HYPERSPECTRAL TECHNOLOGY TRANSFER TO THE U.S. DEPARTMENT OF INTERIOR: STATUS AND RESULTS OF THE NASA/DEPARTMENT OF INTERIOR HYPERSPECTRAL TECHNOLOGY TRANSFER PROJECT

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1. Introduction

In 1997 the Office of Biological Informatics and Outreach (OBIO), Biological Resources Division, US Geological Survey and NASA, Office of Earth Science (OES), initiated a coordinated effort for applying AVIRIS data and analysis, as a technology transfer project, to critical Department of Interior (DOI) environmental issues on four study sites throughout the United States. This work is being accomplished by four DOI study teams with support from NASA/OES principal investigators and the Office of Earth Science programs. Descriptions of these study sites including personnel, objectives, background, project plans and milestones were described in Getter and Wickland (1998), and may also be viewed on the project website at <http://biology.usgs.gov/hwsc>. This presentation is a status report of the second year's effort of a multi-year project detailing accomplishments to date, benefits realized to participating DOI bureaus, and lessons learned up to present time.

2. Background

The goals of this undertaking, as originally developed by the project's steering committee are: (1) Provide DOI technical and resources management personnel information and technical assistance on hyperspectral systems and advanced technologies, (2) Focus on a limited number of resource issues or problems of interest to DOI that could potentially be addressed using hyperspectral remote sensing technologies, and (3) Use workshop formats for introducing DOI resource personnel to hyperspectral technologies, and to evaluate the results of the four pilot studies.

These studies are being conducted only with funds and/or resources committed by the participating bureaus. Studies were selected on the basis that baseline information pertinent to each of the studies proposed was already well developed and readily available. NASA contributed AVIRIS missions for each of the selected sites, and provided technical assistance both directly and through partnering organizations. Details about each of the four study sites may be found in Getter and Wickland (1998), but for summary purposes, a synopsis of each study site is provided below under the discussion of project status.

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3. Anticipated outcomes

The entire project, including all technical and logistical aspects will be documented in a formalized report to the DOI Science Board. It is also anticipated that results of this research will be published in an appropriate journal in the scientific literature. The results will also be available through the National Biological Information Infrastructure (NBII) at <http://www.nbii.gov>.

A workshop is planned as a method for porting the technology to the DOI/Bureau technical line manager. The strategy is to use the experience of these selected studies to develop the curriculum for a workshop sponsored by NASA and DOI and probably held at the USGS EROS Data Center. The workshop agenda will provide for a tutorial of the advanced systems covering: 1) characterization of system hardware and software, 2) characterization of hyperspectral data, 3) exploitation and expectations of the data, and 4) known successes and failures in the use of the data and/or technology.

4. Project status

A summary of each of the four study sites is provided below including the personnel involved, objectives, and brief background information. The current status of each site is also described in terms of accomplishments to date, benefits to DOI land managers and study site partners, and discussion of lessons learned.

Study site 1 - Mapping vegetation alliances, Congaree Swamp National Park, South Carolina.

Personnel:

PI's: Mike Story of the National Park Service and Dr. Mary Martin, University of New Hampshire.

Objectives:

The primary objective of this project is to incorporate the use of AVIRIS imagery with existing aerial photography and field collected vegetation data in order to evaluate the ability of the AVIRIS data to accurately map the variety of tree species found at COSW.

Background:

The COSW project includes approximately 30,000 acres of old-growth forest just Southeast of Columbia, SC. It contains a complex mosaic of wetland and upland communities. COSW is subjected to occasional hurricanes that can cause severe destruction to these communities. An important element of the NPS mission to manage the resources at COSW includes understanding the complex relationships of these communities and the changes that occur as a result of the destructive winds.

Accomplishments to date:

Low altitude AVIRIS data were acquired October 24, 1998 during fall leaf change, which is an ideal time to optimize species distinction. High altitude AVIRIS data were also acquired on May 17, 1999. Limited field spectra were obtained in July, 1998. Color composites of selected bands and 3-color composites of selected principal components show strong spectral contrasts. Detailed forest canopy texture is visible in the low altitude data. Preliminary spectral analysis of both low and high altitude data sets have yielded very promising results for mapping at the vegetation alliance level, and in some cases the species level.

Benefits realized to DOI land managers and study site partners:

These data are helping land managers at Congaree Swamp better understand the complexity of the distribution of old growth tree species within the park and NPS personnel are gaining experience in hyperspectral imaging analysis.

Lessons learned:

Hyperspectral characteristics of AVIRIS can contribute to the understanding and mapping of species and vegetation associations. However, geometric anomalies, which were found in both the low and high altitude data are inhibiting use of the data for mapping purposes. Both scenes were found to contain non-systematic geometric characteristics that cannot be eliminated via traditional registration techniques.

Study site 2 - Estimating the effect of invasive woody species on grasslands, Great Plains Basin.

Personnel:

PI's: Dr. Dave Meyers, B. Wylie, M. Choate, US Geological Survey, EROS Data Center and Dr. Carol Wessman, University of Colorado with The Nature Conservancy, Augustana College, North Dakota State University, the University of Toronto, the University of Nebraska, and Oklahoma State University.

Objectives:

The objective of this study is to use spectral signature analysis and linear spectral mixing models to determine the degree to which a grassland spectral signature is influenced by woody species. Ultimately, these results will provide a means to quantify species gradients, allowing the isolation of the woody components in land cover mapping over the grasslands.

Background:

The focus of this study is to investigate the effectiveness of AVIRIS for mapping the encroachment of woody species on grasslands in the Great Plains. Several test sites, owned by the Nature Conservancy, were chosen to map specific invasive plants: Tallgrass Prairie Preserve (OK) and Konza Prairie Preserve (KS) for mapping oak and juniper species, and the Niobrara Valley Preserve (NE) for mapping sumac and juniper species. The preliminary work reported here focuses on the Niobrara site, because the intermixing of eastern red cedar with ponderosa pine poses a particularly difficult spectral discrimination problem.

Accomplishments to date:

The 1999 data acquisition season was highly productive, with extensive ER-2 (high altitude) coverage over all three sites (Niobrara on 7/7/1999, Tallgrass on 7/13/1999 and 7/19/1999, and Konza on 7/13/1999), and multiple Twin Otter (low altitude) visits to Niobrara (7/22/1999 and 11/11/1999). Work began on the 7/22 low-altitude acquisition at Niobrara, because necessary geolocation information was missing from the other acquisitions that are required for identifying GPS measured reference points in the imagery. An agreement with JPL will give us access to geolocation information in the future, allowing us to (1) reproduce the JPL geocoding technique, and (2) add terrain correction to the JPL method to remove site-specific geometric artifacts.

The 7/22 low-altitude AVIRIS data at Niobrara was used to develop several methods for discriminating the eastern red cedar (a juniper) from ponderosa pine. The georectified data were corrected for atmospheric effects using ATREM, bands associated with water vapor and ultraviolet ozone absorption were removed, and a minimum noise fraction (MNF) transformation was applied to prepare the data for analysis. For our purposes, an MNF threshold of 2.0 was chosen, yielding 23 MNF bands.

The first approach followed the “spectral endmember” approach: (1) find “pure” pixels, (2) identify endmember via “n-dimensional visualization” tools, identify endmembers then perform unmixing. Up to 40,000 iterations of the “pixel purity index” algorithm was run in an attempt to find endmembers associated with the different species, without success. We attribute this failure largely to our inexperience with hyperspectral data, coupled with the difficulty in separating juniper from pine as endmembers. In another approach, field training sets of different woody types (juniper, pine, deciduous and sumac) were used in a “matched filtering” scheme on MNF transformed data. Errors of omission and commission were reasonable using this approach.

A third approach, employing decision trees, met with considerable success, the results of which will be presented at the JPL Airborne Science Workshop (February 23-25, 2000). This uses hyperspectral data in a manner similar to the classification techniques used to generate the Multiresolution Land Cover (MRLC) classification, with considerable success.

We look forward to receiving the 11/11/1999 acquisition, because the deciduous leaves were off at that time, exposing the junipers under the canopy. This is a common propagation method for the junipers: develop in the understory, then spread into the grasslands. Also, the junipers dried down more rapidly than the ponderosas, causing a significant color difference between the two species. This provides ideal conditions for identifying junipers distinctly from pines.

Future plans:

(1) develop precision corrections for ER-2 and Twin Otter, (2) complete the 7/22 analysis, (3) analyze the 11/11 data, (4) analyze the ER-2 data, (5) post-validation of results.

Benefits realized to DOI land managers and study site partners:

Ability to remotely distinguish between exotic eastern red cedar and native ponderosa pine is of significant value to a variety of Great Plains land managers committed to monitoring and/or controlling increasing populations of invasive eastern red cedar.

Lessons learned:

End-member pixel unmixing analysis appeared to have limited usefulness for separating eastern red cedar from ponderosa pine, possibly because of the study team’s inexperience with the technique, but more likely because of the closeness of their spectral signatures.

Matched filtering and the MRLC decision tree classification techniques both appear to be effective for separating eastern red cedar and ponderosa pine.

In order to effectively validate classification results, geocoding techniques applied to AVIRIS data need to be refined to handle localized geometric artifacts and provide for terrain correction.

Study site 3 - Identify and map leafy spurge infestations, Theodore Roosevelt National Park, North Dakota

Personnel:

PI's are Dr. Ralph Root, USGS-BRD, Steve Hager, Theodore Roosevelt National Park, Dr. Gerald Anderson, Agricultural Research Service, Dr. Susan Ustin and Michael O'neill, University of California – Davis.

Objective:

The objective of this project is to determine the extent to which hyperspectral imaging can be used to develop automated methods for detecting and mapping the extent of the leafy spurge (*Euphorbia esula L.*) infestation in Theodore Roosevelt National Park

Background:

Leafy spurge (*Euphorbia esula L.*) is a troublesome invasive non-native plant on the Northern Great Plains of the United States. Current research shows that leafy spurge is a serious invader into the south unit of Theodore Roosevelt National Park near Medora, North Dakota. This aggressive invasion has displaced many native plant species. In addition to destroying the rich species diversity unique to the badlands, significant ecological impacts are resulting. Infestations have grown from 13 ha. in 1972 to an estimated 702 ha. in 1993, 4% of the park's 18,680 ha. land base. Currently, leafy spurge is the number one resource threat to the park and environs. The Resource Management Plan of Theodore Roosevelt National Park identifies a requirement of intensive management to reduce and contain these infestations in keeping with the "preserve and protect" mandate of the National Park Service.

Accomplishments to date:

Low altitude AVIRIS data were acquired in October, 1998. High altitude AVIRIS data were acquired in July, 1999. Ground calibration and field spectra were collected in support of both data collection events. Leafy spurge has been successfully extracted via a "selected end member" pixel unmixing technique. Further work will include analysis of additional hypercubes and neighboring flight lines. Results will be validated via quantitative accuracy assessment with ground data delineated by sub-meter global positioning systems. Difficulties were found with consistent geo-positioning on both the AVIRIS data and photo-interpreted verification data, making quantitative accuracy assessment a problematic issue.

Benefits realized to DOI land managers and study site partners:

The study team is contributing to the park's top priority resource management problem, which is controlling highly aggressive leafy spurge infestations. As a result of this study, the park's visibility in the scientific community has been elevated as its management challenges with invasive plants are communicated to many of the nation's leading remote sensing specialists. Partners involved in the study are learning a valuable and potentially effective new technology for invasive species management. Two additional studies have been spawned as a result of the current study. Detection and mapping of leafy spurge using orbital hyperspectral imaging was selected as one of three invasive plant studies on NASA's EO-1 Validation Team. A more regional study, sponsored by TEAM Leafy Spurge in North Dakota <http://www.team.ars.usda.gov/>will compare the cost effectiveness of a cross section of remote sensing techniques and scales for mapping leafy spurge annually on a regional basis. An additional by-product of this study was the development of the Spectral Analysis Management System (SAMS) by the Center for Spatial Technologies and Remote Sensing at UC Davis. SAMS permits a user to browse, sort, and analyze/combine large numbers of ground spectra in support of hyperspectral image analysis.

Lessons learned:

Field activities in support of hyperspectral imaging are costly in terms of equipment, people, and time required.

Because of the need to be in the field at the time of aerial data collection, effective planning and coordination of fieldwork is critical. The timing of overflights in relation to growing season characteristics and field crew logistics are vital to successful data collection.

The study team found that having a state-of-the-art well equipped geospatial laboratory on-site was extremely valuable for nightly downloads and near real-time review/evaluation of ground data collected each day.

The study team's first attempt at constructing a quantitative accuracy assessment revealed geo-locational problems in both the AVIRIS data and in the manually interpreted verification data. This underscores the importance of developing consistent and accurate geo-positioning in AVIRIS missions if the data are to be effectively used for mapping applications and merged with other types of geodata in land manager's GIS data bases.

The project, especially in its early stages, was a frustration to park managers as things did not happen any faster than they did, in the context of a time-sensitive and pressing resource problem. As the project evolved and promising results emerged, the relation between pragmatic time sensitive management needs and the characteristic longer-term nature of research came into perspective.

Study site 4 - Mapping of mercury-containing mineral sources in the Owyhee Reservoir watershed, Oregon

Personnel:

PI's Ron Pearson, Douglas Craft, and David Zimmer, Bureau of Reclamation, Dr. Roger N. Clark, U.S. Geological Survey, and Paul Seronko, Bureau of Land Management

Objectives:

This study proposes to include Landsat TM and AVIRIS mineral classification as a cost effective means for mapping the (largely) exposed surface mineralogy of the watershed and identifying source areas for naturally occurring Mercury containing minerals. Due to the areal extent of the Owyhee watershed, an initial assessment of tributary basins will be conducted using Landsat TM imagery to identify those tributary basins with geologic and mineralogic anomalies related to mining and geologic formations associated with mercury. AVIRIS data will then be acquired over those specific watershed tributaries and the reservoir basin to identify specific suspected sources at the much higher spectral and areal resolution of AVIRIS. The AVIRIS mapping will be used to develop land management plans and reservoir watershed management alternatives to limit the amount of Mercury influent to the reservoir.

Background:

Owyhee Reservoir was constructed during the 1930's by the Bureau of Reclamation, and covers approximately 13,900 acres over a lateral distance of 50 miles. Research projects and data collection activities have been limited. While anthropogenic Mercury source areas have been generally identified, very little is known regarding natural sources in the area. The Bureau of Reclamation is currently performing a baseline survey of Owyhee Reservoir for general chemistry and Mercury fate and transport. The reservoir study is evaluating the fate, transport, and transformation of Mercury in Owyhee Reservoir and inflow streams, and is interested in developing a more detailed knowledge of naturally occurring geologic Mercury source areas in the reservoir watershed. The natural and anthropogenic sources of Mercury in the watershed have produced Mercury bioaccumulation problems in local reservoirs, streams, and water bodies. Both Oregon and Idaho public health organizations have issued fish consumption advisories for Owyhee Reservoir, Antelope Reservoir, and several other watershed streams.

Accomplishments to date:

An AVIRIS overflight was successfully completed in July, 1998 and the data were received in mid-1999. Field spectrometer ground calibration and water quality data were successfully collected with USGS Spectroscopy Laboratory and USBR Research Chemistry Laboratory cooperators. Both the flight data and ground calibration spectra were reviewed and determined to be acceptable for the study. Continued work in FY 2000 is contingent upon BOR funding and scheduling priorities.

Benefits realized to DOI land managers and study site partners:

If Mercury-rich volcanic source materials are successfully located and mapped, their contributions to reservoir Mercury levels might be more accurately quantified. Knowing where the sources are, managers may find new options for locally controlling, reducing, or diverting Mercury-laden runoff into the reservoir.

5. References

Getter, James R., and Diane Wickland. 1998. DOI Use of AVIRIS Data In Natural Resources Management – A Technology Transfer Project – Status Report. Summaries of the Seventh JPL Airborne Earth Science Workshop. January 12-16, 1998. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA. Volume 1. AVIRIS Workshop, pp. 149-157.