**NASA DEVELOP National Program**

****NASA Jet Propulsion Laboratory

*Summer 2017*

**Short Title: California Health & Air Quality**

**Subtitle:** Identifying Methane Emissions Patterns from Dairy Farms Using Aircraft Remote Sensing Observations and Image Classification

**VPS Title:** Got Methane?

**Project Team**

**Project Team:**

Jacob Arndt (Project Lead), arndt204@umn.edu

Kelsey Foster

Erika Higa

**Advisors & Mentors:**

Kristal Verhulst (NASA Jet Propulsion Laboratory, California Institute of Technology)

Charles Miller (NASA Jet Propulsion Laboratory, California Institute of Technology)

**Project Overview**

**80-100 Word Objectives Overview:**

Greenhouse gases and their role in the radiative forcing of climate have long been a focus for scientists. Current research suggests that our understanding of the methane life-cycle and the processes that emit methane is incomplete. This has been highlighted in the many studies that find contradicting estimates between bottom-up and top-down analyses. These discrepancies reduce the ability of officials to implement effective emission mitigation strategies. The goal of our project was to better understand methane emissions from dairy farms by using satellite data, aircraft data, and ground-based measurements.

**Abstract:**

Methane (CH4) is a potent greenhouse gas (GHG) with a lifetime of less than 10 years and a global warming potential that is 25 times greater than carbon dioxide (CO2) over a 100 year time period. Between the energy, industrial processes and product use, agriculture, and waste sectors, the majority of CH4 emissions in the United States come from the agriculture sector. Within this sector, enteric fermentation by domestic livestock and manure management are the largest sources of emissions. California is the leading dairy producer in the United States and thus, enteric fermentation and manure management make substantial contributions to the state’s CH4 budget. Furthermore, a number of studies suggest that EPA bottom-up methodologies are underestimating CH4 emissions in many regions across California. Total number, location, size, and manure management infrastructure of dairy farms throughout the state is also uncertain. Given these uncertainties, in addition to dairy production’s large contribution to CH4 emissions, its industrialization, and the need to more accurately account for and understand CH4 emissions, we located and inventoried dairy farms across California’s Central Valley using RapidEye imagery and image classification techniques. We used the resulting classifications to create a spatial dataset of dairy farms and that were used to help interpret AVIRIS-NG and HyTES CH4 plume data collected over the dairy farms. This will ultimately provide insight into an important source of CH4 and help policy makers, dairy farmers, and management officials make more informed decisions on how best to mitigate CH4 emissions within the state of California.

**Keywords:**

Greenhouse gases, emissions, methane, land classification, AVIRIS-NG, HyTES, RapidEye

**Partner Organizations:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| California Environmental Protection Agency, Air Resources Board | Dr. Anny Huang, Manager, Greenhouse Gas Inventory | End User | No |
| University of California, Riverside | Dr. Francesca Hopkins, Assistant Professor | Collaborator | No |

**Community Concerns:**

* Methane is a potent greenhouse gas with a lifetime of less than 10 years and a global warming potential that is approximately 25 times greater than carbon dioxide over a 100 year time period.
* Methane emission estimates derived from bottom-up and top-down approaches are consistently at odds with each other, suggesting that the life cycle of methane and the processes that produce methane are not fully documented or understood.
* The life cycle of methane and processes that produce methane need to be better understood to more accurately estimate and reduce emissions, and ultimately mitigate the adverse effects of a changing climate.

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

Over the past 11 years, the California State Legislature has passed important legislation regarding air quality and the monitoring of greenhouse gases in the state. This legislation has long guided the actions of our project partner, the California Environmental Protection Agency’s Air Resources Board (ARB), and is the primary driver of our project. The passage of California’s Assembly Bill No. 1803 in 2006 (H&SC §39607.4) (AB 1803) requires that the ARB develop and maintain a greenhouse gas emissions inventory for the state. Assembly Bill No. 32 (AB 32), the California Global Warming Solutions Act of 2006, extended ARB’s responsibility of monitoring and regulating sources of emissions of greenhouse gasses and addressing climate change for the state of California. Specifically, this bill requires that the state reduce its greenhouse gas emissions to 1990 levels by 2020. While AB 32 places equal emphasis on monitoring and regulating all greenhouse gasses, Assembly Bill No. 1496 (AB 1496) requires that the ARB make a focused effort in understanding and monitoring methane emissions. Passed in September 2016, Assembly Bill No. 197 (AB 197) requires the ARB to provide annual estimates of facility level emissions of greenhouse gases, criteria pollutants, and toxic air contaminants as well as break down these estimates to a local and sub-county level. Currently, the ARB statewide emission estimates rely on regional, state, and national data. Facilities throughout the state are required by the Mandatory Reporting Regulation, established by AB 32, to report all greenhouse gas emissions. These data reports must follow the established requirements and be submitted to the ARB. To estimate emissions, they follow the guidelines established in the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas (GHG) Inventories report.

**Decision Support Tools & Benefits:**

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software****Release** |
| California Dairy Farm Map | RapidEye | This provides an accurate GIS polygon dataset of the locations and attributes of dairy farms. Partners will use the information for validation and research of emission estimates. These maps can also be used for the partner to plan future airborne surveys. | N/A |
| Land Cover Classification | RapidEye | These maps help identify dairy farms and farm infrastructure (ex. the extent of the feedlot, solid and liquid manure management systems, nearby crops). It will be used to derive the GIS polygon dataset. This map identified other dairy farms not in the partner’s inventory and improve their understanding of dairy farms in California. | I |
| Spatial Emissions Data Analysis | AVIRIS-NG, HyTES | Plume data derived from AVIRIS-NG and HyTES was compared with the land classification. | N/A |

**Project Benefit to End User**:

By utilizing airborne and satellite observations, we developed a methodology with which the ARB will be able to more accurately identify and measure methane emissions. Through our project, ARB will more fully understand the discrepancies between bottom-up and top-down analyses when estimating emissions for their inventory. By providing insight into these key issues, we will be assisting them in their commitment to Assembly Bills No. 1803, 32, 1496, and 197 and increasing their ability to accurately identify, monitor, and verify methane emissions. We also anticipate that our methodology and data product will be extremely useful to the ARB’s Dairy Working Group. Overall, this work will help build the ARB’s knowledge of emissions from dairy farms in the state of California and the various observational strategies that they can employ.

**Project Details**

**Applied Sciences National Application Addressed:** Health & Air Quality

**Study Area:** California (CA)

**Study Period:** January 2014 – August 2017

**Earth Observations & Parameters:**

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| AVIRIS-NG | Methane plume retrievals | Methane plumes can be measured using absorption features in the shortwave infrared. |
| HyTES | Methane plume retrievals | Methane plumes can be measured using absorption features in the thermal infrared. |
| RapidEye | Surface reflectance, spectral classification | Higher spatial resolution imagery will be used for classification mapping of certain land features. |

**Ancillary Datasets Utilized:**

* California Greenhouse Gas Emission Inventory - 2017 Edition – statewide CH4 emissions estimates for facilities
* EPA Gridded National Inventory of U.S. Methane Emissions – gridded 0.1° x 0.1° resolution anthropogenic CH4 emissions estimates across the U.S.

**Software Utilized:**

* Esri ArcGIS – image analysis, dataset development, cartography, data management
* Exelis ENVI – image analysis
* Python – image analysis, dataset development, data management

**Project Handoff Package**

**Transition Plan:**

We will have a teleconference with the ARB’s GHG inventory team and research division, emission monitoring group on August 8, 2017. We will present the products we produced through a presentation and email the handoff package to the ARB.

**Team POC:** Jacob Arndt, arndt204@umn.edu

**Partner POC**: Anny Huang, anny.huang@arb.ca.gov

**Handoff Package:**

* Final presentation
* Copy of the technical paper
* Land classification maps of dairy farms in California
* GIS polygon dataset of dairy farms in California
* Analysis of co-located AVIRIS-NG and HyTES CH4 plume data and classified dairy farms