How Important are Fires for the Atmosphere?

• Summary of Emission impacts

<table>
<thead>
<tr>
<th></th>
<th>Emissions</th>
<th>Percentage of Global Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO\textsubscript{x}</td>
<td>6–10 TgN/yr</td>
<td>12–20%</td>
</tr>
<tr>
<td>CO</td>
<td>300–600 Tg/yr</td>
<td>30–45%</td>
</tr>
<tr>
<td>VOC</td>
<td>20–40 Tg/yr</td>
<td>10–20%</td>
</tr>
<tr>
<td>CH\textsubscript{4}</td>
<td>15–30 Tg/yr</td>
<td>3–6%</td>
</tr>
<tr>
<td>H\textsubscript{2}</td>
<td>5–15 Tg/yr</td>
<td>15–40%</td>
</tr>
<tr>
<td>BC</td>
<td>1–4 Tg/yr</td>
<td></td>
</tr>
<tr>
<td>OC</td>
<td>10–30 Tg/yr</td>
<td></td>
</tr>
<tr>
<td>SO\textsubscript{2}</td>
<td>2–8 Tg/yr</td>
<td>2–8%</td>
</tr>
</tbody>
</table>

Data sources: EDGAR, GEIA, RETRO, POET, GFED

– Fires have a large influence on tropospheric composition
CO columns from MOPITT during the ICARTT measurement campaign:
19-21 July 2004
CO features dominated by biomass burning
With meteorology from ECMWF and satellite-based emission estimates can reproduce features with CTMs
But how well do we understand the atmospheric impacts?
Cook et al., 2007
Mean Impact of Fires: Emissions

- Global CTM runs
  - FRSGC/UCI CTM
- Emissions from GFED v1.0
  - van der Werf 2003
  - NO\textsubscript{x}, CO, VOC

- January
  - Equatorial Africa
  - S.E. Asian agriculture
- July
  - Southern Africa, Amazon
  - Boreal forest fires
Mean Impact of Fires: NOy Deposition

January

July
Mean Impact of Fires: Zonal Ozone

January

July

kgN/km²/month

ppbv
Global Response to Fires

- **Impact on Tropospheric Budgets**

<table>
<thead>
<tr>
<th></th>
<th>With Fires</th>
<th>Without Fires</th>
<th>Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>O₃ Burden (Tg)</td>
<td>322</td>
<td>303</td>
<td>6%</td>
</tr>
<tr>
<td>O₃ Production (Tg/yr)</td>
<td>5070</td>
<td>4490</td>
<td>10%</td>
</tr>
<tr>
<td>Net O₃ Production (Tg/yr)</td>
<td>290</td>
<td>190</td>
<td>10%</td>
</tr>
<tr>
<td>O₃ Deposition (Tg/yr)</td>
<td>900</td>
<td>810</td>
<td>10%</td>
</tr>
<tr>
<td>NOₓ Deposition (Tg/yr)</td>
<td>50.1</td>
<td>39.9</td>
<td>20%</td>
</tr>
<tr>
<td>CH₄ lifetime (yr)</td>
<td>8.4</td>
<td>8.5</td>
<td></td>
</tr>
</tbody>
</table>
Features not included here…

• **Strongly episodic nature of fires**
  – Mean emissions distributed over a month (overestimate influence)
• **Self-lofting of emissions into free troposphere**
  – Emissions only injected into boundary layer (underestimate extent)
• **Surface changes following fires**
  – Reduction in biogenic VOC emissions
  – Changes in deposition processes
  – Reduced albedo over burn scars affecting photolysis rates
  – Reduced albedo due to soot over snow/ice surfaces
• **Chemistry-Aerosol interactions**
  – Scattering/absorption effects associated with smoke plume
  – Heterogeneous chemistry on aerosol particles
Earth System Interactions

- **Climate: radiative impacts**
  - Increased $O_3$ and Aerosol, but reduced $CH_4$ lifetime
  - Albedo changes: effect radiation and chemistry

- **Potential feedbacks through**
  - Sensitivity of fire ignition to climate through drought, lightning
  - Surface $O_3$ – vegetation damage – VOC emissions, $CO_2$
  - $NO_y$ deposition – fertilization effects – VOC emissions, $CO_2$
Earth System Interactions

- $\Delta O_3$
- $\Delta CH_4, \tau_{CH4}$
- $\Delta BC$
- $\Delta$ Albedo
- $\Delta$ NOy depos
- $\Delta$ VOC emissions

Fires $\rightarrow$ Climate

$\Delta H_2O, CO_2, etc.$ $\rightarrow$ Vegetation
Summary: Requirements for Fire Emissions

• Magnitude of emissions
  – $\text{NO}_x$, CO, VOCs, BC/OC and appropriate speciation

• Timing of emissions
  – Episodic in nature
  – Evolution in magnitude, intensity, speciation

• Injection height
  – Self-lofting, intensity-dependence

• Current chemistry-climate models use:
  – Monthly-mean emissions climatology (still typical)
    • But daily climatology for some periods (e.g. RETRO emissions)
  – Surface-based emissions, limited lofting
  – No albedo or vegetation interactions