Emerging Techniques for Vicarious Calibration of Visible Through Short Wave Infrared Remote Sensing Systems

Authors: Robert E. Ryan, Gary Harrington, Kara Holekamp, Mary Pagnutti, Jeffrey Russell, Troy Frisbie, Thomas Stanley

Background
- Over the next several years, more than 50 optical remote sensing systems with 39-nm or better resolution will be in orbit.
- 13 countries presently have imaging satellites in orbit; 20 countries will have imaging satellites in orbit by 2010.
- 30 imaging systems are in orbit; 25 imaging systems are planned by 2010.
- These figures do not include the large number of advanced airborne multispectral imaging systems.

Issues
- The scientific community needs geodetically and radiometrically accurate products from the present and future "constellation" of spacecraft and airborne systems.
- Insight into the system construction, calibration, and performance will be limited in many cases.
- Most systems will not have any onboard radiometric calibration.
- Cal/Val (calibration and validation) will be essential.
- Multiple approaches are available.
- Ground-based radiometric calibration has the greatest utility because all systems image the ground.

Typical Radiometric Vicarious Calibration

**Radiative Transfer Validation**
- Verify parameters used to generate MODTRAN radiative transfer estimates.
- Measure the radiance of a Spectran solar panel with a well-calibrated spectroradiometer.
- Use ground-truth data and geometry that models an ASD FieldSpec FR (full range) spectroradiometer measuring a 99% reflectance Spectran panel as input to MODTRAN to predict the radiance.
- Compare MODTRAN-calculated radiance to actual radiance measured from Spectran panel to verify the atmospheric model.
- After panel Bi-directional Reflectance Distribution Function (BRDF) correction and radiometric calibration with NIST calibrated integrating sphere, the expected panel radiance measurement uncertainty is <2%.

**Shadowband Sun Photometer Measurements**
- The radiance difference is the sum of the direct component and the diffuse component:
- \[ E_{direct} = E_{diffuse} + E_{direct} \]
- The direct component of radiance can be written in the following terms:
- \[ E_{direct} = E_{atm} c sin(\theta) \]
- Solving for \( \tau \):
- \[ \tau = \frac{\ln(1 - E_{total})}{E_{atm} c sin(\theta)} \]
- Diffuse-to-global ratio (D2G) used to determine molecular scattering can be defined as:
- \[ D2G = \frac{E_{diffuse}}{E_{total}} \]

**Alternative Sun Photometer Implementation**
- Spectran can be considered an in-situ-vicarious container for the spectroradiometer to calibrate a sun photometer.
- Knowing the reflectance factor \( \rho \) as a function of zenith angle and azimuth angle:
- \[ E_{atm} = E_{atm} c sin(\theta) \]
- \[ \tau = \frac{\ln(1 - E_{total})}{E_{atm} c sin(\theta)} \]
- Diffuse-to-global ratio (D2G) used to determine molecular scattering can be defined as:
- \[ D2G = \frac{E_{diffuse}}{E_{total}} \]

**Test Case Evaluations**
- TCA radiance values for selected targets on two days. Radiance values generated with alternative sun photometer method are compared to radiance values generated with the traditional method.

**Alternative Sun Photometer Summary**
- Differences between the alternative and traditional sun photometer data (tau, D2G) are relatively small in most cases (<10%).
- Additional analysis shows that in certain cases, the prototype may produce more accurate measurements than the traditional method in a Sierra-like environment for lack of sufficient langley standards.
- Improved techniques in all sun photometer calibrations.
- Utilizes existing commonly used vicarious calibration equipment.
- Spectral drift and calibrated spectroradiometer for the need to be deployed to catch many sunrises and sunsets can be minimized.
- Spectral range for hyperspectral measurements.
- Current processing uses spectral signatures to generate bands for either MFRSR or ASD.
- Spectroradiometer calibration critical to success.
- High-quality, in-situ calibration can be extremely beneficial.

**Desired In-field Radiometric Calibration Source**
- Radiance level comparable to sea-level solar radiation values off terrestrial targets at the polar regions.
- Radiometric stability equal to or better than 1%.
- Capability of operating over a wide temperature range (10-40°C).
- Spatially uniform light field over at least a 25 mm diameter aperture.
- Stability better than 0.1%.
- Capability of operating for a continuous period of 8 hours without a fine source.
- Single-pen aerosol portable.

**Typical Laboratory Radiometric Sources**
- 1) Integrating sphere (not field deployable or reliable)
- 2) Spectroradiometers with traditional tungsten-Halon lamps (relatively source)

**Illumination Sources**
- **LED-based Source**
  - Exploit recent developments in high-power LED sources.
  - Utilize integrating sphere to create uniform light field.
  - Use high-stability control to achieve radiometric stability.
  - Test and characterize system with environmental chamber and independent spectroradiometer.

- **LED-based Radiance Source Characteristics**
  - Temperature-stabilized white LED.
  - Spectral range: 420-780 nm.
  - Other LEDs would increase the spectral range.
  - Temperature-stabilized photodetectors.
  - Feedback loop stabilizes integrating sphere radiance level.
  - Short-term drift <0.2%.
  - Short-term drift <0.5% over temperature range 10-40°C and over large spectral range.

- **LED-based Radiance Source Calibration Spheres**
  - Spectralon panel and calibrated spectroradiometer.
  - Environmental conditions can be controlled.

- **POC:** Robert E. Ryan, rryan@ssc.nasa.gov; Mary Pagnutti, mpagnutti@ssc.nasa.gov