HyspIRI Airborne Campaigns, Science, Applications and Lessons

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2. NASA Headquarters, Washington DC
3. NASA Ames Research Center, Moffett Field, CA

- Objective: Advance HyspIRI Mission Science and Algorithm Readiness
  - Ecosystem composition, function, biochemistry, seasonality, structure, and modeling
  - Coastal ocean phytoplankton functional types, habitat
  - Urban land cover, temperature, transpiration
  - Surface energy balance
  - Atmospheric characterization and local methane sources
  - Surface geology, resources, soils, hazards
  - Coral Reefs
  - Volcanos
- Results:
  - 75 Peer Reviewed Publications
  - At Least 12 Grad Student thesis/dissertation

HyspIRI Airborne Campaigns, Instruments, Science and Applications

Key HyspIRI climate objectives from the 2007 ESAS Decadal Survey and IPCC

- Ecosystem Measurement for Climate Feedback
- Black Carbon/Dust Effects on Snow and Ice
- Carbon Release from Biomass Burning
- Evapotranspiration and Water Use and Availability
- Critical Volcanic Eruption Parameters

Imaging Spectrometer (VSWIR)

- Pattern and Spatial Distribution of Ecosystems and their Components
- Ecosystem Function, Physiology and Seasonal Activity
- Biogeochemical Cycles
- Changes in Disturbance Activity
- Ecosystem and Human Health
- Earth Surface and Shallow Water Substrate Composition

Multi-Spectral Thermal InfraRed (TIR)

- Volcanoes/Earthquakes
- Wildfires
- Water Use and Availability,
- Urbanization/Human Health
- Earth surface composition and change

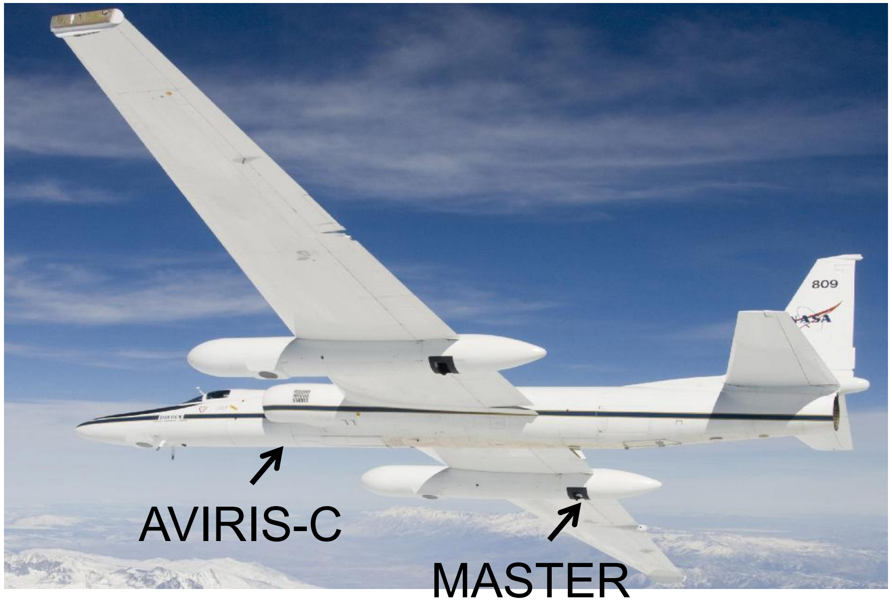
Combined Imaging Spectrometer and Multi-Spectral Thermal Science

- Coastal habitats, and inland aquatic environments
- Wildfires
- Volcanoes
- Ecosystem Function and Diversity
- Land surface composition and change
- Human Health and Urbanization

Datasets to Simulate Future HyspIRI Satellite

Flights on NASA ER-2 Flown at 65,000 ft with Airborne Visible and Infrared Imaging Spectrometer and MODIS/ASTER Airborne Simulator

AVIRIS-C (VIS/SWIR)	MASTER (TIR)
10 nm spectral resolution	50 bands
224 bands	0.4-13 um
400-2400 nm	2.5 mrad IFOV
1 mrad IFOV	85.92 degrees FOV
34 degree FOV	50 m Spatial Resolution
18 m Spatial Resolution	35 km Swath Width
11 km Swath Width	



HyspIRI Preparatory Airborne Campaign L1 and L2 Data Product

Objective:
Deliver L1 and L2 products to the Science Team

MASTER simulating HyspIRI TIR

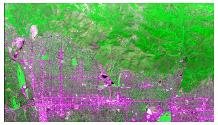
- Delivered Calibrate L1B radiance at sensor
- Delivered L2 Surface Temperature and Spectral Emissivity products using MASTER LWIR

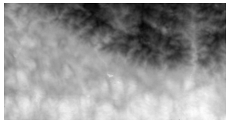
AVIRIS-C simulating HyspIRI VSWIR

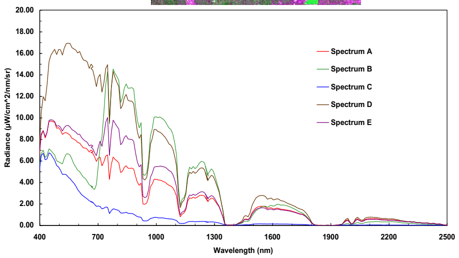
- Delivered radiance with full laboratory spectral, radiometric, and spatial calibration
- Delivered reflectance with HyspIRI like radiative transfer algorithm

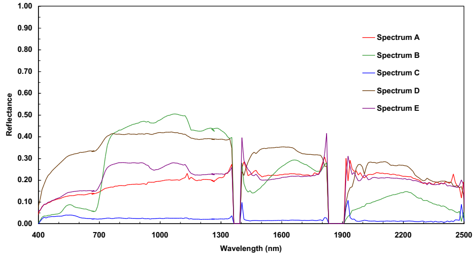
-Used the latest laboratory calibration methodologies and measurements for accurate L1 calibration of AVIRIS-C

-Used the HyspIRI baseline radiative transfer based atmospheric correction to provide the L2 data to the science team

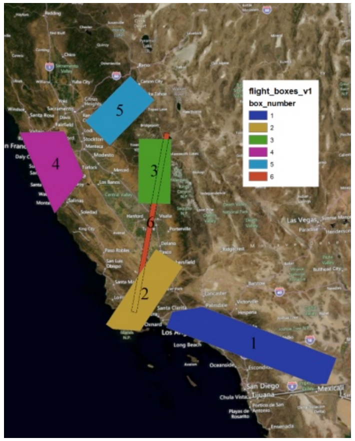


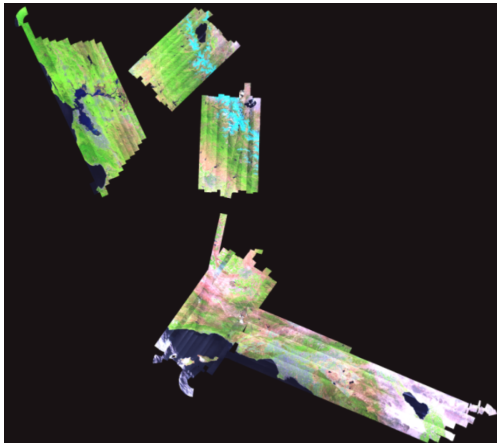






Example Mosaic of AVIRIS-C Products





Simulating HyspIRI VSWIR and TIR
-All data have been delivered as radiance (L1)
-All data have been
-delivered as reflectance (L2)
Contributors: The AVIRIS team and MASTER team

L1 and L2 AVIRIS Data located at:
https://aviris.jpl.nasa.gov/alt_locator/

L1 and L2 MASTER Data located at:
https://masterweb.jpl.nasa.gov/data/
https://masterprojects.jpl.nasa.gov/L2_Products

L2 Simulated HyspIRI TIR Products

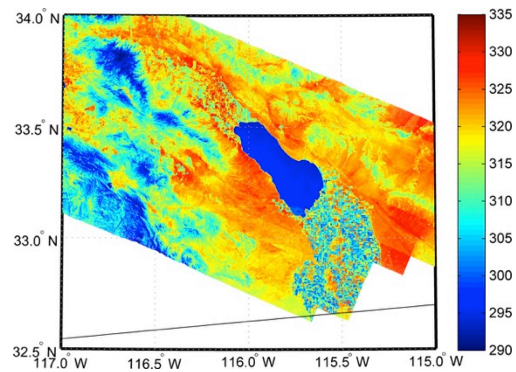
Primary Objectives

- Generate MASTER L2 Surface Temperature and Spectral Emissivity products using MASTER LWIR bands 42-50.
- Distribute the data via online ordering tool (http://masterprojects.jpl.nasa.gov/L2_products)

Secondary Objectives

- Calibrate MASTER L1B radiance at sensor using Lake Tahoe and Salton Sea in situ validation data.
- Validate MASTER L2 products using Lake Tahoe and Salton Sea in situ validation data as well as field measurements from pseudo-invariant sand sites.

LST (resampled to HyspIRI TIR 60-m)



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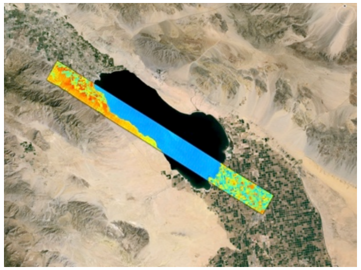


Approach:

- MASTER L2 processing uses the Temperature Emissivity Separation Algorithm (TES) with a Water Vapor Scaling (WVS) based atmospheric correction scheme.
- For calibration, in situ measurements are forward modeled with atmospheric profiles to simulate MASTER at-sensor radiances at ~20 km altitude.
- For Validation, MASTER LST are matched with in situ buoy data at Tahoe/Salton Sea. Emissivity spectra are matched with lab measurements of samples collected in the field.

- All MASTER campaign data have been processed to L2 LST and Emissivity products.
- MASTER L2 data are available for ordering at: (http://masterprojects.jpl.nasa.gov/L2_products)
- Browse images including km files are available
- More extensive LST and emissivity validation is planned for campaign data over more diverse set of validation sites.

PI: Glynn Hulley/Simon Hook, JPL

Co I: Jeffrey Myers, ARC

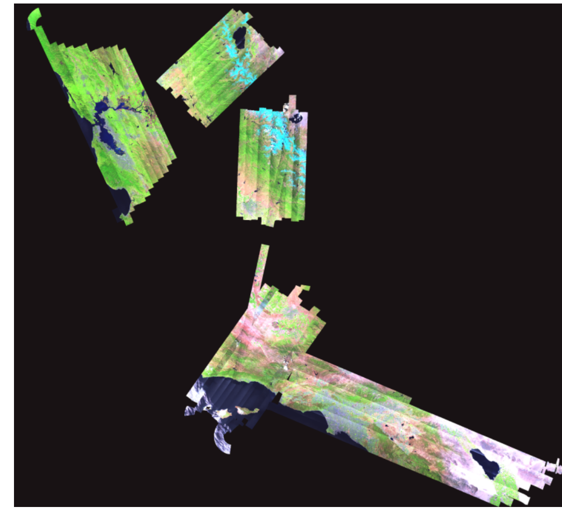
L2 Simulated HyspIRI VSWIR Products

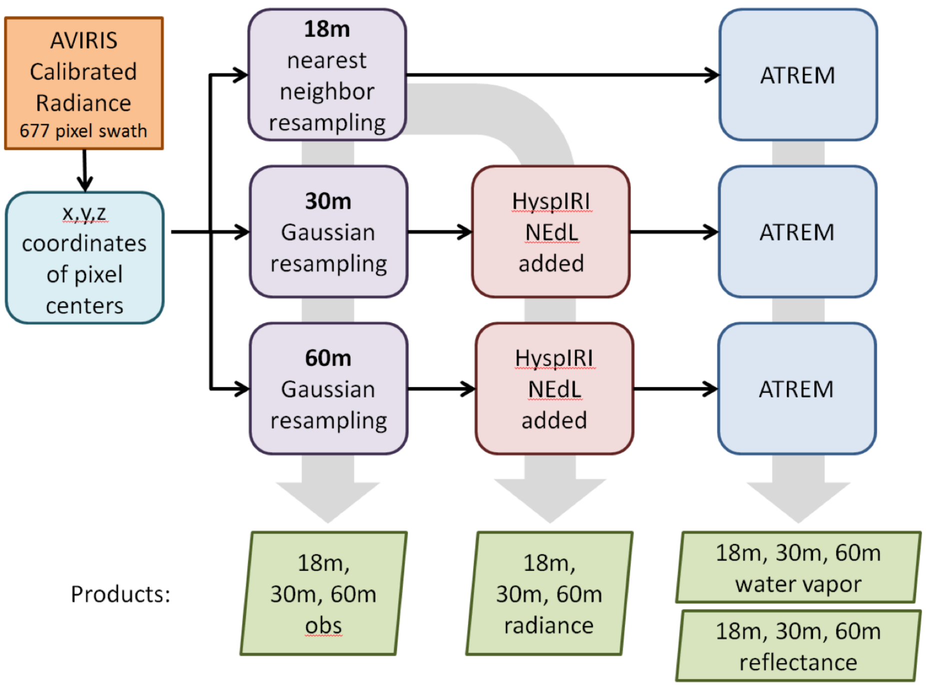
Objective

Create orthorectified reflectance data with similar spatial and noise characteristics to HyspIRI VSWIR for the HyspIRI Preparatory Campaign

Approach

- Ray-traced pixel center coordinates were resampled using a Gaussian point spread function to create 30m and 60m radiance data
- Random noise with a Gaussian distribution was scaled based on NEdL calculated from radiance and VSWIR radiometric model, then added to radiance
- ATREM was used to retrieve reflectance and column water vapor from the noise-added radiance data





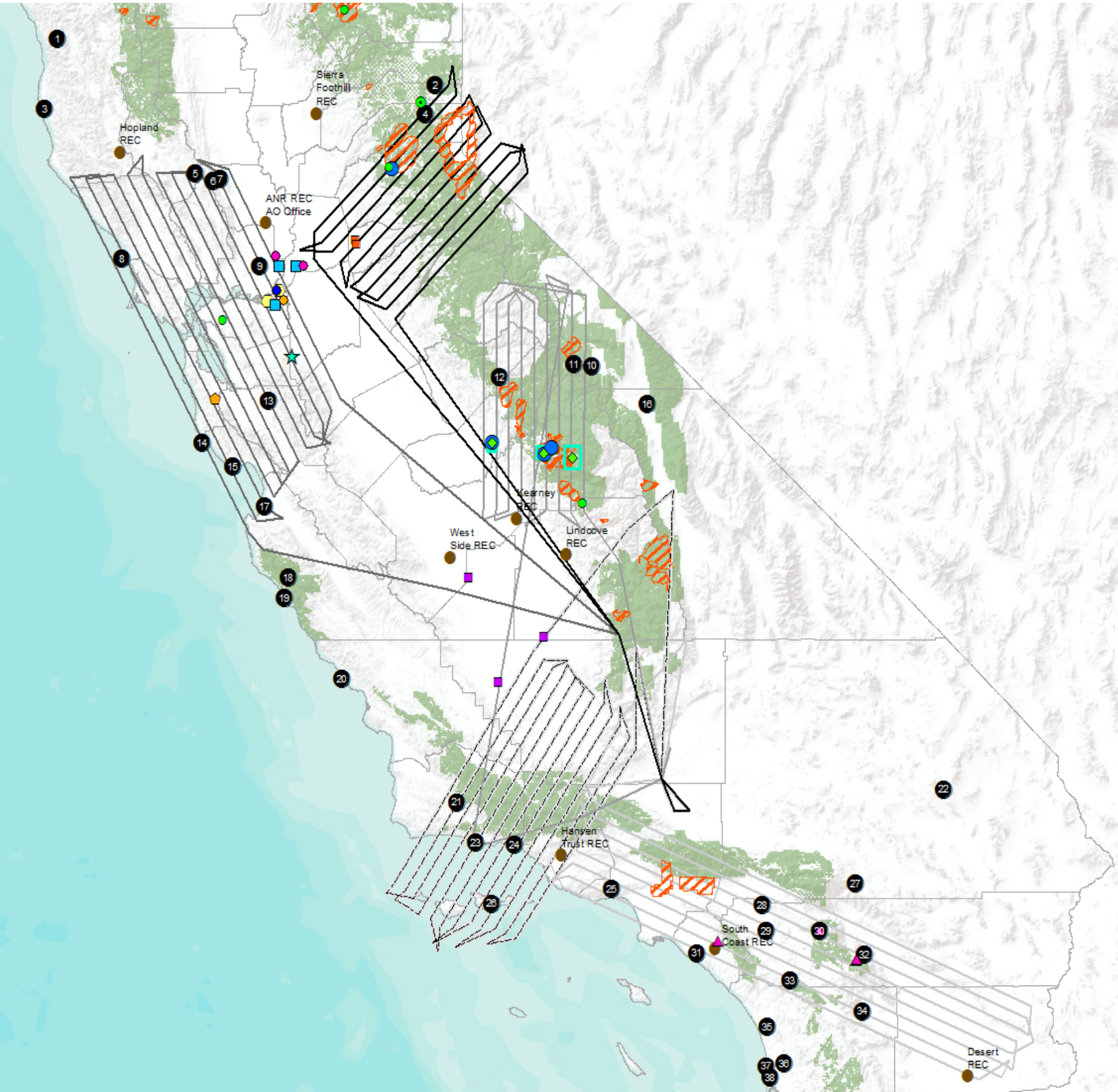
Progress and Expected Results

- Orthorectified radiance, reflectance, water vapor, and obs files are available at 18m, 30m, and 60m resolutions http://aviris.jpl.nasa.gov/data/AV_HyspIRI_Prep_Data.html
- 197 flightlines processed by JPL as of Mar 14
- Based on March-April 2013 mosaic, campaign covers more than 130,000 km^2
- Validation needed for orthorectification, reflectance

Contributors

David Thompson, Rob Green (Jet Propulsion Lab)
Phil Dennison (University of Utah)
Bo-Cai Gao (Naval Research Lab)
Joe Boardman (Analytical Imaging and Geophysics)

HyspIRI Preparatory Airborne Mission - CA



3 Seasons of Collections

- 2013, 2014, 2015
  - Spring (April)
  - Summer (June/Aug)
  - Fall (Sept – Nov)

3 Years of Only Summer Collection

- 2016, 2017, 2018

A total of 452 ER-2 flight hours

- 100 - 120 hours for 3/year
- 30 – 45 hours for 1/year

Participated in Validation and Calibration of:

- Landsat 8
- Suomi NPP
- GOES-R/16 ABI

Piggyback opportunities for:

AirMSPI, RSP, NAST-I/M, S-HIS, DCS, PRISM, CPL, HyTES, MISTIC WINDS, CAML

HyspIRI Preparatory Airborne Activities and Associated Science and Applications Research (NNH11ZDA001N - HYSPIRI)

The National Aeronautics and Space Administration (NASA) Earth Science Division within the Science Mission Directorate solicited proposals using airborne measurements resulting from planned airborne campaigns in FY2013 and FY2014. For these campaigns, NASA plans to fly the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) and the MODIS/ASTER Airborne Simulator (MASTER) instruments on a NASA high-altitude aircraft to collect precursor datasets in advance of the Hyperspectral Infrared Imager (HyspIRI) mission. NASA solicited proposals that would use these airborne data to address one, or more, science or applications research topic aligned with the science questions for the HyspIRI Mission. A goal of this solicitation was to generate important science and applications research results that are uniquely enabled by HyspIRI-like data, taking advantage of the contiguous spectroscopic measurements of the AVIRIS, the full suite of MASTER TIR bands, or combinations of measurements from both instruments.

PI	Organization	Investigation
Paul Moorcroft	Harvard	Linking Terrestrial **Biosphere Models** with Imaging Spectrometry Measurements of Ecosystem Composition, Structure, and Function
Dar Roberts	UC Santa Barbara	HyspIRI discrimination of **plant species** and functional types along a strong environmental-temperature gradient
Philip Townsend	UWI	Measurement of **ecosystem metabolism** across climatic and vegetation gradients in California for the 2013-2014 NASA AVIRIS/MASTER airborne campaign
Susan Ustin	UC Davis	Identification of **Plant Functional Types** By Characterization of Canopy Chemistry Using an Automated Advanced Canopy Radiative Transfer Model
Matthew Clark	Sonoma State	Spectral and temporal discrimination of **vegetation cover** across California with simulated HyspIRI imagery
Bo-Cai Gao	NRL	Characterization and **Atmospheric Corrections** to the AVIRIS-Classic and AVIRISng Data to Support the HyspIRI Preparatory Airborne Activities
Bernard Hubbard	USGS	Using simulated HyspIRI data **for soil mineral mapping**, relative dating and flood hazard assessment of alluvial fans in the Salton Sea basin, Southern California
George Darrel Jenerette	UC Riverside	Assessing Relationships Between **Urban Land Cover, Surface Temperature, and Transpiration** Along a Coastal to Desert Climate Gradient
Thomas Kampe	NEON	Synergistic high-resolution airborne measurements of ecosystem structure and process at **NEON** sites in California
Raphael Kudela	UC Santa Cruz	Using HyspIRI at the Land/Sea Interface to Identify **Phytoplankton Functional Types**
Ira Leifer	Bubbleology	Hyperspectral imaging spectroscopic investigation of California natural and anthropogenic fossil **methane** emissions in the short-wave and thermal infrared
Shunlin Liang	UMD	Characterizing **surface energy budget** of different surface types under varying climatic conditions from AVIRIS and MASTER data
Jan van Aardt	RIT	Investigating the impact of spatially-explicit **sub-pixel structural variation** on the assessment of vegetation structure from HyspIRI data
Wendy Calvin	UNV	**Energy and Mineral Resources**: Surface composition mapping that identifies resources and the changes and impacts associated with their development

What was the best thing about the HyspIRI CA Airborne Activities?

- Getting reflectance pipeline products for large regional areas.
- Funding for students.
- The large spatial coverage over multiple sites with diverse ecosystems; temporal coverage, including 3 seasons and multiple years; processing of data to HyspIRI products with ATREM reflectance retrieval.
- Access to high quality combined AVIRIS/MASTER has provided key data sets for numerous projects, including many Dissertations, theses and student internships.
- Airborne campaign allows us to customize remote sensing data, in terms of data type, area of interest, overpass time and frequency etc. This creates the ideal data sets for algorithm development and case studies.
- Multi-temporal imagery, across a range of land cover types, and elevations.
- Coincident NEON data at higher spatial resolution, for unmixing studies.
- The phenomenal support of the NASA team in every aspect of the campaign.
- The creation of a long time series
- Good communication about acquisitions, and definitely the volume of data. The advances with processing to L2 reflectance were a major advance, and are now part of default processing.
- The collaborators and contacts made through the HyspIRI Aquatics Study Group have established new project teams. Also, it was a great opportunity to be part of and work with the CA HyspIRI science team and participate in the airborne missions.
- Opportunity for seasonal and interannual evaluation of combined visible and thermal imagery

What was the biggest challenge of the HyspIRI CA Airborne Activities?

- We were not able to field check all the sites we hoped to.
- Getting some missing/bad runs of HyspIRI products processed in a timely manner, or at all.
- Many of the data sets took multiple years to be released and often required multiple rounds of processing due to artifacts.
- Limited data of field measurements are available.
- The government shutdown in October 2013. We had high hope for getting mid-fall data, and our collects were pushed into November. It made comparing seasonality for later dates a little more challenging.
- Variability in precip within the region. I don't think anyone planning the campaign anticipated the drought, and we were able to produce some good science in relation to the drought, but it wasn't easy dealing with timing of flights and timing of seasonal precipitation that were out of sync from year to year.
- Lack of coordination amongst the science team after the initial funding period so products, algorithms and insights could be shared and collaborations continued
- Coordination of field efforts. In hindsight, this should have been run more like other NASA field campaigns, with centralized field access coordination, etc. This would have led to better coordination and collaboration among different PIs.
- Volume of data. The volume of image data was quite large. Some proportion of the image data had issues, due to a range of problems. Sometimes these were identified and fixed, but others persist in the data set and its not altogether certain what caused those issues and how they can be corrected.
- For data acquisition, the greatest challenge was fog. Further without greater representation of projects funded in coastal and inland waters, it was challenging to be the only team impressing the data acquisition requirements for aquatic remote sensing.
- The Bay Area Box was a large site with different weather conditions. Choices had to be made to fly regardless of weather conditions in Monterey Bay.
- For data quality, the biggest challenge was signal and atmospheric correction. Basic ocean color algorithms did not perform with the atmospherically corrected data.
- Training students and postdocs to use data resources

Plan was for two years of data, did the additional years of HyspIRI CA Airborne Activities collection benefit your project?

- Data from this effort for class projects in my graduate remote sensing course, applications were diverse including fire, snow, and geology.
- Used the calibration pipeline for Sierra Snow scenes that were acquired for a different project.
- Used the 2015 Bay Area data for three research papers. The 2013 data were incorporated into a new detailed vegetation map of Sonoma County. We also used 2015 data for a Prototype phase project under NASA's Citizen Science for Earth Systems Program in which we are monitoring bird diversity with species distribution models and remote sensing variables. We will continue to use HyspIRI data over Sonoma County for that project, as we received 3 years of Implementation phase funding. The HyspiRI metrics data for the Bay Area have been used in undergraduate student GIS and remote sensing classes and projects.
- The addition of 2015 was very critical, because it provided the key third year of the drought. Additional years (2016 and 2017) have further extended this record. We have been using these data primarily to explore drought impacts.
- Yes, additional years of data can help us further tune the retrieval algorithms and improve the accuracy of data estimation.
- Yes, the additional data were useful, although we ran out of funding long before that data came along and that has restricted the science my team has been able to do.
- The additional years were crucial, as it turned out, to building the insights and tools needed for a space mission observing over time and detecting change, and the California drought provided a perfect test bed.
- I am now working with the full record of data, now linking the full data set (5 yrs) to 5 yrs of flux tower data, and building a SDS at JPL to map traits across the full record.
- Time series analysis in the Angeles National Forest and Santa Monica Mountains to advance IS algorithms to information products considering change detection as well as value-added to landscape ecology
- The above scientific advancements directly contribute to meet land management goals (SMM National Park Service and ANF National Fish and Wildlife Foundation and USFS ANF)
- The repeating data are valuable. We are still working on analyses of subsequent years. We are continuing assessments other regions.

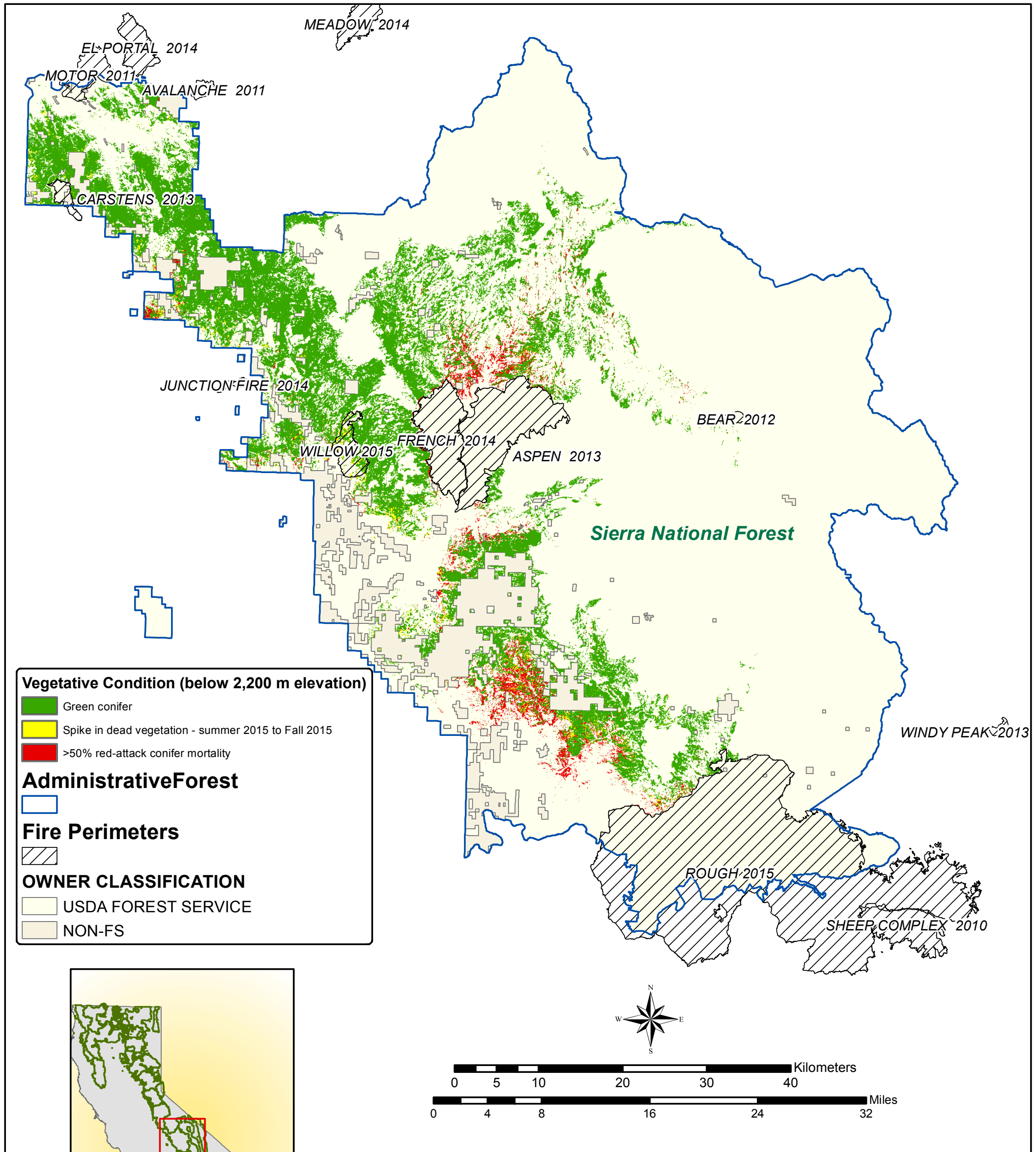
What results has your team produced from HyspIRI CA Airborne Activities?

- We focused on the Bay Area box to compare multi-seasonal HyspIRI to Landsat 8 (L8) and Sentinel-2 (S2) for mapping regional-scale land-cover and detailed forest alliances. We initially tried multiple-endmember spectral mixture analysis (MESMA), but came to appreciate the efficiency and accuracy of machine learning for these applications.
- We generated products of surface broadband albedo, incident shortwave radiation, surface shortwave net radiation and surface net radiation.
- Novel LAI modeling technique
- An evaluation of how within-pixel structural variability impacts the output spectral signal
- Two novel unmixing approaches, using higher spatial resolution spectrometer data
- Multiple papers and published L3 and L4 data products
- We demonstrated the ability to measure/map foliar biochemistry (2 traits: Vcmax, and the temperature sensitivity of Vcmax) from imaging spectroscopy (Serbin et al. 2015)
- We demonstrated the ability to map instantaneous physiology using the results from Serbin et al. 2015 above and MASTER thermal IR
- We demonstrated the ability to use imaging spectroscopy to spatially map GPP as derived from flux towers across ecosystem types and seasons (Dubois et al. 2018). This method greatly outperformed MODIS based approaches, and without the bias illustrated a
- We have implemented a processing flow based on the California HyspIRI data to go from JPL produced reflectance to traits, automated on the JPL SDS. This includes over 20 traits, starting with what was originally published in Singh et al. 2015
- Tested phytoplankton functional type (PFT) algorithm and existing operational chlorophyll algorithms, but AVIRIS data did not have the sensitivity, calibration and atmospheric correction appropriate for aquatic targets.
- We have identified spatial changes in vegetation cooling effectiveness across coastal to inland gradient
- We have developed new outdoor water use approaches to evaluate effect of drought

Mapping forest mortality using imaging spectroscopy from AVIRIS data 2013-2017

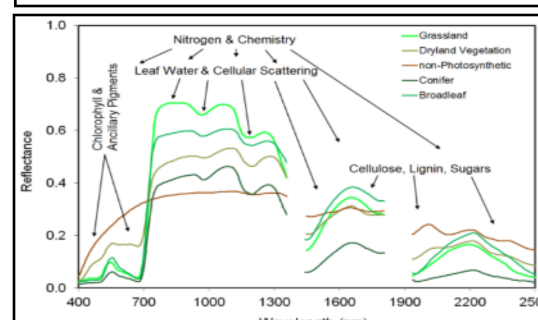
Data collected by JPL, analyses by JPL and the USDA Forest Service, Region 5.

This analysis is now being made operational to support ongoing forest management in California.



USDA Forest Service, Pacific Southwest Region, Remote Sensing Lab, Map created 5/18/16

This map represents a time-series analysis of images acquired by the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS; http://aviris.jpl.nasa.gov/) from Spring 2013 to Fall 2015. Mortality for Summer 2015 was manually interpreted from Worldview imagery from Spring - Summer 2015 and used for the training the statistical-learning classifier. Landcover was classified into shrub dominant, green conifer dominant, and newly killed (red-attack) conifer dominant. Spectral mixture analysis was used to evaluate the Fall 2015 mortality by comparing 2013 - 2015 changes in the cover fractions and flagging changes greater than 10% in the non-photosynthetic vegetation fraction in Fall 2015 imagery.



Western US HyspIRI Extended Time Series

The Western US AVIRIS-C and MASTER Data Sets were extended to 2016, 2017 and 2018 for a single season each year. The time series and diverse environment coverage are being used for a mix of science and applications research as well as graduate student and SARP research.

Bay Area Environmental Research Institute — NASA Airborne Science Program

NASA Student Airborne Research Program (SARP)

Summer Internship for Advanced Undergraduate STEM Majors
Research in the Earth & Atmospheric Sciences from onboard a NASA Aircraft
June 18 - August 11, 2017, Southern California

The NASA Airborne Science Program announces the opportunity for highly motivated rising senior undergraduates to participate in an 8-week summer 2017 internship program in Earth system science using its C-23 Sherpa and ER-2 flying laboratories.

The NASA Student Airborne Research Program (SARP) is funded by the NASA Ames Cooperative for Research in Earth Science and Technology (ARC-CREST) and managed by the National Suborbital Research Center (NSRC). SARP 2017 will take place in Southern California with research locations based at the University of California, Irvine and at the NASA Armstrong Aircraft Operations Facility in Palmdale.

Participants will acquire hands-on research experience in all aspects of a scientific campaign, including flying onboard the NASA C-23 Sherpa, a highly-specialized research aircraft used for studying Earth system processes.

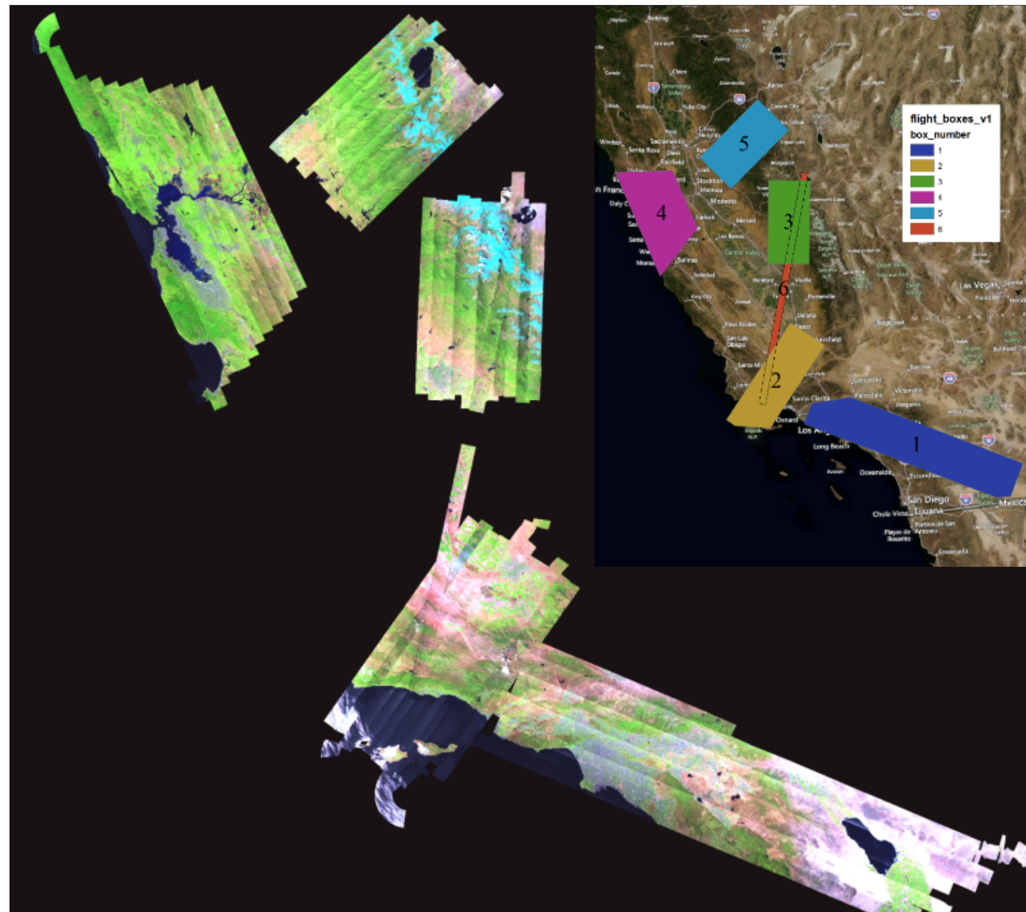
Multi-disciplinary Research Projects
Participants will work in four multi-disciplinary teams to study surface, atmospheric, and oceanographic processes. Participants will fly onboard the NASA C-23 Sherpa and assist in the operation of instruments to sample and measure atmospheric gases. They will also use remote sensing data collected during the program from the NASA ER-2 high-altitude research aircraft to image land and water surfaces in multiple spectral bands. Along with airborne data collection, students will participate in taking measurements at field sites.

APPLICATION DEADLINE:
FEBRUARY 1, 2017
Application can be found at:
http://earthscience.arc.nasa.gov/nsrc/sarp
Email questions to nasasarp@baeri.org

Mission faculty and research mentors will guide participants through instrument operation, sample analysis, and data reduction. Each student will develop an individual research project from the data collected and will deliver a final presentation on their results. Many students in the past have gone on to present their research at national conferences.

Academic Background
Applicants must have a strong academic background in any of the physical, chemical, or biological sciences, or engineering and an interest in applying their background to the study of the Earth system. We especially encourage applications from students majoring in Earth, environmental or atmospheric sciences and related disciplines. All participants will receive a stipend, travel costs, as well as housing and transportation during the program.

Applicants will be selected based on:
- Excellent Academic Performance (GPA of at least 3.0/4.0)
- Science, Technology, Engineering or Mathematics Major
- Evidence of interest in Earth system science and hands-on research
- Leadership qualities and ability to perform in teams



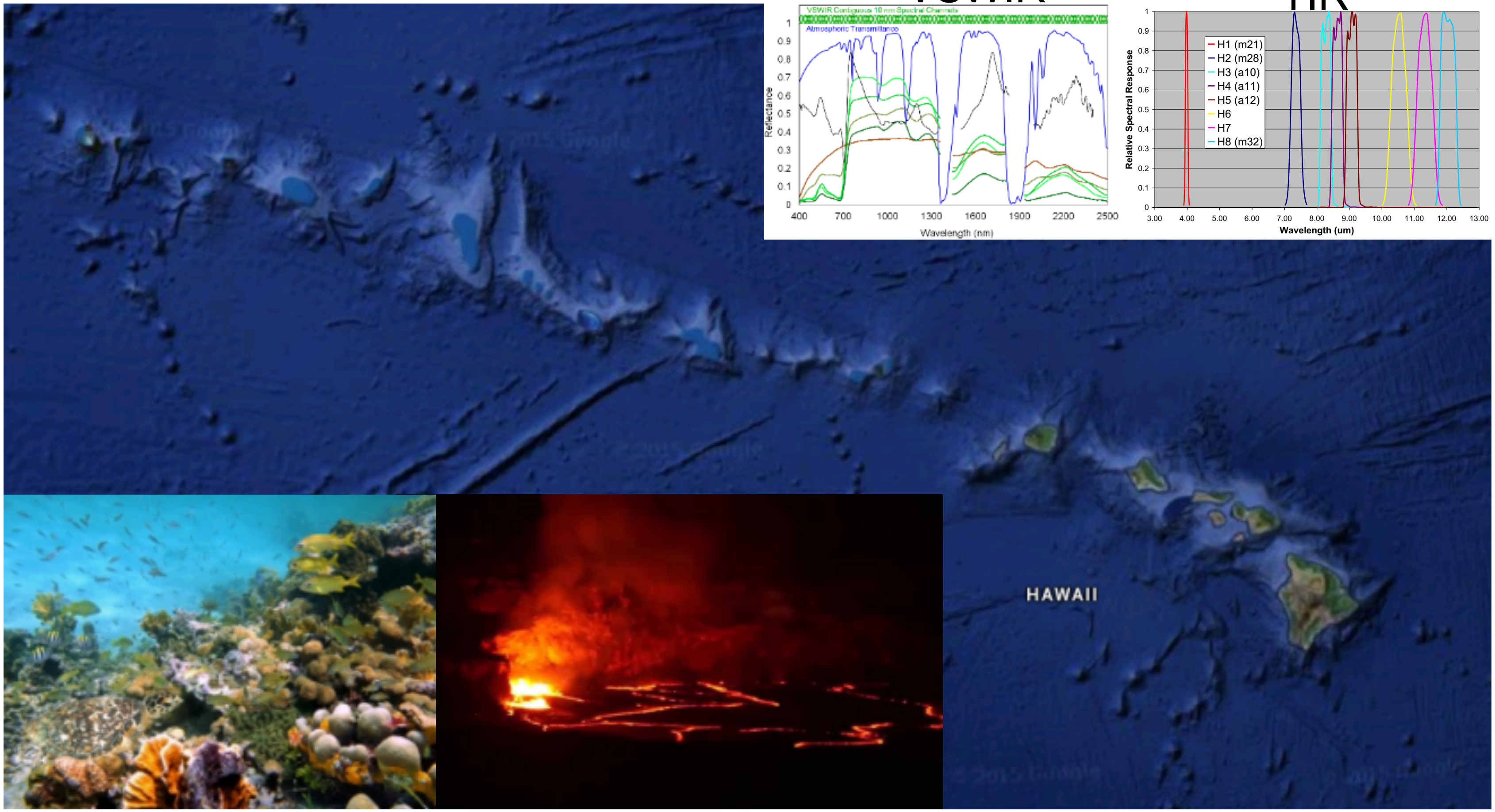
HyspIRI Volcano and Coral Reef Airborne Campaign

A.45 HyspIRI Preparatory Airborne Activities and Associated Science: Coral Reef and Volcano Research

- 10 investigations selected
- Test Level 1 and 2 products for VSWIR and TIR HyspIRI-type measurement
- Advance maturity of higher level products and related algorithms

VSWIR

TIR



HyspIRI Preparatory Airborne Activities and Associated Science: Coral Reef and Volcano Research (NNH14ZDA001N-HYSP)

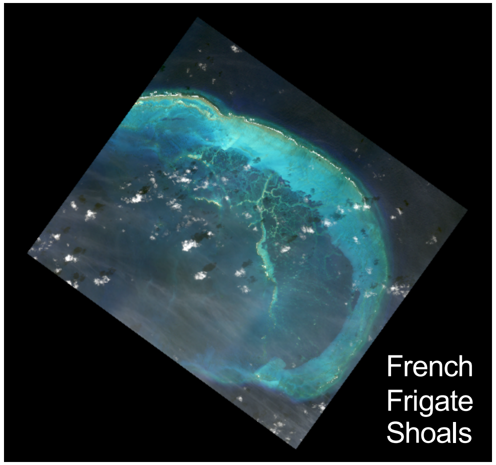
The National Aeronautics and Space Administration (NASA) Earth Science Division within the Science Mission Directorate solicited proposals using airborne measurements resulting from a planned airborne campaign in 2016 in the Hawaiian Islands for volcano and coral reef research. For this campaign, NASA plans to fly the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) and the MODIS/ASTER Airborne Simulator (MASTER) instruments on a NASA high-altitude aircraft to collect precursor datasets in advance of the Hyperspectral Infrared Imager (HyspIRI) mission. NASA solicited proposals that would use these airborne data to address one or more of the science questions for the HyspIRI mission relevant to volcano or coral reef research. A goal of this solicitation is to generate important science and applications research results that are uniquely enabled by HyspIRI-like data, taking advantage of the contiguous spectroscopic measurements of the AVIRIS, the full suite of MASTER

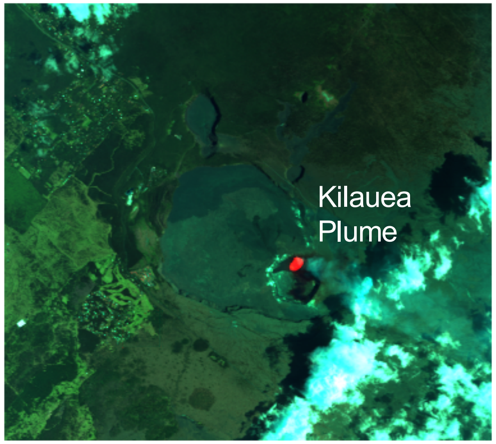
Hiedi Diersen	Univeristy of Connecticut	Hyperspectral remote sensing of coral reefs: Assessing the potential for spectral discrimination of coral symbiont diversity
Steven Ackleson	Naval Research Laboratory	Assessing Simulated HyspIRI Imagery for Detecting and Quantifying Coral Reef Coverage and Water Quality Using Spectral Inversion and Deconvolution Methods
Kyle Cavanaugh	University of California, Los Angeles	Using HyspIRI to Identify Benthic Composition and Bleaching in Shallow Coral Reef Ecosystems
Paul Haverkamp	University of California Davis	Modeling of Environmental Variables and Land-Use/Land-Cover Change Influence on Declining Hawaiian Coral Reef Health Since 2000 Using HyspIRI-Like Images
Eric Hochberg	Bermuda Institute of Ocean Science	Coral Reef Condition Across the Hawaiian Archipelago and Relationship to Environmental Forcing
ZhongPing Lee	University Of Massachusetts, Boston	Evaluation and Application of the AVIRIS Data for the Study of Coral Reefs
David Pieri	Jet Propulsion Laboratory	In Situ Validation of Remotely Sensed Volcanogenic Emissions Retrievals Using Aerostats and UAVs
Michael Ramsey	University of Pittsburgh	Quantifying Active Volcanic Processes and Mitigating their Hazards With HyspIRI Data
Vincent Realmuto	Jet Propulsion Laboratory	Mapping the Composition and Chemical Evolution of Plumes from Kilauea Volcano
Greg Vaughn	United States Geologic Survey	Developing an automated volcanic thermal alert algorithm using moderate spatial resolution VSWIR and TIR data: Implications for the future HyspIRI mission
Chad Deering	Michigan Technological University	Understanding Basaltic Volcanic Processes by Remotely Measuring the Links Between Vegetation Health and Extent, and Volcanic Gas and Thermal Emissions Using HyspIRI-Like VSWIR and TIR Data

HyspIRI Hawaii 2017 – ER-2 AVIRIS, MASTER

Airborne Campaign January 17 – March 1, 2017

- Comprehensive Coral Dataset Collected
  - All Main Islands Targets
  - NW Islands out to Laysan Island
- Comprehensive Volcano Dataset Collected
  - Multiple clear Kilauea plume passes
  - Day ASTER overpass
- All In-Situ Sites Covered
  - Kilauea
  - Volcano Vegetation
  - Kaneohe Bay (Coconut Island)
  - Kona
  - Molokai
  - Maui
  - Moby Buoy
- Well Received Press Day
  - Facebook Live Stream (315,000 views)
  - Front page of local paper (Star Advertiser)
  - Local ABC (KITV) Article
  - Scientific American Article

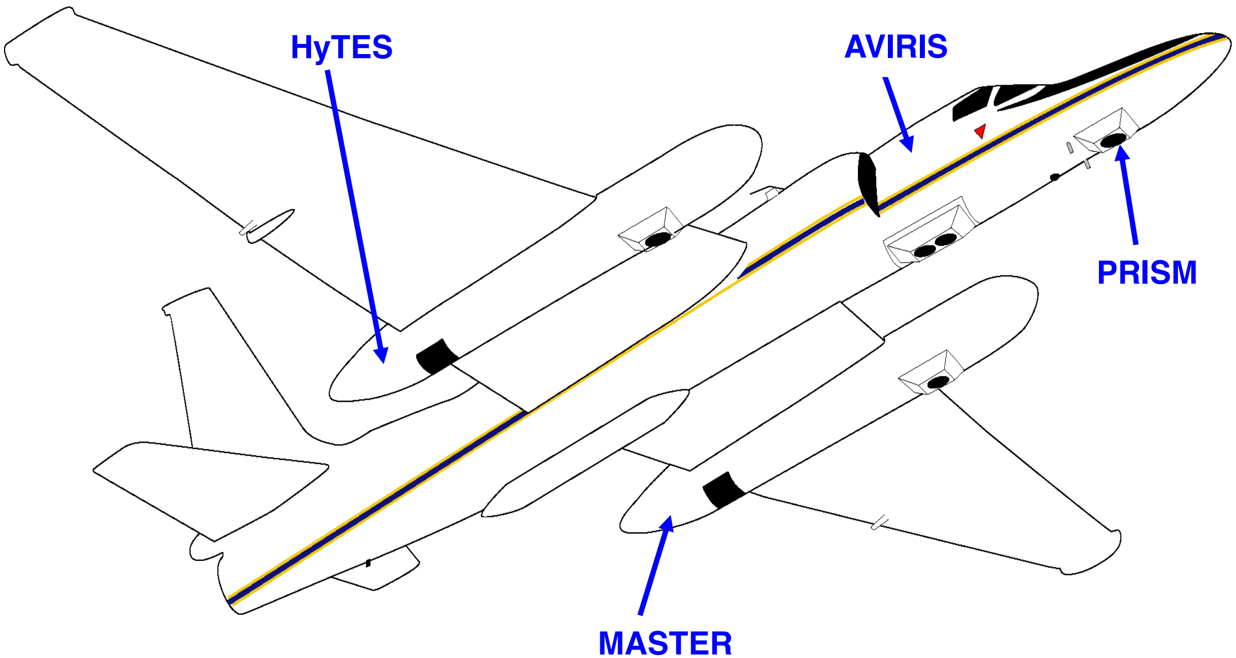


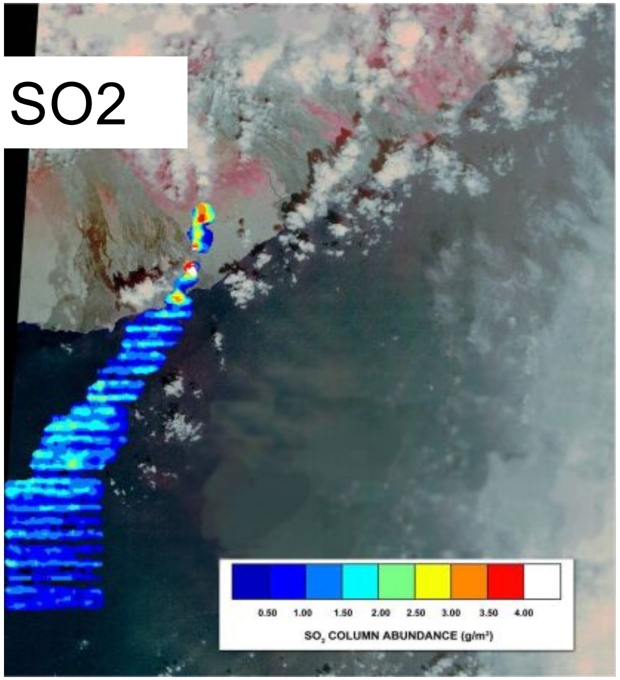


2018 HyspIRI Hawaii Deployment
ER-2 with MASTER, AVIRIS, HyTES, PRISM

Airborne Campaign January 18 - February 16,2018

- Focus was Volcano flights, with addition of hours to recollect Coral Reefs
- ASTER day and night overpasses
- ASTER project provided supporting coincident meteorological measurements with radiosonde launches





What was the best thing about the HyspIRI HI Airborne Activities?

- Participating twice in meaningful science campaign
- We were provided the unprecedented opportunity for field data collection for remote sensing reflectance in optically shallow waters. Many of our field measurements can be used to evaluate and validate the AVIRIS and PRISM remote sensing products.
- Probably the best aspect of the campaign was the ability to work directly with the flight crew in 'real time' to adjust schedule and flight lines to meet our needs. This ended up being crucial in the area we were studying due to significant challenges with weather/cloud cover.
- The ability to collect coincident data from several different TIR sensors of 2 different volcanic eruptions, at a variety of spatial and spectral resolutions. This coupled with the large team providing expertise in many different areas (very god learning experience for the graduate student).
- We were able to obtain multiple overflights of an area where we were pre-positioned to collect detailed in situ observations. AVIRIS data were collected at multiple altitudes, offering a range of spatial resolution, and under a variety of environmental conditions (sun angle, cloud cover, wind speed and direction, water quality, tidal stage, etc.). At the same time, since we were on site for the duration of the campaign, we were able to collect in situ data close to the overpass times. Communication with the aircraft/sensor team on a daily basis was critical to the success of the campaign.
- The best thing about the campaign was the dedication and commitment of the entire airborne mission team. This was a great opportunity to collect repeat data over Hawaiian reefs, and to have data collection focused on reefs. We are investigating coral reef structural change, which is highly important due to the increasing number of bleaching events, and the data collection focused on ways to help eliminate sunglint, which is typically a large challenge to overcome. Having access to high-quality, state-of-the-art research data is what makes the science possible.
- Perhaps the best thing about our campaign was being able to collect data of an unprecedented kind, i.e., in situ low altitude airborne chemistry data in a volcanic plume using UAVs. Being able to use a variety of in situ platforms and instruments, some for the first time applied to volcanology, was also very gratifying, including fixed and rotary wing aircraft, tethered aerostats (blimps and balloons), miniature field-portable mass spectrometers, a hyper-spectral TIR video imager, and an ultra-precise laser CO2 measurement device. We were also able to refine our SO2 measurements to reliably measure sub-ppm concentrations, which is important for orbital/airborne model-based SO2 retrievals, as well for validating VOG models up to 1500ft AGL.
- The organization of the data collection and processing has been excellent. We have been very happy with the speed at which the data has been made available.
- Unique opportunity to collect AVIRIS and HyTES (i.e., imaging spectrometers) data over Kilauea plumes
- From logistics point of view, best thing was the level of communication between the airborne and science teams, through telecons, texting, email, and the real-time Airborne Assets website. This communication was crucial during the 2018 campaign,

What was the biggest challenge of HyspIRI HI Airborne Activities?

- Unfavorable weather is the biggest challenge.
- Communication the first year. We weren't connected to flight ops, and relied on second-hand for info on plane logistics. Only worked some of the time
- Coordinating our ground team with the airborne operations. The communication (especially on the first campaign) was lacking, which made our interactions with the USGS and access to the restricted areas much more complex. The other challenge was having instrument failures on the aircraft, which was very important on a clear evening of an ASTER overpass, a field crew, and then to be told that MASTER didn't work.
- Collecting diverse, high-quality in situ data coincident with the overpasses. Weather conditions were challenging, which meant that the field campaign had to be of long enough duration to insure enough weather windows to conduct both the airborne and in situ operations. Six weeks was appropriate for Kaneohe Bay in the winter.
- The biggest challenge of the campaign was the weather conditions, but the mission team did a remarkable job of working around the clouds and wind to meet our acquisition requirements. Coordinating the interests of multiple research teams with different research objectives and study areas was also a challenge; again, the mission team did a great job balancing the many competing interests to collect a broad array of high-quality image data for multiple research projects. Our project focuses on identifying change since 2000, so the biggest challenge so far has actually been modifying images from 2000-2001 to match the 2017 images. The hardware, software, and algorithms have changed over the past 18 years
  Satisfying the regulatory requirements for the granting of permission to operate within HAVO. There were a variety of constituencies to satisfy, and a variety of technical, environmental, and cultural concerns to address. Also, managing the inter-agency liaison between NASA, the FAA, the NPS, and the US Geological Survey was at times an extremely challenging exercise. Operating within an active volcanic environment with UAVs is always a challenge, however, our team has unique capabilities and experience in this arena, and so that was the lesser challenge as compared to the former.

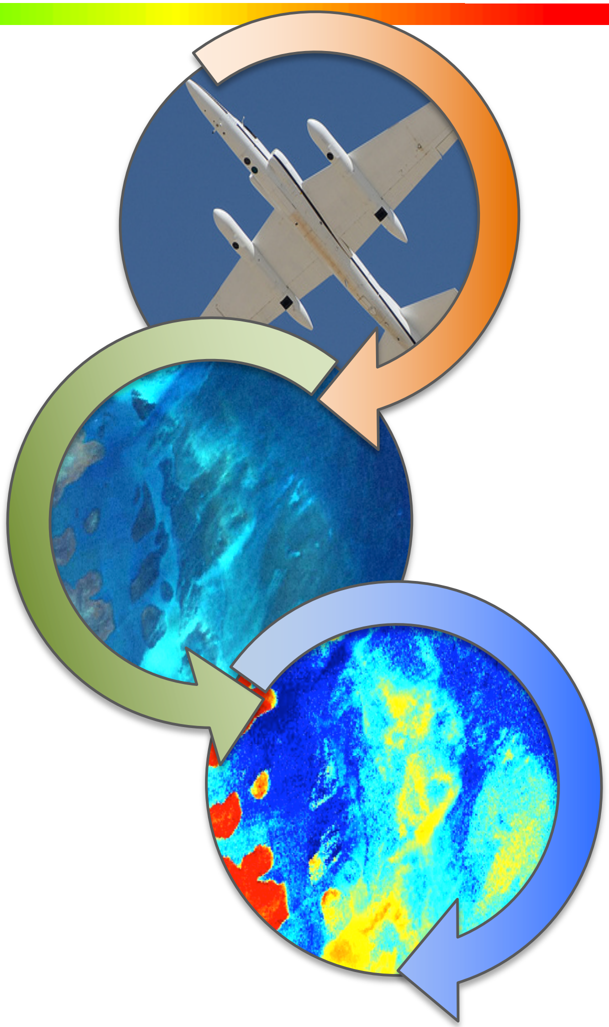
What results has your team produced from HyspIRI HI Airborne Activities?

- In situ data of remote sensing reflectance in shallow waters; Refined cloud-shadow method for atmospheric correction; Enhanced benthic classifier;
- Initial data quality assurance model for AVIRIS/PRISM reflectance products in shallow waters;
- We are also developing specific correlations between individual gas species (CO2 and H2S) and ground temperature and specific types of plant stress – a product that cannot be obtained from the multispectral data. This product will allow users to eventually uniquely identify different types of plant stress that occur as magma ascends to different depths prior to an eruption, therefore providing one with the ability to potentially predict magma movement towards the surface at disparate times before the actual volcanic activity commences.
- Ground-based broadband and multispectral TIR data, at high spatial and temporal resolution. These high spatial resolution temperature and emissivity products are being used to validate the lower spatial resolution airborne and satellite data. The high spatial and spectral resolution data was acquired by a new instrument funded by the HyspIRI campaign funding. These data improve the accuracy of derived temperature and emissivity data and future lava flow cooling models.
- We were able to high resolution (<0.5 m) across a small patch reef in the southern portion of Kaneohe Bay using an autonomous surface vessel (modified kayak) instrumented with acoustical, chemical, and optical sensors. With this data we were able to investigate the impacts of sensor noise and sub-pixel variability on the uncertainty in the retrieval of benthic and water column properties from airborne hyperspectral imagery. While we are still investigating issues related to ground sampling distance, we conclude that sensor SNR will be critical in defining the limits of capabilities for a space-borne sensor such as HyspIRI. The minimum SNR (peak SNR for a typical silicon detector) considered for shallow-water coastal applications is 500 (Ltyp = clear ocean under a clear maritime atmosphere and a 5% surface reflectance). The project is a work-in-progress, but so far, we have generated co-registered, atmospheric and sunglint corrected, resampled (18, 30 and 60 m) AVIRIS data from Kaneohe Bay from 2000 and 2017. This data has been further processed using an inversion model to generate water depth, benthic reflectance, and water properties for all three spatial resolutions and both image dates. The team has also produced an estimate of changes in land-use/land-cover for the watershed surrounding Kaneohe Bay for the period 2000 to 2017 using historic multispectral satellite data. We have also generated atmospheric corrected AVIRIS data for the south coast of Molokai from 2001 and 2017, and French Frigate Shoals from 2000 and 2017.
- We have used our in situ benthic spectra data to conduct a simulation analysis to assess the ability of a satellite-based imaging spectrometer to distinguish subpixel fractional cover of coral reef benthic types.
- Collected 250 in situ Phototransects across 5 of the Main Hawaiian Islands. We have measured the fractional coverage of coral reef benthic cover on each image and will be using this data to validate our AVIRIS based fractional cover estimates. This validation analysis is currently in progress.
- Screened all of the MASTER data for plume detections, comparison of contemporaneous SO2 retrievals based MASTER, ASTER, MODIS, and VIIRS data, AVIRIS-based map of aerosol optical depth (AOD) related to the plume, HYTES-based SO2 detections

Change detection in Hawaiian coral reefs from 2000-2017/2018 using AVIRIS and simulated HyspIRI imagery

Hawaii 2017/2018 HyspIRI Preparatory Campaign

P.J. Haverkamp (University of Zurich)
J. Goodman (HySpeed Computing)
L. Ramirez (Nova Southeastern University)
M. Lay, S.L. Ustin (University of California Davis)



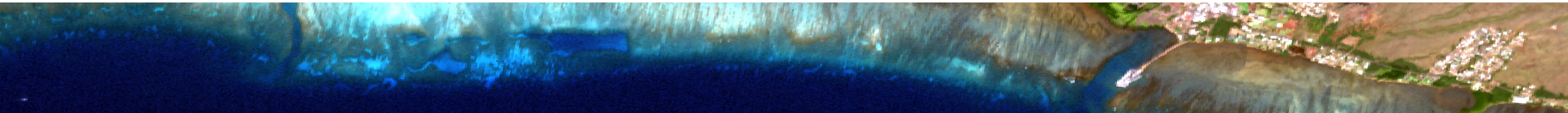
Project Objective: This project examines changes in habitat composition in Kaneohe Bay, the south coast of Molokai, and French Frigate Shoals by comparing benthic classifications from the early 2000s and 2017/2018.

1. Leverages the unique ***temporal record*** of AVIRIS data in Hawaii to advance the science of coral reef remote sensing

2. Investigates how different ***image resolutions*** (18, 30 and 60 m) impact benthic classification and change detection

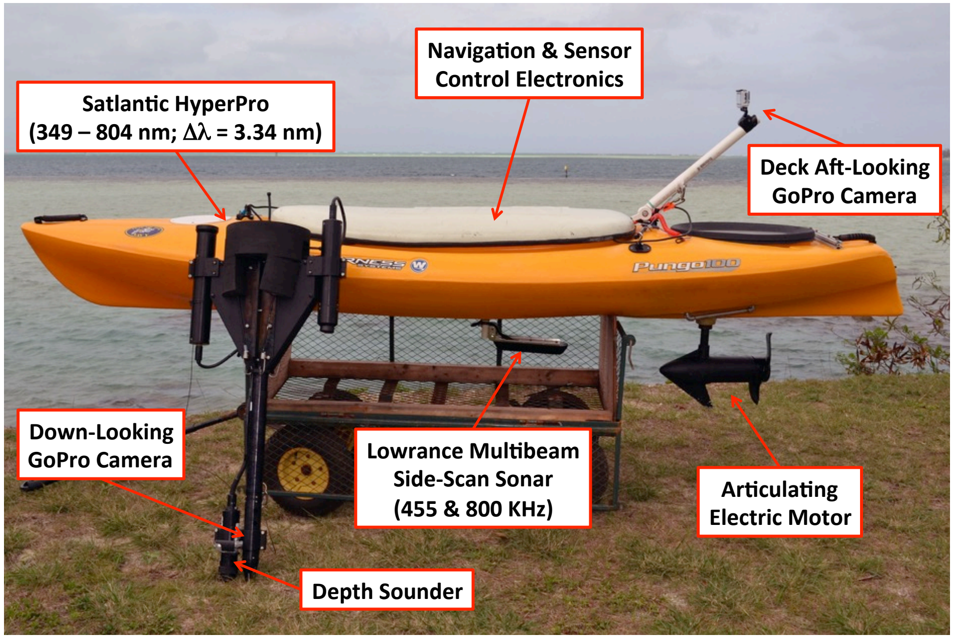
3. Evaluates ***environmental factors*** that influence benthic habitat change, including land-use/land-cover and sea surface temperature

4. Develops ***workflows*** for analyzing coral reef imagery from future airborne and satellite imaging spectrometers

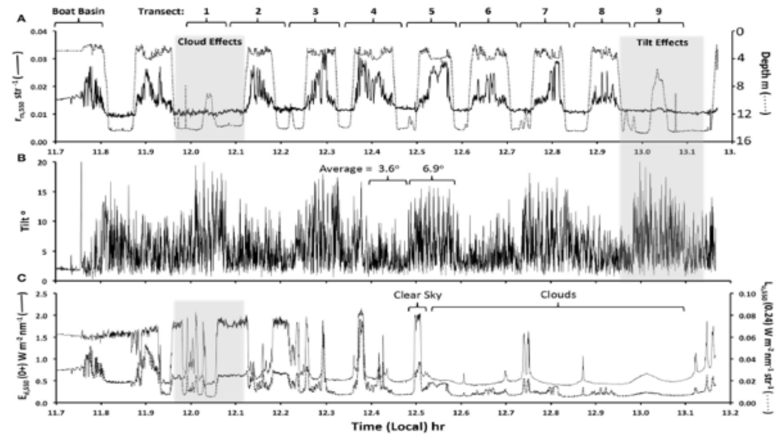


HyspIRI Coral Reef Assessment

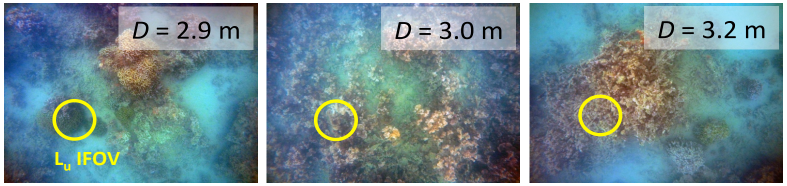
Autonomous Reef Surveys



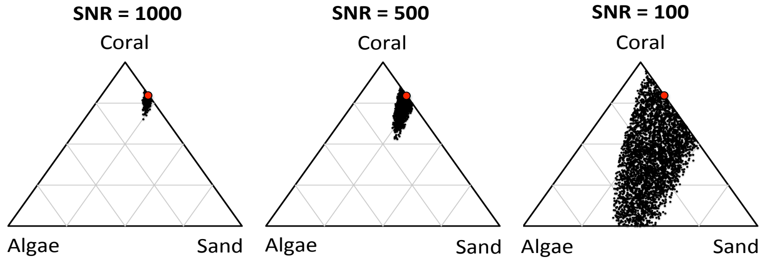
Example Radiometry



Example Benthic Cover



Sensor Noise Model



U.S. NAVAL RESEARCH LABORATORY

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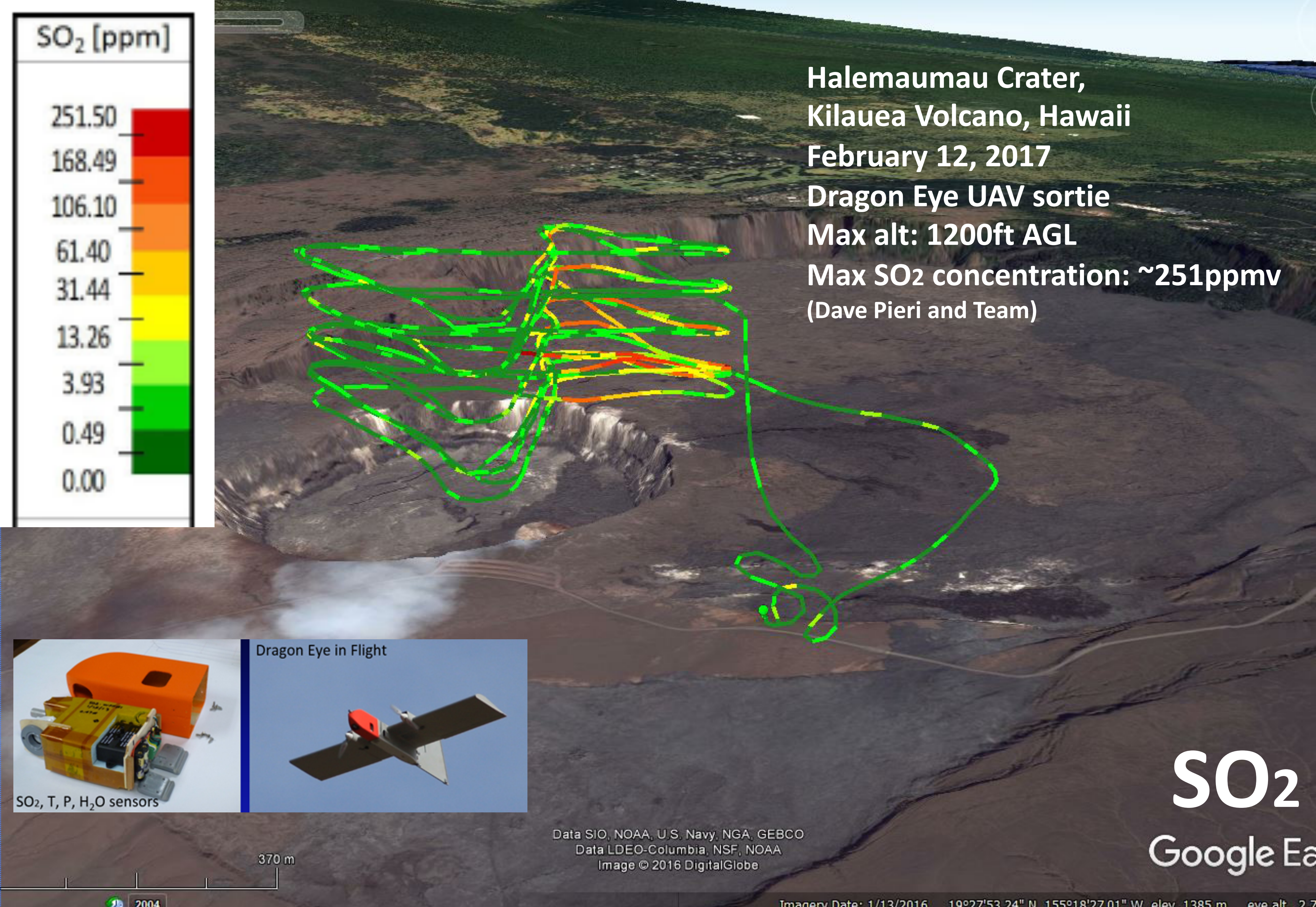
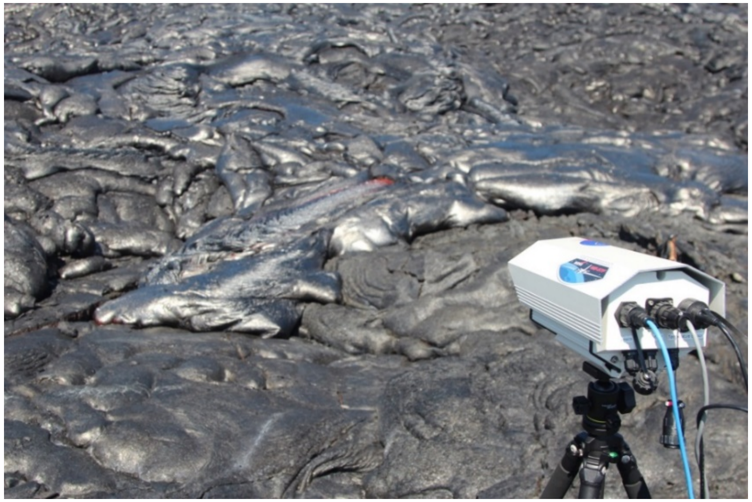
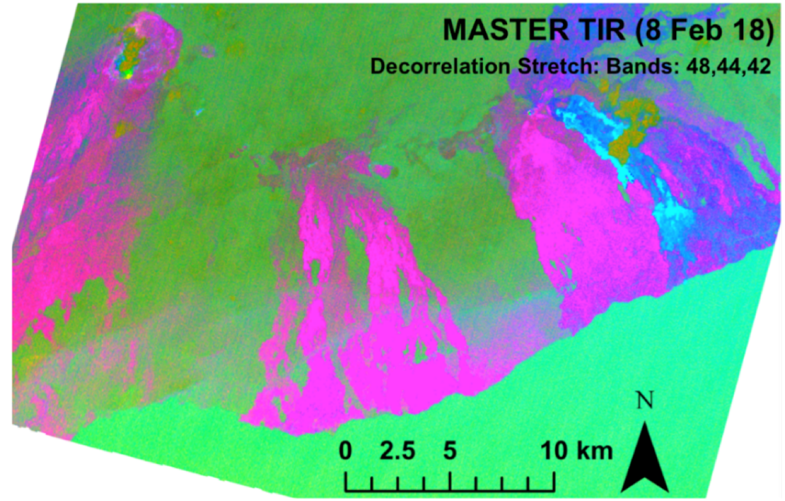

SO₂ [ppm]
251.50
168.49
106.10
61.40
31.44
13.26
3.93
0.49
0.00
Halemaumau Crater,
Kilauea Volcano, Hawaii
February 12, 2017
Dragon Eye UAV sortie
Max alt: 1200ft AGL
Max SO2 concentration: ~251ppmv
(Dave Pieri and Team)
SO2, T, P, H2O sensors
Dragon Eye in Flight
SO2
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Data LDEO-Columbia, NSF, NOAA
Image © 2016 DigitalGlobe
370 m
2004
Imagery Date: 1/13/2016 19°27'53.24" N 155°18'27.01" W elev 1385 m eye alt 2.7

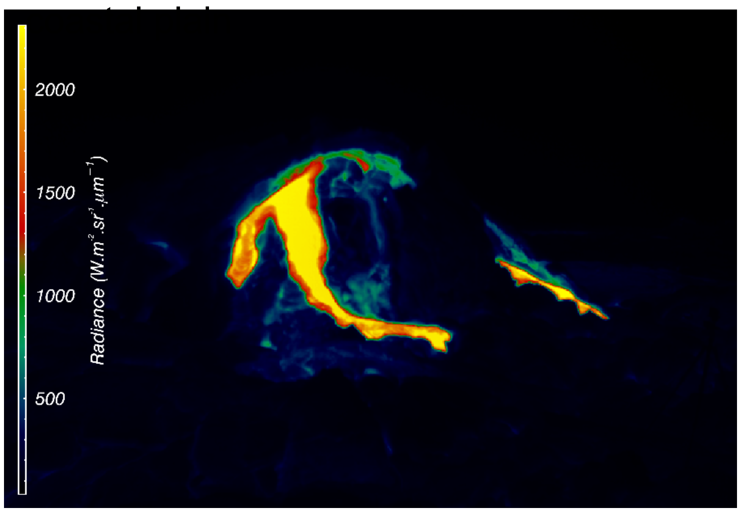
HyspIRI Airborne Campaign: Univ. Pittsburgh



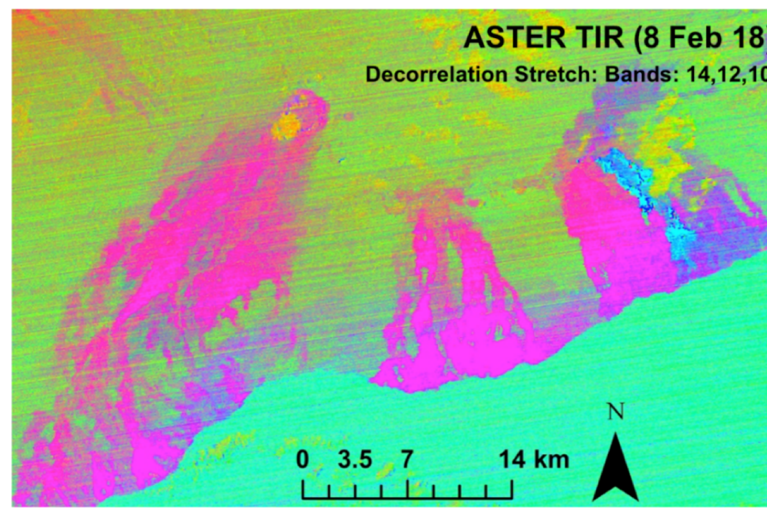
MMT-Cam in the field acquiring TIR data of active pahoehoe lava lobe on the



MASTER TIR decorrelation stretch using bands 48,44,42 (RGB). Active lavas appear cyan



Broadband MMT-Cam radiance image of lava tumulus on the night of Feb 8, 2018



ASTER TIR decorrelation stretch using bands 14,12,10 (RGB). Gas plumes appear orange

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