Hyperspectral Technology

Overview

Comparing Hyperspectral to Multispectral

Collecting Spectra in the Field to Calibrate Airborne Data

Mapping Oil Seeps, Soils, Geology

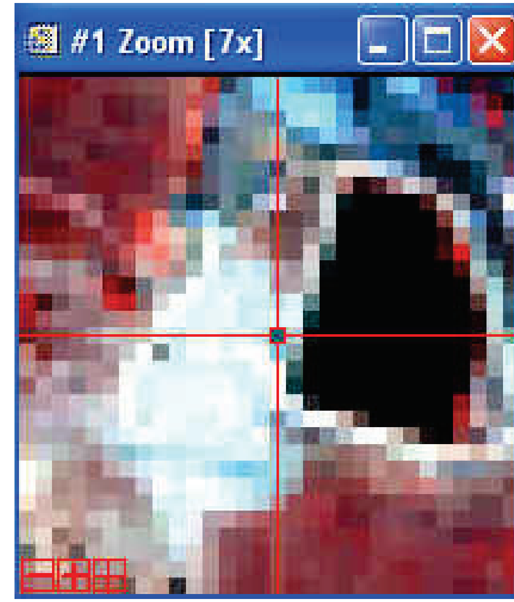
Mapping Vegetation with VNIR only

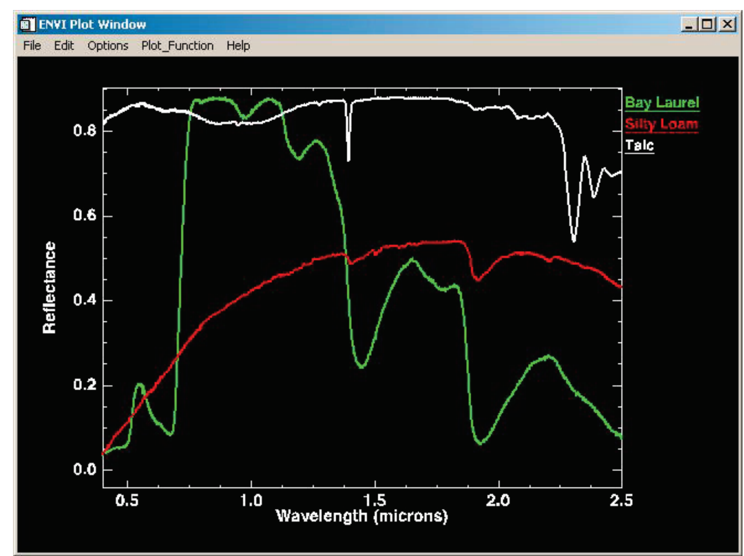
Mapping Vegetation with VNIR-SWIR

EAFB Poster

Demo of AVIRIS 124-band Data

Lessons Learned

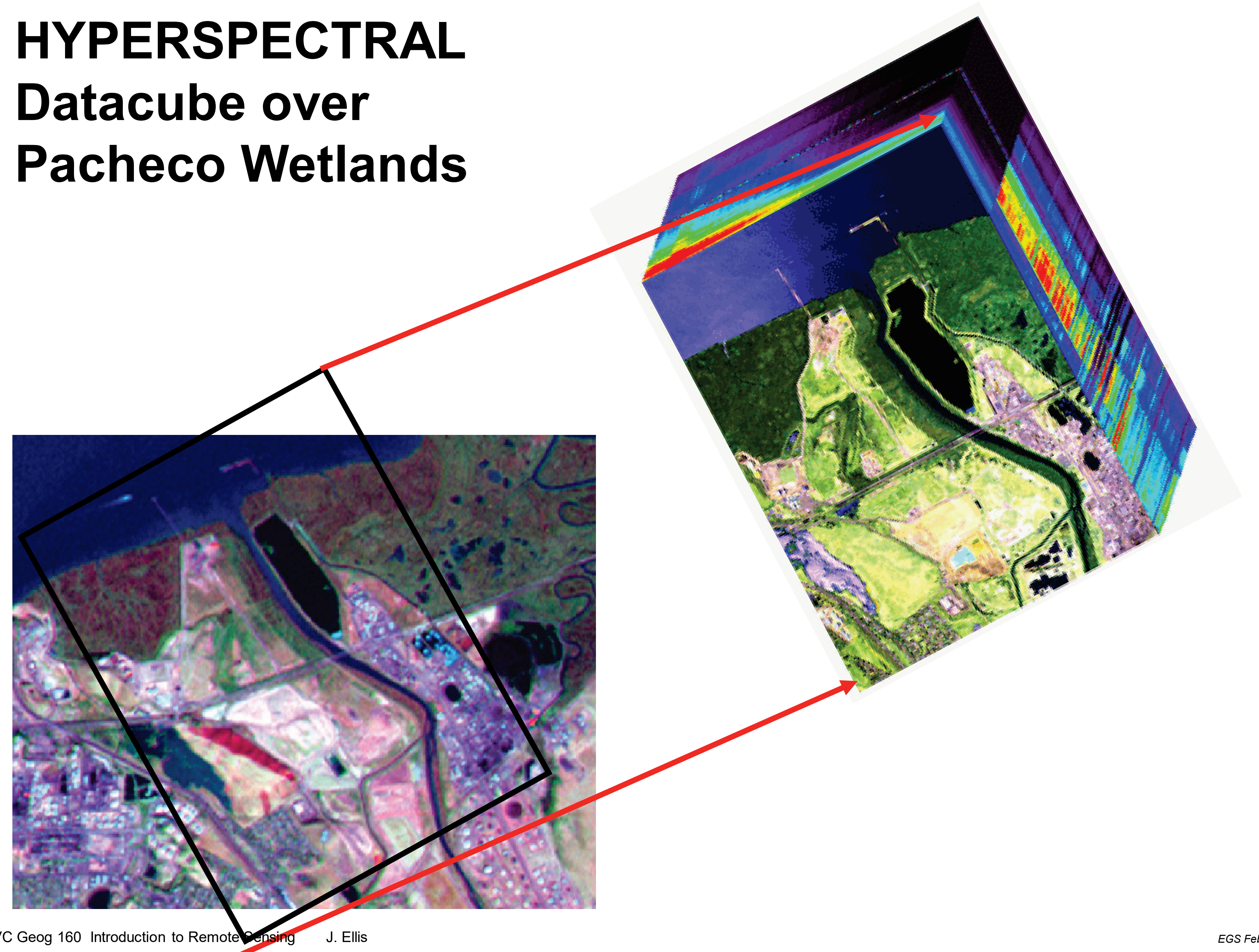




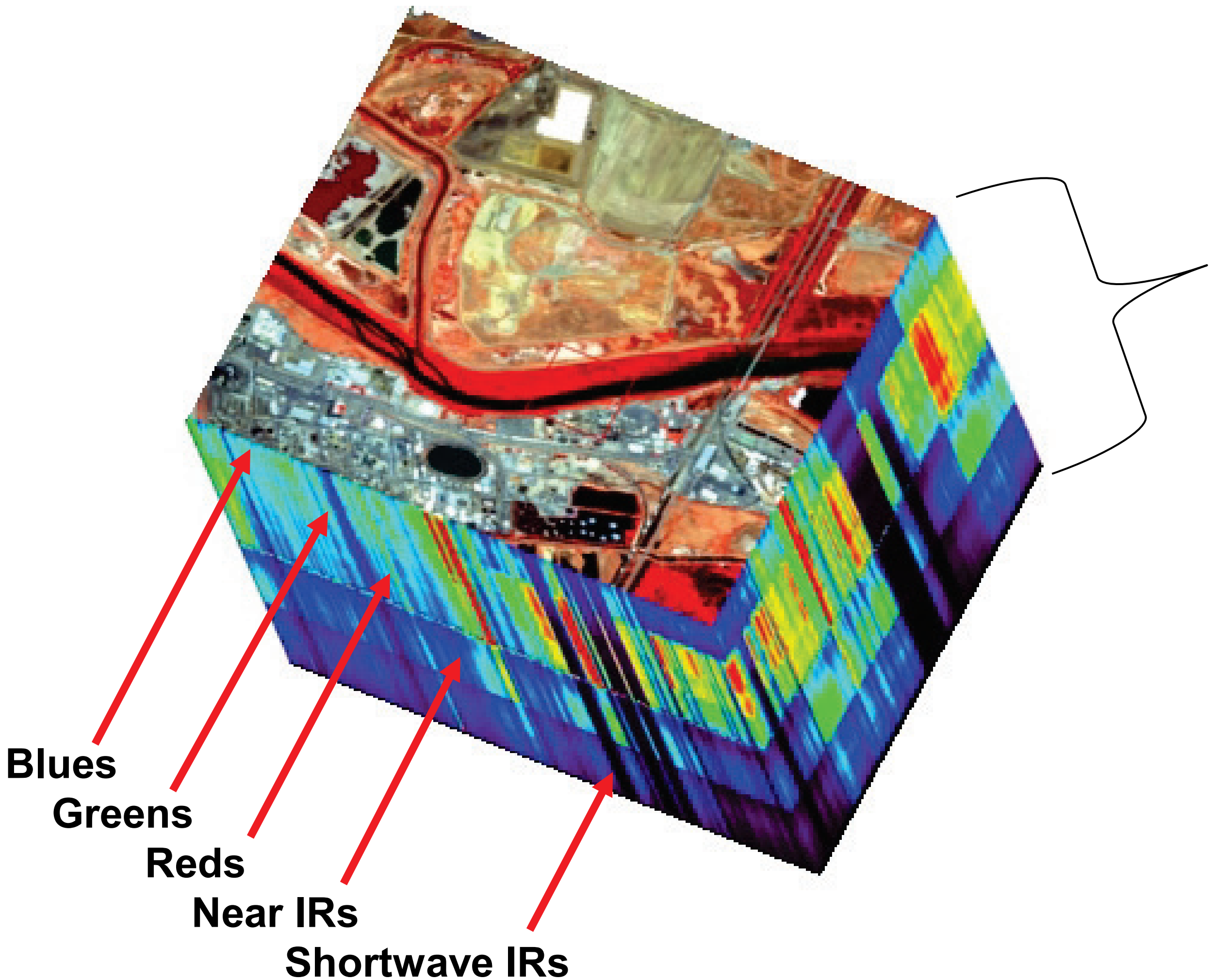
Experience with Hyperspectral

1997	Mongolia*	airborne HyMAP VNIR-SWIR mineral exploration
1998-2002	Industrial facilities – CA, TX, OH	airborne HyMAP VNIR-SWIR land cover, oil spills
2001-2003	Niger Delta	airborne HyMAP VNIR-SWIR vegetation communities/species
2001	Venezuela	airborne CASI VNIR vegetation, oil detection
2002	Central Asia*	satellite Hyperion landcover, oil detection
2009	Red Sea	airborne SPECTIR VNIR-SWIR nearshore sea bottom features
2009-2010	Mojave Desert*	airborne Galileo VNIR vegetation communities, soils
2011-2013	Afghanistan	airborne AVIRIS mineral exploration
2013	Peru	Satellite Hyperion mineral exploration

HYPERSPECTRAL Datacube over Pacheco Wetlands



HYPERSPECTRAL DATACUBE
Continuous spectrum collected

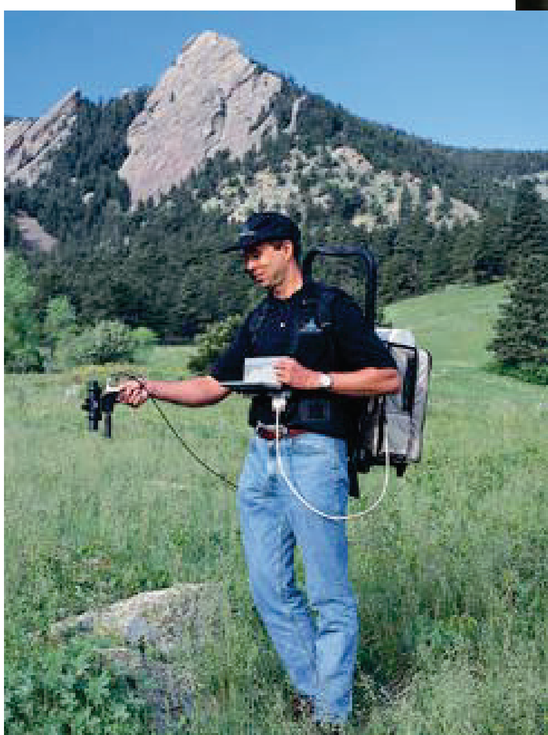


Stack of B&W images, each a narrow wavelength band - from reflected visible Blue to shortwave IR

~50 - 300 bands

REMOTE SENSING TECHNOLOGY

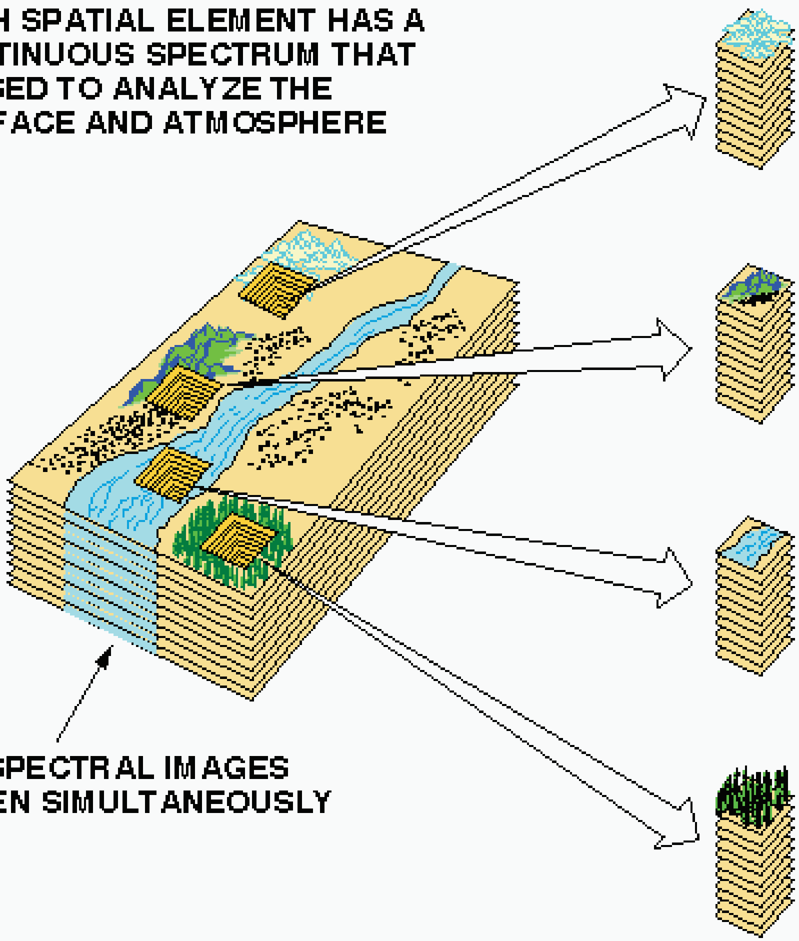
- Lab
- Ground
- Airborne
- Satellite

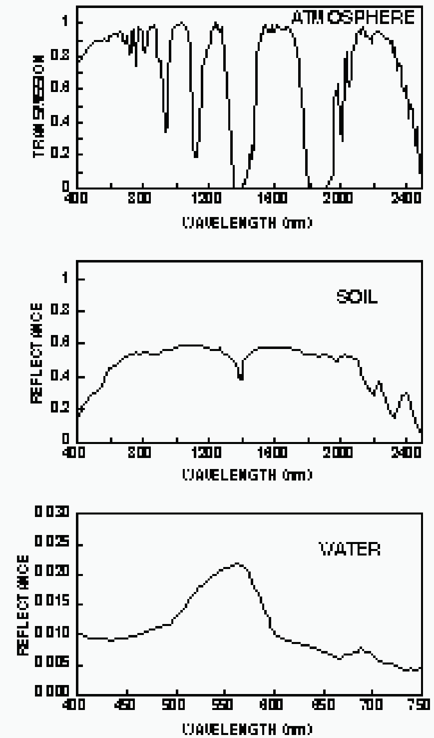


A HYPERSPECTRAL SENSOR

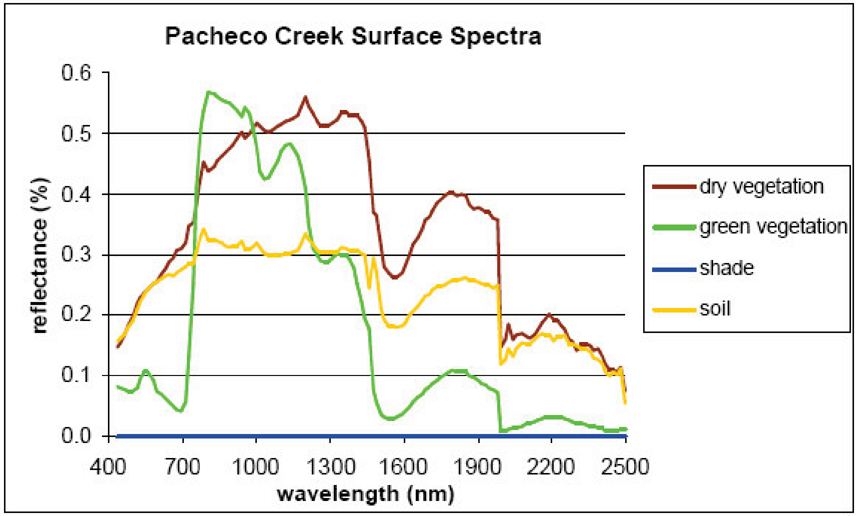
HYPERSPECTRAL

EACH SPATIAL ELEMENT HAS A CONTINUOUS SPECTRUM THAT IS USED TO ANALYZE THE SURFACE AND ATMOSPHERE





224 SPECTRAL IMAGES TAKEN SIMULTANEOUSLY

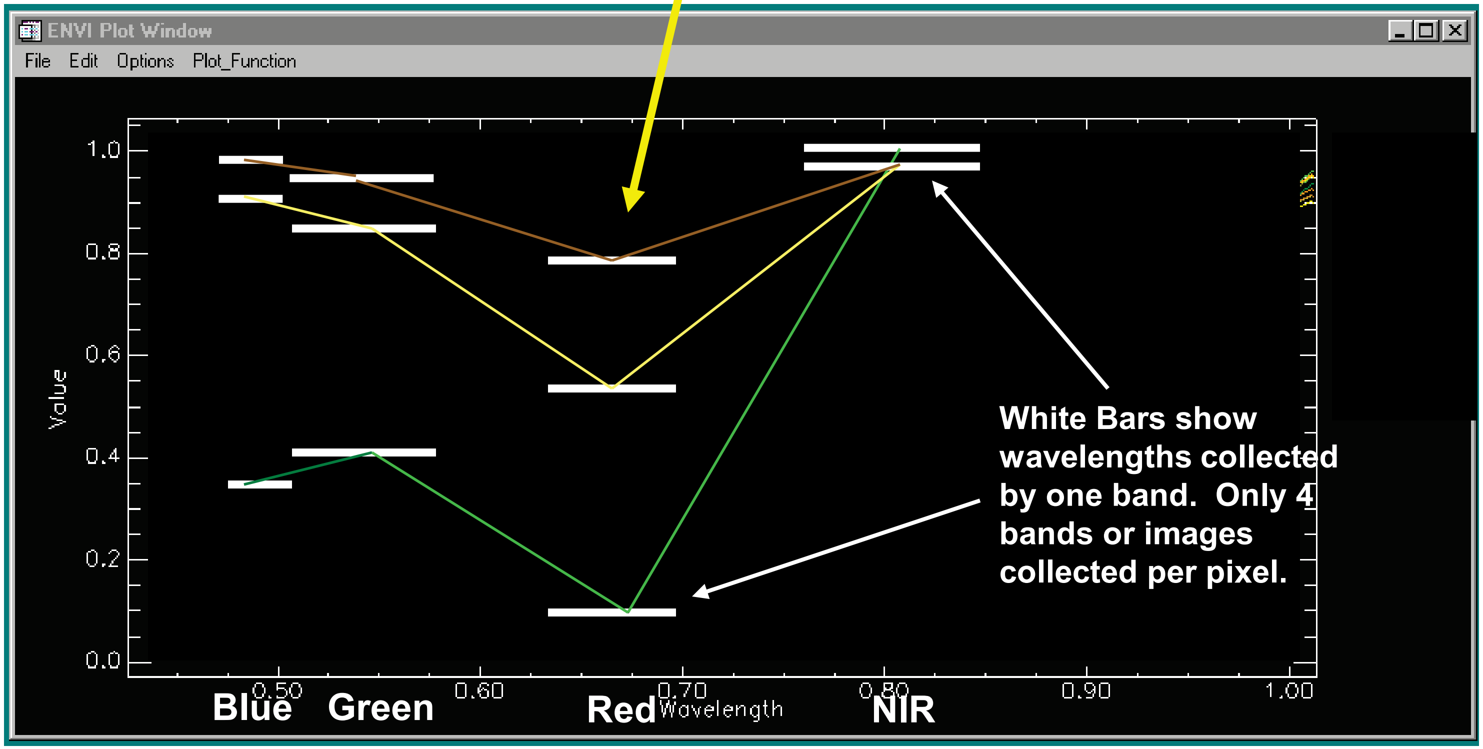


CSTARS
Ground-based
Spectral Library
Probe-1 Data
The GeoSat Committee, Inc.

VEGETATION VIGOR

The Chlorophyll Absorption Feature

Multispectral
(Quickbird, Ikonos, Landsat SPOT, ASTER, ADS-40, etc.)



Example of Quickbird's three Visible (Blue,Green, Red) and one NIR (Near-Infrared) Bands (white bars) response to vegetation with different vigor. IKONOS and Landsat record similar wavelengths. <u>Much less detail</u> compared with Hyperspectral on plant type, chlorophyll, & internal structure. NDVI from normalized ratio of Red & NIR brightness values (vertical axis above).

Highest Lowest

VIGOR

VEGETATION VIGOR

Hyperspectral

The Chlorophyll Absorption Feature

Highest

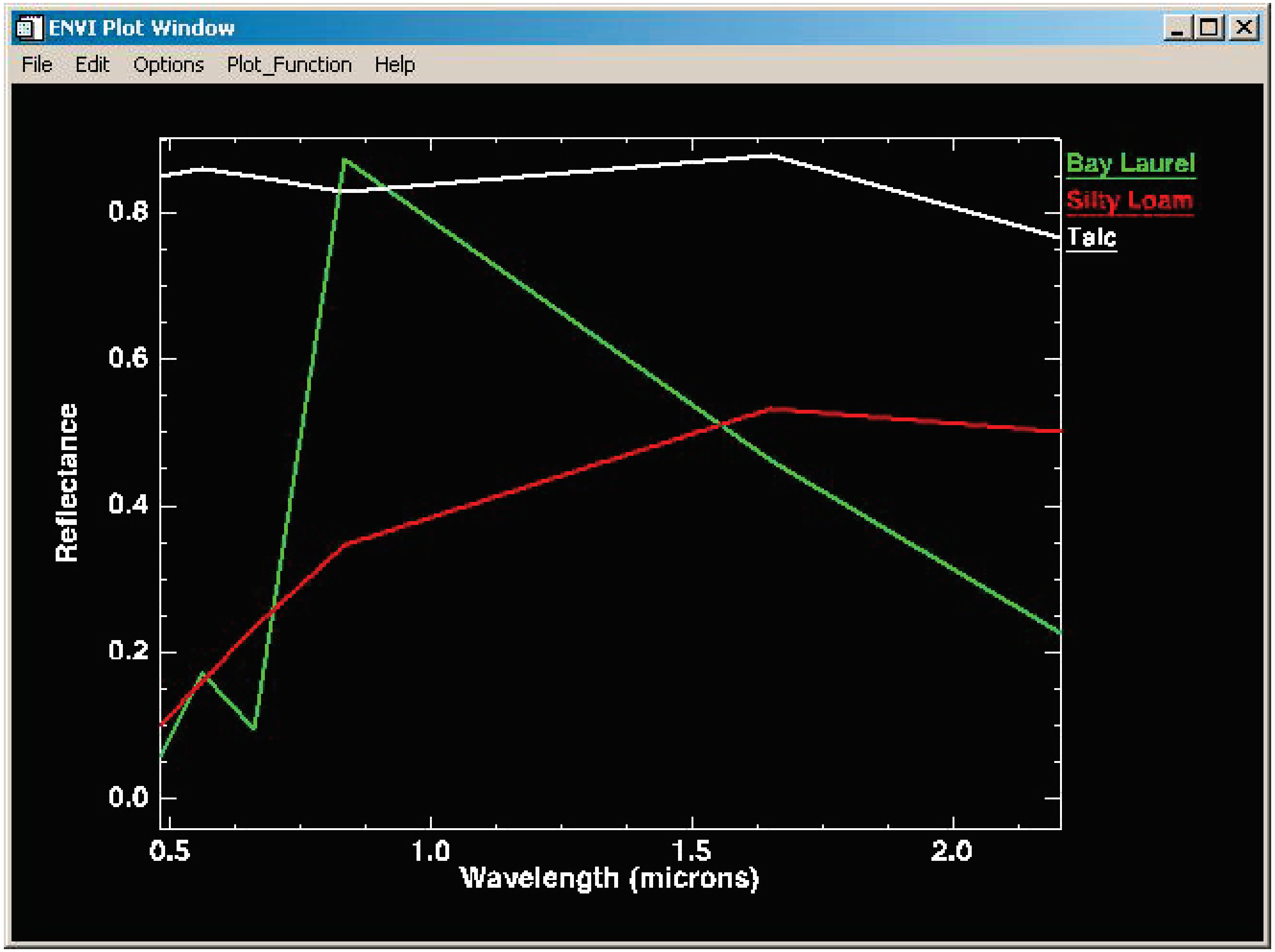
Lowest

VIGOR

Hyperspectral records 10-50 wavelengths between Blue-Green-Red-NIR. A <u>continuous</u> response of the plant to these wavelengths is documented. The shape & depth of the chlorophyll absorption feature & Blue-Green-Red, and the position of the "red edge" reveal vegetation type and vigor (or stress) with <u>exceptional detail</u>.

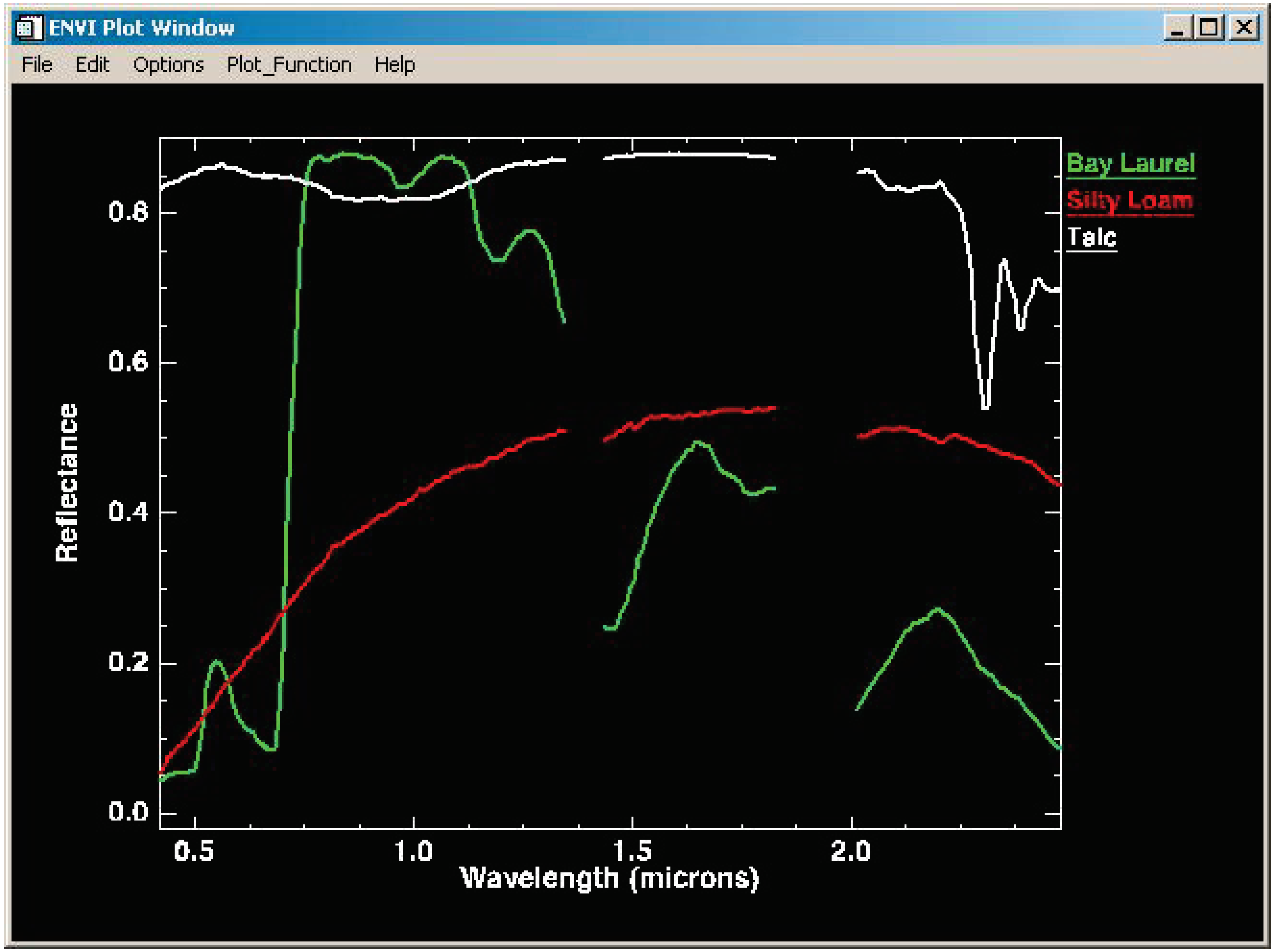
NDVI from a normalized ratio of Red & NIR brightness values (vertical axis above).

Multispectral Spectral Signatures



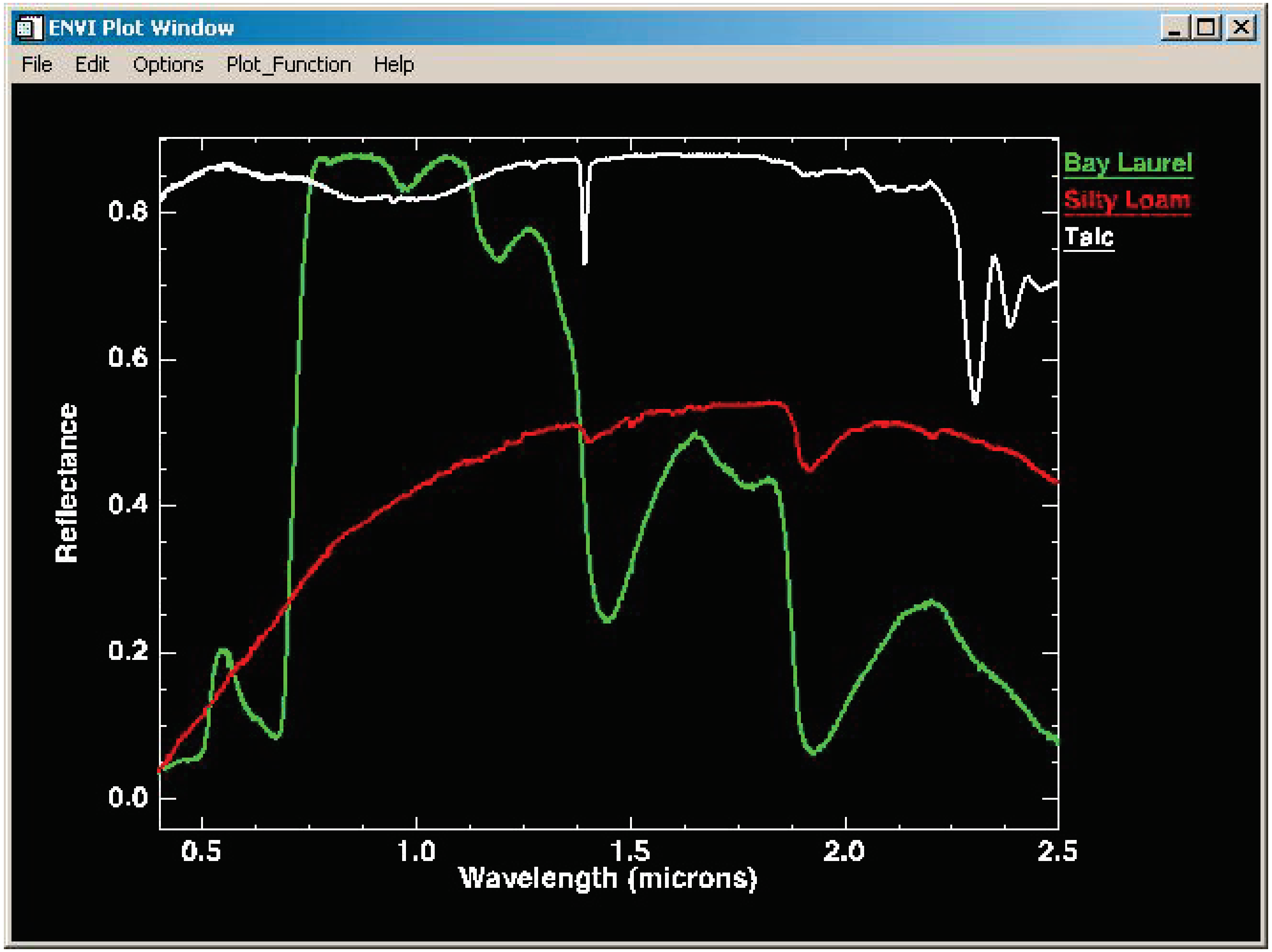
Shippert, 2001

Airborne Hyperspectral Spectral Signatures



Shippert, 2001

Lab Hyperspectral Spectral Signatures

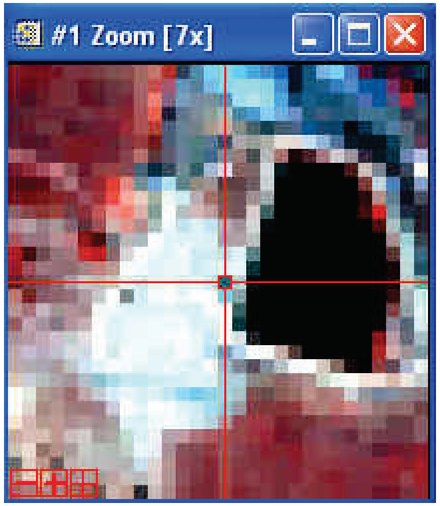


Shippert, 2001

SENSOR	Spatial Resolution	Spectral Resolution	Application
Airborne Hyperspectral			
HyVista, Australia	3 – 20 m Whiskbroom	128 bands of visible, NIR &SWIR light	Geologic and environmental, large areas
Galileo, Florida	1 – 5 m Push Broom	244 - 365 bands of visible, NIR & SWIR	Detailed environmental, soils, geology, urban, agriculture, water quality
SpecTIR, Reno	1 – 5 m Push Broom	244 - 365 bands of visible, NIR & SWIR	Detailed environmental, soils, geology, urban, agriculture, water quality
CASI/SASI/TASI, Calgary	0.5 – 5 m Push Broom	15-40+ bands of visible & NIR, SWIR, Thermal	Detailed environmental, soils, geology, urban, agriculture, water quality

WHY IS HYPERSPECTRAL A UNIQUE MAPPING TOOL?

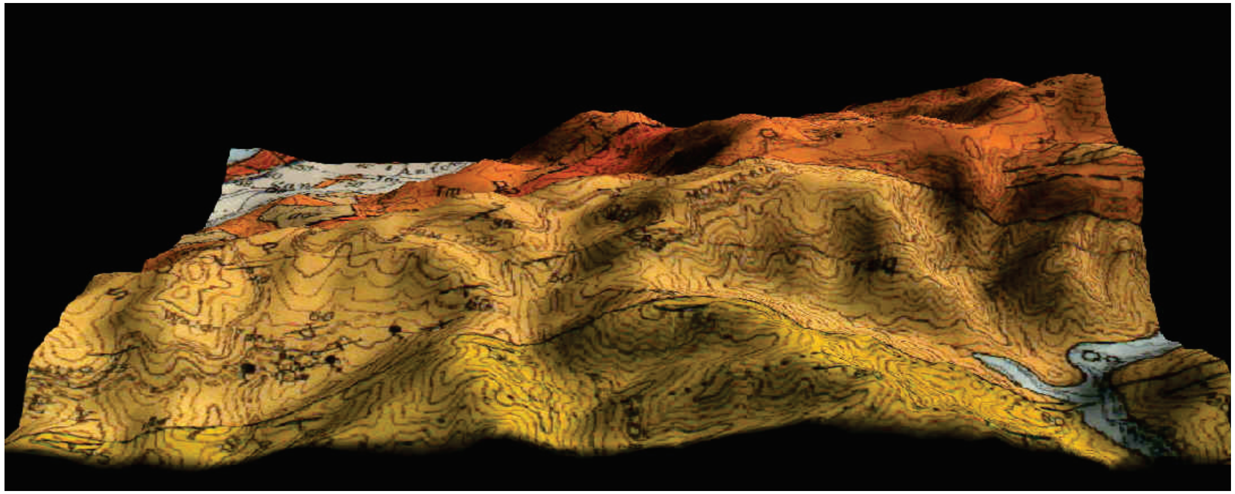
- CAN IDENTIFY MANY MATERIALS BASED SOLELY ON SPECTRAL SIGNATURE



- FOCUS IS ON INDIVIDUAL PIXELS
- SUPPORTS DETAILED MAPPING
- SUBPIXEL AND UNMIXING ALGORITHMS COMPENSATE FOR RELATIVELY LARGE PIXELS
- SPECTRAL LIBRARIES JUMPSTART PROJECTS

MAPPING OIL SPILLS & SEEPS

DETECTING OIL SEEPS WITH HYPERSPECTRAL

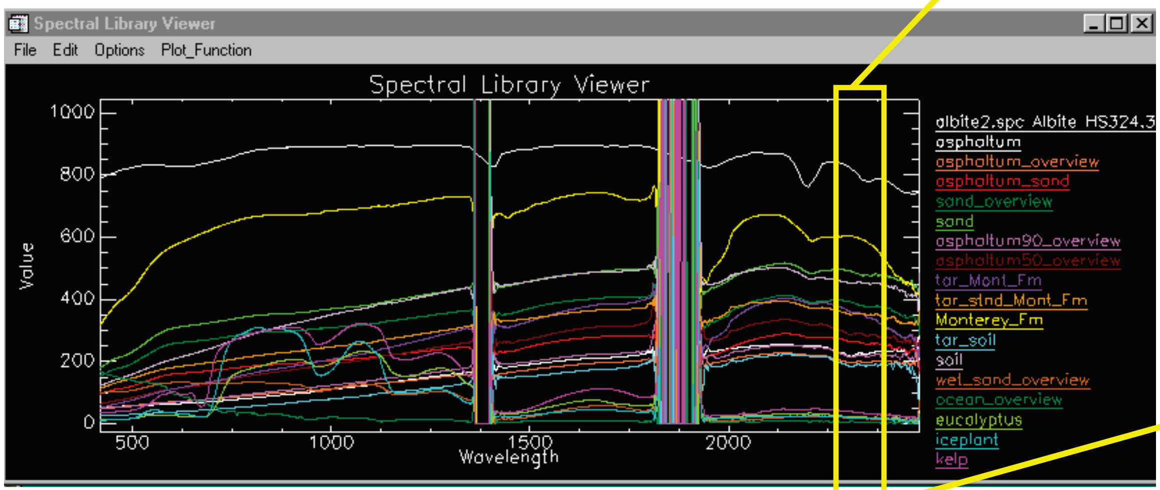


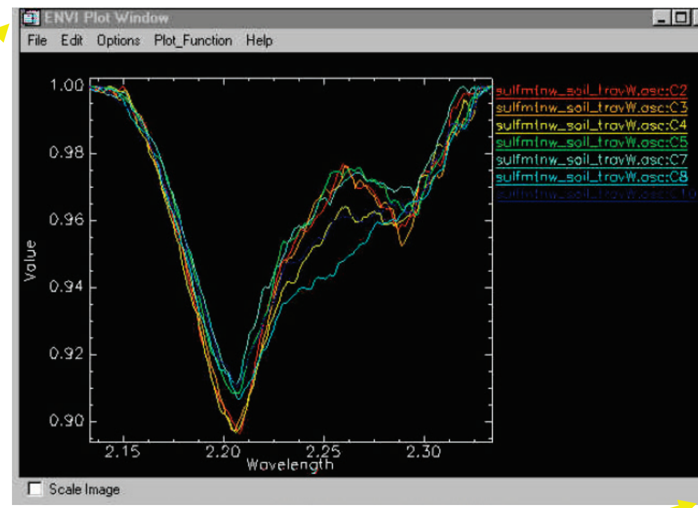
“Dibblee Oil Seep”

Probe-1 & GeoSat Committee

OIL SEEP IN AREA

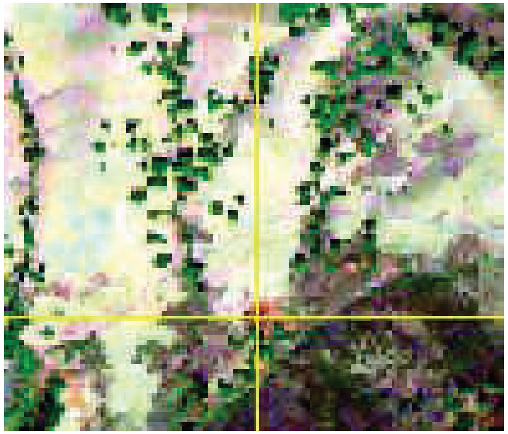
BUILDING AN OIL SPECTRAL LIBRARY BASED ON FIELD MEASUREMENTS





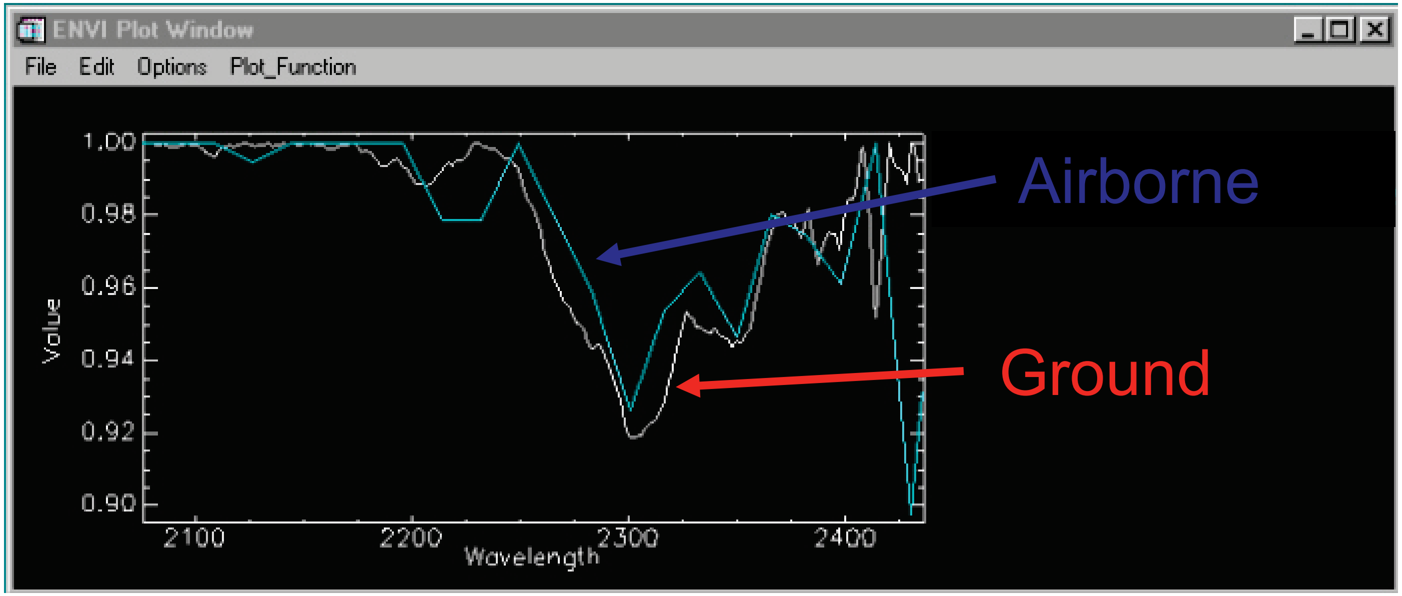
PROVING AIRBORNE SENSING MATCHES GROUND MEASUREMENT

Geologic Map

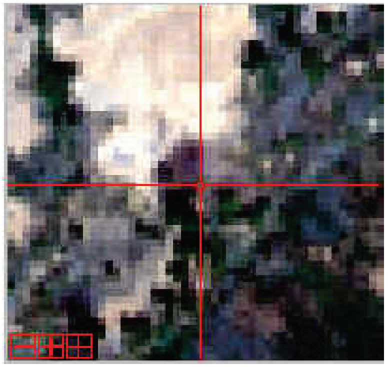


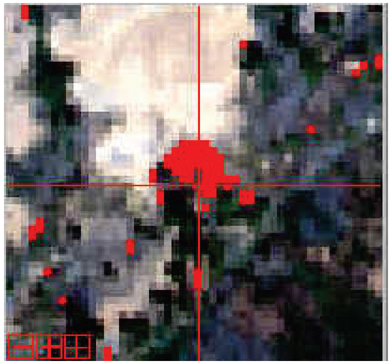
Hyperspectral Image

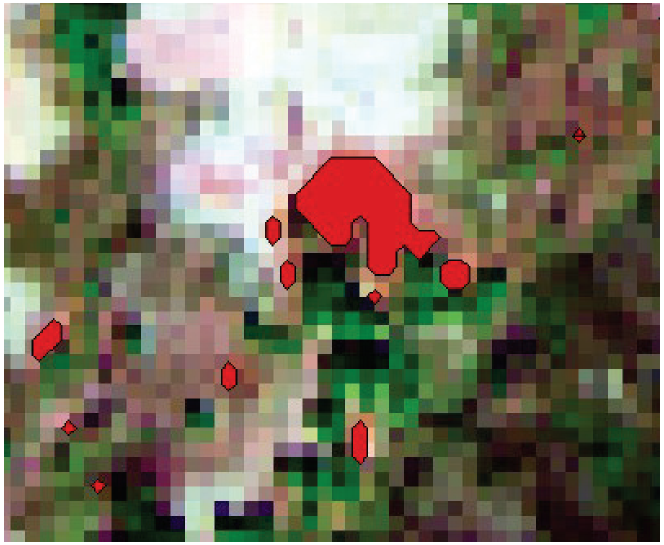
Zoom-in to pixel

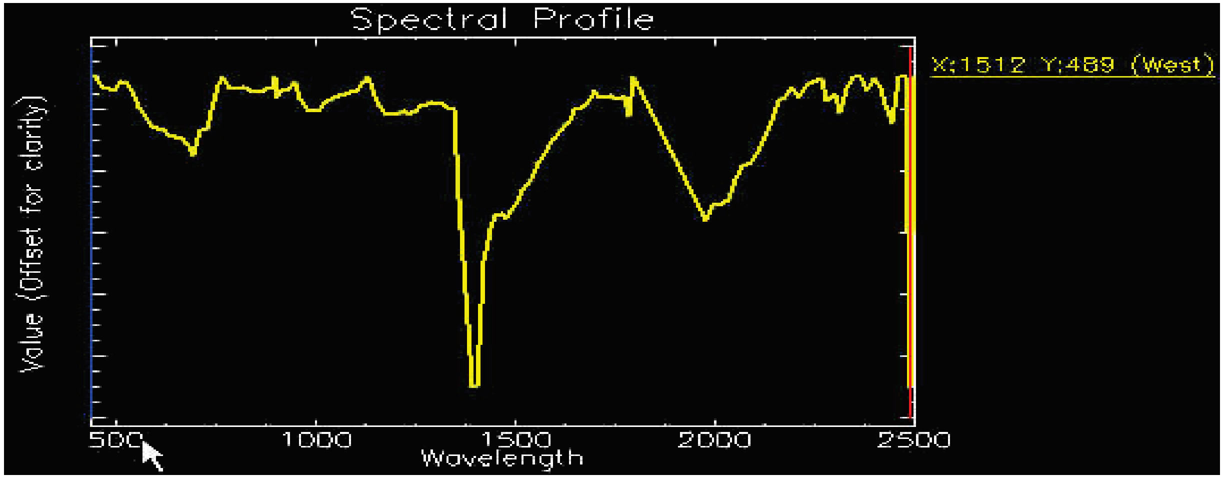


USING SPECTRAL SIGNATURE CONFIRMED IN FIELD TO FIND OTHER PIXELS THAT HAVE OIL







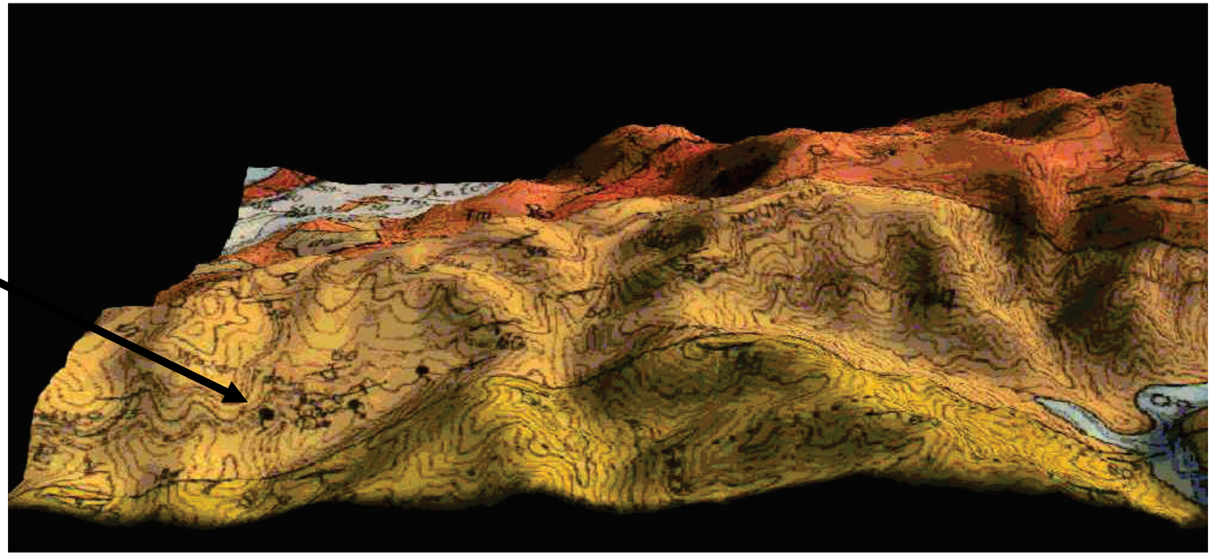


Hydrocarbon Spectral Signature

Extrapolation of Dibblee oil seep.

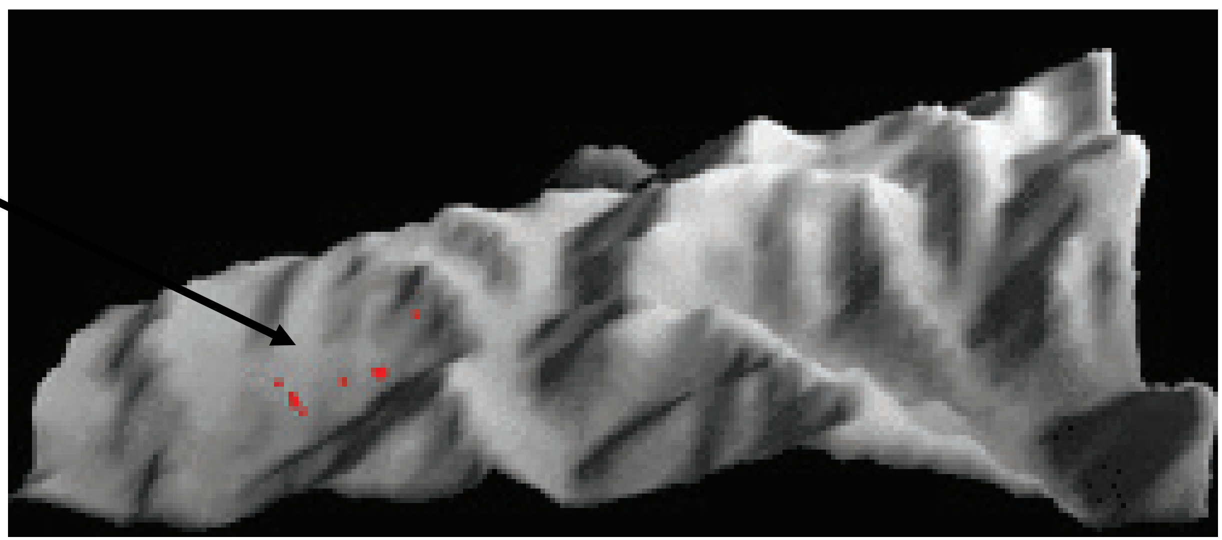
Spectral signature from training site pixel extrapolated to surrounding area.

OIL SEEP DETECTION & MAPPING



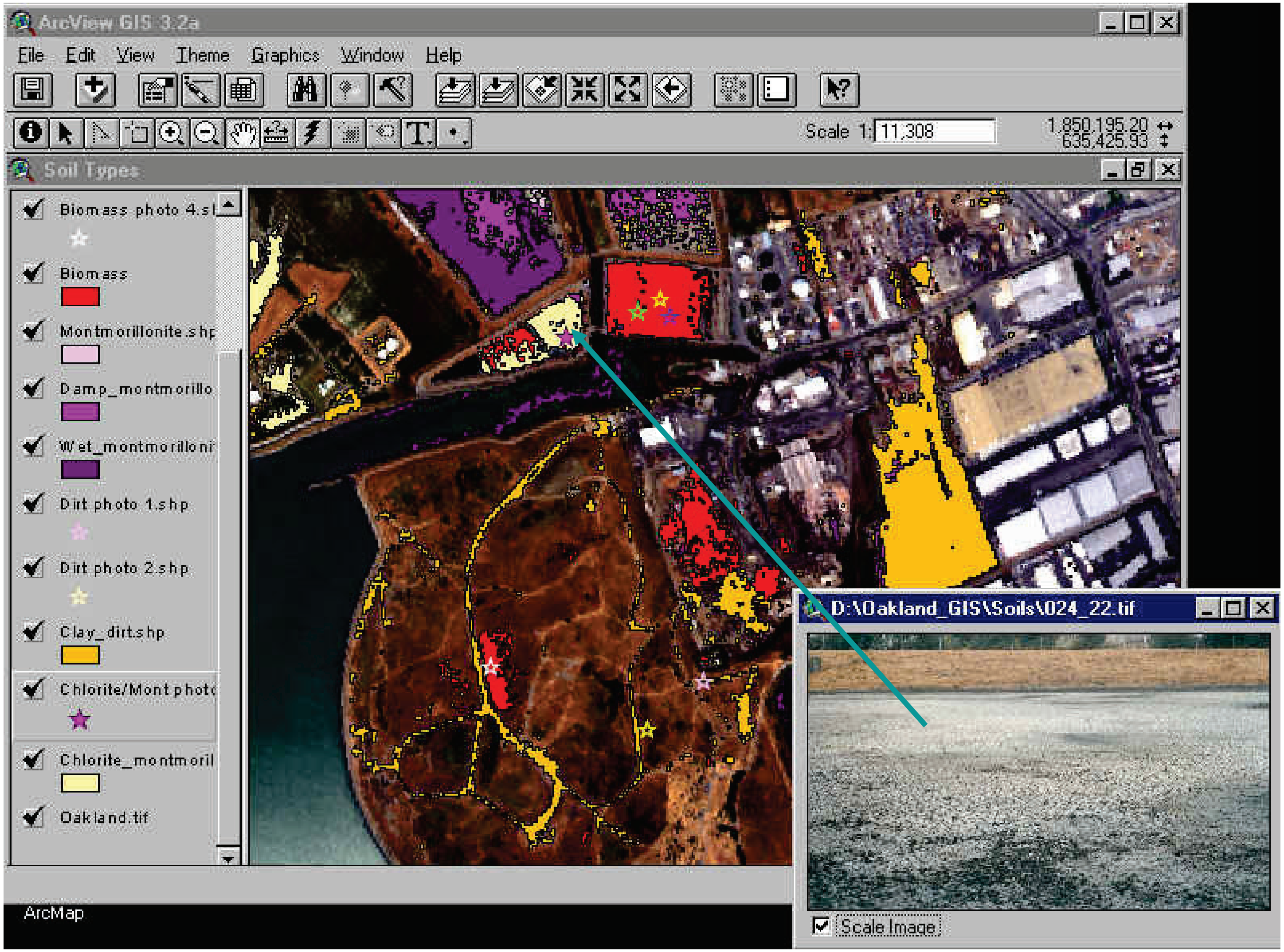
Original Map

Red Dots Mapped As Oil Seeps

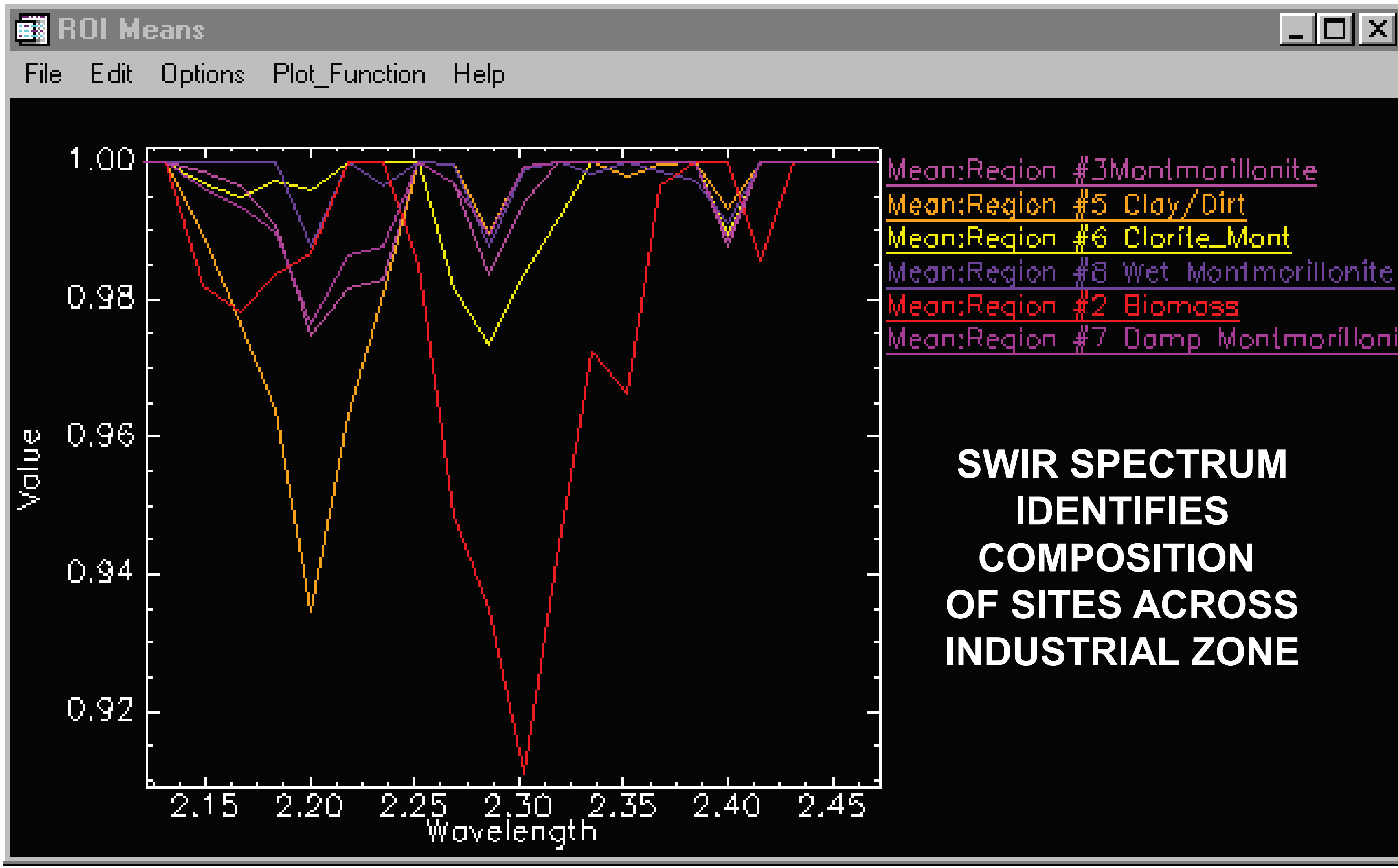


Actual Locations Of Oil Seeps

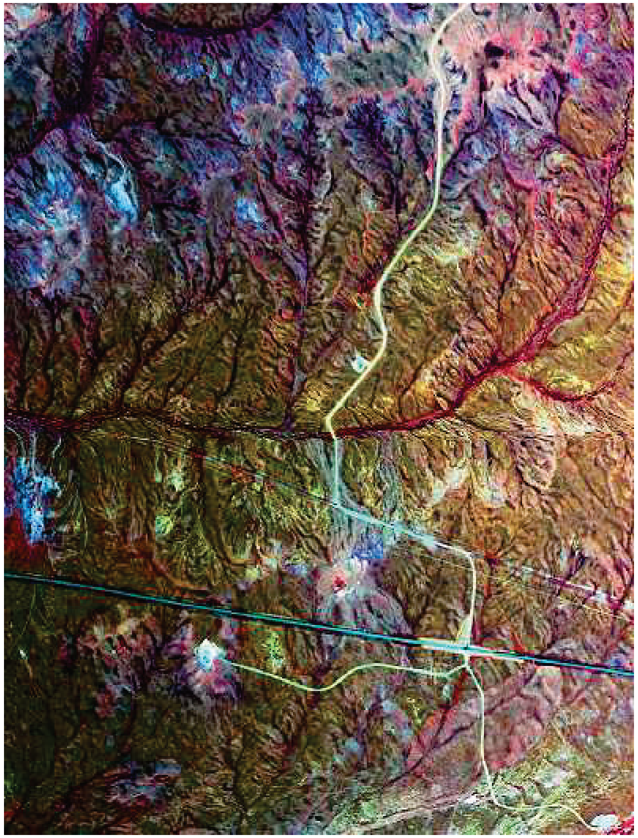
SOILS ANALYSIS



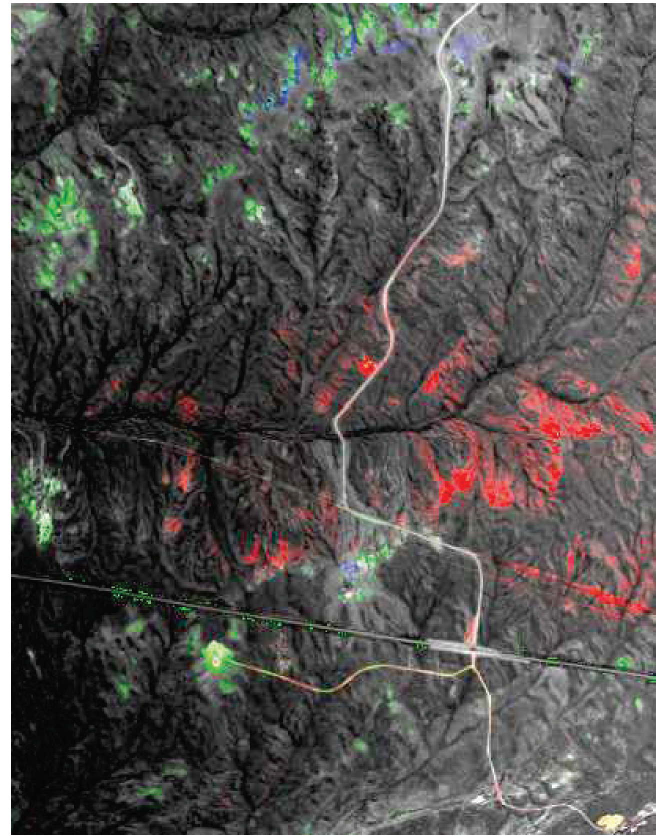
SOILS - SPECTRAL SIGNATURES



AIRBORNE VNIR-SWIR HYPERSPECTRAL IMAGE



Equivalent of TM 4,3,2
(veg is red)

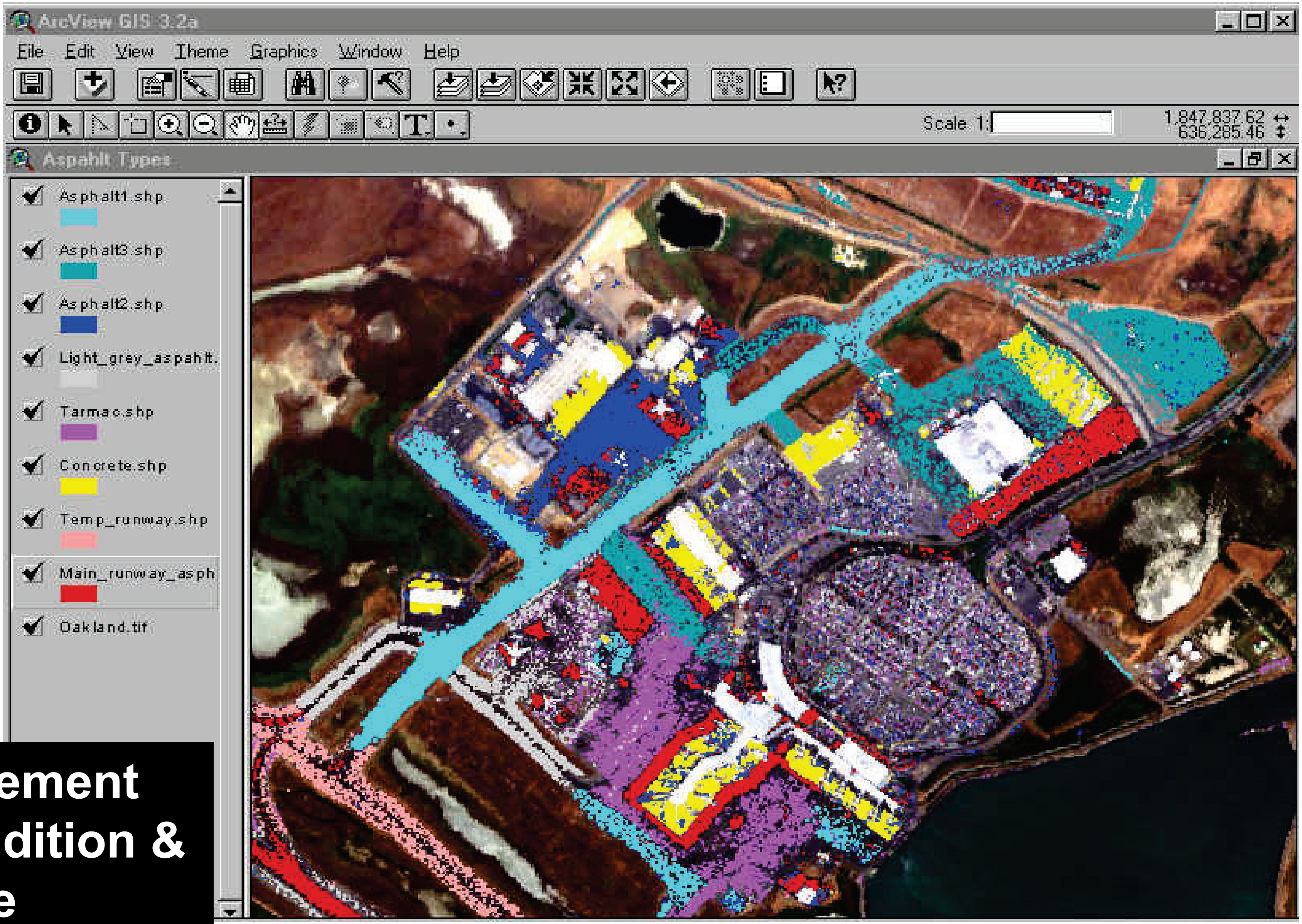


Minerals
kaolonite-smectites (red)
montmorillinite-Illites (green)
Calcite (blue)

Hyperspectral provides clay composition of exposed terrain

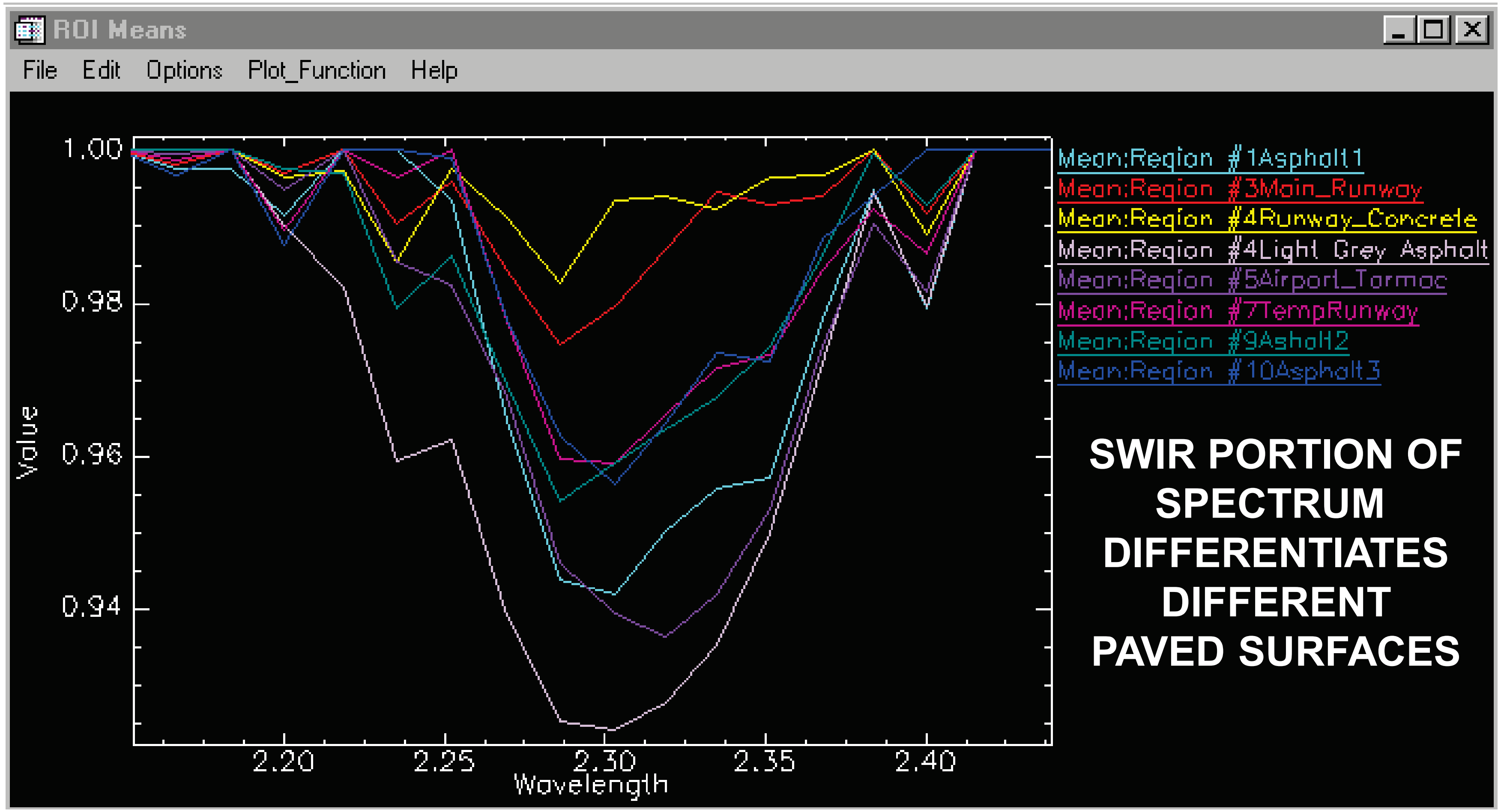
EVALUATING PAVEMENT AT OAKLAND AIRPORT

EVALUATING PAVEMENT AT OAKLAND AIRPORT



Pavement Condition & Type

PAVED SURFACES - SPECTRAL SIGNATURES

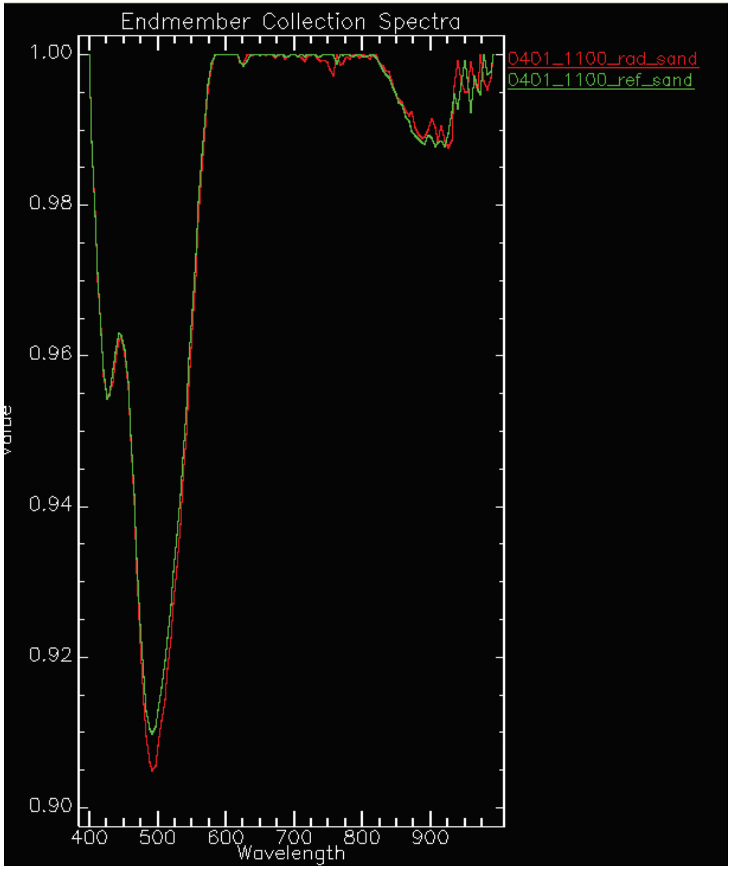


MAPPING PLANT COMMUNITIES
VNIR only

Calibrating Ground Spectrometer

VNIR Sensor

Measuring Reflectance from Sand

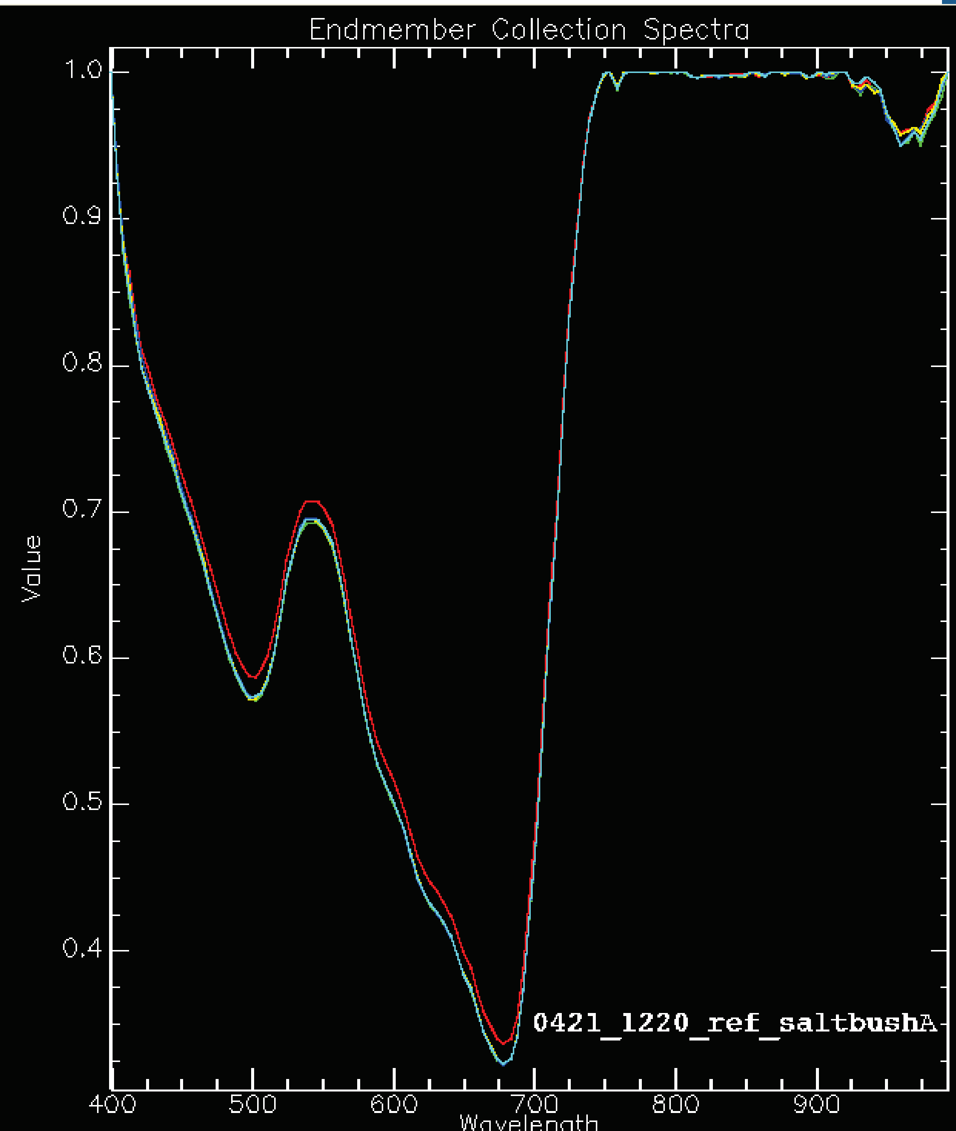


VNIR Sensor

Measuring reflectance from vegetation

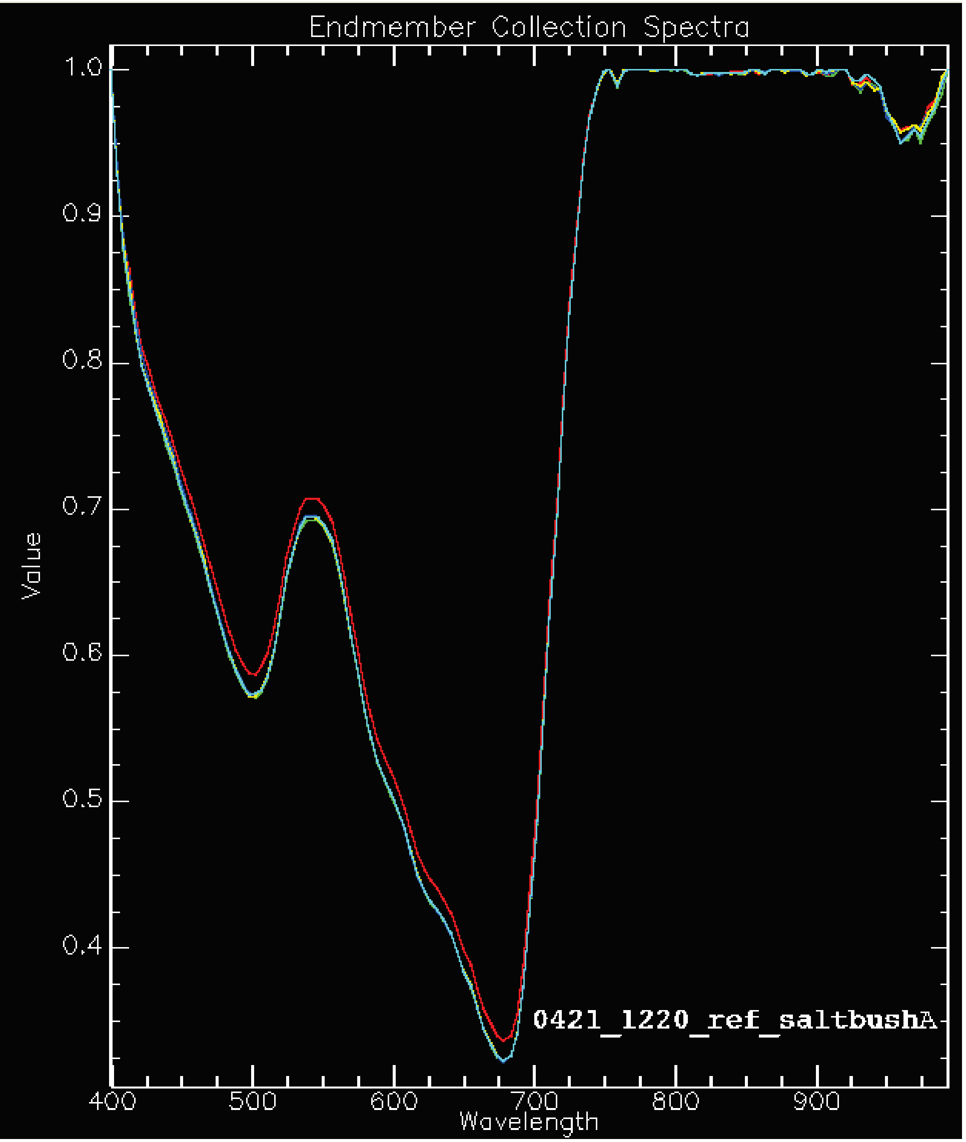
VNIR Sensor

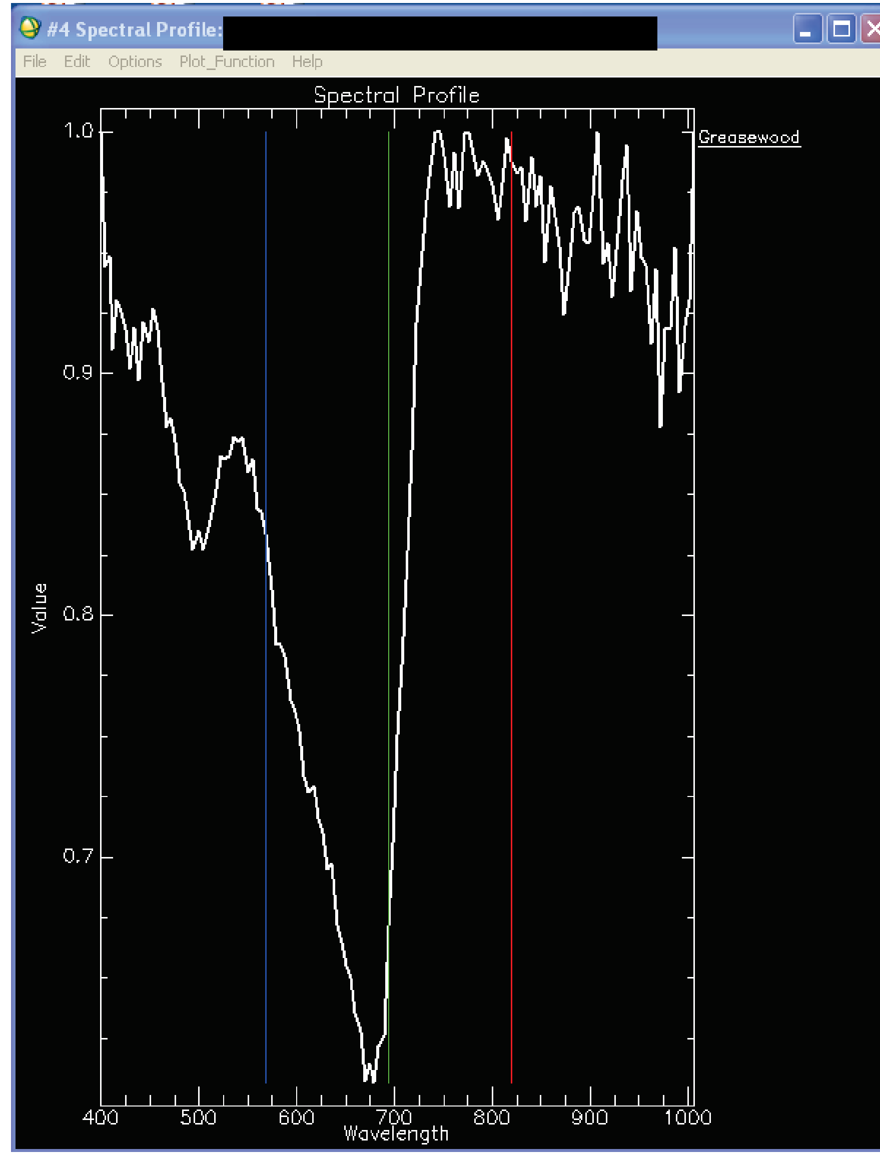
Ground Spectra for Saltbush



Ground Spectra for Saltbush

Airborne Spectra for Saltbush



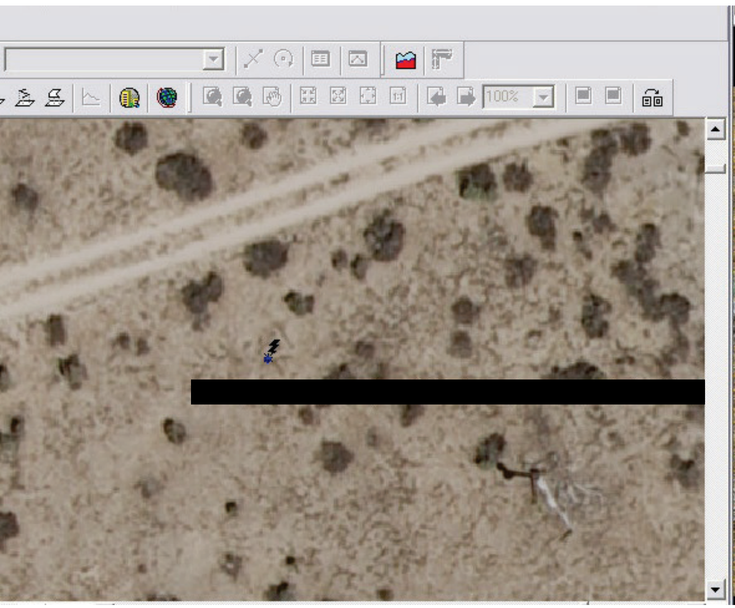


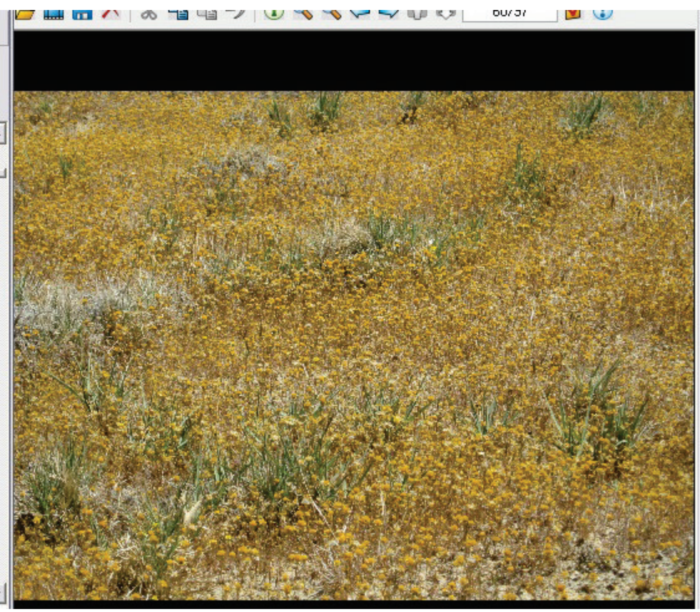
VNIR Sensor

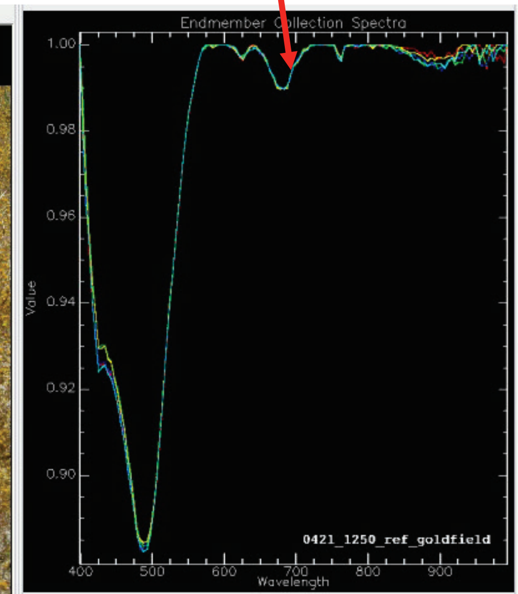
Gold Fields

Sampling site, ground photo, and ground spectra in GIS

Vegetation
Red Edge







Blue-Green-Red

Near IR

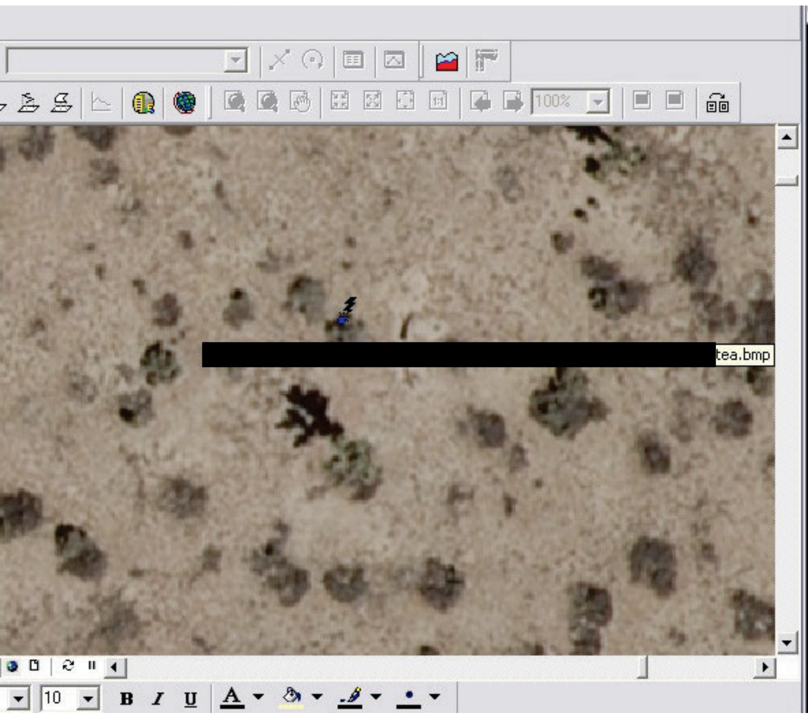
UltraCam natural color image In GIS with hyperlink lightning bolt showing path to displayed graphics on right

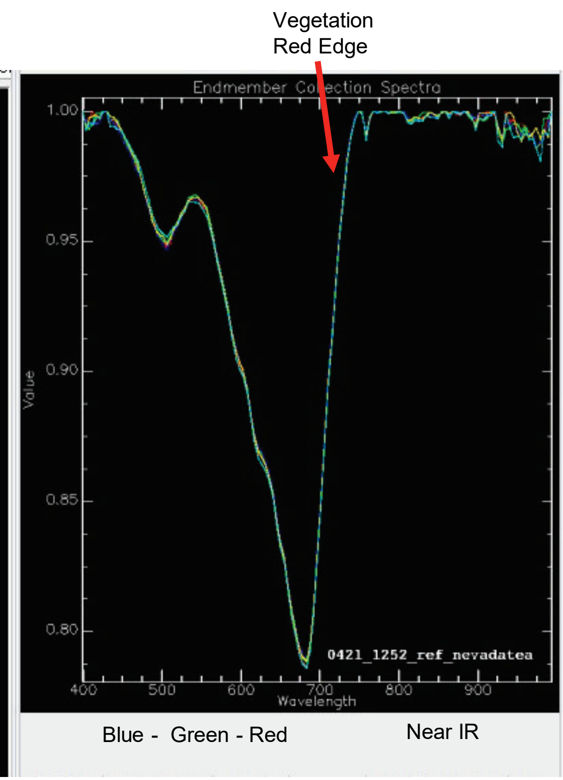
Field photograph of feature where Visible-Near IR spectral signature collected

Visible-Near IR spectral signature of feature shown on left

VNIR Sensor

Morman Nevada Tea
Sampling site, ground photo, and ground spectra in GIS





UltraCam natural color image In GIS with hyperlink lightning bolt showing path to displayed graphics on right

Field photograph of feature where Visible-Near IR spectral signature collected

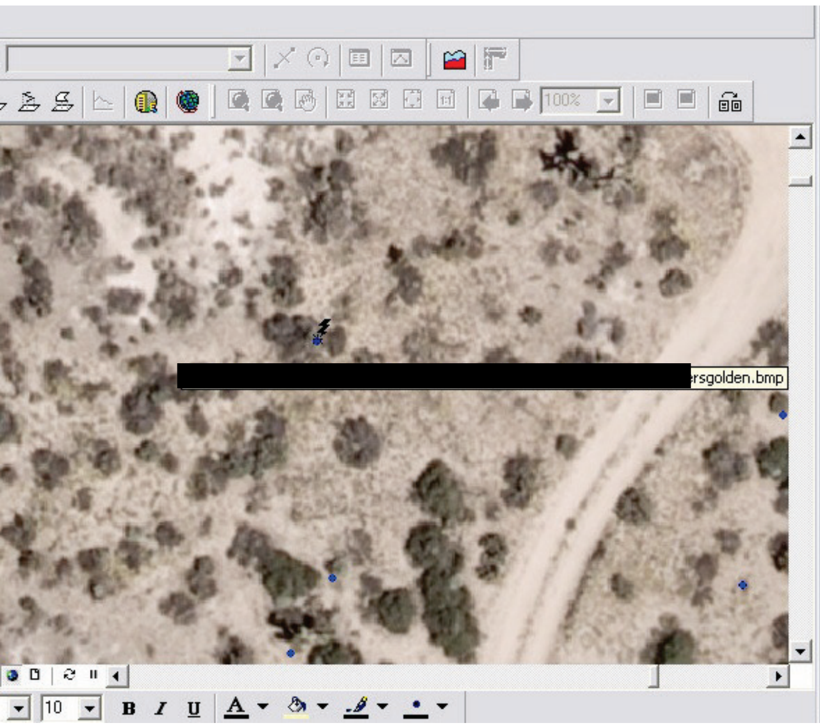
Visible-Near IR spectral signature of feature shown on left

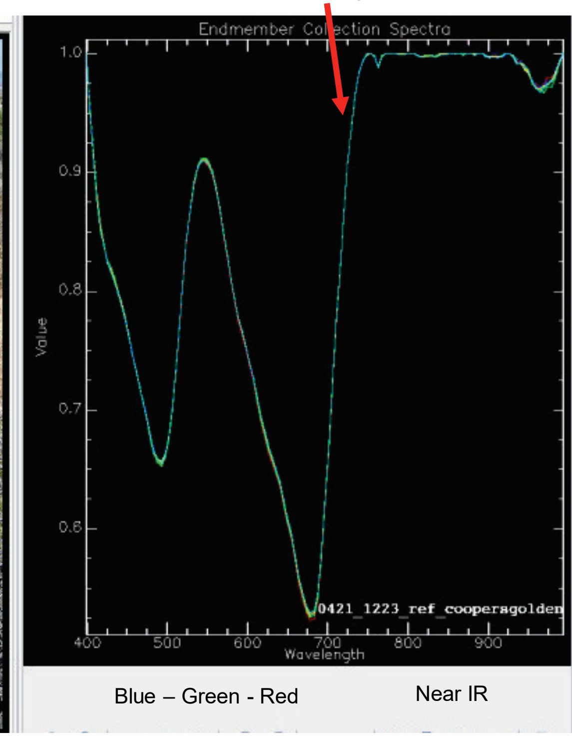
VNIR Sensor

Coopers Goldenbush

Sampling site, ground photo, and ground spectra in GIS

Vegetation
Red Edge





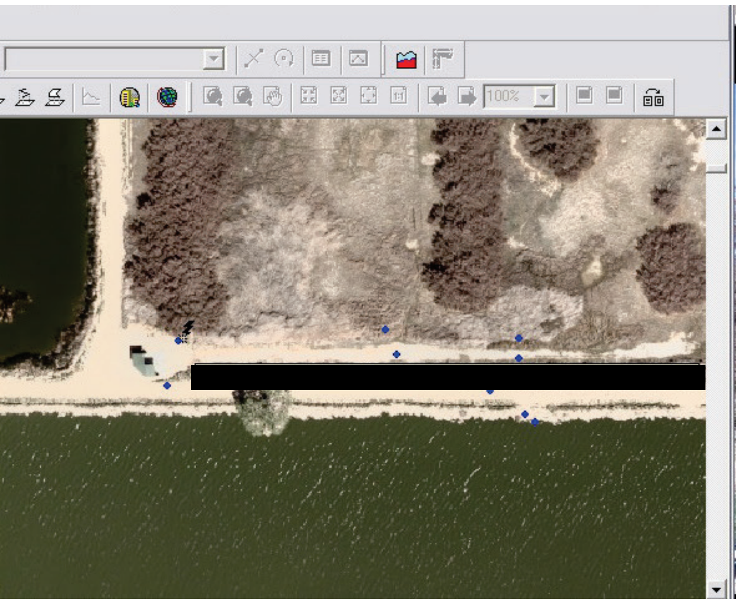
UltraCam natural color image In GIS with hyperlink lightning bolt showing path to displayed graphics on right

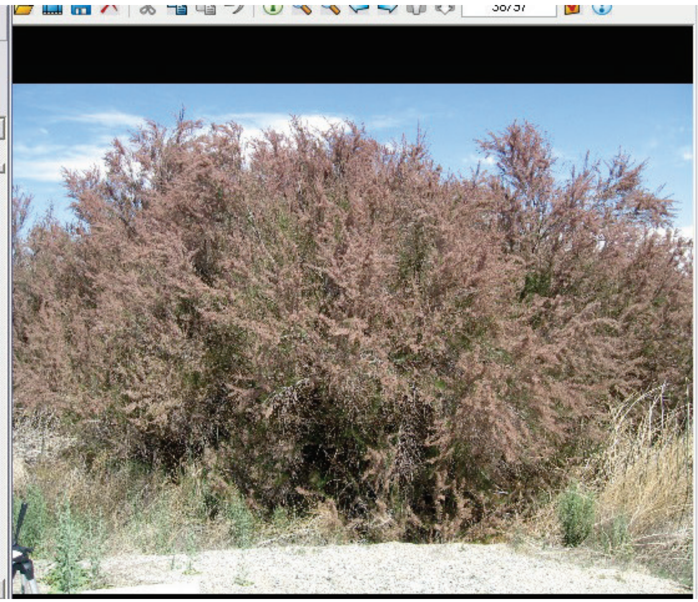
Field photograph of feature where Visible-Near IR spectral signature collected

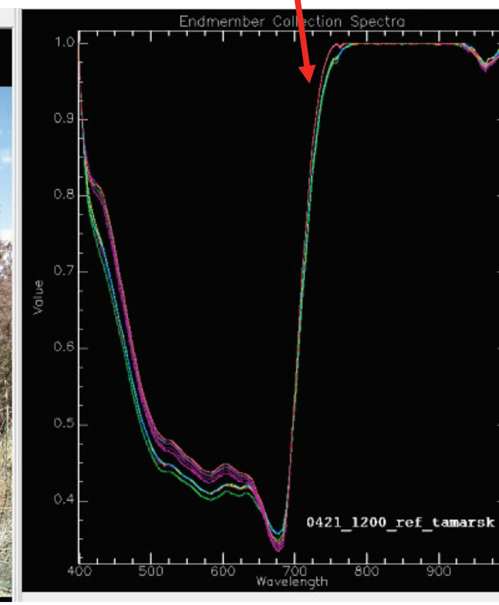
Visible-Near IR spectral signature of feature shown on left

VNIR Sensor

Tamarisk
Sampling site, ground photo, and ground spectra in GIS







UltraCam natural color image In GIS with hyperlink lightning bolt showing path to displayed graphics on right

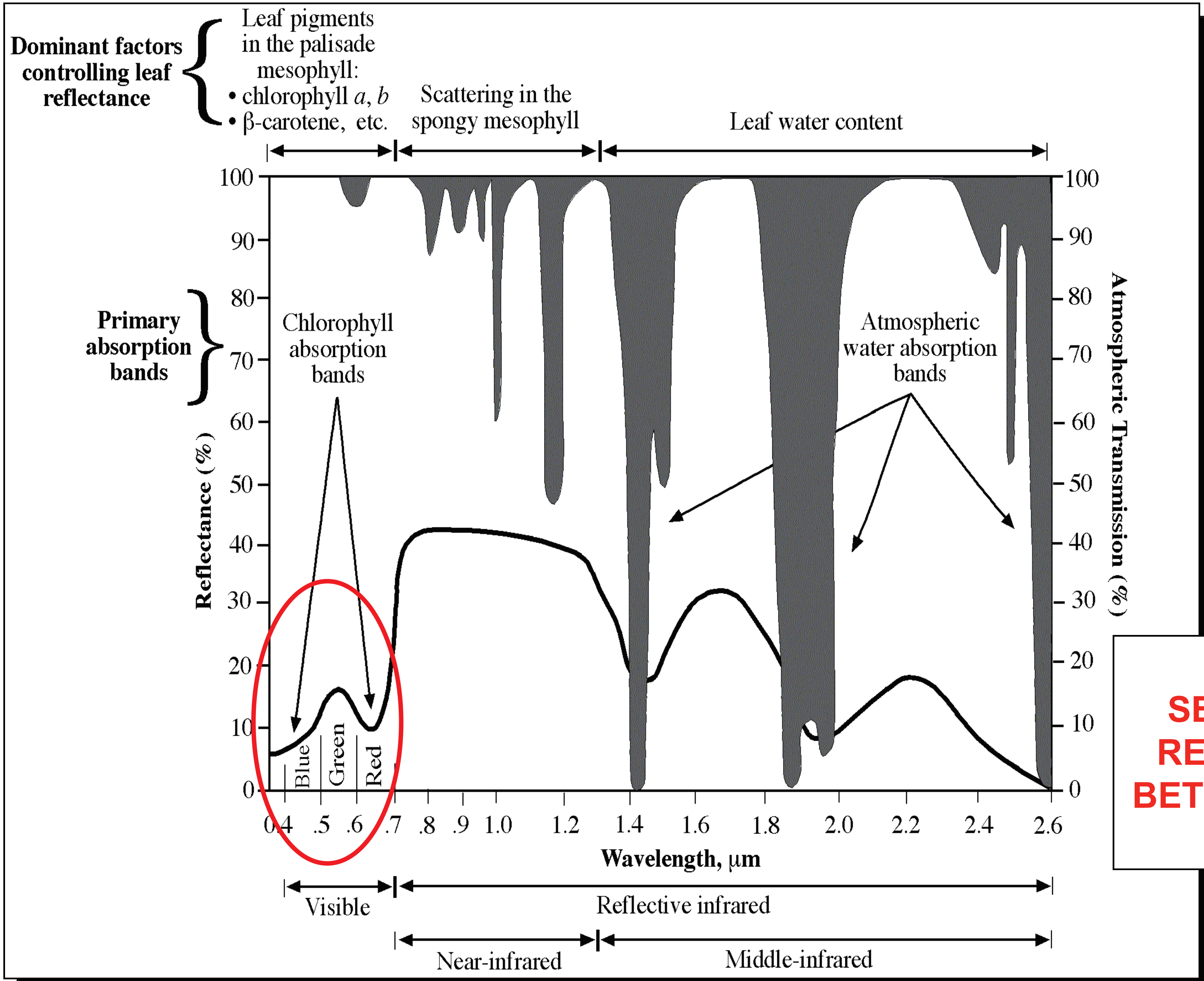
Field photograph of feature where Visible-Near IR spectral signature collected

Visible-Near IR spectral signature of feature shown on left

VNIR Sensor

MAPPING PLANT COMMUNITIES VNIR - SWIR

Dominant Factors Controlling Leaf Reflectance

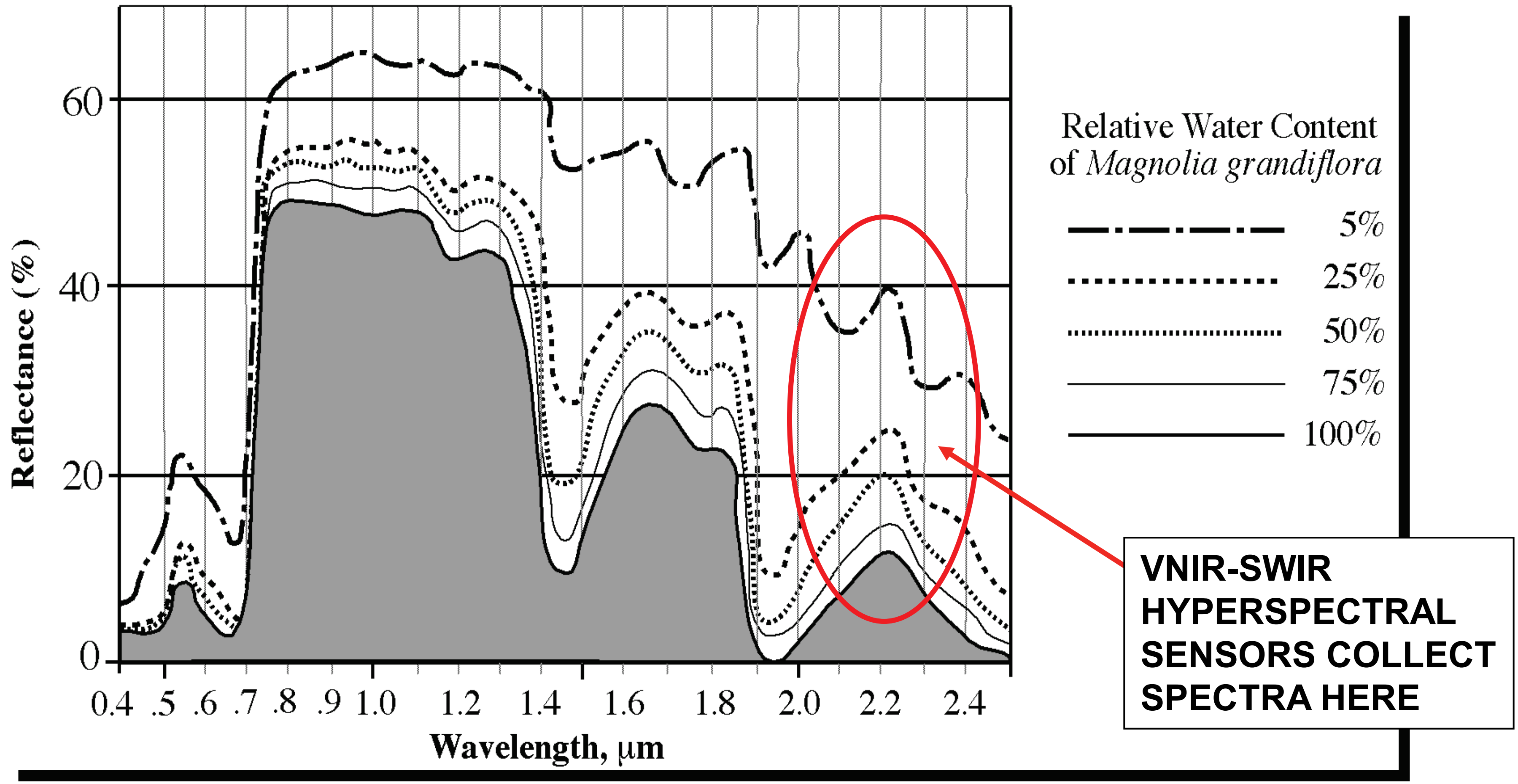


Water absorption bands:
0.97 mm
1.19 mm
1.45 mm
1.94 mm
2.70 mm

VNIR-SWIR SENSOR COLLECTS REFLECTED ENERGY BETWEEN ABSORPTION WINDOWS

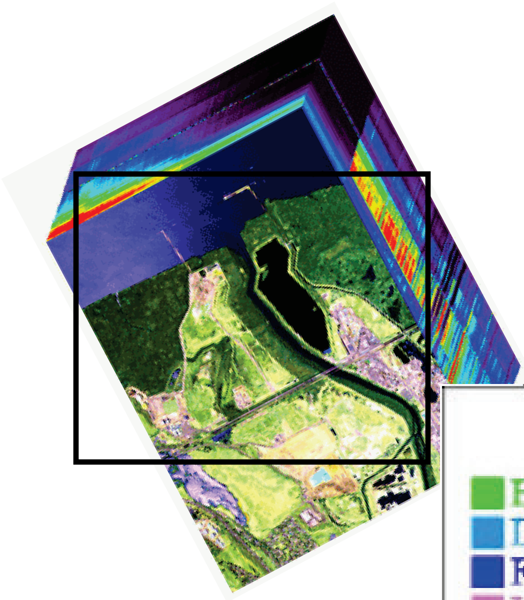
Jensen, 2000

Reflectance Response of a Single Magnolia Leaf (*Magnolia grandiflora*) to Decreased Relative Water Content

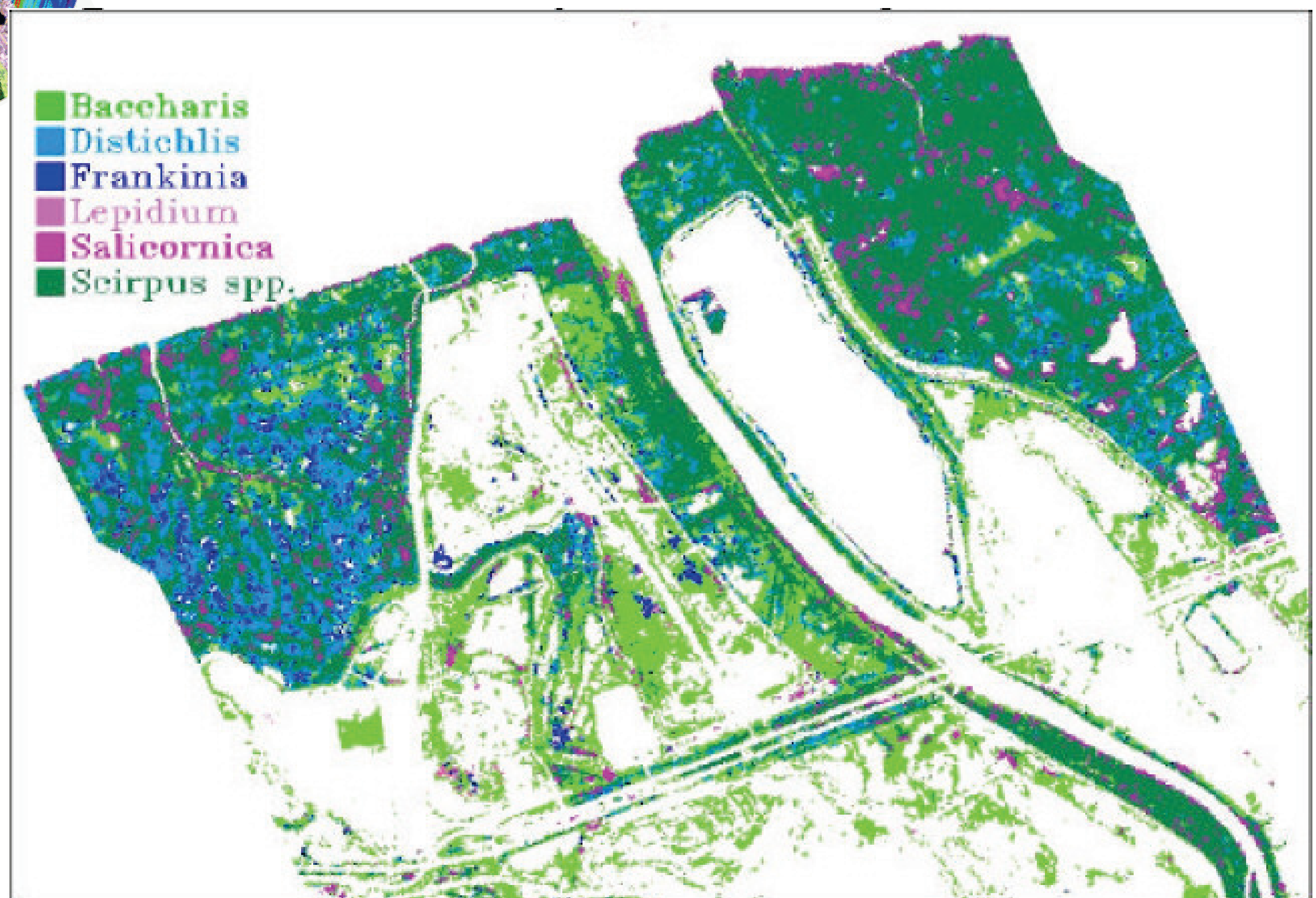


Leaf moisture changes can be significant for identification

Jensen, 2000



PLANT COMMUNITY – SPECIES LEVEL MAPPING VNIR-SWIR



CSTARS
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Spectral Library
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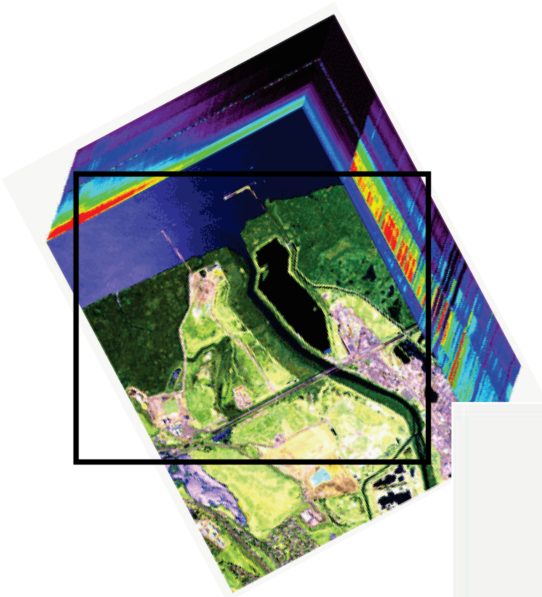
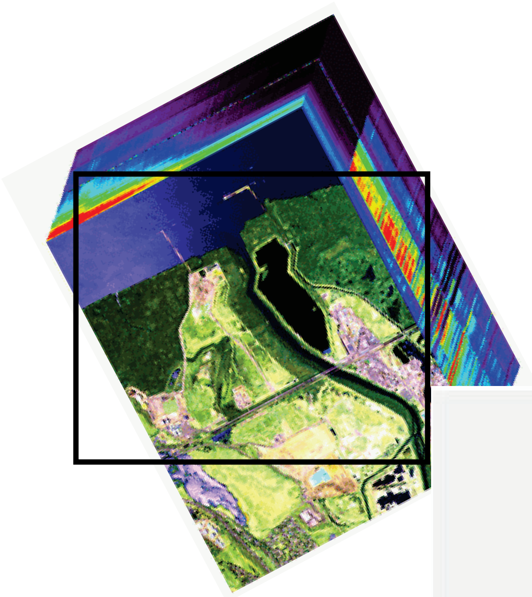


Coyote Bush VNIR-SWIR

CSTARS
Ground-based
Spectral Library
Probe-1 Data
The GeoSat Committee, Inc.

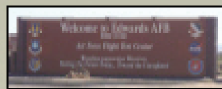
Pickleweed VNIR-SWIR



CSTARS
Ground-based
Spectral Library
Probe-1 Data
The GeoSat Committee, Inc.

Application of Hyperspectral Remote Sensing at Edwards Air Force Base

Introduction

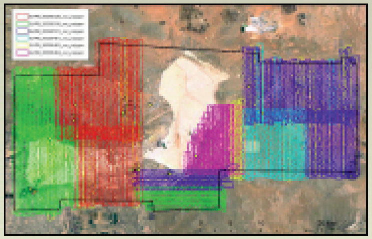


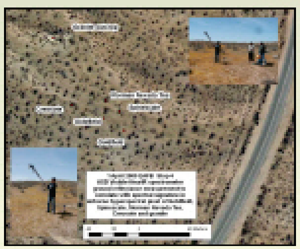
Edwards AFB requires remotely-sensed data to facilitate determining how plant communities change spatially over time, modeling ecosystem health, and predicting sensitive species habitat. The hyperspectral imagery collected at Edwards AFB will be used in future surveys to evaluate recovery of various habitats from mission related projects, activities and operations, as well as the implementation of environmental projects to benefit the Mojave Desert ecosystem. This imagery will also be used to determine habitat stability, help establish an environmental baseline, and support the regional recovery effort for some of the goals and objectives of the Mojave Desert Recovery Plan.

Data Collection

Airborne Data Collection

- Over 400 square miles of hyperspectral data collected over Edwards AFB
- Airborne AISA EAGLE Visible to near-IR (VNIR ca. 400 – 1,000 nm spectral range)
- Spectral resolution of around 5 nm (VNIR)
- Project area flown March 28th - April 4th, 2009
- 190 flight lines, 128 separate bands, spatial resolution 1m

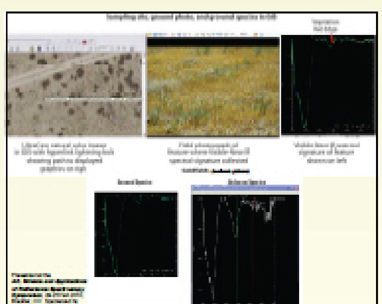




Ground Spectra Collection

- Ground spectra measured with an ASD FieldSpec® handheld spectrometer
- 100 ground spectra (VNIR), photographs, field observations and GPS locations recorded
- Data collected March 31st - April 23rd, 2009
- GIS integration of ground spectral library, photographs and field observations

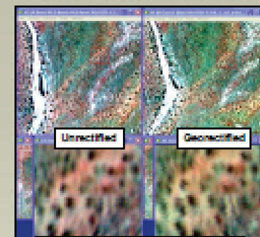
Spectral Quality of Ground & Airborne Data

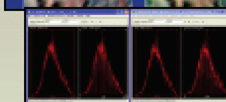


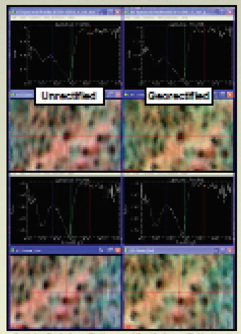
- Atmospherically corrected and continuum removed spectra were correlated over the Piute Ponds pilot-project area.
- The spectral quality of airborne pixels compares favorably with spectra collected on the ground at the same location.
- Spectra collected for known plant species on the ground are represented in the airborne data cubes. Therefore, each plant species has a much greater probability of being successfully identified in processing and mapping the airborne images.

Spectral Quality of Georectified Data Cubes

- Hyperspectral pixels are subjected to considerable shifting, rotating, and resampling during the georectification process.
- Visual comparison of unrectified and georectified images reveals subtle changes of some feature edges (at a pixel level) and even more subtle changes of color; however the histograms of the unrectified and rectified data are remarkably similar, confirming the effectiveness of the nearest-neighbor resampling technique for preserving spectral integrity.



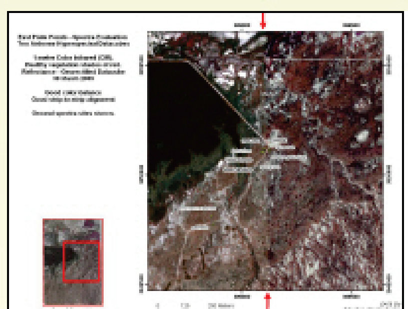


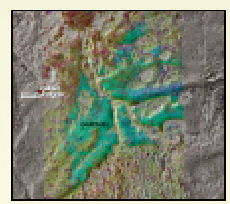


- Spectral profiles of matching pixels in the unrectified and georectified imagery range from visually identical to very similar.
- The spectral profiles confirm that the georectified imagery has pixels with spectral characteristics identical to (or very similar to) the original unrectified data cubes. This spectral quality is critical for production-style processing and mapping using georectified data cubes.

Spatial Quality of Georectified Data Cubes

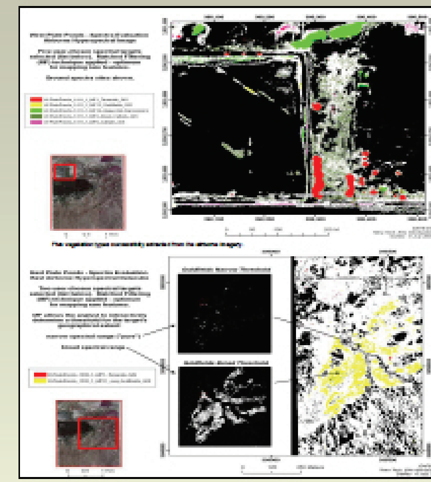
The spatial fit of the georectified flight strips is good compared with the UltraCAM orthorectified aerial photography of EAFB, and the LIDAR DEM.





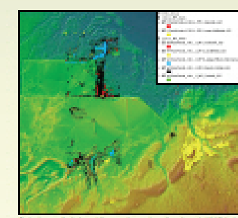
Piute Ponds Image-Processing & Mapping Pilot Project

A mapping pilot project was completed at Piute Ponds, a freshwater marsh area located in the southwestern portion of Edwards AFB, to evaluate the spectral richness and consistency of the airborne hyperspectral data. The reflectance georectified datacubes were used to facilitate integration with the many ground spectra training sites.

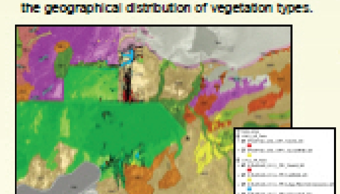


Results

- The airborne VNIR data cubes have enough spectral variation and depth to effectively map plant species and many different plant communities. Several plant species were successfully differentiated and identified using ENVI image-processing algorithms.
- The ground spectral library matches the airborne spectra very well, making the ground spectra an invaluable resource for interrogating the airborne data cubes about specific targets.
- Superimposing the spectra demonstrates the importance of elevation and topographic relief to the geographical distribution of vegetation types.



- Superimposing the spectra demonstrates how existing maps can be correlated with and upgraded.
- The Piute Ponds pilot project clearly demonstrates that the spectral and spatial quality of the georectified imagery enables excellent mapping of different types of vegetation.



Acknowledgements

Hyperspectral Demo

AVIRIS 30m VNIR-SWIR
Afghanistan

Figure 4-1. NASA RB 57 aircraft used to acquire HyMap hyperspectral images of Afghanistan in 2007.

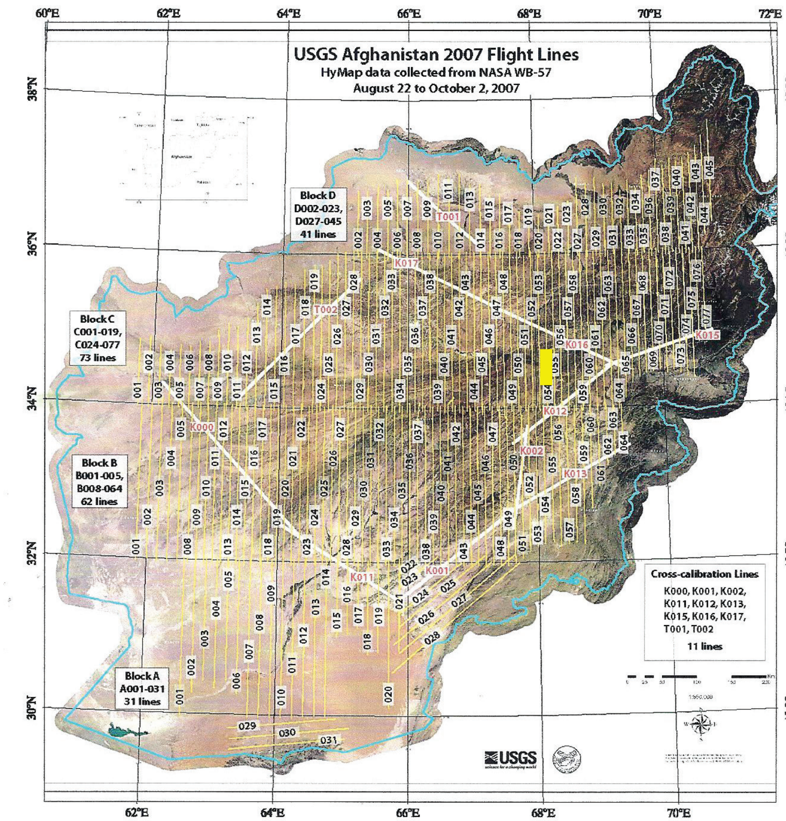
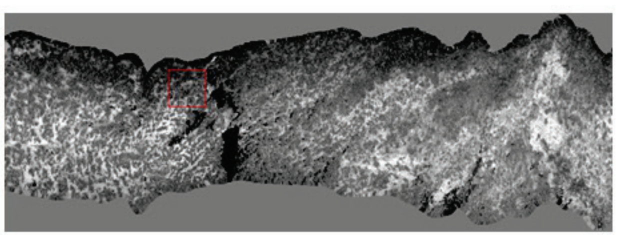


Figure 4-2. Index map of HyMap flight lines, Afghanistan. Yellow rectangle is the portion of image strip C54that covers West and North Aynak AOIs shown in Figure 4-3. Map from Kokaly and others (2008, Figure 3).

Lessons Learned

- Protocol for Ground Training Sites
  - Note taker, photographer, instrument handler
  - Clothes, orientation,
- Flight Planning
  - Mow the lawn, N-S vs. E-W
- VNIR or VNIR-SWIR?
- Size of Pixels
- Mixtures in pixels
- Atmospheric conditions
  - Clouds, shadows
- Calibration – Field & Airborne
- Rectification

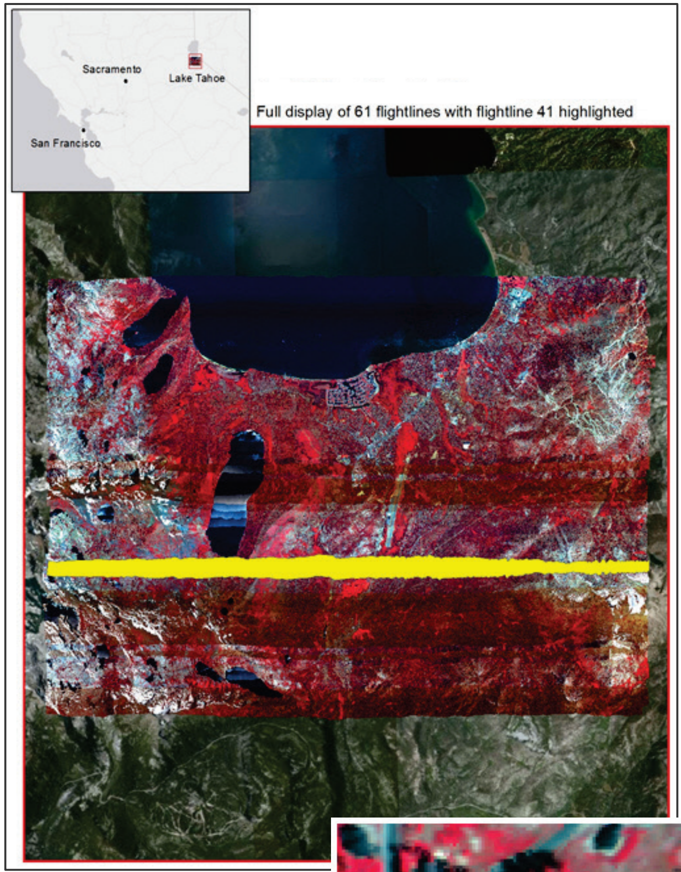


- Phenology – timing!
- Percent canopy cover
- Image Processing
  - Decide on rectified or raw imagery
  - Build spectral library
  - Masking, Band Elimination?
  - Data compression (PC, MNF)
  - Whole Pixel Analysis
    - Spectral classification (unsupervised & supervised)
    - Spectral Angle Mapper (SAM)
  - Subpixel Analysis
    - Endmembers – linear spectral unmixing
    - Matched Filtering
  - Editing
  - Raster to Vector polygons
  - GIS attribution & Metadata
  - Display maps – not imagery….
- Use Hyperspectral to Train More Extensive Multispectral Mapping

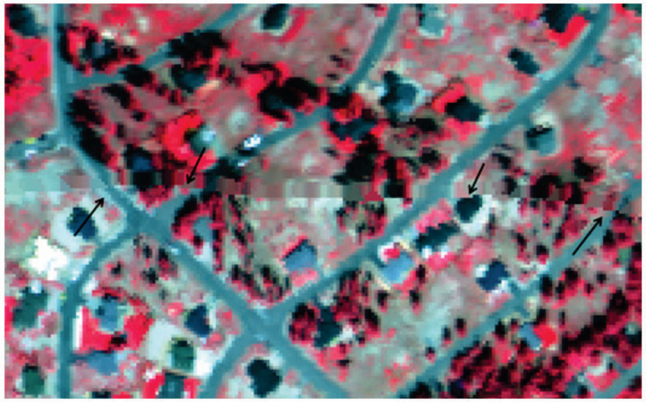
How Best to Use Airborne Hyperspectral?

Use for high-value targets

- **wetlands**
- **industrial facilities**
- **geologic exploration**
- **high-value crops**
- **UXO**
- **remediation**



Geographically extend mapping by using hyperspectral library to establish training sites for multispectral classification



Use LiDAR to increase classification accuracy

Don't show imagery….