MODELING STUDY OF SEASONAL AND INTERANNUAL VARIATION OF TRANS-BOUNDARY AIR POLLUTION IN EAST ASIA

Itsushi UNO*
Research Institute for Applied Mechanics, Kyushu University, Kasuga, Fukuoka, JAPAN

Toshimasa OHARA, Hiroshi TANIMOTO
National Institute for Environmental Studies, Tsukuba, Ibaraki, JAPAN

Kazuyo YAMAJI
Frontier Research Center for Global Change, Yokohama, Kanagawa, JAPAN

1. INTRODUCTION

Fast growing East Asian countries with their rapid increase in population and economies and, consequently, with their augmented energy consumption and production, show a dramatic increase in emissions of air pollutants like sulfur oxides, nitrogen oxides, ozone and particulates. As a consequence, long-range transboundary air pollution and acid deposition are becoming major concerns of environmental protection agencies in each country.

Recently it was reported that tropospheric O_3 levels observed over Japan have been rising in the last three decades, likely as a consequence of increasing emissions of nitrogen oxides (NO_x) from Asia. Emissions from Asia also have a potential impact through intercontinental transport on air quality over the United States, and on widespread O_3 pollution in the Northern Hemisphere [e.g., Jacob *et al*., 1999; Jaffe *et al*., 1999]. Chemical transport model studies predicted that O_3 levels would be enhanced in future particularly over Asia, where NO_x emissions were estimated to increase most severely [Prather *et al*., 2003]. Under these circumstances consideration of hemispheric and regional influences is crucial to design strategies to meet with National Ambient Air Quality Standards (NAAQS) in Japan, which is currently set at 60 ppb as hourly mean.

The present study focuses on the seasonal and inter-annual variation and distribution of pollutants over East Asia using the Community Multi-scale Air Quality model (CMAQ) [Byun and Ching, 1999] based on the multi-year simulation. The CMAQ modeling system has been applied previously to study of the transport and photochemical production of tropospheric O_3 in East Asia [Zhang *et al*. 2002; 2003; 2004]. While these studies were limited to particular months or seasons, this study is the first attempt to apply the CMAQ system to a full-year simulation over East Asia. In this paper, the reproducibility of O_3 concentrations from CMAQ are first confirmed by comparison with observed O_3 concentrations at Japan monitoring sites. Next, we show the seasonal/inter-annual variation in the distribution of O_3 concentrations over East Asia.

2. MODEL DESCRIPTIONS

The transport and transformation of air pollutants and aerosols over East Asia for years between 1998 and 2004 was simulated using CMAQ version 4.4 driven by meteorological fields obtained from the Regional Atmospheric Modeling System (RAMS) version 4.3 [Pielke *et al*., 1992]. The Statewide Air Pollution Research Center, Version 99 (SAPRC-99) chemical mechanism which includes 72 species and 214 reactions [Carter, 2000] with an Euler Backward Iterative (EBI) solver was adopted for gas phase chemistry. The RAMS simulation used three-dimensional meteorological fields from NCEP/NCAR 2.5° × 2.5° reanalysis data sets every 6 hours, and the validation of this simulation has been confirmed by Uno *et* al. (2005). The horizontal model domain for the CMAQ simulation is 6240 × 5440 km^2 on a rotated polar stereographic map projection centered at (25° N, 115° E) with 80 × 80 km^2 grid resolution. For vertical resolution, there are 14 layers in the terrain-following coordination system up to 23 km, with about 7 layers within the boundary layer below 2 km. Initial conditions for the chemical species modeled are based on lowest values of the observed range and the validity of these has been examined in previous studies [Zhang *et al*., 2003]. Boundary conditions

* *Corresponding author:* Itsushi Uno, Research Institute for Applied Mechanics, Kyushu University, Kasuga Park 6-1, Kasuga 816-8580; e-mail: iuno@riam.kyushu-u.ac.jp

for CMAQ were taken from monthly average output from a coupled global chemistry-climate model (CHemical AGCM for Study of atmospheric Environment and Radiative forcing; CHASER) [Sudo *et al*., 2002]. To depict aerosol evolution processes in the atmosphere, the aerosol module, AERO3 with RADM base aqua-phase chemistry was used in this study.

For this CMAQ modeling system, the anthropogenic emissions were obtained from an emission inventory with a 0.5° × 0.5° resolution developed by FRCGC (Frontier Research Center for Global Change) for the year 2000 base case (T. Ohara 2005, private communication). FRCGC-NMVOC emissions were divided into the lumped-hydrocarbon categories of SAPRC-99 using the method of Carter(2000). Emissions from biomass burning were based on monthly data estimated by Streets *et al*. (2003).

3. OBSERVATION DATA

In the present study observational data at 7 Japanese ground-based remote stations (from the Acid Deposition Monitoring Network in East Asia (EANET) for Rishiri, Tappi, Sadoseki, Oki, Tsushima, Ebino, and Hedo and from the WMO World Data Centre for Greenhouse Gases (WDCGG) for Yonaguni) during recent 7 years (1998-2004) have been collected to analyze chemical climatology over East Asian.

4. RESULTS AND DISCUSSION

We will analyze the observation data to get the typical seasonal and inter-annual variation of pollutant. Potential impact of continental-scale O_3 transport on NAAQS in Japan is also discussed. Here we will briefly summarize the main results to be presented at workshop place.

At first, the 3-hour averaged time variation of simulated and observed O_3 concentrations at each monitoring site are intensively compared and will show that CMAQ multi-year application retrieves the observed major seasonal variation.

Secondly, we will show the latitudinal concentration gradients (from 25˚N – 45˚N along the Japan islands) and its seasonal variation. We also try to analyze the typical outflow flux of trans-boundary pollutants. Some of the sensitivity analysis will be conducted to show the role of chemical reactions for controlling the O_3 level in East Asia.

Thirdly, we will show the inter-annual variation of pollutants level based on the 7 years observation and CMAQ simulation. One of the important points is the magnitude of inter-annual variations of O_3 with fixed emission intensity (year 2000 base) shows the large variation and its range of variation is almost comparable with that of observation. This fact indicates the inter-annual variation of regional meteorology/climate plays an important role to understanding the inter-annual increase of concentration level.

We will make a systematic analysis for O_3, CO, NO_y and SO_4 based on the CMAQ multi-year simulation.

5. CONCLUSION AND FUTURE PLANS

Multi-year CMAQ simulation from the year 1998 and 2004 is quite successful (using the AMD Opteron cluster computers), and model results are compared with the 7 year O_3 and CO observation data. Model results provide important information to understanding the seasonal and inter-annual pollutant concentration change.

We will continue our research in the following directions. (1) establish the web site to open the model results for field observation groups, (2) extend the model study by introducing the nesting capability and try to make similar multi-years simulation with horizontally 20 km resolution around Japan, (3) CMAQ simulation for the year 2020 based on the IPCC AGCM/RAMS meteorology and FRCGC 2020 emission inventory to examine the O_3 and other pollution level in East Asia.

References

Byun, D.W., Ching, J.K.S., 1999. *Science algorithms of the EPA Models-3 community multi-scale air quality (CMAQ) modeling system.* NERL, Research Triangle Park, NC. EPA/600/R-99/030

Carter, W.P.L., 2000. Documentation of the SAPRC-99 chemical mechanism for VOC reactivity assessment. *Final report to California Air Resource Board*. Contract No. 92-329 and 95-308.

Jacob, D.J., et al., 1999. Effect of rising Asian emissions on surface ozone in the United States, *Geophys. Res. Lett.*, 26, 2175-2178.

Jaffe D.A., et al., 1999. Transport of Asian Air Pollution to North America, *Geophys. Res. Lett*. 26, 711-714.

Pielke, et al, 1992. A comprehensive meteo-rological modeling system –RAMS. *Meteorology and Atmospheric Physics*, 49, 69–91.

Prather, M., et al., 2003: Fresh air in the 21st Century? *Geophys. Res. Lett*., 30, 1100, doi:10.1029/2002GL016285.

Streets, et al., 2003. An inventory of gaseous and primary aerosol emissions in Asia in the year 2000. *J. Geophy. Res.* 108, 8809, doi:10.1029/2002JD003093

Sudo, K., et al., 2002. CHASER: A global chemical model of the troposphere - 2 . Model results and evaluation. *J. Geophy. Res*. 107, 4586, doi:10.1029/2001JD001114.

Uno, I. et al., 2005. Development of RAMS/CMAQ Asian Scale Chemical Transport Modeling System, *J. Jpn. Soc. Atmos. Environ*. 40, 148-164 (in Japanese).

Zhang, M. et al., 2002. Numerical study of boundary layer ozone transport and photochemical production in east Asia in the wintertime. *Geophys. Res. Lett*, 29, 1545, doi:10.1029/2001GL014368.

Zhang, M. et al., 2003. Large-scale structure of trace gas and aerosol distributions over the western Pacific Ocean during the Transport and Chemical Evolution Over the Pacific (TRACE-P) experiment. *J. Geophy. Res* 108, 8820, doi:10.1029/2002JD002946.

Zhang, M. et al., 2004. Transport and Transformation of Sulfur compounds over East Asia during the TRACE-P and ACE-Asia Campaigns' *Atmos. Environ*. 38, 6947-6959.