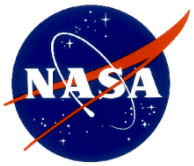

Hyperspectral Thermal Emission Spectrometer (HyTES) L3 Data Product User Guide

Glynn Hulley, Nick Vance, Le Kuai, Simon Hook

Jet Propulsion Laboratory, California Institute of Technology

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

May 2016

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

Change History Log

Revision	Effective Date	Prepared by	Description of Changes
Draft	05/18/2016	Glynn Hulley	Outline and first draft
Draft	05/18/2016	Nick Vance	Included details on L3 CMF product file and formats
Draft	05/19/2016	Le Kuai	Included details on quantitative retrieval (QR) product file and formats

Contacts

Readers seeking additional information about this study may contact the following:

Glynn Hulley
MS 183-509
Jet Propulsion Laboratory
4800 Oak Grove Dr.
Pasadena, CA 91109
Email: *glynn.hulley@jpl.nasa.gov*
Office: (818) 354-2979

Contents

Figures

Tables

1

2 Introduction

The Hyperspectral Thermal Emission Spectrometer (HyTES) is a new airborne imaging spectrometer developed by the NASA Jet Propulsion Laboratory. HyTES has 256 contiguous spectral channels between 7.5 and 12 μm and a 50 degree total field of view. The instrument has an instantaneous field of view of 1.7066 milliradians with pixel size dependent on flight altitude. Currently the instrument operates on a Twin Otter aircraft with plans underway to modify the instrument so that it can also be flown on the NASA ER2 in 2016. The Twin Otter is a low altitude aircraft and the ER2 is a high altitude aircraft. The two aircraft allow the acquisition of data with pixel sizes between 1.7 m (1 km above surface) and 34 m (20 km above surface). HyTES is the first high spatial and high spectral resolution thermal infrared imaging spectrometer developed by NASA.

The HyTES L3 gas detection products include two products: 1) information on plume location and intensity from a Clutter Matched Filter (CMF) algorithm, and 2) quantitative retrievals (QR) of methane concentration and enhancement on subsets of identified plumes from the CMF. The CMF product can be used to efficiently detect and characterize the spatial structures of individual plumes of CH_4, H_2S, NH_3, NO_2, and SO_2 emitters, while at present the QR products are only available for CH_4 at Aliso Canyon. More information on HyTES including product ordering can be found at http://www.hytes.jpl.nasa.gov

The CMF algorithm used for generating the L3 CMF product is described in detail in the following publication:

Hulley, G. C., Duren, R. M., Hopkins, F. M., Hook, S. J., Vance, N., Guillevic, P., Johnson, W. R., Eng, B. T., Mihaly, J. M., Jovanovic, V. M., Chazanoff, S. L., Staniszewski, Z. K., Kuai, L., Worden, J., Frankenberg, C., Rivera, G., Aubrey, A. D., Miller, C. E., Malakar, N. K., Sánchez Tomás, J. M., and Holmes, K. T.: High spatial resolution imaging of methane and other trace gases with the airborne Hyperspectral Thermal Emission Spectrometer (HyTES), Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-8, in press, 2016.

The QR algorithm used for generating the L3 QR product is described in detail in the following publication:

Kuai, L., Worden, J. R., Li, K., Hulley, G. C., Hopkins, F. M., Miller, C. E., Hook, S. J., Duren, R. M., and Aubrey, A. D.: Characterization of anthropogenic methane plumes with the Hyperspectral Thermal Emission Spectrometer (HyTES): a retrieval method and error analysis, Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2015-402, in review, 2016.

3 File Formats

HyTES L3 CMF products are composed of a HDF5 file for each line. For each of the gas types (CH_4, H_2S, NH_3, NO_2, and SO_2) there is a group that has a binary flag indicating if that gas was detected for the specific line. For example: "CH4/CH4_Found" would be set to True if CH_4 was detected or False if it was not (the first "CH4" indicates the group). If found there will also be two arrays named "CH4/CH4_CMF1" and "CH4/CH4_CMF2". CMF 1 is the raw CMF data computed directly from the radiances, and CMF 2 is the thresholded CMF which uses interquartile range statistics to identify plume pixels, in addition to a plume dilation and contiguity algorithm to enhance any detected plume pixels. This procedure is described in detail in Hulley et al. 2016. The data are arrays of 32-Bit Float values corresponding to each HyTES pixel and the arrays are shuffled and compressed with GZIP to reduce file size. The HDFs also include Fletcher32 checksums to ensure data integrity. These features are seamlessly supported by standard HDF5 readers.

Metadata attributes included at the base level of the HDF structure describe "product_version" and "acquisition_time".

HyTES L3 QR products are also composed in a HDF5 file but only for the lines with plume detection in the QR. For Aliso Canyon, the QR is estimated on a 3 by 3 resampling HyTES pixel. The QR data are only for a subset region over the identified plumes from the CMF.

The data attributes included "Data Fields" and "Geolocation Field". The methane concentration and column enhancement from surface to aircraft in "Data Fields" are arrays of 32-Bit floating-point for the subset of HyTES pixels and north up orientated. Additional information of pixel size and aircraft altitude is also provided. The latitude and longitude of each pixel for the subset region are included in the geolocation field.

4 Products

Details and product characteristics of each L3 CMF and QR product are described in Tables 1 and 2 below.

Table 1. Description of Scientific Data Sets (SDS) available in the HyTES L3 CMF Product

SDS	Long Name	Data type	Units	Valid Range	Fill Value	Scale Factor	Offset
CMF1	Raw Clutter Matched Filter Data	Float32	n/a	[0 1]	NaN	1.0	None
CMF2	Thresholded Clutter Matched Filter Data	Float32	n/a	[0 1]	NaN	1.0	None

Table 2. Description of Scientific Data Sets (SDS) available in the HyTES L2 QR Product.

SDS	Long Name	Data type	Units	Valid Range	Fill Value	Scale Factor	Offset
CH_4	Methane concentration	Float32	ppm	>0	-999.0	1.0	None
dCH_4	Methane column enhancement	Float32	ppm-m	>0	-999.0	1.0	None
pixel_size	Averaged pixel size	Float32	m	>0	-999.0	1.0	None
z_aircraft	Altitude of aircraft fly	Float32	m	>0	-999.0	1.0	None
Lat	Latitude	Float32	degree	-90 to 90	-999.0	1.0	None
Lon	Longitude	Float32	degree	-180 to 180	-999.0	1.0	None

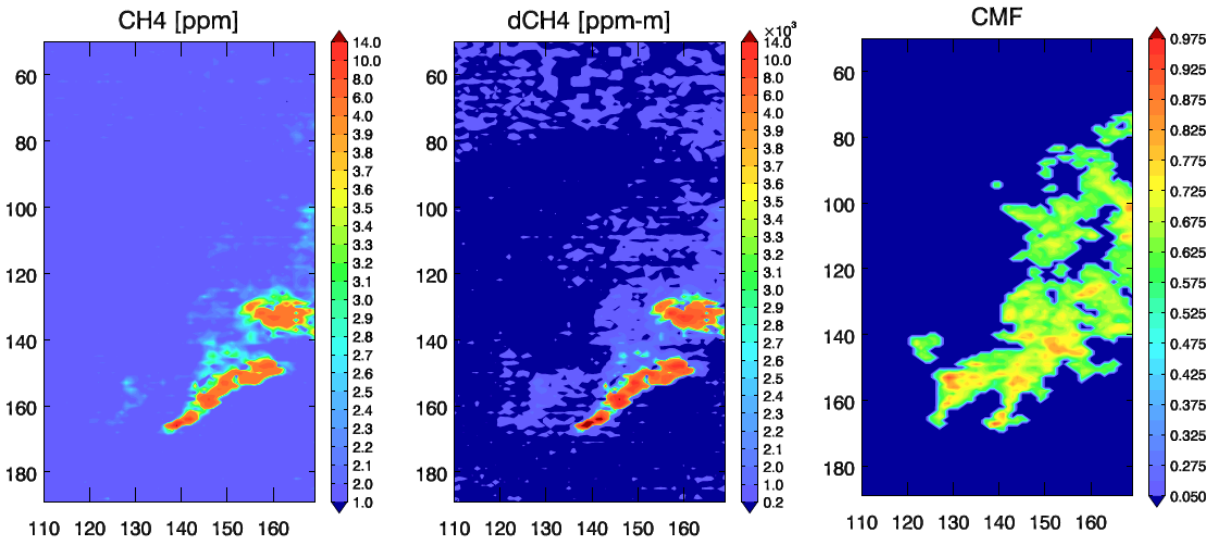

Figure 1. Example of the HyTES L3 QR and CMF products for the Aliso Canyon methane plume. Left: methane concentration. Middle: methane column enhancement. Right: The matching CMF.

5 Caveats

- We used the same thresholds and settings in the CMF algorithm to produce the gas detection browse images on the L3 order page (data available in CH4/CH4_CMF2 product) for all campaigns and for all different types of gases detected. As such there will be false positives in some images, in addition to possible missed detections for certain gases. This is primarily because of different environmental conditions, instrument calibration, and thermal contrast at different locations and times. Therefore, it is up to the user to refine these thresholds or use their own custom techniques for interpreting the raw CMF data available in CH4/CH4_CMF1 product. The target filter function for each individual gas was extracted from the HITRAN2012 database and detailed in Hulley et al. 2016.
- Methane false positives will be mostly apparent over man-made surfaces such as roofs and other buildings and structures. For example, over Bakersfield dairies there are several cases of false positives over roofs such as illustrated in Figure 2a (linear features). We have developed a prototype algorithm to remove these false positives based on their emissivity features (e.g. Figure 2a), but this is still a work in progress and will be applied to the next version of the L3 products. The ammonia products also have false positives along roads and other bare surfaces due to similar spectral features in the 10-12-µm range. The emissivity filter is currently being adapted for these types of surfaces too.

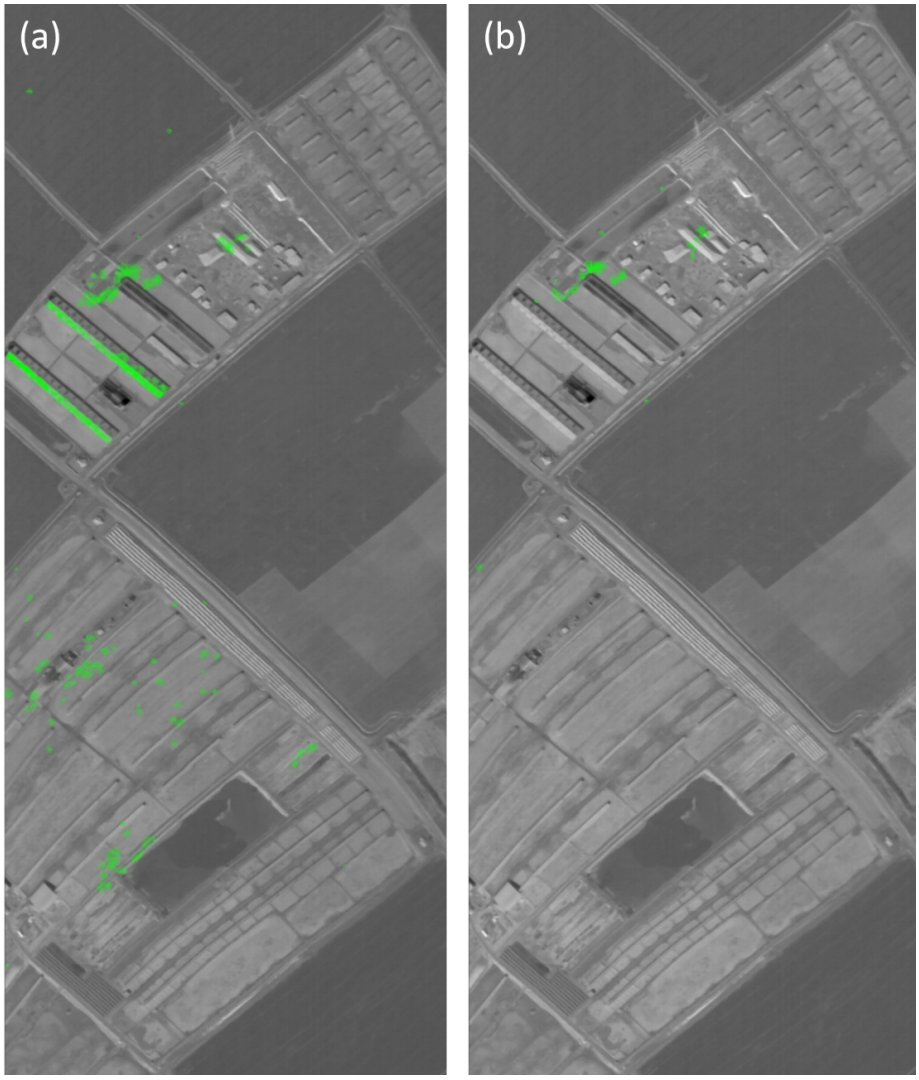

Figure 2. HyTES methane detection image overlayed on surface temperature image over a dairy farm in the SJV, California showing (a) original detection without false positive emissivity filter applied, and (b) with false positive removal using the emissivity different filter test.

Acknowledgements

This research was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration (NASA). We are thankful for the support of the NASA Earth Science Directorate. Many thanks to the HyTES team and others at JPL for making this research possible: Simon Hook (JPL), Riley Duren, William Johnson, Bjorn Eng, Le Kuai, Jonathan Mihaly, Veljko Jovanovic, Francesca Hopkins, Seth Chazanoff, Zak Staniszewski, John Worden, Gerardo Rivera, Andrew Aubrey.