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Technical Report

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Satellite Detection of Cannabis sativa Outdoor Grow Operations

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Executive Summary

The main objective of this project was to generate a retrospective assessment to highlight the utility of remote sensing (i.e. spectrometry and airborne/satellite imagery) to locate illegal grow-operations of *Cannabis sativa**.

The main tasks associated with the objective were:

- To conduct a detailed spectral assessment of reflectance collected *in-situ* for *Cannabis* in comparison to the vegetation in which it is most often camouflaged.

- To conduct an assessment of airborne and satellite imagery where outdoor grow-ops are known to be located.

The main outcomes of the project were:

- From the *in-situ* reflectance, the spectral signature of *Cannabis* is distinguishable from other herbaceous vegetation without error. Wavelength regions of interest are highlighted to be in the 450-500nm and 630-690nm regions.

- From the airborne hyperspectral imagery, the points representing the outdoor operations not under canopy have a spectral signature that is different from other land covers such as grass, low vegetation, soil, etc.

- The spectral angle between the signature of the *Cannabis* grow operations and other land covers can be exploited to locate other grow operations in the same scene.
    - Due to complications with the calibration of the imagery, comparison between the signatures of *Cannabis* among scenes was not feasible, only multiple sites within the same scene.

- From the high resolution satellite imagery the spectral signature of the Cannabis grow operations is similar low vegetation, but dissimilar from other land covers such as soil, forest, etc. In this imagery the site are more difficult to detect because of the limited spectral resolution of the data. From the predicted site up to twenty-five percent are likely false positives. Hyperspectral data is recommended for operational use.

***Note:** The analysis is not focused solely on *Cannabis sativa*. If other *Cannabis* such as *C. sativa-indica* hybrids were encountered, they were equally considered. No chemical or genetic typing was conducted to identify the exact species or variety measured in the field.

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1. Introduction

The use of satellite imagery to monitor the growth of illicit crops such as marijuana, opium and coca has proven to be useful for the United Nations Office on Drugs and Crime (UNODC). Such analyses are currently being conducted successfully in Afghanistan, Morocco, Myanmar, Laos, Peru, Colombia and Bolivia. Currently, methodologies employed by the UNODC in the different countries are not standardized, but all follow similar principles. Plantations of opium, coca and marijuana have distinct spectral signatures (i.e. reflectance of light over a range of wavelengths) from the surrounding vegetation (forest or other crops). Multispectral imagery (i.e. SPOT, IKONOS, Quickbird), containing only a few bands sensitive to radiation spanning from the blue to infrared wavelengths, is the type of data most often used in the surveys due to its relatively low cost and high repeat acquisition. Due to its limited spectral resolution however, imagery is generally acquired several times over a growing season to exploit phenological differences between the illicit crops and other vegetation. The illicit crop plantations in these countries are generally large in size and limited efforts have been made to hide them.

In North America, outdoor grow operations are considerably smaller and in many cases significant efforts have been made by the growers to make their sites difficult to locate; posing a more difficult detection problem. As a result, efforts in North America have encountered several problems and have not had the same success as seen elsewhere. In cases where hyperspectral imagery (i.e. over 100 bands) is available, exploitation of the increased spectral information is most likely to produce favourable results, even in difficult detection problems. This type of imagery however, is far more costly than multispectral imagery. In order to reduce the costs of the project and take advantage of existing airborne hyperspectral imagery, this project uses imagery that had been collected for a previous project, in addition to newly acquired satellite imagery and field data.

The properties of hyperspectral data differentiate it from conventional two and three dimensional forms. While one of the most common reasons for using hyperspectral data is to enhance the information available, especially for difficult or complex problems.

However, the large number of dimensions (can be over 2000 from *in-situ* data) also poses complications such as an exponential increase in computational effort and problems with parameter, density or state estimations (Jimenez and Landgrebe 1998). Jimenez and Landgrebe (1998) demonstrate five unusual geometric, asymptotic and statistical characteristics of hyper-dimensionality that influence the analysis techniques one can employ for its analysis, meaning statistical assumptions or analysis techniques used for two or three dimensional data are not always appropriate. In this project the analysis of the hyperspectral data was conducted using machine learning techniques and standard image analysis techniques specific to hyperspectral data.

The main objective of this project was to generate a retrospective assessment for one or two regions within Canada to highlight the utility of remote sensing (i.e. spectrometry and airborne/satellite imagery) to locate illegal grow-ops of *Cannabis sativa*.

The main tasks associated with the objective were:

- To conduct a detailed spectral assessment of the reflectance collected *in-situ* of *Cannabis sativa* in comparison to the vegetation in which it is most often camouflaged.

- To conduct an assessment of airborne and satellite imagery acquired for one or two regions within Canada where outdoor grow-ops are known to be located.

The planning, site selection and fieldwork component of this project was conducted with the collaboration and logistical assistance of the Abbotsford Police Department, Mission RCMP detachment, Chilliwack RCMP detachment, E Division RCMP Air Services and the Vancouver Island RCMP detachment.

Jimenez, L.O. and D. Landgrebe, *Supervised classification in high-dimensional space: geometrical, statistical, and asymptotic properties of multivariate data.* IEEE Transactions on systems, man and cybernetics - part c: applications and reviews, 1998. **28**(1): p. 39-54.

2. Methods

2.1 Field data Collection

Between August 8 and August 25, 2006 reflectance measurements were taken at outdoor grow operations in two regions in British Columbia: Harrison and Vancouver Island (Figure 1). The data was collected during operation SABOT on Vancouver Island and in conjunction with Chilliwack RCMP in Harrison, BC. Data were collected with an ASD FieldSpec Handheld spectrometer (Analytical Spectral Devices Inc. Boulder, CO). This spectrometer measures reflectance from 325nm - 1075nm. The resolution of full width at half maximum is 3.5nm with a sampling interval of 1.5nm. The integration time was automatically set using a 99% reflective Spectralon™ white reference panel. Subsequently, a dark current correction was performed to eliminate instrument noise from spectral measurements. White reference measurements with the Spectralon™ standard were repeated at five minute intervals. Reflectance of the samples was computed as a ratio of each sample spectrum to the white reference spectrum. The following is an example of the metadata associated with the field spectra:

```
Text conversion of header file
 ---------------------------------------------------------------
The instrument number was: ####/1
New ASD spectrum file: Program version = 3.01 file version = 4.03
Spectrum saved: 08/25/2006 at 12:23:54
Integration time : 68
Channel 1 wavelength = 325 wavelength step = 1
There were 5 samples per data value
xmin = 325 xmax= 1075
ymin= 0 ymax= 1
The instrument digitizes spectral values to 16 bits
VNIR dark signal subtracted
10 dark measurements taken Fri Aug 25 12:18:58 2006
DCC value was 0
Data is compared to a white reference
10 white reference measurements taken Fri Aug 25 12:19:00 2006
There was no foreoptic attached
Spectrum file is reflectance data
```

The spectral response was measured for the *Cannabis* plants, other herbaceous vegetation and soil. In the Harrison site, the spectra of cut *Cannabis* was also measured.

Figure 1a: Aerial view of grow operation in Harrison, BC.

Figure 1b: Ground view of Harrison site.

Figure 1c: Canopy view of plants at the Harrison site.

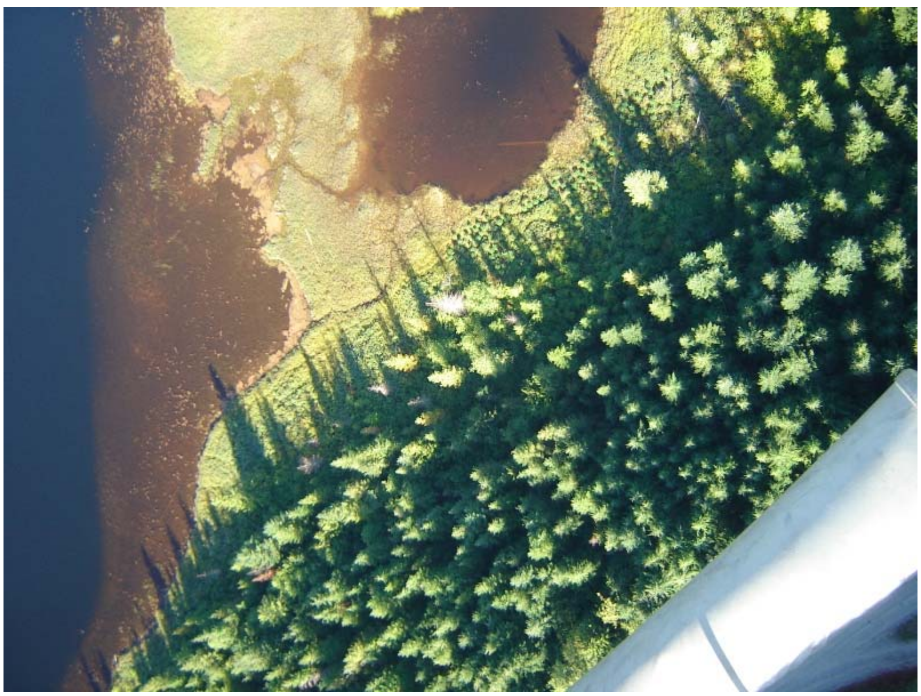


Figure 1d: Aerial view of one of the Vancouver Island sites.

Figure 1e: Ground view of one of the Vancouver Island sites.

Figure 1f: Ground view of one of the Vancouver Island sites.

2.2 Satellite Imagery Acquisition

High resolution Quickbird satellite imagery (2.4m multispectral) was tasked for three locations: Harrison, Malcolm Island, Northern Vancouver Island (Table 1) through GCS Research. IKONOS imagery (4m Multispectral) was tasked for two scenes representing the Abbotsford area through MDA (Table 1). Areas were chosen based on consultation with Abbotsford police department, Mission RCMP detachment, Chilliwack RCMP detachment and the Vancouver Island RCMP detachment. All imagery was provided as geocorrected, scaled radiance data.

Table 1. Acquisition dates and times of high resolution satellite imagery

Scene ID	**Sensor**	**Date**	**Type**	**Figure**
203001000BC10100	Quickbird	Aug 20 2006	Standard	2
203001000B94CD00	Quickbird	Aug 13 2006	Standard	3
203001000BFD3C00	Quickbird	Sept 1 2006	Standard	4a
203001000BFD3D00	Quickbird	Sept 1 2006	Standard	4b
2006090419333530000011621517	IKONOS	Sept 4 2006	Standard	5
2006091219242180000011632716	IKONOS	Sept 12 2006	Standard	6

Figure 2: Quickbird image from Harrison, BC

Figure 5: IKONOS image from Abbotsford and Matsqui Island, BC

Figure 3: Quickbird image from Vancouver Island, BC.

Figure 6: IKONOS image from Southeast Abbotsford, BC.

Figures 4a and b: Quickbird imagery from Malcolm Island, BC.

All Quickbird and IKONOS images are displayed as true-colour composites (i.e. **3**-**2**-**1**)

2.3 Airborne Imagery

The airborne imagery from 2002 acquired with the CASI sensor (36 bands) during project Evening Light was provided by MDA upon request from CPRC for Texada Island. Data provided also included GPS points of known grow sites from 2002. Imagery was provided at three spatial resolutions: 60cm, 1m and 2m. The imagery collected at 60cm and 2m had not been geocorrected, therefore, only the 1m data was used in the analysis. The 1m data for the south-central portion of the island consisted of twelve separate files. The data also included a mosaic of Quickbird images for the entire island collected in 2002. The geocorrection of the Quickbird mosaic was assumed to be the original geocorrection applied by the imagery provider (Digital Globe). Figure 7 illustrates the Quickbird mosaic of Texada Island with a detailed view of the south-central section of the island and known grow sites from 2002. Figure 8 illustrates an example of one of the flight lines. The remainder of the flight lines can be seen in Appendix I.

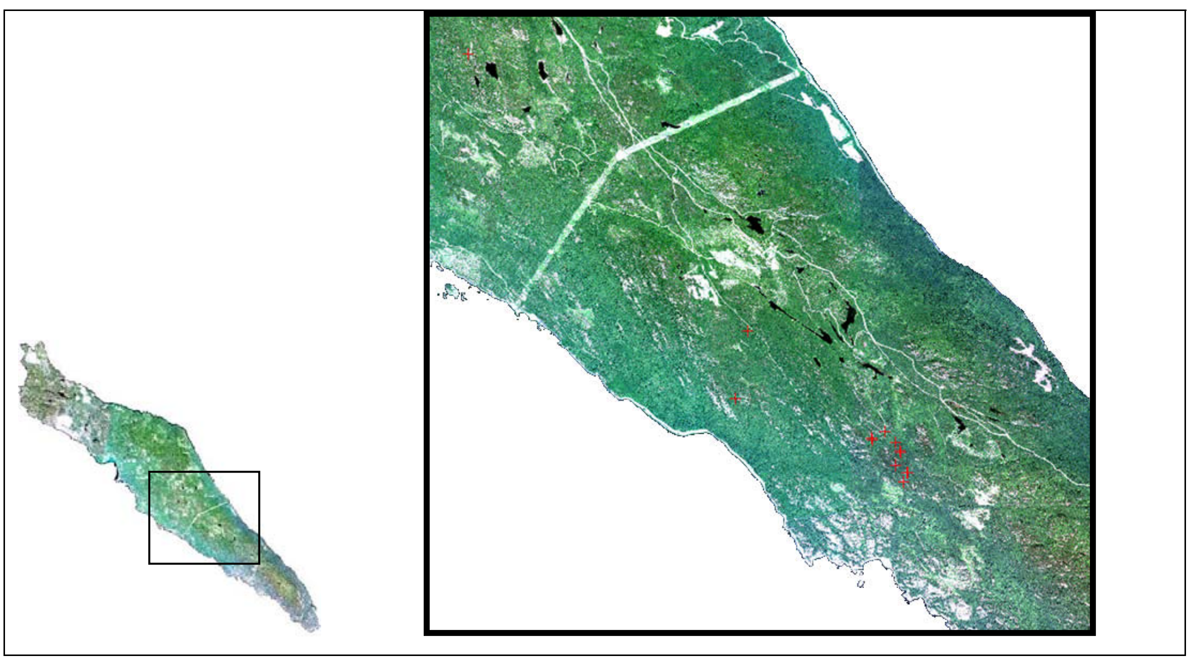


Figure 7: Quickbird mosaic of Texada Island with detailed view of the south-central sector of the island. Red + represent known sites from 2002.

Figure 8: Example of one of the CASI flight lines (1A) from 2002.

2.4 Quality Control

During this phase of the project both the *in-situ* spectral data and the airborne and satellite imagery was examined as part of the quality control process. For the *in-situ* data, any spectra with too much noise, or erroneous spectra were first removed from the database. For the remaining spectra, the regions below 450nm and above 900nm were cut. While the data in both regions was collected under good atmospheric conditions, certain atmospheric effects were still apparent in the spectra. These effects were minimized with a Savitsky-Golay smoothing filter. No technical problems were encountered.

No technical issues were encountered with the newly acquired satellite images nor with the mosaic of images over Texada Island from 2002.

The airborne imagery received from Project Evening Light had certain technical complications. The geocorrected product appeared to have been registered to the wrong UTM zone (i.e. Zone 0 vs. Zone 10) (Figure 9).

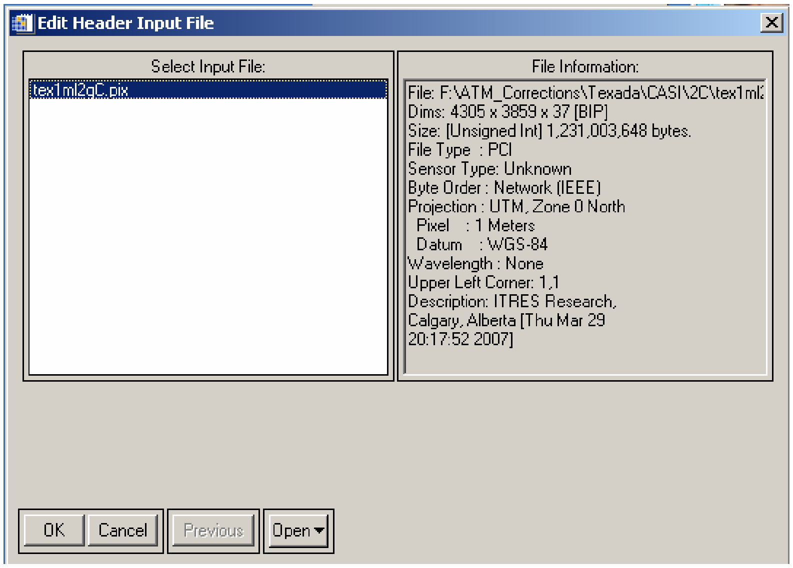


Figure 9: Example of header information associated with the CASI flight lines.

The imagery was tested with both ENVI and Erdas IMAGINE and both image processing suites showed the same problem with registration. A work-around was attempted whereby all the flight lines were exported as Geotiff files. They were then imported back into ENVI and assigned the correct UTM zone (i.e. Zone 10). Examination of the results from this work-around showed that there was still a mean mis-registration of 200m in a southwest direction between the flight lines and the mosaic. Because each flight line was analyzed individually, the geographic coordinates were only necessary for a correct registration with the GPS points from known sites and subsequent examination of the spectral signature of the *Cannabis* grow operations. The known sites were therefore, displayed over the mosaic and were subsequently located manually in each flight line, as one would do with aerial photographs.

2.5 CASI, IKONOS and Quickbird Data Calibration

Because the majority of the studies in the remote sensing literature employs reflectance rather than digital numbers or radiance data, and thus allow for easier interpretation of the results as well as direct comparison with the *in-situ* data, all imagery was calibrated to reflectance. The imagery was converted from radiance to reflectance using the FLAASH module of ENVI. Standard input parameters for the processing of imagery are illustrated in Figure 10.

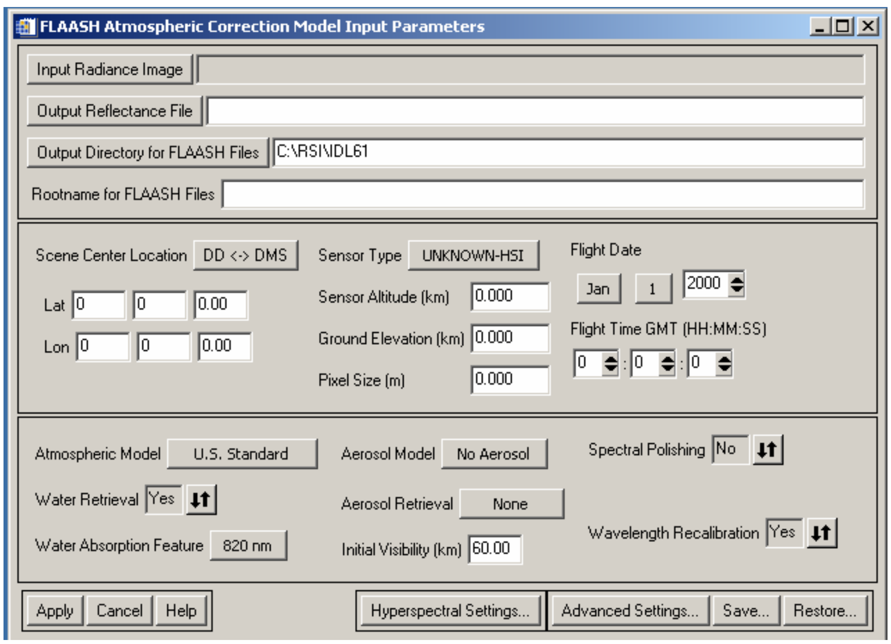


Figure 10: Input parameters for the atmospheric correction module to convert radiance to reflectance.

For conventional satellite sensors, altitudinal information and wavelength calibration information is included with the module. Standard input parameters for both airborne and satellite sensors include: date and time of image acquisition, elevation, scene centre, band centres and pixel size. For hyperspectral data (i.e. such as the airborne imagery) an addition parameter, the full-width-at-half-maximum (FWHM) of each band is also required. For airborne data the altitude of the aircraft is also required. All of the necessary parameters for the satellite imagery were provided by the image suppliers as part of the metadata (GCS Research and MDA). For the airborne imagery, the parameters not included with the metadata were estimated. Table 2 lists the necessary parameters and the source from which they were estimated if they were not provided.

Table 2 Necessary parameters for the atmospheric correction of the CASI imagery

Parameter	**Metadata Provided**	**Estimated From**	**Estimated/Provided Value**
Scene Centre	**See Note 1	Quickbird image	Different for each scene
Time of collection	No	Email inquiry	19:30 GMT (12:30 PT)
Sensor altitude	No	IFOV posted at www.itres.com	745m
Elevation	Yes	DEM	-
Date of image collection	Yes	-	July 12, 2002
FWHM	No	www.itres.com	2.2nm
Band Centre	Yes	-	Provided with imagery file, 36 bands

**Note 1: Due to geocorrection errors, scene centre coordinates were visually assessed from Quickbird imagery.

The satellite images were processed as entire scenes. Each flight line of the airborne data was processed in thirds due to logistical constraints with the large file sizes. Prior to the actual execution of the atmospheric correction for the hyperspectral data (CASI), a wavelength recalibration was performed with FLAASH (Appendix 2). An example of the input parameters for one of the CASI flight lines is illustrated in Appendix 3 and a sample output of the FLAASH module is shown in Appendix 4. Example spectra of common targets in comparison to the signature of *Cannabis* from the airborne image are shown in Figure 11. The pixels representing the *Cannabis* are most likely mixed pixels with a portion being from *Cannabis*, and the remainder of exposed soil or other vegetation, but this is expected with such classification problems. From the field visits the range of planting densities ranged from 0.6 – 2 plants per square meter.

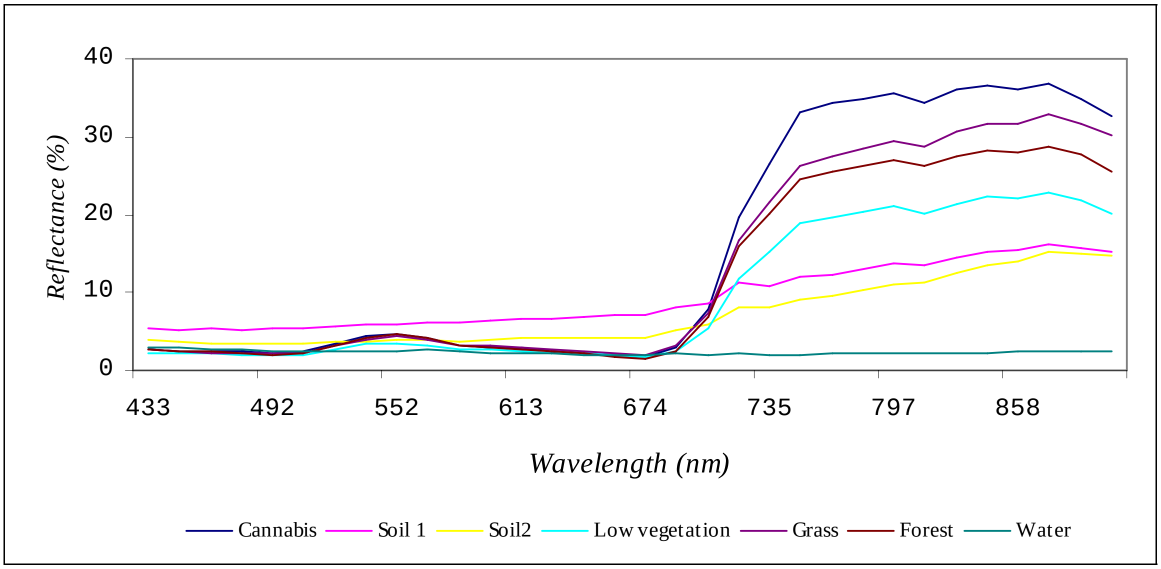


Figure 11. Mean spectra of several common land cover classes and *Cannabis* from one of the flight lines of the CASI data.

Analysis as detailed in section 2.6 was conducted on each flight line separately without cross-comparison due to the number of assumptions that had to be made in order to calibrate the imagery (Table).

2.6 Analysis – Field spectra

The smoothed reflectance spectra were analyzed using feature selection followed by pattern classification. Feature selection was used to:

1) Reduce the dimensions of the data
2) Determine the optimal wavelengths with the greatest difference between the *Cannabis* and other vegetation
3) Determine the optimal number of features (wavelengths) for classification with the lowest error.

The maximum number of features that can be used without overfitting is F=(n-g)/3 where n is the number of spectra and g is the number of classes. The optimal number of features was where the two measurements of error (training and testing) were at global minima. The dataset was split in half to construct training and testing datasets. Hard labels were used (i.e. not probabilistic) in both the training process and in the validation data set. Testing error represents the validation error. The selected features were then used to classify the spectra of the *Cannabis* and other vegetation using standard parametric and non-parametric pattern classifiers: linear, quadratic, decision tree, k-NN (nearest neighbour), neural network (feed forward network with Levenburg Marquardt optimization). For the k-NN classifier, the optimal number of "neighbours" was determined during the training process. For the neural network classifier, 2-5 layers were tested. Classifications were conducted as follows:

- *Cannabis* vs. other herbaceous vegetation
- *Cannabis* vs. soil and cut plants

2.7 Analysis of Airborne Imagery

As mentioned above, each flight line was examined independently because calibration problems precluded between scene comparisons. Using the Quickbird mosaic, GPS points from the 2002 database were identified in the flight lines. Five flight lines included the points. Regions of interest isolated the pixels representing the *Cannabis* and other common land covers in the scenes. These pixels were examined in *n*-dimensional space. Subsequently, the most significant bands were selected (i.e. feature selection) and the spectral angle was used to discriminate the spectra of the *Cannabis* from the other land covers in the scene.

2.8 Analysis of Satellite Imagery

For imagery from Vancouver Island and Malcolm Island, the spectra of known sites collected during the 2006 Operation SABOT were extracted from the images. The coordinates from the site in Harrison were obtained in the field. Points from the Abbotsford area were obtained from the Abbotsford police department. As with the airborne imagery, the spectra were examined in *n*-dimensional space however in this case, *n* equals a maximum of 4. The entire spectra were examined (i.e. feature selection was not performed) because the imagery contained only four bands.

3. Results

3.1 Field spectra *Cannabis* vs. herbaceous vegetation

With only ten features, perfect separability (0% training error; 0% testing error; 0% overall error) was achieved with all but one of the classifiers tested. The decision tree classifier was the only one with an error above 0% at 0% training error and 2.68% testing error. The relative separability of the mean spectra of the *Cannabis* and the herbaceous vegetation was also mapped with a second distance/separability measure to compare with the feature selection process (Figure 12).

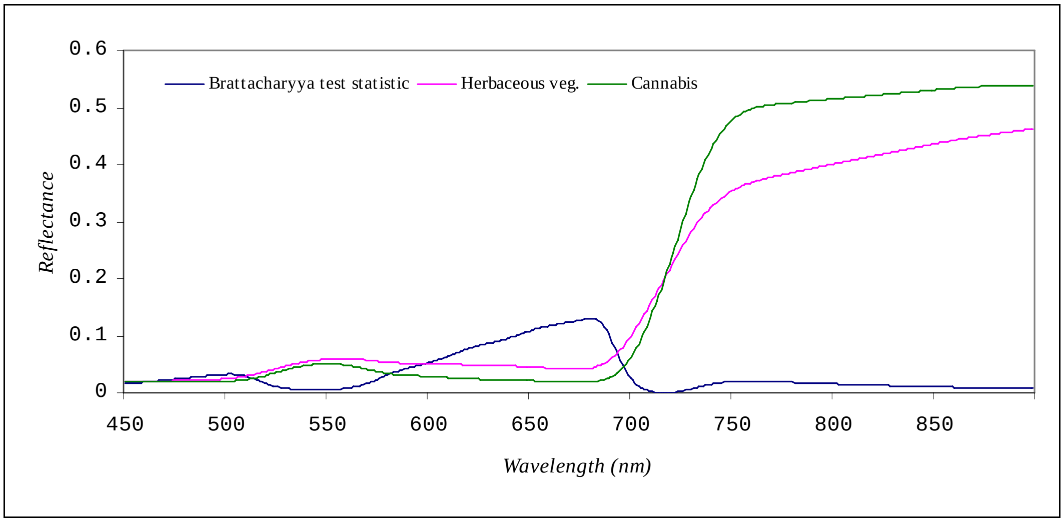


Figure 12. Mean spectra of herbaceous vegetation and *Cannabis* from field data collected with an *in-situ* spectrometer. Brattacharyya test statistic highlights wavelength regions with the greatest separability. *Cannabis* spectra represents mean from both regions (Harrison and Vancouver Island).

3.2 Field spectra results of *Cannabis* vs. soil spectra and comparison of spectra from canopies vs. cut plants

As with the examination of the spectra between *Cannabis* and other herbaceous vegetation, there was no confusion between the spectra of *Cannabis* and soil with any classifier as expected. Also, in the classification of the standing *Cannabis* canopies and cut plants there was no confusion in the discrimination of the spectra (i.e. 0% testing and training errors).

3.3 Airborne Imagery

Endmembers were identified in the imagery using the confirmed grow sites from 2002. Four and six dimensional visualizations of spectra representative of *Cannabis*, grass, low vegetation, soil and water are shown in Figures 13 and 14. Mean spectra of these classes were illustrated in Figure 11.

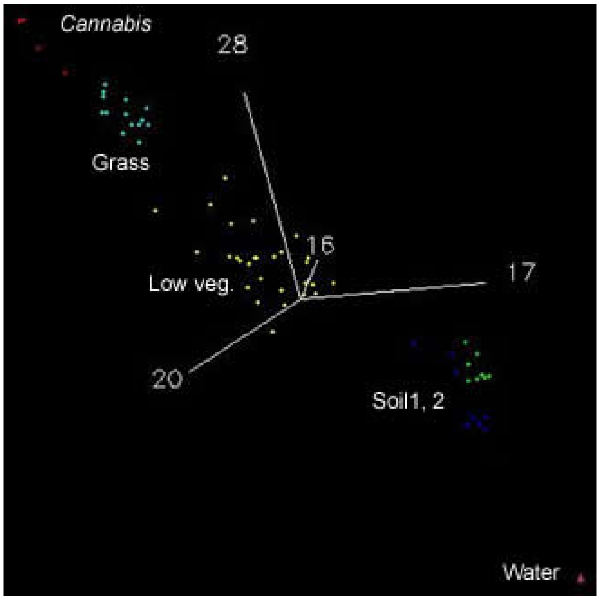


Figure 13: Four dimensional representation of the spectral signatures of *Cannabis* and other common land cover classes form the CASI imagery.

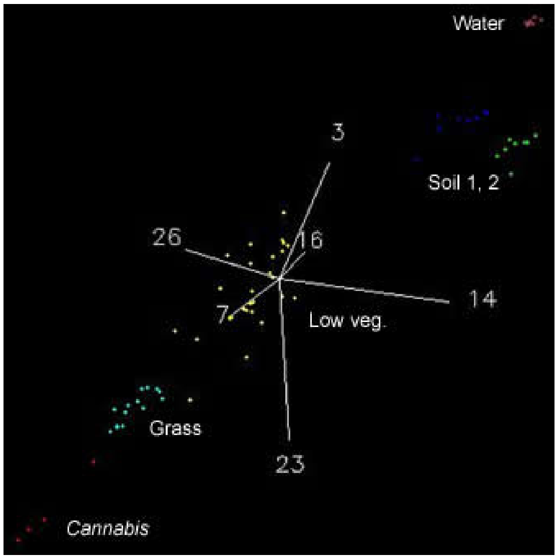


Figure 14: Six dimensional representation of the spectral signatures of *Cannabis* and other common land cover classes form the CASI imagery.

A spectral angle threshold was applied to the results of the classification. Figure 15 illustrates the locations with the most probably grow operations based on the similarity of the spectral signature of those pixels to the spectral signature of the known site.

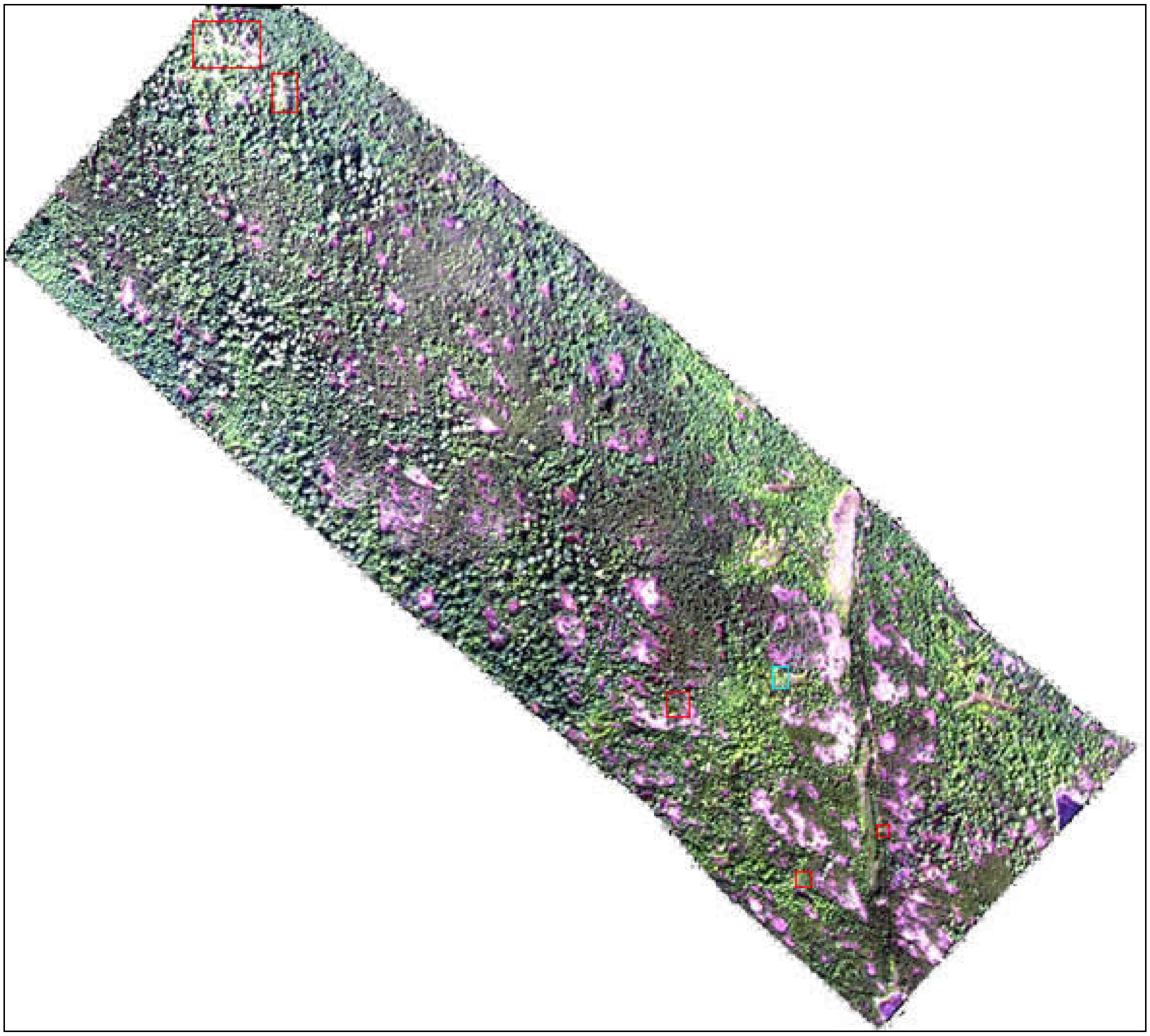


Figure 15. Red squares highlight areas with that meet the spectral angle threshold; blue square highlights known site (CASI imagery).

3.4 Satellite imagery

Figure 15 illustrates the spectra of *Cannabis* and other land covers from the Quickbird image in Figure 3. Good separation can be seen between the *Cannabis* and other land covers except low vegetation.

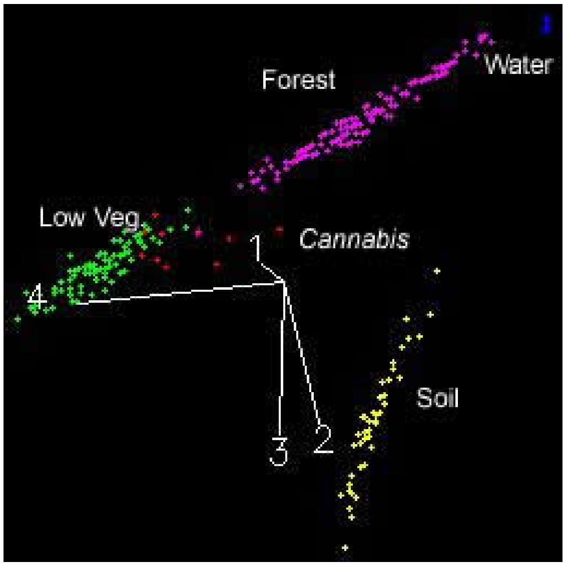


Figure 15. Four dimensional visualization of *Cannabis* and other land cover spectra from the Quickbird image illustrated in Figure 3.

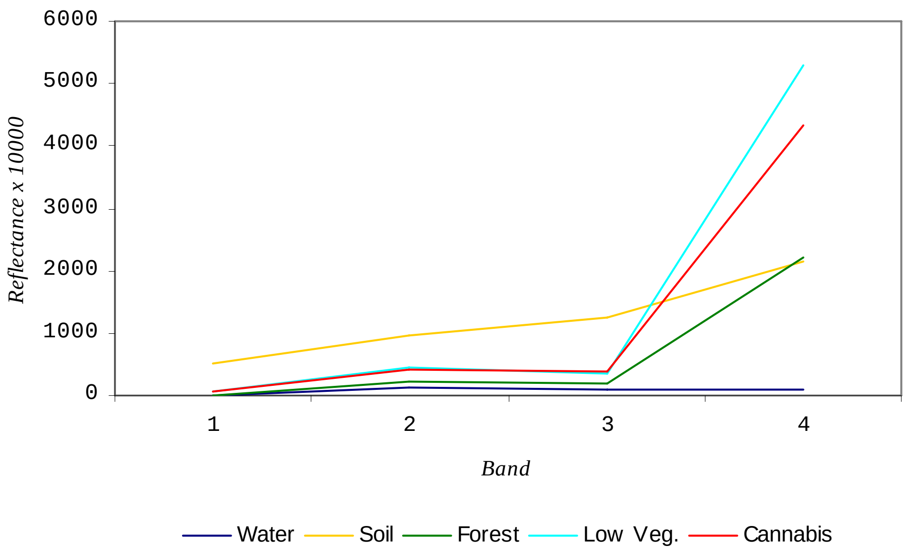


Figure 16. Examples of mean spectral signatures of the classes illustrated in Figure 15.

As can be seen in Figures 15 and 16, there is considerable similarity between the signatures of low vegetation and *Cannabis* from the multispectral imagery. It is for this reason that it is recommended to employ hyperspectral imagery for the smaller grow operations seen in Canada. Classification results of the multispectral images highlighted both the known field sites as well as additional sites in the imagery. However, due to the limited spectral resolution of the data, it is believed that up to thirty percent of the additional sites highlighted by the classification are false positives.

4. Conclusions

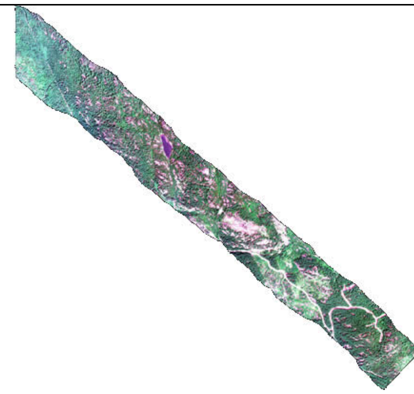
- The spectral signature of *Cannabis* is different from other common vegetation types in Western Canada. The greatest differences are located in specific areas of the spectrum that can be readily exploited from hyperspectral imagery.
- Hyperspectral data from *in-situ* and airborne data can be used to discriminate *Cannabis*, despite problems with calibration in the airborne data. Additional probable sites were located from the imagery.
- Better calibration (i.e. with complete metadata included with the imagery) would improve the results from airborne data even further and allow for across-scene comparisons.
- Multispectral data shows similarity between the signature of *Cannabis* and low vegetation, making discrimination difficult and up to thirty percent of the sites chosen from the multispectral data are likely false positives.
- Airborne hyperspectral surveys could be used efficiently to locate the most probable locations for grow-operations on an operational basis.

5. Acknowledgements

This project was supported by the Canadian Police Research Centre (financial and logistical support). The field data collection logistical support and GPS points were provided by Chilliwack RCMP detachment, Abbotsford Police department, Vancouver Island RCMP detachment and E Division RCMP Air Services. Satellite imagery was provided by GSC Research and MDA. Airborne imagery and data from 2002 was provided by MDA.

APPENDIX 1 CASI flight lines

Flight line 1B

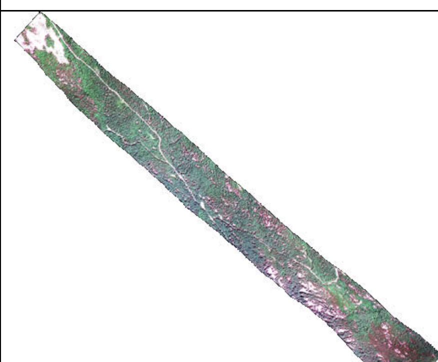


Flight line 2A

Flight line 1C

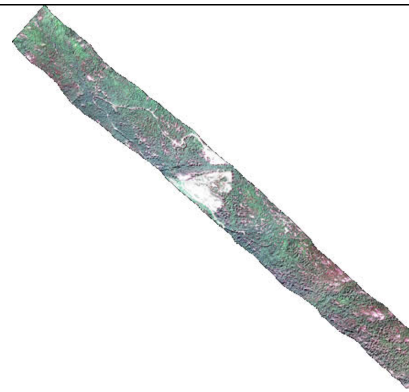
Flight line 2B

Flight line 1D

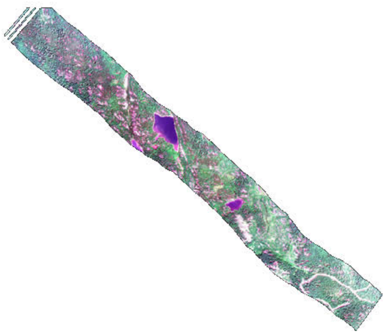


Flight line 2C

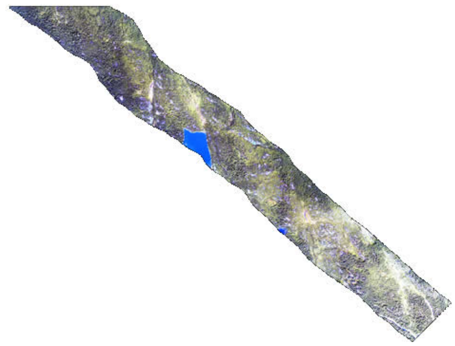
Flight line 2D



Flight line 3D



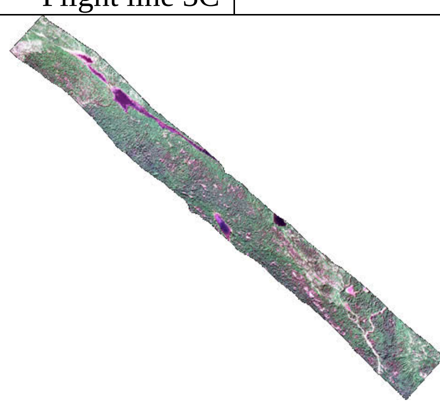
Flight line 3A



Flight line 4A

Flight line 3C

Flight line 4B



Flight line 4C

APPENDIX 2 Output from wavelength recalibration during atmospheric correction process.

Input Wavelength	Output Wavelength	Wavelength Shift
433.50000	432.89499	-0.60501
448.20001	447.59500	-0.60501
463.10001	462.49500	-0.60501
477.89999	477.29501	-0.60498
492.79999	492.19501	-0.60498
507.79999	507.19501	-0.60498
522.79999	522.19501	-0.60498
537.79999	537.19501	-0.60498
552.79999	552.19501	-0.60498
567.90002	567.29498	-0.60504
583.09998	582.49500	-0.60498
598.20001	597.59497	-0.60504
613.40002	612.79498	-0.60504
628.59998	627.99500	-0.60498
643.90002	643.29498	-0.60504
659.20001	658.59497	-0.60504
674.50000	673.89502	-0.60498
689.79999	689.19501	-0.60498
705.09998	704.49500	-0.60498
720.40002	719.79498	-0.60504
735.79999	735.19501	-0.60498
751.20001	750.59497	-0.60504
766.59998	765.99500	-0.60498
782.00000	781.39502	-0.60498
797.40002	796.79498	-0.60504
812.79999	812.19501	-0.60498
828.20001	827.59497	-0.60504
843.59998	842.99500	-0.60498
859.00000	858.39502	-0.60498
874.40002	873.79498	-0.60504
889.79999	889.19501	-0.60498
905.20001	904.59497	-0.60504
920.59998	919.99500	-0.60498
936.00000	935.39502	-0.60498
951.40002	950.79498	-0.60504
966.79999	966.19501	-0.60498

APPENDIX 3 Example of atmospheric correction parameters as output by atmospheric correction module.

```
; Project Parameters
enviacc.prj.radiance_file = E:\ATM_Corrections\Texada\CASI\1A\ROI1_bil
enviacc.prj.reflect_file = E:\ATM_Corrections\Texada\CASI\1A\ROI1_ref
enviacc.prj.water_band_choice = .82
enviacc.prj.water_retrieval = 1
enviacc.prj.user_stem_name = roi1_
enviacc.prj.modtran_directory = E:\ATM_Corrections\Texada\CASI\1A\
;
; MODTRAN Parameters
enviacc.modtran.visvalue = 60.0000
enviacc.modtran.f_resolution = 15.0000
enviacc.modtran.day = 12
enviacc.modtran.month = 7
enviacc.modtran.year = 2001
enviacc.modtran.gmt = 19.5000
enviacc.modtran.latitude = 49.5793
enviacc.modtran.longitude = -124.2694
enviacc.modtran.sensor_altitude = 0.7450
enviacc.modtran.ground_elevation = 0.3000
enviacc.modtran.view_zenith_angle = 180.0000
enviacc.modtran.view_azimuth = 0.0000
enviacc.modtran.atmosphere_model = 6
enviacc.modtran.aerosol_model = 0
enviacc.modtran.multiscatter_model = 2
enviacc.modtran.disort_streams = 8
enviacc.modtran.co2mix = 390.0000
enviacc.modtran.water_column_multiplier = 1.0000
;
; Image Parameters
enviacc.img.nspatial = 1513
enviacc.img.nlines = 1307
enviacc.img.data_type = 12
enviacc.img.margin1 = 0
enviacc.img.margin2 = 0
enviacc.img.nskip = 0
enviacc.img.pixel_size = 1.0000
enviacc.img.sensor_name = CASI
;
; Analysis Parameters
enviacc.ana.aerosol_scaleht = 2.0000
enviacc.ana.use_adjacency = 1
enviacc.ana.output_scale = 10000.0000
enviacc.ana.polishing_res = 0
enviacc.ana.aerosol_retrieval = 0
enviacc.ana.calc_wl_correction = 1
enviacc.ana.reuse_modtran_calcs = 0
enviacc.ana.use_square_slit_function = 0
enviacc.ana.convolution_method = fft
enviacc.ana.use_tiling = 1
enviacc.ana.tile_size = 100.0000
;
; Spectral Parameters
enviacc.spc.wavelength_units = nanometer
enviacc.spc.lambda = [
  433.5000,   448.2000,   463.1000,   477.9000,   492.8000,   507.8000,   522.8000,
  537.8000,   552.8000,   567.9000,   583.1000,   598.2000,   613.4000,   628.6000,
  643.9000,   659.2000,   674.5000,   689.8000,   705.1000,   720.4000,   735.8000,
  751.2000,   766.6000,   782.0000,   797.4000,   812.8000,   828.2000,   843.6000,
  859.0000,   874.4000,   889.8000,   905.2000,   920.6000,   936.0000,   951.4000,
  966.8000]
enviacc.spc.fwhm = [
  2.200000,   2.200000,   2.200000,   2.200000,   2.200000,   2.200000,   2.200000,
  2.200000,   2.200000,   2.200000,   2.200000,   2.200000,   2.200000,   2.200000,
  2.200000,   2.200000,   2.200000,   2.200000,   2.200000,   2.200000,   2.200000,
  2.200000,   2.200000,   2.200000,   2.200000,   2.200000,   2.200000,   2.200000,
  2.200000,   2.200000,   2.200000,   2.200000,   2.200000,   2.200000,   2.200000,
  2.200000]
```

```
enviacc.img.p_input_scale = [
  100.0000,   100.0000,   100.0000,   100.0000,   100.0000,   100.0000,   100.0000,
  100.0000,   100.0000,   100.0000,   100.0000,   100.0000,   100.0000,   100.0000,
  100.0000,   100.0000,   100.0000,   100.0000,   100.0000,   100.0000,   100.0000,
  100.0000,   100.0000,   100.0000,   100.0000,   100.0000,   100.0000,   100.0000,
  100.0000,   100.0000,   100.0000,   100.0000,   100.0000,   100.0000,   100.0000,
  100.0000]
```

APPENDIX 4 Example of output from atmospheric correction routine.

```
********************************************************************************
** Recalibrating Wavelengths
********************************************************************************

Warning: first requested MODTRAN run calls for existing statistics; changing to no-
statistics

      Spectral Sciences Atmospheric Correction Code
      1998-2004
          Version 07292004
    ** See Instructions for Use **

*************  MAIN MENU   ***************

Commands:
     m = set up MODTRAN input file
     r = Run MODTRAN
     h = Hyperspectral data analysis
     a = About ACC (Instructions)
     c = Convert existing MODTRAN tape7
     w = Read Warfighter run file, create initial tape5
     q = Quit

script command h

Path for output files (except output reflectance cube) is
E:\ATM_Corrections\Texada\CASI\1A\
Enter  u = Use this path   or    a = select Another path :
script command u

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
     s = I/O Setup via serial queries
     d = new radiance Data cube
     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
     i = simulate radiance Image from reflectance
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command d
Reading header (if any) from image file E:\ATM_Corrections\Texada\CASI\1A\ROI1_bil
Enter  u = Use this file,  a = select Another file (dialog),
or  d = select another file (Direct filename entry) :
script command u
 Select method for representing instrument spectral filter function.
 Type 1 for calculated function, 2 for a function defined by a file, 3 for external
channel definitions passed in.
```

```
...type 99 to accept default from call.
script command 99
Computing wavelength response functions for each channel...

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
     s = I/O Setup via serial queries
     d = new radiance Data cube
     l = Load and display radiance data cube
     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
     i = simulate radiance Image from reflectance
     v = aerosol Visibility determination
     k = Kaufman (ratio) visibility retrieval
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command l
Channel definitions: type 1 to use passed-in default,
                     2 to select manually between automatic
                          and external-file channel definitions.
script command 1
Warning: no nearby cirrus channel selected; using channel 1 instead
Calculated channel nos. are
  Oxygen (altitude) ref=      22      24 abs=           23
  Water ref=      24      29 abs=           26          27
  R,G,B display=          11          12          13
          14          15          16          17
          18           5           6           7
           8           9          10          11
           1           2           3           4
  Cirrus=       1
  0.82 Water ref=      24      29 abs=           26          27
  Vegetation-rise cutoff=    0.0547469 from channel 19 to 22
Loading spectral data...
      646037 blank pixels out of       989399 were found.
*Not displaying RGB radiance image, cirrus cloud image and last-line spectra

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
     s = I/O Setup via serial queries
     d = new radiance Data cube
     l = Load and display radiance data cube
     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
     i = simulate radiance Image from reflectance
     v = aerosol Visibility determination
     k = Kaufman (ratio) visibility retrieval
     c = Column water retrieval
   MSc = User-specified Column water
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
```

```
     e = display Existing reflectance file

script command M
Select option:
   g = standard GUI interface
   v = visibility setup
script command call
Estimated MODTRAN run time:      0.063060699 min
Estimated MODTRAN run time:      0.062761013 min

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
     s = I/O Setup via serial queries
     d = new radiance Data cube
     l = Load and display radiance data cube
     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
     i = simulate radiance Image from reflectance
     v = aerosol Visibility determination
     k = Kaufman (ratio) visibility retrieval
     c = Column water retrieval
   MSc = User-specified Column water
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command R
Run MODTRAN using tape5 in current directory:
     Are you sure?  y=yes  n=no
script command y
Converting tape7 to ACC archive (.fla) file for storage
Select archive filename
Opening archive file to write:   E:\ATM_Corrections\Texada\CASI\1A\acc_modroot.fla
Enter  u = Use this file,  a = select Another file (dialog),
or  d = select another file (Direct filename entry) :
script command u
No. of spectra=       1
No. of spectra=       2
No. of spectra=       3
No. of spectra=       4
No. of spectra=       5
No. of spectra=       6
No. of spectra=       7
No. of spectra=       8
No. of spectra=       9
Column water range=       1.12324  to        1.37285 g/cm2
       (       1397.51 to       1708.07 atm-cm)
No. of frequencies=    1765
File archived
Use E:\ATM_Corrections\Texada\CASI\1A\acc_modroot.fla  as current MODTRAN archive file?
    0 = no
    1 = use as altitude loop file
    2 = use as water loop file
    3 = use as aerosol loop file
script command 2

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
     s = I/O Setup via serial queries
     d = new radiance Data cube
```

```
     l = Load and display radiance data cube
     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
     i = simulate radiance Image from reflectance
     v = aerosol Visibility determination
     k = Kaufman (ratio) visibility retrieval
     c = Column water retrieval
   MSc = User-specified Column water
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command c
Reading archive file of previous MODTRAN calculation
E:\ATM_Corrections\Texada\CASI\1A\acc_modroot.fla
(NOTE:  this calculation must be appropriate for the current data cube)
     u = Use this file
     a = select Another existing file (dialog)
     d = use Another existing file (Direct filename entry)
     q = Return to the hyperspectral menu
     m = Set up new MODTRAN calculation
script command u
Calculating doverb
*Not displaying surface image of look-up table
Not plotting calculated MODTRAN spectra
Completed processing MODTRAN calculations

Warning: water column calculation used invalid parts of the water
column look-up table.  Please examine the ACC archive file (.fla)
used.  You may need to carry out another MODTRAN calculation to
extend the humidity range covered.   ACC will display a map of the
invalid column locations, and store it in "LUTinval.dat"
      976170 pixels out of       989399 pixels are invalid.
Enter minimum reflectance for water column display
(0.1 recommended):
script command 0.000000
Pixels below minimum reflectance are displayed in blue
  Minimum H2O =      1.30455 g/cm2 =       1623.09 atm-cm  displayed in white
  Maximum H2O =      1.32142 g/cm2 =       1644.08 atm-cm  displayed in black
  Mean H2O =      1.31362 gm/cm2 =       1634.38 atm-cm
          = 95.6858% of maximum MODTRAN water column.
  Standard deviation of H2O distribution=
                         0.0705403 gm/cm2 =       87.7648 atm-cm
    (For comparison, MODTRAN standard atmosphere values [atm-cm] are:
    5119 -- tropical;  3636 -- mid-latitude summer; 1060 -- mid-latitude winter;
    2589 -- sub-arctic summer;  518 -- sub-arctic winter;  1762 -- US Standard)
  Failed water table look-ups in red.

Not displaying water column map.
Storing unsmoothed water column map in E:\ATM_Corrections\Texada\CASI\1A\roi1_water.dat
Not plotting water column histogram.
No. of cloudy pixels from 1st test=      492.000
No. of cloudy pixels from 2nd test=      3.00000
No. of cloudy pixels=     0.000000
Type <Enter>
script command
Not displaying LUT failures.

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
     s = I/O Setup via serial queries
     d = new radiance Data cube
```

```
     l = Load and display radiance data cube
     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
     i = simulate radiance Image from reflectance
     v = aerosol Visibility determination
     k = Kaufman (ratio) visibility retrieval
     c = Column water retrieval
   MSc = User-specified Column water
     r = Reflectance determination
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command WC
Determined Wavelength Shift Using NODD Algorithm    -0.605000
Determined Shift variance                                     -NaN

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
     s = I/O Setup via serial queries
     d = new radiance Data cube
     l = Load and display radiance data cube
     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
     i = simulate radiance Image from reflectance
     v = aerosol Visibility determination
     k = Kaufman (ratio) visibility retrieval
     c = Column water retrieval
   MSc = User-specified Column water
     r = Reflectance determination
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command q
Overwrite old file name list (filename.txt) with current file names?  n=no   y=yes
script command n

********************************************************************************
** FLAASH Tile 1 Reflectance Retrieval Using Scriptfile.002
********************************************************************************


      Spectral Sciences Atmospheric Correction Code
      1998-2004
          Version 07292004
    ** See Instructions for Use **

*************  MAIN MENU   ***************

Commands:
     m = set up MODTRAN input file
     r = Run MODTRAN
     h = Hyperspectral data analysis
     a = About ACC (Instructions)
```

```
     c = Convert existing MODTRAN tape7
     w = Read Warfighter run file, create initial tape5
     q = Quit

script command h

Path for output files (except output reflectance cube) is
E:\ATM_Corrections\Texada\CASI\1A\
Enter  u = Use this path   or    a = select Another path :
script command u

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
     s = I/O Setup via serial queries
     d = new radiance Data cube
     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
     i = simulate radiance Image from reflectance
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command d
Reading header (if any) from image file E:\ATM_Corrections\Texada\CASI\1A\ROI1_bil
Enter  u = Use this file,  a = select Another file (dialog),
or  d = select another file (Direct filename entry) :
script command u
 Select method for representing instrument spectral filter function.
 Type 1 for calculated function, 2 for a function defined by a file, 3 for external
channel definitions passed in.
...type 99 to accept default from call.
script command 99
Computing wavelength response functions for each channel...

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
     s = I/O Setup via serial queries
     d = new radiance Data cube
     l = Load and display radiance data cube
     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
     i = simulate radiance Image from reflectance
     v = aerosol Visibility determination
     k = Kaufman (ratio) visibility retrieval
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command l
Channel definitions: type 1 to use passed-in default,
                     2 to select manually between automatic
                          and external-file channel definitions.
script command 1
```

```
Warning: no nearby cirrus channel selected; using channel 1 instead
Calculated channel nos. are
  Oxygen (altitude) ref=      22      24 abs=           23
  Water ref=      24      29 abs=           26          27
  R,G,B display=          11          12          13
          14          15          16          17
          18           5           6           7
           8           9          10          11
           1           2           3           4
  Cirrus=       1
  0.82 Water ref=      24      29 abs=           26          27
  Vegetation-rise cutoff=    0.0547470 from channel 19 to 22
Loading spectral data...
      646037 blank pixels out of       989399 were found.
*Not displaying RGB radiance image, cirrus cloud image and last-line spectra

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
     s = I/O Setup via serial queries
     d = new radiance Data cube
     l = Load and display radiance data cube
     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
     i = simulate radiance Image from reflectance
     v = aerosol Visibility determination
     k = Kaufman (ratio) visibility retrieval
     c = Column water retrieval
   MSc = User-specified Column water
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command M
Select option:
   g = standard GUI interface
   v = visibility setup
script command call
Estimated MODTRAN run time:       0.24859869 min
Estimated MODTRAN run time:       0.24859869 min

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
     s = I/O Setup via serial queries
     d = new radiance Data cube
     l = Load and display radiance data cube
     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
     i = simulate radiance Image from reflectance
     v = aerosol Visibility determination
     k = Kaufman (ratio) visibility retrieval
     c = Column water retrieval
   MSc = User-specified Column water
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
```

```
     p = Plot pixel spectra
     e = display Existing reflectance file

script command R
Run MODTRAN using tape5 in current directory:
     Are you sure?  y=yes  n=no
script command y
Converting tape7 to ACC archive (.fla) file for storage
Select archive filename
Opening archive file to write:   E:\ATM_Corrections\Texada\CASI\1A\acc_modroot.fla
Enter  u = Use this file,  a = select Another file (dialog),
or  d = select another file (Direct filename entry) :
script command u
No. of spectra=       1
No. of spectra=       2
No. of spectra=       3
No. of spectra=       4
No. of spectra=       5
No. of spectra=       6
No. of spectra=       7
No. of spectra=       8
No. of spectra=       9
No. of spectra=      10
No. of spectra=      11
No. of spectra=      12
No. of spectra=      13
No. of spectra=      14
No. of spectra=      15
No. of spectra=      16
No. of spectra=      17
No. of spectra=      18
No. of spectra=      19
No. of spectra=      20
No. of spectra=      21
No. of spectra=      22
No. of spectra=      23
No. of spectra=      24
No. of spectra=      25
No. of spectra=      26
No. of spectra=      27
No. of spectra=      28
No. of spectra=      29
No. of spectra=      30
No. of spectra=      31
No. of spectra=      32
No. of spectra=      33
No. of spectra=      34
No. of spectra=      35
No. of spectra=      36
Column water range=      0.124804  to        1.87207 g/cm2
       (       155.279 to       2329.19 atm-cm)
No. of frequencies=    1765
File archived
Use E:\ATM_Corrections\Texada\CASI\1A\acc_modroot.fla  as current MODTRAN archive file?
    0 = no
    1 = use as altitude loop file
    2 = use as water loop file
    3 = use as aerosol loop file
script command 2

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
     s = I/O Setup via serial queries
     d = new radiance Data cube
     l = Load and display radiance data cube
     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
```

```
     i = simulate radiance Image from reflectance
     v = aerosol Visibility determination
     k = Kaufman (ratio) visibility retrieval
     c = Column water retrieval
   MSc = User-specified Column water
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command c
Reading archive file of previous MODTRAN calculation
E:\ATM_Corrections\Texada\CASI\1A\acc_modroot.fla
(NOTE:  this calculation must be appropriate for the current data cube)
     u = Use this file
     a = select Another existing file (dialog)
     d = use Another existing file (Direct filename entry)
     q = Return to the hyperspectral menu
     m = Set up new MODTRAN calculation
script command u
Calculating doverb
*Not displaying surface image of look-up table
Not plotting calculated MODTRAN spectra
Completed processing MODTRAN calculations

Warning: water column calculation used invalid parts of the water
column look-up table.  Please examine the ACC archive file (.fla)
used.  You may need to carry out another MODTRAN calculation to
extend the humidity range covered.   ACC will display a map of the
invalid column locations, and store it in "LUTinval.dat"
      969095 pixels out of       989399 pixels are invalid.
Enter minimum reflectance for water column display
(0.1 recommended):
script command 0.000000
Pixels below minimum reflectance are displayed in blue
  Minimum H2O =      1.67280 g/cm2 =       2081.26 atm-cm  displayed in white
  Maximum H2O =      1.74471 g/cm2 =       2170.73 atm-cm  displayed in black
  Mean H2O =      1.72053 gm/cm2 =       2140.65 atm-cm
           = 91.9055% of maximum MODTRAN water column.
  Standard deviation of H2O distribution=
                          0.173070 gm/cm2 =       215.330 atm-cm
    (For comparison, MODTRAN standard atmosphere values [atm-cm] are:
    5119 -- tropical;  3636 -- mid-latitude summer; 1060 -- mid-latitude winter;
    2589 -- sub-arctic summer;  518 -- sub-arctic winter;  1762 -- US Standard)
  Failed water table look-ups in red.

Not displaying water column map.
Storing unsmoothed water column map in E:\ATM_Corrections\Texada\CASI\1A\tile0_water.dat
Not plotting water column histogram.
No. of cloudy pixels from 1st test=      702.000
No. of cloudy pixels from 2nd test=      1816.00
No. of cloudy pixels=      29.0000
Type <Enter>
script command
Not displaying LUT failures.

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
     s = I/O Setup via serial queries
     d = new radiance Data cube
     l = Load and display radiance data cube
     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
```

```
     i = simulate radiance Image from reflectance
     v = aerosol Visibility determination
     k = Kaufman (ratio) visibility retrieval
     c = Column water retrieval
   MSc = User-specified Column water
     r = Reflectance determination
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command a
Generating spatially smoothed image E:\ATM_Corrections\Texada\CASI\1A\smooth
Enter 1 to process radiance image E:\ATM_Corrections\Texada\CASI\1A\ROI1_bil (for
reflectance determination)
         2 to process reflectance image E:\ATM_Corrections\Texada\CASI\1A\tile0.img (for
radiance simulation)
script command 1.00000
Smoothing parameters passed in:
sensor altitude (Km)=     0.745000
IFOV (millirad)=      1.34228
aerosol scale height (Km)=      2.00000
    Estimated 1/e scattering range=      0.120100 km
Loading data cube...
Generating smoothed image for adjacency correction...
Convolution kernel dimension is equivalent to      324 image pixels
Smoothing...
Writing output to file...

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
     s = I/O Setup via serial queries
     d = new radiance Data cube
     l = Load and display radiance data cube
     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
     i = simulate radiance Image from reflectance
     v = aerosol Visibility determination
     k = Kaufman (ratio) visibility retrieval
     c = Column water retrieval
   MSc = User-specified Column water
     r = Reflectance determination
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command r
Use adjacency correction?   y = yes   n = no
script command y
The output resolution sets the number of wavelength channels over
which spectral polishing will be carried out.  Values less than 2
give no polishing.  Present value is        2
Please enter an integer for output resolution, or <Enter> for present value.
Polishing resolution passed in=

Spectral polishing will not be used for resolution=   0
Total radiance coefficients calculated
Opening output reflectance file to write:   E:\ATM_Corrections\Texada\CASI\1A\tile0.img
```

```
Enter  u = Use this file,  a = select Another file (dialog),
or  d = select another file (Direct filename entry) :
script command u
Begin image correction loop
Completed line       1
Completed line       2
…
Completed line    1307
Not displaying RGB reflectance image.

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
     s = I/O Setup via serial queries
     d = new radiance Data cube
     l = Load and display radiance data cube
     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
     i = simulate radiance Image from reflectance
     v = aerosol Visibility determination
     k = Kaufman (ratio) visibility retrieval
     c = Column water retrieval
   MSc = User-specified Column water
     r = Reflectance determination
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command q
Overwrite old file name list (filename.txt) with current file names?  n=no   y=yes
script command n

********************************************************************************
** FLAASH Tile 2 Reflectance Retrieval Using Scriptfile.003
********************************************************************************


      Spectral Sciences Atmospheric Correction Code
      1998-2004
          Version 07292004
    ** See Instructions for Use **

*************  MAIN MENU   ***************

Commands:
     m = set up MODTRAN input file
     r = Run MODTRAN
     h = Hyperspectral data analysis
     a = About ACC (Instructions)
     c = Convert existing MODTRAN tape7
     w = Read Warfighter run file, create initial tape5
     q = Quit

script command h

Path for output files (except output reflectance cube) is
E:\ATM_Corrections\Texada\CASI\1A\
Enter  u = Use this path   or    a = select Another path :
script command u

************  DATA ANALYSIS MENU   *************

Setup Commands:
```

```
     S = I/O Setup, interactive
     s = I/O Setup via serial queries
     d = new radiance Data cube
     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
     i = simulate radiance Image from reflectance
     M = prepare MODTRAN run
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     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command d
Reading header (if any) from image file E:\ATM_Corrections\Texada\CASI\1A\ROI1_bil
Enter  u = Use this file,  a = select Another file (dialog),
or  d = select another file (Direct filename entry) :
script command u
 Select method for representing instrument spectral filter function.
 Type 1 for calculated function, 2 for a function defined by a file, 3 for external
channel definitions passed in.
...type 99 to accept default from call.
script command 99
Computing wavelength response functions for each channel...

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
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     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
     i = simulate radiance Image from reflectance
     v = aerosol Visibility determination
     k = Kaufman (ratio) visibility retrieval
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command l
Channel definitions: type 1 to use passed-in default,
                     2 to select manually between automatic
                          and external-file channel definitions.
script command 1
Warning: no nearby cirrus channel selected; using channel 1 instead
Calculated channel nos. are
  Oxygen (altitude) ref=      22      24 abs=           23
  Water ref=      24      29 abs=           26           27
  R,G,B display=          11          12          13
          14          15          16          17
          18           5           6           7
           8           9          10          11
           1           2           3           4
  Cirrus=       1
  0.82 Water ref=      24      29 abs=           26           27
  Vegetation-rise cutoff=    0.0547470 from channel 19 to 22
Loading spectral data...
      618692 blank pixels out of       988092 were found.
```

```
*Not displaying RGB radiance image, cirrus cloud image and last-line spectra

************  DATA ANALYSIS MENU   *************

Setup Commands:
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Processing Commands:
     i = simulate radiance Image from reflectance
     v = aerosol Visibility determination
     k = Kaufman (ratio) visibility retrieval
     c = Column water retrieval
   MSc = User-specified Column water
     M = prepare MODTRAN run
     R = run MODTRAN
     WC = Channel Wavelength Correction

Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command c
Reading archive file of previous MODTRAN calculation
E:\ATM_Corrections\Texada\CASI\1A\acc_modroot.fla
(NOTE:  this calculation must be appropriate for the current data cube)
     u = Use this file
     a = select Another existing file (dialog)
     d = use Another existing file (Direct filename entry)
     q = Return to the hyperspectral menu
     m = Set up new MODTRAN calculation
script command u
Calculating doverb
*Not displaying surface image of look-up table
Not plotting calculated MODTRAN spectra
Completed processing MODTRAN calculations

Warning: water column calculation used invalid parts of the water
column look-up table.  Please examine the ACC archive file (.fla)
used.  You may need to carry out another MODTRAN calculation to
extend the humidity range covered.   ACC will display a map of the
invalid column locations, and store it in "LUTinval.dat"
      948332 pixels out of       988092 pixels are invalid.
Enter minimum reflectance for water column display
(0.1 recommended):
script command 0.000000
Pixels below minimum reflectance are displayed in blue
  Minimum H2O =      1.59671 g/cm2 =       1986.59 atm-cm  displayed in white
  Maximum H2O =      1.71669 g/cm2 =       2135.87 atm-cm  displayed in black
  Mean H2O =      1.67115 gm/cm2 =       2079.22 atm-cm
           = 89.2679% of maximum MODTRAN water column.
  Standard deviation of H2O distribution=
                            0.207544 gm/cm2 =       258.222 atm-cm
    (For comparison, MODTRAN standard atmosphere values [atm-cm] are:
    5119 -- tropical;  3636 -- mid-latitude summer; 1060 -- mid-latitude winter;
    2589 -- sub-arctic summer;  518 -- sub-arctic winter;  1762 -- US Standard)
  Failed water table look-ups in red.

Not displaying water column map.
Storing unsmoothed water column map in E:\ATM_Corrections\Texada\CASI\1A\tile1_water.dat
Not plotting water column histogram.
No. of cloudy pixels from 1st test=      2878.00
No. of cloudy pixels from 2nd test=      4881.00
No. of cloudy pixels=      280.000
Type <Enter>
script command
```

```
Not displaying LUT failures.

************  DATA ANALYSIS MENU   *************

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     a = Adjacency algorithm setup (create averaged image)
     q = Quit to main menu

Processing Commands:
     i = simulate radiance Image from reflectance
     v = aerosol Visibility determination
     k = Kaufman (ratio) visibility retrieval
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   MSc = User-specified Column water
     r = Reflectance determination
     M = prepare MODTRAN run
     R = run MODTRAN
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Utility Commands:
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     p = Plot pixel spectra
     e = display Existing reflectance file

script command a
Generating spatially smoothed image E:\ATM_Corrections\Texada\CASI\1A\smooth
Enter 1 to process radiance image E:\ATM_Corrections\Texada\CASI\1A\ROI1_bil (for
reflectance determination)
         2 to process reflectance image E:\ATM_Corrections\Texada\CASI\1A\tile1.img (for
radiance simulation)
script command 1.00000
Smoothing parameters passed in:
sensor altitude (Km)=     0.745000
IFOV (millirad)=      1.34228
aerosol scale height (Km)=      2.00000
    Estimated 1/e scattering range=      0.120100 km
Loading data cube...
Generating smoothed image for adjacency correction...
Convolution kernel dimension is equivalent to      324 image pixels
Smoothing...
Writing output to file...

************  DATA ANALYSIS MENU   *************

Setup Commands:
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Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file
```

```
script command r
Use adjacency correction?   y = yes   n = no
script command y
The output resolution sets the number of wavelength channels over
which spectral polishing will be carried out.  Values less than 2
give no polishing.  Present value is       2
Please enter an integer for output resolution, or <Enter> for present value.
Polishing resolution passed in=

Spectral polishing will not be used for resolution=   0
Total radiance coefficients calculated
Opening output reflectance file to write:   E:\ATM_Corrections\Texada\CASI\1A\tile1.img
Enter  u = Use this file,  a = select Another file (dialog),
or  d = select another file (Direct filename entry) :
script command u
Begin image correction loop
Completed line       1
Completed line       2
…
Completed line    1307
Not displaying RGB reflectance image.

************  DATA ANALYSIS MENU   *************

Setup Commands:
     S = I/O Setup, interactive
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     M = prepare MODTRAN run
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Utility Commands:
     ? = menu help
     p = Plot pixel spectra
     e = display Existing reflectance file

script command q
Overwrite old file name list (filename.txt) with current file names?  n=no   y=yes
script command n
```