ISRO Agency Report

Indian CAL-VAL Activities
- Present and Future

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WGCV – 37 Meeting
Indian Earth Observation Satellites

- One of the largest constellations
- Provides remote sensing data in a variety of spatial, spectral and temporal resolutions
- Both Optical and Microwave

**2009**
- RISAT-2
  - X-SAR

**2012**
- RISAT-1
  - C-SAR

**2011**
- RESOURCESAT-2
  - LISS 3; LISS 4; AWiFS

**2003**
- RESOURCESAT-1
  - LISS 3; LISS 4; AWiFS

**2008**
- IMS-1
  - MX-T; HySI

**2005**
- CARTOSAT-1
  - Stereo PAN, F/A

**2007/2008/2010**
- CARTOSAT-2/2A/2B
  - PAN

**2001**
- Step & Stare PAN

**2013**
- INSAT-3D
  - IMAGER, SOUNDER

**2013**
- SARAL
  - ALTIKA, ARGOS

**2011**
- Megha-Tropiques
  - MADRAS, SAPHIR, SCaRaB

**2009**
- OCEANSAT-2
  - OCM, SCAT ROSA

**2003**
- INSAT-3A
  - VHRR, CCD

**2002**
- KALPANA-1
  - VHRR
Resourcesat-2 (2011)

- LISS-4 MX camera: 5.8m Resolution and 70 Km swath
- LISS-3: 23.5m Resolution and 141 Km Swath
- AWiFS: 56m Resolution and 740km Swath
- Repetitivity: 5 days (AWiFS) to 24 days (LISS 3) &
- Revisit: 5 days (LISS 4) with tilting 26 deg tilt

<table>
<thead>
<tr>
<th>SENSORS</th>
<th>SPECTRAL BANDS</th>
<th>Ground Res. (m)</th>
<th>Swath (km)</th>
<th>Rad. Res. (bits)</th>
<th>Revisit cycle (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LISS III</td>
<td>B2 B3 B4 B5</td>
<td>23.5</td>
<td>141</td>
<td>10</td>
<td>24</td>
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<td>VNIR/SWIR</td>
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<tr>
<td>LISS-IV MX</td>
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<td>70</td>
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<tr>
<td>AWiFS</td>
<td>B2 B3 B4 B5</td>
<td>56</td>
<td>740</td>
<td>12</td>
<td>5</td>
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</tbody>
</table>
### Major Objectives
- To provide continuity of on-going services of Resourcesat-2 and ensure in-orbit redundancy of the satellite
- Increased frequency of observations in tandem with Resourcesat-2 during overlap period
- To explore newer application areas in Land and Water Resources monitoring & management

<table>
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<tr>
<th>SENSORS</th>
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<th>Ground Resolution (meters)</th>
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</tbody>
</table>
Cartosat-1 and 2 (2005, 2007)

**Cartosat-1**
- 2.5 m resolution, 30 km Swath
- Stereo mission; +26° / -5° forward/ Aft view
- Revisit: 5 days
- Along Track Stereo viewing - first of its kind in the world

**Cartosat-2**
- Swath (km): 10
- SNR: $\geq 180$
- IGFOV (m): 0.8
- SWR (%): $\geq 10$

**Cartosat-2 Data Products - Handling of unique imaging modes**
- *paint brush*
- *multi-view in step and stare*
- *spot scenes*
Panchromatic camera; 0.65 m
Multispectral: 2 m
No. of Bands: 4
Swath: 10 km
Radiometric Resolution: 11 bit
Steering up to ±26°
Altitude: 500 km
Solid State Recorder: 600 Gb
Local time: 0930 hrs
Revisit: 5 days

**Major Objectives**

- To provide continuity of on-going data services of Cartosat-2
- To design and develop a highly agile and advanced satellite with high spatial resolution both in panchromatic and multi-spectral bands
- To meet the increasing user demands for cartographic and cadastral level applications with improved revisit capability in tandem with Cartosat-2 missions.
Oceansat-2 (2009)

A global mission, providing continuity of ocean color data and wind vector in addition characterization of lower atmosphere and ionosphere from ROSA payload.

Global data acquisition of Ocean colour
- High Resolution Data - NRSC and INCOIS
- 1km resolution global products through NRSC Website
- Global Chlorophyll, Aerosol Optical Depth through NRSC Website
- Regional/Global NDVI, VF, Albedo products

Scatterometer Wind Products
- Reception Station at Svalbard
- Real time transfer and processing
- Uploading to Web within 3 hrs through EUMETCAST
- 1.72 Lakhs data are downloaded from NRSC Website

Data Dissemination Mechanism
- Established Ground station at INCOIS
- Ground station at Bharti, Antarctica is commissioned.
- EUMETCAST, NRSC Website for data and products
Global Vegetation Index Products from OCM sensor

OCT - 2013

Pixel Size: 8 km; Cycle: Monthly; Method: Max. Value Composite (to reduce cloud cover) CC>80% with MODIS NDVI
Microwave Digital Earth from OSCAT @2.5km pixel

• OSCAT scatterometer
• Temporal resolution 2 days.
• Operational frequency is 13.5 GHz.
• Originally developed to measure winds over the ocean from space,
• OSCAT data useful in a variety of Land studies including polar ice and tropical vegetation.

OSCT data draped on Google Earth
Date: Oct. 23-24, 2012

• NASA sponsored Scatterometer Climate Record Pathfinder at Brigham Young University (courtesy: David G. Long) by SIR algorithm available at 2.225km pixel.
• Datasets further processed for geometric rectification and mosaicking to realize a 3-D virtual reality land product at 2.5km after ocean regions are masked.
• Probably first microwave 2D-Digital Earth at this spatial/temporal resolutions available todate in public domain (nrsc website).
OCEANSAT-3 is a global mission and is configured to cover global oceans and provide continuity of ocean colour data with global wind vector and characterization of lower atmosphere and ionosphere.

**Payloads:**
- An 13-band Ocean Colour Monitor (OCM) in VNIR (400-1010 nm range) with 360 m spatial resolution and 1400 km swath for ocean Colour monitoring
- 2-band Long Wave Infra Red (LWIR) around 11 and 12 μm for Sea Surface Temperature (thermal channels) at 1080 m resolution.
- A Ku-Band Pencil beam SCATTEROMETER with a ground resolution of 50 km x 50 km for Continuity of wind vector data for cyclone forecasting and numerical weather modelling

**Objectives:**
- Continuity of ocean colour data with improvements to continue and enhance operational services like potential fishery zone and primary productivity.
- To enhance the applications by way of simultaneous Sea Surface Temperature (SST) measurements, in addition to chlorophyll, using additional thermal channels, is envisaged in this mission.
- Continuity of wind vector data through repeat of Scatterometer for cyclone forecasting and numerical weather modelling.
- The mission, in tandem with Oceansat-2 (on availability), will improve the repetivity of ocean colour measurements to every 24 hour and wind vector measurements to every 12 hour.

**LAUNCH: 2016-17**
Megha-Tropiques (Indo-French Mission: 2011)

For studying water cycle and energy exchanges to better understand the life cycles of the tropical convective system. The satellite is contributing to Global Precipitation Mission (GPM)

**SAPHIR**
- Water vapour profile
- Six atmospheric layers upto 12 km height
- 10 km Horizontal Resolution

**SCARAB**
- Outgoing fluxes at TOA
- 40 km Horizontal Resolution

**MADRAS**
- Precipitation and Cloud properties
- 89 & 157 GHz: Ice particles in cloud top
- 18 & 37 GHz: Cloud Liquid Water and precipitation; Sea Surface Wind speed
- 24 GHz: Integrated water vapour

**Applications:**
Observations of tropics for
- Water vapour
- Clouds
- Cloud condensed water
- Precipitation
- Evaporation
Space borne SAR in C-band at 5.35 GHz

- Stripmap FRS-1 / FRS-2 (Range Doppler/ Chirp Scaling)
- ScanSAR MRS & CRS (Range Doppler/Specan)
- Spotlight (modified sub-aperture) modes.

Single/ Dual / Quad Polarisation imaging with 3 - 50 m Resolution & 10 - 240 km Swath
Altika/SARAL mission belongs to the global altimetry system for the precise and accurate observations of ocean topography, circulation and sea surface monitoring.

**Mission:**
- Sun-synchronous, polar orbiting satellite
- Inclination: 98.38 Deg.
- Altitude: ~800 km
- Repeat cycle: 35 days

**Altika Payload:**
- Ka-band (35.75 GHz, BW 500 MHz) radar altimeter
- Dual-frequency microwave radiometer (23.8 & 37 GHz)
- DORIS
- Laser Retro-reflector Array

SARAL/AltiiKA SSHA observation overpass over Indian Ocean on Feb 28, 2013 and SLA from POM model at 0.5 degree resolution.
**INSAT-3D (2013)**

*Follow Mission to Kalpana*

**Payloads:**

**IMAGER**
- Spectral Bands (6): VIS, SWIR, MWIR, WV, TIR- 1 &2
- Spatial Resolution: 1 km for VIS & SWIR
  4 km for MIR & TIR
  8 km for WV

**SOUNDER – Water Vapour & Temperature profiles**
- Spectral Bands (19): SWIR (6), MWIR (5), LWIR (7), Vis (1)
- Resolution (km): 10 X 10 for all bands
- No of simultaneous sounding: 4 per band

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**Potential Applications**

Quantitative precipitation estimation, vertical temperature and moisture profile of the atmosphere, surface and cloud top temperatures, ozone distribution, Sea Surface Temperature (SST), fire, smoke, fog detection, etc.
**INSAT - 3DR**

Advanced weather satellite of India configured with improved Imaging System and Atmospheric Sounder

**LAUNCH: 2016**

### 6 Channel IMAGER

- **Spectral Bands (µm)**
  - Visible: 0.55 - 0.75
  - Short Wave Infra Red: 1.55 - 1.70
  - Mid Wave Infra Red: 3.70 - 3.95
  - Water Vapour: 6.50 - 7.10
  - Thermal Infra Red – 1: 10.30 - 11.30
  - Thermal Infra Red – 2: 11.30 - 12.50

- **Resolution**: 1 km for Vis & SWIR
  4 km for MIR & TIR
  8 km for WV

### 19 Channel SOUNDER

- **Spectral Bands (µm)**
  - Short Wave Infra Red: Six bands
  - Mid Wave Infra Red: Five Bands
  - Long Wave Infra Red: Seven Bands
  - Visible: One Band

- **Resolution (km)**: 10 X 10 for all bands

- **No of simultaneous**: 4 sounding per band
Geo Imaging Satellite (GISAT)

- Multiple acquisition capability from a Geosynchronous Orbit
- Geostationary orbit of 36,000 km
- Every 30 minutes observation over India

LAUNCH: 2016-17

High resolution multi-spectral VNIR (HRMX-VNIR): 50m Resolution

Hyper spectral VNIR: 320m Resolution

Hyper spectral SWIR (HySI-SWIR): 192m Resolution

High resolution Multi-spectral (HRMX-TIR): 1.5km Resolution
Scenario in next 5 Years

Cartosat-2C
0.65 m PAN, 2 MX

MEGHA-TROPIQUES
SAPHIR, SCARAB & ROSA

RISAT-2
X-band

Oceansat-2
OCM, SCAT

Resourcesat – 2
LISS III, LISS IV, AWiFS

Oceansat-3
OCM, SCAT

RISAT-1
C-band

Resourcesat -2 A
LISS III, LISS IV, AWiFS

SARAL
Altika & Argos

GISAT
MX, Hyperspectral, Thermal

INSAT-3D Imager,
Sounder

INSAT-3DR Imager,
Sounder

Resourcesat – 2 A
LISS III, LISS IV, AWiFS

Oceansat-3
OCM, SCAT

Oceansat-2
OCM, SCAT, ROSA
ISRO Cal Val Activities - Overview

• Establishing an Indian Cal-Val Program - by setting up instrumented CAL sites for theme-oriented ISRO missions.

• Collaborating with WGCV teams for Inter-Sensor Calibration with contemporary sensors over CEOS specified global calibration sites.
## Functional Activities of Indian Cal-Val Sites

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Name of site</th>
<th>Type</th>
<th>Project</th>
<th>Sensor</th>
<th>Parameters/products</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kavaratti</td>
<td>Ocean/Atmosphere</td>
<td>Oceansat-2, Saral/AltiKa, Meghatropiques</td>
<td>OCM-2, Scatterometer, Radar Altimeter, Madra Sapphire, ScaRaB</td>
<td>VC, nLw, Rsr, Chl, AOD, SSA, WV, TSM, Kd, WS, WD, Vertical profile of atmosphere, SSH, AP, AT, SST, Oz.</td>
</tr>
<tr>
<td>4</td>
<td>Bhopal</td>
<td>Land/Atmosphere</td>
<td>Resourcesat-2, Meghatropiques, INSAT-3D</td>
<td>AWIFS, LISS-3, Sapphire, ScaRaB, Madras, Imager, Sounder</td>
<td>LPV, SR, LAI, NDVI, AOD, SSA, WV, WS, WD, Vertical profile of atmosphere, AP, AT, WS, WD, Ozone</td>
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<tr>
<td>5</td>
<td>Krishna Godavari (KG)</td>
<td>Coastal ocean/Atmosphere</td>
<td>Oceansat-2, Saral/AltiKa, Meghatropiques, INSAT-3D</td>
<td>OCM-2, Scatterometer, Radar Altimeter, Sapphire, ScaRaB, Madras, Imager, Sounder</td>
<td>PV, nLw, Rsr, Chl, AOD, SSA, WV, TSM, Nitrate, Phosphate, BS, PAR, WS, WD, Vertical profile of atmosphere, SSH, AP, AT, SST</td>
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<tr>
<td>6</td>
<td>Machilipatnam</td>
<td>Coastal ocean</td>
<td>Saral/AltiKa</td>
<td>Radar Altimeter</td>
<td>SSH</td>
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<tr>
<td>7</td>
<td>Kanya kumari</td>
<td>Coastal Ocean</td>
<td>Saral/AltiKa</td>
<td>Radar Altimeter</td>
<td>SSH</td>
</tr>
<tr>
<td>8</td>
<td>Nirma/MG Sci.</td>
<td>Land</td>
<td>RISAT-1</td>
<td>SAR</td>
<td>SAR cal., Soil Moisture</td>
</tr>
<tr>
<td>9</td>
<td>Roorkie</td>
<td>Land</td>
<td>RISAT-1</td>
<td>SAR</td>
<td>SAR cal., Soil Moisture</td>
</tr>
<tr>
<td>10</td>
<td>Chhota Shigri</td>
<td>Land/Atmosphere</td>
<td>Resourcesat-2, Meghatropiques, INSAT-3D</td>
<td>AWIFS,LISS-3, Sapphire, ScaRaB, Madras, Imager, Sounder</td>
<td>Snow cover, SR, AOD, SSA, WV, WS, WD, AP, AT, Ozone</td>
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<tr>
<td>11</td>
<td>Punjab (planned)</td>
<td>Land/Atmosphere</td>
<td>Resourcesat-2, Meghatropiques, INSAT-3D</td>
<td>AWIFS,LISS-3, Sapphire, ScaRaB, Madras, Imager, Sounder</td>
<td>LPV, SR, LAI, NDVI, AOD, SSA, WV, WS, WD, Vertical profile of atmosphere, AP, AT, Ozone</td>
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<td>12</td>
<td>North East (planned)</td>
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<td>Resourcesat-2, Meghatropiques, INSAT-3D</td>
<td>AWIFS,LISS-3, Sapphire, ScaRaB, Madras, Imager, Sounder</td>
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<td>Leh (planned)</td>
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<td>Instrument calibration, SR, AOD, SSA, WV, WS, WD, Vertical profile of atmosphere, AP, AT, Ozone</td>
</tr>
</tbody>
</table>
Activities carried out in 2013

• Development activities of Cal-Val sites in Rann of Kutch (medium and coarse resolution), SAC-Bopal, Ahmedabad (high resolution) and in Bhopal (Land Product Validation). The site consists of land and atmospheric fully automated in-situ parameter measuring instruments (e.g. surface reflectance, AOD, SSA, Rain fall/rate, weather para., etc.)

• Development initiated for a Coastal site in Krishna-Godavari basin.

• Vicarious calibration of OCM using Kavaratti Cal-Val site, Resourcesat-2 sensors using Rann of Kutch site and inter-comparison with Landsat-7, absolute calibration of Saral Radar altimeter of using Kavaratti site, RISAT-1 SAR calibration using Ahmedabad sites.

• Validation of OCM2, AWIFS, Saral, Meghatropiques, INSAT-3D products.
Future plan of action in 2014

• Operationalization of Rann-of-Kutch, SAC-Bopal and Bhopal sites
• Development and operationalization of Coastal site for ocean color
• Periodic vicarious calibration of ISRO sensors, implementation of gain coefficients and inter-comparison(other sensors) using sites
• Operational validation of Bio-geo-physical products using sites
• Feasibility studies and site selection for planned sites development
• Operationalization INCVSLOA and database for all sites
• International collaboration and data exchange for all sensors
### RESOURCESAT-2/IRS-P6

#### Sensor / Band

<table>
<thead>
<tr>
<th>Sensor / Band</th>
<th>Radiance (mw/cm²/sr/micron)</th>
<th>S.D.</th>
<th>Ratio (RS2/6S)</th>
<th>S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS2 green</td>
<td>7.85</td>
<td>0.16</td>
<td>0.91</td>
<td>0.17</td>
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<tr>
<td>6S green</td>
<td>8.57</td>
<td>0.9</td>
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<tr>
<td>RS2 red</td>
<td>7.72</td>
<td>0.19</td>
<td>0.94</td>
<td>0.11</td>
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<tr>
<td>6S red</td>
<td>8.19</td>
<td>0.58</td>
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<tr>
<td>RS2 NIR</td>
<td>5.87</td>
<td>0.14</td>
<td>0.92</td>
<td>0.09</td>
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<tr>
<td>6S NIR</td>
<td>6.34</td>
<td>0.46</td>
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<tr>
<td>RS2 SWIR</td>
<td>1.40</td>
<td>0.03</td>
<td>0.84</td>
<td>0.02</td>
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<tr>
<td>6S SWIR</td>
<td>1.67</td>
<td>0.14</td>
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#### Sensor / IRS-P6

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<thead>
<tr>
<th>Sensor / Band</th>
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<th>Ratio (P6/6S)</th>
<th>S.E.</th>
</tr>
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<tbody>
<tr>
<td>P6 green</td>
<td>6.75</td>
<td>0.14</td>
<td>0.76</td>
<td>0.16</td>
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<tr>
<td>6S green</td>
<td>8.87</td>
<td>1.02</td>
<td></td>
<td></td>
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<tr>
<td>P6 red</td>
<td>8.21</td>
<td>0.21</td>
<td>0.99</td>
<td>0.19</td>
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<tr>
<td>6S red</td>
<td>8.33</td>
<td>0.94</td>
<td></td>
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<tr>
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<td>5.96</td>
<td>0.13</td>
<td>0.92</td>
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<tr>
<td>6S NIR</td>
<td>6.47</td>
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<tr>
<td>P6 SWIR</td>
<td>2.24</td>
<td>0.04</td>
<td>1.34</td>
<td>0.04</td>
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<tr>
<td>6S SWIR</td>
<td>1.67</td>
<td>0.15</td>
<td></td>
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</tbody>
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#### RS 2 AWIFS

- Equation: \( y = 1.0644x + 0.1282 \)
- \( R^2 = 0.9708 \)
- 6s Radiance
- Linear (6s Radiance)

#### P6 AWIFS

- Equation: \( y = 1.1605x - 0.3633 \)
- \( R^2 = 0.8722 \)
- 6s Radiance
### Landsat-7

<table>
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<tr>
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<th>S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>L7 green</td>
<td>7.93</td>
<td>0.71</td>
<td>0.90</td>
<td>0.19</td>
</tr>
<tr>
<td>6S green</td>
<td>8.79</td>
<td>0.74</td>
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<tr>
<td>L7 red</td>
<td>7.5</td>
<td>0.56</td>
<td>0.87</td>
<td>0.15</td>
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<tr>
<td>6S red</td>
<td>8.64</td>
<td>0.55</td>
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<tr>
<td>L7 NIR</td>
<td>5.7</td>
<td>0.36</td>
<td>0.91</td>
<td>0.12</td>
</tr>
<tr>
<td>6S NIR</td>
<td>6.23</td>
<td>0.51</td>
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<tr>
<td>L7 SWIR</td>
<td>1.36</td>
<td>0.17</td>
<td>0.81</td>
<td>0.05</td>
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<tr>
<td>6S SWIR</td>
<td>1.67</td>
<td>0.26</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Saral/AltiKa

\[
y = 1.1342x - 0.0316 \quad R^2 = 0.9477
\]

### Meghatropiques

Validation of the SARAL/AltiKa SWH (OGDR) using the NDBC Buoy Data

- y = 0.945x + 0.146
- R² = 0.907

**Data Analysis:**
- **L7 green:**
  - Radiance: 7.93 mw/cm²/sr/micron
  - S.D.: 0.71
  - Ratio (RS2/6S): 0.90
  - S.E.: 0.19
- **6S green:**
  - Radiance: 8.79 mw/cm²/sr/micron
  - S.D.: 0.74
  - Ratio (RS2/6S): 
  - S.E.: 
- **L7 red:**
  - Radiance: 7.5 mw/cm²/sr/micron
  - S.D.: 0.56
  - Ratio (RS2/6S): 0.87
  - S.E.: 0.15
- **6S red:**
  - Radiance: 8.64 mw/cm²/sr/micron
  - S.D.: 0.55
  - Ratio (RS2/6S): 
  - S.E.: 
- **L7 NIR:**
  - Radiance: 5.7 mw/cm²/sr/micron
  - S.D.: 0.36
  - Ratio (RS2/6S): 0.91
  - S.E.: 0.12
- **6S NIR:**
  - Radiance: 6.23 mw/cm²/sr/micron
  - S.D.: 0.51
  - Ratio (RS2/6S): 
  - S.E.: 
- **L7 SWIR:**
  - Radiance: 1.36 mw/cm²/sr/micron
  - S.D.: 0.17
  - Ratio (RS2/6S): 0.81
  - S.E.: 0.05
- **6S SWIR:**
  - Radiance: 1.67 mw/cm²/sr/micron
  - S.D.: 0.26
  - Ratio (RS2/6S): 
  - S.E.: 

**Graphs:**
- Graph showing the linear relationship between Landsat-7 and Saral/AltiKa data.
- Graph indicating validation using NDBC Buoy Data.
Salient Features:

- **First Integrated site, to characterize Aerial and Satellite sensors at one location. Site is constructed with sub-soil drainage system to protect soil erosion and water logging.**

**Characterization of Aerial sensors (GSD <= 1.3m):**
- Spectral -Red, Green, Blue & White Colors.
- Radiometry -Seven grey levels in White-Black.
- Spatial : Bar, Siemens star and High contrast edge targets.
- Height: Six discrete steps in 10-50 cm range.

**Characterisation of Satellite sensors (GSD <= 24m):**
- Radiometry; Five natural targets with R=9-69 %.
- Sensor spatial quality MTF -High contrast edges.
- In-situ measurements: Met, Atmospheric & surface reflectance measurements at the site.
AN UNIFIED CALIBRATION FIELD FOR AERIAL/VVHR REMOTE SENSING

STEP HEIGHTS ARE EXAGGERATED (Actual: 10cm to 50cm)
Jaisalmer site- Reflectance in INSAT-3D Vis-channel

Statistics over 5 Tiles:
Mean of Mean: 29.94 %
Mean of Std : 5.83 %

INSAT-3D Vis-Channel: 0.55 to 0.75 microns
Joint Calibration Exercise:
RS2 AWIFS & MODIS Cross Calibration over Libya-4 CEOS Site

Collaboration with MODIS (NASA) – FP: Jack Xiong

- Cross calibration was based on 14 AWIFS acquired during June 2011 – Dec. 2012 and corresponding day data of MODIS
- BRDF, Spectral Mismatch, Water Vapor effects are compensated to obtain Radiometric Bias* between two sensors

\[ \text{Bias} = \frac{\rho_{\text{TOA MODIS}}}{\rho_{\text{TOA AWIFS}}} \]

<table>
<thead>
<tr>
<th>Bands</th>
<th>TERRA -</th>
<th>Bias</th>
<th>CE-95 Limits</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(%)</td>
</tr>
<tr>
<td>AWIFS B2</td>
<td>MODIS B4</td>
<td>1.014</td>
<td>0.967 – 1.06</td>
<td>8.552</td>
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<tr>
<td>AWIFS B3</td>
<td>MODIS B1</td>
<td>1.027</td>
<td>0.994 – 1.06</td>
<td>6.095</td>
</tr>
<tr>
<td>AWIFS B4</td>
<td>MODIS B2</td>
<td>1.045</td>
<td>1.020 – 1.069</td>
<td>4.513</td>
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<tr>
<td>AWIFS B5</td>
<td>MODIS B6</td>
<td>1.096</td>
<td>1.061 – 1.130</td>
<td>6.302</td>
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<table>
<thead>
<tr>
<th>Bands</th>
<th>AQUA -</th>
<th>Bias</th>
<th>CE-95 Limits</th>
<th>Std. Dev.</th>
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<tbody>
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<td>(%)</td>
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<tr>
<td>AWIFS B2</td>
<td>MODIS B4</td>
<td>1.012</td>
<td>0.962 – 1.061</td>
<td>9.076</td>
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<tr>
<td>AWIFS B3</td>
<td>MODIS B1</td>
<td>1.024</td>
<td>0.992 – 1.056</td>
<td>5.871</td>
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<tr>
<td>AWIFS B4</td>
<td>MODIS B2</td>
<td>1.045</td>
<td>1.016 – 1.074</td>
<td>5.347</td>
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<tr>
<td>AWIFS B5</td>
<td>MODIS B6</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Results:
1) Biases for AWIFS B2, B3 within 2% while ~4.5% for B4
2) Bias is about 9.6% for AWIFS B5
3) Std. Dev. is higher; further acquisitions /long term analysis in progress.
Joint Calibration Exercise:
LISS4 Calibration Exercise over CEOS Geometric Sites (Sioux Falls, Pueblo)

• Statistics generated were from 560 and 670 control points.
• Control points from a high resolution, high accuracy (<60cm) aerial imagery.

**Band Misregistration Error (Specs: ± 0.3 p RMSE)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Red (B3) – Green (B2)</th>
<th>Near IR (B4) – Red (B3)</th>
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<tbody>
<tr>
<td></td>
<td>Line (AL)</td>
<td>Pixel (AX)</td>
</tr>
<tr>
<td>Min</td>
<td>-0.24</td>
<td>-0.32</td>
</tr>
<tr>
<td>Mean</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Max</td>
<td>0.25</td>
<td>0.32</td>
</tr>
<tr>
<td>RMSE</td>
<td>0.12</td>
<td>0.16</td>
</tr>
</tbody>
</table>

**Location Inaccuracy  Specs: < 200m RMSE**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Location Error pixels (in m)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Line (AL)</td>
</tr>
<tr>
<td>Min</td>
<td>0.75</td>
</tr>
<tr>
<td>Mean</td>
<td>28</td>
</tr>
<tr>
<td>Max</td>
<td>55.4</td>
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<tr>
<td>Std.Dev.</td>
<td>14</td>
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<tr>
<td>RMSE</td>
<td>31.3</td>
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</table>

In Progress:
• Radiometric Calibration with L7/L8 over CEOS sites
• Geometric calibration to be repeated for consistency
RISAT-1 Calibration Exercise at Gunning (Canberra, Australia)

Joint Calibration Exercise - with Passive Corner Reflectors
Image Acquisition planned between Dec13 and Mar14

18 Triangular Trihedrals installed at Location ~ (149.20 Lat/-34.8 Long)

<table>
<thead>
<tr>
<th>CR Type</th>
<th>CR No.</th>
<th>CR Size (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesh</td>
<td>1,6,10</td>
<td>1.5</td>
</tr>
<tr>
<td>Powder</td>
<td>4,9,12</td>
<td>1.5</td>
</tr>
<tr>
<td>Metal</td>
<td>(7,11,15)</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>(5,8,16)</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>(3,13,17)</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>(2,14,18)</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Installation completed by 20DEC13
RISAT-1 Imaging and Processing in progress
## Background Clutter Analysis

RISAT-1 Imaging on 17Nov13  
Inc Angle : 21.01 deg

<table>
<thead>
<tr>
<th>CR</th>
<th>$\sigma_o$</th>
<th>CR</th>
<th>$\sigma_o$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2</td>
<td>11.36</td>
<td>12</td>
<td>10.78</td>
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<tr>
<td>3,4</td>
<td>11.32</td>
<td>13</td>
<td>10.41</td>
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<tr>
<td>5,6</td>
<td>10.15</td>
<td>14</td>
<td>11.24</td>
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<tr>
<td>7</td>
<td>10.19</td>
<td>15</td>
<td>10.99</td>
</tr>
<tr>
<td>8</td>
<td>10.0</td>
<td>16</td>
<td>10.59</td>
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<td>9</td>
<td>9.93</td>
<td>17</td>
<td>10.04</td>
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<tr>
<td>10</td>
<td>9.22</td>
<td>18</td>
<td>10.55</td>
</tr>
<tr>
<td>11</td>
<td>9.26</td>
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</tbody>
</table>
RISAT-1 Imaging of CRs at Gunning

Site map

CRs 1 to 6

Imaging

CRs 7 to 11

CRs 12 to 18
Preliminary Results

<table>
<thead>
<tr>
<th>CR#</th>
<th>TYPE</th>
<th>Size</th>
<th>Loc. Incid. Ang. (deg)</th>
<th>PSLR (dB)</th>
<th>Res. (m)</th>
<th>Azimuth Range</th>
<th>Azimuth Range</th>
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</thead>
<tbody>
<tr>
<td>7</td>
<td>Metal</td>
<td>1.0m</td>
<td>31.64</td>
<td>-24.4</td>
<td>3.92</td>
<td>-19.38</td>
<td>2.25</td>
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<tr>
<td>8</td>
<td>Metal</td>
<td>1.5m</td>
<td>31.63</td>
<td>-20.79</td>
<td>4.97</td>
<td>-15.85</td>
<td>2.47</td>
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<tr>
<td>9</td>
<td>Metal</td>
<td>1.5m</td>
<td>31.67</td>
<td>-22.7</td>
<td>3.47</td>
<td>-17.15</td>
<td>2.36</td>
</tr>
<tr>
<td>10</td>
<td>Mesh</td>
<td>1.5m</td>
<td>31.65</td>
<td>-18.29</td>
<td>5.12</td>
<td>-17.58</td>
<td>2.7</td>
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<tr>
<td>11</td>
<td>Powder</td>
<td>1.0m</td>
<td>31.73</td>
<td>-26.35</td>
<td>3.47</td>
<td>-21.34</td>
<td>2.36</td>
</tr>
</tbody>
</table>

Specs: PSLR = -17db
Summary

• Indian Cal-Val program – aiming to set up instrumented cal-val site for radiometric calibration and land/ocean/atmospheric information products validation.

• Collaboration with CEOS WGCV in joint campaigns for inter-sensor calibration and validation pertaining to ECVs and SBA information products.
Thank you for your attention