Effects of climate change on future wildfire and its impact on regional air quality

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Introduction

- Downscaling from Global simulation to regional simulation is crucial
  - GISS $\rightarrow$ MM5
  - GEOS-Chem $\rightarrow$ CMAQ
  - Global scale Wildfire emission $\rightarrow$ fine resolution wildfire emission
Downscaling (1) meteorology

- GISS (4°x5°) → 108 km MM5 → 36 km MM5 (grid nudging applied)
- Surface Temperature (JJA)

**GISS**

2000 JJA

2050 JJA

2050 - 2000
“Geos2cmaq-3.0” linkage tool was used to generate boundary condition (BCON) of CMAQ simulation from GEOS-Chem output.
Downscaling (3) wildfire

- Prediction of future wildfire (Spracklen, 2009)
- Area burned in 2000 and 2050 are regressed based on observed meteorological fields and fire indices from the Canadian Fire Weather Index system.

1. Area Burned Predictors in Western United States

   - Annual area burned (AB) on 1° x 1° [Westerling et al., 2002]
   - Stepwise regression of natural log (de-seasonalised monthly Area Burned) against monthly mean and max met. and FWI parameters

Predicting forest fire area burned in a future climate
Downscaling (3) wildfire – conti.

- Fire occurrence is a function of land cover and weather condition.
- Using Haines index and HMS fire data, 1km x 1 km x 1 day fire occurrence probability table is set.
- Given area burned data, fire events are generated from the highest fire probability pixels.
Simulation options

<table>
<thead>
<tr>
<th>Model</th>
<th>version</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>MM5</td>
<td>3.6.1</td>
<td>USGS24, Grell convection, RRTM radiation, MRF pbl, NOAH LSM</td>
</tr>
<tr>
<td>MCIP</td>
<td>3.2h</td>
<td></td>
</tr>
<tr>
<td>SMOKE</td>
<td>2.1h</td>
<td>NEI99</td>
</tr>
<tr>
<td>Fire</td>
<td></td>
<td>80/20 plume rise, 50% decaying rate</td>
</tr>
<tr>
<td>CMAQ</td>
<td>4.6</td>
<td>CB4 (cb4_aq_ae4), PPM advection, Eddy vertical diffusion, RADM cloud</td>
</tr>
</tbody>
</table>

- Domain: CONUS 36km
- 2000 ("normal" year) & 2050 ("worst" year, active wildfire year) during summertime (JJA)
- Same emission and land cover/vegetation data are used for 2000 and 2050
- Fire emission retrieval method by Wiedinmyer (2006)
Results - Ozone

- Mean ozone increase by wildfire emission is smaller than the increase by temperature change.
- Fire emission enhances Ozone during the daytime, but could decrease during the nighttime.
- Daily max 8 hr Ozone over 85 ppb (pixel count):
  - 2000 base → 2050 base: 107% increased
  - 2050 base → 2050 fire: 9% increased

Ozone increase by wildfire emission

Ozone increase by temperature change

Ozone change by fire emission
Results – OC, EC & PM

OC

2000 base

2050 fire

2050 fire – 2000 fire

EC

PM2.5

OC/EC

sulfate
Summary

• Impact of climate change on wildfire activity and its consequential impact on regional air quality is studied. For regional scale air quality simulation, we have downscaled Global model outputs (GISS, GEOS-Chem, Area burned) to regional scale (MM5, CMAQ, fine resolution fire emission).

• By adding wildfire emission, PM2.5 is much enhanced, and Ozone shows some decrease at nighttime and increase during daytime.

• Changes of PM and carbonaceous aerosols are shown in the table (JJA)

<table>
<thead>
<tr>
<th>Unit : ug/m3</th>
<th>2000 base (USA/west only)</th>
<th>2000 fire</th>
<th>2050 base</th>
<th>2050 fire</th>
<th>2050 fire - 2000 fire (increase %) USA/west USA only</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM2.5</td>
<td>3.7 / 2.9</td>
<td>4.1 / 4.1</td>
<td>4.4 / 3.4</td>
<td>5.4 / 6.9</td>
<td>31 % / 68%</td>
</tr>
<tr>
<td>OC</td>
<td>0.47 / 0.79</td>
<td>0.8 / 1.83</td>
<td>0.47 / 0.85</td>
<td>1.18 / 3.23</td>
<td>47 % / 76 %</td>
</tr>
<tr>
<td>POC</td>
<td>0.12 / 0.11</td>
<td>0.39 / 0.97</td>
<td>0.12 / 0.10</td>
<td>0.73 / 2.13</td>
<td>87 % / 119 %</td>
</tr>
<tr>
<td>SOC</td>
<td>0.34 / 0.68</td>
<td>0.40 / 0.86</td>
<td>0.34 / 0.74</td>
<td>0.45 / 1.10</td>
<td>13 % / 28 %</td>
</tr>
<tr>
<td>EC</td>
<td>0.062 / 0.055</td>
<td>0.100 / 0.17</td>
<td>0.061 / 0.055</td>
<td>0.147 / 0.342</td>
<td>47 % / 101 %</td>
</tr>
</tbody>
</table>