AUTONOMOUS VEGETATION COVER SCENE CLASSIFICATION OF EO-1 HYPERION HYPERSPECTRAL DATA.
R. J. Lee[1], A. G. Davies[2], and the ASE Science and Flight Teams. [1]Department of Geosciences, Trinity University, San Antonio, TX, 78221 (Tel: 210-771-1880. Email. rlee@trinity.edu) [2]Jet Propulsion Laboratory-California Institute of Technology, Pasadena, CA 91109.

Introduction: The Autonomous Sciencecraft Experiment (ASE) is a JPL-led, New Millennium Program mission containing new technology in the form of software to be flown on the Earth Observer-1 (EO-1) satellite in early 2004 [1, 2]. This new technology will facilitate an artificially intelligent machine with autonomous science-driven capabilities. Among the ASE flight software is a set of onboard science algorithms designed for autonomous data processing, primarily based on change detection from observation to observation [1, 2, 3]. Using the output from these algorithms, ASE has the ability to autonomously modify the EO-1 observation plan, retargeting itself for a more in-depth observation of a scientific event in progress. Furthermore, intelligent and selective information down-linking will maximize return of the most valuable scientific data. Among the algorithms developed for use on ASE is a Lava-Vegetation (L-V) detection algorithm. This algorithm can effectively identify the initial location and extent of lava and vegetation coverage based on spectral shape. Comparison of several different observations, all classified via this algorithm, can make change detection possible.

The Hyperion Instrument: Hyperion is a hyperspectral imaging spectrometer on board the EO-1 spacecraft, which is in Earth-orbit. Hyperion produces spectra with 226 wavelengths covering the range 0.4 to 2.4 microns with a spatial resolution of 30 m per pixel. For ASE purposes, the instrument images a 7.5 by 15 km swath.

Algorithm Development: In order to derive the L-V algorithm, six Hyperion daytime images of volcanic areas were used: two of Kilauea in Hawaii, two of Mt. Etna in Sicily, Italy, and two of Erta‘Ale in Ethiopia. Using ENVI software to view the images, the spectra from approximately forty randomly chosen pixels on one Kilauea image were closely examined. A strong absorption of red light at band 34, called the “red edge”, was observed in some of the spectra. [4] Because this spectral feature is characteristic only to vegetation spectra, those spectra containing the “red edge” were determined to represent vegetated pixels. Those spectra that did not contain the “red edge” therefore represent non-vegetated pixels. Two bands were chosen from the spectrum for analysis: band 34 and band 41. The choice of these bands was based primarily on ease of identification in the spectrum. In spectra representative of vegetated areas, the “red edge” was present, and the DN value of band 34 was consistently of an equal or lower value than band 41. When the behavior of these two bands was observed on spectra from the remaining five Hyperion images, the same spectral observations were made. Based on these observations, the following algorithm was developed: If 34< or = 41, then vegetation. If 34 > 41, then lava (non-vegetated). This algorithm has proved highly effective in discerning areas of lava (non-vegetation) from areas of vegetation.

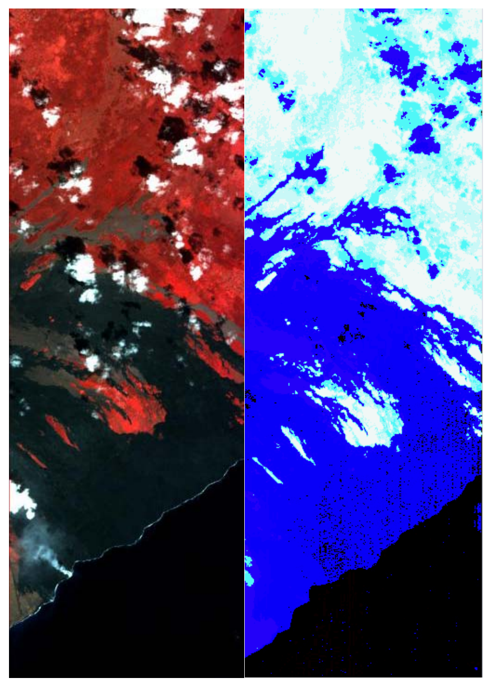

Figure 1: University of Arizona Land/Water Classifier. *The left image (above) is the original Kilauea image and on the right is the classified image using the designated algorithm running order. On the classified image, water is black, lava is dark blue, and vegetation is white/light blue. Clouds have not yet been removed from this image, and have been classified as lava. All vegetation and most lava have now been correctly classified by the L-V classifier. Some misclassifications exist, but this particular land-water classifier is extremely promising.*

Results: Formal testing of the algorithm on each of the six Hyperion images produced six different "classified" images, depicting each pixel classified as either vegetation or lava (non-vegetated). Through comparison of these images, the L-V algorithm has proved to be a very accurate detector of vegetated and non-vegetated (lava) pixels. However, the classifier proved to be problematic when analyzing cloud and water pixels, incorrectly classifying them as lava based on spectral similarities.

Land/Water Classification: In order to improve the accuracy of the L-V algorithm, several different science algorithms were applied to the Kilauea image in a particular order. Firstly, a cloud algorithm, developed by MIT Lincoln Labs, was applied to the data. All pixels classified as cloud were "removed" from the image. Then the SWIL (Snow, Water, Ice, Land) classifier, developed by ASE Team members at Arizona State University, was applied to the image. The SWIL classifier was specifically developed to distinguish ice, snow, water, and land areas from each other. Since SWIL was not engineered to recognize and accurately classify lava, it actually classified the lava areas as ice, a problem as correct classification of land features and water is vital to the accuracy of the L-V algorithm. A land-water algorithm developed by ASE Team members at the University of Arizona was applied to the Kilauea image in an effort to test its accuracy against that of SWIL. Because this algorithm was developed specifically for the classification of land and water, it was hypothesized that it would prove more accurate. Figure 1 shows the resulting classified image using this new classifier. Algorithms were run in the same order as above. It is clear that with the use of this new land-water algorithm, land and water are slightly more correctly classified, even though a few lava pixels on the image remain incorrectly classified as water (black). In order to correct this, the land-water algorithm must be modified.

Conclusions: The L-V algorithm best serves as a vegetation detector, classifying all pixels not representing vegetation as "non-vegetated", or in this case "lava". In many other images other ground types besides lava and vegetation exist. Applying the current L-V algorithm to these images will result in all non-vegetated ground types being classified as lava, regardless of actual composition. This can prove to be a significant problem, specifically in regards to accuracy in the identification of lava coverage. The problem can be overcome, however, through the development and use of more algorithms, each tailored to take many different non-vegetated ground types into account. Although the L-V classifier does not have the ability to distinguish new, hot lava from older, cool flows, an ASE thermal anomaly classifier has been developed specifically to address this issue [2]. Nevertheless, the L-V algorithm has proven to be a very accurate classifier of both shadowed and non-shadowed vegetated and non-vegetated (lava) areas on these six Hyperion images, using only two bands. Additionally, a new land-water classifier has being developed by the ASE Science Team. Currently, the L-V algorithm is undergoing sensitivity testing to ensure that the bands used in the algorithm are the most effective, and the classifier will be tested on more data in the future in an effort to understand its full effectiveness. Using the L-V algorithm, it will be possible to compare several 'classified' images and study the encroachment of lava, extent of ash fall, or deforestation by fires over vegetated areas, thus fulfilling one of the main goals of ASE (detection and quantification of change).

Application: The L-V Classifier will be uploaded as part of ASE to EO-1 in early 2004, a part of the new technology demonstration of autonomous, science-driven, spacecraft operations.

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