ENVIRONMENTAL APPLICATIONS OF HYPERSPECTRAL IMAGERY

James Ellis, Ellis GeoSpatial, Walnut Creek, CA

Ellis GeoSpatial

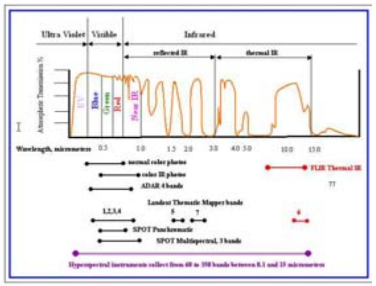
ABSTRACT

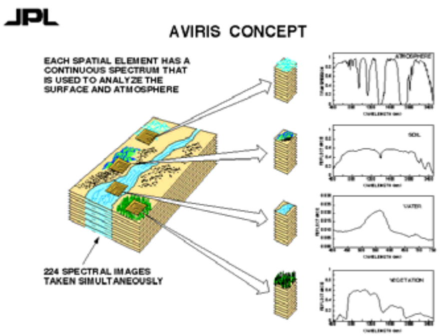
Hyperspectral imaging provides new information about environmental and geologic conditions across open terrain, urban landscapes, industrial facilities, and brownfields. Sensors that record signatures of reflected light spanning visible through near-infrared to shortwave-infrared wavelengths (VNIR-SWIR) are particularly useful for earth scientists.

Earth scientists can use VNIR-SWIR data cubes to map the characteristics of soils, including the surface distribution of different clays (kaolinite, montmorillonite, illite, chlorite, etc.), iron oxides (hematite, goethite, jasperite), calcite, dolomite, and other minerals. Key environmental indicators such as vegetation stress, plant communities, surface water conditions, and land use can also be derived from data cubes. Maps of natural hazards and structural geology are improved by integration of derived maps and enhanced images with DEM's.

Recently we completed a new VNIR-SWIR spectral library for detecting oil-impacted soils and surfaces (including onshore oil seeps). A cooperative R&D effort coordinated by The Geosat Committee, Inc. and sponsored by progressive petroleum companies enabled the library to be built. With this library, VNIR-SWIR hyperspectral technology can be more effectively applied to detect oil-impacted soils and surfaces within industrial sites and brownfields.

OVERVIEW OF HYPERSPECTRAL TECHNOLOGY





Airborne hyperspectral imagery is used to map different materials at the surface of the earth based on their spectral characteristics. Hyperspectral sensors measure the intensity of solar energy reflected from materials over hundreds of different wavelengths. They can record visible light (comprised of relatively short wavelengths - blue, green and red) as well as longer, near-infrared and short wave-infrared light (VNIR-SWIR sensors). This large number of spectral bands is the basis of the name “hyperspectral” which differs from multispectral sensors having a handful of spectral bands. Hyperspectral sensors are unique in that they have sufficient spectral resolution to identify different surface materials based solely on spectral signatures.

128 BAND HYPERSPECTRAL FLIGHT STRIP

A flight strip collecting reflected VNIR-SWIR light over the Oakland airport was processed for multiple applications,including soils, plant communities, paved surfaces, vegetation vigor, and land use/land cover. It is most cost effective to use the data-rich VNIR-SWIR datacubes to support a broad range of applications.

ACKNOWLEDGEMENTS

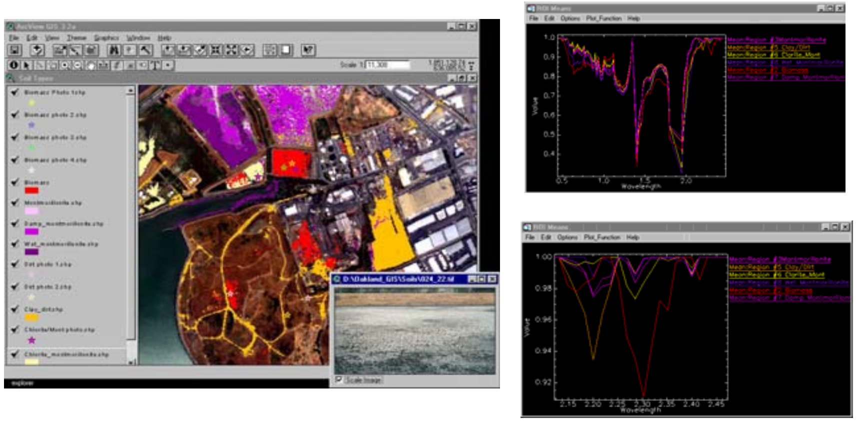
The hyperspectral processing was done by Hattie Davis (now principal of Artistic Earth) with support from Michael Quinn (now with Diablo Valley College using ENVI software. The Oakland Airport flight strip was acquired during cooperative georeferencing work with HyVista and AIG. Hugh Dodd of HJW GeoSpatial did the land use/land cover classification using ERDAS software.

The oil-detection work was supported through The Geosat Committee by Dr. Tod Rubin of Chevron Information & Technology Company, Drs. Mark Little and Hong Yang of Shell International Exploration and Production, and Mr. Jerry Helfand of ExxonMobil. Dr. Rebecca Dodge of The Geosat Committee, Inc. (www.geosatcom.com) coordinated the proposal and funding. Dr. Joseph Zamudio of ESSI provide expertise with field measurements and the spectral library. ESSI provided the hyperspectral flight strips. ImageLinks provided the geometric corrections. Patrick Caldwell, now of Pacific Estuary, provided critical field locations for the work.

Modified from Poster presented at GSA National Conference, Boston, Nov 2001

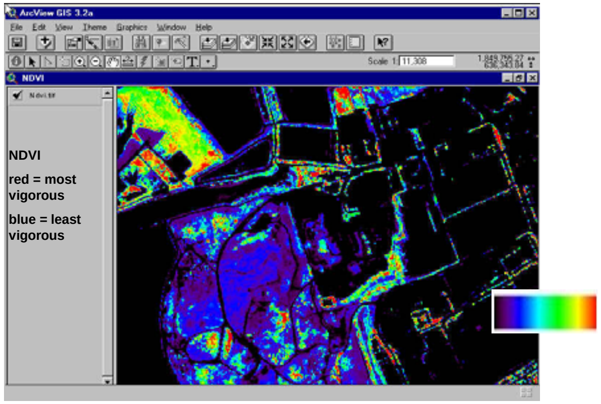
Affiliations updated in 2005

SOILS



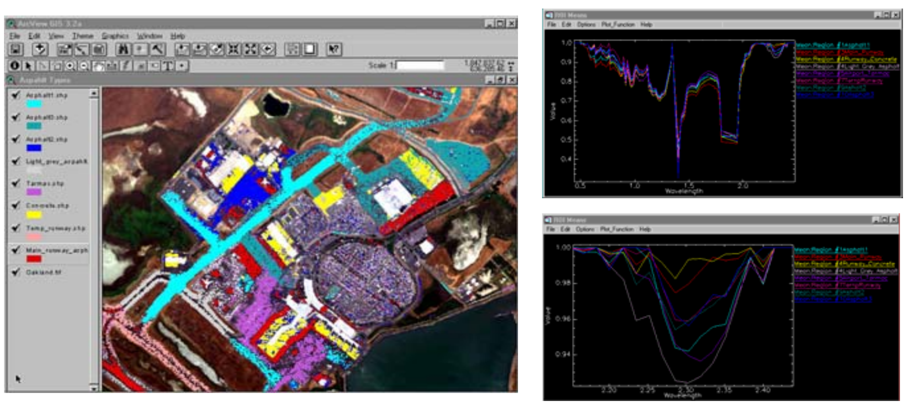
Mapping the spatial distribution and type of different soils may enable better understanding of a features's engineering performance.

VEGETATION VIGOR



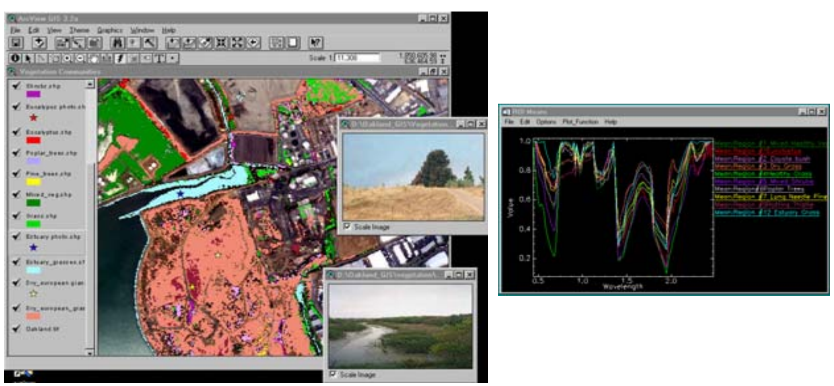
Red Edge shift, chlorophyll absorption or NDVI is used for mapping vegetation vigor. Determining what pixels have vegetation is essential for mapping other materials.

PAVED SURFACES



VNIR-SWIR imagery can differentiate paved surfaces based on composition and perhaps condition - improving monitoring the engineering performance of paved surfaces.

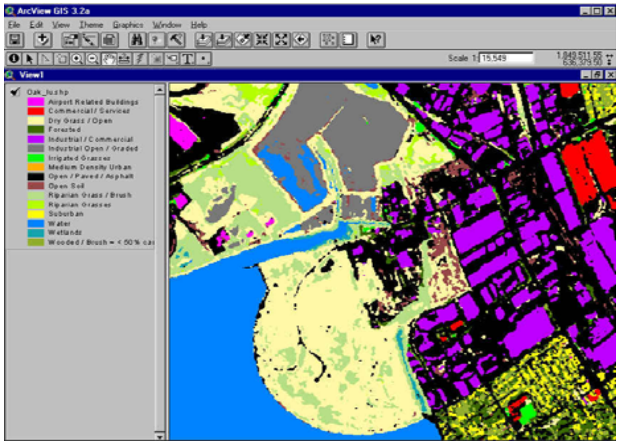
PLANT COMMUNITIES



Spectrally-unique maps of plant communities for a baseline & monitoring.

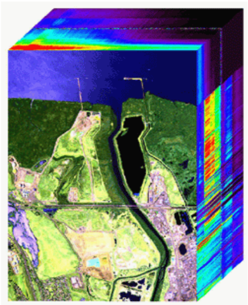
LAND USE/LAND COVER

Land use/land cover classification of hyperspectral imagery provides a comprehensive background map that can improve understanding of the spatial distribution of spectrally unique materials ("biomass, montmorillinite, asphalt1, etc") . Statistics can be developed to determine areal extent of different land uses/land covers for use in modelling storm run-off, irrigation amounts, and degree of development. Each pixel is classified with this process.

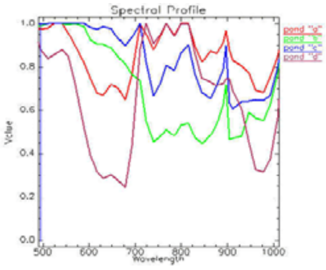


WATER CONDITIONS

A ESSI Probe-1 VNIR-SWIR datacube over an industrialized estuary north of the Oakland Airport provides insight about water bodies



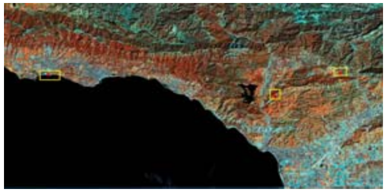
The spectral response of pond "a" and "d" are similar and show the 0.67 chlorophyll absorption feature (note depth and width of 550-700 nm curves). However, this chlorophyll absorption feature is missing within in ponds "b" and minimal in pond "c", perhaps indicating a lack of healthy biomass with chlorophyll at the surface.

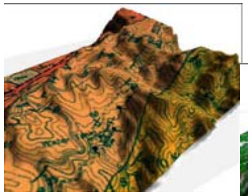


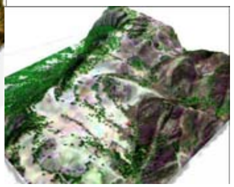
ORTHO BASE

Orthophotography provides a high resolution base with engineering-level x,y accuracy. It can be used to assist with interpreting features on the hyperspectral imagery.

LEARNING TO DETECT OIL-IMPACTED SOILS



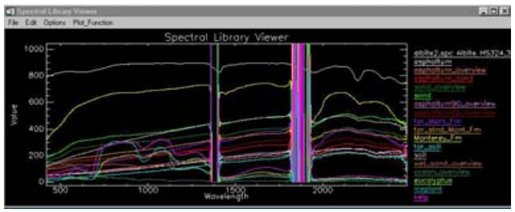




The author (then with The MapFactory), with Hattie Davis (now of Artistic Earth) and Mike Quinn (now with Diablo Valley College), and The Geosat Committee developed a cooperative R&D program to measure with ground and airborne hyperspectral technology different materials associated with onshore oil seeps and oil-impacted soils in Southern California. The primary objectives of the study were to develop an understanding of the spectral characteristics of oil-impacted soils and seeps and to build a spectral library that would make the detection process more rapid and reliable. Maps produced by The Dibblee Geological Foundation were essential for the study.

BUILDING A SPECTRAL LIBRARY

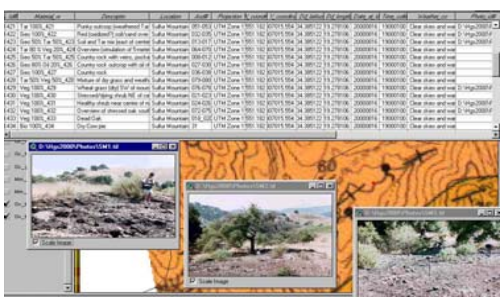
In order to correlate spectral signatures with specific materials, we try to obtain "pure" samples of the material and collect highly accurate, reflected light measurements in the lab or in the field using a portable spectrometer. The measurements allow spectral libraries to be built that contain various hyperspectral signatures that have been positively identified with specific materials at the earth's surface. Spectral libraries have been constructed for numerous minerals, plants, and manmade materials. This may be the first onshore oil seep library.



Field spectrometer measurements for different materials

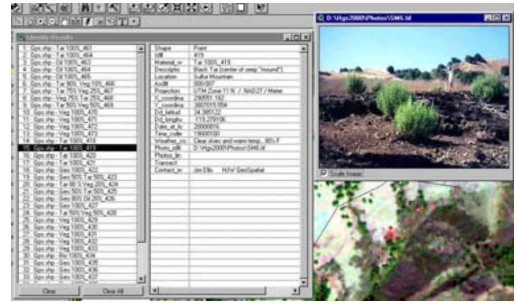
	A	B	C	E	G	H
1	ID#	MATERIAL_WITH %	DESCRIPTION	ASD#	X_COORDINA	Y_COORDINA
2	401	Tar 100%_401	Large semi-smooth knob of seep above or at extent of	000-006	241693.905	3811728.597
3	402	Tar 50% Geo 50%_402	Overview of Tar/soil mix	040-045	241693.905	3811728.597
4	403	Tar 50% Geo 50%_403	Mixed pixels of Tar and dry sand	046-050	241693.905	3811728.597
5	404	Geo 100%_404	Overview of sand	051-054	241693.905	3811728.597
6	405	Geo 100%_405	Dry sand on beach adjacent to seep	076-080	241693.905	3811728.597
7	406	Tar 90% Geo 10%_406	Overview of tar/rock (90/10)	018-021	241693.905	3811728.597
8	407	Tar 50% Geo 50%_407	Overview of tar and rock mix (50/50)	022-025	241693.905	3811728.597
9	408	Tar 50% Geo 50%_408	Soil and weathered Monterey Formation with Tar	007-011	241693.905	3811728.597
10	409	Geo90% Tar 10%_409	Tar stained or discolored Monterey Formation	012-017	241693.905	3811728.597
11	410	Geo 100%_410	Exposed Monterey Formation at sea cliff (west of seep	081-085	241693.905	3811728.597
12	411	Tar 50% Geo 50%_411	Stratified layers of Tar and soil	026-028	241693.905	3811728.597
13	412	Geo 100%_412	Soil/sand on terrace adjacent to seep	059_061	241693.905	3811728.597
14	413	Geo 100%_413	Wet sand	062-064	241693.905	3811728.597
15	414	Geo 100%_414	Overview of ocean, beyond surf	037-039	241693.905	3811728.597
16	415	Veg 100%_415	Eucalyptus tree (adjacent to seep)	065-067	241693.905	3811728.597
17	416	Veg 100%_416	Iceplant	056-058	241693.905	3811728.597
18	417	Veg 100%_417	Kelp	073-075	241693.905	3811728.597

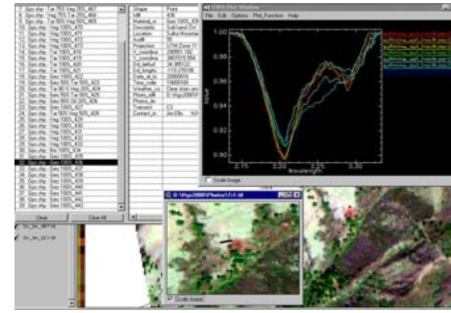
Example of spectral library sites with differing mixtures



Hyperspectral GIS with field site attributes, hot links to ground photos, and Dibblee map showing seeps.

CHARACTERIZING AN OIL SEEP





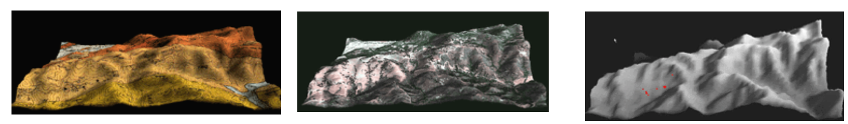
The spectral signatures of ground and airborne data for similar materials were consistent. The airborne sensor successfully detected the signal from surfaces impacted by oil. Above is some of the data collected at each site and a traverse away from an oil seep as recorded with the "bitumen absorption feature."

DETECTING OIL-IMPACTED SURFACES

A

B

C



A. A facility within the airborne flight strip seen as (left) natural color image and (right) classified for oil-impacted surfaces (red). The classification has not been field-checked. The terrain around this facility has natural oil seeps.

B. A wharf where an oil spill was documented in 1992. Hyperspectral imaging detects oil-impacted surfaces (red) along the edge of the wharf. The right-most image is a classification showing wetlands and onshore roads.

C. The primary Dibblee seep area with geologic map, imagery, and detected onshore oil seeps in red.

CONCLUSIONS

Airborne VNIR-SWIR hyperspectral datacubes are very rich sources of information about environmental conditions. Disturbed soils, geology, vegetation type and vigor, water conditions, and land use/land cover can be derived from one datacube. The technology can be applied to brownfields, industrial sites, open space, urban landscapes, and infrastructure.

For more information please contact Jim Ellis E-mail: jellis@ellis-geospatial.com, Tel: 925-280-0720, Web: www.ellis-geospatial.com

Ellis GeoSpatial