NISAR Science and Applications Overview - India Perspective

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NISAR: Objectives

Key Scientific Objectives

• Understand the response of ice sheets and glaciers to climate change and the interaction of sea ice and climate
• Understand the dynamics of carbon storage and uptake in wooded, agricultural, wetland, and permafrost systems
• Determine the likelihood of earthquakes, volcanic eruptions, and landslides

Key Applications Objectives

• Understand societal impacts of dynamics of water, hydrocarbon, and sequestered CO₂ reservoirs
• Enhance agricultural monitoring capability in support of food security objectives
• NISAR’s data to explore the potentials for urgent response and hazard mitigation

To be accomplished in partnership of ISRO and NASA through the joint development and operation of a space-borne, dual-frequency, polarimetric, synthetic aperture radar (SAR) satellite mission with repeat-pass interferometry capability
<table>
<thead>
<tr>
<th>Parameters</th>
<th>L-band SAR</th>
<th>S-band SAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit</td>
<td>747 Km with 98.5° Inclination</td>
<td>3.20 (9.3cm)</td>
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<tr>
<td>Frequency (wavelength)</td>
<td>1.25GHz (24cm)</td>
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<tr>
<td>Repeat cycle</td>
<td>12 days</td>
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<td>Time of Nodal Crossing</td>
<td>6AM / 6PM</td>
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<tr>
<td>Polarization</td>
<td>Single (SP), Dual (DP), Circular (CP), <strong>Quad</strong> (QP) and <strong>Quasi-quad pol</strong> (QQP)</td>
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<tr>
<td>Incidence angle range</td>
<td>33 – 47 deg</td>
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<tr>
<td>Available Range Bandwidths</td>
<td>5 MHz, 20 MHz, 40 MHz, 80 MHz</td>
<td>10 MHz, 25 MHz, 37.5 MHz, 75 MHz</td>
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<tr>
<td>Resolution (Azimuth × Slant range)</td>
<td>6.9m × 7.5m (for 20MHz bw)</td>
<td>6.4m × 6m (at 25MHz bw)</td>
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<td></td>
<td>6.9m × 1.9m (for 80MHz bw)</td>
<td>6.4m × 2m (for 75MHz bw)</td>
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<tr>
<td>Max. Swath width</td>
<td>&gt; 240 Km</td>
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<tr>
<td>Data and Product Access</td>
<td><strong>Free &amp; Open</strong></td>
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</tbody>
</table>
**S-SAR**

- Science require frequent coverage over global targets
- NISAR would acquire sufficient swath with high resolution
- New SweepSAR technology being implemented by both JPL and ISRO
- S-SAR Operation:
  - Thermal constraints (0 to +40degC / 45degC thermal design limit)
  - Data Volume (>3Gbps Max.)
- Desired Science requirement
  - 4 Orbits / 14 Orbits – 15Minutes over SAARC and Antarctica regions.
  - 10 Orbits / 14 Orbits - 2 Minutes globally / orbit
- Thermal analysis of S-SAR
  - 14 Orbits / 14 Orbits – 10 Minutes over SAARC and Global regions
- Comfortable Thermal Margins to meet desired science requirements
- Payload to JPL by end 2019
- Launch by January 2022
NISAR Science Observation Overview

- Wide swath in all modes for global coverage at 12 day repeat (2-5 passes over a site depending upon latitude)
- Data acquired ascending and descending

<table>
<thead>
<tr>
<th>NISAR Characteristic:</th>
<th>Would Enable:</th>
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</thead>
<tbody>
<tr>
<td>L-band (24 cm wavelength)</td>
<td>Low temporal decorrelation and foliage penetration</td>
</tr>
<tr>
<td>S-band (9 cm wavelength)</td>
<td>Sensitivity to light vegetation</td>
</tr>
<tr>
<td>SweepSAR technique with Imaging Swath &gt; 240 km</td>
<td>Global data collection</td>
</tr>
<tr>
<td>Polarimetry (Single/Dual/Quad)</td>
<td>Surface characterization and biomass estimation</td>
</tr>
<tr>
<td>12-day exact repeat</td>
<td>Rapid Sampling</td>
</tr>
<tr>
<td>3–10 m mode-dependent SAR resolution</td>
<td>Small-scale observations</td>
</tr>
<tr>
<td>3 years science operations (5 years consumables)</td>
<td>Time-series analysis</td>
</tr>
<tr>
<td>Pointing control &lt; 273 arcseconds</td>
<td>Deformation interferometry</td>
</tr>
<tr>
<td>Orbit control &lt; 500 meters</td>
<td>Deformation interferometry</td>
</tr>
<tr>
<td>&gt; 30% observation duty cycle</td>
<td>Complete land/ice coverage</td>
</tr>
<tr>
<td>Left/Right pointing capability</td>
<td>Polar coverage, north and south</td>
</tr>
</tbody>
</table>

NISAR Will Uniquely Capture the Earth in Motion

Observation Geometry

747 km
6 AM / 6 PM

Earth surface

> 240 km

33°

47°
NISAR Mode-Specific Science Targets in Observation Plan

- Each colored region represents a single radar mode chosen to satisfy multiple science objectives over that area.
- Avoids mode contention that would interrupt time series.

Planned Acquisitions:
- Background Land
- Land Ice
- Sea Ice
- Urban (small targets)
- US Agriculture
- Himalayas
- India Agriculture
- India Coastal Ocean
- Sea Ice Type

Background Land satisfies most Solid Earth and Ecosystems objectives.
**NISAR: Proposed Applications**

**Ecosystem Structure:**
- 1.1 Agriculture biomass & Crop monitoring
- 1.2 Forest biomass
- 1.3 Forest disturbance
- 1.4 Mangroves / Wetlands
- 1.5 Alpine vegetation
- 1.6 Vegetation phenology
- 1.7 Soil moisture
- 1.8 Ecosystem stress assessment

**Land Deformation:**
- 2.1 Inter-seismic / Co-seismic deformations
- 2.2 Landslides
- 2.3 Land subsidence
- 2.4 Volcanic deformations

**Cryosphere:**
- 3.1 Polar Ice Shelf / Ice sheet
- 3.2 Sea Ice Dynamics
- 3.3 Mountain snow/glacier
- 3.4 Glacier dynamics/hazard (Himalayan Region)
- 3.5 Climate response to glaciers
- 3.6 Sea-Ice advisory on safer marine navigation in Antarctica region

**Coasts & Ocean:**
- 4.1 Coastal erosion/shoreline change
- 4.2 Coastal subsidence and vulnerability to sea-level rise
- 4.3 Coastal bathymetry
- 4.4 Ocean surface wind
- 4.5 Ocean wave spectra
- 4.6 Ship detection
- 4.7 Coastal watch services
- 4.8 Tropical cyclone

**Disaster Response:**
- 5.1 Floods
- 5.2 Forest fire damage assessment
- 5.3 Coastal oil spill
- 5.4 Earthquakes / Others

**Geological Applications:**
- 6.1 Structural & Lithological mapping
- 6.2 Lineament mapping
- 6.3 Paleo-Channel study
- 6.4 Geomorphology
- 6.5 Land degradation mapping
- 6.6 Geo-archaeology
- 6.7 Mineral explorations
**ISRO Observation Plan**

**Background Land**
(Systematic Coverage)

- **S** (DP/CP) 37.5/25 MHz; **L** (DP) 20+5 MHz
- Period of Obs.: Jan – Dec; All 30 cycles

**Agriculture, Forest & Wetland**

- **S** (CP) 25 MHz; **L** (QP) 40+5 MHz
- Period of Obs.: Jan – Nov; 16/30 cycles

**Coasts / Coastal Ocean**

- **S** (CP) 25 MHz; **L** (VV+VH) 20+5 MHz
- Period of Obs.: Jan – Dec; Every Alternate cycles

**Indian Ocean**

- **S** (DP-VV+HV) 10 MHz
- **L**(SP) 5 MHz
- **BoB**: Jun – Dec; All cycles
- Arabian Sea: Apr- Sep; All cycles

**High Resolution Urban / Landslide**

- **S** (SP) 75 MHz; **L** (DP) 40+5 MHz

**Polar Science (ISRO targets)**

- **Ice Charactn (Ant; Svalbard; Bohai)**
  - **S** (CP) 25 MHz; **L** (VV+VH) 20+5 MHz
  - **Ant**: Every/ alternate cycle; **BoB**: Oct-Apr (Antarctica); Dec-May (Svalbard & Bohai)

**Polar Region (Antarctica + Greenland)**

- **S** (CP) 25 MHz; **L**(SP) 80 MHz
- **Ant**: Every/ alternate cycle; **Greenland**: every cycle

**Important Obs. Modes**

- **Deformation Studies**
  - **S** (DP) 37.5 MHz; **L** (DP) 20+5 MHz
  - Period of Obs.: Jan – Dec; Every Alternate cycles

**Indian Research Stns**

- **INDIA**
- **Bhutan**
- **Myanmar**
- **Sri Lanka**
- **Maldives**
- **Bangla Desh**

**ISPRS Technical Commission V - Education & Outreach, Mid-Term Symposium, November 20-23, 2018, Dehradun, India**
ISRO Targets over India and Surroundings
These exclude polar targets

- India + neighbors boundary
- Agriculture/ Forest/ wetland
- Jute crop
- Alpine forest
- Seismic Deformation
- Land Subsidence
- Landslide
- Urban subsidence
- Volcanic deformation/ studies
- Coastal region (sea 300km)
- Coastal habitat
- Coastal deformation
- Coastal mud bank
- Coastal region (land, 100 km)
- Ocean – Arabian Sea
- Ocean – Bay of Bengal
- Disaster – floods
- Disaster – forest fire
- Disaster – oil slick
- Cryosphere - Himalayas
Sea Ice Q1 (L single-pol: 5 MHz) - same as NASA requirement

Sea Ice Q2 (L single-pol: 5 MHz) - same as NASA requirement

Sea Ice Q3 (L single-pol: 5 MHz) - same as NASA requirement

Sea Ice Q4 (L single-pol: 5 MHz) - same as NASA requirement

Ice Characterization: S (CP) 25MHz & L(VV+VH) 20+5MHz; Sep-Apr, every 3days

Land Ice Antarctica: S (CP) 25MHz; Jul-Sep, 2 sets of mosaics L (SP) 80 MHz, Half swath (same as NASA requirement)

Priority Ice: L (SP) 80 MHz half swath – same as NASA reqmt

Svalbard Ice Characterization: S (CP) 25MHz & L(VV+VH) 20+5MHz; Dec-Mar, every 12 days

Bohai Bay Ice Characterization: S (CP) 25MHz & L(VV+VH) 20+5MHz; Dec-Mar, every 12 days

Land Ice Greenland: S (CP) 25MHz; Dec-Mar, 2 sets of mosaics L (SP) 80 MHz, Half swath (same as NASA requirement)
Revised Observation Plan over ISRO Targets

**In view of Left Only Look direction and 6PM Descending Orbit**

(Coloured bars show different imaging modes and period of observation)

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<thead>
<tr>
<th>ISRO Targets</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>OCT</th>
<th>NOV</th>
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<td>Systematic Coverage (Background Land)</td>
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<td>Deformation - Seismic/subsidence/volcanic</td>
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<td>Disaster - Forest fire / Flood / Any others</td>
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<td>Ocean - Bay of Bengal</td>
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<td>Coastal Ocean (300 km Buffer)/ Oil spill</td>
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<td>Svalbard + Bohai Bay (North Hemis)</td>
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<td>Antarctica (Ice Characterization)</td>
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<td>Land Ice - Greenland (Dec - Mar)</td>
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<td><strong>DESCENDING NODE</strong></td>
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<td>Cryosphere - Himalayas</td>
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<td>Agriculture (Kharif)</td>
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<td>Agriculture (Jute-crop)</td>
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<td>Forest-Biomass</td>
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<td>Forest-Wetland</td>
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<td>Forest - Alpine Vegetation</td>
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<td>Deformation - landslide/Urban</td>
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<td>Coastal - Habitat/deformation/coasts</td>
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<td>Antarctica (Ice Characterization)</td>
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<tr>
<td>Land Ice - Antarctica (full cov upto 87.5 deg S)</td>
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**Colour Scheme for Obs. Modes**

- S (CP) 25 MHz; L(DP) 20+5 MHz
- S(DP) 37.5 MHz; L(DP) 20+5 MHz
- S (CP) 25 MHz; L(VV+VH) 20+5 MHz
- S (DP) 10 MHz; L(SP) 5 MHz
- S (CP) 25 MHz; L(DP) 40+5 MHz
- S (SP) 75 MHz; L(HH+HV) 40+5 MHz

**Revision (from earlier version):**
- Asc and Desc targets are switched based on 6 PM Descending orbit
- Indian Seas are considered for low resolution ‘Joint Mode’ in addition to Indian coastal ocean (300 Km from coast line)
- With Left-only/look mode, targets like Svalbard may not be covered at all and Greenland -land ice will be partially covered.
- Antarctica-Land ice will be collected in ‘S-only’ mode in every cycle apart from ‘L-only’ mode planned in 80 MHz half swath mode

*2 adjacent smallest boxes jointly show one observation cycle (12 days) of NISAR*

Antarctica is considered up to 87.5° S latitude in view of Left-looking only NISAR orbit.
CALIBRATION SITES (Point target Sites)

Indian Sites

- Desalpar, Rann of Kutch
- Ahmedabad
- IMGEOS, Shadnagar

International Point Target Sites

- Rosamond CR array, California, USA
- Australian CR array, Queensland

Distributed Target Sites

- Amazon rainforest
- Congo rainforest
**Calibration**

- **Detachable Panels**

- **Assembled 2m Perforated CR**

- **SAC-Bopal New Campus**

- **SAC-Bopal CAL-VAL Site**

- **Perpendicularly Check**

- **Response of perforated CR in L-band airborne image of 14th February 2018**

- **SIMULATED NISAR Coverage and response of Amrapur**

- **Customised & Built perforated 2m CR, based on the design by JPL**
- **Compact light weight detachable CR design is in progress**
- **90cm CR planned to be deployed in Antarctica, Designed & developed in SAC**
- **In-house development of ARC in progress**
### NISAR Calibration Validation Plan - Validation Parameters

<table>
<thead>
<tr>
<th>THEME</th>
<th>Parameter</th>
<th>ROI</th>
<th>Validation Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oceanography</td>
<td>Coastline change</td>
<td>Andhra Coast</td>
<td>To be validated using optical and <em>in-situ</em> data</td>
</tr>
<tr>
<td></td>
<td>Ship detection</td>
<td>North Indian Ocean</td>
<td>To be validated using optical/DG-Shipping Corporation data</td>
</tr>
<tr>
<td></td>
<td>Oil-spill/dark spot detection</td>
<td>Indian coastal region</td>
<td>To be validated using optical/ <em>in-situ</em> (if possible) data</td>
</tr>
<tr>
<td>Mountain, Snow &amp; Glacier</td>
<td>Glacier ice-velocity product</td>
<td>Bench-mark glaciers</td>
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<tr>
<td>Geological Studies</td>
<td>Mineral map</td>
<td>Selected sites in Rajasthan, Jharkhand etc.</td>
<td>To be validated through structural data collection in the field Mineral potential of structures validation using geochemical analysis (XRD and Spectroscopy) For palaeochannel studies, GPR, DGPS and resistivity survey on palaeochannels and also detailed ground truth data collection</td>
</tr>
<tr>
<td>Coastal applications</td>
<td>Coastal land cover map</td>
<td>Coastal regions in Gujarat, Maharshtra and Andhra</td>
<td>Using ground truth data and ancillary data (published thematic map)</td>
</tr>
<tr>
<td>Ecosystems agriculture</td>
<td>Radar vegetation index</td>
<td>Selected regions in Gujarat, Indo-Gangetic plains, sites in Tamilnadu etc.</td>
<td>Validation through vegetation water content and ancillary data</td>
</tr>
<tr>
<td></td>
<td>Radar Roughness index</td>
<td></td>
<td>Through ground truth data (vegetation and soil moisture)</td>
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<tr>
<td></td>
<td>Surface Soil moisture content</td>
<td></td>
<td>Through in-situ measurements and other sensors</td>
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<td></td>
<td>Vegetation optical depth</td>
<td></td>
<td>Validation through biomass and backscattering model</td>
</tr>
<tr>
<td>Hydrology studies</td>
<td>Soil moisture, flood inundation</td>
<td>Kosi, Godavari, Mahanadi delta, Bikaner Rajasthan</td>
<td>Soil moisture measurements, Ground truth data for inundation, resistivity survey for perched aquifers.</td>
</tr>
<tr>
<td>Ecosystems forests</td>
<td>Forest Cover and Change Detection where change &gt;50%</td>
<td>Selected forests in India</td>
<td>By ground truth and published information from respective ministries</td>
</tr>
<tr>
<td>Soil moisture</td>
<td>Surface Soil Moisture (SSM)</td>
<td>Selected core study sites over India (Gujarat, Karnataka, MP, UP and Raj. etc.)</td>
<td>To be validated using in-situ soil moisture stations, field campaign and satellite data products with models</td>
</tr>
</tbody>
</table>
MIDAS (MIcrowave Data Analysis Software)

- **SAR Polarimetry (PolSAR)**
- **SAR interferometry (InSAR)**
- **Polarimetric SAR interferometry (PolInSAR)**

- Written in C/C++
- Capable GUI in JAVA
- SAR radiometric analysis tools like SAR image quality parameter estimation and impulse
- Other modules like $\sigma^0$, $\gamma^0$ generation, etc
- Support for full & Hybrid-pol decompositions
- Support for RISAT-1 hybrid pol analysis and various spaceborne and L&S airborne sensor
- Polarimetric speckle filter integrated (POLSAR refined Lee)
- Modular and easily extensible
- Applications such as Glacier, Ship detection, Oil Spill, Supervised Classifier, Polarimetry based Crops discrimination
M-delta decomposed RISAT-1 Hybrid-Pol data over Mysore after POLSAR filtering

Python based InSAR Processing tool
Joint Science Activities on Ecosystem Theme

NASA and ISRO have regular telecon for focused discussion on development of algorithms and validation of results through sharing of ground validation data and time series SAR data for forest biomass retrieval, crop area and inundation mapping.

Recently, ISRO has shared ground validation data for Forest AGB over Dehradun and Hoshangabad regions to NASA ecosystem team and NASA shared time series ALOS-PALSR and Sentinel-1 data over Hoshangabad area and Chilika Lake for forest and inundation studies, respectively.

Both teams have shown interest in identifying global targets of common interest for L&S band joint mode data acquisition.

Sharing of ground measured data for validation of forest AGB over Indian test sites

Spatial distribution of ground data pertaining to forest biomass

Time series ALOS PALSAR data over Hoshangabad in MP
Joint studies in Solid Earth

Barren Island volcano deformation

Cumulative Deformation 2007-2009 (ALOS-1)

Mean Deformation rate 2014-2017 (Sentinel-1)

(Seth et al, 2014)
A 3-day tutorial was convened in Ahmedabad, India entitled *Soil Moisture and Agricultural Monitoring using Microwave Remote Sensing* by the NASA Soil Moisture Active Passive (SMAP) Project, NASA ISRO SAR (NISAR) Science Team, Indian Space Research Organisation (ISRO) Space Applications Centre (SAC), and IEEE Geoscience and Remote Sensing Society (GRSS). The goals of the tutorial were international cooperation, networking, and lasting scientific connections. A measure of success was to have 20-30% of the participants engaged in serious post-tutorial research in microwave remote sensing.
# L&S Band Airborne SAR System Specifications

<table>
<thead>
<tr>
<th>S.N</th>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Platform</td>
<td>Beech craft B-200</td>
</tr>
<tr>
<td>2</td>
<td>Aircraft Height</td>
<td>8.0 kms</td>
</tr>
<tr>
<td>3</td>
<td>Platform Velocity</td>
<td>120 m/s</td>
</tr>
<tr>
<td>4</td>
<td>Operating Frequency</td>
<td>1250MHz (L) &amp; 3200MHz (S)</td>
</tr>
<tr>
<td>5</td>
<td>Chirp Bandwidth</td>
<td>10MHz</td>
</tr>
<tr>
<td>6</td>
<td>Resolution - (Az X SL)</td>
<td>2m X 15m</td>
</tr>
<tr>
<td>7</td>
<td>Sampling Frequency (MHz)</td>
<td>250 (Output Samples decimated according to bandwidth)</td>
</tr>
<tr>
<td>8</td>
<td>SAR Mode</td>
<td>Stripmap</td>
</tr>
<tr>
<td>9</td>
<td>Polarization Modes</td>
<td>Single</td>
</tr>
<tr>
<td>10</td>
<td>Effective Antenna dimensions</td>
<td>1.0m (Azimuth) x 0.35m (Elevation)</td>
</tr>
<tr>
<td>11</td>
<td>Antenna Roll Bias</td>
<td>37° - Nominal</td>
</tr>
<tr>
<td>12</td>
<td>Imaging Swath (S+L)</td>
<td>5.9km @ 37°</td>
</tr>
<tr>
<td>13</td>
<td>Integrated Ambiguities</td>
<td>&lt;-20dB</td>
</tr>
<tr>
<td>14</td>
<td>Sigma Naught Threshold</td>
<td>&lt;-20dB</td>
</tr>
<tr>
<td>15</td>
<td>Radiometric Resolution</td>
<td>3dB-Single Look</td>
</tr>
<tr>
<td>16</td>
<td>RF Power Transmit</td>
<td>40W (L) &amp; 165W (S)</td>
</tr>
<tr>
<td>17</td>
<td>Incidence Angle Range</td>
<td>24° to 77°</td>
</tr>
</tbody>
</table>
Science Plan and Research Announcement for L&S Airborne SAR

Region-wise distribution of Project Proposers

Airborne SAR R.A. Project Proposal Statistics:
77 Proposals; 45 Institutions

No. of Projects (Total: 77)
- 1 - 2
- 3 - 4
- 5 - 8
- 9 - 10
- 11 - 15

Number of Proposals under different Application Themes:
L&S Band Airborne SAR Flight Campaign-2017/2018

<table>
<thead>
<tr>
<th>Phase</th>
<th>June 2017</th>
<th>February 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>Gujarat Sites (8 sites)</td>
<td>Andra/Telengana (5 sites)</td>
</tr>
<tr>
<td>Base</td>
<td>Ahmedabad</td>
<td>Hyderabad</td>
</tr>
</tbody>
</table>

Themes

- Agriculture
- Soil Moisture Study
- Urban Applications
- Hydrology/Flood Mapping
- Wetland Mapping
- Coastal Applications
- Oceanography
- Mangroves
- Geological Applications
- Forest

Total sites: 66
Outreach Programs

Satellite Meteorological and Oceanographic Research and Training (SMART)

Training & Research in Earth-Eco Systems (TREES)

ISRO’s initiative to promote use of Indian EO data & products for research in Satellite Meteorology & Oceanography and Earth eco-system studies among students, researchers & academia

Outreach activities provide:

- Familiarization with Indian EO data
- Short-term advanced training courses
- Long duration 3-9 months - Research

- Data analytics and advanced visualization
- State-of-the-art computing facilities
- Research guidance
- Subsidized accommodation & food

Fields of Research

- Processes
- Retrieval
- Assimilation
- NWP
- Vegetation Dynamics
- Hydrology
- Digital Image Processing and m/c learning

Research Programme

SMART / TREES

- Research Initiation Programme
- Advance Research Programme
- Data Exploration Programme

Training Programme

- Student & Researchers
- Trainers
- Operational Agencies
- Popularise ISRO Missions, Data & Products

- University
- Institutes
- R & D Organ.
- Faculty
- Teachers
- IMD
- NCMRWF
- INCOIS
- IAF
- NAVY
- State RS Centers

ISPRS Technical Commission V - Education & Outreach, Mid-Term Symposium, November 20-23, 2018, Dehradun, India
TREES & SMART: Research and Training opportunities at EPSA

Participants Trained: 723
Research Projects Completed: 148
Trainings: 34

Crop Suitability Analysis for UP

Generation of 3D building model & shadow analysis

Human Discomfort Index

Global analysed wind fields from ScatSat-1 and its application

Effect of ships on scatterometer measurements

AltKa derived Global ship count Mar, 13 to June, 18 at 1° x 1°

Convective Overshooting using Satellite Data
Visualization of Earth Data and Archival System (VEDAS)

Training & Research in Earth-Eco Systems (TREES)

<table>
<thead>
<tr>
<th>Training Title</th>
<th>Start Date</th>
<th>End Date</th>
<th>Participants</th>
<th>Institutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarimetric SAR data Processing and Analysis</td>
<td>20-Dec-16</td>
<td>21-Dec-16</td>
<td>21</td>
<td>12</td>
</tr>
<tr>
<td>SAR and Hyper-Spectral Data Analysis for Forest Applications</td>
<td>30-Oct-17</td>
<td>03-Nov-17</td>
<td>24</td>
<td>13</td>
</tr>
<tr>
<td>SAR Data Processing and Analysis for Land Applications with Special Emphasis on L &amp; S Bands</td>
<td>06-Aug-18</td>
<td>10-Aug-18</td>
<td>32</td>
<td>27</td>
</tr>
<tr>
<td>SAR Data Processing and Analysis for Land Applications with Special Emphasis on L &amp; S Bands</td>
<td>24-Sep-18</td>
<td>28-Sep-18</td>
<td>25</td>
<td>19</td>
</tr>
</tbody>
</table>

Total 102 Participants from 4 Trainings
Thanks