Cross-calibration of Wide Field Sensors (WiFS) of IRS-1C, -1D and –P6 using Near-synchronous Matching Scenes

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IRS WiFS Cameras : Purpose & Need for Cross-calibration

- Designed for a quick and continuous crop monitoring with
  - A revisit time of once in 5 days
  - Larger swath coverage of 720 km at a pixel size of 188m
  - At least two bands essential for producing NDVI
- Equipped in successive three IRS spacecrafts for continued data services to user community.
- **Cross calibration** – inevitable for seamless integration of data products from these sensors

WiFS – Sensors Parameters

Sensor	Band	*Range*	*Esun*	bpp	GIFOV (m)	Swath (km)
1C-WIFS	B3	0.62-0.69	157.78	8	188	810
	B4	0.77-0.86	110.84			
1D-WIFS	B3	0.62-0.69	157.83	8	188*	720
	B4	0.77-0.86	110.94			
P6-AWIFS	B2	0.52-0.58	185.47	10	56	737
	B3	0.62-0.69	155.67			
	B4	0.77-0.86	155.68	10		
	B5	1.55-1.70	108.27			

*GIFOV varies between 169 m and 188 m; data products are supplied resampled at 188 m.

E_{sun} – the band-weighted exo-atmospheric solar irradiance (in mw/cm^2-sr)

Cross-calibration is attempted here for Bands B3 and B4.

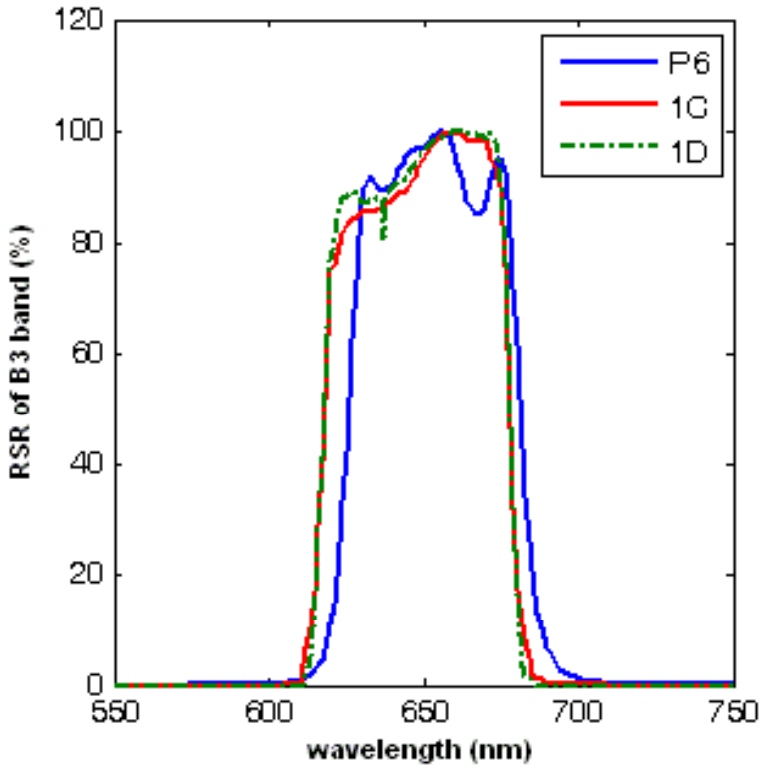
Orbital Characteristics

Parameter	IRS-1C	IRS-1D	IRS-P6
Orbits/cycle	341	358	341
Altitude (*km*)	817	737 - 821	817
Eccentricity	0.0012	0.006	0.001
Inclination	98.67°	98.53°	98.69°
Local Time (a.m.)	10:30	10:30 - 10.47	10:30
Revisit (days)	24	25	24
Orbit Period (min)	101.35	100.56	101.35

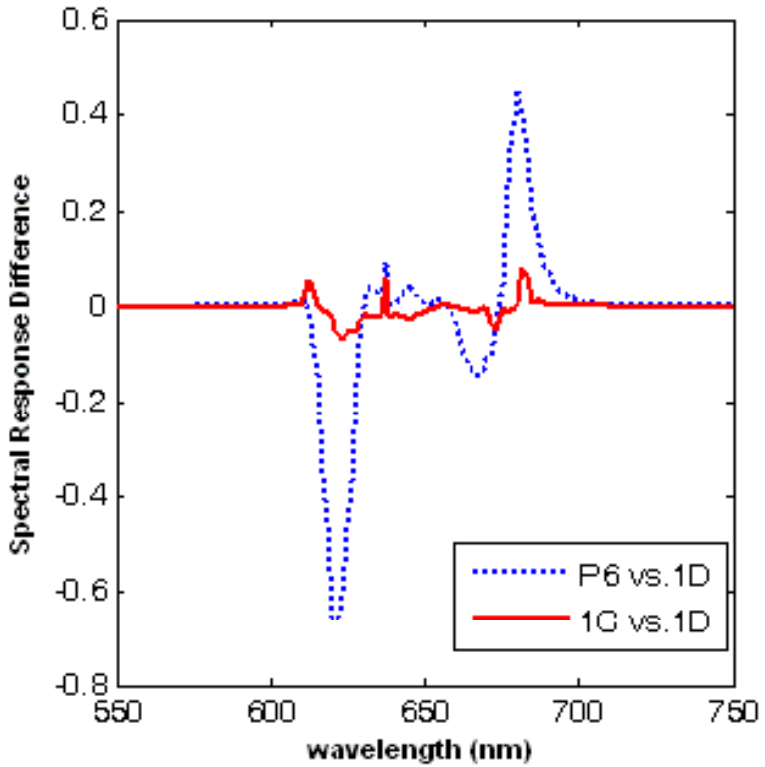
- Elliptical orbiting characteristics of IRS-1D provides opportunity to cover synchronous scenes in certain days of its cycle

Spectral Characteristics of WiFS in B3 Band

Relative Spectral Response curves

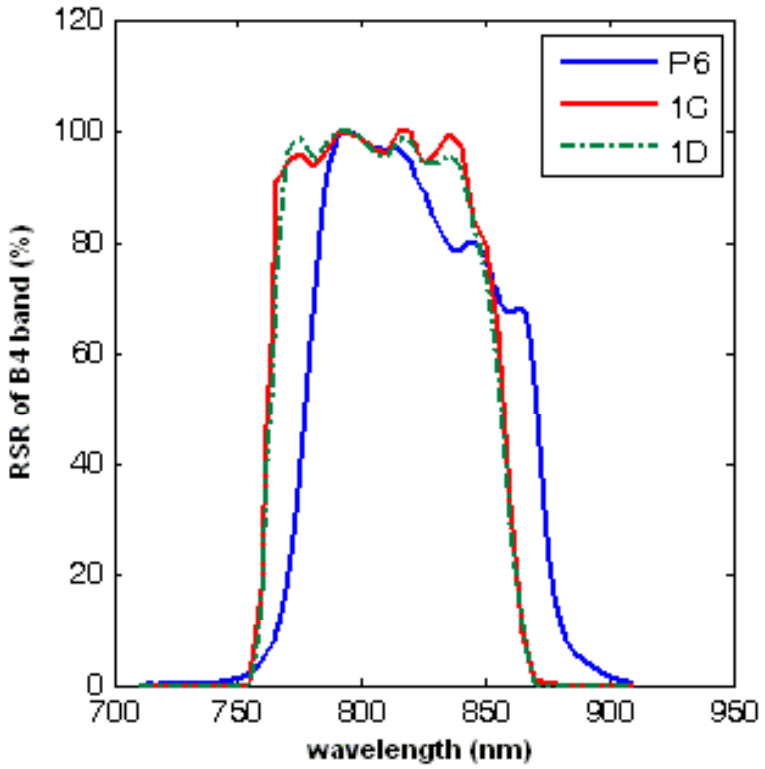


Spectral Response Differences

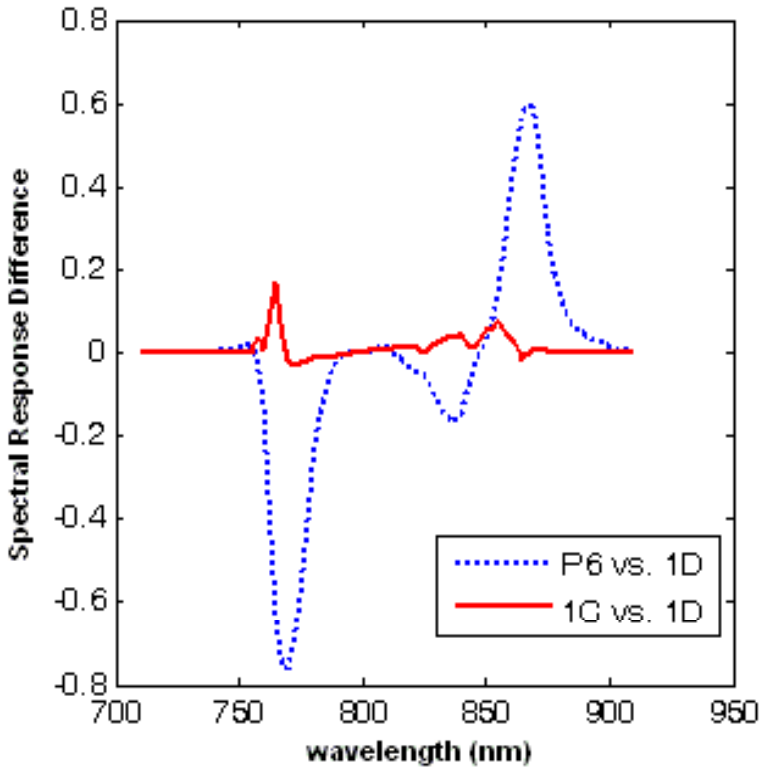


Spectral Characteristics of WiFs in B4 Band

Relative Spectral Response curves

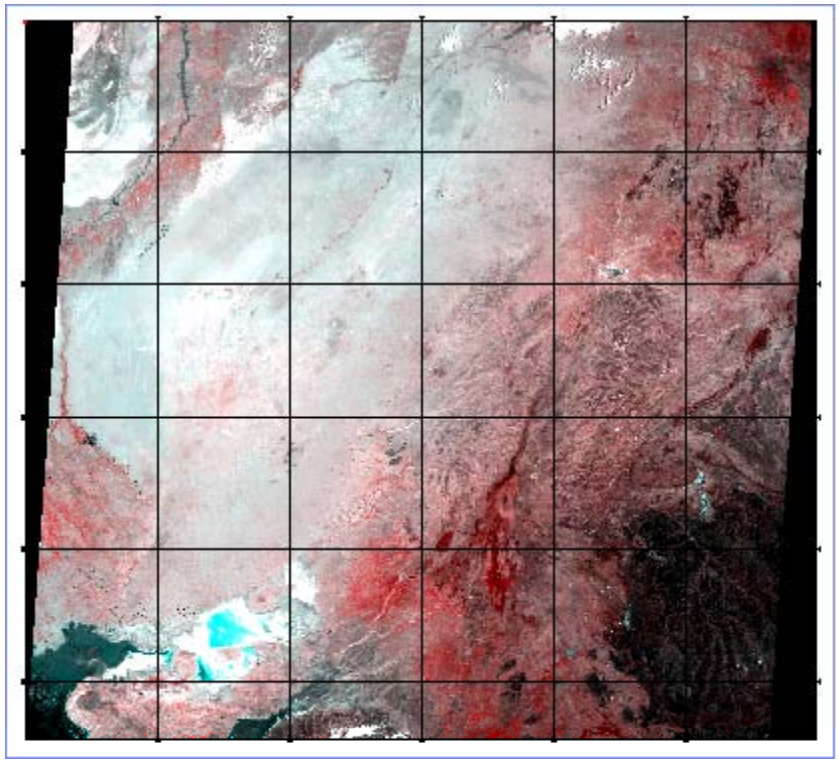


Spectral Response Differences



Scene : The Thar Desert (TD)

Location: 27° 40’ N ; 70 ° 19’ E

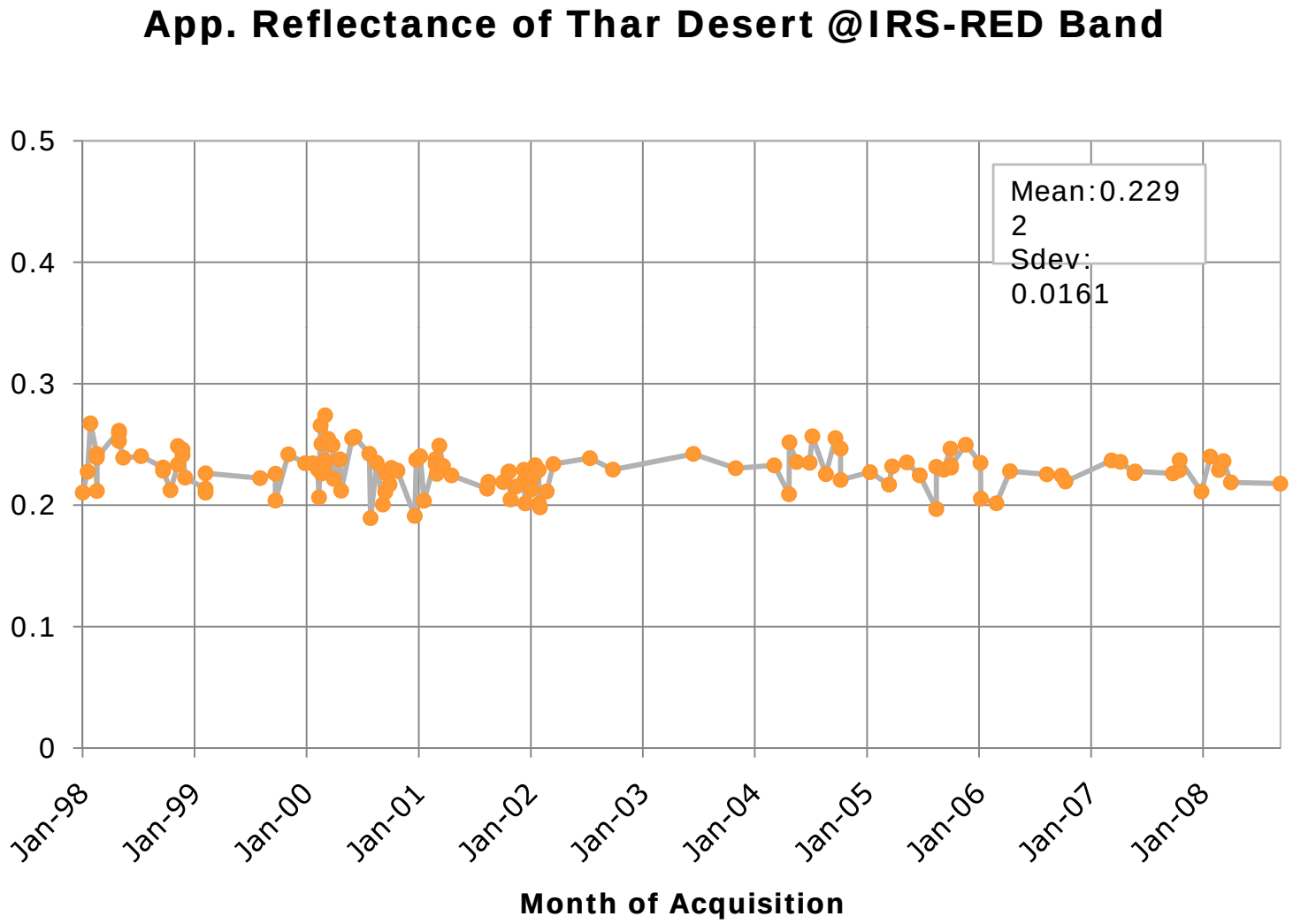


IRS-1D: WIFS image of The TD site

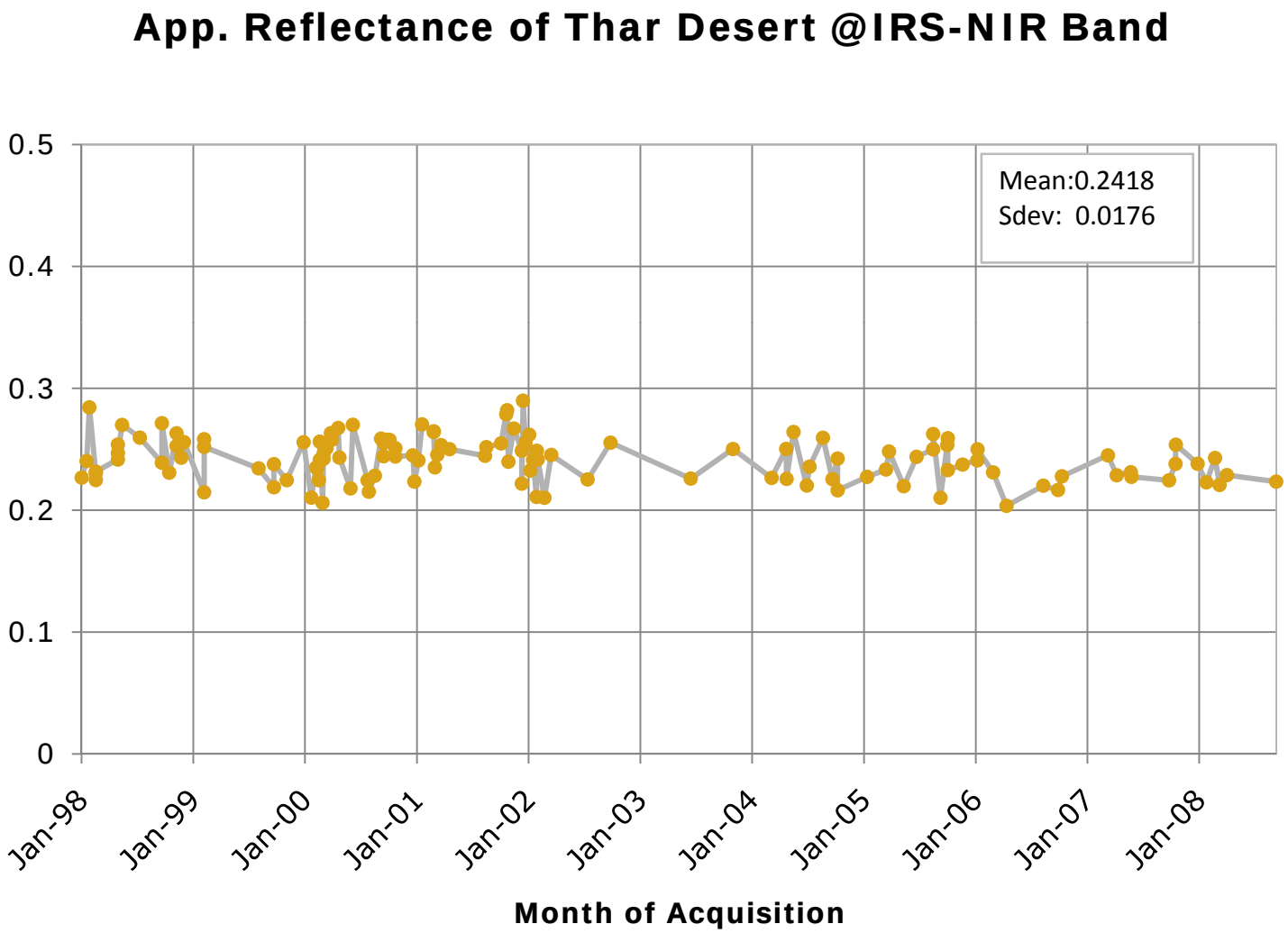
More about The Thar Desert (TD) …

- Also known as Great Indian desert
- 9th largest subtropical desert
- Area ~ 200,000 sq. km
- Rainfall: 100-500 mm per annum – all falling in between July – Sept months
- Climate: Very harsh with temp varying from 0 to 50 deg. C.
- Sand dumes are ~ 150m height

Stability of Spectral Reflectance of the TD @ B3 (Red)



Stability of Spectral Reflectance of the TD @ B4 (NIR)

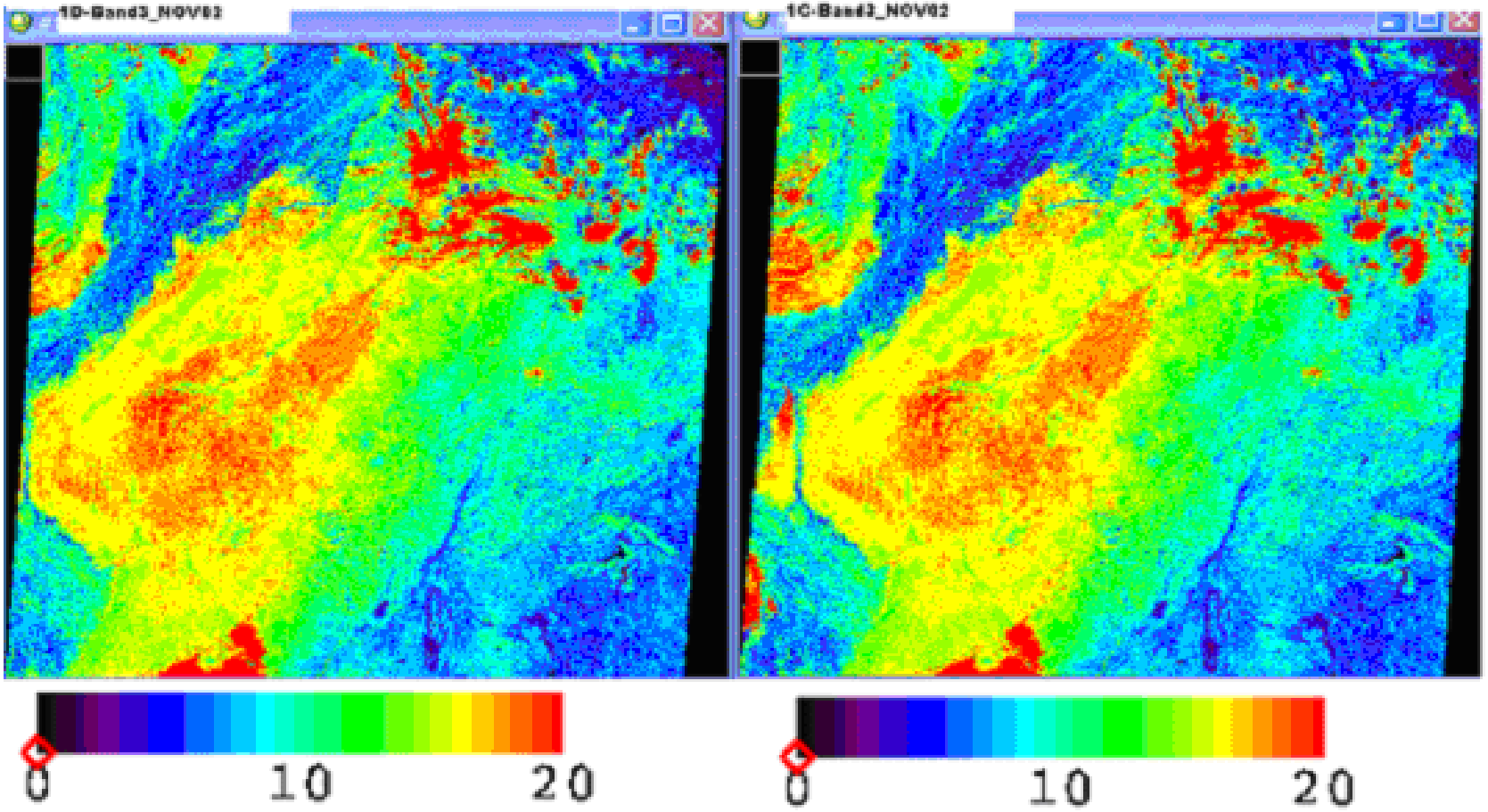


Spatial Invariance Analysis of WiFS over TD

1. GETIS Statistics Images

1D-Red Band (nov.2002)

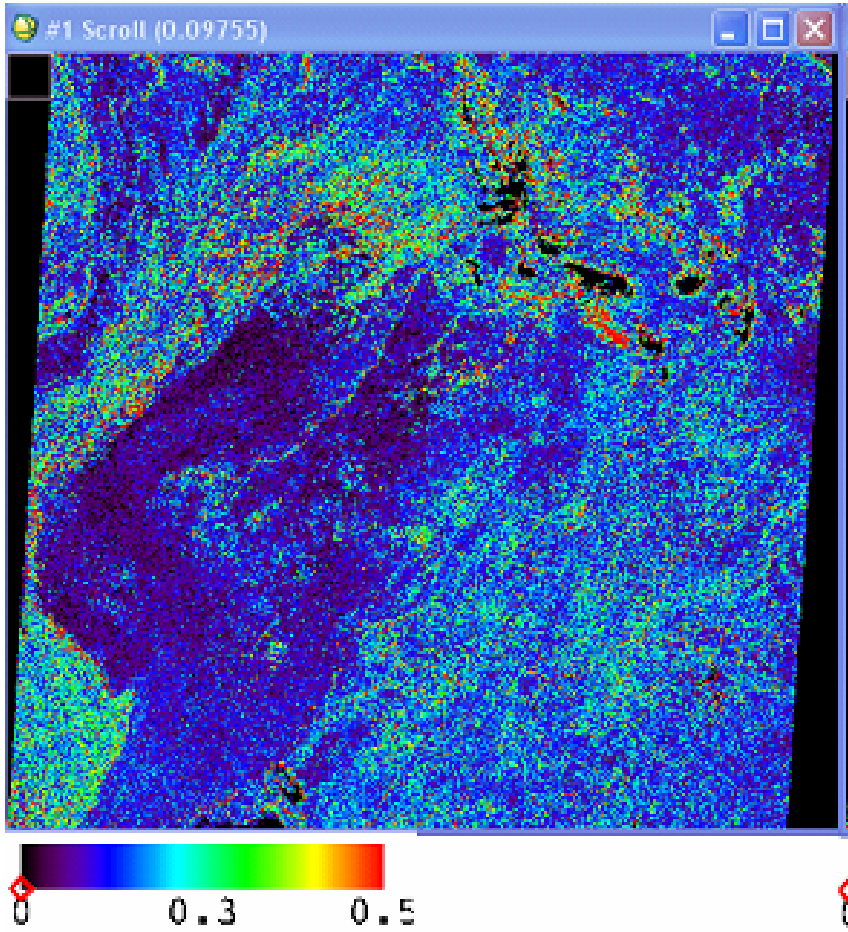
1C-Red Band (nov.2002)



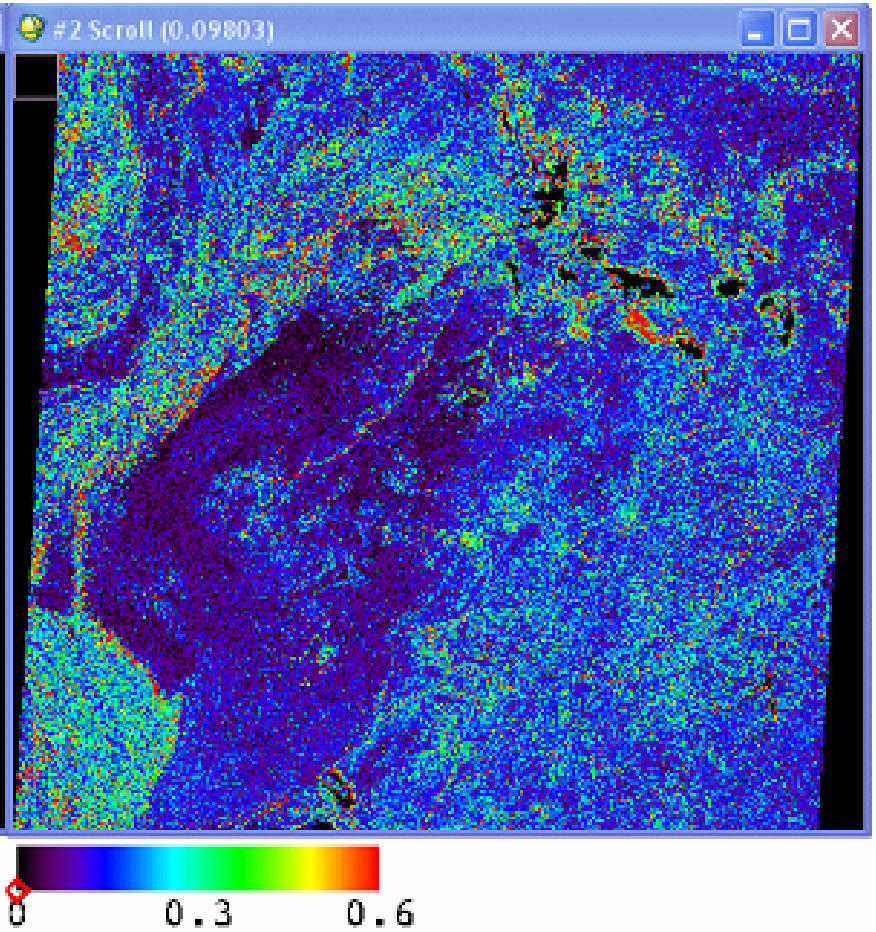
Spatial Invariance Analysis of the Thar Desert

2. Coefficient of Variation (CV) Images

1D-Red Band (Nov. 2002)

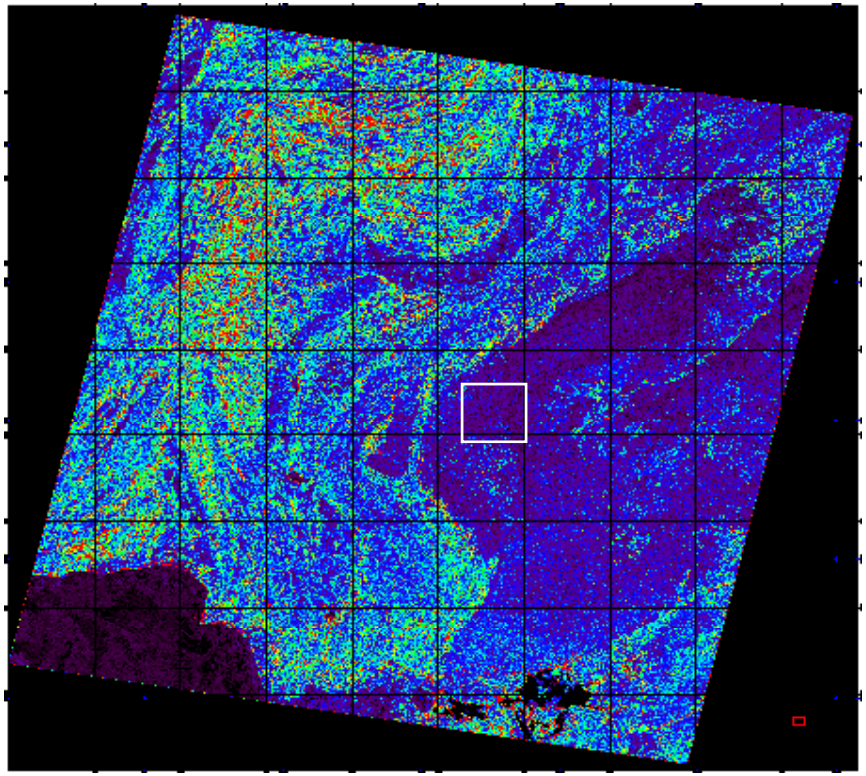


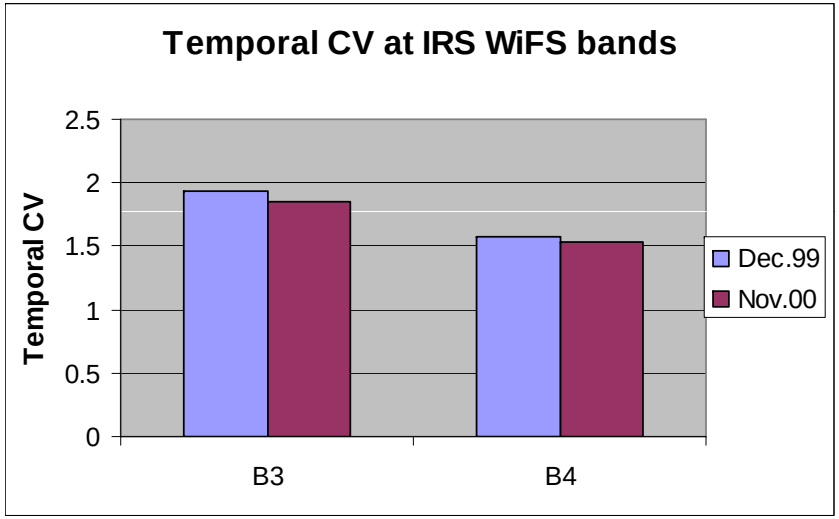
1C-Red Band (Nov. 2002)



Temporal Invariance Analysis of the TD site

1. Comparison of images acquired same season after a year





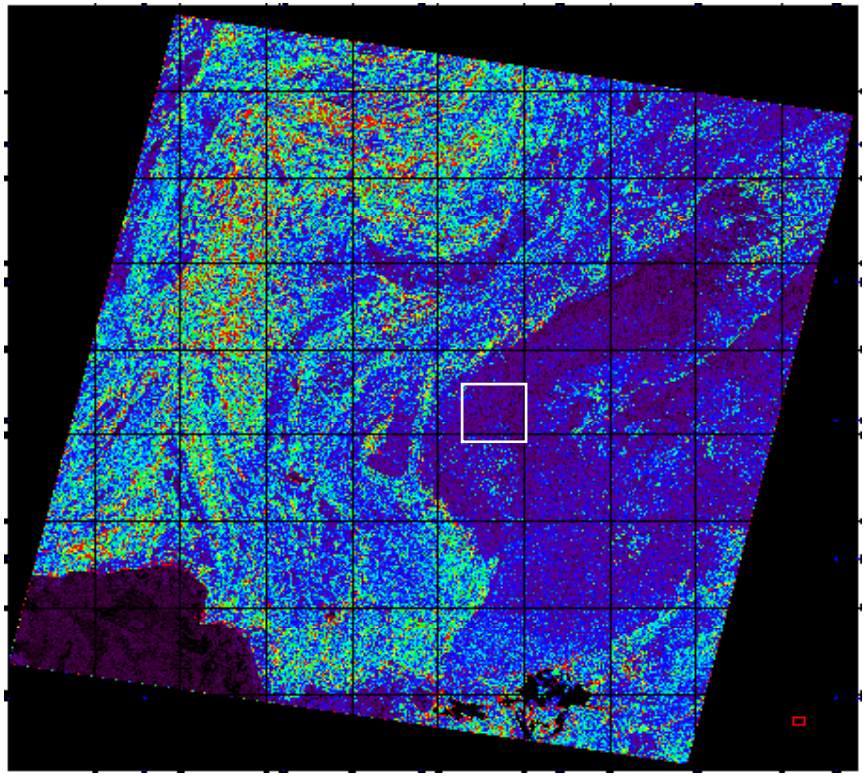
Temporal variation of Nov.00 data with reference to Dec.99 data:

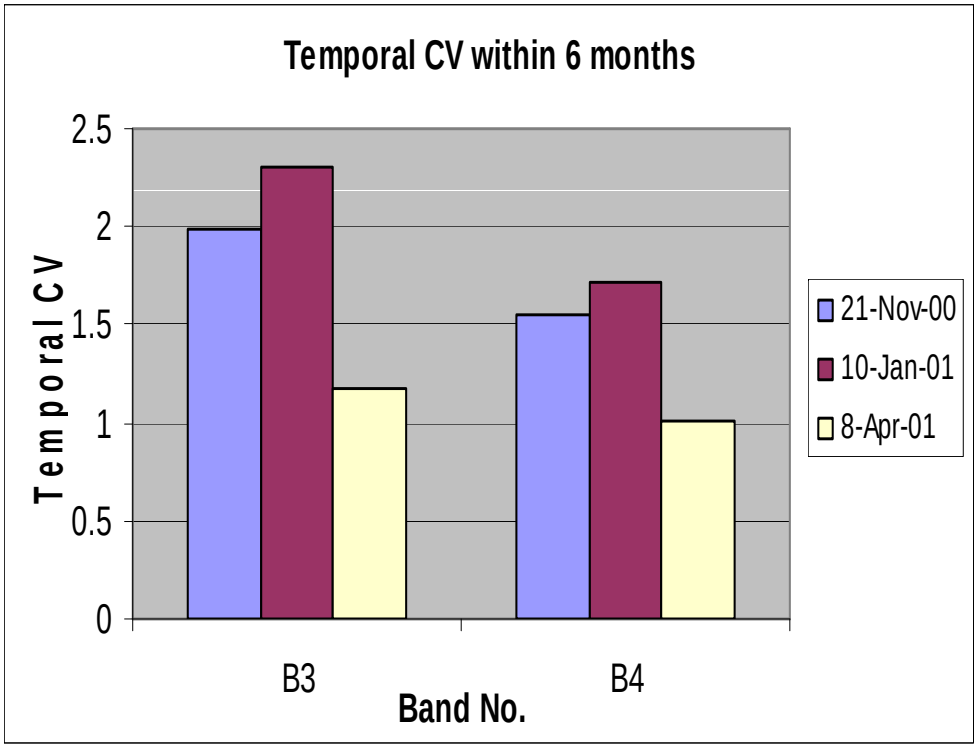
B3 (Red) : 4.152 %

B4 (NIR) : 2.534 %

Temporal Invariance Analysis of the TD site

2. Comparison of images acquired within 6 months





Large temporal variation across the seasons from summer to winter

Assumptions

- No significant change in atmospheric conditions within seasonal months; however to avoid any variation – in near synchronous dates of passes (< 3-5 days) for cross-calibration
- Relationship between the sensors – linear
- Images are corrected only for DOS
- Bi-directional reflectance variation with view angle less effective to final results

Data Pairs for Calibration / Validation

(a)	IRS 1C		IRS 1D		
Path/Row	Date of Pass	Sun angle	Date of Pass	Sun angle	Purpose of study
88/52	16 Nov. 1999	38.9º	16 Nov. 1999	39.8º	calibration
88/52	05 Jan. 2001	38.0º	10 Jan. 2001	39.2º	calibration
92/52	07 Apr. 2001	61.5º	08 Apr. 2001	64.5º	calibration
92/52	04 Nov. 2002	43.1º	04 Nov. 2002	44.6º	calibration
88/52	18 Nov. 2000	42.1º	21 Nov. 2000	42.3º	validation: set-1
92/52	14 Mar. 2001	53.1º	14Mar. 2001	55.4º	validation: set-2

(b)	IRS P6		IRS 1D		
Path/Row	Date of Pass	Sun angle	Date of Pass	Sun angle	Purpose of study
88/53	27 Nov. 2003	40.4º	26 Nov. 2003	39.9º	calibration
92/51	02 Jun. 2004	72.6º	01 Jun. 2004	69.2º	calibration
88/53	10 Sep. 2004	63.3º	09 Sep. 2004	58.5º	calibration
92/54	17 Dec. 2003	36.7º	21 Dec. 2003	36.8º	calibration
88/53	07 Feb. 2004	43.4º	09 Feb. 2004	42.4º	validation: set-1
92/52	24 Oct. 2004	48.5º	29 Oct. 2004	45.1º	validation: set-2

Calibration Approach

At-sensor spectral radiance in band *k*: $L(k) = DN(k) \cdot P(k)$

Where L(k): spectral radiance (in mW/cm^2-sr-µm)
P(k): absolute calibration coefficient

Cross-calibration formula for sensor 1C w.r.t. Reference 1D:

$$L(k)_{1D} = M(k)_{C\_D} L'(k)_{1C} + C(k)_{C\_D}$$

Where L'(k) = L(k) × A_k
: adjusted 1C radiance in band k
M, C : Slope and Offset from linear regression

The coefficient:

$$A_k = \frac{\langle \rho(k)_{1D} \rangle E(k)_{1D} \cos\theta_{1D} + L_{P-1D}(k)}{\langle \rho(k)_{1C} \rangle E(k)_{1C} \cos\theta_{1C} + L_{P-1C}(k)}$$

Calibration Approach (2)

integrated spectral reflectance

$$\langle \rho(k) \rangle = \int \rho(k,\lambda)\, S(k,\lambda)\, d\lambda \Big/ \int S(k,\lambda)\, d\lambda$$

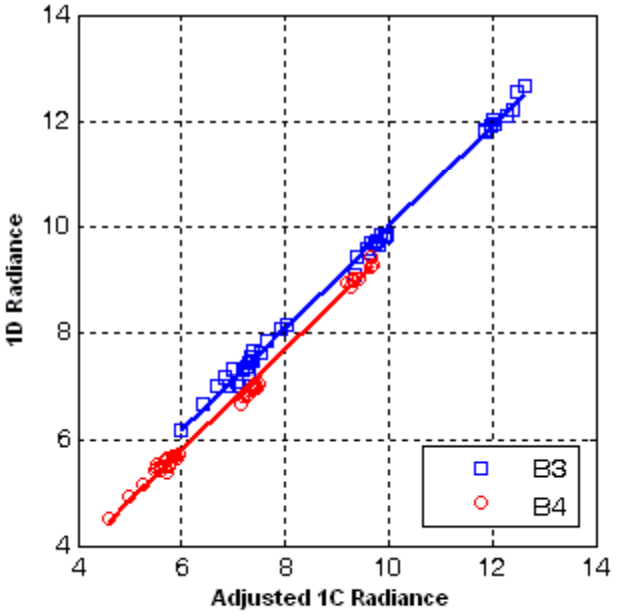
Where S(k): relative spectral response
P(k): absolute calibration coefficient

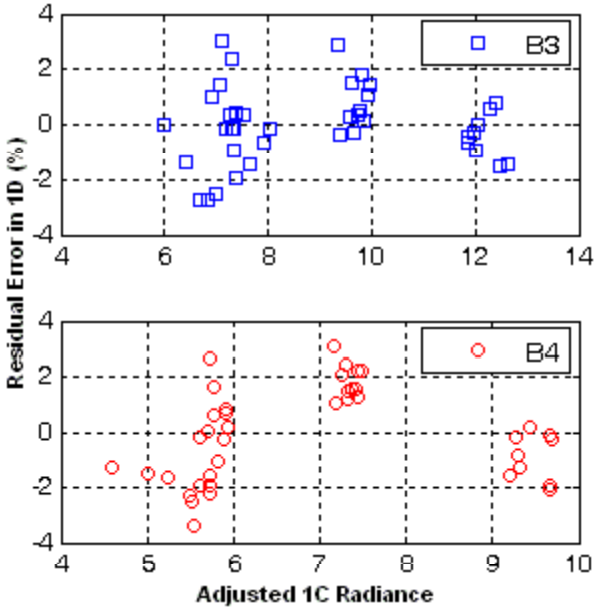
Prior to the above steps, photometric variation across the image pixels due to different sun incident angles was applied.

$$B_c(m,n) = \frac{B(m,n)}{\cos[h(m,n)]} \cos[h(m_0,n_0)]$$

***B* & *Bc* : the original & corrected pixel DN values,**
(m_0, n_0): the pixel positions of a reference point (scene center)
***h*(m,n) - the solar altitude.**

Results: 1C vs.1D (cal-set)





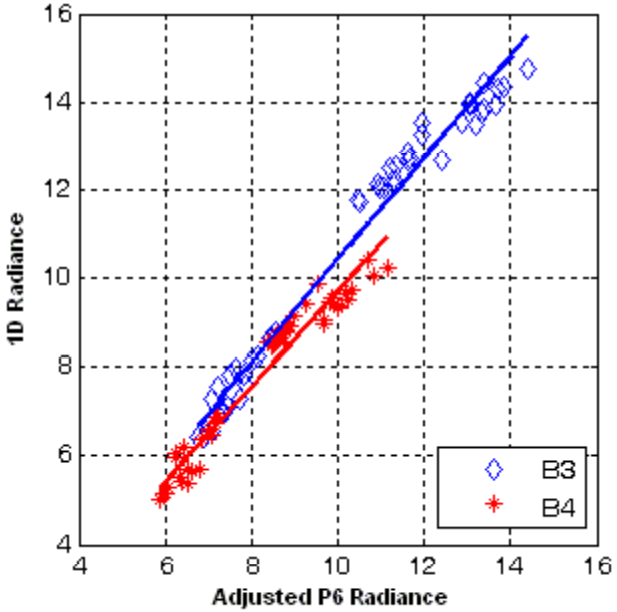
Model	Band	Fitted Equation	Goodness of-fit R^2	SSE after fit	SSE before fit	Gain Factor
with offset	B3	Y= 0.9558 X +0.4292	0.9966	0.5155	2.7688	5.371
	B4	Y= 0.9408 X +0.1318	0.9943	0.4938	1.0471	2.121
without offset	B3	Y =1.0011 X	0.9943	0.8774	2.7688	3.156
	B4	Y = 0.9989 X	0.9939	0.5270	1.0471	1.987

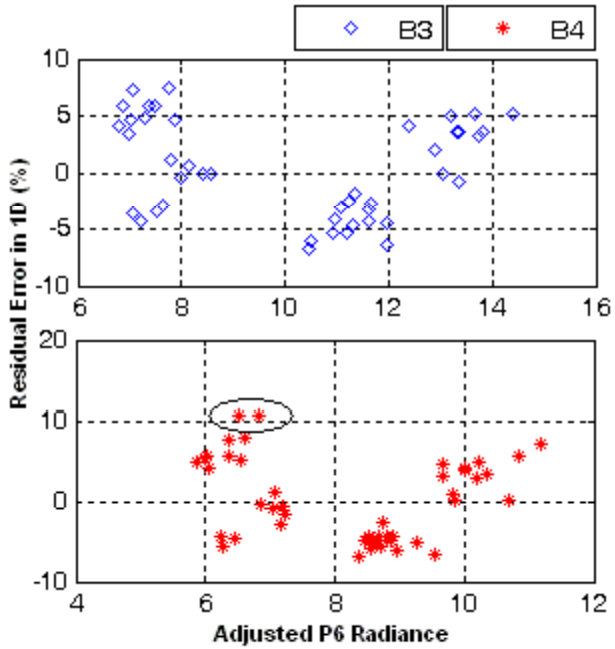
Results: 1C vs.1D (val-set)

Set	No.	Band *k*	Dates of pass (1C/1D)	SSE after fit	SSE before fit	Gain Factor
1		B3	14.Mar.2001/ 14.Mar.2001	0.0333	0.0842	2.527
		B4	14.Mar.2001/ 14.Mar.2001	0.0977	0.2125	2.174
2		B3	18.Nov.2000/ 21.Nov.2000	0.1978	0.4555	2.303
		B4	18.Nov.2000/ 21.Nov.2000	0.3577	1.1320	3.165

- Strong correlation (R^2 ~ 0.99) between 1C & 1D WiFS sensor data
- One bias coefft. (slope) may suffice to a great extent
- Application of derived CCs will help to provide two sensors' data function in tandem.

Results: P6 vs.1D (cal-set)





Model	Band	Fitted Equation	Goodness-of-fit R^2	SSE after fit	SSE before fit	Gain Factor
with offset	B3	Y=1.1574 X –1.1434	0.9762	9.236	12.977	1.405
	B4	Y=1.0697 X –0.9922	0.9509	6.581	12.207	1.855
without offset	B3	Y = 1.0520 X	0.9677	12.55	12.977	1.034
	B4	Y = 0.9533 X	0.9392	8.146	12.207	1.499

Results: P6 vs.1D (val-set)

Set	No.	Band *k*	Dates of pass (P6/1D)	SSE after fit	SSE before fit	Gain Factor
1		B3	07.Feb.2001/ 09.Feb.2001	1.1255	1.3729	1.22
		B4	07.Feb.2001/ 09.Feb.2001	2.1811	0.0738	0.03
2		B3	24.Oct.2004/ 29.Oct2004	0.4162	0.5344	1.28
		B4	24.Oct.2004/ 29.Oct2004	0.1408	5.5850	39.66

- Goodness of fit - moderate when compared to 1C-1D case
- Two bias coefficients unavoidable
- Inconsistency in results esp. B4 data results

Conclusions

- Good spatial & temporal invariance properties of the TD site across the year of same season - well within tolerance level

- Strong dependence on temporal invariance for dates covering different seasons within a year – impact on acquisition of scenes to a near synchronous condition

- 1C-1D cross calibration –well within specified limits due to high correlation of their data sets.

- More efforts probably including bidirectional reflectance and atmospheric models needed to minimize uncertainty in the cross calibration results of 1D-P6.

Thank you

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