Thirty Years of Atmospheric CH$_4$ Monitoring: What Have We Learned?

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\[ [CH_4](t) = [CH_4]_{ss} - ([CH_4]_{ss} - [CH_4]_0)e^{-t/\tau} \]

Lifetime \( \approx 9 \text{ yr} \)
IAV: Better Process Understanding

- Mt. Pinatubo and CH$_4$ lifetime
  - SO$_2$ and SO$_4^{2-}$ affected OH production
- Economic collapse in fSU
  - Decreased emissions at high northern latitudes
- Increase since 2007
  - Tropical wetlands
O$_3$ + hv (330 ≥ λ ≥ 290 nm) → O($^1$D) + O$_2$
O($^1$D) + H$_2$O → 2 OH
Rate of formation O($^1$D) = j [O$_3$]
No significant change in Arctic emissions.
In situ CH$_4$ monitoring: Summary

- CH$_4$ approaching steady state
  - Current imbalance $\sim$16 Tg CH$_4$ yr$^{-1}$
- Eruption of Mt. Pintubo
  - Test understanding of OH sink processes
- Economic collapse of former Soviet Union
  - Altered trajectory of atmospheric CH$_4$
- Tropical precipitation: wetland emissions
  - Correlates with ENSO
  - Driver of recent CH$_4$ increase
Increases in SCIA in 2007 and 2008 consistent with in situ observations. Insufficient S/N to identify cause of recent $\text{CH}_4$ increase. Frankenberg et al., JGR, 2011.

GOSAT may be better.
Conclusions

• Global CH$_4$ increase continues in 2010:
  – ~6.0 ppb yr$^{-1}$ from 2007 to 2010
  – Largest, most persistent anomaly in record

• Observation-based assessment of causes:
  – T and precipitation are key drivers

• Current observation network is insufficient:
  – Satellite sensors: low S/N and disinformation
  – *In situ* measurements: increase spatial coverage
$[CH_4](t) = [CH_4]_\text{ss} - ([CH_4]_\text{ss} - [CH_4]_0)e^{-t/\tau}$

Lifetime $\approx 9$ yr
## Global CH$_4$ Budget by Source

<table>
<thead>
<tr>
<th>Source</th>
<th>Bousquet (Tg/yr)</th>
<th>IPCC Range (Tg/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anthropogenic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td>110±13</td>
<td>74-106</td>
</tr>
<tr>
<td>Enteric fermentation</td>
<td>90±14</td>
<td>76-92</td>
</tr>
<tr>
<td>Rice agriculture</td>
<td>31±5</td>
<td>31-112</td>
</tr>
<tr>
<td>Biomass burning</td>
<td>50±8</td>
<td>14-88</td>
</tr>
<tr>
<td>Waste</td>
<td>55±11</td>
<td>35-69</td>
</tr>
<tr>
<td><strong>Natural</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wetlands</td>
<td>147±15</td>
<td>100-231</td>
</tr>
<tr>
<td>Termites</td>
<td>23±4</td>
<td>20-29</td>
</tr>
<tr>
<td>Oceans</td>
<td>19±6</td>
<td>4-15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>525±8</td>
<td>503-610</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sinks</th>
<th>Bousquet (Tg/yr)</th>
<th>IPCC (Tg/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Troposphere</td>
<td>448±1</td>
<td>428-511</td>
</tr>
<tr>
<td>Stratosphere</td>
<td>37±1</td>
<td>30-45</td>
</tr>
<tr>
<td>Soil</td>
<td>21±3</td>
<td>26-34</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>506</td>
<td>492-581</td>
</tr>
</tbody>
</table>

Constraints on Global CH$_4$ Budget

- Globally averaged CH$_4$
  - Atmospheric burden: ~4990 Tg CH$_4$ in 2011
  - Radiative forcing (since PI): 0.5 W m$^{-2}$
- Rate of increase
  - Imbalance between emissions and losses
- Spatial distribution of CH$_4$ abundance
  - Spatial distribution of emissions
- Seasonal cycle
  - Temporal distribution of emissions