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## **Abstract**

**DOI Use of AVIRIS Data In Natural Resources Management - A  
Technology Transfer Project - Status Report**

**By**

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The Office of Biological Informatics and Outreach (OBIO), Biological Resources Division, US Geological Survey and NASA, Office of Earth Science (OES), program are coordinating an effort for the use of AVIRIS data and analysis, as a technology transfer project, to critical 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. The four study sites were selected through a DOI competitive proposal process and include mercury contamination at the Owyhee Reservoir, OR; invasive species (leafy spurge) detection, Theodore Roosevelt National Park, ND; National Vegetation Classification System delineation to the alliance level, Congaree Swamp, SC; and separation of woody stems from grasses in the Great Plains Basin Region. This presentation will be a status report of the first years effort of a multi-year project detailing the objectives and plans for the four identified projects.

## **DOI Use of AVIRIS Data In Natural Resources Management - A Technology Transfer Project - Status Report**

### **Introduction**

A meeting was held in December 1996, attended by representatives from Department of the Interior (DOI) and National Aeronautical and Space Administration (NASA) at the request of Department of the Interior Secretary, Bruce Babbitt and NASA, Administrator Director Dan Goldin, to discuss the use of hyperspectral systems and related remote sensing technologies in addressing environmental issues of environmental importance to the (DOI).

It was determined that NASA/DOI Coordination be established, comprised of representatives from each agency, designated to address the environmental issues and resulting technologies. A steering committee was formed consisting of representatives from NASA Headquarters, NASA PI's from University California-Davis, University of Colorado-Boulder, University of New Hampshire and DOI Bureaus ( Indian Affairs, Land Management, Reclamation, National Park Service, and US Geological Survey).

### **Background**

The steering committee provided three primary goals for the activities that were to and are taking place:

Goal 1) Provide technical and resource program personnel from DOI with scientific and technical information on hyperspectral systems and advanced technologies.

Goal 2) Focus on a limited number of resource issues or problems of interest to DOI that could potentially be addressed using hyperspectral, or complementary, remote sensing technologies.

Goal 3) Use of workshop format for DOI Resource Managers tutorial on hyperspectral and/or other advanced remote sensing technologies.

The steering committee solicited environmental issues believed to be most significant to DOI Bureaus as well as the identification of ecosystem areas, throughout the U.S., of importance to current DOI initiatives, to include technical and scientific interest thru a call for proposals, initiated in April 1997, to DOI Bureaus. It should be noted that there were no funds and/or resources to be provided interested parties other than the promise of limited NASA collects for the selected site(s) and a lot of hard work. Other constraints outlined in the solicitation were 1) a commitment from the bureau management that time and resources would be available to work on the project and 2) that there be baseline information readily available on the study site pertinent to the study proposed.

In May 1997, the committee selected four proposed study sites, of ten proposals received, that met the goals and constraints previously set by the committee and the proposal solicitation. All ten proposals were responsive to the solicitation but given the limited resource availability a ranking, rating and prioritization took place. The four selected study sites follow and are not listed in any specific priority order:

- 1- Mapping vegetation alliances, Congaree Swamp National Park, South Carolina.
- 2- Estimating the effect of invasive woody species on grasslands, Great Plains Basin.
- 3- Identify and map leafy spurge infestations, Theodore Roosevelt National Park, ND.
- 4- Mapping of mercury-containing mineral sources in the Owyhee Reservoir watershed, OR.

### **Mini-Workshop**

In July 1997, the DOI and NASA PI's met in Denver, Colorado to discuss each of the selected proposals as it related to each of the studies problem statement to include, description of the area, existing baseline data, ancillary data collection efforts, analysis capability, knowledge of the technologies involved, milestones to be achieved, resource availability, logistics and expectations. Robert Green, NASA/JPL provided an overview of the AVIRIS platform, hardware, software and analysis capabilities along with an appreciation for flight planning logistics. The resulting actions of this two day workshop was to have the DOI and NASA PI's develop implementation plans defined well enough to carry out those activities necessary for the data collection, analysis and evaluation of hyperspectral technology on their respective environmental parameters to be measured. Planning efforts on flight line parameters were to be developed so that information could be transmitted to the NASA, Airborne Science and Applications Program flight control group for mission planning for 1998.

### **Transfer-Communications to Others**

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.nbio.gov](http://www.nbio.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 the hardware, software system, 2) characterization of the system data set, 3) exploitation and expectations of the data, and 4) data fusion, techniques, degree of difficulty in the use, known successes and failures in the use of the data and/or technology.

The US Geological Survey, Office of Biological Informatics and Outreach (OBIO) hosts a World Wide Web (WWW) page for this activity at <<http://biology.usgs.gov/hwsc/>>. The contents of this page consists of a steering committee membership list, the four implementation plans, a hyperspectral imaging searchable bibliography, a list of 200 URL's with hyperspectral

information, links to USGS Spectroscopy Lab, NASA AVIRIS Data Facility, AVIRIS flight line map and some University and vendor sites. It is the intent to use this page as a vehicle for communication to interested parties regarding these study efforts and outcomes.

### **1998 Study Activities**

The study site implementation plans include methodologies and milestones consistent with both budget and personnel constraints of natural resource managers budgets. Milestones for each of the studies are listed with the particular study. The general activities to be performed are: 1) preparation and planning, which is currently on-going; 2) overflight collection with concurrent field observations, April through August 1998; 3) data preparation and analysis will occur as collects become available; 4) products development (ie., maps and stats) to include final study plans, which will be complete by January 1999.

### **Synopsis of DOI Studies**

#### **Mapping Vegetation Alliances at Congaree Swamp National Park South Carolina**

##### **Personnel:**

PI's Mike Story and Rick Clark 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.

The NPS/BRD Vegetation Mapping Program initiated an effort at COSW in the summer of 1996. This effort includes the expertise of personnel from the National Park Service, USGS Biological Resources Division, Nature Conservancy, and the Savannah River Ecology Lab. To date, new CIR photography at 1:12,000 has been collected, initial interpretation of the photography has been completed, 125 vegetation plots have been located and data recorded representing approximately 31 Alliances.

This year, the plot data analysis will be completed followed by the final interpretation of the aerial photography. It is anticipated that the complex mosaics of forest types will be difficult to distinguish with the existing photography. It may be possible to make these distinctions by using the Hyperspectral capabilities of the AVIRIS system. By correlating the data from the known locations of the field sites with geocoded AVIRIS data, we should be able to train one of the spectral classifiers and classify the AVIRIS data into forest types.

#### Transition Plan:

The information gained from this project will be of immediate benefit to the Park and will be made available to them. Results from this project will help further the understanding of the capabilities of the AVIRIS system for mapping complex forests and will be made available to all interested parties.

#### Milestones:

Completed the analysis of field data by Sept. 1997.

Completed the final photo interpretation by Dec. 1997.

Obtain AVIRIS data of COSW in May 1998.

Complete normalization and geocorrection of the AVIRIS data by July 1998.

Complete the classification of the AVIRIS data by Sept 1998.

### **Estimating the Effect of Invasive Woody Species On Grasslands**

#### Personnel:

PI's Dr. Dave Meyers, 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 will be 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 proposed project is a continuation of extensive field, airborne and satellite data collection over several sites across the Great Plains of North America, initially funded by The Nature Conservancy, and later supported by grants from the Centre National d'Etudes Spatiales (CNES) to study the utility of the upcoming Vegetation Monitoring Instrument aboard the System Pour l'Observation de la Terre (SPOT) - 5 platform, and the National Aeronautics and Space Administration (NASA) to study the utility of the enhanced TM Plus (ETM+) system scheduled for launch on the Landsat-7 platform for the given application. This study also complements several projects under consideration for funding, including a study similar to those mentioned above, only using the Moderate Resolution Imaging Spectrometer (MODIS) aboard the Earth

Observing System's (EOS's) AM-1 platform, a grasslands carbon budget study submitted to the National Institute for Global Environmental Change (NIGEC), and a proposal submitted by a Northern consortium to study carbon and water budgets over the upper Missouri River Basin in consideration of the GEWEX/GCIP Northwest study area. EDC possesses the capacity for the management, processing, field validation and analysis of hyperspectral data, hence our requirements are only for data acquisition. We request two AVIRIS overflights at each of two grasslands test sites (4 total): two at the Tallgrass Prairie Preserve Oklahoma, within the Atmospheric Radiation Measurement program's Clouds and Radiation Testbed region (ARM/CART), a warm season tallgrass prairie in the southern Flint Hills; and two at the Niobrara Valley Preserve in Nebraska, partially within the Sand Hills, a prairie having a mixture of warm season and cool season grasses. The Tallgrass site is an area where tallgrass prairie has seen an increase in invasive oak species due primarily to changes in burning practices as lands are taken out of rangeland, and the study at this site will use linear mixture modeling to identify the degree to which these species are intruding into the grasslands. The Niobrara site serves two purposes: first, the identification of cedar and sumac species intruding into the Sand Hills grasslands, and also to determine the effect of the bright, sandy soils on vegetation species identification. At both sites, attempts will be made to identify nitrogen and lignin content and (indirectly) relationships between hyperspectral signatures and expressions of stable carbon isotope ratios as indicators of warm season or cold season grasses (C4 & C3 photosynthetic pathways).

#### Transition Plan:

The primary purposes of this study are to (1) improve the ability to characterize grasslands land cover, (2) determine the sensitivity of grasslands signatures to various influences, such as soil brightness, atmospheric conditions, and woody species invasion. It is anticipated that these findings will be applicable to the study of the effects of land management and climate on grasslands ecosystems function and species biodiversity.

#### Milestones:

summer 1997: overflight at Tallgrass prairie (peak greenness; late July to early August)  
fall 1997: overflight at Tallgrass prairie (post greenness; late October to early November)  
January 1, 1998: interim report on Tallgrass prairie  
spring 1998: overflight at Niobrara (onset of cool season grasses; before May 1)  
summer 1998: overflight at Niobrara (post cool-season, late June to early August)  
January 1, 1999: final report on Niobrara study.

### **Detection and Mapping of Leafy Spurge at Theodore Roosevelt National Park and Vicinity Using AVIRIS Hyperspectral Imaging.**

#### Personnel:

PI's are Dr. Ralph Root, USGS-BRD, Steve Hager, Theodore Roosevelt National Park, Gerald Anderson, Agricultural Research Service, Dr. Susan Ustin and Larry Costick, University of California - Davis, Jim Smith, NASA-GSFC, and Robert Green, NASA-JPL.

#### 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 (THRO) 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.

Geographic Information System (GIS) and remote sensing technologies have recently been integrated at THRO for a variety of natural resource applications, including mapping the distribution of non-native invasive plant species. Prior to 1993, mapping of leafy spurge was derived from ground estimates delineated on topographic maps. In 1993, Theodore Roosevelt National Park entered into a cooperative agreement with the Agricultural Research Service (ARS) in Weslaco, Texas to map the infestation using low-altitude aerial photographs. Interpretation of these photographs identified 702 ha. of leafy spurge and provided a digital product which was incorporated into the park's GIS in 1995. While this process produced a relatively accurate product, it required extensive preparation and personnel commitment. More automated techniques for monitoring the status of leafy spurge on a seasonal basis clearly would enhance the efficiency and effectiveness of control measures.

#### Transition Plan:

The resulting information will be incorporated into the park's GIS and used to develop Integrated Pest Management (IPM) strategies (chemical treatment and biological control) and evaluate control measures. These data will also support a major USGS-Biological Research Division (BRD) project at Theodore Roosevelt National Park designed to quantify the impact of leafy spurge on native vegetation and determine the effectiveness of Integrated Pest Management (IPM) techniques.

#### Milestones:

AVIRIS flight planning and mission execution, May-June, 1998.

Project preparation: January, May, 1998.

Ground data collection preparation, March-April, 1998.

Low altitude aircraft digital video data acquisition, March-June, 1998.

Ground spectrometer field work, May-June, 1998.

AVIRIS data pre-processing, June-July, 1998.

Data analysis, August - September, 1998.

Creation of map products and development of accuracy assessment, October - November, 1998.  
Report preparation, June - November 1998.

## **Mapping of Mercury-containing Mineral Sources in the Owyhee Reservoir Watershed using AVIRIS Imaging**

### **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.

The Owyhee Basin is a large and remote watershed (approximately 11,000 km<sup>2</sup>) located in southeastern Oregon (Malheur County), southwestern Idaho (Owyhee County), and a portion of northern Nevada (Elko County). The watershed geology is comprised primarily of igneous rocks: Quarternary and Tertiary silicic volcanic rocks, massive Tertiary tuffaceous sedimentary rocks with interbedding of basalts and



rhyolite, and older Miocene siliceous volcanics, mostly rhyolite and welded tuffs.

Mercury concentrations in watershed soils, measured to date, range from 0.1 - 565 mg/kg, and up to 6.2 mg/kg in rock samples. There are several small Mercury mining prospects in the general region. The Silver City area was also the site of extensive gold and silver mining, milling and extraction during the late 1800's, which introduced a significant anthropogenic source of Mercury to the watershed.

The primary occurrence of Mercury is in the mineral cinnabar, Mercury sulphide, which is associated with younger low-temperature hydrothermal systems in regions of late Tertiary orogeny and volcanic activity. Mercury deposits in the Owyhee Basin are located in altered tuff and tuffaceous lakebeds that have been silicified to opaline deposits. Erosion and transport of soils from these deposits may result in adsorption of Mercury onto suspended particles. In low pH environments, such as conditions produced in acid mine or acid rock drainage, or in natural low pH environments, inorganic Mercury is converted by anaerobic bacteria to methylmercury which is more mobile. Significant mining activity has occurred in the Jordan River watershed a major tributary to the Owyhee Reservoir. .

The spectral resolution of AVIRIS is needed to discriminate the occurrences of natural deposits of Cinnabar and where Mercury is concentrated in the environment by other processes such as mining, or erosion, weathering and leaching of soils. Cinnabar has a very strong absorption in the visible due to a conduction band. The feature is a sharp step function that can be mapped with AVIRIS when concentration is high enough. Other low pH, secondary iron-minerals indicative of mining activity will also be mapped as indicators of possible sources of Mercury, as these same processes release methylmercury into the environment. These low pH, iron-bearing minerals have been successfully mapped and sources of acid rock drainage identified by USGS Spectroscopy Lab and Reclamation, using the Tricorder algorithm at the California Gulch Superfund Site in Leadville, Colorado. Due to the arid climate and volcanic bedrock at the surface, vegetative cover over most of the basin is very sparse and should not pose a significant problem in mapping mineralogy from the AVIRIS spectra..

#### Transition Plan:

This study will be conducted as a cooperative effort of the Bureau of Reclamation's Technical Service Center and Boise Regional Office, the Bureau of Land Management and the U.S. Geological Survey's Spectroscopy Laboratory. There are a number of other local and state agencies participating in the overall investigations and study of the Owyhee Reservoir watershed.

The ultimate application of AVIRIS imaging data for this project is to provide important information regarding identification and mapping of natural Mercury-source minerals that will be used to identify and implement strategies to reduce the Mercury bioaccumulation problems in this watershed.

This project is important because of several issues. First is the fact that natural mineral sources of Mercury may contribute directly to public health concerns. Second, the size and remoteness of the watershed makes the application of AVIRIS technology a potentially cost effective mapping technique that may be more routinely applied in other volcanic rock watersheds besides the Owyhee Basin. Third, the mapping of volcanic rock and Mercury-containing minerals represents a scientifically legitimate research topic deserving further development. Finally, the remoteness of the reservoir watershed and lack of local population has produced a situation where funding for Mercury research is extremely limited. The addition of AVIRIS image data would certainly help existing modest programs attempting to provide the information needed to identify a reservoir or land management plan to reduce the Mercury public health impacts

**Milestones:**

Acquisition of Landsat TM imagery of entire watershed in 1997.

Mapping geologic anomalies using band ratios 5/7, 3/1, 4/5 of TM images.

Selection of tributary basin and reservoir area for AVIRIS flightline(s), early 1998.

Development and calibration of mineralogy using USGS "Tricorder" algorithm.

Analysis and mapping of AVIRIS data.

Publication of research results.

Incorporation of AVIRIS maps into GIS data base.

Assessment and development of watershed management options.

Publication of watershed management assessment.