

Improving Satellite Monitoring of Methane Emissions

Data science is fundamental to better emissions tracking

By Dorit Hammerling, William Daniels, Morgan D. Bazilian, and Brooke Bowser

Reducing methane emissions is a focus of addressing climate change. To do so effectively requires a robust monitoring and reporting system. Using data science, researchers at the Payne Institute are able to reduce the limitations of existing satellite data by providing localized estimations of methane fields to help fill the gaps of current monitoring.

Although the atmospheric concentration of methane is much lower than the atmospheric concentration of carbon dioxide (methane is typically measured in parts per billion while carbon dioxide is measured in parts per million), methane is a more potent greenhouse gas and has a disproportionate effect on rising temperatures. According to the International Energy Agency (IEA), about [30%](#) of the global rise in temperatures to date can be attributed to methane. Its short lifespan provides an opportunity for mitigating climate change because removing the fast-acting methane can provide significant, near-term results while other decarbonization efforts continue.

There are numerous sources of methane emissions, including oil and gas production, coal processing, agriculture, landfills and wetlands. The energy sector, particularly the oil and gas industry, likely has the [greatest potential](#) for reducing emissions by the end of this decade.

A 45% reduction in anthropogenic methane emissions by 2030 may be enough to limit global temperature rise to 1.5° C, according to a [Global Methane Assessment](#) launched by [Climate & Clean Air Coalition](#) and the [United Nations Environment Programme](#). The approach described by the

assessment includes several strategies for the oil and gas sector, including upstream and downstream leak detection and improved control of unintended fugitive emissions.

The Biden administration is incorporating methane reduction into its climate plans as leaders gather at the 26th UN Climate Change Conference of the Parties (COP26). In September, the United States and European Union (EU) initiated a [global pledge](#) to reduce methane emissions by at least 30% by 2030. So far, more than [100 governments](#) have joined the pledge, including six of the world's top 10 methane emitters. President Biden also unveiled the [U.S. Methane Emissions Reduction Action Plan](#), which will include new regulations that would reduce emissions from covered sources, equipment, and operations in the oil and gas industry by about 75%.

With stricter regulations likely approaching, facilities will need to more accurately quantify their emissions. Effective monitoring of this colorless and odorless gas continues to be a challenge, but it is key to reducing emissions in the energy sector.

DATA SCIENCE

Currently, various monitoring technologies are used, including sensors on satellites, planes, drones, and ground-based sensors. Ground-based sensors provide more frequent and localized measurements than other technologies, but they can be difficult to deploy globally. Satellite-based sensors have significant potential because of their extensive, global reach, but as of now, they are unable to produce highly localized observations.

One way methane is currently measured is by the TROPOspheric Monitoring Instrument (TROPOMI) on board a satellite that has been monitoring the Earth's atmosphere since 2017. It provides daily methane measurements across the world. TROPOMI has a limited spatial resolution of 7x5.5 km, which means this is the smallest area that can be attributed to a single observation.

Each methane observation provided by TROPOMI is an average of the methane concentration within the 7x5.5 km area. At this scale methane emissions can be detected, but it is challenging to attribute the emission to a particular facility within the 7x5.5 km area. This makes it hard to quickly locate and respond to the emission source, such as a leak on an oil and gas facility.

To make the TROPOMI data more useful, researchers at the Payne Institute have developed a statistical model to estimate the underlying methane field at a higher resolution than the observations provided by TROPOMI.

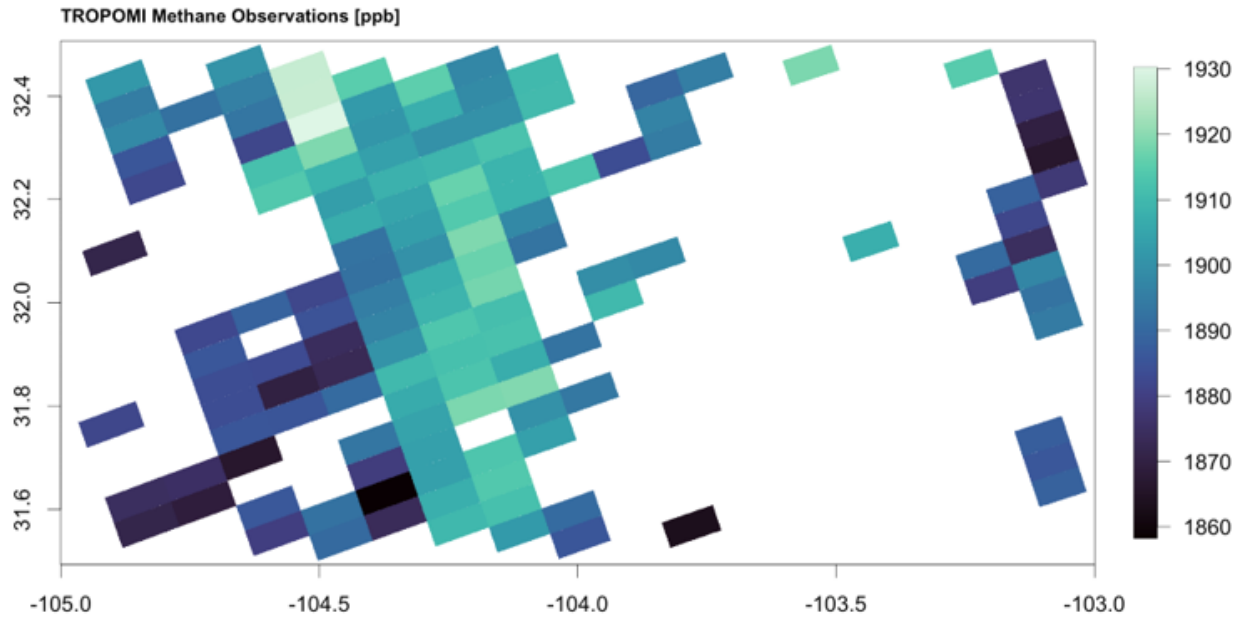


Figure 1: TROPOMI methane observations on Aug. 23, 2021, over part of the Permian basin.

Developing this model required researchers to work backwards from the coarse TROPOMI data and estimate the more detailed information that makes up those observations.

The model is broken down into different levels, with the top level being the coarse TROPOMI data directly observed and the bottom level being the fixed parameters that influence the data. Because the exact value of the parameters influencing the data are unknown, researchers estimated them using a statistical method called maximum likelihood estimation. Following this method, they use the parameter values that make the observed data most likely.

Using this model, researchers are able to make localized predictions of the methane field and quantify the uncertainty in their predictions.

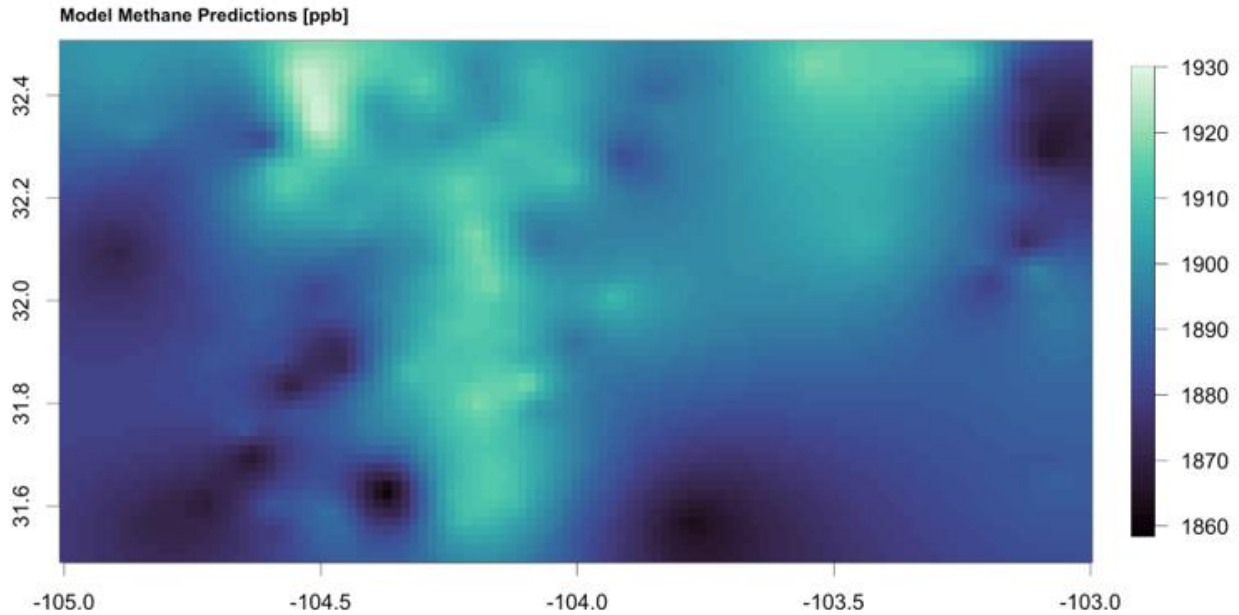


Figure 2: Model predictions of the methane field during the Aug. 23, 2021 TROPOMI overpass.

The TROPOMI observations, although directly observed, have some measurement error, and factors such as cloud cover can reduce the amount of data available. As expected, the predictions are accurate closer to the TROPOMI observations, and the statistical model allows for quantifying how the uncertainties vary over the spatial area. Understanding this uncertainty is important because it affects the information content of the data from which decisions will be made.

The ability to extract more meaningful information from coarse satellite data is an important step towards creating a robust monitoring and reporting system. By using predictions from this model and having them coupled with data from continuous ground monitoring, regulators would have a more detailed and complete map of methane concentrations across a basin. Using these techniques to detect abnormal methane concentrations can help operators and governments meet regulations and reduce methane emissions to support climate goals.

ABOUT THE AUTHORS

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After 8 years working in the cement industry on process and quality control, Prof. Hammerling obtained a M.A. and PhD (2012) from the University of Michigan in Statistics and Engineering developing statistical methods for large satellite data. This was followed by a post-doctoral fellowship at the Statistical Applied Mathematical Sciences Institute in the program for Statistical Inference for massive data. Prof. Hammerling subsequently joined the National Center for Atmospheric Research, where she led the statistics group within the Institute for Mathematics Applied to the Geosciences and worked in the Machine Learning division before becoming an Associate Professor in the Department of Applied Mathematics and Statistics at the Colorado School of Mines in January 2019. Prof. Hammerling received the Early Investigator Award from the American Statistical Association, Section on Statistics and the Environment, in 2018.

William Daniels

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William Daniels is currently pursuing a MS in Statistics at the Colorado School of Mines. He recently obtained a BS in Engineering Physics from Mines, graduating with the Physics Faculty Distinguished Graduate Award in 2019. His work in the Physics Department involved modeling and simulation of certain transient luminous events in the upper atmosphere. His current work in the Applied Mathematics and Statistics Department involves statistical inference problems related to large satellite data. Starting in the spring of 2020, he has been working with the Payne Institute for Public Policy on the Responsible Gas Initiative, which seeks to better monitor oil and gas operations via multiple levels of emission detection technology.

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Morgan Bazilian is the Director of the Payne Institute and a Professor of public policy at the Colorado School of Mines. Previously, he was lead energy specialist at the World Bank. He has over two decades of experience in the energy sector and is regarded as a leading expert in international affairs, policy and investment. He is a Member of the Council on Foreign Relations.

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Brooke Bowser is a recent graduate from the University of Wisconsin - Madison where she earned a degree in Environmental Sciences and Life Sciences Communication. Her background in ecological research and environmental communications led to her development as a science writer striving to craft engaging and accessible science stories for all audiences.

The Payne Institute for Public Policy



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The Payne Institute Commentary Series offers independent insights and research on a wide range of topics related to energy, natural resources, and environmental policy. The series accommodates three categories namely: Viewpoints, Essays, and Working Papers.

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