Calibration, Validation and the NERC Airborne Remote Sensing Facility

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Abstract

The application of airborne and satellite remote sensing to terrestrial applications has been dominated by empirically-based, semi-quantitative approaches, in contrast to those developed in the marine and atmospheric sciences which have often developed from rigorous physically-based models. Furthermore, the traceability of EO data and the methodological basis of many applications has often been taken for granted, with the result that the repeatability of analyses and the reliability of many terrestrial EO products can be questioned. 'NCAVEO' is a recently established network of Earth Observation experts and data users committed to exchanging knowledge and understanding in the area of remote sensing data calibration and validation. It aims to provide a UK-based forum to collate available knowledge and expertise associated with the calibration and validation of EO-based products from both UK and overseas providers, in different discipline areas including land, ocean and atmosphere. This paper will introduce NCAVEO and highlight some of the contributions it hopes to make to airborne remote sensing in the UK.

1 Introduction

'NCAVEO' is a recently established network of Earth Observation experts and data users committed to exchanging knowledge and understanding in the area of remote sensing data calibration and validation (cal/val). The aim is to provide a co-ordinated resource for users from industry and academia and also to facilitate access to benchmark methods and algorithms as well as identifying areas where additional research and improved methods are required. The emphasis of the network will be on the validation and traceability of EO products. The network will promote the paradigm of remote sensing as a quantitative physical science, based upon traceable physical measurements and repeatable methodologies. The aim of the network will be to support this view, to facilitate its extension to application areas currently dominated by qualitative approaches, and to educate and inform end-users of remote sensing products about the importance of cal/val and its relevance to their scientific applications.

2 Calibration and Validation

Calibration of a sensor may be absolute or relative. Most sensors are designed to be linear, in which case absolute calibration is achieved by recording the digital number (DN) output from the sensor when its entrance port is filled with a stable, spatially uniform target of known radiance. Relative calibration is achieved by normalising the output of different detectors, or different sensors, so that they all give the same value when viewing a stable, spatially uniform radiance field. The techniques for sensor radiometric calibration are complex and technically demanding, but are reasonably well established. Dinguirard and Slater (1999) identify three types of sensor radiometric calibration: on the ground prior to launch, on-orbit or in-flight methods using lamps, diffusers or panels, and vicarious calibration in which the absolute calibration of a sensor is checked by an independent method, often involving ground targets.

From the user's perspective, sensor radiometric calibration is only the first step towards the desired goal, which is an EO system than can generate consistent and accurate geophysical and biophysical products from different sensors, using different measurement methods. Progress towards this more general goal is usually termed 'validation' and includes factors such as atmospheric correction, spectral characterisation, and the correction for angular and geometric effects (e.g. brdf). Accurate sensor radiometric calibration is necessary but not sufficient to deliver a validated product from EO.

3 Objectives of the network

- to establish a UK-based forum to collate available knowledge and expertise associated with the calibration and validation (cal/val) of EO-based products from both UK and overseas providers, in different discipline areas including land, ocean and atmosphere.
- to establish and promote best practice in the area of cal/val through lively, thought-provoking meetings, state-of-the-art technical workshops, e-learning and the internet.
- to establish the UK as a base for a future European centre of excellence for cal/val related activities particularly in the context of the EC/ESA Global Monitoring for Environment and Security programme (GMES), and to provide a lead role in support of the cal/val needs of international programmes.

4 Organisation of the network

The network will be co-ordinated from the University of Southampton, and funding has been provided by NERC for that purpose. The initial list of partners in the network comprises 14 groups, drawn from academia, the commercial world and government (see appendix). Each partner has committed resources, either direct or in-kind, to the activities of the network and prospective partners are welcome to join on the same basis. The network will hold technical workshops at various sites around the country and more general meetings on the subject of cal/val.

5 Strategic role of the network in relation to NERC science

Earth Observation data have a central role in environmental science and cal/val of these data is essential to ensure that they are fit for the purpose intended. Vegetation monitoring relies upon accurate time series of EO data, and for practical reasons (e.g. cloud cover) it is often necessary to combine data from different sensors or from different processing methods. Inaccurate or unvalidated data severely compromise the value of EO data for monitoring habitat change, biodiversity assessment and resource mapping. Long time series of EO data are vital in studying the process affecting climate and the nature and rate of change of carbon fluxes in the oceans and on land. It is essential that researchers and policy makers have confidence in the data provided by EO, and that requires the data to be carefully validated against conventional, ground-based observations. Airborne remote sensing has an important role to play in bridging the gap between ground-based observations and data from satellite-based sensors. Furthermore, airborne sensors can be used to provide on-orbit vicarious calibration of satellite sensors.

6 NCAVEO and the NERC ARSF

The NERC Airborne Remote Sensing Facility (ARSF) has been acquiring high-quality EO data of the UK since 1982, and an extensive archive of those data now exists in the NERC EO Data Centre. The data are provided to researchers as DN values, together with the information necessary to calibrate to spectral radiance. The atmospheric data which would be needed to convert the data to ground-leaving radiance are not provided, although qualititative observations made by the flight crew are available from the flight logs, which are provided on request. In some cases, ground-based atmospheric measurements would have been made by researchers at the time of the flight, but these are not archived or documented in any systematic way. NCAVEO will seek to influence data providers and data users to recognise the long-term value of calibrated and validated data, thus maximising the potential of newly acquired data for use by future generations.

6.1 Better characterisation of ARSF sensors

The airborne sensors operated by the ARSF are generally calibrated to spectral radiance using a procedure recommended by the manufacturer, for example, that for the CASI was described by Riedmann (2003). However, such procedures are always a compromise between what it scientifically desirable and what it economically practicable. In the case of the CASI, for instance, the standard procedure does not include full characterisation of the Incident Light Sensor (ILS), nor does it include measurement of the spectral response function (SRF) of each detector in the sensor array. Both of these factors affect the quality of the data produced, and the SRF is crucial when using CASI data to simulate other sensors or to study red edge shifts, for example. NCAVEO will provide a forum for scientists, engineers and end-users to evaluate the importance of such issues and recommend a way forward. This may not always mean pursuing the most elaborate and expensive scheme, and in the case of the CASI SRF, an approximation of this important parameter has recently been made by Choi and Milton (2004) using a simplified method which suggests that the CASI SRF is variable across the range of wavelengths sensed, from a full-width half maximum (FWHM) of 2.7 nm at approximately 668 nm, to a FWHM of over 5 nm in the near IR. Although this estimate is in no way a substitute for a proper determination of the SRF, it does raise important issues for discussion, such as whether it matters that the FWHM of the CASI instrument is variable across the range of wavelengths of most interest to vegetation remote sensing.

6.2 Improved access to international expertise

NCAVEO includes partners with strong and active links to international cal/val programmes, including a wide range of EO missions, both NASA and ESA. It also includes representatives on the main cal/val working groups such as the CEOS Working Group on Calibration and Validation and partners with experience of large-scale international cal/val experiments. Part of the aim of NCAVEO will be to translate that knowledge and experience into the local context, so that, for example, users of the NERC ARSF can access best practice more easily and generate better data products as a result. An example of excellent user-focused guidance can be seen in the AVIRIS atmospheric correction tutorial produced by Roger Clark and colleagues at the USGS (Clark *et al*., 2002).

6.3 Access to methods, models and datasets for education and training purposes

Unlike the ocean and atmospheric communities, the land community has relatively few fully validated methods and models which can be applied by end-users. Atmospheric correction is often neglected or performed using sub-optimal methods, despite it being essential if the data are to relate to the ground surface, rather than to the conditions of measurement at the time. NCAVEO will draw upon the expertise of the partners and the data holdings within NERC to facilitate access to exemplar data sets which may be used for education and training purposes and for testing algorithms and methods. An example of such a dataset which will be made available by NCAVEO partners is shown in Table 1.

In addition to supporting improved radiometric characterisation of sensors and increased awareness of pre-processing methods, NCAVEO will also provide access to information on models and methods used to produce and validate EO products, such as maps of albedo, estimates of net primary productivity and land cover classifications.

Table 1. Example of a dataset for investigating atmospheric correction methods to be made available through NCAVEO

Sensor:	Itres Instruments CASI
Location of site:	Thorney Island, Chichester harbour (??°W,°N)
Date flown:	24th July 2001
CASI data:	C20502 : 10,200 ft, N-S, spectral mode, vegetation bandset C20503 : 2,800 ft, N-S, spectral mode, vegetation bandset C20504 : 2,900 ft, E-W, spectral mode, vegetation bandset C20505 : 2,900 ft, W-E, spectral mode, vegetation bandset C20506 : 2,900 ft, N-S, hyperspectral mode
Ancillary data:	Spectra from ground calibration targets: **Asphalt** : spectral radiance, 300-1,000 nm, every 30 s during the flights. Spectral reflectance 300-1,000 nm immediately after the flights. **Concrete and Grass** : Spectral reflectance 300-1,000 nm immediately after the flights. Atmospheric data: Water vapour (equivalent thickness) Aerosol optical thickness (AOT) : 5 spectral bands. Direct beam irradiance : 5 spectral bands. Global and diffuse quantum flux (PAR) : every 5 s Global broadband irradiance : every 5 s Global spectral irradiance : 300-2,400 nm, every 30 s Relative humidity, air temperature and barometric pressure, every 30 s.

7 Conclusion

The establishment of a knowledge transfer Network for Calibration and Validation of Earth Observation data complements the exisiting NERC facilities that support EO, notably the Airborne Remote Sensing Facility, the Equipment Pool for Field Spectroscopy and the EO Data Centre. However, the remit of NCAVEO is also strategic, as it aspires to set the agenda for the subject as well as facilitating best practice. The success of NCAVEO will be measured by the extent to which cal/val becomes embedded within programmes such as that operated by the ARSF.

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Appendix : Founding partners of NCAVEO (contact persons)

Academic partners
CASIX[1] / Plymouth Marine Laboratory (Jim Aiken)
CLASSIC[2] (Peter North)
University of Nottingham, School of Geography (Mike Steven)
University of Southampton, School of Geography (Ted Milton)
University of Surrey, Surrey Space Centre (Steve Mackin)

Commercial partners
Infoterra (Alistair Lamb)
NPA group (Mike Oehlers)
QinetiQ (Gordon Keyte)
SIRA (Mike Cutter)
Surrey Satellite Technology Ltd. (Wei Sun)

HM Government / Research centres
CCLRC Rutherford Appleton Laboratory (Charles Wrench)
Centre for Ecology & Hydrology, Monks Wood (Andrew Wilson)
DEFRA (Simon Leach)
National Physical Laboratory, Optical Radiation Measurement Group (Nigel Fox)

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[1] NERC Centre for the Observation of Air-Sea Interactions and Fluxes.

[2] NERC Climate and Land-Surface Systems Interactions Centre.