UPDATING ESTIMATES OF METHANE EMISSIONS: THE CASE OF CHINA

Background

Methane has a short atmospheric lifetime — only 10 years, compared with over 100 years for carbon dioxide (CO_2). It also has a much higher global warming potential than CO_2. Therefore, although the absolute quantities of human-caused methane emissions are much less than those of CO_2, methane-emissions abatement can significantly reduce concentrations, temperature, and damages from climate change in the short term, which is crucial to achieve U.S. and global targets for 2030. Indeed, according to the Intergovernmental Panel on Climate Change (2023), fully one-third of warming during 2010-2019 (relative to 1850-1900) is due to historical anthropogenic emissions of methane.[1] Reducing methane emissions would give the world time to "bend the curve" on CO_2 emissions, conduct research on carbon removal, and, more generally, implement longer-term strategies to mitigate and adapt to climate change.

Methane emissions are difficult to measure: emissions are less concentrated in the energy sector than is true for CO_2, and emissions from landfills and agriculture are geographically dispersed. Methane inventories submitted by national governments under the UNFCCC are typically generated via "bottom-up" methods by applying constant emission factors to known activities and sources. This method is susceptible to large uncertainties: bottom-up estimates of China's methane emissions in 2010 ranged from 44 to 58 teragrams[2] (Tg), with larger relative differences for individual sectors.

The advanced satellite technology and analytical techniques used in the study summarized here[3] improve upon previous methods and, in some cases, correct emissions figures formerly reported by national governments. This is indeed the case for China, which, according to one study, accounted for 12%–20% of global anthropogenic methane emissions in the decade from 2008 through 2017, more than any other single country.

Overview

Atmospheric scientists at Harvard University, led by Professor Daniel Jacob and, in the case of the paper summarized here, postdoctoral fellow Zichong Chen, use high-resolution data from the TROPOspheric Monitoring Instrument (TROPOMI), onboard a satellite launched in 2017,[4] to estimate national and sectoral methane emissions more accurately than has been possible in the past. They draw upon atmospheric transport models to invert the satellite observations of methane concentrations, using advanced statistical methods,[5] and infer emissions quantities and locations from the observed atmospheric concentrations. This method has yielded generally higher estimates of emissions than in previous reports, including in the case of China. In this study, satellite observations were combined with data from a 2014 report[6] from the Chinese government to the United Nations Framework Convention on Climate Change (UNFCC) to develop "top-down" estimates of sectoral emissions.

Key Findings

1. In Chen *et al*. (2022), the estimate of 65 Tg/year for total anthropogenic methane emissions in China is 20% higher than the 2014 value of 54 Tg reported by China to the UNFCCC.
2. Methane emissions in key sectors — including livestock, rice paddies, waste, oil, and natural gas — all showed increases over the 2014 inventory, ranging from +24% to +147%. (Natural gas is composed primarily of methane.) The only sector showing downward adjustment in this analysis is coal, with an estimated -15% emissions.
3. The downward adjustment in coal emissions can be attributed to closure of inefficient, high-methane-emitting mines, and a significant increase in methane capture and utilization, driven by policy efforts, over the last decade.
4. The largest upward adjustment in methane emissions was found in the oil sector, estimated at +147%. This correction might be attributed to natural gas leakage from oil extraction not fully accounted for in the 2014 UNFCCC report. Results from previous studies that use TROPOMI observations to identify ultra-emitters in oil production fields are consistent with locations where this analysis finds large upward adjustments in oil sector emissions.
5. Methane emission from natural gas production in China is relatively low, but this is partly because a large fraction (42%) of the natural gas used in China is imported.
6. This study derives a lifecycle loss rate of 1.7% (1.3%–1.9%) from natural gas production in China, lower than the 3.2% break-even point for a coal-to-gas transition to be beneficial for climate. However, this does not account for imported gas, the majority coming from Turkmenistan, where emissions per unit of gas production is exceptionally high.
7. Estimated methane emissions from livestock are higher than in any previous study. This reflects a large upward correction in livestock emissions for northwestern and northeastern China.
8. A higher estimate for waste emissions reflects a large (44%) increase in wastewater treatment plants since 2014, following major policy efforts to reduce water pollution. China has also seen an increase in solid waste generation, but a larger share of this waste is incinerated rather than landfilled.

Conclusion

An accurate picture of aggregate and sector-level methane emissions is important to better target mitigation policies. Utilizing TROPOMI data and advanced statistical methods, this study finds substantially higher anthropogenic methane emissions in China than previously reported, both overall and in some key sectors. The authors and their colleagues are conducting similar analyses of methane emissions in the United States, Latin America, and other countries and regions. It is hoped that the results will advance national efforts and international collaboration aimed at reducing methane emissions.

Endnotes

1 Intergovernmental Panel on Climate Change. 2023. Sixth Assessment Report (AR6) Synthesis Report (SYR) Summary for Policy Makers (SPM), page 4, footnote 8. https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf.

2 One teragam denotes 10^{12} grams and is equal to 1 million metric tons.

3 Chen, Zichong, *et al*. "Methane Emissions from China: A High-Resolution Inversion of TROPOMI Satellite Observations." *Atmospheric Chemistry and Physics* 22, no. 16 (August 26, 2022): 10809–26. https://doi.org/10.5194/acp-22-10809-2022.

4 http://www.tropomi.eu

5 See paper by Chen *et al*., on which this brief is based and which is referenced above, and:

Cusworth, Daniel H., A. *et al*. "A Bayesian Framework for Deriving Sector-Based Methane Emissions from Top-down Fluxes." *Communications Earth & Environment* 2, no. 1 (November 25, 2021): 1–8. https://doi.org/10.1038/s43247-021-00312-6

Varon, Daniel J., *et al*. "Integrated Methane Inversion (IMI 1.0): A User-Friendly, Cloud-Based Facility for Inferring High-Resolution Methane Emissions from TROPOMI Satellite Observations." *Geoscientific Model Development* 15, no. 14 (July 27, 2022): 5787–5805. https://doi.org/10.5194/gmd-15-5787-2022.

6 https://di.unfccc.int/detailed_data_by_party. Under "Select Party" drop-down, scroll down to "Non Annex I" and under that heading, "China"; under "Aggregate GHGs" drop-down, choose "CH4".

About the Program

The Reducing Global Methane Emissions Research Cluster seeks meaningful and sustained progress in reducing global emissions of this very important greenhouse gas — through research and effective engagement with policymakers and key stakeholders. This project is funded and supported through the Climate Research Clusters Program of the Salata Institute for Climate and Sustainability at Harvard University. The Program funds interdisciplinary research focused on producing practical solutions to some of the toughest climate challenges. The five currently-supported Clusters comprise interdisciplinary teams of researchers from across Harvard's schools, whose varied expertise is required to address the complexity of the problems that they seek to solve. Robert N. Stavins, A.J. Meyer Professor of Energy and Economic Development at Harvard Kennedy School, directs the Methane Cluster; the Harvard Project on Climate Agreements collaborates on the initiative. The findings, views, and conclusions in this publication are those of the authors alone.