Dual spectral radiance standards can minimize calibration uncertainty in the SWIR region, 1-2 µm

Chris MacLellan
NERC Field Spectroscopy Facility,
University of Edinburgh, UK
Background

• NERC Field Spectroscopy Facility
  • Calibration labs in Edinburgh and Cambridge, UK
  • FEL irradiance standards & sphere sources calibrated by NMI
  • Radiance calibration of airborne sensors
    • Itres CASI
    • Specim AISA – Eagle, Hawk, Fenix
AVIRIS Radiance Calibration (1993)

*Figure 7.* Radiometric calibration laboratory setup. A spectroradiometer is calibrated using a NIST-traceable lamp. The calibrated spectroradiometer is used to calibrate a 100 cm integrating sphere which provides the spectral radiance input for the calibration of AVIRIS.

Radiance Source from Irradiance Standard & Panel

- **Equipment**
  - FEL Lamp, stabilised current source
    - calibrated for spectral irradiance, $E$
  - Diffuse reflectance panel or tile,
    - calibrated spectral radiance factors, $\beta$
      for a specific viewing geometry, $0^\circ : 45^\circ$
  - Collimator optics (not used here)

- Radiance of panel, $L = E \times \frac{\beta}{\pi}$

- **Sources of uncertainties**
  - Non uniformity of panel illumination -> radiance across FOV
  - Radiance factors
  - Stray light
  - Setup (alignment & distance)
Radiance Sphere Sources

- **Benefits:**
  - Simplicity
  - Uniformity
  - Variable output
  - Built in monitoring

- **Sources of uncertainty:**
  - Internal coating absorption
  - Coating instability / ageing
  - Small contamination -> large change in radiance output
  - Phase change (PTFE) @ 19°C
Why bother with dual calibration?

Comparison of NMI Calibration Uncertainty, Radiance Sphere vs FEL Irradiance Standards

- Uncertainty vs Wavelength [nm]
- Line graph showing uncertainty percentages for different wavelengths for Sphere Source and FEL Standard.
Calibration Standard Data
Interpolation & Sampling Issues

[Spectral Radiance Sphere Source
Internal Coating: BaSO₄]

Radiance mW/sr/m²/nm vs Wavelength [nm]

- Manufacturer Cal.
- NMI Calibration
Δ SWIR Region (Sphere Source)

Spectral Radiance Sphere Source
10 & 50nm Sample Intervals

Radiance mW/sr/m²/nm vs. Wavelength [nm]
- Manufacturer Cal.
- NMI Calibration
- Δ (Manufacturer)
- Δ (NMI)
Poorly Interpolated Data

Spectral Radiance Sphere Source

Wavelength [nm]

Radiance mW/sr/m²/nm

- Manufacturer Cal.
- NMI Calibration
- $\Delta$ (Manufacturer)
- $\Delta$ (NMI)
Δ SWIR Region (Sphere Source)
Pressed PTFE Sources

Spectral Radiance Sphere Source
Internal Coating: Pressed PTFE

Radiance W/sr/cm²/nm vs. Wavelength (nm)

- Manufacturer Cal.
- $\Delta$
Filling in the blanks

Spectral Radiance Sphere Source
Calibrated w.r.t. FEL Standard

Radiance mW/sr/m²/nm

Wavelength [nm]

Preferred Wavelengths

WRT FEL Std.

Preferred Wavelengths
Irradiance Standard

![Graph showing the spectral irradiance of FEL F-979 with wavelength in nm on the x-axis and spectral irradiance in mW.m⁻².nm⁻¹ on the y-axis.]
SWIR Region 1000 – 2000nm

NMI Calibrated FEL Irradiance Standard
(10nm Sample Interval)
Water Absorption Bands
HITRAN $\text{H}_2\text{O}$ Data

$\text{H}_2\text{O}$ Spectral Transmission, High & Low Resolution Data
0.5 & 1m Path Length, 10,000 ppm, 24°C

~0.23nm, 0.5m
~9nm, 1m
~9nm, 0.5m
Radiance (with Absorption)

Radiance: FEL Standard + Panel
Measured at 1m with Spectroradiometer (FWHM = 1.2nm)
Radiance (with Absorption)

Radiance: FEL Standard + Panel
Measured at 1m with Spectroradiometer (FWHM = 6.9nm)
**AVIRIS Radiance Calibration (1993)**

*Figure 7.* Radiometric calibration laboratory setup. A spectroradiometer is calibrated using a NIST-traceable lamp. The calibrated spectroradiometer is used to calibrate a 100 cm integrating sphere which provides the spectral radiance input for the calibration of AVIRIS.

Sphere Source Cal. wrt FEL Std

Radiance - Sphere Source
Measured with Spectroradiometer (FWHM = 6.9nm)
Radiance Calibration
Radiance Calibration (SWIR)

Radiometric Calibration Function
with FEL Standard & Panel, FWHM @ 1.2nm

- Rad. Cal. Function
- Water bands
- Δl
Spline Fit Across Water Bands

Radiometric Calibration
with FEL Standard & Panel, FWHM @ 1.2nm

Wavelength [nm]
Smoothed Rad. Cal. Function

Smoothed Rad. Cal. Function

Radiometric Calibration Function

Wavelength [nm]

Smoothed RSR

Water bands

Δ
Conclusions

- Irradiance standards have lower uncertainties compared to calibrated radiance spheres.
- However, radiance sphere calibrations offers many benefits.
- Be aware of interpolation of data for your calibration standards.
- Use 1\textsuperscript{st} derivative to identify discontinuities in the calibration data.
- More difficult to negate effects of atmospheric water absorption from a radiance sphere compared to radiance from ‘FEL’ illuminated panel.
- All spectral features in a radiometric calibration function should have an explanation, again use 1\textsuperscript{st} derivative to identify discontinuities
- The FEL illuminated panel offer possibility to perform a radiance radiometric calibration across water bands.
- Multiple traceability paths back to NMI