HUNTING METHANE *Using Satellites*

A Guide for Policymakers

APRIL 2025
Explainer

UC Berkeley Center for Law, Energy & the Environment

UCLA School of Law Emmett Institute on Climate Change & the Environment

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I. INTRODUCTION

We are in the midst of a methane data revolution. Space-based instruments can now spot emissions of methane—a highly potent greenhouse gas—at different spatial scales with near-global reach. The result: powerful new streams of data, much of it available publicly, that are helping public officials understand emissions like never before. Consequently, governments have the opportunity to meet their climate targets, improve local air quality, and help operators locate expensive leaks.

This explainer is intended for policymakers interested in employing methane data from satellites. It discusses how methane detection satellites work, what data they provide, and how they can be used by policymakers. Section 1 is an introduction to methane tracking. Section 2 elaborates on current and near-future satellite systems, and Section 3 lays out some use cases of satellite-detected methane data. Section 4 provides information on channels to access these data, and finally, Section 5 lays out five case studies where policymakers are currently applying satellite data to facilitate methane mitigation.

MEET METHANE

Methane is a powerful greenhouse gas. It accounts for about one-third of Earth's warming and is 84 times more potent than carbon dioxide over a 20-year period. By reducing methane emissions, governments can help to activate a sort of "climate emergency brake," slowing the climb of global temperatures. Meanwhile, they can achieve local improvements in public health and economic productivity. This is because steps to cut methane often reduce the release of other toxins; make agricultural and energy development more profitable; and prevent the waste of a valuable fuel source. By tracking methane emissions within their jurisdictions, governments can position themselves to maximize these opportunities.

Methane is released when organic matter decomposes in oxygen-deprived environments. Such conditions are found in cow stomachs, fossil fuel deposits, landfills, wastewater facilities, and flooded rice paddies—all major sources of methane.

Traditionally, methane emissions have been estimated using **bottom-up** approaches, in which reported activity levels (e.g., levels of oil production or volume of landfill waste) are multiplied by emission factors, which are generic estimates of a given unit's rate of emissions. These methods continue to have an important place, especially for small emissions sources, but they also have limitations.

Bottom-up estimation methods often fail to capture the full extent of emissions due to:

1. Limits in the accuracy of production data, especially in the waste and agricultural sectors.

2. Flawed emissions factors, which may be outdated and overlook the variability and scope of emissions, including by missing large "super emitter" events.[1]

By contrast, **top-down** approaches, including remote sensing technology, enable direct observation. Airborne and satellite instruments are now capable of detecting and quantifying methane emissions at unprecedented scales. These instruments utilize infrared light to measure methane concentrations, which can be used to estimate emissions volumes and rates from a range of sources. Satellites can observe vast areas, including regions previously inaccessible to efficient ground-based monitoring. They can also detect intermittent emissions, such as those resulting from maintenance events or sporadic leaks, and spot high-emitting point sources with precision. By combining satellite, airborne, and ground-based observations, it is now possible to create detailed pictures of methane emissions over large regions.

Like any data-gathering method, satellite-based methane detection and quantification comes with a set of challenges.

1. Factors like weather conditions and data processing challenges can affect the reliability of satellite methane estimates.

2. A satellite's detection limit, spatial coverage, and sample frequency all factor into how much methane it can spot, or its "completeness."[2] Depending on the region and sector, completeness of satellite observations can be low. Lack of sufficient funding also constrains the ability to operationally expand the satellite systems necessary to achieve near 100% completeness in key regions and sectors.

3. Users may need specialized knowledge to integrate data from multiple sources. For instance, if an official is trying to determine the annual net emissions from a facility, they might need to combine satellite and bottom-up data to derive a complete picture.

4. This is a rapidly evolving area of research, with methods still being developed. This means that protocols for calculating emissions have not yet been standardized.

The expertise to synthesize data is, however, readily available through several international bodies and NGOs, while data platforms are increasingly user-friendly. Moreover, the benefits of remote sensing technology for methane monitoring are substantial. By providing more accurate, widespread, and timely information, satellites allow policymakers and industry leaders to take more immediate action, seizing major economic, health, and climate benefits.

HOW DO METHANE-DETECTING SATELLITES WORK?

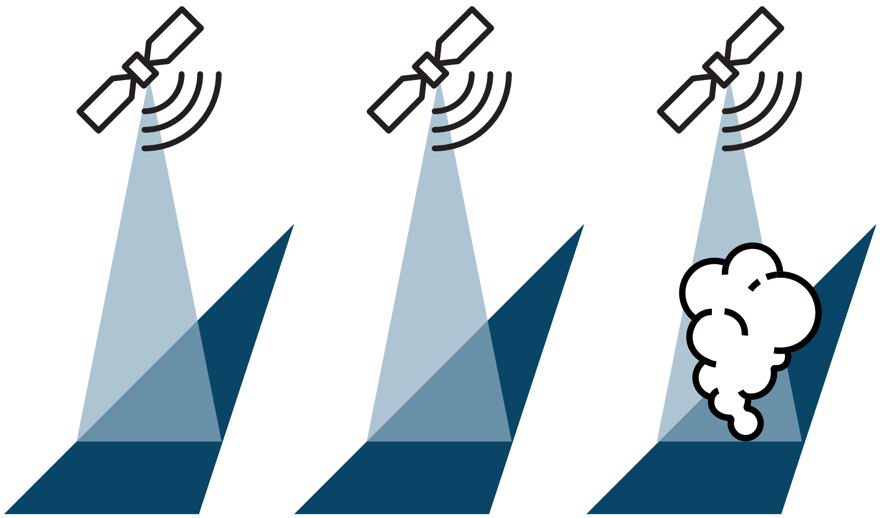
Methane estimates have historically been developed without the benefit of direct observation. Instead, they have largely relied on bottom-up approaches, discussed above. The field of remote sensing now provides a variety of valuable insights into the Earth's surface, oceans, and atmosphere. Aerial platforms, including aircraft and drones, have been used widely by officials and scientists for a wide range of environmental observations.

While some oil and gas operators may employ optical gas imaging cameras to monitor gas concentrations at the component or site level, these devices can be costly and challenging to operate.[3] Moreover, data from such site-level detections is often one-time, rather than periodic, and is not typically made available to regulators. Aerial drones and aircraft have also been used to detect methane remotely at particular sites and even across broader regions, but those methods are spatially limited and expensive.

By contrast, a growing number of satellites are now optimized for and solely devoted to methane, using devices called **spectrometers** to see methane's telltale signature in infrared light. This light signature permits observers to directly observe methane in the air below the satellite and to calculate information about methane abundance. For the first time, a network of such instruments is now providing practical, near-global monitoring of atmospheric methane, often at a low cost and with strong data availability.[4]

Each chemical compound in the atmosphere has a unique molecular structure that determines its interaction with specific wavelengths of light. This interaction pattern, known as the molecule's **spectral fingerprint**, is a distinctive characteristic of each chemical species. Satellite instruments can detect methane in the atmosphere when they pick up a wavelength pattern that corresponds to methane's spectral fingerprint, particularly its strong absorption of light at 1.65 and 2.3 microns in the near-infrared spectrum. By analyzing satellite data showing changes in radiance (i.e., the intensity of light the instrument "sees" in the scene), observers can estimate methane abundance (i.e., the concentration of methane within a given area). They can also estimate methane emission flux rates (i.e., emission rate per unit time and area) from nearby sources.

Most (not all) methane mapping satellites are "pushbroom" imagers that observe long strips, not just individual spot-images. GHGSat is an exception in that it's limited to relatively small snapshots (typically 12 x 12 km2). Carbon Mapper can image strips as long as 480 km. MethaneSAT images are about 200 km long. TROPOMI (a truly global mapper) can image even longer strips.



CARBON MAPPER: *A public-private initiative deploying satellites for high-resolution methane and CO_2 monitoring.*

METHANESAT: *A satellite launched by the Environmental Defense Fund to track methane emissions from the oil and gas sector.*

TROPOMI (TROPOSPHERIC MONITORING INSTRUMENT): *A European Space Agency instrument on the Sentinel-5P satellite, used for detecting methane and other atmospheric gases.*

Types of instruments

Methane monitoring satellites vary in their spatial coverage and resolution. There are two main classes of satellites:

1. **Point source imagers**, like GHGSat and Carbon Mapper, identify and quantify emissions from specific sources (e.g., a given facility).

2. **Area flux mappers**, such as MethaneSAT, Sentinel-5P, and GOSAT, are designed to measure average methane concentrations over large areas, providing a broad understanding of methane emissions across regions (e.g., the Permian Basin in the United States).

Point source imagers allow observers to identify leaks, accidents, and new sources of methane from individual sources such as oil and gas facilities and landfills—or to verify that previously detected leaks have been fixed. Within the limits of their orbital flight path, they can be aimed to measure emissions from specific locations.

Area flux mappers are best used to estimate emissions at larger regional or jurisdictional levels, across broader swaths of territory. Area flux mappers can be very accurate in estimating total methane abundance in a given area. When flown over the same region repeatedly, these systems can track changes in total emissions resulting from policy, management, or other factors.

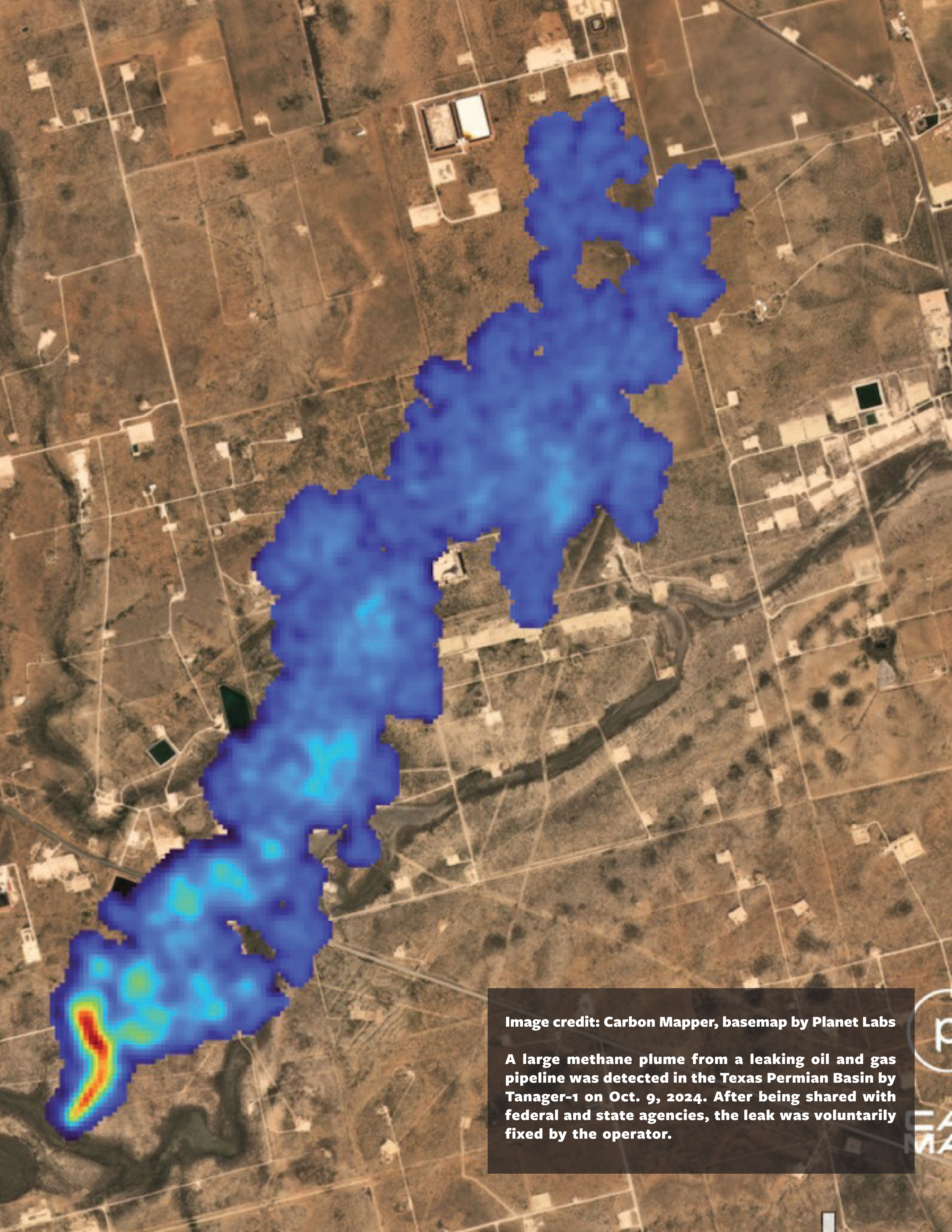


Image credit: Carbon Mapper, basemap by Planet Labs

A large methane plume from a leaking oil and gas pipeline was detected in the Texas Permian Basin by Tanager-1 on Oct. 9, 2024. After being shared with federal and state agencies, the leak was voluntarily fixed by the operator.

II. CURRENT AND NEAR-FUTURE SATELLITE SYSTEMS

MEET THE METHANE SATELLITES

Methane-spotting satellites have evolved significantly in recent decades. Early efforts, such as the European Space Agency's 2002 launch of the Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY), laid the groundwork for space-based atmospheric monitoring.[5] In the mid-2010s researchers used the SCIAMACHY sensor for one of the earliest identifications of a large methane leak from space near the Four Corners region of the Southwestern United States.[6] Gradually, governments in North America, Europe, and Asia have continued to launch new satellite platforms devoted to greenhouse gas observations, while private companies have begun to offer high-resolution industrial site monitoring as a commercial service.

Recently, technological advances and an international focus on methane have enabled the development of additional satellites. Two of the newest methane satellites, both launched in 2024, are MethaneSAT, from the Environmental Defense Fund, and Tanager-1, from a partnership among Carbon Mapper, NASA JPL, and Planet Labs.[7] [8]

MethaneSAT and Carbon Mapper differ in their design and observing strengths:

1. **MethaneSAT** is focused on area sources (i.e., entire basins)

2. **Carbon Mapper** is focused on identifying point sources (i.e., specific plumes)

Both platforms are highly anticipated for their operational monitoring of anthropogenic methane sources including oil and gas, coal, and waste systems. MethaneSAT and Carbon Mapper join a constellation of more than a dozen satellites capable of detecting methane.

These platforms are commonly referred to by the name of the imaging instrument (i.e., "TROPOMI" or "Tropospheric Monitoring Instrument"), the name of the satellite on which the instrument sits (i.e., "MethaneSAT"), or the operating organization (i.e., "Carbon Mapper"). Table 1 introduces 14 active satellite platforms capable of detecting methane, all of which utilize passive sensing with sunlight, rather than active laser-based sensing.

Table 1. Fourteen methane-capable instruments.

Note: List is not exhaustive. Satellite missions that have been previously retired are not included.

SATELLITE AND/OR INSTRUMENT NAME	OPERATOR	LAUNCH DATE	DESCRIPTION
Government satellites			
GOSAT, GOSAT-2, GOSAT-GW ("Greenhouse Gases Observing Satellite")	Japanese Aerospace Exploration Agency (JAXA)	2009, 2018, Planned launch in 2025[9]	Measures CO_2 and methane
Landsat 8 and 9	US Geological Survey & the National Aeronautics and Space Administration (NASA)	2013	Primarily focused on land use and land cover changes; also provides data related to methane emissions
Sentinel-2A, 2B, 2C	European Space Agency (ESA)	2015, 2017, 2024	Primarily provides high-resolution imagery for land and vegetation monitoring but can detect methane through specific analyses
Sentinel-5P, TROPOMI ("Tropospheric Monitoring Instrument")	European Space Agency (ESA)	2017	Monitors methane with the TROPOMI instrument; part of the Copernicus program
Gaofen 5 and 5-02	China National Space Administration (CNSA)	2018, 2021	Contains multiple instruments for environmental monitoring
Ziyuan-1 02D and 02E	China National Space Administration (CNSA)	2019, 2021	Used primarily to study natural resources
PRISMA ("Precursore Iperspettrale della Missione Applicativa")	Italian Space Agency (ASI)	2019	Provides detailed observations of Earth's surface, including the ability to detect methane
EMIT ("Earth Surface Mineral Dust Source Investigation")	National Aeronautics and Space Administration (NASA)	2022	Designed to study mineral dust but also measures methane; sits aboard the International Space Station
EnMAP ("Environmental Mapping and Analysis Program")	German Aerospace Center (DLR)	2022	Measures both terrestrial and aquatic ecosystems

SATELLITE AND/OR INSTRUMENT NAME	OPERATOR	LAUNCH DATE	DESCRIPTION
Public and public-private satellites			
MethaneSAT	Environmental Defense Fund (EDF)	2024	Designed to observe methane emissions over wide areas, especially of oil and gas production regions; developed by a subsidiary of the non-profit Environmental Defense Fund
Carbon Mapper's Tanager-1	Carbon Mapper, NASA's Jet Propulsion Lab, & Planet Labs	2024	Measures greenhouse gas point-source emissions on a global scale; part of a broader effort by the nonprofit Carbon Mapper
Private satellites			
Worldview-3	Maxar	2014	Provides high-resolution imagery
GHGSat	GHGSat Inc.	2016, with many subsequent launches	Detects methane from industrial facilities worldwide; Canadian company
GHOSt ("Global Hyperspectral Observation Satellite")	Orbital Sidekick	2023, with subsequent launches	Produces high-resolution commercial imagery

HOW ARE VARIOUS METHANE SATELLITES DIFFERENTIATED BY TECHNICAL DESIGN AND FUNCTION?

Spectral range and resolution:

Satellites differ in their **spectral range**, which describes the span of light wavelengths the instrument can see. They also differ in terms of **spectral resolution**, or how well they distinguish different wavelengths within the span. So-called **hyperspectral satellites** (e.g., Carbon Mapper, EMIT, EnMAP) capture a near-continuous spectrum of light wavelengths, while multispectral satellites (e.g., Sentinel-2) observe within several discrete bands. Finally, some satellites are dialed into only a few bands that are specific to methane's spectral fingerprint, making them purpose-built but limited in other types of imaging applications compared to satellites with broader spectral capabilities.

Spatial resolution and spatial coverage:

Spatial resolution, or pixel size, describes the smallest spatial unit an instrument can discern within its **spatial coverage**, or the swath viewing area. One way of thinking about this is by considering a camera with a wide angle lens compared to one with a telephoto lens, as methane satellites are either optimized for one or the other. For example, WorldView-3 has a spatial resolution of a few meters (i.e., "zoomed in") and is considered to have a high resolution compared to Sentinel-5P's coarser pixel size of several kilometers on each edge (i.e., "zoomed out"). Typically, dozens to hundreds of pixels can fit within a satellite's swath area. This means that satellites with high spatial resolution usually cover less total area in a single shot compared to coarser instruments that see a wider area.

Temporal coverage:

Satellites vary in how frequently they can revisit to re-observe a specific location on Earth's surface. Generally, higher **temporal coverage** (quick revisits) is traded for lower spatial resolution. Global scanning satellites, like those in the Sentinel series, often have relatively rapid revisit times in the range of one to five days. Targeted instruments typically have longer revisit intervals in the range of 5 to 14 days, which can limit their effectiveness in tracking rapid changes in methane emission sources. To combat this, operators sometimes launch multiple point source satellites in a series to achieve both high spatial and high temporal coverage.

Detection threshold:

When measuring methane point sources, each satellite has a flow rate limit, typically measured in kilograms of methane per hour (kg/hr), below which it becomes difficult to detect individual methane sources. For satellites included in this text, threshold rates can vary by orders of magnitude from approximately 100 kg/hr to 10,000 kg/hr (Table 2). An instrument's performance in measuring leak rates is often called its **minimum detection limit** (MDL) or **lower detection limit** (LDL). However, these terms can be misleading because detection abilities are not fixed. They depend on environmental conditions, such as the local wind speed. There have been few intercomparison studies of satellites' detection limits under consistent conditions. The preferred best practice is to describe the detection limit as a **probability of detection** (POD) under specific environmental conditions. Research groups are working to characterize POD for each satellite using empirical methods and controlled releases of methane.[10]

Table 2. Technical characteristics of satellites, listed alphabetically

SATELLITE NAME	TYPOLOGY	IMAGING TYPE	SPATIAL RESOLUTION	POINT-SOURCE DETECTION THRESHOLD APPROXIMATE (KG CH4/HR)
EMIT	Point source imager	Hyperspectral	60m	500-1000
ENMAP	Point source imager	Hyperspectral	30m	500-1000
Gaofen 5	Point source imager	Hyperspectral	50m	1500
GHGsat	Point source imager	Methane-specific bands	25m	100
GHOSt	Point source imager	Hyperspectral	8m	unknown
GOSAT	Flux Mapper	Hyperspectral	~10000m	n/a
Landsat	Point source imager	Multispectral	30m	1500
MethaneSAT	Flux Mapper	Methane-specific bands	100x400m	1000
PRISMA	Point source imager	Hyperspectral	30m	500-1000
Sentinel-2	Point source imager	Multispectral	20m	1500
Tanager-1	Point source imager	Hyperspectral	30m	100
TROPOMI	Flux Mapper	Multispectral	5500x7500m	10000
Worldview-3	Point source imager	Multispectral	3.7m	100
Ziyuan-1	Point source imager	Multispectral	30m	1500

Sources: Multiple, including Jacob et al. https://acp.copernicus.org/articles/22/9617/2022/acp-22-9617-2022-discussion.html

III. USE CASES OF SATELLITE-DETECTED METHANE DATA

Methane-detecting satellites are already providing valuable information about emissions to governments worldwide. Over the next few years, ongoing advances in methane remote sensing may converge toward a consistent, integrated, widely available, and finely detailed picture of emissions at multiple scales, from the point source to the globe. This progress raises an important question: How can these data help governments capitalize on the benefits of methane action?

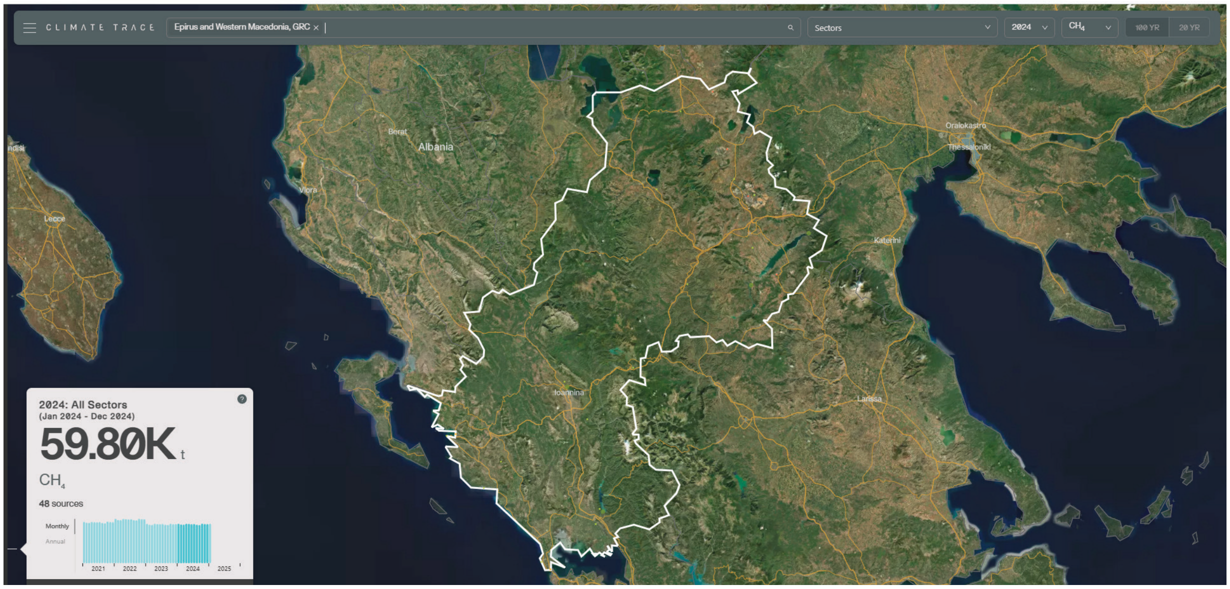
There are many opportunities for policymakers to use these data sources.[11] Advances in methane remote sensing are currently enabling:

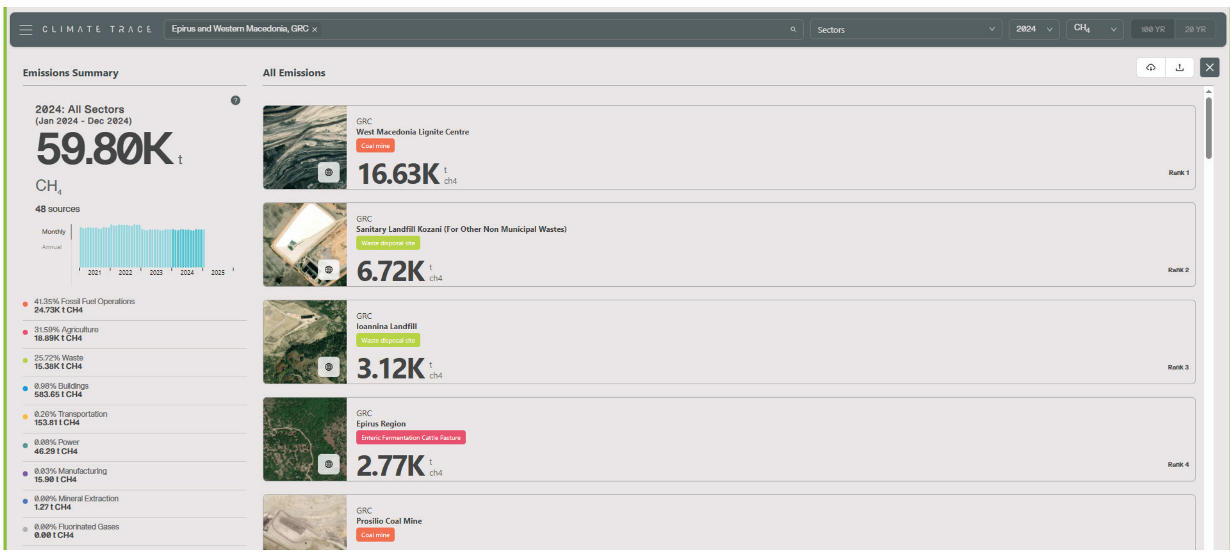
- **Development of new emissions inventories** informed by direct observation, which in some cases reveal prior under-estimates
- **Verification of existing inventories** based on new and refined data
- **Fast reporting** to help authorities and businesses respond to leaks
- **Identification of major point sources,** many not previously quantified or known
- **Refined descriptions of emissions variability** across time, location, and source activity

USE CASE: JURISDICTIONAL EMISSIONS INVENTORIES

Remote-sensed data can improve the accuracy of **jurisdictional emissions inventories** by incorporating observed leaks or other uncounted emissions and by correcting emissions factors. Satellite or other remote sensing data can supplement and improve inventories by incorporating omitted sources, correcting emissions factors, and providing a stronger understanding of temporal variation of emissions, both daily and seasonal.[12] Consolidating such data is the mission of **Climate TRACE**, a coalition that works to blend bottom-up and top-down data for use by city, state, and national governments worldwide. Their platform is publicly available and free to use, with many major jurisdictions (countries, states, and municipalities) already represented.

User interface on Climate TRACE, a free online data platform





Remote sensing alone cannot give a reliable and complete picture of *regional* emissions. This is due to challenges associated with emissions sources that are intermittent or spatially diffuse, as well as barriers presented by weather, surface conditions, and sun angle. There is growing interest, however, in hybrid estimates that combine multi-pass aerial measurements with bottom-up measurement of sources that are challenging or costly to measure directly. One recent hybrid inventory of the oil and gas sector in British Columbia, Canada, estimated that true emissions were 70 percent higher than the official inventory.[13] Canada is currently working with university researchers and satellite operators to incorporate direct measurements into official inventories.[14]

While researchers continue to integrate remote sensing data with *in situ* and bottom-up data, ongoing advances will provide new opportunities to improve emissions transparency, identify profitable opportunities to cut emissions and help jurisdictions tailor their reduction efforts to their individual needs.[15]

USE CASE: LEAK DETECTION AND NOTIFICATION

Another well-developed use case involves **leak detection and notification**. As remote sensing technologies have advanced, governments have recognized their utility to detect previously hidden methane leaks, particularly from high-emitting events. Satellite operators and others are now sharing information about major emissions events with source operators and governments.

IMEO (INTERNATIONAL METHANE EMISSIONS OBSERVATORY): *A UN-led initiative providing data on methane emissions to governments and industry.*

For example, NASA has historically used methane detection instruments, including satellites and airplanes, to notify operators and authorities of large methane plumes. In 2015 and 2016, NASA employed satellites to detect gas during a major methane leak near Porter Ranch, California.[16] Today, such efforts have become more widespread and regularized. The United Nations' International Methane Emissions Observatory (IMEO) program regularly notifies jurisdictions about major emissions events detected by a network of satellites, with the goal of prompting leak repair. This program is known as the **Methane Alert and Response System** (MARS).[17] The California Air Resources Board (CARB) has also developed a sophisticated leak detection and notification process, detailed below.

IV. ACCESSING DATA FROM METHANE-DETECTING SATELLITES

Satellite-derived methane data undergoes multiple stages of processing before it is ready for analysis and use in policy applications. These stages are commonly referred to as data levels, and each level transforms the raw measurements into increasingly refined data.

The first level, **Level 0**, consists of raw radiances, or the brightness of each wavelength of light captured by the sensor. Measurements are further calibrated in **Level 1**, and by **Level 2**, they are transformed into methane concentration enhancements—or measurements of the elevated amount of methane in a column of the atmosphere compared to background levels. Once data reach **Level 4**, they are typically in the form of quantified emission rate estimates (e.g., kilograms per hour for a given source).

Government agencies that operate satellite missions, such as NASA and the European Space Agency (ESA), maintain public data portals that regularly show data at Levels 1 and 2. However, these data are often not immediately usable for policy audiences since they require specialized software and expertise to interpret and analyze.

Several organizations and companies offer methane data products at relevant spatial and temporal scales. For example, Carbon Mapper and the International Methane Emissions Observatory (IMEO) provide quantified emission rates and attribute emissions to the responsible emitting sector or ground source. The International Energy Agency collaborates with Kayrros, a French satellite data company, to aggregate annual satellite-detected events at the country level. Below, we tabulate the status of public data sharing for each satellite and describe key data portals for accessing processed methane data.

Table 3. Status of and access to public data sharing for methane satellites.

SATELLITE NAME	HOW MUCH METHANE DATA IS MADE PUBLICLY AVAILABLE?	PRIMARY WAY(S) TO ACCESS	EASE OF USE FOR POLICYMAKERS
EMIT	Most to all	NASA-JPL open data portal: Coverage and Forecasts | EMIT Open Data Portal Carbon Mapper data portal Also processed on IMEO data portal.	High
ENMAP	Most to all	EnMAP Instrument Planning data access portal (login required) Also processed on IMEO data portal.	High
Gaofen 5	Little to none	China Centre for Resources Satellite Data and Application (official application required)	Low
GHGSat	Little to none	SPECTRA Emissions Intelligence Platform - GHGSat	Low
GHOSt	Little to none	Orbital Sidekick	Low
GOSAT	Most to all	JAXA Satellite Data	Low
Landsat	Most to all	USGS Earth Explorer: Landsat Data Access | U.S. Geological Survey Also processed on IMEO data portal.	High
MethaneSAT	Most to all	Methane Emissions Map - MethaneSAT Expected integration with Google Earth Engine in mid-2025.	High
PRISMA	Most to all	PRISMA data access portal (login required) Also processed on IMEO data portal.	High
Sentinel-2	Most to all	Copernicus Open Access Hub Also processed on IMEO data portal.	High
Tanager-1 (Carbon Mapper)	Most to all	Carbon Mapper data portal	High
TROPOMI	Most to all	Copernicus Open Access Hub Also processed on IMEO data portal.	High
Worldview-3	Little to none	Mapping Methane Emissions Using Maxar's WorldView-3 Satellite	Low
Ziyuan-1	Little to none	China Centre for Resources Satellite Data and Application (official application required)	Low

Note: All links in Table 3last accessed on March 3, 2025.

In addition, there are NGOs and third parties processing and compiling methane data from satellites listed in table 3. These portals often simplify data and present it in various formats for a range of users. Below is a selection of open-source and subscription-based data portals for accessing such data (listed alphabetically, non-exhaustive). These are dynamic portals, frequently updated with new detections and calibrations.

1. **Carbon Mapper Data Portal (public)**: Carbon Mapper provides free access to data on methane and CO_2 super emitters across the globe, with emission rates attributed to specific sectors or ground sources. The portal is updated frequently and integrates observations from sensors aboard aircraft and satellites, including EMIT and Tanager. There is currently a processing lag of 30 days between detections and the public release of data.

2. **ESA's Copernicus Data Space Ecosystem (public)**: This portal provides free access and visualization of methane data cataloged from the Sentinel series, which includes maps of methane concentration enhancements. The newly released CAMS Methane Hotspot Explorer shows large methane plumes from strongly emitting localized sources detected using the operational Copernicus Sentinel-5P TROPOMI methane satellite data. The data are updated daily and provide global coverage.

3. **GeoLabe (private)**: This company offers an interactive map showcasing methane emissions, but public data is limited to a handful of example detections from controlled release studies. For detailed methane emissions from specific areas of interest, users can request access to their automatic detections, which the company states is updated every 4.5 days with historical data available from 2015 onward.

4. **GHGSat (private):** This company provides subscription-based methane monitoring services, including high-resolution plume emissions data and analysis of proprietary and third-party satellite data. Their products include emission rate estimates, visual concentration maps, and access to historical satellite data.

5. **IMEO's Eye on Methane Portal (public):** IMEO's portal offers free emission rate estimates from global satellite-detected methane plumes attributed to ground sources and emitting sectors. The data, updated periodically, includes plumes from Sentinel-2, Landsat, EMIT, PRISMA, and ENMAP, and it also features emissions reports from companies through the Oil and Gas Methane Partnership.

6. **International Energy Agency's Methane Tracker Database (public)**: The IEA provides free, detailed country-specific estimates of energy-related methane emissions with annual totals reported in kilotons. The tool also highlights satellite-detected large-emitting events, estimates abatement potential and costs, and offers an assessment of current and potential policy actions to reduce emissions.

7. **JAXA's GOSAT Portal (public)**: This portal provides free global column concentration enhancements from the GOSAT series, intended for use in climate research and policy applications.

8. **Kayrros Methane Watch (semi-private)**: Kayrros provides some public access to methane super emitters detected using Sentinel-5P and EMIT and includes attribution to source type (e.g., oil and gas, coal). Higher-resolution methane detections and additional features are available through a paid subscription, which users must request a demo to unlock.

9. **MethaneSAT Portal (public)**: As of early 2025, MethaneSAT focuses on a few major oil and gas production regions in the US and globally. Early observations include large area emissions (in kg/hr) and a handful of smaller, dispersed point sources. Once at full capacity, the public platform will provide comprehensive insights into total regional emissions with broader global coverage.

10. **NASA's Earthdata Portal (public)**: This portal catalogs free access to methane data from numerous satellites and at various processing levels. This includes column concentration enhancements of methane (Level 2) and a global gridded inventory of methane emissions from fossil fuel sources (Level 4). The data are updated frequently, often within days to weeks of acquisition, depending on the satellite mission.

11. **NASA-JPL's VISIONS EMIT Open Data Portal (public)**: An interactive map that shows locations and timestamps of global methane plumes detected by the EMIT instrument. VISIONS also displays the satellite's past and future viewing coverage.

12. **SRON's Methane Plume Maps (public):** The portal uses the Dutch space instrument TROPOMI onboard Sentinel-5P to automatically detect large methane emission plumes across the globe.

The next section lays out five curated policy case studies using currently available satellite-detected methane data.

V. POLICY CASE STUDIES OF SATELLITE-DETECTED METHANE DATA

Data from methane monitoring satellites are increasingly being incorporated into policy, legal, and regulatory contexts. Below we give examples of how government agencies and organizations are starting to use this technology to enhance methane control.

We present five policy case studies:

- The first, focused on the **International Energy Agency**, showcases the use of data to improve national methane emissions estimates.
- The second, focused on the UN's **IMEO MARS program**, describes a robust leak notification program.
- Case studies three and four, which describe the **US Super Emitter Response Program** and **California's 'Satellite Methane Project (CalSMP)**, give examples of jurisdictions using satellite data to prompt required leak repair in concert with existing regulatory programs.
- The fifth, describing **Colorado's oil and gas regulatory program**, shows an innovative regulatory approach in which satellite data can be used to enhance the implementation and enforcement of an existing greenhouse gas intensity regulation.

CASE STUDY 1: INTERNATIONAL ENERGY AGENCY'S USE OF SATELLITE DATA TO IMPROVE ITS GLOBAL METHANE TRACKER

Each year, the International Energy Agency (IEA) publishes its Global Methane Tracker report. The report includes information on all anthropogenic methane emissions and is a widely used tool for informing governmental policies and the work of several organizations worldwide. The IEA's methodology for gathering and interpreting methane emissions information varies from year to year.

For the first time, the 2024 Global Methane Tracker report incorporated information on methane emissions from satellite detections in order to improve its estimates of national emissions. This report uses data gathered by Kayrros, a private company that processes satellite data and identifies large methane emissions by analyzing readings of atmospheric methane concentrations.[18] The IEA includes satellite data to help "ensure that country-by-county estimates provide a comprehensive picture of all methane emissions sources."[19] In IEA's view, "[t]he increasing amount of data and information from satellites will continue to improve global understanding of methane emissions levels and the opportunities to reduce them."[20]

While using satellite data has significant advantages in allowing IEA to improve its national estimates, IEA also acknowledges limitations in the data, as follows:

- The satellite data covers only large sources of methane.
- It is difficult for current satellites to measure methane emissions in equatorial regions, high latitude areas, mountainous terrain, offshore regions, and regions covered by snow or ice. Consequently, some oil-producing areas remain unobserved.
- In addition, while satellites are designed for daily global methane monitoring, cloud and other weather conditions can hinder their effectiveness. Satellite coverage and detection are generally strongest in the Middle East, Australia, and parts of Central Asia.
- There are considerable uncertainties in the process of estimating emissions from changes in atmospheric methane concentration due to the extensive auxiliary data sources required.[21]

IEA writes that as "additional data becomes available from measurement campaigns—whether recorded from ground or aerial processes or by satellites—these will be incorporated into the Global Methane Tracker and estimates adjusted accordingly."[22]

> **Takeaway for Policymakers: The IEA data can be utilized by government agencies at all levels to set up or supplement an observation-based methane inventory. The given agency and policymakers can also seek support from IEA in the use of their data.**

CASE STUDY 2: IMEO'S METHANE ALERT AND RESPONSE SYSTEM (MARS) PROGRAM

The International Methane Emissions Observatory (IMEO) is a project of the United Nations Environment Program whose purpose is to provide information on methane emissions to those with the power to reduce those emissions. IMEO leads the Methane Alert and Response System program (MARS),[23] a satellite detection and notification effort that provides data on very large emissions globally.

The MARS program involves several key steps to address methane emissions. First, IMEO works with satellite methane detection partners, such as SRON and Kayrros, to identify significant methane plumes and hotspots using satellite technology. By combining data from various satellites and other sources, IMEO can help trace emissions events back to specific facilities.

Once a significant emissions event is detected, IMEO notifies relevant governments and companies. Ongoing engagement ensures that stakeholders are informed as more details emerge. After notification, it is the responsibility of these stakeholders to determine appropriate responses and share their actions with IMEO. IMEO monitors event locations for future emissions and makes data publicly available within 45-75 days of detection. Additionally, IMEO fosters collaboration among MARS partners to learn from these events and enhance both the MARS process and overall methane mitigation strategies.[24]

This system can work well. For example, in Argentina, the International Space Station's EMIT sensor detected multiple, significant methane emissions events from the country's oil and gas facilities.[25] In March 2023, the International Methane Observatory (IMEO) notified the Argentinian government about the observed emissions, providing information on their location, size, potential sources, and the operators of the pertinent facilities. Investigations revealed that a ruptured heat exchanger had inadvertently allowed methane to escape into the atmosphere. The Argentinian government responded by sharing information with the relevant operators, prompting them to take swift action. The operator removed the damaged equipment and conducted necessary repairs to prevent further emissions. Additionally, a leak verification plan was implemented to safeguard against future incidents.

However, the fact that the MARS program relies entirely on voluntary actions to address leaks can limit its efficacy. Most notifications have not, in fact, prompted responsive action. According to IMEO and recently released UNEP data, the MARS program delivered 1,200 notifications to governments and companies in 2023 and 2024, yet just one percent of notifications received a response.[26]

> **Takeaway for Policymakers: Subnational as well as national-level policymakers can use IMEO's capabilities and MARS data insights to develop a direct methane mitigation process, in association with facility operators of point sources**.

CASE STUDY 3: US EPA SUPER EMITTER RESPONSE PROGRAM (SERP)

Information from satellites can also be used to improve the operation of existing regulatory programs that require leak detection and repair (LDAR). For example, in 2024, the US EPA adopted a rule to control methane emissions from the oil and gas sector using its authority under the US Clean Air Act. The final rule strengthened methane regulations for the oil and natural gas industry through the inclusion of requirements for new and existing sources of methane emissions. As of March 2025, this rule has been rescinded by the current administration. However, the process can be useful as a model for future reinstatement and also for adoption by other governments.

> **SUPER EMITTER RESPONSE PROGRAM (SERP):** *A US EPA initiative requiring operators to respond to and repair major methane leaks detected by remote sensing.*

The rule mandated more rigorous technology standards, enhanced leak detection and repair protocols, and established the Super Emitter Response Program (SERP).[27] The SERP required oil and gas operators to fix major methane leaks. Importantly, the US EPA had incorporated third-party monitoring provisions into the SERP that allowed for the use of satellite data.[28] The Super Emitter Program allowed the US EPA to approve third-party remote sensing operators, including those that use aerial surveys and satellites, based on specific technological standards.[29] These third parties would have conducted monitoring and would be required to inform the US EPA of super emitter events within fifteen calendar days. Third parties would have been required to notify the US EPA, not the facility directly, of potential leaks. The agency would have passed this information along and required oil and gas facility operators to respond to leak reports within five days.[30](29)

> **Takeaway for Policymakers: Even as the US EPA under the Trump Administration has rescinded this rule as of March 2025, ambitious subnational policymakers can continue to use SERP's process and insights to develop their own strategies and communications with oil & gas facilities to coordinate methane mitigation from their leaking infrastructure.**

CASE STUDY 4: CALIFORNIA SATELLITE METHANE PROJECT (CALSMP)

California's primary climate regulator, the California Air Resources Board (CARB), has made significant strides in using remote sensing data to fight methane emissions. Over the last few years, CARB has contracted with the University of Arizona and Carbon Mapper to perform methane detection flight campaigns over the state. In 2024, CARB released its Summary Report of these airborne methane plume mapping studies with the goal of demonstrating "that data collected by these airborne plume mapping sensors can be used to directly support methane mitigation."[31]

According to that report, the monitoring campaigns detected 502 methane plumes, primarily from oil and gas facilities and landfills. CARB contacted the 75 operators who were identified as responsible for these emissions and shared the findings with them. Operators were asked to identify the source of the emission, repair the source, and report back to CARB. According to CARB, operators in the oil and gas sector responded 94 percent of the time, taking action and reporting back within approximately two weeks; landfill operators tended to respond within a month. In 40 percent of the emission incidences, the operator had been previously unaware of the leakages—and in all of those cases, operators were able to repair the source and mitigate emissions. In this campaign, remote-sensed data was instrumental in mitigating methane emissions.

While these efforts relied on data gathered from aircraft, they showed great potential for satellite-borne instruments.[32] CARB has since formalized and strengthened its use of satellite data to enforce existing methane regulations through its *Amendments to the Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities*.[33] These regulations allow CARB to notify operators of satellite monitoring data, provided that the satellite meets specified technical standards (including spatial resolution, speed of data availability after collection, and plume visualization).[34] Under these regulations, when operators are notified of a methane leak, they will have five days to inspect the emitting facility. They must then make repairs, with repair timelines set based on methane concentration in the plume.[35]

However, CARB has also cautioned against sole reliance on satellites for methane detection. The agency has stated that given the current technology, more than half of the methane emissions in California would not be detected by satellites. Therefore, they say, this technology should be considered as part of an integrated monitoring system and not as the sole method for detection.

> **Takeaway for Policymakers: Subnational policymakers can replicate CARB's established CalSMP process to set up a leak detection and alerting system in their own jurisdictions.**

Please email the authors if you'd like to receive and view the CalSMP process in detail.

CASE STUDY 5: COLORADO'S USE OF MEASUREMENT-INFORMED INVENTORIES TO SUPPORT A GREENHOUSE GAS INTENSITY STANDARD

Among Colorado's major oil and gas methane rules is its greenhouse gas (GHG) intensity standard, which requires oil and gas production facilities to reduce their emissions intensities each year.[36] The intensity standard places declining limits on total greenhouse-gas emissions of both facilities and companies, per unit of oil and gas production.

Colorado has done innovative work to assess whether and how to use satellite data to implement and enforce this standard. The state's carbon intensity reduction program centers on a measurement-informed inventory that oil and gas operators must develop to demonstrate compliance with GHG intensity targets.[37] This inventory is the key component of Colorado's methane framework relevant to satellite monitoring. Its purpose is to enhance bottom-up emissions estimates with quantitative measurements and monitoring, addressing potential gaps in traditional accounting methods. A 2023 rule by the Colorado Air Pollution Control Division requires oil and gas producers to conduct and report on-site methane monitoring, verified by accredited third parties, to ensure they conform with the state's greenhouse gas intensity standards.[38] While the 2023 rule requires operators to report direct *in situ* measurements, the state will also conduct its own measurements using satellite, aircraft, and ground-based instruments.[39]

If a facility fails to report using direct observation technologies, it must report its methane emissions intensity using annually-updated default emissions factors, supplemented by the state's own remote-sensed data. The intensity verification protocol takes an iterative approach, encouraging the agency to periodically revise its approved technologies and standards as data availability improves.

Currently, satellite monitoring can be integrated into measurement-informed inventories, but only in conjunction with other strategies or as a supplementary tool. The *Colorado Air Quality Control Commission's Greenhouse Gas Intensity Verification Protocol* outlines approved technologies for these inventories, including the option of developing operator-specific verification programs or adopting state-designed verification factors.

While satellite monitoring is not an approved primary strategy yet, it can be used as a supplement. The primary limitation preventing the full integration of satellite monitoring is its current inability to capture a sufficient portion of expected emissions. However, with ongoing advancements, satellite monitoring may become a more prominent component of operator verification programs. The Colorado protocol acknowledges the rapid advancements in satellite technology and its potential to cover large emission sources. Beginning in 2027, operators will have more flexibility to develop their own measurement strategies, potentially including satellite monitoring that meets required criteria.

> **Takeaway for Policymakers: Subnational policymakers can borrow insights from Colorado's regulatory inclusions for satellite-detected data to mitigate methane emissions from their own oil & gas facilities.**

VI. THE WAY FORWARD

The satellite methane revolution is here. Leaders and policymakers can successfully use these data *today*. For public officials, satellite-based methane observation provides a major opportunity to showcase cutting-edge climate leadership while securing economic and health benefits for local populations.

Today, remote sensing for methane often focuses on the oil and gas sector, which represents only one-third of global anthropogenic methane emissions.[40] This matches the broad pattern of methane control across jurisdictions, where oil and gas sources are more heavily regulated while other sectors are often addressed through voluntary or incentive-based programs.[41] Remote sensing has significant potential to also aid regulation and enforcement in other sectors, particularly large point sources from waste, coal, and agriculture. Both California and Colorado, for instance, are considering incorporating remote sensing into landfill regulations.[42] We can expect more creative use cases down the road, especially those that empower at-risk communities with information about methane and co-pollutants.

Policymakers can use reliable, transparent, and accessible satellite data from public-facing providers to develop better-informed methane control policies. In parallel, public officials can build capacity in order to make full use of the satellite data influx and continue innovation. As the scope of satellite detection is global, it is a promising avenue for international collaboration in methane mitigation.

With a growing number of 'eyes' in the sky, satellite detection will continue to generate new and refined methane data. But data alone cannot address the daunting challenge of methane emissions. It is now up to governments to innovate and lead, using these unprecedented insights to take bold action.

GLOSSARY

Absorption Spectrum – The specific pattern of wavelengths a substance absorbs, used to identify methane in satellite data.

Area Flux Mapper – A type of methane-detecting satellite designed to measure total methane emissions over a large area.

Column Concentration Enhancement – The measured increase in methane concentration in a column of air, derived from satellite data.

Detection Threshold – The minimum methane emission rate that a satellite instrument can reliably detect.

Emission Rate – The amount of methane released into the atmosphere over a given time, typically measured in kilograms per hour (kg/hr).

Flux Mapper – A satellite instrument designed to measure regional methane emissions over a broad area.

Hyperspectral Imaging – A technique where sensors capture data in a continuous spectrum of wavelengths, allowing precise methane detection.

Intensity Standard (GHG Intensity Standard) – A regulatory approach that sets emission limits relative to production output.

Lower Detection Limit (LDL) – The smallest methane leak rate a satellite instrument can detect under ideal conditions.

Minimum Detection Limit (MDL) – The lowest measurable methane emission rate under specific conditions.

Point Source Imager – A satellite instrument designed to detect methane emissions from specific facilities, such as landfills and oil rigs.

Probability of Detection (POD) – The likelihood that a satellite can successfully identify methane emissions under given conditions.

Remote Sensing – The use of satellites, aircraft, or drones to collect data about the Earth's atmosphere and surface from a distance.

Spectral Resolution – The ability of a satellite instrument to distinguish between different wavelengths in the electromagnetic spectrum.

Super Emitter – A facility or source responsible for disproportionately high methane emissions.

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