Indian CAL-VAL Activities

- *Present and Future*

A. Senthil Kumar
NRSC, ISRO

Indian Imaging Capability

1988/91
IRS-1A & 1B
LISS-1&2

1990
INSAT-1D
VHRR

1992
INSAT-2A
VHRR

1993
INSAT-2B
VHRR

1995/97 IRS-1C/1D LISS-3, PAN & WiFS

1996 IRS-P3 WiFS, MOS X-Ray

1999
INSAT-2E
VHRR, CCD

1999
OCEANSAT-1
OCM & MSMR

2001 TES
Step& Stare
PAN

2002 KALPANA-1
VHRR

2003 INSAT-3A
VHRR,CCD

2003
RESOURCESAT-1
LISS 3; LISS 4; AWiFS

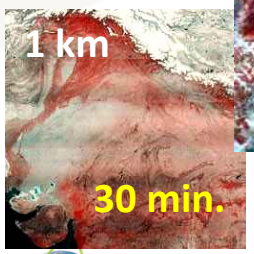
2005 CARTOSAT-1 PAN, F/A

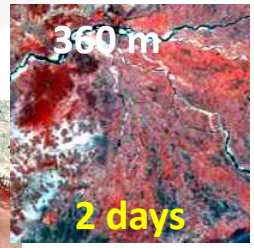
2007/ 08
CARTOSAT-2 & 2A
PAN

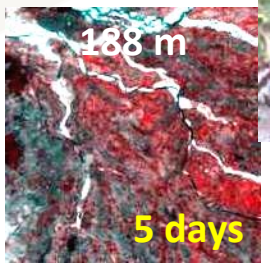
2009
RISAT-2
X-SAR

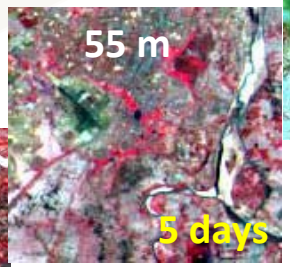
2009
OCEANSAT-2
OCM, SCAT & ROSA

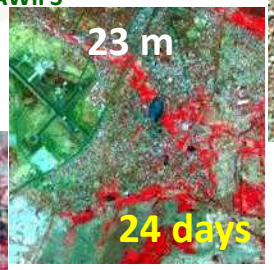
2011
RESOURCESAT-2
LISS-IV, III
AWiFS

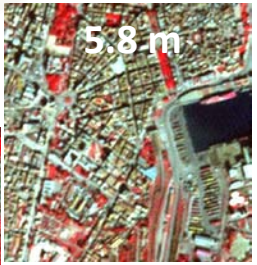


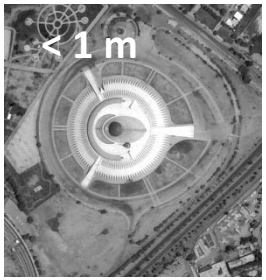


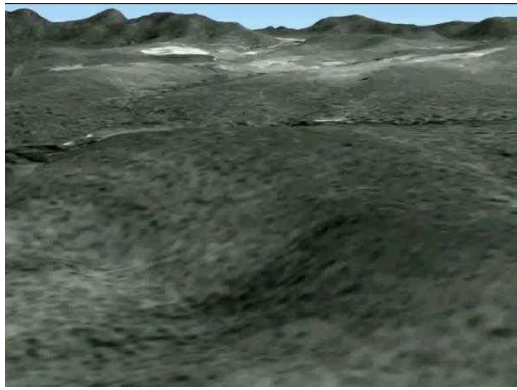




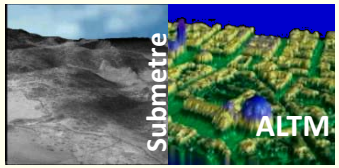








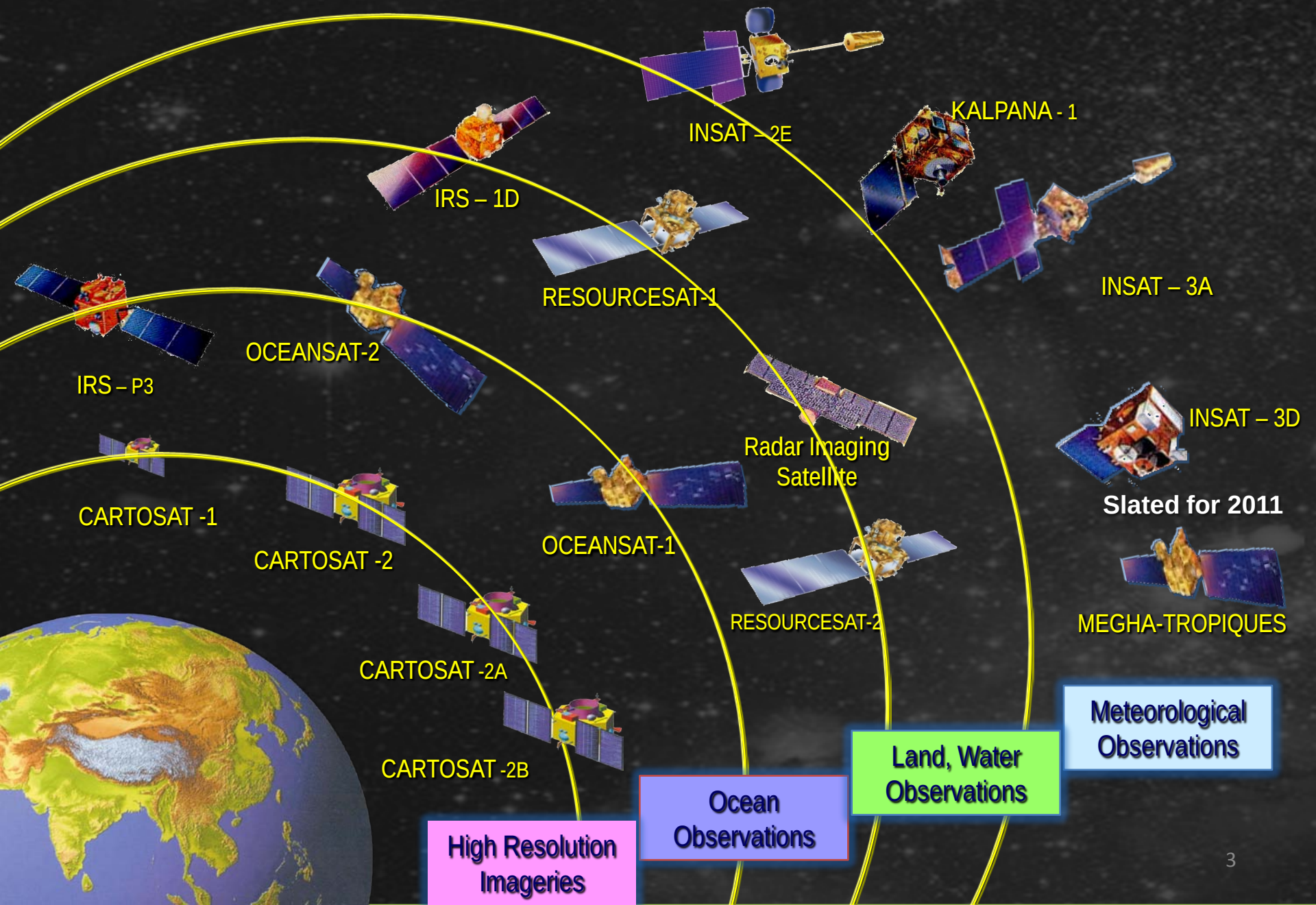
Aerial



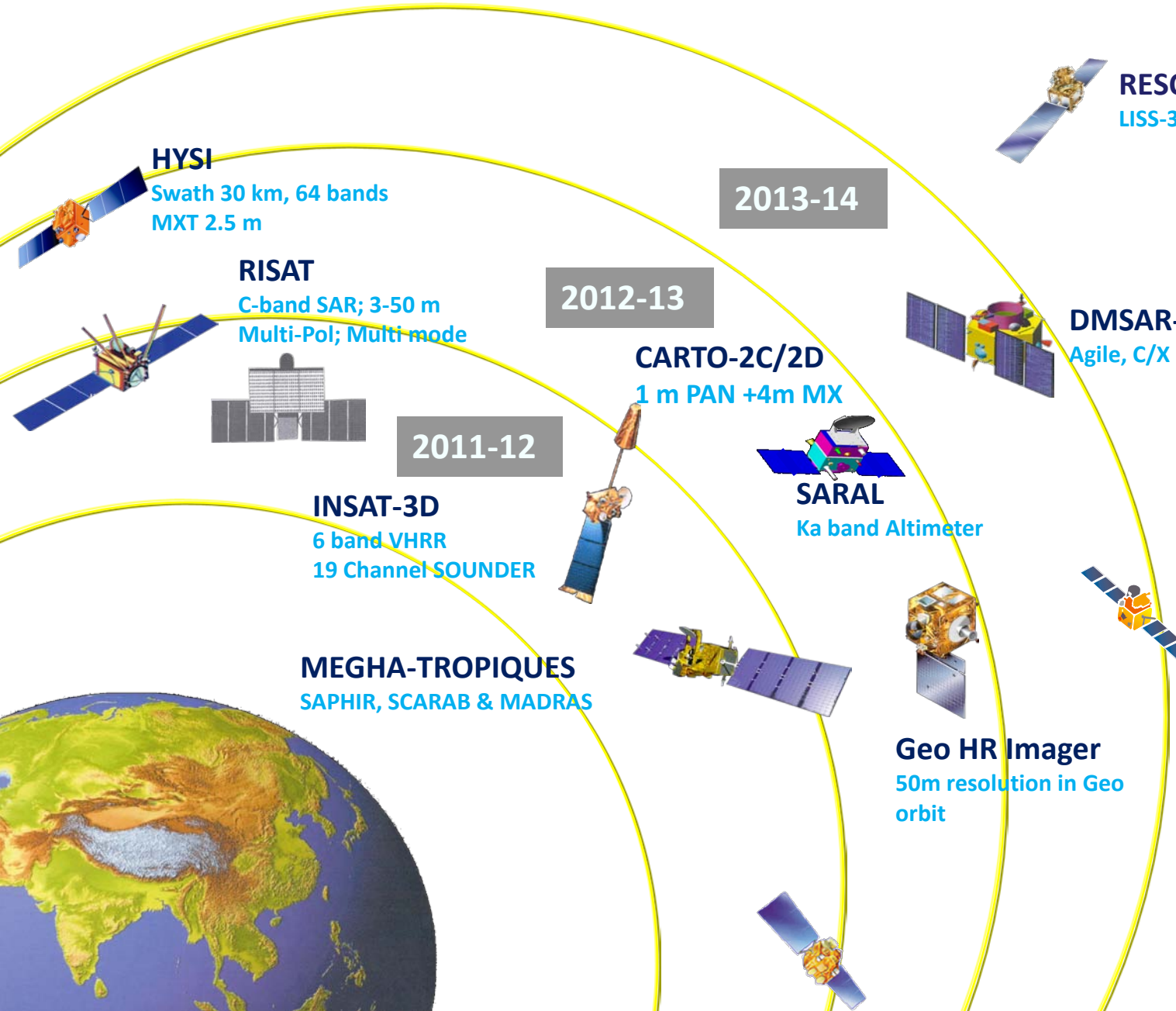
Digital Camera
Laser Terrain Mapper

A Valuable infrastructure in Space for monitoring NR & Environment

Indian Earth Observation Satellite Constellation



Indian EO Missions – 2012 & beyond



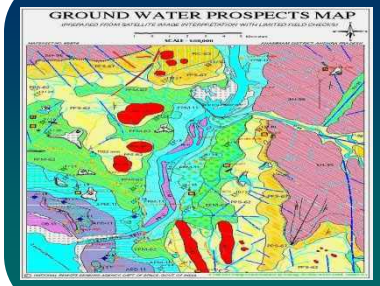
IMGEOS: Integrated Multi-mission Ground Segment for Earth Observation Satellites

Planning Solar Power Plant

EO Applications for Societal Outreach

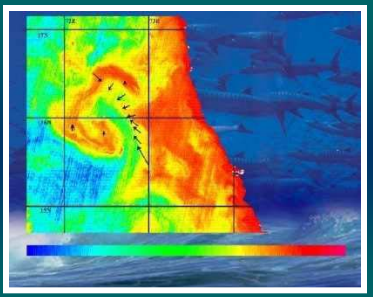
Agriculture

- National Wheat forecast - 27.25 Mha & 75.90 Mt
- Kharif Rice forecast - 35.66 Mha & 76.82 Mt



Drinking Water

- Prospective groundwater zones
- >200,000 wells drilled, with >90% success
- 10 States covered; 17 more taken up



Fisheries

- Potential Fisheries Zone (PFZ) Forecast to > 300 Stations
- ~ 30,000 Users
- Enhanced fish catch with less effort

Wasteland mapping

- 55.27 Mha (17.45%) - 2003 estimates
- Desertification & land degradation assessment

Watershed Dev - Sujala

- 854 Micro-watersheds in Karnataka
- Support to Rain-fed area development
- World Bank to replicate in Sri Lanka, Africa

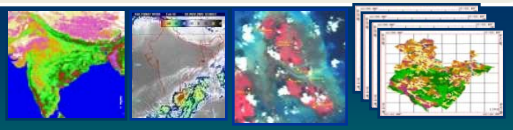
Monitoring Irrigated Commands

- Assessment of irrigation potential created using high-res data
- 5.4 Mha in 18 States

Networking, Early Warning [CWDS, IOTWS, INFFRAS, ..]

Disaster Management Support (DMS) System

CEOS - WGCV / WGISS Joint Meet, Sept. 24-28, 2012, NRSC (ISRO), Hyderabad



NDEM, Hazard Zonation, Risk Assessment, ...

Capacity building

CSSTE-AP

INDIAN INSTITUTE OF REMOTE SENSING, DEHRADUN

SPACE APPLICATIONS CENTRE, AHMEDABAD

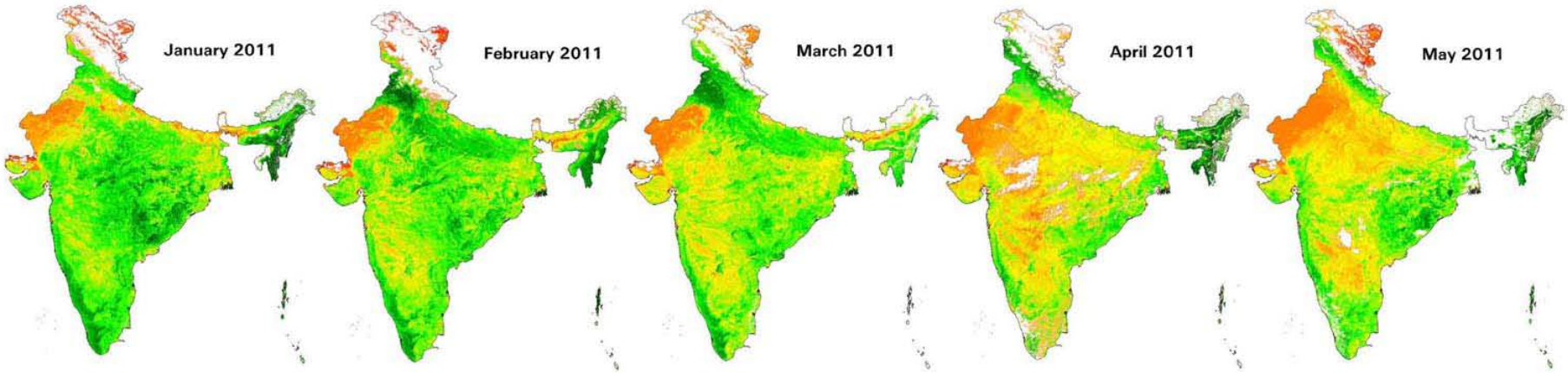
PHYSICAL RESEARCH LABORATORY, AHMEDABAD

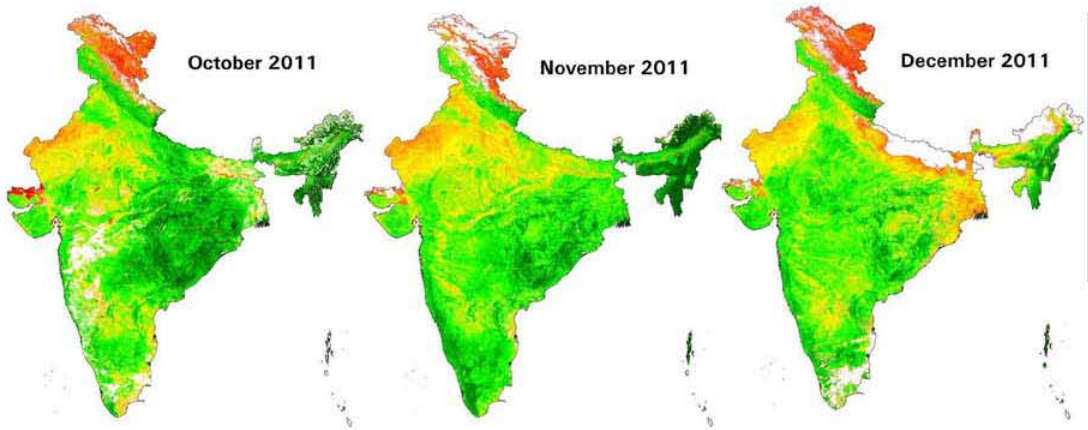
- United Nations Centre for Space Science & Technology Education in Asia & the Pacific (CSSTE-AP) established in India for benefitting Asia Pacific Countries in Space Technology
- Offers 10 Months Post Graduate Courses in:
  - Remote Sensing & GIS
  - Satellite Communications
  - Satellite Meteorology
  - Space Science
- So far 24 PG Courses and 19 Short-term Courses
- 900 participants from 31 Countries in this region
- 28 participants from 17 Countries outside this region

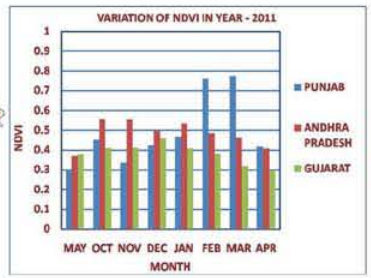
Indian Institute of Space Science & Technology

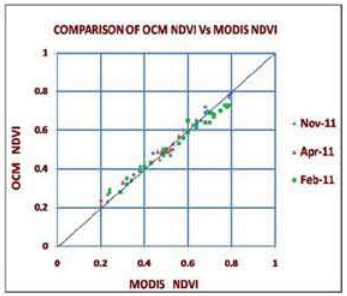
- Setup in September 14, 2007 under DOS, GOI
- The first professional Space University in India - the third in the World
- Offers programmes in Space Science and Space Technology in Aerospace Engineering, Avionics and Physical Sciences

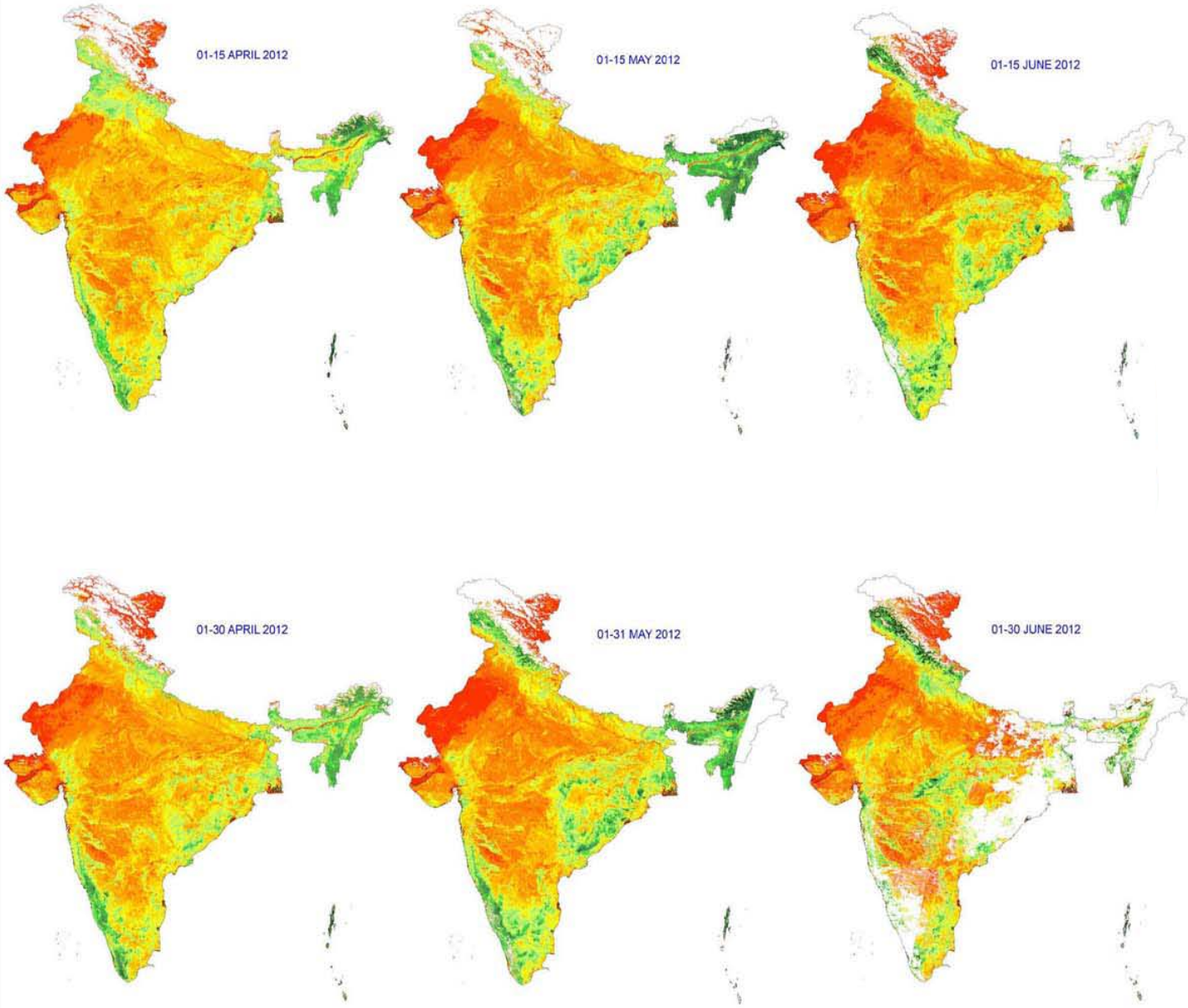
Vegetation Products from OCM



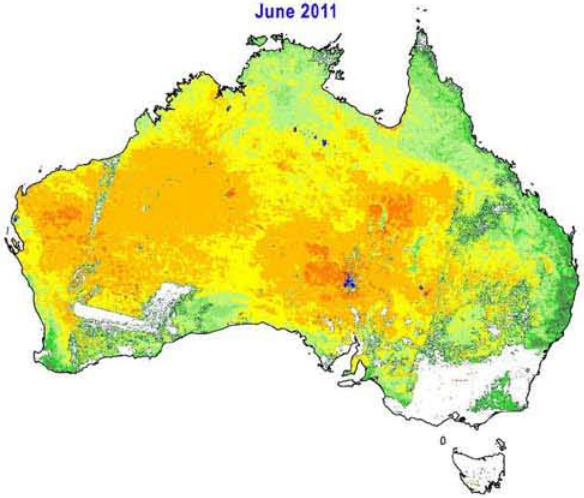


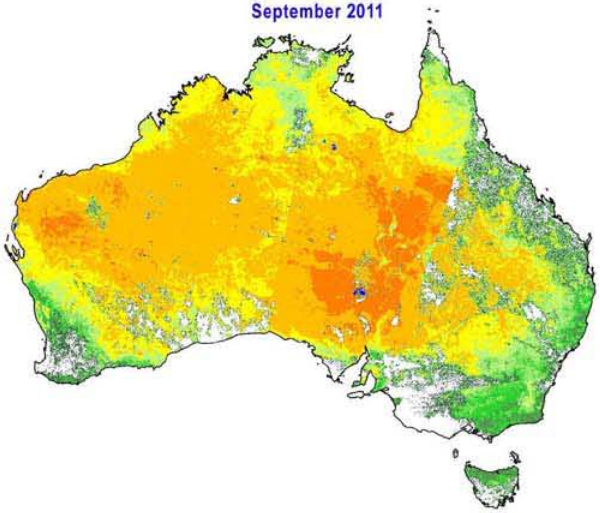


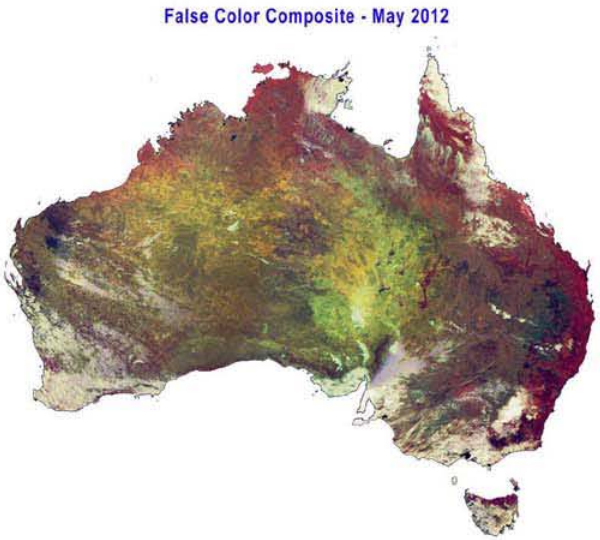


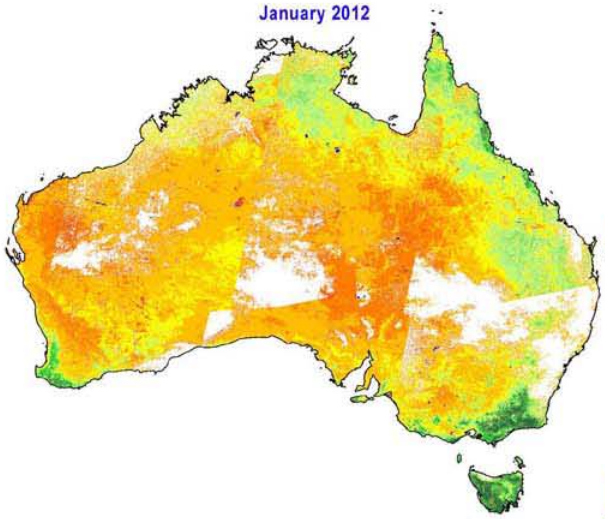

01-15 APRIL 2012
01-15 MAY 2012
01-15 JUNE 2012
01-30 APRIL 2012
01-31 MAY 2012
01-30 JUNE 2012
0
1
Cloud

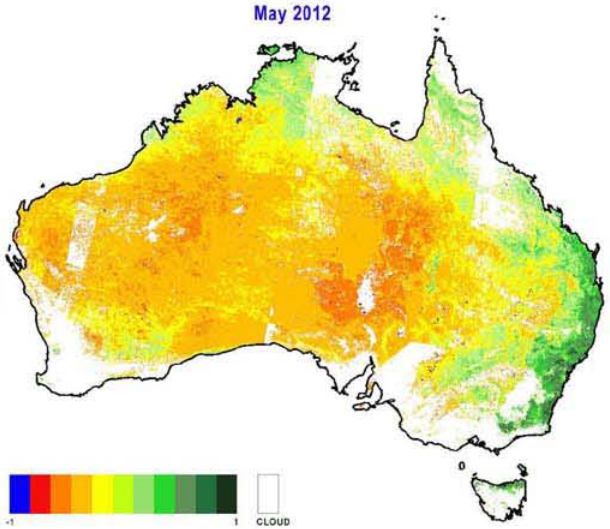
Seasonal NDVI Generation Covering Australia

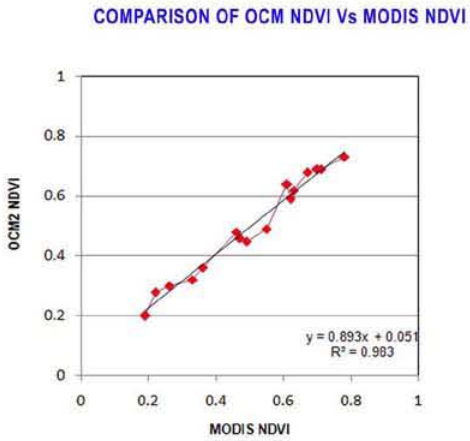






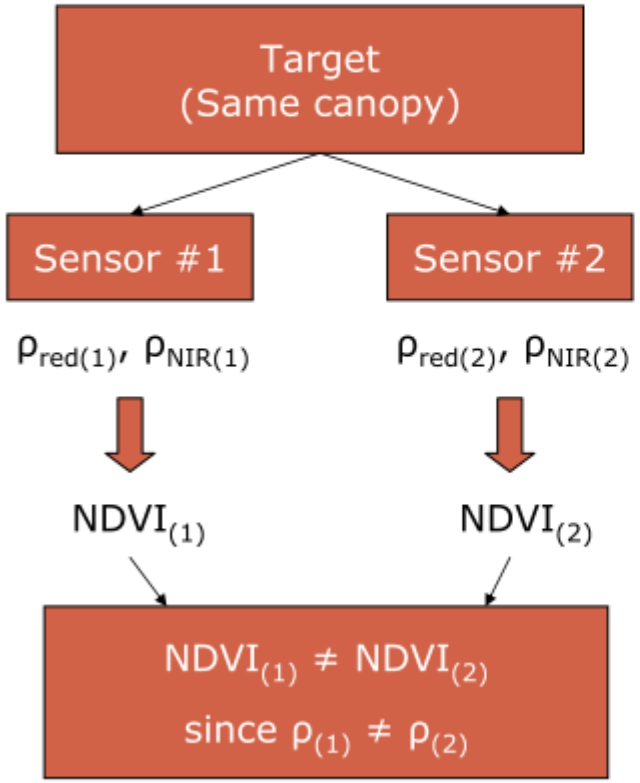






Impact of cross calibration on Information products

Multi-sensor Comparison

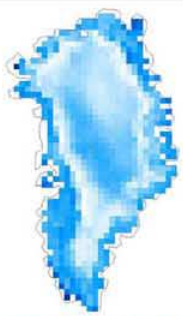


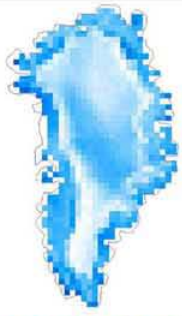
- Sensor/platform characteristics
  - Spectral bandpass
  - Spatial resolution
  - Radiometric resolution
  - Geometric registration
  - Sun-target-view geometry
  - Overpass time
- Algorithms
  - Radiometric calibration
  - Atmospheric correction
  - Temporal compositing
  - Cloud/snow masking

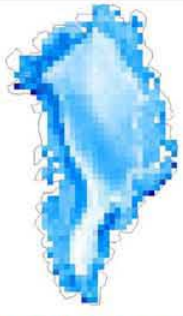
(Yoshioka et al., 2003; Miura et al., 2006; Swinnen & Veroustraete, 2008)

Monitoring of Greenland's Snow- Ice melt using Oceansat-2 Scatterometer

nrsc


20-JUN-2011


05-JUL-2011

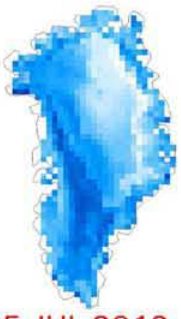

24-JUL-2011

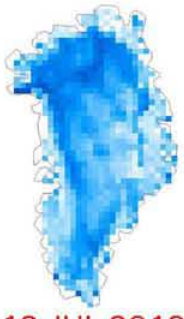

31-JUL-2011


07-AUG-2011

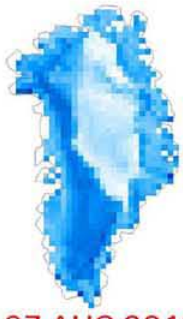

15-SEP-2011


20-JUN-2012

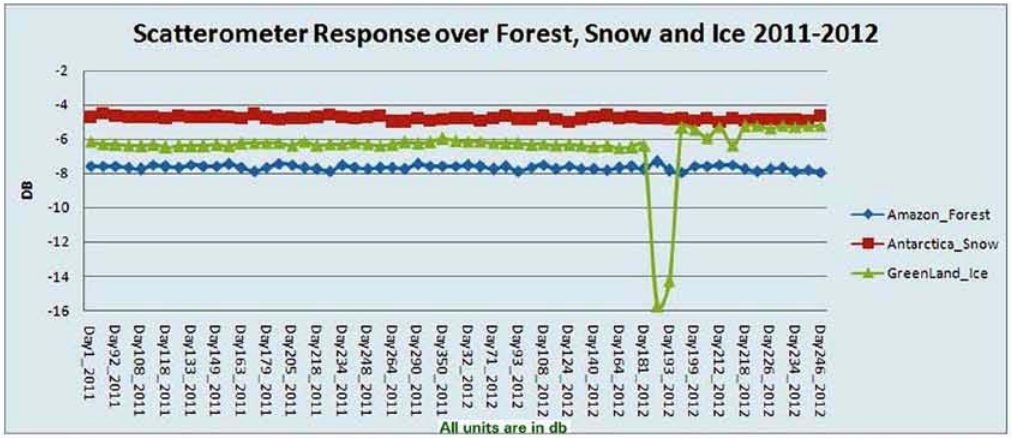

05-JUL-2012


12-JUL-2012


31-JUL-2012


07-AUG-2012


05-SEP-2012

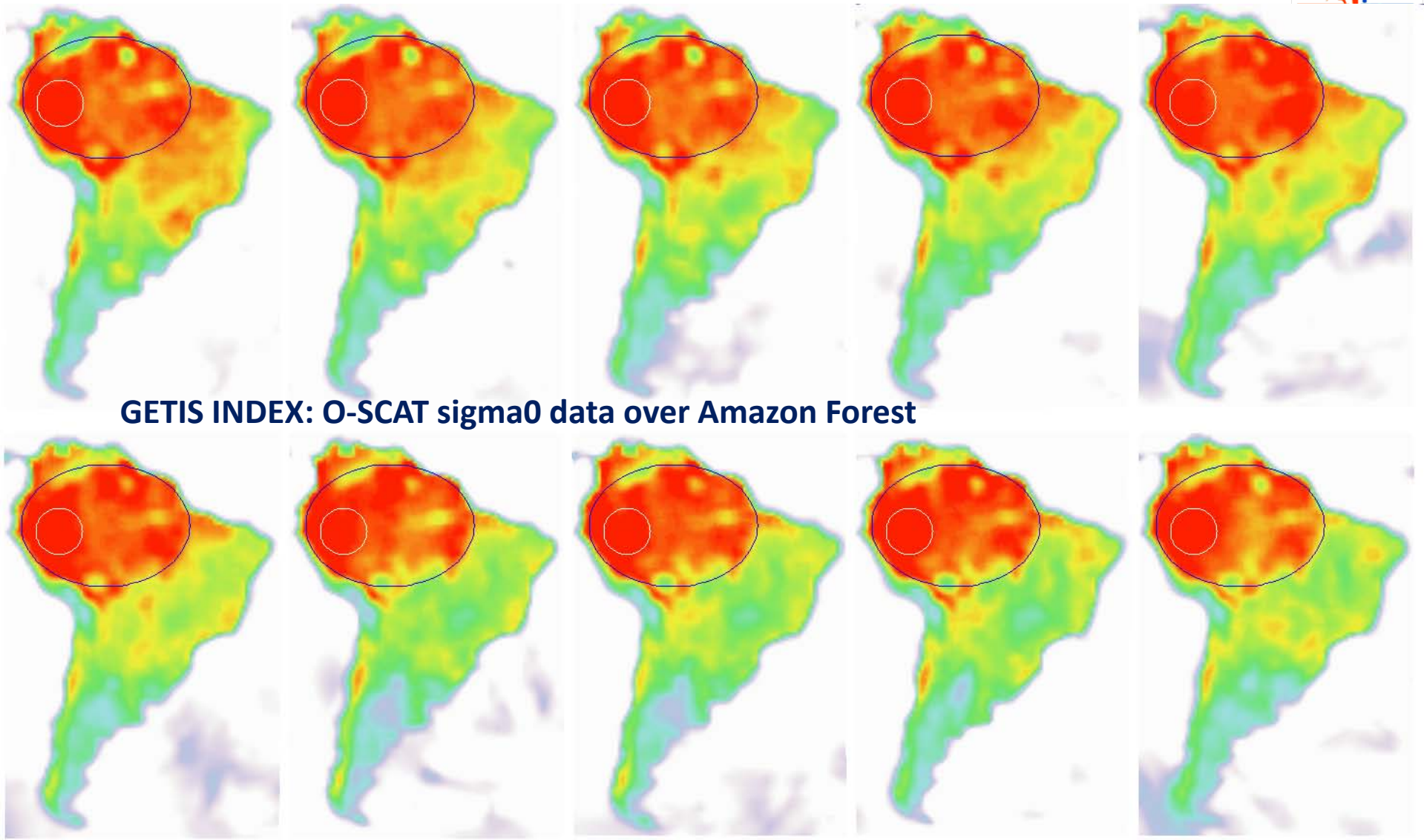


The above Pseudo color coded images are from Oceansat-2's Ku band Scatterometer(horizontal polarization)over Greenland for the year 2011 and 2012.The snow melting season in Greenland usually begins in June and lasts through early September.
Following observations were derived from the Oceansat's SCAT data. It can be seen most that of the thawing (40 to 97 %) occurred within a week (5-Jul-12 to 12-Jul-12). The graph represents sigma naught values over Amazon Forest,Antarctica and Greenland.
It is clear from the plot that sigma naught values over Greenland dropped from -4db to -16db during the above mentioned period which indicates the abnormal thawing of Ice sheet .
Greenland is back to normal within a week after.

www.nrsc.gov.in

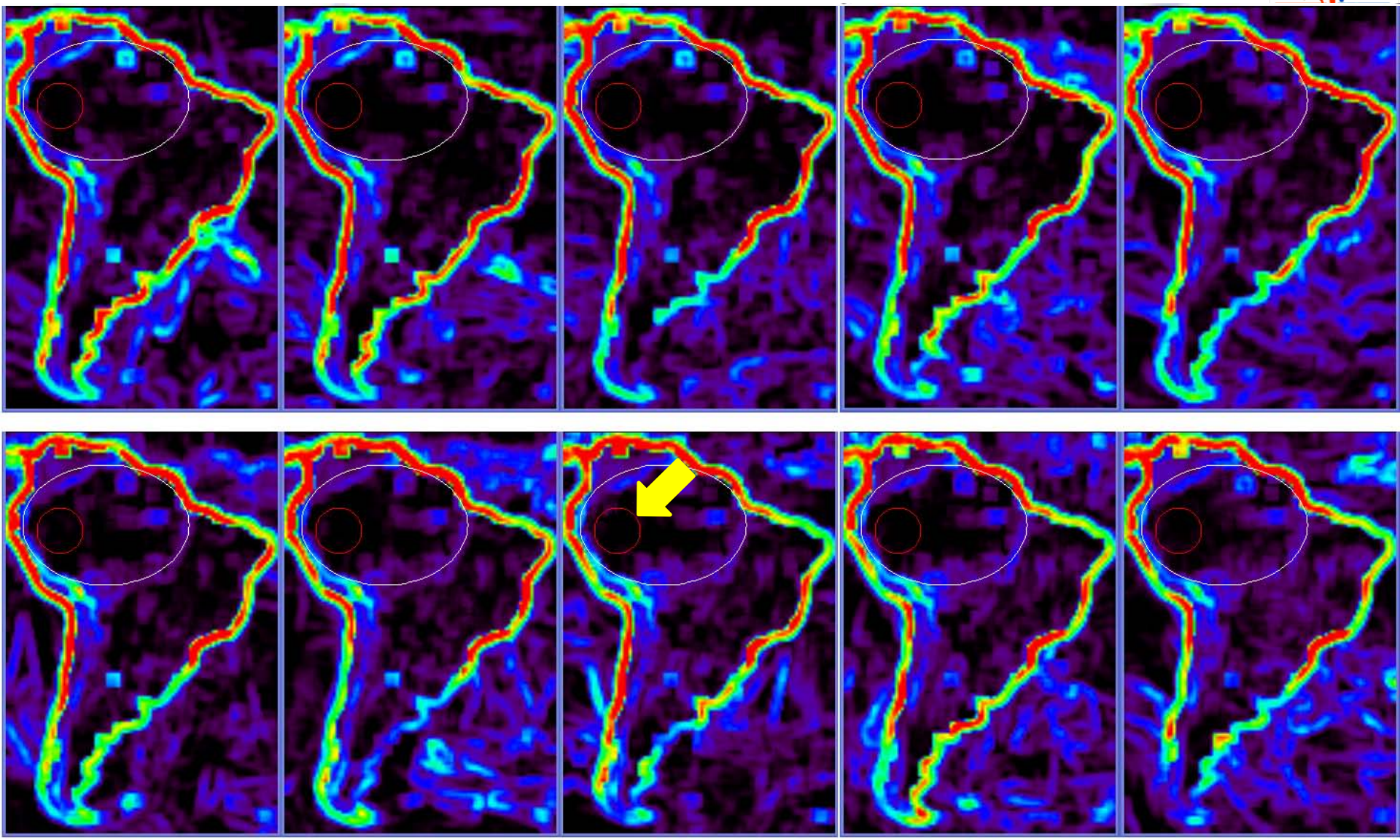
www.isro.gov.in

The Question of Spatial Homogeneity for Calibration



GETIS INDEX: O-SCAT sigma0 data over Amazon Forest

The Question of Spatial Homogeneity for Calibration

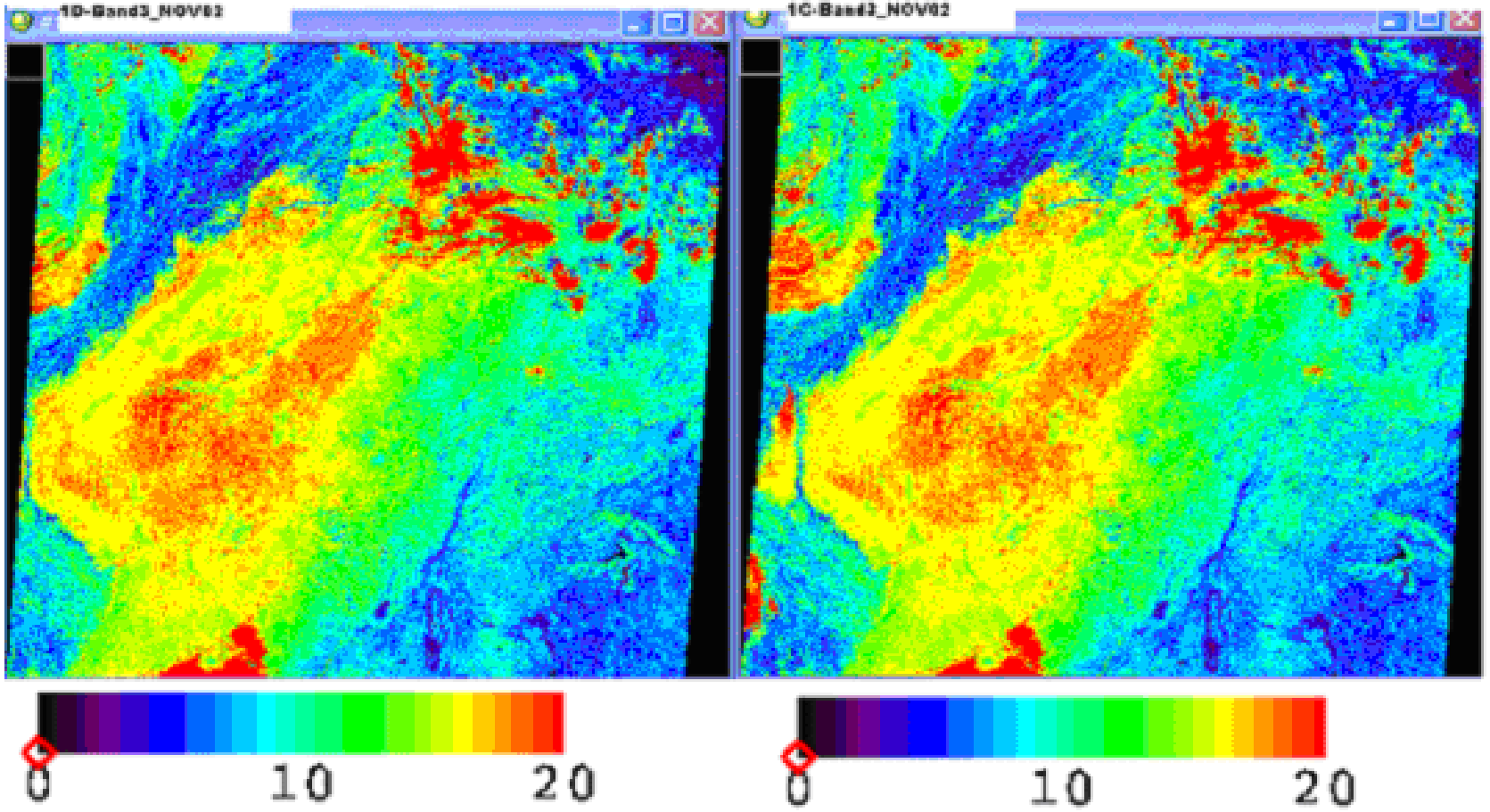


Spatial Invariance Analysis of WiFS over TD

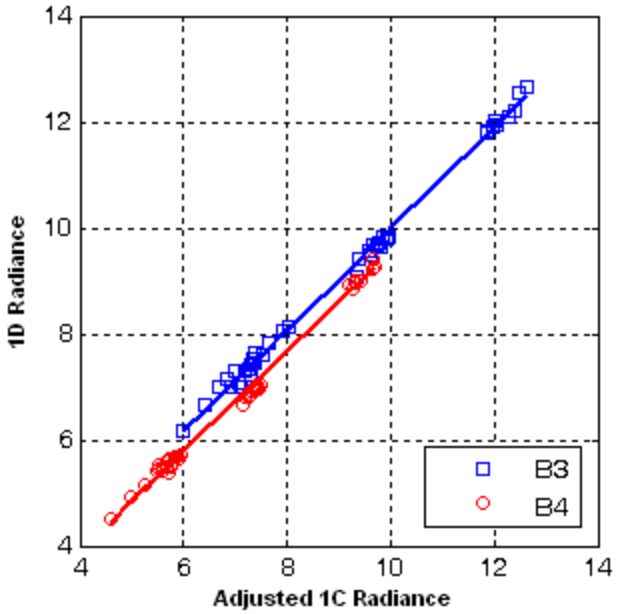
GETIS Statistics Images

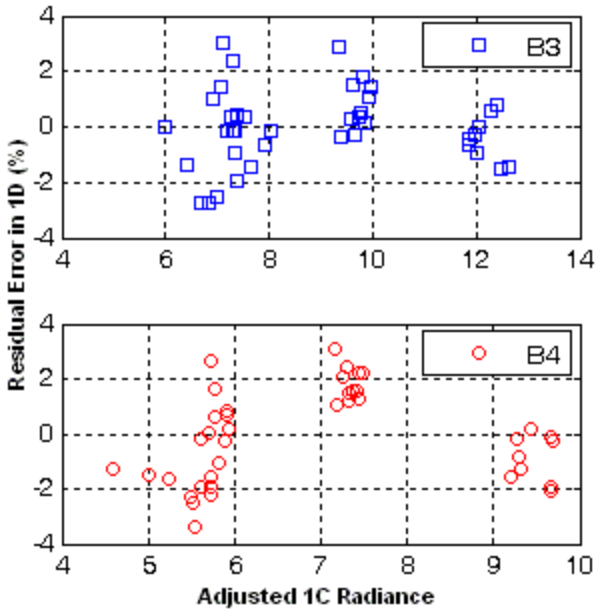
1D-Red Band (nov.2002)

1C-Red Band (nov.2002)



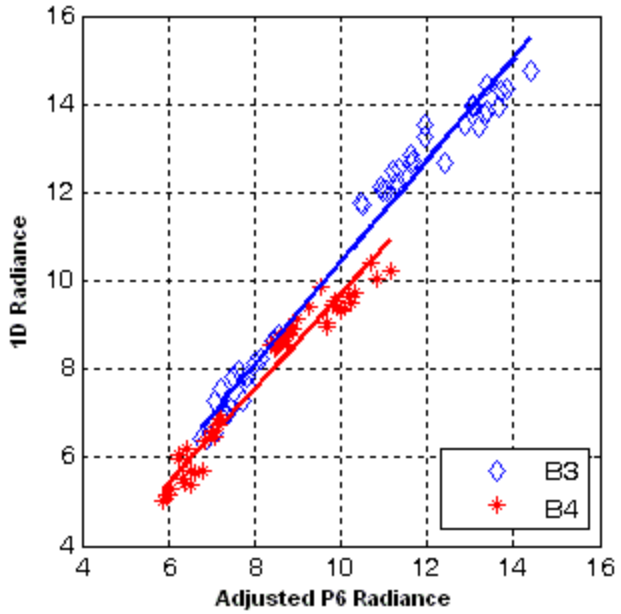
Results: 1C vs.1D (cal-set)

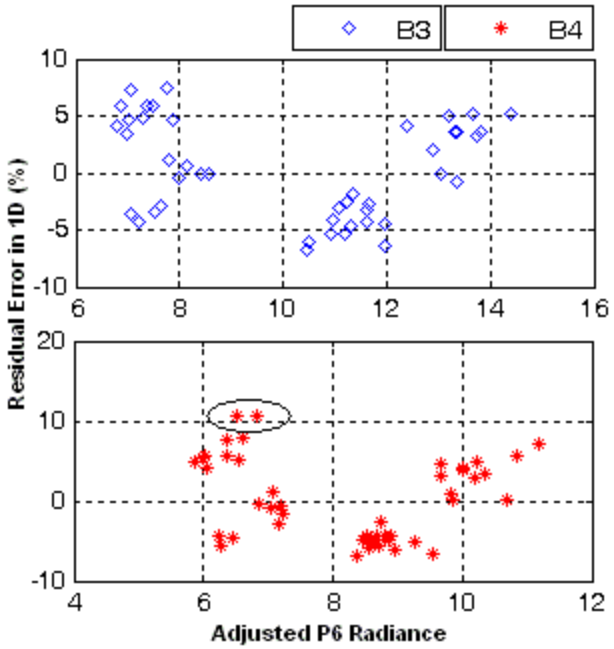




Model	Band	Fitted Equation	Goodness of-fit R^2	SSE after fit	SSE before fit	Gain Factor
with offset	B3	Y= 0.9558 X +0.4292	0.9966	0.5155	2.7688	5.371
	B4	Y= 0.9408 X +0.1318	0.9943	0.4938	1.0471	2.121
without offset	B3	Y =1.0011 X	0.9943	0.8774	2.7688	3.156
	B4	Y = 0.9989 X	0.9939	0.5270	1.0471	1.987

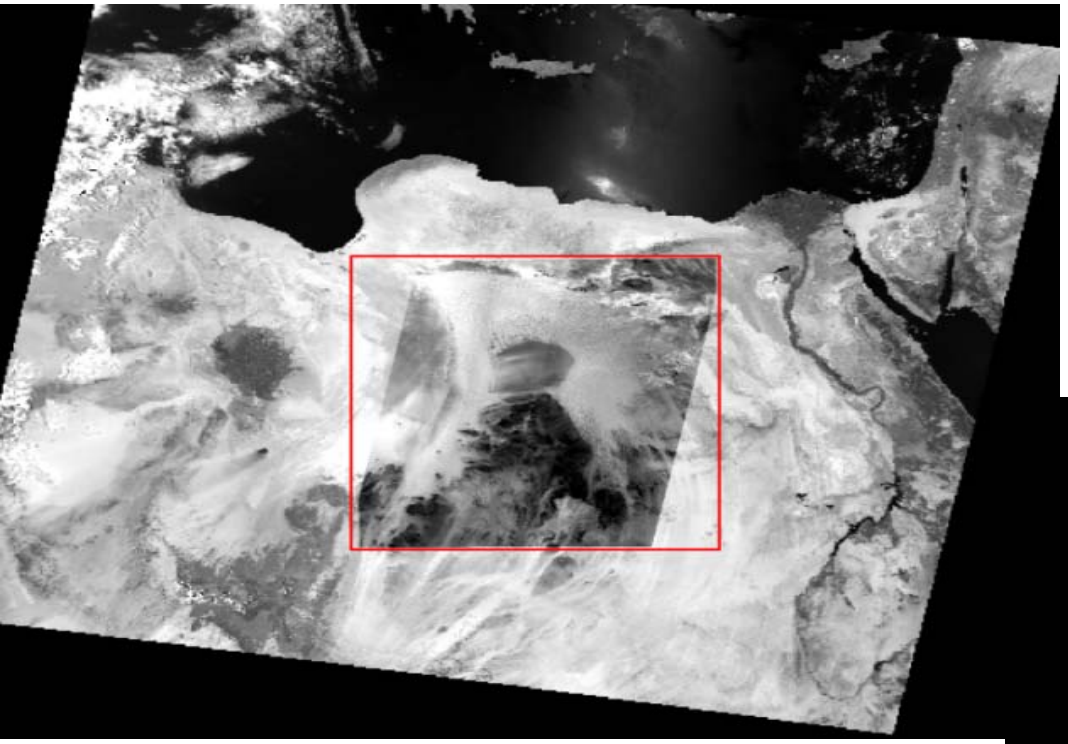
Results: P6 vs.1D (cal-set)

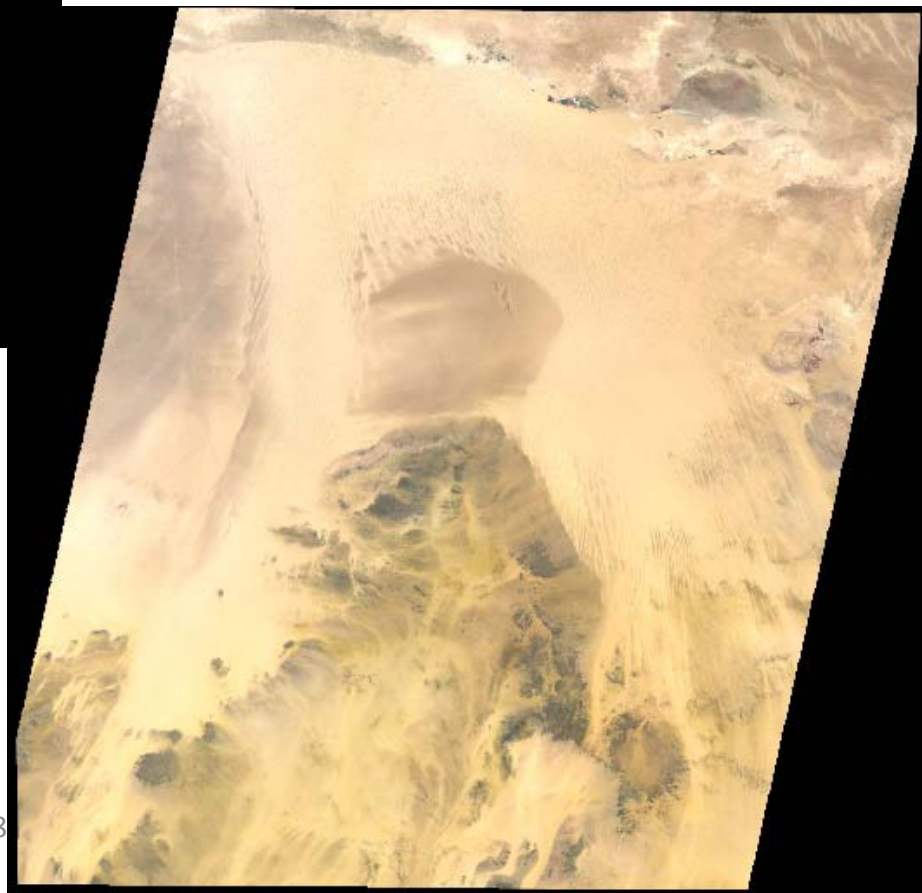


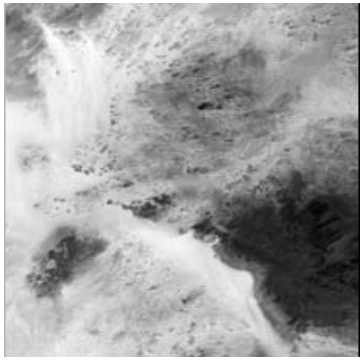


Model	Band	Fitted Equation	Goodness-of-fit R^2	SSE after fit	SSE before fit	Gain Factor
with offset	B3	Y=1.1574 X –1.1434	0.9762	9.236	12.977	1.405
	B4	Y=1.0697 X –0.9922	0.9509	6.581	12.207	1.855
without offset	B3	Y = 1.0520 X	0.9677	12.55	12.977	1.034
	B4	Y = 0.9533 X	0.9392	8.146	12.207	1.499

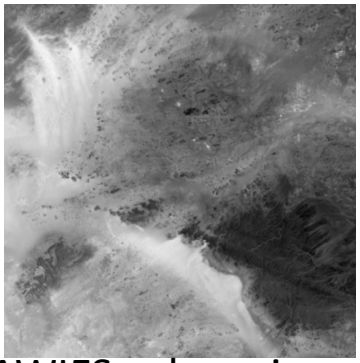
Libya-4 CEOS site Calibration







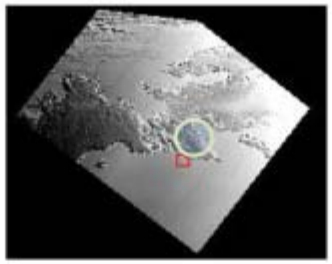
Terra MODIS



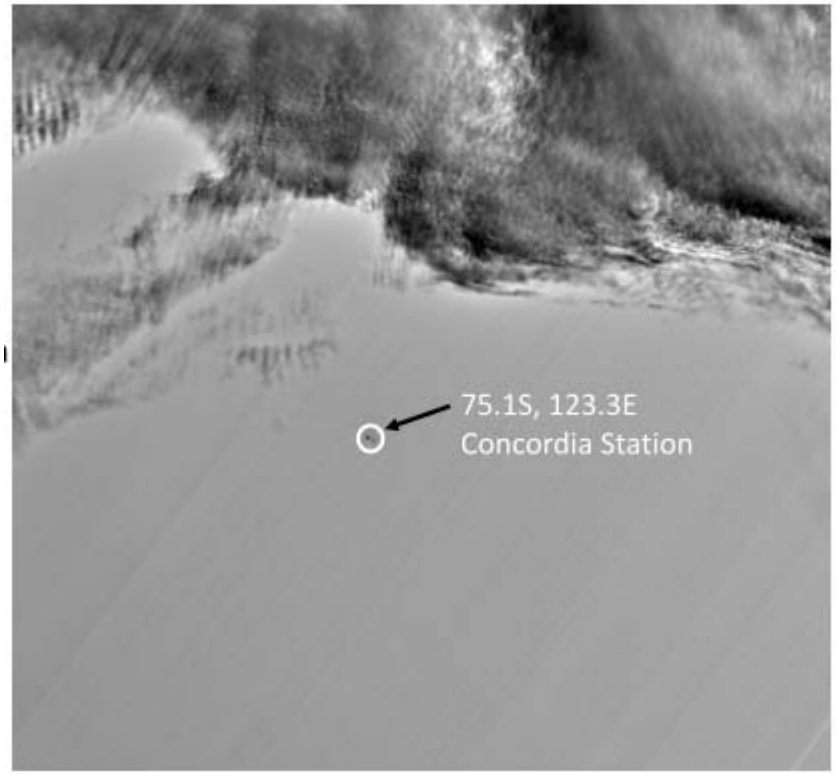
AWIFS sub-regions

DOME-C CEOS site Calibration

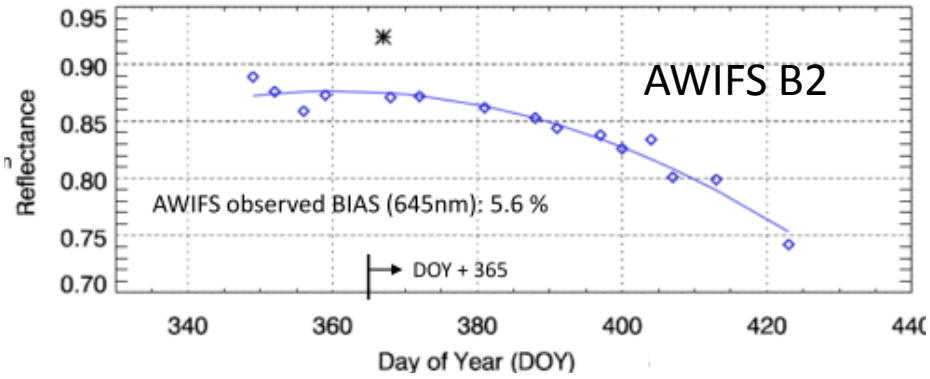
2-JAN-2012

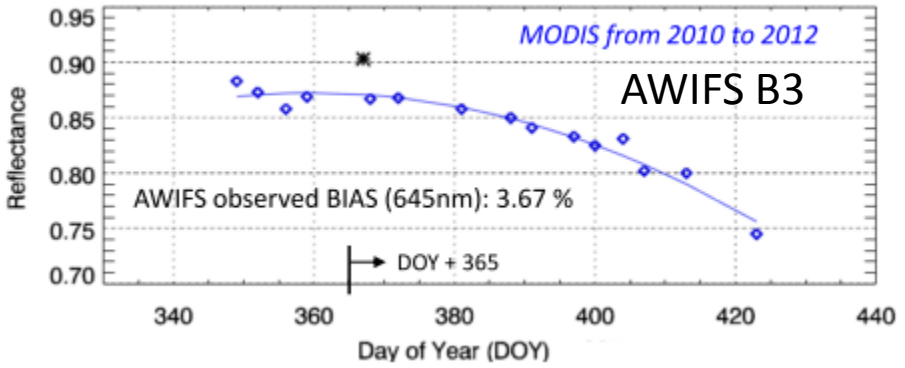


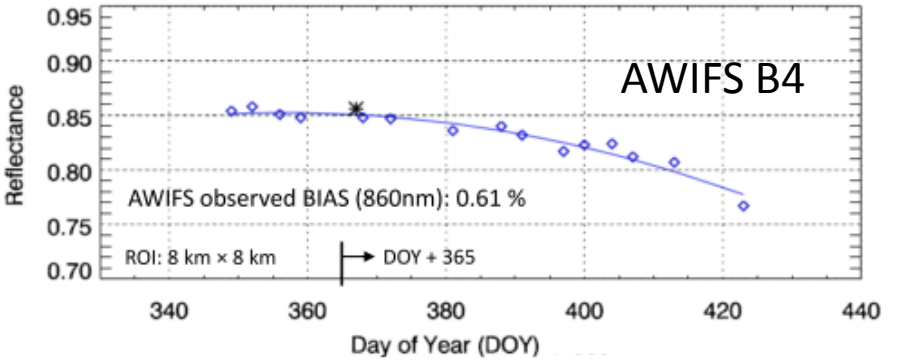
AWIFS



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

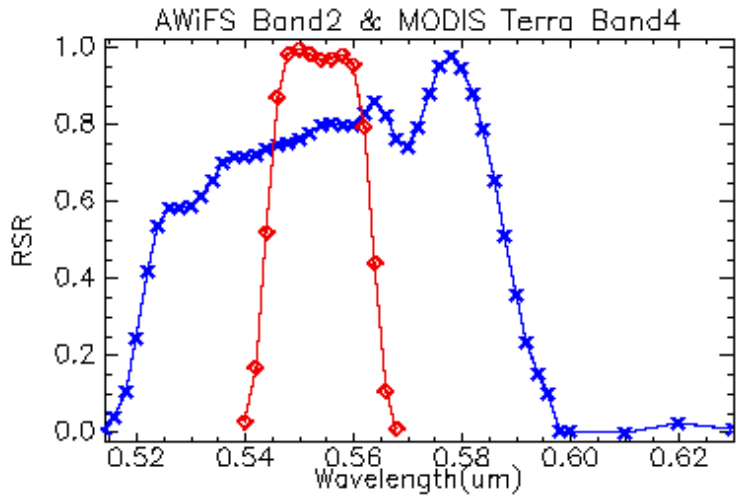


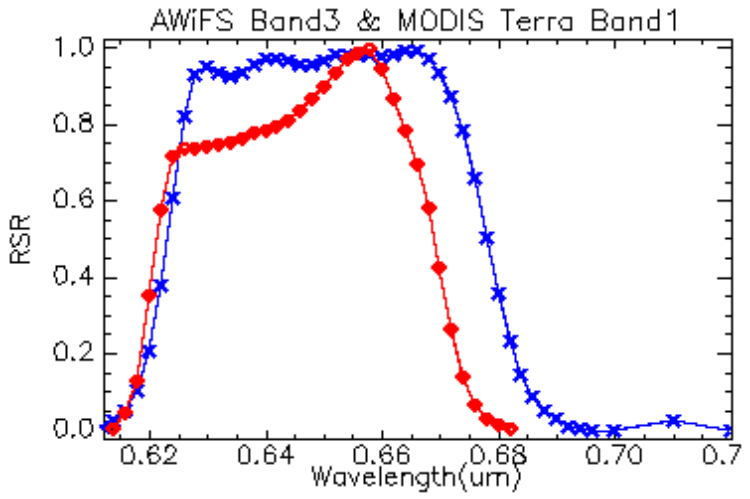


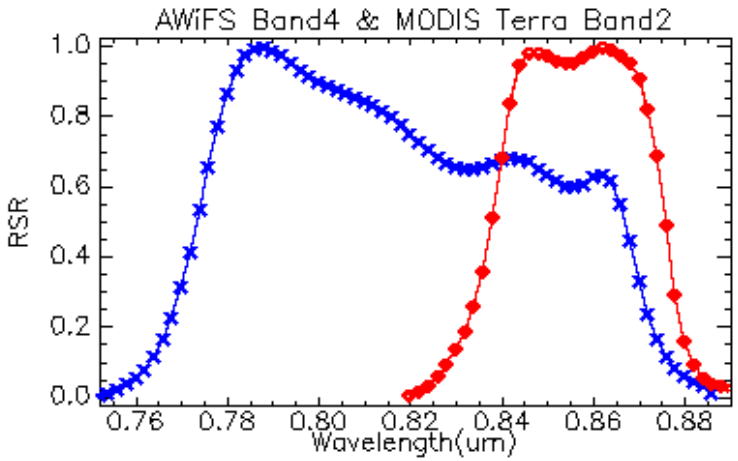


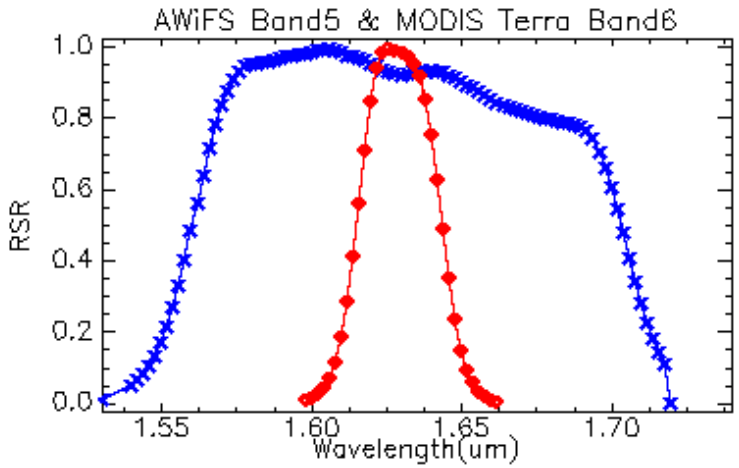
Spectral Bandpass Variations

RS2 AWIFS vs. MODIS





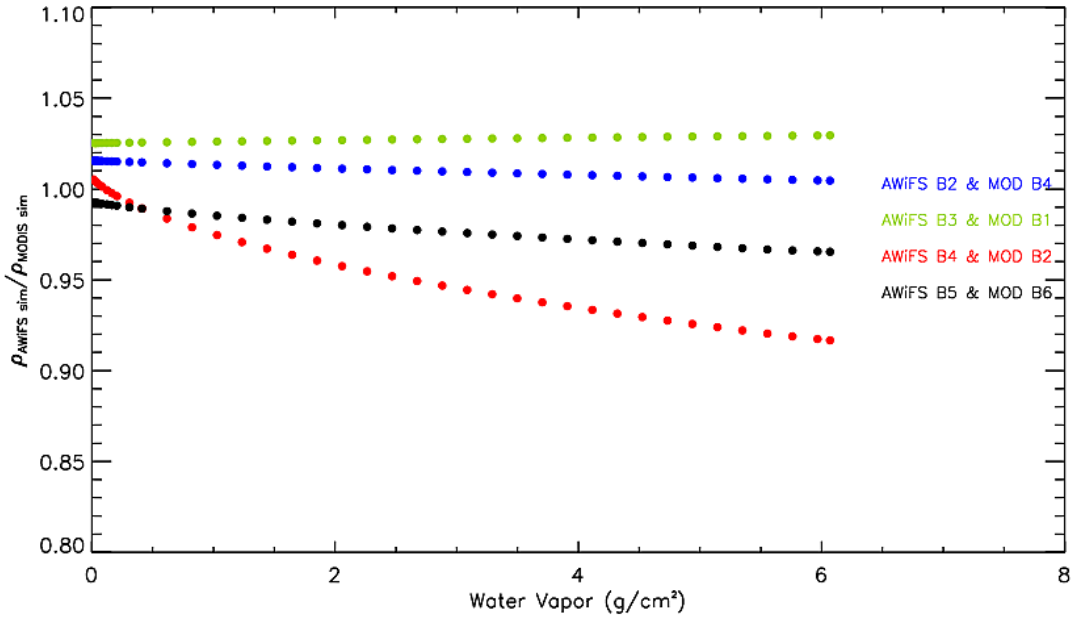




Spectral Variations Impact

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-RSR_{MODIS}/ RSR_{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

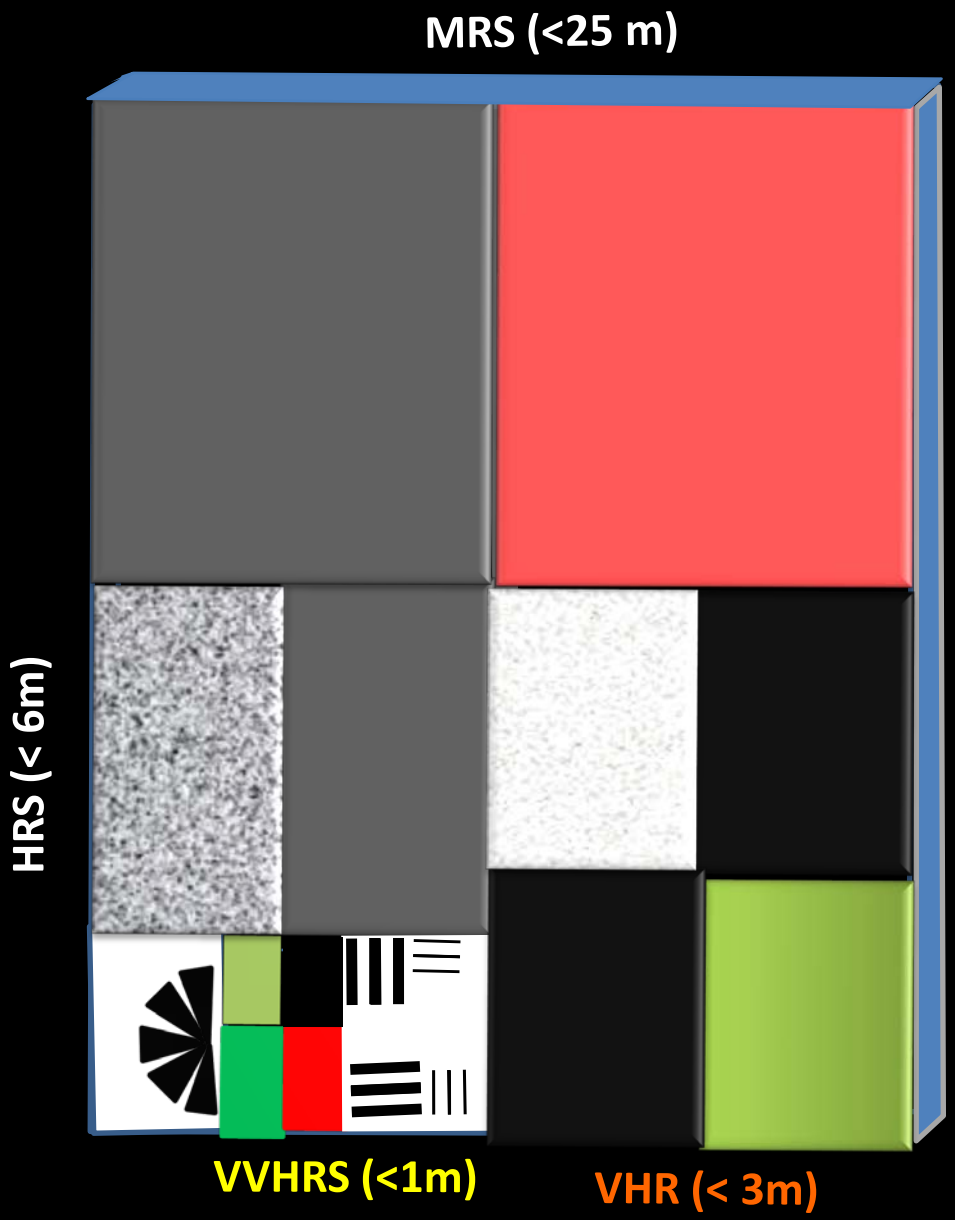
Supposedly highly consistent in terms of radiometric stability

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

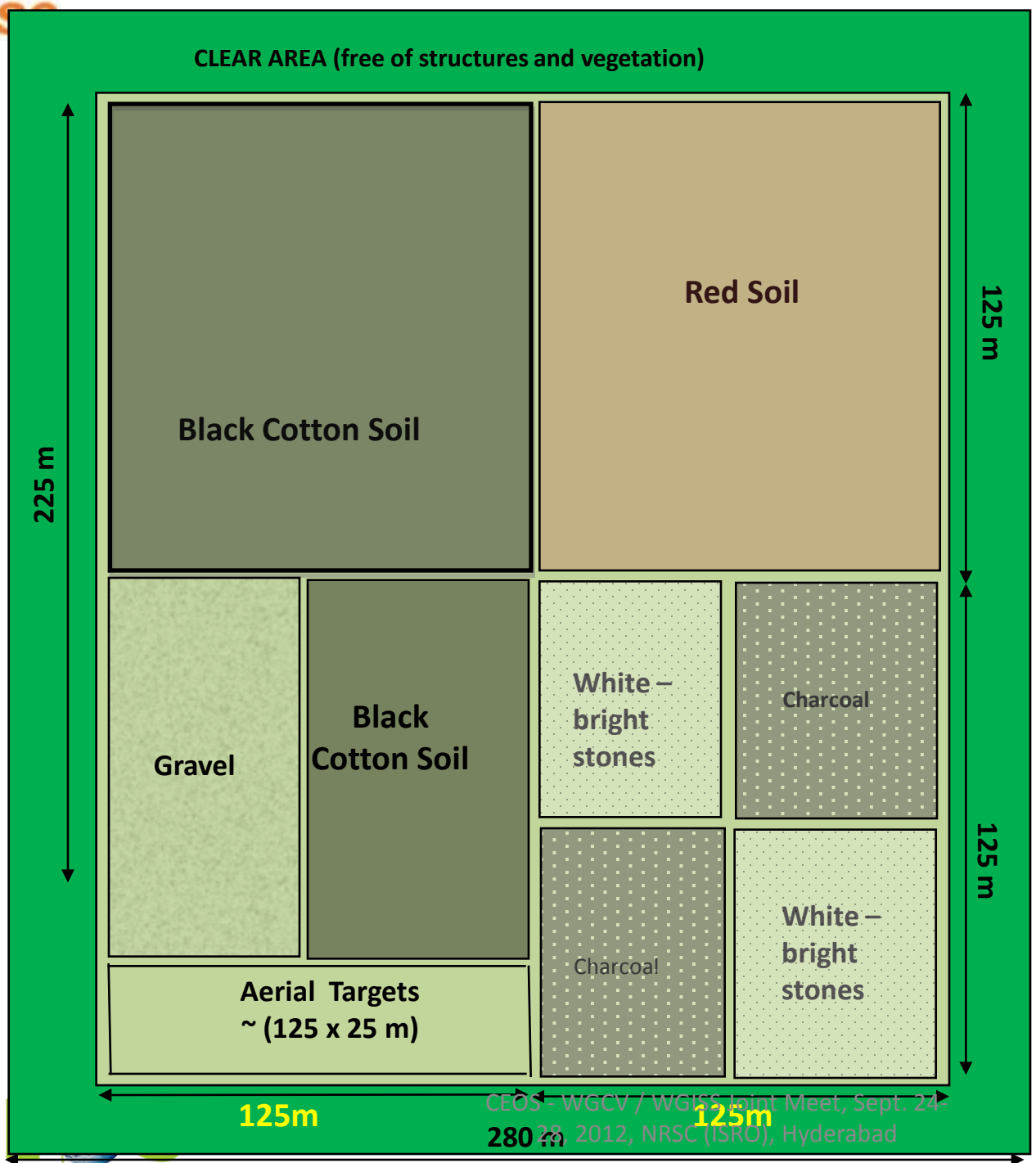


NRSC Cal-Val Site (to be ready by early 2013 at Shadnagar Campus

Aerial Survey and Digital Mapping
Remote Sensing & GIS Area
Satellite Data Acquisition & Product Services Area

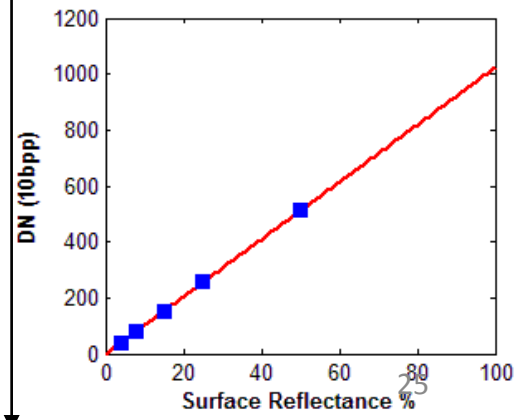
Scope:

- 5 cm to 25 m res. EO sensor calibration
  - Radiometry, Geometry, Height (<50cm)
- Aerial / Terrestrial LIDAR for above MSL
- Atmospheric – columnar & Near surface
- Microwave sensor calibration
- Meteorological - AWS
- GPS GCPs for Horizontal Control & Continuous Ops Ref. Station (CORS)

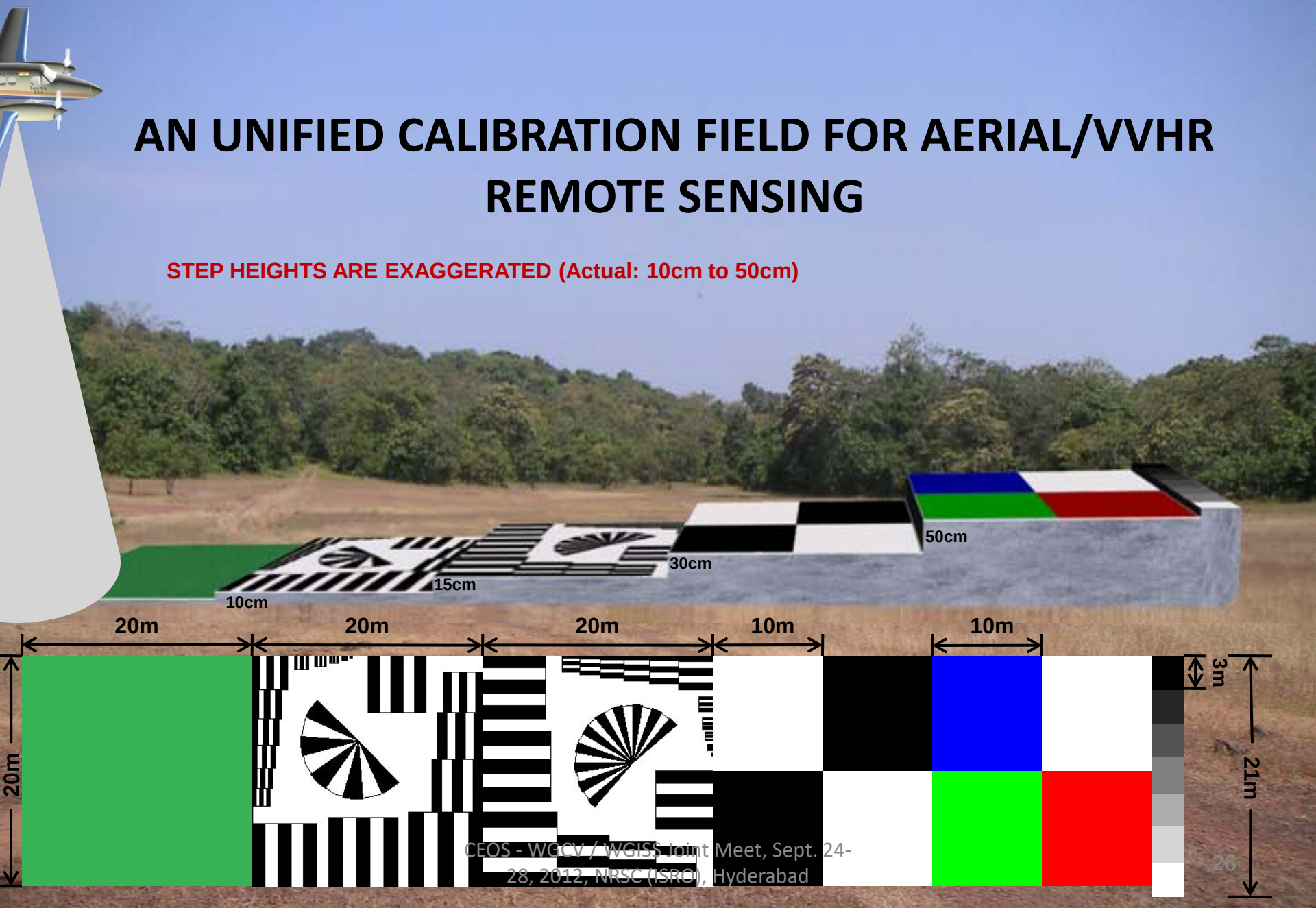


Radiometric Targets for Satellite sensor analysis

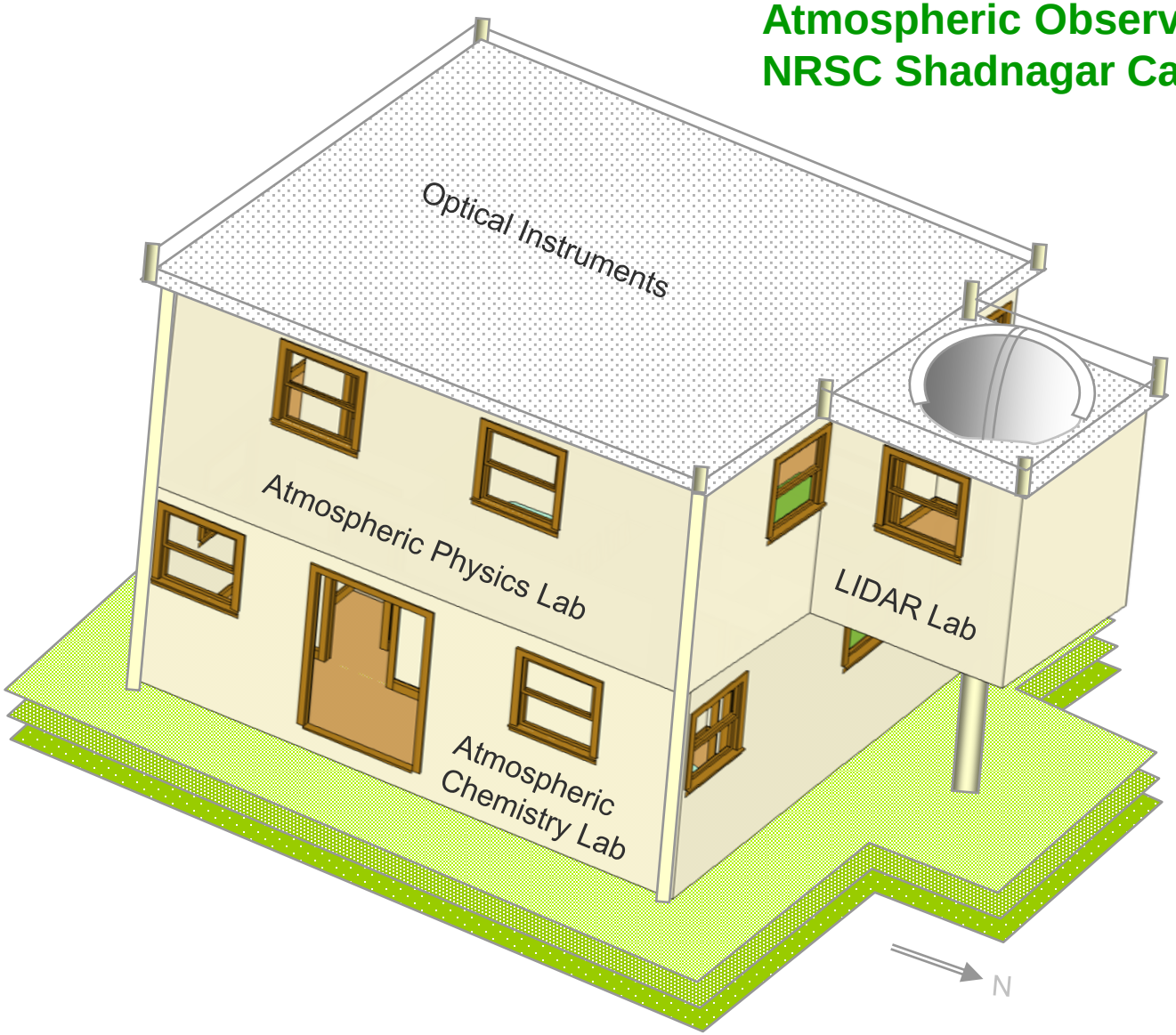
Sl. No	Type (typical Reflectance)
1	Charcoal (R)~4%)
2	Black cotton soil (R~8%)
3	Red soil (R~15%)
4	Gravel (R~25%)
5	White stones (R~50%)



AN UNIFIED CALIBRATION FIELD FOR AERIAL/VVHR REMOTE SENSING



Atmospheric Observatory at NRSC Shadnagar Campus



Atmospheric observatory to house various instruments for measuring trace and GHGs, Physical and Optical characterization of aerosols and Radiation.
BLL will operate in the unfurlable dome.

Salient Features of the Site

- **First of its kind – catering calibration requirements for sensors from sub-m to 30 m resolution**
- **Five radiometric targets to characterize the absolute calibration of sensors**
- ***In situ* measurement of ground / atmospheric parameters synchronous to aerial/space craft passes**
- **An Independent Atmospheric observatory with state-of-art equipments for monitoring radiation, aerosol and other gas traces, meteorological measurements**

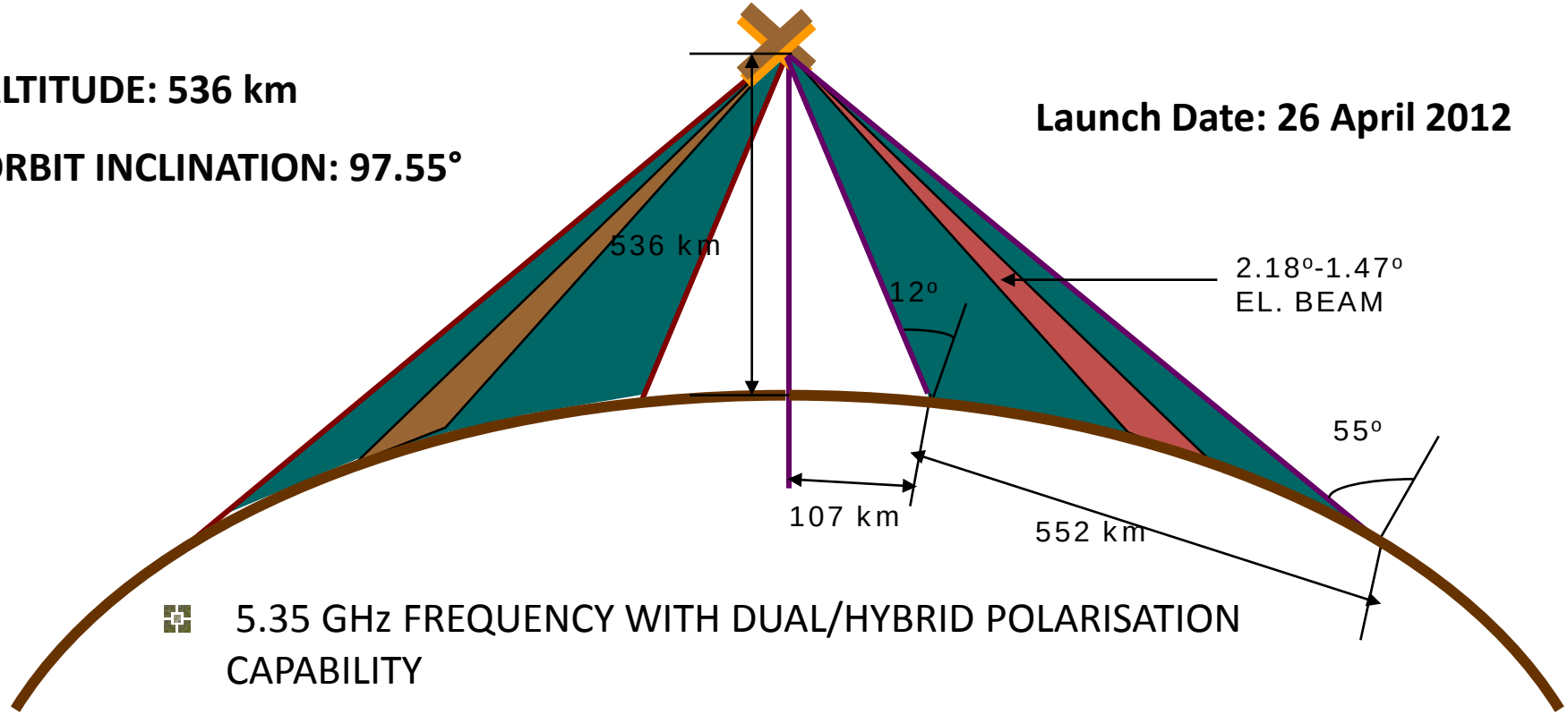

RISAT
RISAT-1 Cal-Val

RADAR IMAGING SATELLITE (RISAT-1)

ALTITUDE: 536 km

ORBIT INCLINATION: 97.55°

Launch Date: 26 April 2012



- 5.35 GHz FREQUENCY WITH DUAL/HYBRID POLARISATION CAPABILITY
- ACTIVE ANTENNA CONFIGURATION
- SUN-SYNCHRONOUS ORBIT
- 25-DAY REPEATIVITY
- SWATH SELECTIBILITY REGION: 107KM TO 659KM FROM EITHER SIDE OF THE SUB-SATELLITE TRACK

OPERATION MODES OF RISAT1-SAR

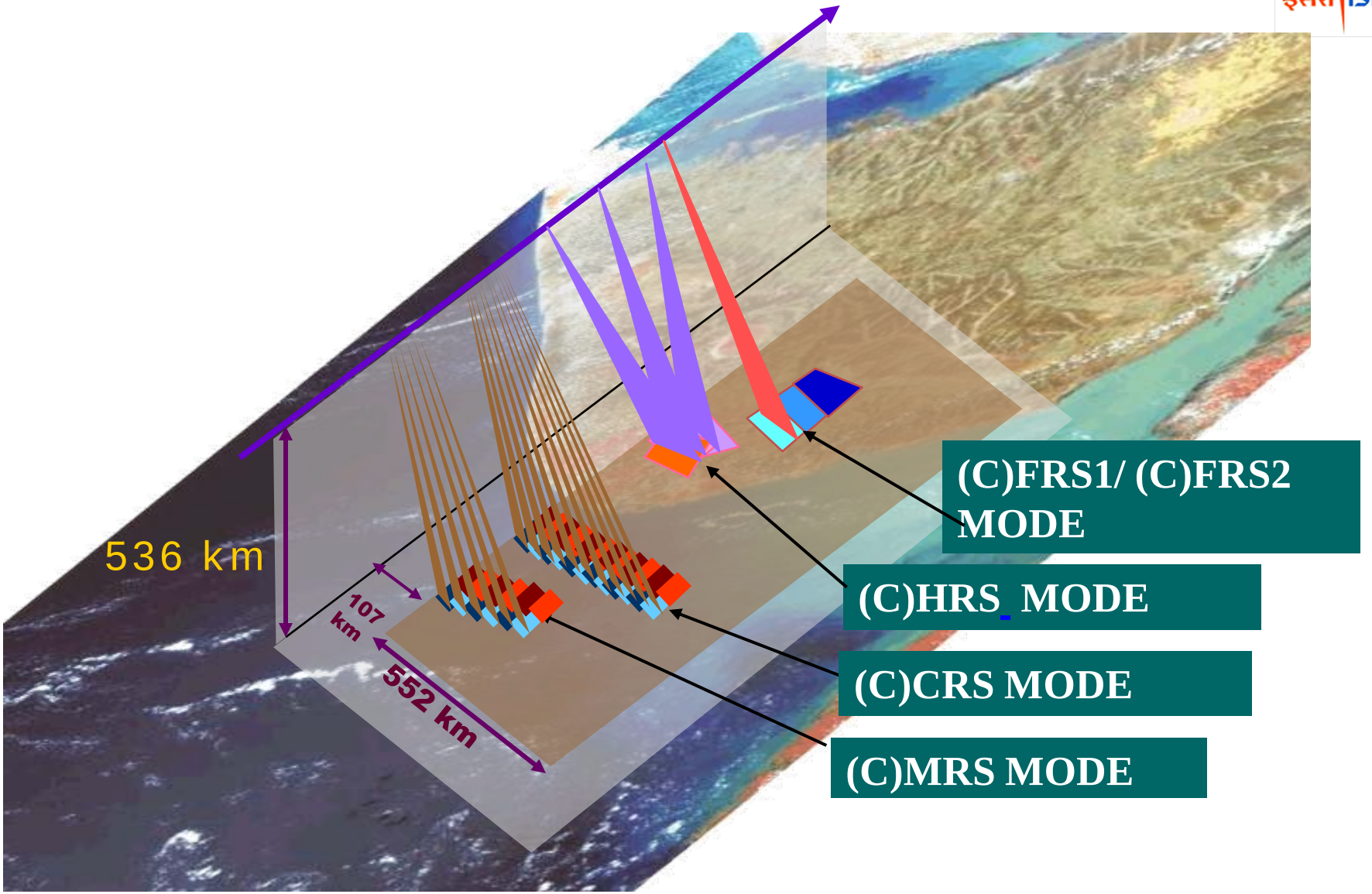


IMAGE QUALITY PARAMETERS

	Single Pol HH/HV/VV /VH	Dual Pol HH+HV/ VV+VH	Circular Polarimetry TX: CP Rx: V and H	Quad Pol HH+HV+VV+VH
High Resolution Spotlight Mode (HRS)	0.7m x 1m resolution, 10 x 10 Km (10x100 km Experimental) Spot σ_o= -16 dB			
Fine Resolution Stripmap Mode-1 (FRS-1)	2m x 3m resolution, 25 Km swath σ_o= -17 dB			
Fine Resolution Stripmap Mode-2 (FRS-2)			4m x 3m resolution, 25 Km swath σ_o= -20 dB	4m x9m resolution, 25Km swath σ_o= -19dB
Medium Resolution ScanSAR Mode (MRS)	8m x 25m resolution,115 Km swath σ_o= -17 dB			
Coarse Resolution ScanSAR Mode (CRS)	8m x 50m resolution, 223 Km swath σ_o= -17 dB			

Resolution definition as (SL Range x Az); Radiometric Resolution: 3dB

Gnd resolution factor: 4.8 (for 12deg incidence) – 1.2 (for 55deg incidence)

P/L Performance Evaluation Activities

1. Onboard Calibration
2. External Calibration with CRs
3. Active Radar Calibrator (ARC)
4. Azimuth Antenna Pattern Estimation
5. Amazon based Radiometric / Polarimetric Calibration

Onboard Calibration

Transmit Calibration (TR-SSPA CAL): This is used to obtain transmit mode gain and phase information of the TR-Modules.

Receive Calibration (TR-LNA CAL): This is used to obtain receive mode gain and phase information of the TR-Modules.

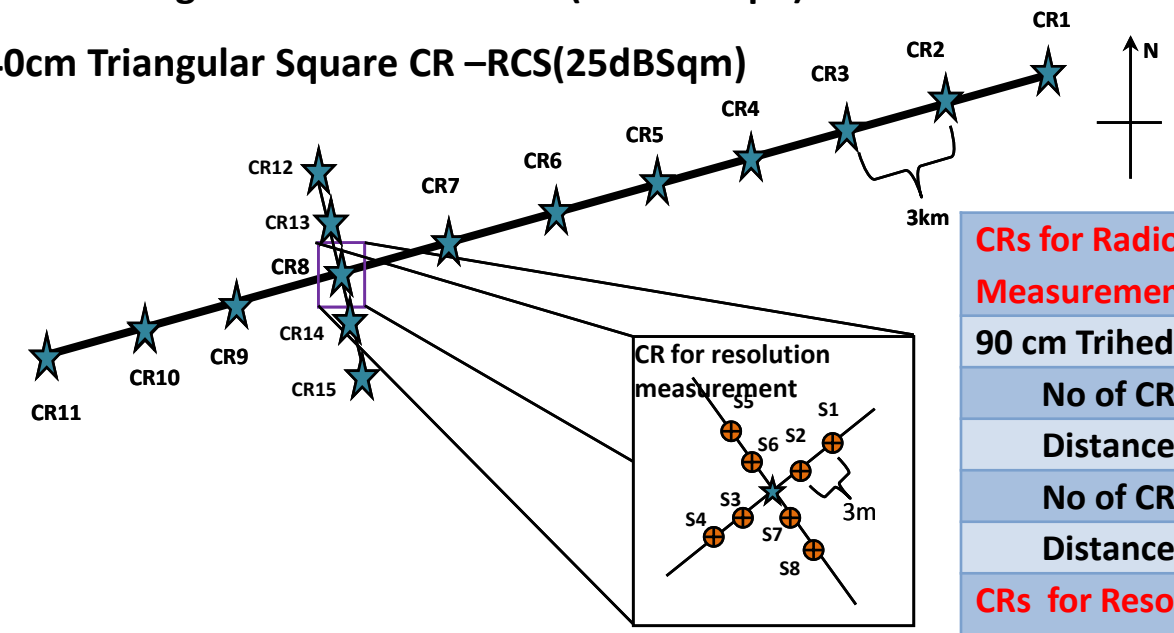
TX-RX CAL: This mode is used to obtain reference chirp data, required for pulse compression ; Active Antenna is bypassed.

Frequency of calibration: every 60 days

External Calibration Plan for Full Beam Calibration

-90cm Triangular Trihedral CR-RCS(29.5 dBSqm)

-40cm Triangular Square CR –RCS(25dBSqm)

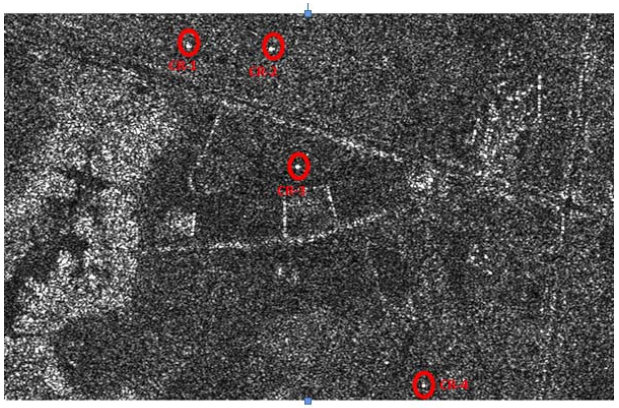


CRs for Radiometric & Geometric Performance Measurement	
90 cm Trihedral Triangular CR	15
No of CRs deployed in RA Direction	11
Distance Between 2 CRs	3 Km
No of CRs Deployed in AZ Direction	4
Distance Between 2 CRs	500 m
CRs for Resolution & Geometric Accuracy Measurement	
40 cm Trihedral Square	8
No of CRs deployed in RA Direction	4
No of CRs Deployed in AZ Direction	4
Distance Between 2 CRs	3 m

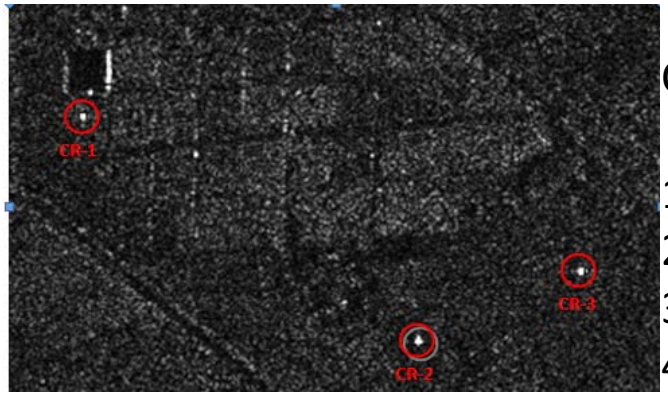
AREA: Little Rann of Kuchchh

Frequency : Once in a year during April-May

External Calibration



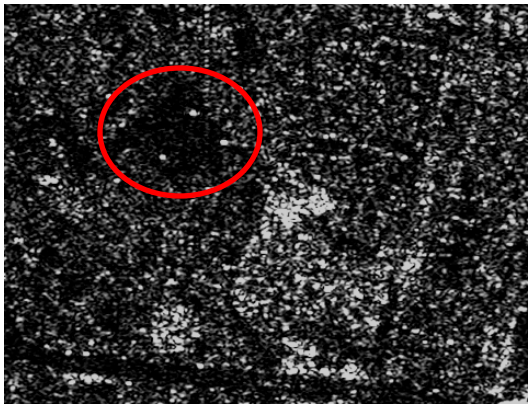
NALSAROVAR



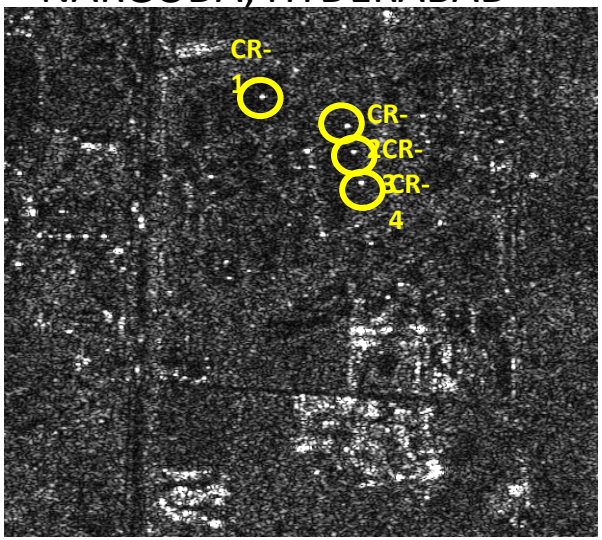
NARGODA, HYDERABAD

CR Deployment

1. NALSAROVAR(4)
2. SAC(3)
3. NIRMA UTY(4)
4. HYDERABAD(3)



SAC



NIRMA UNIVERSITY, AHMEDABAD

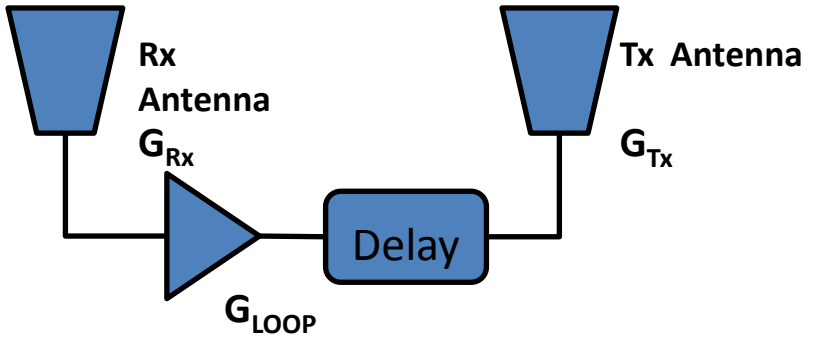
Active Radar Calibrator (ARC)

- Mainly used to achieve very high RCS with small physical size.
- Useful mainly at low frequency or poor spatial resolution SAR calibration.
- Useful for cross polarization calibration.
- Typical calibration requirement :

RCS to background ratio :

> 17 db corresponding to 2 % error.(0.08 dB)

> 10 dB corresponding to 10 % error (0.4 dB)



$$RCS = \frac{G_{Rx} G_{Tx} G_{Loop} \lambda^2}{4\pi}$$

SPECIFICATIONS:

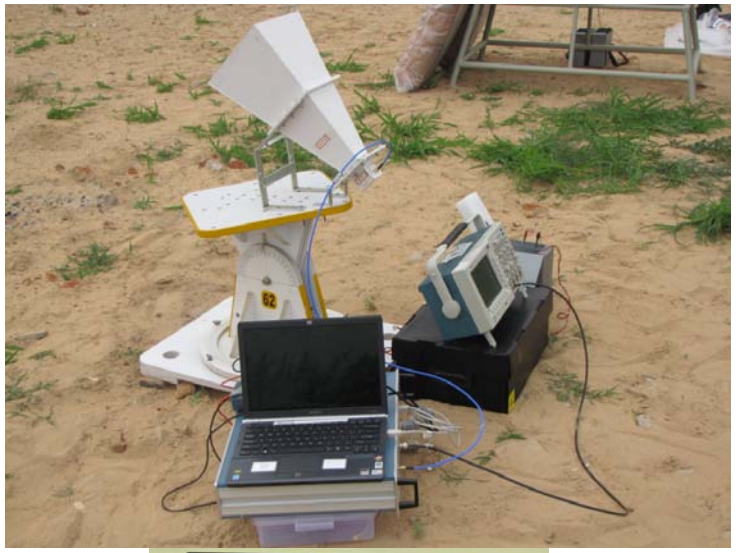
Targeted RCS : 40 to 50 dBm^2

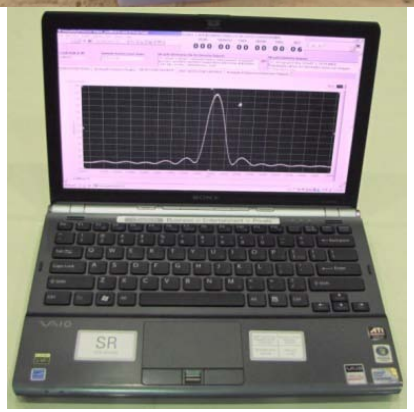
Type of Antenna : Printed dual polarised patch array

Amplifier gain : 45dB.

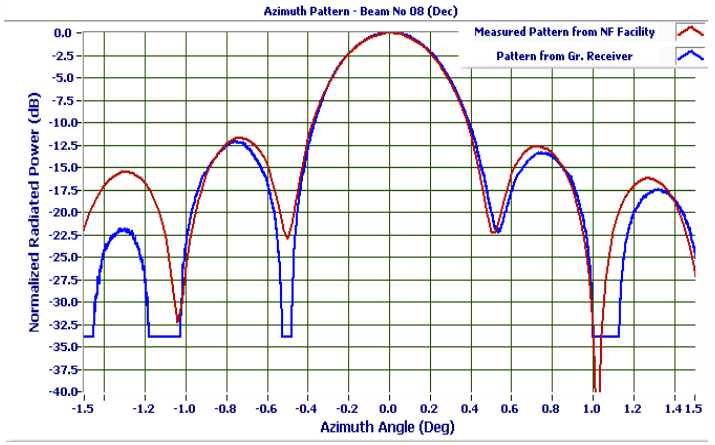
Over all stability : < 1 dB over 10 minutes duration

ANTENNA AZIMUTH PATTERN MEASUREMENT

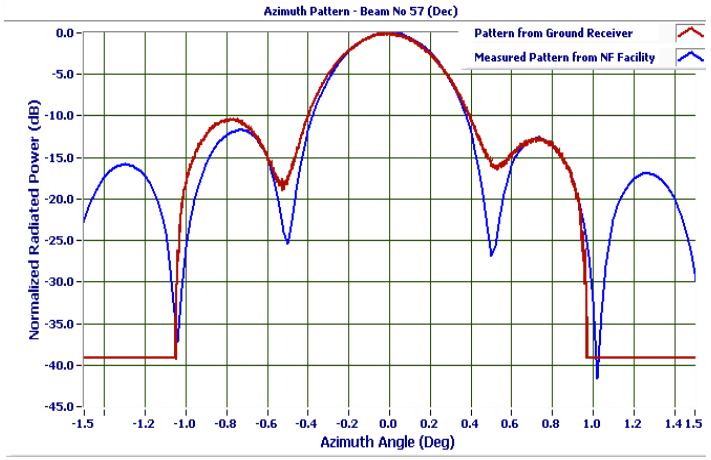




Tx-V Azimuth Pattern – Comparison for cFRS-1(Beam-8)



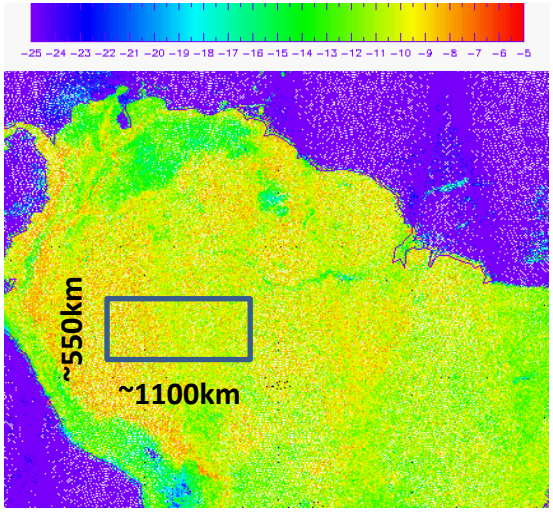
Tx-H Azimuth Pattern – Comparison for cFRS-1(Beam-57)



Mapped Pattern using corresponding detector reference file with Temperature correction in Comparison with azimuth pattern obtained in RISAT-1 Near-field facility.

Amazon Calibration

a. Elevation Transmit-Receive Pattern (relative) can be estimated by imaging over Amazon forest.
b. Area of Uniform sigma-naught over 4°S – 9° S Latitude, 55°W – 66°W Longitude identified over Amazon rainforests.
c. For C-band, sigma-naught ~ -8dB, with RMS variation of 0.6dB
d. With incidence angle variation over entire coverage area, sigma-naught varies from -7dB to -9dB

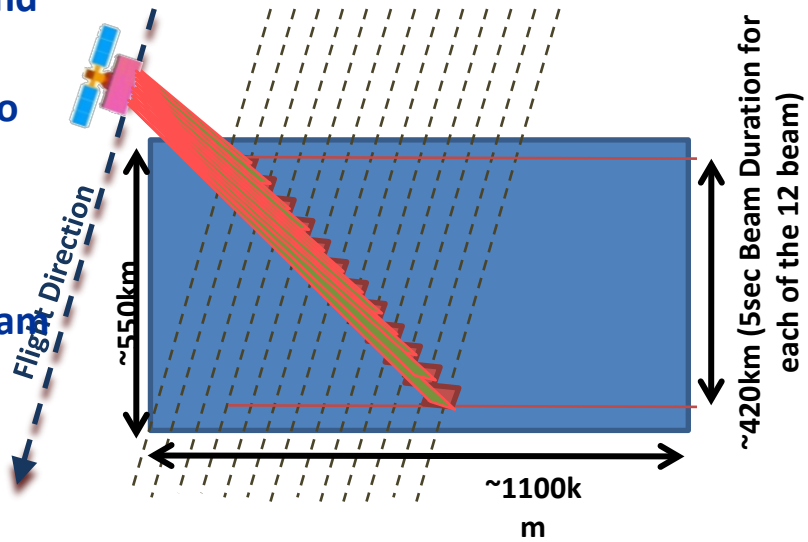


HH-Polarization

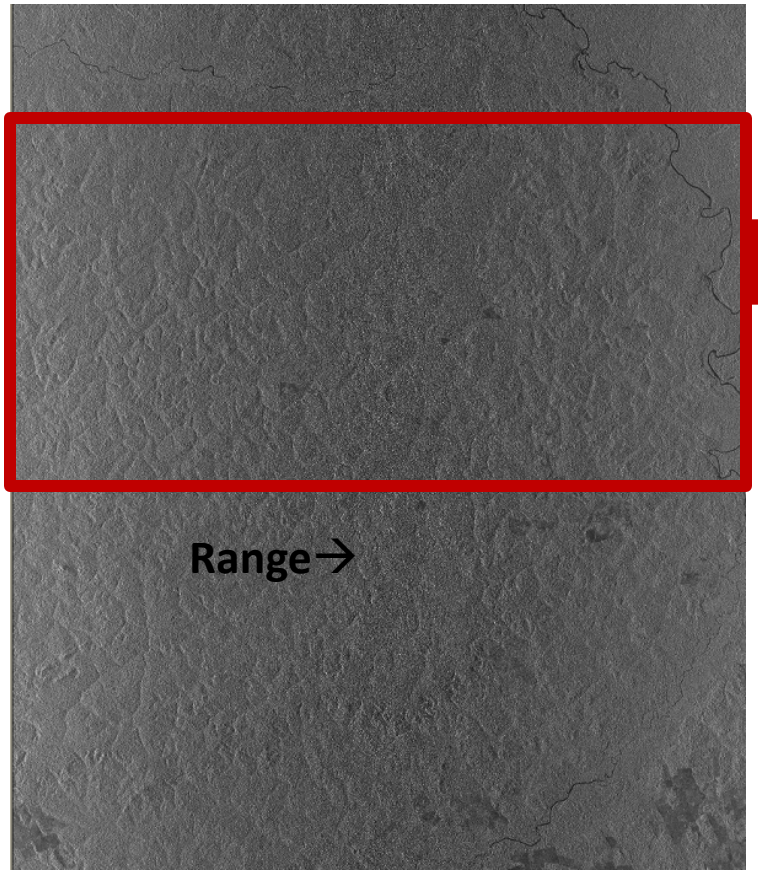
PLAN

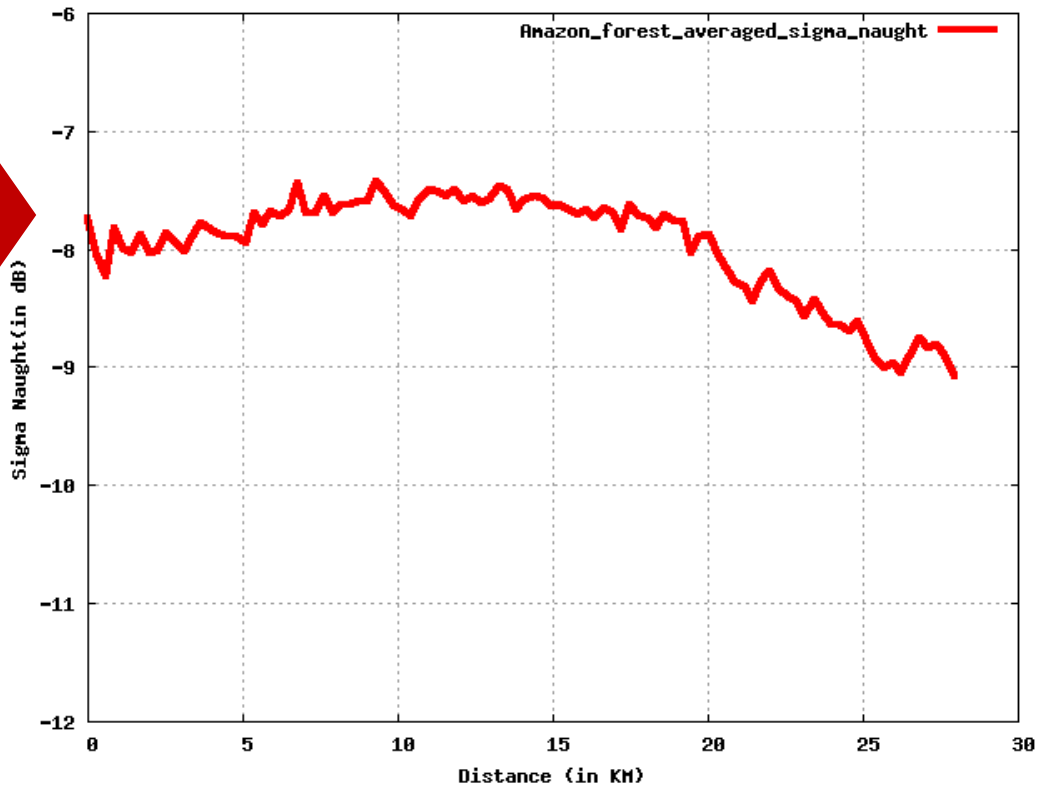
a. Characterisation of all 128 Antenna Beams for both H and V Polarization
b. Both Ascending and descending data sets are planned to observe/ compensate any angle dependent / feature dependent local bias.
c. 12 alternate antenna beams should be imaged in one imaging strip (similar to CRS) over this region. (Each beam should be imaged for 5sec)

Results obtained from Ku-band Scatterometer data



Amazon Rain Forest Sigma Naught Value Across Range





The above plot show the sigma naught values across range averaged in the azimuth direction for the box shown above in red color

Post-launch Calibration for IRS Sensors

- As a part of joint calibration activity with CEOS identified teams, ISRO will be ready to share the image data and the sensor data in a campaign mode plan
- ISRO will also provide access to the in situ information available of ground and ocean sites of India for campaign studies
- ISRO also request the in situ information of CEOS ground and ocean sites and relevant information of other comparing sensors acquired over the CEOS CV sites.
- ISRO extend support for QA4EO implementation of basic and higher level products

From Pixel to People.. Future need

Petabytes

Multi-platform, Multi-Parameter, high spatial and temporal resolution, remote & in-situ sensing

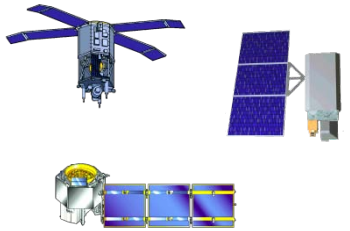
Terrabytes

Gigabytes

Knowledge

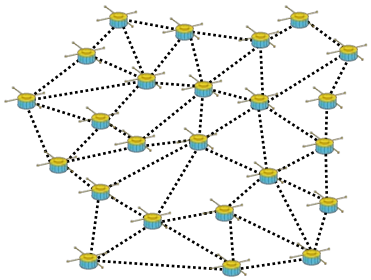
Megabytes

Autonomous; Formation Flights



Autonomous, In-space Calibration and Data Reduction

Sensor Webs



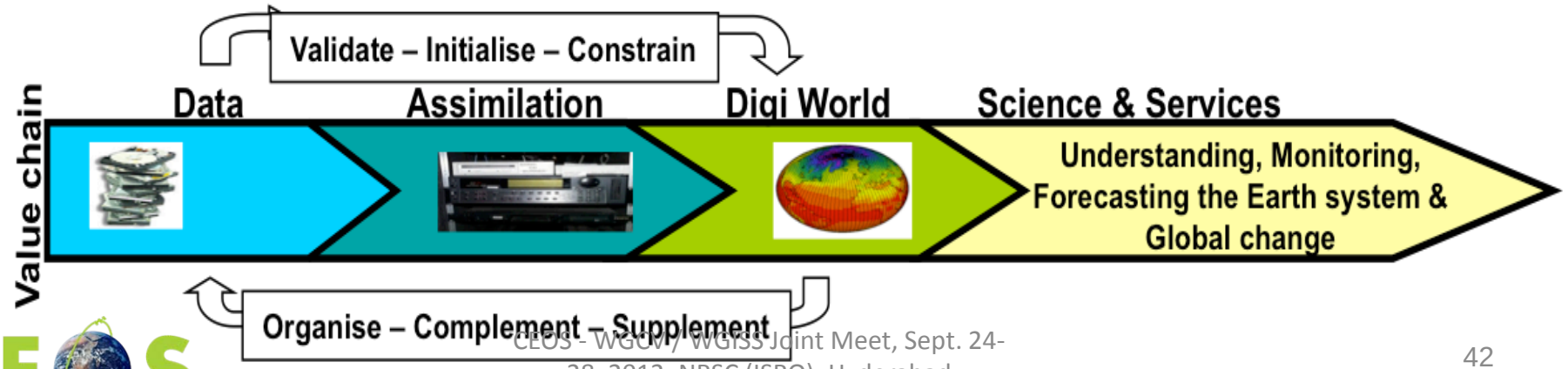
Synergy and convergence of observational networks

Data Fusion/ Advanced Models

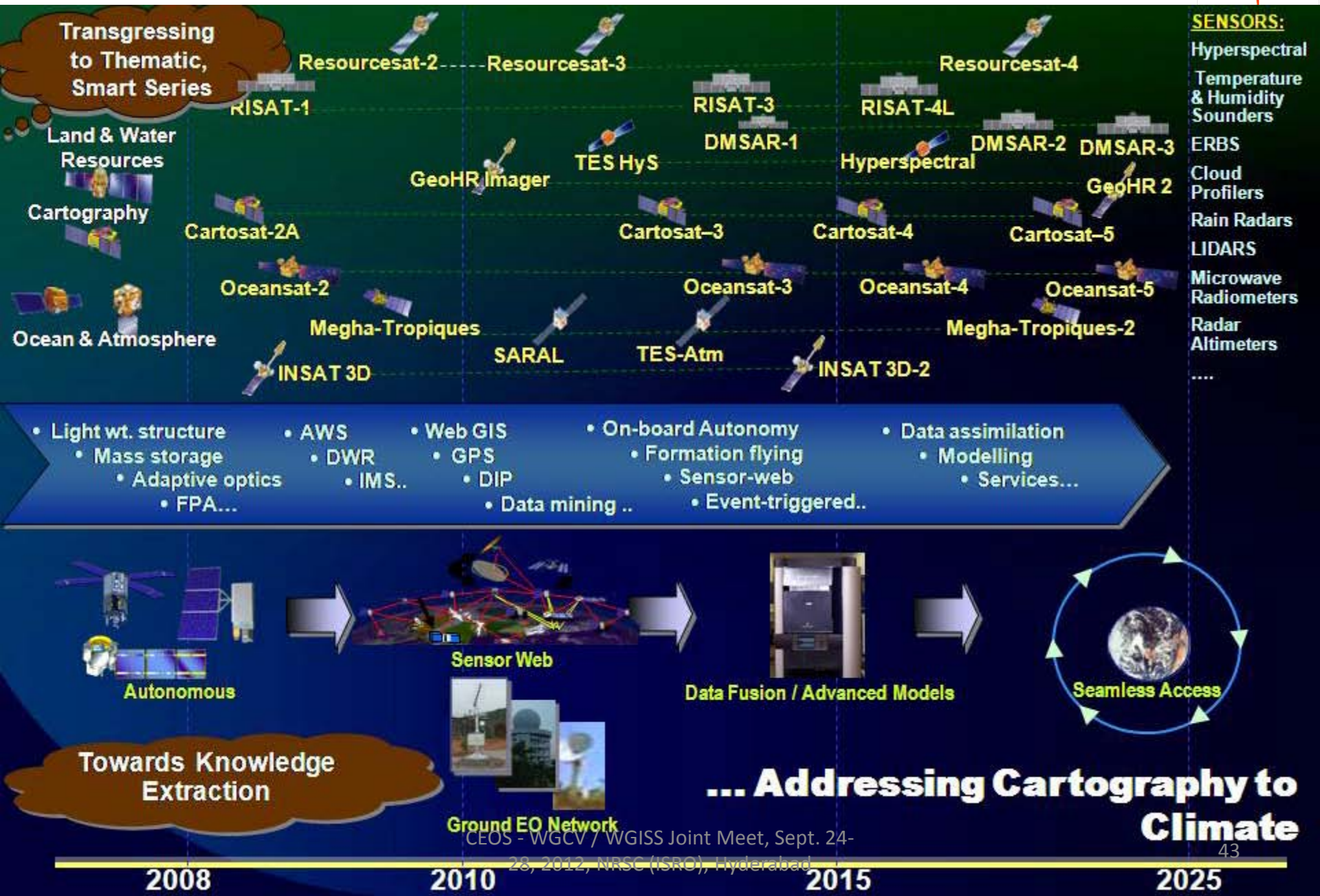
Interaction Between Modeling/Forecasting and Observation Systems

Seamless Access

Interactive Dissemination



EARTH OBSERVATION SYSTEM – VISION 2025



Thank you for your kind attention