A Semi-Automated Vegetated Radiometric Calibration Site

Image Processing (IP) Lab

South Dakota State University

Dennis Helder

David Aaron

Larry Leigh

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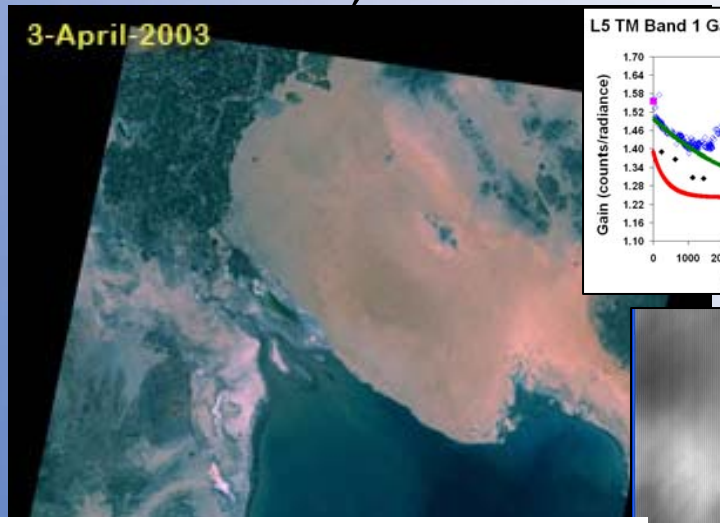
South Dakota State University
Image Processing Lab

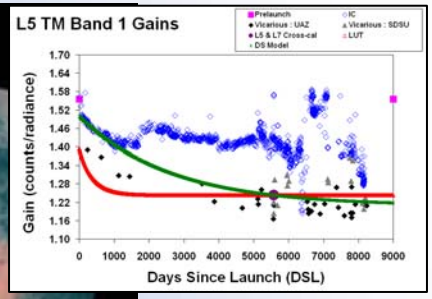
Background—The SDSU Image Processing Lab

Founded: 1990; Currently 17 staff and students

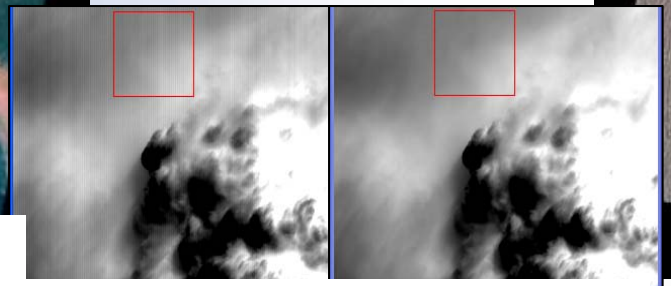
Purpose: Radiometric, Geometric, and Spatial Characterization, Correction, and Calibration of Satellite and Airborne Imaging Systems.



Cal of Landsat from 1972-2010



Pseudo-Invariant Cal Sites



Rel. Gain Correction for ALI/OLI

MTF (Image Blur)Estimation

Vicarious Calibration

A Semi-Automated Vegetated Radiometric Calibration Site

- Why use a vegetated site?
- Automating the site
  - Atmospheric measurements
  - Surface measurements
  - Data Processing
- An example using Landsat 7 ETM+
- Summary comments

Why use a vegetated site?

Desert (& semi arid) sites:

+ High Reflectance
+ Generally quite uniform
- Band Saturation, water based non-uniformity
- Lack of Proximity to SDSU
- No need to replicate University of Arizona work

Why use a vegetated site?

Vegetated sites:

+ Excellent proximity to SDSU

Maintain a permanently based instrument set on/near campus

Direct Sunphotometer, MFR-Shadowband Radiometer, FAA Weatherstation

Efficient resource allocation for field campaigns (~2 km from lab)

+ Calibration using a site with characteristics closer to typical user's interest

- Fairly dark (low DN count) with plant based spectral characteristics

Instrument saturation is not encountered

- Can be non-uniform, exhibit plant shadowing, and can strongly exhibit effects due to wind patterns

+ Can be fairly easily groomed to minimize above non-uniformities via a program of site maintenance

+ Complements the 'bright target work' done by U of A.

Calibrate at more points in sensor's dynamic range

Collection Sites Exhibit Varied Surfaces

Note: typical Landsat Band 2 (‘green’) and 4 (NIR) reflectances shown

ρ_{band2}= 0.35

ρ_{band4}= 0.44

ρ_{band2}= 0.06

ρ_{band4}= 0.27

SDSU Vicarious Calibration Process:

- ‘Simultaneous’ satellite imaging and hyperspectral measurement of upwelling radiance at grass target area (“3M” in Brookings SD).
  - ASD Fieldspec 3 with 8 degree optic
  - 12” Spectralon 99% panel, BRDF characterized
- Monitor atmospheric transmittance over time interval including overpass
  - Primary monitor: 10 Channel ASR unit 30
- Use ASR Langley analysis to determine extinction values
  - Supplement with MFR Shadowband units (global/diffuse measurement)
- Populate MODTRAN using extinctions, angles, etc; optimize thru measured ASD values
  - MODTRAN 5
- Transfer (hyperspectral) Top of Canopy (TOC) to TOA using parameters from MODTRAN model
- Band hyperspectral radiances to produce in-band TOA radiance
- Calculate gain by comparing satellite DN to in-band TOA radiance values

Automated Atmosphere Monitoring

Three automated components: Sun Radiometer, Shadowband Radiometer, weather station

Radiometers are mounted on roof of Engineering Building (can also be field deployed)

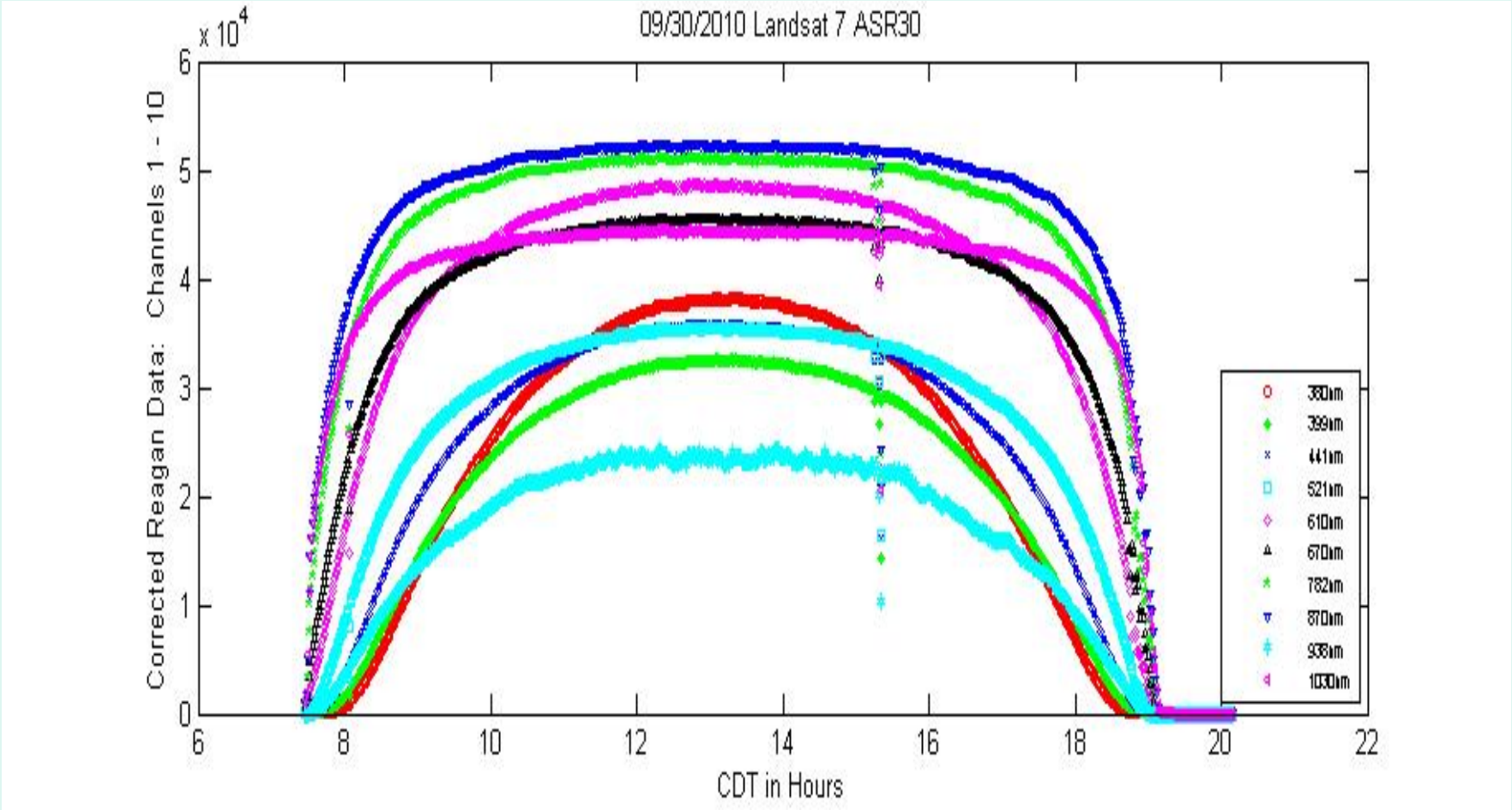
Horizon to Horizon View

Elevation of 518 meters

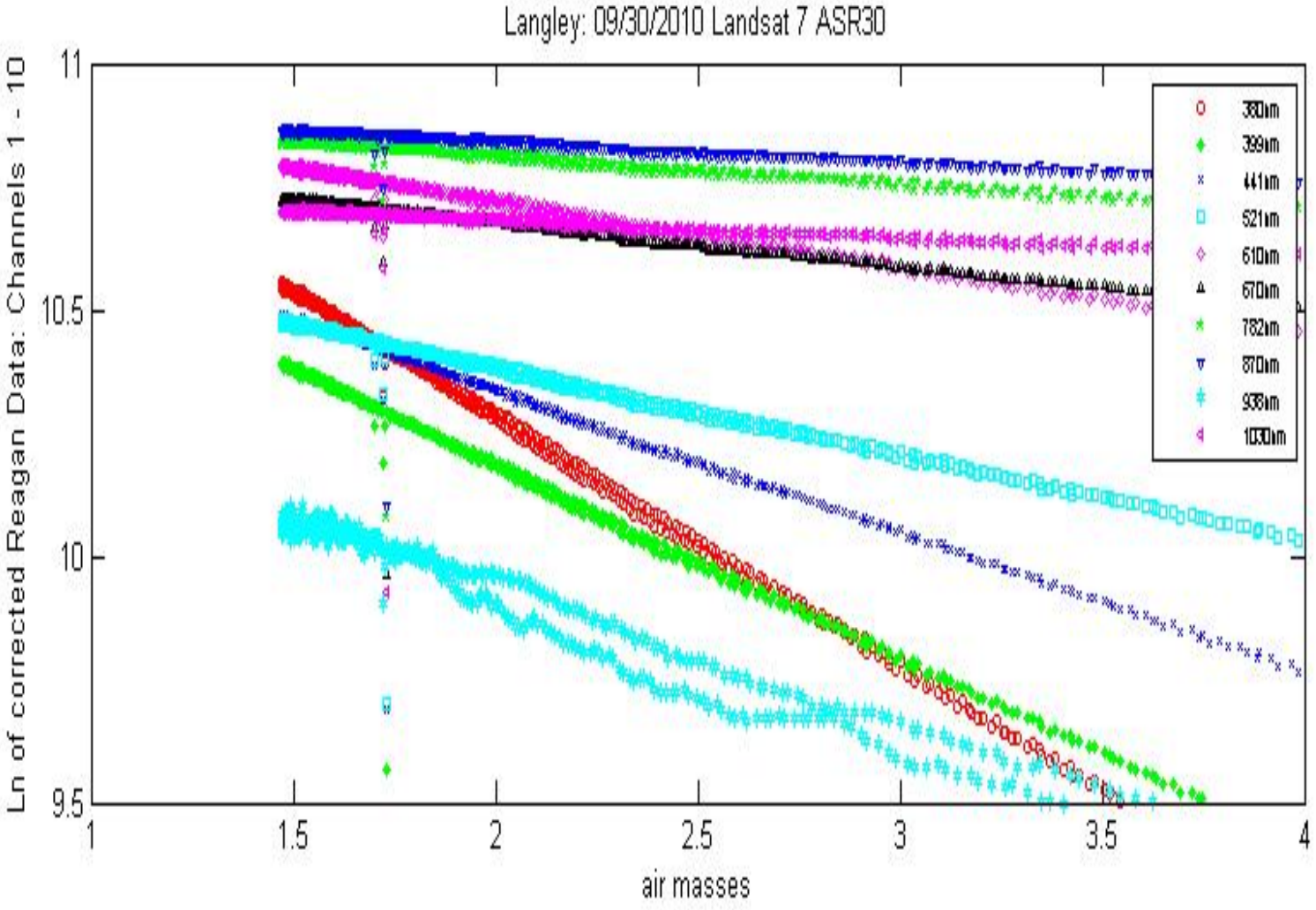
(N*ote: target site is 2km SE at an elevation of 505 meters)*

Weather Station is local airport (KBKX), 2km W of target site, barometric pressure, temperature, wind direction and velocity, dew point

ASR Measurement on Sept 30, 2010



Langley plot on Sept 30, 2010



Atmosphere Data: Automation and Special Techniques

ASR is deployed (sunrise to sunset) for satellite overpass days

- primary output is 10 Channel extinction input for MODTRAN model
- *also deployed for any 'excellent' sky day*

MFR is continuously deployed (non-winter months) with direct computer downlink and in-house automated data reduction.

- Primary output is temporal diffuse to global ratio
- Secondary output is extinction values for 7 bands

Key advantages of Automation:

- *Maintain precise '0 air mass atmosphere' calibration*
- *Can extract good instantaneous extinction values even for partly cloudy days*
- *Critical in that instrument can exhibit long term drift of up to 2%/year*

“3M” Site Characteristics

- 180 X 160m ‘grass’ site (approx)
  - rotated 9 degrees off N-S
  - NW corner:
    - Lat: 44°17'31.12383"N
    - Long: 96°45'59.33636"W
    - Elevation 503 m
  - Elevation change = 4.89 meters

    Differential GPS values measured by the Stennis GRIT Staff

- Maintenance mowing
  - 5 ft rotary mower, maintain grass height of approximately 10cm.

Ground data collection

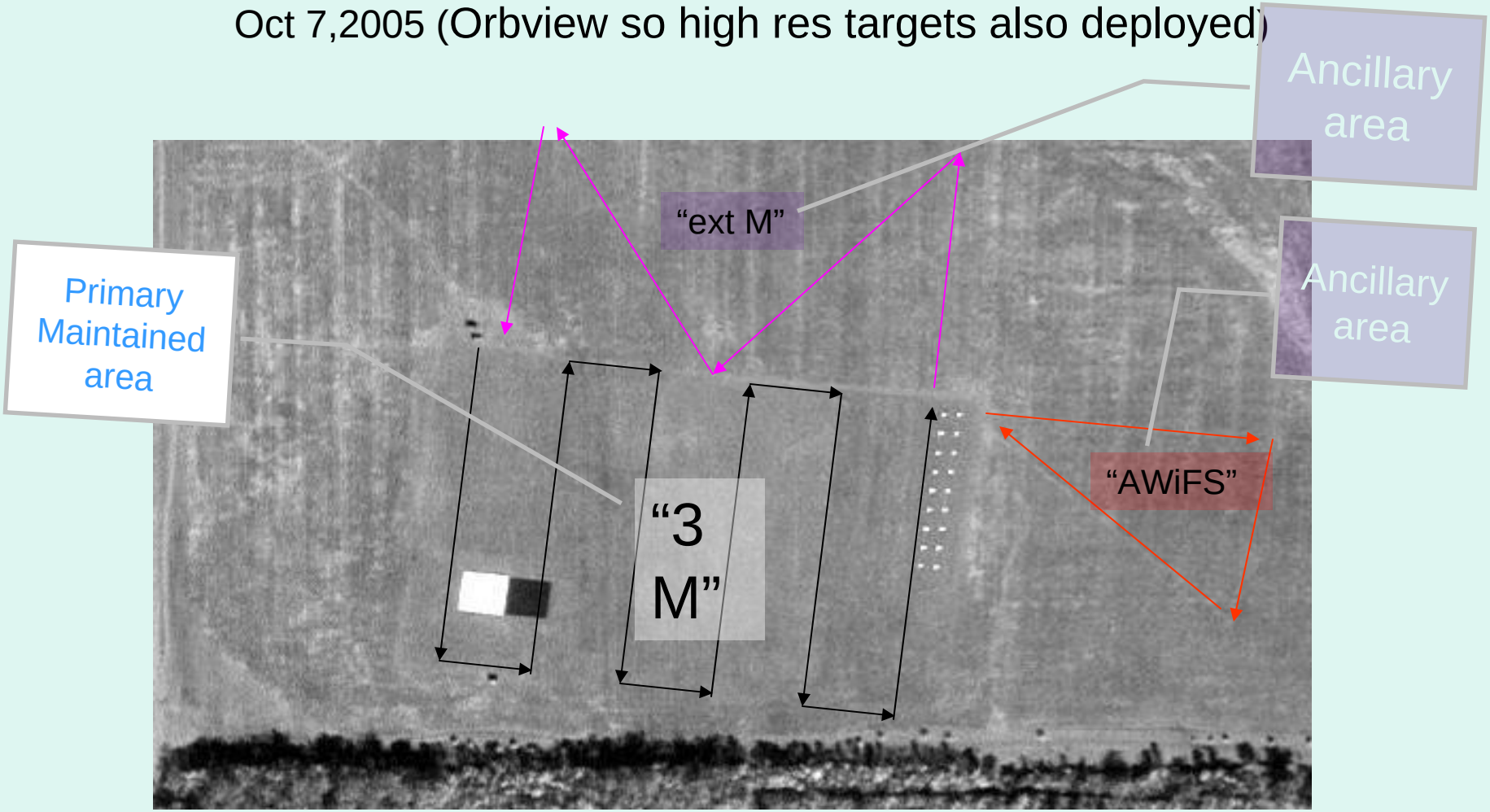
ASD FS FR with 2 meter cable

- 8 deg optic on pole held 1.5 to 2 m above ground
  - Nadir view (~25cm diameter sample area)

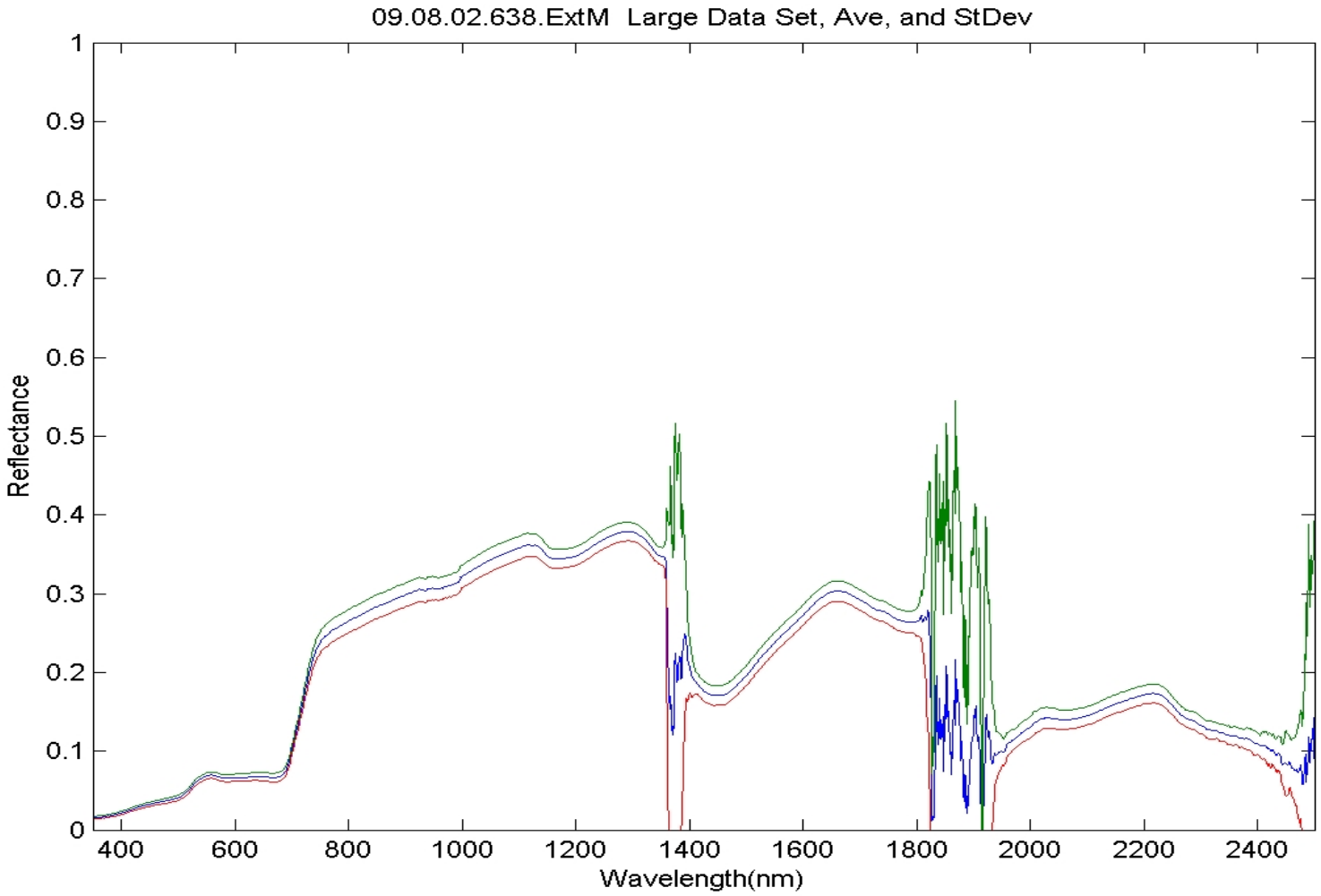
- Collect while walking ASD along 150 m N-S rows
  - 20 spectra/file, 10 files/save
    - Results in 50 files per row so about 300 files per collection
    - ~ 20 minutes for 6 row collection

•Spectralon (fully BRDF characterized) 12 inch white reference panel at end of each row pair (north end)

Site and transects with “AWIFS” and “ext M” shown
Oct 7,2005 (Orbview so high res targets also deployed)



Typical 3M Maintained Site Ground Reflectance with ±1σ variation indicated



Data Reduction

Primarily automated process:

For the ‘Reflectance Based Method’ the ASD data ‘ground’ radiance data is transformed point by point into point reflectance data (using white reference panel data interpolated between the approximate 4 minute reference panel readings).

Atmospheric Data (ASR based) is analyzed using a Matlab based data reduction routine to provide atmospheric extinction values (average for stable days, short term for more unstable days).

Atmospheric Diffuse to Global (MFR based) to validate MODTRAN developed ‘skyshine’ parameter.

Image analysis tool to select target area from image.

Key advantages of Automation:

- Faster, better use of resources
- Reduction of human error
- Better repeatability

Automation Limitations

Primarily manual or only partially automated processes:

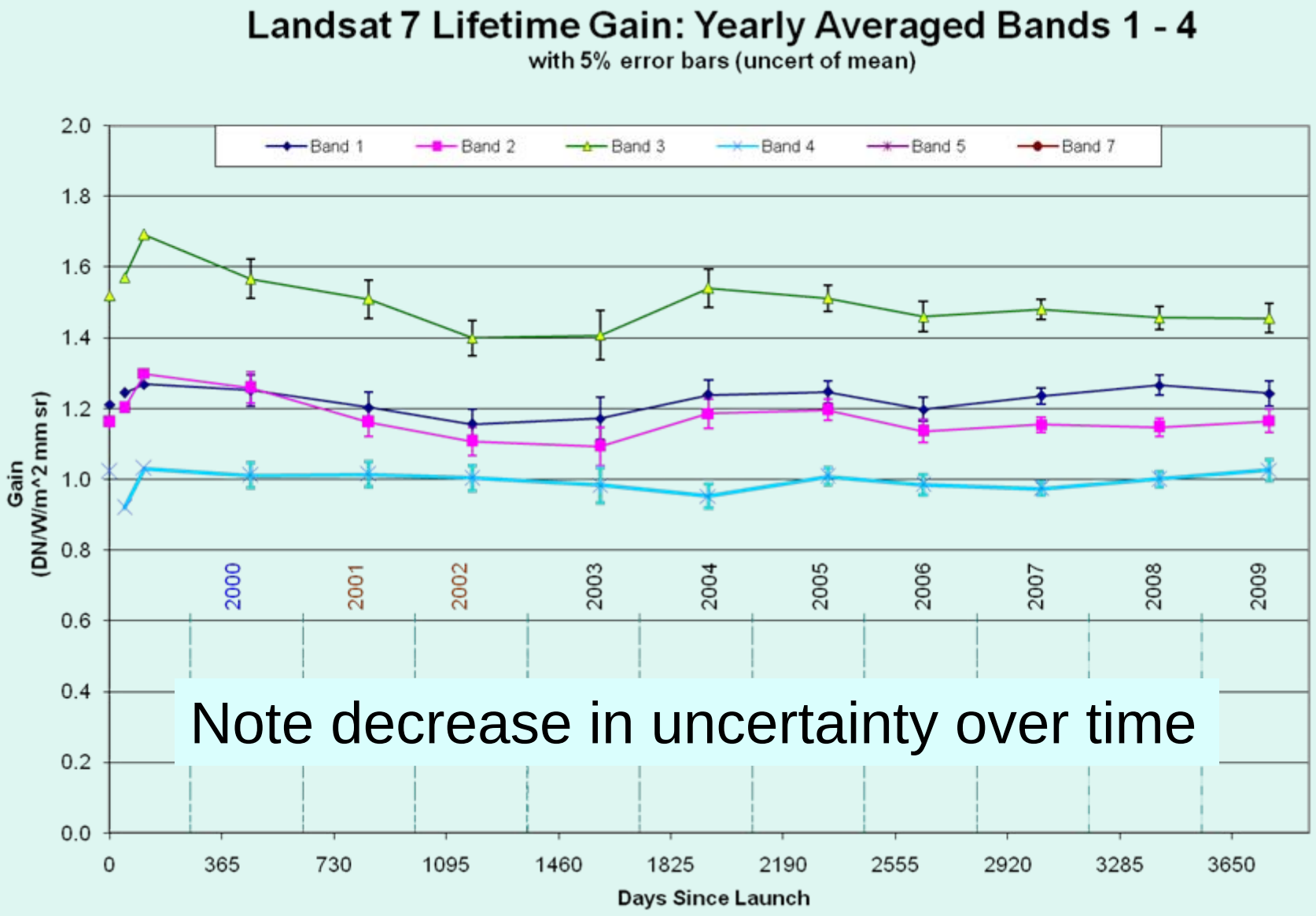
Ground radiance data collection (i.e. “Walking the ASD”)

- Necessary to obtain a good set of average values over pixel sized areas.

MODTRAN model optimization (semi-automated)

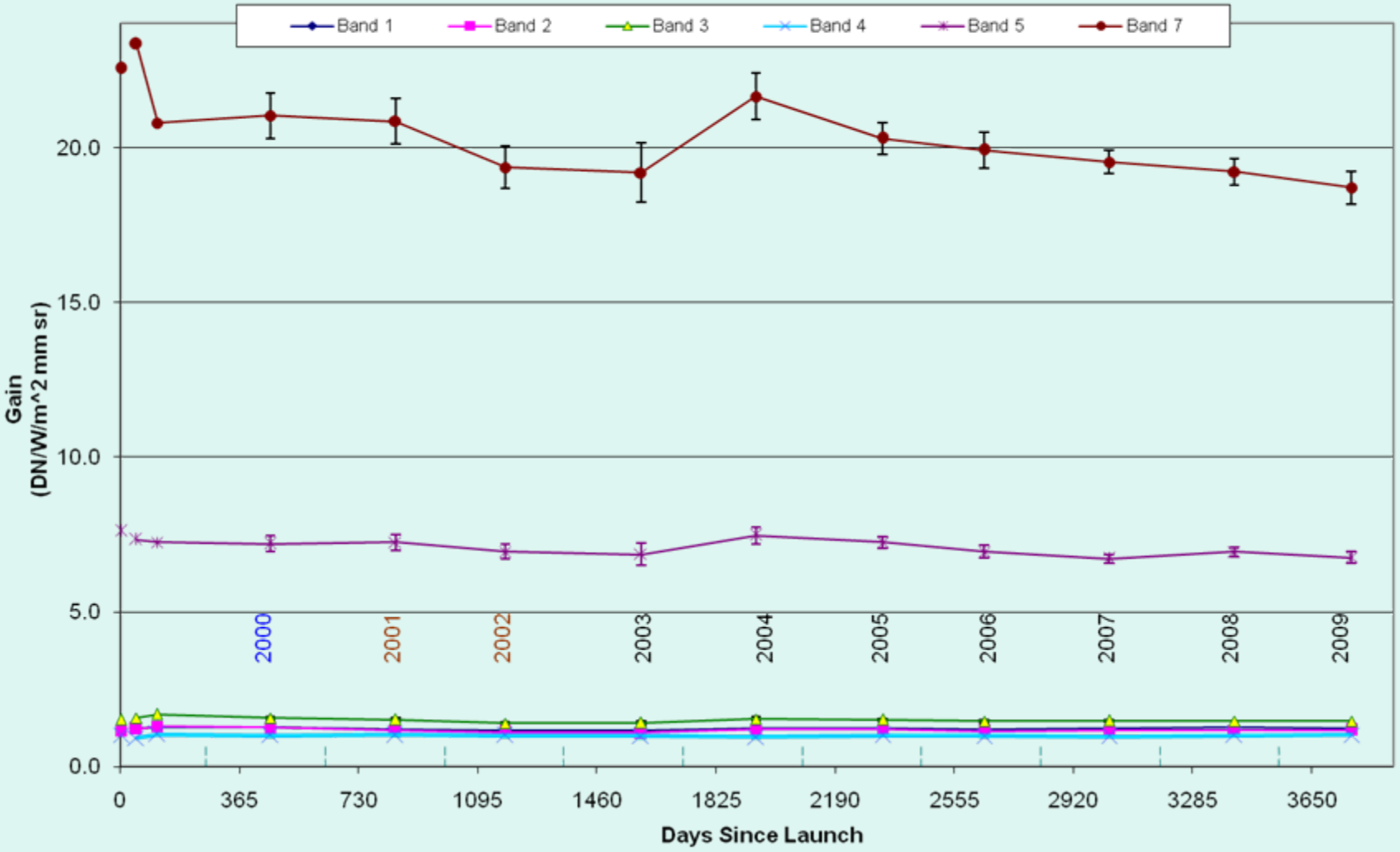
- Repeated runs are needed to optimize match to exact extinction and diffuse/global parameters.

Site maintenance, equipment maintenance and calibration, field deployment and field ‘walk sheets’.


Landsat 7 Lifetime Gain: Yearly Averaged Bands 1 - 4
with 5% error bars (uncert of mean)
Band 1
Band 2
Band 3
Band 4
Band 5
Band 7
Gain
(DN/W/m^2 mm sr)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
0
365
730
1095
1460
1825
2190
2555
2920
3285
3650
Days Since Launch
Note decrease in uncertainty over time

Landsat 7 Lifetime Gain: Yearly Averaged Bands 5 & 7

with 5% error bars (uncert of mean)



Summary Comments

- Vegetated sites can be used successfully for radiometric calibration
- Automation of site and procedures has produced more consistent calibrations
  - Improved sun photometer calibration consistency
  - Improved consistency in data processing
- Automation has improved efficiency and reduced costs
  - Deployment takes 2 people 2 hours
  - ~10hours/month maintenance
- Automation of site measurements has potential for improved consistency through more dense and repeatable data collection