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COMMENT

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Untangling variations in the global methane budget

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The drivers of trends in methane concentrations in the atmosphere over past decades are still poorly understood. Simulations from a chemistry transport model and box model show that human activity is the main driver of a complex system.

The observational record for the global atmospheric burden of methane over the past 40 years tells a complex story of competing influences. Methane, a strong greenhouse gas with a mean lifetime in the atmosphere of around a decade, is emitted via an array of natural and anthropogenic sources. Over the past few decades, its rate of accumulation in the atmosphere has varied significantly due to the changing magnitudes of various source sectors and the main atmospheric sink. However, our understanding of methane emissions from diverse sources such as wetlands, fossil fuels, waste, cattle, forest fires, and even termites remains incomplete, leaving a number of enduring questions regarding the causes of the observed changes. Now, Ragnhild Skeie and colleagues[1], writing in Communications Earth & Environment, have shown how the changing influence of three of the most uncertain aspects of the methane budget—anthropogenic emissions, wetlands and chemical loss—have contributed to the observed changes in its growth rate.

Atmospheric methane (CH_4) rose quickly in the early 1980s, mainly due to the increasing global reliance on fossil fuels. The rate of increase slowed to near-zero in the early 2000s, but since 2007 it has once again been rising, at a pace that has increased over time. Debate continues amongst scientists as to whether this renewed growth is again due to the increasing use of fossil fuels or is a consequence of increased agricultural production, climate change-related feedback affecting wetland emissions, variations in the atmospheric sink, or a combination of factors[2–10].

Measuring isotopes of methane in the atmosphere provides additional information regarding the changing mixture of sources and sinks, which have different individual isotopic 'signatures'. The atmospheric ratio of methane molecules containing carbon-13 ($^{13}CH_4$) to those containing carbon-12 ($^{12}CH_4$) has been decreasing since around 2007, the same year that total CH_4 began to increase. This evidence indicates that increasing fossil fuel use, which would increase the $^{13}CH_4/^{12}CH_4$ ratio, cannot alone be responsible for the renewed CH_4 growth.

Ragnhild Skeie and colleagues tackle this problem using a simple box model of the atmosphere to quantify the contributions of anthropogenic emissions, wetland fluxes and the main atmospheric CH_4 sink to the observed growth since the 1980s. In addition, a similar model was used to simulate the atmospheric $^{13}CH_4/^{12}CH_4$ ratio. Box models treat the atmosphere as a single reservoir, which allows computationally efficient calculation of individual source sector contributions and their uncertainties over this long time period, whilst using state-of-the-art inventories and models for the input flux parameters. The results show that anthropogenic emissions (broadly fossil fuels, agriculture and waste, Fig. 1) were responsible for driving the long-term trends of the observed CH_4. No evidence was found of a trend due to wetland emissions, but wetlands were found to display significant year-to-year variability and substantially influenced the observed atmospheric CH_4 variation over shorter periods.

One strength of this work is its investigation of the major loss pathway for CH_4 in the atmosphere. CH_4 destruction is mainly through a reaction with hydroxyl (OH) radicals.

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Fig. 1 Cows on a farm. Agriculture is just one of the ways that human activity is increasing the amount of methane in the atmosphere at unprecedented rates.Credit: Joachim Süß/Unsplash.

Temporal variation of OH in the atmosphere is not well-understood because OH radicals' extremely brief atmospheric residence time of about 2 s makes them difficult to measure directly. Here, the authors assess how global concentrations of OH in the atmosphere have changed over the previous two decades using an atmospheric chemistry transport model, simulating chemical reactions and transport across thousands of grid cells representing the Earth's atmosphere. They find, in accordance with previous studies, that atmospheric OH concentrations were increasing in the atmosphere in the 1990s and 2000s. This increase in the availability of its major sink led to a shorter CH_4 lifetime, which in turn contributed to the observed slowdown in CH_4 growth in the 2000s. Combining the anthropogenic and natural emissions and OH variations together in the box model matches the observed growth rate well.

Discussing a mechanism for the variations in OH, the authors show how the ratio of two anthropogenic pollutants (nitrogen oxides, NO_X, and carbon monoxide, CO) in the atmosphere plays a key role in determining the global OH budget. High NO_X/low CO conditions favour OH production, and so increasing NO_X and decreasing CO concentrations during the 2000s contributed to the CH_4 growth hiatus at that time, via increasing OH. The authors also show that decreased NO_X emissions due to the reduced economic activity during the COVID-19 lockdowns in 2020 were responsible for up to two-thirds of the anomalous CH_4 growth observed during that year. This work builds on previous papers that found a significant role for OH variations on CH_4 growth, without discussing mechanisms for the OH variations[4,5].

The authors applied an isotopic box model to show how elevated levels of OH in the early 2000s may have had long-lasting and somewhat counterintuitive effects on the observed $^{13}CH_4/^{12}CH_4$ ratio. A proportion of the observed decrease in this ratio since 2007 may have been due to its slow response to the earlier increase in OH concentrations. Previous studies have highlighted this slow response by simulating idealised step-changes in OH[11,12], but it is demonstrated here to what extent it affected the observed CH_4 growth rates post-2007.

Bringing together and building on strands from previous works, Ragnhild Skeie and colleagues treat the CH_4 cycle holistically, allowing them to quantify the relative contributions of a number of the driving factors of atmospheric CH_4 concentrations. They show that a single process is not enough to explain the observed changes in CH_4 in recent years. The uncertainty for many controlling processes remains relatively high, however, and a broader understanding of these past variations is needed.

We have reached an important moment when global emissions of greenhouse gases to the atmosphere must decrease if we are to minimise the anthropogenic influence on the Earth's temperature. Whilst many countries have pledged to significantly decrease their CH_4 emissions this decade, its atmospheric burden is rising at rates unprecedented since monitoring began. Only through a thorough understanding of past variations can we target our efforts to best mitigate CH_4.

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Author contributions

Chris Wilson conceptualised and wrote the article.

Competing interests

The author declares no competing interests.

Additional information

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