National Aeronautics and Space Administration

Characterization of fire emission processes from high-altitude hyper-spectral observations of smoke plumes, ammonia, and fuel loadings

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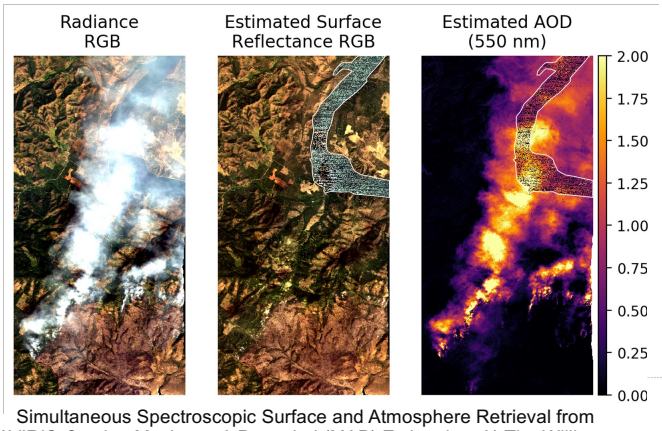
Program: FY22 R&TD Topics
Strategic Focus Area: Atmospheric composition and dynamics

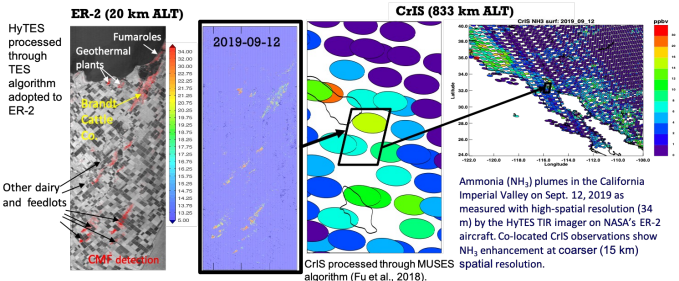
AVIRIS Aerosol Characterization and HyTES NH_3

Instrument Characteristic	AVIRIS-C
Spectral range	0.37-2.55 µm
Spectral resolution	9.8 nm
Swath	11 km
Pixel size	20 m

Instrument Characteristic	HyTES
Number of pixels x track	512
Number of bands	256
Spectral Range	7.5-12 um
Integration time	30 ms
Total Field of View	50 degrees
Pixel size at 2000 m flight altitude	3.64 m
Pixel size at 20,000 m flight altitude	36.4 m



Simultaneous Spectroscopic Surface and Atmosphere Retrieval from AVIRIS-C using Maximum A Posteriori (MAP) Estimation: A) The Williams Flats Fire, Aug. 6, 2019, observed in visible radiance channels; B) Visible channels of estimated surface reflectance spectrum; C) Estimated Aerosol Optical Depth (550 nm); Adapted from [B]



We developed an optimal estimation retrieval algorithm for NH_3 from HyTES and adapted for ER-2 altitudes, performed sensitivities, quantified uncertainties, and tested with September 2019 HyspIRI datasets. Figure 3 shows the newly developed HyTES ER-2 retrievals of NH_3 over the Salton Sea in comparison with the coincident NOAA Cross-track Infrared Sounder (CrIS) NH_3 product. The paper describing the NH_3 retrieval is currently in review.

Biomass burning (BB) emissions are a significant global air pollution source, and the gases and particles emitted from fires can directly and indirectly affect climate, air quality, and human health. This project aims to improve our understanding of particulate matter (PM)-relevant BB emissions, with an emphasis on ammonia (NH_3) – a secondary aerosol precursor – as a function of combustion phase (flaming/smoldering) through the use of the combined capabilities of JPL's remote sensing imaging spectrometers, AVIRIS and HyTES, onboard NASA's ER-2 aircraft, and datasets from the 2019 FIREX-AQ field campaign and 2018-2020 joint flights.

Our specific objectives:

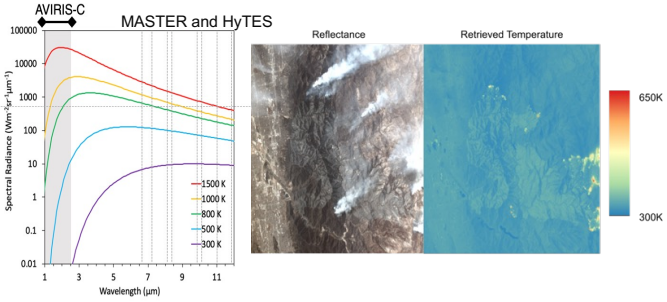
(a) Determine NH_3 enhancements over various point sources;

(b) Determine AVIRIS retrieval sensitivity to different aerosol components;

(c) Establish relations between fire temperature and/or combustion phase, AOD, NH_3 fire emissions, and ambient conditions;

(d) Formulate requirements and quantify uncertainties for fire emission remote sensing for PM air quality.

AVIRIS + HyTES + MASTER Fire Energetics



Fire temperature retrieval using combined spectra approach applied to AVIRIS, HyTES, and MASTER data collected over Bobcat Fire on 9/17/20 at 20:32 UTC.

Significance/Benefits to JPL and NASA:

- This project is a pathfinder towards airborne and spaceborne characterization of the critical linkages between fire energetics and PM from BB emissions by the analysis of combined data from JPL's imaging spectrometers – AVIRIS and HyTES – for studies of atmospheric pollution.
- This project increases the diversity of JPL projects, with a clear goal of future use of NASA products from imaging spectrometers by regulatory agencies (CARB, EPA, etc.)
- Ultimately this effort sets the stage for robust planned EV proposals. In particular, our project provided science justification for MWIR instrument concept: Compact Fire Infrared Radiance Spectral Tracker (c-FIRST) selected in 2022 under the NASA ESTO IIP program (~$4.5M).

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Publications:

[A] Kuai L., O. V. Kalashnikova, H. Lee, F. Hopkins, G. Hulley, R. Duren, J. Worden, M. J. Garay, and S. Hook, Quantification of ammonia emissions with high-resolution thermal infrared observations from the HyTES instrument: Comparison of multiple sources including a wildfire, JSTARS, doi: 10.1109/JSTARS.2019.2918093, 2019
[B] Brodrick P., D. B. Thompson, M. J. Garay, D. M. Giles, B. Holben, and O. V. Kalashnikova, Simultaneous characterization of wildfire smoke and surface properties with imaging spectroscopy during the FIREX-AQ field campaign, JGR-Atmospheres, 127, e2021JD034905. https:doi.org/10.1029/2021JD034905, 2022
[C] Stephens G. L., O. V. Kalashnikova, P. Pilewskie, J. J Gristey, D. R. Thompson, X. Huang, M. Lebsock, S. Schmidt, The spectral nature of Earth's reflected radiation: measurement and science applications, Frontiers Remote Sensing, V2, p11, doi:10.3389/frsen.2021.664291, 2021

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