Radiometric Calibration Assessment of Commercial High Spatial Resolution Multispectral Image Products

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3 Presentations:

- South Dakota State University
  David Aaron
- University of Arizona
  Kurt Thome
- SSC: Science Systems and Applications, Inc
  Kara Holekamp

Reflectance Based Calibration Base Process:

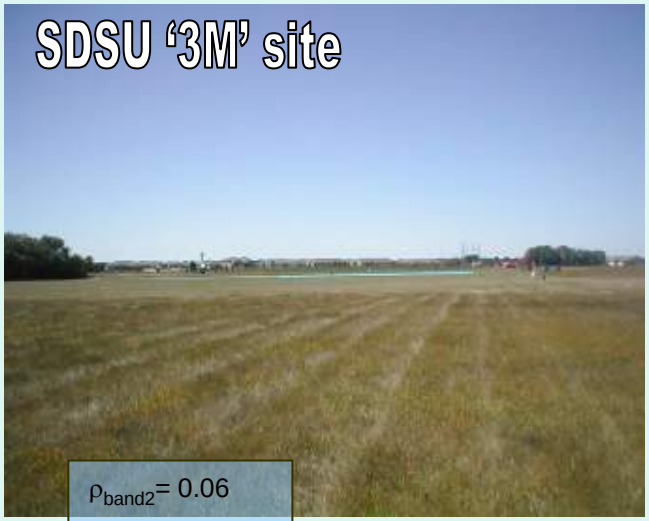
1. Identify a target area that has uniform reflectance over a multi-pixel area
2. During satellite imaging overpass: ground level reflectance measurement
3. Hours preceding and subsequent to overpass: continually monitor select wavelengths for direct and diffuse downwelling solar radiance
4. From above: Calculate extinction parameters using Langley analysis
5. From extinctions and other atmospheric parameters calculate hyperspectral atmospheric model
6. Propagate Top of Canopy radiances thru atmosphere via above model
7. Band these Top of Atmosphere hyperspectral radiances
8. Use satellite image DN counts of target area to calculate gain

Independent Groups make up the JACIE Radiometric Evaluation Team

- Scheduling: Coordinated through SSC
- Diverse locations and collection seasons
  - Collections represent various times of the year
  - Collections thru different atmospheres
- Diverse target set:
  - Radiance
    - ‘dark’ targets (vegetation)
    - ‘bright’ targets (playa)
    - high contrast (tarps)
  - Spectral response:
    - vegetation signatures
    - high reflectance natural surfaces
    - flat response manmade targets

Collection Sites Exhibit Varied Surfaces

Note: typical Band 2 and 4 reflectances shown



Radiometry Groups (cont)

- Similar (but certainly not identical) equipment sets
  - spectroradiometers (primarily Analytic Spectral Devices Field Spec)
  - Sunphotometers, shadowband radiometers, reference panels, etc
    - some common basis but also considerable variation/replication/modification from group to group
- Data collection: Each group has developed their own protocols
- Data reduction: Each group has developed their own techniques
  - Atmospheric modeling:
    - SDSU & SSC: all MODTRAN based
    - UOA RSG: Combination of custom code and MODTRAN

SDSU
Satellite Calibration

Physics Department (Satellite Calibration Group):

- David Aaron
- Larry Leigh
- Sara Landau

Electrical Engineering and Computer Science (Image Processing Lab):

- Dennis Helder
- Jason Choi
- Tim Ruggles
- Jim Dewald
- (see Dennis' slides for a complete list of graduate and undergraduate engineers)

SDSU Radiometry Goals: 2004-2005

Vegetated target collections
- IKONOS
- QuickBird
- OrbView 3
- Landsat 5
- Landsat 7
- AWiFS (2005)
- EO1 (2004)

Complete re-establishment of full SDSU processing capability
- Partial 2004
- Full 2005
- *(2001-2003 atmospheric modeling courtesy of UOA and SSC)*

SDSU Vicarious Calibration Process:

- ‘Simultaneous’ satellite imaging and hyperspectral measurement of upwelling radiance at grass target area (“3M” in Brookings SD).
  - ASD FS FR unit 638 with 8 degree optic
  - 18” 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 4.3.2
- Transfer (hyperspectral) Top of Canopy (TOC) to TOA using MODTRAN model
- Band hyperspectral radiances to produce in-band TOA radiance
- Calculate gain by comparing satellite DN to in-band TOA radiance values

2005 SDSU Calibration Collection Summary:

Data collections summary (perceived useful collections only)

2005:

- May 19: L5 good +: some cumulus later in day
- June 22: QB + AWiFS okay, some clouds
- July 6: L5 good – considerable cirrus
- July 14: L7 popcorn clouds but probably okay
- July 18: OV (pan)
- **July 29: OV (MS) *OV failed decompression, data not retrievable*
- Aug 1: OV (MS) + IK shot thru considerable popcorn cumulus
- Aug 23: L5 okay but lots of cumulus

Aug 29: Katrina

- Aug 31: L7 good - : cumulus just passed by
- Sept 16: L7 very good pm, okay late am
- Oct 7: OV (pan) excellent
- Oct 18: QB + L7 good

Year 2005: Added Goal
Process Capability

- Pre 2005 Mode: Data processing is primarily ‘post season’
- Agriculture applications require ‘real-time’ reflectance correction
- Pilot analysis of processing streams:
  - Image acquisition
  - Atmospheric correction
  - Image correction
  - Data archiving
- Pilot study of atmospheric correction
  - May 19 pilot run(L5): Less than 1 week for all steps
  - scattered clouds: still implementing auto filter algorithm

“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
  - 6 ft rotary mower (rough, not finish cut) for easternmost 2/3 of site
  - western 1/3 of site, finish cut

    (target area for high resolution MTF collection)

- To accommodate AWiFS, new markers in unmowed area

3M Site
Oct 7,2005 (OrbView)

Oct 7, 2005

Initially cloudy but clear at overpass

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)

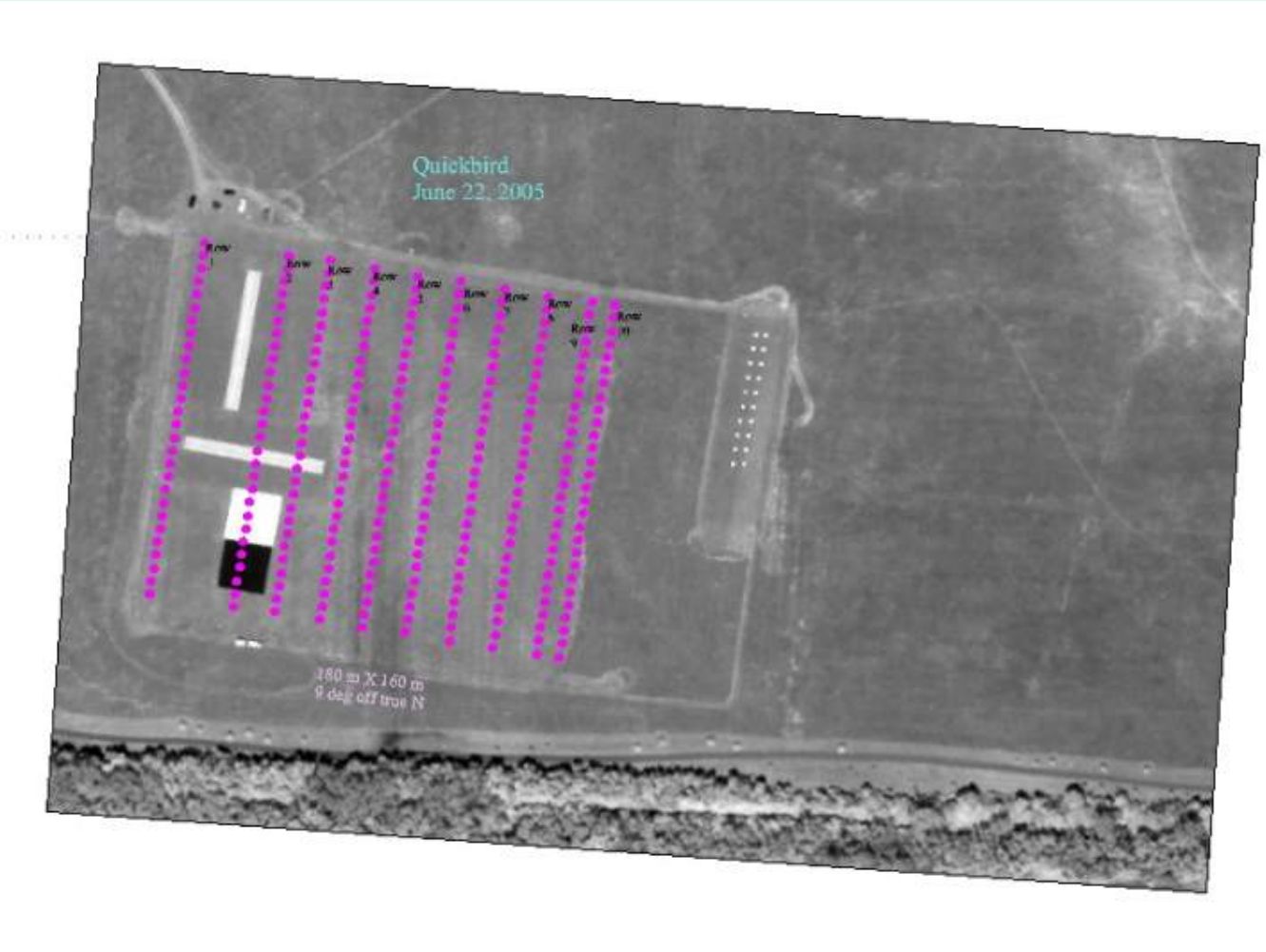
- Collect while walking ASD along 150 m N-S rows
  - 20 spectra/file, 10 files/save
    - Results in 60 files per row so about 600 files per collection
    - ~ 20 minutes for 10 row collection

- White reference at end of each row pair (north end)

Brookings ‘3M’ Grass Site
Shown with targets deployed

Standard ASD Data Acquisition Paths

(note: When SSC tarps deployed, Row 2 is skipped)



MTF Tarp collection
(SSC 3.5 and 52% tarp sets)

Generally tarps are laid out EW with 3.5% to E

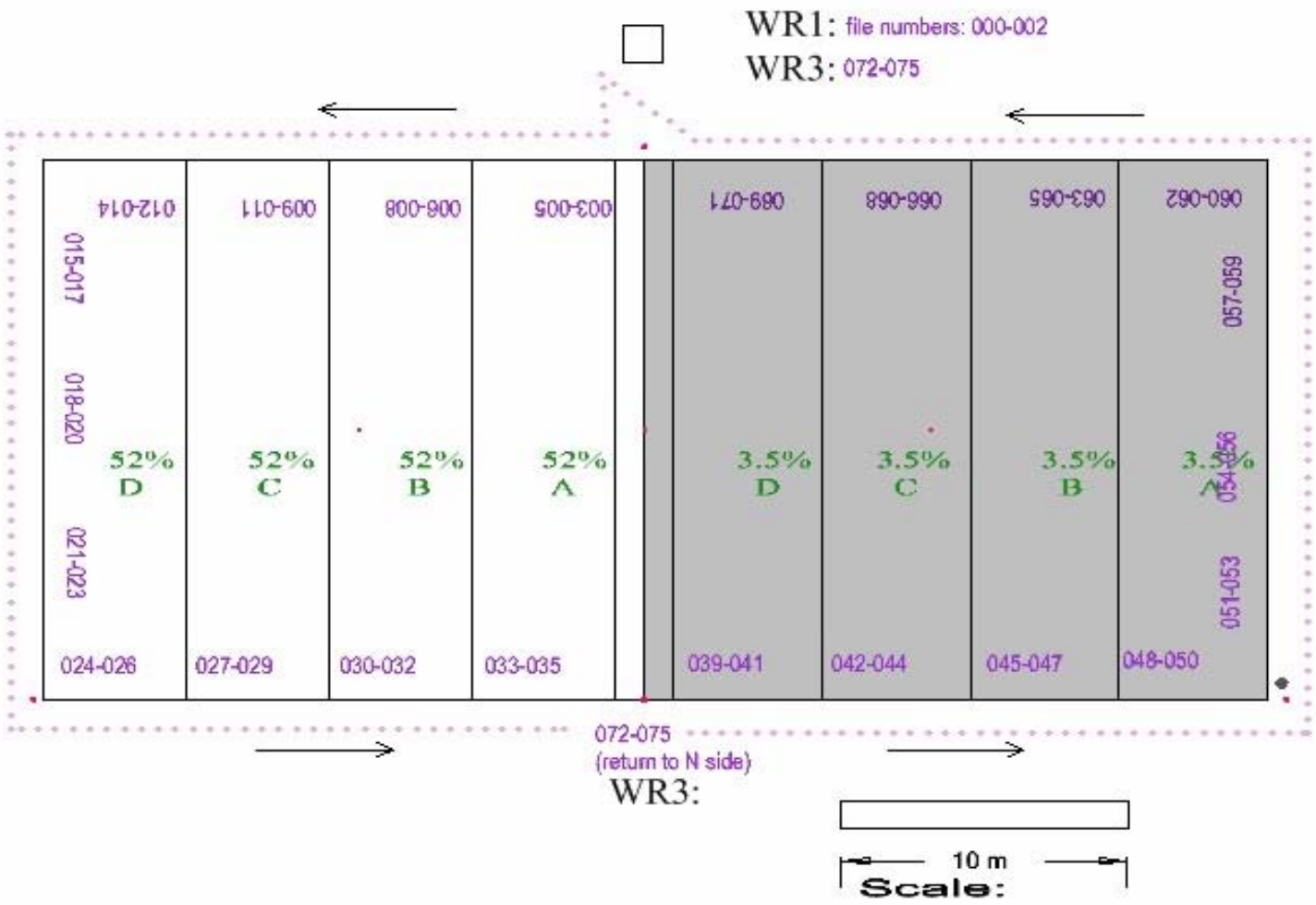
Nominal collection:

- Start at N center (White ref) and sample ‘in’ ~1m from edge.

- Sample tarp edge perimeter CCW
  - 10 spectra/file, either 3 or 5 files per save
  - 4 saves per ‘side’ (each tarp set)
  - a second WR when get to S center
  - a third WR when return to N center

- Radiance values are BRDF corrected as part of standard analysis

MTF tarp data collection 'walk' paths and file numbers for standard 3 files/save



2004 SDSU Calibration Collection Summary:

Data collections summary (useable collections only)

We weren't at all happy in 2004
May thru Aug 20, ~5 'clear' days at noon
(and none of these coincided with overpasses)

<u>2004</u>

- June 28: L7 + E01 Scattered clouds used Schiller trapped light model
- Aug 30: QB + OV
- Sept 29: L7 + EO1
- Oct 5: QB
- Oct 8: OV

2005 SDSU Calibration Collection Summary:

Data collections summary (perceived o.k. collections only)

2005:

• May 19:	L5	good +: some cumulus later in day
• June 22:	QB + AWiFS	okay, some clouds
• July 6:	L5	good – considerable cirrus
• July 14:	L7	popcorn clouds but probably okay
• July 18:	OV (pan)	
• Aug 1:	OV (MS) + IK	shot thru considerable popcorn cumulus
• Aug 23:	L5	okay but lots of cumulus
• Aug 31:	L7	good - : cumulus just passed by
• Sept 16:	L7	very good pm, okay late am
• Oct 7:	OV (pan)	excellent
• Oct 18:	QB + L7	good

IKONOS

VICARIOUS CALIBRATION RESULTS

SDSU

2005

Aug 1, 2005
IKONOS

IKONOS Results:

Only one data collection performed at SDSU 2004-2005

- Aug 1, 2005: Site was ‘shot between the clouds’ (IKONOS + Orbview)
- Attempted a ‘light trapping’ model but results to date show too large an uncertainty to be reportable.

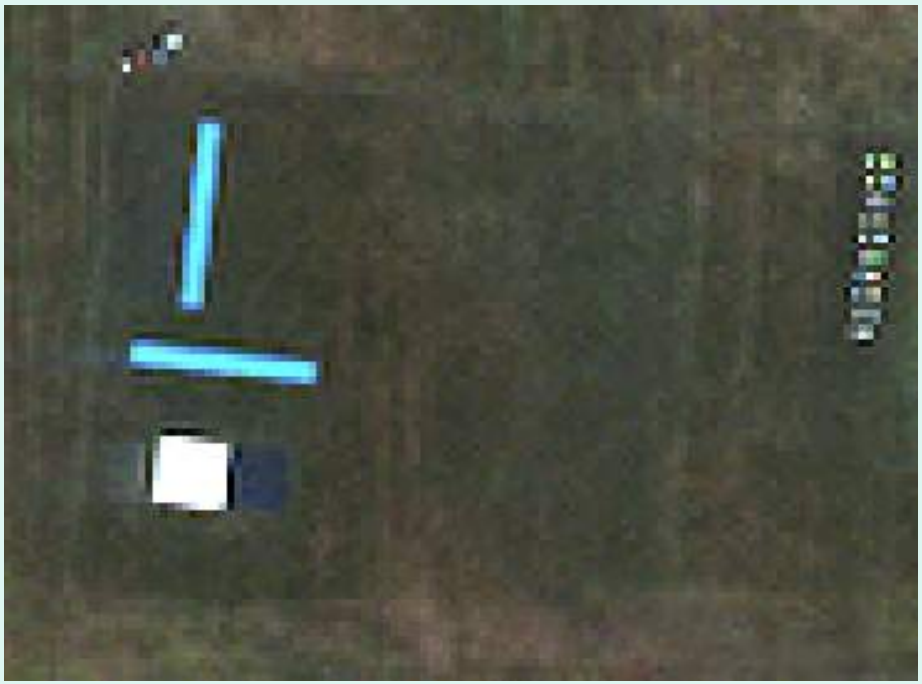
Note: Aug 1, 2005
also an OrbView (MS) overpass

QUICKBIRD

VICARIOUS CALIBRATION
RESULTS
SDSU
2004 AND 2005

June 22, 2005
QuickBird

3M Site: Oct 18, 2005
QuickBird

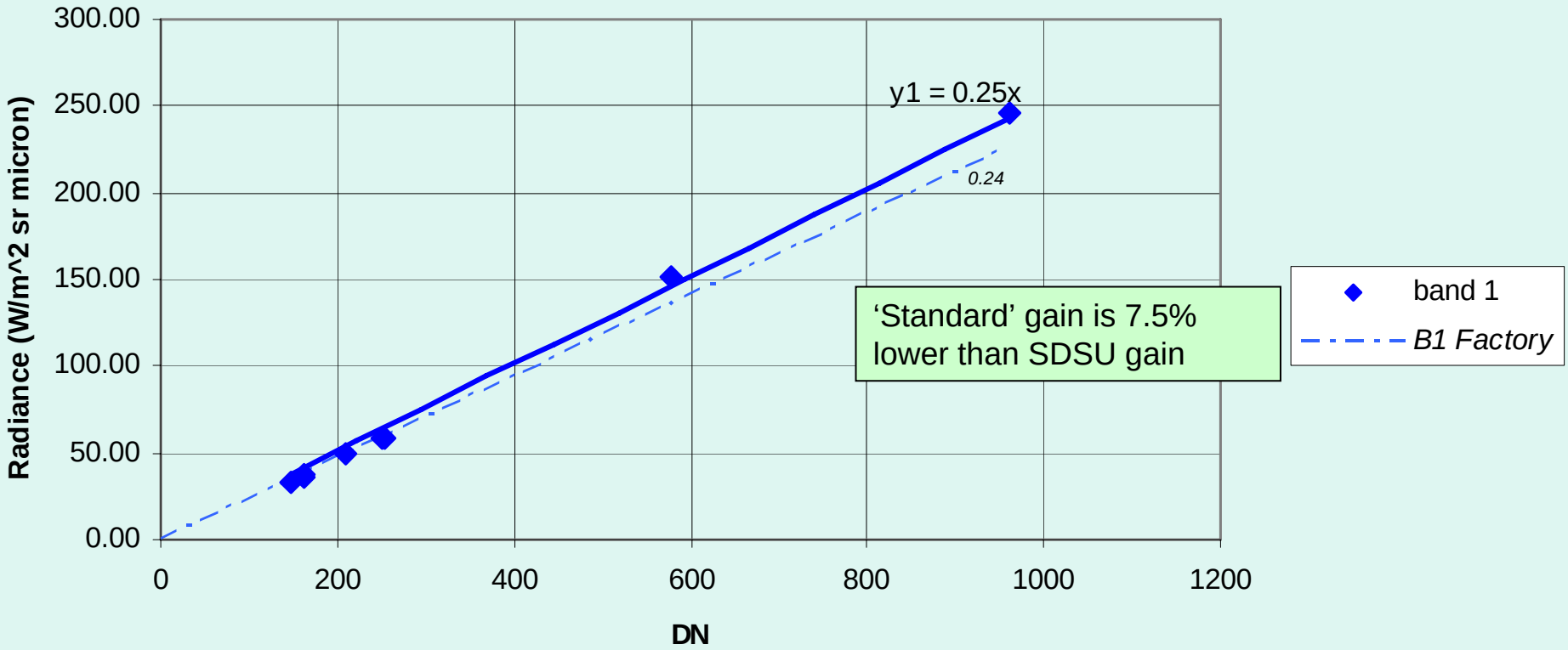


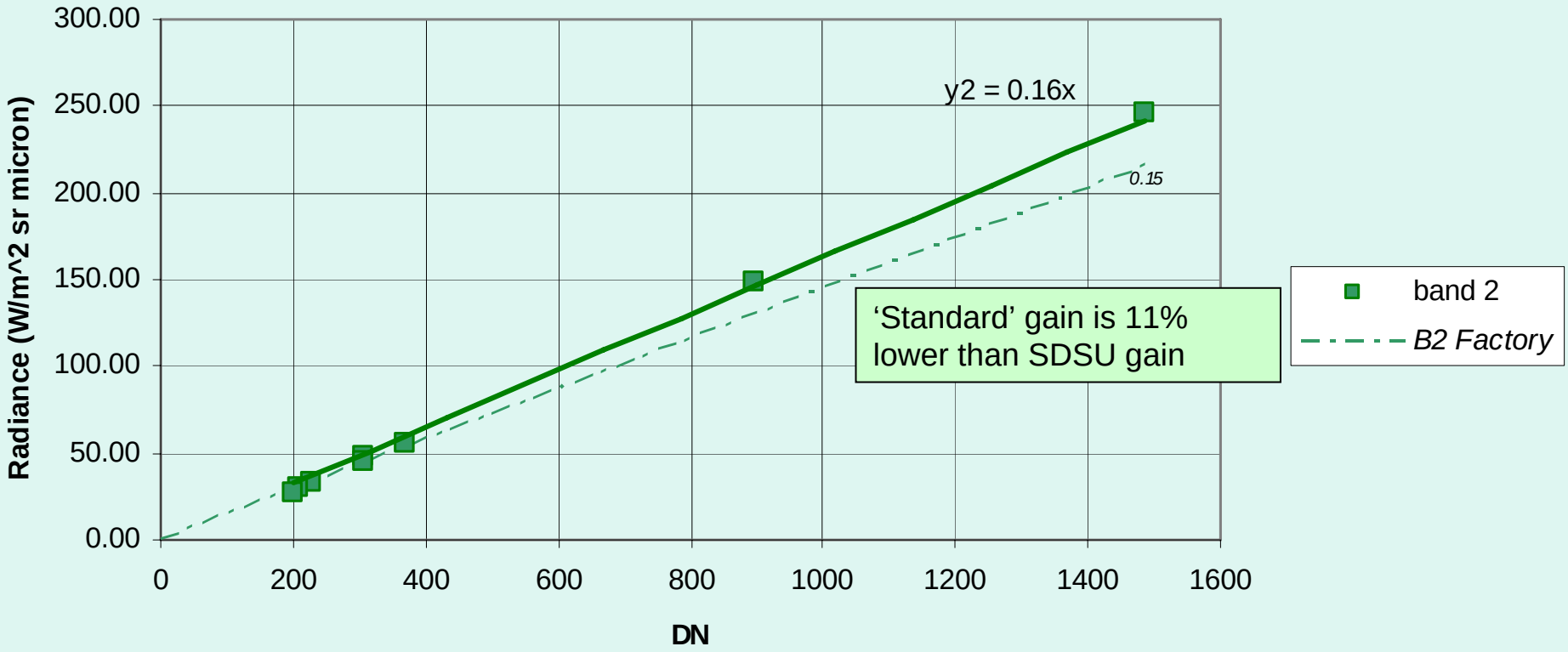
QuickBird Band Gains: 2004-2005

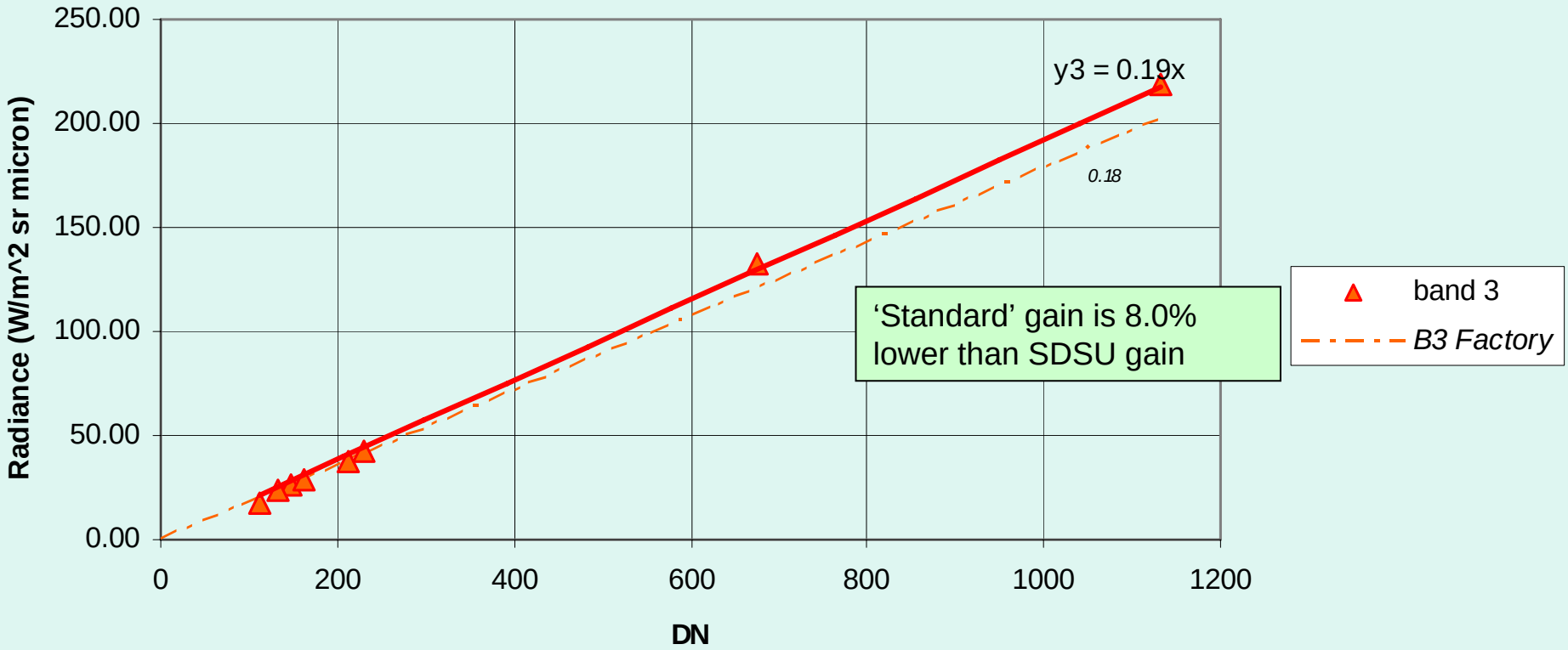
Basic Radiance(W/m^2 sr μm) to DN ratio

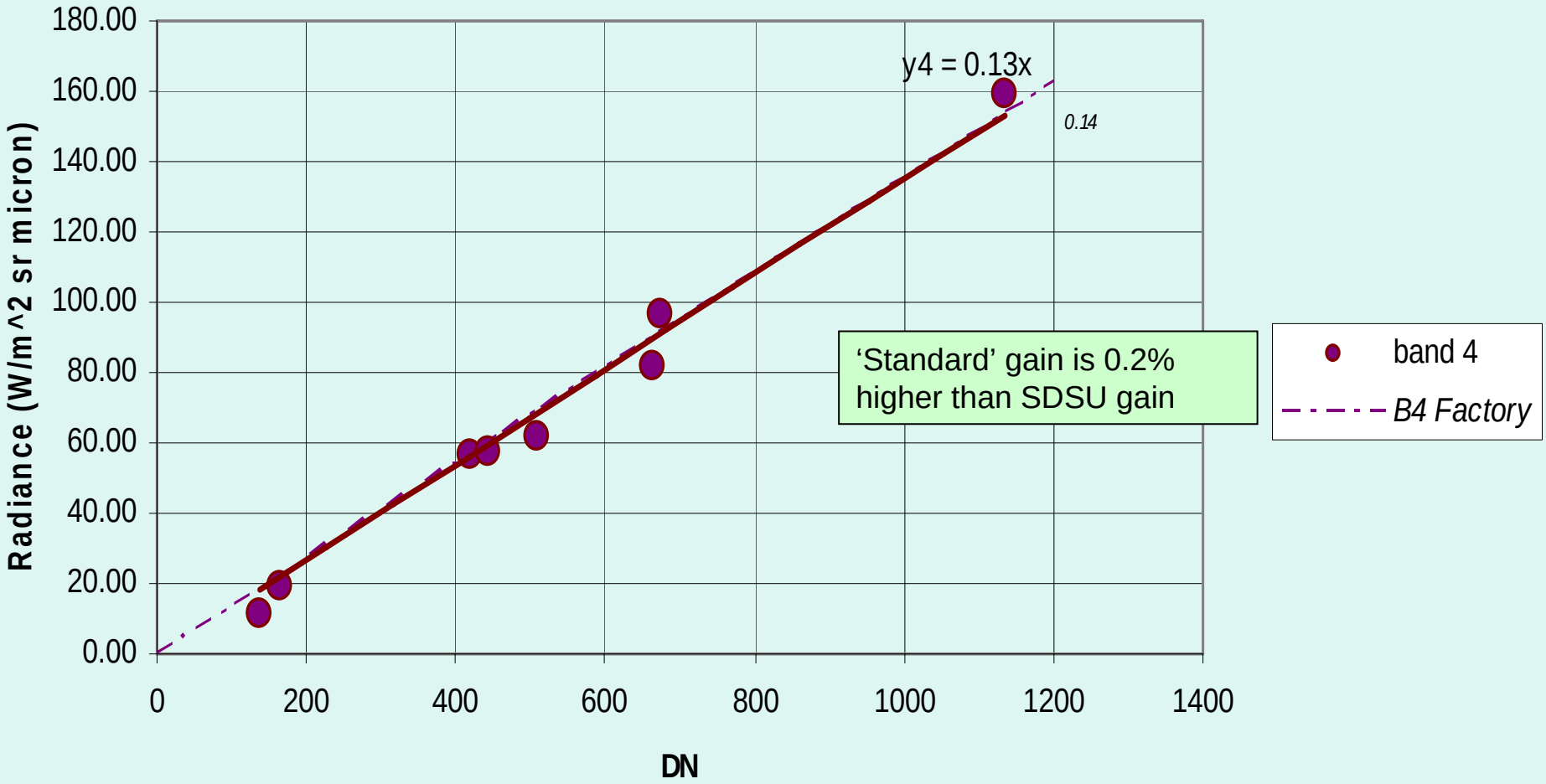
3M Grass	Band 1	Band 2	Band 3	Band 4
Aug 30 2004	0.234	0.156	0.174	0.122
Oct 5 2004	0.232	0.146	0.174	0.135
Jun 22 2005	0.236	0.149	0.183	0.123
Oct18 2005	0.227	0.146	0.179	0.130
52% Tarps				
Jun 22 2005	0.256	0.165	0.193	0.141
Oct18 2005	0.263	0.165	0.196	0.143
3.5% tarps				
Jun 22 2005	0.230	0.146	0.174	0.116
Oct18 2005	0.220	0.131	0.150	0.083

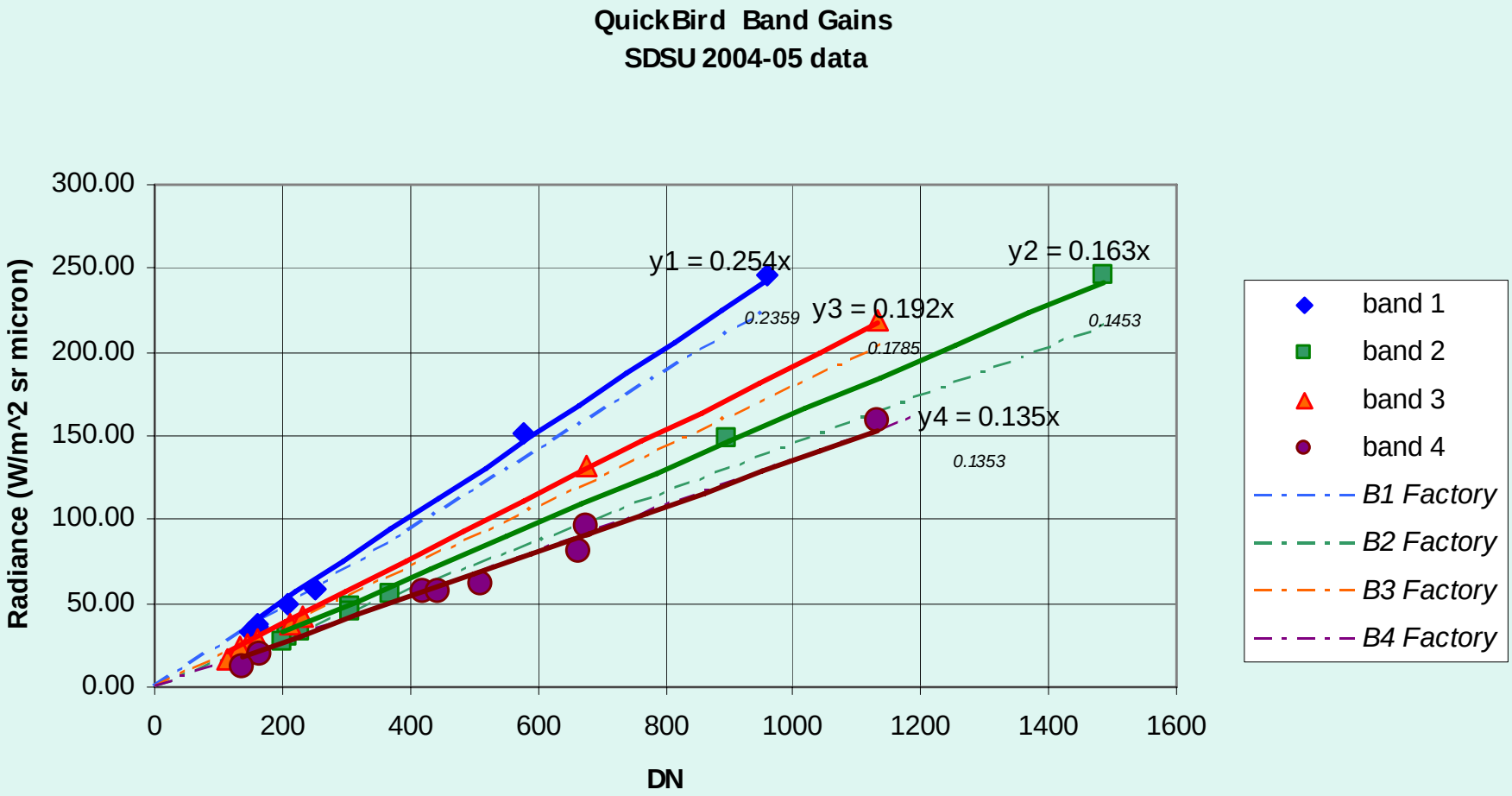
average	0.237	0.151	0.178	0.124
standard deviation (1 sigma)	0.015	0.011	0.014	0.019


QuickBird Band 1 Gain: Forced Zero Intercept
SDSU 2004-05 data
Radiance (W/m^2 sr micron)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
200
400
600
800
1000
1200
DN
y1 = 0.25x
0.24
‘Standard’ gain is 7.5% lower than SDSU gain
band 1
B1 Factory


QuickBird Band 2 Gain: Forced Zero Intercept
SDSU 2004-05 data
Radiance (W/m^2 sr micron)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
200
400
600
800
1000
1200
1400
1600
DN
y2 = 0.16x
0.15
‘Standard’ gain is 11% lower than SDSU gain
band 2
B2 Factory


QuickBird Band 3 Gain: Forced Zero Intercept
SDSU 2004-05 data
Radiance (W/m^2 sr micron)
250.00
200.00
150.00
100.00
50.00
0.00
0
200
400
600
800
1000
1200
DN
y3 = 0.19x
0.18
‘Standard’ gain is 8.0% lower than SDSU gain
band 3
B3 Factory


QuickBird Band 4 Gain: Forced Zero Intercept
SDSU 2004-05 data
Radiance (W/m^2 sr micron)
DN
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0
200
400
600
800
1000
1200
1400
y4 = 0.13x
0.14
‘Standard’ gain is 0.2% higher than SDSU gain
band 4
B4 Factory


QuickBird Band Gains
SDSU 2004-05 data
Radiance (W/m^2 sr micron)
DN
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
200
400
600
800
1000
1200
1400
1600
y1 = 0.254x
0.2359
y2 = 0.163x
0.1453
y3 = 0.192x
0.1785
y4 = 0.135x
0.1353
band 1
band 2
band 3
band 4
B1 Factory
B2 Factory
B3 Factory
B4 Factory

ORBVIEW-3

VICARIOUS CALIBRATION
RESULTS
SDSU
2004 AND 2005

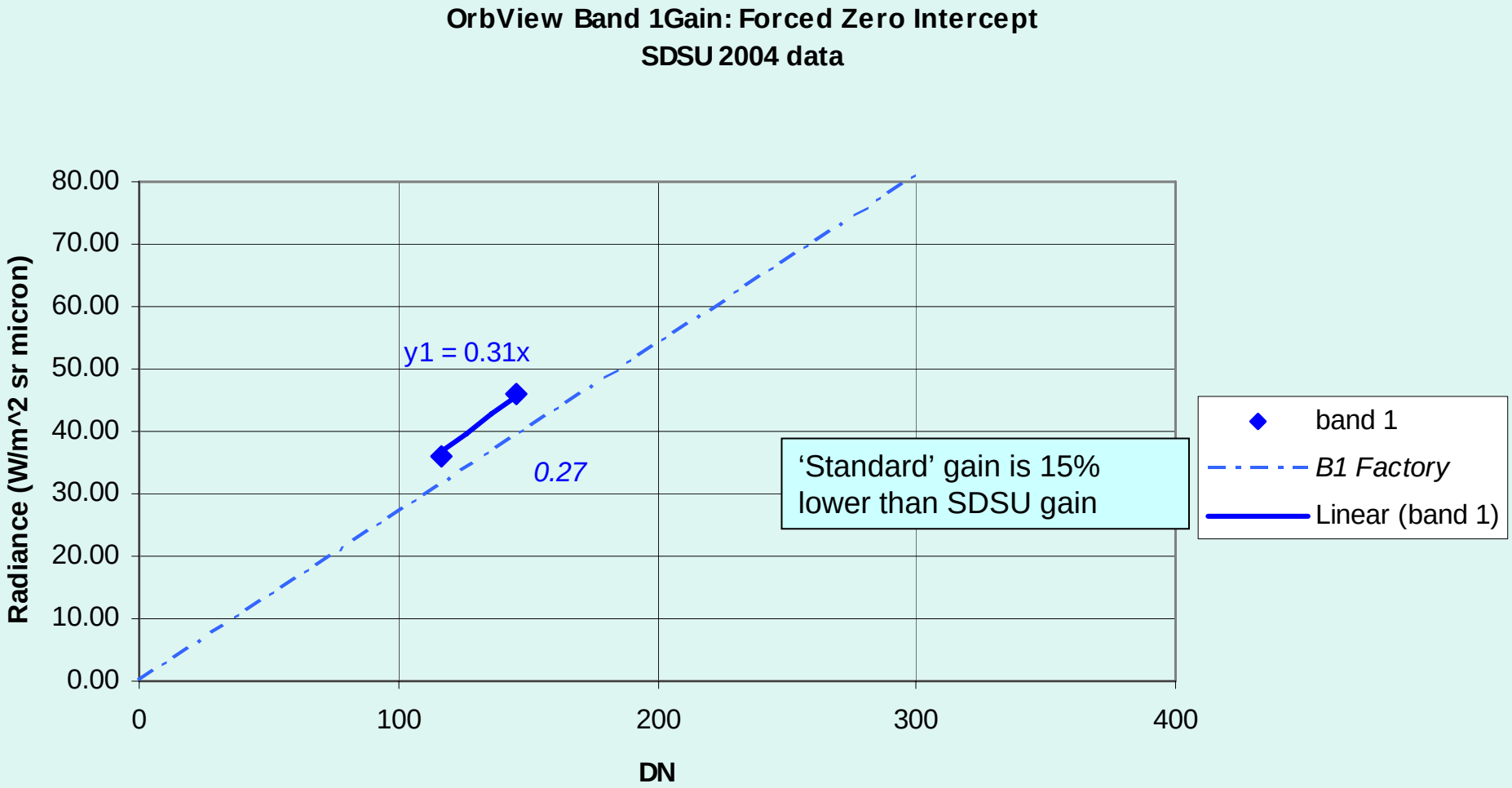
Oct 7, 2005
OrbView (pan)

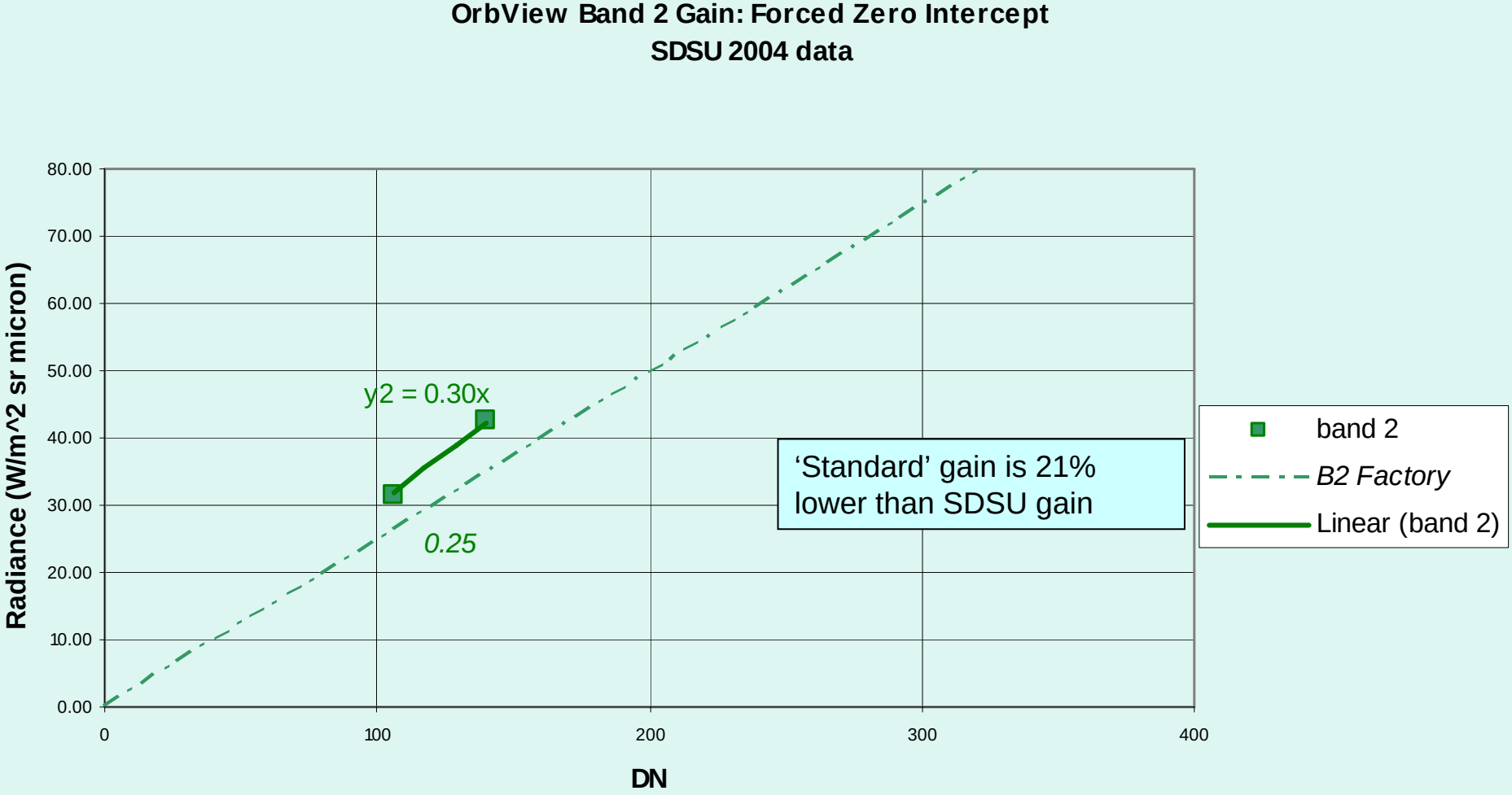
OrbView Band Gains: 2004

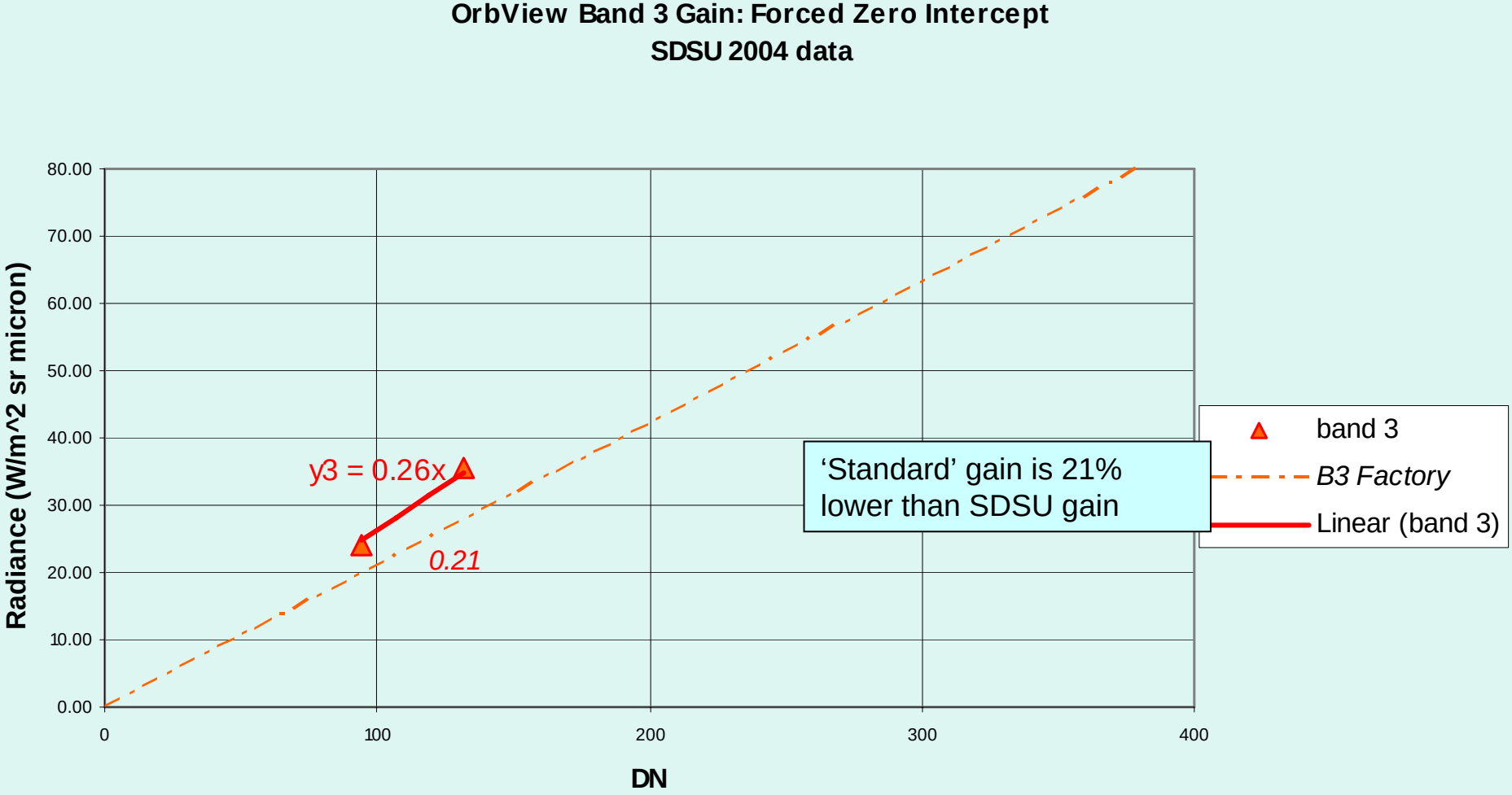
Basic Radiance(W/m^2 sr μm) to DN ratio

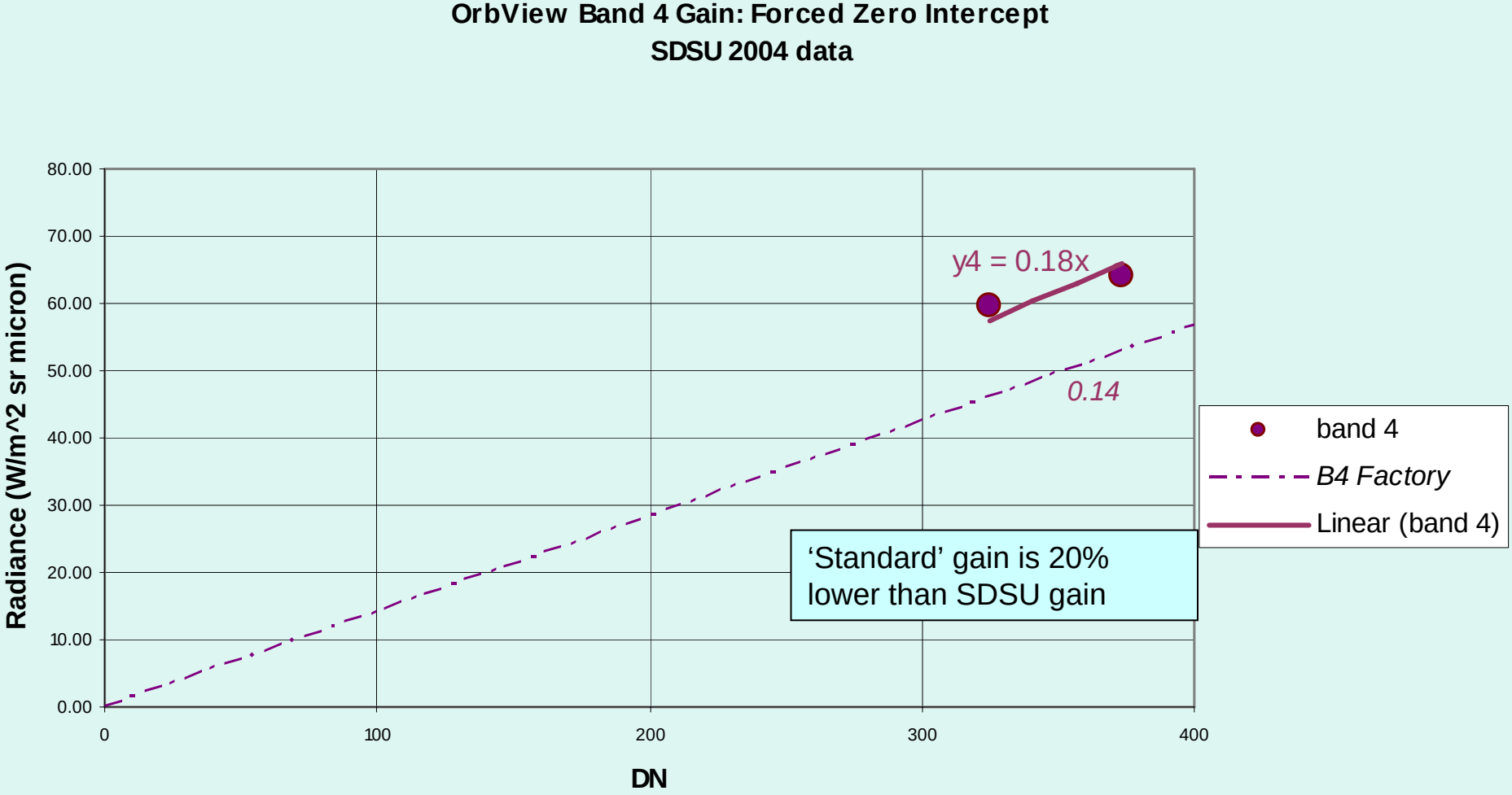
3M Grass	Band 1	Band 2	Band 3	Band 4
Aug 30 2004	0.317	0.304	0.269	0.172
Oct 8 2004	0.310	0.295	0.256	0.183

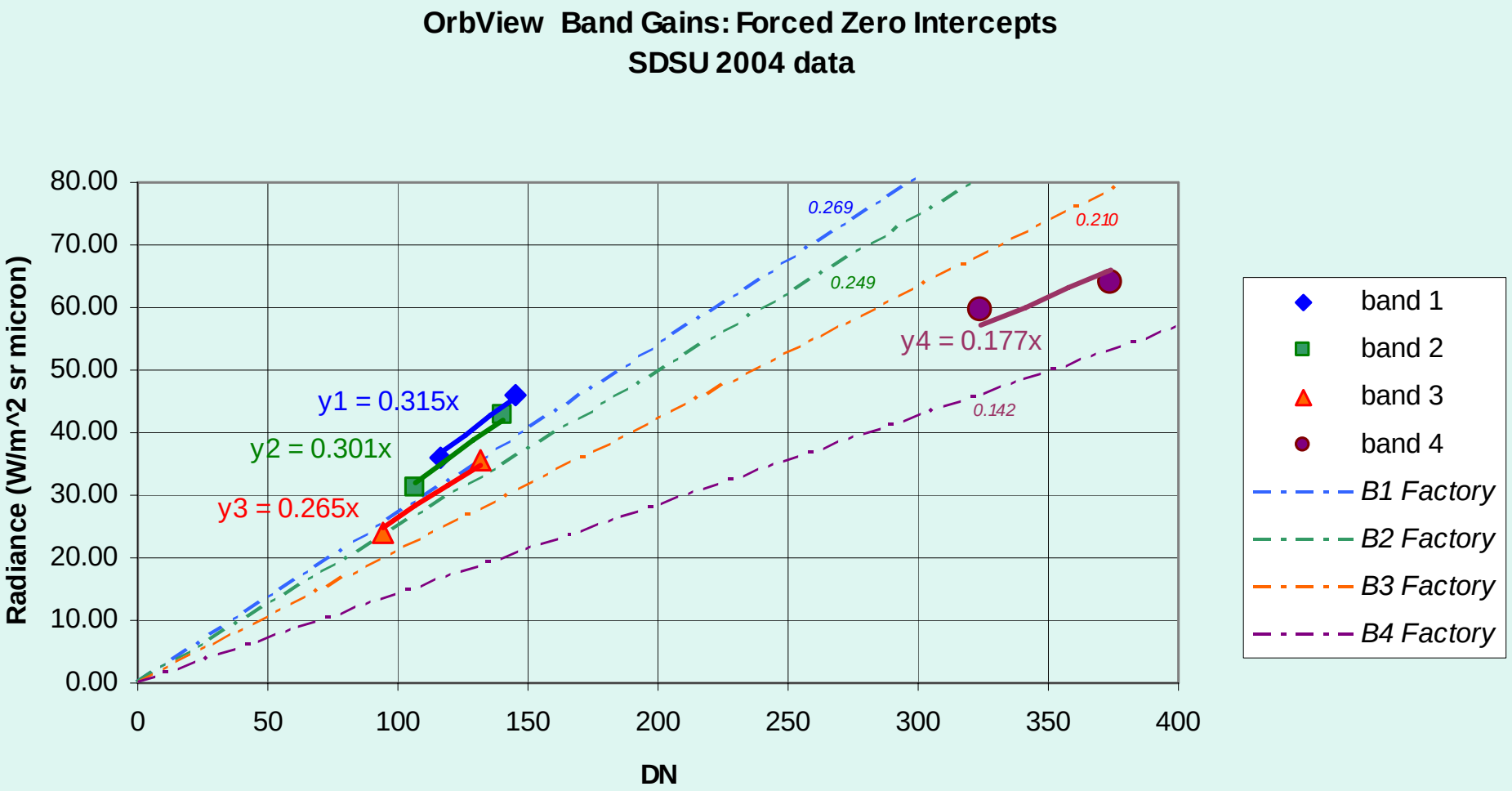
average	0.314	0.300	0.263	0.177
standard deviation (1 sigma)	0.014	0.014	0.015	0.009


OrbView Band 1Gain: Forced Zero Intercept
SDSU 2004 data
Radiance (W/m^2 sr micron)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
100
200
300
400
DN
y1 = 0.31x
0.27
'Standard' gain is 15% lower than SDSU gain
band 1
B1 Factory
Linear (band 1)


OrbView Band 2 Gain: Forced Zero Intercept
SDSU 2004 data
Radiance (W/m^2 sr micron)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
100
200
300
400
DN
y2 = 0.30x
0.25
‘Standard’ gain is 21% lower than SDSU gain
band 2
B2 Factory
Linear (band 2)


OrbView Band 3 Gain: Forced Zero Intercept
SDSU 2004 data
Radiance (W/m^2 sr micron)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
100
200
300
400
DN
y3 = 0.26x
0.21
‘Standard’ gain is 21% lower than SDSU gain
band 3
B3 Factory
Linear (band 3)

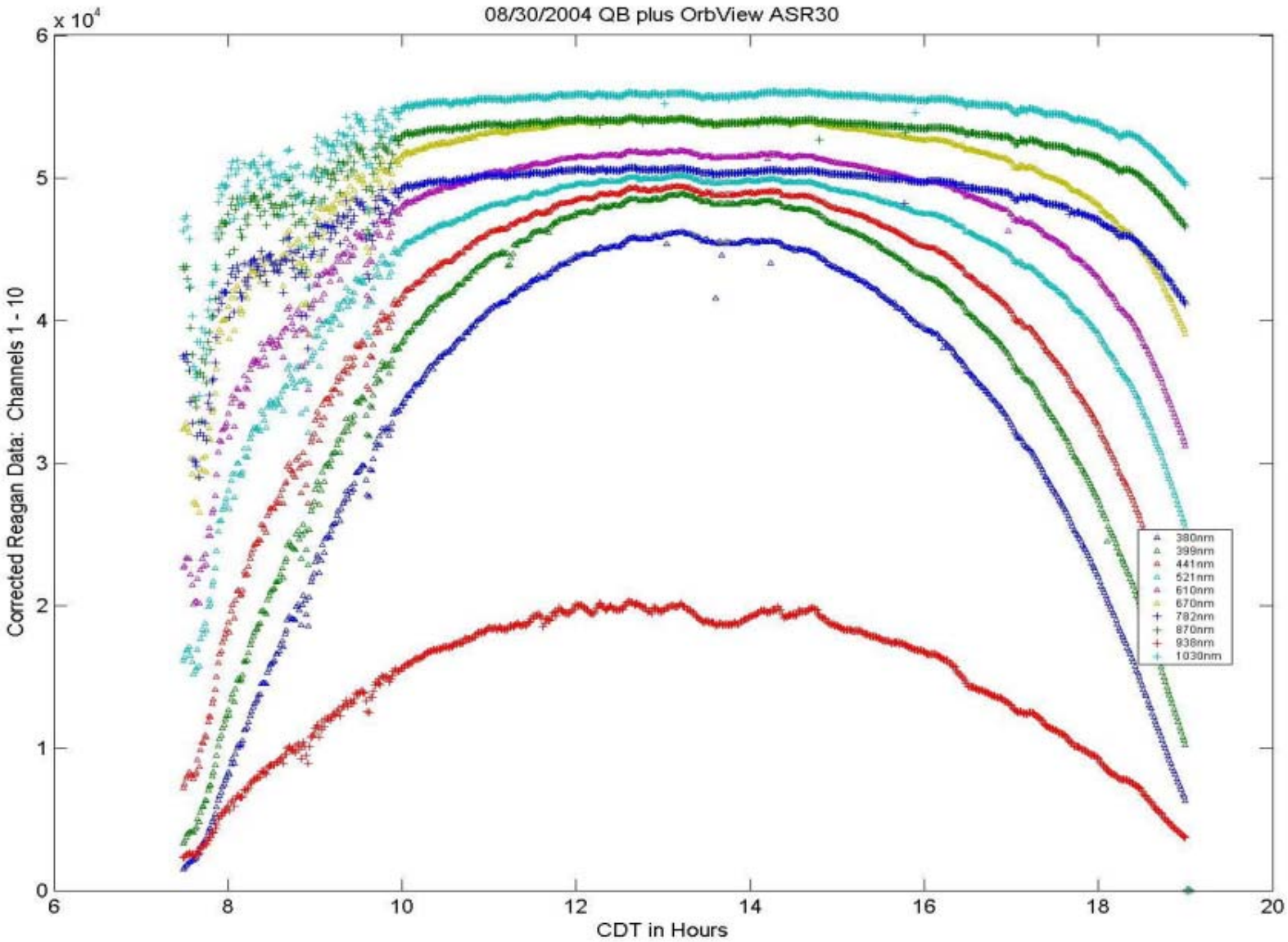

OrbView Band 4 Gain: Forced Zero Intercept
SDSU 2004 data
Radiance (W/m^2 sr micron)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
100
200
300
400
DN
y4 = 0.18x
0.14
band 4
B4 Factory
Linear (band 4)
‘Standard’ gain is 20% lower than SDSU gain

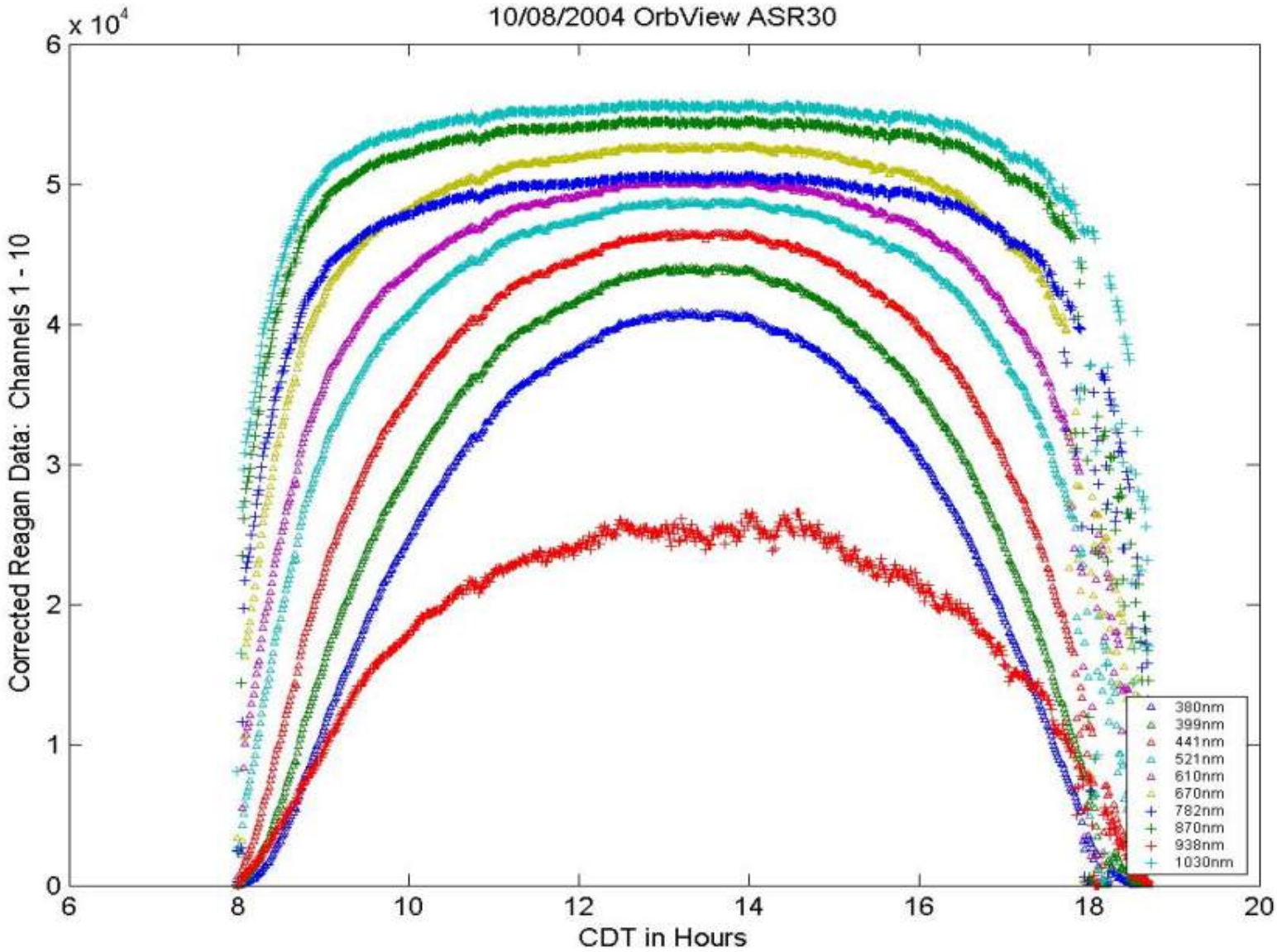

OrbView Band Gains: Forced Zero Intercepts
SDSU 2004 data
Radiance (W/m^2 sr micron)
DN
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
50
100
150
200
250
300
350
400
y1 = 0.315x
y2 = 0.301x
y3 = 0.265x
y4 = 0.177x
0.269
0.249
0.210
0.142
band 1
band 2
band 3
band 4
B1 Factory
B2 Factory
B3 Factory
B4 Factory

Acknowledgements:

The SDSU team would like to thank:

- NASA NNS04AB66C
- NASA EPSCoR NCC5-588


08/30/2004 QB plus OrbView ASR30
x 10^4
Corrected Reagan Data: Channels 1 - 10
CDT in Hours
0
1
2
3
4
5
6
6
8
10
12
14
16
18
20
380nm
399nm
441nm
521nm
610nm
670nm
782nm
870nm
938nm
1030nm


10/08/2004 OrbView ASR30
x 10^4
Corrected Reagan Data: Channels 1 - 10
CDT in Hours
0
1
2
3
4
5
6
6
8
10
12
14
16
18
20
380nm
399nm
441nm
521nm
610nm
670nm
782nm
870nm
938nm
1030nm