SRG 1a (2009)

Services Review Group 2009

NERC Services & Facilities

Application To Seek Service Infrastructure Funding Or Service Recognition From NERC

Application Number: **SRG/2009/________**

Name Of Service/Facility:	**Field Spectroscopy Facility** NATURAL ENVIRONMENT RESEARCH COUNCIL

This application is a bid for:

(Please tick, as appropriate)

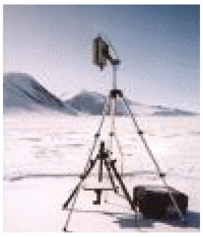
Existing Facility (renewal bid)	√	Block Funding
		Pay-As-You-Go
Existing Facility (rival bid)		Block Funding
		Pay-As-You-Go
Recognised Facility Status		Pay-As-You-Go

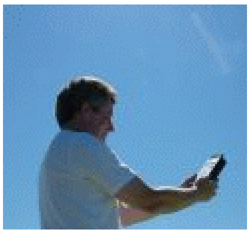
Name of Applicant(s) and Contact Details:	*Please provide local contact information for facility if different from address of Applicant.*

Dr Tim J Malthus
School of GeoSciences, University of Edinburgh, Grant Institute, Kings Buildings, West Mains Road, Edinburgh EH9 3JW
Email: tjm@geo.ed.ac.uk; Tel: 0131 6504915; Fax: 0131 668 3184.

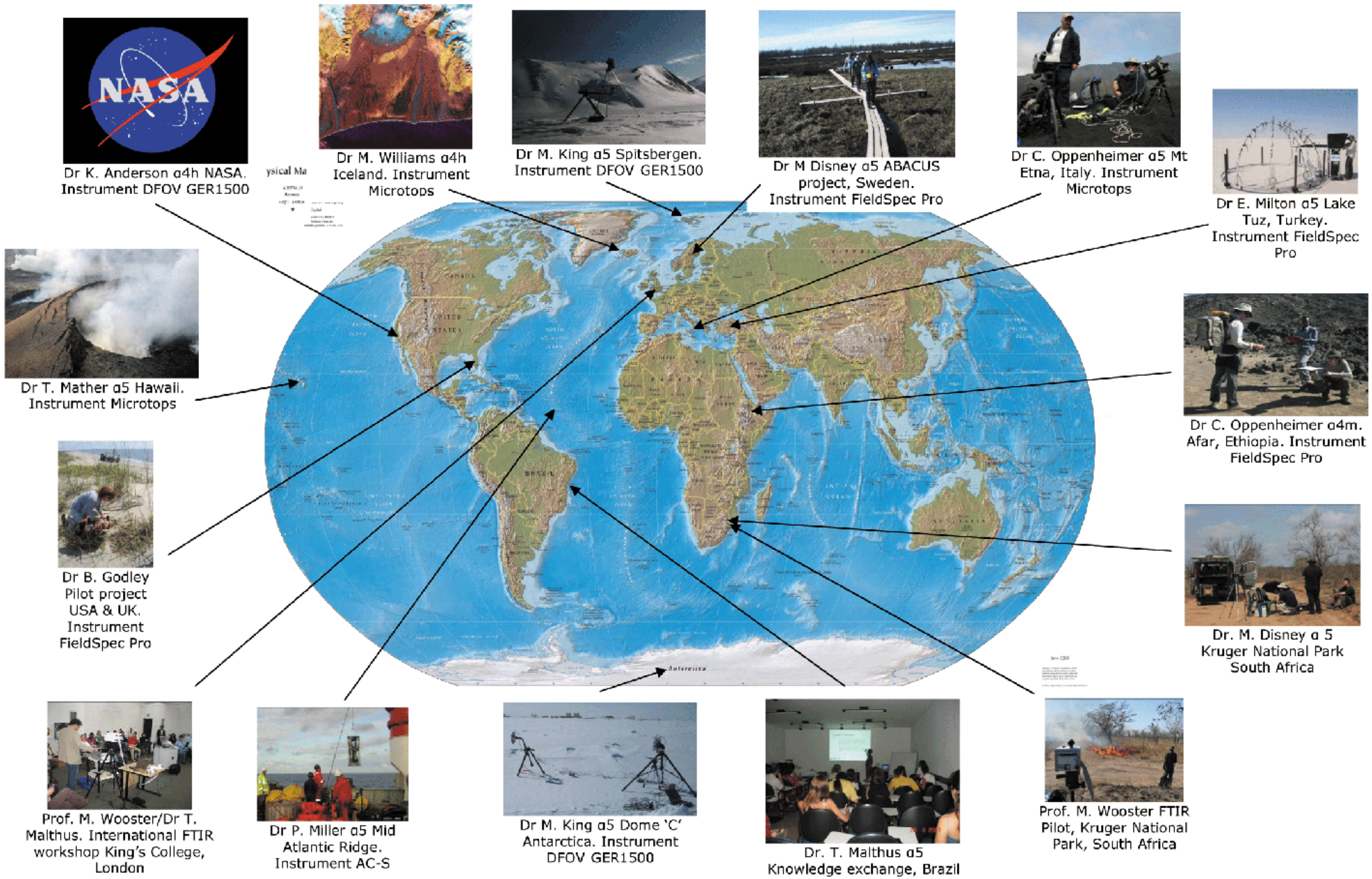
Facility contact details: School of GeoSciences, University of Edinburgh, Grant Institute, Kings Buildings, West Mains Road, Edinburgh EH9 3JW
Email: fsf@nerc.ac.uk; Tel: 0131 6505927; Fax: 0131 6505901

Signature of applicant(s):	**Date:**
Dr Tim J Malthus, Head of Facility	
Signature of Head of Department/Director:	**Date:**
Professor Martin J Siegert, Head of School	

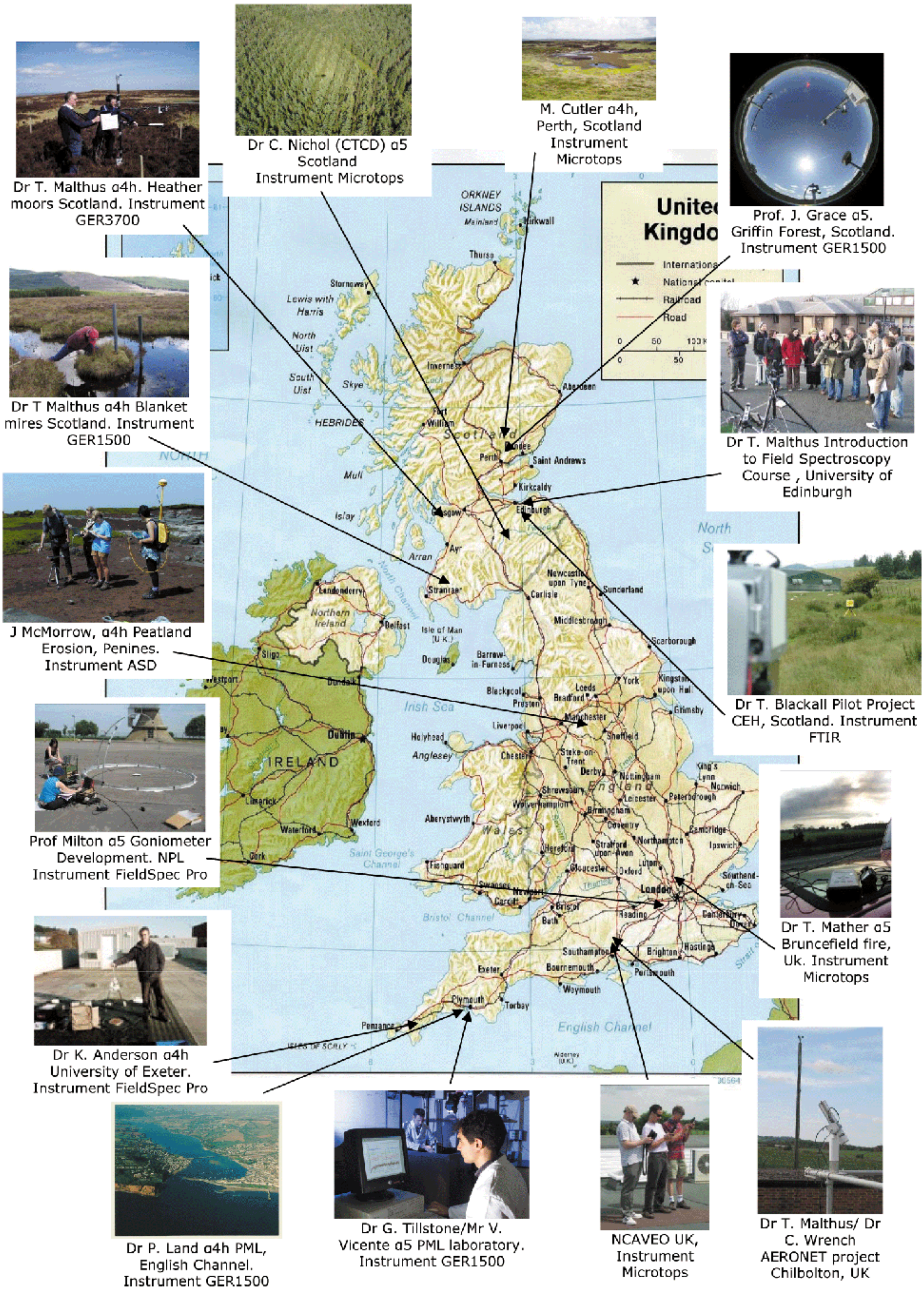



Global distribution of highly regarded FSF supported projects 2006 to 2008



UK distribution of highly regarded FSF projects 2006 to 2008



Executive Summary

- This application reports on the activities of the NERC Field Spectroscopy Facility (FSF) over the period 2006 to 2008.

- FSF is a world class, internationally respected facility supporting Earth Systems science. It comprises a collection of well maintained high quality modern field spectroradiometers, sun photometers, FTIR spectrometer and underwater equipment, operating over optical and thermal wavelengths, with associated calibration and support equipment. Uses include the high-spectral resolution measurement of the optical properties of the Earth surface, water or atmosphere in field situations, the calibration and validation of airborne and satellite derived images and laboratory-based specific measurement of field samples. As such, the Facility supports a diverse and highly interdisciplinary customer base.

- All our equipment is calibrated to National Physical Laboratory or equivalent standards. It currently employs two personnel (1.5 RA FTE in total).

- The Facility and its model of support remains a unique facility worldwide; no comparable facility exists anywhere where equipment and services in field spectroscopy are made available to national scientific research groups and where the funding mode allows access at no cost to the user. This gives the UK research community access to world class capabilities to support remote sensing and environmental research and access to experienced staff. In return, FSF has access to a strong interdisciplinary user base, using frequent user surveys to assess changing demand. This, combined with close contact with instrument manufacturers, allows FSF to influence future developments in instrument design.

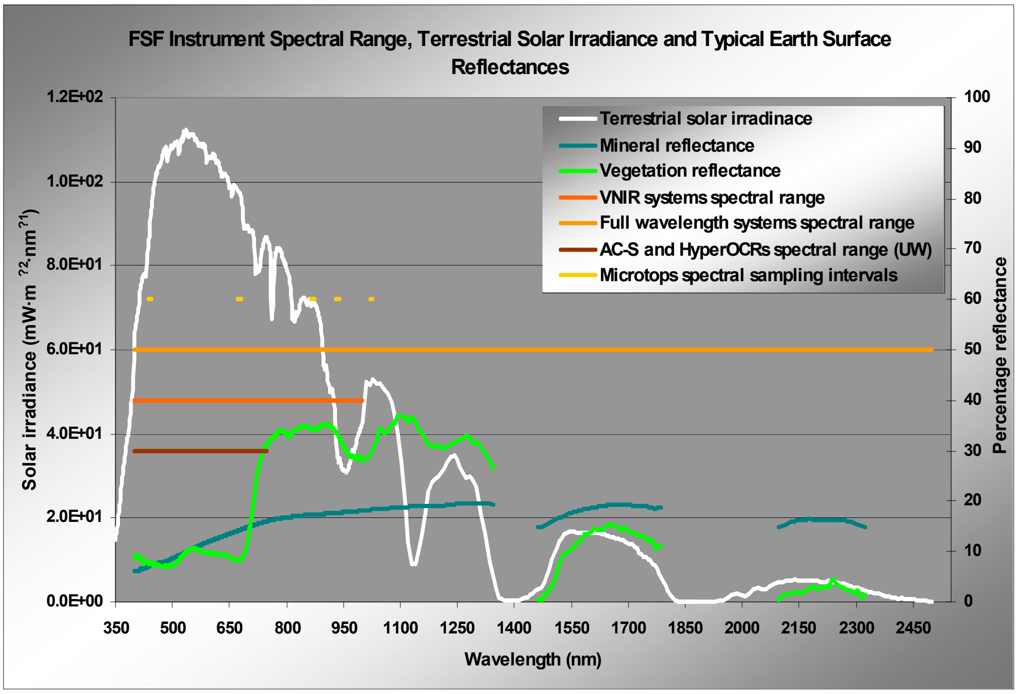
- FSF is of strategic importance and increasing relevance to NERC in underpinning Directed and Responsive mode research programmes and makes a strong contribution to all Science Priority areas. It also contributes to the training of PhD students and up and coming academics. Users publish a large amount of high quality science with support from FSF. The quality of the research it supports is overseen by the FSF Steering Committee. The Facility's internal R&D programme has a direct bearing on the type of science being supported with impacts in both the commercial and academic arenas.

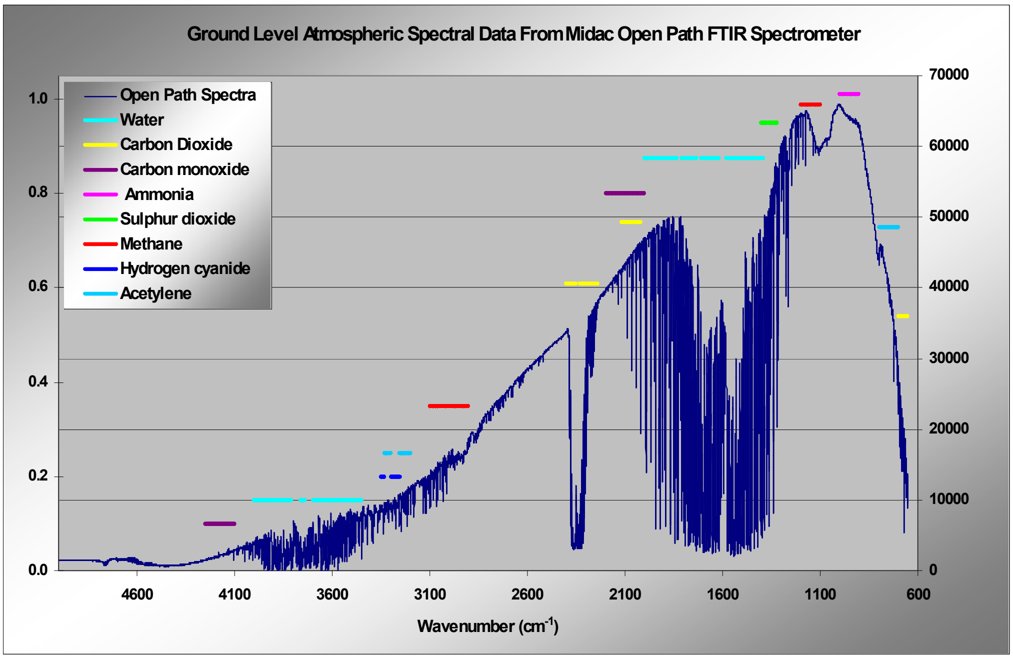
- During 2006-08 both our demand and capacity has risen significantly with capability expanded in terms of the service provided, the range of methods used and equipment provided. This allows us to support a wider range of science and applications. Some 33 NERC funded research (grant and studentship) projects were supported accounting for 45% of total capacity. The Facility supported 32 PhD students loans and supported loans across a wide geographic area.

- Feedback from users rates the high quality of service provided by the Facility extremely favourably (Appendix 10). Operations are streamlined to ensure the full capacity of FSF is available, including liaison with ARSF. The Facility offers real-time support to science teams in the field enabling time-critical data acquisitions to be successfully completed on schedule.

- FSF staff have considerable expertise in technical instrument development which allows for the development of new instrumentation and initiatives (e.g. in FTIR and V-SWIR instrumentation) beyond that currently available and with the potential for commercial exploitation. Our research has highlighted shortcomings in existing instrumentation and influenced manufacturers to improve instrument performance and design.

- The Facility places a strong emphasis on training. All new users receive a tailored one-to-one personal training in instrument use prior to loans. An annually delivered two-day 'Introduction to Field Spectroscopy' training course was begun in late 2005. We have organised topic specific workshops and demonstrations at relevant meetings. User support is also available online at our website (http://fsf.nerc.ac.uk) where all our user guides can be downloaded.





1. Present arrangements for the host service/facility of which the proposed NERC service/facility is to be part:

The NERC Field Spectroscopy Facility (FSF) provides unique and essential infrastructure support for research and training integral to NERC's scientific objectives and strategy through the provision of spectroscopy-related equipment for Earth System science. It is located in the School of GeoSciences, University of Edinburgh. In the recent RAE (December 2008) 70% of the School's staff were classed as either Category 4* (world-leading) and 3* (internationally excellent) in Earth Systems and Environmental Sciences making the School top in this category in the UK (Nature, January 2009).

The FSF is funded on contract under NERC National Capability funding and currently employs two personnel at 1.5 RA FTE (0.75 each). The posts are filled by an operations manager and an equipment manager, employed by the University of Edinburgh. Funds for capital items of equipment are obtained through separate applications to NERC. Over the last contract period (2007-2010) an additional 0.5 RA FTE has been provided from NERC S&F to: 1) develop a field portable Fourier Transform Infrared (FTIR) spectroradiometer (completed March 2007), and; 2) develop a dual field-of-view visible to short-wave infrared (V-SWIR) spectroradiometer with off-the-shelf components and with much improved fore-optics (for completion March 2009).

The current financial arrangement for FSF exploits synergies with the Geophysical Equipment Facility (GEF), also located in the School of GeoSciences and next door to FSF, drawing specifically on the latter's expertise in electronics. With resources thus combined, this has meant support at lower unit cost than would otherwise be the case, while supporting a widening range of instruments and users.

FSF is comprised of:

- Expert staff in the form of an Operations Manager and an Equipment Manager
- A fully equipped dedicated combined office and laboratory comprising a calibration facility and an equipment store, provided by the University of Edinburgh
- A suite of modern loan instruments
- Further storage space, provided by the University of Edinburgh
- Underwater testing facilities, provided by the University of Edinburgh
- Computing facilities including network, central servers and archiving, internet access and support, provided by The University of Edinburgh.

These are the essential components of the Facility which allow us to operate an efficient loan service, calibrate and validate our instruments prior to them going on loan, and offer training to users.

The service provided by FSF is overseen by a Steering Committee comprising members drawn from the research community. The Steering Committee (Appendices 3 and 4) are responsible for peer reviewing and grading applications for loans of equipment. The grading system means that only the highest quality research is supported, meeting NERC's scientific objectives. The Steering Committee, which meets once or twice per year, also provides an independent source of advice in its role as an executive committee helping to meet the future needs of the Facility. As such it also fulfils an independent quality assurance role.

2. Infrastructure funding history for the host service/facility of which the proposed NERC service/facility is to be part, including original installation and upgrade capital and recurrent from all sources:

The FSF moved to Edinburgh in 2004 from the University of Southampton where it had been located since its establishment in 1988. The Facility began with a few spectroradiometers available for loan, but had grown (at the time of the last SRG in 2006) to having 7 spectroradiometers and 3 sun photometers, and housings to make measurements underwater using the existing spectroradiometers. In the three years since this last SRG, the instrumentation available for loan has been considerably augmented to include:

- Instrumentation for the measurement of underwater optical properties, built around a Wetlabs AC-S instrument for the measurement of inherent optical properties (as a result of small grant funding to the University of Exeter).
- A field portable FTIR instrument, developed by the Facility (funded by NERC Services and Facilities), extending the Facility’s capabilities into the thermal range, and covering both atmospheric and surface observations.
- Two new spectroradiometers (ASD FieldSpec 3 and SVC HR1024, both now with capabilities of simultaneously measuring irradiance) as replacement for aging full wavelength systems that are at the core of the Facility’s provision (acquired under NERC Capital Grant funding).
- Three new Satlantic HyperOCR underwater spectroradiometers to complement the underwater instrumentation suite, for the measurement of subsurface downwelling and upwelling light attenuation profiles
- Two new MicroTops sunphotometers to satisfy increasing demand for these instruments, particularly when supporting observations made by NERC ARSF, and to extend users ability to measure ozone concentrations.
- FSF designed integrating sphere (manufactured by SVC) for attachment to a field spectroradiometer, to allow for improved high accuracy measurement of irradiance in the field.

The Facility’s new ASD FieldSpec3 full wavelength system, during training in its use

We are in the process of developing a new V-SWIR spectroradiometer as a replacement to our existing but aging V-NIR instrumentation. The value of this new instrument development is £121.9k. The development is taking place to allow us to address limitations of existing commercial instruments in the near-simultaneous measurement of incident and reflected irradiance with a single instrument and to field-of-view detector response function problems (Section 6).

The funding profile of the last 3 NERC financial years is provided below

Funding history of the FSF FY 2006 – 2009

	2006-2007*	**2007-2008**	**2008-2009**	**2009-2010**
Recurrent	£127,940	£201,632	£183,678	168,382
Capital	£137,050	£152,654	£83,800	42,317
Total	**£264,990**	**£354,286**	**£267,478**	**£210,699**

The 2006-2007 figures are under the old overheads model, the remaining three years are funded under the FEC model. The 2009-2010 figures are projected ones. Recurrent costs vary as calibration of our in-house standards by NPL occurs every two years. Commercial income over the previous three years has amounted to £6.75k. Savings are made in terms of synergies with GEF, our sister Facility at the University of Edinburgh, through the sharing of resources and technical expertise.

The calibration laboratory dark room facility was built in 2004 and was paid for separately by NERC as a one-off FSF setup cost of £17,625.

3. Description of proposed NERC service/facility:

The NERC Field Spectroscopy Facility is a world-class facility supporting **the NERC research community in high quality Earth Systems science** through the loan of high resolution, calibrated, and well maintained optical sensing equipment including high quality modern field spectroradiometers, sun photometers, an FTIR spectrometer and equipment for the measurement of underwater inherent optical properties (Tables 1 and 2). The wavelength regions covered by the Facility's instruments are shown in Figures displayed with the Executive Summary.

FSF's **model of support to users** (equipment free at the point of delivery) is unique in Europe and the rest of the world. This equipment is supported by associated calibration, testing and support equipment. Successful applicants to the Facility are provided with instrumentation, training and the technical support necessary to meet the objectives of their proposed research projects.

Equipment use is largely for the high-spectral resolution measurement of the optical properties of the Earth surface, water or atmosphere in field situations, for the calibration and validation of airborne and satellite derived images and for the laboratory-based specific measurement of field samples. As such, the Facility supports a diverse and highly interdisciplinary customer base encompassing fields such as Earth observation science, glaciology, atmospheric sciences, geology, terrestrial sciences including ecology, and the marine and freshwater sciences.

Strategic underpinning of NERC Science: FSF underpins a wide swath of NERC science programmes, including Responsive and Directed research programmes, and all of NERC's Strategic Science Themes. It contributes to the training of PhD students and new academics, and is integral to the NERC National Centre for Earth Observation (NCEO, which came into existence in April 2008), which now incorporates the former Earth Observation Centres of Excellence. FSF supplies vital support to the NERC Airborne Research and Survey Facility (through the calibration of their EAGLE/HAWK hyperspectral sensor) and other airborne sensor operations (e.g. FAAM), and via the provision of ground-based instrumentation for coincident measurement of atmospheric and/or surface properties during ARSF deployments.

Calibration plays a key role in the Facility's operation and is critical to the compilation of reliable long-term data sets, for example for studying the effects of climate change and the fluxes of carbon to and from the oceans and land. Emphasis is thus placed on the provision to users of calibrated equipment traceable to standards held by the National Physical Laboratory. This is key to minimising uncertainty if we are to attribute detected changes observed in satellite and aircraft data to real environmental changes occurring in the Earth system, where the issues associated with the calibration of the space-borne sensors used to detect these changes is receiving increasing attention.

Training: All new users are trained on a one-to-one basis in the use of Facility equipment. Additionally, an extended, highly rated, two and a half day *Introduction to Field Spectroscopy* training course is offered annually. On average 11 loans each year are associated with postgraduate PhD research, of which 55% are NERC research studentships, with loans frequently extending over two summer seasons in order to study inter-annual variations.

Access to resources is available to the UK research community, subject to expert peer-review by the FSF Steering Committee. Circa 25 applications are received each year and the total requested loan time typically exceeds available capacity. The science supported by the Facility is reported in a diverse range of high quality international journals.

A complete description of the FSF is provided in Appendix 1.

Table 1. Key present and planned capabilities of the Facility. Includes actions identified as future priorities in the last SRG in 2006.

Capability	**Explanation**	**Example of NERC science recently supported or to be supported in 2009**
High spectral resolution	Providing UK users with the highest spectral resolution available in field portable and environmentally rugged optical instrumentation	• Investigations into the inherent optical properties of phytoplankton (Tilstone, PML) • Photosynthetic processes in northern peatland (Harris, Southampton) • Remote sensing of blanket mire microhabitats (Malthus, Edinburgh)
Covers wide wavelength range	Suite of instruments covering 0.4 to 2.5 µm wavelength range, augmented in 2007-08 by the development of a portable field FTIR instrument covering 2 to 15 µm.	• Compatible with datasets from a wide range of airborne and satellite sensors for calibration purposes. • Field-based calibration of the new ARSF AISA Eagle+Hawk hyperspectral sensor covering 0.4 to 2.5 µm range. • FTIR confers greater support to air/atmosphere research community for the estimation of key atmospheric gases important in global climate regulation

Capability	Explanation	Example of NERC science recently supported or to be supported in 2009
Field portability	Hand-held or backpack-based instrumentation for use in remote locations worldwide	• Remote sensing of halogen oxides, water vapour and aerosols in volcanic plumes, Hawaii (Mather, Cambridge); Sicily (Oppenheimer, Cambridge) • Photochemical oxidation in snowpacks, Spitsbergen (King, Royal Holloway) • Reflectance spectroscopy of Antarctic Peninsula lithologies (Riley, BAS) • Visible photochemical oxidation in snow and ice: Organic photochemistry, Alaska (King, Royal Holloway)
Broad-band atmospheric measurement	Hand-held instrumentation for the determination of aerosol optical thickness, water vapour and other atmospheric properties in remote environements	• Sunphotometry as a data source for atmospherically correcting ARSF imagery (Williams, Newcastle) • Nitrate evolution in Dome C, Antarctica (King, Royal Holloway) • Apparent reflectance translation for Andean Biomass estimates (Mahli, Oxford) • Evaluation of potential health hazards related to biomass burning (Oppenheimer, Cambridge)
High spectral resolution thermal wavelength range	Development of field portable FTIR instrument, completed 2007 and covering 2 to 15 µm. At a resolution of 0.5 cm^{-1}	• Intercomparison of NH_3 and HNO_3 concentration sensors (Blackhall, Kings College London). • Magma dynamics at persistently degassing volcanoes (Oppenheimer, Cambridge) • Biomass burning and carbon release, South Africa (Wooster, Kings College London)
Satellite and airborne sensor calibration	Of target radiance or reflectance. FSF now provides two sets of white, grey and black reflectance targets to the ARSF research community	• Allowing simultaneous measurement of vicarious calibration and other ground surface targets (radiance or reflectance) and of concurrent atmospheric properties critical in the quantitative use of satellites or airborne data • Calibration (via empirical line) or validation of ARSF Eagle/Hawk data • Sunphotometry as a data source for atmospherically correcting ARSF imagery (Williams, Newcastle) • Investigating the urban energy balance of London (Wooster, Kings College London) • Mapping glacier debris cover thickness and extent using aerial photography, Lidar and spectral emissivity (Rippin, Hull)
Calibration to NPL standards	State-of-the-art calibration facilities and instruments calibrated traceable to National Physical Laboratory standards	• An evaluation of VIS-SWIR radiometric calibration approaches for high latitude environments (Williams, Newcastle) • Radiative transfer modelling for the characterisation of natural burnt surfaces (Disney, UCL)

Capability	Explanation	Example of NERC science recently supported or to be supported in 2009
Underwater reflectance measurement	The use of fibre optics and protective housings to enable the measurement of subsurface underwater optical properties to a range of depths.	• Rapid marine benthos sampling , Gulf of Eilat (Meaden, Canterbury Christ Church) • Detection of benthic micro-algal communities in gravel bed streams (Visser, Worcester)
Measurement of underwater optical properties	Underwater instrument suite based around a Wetlabs AC-S instrument for the measurement of inherent optical properties (beam attenuation and absorption) in 90 different wavelengths, complemented by 3 band backscatter meter and underwater spectroradiometers for upwelling and downwelling attenuation.	• Investigations into the inherent optical properties of phytoplankton (Tilstone, PML) • Measurement of absorption at the Mid Atlantic Ridge for use in bio-optical models of primary production (Miller, PML) • Estimating temporal and spatial variability of inherent optical properties of turbid coastal waters (Eisner, Birkbeck) • Climate-driven habitat transience and the evolution of visual systems in cichlid fishes (Partridge, Bristol)
The UK's only two AErosol RObotic NETwork (AERONET) sites	Location of the Facility's CIMEL instrument at CFARR, Chilbolton (since 2005). Upgrade, set-up and relocation of CEH CIMEL instrument near CEH Wallingford (in late 2008). Both provide UK researchers with access to continuous observations of spectral aerosol optical depths, inversion products, and precipitable water at UK sites, free at the point of delivery. For the validation of satellite retrievals of aerosol optical properties.	• Contributions to NASA/International Aeronet network and global aerosol coverage

Table 2. Key short-term future development of capability.

Future capability	Explanation	Benefit	Expected
Measurement of the bidirectional reflectance distribution function	Use of innovative optical technologies and lightweight construction to develop portable field goniospectroradiometer for near-instantaneous measurement of surface reflectances from 36 view angles (NERC and DTI funded).	Improved, rapid characterisation of BRDF with high portability, ease of use, and speed of measurement	Early 2009
Increased capacity of processing software available on website	Augmention of existing processing software hosting on web (processing templates, LIBERTY model, MicroTops modelling and processing software) with PlanarRad underwater radiative transfer model, sensor spectral response function filters and Matlab and IDL script exchange forum for processing spectroradiometric data.	To support user's capabilities in data processing and modelling with data obtained by the Facility's instruments.	2009

Future capability	Explanation	Benefit	Expected
Calibration and test fixtures for sun photometers and reference panels.	The development of in-house test fixtures and calibration procedures for the routine quality assurance of sun photometers and reference panels between individual loans. These are currently not assessed in our QA routines.	Improved quality assurance, instrument reliability and characterisation of reflectance panels	2009
Development of continuous irradiance measurement capabilities with field spectroradiometric measurments	Automated narrow band sensor suite for the simultaneous measurement of irradiance with reflected radiance measurements, integrated into the SVC HR-1024 instrument.	Monitoring and modelling of variations in ambient solar irradiance during field reflectance measurement.	Late 2009
Ground-based hyperspectral imaging capabilities	Acquisition of novel hyperspectral imaging capabilities to better characterise reflectances from heterogeneous ground targets	Improved spatial characterisation of reflectance from ground targets; investigations into the heterogeneity of reflectance over small distances; greater understanding in the contribution of different objects to target reflectance; scaling up.	2011
Thermal instrumentation to support ARSF thermal capabilities	Enhancement of the Facility’s capabilities in thermal wavelengths in ground calibration support of proposed new developments in thermal sensing of NERC ARSF.	Calibration of future ARSF thermal sensors	Ongoing
Knowledge exchange	Maintain and develop position as the national centre for the development, maintenance, processing and analysis of field spectral data; develop knowledge exchange connections with university and commercial sector; convene instrumentation related meetings	Prominence in knowledge exchange and training; improved access to our knowledge base and data; joint development of instruments with potential exploitation sharing expertise	Ongoing

4. Service to be delivered:

Emphasis is placed on the delivery of a high-quality and cost-effective service. Although the nature of the service to be delivered is very much determined by the demands of the user community, its principal services include:

- Access to a collection of well maintained, state-of-the-art instrumentation for a wide range of applications.
- Access to calibrated instrumentation such that the measurements obtained are traceable to National Physical Laboratory (NPL) standards.
- Expert training in the use of the equipment provided.
- Expert training and advice in the methods of field spectroscopy, the planning of experiments, data analysis and how to make best use of the equipment.
- Technical advice and technical support.

- Provision of tools for, and assistance and advice in, data processing.

These key services are achieved through:

Efficient management:
- Peer-review to high standards provided by the FSF Steering Committee.
- An efficient and well-run loans service.
- A flexible equipment scheduling service that optimises the use of the equipment whilst at the same time meeting user needs within resource limitations.
- The development of a set of formal procedures following PRINCE-2 project management guidelines, covering all key Facility activities including loan applications and review, loan scheduling, training, calibration and QA.
- Consultation with users through the acquisition of loan feedback (Appendix 10), user meetings and informal discussions and biennial user surveys.
- The maintenance of regular and rigorous Quality Assurance and Calibration procedures for the Facility's instrumentation.
- A formal and rigorous commissioning and acceptance procedure for new equipment.
- Promotion of the facility and the potential applications supported, both within the existing user community and to potential new customers, through presentations at conferences and meetings.
- A dedicated email address representing a single point of access to the community.

Training and support:
- One-to-one discussions with users prior to training to ensure their requirements are met.
- One-to-one training of all new users in the equipment and data collection techniques.
- The delivery of equipment to users and advice on how best to transport the equipment.
- Technical support in the field as required by the user.
- An annually delivered 'Introduction to Field Spectroscopy' course.
- A well maintained and accessible website, the Facility's principal publicity tool, providing up-to-date information and a focus for the wider community.
- Bespoke software designed by the Facility for post-processing data.
- An office usually staffed during normal working hours five days per week.

Potential improvements and expansion. Whilst the Facility is in a very strong position to continue to support a wide diversity of international quality NERC Science, we have ambitions to improve and expand our service. The Facility will pursue new investment programmes/funding opportunities to acquire new equipment to expand the range of NERC science and services supported and also to further improve the measurements. As with current practice, this expansion and diversification will be informed and driven by regular consultation with users and the FSF Steering Committee. Potential funding sources include NERC's capital bids, research grants scheme, and external funding sources. Where practicable, new developments will continue to involve collaboration with other NERC facilities providing complementary services (e.g. MSF and Facility for Scientific Diving).

Planned support for key new science areas: Key new science areas to be supported in the very near future include:
- Atmospheric and Earth observation communities supported through widened access to AERONET data with the dedication of a CIMEL sunphotometer to Wytham Wood near to

CEH Wallingford. This will provide continuously monitored observations of aerosol spectral optical depths, precipitable water, from which aerosol size distributions and phase function data can be calculated.

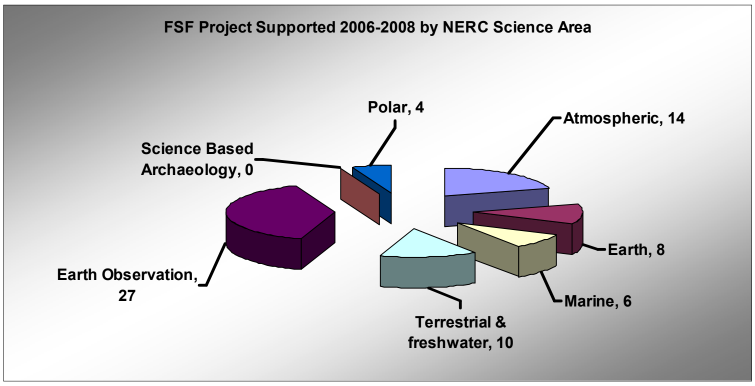
- The Facility will also further develop and improve its calibration procedures both to better characterise and reduce the uncertainties associated with the calibration of its instruments. It will continue to support the wider research community through the provision of calibration services for non-NERC owned spectroradiometric equipment (further discussed below).

5. Description of science to be carried out by users of the existing/proposed NERC service/facility:

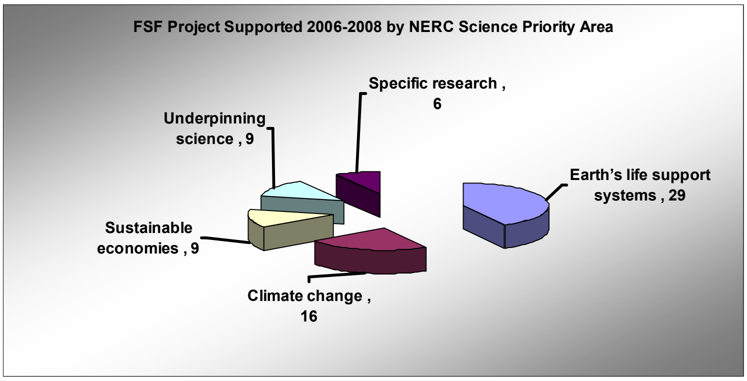
Context

The Facility ensures that the science carried out by the FSF and its users is directly guided by the **NERC Strategic Science Themes** for researching the major global environmental challenges facing Planet Earth. To illustrate the diversity and range of distinctly different applications the Facility supports, a list of specific projects collated from previous annual reports over 2006-08 is presented in Appendix 5. Highlights of the specific research projects are outlined below.

Measurements made using FSF equipment make an important contribution to NERC's scientific strategy '**Next Generation Science for Planet Earth**' which identifies the strategic and scientific priorities for UK environmental science (Climate systems, Biodiversity, Sustainable use of natural resources, Natural hazards, Environment pollution and human health, Earth system science and Technologies). As the Facility's capabilities have expanded, so has the range of science supported by the Facility.



NERC Science Areas supported by FSF (with number of projects) – previous categories



Projects supported by FSF by NERC science priority area – previous categories

The Facility's remit meshes well with the expressed aims of the **NERC Centre for Earth Observation** (NCEO) established in April 2008. The Centre emphasises that, in order to derive scientific and societal benefits from EO measurements, the properties of the measurements and their uncertainties must be more fully characterised. In the future, NCEO will provide strategic leadership for the common evolution of NERC's EO Facilities. Professor Alan O'Neil, the Director of NCEO, visited the Facility in November 2007 and witnessed its new developments at the RSPSoc meeting in September 2008.

Since its last strategic review the FSF has continued to support the **NERC Centres of Excellence in Earth Observation**, notably the Centre for Terrestrial Carbon Dynamics (CTCD); the Climate & Land-Surface Systems Interaction Centre (CLASSIC); and the Centre for observation of Air-Sea Interactions and fluXes (CASIX). The activities of these centres were incorporated into NCEO in April 2008.

Impacts on the science of equipment and new acquisitions

Field spectroscopy plays a key role in the support of research in the environmental sciences by:

- facilitating quantitative interpretation of remotely sensed image data (e.g. for accurate atmospheric correction,
- vicarious sensor calibration,
- quantifying uncertainties in multi-temporal RS datasets,
- provision of spectral end-members to unmixing algorithms)
- *in situ* measurement of surface bidirectional reflectance factors to better understand the interaction of radiation with Earth surface objects (e.g. for determining wavelengths for better quantitative characterisation of Earth surface objects, for the parameterisation and validation of physical models).

Recent acquisitions of underwater instrumentation allow for the investigation of improved algorithms for CASE 1 and CASE 2 waters using inversion-based radiative transfer modelling approaches. The development of the Facility's new field portable FTIR instrument expands capabilities into the thermal region and allows for the accurate determination of near surface gaseous emissions from a range of phenomena over variable pathlengths, and for the determination of surface specific emissivity, required for the accurate estimation of land surface temperatures to allow better simulations of surface energy budgets.

FSF's role in addressing NERC's Strategic Science Themes:

1. Climate systems

The quality of climate change prediction and our reassessment of it ultimately relies on the ability to accurately observe the planet. Observations are identified as playing a key role in understanding the highly variable impacts of climate change and in understanding of the impacts of climate change on environmental services, human welfare and economic development. Observations are thus crucial, combined with basic understanding and modelling, to making risk-based predictions of the future state of the climate.

FSF equipment is thus critical to NERC's stated intentions to improve and expand on climate related observations of the past and present where accurate long-term observations of the global climate system are required to quantify changes and to test and evaluate climate models. Field spectroscopy plays a vital underpinning role in the study of global environmental change and in understanding variability in climate and change at a range of scales.

Reducing uncertainties - Critical to the delivery of *accurate* climate related observations from space is the requirement to reduce uncertainties in those observations. FSF's range of equipment (e.g.

sunphotometers, spectroradiometers, AERONET sites) is critical in this role, playing an important part in the calibration and validation of data obtained at altitude (i.e. from aircraft or satellite).

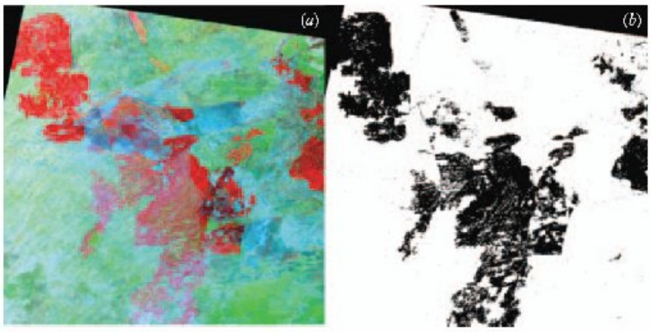
> The *calibration* of earth observation data is critical if we are to reliably attribute detected changes observed in satellite and aircraft data to real environmental changes occurring at ground level. Without calibration we are unable to rule out the influence of other factors such as instrument error or influences of the atmosphere. This problem is exacerbated by the myriad of sensors operated by multiple countries and organisations. Calibration allows the traceability of sensor data to the same physical standards and is routinely required as sensors decay throughout their lifetime in space. Calibration is critical to the compilation of reliable long-term data sets for studying the effects of climate change and the fluxes of carbon to and from the oceans and land.
>
> *Validation* refers to the independent verification of the physical measurements made by a sensor as well as of the derived geophysical variables. Validation allows for the verification and improvement of the algorithms used (e.g. for atmospheric correction and vegetation state). To achieve this, conventional, ground-based observations are required using calibrated and traceable field instrumentation.

Atmospheric correction and accurate calibration of airborne and satellite-borne image datasets is critical in allowing the quantitative use of such images either for estimation of surface reflectance at a single point in time, or for the comparison of multi-temporal datasets. FSF has continued to support research to develop and validate atmospheric correction algorithms for airborne hyperspectral data obtained over both Case 2 waters and land (Land, PML, α4). Furthermore, field generated instrument inter-calibration functions (ICFs) of dual-beam sensor pairs, obtained close in time and space to real field measurements, are superior to laboratory based generated functions. (Milton et al. 2007; Anderson et al. 2007).

Science Highlight 1

Estimating Emissions from Wildfires (Wooster, α5, Kings College London)

Wildfires are a major contributor of many chemical species to the atmosphere, on average burning many millions of km² annually and releasing an amount of carbon estimated to be equivalent to ~ 40% of yearly fossil fuel C emissions. Worldwide fire activity shows extreme interannual variation, and climate and landuse changes are expected to increase wildfire incidence in many areas. Such activity must be properly represented in global models of the Earth's carbon cycle, and in applications aiming to quantify smoke-related pollutant emissions in order to forecast their atmospheric dispersion (including for the development of early warning systems related to air quality and health). The typical approach to such quantification has been to rapidly map the areas burned from high temporal frequency satellite remote sensing data. The FSF GER3700 was used to support this work by determining the spectral properties of newly burned surfaces in high and low intensity fires, together with those of bare soil, senesced vegetation and leaf litter that are all present in fire-prone areas of southern Africa. Mapping burns repeatedly over large areas typically requires the use of moderate spatial resolution imagery such as that from MODIS or AATSR. Results must be validated against those from a limited number of higher spatial resolution "reference" images so that, for example, adjustments can be made where necessary for the proportion of smaller, missing fires that are typically missed by the lower spatial resolution data. Using the field spectra, this work developed processing methods for deriving optimum "reference" burned area maps from Landsat ETM+ imagery, and used this to explore the quality of the lower spatial resolution mapping (Smith et al., 2007).

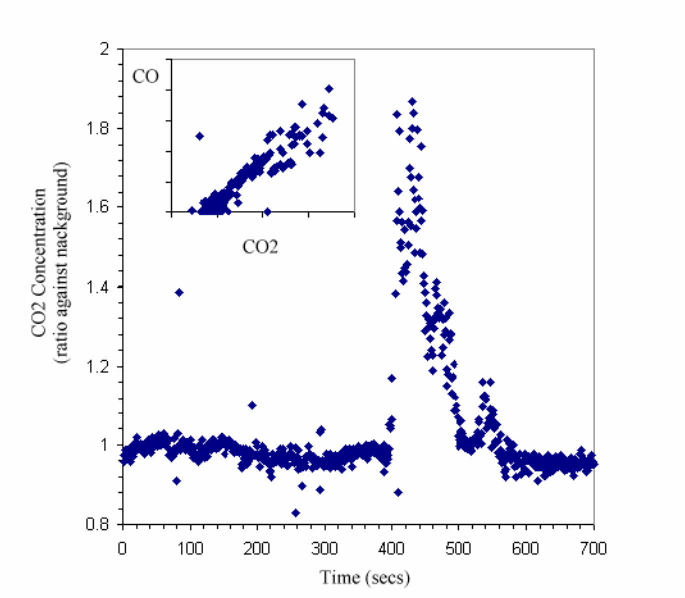


(a) Landsat image highlights recently burned areas in Chobe National Park, Botswana (October 2001), and (b) burned area reference image derived using spectral mixture modeling.

To calculate carbon emissions, the burned area data are multiplied by the fuel consumption per unit area and the carbon fraction of the vegetation. However, the carbon is actually released as many different chemical compounds, including CO_2, CO, CH_4 and formaldehyde, each having different atmospheric impacts, fates and lifetimes. The FSF FTIR is being used to investigate whether open-path measurements of the IR absorption characteristics of fire-emitted smoke can be used in the field to determine the chemical makeup and gas emission ratios of real wildfires. In 2007 and 2008, the open path FTIR was successfully deployed on a series of 7-hectare test fires in Kruger National Park, South Africa. Smoke from the fire is made to pass between a IR "heat" lamp and the FTIR spectrometer placed ~ 100 m away that is measuring the infrared radiation from the lamp at high wavenumber resolution (0.5 cm^{-1}) across the TIR wavelength region between ~ 2.5 and 12 µm. Chemicals in the smoke absorb at certain IR wavelengths, and the resulting changes in the spectra recorded by the FTIR during the smoke's passage across the field-of-view allow both the smoke chemical constituents and their

FSF FTIR open path system deployed on experimental fires in Kruger National Park, South Africa.

concentrations to be determined during subsequent analysis. Preliminary results demonstrate accurate retrievals of the background CO_2 concentrations prior to the fire, with concentration doubling during the fire's passage over the landscape. The ability to determine relative gas emission ratios from analysis of multiple spectra taken over the duration of the fire has also been demonstrated.



FSF FTIR open path retrieval of smoke plume CO_2 concentration downwind of an experimental fire over a >100 m path length. At the peak, concentrations reach almost twice those of the pre-fire ambient atmosphere. Inset shows ratio of CO to CO_2 concentration.

In addition to the deployments in southern Africa, the open-path FTIR approach was piloted in an experimental Canadian boreal forest burn, with the results of this and related work reported in a 2-page News & Focus article in the journal "Science" (Appendix 11).

Science Highlight 2

Snowpack photochemistry and climate change (King, α5, Royal Holloway)

The prediction of future climate change relies on an understanding of previous climate change. The variation with depth of chemicals such as nitrate trapped in Antarctic ice cores potentially provides the strongest evidence available for past climate and climate change events. However, deciphering the chemical signals present in the ice cores is a major challenge as various processes can lead to the loss of chemicals from the ice core after initial deposition. UK researchers have developed a method by which the nitrate concentration depth profiles recorded in ice cores can be used to obtain mixing ratios of the atmospheric gases NOx (NO_2 + NO) in past atmospheres and thus the palaeo atmospheric oxidizing capacity.

NOx is deposited to snowpack in precipitation as nitrate. The aim of the research has been to determine the amount of nitrate lost from the ice core since deposition, as a result of remobilization of nitrate (reversible processes such as evaporation, condensation, sublimation and diffusion) and irreversible processes such as photodissociation by sunlight or chemical reaction. Thus nitrate may also be a measure of the palaeo surface UV irradiance. It is well known that isotopic chemistry is capable of separating and quantifying biological, physical and chemical effects. Isotopologues (i.e. $15NO_3^-$ & NO_2^{18O-}, etc) of nitrate have been used to distinguish and establish the main processes at play at Dome C in Antarctica, an important European ice core drilling site.

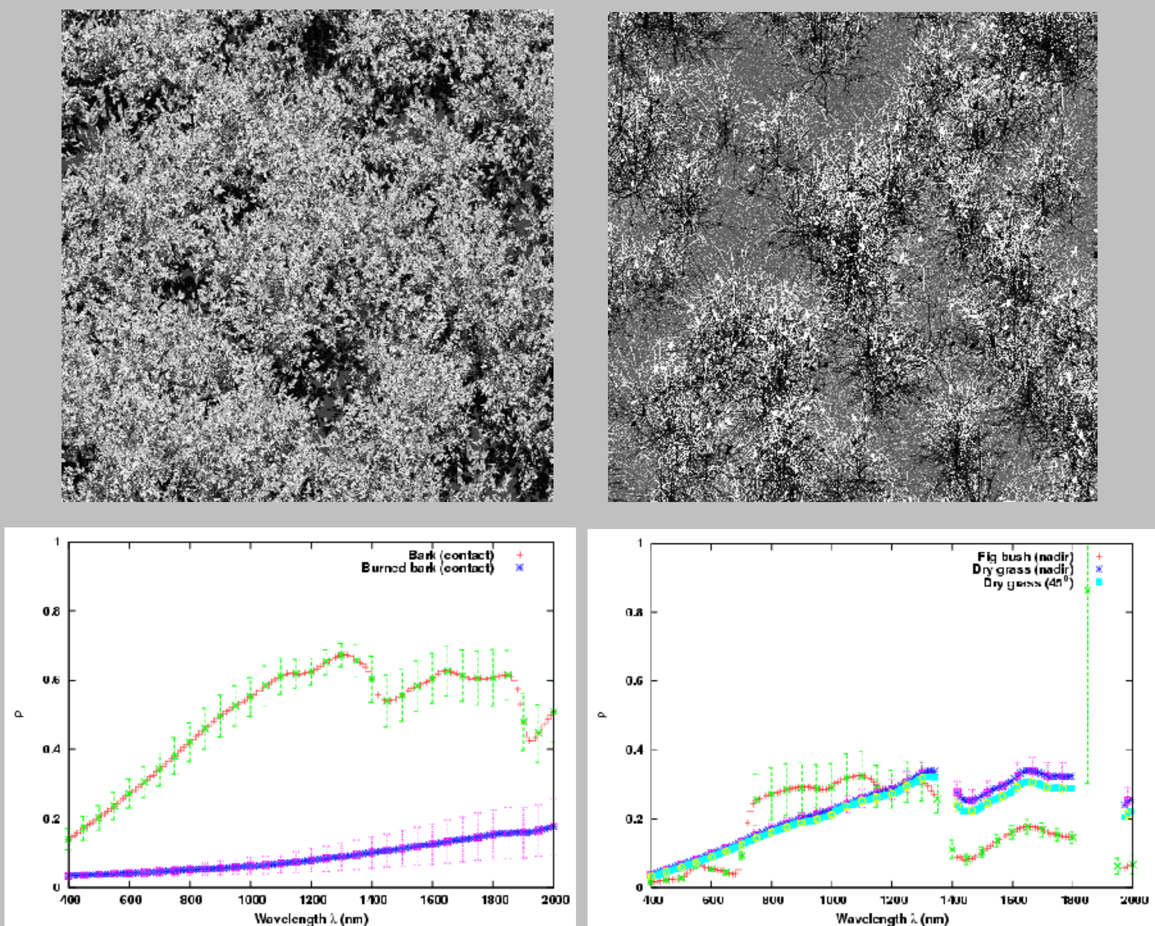
In a IPY project with international partners from France and USA, UK researchers used GER1500 spectroradiometers and Microtops instrumentation to measure the optical properties of snow at Dome C (light penetration depth and nadir reflectance around 400nm), to help calculate and measure atmospheric and in-snow photolysis rates of nitrogen oxides and nitrate. The optical properties of the snowpack showed large heterogeneity with some of metamorphosed snow having penetration depths of 12-15 cm and the old wind-packed snow having penetration depth of 4 cm, The albedo was extremely high and most sites were between 0.95 and 0.98. Radiative-transfer calculations based on the photochemistry in snow show that the heterogeneity is key in controlling the light photochemistry.

Science Highlight 3

Radiative Transfer Modelling for the Characterisation of Natural Burnt Surfaces (Disney, α5, UCL)

To exploit ESA and NASA satellite data to monitor where fires have occurred, quantify the burned area, and estimate associated loss of biomass, understanding of how land surface reflectance changes after fires is needed. This has important implications for climate (carbon release, land cover change), management and disturbance monitoring. ESA and NERC (NCEO Carbon Theme and QUEST) funded research aimed to develop a spectral, structural model of the surface change following fires to obtain observations against which to validate the model on an experimental burn site that has been running for 50 years in Kruger Park, South Africa. Structural and spectral measurements of the surface areas before and after plots were burned, as well as monitoring the intensity and the carbon released during the burns. Two full wavelength spectroradiometers were used to obtain both ground and helicopter based radiance and irradiance over the burn sites.

From this detailed 3D scene models are used to simulate the pre- and post-burn reflectance signal over larger areas and which is parameterized using measured scene reflectance spectra. Model outputs are then validated against the helicopter reflectance measurements to enable understanding of what a satellite would see before and after a fire. Archives of satellite data can then be used to detect where and when fires occurred, and quantify their area and ultimately to determine carbon loss.



Top: 3D model simulations of a shrub-covered landscape, pre (left) and post (right) 'burn'. Bottom: examples of pre and post burn scene component reflectance, bark (left) and above canopy reflectance of a green bush and dry grass.

2. Biodiversity

FSF supports research leading to greater understanding of the threats to biodiversity loss, the consequent impacts of such losses and of the role of biodiversity in key ecosystem processes. FSF spectroradiometers have been used to derive indices to estimate near surface moisture conditions in *Sphagnum* dominated wetlands, critical for understanding carbon-balance (CO_2 and CH_4 emission) processes (Harris et al. 2005; 2006). Field reflectance and hyperspectral image spectra of wetland surface components were used to define endmembers for multi-temporal image analysis to show significant anthropogenic impacts on salinity and the nature of hygrophytic vegetation (Schmid et al. 2005). FSF ASD equipment has been used to examine the possibilities for using EO data in monitoring and modelling vegetation state and dynamics under catchment-scale treatment regimes linking mesocosm studies with manipulation experiments in Wales (Disney, UCL, α4h).

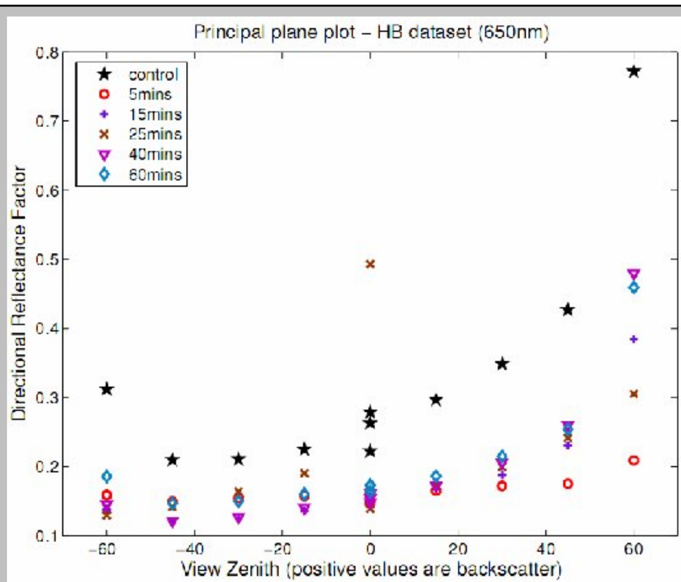
3. Sustainable use of natural resources

FSF equipment is contributing to research leading to potential solutions aimed at protecting soil quality. FSF ASD spectroradiometric equipment was used to measure reflectance of soils susceptible to wind erosion in simulated rainfall and wind tunnel abrasion experiments (Chappell et al. 2006). FSF kit has been used test the feasibility of an imaging technique to record spectral profiles of loess sediments in China (Smith, Kingston). ASD equipment has been used to evaluate hyperspectral methods for identifying peat erosion and monitoring peatland restoration (McMorrow, Manchester, α4h).

Science Highlight 4

Protecting soil quality (Anderson, α5, Exeter)

Soils experience rapid degradation of structure and composition in response to human induced land use and land cover changes. Many of the effects of land use and cover change on soil properties, e.g. the decline of organic matter content and structural stability, and are known qualitatively, but spatially distributed quantitative information is scarce. Remote sensing has the potential to provide such data to soil scientists. Anderson and Kuhn (2007) used an ASD spectroradiometer in an experiment to test the feasibility of using multiple view angle hyperspectral data for detecting differences in soil structure during a controlled crusting process induced using a rainfall simulator. Changes in soil structure, were best described by backscattered radiation measured at + 30º in the visible and near-infrared and at + 15º in the short-wave infrared, demonstrating the potential of combining spatial and multiple view angle hyperspectral measurements for discriminating fine scale differences in soil surface roughness. When considered in the context of the new pointable remote



Principal plane plot showing directional reflectance factor variations at 650nm for soils exposed to different wetting and drying durations.

sensing systems in operation, coupled with new-generation sensors with in-built directional capabilities, the results show great promise for broader-scale monitoring of soil condition.

4. Natural hazards

A key role for FSF is contributing to research aimed at quantifying the effect of volcanic emissions and forest fires on the climate by investigating their effects on atmospheric chemistry and integrating the data with climate change models (e.g. Jones et al. 2007; Oppenheimer α5, Cambridge). Contributions to studies on the effects of biomass burning have been outlined above.

5. Environment, pollution and human health

The Buncefield oil depot explosion in December 2005 afforded study of the atmospheric consequences of a major oil fire at close range (Mather et al. 2007). FSF sunphotometer equipment were used to estimate plume particle composition and radius, trace gas concentrations and effects on the reduction in solar flux. FSF is now hosting software aimed to assist users to retrieve columnar optical thickness of aerosols concentrated in plumes (resulting from volcanoes, fires or industrial plants) from measurements made with its' Microtops sunphotometers. Using a FSF spectroradiometer in field studies of an abandoned mine in Spain, Ferrier et al. (2007; 2008) derived correlations between spectral reflectance and hazardous mine waste, notably secondary iron species, cyanide and heavy metals concentrations. A pilot study assessing spectral responses from *Pinus sylvestris* at differing ages and with varying levels of ^{137}Cs Chernobyl contamination showed the potential to infer contamination levels from spectra of forests, partitioned by age, thus indicating the possibility of using imaging spectrometry to monitor radionuclide contamination, ultimately to return areas of land no longer posing a risk, back to an appropriate use (Boyd et al. 2006).

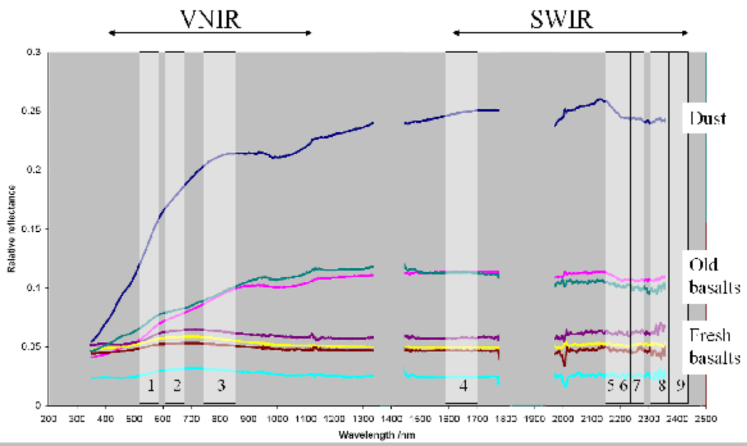
6. Earth system science

FSF spectroradiometers and MicroTops sunphotometers were used in the support of the ARSF deployment to Ethiopia linked to the NERC Afar Consortium project, which is investigating magmatism and tectonics associated with plate rupture in the Afar region of Ethiopia. Spectroradiometric data have been used to apply advanced remote sensing techniques to synoptic- and local-scale geological and geomorphological characterisation of erupted materials and their relationships to faulting and fracturing (Oppenheimer, α5, Cambridge). Initial objectives include discrimination of lava compositions from remotely sensed data and characterisation of temporal relationships in lava flow field development. Key questions to be addressed are the relative abundances of silicic and mafic lavas, temporal trends in erupted composition, and spatial relationships between volcanism, dyke intrusion and faulting. The ground-based spectroscopy, combined with petrological analysis of rock samples will be used to aid analysis of the airborne imagery, and to contribute to some more generic tools for geological interpretation of remotely sensed data in volcanic terrains.

Science Highlight 5

Remote sensing of the volcanic geology of the Afar Depression, Ethiopia (Oppenheimer, α5, Cambridge)

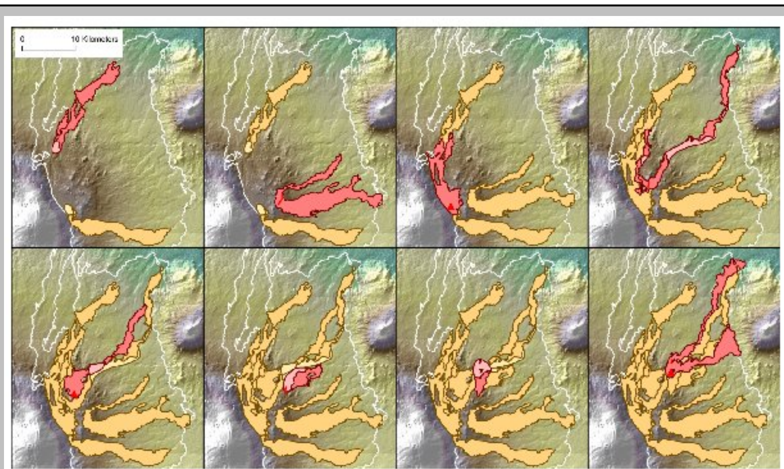
The Afar Depression, at the northern end of the East African Rift valley, provides a unique opportunity to study the seismic and volcanic activity associated with the break up of continents and the development of a new ocean basin. This break up proceeds by rifting events, periods of intense seismicity and volcanism associated with the intrusion of sheets of magma as the plates move apart. Since 2005, a series of rifting events and dramatic eruptions (the most recent in November 2008) in the north of Afar has sparked intense scientific interest. As part of the AFAR NERC Consortium project FSF spectroradiometers have been used to assist in studies to understand the longer term relationships between tectonic rifting, the storage, transport and eruption of magma, and the resulting landscape evolution. This requires the characterisation of volcanic geology over large areas, a task that lends itself to remote sensing techniques.



Reflectances of various surfaces in Afar, with ASTER bands shown for reference.

Spectral measurements of fresh, recently erupted basalts, old basalts and wind blown dust enables the identification of the importance of the accumulation of windblown dust in explaining the changing reflectance of basalt surfaces as they age. This important results allows for:

- the discrimination of neighbouring flows and their mapping,
- the derivation of a relative chronology of flows on the basis of spectral properties and thus the deconstruction of the eruptive history of the area
- the possibility to derive rough absolute dates if assumptions about the rate of deposition of dust can be made.


Eruptive history of the Alayta flow field, north Afar, derived using superposition relations and spectral properties. Panels from oldest in top left to youngest in bottom right (yellowflows are old, red flows most recent.

7. Technologies

The Facility's in-house research programme is focused at addressing technological issues with its instrumentation with the aim of ensuring users have state-of-the-art equipment designed to maintain UK research capabilities at the competitive edge. As such, the Facility's research is improving UK capabilities to observe, measure and monitor earth surface features and extending our capabilities to support a wider range of applications and users. New directions are informed by regular consultation with users and the Facility's equipment replacement strategy which seeks to ensure new instrument purchases maintain capabilities at the cutting edge.

Whilst much of the Facility's in-house research programme is explained in detail in section 6, the focus of this research effort has been aimed at:

- *Developing new instrumentation from emerging trends* to support new areas of science (e.g. development of field portable FTIR instrument and underwater instrumentation for near-complete characterisation of underwater optical properties).
- *Reducing uncertainties in existing measurements*, e.g. external sensors to characterise variations in incident irradiance during field reflectance measurements, research into the calibration and care of Spectralon reference panels, and an improved goniometer for the rapid measurement of BRDF related reflectance properties in the field.
- *Ease of use of the Facility's instrumentation in the field* (e.g. wireless communications between control PCs and instrumentation, incorporation of GPS positioning as standard).
- *Development of novel field portable dual field-of-view V-SWIR spectroradiometer* with input from the Astronomy Technology Centre, Royal Observatory, Edinburgh.
- *Development of purpose-built facilities* for calibration of ARSF's EAGLE/HAWK system.

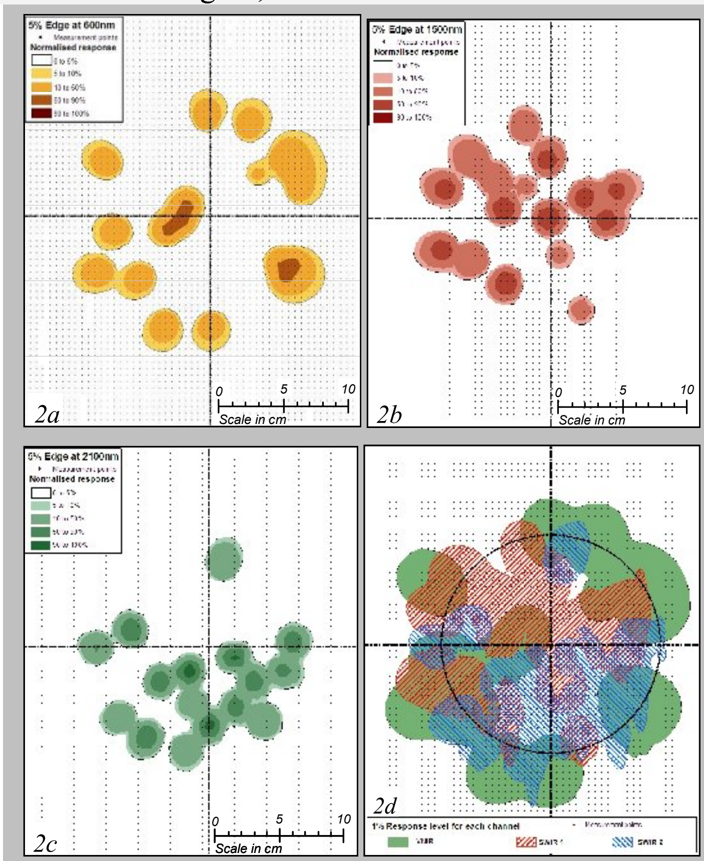
Science Highlight 6

Investigation of the Fields-of-View of full wavelength spectroradiometers

The Facility's in-house research has highlighted significant issues in the fields-of-view of its instrumentation. For the first time, a full suite of measurements were performed on the fields-of-view of two full wavelength spectroradiometers. This involved a point light source mounted on orthogonal linear stages and moved across the 10º fields of view of each instrument which was mounted at 1 m distance from the light. The fields-of-view of the GER3700 and ASD FieldSpec Pro instruments were measured.

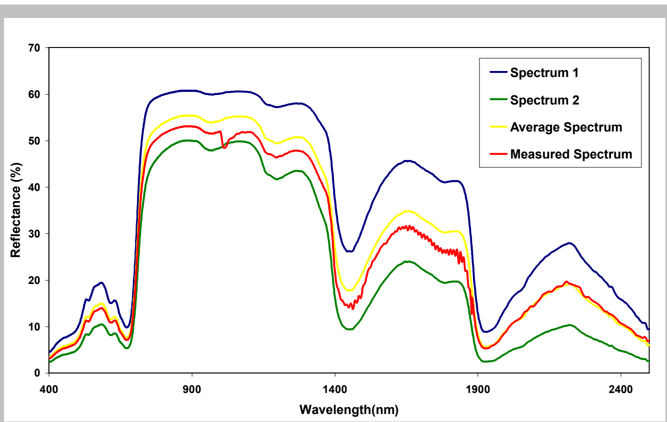
The results demonstrate alarming spatial non uniformity which varies with wavelength in both instruments. In the case of the ASD spectroradiometer, the lens-based fore-optic is essentially focussing the instrument's fibre optic input bundle onto the target which means that each spectrometer in the instrument (VIS-NIR, SWIR1 and SWIR2) is effectively measuring different parts of the target under view. Measurement also includes areas well outside the 10º circle. If the target is a heterogeneous one, then it can't be assumed that the spectrum measured is an average of the entire field-of-view. Without correction the results suggest that a high degree of the uncertainty present in observed relationships between reflectance and bio-physical parameters may be a result of uncertainties in the fields-of-view.

Different but equally serious field-of-view issues were found with the GER3700 spectroradiometer. The impact of field-of view non uniformity on the measurement of heterogeneous targets is demonstrated for the GER3700 instrument in the second figure, which demonstrates the simulated measurement of two distinctly different vegetated surfaces (Spectrums 1 and 2) placed side by side each occupying half of the target surface. A spectroradiometer with a uniform field-of-view FOV would measure reflectance of the target surface representative of the Average Spectra. However, as the FOV is non-uniform the reflectance measured (Measured Spectrum) deviates from the Average Spectrum with deviations being wavelength dependent. Across most of the VIS to SWIR range, the differences between measured and average spectrums varied from between 4% and 10% demonstrating that the influence of field-of-view non-uniformity can indeed be significant.



Normalised response contours for ASD FieldSpec Pro FR with 10° FOV lens:(2a) VNIR channel @ 600nm ; (2b) SWIR-1 channel @1600nm ; (2c) SWIR-2 channel @ 2100nm. Combined (2d) ASD 1% contour plots at 600, 160 and 2100nm.

Initial results of the research were forwarded to both instrument manufacturers who have noted the issues and have indicated that they are working on resolving the problems. As an indication of the influence FSF has with the principal instrument manufacturers, subsequent modifications have been made to improve the fields-of-view in new instrumentation. These have taken the form of an ‘optical scrambler’ (a suggestion of FSF) waveguide for placement between lens foreoptic and fibre optic in the ASD pistol grip. In the purchase of the new SVC HR-1024, care has been taken to minimise field-of-view variations through new foreoptic design and careful alignment of the instruments optics.



Simulated influence of field-of-view non-uniformity on spectral measured over a simple heterogeneous target.

6. Description of research and development carried out or proposed to sustain the existing/proposed NERC service/facility:

Examples of R&D completed by the Facility since the last SRG (2006) includes:

FTIR development project

This project aimed to design and manufacture a high resolution, light weight and portable FTIR spectroradiometer (capital investment of £130K and a two year 0.5 FTE position at the Facility). In so doing, it would extend the capabilities of FSF into applications in the thermal region. The instrument was based on hardware developed by Midac Corporation. The project included the development and purchase of a field portable FTIR spectrometer with accessories, field trials of the equipment, training through a workshop and the means for processing data retrievals. The funding for this project ended in March 2008.

The new FSF lightweight FTIR instrument.

Acceptance testing for the new instrument was completed in June 2006 and the instrument was delivered to FSF in November 2006. The result is an instrument which has reduced the weight from the standard 35 kg MIDAC instrument to an instrument of some 11 kg in weight. The basic characteristics of the new field portable instrument are: a lightweight high resolution FTIR with Stirling pump cooled MCT detector covering the wavelength region 5000 cm^{-1} – 700 cm^{-1} at a 0.5cm^{-1} resolution, with a compact 3-inch optical telescope. A number of field sources were also purchased including a 20” collimator for open path measurements and two new 5” sources for greater field portability. Calibration sources, including gold diffuse reflectance plaques, were also supplied. The final part of the project has been the purchase of a multi-pass cell for closed cell measurements; this is being developed for field use and will be available for loan during the 2009 loan season.

The instrument undertook its first field trial in an experimental forest burn in Canada in late 2006. FSF is now working with the Molecular Spectroscopy Facility to develop a scanning instrument with blackbody reference sources for the measurement of ground radiance/emissivity, which will be funded separately by NERC S&F.

First field deployment of the Facility’s new FTIR instrument at an experimental forest burn in Canada

As part of a series of field trials for the instrument a number of research projects were undertaken in support of user’s research:

2007

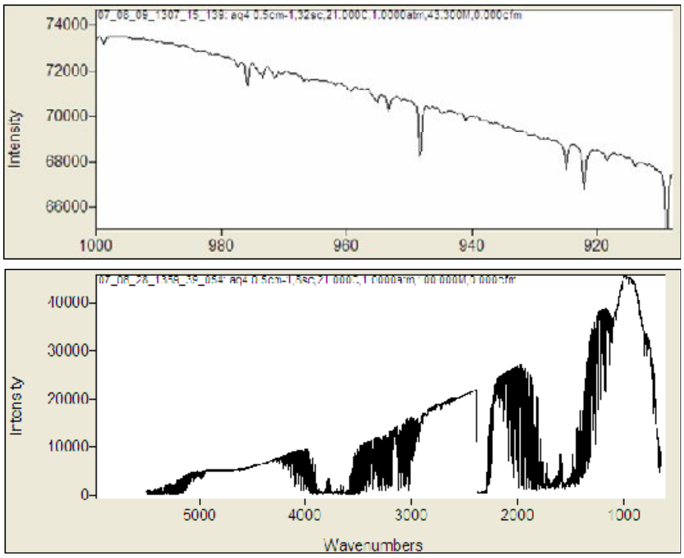
- Sun-occultation measurements for Prof M Wooster, Kings College London, performed in Canada.
- Open path field trials for Dr Graham Ferrier, University of Hull, performed near Rosyth.
- Open path measurements of burning bush/savannah for Prof M Wooster, Kings College London, in South Africa.

- Open path measurements for LAMP project, Dr Roland Leigh, University of Leicester, at Leicester.

2008

- Open path & closed cell measurements, Dr Trevor Blackall, Kings College London.

Retrievals software has been installed on FSF's computer suite and staff have been trained on IDL-based retrievals software developed by Dr Mike Burton of the Istituto Nazionale di Geofisica e Vulcanologia, Catania, in Sicily. A guide for the installation of HiTRAN and RFM and operation of the IDL code has also been completed. The development of a more user-friendly version of the retrieval code remains a priority and attempts will be made to fund this development from outside sources.



Example FTIR output

Workshop: To stimulate the development of a user community for the instrument, an FTIR workshop was held at King's College London on June 6th and 7th 2007 to both raise awareness of the technique and to bring together experienced and new users alike. The workshop was highly successful and attracted 44 participants from across the UK as well as Europe.


The principles of emissivity measurement being demonstrated at the FTIR workshop held June 2007, in London

The FTIR instrument was further demonstrated to the user community at the Remote Sensing and Photogrammetric Society (RSPSoc) Annual Conference at the University of Exeter, Tremough campus on 15th-17th September 2008. Dr Georgina Sawyer of the University of Cambridge also contributed to the demonstration illustrating the retrievals of concentrations of common gases using the RFM code.

Investigation of the Fields-of-View of full wavelength spectroradiometers

Results are outlined above. The results of this research were presented in poster form at the RSPSoc Annual Conference in Cambridge in September 2006 (which won **Best Poster Prize** at the meeting) and similar presentations were made at: the 10th International Symposium on Physical Measurements and Signatures in Remote Sensing in Davos from March 12.-14 2007; the 5th

EARSeL Special Interest Group on Imaging Spectroscopy Workshop in Bruges, 23-25 April 2007; IGARSS07, Barcelona, 23-27 July 2007, to the Division of Land and Water, CSIRO, Canberra, 30th January 2008; to the Australian Centre for Remote Sensing, GeoScience Australia, Canberra, 29th February 2008 and; at the RSPSoc Annual Conference in Tremough, Cornwall in September 2008. The results of the research have also been submitted to the Transactions in GeoScience and Remote Sensing journal.

Development and hosting of processing software

In financial year 2005-06 attention was diverted away from other R&D projects in favour of addressing a critical need to replace the data post-processing software provided to users. Issues of compatibility with the older DOS-based programs received following the transfer of the Facility from the University of Southampton arose as a result of the software and hardware upgrades to all GER equipment during 2005. The solution was the development of a number of MS Excel templates with embedded Visual Basic macros designed to replace the existing Dos-based programs. A single spreadsheet effectively replaces a number of DOS programs and allows users to process their data to absolute reflectance with minimal effort and very quickly. Templates have been produced for each of the instruments and for different measurement modes (e.g. for reflectance or radiance data). A full suite of templates is now available on the Facility's website. Usernotes specific to each template have been provided along with the spreadsheets on the Facility's website.

Spreadsheets have also been developed to process the spectra acquired during the quality assurance of each instrument after they return from individual loans. These are designed to assess the accuracy of the spectroradiometers' wavelength scales and calculate various system response calibration files.

To further support user's capabilities in processing the data obtained by the Facility's instruments, we have provided host website space for key software routines developed by our user community. The software is offered with a support disclaimer. The software hosted includes:

- Microtops Inverse, developed by Vitchko Tsanev and Tamsin Mather of the University of Cambridge, and which is designed to allow the retrieval of columnar aerosol optical thickness, concentrated in plumes, from Microtops II sunphotometer measurements. The software include calculations of surface and volume distributions and sets of effective radi (available now and located at: http://fsf.nerc.ac.uk/resources/software/MicrotopsInverse.shtml).

- PlanarRad, an open-source C++ implementation of the invariant imbedded numerical integration technique for calculating radiative transfer in plane-parallel shallow-water environments (i.e. where the substrate reflectance and water column optical properties can be assumed horizontally homogenous). The software, developed by John Hedley of the University of Exeter, follows the formulation developed by Curtis Mobley and is capable of calculating angular radiance through the water column, and above-water reflectances, based on the Inherent Optical Properties (IOPs) of the water. Multiple model runs and data from underwater profiling spectroradiometers can be directly compared in the visualisation tools provided, to examine model sensitivity to input parameters or for model closure experiments. The software is ideal for use with the FSF suite of aquatic instrumentation (available from the end of January 2009 and located at: http://fsf.nerc.ac.uk/resources/software/planarrad/planarrad.shtml).

- The establishment of a Field Spectroscopy Facility user forum, intended to provide a series of useful software utilities to facilitate the extraction and processing of field spectrometer data collected by the Facility's equipment suite. This includes Matlab and IDL open-source macros and useful programs. The first elements of this forum will go live in early 2009.

Development of the FSF database

This development project, initiated in 2005, aimed to streamline Facility functioning and reporting requirements. A database structure was designed and implemented in MS Access to hold information on users, their loans of FSF equipment, subsequent publications and on the inventory of equipment held by the Facility (and borrowed by users). The database is now fully populated and has already provided significant savings in time in the compilation of statistics for annual reporting and SRG submission purposes.

NCAVEO cross calibration experiment

FSF actively participated in the NERC Knowledge Transfer funded Network for Calibration and Validation of Earth Observation data (NCAVEO) field campaign, undertaken at Chilbolton, from June 13th to June 23rd 2006. This campaign involved ~50 researchers from a range of the UK’s research institutions. The Facility played a key role in providing optical instrumentation, and in the calibration of instruments and reference panels to insure the intercomparability of the measurements obtained.

Due to unacceptable variations in reference panel measurements during the field measurements, the Facility offered to recalibrate all NCAVEO user’s reference panels using our in-house reference standards. This was completed in late 2006 with panel calibration files supplied to the panel owners and the data logged with NEODC. As a result of problems in inter-panel calibrations highlighted during this field campaign, a existing research project has been altered to focus on the development of rigorous methods for the calibration of field reference panels. This project is outlined below.

Examples of current R&D at the Facility include:

Development of a Goniospectroradiometer

The project is being undertaken as a collaboration between FSF, the University of Southampton and the National Physical Laboratories and is jointly funded by NERC and the DTI. The project is developing an innovative and configurable device to near-instantaneously measure BDRF at up to 36 view angles and which will interface with any FSF spectroadiometer. The device uses innovative technology, notably in the optical design of the system and the use of lightweight components to reduce the overall weight of the instrument. It is being developed as part of a PhD project of an NPL member of staff (Heather Pegrum-Browning). The overall benefits to users will be in


The fully assembled goniospectroradiometer instrument in the laboratory.

portability, ease of use, and speed of measurement over existing goniometer instruments (e.g. the FIGOS instrument weighs 230 kg).

A simplified instrument structure was tested during the NERC Knowledge Transfer funded Network for Calibration and Validation of Earth Observation data (NCAVEO) field campaign in the summer of 2006. When fully built, the instrument required strengthening to cope with the weight of the fibre optic attachments which distorted the structure of the previous design. A considerable focus of the research is in developing the optimum method of coupling 36 channels (angles) to the single input of the field spectrometers. Some software linkages that need to interface the device to a spectroradiometer to trigger data acquisition have been completed during 2008.

There are some sensitivity issues that require attention if the apparatus is to be used in the laboratory with relatively low light source, as noise levels appear to be quite high. However, this has not been a problem in full sunlight. The full instrument was field trialled in Turkey in August/September 2008 and the measurements are currently being analysed.

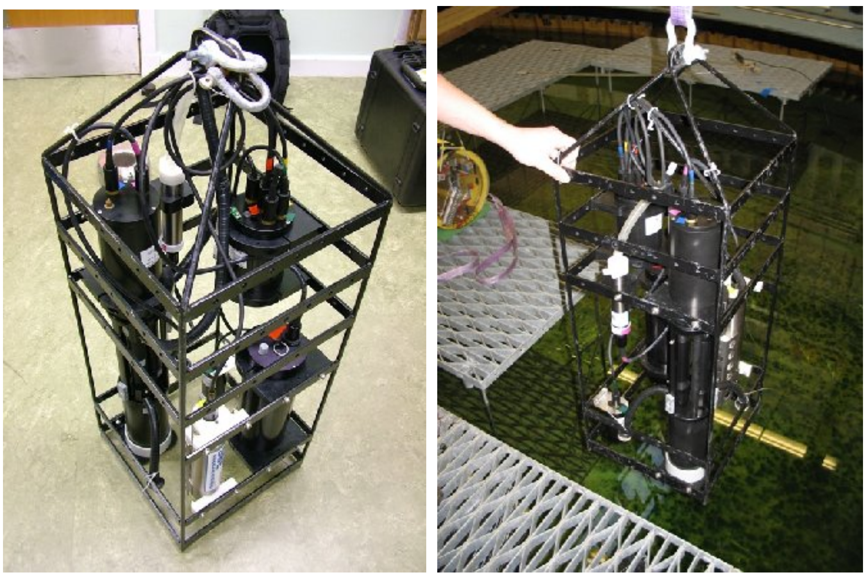
We anticipate receiving the instrument in time for loans to be considered during summer 2009. The Facility will also purchase a large reference panel to support this project and for future loans of the instrument.

Commissioning and augmentation of the Wetlabs AC-S instrument.

The instrument was supplied to the Facility in early February 2007 and was purchased on a NERC small grant application to Professor Peter Mumby of the University of Exeter. Dr John Hedley from the University of Exeter provided preliminary training to FSF staff in the use and care of the equipment. The instrument suite delivered consisted of:

- A Wetlabs AC-S spectrometer measuring absorption (**a**) and beam attenuation (**c**) along a 20 cm pathlength (the difference between the two gives an estimate of scattering, **b**)
- CTD instrument measuring depth, temperature and salinity.
- A data logger, battery and pump, to circulate water through the AC-S instrument.

A Wetlabs BB-3 backscatter instrument was purchased in 2007 to complement the suite. This allows the simultaneous measurement of backscattering in three visible wavebands, critical to understanding the relationship between reflectance and water quality parameters. In 2008 the suite was further augmented by the purchase of three SAtlantic HyperOCR spectroradiometers for the measurement of above-surface downwelling

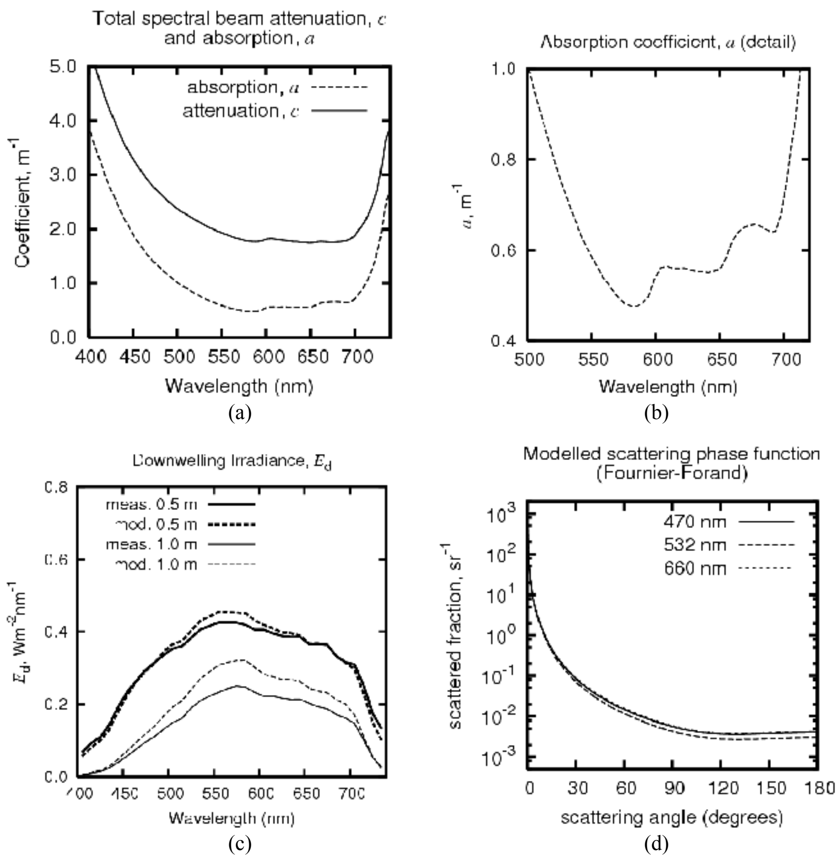


Commissioning and testing of the AC-S instrument suite.

irradiance, underwater downwelling irradiance and upwelling radiance at high spectral resolution (purchased on Capital Equipment monies). These are integrated with the existing Wetlabs data logger. The instrument suite now allows for near-complete profiling of the underwater light environment. The Facility is currently in the process of completing userguides and data processing templates for the instrument.

The underwater instrument suite was demonstrated to the user community at the Remote Sensing and Photogrammetric Society (RSPSoc) Annual Conference at the University of Exeter, Tremough campus on 15th-17th September 2008. Fourteen potential users attended the demonstration session and the session was also attended by Dr Ian Walsh, Vice President of Operations of Wetlabs Inc. from Oregon and Dr Terry Sloane from Planet-Ocean Ltd., representing the UK agents for the Satlantic instruments. The demonstration included an introduction to the principles of underwater optics followed by the deployment of the instrument suite in a local lake.

Demonstration of the AC-S underwater instrument suite, during RSPSoc Annual Conference 2008



Underwater inherent (a, b) and apparent (c) optical properties measured at Stithians Lake during the RSPSoc meeting demonstration. Figure d demonstrates phase functions estimated from the backscatter coefficients.

Optical properties of Spectralon reference panels

Recent focus on this work has been on the geometry of methods for calibrating reference panels. FSF's Spectralon panels are calibrated annually at the Facility using a 0°/45° configuration and by comparing the reflectance values to the Facility's NPL calibrated panel. This configuration, termed a biconical reflectance factor (BCRF), uses a light source to provide illumination at 0° (perpendicular to the panel) and with reflectance measurements made using a spectroradiometer at 45° angle to the panel. An alternative calibration configuration exists, which involves a spectroradiometer fitted to an integrating sphere accessory and where illumination is provided at 8° from the normal with an integrating sphere measuring the total hemispherical reflectance from the panel (termed a conical-hemispherical reflectance factor, CHRF).

When measured with high quality instrumentation the calibration values for both BCRF and CHRF configurations should be identical for Lambertian reflectance panels. The anisotropic properties of a reference panel can not be measured using a bi-conical configuration at a single angle but instead requires multiple angles to build up a complete hemispherical measurement of the reflected flux. But differences between measurements made with the two configurations, CHRF and BCRF with multiple measurements, are solely the result of non-Lambertian reflectance properties. Thus, employing both measurement configurations makes it possible to determine if there is a change in the panel anisotropy or the extent of the anisotropy of one panel with respect to another.

To effect the measurement of CHRF, a new integrating sphere has recently been purchased which will allow calibration and QA measurements to be performed on Facility panels for both photometric and spectroradiometric values. The combination of hemispherical and bi-conical measurements will provide a means to quantify the panel anisotropy. Results will also inform on the best method for absolute calibration of our in-house reflectance standard by NPL.

Calibration procedures for the NERC ARSF optical instruments

FSF has been actively involved with ARSF on issues associated with the calibration of ARSF's Itres CASI and the SpecIm AISA Eagle/Hawk systems. With the effective replacement of the CASI sensor by the Eagle/Hawk system, the frequency of calibration of the CASI sensor has been reduced to an as-needs basis. No calibrations of this sensor were undertaken in 2008.

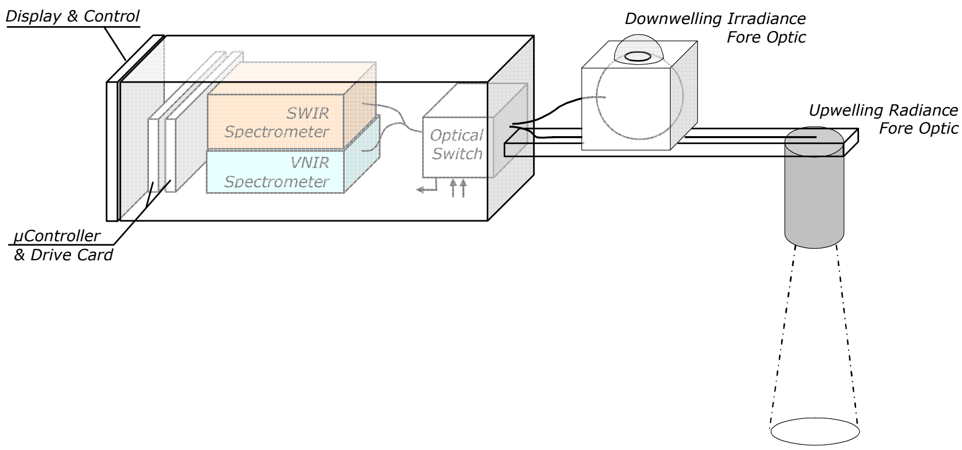
For the Eagle/Hawk sensors, two failures of our 12 inch Labsphere integrating sphere, prevented their full calibration. Due to other issues related to the uniformity of the output from this particular sphere, we are now working with ARSF on the purchase of a 20-inch integrating sphere source that is especially optimised for push-broom sensors, such as the Eagle/Hawk system. Despite these problems, a calibration procedure for the Eagle/Hawk calibration has been drafted. Furthermore, we have assisted the ARSF Data Analysis Node (DAN) based at NEODAAS at PML on diagnosis of a fault in the HAWK radiance calibration, highlighted during post-processing of its data.

Development of V-SWIR instrument.

This project is supported with a capital investment of £122K from S&F and includes a two year 0.5 FTE position. The project was started in January 2008. The aim is to develop a hand-held, field portable spectroradiometer operating in the VNIR/SWIR (400 to 1650nm) wavelength range as an improved replacement for the Facility's aging VNIR (400 to 1100 nm) spectroradiometers. Informed by the Facility's equipment replacement strategy and research projects, it is clear that currently available commercial instruments fail to address key problem areas in: uniformity of field-of-view; the ability to deliver dual field-of-view measurements without the purchase of two instruments, and; improvements in sensor technologies and instrument performance and size.

The project will design a working prototype field spectroradiometer taking advantage of a novel optical input design and recent advances in optical technologies to deliver an instrument which significantly improves on the performance of the products currently in existence. To deliver this, a new fore-optic design is required which resolves the problems of: dual field of view using a single instrument and; poor uniformity in field-of-view but without sacrificing spectroradiometer signal to noise performance. A range of off-the-shelf VNIR and SWIR spectrometers have been tested and compared to the performance of our ASD FieldSpec spectroradiometers. Signal to Noise and stray light issues have been highlighted. Options for control and data communication to and from the spectrometers (e.g. USB versus RS232) have been evaluated with an embedded micro controller card purchased for bench testing.

A DFOV system design has been proposed with high speed (~1Hz) switching between upwelling and downwelling radiation measurements. This design will incorporate an integrating sphere for the accurate measurement of downwelling irradiance. The design and development of the prototype optic has been outsourced to the Astronomy Technology Centre (ATC, Royal Observatory, Edinburgh) and is due for delivery in February 2009. In the meantime, Nemphlar Biosciences have been contracted to develop the control electronics for the instrument.



Configuration of the V-SWIR instrument.

SVC HR-1024 and external sensor suite development

The Facility's new SVC HR-1024 full wavelength system, here with integrating sphere fitted.

Variations in ambient solar irradiance between reference and target field measurements and between individual target reflectance measurements during sequences of measurements may introduce considerable uncertainties. With no record of this variance changes in reflectance or radiance between targets may erroneously be ascribed to target properties rather than to changes in ambient irradiance. Changes in ambient solar irradiance are prevalent in the UK due to oceanic weather effects such as varying atmospheric water vapour content and may often be sub-visual. Dual field-of-view (DFOV) field spectroscopy systems may be deployed to record variance in irradiance while taking target measurements, but these systems normally only cover the 400nm to ~1000nm range, and require the purchase of two expensive spectroradiometers, one measuring target radiance and the other simultaneously measuring irradiance. Therefore, DFOV systems are rarely used although it can be argued that their use can improve the quality of field spectroscopy measurements and subsequent data analysis.

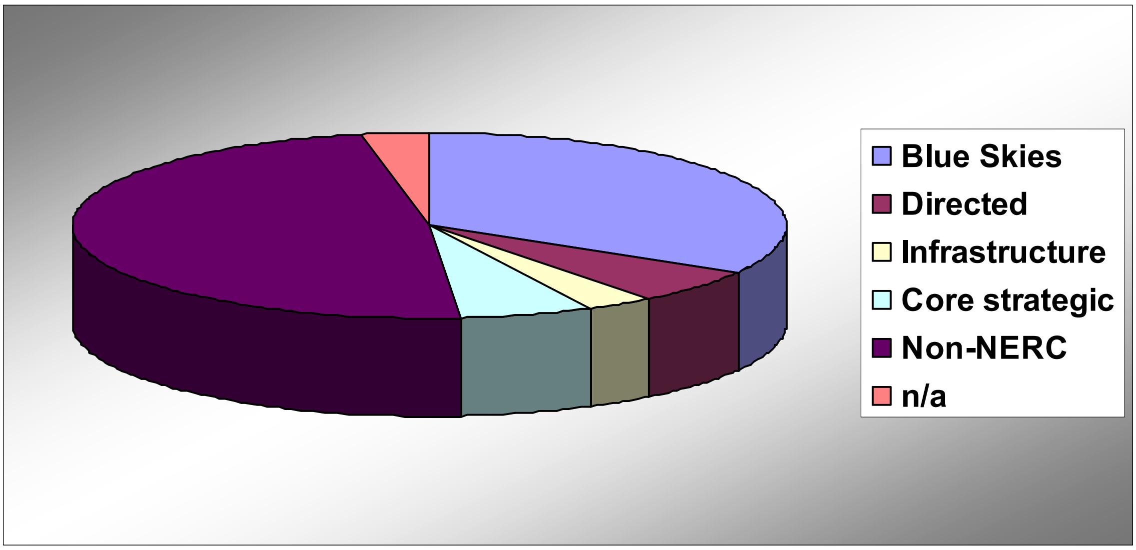
A state-of-the-art SVC HR-1024 full wavelength system (400nm to 2500nm) has been purchased to replace an aging full wavelength GER3700. In line with the Facility's Equipment Replacement Strategy, a further development is being implemented to interface an external suite of sensors for simultaneous acquisition with target measurements. Viewing spectra in real time allows for decisions to be made in the field as to whether irradiance conditions are suitable to continue target measurements. At the data processing stage, they enable the irradiance conditions and variability to be analysed, and the quality of target reflectance to be assessed. A light weight portable external sensor suite comprising 6 narrow band irradiance sensors and a sunshine pyranometer measuring total and diffuse irradiance, is being developed to interface with the HR-1024. From the irradiance measurements and models, informed decisions will be able to be made as to the quality of spectroscopic data collected in the field, the variance present and the validity of any changes between target reflectance or the radiance measurements being assessed.

7. NERC Theme Science Priority Areas likely to be addressed (please tick, as appropriate):

Climate System	√	Biodiversity	√	Sustainable Use of Natural Resources	√
Earth System Science	√	Natural Hazards	√	Environment, Pollution and Human Health	√
Technologies	√				

8. Current grants, directed/research programmes and applications, both ongoing and proposed:

FSF makes major contributions to NERC strategic and directed programmes. Full details of the projects supported during 2006-08 are presented in Appendix 6. In total, 69 projects were supported over the period. The distribution by funding is summarised below. Almost half of the projects (49%) were for NERC funded research projects over a broad range of programmes, of which the largest proportion (69%) was for Blue Skies funded research.



Distribution of FSF-supported projects by funding mode.

9. Recent publications relevant to the proposed NERC service/facility:

A full list of publications produced can be found in Appendix 7. The publication listing covers the period 2006 to 2008 since the Facility was last reviewed.

For the three years covered by the review, 33 articles have been published in the international journal literature or as papers in edited books, representing an average of 11 publications in journals and edited texts per year. During this period there has also been an average of 14.3 non-referred publications per year (43 in total for the three year period). Publications have included articles in journals with high impact factors. Examples of the journals in which FSF related research has been published include:

- Atmospheric Chemistry and Physics (2 papers, *Impact Factor: 4.865*)
- Atmospheric Environment (*Impact Factor: 2.549*)
- Catena (*Impact Factor: 1.356*)
- Climate Dynamics (*Impact Factor: 3.961*)
- Continental Shelf Research (*Impact Factor: 1.684)*
- Ecosystems (*Impact Factor: 2.684*)
- Estuarine and Coastal Shelf Science (*Impact Factor: 1.799*)
- European Journal of Soil Science (*Impact Factor: 2.730*)
- Geomorphology (*Impact Factor: 1.854*)

- Geophysical Research Letters (*Impact Factor: 2.744)*
- Journal of Climate (*Impact Factor: 3.550*)
- Journal of the Geological Society of London (*Impact Factor: 2.304*)
- Journal of Geophysical Research (3 papers, *Impact Factor: 2.953*)
- Optics Express (*Impact Factor: 3.709*)
- Remote Sensing of Environment (5 papers, *Impact Factor: 3.013*)
- Proceedings of the Royal Society (*Impact Factor: 1.523*)
- International Journal of Remote Sensing (5 papers, *Impact Factor: 0.987*)

In addition, seven PhD theses have been completed during this time, in which FSF support has been instrumental (Appendix 9).

10. Details of expected usage over a three-year period and the uncertainty in those figures:

During the summer period in particular, the FSF instrumentation is near fully allocated. High demand for its MicroTops sunphotometers in 2006 led to the purchase of two more instruments to meet increased demand into the future.

We anticipate that demand will remain strong and increase in line with the increased diversity of equipment we have to offer. Now that data delivery issues with ARSF have largely been resolved, and with the inclusion of requests for FSF equipment on the ARSF application form, we are expecting an increased demand for our equipment in support of acquisitions of ARSF AISA Eagle+Hawk hyperspectral data. Presently, on the basis of applications for instrumentation in 2009, Forecast instrument demand is well oversubscribed, as is highlighted in Section 16.

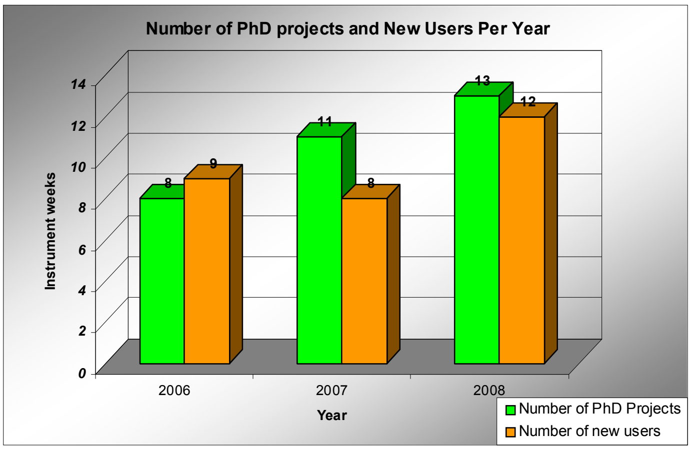
In line with its stated objectives at the last SRG, the Facility has been engaging with potential new users by actively presenting its instrument range, services and research at relevant UK meetings. A full list of the presentations made over the last two years is given in Appendix 8. These have included presentations at NERC Earth Observation Conferences, RSPSoc Annual Conferences and student meetings, the British Ecological Society and Institute of Physics.

FSF continues to ensure the Facility operates to its maximum capacity through measures such as:

- Maintaining close contact with our users and regularly informing them of changes within the Facility and new capabilities as they arise.
- Attending relevant remote sensing conferences and present papers on new developments within the Facility as well as advertising our services.
- Customised field spectroscopy training courses for new researchers.
- Keeping our website up-to-date with Facility developments and news items.
- Development of new instrumentation thus expanding our user base into new research spheres, particularly atmospheric and marine applications.
- The establishment of UK AERONET sites has widened our impact as part of the AERONET community, providing the wider EO community with aerosol optical properties and data to validate satellite retrievals.

11. Likely contribution to student training:

Over the last three years 32 PhD student loans and 29 new users have received support from the Facility for their research projects (Appendix 9). All new postgraduate users (and other new users) come to Edinburgh and receive a fully customised, one-to-one, personalised training course designed by FSF staff where they are introduced to the equipment they will use in their research and where their specific research needs can be discussed in greater detail. It is anticipated that this high level of demand is likely to continue and may increase in anticipation of new instrumentation being provided by the Facility.



PhD loans and new users supported 2006-08

Since 2006, 30 individuals have received one-to-one training in instrument use, including 16 PhD students (details Appendix 9).

The Facility's website (http://fsf.nerc.ac.uk) provides an additional resource for training with access to: user guides detailing aspects of use of the instrumentation and aspects of data analysis, logsheets, calibration data files, processing software, references and links to other resources in the field.

Introduction to Field Spectroscopy course

As part of new training initiatives, we introduced an annually run training course entitled '*An Introduction to Field Spectroscopy*' in late 2005. Initially a two day course and now extended to two and a half days, the course has been delivered on three occasions (19th and 20th December 2005; 26th to 28th February 2007; 30th April to 2nd May 2008). Although the course is aimed at first year PhD students, it has also been attended by postdoctoral researchers, academic and NERC staff (full attendance listings in Appendix 9). The course is timed to be of early interest to new users before they embark on field programmes. It is designed to address the wider issues of methods in field spectroscopy (e.g. its role as a primary research tool and in support of wider earth observation research, instrumentation, best practice in methods and sampling design, data analysis) which are not addressed when students attend for training in specific instrument use (full programme listing, Appendix 9). With some emphasis on tools for calibration and validation, the course is also designed to be of benefit to proposers to the NERC Airborne Research and Survey Facility, especially those hoping to take advantage of the hyperspectral capabilities of the AISA Eagle+Hawk system. The course is offered free to the UK academic community.

Introduction to Field Spectroscopy Training course, held 2007

A number of enquiries from individuals in other European countries to attend the training course have been received. Strong interest in the course was also expressed by members of the HYperspectral REmote Sensing in Europe - Specific Support Actions (HYRESSA) EU funded network when they visited the Facility in November 2007. This demonstrates wider interest across Europe in the availability of such training and in the model upon which the Facility operates. Typically, we have turned these enquiries down in favour of supporting interest from with the UK and keep numbers on the course around the optimum 8 to 10 level. The enquiries do demonstrate, however, the potential for income generation if places on the course to students outside the UK were charged, if capacity allowed.

FTIR Spectroscopy Workshop

FSF also hosted a highly successful *FTIR Spectroscopy Workshop* at King's College London on the 6th and 7th of June 2007 (Flyer and programme presented in Appendix 11). Training of researchers new to the field of FTIR methods was an integral part of the workshop, where the aim was to link potential new users to experts in the field. The workshop thus brought together new and existing users of FTIR interferometers for remote sensing applications to share knowledge and experience in the design and implementation of field measurement campaigns. Hands on demonstrations of the equipment were provided in open path configuration using a collimated infrared source and sun occultation, and methods for the measurement of ground radiance, surface temperature and emissivity using field and laboratory black body sources. Data processing methods for the retrieval of gas concentrations were also presented. Specifics covered at the meeting included:

- Field measurements with Fourier Transform Infrared spectrometers
- Remote sensing and gas retrievals from volcanic plumes
- Open path measurements of fugitive emissions
- Ground radiance and surface emissivity
- Estimating gas releases in biomass fires
- Radiometric calibration of FTIR systems
- Data retrieval techniques, including least squares fit and the Reference Forward Model.

The workshop was attended by 44 researchers, including staff from the USGS and the Istituto Nazionale di Geofisica e Vulcanologia in Sicily. The meeting was also attended by representatives of MIDAC Corporation (full list of attendees, Appendix 9).

Demonstrations at RSPSoc 2008

The Facility also presented its latest equipment and R&D developments at the RSPSoc Annual Conference at the University of Exeter, Tremough campus on 15th-17th September 2008. Separate demonstrations included:

- The FTIR instrument, approach to measurements and the retrievals of concentrations of common gases using the RTF code.
- The ASD FieldSpec 3 instrument and the acquisition of field spectra
- The SVC HR1024 instrument and the acquisition of spectra
- The underwater optical properties instrumentation suite including a demonstration of measurement in a local lake.
- The Headwall hyperspectral imaging spectrometer

The demonstrations for the latter four were presented jointly with the equipment manufacturers.

Other training activities

The FSF Director also contributed an invited one-day Introduction to Field Spectroscopy training course at the “Marine hard bottom physiognomic characterisation” Workshop which took place in Vitòria, Brazil between the 25th and 29th June 2007. This meeting was sponsored by the Foundation of Support to the Research of the Espírito Santo State (FAPES), Brazil.

Informal discussions have also been held with the Director of the NERC Earth Observation Data Acquisition and Analysis Service (NEODAAS) about the possibilities of jointly organised training sessions in collaboration with the NERC ARSF as support to users of ARSF to provide training in best practice in: the implementation of field programmes for the improved acquisition of airborne imaging data, and in data processing, notably geocorrection and atmospheric correction.

The development of further online training material is being considered (e.g. slides and videos from the FTIR workshop and aspects of the Introduction to Field Spectroscopy course).

12. Expected extent of the user community, eg naming departments, institutions, or generic groups of users where possible:

The userbase of the Facility has enlarged over the last two years where support has been provided to the following institutes and departments:

2006
Chester College, Department of Geography
Forestry Commission, Forest Research
Heriot-Watt University, Institute of Petroleum Engineering
National Physical Laboratory, Quality of Life
Plymouth Marine Laboratory,
Royal Holloway University of London, Department of Geology
University of Birmingham, School of Geography, Earth and Environmental Sciences
University of Cambridge, Department of Geography,
University of Cambridge, Department of Earth Sciences
University of Cardiff, Cardiff School of Biosciences
University of Edinburgh, School of Geosciences
University of Hertfordshire, Division of Geography & Environmental Sciences
University of Hull, Department of Geography
University of Manchester, School of Environment and Development
University of Reading, Department of Meteorology
University of Southampton, School of Geography
University of Southampton, School of Civil Engineering and the Environment
University of Wales, School of Ocean Sciences

2007
BAS, Geological Sciences
British Geological Survey,
Bornemouth University, School of Conservation Geosciences
Canterbury Christ Church University, Department of Geography
CEH - Monks Wood, Section for Earth Observation
Forestry Commission, Forest Management
King's College London, Department of Geography
Plymouth Marine Laboratory,

Royal Holloway University of London, Department of Geology
SEPA,
University College London, Department of Geography
University of Cambridge, Department of Geography
University of Dundee, Department of Geography
University of Edinburgh, School of GeoSciences
University of Exeter,, Department of Geography,
University of Hull, Department of Geography
University of Leicester, Department of Geography
University of Newcastle, School of Civil Engineering & Geosciences
University of Nottingham, School of Geography

2008
Aberystwyth University, Institute of Geography and Earth Sciences
BAS, Geological Sciences
King's College London, Department of Geography
Kingston University, School of Earth Sciences and Geography
National Physical Laboratory,
Plymouth Marine Laboratory,
Royal Holloway University of London, Department of Geology
Royal Holloway University of London, Department of Earth Sciences
Swansea University, Department of Geography
University College London, Department of Geography
University of Cambridge, Department of Geography
University of Edinburgh, School of Geosciences
University of Exeter, Department of Geography
University of Exeter, Department of Geography
University of Hull, Department of Geography
University of Manchester, School of Environment and Development
University of Oxford, Environmental Change Institute
University of Southampton, School of Geography
University of St Andrews, School of Geography and Geosciences
University of Worcester, Department of Geography

Based on the current applications for the remainder of 2008 and during 2009, the following institutions are expected to make use of the Facility’s equipment:

Birkbeck College, Univesity of London, School of Geography
University of Bristol, School of Biological Sciences
University of Cambridge, Department of Geography
Coventry University, Department of Geography
University of Plymouth, Marine Institute
University of Edinburgh, School of GeoSciences
University of Hull, Department of Geography
King’s College London, Department of Geography
University of Lancaster, Lancaster Environment Centre
University of Manchester, School of Environment and Development
University of Oxford, Environmental Change Institite
University of Southampton, School of Geography
University College London, Department of Geography
University of Wales, Swansea, Department of Geography
University of Worcester, Department of Geography

13. Details of any comparable facilities in the UK and Europe:

The FSF remains a unique facility worldwide; no comparable facility exists anywhere in the world where equipment and services in field spectroscopy are made available to national scientific research groups and where the funding mode allows access at no cost to the user. This gives the UK research community access to world class capabilities to support remote sensing and environmental research, access to experienced staff and the opportunity to influence future developments though frequent user surveys (Appendices 6 and 7). The state-of-the-art equipment, our high specification laboratory in Edinburgh, the excellent quality of service and expertise of staff would be unaffordable or uneconomic for any single department or HEI within the UK.

Other institutions and companies across the UK and Europe possess their own dedicated spectroradiometer and optical instruments to support earth observation research (examples include VITO in Belgium, University of Zurich, DLR and GFZ in Germany). However, the instruments in these facilities are largely only available for the use of staff and students within each institution. FSF receives requests to both calibrate and support these instruments.

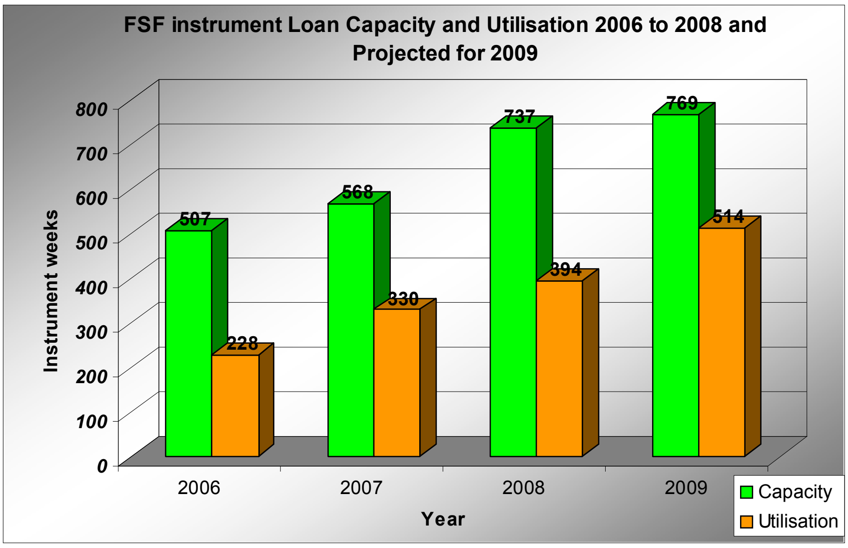
We have also offered calibration of other UK instruments in return for the use of those instruments to cover periods of high FSF user demand (e.g. in support of ARSF campaigns). Through its biennial user survey, the Facility regularly polls UK users on the range of instruments held in UK research institutions, businesses and government agencies, the facilities and practices that are used for their calibration and validation (Appendix 10). This allows us to assess the likely demand for calibration and support services from FSF. Responses indicate a range of instruments held but with a wide variety of practices in care and calibration with few dedicated calibration programmes reported.

If Applying For Service Recognition, The Remainder Of The Form Does Not Need Completing.

14. Time before the proposed NERC service becomes operational:

FSF at Edinburgh is fully operational, with a full list of commitments to NERC supported research and users.

15. Capacity of the facility, both theoretical and as it is proposed to be operated:



Instrument loan capacity and utilisation 2006-08 and projected for 2009. Differences between the two reflect unavailability due to instrument turn around time between loans, maintenance and seasonality.

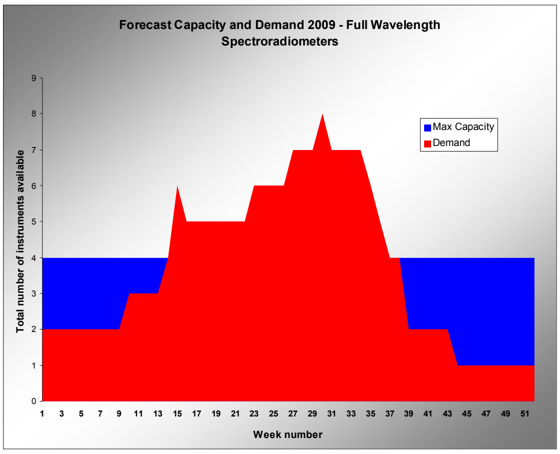
The full capacity of the FSF is available to NERC users. Capacity and utilisation increases have occurred during the period through the purchase of additional sunphotometers to meet user demand and increases in GER1500 instrument utilisation (2007), the addition of the AC-S/HyperOCRs instrument suite, the FTIR instrument and a second CIMEL instrument (2008). Capacity has also increased given efficient instrument turn around and good instrument maintenance. In 2009 capacity and utilisation will further increase with the availability of the goniospectroradiometer adding 32 loan weeks to Capacity. Projected use for 2009 is taken from current loan applications including those requesting instruments to support ARSF campaigns. The figures assume unavailability due to instrument turnaround time between loans, QA, essential maintenance and calibration, use in the in-house research programme and unexpected instrument failures (Appendix 10).

In 2009 we estimate 67% utilisation of our theoretical operational annual capacity. Given the seasonal nature of loans, the vast majority of which take place in the summer months, anticipated demand will exceed capacity for 6 months of 2009.

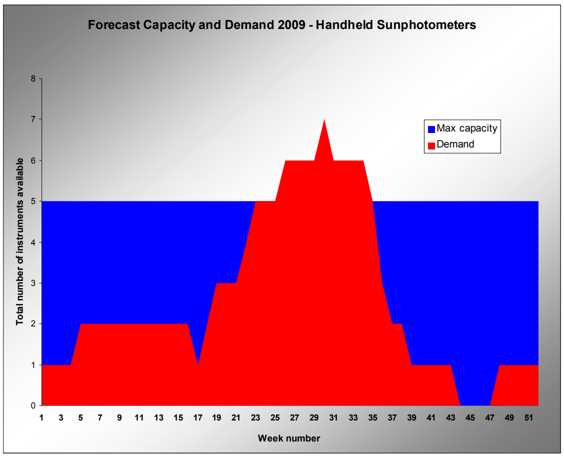
To ensure a continued high level of operational instrument loan days per year, there is a requirement for replacement of some equipment shortly (within next 5 years). Expected new instrumentation will bring benefits in state of the art electronics and hardware which have advanced since the current suite of instrumentation was developed. Therefore, with the support of the Steering Committee the Facility plans to submit capital bids to the NERC Capital competition for replacement instrumentation in due course. It is possible that demand for the new FTIR may stimulate demand for a second such instrument.

16. The proportion of time that is to be made available to the community and how the balance of capacity (and hence costs) is to be funded:

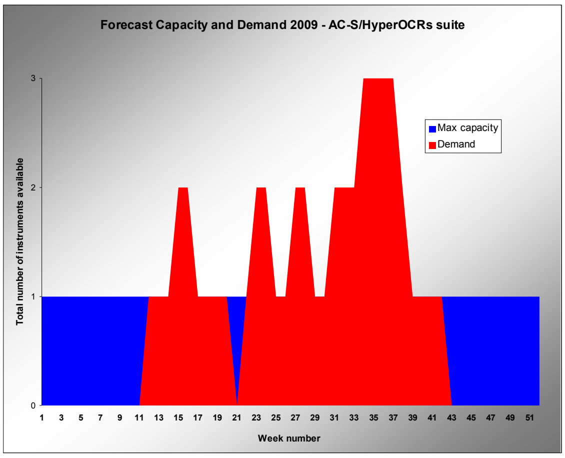
NERC supports 100% of the Facility's capacity at 1.5 person-years with additional technical input from the GEF. The Facility has actively sought opportunities to increase its funding to 2.0 person years to support its ambitious R&D programme. Since 2006 a number of commercial loans have been supported where the loan schedule has allowed. Conflicts between scheduled loans to the research community and commercial loans are resolved with the assistance of the FSF Steering Committee.



The Facility has also further developed commercial opportunities through the provision of traceable calibration services to institutions and other agencies with their own optical instrumentation. These services along with prices are available on application to the Facility.



The new equipment now housed in the Facility, achieved via new equipment purchases and its research and development programme, has extended the capabilities of the Facility, into new areas of application and to support a wider body of users. The imminent receipt of the GRASS goniospectroradiometer under development at NPL will improve capabilities in BRDF measurement.



Applications from the user community for loans of the expanded range of instrumentation are extremely healthy and are coming from a more diverse range of research groups. Our capacity figures also show a high and increasing utilization of the equipment held by FSF (figure, Section 15). The quality of our training and data processing software is highly rated in user feedback (Appendix 10).

However, the diversity of the instrumentation the Facility now supports has also meant that the support they require is also more diverse in terms of training and training materials (including user guides), QA and calibration procedures, and data processing routines and templates. In addition, the technicalities of the FTIR, AC-S and goniospectroradiometer instruments means ideally the Facility should offer in-field support to users of this instrument, particularly to those groups using the instrument for the first time. In terms of training, our new equipment often needs more support than our traditional spectroradiometric equipment.

Currently, at 1.5 FTE, the recurrent FSF contract is insufficient to meet these essential tasks, as well as to both maintain and increase our external profile to ensure a high awareness amongst potential users. Our commitment to NERC ARSF has also been over and above that which is provided through the recurrent contract (2 months as opposed to 1 month funded). Concerns on the levels of staffing and pressures of the current work load on the existing FSF staff have also been aired by the Steering Committee (at both the 5th June 2007 and 17th June 2008 SC meetings).

To cover the increased workload placed upon us, we therefore seek to increase our recurrent contract to 2 FTE plus 1 month extra support for ARSF. Where appropriate, the Facility would always continue to seek additional funding via alternative means to support its R&D programme. An example includes the development of post-processing routines for the FTIR instrument, which could be undertaken in collaboration with other research groups as part of a Small Grant or Technologies application. We will also exploit the possibility of 6 month internships on defined topics.

This request for an increase in personnel funding comes with the full support of the FSFSC.

17. Risks associated with a proposal to install untried technology or new applications of existing technology:

Much of the equipment held by FSF (e.g. spectroradiometers and sunphotometers) is externally developed by commercial companies and has been the result of a significant amount of research and development and which has developed incrementally on experience gained from previous instrument models. As such the technology is less ‘untried’ than in other areas of application. The Facility also maintains a highly rigorous acceptance testing programme for all new equipment to ensure the new equipment it is purchasing meets the detailed specifications set out in our tender documents. Purchases of all new equipment are made from recognised sources. FSF has a good relationship with both the main spectroradiometer manufacturers and we closely work with them to improve instrument performance for the benefit of all instrument purchasers. Examples of this two-way relationship include the Facility’s research into the fields-of-view of its full wavelength spectroradiometers and it’s aim to reduce uncertainties in field measurement through the incorporation of additional incident irradiance sensors.

Risks associated with the instrument and software developments undertaken as part of the Facility’s in-house R&D programme (e.g. FTIR instrument, V-SWIR instrument, software templates) include:

- Development in consultation with leading research groups through their involvement in project committees, for example the FTIR project was overseen by a project committee of research groups from around the UK.
- Developing the instrument in collaboration with other organisations (e.g. Advanced Photonics) and other NERC Facilities (i.e. MSF)
- Through maintaining a close contact with the instrument manufacturers (e.g. MIDAC).
- The use of largely ‘off the shelf’ technologies in the new instruments.
- Good use of project management to ensure progress is on time and within budget.
- Outsourcing of critical elements to expert organisations (e.g. Royal Observatory ATC)
- Rigorous testing of instrumentation in-house, which allows us to solve problems with the equipment and to develop best practice strategies for user guides and training.
- Rigorous testing of software components.

The likely benefits to the UK research community of the Facility's in-house research and development projects far outweighs the risks involved.

18. Likely usage by non-NERC fund-holders, who might be charged:

The Facility meets external commercial demand for its instruments where instrument availability has allowed such that there is little or no impact on its core academic research community. Typically, many of the commercial loans are for optical instrumentation for the calibration of high spatial resolution spaceborne imagery.

Such loans have supported projects commissioned by Scottish Natural Heritage and the Scottish Environmental Protection Agency. Use of our calibration facilities has also been made by commercial organisations seeking access to calibrated radiance sources. Any income generated contributes to the running costs of the Facility.

In response to demand identified in our user surveys, we have developed an instrument calibration service to owners of instruments from other Universities and outside organisations. Access to the data obtained by FSF's AERONET CIMEL instrument is provided by the Facility via NASA's AERONET website free of charge. However, annual calibration and future upgrades to the CIMEL are provided free of charge from NASA.

Despite the possibilities for a small amount of income generation, the Facility could not function if its funding was changed to a Pay As You Go cost model. There would be insufficient income generated required to meet both staff salaries and the recurrent costs required to ensure NPL traceability of its calibration standards. The University of Edinburgh would not be able to operate the Facility on this basis.

19. Commercial exploitability:

We are keen to ensure that commercial activity does not significantly impact on scheduled loans to our principal user base in the research community (and hence affect our main raison d'etre which is to support NERC Science). The principal avenues for income generation include:

- the loan of optical instrumentation to support commercial contracts;
- satisfying demand for instrumentation for external training courses;
- provision of calibration services and access to calibration facilities
- charging for delivery of the Introduction to Field Spectroscopy course, particularly to allow access for overseas candidates.

The Facility has strengths in the provision of well maintained instrumentation capable of satisfying a wide range of applications, with calibrations traceable to NPL standards. There is equally a role for the Facility in the education of potential end users of the benefits of such technologies, particularly for the calibration and atmospheric correction of EO datasets.

20. Estimates of funds required from NERC over a three-year or five-year period:

The estimates of recurrent FEC funds required for the next 5 year funding period are reported in the Excel spreadsheet (form SRG1b) accompanying this submission.

End of SRG 2009 Application Form

List of Appendices

1. Detailed Description of FSF
2. Mission Statement
3. Remit and Terms of Reference of the FSF Steering Committee
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6. Detailed listings of projects supported during 2006 – 2009
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Appendix 1 - Detailed description of the NERC Field Spectroscopy Facility

The NERC Field Spectroscopy Facility is a unique world class facility supporting Earth Systems science. It comprises a collection of high quality modern instrumentation operating over the optical and thermal wavelengths. The equipment consists of field portable spectroradiometers and sun photometers, a field portable FTIR instrument and instrumentation for the measurement of underwater optical properties, and associated calibration and support equipment.

The Facility is based at the School of GeoSciences, University of Edinburgh where it currently employs two personnel (an Operations Manager and Equipment Manager at 0.75 each) 0 (1.5 RA FTE). When required, it draws on electronics expertise of the Geophysical Equipment Facility, also based in Edinburgh.

FSF is committed to operate on high standards of service, training, instrument performance and of the Environmental Science it exists to underpin. Strategically, FSF underpins a wide variety of NERC science programmes, including Thematic and non-Thematic research programmes, and a broad range of NERC's Strategic Priority areas. It contributes to the training of PhD students and new academics and supports the NERC Centre for Earth Observation (NCEO), including EO Centres of Excellence, notably CTCD. FSF also vitally supports the NERC Airborne Research and Survey Facility and other airborne sensor operations (e.g. FAAM).

FSF distinctively focuses on techniques to make accurate measurements of the spectral properties of objects in the natural environment, such data being essential to underpin quantitative Earth Observation from aircraft and satellite systems. Traditional laboratory-based spectroscopy cannot capture the complexity of natural targets such as plant canopies and does not reproduce the illumination conditions under which airborne and satellite sensors operate. Field spectroscopy plays a central role in the application of quantitative Earth Observation (EO) to key scientific issues such as global change, pollution monitoring and biodiversity assessment. The FSF also performs a vital strategic function in underpinning the use of data from airborne sensors, especially those flown by the NERC Airborne Research and Survey Facility.

The Facility places a strong emphasis on training. New users all receive one-on-one training in instrument use prior to loan, further supported by the resources available on the FSF website (http://fsf.nerc.ac.uk). Additionally, an extended, highly rated, two and a half day *Introduction to Field Spectroscopy* training course is annually offered, designed to address the wider issues of methods and best practice in field spectroscopy which are not addressed when users attend for training in specific instrument use. 11 projects in the year 2007-08 were associated with postgraduate PhD research including a significant number of NERC research studentships, frequently extending over two summer seasons. When demand has allowed it, the Facility's instrumentation has also been used in wider training of postgraduate students through the commercial loan of instrumentation for field courses at specific institutions.

Calibration plays a key role in the Facility's operation and is critical to the compilation of reliable long-term data sets for studying the effects of climate change and the fluxes of carbon to and from the oceans and land where sustained observation is a key component of national capability. Emphasis is thus placed on the provision to users of calibrated equipment traceable to standards held by the National Physical Laboratory. This is key to minimising uncertainty if we are to reliably attribute detected changes observed in satellite and aircraft data to real environmental changes occurring at ground level, where the issues associated with the calibration of the space-borne sensors used to detect these changes is receiving increasing attention.

Access to FSF resources is available free of charge to the UK research community, subject to expert peer review by the FSF Steering Committee. ~20 applications are received each year and the total requested loan time typically exceeds available capacity. The science supported by the Facility is of high quality and diverse; this year papers were published in the *Atmospheric Environment, Atmospheric Chemistry and Physics Discussions, Atmospheric Environment, Climate Dynamics, Estuarine and Coastal Shelf Science, Remote Sensing of Environment, Proceedings of the Royal Society*, *Journal of Geophysical Research* and *International Journal of Remote Sensing*.

Facility staff have considerable expertise in technical **instrument development and support**. Not only does this allow for the rapid resolution of unexpected problems encountered by users, but it also allows for the development of new instrumentation and initiatives (e.g. in FTIR and V-SWIR instrumentation). However, where required the facility draws on expertise from other NERC facilities (e.g. GEF and MSF and NEODAAS).

Operations are streamlined to ensure the full capacity of the FSF is available to NERC users. **Feedback** from users (Appendix 9) rates the high quality of service provided by the Facility extremely favourably, reporting a high degree of satisfaction with the instrumentation provided, of its performance and in the training provided in its use. They also rate as excellent the quality of service provided by FSF staff. The opinions of users are regularly sought as a guide to how user support can be improved and to guide further developments in the field.

Appendix 2 – Mission Statement

NERC Services and Facilities

FIELD SPECTROSCOPY FACILITY

MISSION STATEMENT

The mission of the Field Spectroscopy Facility is to:

- support high-quality, peer reviewed NERC science;
- maintain a pool of modern, high quality field instruments and associated calibration facility compatible with user requirements, and make them available for loan to environmental scientists in support of their research. The equipment includes spectroradiometers, sun photometers, FTIR, underwater optical instrumentation and associated equipment to support their use in the field;
- provide training and user support, and to promote good practice in the application of field spectroscopy;
- promote the awareness, application and technology of field spectroscopy and to disseminate to a wider scientific community, thereby contributing to the economic competitiveness of the United Kingdom, the effectiveness of public services and policy and the quality of life;
- undertake research into calibration procedures, measurement methodology, data analysis and display appropriate to the FSF mission and to disseminate the results by the most appropriate means.

In order to achieve its objectives the FSF will:

- maintain and calibrate the equipment using in-house irradiance, radiance and reflectance calibration standards which are traceable to the UK National Physical Laboratory and appropriate to the task of supporting the Facility;
- maintain a core of appropriate documentation and data processing software;
- operate procedures to ensure that the best science is supported via peer review of the quality and relevance of applications;
- disseminate knowledge and promote public understanding of field spectroscopy by providing training, particularly of post-graduate students, and offering advice to all users, reaching the wider community via workshops and conferences;
- maintain an awareness of developments in instrumentation for field spectroscopy and associated fields, and evaluate the requirements of future demand;
- carry out development work to modify the available commercial equipment to more closely match user requirements;
- pursue collaborative opportunities with industries in development of new applications, instruments and techniques;
- establish and maintain international collaborative links with related organisations, facilities and programmes;
- maintain close links with the NERC Airborne Remote Sensing Facility to ensure calibration and validation needs are satisfied;
- monitor user satisfaction with the service provided and maintain an awareness of users requirements.

User Community:

The Field Spectroscopy Facility exists primarily to provide specialist services to the environmental sciences community. It supports the Councils remit to promote and support high quality research to meet the needs of the User communities identified in the NERC Mission. The Facility is supported by a steering committee (FSFSC) drawn from members of the user community. It peer reviews applications for the loan of equipment and advises on future trends within the sciences supported, the level of service and the equipment required to meet the demands of the user community.

Appendix 3 - Remit and Terms of Reference of the FSF Steering Committee

NERC Science and Innovation Funding

REMIT AND TERMS OF REFERENCE FOR THE NERC FIELD SPECTROSCOPY FACILITY STEERING COMMITTEE (FSFSC)

<u>REMIT</u>

The NERC Field Spectroscopy Facility Steering Committee exists to:

review applications for use of the NERC Field Spectroscopy Facility;

monitor outputs from the Facility;

provide advice to Director, Science and Innovation on aspects of the operations of the Facility.

Director, Science and Innovation, in turn, provides advice to the Science and Innovation Strategy Board of Council on Services and Facilities relevant to their remit.

Terms of Reference

1. To review applications and establish priorities, for the Manager of the Facility, for the allocation of those of the Facility's resources funded from the Services and Facilities science budget, taking into account recommendations made through the NERC peer review mechanisms.

2. To review the scientific quality of work undertaken by users utilising the Facility, based on reports and publications.

3. To monitor the level of user satisfaction with the service and to analyse the user base.

4. To give guidance to the Manager of the Facility on improvement of the Facility's equipment and on its service function.

5. To advise Director, Science and Innovation on:

    a. the level and direction of the internal R&D programme for the Facility.

    b. anticipated changes in requirements from the Facility and the anticipated levels of future demand for the Facility.

6. To receive annually a report from the Manager of the Facility and to comment thereon as appropriate prior to submission of the report to the Director, Science and Innovation.

7. To report annually to the Director, Science and Innovation and to provide advice at other times as appropriate.

Membership constraints

Membership of the Committee will be decided by Director, Science and Innovation with advice from the Science and Innovation Strategy Board and suggestions from the Committee itself. It will include the Manager of the Facility and a representative from the Services and Facilities Management Team.

Members, other than ex-officio members, will be invited to serve for a term of up to four years with a maximum extension of a further two years. The Chair will serve a maximum of four years.

Appendix 4 – FSF Steering Committee membership

NERC Science & Innovation Funding

Field Spectroscopy Facility Steering Committee

Membership List

Chair	Professor Martin Wooster Department of Geography King's College London Strand London, WC2R 2LS. Tel: 020 7848 2577 Fax: 020 7848 2287 martin.wooster@kcl.ac.uk	10/03
Expertise	Thermal remote sensing.	
Member	Dr Graham Ferrier Department of Geography University of Hull Cottingham Road Hull HU6 7RX Tel: 01482 466060 Fax : 01482 466340 g.ferrier@hull.ac.uk	07/06
Expertise	Hyperspectral remote sensing for geological and geomorphological applications. Coral reef remote sensing, marine eutrophication and estuarine hydrodynamics.	
Member	Mr Andrew Wilson Section for Earth Observation Centre for Ecology & Hydrology Monks Wood, Abbots Ripton Huntingdon PE28 2LS Tel: 01487 772489 Fax: 01487 773277 akw@ceh.ac.uk	06/04
Expertise	Optical and airborne remote sensing ; sensor calibration, atmospheric and geometric correction, navigation systems, and instrumentation design.	

Member Julia McMorrow
School of Environment and Development
University of Manchester
Oxford Road,
Manchester
M13 9PL

Tele 0161 275 3649

julia.mcmorrow@manchester.ac.uk

Expertise Terrestrial remote sensing with research interests in upland peat and humid tropical land cover change.

Ex-officio FSF Director Dr Tim Malthus
School of GeoSciences
University of Edinburgh
Grant Building
Kings Buildings
West Mains Road
Edinburgh EH9 3JW

Tel: 0131 650 2546
Fax: 0131 650 2524
tjm@geo.ed.ac.uk

Ex-officio & Secretary to the FSF SC Alasdair Mac Arthur
Operations Manager
NERC FSF
University of Edinburgh
Drummond Street
Edinburgh EH8 9XP

Tel: 0131 650 5926
Fax: 0131 650 5901
Alasdair.macarthur@ed.ac.uk

Ex-officio Chris Maclellan
Equipment Manager
NERC FSF
University of Edinburgh
Drummond Street
Edinburgh EH8 9XP

Tel: 0131 650 5926
Fax: 0131 650 5901
chris.maclellan@ed.ac.uk

Ex-officio Michelle Manning
NERC
Polaris House
North Star Avenue
Swindon SN2 1EU

Tel: 01793 411600
Fax: 01793 411610
rlfk@nerc.ac.uk

FSF Steering Committee Attendance

		Date appointed	EPFS 2003	FSF SC 2004	FSF SC 2005	FSF SC 2006	FSF SC 2007	FSF SC 2008
Rotating members	Dr M. Danson	05/02	15th May (apologies)	14th Sept. (Chair)	26th Sept. (Chair)	10th July (Chair)	5th June	Rotated off committe e
	Dr G. Ferrier	07/06				10th July	5th June	17th June
	Prof. M. Wooster (Chair from 2008)	10/03		14th Sept.	26th Sept.	10th July (apologies)	5th June	17th June
	Mr. A. Wilson	06/04		14th Sept.	26th Sept.	10th July	5th June	17th June
	Ms J. McMorrow	04/08						17th June
Ex-officio	Dr L. Kay (NERC)			14th Sept.	26th Sept.	10th July	N/A	N/A
	MissM. Manning						5th June	17th June
	Dr T. Malthus (Director)			14th Sept.	26th Sept.	10th July	5th June	17th June
	Dr F. Taylor (Secretary to the FSFSC)				26th Sept.	Maternity leave	Maternity leave	Resigned
	Mr. A. Mac Arthur (Secretary to the FSFSC from 2007)					10th July	5th June	17th June
	Mr C. MacLellan FSF Equipment manager				26th Sept.	10th July	5th June	17th June

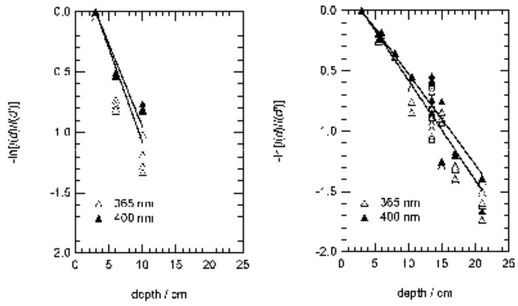
N/A: did not attend

Appendix 5 – FSF Projects

Further descriptions of science undertaken by users or the Field Spectroscopy Facility (2005-08)

1. Climate systems

NOx gas release from snowpacks - FSF equipment was used in a field and modelling study of the optical properties of wet mid-latitude mountainous snow (Cairngorms). UV penetrated to greater depths than polar (tundra) snowpacks, suggesting that the snow has fewer absorbing impurities than snow from the Arctic. Mid-latitude snow may thus release more NO_2 gas to the atmosphere due to photolytic destruction of nitrate anions in the snowpack. **Fisher et al. (2005).**



Log plot of relative light penetration at two wavelengths versus snow depth at one site on days 3 and 53.

Validating estimates of aerosol optical thickness from satellite data - In research undertaken by the Climate & Land-Surface Systems Interaction Centre (CLASSIC) FSF Microtops sunphotometers and AERONET data have been used to validate AOT estimates that have been output from a coupled surface/atmosphere radiative transfer model which is parameterised by CHRIS instrument data (North, Swansea, α4). The reliability of the predictions that climate models make is dependent on the reliability of atmospheric aerosol measurements and their direct and indirect effects on the Earth's radiation budget. Uncertainties in the effect of aerosols on the climate is due to a lack of information on the shape, size and chemical composition of aerosols including their global distribution. Satellite remote sensing offers the only way for routinely monitoring the global effect of aerosols, but a variety of wavelengths is required to identify chemical composition and a variety of viewing angles is required to identify shape and size of aerosols. The CHRIS instrument on the PROBA satellite, with its hyper spectral, multi-angular and relatively high resolution data, presents an opportunity to integrate various techniques and instrumentation to improve the quality of estimates of aerosol concentrations and distributions.

Effect of changing climate on the CO_2 uptake of forests - In the context of climate change as part of the EU Carboeurope-IP, FSF spectroradiometers have been used to assess the effect of changing climate on the CO_2 uptake of forests (Grace, Edinburgh α5). The instrumentation has been used to assess the effects of varying sky conditions and their associated changes in spectral quality in direct and diffuse radiation and under clouds on the photosynthesis of forest canopies and related to direct measurements of CO2 flux made using eddy covariance.

Feedback mechanisms between the atmosphere and snow interstitial photochemistry - FSF instrumentation contributed to research into gaseous nitrous acid (HONO) fluxes at Browning Pass, Antarctica, where it was used to measure snow and atmosphere optical properties, notably albedo in the UV and visible wavelength regions and wavelength dependent light extinction both within and above snowpacks. The measurements are being used to constrain snowpack radiative properties in a snowpack-atmosphere model to investigate critical feedback mechanisms between the atmosphere and snow interstitial photochemistry and how climate change affects chemical exchange between the two. **Beine et al. (2006)** found HONO fluxes to be very low (close to zero), despite conditions that were favorable for HONO emissions including: acidic snow surfaces, an abundance of NO3− anions in the snow surface, and abundant UV light for NO_3^- photolysis. HONO production from nitrate appears to strongly depend on its physical (surface or volume) and chemical (ice or salt) environment and suggested that laboratory experiments would seem necessary to solve the puzzle.

Similarly, atmospheric chemistry directly above snowpacks is strongly influenced by ultraviolet (UV) radiation initiated emissions of chemicals from the snowpack. The emission of gases from the snowpack to the atmosphere is in part due to chemical reactions between hydroxyl radical, OH (produced from photolysis of hydrogen peroxide (H_2O_2) or nitrate (NO_3^-)) and impurities in the snowpack. **France et al. (2007)** used FSF instrumentation (GER1500 Spectroradiometers and MicroTops II Sun Photometers) to measure the optical properties of different snowpacks at a range of solar zenith angles. Radiative-transfer models were used to calculate depth integrated production rates of hydroxyl radical from the photolysis of hydrogen peroxide and nitrate anion in snow and demonstrated the importance of hydrogen peroxide photolysis to produce hydroxyl radical relative to nitrate photolysis for different snowpacks, different ozone column depths, and snowpack depths. The importance of hydrogen peroxide photolysis over nitrate photolysis for hydroxyl radical production was found to increase with increasing depth in snowpack, column ozone depth, and solar zenith angle. With a solar zenith angle of 60º the production of hydroxyl radical from hydrogen peroxide photolysis accounts for 91–99% of all hydroxyl radical production from hydrogen peroxide and nitrate photolysis.

Intercalibrating NDVI estimates from different satellite sensors - Using field spectra, **Steven et al. (2007)** updated intercalibrations for the comparisons on vegetation indices obtained from different satellite sensors. These demonstrated that such sensors cannot be regarded as directly equivalent due to variations in spectral sensitivity between sensors. While the incentive to combine data from narrow and wide swath instruments to fill gaps in observation for both high resolution and global applications is strong, vegetation indices from different systems must be standardised to ensure consistency of observations for the reliable detection of environmental change.

Continuous measurements of UK atmospheric properties - FSF's CIMEL sun photometer based at Chilbolton as part of the AErosol RObotic NETwork (AERONET) (operated in collaboration with CCLRC), continues to support future national atmospheric research capabilities (http://aeronet.gsfc.nasa.gov/photo_db/Chilbolton.html). The site (along with a newly installed instrument at Wytham Wood) provides currently the only UK continuously monitored information on observations of aerosol spectral optical depths, aerosol size distributions, phase function data and precipitable water.

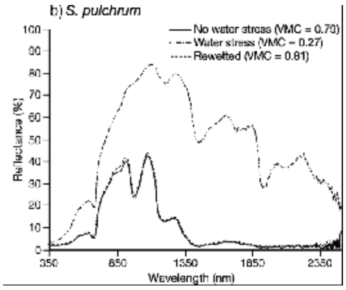
Cimel sun photometer installed at Chilbolton to become the UK's only AERONET site.

FSF has been active in 2008 establishing a second AERONET site based near CEH Wallingford at a long-term ECN site and which will be active from December 2008. The data from both sites provide algorithm validation of satellite aerosol retrievals and as well as characterization of aerosol properties for satellite atmospheric correction systems. Over time, the accumulated data can be used to analyse spatial and temporal variations of aerosol optical depth over the UK to both parameterise and validate outputs of regional climate models.

2. Biodiversity

Methods for the improved monitoring of wetlands - Wetland systems are fragile and highly dynamic ecosystems which are affected by degradation processes as a result of anthropological influences, such as overexploitation of groundwater for agriculture and associated land use. Field reflectance and hyperspectral image spectra of surface components were used to define endmembers in a site-specific spectral library; the information was extrapolated to a temporal series of broadband multispectral imagery with spectral unmixing analyses performed to detect changes in the wetlands over time. The results indicate the significant impact of anthropogenic impact, but that natural seasonally-induced fluctuations confuse the changes detected. Water regulation and agricultural practices directly influences the salinity of the soils and therefore the nature of the hygrophytic vegetation (**Schmid et al. 2005)**.

Monitoring peatland hydrological conditions - Climatically sensitive wetness factors are the primary factors controlling rates at which CO_2 and CH_4 are emitted from peatlands (which may contain up to 1/3 of world soil carbon). Studies using FSF spectroradiometers shows that near-surface moisture conditions can be estimated from the reflectance spectra of *Sphagnum* moss. Supporting airborne data shows that the technique offers great potential for large-scale monitoring of near-surface peatland hydrological conditions. A Moisture Stress Index derived from airborne data was significantly correlated with both field moisture and the water-table position. (**Harris et al. 2005; 2006**).

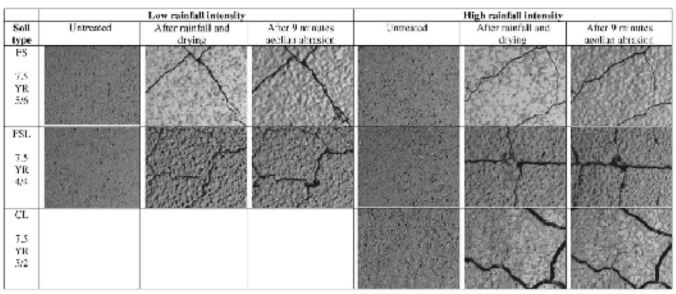


Spectral reflectance profiles for Sphagnum species at three key moisture

Ecosystem resilience - In research on ecosystem resilience, funded by the NERC Centre for Terrestrial Carbon Dynamics (Disney, UCL, α5), FSF ASD equipment has been used to examine the possibilities for using Earth Observation (EO) data in monitoring and modeling vegetation state and dynamics under catchment-scale treatment regimes. The research aims to link mesocosms study in controlled climate conditions with manipulation experiments at Lake Vyrnwy in Wales where restoration is being accomplished through controls on grazing, blocking of drainage ditches. Another objective of the project is to relate changes in ecosystem state (fluxes of carbon and water) to changes in the EO signal. Preliminary results from field studies suggest that the net carbon flux may be primarily a function of soil moisture.

3. Sustainable use of natural resources

Wind erosion of soils - Agricultural sustainability requires accurate determination of wind erosion rates of soils across several spatial scales to identify controlling environmental processes. Remote sensing allows consideration of the processes controlling erodibility on a spatial continuum. FSF ASD spectroradiometric equipment was used to measure multi-angular spectral



Nadir images of soils before treatment, after low and high rainfall intensity and drying treatment and after an accumulated 9 minute aeolian abrasion treatment for different soil types.

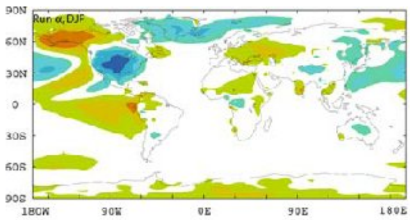
reflectance of soils susceptible to wind erosion in an experiment incorporating simulated rainfall and wind tunnel abrasion. Results showed that much of the variation in soil reflectance model parameters was explained by scattering properties and roughness, and that variation in reflectance was not solely due to soil type - low intensity rainfall combined with short and long duration abrasion explained a significant portion. The method has good potential for improving understanding of erodibility and for identifying and quantifying soil erosion (**Chappell et al. 2006, *Remote Sensing of Environment*, 102:328–343.**

Imaging methods for profiling loess sediments - In a pilot project (Smith, Kingston), FSF kit was used test the feasibility of an imaging technique to record spectral profiles of loess sediments in China. The project aimed to determine whether the spectral reflectance and calibrated low cost imaging of loess sediments are correlated to their magnetic susceptibility and thus to investigate facies variations over short lateral distances. Facies differences revealed will complement calculated sedimentation rates and together will form a powerful approach to constraining local influences on loess deposition and alteration ultimately allowing the extraction of broad monsoonal influences.

Measurement of the reflectances of Loess sediments, China.

4. Natural hazards

Climatic effects of volcanic eruptions of dry volcanic ash - FSF spectroradiometers were used to measure the reflectivity of dry volcanic ash and other materials to understand the climatic impact of supervolcanic ash blankets. Dry volcanic ash albedos values can be as high as those for snow, implying that the effects on long-term climate change of an ash blanket erupted from supervolcanoes could be severe, and may be linked to previous ‘bottlenecks’ in human and animal populations. GCM modelling to simulate the effect of an ash blanket covering much of North America showed major disturbances to the climate, particularly to oscillatory patterns (e.g. ENSO). Such disruptions would continue for decades due to extended ash blanket longevity, though this is only one of several impacts associated with a super-eruption which may induce long-term climatic change (**Jones et al. 2007**).



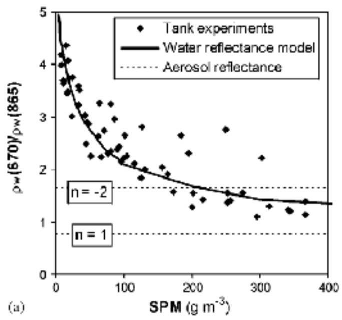
Simulated mean surface aire temperature change

5. Environment, pollution and human health

Pollutive and climatic impacts of major oil fire - The Buncefield oil depot explosion in December 2005 afforded study of the atmospheric consequences of a major oil fire at close range. Using FSF sunphotometer equipment and other ground-based instruments, near-source measurements suggested that plume particles were approximately 50% black carbon , effective radius of 0.45–0.85 mm and mass loading approximately 2000 mg mK^3. 50 km downwind, black carbon content increased (up to 75%) as did effective radius but mass loading decreased three-fold. Near-source trace gas concentrations of SO_2, NO_2, HONO, HCHO and CS_2 were elevated. Overall, effects were manifest in reduced solar flux reaching the surface, but little effect on atmospheric potential gradient. Results were consistent the 1991 Kuwaiti oil-fire plumes with differences reflecting contrasts in combustion efficiency and source composition leading to important potential differences in atmospheric impacts. **(Mather et al. 2007).**

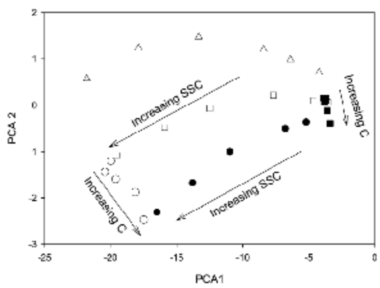
Pollution from mine wastes - The release of hazardous mine waste from abandoned gold mining areas is a major global environmental problem, but complexity, scale and accessibility limit field-based survey methods. Using a FSF spectroradiometer in field studies of an abandoned mine in Spain, **Ferrier et al. (2007; 2008)** derived correlations between spectral reflectance and hazardous mine waste, notably secondary iron species, cyanide and heavy metals concentrations. The results were used to scale-up observations from airborne-mounted hyperspectral imaging sensors to resolve the distributions of mine waste and secondary iron species on the mine site and in adjacent rivers and ultimately a more accurate understanding of the environmental status of the mine area.

Improved methods for the atmospheric correction of images over Case II waters - Case II surface waters typically have high reflectance at near infra-red wavelengths which invalidates ''dark pixel'' atmospheric correction methods where negative reflectances are often given. A laboratory-based tank experiment using FSF equipment, complemented by coupled ocean-atmosphere modelling and validated against test images from Europe, characterised NIR reflectances of different concentrations of suspended sediments representing diverse sediment minerologies. The modified atmospheric correction methods led to significant increases in normalised water leaving-radiances across the whole spectrum and to fewer negative water leaving radiances (**Lavender et al. 2005**).



NIR and aerosol reflectance ratios as a function of SPM for the ratio 670/865nm. A comparison of measured and modelled results

Improved algorithms for monitoring European lakes with satellite data - In situ reflectance measurements in Lake Balaton were supplemented by controlled tank experiments to characterize the influence of suspended sediment (SS) and Chl a on spectral reflectance and simulated Landsat satellite responses. These confirmed that Chl a could not be estimated directly from Landsat data in waters characterized by heterogeneous suspended matter. However, principal component analysis indicated that a spectral linear mixture modelling approach combined with a multivariate regression analysis could be used to provide estimates of Chl a concentrations, independent of SS concentrations (**Svab et al. 2005**).



PCA scatterplot Landsat simulation with location of end-members identified.

Monitoring ^{137}Cs contamination in vegetation - Vegetation has been shown to be an important agent in the cycling of radioactive isotopes in the environment and therefore a useful indicator of radionuclide contamination. Consequences of the 1986 Chernobyl accident continue to affect Belarus long after initial contamination, which in turn has placed strain upon social, economic and political infrastructures. A pilot study assessing spectral responses from *Pinus sylvestris* at differing ages and with varying levels of ^{137}Cs contamination, showed that for older forests (c. 35 years) significant spectral differences between low and high contaminated sites exist at wavelengths that are causally related to foliar biochemicals (**Boyd et al. 2006**). The results signify the potential to infer contamination levels from spectra of forests, partitioned by age, thus indicating the possibility of using imaging spectrometry to monitor radionuclide contamination, ultimately to return areas of land no longer posing a risk, back to an appropriate use.

Software hosting service - FSF is now hosting software aimed to assist users to retrieve columnar optical thickness of aerosols concentrated in plumes (resulting from volcanoes, fires or industrial plants) from measurements made with its' Microtops sunphotometers. To investigate the aerosol properties of the plume, it is necessary to make measurements observing the Sun through both the plume and the background atmosphere (clear from plume). The optical thickness of the plume can then be obtained by subtracting the optical thickness of the background atmosphere from the total through-plume optical thickness. The software package was developed by Drs V.I. Tsanev and T.A. Mather of the University of Cambridge. The methods applied in the software were used to study the volcanic plumes resulting from an eruption of Mount Etna in 2006 and to examine the atmospheric consequences of the Buncefield Oil Depot fire in December 2005.

6. Earth system science

FSF spectroradiometers and MicroTops sunphotometers were used in the support of the ARSF deployment to Ethiopia linked to the NERC Afar Consortium project, which is investigating magmatism and tectonics associated with plate rupture in the Afar region of Ethiopia. Spectroradiometric data have been used to apply advanced remote sensing techniques to synoptic- and local-scale geological and geomorphological characterisation of erupted materials and their relationships to faulting and fracturing (**Oppenheimer, Cambridge, α5**). Initial objectives include discrimination of lava compositions from remotely sensed data and characterisation of temporal relationships in lava flow field development. Key questions to be addressed are the relative abundances of silicic and mafic lavas, temporal trends in erupted composition, and spatial relationships between volcanism, dyke intrusion and faulting. The ground-based spectroscopy, combined with petrological analysis of rock samples will be used to aid analysis of the airborne imagery, and to contribute to some more generic tools for geological interpretation of remotely sensed data in volcanic terrains.

7. Technologies

Reducing uncertainties in earth observation data - Ground calibration targets fulfil a key role in vicarious calibration and atmospheric correction but assume temporal stability of reflectance. Use of FSF instrumentation has demonstrated that reflectance stability is far from the case where up to two-fold variations in reflectance throughout the year may be observed. This has significant implications for monitoring change where results are assumed to be independent of the sensor used and of the conditions of measurement (**Anderson and Milton 2006**). Similarly, field spectroscopic measurements will make increasingly important contributions to EO-based global observations, specifically through assimilation into numerical models. High quality data with stated levels of accuracy and uncertainty are required as are standardised terminologies and refinements in field measurement methodologies. FSF supported research has shown that; field generated instrument inter-calibration functions (ICFs) of dual-beam sensor pairs, obtained close in time and space to real field measurements, are superior

Measuremetn of the variations in concrete and tarmac reflectance.

to laboratory based generated functions (**Milton et al. 2007; Anderson et al. 2007**). Similarly, in collaborative research with NASA, a paired set of FSFs GER 1500 spectroradiometers have been used in research aimed at empirically quantifying uncertainties in field-measured reflectance factors as a result in variations in the proportion of diffuse irradiance or sky haziness (Anderson, Exeter, α4h). The effect is most pronounced in non-Lambertian surfaces, common in a wide range of natural surfaces. The effect needs to be understood as it could introduce large uncertainties into remote sensing data products, most notably those derived using multi-temporal information.

The Facility's in-house research has highlighted significant issues in the fields-of-view of its instrumentation; without correction the results suggest that a high degree of the uncertainty present in observed relationships between reflectance and bio-physical parameters may be a result of uncertainties in the fields-of-view (**MacArthur et al.** submitted).

The Facility's in-house research programme is largely focused at addressing technological issues with its instrumentation with the aim of ensuring users have state-of-the-art equipment designed to maintain UK research capabilities at the competitive edge. As such, the Facility's research is improving UK capabilities to observe, measure and monitor earth surface features. At the same time much of the developments have extended the capabilities of the Facility to support a wider range of applications and users. Much of the development in new or existing instrumentation undertaken by the Facility, relies on consultation and feedback from users which is undertaken through regular questionnaires to that user base. New directions are also informed by the Facility's equipment replacement strategy which seeks to ensure any purchases of replacement instruments maintains the Facility's capabilities at the cutting edge. Whilst, much of the Facility's in-houses research programme is explained in detail in the following section, the focus of this research effort has been aimed at:

a) <u>developing new instrumentation from emerging trends</u> leading to possible new areas of science that can be supported. This includes the development of the first field portable FTIR instrument available in the UK and the acquisition of underwater instrumentation for near-complete characterisation of underwater optical properties.

b) <u>reducing uncertainties in existing measurements</u>. Examples include the incorporation of external sensors and sensor suites into replacement spectroradiometers designed to better characterise variations in incident irradiance during field reflectance measurements, research into the calibration and care of Spectralon reference panels, and an improved goniometer for the rapid measurement of BRDF related reflectance properties in the field.

c) <u>ease of use of the Facility's instrumentation in the field</u>. This includes the incorporation of wireless communications between control PCs and PDA's and the instrumentation themselves, the incorporation of GPS positioning as standard within some of the new instruments acquired.

d) <u>development of novel field portable V-SWIR spectroradiometer</u> as an improved replacement for the Facility's aging VNIR (400 to 1100 nm) spectroradiometers with particular emphasis on off-the-shelf technologies, delivering dual-field-of-view as standard, ensuring uniformity of field-of-view, and improvements in sensor technologies and instrument performance and size. The prototype optics will be developed by the Astronomy Technology Centre (ATC, Royal Observatory, Edinburgh)

e) <u>the development of a new, purpose-built, 20-inch integrating sphere</u> especially optimised for push-broom sensors and with a focus on uniformity, for the calibration of ARSF's EAGLE/HAWK system.

Appendix 6 – Detailed listings of projects supported during 2006 – 2009

Key to funding modes: NT, NERC Blue Skies; T, NERC Directed; CS, NERC Core Strategic; INF, NERC Infrastructure; NN, Non-NERC funding

Projects supported during 2006 - total 21

PI	HEI name	Grant Number	Project title	Funding Mode
Dr M. King	Royal Holloway and Bedford New College	NER/S/A/200412177	Photochemical oxidation in snowpacks: An OASIS international field campain	NT
Dr E. Highwood	The University of Reading	NER/S/A/2005/13744	Dust outflow and deposition to the ocean	NT
Dr T. Mather	University of Cambridge	NE/B504622/1	Emergency loan of MTP to monitor the Hemel Hempstead oil plume disaster	NT
Dr T. Malthus	University of Edinburgh	NER/S/A/2004/127320	Remote Sensing for Continuous Cover Forestry; Quantifying Spatial Forest Structure.	NT
Dr C. Oppenheimer	University of Cambridge	NE/B504622/1	Remote sensing of halogen oxides, water vapour and aerosols in volcanic plumes	NT
Dr A. Harris	University of Southampton		Photosynthetic processes in northern peatlands	NN
Prof E. Milton	University of Southampton	NERC/FSF/NPL in house funding	Development and testing of a field Goniospectrometer for the NERC FSF	INF
Dr T. Malthus	University of Edinburgh	NER/S/A/2005/13744	From micro to macro scales: hyperspectral remote sensing of blanket mire landscapes	NT
Dr R. Alexander	University of Chester		Mapping biological soil crusts in the Tabernas Desrt, Almeria, Spain	NN
Dr G. Ferrier	University of Hull		Mapping and modelling the environmental impact of contaminants dispersed from abandoned mines	NN
Dr P. Zukowskyj	University of Hertfordshire		Assessment of changes in semi-natural vegetation density and clearance extent in Sorbas, south east Spain	NN
Dr T. Malthus	University of Edinburgh		Hyperspectral and Phenological Characterisation of Upland Heather Dominated Ecological Communities	NN
Dr D. Bowers	University of Wales, Bangor	NER/S/D/2004/12688	Remote Sensing Of Chlorophyll Concentrations in Turbid Shelf Seas	NT
Dr R. Teeuw	University of Portsmouth		Multi-sensor geohazard mapping, SE Spain	NN
Dr P. Osborne	University of Southampton		Using multi-scale remote sensing to study habitat selection by cereal steppe birds in Portugal	NN

PI	HEI name	Grant Number	Project title	Funding Mode
Dr R. Thomas	Cardiff University	NER/S/A2004/12120	Street lighting effects on wild birds	NT
Dr G. Tilstone	Plymouth Marine Laboratory	NE/C514215/1 & NE/C516101/1	An investigation of the inherent optical properties of Phytoplankton for the improvement of ERSEM and satellite maps	NT
Dr C. Nichol	University of Edinburgh	NE/C518281/1	Measuring aerosol optical thickness for atmospheric correction of CHRIS-PHOBA data	NT
Dr T. Malthus	University of Edinburgh		Biotope mapping of the Sound of Harris	NN
Dr M. Disney	University College London		ABACUS project	T
Dr M. Mencuccini	University of Edinburgh		Sitka spruce seedling and aphid response to light quality: a comparison between forest understorey and shadehouses	NN

Projects supported during 2007 - total 20

PI	HEI name	Grant Number	Project title	Funding Mode
Dr P. Land	Plymouth Marine Laboratory		Integrated Land-Sea Atmospheric Correction Experiment	NN
Dr M. Cutler	University of Dundee		Hyperspectral remote sensing of the physico-chemical properties in Glenogil, Angus: spatial transferability of Pennine results	NN
Dr G. Ferrier	University of Hull		Characterising Contaminated Land using Integrated Thermal, Hyperspectral and Geophysical data	NN
Dr K. Anderson	University of Exeter	CROFT14137	Hyperspectral, multiple view angle measurements for soil degradation monitoring	NT
Dr M. Mencuccni	University of Edinburgh		Sitka spruce seedling and aphid response to light quality: a comparison between forest understorey and shadehouses	NN
Dr P. Miller	Plymouth Marine Laboratory	NE/C513018/1	Measurement of absorption at the Mid Atlantic Ridge for use in bio-optical models of primary production	T
Dr M. Williams	University of Newcastle		An evaluation of VIS-SWIR radiometric calibration approaches for high latitude environments	NN

PI	HEI name	Grant Number	Project title	Funding Mode
Dr D. Boyd	University of Nottingham		Investigating the factors affecting the relationship between the Envisat Terrestrial Chlorophyll index and chlorophyll content	NN
Dr T. Malthus	University of Edinburgh	NER/S/A/2005/13744	Remote sensing of blanket mire microhabitats	CS
Dr M. Disney	University College London		ABACUS project	T
Dr C. Oppenheimer	University of Cambridge	NER/S/A/2006/14107	Evaluation of potential health hazards related to biomass burning emissions	CS
Dr T. Malthus	University of Edinburgh		Hyperspectral and Phenological Characterisation of Upland Heather Dominated Ecological Communities	NN
Dr M. King	Royal Holloway University of London		Nitrate Evolution in Dome C Antarctica (NITE-DC) – An International Polar year project	NN
Dr T. Riley	British Antarctic Survey	NER/S/A/2006/14242	Reflectance spectroscopy of Antarctic Peninsula lithologies	CS
Dr B. Godley	University of Exeter		Measuring the albedo of loggerhead turtle nesting sites	NN
Dr K. Tansey	University of Leicester		Influence of land use, climate and topography on the fire regime in the Colombian eastern savannas "Llanos Orientales	NN
Dr L. Bateson	British Geological Survey		Testing remote sensing monitoring technologies for potential CO2 leaks from storage sites	NN
R. Park	Scottish Environmental Protection Agency		Commercial loan	NN
Dr G. Meaden	Canterbury Christ Church University		Rapid marine benthos sampling at the Gulf of Eilat using hyperspectral remote sensing	NN
Dr T. Malthus/ Dr C. Wrench	Chilbolton Observatory	NERC/FSF in house	Intercalibration of CIMEL sunphotometer	NT

Projects supported during 2008 - total 26

PI	HEI name	Grant Number	Project title	Funding Mode
Dr P. North	Swansea University		Estimating Aerosol Optical Depth using CHRIS/PROBA	NN
Dr M. Disney	University College London	NE/F008279/	Bringing the outside in; linking landscape-scale ecosystem manipulation to controlled environment studies	NT
Dr C. Oppenheimer	University of Cambridge	NE/F009208/1 and NE/E005535/1	How does the Earth's crust grow at divergent plate boundaries? A unique opportunity in Afar, Ethiopia	NT

PI	HEI name	Grant Number	Project title	Funding Mode
Dr K. Anderson	University of Exeter	CROFT14137	Upscaling hyperspectral, directional reflectance measurements for soil degradation monitoring	NT
Dr T Malthus	University of Edinburgh	NER/S/A/2005/13744	Remote sensing of blanket mire microhabitats	NT
Dr J. Grace	University of Edinburgh		Influence of sky conditions on carbon dioxide uptake by forests	NN
Dr K. Anderson	University of Exeter	Winston Churchill Memorial Trust	Exploring skylight effects on reflectance uncertainty	NN
Dr M. Mencuccini	University of Edinburgh		Impact of pre-afforestation site preparation practices on CO2, CH4 and N2O fluxes at Harwood Forest	NN
Dr T. Blackall	King's College London		Trace gas emissions from seabird colonies	NN
Dr G. Ferrier	University of Hull		Quantifying methane emissions from northern peatlands	NN
Dr P. Miller	Plymouth Marine Laboratory	NE/C513018/1	Measurement of absorption at the Mid Atlantic Ridge for surface productivity estimates	CS
J. McMorrow	University of Manchester	NE/F013787/1	Landscape-scale restoration of peatland: evaluating the contribution of hyperspectral remote sensing	NT
Dr C. Bates	University of St Andrews	NE/D012996/1	Late Pleistocene desiccation of Lake Tana, Source of the Blue Nile	NT
Dr F. Visser	University of Worcester		Field spectroscopy for detection of benthic micro-algae communities in gravel bed streams	NN
Dr M. Wooster	King's College London	EU ENV.2007.2.1.5. - 211345	Investigating the Urban Energy Balance of London	NT
Dr M. Smith	Kingston University		Loess spectrometry and its use as a proxy for past climate change	NN
Dr M. Disney	University College London		ABACUS project	T
Dr T. Malthus/ Dr C. Wrench	Chilbolton Observatory	NERC/FSF in house	Intercalibration of CIMEL sunphotometer	NT
Dr M. King	Royal Holloway University of London	NE/F010788/1	Visible photochemical oxidation in snow and ice: organic photochemistry	NT
Dr T. Riley	British Antarctic Survey		Field spectroscopy on Adelaide Island, Antarctic Peninsula, in support of lithologic remote sensing	n/a
Dr C. Oppenheimer	University of Cambridge	NE/F009208/1 and NE/E005535/1	How does the Earth's crust grow at divergent plate boundaries? A unique opportunity in Afar, Ethiopia	NT
Prof.Y.Malhi	University of Oxford		Apparent reflectance translation for Andean biomass estimates	n/a
Dr C. Nichol	University of Edinburgh	NE/C518281/1	Detection of drought in sycamore using reflectance and fluorescence measurements	NT
Dr T. Blackall	King's College London	NitroEurope	Measuring ammonia emissions frm agricultural field pre and post application	NN

PI	HEI name	Grant Number	Project title	Funding Mode
Prof. E. Milton	University of Southampton	NERC/FSF/NPL in house funding	Goniometer	INF
Dr M. Disney	University College London	European Space Agency, AO/1-5526/07/NL/H	Radiative Transfer Modelling for the characterisation of burnt surfaces	NN

Appendix 7 – Publications

A full list of publications is presented for each year of review, in reverse order

2008

ISI publication

CROFT, H., ANDERSON, K. & KUHN, N. (2008, in press) Characterising soil surface roughness using a combined structural and spectral approach. *European Journal of Soil Science.*

FERRIER, G., HUDSON, K. A. & POPE, R. J. (2009) Characterisation of the environmental impact of the Rodalquilar mine, Spain by ground-based reflectance spectroscopy. *Journal of Geochemical Exploration,* 100**,** 11-19.

HAMYLTON, S. (2009, in press) Determination Of The Separability Of Coastal Benthic Assemblages Of The Al Wajh Barrier Reef, Red Sea, From Hyperspectral Data. *European Journal of GeoSciences*.

HEDLEY, J. D. (2008, in press) A three-dimensional radiative transfer model for shallow water environments. *Optics Express*.

PAGE, S. E., HOSCILO, A., WÖSTEN, H., JAUHIAINEN, J., SILVIUS, M., RIELEY, J., RITZEMA, H., TANSEY, K., GRAHAM, L., VASANDER, H. & LIMIN, S. (2008) Restoration Ecology of Lowland Tropical Peatlands in Southeast Asia – Current Knowledge and Future Research Directions. *Ecosystems,* DOI: 10.1007/s10021-008-9216-2.

PAGE, S. E., HOSCILO, A., LANGNER, A., TANSEY, K. J., SIEGERT, F., LIMIN, S. & RIELEY, J. O. (2008, in press) Chapter 9: Tropical peatland fires in Southeast Asia. . IN COCHRANE, M. A. (Ed.) *Tropical Fire Ecology: Climate Change, Land Use and Ecosystem Dynamics.* Heidelberg, Germany, Springer-Praxis.

RIELEY, J. O., WÜST, R. A. J., JAUHIAINEN, J., PAGE, S. E., WÖSTEN, H., HOOIJER, A., SIEGERT, F., LIMIN, S., VASANDER, H. & STAHLHUT, M. (2008) Chapter 6: Tropical peatlands: Carbon stores, carbon gas emissions and contribution to climate change processes. IN STRACK, M. (Ed.) *Peatlands and Climate Change.* Jyväskylä, Finland, International Peat Society.

TANSEY, K., BESTON, J., HOSCILO, A., PAGE, S. E. & PAREDES HERNÁNDEZ, C. U. (2008, in press) The relationship between MODIS fire hotspot count and burned area in a degraded tropical peat swamp forest in Central Kalimantan, Indonesia. *Journal of Geophysical Research,* doi:10.1029/2008JD010717.

TODD, M. (2008, In press) Quantifying uncertainty in estimates of mineral dust flux: an inter-comparison of model performance over the Bodele Depression, Northern Chad. . *Journal of Geophysical Research,* In Press.

TODD, M. C., WASHINGTON, R., LIZCANO, G., RAGVAHAN, S. & KNIPPERTZ, P. (2008) Regional model simulations of the Bodele low-level jet of Northern Chad during BoDEx 2005. *Journal of Climate,* 21**,** 995-1012.

VAN DE LEE, E. M., BOWERS, D. G. & KYTE, E. (2008, in press) Remote sensing of temporal and spatial patterns of suspended particle size in the Irish Sea in relation to the Kolmogorov microscale. *Continental Shelf Research*.

WOSTEN, J. H. M., CLYMANS, E., PAGE, S. E. & LIMIN, S. H. (2008) Interrelationships between peat and water in a tropical peatland ecosystem in Southeast Asia. . *Catena,* 73**,** 212-224.

ISI publications in review:

DAVIES, W. H., NORTH, P. R. J., GREY, W. M. F. & BARNSLEY, M. J. (2008, in review) Improvements in Aerosol Optical Depth Estimation using Multi-angle CHRIS/PROBA Images. *IEEE Transactions on Geoscience and Remote Sensing*.

FREEDMAN, A. H., SMITH, T. B., MITCHARD, E. T. A., SAATCHI, S. S. & BUERMANN, W. (2008, in review) Loss of phenotypic variation due to human alteration of the rainforest-savanna gradient in West Africa. *Science*.

MARTIN, R. S., MATHER, T. A., PYLE, D. M., POWER, M., TSANEV, V., OPPENHEIMER, C., ALLEN, A. G., HORWELL, C. J. & WARD, E. P. W. (Submitted 2008) Size distributions of fine silicate and other particles in Masaya's volcanic plume. *Journal of Geophysical Research - Atmospheres*.

PhD thesis

GAULTON, R. (2008). Remote sensing for continuous cover forestry: quantifying spatial structure and canopy gap distribution. University of Edinburgh.

GOLDSMITH, P. C. (2008) Remote sensing the radionuclide contaminated Belarusion landscape. Centre for Earth and Atmospheric Science Research. London, Kingston University, UK.

KYTE, E. (2008) Remote sensing of chlorophyll concentrations in a turbid shelf sea. Bangor, University of Wales.

MARTIN, R. S. (2008) Formation of volcanic aerosol. University of Cambridge.

WHITE, D. C. (2008) Hyperspectral remote sensing of canopy scale vegetation stress associated with buried gas pipelines. Newcastle upon Tyne, University of Newcastle upon Tyne.

Conference proceedings

CARAS, T., KARNIELI, A. & BEN DOR, E. (2008) Spectral unmixing of coral reef using hyperspectral spaceborne imagery (Hyperion) paired with groundtruthing spectrometry. *Proceedings of the Remote Sensing and Photogrammetry Society Conference.* University of Exeter, Falmouth Campus, UK.

GAULTON, R. & MALTHUS, T. J. (2008) LiDAR mapping of canopy gaps in continuous cover forests; a comparison of canopy height model and point cloud based techniques. *Proceedings of SilviLaser 2008.* Edinburgh, U.K.

HASELWIMMER, C. E., RILEY, T. R. & LIU, J. G. (2008) Lithologic mapping in the Oscar II Coast, Graham Land, Antarctic Peninsula using Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data. *33rd International Geological Congress.* Oslo, Norway.

HOSCILO, A., PAGE S.E. & TANSEY, K. (2008a) Repeated and extensive fire as the main driver of land cover change in Block C of the former Mega Rice Project area. *Proceedings of the 13th International Peat Congress.* Tullamore, Ireland, International Peat Society, Finland.

HOSCILO, A., PAGE, S. E. & TANSEY, K. (2008b) Spatial and temporal alterations of tropical peatlands (Indonesia) due to widespread and repeated fires over the last 30 years. *Proceedings of the Remote Sensing and Photogrammetric Society Annual Conference. .* University of Exeter, Falmouth Campus, UK.

MAC ARTHUR, A. A. & MALTHUS, T. J. (2008) An Object-Based Image Analysis Approach to the Classification and Mapping of Calluna Vulgaris Canopies. *Proceedings of the Annual Conference of the Remote Sensing and Photogrammerty Society.* Exeter.

PEGRUM-BROWNING, H., FOX, N. & MILTON, E. (2008) The NPL Gonio Radiometric Spectrometer System (GRASS). *Proceedings of the Annual Conference of the Remote Sensing and Photogrammerty Society.* Exeter.

TANSEY, K., BESTON, J., HOSCILO, A. & PAGE, S. E. (2008) Relationships between burnt area and MODIS fire hotspot data in a degraded tropical forest in Borneo. *Proceedings of the Remote Sensing and Photogrammetric Society Annual Conference.* University of Exeter, Falmouth Campus, UK.

VIERGEVER, K. M., WOODHOUSE, I. H., MARINO, A., BROLLY, M. & STUART, N. (2008) SAR Interferometry for Estimating Above-Ground Biomass of Savanna Woodlands in Belize. *IGARSS Conference Proceedings.* Boston, Massachusetts, USA.

WALKER, P. R., MALTHUS, T. J. & KARPOUZLI, E. (2008) Improvements in the mapping of shallow marine habitats through predictive spatial modelling. *Remote Sensing and Photogrammetry Society conference.* University of Exeter, Exeter, RSPSoc.

WHITE, D. C., WILLIAMS, M. & BARR, S. L. (2008) Detecting sub-surface soil disturbance using hyperspectral first derivative band ratios of associated vegetation stress. *ISPRS Congress 2008.* Beijing, China.

WILLIAMS, M., WHITE, D. C. & BARR, S. L. (2008) The potential for robust operational vegetation stress detection from airborne visible-NIR hyperspectral imaging under heterogeneous measurement conditions. . *Proceedings of the 2008 Annual Conference of the Remote Sensing & Photogrammetry Society.* RSPSoc.

ZELAZOWSKI, P. & MALHI, Y. (2008) Removal of atmospheric bias from mountainous satellite images and prospects for analysis of historical data. *3rd annual meeting of the Andes Biodiversity and Ecosystems Research Group.* Bettmeralp, Switzerland.

Conference presentation

BATESON, L. & FLEMING, C. (2008) Testing hyperspectral remote sensing monitoring techniques for geological CO2 storage at natural seeps. *The Annual General Meeting of the Geological Remote Sensing Group (GRSG).* The Geological Society, Burlington House, Piccadilly, London W1J 0BG.

CORL, T. & MALTHUS, T. J. (2008) Field Spectroscopy - SVC Technical Presentation and Demonstration. *RSPSoc 2008.* University of Exeter, Falmouth Campus. Cornwall UK.

CURTISS, B. & MALTHUS, T. J. (2008) Field Spectroscopy - ASD Technical Presentation and Demonstration. *RSPSoc 2008.* University of Exeter, Falmouth Campus. Cornwall, UK.

LAND, P., CHERUKURU, N. & TILSTONE, G. H. (2008) Primary production in a turbid estuary measured from aircraft. *Proceedings of the Remote Sensing and Photogrammetry Society Annual Conference* University of Exeter, Falmouth Campus, Cornwall, UK. RSPSoc.

MACLELLAN, C. (2008a) Calibration Sphere System for Reflectance Targets. *SphereOptics.* Uhldingen, Germany.

MACLELLAN, C. (2008b) Detailed specification of a radiance standard for the calibration of airborne hyper-spectral imaging systems. *Optical Technologies & Measurement Network.* National Physical Laboratory, London.

MACLELLAN, C. & SAWYER, G. M. (2008) FTIR Spectroscopy Technical Presentation and Field Demonstration *Remote Sensing and Photogrammetry Society Annual Conference.* University of Exeter, Falmouth Campus. UK

MALTHUS, T. J. (2008) New developments at the NERC Field Spectroscopy Facility. *Presented at the Institute of Physics Hydrological Optics seminar*

MALTHUS, T. J., MAC ARTHUR, A. & MACLELLAN, C. (2008) Determining the FOV and Directional Response of Field Spectroradiometers. *Remote Sensing and Photogrammetry Society Conference.* University of Exeter, Falmouth Campus. UK, RSPSoc.

POLLARD, A. L. (2008) Is a night life good for robins? *Big city, bright lights - dark spaces, natural places conference.* WWT London, City of London

SMYTH, T. J., WRENCH, C. L., MULLER, J.-P., SHANKLIN, J., CLAXTON, B., HAMPTON, K. & LADD, D. N. (2008) 'Improved Representation and Validation of the Radiative Properties and Impacts of Aerosols and Clouds: A Sun Photometer Intercomparison'. *APPRAISE Science meeting.* University of Leeds.

ZAKRZEWSKI, J. & MALTHUS, T. J. (2008) Field Spectroscopy - Headwall Technical Presentation and demonstration. *RSPSoc 2008.* University of Exeter, Falmouth Campus. Cornwall, UK.

Conference posters

ANDERSON, K. & DUNGAN, J. (2008a) Sources of uncertainty in field spectra of vegetation canopies. *Proceedings of the Annual Conference of the Remote Sensing and Photogrammetry Society.* University of Exeter, Falmouth, UK. **(Merit Poster Award)**

ANDERSON, K. & DUNGAN, J. (2008b) Uncertainty in vegetation products derived from field spectral measurements: an error budget approach. *American Geophysical Union fall meeting.* San Francisco.

LEWALL, A. (2008) Remote sensing of glacifluvial landscapes, SE Iceland. *Newcastle University Vacation Scholarship Poster Session.* Newcastle University.

MARTINEZ-VICENTE V, TORRES R, SMYTH T, TILSTONE G. H & MOORE G (2008) Using bio-optical measurements to validate a new description of spectral light propagation in ERSEM in the coastal zone. *AMEMR 2008 international conference.* Plymouth.

MAC ARTHUR, A. A. & MALTHUS, T. J. (2008) The objective classification of upland heather canopies by optical methods. *Interdisciplinary Research on Ecosystem Services: Fire and Climate Change in UK Moorlands and Heaths (FIRES). NERC sponsored seminar series.* University of Edinburgh

MAC ARTHUR, A. A, MACLELLAN, C. & MALTHUS, T. J. (2008) Optical instruments to assist FIRES research. *Interdisciplinary Research on Ecosystem Services: Fire and Climate Change in UK Moorlands and Heaths (FIRES). NERC sponsored seminar series.* University of Edinburgh

FSF Reports and important documents

Software manual

MACCALLUM, S. (2008) Gas retrievals from FTS data using the Reference Forward Model, HITRAN and M Burton IDL code.

MACLELLAN, C. (2008c) Angular Response Measurements for two Irradiance Input Accessories. Edinburgh, NERC FSF.

MACLELLAN, C. (2008d) Operating Guidelines for FSF Labsphere Source USS 1200. Edinburgh, NERC FSF.

MACLELLAN, C. (2008e) Operating Report on performance of RTS-3ZC. Edinburgh, NERC FSF.

MACLELLAN, C. (2008f) FSF Optical Test & Calibration Procedure for Specim Eagle & Hawk Hyperspectral Imaging Sensors., NERC Field Spectroscopy Facility.

Publicity

HEDLEY, J., MAC ARTHUR, A. & MALTHUS, T. J. (2008) NERC Field Spectroscopy Facility Aquatic Instrument Demonstration at RSPSoc 2008. University of Edinburgh, NERC Field Spectroscopy Facility.

MALTHUS, T. J. (2008a) Field Spectroscopy Facility. *Presented at NCEO/Services and Facilities meeting.*

MALTHUS, T. (2008b) The fields-of-view of field spectroradiometers - is all what it seems? Presented to Division of Land and Water, CSIRO, Canberra, 30th January 2008

MALTHUS, T. J. (2008c) The NERC Field Spectroscopy Facility - Related research, Spectral libraries. *Presented to Australian Centre for Remote Sensing (ACRES), GeoScience Australia.* Canberra, Australia. 29 February 2008.

MALTHUS, T. J. (2008d) The NERC Field Spectroscopy Facility – a model for Australia? *Presented to Division of Land and Water, CSIRO,* Canberra, Australia. 30th January 2008.

MALTHUS, T & MAC ARTHUR, A. (2008) New developments at the NERC Field Spectroscopy Facility. Presented at the Institute of Physics Hydrological Optics seminar 28th March 2008

2007

ISI publication

ANDERSON, K. & KUHN, N. (2007) Variations in soil structure and reflectance during a controlled crusting experiment. *International Journal of Remote Sensing,* doi:10.1080/01431160701767435.

BOUET, C., CAUTENET, G., WASHINGTON, R., TODD., M. C., LAURENT, B., MARTICORENA, B. & BERGAMETTI, G. (2007) Mesoscale modeling of aeolian dust emission during the BoDEx 2005 experiment. *Geophysical Research Letters,* 34.

FERRIER, G., RUMSBY, B. T. & POPE, R. J. (2007) Application of hyperspectral remote sensing data in the monitoring of the environmental impact of hazardous waste derived from abandoned mine sites. *Journal of the Geological Society of London, special publications,* 283**,** 107-116.

FRANCE, J. L., KING, M. D. & LEE-TAYLOR, J. (2007) Hydroxyl (OH) radical production rates in snowpacks from photolysis of hydrogen peroxide (H_2O_2) and nitrate (NO_3^-). *Atmospheric Environment,* 41**,** 5502-5509.

HEDGER, R. D., MALTHUS, T. J., FOLKARD, A. M. & ATKINSON, P. M. (2007) Spatial dynamics of estuarine water surface temperature from airborne remote sensing. *Estuarine, Coastal and Shelf Science,* 71**,** 608-615.

JONES, M. T., SPARKS, R. S. J. & VALDES, P. J. (2007) The climatic impact of supervolcanic ash blankets. *Climate Dynamics,* 29**,** 553-564.

MATHER, T. A., HARRISON, R. G., TSANEV, V. I., PYLE, D., KARUMUDI, M. L., BENNETT, A. J., SAWYER, G. M. & HIGHWOOD, E. J. (2007) Observations of the plume generated by the December 2005 oil depot explosions and prolonged fire at Buncefield (Hertfordshire, UK) and associated atmospheric changes. *Proceedings of The*

Royal Society A, 463**,** 1153-1177.

MILTON, E. J., SCHAEPMAN, M., ANDERSON, K., KNEUBÜHLER, M. and FOX, N., 2007. Progress in Field Spectroscopy. *Remote Sensing of Environment,* doi: 10.1016/j.rse.2007.08.001.

SMITH, A. M. S., DRAKE, N., WOOSTER, M. J., HUDAK, A. & HOLDEN, Z. A. (2007) Production of Landsat ETM+ reference imagery of burned areas within Southern African savannahs: comparison of methods and application to MODIS. *International Journal of Remote Sensing,* 28**,** 2753-2775.

WARREN, A., CHAPPELL, A., TODD, M. C., BRISTOW, C., DRAKE, N., ENGELSTAEDTER, S., MARTINS, V., MBAINAYELL, S. & WASHINGTON, R. (2007) Dust raising in the dustiest place on earth. *Geomorphology,* 92**,** 25-37.

PhD thesis

ALROICHDI, A. (2007) Hyperspectral remote sensing for biochemical and physical properties of exposed upland peat., University of Manchester.

FISHER, F. (2007) A field and modelling study of photochemistry in mid-latitude snowpacks. King’s College, London

MSc thesis

BESTON, J. (2007) An examination of the suitability of use of MODIS hotspot data in the quantification of peat fire areas in Kalimantan, Indonesia. *Department of Geography.* Leicester, University of Leicester.

Conference proceedings

ALMOND, S., BOYD, D., CURRAN, P. & DASH, J. (2007) The response of UK vegetation to elevated temperature in 2006: Coupling ENVISAT MERIS Terrestrial Chlorophyll Index (MTCI) and mean air temperature. *Annual Conference of the Remote Sensing and Photogrammetry Society 2007.* Newcastle, UK.

ALROICHDI, A., MCMORROW, J. M. & EVANS, M. G. (2007) Laboratory spectro-radiometric prediction of peat decomposition: comparison of transmission, lignin-cellulose and other biochemical indices. *Remote Sensing and Photogrammetry Society Annual Conference.* Newcastle.

BOWERS, D., G, KYTE, E. & MITCHELSON-JACOB, E. G. (2007) Spectral fitting techniques in turbid water. . *IEEE conference proceedings Oceans ’07,.* Aberdeen, Scotland.

GAULTON, R. & MALTHUS, T. J. (2007) Monitoring continuous cover forests; describing fine-scale spatial structure from high resolution airborne imagery. *ForestSAT 2007.* Montpellier, France.

GAULTON, R. & MALTHUS, T. J. (2007) Monitoring continuous cover forests; describing spatial structural heterogeneity from high resolution optical imagery. *2007 Annual Conference of the Remote Sensing and Photogrammetry Society.* Newcastle, UK.

MACARTHUR, A., MACLELLAN, C. & Malthus, T. (2007) Determining the FOV and Directional Response of Field Spectroradiometers. *5th EARSeL SIG Imaging Spectroscopy Workshop.* Bruges, Belgium.

MARTIN, R. S., MATHER, T. A., PYLE, D., M., POWER, M., ALLEN, A. G., AIUPPA, A., TSANEV, V., OPPENHEIMER, C., HORWELL, C. J. & WARD, E. P. W. (2007) Silicate particles in the Mt Etna and Masaya Plumes. *American Geophysical Union Conference 2007.* San Franscisco, California.

MARTINEZ-VICENTE V, TILSTONE G. H, TORRES R, ALLEN J.I & SMYTH T (2007) Opti-tank experiment: An investigation of the inherent optical properties of suspended material for the improvement of ERSEM. *6th Workshop of the Dynamic Green Ocean Project.* Villefranche sur Mer (Fr).

POLLARD, A. L. (2007) How street lights affect European Robin behaviour and their control of body mass. *Postgraduate Students Integrative Physiology Conference.* Aberdeen University.

POLLARD, A. L. (2007a) Artificial lighting and birds. *Proceedings of the Dark-Skies Symposium.* Portsmouth, UK.

VIERGEVER, K. M., WOODHOUSE, I. H., MARINO, A. & STUART, N. (2007a) Synthetic aperture radar for estimating the aboveground biomass of a sparse savanna woodland. *ForestSAT Conference Proceedings* Montpellier, France.

VIERGEVER, K. M., WOODHOUSE, I. H. & STUART, N. (2007b) Backscatter and Interferometry for Estimating Above-ground Biomass in Tropical Savanna Woodland. *IGARSS Conference Proceedings.* Barcelona, Spain.

WHITE, D. C., WILLIAMS, M. & BARR, S. L. (2007) Characterising pipeline earthworks associated vegetation stress with field spectroradiometry. *Annual Conference of the Remote Sensing and Photogrammetry Society.* Newcastle, UK, RSPSoc.

WHITE, D. C., WILLIAMS, M. & BARR, S. L. (2007b) Hyperspectral characterisation of arable crop stress associated with buried gas pipeline earthworks. *Proceedings of the 5th EARSeL Workshop on Imaging Spectroscopy.* Bruges, Belgium.

Conference presentation

ALROICHDI, A., MCMORROW, J. M. & EVANS, M. G. (2007) A decision tree approach to predict humification of organic soils. *EARSeL 5th Workshop on Imaging Spectroscopy.* Bruges, Belgium.

ANDERSON, K. & KUHN, N. (2007) Directional anisotropy in hyperspectral reflectance data: applicability for soil degradation monitoring. *European Geosciences Union Conference.* Vienna.

LEITAO, P. J., MILTON, E. J., MOCKRIDGE, B., OSBORNE, P. E. & MOREIRA, F. (2007) Pre-processing issues affecting the use of CASI and LiDAR data for steppe bird habitat monitoring and management in southern Portugal. *Annual NERC Airborne Research and Survey Facility Workshop.* Newcastle-upon-Tyne, UK.

MACARTHUR, A., MACLELLAN, C. & Malthus, T. (2007) Determining the FOV and Directional Response of Field Spectroradiometers. *5th EARSeL SIG Imaging Spectroscopy Workshop.* Bruges, Belgium.

MATHER, T. A., HARRISON, R. G., TSANEV, V. I., PYLE, D. M., KARUMUDI, M. L., BENNETT, A. J., SAWYER, G. M. & HIGHWOOD, E. J. (2007) Observations of the plume generated by the December 2005 oil depot explosions and prolonged fire at Buncefield (Hertfordshire, UK) and associated atmospheric changes. *Annual Aerosol Meeting.* UCL, UK.

MILTON, E. J. (2007) NCAVEO: Network for Calibration and Validation of EO data. Cal/Val Experiment in June 2006. *18th Meeting of the CEOS Working Group on Calibration and*

Validation, Sub-group on Infrared and Visible Optical Sensors. Part of the 27th Plenary Meeting of the CEOS Working Group on Calibration and Validation, 12th - 15th June. NPL, Teddington, UK.

MILTON, E. J. (2007) Progress in Field Spectroscopy. *Annual Meeting of the Optical Technologies Measurement network.* NPL, Teddington, UK.

MILTON, E. J. & ANDERSON, E. (2007) The contribution of NCAVEO to the VALERI project. *VALERI Workshop.* Davos, Switzerland.

MILTON, E. J. & ANDERSON, E. (2007) The NCAVEO 2006 cal/val experiment. *10th International Symposium on Physical Measurements and Spectral Signatures in Remote Sensing.* Davos, Switzerland, ISPRS.

MILTON, E. J., FOX, N. P. & MACKIN, S. (2007) NCAVEO: achievements of the last three years and plans for the future. *Annual Conference of the Remote Sensing and Photogrammetry Society.* Newcastle, UK.

POLLARD, A. L. & THOMAS, R. J. (2007) Robins singing at night: Effects of artificial lighting on nocturnal behaviour. *BEPG Series.* Cardiff University.

Conference posters

BOYD, D., ALMOND, S., DASH, J. & CURRAN, P. (2007) Investigating the factors affecting the relationship between the ENVISAT MERIS Terrestrial Chlorophyll Index (MTCI) and chlorophyll content: preliminary findings. *Annual Conference of the Remote Sensing and Photogrammetry Society.* Newcastle, UK.

DOWENS, J. S., MALTHUS, T. J. & BELYEA, L. R. (2007) Monitoring Peatland Microhabitats using Field and Imaging Spectroscopy. *10th International Symposium on Physical Signatures and Remote Sensing.* Davos, Switzerland.

DOWENS, J. S., MALTHUS, T. J. & BELYEA, L. R. (2007) Monitoring peatland microhabitats using field and imaging spectroscopy. *5th EARSeL SIG Imaging Spectroscopy Workshop.* Bruges, Belgium.

MACARTHUR, A., MACLELLAN, C. & MALTHUS, T. (2007) The Characterisation of Heather Foliage and Canopies by Hyperspectral Reflectance. *10th International Symopsium on Physical Measurements and Spectral Signatures in Remote Sensing.* Davos, Switzerland.

MACARTHUR, A., MACLELLAN, C. & MALTHUS, T. (2007) Determining the directional response of field of view of two Spectroradiometers. *10th International Symopsium on Physical Measurements and Spectral Signatures in Remote Sensing.* Davos. Switzerland.

KARPOUZLI, E. & MALTHUS, (2007) T**.** Integrating side scan sonar and high spatial resolution satellite imagery for monitoring coral reef benthic communities. IEEE International Geoscience and Remote Sensing Symposium, Barcelona

MCMORROW, J. M., EVANS, M. G., ALROICHDI, A. & CUTLER, M. E. (2007) Hyperspectral remote sensing of peat humification. *Peatland Restoration, Symposium sponsored by Natural England.* University of Manchester

PEGRUM, H. M., FOX, N., MILTON, E. & CHAPMAN, M. (2007) Development of the Gonio Radiometric Spectrometer System to conduct multi-angular measurements of terrestrial surfaces. IN SCHAEPMAN, M. E., LIANG, S., GROOT, N. E. & KNEUBUHLER, M. (Eds.) *10th International Symopsium on Physical Measurements and Spectral Signatures in Remote Sensing.* Davos, Switzerland

POLLARD, A. L. & THOMAS, R. J. (2007a) Effects of artificial lighting on the European Robin. *BTO Welsh Ringers conference.* Cardiff.

FSF Reports and important documents

Software manual

TSANEV, V. I. & MATHER, T. A. (2007) Microtops Inverse: Software package for retrieving aerosol columnar size distributions using Microtops II data. Available from http://www.fsf.nerc.ac.uk.

MACLELLAN, C. (2007) ASD Reflectance and Transmittance Integrating Sphere User Guide. NERC FSF, Edinburgh.

Publicity

MAC ARTHUR, A., MACLELLAN, C., & MALTHUS, T. (2007) New developments at the NERC Field Spectroscopy Facility, Poster display at the British Ecological Society, Annual Meeting, University of Glasgow, 10th to 12th September 2007

MAC ARTHUR, A., MACLELLAN, C., & MALTHUS, T. (2007) New developments at the NERC Field Spectroscopy Facility, Poster display at the Remote Sensing and Photogrammetry Society, University of Newcastle, 11th to 14th September 2007

MALTHUS, T. (2007) An Introduction to the NERC Field Spectroscopy Facility. Presented at the International FTIR workshop, King's College London, 6th June 2007

MALTHUS, T. Field Spectroscopy Facility. Presented at NCEO/Services and Facilities meeting, London, 6th November 2007

WEBSTER, P. (2007) Setting the forest alight. *Science,* 317**,** 1854-1855.

<u>2006</u>

ISI Publications 2006

ANDERSON, K. & MILTON, E. J. (2006) On the temporal stability of ground calibration targets: implications for the reproducibility of remote sensing methodologies. *International Journal of Remote Sensing,* 27**,** 3365-3374.

ANDERSON, K., MILTON, E. J. & ROLLIN, E. M. (2006) Calibration of dual-beam spectroradiometric data. *International Journal of Remote Sensing,* 27**,** 975-986.

BEINE, H. J., AMOROSO, A., DOMINE, F., KING, M. D., NARDINO, M., IANNIELLO, A. & FRANCE, J. L. (2006) Surprisingly small HONO emissions from snow surfaces at Browning Pass, Antarctica *Atmospheric Chemistry and Physics***,** 6, 2569–2580.

BOYD, D. S., ENTWISTLE, J. A., FLOWERS, A. G., ARMITAGE, R. P. & GOLDSMITH, P. C. (2006) Remote sensing the radionuclide contaminated Belarusian landscape: a potential for imaging spectrometry? *International Journal of Remote Sensing,* 27**,** 1865-1874.

CHAPPELL, A., ZOBECK, T.M., BRUNNER, G. (2006) Using bi-directional soil spectral reflectance to model soil surface changes induced by rainfall and wind-tunnel abrasion. *Remote Sensing of Environment,* 102**,** 328-343.

HARRIS, A., BRYANT, R. G. & BAIRD, A. J. (2006) Mapping effects of water stress on Sphagnum: Preliminary observations using airborne RS. *Remote Sensing of Environment,* 100**,** 363-378.

HARRIS, A., BRYANT, R. G. & BAIRD, A. J. (2005) Detecting water stress in Sphagnum sp. *Remote Sensing of Environment,* 97**,** 371-381.

HUCKLE, J. M., MARRS, R. H. & POTTER, J. A. (2006) Characterising the salt-marsh resource using multi-spectral remote sensing: a case study of the Dee estuary in North-west England. . *Journal of Practical Ecology and Conservation* 6**,** 1-22.

MILTON, E. J. & ROLLIN, E. M. (2006) Estimating the irradiance spectrum from measurements in a limited number of spectral bands. *Remote Sensing of Environment,* 100**,** 348-355.

TEGEN, I., HEINOLD, B., TODD, M. C., HELMERT, J., WASHINGTON, R. & DUBOVIK, O. (2006) Modelling soil dust aerosol in the Bodl depression during the BoDEx campaign. *Atmospheric Chemistry and Physics,* 6, 4345-4359.

WASHINGTON, R., M. C., TODD, S., ENGELSTAEDTER, S., MBAINAYEL, S. & MITCHELL, F. (2006) Dust and the low-level circulation over the Bodele Depression, Chad: Observations from BoDEx 2005,. *Journal of Geophysical Research,* 111.

Conference Proceedings

GOLDSMITH, P., BOYD, D., ENTWISTLE, J. & FLOWERS, A. (2006) Impacts of Caesium-137 on the reflectance spectra of Pinus sylvestris under laboratory controlled conditions. IN RSPSOC (Ed.) *Proceedings of The Remote Sensing and Photogrammetry Society Annual Conference, Understanding a Changing World.* Fitzwilliam College, University of Cambridge, 5th - 8th September 2006

GOLDSMITH, P. C., ENTWISTLE, J. A., FLOWERS, A. G. & SMITH, E. (2006) Chlorophyll fluorescence and its relationship with radioactively induced stress in Pinus sylvestris *Coordinating Group on Environmental Radioactivity (COGER), 20th anniversary special meeting.* Westlakes, Cumbria.

KYTE, E., BOWERS, D. G. & MITCHELSON-JACOB, E. G. (2006a) Do Ocean Colour Algorithms Always Overestimate Chlorophyll Concentrations in Turbid Waters? *CASIX Annual Science Meeting.* Liverpool.

KYTE, E., BOWERS, D. G. & MITCHELSON-JACOB, E. G. (2006b) Do Ocean Colour Algorithms Always Overestimate Chlorophyll Concentrations in Turbid Waters? *Proceedings of the Ocean Optics Symposium,.* Montreal.

KYTE, E., BOWERS, D. G. & MITCHELSON-JACOB, E. G. (2006c) Remote Sensing of Chlorophyll Concentrations in Turbid Shelf Seas: Correcting a NASA Algorithm. *Proceedings of the Coastal and Shelf Seas, Present Understanding and Future Challenges Conference to mark the retirement of Professor John H Simpson.* Bangor, N Wales.

KYTE, E., BOWERS, D. G. & MITCHELSON-JACOB, E. G. (2006d) Remote Sensing of Chlorophyll Concentrations in Turbid Shelf Seas: Correcting a NASA Algorithm. *CASIX Annual Steering Committee Meeting.* Edinburgh.

MAC ARTHUR, A. A., MACLELLAN, C. & MALTHUS, T. J. (2006) What does a spectroradiometer see? *Proceedings of The Remote Sensing and Photogrammetry Society Annual Conference. Understanding a Changing World.* Fitzwilliam College, University of Cambridge, 5th - 8th September 2006.

MAC ARTHUR, A. A. & MALTHUS, T. J. (2006) The hyperspectral and phenological characterisation of upland heather dominated ecological communities: Preliminary Results.

Proceedings of The Remote Sensing and Photogrammetry Society Annual Conference. Understanding a Changing World. Fitzwilliam College, University of Cambridge, 5th - 8th September 2006.

MACLELLAN, C. (2006) NCAVEO Field Experiment - Ground instruments. *NCAVEO Field Experiment.* UCL, London.

MACLELLAN, C., MALTHUS, T. J. & WILSON, A. (2006) NERC Field Spectroscopy Facility - Field Portable FTIR Spectroradiometer. *Proceedings of The Remote Sensing and Photogrammetry Society Annual Conference. Understanding a Changing World.* Fitzwilliam College, University of Cambridge, 5th - 8th September 2006.

MILTON, E. J., SCHAEPMAN, M. E., ANDERSON, K. E., KNEUBÜHLER, M. & FOX, N. P. (2006) Progress in field spectroscopy. *IEEE International Geoscience and Remote Sensing Society Symposium and 27th Canadian Symposium on Remote Sensing.* Denver, Colorado.

PEGRUM, H., FOX, N., MILTON, E. J. & CHAPMAN, M. (2006) Design and testing a new instrument to measure the angular reflectance of terrestrial surfaces. *IEEE International Geoscience and Remote Sensing Society Symposium and 27th Canadian Symposium on Remote Sensing.* Denver, Colorado, IEEE.

POLLARD, A. L. (2006) Street lighting - a bird's eye view. *6th European Dark Skies Symposium (CfDS).* Portsmouth.

WHITE, D. C., WILLIAMS, M. & BARR, S. L. (2006a) Hyperspectral detection of arable crop stress associated with buried gas pipeline soil disturbance. *Atlantic Europe Conference on Remote Imaging and Spectroscopy.* University of Central Lancashire, Preston, UK.

WHITE, D. C., WILLIAMS, M. & BARR, S. L. (2006b) Minimizing background effects in field spectra of arable crops to detect stress associated with soil disturbance. *Proceedings of The Remote Sensing and Photogrammetry Society Annual Conference. Understanding a Changing World.* Fitzwilliam College, University of Cambridge, 5th - 8th September 2006.

WHITE, D. C., WILLIAMS, M. & BARR, S. L. (2006c) Minimizing background effects in field spectra of arable crops to detect stress associated with soil disturbance. *Proceedings of The Society for Experimental Biology (SEB). Workshop Imaging Techniques for Understanding Plant Responses to Stresses.* Canterbury.

PhD Thesis

NONE

FSF Reports and important documents

MAC ARTHUR, A. A. (2006) Field Guide for the ASD FieldSpec Pro – Radiance/Irradiance Measurements in Raw DN Mode. Edinburgh, NERC FSF.

MAC ARTHUR, A. A. (2006) Field Guide for the GER1500 - Single Beam Mode - Radiance/irradiance measurements. Edinburgh, NERC FSF.

MACLELLAN, C. (2006) Guidelines for Post Processing ASD FieldSpec Pro Spectral Data Files using a FSF Excel Template. Edinburgh, NERC FSF.

MACLELLAN, C. (2006) Guidelines for Post Processing GER 1500 Dual Field of View Data Files using a FSF Excel Template. Edinburgh, NERC FSF.

MACLELLAN, C. (2006) Guidelines for Post Processing GER 1500 Spectral Data Files using a FSF Excel Template. Edinburgh, Nerc FSF.

MACLELLAN, C. (2006) Guidelines for Post Processing GER 3700 Spectral Data Files using a FSF Excel Template. Edinburgh, NERC FSF.

MACLELLAN, C. (2006) Wavelength Verification Procedure. Edinburgh, NERC FSF.

TAYLOR, F. (2006) Field Guide for the GER1500 with underwater housing. Edinburgh, NERC FSF.

TAYLOR, F. (2006) Application and Review Procedure Version 2. Edinburgh, NERC FSF.

TAYLOR, F. (2006) Incoming Loan Procedure Version 1 updated. Edinburgh, NERC FSF.

TAYLOR, F. (2006) Packing Procedure Version 2. Edinburgh, NERC FSF.

Poster presentations

BERTIN, S. & MENCUCCINI, M. (2006) Is it the dark side or sap suckers who kill the seedling trees? *University of Edinburgh Postgraduate Conference* Edinburgh.

GAULTON, R., MALTHUS, T. J., SUAREZ, J. C., WOODHOUSE, I. H. & GASTELLU-ETCHEGORRY, J. P. (2006) Describing spatial structural heterogeneity in Continuous Cover Forests; a role for high resolution optical imagery and image simulation. *NERC Earth Observation Conference.* Edinburgh.

MAC ARTHUR, A. A., MACLELLAN, C. & MALTHUS, T. J. (2006) What does a spectroradiometer see? *The Remote Sensing and Photogrammetry Society Annual Conference. Understanding a Changing World.* Fitzwilliam College, University of Cambridge, 5th - 8th September 2006 (**Won Best Poster prize**).

MALTHUS, T. J. (2006) New developments at the NERC Field Spectroscopy Facility. *NERC Earth Observation Conference, Dynamic Earth, June 2006.* Edinburgh, 21 June 2006.

MALTHUS, T. J. (2006) New developments at the NERC Field Spectroscopy Facility. *The Remote Sensing and Photogrammetry Society Annual Conference. Understanding a Changing World.* Fitzwilliam College, University of Cambridge, 5th - 8th September 2006

MATHER, T. A., HARRISON, R. G., TSANEV, V. I., PYLE, D. M., KARUMUDI, M. L., BENNETT, A. J., SAWYER, M. & HIGHWOOD, E. J. (2006) Observations of the smoke plume from the December 2005 explosions and prolonged oil fire at Buncefield oil depot, southern UK and associated atmospheric changes. *AGU Fall meeting.* San Francisco.

Conference presentations

MACLELLAN, C. (2006) NCAVEO Field Experiment - Ground instruments. *NCAVEO Field Experiment.* UCL, London.

MACLELLAN, C., MALTHUS, T. J. & WILSON, A. (2006) NERC Field Spectroscopy Facility - Field Portable FTIR Spectroradiometer. *Proceedings of The Remote Sensing and Photogrammetry Society Annual Conference. Understanding a Changing World.* Fitzwilliam College, University of Cambridge, 5th - 8th September 2006.

Publicity

PEGRUM, H. (2006) Climate Modelling with confidence. *Environmental Measures: A National Measurement Newsletter. NPL.* Teddington.

Appendix 8 – Full list of presentations made by FSF to users (2006-08)

- Poster at the NERC Earth Observation Conference, Dynamic Earth, June 2006,
- Oral presentations and poster at the RSPSoc Conference in Cambridge 5th – 8th September 2006,
- Oral presentation at the RSPSoc Student meeting 29th - 30th March 2007.
- Oral presentations, posters and an equipment stand as part of the RSPSoc Meeting in Newcastle, 11 – 14 September 2007.
- Presentations and demonstrations at the FTIR workshop in London on June 6th and 7th 2007.
- Posters and flyers on the Facility's equipment presented at the British Ecological Society Annual Meeting, University of Glasgow, 10th to 12th September 2007.
- Flyers advertising the underwater instrument suite were distributed at the Institute of Physics (IOP) Hydrological Optics meeting, London, on 28th March 2008.
- A presentation on the Facility at the RSPSOc Student meeting, held at the University of Edinburgh on 29th March 2007.
- A short presentation on the Facility to a CEH/Edinburgh University joint collaboration meeting on 16th January 2008.
- Presentations at the Fire Interdisciplinary Research in Ecosystem Services; fire and climate change in UK moorlands and heaths (FIRES) meeting in Edinburgh on 1st of April 2008.
- Presentations, demonstrations and an exhibitors stand at the RSPSoc Annual Conference, Tremough, Cornwall, 15 – 17th September 2008.
- Research and Facility posters and an exhibitors stand at NERC-Natural England UKPopNet workshop Gregynog Hall, Wales, 9th – 10th December 2008.

Appendix 9 – Detailed contributions by FSF to training

PhD projects completed during 2006-08 and which have used Facility equipment are:

Alroichdi, A. (2007). Hyperspectral remote sensing for biochemical and physical properties of exposed upland peat., University of Manchester.
Fisher, F. (2007). A field and modelling study of photochemistry in mid-latitude snowpacks. Kings College London
Gaulton, R. (2008). Remote sensing for continuous cover forestry: quantifying spatial structure and canopy gap distribution. University of Edinburgh.
Goldsmith, P. C. (2008). Remote sensing the radionuclide contaminated Belarusion landscape. Centre for Earth and Atmospheric Science Research. London, Kingston University, UK.
Kyte, E. (2008). Remote sensing of chlorophyll concentrations in a turbid shelf sea. University of Wales, Bangor.
Martin, R. S. (2008). Formation of volcanic aerosol. University of Cambridge.
White, D. C. (2008). Hyperspectral remote sensing of canopy scale vegetation stress associated with buried gas pipelines. Newcastle University, Newcastle upon Tyne.

One to one training in instrument us

The following table details those PIs and students (indicated *) that have recently received training from FSF as part of their research projects:

Date trained	Project	PI	Person(s) trained	Institution	Instrument
23rd February	505	Dr P. Osborne	P. Leitao*	University of Southampton	GER1500 & Microtops
28th February 2006	489	Dr M. King	Dr M. King	Royal Holloway University of London	GER1500 & Microtops
1st April 2006	496	Dr T. Malthus	J. Dowens*	University of Edinburgh	ASD FieldSpec Pro & Microtops
16th May 2006	500	Dr P. Zukowskyi	Dr P. Zukowskyi Dr R. Teeuw Dr R. Alexander	University of Hertfordshire	ASD FieldSpec Pro & Microtops
28th June 2006	490	Dr T. Malthus	R. Gaulton*	University of Edinburgh	ASD FieldSpec Pro & Microtops
3rd July 2006	492	Dr C. Oppenheimer	Dr V. Tsanev	University of Cambridge	GER1500
20th September 2006	506	Dr R. Thomas	A. Pollard*	University of Cardiff	GER1500
14th January 2006		Dr T. Malthus	J. Dowens*	University of Edinburgh	ASD FieldSpec Pro & Microtops
30th March 2007	517	Dr K. Anderson	H. Croft*	University of Exeter	ASD FieldSpec Pro
2nd April 2007	521	Dr D. Boyd	S. Almond*	University of Nottingham	GER1500
24th July 2007	518	Dr M. Mencuccini	S. Bertin*	University of Edinburgh	GER1500
29th July 2007	534	R. Park	S. Drain	SEPA (commercial loan)	GER1500
21st September 2007	529	Dr T. Riley	C. Hasselwimmer*	BAS	ASD FieldSpec Pro
31st October 2007	535	Dr G. Maeden	T. Caras	Canterbury Christ Church University	GER1500 with underwater housing
22nd November 2007	528	Dr M. King	J. France*	Royal Holloway University of London	GER1500
4th January 2008	538	Dr C. Oppenheimer	T. Barnie*	University of Cambridge	ASD FieldSpec Pro & Microtops
8th January 2008	549	Dr R. Bates	Dr R. Bates Dr A. Prave Dr H. Torland	University of St Andrews Aberystwyth University	ASD FieldSpec Pro & Microtops
2nd April 2008	537	Dr M. Disney	N. McBean*	UCL	ASD FieldSpec Pro
21st April 2008	542	Prof. J. Grace	S. Dengal*	University of Edinburgh	GER1500
7th July 2008	559	Dr C. Nichol	J. Atherton*	University of Edinburgh	ASD FieldSpec Pro
2nd July 2008	552	Dr M. Smith	Dr M. Smith Dr T. Stevens	Kingston University	GER1500
15th July	551	Prof. M. Wooster	Dr T. Blackall T. Smith*	King's College, London	ASD FieldSpec3 & Microtops
18th July 2008	552	Prof Y. Malhi	Dr P. Zelazowski	University of Oxford	GER3700 & Microtops with GPS
21st August 2008	550	Dr F. Visser	Dr F. Visser	University of Worcester	GER1500 with underwater housing

Introduction to Field Spectroscopy course – Lists of attendees

19th and 20th December 2005

- Enrique Pacheco-Cabrera, University of Surrey, Phd Student
- Adel Elmetwalli , University of Stirling , PhD student
- Helen Gibbs, University of Chester, Postgrad RA
- Heather Pegrum, National Physical Laboratories, PhD student
- Emma McLoughlin, University of Edinburgh, PhD student
- John Dowens, University of Edinburgh, PhD student
- Rachel Gaulton, University of Edinburgh, PhD student
- Alasdair MacArthur, University of Edinburgh, PhD student
- Cameron Orr, University of Edinburgh, MSc in GIS
- Daniela Gurlin, University of Edinburgh, MSc in GIS
- Cristina Aparicio, University of Sao Paolo, Brazil, Visiting PhD student
- Luciana de Resende Londe, Brazilian National Space Agency, INPE, Visiting PhD student

2005 Training course attendees

26th to 28th February 2007

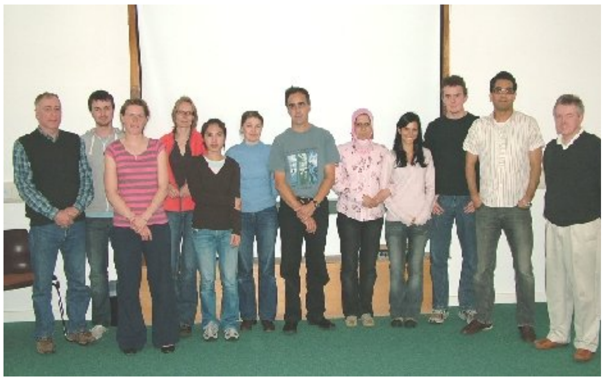
- Dr Melanie Witt, University of Oxford, Post Doc
- Samuel Almond, University of Bournemouth., PhD student
- Ana Prieto, University College London, Post Doc
- Chris Wilson, University of Chester, RA
- Michael Lim , University of Newcastle, Post Doc
- Holly Croft, University of Exeter, PhD student
- Sophie Bertin, University of Edinburgh/Forest Research, PhD student
- Jennifer Le Blond, University of Cambridge/Natural History Museum, London, PhD student
- Christian Haselwimmer, British Antarctic Survey, PhD student
- Alf Ball, NERC GEF, Elect. Engineer
- Andrew Hardy, Newcastle University, PhD

2007 Training course attendees

30th April to 2nd May 2008

- Jon Atherton, University of Edinburgh, PhD student
- Nima Pahlevan, University of Durham, PhD student

- Maria Tattaris, King's College London, PhD student
- Sarah Hamylton, University of Cambridge, PhD student
- Orn-uma Summart, University of Newcastle , PhD student
- Turkia Almoustafa, University of Salford, PhD student
- Talfan Barnies, University of Cambridge, PhD student
- Fleur Visser, University of Worcester, Lecturer
- Sigrid Dengel, University of Edinburgh, PhD student


2008 Training course attendees

Introduction to Field Spectroscopy course – Programme (2008)

Wednesday 30th April – Room 304b Grant Institute, King's Buildings, EH9 3JW

9:15 – 9:30	Coffee and introductions
9:30 – 10:45	Introduction - The role of field spectroscopy in research
10:45 – 11:00	Coffee break
11:00 – 12:30	The principles of field spectroscopy
12:30 – 1:30	Lunch
1:30 – 3:00	The design and calibration of spectroradiometers
3:00 – 3:15	Coffee break
3:20 – 6:00	Tour of the Field Spectroscopy Facility / Practical introduction to the spectroradiometers

Evening Dinner - arranged by FSF

Thursday 1st May–, Room 304b Grant Institute, King's Buildings, EH9 3JW

09:30 – 10:45	Measurement in the laboratory and field
10:45-11:00	Coffee break
11:00 – 12:30	Measurement in the environment – spectroradiometers and sun photometers
12:30 – 1:30	Lunch
1:30 – 3:00	Afternoon session - Sampling design and measurement uncertainty Part 1
3:00 – 3:15	Coffee break
3:15 – 5:00	Afternoon session - Sampling design and measurement uncertainty Part 2

Evening Dinner - by free arrangement

Friday 2nd May - Room 304b Grant Inst., Kings Buildings, West Mains Road, EH9 3JW

9:30 – 10:45	The processing and analysis of spectral datasets Part 1
10:45 – 11:00	Coffee break

11:00 – 12:30 The processing and analysis of spectral datasets Part 2
12:30 Close of meeting

Full list of attendees at the FTIR Spectroscopy Workshop, Kings College London, 6th and 7th of June 2007

- Grant Allen, Centre for Atmospheric Science, University of Manchester, Sackville St Building, Sackville St, Manchester. M60 1QD
- Stefania Amici, Istituto Nazionale di Geofisica e Vulcanologia, via di Vigna Murata 605
- Karen Aplin, Space Science and Technology Department, Rutherford Appleton Lab, Chilton, Didcot, Oxon OX11 0QX
- Peter Bernath, Department of Chemistry, University of York, Heslington, York YO10 5DD
- Trevor Blackall, KCL
- Doreen Boyd, School of Geography, University of Nottingham, University Park, Nottingham, NG7 2RD
- Susana Briz,
- Mike Burton, Istituto di Geofisica e Vulcanologia (INGV) sez. Catania, Piazza Roma 2, Catania, 95123 Italy
- Reno Choi, Environment Agency
- Thomas Christopher, Montserrat Volcano Observatory, Flemmings, Montserrat West Indies
- Pierre Delmelle, Environment Department – University of York
- Mat Disney, UCL Geography, Gower Street, London, WC1E 6BT
- Nick Drake, Department of Geography, Kings College, Strand, London WC2R 2LS
- Anu Dudhia, Oxford
- Graham Ferrier, University of Hull
- Patrick Freeborn, Department of Geography, Kings College, Strand, London WC2R 2LS
- Sue Grimmond, Department of Geography, Kings College, Strand, London WC2R 2LS
- Jock Joel, Université des Antilles et de la Guyane, UFR Sciences exactes et naturelles ; L.P.A.T. , 97159 Pointe-à-Pitre Cédex
- Alessandro La Spina, Istituto di Geofisica e Vulcanologia (INGV) sez. Catania, Piazza Roma 2, Catania, 95123 Italy
- Alasdair Mac Arthur, NERC FSF, School of Geosciences, University of Edinburgh, West Mains Rd, Edinburgh EH9 3JW
- Chris MacLellan, NERC FSF, School of Geosciences, University of Edinburgh, West Mains Rd, Edinburgh EH9 3JW
- Tim Malthus, NERC FSF, School of Geosciences, University of Edinburgh, West Mains Rd, Edinburgh EH9 3JW
- Robert Martin, Department of Earth Sciences, Downing Street, Cambridge, CB2 3EQ
- Julia McMorrow, Geography, School of Environment And Development, University of Manchester, Manchester M13 9PL
- Johan Melqvist, Chalmers University of Technology, Götborg, Sweden
- Dan Mullally, Midac Corp.
- Filippo Mure, Istituto di Geofisica e Vulcanologia (INGV) sez. Catania, Piazza Roma 2, Catania, 95123 Italy
- David Newnham, Sensors Knowledge Transfer Network, Qi3, St John's Innovation Centre, Cowley Road, Cambridge CB4 0WS
- Tim Nightingale, RAL
- Clive Oppenheimer, Department of Geography, Downing Place, Cambridge CB2 3EN

- Angelo Palombo, Area della Ricerca di Roma 2 - Tor Vergata Via del Fosso del Cavaliere, 100 - 00133 Roma
- Manasvi Panchal, Earth Observation Science, Space Research Centre, Department of Physics and Astronomy, University of Leicester,Leicester, LE1 7RH
- Vasileios Pappas, Department of Geography, King’s College London, WC2R 2LS, London
- Robert Parker, Earth Observation Science, Space Research Centre, Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH
- Simone Pascussi, Area della Ricerca di Roma 2 - Tor Vergata Via del Fosso del Cavaliere, 100 - 00133 Roma
- W Jolyon Reburn, Rutherford Appleton Laboratory, Chilton, Didcot, Oxon
- Dr John Remedios, Earth Observation Science, Space Research Centre, Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH
- Beatriz Ribeiro da Luz, US Geological Survey, Mail Stop 954, 12201 Sunrise Valley Drive, Reston, VA, 20192
- Tjarda Roberts, Department of Chemistry, University of Cambridge, Lensfield Road, CB2 1EW
- Georgina Sawyer, Department of Geography, University of Cambridge, Downing Site, Cambridge, CB2 3EN
- Kevin Smith, STFC Rutherford Appleton Laboratory, Chilton, DIDCOT, Oxon. OX11 0QX
- Sampo Smolander, UCL, Department of Geography, Room 103, Pearson Building, Gower St., University College London, London WC1H 6BT
- Ben Stephenson, Cambridge University Department of Geography, Downing Place, Cambridge CB2 3EN
- Vitchko Tsanev, Department of Geography, Downing Place, Cambridge CB2 3EN
- Alan Vance, Met Office, FitzRoy Road, Exeter, Devon, EX1 3PB
- Andrew Wilson, CEH
- Martin Wooster, Department of Geography, Kings College, Strand, London WC2R 2LS
- Peter Zemek, Midac Corp.

Appendix 10 – Facility capacity and demand for service

Contents

1 – Standard Performance Measures requested in Appendix 1 SRG Guidelines

1.1 - Facility Capacity

Instrument Capacity wholly funded by NERC

Instrument utilisation 2006 (in weeks)

Instrument	Qty	Weeks/year	Gross Capacity	Q.A. etc	Calibration	Repair & Upgrades	Capacity	Utilisation	% Utilisation
ASD	3	46	138	8	2	12	116	56	48%
GER 1500	4	46	184	10	2	0	172	59.72	35%
GER 3700	1	46	46	2	1	4	39	28.57	73%
MicroTops II	3	46	138	4	0	0	134	37.71	28%
Cimel	1	52	52	0	6	0	46	46	100%

Additional Notes:

- One ASD was taken out of service due to erratic performance and was returned to the manufacturer for repair and a major upgrade.
- During in-house research and development anomalies were noted in the GER3700 data and it was returned to the manufacture for servicing.
- Demand for Microtops sunphotometers is concentrated in the summer months during time of ARSF flights and we were unable to satisfy demand, at one stage having one Microtops to cover three projects. NERC approved the purchase of two further instruments 2007.
- In 2005 the NERC Centre for Terrestrial Carbon Dynamics acquired an ASD FieldSpec spectroradiometer. This instrument is calibrated and quality assurance tests carried out by FSF and the instrument made available to the wider community when not required by CTCD. Therefore the Facility had a total of eight field spectrometers and four sun photometers available for research projects in 2006.

Instrument utilisation 2007 (in weeks)

Instrument	Qty	Weeks/year	Gross Capacity	Q.A. etc	Calibration	Repair & Upgrades	Capacity	Utilisation	% Utilisation
ASD	3	46	138	8	2	4	124	65.43	53%
GER 1500	4	46	184	10	2	16	156	125.71	81%
GER 3700	1	46	46	2	1	2	39	24.57	63%
MicroTops II	5	46	230	6	0	16	198	63.86	32%
FTIR	Field trials								
Cimel	1	52	52	0	11.14	0	50.86	50.86	100%
AC-S	1	38	38	0	6	2	30	12	40%

Additional Notes:

- The period that instruments were on loan to applicants to carry out their research has been maximised and has led to a general increase in instrument utilisation.
- One GER1500 was taken out of service for 16 weeks for repair and recalibration.
- Two GER Dual Field of View projects, including deployment to Antarctica over winter, has contributed to the increase in GER1500 utilisation.
- NERC authorised the purchase of two additional Microtops as demand was exceeding capacity during peak periods of the summer NERC ARSF campaigns. During the summer all five Microtops have been on loan concurrently.
- A Wetlabs AC-S was acquired by the Facility in February 2007 and has increased the Facility's capacity and generated additional demand.

Instrument utilisation 2008 (in weeks)

Instrument	Qty	Weeks/year	Gross Capacity	Q.A. etc	Calibration	Repair & Upgrades	Capacity	Utilisation	% Utilisation
ASD	3	46	138	4	2	0	132	123.14	93%
GER 1500	4	46	184	10	2	0	172	92.86	54%
GER 3700	1	46	46	2	1	1	42	8.71	21%
MicroTops II	5	46	230	6	8	12	204	65.86	32%
AC-S	4	46	46	2	2	6	36	13.43	37%
HyperOCRs (set)	1	46	46	4	0	0	42	13.43	32%
FTIR	1	40	40	5.57	0	1.86	38.14	8.71	23%
Cimel	1	52	104	17.57	0	15.14	71.29	68.29	69%

Additional Notes:

- As in previous years, the greatest demand for Microtops has been during ARSF campaigns when all five instruments have been on loan concurrently.
- The deployment of one ASD to Antarctica over winter 2008 significantly increased the ASD demand and the CTCD ASD was been deployed from April to November.
- A GER1500 had to be borrowed from the University of Edinburgh during summer 2008 to allow an alpha 5 DFOV project, an alpha 4h DFOV collaborative project with NASA and an alpha 4h PhD project in its final year to proceed concurrently.

- The HyperOCR underwater spectrometers were acquired in March 2008 to compliment the AC-S suite of instruments but can also be deployed independently.
- A SVC HR-1024 full wavelength spectroradiometer configured to the Facility's requirements been purchased as a replacement of the aging GER3700 (+10 years). The retired GER3700 will continue to be maintained and calibrated and used as a back up in the event of a instrument failure. The HR-1024 will be field tested during 2009 and will be available for loan from 2010. The introduction of this state-of-the-art instrument will also ease the demand on the ASDs.
- The oldest ASD (+11 years) is being retired in 2009 and an ASD FieldSpec3 has been purchased to replace it. The retired ASD will continue to be maintained and calibrated and used as a back up in the event of an instrument failure.
- FTIR QA includes training of FSF personnel. Utilization is low on account that most projects this instrument has supported have been pilot projects ahead of the instrument being fully available for loan.
- CIMEL QA includes prolonged operational system testing

Capacity lost or wasted due to problems within Facility[1]

One Microtops failed during deployment to the Peruvian Andes during 2008 leading to a loss of data and reduction in the data that could be collected during deployment. The loan was extended to maximise availability to the user and the Microtops is being returned to manufacturer for further investigation. See Loan Report section for further details.

1.2 – Demand for service

Total number of new users

2006	9
2007	8
2008	12

Note a project can have more than one user

Total number of applications received by peer-review grade

	Total number of applications received								
Year	Alpha 5	Alpha 4h	Alpha 4m	Alpha 4l	Alpha 4	Alpha 3h[1]	Pilot	R*[2]	Reject
2006	7	3	2	3	2	2	1	0	0
2007	3	2	7	2	1	1	1	1	0
2008	6	5	5	5	1	0	2	1	1

[1] Two Alpha 3 projects were supported as they are PhD projects and one alpha 3 project was supported as it was in support of a NERC ARSF campaign

[2] The projects graded R* did not resubmit

Total number of applications satisfied by peer-review grade

	Total number of applications received						
Year	Alpha 5	Alpha 4h	Alpha 4m	Alpha 4l	Alpha 4	Alpha 3h	Pilot
2006	7	3	2	3	2	2	1
2007	3	2	7	2	1	1	1
2008	6	5	5	5	1	0	2

Percentage of applications satisfied by peer-review grade

	Total number of applications received						
Year	Alpha 5	Alpha 4h	Alpha 4l	Alpha 4m	Alpha 4	Alpha 3h	Pilot
2006	100%	100%	100%	100%	100%	100%	100%
2007	100%	100%	100%	100%	100%	100%	100%
2008	100%	100%	100%	100%	n/a	n/a	100%

Note that data now being collected by NERC strategic mode and will be reported in this format in the next Annual Report

Total number of applications not currently in receipt of direct NERC support received by peer-review grade

	Total number of applications received								
Year	Alpha 5	Alpha 4h	Alpha 4m	Alpha 4l	Alpha 4	Alpha 3h[1]	Pilot	R*[2]	Reject
2006	0	1	2	2	1	1	1	0	1
2007	1	2	5	1	0	1	1	1	0
2008	3	2	4	3	0	0	2	1	1

[1] One Alpha 3 project was supported as it was a PhD projects and one alpha 3 project was supported as it was in support of a NERC ARSF campaign
[2] The projects graded R* did not resubmit

Total number of applications not currently in receipt of direct NERC support satisfied by peer-review grade

	Total number of applications received						
Year	Alpha 5	Alpha 4h	Alpha 4m	Alpha 4l	Alpha 4	Alpha 3h	Pilot
2006	0	1	2	2	1	1	1
2007	1	2	5	1	0	1	1
2008	3	2	4	3	0	0	2

Percentage of applications not currently in receipt of direct NERC support satisfied by peer-review grade

	Total number of applications received						
Year	Alpha 5	Alpha 4h	Alpha 4l	Alpha 4m	Alpha 4	Alpha 3h	Pilot
2006	n/a	100%	100%	100%	100%	100%	100%
2007	100%	100%	100%	100%	n/a	100%	100%
2008	100%	100%	100%	100%	n/a	n/a	100%

Note that data now being collected by NERC strategic mode and will be reported in this format in the next Annual Report

1.3 – Customer satisfaction indicators

1.3.1 User survey

<u>November 2008 FSF User Survey Questionnaire Results</u>

The Field Spectroscopy Facility regularly conducts surveys of its user base, to enable it to assess its performance, to determine areas for improvement and to assist it in identifying potentially new areas of research to support. The results reported here are taken from the latest survey of users, conducted in November 2008. Of the user base invited to respond 36 users completed the questionnaire either in part or wholly. The questionnaire could be submitted anonymously or the respondent identified by email. 23 respondents made their identities known and these respondents and their institutions are listed in Section 12.

1. Questionnaire respondents use profile

The number of years that respondents have been using FSF is presented in Figure 1 and there has been an even distribution of user cohorts.

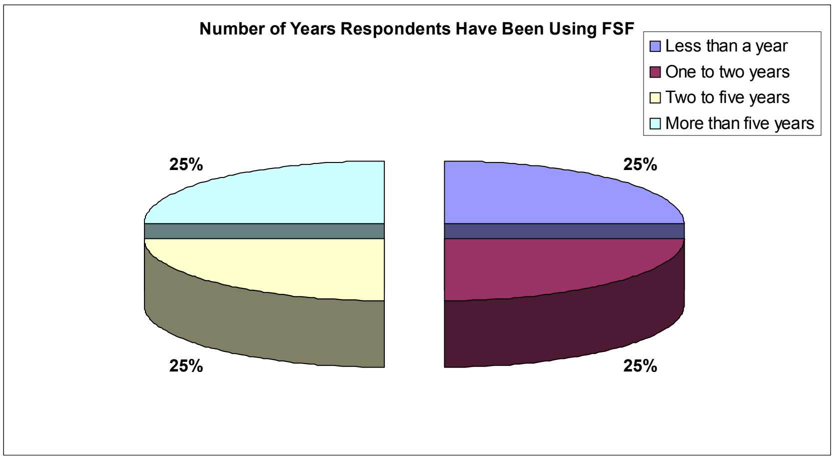


Figure 1

The frequency of each respondent's use of the Facility is displayed in Figure 2; 50% of the 36 respondent use the Facility on average once a year or more frequently.

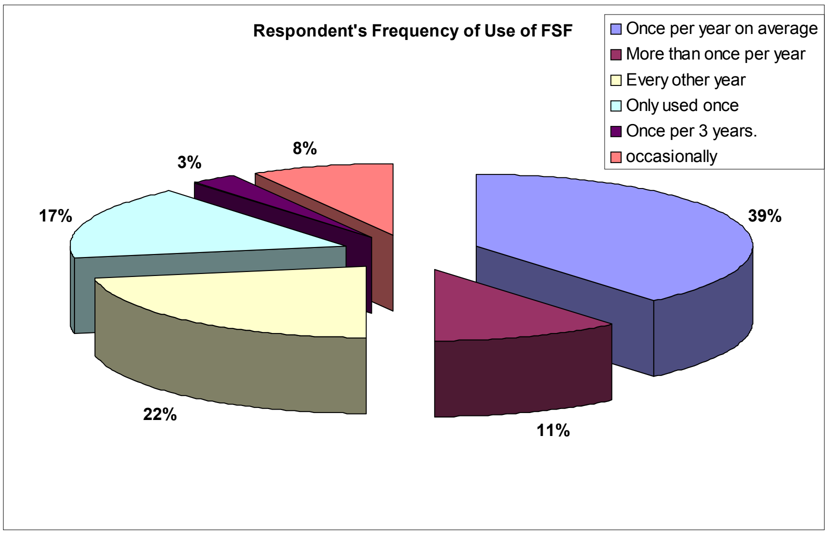


Figure 2

2. Application process

Of the 36 respondents, 13 were PIs and the remainder were Users. 35 of the respondents considered the FSF application procedure was a reasonable one did not answer this question. Nearly all (94%) of respondents considered that there was sufficient information on the FSF website to enable the application to be completed. However, one person did not answer the question and one noted that the application deadline date had not been changed from 1st December to 1st November on one web page.

FSF response: All web pages have now been updated.

Twenty three respondents (64%) considered two review periods a year "about right". However, 13 respondents considered that the FSF Steering Committee should review applications on a more frequent basis. All respondents considered the response time to their request for support to be either 'prompt' or 'reasonable'.

As displayed in Figure 3, most respondents considered FSF's instruments to be modern (72%) or state-of-the-art (22%). Two users considered the instruments available to be dated.

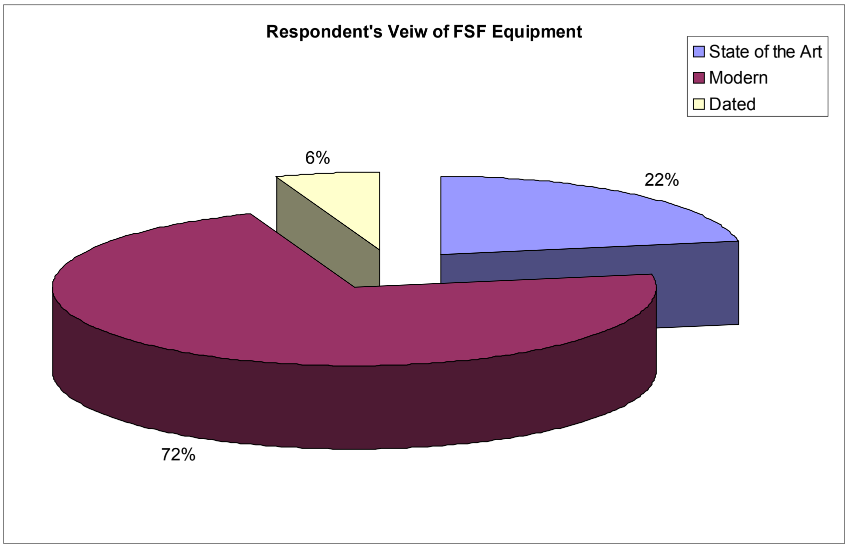


Figure 3

FSF response: FSF has recently purchased 2 'state-of-the-art' full wavelength systems in 2008, one of which underwent field trials during 2008. The other will undergo field trials during 2009 and be introduced into service in 2010. The instruments considered 'dated' are the GER1500s and a replacement for these is currently being developed by FSF with funding from NERC Services and Facilities (the V-SWIR project).

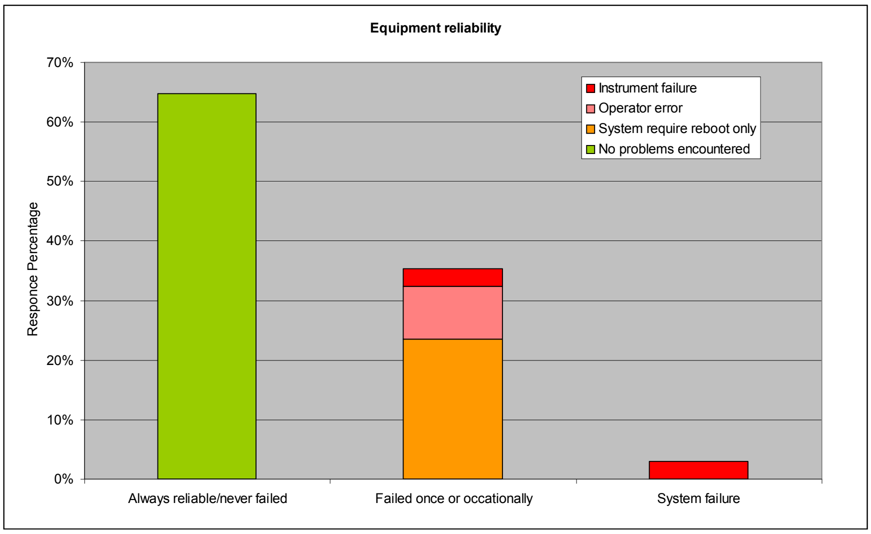


Figure 4

Most respondents reported that the instruments were always reliable (Figure 4), while 34% found the instruments failed once or occasionally. Only one user found that their instrument failed systematically.

FSF response: Of the reports of instruments 'failing once or occasionally' (10 instances out of 36) 3 were due to operator error, 7 had not previously been reported to FSF and on further investigation were found to have only required the instrument and/or its control software to be rebooted. One instance where the instrument was found to 'fail occasionally' was reported to FSF at the end of the loan and an underwater actuator cable was found to be faulty. However, with telephone support from FSF the user had managed to complete their project.

FSF response: A replacement part has been ordered.

One user had a sunphotometer fail systematically and this element of their project was compromised.

FSF response: During the loan (in the Peruvian Andes), FSF offered real-time telephone and email support and helped the user re-programme the instrument and download data. However, this was only partially successful. FSF put the user in contact with the instrument manufacturer's customer support in a further attempt to assist. Unfortunately, the instrument was found to have developed a fault during deployment which could not be rectified in the field. The Sunphotometer was subsequently returned to the manufacturer for investigation and repair.

FSF are now considering, where possible, supplying a backup sunphotometer to projects in remote locations and where the sunphotometer data collection is critical to the project's success.

3. Quality of service

All respondents reported the Quality of Service supplied by FSF as either excellent or good and all regarded the mechanism for reporting problems not adequately addressed by FSF to the FSF Steering Committee as either good or they expressed no opinion. No respondent suggested any improvements they would like to see.

4. Website

78% of respondents visited the FSF website at least a 'couple of time a year'. On a scale of 1 to 5, 5 being good and 1 being poor, 77% scored the user friendliness of the FSF website as 4 or greater, 73% rated the website design as 4 or greater and over 80% rated the website as being 'informative' and 'user friendly'.

5. Training

All respondents considered the Introduction to Field Spectroscopy and the one-to-one training they received at FSF as being 'good' or 'excellent' and, with one exception, all considered the one-to-one training to be necessary and worthwhile.

6. User's access to field spectroscopy instruments

64% of users only had access to field spectroscopy instrumentation through FSF and 90% reported that their institutions were not planning to purchase instruments.

7. User's own instrument calibration

Of those respondents with access to their own institutions instruments 2 acknowledged that the instrument were calibrated once a year while 5 acknowledged that their institutions instruments were calibrated every 2 years or less frequently. 5 respondents considered that their institutions instruments were calibrated to NPL standards and 7 would consider using FSF to calibrate and QA their institutions instruments.

8. Equipment Use and Future Needs

63% of respondents considered FSF to provide a major supplement to their existing equipment and 34% considered that FSF meet all their major equipment requirements. Only one respondent advised that they were never dependent on FSF services and equipment.

43% of respondents did not consider that there was any equipment, currently not available at the FSF, which should be purchased to benefit the spectroscopy community. However, 57% did consider that the user community would benefit from FSF purchasing additional instrument and their comments and suggestions are included in Table 1 below.

Table 1

8.1 My field of research is marine and freshwater optics, with applications in aquatic photobiology and remote sensing, which links to biodiversity, Earth system science and natural resources. The IOP profiling equipment (WETLabs ACS etc) recently acquired by the FSF represents a major step forward for capacity of the UK research community to conduct research requiring data of aquatic light fields and optical properties. At recent conferences I have detected a real interest from UK researchers to develop work in these areas, stimulated by the capability now provided by the FSF. I believe this could be exciting growth area for UK-based research on topics of global importance. There are several instruments which I think would compliment the current FSF capability in this area and provide a truly state-of-the-art instrumentation suite. 1) Multi-angle volume scattering meters - WETLabs have several models. This would be useful for improving models of the angular scattering phase function, which is still a big unknown in many environments and required for accurate aquatic radiative transfer modelling. 2) Chlorophyll / CDOM fluorescence meters. Would enable quantification of Chl and CDOM in the water column: useful information in its own right for many applications in remote sensing and primary productivity, and also required for accurate modelling of light fields. 3) LISST instrument for particle size distributions (Sequioa Scientific). In conjunction with the current FSF instruments this would be useful for relating properties of suspended sediments to optical properties, with applications in remote sensing of suspended sediments. Also very handy for looking at sedimentation rates (though thats not strictly an spectroscopy application). 4) Satlantic have recently developed a submersible hemispherical radiance camera - not sure if its commercially available yet, but this can be used to investigate the directional distribution of light underwater, good for model closure/validation (e.g. HydroLight etc) and also for looking at the interaction of light with underwater photosynthetic canopies, e.g. macroalgae, seagrasses, coral reefs.

FSF response: we are currently seeking funding to enhance existing UW instrument suite.

8.2 The high demand for ASD FieldSpec and GER3700 spectroradiometers meant that we could only use the GER1500, which did not capture information on the mid-IR wavelengths. Perhaps acquiring more devices could solve these situations.

FSF response: V-SWIR project will address this request.

8.3 Underwater instruments for deep sea work. (e.g. with depth capabilities to > 4000m depth)

8.4 Small, modular spectrometers which may be limited in wavelength range, but are light and highly portable (e.g. a suite of Ocean Optics type USB sensors). This would allow field measurements to be made more quickly than at present with some of the larger kit (ASD for eg), and possibly even from UAV-type platforms. This would require modular mounts, and up- and downward looking sensors, but these are relatively cheap (compared with the larger full-spectrum sensors).

FSF response: A modular system for mounting on a UAV is currently under consideration

8.5 Thermal spectrometer/ Thermal camera (multi-filters if possible) - support to existing field equipment.
FSF response: currently being investigated in conjunction with ARSF.

8.6 Hyperspectral imager. Would be of great use in geological field-based applications examining at facies/stratigraphic changes of environmental archives.
FSF response: FSF has recently supported a bid to NERC for a hyperspectral imager by a 3rd party.

8.7 Additional (portable) CIMEL sunphotometer
FSF response: A tracking system for Microtops sunphotometers, which would address this suggestion is currently being developed by a 3rd party and FSF are being kept informed of its development

8.8 4pi steradian spectroradiometer from "metologie consult" Rainer Schmitt

8.9 More dual-beam instruments (VNIR and full-range), so some could be on long-term loan around the country.
FSF response: V-SWIR project will address this request.

8.10 Hand-held geo-material spectroradiometer
FSF reponse: Contact probes for ASD instruments support this kind of application.

8.11 The ability to take multi angle rf measurements would be beneficial. But I believe this has been addressed recently
FSF response: A goniospectroradiometer has been developed as part of a FSF-sponsored project and will be field trialled during 2009 for deployment to the user community in 2010.

8.12 PAR sensors and flourescence equipment e.g. PAM (not just diving PAM)

8.13 Ultraviolet/Visible spectrometer

9. FSF Post processing software

63% of respondents used FSF's Excel based templates to post process their data and 54% found the templates 'Very user friendly', 42% found them of 'Average' friendliness and only one user found them 'Not user friendly'. 31% of respondents considered that FSF should update its current software. Matlab and IDL were the most popular suggestions but there was also a request for satellite/airborne sensor filter functions to be made available.

FSF response: FSF is currently developing a web page to host Matlab scripts developed by Facility staff and are requesting the Facility users contribute scripts they develop to make this a field spectroscopy Matlab script exchange. FSF are also requesting the IDL scripts be submitted. These web pages form part of the FSF software exchange web site which includes 'Planrad' software developed by Dr John Hedley for under water light modelling, 'Microtops Inverse' software developed by Dr V. Tasnev and Dr T. Mather and LIBERTY software developed by Prof. T. Dawson. See FSF web site < http://fsf.nerc.ac.uk/resources/software/>for further details.

10. New instrument suites available through FSF

27% of respondents expressed an interest in borrowing the Facility's FTIR within the next two or 'few' years. 10% of respondents indicated that they would like to borrow the GER1500 and underwater housing in the near future or in the longer term while only one respondent expressed an interest in borrowing the Waltz Diving Pam flourometer (the Diving PAM is not owned by NERC but by Prof. T. Dawson and is made available to the research community through FSF). 17% of respondents expressed an interest in borrowing the AC-S/BB3/HyperOCR underwater suite of instruments in the near future or in the longer term.

11. Other suggestions from respondents

Other general comments and suggestions from respondents are included in Table 2 below along with FSF responses where appropriate.

Table 2

11.1 The FSF has allowed me to do research that would otherwise not have been possible, as the demand for a spectroradiometer is not high enough in my department to warrant purchase and maintenance of such equipment. In addition to this it provides opportunities to test more 'exotic' equipment such as the GER1500 underwater housing. Another great advantage is that the calibration can be assumed up-to-scratch. When borrowing equipment from other institutions one does not have much insight in this. My first loan has certainly motivated me to think about wider application of the equipment and to make more use of this facility. Thanks!

11.2 As a user (within a PI's application) I have received all the support necessary for the experiment. Everything I learned during my one-to-one training day was very detailed and comprehensible. The theoretical part of the training was easy to follow. FSF always replied to questions and gave advice where necessary. As part of the training we spend 1 day in the field where a FSF staff member advised on how to handle equipment under complex field conditions (handling fragile fibre optical cables) and how to improve measurements. This training made the handling of equipment easy when using it unsupervised later during field campaigns. It was fun undertaking the measurements, thanks to FSF. Well done!

11.3 The support from the FSF is critical to our work, they are always helpful and accommodating and we couldn't complete our work, without their hard work. Thank you.

11.4 I am extremely satisfied with the support I received from FSF. I had a full one-on-one training day with the ASD and have never had any queries on how to use it since. I have been able to extend my loan period very easily and FSF have been very accommodating to my requests to do so. I have had questions answered promptly and feel very at ease with emailing and asking for help.

11.5 Support from the facility has been first class.

11.6 I haven't received much personal support but I have been involved with the FSF through assisting them with training and promotion of the aquatic spectroscopy kit. I believe the role of the FSF in providing this high-end equipment is not only invaluable to the UK research community but can pro-actively promote and shape excellence in research in the UK. Personally acquiring this kind of expensive equipment is substantial barrier to entry to cutting edge research for many UK academics. The FSF removes that barrier to entry and thus enables UK researchers to compete academically with those in other (perhaps) more well resourced countries. This clearly has a knock on effect to generation of IP and commercialisation within the UK. However, the uptake of new instrumentation by the community will obviously take time, while the users become familiar with what is available and and formulate their own research strategies. Therefore, I sincerely hope the current FSF contract will be renewed, so the FSF will have sufficient time to demonstrate the benefit of the groundwork that they have done in recent years.

11.7 I have been very happy with the service, training and equipment provided by the FSF. This really is an excellent service and one that should definitely continue.

11.8 I have had very limited interaction with FSF but that I have had has been helpful, prompt and excellent.

11.9 The existence of FSF was crucial for my PhD research. At least two peer-reviewed papers will stem from my field work done with FSF support, and a number of others will partly build on my work (I process satellite imagery for the Tropical Andes Biodiversity and Ecosystems Research Group). It seems to me that I paved the way for my research group ('Ecosystems' in the Environmental Change Institute, Oxford University), which is now aware of the FSF-related opportunities and is committed to use them. Not having the FSF in the future would be a great loss to the scientific community.

11.10 As described above, I have been very impressed and happy with FSF over the past few years. We have an ASD spectroradiometer which is looked after by FSF and made available to other researchers when not required by us. The FSF staff have been invaluable in helping us get the best deal for the kit in the first place, modifying it for various uses as required, training us, making suggestions for improving measurements, liaising with the manufacturers and generally being extremely responsive. The staff general expertise in spectroscopy is valuable, but combined with the wider practical knowledge of engineering, electronics and the requirements for a range of measurement in general, they have given us outstanding service. This has improved our capability to do science significantly.

11.11 Very helpful, thank you

11.12 FSF is a core facility without which spectroscopy research would be reduced to few lucky universities or individuals with access to spectroscopy equipment. Its place as a national organization helps to expose workers to the option (and potential) of spectroscopy and should keep doing just that. Most large institutions may acquire their own gear after this point. I think FSF is a crucial service and should be supported.

11.13 FSF in Edinburgh provide a hugely beneficial resource to the research community. Their pool of state-of-the-art instrumentation provides the opportunity for high quality research that may otherwise be too costly (in capital terms) for individual institutions. The service provided by the FSF team in Edinburgh is first class. They are approachable to those with a non-spectroscopy background, thus creating the opportunity for a wider user community than may be expected. Furthermore, the level of technical support is excellent, ensuring that the loaned instrumentation is in excellent working order, that clear and detailed instruction is provided to users and that further support is available when necessary.

11.14 The service was excellent. All hardware was shipped to us in good time for our fieldwork. We were given very good training on the use of the equipment and they even suggested additional equipment that might be of use and then lent that to use too.

11.15 FSF provides high quality support for a range of users. FSF support has been essential for international collaborative work that I have undertaken this year at NASA, and for supporting my NERC-funded PhD student. Without FSF we would not have been able to collect high-quality traceable data in support of our projects. I am particularly impressed with the radiometric support I recieved in relation to the NASA project, calibration data were supplied very rapidly.

11.16 The facility was able to loan us equipment at short notice, provided excellent support when we had problems with equipment in the field, one day introduction to the equipment very useful and was tailored to our particular needs, excellent support after data collection in terms of providing software and guides for converting raw data to calibrated reflectance

11.17 Without the support of the facility it simply would not be possible to conduct the research we are currently involved in. The support has been essential in terms of the access to equipment, but also for training and input of fresh ideas. The application of field spectroscopy is relatively uncommon in our area of research so any access to such support is essential. Access to the facilities at NERC FSF, as well as the further support offered, has enabled the initiation of our project and promises to play a key part in the further development of the research. For example, the facility plays a vital roll (sic) in combining the interest and application ideas of its users, with the facility team's knowledge of potential suitable equipment. Further, I strongly believe that facilities such as the FSF are vital for the health of 'blue skies' scientific research in the UK. Access to otherwise unavailble equipment enables testing of ideas and the formulation of projects that are then backed by initial data. Without such opportunities blue skies research will rarely have the chance to get off the ground. If anything this is as important an aspect of NERC as are the opportunities for project funding via grants. The FSF is no exception here, particularly because much of the equipment is otherwise inaccessible and the staff have an extensive knowledge of potentially applicable techniques.

11.18 Happy with support received. Journal paper been submitted to IEEE TGARS, awaiting reviews, using data from FSF Microtops sun photometer.

11.19 The personal (sic) at the FSF in Edinburgh were outstanding in their information, explanations, training and friendliness.

11.20 I have received support from FSF on 4 occasions borrowing the GER1500 and the acs+bb+radiometers suite. In all occasions the instruments have been provided in a timely way and in an excellent working condition (i.e. recently calibrated). Not only the service was accommodating with time required, but also staff made all efforts to resolve problems fastly and effectively, in a very satisfactory way. I think that having a national capability in field spectroscopy for the marine optics community is essential as these instruments require regular calibrations and attentions to ensure the quality of the data. Unfortunately, quite often there is not an explicit funding for this maintenance in normal science proposals, hence the great advantage of keeping the FSF in operation and fully funded by NERC, to keep marine optics research at its highest standard.

11.21 My main use of the facility as PI during this period was in support of the NCAVEO 2006 Field Campaign. The support provided by FSF was exemplary, and contributed significantly to the success of the campaign. I feel strongly that the FSF should continue. There is a demonstrable need for a national facility of this sort, and the present arrangement appears to be working well.

11.20 The research I needed to undertake was supported by the FSF but was central on the ARSF. The FSF provided instrumentation that added significant value to the data collected by the ARSF, added value which would not have been possible without the FSF's provision.

11.21 I received excellent support from all members of FSF staff. They were friendly, professional and provided excellent training on the equipment. Staff also provided valuable long-term support after the period of use of the equipment. Without the support I received I would not have been easily able to utilise the equipment or evaluate my data.

11.22 The FSF has provided with excellent support over a number of years. In conjunction with the ARSF the FSF provides a unique capability in the world for the support and advancement of Earth Observation Science.

11.23 Have always recieved prompt and excellent support from the facility.

11.24 The support has been good. Reading have now purchased their own Microtops sunphotometer so I am not sure how much we will use the facility in the future.

12 Identified Respondents

Those respondents who made their identities known in the User Survey Questionnaire, listed in the order they responded.

Dr Fleur Visser	University of Worcester
Ms Sigrid Dengel	University of Edinburgh
Mr John Dowens	University of Edinburgh
Ms Natasha MacBean	University College London
Dr Charles Wrench	STFC- CCLRC Rutherford Appleton Laboratory
Dr John Hedley	University of Exeter
Mr Christian Haselwimmer	British Antarctic Survey
Prof. Julian C Partridge	University of Bristol
Dr Nigel Trodd	University of Coventry
Mr Przemyslaw Zelazowski	University of Oxford
Dr Mathias Disney	University College London
Mr Tamir Caras	Canterbury Christ Church University
Dr Trevor Blackall	King’s College London
Dr Luke Bateson	British Geological Survey
Dr Karen Anderson	University of Exeter
Mr Talfan Barnie	University of Cambridge
Mr Thomas Stevens	King’s College London
Mr Peter North	Swansea University
Mr Victor Martinez Vicente	Plymouth Marine Laboratory
Prof. Ted Milton	University of Southampton
Dr Paul Zukowskyj	University of Hertfordshire
Mr Sam Almond	Bournemouth University
Dr Martin Todd	University College London

1.3.2 User Loan Report Summaries

Summaries from the Loan Reports returned to FSF by users on completion of each loan.

Loan Report 2006 Summary

Loan report item	Response		Reason for deficiency	Action taken by FSF
Instrument Performance	Good	54%		
	Satisfactory	38%		
	Poor	8%	ASD power supply fault	ASD power board upgraded
	Major	7%	As above plus required to share Microtops with another project	Additional Microtops purchased for 2007
Problems encountered	Minor	21%	ASD weight. Faulty GER1500 battery connector	None. Connector repaired
	Operator error	7%		
	Inclement weather	29%		
	None	36%		
Amount of Data collected	All	36%		
	Some	57%	Mainly due to inclement weather	
	None	7%		
Objectives met	Fully	43%		
	Partially	50%		
	Not at all	7%		
How valuable was data collected	Essential	69%		
	Useful	31%		
	Little value	0%		
How do you rate the post processing software	Excellent/ very good	45%		
	Good	55%		
	Satisfactory	0%		
	Poor	0%		
How did you find the service provided by FSF	Excellent/ very good	73%		
	Good	20%		
	Satisfactory	0%		
	Poor	7%	FSF required scheduled return of Microtops for deployment on alpha 5 project prior to data being acquired. Data collection had been delayed due to inclement weather	Additional Microtops purchased for 2007
How did you rate the training & guides provided by FSF	Excellent/ very good	55%		
	Good	45%		
	Satisfactory	0%		
	Poor	0%		

Loan Report 2007 Summary

Loan report item	Response		Reason for deficiency	Action taken by FSF
Instrument Performance	Good	92%		
	Satisfactory	8%	Intermittent problem with communication between instrument and laptop Power consumption demand	System checked and unable to replicate problem. However, cables replaced. Operator issue
	Poor	0%		
	Major	0%		
Problems encountered	Minor	33%		
	Operator error	0%		
	Inclement weather	0%		
	None	67%		
Amount of Data collected	All	58%		
	Some	42%	ARSF campaigns cancelled	
	None	0%		
Objectives met	Fully	58%		
	Partially	42%	Inclement weather ARSF campaigns cancelled	
	Not at all	0%		
How valuable was data collected	Essential	92%		
	Useful	8%		
	Little value	0%		
How do you rate the post processing software	Excellent/very good	30%		
	Good	50%		
	Satisfactory	20%	Slow and only takes in 100 files Useful to have Matlab version	None - Excel limitation Currently under consideration
	Poor	0%		
How did you find the service provided by FSF	Excellent/ very good	91%		
	Good	9%		
	Satisfactory	0%		
	Poor	0%		
How did you rate the training & guides provided by FSF	Excellent/very good	100%		
	Good	0%		
	Satisfactory	0%		
	Poor	0%		

Loan Report 2008 Summary

Loan report item	Response		Reason for deficiency	Action taken by FSF
Instrument Performance	Good	92%		
	Satisfactory	4%		
	Poor	4%	Microtops failure	Supported user by email and phone 'out of hours'
Problems encountered	Major	4%	Microtops ceased data acquisition	User supported out-of hours by phone and email - to reprogramme Microtops and attempt data retrieval. Problem persisted. Microtops being returned to SolarLight for investigation FSF considering supplying back up instrument when data critical and location remote and will discuss with NERC
	Minor	63%	Problem with time code from GPS. Ethernet connection not available. General spectroscopy operational issues. FTIR IR source moved in wind.	Problem being investigated. ASD software upgrade - proposed to NERC for 2008/9. i.e. dust, cloud, access issues Smaller source has been purchased and improvements to support developed
	Operator error	8%	Difficulty holding instrument steady. Blown fuse	FSF currently investigating a 'tracker' to mount Microtops on. User wire battery incorrectly
	Inclement weather	8%	cloud cover	
	None	17%		
Amount of Data collected	All	42%		
	Some	58%	Inclement weather Microtops failure (see above)	
	None	0%		
Objectives met	Fully	58%		
	Partially	42%	Limited access to good viewing geometries inclement weather Microtops problem	
	Not at all	0%		
How valuable was data collected	Essential	67%		
	Useful	33%	Will inform future campaigns	
	Little value	0%		
How do you rate the post processing software	Excellent/very good	27%		
	Good	36%		
	Satisfactory	0%		

Loan report item	Response		Reason for deficiency	Action taken by FSF
	Poor	9%	Large file size & unable to share with Linux/ non Excel users	limitations of Excel
How did you find the service provided by FSF	Excellent/ very good	100%		
	Good	0%		
	Satisfactory	0%		
	Poor	0%		
How did you rate the training & guides provided by FSF	Excellent/ very good	92%		
	Good	8%		
	Satisfactory	0%		
	Poor	0%		

Appendix 11 – Further output and performance measures

MAC ARTHUR, A. A., MACLELLAN, C. & MALTHUS, T. J. (2006) What does a spectroradiometer see? *The Remote Sensing and Photogrammetry Society Annual Conference. Understanding a Changing World.* Fitzwilliam College, University of Cambridge, 5th - 8th September 2006 (**Won Best Poster prize**).

What does a spectroradiometer see?

Alasdair A. Mac Arthur[1], Christopher J. MacLellan[1] & Tim J. Malthus[2]

[1] NERC Field Spectroscopy Facility, Grant Institute, University of Edinburgh

[2] School of Geosciences, Grant Institute, University of Edinburgh

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Introduction

The field of view (FOV) and it's uniformity are poorly considered in field spectroscopy and manufacturer's specifications generally lack detail. For users, determining the scene within the FOV is largely an exercise in guess work. If the FOV and its uniformity are unknown, the surfaces contributing to the reflectance recorded will be ill defined. Especially for heterogeneous earth surfaces these details matter. We report here initial findings into accurate measurement of the FOV and its uniformity for GER 3700 and ASD FieldSpec Pro field spectroradiometers.

Methods

Field of view is used to define the solid angle through which light incident on the input or fore optics will enter the detector system. It is a vague parameter and gives no indication as to the responsivity of the system to light from different angles within the FOV. An alternative approach is to generate a *directional response function* (DRF), which details the response of the system to the angle of incident light.

To determine the DRF of a spectroradiometer, linear stages with micrometers were used to move a point source vertically and horizontally with respect to the optical axis of the spectroradiometer (figure 1). This method allowed great precision over the small angles of movement required.

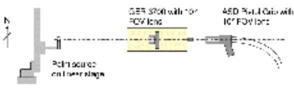


Figure 1 Setup of spectroradiometer fore optics

Instruments

The FOVs of an ASD FieldSpec Pro FR and a SVC GER 3700 spectroradiometer were measured. Both these instruments cover the spectral range 350 to 2500nm but the two systems use different technologies. The ASD records the full spectral range using three separate spectrometers with light from the fore optic being transmitted to the individual spectrometers via a randomised optical fibre bundle (figure 2).

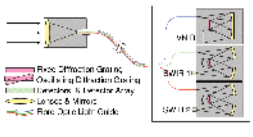


Figure 2. Optical layout of ASD FieldSpec Pro FR

The optical path through the GER 3700 is split into three spectrometers using a combination of lenses, apertures, mirrors and beam splitters (figure 3). This complex arrangement requires careful design and alignment to minimise differences in the directional response. Both systems were fitted with their manufacturer's 10° FOV lens for measurements in this research.

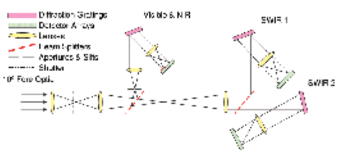


Figure 3. Optical layout of the GER 3700

Results - ASD FieldSpec Pro FR

The geostatistically interpolated data presented in figure 4 represents the DRF for the upper two quadrants of the FOV for wavelengths typifying the response of each of the three spectral channels, VNIR, SWIR 1 and SWIR 2.

The blue dashed semi-circle represents the theoretical FOV of the 10° fore optic at a distance of 1750mm.

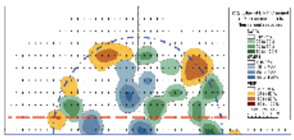


Figure 4 25, 50 and 90% directional response contours for ASD FieldSpec Pro FR at 650, 1600 and 2100nm.

A cross-section (red dashed line, figure 4) of the ASD's system's responsivity from the three channels is shown in figure 5. This also highlights the strong spectral and spatial dependencies across the spectroradiometer's field of view.

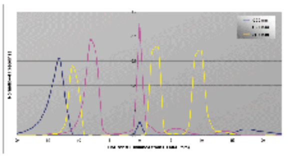


Figure 5 Normalized response across the field of view of the ASD FieldSpec Pro FR

The combined FOV (5% response level) for the three channels demonstrates that areas outside the theoretical FOV influence the reflectance recorded (figure 6).

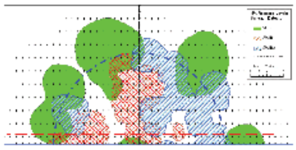
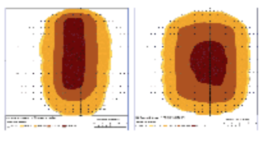


Figure 6 ASD FieldSpec Pro FR 5% directional response contours for VNIR, SWIR1 and SWIR2 channels.

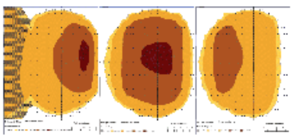
Results - GER 3700

The normalised response plots for the SWIR-1 and SWIR-2 channels of the GER 3700 demonstrate the influence of the rectangular aperture slit (figures 7a & b).



Figures 7a & 8b SWIR 1 (1350 nm) & SWIR 2 (2100 nm) directional response contours of the GER 3700 with 10° fore optic.

The DRF of the VNIR channel at 450, 705 and 950nm respectively are shown in figure 8. The peak response contours show a marked shift from left to right of the FOV as the wavelength is scanned from the blue to the near infrared. Thus, the left hand side of the DRF has a greater bias to blue light compared to the right hand side where the NIR has its maximum response.



Figures 8a, 8b & 8c Directional response contours for 450, 705 & 950 nm wavebands of the GER 3700 with 10° fore optic

The shaded area on the left side of figure 8a, where the signal at 450nm would be expected to drop to zero, remains high due to NIR stray light being detected at the blue end of the detector array.

The FOV data is summarised in Table 1 which lists the horizontal and vertical view angles at the 90, 50, 10 and 5% responsivity contours.

Table 1. View angles and offsets for the GER3700 instrument

Waveband (nm)	90% contour				50% contour			
	Horizontal (E-W)		Vertical (N-S)		Horizontal (E-W)		Vertical (N-S)	
	View angle	Offset	View angle	Offset	View angle	Offset	View angle	Offset
450	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
950	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Waveband (nm)	10% contour				5% contour			
	Horizontal (E-W)		Vertical (N-S)		Horizontal (E-W)		Vertical (N-S)	
	View angle	Offset	View angle	Offset	View angle	Offset	View angle	Offset
450	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
950	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Conclusions

The general use of the term 'field of view' by manufacturers has been shown to be inadequate in the two instruments tested. If the responsivity is uneven across the measurement field and the area measured is different from that assumed, the components considered to be within a scene may not be represented in the gross reflectance recorded. This may lead to erroneous characterisation and poor quantification of (bio)physical and (bio)chemical variables.

Field campaigns on heterogeneous targets should include procedures to verify the performance and repeatability of the optical equipment used. New designs should also be sought for fore optic accessories or systems which offer improved uniformity without totally sacrificing spectroradiometer sensitivity.

Acknowledgements

This research is part of the NERC Field Spectroscopy Facility in-house research programme. The support given to A. Mac Arthur by Clyde Muirshiel Regional Park to carry out research which initiated the investigation reported in this paper is acknowledged.

NATURAL ENVIRONMENT RESEARCH COUNCIL
NERC Field Spectroscopy Facility, Room 243, Grant Institute, School of GeoSciences, University of Edinburgh, West Mains Road, Edinburgh EH9 3JW.
Tel: 0131 650 5926. Fax: 0131 650 5901. Email: fsf@nerc.ac.uk

Poster presentation at IGARSS07 meeting, Barcelona 2007.

The '*Field of View*' is an inadequate term: two spectroradiometers compared

Alasdair A. Mac Arthur[1], Christopher J. MacLellan[1] & Tim J. Malthus[2]

[1] NERC Field Spectroscopy Facility, Grant Institute, University of Edinburgh

[2] School of Geosciences, Grant Institute, University of Edinburgh

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Introduction

The field of view (FOV) and it's uniformity are poorly considered in field spectroscopy and manufacturer's specifications generally lack detail. For users, determining the scene within the FOV is largely an exercise in guess work. **If the FOV and its uniformity are unknown, the surfaces contributing to the recorded reflectance will be ill defined**, especially for heterogeneous earth surfaces where these details matter. **We report here** our findings into **accurate measurement of the FOV and its uniformity for two full range field spectroradiometers**

Methods

Field of view is used to define the solid angle through which light incident on the fore optics will enter the detector system. **It is a vague parameter** and gives no indication as to the responsivity of the system to light from different angles within the FOV. **An alternative approach is to generate a *directional response function* (DRF)**, which details the response of the system to the angle of incident light.

To determine the DRF of a spectroradiometer, linear stages with micrometers were used to move a high intensity point source vertically and horizontally with respect to the optical axis of the spectroradiometer (Figure 1). This method allowed great precision when measuring over small angles of movement.

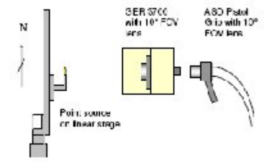


Figure 1 Setup of spectroradiometer fore optics

The FOVs of two spectroradiometers, an ASD FieldSpec Pro FR and a SVC GER3700, were measured and the DRF determined. Both these instruments cover the spectral range 350 to 2500nm but the two systems use different technologies and significantly different results have been obtained.

ASD FieldSpec Pro FR

The ASD records the full spectral range using a spectrometer and two monochromators with light from the fore optic being transmitted to the individual channels via a randomised optical fibre bundle (Figure 2).

Results - ASD FieldSpec Pro FR FR

The data presented in Figure 3 represents the DRF for the ASD spectroradiometer with 10° FOV lens at wavelengths typifying the response of each of the three spectral channels. The contour lines show the spatial **separation of the three channels.** The shaded areas in Figure 4 show the sensitivity for the individual spectral channels down to 5% of the peak response. The blue dashed circle represents the manufacturer's specified FOV for the fore optic at 1000mm. **This demonstrates that areas outside the theoretical FOV influence the recorded reflectance while some regions inside the FOV are not measured** (at the 5% level) by any of the three channels. A cross-section (red dashed line, Figures 3 & 4) of the ASD's system's responsivity from the three channels is shown in Figure 5. **This also highlights the strong spectral and spatial dependencies across the spectroradiometer's field of view.**

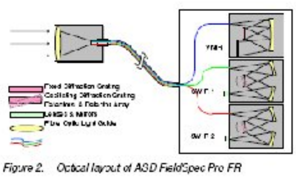


Figure 2. Optical layout of ASD FieldSpec Pro FR

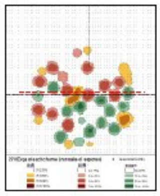


Figure 3 25, 50 & 90% contours

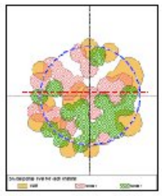


Figure 4 5% contour

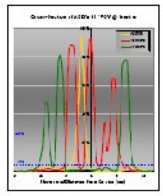


Figure 5 10° FOV cross section

SVC GER 3700

The optical path through the GER 3700 is split into three spectrometers using a combination of lenses, apertures, mirrors and beam splitters (Figure 6) and requires careful design and alignment to minimise differences in the directional response.

Results – SVC GER 3700

Figure 7 shows the DRF at three wavelengths within the Vis-NIR spectrometer. The peak response contours **show a marked shift from left to right as the wavelength are measured from blue to the near infrared.** Thus, the left of the FOV has a bias to blue light compared to the right hand side where near infrared has its maximum response. **The normalised response plots for the SWIR 1 and SWIR 2 channels of demonstrate the influence of the rectangular aperture slit.**

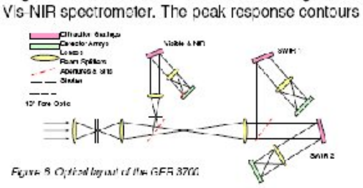


Figure 6 Optical layout of the GER 3700

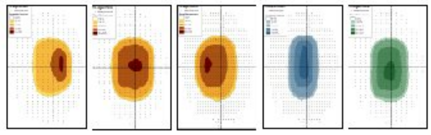


Figure 7 Directional response contours for VNIR (450, 700 & 900 nm), SWIR 1 (1500 nm) & SWIR 2 (2100 nm)

Conclusions

If the responsivity is uneven across the measurement field and the area measured is different from that assumed, the components considered to be within **the scene may not be represented** in the **gross reflectance recorded**. This may lead to erroneous characterisation and poor quantification of state variables. **Therefore,** the **'field of view' is** an inadequate term to describe **this critical parameter and a detailed Directional Response Function is recommended.**

In addition, **Field campaigns on heterogeneous targets should include procedures to verify the performance and repeatability of the optical equipment used. New designs should also be sought for fore optic accessories or systems** which offer improved uniformity without totally sacrificing spectroradiometer sensitivity.

Acknowledgements

This research is part of the Field Spectroscopy Facility (FSF) in-house research programme, based at the University of Edinburgh. FSF is a facility fully supported by the Natural Environment Research Council.

NATURAL ENVIRONMENT RESEARCH COUNCIL

NERC Field Spectroscopy Facility, Grant Institute, School of GeoSciences, University of Edinburgh, West Mains Road, Edinburgh EH9 3JW. Tel: 0131 650 5926, Fax: 0131 650 5901, Email: fsf@nerc.ac.uk

FTIR Spectroscopy Workshop

6th to 7th June 2007 – King's College London




a 2-day workshop in remote sensing with FTIR Interferometers

Aims

The workshop aims to bring together new and exiting users of FTIR interferometers for remote sensing applications, to share their knowledge and experiences when designing and implementing field measurement campaigns. Two FTIR systems will be used for hands on demonstration of the equipment in both open path and ground radiance configurations. Data processing techniques, for retrieval of gas concentrations and ground emissivity values will be discussed. Throughout the two days, opportunities will arise for users new to FTIR remote sensing to discuss their projects in detail and to establish links to experts in this field.

Topics

Topics covered include:

- Field measurements with Fourier Transform Infrared interferometers
- Remote sensing and gas retrievals from volcanic plumes
- Open path measurements of fugitive emissions
- Ground radiance and surface emissivity
- Estimating gas releases in biomass fires
- Radiometric calibration of FTIR systems
- Data retrieval techniques including least squares fit and the reference forward model.

Field Measurement Demonstrations

The demonstration on the first day will include an open path configuration using a collimated infrared field source and, weather permitting, a sun occultation measurement.

The experiment on the second day will aim to demonstrate the techniques and methods required to measure ground radiance, surface temperature and emissivity using field and laboratory black body sources.

Cost

The workshop is open at no charge to all FTIR users new and old, but participants will need to fund their own travel and accommodation during their stay in London.

Registration

For registration and further enquiries please contact the NERC Field Spectroscopy Facility at:

NERC Field Spectroscopy Facility,
University of Edinburgh, Grant Institute,
West Mains Road, Edinburgh EH9 3JW

Tel: 0131 6505926; Fax: 0131 6505901;

Email: fsf@nerc.ac.uk;

Web: http://fsf.nerc.ac.uk

Programme

Wednesday 6th June
Venue: War Studies meeting room, Strand Building, King's College London

Time	Topic	Speaker	
9:00 – 9:45	Registration		
9:45 – 10:00	Welcome	Martin Wooster & Tim Malthus	King's College London Univ. of Edinburgh
10:00 – 10:20	Principles of FTIR Interferometers	C MacLellan	NERC FSF
10:30 – 11:00	Open path	Mike Burton	Istituto Nazionale di Geofisica e Vulcanologia (INGV)
11:00 – 11:30	Comparison of different analysis techniques of Open-Path FTIR spectra	Susana Briz	Universidad Europea de Madrid
11:30 – 12:00	Coffee		
12:00 – 12:30	Using FTIR to Measure the Influence of Biomass Fires on the Atmosphere (R.J. Yokelson)	Pete Zemek	Midac Corp.
12:30 – 13:00		Johan Mellqvist	Chalmers U. of Technology, Göteborg,
13:00 – 14:00	Lunch (provided)		
14:00 – 14:30	Open path	Clive Oppenheimer	Univ. of Cambridge
14:30 – 16:00	FTIR spectroradiometer measurement demos. Open path with field source & sun occultation. (Auto-quant Pro & Essential FTIR)	& Chris MacLellan	NERC FSF
16:00 – 16:30	Coffee & discussion		
16:30 – 17:30	Data retrievals with Reference Forward Modelling	Anu Dudhia	Univ. of Oxford
18:30	Workshop dinner at TBA		

Thursday 7th June
Venue: Pyramid Room, Strand Building, King's College London

Time	Topic	Speaker	
9:30 – 10:00	Radiometric Calibration of Field Spectrometers	Tim Nightingale,	CCLRC, RAL
10:00 – 10:30	Gas Retrievals from Spectroscopic Measurements	Jolyon Reburn	CCLRC, RAL
10:30 – 11:00	Scanning system	Andrew Wilson	Centre for Ecology & Hydrology
11:00 – 11:30	Coffee		
11:30 – 12:00	Ground radiance & emissivity	Vitchko Tsanev	Univ. of Cambridge
12:30 – 13:00	Ground radiance & emissivity	TBA	
13:00 – 14:00	Lunch (provided)		
14:00 – 15:30	Ground radiance & emissivity demo	Martin Wooster/ Chris MacLellan	
15:30 – 16:00	Reactor based open-path measurements using the Illuminator portion of the MIDAC OP-system	Pete Zemek	Midac, Corp.
16:00 – 16:30	Midac FTIR system options & accessories	Don Mullally,	Midac, Corp.
16:30 – 17:00	Coffee & round up discussions	Clive / Martin / Tim	

Venue and Transport (information and maps from http://www.kcl.ac.uk/about/campuses/strand-det)

Rooms: War Studies Meeting Room (6th June) & Pyramid Room (7th June)
Department of Geography,
King's College London,
Strand,
London WC2R 2LS

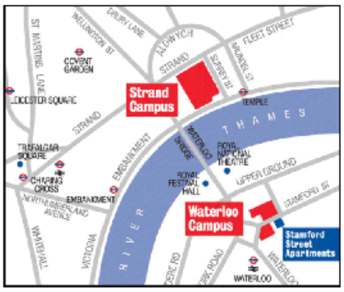
Tube - nearest stations
Temple (District and Circle lines), 2 minute walk
Charing Cross (Bakerloo, Northern lines), 10 minute walk
Embankment (District, Circle, Bakerloo lines), 10 minute walk
Waterloo (Jubilee, Northern, Bakerloo, Waterloo & City lines), 12 minute walk
Holborn (Central, Piccadilly lines), 12 minute walk
Chancery Lane (Central line), use exit 4, 15 minute walk

By train - nearest stations
Charing Cross, 9 minute walk
Waterloo, 12 minute walk
Waterloo East, 10 minute walk
Blackfriars, 12 minute walk

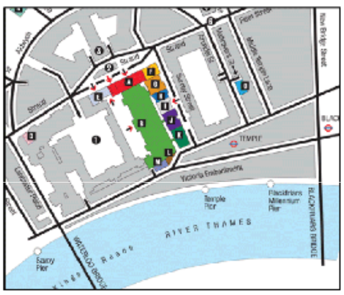
By bus
Buses stopping outside the College: 6 (24 hour service), 9, 11, 15, 23 (24 hour service), 91, RV1
Buses stopping near the College: 1, 4, 26, 59, 68, 76, X68, 168, 171, 172, 176 (24 hour service), 188, 243 (24 hour service), 341 (24 hour service), 521

Parking
The Strand Campus has no public parking, but a pay and display parking system operates in nearby streets including Surrey Street. Motorcycles: bays in the Strand, Arundel Street, Temple Place and other nearby streets.

Bicycles
Bicycle stands in the quadrangle of the Strand Campus (next to the School of Law).



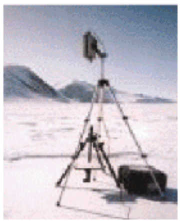
Department of Geography - Building A entrance on Strand opposite Bush House - BBC world service building



Field Spectroscopy Facility
NATURAL ENVIRONMENT RESEARCH COUNCIL

Introduction to Field Spectroscopy

30th April to 2nd May 2008 – University of Edinburgh


a 2½-day intensive course for post doctoral researchers and PhD students

Aims

The course aims to provide an introduction to instrumentation, techniques and best practice in field spectroscopy and its role as a primary research tool and in support of wider earth observation research. Drawing on the equipment and facilities owned by the NERC Field Spectroscopy Facility, the course is designed to better equip users with the skills and know-how to improve both the measurements made in the field and the analysis of the data collected. The course will be delivered by the Director and Staff of the Facility.

Topics

Topics covered include:

- The role of field spectroscopy in research
- Radiometric terms and concepts, BRDF and reflectance
- Instrument design and calibration
- Measurement modes and reference measurements
- Measurement uncertainty
- Issues in field measurements, sampling design and supporting measurements
- The processing and analysis of spectral datasets

Who should attend

The course will be of interest to first year PhD students or post doctoral researchers embarking on research projects where the use of field spectroradiometric instruments and data are planned. It will also be of benefit to proposers to the NERC Airborne Research and Survey Facility, especially those hoping to take advantage of the hyperspectral capabilities of the new AISA Eagle+Hawk system.

Cost

The course is free to postgraduate students, but participants will need to fund their own travel and accommodation during their stay in Edinburgh.

Registration

For course registration and further enquiries please contact the Facility at:

NERC Field Spectroscopy Facility,
University of Edinburgh, Grant Institute,
West Mains Road, Edinburgh EH9 3JW

Tel: 0131 6505926; Fax: 0131 6505901;

Email: fsf@nerc.ac.uk; Web: http://fsf.nerc.ac.uk

NATURAL ENVIRONMENT RESEARCH COUNCIL

RSPSoc Office
c/o The School of Geography
The University of Nottingham
University Park
Nottingham NG7 2RD UK

Telephone: +44 (0) 115 9515435
Facsimile: +44 (0) 115 9515249
Email: rspsoc@nottingham.ac.uk
http://www.rspsoc.org

PA/KL

14th October 2008

Dr Tim Malthus
NERC FSF
University of Edinburgh
Grant Institute
School of GeoSciences
University of Edinburgh
West Mains Road
Edinburgh EH9 3JW

Dear Tim

RSPSoc2008 Conference

I am writing to express the Society's thanks to you and the NERC FSF for contributing and exhibiting at this year's Annual Conference, RSPSoc2008, in Falmouth last month. The strong involvement of organisations like FSF was undoubtedly a big factor in achieving a very successful conference and the Society and the RSPSoc2008 Organising Committee are very grateful for this. We hope the event was successful from your perspective, too. We would like to also take this opportunity to thank you for the contribution that FSF made to the technical exhibition, through your contacts with spectroscopy companies. We recognise the significant amount of time that was dedicated to attracting international exhibitors to the conference and the importance of these to the success of the meeting. We have received good feedback from delegates who enjoyed the workshops.

Preparations for RSPSoc2009, to be held at the University of Leicester, 8th – 11th September 2009, are well underway. The web site is live at www.rspsoc2009.org where you can keep up to date with the latest conference developments. Kevin Tansey, the RSPSoc2009 Local Organiser, has already contacted many sponsoring/exhibiting companies and organisations with more information about RSPSoc2009 and the opportunities associated with it. If you have any ideas or suggestions as to how we can further improve the conference from your perspective, we would be delighted to hear them.

We very much hope that you will want to stay involved in 2009 and, in the meantime, we thank you once again for your valued support.

Yours sincerely

Dr Paul Aplin
Chairman

Patron:
HER MAJESTY THE QUEEN

15 Queen's Gate Terrace
London
SW7 5PR
Telephone: 020 7584 9315
Fax: 020 7581 0410
Email: office@wcmt.org.uk
Website: www.wcmt.org.uk

WINSTON CHURCHILL MEMORIAL TRUST

Mr Alasdair MacArthur
NERC Field Spectroscopy Facility
Grant Institute
School of GeoSciences, University of Edinburgh
West Mains Road
EDINBURGH EH9 3JW

16 July 2008

Dear Mr MacArthur,

Dr Karen Anderson has written to say how much she valued your involvement and help with her recent Winston Churchill Travelling Fellowship, which she much enjoyed and learnt a great deal from the visit.

The Council of the Trust have asked me to say how grateful they are to you for your support, and the significant contribution that you have made to the success of this Churchill Fellow. Thank you for your help.

Yours sincerely,

Jamie Balfour

Major General Jamie Balfour
Director General

News article in Science detailing research on forest fires

can get infected without coming anywhere near a biodefense lab.)

Some scientists and biosafety experts are more worried about risks at BSL-3 labs, because the standards at these labs are not as stringent. But even most of these pathogens with the exception of SARS, avian influenza, and 1918 flu—are not very communicable, and in any case vaccines and other treatments are available. At most, says infectious disease modeler Ira Longini of the University of Washington, Seattle, "the result could be a handful of cases and maybe deaths." Another exception is foot-and-mouth disease, which doesn't infect humans but is extremely contagious among animals; the escape in the United Kingdom, which has been tied to an outdated effluent treatment system, would be unlikely to occur at more modern facilities in the United States, Richmond says.

Peters worries that the "hysteria and witch hunting" by people like Hammond of the Sunshine Project is compromising safety by making lab workers worry that reporting potential exposures will get them fired. "People can't be terrified to report," agrees Jean Patterson of the Southwest Foundation for Biomedical Research in San Antonio, Texas, which runs a BSL-4 lab.

Safety check

So how can biosafety be improved? One proposal is an anonymous, mandatory reporting system for all laboratory accidents. Such a system would enable labs to learn from one another's mistakes, as do the data compiled on aviation accidents by the National Transportation Safety Board, says Gigi Kwik Gronvall of the Center for Biosecurity of the University of Pittsburgh Medical Center in Baltimore, Maryland, who co-authored a paper describing this proposal earlier this year in *Biosecurity and Bioterrorism*. "Other industries have gone through this," says Gronvall. The system would also capture lab exposures to pathogens not on the select-agent list, such as HIV and tuberculosis. Reporting these to NIH or CDC is not mandatory, Rutgers's Ebright notes.

But some microbiologists caution that reportable incidents should be well-defined, lest the system become glutted with minor mishaps. (Peters cites UTMB's recent decision to release, at a community group's request, a list of its 17 near-misses in the past 5 years.) Also important, says biosafety consultant W. Emmett Barkley of Bethesda, Maryland, reports should include not just bare facts but analysis, as CDC now provides for selected lab accidents in its *Morbidity and Mortality Weekly Report*.

A more radical idea is to require that BSL-3 and BSL-4 labs be licensed by the federal government. This would mean that all these labs, not just those working on select agents, would be inspected and they would be required to follow the same operating procedures. One supporter of this proposal, biosecurity expert Anthony Della-Porta of Geelong, Australia, says the problem now is that *BMBL* offers only general guidance. Others, such as Barkley, say institutions need flexibility, especially the many BSL-3 labs that don't do biodefense work.

There's one fact that nobody disputes: The risk of accidents in biosafety labs goes up with the number of workers. For that reason, watchdog groups and even some biodefense researchers lament the lack of analysis on whether all of the six planned BSL-4 and two dozen new BSL-3 biodefense labs are actually necessary to protect the nation from bioterrorism (see map). Says Gronvall: "Is there too much [biodefense research]? Without seeing the plan of action, it's hard to say."

–JOCELYN KAISER

ECOLOGY

Setting the Forest Alight

To validate satellite data for carbon-emissions modeling, researchers this summer torched a jack-pine forest in Canada and tried to ignite a stand of larch in Siberia

KODINSK, RUSSIA—In July, as temperatures soared during a heat wave in eastern Siberia, scores of large fires flared through the region's dense pine forests. For 500 kilometers along the Amur River northwest of Lake Baikal, thick smoke blanketed the wilderness. Officials with Russia's famous airborne forest fire fighting service, Avialesookhrana, were tracking the wildfires at an airbase here in Kodinsk, a small city on the Amur. They were tense. To them it seemed bizarre that a team of international scientists had received permission to burn a patch of nearby forest. Even with every local helicopter and plane conscripted to serve their firefighting crews, millions of dollars' worth of timber was going up in smoke in wildfires. "It's not as though we don't have enough to worry about already," mused Oleg Mityagin, the overtaxed local Avialesookhrana boss. "We're in no position to help them if they lose control."

Safe distance. Douglas McRae checks out a gap in a pine forest during an experimental burn in Ontario, Canada.

CREDIT: PAUL WEBSTER

Sixty kilometers to the west at the experimental site, a group of Russian, American, and Canadian researchers hoped to set a test fire that would thoroughly burn a hectare-sized patch of larch forest, Siberia's dominant conifer. Their aim was to quantify carbon emissions from fires in larch forests across Siberia, now inadequately documented, according to Douglas McRae, a forest-fire researcher with the Canadian Forest Service. McRae has been conducting experimental burns in Canada and Russia since 1999 as part of project FIRE BEAR (Fire Effects in the Boreal Eurasia Region), a research program aimed at studying forest-fire behavior, ecological effects, emissions, carbon cycling, and remote sensing.

Conceived in 1997, FIRE BEAR brings researchers from the U.S. Department of Agriculture (USDA) Forest Service and the Canadian Forest Service together with colleagues at the Siberian branch of the Russian Academy of Sciences' (RAS's) V. N. Sukachev Institute in Krasnoyarsk. As the group's previous studies have shown, extreme forest fires are growing more frequent in Siberia. And some models predict that climate change will bring dramatic warming—and more forest destruction—in eastern Siberia and other northern regions. The experimental burn, the FIRE BEAR team hoped, would yield direct observations to buttress satellite data and fill gaps in the models.

Published by AAAS

Hot results. A sudden gust of wind sent flames temporarily out of control in a Canadian test area, but the fire produced terrific data.

Flaming wilderness

The searing summer heat in Kodinsk presented a dilemma for the scientific team. "We want the larch to burn well in order to obtain good data," McRae explained, "but we risk losing control if it burns a little too well." In the days leading up to the experimental burn, bulldozers hacked firebreak lanes around the test patch, and researchers wired the forest floor with probes to gauge heat release, carbon emissions, and effects on vegetation and microbes. McRae had good reason to be anxious. In May, in similar weather, he and his FIRE BEAR colleagues conducted an experimental burn near Sault Ste. Marie, Canada, in which a hectare-sized patch of bone-dry jack-pine forest fanned out of control. That experiment was meant to show how infrared technology can be used to estimate fuel consumption and carbon emissions during fires. McRae and his colleagues hoped it would help them gauge how Russian wildfires contribute to greenhouse gas emissions. (Russian security laws prevent infrared filming from the air.)

Only minutes before the scientists ignited the fire in Ontario, wind gusts unexpectedly blew through the treetops. After ignition, the entire test plot flared in an explosive burst that melted computerized monitoring equipment. The equipment technicians got out unharmed with much of the damaged, although still-functioning, gear belonging to Martin Wooster, a geographer at King's College London.

Wooster believes that the amount of carbon emitted from wildfires every year is possibly half that released by fossil-fuel consumption. He has been traveling the world collecting data to confirm his theory. In the Canadian test, he had an opportunity to gather data at ground level and at 300 meters above the fire in a helicopter. Researchers will use the observations to test the accuracy of satellite data.

While making an infrared film, Wooster watched the test fire jump across the firebreaks around the experimental site. Within a few hours, more than 1400 hectares of magnificent pine forests were ablaze. Water bombers, surveillance planes, and Wooster's rented helicopter scrambled to get the situation under control. Wooster came away with an impressive data haul that will help to validate the usefulness of infrared measurement, he said later. But Ontario forest officials were not pleased. "I strongly doubt they'll be quick to give permission for more such experimental fires in future," Wooster said.

Foresters aren't the only ones to express doubts; Russian security officials have been wary, too. Thanks to an infusion of funding from the International Science and Technology Center in Moscow, which supports nonmilitary collaboration between Western scientists and those within the Russian weapons complex, FIRE BEAR has attracted former-Soviet military experts in remote sensing. Other scientists have joined, including members of the Siberian RAS's Institute of Chemical Kinetics and Combustion in Novosibirsk, as well as U.S. researchers funded by NASA.

Some Russians have complained of being arrested and undergoing harrowingly long interviews, says Anatoly Sukhinin, a remote-sensing expert who joined FIRE BEAR after a career in the Soviet military. "I still spend a fair amount of my time explaining our work to the police," complained Sukhinin, sitting in his laboratory in Krasnoyarsk, which NASA helped equip to receive and interpret Siberian fire data beamed from American and Russian satellites. "It doesn't help that we're doing these experiments in a region which was until recently secret and still remains heavily militarized."

Despite the hassles, the partnership seems to be paying off. In recent years, says Amber Soja, a research scientist with the U.S. National Institute of Aerospace, currently resident in the Climate Dynamics branch of NASA's Langley Research Center in Hampton, Virginia, FIRE BEAR papers have widened knowledge of Siberian forest fires and their global atmospheric effects. In 1998, Brian Stocks of the Canadian Forest Service reported a positive correlation between climate-change impacts and an increase in the severity of Siberian fires. A 2004 paper by Soja, along with McRae, Sukhinin, and Susan Conard of the USDA Forest Service, concluded that disparities in the amount of carbon stored in different forest types and the severity of fires within them can affect total direct carbon emissions by as much as 50%. This is why they need specific data on larch fires, which emit less carbon than pine. In extreme fire years, they found, total direct carbon emissions from wildfires can be 37% to 41% greater than in normal ones, because severer fires consume more organic matter in the forest floor.

Last year, Soja, Stocks, and Sukhinin published a review of predictions of climate-induced boreal forest change. Four of seven models predict that warming in Siberia will be 40% greater than the global mean. Soja spent several weeks at the FIRE BEAR camp near Kodinsk last summer, living in a tent and subsisting largely on tinned fish and buckwheat cereal while comparing notes with her Canadian and Russian co-investigators in the run-up the test burn. The predictions she co-reviewed, she says, are already coming true in Alaska, Canada, and Russia. In Siberia, 7 of the last 9 years have resulted in extreme fire seasons, she explains. Speaking from the camp, she said, "If you are looking for climate-change impacts on forests, this is the place to be."

On the day of the big test burn this summer in Kodinsk, however, all predictions went up in smoke. Minutes after local fire crews ignited the perimeter of the experimental larch site with benzene, dark clouds suddenly appeared and rain doused the flames. "You'd be surprised how often this sort of thing happens," McRae said with a shrug. "That's what you get for playing with fire." The researchers, who still need the larch data, are already planning to torch a forest in Siberia next summer.

–PAUL WEBSTER

Paul Webster writes from Toronto, Canada.

CREDIT: PAUL WEBSTER

Published by AAAS

Appendix 12 – Letters of support and further comments from users

DEPARTMENT OF GEOGRAPHY, DOWNING PLACE, CAMBRIDGE CB2 3EN, UK

+44 (0)1223 333386 & 719712; 07905 368818 (mobile)

+44 (0)1223 333392

co200@cam.ac.uk

http://www.geog.cam.ac.uk/people/oppenheimer/

Dr. T.J. Malthus,
NERC Field Spectroscopy Facility (FSF),
Grant Institute, School of GeoSciences,
University of Edinburgh, West Mains Road,
Edinburgh EH9 3JW.

1st December 2008

Re: NERC FSF

Dear Tim,

I am writing to express our group's immense appreciation for all the support we have received from FSF, and to commend the Edinburgh team for its outstanding service to the UK scientific community. The loans of Sun photometer and spectroradiometers we have received have played a key role in several field campaigns, enabling a range of novel geological and atmospheric measurements. These have included characterisation of aerosol emitted by volcanoes, agricultural fires, and the Buncefield oil depot fire, and recently, measurement of surface reflectance of lavas in the Danakil region of Ethiopia (as part of a major field mission carried out by the NERC Afar consortium). The Buncefield case is worth elaborating on: it was one most significant industrial accidents in the UK, and it is thanks to the rapid response and flexibility of FSF that we were able to deploy the Microtops in time, yielding some of the only reported measurements of the smoke plume (Mather, T.A. et al., 2007, Observations of the plume generated by the December 2005 oil depot explosions and prolonged fire at Buncefield (Hertfordshire, UK) and associated atmospheric changes, *Proc. Royal Soc. A*, 463, 1153-1177).

We have enjoyed rich discussions and advice from Chris and Alasdair over the years, and particularly appreciated the FTIR workshop they co-organised with Martin Wooster in London last year. This was a really informative and well-attended meeting, which highlighted the broad interest in trace gas spectroscopy across the environmental science community. The FSF is to be strongly commended for championing investment in its new custom-built, compact FTIR spectrometer. This instrument can measure many environmentally significant gas species, as well as IR emissivity signatures, and is particularly flexible for field operation. It will surely support a wide range of innovative studies in terrestrial ecology, atmospheric science, optics and radiative transfer, etc.

To sum up, we affirm that the FSF has been doing a wonderful job in supporting UK science, and we are certainly looking forward to future collaborations with the Edinburgh team.

Yours sincerely,

Clive Oppenheimer, University Reader in Volcanology and Remote Sensing

UCL

04 January 2009

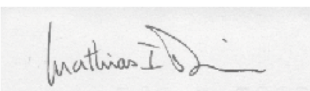
I am very happy to be able to write a letter of support for the NERC Field Spectroscopy Facility. Over the past few years we have relied heavily on the FSF to help support our field-based activities. This support has not been limited to the role of providing FSF equipment for field campaigns, but has encompassed help in maintaining and calibrating our own equipment, training our PhD students and postdocs, as well as providing advice regarding measurements, data processing and so on.

Over the past few years we have been part of the NERC Centre for Terrestrial Carbon Dynamics and are now part of the new NERC Centre for Earth Observation (Carbon Theme). During this time we have participated in a number of our own field campaigns, as well as taken part in larger international campaigns in support of ESA and NASA missions (e.g. the Sen2Flex campaign for the proposed ESA FLEX Explorer mission). In October of this year for example, we undertook a field campaign in South Africa as part of an ESA-funded project to develop a new fire scar detection algorithm. FSF responded very quickly to a late request for equipment, and subsequently provided invaluable advice on handling of the resulting data. This rapid turnaround and flexibility makes the service provided by FSF invaluable.

We have been fortunate enough to acquire various pieces of field spectroscopy equipment over the past few years, including a Microtops sun photometer, an ASD FS Pro and an integrating sphere. We are more than happy to have the ASD looked after by the FSF and to be made available to support other NERC-funded research. Another example of FSF help has been in addressing issues with our integrating sphere. We were one of the first to draw the manufacturer's attention to fundamental flaws in the design which rendered it unfit for purpose. But this was only possible through consultation with FSF staff, who identified and quantified the problem and then mediated with the manufacturer to see what could be done. As a result the basic instrument design has been modified and we are receiving a new instrument.

The kind of support and expertise FSF have provided to us is difficult to quantify but I am absolutely certain it has increased our ability to do good field-based research and has made our use of NERC funding and equipment much more effective than it would otherwise have been.

Yours sincerely,



Dr. Mathias Disney
Lecturer in Remote Sensing
UCL Department of Geography
London WC1E 6BT
E: mdisney@geog.ucl.ac.uk

UCL Geography
University College London Gower Street London WC1E 6BT
Tel: +44 (0)20 7679 0592 Fax: +44 (0)20 7679 0565
mdisney@geog.ucl.ac.uk
www.geog.ucl.ac.uk/~mdisney

Further comments from users:

Dr T. Blackall, King's College London	"FSF are one of the most efficient, well-organised and professional organisations that I interact with during both my research and broader academic work. Their efforts to open up the possibilities of spectroscopy to those of us from other backgrounds are very much appreciated!"
Dr K. Anderson, University of Exeter	"I did not receive training due to previous experience with the equipment. However the online help manuals were great and I received near real time support from FSF staff over email, which, from California, was impressive!" "FSF provides high quality support for a range of users. FSF support has been essential for international collaborative work that I have undertaken this year at NASA, and for supporting my NERC-funded PhD student. Without FSF we would not have been able to collect high-quality traceable data in support of our projects. I am particularly impressed with the radiometric support I recieved in relation to the NASA project, calibration data were supplied very rapidly."
Dr Mike Smith, University of Kingston	Sun, 06 Jul 2008 I spent a day this week at the NERC Field Spectroscopy Facility receiving some training in the use of a GER1500 that is being used to study loess profiles. The facility is extremely well run with the training not only being thorough but also very practical indeed. They have a good pool of equipment (GER, ASD etc) that can be used in a variety of environments (e.g. marine) with a rolling programme of upgrades. They are also very active in both the development of field spec techniques as well as their application and are in regular contact with the manufacturers. As with any NERC equipment (e.g ARSF), an application form should be completed with deadlines of 1 June and 1 November. This should provide a supporting science statement and detail of the methodology. It's not onerous, but clearly the FSF has to be sure it is funding appropriate projects. [Blog at http://www.journalofmaps.com/cgi-bin/blosxom.cgi/remote_sensing/fsf.html]
Dr John Hedley, University of Exeter	"I haven't received much personal support but I have been involved with the FSF through assisting them with training and promotion of the aquatic spectroscopy kit. I believe the role of the FSF in providing this high-end equipment is not only invaluable to the UK research community but can pro-actively promote and shape excellence in research in the UK. Personally acquiring this kind of expensive equipment is substantial barrier to entry to cutting edge research for many UK academics. The FSF removes that barrier to entry and thus enables UK researchers to compete academically with those in other (perhaps) more well resourced countries. This clearly has a knock on effect to generation of IP and commercialisation within the UK. However, the uptake of new instrumentation by the community will obviously take time, while the users become familiar with what is available and and formulate their own research strategies. Therefore, I sincerely hope the current FSF contract will be renewed, so the FSF will have sufficient time to demonstrate the benefit of the groundwork that they have done in recent years."

Professor Ted Milton, University of Southampton	“My main use of the facility as PI during this period was in support of the NCAVEO 2006 Field Campaign. The support provided by FSF was exemplary, and contributed significantly to the success of the campaign. I feel strongly that the FSF should continue. There is a demonstrable need for a national facility of this sort, and the present arrangement appears to be working well.”
Anonymous questionnaire response	“FSF in Edinburgh provide a hugely beneficial resource to the research community. Their pool of state-of-the-art instrumentation provides the opportunity for high quality research that may otherwise be too costly (in capital terms) for individual institutions. The service provided by the FSF team in Edinburgh is first class. They are approachable to those with a non-spectroscopy background, thus creating the opportunity for a wider user community than may be expected. Furthermore, the level of technical support is excellent, ensuring that the loaned instrumentation is in excellent working order, that clear and detailed instruction is provided to users and that further support is available when necessary.”
Anonymous questionnaire response	“Without the support of the facility it simply would not be possible to conduct the research we are currently involved in. The support has been essential in terms of the access to equipment, but also for training and input of fresh ideas. The application of field spectroscopy is relatively uncommon in our area of research so any access to such support is essential. Access to the facilities at NERC FSF, as well as the further support offered, has enabled the initiation of our project and promises to play a key part in the further development of the research. For example, the facility plays a vital roll (sic) in combining the interest and application ideas of its users, with the facility team's knowledge of potential suitable equipment. Further, I strongly believe that facilities such as the FSF are vital for the health of 'blue skies' scientific research in the UK. Access to otherwise unavailble equipment enables testing of ideas and the formulation of projects that are then backed by initial data. Without such opportunities blue skies research will rarely have the chance to get off the ground. If anything this is as important an aspect of NERC as are the opportunities for project funding via grants. The FSF is no exception here, particularly because much of the equipment is otherwise inaccessible and the staff have an extensive knowledge of potentially applicable techniques.”
Anonymous questionnaire response	“I have received support from FSF on 4 occasions borrowing the GER1500 and the acs+bb+radiometers suite. In all occasions the instruments have been provided in a timely way and in an excellent working condition (i.e. recently calibrated). Not only the service was accommodating with time required, but also staff made all efforts to resolve problems fastly and effectively, in a very satisfactory way. I think that having a national capability in field spectroscopy for the marine optics community is essential as these instruments require regular calibrations and attentions to ensure the quality of the data. Unfortunately, quite often there is not an explicit funding for this maintenance in normal science proposals, hence the great advantage of keeping the FSF in operation and fully funded by NERC, to keep marine optics research at its highest standard.”

Anonymous questionnaire response	“The FSF has provided with excellent support over a number of years. In conjunction with the ARSF the FSF provides a unique capability in the world for the support and advancement of Earth Observation Science.”