A global simulation of tropospheric ozone and related tracers: Description and evaluation of MOZART, version 2

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April 16, 2001
MOZART-2

• Model description
  - Overview
  - Recent modifications

• Comparison with observations

• O₃ budget
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**Model resolution:** 2.8° latitude × 2.8° longitude (≈T42), 20 min timestep, 34 vertical layers (hybrid), surface to ~35 km (5 mb)

**Meteorology:** Winds, T, P, humidity, surface fluxes
   From MACCM-3 (truncated to 34 layers), every 6 hours

**Surface emissions:** NO<sub>x</sub> (fossil fuel, biomass burning, soils)
   CO, non-methane hydrocarbons (FF, vegetation, biomass burning, oceans)

**Lightning:** NO<sub>x</sub> source based on convection [Price et al., 1997; Pickering et al., 1998]

**Photochemistry:** 58 chemical species, 132 kinetic + 31 photolysis reactions
   Photolysis rates computed from lookup table

**Advection:** Flux-form semi-Lagrangian scheme [Lin and Rood, 1996]

**Convection:** Rediagnosed from MACCM-3 data using Hack [1994] and Zhang and MacFarlane [1995] schemes

**Boundary layer diffusion:** Based on Holtslag and Boville [1993]

**Dry deposition:** Deposition velocities computed with Wesely [1989] scheme, using NCEP meteorology and DeFries and Townshend [1994] vegetation map

**Wet deposition:** Based on Giorgi and Chameides [1985]
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- Recent modifications
  - Emissions
  - Dry deposition velocities
  - New isoprene scheme
  - Lightning NO\textsubscript{x}
  - “Flexible” architecture version
  - Updated reaction rates
  - Improved O\textsubscript{3} upper BC
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CO Emissions

Industrial CO \(10^{10} \text{ molec cm}^{-2} \text{ s}^{-1}\)

Biomass burning CO \(10^{10} \text{ molec cm}^{-2} \text{ s}^{-1}\)

Soil CO \(10^{10} \text{ molec cm}^{-2} \text{ s}^{-1}\)

Ocean CO \(10^{10} \text{ molec cm}^{-2} \text{ s}^{-1}\)
Acetone Emissions

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Industrial Acetone $10^{10}$ molec cm$^{-2}$ s$^{-1}$

Biomass burning Acetone $10^{10}$ molec cm$^{-2}$ s$^{-1}$

Biogenic Acetone $10^{10}$ molec cm$^{-2}$ s$^{-1}$

Ocean Acetone $10^{10}$ molec cm$^{-2}$ s$^{-1}$
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Deposition Velocities (July)
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Lightning NO<sub>x</sub>
(Global Annual Total = 2.5 Tg y<sup>-1</sup>)

JAN  Gg N y<sup>-1</sup>  APR  Gg N y<sup>-1</sup>

JUL  Gg N y<sup>-1</sup>  OCT  Gg N y<sup>-1</sup>

[Map images showing global distribution of Lightning NO<sub>x</sub> emissions for different months]

0.01  0.1  0.3  1  2  5  10
## MOZART-2

### Emissions

<table>
<thead>
<tr>
<th>Species</th>
<th>Fossil fuel combustion</th>
<th>Biomass burning</th>
<th>Biogenic / Soil</th>
<th>Oceans</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO (TgN/y)</td>
<td>23.1</td>
<td>8.7</td>
<td>6.6</td>
<td>0</td>
<td>38.4</td>
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<tr>
<td>CO (Tg/y)</td>
<td>306.9</td>
<td>711.2</td>
<td>181.0</td>
<td>2.0</td>
<td>1201.1</td>
</tr>
<tr>
<td>C&lt;sub&gt;2&lt;/sub&gt;H&lt;sub&gt;6&lt;/sub&gt; (TgC/y)</td>
<td>6.4</td>
<td>4.5</td>
<td>0.8</td>
<td>0.1</td>
<td>11.7</td>
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<tr>
<td>C&lt;sub&gt;3&lt;/sub&gt;H&lt;sub&gt;8&lt;/sub&gt; (TgC/y)</td>
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<td>2.2</td>
<td>1.6</td>
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<td>12.3</td>
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<td>20.7</td>
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<tr>
<td>C&lt;sub&gt;3&lt;/sub&gt;H&lt;sub&gt;6&lt;/sub&gt; (TgC/y)</td>
<td>0.9</td>
<td>5.6</td>
<td>0.9</td>
<td>2.5</td>
<td>9.8</td>
</tr>
<tr>
<td>C&lt;sub&gt;4&lt;/sub&gt;H&lt;sub&gt;10&lt;/sub&gt; (TgC/y)</td>
<td>22.2</td>
<td>23.0</td>
<td>21.4</td>
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<td>72.9</td>
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<tr>
<td>CH&lt;sub&gt;3&lt;/sub&gt;COCH&lt;sub&gt;3&lt;/sub&gt; (Tg/y)</td>
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<td>16.1</td>
<td>10.2</td>
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<td>37.3</td>
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<td>ISOP (TgC/y)</td>
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<td>C&lt;sub&gt;10&lt;/sub&gt;H&lt;sub&gt;16&lt;/sub&gt; (TgC/y)</td>
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<td>0</td>
<td>129.1</td>
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<td>H&lt;sub&gt;2&lt;/sub&gt; (Tg/y)</td>
<td>13.5</td>
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<td>7.8</td>
<td>40.6</td>
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### MOZART-2

#### Emissions (new, old)

<table>
<thead>
<tr>
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<td>711.2</td>
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<td>4.5</td>
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<td>0.1</td>
<td>11.7</td>
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<tr>
<td>C&lt;sub&gt;3&lt;/sub&gt;H&lt;sub&gt;8&lt;/sub&gt; (TgC/y)</td>
<td>10.0</td>
<td>2.2</td>
<td>1.6</td>
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<td>5.0</td>
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<td>1.1</td>
<td>10.2</td>
</tr>
<tr>
<td>C&lt;sub&gt;2&lt;/sub&gt;H&lt;sub&gt;4&lt;/sub&gt; (TgC/y)</td>
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<td>12.3</td>
<td>4.3</td>
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<td>20.7</td>
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<td>14.1</td>
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<td>0.9</td>
<td>5.6</td>
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<td>9.8</td>
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<td>23.0</td>
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<td>Isoprene (TgC/y)</td>
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<td>500.3</td>
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<td>500.3</td>
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</table>
MOZART-2

• Comparison with observations
  - Ozonesondes
  - CMDL (CO)
  - Aircraft measurements
    → DIAL $O_3$
    → CO
    → Acetone
    → others?
SUMMARY

• $O_3$, $NO_x$, CO, NMHCs, peroxides
  - very good agreement with obs

• PAN, CH$_2$O
  - good agreement at most locations

• HNO$_3$, acetone
  - significant disagreement at some locations
### Ozone budget

<table>
<thead>
<tr>
<th>Process</th>
<th>Global</th>
<th>Northern Hemisphere</th>
<th>Southern Hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influx from stratosphere(a)</td>
<td>(409^b)</td>
<td>267</td>
<td>142</td>
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<tr>
<td>Photochemical production</td>
<td>4671</td>
<td>2750</td>
<td>1921</td>
</tr>
<tr>
<td>Photochemical loss</td>
<td>-4238</td>
<td>-2463</td>
<td>-1775</td>
</tr>
<tr>
<td>Dry deposition</td>
<td>-847</td>
<td>-557</td>
<td>-290</td>
</tr>
</tbody>
</table>

For this budget, the tropopause is defined as the hybrid model level interface corresponding to approximately 100 hPa in the tropics (30°S-30°N) and 250hPa in the extratropics.

\(a\). Includes advection, pressure consistency correction, and convection and vertical diffusion.

\(b\). This term consists of advection (310 Tg/y), pressure consistency correction (91 Tg/y), and convection and vertical diffusion (8 Tg/y).
Ozone fluxes (Tg y$^{-1}$)

Stratosphere

Troposphere

\[ ? = 91 \]

\[ P = 4671 \]
\[ L = 4238 \]

90°S  Eq  90°N