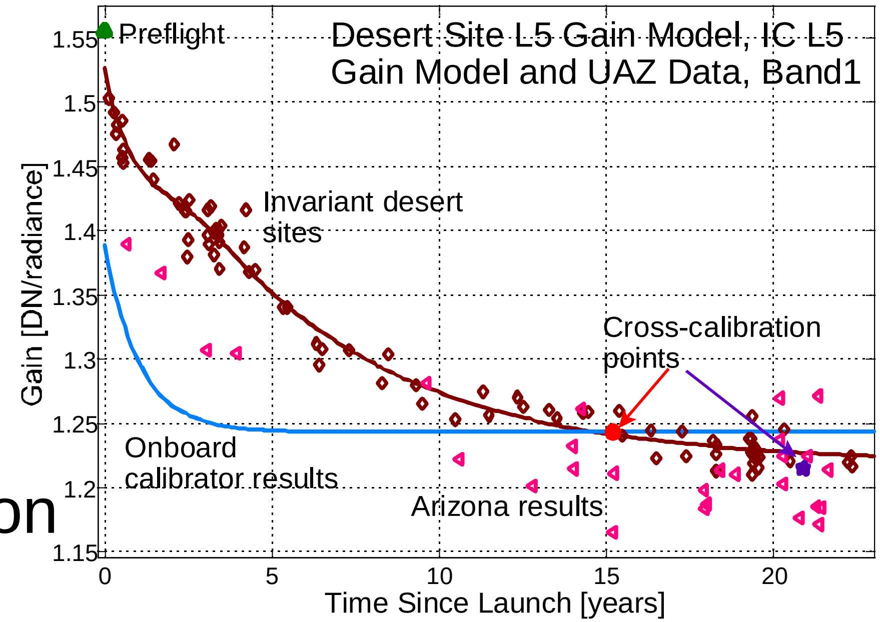
Methods for radiometric cross-calibration of imaging sensors with and without overlapping collections

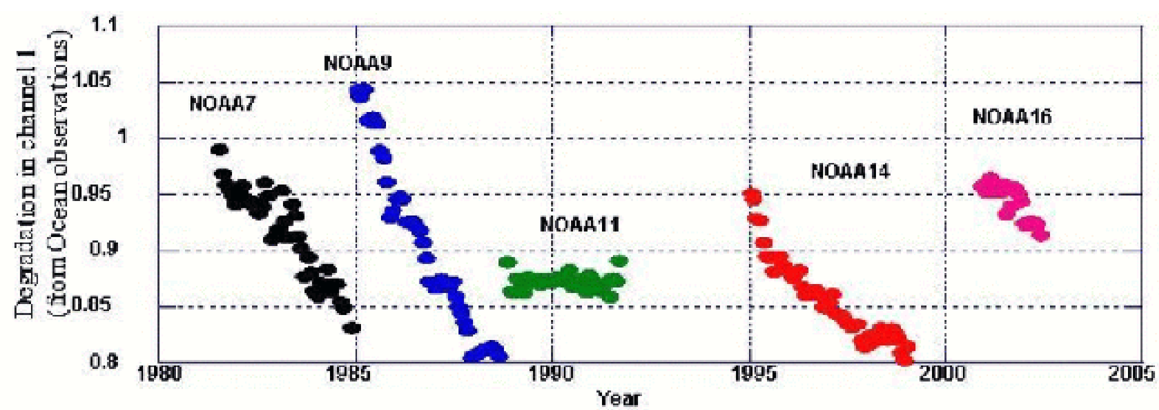
K. J. Thome
Biospheric Sciences Branch
Goddard Space Flight Center

Introduction

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

- Invariant sites
- In-situ measurements
- Lunar
- With and without overlap
- All approaches basically rely on understanding the output of a source





Talk overview

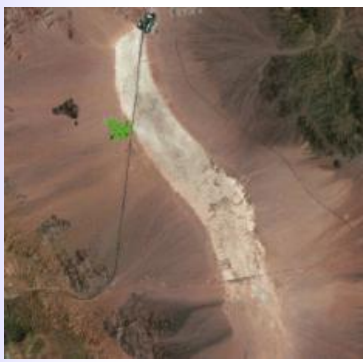
Discuss SI-traceable approach that permit cross-calibration

- Much of what is shown is not new/original but it is the end concept that has a twist on past efforts
- Review typical on-orbit cross-calibration methods
  - With overlapping views
  - Without overlapping views
- Past results
  - Coincident views of same site
  - Reflectance-based method
- Method without overlapping views without on-site measurements
- Summary and recommendations

Result

SI-traceable approach to cross-calibration using well understood sources

Selected Test Site



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

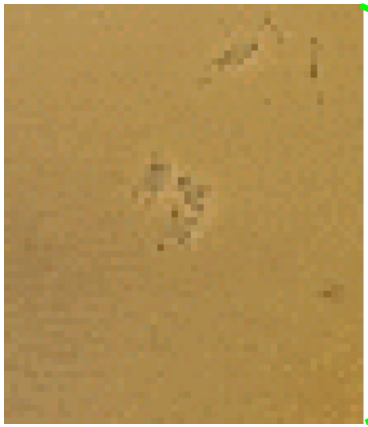
SI-Traceable with documented error budget and uncertainty

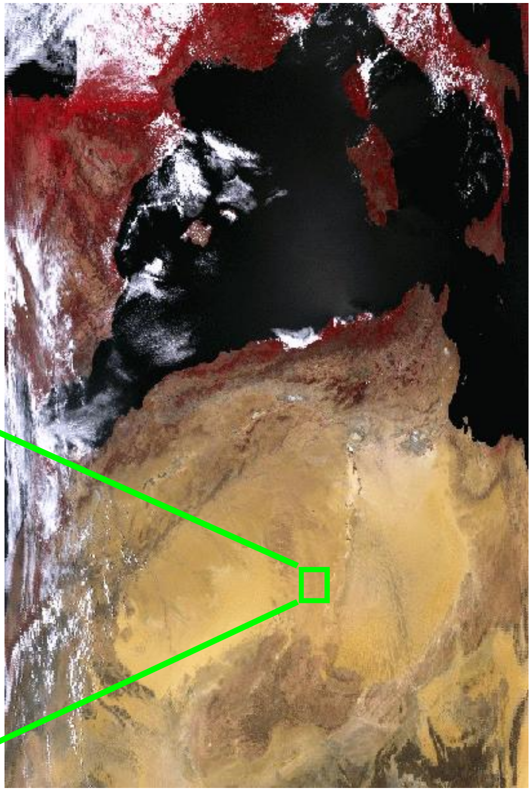
Need to move away from solely using empirically-based approaches

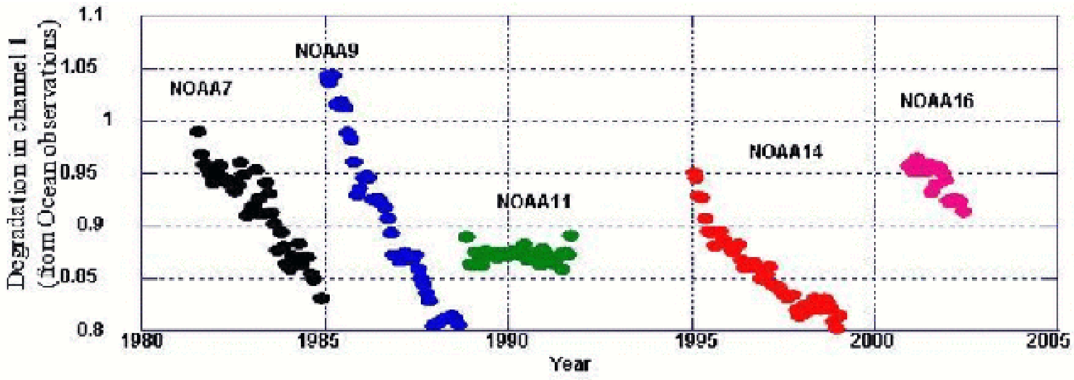
On-orbit cross calibration

Have been 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 with SNO
- Lunar views
- Data product approaches
- In-situ ground measurement methods



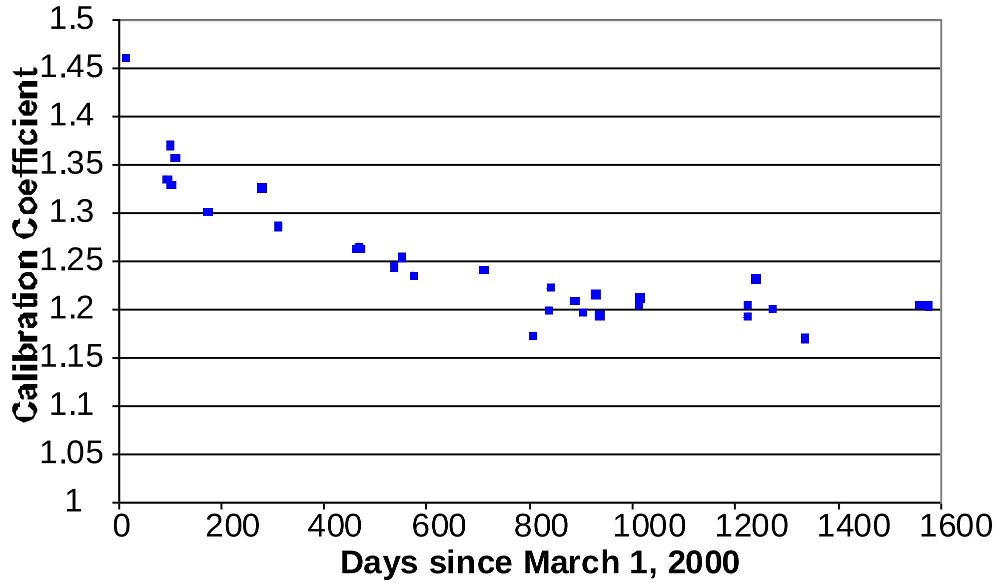


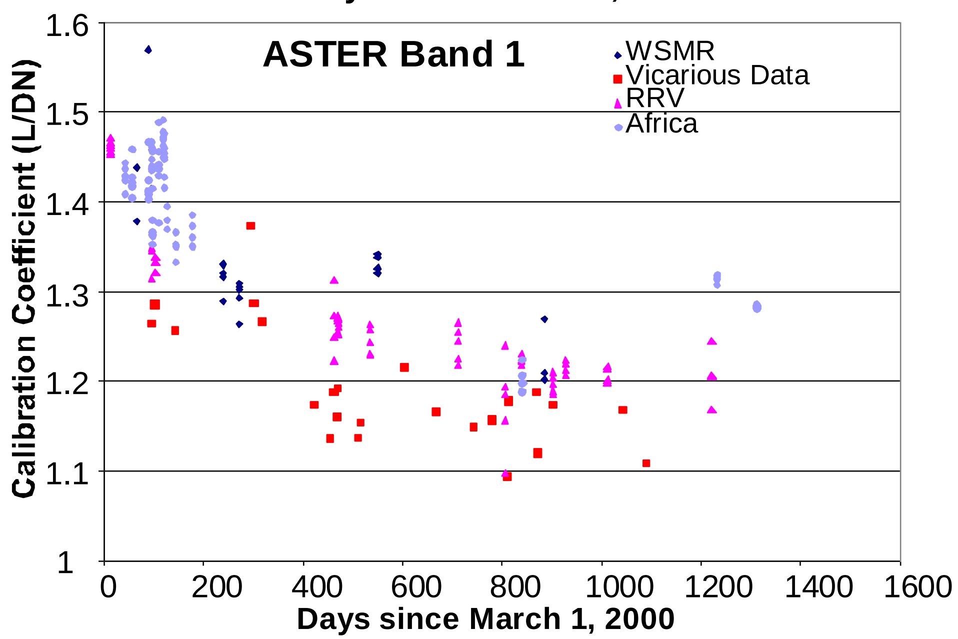


Radiance comparisons

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

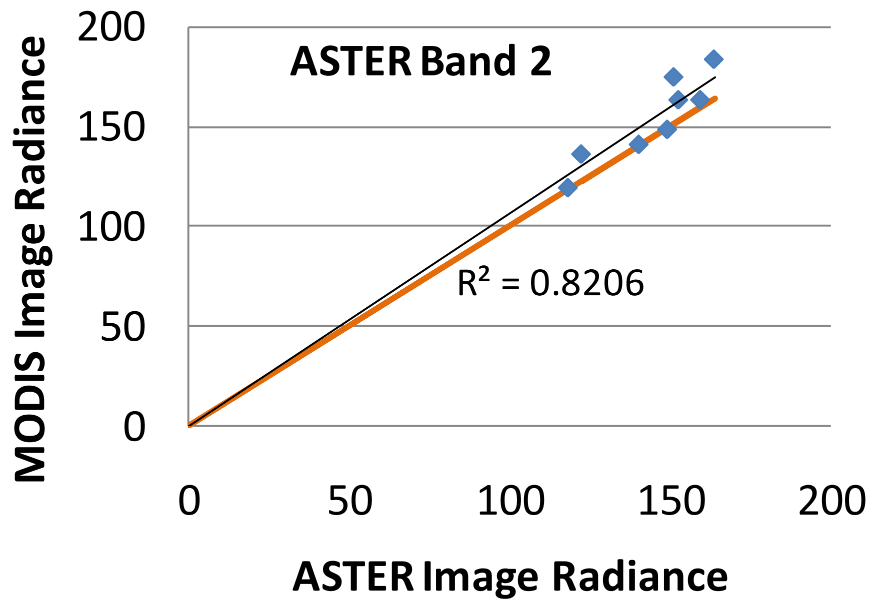




MODIS vs. ASTER

Sensors on same platform offer essentially identical views at identical times

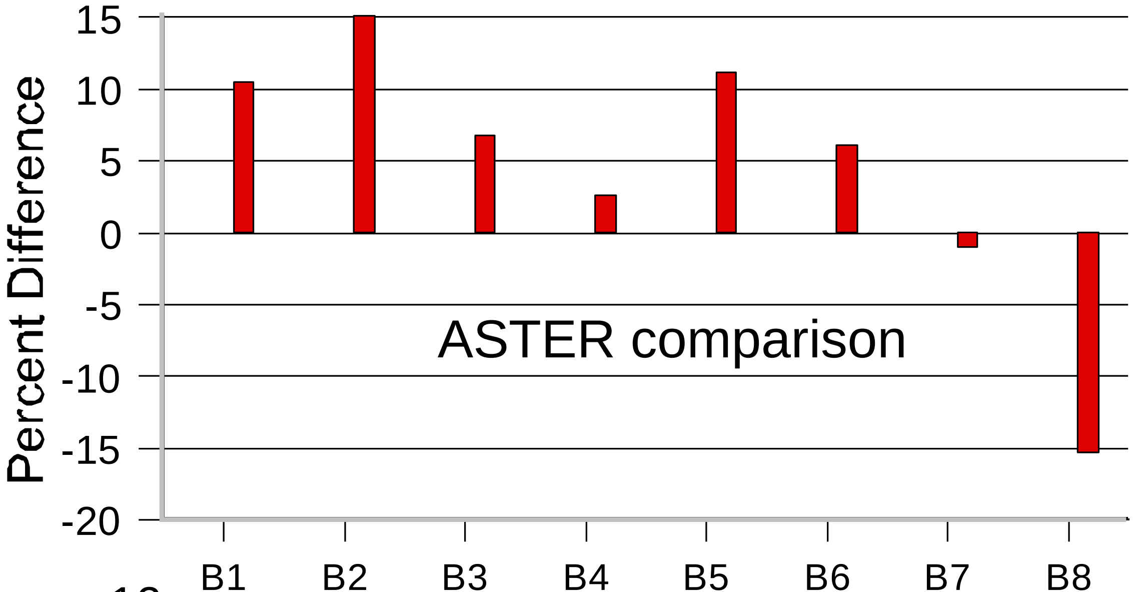
- Corrections needed for differences in spectral bandpass
- Registration effects and surface inhomogeneity cause added uncertainties
- Uncertainties increase as time between sensors increases
- Knowledge of surface and atmosphere reduces uncertainties

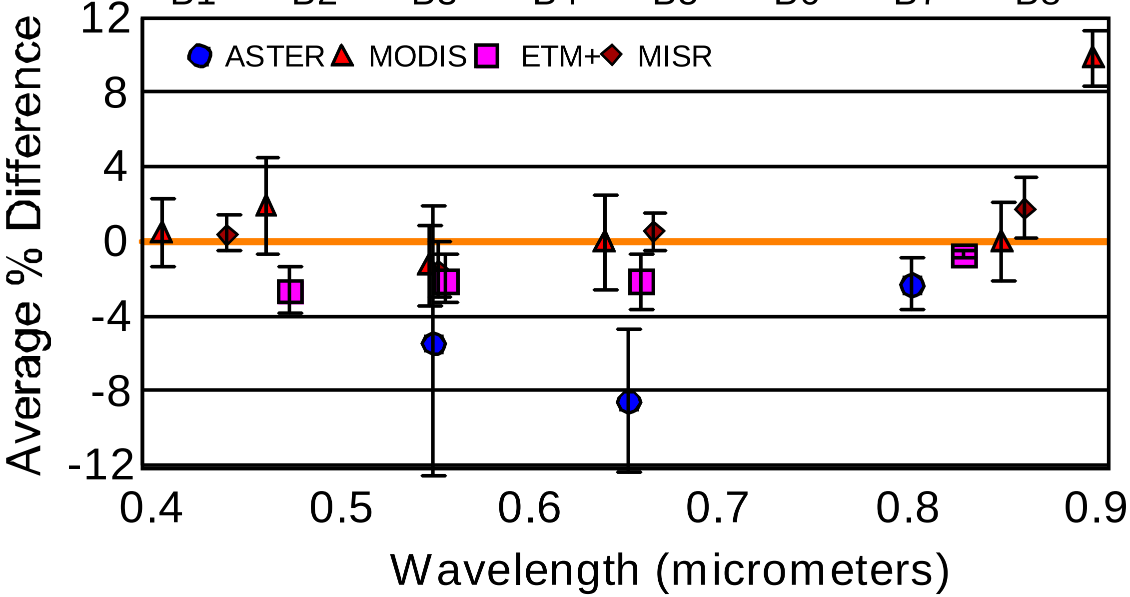


Calibration to in-situ

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
- Draw back is that it requires sensor at site at overpass

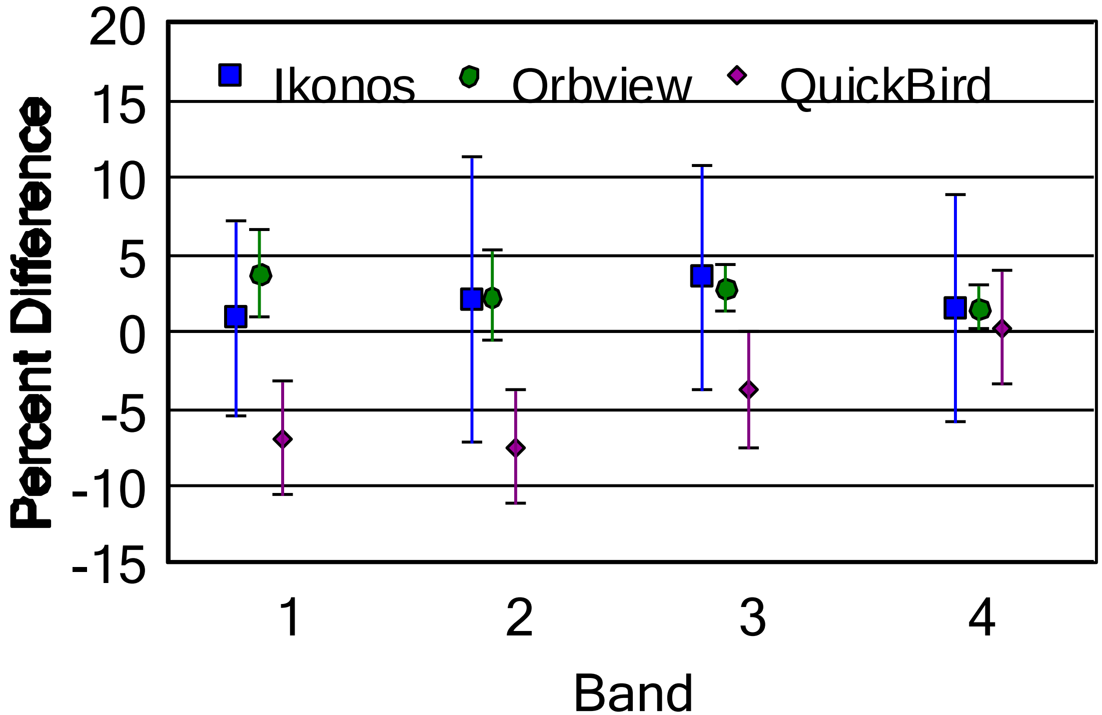




High resolution sensors

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

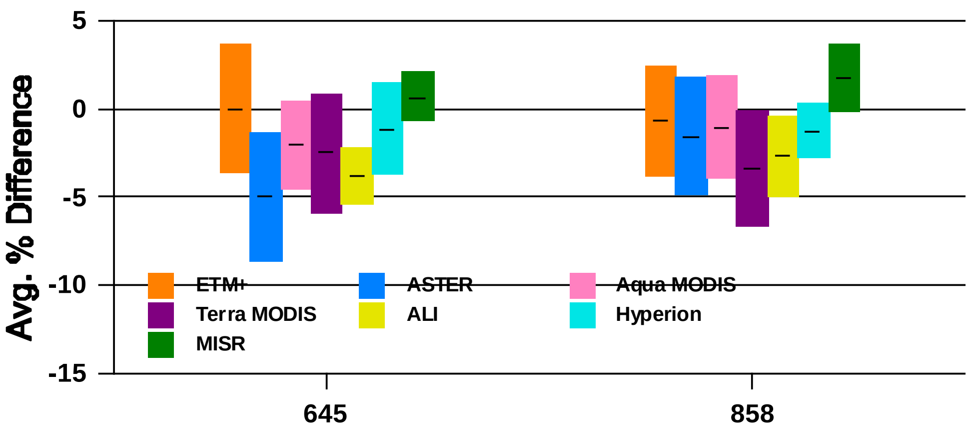
- Ikonos and Orbview agreement is expected since the sensor calibration was altered to match reflectance-based results
- Quickbird results were modified to match ETM+ based on reflectance-based results



What causes the differences?

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

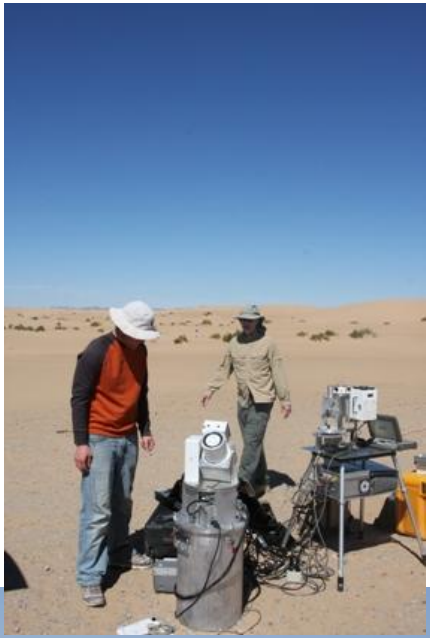
- View/solar geometry differences
  - Surface reflectance changes
  - Atmospheric effects
  - Lunar phase effects
- Temporal differences
  - Solar angle
  - Atmospheric changes
  - Lunar phase



- Registration effects
- Spectral difference
- All successful methods attempt to account for these effects or minimize the sensitivity

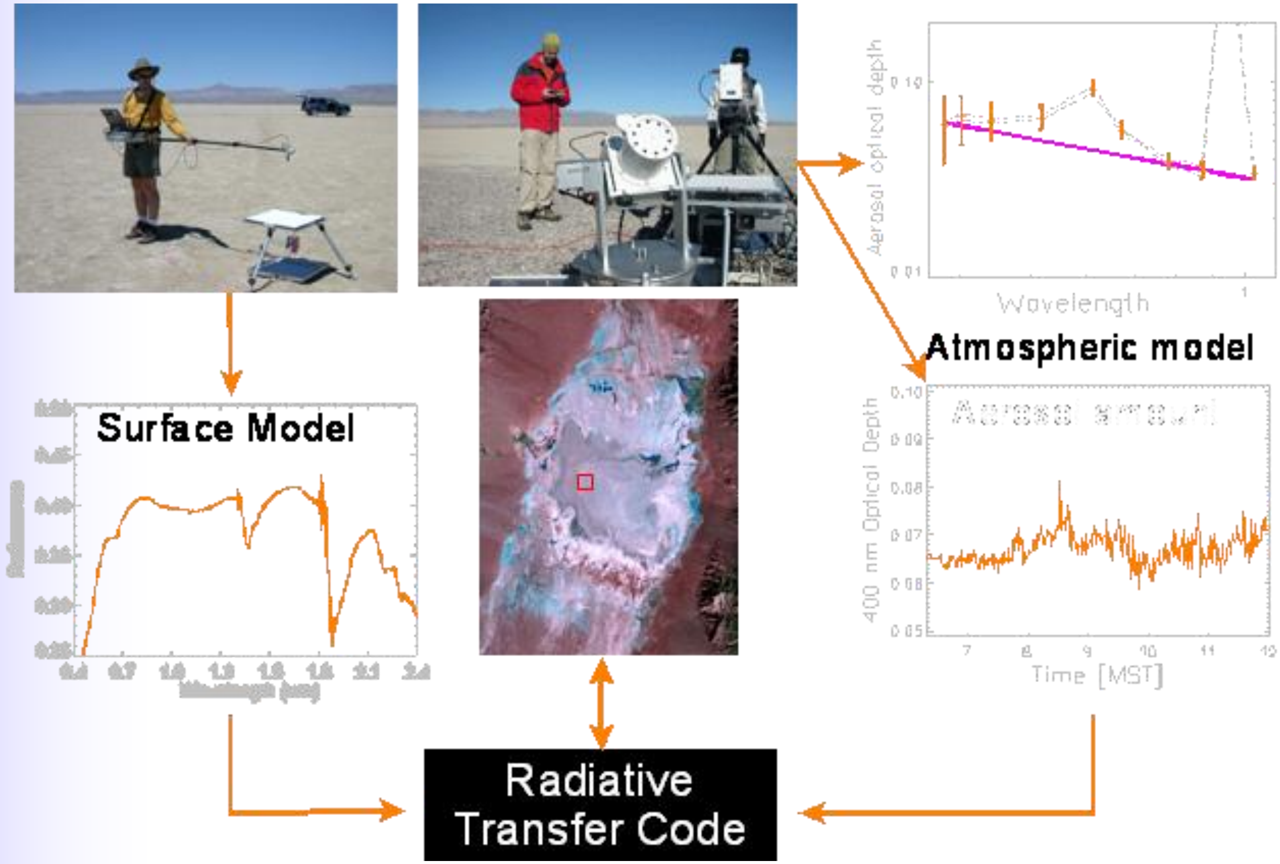
Next step

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

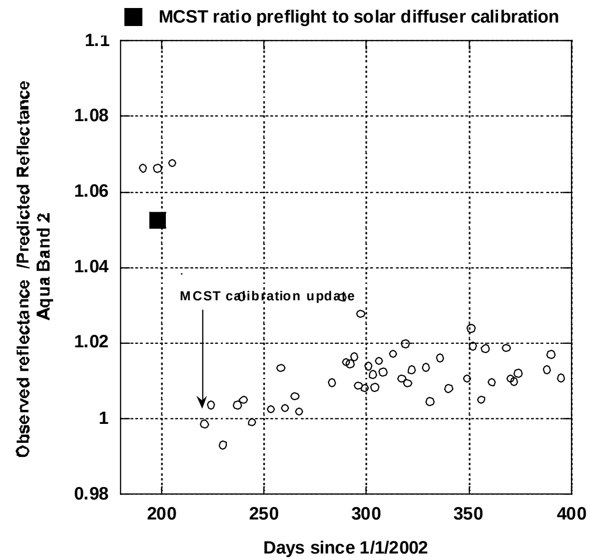
Basic method

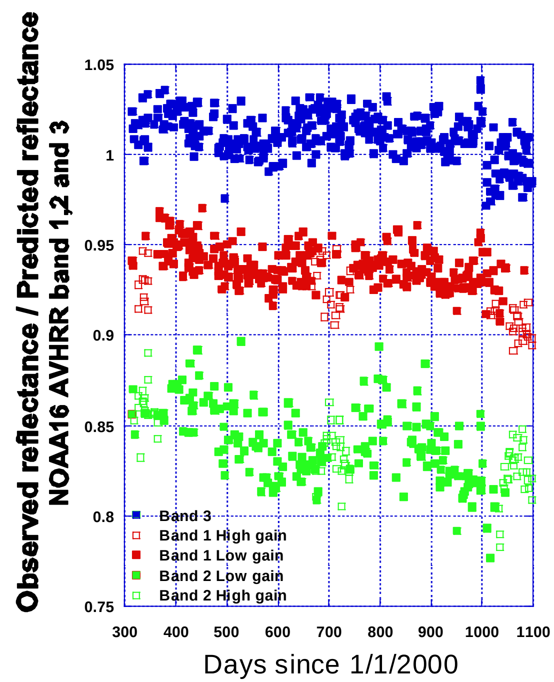


- Key is that measurements to create the models need not be in-situ
- Satellite and airborne-based measurements are a good starting point

Model-based measurements

- 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





Result

SI-traceable approach to cross-calibration that does not require coincident views

Selected Test Site

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

Summary

Ensemble of current sensors and expertise in calibration/validation is unprecedented

- Has led to dramatic improvements in cross-calibration methods
  - Both precision and accuracy
  - Several independent methods
- Recognition of importance of SI-traceable methods with documented error budgets
- Multi-national data sets and collaborations has been key to this as well
  - CEOS
  - GEOSS

Summary

Requires a switch from a sensor-centric approach to a source-centric mentality of cross-calibration

- One-by-one empirical comparisons between sensors have been very successful but have limits
- Combination of physically-based modeling and empirical data will not be trivial
  - First results may only have 50% accuracy
  - Results will improve with time
- Inclusion of highly-accurate spaceborne sensors would greatly improve results
- Result will be improved relative calibration precision and absolute calibration that has the capability of matching current methods