Importance of Calibration/Validation Traceability for Multi-sensor Imaging Spectrometry Applications

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Continue the push for SI-traceable, high accuracy data

Especially important to maximize results from future imaging spectroscopy missions

- Current inter-consistency methods are not well suited for imaging spectroscopy’s orbits and narrow swaths
- Interchangeable data sets from multiple sensors will require improved traceability and error budgets
- Need to ensure that techniques to reduce sensor radiometric uncertainty are applicable to field and airborne systems

**How best to ensure compatibility of data sets?**

**Correcting band-to-band differences will be more critical**

![Graph showing differences between various sensors](image-url)
Use CLARREO Pathfinder work to illustrate benefits of traceability

- CLARREO Pathfinder is a directed mission through the NASA Science Mission Directorate – Earth Science Division
- Targeted for launch in late CY2020 – early CY2021 to International Space Station for one-year mission

Demonstrate high accuracy
SI-Traceable Calibration

Demonstrate Inter-Calibration
Site characterization a part of CPF interconsistency

- CPF will concentrate on CERES and VIIRS
  - Demonstrate view and temporal matching
  - Show importance of imaging spectrometry
  - Use a full range of scene types

- Lunar views will improve knowledge of moon’s calibration
- CPF will be tasked regularly to view a range of vicarious calibration sites
  - Characterize sites used by other sensors besides VIIRS and CERES
  - Simplifies tasking of CPF

Ground-based Measurements

Satellite-based Measurements

Airborne-based Measurements

Model-based “Measurements”

Predicted At-sensor radiance

Radiance is for arbitrary
1) Time
2) View angle
3) Sun angle

SI-Traceable with documented error budget and uncertainty

Selected Test Site

Lunar views will improve knowledge of moon’s calibration

CPF will be tasked regularly to view a range of vicarious calibration sites

- Characterize sites used by other sensors besides VIIRS and CERES
- Simplifies tasking of CPF
Why is CPF (or something similar) needed?

Results from desert sites show variability not explained by known uncertainties.

No singular cause for outlier data sets has been found.

Either many small error sources, correlated errors, or unknown errors.
CPF’s high accuracy will help to decouple uncertainties

Are differences and variability from the sensor under study, atmospheric or surface effects, or field instruments?

Increasing reflectance with time - BRDF or instrumental?

Are differences due to instruments or change in surface or sampling?
Rely on modeling results to give insight

Atmosphere causes spectrally varying effects

But atmospheric effects do not appear to be the dominant uncertainty factor at some test sites

Landsat 7 Band 3 TOA Radiance Comparison

- Avg Atmo % Diff from Normal @ Ivanpah
- Avg Atmo % Diff from Normal @ RRV
CPF work has led to improved modeling of uncertainties

Monte Carlo results based on input uncertainties to radiative transfer code modeling of predicted top-of-atmosphere radiance

High aerosol loading with large sized aerosols for small solar zenith angle and six surface reflectance values
Modeling appears to match real life

Modeled uncertainties from a case typical of a desert calibration site

Low aerosol loading with small-sized aerosols and small solar zenith angle and six surface reflectance values

Compare the model results to those obtained by averaging calibration results from multiple dates
One key is to coordinate calibration approaches between airborne, satellite-based, and ground-based equipment.
CPF will provide a link between the laboratory and the field

**Source-based** - Absolute uncertainty (RSS, $k = 2$) at 650 nm is <1.5%

FEL lamp [1 kW quartz halogen lamp]

NIST calibrated 10’’ Spectralon panel illuminated at 50 cm

**Detector-based** - Absolute uncertainty (RSS, $k = 2$) <0.5%

Metrology facility

Vendor or other facility

![Graphs showing spectral comparison]
Portable, field transfer radiometers – multispectral to start

Response to a recommendation from CEOS Tuz Golu campaigns for a standardised radiometer that can act as a transfer standard to link test-sites traceability

Portability, size, and one-person operation were key design drivers

Optical design follows that of field radiometer with electronic design relying on the University of Arizona transfer radiometer designs

Primarily for on-site field calibration
Lead to better calibration of field radiometers

- Assess degradation of on-site radiometers without requiring returning instruments to laboratory
- Stability of transfer radiometer and radiance-based calibration provides a check on field radiometers used to assess surface properties
Summary

Development of well-understood, imaging spectrometers with high radiometric accuracy solves many issues

- Better radiometric accuracy implies better sensor quality
- Radiometric traceability allows use of data from multiple sensors without the need for on-orbit inter-comparisons
- On-orbit sensors with known absolute uncertainty and defensible traceability can act as transfer standards
- These are key concepts of CLARREO and CLARREO Pathfinder (CPF) mission
Conclusions

CLARREO Pathfinder will be an excellent tool for both direct interconsistency and for site characterization

- Will give another excellent example of the utility of imaging spectrometry
- Site characterization does not provide the same accuracy as direct interconsistency approaches
  - Fortunately, some sensors do not require full accuracy of CLARREO
  - Currently-used test sites will be understood to a level that should allow absolute calibrations rather than only trend analysis
  - Clearer understanding of Instrumented test sites and uncertainties caused by atmospheric and surface bi-directional effects
- Coordinated international efforts to understand ground sites will permit physically-based understanding leading to at-sensor radiance with absolute uncertainties <1%