Chapter 1. **Introduction**

A.Held[1] , *S.Phinn*[2], *M. Soto-Berelov*[3,4], *S. Jones*[3,4]

[1] CSIRO, Marine and Atmospheric Research, Canberra

[2] School of Geography, Planning and Environmental Management, The University of Queensland, Brisbane, Australia.

[3] Southern Earth Observatory, School of Mathematical and Geospatial Sciences, RMIT University, Melbourne, Australia

[4] Cooperative Research Centre for Spatial Information, Victoria, Australia.

*Corresponding author:
Alex.Held@csiro.au

In *AusCover Good Practice Guidelines: A technical handbook supporting calibration and validation activities of remotely sensed data products*.

1.1 Background

Images collected from aircraft or satellites and transformed to produce maps of features of the surface of the earth are commonly referred to as Earth Observation (EO) data. They are one of the most widely used sources of information and are used globally for mapping, monitoring and modelling our environments and their changes over time (e.g., Loveland and Dwyer, 2012; Magurran et al. 2010; Mathieu and O'Neill, 2008; Purkis and Klemas, 2011; Wulder et al., 2012). However, the applicability of such data is limited unless it has been matched to suitably sampled ground measurements of the mapped products (e.g. biomass, ground cover, Leaf Area Index or LAI). This involves the calibration of sensors, application of mapping algorithms, and validation of the products. In some cases, this is referred to as "ground truthing". However, it should be recognised that field measurements are still not "truth", as all data are collected using sampling approaches and their match to satellite and airborne data is often not exact. The aim of this handbook is to present good practice methods for the collection and use of suitable ground measurements that can be used to calibrate and validate (Cal/Val) airborne and satellite image based data and derived mapped products.

To date, there has been little effort in documenting the different aspects involved in field and airborne campaigns used to calibrate and validate EO data in a single source. Furthermore, recommendations for the necessary field guidelines and techniques are often lacking or dispersed throughout the literature. This *"AusCover Good Practice Guidelines: A technical handbook supporting calibration and validation activities of remotely sensed data products"* is designed to provide practical advice on generally accepted field-based measurement standards, calibration, and validation protocols for remote sensing data and derived products. An additional benefit that has accrued during the creation of this guide is the coming together of the Australian remote sensing community in a collaborative effort.

1.2 A Dynamic, Community Based Resource for Guiding and Advancing Satellite and Airborne Imagery Use

An intrinsic component of high quality remote sensing or EO data is the explicit link between the satellite or airborne image data and corresponding field information used for producing maps of environmental properties. Although a large body of knowledge surrounding Cal/Val exists, it is often scattered across government reports that are highly specific to a particular project, location, and data type. There is often no explicit coverage of this topic in textbooks on remote sensing, image processing and/or ecological and bio-geophysical mapping and modelling. However, it is clearly acknowledged that for EO data to be useful for conducting scientific enquiry, mapping, monitoring, modelling and management purposes, it must be validated.

This carefully constructed instructional handbook is part of an enduring national research infrastructure program in Australia (www.tern.org.au). It represents a unique contribution to the topic of Cal/Val of EO data. The handbook provides direct guidance on how to collect the multitude of field and image data sets required for producing accurate and repeatable maps of environmental properties. To facilitate continual revision and addition as the field develops and as new data and methods arise, it is also presented in digital format.

1.3 Accurate, Precise and Repeatable Environmental Monitoring Requires Image and Field Data

Earth Observation data are regarded as critical information across multiple sectors including government (at various levels), non-governmental organizations (NGO), research institutions, and private companies. They underpin a wide a wide range of activities across these sectors in Australia and around the world (ACIL 2008). But to improve the ability to obtain accurate representations of the earth and its processes, EO data must be calibrated and validated. Appropriate procedures need to be followed. These have been published across scientific papers and grey literature, but have not been compiled in a format specifically designed to guide such activities so they deliver accurate, precise and repeatable environmental information. Data should be accurate in that the ground measurements match the type of variable being estimated, and the location in time and space is the same. The measurements should be precise, in that they measure the same environmental variable at the same level of detail. The measurements should also be taken using specific instruments, techniques, and analytic procedures. This handbook has been designed to serve as a resource for conducting environmental science, mapping and monitoring using satellite and airborne image data. It covers a spectrum of image and field data sets and RS data products.

1.4 Collaborative, Shared Infrastructure, Algorithms and Data

This handbook has been structured around a unique collaboration across the remote sensing community in Australia developed by Australia's Terrestrial Ecosystem Research Network or TERN (www.tern.org.au). The goal is to build networks across the Australian ecosystem science communities, thus enabling them to share the infrastructure needed for collecting, processing, analysing and distributing environmental data. A central component is an explicit link between field (Figure 1.1a) and satellite/airborne image collection (Figure 1.1b), processing, and analysis that result in the delivery of maps of environmental properties. This is done by TERN's remote sensing facility, Auscover (www.tern.org.au), following the schema shown in Figure 1.1. This approach has triggered collaboration across various levels of government, research institutions, academia and private industry entities involved with the collection, processing and use of information derived from satellite and airborne sensors.

The methods outlined in this resource are based on such collaborations amongst the Australian remote sensing community. The handbook also makes reference to international guidelines and is built on protocols developed in other national environmental data facilities within TERN, where vegetation structure, composition and ground cover information is collected using systematic and clearly defined methods. An example is the multi-scale plot network (http://tern.org.au/Multi-Scale-Plot-Network-pg17730.html), the supersites network (www.tern-supersites.net.au/), and the AusPlots program (http://tern.org.au/AusPlots-Rangelands-Survey-Protocols-Manual-pg23944.html).

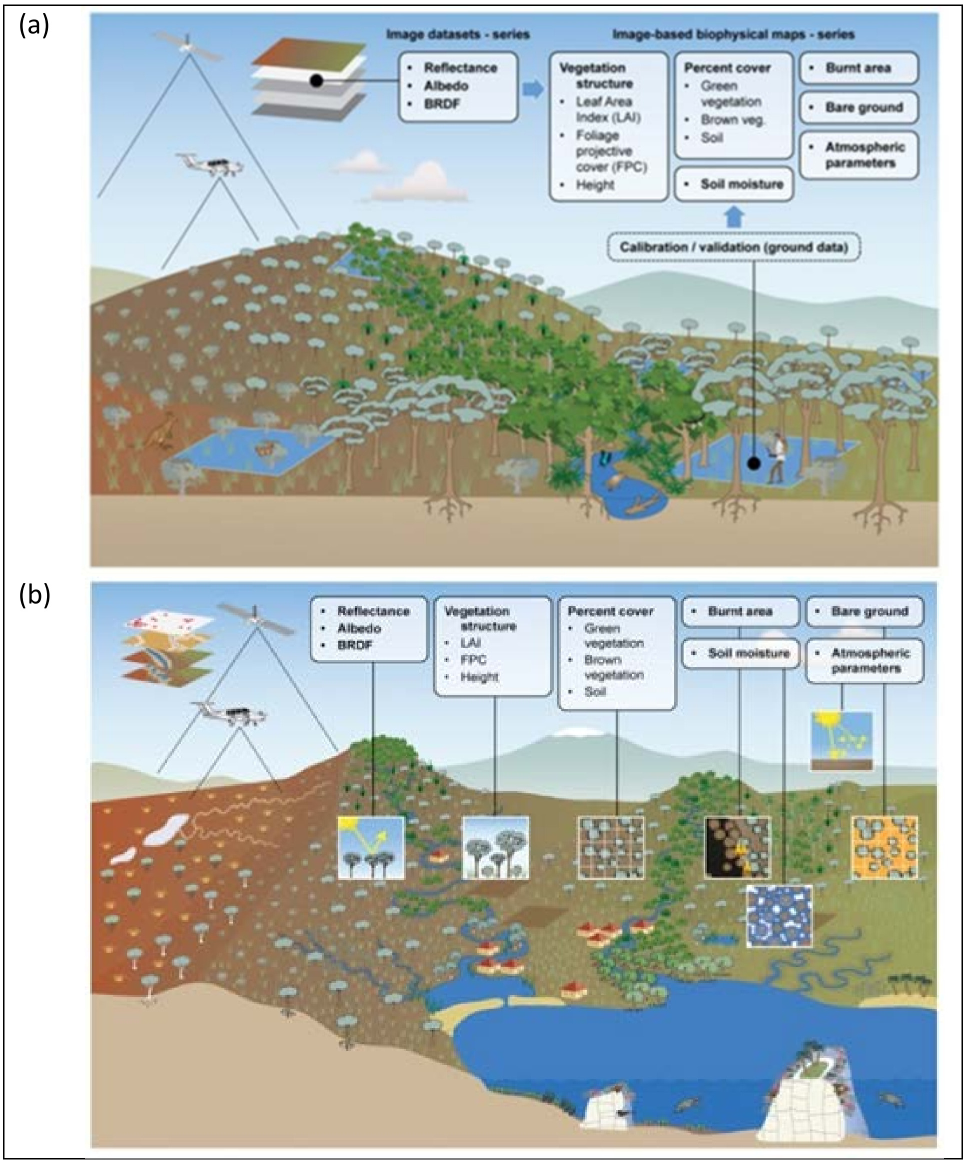

Figure 1.1 (a) Field data collection activities in TERN Auscover used to collect data for calibration and validation of satellite/airborne image maps of environmental properties. **(b)** Satellite and airborne image data collection and processing activities for mapping Australian environmental properties.

1.5 How to Engage, Use and Contribute to this Resource

This handbook is not meant to be a static resource. It is intended to present state of the art knowledge and promote discussion. As such, it should be refined and updated periodically. We have not been able to cover all of the essential components of this process, and the flowchart below indicates the intended structure and sections included in this version of the handbook. We conclude by commending you to read, assess, and contribute to this resource which endeavours to ensure that a sound link between ground and image data is maintained. This will allow EO data to be used for ecosystem science and management. The next revision of this handbook intends to include Cal/Val activities for land cover, reflectance, Burned area, and soil/geologic products.

1.6 Outline of the Handbook

The outline of the handbook is shown in Figure 1.2. While most chapters present reviews and comparisons from the general literature, examples and recommendations focus on Australian ecosystems. After a brief introduction, Chapter 2 summarises some of the major aspects involved when using ground-reference data to validate biophysical products derived from Earth Observation (EO) sensors. Aspects such as site selection, site extent, and sampling design are discussed within the context international and national validation campaigns. The authors also draw recommendations from the Committee on Earth Observing Satellites Working Group on Calibration and Validation (CEOS-WGCV).

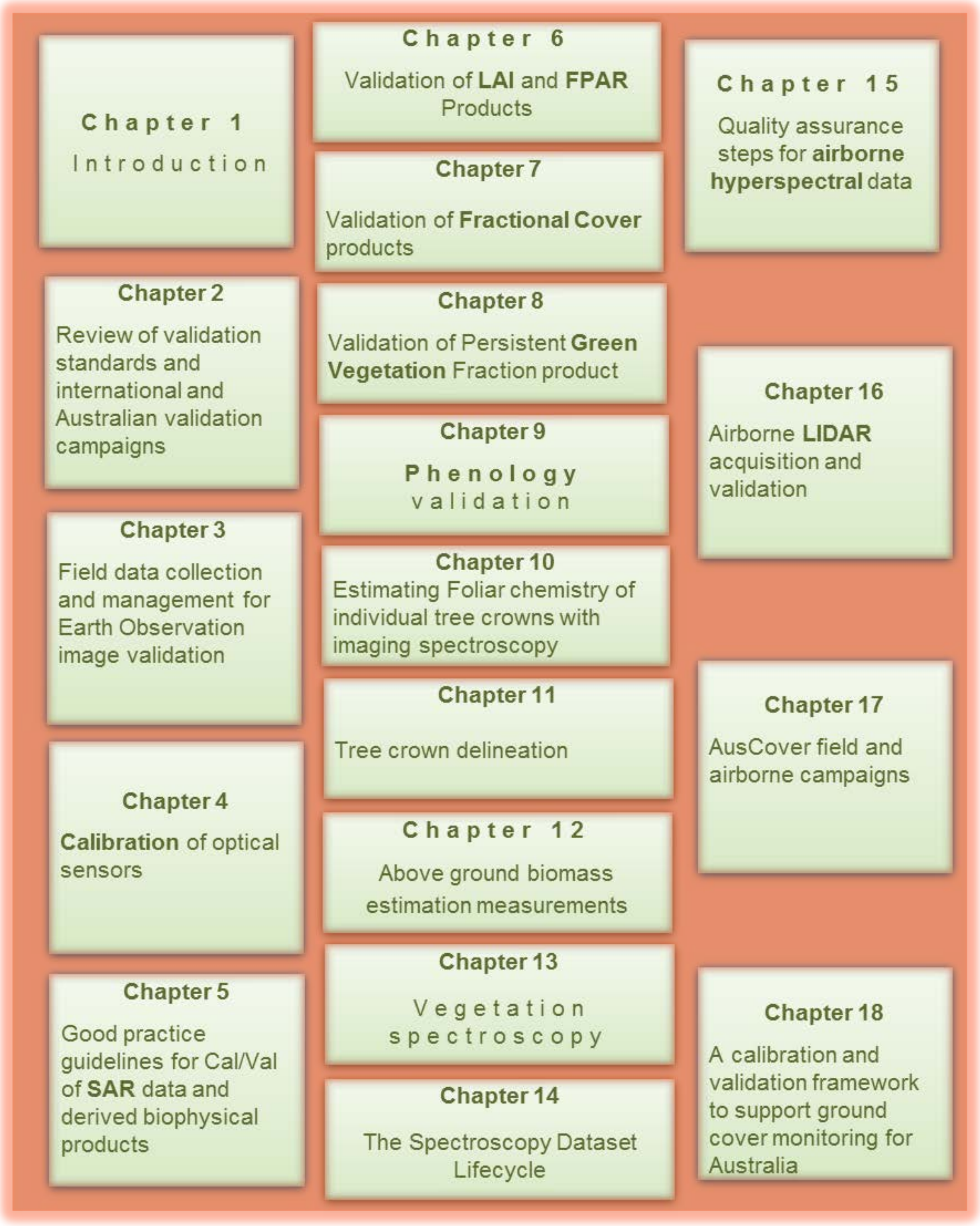

Figure 1.1 Logical progression of image and field data collection, processing and integration as followed in this resource (click on rectangles to go to individual chapters).

Calibration and validation activities frequently require data to be independently collected across different scales using a range of instrumentation. For the data to be of value across the scientific community it needs to be managed appropriately. Chapter 3 summarises guidelines that promote good practice field data management and delivery. The author covers different topics associated with in-situ data collection and stresses the importance of quality assurance and data quality aspects. Furthermore, data collected should be reportable to international standards and shared openly where possible.

The next two chapters focus on calibration. Key components related to the calibration of optical satellite data, including atmospheric correction, are covered in Chapter 4. The geometric and radiometric calibration of Synthetic Aperture Radar (SAR) derived biophysical products such as forest and land-cover are then presented in Chapter 5, which also includes validation aspects associated with SAR data and derived biophysical products.

The next chapters are devoted to the validation of specific EO derived products. Chapter 6 discusses the validation of Leaf area index (LAI) and Fraction of absorbed photosynthetic active radiation (f_{APAR}), two closely related biophysical parameters that are often measured and validated in tandem. This chapter includes a review of some of the major global LAI and f_{APAR} product validation programs and a discussion of methods and instruments that can be used to collect measurements. It concludes by presenting a methodology designed for validating the MODIS collection 5 LAI products across Australian ecosystems.

The validation of three national fractional cover products created using different sensor technologies (MODIS and Landsat) is then presented in Chapter 7. This is followed by the validation of a national Persistent green vegetation fraction product (which shows the fraction of persistent green vegetation between 2000 and 2010) using airborne LiDAR derived estimates of vertically projected cover (Chapter 8).

The next chapters focus on activities associated with validating different vegetation parameters. Chapter 9 is concerned with the validation of MODIS derived phenology metrics. These are obtained by timing and measuring the magnitude of seasonal changes in vegetation indices. Chapter 10 then outlines a methodology for estimating foliar nutrients and plant secondary metabolites at an individual tree-crown level with imaging spectroscopy data. Chapter 11 reviews the most common algorithms used to delineate individual tree crowns and presents a step by step case study using image segmentation techniques. A *biomass estimation* chapter then provides a review of different validation methods that include remote sensing and *in situ* biomass measurement techniques. Chapter 13 (*Vegetation spectroscopy)* covers guidelines required for acquiring spectral measurements in the field. After presenting some basic theory surrounding the interaction of photons and vegetation, the authors warn readers about aspects that can perturb the spectral signal of vegetation. These include soil background or the viewing and illumination geometry. With this in mind, the necessary steps for obtaining field spectroscopy measurements are discussed (e.g., sampling design, data collection, associated metadata and data storage).

In today's information age, spectroscopy data management is a significant consideration for researchers and practitioners presenting challenges imposed by multi-disciplinary data producing activities. When data are created, published, exported, imported, transformed and shared by different parties and used for different purposes, these actions form a data lifecycle. Creating a conceptualized model of this data lifecycle helps to better understand the nature of the data and the integration of previously disparate implementation efforts. Chapter 14 presents the newly enhanced AUS-SPECCHIO(V3) spectral information system within the context of a spectroscopy data lifecycle model for remote and proximal sensing activities, through a common set of lifecycle phases, features and roles established as best practice procedures.

Airborne sensors are frequently deployed for high-resolution mapping programs *per se*, but often also as part of satellite calibration programs and field campaigns. For example, high resolution hyperspectral, radar and LIDAR data can be used to upscale ground gathered observations, or to help calibrate satellite sensors passing overhead. Chapter 15 explains how to georeference and atmospherically correct hyperspectral data. It also offers suggestions for assessing the quality of the georeferenced products; the spatial coverage of the data set; and the spectral at-surface reflectance image pixel values when compared against in-situ spectrophotometer measurements of ground calibration targets. Chapter 16 provides a brief review of LiDAR sensors; discusses the major considerations that impact a LiDAR survey (e.g., extent, vertical accuracy, point spacing, ground cover types and temporal variations); offers guidance regarding technical specifications; outlines a series of validation checks to assess the quality of LiDAR products; and presents a LiDAR Compliance and Quality Assurance Tool.

The handbook concludes by presenting a series of case studies that report on field validation campaigns that have taken place in Australia. Chapter 17 presents several AusCover campaigns carried out across TERNs Supersite Network, where sites that are representative of different ecosystems have been intensively characterized using data collected across multiple scales (ground based, airborne, and satellite). Chapter 18 then presents a national validation campaign of ground cover conducted/collected to validate two of the Fractional Cover products presented in Chapter 7. These last two chapters cover a variety of topics associated with the collection of field data used to calibrate and validate EO data (from the planning to the implementation phase).

Nevertheless, the protocols and approaches presented aim to link closely to internationally agreed protocols, such as those set by the Committee on Earth Observations (CEOS) ‐ Working Group on Cal/Val. This guide is not intended to provide all of the answers, but rather act as a starting point for collating information on Cal/Val.

We wish to express our deep appreciation to all authors and contributors of this handbook, who shared their experience gained through years of effort in the field. We also acknowledge the support of the federal Department of Industry, Innovation, Climate Change, Research, Science, Training and Education, towards the establishment of TERN. The growing network of remote sensing experts and TERN will strive to keep this handbook updated and scientifically current.

We wish you a successful field validation effort!

References

AAS and AATSE (2009a). An Australian Strategic Plan for Earth Observation from Space. Canberra

AAS and AATSE (2009b). Decadal Plan for Australian Space Science 2009-2019. Canberra.

ACIL-Tasman (2010). Economic Value of Earth Observation From Space. Canberra.

ACIL (2008). The Value of Spatial Information: The impact of modern spatial information technologies on the Australian economy. CRC Spatial Information, ANZLIC- The Spatial Information Council. Melbourne, Australia: 171.

CSIRO (2012). Continuity of Earth Observation Data for Australia: Research and Development (2012,CEODA-R&D) G. Australia. Canberra.

Lindenmayer, D., E. Burns, N. Thurgate and A. J. Lowe (2013). Monitoring Environmental Change. Canberra, CSIRO Publishing.

Loveland, T.R. and J.L. Dwyer (2012). "Landsat: Building a strong future." Remote Sensing of Environment 122: 22-29.

Magurran, A.E., S.R. Baillie, S.T. Buckland, J.M.P. Dick, D.A. Elston, E.M. Scott, R.I. Smith, P.J. Somerfield and A.D. Watt (2010). "Long-term datasets in biodiversity research and monitoring: assessing change in ecological communities through time." Trends in ecology & evolution 25(10): 574-582.

Mathieu, P.P. and T O'Neill (2008). "Data assimilation: From photon counts to Earth System forecasts." Remote Sensing of Environment 112: 1258-1267.

Purkis, S. and V. Klemas (2011). Remote Sensing and Global Environmental Change. . London, Wiley-Blackwell.

Wulder, M.A., J.G. Masek, W.B. Cohen, T.R. Loveland and C.E. Woodcock (2012). "Opening the archive: How free data has enabled the science and monitoring promise of Landsat." Remote Sensing of Environment 122: 2-10.

Acronyms

Cal/Val	Calibration and Validation
CEOS	Committee on Earth Observations
CEOS-WGCV	Committee on Earth Observing Satellites Working Group on Calibration and Validation
EO	Earth Observation
NGO	Non-governmental organization
TERN	Terrestrial Ecosystem Research Network