Report on ISRO Cal/Val activities

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Agenda Item #3.10

WGCV-53, Córdoba, Argentina

5th - 8th March 2024

Committee on Earth Observation Satellites

Outline of the presentation

1. Radiometric calibration status

- EOS-6
- Resourcesat-2A
- High resolution sensors characterization
- INSAT-3D vs INSAT-3DR
- EOS-4

2. Readiness for NISAR

- ASAR Data
- NOVASAR Data
- ALOS Data

3. ISRO-ASI project

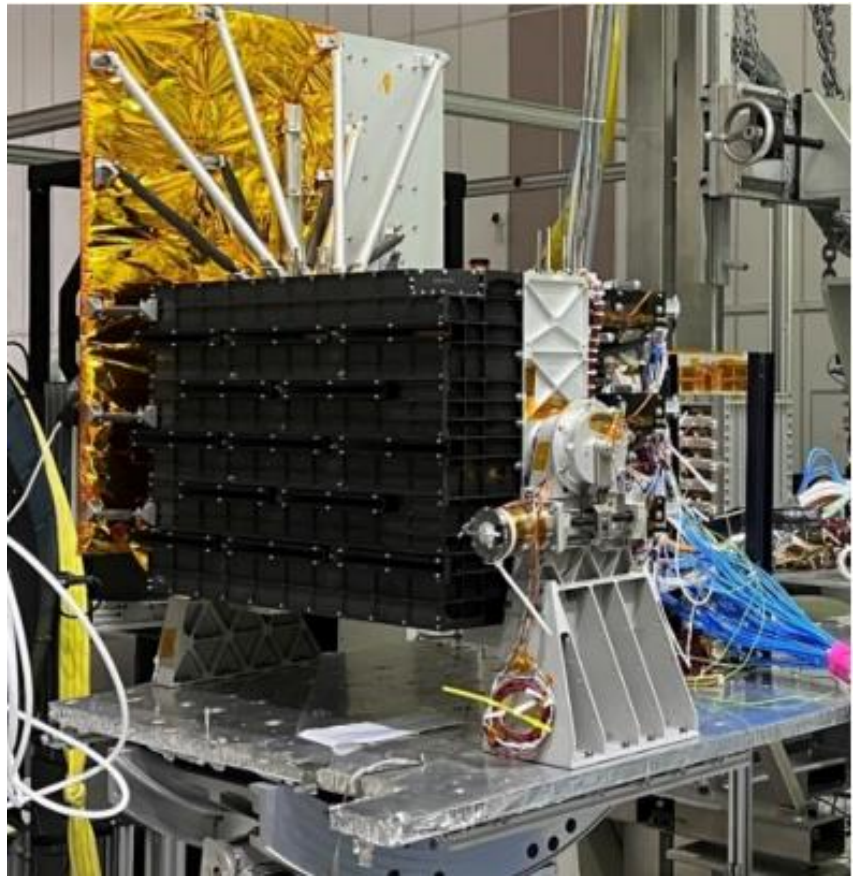
Recent Operationalized EOS-6

EOS-06 (Oceansat-3)

Launch date: 26 Nov 2022
Orbit: SSPO
Altitude: 740km

Payloads on EOS-06 are :

- Ku-band Scatterometer (SCAT-3)
- 13-band Ocean Colour Monitor (OCM-3)
- 2-band Sea Surface Temperature Monitor (SSTM)
- ARGOS by CNES French Space Agency



OCM-3 payload Electro-Optical Flight Module

Ocean Color Monitor-3

OCM-1 (CWL)	OCM-2 (CWL)	OCM-3 (CWL)
B1 – 412 nm	B1 – 412 nm	B1 – 412 nm
B2 – 443 nm	B2 – 443 nm	B2 – 443 nm
B3 – 490 nm	B3 – 490 nm	B3 – 490 nm
B4 – 510 nm	B4 – 510 nm	B4 – 510 nm
B5 – 555 nm	B5 – 555 nm	B5 – 555 nm
B6 – 670 nm	B6 – 620 nm	B6 – 566 nm
B7 – 765 nm	B7 – 740 nm	B7 – 620 nm
B8 – 865 nm	B8 – 865 nm	B8 – 670 nm
		B9 – 681 nm
		B10 – 710 nm
		B11 – 780 nm
		B12 – 870 nm
		B13 – 1010 nm

*B stands for Spectral Band

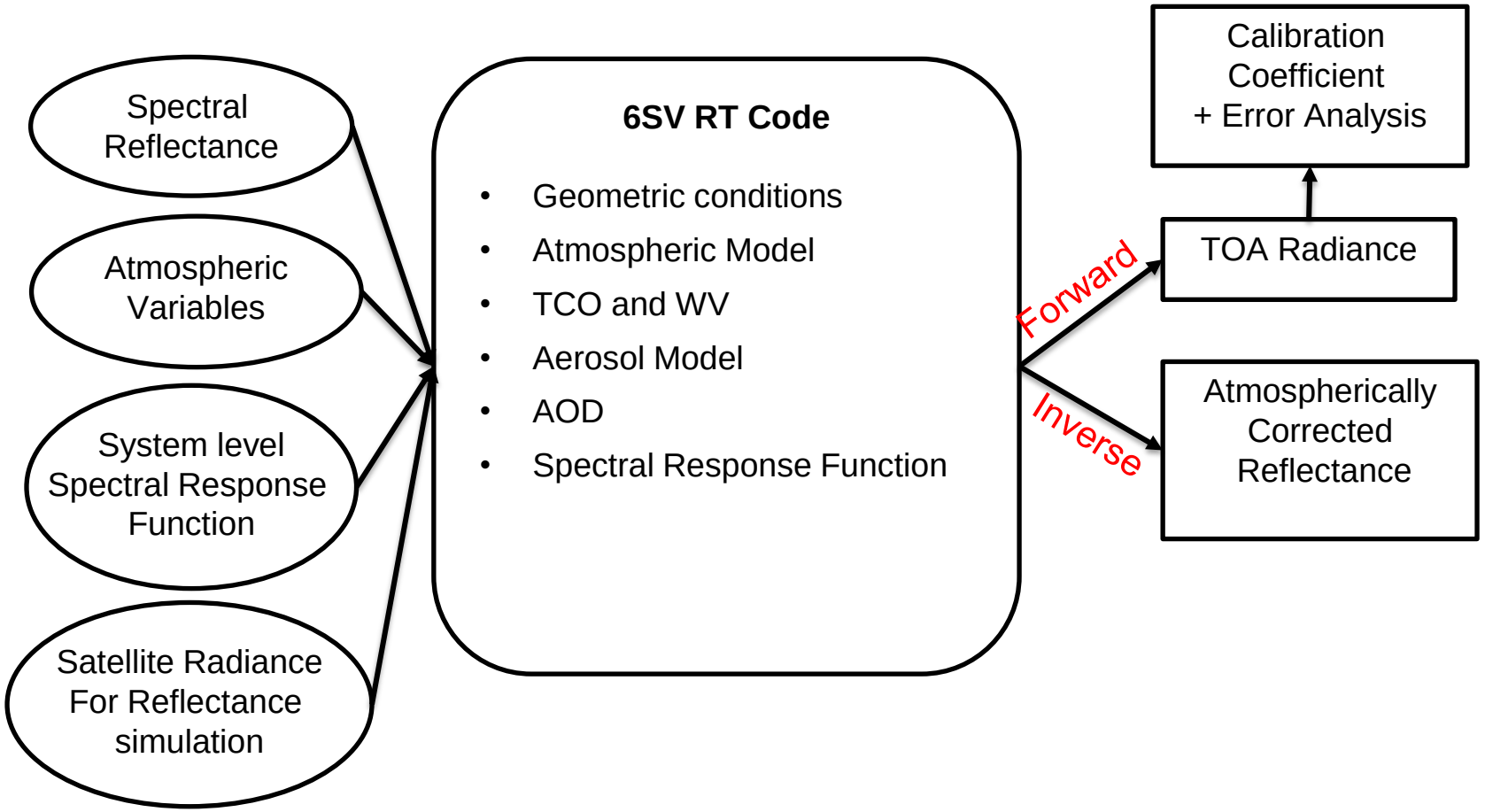
Parameter	OCM-1 and 2	OCM-3
Number of Spectral bands	8	13
Spectral Resolution (bandwidth nm)	20 (Application Bands) 40 (Atmospheric correction bands)	20/10/8 (Application Bands) 20/40 (Atmospheric correction bands)
SNR (at sea ref.)	300	650

Major specifications

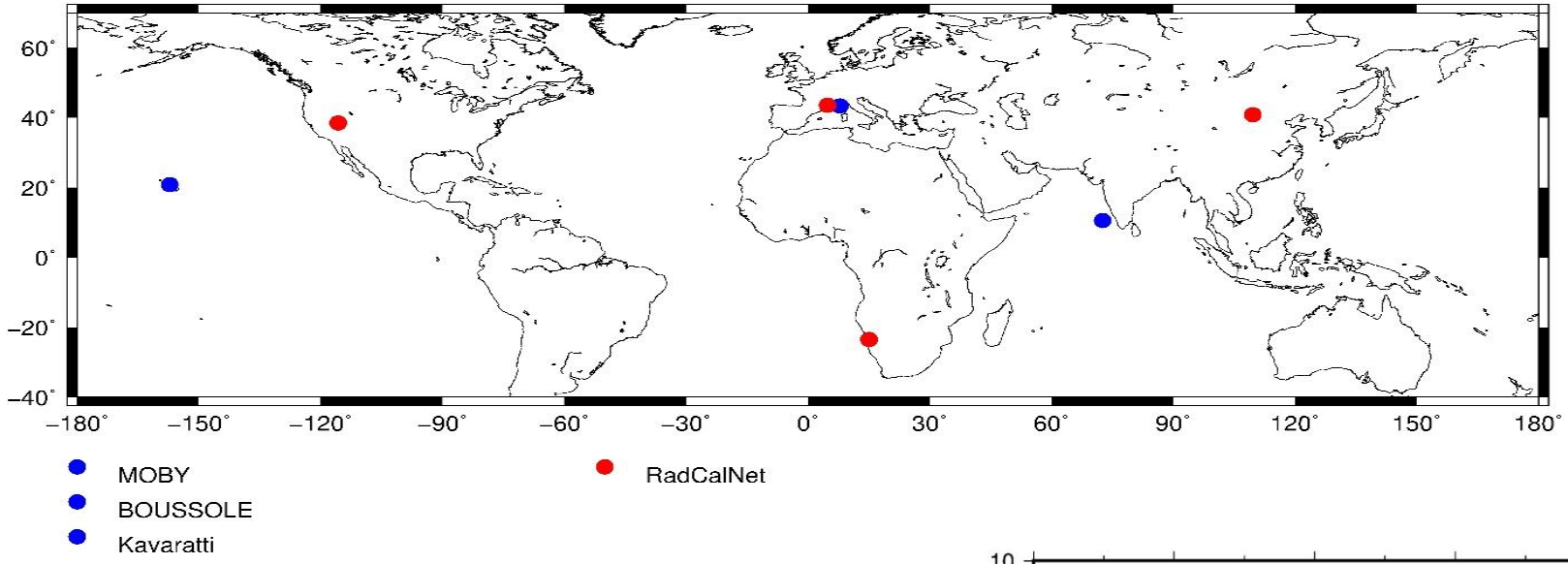
- Spectral Bands: 13
- Field of View: ± 43.5 Deg
- Swath coverage: >1440 km @nadir
- Local Area Coverage (LAC) GSD: 366m @nadir
- Global Area Coverage (GAC) GSD: 1080m @ nadir
- Levels of products: Level-1, 2 and 3
- LAC product bit depth: 12 bits
- GAC product bit depth: 16 bits
- Repeativity: 13 days
- Revisit: 2 days

Products are available for free download: ***https://bhoonidhi.nrsc.gov.in/bhoonidhi/index.html***

Vicarious Calibration of OCM3

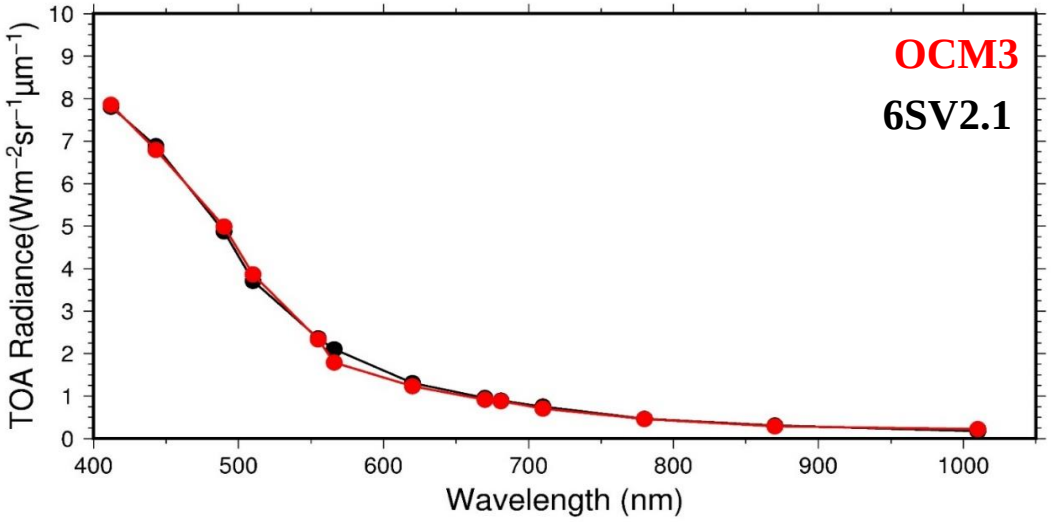


Sites for vicarious calibration of OCM3



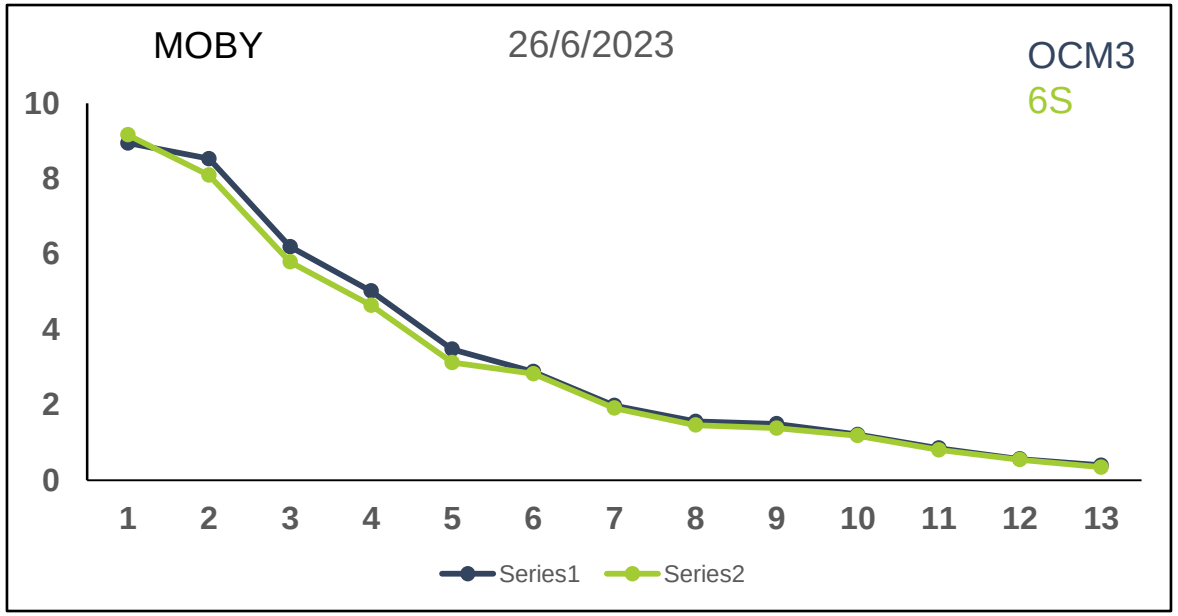
- The MoBY and Kavaratti observations (December 2022 – May 2023) were used to ascertain the OCM3 radiometric performance.
- The first ocean Vcal has been generated using these data sets.
- The observations from Cal-Val cruises, MoBY observations are further used to strengthen the matchups data sets.

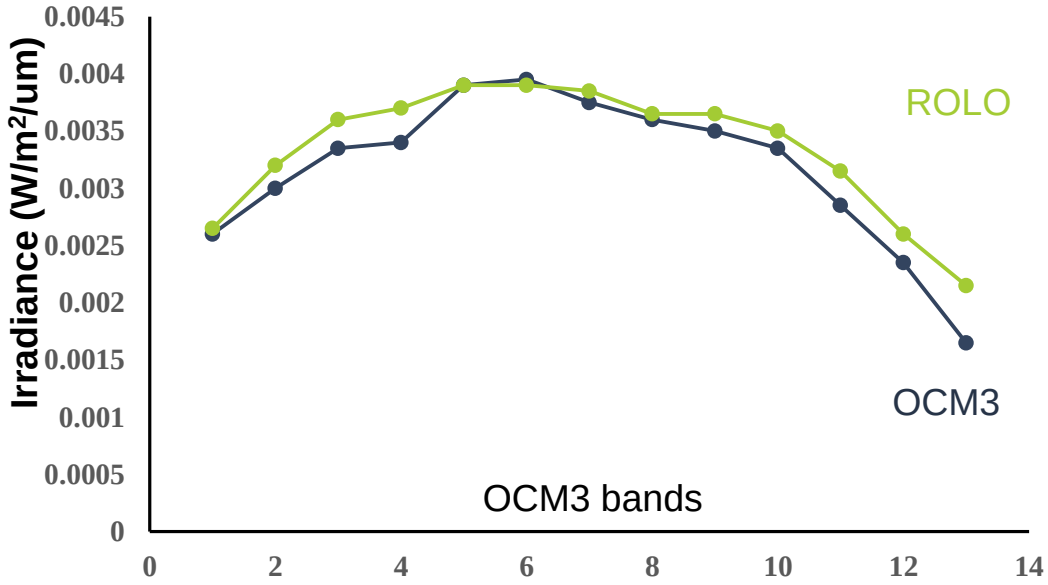
In the water OCM3 rad response is in close agreement with the ground measurements



Validity of TOA radiance after 1st Vcal implementation in operational chain

Second lunar calibration (7-Jan-2023)





Average Vicarious Calibration Gain (June – August 2023)

B1	1.00
B2	0.94
B3	0.93
B4	0.91
B5	0.89
B6	0.98
B7	0.96

B8	0.94
B9	0.93
B10	0.99
B11	0.98
B12	0.99
B13	0.91

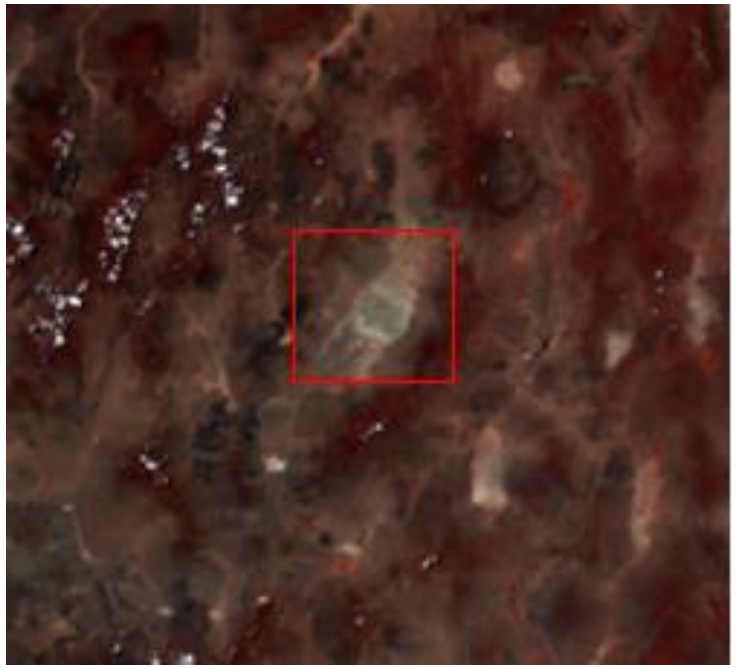
Validation results are consistent

Bandwise mean coefficients (7th Jan. 2023)

B1	1.04
B2	1.06
B3	1.09
B4	1.09
B5	1.00
B6	1.00
B7	1.03

B8	1.03
B9	1.05
B10	1.06
B11	1.01
B12	1.03
B13	1.29

OCM-3 observations over RVUS



RVUS site as imaged by OCM3 on 1st Jul 2023. 3kmx3km area was used for calibration which corresponds to 3x3 pixel in GAC Image

Site: Rail Road Valley Playa, Nevada, USA

Geocoordinates: 38.504°N, 115.692°W

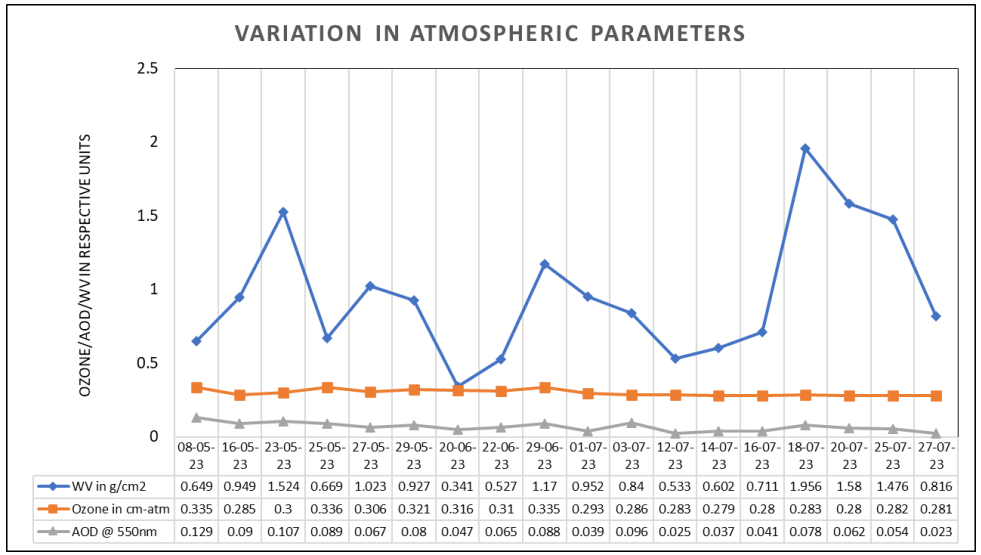
ROI: 1km * 1km >> 3*3 GAC pixels

- ✓ Calibration Ratio calculated using 18 cloud free observations of OCM3 data from May'23 to Jul'23.
- ✓ Only observation with view angle <35 considered for analysis

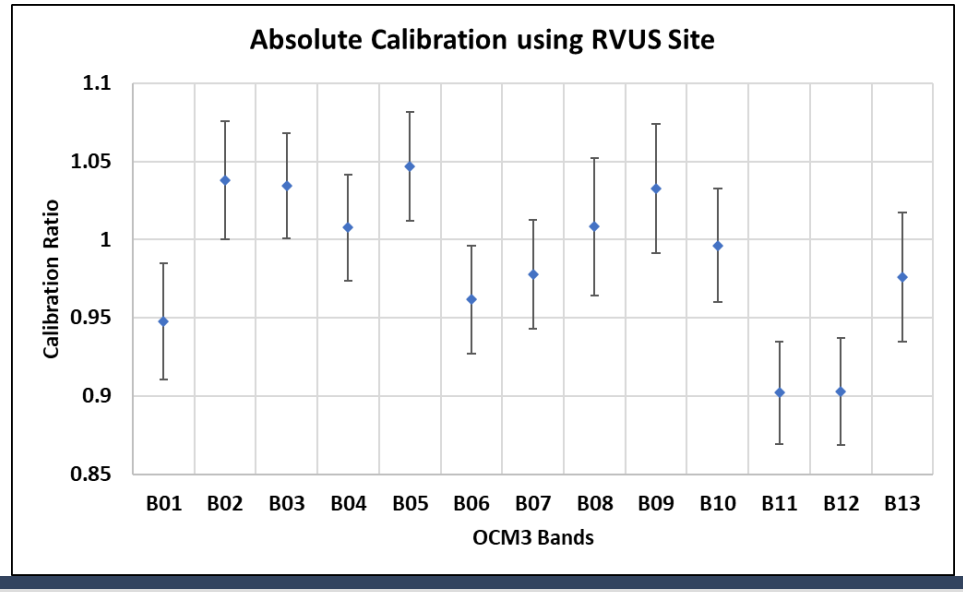
Calibration Ratio

$$Ratio = \frac{\rho_{TOA\_OCM3}}{\rho_{TOA\_RadCalNet}}$$

Consistent response observed after reprocessing

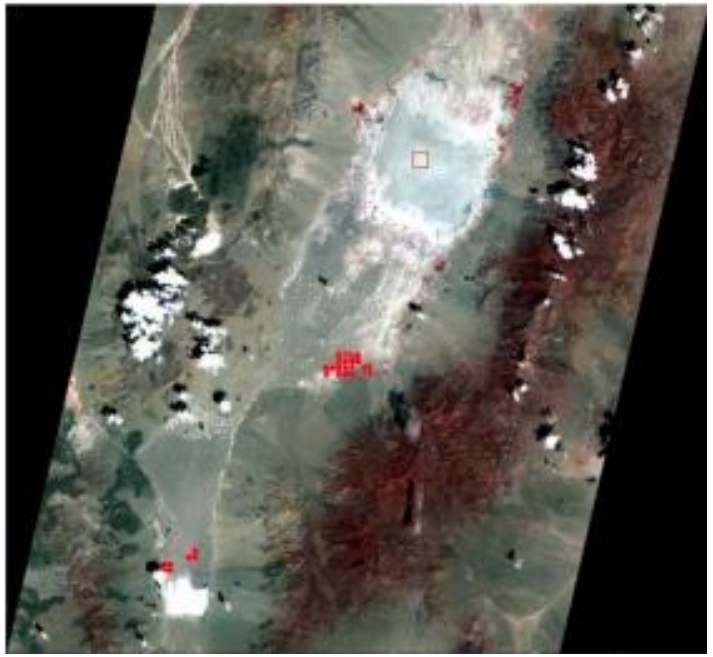


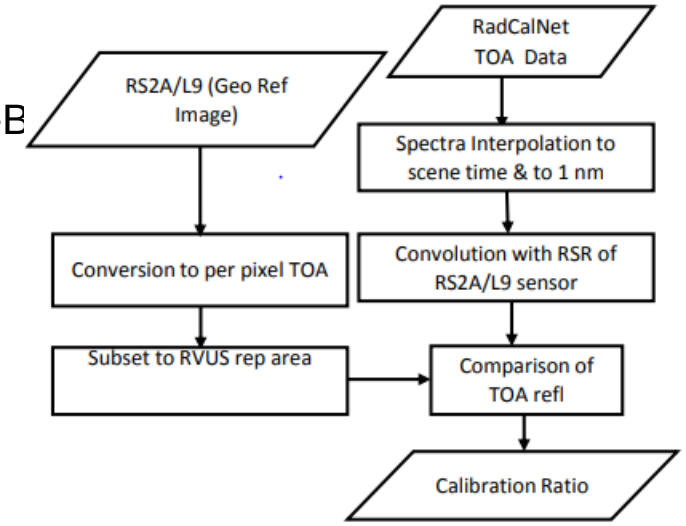
	08-05-23	16-05-23	23-05-23	25-05-23	27-05-23	29-05-23	20-06-23	22-06-23	29-06-23	01-07-23	03-07-23	12-07-23	14-07-23	16-07-23	18-07-23	20-07-23	25-07-23	27-07-23
WV in g/cm2	0.649	0.949	1.524	0.669	1.023	0.927	0.341	0.527	1.17	0.952	0.84	0.533	0.602	0.711	1.956	1.58	1.476	0.816
Ozone in cm-atm	0.335	0.285	0.3	0.336	0.306	0.321	0.316	0.31	0.335	0.293	0.286	0.283	0.279	0.28	0.283	0.28	0.282	0.281
AOD @ 550nm	0.129	0.09	0.107	0.089	0.067	0.08	0.047	0.065	0.088	0.039	0.096	0.025	0.037	0.041	0.078	0.062	0.054	0.023

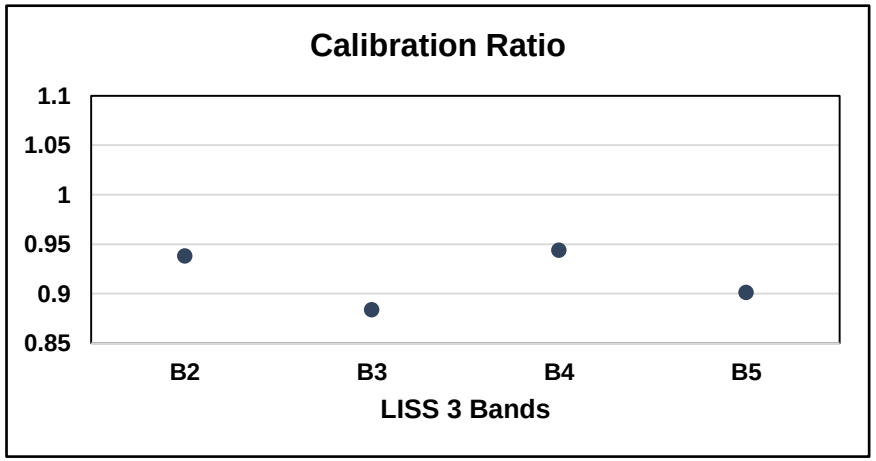


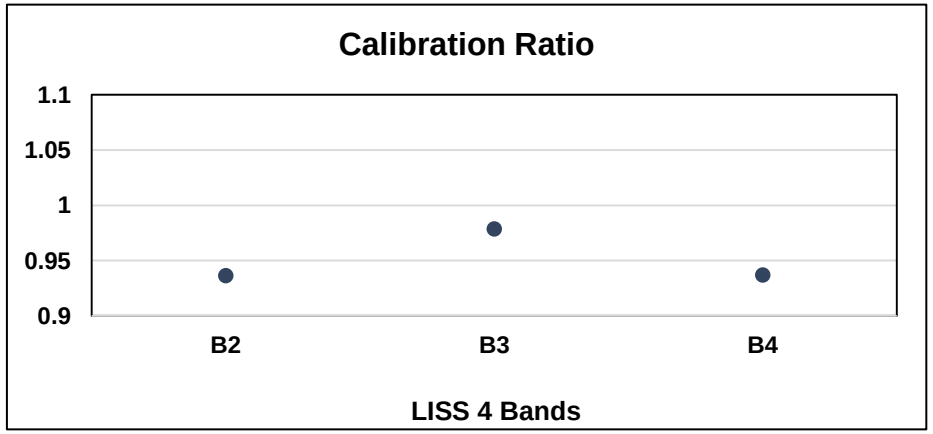
Resourcesat-2A

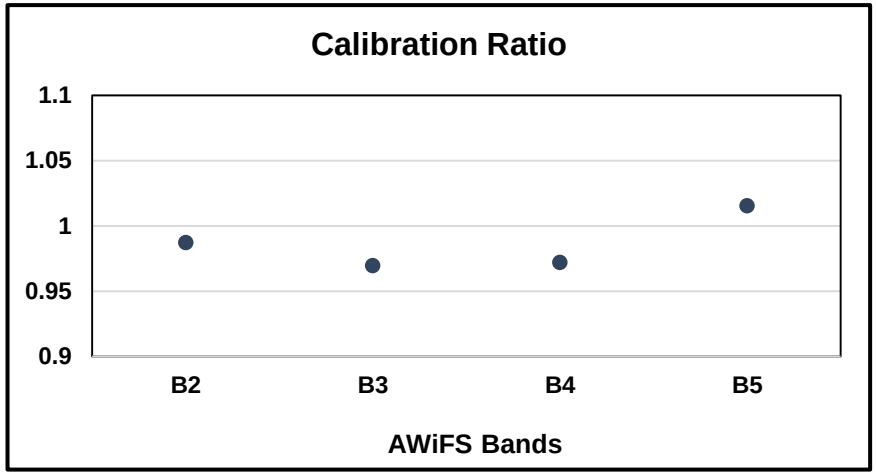
Site: Rail Road Valley Playa, Nevada, USA
ROI: 1km * 1km
Sensors evaluated: LISS-4, LISS-3, AWiFS-B











Calibration Ratio

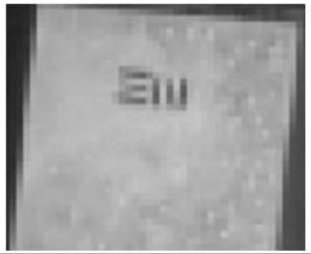
$$Ratio = \frac{\rho_{TOA\_sensor}}{\rho_{TOA\_RadCalNet}}$$

Post launch response is consistent for all 3 payloads

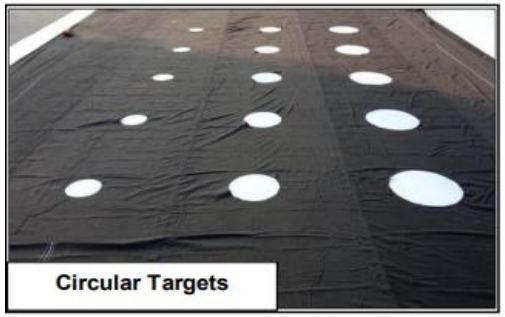
High resolution sensors characterization

Artificial targets for spatial characterization

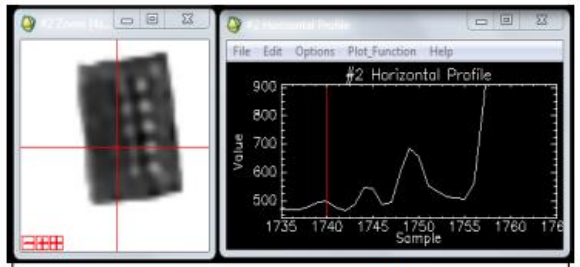
Bar Target



Bar Target in Cartosat-2S (MX) image

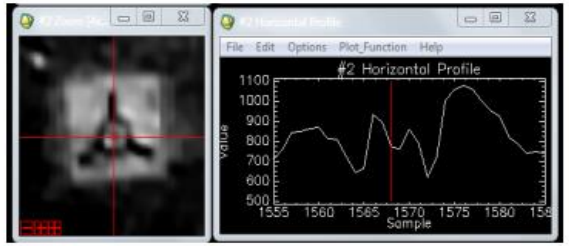


Circular Targets



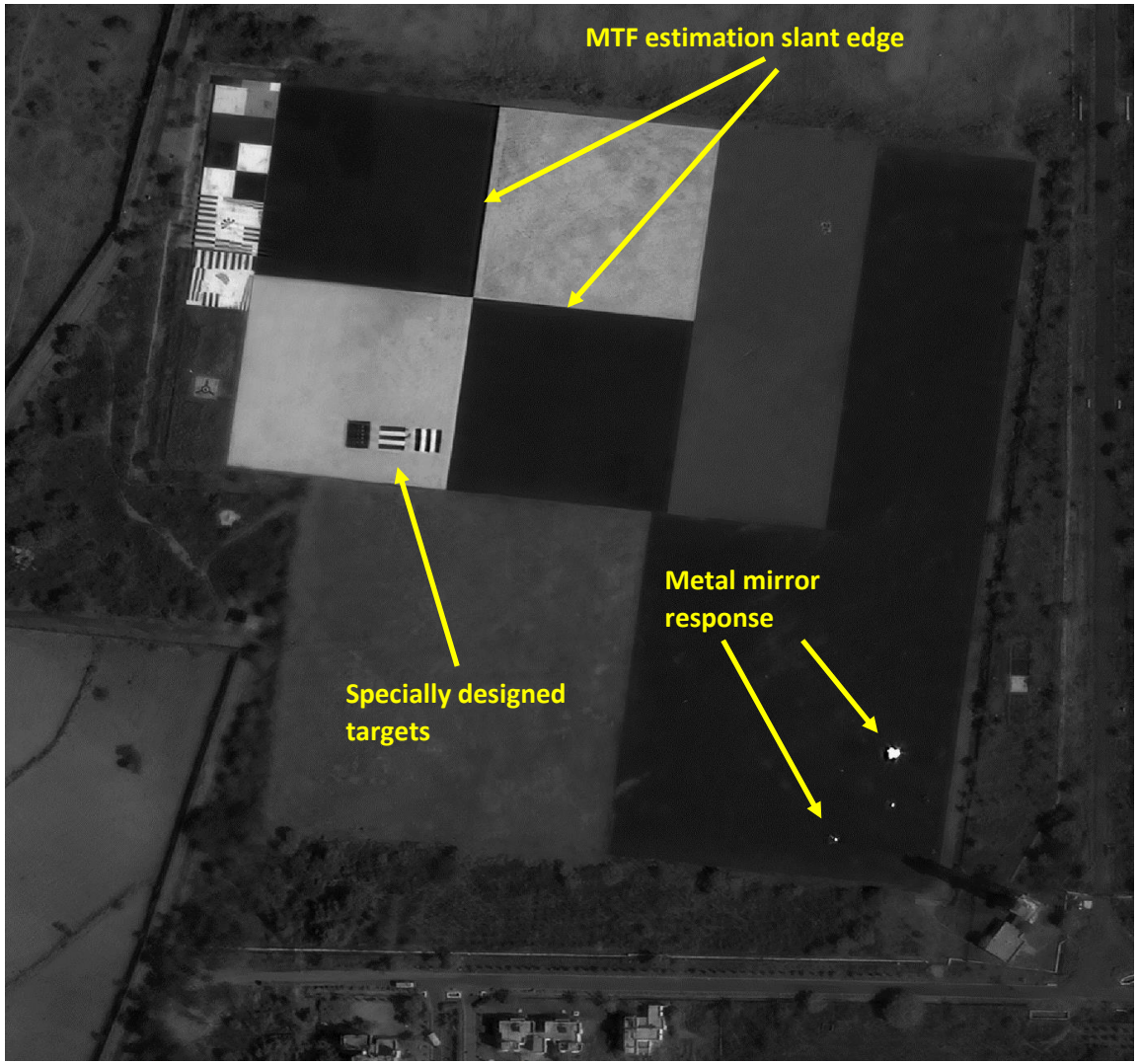
Circular target in Cartosat-3 (PAN) image

Resolution based GCP



GCP target in Cartosat-3 (PAN) image

Realised High resolution customized targets, @ IMGEOS Complex,NRSC,ISRO.



INSAT-3D and INSAT-3DR

INTERNATIONAL JOURNAL OF REMOTE SENSING
2023, VOL. 44, NO. 20, 6298–6328
https://doi.org/10.1080/01431161.2023.2265541

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RESEARCH ARTICLE

Check for updates

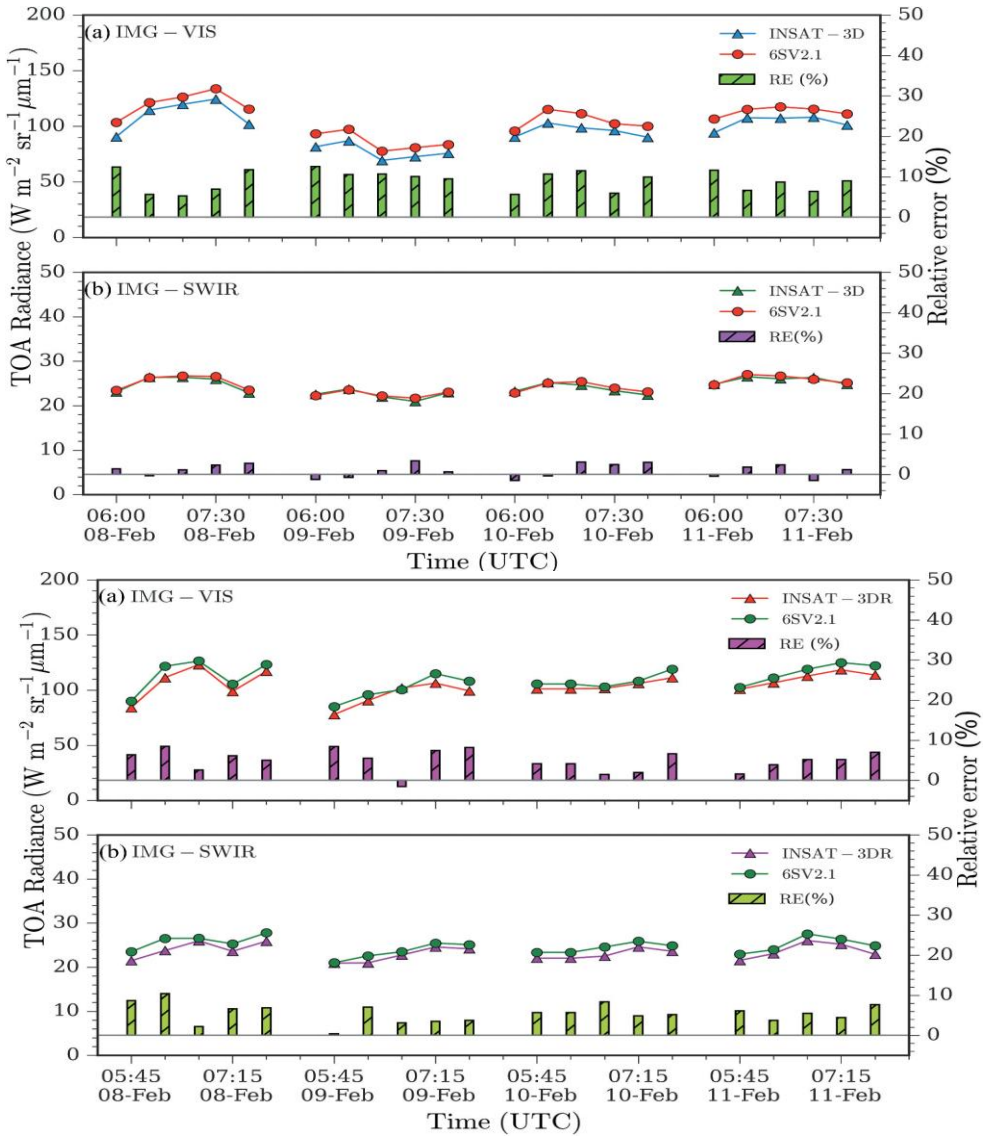
Towards Accurate Radiometric Calibration of INSAT-3D and INSAT-3DR IMAGER: Addressing Uncertainty and Error Sources

Nandkishor Kumawat [a,b], K. N. Babu [a], Mehul R. Pandya [a,b], Saurabh Tripathi [a] and V. Sathiyamoorthy [c]

Summary of radiometric calibration results of the IMAGER bands

		INSAT-3D					INSAT-3DR				
Band	Date	L_{measu}	L_{estim}	Gain	RE (%)	RMSE	L_{measu}	L_{estim}	Gain	RE (%)	RMSE
VIS	08 Feb. 2022	110.19	120.00	1.09	8.18	4.57	106.97	113.34	1.06	5.62	3.02
	09 Feb. 2022	77.20	86.42	1.12	10.67	4.18	95.20	100.87	1.06	5.62	3.05
	10 Feb. 2022	95.59	104.88	1.10	8.86	4.38	105.02	108.98	1.04	3.63	2.07
	11 Feb. 2022	103.60	113.1	1.09	8.40	4.33	110.50	115.92	1.05	4.68	2.64
SWIR	08 Feb. 2022	24.95	25.31	1.02	1.42	0.20	24.15	25.94	1.07	6.90	0.86
	09 Feb. 2022	22.44	22.57	1.01	0.58	0.17	22.69	23.53	1.04	3.57	0.44
	10 Feb. 2022	23.78	24.10	1.01	1.33	0.25	23.20	24.68	1.06	6.00	0.66
	11 Feb. 2022	25.71	25.90	101	0.73	0.19	23.77	25.14	1.06	5.45	0.63

INSAT-3D & INSAT-3DR found to be within 10% Radiometric error



EOS-4 stability

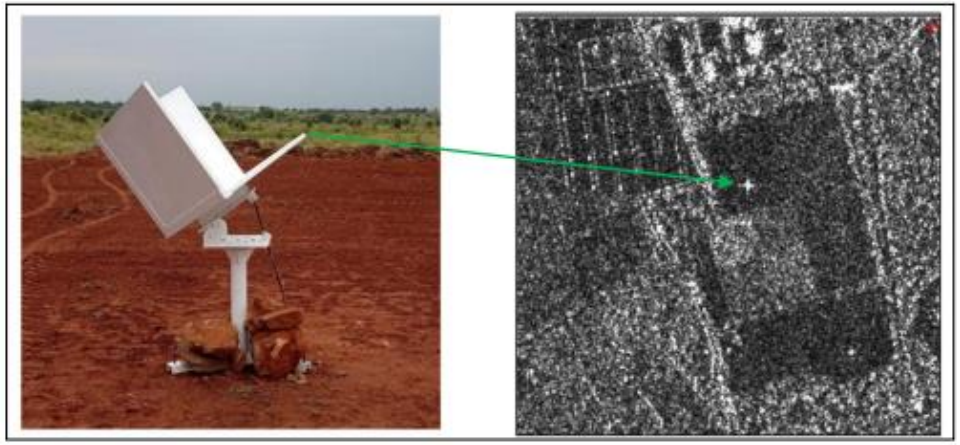
Stability of quality parameters using the corner reflectors in Shadnagar site for one year period

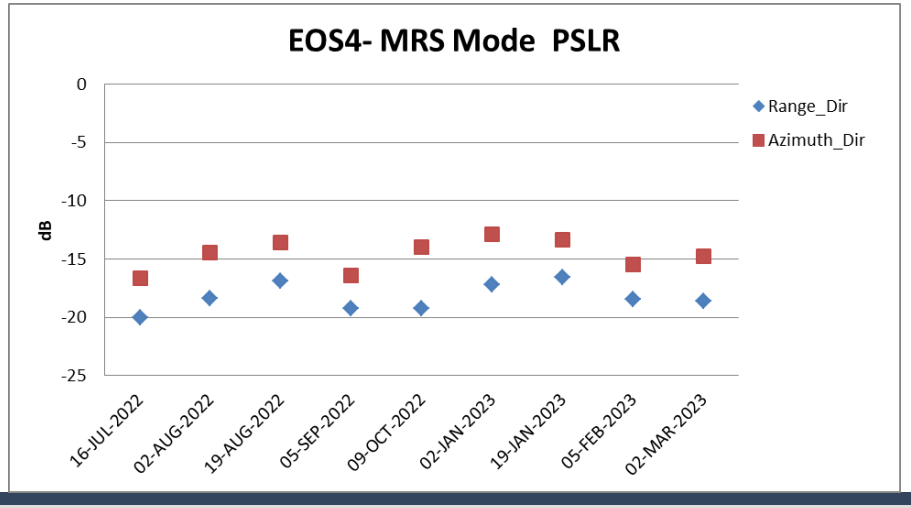
EOS-4 microwave imaging satellite launched by ISRO on 14-Feb- 2022

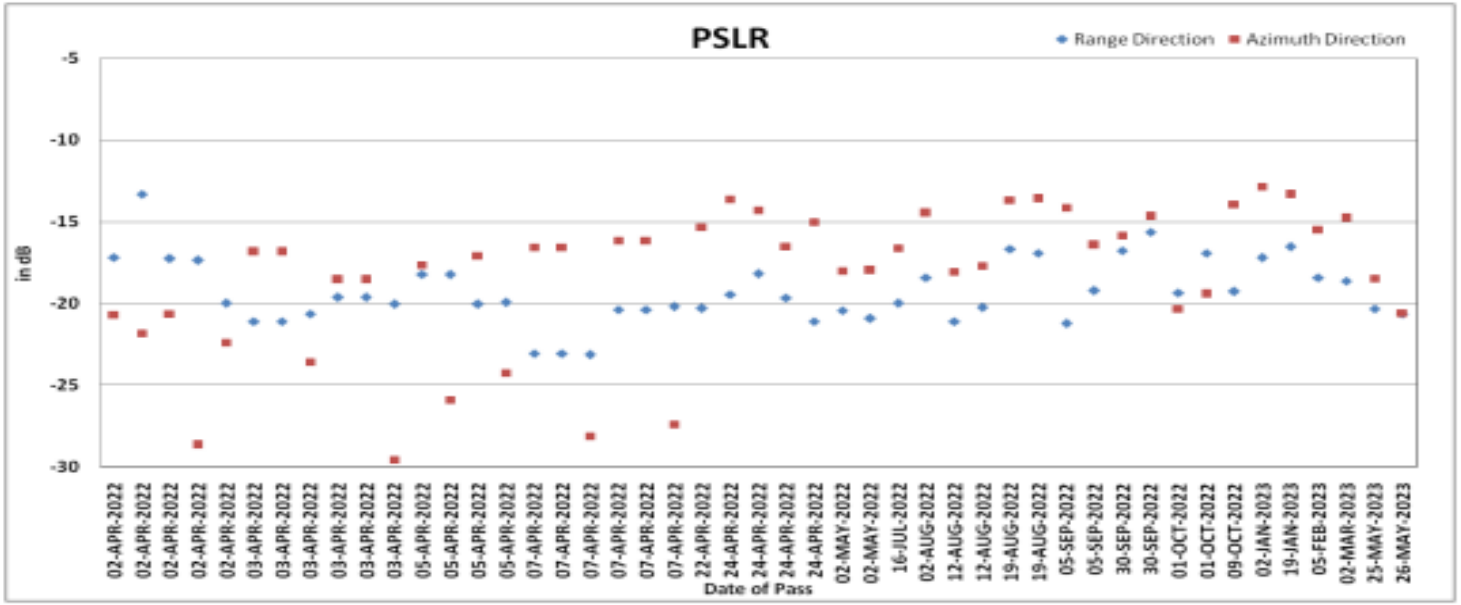
Imaging Mode	Swath in km	Off-nadir Coverage in km	Polarization	Resolution (Azi. x Sl Rng.)
FRS-1	25 #20	100-650 #100-400	Single, Dual, Circular, Full	3m x 2m
FRS-2	25 #20	100-650 #100-400		3m x 4m
MRS (8-Beam)	160 #115	100-650 #100-400		33m x 8m
CRS	223 #168	100-650 #100-400		50m x 8m
*HRS	10	100-650	Single, Dual, Circular,	1m x 2m

FRS- Fine Resolution Stripmap; MRS - Medium Resolution ScanSAR; CRS Coarse Resolution ScanSAR; HRS- High Resolution Spotlight.

On Orbit Consistency observed with respect to Geometry & Radiometry

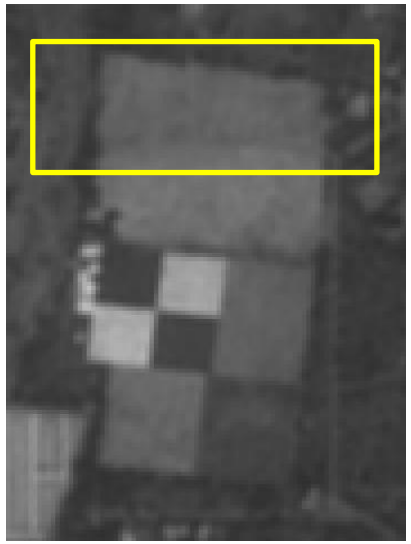




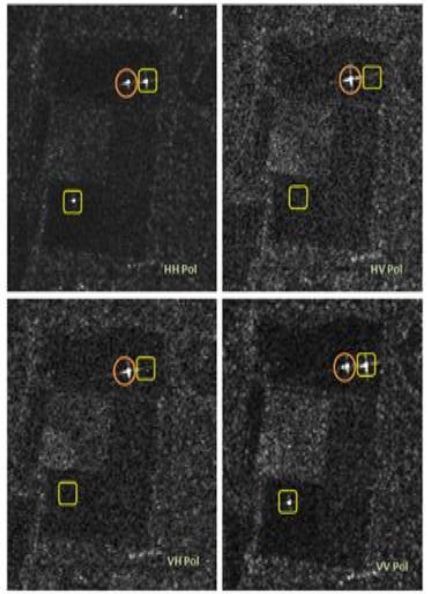


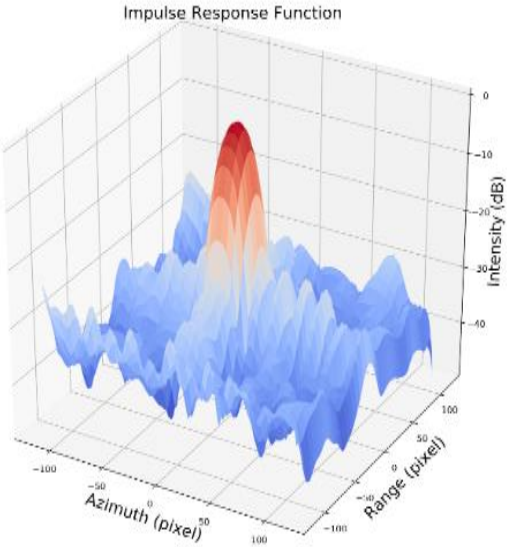
Readiness for NISAR mission

Extension of site to deploy newly developed corner reflectors



- Deployed ISRO's indigenously developed Multi-band Active Radar Calibrator (ARC) at IMGEOS Microwave Cal-Val Site and tested functional capability in X,C and S bands using RISAT-2B Series, EOS-04 and NovaSAR successfully.



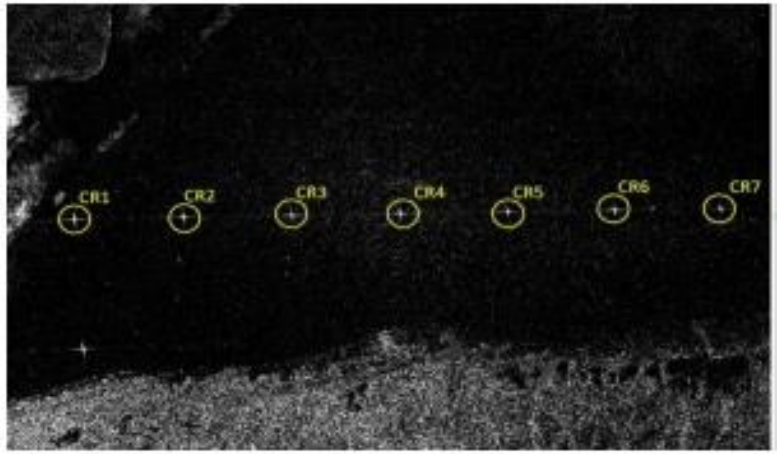


Corner reflector designed & developed for NISAR mission deployed

Size: 1.5m
Shape: STH/ TTH

- Active Radar Calibrator
- Square Trihedral Corner Reflector

NISAR mission pre-preparatory activities



Rosamond Corner Reflector Array
in L&S airborne SAR imagery

Signal- Clutter Ratio

SCR (in dB)	L band		S band	
	HH	VV	HH	VV
CR1	52.60	49.67	55.63	54.92
CR2	52.59	48.92	53.45	52.99
CR3	55.72	48.65	52.06	52.29
CR4	49.30	48.94	53.84	53.18
CR5	48.42	46.95	51.23	50.19
CR6	49.65	48.16	52.12	52.56
CR7	49.81	48.19	52.97	50.90

Envisaged computational methods for calibration parameter derivation verified using ASAR Data
Results published in InGARSS-2021

Quality parameters for L-band

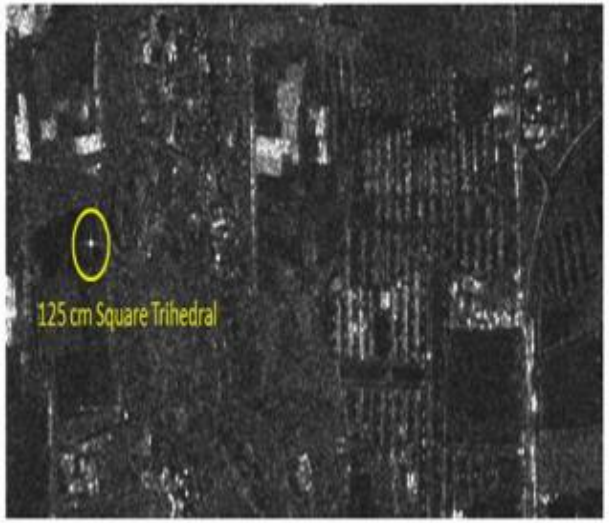
Pol	L Band					
	Azimuth			Range		
	PSLR (dB)	ISLR (dB)	SR (m)	PSLR (dB)	ISLR (dB)	SR (m)
HH	-27.25	-20.91	2.47	-26.04	-21.11	2.21
VV	-28.21	-21.79	2.6	-25.99	-22.79	2.22

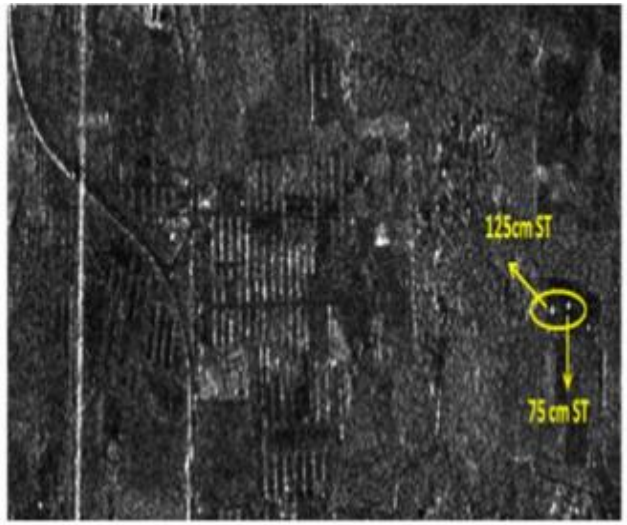
Quality parameters for S-band

Pol	S Band					
	Azimuth			Range		
	PSLR (dB)	ISLR (dB)	SR (m)	PSLR (dB)	ISLR (dB)	SR (m)
HH	-27.05	-20.50	2.42	-25.28	-19.70	2.23
VV	-26.84	-19.99	2.3	-22.89	-19.70	2.2

NISAR mission pre-preparatory activities

NOVASAR imaging over Shadnagar site





CR Type	Size	RCS (dBsqm) in S-Band
Square Trihedral	125cm	40.2
	75cm	31.326
Square Dihedral	100cm	34.563

Date of Pass	Target Type	Azimuth			Range		
		PSLR (dB)	ISLR (dB)	Resolution (Mts)	PSLR (dB)	ISLR (dB)	Resolution (Mts)
30-03-2021	125cm Square Trihedral	-22.87	-18.54	5.94	-23.94	-18.25	5.94
13-04-2021	125cm Square Trihedral	-22.84	-19.09	7.5	-22.93	-17.11	6.25
	75cm Square Trihedral	-21.52	-16.75	7.81	-19.58	-14.3	6.25
26-07-2021	125cm Square Trihedral	-22.24	-18.63	6.88	-21.95	-18.02	6.25

Computational methods for calibration parameter derivation for 'S' band data were verified.

NISAR mission pre-preparatory activities

ALOS-2 PALSAR imaging over Shadnagar site

Corner Reflector Type	Size (m)	RCS (dBsm)	Qty	Identification
Square Trihedral	1.25	31.947	02	STH
Square Dihedral	1.0	26.309	02	SDH

- Low background to peak ratio is observed.
- Quality parameters like PSLR, ISLR, IRW closely match with product specifications.

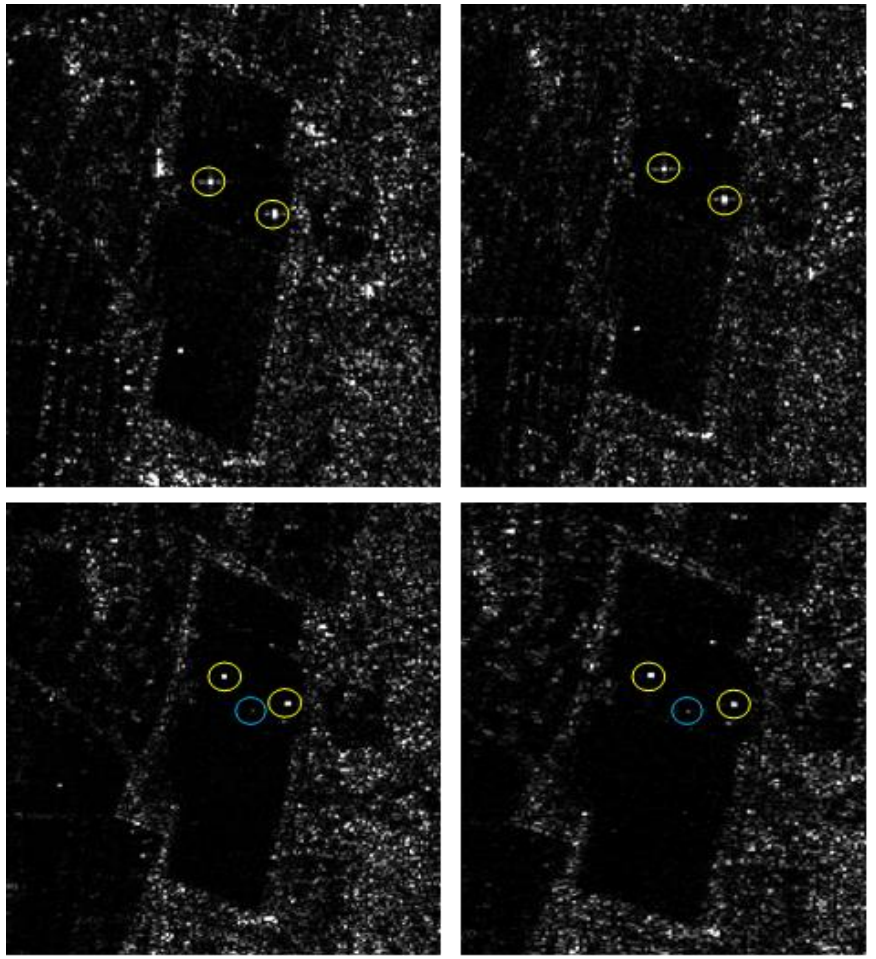
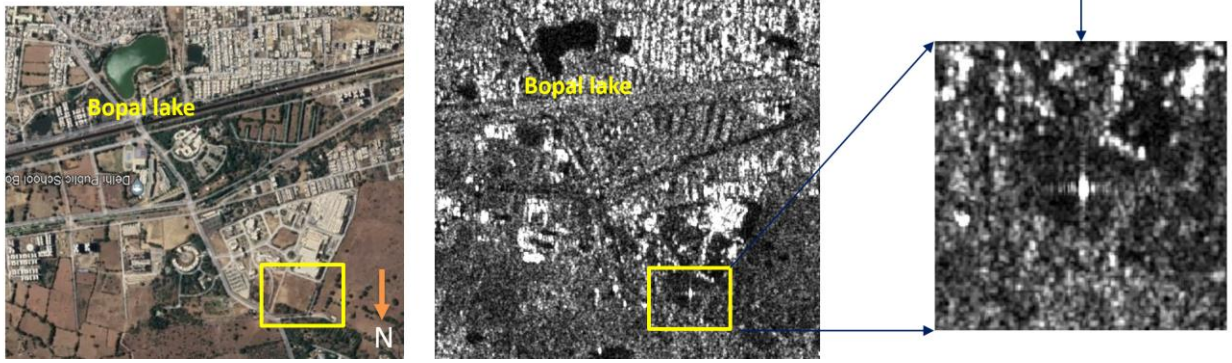


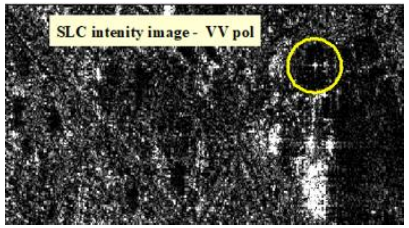
Figure 1 Corner reflectors detected in four bands. Top row: HH, VV, Bottom row: HV, VH.

NISAR mission pre-preparatory activities

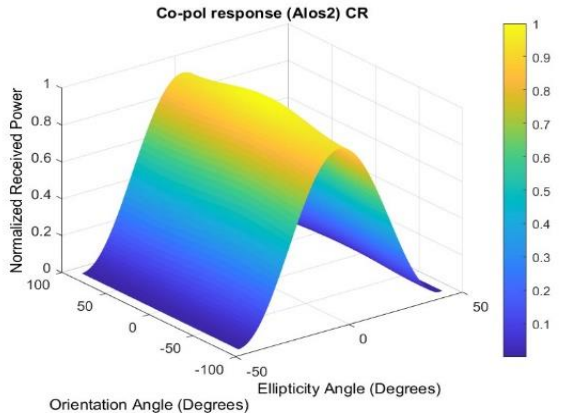
Response of NISAR CR as seen in NovaSAR image (S-band)

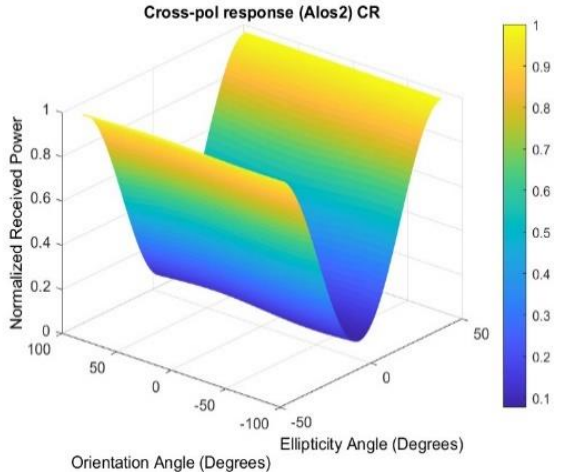


Ground snap of NISAR CR deployed at Bopal calibration site



Response of NISAR CR as seen in ALOS-2 image (L-band)



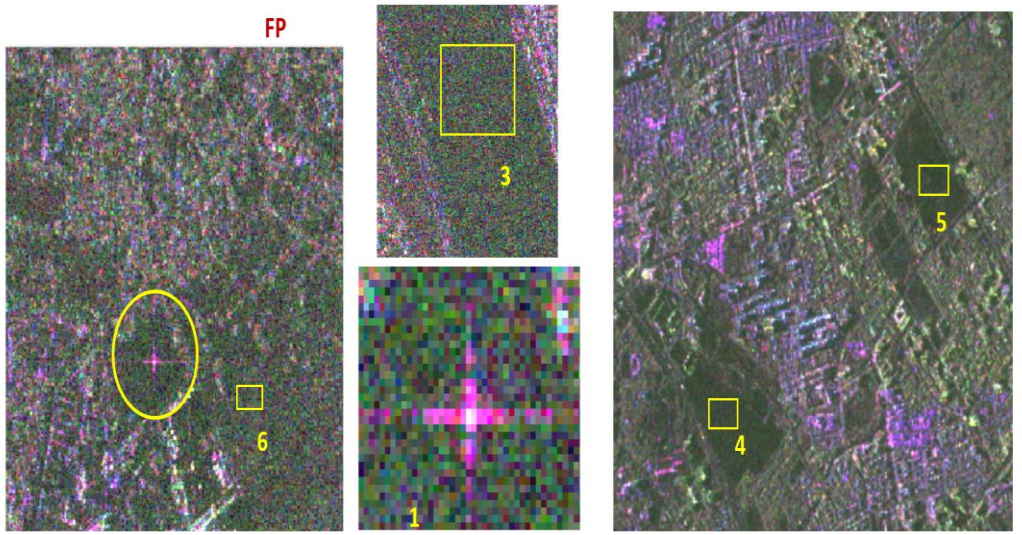


- In-house designed Corner reflector developed specifically for NISAR data calibration was deployed at Bopal and Challakere calibration sites.
- Evaluation of its response was carried out using ALOS-2 and NovaSAR image and was found to be satisfactory

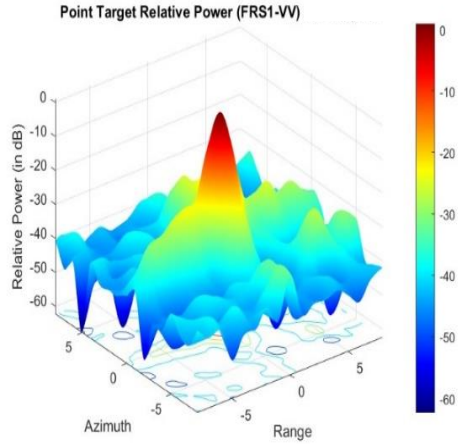
EOS-04 calibration stability monitoring

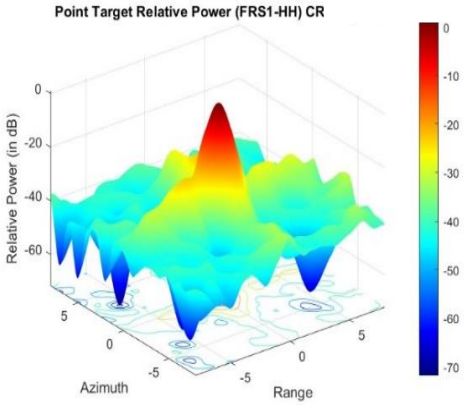
- The CRs deployed at different calibration sites (Bopal, Ladakh, Antarctica, Challakere) were utilized for the monitoring of calibration stability of EOS-04 data.
- The difference between estimated RCS and the theoretical RCS for EOS-04 FRS-1 was found to be within 1.2 dB for both HH and VV.
- The phase difference was found to be well within the specified values.
- The polarimetric signatures generated using the response of the point target closely matched the ideal signatures.

Response of CR as seen in one of the analysed EOS-04, FP images



Target	Co-pol phase difference (deg)	No. of pixels
Bopal CR (1.5 m SqT) (1)	-0.54	At peak response
Bopal Lake (2)	1.37	31*31 pixels
Sabarmati River (3)	-0.82	63*100
GMDC ground (4)	2.41	72*46
Ground near GMDC (5)	-2.88	72*46
Ground behind Bopal cal site	-1.70	72*46

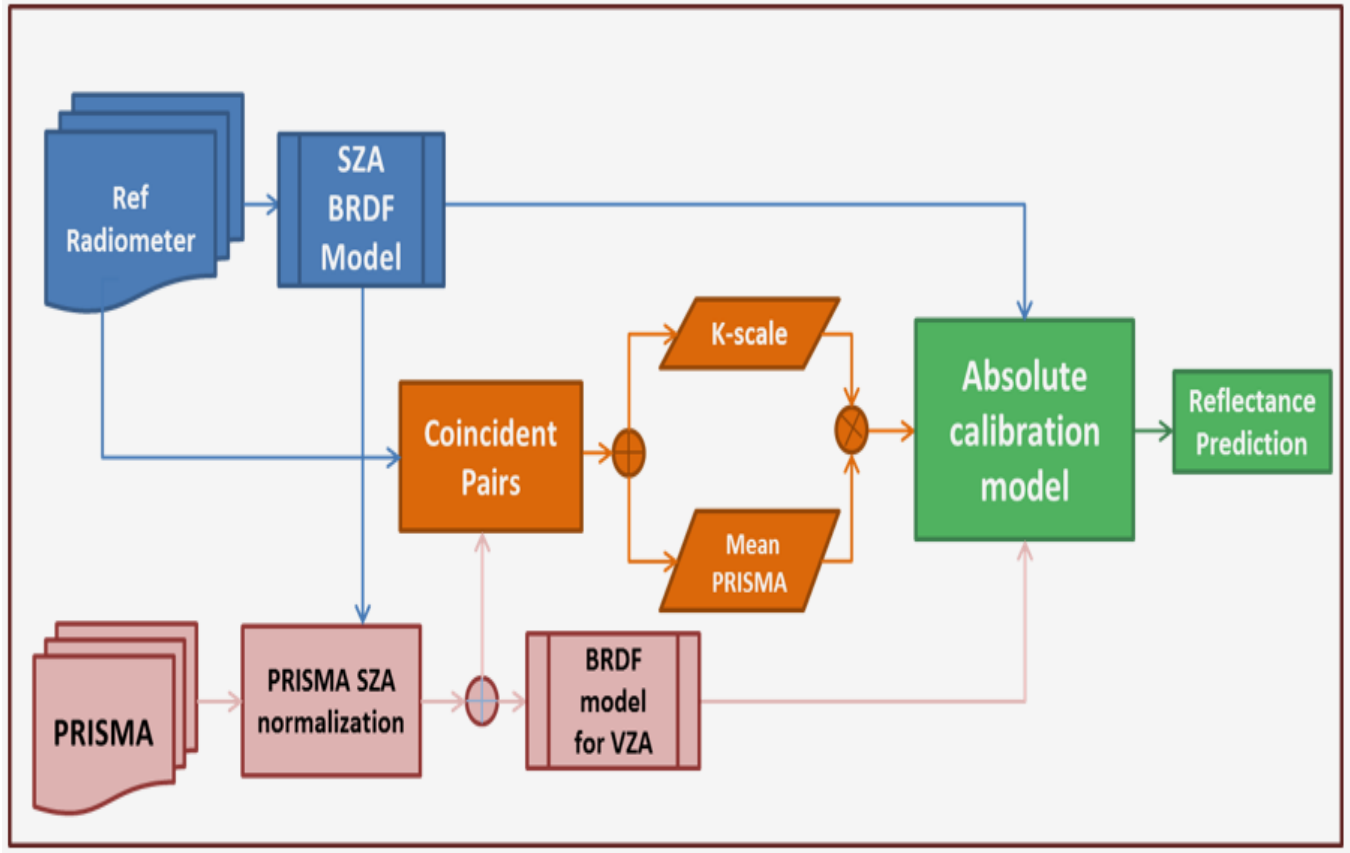




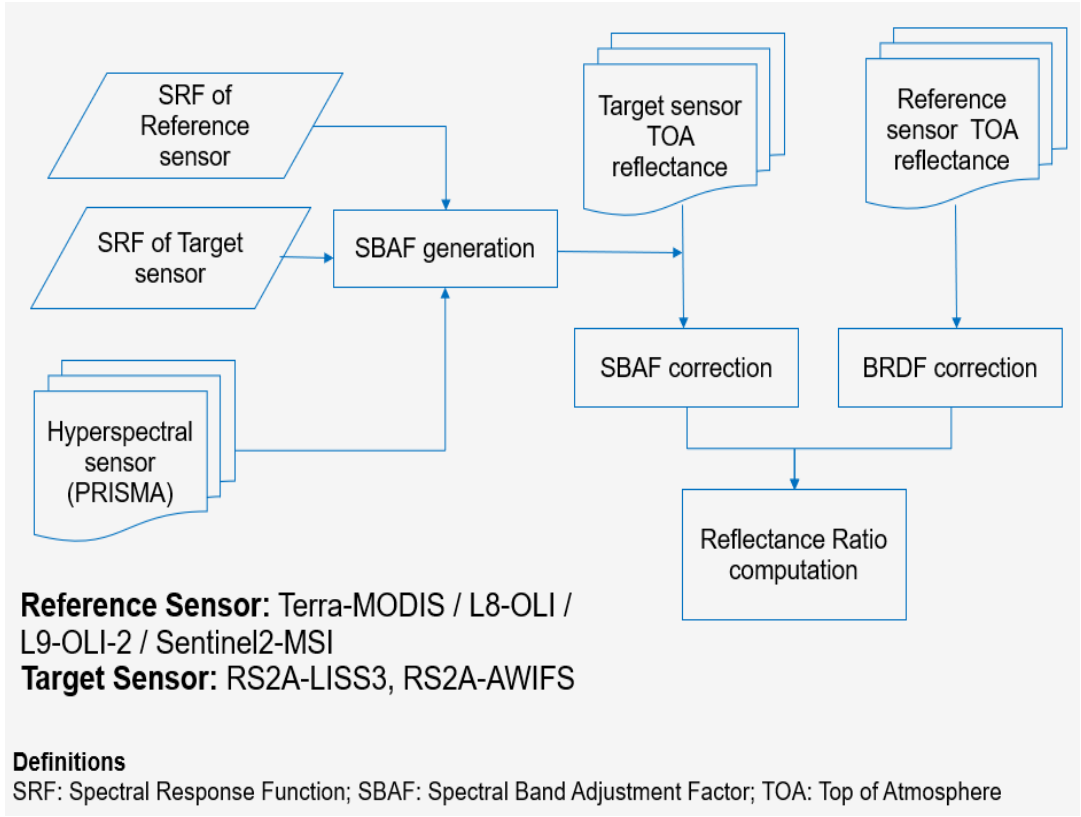
ISRO-ASI project

Project: Calibration of optical space borne sensors over pseudo invariant calibration sites.
-- Under Progress

Empirical absolute calibration model using PRISMA



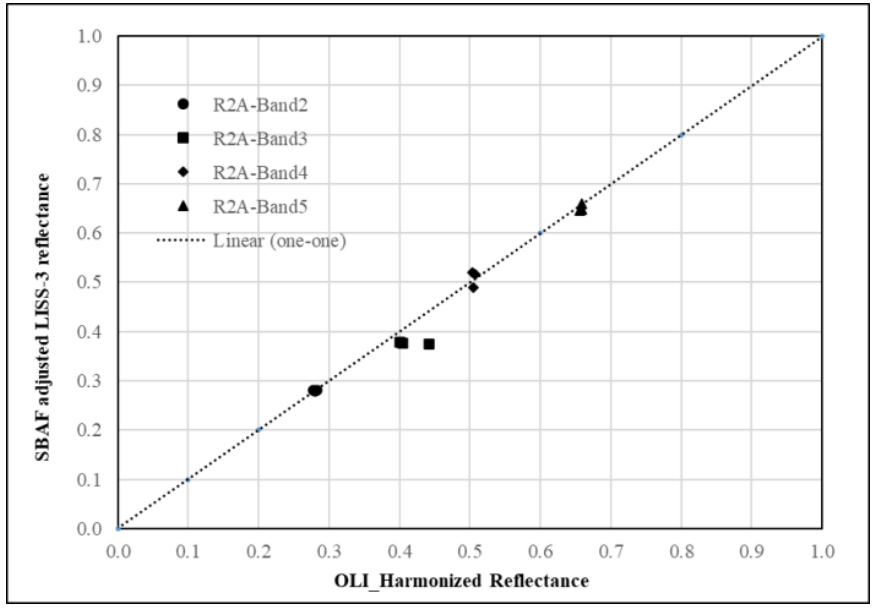
Cross calibration with SBAF generated using PRISMA



Reference Sensor: Terra-MODIS / L8-OLI / L9-OLI-2 / Sentinel2-MSI
Target Sensor: RS2A-LISS3, RS2A-AWIFS

Definitions
SRF: Spectral Response Function; SBAF: Spectral Band Adjustment Factor; TOA: Top of Atmosphere

Cross calibration of RS2A LISS-3 and Landsat-8 OLI



$$SBAF(\lambda) = \frac{\frac{\int \rho_{hyp}(\lambda) RSR_{OLI}(\lambda) d\lambda}{\int RSR_{OLI}(\lambda) d\lambda}}{\frac{\int \rho_{hyp}(\lambda) RSR_{LISS-3}(\lambda) d\lambda}{\int RSR_{LISS-3}(\lambda) d\lambda}}$$

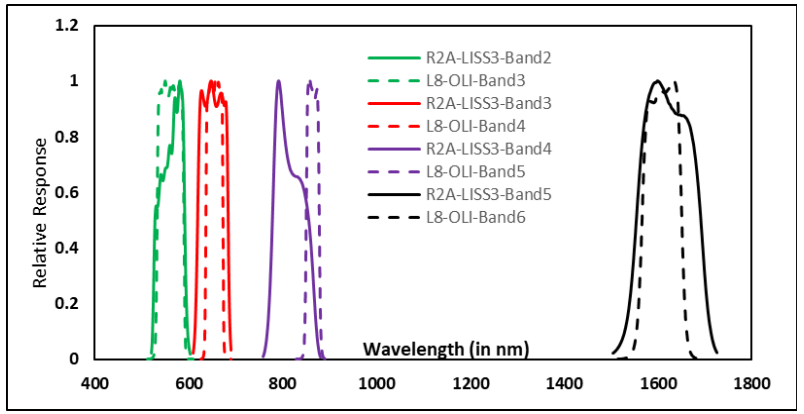
Calibration Ratio without RSR compensation

Date / Band	17-Jun-21	04-Aug-21	21-Sep-21	Mean
Band-2	1.0180	0.9958	1.0043	1.0060
Band-3	0.9350	0.8366	0.9214	0.8977
Band-4	0.9720	0.9119	0.9563	0.9467
Band-5	1.0012	0.9826	0.9835	0.9891

Calibration Ratio with RSR compensation

Date / Band	17-Jun-21	04-Aug-21	21-Sep-21	Mean
Band-2	1.0111	0.9890	0.9976	0.9992
Band-3	0.9458	0.8463	0.9319	0.9080
Band-4	1.0333	0.9696	1.0165	1.0065
Band-5	1.0024	0.9838	0.9848	0.9904

Radiometric response for Spectrally similar bands of RS2A-LISS3 and L8-OLI, are comparable.
Published in InGARSS 2023



…….. looking forward for Global collaboration towards interoperability of Data Products

CAL-VAL TEAMS:

National Remote Sensing Center(NRSC), Hyderabad, ISRO, INDIA

Space Application Center (SAC), Ahmadabad, ISRO, INDIA

Thank you….