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A community approach to the standardised validation of surface reflectance data

A technical handbook to support the collection of field reflectance data

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Important disclaimer

This technical handbook is to be treated as a live, draft document. New releases will be made periodically as the work contained continues and methods are modified.

Cover plate : CSIRO's Matt Paget in a reflective mood during the 2009 Landsat validation program at Lake Frome, South Australia. Photo supplied by G. Byrne

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26/3/2018 v14(gtb)	Peter Fearns	Various people have contributed bits and bobs to create what we now call V14(gtb)
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11/07/2018	Tim Malthus	Updated with new field recording forms
30/09/2018	Tim Malthus	Fully revised version following external review and outcomes of workshop held 16-17 August 2018 allowing a review of some of the lessons learned.

Table of contents

1 Purpose and use of the handbook

This handbook has been designed to support the systematic collection of *in situ* field spectroscopic data for the purposes of validation of surface reflectance satellite products across large regional scales such as across the continent of Australia.

The purpose of this handbook is to provide guidelines on the collection of data to ensure a high level of consistency between teams including the selection of specific sites for measurement and in the systematic collection of both site description data and of ground-level spectral radiance and reflectance measurements using field spectroradiometers.

The methods are designed to be pragmatic, straightforward and repeatable and should ensure consistency and enduring value in the data collected.

The data collected following the methods outlined here will be used, in the first instance, for the validation of, and quantification uncertainty associated with, the Digital Earth Australia (DEA) Surface Reflectance (SR) products (see Section 2, Introduction). These data will additionally form a valuable archive of measurements suitable for validation of similar reflectance products. It is envisaged that this work will be a critical building block in the establishment of a long-term approach to comprehensively monitor and quantify the accuracy and uncertainties of national/continental scale surface reflectance validation data.

This document also describes the process and method of archiving data to allow future users to extract reliable and relevant information, ensuring continued long-term effective use of legacy data.

At this stage the program is focussed on a relatively small number of sites. The intention is to periodically review sites adding new ones and removing others where appropriate. Longer term these will form a network of national validation reference sites. This handbook is a first step and is designed to build toward the development of a coordinated, long-term, national/continental scale approach to collecting invaluable data in support of Australian Earth Observation and Environmental Monitoring.

2 Rationale

Committee on Earth Observation Satellites (CEOS) **Analysis Ready Data for Land** (CARD4L) are defined as:

> *“satellite data that have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with a minimum of additional user effort and interoperability both through time and with other datasets” (http://eohandbook.com/ceos-ard/).*

CARD4L data lie at the heart of initiatives to establish “Data Cubes” of earth observation data to ensure that the preparation of such data are both fully accounted for and fully understood, subsequently making it easier for global satellite data users to develop applications with satellite data (e.g. https://www.opendatacube.org). For optical satellite data, the level of data that has been specified is surface reflectance, such as the DEA Surface Reflectance product. It is the validation of CARD4L data that this handbook primarily addresses.

Vicarious calibration and validation are among the few means we have to achieve independent verification of satellite surface reflectances and products and their uncertainties; they establish the link between the satellite products and measurements made on the ground (see box below for appropriate definitions). Without vicarious calibration uncertainties can only be derived from pre-launch and on-board sensor calibrations (e.g. Thome 2001). To enable for the verification of the reflectances and products, conventional ground-based observations are required using calibrated and traceable field instrumentation and associated methods. It is only when we can quantify the uncertainty of the data products using **validation** (the subject of this handbook), can we then develop improved algorithms to reduce the uncertainty (Malthus et al. 2014).

The definition of key terms used throughout this report*

- Calibration - The process of quantitatively defining the responses of a system to known, controlled signal inputs;
- Validation - The process of assessing, by independent means, the quality of the data products derived from the system outputs;
- Traceability - A property of a measurement result relating the result to a stated metrological reference through an unbroken chain of calibrations of a measuring system or comparisons, each contributing to the stated measurement uncertainty;
- Uncertainty - A parameter that characterises the dispersion of the quantity values that are being attributed to a measured mean, based on the information used;
- Vicarious Calibration - Vicarious calibration refers to techniques that make use of natural or artificial sites on the surface of the Earth for post[-launch] calibration of airborne or spaceborne sensors.

*As defined by the CEOS WGCV (CEOS, http://www.ceos.org; copied from Malthus et al. 2014).

Optical satellite sensors, such as the Landsat 8 (L8) Operational Land Imager (OLI) and similarly designed medium resolution sensors such as the MultiSpectral Instruments (MSI) on board the Sentinel-2 series satellites (S2a and S2b), are passive optical instruments measuring a combination of atmospheric and surface radiance at the top of the atmosphere (TOA) in discrete spectral bands across the ~400 – 2500 nm range. The surface radiance in each band is calibrated to absolute physical measurements of mW m^{-2} sr^{-1} nm^{-1}. In the case of DEA and other data cubes these TOA radiances are further processed to analysis ready surface reflectance data (Li et al. 2012, Lewis et al. 2017). Each spectral band of each satellite has a spectral response function (SRF); in order to take specific SRFs into account measurements of surface reflectance at each validation site need to be made using a high spectral resolution instrument.

The rationale for the approach taken in this handbook is thus to establish a repeatable, practical and traceable field validation procedure to achieve a lasting "infrastructure" for DEA SR validation and uncertainty. Key steps in the process include:

- The establishment of the calibration sites and associated infrastructure

- The methodology behind the field calibration itself
- The data processing and associated quality assurance and quality control
- The establishment of an ongoing and repeatable vicarious calibration program.

The delivery of accurate and precise surface radiance and reflectance data through the application of a repeatable field protocol is the goal of this project, the rationale for which is illustrated in Figure 1. Initially, the validation data will be acquired by field teams through regular visits to the field sites at the time of satellite overpasses. A longer term goal for this work will be for the provision of autonomously collected continuous data of surface radiance / reflectance, but such approaches will need to be undertaken with considerable accuracy. Methods can be both radiance-based (Milton et al. 2009) or reflectance-based (Thome 2001, Thome et al 2005). For this study we will be using radiance based methods.

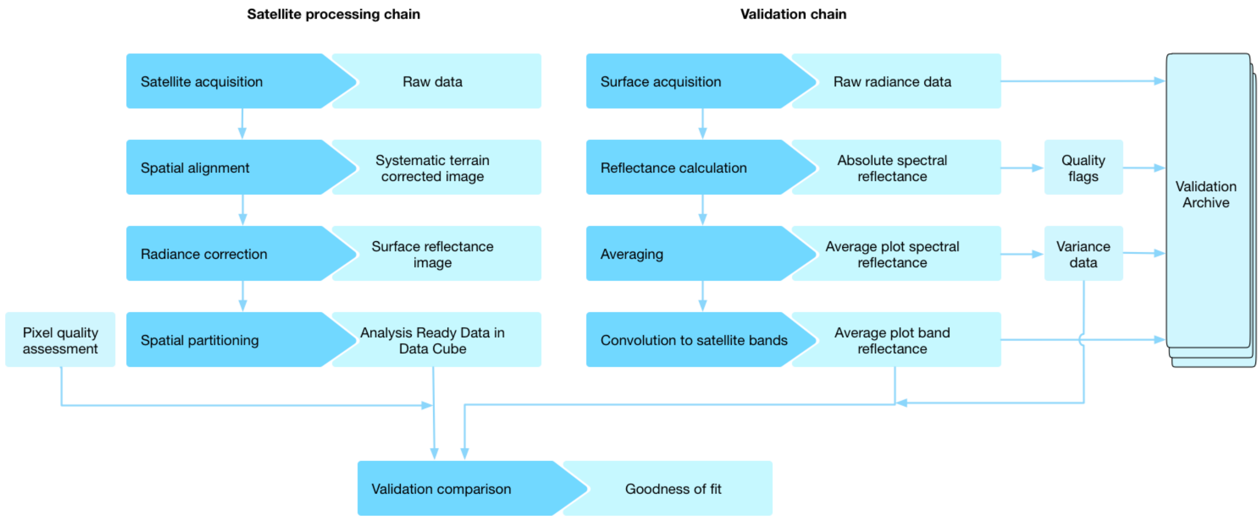


Figure 1 Diagram of to illustrate the role that field measurements play in the validation of Analysis Ready Data The left hand side of the diagram illustrates the satellite data process flow from raw data to Analysis Ready Data (summarised from Lewis et al. 2017). The right hand side shows the field data acquisition and data process flow.

3 Background

In May 2017, the Australian Government announced investment in the creation of Digital Earth Australia (DEA, Dhu *et al.* 2017). The DEA builds on the success of the Australian Geoscience Data Cube (AGDC, Lewis *et al.* 2017) and aims to provide open access for users across business, research and government organisations, to an analysis platform containing long-term and consistently processed satellite Earth Observation (EO) datasets for the Australian continent.

The DEA funding provides the opportunity to validate the products generated, and to characterise the uncertainty associated with those products. An important first step is to characterise the fitness for purpose of the fundamental **DEA standardised surface reflectance (SR) product** (http://geoscienceaustralia.github.io/digitalearthau/data/data.html).

Previous validation of the SR product was limited, with only a few historical surface reflectance datasets available, for example from Lake Frome (Jupp and Datt 2004), Gwydir (Li et al 2014) and TERN AusCover Facility campaigns (e.g. Johansen et al. 2015). With the DEA initiative, the opportunity now exists to develop a more tailored and representative SR validation program across a range of surface types and regions and to provide the opportunity to **initiate standardised datasets, best practice methods and protocols** in a national framework following the recommendations of the Australian EO Community Plan 2026 (AEOCCG 2016). However, achieving this will require the collaboration of a number of Australian agencies and institutions.

Thus, whilst the methods outlined here are intended initially to support validation of the DEA surface reflectance product, it is expected that the strategy will also serve as the basis for community-led validation of other optical EO products, not just those of DEA. The aim is to achieve a collaborative and coordinated approach to the validation effort that is based on best practice and serves as a model for a range of field validation activities.

In the context of this handbook, we refine the CEOS WGCV definition of **validation** to describe:

> *the acquisition of surface reflectance and associated supporting data to establish the quantitative accuracy of the DEA standard surface reflectance product as fitness for purpose guide to DEA users for its subsequent use.*

Rigour in this approach is driven by the establishment of common guidelines for site selection, sampling methodology (including metadata and spectral reference standards collected in the field), training, inter-calibration and traceability.

The information in this document has been assembled primarily to support validation of the Landsat 8 (L8) Operational Land Imager (OLI) and similarly designed medium resolution sensors such as the MultiSpectral Instruments (MSI) on board the Sentinel-2 series satellites (S2a and S2b) and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on board the Terra satellite. However, many of the techniques and methods of data measurement and archive described here are directly transferable to higher spatial resolution sensors as well as high spectral resolution (i.e. hyperspectral) remote sensing instruments (such as airborne and in the near-future satellite hyperspectral missions).

4 Site selection

Sixteen homogeneous, geographically dispersed validation sites representative of a range of brightness (reflectance) levels were identified and are listed in Table 1 and Table 2. Two aquatic sites are also included to provide reflectance measurements for homogeneous targets at low reflectance levels.

Success in the validation exercise, in terms of data quality and usefulness, depends on the careful consideration of site selection. Thus, for the purposes of this project, site selection was governed by a set of principles, which are further outlined here. Site selection was also influenced by a pragmatic approach to maximising data collection within the context of minimising cost, effort and logistical issues.

1. **Use existing sites where possible** including current vicarious calibration sites (such as Lake Lefroy and The Pinnacles) and, where appropriate, other sites drawn from other validation efforts (e.g. fractional cover validation; soil moisture validation programs). The use of existing sites leverages valuable past experience and builds on existing relationships with landholders to minimise delays caused by negotiating access, hence allowing deployments to take place earlier in the project. Previous spectral characterisation would be useful.
2. **Scale and homogeneity** - Validation sites should contain homogeneous features (at the L8 and Sentinel-2 pixel scales, 10 to 60 m) of a minimum of 180 x 180 m (3 x 3 pixel area at 60 m scale, 3.2 ha) in plot size within a larger homogeneous region (e.g. 5 ha). Where possible, the area surrounding the site should be homogeneous of at least a further 25 hectares to allow for positional errors and for validation of coarser resolution imagery (e.g. Visible Infrared Imaging Radiometer Suite, VIIRS, and Sentinel-3). Within the confines of them being 'natural' sites, sites should be as homogeneous as possible in terms of background colour and vegetation cover (if present) to minimise within-site variation such that field reflectance values measured are representative over the scale of several satellite pixels in the imagery to be validated. Most of the sites will, in the first instance, preferably have little to no vegetation to minimise bidirectional reflectance distribution function (BRDF) effects (although lack of vegetation does not completely remove BRDF issues). However, the inclusion of sites with homogenous vegetation such as grassland sites should also be considered. Agricultural crops should normally be avoided, although large ploughed or harvested (stubble) fields could be a useful opportunistic site measured on the way to or from a validation site (see Section 2.2).
3. **Site proximity** - To reduce adjacency effects, edges of the site should be at least 180 m from roads, powerlines or other features not characteristic of the surface to be measured and reflectance differences between the site and any surrounding background material should not be large.
4. **Site accessibility** - While meeting the other site selection criteria, preferred sites should be easily accessible (preferably close to validation team bases, driveable within a day, or within close proximity to major airports), within the financial limitations per field visit.
5. **Cloud cover and aerosols** - Cloud cover and frequency of cloud cover should be considered for long-term temporal suitability of the site (see below)[1]. Aerosol type is also important; the influence of aerosols should be a consideration but should not be used to restrict measurements to inland Australian sites only. Understanding the potential errors under higher aerosol conditions will be useful. Atmospheric compositions should be well characterised during acquisition – doing so helps assess the variety of atmospheric conditions tested and limitations of atmospheric compensation algorithms.

Potential resources for analysing annual variability in cloud cover are available on the Bureau of Meteorology web site.

[1] This project will evaluate cloud cover statistics for each site at the end of the first phase of the work in June 2018.

- The page “Average 9 am and 3 pm clouds” provides maps of 9 am and 3 pm averaged annual and monthly cloud distribution for Australia (http://www.bom.gov.au/jsp/ncc/climate_averages/cloud/index.jsp).
- The page “Climate statistics for Australian locations” provides detailed tables of monthly climate statistics, including clear days and cloudy days per month (http://www.bom.gov.au/climate/averages/tables/cw_070014_All.shtml).

4.1 Final list of sites selected

The tight timeframe in which this project was initiated and proposed required the prior selection of sites to maximise opportunities for site measurements. A decision was made to define **primary** and **secondary** sites to allow for a focussed effort to collect a high number of repeat measurements at the selected primary sites (Table 1 and Table 2). It is envisaged that a smaller set of ongoing semi-permanent revisit sites will be established (where permanent automated infrastructure will be available such as currently exists at Tumbarumba and Lucinda Jetty, and is in preparation at the Pinnacles). These will be augmented by a number of opportunistic sites chosen for their suitability and short excursion “quick response” locations. Data from these sites will form second tier validation data and are seen as useful both as a fall-back measurement if conditions at prime sites are less than optimal, and a means of ensuring greater value for money from the field excursions. The primary sites are indicated in Table 1 and secondary sites in Table 2, along with the shortened naming convention for the sites.

In addition to the key selection criteria above, additional factors that were used to select the primary sites consisted of:

1. Distance to the site for the site owners and associated instrumentation required;
2. Site access and local knowledge;
3. Geographic location of the site so that it forms a component of the overall aim of wide geographic coverage across the continent;
4. Cover type of the site so that it forms a component of the overall aim of a range of cover types across the continent;

For all the sites (primary and secondary), the priority for planning field measurements (besides good weather conditions) are as follows:

1. Where there will be concurrent L8 and S2a or S2b overpasses;
2. Where there will be consecutive L8 and S2a or S2b overpasses;
3. Where there will be a single L8, S2a or S2b overpass;

Frequency of acquisitions/measurements.

1) For the primary sites:

a. It is envisaged that these will be visited almost as frequently as there is a L8 or S2 satellite overpass, weather permitting, and can be done as a day trip. This will increase the number of measurements possible and reduce the cost associated with each measurement.
b. Where there are concurrent overpasses and the next day's conditions are conducive for measurements, all attempts will be made to acquire data from the concurrent day as well.
c. For each primary site we envisage a total of 4-5 measurements in the next 3 months.

2) For the secondary sites:
   a. As many of the primary sites are remote, logistically these sites are more difficult to visit frequently. It is envisaged that secondary sites will be visited once and at best twice. However, these sites are also important in the long term as they provide more comprehensive range of cover types, landscapes, geographic location and atmospheric conditions, etc.

Table 1. List of the primary SR product validation sites covering a range of brightnesses and geographical dispersion, with local teams and instrumentation included. (coordinates are in geographic Lat./Lon., Datum GDA 1994). The list is provisional and may change into the future.

SITE NAME	SITE ABBREVIATION	LATITUDE	LONGITUDE	RELATIVE BRIGHTNESS	LOCAL SITE COORDINATORS	INSTRUMENTATION	SITE PRINCIPLES SATISFIED	COMMENTS
Pinnacles, WA	PIN	-30.5905 S	115.1597 E	Bright 40% target	CSIRO WA, Cindy Ong and Ian Lau	ASD3, ASD4, MICROTOPS	Existing site, large, homogeneous, accessible, no vegetation, coastal aerosol, bright	Future automated vicarious calibration site
Lake George	LKG	-35.0141 S	149.3969 E	Flat, level, grassed site	GA, Guy Byrne	ASD4	Large, flat, homogeneous, accessible, low in vegetation, inland	GA scientific site
Dookie	DOK	-36.3881 S	145.7180 E	Grassed site	Uni Melbourne, Lola Saurez	ASD4 from UoW or ASD3 from CSIRO Clayton	Large, flat, homogeneous, accessible, grassed	
Blanchetown, SA	BLA	-34.3847 S	139.6003 E	Very dry (low rainfall), pretty sparse low grass and forbs	Uni Adelaide, Ken Clarke	ASD3		
Lake Lefroy, WA	LLF	-31.2622 S	121.7117 E	Bright 40% target	CSIRO WA, Cindy Ong and Ian Lau	ASD3, ASD4, MICROTOPS, CIMEL AeroSpan site	Existing site, large, flat, homogenous salt pan, no vegetation, inland aerosol, bright	
Fowler's Gap, NSW	FGR	-29.2681 S	142.0244 E	30% target, arid	Uni Adelaide, K Clarke	ASD3 CIMEL on site	Large, flat, homogenous, red soils, little vegetation, inland aerosol	UNSW Arid Zone Research Station, CIMEL AeroSpan site.
Winton, QLD	WIN	-22.5244 S	142.9350 E	Claypan surrounded by shrubs and grassland. Image area = 23,125 m^2	CSIRO Brisbane, Tim Malthus UQ/JRSC, Peter Scarth & Stuart Phinn	ASD, MICROTOPS	Previous validation site (De Vries et al. 2007), large, flat, homogenous, bare soil, inland aerosol	Accessible by air from Brisbane via Longreach
Warrabin, QLD	WAR	-26.2833 S	143.6542 E	Claypan surrounded by grassland and ironstone areas, Image area = 44,375 m^2	CSIRO Brisbane, Tim Malthus UQ/JRSC, Peter Scarth & Stuart Phinn	ASD, MICROTOPS	Previous validation site (De Vries et al. 2007), large, flat, homogenous, bare soil, inland aerosol	Less accessible by air
Mitchell Downs / Longreach, QLD	MDN	-23.5233 S	144.3104 E	Grassland site	CSIRO Brisbane, Tim Malthus UQ/JRSC, Peter Scarth & Stuart Phinn		Recently etablished TERN Supersite (flux tower), large, flat, homogenous, grassland, inland aerosol	
Lake Hume	LHU	-36.1178 S	147.0358 E	Low reflectance site, aquatic	CSIRO Canberra, Janet Anstee	ASD, MICROTOPS	Large, homogeneous dark target, inland aerosol, accessible from Canberra	
Lucinda Jetty	LUC	-18.5197 S	146.3861 E	Low reflectance site, aquatic	CSIRO Brisbane, Tim Malthus	Instrumented site	Existing coastal ocean colour validation site, large, dark target, coastal aerosol	Automated site, accessible. (seaprism/CIMEL on site)
Tumbarumba, NSW (dark site)	TUM	-35.7606 S	148.0703 E	Dark site vegetation site	CSIRO Canberra, Will Woodgate	Not required as the site is automated	Existing TERN supersite, large, homogeneous, forested, accessible from Canberra	Existing TERN supersite with automated VNIR reflectance

measurement. Requires CIMEL installation

Table 2. List of the secondary SR product validation sites covering a range of brightnesses and geographical dispersion, with local teams and instrumentation included. (coordinates are in geographic Lat./Lon., Datum GDA 1994). The list is provisional and may change into the future.

SITE NAME	SITE ABBREVIATION	LATITUDE	LONGITUDE	RELATIVE BRIGHTNESS	LOCAL SITE COORDINATORS	INSTRUMENTATION	SITE PRINCIPLES SATISFIED	COMMENTS
Dharawal Nature Reserve, NSW	DWH	-34.2509 S	150.9265 S	Low vegetation sites	Uni Wollongong, Laurie Chisolm	ASD4	Large, flat, relatively homogeneous, accessible to Wollongong	Heathland site of mixed species (*Banksia oblongifolia Hakea teretifolia Xanthorrhoea resinifera*)
Narrabundah Oval, ACT	NRB	35.3334 S	149.1459 E	Grassed sports oval	GA, Guy Byrne		Large, flat, homogeneous, accessible to GA	
Litchfield, NT	LCH	-13.1805 S	130.7895 E	Forested savanna site	Maitec, Stefan Maier		Existing TERN supersite, large, flat, homogeneous, forested savanna, accessible from Darwin.	UAV acquisition test site
JF O'Grady Memorial Park, QLD	JFO	-27.5067 S	153.0232 E	Grassed sports ground	CSIRO Brisbane, Tim Malthus		Accessible to Brisbane teams, flat, homogeneous grassed site, coastal aerosol	Approx 150 x 130 m in size

4.2 Site access

If a potential site is located on private land and access needs to be organised extra time must be allowed for to identify and contact the landholder, and if needs be arrange for a face to face meeting to discuss the sampling protocol and issues of access. Land holders are often happy to permit access for this sort of work provided they have sufficient detail and notice; this investment of time to create a good relationship can be well worth it in the long run.

4.3 Use of imagery to select and locate potential measurement sites

Prior to the initial site visit, visual inspection of high resolution satellite imagery (e.g. as available in Google Maps and Google Earth) is useful to assess scale, homogeneity and access criteria to help pinpoint the best locations at which to perform the reflectance measurements. Further, site selection can be informed by an analysis of homogeneity and 'pseudo-invariance' of reflectance over time using the multi-temporal data available within the DEA data cube itself or similar datasets.

For example, the Pinnacles site was selected after assessment of the temporal and spatial variation using a 10-year archive of Landsat TM data (Figure 2) and compositional variations determined using historical ASTER data (Figure 3).

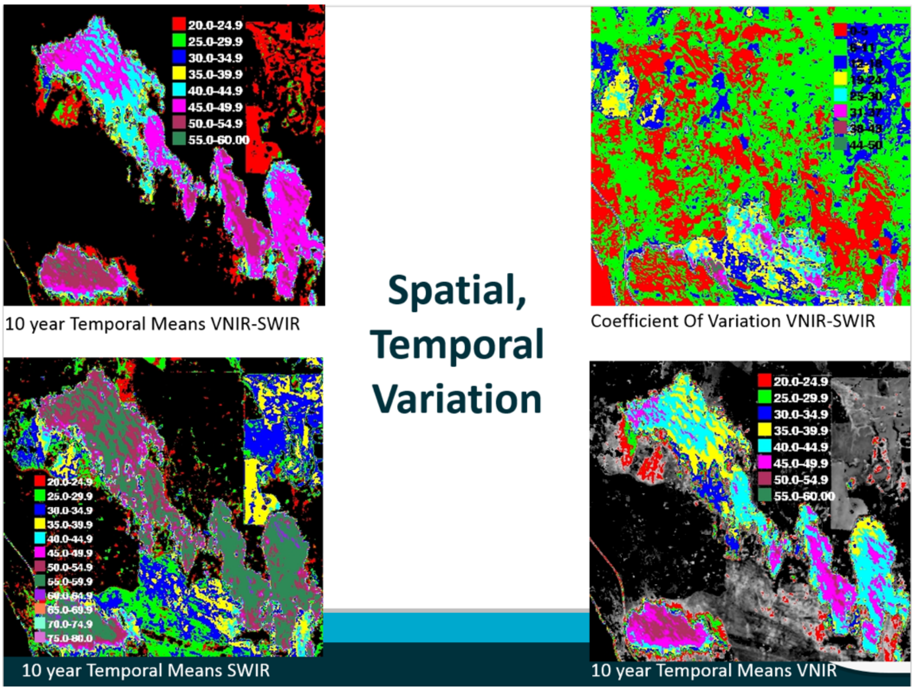


Figure 2 Spatial and temporal variation of Pinnacles site determined from Landsat TM archive data (Ong et al. 2017).

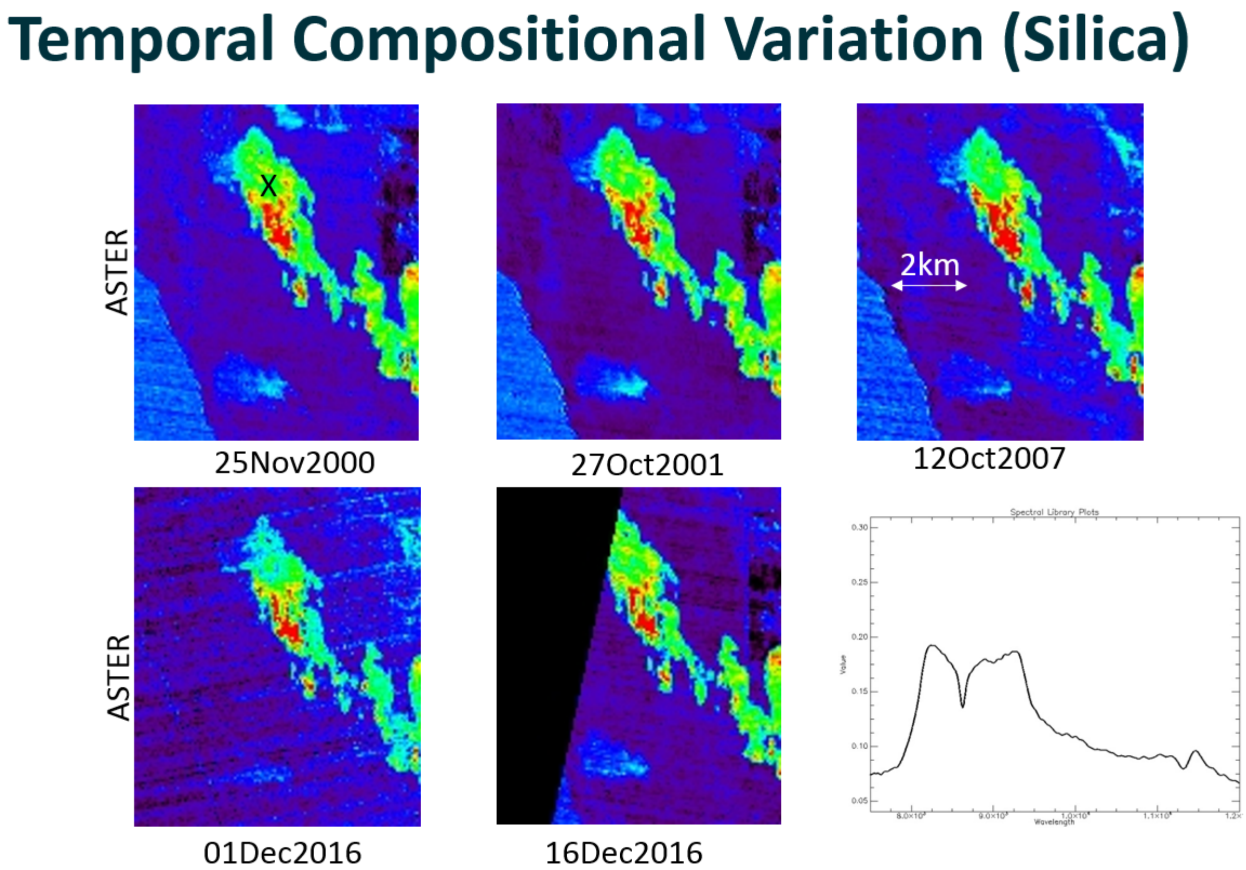


Figure 3 Temporal compositional variations of the Pinnacles site determined using ASTER data (Ong et al. 2017).

4.4 Timing of field data collection

Measurement of surface reflectance is required to be undertaken simultaneous to the overpass of the L8 OLI or Sentinel 2 MSI sensors. Tools exist for the calculation of Landsat/Sentinel overpass times. Overpass schedules for each field site will be calculated and distributed to each field team.

The USGS L8 USGS Acquisition Calendar web site allows search and display of Landsat 8 orbits (https://landsat.usgs.gov/landsat-8-acquisition-calendar). Users must be careful with interpreting orbit information at the boundaries of UTC days.

Tables of satellite overpass times can be produced using the N2YO web interface (http://www.n2yo.com/). It is advisable to cross check UTC and local time results; inconsistencies have been observed. Another site that produces tables of satellite overpass times is Heavens Above (http://www.heavens-above.com/). All tables are produced in local time, but the results appear more accurate than the N2YO site.

The intent is to target days where the potential for adverse effects of cloud are minimised. A number of on-line resources are available that provide cloud observations and cloud cover predictions, including:

- http://philhart.com/content/cloud-forecasts-australian-astronomers. General background and discussion on cloud observations and predictions written for astronomers but very relevant for remote sensing.

- https://www.yr.no. This site provides detailed predictions of cloud cover at hourly resolution, as well as longer term predictions at 6 hourly resolution. Maps of cloud cover can also be displayed.
- https://www.windy.com/, via the Clouds tab. A well designed intuitive interface supports real time displays of projected winds, cloud and rainfall out to 8 days ahead. Clicking on a location gives summary statistics for that locality. Forecasts of airflow and percentage cloud cover have proved reliable in recent uses of the tool to assess the potential for field visits (Figure 4).

Figure 4 Example taken from windy.com to show forecast cloud cover for satellite overpass at Lake George validation site 10th April 2018.

- http://www.skippysky.com.au/Australia/ and http://www.cloudfreenight.com/. Users can access cloud cover predictions in increments of 3 hours ranging from +6 to +120 hours.
- https://darksky.net/ This site provides detailed cloud prediction maps and tables. Users can also interact with the site using the DarkSky API to access 1 week of hourly forecast data programmatically (Figure 5).
- http://satview.bom.gov.au/. The Himawari satellite produces observations of the Earth at 10 minute intervals. These images are very useful to provide a regional view of the cloud distribution in near real time.

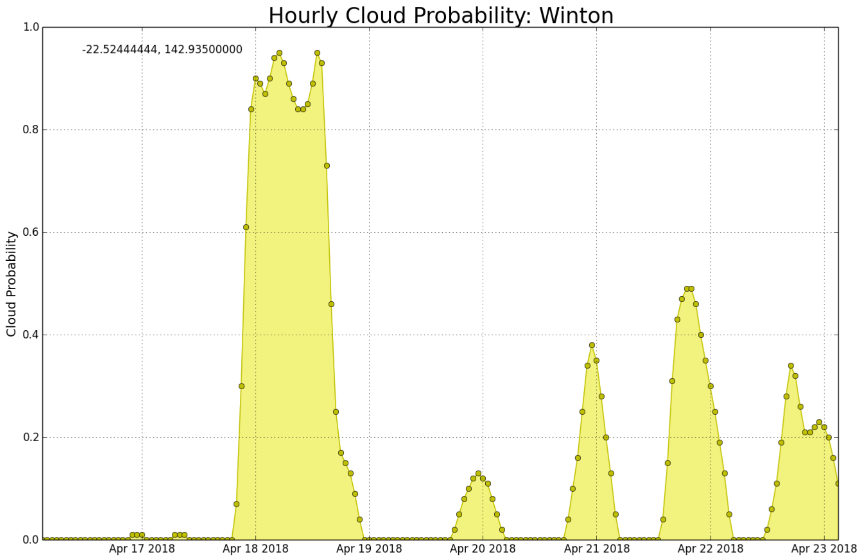


Figure 5 Example of cloud cover forecast from darksky.net to show cloud cover outlook for the Winton validation site in mid April 2018.

The go/no-go decision for a field campaign is primarily decided on the likelihood of cloud cover. However, it is difficult to specify a definitive threshold value for predicted cloud cover that should be applied. The extent of the cloud cover prior to the satellite overpass, the expected duration of cloud or clear sky, and the predicted cloud cover in the vicinity are all factors that need to be considered. Also, rainfall is often associated with cloud, so the likelihood of rainfall affecting the surface measurements is also important. Damp soil may not be an issue, but waterlogged patches or puddles may severely change the spatial variability in surface reflectance. Long term experience with a site helps inform this decision; having a 'local' point of contact to phone on the day is also invaluable.

The field campaign for this project is scheduled to run from mid-March 2018 to mid 2019. During this period the maximum solar elevation will decrease gradually, but will not capture the full range of solar geometries representative of a whole year[2]. Notwithstanding the fact that we are undertaking less than a full annual cycle, the intention of this work is to capture reflectance data that includes variations in sun angle and, in some cases where vegetation is present, in phenology.

Temporal revisits: Although repeated visits to sites are necessary and are important for developing an ongoing reflectance seasonal/phenological record, the frequency of visits will be dependent mainly on weather conditions. In this first instance we are aiming for 2 revisits where optimal data are acquired in the first round to refine the method. The aim is to minimise deployments where data acquisition may not be possible due to cloud cover, etc. Sites that are relatively close to validation team bases would best facilitate rescheduling at short notice should a planned visit need to be postponed. Additionally, there are options for a third visit to some sites.

[2] Validation sites situated in satellite overlap regions will be dealt with in a later edition of this report

5 Field measurement methodology

This section outlines the method and equipment needed for collecting the field measurements.

The minimum amount of equipment needed for the collection of field spectral data and the characterisation of the site is outlined below. On top of these essential items, there are important equipment that would improve the reliability of the data collected, or reduce the uncertainty of the data. In addition, there are items of equipment which may help to ease the data collection.

5.1 Field spectroscopy: some recommended reading

While this handbook deals with the practical steps of obtaining high quality field spectral data it is important that anyone intending to undertake a field program be cognisant of the radiative physics, nomenclature and measurement issues associated. It is relatively easy to get good field spectra – and easier still to get bad spectra.

CRCSI (2017) contains a concise, readable and fundamental description of the interactions between electromagnetic radiation within the atmosphere and between target and sensor systems. Milton et al. (2009) describe the history of field spectroscopy and provide a good summary of the often confused terminology of reflectance measurement. Finally, while detailing best practise in field radiometry, Hueni et al. (2017) emphasise the difficulties and uncertainties posed by field spectroscopy and the value and constraints it brings to earth observation validation.

5.2 Required field equipment

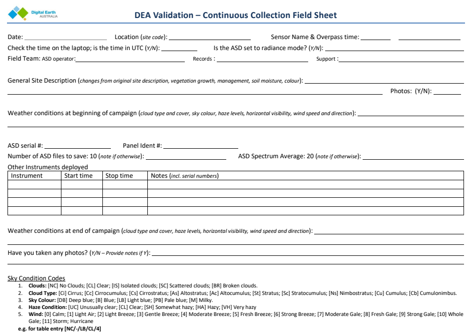
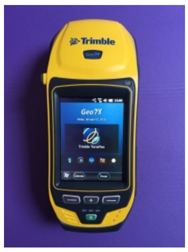
A check list of the field equipment can be found in Appendix A2. The items required have been split into essential and highly desirable.

Essential equipment

Spectroradiometer (recently wavelength checked and radiometrically calibrated) with Visible, Near Infrared (VNIR)-Shortwave Infrared (SWIR) wavelength range, such as an Analytical Spectral Devices (ASD) FieldSpec Pro, with spare battery	
Pistol grip for optical fibre with 8 degree foreoptic	

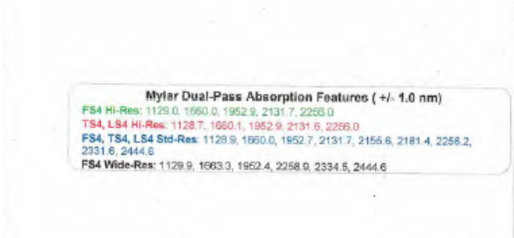
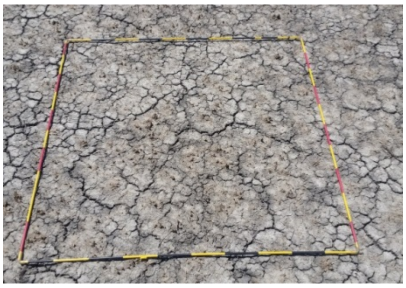
Remote Cosine Receptor (RCR) foreoptic	
Boom pole (or monopod) for spectrometer head/pistol grip with spirit level to indicate horizontal positioning	
Minimum **10 inch (24.5 cm)** square Spectralon[†] reflectance panel (recently calibrated) and levelling tripod	
Method for levelling panel (spirit level, that does not touch the Spectralon part of panel)	
Bluetooth or hard wired GPS to spectrometer/controller	
Portable sunphotometer, such as the MicroTops II sunphotometer (https://solarlight.com/product/microtops-ii-sunphotometer/).	

[†] https://www.labsphere.com/labsphere-products-solutions/materials-coatings-2/targets-standards/test-child/

Flags or pegs for marking corner points and transects. Coloured markers such as sand bags can be used where the surface is hard[+]	 
Note taking equipment and logging sheets (see Appendix A3)	 Digital Earth AUSTRALIA **DEA Validation – Continuous Collection Field Sheet** Date: ___ Location (*site code*): ___ Sensor Name & Overpass time: ___ Check the time on the laptop; is the time in UTC (*Y/N*): ___ Is the ASD set to radiance mode? (*Y/N*): ___ Field Team: ASD operator: ___ Records : ___ Support : ___ General Site Description (*changes from original site description, vegetation growth, management, soil moisture, colour*): ___ Photos: (Y/N): ___ Weather conditions at beginning of campaign (*cloud type and cover, sky colour, haze levels, horizontal visibility, wind speed and direction*): ___ ASD serial #: ___ Panel Ident #: ___ Number of ASD files to save: 10 (*note if otherwise*): ___ ASD Spectrum Average: 20 (*note if otherwise*): ___ Other Instruments deployed Instrument | Start time | Stop time | Notes (*incl. serial numbers*) Weather conditions at end of campaign (*cloud type and cover, haze levels, horizontal visibility, wind speed and direction*): ___ Have you taken any photos? (*Y/N – Provide notes if Y*): ___ Sky Condition Codes 1. **Clouds:** [NC] No Clouds; [CL] Clear; [IS] Isolated clouds; [SC] Scattered clouds; [BR] Broken clouds. 2. **Cloud Type:** [Ci] Cirrus; [Cc] Cirrocumulus; [Cs] Cirrostratus; [As] Altostratus; [Ac] Altocumulus; [St] Stratus; [Sc] Stratocumulus; [Ns] Nimbostratus; [Cu] Cumulus; [Cb] Cumulonimbus. 3. **Sky Colour:** [DB] Deep blue; [B] Blue; [LB] Light blue; [PB] Pale blue; [M] Milky. 4. **Haze Condition:** [UC] Unusually clear; [CL] Clear; [SH] Somewhat hazy; [HA] Hazy; [VH] Very hazy 5. **Wind:** [0] Calm; [1] Light Air; [2] Light Breeze; [3] Gentle Breeze; [4] Moderate Breeze; [5] Fresh Breeze; [6] Strong Breeze; [7] Moderate Gale; [8] Fresh Gale; [9] Strong Gale; [10] Whole Gale; [11] Storm; Hurricane **e.g. for table entry [NC/-/LB/CL/4]**
Camera for sky and site photos	
Global positioning system (GPS) (+/- compass)	
100 m measuring tape	

[+] Available for purchase from https://prospectors.com.au

Highly desirable equipment

Mylar sheet for collecting wavelength calibration data	
Temperature, humidity, barometer (calibrated) with logging capability (the MicroTops sunphotometer has these sensors, but will not log the data unless continuous measurements are collected)	
Fisheye sky camera or 360 degree camera	
Dust blower (handheld bulb type, like ones used for cameras)	
Square metre quadrat for taking standard photos of surface cover	
Small bottle of demineralised water for rinsing off the reflectance panel should it get dusty or dirty	
Sun disk for taking diffuse and direct irradiance measurements (see Appendix A6)	

Photometer/radiometer/lux meter with logging capability and ability to mount it level and stable. An example is an Irradian (Macam) L203 photometer (http://www.irradian.co.uk/products/view/4)	
Laser distance meter/rangefinder	
Compass (if GPS compass is not functional)	
2 axis gimbal mount for the ASD pistol grip	
Kestrel weather meter (includes temperature, humidity, pressure, wind speed and direction)	
Additional tripods, for deploying MicroTops, photometer and weather meters	

5.3 Site description

Protocol for site description follows those outlined in Muir et al. (2011) (Table 3). An example of the site description and field data collection forms can be found in Appendix A3.

Table 3 Key characteristics for the description of the site.

SITE DESCRIPTOR	DEFINITION
Location description	Description of the general location of the site
Basic site description	A general description of the main attributes of the site
Site identifier	A unique reference identifier (ID) for the site given as two or three letters for state abbreviation, and three digits for site number (STATEsitenumber)
Revisit	Number to indicate the n^{th} visit to the site.
Field observers	Names of those undertaking the field measurements
Date	
Time	

Position	The geographical position of the centre of the site as measured with a global positioning system (GPS), recorded in Lat/Long, Geodatum GDA94.
Orientation	Principle orientation bearing of the transect collection
Slope and aspect	Slope in percentage, aspect in degrees
Land use	Predominant land use on the site
Plant growth stage	If present, and indicate predominant plant type/species
Management phase	e.g. none, semi-natural, abandoned, cultivated, grazed, burnt, other
Site photos	Take numerous photos of the surface from a number of angles, record the photo numbers
Field spectra collected	Index numbers for the full set of spectra recorded
Vegetation description	Height, type, cover percentage, evidence of fire
Soil description	Basic soil colour and type. Evidence of erosion (water/wind), deposited materials, microrelief, cryptogams cover and colour. Evidence of soil moisture, condition of soil, rock colour, abundance and size

5.4 Reflectance collection method

Setting up of transects

The transects need to be orientated to maximise the collection of pixels and to some degree to avoid sampling within the illumination specular point. As most satellite systems are push broom and have a path that is not directly north-south, the orientation and length of the transects is important. Landsat orientation is approximately 8.2 degrees, and Sentinel 2 satellites are 8.5 degrees.

What is outlined here is the **suggested minimum layout and transect coverage**; if time and weather conditions allow further transects may be obtained both beyond and in between the existing transect lines. As the field teams become more experienced more transects can be undertaken.

As a minimum the transects should be twice the length of a pixel and should cover an area that collects over three pixels. Therefore, the minimum transect would be 60 metres long and cover an area of 90 metres wide, but preferably wider. However, for simplicity and to be consistent for this work, each transect should be **100 metres in length** and there should be a total of **6 transects at 20 metres apart**. Therefore, an area of 100 x 100 m is covered.

Marking out of the transects is aided by the use of flags (Figure 6, Figure 7). Multiple flags can be placed at the start and end of the transects to denote what number transect it is (i.e. 1 flag for the first transect, 2 flags for the second etc.). Flags should be placed along the transect to assist the spectrometer operator with keeping a straight path and for assisting with timing of the collection of the spectra. A tape measure is useful for this purpose. It has been found that spacing of 20 metres is approximately the distance needed for a moving acquisition of 10 spectra (with an average of 20).

The location of the panel should be designated as the transects are being constructed. For example, the panel could be set up on the southern edge of the area between transects 1 and 2. It could be moved while transect 2 is being collected to between transects 3 and 4 and then while transect 4 is being measured, it is moved between 4 and 5. Issues with panel placement and measurement are further discussed below.

Figure 6 Putting out the flags for the transects. For a 100 m transect, flags should be positioned at the start and end, and every 20 metres along the transect. The number of flags at the start and end can signify the transect number.

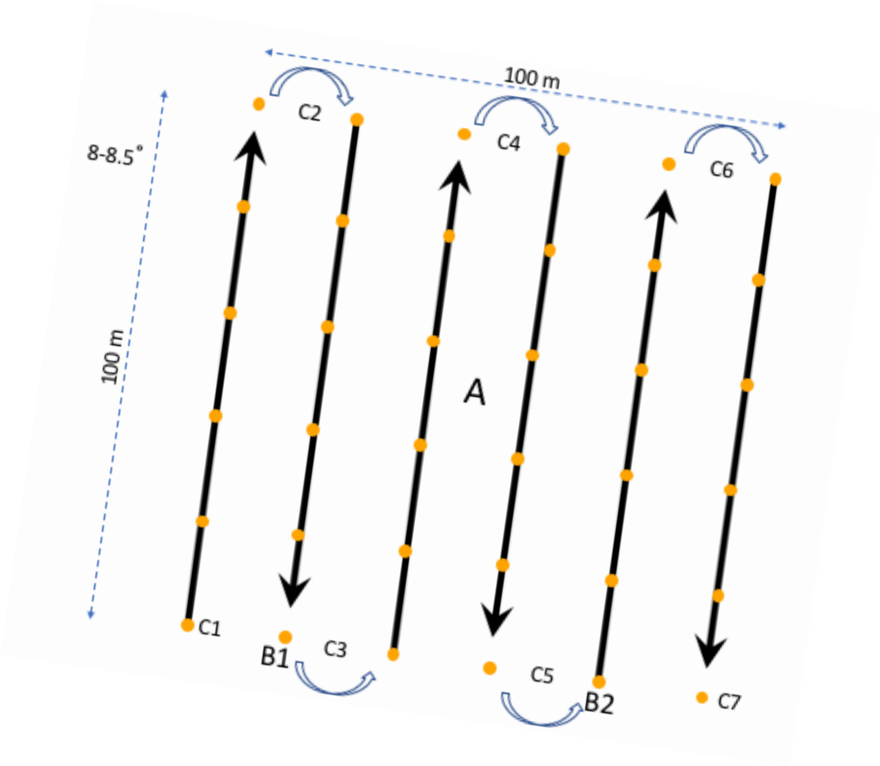


Figure 7 Example of the layout of the 6 x 100 m transects, with transects spaced 20 m apart and flags or other markers spaced 20 m apart along each transect as indicated by orange dots. Depending on the site conditions, the white Spectralon panel can 1) remain at A, or 2) be moved once, from B1 to B2, or 3) be moved for every transect from C1 to C7.

Warming of the spectroradiometer

Traditionally, it is stated in instrument manuals that spectroradiometers should be warmed up before operation. Time for warm up varies between 15 to 30 minutes to 1 hour for different instruments and age of manuals. New research and findings from long-term operation by expert users has found that the detectors are known to drift considerably with different internal temperatures. The time for the drift to settle down is much longer than what could be expected for field use. The change in temperatures of a spectroradiometer from transport to operation in the field may also induce variation. From these findings it can be assumed that the radiometric calibration supplied by spectroradiometer manufacturers may only be valid for certain instrument temperatures, as the manufacturers state it is warmed up for an hour before measurement of a calibration standard. Therefore, it is not completely clear if a long warm up time is greatly beneficial, but a warm up of **at least 15 minutes** will show an improvement in instrument stability. Older instruments may have difficulty cooling the detectors in extremely hot weather conditions, and may require strict timing of warm up and measurement. It is useful to have a spectroradiometer spare battery, one used for warm up, one used for field collection.

An 8 degree foreoptic is to be used for the measurements. When held at 1 metre above the surface it provides an approximately 0.14 m diameter sampling area. The foreoptic is to be held at nadir. This small FOV means only a small area is measured.

Spectroradiometer settings

The spectroradiometer (ASD) should be set up with the following settings:

- Dark current (if a VNIR shutter is present): 20
- Spectrum averaging: 20
- Radiance mode
- Number of files to save: 10
- Time between saves: 0 sec
- New file format
- Mode: Radiance
- Time on the laptop controller should be set to UTC
- GPS should be activated
- Fore optic set to 8 degrees

With the 10 spectra saved per space bar push (or remote trigger if used) the operator should be able to cover 20 metres during the reflectance acquisition. Therefore 5 pushes of the spacebar/remote trigger are needed per 100m transect. Thus, the 20 m spaced flags along a transect help the operator time their walking speed.

Spectroradiometer optimisation/calibration

Optimisation of the spectroradiometer is required at the start of the measurements. This must be done as close in time as possible to the collection of data. To account for changing solar conditions, **at the start of each transect, a re-optimisation of the spectrometer needs to be performed**.

Dark current

Newer ASD instruments have been manufactured without a shutter for the VNIR spectrometer. The two SWIR detectors still use data from the beginning and end of the internal moving optics that are outside the view of the fibre optic bundle to establish the dark current correction. The shutter was found to be a potential point of failure on the instruments and a dark current calculation was created to concur with the shutter removal. ASD documentation states that the VNIR dark current is 'stable' and that a table can be used for the dark current values for different integration times. To compensate for the removed shutter there is now a software program on the spectrometer controller called dark current calibration (version 1.2 currently available from ASD web page) which generates a (ASD serial number) darkcurrent.ini file. The file contains the dark current values for 5 integration times. It is stated in the ASD documentation that under extreme environmental conditions it may be 'desirable' to create a new dark current table using the software. A cap should be placed on the end of the fibre tip for these measurements. An example of the data in the .ini file is shown in Figure 8.

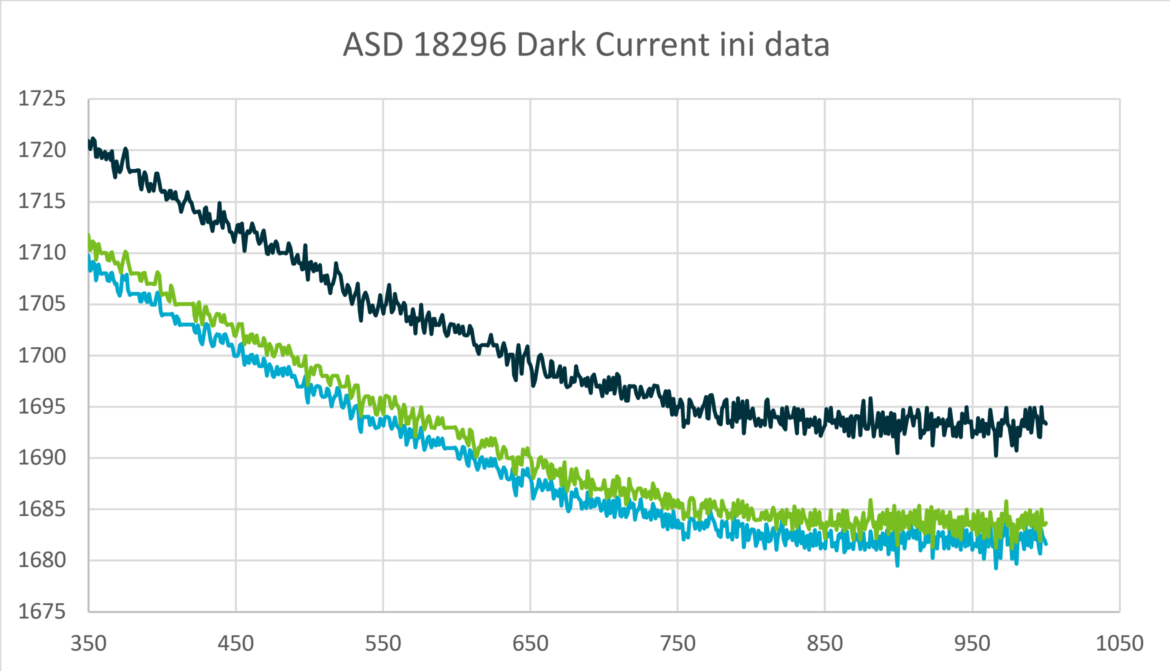


Figure 8 Example of the data in a dark current .ini file showing the different dark current values for various integration times. The y axis is digital numbers and the x axis is wavelength.

Wavelength tracking using a Mylar sheet

As a field check of the instrument's wavelength calibration, collect wavelength reference spectra at the beginning and end of the field excursion. A sheet of Mylar (containing fixed wavelength absorption features) should have been included in the ASD standard equipment. The Mylar sheet can be used to project a shadow onto the Spectralon sheet (Figure 9), or it can be placed in front of the foreoptic (Figure 10).

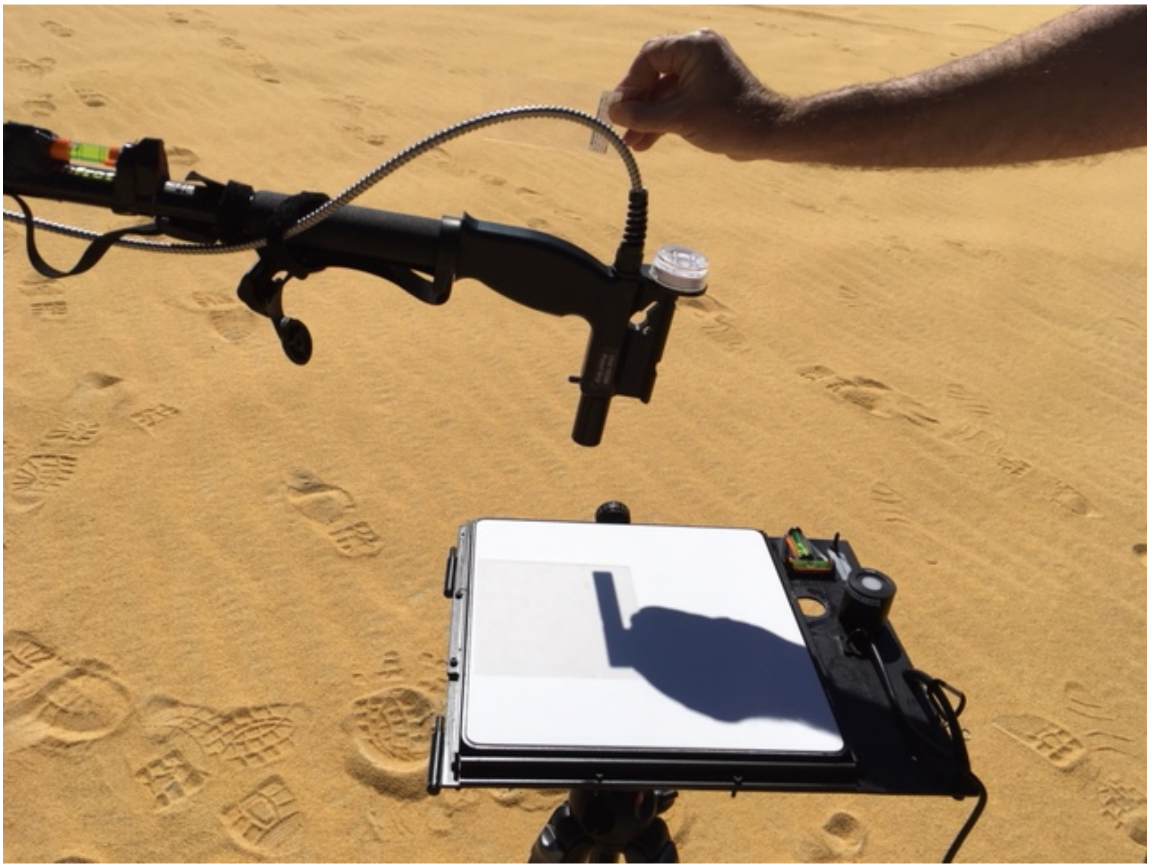


Figure 9 Projecting a shadow onto the Spectralon using the Mylar wavelength reference.

Figure 10 Measuring the Spectralon through the Mylar wavelength reference.

Setting up of the Spectralon reference panel

Larger panels are ideal (i.e. 500 x 500 mm) but are very expensive. Thus a **250 x 250 mm panel** should be the minimum size used in this validation exercise.

DO NOT TOUCH THE PANEL SURFACE. The Spectralon panel should be clean and free of dirt, dust and visible marks. Ideally, it should not have any damage to the surface, such as deep scratches or indentations, which will cause shadowing. The panel should not have a shiny surface when viewed from a low angle, which would indicate that the panel surface is not as Lambertian as when it was manufactured and calibrated. When the panel is not in immediate use, it should be covered; this greatly reduces its exposure to the sun and air and its subsequent degradation.

The reflectance characteristic of the Spectralon panel and its factory calibration should be known. If the panel has been in use for a long period of time, its reflectance characteristics should be remeasured in the calibration laboratory. Extra information about the care of the panel can be found in the Appendix A4.

A marking should be made on the frame of the panel to assist with orientation. Traditionally, Spectralon panels from LabSphere (https://www.labsphere.com/) have a piece screwed on the bottom to allow the panel to be mounted vertically. This can be used as the marker for orientation towards the sun. Thus, in the southern hemisphere, this side of the panel should point towards the north/sun.

The panel needs to be mounted so that it is orientated towards the sun and is completely level (horizontal). Figure 11 shows calculated changes in measured irradiance for a 1 degree tilt in the panel from horizontal.

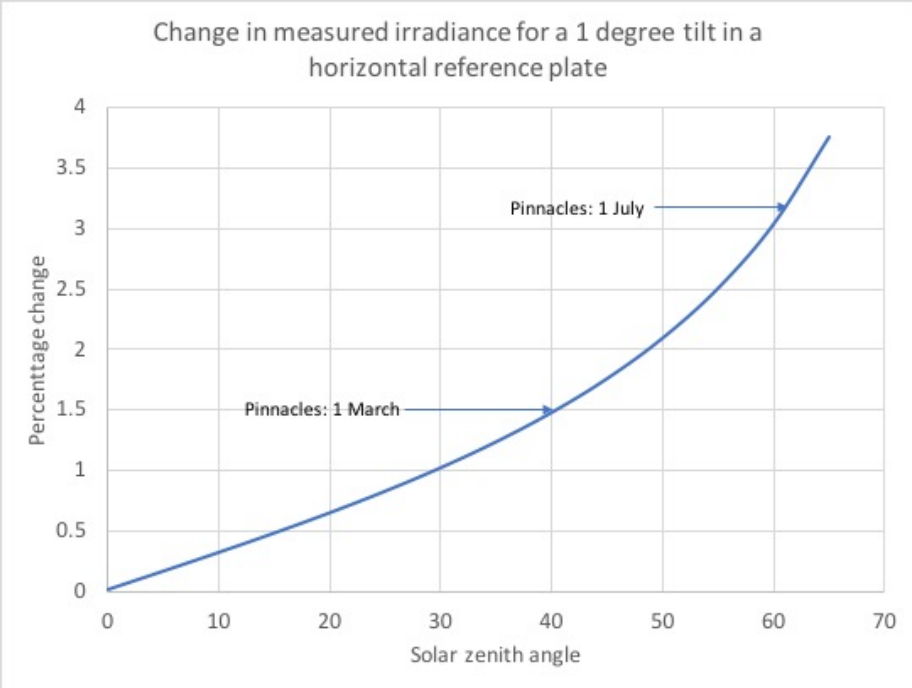


Figure 11 Calculated change in measured irradiance for a change of 1 degree in tilt of the reference panel from the horizontal. The impact increases as the sun moves further from the zenith.

The mounting must be stable to not allow the panel to tip over and be damaged. A bracket can be manufactured which allows the stable deployment and easy adjustment of the panel on a sturdy tripod (Figure 12). The bracket should incorporate a bubble level to ensure it is horizontal and a short pin to maintain orientation with respect to the sun.

A panel should not be placed at ground level, due to the increased likelihood of contamination from dust and debris from footsteps and the prevailing wind. However, even a panel placed on a high platform may not prevent wind-blown material affecting it if the wind is strong enough.

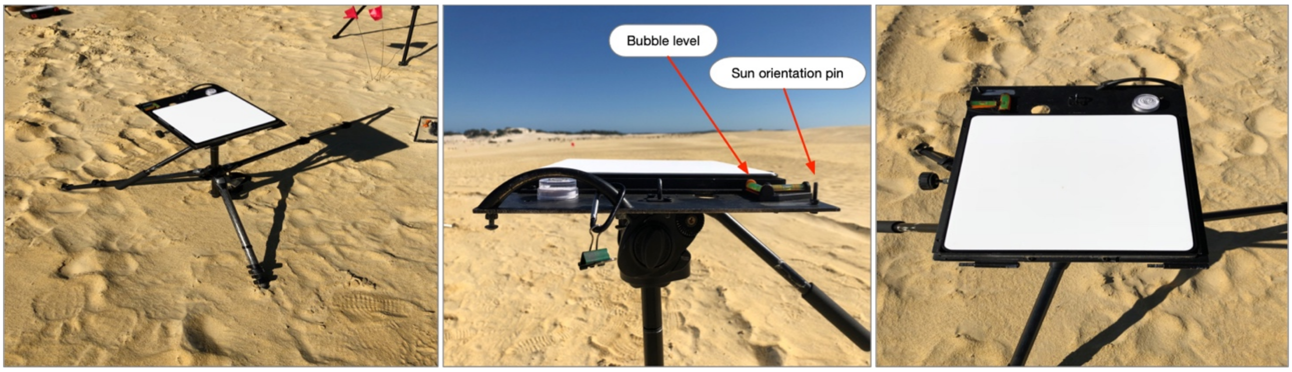


Figure 12 Levelled Spectralon panel (note horizon and bubbles), orientated to look directly at the sun.

Reference panel measurement

Measurement of the reference panel (including saving of the panel measurement) is to made **before and after** each transect/series of point measurements (i.e. each transect is 'book-ended' by a set of panel measurements). Re-optimisation should be conducted each time before the panel measurement is made at the start of a new transect. Measurements of the panel should be conducted with the operator facing the sun and standing alongside the panel (i.e. to the east or west of the panel) as shown in Figure 13.

Figure 13 Operator measuring the panel while the spotter checks the level and if the fore optic is centred over the panel. Note the bubble/level on the boom pole near the operator's hand.

The FOV should be considered when setting the **height** of the foreoptic from the panel. For example, a 25 degree FOV will start to capture the edges of a 250 x 250 mm panel at a height of 563 mm, and an 8 degree FOV will capture a 250 x 250 mm panel edge at 1.787 m. If held at waist height over a panel suspended on a tripod the height of the FOV over the panel may be ~0.5 m which equates to a 7 cm diameter field of view on the panel. It is important that the reading is from the centre of the panel.

The head of the spectroradiometer (i.e. foreoptic) should be level and pointed directly downward (**nadir**), as shown in Figure 14. Booms or tripod holders can be used, but must not shadow the panel or impede on the field of view (FOV) of the spectrometer. The use of levels and bubbles is recommended, as well as a second operator to spot the person holding the foreoptic (as shown in Figure 13).

Figure 14 A close up of the ASD fore optic boom pole with the bubble level, showing that the boom needs to be raised slightly to be level.

An example of how not to measure is shown in Figure 15, where the panel is not aligned, the operator is standing in the wrong place and the pistol grip and foreoptic is reflecting onto the panel.

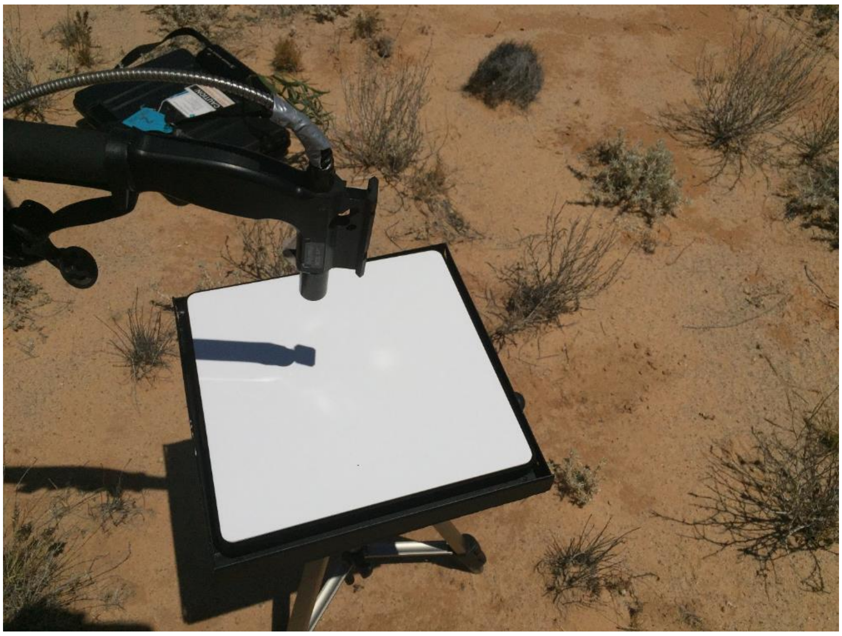


Figure 15 Example of the fore optic being too close and not orientated properly. Note the reflection from the pistol grip on the panel. Also note the speck of material on the panel and that the operator is coming in from the wrong angle. Also, the pan is not orientated properly, facing into the sun.

As the spectroradiometer is set to collect 10 spectra per spacebar push, only one spacebar push is required to collect the 10 panel spectra.

5.4.1 Collection of transect reflectance measurements

The ground data collection will be performed using the continuous sampling approach. The head of the spectroradiometer is to be held at waist height, level and pointed directly downward (nadir), similar to that as described for the panel measurement[3]. The spectroradiometer operator then walks at a constant pace along the transect.

The spacebar should be pushed at the location of each flag marking 20 m. Avoid stopping, continue walking at a constant pace.

At the end of each transect, return to the panel and re-acquire 10 panel spectra. The total number of measurements for each transect should be approximately 70 (50 transect plus 20 before and after panel measurements). Do not worry if this is not the exact number but ensure the exact number is noted by the note taker.

At the end of the first 6 x 100 m transects and up to 12 panel measurements there should be ~420 spectra saved (plus the additional mylar and direct/diffuse measurements).

5.5 Field data sheet completion

5.5.1 The role of the note taker

While the operator is using the spectroradiometer, the second person, acting as the spotter, note taker and panel mover, has a very important role during the acquisition. As the measurements are acquired by the operator, the note taker will be filling out the data sheet. The information that should be recorded include: the operator's names, the instrument serial number, panel number (serial and calibration date is preferred), site, conditions, date, time, weather, clouds, wind, cover and surface, topography. The note taker will also collect weather and sky condition information during the measurement period and track anomalous incidents. Sky condition information includes capturing solar data using the MicroTops Sun Photometer. An example of the field note sheet is shown in Appendix A3.

It is the note taker's job to ensure that the spectrometer operator is doing their job properly (as noted above), and, for taking notes about what could cause issues for each measurement being collected. The note taker needs to be in communication with the spectrometer operator and ask what spectrum number they are up to during the collection, especially at the end of transects and after panel measurements. The note take should record the number of spectra acquired during each transect as well as the type of spectra (transect, panel etc). The note taker watches the operator to ensure that the foreoptic is kept at nadir, that the field of view is being held in a stable position, that they follow the correct path along each transect and measure the reference panel when required. An example of a good location for the note taker to be is shown in Figure 13.

Importantly, the note take will also keep an eye on the health of the operator, which is especially important during hot conditions.

[3] A longer pole may be used held at an upward angle; this gets the foreoptic higher off the ground to measure over a larger sample area. Whatever approach is used the key is to ensure that the head is pointing directly downwards no matter what.

5.6 Field data storage

At the end of each day's field work, the measured data must be extracted and checked. In all cases, copies of the data should be saved to a local hard drive or USB drive. Ideally, the data will be ingested directly into SPECCHIO[4] and the procedure will include attaching the related metadata collected for the datasets and any additional notes recorded on the field sheet, photographs, GPS locations, etc. and, any other QA/QC parameters recorded when checking the spectra such as "noisy data", atmospheric absorption features, etc.

A data repository has been set up at http://teams.csiro.au/units/SVS. After each field trip all data are to be uploaded to the Sharepoint web site. To aid in processing campaign data, files should be distributed into a meaningful directory structure prior to upload (see below). The simplest approach is to create a directory structure on your local computer, place files in the appropriate sub-directories, then drag and drop the whole directory structure to the Sharepoint directories.

At the end of the campaign or when internet services are available, data should be uploaded to this and to the central SPECCHIO server maintained by GA (see below).

5.7 File naming convention

1) Make a directory with the site short site name (refer to Table 1 and Table 2).
2) For the spectral data the naming convention shall be Short site name_yyyymmdd. For example, data acquired at the Pinnacles site on 9 March 2018 would take the filename convention "PIN_20180309.xxx".

5.8 Folder structure

The spectroradiometric data acquired in the field needs to be arranged in a specific manner for the correct import into AUS-SPECCHIO. A lot of individual files are produced in the process and common folder structure is essential. The top level of the structure is the site code. Each field visit should be arranged under this main folder with folders named by site code and date in YYYYMMDD format. An example of the folder structure to be used is shown in Figure 16. See Table 3 for further description of these items.

Sub folders then partition the spectroradiometric data into directories for each transect line. A folder for atmospheric data (with sub folders for MicroTops data and direct/diffuse measurements). Scanned data sheets and field photos should be placed in separate folders and finally a directory containing the ASD calibration files and panel reflectance factor should also be included.

Further details on how to upload data to the DEA Satellite Validation Support site on Sharepoint can be found in Appendix A9.

[4] Version currently called SPECCHIO for Australia

- YYYYMMDD_LOC
  - Photos
  - Atmosphere
    - Direct_Diffuse
    - Microtops
  - Field_Sheets
  - Calibration_Files
    - Mylar
  - Line1
    - Panel
    - Ground
  - Line2
    - Panel
    - Ground
  - Line3
    - Panel
    - Ground
  - Line4
    - Panel
    - Ground
  - Line5
    - Panel
    - Ground
  - Line6
    - Panel
    - Ground
  - Other_directories_as_needed

Figure 16 Recommended data file structure shown for an example data set captured at Lake George on the 17th April 2018

Table 3 Description of items to be included in the directory structure

ITEM	DESCRIPTION
YYYYMMDD_LOC	Date in year, month, day format, followed by the 3 letter abbreviation of your field site. E.g. for Pinnacles, 2018 3rd July the directory name is 20180703_PIN
Photos	Sky photos, general surroundings, people doing things, equipment setup etc.
Atmosphere:	
Direct_Diffuse	Measurements of the panel with and without occultation by the "black disk". The protocol also suggests measurements of the panel with the helper standing by but not holding the black disk. See the example on Sharepoint, Pinnacles site, 20180328_PIN, where we created sub-directories with names such as "Blocked", "Adjacent helper, not blocked", and "Reflectance with adjacent helper" (and others). We could have used different filenames to indicate the individual data files, but directories made more sense.
RCR measurements	We also included a directory for the RCR measurements.
Microtops	All the Microtops data. Include here in separate folders data for any PAR and weather station measurements.
Field Sheets	Scans or photographs of the field sheets.
Calibration files	
Mylar	A Mylar sheet is provided with the ASD to collect wavelength calibration data. Collect panel measurements with and without the Mylar in front of the foreoptic.
Line 1	
Panel	Spectralon panel measurements collected just before and/or just after each transect (line).
	Measurements of ground-reflected radiance you collected as you walked along the transect.
Ground	
Photos	Photographs of the general setting of the sites, sky conditions, close ups of the surface with reference for scale, operators at work, instrument deployments, panel set up, etc.
Other_directories_as_needed	Most sites may collect more than 6 lines of data. You may also collect "background" measurements along lines outside the 100 m x 100 m grid. We (see Pinnacles site, 20180328_PIN) did some repeat measurements of line 3 so included these in a separate directory.

5.9 SPECCHIO upload

Accounts have been created for each node with a user and a login which has been linked to the DEA project.

Once the data has been correctly arranged in the folders, it can be uploaded to SPECCHIO. Once it has been uploaded the metadata needs to be edited.

If the spectral data was not collected in UTC then SPECCHIO cannot process the data.

SPECCHIO can then calculate the sun angles based on the UTC and GPS data.

It should be noted that all users have all access rights to the data, which means that they could potentially edit/delete files.

6 Acronyms / Glossary of terms

ACT	Australian Capital Territory
AEOCCG	Australian Earth. Observation Community Coordinating Group (Now EOA)
AeroSpan	The Australian component of AERONET, a network of sun photometers
ASD	Analytical Spectral Devices, now owned by Malvern Panalytical
ASD3	ASD FieldSpec Pro 3
ASD4	ASD FieldSpec Pro 4
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BRDF	Bidirectional Reflectance Distribution Function
BRF	Bidirectional Reflectance Function
Cal	calibration
CEOS	Committee on Earth Observation Satellites
CIMEL	Company that manufactures sun photometers and weather stations (etc), typically the term refers to the automated sun photometer
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Curtin	Curtin University
DAP	CSIRO's Data Access Portal
DEA	Digital Earth Australia
EO	Earth observation
EOA	Earth Observation Australia
ETM+	Enhanced Thematic Mapper plus, sensor on Landsat 7
FOV	Field of view
GA	Geoscience Australia
GDA94	Geocentric datum of Australia (1994)
GPS	Global positioning system
GUI	Graphical user interface
Ha	hectares, 100x100m
Himawari (JMA)	geostationary weather satellites operated by the Japan Meteorological Agency
L8	Landsat 8 Operational Land Imager (OLI)
Lat	latitude
Long	longitude

MODIS	Moderate Resolution Imaging Spectroradiometer
MSI	MultiSpectral Instrument (on board Sentinel satellites)
NBAR	nadir BRDF-adjustment reflectance product
NSW	New South Wales
OLI	Operational Land Imager
QA	Quality assurance
QC	Quality control
QLD	Queensland
RCR	Remote Cosine Receptor
RS232	Recommended Standard 232 (cable type for communication with devices)
S2a	Sentinel 2a Multispectral Instrument (MSI) satellite
S2b	Sentinel 2b Multispectral Instrument (MSI) satellite
SA	South Australia
SN	Serial number
SPECCHIO	Spectra in-out, an spectral database and GUI for interacting with the database. AUS-SPECCIO is the Australian version, initially hosted at the University of Wollongong
SR	Surface reflectance
SWIR	Shortwave infrared
TBD	To be determined
TERN	Terrestrial Ecosystem Research Network
TM	Thematic Mapper (sensor on previous versions of Landsat 4 and 5)
UofA	University of Adelaide
UofM	University of Melbourne
UofW	University of Wollongong
UQ	University of Queensland
UTC	Coordinated universal time
USB	Universal serial bus
UV	Ultraviolet
VIC	Victoria
VIIRS	Visible Infrared Imaging Radiometer Suite
VNIR	Visible and near infrared
WA	Western Australia

7 APPENDICES

A.1 Field Quick Guide

Pre-visit:

- ☐ Check weather conditions. The following link will give you recent cloud prediction plots (https://drive.google.com/open?id=1RWgxUjSWFnwxmCz7LeS5ralmUYEsiYmm). Also refer to windy.com, darksky.net and the other resources referred to in Section 2.4.
- ☐ Organise staff availability, travel arrangements, vehicles, equipment, accommodation and health and safety plans.
- ☐ Inform landholders of intention to access.
- ☐ Pre-print field data recording sheets.
- ☐ Make sure all batteries are charged and spares for instruments (e.g. GPS and MicroTops) are packed.
- ☐ Make sure that all relevant cables, adaptors, etc. are packed.
- ☐ Check the equipment list.

On arrival:

☐ Ensure times on all devices have been set to UTC.

☐ Select most suitable site (flat and uniform over at least 100 x 100 m). Evaluate height of vegetation and ease to walk through.

☐ If applicable to the surface and location, use marker pegs to mark off bounds (100 x 100 m) of site to be measured. Suggested orientation ~ 8° E of N. Use the GPS to measure the locations of the marker pegs.

☐ Place marker pegs at 20 m intervals along the 6 transects of the 100 x 100 m plot (see the set up in Figure 17).

☐ Take photographs of the surface and the surroundings sufficient to characterise the validation site, its scale and the context of its surrounding environment (slope, distance to horizons, sky, vegetation type and height, soil colour)

☐ Evaluate overhead atmospheric conditions. Take photos (preferably geotagged) of the overhead sky conditions.

☐ Warm up spectroradiometer and prepare for measurements. Check the time on the computer has been set to UTC.

☐ Prepare the MicroTops and GPS. Sync the MicroTops with the GPS. If no GPS is available to sync with the MicroTops ensure the correct coordinates are entered manually. Ensure the time on the MicroTops is set to UTC.

☐ Set up the photometer and weather meters in continuous logging mode at a suitable distance away from any extraneous influences. Ensure the time on these devices is set to UTC.

- ☐ Check the settings of the ASD:

  Spectrometer settings

  - Dark current (if a VNIR shutter is present): 20
  - Spectrum averaging: 20
  - Radiance mode
  - Number of files to save: 10
  - Time between saves: 0 sec
  - New file format
  - Mode: Radiance
  - Time on the laptop controller should be set to UTC
  - GPS should be activated
  - Fore optic set to 8 degrees

- ☐ Start filling in the Site Description and Field Data Collection Form.
- ☐ Decide how you will manage the Spectralon Panel measurements. See the three suggestions/choices below (Figure 17).
- ☐ Set up the Spectralon panel, level and oriented to the sun. Consider keeping the panel covered when not being viewed by the ASD. DON'T TOUCH THE WHITE SURFACE.

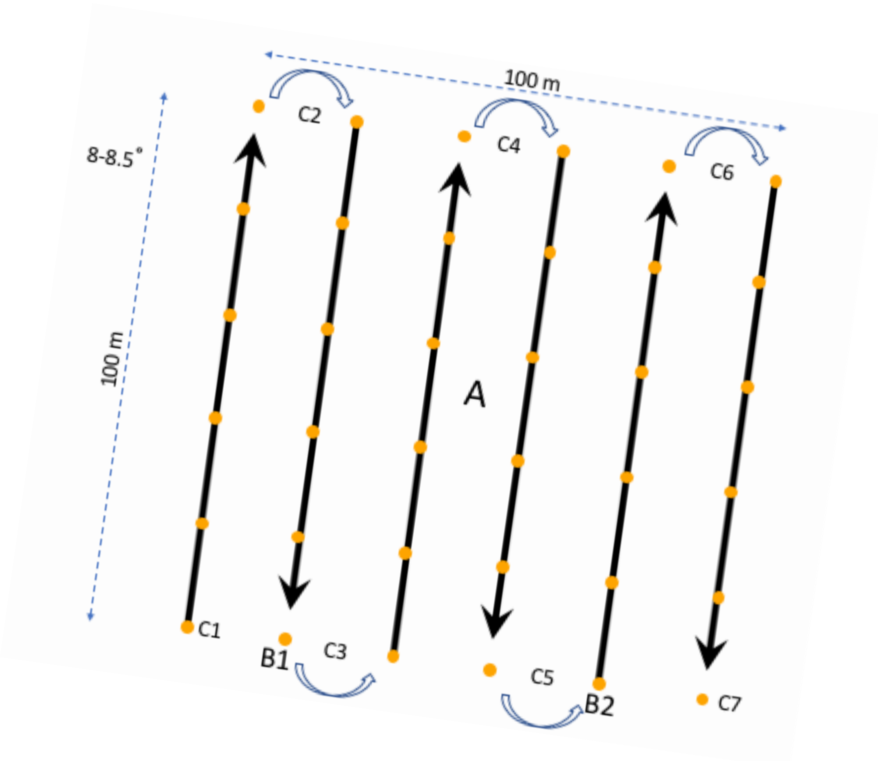


Figure 17 Example of the layout of the 6x100 m transects, with transects spaced 20 m apart and flags or other markers spaced 20 m apart along each transect as indicated by orange dots. Depending on the site conditions, the white Spectralon panel can 1) remain at A, or 2) be moved once, from B1 to B2, or 3) be moved for every transect from C1 to C7.

Three suggestions of how to handle the Spectralon reference panel

As sites are flat and open with very little vegetation, by definition the trafficability (the ease at which they can be walked) should be quite high. The only complication will be how firm the surface is.

1. **No moving**

Place the panel in the centre of the transect grid (position A in Figure 17). Walk back and forth to the panel as required at the start/end of each transect.

Benefit – No moving of the panel. Levelled only once, can be easily re-orientated to sun position.

Issue – Potential for footprints across the transects, affecting surface reflectance.

Issue – Increased time between panel readings and transect readings.

Issue – Longer distance for ASD operator to walk.

2. **Minimal moving**

Place the panel at the end of transect 2 (B1 in Figure 17) for measurements of transects 1, 2 and 3, and at the end of transect 5 (B2 in Figure 17) for measurements of transects 4, 5, and 6.

Benefit – Only one move of the panel, followed by alignment and re-levelling.

Benefit – Compared to method 1, less chance of footprints on the transects.

Issue – Increased time between panel readings and transect readings.

Issue – longer distance for ASD operator to walk.

3. **Move for every transect**

Place the panel at the start of transect 1 (C1 in Figure 17) with alignment and levelling. While the ASD operator is measuring transect 1, the helper moves the panel to the opposite end and places it between the ends of transects 1 and 2 (C2 in Figure 17) with re-alignment and re-levelling. The panel is moved back and forth for every transect (from C2 to C3 etc. up to C7) and is aligned and re-levelled each time.

Benefit – Minimal time between transect readings and panel readings. Useful for dealing with atmospheric impacts.

Issue – Potential impact on data quality due to moving, re-alignment and re-levelling of the panel

Data Collection:

<u>Pre-transects</u>

- Record or note down environmental conditions, site descriptions, instrument and parameters.
- Ideally teams should also take a hyperspectral ASD (RCR fore-optic) reading of direct and diffuse irradiance at the beginning and end of the survey (Appendix A6). Also spectral readings of the wider background reflectance in the vicinity of the MicroTops (radiating out 100m) are useful for defining the background adjacency effect.
- Collect a wavelength reference measurement with the Mylar sheet and Spectralon panel. Note orientation of ASD in Figure 18.

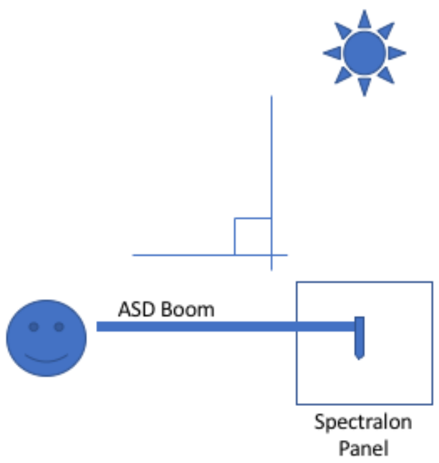


Figure 18 Orientation of the ASD boom relative to the solar direction.

Transect ground measurements

1. At the beginning of each transect perform an ASD optimisation for the Spectralon panel.
2. Collect a second set of Spectralon panel spectra, in Radiance mode (1 spacebar press). At the same time, collect a set of MicroTops data to coincide with the set of Spectralon panel measurements.
3. Position yourself at the start of a transect. Press the space bar to initiate data collection and start walking along the transect at moderate pace at a constant rate. The ASD is collecting data as you walk along the transect so keep the boom oriented appropriately at all times (approximately right angles to the solar direction, see Figure 18). Aim to adjust your walking pace such that you arrive at each flag (20 m spacing) as the data collection ends (indicated by the length of the progress-bar on the laptop). You should therefore press the space bar to initiate a new set of measurements every time you cross a flag.
4. If the helper has time, collect a number of MicroTops datasets while the transect is being measured.
5. At the end of the transect, return to the Spectralon panel, collect another set of Radiance data for the Spectralon panel.
6. Repeat Steps 1 To 5 for the next transect.

Post-transects

- Collect a wavelength reference measurement with the Mylar sheet and Spectralon panel.
- Teams should also take a hyperspectral ASD (RCR foreoptic) reading of direct and diffuse irradiance at the beginning and end of the survey.
- Collect a set of direct and diffuse measurements over the panel using the occultation method (black sun disk).
- If time permits, spectral readings of the wider background reflectance in the vicinity of the site is useful for defining the background adjacency effect.
- Ensure all field sheets are completed.
- Review the equipment checklist when packing up equipment.

Post-visit:

- Ensure field data recording sheets are completely filled in.
- Collate and rename spectral files following the file naming convention.
- Collate photos and rename following the file naming convention.
- Archive all data, as described in Sections 3.6 and 3.7.

A.2 Field equipment checklist

ITEM	
Spectroradiometer (ASD) and accessories	☐
laptop and perspex tray	☐
backpack, batteries	☐
foreoptics (8 and rcr)	☐
bluetooth gps	☐
spare ethernet cable	☐
boom pole / monopod	☐
Sunphotometer - MicroTops	☐
cable for MicroTops	☐
GPS for MicroTops	☐
tripod and mounting plate for MicroTops	☐
Calibrated 10 inch square white Spectralon reference panel	☐
tripod and mounting for Spectralon panel	☐
spirit level for levelling the Spectralon panel	☐
Clipboard and pre-printed field recording sheets	☐
GPS (differential) set to (ref) with accuracy of 1 m or less.	☐
Marker pegs	☐
Compass	☐
Polaroid sunglasses, for evaluating atmospheric and sky conditions	☐
Appropriate clothing (OHS, sun-smart, pale neutral colours, natural fibre)	☐
Digital camera	☐
Munsell soil colour charts	☐
Measuring tape and/or laser distance meter/rangefinder	☐
Black sundisk	☐
1 metre quadrat	☐
Mylar sheet for wavelength checks	☐
Temperature, Humidity, Barometer sensors	☐
Fisheye sky camera	☐
Dust blower	☐
Distilled water	☐
Photometer, Lux meter	☐

A.3 Field record forms

DEA Validation – Continuous Collection Field Sheet

Date: ______________________ Location (*site code*): ______________________ Sensor Name & Overpass time: ________ ______________

Check the time on the laptop; is the time in UTC (*Y/N*): __________ Is the ASD set to radiance mode? (*Y/N*): ______________________

Field Team: ASD operator:______________________ Records : ______________________ Support :______________________

General Site Description (*changes from original site description, vegetation growth, management, soil moisture, colour*): ______________________

____ Photos: (Y/N): ________

Weather conditions at beginning of campaign (*cloud type and cover, sky colour, haze levels, horizontal visibility, wind speed and direction*): ______________________

____

ASD serial #: ______________ Panel Ident #: ______________

Number of ASD files to save: 10 (*note if otherwise*): ______________ ASD Spectrum Average: 20 (*note if otherwise*): ______________

Other Instruments deployed

Instrument	Start time	Stop time	Notes (*incl. serial numbers*)

Weather conditions at end of campaign (*cloud type and cover, haze levels, horizontal visibility, wind speed and direction*): ______________________

____

Have you taken any photos? (*Y/N – Provide notes if Y*): ______________________

____

Sky Condition Codes

1. **Clouds:** [NC] No Clouds; [CL] Clear; [IS] Isolated clouds; [SC] Scattered clouds; [BR] Broken clouds.
2. **Cloud Type:** [Ci] Cirrus; [Cc] Cirrocumulus; [Cs] Cirrostratus; [As] Altostratus; [Ac] Altocumulus; [St] Stratus; [Sc] Stratocumulus; [Ns] Nimbostratus; [Cu] Cumulus; [Cb] Cumulonimbus.
3. **Sky Colour:** [DB] Deep blue; [B] Blue; [LB] Light blue; [PB] Pale blue; [M] Milky.
4. **Haze Condition:** [UC] Unusually clear; [CL] Clear; [SH] Somewhat hazy; [HA] Hazy; [VH] Very hazy
5. **Wind:** [0] Calm; [1] Light Air; [2] Light Breeze; [3] Gentle Breeze; [4] Moderate Breeze; [5] Fresh Breeze; [6] Strong Breeze; [7] Moderate Gale; [8] Fresh Gale; [9] Strong Gale; [10] Whole Gale; [11] Storm; Hurricane

e.g. for table entry [NC/-/LB/CL/4]

Transect #	Opt. (y/n)	Start Panel		Surfaces		End panel		Microtops scan # & times	Comments (Time/Temp/Humidity/Pressure/Conditions)
		Enter actual scan numbers at end of each event							
RCR		009							
RCR shade		019							
noRCR+help		029							
Mylar		039							
Panel		049							
Diff. Panel		059							
Panel+help		069							
1		079		129		139			
2		149		199		209			
3		219		269		279			
4		289		339		349			
5		359		409		419			
6		429		479		489			
Mylar		499							
Panel		509							
Diff. Panel		519							
Panel+help		529							
RCR		539							
RCR shade		549							
noRCR+help		559							
Notes									

DEA Validation - Site Description Form

Date: ___________________ **Site Name:** ___________________________________ **Site Identifier:** ___________________

Field Team:

____

____

____

Location Description: ____

Basic site description: ____

Slope (*degrees*):______________________________ Aspect (*compass bearing*): ____________________________________

Land use (*e.g. agricultural, national park, reserve, management phase*): ____

Surface cover (*e.g. bare soil, vegetation, percentage cover*): ____

Vegetation description (*predominant species, type, growth stage, height, type, cover percentage, evidence of fire, etc*): ______________________________

____

Soil description [*type and condition, Munsell colour and type, erosional state (water/wind), deposited materials, microrelief, moisture, cryptogams cover and colour, rock colour, abundance and size*]:

____

____

Grid coordinates:

(*lat/long, GDA94*)

Corners:

1. ___________________
2. ___________________
3. ___________________
4. ___________________

Site Photos Information ____

Uniformity of surface (*refer to patchiness, scale, colour variability etc.*)____

Constancy of surface (*do you expect the surface to change throughout the year? If not, why not?*) ____

<u>Context of site within surrounds</u>

Land use of surrounds: ____

Surface cover of surrounds: ____

General aspect, slope etc. of surrounds: ____

Proximity to coast, mountains, relevant topography, towns, sources of aerosols etc.: ____

A.4 Spectralon panel care

Spectralon reference panels are easy to damage due to their soft nature. Care should be taken with the panels so that they are not scratched or gouged in any way. Impacts on the panel surface will cause dents and therefore shadowing. Dirt, fingerprints and insect gunk can all be removed by proper cleaning (http://www.labsphere.com/site/assets/files/2569/an-13011-000rev00.pdf) but physical damage cannot, unless the panel is sanded down to the level of the damage, which reduces its thickness and potentially its reflectance properties.

If the panel does need abrasive or significant cleaning then the panel's reflectance factor will have to be re-determined. Ideally, this should be undertaken in the calibration laboratory but if necessary it can be performed in the field using the ratio of downwelling irradiance made using an RCR foreoptic followed by a panel reading made using the 8 degree foreoptic. These measurements should ideally be made at solar noon. Defining a new reflectance factor can wait until after the field campaign so long as users note which data are impacted.

It is important to note that reference panels change properties with temperature (coefficient of thermal expansion) and that this may potentially affect their reflectance. Any significant changes in temperature should be noted.

Older panels may degrade in the UV/blue wavelength region with prolonged exposure to the sun. There are reports that some panels yellow with age and with exposure to sun light.

A.5 Sunphotometer methods

Portable Solarlight MicroTops II sun photometer and Ozone meters are used for calculating the atmospheric water and ozone abundances required for radiative transfer modelling and for verifying the measurements acquired by other instruments if present, such as a CIMEL sun photometer (https://www.cimel.fr/).

The instrument has an internal temperature and pressure meter. It should be removed from its case and allowed to equilibrate to the ambient conditions before use. It should not be left in the sun for prolonged periods of time.

Measurements are made by turning the device on, updating the location and time information with a GPS via the supplied cable (or manually) and collecting a measurement. The measurement is performed by opening the cover flap and pointing the device towards the sun (Figure 19, Figure 20). An indicator on the front panel will show when the instrument is correctly pointed towards the sun. When the circle of light is in the bullseye and the device is steady, the acquisition button should be pressed to collect a measurement. A series of measurements should be collected (5 is ideal) and the data averaged (the standard deviation can be used for the uncertainty). Data with a standard deviation of more than 2% should not be used.

Data should be downloaded from the MicroTops after returning from the field using the Mtporg software (Figure 21). A USB to serial converter may be required to interface with the RS232 cable that plugs into the MicroTops. A second method of downloading the data using Windows Hyper Terminal is outlined at http://fsf.nerc.ac.uk/resources/guides/index.shtml.

Figure 19 Dawn measurement with a MicroTops II photometer. Note the GPS on the tripod attached to the photometer by a cable.

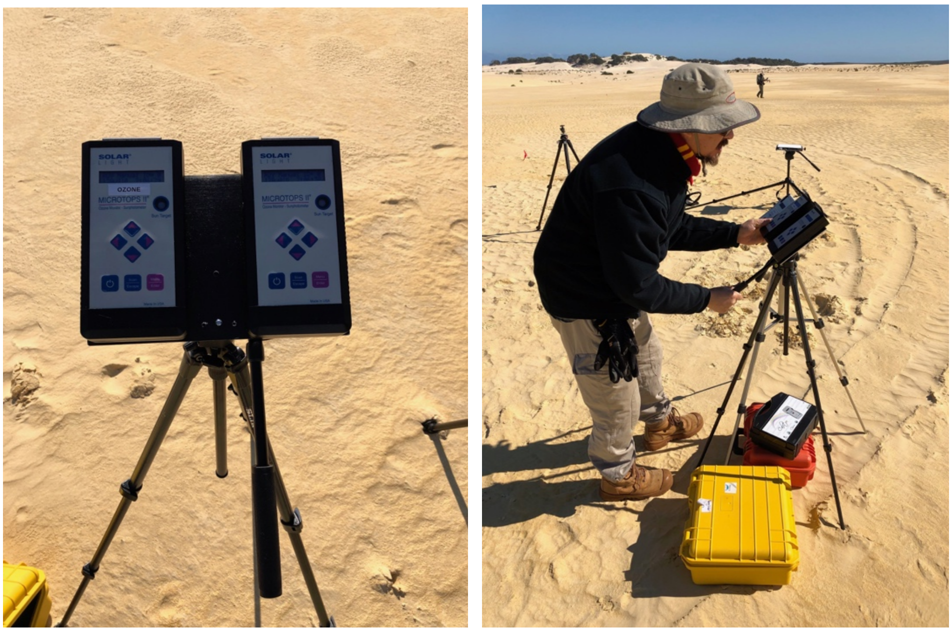


Figure 20 Collecting Microtops II sun photometer and ozonemeter measurements at the Pinnacles.

S/N	DATE	TIME	LAT.	LONG	ALT.	PRES.	SZA	S305	S312	S320	SIG940	SIG1020	OZ305_312	OZ312_320	OZONE	WATER	AOT 1020
3103	x/xx/xx	15:06:00	40.01	-75.13	20	1018	65.4	1.82	27.9	55.01	58.95	132.36	216.5	241.8	243	1.04	0.086
3103	x/xx/xx	15:06:11	40.01	-75.13	20	1018	65.4	1.81	27.8	54.71	58.8	132.2	216.7	241.7	242.8	1.04	0.087
3103	x/xx/xx	15:06:23	40.01	-75.13	20	1018	65.4	1.8	27.91	54.77	58.82	131.32	217.7	241.4	242.5	1.03	0.089
3103	x/xx/xx	17:48:32	40.01	-75.13	20	1014	62.6	1.56	20.9	35.55	20.85	48.42	228.4	245.1	245.8	0.96	0.56
3103	x/xx/xx	17:48:43	40.01	-75.13	20	1014	62.6	1.39	19.13	34.96	18.49	43.01	230.5	244.9	245.5	0.94	0.614

Figure 21 Example of the data output from a MicroTops (521 Ozone model, including solar zenith angle SZA) after downloading.

7.1.1 Powering up

Before turning on, make sure that the sensor head flap is closed as to cover the detectors.

To turn ON MicroTops II press the ON/OFF switch for about 1/2 second.

Once the instrument starts to power up it will display the message "Hardware test" and the version number of the firmware loaded into the instrument. For the next 2 seconds the "Initialization - keep covered" message is displayed. Keep the top window cover closed until the display shows RDY (ready mode, Figure 23).

To return to ready mode from any other mode press the Scan/Escape button until the RDY message appears on the LCD. All buttons are inactive during the measurement scan. The meter will automatically shut off after 10 minutes of inactivity.

Figure 22 Paired MicroTops sunphotometer and ozone instruments used as part of this project. Showing the 7 buttons, LCD and sun target bulls eye.

7.1.2 Turn off

To turn the instrument OFF press the ON/OFF button. It will turn off only when in the ready mode. Otherwise the ON/OFF button is not active.

7.1.3 Display

The LCD display

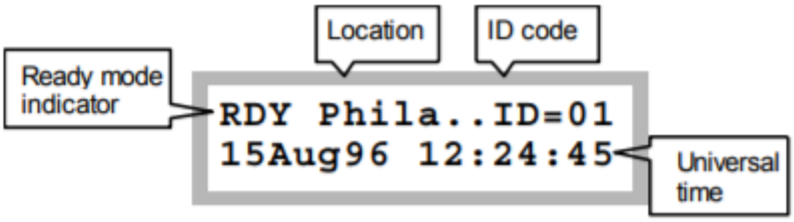


Figure 23 LCD display of the MicroTops in the ready mode screen, showing the location, ID number of the next scan, date and universal time.

7.1.4 Setup and GPS (time/location) synchronisation

The instrument should already be setup to communicate with a GPS, but if not here is the procedure:

Set the baud rate to 4800 by pressing the Menu/Enter button once and then pressing the up arrow button once. Press the Menu/Enter button again and use the left and right arrow buttons to change the baud rate to 4800. Once it is correct press the Scan/Escape button to return to the main menu (Ready mode).

Turn on the GPS and let it find the local satellites. You may need to be in an open area with an unobstructed view of the sky. Once it has connected and has a good fix on multiple satellites it is ready to sync.

The GPS may need to be setup to have a baud rate of 4800 and that it is sending out NMEA data. Consult the GPS manual for how to do this (typically in settings or setup menu and the Interface menu).

Connect the GPS cable to the GPS and the 3.5mm jack plug to the left side of the MicroTops II instrument. If the GPS has a good fix it will communicate with the MicroTops and the unit will acknowledge that it has a valid latitude, longitude and time by sounding out 3 beeps every few seconds. When the MicroTops has received altitude information it will sound out 2 beeps and any manually entered information for altitude will be overwritten.

If the unit has received all information it will beep 5 times continuously. Remove the GPS cable so that the beeping stops and the measurement beeps can be heard.

The unit also has an inbuilt pressure sensor. Setting the value to 0000 mBar will enable the value to be recorded automatically when a scan is collected, otherwise the unit will use the pre-set value.

7.1.5 Measurement

The internal memory has space for 800 measurements.

Check that the instrument is the Ready mode, where it should be displaying RDY in the top left line. If not press Escape.

Open the cover and point the unit at the sun. Use the circular window labelled Sun Target to position the bright dot in the centre of the bullseye. Once the sun is aligned keep the unit stable and press Scan. The unit will beep once and display the message stating the scan number and inform you to point at the sun. When finished it will beep twice. Take a note of the Scan ID and write this on the measurement log sheet.

Downloading of the data will be dealt with in a later edition.

A.6 Direct and Diffuse Irradiance Measurements

Data characterising the atmospheric optical depth and atmospheric water vapour is essential for each validation campaign. In addition to MicroTops data, teams should capture hyperspectral readings of the fractions of direct and diffuse irradiance using their ASD spectroradiometer. An example of direct and diffuse spectra is shown in Figure 26.

The protocol is simple and requires two people, the ASD with its cosine diffuser (RCR foreoptic) mounted on the tripod (and levelled) and a black sundisk. Figure 24 shows an example of a diffuse measurement being collected during occultation of the RCR cosine diffuser.

Section 6.1.1 of (Jupp, 1997) (http://www.eoc.csiro.au/millwshop/ref_cal.pdf) describes the theory and application of capturing these data. While this document talks with respect to a Licor LI1800uw spectroradiometer the essentials remain the same. Figure 25 shows an example of a diffuse measurement being collected during occultation of the reflectance panel.

To get diffuse readings using a sun disk, the procedure is as follows:

1. Have a sun disk 10cm diameter and blackened on a thin stick about 50cm length.

2. The person using disk should stand on the opposite side of the instrument from the sun and hold the disk ~1 m from the sensor head with the shadow centred on the sensor.

3. Take four readings:

   a) One reading with no disk and no person,

   b) one reading with person in place but disk not used,

   c) one reading with person in place and shading the sensor head and lastly

   d) one with no person and no disk to see that there has not been significant change.

Note : The person shading the sensor (this applies to anyone doing field radiometry), should wear pale matt coloured clothes which are not too reflective. For example denim is very bright in the near infrared!

If the four readings above are denoted [E_1 E_2, E_3, E_4] then the quantities needed are derived as:

$$E^*_{d} = E_1$$

$$Edir = E2 – E3$$

$$E_{diff} = E_d - E_{dir}$$

$$E_4 \sim E_1{}'$$

Figure 24 Using a sun disk to occult the RCR foreoptic during a diffuse sky measurement showing the sequence of measurements Left to right, direct and diffuse (no sun occultation), diffuse (with occultation), with helper remaining in position.

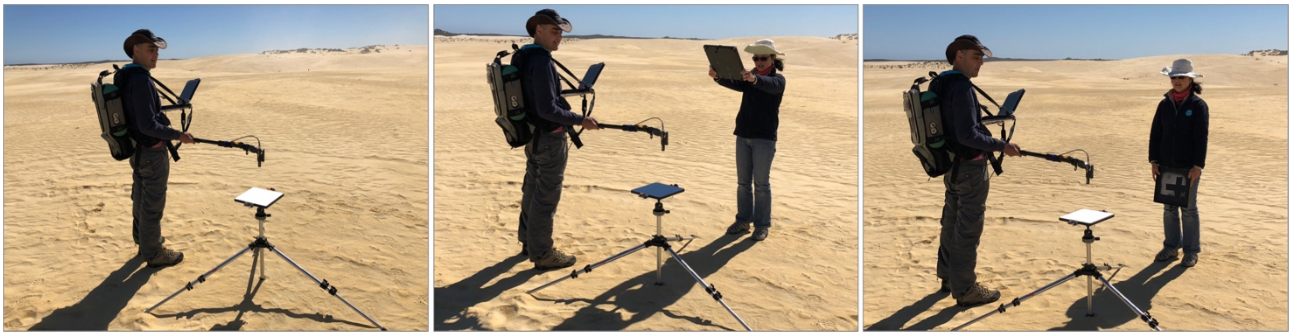


Figure 25 Using a sun disk to occult the reference plate during a diffuse sky measurement showing the sequence of measurements Left to right, direct and diffuse (no sun occultation), diffuse (with occultation), with helper remaining in position.

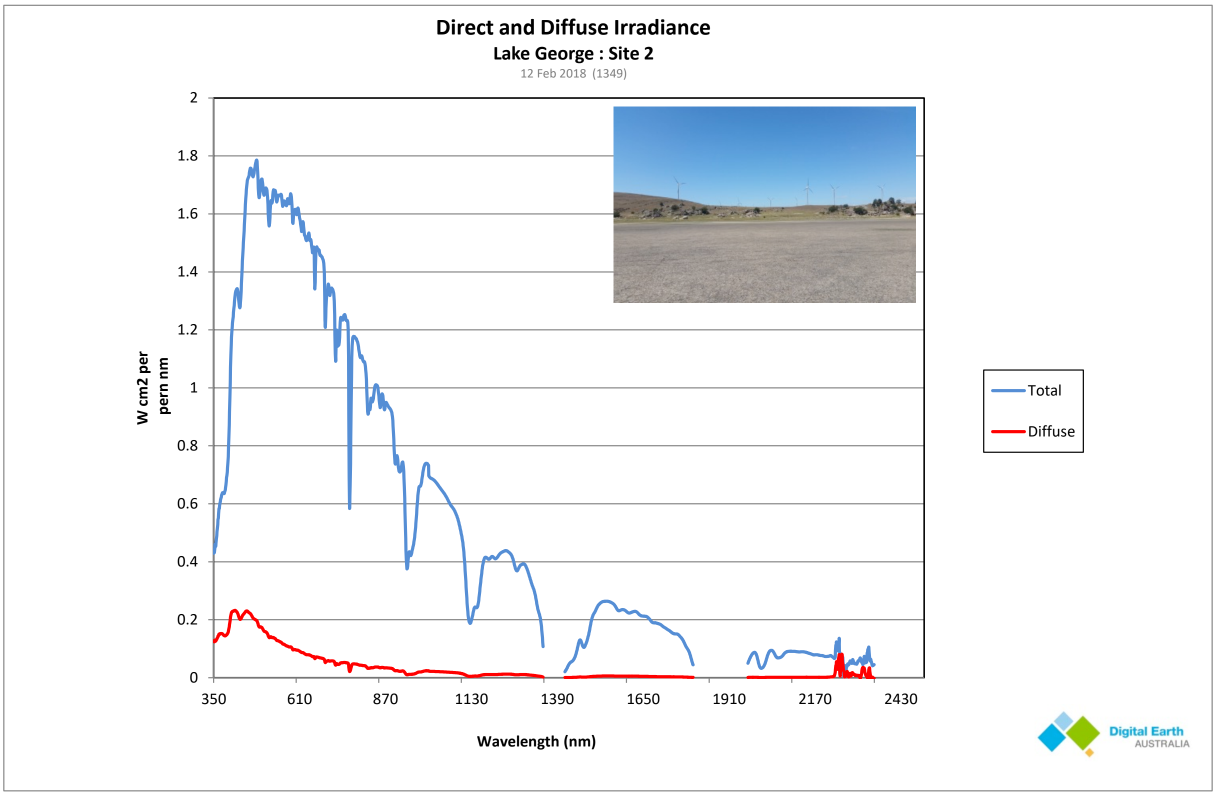


Figure 26 Example of direct and diffuse spectra collected at Lake George, NSW.

A.7 Health and safety issues

To ensure the safety of all personnel involved, all fieldwork activities undertaken as part of this validation activity must be carefully planned before fieldwork is commenced. The planning must consider the field location, travel arrangements, work to be undertaken and the measures to be implemented to control all foreseeable hazards.

As the validation sites to be visited as part of this work are remote, it is recommended that the fieldwork is supported by a Field Trip Plan which includes a nominated Base Contact for at least a daily check-in. A call-in schedule (phone call, text, SPOT check-in) should be established with the Base Contact and followed. The actions to be taken in the event of a missed call, should also be documented on the field trip plan and agreed to by all parties.

Suitable communication and safety equipment must be taken into the field. When planning the field trip, assess mobile phone coverage for the site and assess other options for communicating with the Base Contact or emergency services (e.g. mobile phone, satellite phone, SPOT device, email). Safety equipment such as first aid equipment, personal locating beacons (PLBs), emergency position indicating radio beacons (EPIRBs), vehicle recovery equipment, and sufficient supplies of food and water should also be considered at the planning stage.

All equipment taken into the field should be operational and fit for purpose. Staff involved in fieldwork should be familiar with, trained and competent in the operation of all equipment taken into the field, including communication equipment. Four-wheel driving training should be undertaken if the field team are required to drive in 4WD conditions in the field.

Project staff should not undertake fieldwork outlined in this document alone. Staff undertaking fieldwork should have first aid training commensurate with the level of risk of fieldwork activities and location. Sufficient members of the field team are required to have first aid training to assist each other in the event of an emergency situation.

The Field Trip Plan should include a risk assessment which addresses a number of key risks (and the means to mitigate them) that might be faced by individual teams. These risks might include:

RISK	SYMPTOMS / RISK	MITIGATION
Heatstroke	Headache, dizziness, or fainting; Weakness and wet skin Irritability or confusion Thirst, nausea, or vomiting	Wear lightweight loose fitting but full length clothing. Consider wearing a cooling bandana. Take breaks to avoid excessive exposure to the sun. Provide ample cooled water and drink frequently. Monitor fellow team members for heat stress symptoms.
UV exposure (sun burn)	Sunburn	Wear protective clothing including a wide brimmed hat. Regularly apply SPF 50 suncream amply to exposed skin areas,including lips, ears, back of hands, and neck. Wear wraparound UV protective sunglasses.
Looking at sky/sun	Eye damage (blurred vision, dark or yellow spots, pain in bright light or loss of vision in the fovea). Permanent damage to retina, blindness.	Use high quality UV protective, polaroid sunglasses. Use a solar filter.
Carrying and lifting heavy equipment cases	Body stressing, back pain/back strain	Apply appropriate manual handling techniques (Principles of Safe Lifting and Carrying), use mechanical lifting aids (trolleys), use two person lift for heavy/awkward loads.

Driving long distances	Fatigue	Stop, revive, survive – Avoid driving when tired – on long trips, stop and rest every 2 hours of driving for at least 15 minutes. Share driving duties. Consider flying to towns in vicinity of work sites, hire a vehicle locally when required.
4WD driving over rough terrain	Collision, accidents, roll-overs	Select 4WD when travelling away from major roads, country towns and dirt roads. All vehicles hired or owned need to have an ANCAP 4 star rating as a minimum. 4WD vehicle users to be trained in correct vehicle use. No remote driving alone.
Communications in remote regions	Unable to communicate in time of emergency	Before visit, assess mobile phone coverage for areas to be visited. Take at least one back up communication device (e.g. satellite phone, personal locator beacon, EPIRB, inReach satellite communicator, SPOT satellite messenger).

A.8 Upload of data to the DEA Satellite Validation Support site on Sharepoint

A data repository has been set up at http://teams.csiro.au/units/SVS

After each field trip all data are to be uploaded to the Sharepoint web site. To aid in processing campaign data, files should be distributed into a meaningful directory structure prior to upload. The simplest approach is to create a directory structure on your local computer, place files in the appropriate sub-directories, then drag and drop the whole directory structure to the Sharepoint directories.

A directory structure as displayed in Explorer is shown in Figure 27. Figure 27 Sample directory structure. Place all field data into the appropriate directories.

The top level directory is called yyymmdd_LOC in this example.

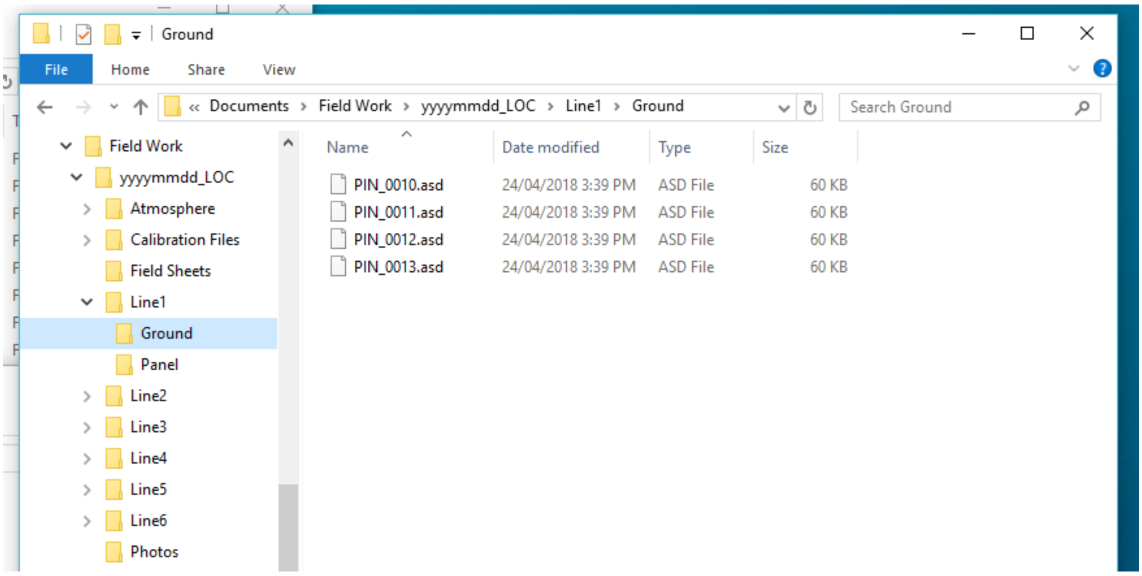


Figure 27 Sample directory structure. Place all field data into the appropriate directories.

Figure 28 shows the front page of the Sharepoint SVS web site. Select "Data" from the left hand menu to list the various data directories. Manoeuvre through the directories by clicking on the directory names.

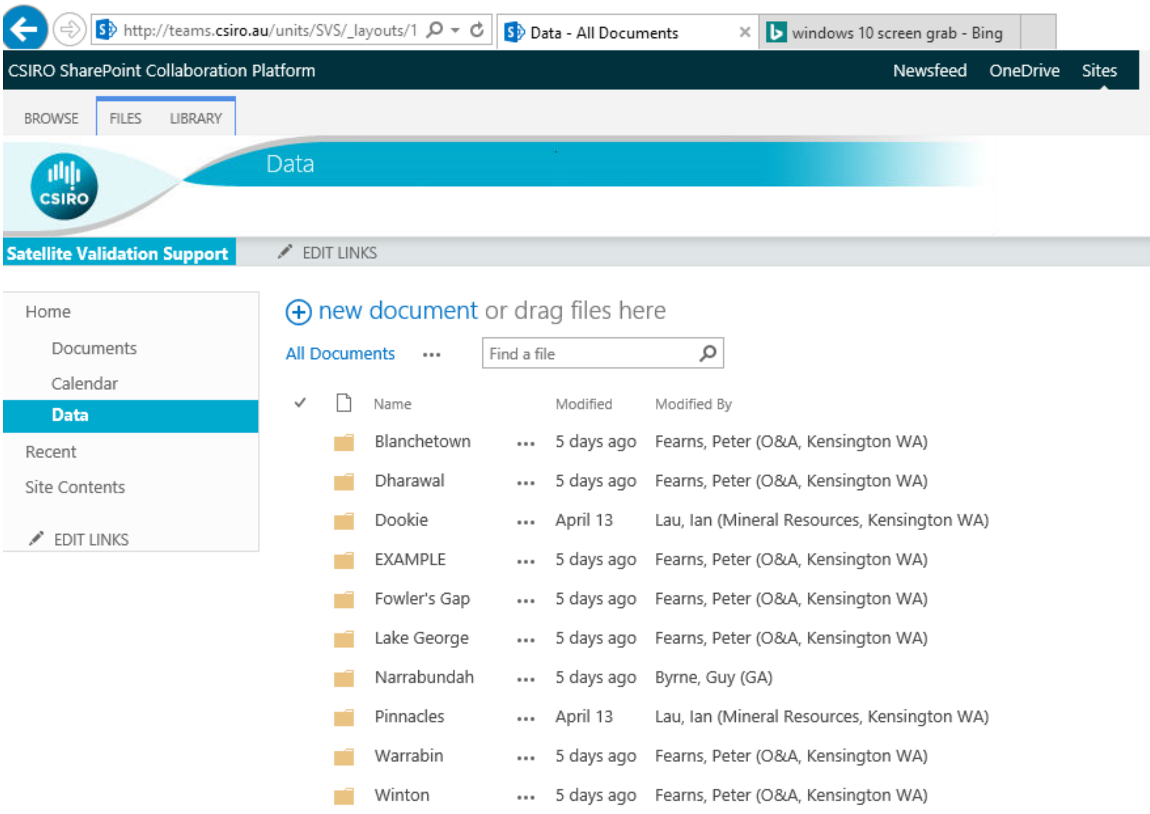


Figure 28 Front page of the SVS Sharepoint web site.

Move back through directories by clicking on the headings in the blue banner. In the example below (Figure 29) you would click on “Pinnacles” to move up one directory level.

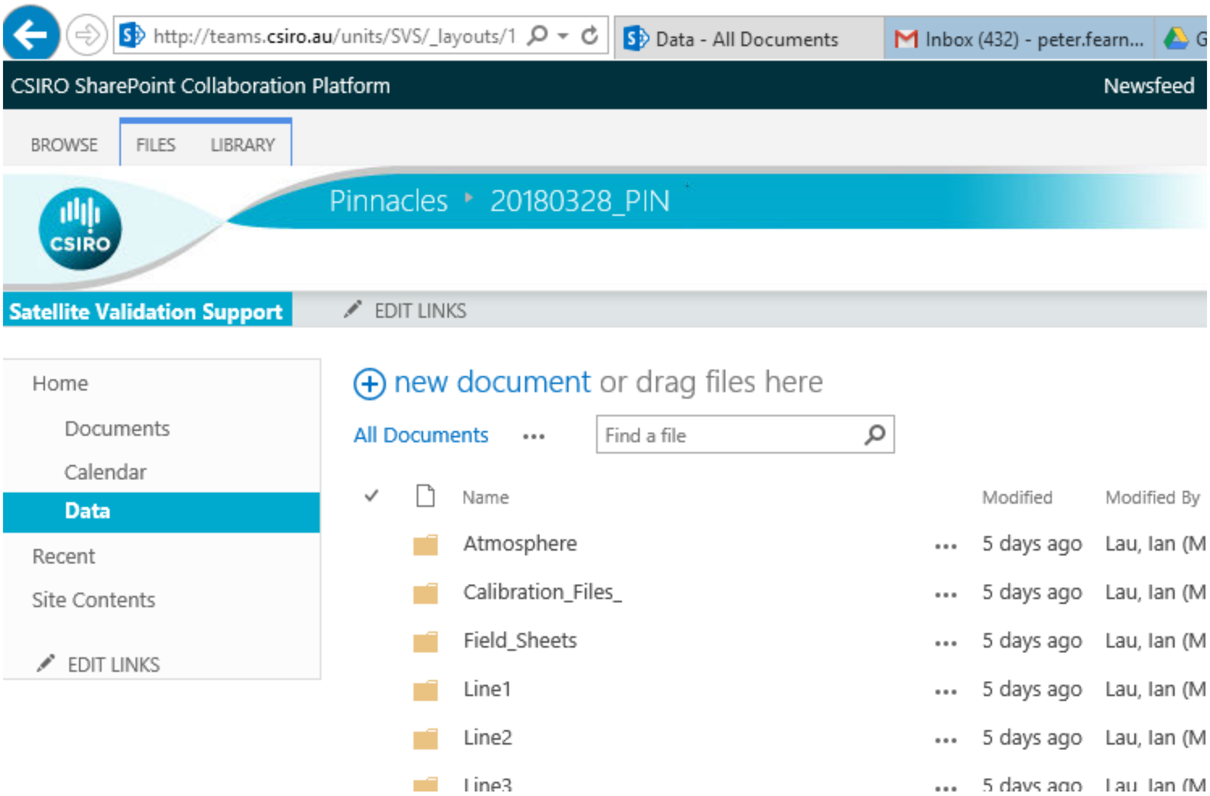


Figure 29 Manoeuvre up and down the directory structures by selecting directory names.

To upload your directory structure select the “LIBRARY” tab (left side ofFigure 30). Then click on “Open with Explorer” icon (right side of Figure 30) to list the directories external to the web site, in Explorer.

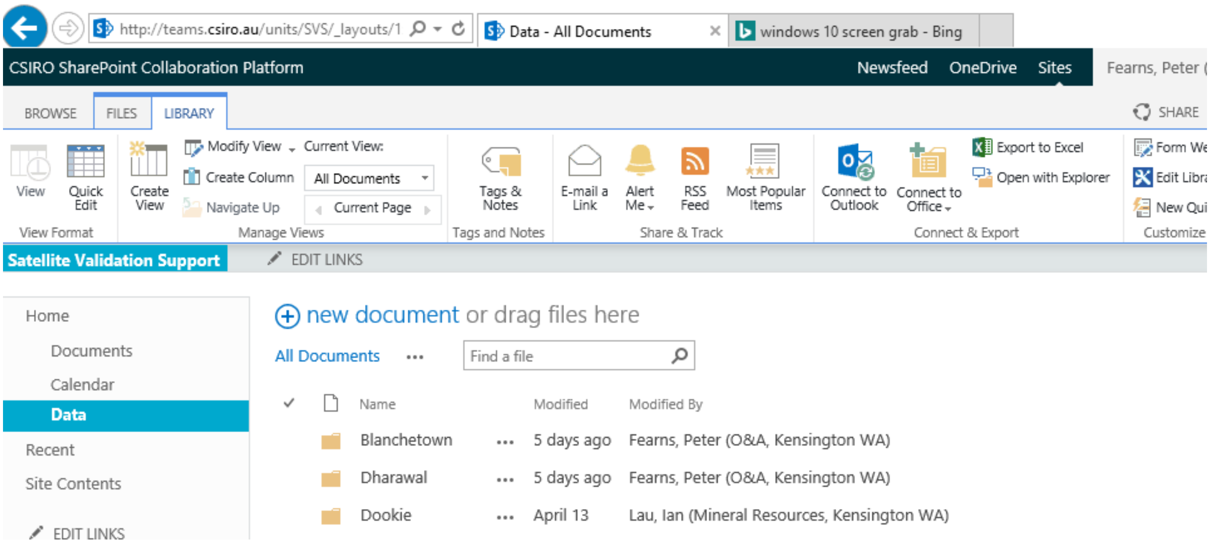


Figure 30. The "Library" tab gives access to tools for uploading data.

The SVS directories will be displayed external to the SVS web page in a new Explorer window (Figure 31).

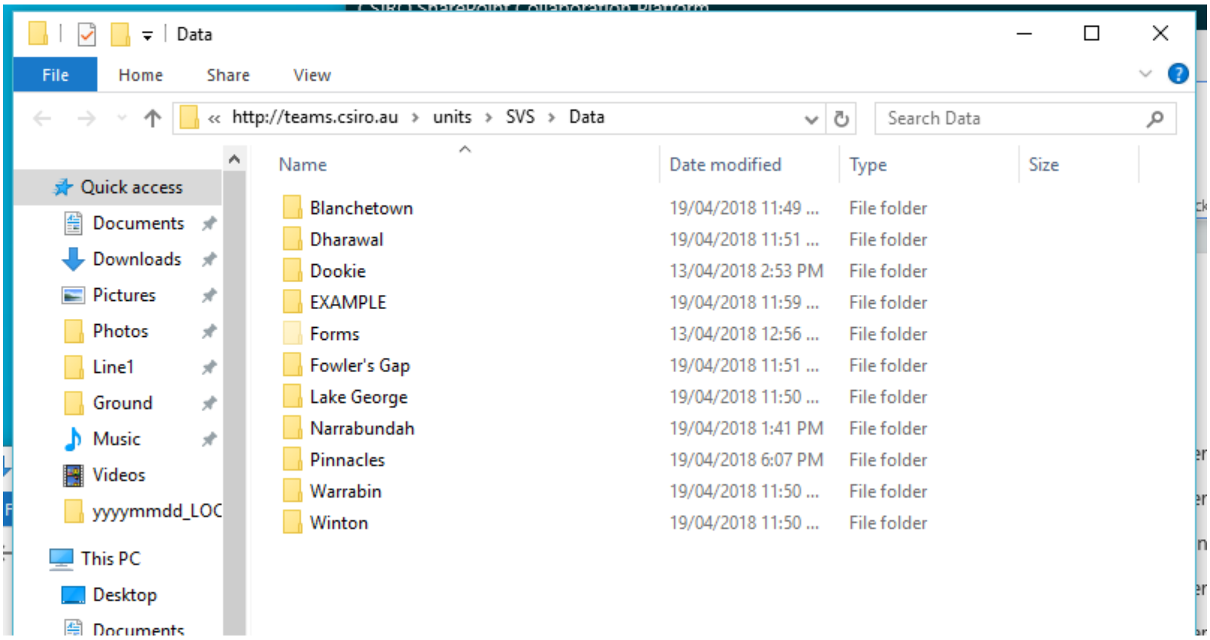


Figure 31. SVS contents are displayed in an Explorer window.

You can explore the contents of the SVS site, add and remove directories and files. Select the directory for your field site. Pinnacles was selected for the example in Figure 32. This is where you upload your campaign data directories.

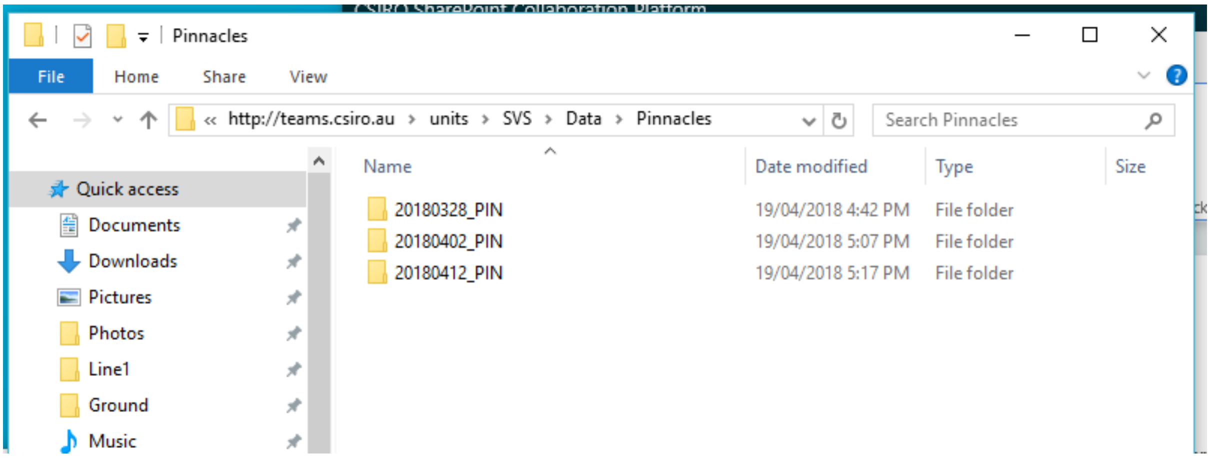


Figure 32. Select directory names to navigate to the top level directories for each field campaign. This example shows three Pinnacles campaigns..

It is easiest to have two Explorer windows open. One with the field data and the other with the SVS contents. Simply drag and drop the top level field data directory (yyymmdd_LOC in Figure 27) to the SVS Explorer window (Figure 31). When transfer is complete it is OK to close the Explorer window.

A.9 List of node participants

NODE	ORGANISATION	LOCATION	PERSONS
CSIRO Perth	CSIRO	Kensington, WA	Cindy Ong Ian Lau Peter Fearns
CSIRO Brisbane	CSIRO	St Lucia, QLD	Tim Malthus
CSIRO Melbourne	CSIRO	Clayton, Vic	Glenn Newham Neil Sims
CSIRO Canberra	CSIRO	Black Mountain, ACT	Janet Anstee
GA Canberra	Geoscience Australia	Symonston, ACT	Guy Byrne Medhavy Thankappan
UQ	University of Queensland	St Lucia, QLD	Stuart Phinn Peter Scarth
UofW	University of Wollongong	Wollongong NSW	Laurie Chisholm
UofA	University of Adelaide	Adelaide, SA	Kenneth Clarke
UofM	University of Melbourne		Lola Suarez Barranco

A.10 List of equipment at each of the nodes

NODE	SPECTROMETER	PANEL	PHOTOMETER
CSIRO Perth	ASD FieldSpec4 SN:18296_3 QA:TBD Cal:Feb 2018 ASD FieldSpec 3 SN:16446_2 QA:21/2/2018 Cal:Oct 2011	2x 10" (2010/2014) QA:2/2/2018 QA:21/2/2018 1x10" (1999)	MicroTops II Ozone and sun photometers Cal: SN:16814 (sun) SN:20786 (O_3)
CSIRO Melbourne	ASD FieldSpec3 SN:16295_1 QA:4/12/2013 Cal:Mar 2009	5" (2009) QA: TBD (Loaning one 10" panel from Curtin University)	(loaning MicroTops from Curtin University)
UofW	ASD FieldSpec4 SN:18616_1 QA:21/2/2018 Cal:Feb 2018	10" (2017) QA:21/2/2018	
GA	ASD FieldSpec4 SN:18179_2 QA:2/2/2018 Cal:May 2014	5" (2013) QA:2/2/2018 (Loaning one 10" panel from Curtin University)	
UofA	ASD FieldSpec3 SN:163??_? QA:?9/3/2018 Cal:?	10" (20??) QA:TBD	(Loaning Microtops from University of Edinburgh)
UQ	? Cal:?	10" (1999) QA:2/2/2018	MicroTops II sun photometer SN: Cal:
Curtin	ASD FieldSpec Pro FR SN:? QA:none	2x Curtin University 10" panels: QA:9/3/2018	MicroTops II Ozone and sun photometers SN: Cal:
UofM	?ASD Fieldspec4? SN:? QA:? Cal:?	?	?
University of Edinburgh			MicroTops II Sun photometer SN: Cal:May 2017

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