SCIENTIFIC NOTEBOOK #432

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GHGC

USFIC KTI

Volume II – IKONOS Satellite Imagery

April 12, 2001 notebook submission
Volume II, Pages 1-17

2 CDRs written 4/12/01
1. bubo: J:\SpectralData* (includes all the field data plus some working files)
2. bubo: J:\AVData\Ikonos* and J:\AVData\Ikonos-Purchase* (ArcView files)

IKONOS Satellite Image

10/3/00

Scientific Notebook #432E, Volume II, Satellite Imagery, will contain field, laboratory, and computational image manipulation/interrogation related to the 1 m2 resolution IKONOS satellite purchased in August 2000. Acquisition dates are set for September 2000, January 2001, April 2001, and July 2001. Consultations aiding the purchase and the initial field work included: Ralph Hill (SwRI) spectrometer expertise
Mitchel Bell (AGS, Space Imaging reseller)
Pat Chavez (USGS Flagstaff office) (520)556-7221

Chavez contributed the following suggestion to assist field work. He uses satellite images in support of California dust storms/soil studies:

1. Avoid <35° sun angle "because the effects are not the same"
2. Take 100-200 readings per area (mixed category sites);
3. Normalize, partition out profiles, average 100-200 readings from each category;
4. Lean pod away from body (use a post) and avoid your own shadow, but maintain probes at vertical;
5. Use dark and bright targets to look for changes between satellite flyover & spectrometer measurements;
6. Either (i) use white standard before and after capturing each reflectance profile, or (ii) get concurrent upward and downward facing spectral profiles.

Purchase requirements were based on the ArcView 3.2 file:
J:\AVData\Ikonos\purchase.apr and .\repository.apr

The IKONOS image will be shot in 1 pass, though the size of our area nearly max'd out the satellite's capability (2 orbits were not needed). As part of the image processing, stereo imagery from 1 or 2 nadirs will be used to make the ortho-rectified image; thus, a photogrammatic-grade DEM is created. I have to inquire into the availability of obtaining this DEM even though there will be no guaranty of its reliability.

The computers used for this work are the NT Box (Windows NT) called bubo, which is a 450 MHz pentium III with 256 MBytes of RAM. Bubo will be used for programming and ArcView (version 3.2) use. Pluto, the SGI server in the GIS Lab, will be used to run ERDAS Imagine (version 8.4).

Field Work September 17-19, 2000 & Associated Data Processing

Objective:
Creating initial catalogue of spectral profiles at about the same time as the image was taken; estimates of water content were also made.

David Farrell & David Groeneveld assisted in the field work. They are shown in the 2 photographs in figure II-1 (following page) with the spectrometer setup in the field (center pivot alfalfa field in Amargosa Farms).

Maps used during field work were created using the 1999 YMP GIS CDROM obtained from the DOE via Ron Martin. Rick Klar's old Landsat image was added as a theme backdrop to help locate ourselves in the field and to help determine which features to measure in the field (since the Landsat image may show some of the same larger features and contrasts as the IKONOS image). The project file to upload in ArcView is:
J:\AVData\Giscd\giscd-landsat.apr

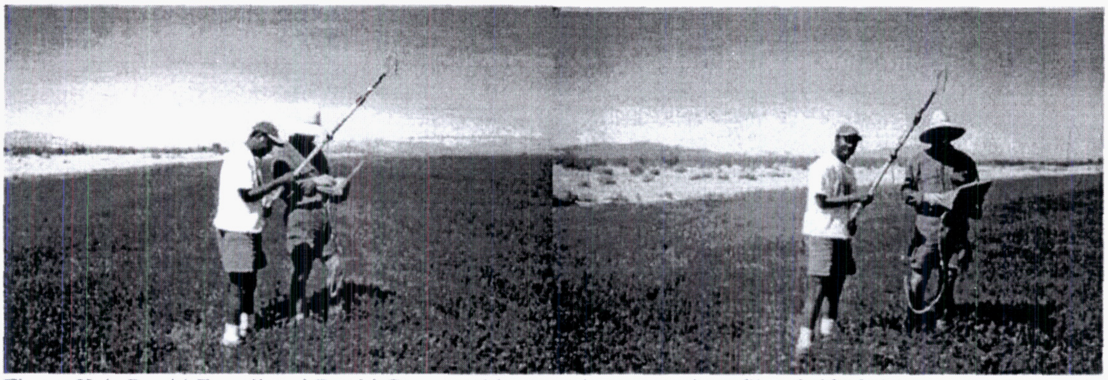


Figure II-1. David Farrell and David Groeneveld measuring spectral profile of alfalfa in a center pivot plot. J:\Spectral\Photo\Sept2000\spectral1-300.jpg and spectral2-300.jpg (600 and 1200 dpi versions also saved).

Recent Precipitation:

There was evidence of a recent rain event that led to runoff in Fortymile Wash near Highway 95 as well as wet soils at depth elsewhere. Enough hot sunny days had passed since the storm so that the top 5 cm were fairly dried out from evaporation. The parking lot of the Burro Motel had evidence of recent flooding. Locals in Beatty remembered the last rain event as being the last few days of August. Up-to-date Las Vegas data is available from:

http://www.wrcc.dri.edu/monitor/statereg.html#Preliminary which leads to
http://nimbo.wrh.noaa.gov/LasVegas/mosummary.html

These tables indicated that there was a storm event passing through this part of southern Nevada on August 29-31st that led to 0.46, 0.01, and 0.02 inches of rain at the Las Vegas airport. There were no precipitation events in September. Events earlier in August are 0.11 inches August 26th and trace amounts August 14-16th, 22-25th, 28th.

Paul Fransioli (head meteorologist, 702-295-5034) and Tim Moran (Ranch Control Meteorology Group, technician, 702-295-6300) for SAIC at YM were contacted for preliminary precipitation data for August and September events (the only "real" one was at the end of August). Paul is checking into methods for releasing preliminary data to NRC. Storage gage data only was requested (not tipping bucket data). Fransioli contends that his data is much better than the USGS or NTS data, in terms of well-maintained equipment and data checking.

[A file was received from DOE/Fransioli that had the August and September (up to 9/5/00) daily precipitation for all the Yucca Mountain project meteorological stations confirming the August 29-31 event (all station average = 1.64 inches, and a range of 0.19 to 2.88 inches) and another light event on September 5, 2000 (0.00 to 0.05 inches across the YM station network). The spreadsheet file was labeled by DOE as "preliminary data" and is stored as: J:\SpectralData\ProfilesSept2000\SG_Aug2000_YMPrecip.xls]

--- 11/3/00

Water Content:

A Campbell Scientific HydroSense TDR probe was used in the field to estimate water content. This particular probe was borrowed from Dani Or and Utah State University (Serial Number 001581). Regression equations developed by Dani Or and his associates at Utah State University are used as an initial estimate for the water content. Water content of samples collected during the fieldwork will be measured in the laboratory to verify the accuracy of the probe. Water contents +/- 5 percent are sufficiently accurate (color changes of soils as water content varies)

The following scanned figures (figures II-2 and II-3) with measured soil water content versus the HydroSense probe (borrowed) were supplied by Dani Or along with the table of data used to create the figure. The table of data and the regression equations are re-typed here for clarity. The top, single graph figure box (figure II-2) is the graph from the lower left of the scanned entire sheet of figure II-3.

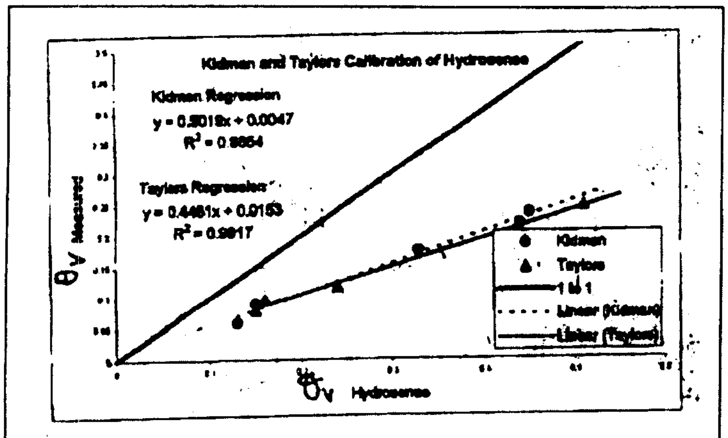


Figure II-2. Scan of fax from Dani Or.

Kidman (sandy)		
TDR	Hydrosense	Measured
0.0761	0.15	0.090422
0.2686	0.45	0.23471
0.3205	0.53	
0.04079	0.13	0.058482
0.1897	0.33	0.175446
0.2727	0.44	0.217219
Taylors (silt loam)		
TDR	Hydrosense	Measured
0.0573	0.15	0.096291
0.1774	0.3	
0.1762	0.3	
0.2952	0.55	
0.04075	0.15	0.077976
0.125	0.24	0.116964

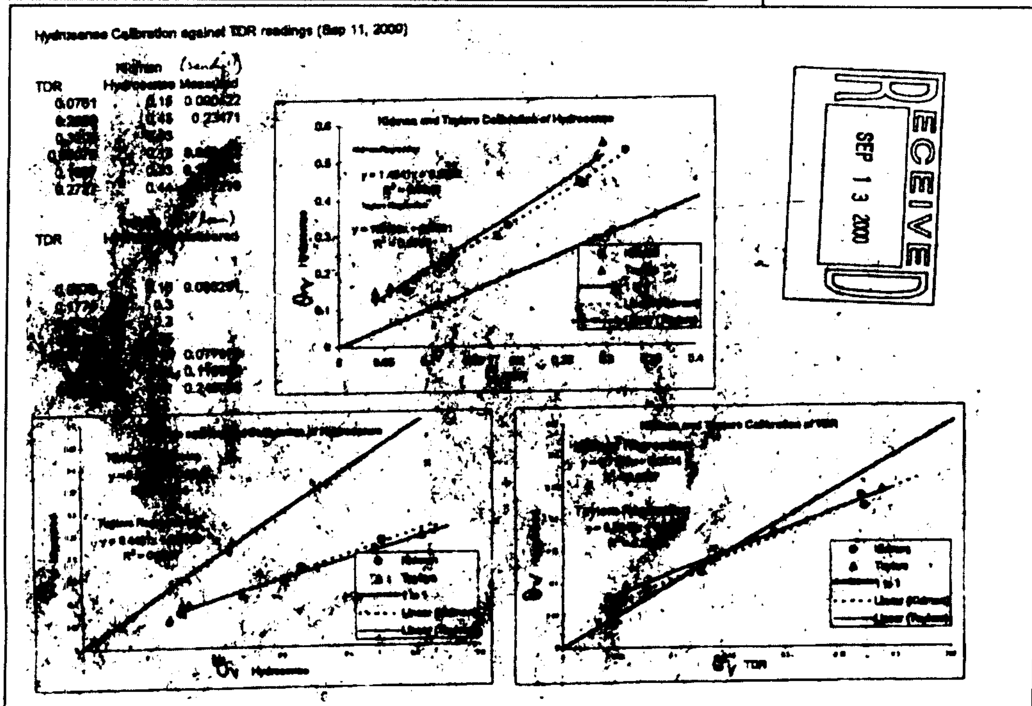


Figure II-3. Scan of fax from Dani Or, entire page.

The regression equations developed by Utah State (Dani Or) are:
Kidman soil (sandy)   y = 0.5019 x + 0.0047
Taylor soil (silt loam)   y = 0.4481 x + 0.0153
where y is the water content and x is the HydroSense probe reading.

Since the gravimetric soil water content measurements made at Utah State University are not acceptable for our QA program. Measurements of gravimetric water content in the CNWRA laboratory (bldg 51) are being used to establish the regression equations as reasonable. Eight soil samples were collected in the field. At these 8 locations, HydroSense readings of the sampled horizon were also taken. The laboratory measurement of gravimetric water content is extremely simple: (i) weigh the field sample on a calibrated scale, (ii) oven dry the sample at 95° C, and (iii) re-weigh the dry sample. The gravimetric water content is the weight of the water (wet sample minus dry sample weight) divided by the dry sample weight.

The following is a summary of the laboratory results. Specifics of methodology and calibrated scales used for the measurements are retained in the following spreadsheet. The spreadsheet also contains the laboratory work to estimate porosity bulk density and volumetric water content (which requires porosity bulk density).

J:\Spectral\SoilMeasurements\waterContent.xls

The table below contains HydroSense field readings (see sci ntbk 338, David Farrell) and laboratory water content measurements from the 8 soil samples (see Sept2000 sheet of waterContent.xls spreadsheet file). There are samples from each area: Amargosa Desert, Fortymile Wash, Crater Flat, and Jet Ridge. Some are dominantly alluvial while others are fluvial sheet wash with eolian processes also coming in to play. The Jet Ridge (Jet-1) sample is the only one that is dominantly eolian.

Field Ntbk (#338) Names	Lab ntbk (#432) Names	HydroSense	gravimetric water content	Texture
091700-2(2)	Lab#1	0.09	0.037	loamy sand
091700-2(3)	Lab#2	0.07	0.010	loamy sand
091700-1	Lab#3	0.06	0.010	fine sandy loam
091700-2(1)	Lab#4	0.18	0.128	sandy loam
0919-1	Lab#5	0.09	0.031	fine sandy loam
Jet-1	Lab#6	0.075	0.075	fine sandy loam
0919-2a	Lab#7	0.07	0.009	loamy sand
0919-2b	Lab#8	0.09	0.041	sandy loam

Sample Lab#5 has a HydroSense reading of 0.075 because it is an average. Other readings are reported as typical for the horizon sampled with little variation. The probe was generally inserted horizontally. The rock fragment (>2 mm) fraction ranged from 5% to 36%. The gravimetric water contents reported account for the rock fragment fraction. The gravimetric water content is the weight of the water in the field sample divided by the weight of the soil fraction excluding rock fragments (>2 mm); and, is calculated using the measured weights as described in the equation below:

$$\text{Gravimetric Water Content} = \frac{\text{Wet Sample} - \text{Oven Dry Sample}}{\text{Oven Dry Sample - Rock Fragment}}$$

A #10 Sieve (U.S. Standard Testing Sieve, ASTME-11 Specification, Tyler Equivalent 9 mesh, W.S. Tyler, Inc.) with 2 mm openings in the mesh was used to separate the soil fraction from the >2 mm rock fragments. The Sartorius 30,000 g scale in the rock cutting room of bldg 51 (calibrated 8/28/00 by jaw [AN 001444]; S/N 3903006) was used to weigh the samples before and after 7 days of oven drying. Little change in weights was noted between 4 and 7 days of oven drying.

For the regressions (done in EXCEL 97 SR-2), I used all of the data (both CNWRA and Utah State) where I had measured gravimetric water contents and HydroSense readings. The graph below (figure II-4) with "All Measured Data" illustrates the Utah State data is consistent with the CNWRA data. The regressions were done in the "TDR calibration" sheet of waterContent.xls.

Using all of the data combined, the linear regression is: $y = 0.49195\,x + 0.00036$ $[R^2 = 0.813]$

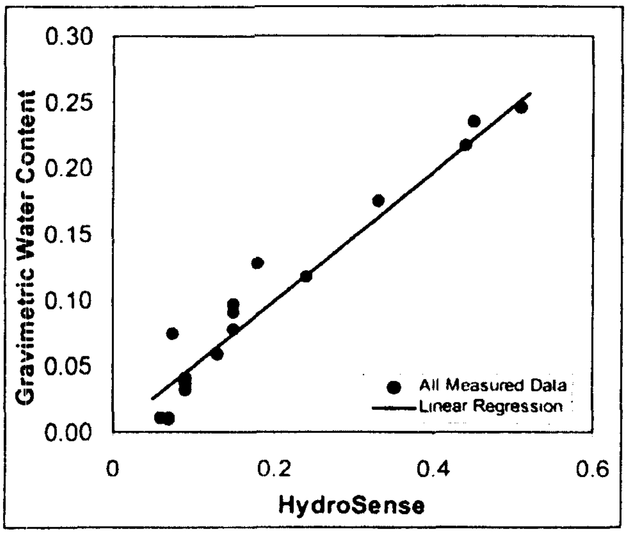


Figure II-4

Note that the data appears to trail off to a minimum HydroSense reading of 0.06. I just used a linear regression, though the trailing off at the low end may warrant a different curve. Some of these samples were extremely dry (as opposed to downright dry). As more readings are taken with the HydroSense, particularly in wetter samples, more laboratory measurements of water content will be obtained to support the regression curve. When CNWRA receives its own HydroSense (on order), it will have to be calibrated entirely itself (not using this data).

The regressions (EXCEL 97 SR-2) for the split data sets are (see also Figure II-5):
(i) Kidman + loamy sands, sands $y = 0.5574\,x - 0.0165$ $[R^2 = 0.982]$
(ii) Taylor + loams $y = 0.4762\,x + 0.0952$ $[R^2 = 0.906]$

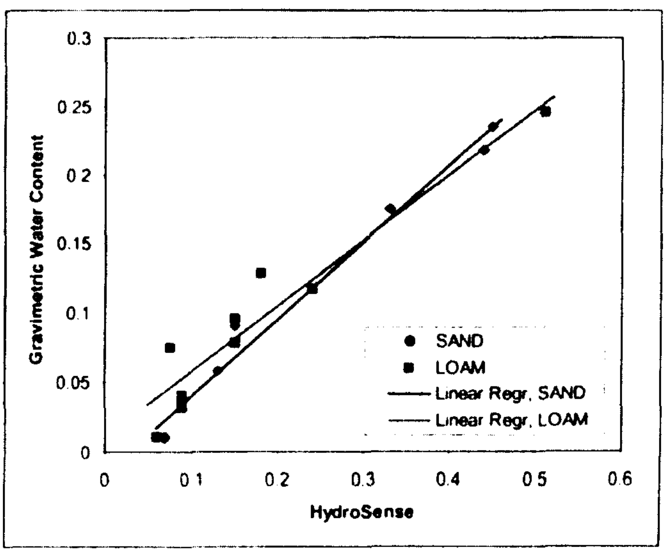


Figure II-5

Using a quadratic polynomial fit instead of a simple linear fit (see figure II-46):
All Data $y= .02983 + .8384\ x + (-.5954)\ x$ $[R^2 = 0.956]$

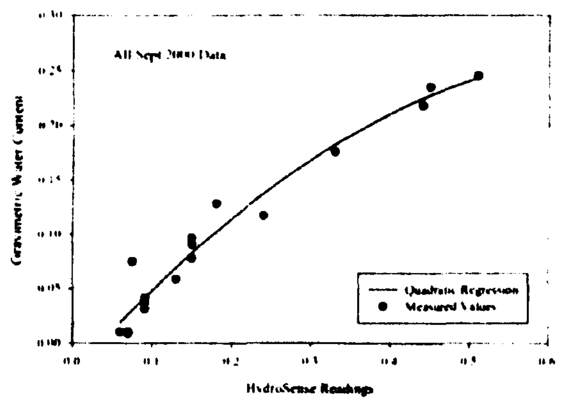


Figure II-6

Since EXCEL can only do simple linear regression, I did the quadratic fit in SigmaPlot:
J:\Spectral\SoilMeasurements\waterContentFit.JNB

Initial Spectral Profile Analysis

Figure II-7 illustrates the locations of field measurements using the Rick Klar landsat as a backdrop. The locations of the field measurements are incorporated into the ArcView 3.2 project file: J:\AVData\Ikonos\sept2000.apr. The names of sites are derived from field notes in scientific notebook #338 (David Farrell).

Two avenues for analyzing the profiles:
1. catalog of profiles to link to IKONOS multispectral bands
2. mixtures and percentage (of soil versus vegetation, and ratio of vegetation types)

The IKONOS satellite multispectral image will include 4 bands

Blue	0.445 - 0.516 µm
Green	0.506 – 0.595 µm
Red	0.632 - 0.798 µm
NIR	0.757 – 0.853 µm

These data are from http:/www.spaceimaging.com/carterra/geo/prodinfo/geotech.htm and are saved as J:\Spectral\geotech-Bands.htm. The Space Imaging catalogue and the Invoices from Mitchel Bell gave slightly different spectral ranges for the bands. The panchromatic range is 0.45 – 0.90 µm. The spectral profile from the spectrometer includes the entire profile from 362 to 900 nm (0.362 µm to 0.900 µm). The resolution (number of data points) along the wavelength span is 1100; the spacing of data values varies slightly. This is called spectral resolution, which happens to be slightly variable across the spectrum. Wide spectral resolution is the ability to record many different bands across the electromagnetic spectrum. Radiometric resolution is the ability of the remote sensing device to record many different levels of values (e.g., 0 to 255). Spatial and temporal resolution are self-explanatory. With any spectrometer, the sensors do not evenly respond across the entire spectrum. Hence a response multiplier is needed across the spectrum. According to Ralph Hill (SwRI), this is usually obtained from the manufacturer. I have asked Mitchel Bell (AGS) to get the IKONOS response multiplier, or a statement that Space Imaging has already applied the response multiplier to the data.

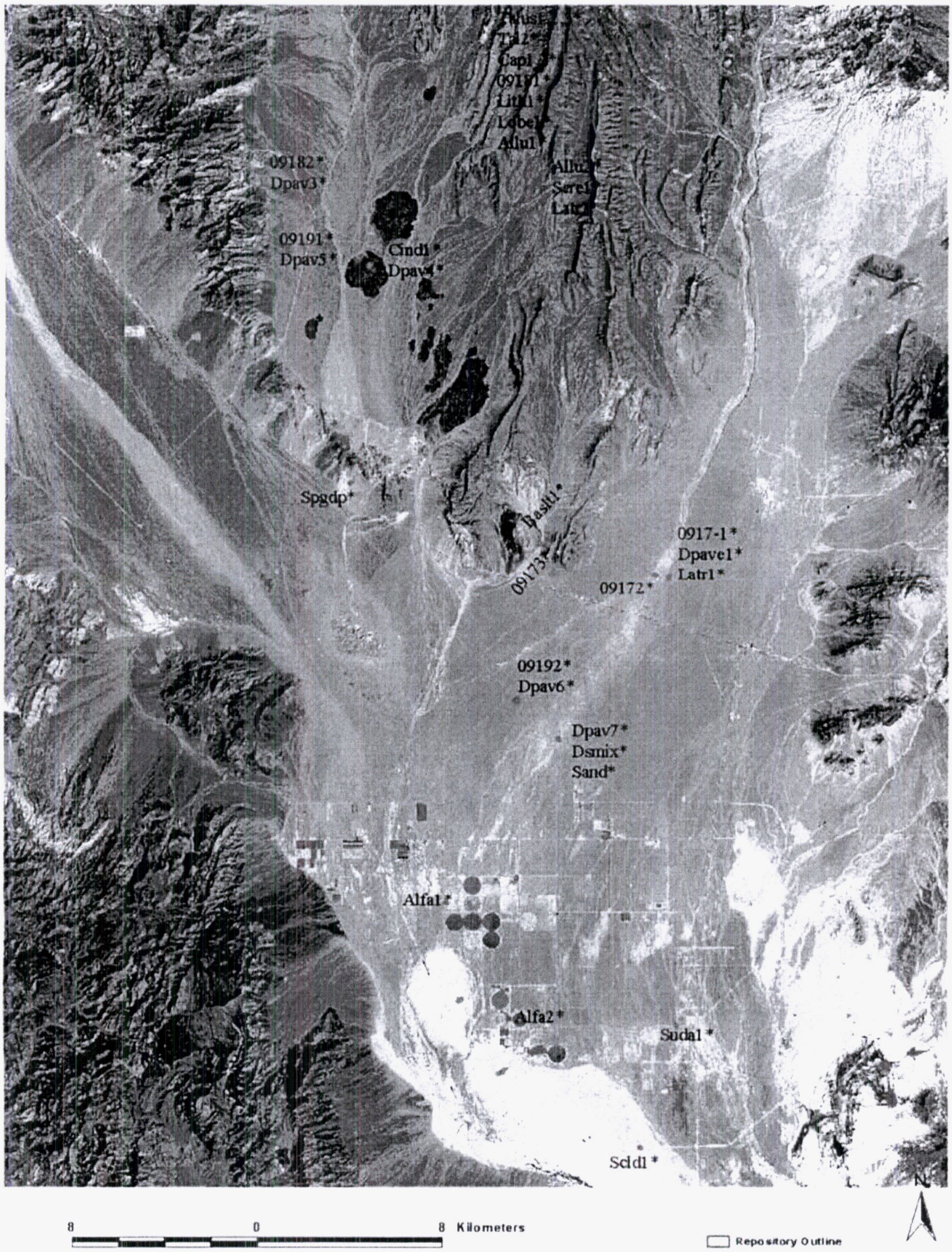


Figure II-7. Locations of September 2000 ground-based spectral profile readings.

A crucial assumption is that cover types are spectrally separable in the electromagnetic range of visible light to near-infrared. The high resolution of the IKONOS will help delineate different cover types (as compared to the low resolution Landsat, for example). It will be much easier to delineate boundaries and high-contrast small scale features such as faults and roads. Previously, on a 30 m pixel Landsat, the road would show up as a linear feature but the averaging over 30 m would smooth out the contrast. This should be particularly useful for fault delineation from linear features. Also, the improved ability to delineate boundaries of cover types on the IKONONS satellite image will improve the analysis of low-resolution imagery dating back to 1972 by allowing the cover type boundaries to be transferred to the low resolution images.

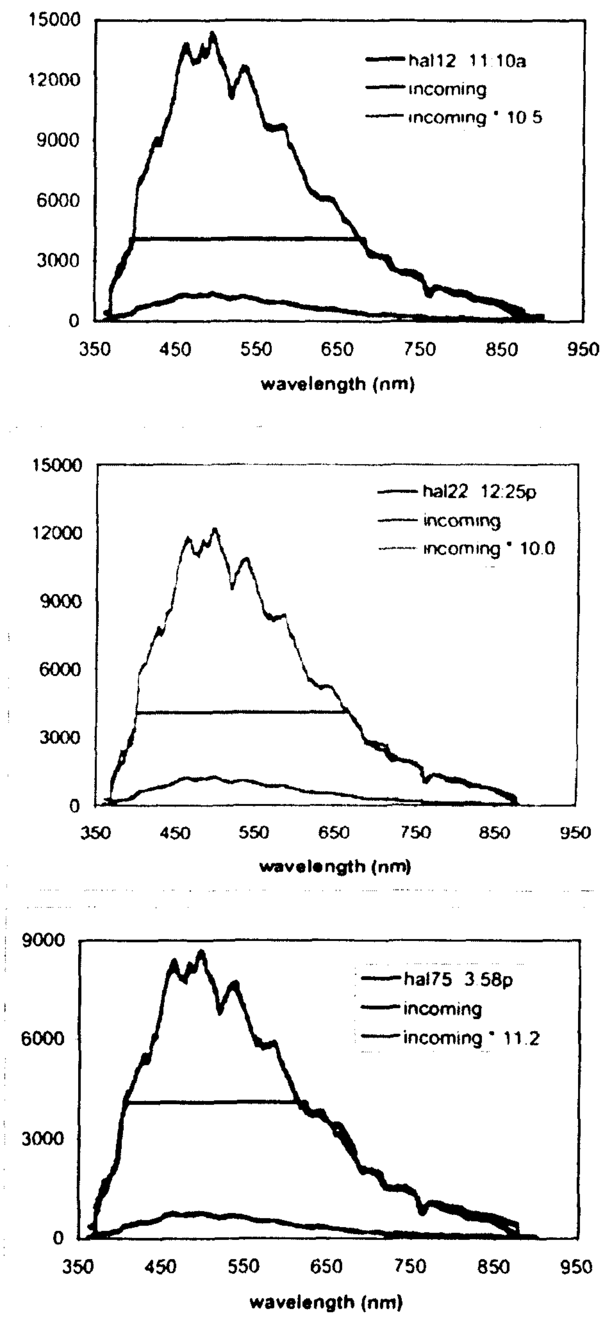
The visible light and near-infrared (V-NIR) portion of the electromagnetic spectrum is either reflected, absorbed, or transmitted as it enters the earth's atmosphere and reaches the ground surface. Without clouds, there is only a small distortion of the insolation (incoming solar). The ground-truthing of the incoming and the reflected (outgoing) will enable us to get a handle on that distortion and how it varies during the day. The distortion ground-truthing refers to the reflected light as it goes back up to the satellite through the atmosphere. Since this is what the satellite imagery takes an image of, the distortion will be evident when looking at ground-based spectral profiles of known features. Hence, corrections for atmospheric effects will be confirmed by the ground-based measurements.

It was deduced that the first 2 columns in the *.ssm files are in outgoing and the 3rd and 4th columns are the incoming spectral profiles. The *.sam files contain only the energy readings; the wavelength positions do not change from profile to profile.

J:\Spectral\ProfilesSept2000\spectral.xls sheets: "CoverTypes" and "Halon"

Matching the halon standard standard with the incoming profile was made more difficult because the halon standard swamped out the spectrometer signal. Different factors (figure II-8), dependent on the time of day, are used to match the incoming profile with the halon standard reflectance (note the halon standard has a nearly uniform reflectance across the wavelength spectrum).

Figure II-8. Halon standards, effect of irradiance probe and its 180° view; function of time of day and the surrounding terrain



One could look at the raw profiles or the outgoing minus the incoming such as the two plots in figure II-9, below.

The vegetation (such as the creosote in the sample profiles of the figure) preferentially reflects the near-infrared radiation over that of the visible light range) because of the chlorophyll. The creosote profile (latr22.ssm) example is shown in the two figures below and is contrasted against the pavement profiles. For initial interrogation of the field data, the profiles were imported into:

J:\Spectral\Profiles2000\spectral.xls

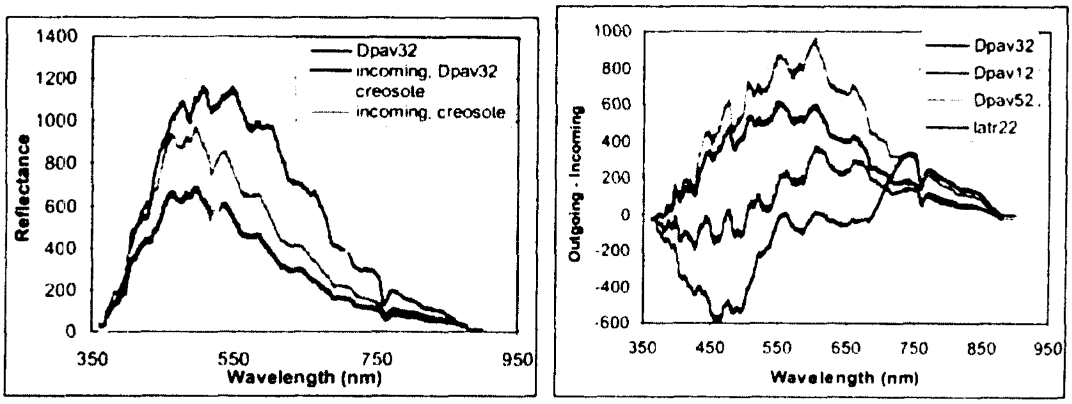


Figure II-9.

Another way to analyze the data is to normalize out the incoming radiation. In this initial analysis, only a single profile is incorporated. A better analysis will average the multiple spectral profiles taken at a location and then determine a representative incoming profile to normalize the data to. The incoming profile depends on time of day, nearby terrain (reflectance from other features as picked up by the 180° irradiance probe), and season of the year. Clearly the sun angle has a large effect. The reflectance factor is:

$$\text{reflectance factor} = \frac{\text{reflected radiation}}{\text{insolation}}$$

The albedo is actually the reflected radiation divided by the radiation from the entire spectrum from 0.3 – 4.0 μm.

To bring out the portions of the electromagnetic spectrum that are reflected by the cover type, the inverse of the reflectance factor seems to be useful. The graph below (figure II-10) illustrates the strong reflectance of the NIR by creosote.

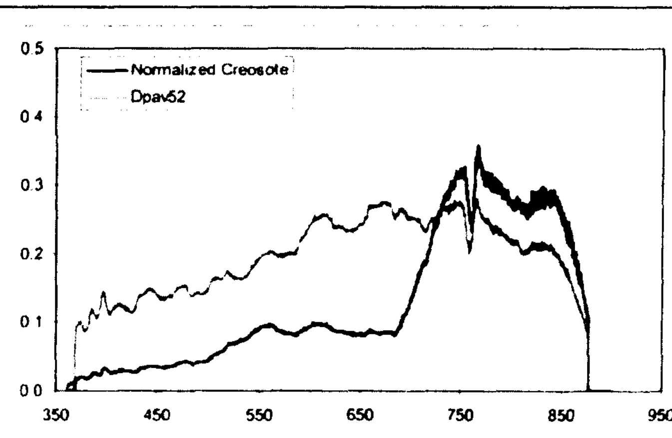


Figure II-10. Inverse of reflectance factor plotted against wavelength.

Two comments:

As I am learning more here and setting up the computer software differently, I have come to the conclusion that the 11 bit version would be better than the 8 bit. ArcView's Image Analyst will be run off of vulcan or pluto, not off an NTBox because of licensing issues costs. ERDAS will be run off of the UNIX machines also. I envision importing the 11 bit image and knocking it down to 8 bit if needed, or cutting out portions to make it more manageable. Either way, it is best to start out with the 11 bit version. I had earlier believed that the 11 bit was not a standard and that the 8 bit file would already be taxing our computer limits. ERDAS was contacted to make sure that Imagine could read in the 11 bit image (it can only import, it cannot export the 11 bit) from IKONOS. The 11 bit image gives us 2024 different colors (numbers) instead of the 8 bit limit of 256 different colors. I had estimated the file size of a single band (I asked for 4 separate files, one for each band) to be around 3 GBytes for the 8 bit data [$(3029\ km^2)(10^6\ m^2/km^2)(1/1024\ kilobytes/byte)(10^{-6}\ GBytes/kilobyte) = 2.958$ GBytes] noting that 8 bits = 1 byte. Hence, using the ratio of 11/8, the 11 bit file size would be about 4.07 GBytes.

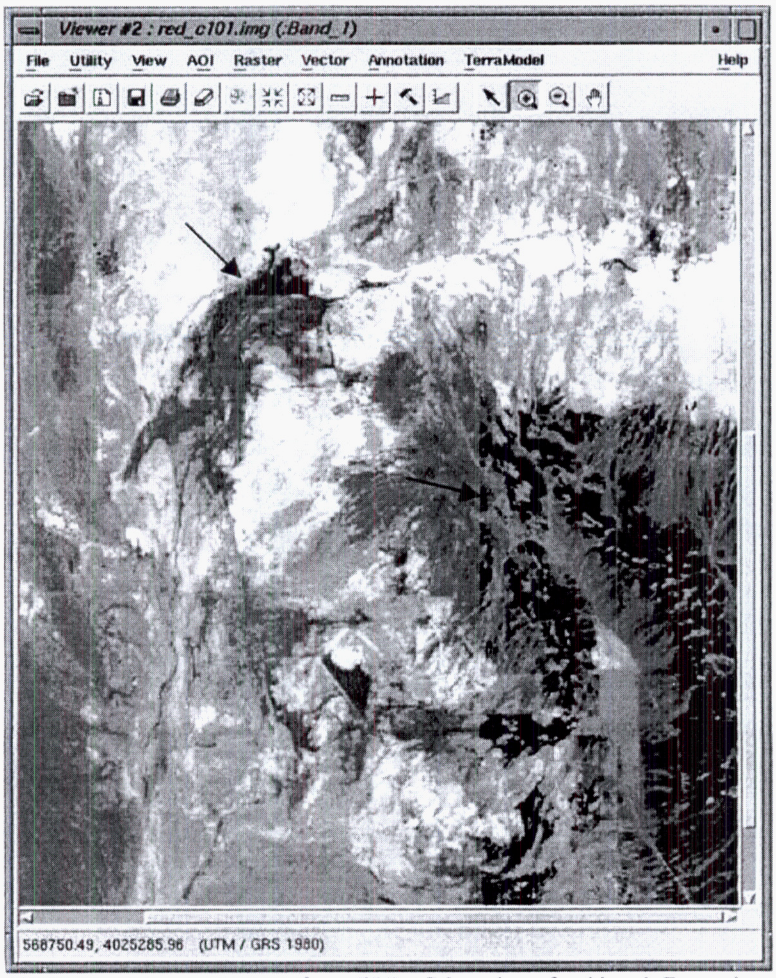
An article (Imaging Notes vol 15(3) Sept/Oct 2000) by Rick Oleszczuk of Space Imaging mentioned that there are three corrections that IKONOS may make:

1. sensor geometric correction
2. modulation transfer function compensation (MTFC)
3. radiometric calibration

The last one sounds like what I asked Mitchel Bell (AGS) last week to find out from Space Imaging. Specifically, what is the sensor response across the spectrum. Based on what Ralph Hill told me about the spectrometer sensors, I need to multiply the response factor (changes across the spectrum) times the energy reading that is the recorded profile. I assumed the IKONOS sensors also need this response correction, though I did not know if Space Imaging already corrected for this in their final product. Ralph Hill says that I can request the response curve from the manufacturer for the Ocean Optics spectrometer (this is much easier than having Ralph estimate it in the laboratory). The first one, the sensor geometric correction removes optical distortions and roughly geocodes the image. The second one, MTFC is the modulation transfer function correction that is top secret (Space Imaging statement), which removes signal degradation characteristics of the system from physical limitations and phenomena from motion, vibration, optics finite pixels.

Rejection of First Shipment (Item C, Amargosa Farms area) January 4, 2001

The delivery of December 2000 of the ItemC area (southern half of imagery, Amargosa Valley) was rejected because of internal radiometric errors. Figure II-11 illustrates the problem. Continuous features crossing between subimages had a sharp change in pixel values. This is not a problem with the palette (lookup table) for each subimage; the actual pixel values were checked. On one side of the line, the pixel values are 300-600 (okay). But on the neighboring image (the other side of the subimage), the pixel values are zeroes (not okay). The imagery was shipped back January 4th, 2001 (30-day return period was ending). In figure II-11, the lower 3/4th of the image is the red_100 tile, which itself is a composite of two portions of subimages. Initially, the Space Imaging techie thought there might be an internal processing error for the 11-bit version of output.



red_100.img

red_101.img

Figure II-11. Screen capture from ERDAS Imagine of red band, December 2000 product illustrating errors between subimages (arrows)

The metadata files delivered with the product have the acquisition dates. The image for ItemC was composed of 3 subimages collected on different dates, September 3, September 22, and September 25, 2000. I would expect some changes in soil conditions and vegetation between these dates because there was a storm event at the end of August. At any rate, the classification routines will have to be run separately on each subimage.

Ground Control Points 1/26/01

Space Imaging sent a subcontractor onsite (NTS) to collect ground control points. The only reason we found out was that the subcontractor was turned away at the gate (actually, the first rumor was that they were detained by the NTS security guards). I arranged for Pete LaFemina to escort the subcontractor (David Bry of Compasscon) onsite including gaining approval for locations outside of Area 25. Doug Braddock sent the image (figure II-12, stored as J:\SpectralData\GroundControlPoints\Nevada_Pic_Braddock.doc). The key that came with the figure had collection dates ranging from November 16, 2000 to December 23, 2000. These acquisition dates were quite a surprise, considering I believed that our purchase order said acquisition during September 2000.

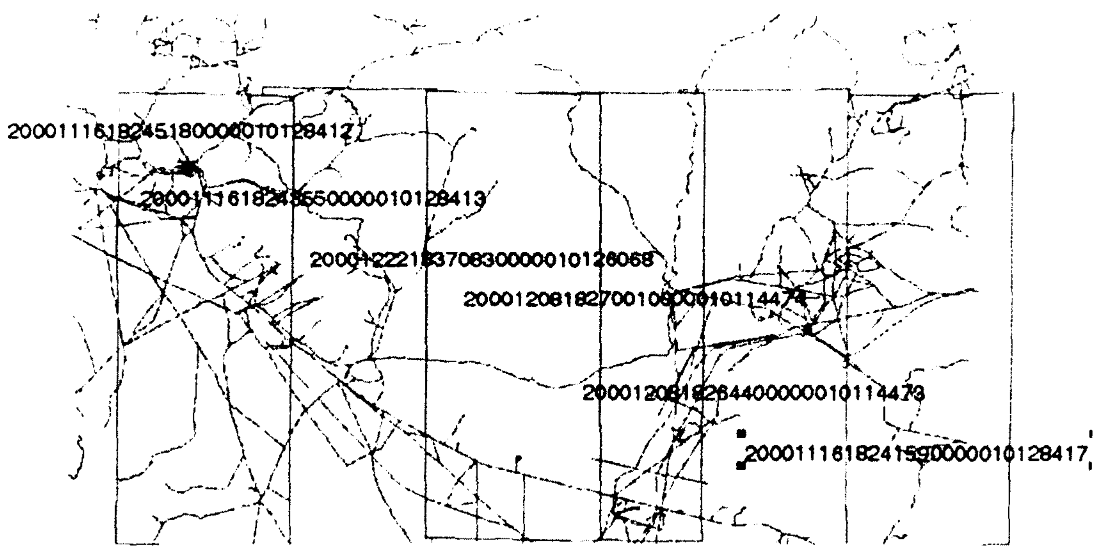


Figure II-12. Image sent along with requested ground control point locations.

The coordinates that Space Imaging/Compasscon (Steve Townsend of Compasscon was coordinator) requested are in the table below; I added the "ID" column to facilitate discussions with NTS/DOE staff for permissions to access these locations. CompassCon uses a satellite-based differential GPS service that they subscribe to; just a receiver on the ground is needed, the satellite does the correction to within centimeters horizontally.

Gcp_	Longitude	Latitude	ID
12	-116.4690361	36.91106667	1
14	-116.4930194	36.82028889	3
16	-116.3783139	36.89277222	7
18	-116.3899694	36.81125	8
19	-116.4437861	36.83876667	5
20	-116.3812361	36.71803889	9
21	-116.2714833	36.82676944	13
22	-116.3183528	36.77639444	12
23	-116.3652944	36.67036111	10
24	-116.2612278	36.94407222	100
25	-116.2922611	36.62428056	11

continued next page

26	-116.2254444	36.79938333	14
27	-116.2316528	36.73089444	15
28	-116.2196778	36.95639444	101
29	-116.166575	36.81670556	104
30	-116.2329389	36.85588889	103
31	-116.1533333	36.68522778	16
32	-116.1720583	36.92904722	102
33	-116.1973222	36.68287222	17
a1	-116.4650139	36.89094722	2
a3	-116.468925	36.8171	4
a5	-116.4224333	36.86283889	6
	-116.4158919	36.76021701	18

Figure II-13 contains the ground control points keyed into the "ID" column of the above table.

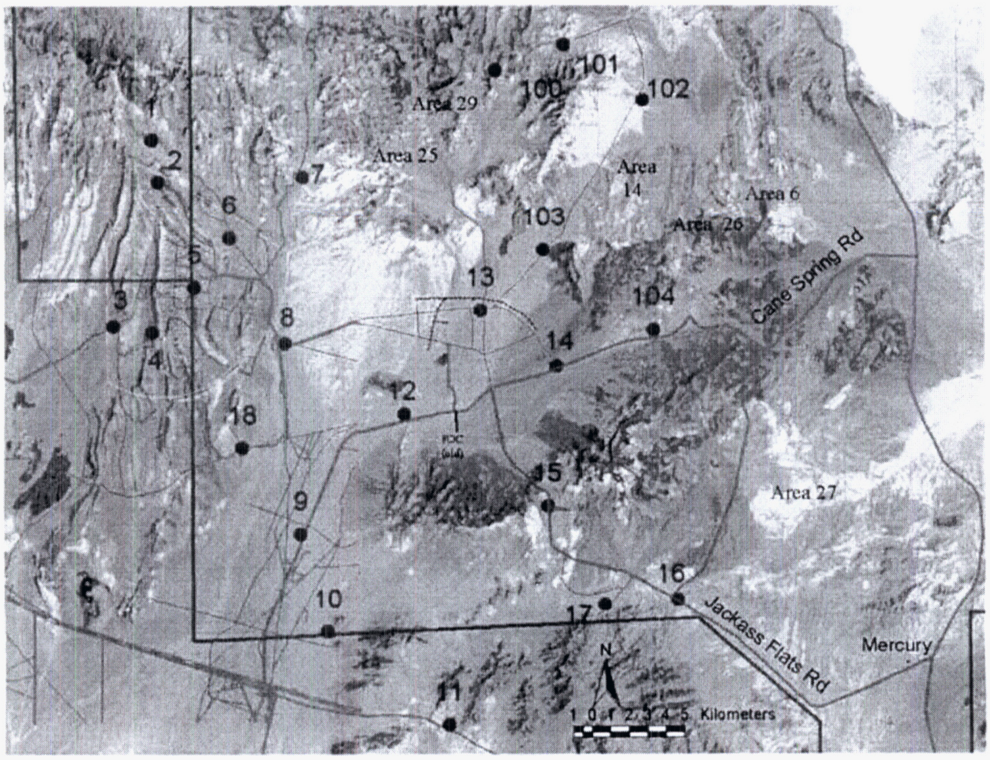


Figure II-13. Ground control points plot as sent to DOE for access approval.

Placement of a Lambertian Target on Yucca Mountain **Jan 26, 2001**

Chad Glenn offered to construct and place the Lambertian target onsite at Yucca Mountain; this is related to the work plan approved by DOE for spectral reading on Yucca Mountain (Land Access Approval, Case 01-001-00). The Lambertian target can be place onsite anytime during the next 2 weeks (Jan 24 to Feb 7, 2001). These comments are copied from the email I sent to him with the figure below as an attachment to the email.

Purpose: Create a Lambertian target for the satellite image (i.e., a perfect diffuse reflector; although painting a plywood board is not perfect, it should do fine for the spectral range of interest, visible and near-infrared)

Satellite Dates: mid-February, May, July (I'll take care of the later dates, for which re-painting might be needed)

Paint: Ultra-white, satan-finish paint (no yellow, blue, red undertones); please get the high quality paint for durability and ease in effectively covering the wood; it is important that there are multiple layers of paint to ensure that the wood is uniformly and completely covered; only the top side (upward-facing when put onsite) needs to be painted.

Wood: Two 4 ft by 8 ft pieces of 3/4 inch thick plywood; these will be set side-by-side on the frame made up of 2in by 4in by 8ft pieces of wood; thus, this will be an 8ft by 8 ft target; the frame will keep the plywood slightly off the ground and it will also add some strength; the frame and plywood should be assembled onsite using nails or screws; the plywood should be painted back in town but will likely need some touch-up after assembling everything onsite. The Lambertian target needs to be greater than 2 meters on each side to ensure that there will be at least one clean pixel, not mixed.

Label information: I would suggest permanent magic marker on a the edge of the frame; include Dick Kovach (702)295-6180, yourself, Randy Fedors [CNWRA, (210)522-6818] on the label along with the dates Feb. 2001 to Aug. 2001; Alan Mitchell didn't say to add his name, but maybe you should.

Site Location: (See figure II-14); find a relatively flat area in the southern portion of the drill pad (presumably out of the way); this is the drill pad that you pass going up Highway Ridge Road just below the crest of Yucca Mountain.

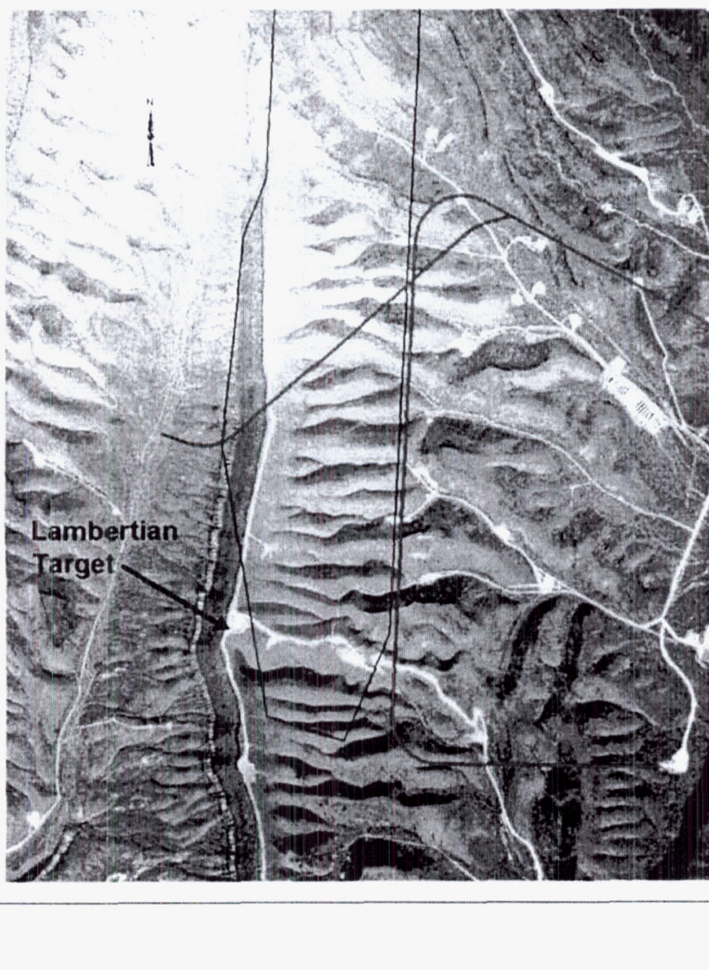


Figure II-14. Lambertian target placed near intersection of Highway Ridge road and the YM crest road.

Operation of USB2000 Spectrometers **3/2/01**

The program "OOIbase32" is distributed with the spectrometers and is designed for usage on Microsoft windowing environment. The spectrometers are distributed with calibrated data for coefficients used in the OOIbase32 program during collection of data. The coefficients convert the electrical signals to intensity measurements across the spectrum. The intensity measurements may be converted to energy per area per wavelength increment if appropriate standards are used. We do not need this capability.

The spectrometers should be configured as follows and attached to the laptop USB port via a splitter prior to starting the software program:

Upward-Facing Probe
- CC-3-UV cosine corrector
- 600 μm fiber optic cable
- optional neutral density filters if signal is swamping

Downward-Facing Probe
- 74-UV collimating lens set to 3° view from perpendicular
- 200 μm fiber optic cable

If the neutral density filters cannot ramp down the signal, then the integration time should be shortened. Check the profiles to ensure that the proper integration time is being used. The intensity range of the software is 0-4092. Make sure the profiles fall into the lower middle of this range. If the default 100ms integration time is too long, and the neutral density filters cannot compensate, then the signal/profile will be cutoff (swamped). If the integration time is too short on the downward facing probe, there will be poor resolution on a weak intensity profile and likely larger error. This can only be compensated for by increasing the integration time. The integration time should be noted for each measurement cycle, or each trip if it is not changed.

Note that the larger fiber optic cable is used with the upward-facing probe (CC-3-UV) because the cosine corrector diffuses light an order of magnitude (180° field of entrant light diffuses the direct sun light beam, geometric argument). The cross-sectional area of the fiber optic line controls the amount of light transmitted, hence the intensity of the spectrometer signal; the area is related to the square of the diameter.

To collect data, connect the spectrometers to the laptop first, then start the OOIbase32 program in the windowing environment.

Program Setup:

[Edit] → [Setting]
- File Saving tab = only box checked is the "Warn if Over-Writing File"
  - Default File Format = standard
  - Save Data Files for = all active channels
- Sounds tab = Change if they get tiring
- Confirmation File tab = C:\Progra~1\Oceano~1\OOIBAS~1\Default.display
  - C:\Spectrometer\USB2E740.spec (note that C:\Spectrometers is working dir)
  - C:\Progra~1\Oceano~1\OOIBAS~1\Default.TimeParameter

[Spectrum] = "Scope Mode" should be enabled

Measurement, Software Mechanics:

USB2E739 is downward facing probe, use collimating lens and 200 μm optic fiber cable
USB2E740 is upward facing probe, use cosine corrector and 600 μm optic fiber cable

1. Start OOIbase32 program after spectrometers are hooked up. The 1st view should open by default with the default specification file/spectrometer info. If not, [Spectrometer] -> [Open Configuration] -> select the file "USB2E740"
2. [Spectrometer] -> [Configure] confirm that the serial number in "Wavelength Calibration" and "A/D Interace" match the spectrometer that is sending the signal to the view, which should be USB2E740.
   Then click [Okay]
3. Open a new view for the other spectrometer and configure as noted above
   [File] -> [New]
   [Window] -> [Tile Vertically]
   [Spectrometer] -> [Open Configuration] and select "USB2E739.spec" file
   [Spectrometer] -> [Configure] again check "Wavelength Calibration" and "A/D Interface" tabs to make sure that USB2E739 is represented
   [Okay]
   Note that I am trying to keep USB740 as the default, no click [No] if prompted to save new default.
4. Both spectrometers should be sending signals and constantly updating.
5. Setup auto-incrementing of file names in each window by making the window active, then:
   [File] -> [Autoincrement] -> [Enabled]
   [File] -> [Autoincrement] -> [Basename] e.g., C:\RFedors\readings\sand2
   [File] -> [Autoincrement] -> [Starting Index] might as well start at default zero
   Now make the other window active and do the same commands & use a different basename (e.g. sand2_up)
6. It's set to start measurements:
   Make window active and hit [Record] icon in main window,
   make other window active and hit [Record] icon again.

Performance Check of Spectrometers [Temporary until HG-1 Lamp Arrives]

Since there are no adjustments for the spectrometers, we just need to ensure that there is no drift in the spectral signals. The HG-1 Mercury- Argon lamp did not arrive before the fieldwork of March 18-22, 2001 so I devised a temporary set of light sources and color chips to check for drift.

The primary tool will be the Energizer fluorescent portable lamp from Home Depot that has the prominent mercury lines that do not change in wavelength position. There are many mercury lines, not just the most prominent one at 546.1 μm. Hence, wavelength migration and expansion will be picked up by checking the fluorescent lamp source profiles periodically as part of the performance validation testing. I will also use reflectance of Chimayo Red satin (SF13C) Ralph Lauren paint chip reflected off an incandescent bulb and off the fluorescent portable lamp as an additional check.

The procedure will be to take 5-15 profiles of the fluorescent lamp, the light bulb, and the reflectance off the red paint chip. All of profiles will be taken by holding the collimating lens 2-5 cm from the light source or at a 45 degrees angle from the paint chip. This should be done before a field trip, possibly during the trip, and after the field trip. It is best done in a room so that the sources of light can be controlled better, though use of the collimating lens instead of the cosine corrector eliminates much of the worry about other light diffusing into the spectrometer intake line.

Once the HG-1 mercury-argon lamp arrives, old and new performance checks can be interspersed to establish continuity before continuing with only the new HG-1 lamp.

Measurement Plan for Field Work Winter 2001:

1. Measure Lambertian target (painted plywood, 8ft x 8ft) on Yucca Crest twice each day between 10:30 and 12:00 if working on top of Yucca Mountain or on the east flank.
2. Measure WS-2 disk at each measurement location (5-10 readings).
3. Solitario Canyon
   - same transect and pavement as were done in September 2000 in bottom of Solitario Canyon
   - colluvial wedge transects and pavements
   - PTn, TSw on west flank
4. Yucca Crest
   - bedrock on western-most crest (west side of crest road)
   - colluvium on broad slope of crest, both transects and pavements (east side of crest road)
5. East Flank upper Washes
   - bedrock lithologies on cliffs and steep slope
   - talus
   - transects and pavements on sideslopes
6. Lower Washes
7. Midway Valley
8. Exile Hill, Fran Ridge
9. Broad slope to Fortymile Wash

Field Work March 19-21, 2000 on Yucca Mountain **3/26/01**

DOE approval Case#01-001.00
DOE Work Plan #TCO-WI-080r.00

Field notebook #428, pages 2-32 contains the field notes and base file names from the spectrometers. The data was transferred to bubo and stored at J:\SpectralData\ProfilesMarch2001*

Equipment:
DELL Inspiron 5000 laptop (CNWRA ID#2592), and modified carrying case from Toshiba laptop
Garmin III Plus global positioning system (GPS) (SN#92138807)
Novetel receiver (CGT97340023) and DAP recorder (Model PC9500, SN#CQ2827)GPS with dome antenna
    SoftServ version 1.3.2 used to download data files off the DAP onto the laptop
Ocean Optics USB2000 spectrometers (serial numbers USB2E739 and USB2E740)
OOIBase32 version 1.00.8 [Driver version 3.04.07] for writing the spectrometer data to ascii files on a Window2000 laptop
Standards: WS-2 reflectance standard (Labsphere certified reflectance standard, AS-01158-060, USRS-99-010, BT55C)

References

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Maidment, D. and D. Djokic, eds., 2000. Hydrologic and Hydraulic Modeling Support with Geographic Information Systems, ESRI Press, Redlands, CA.

Rencz, A.N., ed., 1999, *Remote Sensing for the Earth Sciences*, Manual of Remote Sensing, Third Edition, Volume 3, John Wiley & Sons, New York.

Swadley, W.C., 1985, Map Showing Surficial Geology of the Lathrop Wells Quadrangle, Nye County, Nevada; USGS Map I-1361.

Verbyla, D.L., 1995, Satellite Remote Sensing of Natural Resources, CRC Lewis Publishers, New York.

IKONOS Satellite Image

4/15/00 RF

Field Equipment:
DELL Inspiron 5000 laptop (CNWRA ID#2592)
Garmin III Plus global positioning system (GPS) [SN#92138807, David Farrell's CNWRA unit]
Ocean Optics USB2000 spectrometers (serial numbers USB2E739 and USB2E740)
OOIBase32 version 1.00.8 [Driver version 3.04.07]
Standards: WS-2 reflectance standard (Labsphere certified reflectance standard, AS-01158-060, USRS-99-010, BT55C)
HG-1 Mercury-Argon Lamp [008-00000-STD, only marked on box, not actually on lamp]
Upward facing cosine corrector probe connected to USB2E739 using the 600 μm optic fiber cable.
Downward facing cosine corrector probe connected to USB2E740 using the 200 μm optic fiber cable.
Integration time is adjusted for each series of profiles to ensure that the profile peak registers between 1000 and 4000, but does not go over 4000 (intensity units).

Performance Check of Spectrometers **4/15/01** RF

The performance check on the spectrometers (USB2E739 and USB2E740) were done using spreadsheet calculations and plotting in EXCEL 97 SR-2 and are stored in \:

bubo: J:\SpectralData\Spectral-Calibrations\HG1-calibration.xls

Three tacks were taken for the performance check:

1. Following the initial method (prior to receipt of the HG-1 Mercury-Argon lamp), peak positions and profile shapes for an fluorescent lamp, red paint chip, and an incandescent bulb were plotted and compared;
2. HG-1 lamp spectral profiles were plotted and compared as a quick way of ensuring that the peaks were not shifting;
3. The coefficients for the spectrometers were checked using the HG-1 Mercury-Argon lamp; this is a regression of the signal with the wavelengths of known mercury and argon peaks in the visible and near-infrared region of the spectra.

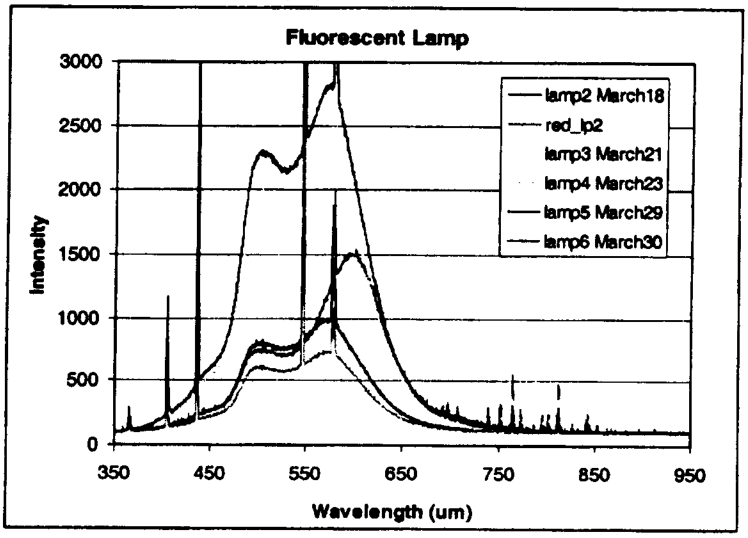
It is anticipated that the last check, calculation of the coefficients of the regression, would be done prior and after each trip. The second approach could be used in the field as a quick check. The first performance check method will be continued only to show that the spectrometers have not changed since their delivery and initial usage prior to HG-1 lamp being used.

The instructions for the performance check that calculates the coefficients are contained in the documentation for the spectrometers (Operating Manual and User's Guide, Appendix A). It is simply a 3rd order regression. The

- Need to wait a few minutes for HG-1 lamp to stabilize; also, use wall plug-in because the battery doesn't last long;
- Read the peak wavelength positions off the plotted profiles on the computer monitor and get the screen pixel number (relative to the y-axis intercept); this is set up in the OOIbase32 software; the wavelength, pixel number, and intensity are display in the lower left corner of the window (the latter is not needed);
- Make use of the toggle cursor (activate using the icons) to find peaks; automatic peak search works in many cases, but does need to be tweaked on occasion; slight adjustments toggling the cursor are necessary because of asymmetric spikes and double peaks (both caused by lack of wavelength resolution of output that is plotted and the pixel resolution of the monitor); one could record the spectral profiles and extract the peak data, then go back and get the pixel data for those peaks but the extra work and tedium doesn't improve the results and hence is not warranted); if the cursor line fell on 2 or 3 pixel positions when aligning with peak of intensity spike, I used the shape of the spike to determine which wavelength and pixel position to record;
- Use a variety of integration times (5 to 500 ms) to best bring out the peaks for positioning of the cursor.

This figure titled "Fluorescent Lamp" (below) shows that the fluorescent lamp spectral peaks were not shifting before, during, and after the field work March 20-23, 2001. The intensity does vary, but that is controlled by the proximity of the collimating lense to the lamp. We are not concerned with absolute intensity. The red2_lp line in the figure is the Chimayo red (Ralph Lauren) paint chip.

Figure with fluorescent lamp spectral profiles



Calculation of coefficients using the HG-1 lamp:

Table from "USB2E739" worksheet in HG1-Calibration.xls; March 30, 2001

March 30, 2001 Using the Dell laptop #2592, readings taken from monitor

actual	1 measured	pixel	new 1 predicted	old coef 1 predicted	difference actual vs new	original coefficients
365.01	365.42	46	365.17	365.42	-0.16	
404.66	404.65	156	404.42	404.65	0.24	
435.84	436.09	245	435.86	436.09	-0.02	
546.08	546.46	564	546.20	546.46	-0.12	
576.96	577.25	655	576.97	577.25	-0.01	
579.07	579.27	661	578.99	579.27	0.08	
696.54	696.71	1018	696.39	696.71	0.15	
706.72	706.97	1050	706.66	706.97	0.06	
727.29	727.68	1115	727.37	727.68	-0.08	
738.4	738.75	1150	738.45	738.75	-0.05	
750.39	751.02	1189	750.73	751.02	-0.34	
763.51	763.85	1230	763.56	763.85	-0.05	
772.4	772.56	1258	772.28	772.56	0.12	
794.82	794.8	1330	794.55	794.80	0.27	
800.62	801.24	1351	801.00	801.24	-0.38	
811.53	811.62	1385	811.41	811.62	0.12	348.8991817996
826.45	826.79	1435	826.61	826.79	-0.16	0.3598891995
842.46	842.14	1486	841.99	842.14	0.47	-1.5920095030E-05
852.14	852.3	1520	852.18	852.30	-0.04	-1.9514081803E-09
866.79	866.84	1569	866.76	866.84	0.03	
912.3	912.32	1725	912.43	912.32	-0.13	

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999999231
R Square	0.999998462
Adjusted R Square	0.999998191
Standard Error	0.212747051
Observations	21

ANOVA

	df
Regression	3
Residual	17
Total	20

	Coefficients
Intercept	348.6370824
X Variable 1	0.360212077
X Variable 2	-1.6735E-05
X Variable 3	-1.51428E-09

Table from "USB2E740" worksheet in HG1-Calibration.xls; March 20, 2001

March 30, 2001 Using the Dell laptop #2592, readings taken from monitor

	1	pixel	$pixel^2$	$pixel^3$	new 1	old coef 1	difference actual vs
actual	measured				predicted	predicted	new
365.01	364.69	43	1849	79507	364.99	364.69	0.02
404.66	404.44	155	24025	3723875	404.76	404.44	-0.10
435.84	435.41	243	59049	14348907	435.71	435.41	0.13
546.08	545.9	563	316969	178453547	546.06	545.90	0.02
576.96	577	655	429025	281011375	577.11	577.00	-0.15
579.07	579.02	661	436921	288804781	579.12	579.02	-0.05
696.54	696.5	1018	1036324	1.055E+09	696.37	696.50	0.17
706.72	706.77	1050	1102500	1.158E+09	706.63	706.77	0.09
727.29	727.5	1115	1243225	1.386E+09	727.33	727.50	-0.04
738.4	738.59	1150	1322500	1.521E+09	738.40	738.59	0.00
750.39	750.56	1188	1411344	1.677E+09	750.36	750.56	0.03
763.51	763.72	1230	1512900	1.861E+09	763.50	763.72	0.01
772.4	772.44	1258	1582564	1.991E+09	772.22	772.44	0.18
794.82	795.02	1331	1771561	2.358E+09	794.79	795.02	0.03
800.62	801.16	1351	1825201	2.466E+09	800.93	801.16	-0.31
811.53	811.86	1386	1920996	2.663E+09	811.63	811.86	-0.10
826.45	826.74	1435	2059225	2.955E+09	826.52	826.74	-0.07
842.46	842.7	1488	2214144	3.295E+09	842.50	842.70	-0.04
852.14	852.27	1520	2310400	3.512E+09	852.08	852.27	0.06
866.79	866.82	1569	2461761	3.863E+09	866.66	866.82	0.13
912.3	912.33	1725	2975625	5.133E+09	912.30	912.33	0.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999999746
R Square	0.999999492
Adjusted R Square	0.999999402
Standard Error	0.122308645
Observations	21

ANOVA

	df
Regression	3
Residual	17
Total	20

	original coefficients	*Coefficients*
Intercept	349.3298701541	349.6196925
X Variable 1	0.3577540928	0.358127867
X Variable 2	-1.3883866723E-05	-1.52979E-05
X Variable 3	-2.4967894538E-09	-1.86459E-09

One can conclude from the changes in coefficient values and the differences in wavelength positions for the peaks that the performance check does not require any modification to the coefficient values for either spectrometer. These differences minor when considering that this data will be compared against the integrated wavelength bands of the satellite sensor (4 bands covering approximately the same range of wavelengths).

Quality Assurance Check on Satellite Imagery – ItemA, ItemB, and ItemC **4/15/01** RF

Quality assurance acceptance testing was previously done on ItemC in January 2001 (see Volume II, page 11 of this scientific notebook) and the imagery was rejected because of inadequacies in pixel values processing.

Three quality aspects of the imagery need to be checked:

(i) temporal consistency of subimages
(ii) pixel value consistency across subimages
(iii) horizontal accuracy

The 80 % cloud-free constraint noted on the purchase order was readily attained. Only the northern extent of 67059 tile 0 has patches of clouds. The 67059 tile 0 image is overlapped on both sides by cloud-free images thus reducing the clouds for the entire area to less than approximately 2 or 3 percent.

Temporal Consistency

The time of the year that the portions of the image were taken can impose an important constraint on the utility of the imagery. For example, classification of vegetation cover would be done on each subimage. The classification of subimages taken between September 3 2000 and December 22, 2000 would be expected to have inconsistent categorization across the entire image because of changes in vegetation between September 3 and December 22.

Although ItemC satisfies the original invoice, portions of ItemB were taken as late as December 22nd. ItemB was rejected on these grounds. Although we really wanted consistency across ItemB and ItemC (they were separated for charging different projects), we were forced to agree that ItemC did satisfy the CNWRA invoice and should not be re-acquired. The fact that the CNWRA invoice was not reproduced by AGS (Mitchel Bell, the reseller) in his invoice to Space Imaging does not enter here as an issue.

ItemA was acquired on January 21, 2001 as part of the chronology series of YM itself. While the original purchase order specified this month for acquisition, we had been in discussions

Pixel Consistency Between Subimages

In January 2001, ItemC was rejected because noticeable discontinuities were noted between subimages. ItemB did not have this problem except where expected (slight variations because of the temporal changes between November 16 and December 22, the range of dates of the different swathes, or subimages, that make up ItemB).

Horizontal Accuracy

Three types of checks were done to verify horizontal accuracy of the IKONOS imagery: (i) consistency with USGS digital orthoquad (DOQ) imagery and USGS 10 foot contour ArcInfo coverage, and (ii) check of borehole and other feature locations against YM project GISCD 1999 data; and (iii) images with boreholes that overlap areas other area provide a consistency check of horizontal position.

The original DOQ for the NW quarter of the Busted Butte Quadrangle (bustedbnwp54424073.mos.img) was used in ERDAS Imagine (version 8.4) to verify consistency in geolocation with the IKONOS imagery in the vicinity of YM. I have been using a reprojected version of the busted butte doq stored in bubo: J:\AVData\Doq\airfoto_nw27.bip and associated world file (UTM NAD27). I used the original file of the doq from vulcan:/project/ . The doq is UTM NAD83, GRS 1980 spheroid, zone 11 (for central Nevada), which is the same as the IKONOS imagery. Note that ERDAS can take in images with different projections and still line them up correctly, ArcView cannot mix projection in a viewer.

The consistency check was done by loading the IKONOS image and the busted butte doq into the same viewer, and then using the Utility→Swipe function to sweep across the images in both the vertical and horizontal direction to ensure that features lined up between the two images. The doq resolution is between ~1.5 to 2 m per pixel, henceforth, it is a good check on the geolocation of the IKONOS imagery (1 m resolution per pixel).

There is high confidence that the DOE has surveyed in the borehole and other features (north portal/pad area). This data was included in the GIS coverage data cdrom released by DOE. The GISCD data is stored in:
bubo: J:\AVData\Giscd\giscd-ikonos.apr

The "Test" and "Design" views had the borehole and North Pad (used for the switchgear bldg coordinates) themes. The metadata file for the north portal pad .\Giscd\metadata\nport_bltu.fgd reconfirms that the data is plotted in UTM NAD27 (Clarke 1855 datum), and also has the statement: "Positional_Accuracy: Horizontal_Positional_Accuracy: This dataset meets the Spatial Registration Standard, Conformance Levels 1 and 2."
Then also load: .\Giscd\covers\test\boreu point coverage into ERDAS Imagine with the IKONOS imagery and use the attribute table get UTM NAD27 coordinates that will be treated as "truth" to compare against the location on the IKONOS images.

Feature	GISCD UTM NAD27 (m)		IKONOS UTM NAD27 (m)		Comment
	Northing	easting	northing	easting	
UE25 b#1	549954.563	4078422.25	549955.3	4078423.5	center of small area, see Groeneveld photo
NRG#4	550075.625	4078982	550075.8	4078981.4	center of white splotch that is a small shed covering collar, note shadow of shed extending to NNW; larger trailer NNW of collar on edge of drill pad; see Q8 Groeneveld airphoto; familiarity also based on previous site visit
switchgear bldg	551088.37	4078345.66	551088.8	4078345	southern-most corner of switchgear building (the long axis of the building trends about 20 degrees east of north)

Feature	GISCD UTM NAD83 (m)		IKONOS UTM NAD83 (m)		Comment
	Northing	easting	northing	easting	
SD-7	548303.99	4076695.86	548303.7	4076696.5	field familiarity and photo of pad
H-5	547588.21	4079038.00	547587.5	4079035.5	field familarity and photo of pad with vegetation patterns (bald spots)

All the locations checked are within 1.5 m horizontal accuracy except for the H-5 borehole collar, which was 2.5 m south of the GISCD data.

Because of the consistency checks, comparison with the DOQ, and the borehole location checks, one can conclude that the ItemA (January 2001 acquisition), ItemB, and ItemC sets of images are horizontally positioned to an accuracy that satisfies the original CNWRA purchase order QA constraints. ItemB was rejected because of temporal consistency problems; parts of ItemB were acquired as late as December 22, 2001. This is compared with the September 3, 2001 acquisition of parts of ItemC.

<u>QA for April 16, 2001 ItemA Acquisition</u> **5/5/01** RF

The same checks were performed on the April 16, 2001 acquisition as noted in the previous section. In addition, ItemA was overlaid on the January 21, 2001 acquisition. All indications suggest that the April 16, 2001 acquisition of ItemA product is acceptable.

Performance check prior to field work in August or September 2001: **8/17/01** RF

Table from "USB2E739" worksheet in HG1-Calibration.xls, August 17, 2001

August 17, 2001 Using the Dell laptop #2592, readings taken from monitor

actual	1 measured	pixel	new 1 predicted	old coef 1 predicted	difference actual vs new
365.01	365.06	45	365.08	365.06	-0.07
404.66	404.65	156	404.65	404.65	0.01
435.84	435.74	244	435.72	435.74	0.12
546.08	546.12	563	546.00	546.12	0.08
576.96	577.25	655	577.09	577.25	-0.13
579.07	579.27	661	579.11	579.27	-0.04
696.54	696.71	1018	696.45	696.71	0.09
706.72	706.97	1050	706.71	706.97	0.01
727.29	727.68	1115	727.41	727.68	-0.12
738.4	738.75	1150	738.49	738.75	-0.09
750.39	751.71	1188	750.45	750.71	-0.06
763.51	763.53	1229	763.28	763.53	0.23
772.4	772.56	1258	772.31	772.56	0.09
794.82	794.8	1330	794.57	794.80	0.25
800.62	801.24	1351	801.02	801.24	-0.40
811.53	811.62	1385	811.41	811.62	0.12
826.45	826.79	1435	826.61	826.79	-0.16
842.46	842.74	1488	842.59	842.74	-0.13
852.14	852.3	1520	852.17	852.30	-0.03
866.79	866.54	1568	866.45	866.54	0.34
912.3	912.32	1725	912.40	912.32	-0.10

original coefficients
348.8991817996
0.3598891995
-1.59200950E-05
-1.95140818E-09

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999999462
R Square	0.999998924
Adjusted R Square	0.999998734
Standard Error	0.17798713
Observations	21

ANOVA

	df
Regression	3
Residual	17
Total	20

	Coefficients
Intercept	348.9159663
X Variable 1	0.35992213
X Variable 2	-1.66455E-05
X Variable 3	-1.52952E-09

Table from "USB2E740" worksheet in HG1-Calibration.xls, August 17, 2001

August 17, 2001 Using the Dell laptop #2592, readings taken from monitor

actual	1 measured	pixel	new 1 predicted	old coef 1 predicted	difference actual vs new
365.01	364.33	42	364.78	364.33	0.23
404.66	404.44	155	404.81	404.44	-0.15
435.84	435.76	244	436.07	435.76	-0.23
546.08	545.9	563	546.05	545.90	0.03
576.96	576.66	654	576.77	576.66	0.19
579.07	579.02	661	579.12	579.02	-0.05
696.54	696.5	1018	696.50	696.50	0.04
706.72	706.77	1050	706.76	706.77	-0.04
727.29	727.19	1114	727.16	727.19	0.13
738.4	738.27	1149	738.24	738.27	0.16
750.39	750.56	1188	750.52	750.56	-0.13
763.51	763.4	1229	763.36	763.40	0.15
772.4	772.44	1258	772.39	772.44	0.01
794.82	795.02	1331	794.96	795.02	-0.14
800.62	801.16	1351	801.10	801.16	-0.48
811.53	811.55	1385	811.49	811.55	0.04
826.45	826.44	1434	826.37	826.44	0.08
842.46	842.4	1487	842.33	842.40	0.13
852.14	852.27	1520	852.20	852.27	-0.06
866.79	866.82	1569	866.75	866.82	0.04
912.3	912.33	1725	912.25	912.33	0.05

original coefficients
349.3298701541
0.3577540928
-1.3883866723E-05
-2.4967894538E-09

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999999466
R Square	0.999998931
Adjusted R Square	0.999998743
Standard Error	0.177367353
Observations	21

ANOVA

	df
Regression	3
Residual	17
Total	20

	Coefficients
Intercept	349.8123607
X Variable 1	0.356993782
X Variable 2	-1.35777E-05
X Variable 3	-2.52711E-09

Performance check post-field work August 2001: **9/20/01**

Table from "USB2E739" worksheet in HG1-Calibration.xls, September 19, 2001

September 19, 2001 Using the Dell laptop #2592, readings taken from monitor by David Farrell

actual	λ measured	pixel	new λ predicted	old coef λ predicted	difference actual vs new	original coefficients
365.01	365.78	47	365.32	365.78	-0.31	
404.66	404.65	156	404.29	404.65	0.37	
435.84	436.09	245	435.78	436.09	0.06	
546.08	546.46	564	546.22	546.46	-0.14	
576.96	577.25	655	576.99	577.25	-0.03	
579.07	579.27	661	579.01	579.27	0.06	
696.54	696.71	1018	696.37	696.71	0.17	
706.72	706.97	1050	706.63	706.97	0.09	
727.29	727.68	1115	727.33	727.68	-0.04	
738.4	738.75	1150	738.40	738.75	0.00	
750.39	751.02	1189	750.68	751.02	-0.29	
763.51	763.85	1230	763.51	763.85	0.00	
772.4	772.87	1259	772.54	772.87	-0.14	
794.82	795.41	1332	795.10	795.41	-0.28	
800.62	801.24	1351	800.93	801.24	-0.31	
811.53	811.93	1386	811.63	811.93	-0.10	348.8991817996
826.45	826.79	1435	826.52	826.79	-0.07	0.3898891995
842.46	841.24	1483	841.00	841.24	1.46	-1.5920095030E-05
852.14	852.59	1521	852.39	852.59	-0.25	-1.9514081803E-09
866.79	866.84	1569	866.68	866.84	0.11	
912.3	912.61	1726	912.65	912.61	-0.35	

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999997093
R Square	0.999994185
Adjusted R Square	0.999993159
Standard Error	0.413726316
Observations	21

ANOVA

	df
Regression	3
Residual	17
Total	20

	Coefficients
Intercept	348.3798212
X Variable 1	0.361181235
X Variable 2	-1.7778E-05
X Variable 3	-1.19847E-09

Some possibly significant changes noted for USB2E739 (at wavelength 841 μm most prominently), though one should also note that in the regions surrounding the points of significant difference, the differences are small. Hence, one can conclude that operator error in the peak finding approach is the likely cause. Previous performance validations hinted at the peak finding method as the weak link in this check. David Farrell performed all these measurements to avoid specific operator bias. The performance check for USB2E740 is an extremely good match throughout the spectrum, which was also done by David Farrell.

Table from "USB2E740" worksheet in HG1-Calibration.xls, September 19, 2001

actual	λ measured	pixel	new λ predicted	old coef λ predicted	difference actual vs new	original coefficients
365.01	365.04	44	364.95	365.04	0.06	
404.66	404.79	156	404.78	404.79	-0.12	
435.84	435.76	244	435.79	435.76	0.05	
546.08	545.9	563	545.99	545.90	0.09	
576.96	577	655	577.09	577.00	-0.13	
579.07	579.02	661	579.10	579.02	-0.03	
696.54	696.5	1018	696.49	696.50	0.05	
706.72	706.77	1050	706.75	706.77	-0.03	
727.29	727.19	1114	727.13	727.19	0.16	
738.4	738.27	1149	738.20	738.27	0.20	
750.39	750.56	1188	750.48	750.56	-0.09	
763.51	763.72	1230	763.61	763.72	-0.10	
772.4	772.44	1258	772.33	772.44	0.07	
794.82	795.02	1331	794.87	795.02	-0.05	
800.62	800.85	1350	800.70	800.85	-0.08	
811.53	811.86	1386	811.69	811.86	-0.16	349.3298701541
826.45	826.74	1435	826.55	826.74	-0.10	0.3577540928
842.46	842.7	1488	842.50	842.70	-0.04	-1.3883866723E-05
852.14	852.27	1520	852.05	852.27	0.09	-2.4967894538E-09
866.79	866.82	1569	866.59	866.82	0.20	
912.3	912.61	1726	912.34	912.61	-0.04	

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999999769
R Square	0.999999539
Adjusted R Square	0.999999457
Standard Error	0.116518569
Observations	21

ANOVA

	df
Regression	3
Residual	17
Total	20

	Coefficients
Intercept	349.1962579
X Variable 1	0.358678409
X Variable 2	-1.49832E-05
X Variable 3	-2.19717E-09

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RL
4/9/2008

Volume II. IKONOS Satellite Imagery

10/26/02 RF

QA on September 2001 Acquisition – Item B

Three criteria will be checked: spatial accuracy, cloud cover, and intensity level. The files from Space Imaging via AGS (Mitchel Bell) are stored on 8mm tapes of the original images and the Erdas Imagine-formatted files (my desk drawer), the original cdroms (my office shelf), and on the SGI called Io:/data1/ikonos/. All Erdas Imagine 8.4 work was done on the SGI workstation called Io.

Spatial Accuracy Check

Check spatial consistency using the SWIPE command in ERDAS IMAGINE 8.4 with the following data:

1. Busted Butte digital orthoquad obtained from Ron Martin, who got it from DOE. The Busted Butte DOQ is also 1 m pixel resolution.
2. Topographic contour (10 ft interval) used by the USGS in the Day et al. 1997 and 1998 maps of YM and surrounding area. The contour data covers the Busted Butte quad.
3. The digitized roads ArcView coverages from the 1999 GISCD (DOE distributed GIS data for YM).
4. I also checked to make sure that there was consistency between images in the collection of September 2001 acquisition by loading all of the green bands for ItemB and checking the overlap areas.
5. The previously accepted December 2000 acquisition, po_67058_red_000000.*, was also compared with the September 2001 corresponding image (these cover slightly offset areas, but generally overlap).

Since (i) the previously delivered products were accepted as spatially located to the degree noted in the purchase order and (ii) the DOE and USGS data spatially match up, the spatial accuracy of the September 2001 acquisition is found acceptable.

Cloud Cover Check

Using visual inspection, it was clear that there was less than 20% cloud cover. Overlapping of images also serves to reduce the cloud cover (clouds on an image taken one day are not an issue when there partial overlap from another image taken on a completely cloud-free day). One of the images has <5 percent cloud cover, but most of the remaining images comprising Item B appear to be 100 percent cloud-free.

Intensity Check

Two checks were done for intensity values: (i) consistency between Sept 2001 images and between Sept 2000 and Sept 2001 corresponding image with the understanding that climatic conditions, soil water content, and vegetation may cause changes; and (ii) make sure that the cropping of pixel values seen in the rejected Item C images was not repeated here.

Check ERDAS IMAGINE 8.4 with the following data:

- I checked to make sure that there was consistency between images in the collection of September 2001 acquisition by loading all of the green bands for ItemB and checking the overlap areas.
- The previously accepted December 2000 acquisition, po_67058_red_000000.*, was also compared with the September 2001 corresponding image (these cover slightly offset areas, but generally overlap).

The intensity values were inspected to make sure that processing did not artificially crop the 0-2048 range as was done with the first delivery of ItemC in January 2001. Histograms of intensities for the following files were inspected; plus visual observation of the entire set of images of the green band did not show large areas of entire black (with intensity equal to zero).

Volume II. IKONOS Satellite Imagery

8/29/02 RF

Aggregating Spectral Data

Lisa Harrell will be aggregating field-based spectral data. The first step is to eliminate outlier profiles, which she will identify graphically. Later, these codes will be modified to normalize the profiles based on upward facing profiles and the halon standard. The following codes read in the files for each measurement site (number of files varies from ~5 to ~120). The code will put appropriate data into separate columns of the aggregated file for easy import into EXCEL. Difficulties did arise because EXCEL 97 was used for testing (on my machine, bubo) while Lisa used EXCEL 2000 (on birch, in her office). These two versions of EXCEL read the same file differently!! Thanks Microsoft. The switch to comma delimited files, rather than space delimited or fixed, took care of the problem.

Two codes were developed, one for the Sept 2000 field spectral readings and one for all the later readings using the Ocean Optics spectrometer. Codes to read in and aggregate data were developed on SUN (Spock) because of system calls to list files for reading in. The code runs the same whether compiled by fortran 77 (f77) or fortran 90 (f90 command). **These codes simply reformat the data for plotting purposes.** The code to read in Sept2000 data was called "sp2000" and is stored in:

Spock: ~rfedors/SpectralData/Fortran/sp2000.f
(and copied to bubo: E:\SpectralData\FortranCode\sp2000.f)

```
      program sp2000
c Use for September 2000 data,
c   which has both upward and downward facing data in the same file.
c Reads in multiple (sequential) spectral data files, data is thrown into
c   one file for plotting of outliers, means are calculated (not yet), and soon
c   (not yet) bands will be aggregated. (Ocean Optics spectrometer data).
c Script to read in sequential files from a directory was done on UNIX (SUN)
c   to utilize ls, grep, and wc commands.
c
c Executable set to run from existing data directories, output files to same.
c
c RFedors  July 26, 2002
c
c23456789 123456789 123456789 123456789 123456789 123456789 123456789 12
      implicit none
      integer mpts, mfiles, ioread, iowrit, i, j
      integer ifiles, ifile1, ifile2, ifile3
      parameter (mpts=1100,mfiles=200)
      integer iup(mpts,mfiles), idown(mpts,mfiles)
      character*60 flist, filelist(mfiles)
      character*10  filebase, filebase1
      real*8 down(mpts,mfiles), up(mpts,mfiles), band(mpts), band2(mpts)
      character*80  file_spec, file_band, file_summary

c set input and output unit numbers
      ioread = 7
      iowrit = 8

c get file list
      write(*,*) 'enter basename '
      read(*,'(a10)') filebase
      filebase1 = filebase//'.'
      flist='ls -1 *.SSM | grep '//filebase1//' | wc -l > /tmp/record'
      call system(flist)
      open(ioread,file='/tmp/record/')
      read(ioread,'(i8)') ifiles
      flist = 'ls -1 *.SSM | grep '//filebase1//' > /tmp/file.list'
      call system(flist)
      open(ioread,file='/tmp/file.list')
      do i = 1, ifiles
        read(ioread,'(a30)') filelist(i)
      end do
      write(*,*) filelist(1)
```

```
      close(ioread)
      call system('/bin/rm /tmp/record')
      call system('/bin/rm /tmp/file.list')

c check if more than maximum number of files
      if(ifiles.gt.155) then
        print*, 'Too many files    Need to modify code    STOPPING'
        stop
      endif

c set file names for output files
      file_spec = 'Spec_down.'//filebase
      file_summary = 'Summ.'//filebase
      file_band = 'SBand.'//filebase

c Read all the files and aggregate into the array matrix
      do i = 1, ifiles
        open (unit=ioread, file=filelist(i), status ='unknown')
        do j = 1, mpts
          read (ioread,*) band(j), down (j,i), band2(j), up(j,i)
          idown(j,i) = int(down(j,i))
          iup(j,i) = int(up(j,i))
        end do
        close (ioread)
      end do

c write out some files in segments for importing into Excel; integers needed
c to avoid silly Excel errors (Note also that Excel 97 and Excel 2000 read in
c files differently).
      ifile1 = ifiles
      ifile2 = ifiles
      ifile3 = ifiles
      if(ifiles.gt.38) ifile1 = 38
      if(ifiles.gt.77) ifile2 = 77
      if(ifiles.gt.116) ifile3 = 116

      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,205)  band(j),(idown(j,i),i =1,ifile1)
      end do
      close(iowrit)
      file_spec = 'Spec_up.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,205)  band2(j),(iup(j,i),i =1,ifile1)
      end do
      close(iowrit)
205   format (f7.2,38(',',i4))
215   format(i4,38(',',i4))

      if(ifiles.gt.ifile1) then
      file_spec = 'Spec2_down.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,215)  (idown(j,i),i =ifile1+1,ifile2)
      end do
      close(iowrit)
      file_spec = 'Spec2_up.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,215)  (iup(j,i),i =ifile1+1,ifile2)
      end do
      close(iowrit)
      endif

      if(ifiles.gt.ifile2) then
      file_spec = 'Spec3_down.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,215)  (idown(j,i),i =ifile2+1,ifile3)
      end do
      close(iowrit)
      file_spec = 'Spec3_up.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,215)  (iup(j,i),i =ifile2+1,ifile3)
      end do
      close(iowrit)
      endif

      if(ifiles.gt.ifile3) then
```

```
      file_spec = 'Spec4_down.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,215)  (idown(j,i),i =ifile3+1,ifiles)
      end do
      close(iowrit)
      file_spec = 'Spec4_up.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,215)  (iup(j,i),i =ifile3+1,ifiles)
      end do
      close(iowrit)
      endif

      stop
      end
```

Code to read in and aggregate data from Ocean Optics spectrometers (all 2001 field data) is stored in:
~rfedors/SpectralData/Fortran/spectral.f
(and copied to bubo: E:\SpectralData\FortranCode\spectral.f).

```
        program spectral
c Reads in multiple (sequential) spectral data files, data is thrown into
c   one file for plotting of outliers, means are calculated (not yet), and soon
c   (not yet) bands will be aggregated. (Ocean Optics spectrometer data).
c Script to read in sequential files from a directory was done on UNIX (SUN)
c   to utilize ls, grep, and wc commands.
c
c Executable set to run from existing data directories, output files to same.
c
c RFedors  July 26, 2002
c
c23456789 123456789 123456789 123456789 123456789 123456789 123456789 12
      implicit none
      integer mpts,mfiles,ioread,iowrit,ifiles,ifile1,ifile2,ifile3
      parameter (mpts=2048,mfiles=200)
      integer  i, j, integ_time, integ_tmp, iarray(mpts,mfiles)
      character*60 flist, filelist(mfiles)
      character*10  filebase, filebase1
      real*8 array(mpts,mfiles), band(mpts)
      character*80  file_spec, file_band, file_summary
      character*80  fdate_time, fspectrometer, junk

c set input and output unit numbers
      ioread = 7
      iowrit = 8

c get file list
      write(*,*) 'enter basename '
      read(*,'(a10)') filebase
      filebase1 = filebase//'.'
      flist = 'ls -1 | grep '//filebase1//' | wc -l > /tmp/record'
      call system(flist)
      open(ioread,file='/tmp/record/')
      read(ioread,'(i8)') ifiles
      flist = 'ls -1 | grep '//filebase1//' > /tmp/file.list'
      call system(flist)
      open(ioread,file='/tmp/file.list')
      do i = 1, ifiles
        read(ioread,'(a30)') filelist(i)
      end do
      write(*,*) filelist(1)
      close(ioread)
      call system('/bin/rm /tmp/record')
      call system('/bin/rm /tmp/file.list')

c check if more than maximum number of files
      if(ifiles.gt.155) then
        print*, 'Too many files    Need to modify code    STOPPING'
        stop
      endif
c set file names for output files
      file_spec = 'Spec.'//filebase
      file_summary = 'Summ.'//filebase
      file_band = 'SBand.'//filebase

c Get initial data from first file
      open (unit=ioread, file=filelist(1), status ='unknown')
```

```
      read (ioread,*) junk
      read (ioread,*) junk
      read (ioread,'(a42)') fdate_time
      read (ioread,*) junk
      read (ioread,'(a36)') fspectrometer
      read (ioread,*) junk
      read (ioread,'(a24,i4)') junk, integ_tmp
      close (ioread)

c Read all the files and aggregate into the array matrix
      do i = 1, ifiles
        open (unit=ioread, file=filelist(i), status ='unknown')
        do j = 1, 6
          read (ioread,*) junk
        end do
        read (ioread,'(a24,i4)') junk, integ_time
c       if (integ_tmp.ne.integ_time) then
c         write (*,*) 'integration time changed'
c         stop
c       else
c       end if
        do j = 1, 7
          read (ioread,'(a30)') junk
        end do
        do j = 1, mpts
          read (ioread,*) band(j), array (j,i)
          iarray(j,i) = int(array(j,i))
        end do
        close (ioread)
      end do

c write out some files in segments for importing into Excel; integers needed
c to avoid silly Excel errors (also note that Excel 2000 & Excel 97 differ).
      ifile1 = ifiles
      ifile2 = ifiles
      ifile3 = ifiles
      if(ifiles.gt.38) ifile1 = 38
      if(ifiles.gt.77) ifile2 = 77
      if(ifiles.gt.116) ifile3 = 116

      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      write (iowrit,'(a42)') fdate_time
      write (iowrit,'(a36)') fspectrometer
      write (iowrit,'(a17,i4)') 'Integration Time ', integ_time
      do j = 1, mpts
         write(iowrit,205)  band(j),(iarray(j,i),i =1,ifile1)
      end do
      close(iowrit)
205   format (f7.2,38(',',i4))
215   format(i4,38(',',i4))

      if(ifiles.gt.ifile1) then
      file_spec = 'Spec2.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,215) (iarray(j,i),i =ifile1+1,ifile2)
      end do
      close(iowrit)
      endif

      if(ifiles.gt.ifile2) then
      file_spec = 'Spec3.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,215)  (iarray(j,i),i =ifile2+1,ifile3)
      end do
      close(iowrit)
      endif

      if(ifiles.gt.ifile3) then
      file_spec = 'Spec4.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,215)  (iarray(j,i),i =ifile3+1,ifiles)
      end do
      close(iowrit)
      endif

      stop
      end
```

These codes (spectral.f and sp2000.f) were run to check for quality of data and to identify outliers in preparation for the next step of normalizing the data (downward facing versus upward facing, or, downward facing versus halon standard).

10/1/02 RF

Email from Lisa Harrell (10/1/02) noting problems with spectral.f handling some of the files:

```
These files have given me probelems even after I have done the "foreach" modifier for
them.

These are the last ones I need to complete and then all the charts will be made.

8-29-01--broml (modify code)
             std14,14u (reads as one)
             std15,15u (reads as one)
             std12,12u (reads as one)
             dbush_1,bush_1 (reads as one)
             082901_3,082901_3u (reads as one) too many files
             082901_4, 082901_4u (reads as one) too many files

8-30-01--083001_1,083001_1u(reads as one) too many files
            std_20,20u (reads as one)
            lamb_3,lamb_3u (unexpected charc.)
            083001_2,083001_2u (reads as one)too many files
            std_23,23u (reads as one)
            sand5,sand5u (reads as one)
            gravel_5 (too many files)
            pave_26,26u ( reads as one) too many files

8-31-01--std26,26u (reads as one)
            creosote_23,23u (reads as one)
            strmbd_1, strmbd_1u (reads as one) too many files
            chanside_1 too many files
            chanside 2 too many files
            rrbl, lu (reads as both)
            basalt_5, 5u (reads as both)
            horset_5, 5u (reads as both)

9-28-01--stdl,lu (reads as both)
            sand-chanl, sand chan 2(reads as both)

9-29-01--transl (too many files)
           std2,2u (reads as both)
           std3,3u (reads as both)
           dry-thorny-1 (reads wrong)
           bould-1 (too many files)
           trans2, trans2u (toomany files)
           std4,4u (reads as one)
           coarse-pave-1 (too many files)
           std5,5u (reads as one)
           pave-trump-1 (too many files)
           trans4,trans4u (too many files)
```

To fix the problem, I had to increase the number of files to be read in to >250 and also to account for the system call not distinguishing between "basename" and "basename_u". For the latter, while typing the system call directly at a UNIX prompt does the correct thing, the system call from the fortran program does the wrong thing. I suspect this is caused by the extra positions (white space) in the variable names; e.g., the variable is a10, if the basename is less than 10 characters, then blank space screws up the system call from the fortran code. But I need to implement the following fix (and also remove the downward and upward facing printing; maybe next week!):

The code snippet to eliminate the problem:

```
c      filebase1 = filebase//'.'
       filebase1 = '\'^' // filebase // '\\.\''

c      Eliminate white space
       index2 = 1
       DO index1 = 1, 25
         IF(filebase1(index1:index1) .EQ. ' ') THEN
           index2 = index1
           found_non_ws = .FALSE.
           DO WHILE((index2 .LT. 25) .AND. (.NOT. found_non_ws))
             index2 = index2 + 1
             IF(filebase1(index2:index2) .NE. ' ') THEN
               filebase1(index1:index1) = filebase1(index2:index2)
               filebase1(index2:index2) = ' '
               found_non_ws = .TRUE.
             ENDIF
           ENDDO
         ENDIF
       ENDDO
```

For now, Lisa Harrell will use the following code to aggregate data, import into EXCEL, and plot in order to find outlier profiles that have to be eliminated before we normalize the data. The code snippet above was not implemented yet (the work-around was not developed and tested until afterward I tested the code below).

The spectral.f code revision:

```
      program spectral
c Reads in multiple (sequential) spectral data files, data is thrown into
c   one file for plotting of outliers, means are calculated (not yet), and soon
c   (not yet) bands will be aggregated. (Ocean Optics spectrometer data).
c Script to read in sequential files from a directory was done on UNIX (SUN)
c   to utilize ls, grep, and wc commands.
c
c Executable set to run from existing data directories, output files to same.
c
c RFedors  July 26, 2002
c   revised Oct 1, 2002  (increase number of files read, fix ls filtering)
c
c23456789 123456789 123456789 123456789 123456789 123456789 123456789 12
      implicit none
      integer mpts, mfiles, ioread, iowrit, ifiles, idown, iup
      integer ifile1, ifile2, ifile3, ifile4, ifile5, ifile6, ifile7
      parameter (mpts=2048,mfiles=622)
      integer  i, j, integ_time, integ_tmp, iarray(mpts,mfiles)
      character*60 flist, filelist(mfiles)
      character*15  filebase, filebase1
      real*8 array(mpts,mfiles), band(mpts)
c     character*80  file_band, file_summary
      character*80  fdate_time, fspectrometer, junk, file_spec

c set input and output unit numbers
      ioread = 7
      iowrit = 8
c get file list
      write(*,*) 'enter basename '
      read(*,'(a15)') filebase
      write(*,*) 'enter number of files, no u files'
      read(*,'(i5)') idown
      write(*,*) 'enter number of files with similar name, but u added'
      read(*,'(i5)') iup
```

```
c     filebasel = filebase//'.'
      filebasel = filebase
      flist = 'ls -1 | grep '//filebasel//' | wc -1 > /tmp/record'
      call system(flist)
      open(ioread,file='/tmp/record/')
      read(ioread,'(i8)') ifiles
      flist = 'ls -1 | grep '//filebasel//' > /tmp/file.list'
      call system(flist)
      open(ioread,file='/tmp/file.list')
      do i = 1, ifiles
        read(ioread,'(a30)') filelist(i)
      end do
      write(*,*) filelist(1)
      close(ioread)
      call system('/bin/rm /tmp/record')
      call system('/bin/rm /tmp/file.list')

      print*, ifiles, idown, iup

c check if more than maximum number of files
      if(ifiles.gt.311) then
        print*, 'Too many files    Need to modify code    STOPPING'
        stop
      endif
      if(ifiles.ne.idown+iup) then
        print*, 'error, check number of files'
        stop
      endif

c Get initial data from first file
      open (unit=ioread, file=filelist(1), status ='unknown')
      read (ioread,*) junk
      read (ioread,*) junk
      read (ioread,'(a42)') fdate_time
      read (ioread,*) junk
      read (ioread,'(a36)') fspectrometer
      read (ioread,*) junk
      read (ioread,'(a24,i4)') junk, integ_tmp
      close (ioread)

c Read all the files and aggregate into the array matrix
      do i = 1, ifiles
        open (unit=ioread, file=filelist(i), status ='unknown')
        do j = 1, 6
          read (ioread,*) junk
        end do
        read (ioread,'(a24,i4)') junk, integ_time
        do j = 1, 7
          read (ioread,'(a30)') junk
        end do
        do j = 1, mpts
          read (ioread,*) band(j), array (j,i)
          iarray(j,i) = int(array(j,i))
        end do
        close (ioread)
      end do

c write out some files in segments for importing into Excel; integers needed
c to avoid silly Excel errors (also note that Excel 2000 & Excel 97 differ).
      ifile1 = idown
      ifile2 = idown
      ifile3 = idown
      ifile4 = idown
      ifile5 = idown
      ifile6 = idown
      ifile7 = idown
      if(idown.gt.38) ifile1 = 38
      if(idown.gt.77) ifile2 = 77
      if(idown.gt.116) ifile3 = 116
      if(idown.gt.155) ifile4 = 155
      if(idown.gt.194) ifile5 = 194
      if(idown.gt.233) ifile6 = 233
      if(idown.gt.272) ifile7 = 272

c set file names for output files
      file_spec = 'Spec.'//filebase
c     file_summary = 'Summ.'//filebase
c     file_band = 'SBand.'//filebase

      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      write (iowrit,'(a42)') fdate_time
```

```
      write (iowrit,'(a36)') fspectrometer
      write (iowrit,'(a17,i4)') 'Integration Time ', integ_time
      do j = 1, mpts
         write(iowrit,205)  band(j),(iarray(j,i),i =1,ifile1)
      end do
      close(iowrit)
 205  format (f7.2,38(',',i4))
 215  format(i4,38(',',i4))

      if(idown.gt.ifile1) then
      file_spec = 'Spec2.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,215) (iarray(j,i),i =ifile1+1,ifile2)
      end do
      close(iowrit)
      endif

      if(idown.gt.ifile2) then
      file_spec = 'Spec3.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,215)  (iarray(j,i),i =ifile2+1,ifile3)
      end do
      close(iowrit)
      endif

      if(idown.gt.ifile3) then
      file_spec = 'Spec4.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,215)  (iarray(j,i),i =ifile3+1,ifile4)
      end do
      close(iowrit)
      endif

      if(idown.gt.ifile4) then
      file_spec = 'Spec5.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,215)  (iarray(j,i),i =ifile4+1,ifile5)
      end do
      close(iowrit)
      endif

      if(idown.gt.ifile5) then
      file_spec = 'Spec6.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,215)  (iarray(j,i),i =ifile5+1,ifile6)
      end do
      close(iowrit)
      endif

      if(idown.gt.ifile6) then
      file_spec = 'Spec7.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,215)  (iarray(j,i),i =ifile6+1,ifile7)
      end do
      close(iowrit)
      endif

      if(idown.gt.ifile7) then
      file_spec = 'Spec8.'//filebase
      open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
      do j = 1, mpts
         write(iowrit,215)  (iarray(j,i),i =ifile7+1,idown)
      end do
      close(iowrit)
      endif
c Write out the upward facing files ("u" added to basename of file)
      ifile1 = iup
      ifile2 = iup
      ifile3 = iup
      ifile4 = iup
      ifile5 = iup
      ifile6 = iup
      ifile7 = iup
      if(iup.gt.38) ifile1 = 38
      if(iup.gt.77) ifile2 = 77
```

```
 if(iup.gt.116) ifile3 = 116
 if(iup.gt.155) ifile4 = 155
 if(iup.gt.194) ifile5 = 194
 if(iup.gt.233) ifile6 = 233
 if(iup.gt.272) ifile7 = 272

 file_spec = 'Spec.u_'//filebase
 open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
 write (iowrit,'(a42)') fdate_time
 write (iowrit,'(a36)') fspectrometer
 write (iowrit,'(a17,i4)') 'Integration Time ', integ_time
 do j = 1, mpts
    write(iowrit,205) band(j),(iarray(j,i),i =idown+1,idown+ifile1)
 end do
 close(iowrit)

 if(iup.gt.ifile1) then
 file_spec = 'Spec2.u_'//filebase
 open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
 do j = 1, mpts
    write(iowrit,215) (iarray(j,i),i =idown+ifile1+1,idown+ifile2)
 end do
 close(iowrit)
 endif

 if(idown.gt.ifile2) then
 file_spec = 'Spec3.u_'//filebase
 open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
 do j = 1, mpts
    write(iowrit,215)  (iarray(j,i),i =idown+ifile2+1,idown+ifile3)
 end do
 close(iowrit)
 endif

 if(idown.gt.ifile3) then
 file_spec = 'Spec4.u_'//filebase
 open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
 do j = 1, mpts
    write(iowrit,215)  (iarray(j,i),i =idown+ifile3+1,idown+ifile4)
 end do
 close(iowrit)
 endif

 if(idown.gt.ifile4) then
 file_spec = 'Spec5.u_'//filebase
 open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
 do j = 1, mpts
    write(iowrit,215)  (iarray(j,i),i =idown+ifile4+1,idown+ifile5)
 end do
 close(iowrit)
 endif

 if(idown.gt.ifile5) then
 file_spec = 'Spec6.u_'//filebase
 open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
 do j = 1, mpts
    write(iowrit,215)  (iarray(j,i),i =idown+ifile5+1,idown+ifile6)
 end do
 close(iowrit)
 endif

 if(idown.gt.ifile6) then
 file_spec = 'Spec7.u_'//filebase
 open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
 do j = 1, mpts
    write(iowrit,215)  (iarray(j,i),i =idown+ifile6+1,idown+ifile7)
 end do
 close(iowrit)
 endif

 if(idown.gt.ifile7) then
 file_spec = 'Spec8.u_'//filebase
 open(unit=iowrit,file=file_spec,status='unknown',form='formatted')
 do j = 1, mpts
    write(iowrit,215)  (iarray(j,i),i =idown+ifile7+1,idown+iup)
 end do
 close(iowrit)
 endif

 stop
 end
```

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