1. Introduction

Understanding the future changes in the surface ozone concentration is crucial for the U.S. Environmental Protection Agency (EPA) to set the national ambient air quality standard. The changing future climate, land-use can contribute to the changes in surface ozone concentration (e.g., Hoguefe et al. 2004; Civerolo et al. 2007). However their impacts remain highly uncertain, in particular, the impacts resulted from land-use change (Hoguefe et al. 2007). This paper addresses the expected ozone changes due to changes in climate and land-use predicted for the year 2050s over the greater Houston area.

2. Modeling Framework

To obtain the high-resolution initial and boundary meteorological conditions, the Weather Research and Forecasting (WRF) model at 12-km coarse grid was run driven by 6-hourly lateral boundary conditions defined by the Community Climate System Model (CCSM) version 3 outputs. The outputs from 12-km runs were used as the inputs for the WRF with chemistry model (WRF-CHEM) (Grell et al. 2005) at 4-km grid spacing centered on the Houston area. The following options were applied for the simulations: Grell cumulus scheme, WSM 5-class microphysics scheme, Yonsei University Planetary Boundary Layer (PBL) scheme, simple cloud interactive radiation scheme and Rapid Radiative Transfer Model (RRTM) longwave radiation scheme. The Regional Acid Deposition Model version 2 (RAD2M) chemical mechanism was used to simulate gas phase chemistry. We used Noah land surface model (LSM) coupled with an Urban Canopy Model (UCM) in the WRF-CHEM model.

3. Experiment Design

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Simulation period</th>
<th>Emissions</th>
<th>Land use</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASE</td>
<td>August, 2001-2003</td>
<td>NE896+BE315</td>
<td>MODIS land cover + NLCD land use</td>
</tr>
<tr>
<td>CL</td>
<td>August, 2001-2003</td>
<td>NE896+BE315</td>
<td>MODIS land cover + NLCD land use</td>
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<tr>
<td>CL + EMIS</td>
<td>August, 2001-2003</td>
<td>Future emissions + BEIS 3</td>
<td>MODIS land cover + Future land use</td>
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<td>MODIS land cover + Future land use</td>
</tr>
</tbody>
</table>

4. Land-Use Datasets

Fig. 1. The three urban land use categories

5. Evaluation of Simulation Results

Fig. 2. Simulated diurnal ozone and 2-m temperature during August, 2001–2003

Figure 2 shows that the major diurnal features of simulated temperature and ozone concentration are fairly similar to the observations, especially during the daytime.

6. Results

Fig. 3. Simulated regional climate change during the afternoon (12-18 LST) differences between CL-LU and BASE simulations

Our model simulates a significant rise of the surface temperature in the year 2050s for August. The highest increase in surface temperature during 12-18 LST occurs over the Houston urban area with the averaged value at 3.3°C. In other regions, the average surface temperature is predicted to increase by about 2°C. Under the future changes in climate and land-use, the Houston urban area becomes drier. The PBL height tends to increase by more than 250 meters over the Houston urban area. Enhanced warming in the Houston area also leads to a decrease in the afternoon wind speed.

Fig. 4. As in Figure 3 but for the differences in (a) ozone concentration and (b) the number of days with the daily maximum 8-hr ozone concentration larger than 84 ppb.

The effect of climate change accounts for an increase of 2.6 ppb in daily maximum 8-hr ozone concentration over the urban area. Land-use change exerts more influence on the daily maximum 8-hr ozone than climate change in the urban area. The combined effect of land-use change and climate change can be up to 6.2 ppb. However, in the Zone B which is more likely affected by the changed water vapor mixing ratio and wind field, the impact of climate change is more distinctive than that of future urban land-use change. The combined effects of climate and land-use change to changes in daily maximum 8-hr ozone concentration from the 2000s to the 2050s.

7. Conclusions

Under the future A1B scenario, the effects of climate and land-use changes on surface ozone are at least equally important in the Houston area. An increase of the number of extreme ozone days is found near the urban area, but not exactly in the urban center. Future change in anthropogenic emissions is also an important factor in raising ozone concentration in the Houston area.

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Land-use change plays an important role in the change of the number of extreme ozone days. The sensitivity experiments on the impacts of anthropogenic emissions show that the impacts of future change in anthropogenic emissions are comparable with the effects of land-use change on ozone concentration.