FIELD SPECTROMETER & RADIOMETER GUIDE

CENTRE FOR REMOTE SENSING & SPATIAL INFORMATION SCIENCE

School of Geography, Planning and Architecture
The University of Queensland

Version 7
(Any comments /corrections welcomed !)
S. Phinn, P.Scarth, T. Gill, C.Roelfsema and M. Stanford
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Purpose:
To establish guidelines for the safe and efficient use the Exotech 100C radiometer and the Analytical Spectral Devices (ASD) FieldSpec UV-VNIR CCD spectrometer and full range spectrometer for field based remote sensing studies

Note that there are separate guides for operation of the Ocean-Optics Underwater USB-2000 spectrometer and the TriOS Ramses Underwater irradiance spectrometer.

Who should read this?
Anyone planning or conducting field based remote sensing for image calibration or empirical investigations.

Essential Readings:
Milton, E.J. (1987) Principles of field spectroscopy, International Journal of Remote Sensing, 8(12):1807-1827

Milton, E.J., Schaepman, M.E., Anderson, K., Kneubühler, M., and Fox, N. (2008) Progress in field spectroscopy. Remote Sensing of Environment, In press

Goetz, A. F. H. 1992. Imaging spectrometry for earth remote sensing. In Imaging spectroscopy: Fundamentals and applications. ed. Toselli, F. and J.Bodechtel, 1-19.

Curtiss, B. and Goetz, A.F.H. (1994) Field spectrometry: techniques and instrumentation, In Proceedings of the International Symposium on Spectral Sensing Research, San Diego, July 10-15, pp, 195-203.

Contents:

1. Field radiometry and spectrometry at the University of Queensland

The goal of radiometry and spectrometry is to measure both incident light (irradiance) on target features and reflected light (radiance) from the features and relate these data to the biological, chemical and physical attributes of the target feature (e.g. vegetation chlorophyll content, organic matter content of water). In most cases for reflectance measurements we are focused on measuring the colour or amount of a target, not its bi-directional reflectance distribution function – BRDF (variation in reflectance at different illumination and viewing angles).

Radiometers are typically broad band multi-spectral systems with large spectral sampling interval (50nm) and producing a broad or low spectral resolution (i.e. Full –Width at Half Maximum response).

Spectrometers are narrow band hyper-spectral systems with very small spectral sampling interval (< 1nm), resulting in a very high spectral resolution, allowing discrimination of narrow band absorption troughs and reflectance peaks.

Phinn's group in the Centre for Remote Sensing and Spatial Information Science at the University of Queensland maintains both radiometer and spectrometer systems to support calibration of multi- and hyper-spectral airborne and satellite imaging sensors and terrestrial or aquatic/marine field spectrometry. These systems also form the ground calibration system for the ADAR-1000 airborne multi-spectral imaging system that is operated in cooperation with Charles Darwin University.

Both the radiometer and spectrometer are extremely high quality scientific instruments and should be treated with an according level of care. The purpose of this document is to present and explain safe operating conditions and sequences to maximise your ability to use the equipment effectively. There are only two other sensors similar to ours in use in Australia and as a result our systems are often off campus for research and consultancy work, so it is wise to book ahead.

SYSTEM SPECIFICS FOR UQ RADIOMETER & SPECTROMETER:

Exotech 100C Radiometer #3670

A four-band sensor in which different filters and field of view attachments can be attached to measure radiance and irradiance:

Output: Voltage (analog) signal with 0-5volts range
Converted to a digital signal (16 bit) using the National Instruments Data Card
Analog/Digital converter attached to a Toshiba Libretto palmtop PC

Band filters: Landsat Thematic Mapper 5 (blue, green, red and near-infrared)
Landsat Multispectral Scanner 5 (green, red and near-infared)
SPOT (HRV) Multispectral 3 (green, red and near-infared)

Field of View: 1 ^{o}
15 ^{o}
Cosine response (hemispheric) for irradiance
Refer to Exotech manual and Dr Phinn if you need to change filters or FOV

Power: 2 x 9V batteries

Waterproof: NO

Data logger: Toshiba Libretto 100CT attached via a National Instruments A/D card running a
Visual basic program (DataAcquire©) to collect and process data.

Output file: ASCII file containing individual records for each sample

(date, time, radiance, gain, notes, sample type)

ASD-Fieldspec UV-VNIR Field Spectrometer #805

A 1024 band sensor which collects data between 350nm and 1050nm with a 0.7nm interval between spectral samples (FWHM = 3nm).
Output: raw DN (12 bit), reflectance or radiance values in a binary and ascii file

Terrestrial FOV:	25 ^{o}
	1 ^{o}
	Cosine response (hemispheric) for irradiance
Underwater FOV:	6 ^{o}
	Cosine response (hemispheric) for upwelling or downwelling radiance
	10m of underwater fibreoptic cable

ASD-Fieldspec Full range Field Spectrometer #6177

A 2150 band sensor which collects data between 350nm and 2500nm with a 1.4nm interval between spectral samples (FWHM = 3nm) in the 350 – 1100nm range and 2nm interval between spectral samples (FWHM = 10-12nm) in the 1000 – 2500 nm range.

Output: raw DN (16 bit), reflectance or radiance values in a binary and ascii file

Terrestrial FOV:	25 ^{o}
	1 ^{o}
	Cosine response (hemispheric) for irradiance

Calibration Panels (Lambertian/diffuse reflectance surface)

Fully calibrated spectralon® panels (25cm x 25cm and 5cm x 5cm)

A couple of important points about Spectralon panels that you will know and adhere to before using them:

PLEASE DO NOT TOUCH THE SURFACE OF THESE PANELS !

MAKE EVERY EFFORT TO KEEP THEM CLEAN AND SCRATCH FREE!

BEFORE EVERY FIELD-TRIP:

(1) Clean the field panel as per the instructions

(2) Calibrate the field panel against the pristine reference panel which is kept in Stuart's office to work out spectral conversion factors for panel based reflectance measurements.

Why are we making a big point of this?

(1)The calibration, precision and accuracy of your data depends on having clean panels. The slightest cover of oil or dirt from your hands alters their reflectance properties significantly.

(2) They are expensive, i.e. $2000 for the 5cm x 5cm and $3500 for the 25cm x 25cm.

2. Project Planning

2.1 Site selection

Determine the location of targets to be measured using the radiometer or spectrometer and what particular target need s to be sampled, e.g. individual leaves, canopies, soil types etc. In some cases lab-based sampling is required and both the radiometer and spectrometer can be set up in tripods and a standard diffuse illumination lamp used as a light source. **To collect accurate indoor samples ensure all fluorescent lamps and lights are turned off and only the standard illumination source is used.**

2.2 Instrument selection multi- or hyper-spectral

What type of information does your study require, are you developing an application or performing field calibration for broad-band multi-spectral sensors such as Landsat TM/ETM or SPOT? Are you conducting exploratory analysis of the spectral signature of a target to determine the biological, physical or chemical properties controlling reflectance and absorption? Are you conducting field calibration for an airborne hyper-spectral overflight? If you only require a multi-spectral system or broad band approach use the radiometer, otherwise use the spectrometer. In some cases, especially for underwater work, the spectrometer may be the only suitable system.

2.3 Terrestrial or aquatic

Determining the target you will be measuring and the sampling environment determines the type of system selected and the sampling approach utilised. Neither of the systems are waterproof and only the optics of the spectrometer with correct Fibre-optic cable and FOV should be used in water bodies. Prior to any water-based samples check with Dr Phinn that your sampling approach is safe and viable.

2.4 Additional measurements (GPS, meteorological, biological, chemical, physical)

Ensure you have established all other field based measurements that need to be made in association with your spectrometer or radiometer samples prior to designing your field sampling scheme and data collection protocol. For example, any ground based assessment to "scale-up" or calibrate satellite or airborne image data must be accompanied by a GPS reading of suitable precision. If you are examining foliar chemical properties of a specific type of vegetation you need to establish how you are going to make these measurements and record data to analyse with your radiometer samples.

2.5 Field data collection protocol and sampling sheets

Having determined the non-spectral data you are going to collect it is essential you spend time to consult related studies to determine a statistically and logistically appropriate sampling scheme. This will include the spatial arrangement of your sampling scheme, e.g. systematic quadrats or transects, how many samples you need to take, how to stratify your samples and what your actual sampling unit is (for both the radiometer/spectrometer and the biological/physical/chemical variables being measured). In addition, the solar geometry and data collection geometry (sensor height, FOV and ground resolution element, view angle and sensor distance above target) must also be clearly established for the project. **All persons developing field sampling schemes using the radiometer and spectrometer must submit a field plan outlining the planned dates, locations, sampling procedure, potential risks and sample data sheets, to Dr Phinn before finalising field work arrangements.** This is also meets our obligations under the University's new field trip guidelines.

2.6 Field data checking

A procedure for checking all radiometer/spectrometer data and field data prior to analysis should also be established to check data consistency and links to field data sheets.

2.7 Post-field data storage, processing, analysis and output

All radiometer and spectrometer data collected are to be processed in a common format and submitted to Dr Phinn for inclusion in a spectral library for use by other students and researchers. The standard format for radiometer data is provided in the output ASCII file, while the standard for field spectrometer data is an ASCII file with the first column being band centres and following columns being headed by an observation number and radiance or reflectance values. Both files should be accompanied by a meta-data file indicating the responsible researcher, date and location of data collection, fore-optic used and listing of data samples.

2.8 Instrument booking

Due to the high demand for use of the radiometer and spectrometer systems it is essential to establish a suitable field time for your project work and book that time with DrPhinn as soon as your field-plan has been approved.

3. Pre-field work preparations

3.1 Instrument selection

Ensure you have selected the appropriate instrument, data collection system, fore-optics and calibration panels for your project before proceeding with field-work preparations. All of the equipment items must be booked ahead of time. Check with the equipment use log in both systems and Dr Phinn prior to changing any of the fore-optics and record any changes you make in the equipment use log kept with each instrument.

3.2 Power supply issues

Both the radiometer and spectrometer and their data collection PC's can be operated from direct power supply in a laboratory or from internal battery supplies in the field. Battery life times vary both systems and you must take these into account when designing your field sampling scheme.

The radiometer operates on two 9V batteries with a life of 8 hours maximum. It is advisable to carry at least two extra sets of batteries on field trips and regularly monitor battery levels when using the system. Always remember to turn off the system after fieldwork and prior to transport. The Libretto PC has a battery life of two hours fully charged and using a low power usage mode. Check battery levels and power usage mode prior to and during fieldwork.

The spectrometer system operates on a series of NiCad batteries carried in the waist-pack which have an operating duration of four and a half hours. The Libretto PC has a battery life of two hours fully charged and using a low power usage mode. Check battery levels and power usage mode prior to and during fieldwork. Make a note of checking the Libretto power usage levels as they will often be set to a maximum power usage option. It is also recommended that the Libretto is powered off its internal batteries while using the Fieldspec system in the field, and only connected to the portable battery when required.

3.3 Personnel selection and training

Due to the sensitive nature and value of the equipment operation of both the radiometer and spectrometer system will only be undertaken by students who have completed background training in field spectrometry and remote sensing. Use of the spectrometer system will always require participation of one of the members of the Remote Sensing Program (Phinn, Stanford , Roelfsema or Scarth), while use of the radiometer system will be less restricted.

3.4 Testing of data collection approach and in-field communication

It is essential prior to any detailed field data collection effort that a pilot or test run be conducted to assess the sampling protocol, data collection techniques and communication between the field crew. Communication between the field crew is essential especially for work in aquatic/marine environments and proper use of the system mus be clearly demonstrated.

3.5 Transport of equipment

Although all the field sampling equipment is insured care should be taken in transporting all the systems. The radiometer and calibration panels should be transported in their respective water-proof Pelican cases. The spectrometer should be packed and stored in its own transport case (which is not waterproof!). Ensure all equipment is dry and turned off before packing. **Optical fibre cables must be kept rolled loosely to avoid any slight or permanent bends or kinks which would render them useless. Please check with Dr Phinn prior to arranging transport of systems and ensure this is also addressed in your field plan.**

4. Equipment set-up

4.1 Field station for set-up and charging

Equipment set up should always be undertaken slowly and in a sheltered, dry, dust and salt-free environment as possible. All equipment should be checked for any damage that may have occurred during transport. All battery levels should be checked (except Libretto on FieldSpec) and all batteries charged as required.

For lab based experiments both the radiometer and the spectrometer can be set up on benches, without using the field collection carrying cases. Standard tripod mounts can be used for the radiometer and spectrometer fore-optics. The Libretto's may be connected to power outlets and calibration panels set up at appropriate viewing locations along with target sample plates. For indoor measurements ensure the standard lamp is used and no fluorescent lights are turned on. There should also be no other sources of direct and diffuse light in the sampling room.

Set-up of the calibration panels should ensure they can be viewed at an appropriate angle by either sensor and that they are only illuminated by the standard lamp for an indoor measurement and direct sunlight and diffuse skylight when outside. Refer to Milton (1987) for further sampling details. **When handling the calibration panels never touch the surface of the panel, always handle the lower surface or use a clean cloth**. For cleaning instructions refer to the Labsphere Calibration booklet in Dr Phinn's office or http://www.labsphere.com/data/userFiles/SRS%20Care%20and%20Handling%20Guidelines.pdf . Any oil or dust on the spectralon panel significantly reduces the close to perfect diffuse reflectance characteristics.
Use of the radiometer and spectrometer in the field requires the systems to be placed in waste-belts able to be worn in the field and allowing significant mobility. These systems are described below and users should become familiar with how the instruments are placed in these and worn correctly. Collection of spectra requires particular attention be paid to the geometry of the sun and the direction, angle and height at which the fore-optics are held in relation to the target feature. All of the data collection parameters including solar and viewing parameters should be set out in the field sampling protocol.

5. Equipment operation

5.1 Radiometer Operation

"Wearing" the equipment correctly and in a manner that enables you to walk comfortably in the environment you are operating in and to collect data. Remember to ensure you are as comfortable as possible as you may be wearing the equipment for up to two hours. For the radiometer you may operate it in a manual mode as described in 5.1.1 to manually record voltage data from the Voltmeter on the sensor, or in an automated mode, using the Libretto PC and A/D conversion card as described in 5.1.2. For the latter option the Libretto and A/D card are strapped into a waste-pack allowing the instrument to be held over a target by the operator or another person and the PC used to acquire and process data for each sample.

5.1.1 MANUAL OPERATION OF THE RADIOMETER

The Exotech-100 is one of the most commonly used hand-held instruments for collecting spectral signatures to validate airborne and satellite images and to establish relationships between a feature's spectral reflectance properties and its controlling factors. As a measurement instrument the radiometer is simple and compact, containing four detector elements, internal filters to select specific wavebands, external lens to control the field of view, gain settings to increase the signal in each detector and a measurement scale for the output of each detector. Each detector element functions as a photon counter, to measure the strength of incident electromagnetic radiation (EMR). The amount and type of EMR incident on each detector is controlled by two factors, (1) the field of view of the lens; and (2) the type of filter used. Each of these factors is explained below in relation to the use of the radiometer to obtain measurements from targets in the field.

The area of ground from which reflected light is recorded by the radiometer is controlled by the angular FOV (α) of the lens attached to each detector and the height (H) that the instrument is held above the target. The equation used to estimate the area covered from a certain height, or conversely, the height at which to cover a specified target area is given by:

$r = (\tan(\alpha/2) \times H)$

where, r = radius of the circular FOV with area A

H = height the radiometer is held above the target surface

α = angular FOV for radiometer

Worked example to establish the area (A) sampled with $\alpha = 15^o$ and H= 1.14m

$r = (\tan(15/2) \times 1.14)$

$= 0.15m$

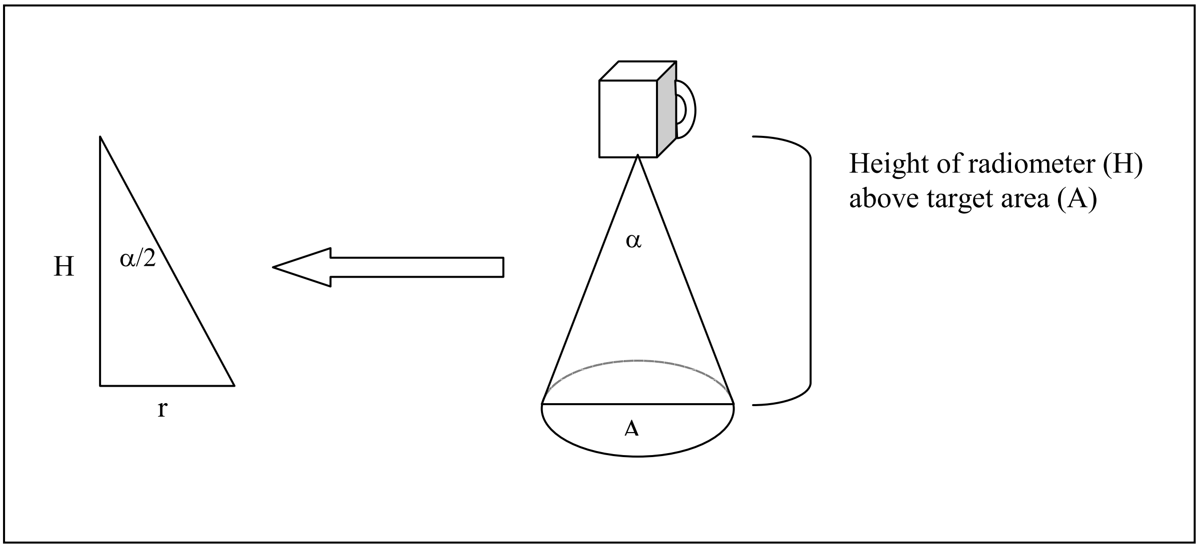
$area = \pi r^2$

$= \pi (0.15m)^2$

$= 0.07m^2$

The area (A) sampled from a height of 1.14m is $0.07m^2$

Instrument Field of View (FOV):



Worked example to establish sample height for a $1.0m^2$ target area (A)

$$r = (area/\pi)^{0.5}$$
$$= (1.0m^2/\pi)^{0.5}$$
$$= 0.56m$$
$$H = r / (\tan(\alpha/2))$$
$$= 0.56m / (\tan(15/2))$$
$$= 4.25m$$

By holding the radiometer 4.25m above a target a $1.0m^2$ area is sampled on the ground

Measurement of Spectral Radiance:
To measure reflected spectral radiance in specific regions of the electromagnetic spectrum (e.g. red and near-infrared), filters are placed over each detector element to restrict the wavelengths of EMR recorded. For our purposes we have loaded filters that match the first four bands of the Landsat 5 Thematic Mapper instrument (for UQ sensor, serial no. 3670):

Radiometer band	Spectral range(μm)		Landsat TM band
A	0.45 - 0.52	blue	1
B	0.52 -0.6	green	2
C	0.63 - 0.69	red	3
D	0.76 - 0.9	NIR	4

To measure the strength of reflected EMR in each of these bands, remove the lens covers from the radiometer and switch the central dial to the band you wish to record. Set the gain level on the band to an appropriate level. Read off the strength of EMR (0 - 1 volt) from the display dial and record it in a data sheet. The suggested column headings for a radiometer data sheet are given below:

1. Observation number
2. Plot number
3. Sky condition

4. Ground condition/photograph
5. Field measurement for blue, green, red and NIR voltage
6. Calibrated blue, green, red and NIR measurements

To convert from voltage values recorded in the field to appropriate physical units (m.watts/cm^2), the following multiplicative constants should be applied to measurements made with a 15^o FOV and a gain setting of 5. Refer to the calibration sheet provided for additional gain and FOV settings.
Band A = 2.32 m.watts/cm^{2}·volts
Band B = 0.927 m.watts/cm^{2}·volts
Band C = 1.01 m.watts/cm^{2}·volts
Band D = 0.85 m.watts/cm^{2}·volts

Worked example for a sample from a grass plot

	Voltage	**Coefficient**	**Spectral radiance (m.watts/cm^2)**
Band A	0.01	2.32	0.0232
Band B	0.12	0.927	0.1124
Band C	0.04	1.01	0.0404
Band D	0.2	0.85	0.1700

5.1.2 AUTOMATED OPERATION OF THE RADIOMETER **DataAcquire Version 1.0**

This help file describes the 'user level' aspects of connection and operation of the Exotech Model 100BX Handheld radiometer and Libretto palmtop computer with DataAcquire version 1.0.

DataAcquire is data acquisition software written in Visual Basic (5.0) to capture data from an Exotech Model 100BX Hand Held Radiometer. The capture calls NI-DAQ functions and library's and writes results to a text file for post-processing.

The DAQCard-500 is an analog input board for computers equipped with a PCMCIA socket and NI-DAQ software and documentation comes bundled with National Instruments products.

The procedure for use is quite simple.

STEP 1

Before a field trip 'set up' the data labels you will need, for example, a recent trip to Heron Island labels were:

Dark
Panel
Substrate
Water
Live Coral
Dead Coral
Beach rock

This should be set up in notepad (or similar) beforehand, any number of labels may be included (within reason). You may also create a series of empty data files with file names pertaining to sites, transects or plots. To have these set up beforehand will save time (and eyestrain) in the field.

STEP 2

Before going into the field check you have all the equipment and it's in working order.

- ***fully charged*** Libretto Windows 95/98
- National Instruments DAQCard-500 analog input board with NI-DAQ software for PC compatibles
- PR27-30F I/O connector with cable
- also Libretto power cable for recharging if you're going for longer than an afternoon.

NOTE: **Start..Control Panel..Power** shows the battery meter for the Libretto Otherwise, simply mouse over the small cord icon in the bottom right of the screen for current power.

STEP 3 In the field
Opening files -
Run the software, and open one of the recently created EMPTY data files – Ctrl + A opens the AppendFile dialog box. You may also type in a filename here and it will be created for you. The current filename will appear in the top right hand corner of the form. The current time and date should appear to its right.

Calibration settings -
The calibration settings in the bottom right will default to TM with a 15 degree Field of view and gain of one. These may need to be changed according to the lenses and gain settings on the radiometer itself. The Libretto *does not know* when the gain has been changed on the radiometer. Alt + S sets the gain according to the sensor selected and radio buttons checked. This will allow the appropriate gain to be written to the file you are appending.

Type of data
Once the calibration information is set focus shifts to the Type of Data frame. This is where the you will use the up/down arrow buttons to select the 'tag' you want for the type of data collected for later processing.

Data Acquisition
Any brief notes may be entered into the notes section although it is advisable to have pencil and paper on hand for details of conditions etc. To save data to file simply press Acquire data or Alt + A. The file written to disk has a format as follows:
radiance1, radiance2, radiance3, radiance4, gain1, gain2, gain3, gain4,time of acquisition, current date, data label, notes

This file can be opened in Excel using the comma delimited option.

Step 4 Closing down
It is advisable to leave the software running between data capture sessions unless it is some distance between sites. To end a session, press END or Alt + E. Remove the DAQCard as described below.
Please note
Under **Start..Control Panel..PC Card** press STOP before removing the PCMCIA Card.

To remove data files from the Libretto there are two options:
1) use the a: drive attachment (RECOMMENDED)
2) use the network card and plug directly into the network in the labs and logging on normally.

5.2 Spectrometer Operation for ASD instruments and RS3 Software

The spectrometer can either be operated in a stable or static mode at a fixed sampling point indoors, or outside on the ground or in a boat. In these situations the spectrometer should be laced on a level, stable and splash-proof surface. The system may also be used in a portable mode, by first fitting the battery waste-pack and shoulder harness. Prior to attaching the spectrometer its top cover should be removed after opening and sliding it to one side. To attach the system to the waist and shoulder harness place it on a desk or waist level surface and attach all of the clips (waist and shoulder). Adjust the straps and ensure the system is secure and comfortable.

Fore-Optics

You will have selected the appropriate fore-optics to use based on your field plan. These should be attached prior to commencing fieldwork and all connections (especially for water measurements) checked to ensure they are tight. In each case you will be attaching the fibre optic cable to one of the fore-optics. **IT IS ESSENTIAL THAT THE FIBRE-OPTIC CABLE IS NOT BENT OR CRIMPED IN ANY WAY AS THIS WILL DISTORT THE LIGHT FIELD REACHING THE SPECTROMETER.** When storing the cable after use ensure it is coiled loosely and placed in its pouch in the top of the spectrometer case **– all fore-optics are to be removed and the cable capped before it is stored.**

Hand-held measurements will require attachment of the pistol grip (25deg. FOV) and the 1deg FOV attachment. A cosine response corrected detector can also be mounted and levelled on a tripod to measure irradiance.

In-water measurements require extreme care in operation and establishing connection of the spectrometer with the 10m underwater fibre-optic cable and its fore-optics (6deg FOV and cosine response corrected detector for upwelling and downwelling radiance).

Connection of Fore-optics:

- Pistol-grip: Remove and store fibre-optic red cap, unscrew the crimp on the pistol grip and insert the end of the cable through the crimp and all the way into the grip until it protrudes from the front of the system. The o secure the cable in place tighten the crimp so that the cable is held in place. DO NOT OVERTIGHTEN as this will damage the fibre-optic cable. DO NOT PULL THE CABLE FROM SPECTROMETER and avoid becoming tangles as this may dis-connect the cable from the spectrometer. The system is now set up with a 25deg FOV. To reduce the FOV to 1deg, attach the 1deg FOV attachment.
- Cosine response corrected irradiance fore-optic: Connect to fibre-optic cable using the same approach as the pistol grip. This unit must then be mounted and levelled on a tripod to record irradiance.
- Underwater cable and 6deg and cosine response fore-optics: To attach the spectrometer fibre-optic to the underwater cable a connection jack must be used to link the two fibre optic cables. When using the spectrometer in this mode the area the spectrometer and cable connections are kept should be isolated from persons walking around the deck or platform. The underwater cable should also be kept loosely coiled in an easily deployable position. The cable is marked with black (0.5m) and red tape strips (1.0m) at set intervals for estimation of depth from the surface. Each of the underwater fore-optics connects to the underwater cables using 4 screws and maintains a waterproof seal by use of an O-ring. Always check the O-ring has not worn away and is sitting correctly in its groove on the fore-optic. All fore-optics and cable should be dried thoroughly prior to disconnection and packing for transport.

Sequence for turning on the system:

Check all direct connections and battery connections are solid

(1) Turn on the spectrometer first

(2) Turn on the PC second

NEVER TURN ON THE PC FIRST AS THE CURRENT THIS GENERATES WILL DAMAGE THE SPECTROMETER.

USE OF GPS WITH THE FULL RANGE SYSTEM
Start up the Spectrometer and Laptop.
Ensure the GPS is set up with “NMEA” output
Once you have started the RS3 program, plug in the GPS cable to the laptop and then goto RS3’s GPS settings and enable the GPS. It should find the GPS and show the coordinates in the lower left corner of the screen.
This will store a log file in ASCII format with the coordinates of the location where a measurement was recorded.
To download any additional data from the GPS please use
http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html
NOTE: DO NOT PLUG IN THE GPS BEFORE STARTING UP THE LAPTOP AS IT RECOGNISES ITS INPUT AS A MOUSE AND YOU WILL LOSE CONTROL OF THE CURSOR.

Data collection program
Once the system has been turned on it usually takes up to 30 minutes for the detector elements to become fully “warmed-up”, although after 10 minutes there is little fluctuation in measurements.
Remember to alter the power settings to a minimum use and maximum conservation mode prior to data collection if working remotely in the field.
To collect and process data from the spectrometer you need to run the “VNIR” program By clicking on the VNIR icon on the desktop.
The VNIR screen/user interface should appear. All of the functions can be run either through pull down menus or hotkeys (as the screen is difficult to see in the sun).

A number of equipment settings must be optimised for the incident light conditions prior to collecting spectra, these include:

Integration time/Optimisation (syn. with exposure time) is the time the sensor takes to acquire a single sample and is displayed in the third text box from the left (e.g. 17ms, milliseconds). The longer the integration time, the more EMR is recorded. For bright sunlit conditions the optimum setting is 17 – 34ms. However, you may wish to optimise this by taking samples over a calibration panel and selecting the time just below that when the response curve is saturated (exceeds maximum DN, flattens out at the top).

Note that for the full range system, its three spectrometers need to have their dynamic range, integration time and output set to incident light levels and matched before operation. This is done automatically (hence no need for setting integration time) before any measurements are made.

Spectrum Averaging is the number of samples taken per observation, the more sample taken, the higher your signal:noise ratio and greater probability of obtaining clean spectra. Using 25 samples produces a 5-fold increase in signal:noise ratio. This parameter is set by going to the top menu list, selecting Control and then Instrument configuration. The next step is to set he number of samples for a sample spectrum, dark current and white reference panel. Ideally these should all be at least 10.

Fore-Optics Selection should be specified in the pull-down menu box next to the integration time. It is essential to set this correctly to ensure that appropriate calibration equations are applied when calculating radiance and reflectance spectra.

Output Spectrum Type is defined in the pull-down menu box next to the Fore-optics selection and can be set to raw DN, reflectance (requires white panel measurement and only for terrestrial) and radiance.

Spectrum (File) Save options control the destination and names applied to spectrum saved from the VNIR window. By pressing the space bar at any stage the spectrum acquired will be saved into a binary file on the PC. The path name and base file name can be established by going to the top pull down menu and selecting Spectrum Save and entering appropriate information. This command may also be used to automate collection of spectra, e.g. for collecting irradiance data during an overflight.

There are two types of reading that are critical for effective spectrometry and these should be completed as often as possible:

Dark Current measurements are made by clicking on the DC pull down menu button. This operation closes a shutter on the spectrometer entrance aperture and measures the response of the system to no external input, i.e. noise due to internal electrical current. This reading is then subtracted from all subsequent readings until another dark current measurement is made.

White Reference measurements should be made over Lambertian reflecting surfaces, such as Spectralon field calibration panels to provide an estimate of irradiance that can be used in calculation of spectral reflectance. When the WR pull down menu button is selected a dark current measurement is also made prior to the measurement over a panel. The orientation of the fore-optics over the calibration panel should match that used for the field samples.
NOTE: Dark current and white references measurements should be made at regular intervals under constant illumination/clear skies and should be made with every target spectra obtained under variable illumination conditions

Spectral Data Collection

Now that you have set up the system to make measurements you should be a the start of transect or sampling operation, ready to acquire spectra. When using the hand-held pistol grip with 25deg or 1deg FOV you must carefully replicate the illumination and sampling geometry at each data sampling point. This involves a collection procedure in which you should be standing opposite to the plane of the sun and using a viewing elevation of 57.5deg. at a height where the resultant GRE only includes the feature(s) you are measuring.
CSIRO guidelines for sample position in relation to solar azimuth and zenith:

Elevation angle of fore-optics = 57.5 deg. from the horizontal plane
Azimuth angle = 90 deg. to the plane of the sun

The rationale for this approach is described in Appendix D from D.Jupp and P. Daniel of CSIRO, and is primarily designed to minimize BRDF effects and maximize measurement of colour properties or cover. "The magic elevation angle is optimized for plant canopy observation and is derived from relationships between measurements of LAI of foliage and observation angle. The 58 degree angle is where the variability of LAI estimation to leaf-angle distribution is minimized (Wilson, Aust. J. Bot..1963, 11, 95-105) or put another way, the solid angle of foliage viewed from this angle (ie, ratio of foliage to background for plants with a low LAI) is more consistent between plants with variation in canopy structure. Apparently, this angle does not take into account any illumination effects; it merely provides a more consistent solid angle of leaf area when observing different plant canopies, particularly if sparse foliage" (P.Daniel, CSIRO Pers.Comm. 28-04-08).

Measurements of irradiance using the cosine corrected fore-optics and underwater sampling requires specific attention be paid to minimising indirect sources of radiance from buildings, field vehicles, field personnel and boats. Keep in mind the bi-directional reflectance distribution of the target you are measuring and how the variations in incident sunlight will affect reflectance throughout the day.

Prior to saving a data set ensure you have all the data collection settings optimised (integration time and sampling interval) and have selected the correct fore-optic and measurement level. After depressing the space-bar, the next spectra acquired will be placed in an output binary file as indicated in the Spectrum Save window. The Spectrum Avg window presents a graphic depiction of how many of the samples have been completed for a specific observation – DON'T MOVE THE SENSOR DURING THIS TIME ! At this stage it is important to link your field records (written) with the name of the spectrum-file you have just saved. This may also include notes of field conditions along with other sampled variables and location of the site.

Continue with your spectrum and field data collection as planned, keeping watch on the time you have spent and the battery levels of the spectrometer and PC. Always cross check you field sheets with the spectrum file names/numbers to ensure there are no mis-matches. The number shown on the menu is the number which belongs the first spectra which will be measured after touching the space bar.

Finishing a Data Collection Program

To finish a data collection session Quit from the VNIR program and then check the files you have created during the sampling run are all present in your data directory and ae all the same size. Connect the 3.5" disk-drive to the Libretto and download all of the files to at least one diskette. Do not erase data from the Libretto until you have safely processed all of your data into the UQ spectral library format.

You may now switch off the PC and then the Spectrometer. ALWAYS SWITCH OFF THE PC FIRST !

All fore-optics should be disconnected and storage caps laced on the fibre-optic cables, which should then be coiled loosely and stored. All fore-optics should be wiped dry with a clean cloth and placed back in their pouches.

Update the equipment use log for the spectrometer, filling in the dates and times of use, fore-optics used and data sets produce and any problems encountered.

ANY PROBLEMS ENCOUNTERED SHOULD BE REPORTED IMMEDIATELY TO DR PHINN

6. Data processing, quality checking and storage

6.1 Data downloading to PC and Quality Checking (QC) procedure

Data collected from the radiometer using the manual approach should be checked to ensure all Voltage, and gain values were recorded along with all dark current and calibration panel measurements.

Data collected from the radiometer using the Libretto and A/D card should be checked by first matching the entries in the output file to the field data sheet and adding comments where necessary. In addition the magnitude of all radiance values should be scrutinised to determine that they were in a suitable range. If reflectance data are required all measurements should be linked to their closed dark current and calibration panel measurement.

Data collected from the spectrometer using a progressive series of binary files e.g. sample001 to sample100 should be downloaded from the Libretto and run through the program ViewspecPro or Viewspec.

This runs on files sample001 to sample100 and creates an output ASCII file where the first column (-xw) contains wavelength values, and successive columns are separated by commas (-cc) and have their filename (-f) on the top row.
Once this is complete it is essential that you check your field data sheets against each column entry and add the appropriate descriptor data.

All field data (e.g. GPS, biomass, water depth) should also be checked for consistency and links to radiometer data at this stage prior to being entered into an appropriate spreadsheet or database.

Each data set should also have an accompanying Meta-data file that identifies: the responsible researcher, date and location of data collection, sky conditions, fore-optics used and listing of data samples and the file names of radiometer/spectrometer and field data.

Both radiometer and spectrometer data sets are now in an ASCII text format able to be imported directly into a spreadsheet (e.g. Excel) or ENVI's spectral library for graphical, statistical and numerical analysis.

6.2 Processing data sets to standard spectral libraries for statistical, numeric and graphic analyses

Processing of data sets can progress in a number of ways, the following are some suggested approaches:

Radiometer data:
- Graphic assessment of spectral signatures and their variability
- Correlation or regression analysis with biological, physical or chemical field data sets

Spectrometer data:
- Graphic assessment of spectral signatures and their variability
- Correlation or regression analysis with biological, physical or chemical field data sets
- Derivative analysis to examine spectral peaks, troughs and inflection points
- Band re-sampling or convolution to match broad band sensors
- Spectral curve matching within a library

7. The CRSSIS Spectral Library

7.1 Why maintain a spectral library ?

To provide a resource for use by students and researchers for interpreting the results of their analyses and to develop a quantitative and accurate means of discriminating features in the next generation of airborne and satellite imaging systems. Most existing spectral libraries are based on North American or European environments and lack a variety of features from Australian forests, soils, minerals, water-bodies, submerged aquatic/marine vegetation and coral reefs.

7.2 Format of data for submission:

Meta Data file containing: the responsible researcher, date and location of data collection, sky conditions, fore-optics used and listing of data samples and the file names of radiometer/spectrometer and field data. This file must enable a link between spectral data and ground sample points and related information.

Excel, ENVI spectral library or ASCII comma/space delimited text file organised in columns with the first column containing band centre wavelengths and following columns radiance or reflectance values for specific samples.

8. Special Considerations for Marine Measurements Using the ASD (C.Roelfsema)

For in-situ marine spectral reflectance measurements the Ocean Optics Underwater spectrometer should be used.

Foe depth profiles of down- or up-welling irradiance, the TriOS Ramses spectrometer should be used.

Field teams should be instructed to watch splashing of:
- people who move out and in the boat
- snorkellers/divers who e.g. clearing water out of snorkel or move of fins
- wet hair or cloth of the field team
- samples, instruments which go out or in the water
- things which are thrown in or out of the boat (e.g. boys, ropes)

How to protect the Spectrometer:
- from splashing water splashing
    - instructed the field team
    - keep the spectrometer in the special designated nally bin
    - keep a towel over spectrometer and computers
    - place it in an area on the boat which can be separated as being the dry area
    - while the boat is moving close the nally bin
    - have a dry cloth handy to dry of water
- keep it in the nally bin on a location where it cannot move or where it is not shaken to much while sailing
- instructed the field team of the small area in the boat and the high expense of the instrument
- take time for installing it

How to protect the optical cable
- while moving have it on top of the nally bin lid
- while using it have the part closest to the boat connected to the boat
- have somebody watch to cable in the boat
- give to much slack so that the optics operator (e.g. diver, snorkeller) in the water will not have to pull on the cable
- let the optics operator (e.g. diver / snorkeller) know that there is not much slack left
- do not pull on the cable
- look out that the cable those not get entangled
- never have the cable in the water when the boat is still moving on its engine

How to protect the fore-optics
- check to o ring before connecting the underwater optics
- test the o ring connection in fresh water before placing in salt water
- attach optics before going into the marine environment
- while not using it leaf it in fresh water or a wet towel this will stop dirt or salt crystals forming on the optics

How to protect the U/W spectralon
- keep it on wrist while in the water
- keep protection cap on while not using
- take time when using it

Consideration when collecting optical measurements

- wind forces 15 kn or higher waves will have such an effect on movement of water surface and therefore also movement of boat that this will influence the results considerably.
- plan the measurements with the optics operator who is going in and under water since communication will not be as effective
  - how to communicate (e.g. hand or line signals or buddyphone system)
  - communicate a minimum (e.g. only name what is been done)
  - do not change plan when optics operator is in water
- dive/snorkeling safety and u/w spectrometery
  - stick to plan
  - diver cannot go up and down (bounce diving) this can cause serious injuries
  - diver has to stick to diving limits
  - limited factors in time spend u/w can be air, temperature, currents or diving tables
  - snorkeller had limited air u/w

- since the boat is on an anchor it will move around it can be a disturbing shade for underwater measurements and above water the position of the optics operator relative to the sun will change ass well
- when measurements are taken above water with a wet optics, water on the optics can interfere with the result
- wet spectralon can interfere the result when used above water
- optics operator has to take care that he those not disturb the sediment since this will influence the u/w light climate
- higher integration time are necessary in underwater environment because of amount of light
- more samples have to be collected to calculate the spectrum average this because of movement of boat (for measurements on boat) which changes the angle of the light on the subject or movement of water surface which causes a change in light going through the water column
- be aware of reflecting effects of wet samples which are taken out of the water
- notes the depth were spectra was taken
- place samples on area with black cloth as background (e.g. shade cloth) to minimize reflectance surrounding environment (e.g. aluminum boat)
- reflectance measurement can have such low values underwater that in most cases it is advised to measure radiance of spectralon and then of subject and calculate reflectance values in the lab
- the constant change of the water surface and column will influence the underwater light climate so much that it is advised to measure before each subject the spectralon

When finished with marine measurements
- check for any water damage
- rinse optical cable and optics with fresh water are preferable leave them in fresh water for 15 minutes or more
- store the spectrometer open so that water vapor on it, can dry and those not settle down in electronic part of instrument
- take a wet cloth and rinse nally bin in and outside

When suspected flooding occurs
- take all power off
- remove batteries (also internal) and other power sources
- disconnect laptop from spectrometer
- do not leave it in a wet environment
- contact Stuart

9. Vegetation Measurements (T.Gill)

Field Spectral sampling protocol for arid and semi-arid vegetation cover estimates

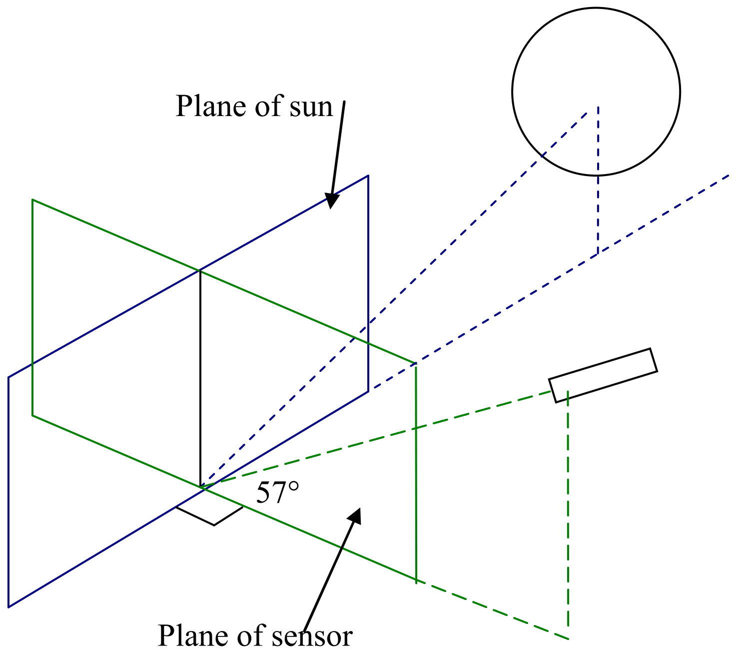
Version 1.0
Date: 11-04-06
By: Tony Gill

General Guidelines

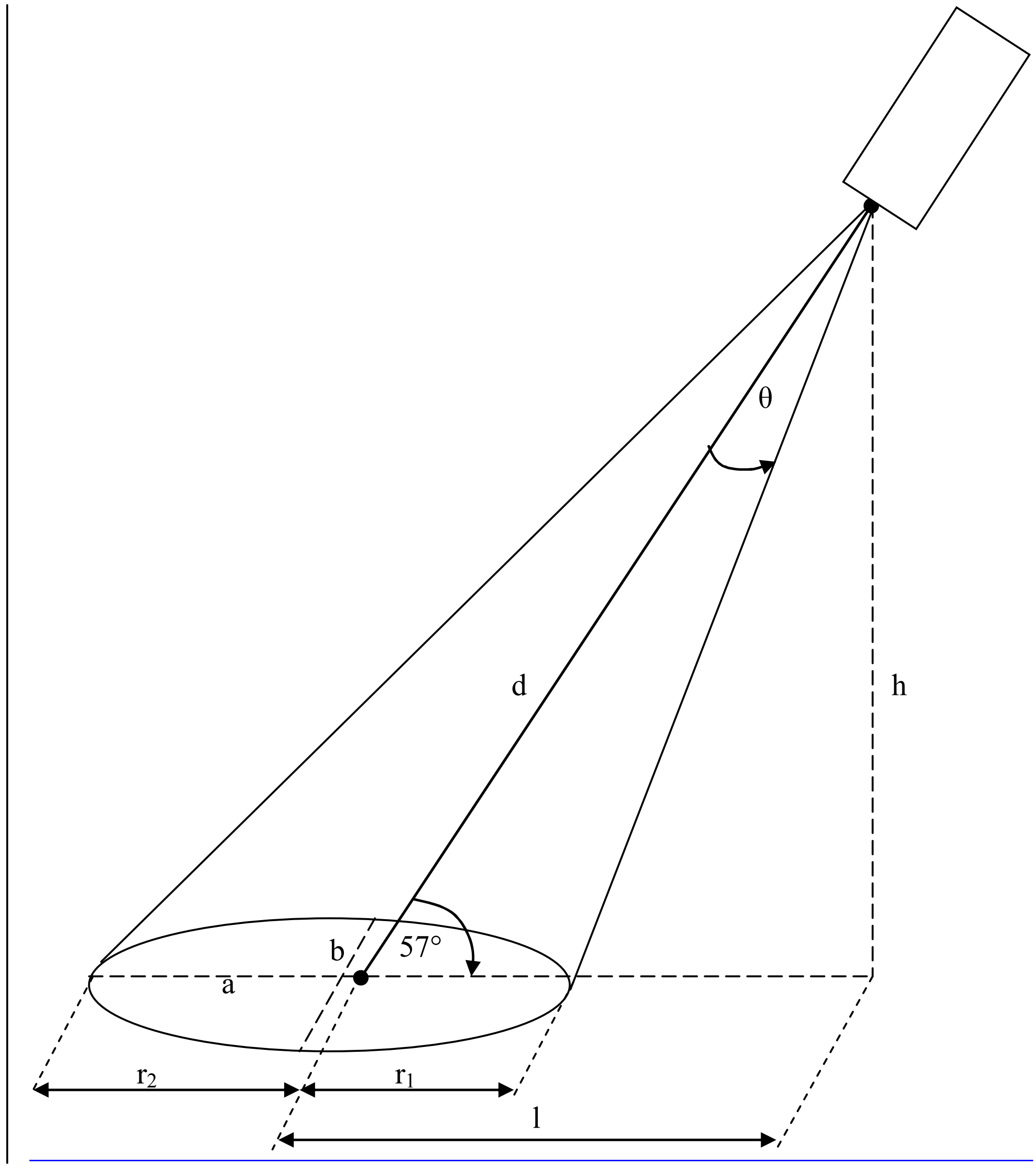
- Allow ASD spectrometer to warm for 10 minutes prior to use.
- For the UN-VNIR unit (#805) Set appropriate integration time for taking measurements. The full range unit (#6177) automatically sets this.
- Use the 25 degree foreoptic (bare fibre) for all reflectance or upwelling radiance measurements.
- Record time of day, GPS location and take a photo at same time as capturing spectral measurement.
- Make in-situ measurements (i.e. don't go harvesting the vegetation if not required).

Sampling geometry:

For all ground measurements of upwelling reflectance or radiance the 25 degree FOV foreoptic (bare fibre) will be used. The geometry of the measurement is shown below. Note the elevation angle of the fore-optics is 57 degrees from horizontal plane and azimuth angle is 90 degrees to the plane of the sun (CSIRO guidelines).



The height at which the spectrometer is held will determine the size of the area sampled as the bare fibre has a 25^o FOV. The region will be a circle of approximately 44cm in diameter when held 1m directly above the target (i.e. at nadir). If the sensor is held 1m above the ground, using the CSIRO geometry the sampled region will be an ellipse with minor axis (b) of length 44cm and major axis (a) of 67 cm.



In the above geometry, if d, the distance from the spectrometer to the target is 1m and θ is 12.5°, i.e. 25° field of view, then h will be approximately 84cm, the major axis, a, will be 52.5cm, and the minor axis, b, will be 37 cm. Note that the "centre beam" from the spectrometer does not intersect the ellipse exactly in the middle. The two distances r1 and r2 are 25.6cm and 30.9cm respectively. Finally, the horizontal distance, l, from the spectrometer to the intersection of the "centre beam" with the ground is 0.544cm. The excel spreadsheet spectro_geometry.xls can be used to compute this geometry and is based on the following equations.

Now, given an arbitrary height h, with the CSIRO geometry, how can we compute d, a, b, r_1, r_2, and l. The equations are (note that 57° has been replaced by ϕ):

$$d = \frac{h}{\sin\phi}$$

$$l = \frac{h}{\tan\phi}$$

$$b = 2h\tan\theta$$

$$r_1 = \sqrt{(h\sin\theta)^2 + (h\cos\theta - d)^2}$$

$$r_2 = \sqrt{\left(\frac{d}{\cot\theta - \cot\phi}\right)^2 + \left[d - \left(\frac{d\cot\theta}{\cot\theta - \cot\phi}\right)\right]^2}$$, note that $\cot\alpha = \frac{1}{\tan\alpha}$

$$a = r_1 + r_2$$

The derivations for d, l and b are straight forward and based on simple right angle geometry. The derivations of b, r_1 and r_2 are given in the appendix. The excel spreadsheet spectro_geometry.xls allows you to compute these values given *h,* θ and ϕ.

Ground measurements

1) A rectangle will be placed around the region on the ground that encloses the viewing ellipse of the sensor.
2) Take spectralon panel reading at a consistent viewing and illumination distance/geometry and
3) Using CSIRO geometry take spectral reflectance measurement 1m above ground:
   a. 1 sample will be considered average of 60 measurements, unless light conditions are variable and therefore a lower number of measurements will be needed per sample to ensure minimal variation in light conditions while the sample is being captured.
   b. Take coincident GPS record
   c. Take coincident field photograph
4) Repeat measurements at Nadir with sensor 1m above ground.
5) Repeat measurements at third angle with sensor 1m above ground.
6) Remember to link the name of the image file (photo) and spectral file to the field notes just collected.

If the rectangle contains a mix of endmembers (e.g. – green grass, dead grass, soil, rocks), take individual spectral measurements of each endmember by moving the foreoptic close enough to the target to ensure reflectance from background objects is minimised.

At the same site also take spectral measurements of other vegetation not in the rectangle. Such measurements include, but are not limited to tree canopies, tree bark, water, other soil and rock signatures, signatures of microbiotic soil crusts. Where possible, try to include spectra of mixed shade and sunlit components. On clear days white reflectance measurements should be made at least every 15 minutes. Ideally a white reflectance measurement will be made before each spectral reflectance measurement.

When measuring tree or shrub canopy spectra it is important to measure the spectra from above the canopy. This may require standing on top of truck, using a ladder or holding the spectrometer forepoptic on the end of a boom.

Other measurements:

Make observation of sky, sun and weather conditions (dust/haze/smoke, cloud cover (in oktas = 1/8 hemisphere, cloud form and height of base, wind)) See appendix for description of clouds.
Take a soil colour chart reading (both wet and dry).
Also need to know how recently it has rained at the site.

10. Contacts and Appendices

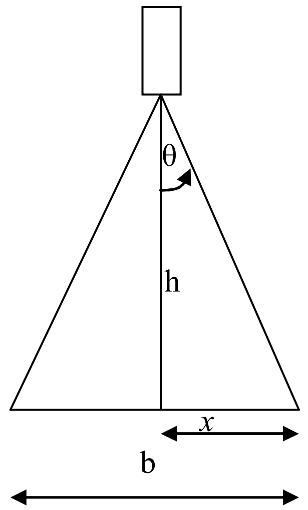
ASD web page:
http://www.asdi.com/

USGS spectral libraries
http://speclab.cr.usgs.gov/index.html

NASA/ASTER spectral libraries:
http://asterweb.jpl.nasa.gov/

APPENDIX A: DERIVATION OF ELLIPSE GEOMETRY

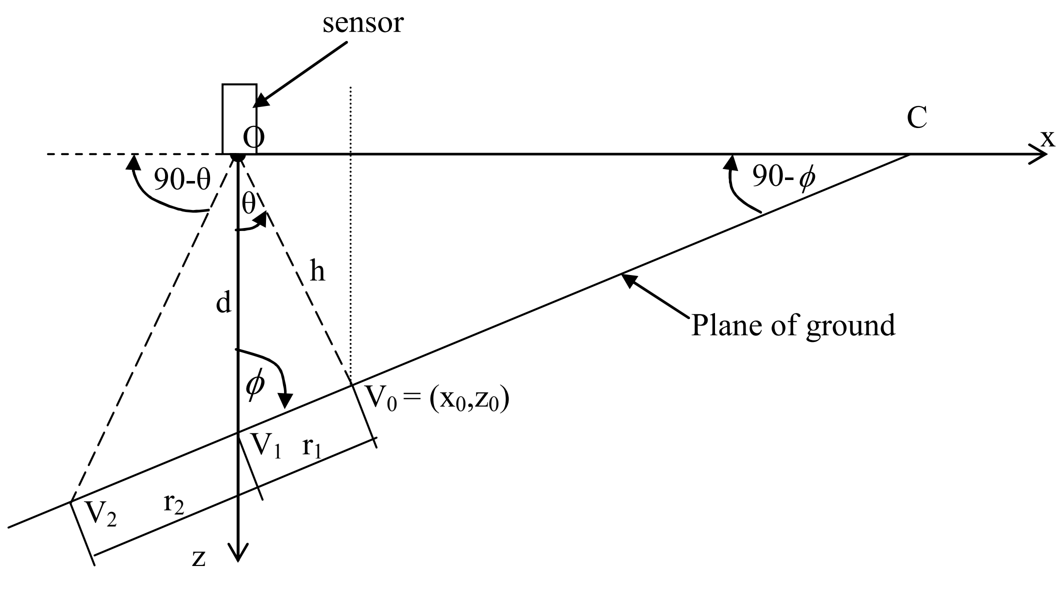
The derivation of the geometry of the ellipse created by the CSIRO geometry is presented here. The minor axis, b, of the ellipse can be computed by considering that the geometry is simply that of a cone intersecting a plane that is perpendicular to the cone. The projected 2D view is:



The calculations for b are based on simple geometry and are:

$$b = 2x = 2h \tan\theta$$

The derivation of r_1 and r_2 is based on the geometry in the figure that follows. Note that in constructing this image the CSIRO geometry has been skewed so that the sensor is vertical with respect to the page, but still at an angle to the plane of the ground.



Note that ϕ is half the foreoptic angle and θ is the angle between the foreoptic and the horizontal plane of the ground (57 degrees in the CSIRO geometry). From the diagram r_1 is equal to the distance from V_0 to V_1 and r_2 is equal to the distance from V_1 to V_2. These distances can be computed using the euclidean distance rule:

$$r_1 = \sqrt{(x_0 - x_1)^2 + (z_0 - z_1)^2}$$
$$r_2 = \sqrt{(x_1 - x_2)^2 + (z_1 - z_2)^2}$$

The problem reduces to that of finding the x and z coordinates of each point.

From the diagram $x_1 = 0$ and $z_1 = d$.

Using simple right angle geometry, x_0 and z_0 are:

$$x_0 = h\cos(90 - \theta) = h\sin\theta$$
$$z_0 = h\sin(90 - \theta) = h\cos\theta$$

x_2 and z_2 can be computed by solving the two simulatenous equations formed by the lines V_2O and V_2C.

The equations of both lines take the form:

$$z = mx + b$$

Where *m* is the slope of the line and *b* is the intercept with the z axis. The slope, *m*, can be computed using the relation:

$m = \tan\alpha$, where α is the angle between the line and the horizontal plane.

The equation of V_2O is:

$$z = \tan(90 - \theta)x = x\cot\theta$$

The equation of V_2C is:

$$z = \tan(90 - \phi)x + d = x\cot\phi + d$$

Solving these equations simultaneously gives rise to:

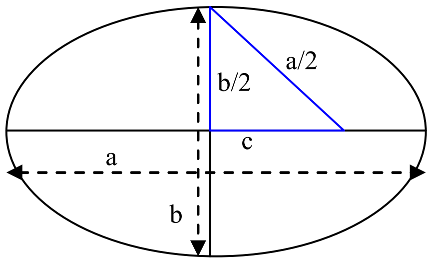
$$x_2 = \frac{2}{\cot\theta - \cot\phi}$$
$$z_2 = \frac{d\cot\theta}{\cot\theta - \cot\phi}$$

Using these results the equations for r_1 and r_2 become:

$$r_1 = \sqrt{(h\sin\theta)^2 + (h\cos\theta - d)^2}$$
$$r_2 = \sqrt{\left(\frac{d}{\cot\theta - \cot\phi}\right)^2 + \left[d - \left(\frac{d\cot\theta}{\cot\theta - \cot\phi}\right)\right]^2}$$

Drawing an ellipse on the ground

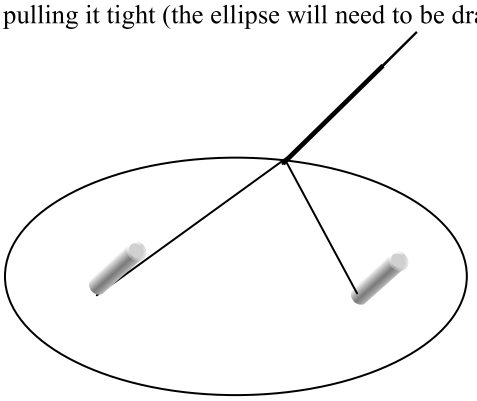
For educational purposes it may be useful to set up the spectrometer with the appropriate geometry and trace out the viewing ellipse on the ground. An ellipse has two foci located c units either side of the ellipse centre as shown in diagram below:



Once the lengths of the major and minor axes (a and b) are known c can be computed using the pythagorean relation:

$$c = \sqrt{\left(\frac{a}{2}\right)^2 - \left(\frac{b}{2}\right)^2} .$$

The ellipse can be drawn (easily if the demo takes place on dirt) by placing two stakes in the ground at each focus. Now tie each end of a string around each stake so that the length of the string is *a*. Pick up a stick and trace the shape of the ellipse into the dirt by resting the stick on the inside of the string and pulling it tight (the ellipse will need to be drawn in two halves).



APPENDIX B: MAKING CLOUD OBSERVATIONS

The following cloud observation notes have been extracted from the uk meteorological office: http://www.met-office.gov.uk

Cloud amount is measured by dividing the sky up into eights, known by meteorologists as oktas, and estimating how much is covered by cloud. If there are lots of patches of individual cloud, estimate how much of the sky they would cover if they were all put together. If you cannot see the sky because it is obscured by fog, this is reported as 9 oktas.

The table below will help as a guide.

CLOUD TYPES

0 oktas	Clear skies
1 okta	Almost clear skies, just the odd cloud
2 oktas	Mostly clear skies, only a quarter of the sky covered by cloud
3 oktas	Partly cloudy, just over half the sky is cloudless
4 oktas	Partly cloudy, half of the sky covered by cloud
5 oktas	More than half the sky covered by cloud
6 oktas	Mostly cloudy, only a quarter of the sky showing
7 oktas	Almost overcast, just a small amount of sky showing
8 oktas	Overcast, no sky showing
9 oktas	Sky obscured by fog

Cloud type

Cloud is divided up into ten different types which are identified by their height and form. They can be described by their height as low, medium or high, and by their form as layered, bumpy, heaped or whispy.

High clouds are usually composed solely of ice crystals and have a base between 18,000 and 45,000 feet (5,500 and 14,000 metres).

- Cirrus - white filaments
- Cirrocumulus - small rippled elements
- Cirrostratus - transparent sheet, often with a halo

Medium clouds are usually composed of water droplets or a mixture of water droplets and ice crystals, and have a base between 6,500 and 23,000 feet (2,000 and 7,000 metres).

- Altocumulus - layered, rippled elements, generally white with some shading
- Altostratus - thin layer, grey, allows sun to appear as if through ground glass
- Nimbostratus - thick layer, low base, dark, rain or snow may fall from it

Low clouds are usually composed of water droplets - though cumulonimbus clouds include ice crystals - and have a base below 6,500 feet (2,000 metres).

- Stratocumulus - layered, series of rounded rolls, generally white with some shading

- Stratus - layered, uniform base, grey
- Cumulus - individual cells, vertical rolls or towers, flat base

Cumulonimbus - large cauliflower-shaped towers, often 'anvil tops', sometimes giving thunderstorms or showers of rain or snow

Cloud Classification

High clouds, C_H
base usually 20,000 ft or above over British Isles)

Type	**Precipitation (ppn) etc.**	**Range of cloud base**	**C code**
Cirrus (Ci)	No ppn. Halo may occur. Dense patches may veil or hide the sun	Usually 20,000-40,000 ft	0
Cirrocumulus (Cc)	No ppn. Position of sun/moon can usually be seen	If at a non-aviation station the height cannot reasonably be estimated, the British practice is to use a nominal height of 25,000 ft, and 35,000 ft for any higher cloud	1
Cirrostratus (Cs)	No ppn. Halo often occurs. Outline of sun normally visible	Cs may thicken to become As	2

Medium clouds, C_M
(base usually between 6,500 and 20,000 ft over British Isles, although Ns may lower to near earth's surface)

Type	**Precipitation (ppn) etc.**	**Range of cloud base**	**C code**
Altocumulus (Ac)	Ac Castellanus occasionally produces ppn. Can be thick enough to hide sun/moon	Usually 6,500-20,000 ft. If at a non-aviation station the height cannot reasonably be estimated, the British practice is to use a nominal height of 10,000 ft, and 15,000 ft for any Ac or As above	3
Altostratus (As)	Often continuous ppn reaching the ground with sun/moon hidden. Thinner As shows sun/moon as ground glass appearance	Altostratus may thicken with progressive lowering of the base to become Ns	4
Nimbostratus (Ns)	Normally continuous ppn (sometimes moderate/heavy) with sun/moon hidden	Usually between the surface and 10,000 ft	5

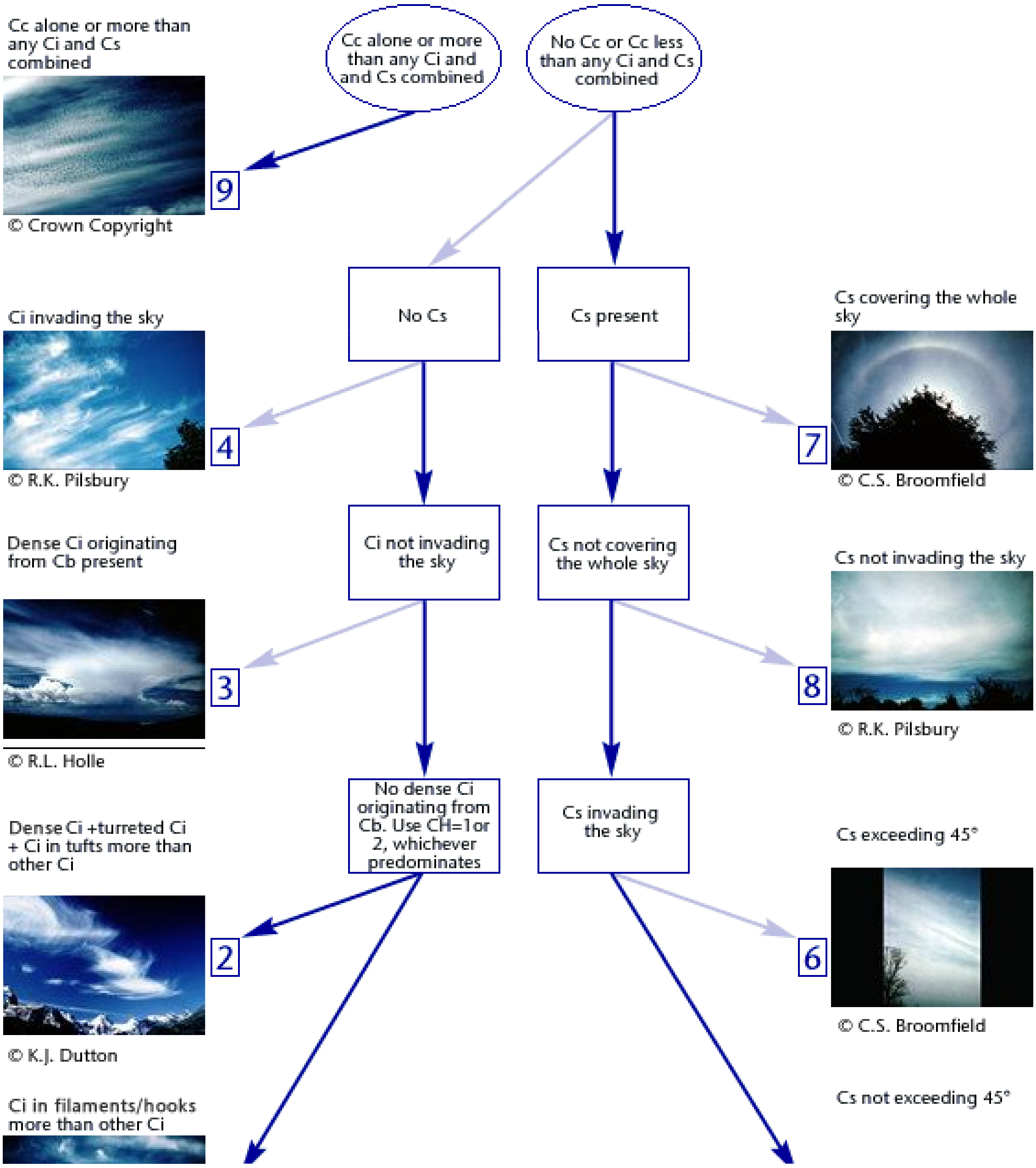
Low clouds, C_L
(base usually below 6,500 ft over British Isles)

Type	**Precipitation (ppn) etc.**	**Range of cloud base**	**C code**
Stratocumulus (Sc)	Normally no ppn, but slight ppn possible over coasts/hills. Can be thick enough to hide sun/moon	Usually between 1,000 ft* and 4,500 ft but may often be observed to 6,500 ft	6
Stratus (St)	Near coasts/hills, ppn can be considerable, but it may be falling from higher cloud such as Ns. Can be thick enough to hide sun/moon. However when thin, sun/moon can be clearly visible	Usually between the surface and 2,000 ft but may sometimes be observed to 4,000 ft	7

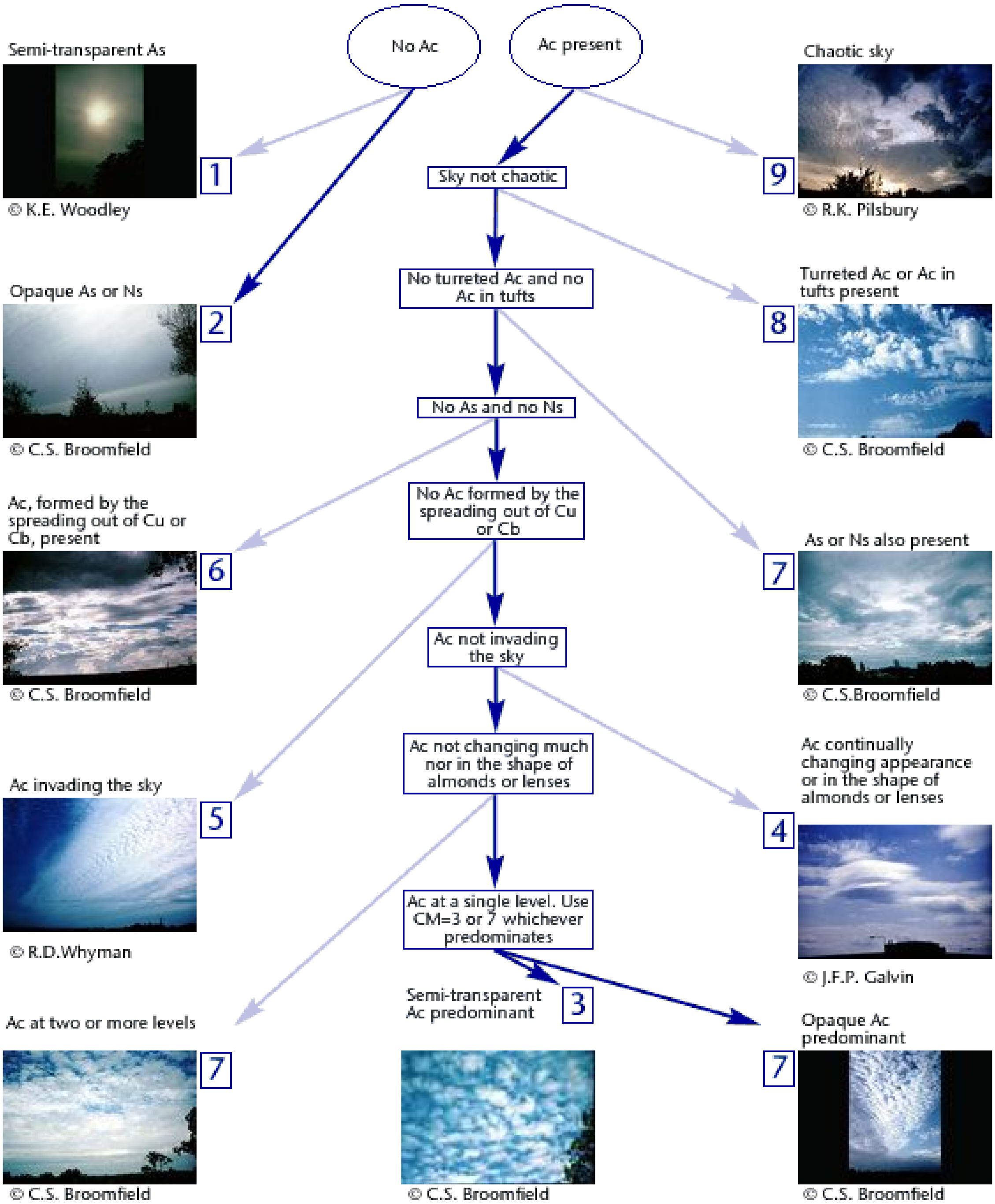
Cumulus (Cu)	Light showers are possible	Usually between 1,000 ft* and 5,000 ft, but may sometimes be observed to 6,500 ft. After initial formation, a rise in temperature often leads to a rise in cloud base	8
Cumulonimbus (Cb)	Always reported when showers/thunderstorms/hail occurs. Squally winds are also common	Usually between 2,000 ft* and 5,000 ft, but may sometimes lower to near surface, or be as high as 6,500 ft	9

*At stations substantially over 500 ft above sea level the base will often be less.

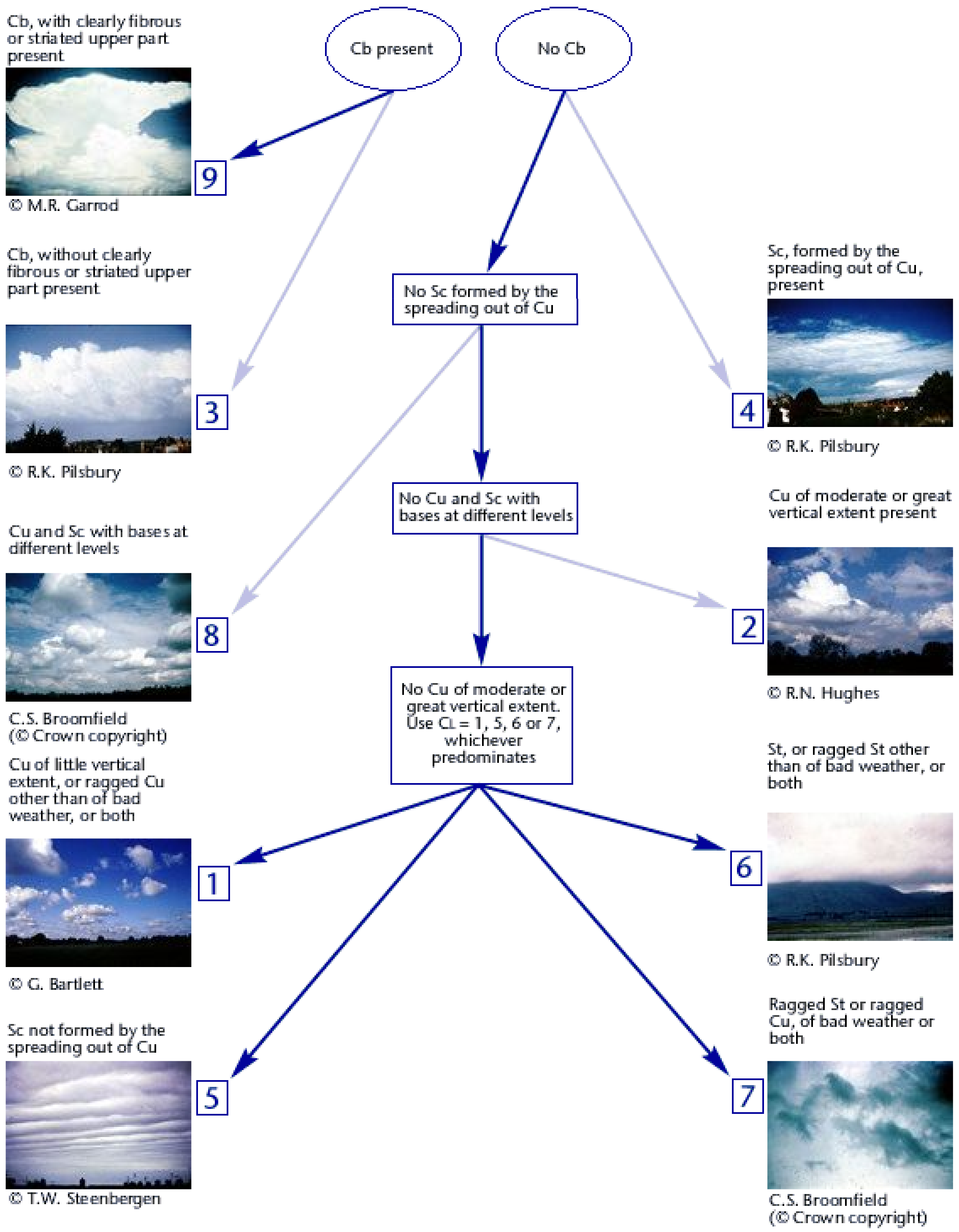
Pictorial guide C_H: Ci-Cc-Cs



Pictorial guide C_M: Ac-As-Ns



Pictorial guide C_L: Sc-St-Cu-Cb



APPENDIX C – DATA SHEETS

Site Name:
Date/Time of site visit:
Site Description:____
____
____
____
____
____
____
____

Site photograph filenames:____

Soil type/Soil colour________________________

Overstorey vegetation Information:
Height class (e.g. low, tall, v.low)_______________________
Dominant Species:____________________________________
Other info:____

Mid-storey vegetation Information:
Dominant Species:____________________________________
Other info:____

Under-storey vegetation Information:
Dominant Species:____________________________________
Other info:____

Site name:
Date:
Quadrat Spectra:
GPS Coordinate(inc datum):

Type (Please tick):
Vegetation___ Bareground___ Soil___ Mixed___
Other(provide description):

1) Off nadir (CSIRO Geometry)
Light/weather/cloud conditions:
Foreoptic:
Spectra filename:
Digital photo filename:
Time:

2) nadir
Light/weather/cloud conditions:
Foreoptic:
Spectra filename:
Digital photo filename:
Time:

3) *Off nadir (specify geometry):*____
Light/weather/cloud conditions:
Foreoptic:
Spectra filename:
Digital photo filename:
Time:

Site name:
Individual Spectra:

Targets include green and dead vegetation on grass, shrubs trees, litter, rocks, microbiotic soil crusts, tree branches, bark.

GPS Coordinate(inc datum):
Light/weather/cloud conditions:
Foreoptic:
Spectra filename:
Digital photo filename:
Time:

GPS Coordinate(inc datum):
Light/weather/cloud conditions:
Foreoptic:
Spectra filename:
Digital photo filename:
Time:

GPS Coordinate(inc datum):
Light/weather/cloud conditions:
Foreoptic:
Spectra filename:
Digital photo filename:
Time:

GPS Coordinate(inc datum):
Light/weather/cloud conditions:
Foreoptic:
Spectra filename:
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APPENDIX D – CSIRO Field Spectrometry Instructions: David Jupp (1993) and Paul Daniel

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Notes on use of Radiometers for Spectral Reflectances

D.L.B. Jupp

1. Basics

The main situations we will be in are the water covered areas and land surface types of target. We have been getting things standardised over water and now the same standardisation needs to be established for our land and other 'hard' target work.

Over water, the procedure has been to take oblique radiometer readings of target with the sun behind and with a depression angle of about 60°. Then a standard is read with the same geometry, In addition, the sky is read at the 'specular' point from the observer to target to sky point to correct for sky glint.

For land and hard targets, the BRDF (Bidirectional Reflectance Distribution Function) is the main concern. Radiometry either needs to avoid its effects or measure them. Since most exercises are more concerned with target colour and the effects due cover or 'amount' of target rather than the effects of shadow and sun/target/observer geometry this document will mainly discuss BRDF avoiding strategies with a short discussion of BRDF measurement at the end.

1.1. Measureing land targets

The basic BDRF and structure avoiding strategy is to use the radiometer obliquely with the sun either from 'the left' or 'the right' and preferably to measure both if it possible given the three dimensional nature of some targets.

The angle of oblique measurement should be a depression angle of about 32° or 58° zenith angle of observation. This is quite oblique and leads to a large footprint. However, at this angle, the effects of vertical and horizontal facets as well as hotspot effects are minimised. The main effects are object and background average colour and object 'amount'. If it is neccessary to use other angles the RECORD THE ANGLES!

Where does this 'magic' angle come from? Well, a very simple model for the fraction of background observed from an observer zenith angle θ is:

$$P_{gap}(\theta) = e^{-(L_H + \frac{2}{\pi} Tan(\theta) L_V)}$$

where L_H and L_V are the Horizontal facet area and Vertical facet area. For vegetation they are usually thought of as horizontally and vertically projected leaf area. But a similar form can be used for buildings etc where they are horizontal and vertical facets - ie roofs and walls. It follows that the vertical and horizontal facets are balanced as obstructions in the field of view when:

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$$\frac{2}{\pi} Tan(\theta) = 1.0$$

or when $\theta = 57.52°$. So there you are.

As with all radiometry, the best times are during the main part of the day avoiding times when diffuse radiation is high.

Unlike the visible/NIR/SWIR data, the thermal can be used at other than high sun times. Make sure data pre-dawn and early afternoon are taken to check thermal inertia. In the day, remember that the thermal also has a BRDF so that sun-left and sun-right also applies.

2. Standardisation

The basic standardisation is the panel. The theory is that the reflectance factor for a target (ρ_t) is:

$$\rho_t = \pi \frac{L_t}{E_T}$$

where L_t is the radiance of the target from the observer position and E_T is the total irradiance on the target. This reflectance factor depends on environmental conditions and is not the BRDF. However, it is what we can measure and is the reflectance factor relevant for remote sensing.

If you have a Lambertian standard with reflectance ρ_{st} and you read it as well as the target then the irradiance as well as calibrations can be cancelled out by the fact that the target reflectance can also be written:

$$\rho_t = \rho_{st} \frac{V_t}{V_{st}}$$

where V_t is the spectroradiometer reading for the target (V for 'Voltage') and V_{st} is the reading for the standard if the standard replaces the target so that the irradiance, the observer/sun geometries and the radiometer optics are the same.

For low targets this is all very well, but for trees and solid objects (such as vehicles and buildings) it is difficult to standardise as the condition that the standard effectively 'replaces the object' is hard to ensure. Also, a standard can be difficult to transport and use in many cases. Hence, the second method we use is the 'paired radiometer' case where both the target radiance and an irradiance are measured. Since there is only one spectron, the irradiances and radiances will not be simultaneous, but we do what we can.

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With the two radiometers you can compute the ratio:

$$r_t = \frac{V_t}{V_{2\pi}}$$

where now $V_{2\pi}$ is the reading of the irradiance by the radiometer. That is, the subscript 2π indicates the 2π diffuser is in place and you measure the cosine irradiance. To convert into reflectance we need a 'K'-factor. This is defined as the factor in the equation:

$$\rho_t = K\, r_t$$

$$= K \frac{V_t}{V_{2\pi}}$$

To obtain K you can use the standard, since if you read the standard and K does exist as a stable factor (it seems to) then:

$$K = \rho_{st} \left[\frac{V_{2\pi}}{V_{st}} \right]$$

where the readings are of the standard and the irradiance at the same or near time. This can be computed using data taken from time to time during a day. The advantage is that K can then be used generally for similar situations.

It is likely that K will depend to some extent on sun and observer geometry as well as the diffuse fraction. Some indication of the extent of stability for K can be found in the unpublished document by Tian & DLBJ.

If possible, keep records of diffuse radiation. If using the 2π irradiance mode of the spectron this means shading out the sun for some readings and if using the standard and 15° FOV mode it means reading the standard as well as the sky at zenith (directly above) and possibly in the principal plane at 90° to the current sun position as well.

NOTE. Interpretation of these diffuse measurements has not been made standard. Maybe that should be gone over back at WLR and then your spreadsheets made standard for the next time. However, to get a result for the customers ...

If the diffuse radiation is measured using the 2π irradiance mode and shading out the sun then the ratio of the two is a valid estimate of diffuse fraction as a function of wavelength. As a summary value, I think it should be averaged over the PAR region 400-700 nm. Simply average the two data sets (irradiance and radiance) then take the percentage from the ratio of the averages. To compute diffuse radiation fraction for the standard and sky data just treat the data as for reflectances. That is, divide the sky

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reading (either vertical or 90°) by the standard radiance and multiply by the standard reflectance (ρ_{st}). The result will be an estimate for diffuse fraction. Again, summarise for the PAR region as a single summary of diffuse fraction.

3. Geometries and Platforms

The basic setup is the standard and radiometer with readings taken either obliquely or from the zenith position. Oblique readings should always be with the sun to the left or right unless the BRDF is being measured.

When the target cannot be fitted into the traditional small low target formulation, the standard is a problem. That is, it is hard to ensure that the irradiance on the standard and the sun/standard/observer geometry for the standard are the same as the irradiance on the target and the sun/target/observer geometry for the target. In this case, paired radiometers are much better.

Readings should be taken of the irradiance ($V_{2\pi}$) at regular intervals and used to reference the radiance readings (V_t). The irradiance at the cherry picker may be satisfactory or may not. The situation must be judged at the time. The K factor can either be a 'library' value or computed from some readings of target radiance and irradiance at the same time when you are not on the cherry picker etc.

From helicopters, you can either get the pilot to land occasionally to get irradiance readings or else find a good reference target like asphalt or concrete (eg a runway) which the helicopter can visit occasionally and read without landing. People have used a large sheet of canvas for this away from good targets. Since the normal mode may be vertical readings from a helicopter note that vertical K factors may be needed as the K factor can depend on view geometry. This happens as few standards are really Lambertian. The reflectance of the 'standard' road, runway or apron etc. should be obtained using the standard in the normal way at the same time of day on another occasion (before it rains!).

4. BRDF

If BRDF is needed, then the best strategy is to use a standard or K factor as now but to measure at least 5 positions. They are near the hotspot (near sun zenith but out of shadow and and sun behind), the two sun left and sun right positions again (but at sun zenith), and the dark point (sun zenith and sun in front) plus the reading from the zenith (vertical view).

BRDF from a helicopter or cherry picker is the same but the cherry picker is slow and hard compared with the helicopter. You will need sun plots or tables to locate sun position for time of day. It is more accurate than eye ball on a moving target.

Note that the thermal also has a BDRF so that there is a hotspot effect too.

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