Progress in Field Spectroscopy

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1976...
1976...
Appendix E
Portable Field Reflectance Spectrometer
A. F. H. Goetz

I. Purpose
At the start of this ERTS investigation and through involvement in other ERTS research in progress, it became evident that field measurements of surface spectral reflectivity would be necessary to:

1. Determine the effects of atmospheric absorption and scattering on ERTS spectral image values.
2. Establish a set of criteria for quantitative image analysis through computer image processing.
4. Establish the correlation between field-measured surface spectral reflectance and the necessarily small, selected samples measured in laboratory reflectance equipment.

To span the wavelength range of the Skylab S-302 multispectral scanner (MSS) in the reflective portion of the spectrum and ERTS MSS bands required a spectral coverage of 0.4 to 2.5 μm. However, no instrument marketed covered the spectral range at the resolution desired or was sufficiently portable for field work in remote areas. In fact, existing specialized systems required a vehicle and generator power to record and analyze data.

The system described here was designed to meet the following criteria:

1. Backpack, field-portable.
2. Complete coverage of the spectral region 0.4 to 2.5 μm with moderate resolution (Δλ/Δλ = 0.02 to 0.04).
3. Stability over a wide range of temperatures.
4. Digital data recording.

II. The System
The portable field reflectance spectrometer (PFRS) system consists of a separate optical head and amplifier-recorder assembly (see Fig. E.1). In the field, the electronics pack is worn continuously by the operator. The optical head, mounted on a tripod, is hand-held, but is carried on a pack frame when moving from area to area. A hand-held meter indicates the signal level and is used to set gain levels. In operation, all results are reduced to spectral reflectance values for comparison of areas measured under various lighting conditions.

A. Optical Head
An artist’s view of the optical head is shown in Fig. E.2. In sequence, the beam enters the instrument at the left...
Progress in Field Spectroscopy – since late 1980s

• Deering (1989)
• Milton (IJRS, 1987)
• Slater (IEEE, 1985)

• Progress in Instrument Design
• Progress in Methodology
• Progress in defining the Role of FS
Progress in Instrument Design
Instrument design challenges

- SNR in SWIR
- Temperature
- Polarisation
- Field-of-view
- Radiometry

- Spectron SE590 : Markham et al. (1995)
- ASD PSII : Markham et al. (1995)
- GER 3700 : Schaepman and Dangel (2000)
- ASD FieldSpec FR : Kindel et al. (2001)
Solar radiometry using an ASD FieldSpec FR

Kindel et al.
Applied Optics, 2001
Some outstanding issues...

- Total cost of ownership
- Sunlight-readable screens
- Optical fibres
- Steps in spectra

http://fsf.nerc.ac.uk/
Of the nine geometric configurations described by Nicodemus et al. (1970), four are measurable in the field and/or lab:

- Biconical
- Conical-Hemispherical
- Hemispherical-Conical
- Bihemispherical

in practice... Reflectance Factors
Reflectance Factors, pros and cons

- Convenient in the field.
- Standardised methodology.
- Spectral reflectance curves.

- Reference panels need calibrating (spectral and angular).
- Reference panels deteriorate over time.
- **Reflectance factors** are not an inherent property of the target.

... need to pay more attention to the spectral irradiance distribution.
Quantifying the irradiance spectrum - 1

Simultaneous measurement

Simultaneous estimation

[Diagram with graph showing reflectance error vs. wavelength]
Representations of the angular irradiance distribution

Hemispherical-Conical

The standard geometry for measurement of Reflectance Factors.

Biconical

The desirable geometry for measurement of non-Lambertian surfaces.

- Direct-to-Diffuse ratio must be measured as well.
- Aerosol Optical Thickness from sunphotometry.
- Sky irradiance distribution (measured or modelled).
- Traceability to SI requires radiance, not reflectance.
Quality metrics for Field Spectroscopy

Repeatability
A property of the instrument. Defined by the precision of a series of measurements of a stable source, e.g. integrating sphere for spectral radiance.

Reproducibility
Depends on the instrument and how it used in the field. Methodology affects reproducibility.

Terminology
Unique description of the measured quantity, not only using proper radiometric terms but also geometrical-optical terms (geometry of incoming and reflected radiance).

Accuracy
Closeness of the measurement to the ‘true’ value. Requires clear definition of the measurand and a demonstrably unbroken chain of traceability to the primary standard, with known uncertainty at every step.
Roles of FS: 1. ‘Spectroscopy in the field’

Iron Chlorite

Mean Reflectance (%) (offset for clarity)

Wavelength (nm)

- Mean Reflectance 100W Lamp (%)
- Mean Reflectance 100W Lamp rotated (%)
- Mean Reflectance Contact Probe (%)
- Pima Reflectance
Role #2: Measuring the radiation environment

Pegrum et al., 2006 (this conference)
Goniospectrometry using a CCD array
Roles of FS : 3. Vicarious Calibration
An Instrument Package for Vicarious Calibration?

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Purpose</th>
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<tbody>
<tr>
<td>1. Constant panel set-up</td>
<td>Time series of irradiance spectra (plus direct/diffuse).</td>
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<tr>
<td>2. Mobile spectrometer</td>
<td>Spatial variation of reflectance</td>
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<tr>
<td>3. Goniospectrometer</td>
<td>Angular variation of reflectance</td>
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<tr>
<td>4. Sky camera</td>
<td>Permanent visual record</td>
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<td>5. Sun photometer</td>
<td>AOT and EWT</td>
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</tbody>
</table>
Seasonal change in playa surface properties
Environmental sources of uncertainty in VC

- Disused airfield in UK
- Concrete, Asphalt, Grass
- Mobile platform
- Dual-beam GER1500
Seasonal change in hemispherical-conical reflectance

TSC1 reflectance vs cosine of solar zenith angle at 650nm

- 6 August 2003
- 12 August 2003
- 14 July 2003 (am)
- 14 July 2003 (pm)
- 24 June 2003 (am)
- 29 May 2003
- 24 June 2003 (pm)
- 09 May 2003
- 16 April 2003
Conclusion

- High performance instruments now available.
- Clear roles for field spectroscopy.
- Methodological development slow.
- Combined geometrical-optical and radiometric terminology for spectroscopic measurements needs to be established.

- Dynamic processes, e.g. solar-excited fluorescence.
- ‘Spectral reflectance’ is a family of related measurands, not a single entity.
- Reflectance Factors are fine for some applications.
- BRDF is an unattainable goal in the field, but a set of measurements allowing the proper parameterization of the BRDF needs to be acquired.
Surface anisotropy 1952 compared with 2003

Knowles-Middleton and Mungall (1952)

Painter et al. (2003)