**Gulf of Mexico Health & Air Quality II**

*Mapping Methane Emission Plumes Using Sunglint-configured Imagery for Monitoring Offshore Oil & Gas Activity*

**Project Team**

***Project Team:***

Ben Dahan (Project Lead)

Vanessa Machuca

René Castillo

Melodi Hess

***Advisors & Mentors:***

Dan Cusworth (CarbonMapper; NASA Jet Propulsion Laboratory, California Institute of Technology; University of Arizona)

Kate Howell (CarbonMapper)

Ben Holt (NASA Jet Propulsion Laboratory, California Institute of Technology)

***Past or Other Contributors:***

Kate Howell

Ashley Fernando

Ephrata Yohannes

J. Kyle Bergerson

***Fellow:***

Katie Lange (JPL)

***Team Contact:*** Ben Dahan, bendahan55@gmail.com

***Partner Contact:*** Holli D. Wecht, holli.ensz@boem.gov, Ramona Sanders, ramona.sanders@bsee.gov

**Project Overview**

***Project Synopsis:***

Oil and gas activity is responsible for a third of all anthropogenic methane (CH4) emissions. This project focused on the potential for greenhouse gas mitigation efforts utilizing the advancement of Earth observations and remote sensing techniques as a prospective solution to the difficulties faced in monitoring offshore emissions. In collaboration with SkyTruth, the Bureau of Ocean Energy Management (BOEM), and the Bureau of Safety and Environmental Enforcement (BSEE), NASA Earth observation imagery was coupled with industry data to produce methane plume maps, furthering the efforts of health and air quality monitoring and regulation.

***Abstract:***

Offshore oil and gas production in the United States is a major source of anthropogenic greenhouse gas emissions and accounts for nearly 30% of global oil and gas production. Methane venting and flaring are primary contributors to offshore emissions and monitoring these activities is crucial for mitigating greenhouse gas emissions. Limited ground truthing and intermittent offshore satellite revisits make monitoring venting and flaring challenging. The Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE) oversee offshore oil and gas activity, but rely primarily on operator-reported data. The non-profit organization SkyTruth monitors natural resources like methane and identifies sources of fugitive emissions. By combining BOEM and BSEE’s operational data along with observations from Sentinel-2 Multispectral Instrument (MSI), Landsat 8 Operational Land Imager (OLI) and 9 OLI-2, and *PRecursore IperSpettrale della Missione Applicativa* (PRISMA), the team further identified ultra-emitter point sources in the Gulf of Mexico using sunglint-configured imagery. The team quantified these methane emission rates and concentration over time using the methodology from Varon et al. (2020). We found 3 plumes in the Gulf of Mexico from 2020 to 2022 in Sentinel-2 MSI and Landsat 9 OLI-2 imagery and quantified a total of 4 plumes. Our matched filter retrieval of 3 PRISMA images over areas of interest yielded no methane plumes, despite a successful test of a known plume in Assam, India. These analyses serve as a proof of concept for the utility of remote sensing for methane emission monitoring offshore, which can complement and validate self-reported operator emission inventories.

***Key Terms***

sunglint, flaring, venting, methane plumes, Landsat 8 OLI, Landsat 9 OLI-2, Sentinel-2 MSI, PRISMA

***National Application Area Addressed:*** Health & Air Quality

***Study Location:*** Gulf of Mexico, TX, LA, MS, AL & FL

***Study Period:*** January 2019 – August 2022

***Community Concerns:***

* Methane is a powerful greenhouse gas that warms the atmosphere approximately 30 times more efficiently than carbon dioxide on a 100-year time scale, resulting in changes to average climate conditions and more frequent and intense extreme weather events, which damage infrastructure, ecosystems, and social systems that provide essential benefits to communities.
* The federally-calculated social cost of carbon for methane is $1500 per metric ton, stemming from changes to agricultural productivity, human health effects, property damage from natural disasters, and the value of ecosystem services.
* Methane is often emitted alongside other heath-damaging air pollutants, exposing communities in the Gulf of Mexico to adverse health impacts such as premature birth, asthma, and cancer

***Project Objectives:***

* Identify methane plumes from venting and flaring in the Gulf of Mexico using a multi-band-single-pass (MBSP) methodology on sunglint-configured Earth observation imagery.
* Quantify methane concentrations and emission rates in identified plumes using integrated mass enhancement (IME).

***Previous Term:***

2022 Spring (JPL) – Gulf of Mexico Health and Air quality

**Partner Overview**

***Partner Organizations:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **U.S. Department of the Interior, Bureau of Safety and Environmental Enforcement** | Jay Cho, Program Manager, Engineer;Ramona Sanders, Senior Environmental Stewardship Coordinator; Jarvis B. Abbott, Safety Performance Enhanced by Analytical Review (SPEAR) Program Coordinators | End User |
| **U.S. Department of the Interior, Bureau of Ocean Energy Management** | Holli D. Ensz, Physical Scientist; Cholena Ren, Physical Scientist; Thomas Kilpatrick, Ocean and Atmospheric Scientist | End User  |
| **SkyTruth** | Jason Schatz, Chief Technology Officer | Collaborator |

***Decision-Making Practices & Policies:***

The Bureau of Ocean Energy Management (BOEM) has a statutory requirement in the Outer Continental Shelf Lands Act (OCSLA) and in the National Environmental Policy Act (NEPA) to perform air quality impact assessments of leasing program activities. BOEM’s mandate from the Clean Air Act focuses on criteria pollutants, but the agency may soon begin issuing regulations on greenhouse gas emissions within its jurisdiction in the Gulf of Mexico. Its sister agency—the Bureau of Safety and Environmental Enforcement (BSEE)—enforces BOEM’s rulemaking, and regulates venting and flaring activity. Monitoring traditionally occurs through bottom-up assessments from self-reported emission inventories, with occasional inspections using infrared cameras to identify fugitive emissions. This data does not reflect the length of time or quantity of methane emitted. There are currently no off-shore monitors.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Sentinel-2 MSI** | Methane Presence | Sentinel-2 imagery with sunglint was used to detect methane plumes from venting and incomplete flaring. |
| **Landsat 8 OLI** | Methane Presence | Landsat-8 imagery with sunglint was used to detect methane plumes from venting and incomplete flaring. |
| **Landsat 9 OLI-2** | Methane Presence | Landsat-9 imagery with sunglint was used to detect methane plumes from venting and incomplete flaring. |
| **PRISMA** | Methane Presence | PRISMA imagery was used to detect methane plumes from venting and incomplete flaring. |

***Ancillary Datasets:***

* Earth Observation Group Annual Flaring Volume Estimate Map – Identify areas of high methane flaring where offshore oil & gas activity may be occurring
* Carbon Mapper Airborne Methane Plume Maps – Verify methane plumes captured by sunglint-configured airborne imagery
* BOEM 2021 Outer Continental Shelf Emissions Inventory – Evaluate the effectiveness of BOEM’s regulations and support environmental analyses and coordination with other agencies

***Software & Scripting:***

* Google Earth Engine – Remote sensing imagery analysis and imagery acquisition
* Esri ArcGIS Pro 3.0.0 – Carbon and Methane plume mapping
* Python 3.9.12 – Plume detection algorithm development, data analysis

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Methane Plume Emission Maps** | Sentinel-2 MSILandsat 8 OLILandsat 9 OLI-2PRISMA | Images and maps will show confirmed methane plumes identified in term one as well as newly identified plumes. End users will utilize these maps to target direct and indirect methane emission reduction regulations and strategies. | N/A |
| **Quantified Plume Product** | Sentinel-2 MSILandsat 8 OLILandsat 9 OLI-2PRISMA | This product will provide the concentrations and emission rates of the methane plumes identified in the sunglint-configured imagery. End users will utilize this information to validate reported offshore inventory and assess the magnitude of methane emissions from venting and flaring. | N/A |

***Product Benefit to End User:***

This team updated the previous term’s analysis of BOEM’s reported venting and flaring activity to include the updated 2021 Outer Continental Shelf (OCS) Emissions Inventory, and a study period of 2020-2022. This will allow BOEM to better monitor and regulate methane emissions within their jurisdiction. The team identified additional methane plumes using sunglint-configured imagery to supplement and validated the previous term’s proof of concept for this technique. The results of these analyses will directly support both BOEM and BSEE in accurately monitoring methane emissions and better ensuring compliance. This work builds on the potential for BOEM and BSEE to utilize future satellite missions to facilitate a more comprehensive and persistent methane emission monitoring program.

**References**

Ayasse, Alana K, et al. “Methane Remote Sensing and Emission Quantification of Offshore Shallow Water Oil and Gas Platforms in the Gulf of Mexico.” *Environmental Research Letters*, vol. 17, no. 8, 11 Aug. 2022, pp. 1–10., <https://doi.org/10.1088/1748-9326/ac8566>.

Cusworth, Daniel H., et al. “Multisatellite Imaging of a Gas Well Blowout Enables Quantification of Total Methane Emissions.” *Geophysical Research Letters*, vol. 48, no. 2, 6 Dec. 2020, <https://doi.org/10.1029/2020gl090864>.

Ehret, Thibaud, et al. “Global Tracking and Quantification of Oil and Gas Methane Emissions from Recurrent *Sentinel-2* Imagery.” *Environmental Science & Technology*, vol. 56, no. 14, 22 Oct. 2021, pp. 10517–10529., <https://doi.org/10.1021/acs.est.1c08575>.

Interagency Working Group on the Social Cost of Greenhouse Gases. “Technical Support Document: Social

Cost of Carbon, Methane, and Nitrous Oxide – Interim Estimates Under Executive Order 13,990.” Feb. 2021, <https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf>