Product Guide

Data Definition & Specification

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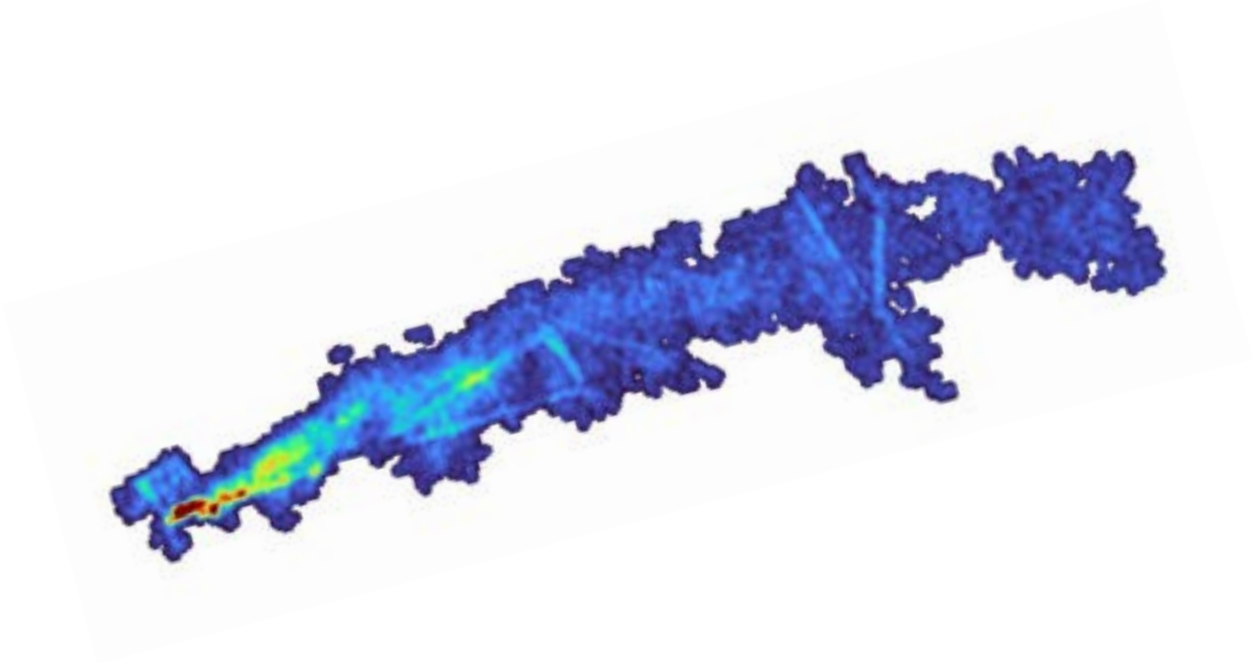

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Introduction

Carbon Mapper is a non-profit organization developing a global observation system to monitor large-scale, human-caused methane and carbon dioxide emissions. We are supported by a unique coalition of private and public partners, including Planet, NASA's Jet Propulsion Laboratory, the State of California, the University of Arizona, Arizona State University, and RMI (formerly the Rocky Mountain Institute). This broad coalition brings together the expertise and resources needed to deploy a science-driven, sustained, and impactful decision support system.

Carbon Mapper utilizes a combination of satellites and aircraft to provide daily to weekly observations of emissions from point sources, such as oil and gas facilities, solid waste, coal, and agricultural operations. This data is freely available to the public and serves as a valuable resource for governments, businesses, and organizations seeking to reduce emissions and combat climate change.

The Carbon Mapper open data platform plays a crucial role in making emissions data accessible to all interested parties. Originally developed at NASA's Jet Propulsion Laboratory, the platform processes data from a range of satellite and airborne hyperspectral systems, including Planet's Tanager constellation, which is central to Carbon Mapper's vision of a global observation system. It also integrates data from NASA's EMIT sensor, airborne sources like NASA's AVIRIS-NG, AVIRIS-3, and Arizona State University's Global Airborne Observatory.

In addition to methane, Carbon Mapper is also capable of tracking carbon dioxide emissions. The system has a CO_2 detection limit sufficient to track 90% of the world's coal power plant emitters, most refineries, and large gas power plants.

The Carbon Mapper global observing system and open data platform are powerful tools for understanding and mitigating emissions. The data is freely accessible at https://data.carbonmapper.org for non-commercial research and development purposes.

Purpose

This document aims to provide an overview of the products and access mechanisms that make up the Carbon Mapper open data platform. A detailed description of each product is included below, along with uses, release latency, data format, and data access. All products defined in this document are derived from calibrated, non-orthorectified radiances. More complete information on the retrieval algorithms underlying these products will be found in forthcoming Carbon Mapper Algorithm Theoretical Basis Documents (ATBDs).

Definitions and Acronyms

Definitions

Flux	A mass of methane per unit time, per unit area, independent of sources.
Emission rate (kg/hr)	A mass of methane per unit time for an individual source, a component of total flux.
Instantaneous emission estimate	The emission rate calculated for a single plume at a specific moment. This value reflects only that individual observation and does not represent the overall emissions from the source.

Plume	An excess mass or concentration of gas in the atmosphere emitted from a specific source. Plumes are the atmospheric manifestation of emission processes occurring across various economic sectors.
Plume ID	A unique identifier for each plume.
Source	A specific geographic location from which emissions originate. Point sources are a type of source that is associated with a large emission from a concentrated area represented by a specific latitude and longitude.
Source ID	A unique identifier for each source.
Plume List	A list of all plumes and associated metadata over a specific time period and region.
Source List	A list of all sources and associated metadata over a specific time period or region.
Persistence	The frequency at which a source emits methane or carbon dioxide, defined as the number of plumes detected divided by the total number of unobscured overpasses.
Null Detect	The absence of detection under optimal observing conditions, such as an unobstructed view of the emission source and a high likelihood of detection.
Source Emission Rate	A mean emission rate of all plumes attributed to a single source multiplied by persistence. A source emission rate is an overall rather than an instantaneous emission rate and can only apply to a source, not a plume.
Source Attribution	Attribution of on-the-ground infrastructure to individual plumes. May include information such as: • Sector (Oil & Gas, Solid Waste, Livestock, Coal Mining, Wastewater, etc.) • Equipment type (Compressor Station, Tank Battery, Flare, etc.) • Facility name • Operator/owner name

Acronyms

PHME	Potentially Harmful Methane Event: An experimental product defined as a methane emissions event whose resulting surface-level concentrations exceed at least one safety or health-based concentration threshold: • Proximity-only: plume origin is within 100 m of the nearest identifiable sensitive receptor (any potentially human-occupied building), which addresses the smallest detectable plumes close to people, OR • Size and proximity: observed plume length exceeds 1000 meters AND overlaps nearest identifiable sensitive receptor – which indicates a reasonably high emission event and potential for surface mixing ratios exceeding a certain lower explosive limit (LEL) within proximity to people
IME	Integrated Mass Enhancement: The total kilograms of methane in a plume above the background concentration at the time of the image capture
MDL	Minimum Detection Limit: The lowest emission rate that a technology can detect given certain environmental conditions (e.g., wind speed, ground reflectivity) that has been validated with ground-truth data

Sensor Information

Carbon Mapper products are derived from various hyperspectral sensors, also known as imaging spectrometers, deployed on satellites and airplanes. These sensors capture light across a broad range of wavelengths, enabling the detection and quantification of atmospheric gases. By integrating data from multiple sensors, Carbon Mapper can generate and release emissions data for numerous plumes across diverse sources and locations, independent of the specific sensor used. This process, known as data fusion, combines and harmonizes data to provide a more comprehensive view of human-caused greenhouse gas emissions over time. The table below outlines the primary sensors used by Carbon Mapper.

Provider	Platform	Type	Approximate GSD*	Spectral Bands
Planet Labs, Inc.	Tanager-1	Satellite	30-43m (varies with look angle)	400-2500 nm 5nm spacing
NASA-JPL	EMIT - Earth Surface Mineral Dust Source Investigation	Satellite	50-60m	381–2493 nm ~7.5 nm spacing
NASA-JPL	AVIRIS-NG - Airborne Visible/Infrared Imaging Spectrometer-Next Gen	Airborne	3-8m	380-2510 nm 5nm spacing
NASA-JPL	AVIRIS-3 - Airborne Visible/Infrared Imaging Spectrometer-3rd Gen	Airborne	3-8m	380-2510 nm 7.5nm spacing
Arizona State University	GAO - Global Airborne Observatory	Airborne	3-5m	380-2510 nm 5nm spacing

**Ground sampling distance (GSD) varies with changes in sensor altitude and off-nadir angle.*

Detailed Tanager-1 Performance Specifications - final operational orbit	
Swath width	18.6-24.2 meters (varies with look angle)
Ground Sample Distance (GSD)	30-43 meters (varies with look angle)
CH4/CO2 image product pixel size	30 meters (resampled for all scenes)
Plume geolocation accuracy (CE90)	50 meters
Spectral response (FWHM)	5.5 nm
Spectral sampling	5 nm
Spectral range	400-2500 nm
Signal-to-noise @ 2200nm	310 – 655 (varies with imaging mode)
CH4 90% Probability of Detection	90-180 kg/hr* (varies with imaging mode)

**3 m/s wind, 35 deg Solar Zenith Angle, 25% albedo, 30 m GSD*

Data Overview

Although methane and carbon dioxide emissions can originate from natural and human-made sources, the Carbon Mapper mission is focused primarily on identifying and monitoring human-made sources. Natural sources of methane include wetlands, rice paddies, wildfires, tundra ecosystems, and the decomposition of organic matter. Human-made sources include oil and gas production, agricultural activities, coal mining, solid waste landfills, and wastewater treatment facilities.

In addition to methane, Carbon Mapper can detect and measure the vast majority of CO_2 point source emissions from electricity generation (power plants), cement production, and other industrial processes.

Carbon Mapper organizes its emissions data into two primary data types: plumes and sources.

- **Plumes** are an excess mass or concentration of gas in the atmosphere emitted from a specific source. They are the atmospheric manifestation of emission processes occurring across economic sectors.
- **Sources** are specific geographic locations from which emissions originate. Point sources are a type of source that is associated with a large emission from a concentrated area represented by a specific latitude and longitude.

Although plumes and sources correspond to real-world features, their locations in the data may not always align perfectly with actual infrastructure on the ground. These discrepancies can arise due to the varying accuracy of the underlying imagery and the methods used to determine the precise origin of the plumes.

Satellites and airborne sensors can detect plumes by measuring the amount of sunlight absorbed by gas in the atmosphere. By combining wind speed and direction with observed plume mass and capturing multiple observations over time to understand the frequency of emissions better, scientists can accurately estimate the emission rate of sources, not just plumes. A time-series-based aggregation approach like this results in a more complete global environmental impact of super-emitting infrastructure.

Sources and plumes are derived from aircraft or satellite imagery, captured as individual scenes or continuous 'strips.' These geographic boundaries define imaged areas, providing essential spatial references for data analysis and interpretation of Earth observation information.

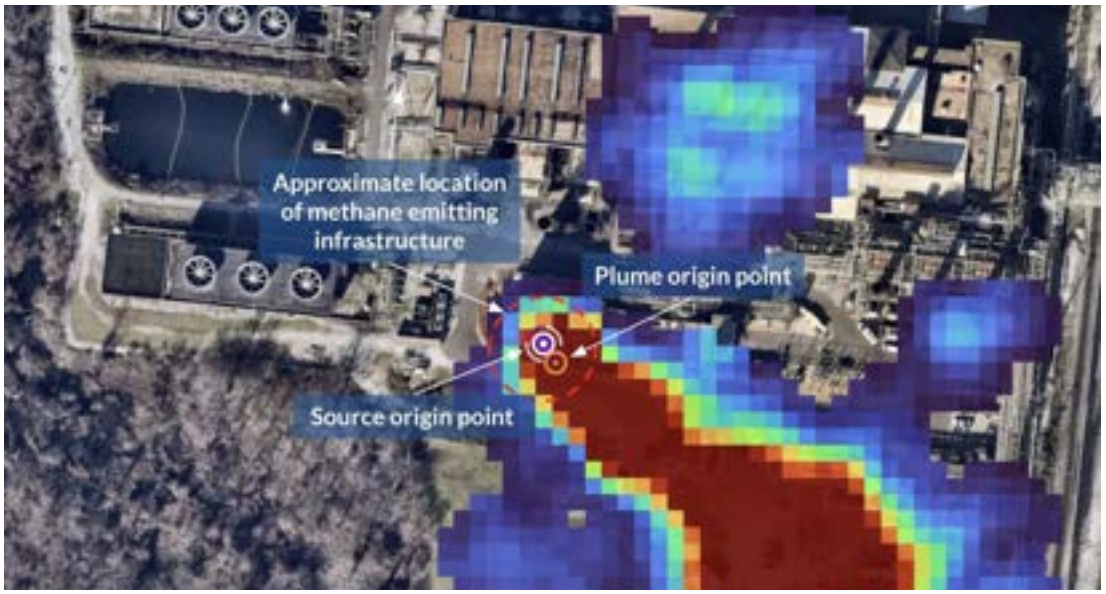

Figure 1: Example of a methane source at an oil and gas refinery and a plume attributed to that source.

Products Overview

Carbon Mapper products are designed to meet the needs of a wide range of users, from researchers and policymakers to industry and the public. They are organized into five levels, each representing a higher degree of processing, ranging from Level 1 raw radiance data to Level 5 advanced analytics. Carbon Mapper products are publicly available for non-commercial use through the Carbon Mapper data portal and APIs. They provide users with access to data, tools, and documentation to help them explore, analyze, and visualize human-caused point source emissions. Please visit our Terms of Use for information on data licensing.

Data Product	Description
Level 1B Calibrated radiance	Calibrated and compressed radiance images, including geolocation and observation geometry information, raster-level masks, and other metadata such as scene and valid pixel outlines, clouds, flares, and specular or dark masks. Generated in sensor and ortho space. *Carbon Mapper Internal Product Only*
Level 2A Simultaneous RGB imagery	Orthorectified simultaneous RGB (Red, Green, Blue) imagery derived from radiance by correcting for atmospheric effects and processing to top-of-atmosphere reflectance.
Level 2B Atmospheric retrievals	Orthorectified whole scene methane and carbon dioxide retrievals derived directly from L1B radiance.
Level 2C Detections	Orthorectified whole scene salience maps, vector data, or tabular files of candidate plume detections.
Level 3A Preliminary plume images (quick looks)	Orthorectified preliminary maps of individual atmospheric CH_4 and CO_2 enhancements (segmented plumes). Otherwise known as "Quick Look" products with • plume image • acquisition date & UTC time • latitude and longitude of plume origin • initial IME, emission rate, and plume length estimates
Level 3A-PHME	Potentially Harmful Methane Event (PHME) products are methane emission events that produce surface-level methane concentrations that exceed at least one safety or health threshold. L3A-PHMEs are experimental products that are identified and released on a best-effort basis.
Level 3B Fully processed plumes	Orthorectified final maps of individual atmospheric methane and carbon dioxide enhancements (segmented plumes) that pass quality control checks with • plume image • sector attribution • acquisition date & UTC time • latitude and longitude of plume origin • IME estimate & uncertainty

	• plume length estimate & uncertainty

Level 4A
Plume emissions
	CH_4 and CO_2 plume emissions list including:
	
	• Tabular plume list with
	  • L3B attributes:
	  • plume image
	  • acquisition date & UTC time
	  • latitude and longitude of plume origin
	  • IME estimate & uncertainty
	  • plume length estimate & uncertainty
	  • quality flags
	  • sector attribution
	  • instantaneous emission rate & uncertainty
	  • wind speed, direction & uncertainty

Level 4B Source emissions	Methane and CO_2 source emissions list including: • source Identifier • latitude and longitude of source origin • source persistence estimate & uncertainty • persistence-adjusted source emission rate & uncertainty • number of overpasses • number of positive detects • sector attribution
Level 5 Analytics	Analytics include aggregated point source emission rates by sector, time, and geography. Future analytics may consist of cumulative distribution functions, emission variances by sector, fusion, and normalization with non-methane or carbon dioxide datasets (e.g., infrastructure, socioeconomic, etc.), histograms, time series, and regional/sectoral up-scaling.

Data Access

All Carbon Mapper data products are publicly available through three channels:

- **Carbon Mapper Data Portal**: This is a web-based platform where users can view and download Carbon Mapper data products and register for advanced functionality such as API access, saved searches, collection notifications, and more.
- **Carbon Mapper Data API**: This developer-friendly API provides programmatic access to Carbon Mapper data products through various endpoints such as methane and CO_2 plume and source data.
- **Carbon Mapper STAC API**: This API provides Carbon Mapper data products access using the SpatioTemporal Asset Catalog (STAC) specification. STAC is a standard format for geospatial data that makes it easy to find, access, and use distributed geospatial products.

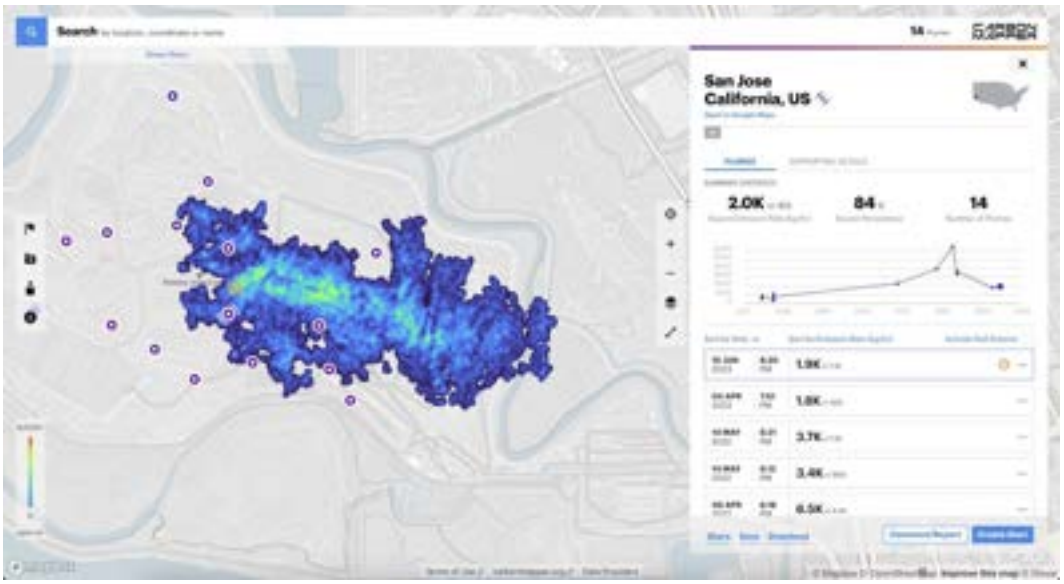

Figure 2: Data portal showing plumes over time at a single source at the Newby Island Landfill, Milpitas, CA

Python

Request:

```
https://api.carbonmapper.org/api/v1/catalog/plumes/annotated?plume_names=emi20240420t101448p07050-A&sort=desc&limit=10&offset=0
```

Response:


```
{
  "bbox_count": 1,
  "total_count": 1,
  "limit": 10,
  "offset": 0,
  "items": [
    {
      "id": "6c8a1b1e-b87a-4385-9419-09f9fbf02fc6",
      "plume_id": "emi20240420t101448p07050-A",
```

```
      "gas": "CH4",
      "geometry_json": {
        "bbox": null,
        "type": "Point",
        "coordinates": [
          46.036003399263535,
          15.586459832180779
        ]
      },
      "scene_id": "35cda215-47b6-4e58-9610-8719f25801e0",
      "scene_timestamp": "2024-04-20T10:14:48Z",
      "instrument": "emi",
      "platform": "ISS",
      "emission_auto": 3610.5812272297344,
      "emission_uncertainty_auto": 377.9456695926191,
      "plume_png": "url",
      "plume_rgb_png": "url",
      "plume_tif": "url",
      "con_tif": "url",
      "rgb_png": "url",
      "plume_bounds": [
        45.97519494794988,
        15.537058582802368,
        46.0475948088854,
        15.606800943939408
      ],
      "plume_quality": "good",
      "wind_speed_avg_auto": 1.8888888888888886,
      "wind_direction_avg_auto": 97.29934710031175,
      "collection": "l2c-ch4-v0",
      "cmf_type": "mfa",
      "sector": "1B2",
      "status": "published",
      "hide_emission": false,
      "published_at": "2024-05-08T22:57:42.324Z"
    }
  ],
  "nearby_items": []
}
```


Figure 3: Example request and response from the Carbon Mapper Plumes Annotated endpoint

Level 1 Products

L1B-calibrated radiance and masks

Definition:

Carbon Mapper ingests raw radiance from various providers, calibrates and compresses it in sensor and ortho space, and then utilizes the resulting cloud-optimized data to create a range of derived downstream products. These products include full-strip raster masks and additional metadata, as follows:

- Scene/valid pixel outlines
- Cloud masks
- Flare or artifact masks
- Specular and dark masks

Data Structure:

L1B data products are stored as orthorectified raster images in compressed cloud-optimized formats.

Data Availability:

Carbon Mapper generates L1B products primarily to derive downstream products, which are not released to the general public. Carbon Mapper makes exemplar radiance products available for research purposes, whereas specific radiance products can be directly obtained from their respective data providers.

Figure 4. Rendering of the Tanager-1 satellite, a primary radiance source for Carbon Mapper products.

Level 2 Products

L2-scene outlines

Definition:

L2 scene outline products define the geographic boundaries, or 'footprints,' of areas captured by Carbon Mapper satellites and aircraft. These outlines, also called 'strips,' comprise one or more individual scenes. Scene outlines help determine where Carbon Mapper data is collected, the quality of that data, and verify when methane or carbon dioxide sources are imaged, but detection was not observed.

In optimal observing conditions, such as an unobstructed view of the emission source and a high likelihood of detection, the absence of detection is termed a "null detect." In emissions remote sensing, a null detect signifies that an emission detection algorithm has not identified any evidence of methane emissions at a specific location. These null detects imply that the source is not emitting methane above the sensor's minimum detection limit.

Carbon Mapper considers a scene a good candidate for a null-detect status for an emission source if it contains less than 25% cloud cover and intersects any plume origin points associated with the source.

Data Structure:

Vector GIS data including but not limited to the GeoJSON format

Data Availability:

With some exceptions, L2 scene outlines and other Carbon Mapper products are released publicly 30 days after acquisition.

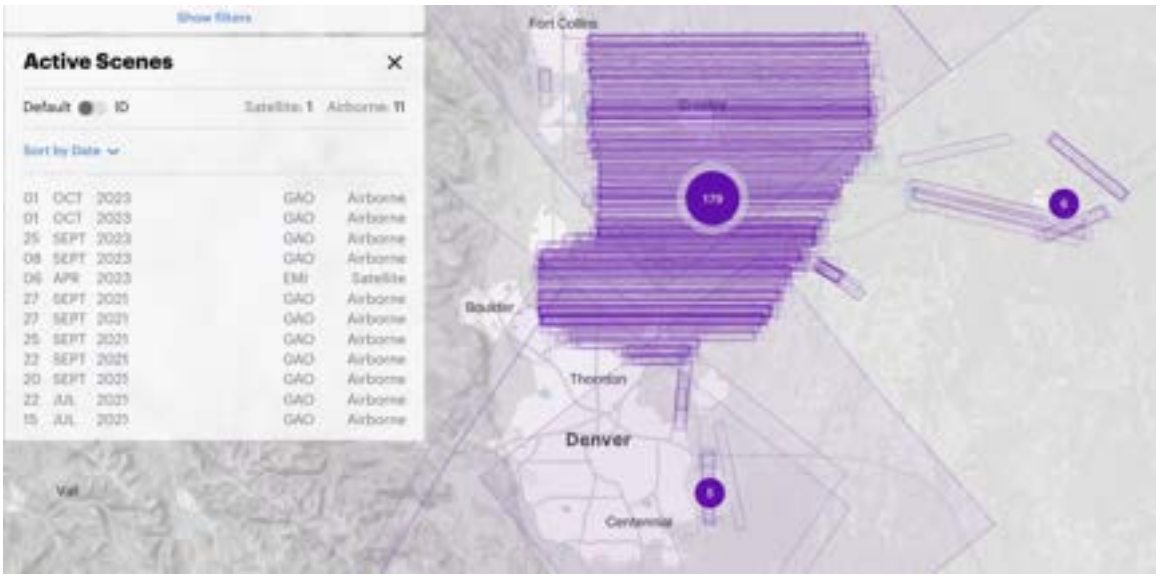

Figure 5. Scene outlines are shown in the Carbon Mapper data portal with a list of active scenes selected for a particular emission source south of Greeley, CO.

L2A-simultaneous RGB imagery

Definition:

L2A products are three-band, natural-color images of the Earth's surface generated from raw satellite radiance. This process involves correcting for atmospheric effects, geometric distortions, and terrain variations to produce accurate and visually appealing representations of the Earth. “RGB” stands for the Red, Green, and Blue bands comprising natural-color imagery.

Data Structure:

L2A data products are stored as orthorectified raster images in compressed cloud-optimized formats.

Data Availability:

L2A products are released publicly alongside other Carbon Mapper products 30 days after acquisition.

Figure 6. Level 2A simultaneous RGB imagery derived from airborne data underlying a methane source.

L2B-atmospheric retrievals

Definition:

L2B products consist of orthorectified full-strip atmospheric retrieval images derived from L1B radiance images. L2B products for methane and carbon dioxide are mixing ratios (i.e., concentrations) estimated for each pixel using a column-wise matched filter algorithm. The matched filter is a fast-running, statistical-based retrieval algorithm validated across multiple airborne controlled releases and aircraft mass-balance surveys.

Different matched filter algorithms are best suited for unique observing environments. Among these, Carbon Mapper has deployed and tested multiple model versions across airborne field campaigns:

- Unimodal (Most validated with airborne controlled releases): Classical column-wise matched filter as described initially.
    - ch4mfa: methane (CH_4) dynamic absorption spectrum
    - co2mfa: carbon dioxide (CO_2) dynamic absorption spectrum
    - co2mfal: carbon dioxide (CO_2) dynamic absorption spectrum, log-normal (used for quantification)

- Multimodal (potentially superior for suppressing systematic artifacts, e.g., flaring): Column-wise matched filter with a clustering of pixels based on radiance values.
    - ch4mfm: methane (CH_4) multimodal
    - ch4mfma: methane (CH_4) multimodal, dynamic absorption spectrum
    - co2mfma: carbon dioxide (CO_2) multimodal, dynamic absorption spectrum

The units for L2B products are typically parts per million per meter (ppm-m). L2B products also include other full-strip images derived directly from L1B radiances; these products may include, but are not limited to, flare retrievals and confuser retrievals that may be used for quality improvements. These products are made from raw L1B data and corrected for geometric distortions so they can be used as the primary input for the plume detection and quality control process.

Data Structure:

L2B data products are stored as orthorectified raster images in compressed cloud-optimized formats.

Data Access:

L2B products are released publicly along with other Carbon Mapper products 30 days after acquisition.

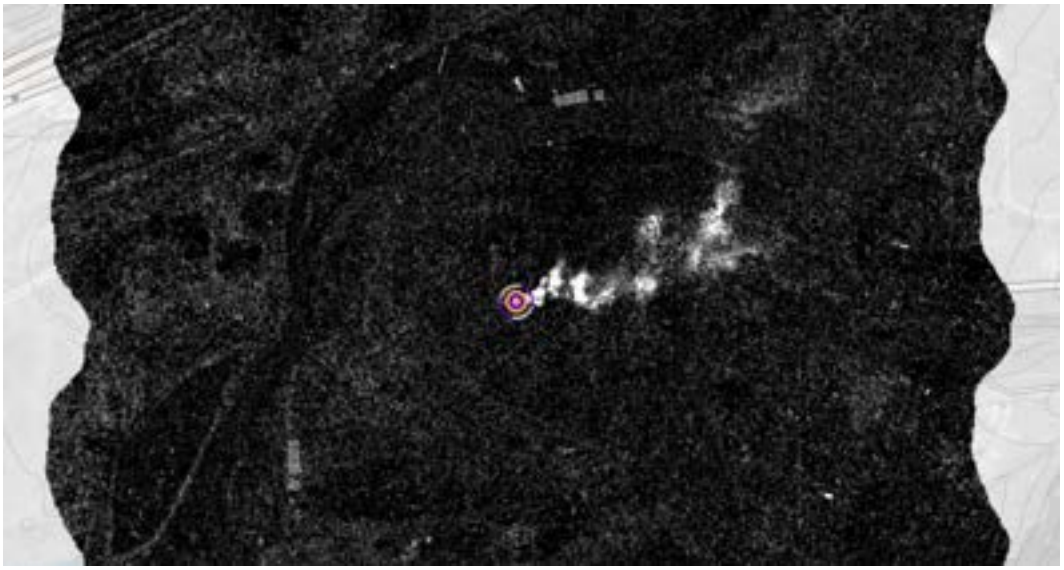

Figure 7. Level 2B methane atmospheric retrieval derived from airborne data underlying a methane source.

L2C-plume detections

Definition:

Vector data, tabular files, or orthorectified whole scene salience maps of possible plume origin locations. Level 2C (L2C) plume detections are generated from L2B atmospheric retrievals by trained analysts using quality assurance and quality control (QA/QC) processes. The analysts leverage whole scene salience maps generated by Convolutional Neural Networks (CNNs) to highlight the essential features in imagery where methane or carbon dioxide emissions are present.

Data Structure:

Tabular and associated raster data (e.g., CSV, GeoTIFF, PNG, GeoJSON)

Data Availability:

L2C products are released publicly along with other Carbon Mapper products 30 days after acquisition.

Level 3 Products

L3A-preliminary plume images

Definition:

L3A products are preliminary methane and carbon dioxide plume images identified by automated or manual processes. They are intended for quick plume size and shape assessment and are unsuitable for final emissions estimates. Each plume includes the following information: acquisition date and time, latitude and longitude of plume origin, initial methane emission estimate, initial emission rate, initial quality flags, and plume length estimate. Carbon Mapper uses L3A products to identify Potentially Harmful Methane Events (PHME) and are only released as part of PHME products.

Latency:

Minimum production latency: ≤ 72 hours from acquisition

Data Structure:

Tabular and associated raster data (e.g., CSV, GeoTIFF, PNG, GeoJSON)

Data Access:

L3A products are not publicly available except in two cases: 1) Potentially Harmful Methane Event (PHME) products, and 2) commercial quick look tasking products from Planet.

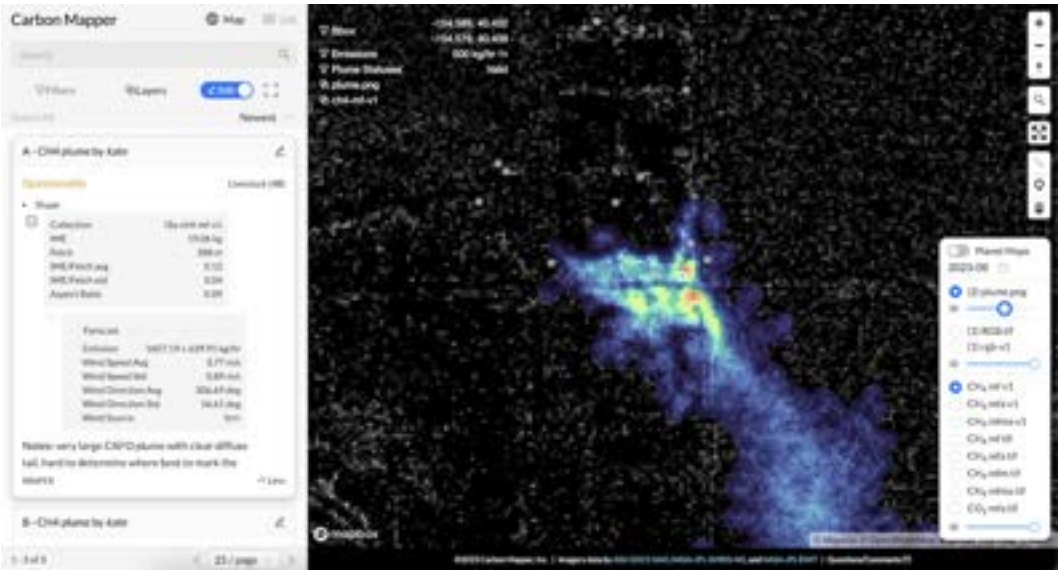

Figure 9. Quality assessment tools for final review of Level 3A methane plume images.

L3A-PHME: Potentially Harmful Methane Event

Definition:

Potentially Harmful Methane Event (PHME) products are methane emission events that produce surface-level methane concentrations that exceed at least one safety or health threshold. L3A-PHMEs are experimental products that will be determined on a best-effort basis. PHME status is activated if plumes meet either of the following criteria. These rules are subject to change and additional consideration by Carbon Mapper analysts:

- Proximity-only: plume origin is within 100 m of the nearest identifiable sensitive receptor (any potentially human-occupied building such as homes, commercial/industrial buildings, schools, hospitals, etc.) which addresses the smallest detectable plumes close to people, OR
- Size and proximity: observed plume length exceeds 1000 meters AND overlaps the nearest identifiable sensitive receptor – which indicates a fairly high emission event and potential for surface mixing ratios exceeding the LEL within proximity to people

PHME products consist of L3A-preliminary plume image products, as defined above.

Latency:

Minimum production latency: ≤ 72 hours from acquisition

Data Structure:

Tabular and associated raster data (e.g., CSV, GeoTIFF, PNG, GeoJSON)

Data Availability:

This is an experimental product. Best efforts will be made to determine PHME status and release associated L3A products within 72 hours after acquisition.

L3B-Fully processed plume images

Definition:

L3B products are georeferenced plume images of segmented atmospheric methane and carbon dioxide enhancements assessed for quality. Each plume image is associated with the following metadata: acquisition date/time, latitude and longitude of plume origin, IME estimate with uncertainty, emission rate with uncertainty, plume length with uncertainty, updated quality flags, and any additional refinement of plume origin. Sector attribution is determined from the following IPCC-defined sector categories.

- Oil & Gas (1B2)
- Solid Waste (6A)
- Waste Water (6B)
- Livestock (4B)
- Coal Mining (1B1a)
- Electricity Generation (1A1)
- Other

When more granular GIS layers are available, additional attribution to the sub-sector, equipment type, or operator level may be possible. When insufficient GIS information exists for source attribution, tasking of current satellite imagery may be initiated.

Quality flags may include but are not limited to

Scene-level quality attributes

- Image artifacts [column, glint, flare, contrast, other]
- Low signal-to-noise [N(default)/Y]
- Atmospheric artifacts [clouds, smoke, haze, other]
- Cloud cover fraction [0, 25, 50, 75, 100] or [0-1]

Plume quality attributes

- Overall rating (Good, Questionable, or Bad)

- plume shape (Y/N)
- artifacts intersect plume (Y/N)
- flare (Y/N)
- high background enhancement (Y/N)
- PHME candidate (Y/N)

Please refer to the Carbon Mapper Quality Control Description Document for a detailed description of the quality flag process.

The L3B product may also undergo alternative retrieval processing using methods such as IMAP-DOAS, Optimal Estimation, etc.). If there is insufficient source data, manual identification, and satellite tasking may require additional time to finalize sector attribution. All data from L3B products are included in all subsequent downstream products.

Data Structure:

Tabular and associated raster data (e.g., CSV, GeoTIFF, PNG, GeoJSON)

Data Access:

L3B products are released publicly along with other Carbon Mapper products 30 days after acquisition.

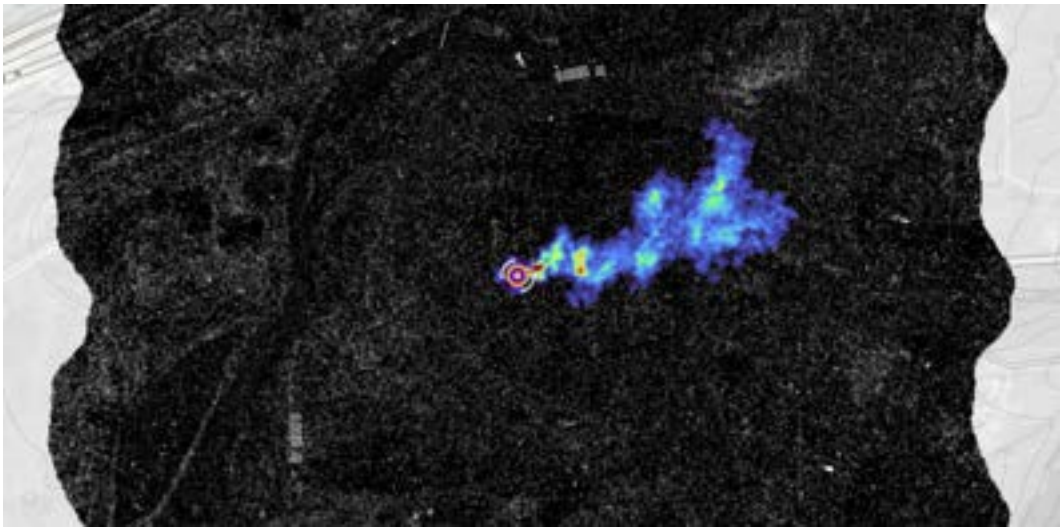

Figure 10. Level 3B final plume image arising from a methane source.

Level 4 Products

L4A-plume emissions

Definition:

L4A plume lists are tabular datasets that consist of plume-level instantaneous emissions estimates and uncertainties, wind speed, direction and uncertainties, and all L3B attributes (quality flags, sector attribution, etc.). All L4A products are derived from L3B products and current conditions or reanalysis weather data.

Data Structure:

Tabular and associated raster data (e.g., CSV, GeoTIFF, PNG, GeoJSON)

Data Availability:

L4A products are released publicly along with other Carbon Mapper products 30 days after acquisition..

L4B-source emissions

L4B source lists are tabular datasets that consist of an aggregation of plumes mapped to discrete emission sources. Attributes include source identifier, latitude and longitude of source origin and uncertainty, sector attribution, number of overpasses, positive plume detections, persistence estimates, persistence-adjusted average emission rate, and uncertainties. All L4B products are derived from L3B products and current conditions or reanalysis weather data.

Data Structure:

Tabular and associated raster data (e.g., CSV, GeoTIFF, PNG, GeoJSON)

Data Availability:

L4B products are released publicly along with other Carbon Mapper products 30 days after acquisition.

Level 5 Analytics and Data Fusion

L5: Analytics

Definition:

Level 5 products are on-demand or bespoke analytics, including histograms, time series, regional/sectoral upscaling, and fusion and normalization with non-CH_4/CO_2 datasets (e.g., infrastructure, socioeconomic, etc). An example is the Summary Statistics feature, which provides aggregated point source emission rates for all sources within a field of view or area of interest (AOI).

Data Structure:

Web application analytics, API endpoints

Data Availability:

All analytics are generated dynamically and are not stored permanently.

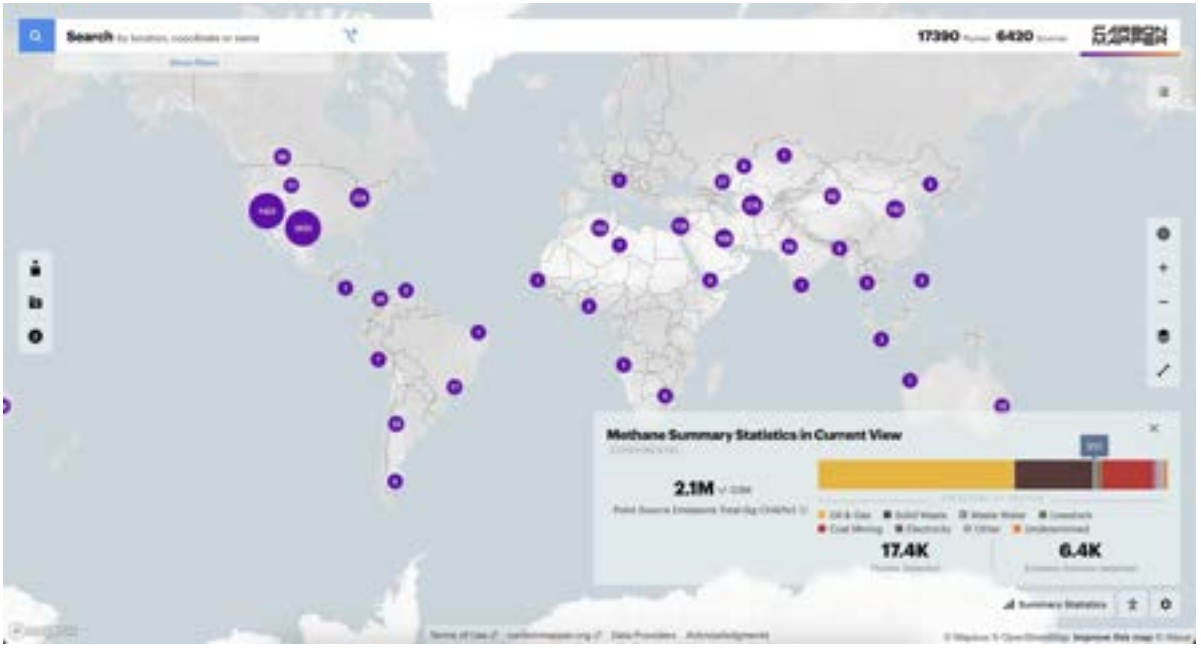

Figure 11. Example L5 analytics include summary Statistics, which summarize total point source emissions across broad geographic areas.

Naming Conventions

Carbon Mapper Level 1, Level 2, and Level 3 data products adhere to the following naming conventions:

```
Unset

Planet Tanager L1B:
20190604_193000_00_4902_basic_radiance.h5
L1-L2b item id:
tan20190604t193000c00s4902 (“tan{YYYYMMDD}t{HHMMSS}c{centisecond}s{satellite}")
L2c-L4 item id:
tan20190604t193000c00s4902-A

EMIT L1B:
EMIT_L1B_RAD_001_20230824T175349_2323612_024
L1-L2b item id:
emi20230824t175349p12024
L2c-L4 item id:
emi20230824t175349p12024-A

Airborne Visible/Infrared Imaging Spectrometer-Next Generation (ANG) L1B:
ang20230121t192729_rdn_v2aa3_clip
L1-L2b item id:
ang20230121t192729
L2c-L4 item id:
ang20230121t192729-A

Global Airborne Observatory (GAO) L1B:
GAO20230614t170959p0000_rad
L1-L2b item id:
GAO20230614t170959p0000
L2c-L4 item id:
GAO20230614t170959p0000-A

Plume Item id = {platform}{YYYYMMDD}{HHMMSS}-{part}
Type: Text, unique primary key
Description: A unique identifier for each plume in the format
{platform}{YYYYMMDD}{HHMMSS}-{part}. The first three characters represent the
platform (e.g., GAO for Global Airborne Observatory), followed by the
acquisition date and time in ISO 8601 UTC format. The part suffix (e.g.,
"p0000-A") retains key information from the original radiance filename and
indicates the order of multiple plumes detected in the same image.
```

Field names and definitions

Plume list fields

Name	Data Type	Description	Access
uuid	UUID, unique primary key	Universally unique object identifier randomly generated using UUIDv4	public (API only)
plume_id	Text, unique	A unique identifier for each plume in the format {platform}{YYYYMMDD}{HHMMSS}-{part}. The first three characters represent the platform (e.g., GAO for Global Airborne Observatory), followed by the acquisition date and time in ISO 8601 UTC format. The part suffix (e.g., "p0000-A") retains key information from the original radiance filename and indicates the order of multiple plumes detected in the same image.	public
plume_latitude	decimal degree	Latitude estimate of plume origin	public
plume_longitude	decimal degree	Longitude estimate of plume origin	public
datetime	UTC timestamp in ISO 8601 format	Date and time of the acquisition in Coordinated Universal Time (UTC)	public
ipcc_sector	text, categorial identifier	IPCC emissions sector, if available (e.g., “Oil & Gas (1B2)") Reference: https://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1ri.pdf	public
gas	text, categorial identifier	The gas molecule detected during imaging operations	public
cmf_type	text, categorial identifier	Statistical-based column-wise atmospheric retrieval algorithm used to threshold methane or carbon dioxide plumes from background concentrations	public
plume_bounds	decimal degrees	The geographic bounds encompassing a plume image	public
instrument	text	Three character abbreviations for sensor (e.g., ang (AVIRIS-NG), av3, (AVIRIS-3), emi (EMIT), tan (Tanager)	public
published_at	UTC timestamp in ISO 8601 format	Date and time the observation was published in Coordinated Universal Time (UTC)	public
ime	float	The total kilograms (kg) of methane in a plume above the background concentration at the time of image capture	available upon request
emission_auto	numerical, kg/hr	The quantified emission rate of a plume, estimated using the Integrated Methane Enhancement method (Duren et al., 2019 - "California's Methane Super-Emitters", Nature)	public

emission_uncertainty_auto	numerical, ± kg/hr range	The uncertainty in an emission rate, derived from uncertainty in IME and wind speed	public
wind_speed_avg_auto	float	Mean wind speed m/s	public
wind_speed_std_auto	float	Standard deviation wind speed m/s	public
wind_direction_avg_auto	float	Wind direction (degrees)	public
wind_direction_std_auto	float	Wind direction standard deviation (degrees)	public
wind_source_auto	string	Wind source from reanalysis (e.g., HRRR, ECMWF_IFS, ERA5)	public
platform	text	The unique name of the platform to which the instrument is attached.	public
provider	Text	A short description of the data provider's name	public
mission_phase	Text	Operational mission phase, such as 'first_light' or 'production.'	public
plume_tif	String (URL)	An HTTPS link that provides access to a GeoTIFF of the delineated plume.	public
plume_png	String (URL)	An HTTPS link that provides access to a PNG of the delineated plume.	public
con_tif	String (URL)	An HTTPS link that provides access to a GeoTIFF pixel map of unsmoothed concentration values in parts per million-meter (ppm-m).	public
rgb_tif	String (URL)	An HTTPS link that provides access to 3-band, natural color full-strip surface-reflectance GeoTIFF.	public
rgb_png	String (URL)	An HTTPS link that provides access to natural color full-strip surface-reflectance PNG.	public

Source list fields

Name	Data Type	Description
id	Text, unique primary key	Unique identifier for the source of a plume Format: gas_sector_cluster-distance_longitude_latitude
source_name	Text	Format: gas_sector_cluster-distance_longitude_latitude
source_lat	Decimal Degree	Latitude estimate of source origin (embedded in GeoJSON)
source_lon	Decimal Degree	Longitude estimate of source origin (embedded in GeoJSON)
cluster_id	Numerical, count	Numerical id for each source cluster
gas	Text, categorical	CH4 or CO2

sector	Text, categorical	IPCC emissions sector code (e.g. "1B2" for Oil & Gas)
plume_count	Numerical, count	Number of plumes attributed to a source
plume_ids	Text	Comma-separated list of plume IDs attributed to a source
emission_auto (source emission rate)	Numerical, kg/hr	Quantified emission rate calculated using the mean of all emissions attributed to a source weighted by persistence
emission_auto_uncertianty (source emission rate uncertainty)	Numerical, ± kg/hr range	Uncertainty in emission rate, derived from uncertainty in IME and wind speed. This combines all plume uncertainty attributed to the source weighted by persistence.
published_at_max	date	The latest published date for a source
published_at_min	date	The earliest publish date for a source
timestamp_max	date	The latest acquired date for a source
timestamp_min	date	The earliest acquired date for a source
date_count	Numerical, count	Number of observation days over a source
persistence	Numerical, ratio	Frequency of detection (number of plume detection days divided by the number of observation days)

Sector attribution codes

Name	Type	Options
Sector (short description) *required	String (single selection)	• Oil & Gas • Solid Waste • Waste Water • Livestock • Coal Mining • Electricity Generation • Other

Sector (database code) *required	String (single selection)	• Following categories from IPCC:
		• 1A1a Public Electricity
		  ○ CO_2 from coal and gas power plants
		• 1A1b Petroleum Refining
		  ○ CO_2/CH_4 from refineries
		• 1A2 Manufacturing Industries and Construction
		  ○ Includes petrochemical, and steel
		• 1B1 a Coal Mining
		  ○ CH_4 from coal mines and mining activities
		• 1B2 Oil and Natural Gas
		• 4A Enteric Fermentation
		• 4B Manure Management
		• 6A Solid Waste Disposal On Land
		• 6B Waste Water Handling
		• Other

Sub-Sector (not currently in use)	String (single selection)	• 1A1a Coal Power Plant • 1A1a Gas Power Plant • 1A2a Iron and Steel

		• 1A2c Chemicals • 1A2f Other (e.g., cement) • 1B1a Coal Mining - Mining • 1B1a Coal Mining - Mining activities (e.g., vents) • 1B1a Coal Mining - post-mining activities (e.g., coal crushers) • 1B2a Oil Exploration • 1B2a Oil Production • 1B2a Oil Transport • 1B2a Oil Storage • 1B2a Oil Distribution • 1B2a Oil Other • 1B2b Natural Gas Production • 1B2b Natural Gas Processing • 1B2b Natural Gas Transmission/Distribution • 1B2b Natural Gas Residential and Commercial • 1B2c Venting and Flaring Oil • 1B2c Venting and Flaring Oil • 1B2c Venting and Flaring Combined • 4A1a Dairy Cattle • 4A1b Non-Dairy Cattle • 4A8 Swine • 4A9 Poultry • 6A1 Managed Waste Disposal on Land • 6A2 Unmanaged Waste Disposal Sites • 6B1 Industrial Wastewater • 6B2 Domestic and Commercial Wastewater
Equipment Type (not currently in use)	String (single selection)	• Power plant exhaust stack • Cogen plant • Hydrogen plant • Surface coal mine • Underground coal mine vent • Coal crusher • O&G separator • O&G condensate tank • O&G stock tank • O&G well head • O&G waste pit • O&G frac pond • O&G waste water • O&G offshore platform • Gathering pipeline • Transmission pipeline • Distribution pipeline • Compressor station • Compressor vent • Compressor turbine • Bypass stack • Metering station • Filter/scrubber • Flare stack • Cold vent • Gas processing plant • LNG export terminal • LNG import terminal • LNG storage tank • CNG storage tank • Livestock manure pond • Livestock manure digester • Livestock - other • MSW landfill

		• Dumpsite • Waste digester • Composting facility • Wastewater digester • Wastewater plant • Tanker ship • Natural methane source