

QA4EO for IRS products

A.Senthil Kumar

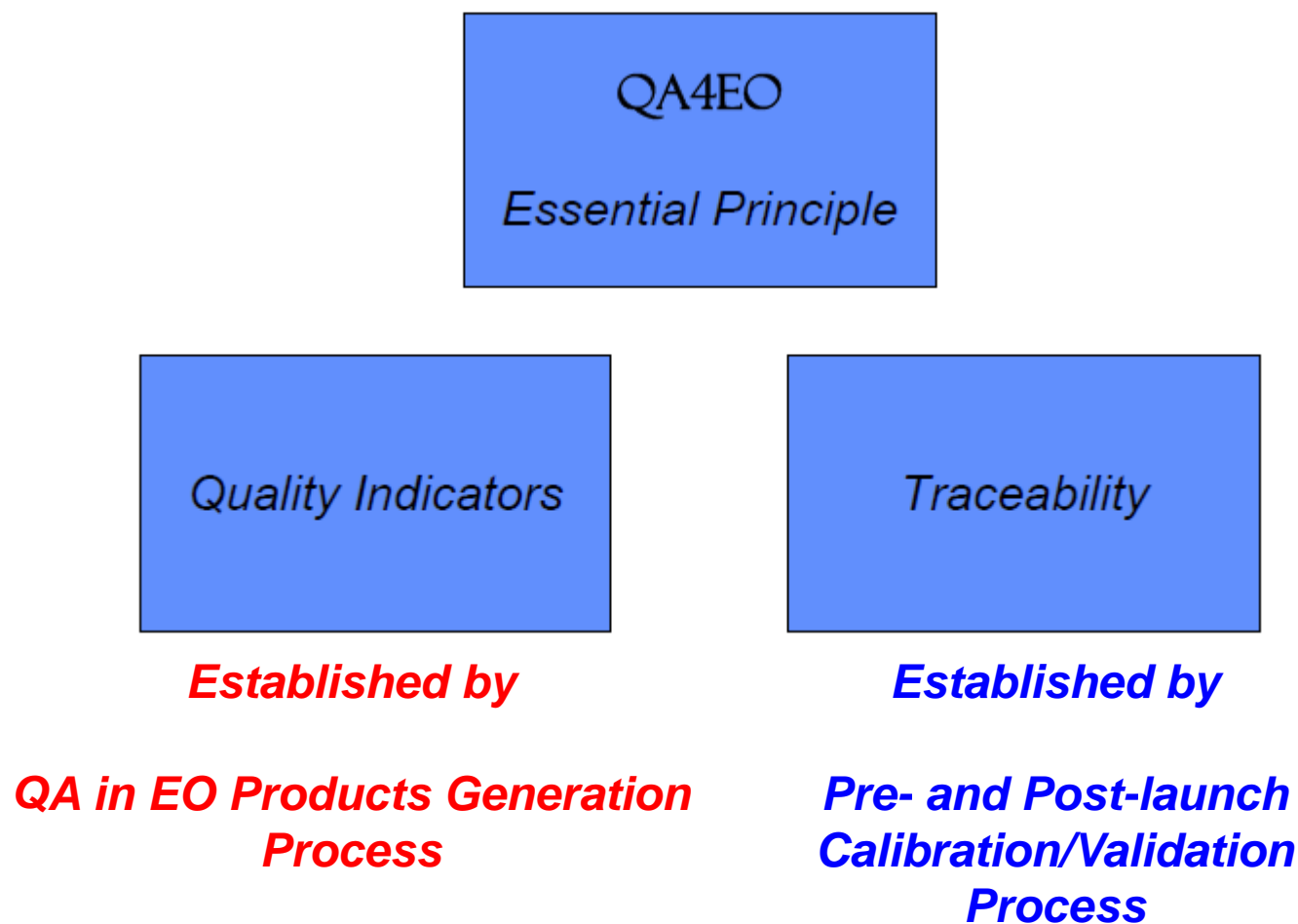
ISRO / NRSC

E-mail: senthilkumar_a@nrsc.gov.in

ISRO's Optical Sensors for Earth Observation Satellites in last 10 years

- Resourcesat-1 and 2 : AWiFS, LISS-3, LISS-4
- Cartosat-1, 2, 2A , 2B: Panchromatic camera
- Oceansat-1 and 2: 8-band camera
- IMS-1: HySI and TMC (& in lunar mission)
- Kalpana : VHRR
- INSAT-3D: Imager, Sounder (ready for launch)

QA for Earth Observation (QA4EO)

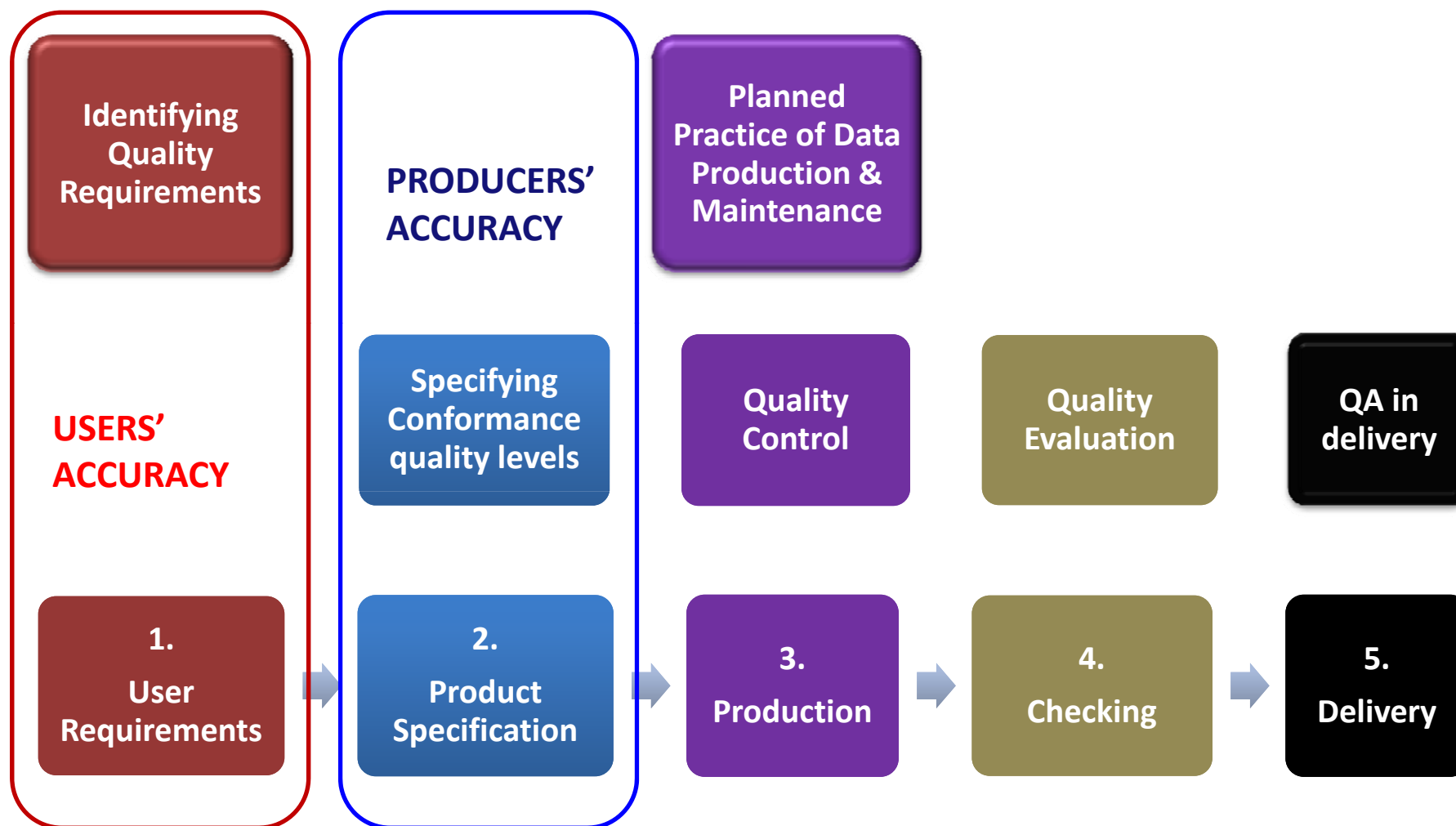


CEOS - QA4EO guidelines



- Onus on a Data providing agency to
 - define **QUALITY INDICATORS** that will aid RS data users to decide on 'fitness of purpose' of its products to the users' requirements
 - Ensure stability of QIs and record deviations, if any, throughout the products' life cycle
- Data providing agency to come out with a plan for **TRACEABILITY** criteria
 - to ensure products' quality assurance with reference to standards (sources for lab. Calibration, sensors, targets), globally agreed upon across the CEOS community for their data products acceptance of inter-operability.

Quality in Data Production Process



QA PROTOCOLS

User Requirements for National Projects

A. IMAGE STANDARDS (Satellite Products)

Parameter (@3 σ)	1:250,000	1:50,000	1:10,000	1:4000
Image resolution	56 m XS-AWiFS	24 m XS; 5.8m P	5.8m XS;2.5m P	1m P; 5.8m XS
Nat. Spat. Frame Work	National	State	State	State
Projection	Geographic / UTM	Geographic / UTM	Geographic / UTM	Geographic / UTM
Datum	WGS 84	WGS 84	WGS 84	WGS 84
Image Frames	1° x 1°	15' x 15'	3' 45" x 3'45"	1.5' x 1.5'
Position (planimetric) accuracy (0.5 mm in scale) in m	125	25	5	1 (0.25 mm of scale)
B2B registration for XS data (0.25 pix) in m	~14	~6	~1.5	~1

Source: National Natural Resources Management System (NNRMS),DOS, v.2.0, 2005

Quality Elements of IRS Data Products



Guidelines of ISO-19113 Quality Principles

- Completeness
- Logical consistency
- Geo-positional Accuracy
- Temporal Accuracy
- Thematic Accuracy

Quality Elements for IRS data products

QI – Element	Sub-QI elements	Definition	Procedure
Completeness	Commission or Omission of data set	Excess or deficiency data present in the data set as per 1. Products specs. 2. Defined user Area of Interest	1. Estimation of Side-lap and Overlap lengths of two adjacent paths at product level (mosaicability) 2. Visual check of user AOI shape file by AOI - products overlay
Logical Consistency	Domain consistency	Checking range of values (DC,Radiance)	Estimation of image statistics (mean, SD, dynamic range) and visual checks on data saturation / anomalies
	Format consistency	Degree of adherence of data structure to agreed product format	Automatic software verification of data products

Quality Elements for IRS data products

QI – Element	Sub-QI elements	Definition	Procedure
Geo-positional Accuracy	1. Absolute or external accuracy	Closeness of product co-ordinate values to values being accepted or being true	Identification of sufficient control points from product and Reference (accepted Image /map)
	2. Relative or internal accuracy (internal distortion, B2B mis-registration)	Closeness of relative positions of ground features product co-ordinate values to values being accepted or being true	Taking a GCP or a Band in MS as Reference, Estimation of relative shifts of other GCPs / between bands with help of Radiometric CPs or PIFs

Quality Elements for IRS data products

QI – Element	Sub-QI elements	Definition	Procedure
Temporal Accuracy	In-flight calibration of detector array	Consistency of response variation of the sensor to std. set of exposures	Estimation of any deviation from previous as well as intended response set in post-launch with a set of LEDs
	Radiometric sensitivity	Acquisition of fixed sites considered as radiometrically stable areas and constantly evaluating any deviations	TOA reflectance and/or surface reflectance to estimate relative and absolute radiometric performance study
Thematic Accuracy	Thematic classification correctness	Comparison of classes assigned to features or their attributes to ground-truth or reference dataset	Best practices that satisfy end users (typically 90% / 90%)

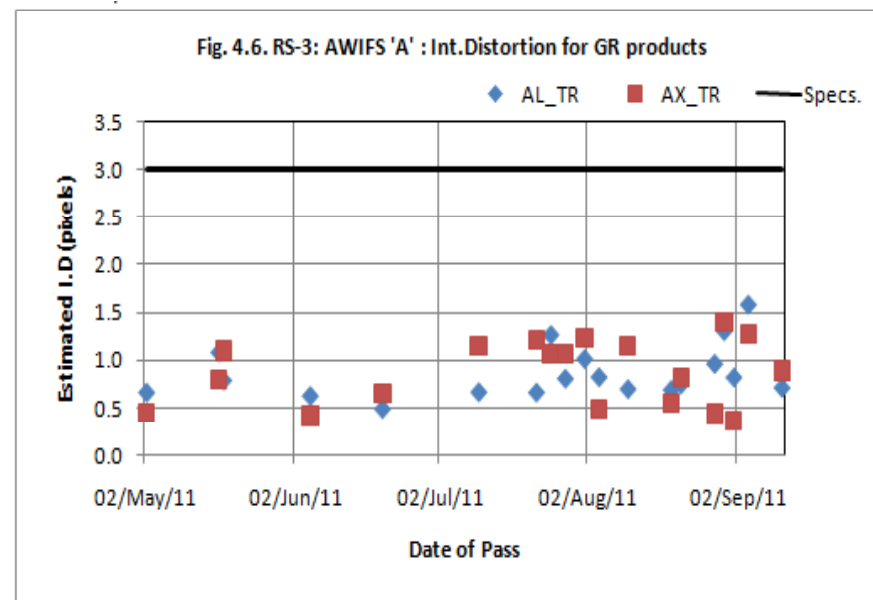
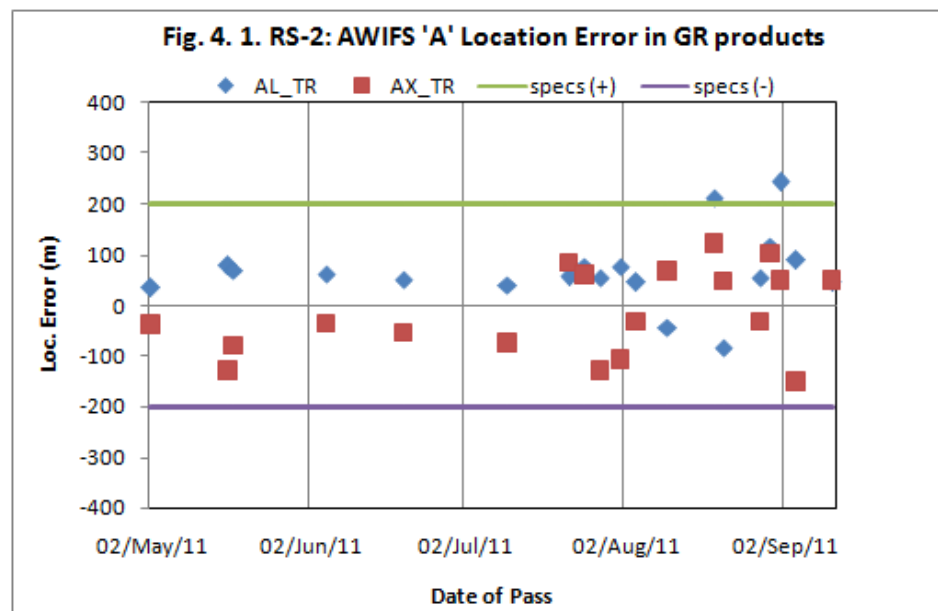
Products Compliance Report

- At the end of Early phase of operations of each IRS mission, a **products compliance report** is prepared following Statistical Quality Control basis to certify Process Control of Data Processing Chain.
- Products are randomly chosen for various conditions and various terrain cover, and evaluated for products compliance.
- Anomalies left uncorrectable through DP process is accepted as **Products Disclaimers** to bring awareness of the issue, in case they may affect their inference.

RS-2 Geopositional Accuracy Results

SENSOR	DATE OF PASS	Scene ID	Scene Description	Location Error rms (m)		Internal Distortion rms (pix)	
		Path/Row		AL_TR	AX_TRK	AL_TRK	AX_TRK
AWIFS	2-May-11	93 /53	flat terrain	35.0	-38.0	0.67	0.44
	17-May-11	94 /58	flat + cloudy	78.4	-129.7	1.09	0.80
	18-May-11	99 /54	hilly + 20 % cloud	68.6	-81.2	0.80	1.09
	5-Jun-11	90 / 49	hilly	61.0	-36.0	0.63	0.41
	20-Jun-11	90 / 54	heterogeneous	52.0	-55.0	0.50	0.65
	10-Jul-11	91 / 53	heterogeneous + cloudy	39.6	-74.3	0.67	1.14
	22-Jul-11	102 /64	coastal + cloudy	56.7	83.6	0.67	1.20
	25-Jul-11	93 /53	desert + scatter cloud	77.7	60.7	1.28	1.07
	28-Jul-11	108 / 57	NER + cloudy	55.2	-129.6	0.82	1.06
	1-Aug-11	104 /55	heterogeneous + cloudy	76.9	-107.4	1.02	1.23
	4-Aug-11	95 /53	flat + cloudy	46.0	-31.7	0.83	0.49
	10-Aug-11	101 / 64	coastal + cloudy	-43.4	68.1	0.71	1.15
	19-Aug-11	98 / 54	cloudy	210.7	122.1	0.70	0.55
	21-Aug-11	108 /56	NER+ scatter cloud	-82.7	48.7	0.75	0.82
	28-Aug-11	95 / 53	flat + cloudy	54.9	-32.7	0.97	0.43
	30-Aug-11	105 / 53	hilly + cloud	115.8	103.2	1.31	1.39
	1-Sep-11	91 / 58	Gujarat coast	242.3	49.0	0.83	0.37
	4-Sep-11	106 /51	hilly	88.9	-151.1	1.59	1.27
	11-Sep-11	93 / 53	flat + scatter cloudy	45.4	49.7	0.72	0.89

Products Conformance Results



Relative Band to band misregistration for RS-2 AWiFS

Ref: Band 3	AL_TRK (pix)	AC_TRK (pix)
Band 2	0.08	0.06
Band 4	0.02	0.08
Band 5	0.13	0.15

- Products clearance to users is based on results of products meeting specs. 95% and above for population set as control threshold

Prelaunch Calibration

- **Calibrated Sources and Standards procured only from reputed vendors in USA and Germany with certificates on measured uncertainty**
- **Calibration traceable to NMI¹ of respective country of the commercial supplier (mainly NIST² / PTB³)**

1-National Measurement Institute

2-National Inst. of Standards and Technology, USA

3-Physikalisch-Technische Bundesanstalt, Germany

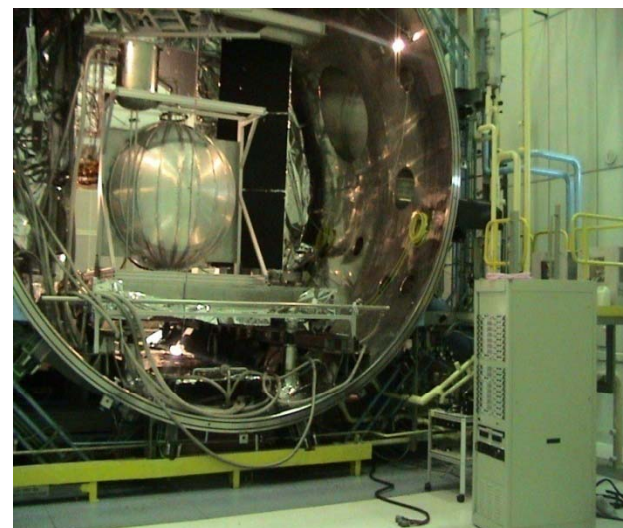
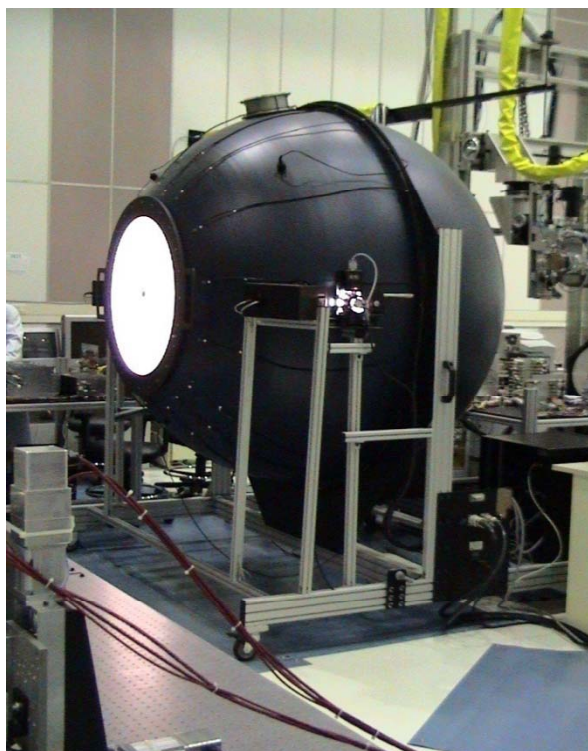
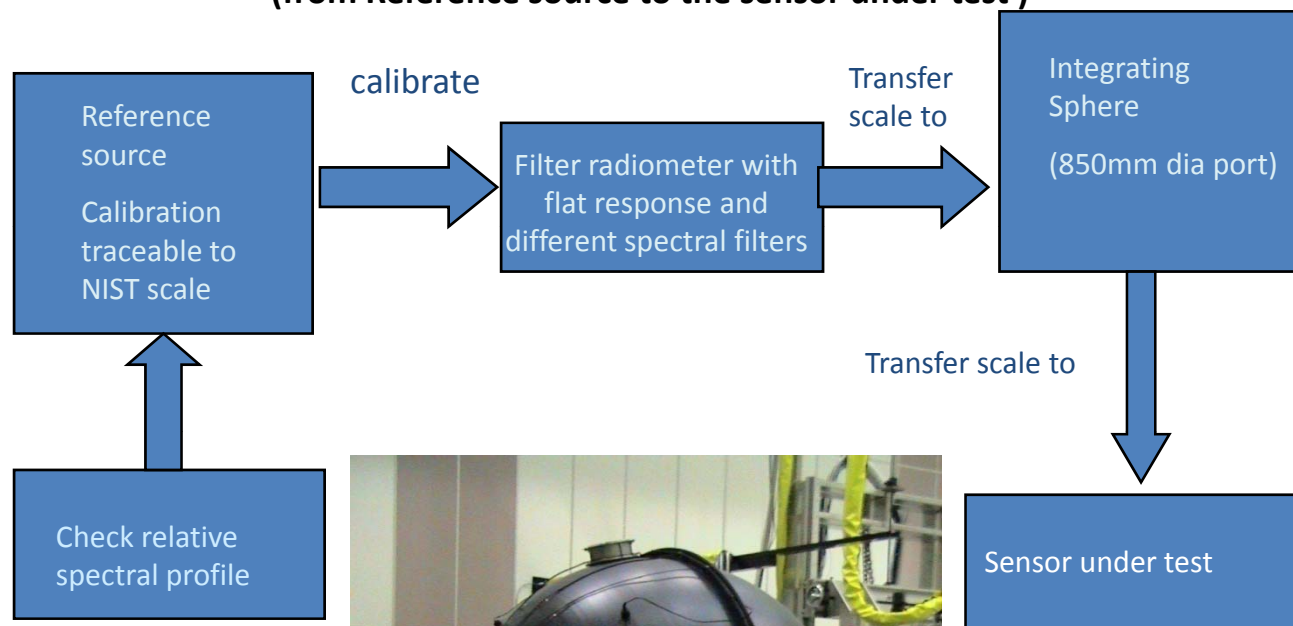
Radiometric Performance

Sensor Design - Practice Followed

- **Optical systems: Refractive (lens assemblies) and Reflective (telescope)**
- **Spectral selection: Optical bandpass filters/ Wedge filters (HySI)**
- **CCD and CMOS based array devices (Linear and Area Array)**
- **Onboard LED for evaluation of response degradation: VNIR/SWIR**
- **Stray signal - Elimination at Pre-launch optimisation**
- **Pre-flight Spectral response evaluation at**
 - **Optical components and detector level**
 - **Integrated system level**
- **Evaluation of Response Linearity, Noise performance, Saturation Radiance, NESR at different levels of design/development**

Transfer of radiance scale (Vis-NIR-SWIR)

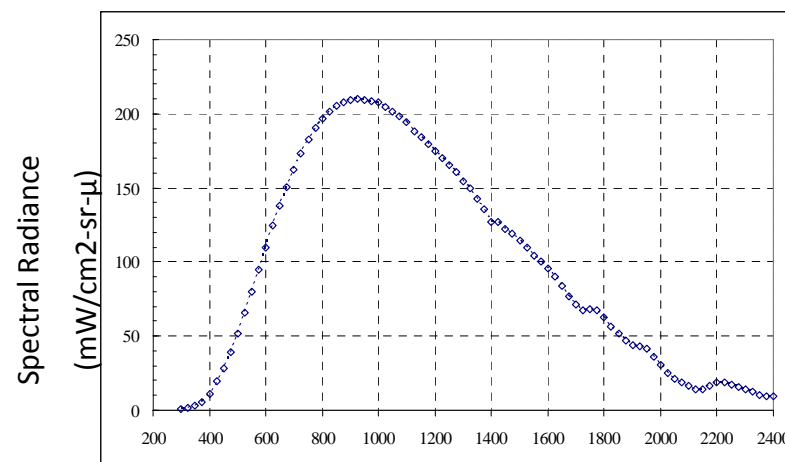
(from Reference source to the sensor under test)



Relative Expanded Uncertainties [%] (k=2)												
	Type	300	400	500	600	700	800	900	1000	1100	1200	1300
1 Blackbody quality	B	0.12	0.07	0.03	0.01	0.00	0.01	0.03	0.04	0.04	0.05	0.05
2 Cal of pyr. lamp	B	0.33	0.27	0.22	0.18	0.15	0.12	0.11	0.10	0.10	0.09	0.08
3 Temp determ & transfer	A	1.32	0.94	0.73	0.55	0.52	0.62	0.47	0.41	0.32	0.35	0.44
4 Wavelength measurement	B	0.12	0.10	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.03
5 Temp Scale	B	0.58	0.46	0.37	0.30	0.27	0.24	0.20	0.19	0.17	0.16	0.15
6 Lock-in amplifier linearity	B	-	-	-	-	-	-	-	-	0.50	0.50	0.50
7 Gain	B	-	-	-	-	-	-	-	-	1.00	1.00	1.00
Overall uncertainty		1.49	1.09	0.85	0.66	0.60	0.68	0.52	0.47	1.18	1.19	1.21
	Type	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
1 Blackbody quality	B	0.05	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07
2 Cal of pyr. lamp	B	0.08	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05
3 Temp determ & transfer	A	0.27	0.33	0.59	0.35	0.21	0.91	1.34	1.22	1.80	2.93	2.34
4 Wavelength measurement	B	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
5 Temp Scale	B	0.14	0.12	0.12	0.11	0.10	0.09	0.09	0.08	0.08	0.07	0.07
6 Lock-in amplifier linearity	B	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
7 Gain	B	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Overall uncertainty		1.16	1.18	1.27	1.18	1.15	1.45	1.75	1.66	2.12	3.14	2.60

NIST calibrated Lab Reference Source Uncertainty in radiance calibration 6" Zenith Integrating Sphere

Wavelength (nm)



Post-launch Cross-calibration

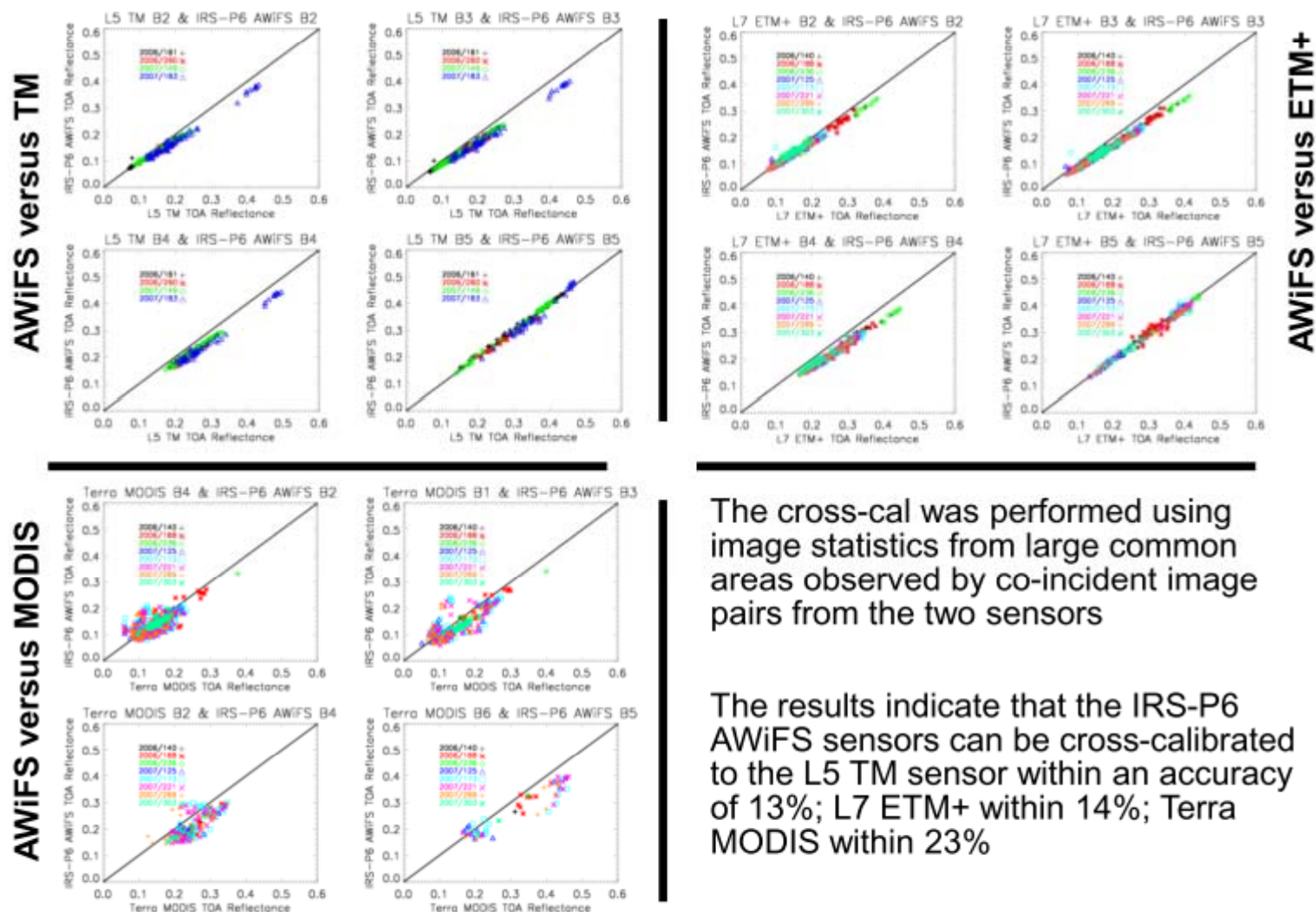


- Establishing cross-calibration relationship between IRS sensors and equivalent calibrated reference satellite sensors (TM, ETM, MODIS)
- Co-ordinating with CEOS CV partners in planning, providing near-synchronous datasets and sharing all necessary spectral and data attributes for estimation of biases
- Participating CV campaign mode on specific CEOS cal-val targets by payload programming for acquisition and dumping of specific sensor data

Earlier results of collaboration

- Focal Point: Gyanesh Chander (USGS)

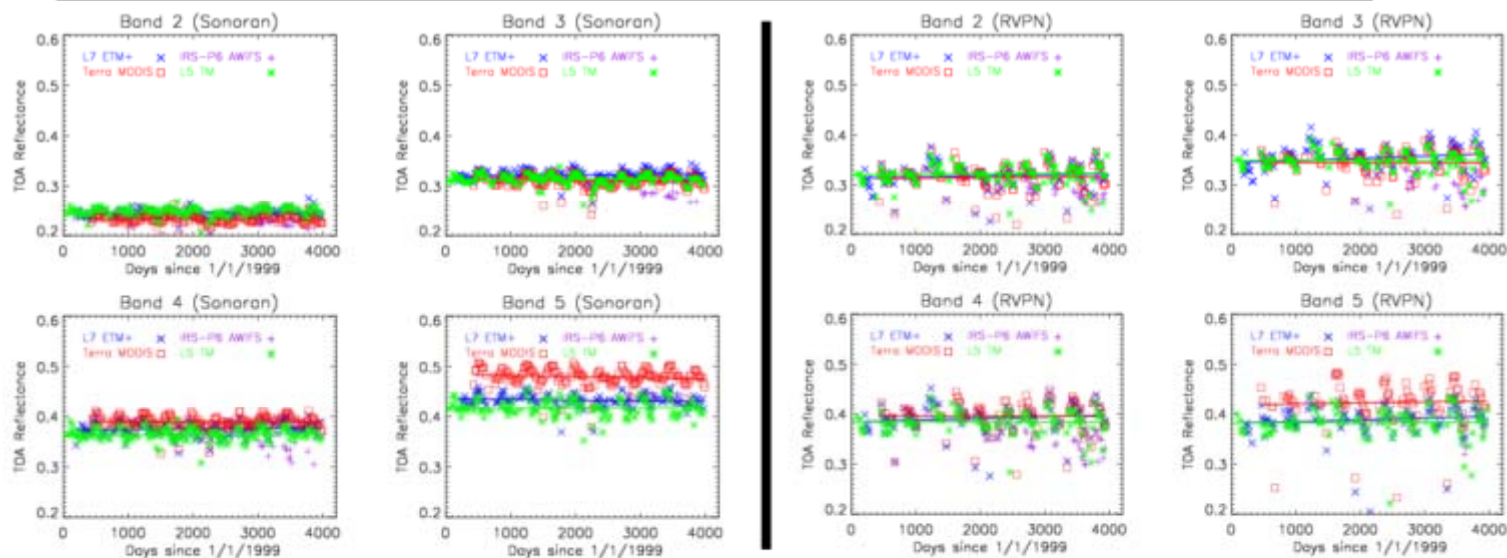
AWiFS cross-cal with TM, ETM+, MODIS



Temporal Stability Characterization

Ref: Chander et al., JACIE Workshop, Mar. 16-18, 2010

Long-term TOA Reflectance Trending (Sonoran & Railroad Valley Test Sites)



- Linear equations are fitted to the long-term TOA reflectance trends
 - Slope values are very small: prove the long term stability of sensors
 - There are constant offsets: caused by a combination of the spectral signature of the ground target, atmospheric composition and the RSR characteristics
- The annual oscillation were caused by BRDF effect

Cross calibration of RS2 AWiFS with MODIS

- Focal Points: Amit Angal, X. Xiong (NASA), Sirish and Cao (NOAA)**

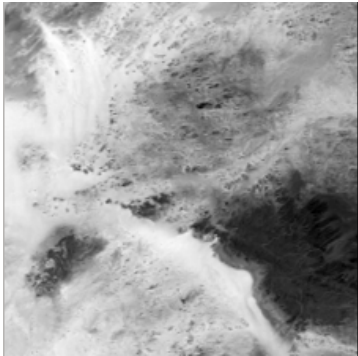
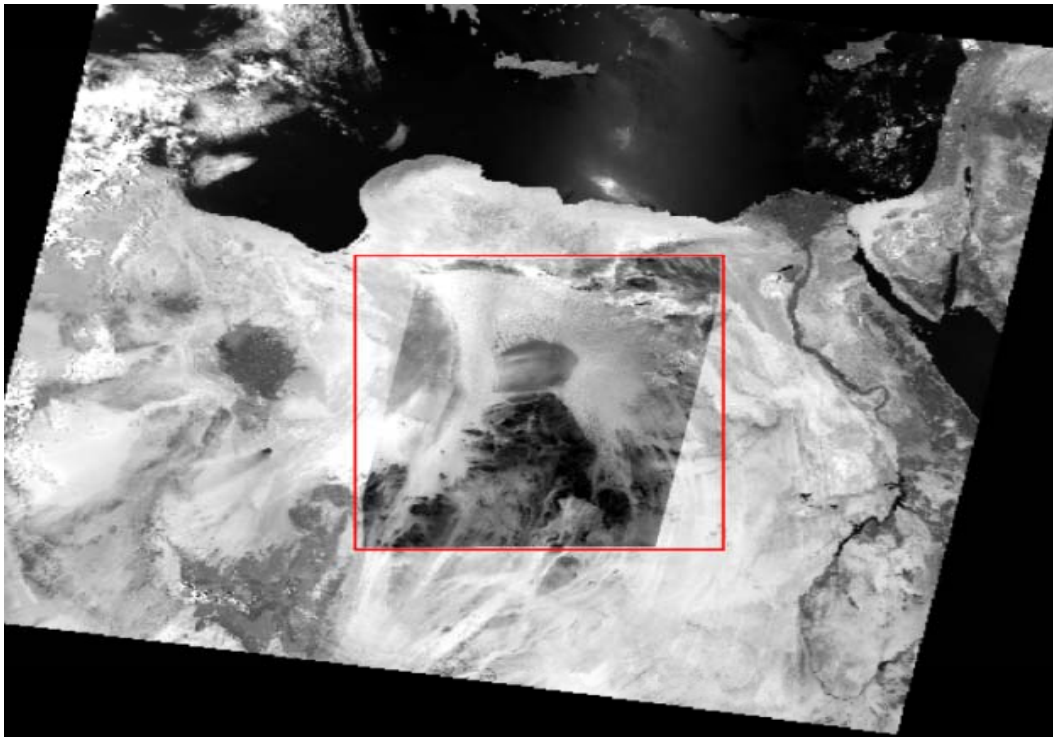
Features	AWiFS Specifications	MODIS Specifications
No. of bands	4	36
Spectral bands (μm)	B2 (0.52 – 0.59) B3 (0.62 – 0.69) B4 (0.77 – 0.86) B5 (1.55 – 1.70)	B4 (0.54-0.56) B1 (0.62-0.67) B2 (0.84-0.87) B6 (1.62-1.65)
Resolution (m)	56	250m, 500m, 1km
Image Swath (km)	740	2330 km
Revisit (days)	5	1-2 days
Quantization (bits)	12	12
Altitude (km)	817	705

RS2 AWiFS and Terra MODIS sensor specifications

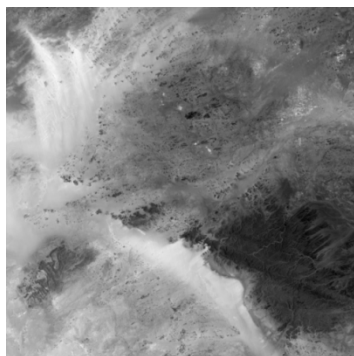
Data Collection over CEOS sites

Date of Acquisition	Lat	Lon	S_Elev	S_Azi	Sitename	Status	Year/DOY	MODIS_granule_id
07-05-2011 07:23	16.645	46.456	67.523	87.245	Arabia-1	processed	2011/127	MOD021KM.A2011127.0720
18-05-2011 08:41	22.682	29.835	72.049	96.636	Egypt-2	processed	2011/138	MOD021KM.A2011138.0840
18-05-2011 10:20	29.739	4.51	68.144	114.11	Algeria-3	processed	2011/138	MOD021KM.A2011138.1020
23-05-2011 05:14	36.618	82.732	66.552	126.566	Taklamakan	processed	2011/143	MOD021KM.A2011143.0535
05-06-2011 09:19	27.364	19.629	69.513	99.845	Libya-2	processed	2011/156	MOD021KM.A2011156.1005
06-06-2011 08:58	26.175	24.414	69.492	96.21	Libya-4	processed	2011/157	MOD021KM.A2011157.0910
08-06-2011 10:02	17.417	7.074	67.207	73.158	Niger-1	processed	2011/159	MOD021KM.A2011159.1040
10-06-2011 09:18	25.853	19.39	69.422	94.2	Libya-2	processed	2011/161	MOD021KM.A2011161.0845
12-06-2011 08:34	39.129	33.466	66.546	128.427	Tuz Golu	processed	2011/163	MOD021KM.A2011163.0830
15-06-2011 14:35	-19.674	-67.2	38.224	35.733	Uyuni	processed	2011/166	MOD021KM.A2011166.1415
02-09-2011 10:35	28.551	1.39	61.007	132.134	Algeria-5	processed	2011/245	MOD021KM.A2011245.1000

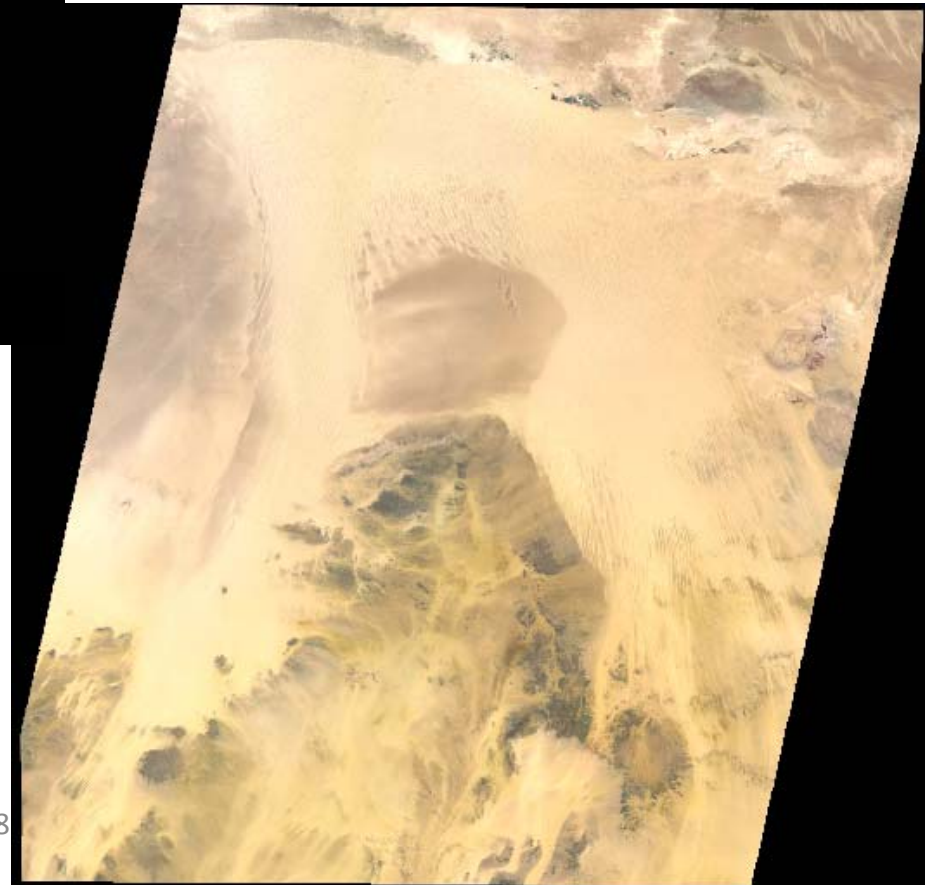
Libya-4 CEOS site Calibration



Terra MODIS

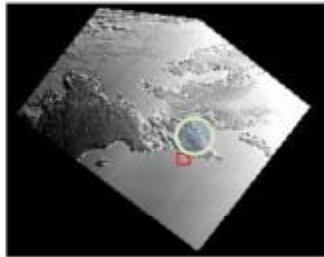


AWIFS sub-regions

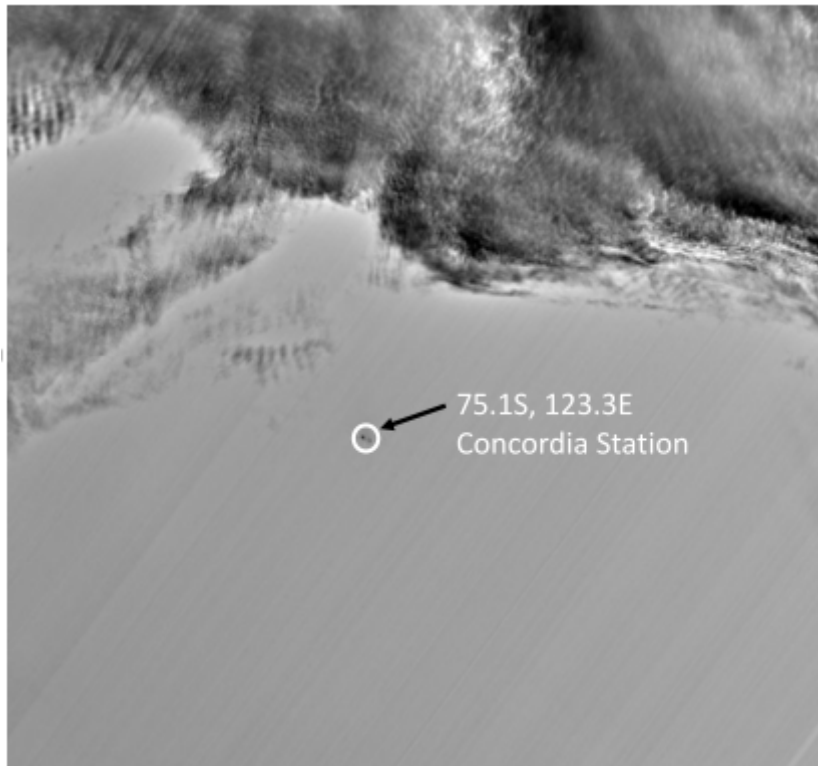


DOME-C CEOS site Calibration

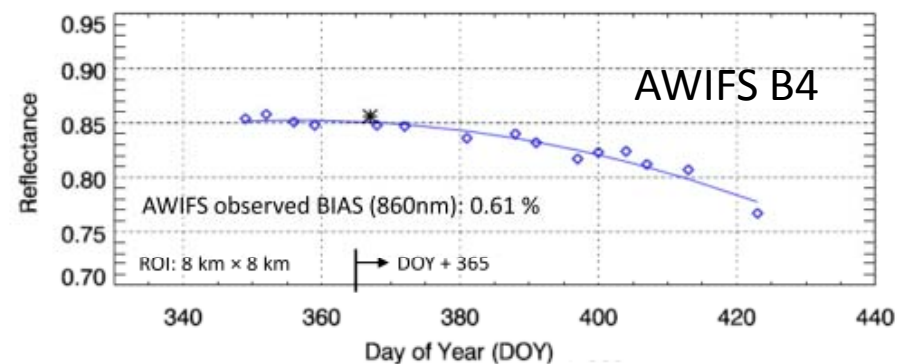
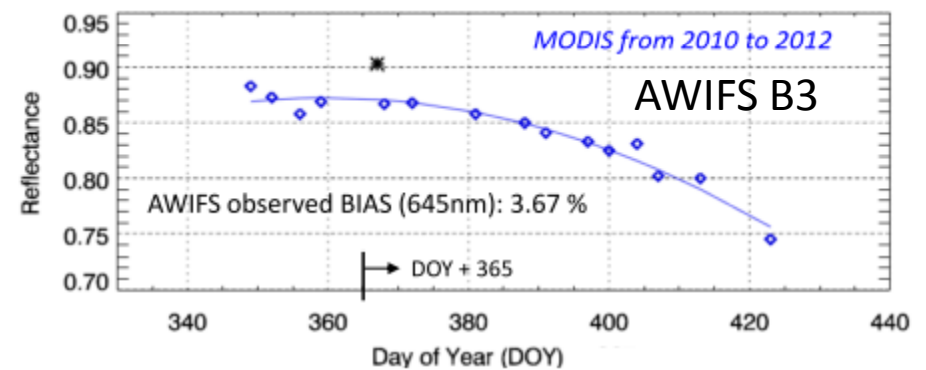
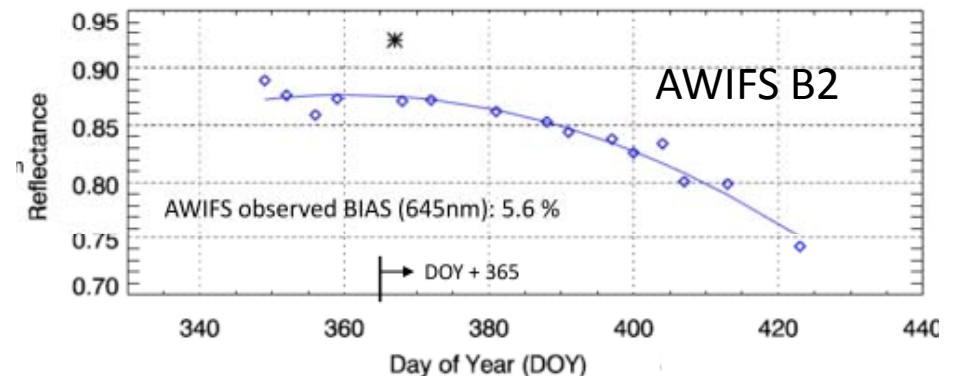
2-JAN-2012



AWIFS

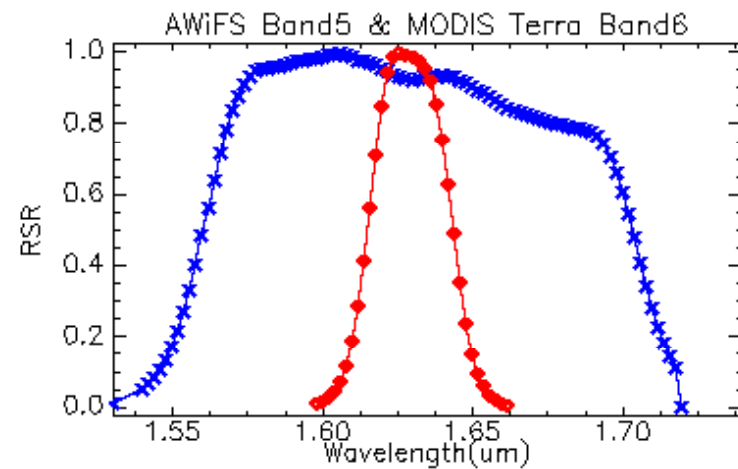
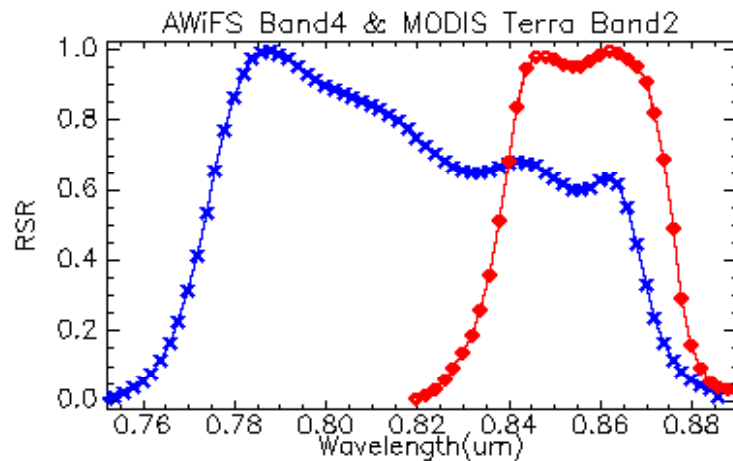
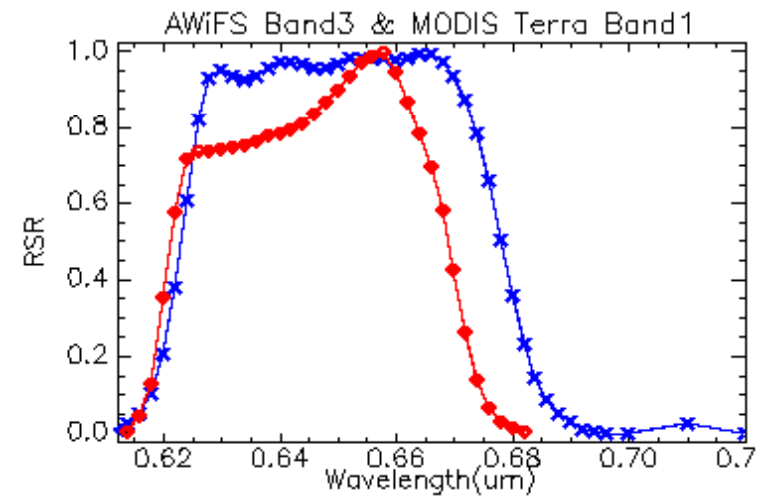
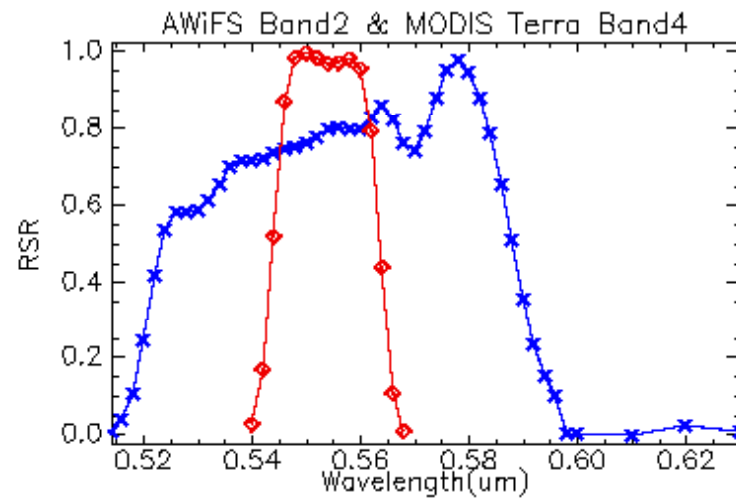


Out of 4 scenes collected between Dec.11-Jan-12, only one could be used for cross calibration for reasons of clouds



Spectral Bandpass Variations

RS2 AWIFS vs. MODIS



Spectral Variations Impact

Sensor:	AW-B2/Mo-B4	AW-B3/Mo-B1	AW-B4/Mo-B2	AW-B5/Mo-B6
MODIS: Esun	1880.1	1584.0	998.2	241.5
AWIFS: Esun	1854.3	1569.8	1092.9	239.0
(M-A)*100/M)	1.37%	0.90%	-9.48%	1.04%

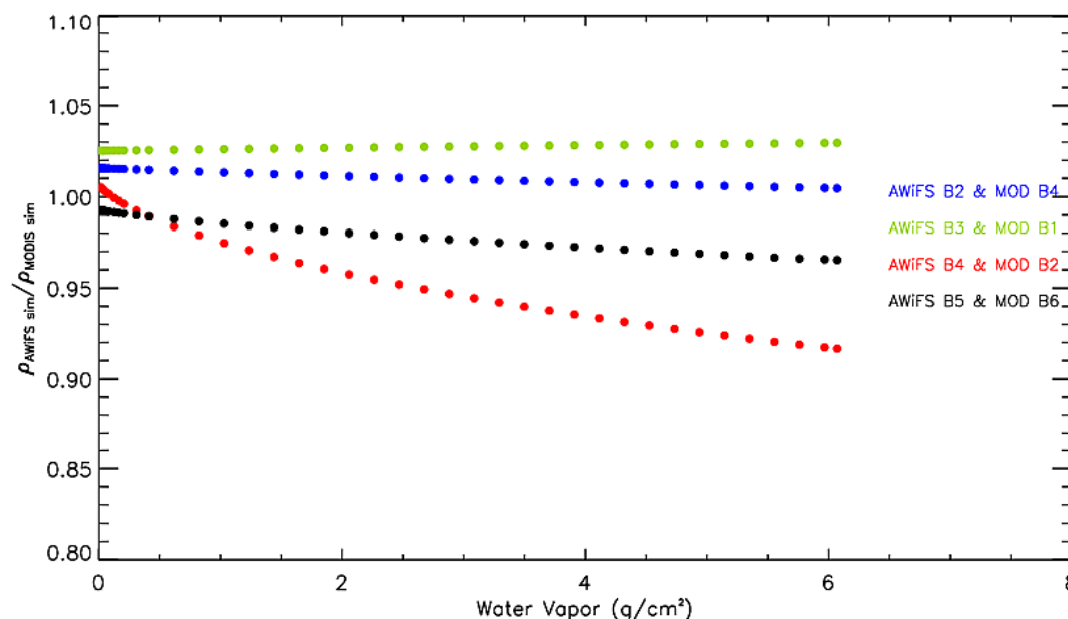
Simulation of **Water Vapor Impact on Spectral band reflectance** (using MODTRAN-5 for mid-latitude atmospheric profile)

AWIFS B2 & MOD B4

AWIFS B3 & MOD B3

AWIFS B4 & MOD B2

AWIFS B5 & MOD B6



Spectral Biases of RS2 AWIFS with MODIS

Spectral Biases (%) between RS2 & MODIS bands $\{(1 - \text{RSR}_{\text{MODIS}} / \text{RSR}_{\text{AWIFS}}) * 100\}$

Site	AWIFS_B2	AWIFS_B3	AWIFS_B4	AWIFS_B5
Arabia-1	4.47 %	1.73 %	-7.60 %	-2.26 %
Algeria-3	3.29 %	1.38 %	-6.04 %	-1.45 %
Libya-4	1.47 %	1.36 %	-8.38 %	-2.25 %
Niger-1	3.10 %	1.75 %	-8.91 %	-2.45 %
Algeria-5	5.12 %	1.80 %	-7.75 %	-2.81 %
Thar*	1.29 %	0.37 %	0.760 %	0.142 %
DOME-C	0.75 %	2.11 %	0.11 %	0.16 %

*based on ground measurement reflectance data at Lanela site
Other sites are results of Hyper-ion reflectance data over the sites

Supposedly highly consistent in terms of radiometric stability

Some Preliminary Results*

Sitename	% Difference with MODIS bands					Std.dev			
	Date	B2	B3	B4	B5	B2	B3	B4	B5
Arabia-1	2011127	1.928	-0.52	-13.297	-1.737	0.051	0.066	0.062	0.051
Egypt-2	2011138	6.758	4.785	-9.275	1.5	0.112	0.116	0.133	0.118
Algeria-3	2011138	1.984	0.077	-9.113	-2.603	0.014	0.017	0.016	0.002
Taklamakan	2011143	10.83	8.036	-4.194	2.913	0.109	0.081	0.075	0.054
Libya-2	2011156	17.168	17.231	1.816	9.41	0.11	0.093	0.111	0.147
Libya-4	2011157	10.959	7.681	-6.806	2.505	0.021	0.016	0.024	0.011
Niger-1	2011159	11.84	11.23	-3.461	6.566	0.083	0.084	0.103	0.073
Libya-2	2011161	9.183	13.155	1.274	11.09	0.174	0.171	0.2	0.192
Tuz Golu	2011163	7.193	6.109	3.437	6.096	0.342	0.375	0.332	0.306
Uyuni	2011166	-13.591	-17.439	-22.531	-12.207	0.28	0.291	0.234	0.191
Algeria-5	2011245	2.143	8.381	-3.079	-0.751	0.187	0.173	0.175	0.126

*before applying spectral bias adjustment factor (SBAF)

Summary of Cross-calibration Analysis

Observed Bias (M-A)*100 %

Site	DATE/YR	A-B2	A-B3	A-B4	A-B5
Arabia-1	2011127	-2.451	-2.623	-4.692	0.567
Egypt-2	2011138	-1.243	-1.306	-2.524	-1.113
Libya-4	2011157	9.654	6.430	2.145	4.699
Algeria-5	2011245	-2.868	6.736	4.915	2.083
DOME-C	2012002	-5.60	-3.520	-0.360	---
Thar	2011-12	-2.676	-3.894	-2.231	-2.446

Still, further experiments are to be conducted to get consistent results across the CEOS sites and for temporal stability

Thank you for your kind attention