2023-01-18

ZEROING METHANE EMISSIONS DATATHON

Zeroing Methane Emissions

Problem Statement & Dataset Information

SPE International Calgary Section

SPE International Gulf Coast Section

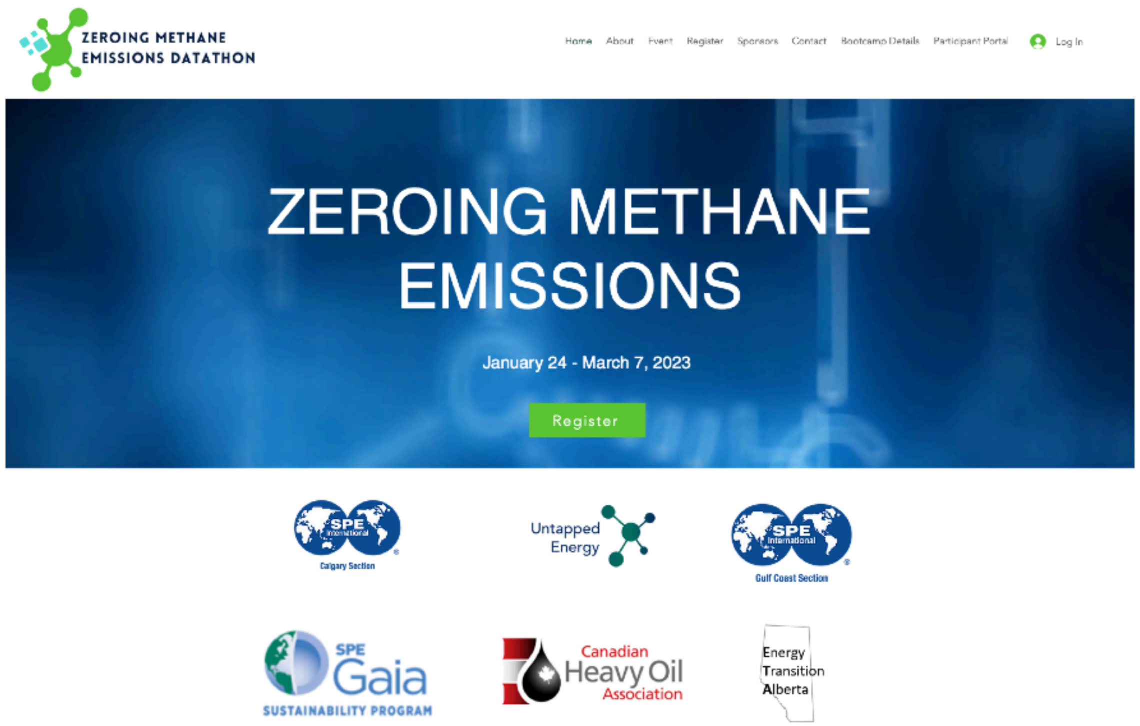
Untapped Energy

About the Event

Welcome to the 2023 Zeroing Methane Emissions Datathon!

The SPE Calgary Section has teamed up with their friends at the SPE Gulf Coast Section, along with ‘Untapped Energy,’ Canadian Heavy Oil Association (CHOA), Energy Transition Alberta, and the SPE Gaia Sustainability Program to organize a data event like no other! Driven by the desire to use real data to solve a real problem, to elevate data literacy and to make new professional connections, all while having fun!

Our goal is to provide datathon participants with a high-quality hands on learning experience in this area by working on an industry relevant problem with real data.



Please take a look at the event webpage for further updates.

https://www.speuntapped.com

Background

Methane emissions from human activities represent the 2nd largest contributor to global warming after carbon dioxide, accounting for around 30% of the temperature increase from pre-industrial levels. The concentration of methane in the atmosphere has more than doubled since pre-industrial times to over 1,900 ppm in 2021. Approximately 60% of the 570 million tonnes of annual global methane emissions are *anthropogenic* emissions. Five industries are responsible for 98% of anthropogenic methane emissions: agriculture, oil & gas, coal mining, solid-waste management, and wastewater management.

Challenges in addressing methane emissions

In recent years, there has been an increasing interest by policy makers, corporate decision makers, and the the wider society in curbing methane emissions. However, there are many challenges in addressing the problem.

One fundamental barrier is the irregularity of emission sources which can be dispersed across wide and remote geographies. Many individual sources also emit intermittently and account for a tiny portion of the aggregate, such as ruminant animals on private owned farms, and small leaks (fugitive emissions) from valves and other oil and natural gas equipment. On the other hand, a small percentage of sites can account for a majority of emissions (super-emitters).

Estimates, reporting, and abatement

Methane emissions are difficult to reliably estimate, making it challenging to build business cases for abatement projects. Moreover, tracking the impact of mitigation efforts is also hindered by the same uncertainty in estimates. Companies cannot manage risk and put in place meaningful actions without accurate information about their emissions intensities and sources. A lack of accounting also limits transparency, including disclosures to the public and stakeholders, as well as alignment and coordination of activities with policy makers.

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Abatement costs and feasibility vary significantly between and within each industry. For example, the cost of methane recovery in coal mining, for example, is four to five times higher than that of leak detection and repair in oil and gas (DeFabrizio, S., 2021). Moreover, solutions require considering trade-offs between costs and benefits to society together with environmental impacts of the emitting activities.

Measurement and Inventories

Methane emission inventories have historically been constructed using bottom-up methods. Bottom-up methods measure emissions from a representative sample of sources or equipment to obtain an *emission factor*. *Activity levels* (e.g., number of livestock) are multiplied by emission factors to relate emissions to the underlying process, and to provide estimates of emissions quantities. However, there can be large differences between the estimated and actual amounts, leading to inaccurate inventories. In some cases, the simple approach using activity levels and emissions factor calculations are not appropriate at all, for example, sources such as landfills and manure.

Addressing these and other challenges in quantifying methane emissions, will require a range of measurement solutions. Many have been proposed, developed, and in some cases commercialized (Erland, B., 2022)

Bottom-up techniques to monitor, detect, and quantify methane emissions from point and area sources leverage site and component level measurement devices, and sometimes are combined with modelling techniques. *Top-down* measurements can be performed at a regional scale as well as for monitoring individual facilities. For example, aircraft-based measurements can also be used to estimate emissions from individual facilities by flying closed flight paths around a source while continuously measuring methane concentrations, wind speed and direction, and applying mass balance approaches to arrive at the emission estimate.

Observations of atmospheric methane from satellites provide top-down information to improve bottom-up emissions estimates by using inverse methods to relate observed concentrations to emissions. Satellite based observations have an advantage of global coverage, but have typically been restricted to methane column concentration retrievals over large areas (e.g., 30x60 km2 pixels). Significant advancements in technology and equipment have recently enabled targeted observation of methane point sources from space (25x25 m2 pixel).

Problem Statement

The robust, accurate, and timely detection and quantification of methane emissions enables decision makers to develop business cases around abatement strategies.

Your mission, should you choose to accept it…

1. **Automated Prediction Models:** Develop a methodology to identify and quantify methane emissions from aerial surveillance data. Automate the process of verifying the presence of methane plumes, characterize the extent, and predict emission source rates. Compare actuals and predictions to also quantify the uncertainty around your models.

2. **Case Study:** Present a case study for decision makers and stakeholders on your technology and findings. Provide analysis of the datasets and consider measurement and mitigation strategies, and abatement options to help develop a business strategy towards zeroing methane emissions.

You are encouraged to augment your findings with other data and information sources to enrich your analysis beyond the basics. For example: How do the emissions compare with “bottom-up” approaches based on activity and emissions factors? Are the plumes clustered around oil & natural gas infrastructure? Do intense plumes necessarily mean large sources/rates? What do you think are the unknown sources? Can you incorporate/identify additional context for the sites? What are some sources of uncertainty in the data/model? Can you build an application for your model?

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Quantitative Challenge

The automated prediction model will be evaluated based on a random subset of data. You will be given a set of 20 raw data examples (1 geotiff for the RGB background, 1 geotiff for the methane plume enhancement). For each example, your model is graded on:

1. ~~Can it determine if a methane plume is present in the image (True/False) - 10%~~

2. ~~Can it identify the point source of the emission (distance from the known location) - Rank relative to other submissions (10%)~~

3. Can it predict the emissions source rate (kg/hour) - Rank relative to other submissions ~~(10%)~~ 20%

Evaluation Criteria

The criteria for evaluating the submissions are defined below:

Component		Weightings
EDA	Includes data cleaning, organization, description, and augmentation	10%
Analysis and Insights	Includes modelling, interpretation, comparative analysis, visualization, relevance, creativity, and insights	30%
Automated Prediction Model	Includes accuracy and usability	30%
Presentation of Case Study	Includes story telling, articulation, and time-management	~~30%~~ 40%

Competition Rules

1. Team size. Teams should have at least 2 people and no more than 7 members.

2. No Plagiarism. Plagiarism is not acceptable. Learning from existing resources online and using open-source code is accepted.

3. Frameworks, libraries, and software. You can only use open source frameworks, libraries, and software.

4. Open Source. The code, presentations, data, and models generated are considered as open source and is to be made available to the public. Please refer to the Open Source Initiative guiding principles: https://opensource.org/osd. All submissions fall under the Apache License 2.0: https://opensource.org/licenses/Apache-2.0

5. Intellectual property. The SPE and its Sponsors make no claim over intellectual property generated during the event.

6. Data: All data used in this event is open source and all work, including code, must include references to the original data (see References and Dataset sections)

7. Social Media Disclosure. By taking part in the event, you agree to allow SPE to include mention of your participation in the event, and to appear in photos and video of the event. Personal information will not be made public without individual consent.

8. Rules. The SPE committee reserves the right to change the rules at any time.

Dataset

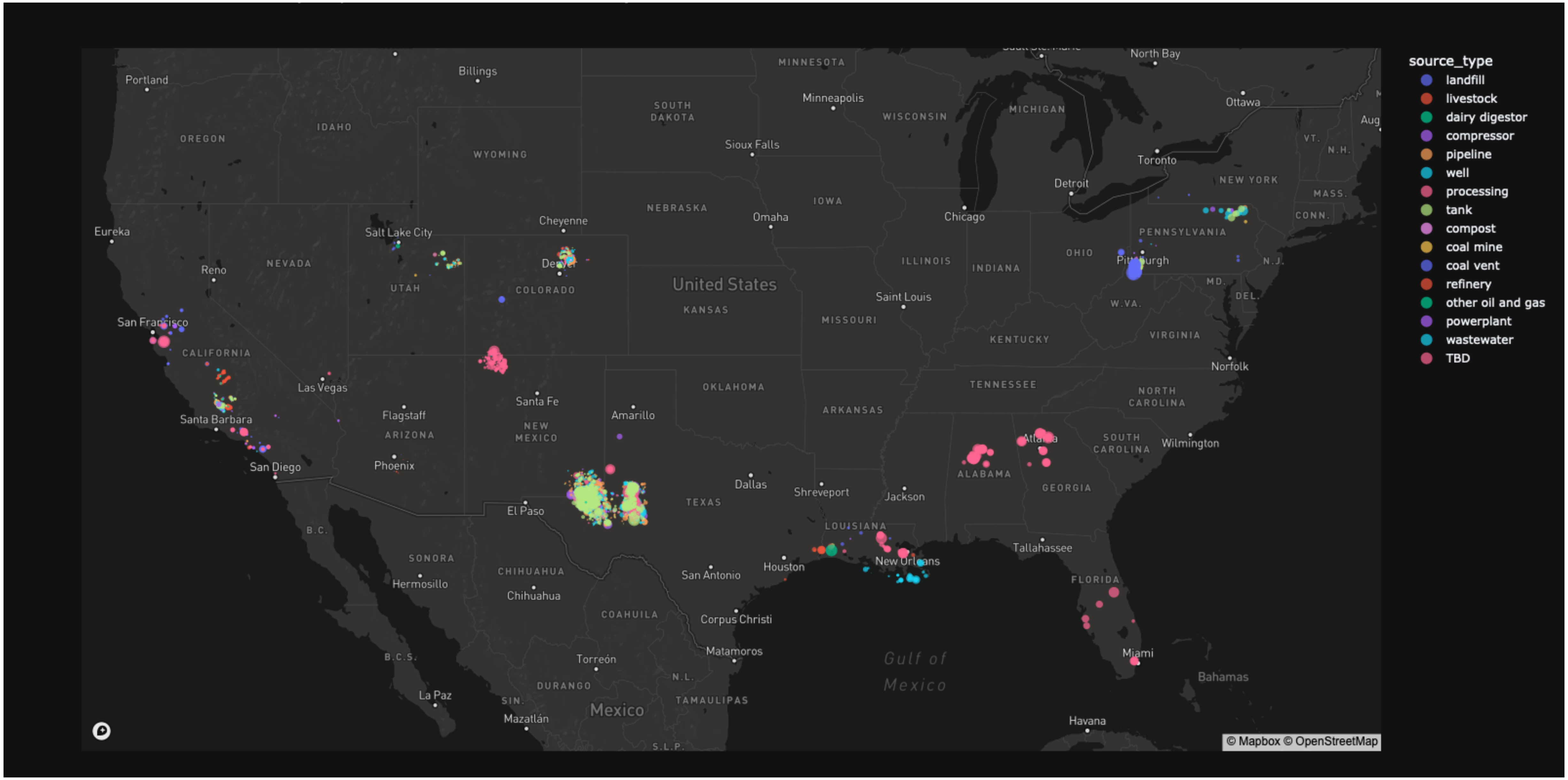
The primary data (i.e, from airborne methane surveys) can be obtained from the Carbon Mapper website: https://carbonmapper.org/. Please read the terms of use: https://carbonmapper.org/terms-of-use/. In particular, the data is provided strictly for non-commercial purposes and subject to the Modified Creative Commons Attribution ShareAlike 4.0 International Public License. https://carbonmapper.org/wp-content/uploads/2021/12/Carbon-Mapper-Modified-Creative-Commons-License-21-11-09.pdf

The Datasets based on airborne methane surveys are available for download from the sources listed here. You are encouraged to conduct your own research and incorporate additional data sources (see Additional Data & Information Sources section. Please read the terms and conditions for each).

- Permian Basin plume imagery (GeoTIFFs) and plume emissions lists: https://doi.org/10.5281/zenodo.5610307, https://doi.org/10.1021/acs.estlett.1c00173 (See to Supporting Information)

- Airborne plume imagery (GeoTIFFs) and plume emissions lists (XLS): https://doi.org/10.5281/zenodo.5606120

Brief descriptions of the measurement devices used are included in the following pages. Please see their references for further information.



Map of plumes and sources contained in the dataset. Size of the markers indicates source rates.

The Dataset provides a snapshot of the range and diversity of methane plumes and sources distributed across a wide area of the continental US. The type of sources range from landfills to wastewater in addition to some unknown (TBD) sources. Some areas have much higher concentrations of plumes/sources. Other areas are sparsely populated or appear to have no sources. However, due to the potential types of sources, for example natural gas infrastructure, survey coverage in these areas may be the reason they are under-represented. On the other hand, there is always detection threshold limit for every type of methane detection technology, method, and dependency on nature (e.g., wind speed, cloud coverage, temperature, and pressure). Examples of individual plumes are shown in the next page.

Zeroing Methane Emissions

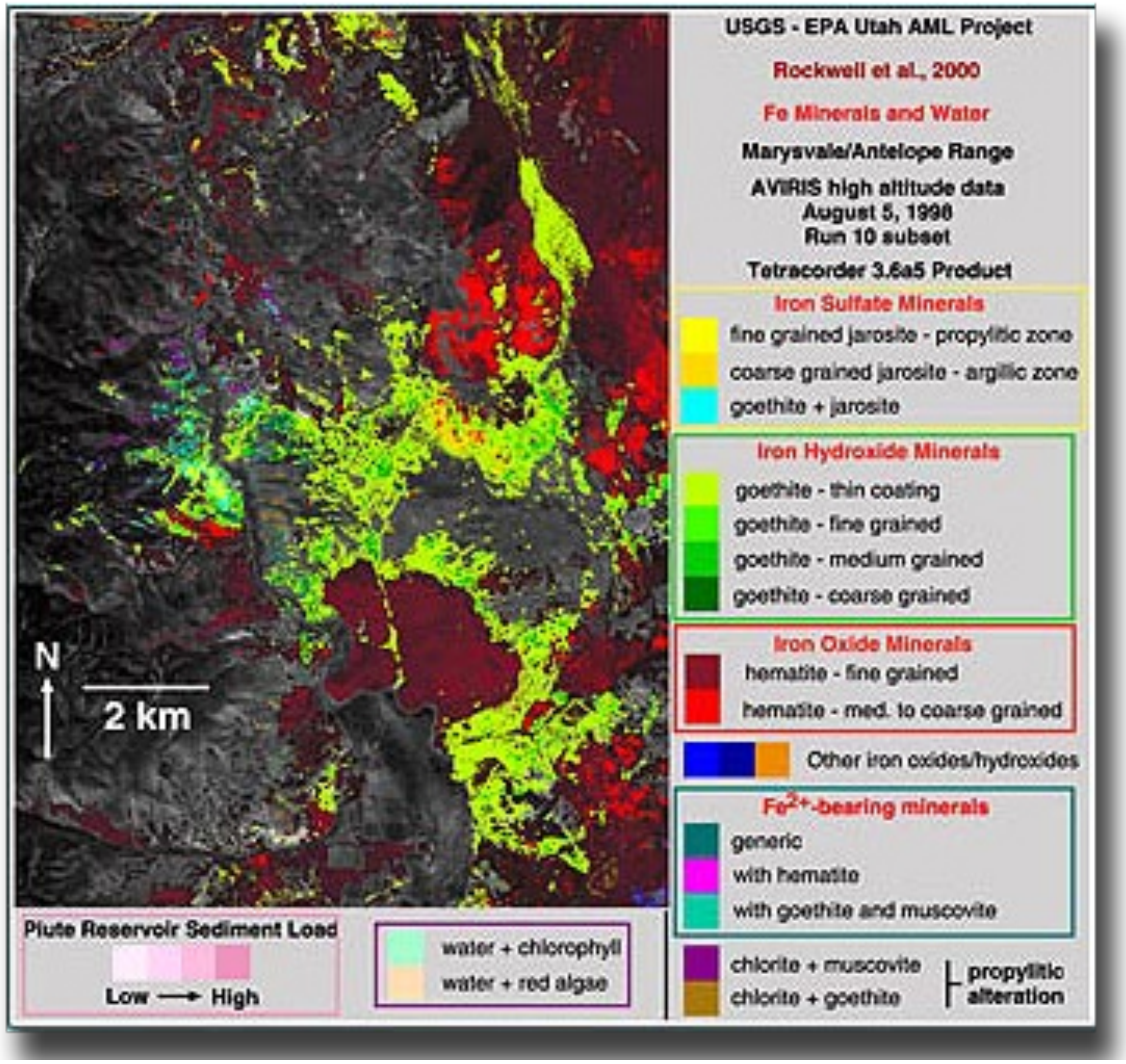
Airborne imaging spectrometers can be used to identify methane point source emissions, estimate emission rates, and attribute emissions to different sectors. The two types used to generate the data for the Application part of this datathon are briefly described below.

AVIRIS Data

AVIRIS stands for “Airborne Visible InfraRed Imaging Spectrometer”. It is an optical sensor that collects data that useful for characterization of the Earth's surface and atmosphere.

The sensor has been mounted on several aircraft platforms: NASA’s ER-2 jet, the Twin Otter International’s turboprop, the Scaled Composites’ Proteus aircraft, and NASA’s WB-57. Aerial surveys are conducted by flying each aircraft at altitudes between 4km-20km above sea level, at 130km/hr to 730 km/hr.

The data can be applied to studies in the fields of oceanography, environmental science, snow hydrology, geology, volcanology, soil and land management, atmospheric and aerosol studies, agriculture, and limnology. Calibration and correction for atmospheric effects allows it to capture measurements of methane emissions from terrestrial and marine sources (see https://aviris.jpl.nasa.gov/documents/index.html).



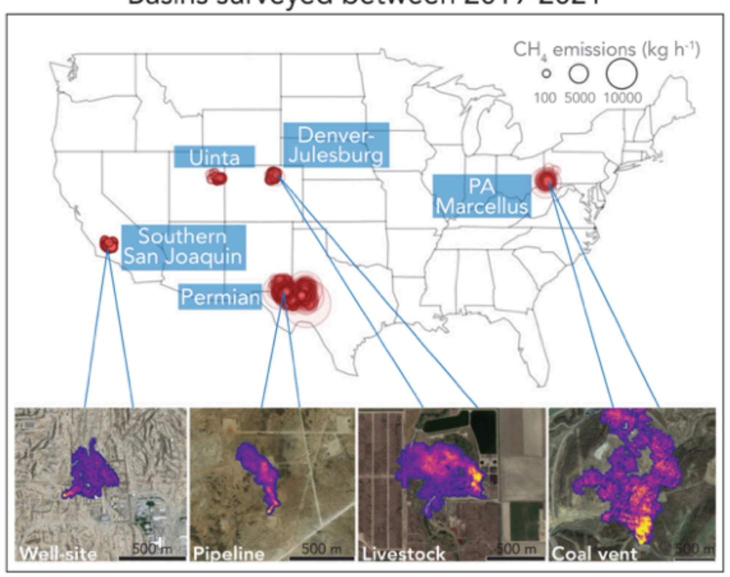
Example image captured by the AVIRIS instrument. Source: https://aviris.jpl.nasa.gov/data/index.html

Zeroing Methane Emissions

Global Airborne Observatory

The University of Arizona together with Arizona State University (ASU) and NASA's Jet Propulsion Laboratory (JPL) have deployed the Global Airborne Observatory (GAO) to provide complete surveys identifying and quantifying methane emissions from industrial and agricultural sites across several key geographical areas of the US. GAO an airborne laboratory baed on a modified Dornier 228-202 aircraft carrying advanced mapping technology, including measurements of ground-reflected solar radiation from the visible to shortwave infrared spectral regions. For more details, see: https://gdcs.asu.edu/programs/global-airborne-observatory; Publications: https://gdcs.asu.edu/publications

Basins surveyed between 2019-2021



Source: Cusworth, D.H., et. al. (2022)

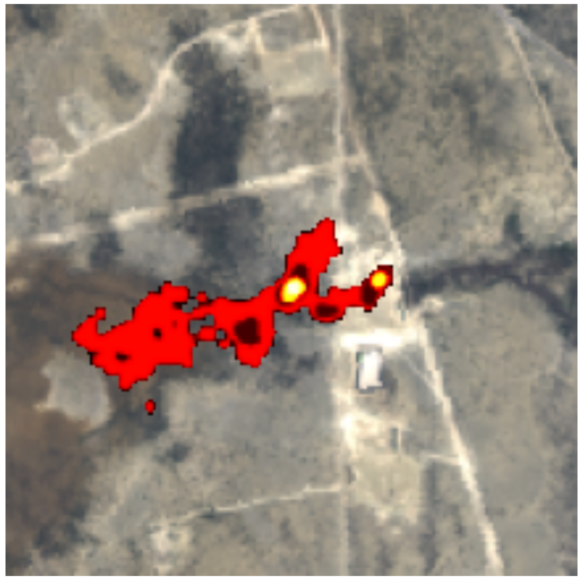
Global Airborne Observatory

Source: https://gdcs.asu.edu/programs/global-airborne-observatory

Application

As part of the problem statement, you are asked to develop methods to detect and classify methane plumes, and predict emission rates and quantities. The dataset containing semi-upgraded images of potential methane plumes from recent aerial surveys, together with information about the emissions sources. The colouring in the images below represent atmospheric methane concentration enhancements.

Basic example

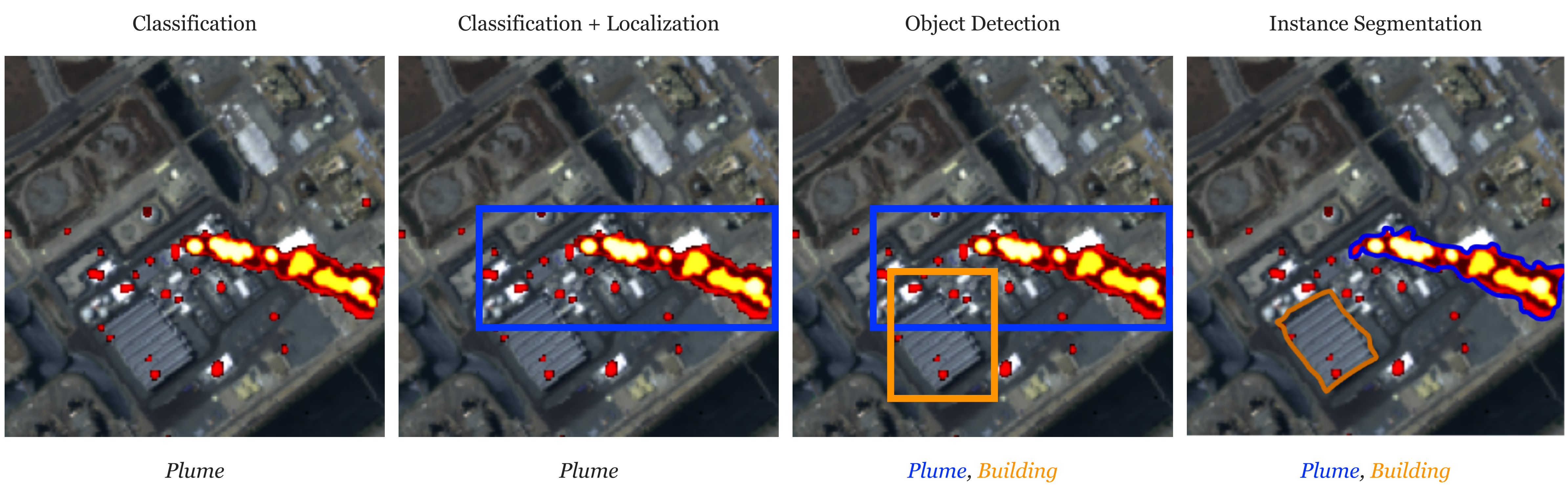


Plume

No Plume

Detailed example

A detection or localization task finds an object in an image and localizes the object with a bounding box. A segmentationo task does pixel-wise classification which gives a separation of objects.



Recommended Reading

Alvarez, R., et. al. (2018, July 13). “Assessment of methane emissions from the US oil and gas supply chain.” Science, 361, 6398, Pp. 186-188. https://www.science.org/doi/10.1126/science.aar7204

Erland, B., et. al. (2022, Dec. 6). “Recent Advances Toward Transparent Methane Emissions Monitoring: A Review.” Environmental Science & Technology, 56(23): 16567–16581. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9730852/

DeFabrizio, S., et. al. (2021, Sept.). Curbing methane emissions: How five industries can counter a major climate threat. McKinsey Sustainability. https://www.mckinsey.com/capabilities/sustainability/our-insights/curbing-methane-emissions-how-five-industries-can-counter-a-major-climate-threat

Jacob, D., et. al. (2022, July 29). “Quantifying methane emissions from the global scale down to point sources using satellite observations of atmospheric methane.” Atmos. Chem. Phys., 22, 9617–9646, 2022. https://acp.copernicus.org/articles/22/9617/2022/acp-22-9617-2022-discussion.html

Nisbet, E. G., Fisher, R. E., Lowry, D., France, J. L., Allen, G., Bakkaloglu, S., et al. (2020). Methane mitigation: methods to reduce emissions, on the path to the Paris agreement. Reviews of Geophysics, 58, e2019RG000675. https://doi.org/10.1029/2019RG000675

McKinsey Sustainability: Greenhouse gas abatement cost curves: https://www.mckinsey.com/capabilities/sustainability/our-insights/greenhouse-gas-abatement-cost-curves

Cusworth, D.H., et. al. (2022). “Strong methane point sources contribute a disproportionate fraction of total emissions across multiple basins in the United States.” PNAS, 119(38): e2202338119. https://doi.org/10.1073/pnas.2202338119

Additional Data & Information Sources

US Environmental Protection Agency (EPA): https://www.epa.gov/ghgemissions/overview-greenhouse-gases

US Environmental Protection Agency (EPA) Air Emissions Factors and Quantification: https://www.epa.gov/air-emissions-factors-and-quantification/basic-information-air-emissions-factors-and-quantification

International Energy Agency (IEA) Methane Tracker: https://www.iea.org/reports/global-methane-tracker-2022

International Energy Agency (IEA) Emissions Factors 2022: https://www.iea.org/data-and-statistics/data-product/emissions-factors-2022

Carbon Mapper: https://carbonmapper.org/

National Oceanic and Atmospheric Administration (NOAA): https://gml.noaa.gov/ccgg/carbontracker-ch4/

TROPOspheric Monitoring Instrument (TROPOMI): http://www.tropomi.eu/

The European Space Agency: https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/Mapping_methane_emissions_on_a_global_scale

NASA Jet Propulsion Laboratory AVIRIS program: https://aviris.jpl.nasa.gov/

The World Bank: https://data.worldbank.org/indicator/EN.ATM.METH.KT.CE

Our World in Data: https://ourworldindata.org/grapher/methane-emissions-by-sector

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US Energy Information Administration (EIA) energy infrastructure data: https://www.eia.gov/maps/layer_info-m.php

National Energy Technology Laboratory (NETL) Energy Data eXchange (EDX): https://edx.netl.doe.gov/

US Environmental Protection Agency (EPA) - Inventory of U.S. Greenhouse Gas Emissions and Sinks (see also “Related Links” inside): https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

References

The following references must be listed in your work, including the code you generate, in addition to any information or data sources you use.

Cusworth, D. H., et. al. (2022). Strong methane point sources contribute a disproportionate fraction of total emissions across multiple basins in the U.S. PNAS. https://www.pnas.org/doi/10.1073/pnas.2202338119

Ayasse, A. K., et. al. (2022). Methane remote sensing and emission quantification of offshore shallow water oil and gas platforms in the Gulf of Mexico. Environmental Research Letters, 17(8), 084039. https://doi.org/10.1088/1748-9326/ac8566

Cusworth, D. H., et. al. (2021). Intermittency of large methane emitters in the Permian Basin. Environmental Science & Technology Letters, 8(7), 567–573. https://doi.org/10.1021/acs.estlett.1c00173

Duren, R. M., et. al. (2019). California's methane super-emitters. Nature, 575(7781), 180–184. https://doi.org/10.1038/s41586-019-1720-3

Duren, R., Thorpe, A., & McCubbin, I. (2020). The California Methane Survey Final Report, CEC-500-2020-047. https://ww2.energy.ca.gov/2020publications/CEC-500-2020-047/CEC-500-2020-047.pdf

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