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Advances in Satellite Methane Measurement: Implications for Fossil Fuel Industry Emissions Detection and Climate Policy

On November 15, 2021, under the authority of Section 111 of the Clean Air Act, the U.S. Environmental Protection Agency (EPA) published a rulemaking that "proposes comprehensive standards of performance for GHG [greenhouse gas] emissions (in the form of methane limitations) ... for new, modified, and reconstructed sources in the Crude Oil and Natural Gas source category, including the production, processing, transmission and storage segments" (86 *Federal Register* 63110, November 15, 2021). Lessening unintended emissions known as *fugitive emissions* is one set of actions in this proposal to constrain large emissions sources known as *super-emitters*. The rulemaking requests both information and comments on alternative measurement technologies for methane emissions, especially those attributed to super-emitters. The EPA is seeking input on technologies that could distinguish large emission events and a definitional emissions level for designating an event as "large." It is specified in the rulemaking that "any emissions visible by satellites should qualify as large emission events" (86 *Federal Register* 63110, November 15, 2021). The role of evolving satellite technologies that have the ability to monitor methane and contribute to the identification of "large emission events" is discussed here.

Background on Methane Emissions

Fossil-fuel-related industries emit methane into the atmosphere. Methane has a global warming potential 28 times greater than carbon dioxide over a 100-year period. It is second only to carbon dioxide in contributions to global temperature increases from human emissions of greenhouse gases. It has been estimated for the United States that approximately 30% of methane emissions from onshore oil and gas production arise from fugitive emissions, while such emissions are approximately 1.8 times greater than emissions from venting for pipelines and liquefied natural gas facilities.

Fugitive emissions are generally described as leaks from pressure containment systems, which can include leaks from valves or flanges, in fossil fuel facilities. Fugitive emissions also include methane that escapes to the atmosphere from incomplete combustion during flaring (burning of excess gas). A small number of fugitive emission events, known as super-emitters, account for approximately 50% of fugitive emissions in the fossil fuel sector and are sourced from approximately 5% of fugitive emission events. Locating, identifying, and attributing these events to specific sources is critical to reducing methane emissions overall.

Reducing fugitive methane emissions, including super-emitter events, is believed by some to be important for achieving climate change mitigation and public health goals. Measuring methane emissions on a large scale is difficult, and the measurement technologies continue to evolve (see CRS In Focus IF10752, *Methane Emissions: A Primer*, by Richard K. Lattanzio).

Advances in remote sensing of methane from satellites may improve monitoring and detection of emissions from oil, coal, and natural gas operations. Improving the measurement of these methane emissions can contribute to the U.S. effort to meet treaty obligations under the United Nations Framework Convention on Climate Change (UNFCCC). These obligations include emissions reporting requirements as well as scientific and technical cooperation (see CRS Report R40001, *A U.S.-Centric Chronology of the United Nations Framework Convention on Climate Change*).

Methane Monitoring Strategies

There are two general categories for methane monitoring. One method, sometimes referred to as "bottom up" (BU), extrapolates measurements from individual components. BU methods rely on averaging numerous leak test measurements of industry components to develop "emissions factors" that are aggregated and used to estimate emissions, based on the number of facilities and the levels of production. However, because emissions factors are based primarily on leakage measured under normal conditions, they may not fully account for abnormal super-emitter events. As a result, BU methods may understate total emissions.

Emerging technologies may enhance the second type of monitoring strategy. Referred to as "top down" (TD), these methods provide direct empirical measurements of methane, not estimates based on emissions factors, at specific locations. Using either ground-based instruments or those on aircraft or satellites, methane emissions may be measured directly. The downsides of TD are relative cost, and coverage limitations. Satellites and aircraft measurements cost more than computer model estimates extrapolated from limited sampling during normal operation. Also, some of these TD methods typically occur only at infrequent intervals, and may miss detection of sporadic emission events. As technologies mature, costs may drop. Increasing satellite sampling frequency offers an opportunity to improve accuracy and precision.

Satellite Measurement of Methane Emissions

Satellite detection methods can involve tradeoffs that may allow some fugitive emissions to go undetected. These may be addressed as technical capabilities improve and datasets from satellites with complementary capabilities are combined. As satellites pass overhead, they scan a continuous strip of the Earth's surface known as a swath. The swath width is the horizontal width of this strip. There is a tradeoff between the swath width and the resolution of the image. A satellite such as the European Space Agency instrument TROPOMI has a swath width of 2,600 kilometers (km) and spatial resolution of 7 km x 5.5 km (across x along track). Such a wide swath scans a large area but typically lacks the resolution to distinguish individual features such as specific oil or gas facilities. A satellite such as the Italian Space Agency instrument PRISMA—with a swath width of 30 km and a spatial resolution of 30 meters (m), with a high-resolution sensor—may be able to distinguish such facilities. Such a narrow swath width restricts the area that can be sampled on any given overpass. This tradeoff means that a wide-survey satellite may detect an area of high emissions but lack the resolution to attribute it to a specific facility, whereas a high-resolution satellite may miss a sporadic emission event altogether if it is outside the narrower swath being sampled.

There are strategies to address these tradeoff issues and improve the detection, quantification, and attribution of fugitive methane emissions. These strategies include increasing satellite survey capacity to detect elevated regional methane concentrations suggesting emission events, increasing satellite capacity for direct location attribution of such events, and using satellites with complementary capabilities in tandem.

Enhanced attribution capability may be obtained by having more high-resolution satellites available for observations. Three high-resolution Canadian GHGSat satellites with spatial resolution of at least 50 m x 50 m are currently operational. These systems are able to discern individual point sources of fugitive emissions at the facility level, allowing specific attribution in some cases. These satellites have a narrow 12 km x 12 km field of view and are capable of sampling locations of high emissions, identified by survey satellites such as the MethaneSAT (American-New Zealand space mission currently scheduled for launch in October 2022) or the European Space Agency TROPOMI instrument on board the Copernicus Sentinel-5 Precursor satellite launched in 2017. The launch of additional GHGSat satellites is planned for mid-2022.

Recent scientific advances in hyperspectral sensing may also increase attribution capability. Experiments have shown that hyperspectral sensors can be used to measure atmospheric methane. Satellites such as PRISMA (launched in 2019 by the Italian Space Agency), Copernicus Hyperspectral Imaging Mission for the Environment (CHIME; European Space Agency mission in collaboration with NASA), and ZY-1 02D (Chinese satellite launched in 2019) combine this ability to measure methane with a spatial resolution better than 50 m x 50 m, which is likely sufficient to allow fugitive emissions attribution to a specific facility. Making use of the data from these satellites for fugitive emissions detection could add to current attribution capabilities. Data from some of these satellites are already publicly available at no cost to users.

Survey capacity may be enhanced by MethaneSAT, a joint project of the Environmental Defense Fund (a U.S. nonprofit) and the New Zealand Space Agency. Its specifications include a swath width greater than 200 km, a spatial resolution of 0.1 km x 0.4 km, and a detection threshold of approximately 2 parts per billion (ppb) of methane. If successful, MethaneSAT would be able to survey large areas and detect methane emissions with some spatial specificity, although its ability to attribute an emission event to a specific facility would be limited.

Alone or in combination, satellite platforms such as MethaneSAT, TROPOMI, the GHGSat satellites, and the methane measurement capabilities of an increasing number of hyperspectral satellites could provide an increase in the detection, measurement, and attribution of super-emitter fugitive methane emission events, with a corresponding increase in researchers' ability to detect such events systematically.

Improving Greenhouse Gas Inventories

Enhanced satellite attribution capabilities may also improve U.S. efforts to develop a more accurate greenhouse gas inventory. EPA prepares an annual Greenhouse Gas Inventory (GHGI; EPA 430-R-21-005, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021*), which is submitted to the United Nations as part of the U.S. commitment under the UNFCCC. The GHGI has been the subject of some criticism, as studies have found that the GHGI may underestimate U.S. methane emissions from the oil and natural gas sectors. Some studies suggest that part of this underestimation may be due to the underrepresentation of emissions from large emission events or super-emitters. Satellite sensors have a demonstrated ability to detect large methane emission events. If this capacity is further developed and then systematically applied in oil- and gas-producing areas of the United States, it might provide information that could increase the accuracy of the GHGI by providing information on large emission events that might otherwise go undetected.

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