The seventh International Conference on Urban Climate,
29 June - 3 July 2009, Yokohama, Japan

EFFECTS OF ANTHROPOGENIC HEAT RELEASE ON REGIONAL CLIMATE AND POLLUTANTS DISTRIBUTION ESTIMATED BY THE METEOROLOGY-CHEMISTRY COUPPLED ATMOSPHERIC MODEL

Kazuya Inoue*, Haruyuki Higashino
National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan

Abstract

Using an on-line meteorology-coupled chemical transport model, two kinds of simulations were conducted in the Kanto area of Japan for 2002 fiscal year; one with anthropogenic heat release and the other without it. Simulation results showed anthropogenic heat release decreased markedly concentrations of primary pollutants (nitrogen oxides) in urban areas mainly because of increased planetary boundary layer height, whereas anthropogenic heat release was found to increase concentrations of one of the secondary pollutants (ozone) in such areas. The simulation results with anthropogenic heat were much better correlated with available observations for both meteorological variables and air pollutants concentrations, suggesting it is crucial to incorporate anthropogenic heat release into the model to estimate regional distributions of long-term average pollutants concentrations reasonably.

Key words: regional atmospheric model, anthropogenic heat release, concentration distribution

1. INTRODUCTION

Owing to growing computational performances, regional distributions of long-term average pollutants concentrations can now be estimated using sophisticated three dimensional Eularian models such as CMAQ. These models often use outputs from meteorological models, such as MM5, WRF, or RAMS, as input meteorological variables (e.g. wind and temperature). In these meteorological models, urban effects are usually considered only by changing surface parameters (e.g. roughness length, albedo, and heat capacity) but not by incorporating anthropogenic heat release (refereed to as “AHR” hereafter). Therefore, it is important to evaluate the significance of the effects of AHR on pollutants concentration distributions to determine whether these effects can be reasonably ignored, as is often the case, or not. The impact of AHR on pollutants concentration distributions, however, has been rarely studied; especially no study has been conducted, as far as we know, on the impact onto the long-term average concentration distribution which is crucial to quantify health effects posed by atmospheric pollutants. In the present study, we estimated effects of AHR on regional distributions of long-term average pollutants concentrations as well as regional climate using an on-line meteorology-coupled chemical transport model.

2. METHOD

2.1. Model description

We developed an on-line meteorology-coupled chemical transport model and utilized it for the above-mentioned purpose. The core of this model consists of a meteorological model, Regional Atmospheric Modeling system (Pielke *et al.* 1992) version 4.4, and a chemistry model, updated Carbon Bond mechanism IV (CB99, Adelman 1999). CB99 represent complicated atmospheric reactions forming secondary pollutants such as ozone (O_3) or aldehydes by 96 chemical equations of 36 chemical species. For calculations of chemical processes which include reaction, deposition, and emission of a specific source category (biogenic emission), meteorological variables are accessed every simulation time step. Weather clustering technique (Yoshikado *et al.* 2006) can also be used for estimating long term average concentrations. This technique includes weather clustering on the basis of synoptic scale pressure distribution and incoming solar radiations, and determination of representative days for each weather pattern on the basis of transport paths of atmospheric pollutants. With this technique, simulations are conducted only for these representative days so that time required estimating long-term average concentrations gets much shorter. This technique was also applied for this study.

2.2. Simulation setup

The simulation domain covered eastern part of Japan with grid 1 which was nested with grid 2 covering the Kanto area which included the Tokyo metropolitan area (Fig.1). The main target area of the present study was the Kanto area so that only the simulation results for grid 2 will be shown in the following section. The horizontal grid spacing was 20 km for grid 1, and 5 km for grid 2. Vertically, both grids expanded from ground surface up to

---

* Research Institute of Science for Safety and Sustainability, 16-1, Onogawa, Tsukuba, Ibaraki, 305-8569, Japan.

20,000 m with variable grid spacing. The vertical spacing of the bottom layer was 50 m. Though target period was set throughout the 2002 fiscal year (FY), simulations were conducted only for 29 days which were representative for each weather pattern. Each bottom grid cell was deviled into at maximum four different land use patches (e.g. water, trees, farming, and urban) to consider heterogeneity in heat / mass exchange at ground surfaces within each grid cell. Emission amounts of primary pollutants, nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOCs), used in the atmospheric model was estimated on the basis of Kannari *et al.* (2007). Biogenic VOCs emission factors were modified to reflect those of Japanese inhabitant plant species measured recently by Bao *et al.* (2008).

Two kinds of simulations were conducted: one with AHR (case 1) and the other without it (case 0)**.** For case 0, urban effects were represented only by changing surface parameters specific to urban landuse, which was original representation of urban effects in RAMS v4.4. For case 1, anthropogenic heat was put directly into the bottom atmospheric grid cells which had urban patches. For each urban patch, AHR of 100 w/m^2 was assumed after Pielke (2002).

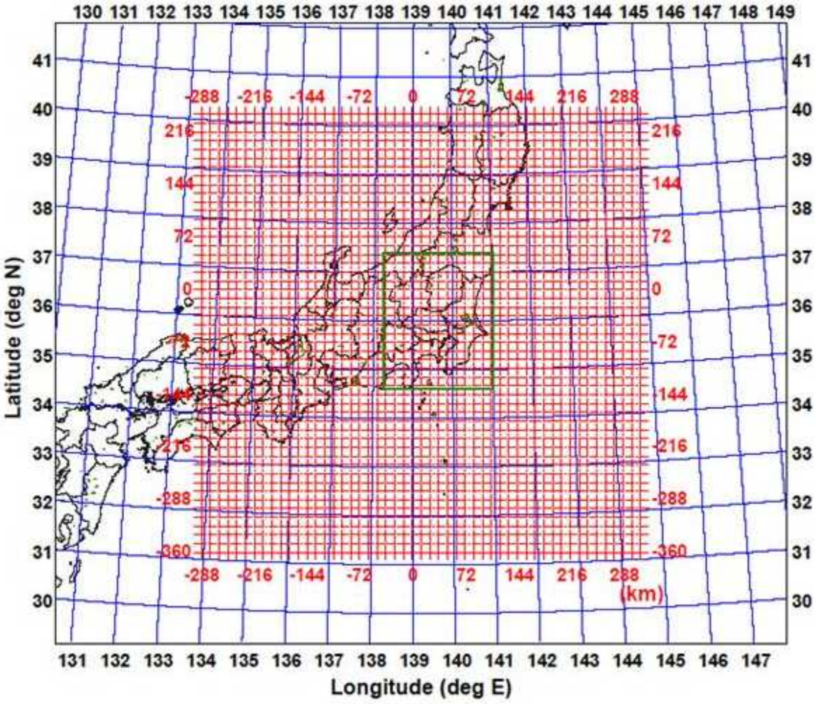

Fig. 1. The simulation domain and grids. Grid 1 are represented by red rectangles and the outer frame of grid 2 is represented by green rectangle.

3. RESULTS AND DISCUSSION

3.1. Geographical distribution of surface air temperature

Figure 2 shows geographical distribution of calculated annual mean temperature at the bottom model layer along with that of observed annual mean surface air temperature at Air Pollution Monitoring Stations over the Kanto area. It can be seen observed temperatures are higher in the Tokyo metropolitan area than in the surrounding area (Fig.2 a). It is noticeable that the distribution of predicted temperature of Case 1 (with AHR) agrees well with that of observations (fig2.c) while that of Case 0 (without AHR) do not.

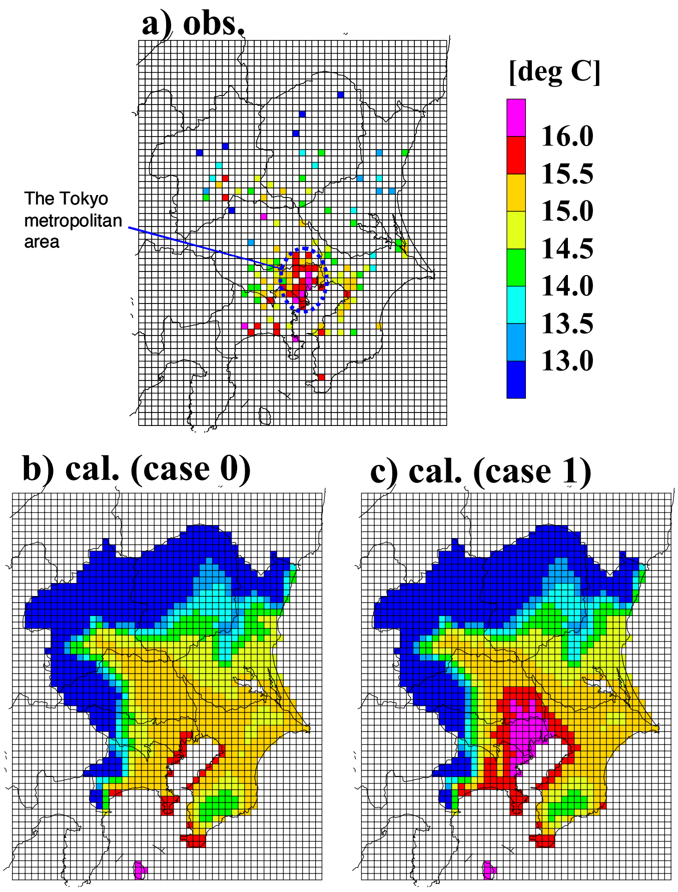

Fig. 2. Geographical distributions of observed and calculated annual mean surface air temperature in the Kanto area for 2002 FY.

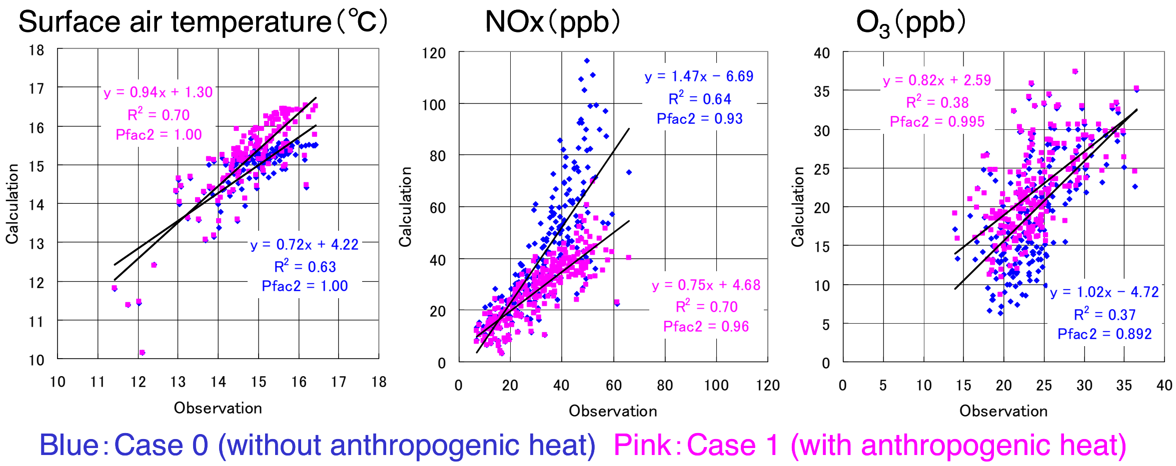

Fig. 3. Scatter plots of observations versus calculation results of each case for the Kanto area of Japan. Each plot represents each grid cell which has monitoring stations. All variables are averaged for 2002 FY. Pfac2 denotes fraction of data points calculated within the accuracy of factor 2. Note that most data within the Tokyo metropolitan area, significant urbanized areas, are plotted in the right (higher) side on the left and the middle panels but are plotted in the left (lower) side on the right panel according to the difference of geographical distribution of each variables.

3.2. Impact of anthropogenic heat release on temperature, concentrations, and model performance

Figure 3 shows scatter plots of observations versus calculation results of each case over the Kanto area of

Japan for different variables. All variables are shown in average values for 2002 FY. The difference between results of case 0 and those of case1 clearly shows that AHR affects significantly pollutants concentrations as well as surface air temperatures. AHR decreased markedly primary pollutants (NOx) concentrations in urban areas, whereas it increased one of the secondary pollutants (O_3) concentrations in such areas. These phenomenon could be explained mainly by the increase of planetary boundary layer height caused by AHR, as can be seen from fig.4. Furthermore, It is noticeable that the simulation results with AHR is much better correlated with observations for both temperature and air pollutants concentrations.

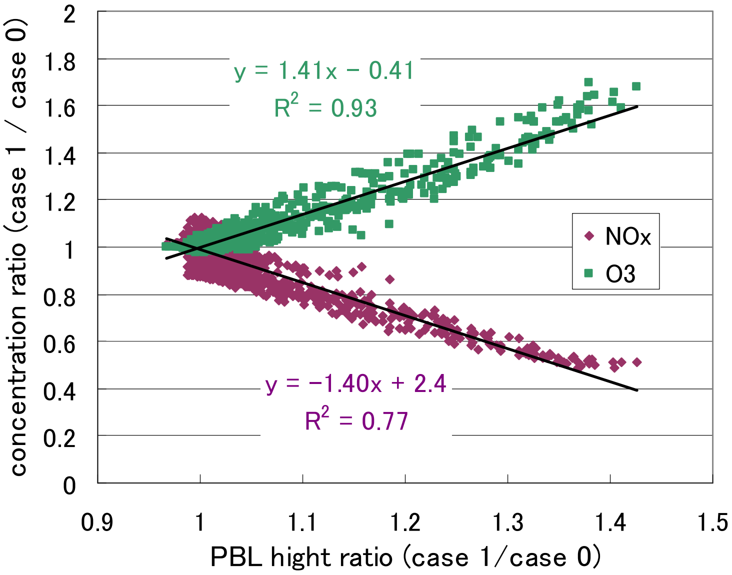

Fig. 4. Scatter plots of calculated planetary boundary layer height (PBL height) ratio (PBL height of case1 / PBL height of case 0) versus calculated concentration ratio (concentration of case1 / concentration of case 0) for NOx and Ozone (O_3). Each plot represents each grid cell of the grid 2. All variables are averaged for 2002 FY. Increase of PBL height caused by AHR is closely related to decrease of NOx concentrations and increase of ozone concentrations.

4. Conclusions

Our simulation results reveal AHR has significant effects on regional distributions of long-term average pollutants concentrations as well as regional climate. Though these effects of AHR on concentrations have been rarely taken into account in the model calculation, AHR is found important to incorporate into the model calculation to estimate regional distributions of pollutants concentrations reasonably.

References

Adelman, Z. H., 1999. A reevaluation of the Carbon Bond-IV photochemical mechanism, http://airsite.unc.edu/soft/cb4/FINAL.pdf

Bao, H., Kondo, A., Kaga, A., Tada, M., Sakaguti, K., Inoue, Y., Shimoda, Y., Narumi, D., Machimura, T., 2008. Biogenic volatile organic compound emission potential of forests and paddy fields in the Kinki region of Japan, *Environmental Research*, 106, 156-169.

Kannari, A., Tonooka, Y., Baba, T., Murano, K., 2007. Development of multiple-species 1 km×1 km resolution hourly basis emissions inventory for Japan. *Atmospheric Environment*, 41:3428–3439.

Pielke, R. A., 2002. Mesoscale meteorological modelling, 2nd ed. Academic Press, Sandi ego CA, USA, pp 417.

Pielke, R. A., Cotton, W. R., Walko, R. L., Tremback, C. J., Lyons, W. A., Grasso, L. D., Nicholls, M. E., Moran, M. D., Wesley, D. A., Lee, T. J., Copeland, J. H., 1992. A comprehensive meteorological modeling system RAMS. *Meteorology and Atmospheric Physics*, 49(1-4), 69-91.

Yoshikado, H., Shirakawa, Y., Nakano, T., Kudo, Y., Suzuki, M., 2006. Feasibility of a method simulating long-term average concentration of pollutants based on a mesoscale meteorological model (I) classification of weather patterns and application to NOx in the Kanto Plain, *Journal of Japan Society for Atmospheric Environment*, 41, 1-14 (in Japanese with English abstract).