EO-1 User Guide v. 2.3

http://eo1.usgs.gov & http://eo1.gsfc.nasa.gov

EO-1 User Guide

Version 2.3

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Supporting materials are available at:
http://eo1.usgs.gov
and
http://eo1.gsfc.nasa.gov

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Designed for use with ENVI 3.5 and FLAASH or ACORN
remote sensing software available from:
http://www.researchsystems.com

and

Analytical Spectral Devices Field Spec Pro spectroradiometer
http://www.asdi.com

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EO-1 Introduction and FAQ

General

What is EO-1's orbit?
EO-1's descending equatorial crossing time is ~10:00 a.m. The satellite is flying in formation with Landsat 7, thus on the World Referencing System (WRS) 2. The acquisitions from Landsat and EO-1 will be within 1 minute of each other. This orbit is very useful for cross comparisons of the instruments on both spacecrafts.

What is the geographic coverage of an ALI or Hyperion scene?
Below is a visual comparison to Landsat 7. For specifics view the Product Descriptions at: http://eo1.usgs.gov/dataproducts/productdesc.asp

What does the browse represent for ALI and Hyperion?
For Hyperion, browses are created from the Level 0 (raw) data. Due to this, vertical lines, zero data values from sensor artifacts, may appear in the browse. Note this anomaly is corrected during Level 1 processing. Hyperion browses are the monochromatic, VNIR band 40. Each band is linearly stretched between the 1% and 97% histogram values. The data is also reduced by a factor of 4 in each direction and jpeg compressed with a quality of 75%.

ALI browses are generated from the Level 1 data and displayed as a RGB (4:3:1). Each band is linearly stretched between the 1% and 97% histogram values. The data is also reduced by a factor of 8 in each direction and jpeg compressed with a quality of 75%.

Are there restrictions for the use of EO-1 data?
No, ALI and Hyperion data is in the public domain. Once a scene has been purchased from the USGS, it can be redistributed as desired.

Data Acquisition Requests (DARs)

What if there is no data in the archive for my area of interest?
EO-1 is a tasking spacecraft, meaning the images acquired are driven by a schedule. This schedule is driven by user's Data Acquisition Requests (DARs). To submit a DAR, please see:
http://eo1.usgs.gov/dataproducts/dar.asp

How many Data Acquisition Requests (DARs) does the spacecraft image daily?
Currently, approximately 12 Data Collection Events (DCE) can be scheduled per day. EO-1 was designed as a technology demonstration mission, thus there are various spacecraft constraints that limit the amount of data that can be collected.

What are the off-nadir pointing capabilities for EO-1 DAR collections?

The spacecraft is capable of pointing over one adjacent WRS, i.e., Landsat, path in each direction from the spacecraft flight path. The off-nadir angle will vary depending upon the location of the target from the instrument flight, i.e. nadir, path.

When does distortion become a significant factor in off-nadir versus nadir collects?

There is no measurement of distortion available. For clarification, nadir generally refers to being within the spacecraft's flight path. For descending acquisitions (daylight) in the nadir path, the instruments are nominally imaging the eastern area of the swath. The amount of distortion depends on where from nadir the target is located. If the target is located in the western area of the path, there will be less distortion imaging from the adjacent path to the west than from the nadir path. In other words, the spacecraft would maneuver less to capture this angle than the western roll that would be required to image the same location from within path. True nadir acquisitions are very rare, less than 1% of the time. Only targets that are physically on the eastern part of the WRS path can even be acquired at true nadir.

What is the geographically length of an E0-1 DAR collection?

A standard collection images for 8 seconds and covers approximately 42 kilometers in the along-track direction. Acquisitions of 185 km can also be collected.

Hyperion Hyperspectral Imager User Guide

Table 1. Current NASA satellites capable of remotely sensing the complete VIS/NIR/SWIR/MIR/TIR spectrum for environmental studies.

Spacecraft/Instrument	Landsat-7 / ETM+	EO-1/ALI	Terra/ASTER	EO-1/Hyperion
Spectral Range	0.4-2.4 10.7-12.7 microns	0.4-2.4 microns	0.5-0.9 1.6-2.4 8.1-11.7 microns	0.4-2.5 microns
Panchromatic Bands	1	1	0	0
Visible Bands	3	6	2	35
Near Infrared Bands	1	2	2 (stereo)	35
Short Wave Infrared	1	1	1	172
Middle Infrared Bands	1	1	5	0
Thermal Band	1	0	5	0
Spatial Resolution	15, 30, 60 m	10, 30 m	15, 30, 60 m	30 m
Swath Width	185 km	37 km	60 km	7.5 km
Spectral Coverage	Discrete	Discrete	Discrete	Continuous
Pan Band Resolution	15 m	10 m	N/A	N/A
Stereo	no	no	yes	no
Number of Bands	7	10	14	220
Number of Spacecraft	1	1	1	1
Temporal Resolution	16 days	16 days	16 days	200 days
	(8 days with Landsat-5)			
Source: NASA EO-1 briefing materials				

Hyperion Introduction and FAQ

What are the bands and spectral ranges for Hyperion data?
There are 220 unique spectral channels collected with a complete spectrum covering from 357 - 2576 nm. The Level 1 Radiometric product has a total of 242 bands but only 198 bands are calibrated. Because of an overlap between the VNIR and SWIR focal planes, there are only 196 unique channels. Calibrated channels are 8-57 for the VNIR, and 77-224 for the SWIR. The reason for not calibrating all 242 channels is mainly due to the detectors' low responsivity. The bands that are not calibrated are set to zero in those channels.

What product formats is available for Hyperion?
Hyperion Level 1 products are available in only Hierarchical Data Format (HDF) with the bands written as band interleaved (BIL). This format was developed by the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign (UIUC).

The "standard" new USGS format 42 km long acquisitions

Are HDF format

BIL

242 bands

256 samples

approximately 3129 lines

Byte Order: Network (IEEE) (integer)

For more information on HDF please visit:
http://hdf.ncsa.uiuc.edu/

For HDF software tools:
http://hdf.ncsa.uiuc.edu/tools.html

Please remember this is for informational purposes only. The USGS does not endorse any particular software product.

What is the geometric accuracy expected for the Hyperion data?
The Level 1 product is only radiometrically corrected and is not geometrically resampled. The user will need to apply the appropriate geometric corrections if necessary.

What is the entity ID naming convention?
E01HPPPRRRYYYYDDDXXXPL

EO1 Satellite
H Hyperion Sensor
PPP Target WRS path
RRR Target WRS row
YYYY Year of acquisition
DDD Julian day of acquisition
X Hyperion 0=off; 1=on
X ALI 0=off; 1=on
X AC 0=off; 1=on
P Pointing mode
L Scene length

How are the radiance values (L) determined within the Hyperion bands?
The digital values of the Level 1product are 16-bit radiances and are stored as a 16-bit signed integer. The SWIR bands have a scaling factor of 80 and the VNIR bands have a scaling factor of 40 applied. The units are W/m2 SRμm.
VNIR L = Digital Number / 40
SWIR L = Digital Number / 80

What is the signal-to-noise ratio (SNR) for Hyperion?
The SNR for Hyperion is 190 to 40 as the wavelengths increase.

What are the files contained within a Hyperion Level 1 product?
An example of the products distributed with an Hyperion L1 product:

entityID.MET	Metadata file
entity.L1R	HDF datasets (image data, spectral center wavelengths, spectral bandwidths, gain coefficients, and a flag mask)
entityID.hdr	ENVI formatted hdr

What are the differences between the earlier TRW products and the new USGS Hyperion products?
The USGS has created a new Hyperion product format. There are packaging and data differences between the 2 sets of code explained below.

The USGS products are packaged in Hierarchical Data Format (HDF) with the datasets being image data, spectral center wavelengths, spectral bandwidths, gain coefficients and a flag mask. The previous TRW was image data with separate files for other ancillary details. The file naming conventions are different as well; the USGS utilizes an entity ID with acquisition target verses the data capture time utilized by TRW.

Comparisons of the data show that the USGS products are very comparable to the TRW products. For most bands the radiometric differences are within 1%. Some differences to note are:

1) Dead detectors are not corrected or interpolated in USGS products, thus vertical stripes will be visible where these known dead detectors exist;

2) Radiometric differences may be greater because of the known dead detectors not being interpolated in USGS products.

3) An additional scan line in the USGS products accommodates for the SWIR shift; and

4) The first scan line in USGS products are not corrected for echo since echo correction requires information from the preceding line; and

5) For the spectral center wavelengths, USGS products represent means across all detectors for each band while the TRW products represented the wavelength at field of view pixel 128.

What is the flag mask?

Three different items are represented by the mask: saturated, dead and flat pixels. The pixels in the flag mask can have several values:

0 = Normal data
1 = Saturated pixel
2 = Dead detector (unresponsive to light, with zero values)
3 = Flat detector (dead but register a constant value)
4 = Fill value (overflow, value exceeds calibration range)

Where is band wavelength specific information located in the Hyperion product?

The center wavelength for each band can be found in 2 locations: the ENVI formatted .hdr or in Dataset #2, spectral center wavelengths. The ENVI .hdr is in ascii format while Dataset #2 is in binary format.

Draft Hyperion Hyperspectral Mapping Exercise
Using Atmospheric Correction and
End Members from Spectral Libraries and Regions of Interest with
Data from Cuprite, Nevada

P. Barry, P. Shippert, D. Gorodetzky and R. Beck

Funded by USGS EROS Data Center and NASA Glenn Research Center

Introduction

The following is an exercise in using atmospheric corrections and end member spectral libraries and regions of interest to make classification maps using short wave infrared (SWIR) hyperspectral satellite image data from the Hyperion hyperspectral imager on the Earth Observing 1 satellite of Cuprite, Nevada. The exercise is derived from a presentation by Pamela Barry at the E0-1 Hyperion Data Users Workshops with additional documentation on the ACORN atmospheric correction by Anne Gravante and the FLAASH atmospheric correction from Peg Shippert and David Gorodetzky as well as detailed exercise instructions for use with ENVI 3.5 or 3.5 RT by Richard Beck.

This exercise has four basic processing steps consisting of

1. converting Hyperion level 1 B data to radiance

2. atmospherically correcting or removing the envelope to convert from radiance to reflectance

3. performing (mineral) mapping using the Spectral Angle Mapping Technique (details available in the ENVI user manual).

4. comparing the resulting Hyperion maps with known maps or other ground "truth".

with two variations in step 3 above, namely,

1) Hyperspectral mapping with spectral end members derived from spectral libraries to determine surface composition when the user has no first hand knowledge or "ground truth"

2) Hyperspectral mapping with spectral end members derived from regions of interest (ROIs) derived from locations of known composition ("ground truth") within an image to extrapolate to unknown areas within the image.

<u>The exercise gives the user two starting points with regard to data processing.</u>

The first option starts at stage I and assumes that the user will start with Hyperion level 1 B data and make the atmospheric corrections. THIS FIRST OPTION REQUIRES ATMOSPHERIC CORRECTOIN SOFTWARE such as ACORN, MODTRAN, ATREM or FLAASH. Two level 1B data sets are provided along with instructions for using ACORN and FLAASH.

The second option assumes that the user will start at step III with Hyperion data that have already been atmospherically corrected with ACORN or FLAASH. This ACORN or FLAASH corrected data set is also provided for those who wish to start at step III.

Background
Cuprite, Nevada is a mineralogical site that has been established as a reference site for remote sensing instruments. Various examples are available via the internet.

A few sites are listed below.

http://speclab.cr.usgs.gov/cuprite.html use with Airborne Visual and Infra-Red Imaging Spectrometer (AVIRIS)

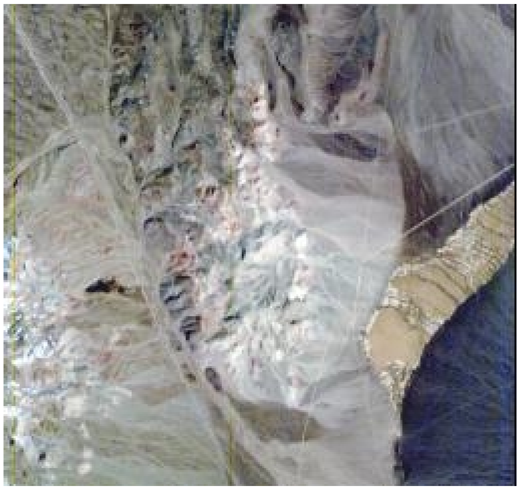
http://www.borstad.com/papers/ use with SWIR Full Spectrum Imager (SFSI)

http://edcdaac.usgs.gov/samples/ use with Landsat ETM +

http://eo1.usgs.gov use with EO-1 (Hyperion and ALI).

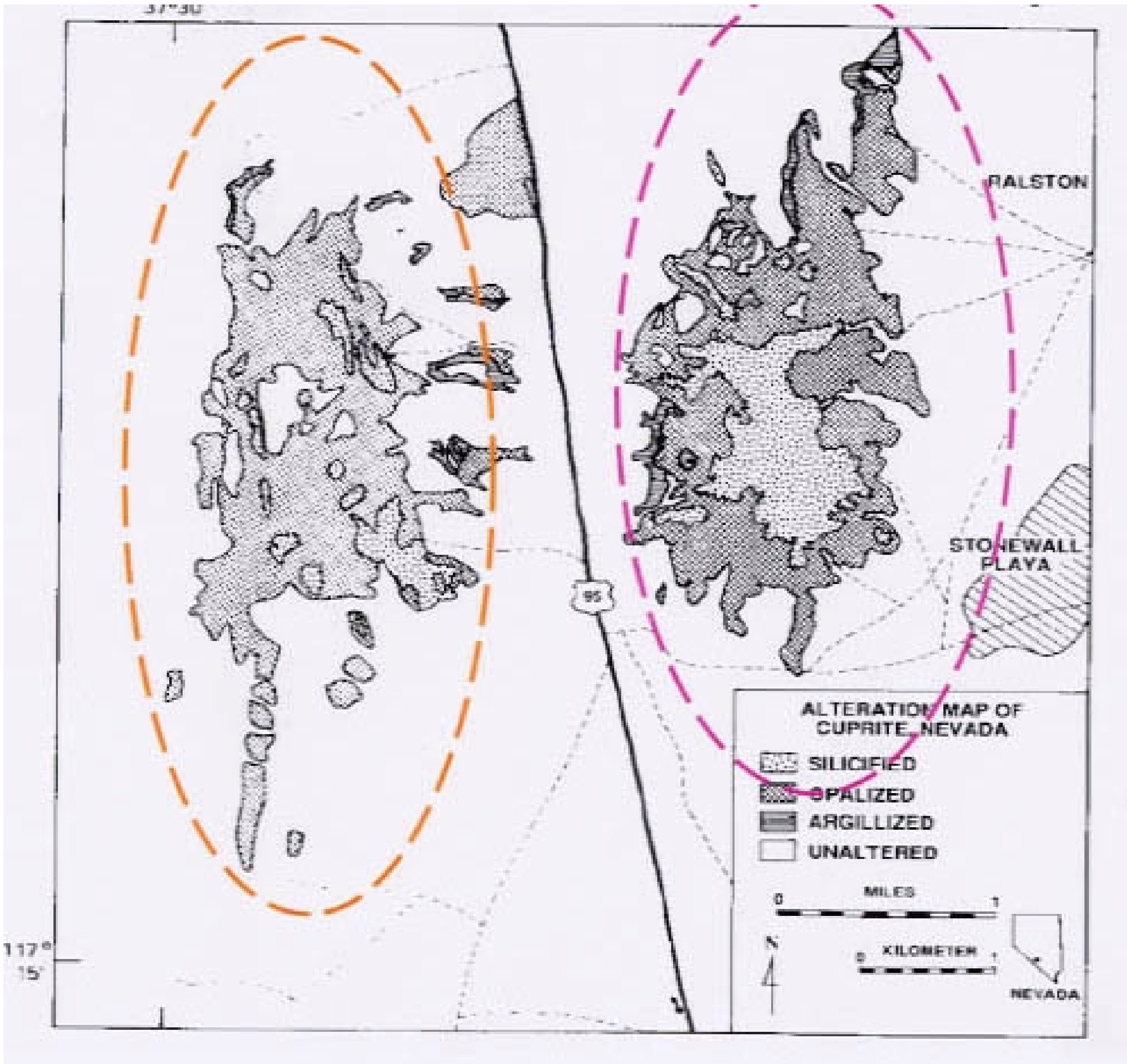
Cuprite is an arid and sparsely vegetated region along the California – Nevada border near Death Valley. The geology is dominated by siliceous to basic volcanic rocks of tertiary age.

Hyperion image of Cuprite, February, 2001



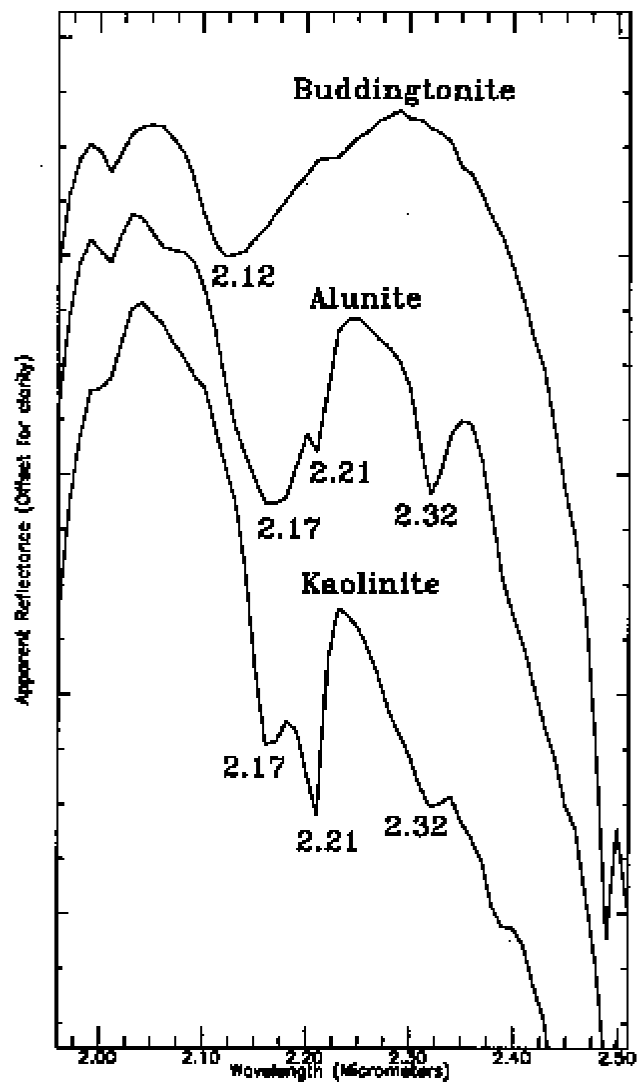
Reference spectra of the geology that is found in the area are available in spectral libraries. For example, ENVI 3.4 contains a USGS and a JPL mineral library containing spectra for numerous minerals including alunite, calcite, buddingtonite, kaolinite and muscovite which are found in the Cuprite site as shown in the following mineral map.

Mineral map of Cuprite, Nevada.



Hyperspectral imaging uses hundreds of closely spaced bands to discern the reflectance spectrum of each pixel. These spectra may then be compared with spectra measured from field samples or spectra from laboratory measurements collected in spectral libraries. Examples are shown in the following figure.

Mineral Spectra for alunite, buddingtonite, and kaolinite from Research Systems Incorporated.



Metadata

The data contained in this CD have been revised from the original TRW format scene used in previous versions of this gudie that were collected by Hyperion on March 02, 2001. The original TRW scene corresponds to a subset contained within Path 092 and Row 084 in Landsat World Reference System number 2 (WRS2) with a spacecraft commanded latitude and longitude of 37.539 and –117.2, respectively . The Hyperion scene ID is EO1041034200106011PP. The data have been subset in the temporal (or length) direction with the resulting dimension of 256x651x242.

The new USGS HDF format .L1R scene was acquired on

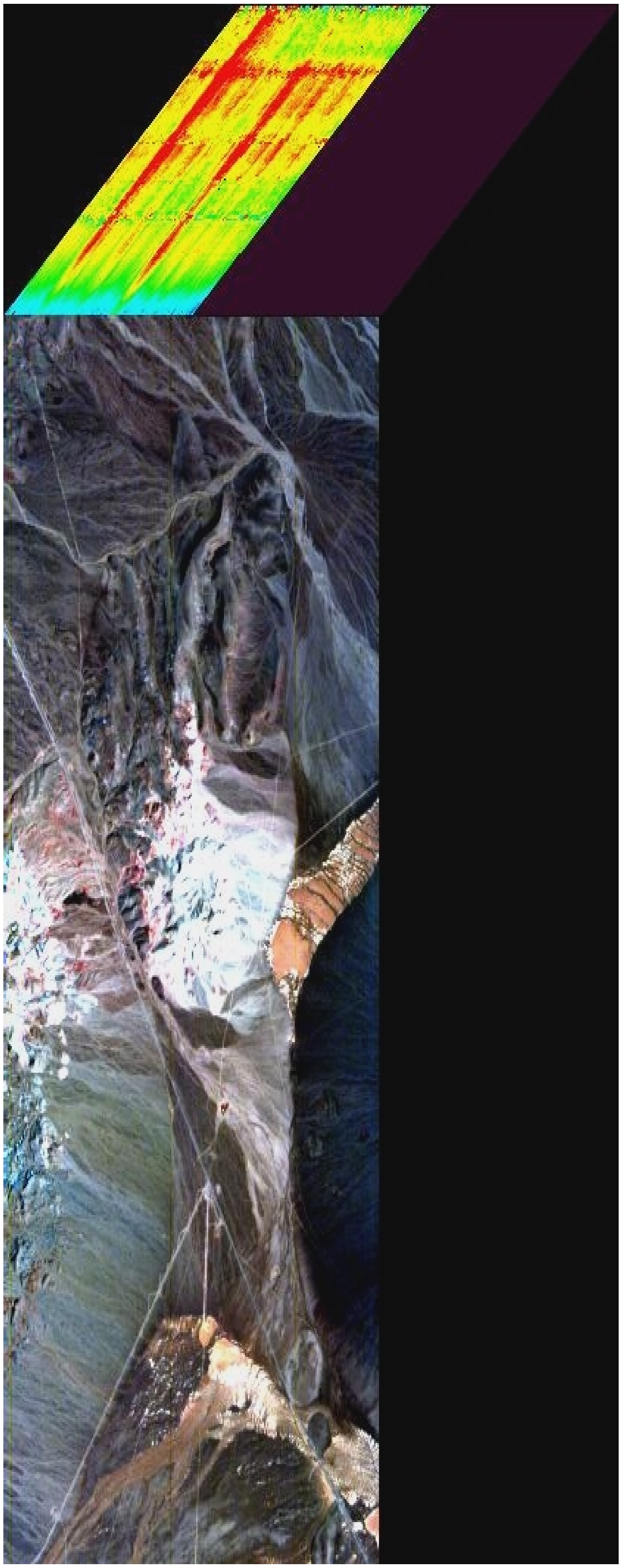
```
Scene Request ID       EO1041034200206311OPY
Site Latitude                37.475800
Site Longitude               -117.491600

HYP Start Time                2002 063 18:16:54
HYP Stop Time                 2002 063 18:18:03

HYP  File  Start              Stop                Duration
HYP  444C  2002063181722.421  2002063181736.421    14.000

DPS Quality Reports      20020641206_SGS_01_A.DQM
                         20020641206_SGS_01_B.DQM

Ground Site ID           SGS
Contact Start Time       2002_064_1206
Contact Stop Time        2002_064_1220
```

Please note that Hyperion level 1b data are in units of W/m**2 micron SR x 40 for the VNIR or x 80 for the SWIR. In contrast, the FLAASH atmospheric correction software uses units of microW/cm**2 nm SR so the scaling factors used in FLAASH should be 400 for the VNIR and 800 for the SWIR because there is an extra factor of 10 when using FLAASH. An example is shown in the figure below.

For other scenes you will need to convert from the numerical date to the calendar date for use in the FLAASH atmospheric correction module.

A converter is located at: http://www.timeanddate.com/date/dateadd.html

Cuprite, Nevada Hyperion FLAASH Cube



I. CONVERTING HYPERION LEVEL 1 B DATA TO RADIANCE

Initial Hyperion Data Preparation Steps with Level 1_B by Pamela Barry

As part of the data recording process, Hyperion data are scaled to limit the amount of saturation and storage space. The steps listed below are provided to assist users in quickly displaying the data and in undoing the scaling. Hyperion actually consists of two instruments that share a common set of optics one for the VNIR and one for the SWIR. For the Level 1_B data product, the SWIR has been aligned with the VNIR. The steps below are provided as suggestions. The user should use their own discretion. The steps were based on using ENVI 3.4 and 3.5.

<u>These instructions pertain to the old TRW HDF format. Please see Part II for instructions regarding new USGS HDF format data.</u>

To convert from HDF to ENVI Standard Format.

1.) Open Data Set
Load in the Hyperion L1_B data set

File Open Data File Select a file
highlight the file that is listed and click OK. You will see the dimension of the file. Ex: (256x242x651):Hyperion L1_B

Choose BIL, and

Click OK

2.) Quick Look
Display single bands as gray scale (40 = vnir, 93 = swir)

Or

Select three bands as RGB (29, 23, 16 = VNIR, 204,150, 93 = SWIR).
From the Available Band List toggle gray scale or RGB button.

Select bands, Load band, and/or click on Display button to select new

Display.

If no visible features in the image, plot spectral profiles if selected an uncalibrated band.

From image window Tools Profiles Z-profiles

3.) Subset Data Set

Use scroll bar to review the scene.

Double click on image window to get cursor location /value for pop up window.

(or From image window Tools cursor location /value)
Select the starting line and ending line encompassing the region of interest.

From main toolbar BasicTools Resize Data From Resize Data Input file Menu.

Select input file.

Select Spatial Subset.

Click OK.

From Resize Data Parameters
Choose file name

4.) Convert subseted Data Set to Absolute Radiance.
(For the VNIR Bands 1-70)

From main toolbar / Basic Tools / Band Math

From Band Math Window, Enter an expression, type b1/40.0

Click OK

From Variables to Band Pairings / Click on “Map Variable to
Input File”,

Select filename, Select Spectral Subset, Highlight bands 1 to
70.
Click OK,

Click OK,

Choose output file name.

This is the Hyperion VNIR
converted to absolute radiance.

(For the SWIR Bands 71-242)

From main toolbar / Basic Tools / Band Math

From Band Math Window / in Enter an expression, type b2/80.0

Click OK

From Variables to Band Pairings ! Click on "Map Variable to
Input File",

Select filename, Select Spectral Subset,

Highlight bands 71 to 242.

Click OK,

Click OK,

Choose the output file name.

This is the Hyperion SWIR converted to absolute radiance.

5.) Combine the two data files
From main toolbar / save file as / envi standard

In New File Builder select (or import if you have to) the VNIR radiance file, then the SWIR radiance file. Reorder option will allow the reordering of

the files by dragging a name above another.
ENJOY!!

OR

II ATMOSPHERICALLY CORRECT OR REMOVE ENVELOPE FROM HYPERION RADIANCE DATA TO CREATE REFLECTANCE DATA

Two options for the atmospheric correction of Hyperion data are offered here. The first option is FLAASH. The second option is ACORN. FLAASH is the more sophisticated option. FLAASH also requires somewhat more preparation and compute time. Beginners might consider starting with ACORN accordingly.

IIa. ATMOSPHERICALLY CORRECT OR REMOVE ENVELOPE FROM HYPERION RADIANCE DATA TO CREATE REFLECTANCE DATA USING FLAASH.

Peg Shippert, David Gorodetzky and Richard Beck

The following are instructions specific to the Hyperion hyperspectral instrument on EO-1. Use the FLAASH user manual from Research Systems or another atmospheric correction method. If you use FLAASH you will need ENVI 3.5 or ENVI RT 3.5. FLAASH requires 2-byte integer data.

The URL for Research Systems to order FLAASH and its manual is http://www.rsinc.com or http://www.researchsystems.com

The following method should be used for the original TRW HDF file format.

Instructions for atmospheric correction of the new USGS HDF file format follow the instructions for the TRW format.

Step 1 for TRW HDF Format Hyperion Data
Open ENVI 3.5 or 3.5 RT with FLAASH installed

Step 2 for TRW HDF Format Hyperion Data
Convert the HDF file to ENVI standard format.
Select File / File Save As ENVI std

In the New File Builder dialog box click Import File.

In the Create New File Input File dialog box click Open File.

In the Please Select a File dialog box select an input level 1B Hyperion HDF file similar to EO12001065_43CD43CC_r1_WGS_01.L1_Bs.dat and newer USGS HDF format .L1R files.

Click Open

In the HDF Dataset Selection dialog box Select All Items
and select BIL.

Name the file "….BSQ" (because that is what you are going to get even though you told it to make a BIL file).

Click OK.

This will take a while and save an ENVI Standard BSQ file
(despite the fact that you told it BIL).

Step 3 for TRW HDF format Hyperion Data
Convert the ENVI standard BSQ to BIL

Select Basic Tools / Convert Data (BSQ, BIL, BIP)

In the Convert File Input File dialog box, Select the BSQ file that you just created in Step 2 (even though you specified BIL).

Click OK

In the Convert File Parameters Dialog Box, Select BIL

Convert in place = NO

Enter the Output file name as ….BIL

Click OPEN

Click OK

This will take a while and really save an ENVI Standard format BIL file this time.

Check the image processing by displaying a Natural Color Image with bands 29, 23 and 16 as RGB.

Step 4 for TRW HDF format Hyperion Data.
Atmospherically correct with FLAASH to create a reflectance image from a radiance image.

Select Basic Tools / Calibration Utilities / FLAASH
In the FLAASH Atmospheric Correction Model Input Parameters dialog box…

Click on Input Radiance Image and select the output from Step 3.

Select Read array of scale factors (1 per band) from ASCII file in the Radiance Scale Factors dialog box

Select the hyperionscalefactors.txt file included with the data and click OK.

The hyperionscalefactors.txt file is made specifically for FLAASH and uses scale factors of 400 for the VNIR and 800 for the SWIR accordingly.

Click on the Output Reflectance File and select a file name.

Click on the Output Directory for FLAASH files.

Type in a root name for the FLAASH files (several extra files will be generated). **Do not include a directory path.**

Type in your Scene Center Location (- values for southern and western hemispheres).
Select Unknown for your sensor type.

Input the Flight date.

Enter a Sensor Altitude of 705.0 kilometers.

Enter the average Ground Elevation of your scene in kilometers.

Select the Flight Time in HHMMSS format.

Select an atmospheric model according to the FLAASH user guide with at least as much atmospheric moisture as your scene.

Select an Aerosol Model.

Select YES for Aerosol Retrieval.

Type in a reasonable Initial Visibility value in kilometers just in case the aerosol retrieval calculation fails.

Select NO for Spectral Polishing.

Click on Advanced Settings.

In the FLAASH Advanced Settings dialog box enter

An Aerosol height of 2.00 kilometers.

A CO2 mixing ratio of 390 ppm.

An IFOV of 0.043 mrad.

Toggle the Reuse MODTRAN Calculations to NO.

Select a Modtran Resolution of 15 or 5 (5 takes longer and is just a little better).

Toggle the Modtran Multiscatter Model to Issacs.

Do not change the For Non-nadir Looking Instruments unless you have tasked the satellite for a view which is significantly off of nadir (not straight down as is usual).

Type in an Output scale factor of 10000 (ten thousand) for Hyperion.

Leave the Automatically Save Template File set to YES.

Leave the Output Diagnostic Files set to NO.

Click OK.

Click Apply.

The calculation will take several minutes.

You now have an atmospherically corrected reflectance image to which you can apply spectral end members for mapping.

Several other atmospheric correction packages are available.

Step 5 for TRW HDF Format Hyperion Data

"Bad Band" Adjustments

Backup the original FLAASH corrected ENVI Standard File and its header file.

Open the ENVI Header File for the FLAASH corrected ENVI Standard File.

Click Edit Attributes.

Select Bad Bands List.

Highlight all of the good bands by holding down the Control Key and clicking on the good bands. If you have only a few bad bands, you can hold down the shift key to select all of the bands and then use the control key to deselect (change from blue to white) the few bad bands.

For at least some of the old TRW format data the good bands include:
9-52
77-120
130-167
180-222

Click OK

Click OK

You will probably have to save the new header in a different directory and then move the new directory into the original directory to replace the old header file.

Instructions for Atmospheric Correction of new (spring 2002) USGS HDF format Hyperion Data using FLAASH.

Step 1 for USGS HDF Format Hyperion Data
Open ENVI 3.5 or 3.5 RT with FLAASH installed.

Make sure that you have installed the new FLAASH envi_fla.sav file that was modified on July 15, 2002 to handle the new USGS HDF format Hyperion data.

Step 2 for USGS HDF Format Hyperion Data
Convert the HDF file to ENVI standard format.
Select File / File Save As ENVI std

In the New File Builder dialog box click Import File.

In the Create New File Input File dialog box click Open File.

In the Please Select a File dialog box select an input level 1B Hyperion USGS HDF file with the .L1R suffix.

Click Open

In the HDF Dataset Selection dialog box Select All Items
and select BIL.

Name the file "….BSQ" (because that is what you are going to get even though you told it to make a BIL file).

Click OK.

This will take a while and save an ENVI Standard BSQ file
(despite the fact that you told it BIL).

Step 3 for USGS HDF format Hyperion Data
Convert the ENVI standard BSQ to BIL

Select Basic Tools / Convert Data (BSQ, BIL, BIP)

In the Convert File Input File dialog box, Select the BSQ file that you just created in Step 2 (even though you specified BIL).

Click OK

In the Convert File Parameters Dialog Box, Select BIL

Convert in place = NO

Enter the Output file name as ….BIL

Click OPEN

Click OK

This will take a while and really save an ENVI Standard format BIL file this time.

Check the image processing by displaying a Natural Color Image with bands 29, 23 and 16 as RGB.

Step 4 for USGS HDF format Hyperion Data

Subset the good bands <u>before</u> applying the FLAASH atmospheric correction method using the following method.

In the main ENVI menu select File/Save as File/ENVI std.

In the new file builder dialog box select Import File.

In the Create New File Input File dialog box select the real USGS BIL file that you created in Step 3.

Click Spectral Subset

You should now see 242 bands highlighted.

Click on band 8.

Hold down the shift key and highlight bands 8-224.

Scoll up to band 57.

Hold down the control key and click on bands 57 through 77 to deselect them. At this point bands 8 through 56 and 78 through 224 should be selected for a total of 196 bands.

Click OK

Click OK

In the New File Builder dialog box enter an Output File Name such as …196.

This will write a BSQ file that you need to convert to BIL again (there is probably a shorter way to do this but this one works).

In the main ENVI menu select Basic Tools/Convert Data (BSQ, BIL, BIP).

In the Convert File Input File dialog box click Open File and navigate to your 196 band file and select it.

Click OK

In the Convert File Parameters dialog box select Output Interleave = BIL and enter an Output file Name such as …196BIL.

Step 5. FLAASH atmospheric correction of USGS HDF format Hyperion Data.

To atmospherically correct your USGS HDF format …196BIL Hyperion data file with FLAASH...

Select Basic Tools / Calibration Utilities / FLAASH
In the FLAASH Atmospheric Correction Model Input Parameters dialog box…

Click on Input Radiance Image and select the output from Step 4.

Select Read array of scale factors (1 per band) from ASCII file in the Radiance Scale Factors dialog box

Select the hyperionscaleUSGSfactors.txt file included with the data and click OK.

BE CERTAIN THAT YOU USE THE USGS SCALE FACTORS FILE WITH USGS HDF FORMAT HYPERION DATA.

The hyperionscalefactors.txt file is made specifically for FLAASH and uses scale factors of 400 for the VNIR and 800 for the SWIR accordingly.

Click on the Output Reflectance File and select a file name.

Click on the Output Directory for FLAASH files.

Type in a root name for the FLAASH files (several extra files will be generated). **Do not include a directory path.**

Type in your Scene Center Location (- values for southern and western hemispheres).

Select Unknown for your sensor type.

Input the Flight date.

Enter a Sensor Altitude of 705.0 kilometers.

Enter the average Ground Elevation of your scene in kilometers.

Select the Flight Time in HHMMSS format.

Select an atmospheric model according to the FLAASH user guide with at least as much atmospheric moisture as your scene.

Select an Aerosol Model.

Select YES for Aerosol Retrieval.

Type in a reasonable Initial Visibility value in kilometers just in case the aerosol retrieval calculation fails.

Select NO for Spectral Polishing.

Click on Advanced Settings.

In the FLAASH Advanced Settings dialog box enter

An Aerosol height of 2.00 kilometers.

A CO2 mixing ratio of 390 ppm.

An IFOV of 0.043 mrad.

Toggle the Reuse MODTRAN Calculations to NO.

Select a Modtran Resolution of 15 or 5 (5 takes longer and is just a little better).

Toggle the Modtran Multiscatter Model to Issacs.

Do not change the For Non-nadir Looking Instruments unless you have tasked the satellite for a view which is significantly off of nadir (not straight down as is usual).

Type in an Output scale factor of 10000 (ten thousand) for Hyperion.

Leave the Automatically Save Template File set to YES.

Leave the Output Diagnostic Files set to NO.

Click OK.

Click Apply.

The calculation will take several minutes.

You now have an atmospherically corrected reflectance image to which you can apply spectral end members for mapping.

OR

IIb ATMOSPHERICALLY CORRECT OR REMOVE ENVELOPE FROM HYPERION RADIANCE DATA TO CREATE REFLECTANCE DATA USING ACORN.

The URL for Research Systems to order ACORN and its manual is http://www.aigllc.com or http://www.aigllc.com/acorn/intro.asp

The following instructions are for the "stand alone" mode of ACORN 4.0

By Anne Gravante, Analytical Geophysics and Imaging, LLC., November, 2002.

For Early Hyperion Data
On Hyperion, the ACORN offsets are currently all zero. The ACORN gains to be used on a particular dataset depend on the processing parameters used to produce the Level-1 data. Early data apparently needed to be multiplied by 100 across the board to get to radiance, corresponding to an ACORN gain of 0.01. Later (Level 1A) data use multipliers of 40 for the VNIR and 80 for the SWIR - this corresponds to gain factors of .025 and .0125 respectively. The Level 1A HDF header now contains the values of the actual multipliers, so check there for the appropriate numbers for your specific dataset.

Get correct gain values from HDF Dataset attributes on L1 file by choosing ENVI Basic Tools->Data Specific Utilities->HDF Dataset Attributes.

You should see something like:

"Attribute 1-20: VNIR Calibration Multiplier w/m^2/sr/micron* 40"
"Attribute 1-21: SWIR Calibration Multiplier w/m^2/sr/micron* 80"

at the end of the HDF listing. The appropriate ACORN gain factos in the above case are: 1/40 = .025 and 1/80 = .0125

For Later Hyperion Data (USGS HDF Level 1B)
For general questions about Hyperion, you can direct users to the EO-1 Homepage at: http://eo1.gsfc.nasa.gov/miscPages/home.html

additional specific information (including examples) can be found at: http://eo1.gsfc.nasa.gov/miscPages/ALIworkshop.html

Setting up ACORN:

1. Gain factors come from the HDF data file. In ENVI 3.5 use Basic Tools->Data Specific Utilities->View HDF Dataset Attributes. Select the Hyperion HDF data file as the input file and click OK.

Choose the data file again in the HDF Dataset Selection dialog and click OK.

The gain information is listed as Attribute 1-4: "VNIR Scaling Factor" and Attribute 1-5: "SWIR Scaling Factor". HDF example extracted information is attached as "Hyperion_HDF_Gains.txt".

Data values may vary, and should be checked, but for the latest EDC-processed data (Level 1B) are "40" for the VNIR and "80" for the SWIR. This translates to ACORN factors of 0.025 and 0.0125 respectively.

The Hyperion ACORN Gains are zero.

An example ACORN Gain and Offset file using these numbers is attached as "Hyperion_ACORN_Gain_1B.txt" and "Hyperion_ACORN_Offset_1B.txt".

2. The Hyperion wavelength file has to be constructed specifically for each Hyperion dataset, as wavelengths vary depending on acquisition date.

Wavelengths are also included in the HDF data, but EDC also (I believe) provide an ENVI header with Wavelengths and FWHM. I usually copy these out of the header and save as single column ASCII data, then use IDL to reformat from micrometers to nanometers). An example header file is attached as "Hyperion_204.hdr.txt" and the corresponding ACORN wavelength/fwhm file in Nanometers as "hyperion_204_waves&fwhm_nm.txt".

Again - these are the wl/fwhm for only one specific dataset/date and each wl/fwhm file should be individually constructed for the appropriate date from the ENVI header or directly from the HDF file.

Note: For those users without IDL, the wavelengths for each band and the FWHM values for each band in the HDR file may be extracted by pulling the file into Microsoft Word. Save the wavelength and FWHM values into separate Microsoft Word files. Use the replace function to replace the commas with paragraph marks to place each value on a separate line. Pull each of these Word files into Microsoft Excel in text format to take care of spacing issues and then paste them into a common XL file with the wavelength values in the first column and the FWHM values in the second column. Eliminate the bands with wavelengths shorter than 400 nm and longer than 2500 nm so that it will work in ACORN. You should have 229 bands (R.B.).

Run ACORN by making a New control file.

3. An example ACORN control file "hyperion_204_acorn_ctrl.in.txt" is included in the sample data set along with the following supporting SAMPLE files (courtesy of AIG). You should use the method above to verify that these are appropriate for your data set.

Hyperion_HDF_Gains.txt
Hyperion_Acorn_Offset_1B.txt
Hyperion_Acorn_Gain_1B.txt
Hyperion_204.hdr.txt
hyperion_204_waves&fwhm_nm.txt
hyperion_204_acorn_ctrl.in.txt

Beck has included an ACORN 4.0 stand alone version Hyperion data set (in BIL format) from Dinosaur National Monument in Utah with acquisition specific control, wavelength and FWHM, gains and offset files. Some versions of ACORN complain when asked to correct Hyperion with bands with wavelengths shorter than 400 nm and longer than 2500 nm (although this does not appear to be the case for AVIRIS for reasons unknown to the author). Regardless, in order to get the job done, I suggest that you use a spectral subset of your new USGS format Hyperion data with ACORN .

To run ACORN 4.0 in stand alone mode on your data set begin by making the 229 band spectral subset in ENVI.

1. Open ENVI 3.5
2. Open the data file with Main Menu/File/Open External File/Landsat/Landsat HDF
3. In the HDF Dataset Selection dialog box Select All Items
4. Click OK
5. In the HDF Data Set Storage Order dialog box check BIL.
6. Click OK
7. In the HDF Data Set Storage Order dialog box check BIL (for the Flag Mask file).
8. Click OK
9. Do NOT try to open the Flag Mask bands. Slide down to Data Set #1 and open band 40 to make sure the ingest has been successful.
10. File / Edit ENVI Header /Data Set #1
11. Click OK
12. Main Menu / Basic Tools / Resize (Spatial/Spectral)
13. In the Resize Data Input File dialog box select Data Set #1
14. Select Spectral Subset
15. Hold down the Ctrl key and turn off bands with wavelengths shorter than 400 nm and longer than 2500 nm. Click Add Range and save the file as ….229 This will save a 229 band ENVI BIL Integer Host (Intel) format file.

You now have a file suitable for input into ACORN 4.0

Richard has created test files for the 229 band spectral subsets

ACORN 4.0 Stand Alone Atmospheric Correction feature

1. Open ACORN 4.0 in stand alone mode.
2. Open a new control file.
3. Choose mode 1.5
4. Set the input file name to the 229 band spectral subset file that you just created (EO1H0360322002229110KY229.LIR or similar)
5. Set the output file name (….out229 or similar)
6. Set the Input File Format to BIL
7. Set the Integer Format to Host (Intel)
8. Open the .HDR and Met files and get the image dimensions, acquisition dates and times etc…
9. Fill in the remainder of the ACORN input variables dialog box in a manner similar to the *following example* (but with data for your USGS format Hyperion scene).

```
ACORN version number: number
4.00
Mode (1=hyp,1.5=hyps,2=sse_h,3=emp_h,4=cnv,5=mlt,6=sse_m,7=emp_m):
number
1.5
Input image file: filename
C:\acorndatafolder\UtahDNMACORN4testfiles\EO1H0360322002229110KYL1R229
Image file format (0=bip, 1=bil): number
1
Integer format (0=little endian, 1=big endian): number
0
Image dimension (bands,samples,lines,offset): 4 numbers
229 256 3129 0
Image center latitude (+N,-S) (deg, min, sec): 3 numbers
40.462480 0.000000 0.000000
Image center longitude (-W,+E) (deg, min, sec): 3 numbers
-109.370300 0.000000 0.000000
Image date: day, month, year
17 8 2002
Image average time (UTC) (hour, minute, second): 3 numbers
17.000000 38.000000 17.000000
Image mean elevation (meters): number
1650.000000
Image acquisition altitude (kilometers): number
705.000000
Atmospheric Model (1=ml summer, 2=ml winter, 3=tropic): number
1
Derive water vapor (1=940, 2=1140, 3=both): number
2
Path radiance in water vapor fit (0=no, 1=yes): number
1
Image atmosphere visibility(5 to 250 kilometers): number
30.000000
Acorn estimated visibility (1=yes, 0=no): number
1
 Image spectral calibration file [wvl(nm),fwhm(nm)]: filename
C:\acorndatafolder\UtahDNMACORN4testfiles\EO1H0360322002229110KYwvfwhmn
m229.txt
Artifact supression type 1,2,3 (1=yes, 0=no): 3 numbers
1 1 1
Gain file (DN to radiance (W/m^2/µm/sr))[value]: filename
C:\acorndatafolder\UtahDNMACORN4testfiles\Hyperion_Acorn_Gain_1B229.txt
Offset file (W/m^2/µm/sr)[value]: filename
C:\acorndatafolder\UtahDNMACORN4testfiles\Hyperion_Acorn_Offset_1B229.t
xt
Output reflectance image file: filename
C:\acorndatafolder\UtahDNMACORN4testfiles\EO1H0360322002229110KYL1R229o
ut
```

10. Save your new control file.
11. Click the Run button.

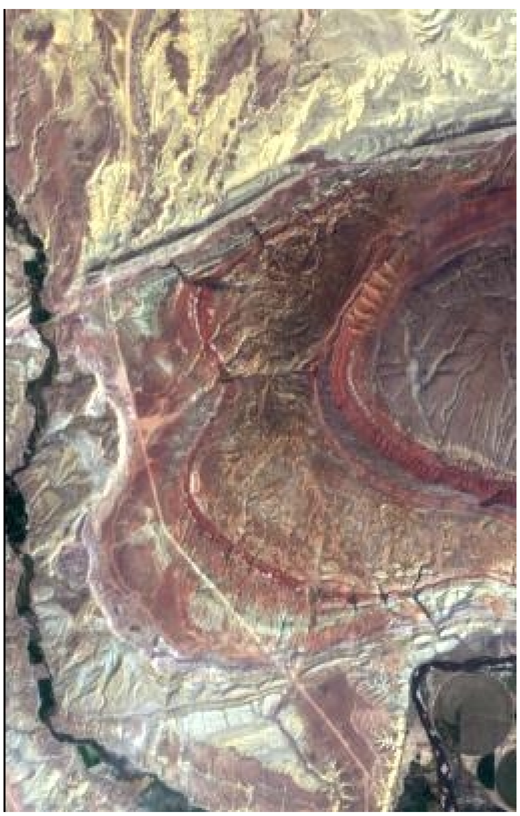
After atmospheric correction, open the file and view a Z-profile. You may need to Edit the ENVI header to include the image dimensions and format.

Use the cursor to obtain the bad band numbers from any remaining artifacts (single spikes or non-zero water bands). Use the bad band option in the Edit ENVI header to click on the bad bands while holding down the control key.

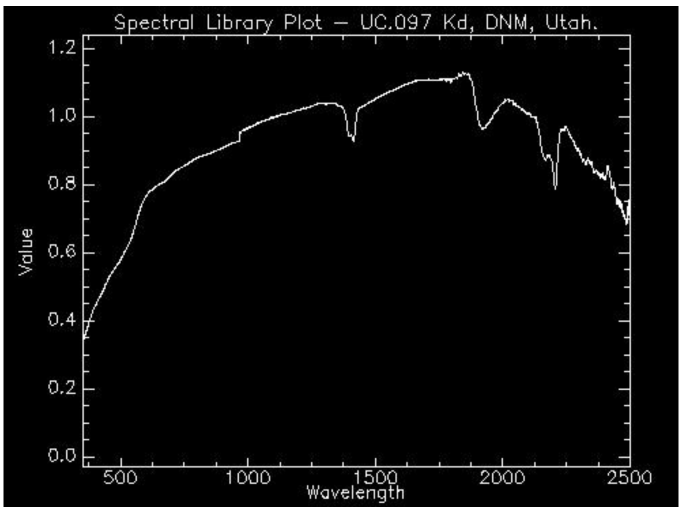
Approximate GOOD BANDS for the ACORN corrected USGS Level 1R data are 457-844 nm, 1083-1265 nm, 1497-1759 nm, and 2092-2385 nm.

Example ACORN results are below.

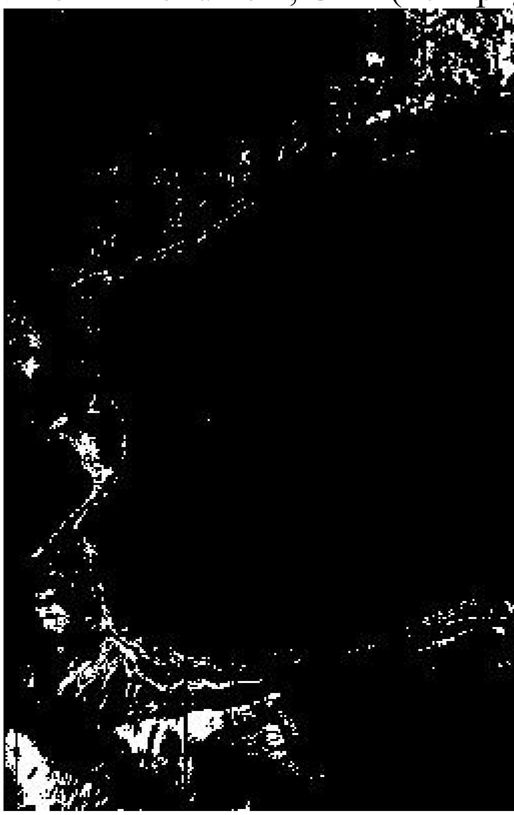
ACORN atmospherically corrected natural color Hyperion image of Dinosaur National Monument, Utah.



Spectrum UC.097 (White sandstone from a dipslope of the Cretaceous, Dakota Formation characterized by hoodoo weathering and a good Kaolinite doublet in the SWIR



Spectral Angle Map of "whole rock" spectrum UC.097 applied to ACORN atmospherically corrected natural color Hyperion image of Dinosaur National Monument, Utah (next page).



Several other atmospheric correction packages are available.

You should now have atmospherically corrected reflectance data to use in the following mapping exercises.

III PERFORMING MAPPING STEPS

a) by comparison with end members from spectral libraries by Richard Beck

This technique allows the user to derive information about the composition of materials within a scene where no “ground truth” is available.

Open ENVI 3.5.

From the main menu choose Open Image (Data) File.

Select cuprite_flaash_refl not cuprite_flash_refl.hdr

In the Available Bands List, click on band 40

Click Gray Scale

Click Load Band

An image will display to give you an idea of what you are working on.

From the main menu select Spectral / Mapping Methods / Spectral Angle Mapper (see the ENVI tutorial for background on SAM).

In the Classification Input File dialog box.

Click cuprite_flaash_refl.dat in the Select Input File list.

Review the File Information

Select Spectral Subset

Select bands 168-193

Click OK

Click OK

In the Endmember Collection: SAM dialog box

Select Import / from Spectral Library

In the Spectral Library Input File dialog box

Select Open Spectral Library

Open directory jpl_lib

Select jpl1.sli

Click OK in the Spectral Library Input File dialog box.

In the Input Spectral Library dialog box scroll down to
KAOLINITE DISORDERED, PS-1B

In the X Data Multiplier box

For the JPL spectral library in microns….

Select an X scale factor of 1000.0

Select a Y scale factor of 10000.0

In the Endmember Collection: dialog box

Click Apply

In the Spectral Angle Mapper Parameters dialog box…
For the Maximum Angle (radians) type 0.07

Enter Output Class File Name

Enter Output Rule File Name

Click OK

In the Available Bands List dialog box
Select Display #1 / New Display

Click on the Output Class File Name that you entered above that should appear now in the Available Bands list.

Click on Load Band

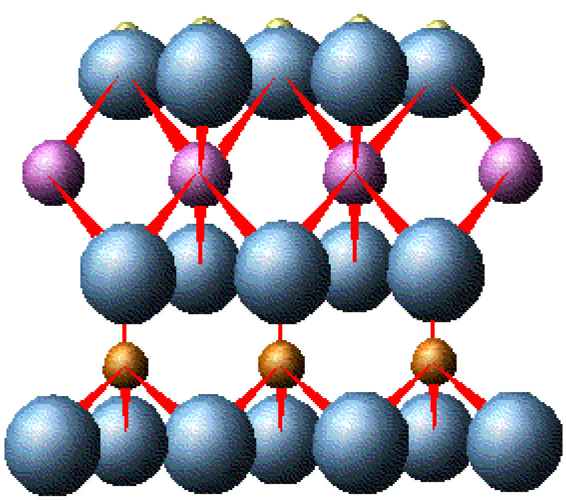
The resulting SAM from library spectral end members image should appear similar to the one below.

Optional: Repeat the above steps for ALUNITE SO-4A

Note:
KAOLINITE $AL_2(OH)_4(SIO_5)$
Description: Kaolinite is a clay mineral which is formed by the weathering of feldspar. It is one of the most common minerals on Earth. Kaolinite can be found in all parts of the Earth. It is very soft with a hardness of 2-2.5. It has a color of white, pink or grey and a streak of white. The chemical make up is Al2 Si2 O5 (OH)4. Kaolinite is used in the ceramics industry for the production of clay products.

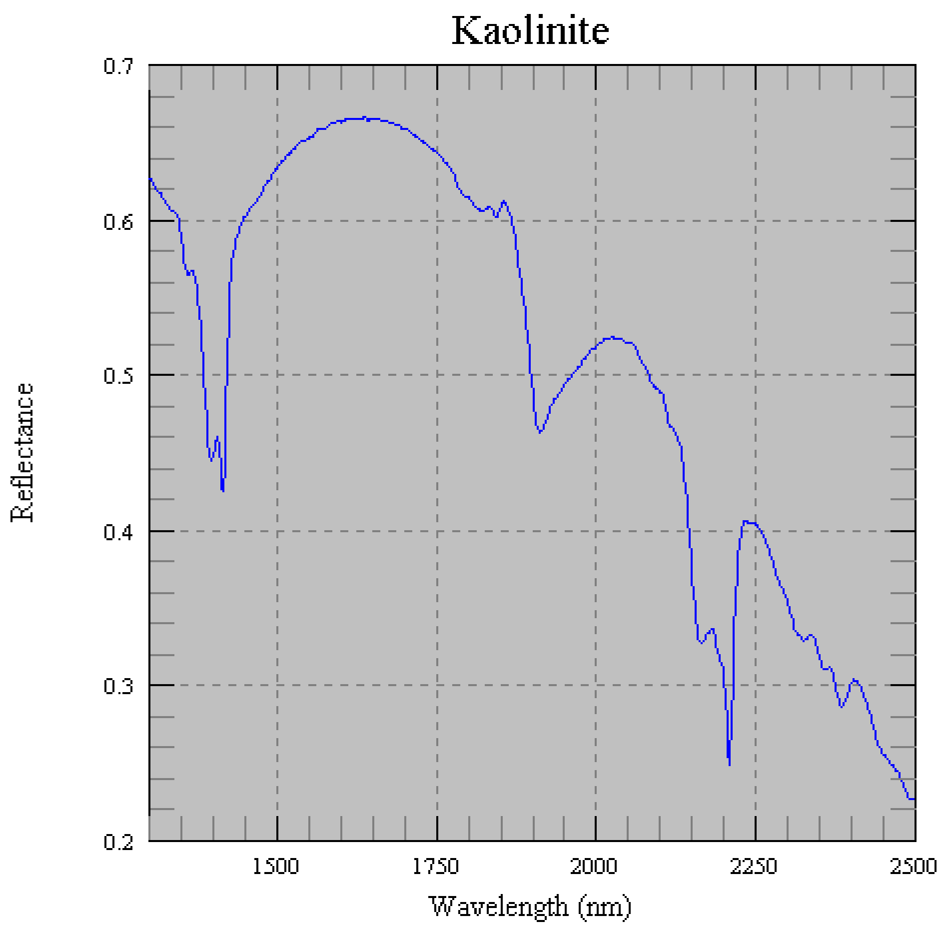
Kaolinite Hand Sample from Swedish National Museum

Kaolinite Structure from French Geological Survey (BRGM)



The crystal structure is important because, in combination with the composition of the crystal, it determines the spectral signature of the mineral. Some physical modeling techniques have been developed to predict the spectral signatures of minerals based on their compositions and structures. Kaolinite was one of the first minerals used for such modeling.

Kaolinite SWIR Spectrum from PIMA Remote Sensing

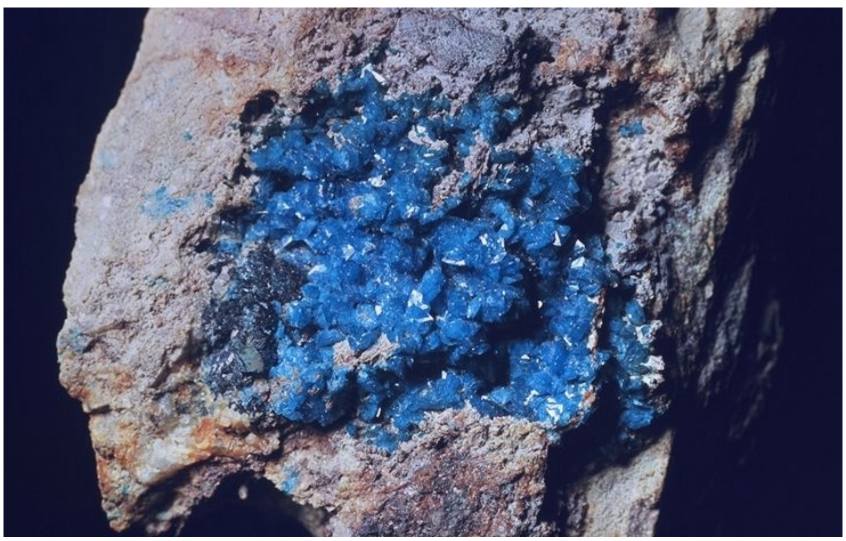


AND…

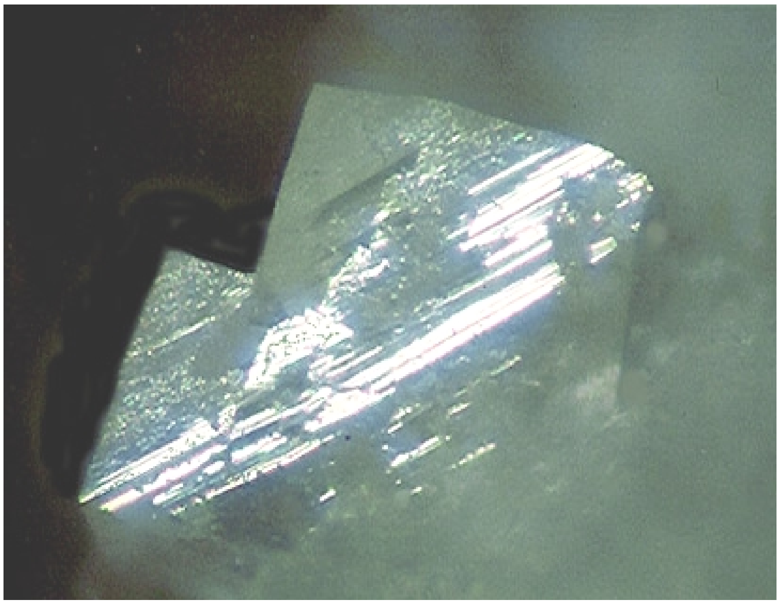
ALUNITE $KAl_3(SO_4)_2(OH)_6$ Hexagonal

Description: Alunite is an inconspicuous greyish massive mineral formed by the alteration of pyrite and other sulfides during weathering or solfatara activity. Its habit, fine-grained nature and common intergrowth with minerals such as hematite, goethite, jarosite, melanterite and pyrite are likely reasons for it being overlooked.

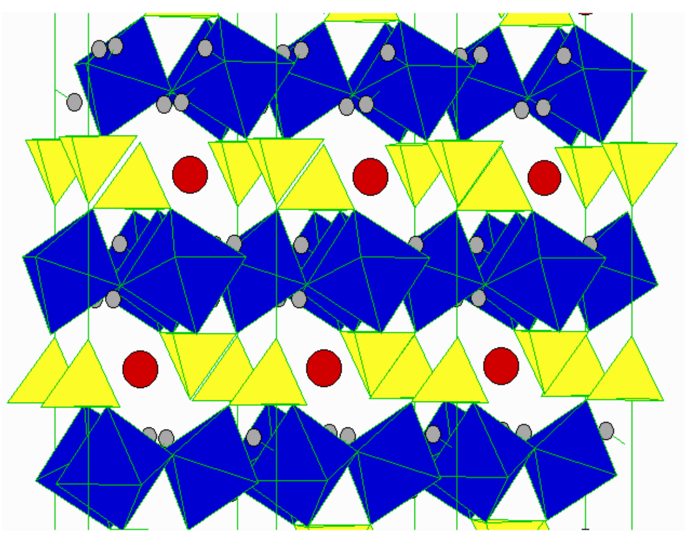
Alunite Hand Sample from French Geological Survey (BRGM)



Individual Alunite Crystals

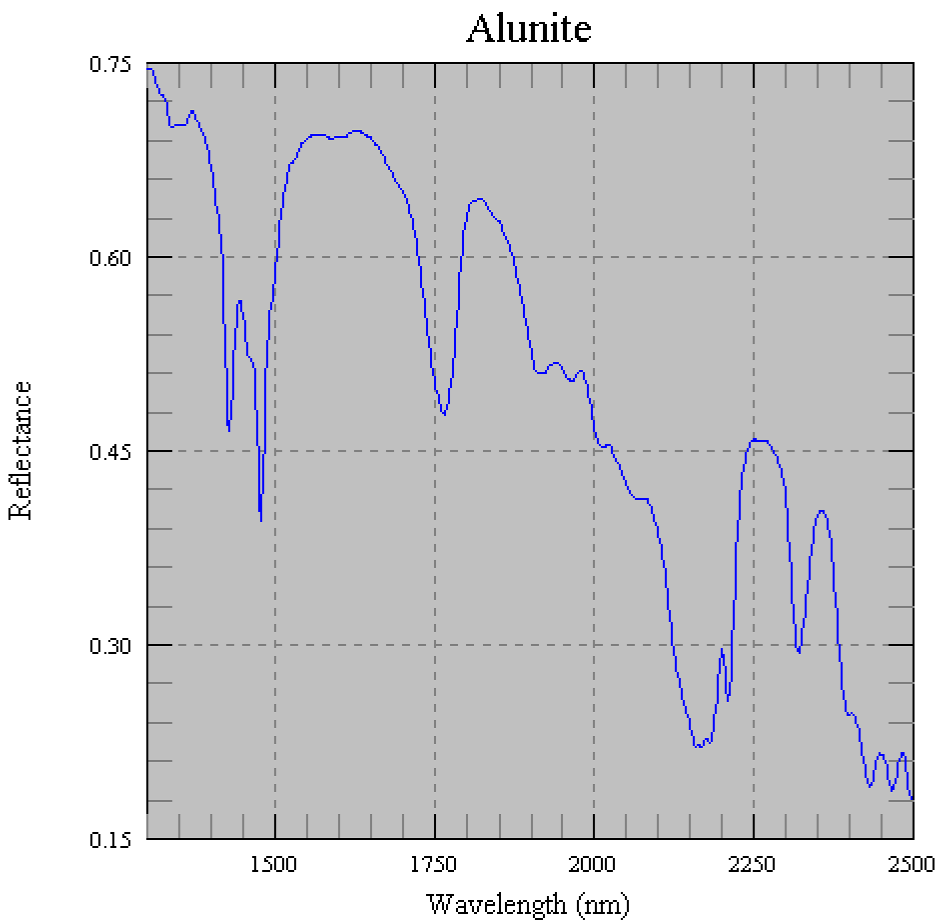


Alunite Crystal Structure



As noted above, the crystal structure is important because, in combination with the composition of the crystal, it determines the spectral signature of the mineral. Some physical modeling techniques have been developed to predict the spectral signatures of minerals based on their compositions and structures.

Alunite SWIR Spectrum from PIMA Remote Sensing



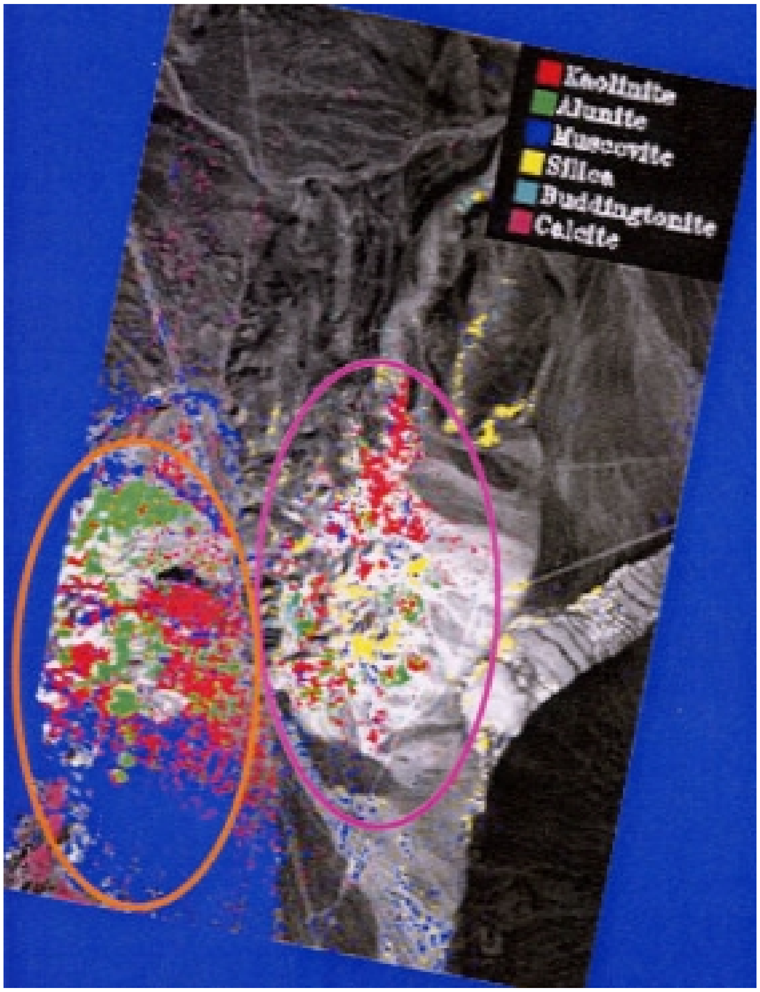
SAM from spectral library end members Hyperion image of Cuprite, February, 2001

You should see a red, white and black image where
Red is Kaolinite
White is Alunite
Black is “other”

The ENVI manual and on-line help describe options for changing the color mapping of these classes.

Compare your output image (hopefully similar to the one above) to the March, 2001 Hyperion Mineral Map – 30m resolution by Fred Kruse of AIG LLC (below).

March, 2001 Hyperion Mineral Map – 30m resolution by Fred Kruse of AIGLLC



b) by comparison with end members from regions of interest by Richard Beck

This technique allows the user to extrapolate “ground truth” to unknown areas within the scene.

Open ENVI 3.4 or 3.5

From the main menu choose Open Data File

Select cuprite_flaash_refl not cuprite_flash_refl.hdr

Click Open

In the Available Bands List, click on band 40

Click Gray Scale

Click Load Band

An image will display to give you an idea of what you are working on.

In the main Image #1 window, position the red zoom window over your region of interest (ROI = place you know what is on the ground)

Select Overlay / Region of Interest

In the ROI Tool window

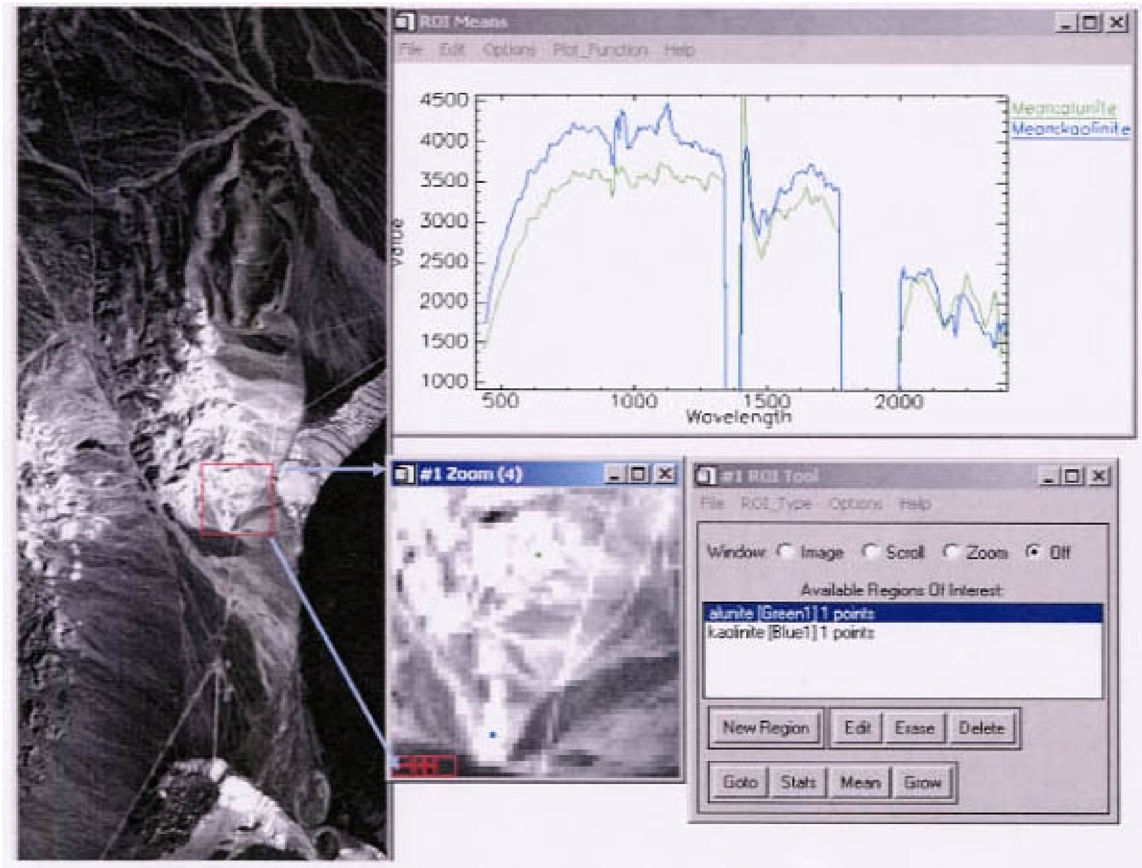
Select ROI_Type / Point

Select Options / Mean for all Regions

Click Edit

Change the name to Kaolinite and adjust the Color to Blue1

Click on the pixel in your #1 FLAASH window that corresponds to the blue pixel (kaolinite training sample) in the “Zoom (4)” window in following figure.



Click New Region in the ROI Tool dialog box

Click Edit

Change the Name to Alunite and the Color to Green1

Click OK

Click on the pixel in your #1 FLAASH window that corresponds to the green pixel (alunite training sample) in the "Zoom (4)" window in the figure above.

In the ROI Tool dialog box

Select Save ROIs

Select the Regions to Save (Select All Items)

Enter Output File Name and Directory

Minimize the ROI Tool dialog box

In the main menu

Select Spectral / Mapping Methods / Spectral Angle Mapper

Click OK

In the Classification Input File dialog box

Select Input File cuprite_flaash_refl.dat

Select Spectral Subset

In the File Spectral Subset List

Select bands 168-193

Click OK

In the Classification Input File dialog box

Click OK

In the Endmember Collection:SAM dialog box

Select Import / from ROI from Input File

In the Input Regions of Interest dialog box

Select All Items

Click OK

In the Endmember Collection: SAM dialog box

Click Apply

In the Spectral Angle Mapper Parameters dialog box

Type 0.07 for the Maximum Angle (radians)

Enter Output Class Filename

Enter Output Rule Filename

Click OK

The computer will compute.

In the Available Bands List dialog box

Select the Output Class Filename you entered above

Click Gray Scale

Select Display #1 / New Display

Select Load Band

In the #2 Sam Image window

Select File /Save Image As / Image File

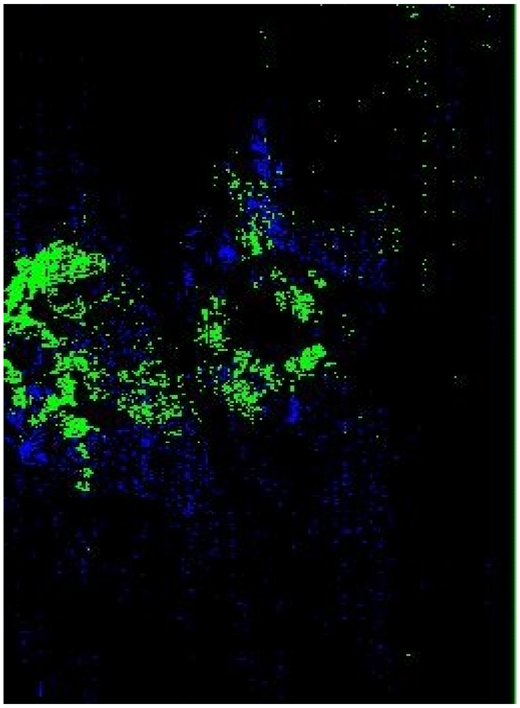
In the Output Display to Image File

Select Output File Type

Select JPEG to save your work.

The resulting SAM from known ROI end members image should appear similar to the one below.

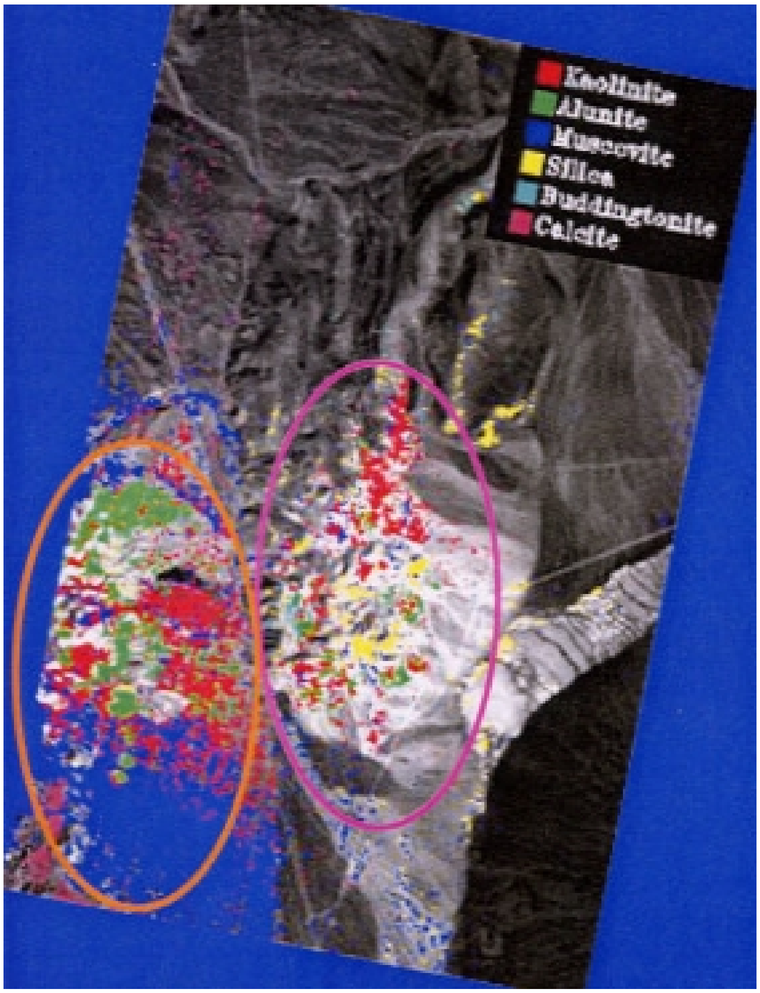
SAM from ROI end members Hyperion image of Cuprite, February, 2001



Blue is Kaolinite
Green is Alunite
Black is “other”

IV COMPARE HYPERION MAPS WITH KNOWN MAPS

Evaluate the relative effectiveness of the two techniques used above relative to the classified image map provided by Fred Kruse of AIGLLC.



How well do they agree?

Adjust the Maximum angle parameters in technique 3a to see if you can approximate the extents of kaolinite and alunite in the map provided by Fred Kruse.

Describe a scenario in which you might use the comparison with end members from spectral libraries.

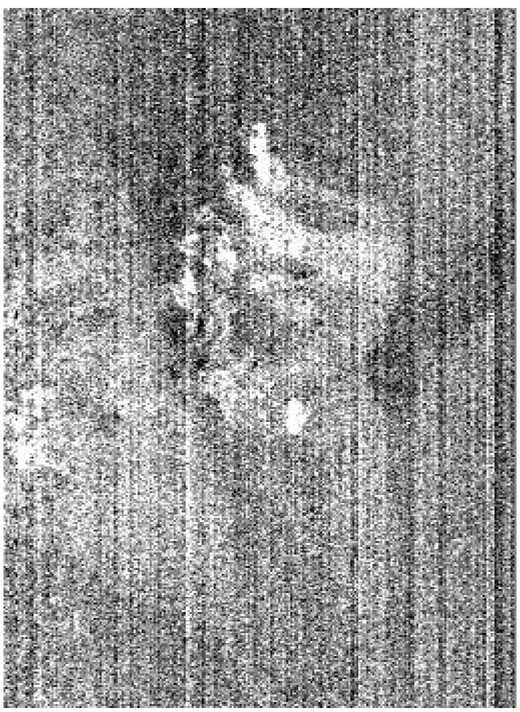
Describe a scenario in which you might use the comparison with end members from

regions of interest technique.

V ADDITIONAL EXERCISES

1. Try the Mixture Tuned Matched Filtering Technique with the ROIs that you defined for use with the Spectral Angle Mapper Technique and compare your results to the image below and to your results from the SAM technique.

MTMF from Kaolinite ROI end member Hyperion image of Cuprite, February, 2001



White is Kaolinite in the image above.

MTMF from Alunite ROI end member Hyperion image of Cuprite, February, 2001

White is Alunite in image above

How do the MTMF results compare with those from SAM?

2. Try these same techniques (Spectral Angle Mapper based on spectral libraries and ROIs) or the Mixture Tuned Match Filter with the agricultural scene. An atmospherically corrected data set is included. Make certain that you are using atmospherically corrected Coleambally data. Save your results and decide which technique works better for vegetation, SAM or MTMF?

A quick start guide for the use of spectroradiometers to collect custom spectral end members follows.

Quick Start Guide for the Analytical Spectral Devices Field Spec Pro Spectroradiometer for use with Hyperion Data

J. Cohea, Analytical Spectral Devices
R. Beck, Geography, University of Cincinnati

The following is a simple quick start guide for the use of the Analytical Spectral Devices Field Spec Pro. It is provided here to provide the user with specific instructions on how to collect spectral signatures to use as end members for land cover classification with Hyperion.

To measure the reflectance spectra of samples.

Before going to the field or laboratory…

1. Charge the Field Spec Pro battery. A spare battery or two and a charger are a good idea.
2. The FR software is installed on the computer.

In the field or laboratory…

3. Take out instrument out of case. Be careful with the fiber optic cable.
4. Attach Field Spec Pro to computer's parallel port.
5. Turn on instrument first (and last).
6. Turn on computer second.
7. Let the Field Spec Pro warm up for 30-60 minutes (You can use the system sooner if you take white references every 10 minutes for the 1st hour).

For indoor laboratory use…

A. Set up special sample illumination light from ASD on first tripod.

B. Feed the fiberoptic cable through the pistol grip.

C. Attach the optional foreoptic to the pistol grip after the fiberoptic cable has been inserted.
D. Set up probe on second tripod at 90 degrees in a horizontal plane to the light.
E. Turn on sample light and let it warm up for 5 minutes.
F. Turn off fluorescent room lights.
G. Since the spotting scope is optional, you may not need to do this step.
H. Place sample so that it fills the entire field of view of the foreoptic.

For outdoor use…

A. Feed the fiberoptic cable through the pistol grip.
B. Attach one, three or eighteen degree field of view foreoptic to the pistol grip if desired. Without the foreoptic, the probe has a 25 degree field of view.
C. Again this is an optional step because the spotting scope is an option
D. Hold the probe so that the sample fills the entire field of view of the probe.

8. The computer should be on now. Double click the FR or FR B+W software. The B+W version is in black and white for use outdoors where the screen may be in sunlight and difficult to see.
9. Click OPT to optimize the Field Spec Pro. This sets the integration time on the VNIR and the gain on the SWIR 1 and 2 sensors within the Field Spec Pro.
10. When the System Status dialog box shows "Initiating dark current correction" Click Continue. The shutter will close and the system will

measure its own noise to subtract from measurements.

11. When the System Status dialog box shows “Finished dark current correction” Click Continue. After optimization you want to see raw DN values of 40,000 – 60,000 to make sure you have enough energy on your sample. If you are outside you will probably see absorption features at 900 and 1400 nanometers. On the other hand, if the peaks are flat the detectors are saturated and you need to reoptimize with same steps as before.
12. Type Alt-C to adjust the configuration. You will now select the number of measurements (“spectral samples”) to average. Ten to Twenty-five are standard. Leave the dark current setting at 25 and the white reference setting at 10. Click OK. The spectrum avg setting on the screen should now read 25.
13. Now set up save directory for data.
14. Type Alt-S
15. Type in Save Path
16. Enter base name
17. Enter starting spectrum number
18. Enter the number of files to save (leave at 1)
19. Enter interval between saves.
20. Enter comment if desired.
21. Re-optimize (Type Alt-O) (Optional at this point).
22. Place the white reference plate under the probe.
23. Click on WR.
24. When System dialog box shows “Initiating Dark Current Collection” Click Continue. When finished there will be a flat line across the top of the screen at approximately 1.0 relative reflectance. Remember that reflectance is a relative measurement.
25. NOW place the sample below the probe.

26. Click the Space Bar to measure and save the reflectance spectrum of the sample.
27. Place a new sample beneath the probe and click the space bar to measure and save the spectrum and repeat as above.
28. Re-optimize and white reference every 10 minutes. (This is very important during the first hour if the system has not warmed up. You also want to re-optimize as the light and cloud conditions change)
29. Click Quit or Type ALT-Q to quit when finished measuring samples.

To view the measured spectra …

1. Click on ASD View Spec Pro.
2. Click File/Open
3. Navigate to the directory in which the raw spectra were saved.
4. Select all of the files with Shift-Click.
5. Click Open.
6. Click View/Graph
7. Click Graph/Customize Dialog/Axis.
8. Click Min/Max.
9. Enter an x axis minimum of 350 nm and an x axis maximum of 2500.
10. Click OK.
11. The maximum number of spectra that can be viewed at one time on the graph is 14

To export the measured spectra for import into ENVI…

1. Click Process / ASCII Export
2. Select the files to be exported
3. Click OK, the files should be about 54k each so several should fit on a

floppy disk.

To import the measured spectra into ENVI…

1. Open ENVI 3.4 or 3.5 if it is not already open.
2. IN the Main ENVI menu Click Spectrum/Spectral Libraries/Spectral Library Builder.
3. In the Spectral Library Builder Dialog Box – Input Spectral Wavelength Form dialog box Click the Input ASCII File radio button.
4. Navigate to your stored ASCII files (not the smaller binary files) from ASD View Spec Pro.
5. In the Input ASCII File dialog box leave the Wavelength Column set to 1, the FWHM Column blank (it is automatic) and the X Data Multiplier at 1.0000.
6. Click OK
7. In the Spectral Library Builder dialog box Click Import/from ASCII file.
8. In the Enter ASCII Plot Filenames dialog box select the same ASCII file again.
9. In the second Input ASCII dialog box do NOT change the X Axis, Y Axis and multiplier values.
10. Click OK
11. Back in the Spectral Library Builder dialog box, make sure the file or files of interest are highlighted and Click File/Save Spectra As/Spectral Library. This gets you ready to convert your ASCII spectrum (spectra) into ENVI format.
12. In the Output Spectral Library Name dialog box choose an output directory and type in a file name.
13. Click OK

14. Close the Spectral Library Builder and the Available Bands List dialog boxes.
15. Return to the ENVI main menu and select Spectral/Spectral Libraries/Spectral Library Viewer.
16. In the Spectral Library Input File dialog box Select an Input File.
17. Click OK
18. In the Spectral Library Viewer dialog box click on the spectrum you want to view. A Spectral Library Plots dialog box will appear with a plot of your spectrum.

You can use this (these) spectrum (spectra) as an end member for mapping purposes and/or empirical line atmospheric correction with Hyperion data that includes similar material using the accompanying ENVI end member mapping instructions. Please see the ENVI and ASD instruction manuals for more detailed background and instructions.

Converting Hyperion Data to Reflectance with Field Spectra

Hyperion DN data may also be converted to reflectance for use with ground truth data by collecting ground truth spectra at locations identifiable within the Hyperion scene and then applying an empirical line calibration (ELC). ELC is a linear regression that is applied to each band to equate DN to reflectance. This removes the solar irradiance and the atmospheric path radiance. The empirical line method calculates the gain and offset values necessary to convert each DN in each band to reflectance.

Ideally, each field spectrum is collected from a large homogenous surface at the time the image is acquired by the spacecraft.

You will need at least one field spectrum for a known point in the image.

In the ideal case this is done by measuring the field spectrum for a large, distinctive and homogenous target such as a tarp in the field during the satellite overpass or by recording the location of the field spectra and geo-referencing the satellite data before performing the ELC. The later is less desirable because georeferencing the data involves resampling the image that may or may not be accurate in terms of location or resulting re-sampled spectra.

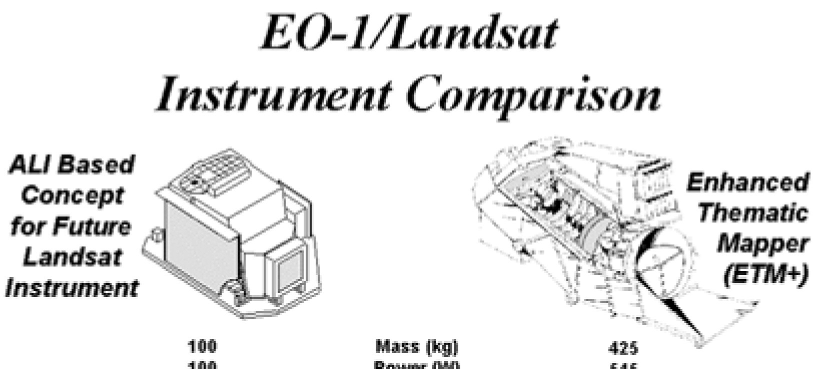
The general steps are:

1. Georeference the data only if necessary. – It is better to find locations for the field spectra collection that you can compare with the spectrum from a pixel in the acquired image. Use a spectrally distinct calibration target or georeference the field spectra and data so that you can correlate the field and image spectra.
2. Locate or create large, homogenous targets.
3. Collect 50-100 field spectra from a homogenous region larger than the pixel size of the imager, ideally during imaging. Average these spectra using the spectral math function (s1+s2+s3+s4…)/n. Where n is the number of spectra averaged.
4. Convert these averaged spectra into an ENVI spectral library according to the method described in the previous section.
5. Apply the empirical line correction (Main ENVI Menu/Basic Tools/Calibration Utilities/Empirical Line/Compute Factors and Calibrate, etc….
6. Examine the Z-profile of the EL corrected data.

7. Edit out the bad bands and the water bands in Edit ENVI header. These are probably the first and last files, the VNIR-SWIR cross-over and the water bands and include
   1-5
   49-90
   116-134
   164-186
   222-242
   You may be able to keep more. Remember, EO-1 is experimental.
8. For the purpose of this exercise, use Main ENVI Menu/Basic Tools/Resize data (spectral) and save only the SWIR (2000-2400 nm) as a separate file. Hyperion suffers from spectral smile and keystone in the VNIR. Hyperion SWIR data are better quality.
9. Run a classification algorithm against your known sample spectrum and make sure that it locates your reference spectra.

Advanced Land Imager (ALI)

ALI and Landsat 7 ETM+ Comparison



100	Mass (kg)	425
100	Power (W)	545
0.2	Size (m^3)	1.4
10	VNIR / SWIR Bands	7
6200	Detectors Per Band	16
None	Thermal Bands	1
300	Data Rate (Mbps)	150
10	Pan Resolution (m)	15
4x	Relative SNR	1x

Advanced Land Imager Introduction and FAQ

What are the files contained in an ALI Level 1 product?
An example of the products distributed with an ALI L1 product:

entityID.MET	Metadata file (site location, start/stop time, etc)
Order#.SUM	Order summary of files
entityID.M1R	First Sensor Chip Assembly (SCA)
entityID.M2R	Second SCA
entityID.M3R	Third SCA
entityID.M4R	Fourth SCA
2002_001_acs.hdf	This file and the following files are related to
2002_001_ali.hdf	Level 0 processing and are useful to the
2002_001_eff.hdf	instrument teams for calibration and validation.
2002_001_gps.hdf	
2002_001_mis.hdf	
2002_001_wrp.hdf	
2002_001_xbd.hdf	

What is the entity ID naming convention?
E01APPPRRRYYYYDDDXXXPL

EO1 Satellite
A ALI Sensor
PPP Target WRS path
RRR Target WRS row
YYYY Year of acquisition
DDD Julian day of acquisition
X Hyperion 0=off; 1=on
X ALI 0=off; 1=on
X AC 0=off; 1=on
P Pointing mode
L Scene length

What are the bands and spectral ranges for ALI?
ALI was built to provide vital information for the next Landsat mission. The ALI bands are thus very similar to Landsat, but note that ALI does not have a thermal band.

Why are there 4 image data files within the Level 1 ALI product?
The Level 1 radiometric processing produces four strips of image data recorded by the instrument's Sensor Chip Assemblies (SCAs). The four files can be mosaicked together from left to right, starting with the .M4R file through the .M1R file. The mosaicked file will represent a geographic

region of 37 kilometers in width. Please note that since this is a radiometric product only, geometric errors may exist along the mosaic lines. The absence of georeferencing in the data is also the reason the files must be mosaicked by pixel-based mosaicking.

The information needed for mosaicking will be contained within each image file's HDF Dataset Attributes 1-8, called the "Number of Cross Track Pixels". This number reflects the number of columns (samples) of the strip of image. This is the offset in the X (column) for each strip from its adjacent strip. There is an overlap between the four SCAs of approximately 10 pixels for the multispectral bands and approximately 30 pixels for the panchromatic band, which is the reason for the odd-numbered offsets in the sample direction. The offset for the Y (row) direction will always be 1 or 0, depending on what the software expects. The HDF Dataset Attribute 1-9, called the "Number of Along Track Pixels", reflects the number of rows (lines) of image data. The four strips should be similar, but not exact, in size, both in rows and in columns.

Example
"Number of Cross Track Pixels" is 315
"Number of Along Track Pixels" is 2740
The following offsets are reflected for the 4 strips:

.M4R offsets y=1, x=1
.M3R offsets y=1, x=316
.M2R offsets y=1, x=631
.M1R offsets y=1, x=946

Total mosaic size would be 2740 rows by 1260 columns.

Also note that the PAN band will need approximately 3X the offset due to its 10 meter resolution in comparison to the 30 meter resolution bands.

What product formats is available for ALI?
ALI Level 1 products are available in only Hierarchical Data Format (HDF) with the bands written as band sequential (BSQ). This format was developed by the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign (UIUC).

For more information on HDF please visit:
http://hdf.ncsa.uiuc.edu/

For HDF software tools:
http://hdf.ncsa.uiuc.edu/tools.html

Please remember this is for informational purposes only. The USGS does not endorse any particular software product.

What are known ALI anomalies?
Leaky detectors (2) with cross talk are present but are constrained to < 1% by the Level 1 correction algorithm. Stray light can exist for scenes with high contrast; dim targets (i.e. small lakes) within bright backgrounds.

What is the geometric accuracy of an ALI Level 1 product?
The Level 1 product is only radiometrically corrected and is not geometrically re-sampled. The user will need to apply the appropriate geometric corrections if necessary.

How are the radiance values (L) derived in the ALI Level 1 product?
The digital values represent 16-bit absolute radiances but are stored as a 16-bit signed integer. A scaling factor of 300 has been applied. The units represent mW/cm2 SR µm.
L = Digital Number / 300

What is the signal-to-noise ratio (SNR) for ALI?
The SNR is much improved in relation to the Landsat 7 ETM+; comparisons show five times better SNR.

What is the conversion to get from ALI Level 1 to a Level 0?
Theoretically it should be possible to get to L0 using the formula. However the calibration coefficients were applied before the leaky pixel correction. Because the leaky pixels corrections vary from scene to scene, the response should be customized for each.

The formula for converting to Level 0:

Level 0 = (L1R/(response x scaling factor)) + offset

Please note that due to leaky pixel correction applied after the calibration process it is not possible to get back to a true Level 0 product.

Instructions for the Import of EO-1 ALI files into ENVI

April 26, 2002

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R. Beck, Geography, University of Cincinnati

Open ENVI 3.5

Choose File / Open External File / Generic Formats / HDF

Navigate to the directory in which you have placed your ALI files.

In the Enter HDF Files Names dialog box change Files of type: from *.HDF to *.*

You should now be able to see HDF data files with the suffix .M*R where the * is a small integer. There is a separate file for each focal plane. For more information on ALI visit the EO-1 web site at http://eo1.usgs.gov

Highlight one of the .M*R files and click Open.

An HDF Data Selection dialog box should appear.

For a 42km long swath…..

The multispectral files are in the data set labeled (320x3257x9):LEVEL1R

The panchromatic file for this data set is labeled (320x3257x9):LEVEL1R

The middle dimension (the swath length in pixels) is variable depending on the swath length acquired.

Click on a Level1R data set.

An HDF Data Set Storage Order dialog box should appear.
Select Interleave = BSQ

An Available Bands List dialog box should appear with either 9 bands for the multispectral Level1R data set or 1 band for the panchromatic Level1R data set.

Select Gray Scale or RGB display mode.

Click Load Band or Load RGB

Enhance or Transform as desired.

Save Image as (the format most useful to you, probably ENVI or GeoTiff)

****
Note:

The focal plane overlaps are as follows.

Focal Plane Boundary	X axis (pan)	Y axis (pan)	X axis (ms)	Y axis (ms)
1-2	31	0	11	0
2-3	28	0	10	0
3-4	31	0	9	0

X axis = approximately North-South
Y axis = approximately West-East
Origin in upper left hand corner.

You may wish to run your experiments in each focal plane data set and then pixel mosaic the resulting images together. Alternatively they may be registered to a Landsat-7 or SPOT panchromatic band and then geographically mosaicked together.