Implications of the Continued Increase in Atmospheric Methane Burden

E. Dlugokencky¹, M. Crotwell¹,², A. Crotwell¹,², P.M. Lang¹, L. Bruhwiler¹, A. Wang¹, K. Thoning¹
¹NOAA ESRL GMD, ²CIRES
*CH₄ budget nearly in steady state: Source/sink imbalance < 6%
*Small reductions in emissions would stabilize CH₄ burden
Assume no trend in lifetime - SS function

$$[CH_4](t) = [CH_4]_{ss} - ([CH_4]_{ss} - [CH_4]_0)e^{-t/\tau}$$
\[ \text{"Emissions"} = \frac{\text{d}[\text{CH}_4]}{\text{dt}} + \frac{[\text{CH}_4]}{\tau} \]

Trend = 0.0 ± 0.6 Tg CH\textsubscript{4} yr\textsuperscript{-1} (95% c.l.)
What we know from atmospheric observations:

• The increase since 2007 started abruptly
• GR suggests tropics are important
• $\delta^{13}C(CH_4)$ is decreasing
  – Constrains possible drivers
• Not likely increased FF emissions
• Not likely increased Arctic emissions
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Globally averaged $\text{CH}_4$ and $\delta^{13}\text{C}(\text{CH}_4)$

$\text{CH}_4$ (ppb)

$\delta^{13}\text{C}$ (%)

Sylvia Michel, INSTAAR
What does $\delta^{13}C$ tell us?

• Schaefer et al., Nature, 2016
  – Increased microbial emissions outside Arctic
  – More likely agricultural sources than wetlands

• Nisbet et al., GBC, 2016
  – Increased microbial emissions in tropics
  – Wetlands and ag sources could contribute
    • Role for meteorology
  – Unlikely that changing lifetime contributed
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Fossil CH$_4$ emissions not increasing (Schwietzke et al., Nature, 538, 88-91, 2016)
What we know from atmospheric observations:

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Arctic permafrost and clathrates?

Difference between northern and southern polar annual means

No recent change in Arctic emissions based on polar zonal means.

Economic collapse in fSU
ENSO Phase: Precipitation

Base: 1961-1990

Source: GPCC

Australian BoM

La Niña

El Niño
Conclusions

• Increased CH$_4$ GR starting in 2007
  – Initiated by tropical wetlands
  • Consistent with: abrupt timing, ENSO, spatial patterns, and observed δ$^{13}$C (CH$_4$)
  – Sustained by increased agricultural emissions
  – Potential contribution from changing lifetime

• Potential Climate Feedback
  – Connection with meteorology
  – Should we be concerned?
\[ [\text{CH}_4](t) = [\text{CH}_4]_{ss} - ([\text{CH}_4]_{ss} - [\text{CH}_4]_0)e^{-t/\tau} \]

Lifetime ≈ 9.2 yr
Why is CH$_4$ Important?

- 0.51* W m$^{-2}$ RF in 2016 (CO$_2$: 1.99 W m$^{-2}$)
  - $\Delta$RF = 25 mW m$^{-2}$ since 2006
- $\sim$0.3 W m$^{-2}$ indirect RF (O$_3$ and H$_2$O)
- Drivers behind current trends are poorly understood
  - Emissions? If so, which sources?
  - Sink? If so, by what mechanism?
“Emissions” = \( \frac{d[\text{CH}_4]}{dt} + \frac{[\text{CH}_4]}{\tau} \)

Trend = 0.0 ± 0.6 Tg CH\(_4\) yr\(^{-1}\) (95% c.l.)
Dlugokencky et al. 2001         tropical WLs
### 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><strong>525±8</strong></td>
<td><strong>503-610</strong></td>
</tr>
<tr>
<td><strong>Sinks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Troposphere</td>
<td>448±1</td>
<td>428-511</td>
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<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><strong>506</strong></td>
<td><strong>492-581</strong></td>
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