Quantitying the impact of tropospheric ozone on crop productivity using JULES-Crop

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Abstract

Tropospheric ozone ($O_3$) is the third most important anthropogenic greenhouse gas. It is harmful to animals and detrimental to plant productivity and it causes significant crop production losses. Currently $O_3$ concentrations are projected to increase globally, which could have a significant impact on agriculture and food security. The Joint UK Land Environment Simulator modified to include crops (JULES-crop) is used here to quantify the impacts of present-day and future tropospheric $O_3$ on crop production at the regional scale until 2050.

Ozone precursors | Natural and anthropogenic sources
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Nitrogen Oxide (NOx) | NOx are the most important and common precursor
Methane (CH4) | Biomass burning and forest clearing
Carbon monoxide (CO) | Paints and coatings, benzene (tobacco smoke, fuels etc.), CFCs (refrigerants)
Volatile Organic Compounds (VOCs) | Some plants emit BVOC during growing season. Some biomass plantations contributed a lot of BVOC emissions.
Biogenic VOC (BVOC) e.g. isoprene | 

Background

Majority of tropospheric ozone is found on the land surface. It is:

- A reactive secondary pollutant formed by the photoreaction of ozone precursors.
- Harmful to animals and plants as it creates reactive oxygen species that damage cell membrane and protein structure.
- Concentrated in rural area because NOx production from vehicles in urban regions would destroy O3.

JULES Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Default</th>
<th>Tuned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top leaf nitrogen concentration</td>
<td>0.073</td>
<td>0.13</td>
</tr>
<tr>
<td>Scale factor of top leaf nitrogen to Vcmax (quantum efficiency)</td>
<td>0.0008</td>
<td>0.001</td>
</tr>
<tr>
<td>Ratio of root N to leaf N</td>
<td>1.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Ratio of stem N to leaf N</td>
<td>1.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Fractional reduction of photosynthesis by O3 (sensitivity)</td>
<td>1.40</td>
<td>0.825</td>
</tr>
<tr>
<td>Threshold of ozone flux</td>
<td>5.0</td>
<td>4.0</td>
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</tbody>
</table>

Methods

- The soybean parameters are tuned and calibrated from literature and SoyFACE results
- $A = A_0 \times f$
  
  \[ UD_O3\text{crit}\text{max}((F_{OA}-F_{O3\text{crit}}), 0.0) \]

Results

The global historical trend of ozone and CO2 impact on maize, wheat, soybean and rice yield between 1961-2005 compares with detrended observed yield from FAO statistic.