Inflight, intersensor radiometric calibration of high- and moderate-resolution sensors using the reflectance-based method

Kurt Thome
Remote Sensing Group, University of Arizona

Civil Commercial Imagery Evaluation Workshop
Fairfax, Virginia
March 25-27, 2008

Kurt Thome
College of Optical Sciences, University of Arizona
kurt.thome@optics.arizona.edu

College of Optical Sciences
THE UNIVERSITY OF ARIZONA
TUCSON ARIZONA

Background

As shown over the past three days, a wide range of sensors are available for terrestrial sensing

- Sensor calibration and characterization plays a key role in the ability to compare data from these sensors
  - Biases between sensors need to be removed
  - Temporal changes in response must be tracked
- Relative calibration is sufficient in some cases
  - Data from single sensor for change analysis
  - Multiple sensors for which significant overlap exists
- Absolute calibration needed for temporal studies between multiple sensors with little to no overlap
- Vicarious methods are an excellent means to do relative and absolute radiometric cross-calibration

Talk outline

The method used here relies on the reflectance-based method for cross calibration

- Does not require coincident views
- Works for various spatial and spectral resolutions
- Talk overview
  - Description of reflectance-based approach
  - Example results
  - Cross-calibration results
  - Accuracy and precision discussion
  - Summary

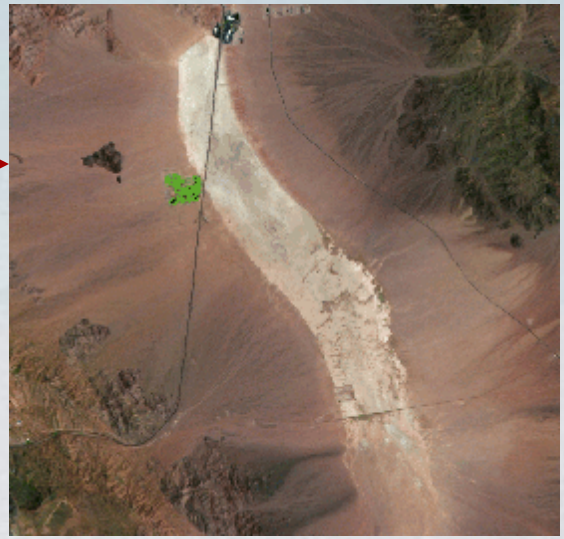
Reflectance-based approach

Measurements of surface reflectance of a homogeneous test site

Measurements of atmospheric conditions

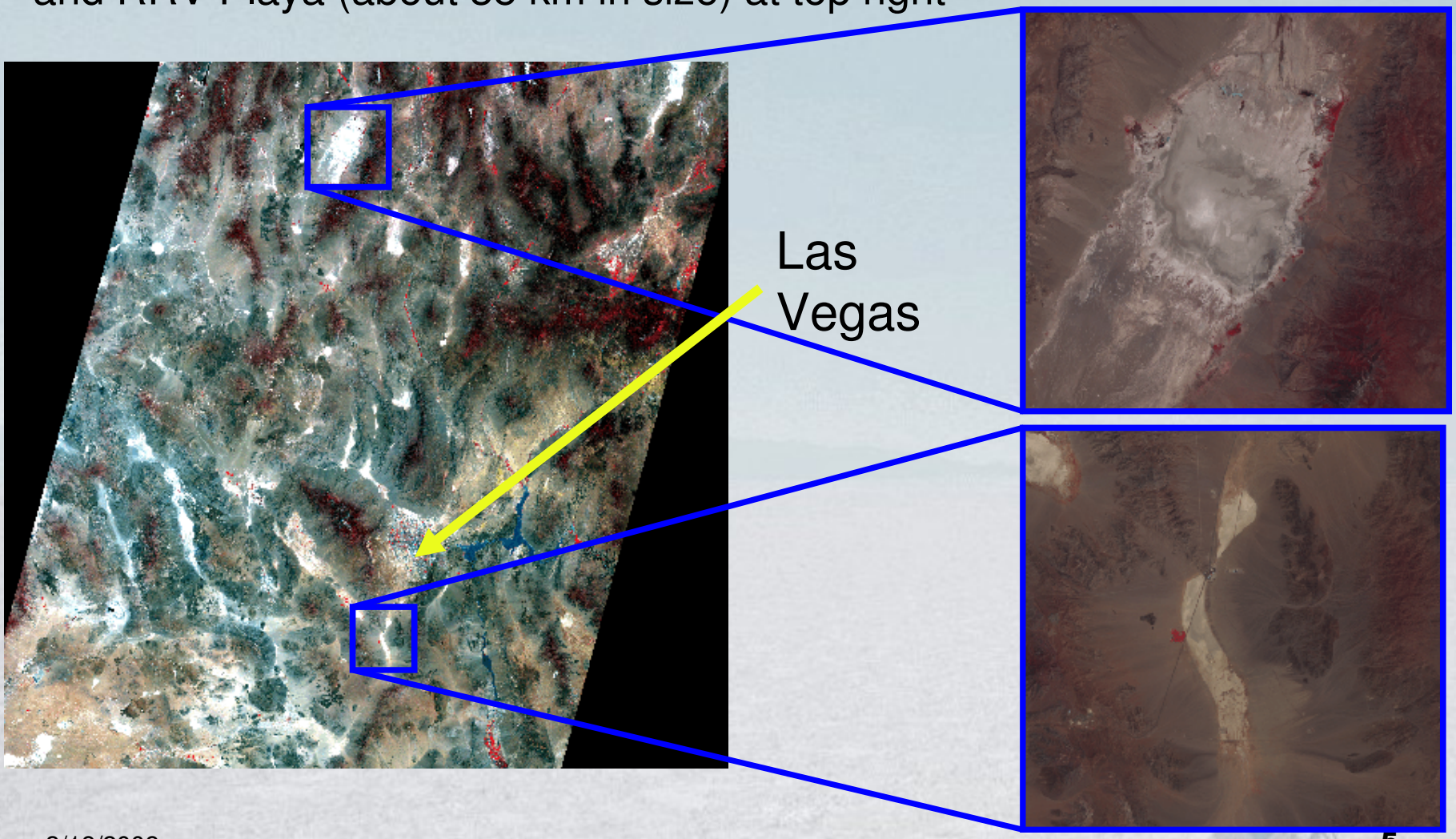
RTC Code

Predict at-sensor radiance for a selected area of the site and compare to imagery



UofA Test Sites

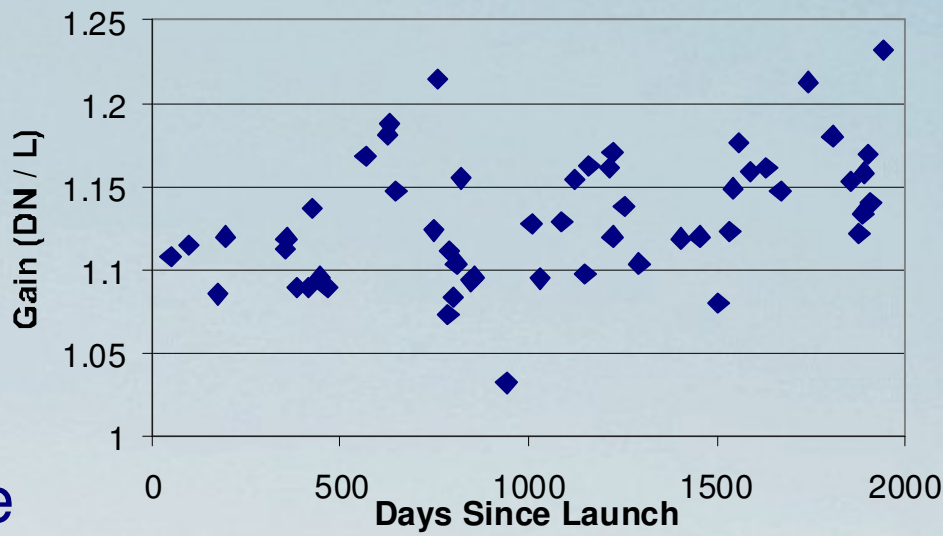
Ivanpah Playa (3 km by 5 km) on the bottom right and RRV Playa (about 35 km in size) at top right

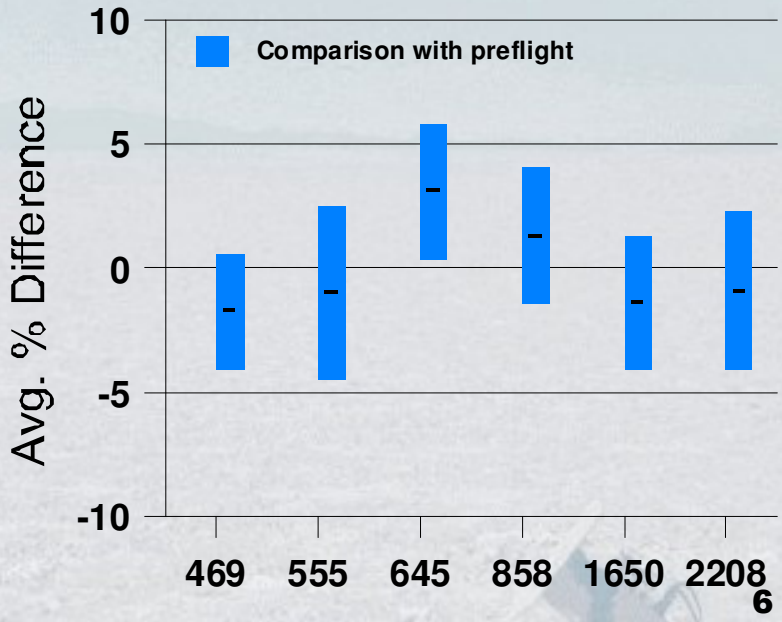


Typical Results

Results from Band 2 of ETM+ as a function of time and the average for all bands compared to preflight calibration

- Results as a function of time show typical scatter in the data
- Agreement with all bands is better than 3%
- Standard deviation of the average is <3%





Cross-calibration methods

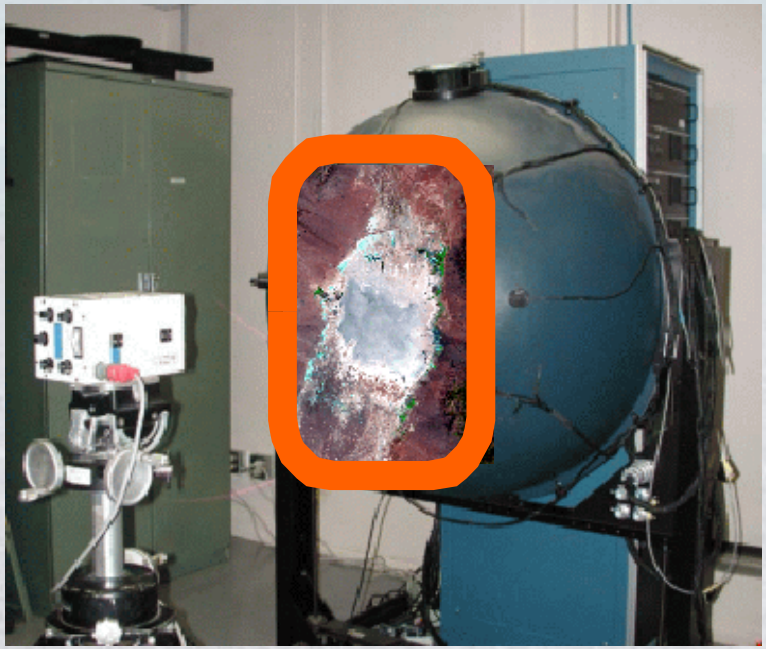
Cross-calibration allows for accurate intercomparison of sensor data

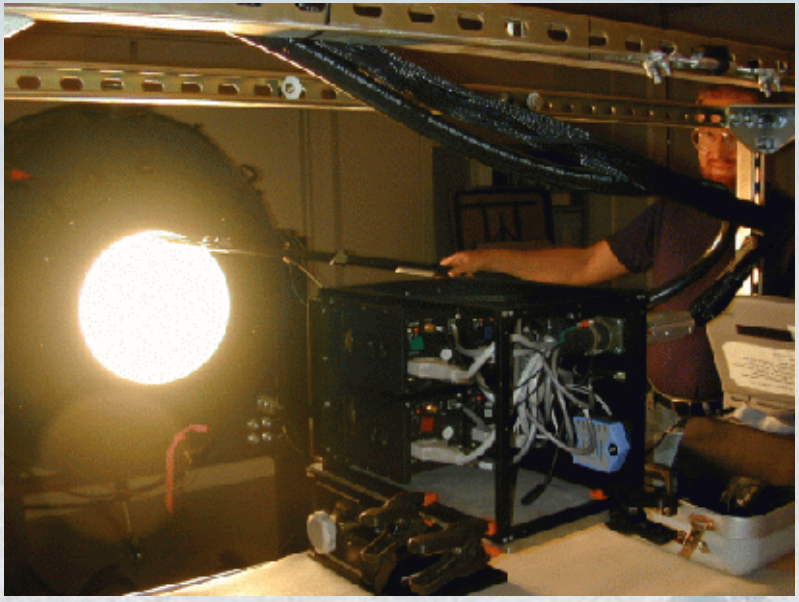
- Cross-calibration typically implies near coincident views
  - Preflight laboratory views of the same source
  - Invariant scene approaches
  - SNO (simultaneous nadir overpass) makes use of crossing orbits near the poles
  - Landsat 7 underflew Landsat 5 for several days after launch
- More recent work has emphasized methods that do not require simultaneous data collections
  - Laboratory transfer radiometers
  - Invariant scene approaches
  - Reflectance-based method

Reflectance-based cross-calibration

Precision & accuracy of reflectance-based method allows it to be a reference between sensors

- Analogous to using radiance source in the laboratory
- Radiance from a given site can be characterized for a given sensor
- Site becomes a common reference between sensors

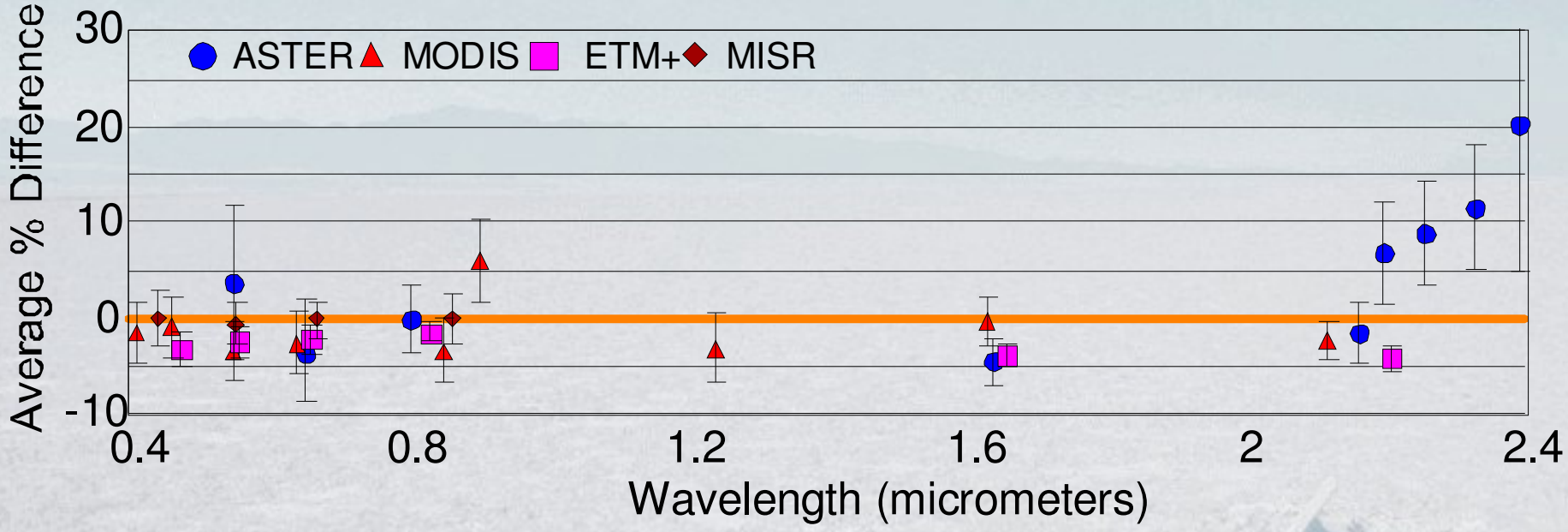




Example result

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



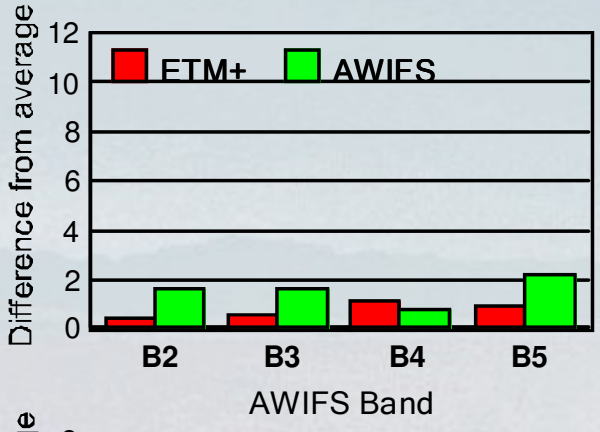
Confidence in results

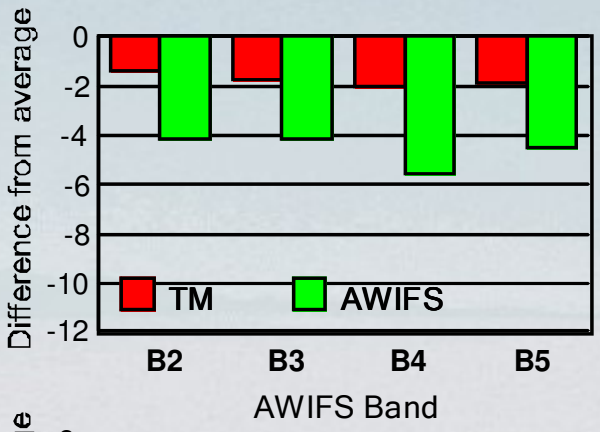
Comparison of reflectance-based results can be used to assess the quality of a data set

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

June 18

Ivanpah

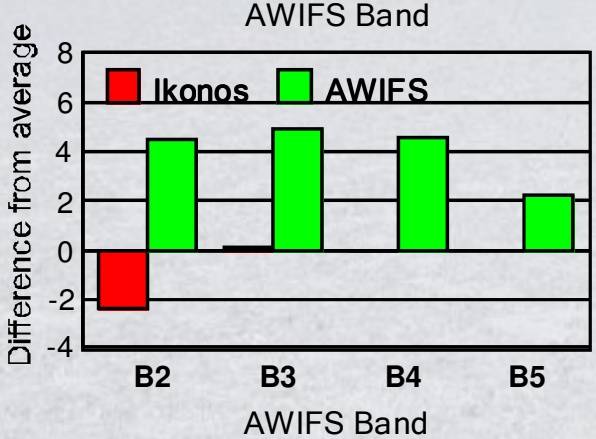


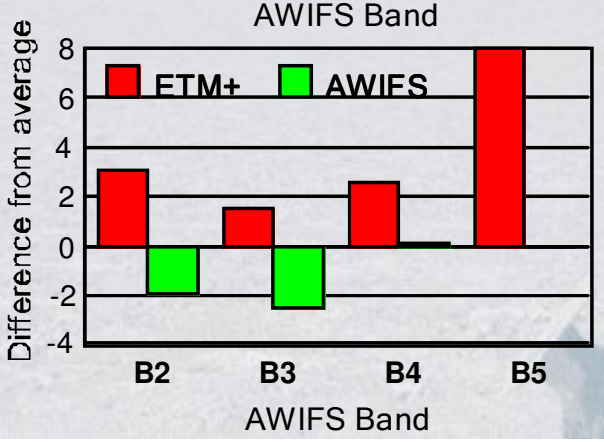


June 18

RRV

June 23



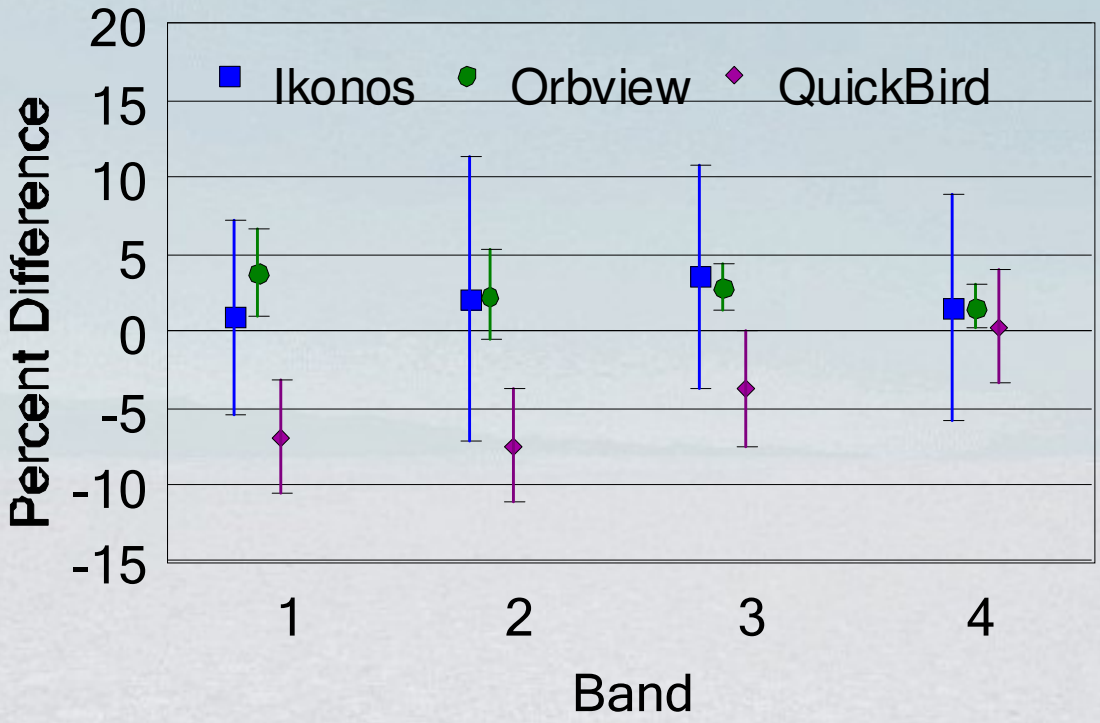


Aug. 10

High resolution sensors

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

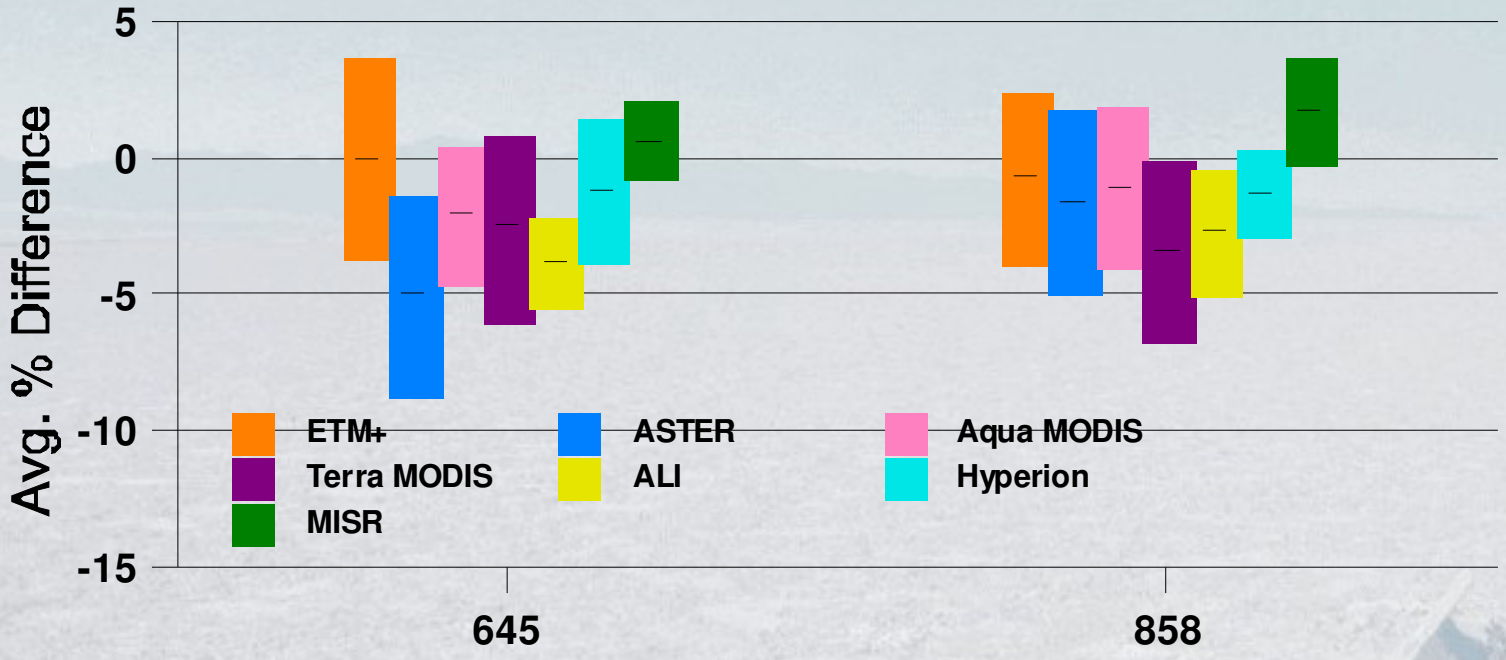
- Ikonos and Orbview agreement is expected since the sensor calibration was altered to match reflectance-based results
- Quickbird results were modified to match ETM+ based on reflectance-based results



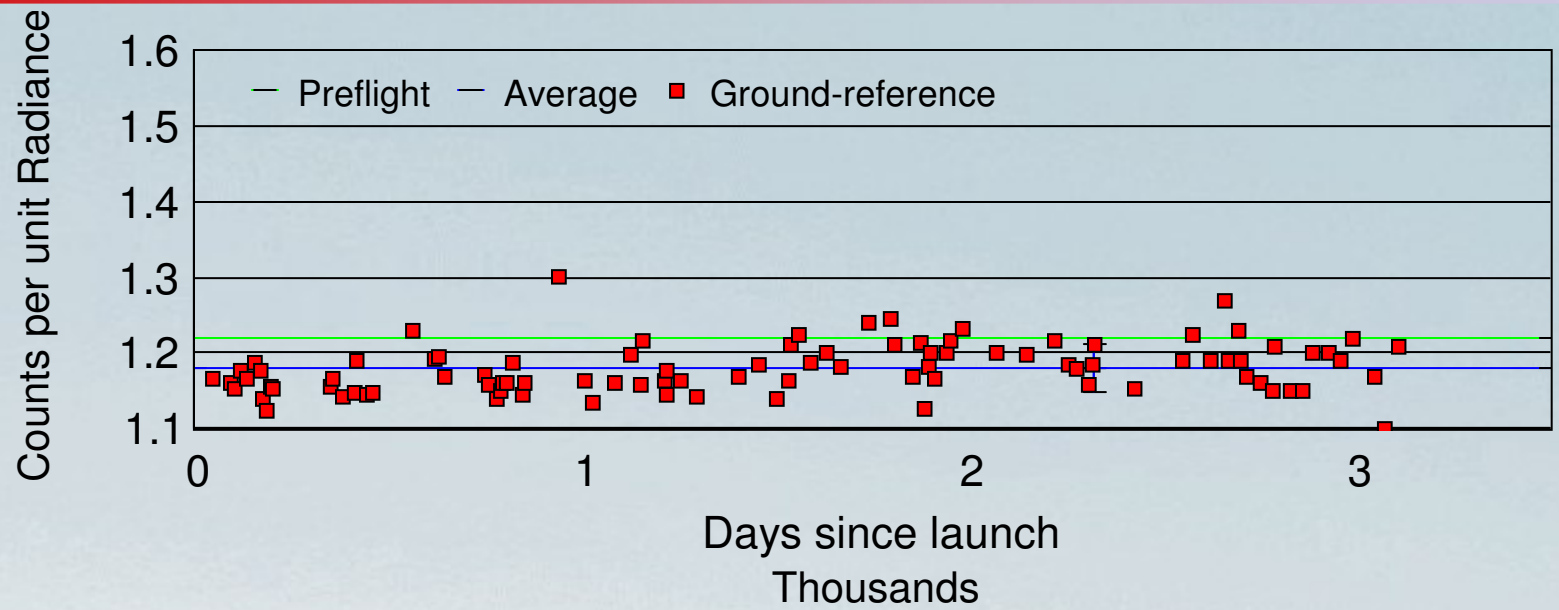
When is a difference a difference?

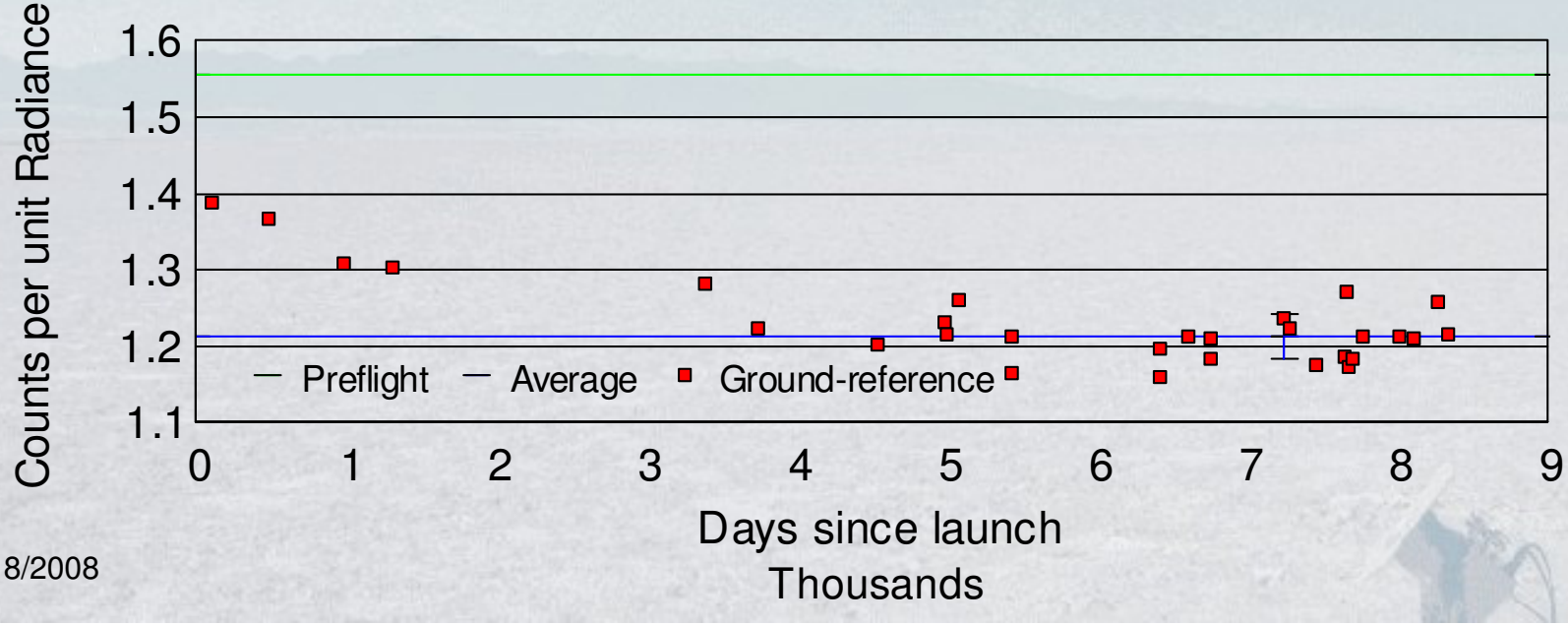
The question remains as to the level of agreement or disagreement between sensors

- Statistical analysis of average and standard deviation can be used
- Only works when there is an official calibration for the sensors



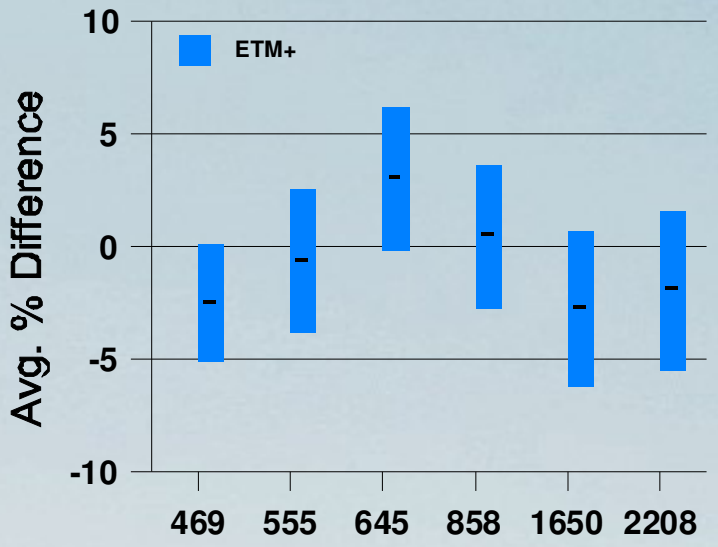
TM and ETM+ Band 1 results

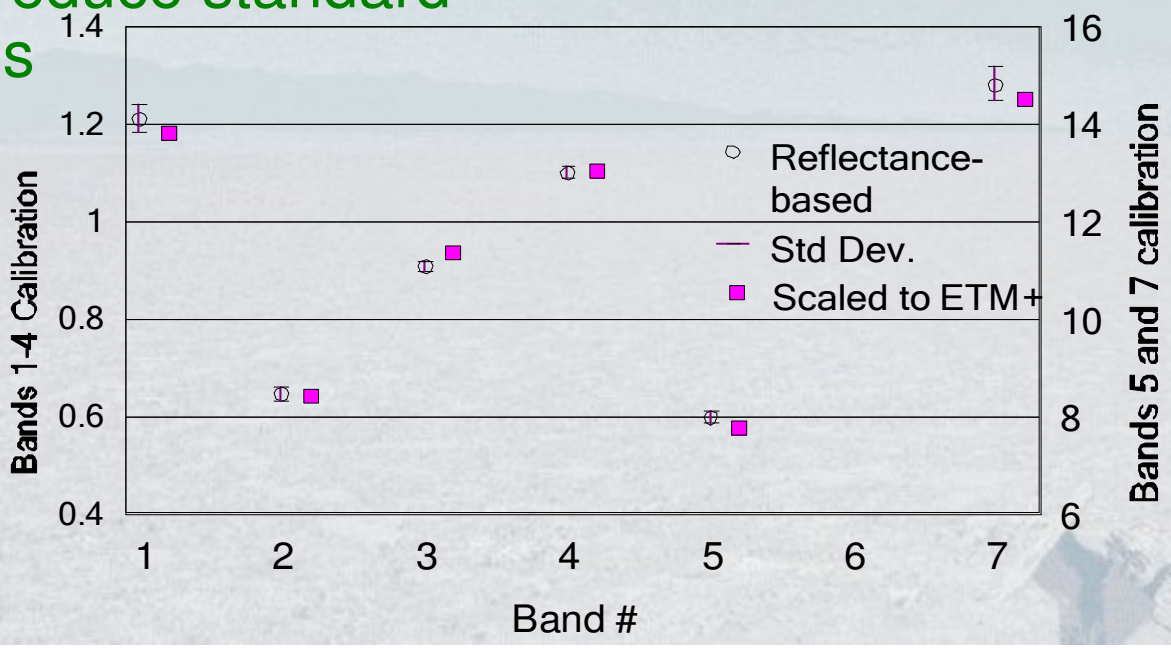




ETM+ and TM averages

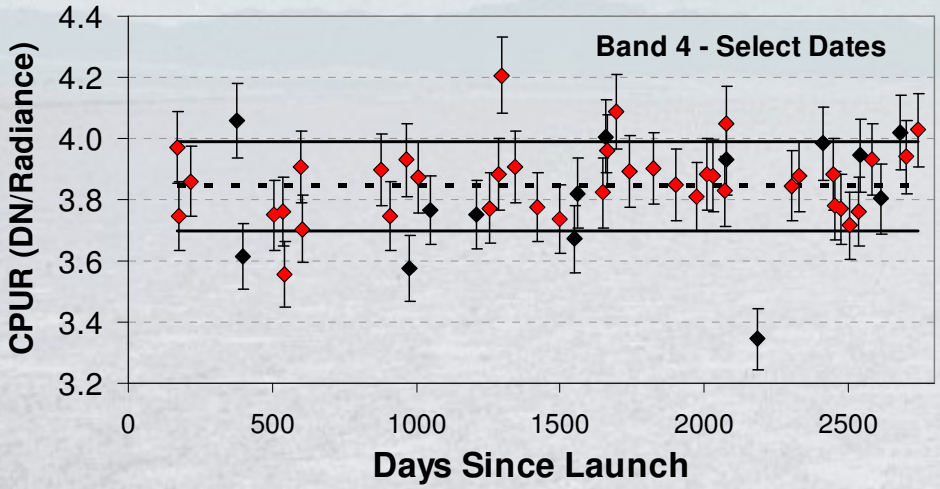
- Square symbols show the TM calibration coefficient that gives agreement with ETM+
- The question remains as to the error bars for the new coefficients
  - RSS of both methods
  - Need to reduce standard deviations





Precision improvement

- Select input parameters to define outlier dates
  - Sensor view >5 degrees
  - Aerosol size
  - Surface variability
- Improves results but still leaves outliers (and removes "good" points)



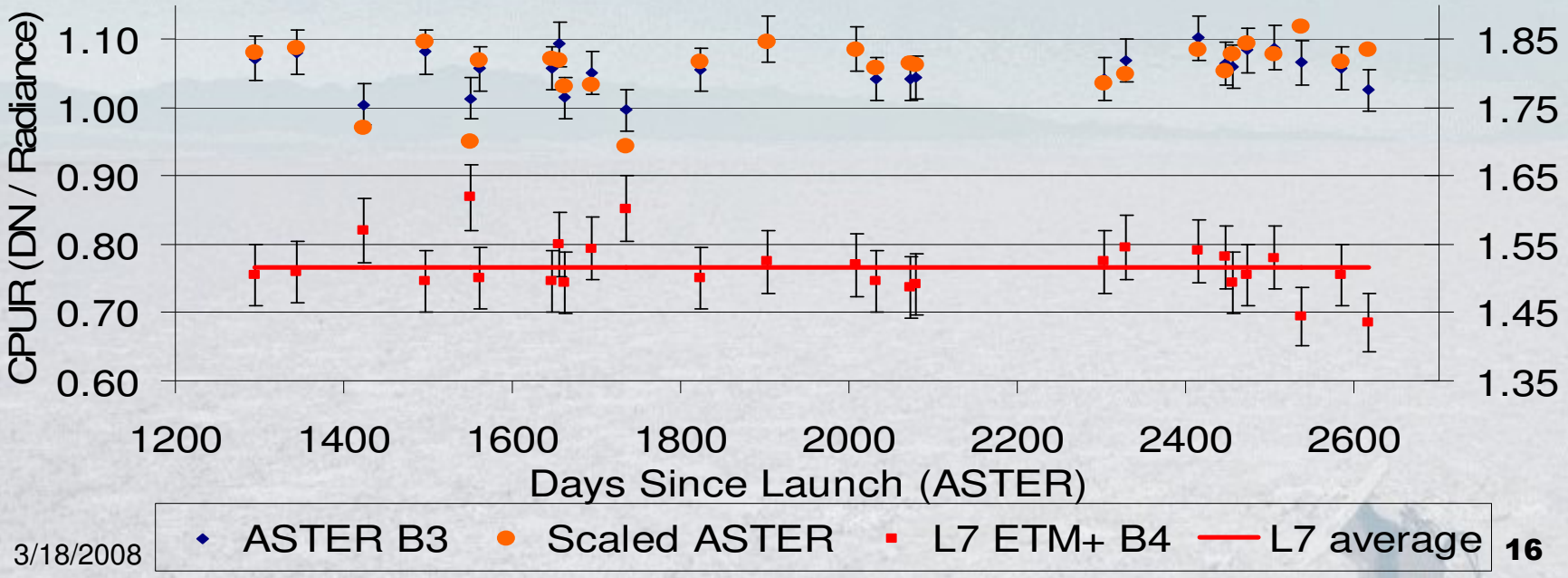
ASTER Band #	ALL dates St Dev (%)	Select dates St Dev (%)	All dates & Select dates % Diff. (Average)
1	3.59	**1.66**	0.21
2	3.32	**2.21**	0.55
3	3.82	**2.81**	0.74
4	3.78	**3.06**	0.35
5	5.80	**4.31**	1.15
6	5.17	**4.24**	1.02
7	5.27	**4.59**	1.04
8	6.00	**5.30**	1.18
9	9.27	**6.65**	1.02

Sensor-to-sensor improvement

Data can be scaled to remove day-to-day biases in vicarious results

- Used ETM+ data to scale ASTER
- Unfortunately, standard deviations increased in all but Band 1
- Implies two collections not correlated (that's good)

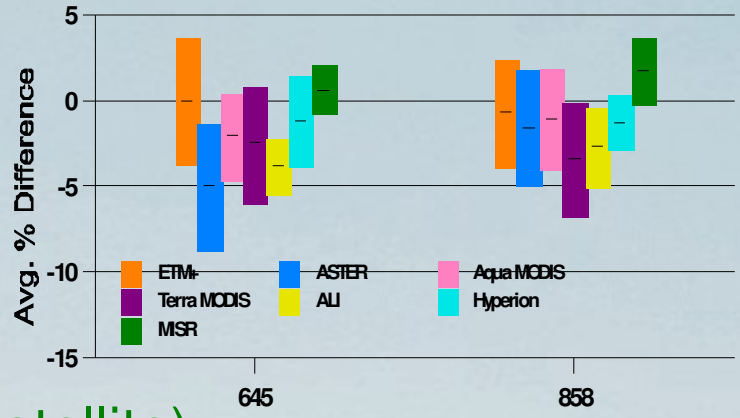
ASTER band	% st dev	Scaled % st dev
1	3.5	3.2
2	2.4	3.3
3	3.2	3.7
4	3.8	4.6

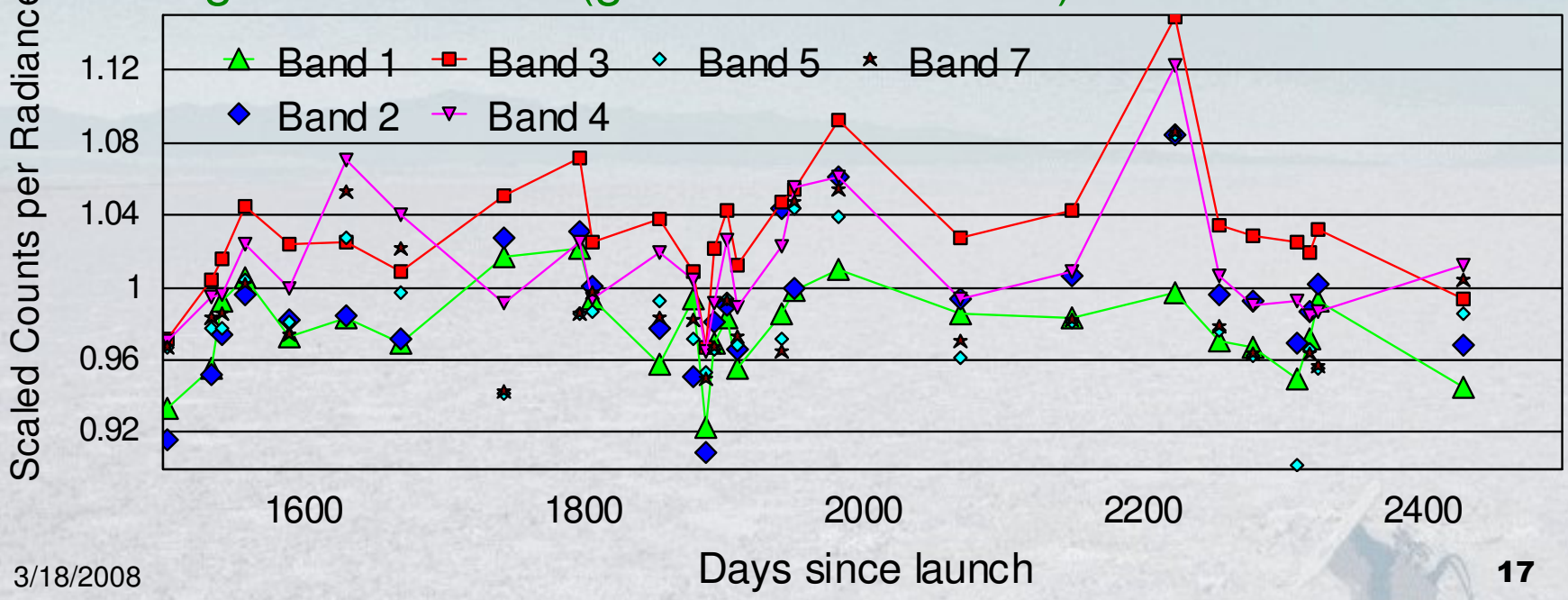


Band-to-band improvement

Data from a given day tends to be correlated by band on that date

- Scale all data relative to that band
- Select a red or NIR band
  - Small standard deviation
  - High reflectance
  - High sensor SNR (ground and satellite)

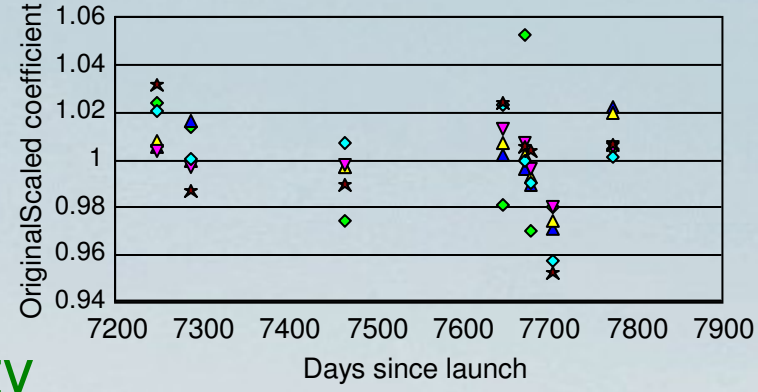


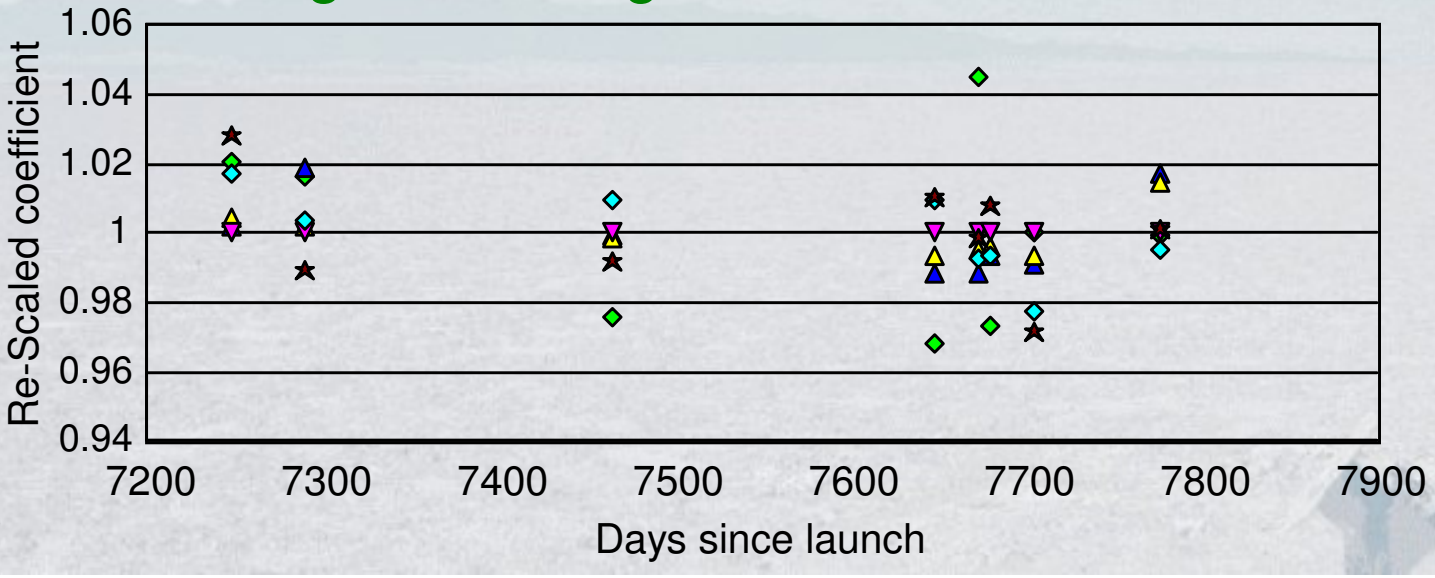


Landsat-5 Reanalysis

Selected eight "good" days for Landsat-5 TM over the period from May 2004 to October 2005

- Flat response in all bands
- "Large" set of data points
- Scaled data relative to band 3
  - Smaller standard deviations
  - All data "centered" about unity
  - Little change in average

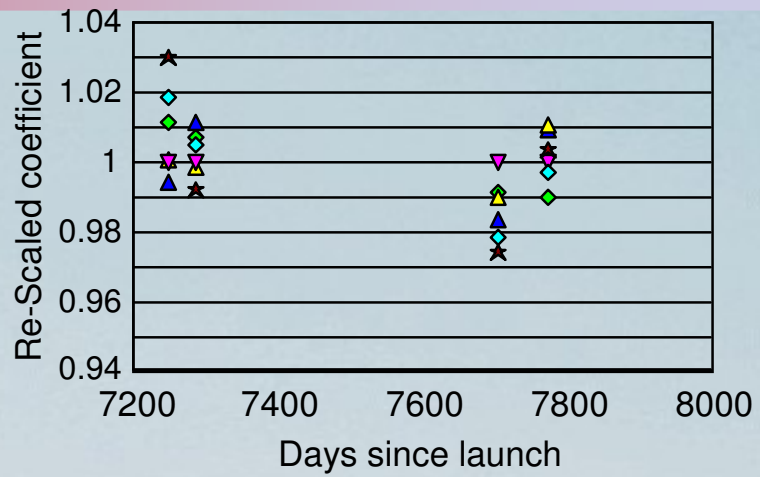




Landsat-5 downselect

Removing dates with large spectral variation reduces scatter

- Surface moisture effects & field spectrometer behavior
- Leaves four dates



TM Band #	Avg. all dates no scaling	Std. dev. All dates no scaling (%)	Avg. all dates scaled	Std. dev. all dates scaled (%)	Avg. select dates	Std. dev. select dates (%)
1	1.21	2.9	1.21	2.6	1.21	1.4
2	0.641	1.6	0.641	0.7	0.642	0.9
3	0.909	1.3	0.909	0.0	0.909	0.0
4	1.10	1.0	1.10	0.7	1.09	0.9
5	8.11	2.0	8.11	1.3	8.06	1.5
7	15.0	2.5	15.0	1.6	14.9	2.0

TM/ETM+ cross calibration

Approach was applied to ETM+ for the same time period & scale TM values to match ETM+ preflight

- Started with 17 data sets during the period
- Downselected to 7 data sets
- Resulting TM coefficients based on this approach matches well with ETM+/TM underflight results

Band #	ETM+ Avg. select dates	ETM+ std. dev. select dates (%)	TM Avg. select dates	TM std. dev. select dates (%)	TM cross cal. result	TM cross cal std. dev. (%)
1	1.19	0.6	1.21	1.4	1.25	1.5
2	1.17	0.7	0.642	0.9	0.650	1.1
3	1.55	0.0	0.909	0.0	0.884	---
4	1.51	0.8	1.09	0.9	1.10	1.2
5	7.39	0.8	8.06	1.5	8.13	1.7
7	21.2	0.8	14.9	2.0	15.0	2.2

Summary

Vicarious methods in general have improved dramatically in recent years

- Not just reflectance-based method
- Cross-calibration approaches have improved their precision and accuracy
- One issue is whether overlap is required
- Reflectance-based method can be used without overlap with 2-3% traceable absolute uncertainty
- Band-to-band and day-to-day variability limits precision at this time
  - Single physical cause is not readily apparent
  - Band correlation appears to be best method to remove day-to-day effects

Summary

Cross-calibration approach shown here is suitable for varying spatial and spectral resolutions

- Spectral effects are taken into account in the ground measurements
- Other work shows that footprints as large as 1-km can be used
  - Requires large-sized sites such as RRV Playa
  - Geolocation between ground data and sensor is an issue
  - Site-to-site and season-to-season biases are not significant
- Automated measurement approaches increase opportunities to obtain data for a given sensor
- Combination of methods shown here should allow cross-calibration relative to a given sensor to approach levels of 0.7% combined uncertainty