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IMPACTS OF INTERSTATE TRANSPORT OF POLLUTANTS ON OZONE AIR QUALITY ATTAINMENT IN THE MID-ATLANTIC REGION

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1. INTRODUCTION

Ozone is formed in the atmosphere through photochemical reactions and has been found to be associated with adverse human health effects. One important indicator of regional air quality is the daily maximum 8-h average ozone (MDA8h O3) which is regulated by National Ambient Air Quality Standards (NAAQS) under the U.S. Clean Air Act. In order to reduce the transported pollution that affects the air quality in the downwind areas, the US Environmental Protection Agency (EPA) issued the Cross-State Air Pollution Rule (CSAPR) to help the nonattainment areas meet the ozone standard in 2012. Observations show that summertime ozone has caused nonattainment of NAAQS over the Mid-Atlantic region in the U.S. Since long-range transport of air pollutants could cause air pollution issues in downwind areas, the goal of this study is to investigate how anthropogenic NOx and VOC emissions from neighboring regions affect ozone air quality attainment in the Mid-Atlantic region.

The results of this study will help policy-makers develop emission control strategies for attaining ozone air quality standards in the Mid-Atlantic region.

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2. METHODOLOGY

2.1 Model Description

The US EPA's Community Multi-scale Air Quality Model (CMAQ) version 4.7.1(Byun; Schere 2006), with CB05 (Yarwood et al. 2005) gas-phase chemical mechanisms, was used to simulate three dimensional gridded concentrations of ambient ozone and other air pollutants over the Ozone Transport Commission (OTC) region for the period of August 1-15, 2007. Ten spin-up days were used in the simulations to minimize the effect of initial conditions on the modeling results. The Fifth-Generation NCAR/Penn State Mesoscale Model (MM5) (Grell et al. 1994; Seaman 2000) was used to provide meteorological fields for the regional air quality simulations. The Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system was applied to prepare the emissions of air pollution precursors.

The modeling domain was divided into four regions: CENRAP, LADCO, MANE-VU and SEMAP (Figure 1). A uniform of 12 by 12 km horizontal cells with 34 vertical layers was configured in the simulations. Impacts of interstate transport of pollutants on ozone air quality for four nonattainment areas, Pittsburgh-Beaver Valley, Washington DC, Baltimore and Philadelphia-Wilmin-Atlantic

City, were specially investigated (Figure 2).

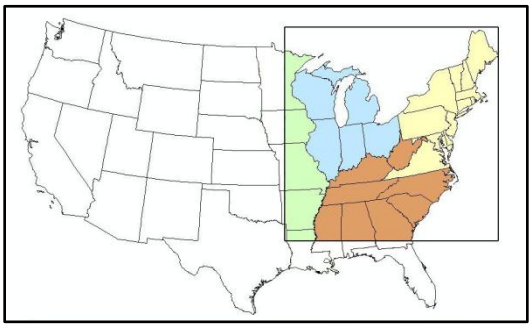

Fig.1 Four regions of the modeling domain (CENRAP, LADCO, MANE-VU and SEMAP)

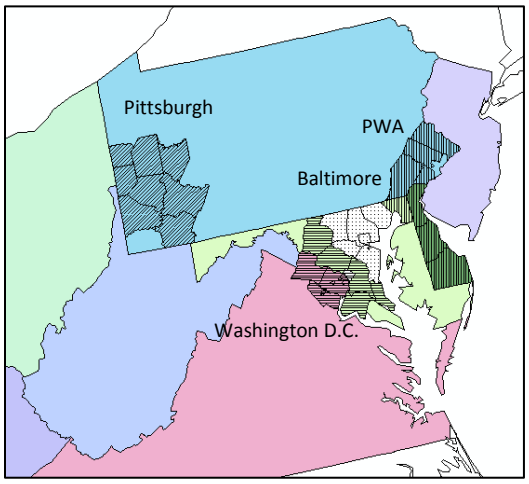

Fig.2 Four nonattainment areas in the Mid-Atlantic region (Delaware, District of Columbia, Maryland, Pennsylvania, Virginia and West Virginia)

2.2 Sensitivity Analysis using the Decoupled Direct Method

The decoupled direct method 3D (DDM-3D), an efficient approach to investigate how precursor emissions affect the air pollutant concentrations, is include in CMAQ v4.7.1 (Dunker 1981, 1984; Dunker et al. 2002; Yang et al. 1997).

CMAQ with DDM-3D directly calculates the first-order sensitivities of both gas- and condensed-phase pollutants to precursor emissions. First-order sensitivities represent the locally linear responses of pollutant concentrations to emission changes and have the same units as the concentrations. We use first-order Talylor series to calculate the sensitivity coefficients as follows:

$$S_{i,j} = E_j \frac{\partial C_i}{\partial E_j} \qquad (1)$$

where $S_{i,j}$ is the first-order sensitivity of pollutant concentration i (C_i) to source emissions j (E_j). These sensitivities are local and represent how pollutant concentrations respond to precursor emission changes as if the systems were linear.

3. RESULTS

Since the simulations of sensitivities of ozone concentrations to emissions from EGU point sources are still in progress, impacts of emissions from EGU point sources on air quality in the Mid-Atlantic region are not included in the discussion here. The Baltimore area has suffered from high ozone concentrations during the summertime. A long-term statistical study shows that ozone air pollution events in Baltimore and Washington, D.C. were related to sunny and hot conditions as well as high wind speeds from the west and northwest (Walsh et al. 2008).

During the modeling episode of August 1-15, 2007, anthropogenic NOx emissions from the MANU-VU region significantly contribute to MDA8hO3 concentrations in D.C. (about 10ppv, not including emissions from EGU sources) (Figure 3). Anthropogenic NOx emissions from the SEMAP region and VOC emissions from the

MANE-VU region also contribute to high MDA8h O3 levels in the D.C. area. Similar to the D.C. area, peak ozone concentrations in Baltimore was attributed to anthropogenic NOx and VOC from MANE-VU region when emissions from EGU sources were not taking into account (Figure 4). Anthropogenic NOx and VOC from the MANU-VU region also contributed to ozone formation in the Philadelphia-Wilmin-Atlantic City area (Figure 5). In these nonattainment areas, the high MDA8h O3 was mainly attributed to emissions from the MANE-VU region. Therefore, reductions in anthropogenic NOx and VOC emissions for the MANE-VU region were expected to improve ozone air quality in the nonattainment areas in the Mid-Atlantic Region.

The MDA8h O3 levels in Pittsburgh-Beaver Valley were attributed to NOx and VOC emissions from the MANU-VU region, which were up to about 8 ppb and 2 ppb, separately (Figure 6). In addition, contributions of anthropogenic NOx from the LADCO and SEMAP regions to MDA8h O3 levels were up to about 7 ppb and 6 ppb, respectively.

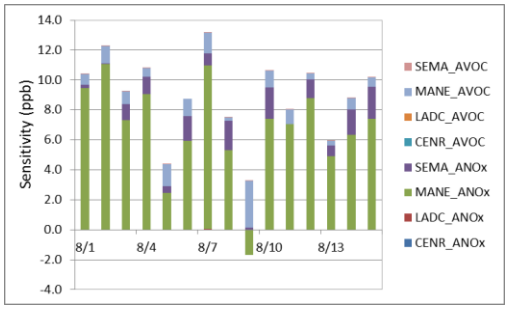

Fig.3 Sensitivity of MDA8hO3 to anthropogenic NOx and VOC emissions for DC

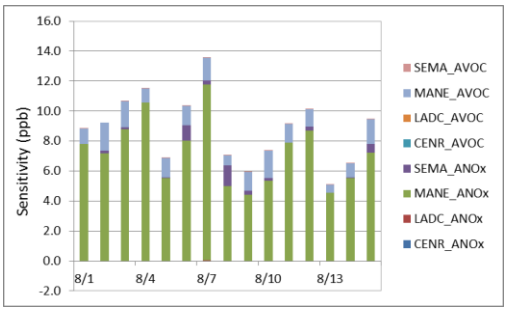

Fig.4 Sensitivity of MDA8hO3 to anthropogenic NOx and VOC emissions for Baltimore

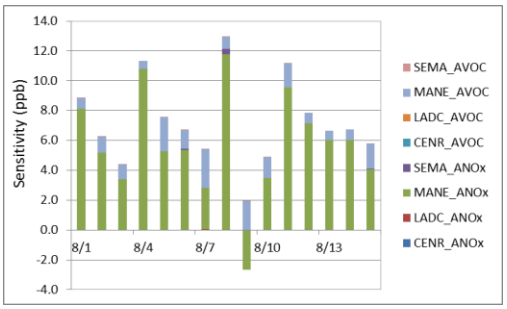

Fig. 5 Sensitivity of MDA8hO3 to anthropogenic NOx and VOC emissions for Philadelphia-Wilmin-Atlantic City

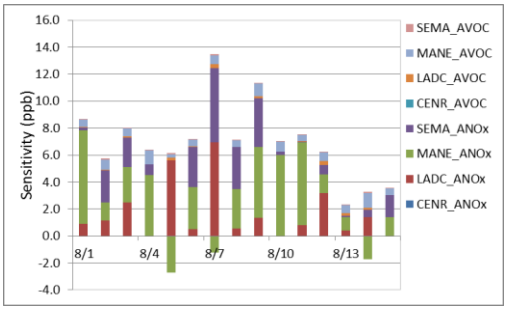

Fig.6 Sensitivity of MDA8hO3 to anthropogenic NOx and VOC emissions for Pittsburgh-Beaver Valley

4. CONCULUSION

The decoupled direct method was used to determine the responses of MDA8hO3 to

anthropogenic NOx and VOC emissions for the Mid-Atlantic region. Anthropogenic NOx and VOC from MANE-VU significantly contributed to MDA8h O3 formation in the nonattainment areas over the Mid-Atlantic region. Interstate transport of air pollutants played an important role in the ozone air pollution issue over the Mid-Atlantic region. In order to meet the ozone NAAQS , reductions in anthropogenic NOx and VOC emissions from the MANU-VU region were expected to help the nonattainment area improve the air quality in Mid-Atlantic region.

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