Where is all the methane coming from?

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Methane – $\text{CH}_4$

- Methane is a “short-lived climate forcer”

- Average lifespan in the atmosphere $\sim 10$ years

- Global Warming Potential (GWP):
  - 34 over a 100-year time span
  - 86 over a 20-year time span

- Methane has attributed equivalent to $\sim 60\%$ of the radiative forcing of $\text{CO}_2$ since 1750
Atmospheric methane concentration (mole fraction)

All values in Tg CH₄ yr⁻¹

- Natural wetlands: 167 Tg CH₄ yr⁻¹ (127-202 Tg CH₄ yr⁻¹)
- Other natural sources: 64 Tg CH₄ yr⁻¹ (21-132 Tg CH₄ yr⁻¹)
- Agriculture and waste: 188 Tg CH₄ yr⁻¹ (115-243 Tg CH₄ yr⁻¹)
- Biomass burning (incl. biofuels): 34 Tg CH₄ yr⁻¹ (15-53 Tg CH₄ yr⁻¹)

Radiocarbon – $^{14}\text{C}$

• Carbon exists as two stable isotope ($^{12}\text{C}$ and $^{13}\text{C}$) and one radioactive isotope ($^{14}\text{C}$)

• $^{14}\text{C}$ has a half life of 5,730 years

• Produced in the lower stratosphere and upper troposphere by cosmic rays which create neutrons and these can strike $^{14}\text{N}$ atoms forming $^{14}\text{C}$
Radiocarbon – $^{14}$C

- Different sources of methane can also have different $^{14}$CH$_4$ signatures depending on the age of the carbon they are formed from.

- For example:
  - Natural gas methane (fossil methane) is radiocarbon “dead” – has no $^{14}$C in it any more.
  - Methane from a cow belch has the same $^{14}$C signature as the contemporary atmosphere.
Methane in ice cores

• The last deglaciation when Earth last showed warming similar to what is predicted for our immediate future (~4°C)
Methane in ice cores

- The last deglaciation when Earth last showed warming similar to what is predicted for our immediate future (~4°C)

- Emission from other old methane sources were small (permafrost thaw and methane hydrates)

- These old methane sources may not be triggered by current and near-future climate change

Adapted from: Dyonisius et al. (2020) Science

Adapted from: Dean (2020) Science
Contemporary ice cores

• Fossil methane emissions increased from “negligible” in preindustrial times to 64.8 Tg CH₄ yr⁻¹ in 1940

• Preindustrial geologic methane emissions = 1.6 (max 5.4) Tg CH₄ yr⁻¹
  • Compared to 40—60 Tg CH₄ yr⁻¹ in previous estimates

Adapted from: Hmiel et al. (2020) Nature
Fossil fuels?

• If 1.6 (max 5.4) Tg CH$_4$ yr$^{-1}$ is correct, these are the probable level of background (natural) emissions of fossil methane today
  • What does that mean for today’s methane accounts?

• Hmiel et al. (2020) estimate modern-day methane emissions from fossil fuel industry:
  • 177 ± 37 Tg CH$_4$ yr$^{-1}$
  • 22% higher than previous estimate: 145 ± 23 Tg CH$_4$ yr$^{-1}$
    • Schwietzke et al. (2016) Nature

• Much higher than “bottom up” estimates of 114—133 Tg CH$_4$ yr$^{-1}$
  • Saunois et al. (2020) Earth Sys. Sci. Data

“Bottom up”?

• “Bottom up” accounting:
  • Inventories of methane emissions from measurements and calculations around the emissions source, upscaled to national or global scale

• Vs.

• “Top down” accounting:
  • Measure the total emissions from atmospheric content (e.g. current measurements, satellites or ice core bubbles), and estimate possible sources
  • e.g. Hmiel et al. (2020) *Nature*

• Recent study suggested that US Environmental Protection Agency methane emission estimates from fossil fuel industry (bottom up) were 60% lower than actual (top down) estimates, likely due to under-reporting by industry
  • Alvarez et al. (2018) *Science*
Conclusions

“Our results imply that anthropogenic fossil CH$_4$ emissions now account for about 30% of the global CH$_4$ source and for nearly half of anthropogenic emissions, highlighting the critical role of emission reductions in mitigating climate change”

Hmiel et al. (2020) Nature

• Leaky gas pipes and legacy infrastructure (especially in USA and Russia) are crucial places to start (Pardikar 2021, EOS)

• Especially if natural gas is to be used as a ‘bridging fuel’ or as part of a shift to ‘renewable’ hydrocarbons.
GLOBAL METHANE BUDGET 2008-2017

Emissions and Sinks

In teragrams of CH₄ per year (Tg CH₄ / yr) average over 2008-2017

The observed atmospheric growth rate is 18.2 (17.3-19) Tg CH₄ / yr. The difference with the TD budget imbalance reflects uncertainties in capturing the observed growth rate.

- **Bottom-up (BU)** view
  - Fossil fuel production and use: 128 (113-154)
  - Agriculture and waste: 206 (191-223)

- **Top-down (TD)** view
  - Fossil fuel production and use: 111 (81-131)
  - Agriculture and waste: 217 (207-240)

- **Total Emissions**
  - BU: 737 (594-880)
  - TD: 576 (550-594)

- **Change in Atmospheric Abundance**
  - BU: > 100 (0-49)
  - TD: 13*

- **Total Sinks**
  - BU: 625 (500-798)
  - TD: 556 (501-574)

- Sink from chemical reactions in the atmosphere
  - BU: 595 (489-749)
  - TD: 518 (474-532)

- Sink in soils
  - BU: 30 (11-49)
  - TD: 38 (27-45)

- Emissions and sinks of methane:
  - Biomass and biofuel burning
  - Wetlands
  - Other natural emissions (inland waters, geological, oceans, termites, wild animals, permafrost, vegetation)
Thank you

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