Radiometric calibration of ALI and Hyperion by reference to "bright" ground sites

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- CONAE and University groups (Argentina)
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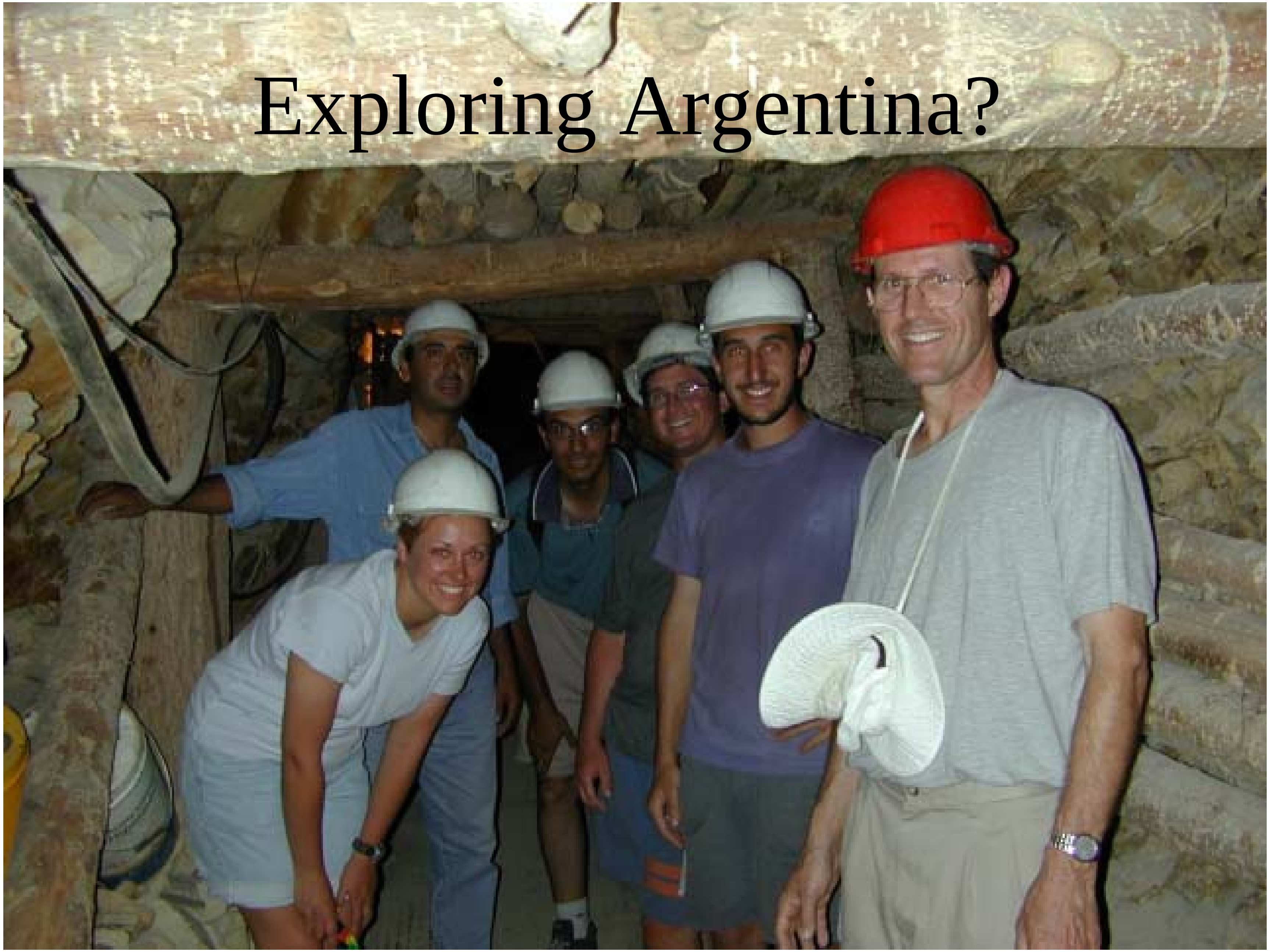
- ALI team at Lincoln Lab
- Hyperion team at TRW
- Students and staff of the Remote Sensing Group at the Optical Sciences Center


Exploring Argentina?

Enough people to do the job?

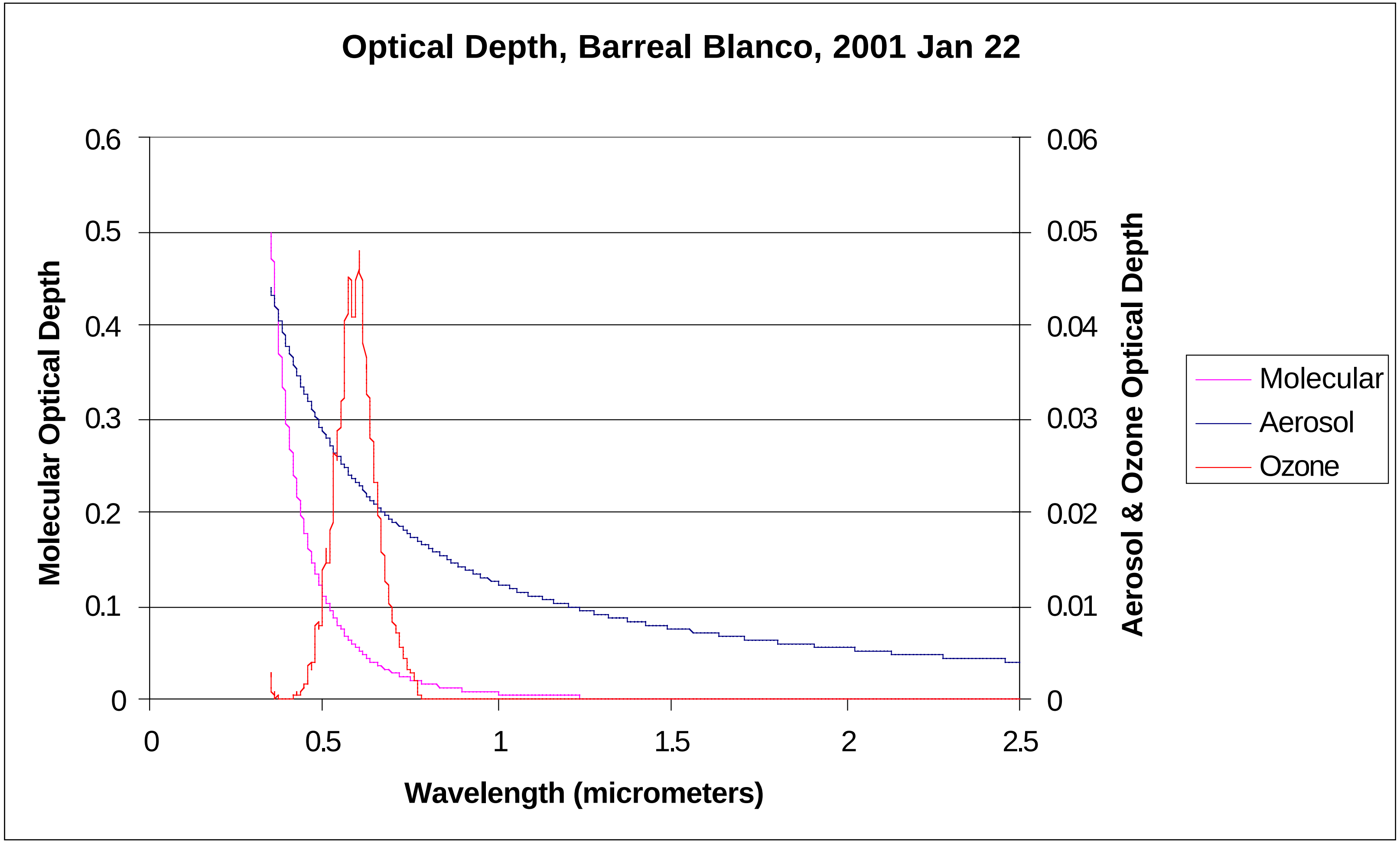
Vicarious Radiometric Calibration

- Extraterrestrial objects
  - Moon
  - Stars
- Cross calibration with other sensors
  - Similar bands
  - Near coincident imagery
- Ground targets
  - Bright, well characterized sites
  - Characterize the atmosphere and surface

Atmospheric characterization

- Measure slant path to the sun with a solar radiometer – 10-band “Reagan” automatic tracking solar radiometer
- Calibrate using Langley method to get the zero airmass intercept
- Measure the spectral optical depth at the time of image acquisition
- Partition extinction optical depth into components such as molecular, aerosol, ozone, water vapor, …


2001 Jan 22, Barreal Blanco

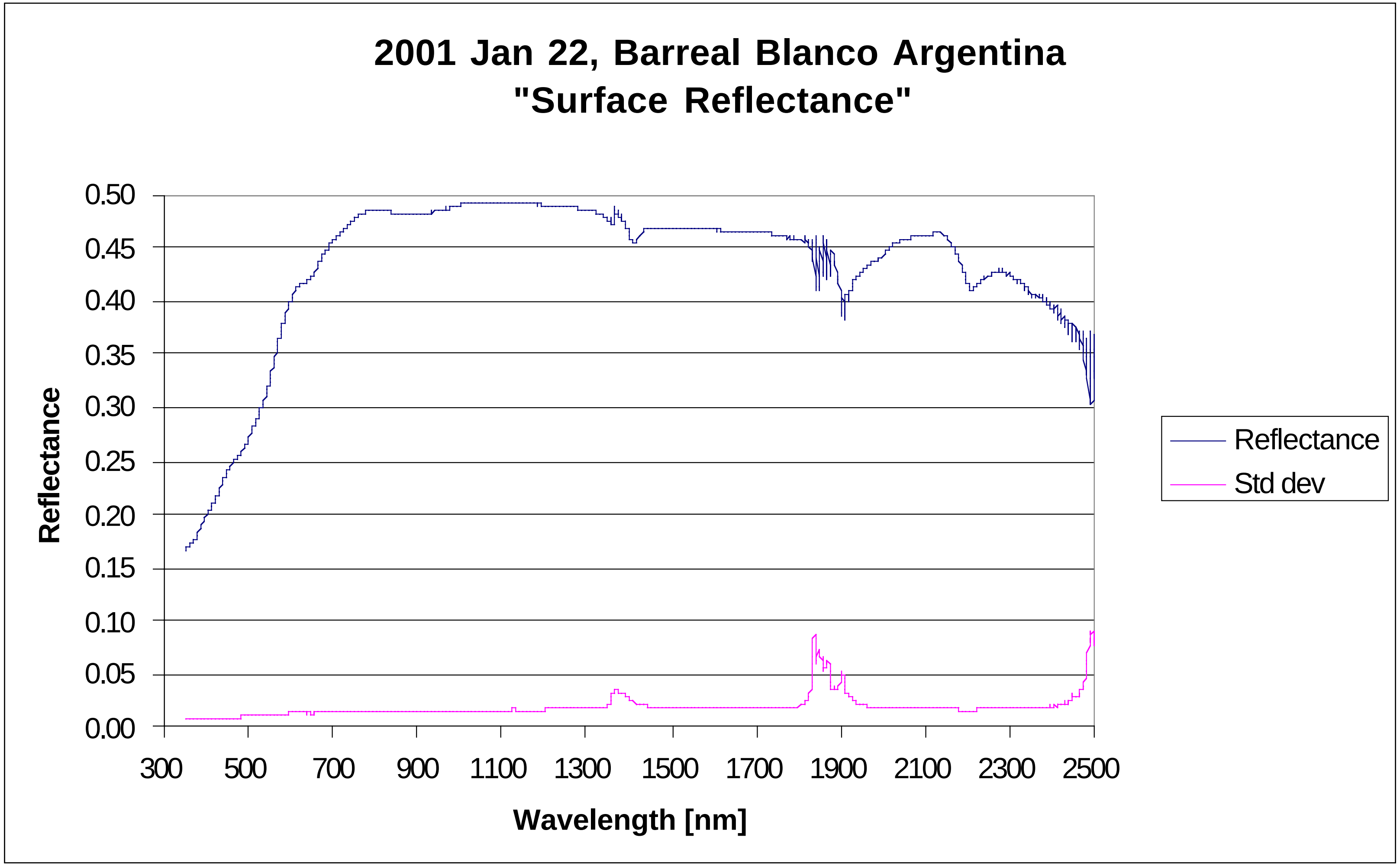


Optical Depth, Barreal Blanco, 2001 Jan 22
Molecular Optical Depth
0.6
0.5
0.4
0.3
0.2
0.1
0
Aerosol & Ozone Optical Depth
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.5
1
1.5
2
2.5
Wavelength (micrometers)
Molecular
Aerosol
Ozone

Ground Reflectance

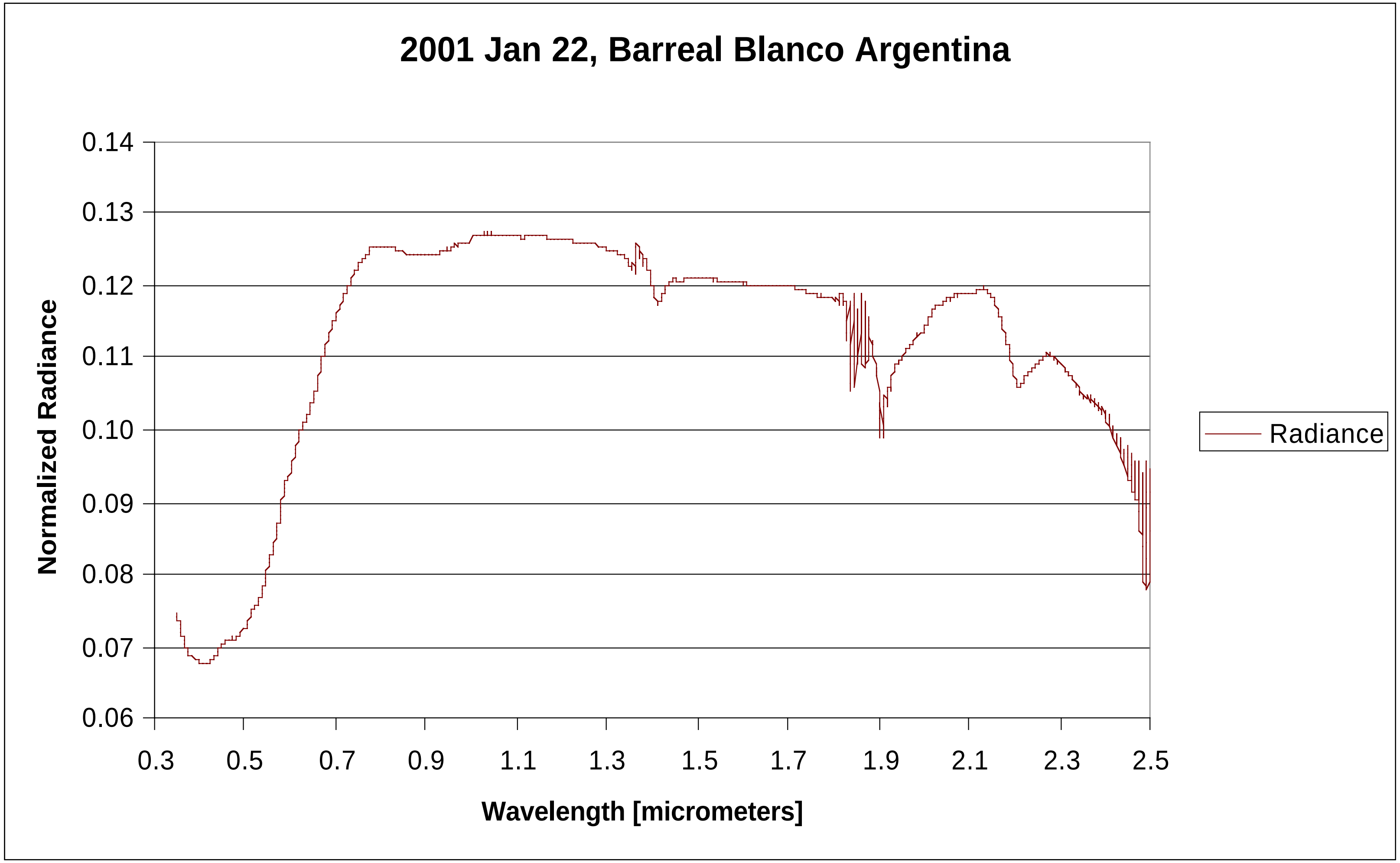
- Use a Spectralon reference with BRDF measured in the laboratory
- Use a portable spectrometer (ASD FieldSpec FR with ~8 degree FOV adapter)
- Sample a representative area of the ground with about 10 data points per pixel (20 or so samples per data point) – about 60 pixels usually
- Compute ground reflectance as ratio of counts (ground/reference times reference BRDF)

Spectralon reference, ASD and tarps at Barreal Blanco


2001 Jan 22, Barreal Blanco Argentina
"Surface Reflectance"
Reflectance
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
300
500
700
900
1100
1300
1500
1700
1900
2100
2300
2500
Wavelength [nm]
Reflectance
Std dev

Radiative Transfer

- Gauss-Seidel numerical integration
- Inputs include spectral optical depth components, aerosol size distribution, ground reflectance and BRDF, solar angle, ozone column amount, etc
- Use a solar model to convert normalized radiance to spectral radiance (Chance database from MODTRAN 4)
- Correct for absorbing gasses other than ozone with MODTRAN



2001 Jan 22, Barreal Blanco Argentina
Normalized Radiance
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.3
0.5
0.7
0.9
1.1
1.3
1.5
1.7
1.9
2.1
2.3
2.5
Wavelength [micrometers]
Radiance

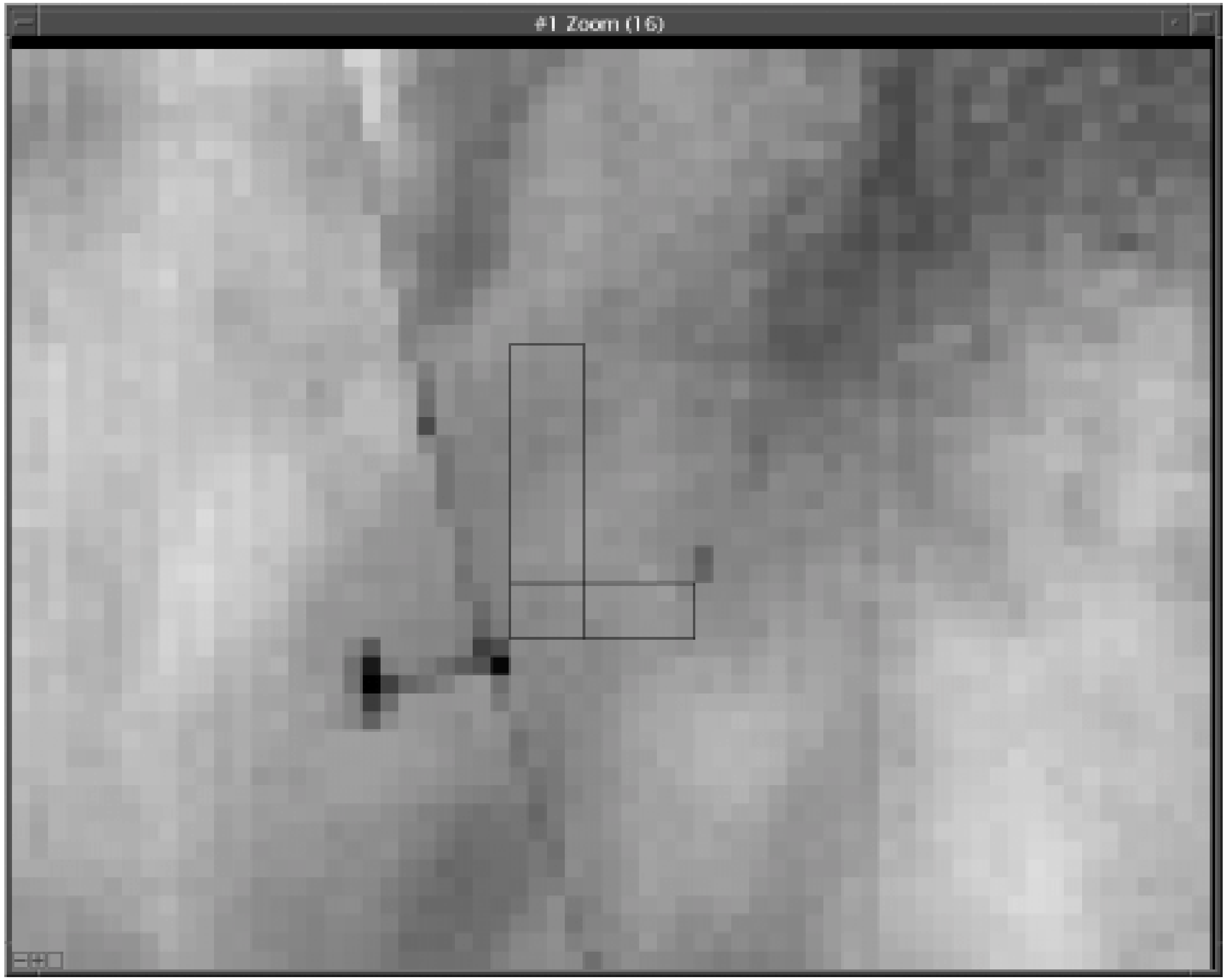
Ground sites used for EO-1

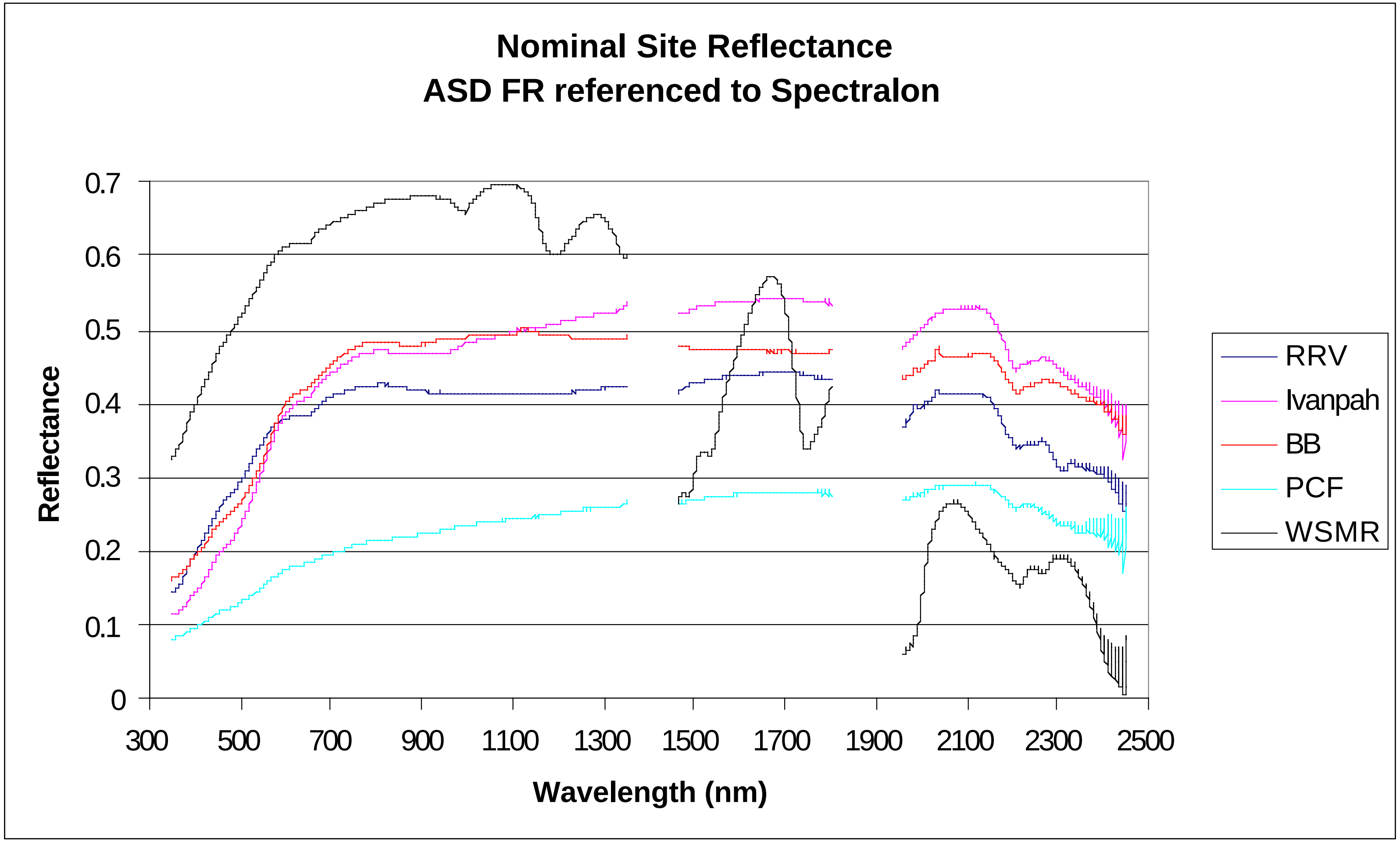
- Barreal Blanco, Argentina
- White Sands Missile Range, New Mexico
- Railroad Valley Playa, Nevada
- Ivanpah Playa, California (near Nevada border and I-15)
- Pima County Fairgrounds weathered asphalt parking lot (southeast of Tucson, Arizona)

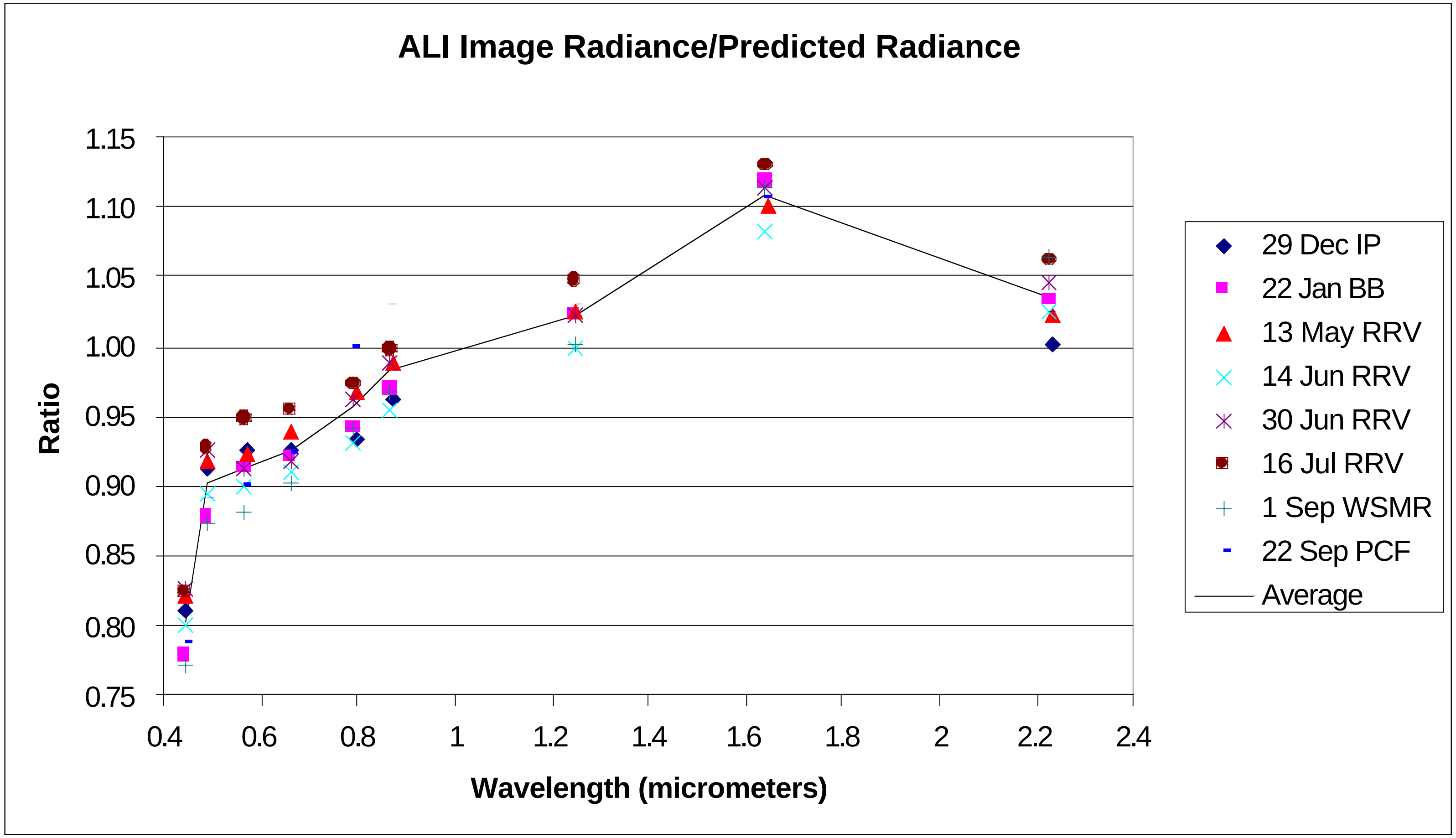
Image data analysis

- Find the tarps in the image – precise geolocation then not required
- Average the image DN for the area measured on the ground
- Apply any required scaling factor
- Compute a calibration (counts per unit radiance for example) or a ratio of in-flight to preflight derived radiances

2001 June 14, RRV example




Nominal Site Reflectance
ASD FR referenced to Spectralon
Reflectance
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
300
500
700
900
1100
1300
1500
1700
1900
2100
2300
2500
Wavelength (nm)
RRV
Ivanpah
BB
PCF
WSMR



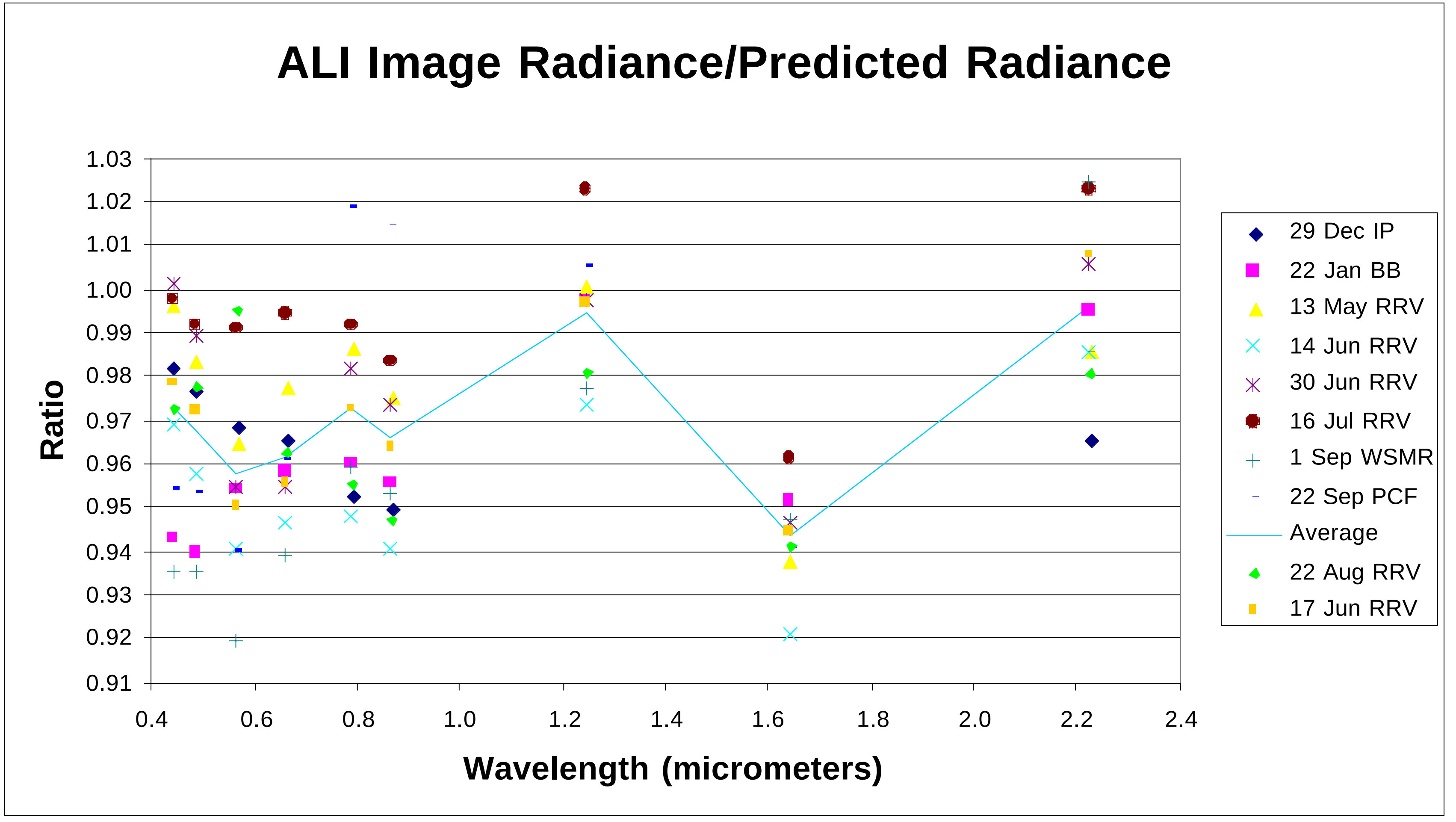
ALI Image Radiance/Predicted Radiance
Ratio
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
Wavelength (micrometers)
29 Dec IP
22 Jan BB
13 May RRV
14 Jun RRV
30 Jun RRV
16 Jul RRV
1 Sep WSMR
22 Sep PCF
Average

ALI observations

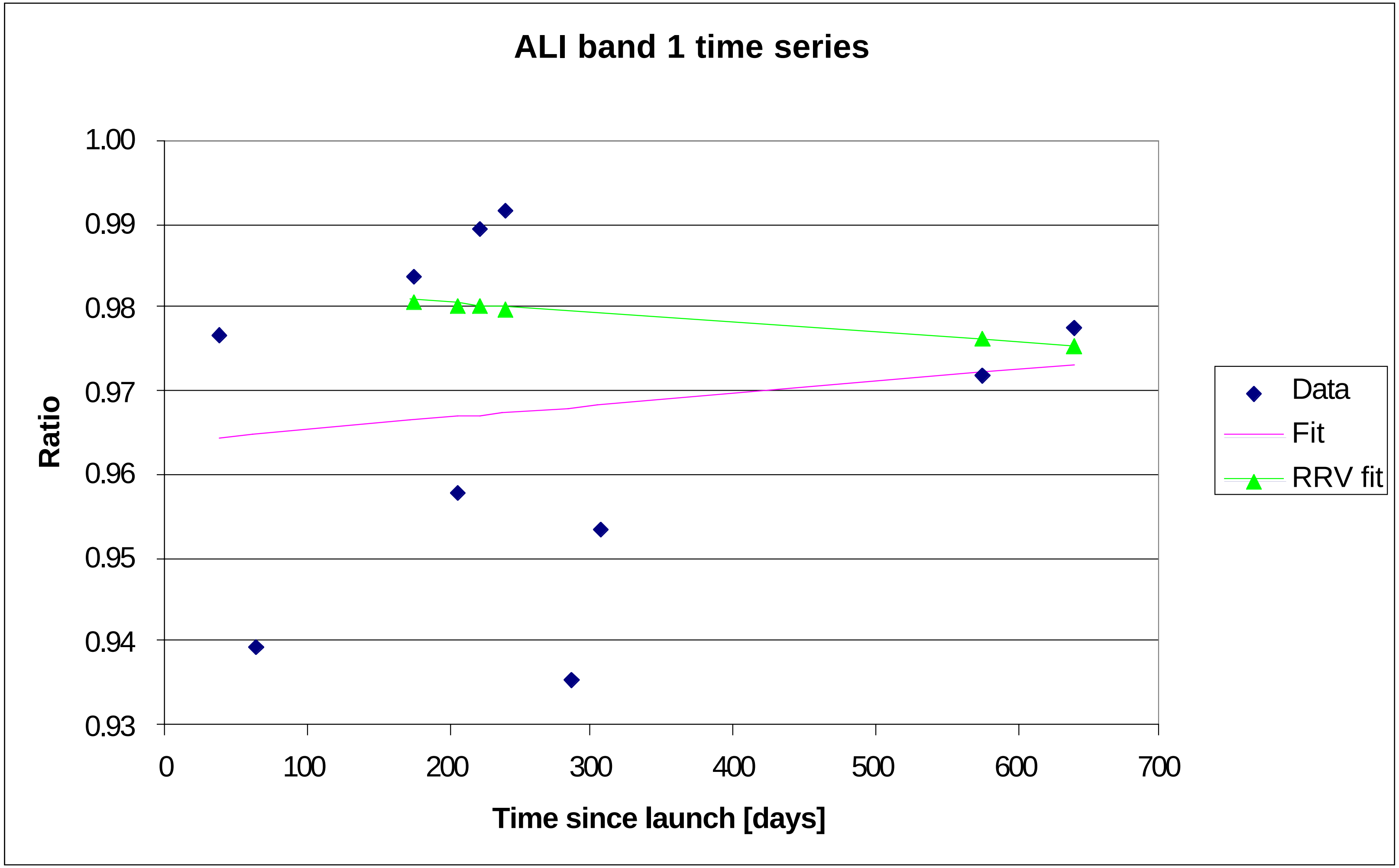
- Significant difference between preflight and in-flight calibrations in the blue (1P especially)
- Results are similar from a wide variety of sites with different reflectance spectra
- SWIR band result at about 1.64 micrometers is not understood
- Solar irradiance spectrum can induce differences depending on choice (MODTRAN, WRC, Thuillier, or other) – MODTRAN used to be consistent with Landsat 7 ETM+

Calibration adjustment

- Solar calibrator (apertures with diffuser over the secondary mirror) are consistent with vicarious ground reference calibrations
- Lunar observations are also consistent
- Cross calibration with other sensors such as ETM+ are consistent
- Calibration adjusted in Dec 2001 – new data comes with the new calibration coefficients



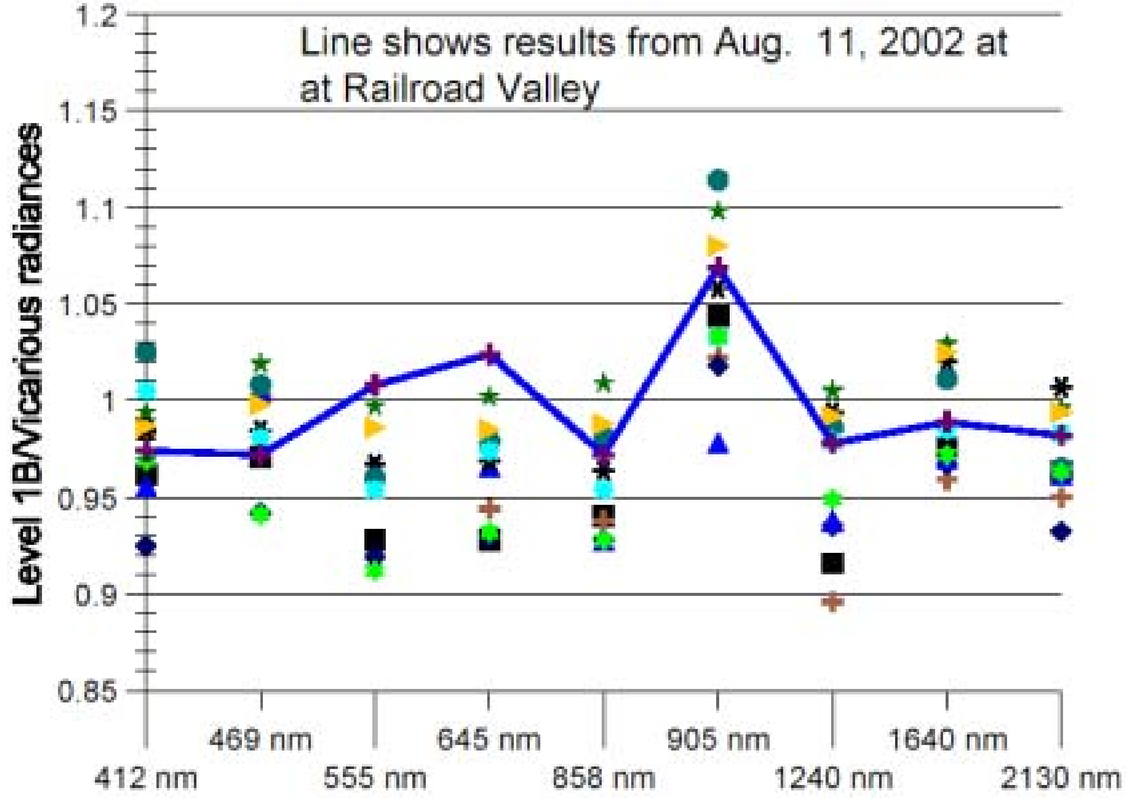
ALI Image Radiance/Predicted Radiance
Ratio
1.03
1.02
1.01
1.00
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
Wavelength (micrometers)
29 Dec IP
22 Jan BB
13 May RRV
14 Jun RRV
30 Jun RRV
16 Jul RRV
1 Sep WSMR
22 Sep PCF
Average
22 Aug RRV
17 Jun RRV

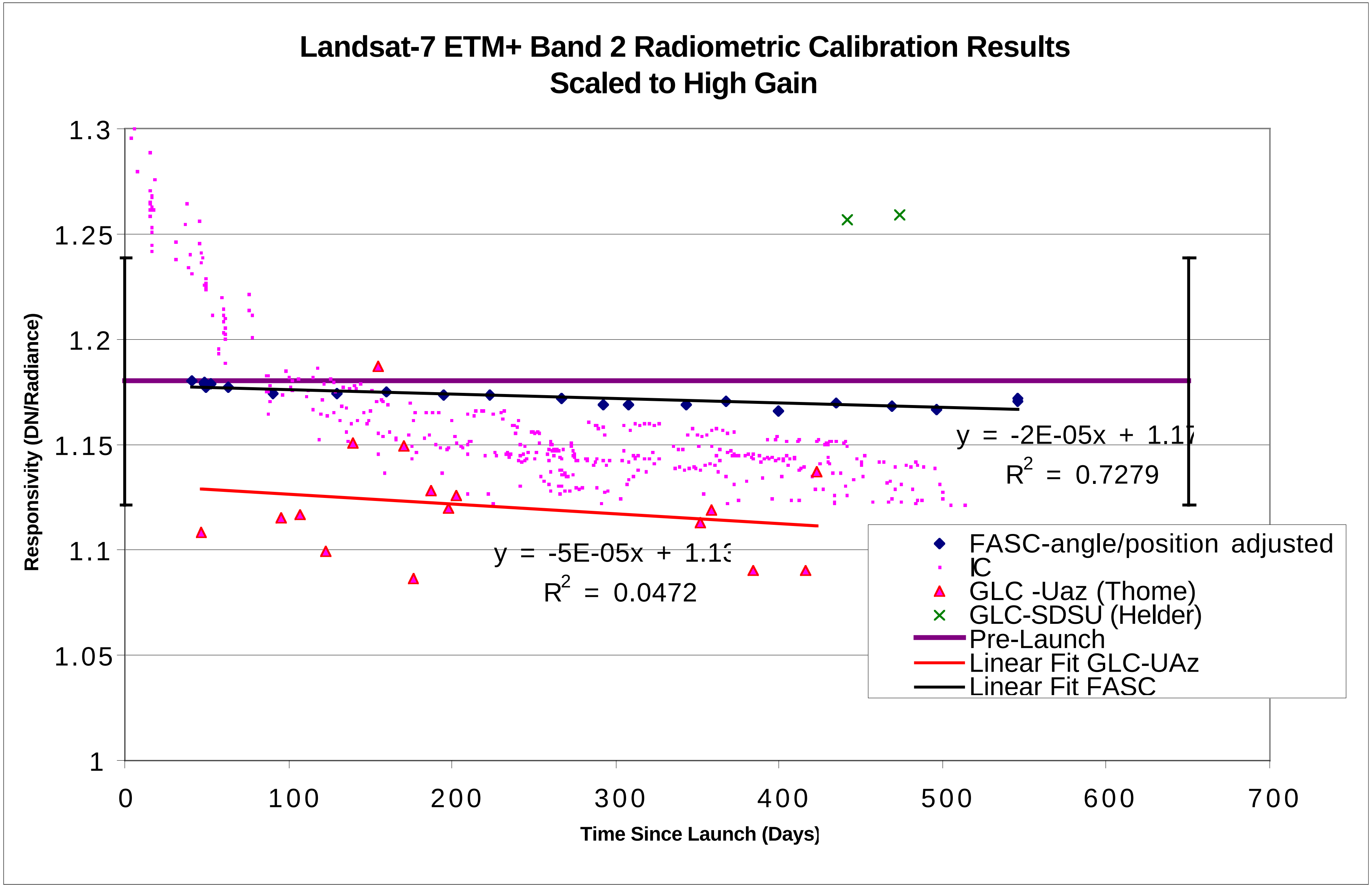

ALI band 1 time series
Ratio
1.00
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0
100
200
300
400
500
600
700
Time since launch [days]
Data
Fit
RRV fit

ALI response ratio

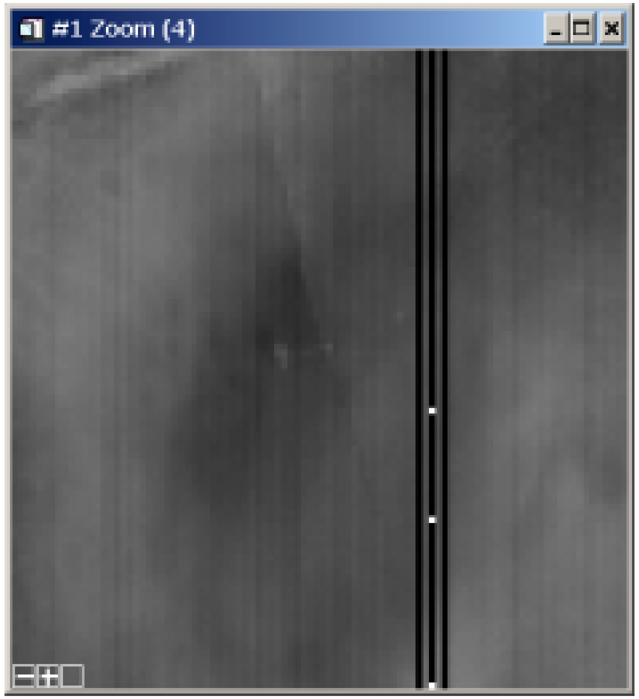
Band	λ	Avg (all 10)	Std dev (all 10)	Avg (RRV)	Std dev (RRV)
1p	0.442	0.973	2.36	0.986	1.42
1	0.485	0.968	2.08	0.979	1.29
2	0.567	0.958	2.42	0.966	2.32
3	0.660	0.962	1.62	0.965	1.83
4	0.790	0.973	2.25	0.973	1.79
4p	0.866	0.966	2.27	0.964	1.74
5p	1.244	0.995	1.54	0.996	1.72
5	1.640	0.944	1.15	0.942	1.38
7	2.226	0.996	1.91	0.998	1.67

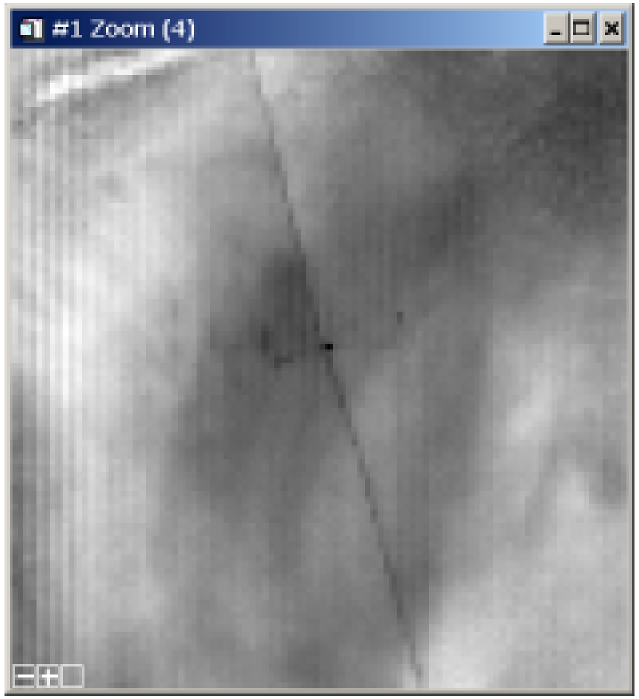
Terra Reflectance-based Results



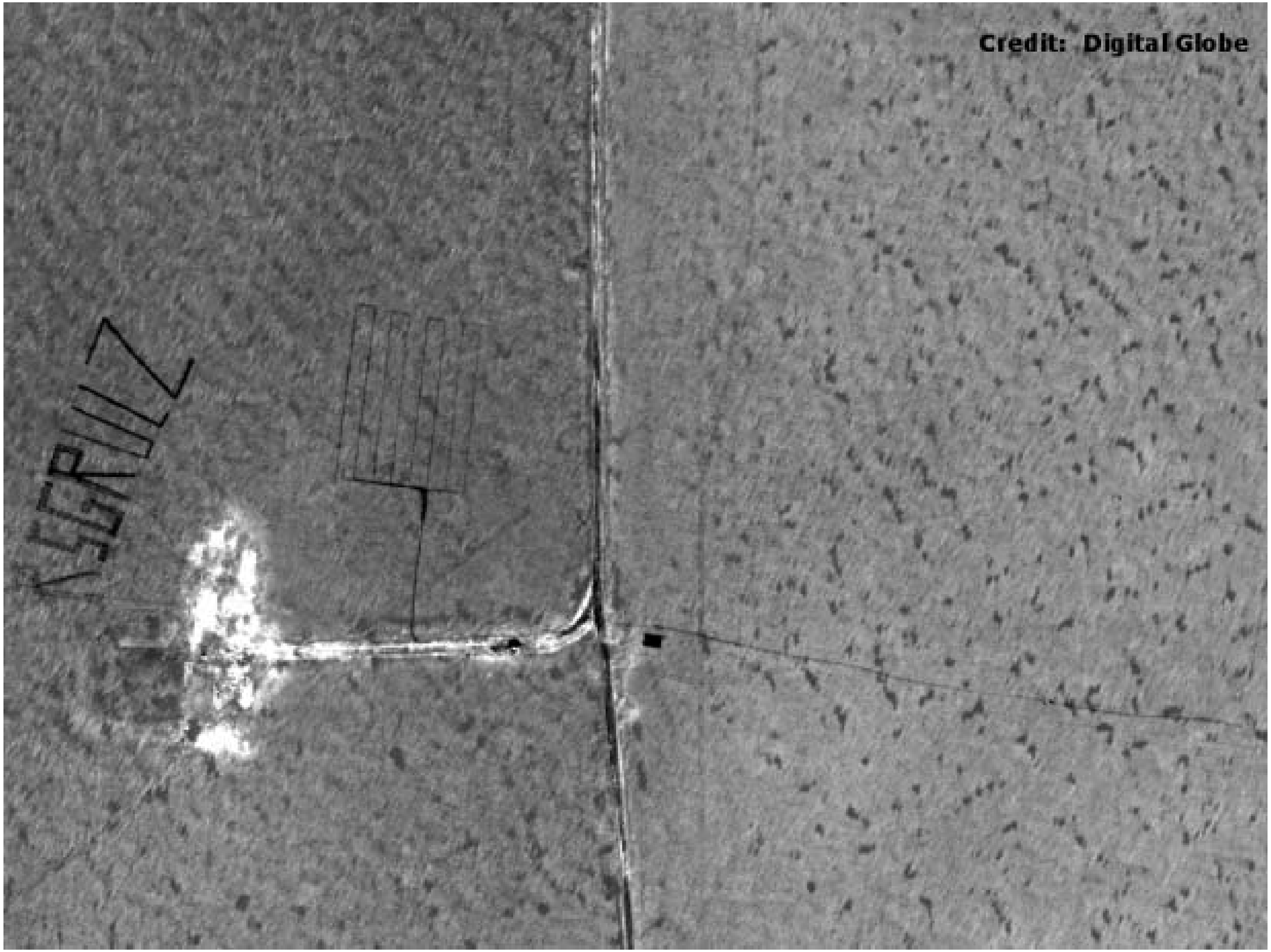

Landsat-7 ETM+ Band 2 Radiometric Calibration Results
Scaled to High Gain
Responsivity (DN/Radiance)
Time Since Launch (Days)
1.3
1.25
1.2
1.15
1.1
1.05
1
0
100
200
300
400
500
600
700
y = -2E-05x + 1.17
R2 = 0.7279
y = -5E-05x + 1.13
R2 = 0.0472
FASC-angle/position adjusted
IC
GLC -Uaz (Thome)
GLC-SDSU (Helder)
Pre-Launch
Linear Fit GLC-UAz
Linear Fit FASC

2002 June 17, RRV
bands 5 and 2



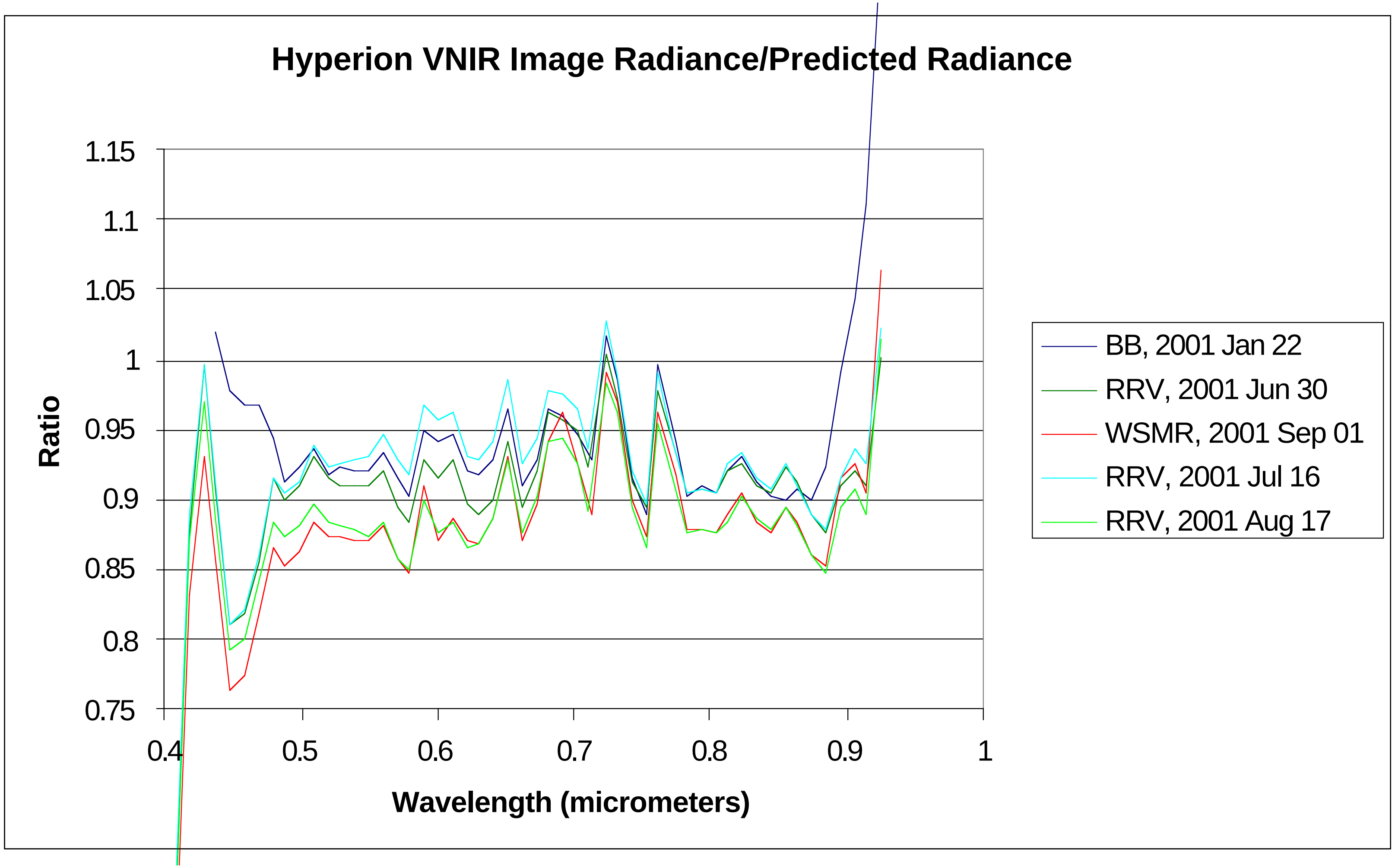


2002 August 20, RRV
band 5, “4-3-2” RGB, and Pan


Credit: Digital Globe

Hyperion

- Same basic strategy and analysis
- Limited number of data sets so far
  - Pointing
  - SWIR not cooled
- We are learning about hyperspectral sensors
  - "Simple" atmospheric correction
  - We do attempt to compensate for the "smile" however we have yet to solve for the shift from preflight measurements



Hyperion VNIR Image Radiance/Predicted Radiance
Ratio
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.4
0.5
0.6
0.7
0.8
0.9
1
Wavelength (micrometers)
BB, 2001 Jan 22
RRV, 2001 Jun 30
WSMR, 2001 Sep 01
RRV, 2001 Jul 16
RRV, 2001 Aug 17

Hyperion

- Average of our results to date in VNIR give a ratio between preflight and in-flight of about 0.91 for all bands between 0.448 and 0.916 (std dev ≈ 4%)
- Average of our results to date in the SWIR give ratios for various sections not in absorption bands of between 0.8 and 0.88 (std dev ≈ 4 to 10%)
- Analysis of preflight lamp/Spectralon radiance data shows a discontinuity in the crossover region between the SWIR and VNIR
- The cal factor adjustments appear appropriate

Continuing work

- We got 4 data sets on 2002 Nov 13
  - 2 are from Ivanpah and have useful Hyperion data but ALI missed our ground site
  - 2 are from Railroad Valley playa
- We intend to reduce the Hyperion data but haven't finished yet with smile correction

Conclusions

- ALI calibration appears stable and noise is much lower than ETM+
- ALI in-flight calibration coefficients appear to have shifted from preflight, especially in the blue
- Hyperion in-flight calibration coefficients for the two arrays have shifted by different amounts from preflight with the SWIR having the larger shift
- Data users needing accurate calibration should have their data reprocessed or apply a scaling factor to data processed before Dec 2001