Cross-Calibration of the Landsat-7 ETM+ and EO-1 ALI sensors

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USGS science for a changing world

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SDSU

Outline

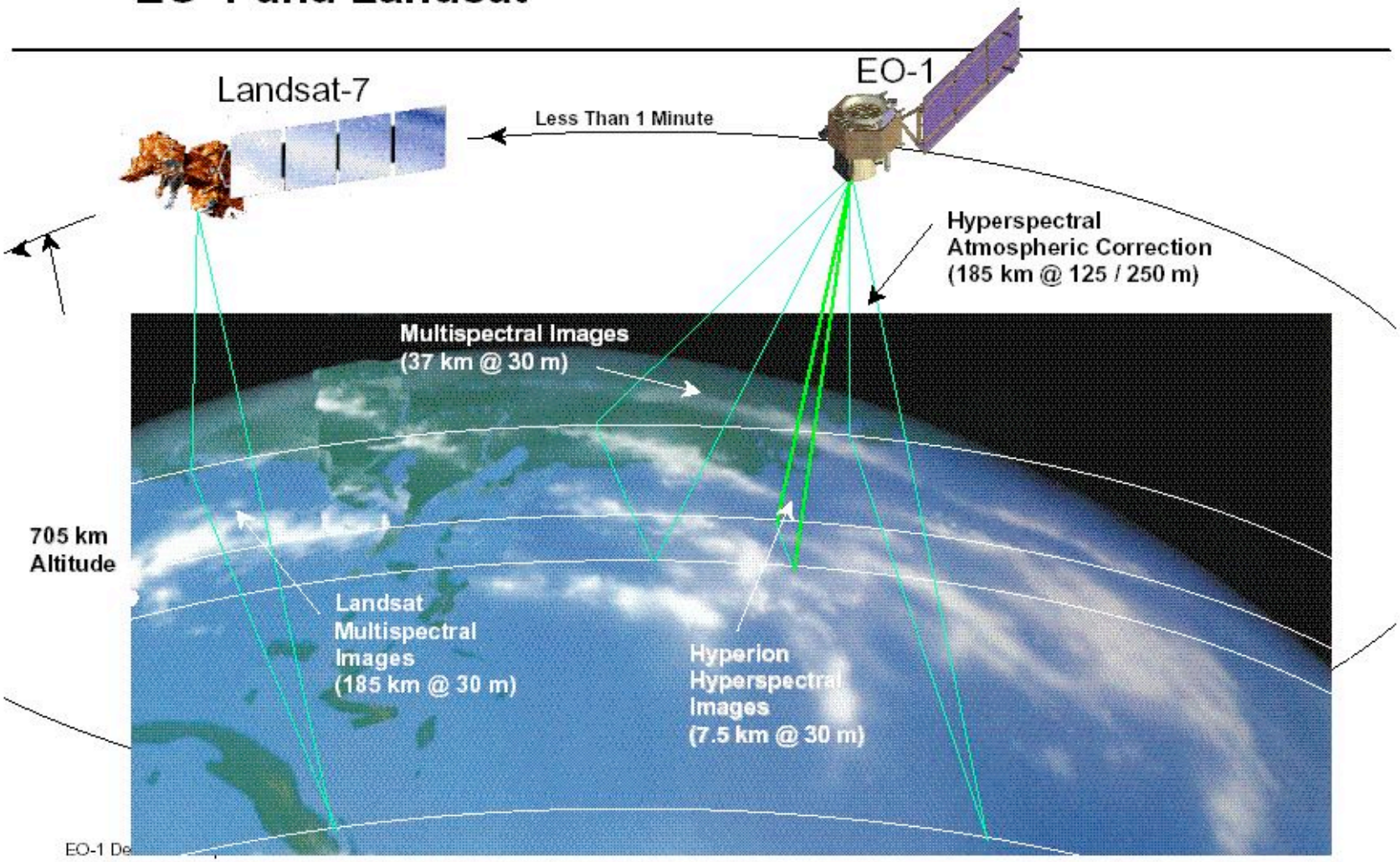
- Physical Specifications
- Spectral Bands
- Cross-Calibration Results
  - Calibration of near simultaneous surface observations
  - Vicarious Calibration
- Conclusion

Physical Specifications & Key ALI Performance

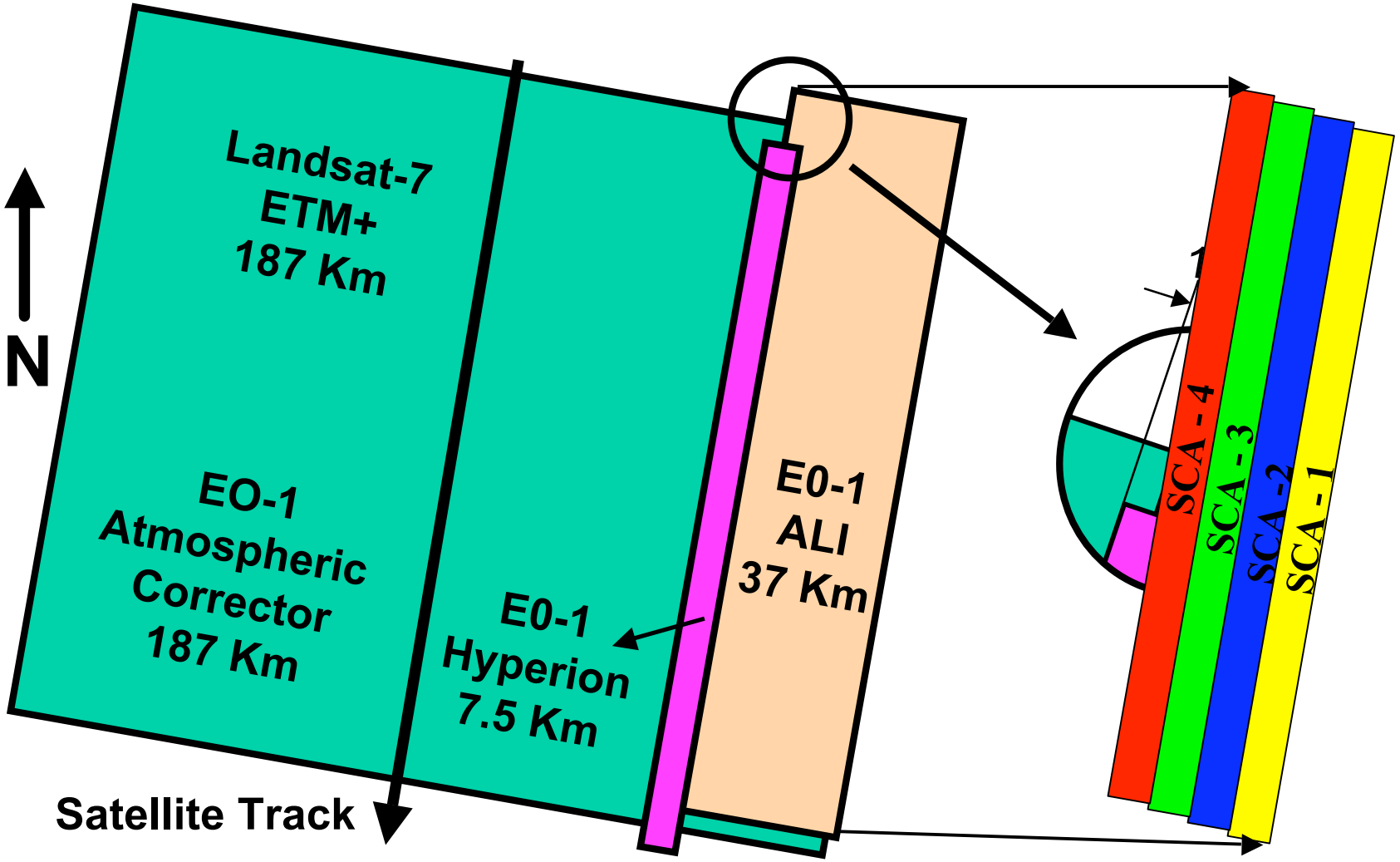
- Meet or exceed ETM+ performance (w/o thermal band) at minimum size, weight, schedule, and cost
  - Push broom imaging
  - 10 m panchromatic GSD
  - On-orbit internal calibration and stability monitoring system
- SNR four to ten times ETM+ values, depending on band
- Demonstrate spatial, spectral, and radiometric calibration for large detector arrays

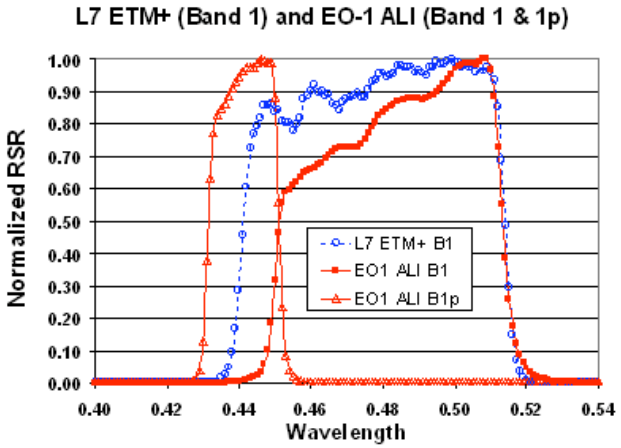
EO-1/L7 Instrument Comparison		
Physical Unit	**L7 (ETM+)**	**EO-1 (ALI)**
Mass (Kg)	425	100
Power (W)	545	100
Size (m^3)	1.4	0.2
Bands	7	10
Detectors per band	16	6200
Thermal band	1	None
Data rate (Mbps)	150	300
Pan Resolution (m)	15	10
Relative SNR	1x	4x

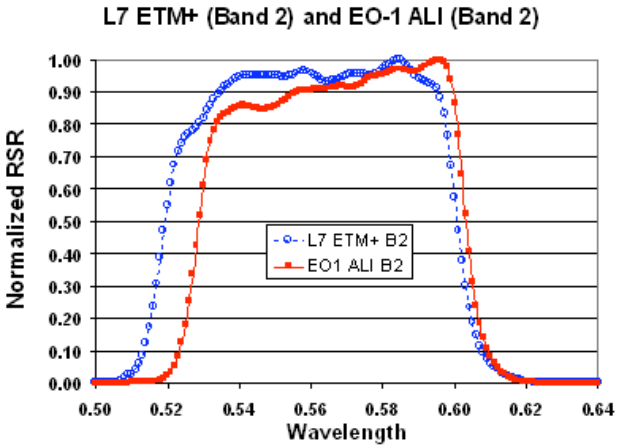
EO-1 and Landsat

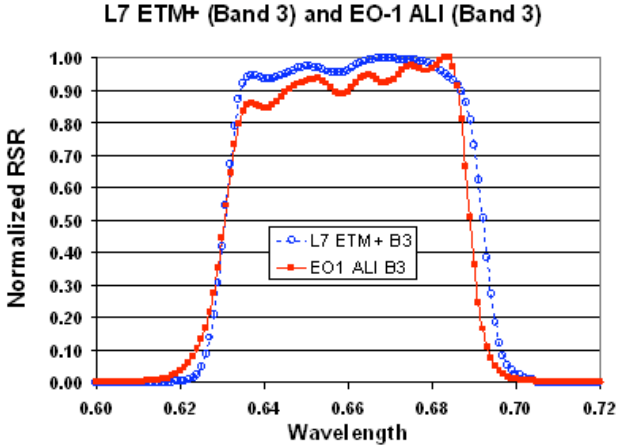


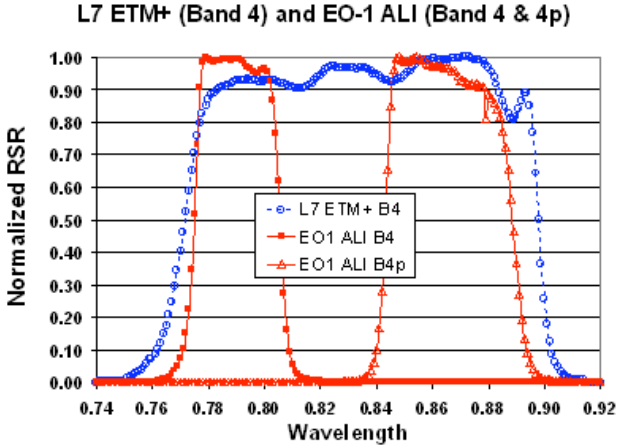
EO-1, L7 Descending Tracks

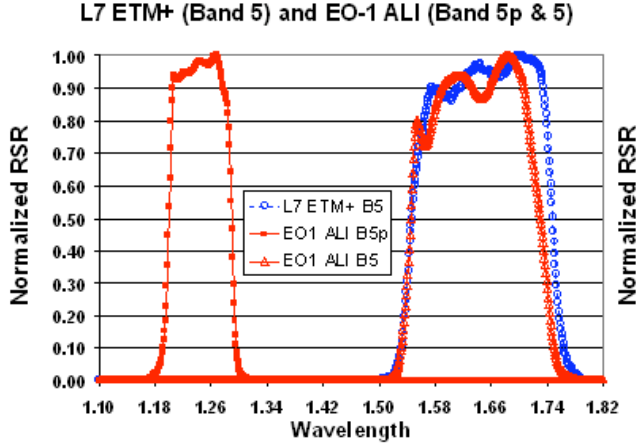


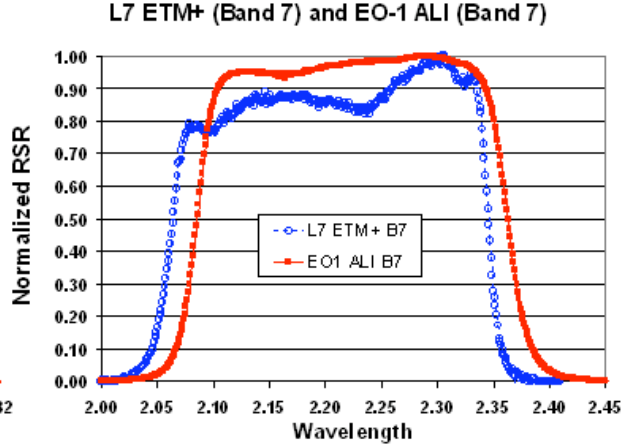












Relative Spectral Response (RSR) Profiles

- **ETM+ Heritage Bands**

  - ETM+ panchromatic band extends into NIR

  - ALI panchromatic band cuts off in the red

  - ETM+ NIR band4 split into ALI bands 4/4p

- **ALI "Prime" Bands**

  - Band 1p "deep" blue

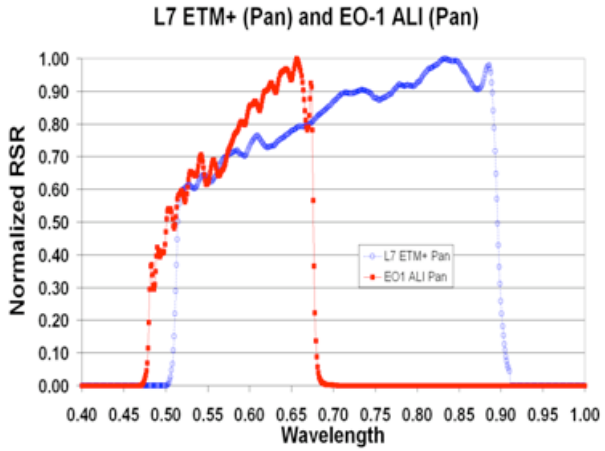
(atmospheric correction, oceanography)

  - Band 4/4p Modified NIR

(avoid water vapor absorption feature)

  - Band 5p SWIR 1

(vegetation mapping applications)

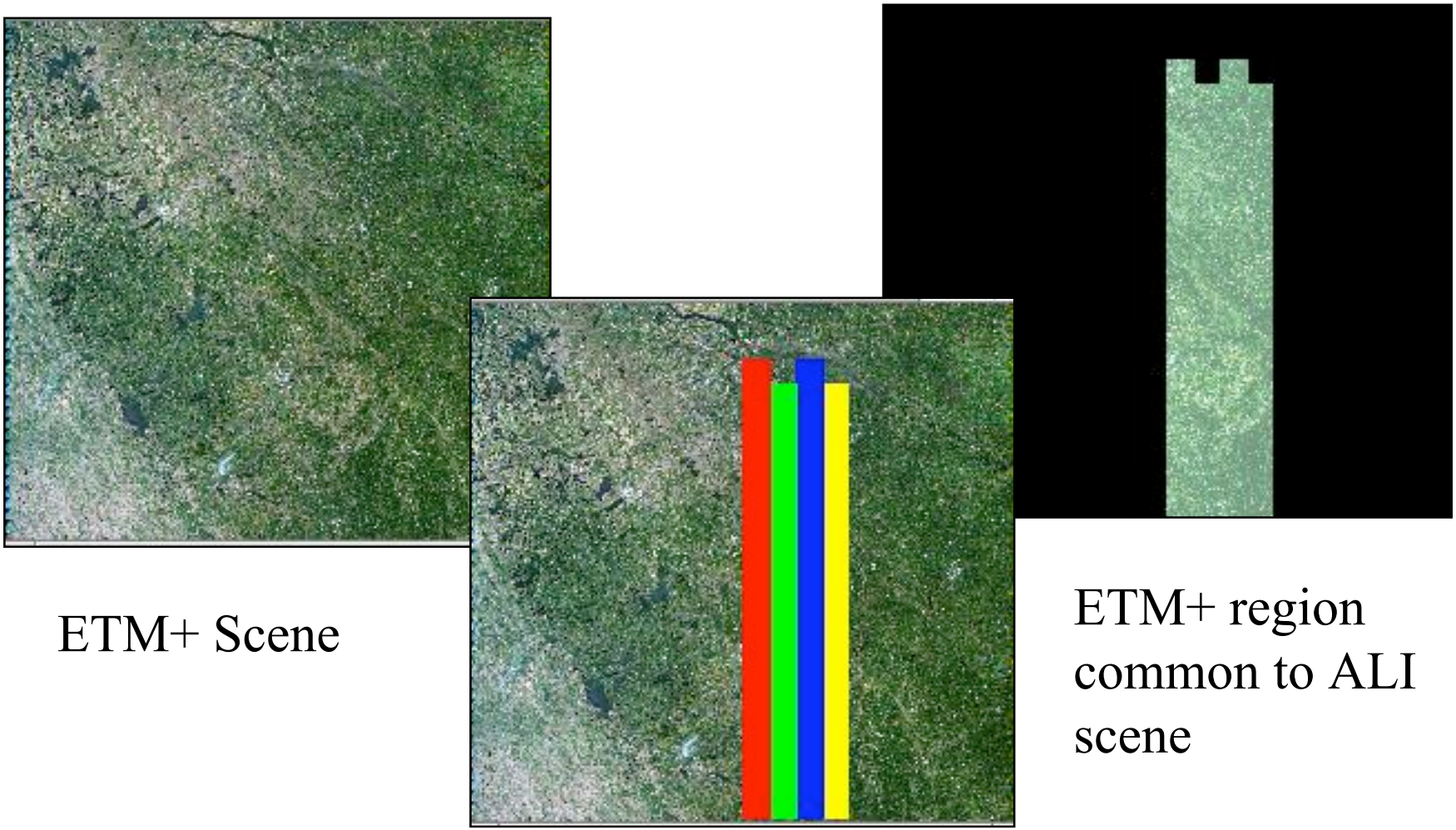


Cross-Calibration

- Image Pairs from ALI and ETM+
  - Image statistics based on large common areas between the image pairs from near simultaneous surface observations
  - Compared Predicted TOA radiance to measured radiance

Location	Date	DOY	Path/Row
Brookings	Sept. 05, 2001.	248	029/029
Railroad Valley	June. 30, 2001.	181	040/033
White Sands	Mar. 25, 2001.	84	033/037

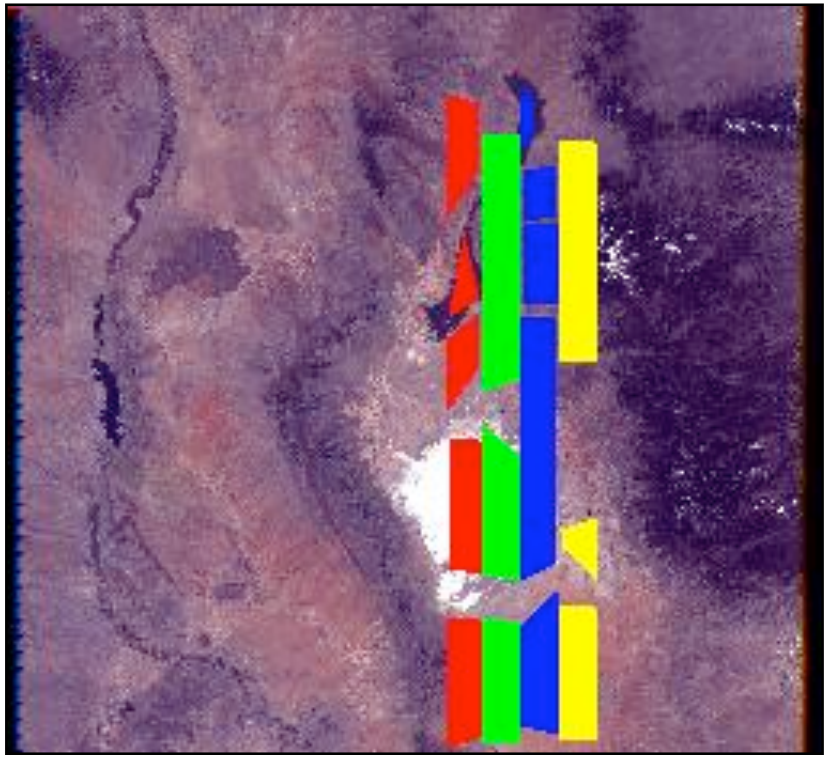
ETM+ / ALI Scenes from Brookings (DOY 248)



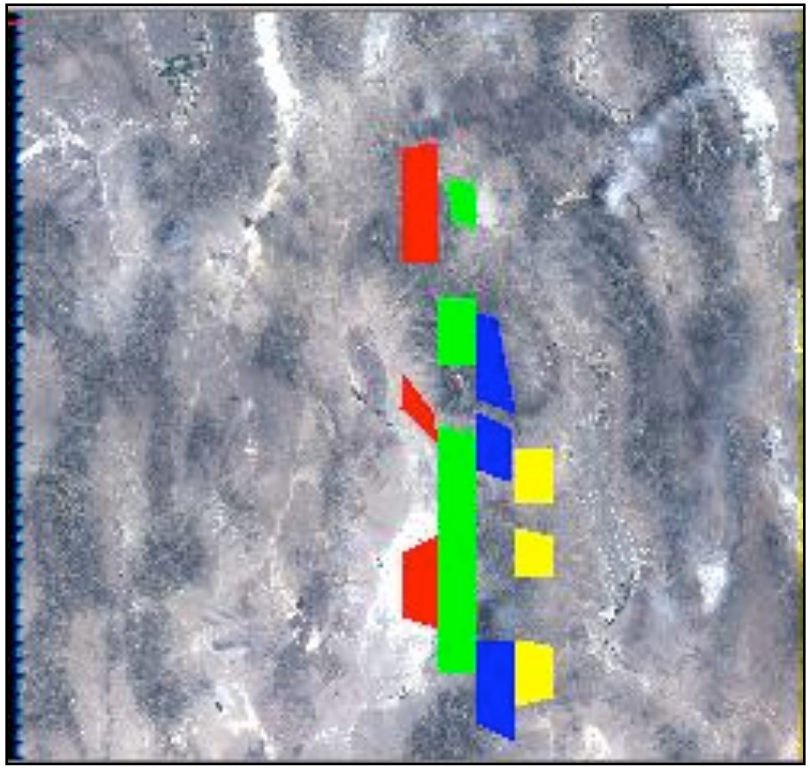
ETM+ Scene

ETM+ region common to ALI scene

Common Ground Regions



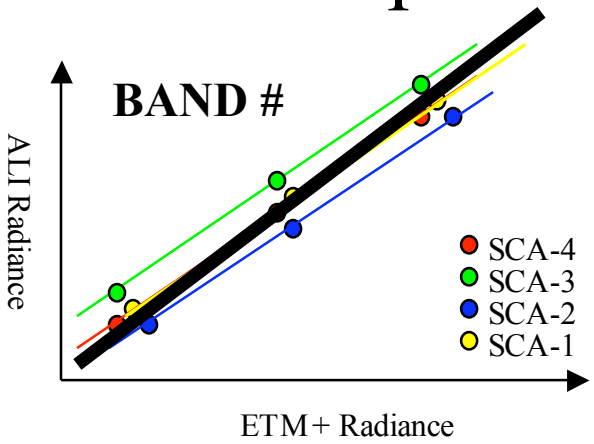
White Sands (084)



Railroad Valley (181)

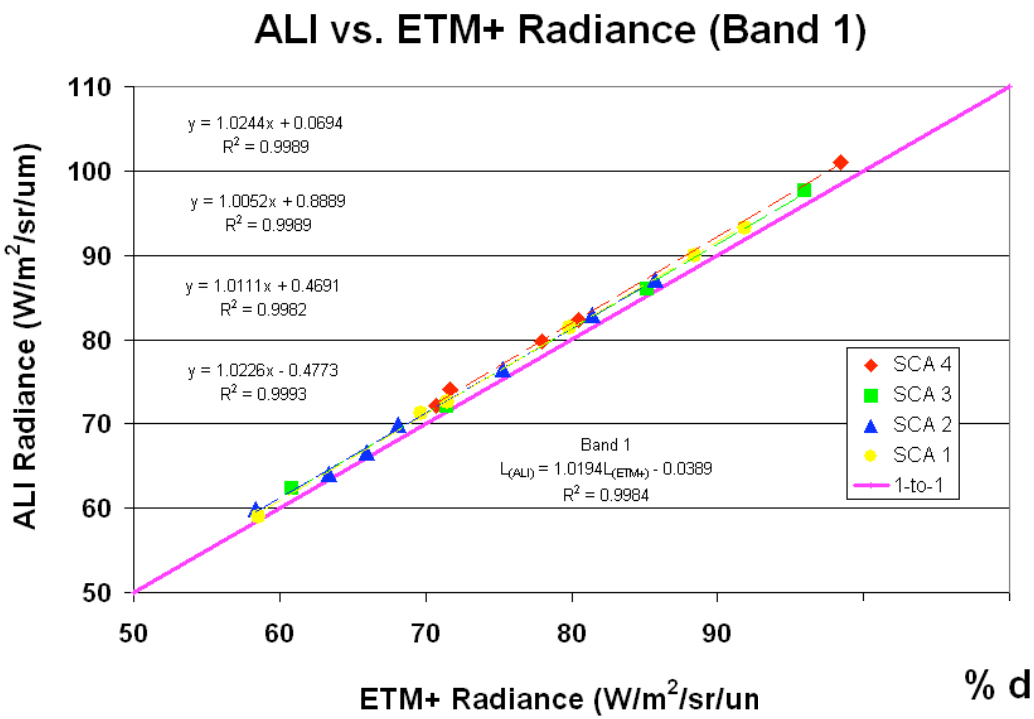
Hypothesis Test

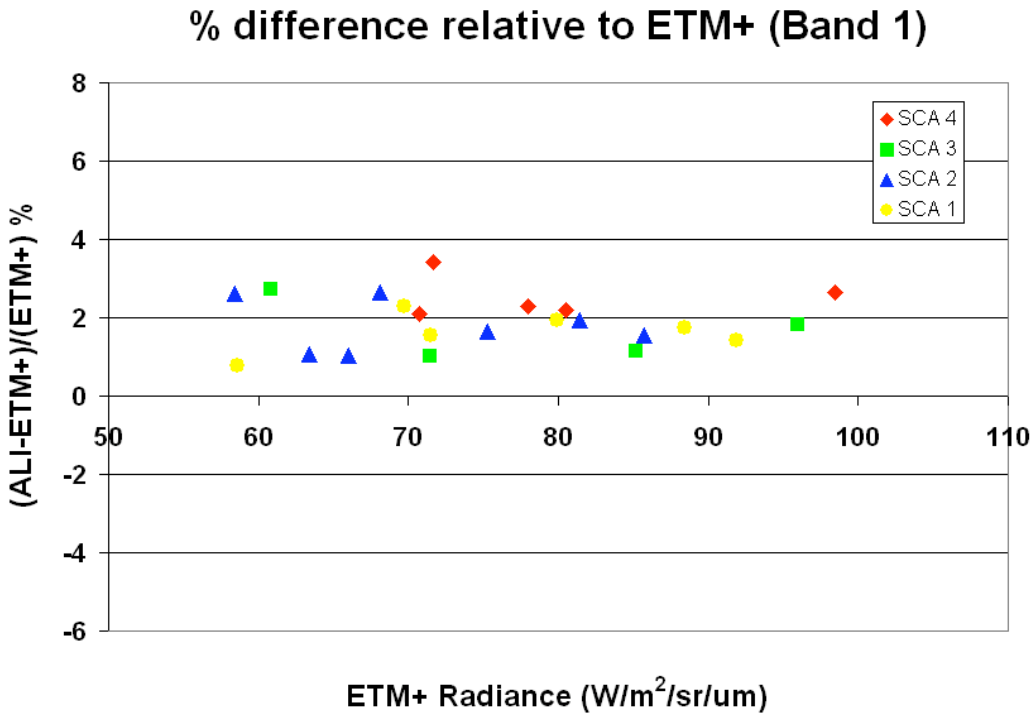
- Cross-Calibration results were tested for slope=1 and intercept=0:
  - Fitting a regression line to each SCA data common to ALI /ETM+
    - $L_{(ALI)} = \beta_1 L_{(ETM+)} + \beta_0$

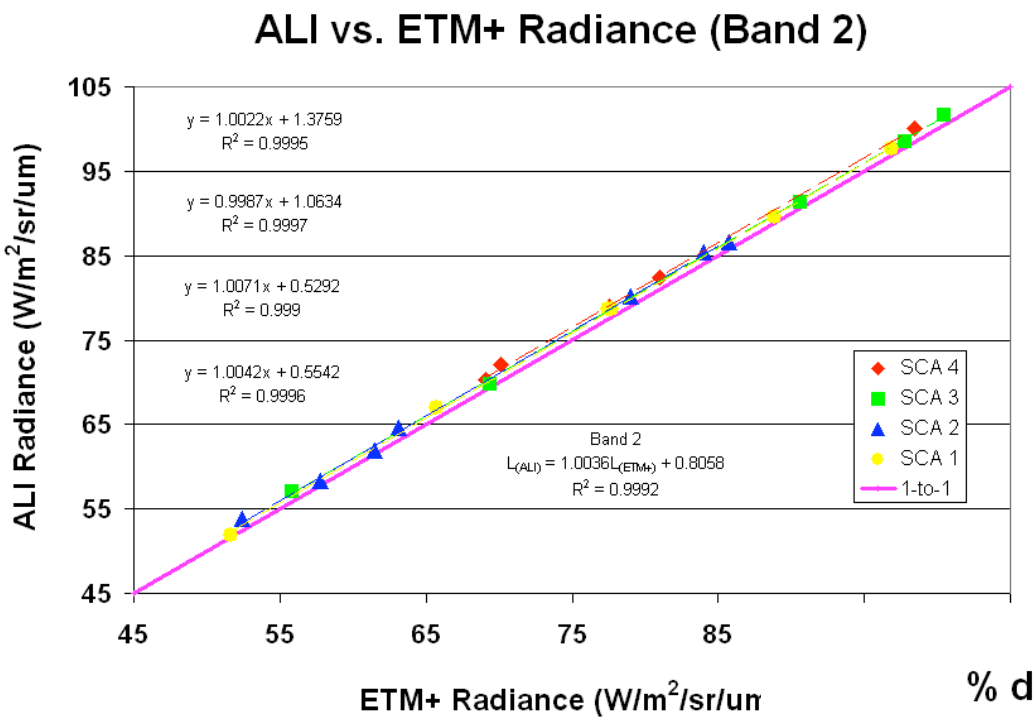


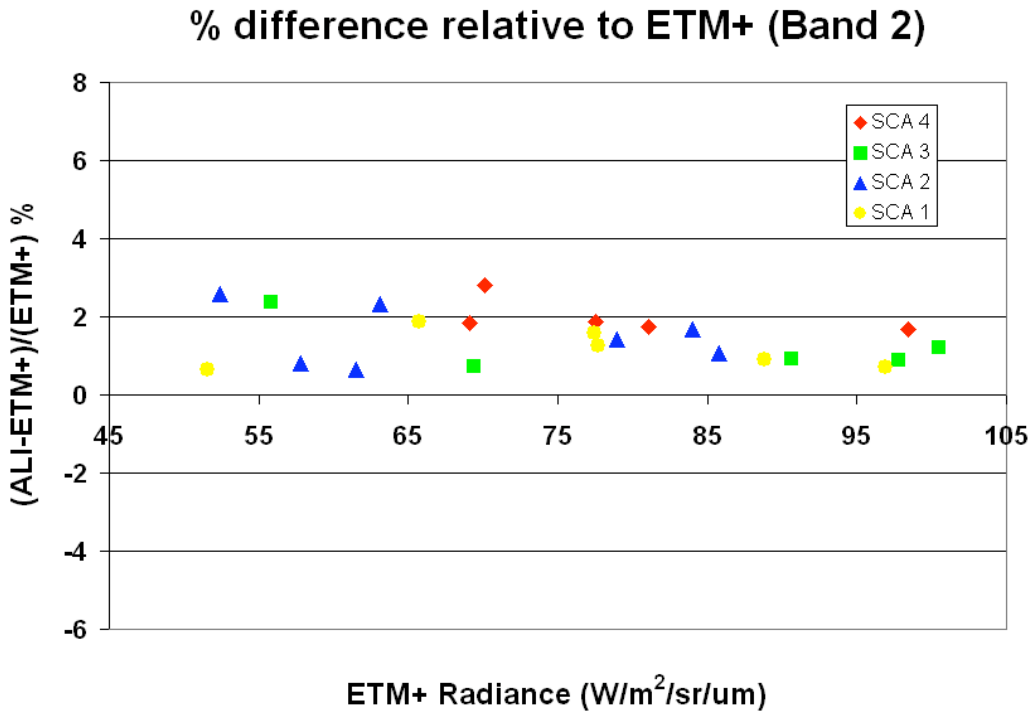
  - Applying a slope/intercept hypothesis test to the regression lines

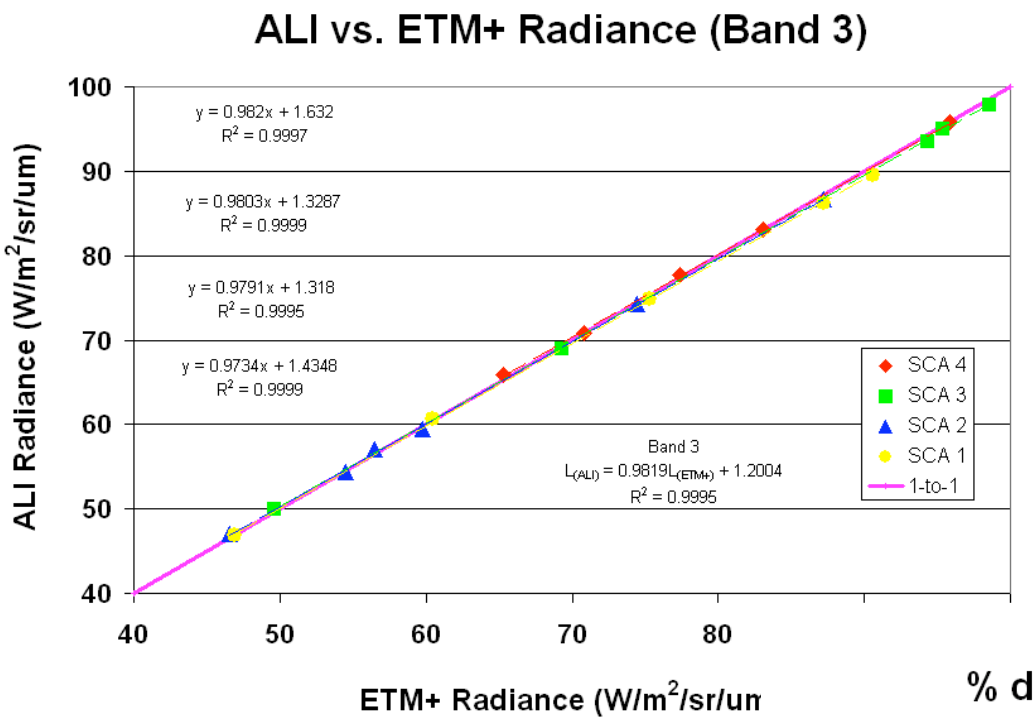
	SLOPE	*Intercept*
■	$H_o: \beta_1 = 1$	$H_o: \beta_0 = 0$
■	$H_1: \beta_1 \neq 1$	$H_1: \beta_0 \neq 0$

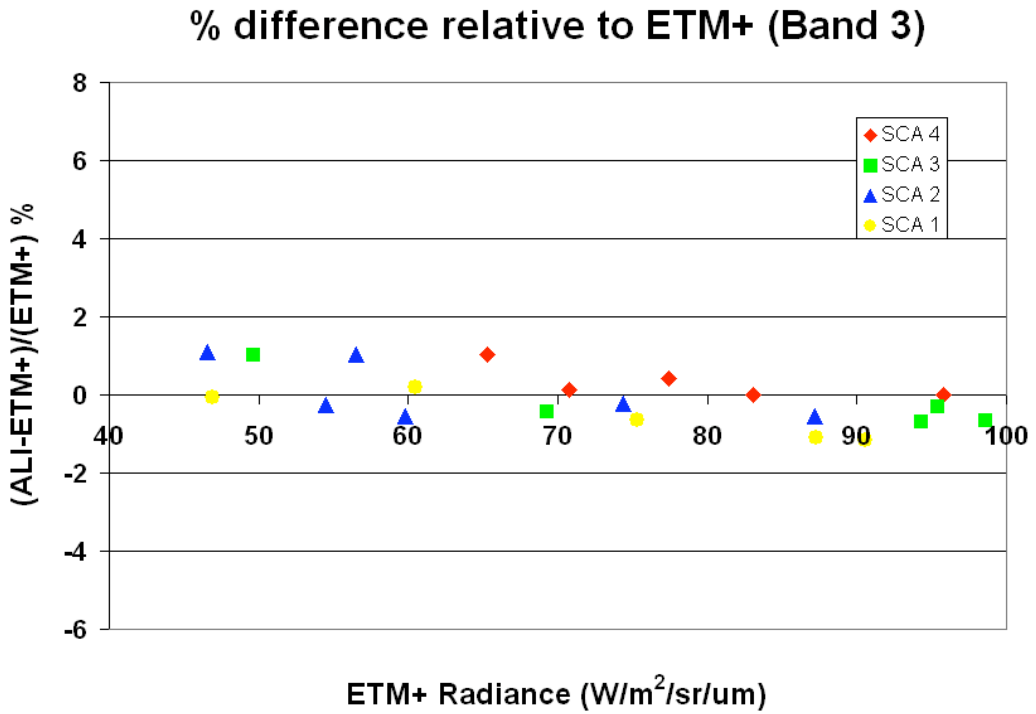

ALI vs. ETM+ Radiance (Band 1)
y = 1.0244x + 0.0694
R² = 0.9989
y = 1.0052x + 0.8889
R² = 0.9989
y = 1.0111x + 0.4691
R² = 0.9982
y = 1.0226x - 0.4773
R² = 0.9993
Band 1
L(ALI) = 1.0194L(ETM+) - 0.0389
R² = 0.9984
SCA 4
SCA 3
SCA 2
SCA 1
1-to-1
ALI Radiance (W/m²/sr/um)
ETM+ Radiance (W/m²/sr/un
110
100
90
80
70
60
50
50
60
70
80
90

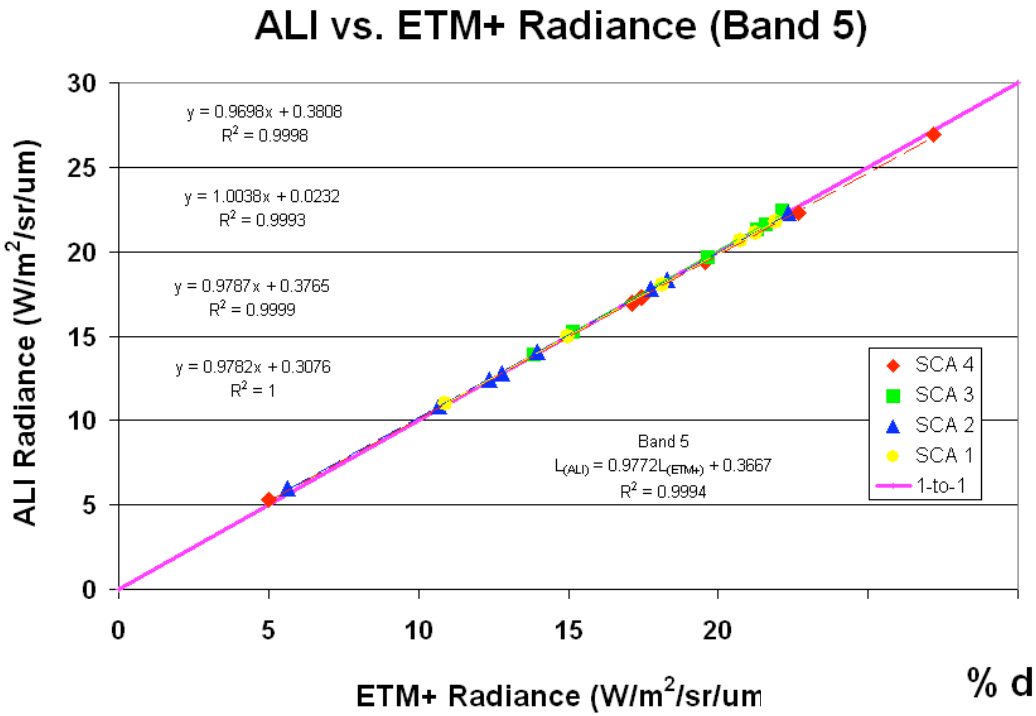

% difference relative to ETM+ (Band 1)
SCA 4
SCA 3
SCA 2
SCA 1
(ALI-ETM+)/(ETM+) %
ETM+ Radiance (W/m²/sr/um)
8
6
4
2
0
-2
-4
-6
50
60
70
80
90
100
110

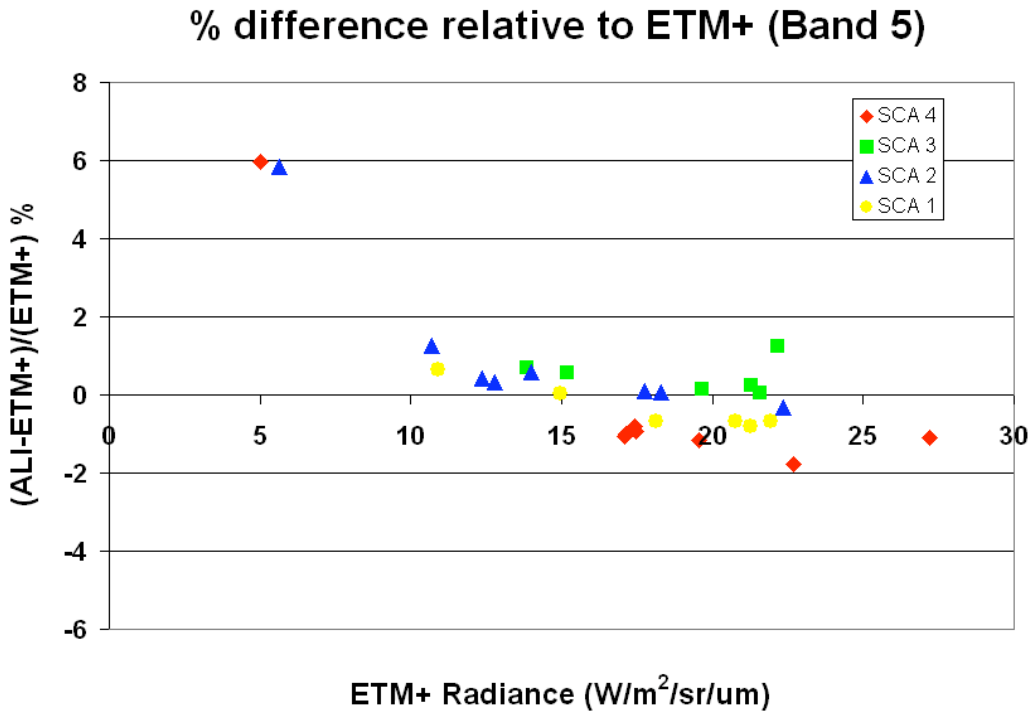

ALI vs. ETM+ Radiance (Band 2)
y = 1.0022x + 1.3759
R² = 0.9995
y = 0.9987x + 1.0634
R² = 0.9997
y = 1.0071x + 0.5292
R² = 0.999
y = 1.0042x + 0.5542
R² = 0.9996
Band 2
L(ALI) = 1.0036L(ETM+) + 0.8058
R² = 0.9992
SCA 4
SCA 3
SCA 2
SCA 1
1-to-1
ALI Radiance (W/m²/sr/um)
ETM+ Radiance (W/m²/sr/um
105
95
85
75
65
55
45
45
55
65
75
85


% difference relative to ETM+ (Band 2)
SCA 4
SCA 3
SCA 2
SCA 1
(ALI-ETM+)/(ETM+) %
ETM+ Radiance (W/m²/sr/um)
8
6
4
2
0
-2
-4
-6
45
55
65
75
85
95
105

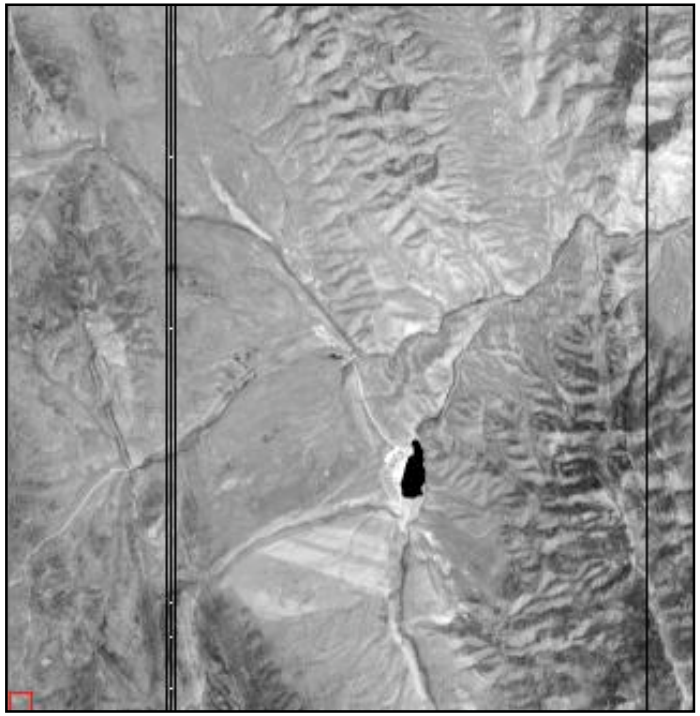

ALI vs. ETM+ Radiance (Band 3)
y = 0.982x + 1.632
R2 = 0.9997
y = 0.9803x + 1.3287
R2 = 0.9999
y = 0.9791x + 1.318
R2 = 0.9995
y = 0.9734x + 1.4348
R2 = 0.9999
Band 3
L(ALI) = 0.9819L(ETM+) + 1.2004
R2 = 0.9995
SCA 4
SCA 3
SCA 2
SCA 1
1-to-1
ALI Radiance (W/m2/sr/um)
ETM+ Radiance (W/m2/sr/um
100
90
80
70
60
50
40
40
50
60
70
80


% difference relative to ETM+ (Band 3)
SCA 4
SCA 3
SCA 2
SCA 1
(ALI-ETM+)/(ETM+) %
ETM+ Radiance (W/m2/sr/um)
8
6
4
2
0
-2
-4
-6
40
50
60
70
80
90
100

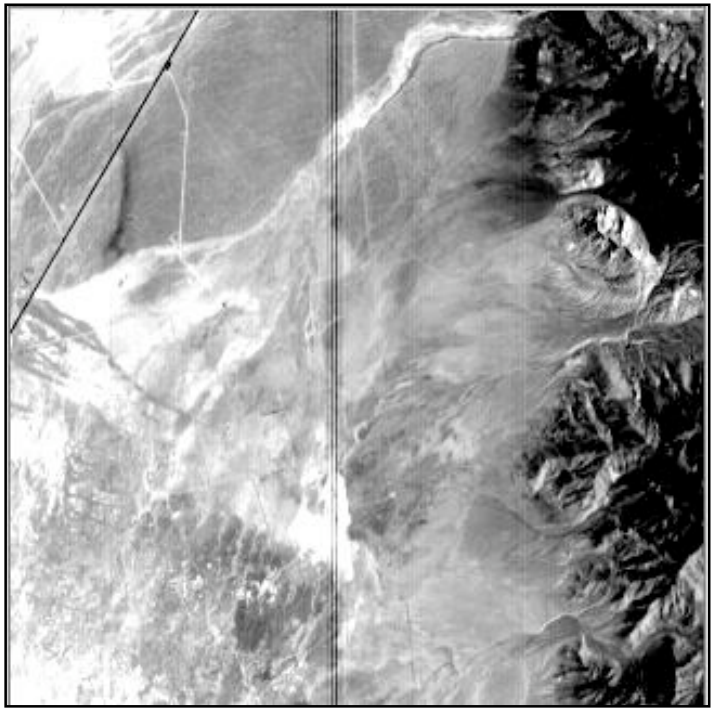

ALI vs. ETM+ Radiance (Band 5)
y = 0.9698x + 0.3808
R2 = 0.9998
y = 1.0038x + 0.0232
R2 = 0.9993
y = 0.9787x + 0.3765
R2 = 0.9999
y = 0.9782x + 0.3076
R2 = 1
Band 5
L(ALI) = 0.9772L(ETM+) + 0.3667
R2 = 0.9994
SCA 4
SCA 3
SCA 2
SCA 1
1-to-1
ALI Radiance (W/m2/sr/um)
ETM+ Radiance (W/m2/sr/um
0
5
10
15
20
25
30


% difference relative to ETM+ (Band 5)
SCA 4
SCA 3
SCA 2
SCA 1
(ALI-ETM+)/(ETM+) %
ETM+ Radiance (W/m2/sr/um)
8
6
4
2
0
-2
-4
-6
0
5
10
15
20
25
30

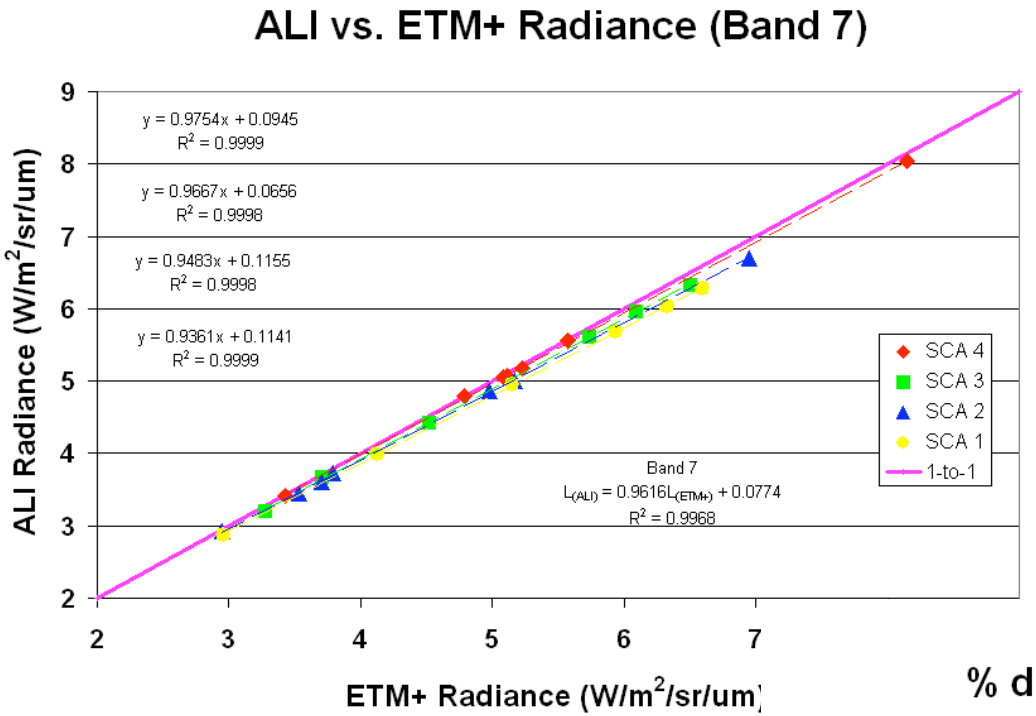
Anomalous detectors in Band-5

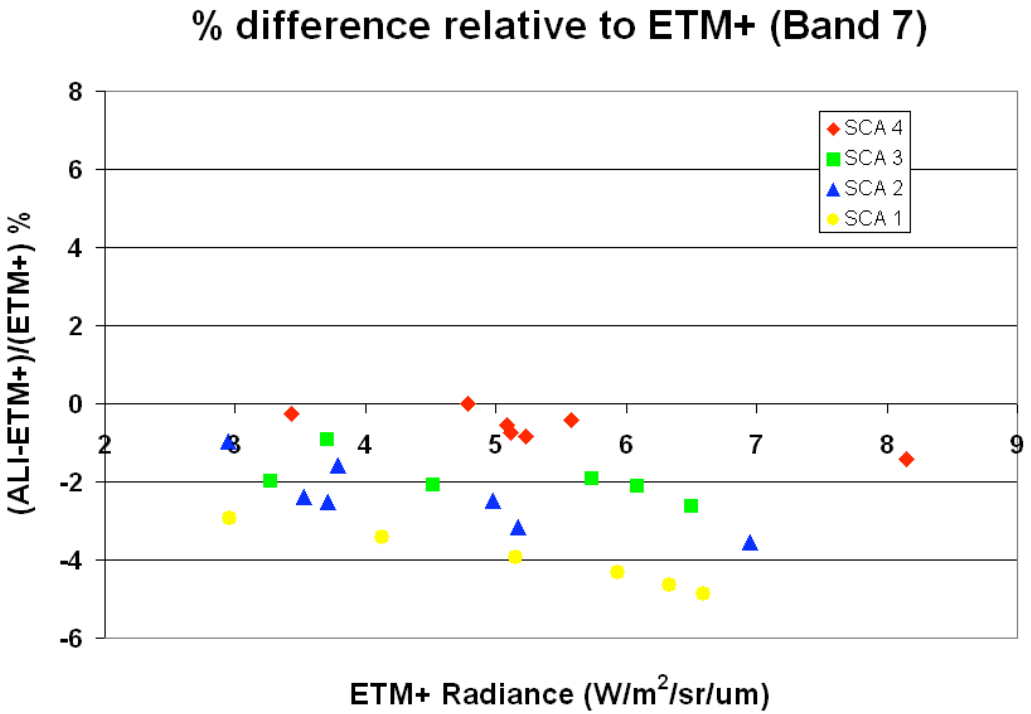


Band:5 (SCA-4)



Band:5 (SCA-3)

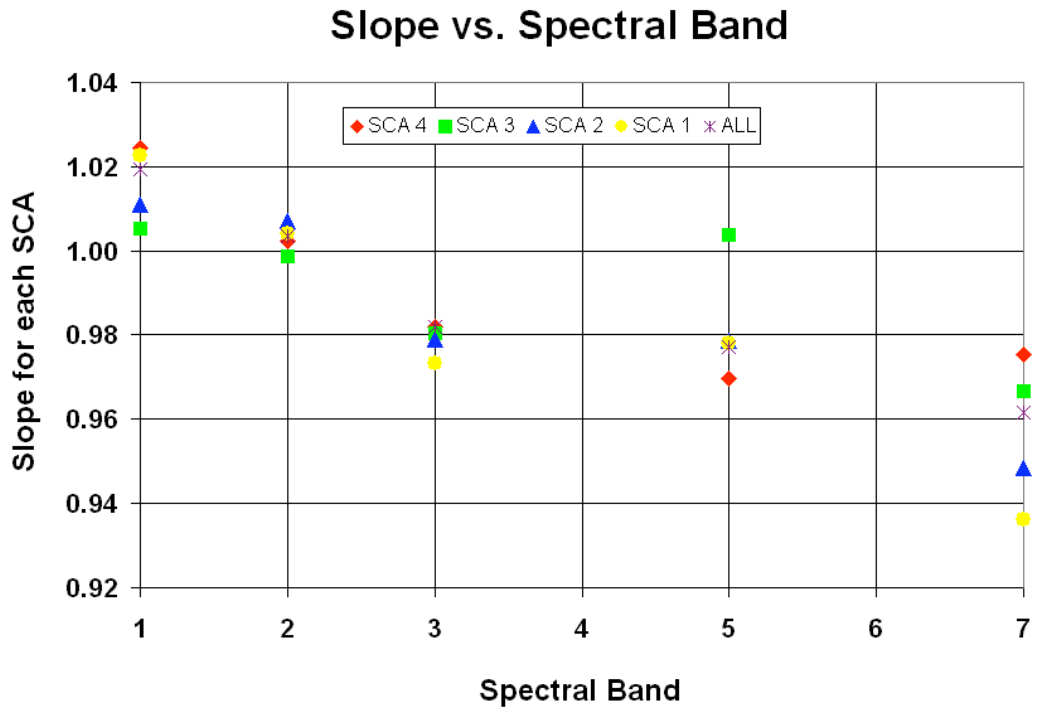

ALI vs. ETM+ Radiance (Band 7)
y = 0.9754x + 0.0945
R² = 0.9999
y = 0.9667x + 0.0656
R² = 0.9998
y = 0.9483x + 0.1155
R² = 0.9998
y = 0.9361x + 0.1141
R² = 0.9999
Band 7
L(ALI) = 0.9616L(ETM+) + 0.0774
R² = 0.9968
SCA 4
SCA 3
SCA 2
SCA 1
1-to-1
ALI Radiance (W/m²/sr/um)
ETM+ Radiance (W/m²/sr/um)
2
3
4
5
6
7
8
9


% difference relative to ETM+ (Band 7)
SCA 4
SCA 3
SCA 2
SCA 1
(ALI-ETM+)/(ETM+) %
ETM+ Radiance (W/m²/sr/um)
8
6
4
2
0
-2
-4
-6
2
3
4
5
6
7
8
9

Slopes

- The slopes from all the regression lines for data points within each SCA and the combined results for all the data in a band

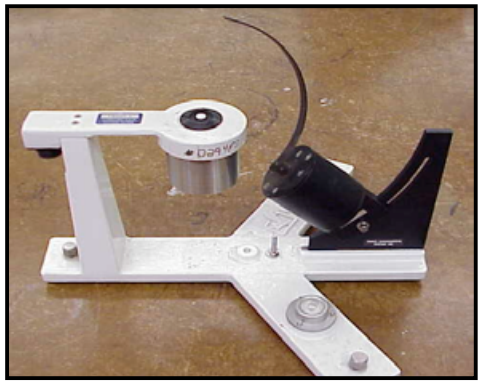
	Slope from the regression lines					% Diff
Band	SCA4	SCA3	SCA2	SCA1	ALL	ALL
1	1.02	1.01	1.01	1.02	1.02	1.94
2	1.00	1.00	1.01	1.00	1.00	0.36
3	0.98	0.98	0.98	0.97	0.98	-1.81
5	0.97	1.00	0.98	0.98	0.98	-2.28
7	0.98	0.97	0.95	0.94	0.96	-3.84



Vicarious Calibration Approach

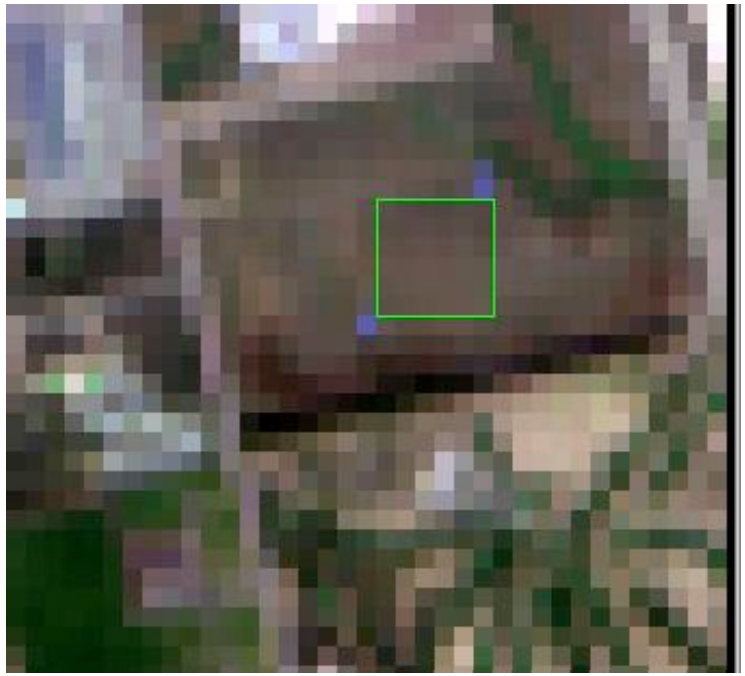
- Instrumentation
  - **Blue Tarps**
  - **ASD-FR** Spectroradiometer
  - **Regan** Sun Radiometer
  - **MFRSR** Shadowband Radiometers



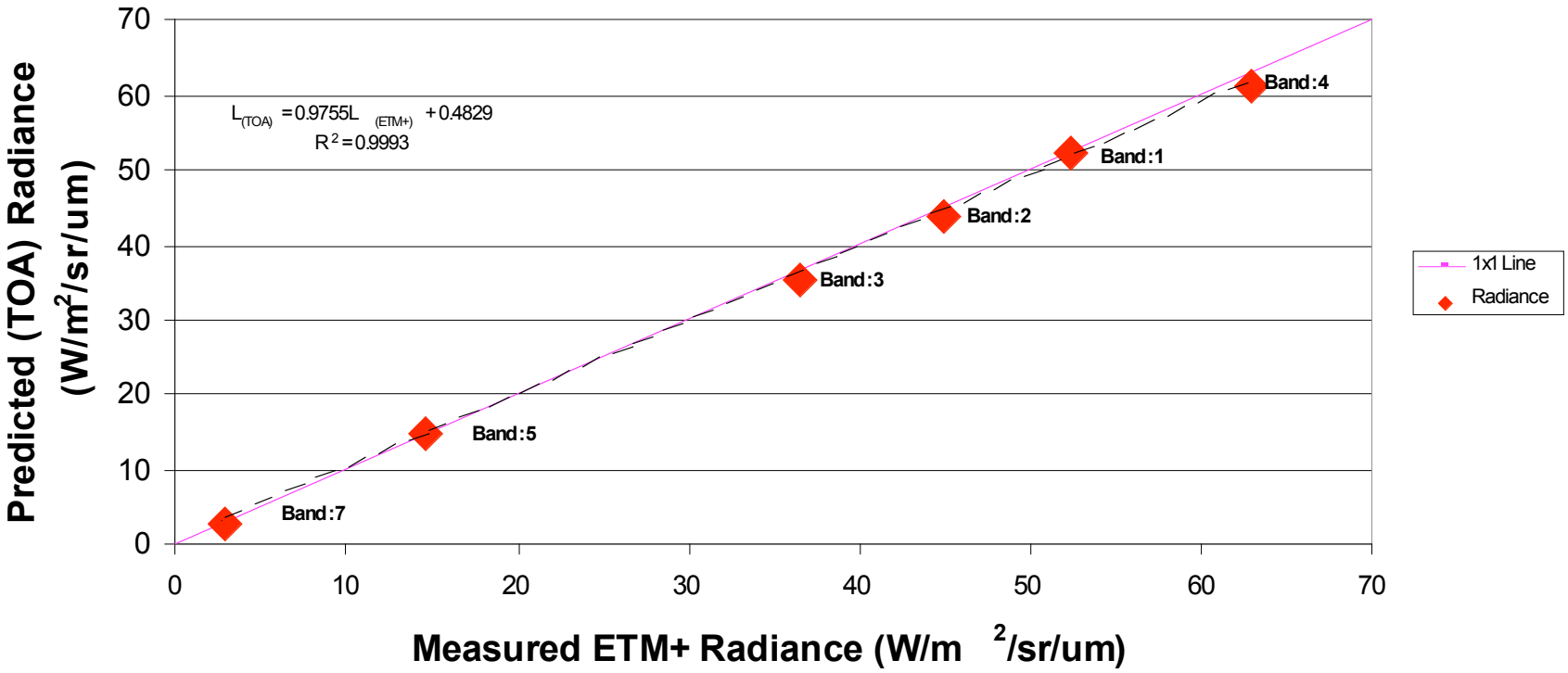
Vicarious Calibration

Blue Tarps serve as ground reference pixels

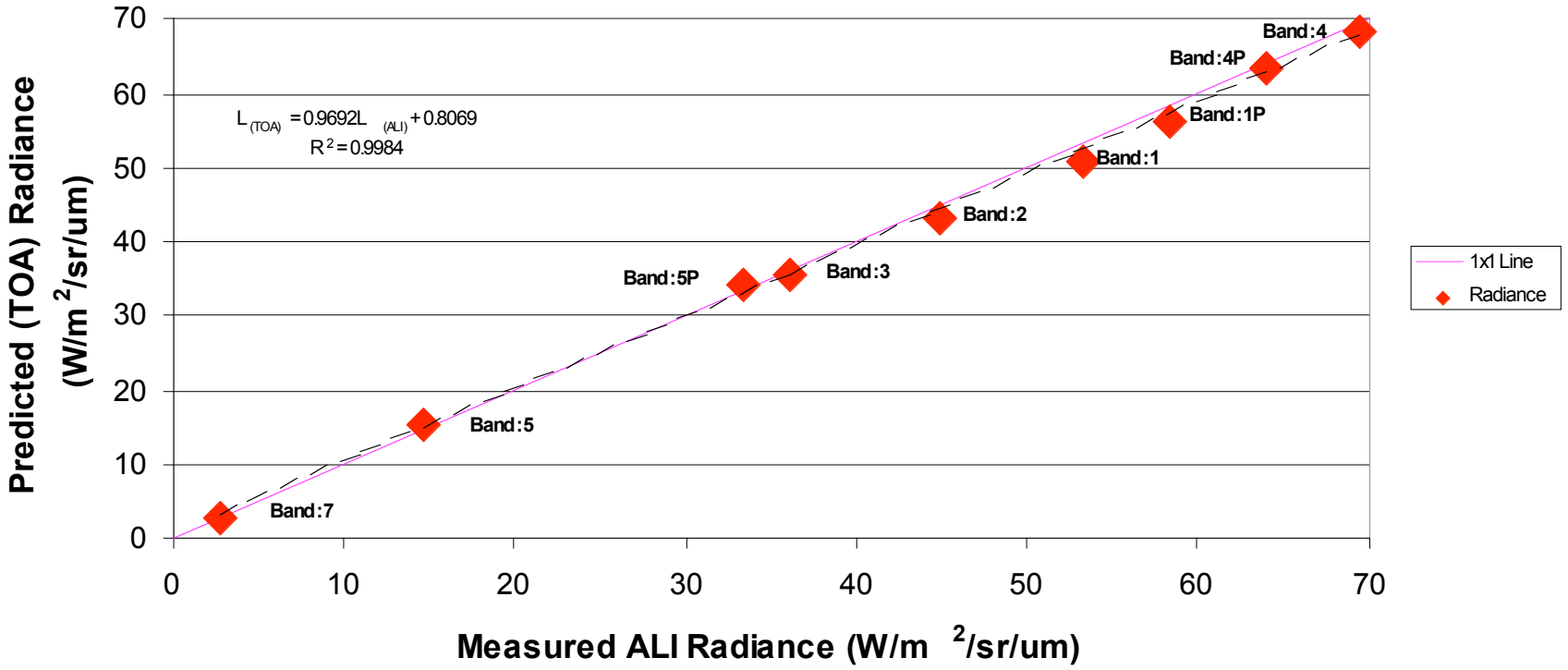


ALI

ETM+

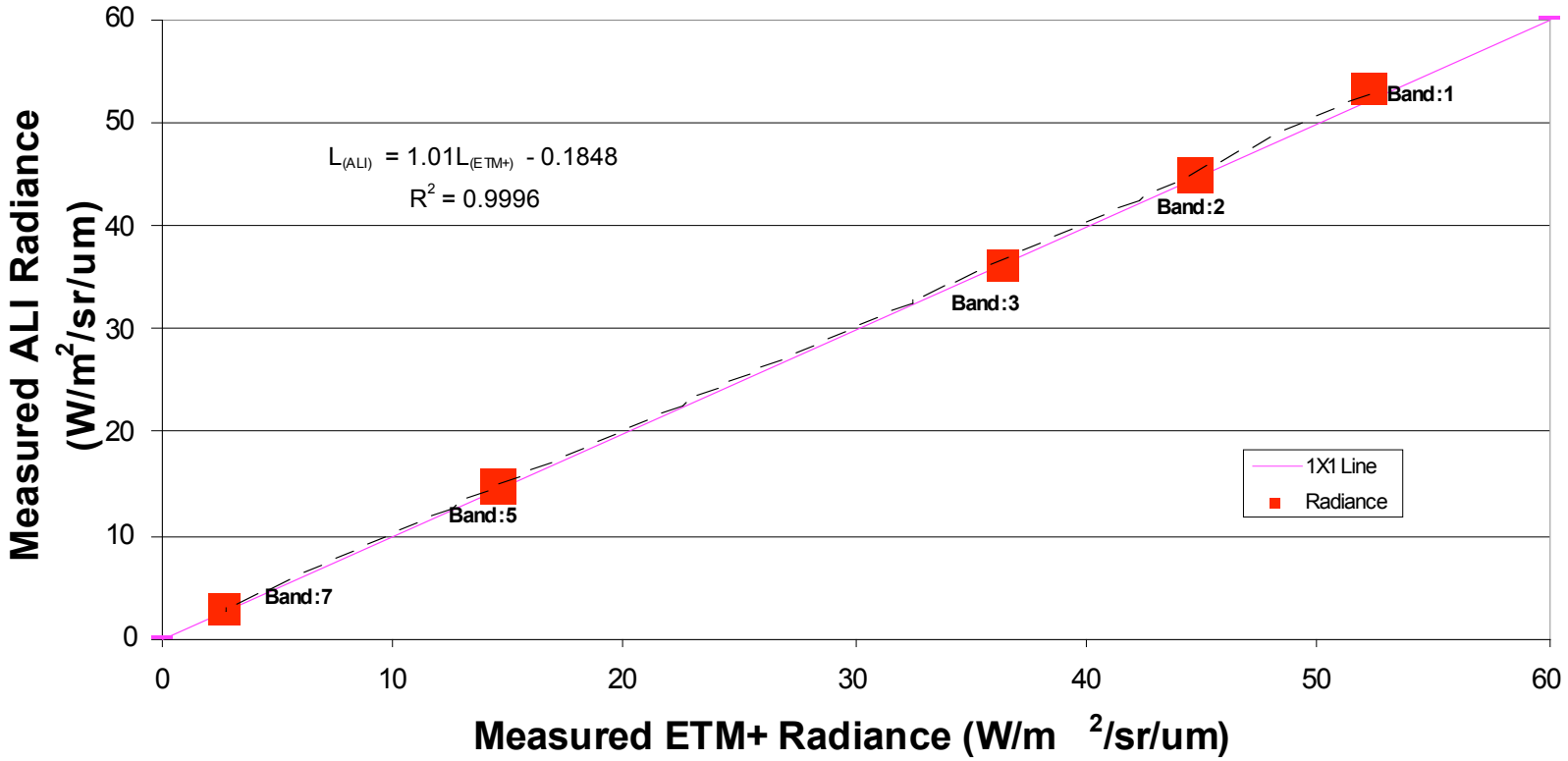


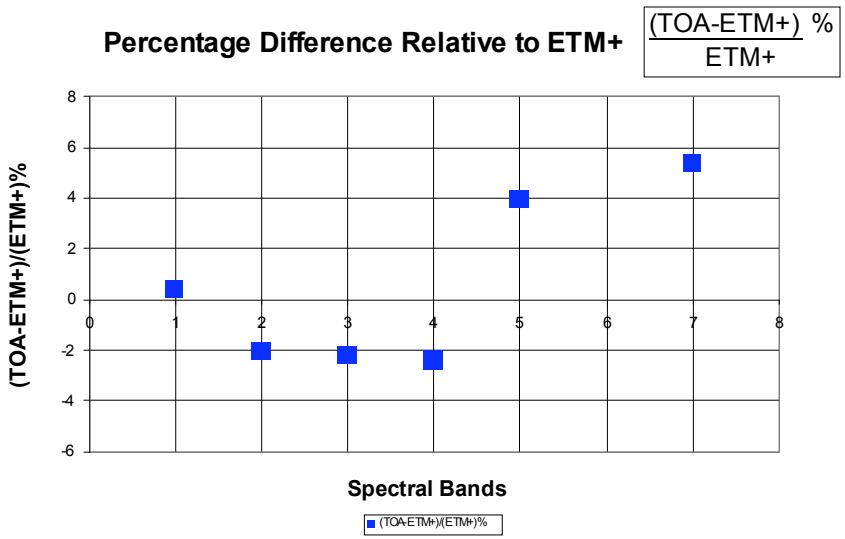
TOA Radiance
Courtesy: Dr. Kurt Thome (U of Az)

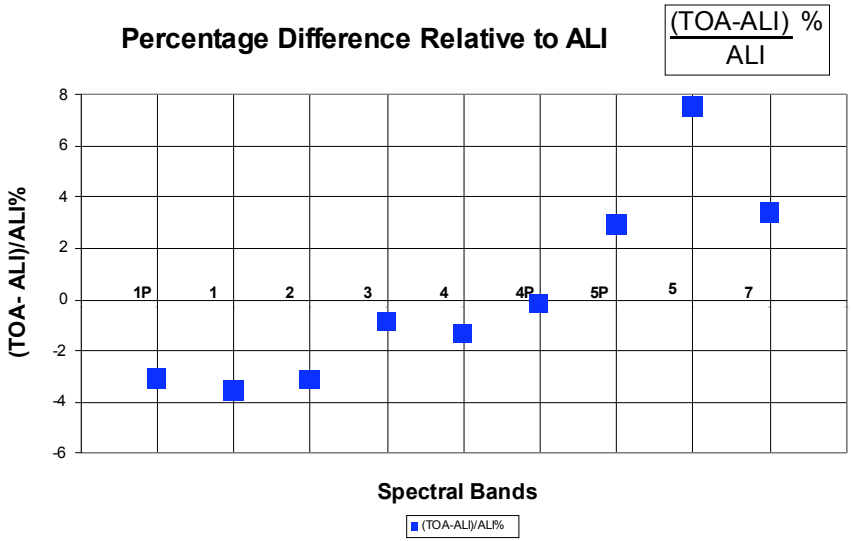


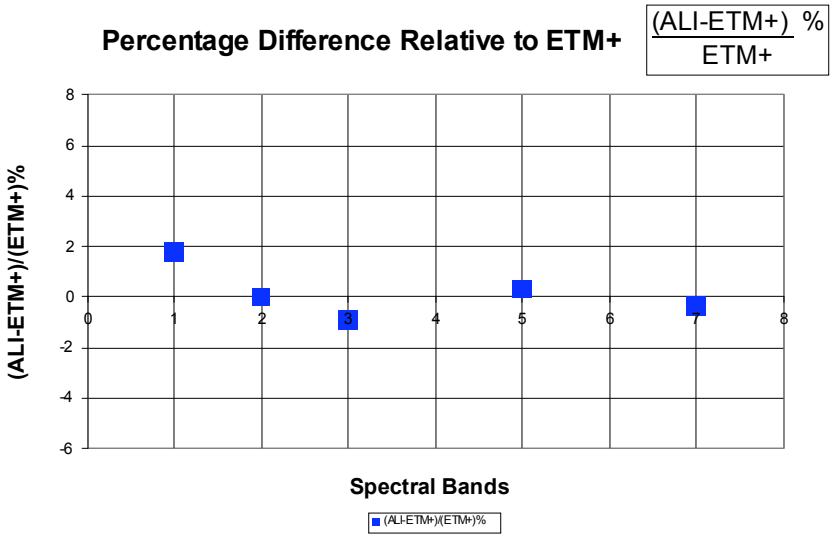
TOA Radiance
Courtesy: Dr. Kurt Thome (U of Az)

Measured ALI vs. Measured ETM+ Radiance
Sept 05th/2001 Day (248)




Percentage Difference Relative to ETM+
(TOA-ETM+) %
ETM+
(TOA-ETM+)/(ETM+)%
Spectral Bands
(TOA-ETM+)/(ETM+)%


Percentage Difference Relative to ALI
(TOA-ALI) %
ALI
(TOA- ALI)/ALI%
1P
1
2
3
4
4P
5P
5
7
Spectral Bands
(TOA-ALI)/ALI%


Percentage Difference Relative to ETM+
(ALI-ETM+) %
ETM+
(ALI-ETM+)/(ETM+)%
Spectral Bands
(ALI-ETM+)/(ETM+)%

Conclusion

- All SCA gains agree with ETM+ reflective bands within ~2% and the SWIR bands within ~4%
- Agreement between SCA gains is greatest among reflective bands, potentially indicating a radiometric calibration problem for SWIR bands
- Vicarious calibration methods indicate differences of 5.3% for all bands for ETM+ and 7.5% for ALI
- TOA estimations appear to be
  - ~0-4% lower for reflective bands
  - ~3-7% higher for SWIR bands