Sensor interconsistency to achieve climate-quality measurements

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Need for inter-consistency

Climate-system modeling relies on a wide array of current (and future) systems

- Research-quality systems
- Operational weather systems
- Requires consistently calibrated and validated data sets
  - Intercalibration to a few high-quality sensors
  - Valid across time and multiple countries
Climate-quality data

“Absolute” uncertainties < 0.3% in band-integrated albedo

- TRUTHS (Traceable Radiometry Underpinning Terrestrial- and Helio-Studies)
- CLARREO (Climate Absolute Radiance and Refractivity Observatory)
Current calibration approaches

Best sensors have reflectance accuracy of 3.6% (k=2) in mid-visible [4.2% in radiance]

3.6% (k=2)

None of these approaches is adequate for climate-quality measurements

Intercomparisons 1.0% (k=2) relative
Detector-based approaches for climate quality

Near-monochromatic sources can be characterized to 0.09% (k=2)
TRUTHS takes that laboratory to space

- Primary reference is electric substitution cryogenic radiometer
- Tunable monochromatic beam calibrates other TRUTHS instruments
- Earth imager aperture illuminated by deployable diffuser
- Measures incoming and reflected solar
CLARREO relies on a ratioing radiometer approach to obtain reflectance

- Advantage is you have a known on-orbit calibration source
- Still requires careful characterization of the sensor in the laboratory
  - Stray light
  - Detector stability
  - Noise behavior

**Benchmark reflectance** from ratio of earth view to measurements of irradiance while viewing the sun

Lunar data provide calibration verification
Two approaches 1) near simultaneous views & 2) site characterization

- Near-coincident views require chance coincidences or active pointing
- Site characterization approaches rely on careful site evaluation to allow at-sensor radiance predictions
- Methods with SI traceability do not require sensor data to overlap in time
Site characterization

SI-traceable, ground-based measurements

- **Not** a sensor-to-sensor approach
- Allows calibration relative to an agreed standard
- **Multiple sensors** can be calibrated
Improved site characterization approach

**Selected Test Site**

- **Ground-based Measurements**
  - Radiance is for arbitrary
    1) Time
    2) View angle
    3) Sun angle
  - SI-Traceable with documented error budget and uncertainty

- **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

Requires highly accurate sensors to decouple atmospheric, surface, and sensor effects

Moves away from one-to-one cross calibrations and empirical only
Why need high-accuracy sensors?

MODIS and ASTER “easiest” case

- Same platform, coincident views, similar bands
- ASTER Band 1 (green band) results using MODIS
- Scatter caused by
  - Spectral band differences
  - Registration effects
  - Sensor effects
Differences between sensors

High-accuracy, imaging spectrometry would provide necessary understanding of test sites

- Cannot decouple
  - On-orbit sensor effects
  - Atmospheric variability
  - Surface variability

- All three play a role
  - Better sensor agreement in the NIR where SNR is largest for sensors
  - Atmospheric effects are not as dominant in NIR

- Improved field sensor design and characterization would improve results
- Improved on-orbit sensors would allow decoupling of uncertainties
### Why need hyperspectral?

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<th>C</th>
<th>D</th>
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Uncertainty due to spectral differences decrease as **hyperspectral** data of sites are accumulated.

Ground data, Hyperion, SCIAMACHY
Key measurements

Spectral and directional reflectance of surfaces are highest priority

- Temporal sampling
  - directional reflectance
  - Site stability
- Imaging provides spatial information
- Spectral samples aggregated to simulate bands
- Imaging spectrometry can lead to knowledge of surface morphology
Developing new laboratory approaches for space sensors allows more accurate characterization of field and airborne systems.
Climate-quality requirements will lead to important improvements in site characterization

- Move away from one by one empirical comparisons between sensors
- Requires agreed upon standard against which to compare sensors and products
- Climate-quality imaging sensors and field instruments will provide the data necessary for accurate physical models
- Such methods will provide improved relative agreement and eventually lead to absolute results with better understood uncertainties