What drove record increases in global atmospheric methane in 2020 and 2021?

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Background

- In 2020 and 2021, global mean atmospheric methane (CH_4) grew by record amounts of ~15 and 18 parts per billion (ppb) (Fig. 1). The continuing CH_4 increase is a challenge for reaching the climate mitigation goals.

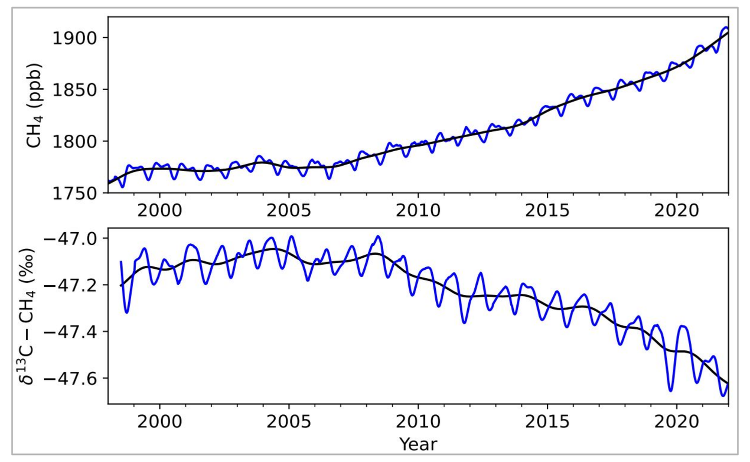

Fig. 1. Globally averaged atmospheric CH_4 (top) and the trend in the ratio of the isotope carbon-13 (bottom) from samples collected by NOAA's Global Greenhouse Gas Reference Network. (Credit: Xin Lan and Sylvia Michel)

Methods

- Measurements of the relative abundance of ^{13}C to ^{12}C (denoted as $\delta^{13}C\text{-}CH_4$) is a useful tracer for disentangling the contribution of the sources and sinks of CH_4 (Fig. 2, Lan et al., 2021)

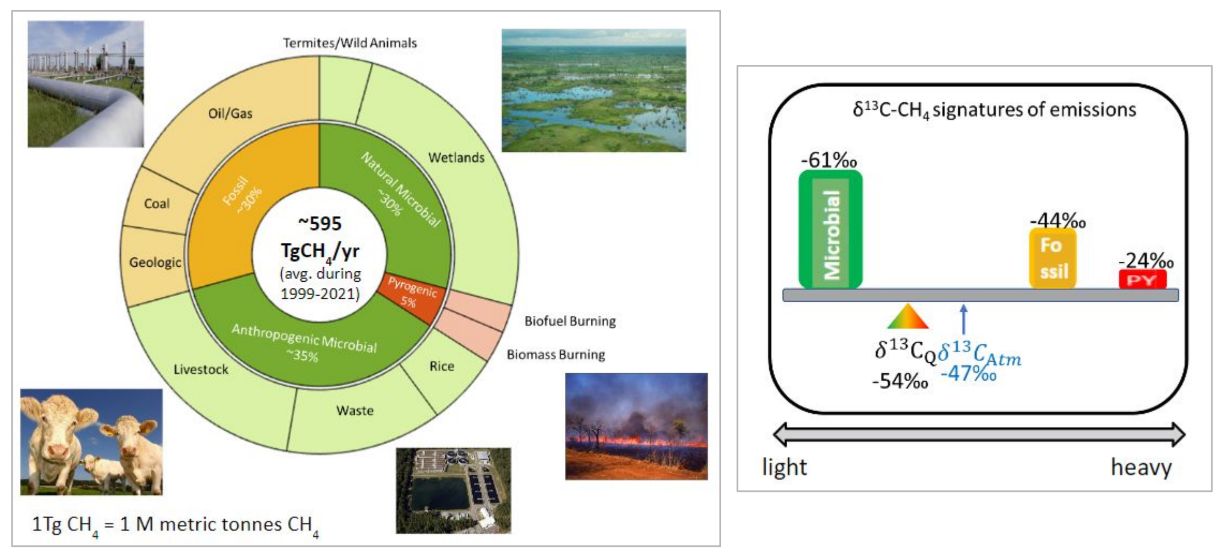

Fig. 2. (left) Bar chart of global mean CH_4 emissions from microbial, fossil, and pyrogenic source sectors. (right) Global mean flux-weighted CH_4 isotopic signature ($\delta^{13}C\text{-}CH_4$) of microbial, fossil, and pyrogenic sources.

- We updated our CarbonTracker-CH_4 inversion system by jointly assimilating measurements of CH_4 and $\delta^{13}C\text{-}CH_4$, optimizing fluxes at a grid scale, and incorporating $\delta^{13}C\text{-}CH_4$ signatures of sources. The system has been extended to estimate fluxes through 2021 (Bruhwiler et al., 2014; Basu et al., 2022)

Results

1. Joint inversion that assimilates both CH_4 + $\delta^{13}C\text{-}CH_4$ measurements matches with both observations, where as CH_4-only inversion does not match with $\delta^{13}C\text{-}CH_4$. Therefore, the joint inversion yields more reasonable partitioning of sources.

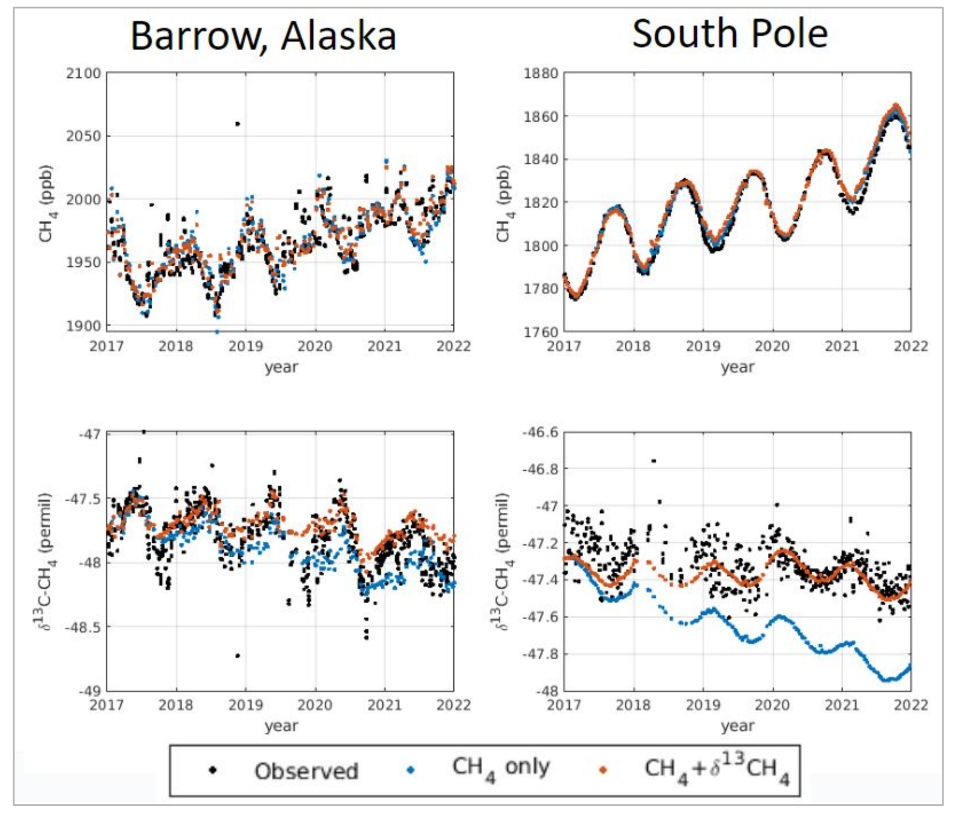

Fig. 3. Model-data comparison of (top) CH_4 and (bottom) $\delta^{13}C\text{-}CH_4$ between observation (black) and simulations from joint (blue) and CH_4-only (red) scenarios for (left) Barrow, Alaska, and (right) South Pole baseline observatories.

2. Total emissions reach to 650 Tg CH_4 yr^{-1} in 2021, ~18% increase since 2000. The averaged contribution of fossil sources to total emissions is larger (~15 Tg CH_4 yr^{-1}) when assimilating $\delta^{13}C\text{-}CH_4$ measurements (joint scenario).

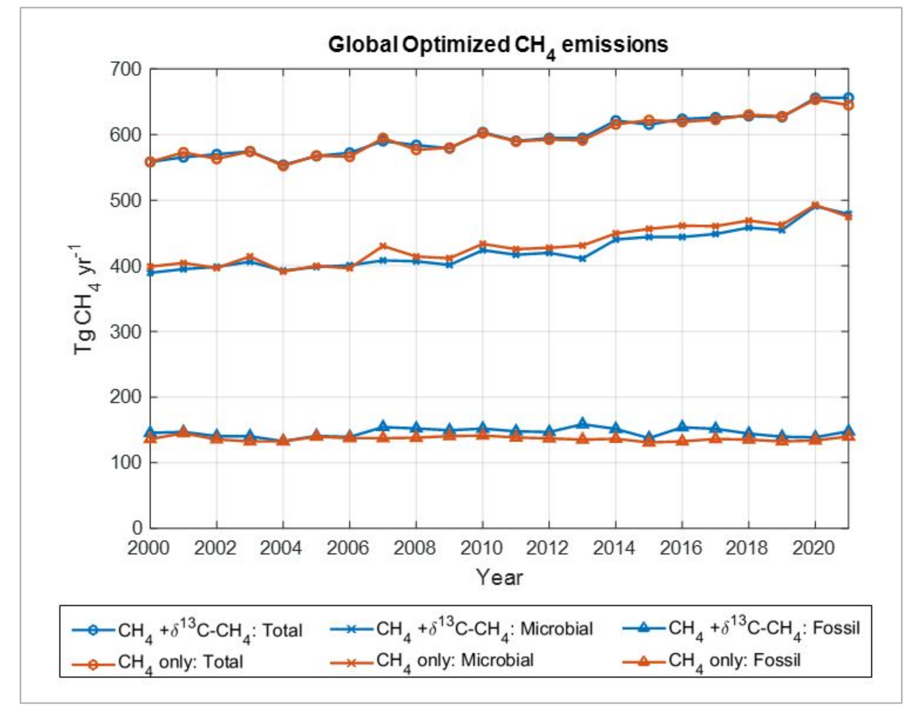

Fig. 4. Optimized annual global CH_4 emissions simulated by joint (blue) and CH_4-only (red) scenarios of CarbonTracker-CH_4 for total (o), microbial (x), and fossil (△) sources in 2000-2021.

3. Microbial emissions caused increase in atmospheric methane in 2020-2021.

- The joint CH_4+$\delta^{13}CH_4$ inversion simulates the large increase in microbial sources and slight decrease in fossil sources (Red in Fig. 5).
- [OH] decrease can contribute to 30-50% of atmospheric CH_4 increase (Yellow in Fig. 5).

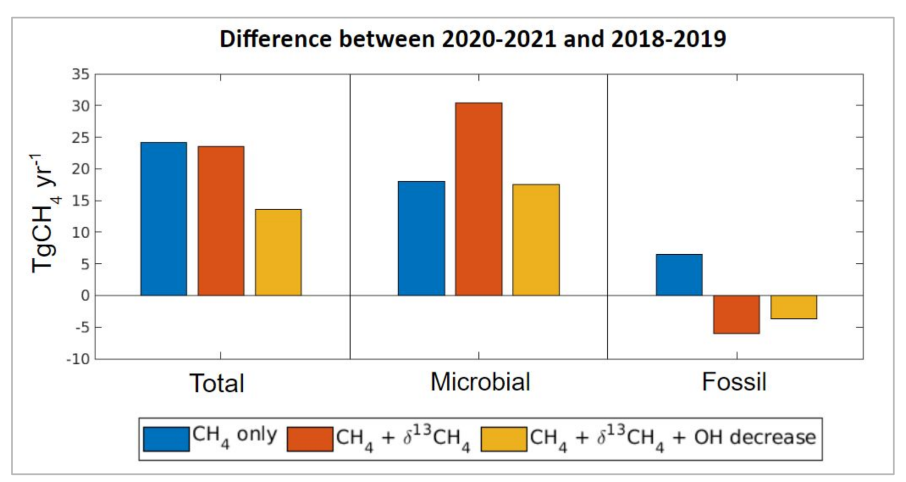

Fig. 5. Changes in global CH_4 emissions (Tg CH4 yr^{-1}) between 2020-2021 and 2018-2019 for total (left), microbial (middle), and fossil (right) emissions. Different color bars represent CH_4-only (blue), joint (CH_4 and $\delta^{13}C\text{-}CH_4$) (red), and joint + OH decrease (yellow) inversion scenarios.

4. Spatial changes in source-specific CH_4 emissions in 2020-2021.

- In 2020, the inversion attributes more than half of the microbial increases to tropical regions and the decrease in fossil emissions to industrialized regions (Fig. 6).
- In 2021, microbial sources increase in both temperate and tropical regions, while fossil emissions rebounce to 2019 levels.

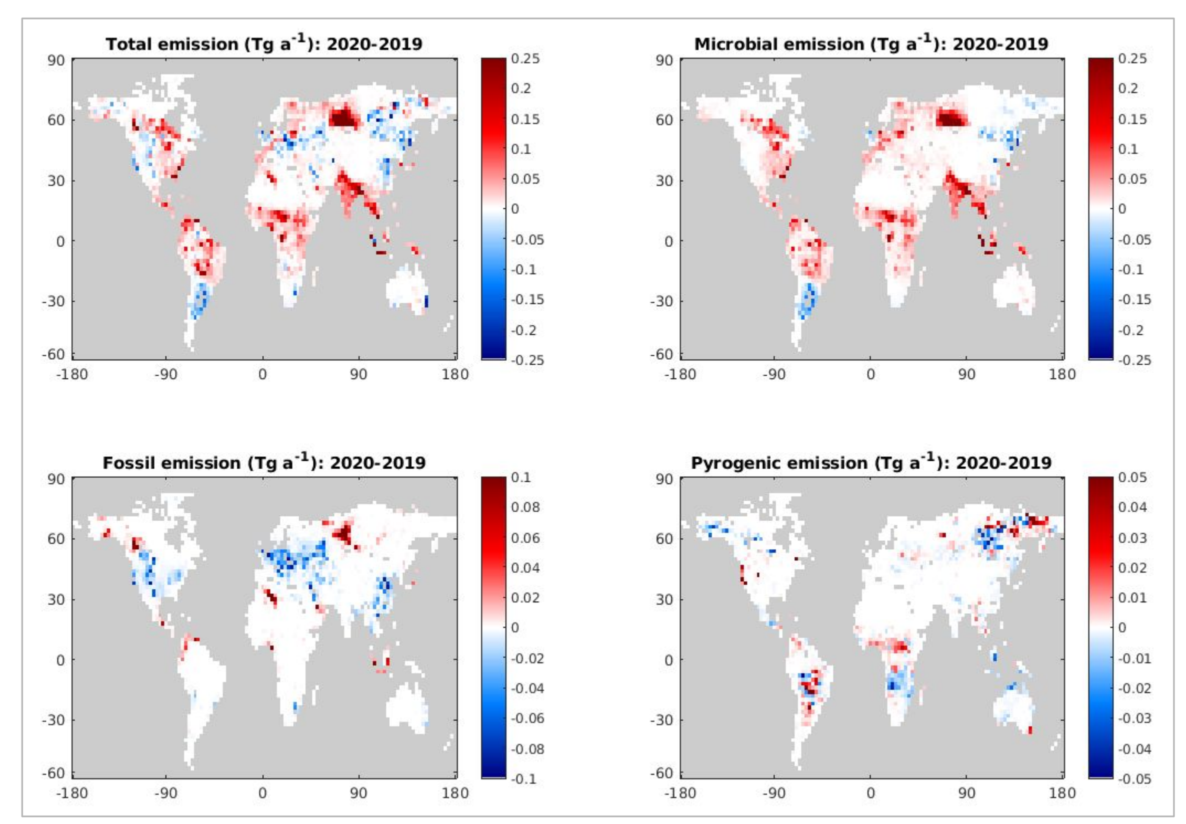

Fig. 6. The difference of global gridded optimized emissions between 2019 and 2020 for (top-right) total, (top-left) microbial, (bottom-left) fossil, and (bottom-right) pyrogenic emissions, simulated by the joint scenario of CarbonTracker-CH_4.

Conclusions

- CarbonTracker-CH_4 is developed to jointly assimilate CH_4 and $\delta^{13}C\text{-}CH_4$ measurements and estimate source-specific emissions.
- Source-specific emissions from CH_4 and $\delta^{13}C\text{-}CH_4$ should be more realistic because CH_4-only inversion yield $\delta^{13}C\text{-}CH_4$ field is inconsistent with observations.
- The total global CH_4 emission increased more than 100 Tg yr^{-1} after 2000 and reached ~650 Tg yr^{-1} in 2021.
- A joint CH_4+$\delta^{13}C\text{-}CH_4$ inversion suggests that the post-2006 and 2020-2021 atmospheric CH_4 increases are due to microbial sources, although we cannot rule out a role of inter-annual variability in [OH].

References

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