

# Guide for Spectroradiometric In-Situ Measurements for Calibration and Validation (Cal/Val) Purposes

## 1 Introduction

In the support of airborne imaging spectroscopy campaigns (and space-based missions), it is crucial to acquire accurate spectroradiometric in-situ measurements. This enables the vicarious validation and calibration of the airborne data and ensures verifiable data quality.

The ground measurements obtained are often defined as “the ground truth”, which is a very daring statement, since there is no such thing as “the ground truth”. Especially in-situ spectroradiometric measurements are not as easy to acquire accurately as it might deceptively appear. When collecting field spectroscopy measurements, many small operator and setup errors can be introduced unintentionally, affecting the certainty of the data.

Hence, in order to deliver high quality airborne products, it is critical that accurate, repeatable and SI-traceable (calibrated) field spectroscopy data are collected, which in the best scenario also include an associated uncertainty budget.

This document provides a guide on how to properly conduct spectroradiometric field measurements within the scope of the *Copernicus Hyperspectral Imaging Mission (CHIME)* airborne campaign. It is a combination of the technical handbook developed by the *Commonwealth Scientific and Industrial Research Organisation (CSIRO)* [1] and the approach established by the *Remote Sensing Laboratories (RSL, University of Zurich)*.

The following procedure should be used when conducting in-situ measurements of non-aquatic land surfaces in order to obtain consistent measurements applying a repeatable approach throughout the entire campaign and future campaigns.

If in-situ measurements of inland or coastal waters are acquired, they should be obtained according to the procedure described by the *International Ocean Colour Coordinating Group (IOCCG)*: <https://repository.oceanbestpractices.org/handle/11329/1171>

(Protocols for Satellite Ocean Colour Data Validation: In Situ Optical Radiometry)

In this case, however, it is still advisable to also collect ground measurements of land surfaces in order to be able to fully validate the airborne products over land and water.

## 2 Selection of Ideal Site for Spectral Ground Control Points (SGCPs)

The choice of the site where the spectroradiometric ground measurements are to be carried out is an important first decision that has to be made.

Several aspects have to be considered when choosing the location: First of all, the location must of course be within the flight line of the airborne imaging sensor. It is best not to choose a location that is close to an edge of a flight line, but rather in the middle. This leads to the validation of the spectra not being influenced by directional edge effects in the airborne imagery.

The target areas should be spatially and spectrally homogenous and temporally rather invariant, natural land surface types, in the sense of for example:

Sand	Gravel	Soil
Concrete	Grassland (mowed)	Etc.

The idea is to choose sites that have minimum within-site variation over a spatial as well as temporal (!) extent, that can be covered by ground measurements (walking) but also still provide minimum variation at the spatial scale of the airborne imagery. Variations of the inherent properties of the target should be characterised rather than positional variations if possible [2].

Agricultural crops are not recommended as spectral references due to too much heterogeneity. Also the proximity to large water bodies is not recommended since they will have an influence on the water vapour concentration in the area. (The latter, of course, only applies to the measurement of land surfaces, not if water bodies are measured.)

As mentioned, the reference area needs to be large enough to provide enough homogeneity for the spatial resolution of the airborne imagery. For the *ESA CHIME* airborne campaign, the *Ground Sampling Distance (GSD)* is either 1, 3 or 6m pixel size (Check the *ARES-Observatory* website for further information on your site: [https://ares-observatory.ch/esa\\_chime\\_mission\\_2021/](https://ares-observatory.ch/esa_chime_mission_2021/) ).

The *CAL/VAL* area to be sampled should best be at minimum three times the size of the *GSD* to ensure a sufficiently large area covered by ground measurements. Possible positional errors are also mitigated by choosing a large sampling area. It would also be preferable that the surrounding terrain is still the same as the chosen location for the in-situ measurements in order to minimise adjacency effects. Also any nearby “edgy” features should be avoided, such as power lines or roads, all in relation to the *GSD*. The overall terrain should be flat to minimise unwanted terrain effects.

Of course, it is best to have as many *SGCPs* as possible, but a minimum of one dark, one bright and one intermediate target should be achieved. Hence, at least three to six spectral samples from different land surfaces would be desirable.

Practical aspects are also important to consider when choosing the appropriate site. Key issues are the proximity and easy accessibility of the site, so that it is quickly reachable in case of short-notice acquisitions. What is also significant is the thorough and friendly communication with the landowner. The latter is important in order to be able to revisit the sites and use them as a long-term location.

#### Long story short:

- 3 – 6 *SGCPs* (min. one dark, one bright and one intermediate, preferably more *SGCPs*)
- Large (in scale with *GSD*) homogenous land surfaces, minimised within variability spatially and temporally
- Flat terrain, minimised adjacency effects of nearby dominant terrain
- Accessibility and proximity
- Maintain good relationship with landowner

#### Example Site Laegern (47.467905°N / 8.309698°E)



### 3 Preparation and Tools

Once the *CAL/VAL* sites are chosen, the necessary equipment for the in-situ spectroradiometric measurements can be prepared.

Several items are used for the field acquisitions. To minimise mishaps, it is best to prepare all the necessary equipment the evening prior to the field measurements.

A checklist of all the tools needed to conduct field work can be found later in the document.

We recommend to conduct in-situ measurements in a team of two and that dark clothing is worn on the day of measurement to reduce unwanted effects caused by the clothing.

The main tool needed is of course a radiometrically well calibrated field spectroradiometer where a few different manufacturers are available (e.g *ASD FieldSpec* range, *SVC*, etc.).

There are differences in the handling of the different instruments and what additional supplies are available. At their core, they remain similar and therefore a more generic approach is described in the following section, but applied to an *ASD FieldSpec* instrument.








Hence, following equipment is needed:

Field spectroradiometer (recently calibrated) (350 – 2500nm) [3]	
<u>Charged</u> battery for spectroradiometer (+ one spare = 2 in total)	
Battery cable	
Pistol grip preferable with bubble level attached [1]	
Monopod (to operate pistol grip) with bubble level to indicate horizontal positioning (min 1m length) [1]	

## CHIME Airborne Campaign

<p>Remote trigger button for measurement initiation [3]</p>	 <p>[3]</p>
<p>Fore optic (e.g. FOV 8°) (optional) → <a href="https://www.azom.com/equipment-details.aspx?EquipID=5438">see Appendix</a>  <a href="https://www.azom.com/equipment-details.aspx?EquipID=5438">https://www.azom.com/equipment-details.aspx?EquipID=5438</a></p>	
<p><u>Charged laptop</u></p>	
<p>Laptop carrier and backpack [3]</p>	
<p><u>Clean, not scratched</u>, recently calibrated Spectralon panel (the larger the better, min. 5inch / 12,7cm), if possible with bubble level attached</p> <p>(How to properly clean a white reference panel see: [4])</p>	

# CHIME Airborne Campaign

<p>Mylar sheet for collecting wavelength calibration data [1]</p>	
<p>Tripod, preferably with bubble level</p>	
<p>Field protocol (logging sheet), already prefilled, what is there to prefill</p>	
<p>GPS (charged) <a href="https://www.marine.com/products/11-51466/garmin-gpsmapreg-64st-handheld-gps-topo-us">https://www.marine.com/products/11-51466/garmin-gpsmapreg-64st-handheld-gps-topo-us</a> <a href="https://www.archos.com/us/products/smartphones/helium/archos_50dhelium/index.html">https://www.archos.com/us/products/smartphones/helium/archos_50dhelium/index.html</a></p>	
<p>Camera (smartphone is fine, charged)</p>	
<p>Dust blower (optional) [1]</p>	
<p>Square metre quadrat for taking standard perpendicular photos of target surface (optional, but recommended) [1]</p>	



It is very important that all batteries for electronic devices are charged. Hence, the preparations the day before the field work include to charge all spare batteries. These are in the case of an ASD field spectroradiometer:

- Field Spectroradiometer batteries (2x)
- Laptop battery
- GPS
- Camera (phone)

If the site used for the ground measurements is an already established site with available GPS coordinates from a previous measurement, it is preferable to target the same coordinates again. This leads to a consistent and valuable validation site over the years, and may also allow studying long-term variations of homogeneous and potentially assumed spectrally stable calibration sites.

It is also important to gather all the essential logistics information the day before: proximity and access to the site should be evaluated, potential landowners informed about the field work, etc.

### 4 Generic Data Acquisition Method

Once in the field, consistency in the method of data collection is important and therefore to be aimed for. This makes it easier to compare data sets and perform validations across a large collection of *SGCPs*.

As mentioned before, per airborne mission it is favourable to have three to six *SGCPs* that represent different land surface covers. A site that offers several different targets close to each other would hence benefit the collection due to proximity and efficiency.

It must be remembered, that spectroradiometric in-situ measurements should be carried out +/- 2h of the airborne overflight.

It is also important that the devices used are appropriately warmed up before the first use. This corresponds to at least 30min, preferably one hour (depending on the instrument). Hence, it must be remembered to turn on the device one hour prior to the first measurement.

It is recommended to acquire wavelength reference measurements using a sheet of Mylar before and after the actual measurements to check the wavelength calibration of the instruments. Due to well-defined absorption features in the Mylar, wavelength accuracy can be examined by collecting data of the white reference panel through a sheet of Mylar.



*Figure 1 Measuring the white reference panel through the Mylar sheet [1].*

## Field Guide for In-Situ Spectroradiometric Measurements for Cal/Val Purposes


### General Preparation Field Measurements

1. Read extensive guide and field protocol (logging sheet).
2. Choose Cal/Val site and check its accessibility.

### Day before Field Measurements

1. Gather equipment (see Section 3).
2. Charge batteries of laptop, field spectroradiometer, GPS & camera (also spare batteries).

### Day of Field Measurement

1. Depending on your field spectroradiometer used: let it warm up sufficiently.
2. Carry out measurements +/- 2h of airborne overflight.
3. Wear dark clothing.
4. Set-up your appliance and field spectroradiometer:
  - a. Mount the white reference panel on the tripod without touching the panel's surface.
  - b. The clean panel should be mounted at a height of 1m above ground and levelled using the attached bubble level (*if not properly levelled: introduction of uncertainty on the measurements up to 0.8% per degree, see [5]*).
  - c. Choose a spot that is not affected by adjacency effects (no objects nearby).
  - d. Attach the monopod to your pistol grip and optionally the fore optic.
5. Acquisition of measurements:
  - a. Acquire the spectral data in the radiance mode of your instrument (not reflectance).
  - b. Check wavelength calibration of instrument: collect 10 readings of the white reference panel through the Mylar sheet.
  - c. Before the actual measurements start, make sure to minimise the following potential operator errors:
    - i. The operator's position should be perpendicular to the solar principal plane.
    - ii. The sensor aperture must point nadir (help by using bubble level).
    - iii. Operate using the monopod (as far away from the panel as possible).
    - iv. The distance of the sensor aperture to the panel should be determinable and be the same for each white reference measurement (preferably between 10 and 20cm to the panel).
  - d. Acquire **5 readings of the white reference panel**.
  - e. Acquire **30 readings of your target**.  
 During the sampling, make sure to cover your targeted area in a sampling pattern similar as shown to the right:
 
    - i. The operator's position should be perpendicular to the solar principal plane.
    - ii. The sensor aperture must point nadir (help by using bubble level).
    - iii. Operate using the monopod (as far away from the panel as possible).
    - iv. Acquire measurements at approx. 1m distance to the target (however, depending on the projected footprint of the instruments FOV).
  - f. Acquire **5 readings of the white reference panel**.
    - i. Same conditions as stated with 5c).
  - g. Acquire another 10 readings of the white reference panel through the Mylar sheet.
6. Take a **picture** of the target, environment etc. (all as indicated on the protocol sheet).
7. Write down the file name.
8. Take a **GPS** reading of the target.  
 → complete the Field Protocol Document of this site for the current target.

### Post-processing of the Field Data

1. Hand data and protocol over to RSL.

## Checklist of Items for Field Campaign:

- ☐ Field spectroradiometer (recently calibrated) (350 – 2500nm)
- ☐ Charged Battery for Spectroradiometer (+ one spare = 2 in total)
- ☐ Charged Laptop
- ☐ Battery cable
- ☐ Pistol Grip preferable (with bubble level attached)
- ☐ Monopod (1m) to operate pistol grip with bubble level to indicate horizontal positioning
- ☐ Remote control button for measurement initiation
- ☐ Fore Optic (FOV 8°) (optional)
- ☐ Laptop carrier
- ☐ Backpack for spectroradiometer
- ☐ Clean, non-scratched, recently calibrated white reference panel (the larger the better, min. 5inch / 12,7cm), if possible with bubble level attached
- ☐ Sheet of Mylar
- ☐ Tripod, preferably with bubble level
- ☐ Field protocols (logging sheet), already prefilled, what is there to prefill
- ☐ Pen
- ☐ GPS
- ☐ Camera (Smartphone is fine)
- ☐ Dust blower (optional)
- ☐ Square metre quadrat for taking standard photos of target surface (optional)
- ☐ Wear dark clothing



## 5 Bibliography

- [1] T. Malthus *et al.*, *A community approach to the standardised validation of surface reflectance data. A technical handbook to support the collection of field reflectance data*, no. 2.0. CSIRO, Australia, 2019.
- [2] E. J. Milton, M. E. Schaepman, K. Anderson, M. Kneubühler, and N. Fox, "Progress in field spectroscopy," *Remote Sens. Environ.*, vol. 113, no. SUPPL. 1, pp. 7–9, 2009, doi: 10.1016/j.rse.2007.08.001.
- [3] "FieldSpec 4 User Manual," 2016.
- [4] Labsphere Inc., "Spectralon reflectance material care and handling guidelines," 2019.
- [5] A. Hueni, A. Damm, M. Kneubuehler, D. Schlapfer, and M. E. Schaepman, "Field and airborne spectroscopy cross validation - Some considerations," *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.*, vol. 10, no. 3, pp. 1117–1135, 2017, doi: 10.1109/JSTARS.2016.2593984.

## 6 Appendix

A note on fore optics:

There are advantages and disadvantages using fore optics that further confine the FOV of a spectroradiometer.

Advantages:

- The projected FOV is smaller and hence easier to handle: unwanted objects can be better avoided, such as shoes or non-representative objects
- For some target surfaces, better results might be achieved with a smaller and more precise FOV, e.g. water bodies

Disadvantages:

- Less radiation reaches the sensor aperture.
- If a lens is built into the fore optic, it might increase unwanted scatter effects such as the size-of-source effect.

In general:

The IFOV (FOV for one pixel) of an airborne imaging sensor is its FOV divided by the number of across track pixels. Hence, in the case of AVIRIS-NG it would be 36° FOV for 640 across track pixels, which results in an IFOV of 0.056°. This has to be borne in mind when choosing the FOV of the field spectroscopy measurements.

## More Detailed Data Acquisition Procedure Using a Device of the ASD FieldSpec Range

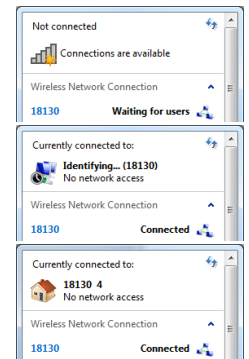
The following measurement procedure should be applied to every *SGCP* collection (at the example of an *ASD FieldSpec*):

### Preparing the ASD FieldSpec

#### What you need to do at the site:

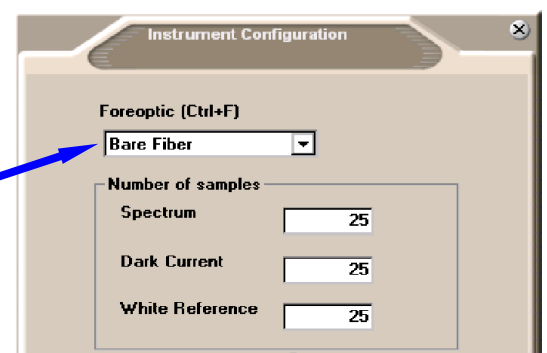
1. Switch on the *ASD* first (warm-up time for the *ASDs*: at least 30min - 1h)
2. Set-up your appliance:
  - a. Mount the white reference panel on the tripod without touching the surface of the panel. The panel should be mounted at a height of 1m above ground and levelled using the attached bubble level (*if not properly levelled: introduction of uncertainty on the measurements up to 0.8% per degree, see [5]*). Choose a spot that is not affected by adjacency effects (no objects nearby). Attach the monopod to your pistol grip and optionally the Foreoptic if used.
3. Strap the *ASD* to the backpack and feed the fibre optic cable into the pistol grip.
4. Switch on the laptop
5. Check that the time is accurate on computer, adjust if not (also of camera and GPS)
6. Start the RS<sup>3</sup> software (or 'Highcontrast RS<sup>3</sup>')  
 The *ASD* will connect to the laptop via wireless:  
 On Windows XP the connection is pretty prompt.  
**Note:** On Windows 7 The wireless symbol on the bottom right will keep the yellow explanation mark as shown below:  
 This is because the *ASD* doesn't offer internet access per se, yet the connection to the *ASD* is established.

On Windows 7 it can take up to 15 seconds till the laptop establishes a wireless connection to the *ASD*. Check the connection procedure as pictured on the right for your convenience.



### Configuring the instrument

- ☐ Number of internal averages for *Dark Current (DC)*, *White Reference* and *Spectrum*: **25**  
Menu: Control → Adjust Configuration and refer to the screenshot to the right.
- ☐ If no fore optic is used: ensure fore optic is set 'Bare Fiber'. If one is used, select it accordingly.



### Measurement

Measurement process for each target:

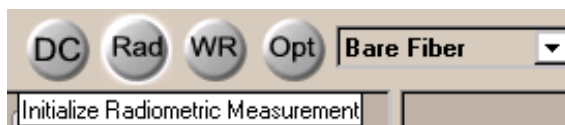
1. Set-up of the spectrum save (Shortcut: Alt-C,S) (Menu: Control → Spectrum Save):
  - a. Create a folder for today's acquisition in the structure: site\_name\_date (e.g. Laegern\_13052021)  
 The root folder structure for the spectra are:  
**C:\Spectral Data\[year]\[campaign name] \[today's acquisition]**

- b. Set the base filename according to your nomenclature (e.g. if you measure grass → “grass\_t1”  
t1 = target1, then you measure sand → “sand\_t2”)
- c. Set the number of files to save to 5
- d. Interval between saves: 0 seconds
- e. Ensure checkbox “Save As New File Format” checked.

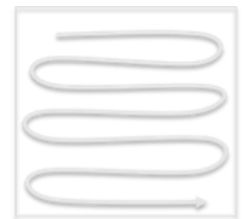
2. **Optimise the instrument** over the white reference panel (unless your target is brighter than the WR, e.g. snow; optimise over the target in that case):  
Press **OPT button** in RS<sup>3</sup> GUI (Shortcut CTRL-O).



3. Switch to **Radiance mode** (this automatically carries out a DC): Press **RAD button** in RS<sup>3</sup> GUI.  
(Make sure that it says ‘Radiance’ and not ‘Digital Numbers’ or ‘Reflectance’ in the box.)



4. Check wavelength calibration of instrument: 10 readings of the white reference panel through the Mylar sheet.
5. Before the actual measurements start make sure to minimise the following potential operator errors:
  - the operator’s position should be perpendicular to the sun azimuth (sun principal plane)
  - the sensor entrance must point nadir (help by using bubble level)
  - operate using the monopod (as far away from the panel as possible)
  - the distance of the sensor entrance (fibre optic cable tip) to the panel should be determinable and be the same for each white reference measurement (preferably between 10 and 20cm to the panel).
6. Acquire **5 radiance readings of the white reference panel** by pressing space once.
7. Set the number of files to save to 30  
(Shortcut: Alt-C,S).
8. Acquire **30 radiance readings of the target** by pressing SPACE once (or the button of your remote trigger). During the sampling time, make sure to cover your targeted area in a sampling pattern similar as shown to the right:
  - the operator’s position should be perpendicular to the sun azimuth (sun principal plane)
  - the sensor entrance must point nadir (help by using bubble level)
  - operate using the monopod (as far away from the panel as possible)
  - Acquire measurements at approx. 1m distance: projected footprint of bare fibre (25°) from 1m distance is approx. 40cm in diameter
9. Set the number of files to save to 5  
(Shortcut: Alt-C,S).
10. Acquire **5 radiance readings of the white reference panel** by pressing space once.
  - same conditions as stated above
11. Acquire another 10 readings of the white reference panel through the Mylar sheet.
12. Take a **picture** of the target, environment etc. (all as indicated on the protocol sheet).
13. Write down the file name.
14. Take a **GPS** reading of the target  
→ complete the Campaign Protocol Document of this site for the current target.



## Shutting down the equipment

### **!! IMPORTANT NOTE !!**

**When closing the RS<sup>3</sup> software, wait till it closes completely** (takes a couple of seconds), then wait another 5 seconds and only then switch off the ASD.

→ **Failing to follow this procedure, the ASD's internal memory can go corrupt, since RS<sup>3</sup> is writing a small log file onto the ASD upon closing the program.**

Alternatively, switch off the ASD first and then close the RS<sup>3</sup> software. In this case, the software just skips writing the log file.

## Mini-Troubleshooting

**Problem:** The laptop cannot establish a wireless connection to the ASD.

**Solution:** Check the status of the wireless connection in the network settings and ensure that the wireless connection is enabled. Restart the computer when no connection is being established after 1 minute.

**In case this doesn't help:** Go to the network settings. For the Wireless Network connection, ensure the following settings are set:

Radio button "Use the following IP address" is selected.

IP address: 10.1.1.55

Subnet mask: 255.255.255.0

Default gateway: Empty

Radio button "Use the following DNS server addresses" is selected

Preferred and Alternate DNS server: Empty.

**In case this doesn't help either:** Under certain circumstances, the orientation between laptop and ASD causes the wireless connection to fail or there are interferences. In the lab, the magnetron of the plasma light source causes interferences when it's on for example.

**Solution:** In this case it's advisable to connect the ASD via Ethernet cable to the laptop. The cable is found in the back of meshed bottom pouch of the ASD backpack.

Ensure that in the network settings the 'Local Area Connection'-settings are set the same as the Wireless Network Connection, except the IP-address, which must be: 10.1.1.22.

**Problem:** The laptop established a wireless connection to the ASD successfully, all is fine, it says 'connected' on the symbol on the bottom right. However, after starting the RS<sup>3</sup> software it fails to establish a communication with the ASD, returning an error message.

**Solution:** Close the RS<sup>3</sup> software, wait for 20s, start the program again. If this doesn't help, restart the laptop.

**Problem:** The G symbol on the icon task list stays red, even though the GPS device is connected and the device displays a position.

**Solution:** Disconnect the GPS device, switch it off and on again, and reconnect the GPS device. Wait for 1 minute (max) till the G symbol turns green. If it stays red, restart the computer.

**Problem:** The G symbol on the icon task list turns yellow instead of green.

**Reason:** This means that the GPS device is being detected by the laptop, however it doesn't have a position.

**Solution:** Ensure that the GPS device gets enough satellites to get a position. Only when the GPS device can display a lat/lon position the G symbol will turn green.