NISAR Science and Applications Overview - India Perspective

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NISAR: Objectives

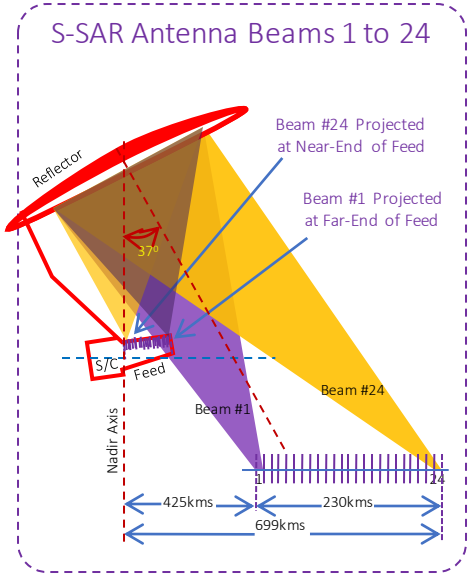
Key Scientific Objectives

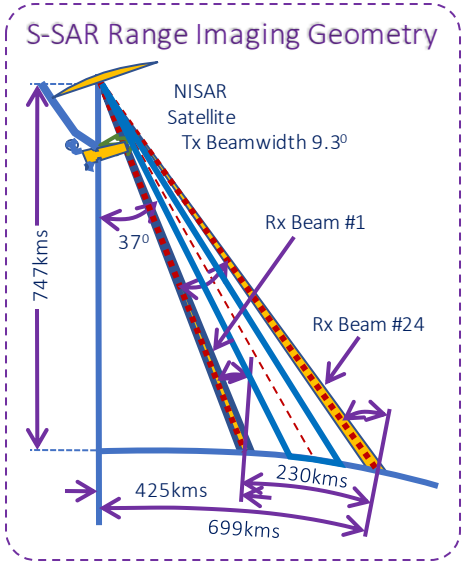
- Understand the response of ice sheets and glaciers to climate change and the interaction of sea ice and climate
- Understand the dynamics of carbon storage and uptake in wooded, agricultural, wetland, and permafrost systems
- Determine the likelihood of earthquakes, volcanic eruptions, and landslides

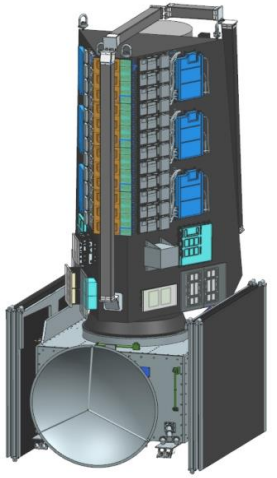
Key Applications Objectives

- Understand societal impacts of dynamics of water, hydrocarbon, and sequestered CO_2 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



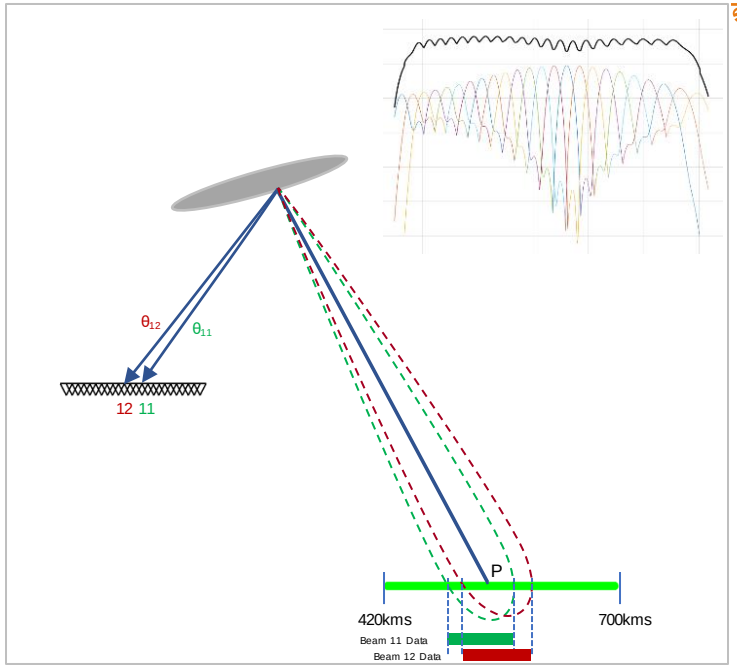


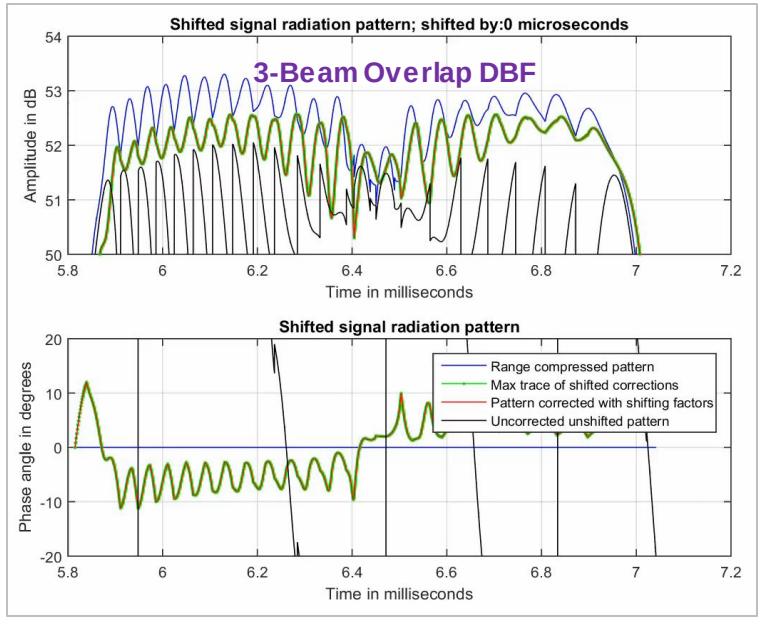


Parameters	L-band SAR	S-band SAR
Orbit	747 Km with 98.5° Inclination	
Frequency (wavelength)	1.25GHz (24cm)	3.20 (9.3cm)
Repeat cycle	12 days	
Time of Nodal Crossing	6AM / 6PM	
Polarization	Single (SP), Dual (DP), Circular (CP), Quad (QP) and Quasi-quad pol (QQP)	
Incidence angle range	33 – 47 deg	
Available Range Bandwidths	5 MHz, 20 MHz, 40 MHz, 80 MHz	10 MHz, 25 MHz, 37.5 MHz, 75 MHz
Resolution (Azimuth × Slant range)	6.9m × 7.5m (for 20MHz bw) 6.9m × 1.9m (for 80MHz bw)	6.4m × 6m (at 25MHz bw) 6.4m × 2m (for 75MHz bw)
Max. Swath width	**> 240 Km**	
Data and Product Access	**Free & Open**	

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**





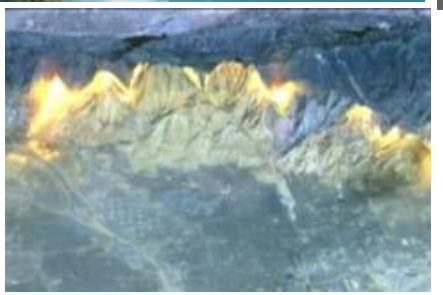
NISAR Science Observation Overview

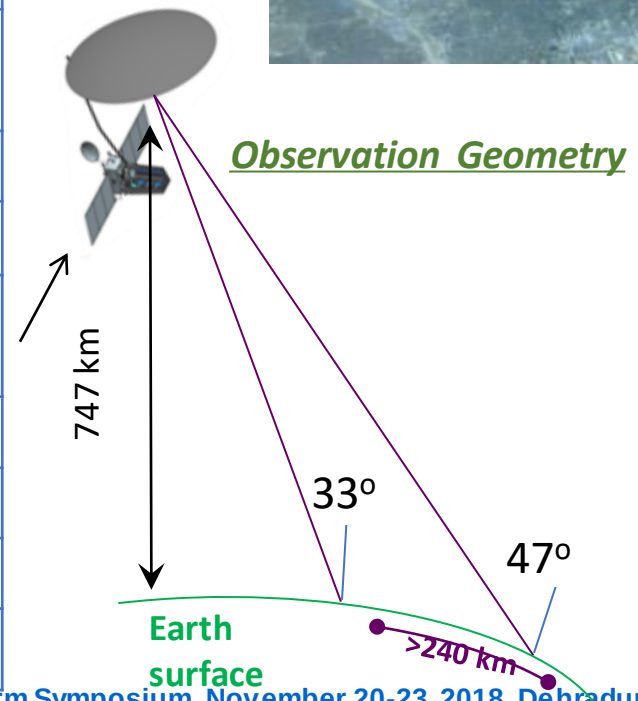
- Wide swath in all modes for global coverage at 12 day repeat (2-5 passes over a site depending upon latitude)
- Data acquired ascending and descending

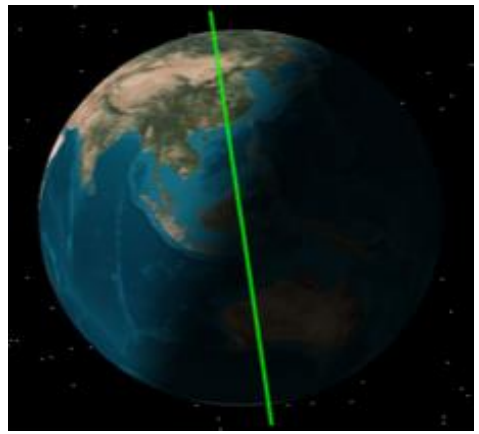
NISAR Characteristic:	Would Enable:
L-band (24 cm wavelength)	Low temporal decorrelation and foliage penetration
S-band (9 cm wavelength)	Sensitivity to light vegetation
SweepSAR technique with Imaging Swath > 240 km	Global data collection
Polarimetry (Single/Dual/Quad)	Surface characterization and biomass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

NISAR Will Uniquely Capture the Earth in Motion



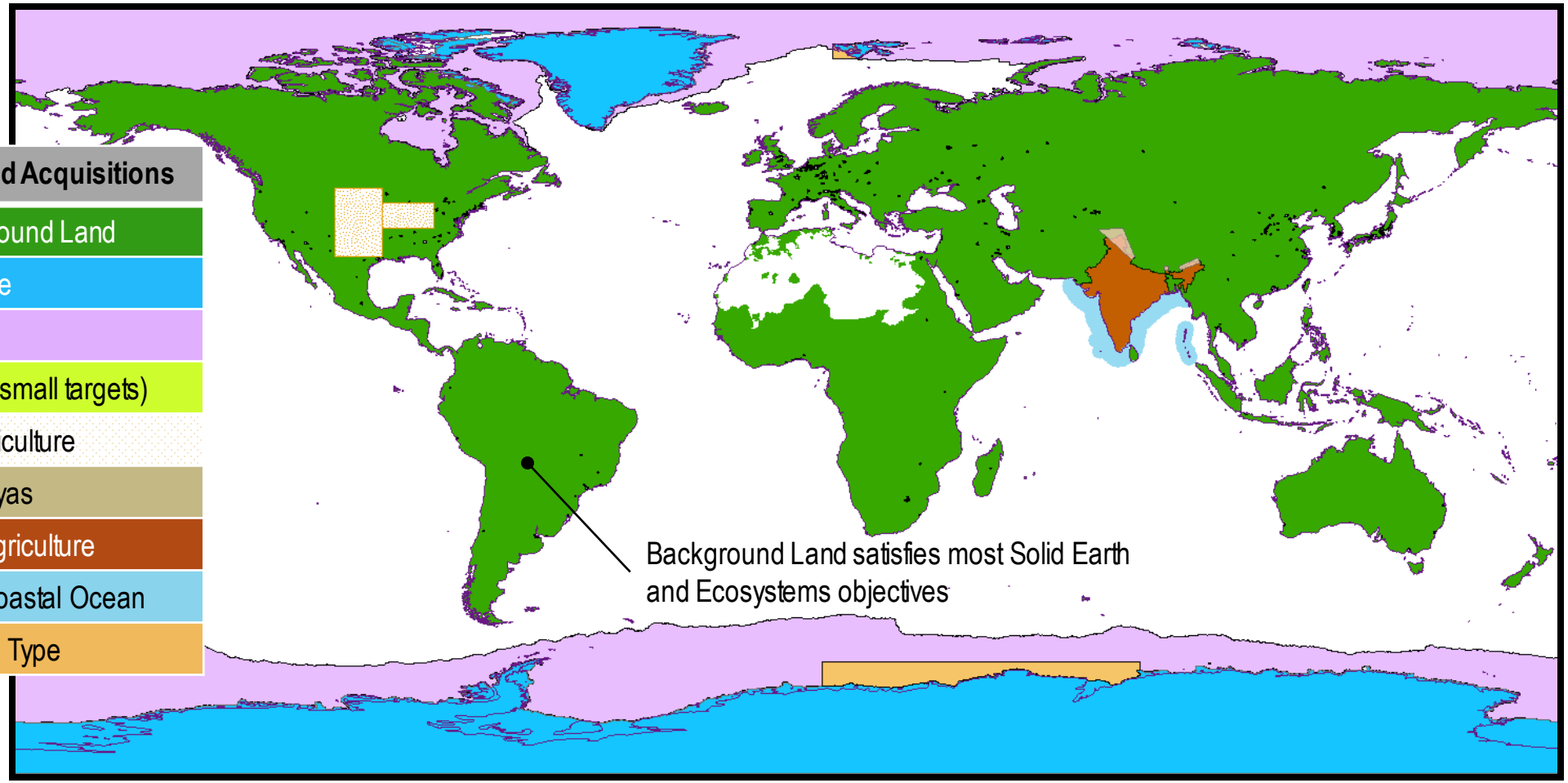




6 AM / 6 PM

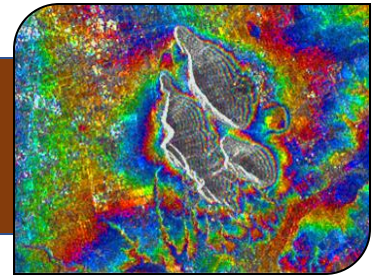
NISAR Mode-Specific Science Targets in Observation Plan



- 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

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

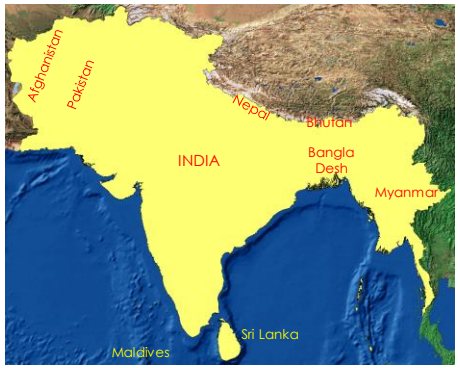
Coasts & Ocean: 4.1 Coastal erosion / shoreline change; 4.2 Coastal subsidence and vulnerability to sea-level rise; 4.3 Coastal bathymetry; 4.4 Ocean surface wind; 4.5 Ocean wave spectra; 4.6 Ship detection; 4.7 Coastal watch services; 4.8 tropical cyclone

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

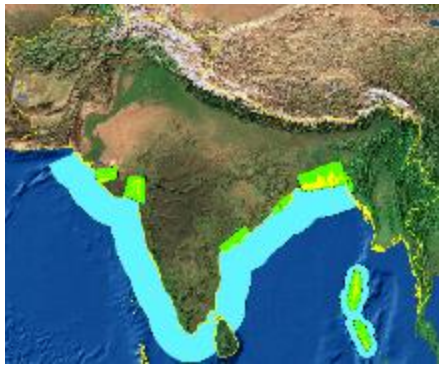
ISRO Observation Plan

Background Land

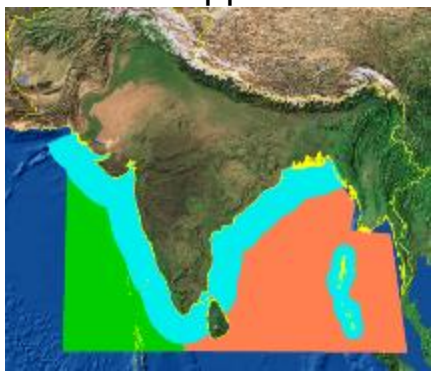


Agriculture & Forest

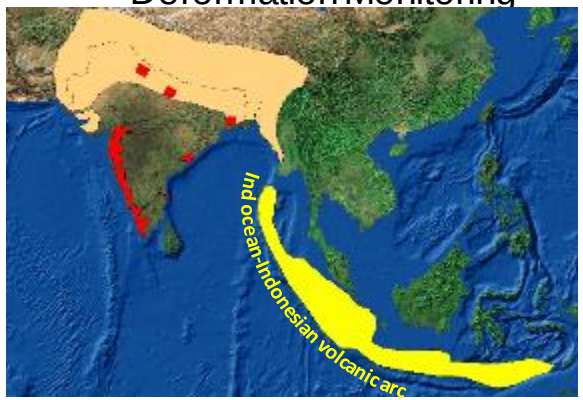
Coastal Applications



Ocean Applications

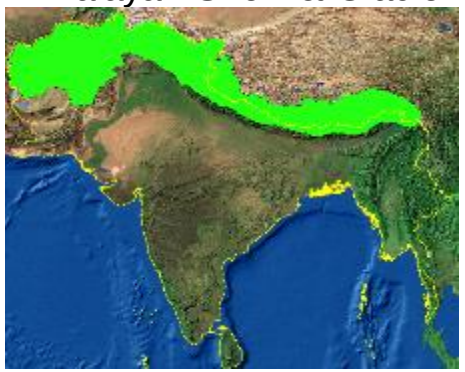


Deformation Monitoring



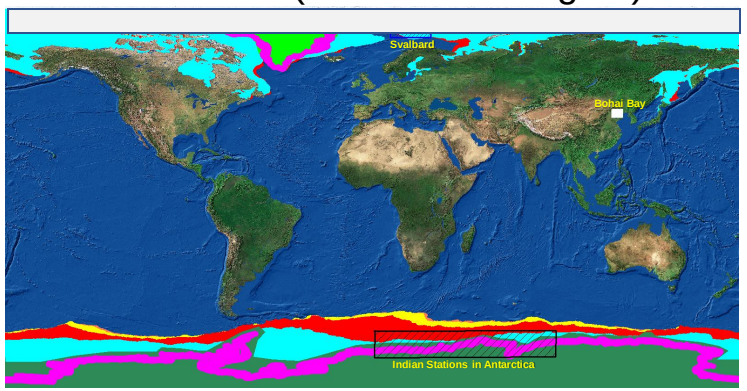
Disaster Management

Himalayan Snow & Glacier



Polar Science (ISRO targets)

Polar Science (ISRO+ Joint targets)



Important Obs. Modes

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
Jan – Nov; 16/30 cycles

Coasts / Coastal Ocean
S (CP) 25 MHz; L (VV+VH) 20+5 MHz
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

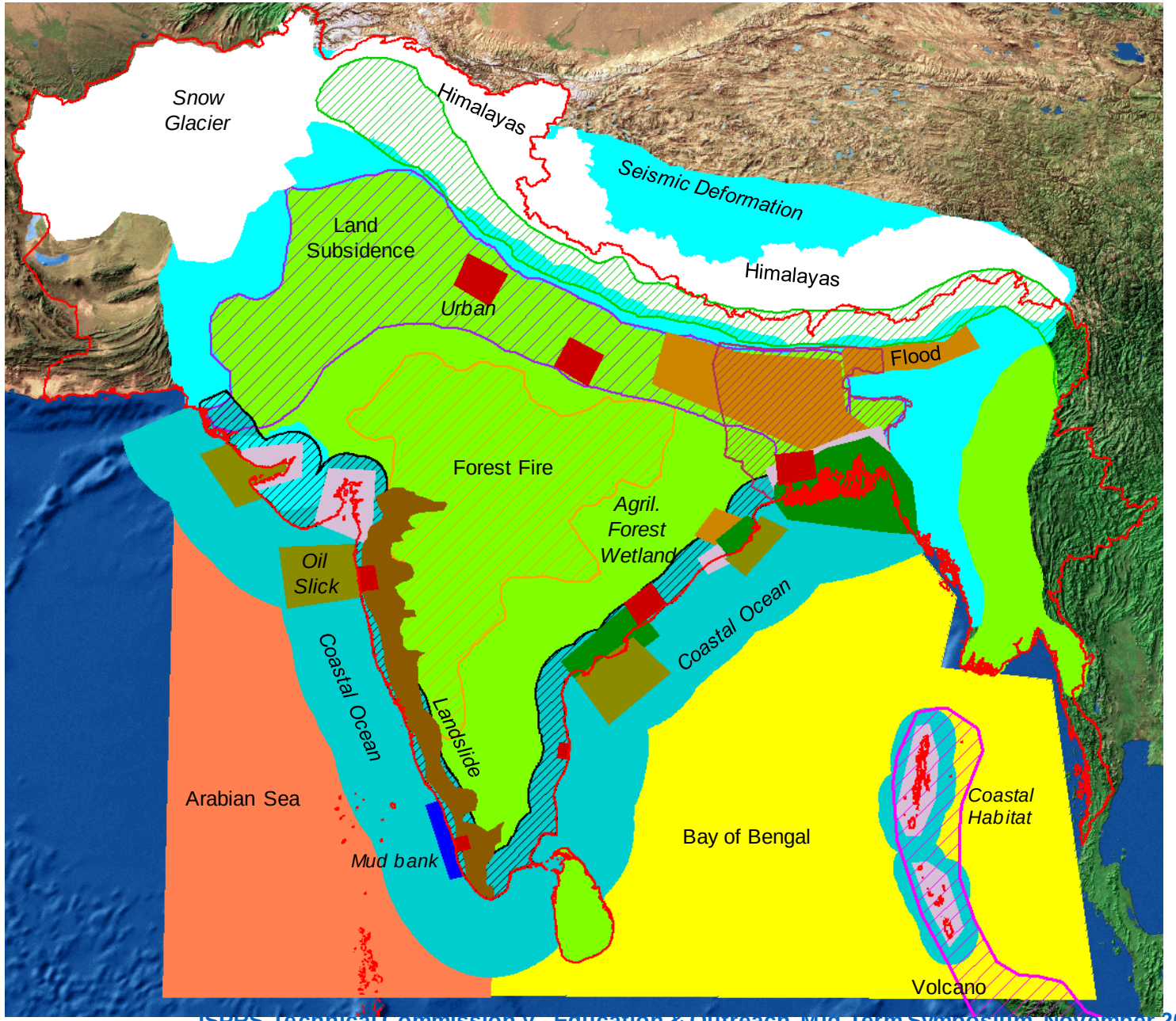
Deformation Studies
S (DP) 37.5 MHz; L (DP) 20+5 MHz
Jan – Dec; Every Alternate cycles

Ice Charactn (Ant; Svalbard; Bohai)
S (CP) 25 MHz; L (VV+VH) 20+5 MHz
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

ISRO Targets over India and Surroundings

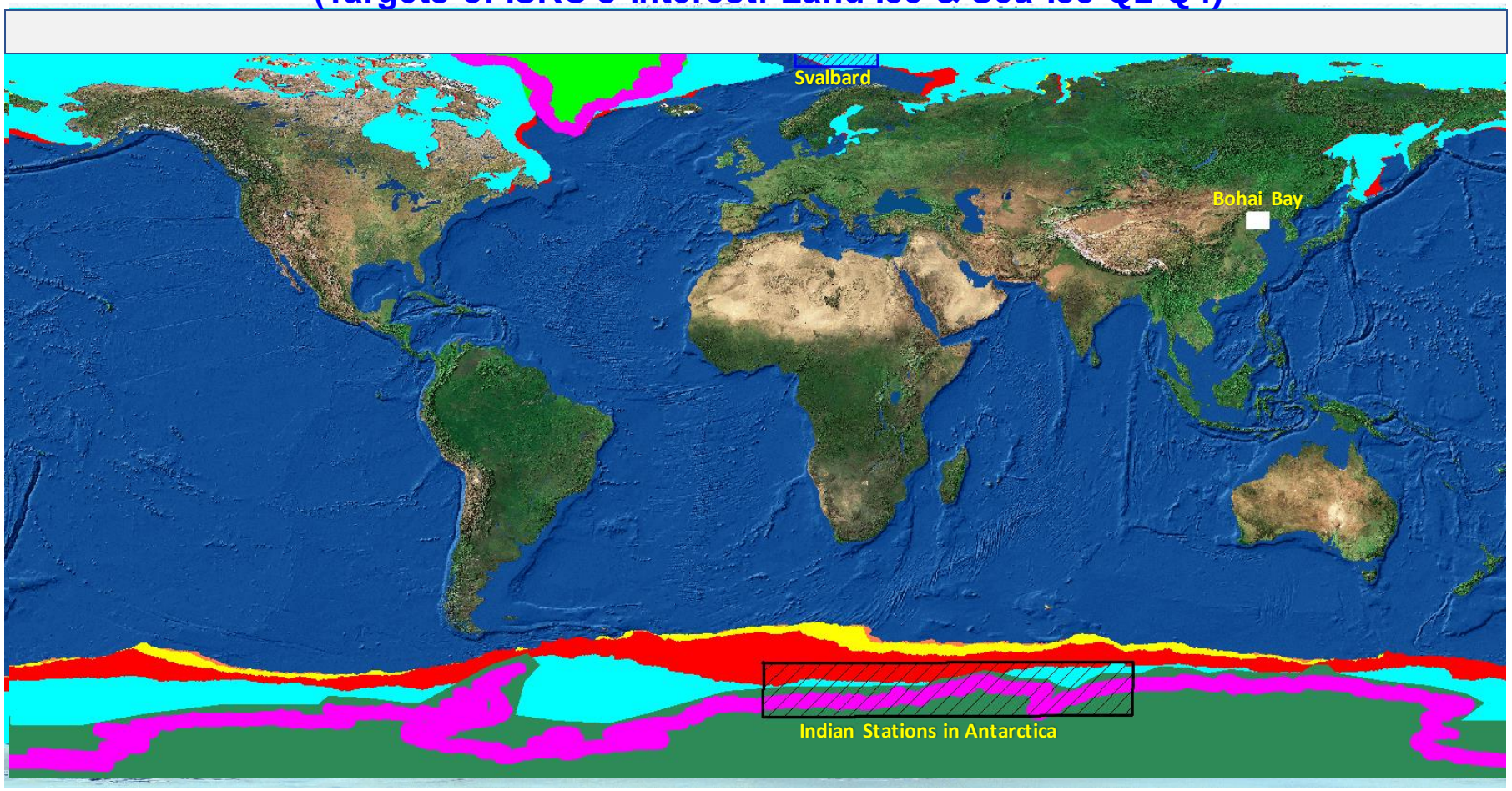
These exclude polar targets



- 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

NASA Polar Cryosphere Targets

(Targets of ISRO's Interest: Land Ice & Sea-Ice Q1-Q4)

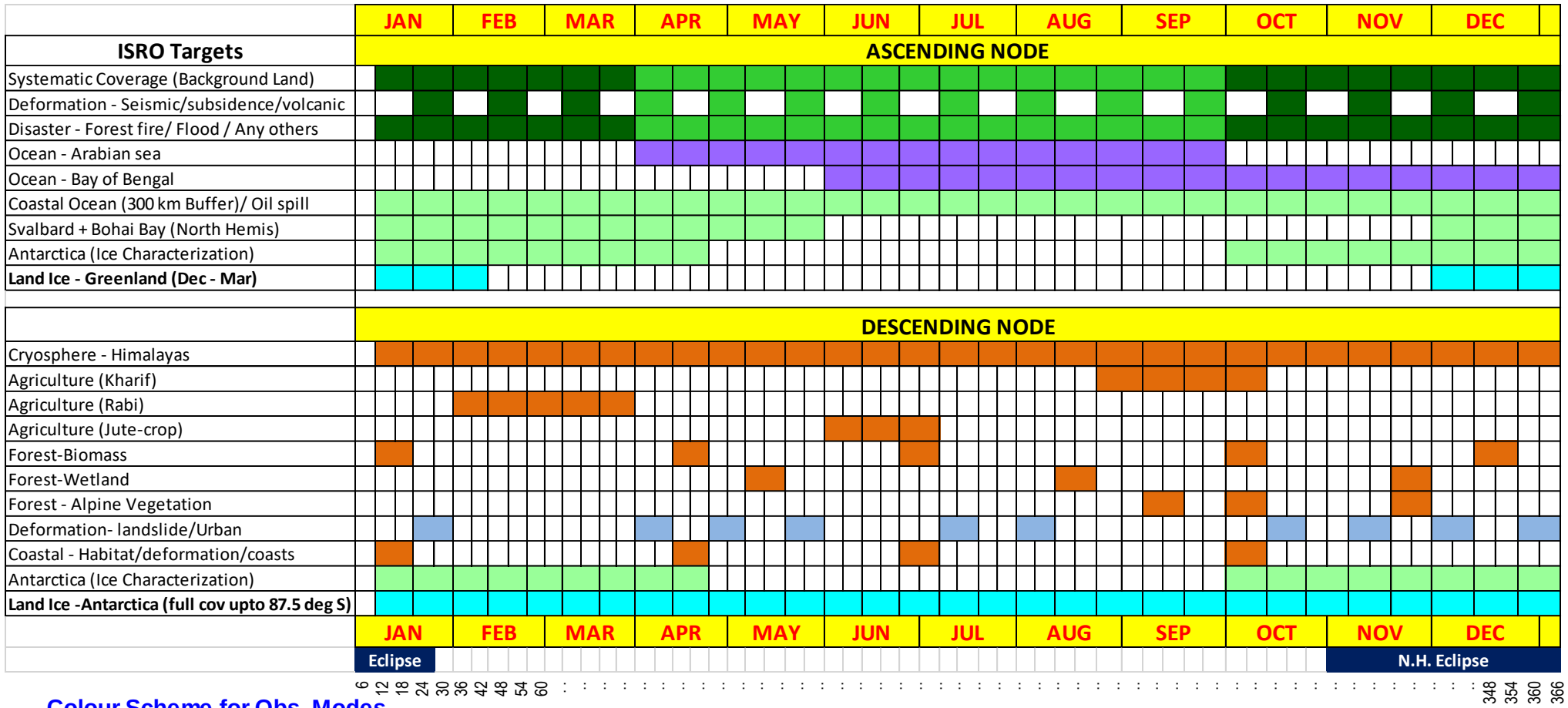


- Sea Ice Q1 (L- single-pol : 5 MHz) - same as NASA requirement
- Sea Ice Q2 (L- single-pol : 5 MHz) - same as NASA requirement
- Sea Ice Q3 (L- single-pol : 5 MHz) - same as NASA requirement
- Sea Ice Q4 (L- single-pol : 5 MHz) - same as NASA requirement
- Ice Characterization: S (CP) 25MHz & L(VV+VH) 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)



Antarctica is considered up to 87.5° S latitude in view of Left-looking only NISAR orbit.

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: VV+VH) 10MHz; L(SP) 5 MHz	
S (CP) 25 MHz	
S (CP) 25 MHz; L(QP) 40+5 MHz	
S (SP) 75MHz; L(HH+HV) 40+5 MHz	

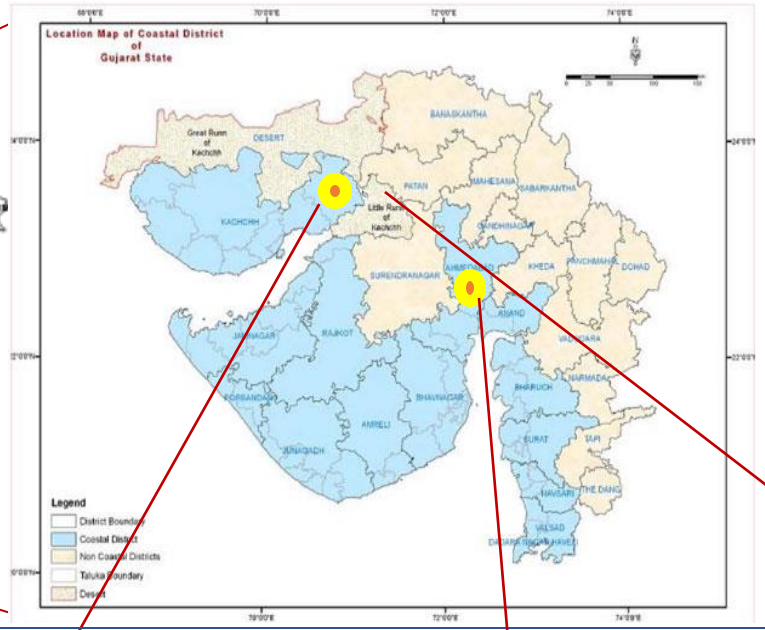
Revision (from earlier version):

- 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

CALIBRATION SITES (Point target Sites)

Indian Sites



International Point Target Sites

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

IMGEOS, Shadnagar

Desalpar, Rann of Kutch

Ahmedabad

Amrapura, Little Rann of Kutch

Image Courtesy: Google Earth

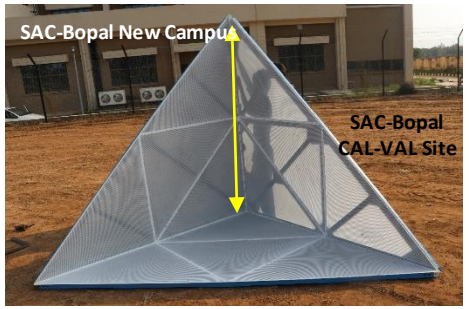
Distributed Target Sites

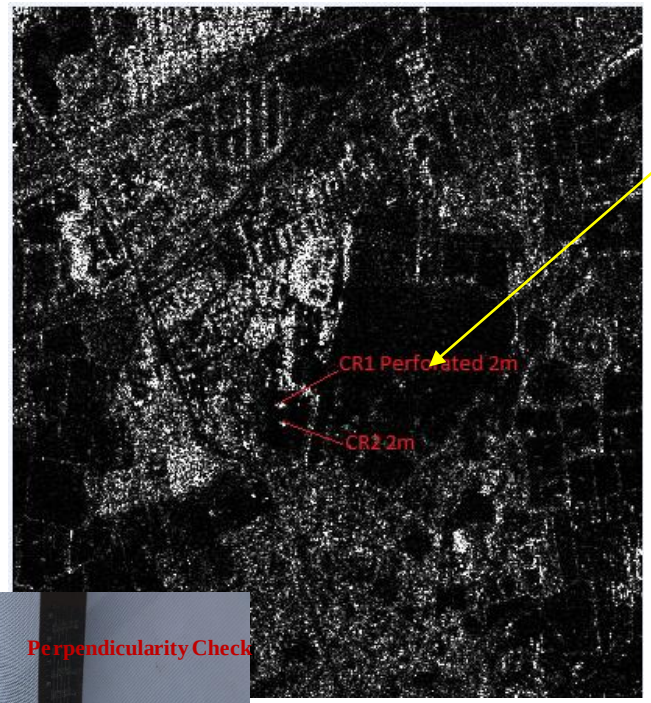
- Amazon rainforest
- Congo rainforest

Calibration

Detachable Panels

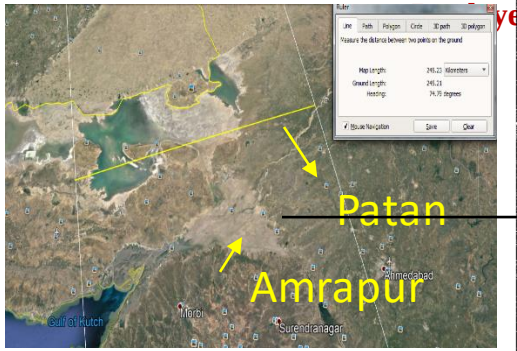
Assembled 2m Perforated CR

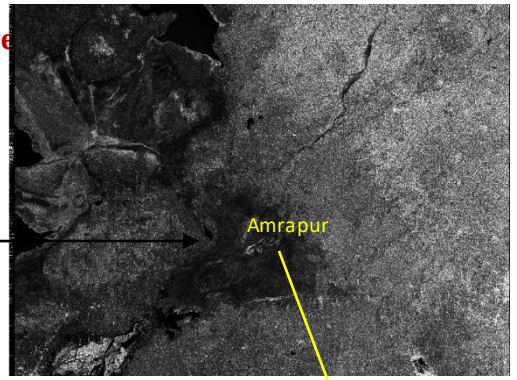




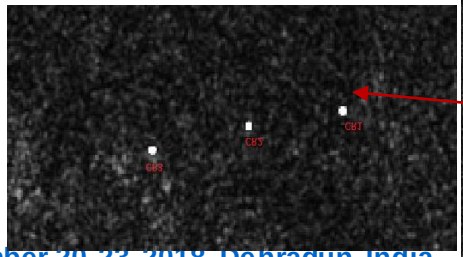
Response of perforated CR in L-band airborne image of 14th February 2018

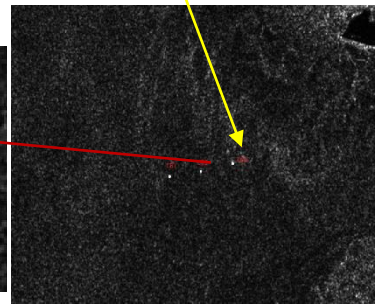
SIMULATED NISAR Coverage and response of Amrapur





- **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

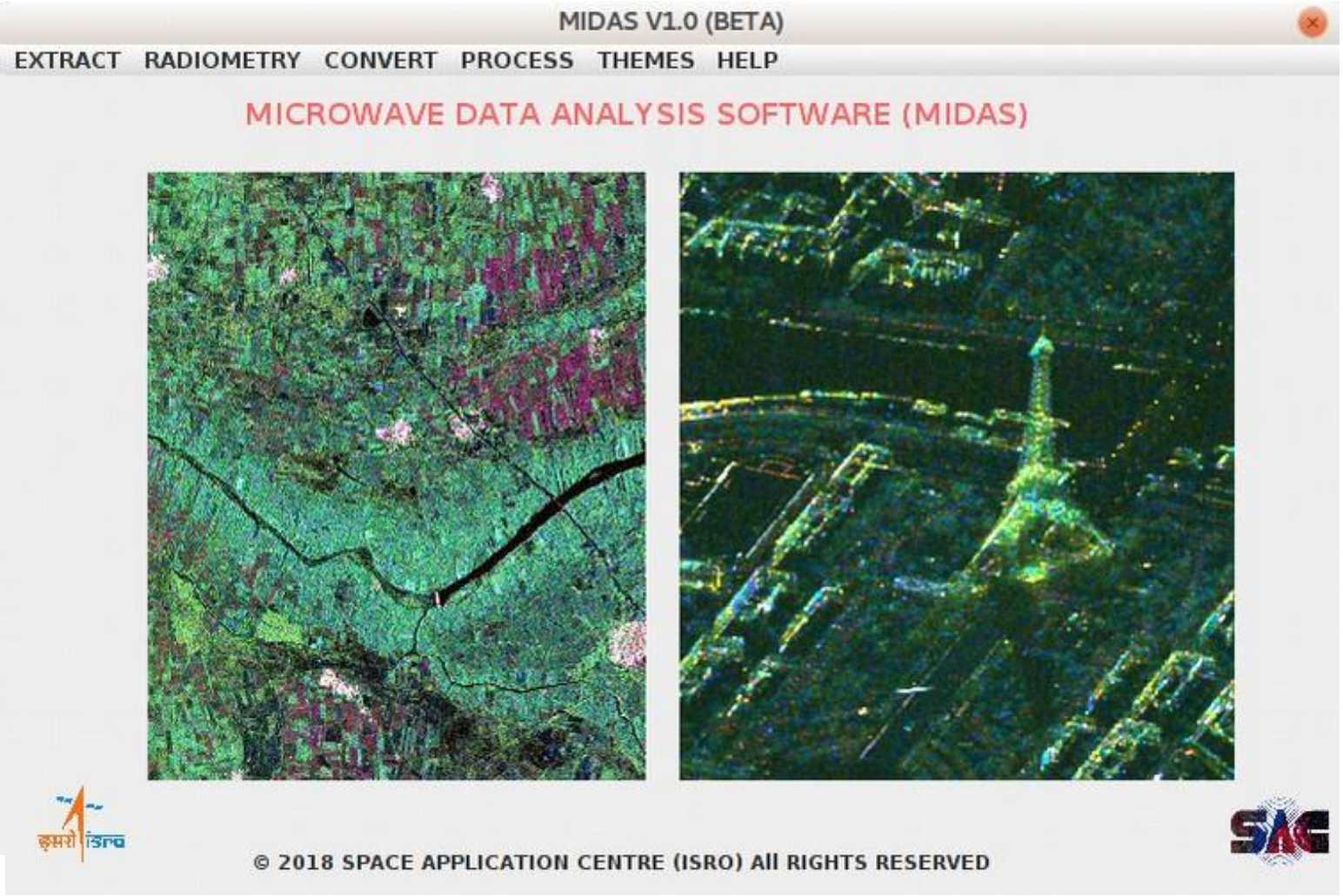




NISAR Calibration Validation Plan-Validation Parameters

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

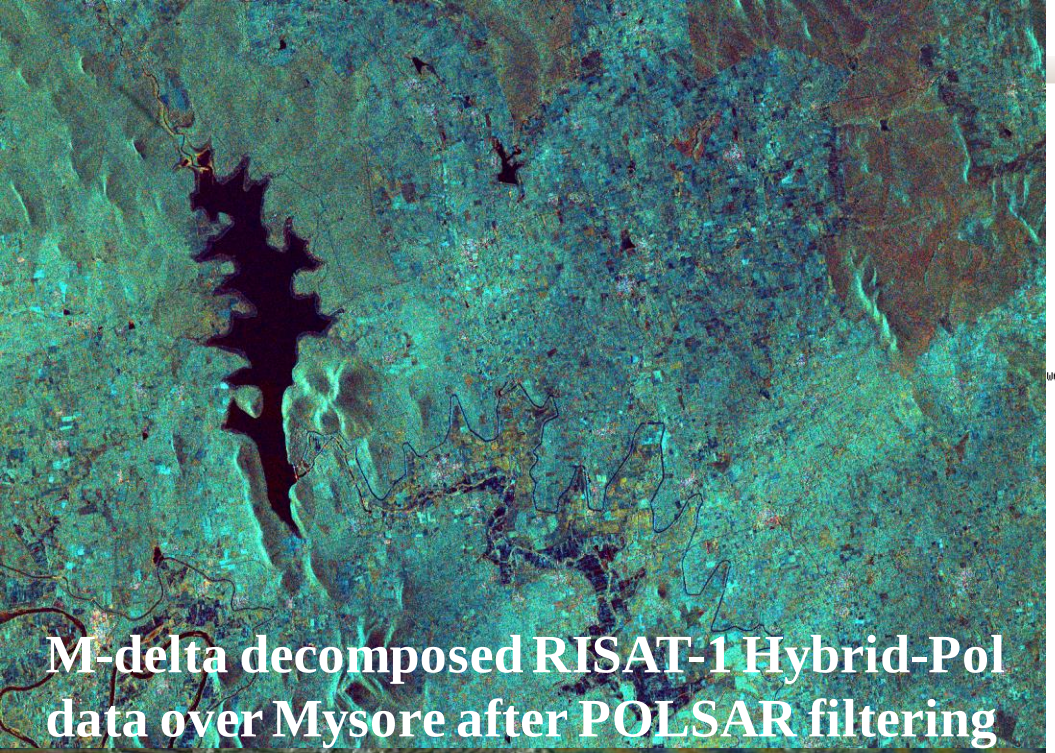
MIDAS (MIcrowave Data Analysis Software)



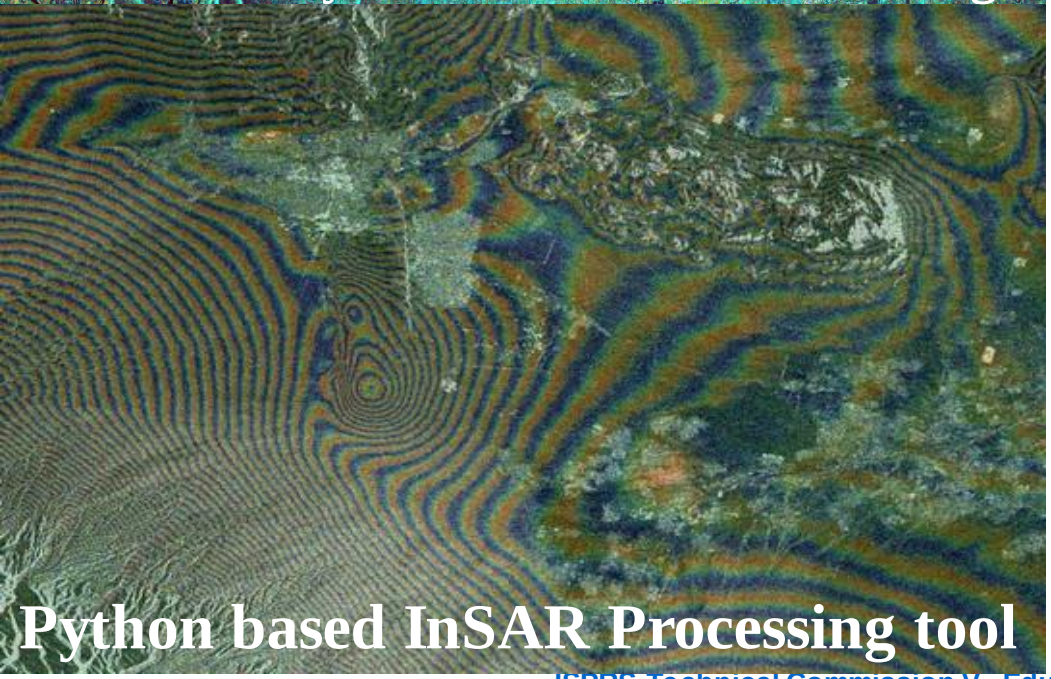
- Written in C/C++
- Capable GUI in JAVA
- SAR radiometric analysis tools like SAR image quality parameter estimation and impulse
- Other modules like σ^o, γ^o generation, etc
- Support for full & Hybrid-pol decompositions
- Support for RISAT-1 hybrid pol analysis and various spaceborne and L&S airborne 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

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

Polarimetric Signature (Van Zyl type) module

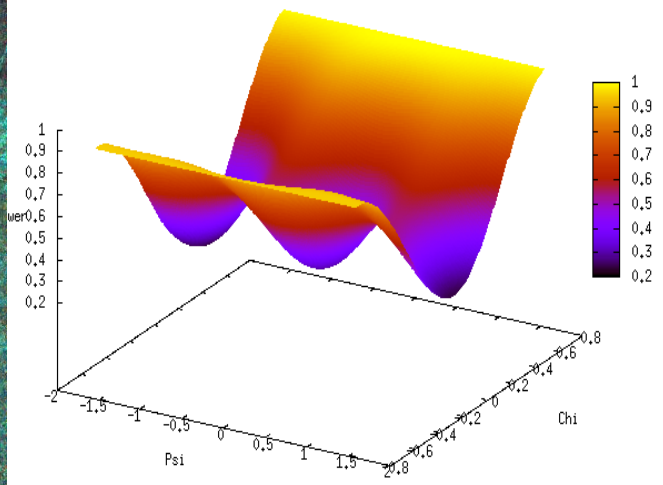


M-delta decomposed RISAT-1 Hybrid-Pol data over Mysore after POLSAR filtering

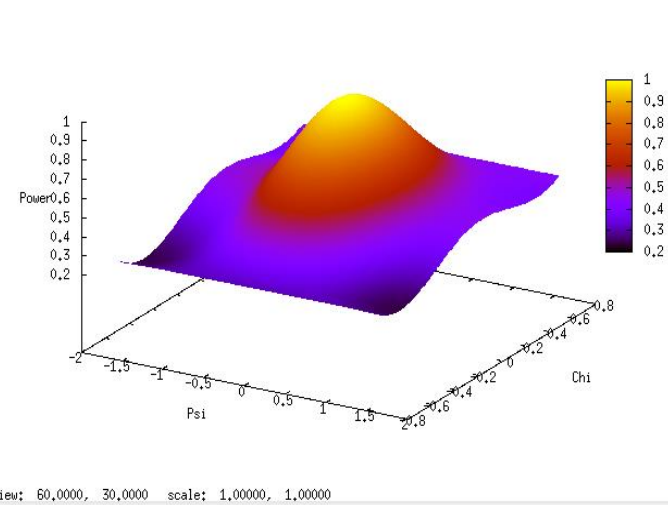


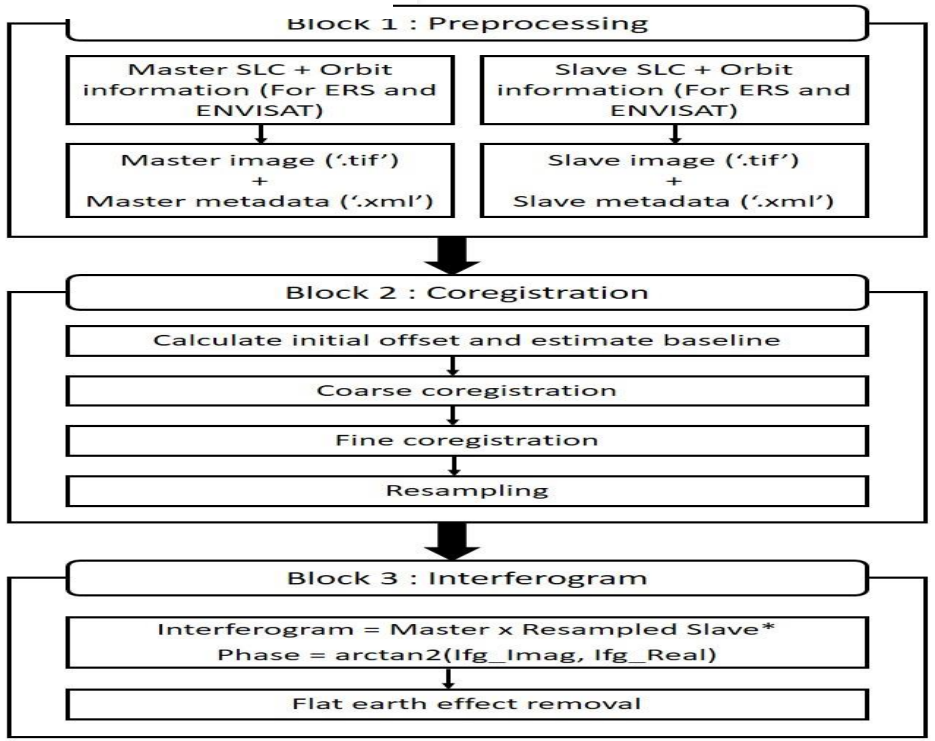
Python based InSAR Processing tool

Cross pol signature generated at (50,500)



Co-pol signature generated at (50,500)



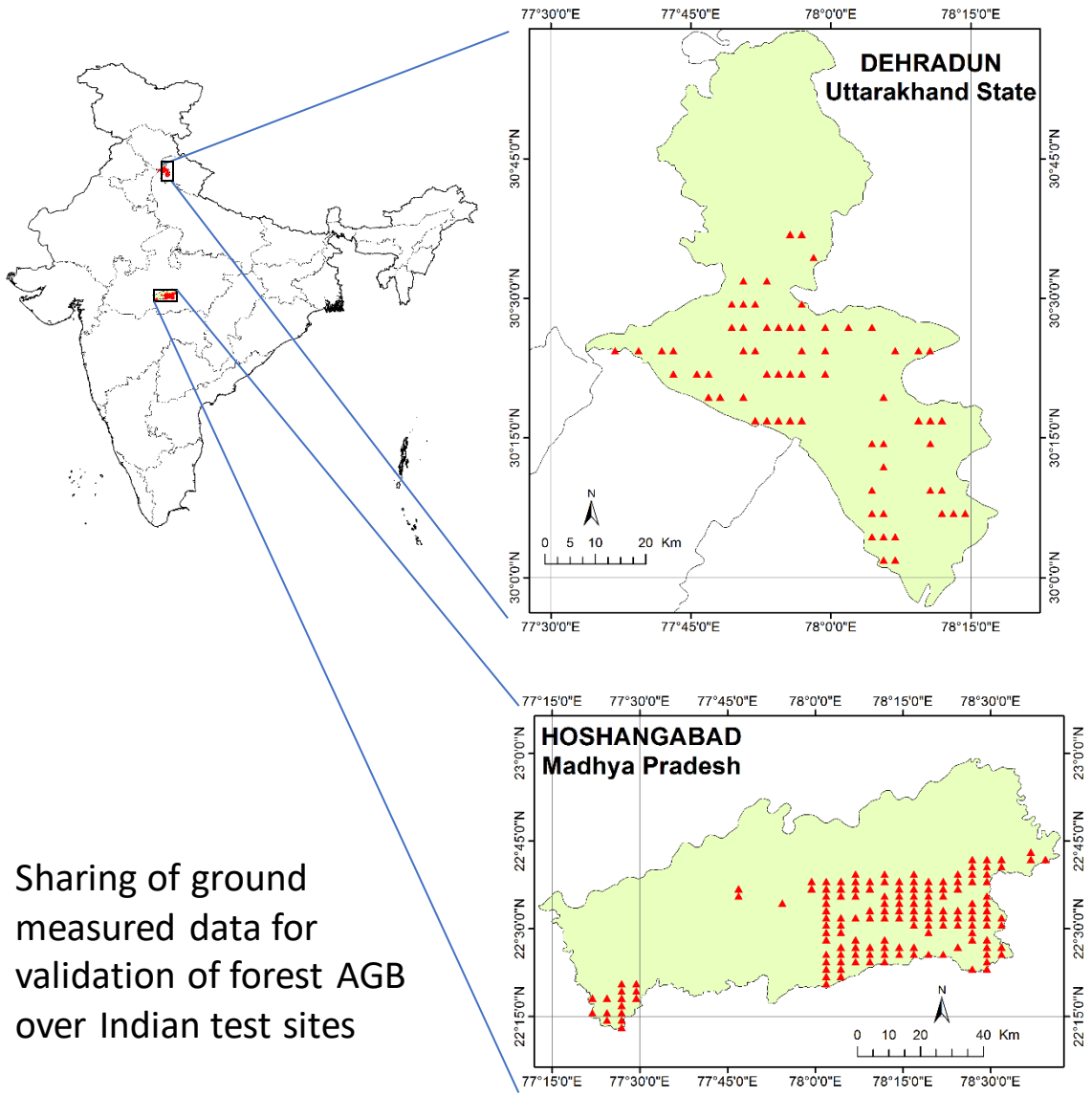


Joint Science Activities on Ecosystem Theme

NASA and ISRO have regular telecon for focussed 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.

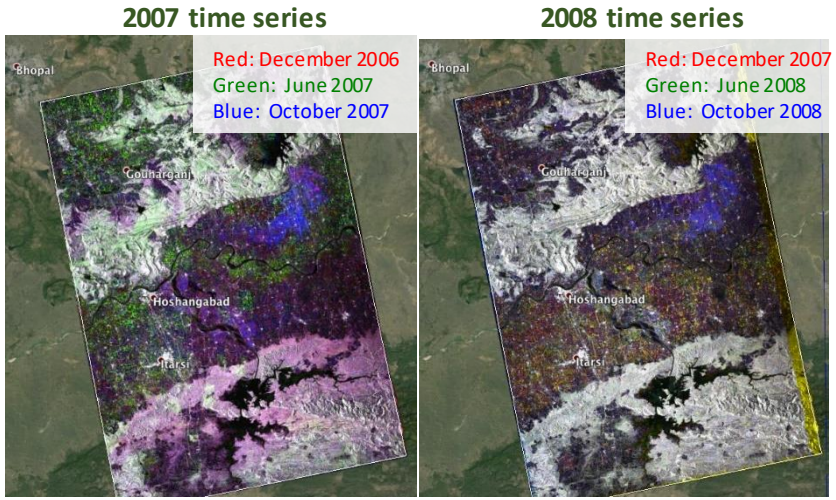
Recently, ISRO has shared ground validation data for Forest AGB over Dehradun and Hoshangabad regions to NASA ecosystem team and NASA shared time series ALOS-PALSAR and Sentinel-1 data over Hoshangabad area and Chilika Lake for forest and inundation studies, respectively.

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

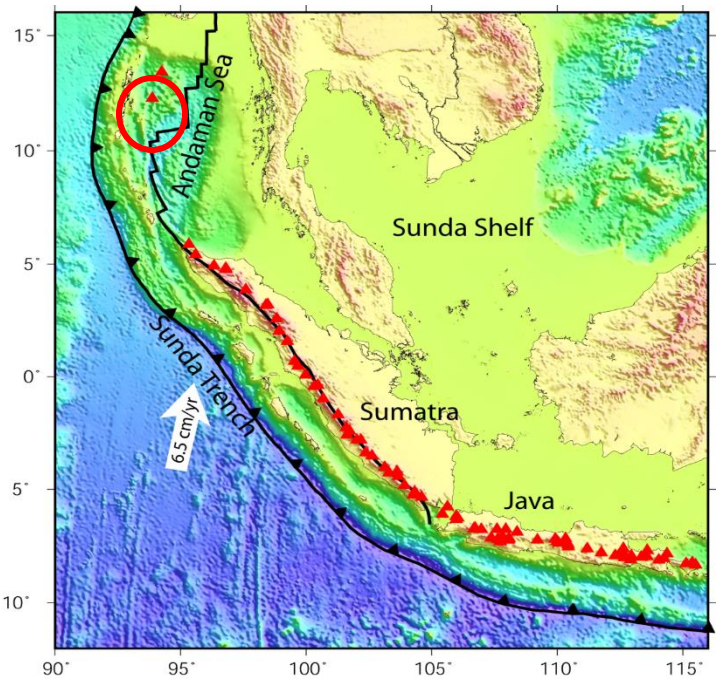
Spatial distribution of ground data pertaining to forest biomass



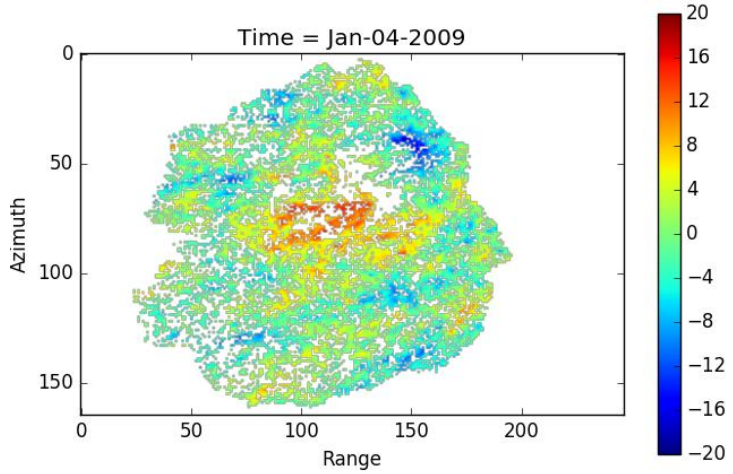
Time series ALOS PALSAR data over Hoshangabad in MP

Joint studies in Solid Earth

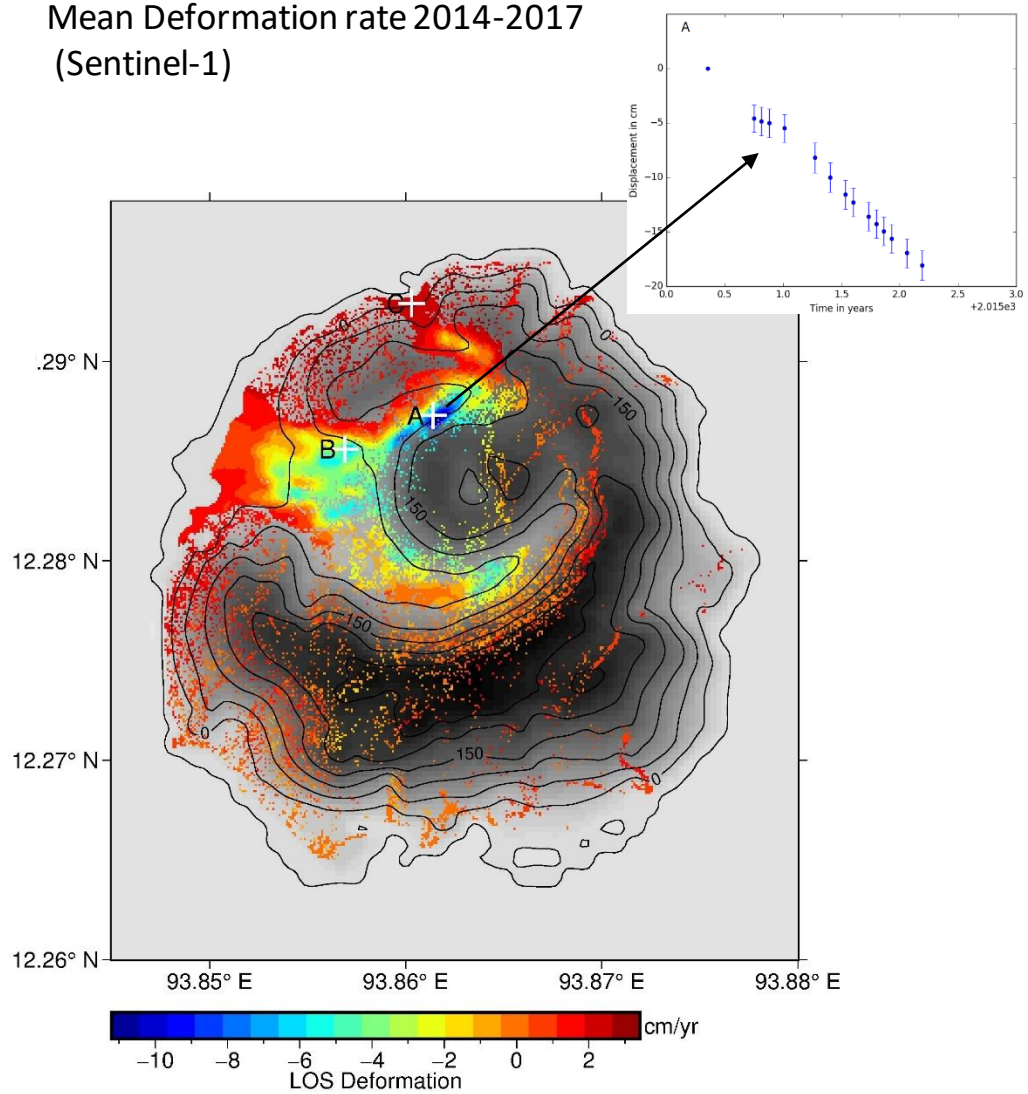
Barren Island volcano deformation



Cumulative Deformation 2007-2009
(ALOS-1)



Mean Deformation rate 2014-2017
(Sentinel-1)



(Seth et al, 2014)

Joint Activities

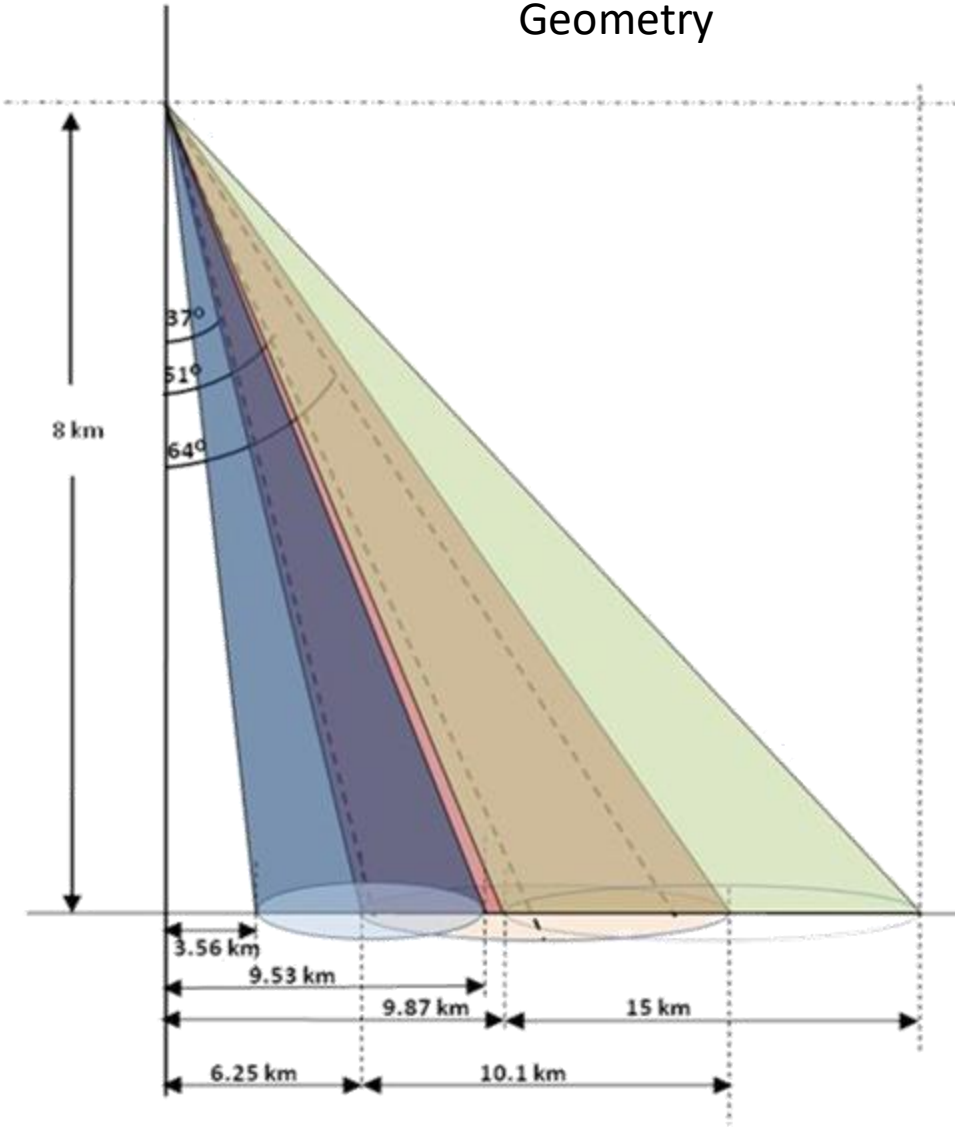
Participants of SMAP NISAR Tutorial in Ahmedabad, India (7-9 Feb 2018) – about 50 persons participated

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

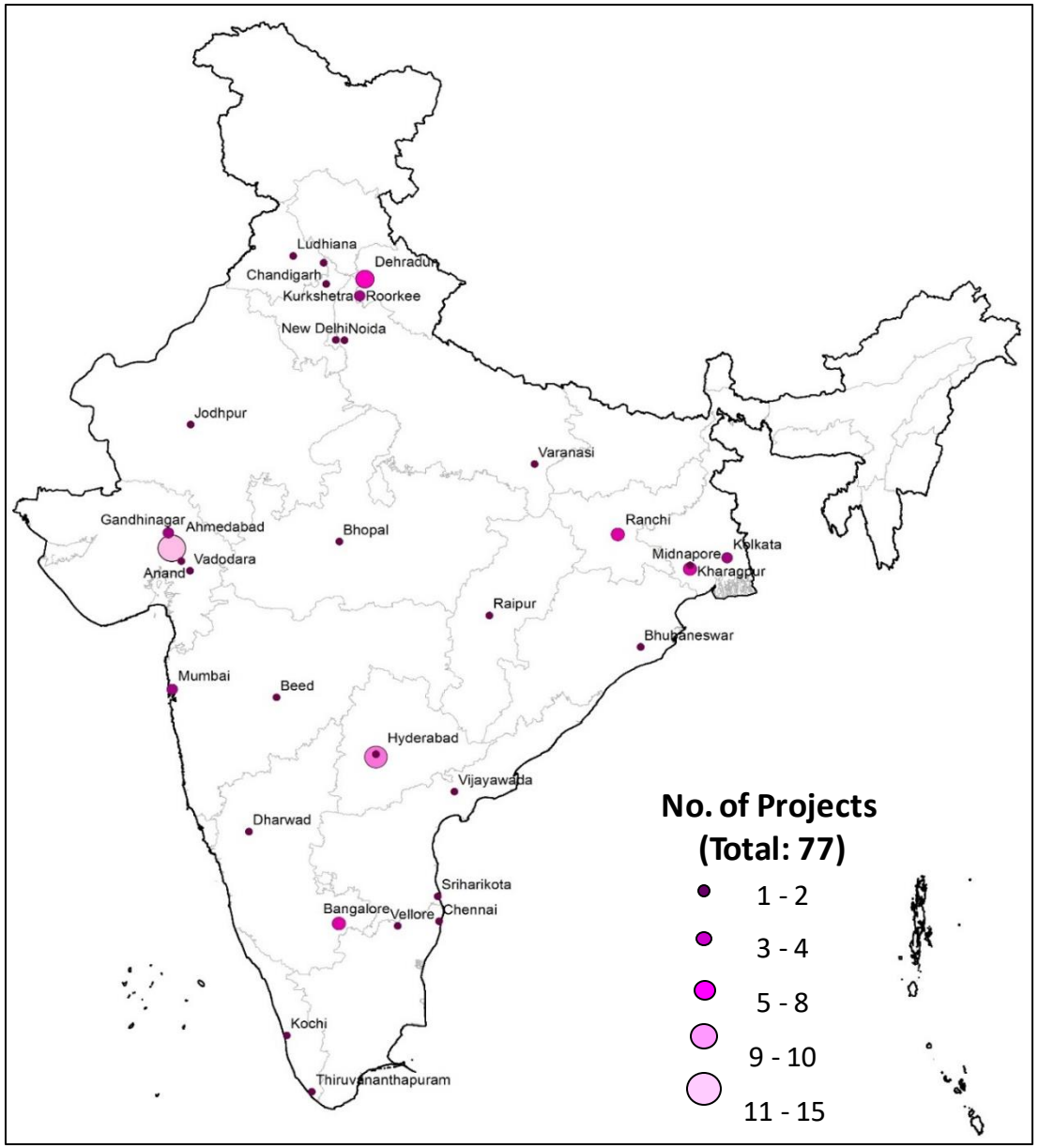
S.N	Parameter	Specification				
1	Platform	Beech craft B-200				
2	Aircraft Height	8.0 kms				
3	Platform Velocity	120 m/s				
4	Operating Frequency	1250MHz (L) & 3200MHz (S)				
5	Chirp Bandwidth	10MHz	25MHz	50MHz	75MHz	
6	Resolution - (Az X SL)	2m X 15m	2m X 6m	2m X 3m	2m X 2m	
7	Sampling Frequency (MHz)	250 (Output Samples decimated according to bandwidth)				
8	SAR Mode	Stripmap				
9	Polarization Modes	Single	Quasi-Quad Pol	Dual Pol	Compact(CP)	Full Pol
10	Effective Antenna dimensions	1.0m (Azimuth) x 0.35m (Elevation)				
11	Antenna Roll Bias	37° - Nominal	51°	64°		
12	Imaging Swath (S+L)	5.9km @ 37°	10km @ 51°	15km @ 64°		
13	Integrated Ambiguities	<-20dB				
14	Sigma Naught Threshold	<-20dB				
15	Radiometric Resolution	3dB-Single Look				
16	RF Power Transmit	40W (L) & 165W (S)				
17	Incidence Angle Range	24° to 77°				

Geometry



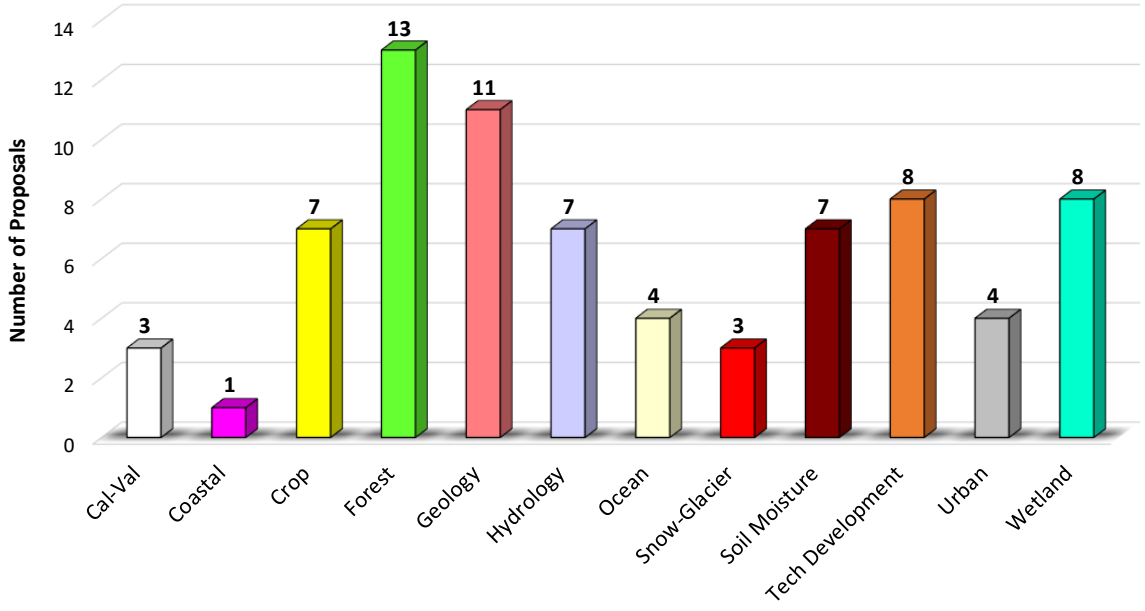
Science Plan and Research Announcement for L&S Airborne SAR

Region-wise distribution of Project Proposers

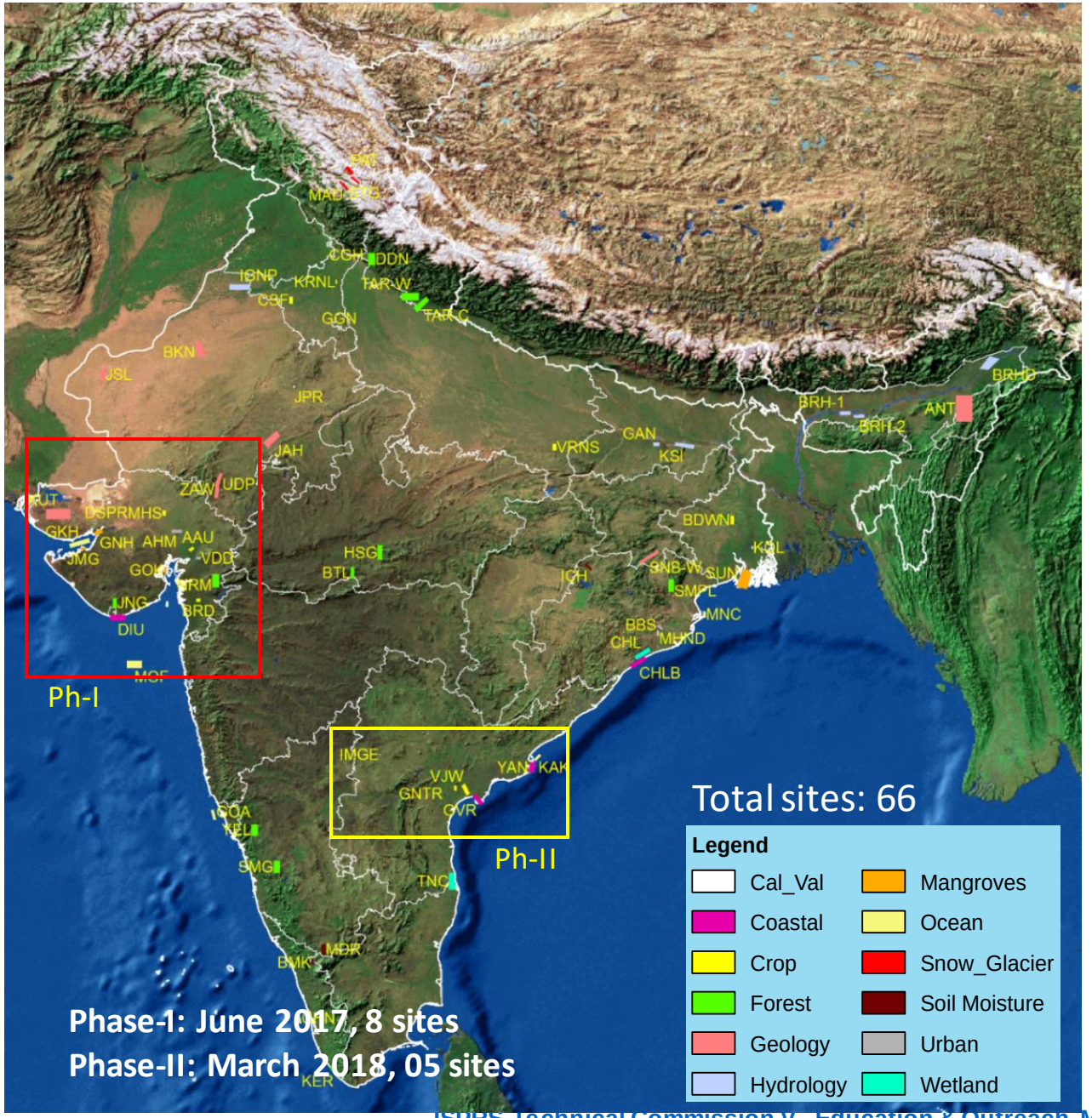


Airborne SAR R.A. Project Proposal Statistics:

77 Proposals; 45 Institutions



L&S Band Airborne SAR Flight Campaign-2017/2018



Phase1	June 2017
Area	Gujarat Sites (8 sites)
Base	Ahmedabad
Phase2	**February 2018**
Area	Andra/Telengana (5 sites)
Base	Hyderabad

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

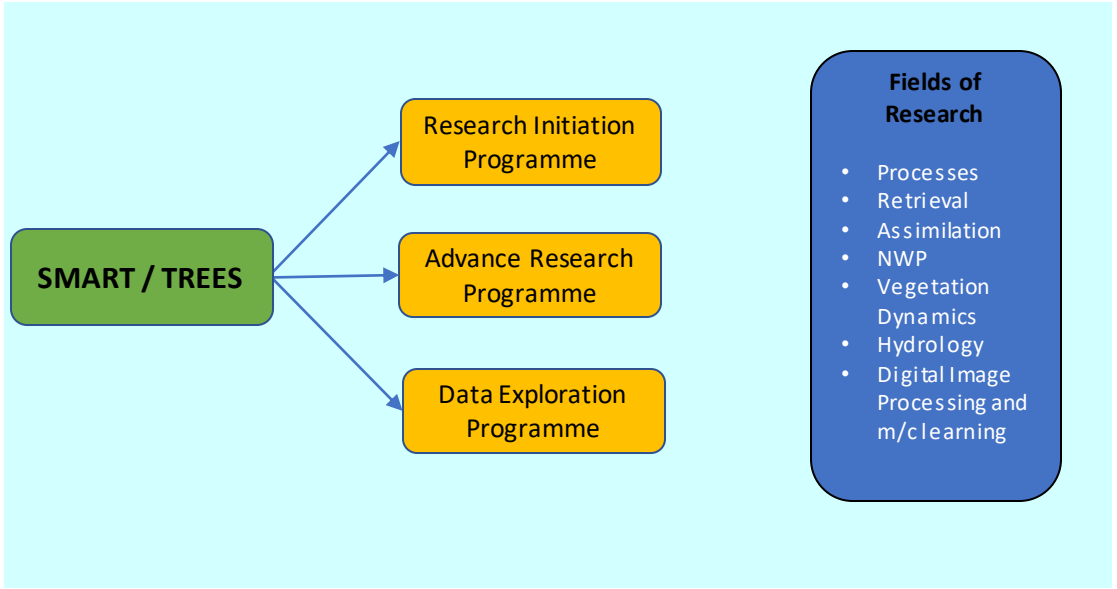
Outreach Programs

Satellite Meteorological and OceAnographic Research and Training (SMART)

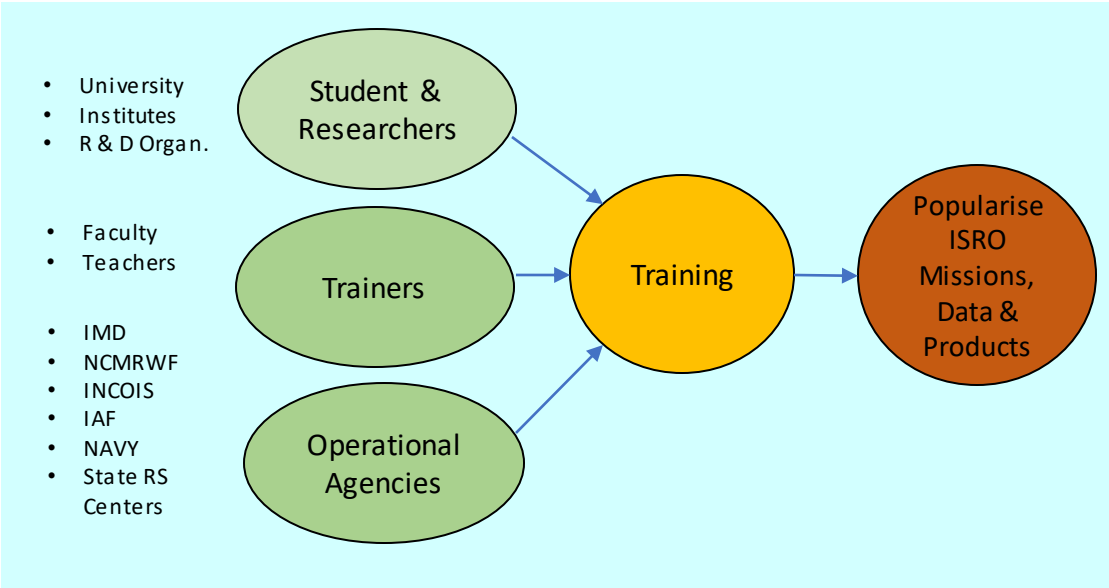
Training & Research in Earth-Eco Systems (TREES)

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

Research Programme



Training Programme

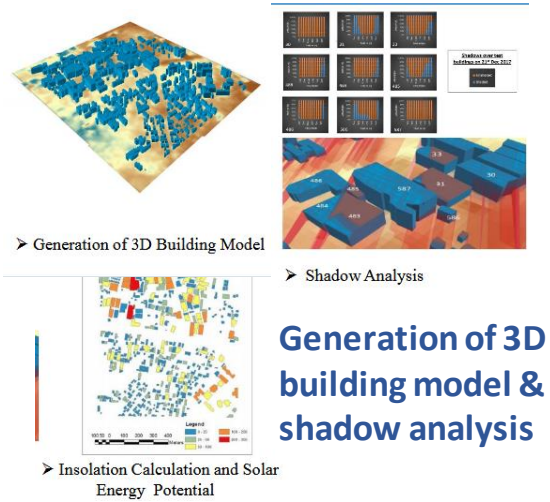


Outreach activities provide:

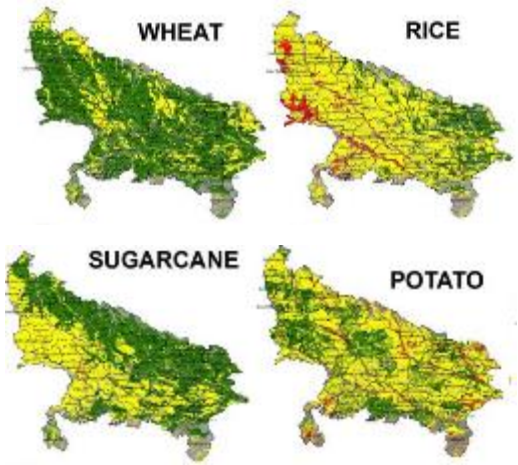
- Familiarization with Indian EO data
- Short-term advanced training courses
- Long duration 3-9 months - Research
- Data analytics and advanced visualization
- State-of-the-art computing facilities
- Research guidance
- Subsidized accommodation & food

TREES & SMART: Research and Training opportunities at EPSA

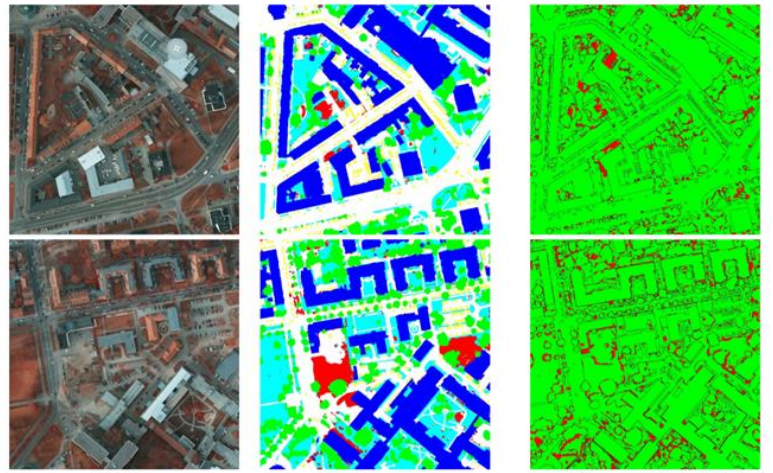
Participants Trained	: 723
Research Projects Completed	: 148
Trainings	: 34



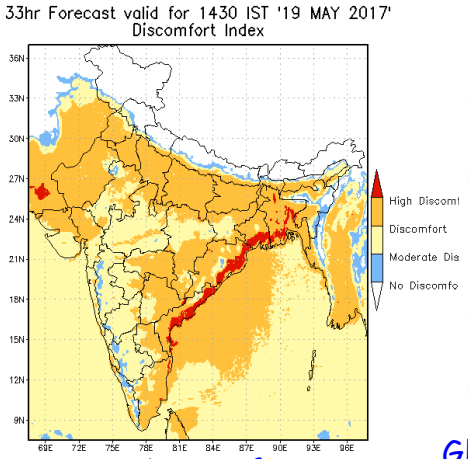
Generation of 3D building model & shadow analysis



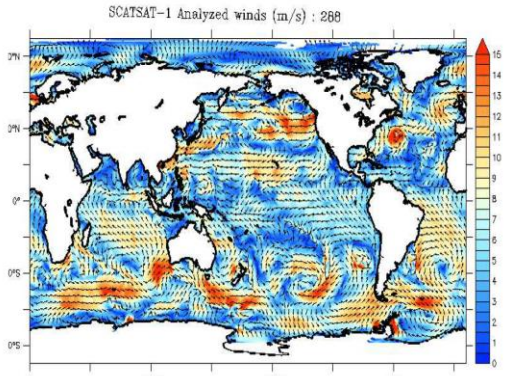
Crop Suitability Analysis for UP



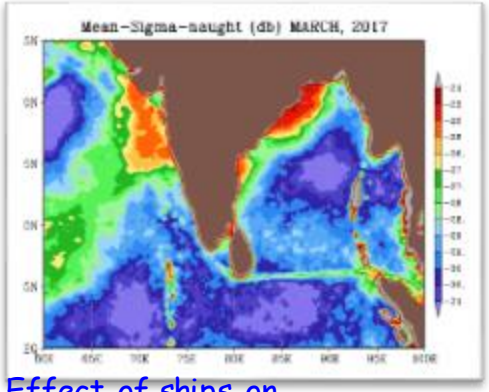
ORTHOSEG



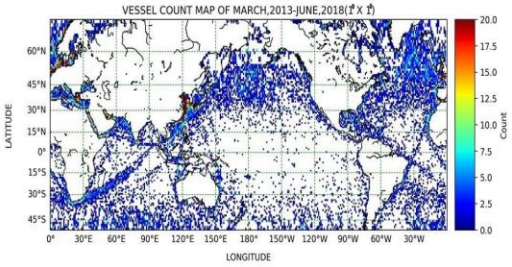
Human Discomfort Index



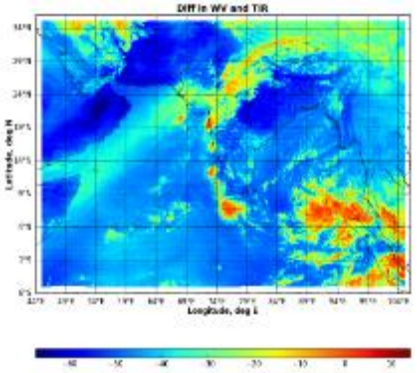
Global analysed wind fields from ScatSat-1 and its application



Effect of ships on scatterometer measurements



AltiKa derived Global ship count Mar,13 to June,18 at1° x 1°



Convective Overshooting using Satellite Data

Visualization of Earth Data and Archival System (VEDAS)

Training & Research in Earth-Eco Systems (TREES)

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

Total 102 Participants from 4 Trainings

Thanks