National Aeronautics and Space Administration

Automated Methane Plume Detection with future orbital imaging spectrometers (EMIT, CPM, SBG)

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Objectives

The objective was to develop algorithms to automatically detect methane plumes in hyperspectral satellite imagery from SBG, CPM, and EMIT. This will facilitate scaling current regional flight campaigns to global coverage, enabling scientists, policy makers, and the private sector to track and mitigate methane emissions.

Background

Methane is an important greenhouse gas with a global warming potential that is 84 times that of CO_2 (Myhre et al., 2013). The contribution of individual sources to rising global CH4 concentrations is poorly understood and leads to large uncertainties in climate projections. Furthermore, 85% of fugitive oil and gas-related CH4 emissions could be mitigated if monthly measurements were available (International Energy Agency, 2017). Therefore, the reliable detection and quantification of methane sources on a global scale is needed. EMIT, SBG and CPM will make global spatially resolved (GSD 30m to 60m) observation from UV to the NIR. These observations will enable retrieval of methane concentration at high spatial resolution. Manual retrieval from such data has already been demonstrated by a number of airborne campaigns with AVIRIS-NG (Frankenberg et al., 2016; Duren et. al., 2019; Cusworth et al. submitted). However, manual methane plume detection is not scalable to global space-borne observations and needs to be automated. Additionally, the lower spatial resolution of satellite data compared to airborne data poses additional challenges.

Approach and Results

In a preprocessing step the pixel wise methane concentration is retrieved with a matched filter (see Figure 1). Using these maps of methane concentrations, we compared multiple machine learning approaches to automates the detection of CH4 plumes: Simple thresholding on a per-pixel basis, TextureCam (Random Forest approach that uses low level spatial features), and GoogleNet (Convolutional Neural Network that can process complex spatial features). To overcome the obstacle of limited training data (~200 CH4 plumes) we further experimented with adding large eddy simulations (LES) of individual methane plumes and combine those with down-sampled AVIRIS-NG imagery from multiple flight campaigns.

Our results indicate that the Convolutional Neural Network (CNN) approach outperforms all other methods we compared to (see Figure 2). The CNN detects 45% of all plumes (recall) and 65% of all plume detected by the CNN are real plumes (precision). An interesting result is that large plumes are not necessarily easier to detect by the CNN since there are only few examples of such plumes in the training data. The performance of the CNN is expected to increase with more training data and a more comprehensive exploration of the network architecture.

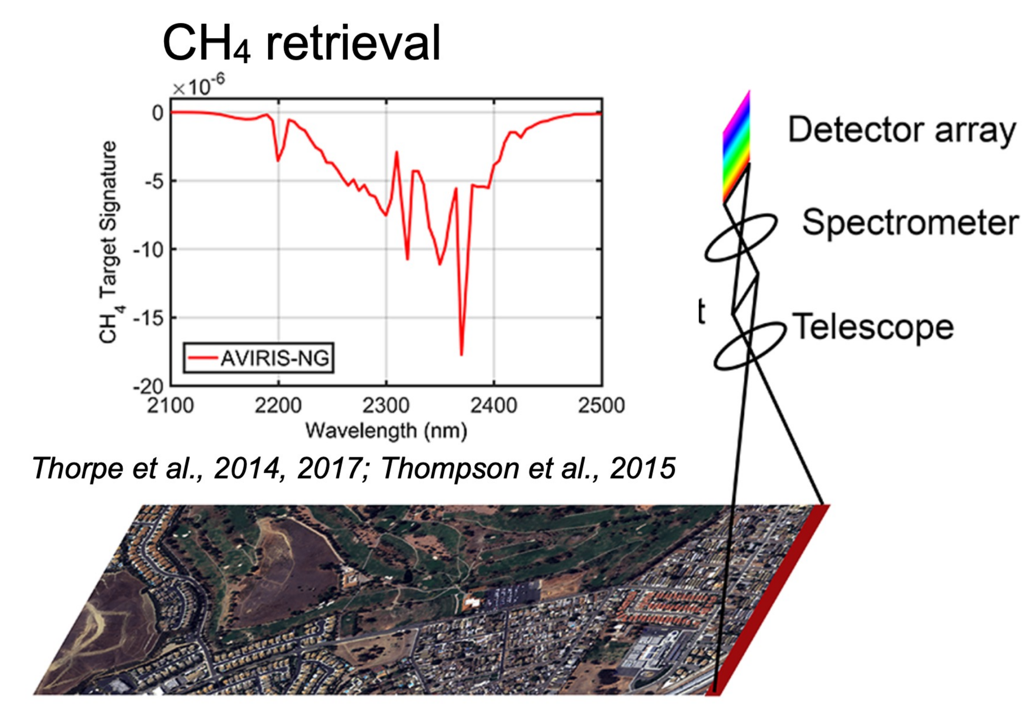

Figure 1: Retrieval of methane using a matched filter from 2100nm to 2500nm on a hyperspectral sensor

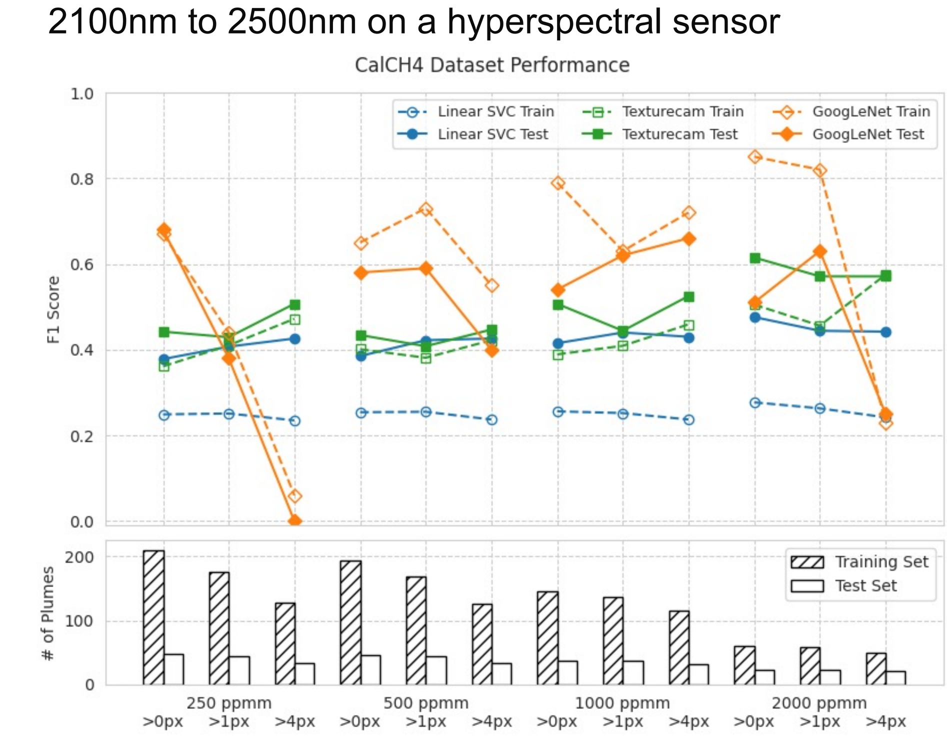

Figure 2: Performance to detect methane plumes in 30m hyperspectral imagery for three different ML approaches: Thresholding on methane enhancement (blue), TextureCam random forest (green), GoogLeNet CNN (orange). The performance is shown for various thresholds on what constitutes a plume (e.g. min methane enhancement >250ppmm with at least >4px labeled as plume)

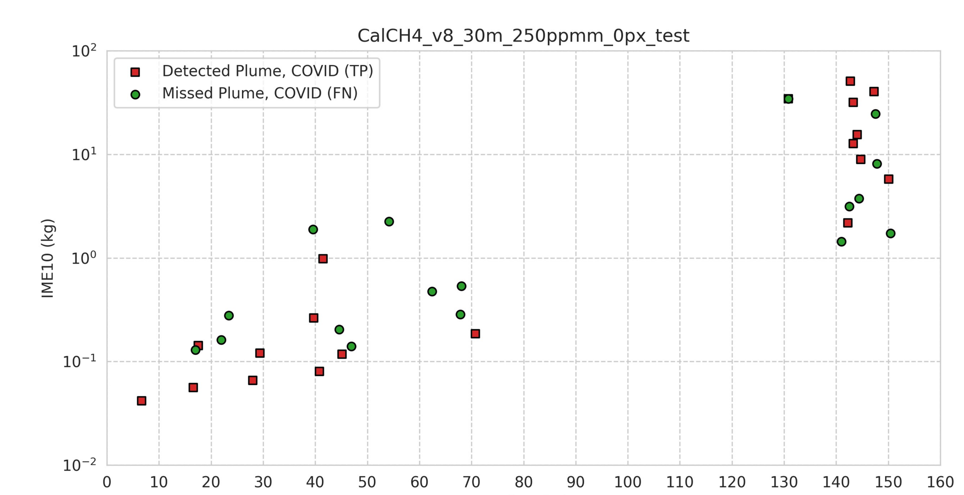

Figure 3: Detected plumes as a function of emission rate (y-axis) and plume size (x-axis)

Significance/Benefits to JPL and NASA

This work is the first exploration of how to detect CH4 plumes from space-born imaging spectrometers in an automated fashion. Our results indicate that a CNN is most suited for this task. This research is a stepping stone for follow on work to develop an operational retrieval of CH4 point sources from space and will be applicable to upcoming JPL missions such as EMIT and SBG.

Publications

[A] Ashok, A., Mauceri, S., Thorpe, A., et al, (submitted), “Improving Imaging Spectrometer Methane Plume Detection with Large Eddy Simulations”, AGU Fall Meeting 2021

[B] Lee, J., Mauceri, S., Dey, S., Ashok, A., et al, (submitted), “Methane Plume Detection with Future Orbital Imaging Spectrometers”, AGU Fall Meeting 2021

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Thorpe, Andrew K., et al. "Airborne DOAS retrievals of methane, carbon dioxide, and water vapor concentrations at high spatial resolution: application to AVIRIS-NG." Atmospheric Measurement Techniques 10.10 (2017): 3833-3850.

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