Attribution of the 2010-2016 trend in atmospheric methane by improved inverse analysis of GOSAT satellite observations

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What drives the increase of methane concentration?

CH₄ concentration in last 35 years

Atmospheric methane budget

9.0 ppbv/yr

5.7 ppbv/yr

Emission
550 ± 60 Tg a⁻¹
What drives the increase of methane concentration?

Atmospheric constraints

- Surface network
- Ethane
- $\delta^{13}$CH4
- Satellite
- CH$_3$CCl$_3$

Atmospheric constraints

- Atmospheric constraints:
  - 9.0 ppbv/yr
  - 5.7 ppbv/yr
  - 3% change in emis or sink
  - ~20 Tg/yr
  - 5%
Inversion of satellite methane observations

Mean GOSAT methane, 2010–2015

Maasakkers et al., ACP, 2019
Inversion of satellite methane observations

Emissions

Emission Trends

OH sink

Zhang et al., ACP, 2018
Improvements on GOSAT inversion

1. Best available prior information
2. Improved stratospheric bias correction
3. Better treatment for wetland emissions
4. Annual hemispheric OH

**Prior Information**
- Global fuel emission inventory (Scarpelli et al.)
- GFED4 fire emissions (Liu et al.)
- Seeps (Etiope et al., 2019)
- Soil absorption (Murguia-Flores et al.)

**Simulated XCH₄**
Bias correction: ACE-FTS satellite observations

**Observations**
GOSAT XCH₄ retrievals 2010-2016

**Inversion**
- Non-wetland emissions and its linear trend from 2009-2017 on 4x5 grid
- Monthly wetland emissions for 14 subcontinental regions
- Annual hemispheric OH
Inversion is performed on each 4x5 grid cells for annual-mean non-wetland emissions and linear trend

... and 14 subcontinental regions for monthly-mean wetland emissions

Superimpose the spatial correlation within a region
Allow for seasonality correction
Inversion results: evaluation

Error against training data: GOSAT

Error against Independent observation

Root mean squared error (ppbv)
Inversion results

Posterior/Prior ratio

Non-wetland emissions

Wetland emissions

OH

Prior Posterior
Inversion results: methane budget 2010-2016

Attribution of increasing growth rates

Anthropogenic (non-wetland) emissions are the main driver of increasing growth rates.
Global trend: 1880 Gg a⁻¹ a⁻¹

DOFS = 22
US: 70 Gg a⁻¹ a⁻¹

China: 720 Gg a⁻¹ a⁻¹

Venezuela + Colombia: 80 Gg a⁻¹ a⁻¹

Russia: -180 Gg a⁻¹ a⁻¹

Iran: 60 Gg a⁻¹ a⁻¹

Global trend: 1880 Gg a⁻¹ a⁻¹
Posterior linear trends for non-wetland emissions

Brazil: 130 Gg a\(^{-1}\) a\(^{-1}\)

South Asia 460 Gg a\(^{-1}\) a\(^{-1}\) (Pakistan+India)

East Africa: 190 Gg a\(^{-1}\) a\(^{-1}\)

Global trend: 1880 Gg a\(^{-1}\) a\(^{-1}\)
Top 5 counties with fastest growing cattle population:

<table>
<thead>
<tr>
<th>Country</th>
<th>Trend (million head per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pakistan</td>
<td>1.4</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>1.2</td>
</tr>
<tr>
<td>Tanzania</td>
<td>1.1</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.9</td>
</tr>
<tr>
<td>Argentina</td>
<td>0.7</td>
</tr>
</tbody>
</table>

UNFAO

South Asia: 460 Gg a\(^{-1}\) a\(^{-1}\) (Pakistan+India)

East Africa: 190 Gg a\(^{-1}\) a\(^{-1}\)

Brazil: 130 Gg a\(^{-1}\) a\(^{-1}\)
Inversion results: wetland

**USA**
- Prior: 7.41 (-0.19)
- Posterior: 2.55 (-0.27)

**East Canada**
- Prior: 14.02 (0.03)
- Posterior: 6.38 (0.27)

**Sub-Saharan Africa**
- Prior: 17.72 (-0.34)
- Posterior: 15.07 (0.84)

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**SEAC4RS**
Sheng et al., ACP, 2018

**(ECCC)Surface**
Baray et al., AGU, 2019

**GOSAT**
Lunt et al., ACP, 2019
Summary

• Update the GOSAT satellite inversion system
  • Improved stratospheric bias correction with ACE-FTS
  • Better treatment for wetland emissions

• Increasing anthropogenic emissions contribute to increasing growth rate
  • Increasing livestock emissions over Southeast Asia, East Africa, and Brazil

• Information for seasonality and trend of regional wetland emissions