropogenic energy consumption and emissions of CO₂, NO_x and VOC in Thailand and Asian countries other than China and India were estimated by Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS)-Asia model (Klimont et al., 2009; Amann et al., 2011) using World Energy Outlook 2011 (IEA, 2011) energy projections. Those in China and India were separately estimated. Details were described in Chatani et al. (2014) and the references therein.

2.2 Regional air quality simulations

The target domain covering South, East, and Southeast Asian countries was defined. It was horizontally and vertically divided into boxes of which the horizontal resolution is 60 x 60 km. Temporal changes in tropospheric ozone concentrations in each box due to various ambient processes including photochemical reactions and transport by winds were simulated by the Community Multi-scale Air Quality modeling system (CMAQ) (Byun and Schere, 2006) version 5.0.1. Details were described in Chatani et al. (2014). The simulations using the precursor emissions of BASE, BAU0, PC0, and PC1 were performed for 14 months from November 2009 to December 2010.

3. Results and discussion

3.1 Estimated energy consumption and emissions

The estimated anthropogenic energy consumption and emissions in Thailand, China, and India are shown in Table 1. In Thailand, the estimated energy consumption, CO₂, and NO_x emissions in BAU0 are 1.5, 1.6, 1.3 times higher while the VOC emission is slightly lower than BASE. They imply that expanding economic activities result in higher energy consumption and CO₂ emissions whereas existing environmental strategies are effective to suppress NO_x and especially VOC emissions. In China and India, the energy consumption and emissions in BAU0 are significantly higher than BASE due to their rapid economic growth. On the other hand, the potential energy and environmental strategies assumed in PC0 and PC1 would be effective to reduce them.

Table 1 Estimated anthropogenic energy consumption and emissions of CO₂, NO_x, and VOC in BASE for 2010, and BAU0, PC0, and PC1 for 2030 in Thailand, China, and India

	Country	BASE	BAU0	PC0	PC1
Energy consumption (EJ year ⁻¹)	Thailand	5.3	7.7		
	China	121.7	199.5	155.0	
	India	26.4	83.8	62.2	
CO ₂ emission (Pg year ⁻¹)	Thailand	0.28	0.44		
	China	8.50	14.10	9.90	
	India	1.71	6.63	4.51	
NO _x emission (Tg year ⁻¹)	Thailand	0.86	1.16		
	China	26.1	35.4	25.2	11.5
	India	5.6	19.5	13.4	6.8
VOC emission (Tg year ⁻¹)	Thailand	0.91	0.81		
	China	22.8	29.0	24.4	16.8
	India	10.2	19.8	16.0	11.4

3.2 Simulated surface ozone

Horizontal distributions of the simulated seasonal mean surface ozone concentration in BASE for 2010, and BAU0 and PC1 for 2030 are shown in Fig. 1. A zone with high concentration encompasses mid-latitude regions from India to Japan in spring and autumn. It is slightly shifted northward in summer and southward in winter. The simulated values over Thailand are seasonally

high in winter and spring. Significant increase around India in BAU0 is evident throughout a year. The values over Thailand in BAU0 are also higher than BASE in all seasons. The potential energy and environmental strategies assumed in PC1 are effective to suppress the increase of surface ozone over China, India, and surrounding countries.

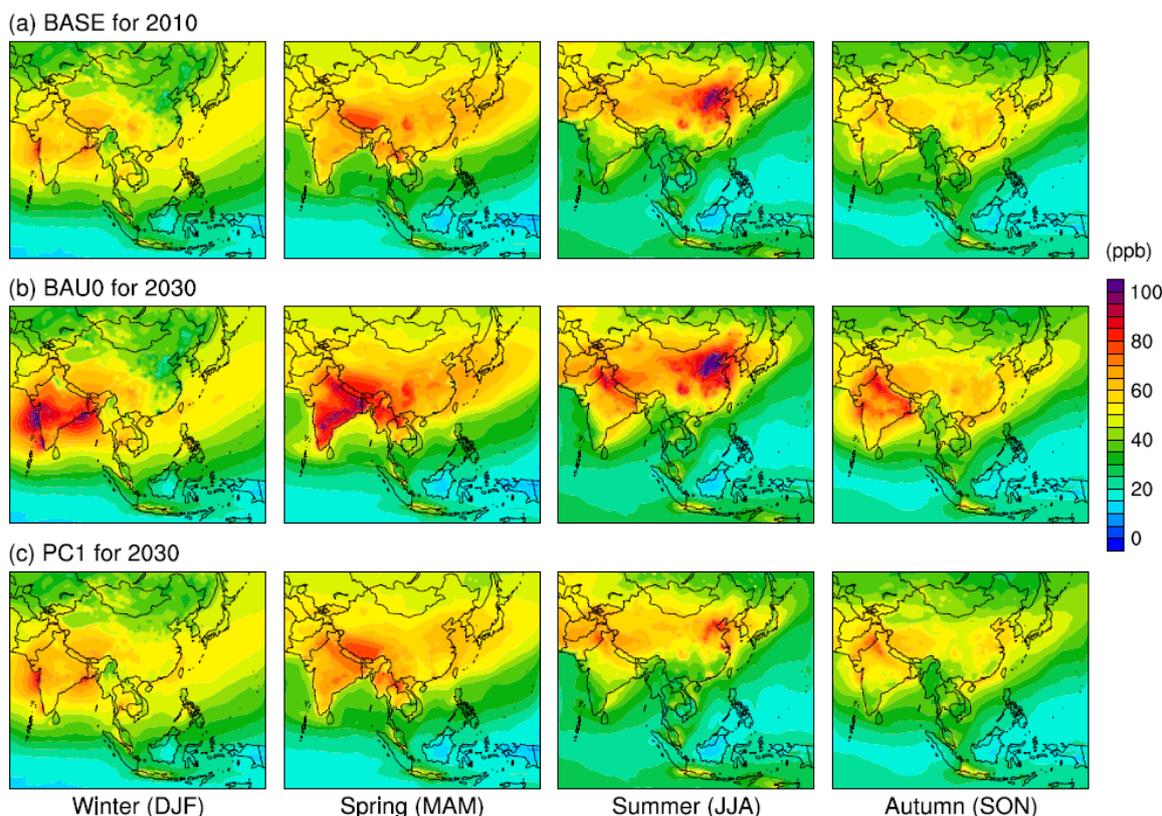


Fig. 1 Horizontal distributions of simulated seasonal mean surface ozone concentration in (a) BASE for 2010, (b) BAU0 for 2030, and (c) PC1 for 2030.

Fig. 2 shows differences in the simulated monthly mean surface ozone concentrations among cases which are averaged over Thailand. The simulated surface ozone in BAU0 is around 5 ppb higher than BASE in all months due to growing precursor emissions in Thailand and surrounding countries. Currently, only potential energy and environmental strategies implemented in China and India were assumed in PC0 and PC1. Nevertheless, they are effective to reduce surface ozone over Thailand especially in early winter. It implies importance of transboundary transport of ozone and its precursors

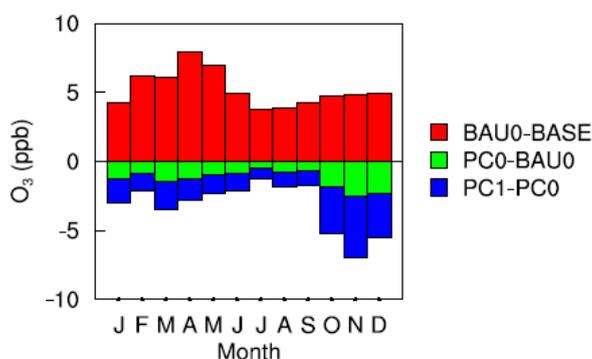


Fig. 2 Differences in simulated monthly mean surface ozone concentrations among cases which are averaged over Thailand.

from surrounding countries to Thailand. However, additional energy and environmental strategies are required to realize net reduction of surface ozone over Thailand in 2030.

4. Conclusion

Significant increase of surface ozone as well as anthropogenic energy consumption and CO₂ emission in BAU0 for 2030 were predicted in South and East Asia including Thailand. The potential energy and environmental strategies assumed in this study could be effective to suppress increase of surface ozone in China, India, and surrounding countries. In addition, the energy strategies could realize co-benefits, which result in simultaneous reduction of energy consumption and CO₂ emission.

The outcomes obtained in this study could provide a broad idea to suppress anthropogenic energy consumption, CO₂ emission, and surface ozone. However, there are following issues remaining to specifically consider effective strategies for suppressing energy consumption and CO₂ emission as well as improving the air quality over Thailand.

- The horizontal resolution of the current emission database and air quality simulation is relatively coarse. It may have difficulties to reproduce heavy air pollution concentrating on urban areas. Finer database and simulations are desired.
- Not only surface ozone, but also particulate matter (PM₁₀ and PM_{2.5}) are concerned in Thailand as critical ambient pollutants. Although the current simulation can calculate concentrations of PM₁₀ and PM_{2.5}, it requires emissions of primary PM and precursors.
- The energy consumption and emissions in Thailand were currently estimated based on the international databases, which are not necessarily represent actual situations in Thailand. Potential energy and environmental strategies which should be implemented in Thailand have not been considered yet.

We are working to solve these issues in the collaboration with JGSEE-KMUTT aiming at contributing to sustainable development of Thailand.

5. Acknowledgement

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