NASA Science Mission Directorate
Research Opportunities in Space and Earth Sciences
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A.45 HyspIRI Preparatory Airborne Activities and Associated Science: Coral Reef and Volcano Research
Abstracts of Selected Proposals
Updated August 6, 2015

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 thermal infrared bands, or combinations of measurements from both instruments.

NASA received a total of 21 proposals and has selected 10 for funding. The total funding to be provided for these investigations is approximately $2.3 million over two years. The investigations selected are listed below. The Principal Investigator, institution, investigation title and abstract are provided. Co-investigators are not listed here.

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

The Naval Research Laboratory will lead a team of coral reef and ocean remote sensing scientists to investigate spatial and temporal gradients in coral reef coverage and water quality around the Hawaiian Islands and adjacent waters of the Papahanaumokuakea Marine National Monument (PMNM). The ecological state of coral reefs will be expressed as one of three possible regimes: 1) healthy calcifying corals, 2) turf and coral rubble-dominated, and 3) fleshy macroalgae. Hyperspectral and Infrared Imager (HyspIRI) data, to be simulated with high-altitude aerial surveys in 2016, and Hyperspectral Imager for the Coastal Ocean (HICO) data, collected between 2010 and 2014, will be inverted for coral reef coverage and associated water quality using methods based on state-of-the-art radiative transfer models (spectral look-up tables and optimization procedures). The radiative transfer models will be constrained using extensive, existing data sets of coral reef feature reflectance spectra. In situ observations will be conducted to augment the existing databases, assess sub-pixel variability, and assess the quality of the HyspIRI and HICO data. Error propagation methods will be used to assess uncertainty within derived products as a function of the expected system noise and uncertainties in atmospheric correction. Existing in situ coral reef survey data collected by the National Oceanic and Atmospheric Administration, Coral Reef Ecosystem Division (NOAA/CRED) will be used to validate regime retrievals. The HyspIRI and HICO results will be used to investigate spatial and temporal gradients in coral reef coverage as a function of proximity to centers of human habitation and human-reef interaction and expected long-term environmental adjustments related to climate change. In addition to new knowledge about spatial and temporal changes in Hawaiian and PMNM coral reef ecosystems, this work will culminate in a more thorough understanding of expected HyspIRI capabilities for assessing coral reef coverage and associated water quality as a function of system noise.

Kyle Cavanaugh/University of California, Los Angeles
Using HyspIRI to Identify Benthic Composition and Bleaching in Shallow Coral Reef Ecosystems

Coral reefs are one of the most ecologically and economically important ecosystems in the world. However, degradation of coral reefs is increasing due to a combination of local- and global-scale stressors. There is a great deal of uncertainty as to the scale and trajectory of this degradation because the biological record of coral reef extent and health is limited. In order to better understand the patterns of reef degradation and the processes behind it, researchers need observations of coral reef extent and health on regional to global scales. This need is mentioned specifically in the NRC's 2007 report, "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond", and in the HyspIRI mission science questions (specifically vq6 and cq1).

The proposed research will use remotely sensed and simulated radiance data to show (1) that retrieval of benthic composition and coral bleaching is uniquely enabled by HyspIRI-like data, and (2) that this capacity will improve our understanding of the causes of coral bleaching. We will achieve these two technical and scientific objectives by performing the following tasks:

Task 1:Use data with HyspIRI-like spectral characteristics to extract information on coral reef benthic composition and coral reef bleaching extent.
Task 2: Use simulated top-of-atmosphere radiance data to characterize the practical limits on discrimination of coral reef benthic composition and coral bleaching as a function of instrument spectral characteristics, atmospheric conditions, instrument noise, and water column properties.
Task 3: Assess the implications of HyspIRI's planned 60-m spatial resolution by determining how sensor resolution impacts estimates of benthic composition and coral bleaching. Develop methods to utilize available high-resolution imagery to enhance the retrieval of benthic composition and bleaching from 60-m HyspIRI imagery.
Task 4: Assess the environmental drivers and thresholds associated with coral bleaching events.

In order to clearly demonstrate the unique capabilities of HypIRI-like imagery, we will perform similar analyses on simulated Landsat OLI reflectance to allow for a direct comparison of HypIRI and OLI capabilities.

The proposed research will take place in the Hawaiian Islands, where we have high-resolution bathymetry and extensive in situ data for evaluation of benthic composition and bleaching in HyspIRI-like AVIRIS imagery. Limited additional in situ data on benthic composition and bleaching will be acquired coincident with the AVIRIS overflights. Spectral unmixing of imaging spectrometer (Task 1) data will require limited collection of in situ reflectance measurements of benthic components. These reflectance spectra will also be used in the spectral simulations (Task 2). The proposed research is poised to take advantage of any bleaching events that occur in 2016, but is not dependent upon the occurrence of a bleaching event. We already have sufficient data on benthic composition and bleaching (associated with a major bleaching event that occurred in Hawaii in 2014) that we can use to assess the environmental drivers and thresholds of coral bleaching (Task 4). This is just the type of data that would be uniquely enabled by HyspIRI (Task 1).

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

The replenishment of a shallow magma reservoir can signal: a) the onset of an eruption at a dormant volcanic system (e.g., Mauna Loa) or, b) significant changes in eruptive behavior at an already active volcano (e.g., Kilauea). Rising magma ultimately results in a flux of volatiles through the ground (e.g., CO2 and H2S) and from active vent plumes (e.g. CO2 and SO2), particulate matter, and/or thermal energy, onto Earth's surface and into the atmosphere.

Gaseous emissions from active volcanoes (SO2, H2S, CO2, and HF) adversely impact surrounding ecosystems and are harmful to people, wildlife, and vegetation. Sulfur dioxide quickly converts to sulfuric acid aerosol, which can lead to acid rain and atmospheric pollution. Carbon dioxide is heavier than air and can, therefore, accumulate in low lying areas and become lethal to local human populations as well as flora and fauna. Fluorine, adsorbed onto ash particles may be distributed over a wide geographic area, contaminating vegetation that can later be ingested by animals.

Detecting and characterizing these fluxes, and the indirect effects that they have on, for example, the health and extent of local vegetation, is important for both basic science (as a means for quantifying aspects of magma ascent dynamics and shallow conduit processes) and hazard managers (for recognizing significant changes in a volcano's behavior and forecasting volcanic events and hazards).

This research effort proposes to use HyspIRI-like data acquired during the planned AVIRIS/MASTER airborne campaign over Hawaii in 2016. We propose to develop and implement data analysis methods to extract key physical parameters from HyspIRI-like VSWIR and TIR data that may signal a change in volcanic state. This project will focus on vegetation health and extent, diffuse soil CO2 and H2S flux, and active vent SO2

plume flux, surface temperature, and heat flux. Linking these landscape characteristics will help quantify the effect that these volcanic processes have on the surrounding ecosystems. HyspIRI-like VSWIR and TIR data will allow the measurement of SO_2 and radiant heat fluxes from active volcanoes (e.g., Kilauea). Maps of the health and extent of vegetation cover will be created by identifying and establishing the optimized hyperspectral vegetation indices and hyperspectral narrow band indices that will detect vegetation health and extent from AVIRIS and field spectroradiometer VSWIR data. Automated vegetation health and extent change detection algorithms for Hawaiian volcanoes will be created from the hyperspectral and multispectral (i.e., MASTER) data. A rigorous comparison of the efficacy and accuracy of hyperspectral versus multispectral vegetation health and extent change monitoring for volcanic regions and potentially for other landscapes will also be conducted.
Important questions to be addressed by this research are:

1. How can the effects that these volcanic processes have on the surrounding landscape be quantified and regularly measured using HyspIRI remote sensing data?
2. What is the spatial / temporal relationship between surface temperature, gas emissions, surface vegetation cover, and volcanic eruptions?
3. Do AVIRIS hyperspectral data perform better in vegetation health and change monitoring compared to multispectral data from MASTER?

The proposed work will also directly answer the following volcanology-related HyspIRI science questions:
CQ3. Do volcanoes signal impending eruptions through changes in the temperature of the ground, rates of gas and aerosol emission, temperature and composition of crater lakes, or health and extent of vegetation cover?
CQ3e. Do changes in the health and extent of vegetation cover indicate changes in the release of heat, gas, and ash from crater regions?

Paul Haverkamp/SP Cramer and Associates
Modeling of Environmental Variables and Land-Use/Land-Cover Change Influence on Declining Hawaiian Coral Reef Health Since 2000 Using HyspIRI-Like Images

The HyspIRI Mission aims to examine how a hyperspectral and thermal imaging satellite can be used to answer questions concerning ecosystem response in the face of global climate change and increasing human development and expansion. Coral reefs are known to be extremely diverse ecosystems supporting up to 25% of marine fish species. Coral reefs are also highly susceptible to environmental stressors caused by climate change and development, including ocean acidification, near-shore pollution and sedimentation, and increasing ocean temperatures. Because coral reef ecosystems support such diverse ocean life, they also represent important human resources (fisheries) that continue to be threatened by impacts of climate change. To better understand how these ecosystems are changing, we aim to use simulated HyspIRI (AVIRIS) data in conjunction with previously collected AVIRIS data (from 2000, 2001, 2005, and 2007) to identify how changes in environmental factors (sea surface temperature, turbidity, cloud cover, irradiance) influence coral health. We will also investigate how land-use/land-cover change in the Hawaiian Islands is related to these environmental variables, and develop predictive models based on the HyspIRI-like data to better understand what causes shifts in benthic community structure. The study will focus on coral reefs in Kaneohe Bay, Oahu and Kealakekua Bay, Hawaii and compare both reef systems to examine how human development can affect coral health. We will use the hyperspectral data to calculate bathymetry and turbidity and validate algorithms for clear coastal waters, and compare derived bathymetry to previously collected LiDAR bathymetry. Our focus will be to use Spectral Mixture Analysis and change detection analysis to identify areas that have shifted from coral dominated to algae dominated, indicating decreased coral health or death. Environmental variable data will then be calculated from the HyspIRI-like data and statistical modeling will be performed to examine how these variables interact in predicting coral conversion to algae from one date to the next over the set of images (e.g., do environmental variables in 2000 predict decreased health in 2001), as well as investigating longer term change to the final state (e.g., do environmental variables in 2000 predict decreased health in 2005, 2007, and 2016). We will then use the HyspIRI-like data to investigate landscape changes in human development, including agriculture and construction, surrounding the study sites to determine how human activity may influence coastal environmental variables. When relationships between environmental variables, coral health, and land-use/land-cover change are established, we will develop and validate predicative models to increase our understanding how these factors impact coral reef community shifts to algae. With further development, these models could be used as HyspIRI products that could develop early warning systems for monitoring worldwide coral health.

Eric Hochberg/Bermuda Institute of Ocean Science (BIOS), Inc.
Coral Reef Condition Across the Hawaiian Archipelago and Relationship to Environmental Forcing

Coral reefs are vital to the cultural and economic lives of hundreds of millions of people around the world. However, many reefs have deteriorated due to local human activities, and the rest may not be able to withstand the added stresses brought by climate change. Predictions are dire, but the underlying data are surprisingly sparse. For the Hawaiian archipelago (from the Big Island to Kure Atoll), no more than 5% of reef area has been quantitatively surveyed in the past 10 years. Further, the data that do exist show patterns that are counter to present understanding of how environment impacts reefs. The HyspIRI Preparatory Airborne Activities bringing high-altitude AVIRIS flights to Hawaii in 2016 is an excellent opportunity to fill the data gap and then to reevaluate the relationships between coral reef condition and the environmental parameters that are thought to be influential. Additionally, since AVIRIS has previously conducted a similar campaign in 2000, there is very good potential to investigate how at least some of Hawaii's reefs may have changed over a decade and a half.

We propose to use the 2016 data to quantify benthic cover and primary productivity for all reefs surveyed by AVIRIS. We will conduct a modest field study in Kaneohe Bay, Oahu for calibration and validation of the remote sensing data and products. We will analyze the remote sensing data products against a suite of biogeophysical parameters readily available from ancillary sources: oceanographic conditions (sea surface temperature, significant wave height, aragonite saturation), reef geomorphology and age (increasing from the Big Island to Kure Atoll), land cover and land-use change, known patterns of biodiversity, and local human threats (pollution, development, overfishing). Pending availability and suitability of the 2000 data set, we will investigate how reef condition has changed over time, as well as how the relationship between reef condition and the environment has changed over time.

Results would be important on many levels. Achieving our objectives requires development and implementation of a remote sensing data processing flow that could potentially be modified for use in other optically shallow water systems besides reefs. The maps of reef condition would provide a dense data set of region-scale reef condition, which would be valuable to both scientists in general and Hawaii reef managers in particular. The analysis relating reef condition to environment would produce a set of quantitative, empirical models that can be used to evaluate the roles of specific drivers of current reef condition and forecast reef condition under predicted scenarios of environmental change. Finally, the change analysis, would be (to the best of our knowledge) the first synoptic (as opposed to a limited number of small sites) analysis of coral reef change at the region scale, potentially identifying both broad regional trends and site-specific areas of concern.

ZhongPing Lee/University Of Massachusetts, Boston
Evaluation and Application of the AVIRIS Data for the Study of Coral Reefs

We propose to take concurrent field measurements in the coral reef environments of the Hawaii region to support the 2016 HyspIRI Airborne Campaigns. In addition to obtain hyperspectral (350-800 nm, 137 bands) remote-sensing reflectance (Rrs, sr-1) with our unique skylight-blocked approach and system, we will collect collocated bathymetry, water's inherent optical properties and videos of the submerged substrates. These measured Rrs will be compared with the match-up AVIRIS Rrs generated at the JPL AVIRIS computing facility to evaluate the quality of AVIRIS surface reflectance data product over coral reef environments. Further, these data will be used to refine remote sensing algorithms for the identification of live corals and to assess the spatial coverage of live corals for the entire flight line. With the collocated optical properties, we will also analyze the relationship between live coral coverage and light availability. These data and efforts will greatly improve our understanding and capabilities of using HyspIRI-like data to observe and monitor coral reef environments.

David Pieri/Jet Propulsion Laboratory
In Situ Validation of Remotely Sensed Volcanogenic Emissions Retrievals Using Aerostats and UAVs

We plan to utilize direct measurements and sampling from instrumentation onboard small unmanned aerial platforms, including free flying unmanned aircraft (UAVs) and tethered aerostats, using such in situ measurements of volcanic emissions (e.g., of gases and aerosols) to validate MASTER and AVIRIS remote sensing observations and quantitative retrievals. Our primary goal is to provide important validation data for estimations of volcanogenic gas and aerosol concentrations derived from remote sensing techniques. These data, in turn, can be used to constrain key proximal and distal boundary conditions for gas and aerosol transport models to substantially improve estimates of emission fluxes (e.g., SO2, CO2). Such information is important for basic characterizations of volcano processes, as well for interpretation of eruption precursor phenomena for restless volcanoes, and for informing the decisions and evaluations by hazard responders and regulatory agencies before, during, and after eruptions. In addition, we will address gaps in knowledge of volcanic processes at local scales in Hawaii (e.g., identification of CO2 sources, CO2-SO2 ratios and dispersion patterns, extent and intensity of SO2 hydrolysis) intrinsically accessible via in situ observations, but which will inform both HyTES/AVIRIS observations, and ultimately those of HyspIRI. Here we propose to use several small, relatively economical unmanned aerial platforms to detect and measure emissions of SO2, CO2, and aerosols from the Kilauea Volcano, including simultaneous airborne sensorweb flights (2D and 3D abundance measurements) using multiple unmanned aircraft. We expect to corroborate such measurements with existing near-field remote sensing observations and will provide validation of species retrieval models from AVIRIS (CO2) and MASTER (SO2) remote observations as well as for species dispersion and transport models, via simultaneous low altitude UAV and aerostat under-flights. Of particular interest will be the detection (and its limits) of the diffuse volcanogenic CO2 flux versus background, the contrast in dispersion mechanisms of the two gases, as well a determination of the stability the SO2/CO2 ratio as perceived in the remotely sensed data as a function of distance-from-source and time as compared to in situ data. In addition, we will utilize a miniaturized field mass spectrometer (<1ppm sensitivity) for determination of the full mass spectra of all gases emitted (up to 100amu), and for field corroboration of abundance values measured by our electrochemical gas-specific detectors (~1ppm sensitivity). In addition, we will task the ASTER instrument to acquire data simultaneously (or as close in time as possible) to the AVIRIS/MASTER-UAV flights to provide yet another layer of comparison of scale and spectral response, especially important for developing a canny strategy to use HyspIRI to extend the already 15 year long ASTER time series of multispectral global volcano observations. Beyond scientific analyses of the MASTER and AVIRIS over-flight data, our larger goal is to develop standard and economical techniques for such in situ measurements that will eventually routinely inform analyses of HyspIRI data, thereby increasing both their accuracy and precision. Finally, all relevant volcano data collected during our UAV flights, along with the relevant collection of corresponding AVIRIS/MASTER data acquired by the planned ER-2 Hawaii overflight, as well as corresponding relevant ASTER data will me made immediately available online to all investigators via a special HyspIRI page that we will institute within our ASTER Volcano Archive (http://ava.jpl.nasa.gov; Pieri, PI). In addition, we will be delighted to offer to host similar data contributions from other investigators within this HyspIRI Prep and Associated Science program.

Michael Ramsey/University of Pittsburgh
Quantifying Active Volcanic Processes and Mitigating their Hazards With HyspIRI Data

The Hyperspectral Infrared Imager (HyspIRI) mission concept brings together two sensors that will allow unique opportunities for synergistic science in a wide range of disciplines. Analysis of the temporal trends in such image-based datasets can provide critical insights into ongoing/dynamic geologic processes. For example, monitoring of the eruption rate (derived from a vent's thermal output) combined with quantitative extraction and correction of the thermal infrared (TIR) radiance data for emissivity and the visible/short wave infrared (VSWIR) radiance data for reflectance gives a complete view of the cooling, emplacement and hazard potential of a lava flow or the explosive potential of lava dome. The PI's research group has shown that sub-pixel temperature anomalies occurring within these volcanic products influence the accuracy of the derived emissivity and therefore the ability to model the pixel-integrated temperature and composition (Lee et al., 2013, Rose and Ramsey, 2009). Such anomalies also relate to non-Lambertian scattering in the VSWIR due to viewing geometry and surface properties. The prior studies have used data from the laboratory and the spaceborne ASTER sensor to model these affects and simulate their impact on a future HyspIRI sensor. The results are reported in HypsIRI high-temperature saturation study and cited for the need to increase the saturation temperature of the mid-infrared channel (Realmuto et al., 2011). What is still lacking, however, is the measurement of active lava flow properties at spatial scales aggregated up to HypIRI's proposed resolution, combined with coincident in-situ ground and spaceborne measurements to validate the modeling approach.

The deployment of NASA airborne assets to the island of Hawaii will provide unique opportunities to simulate future HyspIRI data specifically for the study of active volcanic processes. The current phase of the Pu'u O'o eruption is producing lava flows that are threatening the town of Pahoa and the active lava lake in Kilauea crater is generating large amounts of SO2 that affects much of the islands inhabitants. Therefore there is a both a scientific and hazard relevance to the data collection and this study.

For the research proposed, the airborne data will be forward-modeled using a quantitative resampling methodology to create radiometrically accurate 60m/pixel HyspIRI analog data (Hughes and Ramsey, 2013). During the overflights, ground-based multispectral TIR data will be acquired from a new instrument and the combined results used to understand the compositional, temporal and thermal trends in the VSWIR and TIR data. The goal is to develop a correction approach for thermally-mixed HyspIRI data to better monitor and predict future volcanic hazardous phenomena. This approach will rely on a combination of the VSWIR and TIR data and will address several of the science questions described by the HyspIRI Science Study Group (SSG):

tq1: How can we help predict and mitigate earthquake and volcanic hazards through detection of transient thermal phenomena?

cq3: Do volcanoes signal impending eruptions through changes in the temperature of the ground, rates of gas and aerosol emission, temperature and composition of crater lakes, or health and extent of vegetation cover?

cq5: What is the composition of exposed terrestrial surface of the Earth and how does it respond to anthropogenic and non-anthropogenic drivers?

The temporal and spatial trends extracted from these new HyspIRI-analog datasets will address the science hypotheses: Volcanic processes derived from high temporal, high spatial resolution VSWIR/TIR orbital data can be used for monitoring (e.g., eruption prediction). The proposed research will partially fund the PI and fully fund a graduate student researcher. It will leverage the PI's previously funded NASA and NSF research as well as the long history and experience orbital and ground-based TIR studies of active volcanoes.

Vincent Realmuto/Jet Propulsion Laboratory
Mapping the Composition and Chemical Evolution of Plumes from Kilauea Volcano

The return of eruption activity to the summit of Kilauea in 2008 has increased summit emissions of sulfur dioxide (SO2) gas dramatically, and the conversion of SO2 to sulfate (SO4) aerosol leads to the formation of volcanic smog, or vog, which is a noxious and corrosive suspension of SO2, fine-scaled (PM2.5) SO4 aerosols, and water droplets. The adverse effects of vog on communities downwind of Kilauea include aggravation of respiratory and pulmonary disease, plant disease and death, acidification of drinking water, and corrosion of physical property. To mini-mize the public exposure to vog, the Hawaii Department of Health (DOH) issues air quality alerts based in part on forecasts of SO2 and SO4 concentrations from the Vog Measurement and Prediction Project (VMAP) at the University of Hawaii-Manoa (UH). The VMAP forecasts are initialized with SO2 emission rates measured by the USGS Hawaiian Volcano Observatory (HVO), and the accuracy, or skill, of the forecasts are evaluated through comparisons with air quality measurements at a sparse network of DOH ground stations.

HyspIRI will make substantial contributions to the effort to monitor air quality in Hawaii by providing at least two TIR (day + night-time) observations every five days and at least one VSWIR + TIR observation every 19 days. These observations will be used to estimate SO2 and SO4 concentrations at a spatial resolution of 60 m, and thus improve the initialization and validation of VMAP forecasts. The HyspIRI Airborne Campaign to Hawaii provides a unique opportunity to refine and validate retrieval algorithms and evaluate the contributions of high-resolution SO2 and SO4 data products to the forecasting skill of the VMAP Vog Model. We have designed a comprehensive project, in collaboration with our colleagues at the HVO and UH, to prepare for the use of HyspIRI data to monitor the impact of volcanic plumes on air quality in Hawaii.

We will use MASTER TIR data to map the initial concentrations of SO2 at the summit of Kilauea and track changes in concentration with increasing distance from the vent. We will use AVIRIS VSWIR data to map changes in the mass concentration and physical properties of the aerosols based on changes in the apparent reflectance of surfaces beneath a plume. The age of a plume increases in the downwind direction, and flights along the length of a plume will document its physical and chemical evolution over time. Our TIR and VSWIR data products will provide better constraints on the rates at which

SO2 converts to SO4 and map any spatial variability in the conversion rate. We will validate our data products with ground-based measurements provided by our HVO and UH colleagues, and extrapolate our local airborne measurements to regional scales through comparisons with contemporaneous ASTER. MODIS, VIIRS, OMI, and GOSAT data. Finally, we will input our data products into the Vog Model to demonstrate improvements to the forecasting skill of the model.

With regard to the HyspIRI Science Questions, we will address elements of TQ1 through the use of MASTER TIR data to map volcanic SO2 plumes and track changes SO2 emission rates. We will address CQ3 through the combination of MASTER TIR and AVIRIS SWIR data to study the formation and dispersion of SO4 aerosol. In a broader sense, the impact of vog on the emissivity of lava flows and local vegetation are relevant to Science Questions TQ5/CQ5 and VQ4/VQ5, respectively. Similarly, our research will be relevant to NASA programs in atmospheric science (formation and dispersion of aerosols), solid earth science (surface expression of magma dynamics), and applied sciences (air quality and human health).

Richard Vaughan/U.S. Geological Survey Flagstaff
Developing An Automated Volcanic Thermal Alert Algorithm Using Moderate Spatial Resolution VSWIR and TIR Data: Implications For the Future HyspIRI Mission

Volcanic activity is commonly preceded by anomalous thermal activity on time scales of days to months, yet this is usually only recognized retrospectively. Any possibility of forecasting volcanic unrest or related hazards based on precursory thermal signals requires the rapid and robust detection of relatively subtle anomalies. Every volcanic geothermal area has a spatially and temporally unique background thermal signature. Therefore, even the potential for forecasting can only be accomplished if the background thermal variance is well-understood, and only operationally useful if an automated thermal alert algorithm is implemented and tested in a way that its uncertainties are rigorously known.

Current satellite-based thermal alert systems utilize high-temporal (daily), low-spatial resolution (1-km pixels) satellite data to rapidly analyze the global image dataset for thermal anomalies (e.g., fires and volcanic hot spots). Various thermal anomaly detection methods (e.g., VAST, MODVOLC, RST) use spectral value thresholds, spatial context, temporal variance approaches, or some combination thereof, all trying to minimize human intervention, as well as minimize false positives and false negatives. However, no thermal alert system is perfect.

When HyspIRI is operational, it will offer an unprecedented combination of moderate-spatial resolution (60-m pixels), and visible-shortwave infrared (VSWIR) through thermal infrared (TIR) data, with a temporal resolution of 5 days for the multispectral TIR data and 19 days for the hyperspectral VSWIR data. This offers an opportunity to develop a novel volcanic thermal alert algorithm that will improve our ability to automatically detect thermal anomalies. We have a design for an automated, robust thermal outlier detection algorithm that is based on statistically rigorous numerical methods, which (1) combines positive aspects of pre-exiting methods, (2) takes advantage of the spectral, spatial, and temporal resolution of HyspIRI, and (3) fuses HyspIRI data with other archived and concurrent data sets to add more value to the thermal alert system. We propose to use HyspIRI-like data acquired in Hawaii during the planned 2016 airborne campaign to develop, test, and demonstrate the effectiveness of the new algorithm and to quantify its improvement over current thermal alert algorithms with respect to correctly identifying a wider range of real thermal anomalies while reducing both false positives and false negatives. We will also collaborate with the USGS Hawaiian Volcano Observatory to facilitate concurrent acquisition of high-spatial resolution (<1-m pixel) airborne TIR data (part of their operational monitoring duties) to generate accurate measurements of the sub-pixel-scale temperature structure to compare to the 60-m HyspIRI-like data. With a properly-designed thermal alert algorithm, the number of false negative anomaly detections will decrease significantly, increasing the likelihood of detecting elusive precursor thermal activity.

The proposed work is directly relevant to the following HyspIRI science questions related to volcanology research: TQ1a (Do volcanoes signal impending eruptions through changes in surface temperature or gas emission rates, and are such changes unique to specific types of eruptions?), and TQ1b (What do changes in the rate of lava effusion tell us about the maximum lengths that lava flows can attain, and the likely duration of lava flow-forming eruptions?). Also, the work is indirectly related to HyspIRI science questions: CQ3c (Can measurements of the rate at which lava flows cool allow us to improve forecasts of lava flow hazards?), and TQ5c (How do surface temperature anomalies relate to deeper thermal sources, such as hydrothermal systems, buried lava tubes, underground coal fires and engineering structures? How do changes in the surface temperatures relate to changing nature of the deep seated hot source?).