P1.3 SIMULATING THE EFFECTS OF URBAN-SCALE LAND USE CHANGE ON SURFACE METEOROLOGY AND OZONE CONCENTRATIONS IN THE NEW YORK CITY METROPOLITAN REGION

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1. INTRODUCTION

Large-scale urbanization can have a profound impact on air quality, regional climate, and ecosystem and human health. This is particularly true in a metropolis such as New York City, whose consolidated metropolitan area covers portions of four states and whose population exceeds 21 million. One of the goals of the New York Climate and Health Project (please see http://www.mailman.hs.columbia.edu/ehs/NYCHP1.html) is to develop a modeling framework to examine the effects of global climate and land use change on human health now and in the future. Here we present our preliminary findings on the effects of current and future land cover scenarios on surface meteorological fields and ozone (O_3) concentrations in the New York City region. Analysis of the model simulations is ongoing, and more complete results will be presented at the upcoming AMS Annual Meeting's 7th Conference on Atmospheric Chemistry.

2. MODELING SYSTEM

The nonhydrostatic, primitive equation MM5 (Dudhia 1993) was used to generate the three-dimensional meteorological fields over much of the eastern US from July 12-16, 1995 (Civerolo et al. 2000). The model used 32 pressure-following vertical layers to about 16 km AGL, with the lowest layer 20 m thick. Simulations were performed at a horizontal grid resolution of 4 km, with initial and hourly boundary conditions provided by Seaman (1996). The planetary boundary layer utilized was the Blackadar scheme (Zhang and Anthes 1982), a simplified slab model that does not explicitly predict soil moisture. Figure 1(A) displays the modeling domain.

The New York City metropolitan area was the region of interest for this study, and it was critical to make use of land use/cover information specific to this region. Briefly, high-resolution (~70 m) land use information were obtained from recent SLEUTH model estimates (Solecki and Oliveri 2004) of the conversion of rural-to-urban land cover using the Urban Growth Model (UGM) and Land Cover Deltatron Model (LCDM) across the 31-county metropolitan region. SLEUTH includes the following land use classes: wetlands, water, urban, barren, forest, agriculture, and range. We further subdivided the single urban land use class into three, based upon the remotely sensed vegetative fraction: "high" urban, vegetative fraction <22%; "medium" urban, vegetative fraction 22-51%; and "low" urban, vegetative fraction > 51%. The SLEUTH domain is smaller than the MM5 4 km domain, and where there is overlapping coverage the SLEUTH land use data were aggregated into the appropriate MM5 grid cells. If the dominant land use was an urban category based on the SLEUTH results, the category was assigned to the MM5 grid; otherwise, the default MM5 land use designation was kept.

We generated two sets of MM5-ready land use files, the first corresponding to a base case in which urban growth from 1960-1990 was used to estimate a "current" (ca. 1990) land use pattern. In the second simulation, we used SLEUTH results based on the Intergovernmental Panel on Climate Change (IPCC) "A2" emissions scenario for the year 2050 (please see http://www.ipcc.ch/pub/sres-e.pdf). Briefly, the IPCC A2 scenario assumes large increases in greenhouse gas emissions, relatively weak environmental concerns, and high population growth. Both simulations were driven with the same meteorological fields. See Figures 1(B) and 1(C) for the base year (ca. 1990) and future year (ca. 2050) urban land cover, respectively, in the New York City metropolitan region. Evident in these figures is the substantial increase in the "low" urban cover across the entire metropolitan region as a result of this fairly pessimistic scenario.

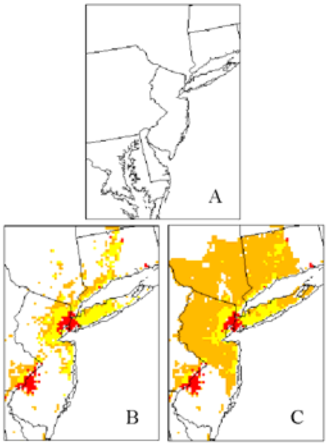

Figure 1. (A) The MM5 modeling domain. (B) Base year urban land cover in the New York City region, where red denotes "high" urban, yellow denotes "medium" urban, and orange denotes "low" urban. (C) Same as (B), except for future year.

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After generating the meteorology for this episode, we used the US EPA Community Multiscale Air Quality (CMAQ) model (Byun and Ching 1999) to predict the O_3 concentrations across the domain. Simulation results are available from July 13-15, 1995, and details of the photochemical model configuration can be found in a similar study by Hogrefe et al. (2004). The anthropogenic and biogenic emissions specific to the summer of 1995 were generated using the Sparse Matrix Operator Kernal Emissions (SMOKE) processing system (Houyoux et al. 2000).

3. PRELIMINARY RESULTS

3.1 Surface meteorology

Figures 2(A)-(C) display the average diurnal variation in temperature, water vapor mixing ratio, and planetary boundary layer (PBL) height from July 13-15 over the 57 non-water grid cells that define New York City. On average, in the A2 scenario: the surface temperatures increased by a few tenths ºC during the afternoon and early evening hours; nighttime mixing ratios generally decreased; and afternoon PBL heights generally increased slightly. All of these effects are small on average, but are consistent with increased impervious surface cover and decreased moisture availability. We are currently examining these parameters – as well as wind speed/direction and cloud cover – over a larger region.

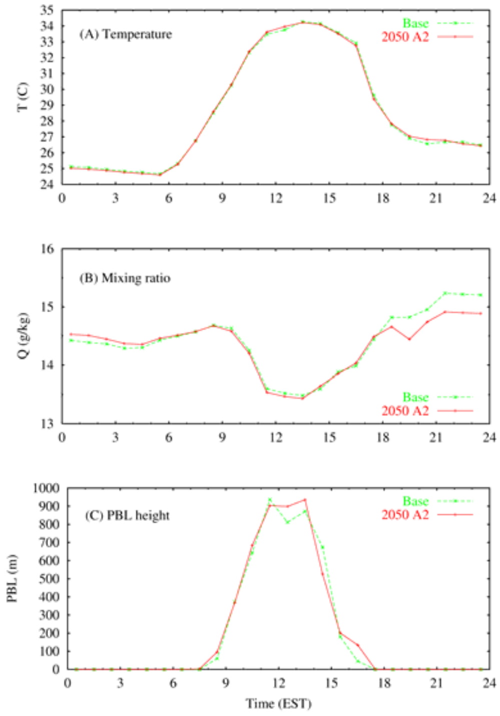

Figure 2. Diurnal variations of (A) surface temperature, (B) water vapor mixing ratio, and (C) PBL heights across New York City from July 13-15. The base year simulation is shown in green, and the future year simulation is shown in red.

3.2 Surface O_3 concentrations

Figures 3(A) and (B) display the episode maximum O_3 concentrations in the New York City region at each grid cell for the base and future years, respectively, and the differences in episode maximum O_3 ("future" – "base") are shown in Figure 3(C). While Figures 3(A) and (B) are qualitatively similar, a few differences are apparent. First, O_3 concentrations in the A2 scenario increased in New York City and parts of eastern New Jersey. The largest increases in O_3 occurred over southern Connecticut, downwind of the core urban area. At the same time, maximum concentrations in central and northern New Jersey were slightly lower in the A2 scenario, possibly due to higher rates of O_3 or peroxy radical titration by nitrogen oxides (NOx). These initial findings highlight the complex interactions between meteorology, emissions, land surfaces, and O_3 fields, and will be explored further.

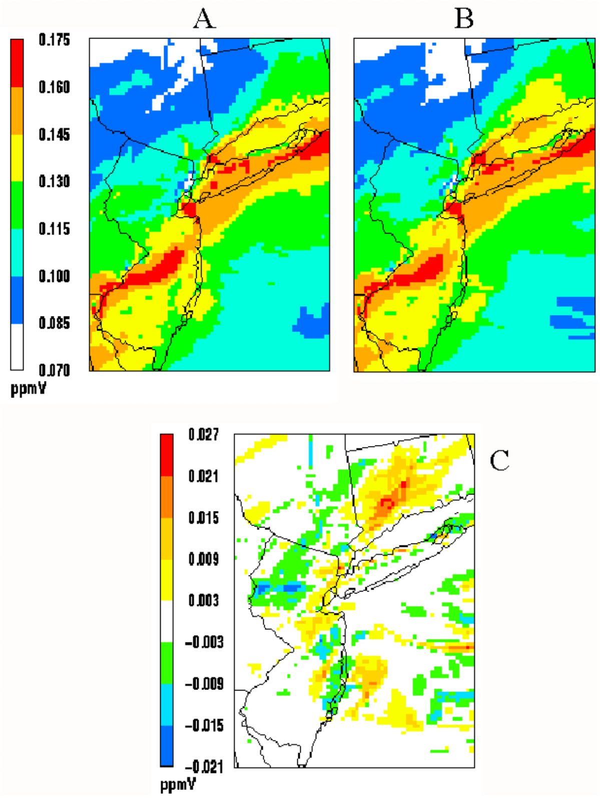

Figure 3. Episode (July 13-15) maximum O_3 concentrations for the (A) base year and (B) future year simulations, in ppm, as well as (C) the difference in episode maximum O_3.

5. ACKNOWLEDGMENTS AND DISCLAIMER

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