2012

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Abstract: Multispectral imagery and imaging spectrometer data are used to develop prototype map products for improved earthquake response. A tiered approach keyed to post-event communications infrastructure is directed at providing critical information to emergency services personnel.

OCIS codes: (280.0280) Remote sensing and sensors; (110.4234) Multispectral and hyperspectral imaging; (100.2960) Image analysis

1. Introduction

The Naval Postgraduate School (NPS) Remote Sensing Center (RSC) is conducting a remote sensing pilot project in support of California post-earthquake-event emergency response [1, 2]. The project goals are to dovetail emergency management requirements with remote sensing capabilities, inform selected California State and local emergency service personnel of current capabilities and potential, and identify gaps between requirements and capabilities. NPS is coordinating with emergency management services to compile information from Subject Matter Experts (SMEs) about essential elements of information (EEI) requirements for earthquake response. A wide variety of remote sensing datasets have been assembled by NPS for the purpose of building imagery baseline data; and to demonstrate the use of remote sensing to derive ground surface information for use in planning, conducting, and monitoring post-earthquake emergency response. These diverse datasets include multispectral and imaging spectrometer (hyperspectral) data, point-cloud LiDAR data and digital elevation models (DEMs), aerial photograph mosaics, and polarimetric Radar. Critical infrastructure information is obtained and integrated with the remote sensing data using on-the-ground surveys tied to SME knowledge for EEIs. Analysis results from these data are being compiled using a geographic information systems (GIS) approach to generate multi-tiered products tied to the communications systems available following an emergency event (internet access + cell, cell only, no internet/cell). Technology transfer of these capabilities to local and state emergency response organizations will ensure that emergency responders will receive timely critical information required for their post-disaster operational scenarios (common operating pictures).

2. Datasets and Approach

This summary discusses preliminary analysis results from imaging spectrometer data at two spatial resolutions and WorldView-2 (WV-2) 8-band multispectral imagery. Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) data [3, 4] were collected during June and September 2011 at 7m and 2.4m spatial resolutions respectively for the Monterey Peninsula area, Monterey County, California. These data were corrected to reflectance using an atmospheric model [5, 6], and analyzed using N-dimensional analysis and spectral-feature-based methods [7-9] to extract locations for key ground-surface materials. Image spectral signatures were used to identify selected materials [10], including several varieties of green vegetation, dry vegetation, surface mineralogy, and specific man-made materials (asphalt and concrete roads and other surfaces, and roofing material types such as red tile roofs, cedar shake shingles, and asphalt shingles). LiDAR point cloud data were also used to help separate materials that were spectrally similar in the HSI data, but with different spatial occurrence and morphology [11]. Partial spectral unmixing [8] was used to extract and map spectral endmembers and abundances using both AVIRIS datasets. WV-2 eight-band data at approximately 2.25m spatial resolution for the Monterey Peninsula were processed to reflectance in a similar fashion, analyzed using the spectral mixing approach [8, 12], and compared to the AVIRIS results to help validate the use of HSI approaches for analysis of multispectral data for material identification and mapping and to determine the effect of spectral resolution on the process.

3. Preliminary Results and Conclusions

Previous research has shown that spectral mapping accuracy generally decreases with decreasing spatial resolution, particularly for materials with similar spectral signatures and for smaller spatial occurrences [7, 13-15]. The use of linear spectral unmixing [8] can help mitigate these effects, as this approach allows non-literal recognition of materials at aerial coverages down to around 3% of a pixel (depending on spectral contrast). The spectral matching approach and linear spectral unmixing were used to extract and map endmembers from both AVIRIS datasets, with identical spectral resolution, but different spatial resolutions at approximately 7m and 2.4m (Fig. 1). Spectral endmembers were generally similar for both spatial resolutions; however, both the number of endmembers and total relative abundance changed between the two for most materials. Initial results support the conclusions of [13-15]. We plan quantitative comparison of the mapping results and abundance estimates. Geographic Information System (GIS) layers are being created from the imaging spectrometer data analysis and the 7m and 2.4m results will be compared further to help determine spatial resolution effects on the spectral mapping. It remains to fully determine the spatial resolution effects on the ability to detect and map specific materials and post-earthquake-event changes.

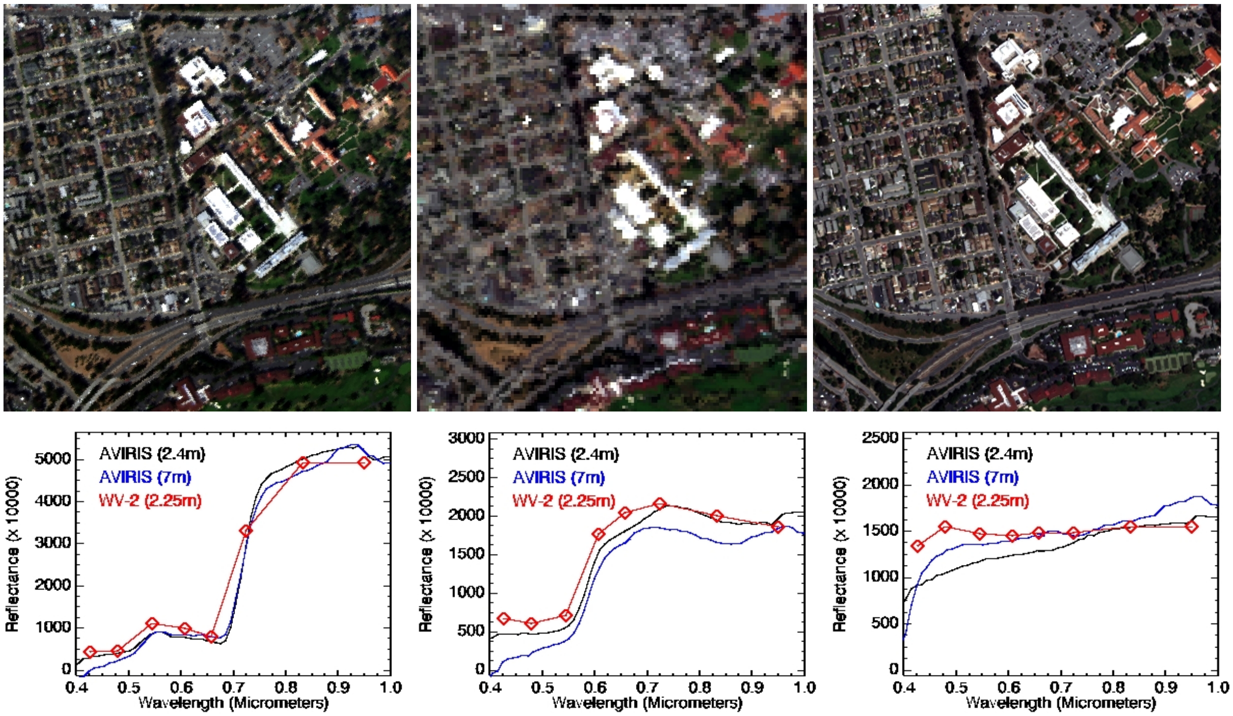

Fig. 1: AVIRIS and WV-2 spatial and spectral data comparisons. Top-Left: AVIRIS true color image at 2.4m spatial resolution. Top-Center: AVIRIS true color image at 7m spatial resolution. Top-Right: WV-2 true color image at 2.25m spatial resolution. Bottom Left: Comparison of green vegetation reflectance spectra (grass) for varying spatial and spectral resolutions. Bottom Center: Comparison of red tile roof reflectance spectra for varying spectral and spatial resolutions. Bottom-Right: Comparison of asphalt pavement reflectance spectra for varying spectral and spatial resolutions.

WV-2 multispectral 8-band data at approximately 2.25m spatial resolution were also analyzed to compare the effect of reduced spectral resolution on identifying and mapping earth surface materials in support of disaster (earthquake) response. Again, the Monterey area was used as the test case. The WV-2 mapping results at approximately 2.25m spatial resolution were compared to the AVIRIS mapping results at approximately 2.4m spatial resolution. Initial results demonstrate that the WV-2 data actually do very well in the VNIR for identification and mapping of selected materials based on multispectral signatures (Fig. 1) and comparison with the HSI signatures. Comparison of WV-2 spatial mapping results to the AVIRIS spectral mapping at both spatial resolutions is in progress and will include quantitative comparison of the multispectral mapping versus the hyperspectral mapping at approximately the same spatial resolution to determine spectral resolution effects on the ability to detect, identify, and map materials important for assessment of earthquake damage.

4. Future Efforts

NPS is also analyzing similar datasets for more seismically active urban areas such as Los Angeles and San Diego California using the same approaches. Image analysis results and supporting geologic, geophysical, and geographic information are being compiled using GIS and we are working on the multi-tiered product concept for distribution of baseline and post-event imagery-extracted information to 1st responders and emergency services personnel. The intent is to utilize remote sensing data analyses to produce a variety of products that insure that emergency responders will receive critical information tied to the communications systems available following an emergency event. We expect that the remote sensing datasets used, approaches, methods, and products developed for this pilot study will provide improved situational awareness in support of earthquake response, and form a model for future, regionally (and potentially nationally) expanded disaster response efforts using remote sensing data. We are also working on "play books" showing how to build the information products that will assist with the technology transfer process.

5. Acknowledgements

This research is supported by the Science and Technology (S&T) Directorate, Department of Homeland Security (DHS). We gratefully acknowledge the participation of emergency responders and managers from the cities and counties of Monterey, Los Angeles, San Diego, and Riverside California. We also appreciate contributions during project definition stage and follow-ups by the California Emergency Management Agency (Cal EMA) and the Federal Emergency Management Agency (FEMA), the U.S. Geological Survey, and DHS. AVIRIS data were acquired by NASA/JPL. The LiDAR data were provided by the Association of Monterey Bay Area Governments, via a USGS grant through the American Reinvestment and Recovery Act of 2009. WV-2 data were provided by the National Geospatial Intelligence Agency (NGA) under the NextView imagery license agreement.

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