Methods for radiometric cross-calibration of imaging sensors with and without overlapping collections

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Introduction

As evident from this conference, there exist numerous methods for on-orbit characterization

- Methods requiring measurements of surface and atmospheric properties at the time of a sensor overpass
- Methods relying on knowledge of the temporal characteristics of the site being viewed
- Cross-calibration methods fall under both categories
  - Relies on knowledge of a source that is common to both sensors
  - Typically near-coincident views
- More recent work has emphasized methods that do not require simultaneous data collections

Talk overview

Discuss SI-traceable approaches that permit cross-calibration

- Describe typical on-orbit cross-calibration methods
  - With overlapping views
  - Without overlapping views
- Sample results
  - Coincident views of same site
  - Reflectance-based method
- Method without overlapping views without on-site measurements
- Highlight expected uncertainties of the methods
- Summary and recommendations

On-orbit cross calibration

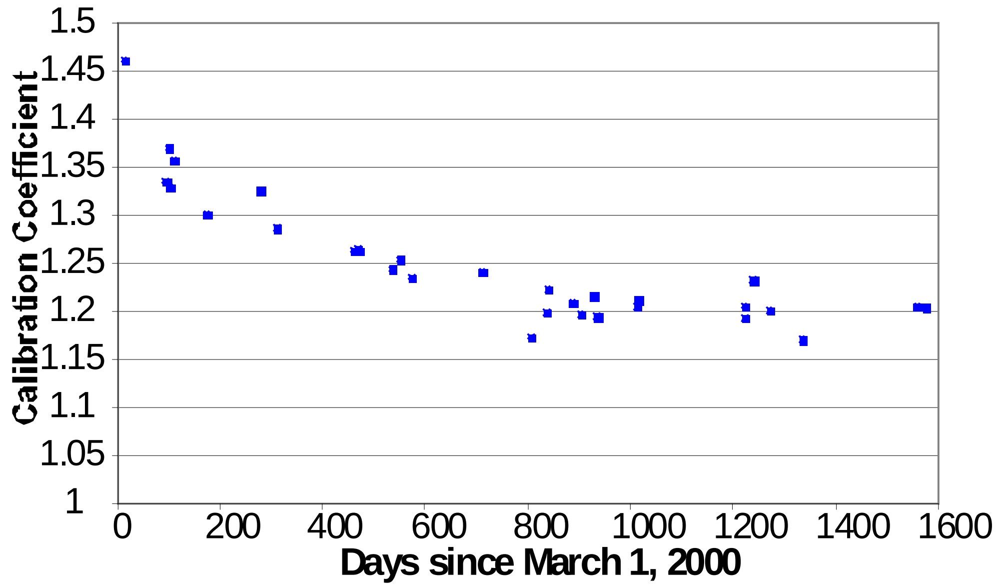
Recent years has seen great advancements in approaches for cross-calibration

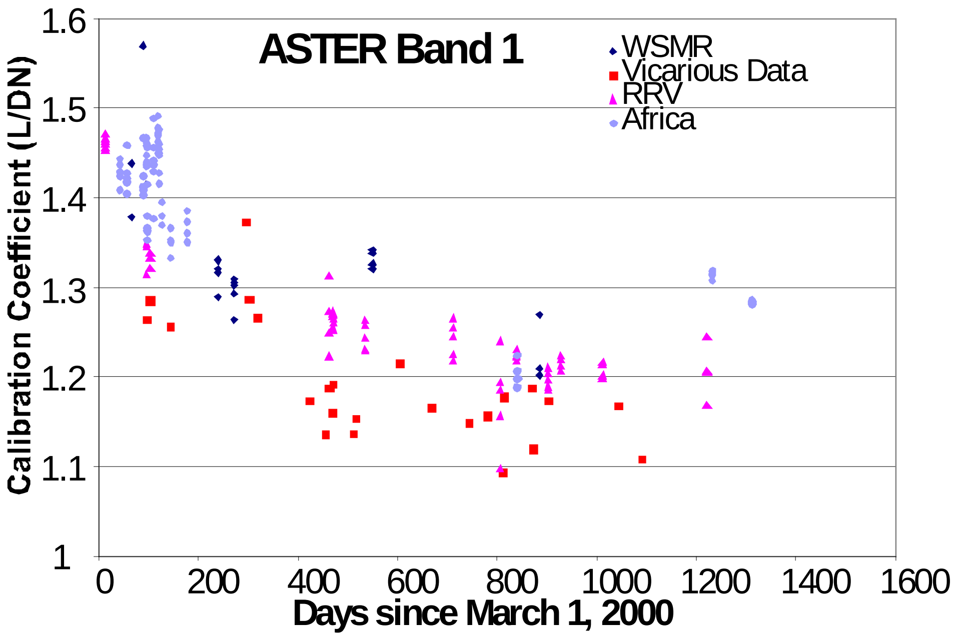
- Desert site work
  - 1980s using ER-2 flights over White Sands and Sonoran desert
  - 1990s with the North African deserts
- Arctic sites
  - Simultaneous Nadir Overpasses
  - Dome C
- More recent work
  - Lunar views
  - Application or data product approaches
  - In-situ ground measurement methods
- Methods with SI traceability do not require sensor data to overlap in time

Radiance comparisons

MODIS and ASTER offer same platform, same view coincident views

- Upper graph shows ASTER Band 1 calibration coefficient derived from Railroad Valley data
- Lower graph shows results from multiple sites
- Lower graph also shows in-situ results

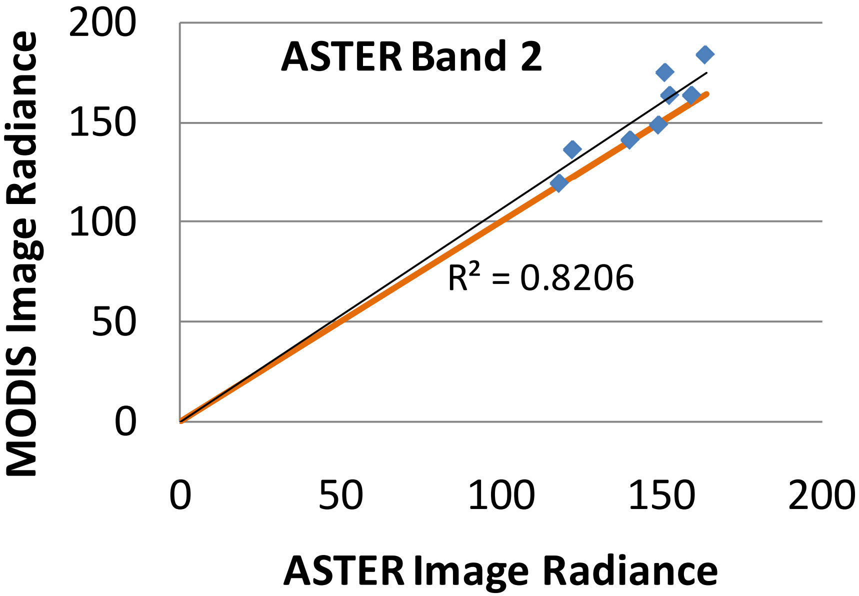




MODIS vs. ASTER

Different view of Railroad Valley data sets later in mission

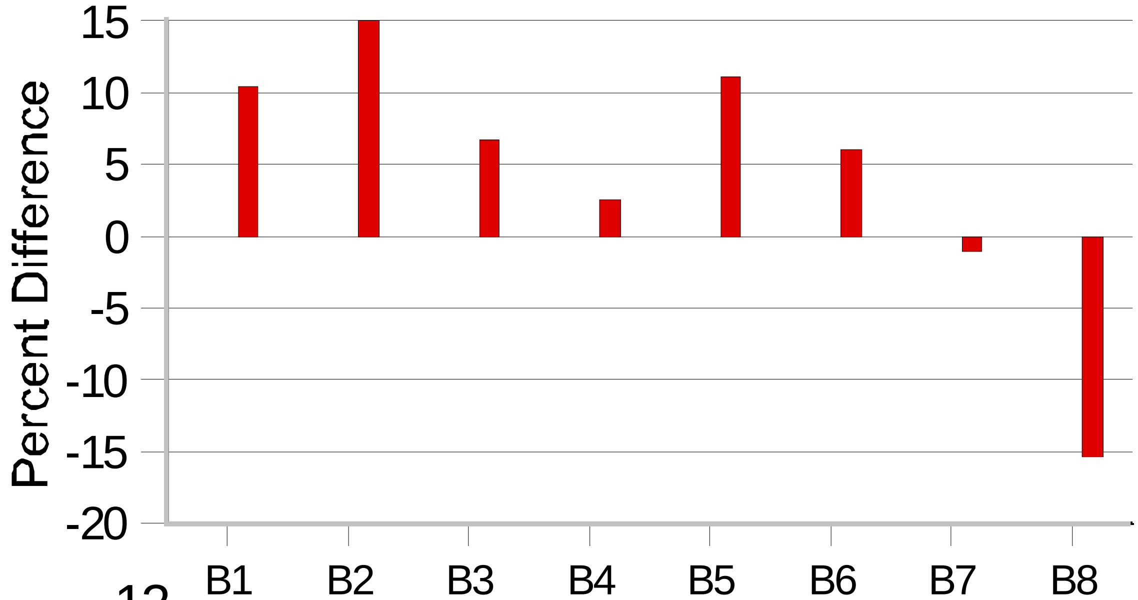
- Previous results showed significant difference between ASTER and other sensors
- Radiance values derived from each sensor's calibration
- Deviation from one-to-one line indicates biases between the sensors

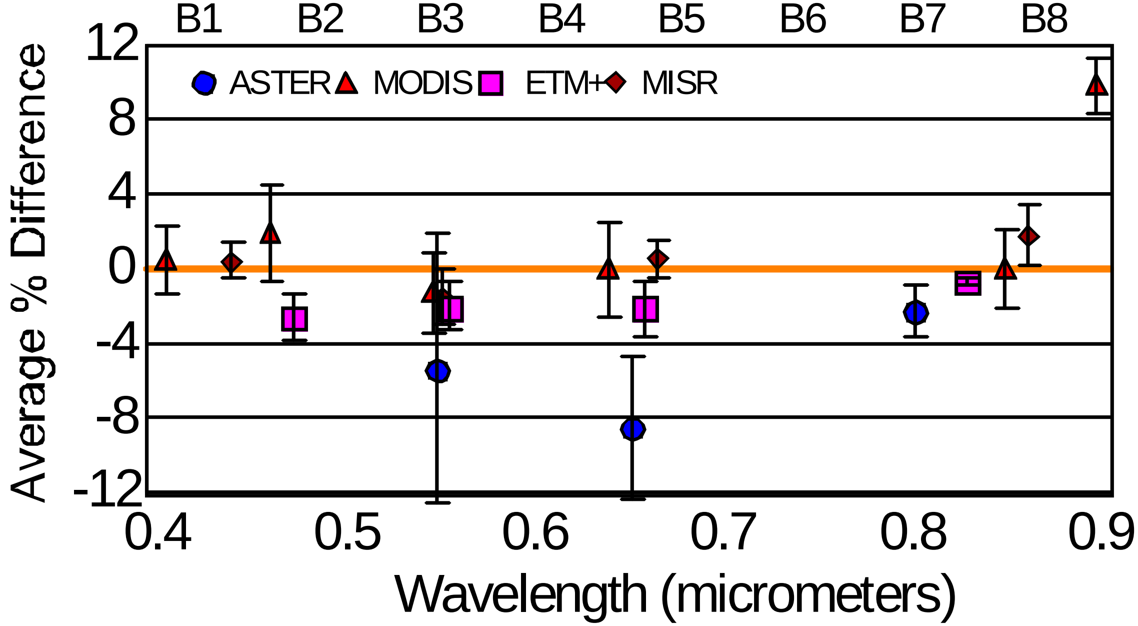


Calibration to in-situ

Calibration to SI-traceable, ground-based measurments

- Show here the bias relative to an independent, SI traceable approach
- Calibration relative to the in-situ data

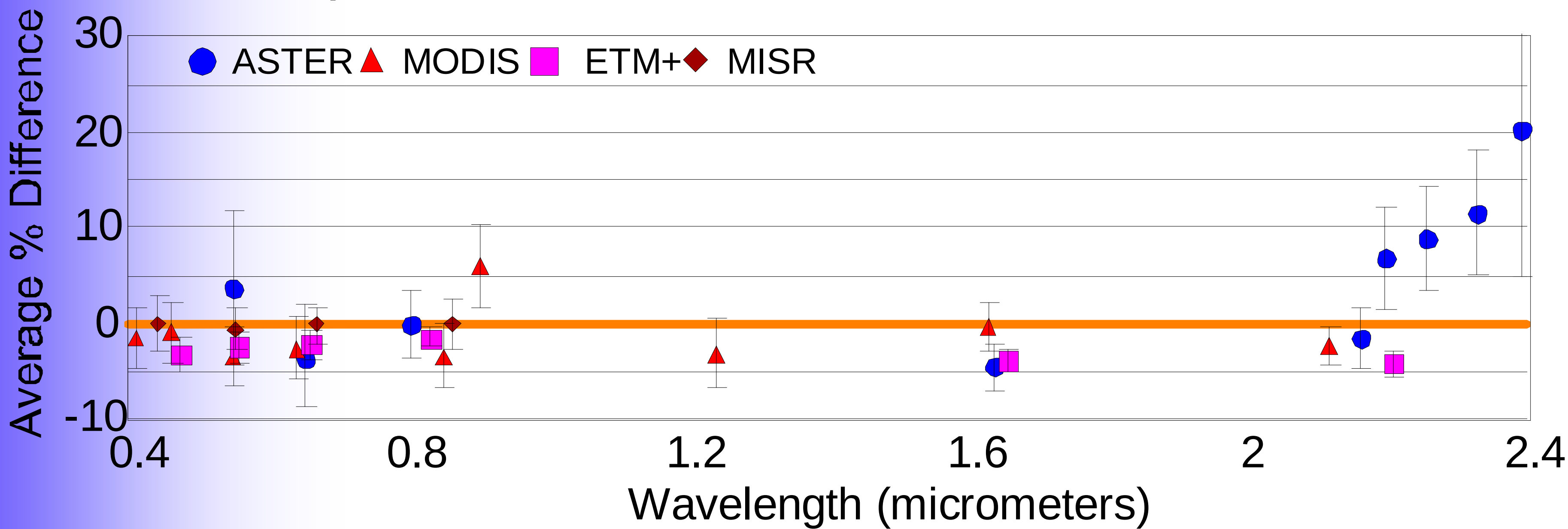




Example result

Results shown below are for the sensors in the morning orbit near in time to Landsat 7

- Averages in this case were for coincident dates and test sites
- % difference is from UofA predicted radiance
- Can compare either in absolute sense or relative



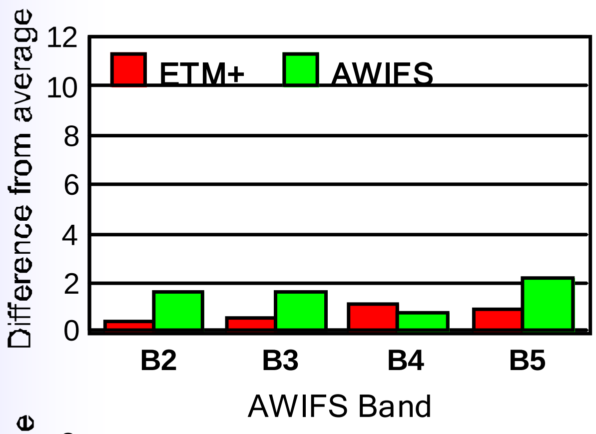
Confidence in results

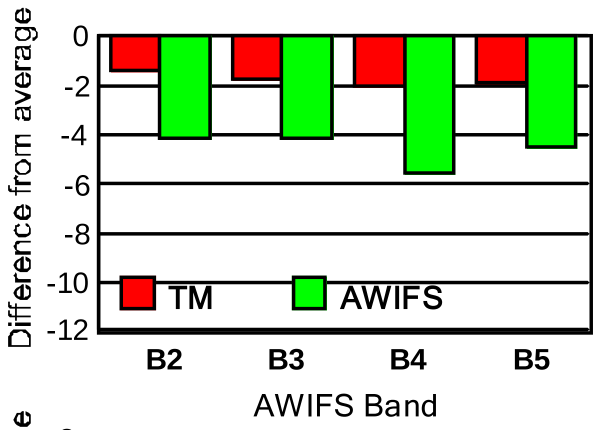
Comparison of reflectance-based results can be used to assess the quality of a data set

- Results show difference between averages
- Similar behavior between sensors gives greater confidence

June 18

Ivanpah





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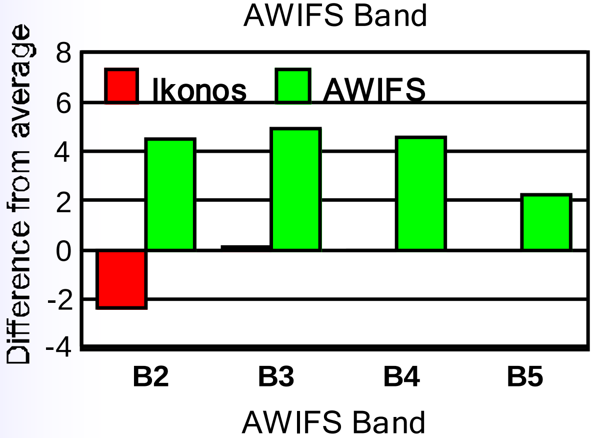

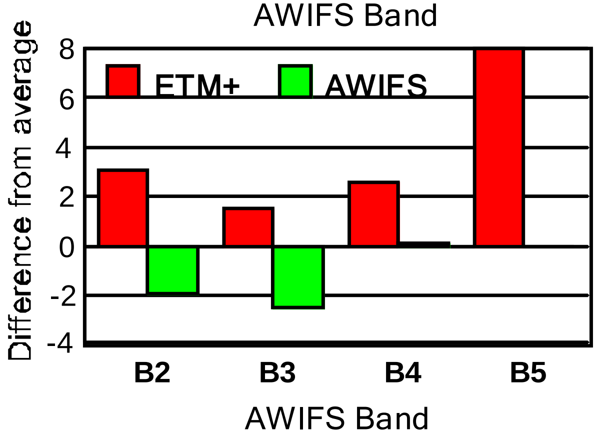

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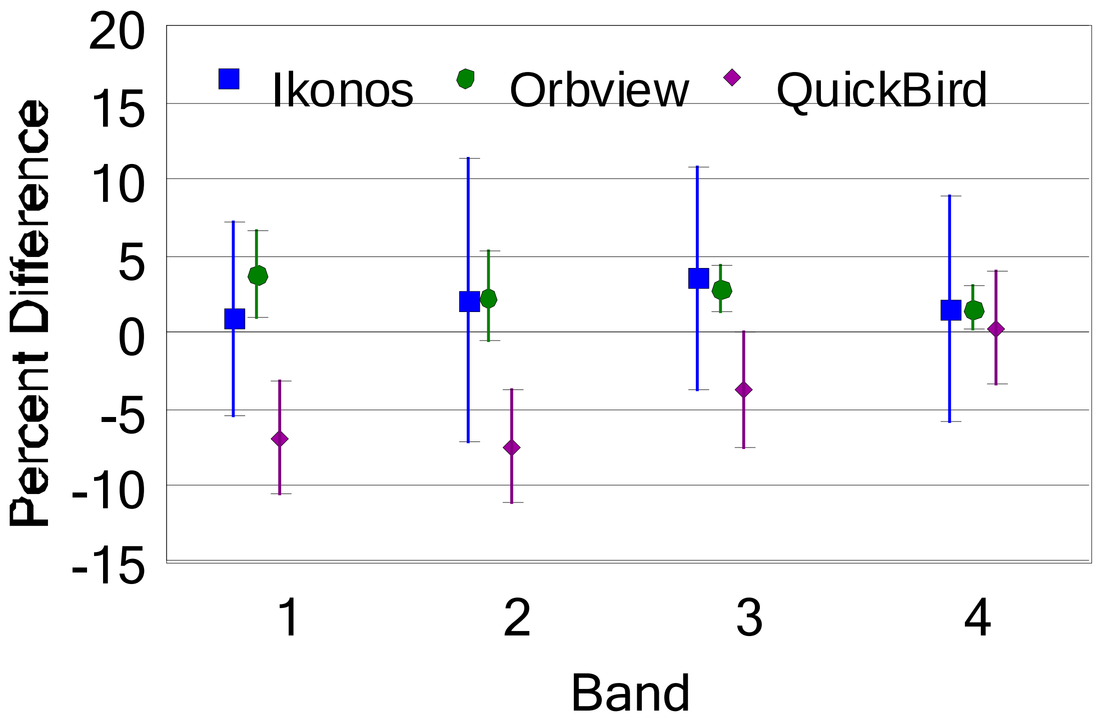
High resolution sensors

Method applied to results shown at past JACIE meetings for QuickBird, Ikonos, and Orbview

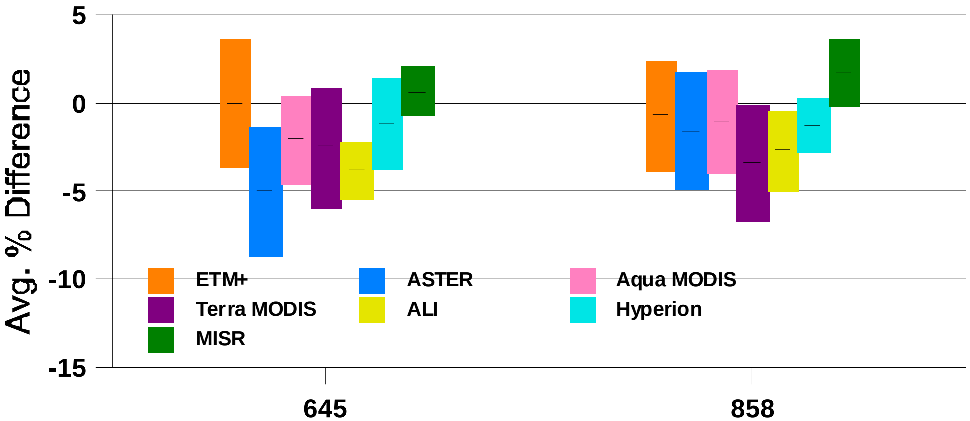
- Ikonos and Orbview agreement is expected since the sensor calibration was altered to match reflectance-based results
- Quickbird results were modified to match ETM+ based on reflectance-based results



When is a difference a difference?

Well known that the multidimensionality of the at-sensor radiance can mask calibration biases

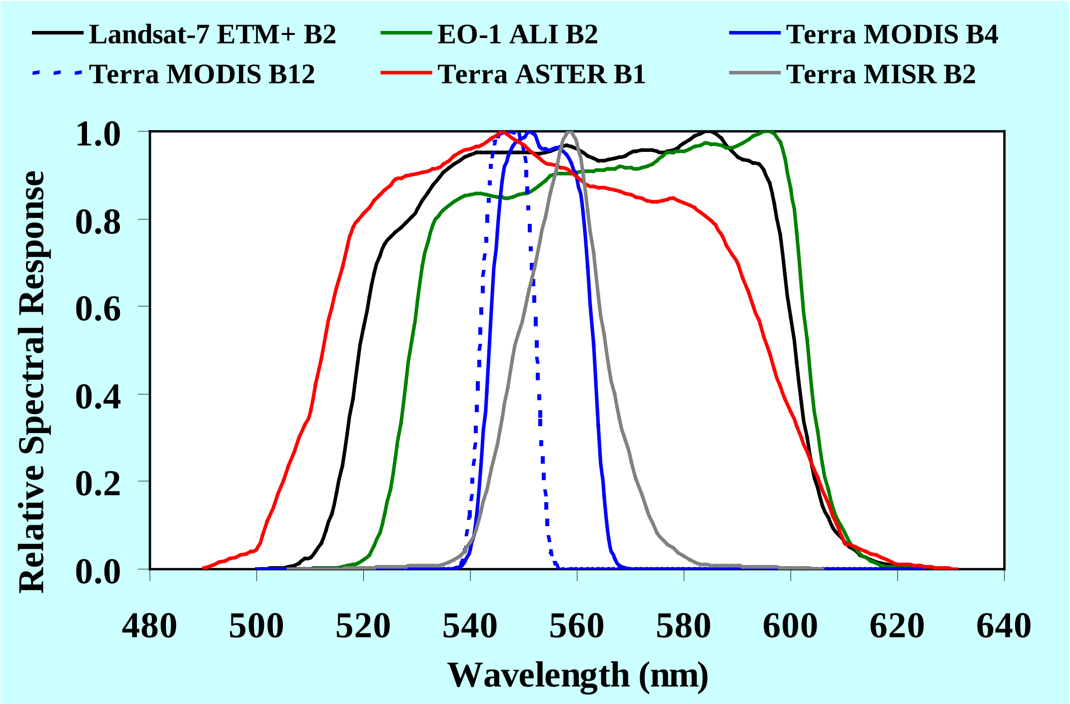
- View/solar geometry differences
  - Surface reflectance changes
  - Atmospheric effects
  - Lunar phase effects
- Temporal differences
  - Solar angle
  - Atmospheric changes
  - Lunar phase
- Registration effects
- All successful methods attempt to account for these effects or minimize the sensitivity



Spectral band differences

ETM+ Band 2 Analogs	A	B	C	D	E	F
A: Landsat-7 ETM+ B2	1	0.996	1.005	0.990	0.988	0.989
B: EO-1 ALI B2		1	1.009	0.994	0.992	0.993
C: Terra ASTER B1			1	0.985	0.983	0.984
D: Terra MODIS B4				1	0.998	0.999
E: Terra MODIS B12					1	1.001
F: Terra MISR B2						1

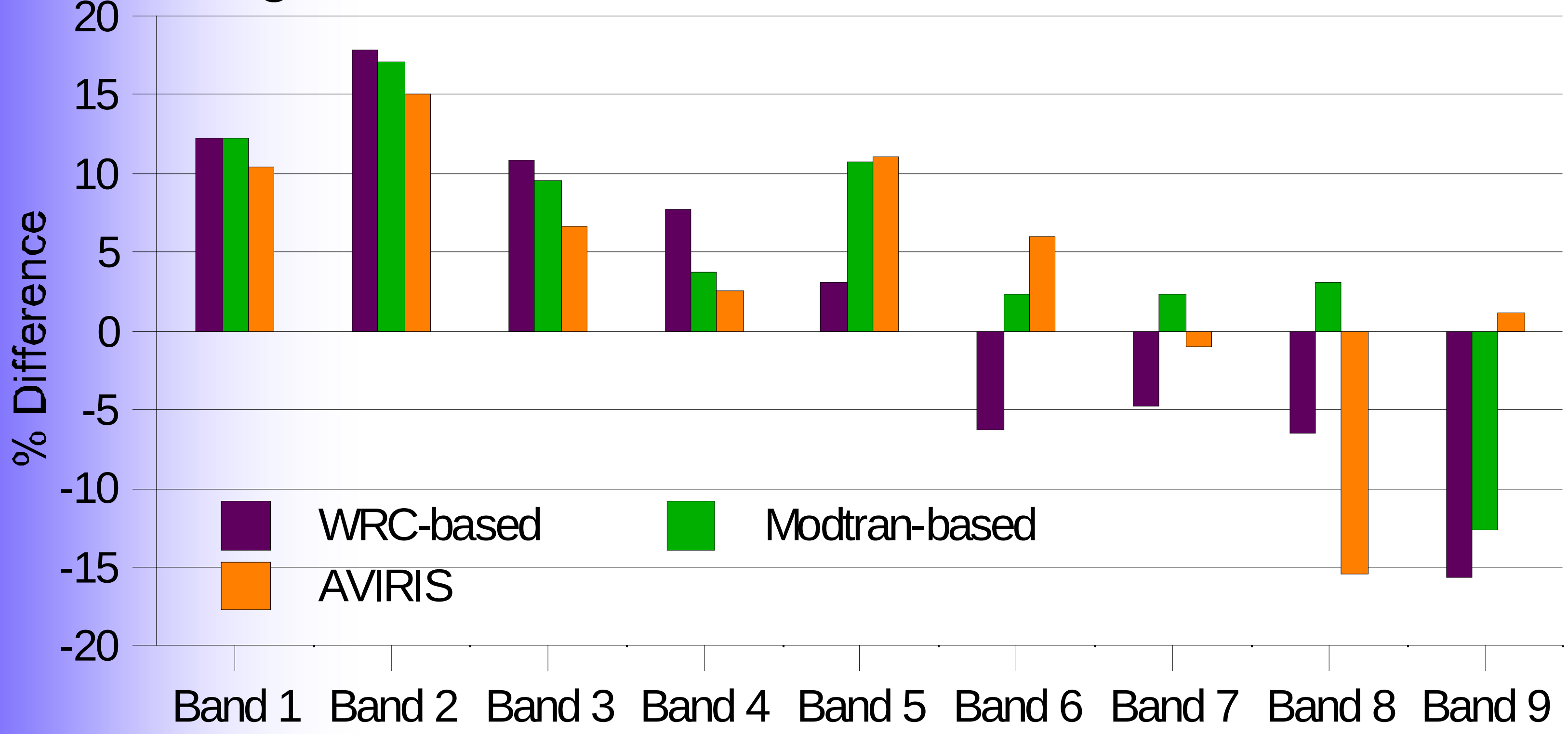
Uncertainty due to spectral differences should decrease as hyperspectral data of sites is accumulated



Solar irradiance effects

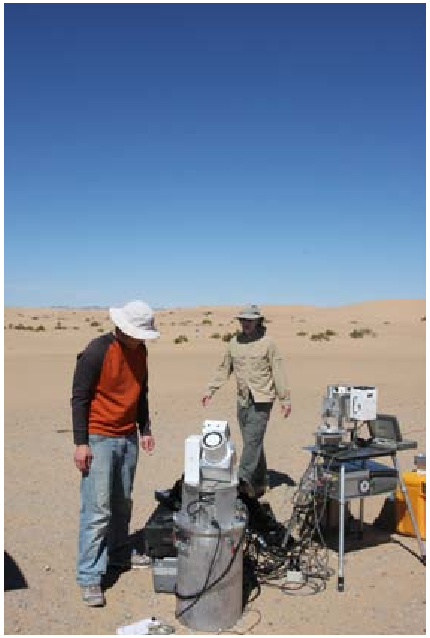
Selection of solar model plays a role in the SWIR

- ASTER results compared to in-situ data and AVIRIS-based radiance
- Bands 4 and 5 are especially of interest
- Working in reflectance removes this issue



Next step

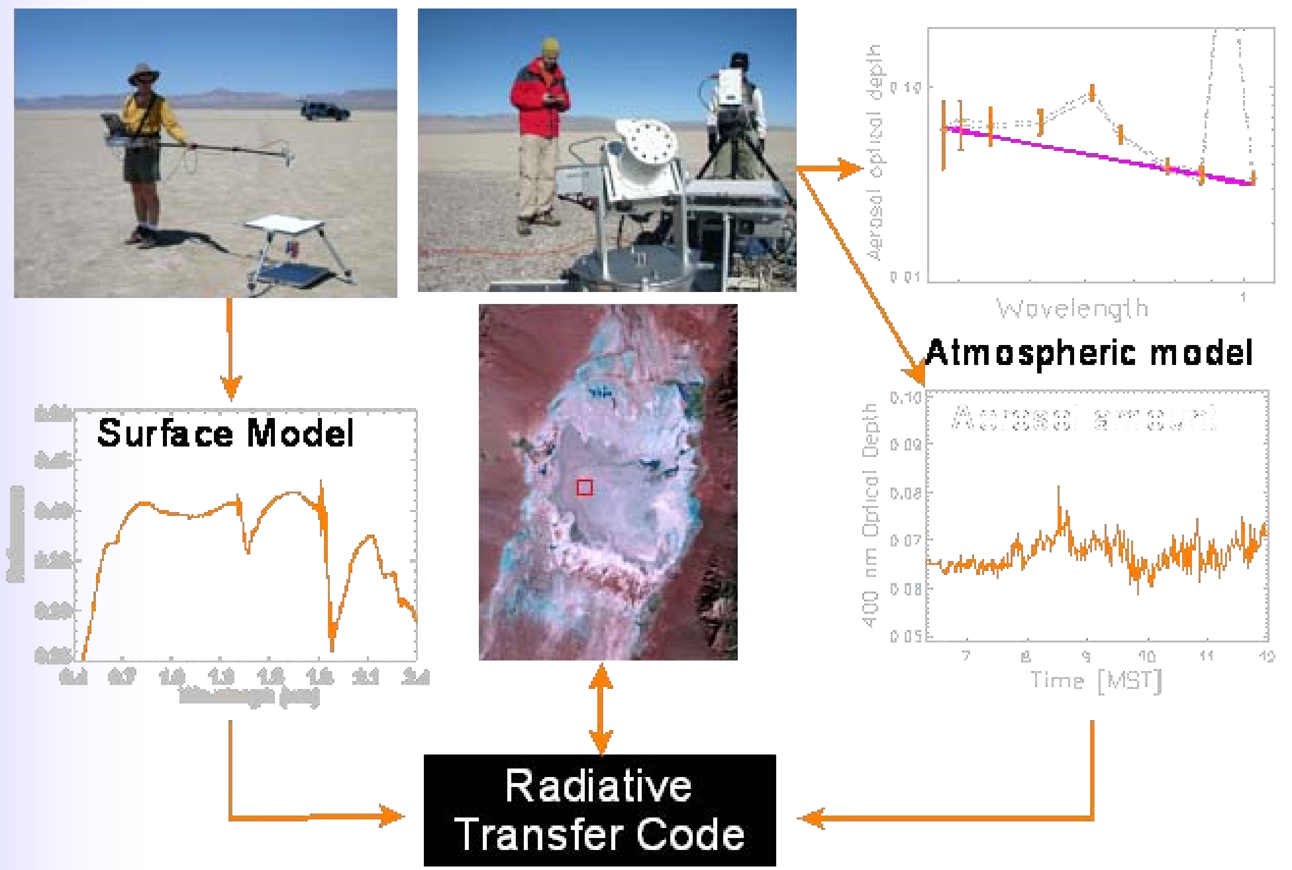
Next logical step is to combine philosophy of in-situ measurements with invariant site work



- In-situ measurements become basis for a physically-based model
  - Atmospheric
  - Surface
- Allows for an SI-traceable result
- Requires innovative measurement approaches

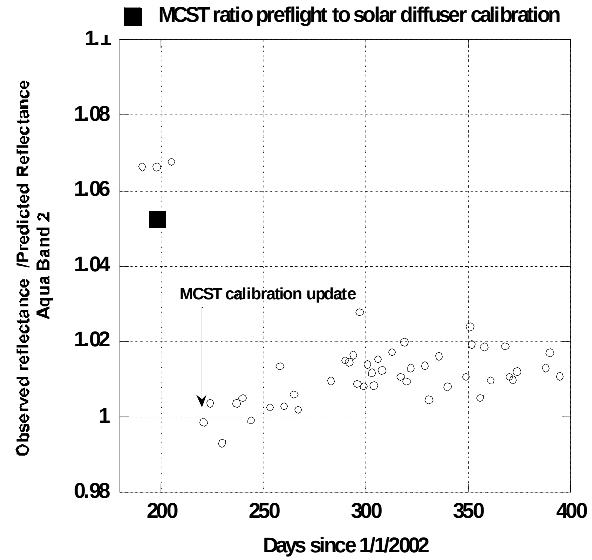
Basic method

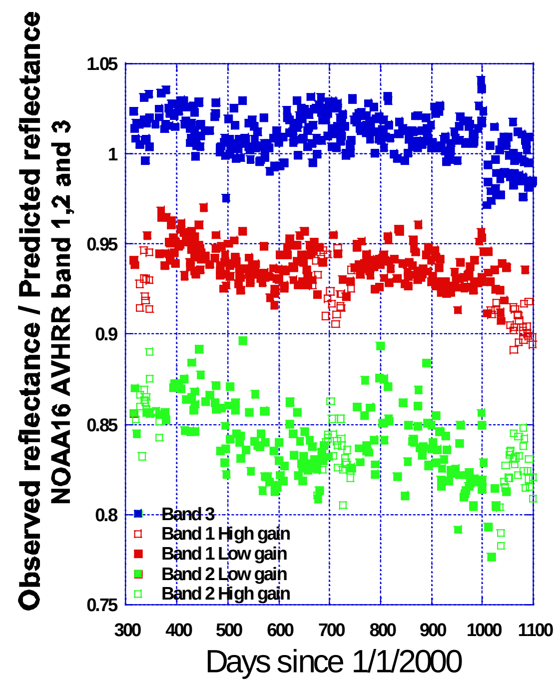
- Key is that measurements to create the models need not be in-situ
- Satellite and airborne-based measurements are a good starting point



Past efforts

- Results have been shown at the last two JACIE conferences using the Dome C site (Mackin and others)
  - Corrections for BRDF
  - Corrections for atmospheric effects
- Work by Vermote with MODIS and AVHRR
  - Surface BRDF model corrected by Terra MODIS
  - Includes atmospheric corrections based on climatological values
- University of Arizona couples automated data with surface models





Summary

Recognize that the material presented is not new or cutting edge

- Cross-calibration methods in general have improved dramatically in recent years
    - Both precision and accuracy
    - Working in reflectance reduces many of the uncertainties
        - Cosine solar zenith angle on radiance
        - Spectral differences
        - Solar model
- Reliance on multi-nation data sets requires further improvements and collaborations
    - CEOS
    - GEOSS

Summary

Several examples exist of recognizing biases <0.5% for intercomparisons

- SI traceability needs to be addressed and included
- Technically overlap is not required if there is SI traceability
  - Reflectance-based method can be used without overlap with 2-3% traceable absolute uncertainty
  - SNO, invariant scenes, lunar have lower uncertainties but accurate traceability to SI is still being developed
- Rapidly approaching the situation where the absolute calibration of the reference sensor is the dominant error source