The influence of ozone from outside state: Towards cleaner air in Minnesota

Extended Abstract # 33368

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INTRODUCTION

Tropospheric ozone is a major air pollutant and greenhouse gas, and is produced by photochemical oxidation of volatile organic compounds (VOCs) and CO in the presence of nitrogen oxides (NO_x). Ozone and its precursors can stay in the lower troposphere for a few days, thus they can undergo long-range transport from one state to another. As the federal air quality standards get stricter, and oil and gas productions in upwind states and Canada rapidly expand, downwind states like Minnesota will face more challenges in future ozone air quality management. It is becoming very important to consider the transport of ozone and its precursors from neighboring states when designing effective air pollution control strategies. The Environmental Protection Agency (EPA) has been trying to address the problem of cross-state transport of air pollution for about three decades[1]. However, little research has been done to quantify the magnitude of transported versus "homemade" ozone on the state scale.

The purpose of this study is to evaluate the contribution of ozone sources outside state (transported ozone) versus the contribution of local sources to the ozone levels in the case of Minnesota State. Focusing on the summer of 2011, we use a combination of field observations and model experiments to quantify the amount of ozone from local pollution sources that may be regulated by air quality management as opposed to the amount from natural background and from regional transport.

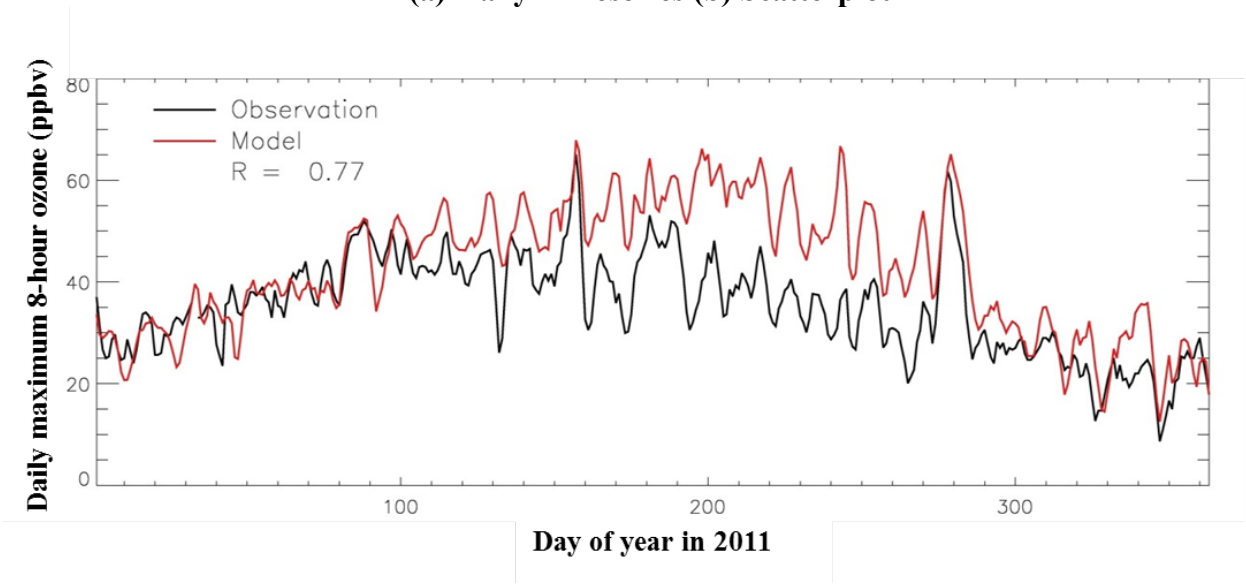
METHOD

We use the state-of-the-art GEOS-Chem 3-D chemical transport model (version 9-01-03) to conduct experimental simulations. GEOS-Chem includes detailed HO_x-NO_x-VOC-Ozone chemistry coupled to aerosols as originally described by Bey et al. (2001)[2], driven by NASA Goddard Earth Observing System assimilated meteorological fields (GEOS-5.2.0). More detailed description of the GEOS-Chem model regarding its development and recent updates can be found at www.geos-chem.org.

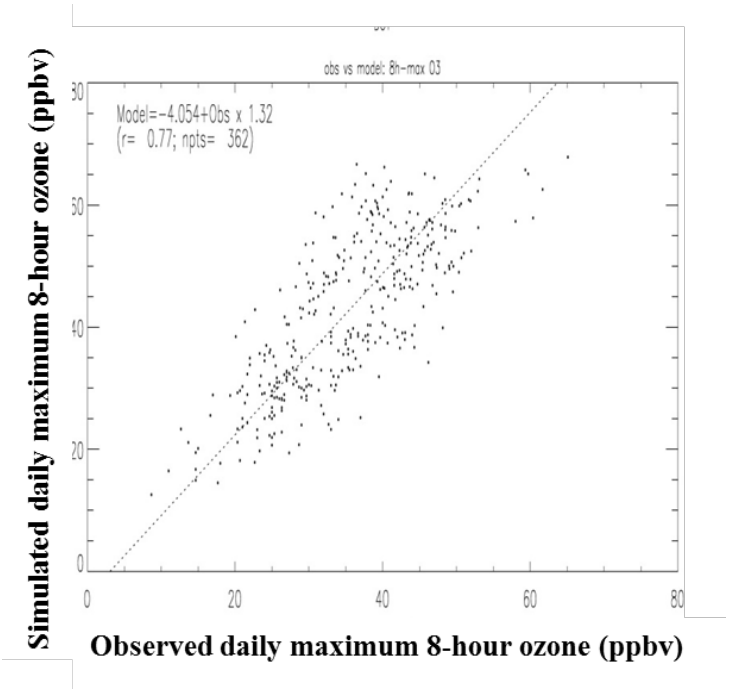
For this work, we use the GEOS-Chem nested grid full chemistry simulation over North America with a focus on the Upper Midwest for 2011. The North American nested grid domain covers 10°N to 70°N and 140°W to 40°W, with 0.5° × 0.667° horizontal resolution (~50 km) and 47 vertical layers with 14 layers below 2 km altitude. The time resolution for model transport and convection is 10 min, and the emission and chemistry time step is 20 min. A one year spin-up is used to remove the effects of initial conditions. Lateral boundary conditions for the nested grid simulations for all species at each vertical layer are based on 3-hourly output from year-long global simulations carried out at 4° × 5° resolution. The detailed model parameter settings are described in our previous work by Hu et al. (2013)[3]. In this work, we use the MEGANv2.1 to compute biogenic VOC emissions and the EPA's National Emission Inventory 2005 for the anthropogenic fluxes for VOCs, CO, and NO_x. Biomass burning emissions are based on the monthly GFED3 inventory.

GEOS-Chem simulations have been previously evaluated extensively with ground/ aircraft/ satellite observational data[4]. Here, we further assess the model's ability to reproduce observed ozone in the Upper Midwest region by comparing simulated daily maximum 8-h average ozone concentration (MDA8h O_3) in 2011 with observed concentration from EPA monitoring stations. The model generally well agrees with the observed data, and it is able to reproduce the trend of daily variations (Figure 1). However, the model over-estimates Minnesota ozone in the summer, which might be due to an overestimation of NO_x emissions.

Figure 1. Comparison of model simulated ozone and observed ozone in Minnesota (a) Daily Timeseries (b) Scatterplot



(a)



(b)

RESULTS

We have conducted two model experiments to estimate the ozone from local pollution sources in Minnesota vs. from regional transport and the "background" (stratosphere intrusion, lightening, intercontinental transport, etc.):

1) Standard simulation (base run).
2) Perturbed run with Minnesota local sources turned off, including anthropogenic sources of CO and NO_x, and both anthropogenic and biogenic sources of VOCs.

The simulated ozone from the perturbed run (left frame of Figure 2) can be considered to represent the contributions of sources outside Minnesota (regional transport + background). The differences between these two runs (right frame of Figure 2) can be used to approximately represent the contributions of Minnesota local sources alone. Note that due to the non-linear nature of ozone response to emission changes of its precursors, this approach cannot perfectly reflect the contributions of local sources alone, but can still provide a good approximation[4,5]. Figure 2 and Figure 3 show that during the summer of 2011 the locally produced ozone is about 5-15ppb (~25%), while the transported and background ozone contribute about 40-45ppb (~75%). The contributions from local sources are much larger in the Twin Cities metro area, revealing the important role of local urban sources.

Figure 2. Model simulations of summer average MDA8h O_3 in 2011: Contribution of sources outside Minnesota state (left) vs. contribution from local source alone (right)

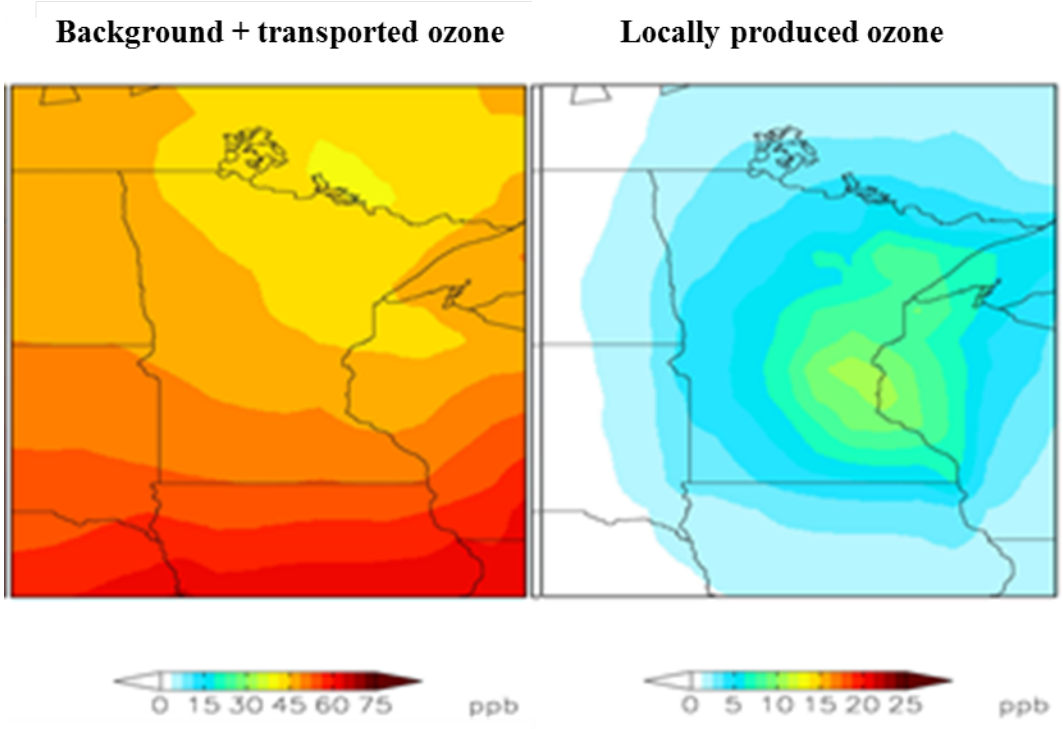
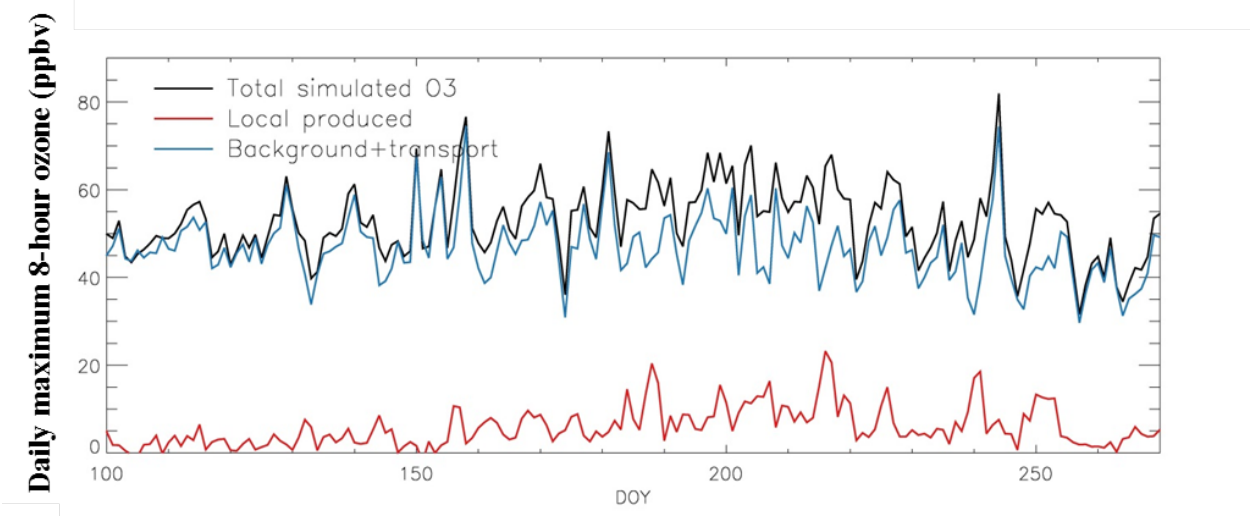


Figure 3. Timeseries of model simulated MDA8h O_3 in Minnesota in 2011



To further examine the magnitude of the transported ozone in Minnesota, we need to know the value of the background ozone. The EPA defined North American background ozone as the surface ozone concentration that would be present in the US in the absence of anthropogenic emissions from North America[6]. Recent studies reported the background ozone in the Midwest is about 27±8 ppb in spring-summer[7, 8]. Assuming the background ozone is 30ppb in Minnesota, the regional transported ozone might be ~10-25ppb (~25%).

SUMMARY

This is the first study to quantitatively estimate the magnitude of transported ozone in the state Minnesota. Our model experiments suggest that emission sources outside the state exert a significant influence on Minnesota's air quality. Local sources and cross-state transport each contributes ~25% of the simulated summer ozone. Controlling only local sources in Minnesota will not be sufficient to attain the air quality goal set in the future.

The methodology developed in this research could be applied to other states for cross border air pollution transport problems. It can also be applied to study other pollutants such as particulate matter. The results will provide scientific basis for regional ozone air quality management and emission control strategies.

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KEYWORDS

ozone, transport, Minnesota, GEOS-Chem.