Chemistry for decadal predictions

Jean-François Lamarque

NCAR
Importance of chemistry

- **Climate forcing**
  - Direct radiative forcing: ozone and methane
  - Aerosol indirect effects
- **Air quality**
  - Ozone and carbon monoxide
  - PM1, PM2.5
- **Impact on vegetation**
  - Ozone poisoning
  - Nitrogen deposition
Impact of climate on chemistry

- Change in water vapor: link with OH
- Change in temperature: different reaction rates
- Change in surface temperature: biogenic emissions
- Change in precipitation: lifetime of soluble species
- Change in stratospheric circulation: STE
- Change in meteorological conditions: heat waves
- ...
- ....
Summer surface ozone

From Wu et al., JGR, 2007
Stratospheric ozone and recovery

Fahey, 2007
Simulation with CAM3

Change in total ozone column 1979-2005

Lamarque et al., 2008
How much chemistry is needed?

• Benchmarking for air quality questions

  Gas-phase tropospheric chemistry only
  ➢ Full mechanism: 79 species
  ➢ Intermediate mechanism: 39 species
  ➢ Fast mechanism: 28 species

• High-resolution simulations (0.5°) for Mexico City and comparison with observations
Air quality: Comparison with aircraft observations

1. On most days, full and intermediate capture well the background and plume ozone; the fast mechanism captures well the background.
2. CO is will captured by all.

Red: Full mechanism
Green: Intermediate mechanism
Blue: Fast mechanism
Dots: observations
Air quality: Comparison with Mexico City surface observations

On most days, full and intermediate capture well the diurnal cycle and amplitude; the fast mechanism is much lower.
Predictability of chemistry

• Decadal variability of tropospheric chemistry is strongly constrained by changes in emissions

• Except for
  ➢ Change in OH
  ➢ Occurrence of heat waves
  ➢Wildfires
  ➢ Change in circulation pattern

• Challenges
  ➢ Reasonable methane lifetime
  ➢ Reasonable emissions
Proposal for chemistry

- Emissions consistent with RCPs
- Tropospheric (and stratospheric) chemistry for offline simulations (long-term IPCC simulations)
- Tropospheric chemistry for short-term simulations
- Aerosols
- Enough simulations to track tails of PDF
- Enough simulations to identify the role of variations in emissions
### Requirements

<table>
<thead>
<tr>
<th>Variable</th>
<th>Units</th>
<th>Spatial scale</th>
<th>Concentrations</th>
<th>Regional and sectoral emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Greenhouse gases</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂ (fossil fuel, industrial, land use change)</td>
<td>ppm and Pg/yr</td>
<td>Global average</td>
<td></td>
<td>Sum</td>
</tr>
<tr>
<td>CH₄</td>
<td>ppb and Tg/yr</td>
<td>Global average</td>
<td></td>
<td>Grid¹</td>
</tr>
<tr>
<td>N₂O</td>
<td>ppb and Tg/yr</td>
<td>Global average</td>
<td></td>
<td>Sum</td>
</tr>
<tr>
<td>HFCs²</td>
<td>ppb and Tg/yr</td>
<td>Global average</td>
<td></td>
<td>Sum</td>
</tr>
<tr>
<td>PFCs²</td>
<td>ppb and Tg/yr</td>
<td>Global average</td>
<td></td>
<td>Sum</td>
</tr>
<tr>
<td>CFCs²</td>
<td>ppb and Tg/yr</td>
<td>Global average</td>
<td></td>
<td>Sum</td>
</tr>
<tr>
<td>SF₆</td>
<td>ppb and Tg/yr</td>
<td>Global average</td>
<td></td>
<td>Sum</td>
</tr>
<tr>
<td><strong>Aerosols²</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfur (SO₂)</td>
<td>Tg/yr</td>
<td>Generated by CM community³</td>
<td>Grid</td>
<td></td>
</tr>
<tr>
<td>Black Carbon (BC)</td>
<td>Tg/yr</td>
<td>Generated by CM community³</td>
<td>Grid</td>
<td></td>
</tr>
<tr>
<td>Organic Carbon (OC)</td>
<td>Tg/yr</td>
<td>Generated by CM community³</td>
<td>Grid</td>
<td></td>
</tr>
<tr>
<td><strong>Chemically active gases</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>Tg/yr</td>
<td>Generated by CM community³</td>
<td>Grid</td>
<td></td>
</tr>
<tr>
<td>NOₓ</td>
<td>Tg/yr</td>
<td>Generated by CM community³</td>
<td>Grid</td>
<td></td>
</tr>
<tr>
<td>VOCs²</td>
<td>Tg/yr</td>
<td>Generated by CM community³</td>
<td>Grid</td>
<td></td>
</tr>
<tr>
<td>NH₃</td>
<td>Tg/yr</td>
<td>Generated by CM community³</td>
<td>Grid</td>
<td></td>
</tr>
</tbody>
</table>

Grid is 0.5°
RETRO y2000 Anth NOx (Tg/yr)  Total: 90.02 Tg/yr
Process

- Workshop in May with representatives from global emission inventories and IAMs
- Define method (regional and sectoral analysis of existing inventories, including regional) to select (or build) inventory
- Harmonization (with past and future) emissions will be made with 2000 HTAP dataset
Regional/World NOx 1960-2100

From D. Stevenson
Expected outcome (October 2008)

- Gridded (0.5°) monthly emissions 1850-2300 (every 10 years) for anthropogenic (including ODSs, biomass burning and ships/aircraft) and natural emissions consistent with the scenarios
- VOC speciation will follow the RETRO procedure
- Much larger biomass burning emissions and black carbon emissions late 1800s-early 1900s
- Many of the natural emissions will be kept constant (not biogenic VOCs)
After the emissions are available

• Emissions will be centralized and publicly distributed

• Testing of emissions will table place in the latter part of the year to identify major issues

• Additional emission datasets will become available from IAMs to study the sensitivity of chemical composition to the trajectory used in the scenario
Proposal for chemistry

- Emissions consistent with RCPs
- Tropospheric (and stratospheric) chemistry for offline simulations (long-term IPCC simulations)
- Tropospheric chemistry for short-term simulations
- Aerosols
- Enough simulations to track tails of PDF
- Enough simulations to identify the role of variations in emissions
Chemistry MIP for AR5

- Coordinated by D. Shindell (NASA/GISS) and myself (in contact with CCMval and AEROCOM)
- Will define science questions and necessary outputs
- Simulations scheduled to start in 09
- Define climatology for AOGCMs
  What to do about aerosols?
  Coordination with P. Ginoux (GFDL) for natural aerosols