Damn Satellite Part 3: Super-emitters and Ultra-emitters

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1. Introduction

In the last part of this series, we identified several methane super-emitters in the Permian Basin oil fields in West Texas and Eastern New Mexico. This post from last October is linked below.

https://energycentral.com/c/ec/damn-satellite-part-2-%E2%80%93-damn-airplane-ch4

The Permian super-emitters have now been located with better precision at the completion of a multi-year aerial survey, and additional surveys have been performed via multiple satellites.

The other news is that the Environmental Protection Agency (EPA) has started a process to define new methane emission rules for oil and gas producers.

Also, an international consortium has identified a new class of methane Ultra-emitters.

Part 3 reports on all of the above new information.

2. Permian Super-Emitters

Today, Carbon Mapper and Environmental Defense Fund released insights generated from three years of airborne surveys (conducted between 2019 and 2021) using advanced remote sensing technology to pinpoint, quantify, and track methane emissions from oil and gas production facilities in the Permian Basin across Texas and New Mexico.[1]

The data reveals that about 30 facilities—including pipelines, well pads, compressor stations and processing facilities—persistently emitted large volumes of methane over multiple years, and that repairing those leaks could immediately reduce 100,000 metric tons of methane per year. These 30 facilities make up less than .001% of the region's oil and gas infrastructure, and yet they produce the same near-term climate pollution as about half a million passenger vehicles. The mitigation of these 30 super-emitters would prevent $26 million a year in wasted gas.

Cutting methane—a super-potent greenhouse gas with vastly greater near-term warming potential than CO_2—has become a heightened priority domestically and internationally given the urgency of the climate crisis. Recently, the U.S. and more than 100 other countries signed the Global Methane Pledge to cut methane 30% by 2030…

Cumulatively, the Carbon Mapper research team detected nearly 1,100 super emitters across the Permian Basin over the course of their research which was performed as part of a joint NASA, RMI, and University of Arizona research program and EDF's Permian-

[1] Kelly Vaughn, Carbon Mapper, "Three years of independent airborne surveys reveal near-term opportunities to meet domestic and international methane reduction targets," Jan 24, 2022, https://carbonmapper.org/dozens-of-super-emitting-oil-and-gas-facilities-leaked-methane-pollution-in-permian-basin-for-years-on-end/

MAP initiative. These facilities ultimately contribute to about half of the basin's total methane emissions. While leaks at these facilities are very large, most are shorter in duration and underscore the need for frequent monitoring of all facilities basin-wide to pinpoint and mitigate as many super emitting sites as possible.

Rules being advanced by the Environmental Protection Agency and New Mexico Environment Department (NMED) have the potential to address oil and gas pollution by requiring regular monitoring at most processing facilities and production sites—including at smaller, leak-prone wells. The NMED rules was finalized in March... EPA is also expected to issue a supplemental proposal this spring that will further address pollution from smaller wells and routine flaring. Comprehensive EPA rules represent the Biden administration's biggest and most immediate opportunity to achieve significant pollution reductions across the Permian region as well as its commitments under the global methane pledge.

The high-resolution data also reveals important insights about the types of equipment releasing methane, to within a few meters of its location. Gathering pipelines appear to be a significant source of leakage in the Permian, responsible for nearly 20% of the observed persistent super-emitters. But of the 435,000 miles of U.S. onshore gathering pipelines, only 11,569 miles (less than 3%) are currently subject to federal leak survey standards set by the Pipeline and Hazardous Materials Safety Administration (PHMSA).

The PIPES Act of 2020 expanded PHMSA's responsibility to protect the environment and specifically called for enhanced oversight of gathering lines. PHMSA issued a new rule to expand leak survey requirements to an additional 20,336 miles of gathering lines, set to take effect in May 2022 – but industry groups oppose that requirement and are seeking reconsideration of the rule.

"PHMSA must continue to improve oversight of gathering lines and require the use of advance methane monitoring to find and fix pipeline leaks," said Erin Murphy, EDF Senior Attorney for Energy Markets and Utility Regulation. "In fact, reports show there are more commercially available solutions for controlling pipeline emissions today than ever before."

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3. Satellite Monitoring

A team of 25 researchers from universities, technology companies, research and development organizations and public interest groups all over the globe recently published a paper that is referenced and linked at the end of this paragraph. The associated project used multiple satellite networks with imaging spectroscopy capability capable of detecting methane plumes to detect large point sources of this gas from oil and gas production facilities in the Permian basin.[2]

…Methane levels in the atmosphere have almost tripled since preindustrial times. Along with agriculture, oil and natural gas (O&G) production operations are one of the primary causes for this increase, but the magnitude, dynamics, spatial distribution, and driving mechanisms of methane (CH_4) emissions from O&G production remain poorly

[2] See the linked paper for authors and their organizations, Science Advances, "Satellite-based survey of extreme methane emissions in the Permian basin," 30 June, 2021, https://www.science.org/doi/10.1126/sciadv.abf4507#

understood. This is especially concerning for the United States, which is the world leader in O&G production, owing to its rapid growth in the last two decades. Alvarez et al. estimated that 13 Tg CH_4 was emitted from the U.S. national O&G supply chain in 2015, which is 78% higher than the most recent estimates by the U.S. Environmental Protection Agency (EPA) for that year, and represents an important fraction of the 68- to 92-Tg CH_4 range estimated globally for upstream and downstream O&G sectors in the 2008–2017 decade...[3]

…O&G production in the Permian basin, located in New Mexico and Texas, has been growing rapidly over the past decade, and the Permian is now the largest O&G-producing basin in the United States. This was covered by a recent study by Zhang et al., which combined satellite observations from the Tropospheric Monitoring Instrument (TROPOMI) onboard the Sentinel-5P satellite with atmospheric modeling methods to find Permian methane emissions from O&G production to be 2.7±0.5 Tg CH_4.[4] *This number represents the largest methane flux ever reported from a U.S. O&G-producing region; it is more than twice the bottom-up estimates for the Permian, and a factor of 4 higher than estimates for any other Unites States O&G basin.*

Better characterizing the nature, intensity, and dynamics of methane point emissions from the world's O&G basins, and in particular from the Permian, is not only critical to close the gap between bottom-up and top-down anthropogenic emission estimates but also to facilitate emission reductions. Better emission characterization is also crucial for understanding the contribution of the O&G production sector to the acceleration of the methane growth rate in the atmosphere. Airborne measurement methods, through either mass balance or imaging spectroscopy, are a powerful approach to detect and monitor methane point sources over large O&G regions. In particular, so-called imaging spectrometers offer a unique observational configuration to map methane point emissions with simultaneously high accuracy and spatial sampling. These instruments produce images of the solar radiation reflected by the Earth surface at hundreds of wavelengths, including those in the shortwave infrared region of the electromagnetic spectrum sampling the strong methane absorption band around 2300 nm (see figure below). High-resolution maps of methane plumes (up to 3 to 4 m for airborne instruments) can be inferred from these observed spectra using atmospheric retrieval techniques.

Satellite remote sensing represents a critical means for systematic monitoring of point emissions from O&G-producing regions around the world. The Sentinel-5P/TROPOMI mission, launched in 2017, is a crucial step toward the monitoring of methane emissions from space, but its 7-km pixel size does not generally allow sampling of individual point sources. Instead, high-resolution (~30-m) methane retrievals can be performed using satellite imaging spectrometers, which trade TROPOMI's fine spectral resolution for fine spatial resolution. This trade-off does not allow retrieval of small methane sources but is ideal for detecting large point sources… The GHGSat-D private satellite has also shown capability of retrieving large methane sources at 50-m spatial resolution.

In this study, we take advantage of the rapid development of space-borne imaging spectroscopy technology and data processing methods to perform the first satellite-

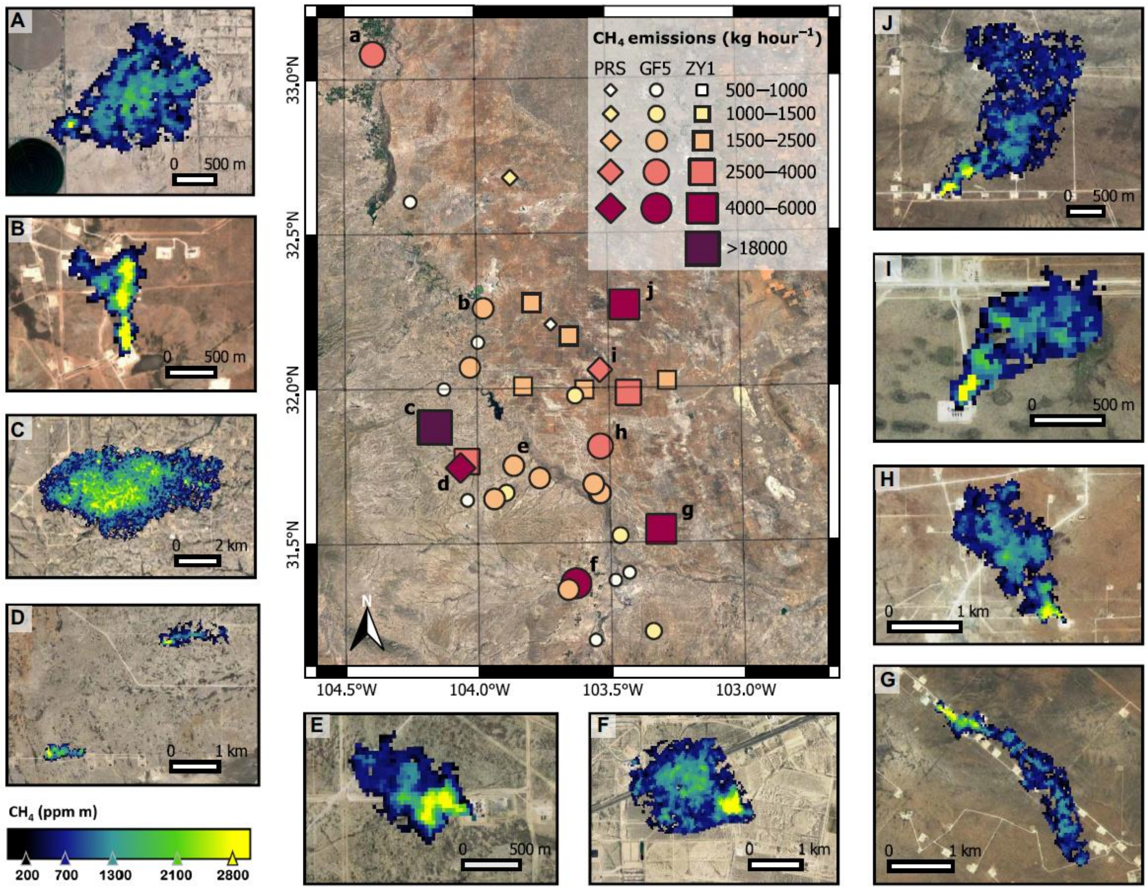
[3] R. A. Alvarez, D. et al, Science 361, 186–188 (2018), "Assessment of methane emissions from the U.S. oil and gas supply chain," https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=924889
[4] Y. Zhang, et al, Science Advances, "Quantifying methane emissions from the largest oil-producing basin in the United States from space," April 22, 2020, https://www.science.org/doi/10.1126/sciadv.aaz5120

based large-scale and high-resolution survey of methane point emitters in the Permian basin. Our dataset was acquired by three satellite missions launched between 2018 and 2019: two versions of the Advanced Hyperspectral Imager (AHSI) onboard China's Gaofen-5 (GF5) and ZY1 satellites and the imaging spectrometer onboard Italy's PRISMA mission. We cover a ~150 km–by–200 km area in the Delaware sub-basin of the Permian basin with a total of 30 images acquired within several days, but mostly on four different dates: 15 May 2019, 1 November 2019, 29 December 2019, and 8 February 2020 ... We generate maps of methane concentration enhancements (ΔCH_4), from which we detect methane plumes through visual inspection. We calculate emission flux rates (Q) for each plume using the integrated methane enhancement (IME) method and large eddy simulations performed specifically for our satellite observations. We evaluated the sensitivity of our satellite measurements to methane enhancements and the uncertainties in methane flux calculation by means of simulation-based studies. The 30-m spatial sampling of our survey allows us to map individual methane plumes and to attribute emissions to specific infrastructure. Our core objective is to identify, characterize, and quantify the largest point emissions in the area, with the overarching motivation of assisting future emission reduction efforts.

3.1. Results

Figure below shows the location and intensity of the 37 methane plumes that we have detected over the Delaware sub-basin of the Permian after the processing of our satellite imaging spectroscopy dataset. The detected point emissions have Q typically between 500 kg per hour (which we assume as both our detection limit and our definition of an "extreme emission") and 6000 kg per hour. Most plumes are located in the 31.0° to 32.5°N, 103.3° to 104.2∘W subregion. This matches the area of highest methane fluxes revealed by top-down estimates by Zhang et al.[4] but is less well aligned with the bottom-up emission inventory based on the U.S. EPA greenhouse gas inventory…

Subpanels around the main panel of the figure below show examples of individual methane plumes. There is a relatively large variability in both emission rates and source types. For example, plume a corresponds to a large emission (3590±1220 kg per hour) from an area devoid of visible infrastructure elements such as well pads and storage tanks; plume b (2119±608 kg per hour) is associated with the incomplete combustion of a flare from a tank battery; plume f is a strong emission (4385±1296 kg per hour) that we attribute to the venting of a gas well; plumes g and j are two very large emissions (5952±2556 and 5472±2159 kg per hour, respectively) from compression stations. Last, plume c is a special case. It corresponds to an emission of an abnormally high magnitude (18,492±6570 kg per hour) from an unknown source. The absence of correlation between the spatial distribution of the methane enhancement and surface brightness and composition indicates that this is a real methane plume and not the result of a processing artifact. We attribute it to a large transient release, potentially from one of the large natural gas gathering pipelines in the area. A strong methane enhancement is seen by TROPOMI at the same location in the days around this event, but we are not able to determine what fraction of the enhancement is actually due to this particular emission.



Author's comment: This paper has much additional information on these methane sources. If you are interested in seeing this, go through the link in reference 2.

4. Ultra-emitters

…Representing a quarter of anthropogenic emissions alone, emissions from O&G production activities have increased from 65 to 80 Mt per year over the past 20 years. This rapid increase imperils the success of the Paris Agreement. Anthropogenic emissions trends are partly explained by the increase in shale gas production in the US, which will soon be followed by the development of large, currently underexploited shale reserves in China, Africa, and South America. Although O&G emissions from national inventories have been widely underestimated by conventional reporting, airborne imagery surveys have confirmed the omnipresence of intermittent emissions, … resulting from very large O&G emissions, often referred to as super-emitters (top 1% of emitters or >25 kg/hour).[5]

Until recently, observation-based Methane (CH_4) emission quantification efforts were restricted regionally to short-duration aircraft surveys (lasting a few weeks) or the deployment of in situ sensor networks. Global efforts were limited by sparse sampling of coarse-resolution CH_4 column retrievals, such as the GOSAT mission. More routine and higher spatially resolved emission quantification was made possible by the European

[5] See the linked article for authors and affiliations, Science, "Global assessment of oil and gas methane ultra-emitters," Feb 4, 2022, https://arxiv.org/ftp/arxiv/papers/2105/2105.06387.pdf

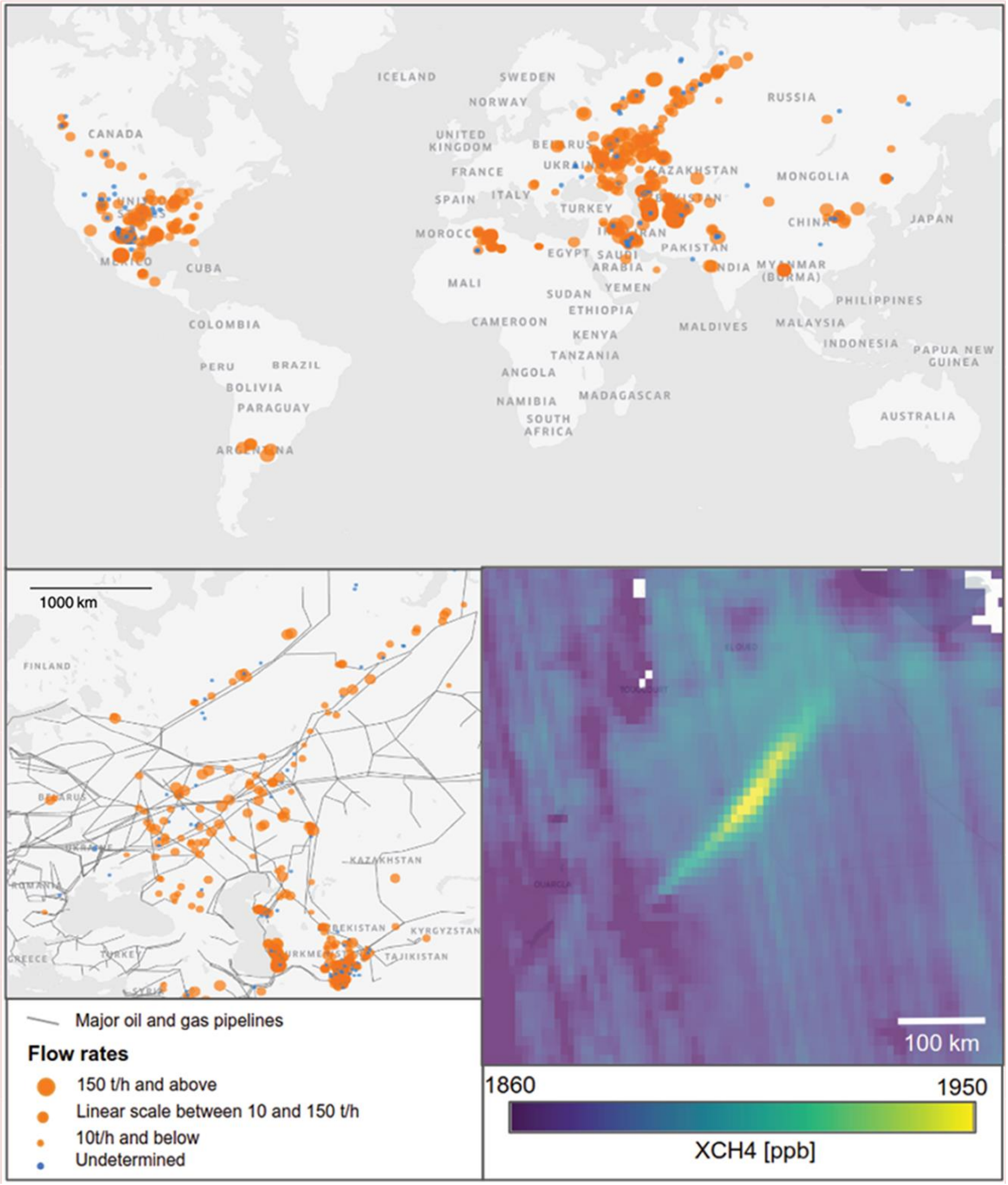
Space Agency Sentinel 5-P satellite mission, which carried the TROPOspheric Monitoring Instrument (TROPOMI; launched 2018). TROPOMI samples daily CH_4 column mole fractions over the whole globe at moderate resolutions (5.5 km by 7 km^2) and has revealed multiple individual cases of unintended very large leaks and regional basin-wide anomalies. We systematically examine this dataset over multiple locations worldwide, which allows us to statistically characterize visible ultra-emitters (>25 tons/hour) of CH_4 from O&G activities across various basins. By nature, reducing these ultra-emitters by enforcing leak detection and repair strategies or by reducing venting during routine maintenance and repairs provides an actionable and cost-efficient solution for emission abatement…

The number of detections of large total column CH_4 mole fraction enhancements around the world, each associated with an ultra-emitter, totals >1800 single observed anomalies over 2 years (2019–2020); a large fraction of them are located over Russia, Turkmenistan, the US (excluding the Permian basin where regional enhancements comprise many small to medium emitters), the Middle East, and Algeria (See figure below). Detections vary in magnitude and number (between 50 and 150 per month), most of them corresponding to O&G production or transmission facilities (about two-thirds of detections, or ~1200), whereas ultra-emitters from coal, agriculture, and waste management represent only a relatively small fraction (33%) of total detections). Ultra-emitters attributed to O&G infrastructure appear along major transmission pipelines and over most of the largest O&G basins, representing more than 50% of total onshore natural gas production worldwide. Offshore emissions remain invisible to TROPOMI, and cloud cover almost entirely blocks O&G basins in tropical areas; hence, these are excluded from our analysis.

Estimated emissions from O&G ultra-emitters rank highest for Turkmenistan with 1.3 Mt of CH_4 per year, followed by Russia, the US (excluding the Permian basin), Iran, Kazakhstan, and Algeria. Because leak duration varies and S5-P provides only snapshots, each leak duration was determined either on the basis of an observed duration deduced from the plume length or setting a 24-hour duration when consecutive images can confirm the presence of the same anomaly over multiple days. Leaks lasting several days were adjusted according to lack of coverage and hence quantized to 24 hours. Two additional scenarios—based on (i) a systematic 24-hour duration and (ii) based on the length of the observed plumes— were constructed to define the upper and lower bounds of durations (supplementary materials). The lack of coverage due to clouds, albedo, or aerosols was quantified by adjusting for the number of observed days compared with the full period length. Uncertainties were quantified by a negative binomial probability function.

Author's Comment: Based on other data, I believe that "Mt" at the beginning of the above paragraph is an official SI abbreviation for 10^6 metric tons (in SI-speak, metric tons = tonnes). For more information see the SI Brochure through the link below.

https://www.bipm.org/en/publications/si-brochure/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SOUTH AFRICA
AUSTRALIA
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Major oil and gas pipelines
Flow rates
150 t/h and above
Linear scale between 10 and 150 t/h
10t/h and below
Undetermined
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