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

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**Background**
- Over the past several years, more than 50 optical/thermal imaging systems with 39 to 76 resolution will be in orbit.
- 13 systems will have imaging satellites in orbit.
- 20 imaging systems are planned by 2010.
- All have potential to contribute to the scientific community.

**Issues**
- The scientific community needs geometrically and radiometrically accurate products from the present and future "constellations" of spaceborne 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/validation) will be essential.
- Multiple approaches are required.
- Ground-based reflectance radiometric methods have the greatest utility because all systems image the ground.
- Ground-based radiometric calibrations currently require teams of trained staff taking coincident data at the time of overpass and analysis to estimate Top-of-the-Air (TOA) radiance.
- Costly.
- Significant coordination is required between the imagery provider and the cal/val team.
- A variety of sites is needed.

**Ground-based Radiometric Cal/Val Needs**
- Improved accuracy and higher confidence in TOA radiance estimates.
- Measurement techniques that reduce or at least not increase staff.
- Simpler and more accurate calibration approaches.
- Mid-term.
- Development of techniques that are compatible with autonomous measurements.
- Longer term.
- Fully autonomous vicarious calibration techniques and sites.

**SSC Near-Term Cal/Val Development Goals**
- Improved accuracy and higher confidence in TOA radiance estimates.
- Radiative transfer modeling of TOA radiance.
- Laboratory calibration of solar radiometers.
- Radiometric calibration.
- Development of measurement systems that are compatible with autonomous measurements.
- Laser and penlamp illuminating spheres.
- Environmental testing.
- Temperature stability testing performed in environmental chamber.

**Radiative Transfer Validation Example**
- Typical radiometric vicarious calibration.
- Ground-based radiometric vicarious calibration.
- Critical to success.

**Typical Radiometric Vicarious Calibration**
- Measurement of Top-of-the-Air (TOA) radiance.
- Typical radiometric calibration.
- Critical to success.

**Typical Sun Photometer Measurements**
- Ground-based radiometry.
- Direct Normal (e.g., Arizona Solar Radiometer).
- Total, Diffuse, and Direct Normal (e.g., Multifilter Rotating Shadowband Radiometers).
- Solar atmospheric transmission.
- Ground-based radiometric vicarious calibration.
- Capable of operating over a wide temperature range (10–40 °C).
- Spatially uniform light field over a 25 cm diameter aperture.
- Spectrally stable.
- Capable of operating for a continuous period of 8 hours without a line source.
- Single-person portable.

**Typical Shadowband Sun Photometer Measurements**
- Total direct irradiance is equal to the sum of the direct component and the diffuse component.
- The direct component of irradiance can be written in the following terms.
- Extraterrestrial irradiance (E0).
- Relative atmospheric thickness (τ).

**Test Case Evaluations**
- TOA radiance values for selected targets on two days.
- Radiance values generated with alternative sun photometer optical path difference in comparison with reference values generated with the traditional method.

**Summary**
- Autonomous Visible to SWIR ground-based radiometric Cal/Val will be an essential Cal/Val component with such a large number of systems.
- Relocatable and calibratable sun photometers can improve confidence in current ground truth data.
- Vicarious calibration.
- Validation or replacement of traditional sun photometer measurements.
- Should enable significant reduction in deployed equipment such as equipment used in traditional sun photometer approaches.

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

**LED-based Radiance Source Characteristics**
- Temperature-stable white light (LED).
- Spectral range: 440–750 nm.
- Other LEDs would increase the spectral range.
- Temperature-stable phosphor and feedback loop stabilize integrating sphere.
- Short-term drift <0.2%.
- Short-term drift <0.5% over temperature range 10–40 °C.
- Large power requirements.

**Test Case Results**
- LED-based Radiance Source Characteristics.
- New Calibration Approach: High-intensity LEDs.
- Diode Lasers with traditional Tungsten–Halon lamps.
- Radiance source.
- illumination sources.
- Laboratory transfer radiometers.
- Surface reflectance for V&V field collection activities.

**Stennis Verification (V&V) Site**
- NASA SSC maintains four ASD FieldSpec FR spectroradiometers.
- Laboratory transfer radiometers.
- Surface reflectance for field collection activities.
- Radiometric stability.
- Spectralon panel and calibrated spectroradiometer.
- Laser and penlamp illuminating sphere.
- Environmental testing.
- Temperature stability testing performed in environmental chamber.

**Calibration and Characterization of ASD FieldSpec Spectroradiometers**
- NASA SSC maintains four ASD FieldSpec FR spectroradiometers.
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**Radiometric Vicarious Calibration Example**
- MODTRAN radiance vs. Average Spectran Radiance from ASD.

**Differences in TOA radiance between the two methods are negligible in most cases.**

**Alternative Sun Photometer Summary**
- Differences between the alternative and traditional sun photometer data (tau, COS) are relatively small in most cases (<0.02).
- Additional analysis shows that in certain cases, the prototype may produce more accurate measurements than the traditional method in a Srenia-like environment for lack of sufficient light.
- Improved performance in all sun photometer systems.
- Utilizes existing commonly used vicarious calibration equipment.
- Precision drift and calibrated solar radiometer.
- Prototype demonstrated less than 0.5% drift over 10–40 °C temperature range.
- Improved stability and larger measurement range.

**LED-based Approach**
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**Comparison of LED Integrating Sphere with Traditional Sources**
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