Ambiguity in the causes for decadal trends in atmospheric methane and hydroxyl

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Global methane budget

Sources

- Anthropogenic
  - Fossil Fuels (14%)
  - Landfills (11%)
  - Ruminants (13%)
  - Rice (4%)
- Natural
  - Wetlands (32%)
  - Geological (8%)

Isotopic Composition ($\delta^{13}$CH$_4$; ‰)

- Pyrogenic
- Thermogenic
- Biogenic

Sinks

- Tropospheric OH (90%)

Kirschke et al. (2013)
Decadal trends in atmospheric methane

$[\text{CH}_4](t) = \tau E(t) - (\tau E(t) - [\text{CH}_4]_0) e^{-t/\tau}$

3% increase in emissions could explain the renewed growth
<table>
<thead>
<tr>
<th>Month</th>
<th>Reference</th>
<th>CH$_4$</th>
<th>$\delta^{13}$CH$_4$</th>
<th>MCF</th>
<th>C$_2$H$_6$</th>
<th>Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEB</td>
<td>Turner et al., <em>GRL</em></td>
<td>✗</td>
<td></td>
<td></td>
<td></td>
<td>US methane emissions increased since 2002</td>
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<tr>
<td>FEB</td>
<td>Schaefer et al., <em>Science</em></td>
<td>✗</td>
<td>✗</td>
<td></td>
<td></td>
<td>Renewed growth due to biogenic, not fossil-fuels</td>
</tr>
<tr>
<td>MAR</td>
<td>Hausmann et al., <em>ACP</em></td>
<td>✗</td>
<td></td>
<td>✗</td>
<td></td>
<td>NH oil &amp; gas CH$_4$ emissions increased</td>
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<tr>
<td>APR</td>
<td>Franco et al., <em>ERL</em></td>
<td>✗</td>
<td></td>
<td></td>
<td>✗</td>
<td>North American oil &amp; gas CH$_4$ emissions increased</td>
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<tr>
<td>APR</td>
<td>Kort et al., <em>GRL</em></td>
<td>✗</td>
<td></td>
<td></td>
<td></td>
<td>Bakken can explain most of the C$_2$H$_6$ growth</td>
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<tr>
<td>APR</td>
<td>Peischl et al., <em>JGR</em></td>
<td>✗</td>
<td></td>
<td></td>
<td></td>
<td>Bakken does not emit much CH$_4$</td>
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<tr>
<td>OCT</td>
<td>Schwietzke et al., <em>Nature</em></td>
<td>✗</td>
<td>✗</td>
<td></td>
<td></td>
<td>No change in fossil-fuel CH$_4$ emissions</td>
</tr>
<tr>
<td>NOV</td>
<td>Zazzeri et al., <em>ACP</em></td>
<td>✗</td>
<td>✗</td>
<td></td>
<td></td>
<td>Isotope signature for fossil-fuel CH$_4$ is too heavy</td>
</tr>
</tbody>
</table>

2016 has been an exciting year for methane!

- **Ethane studies find that fossil-fuels contributed to the renewed growth**
  - Relationship between ethane and fossil-fuel methane may be weaker than we thought

- **Isotope studies usually find that “biogenic” sources are the cause**
  - Some isotope studies disagree & there are uncertainties in the signatures used

- **Methyl chloroform studies find that OH can play a role (in the stabilization)**

Why do so many, apparently, plausible explanations disagree?
Can use a simple 2-box model:

- Jointly estimating the drivers of decadal trends
  - Using atmospheric observations of CH$_4$, $\delta^{13}$CH$_4$, and MCF
- Using conservative (non-Gaussian) prior distributions
- Non-linear, stochastic, Bayesian inversion

What can we say about decadal trends in methane?
Simulated and observed methane, $\delta^{13}\text{CH}_4$, and MCF

Public datasets from NOAA/ESRL$^{1,2,3}$, U. Heidelberg$^2$, UCI$^2$, UW$^2$, & GAGE/AGAGE$^3$

1 = CH$_4$, 2 = $\delta^{13}\text{CH}_4$, 3 = CH$_3$CCl$_3$
“Most likely” set of drivers for decadal trends

Renewed growth may be due to OH decline, not emissions!

*Also jointly solve for MCF emissions (not shown)*
Are these OH anomalies plausible?

Montzka et al., Rigby et al., & McNorton et al. find similar OH anomalies

Patra et al. infer a NH/SH OH ratio of 0.97 ± 0.12

Consistent with previous work looking at global mean OH
What if we don’t allow OH to vary?

No discernable difference in the simulated concentrations
What if we don’t allow OH to vary?

- **varying OH**
  - Multiple (fundamentally different) drivers can explain the observations
    - Problem of attributing decadal methane trends is under-determined
  - Hemispheric isotopic compositions lead to differing interpretations
    - Large overlap in isotopic compositions further complicates the interpretation

- **fixed OH**
  - Assuming OH is fixed will predispose you to a particular subset of solutions
Ambiguity in the causes for decadal trends in CH$_4$ & OH

- Past disagreement is likely due to assumptions, not data
  - Problem of attributing decadal trends in methane is under-determined

- Changes in OH are a likely contributor to renewed growth
  - These results are only valid if our assumptions are correct
  - Need a better mechanistic explanation of potential OH changes

Turner *et al.* (under review)