NISAR Utilisation Programme

Announcement inviting project proposals from Indian researchers

(Deadline for submission of proposals: October 31, 2023)

Space Applications Centre

Indian Space Research Organisation

July 2023

Table of Content

NISAR Utilization Programme

1. BACKGROUND

The NASA–ISRO L & S band Synthetic Aperture Radar (NISAR) mission is a partnership between NASA and ISRO, scheduled to launch in January 2024 and to have a minimum mission lifetime of three years. The mission is optimized with high resolution imaging (2-30 meters), wide swath (240 km), high precision pointing and orbit control and short revisit period (12days) with polarimetry and interferometry for studying hazards and global environmental change, specifically in support of its core science disciplines: Ecosystems, Cryosphere, Solid Earth Science and Coastal Ocean. Some of the important mission and instrument parameters are shown in Table-1. The satellite is designed to provide a detailed view of the Earth to observe and measure some of the planet's most complex processes, including ecosystem disturbances, glaciers and ice-sheet dynamics, land deformations induced by tectonic and non-tectonic processes, coastal process dynamics and natural hazards. In addition to its science requirements, the mission shall support disaster response through expedited event-driven downlinking, processing, and delivery of relevant data. NISAR has an open data policy and the data from the mission will be made available to the global scientific community after necessary post-launch sensor characterization, which is expected to be completed within 6 months of launch. There is a good opportunity for researchers and scientists from various disciplines to plan for the utilization of the NISAR data and interact to learn.

Table-1: *NISAR: Major mission and instrument characteristics*

Parameters	S-band	L-band
Orbit	747 km with 98° inclination (Polar Sun-synchronous)	
Repeat Cycle	12 days	
Time of Nodal Crossing	6 AM / 6 PM (dawn-to-dusk orbit)	
Frequency	3.2 GHz ± 37.5 MHz	1.257 GHz ± 40 MHz
Wavelength	9 cm	24 cm
Available Polarization Modes	Single, Dual, Quasi-Quad, Hybrid circular (in S band only), and Quad Pol (in L-band only)	
Range Bandwidths	10 MHz, 25 MHz, 37.5 MHz, 75 MHz	5 MHz, 20 MHz, 40 MHz, 80 MHz
Swath Width	> 240 Km (except for S-band QQP Mode and L-band 80 MHz BW mode)	
Spatial Resolution	6.5m (Az); 2m-15m (Slant-Ra)	7m (Az); 2m-30m (Slant-Ra)
Incidence Angle Range	33 – 47 deg	
Noise Equivalent σ°	Better than -25 dB (except for quad-pol mode)	
Pointing	Left (South) pointing	
Pointing control	< 273 arc seconds	
Orbit control	< 500 meters	
Data Policy	Free & Open access	
Mission Duration	Minimum 3 years of science operations; mission support for 5 years	

NISAR data products will be structured as raw radar signal data as level-0 product, Single Look Complex (SLC), Multi-Look Detected (MLD), phase unwrapped (UNW) and wrapped nearest-time interferograms (IFG), and polarimetric covariance images (COV) as level-1 products, geocoded level-1 products as level-2 products, large area radiometric terrain corrected mosaic images as level-3 products and science products in physical units as level-4 products. NISAR has an open data policy where all levels of data products will be provided freely to the public in near real time through ISRO (Bhoonidhi) and/or NASA (ASF DAAC) portals.

The NISAR-Utilisation Programme (UP) is open to the Indian scientific community for submission of proposals involving the applications of NISAR data. The NISAR-UP is dedicated for the development/ demonstration of SAR based operational/ quasi-operational applications, new techniques development for the study of earth resources. The overarching goals of the UP are:

- Scientific research leading to development of tools, techniques and methods for demand driven applications of SAR data.
- Engaging a broader scientific community on the utilization of NISAR data and working with interested end users to develop relevant information products.
- Development of analysis ready products including various bio-geo-physical parameters from NISAR data

2. DESCRIPTION OF THE UTILIZATION PROGRAMME (UP)

NISAR will provide near-global coverage of all land surfaces, coastal seas and many sea ice-covered regions through both ascending and descending orbits of a dawn/dusk sun-synchronous, left looking orbit with 12-day revisit period. *Please refer to the NISAR science Plan document (**Appendix-1**) for more details about the mission characteristics, observation plan, science product definitions and cal/val plans.*

Indian Space Research Organisation (ISRO), Department of Space (DOS), Government of India, solicits proposals from potential investigators working in Indian Govt. or Govt. recognized institutions for scientific research leading to applications using L&S band SAR data from NISAR. Under this UP, funding support will be provided to a limited number of projects uniformly distributed over designated applications themes and other categories. **There would also be Non-Funded projects, where the investigator(s) would avail technical support from ISRO and access to ground validation data and other ancillary data for meeting the objectives of the project.** Proposals are solicited for the following categories:

- Development of operational methods/ algorithms culminating in applications in the fields of agriculture, forestry, hydrology, snow/glaciers, solid earth science, disaster management, coastal dynamics, atmospheric sciences and oceanography using NISAR data.

- Development of robust algorithms with validation plan for the retrieval of bio-geophysical parameters using NISAR and ancillary data.
- Development of value-added products/ services catering to the needs of user agencies
- Providing support for cal/val of NISAR data / science products
- Supporting tool development for analysis of NISAR data

3. INVITATION OF PROJECT PROPOSALS

Project proposals are invited from individuals or a group of scientists, academicians and researchers belonging to various Indian Government organisations and Government recognised institutions, universities and departments in India. The proposals must be forwarded through the Head of the Institution, with appropriate assurance for providing necessary facilities for carrying out the projects (formats at the end of this document).This Utilisation Programme is aimed towards stimulating newer research in interferometric and polarimetric SAR; identifying necessary support for calibration and validation of NISAR payloads and for encouraging development of specific techniques for operational use of the data on a regional / global scale. Towards this, the proposals received in response to this will be evaluated considering primarily the scientific/ technical merits. The principal elements considered in selecting the proposals, among other things, would be:

- The overall scientific or technical merit of the proposal, uniqueness and innovative methods, approaches or concepts planned to be demonstrated.
- The competence and relevant experience of the Principal Investigator (PI) and/or Co-Investigators (CIs) for achieving the proposed objectives.
- Potential for contributing to applications by making synergistic use of multi-frequency, multi-date and polarimetric / interferometric SAR data with optical and LIDAR data.
- Facilities available at the host institution for execution of the project
- A research proposal, which is beyond the capability of the payload will not be considered. Therefore, it is important for the proposer to understand the capability of the payload with respect to intended science.

It is expected that the project will be completed within 3 years from the date of its sanction. PIs are required to present the results in review meetings / workshops to be conducted time to time, during the project period.

4. SUGGESTED AREAS OF RESEARCH

Following, but not limited to, are the areas of research categorized into various science themes, suggested under NISAR UP:

Ecosystems Sciences

The broad application areas defined for NISAR ecosystem theme are: crop monitoring, vegetation biomass and carbon sequestration from forest ecosystems, wetland inundation

dynamics, soil moisture variability over agro eco-systems. The utilization programme calls proposals from the following areas of applications and research:

- SAR based multi-sensor approach for management of agricultural resources
- Crop biomass and enhanced crop monitoring
- Estimating forest biomass and carbon sequestration potential of Indian forests
- Assessment of economic value of timber forests
- Development of automated alert system for forest disturbances
- Wetland inundation dynamics: modelling and monitoring
- Modelling and forecasting of land ecosystems dynamics.
- Deriving field scale Root Zone Soil Moisture (RZSM) using satellite derived soil moisture and simplistic soil physics model
- Agriculture drought assessment and early detection using field scale soil moisture and other ecosystem variables.
- Monitoring crop irrigation and irrigation scheduling through Evapo-Transpiration (ET) modeling of satellite derived field scale soil moisture over different agro eco-systems
- Spatio-temporal dynamics of Soil Organic Carbon (SOC) and its linkage with field scale soil moisture
- Spatio-temporal dynamics of crop water stress using field scale soil moisture and its implications on crop productivity
- Characterization of land productivity dynamics using spatio-temporal analysis of high-resolution soil moisture and vegetation indices in dryland regions.

Cryosphere Science

NISAR has a comprehensive observation plan over the Himalayan and the Polar regions covering both continental ice and sea-ice regions throughout the year. The huge volume of data collected over the regions has great potential to boost cryosphere research. The utilization programme calls proposals from the following areas of applications and research:

- Retrieval of ice velocity using NISAR products in the Himalayan and Polar regions
- Development of multi-frequency, multi-polarization SAR based methods for snow parameter retrieval
- Investigation of sea ice drift and deformation derived from dual-frequency NISAR data in parts of polar region
- Assessing the impact of climate change on glacier facies and its relationship with the mass balance
- Impact of mass balance on ice velocity in polar and Himalayan regions
- Measurement of ice surface changes over Greenland, Antarctica and Himalayas using NISAR mosaic data products

- Synergetic use of NISAR and passive microwave data for the investigation of ice surface melt over polar region
- Permafrost characterization using dual-frequency SAR data

Solid-Earth Science

NISAR's wide swath, high resolution, 12-day repeat orbit cycles will allow the mission to provide time series of deformations over tectonically active regions providing new insights to the intriguing dynamic processes. Research proposals addressing one or many of the following key science objectives are invited:

- Observation and modelling of earthquake cycle at active faults and seismic risk assessment
- Volcanic deformation studies
- Kinematics of active landslides
- Landslide inventory mapping in persistent cloud cover area
- Land deformation related to groundwater dynamics
- Monitoring land subsidence related to anthropogenic activities

Oceanography and Atmospheric Sciences

NISAR will collect data in L&S band frequencies over Indian coastal seas including the Arabian Sea and the Bay of Bengal. The data will be useful for detection and mapping of several coastal and oceanic features and atmospheric phenomena that have manifestations on ocean surface. Following are the potential objectives that can be addressed in the research proposals:

- Detection and characterization of Ocean Internal Waves, eddied and small scale filaments in Indian coastal waters to understand small scale ocean dynamics.
- Retrieval of high resolution ocean surface wind
- Investigation of atmospheric features such as marine atmospheric boundary layer, tropical cyclone structures, rain cells through their manifestations on ocean surfaces.
- Estimation of coastal bathymetry from SAR data
- Detection and modelling the trajectory of oil spills

Disaster Management

- Modelling, prediction and mitigation of hydro-meteorological disasters
- Development of framework for mapping, monitoring and information dissemination for natural disasters

5. DATA AVAILABILITY

5.1 NISAR Data

NISAR has global coverage plan. While L-band data are planned all over the globe, excluding the open oceans, S-band data are planned over the South Asia, Antarctica, regions in the Arctic such as Greenland and Beaufort sea and a few global cal/val sites. NISAR S-band data will be downlinked by ISRO ground stations while the L-band data co-located with S-band will be transferred from NASA ground stations to ISRO and both the data will be processed to various levels at ISRO data processing facility at National Remote Sensing Center (NRSC) and distributed through ISRO's Bhoonidhi portal. NISAR data products will be made available to the Principal Investigators (PIs) after the mission-commissioning phase, which is expected to be about 3 months after the launch. PIs are required to register and create user accounts to browse and download data from the ISRO Bhoonidhi portal (https://bhoonidhi.nrsc.gov.in/) managed by NRSC National Data Center (NDC). Bhoonidhi portal also provides support for cloud processing of NISAR data.

5.2 Ground Truth Data

Ground truth data are the *in-situ* data collected on ground for the development, testing and calibration/validation of NISAR science products and algorithms generated for various applications. NISAR UP has a plan to archive all the ground truth data collected through the projects and prepare a virtual repository accessible to all the investigators of the UP. The PIs are required to share the ground truth data collected through the projects with the NISAR-UP Programme Office at SAC and submit a form of declaration (as given in *Annexure 5*) stating their commitment to share the ground truth data.

6. GUIDELINES FOR PROPOSAL PREPARATION

The PI should submit the proposal in a format described in the following sections. The format for the cover page of the proposal is given in **Annexure 2** and the format for the detailed proposal is given in **Annexure 3.** The formats for the declarations to be provided by the PI and PI institution are given in **Annexures 4 & 5.**

6.1 Instructions for Submission of Proposal

Proposals have to be complete in all respects. Incomplete proposals and proposals with missing information will **NOT** be accepted. Proposals should be short and concise, written in the 'Times New Roman' 12 pt. font on standard A4 size paper, typed single-spaced in the prescribed format (see *Annexures 2 & 3*). Duly signed scanned soft copies of the proposal prepared in the prescribed formats should be e-mailed to nisar-ao@sac.isro.gov.in and the original hard copy of the document should be mailed to:

Programme Office,
NISAR Utilisation Programme
Earth and Planetary Science and Applications Area (EPSA)
Space Applications Centre, Ambawadi Vistar P.O.
Ahmedabad-380 015, India.
Telephone: +91 - 79 – 2691 4024

Fax: +91 - 79 - 2691 5825
E-mail: nisar-ao@sac.isro.gov.in

6.2 Description of the Proposal

The initial part of the proposal should contain a summary (briefing the objectives, methodology, deliverables of the project and the time schedule), followed by a detailed description of the objectives, methodology and the scientific rationale being addressed. The data requirement and the analysis methods should be highlighted. Targeted schedule for various stages of the project must be indicated (including the completion date) by Gantt chart. Criteria for assessing the success of the project should also be projected.

6.3 Proposal Evaluation

The project proposals will be evaluated for selection by an ISRO inter-center committee consisting of subject exerts and project personnel. The major criteria for selection of proposals are described in section 3 of this document. Proposals that lack scientific merit and unreasonable commitments will be rejected. If multiple proposals with similar objectives are received, only the best proposal as per the criteria described in section 3 will be selected for funding. The evaluation committee may send back a proposal to the proposer(s) for revision, wherever necessary. **The decision of the evaluation committee regarding acceptance or rejection of a project proposal will be considered final.**

6.4 Personnel

An investigator of a proposed project need to be a regular employee of an institution or department under the Govt. of India or an institution or department recognized by the Govt. of India, with minimum of 3 years of service remaining for superannuation. Persons from private organizations or NGOs are not eligible to carry out a project under the UP.

One or many individuals belonging to the same institution or different institutions may jointly submit a project proposal. However, only one investigator will be recognized as the “Principal Investigator (PI)” and the other investigators would be designated as "Co-Investigators (CI)". The PI, through the PI institution is responsible for handling project fund (if any) and is responsible for ensuring timely completion of the project. PI/CI shall provide Curriculum Vitae clearly stating their educational qualifications, the work carried out in the related areas and list of recent publications. The assurance of necessary administrative and financial support to the PI from the Head of the Institution must be provided by filling out the declaration form.

PIs may recruit research scholars in the project as per need and subject to the justification for the same. The eligibility criteria and stipend of the personnel employed in the projects as research scholars, research associates or project fellows will be governed by the prevailing rules stipulated by the UGC/ CSIR and endorsed by DOS/ISRO.

6.5 Facilities and Equipment

Proposers will clearly state in the proposals the availability of computer facilities, image processing software, field instruments and other related facilities required to run the project in

either the host institution or collaborating institutions and its accessibility for the project. The UP has provision for financial grant only for minor field equipment and a computer system, subject to strong justification for the same.

6.6 Monitoring and Evaluation of Successful Projects

A set of subject/domain experts from ISRO will be identified to mentor the qualified projects. The mentors will coordinate with the principal investigators to provide technical as well as management support to the projects and monitor the progress. The progress of the projects will be periodically evaluated by an ISRO inter center expert committee. Project review meetings/ workshops will be conducted at the end of every year and the PIs of each project are required to participate in these meetings /workshops. It may be noted that there will be stringent review criteria for the projects and ISRO reserves the right to short close or terminate a non-performing project based on the recommendation of the review committee.

6.7 Funding support for the selected proposals

The selected project proposals through this announcement will be provided limited financial support towards meeting the salary of a research student, computational facility, contingencies and travel support to attend project meetings and workshops within India. The project duration is for three years starting from the release of the fund. In addition, in specific cases where the recruitment process of a research scholar takes longer or a research scholar leaves a project midway, the PIs of the selected proposals are allowed to recruit student interns to learn and contribute to the project activities for a period not exceeding 6 months per financial year. The interns should be selected based on merit from the final year students of the M.Sc/ M.Tech programme and they should only work in the designated project. ISRO shall provide funding support (fixed amount of Rs 10,000/- per month) to the project intern as stipend under this UP.

7.0 TERMS AND CONDITIONS

All proposals will be reviewed by a review committee constituted by ISRO. PIs and their team shall cooperate with the members of the review committee, where needed. ISRO reserves the right, depending upon the need or lack of novelty of intended applications, innovative science, suitability, delivery and merits to revoke in part or in whole its support for a proposal at any time without assigning any reason. The decision of ISRO shall be treated as final.

NISAR data is open and free of cost. However, any ancillary data and ground validation data, if specifically provided, must be used only for the purpose specified in the proposal. The project personnel do not have the right to share, lease or loan the ground validation data to persons or entities outside the project, without the prior permission of the UP Programme Office at SAC, ISRO. Also, this data should not be used for any commercial purpose.

Scientific results obtained as part of the project proposal by PIs or any other, shall not be allowed to be used for marketing/business purposes without prior permission from ISRO. ISRO reserves the right to accord permission on such cases, considering the overall national interests.

Any / all Intellectual Property (IP) Rights such as patents, copyrights, design rights etc. acquired by the research academic/institute or the PI, through this project proposal, shall be jointly owned by ISRO and the concerned research institute. Any commercialization of such IP rights shall be done by the research institute only with the consent / permission of ISRO, on specific terms and conditions, which shall be determined on a case by case basis mutually as per its standard practices for such activities.

The user will make available to the scientific community the ground validation data collected through the project (where applicable) and salient results through publication in appropriate journals or other established channels. Acknowledgement of ISRO support must be made in all reports and publications arising out of this project. Copies of all publications resulting from these research projects must be submitted to ISRO to the address mentioned under paragraph 6.1. ISRO reserves the right to use the published results in its reports and publications with due reference to the publication. If the reports or publications are copyrighted, ISRO will have a royalty-free right under the copyright to reproduce, distribute, and use the copyrighted works for their purposes.

All those who use NISAR data processed by ISRO are expected to register and download the data from ISRO's Bhoonidhi portal with due acknowledgement.

The procedure/methodology arising from the project would be made available to ISRO for their operational use.

The PI is required to submit yearly progress report and fund utilization certificate in a prescribed format (for funded projects) during the project to the Programme Office, mentioned in Section 6.1. A detailed report is to be submitted during the mid-term and final reviews in soft copy.

The declaration contained in the proposal format must be signed by the PI and Head of the Institution (Annexure 4). Otherwise, the proposal will not be considered valid and is liable to be rejected.

8.0 SCHEDULE

Announcement for proposal submission: July 15, 2023

Deadline for submission of proposals: October 31, 2023

Notification of evaluation results to Principal Investigators: March 01, 2024

Execution of selected projects: From April 01, 2024

Annexure - 1

DATA PRODUCT SPECIFICATION

NISAR Data products generation will be done by ISRO at NRSC-IMGEOS environment for all the data acquired at ISRO stations. Data pertaining to ISRO requirement from L band SAR acquired at JPL stations will be transported to IMGEOS for generating different levels of data products. NISAR has a free and open data policy and all the products will be hosted at "Bhoonidhi", the digital portal identified for NISAR data dissemination. NISAR data products are categorised into standard products and higher level science data products.

PRODUCTS DEFINITION:

Scene size: Fixed scene or Floating scene of about 10% shift in along track direction. Scene size will be approximately 240 km x 240 km. Scenes will follow a referencing scheme with unique reference numbers associated with a scene. The basic data products are structured as level 0, level 1 and level 2 products and the value added data products are labeled as level 3 and level 4 products representing large area mosaic products of level 2 data and science products, respectively. The standard product definition is given below:

Level 0 : Raw signal data
Individual Channel or Digital Beam Formed (DBF) data as unprocessed radar echo data in complex in-phase and quadrature signal (I & Q) format. This product represents a collection of time-tagged raw data packets and downlinked telemetry information. This product will have Level-0A and Level-0B as two sub-levels:

Level 0A Product is ordered in time. Communication Artefacts, missing data and synchronization errors are not corrected. It is an Intermediate product and is input to L0B processor. This data will not be available for dissemination.

Level 0B Product consists of aligned and filled raw radar signal data. In Level-0A to Level-0B processor, BAQ/BFPQ samples from RAW products are decoded and packed into complete range lines. Sampling Window Start Time (SWST) shifts for each radar pulse are aligned and each pulse is annotated with mode and PRF changes as well as missing data information. Level-0B raw product will be available for dissemination.

Level 1 : Geo-tagged Product
Products in Radar coordinates with Geo-tagging using satellite ephemeris data. The earth geometry uses the Standard Ellipsoid and a dense grid of geo-locations are provided with product. All Level-1 standard (i.e., non-urgent response) products are processed using the Medium-fidelity Orbit Ephemeris (MOE). The SAR image is geo-tagged using ephemeris data from satellite (radar coordinates). This allows latitude and longitude information to be calculated for each line in the image. Following are the products under Level 1:

- Radar Single Look Complex (RSLC) Data product: Refers to the standard Range-Doppler geometry, Single Look Complex (SLC) image. In addition to individual binary raster layers representing complex signal (16-Bit I; 16-Bit Q) return for each polarization layer, the SLC product is also packed with input, instrument and processing facility information; processing, calibration and noise parameters; geolocation grid; and data quality flags.
- Radar Nearest-Time Interferogram (RIFG) Data product: Represents the ellipsoid height-corrected, wrapped Interferogram generated from two Range-Doppler SLC products in

the Range-Doppler geometry of the earlier acquisition. This product is primarily meant for detecting grounding lines and is only generated for acquisitions over Antarctica and Greenland. WGS84 ellipsoid is used as the reference surface for flat earth correction.

- Radar Nearest-Time Unwrapped Interferogram (RUNW) Data product: Represents unwrapped, multi-looked differential Interferogram generated from two Range-Doppler SLC products in the Range-Doppler geometry of the earlier acquisition. The RUNW product is generated between co-pol channels and for all regions other than Greenland and Antarctica.
- Range Doppler Pixel Offsets (ROFF) Data product: Contains a collection of dense pixel offsets layers obtained from applying coherent and incoherent speckle tracking on a pair of coarsely co-registered RSLC products in the range-Doppler geometry. The pair of RSLC is coarsely aligned using geometrical co-registration based on orbit ephemerides and a DEM. Pixel offsets layers within a ROFF product share the same starting pixel in the reference ROFF product. The ROFF product is primarily meant for cryosphere applications and is only generated for Antarctica, Greenland, and pre-identified world mountain glaciers.

Level 2: Terrain Geo-Referenced Products

This product will have provision of providing processed SAR images in geocoded coordinates. There exist provisions for various map projections for the geocoded image. A dense grid of geo-locations will also be associated along with the data file. WGS-84 ellipsoid will be provided as the horizontal datum for the geocoded products. Terrain corrected Geocoded products will be generated using externally supplied DEM. Following are the products under Level 2:

- Geocoded Single Look Complex (GSLC) Data product: Derived from Range-Doppler SLC product using a DEM and the MOE state vectors and output is in Map Projected system. The GSLC product can be directly overlaid on a map or combined with other similar GSLC products to derive Interferogram and create change maps, for example.
- Geocoded Nearest-Time Unwrapped Interferogram (GUNW) Data product: Derived from the Level-1 UNW product by using a DEM to project the data into the map-projected system.
- Geocoded Polarimetric Covariance Matrix (GCOV) Data product: Derived from Level-1 COV product using a DEM to project the data into the map-projected system. The GCOV product contains the multilooked backscatter for single pol data.
- Geocoded Pixel Offsets (GOFF) Data product: Derived from the ROFF product by using a digital elevation model (DEM) to project the data into the UTM/Polar Stereographic system. This product contains individual binary raster layers representing the sub-pixel offset shifts between a pair of coarsely co-registered RSLC granules. Pixel offsets layers within a GOFF share the same starting pixel and are referenced to geographic coordinates. This product is primarily meant for cryosphere applications and is only generated for L-SAR acquisitions over Antarctica, Greenland, and pre-identified world mountain glaciers.

For details of Level 3 and Level 4 products, please refer to the NISAR Science Plan document (Appendix-1)

Annexure - 2

Format of Cover Page of the Proposal

Title of the Proposal

Name and Designation of PI
Telephone, Fax and E-mail Address
Name of Institution with full Address

Signature of PI

Signature of Head of Institution
Seal of Institution

Proposal submitted on (date)

Annexure - 3

Format of the Proposal

(Please read the guidelines for preparing project proposals provided in the section 6)

1. Title of the Proposal:
2. Name of the Principal Investigator:
   Designation:
   Institution;
   Mailing Address:
   Telephone:
   Fax:
   E-mail:
   2.1 Name and affiliation of Co-Investigator(s)
3. Summary of the proposed work (within one page)
4. Description of the project
   4.1 Theme:
   4.2 Title:
   4.3 Introduction:
   4.4 Objectives:
   4.5 Scientific Rationale / Relevance
   4.6 Significant Contribution including Innovation
   4.7 Methodology
   4.7.1 Study Area (where applicable)
   4.7.2 Data requirement (all including ancillary, other missions etc)
   4.8 Anticipated results and significance
   4.9 Potential End User (in case of applications/products/services, if any)
   4.10 Schedule and Milestones (Quarterly schedule using a Gantt chart)
   4.11 Deliverables with delivery schedule with timeline
5. Budget Requirement
   (Item description and year-wise break-ups)

Sl. No.	Item Description	Total Value	FY (2024-25)	FY (2025-26)	FY (2026-27)	Justification
1	Material					Include Minor Equipment with justification
2	Manpower (JRF/SRF/RA / Interns)					Note: please specify the designation and monthly salary for the category
3	Field work /Travel					
4	Contingencies					
5	Others, if any					
6	Institutional charges					
7	TOTAL					

6. Details of the relevant experience of the PI and Co-I in the discipline
   (Please include brief bio-data of all investigators)

6.1 List (with brief summary) of sponsored project(s) the PI and CI are currently involved in, if any

6.2 List of publications in the related field, if any

7. Available facilities and equipment at PI's institution

8. Declarations as per format provided in Annexures 4 & 5

I certify that the information provided above, is true to the best of my knowledge and belief. I also declare that I meet the eligibility criteria specified in Section 6.4 in the document to submit project proposal for the NISAR UP and I have a remaining service of 3 years or more before superannuation, from the date of this application. I understand that if any of the information provided by me is found incorrect, my project proposal will be rejected / project will be terminated, with immediate effect.

(Name and signature of the PI)

Date:

Annexure - 4

[Format for Declaration]

Declaration of Availing Institutional Support

We have carefully read the terms and conditions of NISAR Utilisation Programme and agree to abide by them.

It is certified that if the proposal is accepted and supported by the Indian Space Research Organisation (ISRO), the facilities as identified in the proposal and administrative support available at our institution and needed to execute the project will be extended to the Principal Investigator and other Co-investigators.

We certify that any ancillary data, ground-truth data or value-added products provided during the project would be used only for the intended project. It is also certified that, if the proposal is accepted and funded by ISRO, the same proposal shall not be submitted for funding support from other agencies.

We also certify that the fund availed for the project (in case of funded projects) will be spent for the intended purpose only and fund utilization certificates will be provided to the UP Programme Office at the end of each financial year during the project and a consolidated fund utilization certificate will be provided at the end of the project.

Signature of PI with Name and Designation

Signature of Head of Institution with Name and Designation

Date:

Seal of Head of Institution

Annexure - 5

[Format for Declaration of sharing ground-truth / in-situ data]

Declaration of Sharing Ground-Truth Data

I declare to share any ground truth data or in-situ data collected during the project with the Space Applications Centre, in near real time for development of a centralized repository of ground-truth data.

I understand that the database of ground truth / in-situ information will be accessible to all investigators of the UP and the data will be utilized for the calibration/validation of NISAR data products, science products or algorithms developed for various applications.

Signature of PI with Name and Designation

Date:

APPENDIX - 1

NISAR Science Plan

SPACE APPLICATIONS CENTRE

INDIAN SPACE RESEARCH ORGANISATION

Table of Content

Executive summary

The NASA-ISRO SAR (NISAR) is in its phase of integration and test, preparing for a launch in January 2024. Once deployed, NISAR will be a powerful and unique Earth-orbiting radar instrument that will provide L and S band dual-frequency SAR data with high repeat cycle (12 days), high resolution (2-30 meters range resolution) and large swath (>240 km) achieved through an innovative SweepSAR technology, with capability of acquiring full-polarimetric and repeat-pass interferometric data. NISAR will image the global land and ice-covered surfaces including islands, sea-ice and selected oceans every 12 days, recording more than 40 Tbits/day of raw L-band and S-band data, which will be transferred to NASA and ISRO ground stations via Ka-band downlink with a rate of 2.8 to 4 Gbps. NISAR, a science mission has a free and open data policy, in which all science data will be provided freely to the global users. In the Indian perspective, in addition to the science activities, NISAR data will be utilized for various SAR-based applications with free data for several operational project accomplishments.

NISAR has a comprehensive image calibration plan that involves setting up of pan-India network of corner reflectors through institutional participation, establishment of corner reflectors around Indian research stations in Antarctica and leveraging of SAR calibration sites in the USA. For overall radiometric balance, the project will use the uniform and stable backscatter properties of rain forests in South America and Africa as references. The L- and S-band radars will observe these targets jointly and individually through commissioning and science operations, first for the calibration and validation, and later to check stability.

Various higher level products, called science products, have been planned using NISAR data. The ISRO science team is developing algorithms to produce these higher level products and preparing for the calibration and validation of the algorithms and science products. For products related to ecosystems science a network of validation sites are being established across India in partnership with other Indian institutions. Similarly, for the validation of cryosphere products deployment of field instruments are planned in the Himalayan region for in-situ data collection and GPS network is being planned for Antarctica. The Solid Earth community intends to validate the products over globally distributed GPS networks in a variety of environmental settings through institutional collaborations. In addition, extensive field campaigns are planned during the NISAR commissioning and Science calibration phases to collect in-situ data for calibration and validation of proposed science algorithms through institutional collaborations.

In order to harvest the immense potential of NISAR and in order to ensure optimum utilization of NISAR data, it is planned to involve the Indian researchers for the

development of new applications and contribution to the development of value added products using NISAR data through Utilization Programme (UP). The NISAR UP will invite research proposals from Indian scientific community and stakeholders for research leading to development of applications and value added products and science products within the purview of the objectives defined for NISAR mission using NISAR data. An ISRO inter-center expert committee will evaluate the project proposals under the UP and the projects will be mentored by the subject experts drawn from the NISAR science and project teams. Periodic review and evaluation of the projects will be carried out by the ISRO inter-center expert committee. Duration of the UP projects will be 3 years starting from ***April 2024*** *with a provision for extension up to another one year for selected projects based on their performances and recommendation by the review committee.*

A1. INTRODUCTION

The NASA-ISRO L&S band dual-frequency SAR (NISAR) is a collaborative mission by the Indian Space Research Organisation (ISRO) and the U.S. National Aeronautics and Space Administration (NASA) planned for a launch in January 2024. Towards the realization of NISAR payload, ISRO was responsible for the development of the S-Band SAR system along with the spacecraft, while the NASA Jet Propulsion Laboratory (JPL) was responsible for the development of the L-Band SAR system along with the radar instrument structure, solid state data recorder and GPS system. Both radar systems share a circular common antenna reflector (12m diameter) supported by a 9m deployable boom provided by NASA/JPL. ISRO will provide the I3K structural bus for the radar instrument and NISAR will be launched by ISRO using GSLV-Mark-II launch vehicle from its launch facility at Sriharikota. The mission will exploit synthetic aperture radar to map Earth's surface every 12 days, persistently on ascending and descending portions of the orbit, over all land and ice-covered surfaces. The mission's primary objectives will be to study Earth land and ice deformation, land ecosystems, and oceanic regions in areas of common interest to the US and Indian science communities. The science teams at NASA and ISRO are working jointly to finalize the joint science plan, calibration and validation plan, science products, and operational procedures. NISAR would collect data in L and S band together over the South-Asian region, the Antarctica, parts of Greenland and Beaufort Sea apart from a few global calibration targets and elsewhere, it is planned to collect data in L-band alone. With dual long wavelength capabilities, wide swath and high repetivity, NISAR is well-suited to support a wide variety of applications especially in the South-Asian region, where there is a broad range of terrain types, from deserts, to tropical forests, to high mountain cryosphere conditions. From the Indian perspective, NISAR is considered a science mission with the potential to augment SAR-based applications in India and the countries in the South Asia, feeding data to several operational project activities. In addition, the global L-band coverage will support science and applications everywhere.

Table A1. Major mission and instrument characteristics of NISAR

Parameters	**S-band**	**L-band**
Orbit	747 km with 98° inclination (Polar Sun-synchronous)	
Repeat Cycle	12 days	
Time of Nodal Crossing	6 AM / 6 PM (dawn-to-dusk orbit)	
Frequency	3.2 GHz ± 37.5 MHz	1.257 GHz ± 40 MHz
Wavelength	9 cm	24 cm
Available Polarimetric Modes	Single Pol (SP), Dual Pol (DP), Quasi-Quad Pol (QQP), hybrid Circular Pol (CP) in S-band only, and Quad Pol (QP) in L-band only	
Range Bandwidths Options	10 MHz, 25 MHz, 37.5 MHz, 75 MHz	5 MHz, 20 MHz, 40 MHz, 80 MHz
Swath Width	> 240 Km (except for QQP Mode)	> 240 Km (except for 80 MHz BW)
Spatial Resolution	6.5m (Az); 2m-15m (Slant-Ra)	7m (Az); 2m-30m (Slant-Ra)
Incidence Angle Range	33 – 47 deg	33 – 47 deg
Noise Equivalent σ°	Better than -25 dB (for required full-swath modes)	
Pointing	Left (South) pointing	

Pointing Control	< 273 arc seconds
Orbit Control	< 500 meters
Data and Product Access	Free & open access
Mission Duration	5 years (Baseline mission: 3 years)

A2. NISAR SCIENCE AND APPLICATIONS

A2.1. Science and applications requirements

NISAR is a science driven mission conceptualized based on the 2007 NASA Decadal Surveys for Earth Science and Applications[1] and the NASA Climate Architecture[2] that identified key scientific questions that are global in scale, fine in resolution, densely sampled in time, and notably are uniquely observed by synthetic aperture radar (SAR). Using the decadal survey as guidance, and working with the science community, a set of specific measurement requirements have been developed for the mission[3] that support solid Earth, ecosystems, and cryosphere sciences, and has an applications focus on urgent response. ISRO realized addition of a higher frequency band (i.e., S-band) with the proposed L-band frequency would greatly enhance the capability of the instrument to probe a diversity of targets addressing a host of SAR based applications specific to India and South-Asia.

NISAR is well suited to estimate woody vegetation biomass as well as soil moisture. NISAR will determine changes in carbon storage and uptake resulting from disturbance and subsequent regrowth of global woody vegetation, by regularly measuring the amount of woody biomass and its change in the most dynamic regions of the world. The mission will also be able to track changes in the extent of active crops to aid in crop assessments and forecasting, and further quantify the carbon budget. Changes in wetlands extent also affect carbon exchange and will be a target of NISAR observations. Other areas where NISAR can contribute valuable insights is in characterizing freeze/thaw state and permafrost degradation, as well as monitoring of oceanic parameters and processes in the deep and coastal areas of the south Asian region. Frequent and high resolution observations with larger swath will be highly beneficial from the point of view of monitoring of the storms during their developments and movements in the coastal regions.

NISAR will provide comprehensive measurements to investigate the nature and causes of changes to Earth's ice sheets and sea ice cover in relation to the atmospheric and ocean forces that act upon them, through systematic measurements of Greenland's and Antarctica's ice sheets, seasonal dynamics of highly mobile and variable sea ice, and inventory the variability of key mountain glaciers which are retreating in many places at a record pace.

[1] Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond, Ed. by Committee on Earth Science and Applications from Space, National Research Council, National Academies Press, ISBN 978-0-309-10387-9, 2007.

[2] "Responding to the Challenge of Climate and Environmental Change: NASA's Plan for a Climate-Centric Architecture for Earth Observations and Applications from Space" (2010). Available at: https://smd-prod. s3.amazonaws.com/science-green/s3fs-public/atoms/files/Climate_Architecture_Final.pdf.

[3] "NASA-ISRO SAR (NISAR) Mission Science Users' Handbook," Ver. 1, Jet Propulsion Laboratory, California Institute of Technology, April 9, 2018. (https://nisar.jpl.nasa.gov/files/nisar/NISAR_Science_Users_Handbook1.pdf)

For solid Earth, NISAR will characterize long-term and local surface deformation on active faults, volcanoes, potential and extant landslides, subsidence and uplift associated with changes in aquifers and subsurface hydrocarbon reservoirs, and other deforming surfaces. These measurements will be used to model the physics of the subsurface, potential hazards associated with the deformation, and associated risks. The variable and largely unpredictable nature of these phenomena lead to a systematic collection strategy to capture as many signals as possible.

In addition to keen interest in NISAR's global science objectives in climate, hazards, and resources, ISRO has an operational imperative to support Indian agencies with the following applications:

- **Ecosystems**: Monitoring of agriculture, estimating crop biomass; soil moisture; forest above-ground biomass, biomass change and carbon sequestration; mangroves and wetlands; tree-line ecotone in alpine vegetation.
- **Solid Earth**: Risk assessment and management through monitoring co-seismic, post-seismic and inter-seismic deformation, volcanic deformation; landslides; aquifer systems for groundwater flow, storage, and management.
- **Cryosphere**: Monitoring dynamics of polar ice sheet – ice shelf, land ice velocity and ice discharge to the ocean; sea-ice types, thickness and motion for ship safety; Himalayan snow and glacier dynamics for hydrological assessments.
- **Oceanography**: Retrieval of ocean physical parameters such as surface wind speed, wave spectra and coastal bathymetry for shipping, improvements in the model simulations, cyclone monitoring and storm surge.
- **Coastal Processes**: Monitoring coastal erosion processes, near-shore dynamics and coastal subsidence; assessment of coastal vulnerability to sea-level rise and shoreline change; monitoring coastal critical habitats.
- **Disaster Response**: Mapping and monitoring of damage due to floods, oil spills, earthquake damage and monitoring the damage due to forest fires, impact of extreme weather events such as tropical cyclones. ISRO and NASA have developed a joint strategy with respect to monitoring hazards and disasters. Being part of the International Disaster Charter and Sentinel Asia, information derived using NISAR with other concurrent remote sensing systems of the global agencies will be extremely useful in the monitoring as well in the disaster risk reduction.

A2.2. Science validation products

The NISAR science team is developing algorithms to produce higher level products called science products, that will be validated over local or regional validation sites to meet the required accuracies. The Solid Earth community intends to validate land deformation products over continuous GNSS stations and global GPS networks in a variety of environmental settings. The cryosphere community will validate the products on land ice and ice sheets using bare-rock references and cross-over analysis, as well as some deployed GPS stations on the moving ice. The Himalayan snow/ice and glacier dynamics products will be validated through in situ data collected through campaign mode. The ecosystems community is establishing long-term validation sites across India in partnership with the state departments and academic institutions.

Some of the algorithms for producing these products will be hosted in ISRO Bhoonidhi portal and will be available to the users interested in using NISAR data.

A3. NISAR OBSERVATION PLAN

A3.1. Global observation plan

NISAR will be operated with a predefined reference observation plan, with the provision of revisiting the plan every 6 months by NASA-ISRO joint science team to review the successes of the observations to date and adjust as necessary to optimize. A typical observation scenario of NISAR over a 12-day observation cycle is shown in Figure A3.1. At present, the project has considered a left-only mode of operation to better optimize science return by uninterrupted coverage of Antarctica up to 87.5°S latitude and sacrificing the coverage of Arctic beyond 77.5°N latitude, with the expectation that other international missions can obtain science observations in the high Arctic regions. While L-band data takes are planned over all regions, S-band data are initially planned over the Indian region, Antarctica, a few regions in the Arctic such as Greenland and Beaufort Sea and global cal/val sites.

Figure A3.1 provides an example of the NISAR observation plan (subject to semi-yearly revision), including mode descriptions. The NISAR science observation plan is designed to tackle the science questions posed by persistent and consistent imaging of Earth's land and ice surfaces throughout the life of the mission, delivering time series of approximately 30 images per year from ascending and descending vantage points.

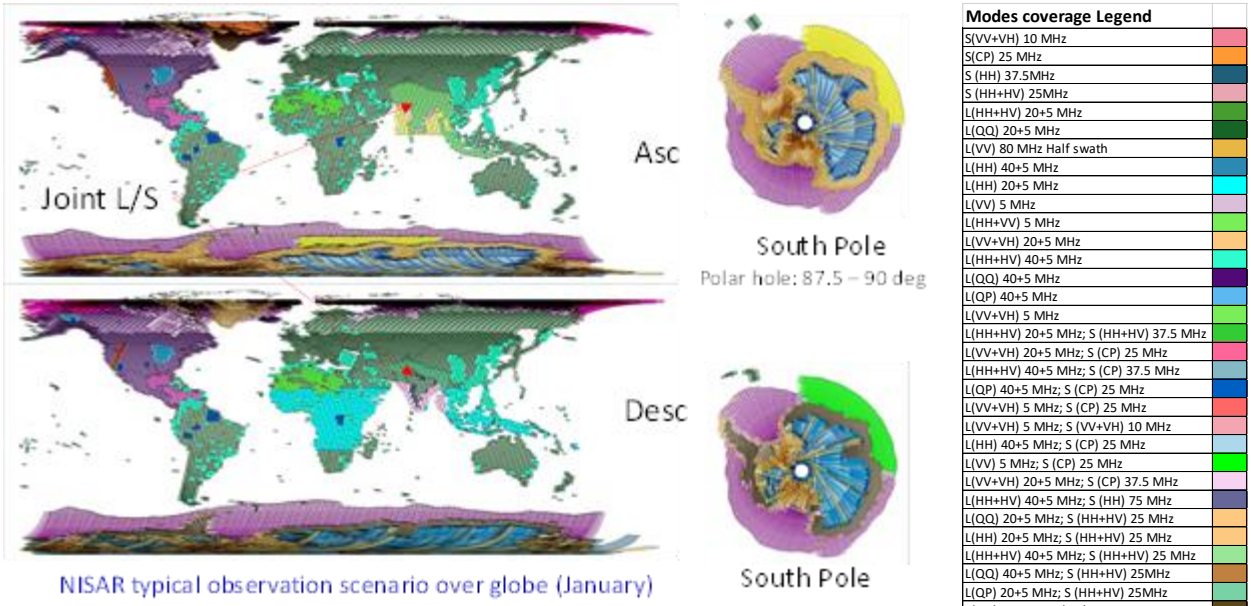

Fig.A3.1: Example of NISAR observation plan over global targets over an observation cycle in the month of January. The pre-defined observation plan varies across cycles (12days) and is subject to revision only on semi-annual basis. While L-band observation is planned globally, S-band observation is limited to the South-Asian region, the Antarctica, parts of Greenland, Bohai bay and Beaufort Sea, apart from few global calibration targets.

A3.2. Observation over targets of Indian interests

ISRO has identified regions of interests to the Indian agencies and user communities for NISAR observation. These regions primarily include the Indian sub-continent with seas around India, regions of Indian Ocean volcanic arc, the Antarctica and Greenland ice masses, sea-ice regions surrounding the Indian research stations in Antarctica, Beaufort Sea and Bohai bay. Apart from that, several global calibration/validation targets of joint interests of ISRO and NASA are also planned as targets of Indian interests. These targets are planned for L and S band joint mode imaging. The mode configurations and the periods over which these targets would be imaged are carefully chosen to capture the unique characteristics of the targets from applications perspectives while avoiding any conflict in the observation plan. Figures A3.2 and A3.3 depict the details of the targets, imaging modes and observation calendar.

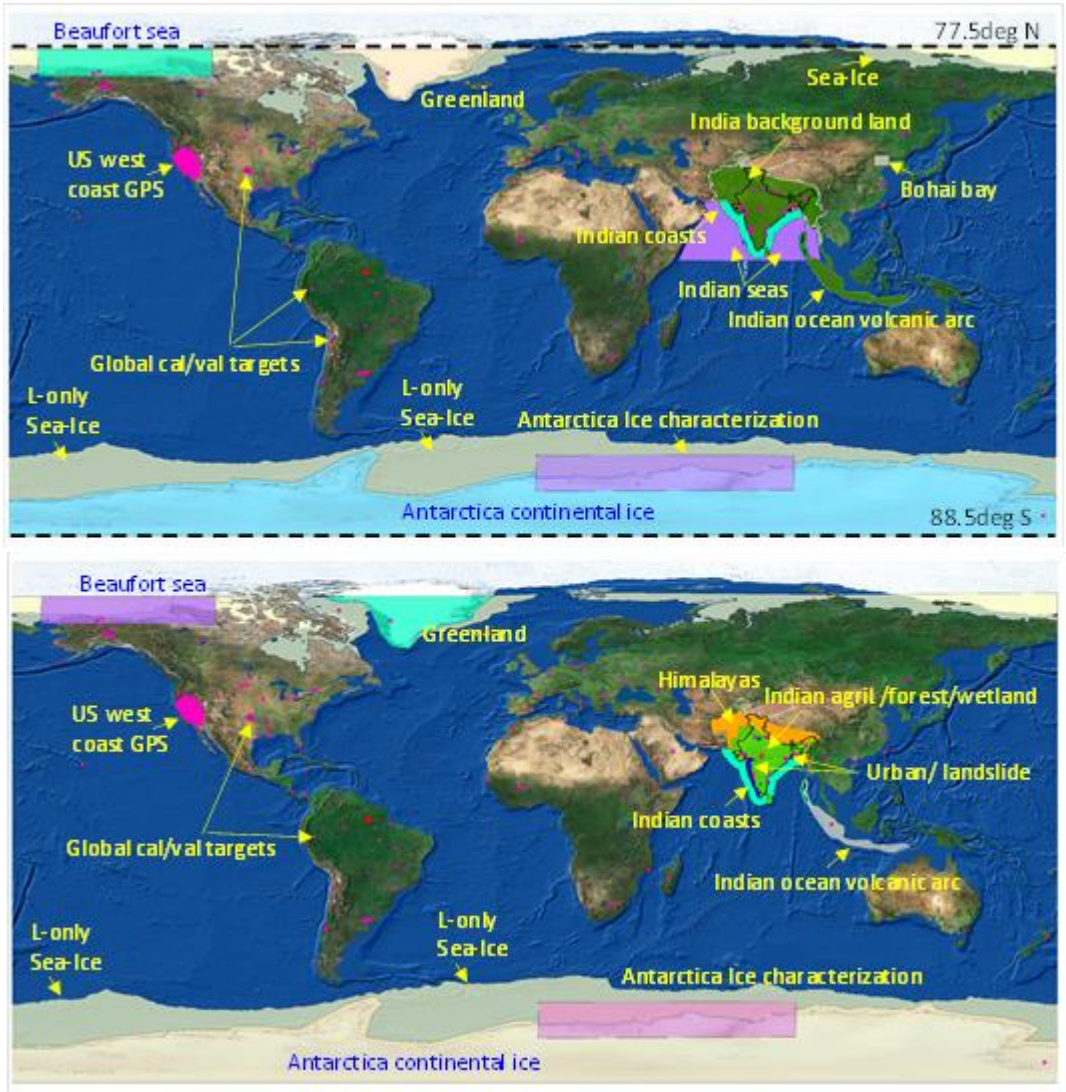

Fig. A3.2: Targets of Indian interests as defined by ISRO for NISAR ascending (top) and descending (bottom) orbits. These targets would be imaged in joint L+S band with various mode combinations and over specific observation cycles as depicted in Fig. A3.3. Due to the tilted orbit and left-looking imaging geometry of NISAR, only targets bounded by latitudes 77.5deg North and 88.5deg South would be imaged.

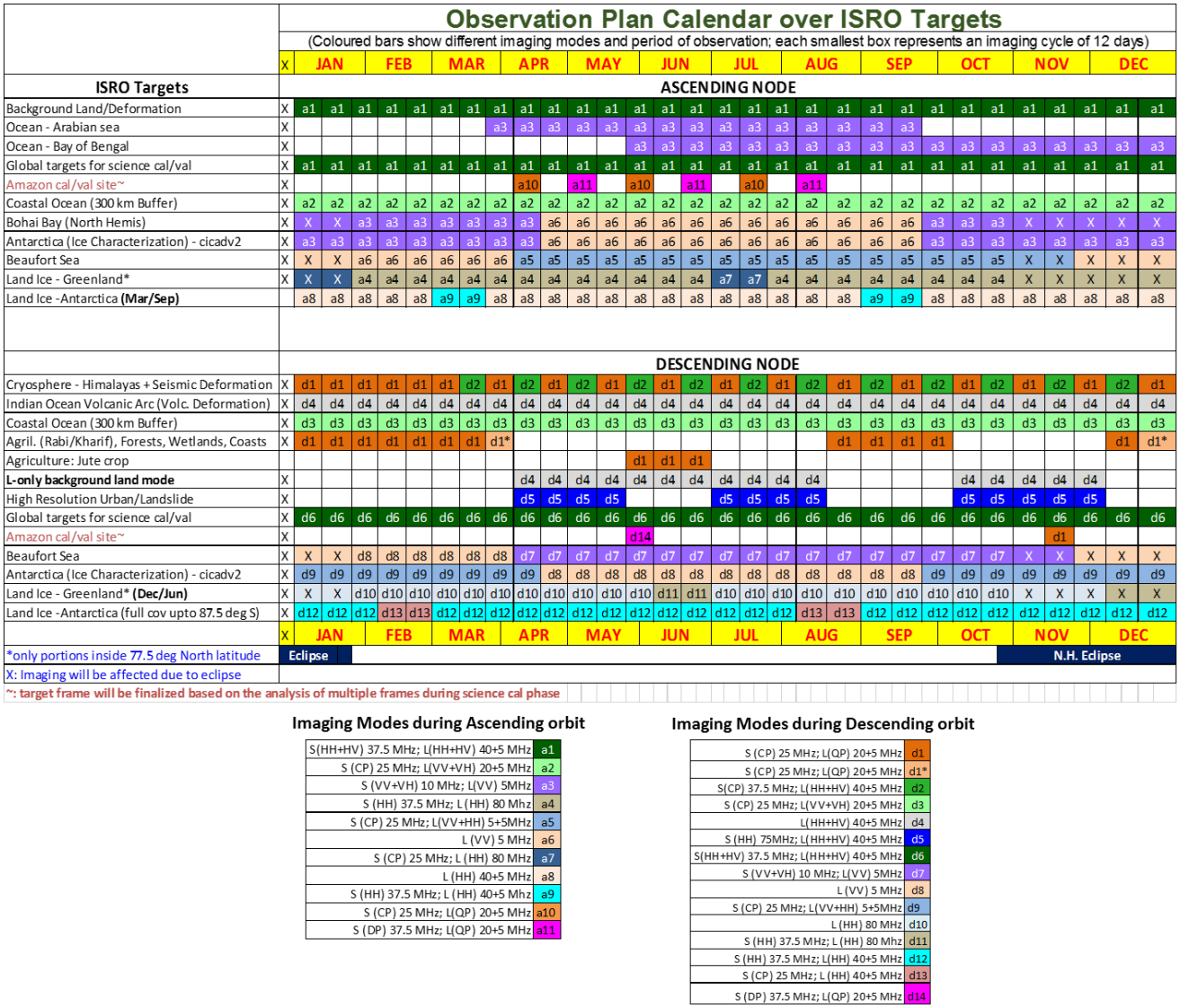

Fig. A3.3: NISAR observation calendar over targets of Indian interests. Each smallest box represents one observation cycle (12 days) of NISAR. Coloured boxes show different imaging modes and period of observation

A4. DATA PRODUCTS AND DISSEMINATION PLAN

NISAR data products will be organized by product level, with Level-0 being a raw form of data and Level-3/ Level-4 being geocoded derived science products in physical units. The L0A product is the received uncorrected raw data while the L0B product is a refined version of the radar signal data with transmission artefacts removed. NISAR L1 products will include all products in radar (range-doppler) coordinates, including the Single Look Complex (SLC), Multi-Look Detected (MLD), phase unwrapped (UNW) and wrapped nearest-time interferograms (IFG), and polarimetric covariance images (COV). The NISAR L2 products will be geocoded versions of all the L1 products (except MLD and the wrapped interferogram). While L0, L1 and L2 products have common definitions, NASA and ISRO have separate definitions for L3/L4 products. ISRO

defines L3 products as large area radiometric terrain corrected mosaic images and L4 products as science products. Some of the examples of L4 science products are: Indian forest above-ground biomass maps and forest disturbance maps generated annually at 100m grids, seasonal crop cover and crop type maps at 100m grids, soil moisture and land inundation maps generated every 12 days at 100m grids, snow density and glacier facies maps of the Himalayas generated every 12 days at 100m grids, weekly sea-ice types map at 100m grid and ocean surface wind speed near Indian coasts every 12 days at 1 km grid.

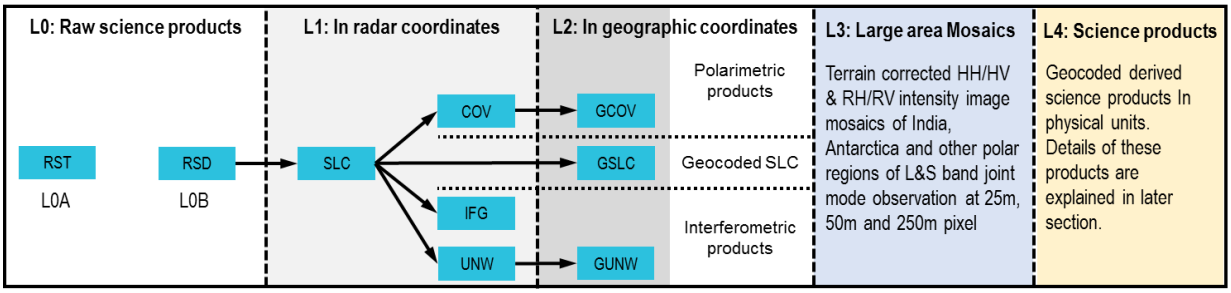

Fig. A4.1: NISAR data product levels: RST –Raw Science Telemetry; RSD-Radar Signal data; SLC- Single Look Complex; COV –Polarimetric Covariance Matrix; IFG - Nearest-Time Interferogram; UNW- Nearest-Time Unwrapped Interferogram

The L0, L1 and L2 data products as well as L3 and L4 science products will be hosted at data archival facilities of NASA and ISRO for dissemination to the users. NASA's Alaska Satellite Facility DAAC will archive all the L0 to L2 products of all L-band, limited S-band data and NASA L3 products. Similarly, L0 to L2 products of all S-band, limited L-band data and ISRO's L3/L4 products will be archived and disseminated from ISRO's data archival portal 'Bhoonidhi' at National Remote Sensing Centre (NRSC), Hyderabad (https://bhoonidhi.nrsc.gov.in/)

A4.1 NISAR Science Products Definition

ISRO has planned several higher-level products, called Level-4 science products using NISAR data. These products have high scientific interests and are identified based on the feedback from the applications science and user communities. These products will cater to the need of many applications and services as envisaged by various user agencies in India. Apart from that, these products would serve as input for development of new products and services. These products definitions are the following:

Ecosystem Science Products:

1. Forest aboveground dry biomass at hectare scale (1ha) generated annually within an RMSE of 20 Mg/ha for 80% of areas of biomass less than 100 Mg/ha over India.
2. Mangrove types and cover maps at 25m grid generated annually with classification accuracy of 80% or more over regions of mangrove vegetation in India.
3. Vegetation disturbance over Indian forests at 1-hectare grid size generated annually for areas losing at least 50% canopy cover with a classification accuracy of 80%.

4. Crop area and major crop types at a resolution of 1-hectare generated over cropping seasons (*kharif* and *rabi* season) in India with a classification accuracy of 80%.
5. Land inundation extent within inland and coastal wetlands of India at a resolution of 1 hectare every 12 days with a classification accuracy of 80%.
6. Surface soil moisture over bare and cropland areas within India at a resolution of 100m every 6/12 days, targeting ~±0.06 m^3/m^3 volumetric accuracy in the top 5cm for vegetation water content ≤ 5 kgm^{-2}

Cryosphere Science Products:

Himalayan Region

1. Snow wetness, snow density and snow-water equivalent maps at 100m pixel generated every 12days cycle during Dec-May over Himalayan region.
2. Glacier facies map at 50m pixel over the Himalayan-Karakoram region, every 12days cycle
3. Glacier velocity map at 50m pixel and 100m pixel over selected sites in the Himalayan region, twice in a year

Polar Region

1. Ice velocity fields map at 100m pixel over selected areas of Antarctica and Greenland, every 12days and over entire Antarctica, once every year
2. Grounding line position vector file within two Indian stations in Antarctica, every year
3. Sea ice product at 100m: deformation matrix- gridded layers of i) area, ii) shear, iii) divergence & iv) vorticity over Antarctica sea, every 6 days.
4. Sea ice type & concentration at 100m pixel over Antarctica sea, every 6 days during observation period
5. Sea-ice motion gridded product at 50m pixel over Antarctica sea, every 6 days during observation period

Solid Earth Science Products:

1. Geocoded Line of Sight (LOS) deformation map at 80m pixel over SE sites, every 12days cycle
2. Time series InSAR deformation map at 80m pixel at selected calibration sites, once in a year.

Coastal & Ocean Science Products:

1. Ocean surface wind map at 1 km pixel over Indian coastal seas, every 12days cycle
2. Coastal Bathymetry map of the Indian coasts at < 20cm error at 100m resolution, every year

3. Coastal shoreline map of India at 10m resolution with accuracy goal of 5m over 80% of area, every year.

A5. NISAR CALIBRATION AND VALIDATION PLAN

A5.1. Image calibration and validation

NISAR has a dedicated post-launch calibration and validation (cal/val) phase of 90 days, during which the radar will be calibrated for data products quality consistency over several standard terrestrial targets, called calibration sites. Both ISRO and NASA have planned to deploy corner reflector (CR) arrays or employ existing facilities with CR arrays for cal/val of NISAR data. ISRO has planned establishment of Pan-India networks of CR in collaboration with the academic institutions apart from extending the cal/val network to Antarctica, where a few CRs have already been deployed near Indian research stations. ISRO is also developing in-house active radar calibrator (ARC) for radiometric and polarimetric calibration of S-band data. ISRO is also considering utilizing International point target sites such as Rosamond and Oklahoma in the USA.

For overall radiometric balance, the project will use the uniform and stable backscatter properties of rain forests in South America and Africa as references. The L- and S-band radars will observe these targets jointly and individually variously through commissioning and science operations, at first for calibration and validation, and later to check stability.

ISRO's calibration plan span over NISAR pre-launch phase, commissioning phase and science calibration phase, where permanent sites have been identified across India for installation and maintenance of corner reflectors through institutional participations. From ISRO, both SAC and NRSC will be responsible for calibration of NISAR data and ISRO calibration sites located at Amrapur in Gujarat, IMGEOS at NRSC, Hyderabad and Antarctica will be equipped with additional CRs and other instruments for NISAR data calibration. Additionally, a network of point target calibrators across India is being established to calibrate and monitor the stability parameters of all the 24 beams across NISAR swath of 240km.

For the antenna pattern calibration, standard distributed targets such as regions of the Amazon and Congo rainforests have been identified over which, joint L and S-band image acquisitions are planned during NISAR commissioning and science calibrations phases.

Fig. A5.1: Pan-India network of point target calibrators, also known as corner reflectors, as depicted by white triangles.

A5.2. Science algorithm calibration and validation

To calibrate the higher-level science products and validate that the science requirements are met the desired accuracy levels, the science team has developed extensive cal/val plans. Calibration of science algorithms uses a combination of space-borne / airborne radar and in-situ observations. NISAR science team is using L and S band SAR data from contemporary SAR missions and ISRO's airborne SAR system, along with in-situ data collected in tandem with SAR data for development of algorithms for level-4 science products. For validation of science products, network of ground validation sites are being developed with field instruments planned to be deployed at the validation sites through institutional participation.

For products related to **ecosystems sciences**, the algorithms typically interpret radar backscatter absolute values or changes in terms of the parameter of interest, such as biomass, disturbance, wetland inundation or agricultural area. These algorithms generally are semi-empirical, and the model coefficients and threshold values can be land cover dependent. NISAR scientists are using NASA's UAVSAR L-band and ISRO's ASAR L- and S-band airborne radar measurements apart from space-borne SAR data from S-band NOVASAR, L-band ALOS PALSAR and C-band EOS04/ Sentinel-1 to determine these values pre-launch, and demonstrating that the algorithms are able to meet requirements.

For the validation of level-4 ecosystem science products, study sites representing different climatic and physiographic regions of India have been identified (figure A5.2), for collection of in situ data. The establishment and maintenance of in situ data collection plots within the study sites are being carried out through institutional collaborations. For the validation of forest AGB and

disturbance products long-term 1ha sized inventory plots are being established in 8 regions distributed across India. Collection of aerial LIDAR and high resolution optical multi-spectral data has also been planned over the inventory sites as ancillary data for product validation. Similarly, for the validation of NISAR **soil moisture** (SM) products, core SM cal/val sites are being established with permanent stations with soil moisture probes and other field instruments in campaign mode through institutional collaborations in different parts of India. Further collaborations are also being explored for existing soil moisture stations with COSMOS India network, state agricultural universities and Indian Meteorological Department (IMD) etc. for NISAR SM product validation as sparse cal/val sites.

For the validation of crop type maps, ground measurement data of crop types, crop conditions and associated parameters have been to be collected from JECAM (Joint Experiment for Crop Assessment and Monitoring) validation sites in India through institutional collaborations. For the validation of wetland inundation and active crop area/ crop type products, experimental sites have been planned for collection of in situ data during NISAR commissioning and science calibration phases as shown below in figure A5.2.

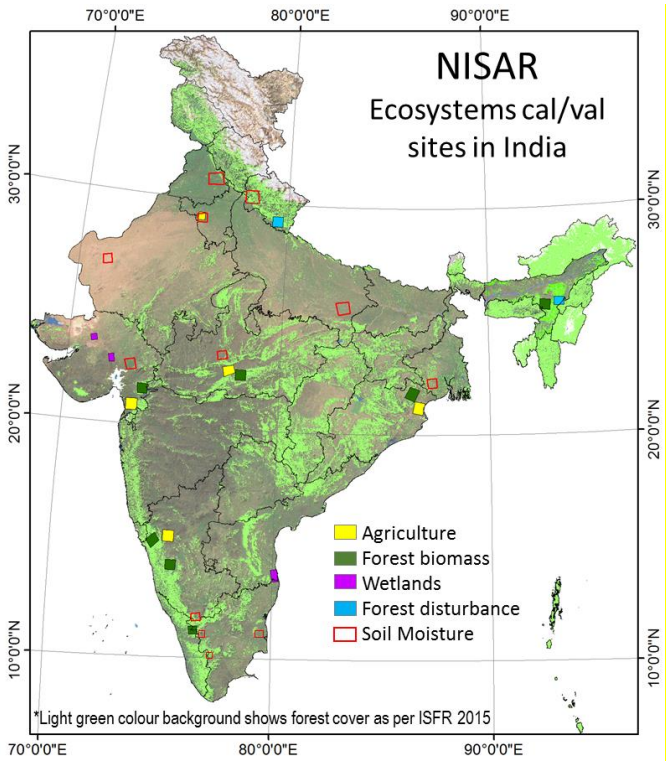

Fig. A5.2.1: Distribution of in-situ data collection sites in India for validation of NISAR ecosystem science products.

Comprehensive plan has been made for validation of **cryosphere science** products, too. Level-4 products related to the Himalayan cryosphere will be generated based on existing algorithms tested over selected snowfields and glaciers. Similarly, algorithms are being developed for generation of Sea-ice and continental ice dynamics products over Antarctica region based on SAR data from contemporary missions and ground data collected through Antarctica expeditions. For validation of products, a few in-situ data collection instruments such as corner reflectors in

Antarctica, GPS stations and ice parameter measurement stations in the Himalayan region have been established. In addition, plan has been made to collect in-situ data in the Himalayan regions through campaign modes during NISAR commissioning and science calibration phases for validation of cryosphere science products. Institutional collaborations are also being established for development and validation of products related to cryosphere science.

NISAR mission is designed to have spatially and temporally consistent surface deformation measurements on global land surfaces through repeat-pass InSAR technique. Secular, co-seismic and transient deformation rates observed from time-series InSAR measurements will be validated with point observations of surface motion collected from continuous GNSS stations. Data from GNSS stations of ISRO in the western and eastern Himalaya and UNAVCO network in Nepal will be used for the validation of **solid earth science** products. Data from GNSS stations of other national institutions will be acquired through collaboration for the purpose of product validation. In addition, Dense GNSS network of the California, USA will be utilized for validation of L and S band products. S-band data over five tracks covering the western U.S. will be acquired for this purpose. Shown below in Fig. A5.2.2 is the distribution of GPS networks that are considered for validation of solid earth products.

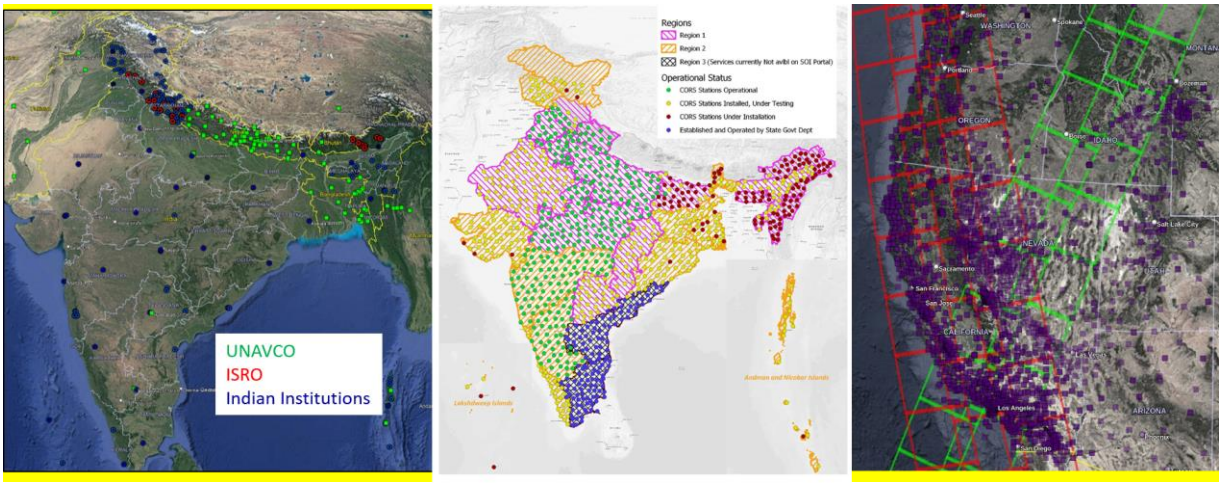

Fig. A5.2.2: Distribution GPS networks of (left) Indian institutions, ISRO and UNAVCO (middle) Survey of India (right) and UNAVCO in Western US to be utilized for validation of solid earth products. Ground tracks of NISAR at Western US proposed for additional S-band data acquisition for validation purpose are also shown.

For products related to the **coastal and ocean sciences**, near-shore and off-shore wind velocity maps and coastal bathymetry maps will be generated using in-house algorithms developed for C-band SAR data from RISAT-1 and EOS04 missions. The methods will be tuned for L&S band NISAR data with optimized model coefficients. Validation of wind velocity products will be made with respect to the in-situ buoy data from RAMA (Research Moored Array for African-Asian-Australian Monsoon Analysis ad Prediction) network. Coastal bathymetry products will be validated with the naval hydrographic bathymetry maps. Also, echo sounder data have been planned to be collected at selected sites through coastal cruises with institutional collaborations.

Post-launch, during the NISAR science calibration phase, field measurements are planned over established sites on campaign basis to validate the products against the requirements, and other data sets such as LIDAR forest structure estimates, high-resolution optical remote sensing data, GPS data, LU/LC products, and bio-geo-physical products derived from other sources will be used for cross-validation of NISAR science products.

A5.3 Collection and Archival of Ground Validation Data

Collection of ground truth data or ground validation data is vital for the success of NISAR science plan and applications requirements. There is a comprehensive plan to standardise the collection of ground validation data through institutional collaborations. It is planned to develop standard protocols and formats for collection of ground data under NISAR science and utilization programme. For example, the *in-situ* data collection protocols developed by CEOS-LPV for forest above-ground biomass[4] and soil moisture[5] product validation and JECAM[6] for crop parameters will be followed in the science plan. The ground validation data thus collected by various participating institutions and agencies through NISAR science, will be achieved at a centralised repository at SAC, ISRO and shall be made available to all the stake holders through NISAR science and utilization programme.

A5.4 Collaborations for NISAR Science and Cal/Val Activities

Several Indian institutions have been identified as potential collaborators for providing necessary support for calibration and validation of NISAR data and science products. Some of these institutions are already empanelled for NISAR science and cal/val activities, while some of the institutions are being pursued for collaborations.

A6. NISAR COMMUNITY ENGAGEMENT AND OUTREACH PLAN

NISAR science will continue to address the needs of Indian user agencies such as ministries, government departments and institutions that require SAR based products and services, by

[4] Dun Duncanson, L., Armston, J., Disney, M., Avitabile, et.al. (2020). Global Aboveground Biomass Product Validation Best Practices Protocol. Version 1.0. In L. Duncanson, M. Disney, J. Armston, D. Minor, F. Camacho, and J. Nickeson (Eds.), Best Practice Protocol for Satellite Derived Land Product Validation, (p. 222): Land Product Validation Subgroup (WGCV/CEOS), doi:10.5067/doc/ceoswgcv/lpv/agb.001

[5] Montzka, C., M. Cosh, B. Bayat, A. Al Bitar, A. Berg, R. Bindlish, H. R. Bogena, J. D. Bolten, F. Cabot, T.Caldwell, S. Chan, A. Colliander, W. Crow, N. Das, G. De Lannoy, W. Dorigo, S. R. Evett, A. Gruber, S. Hahn, T.Jagdhuber, S. Jones, Y. Kerr, S. Kim, C. Koyama, M. Kurum, E. Lopez-Baeza, F. Mattia, K. McColl, S. Mecklenburg,B. Mohanty, P. O´Neill, D. Or, T. Pellarin, G. P. Petropoulos, M. Piles, R. H. Reichle, N. Rodriguez-Fernandez, C.Rüdiger, T. Scanlon, R. C. Schwartz, D. Spengler, P. Srivastava, S. Suman, R. van der Schalie, W. Wagner, U.Wegmüller, J.-P. Wigneron, F. Camacho, and J. Nickeson (2020): Soil Moisture Product Validation Good Practices Protocol Version 1.0. In: C. Montzka, M. Cosh, J. Nickeson, F. Camacho (Eds.): Good Practices for Satellite Derived Land Product Validation (p. 123), Land Product Validation Subgroup (WGCV/CEOS), doi:10.5067/doc/ceoswgcv/lpv/sm.001

[6] Defourny, P., Jarvis, I., and Blaes, X.: JECAM Guidelines for cropland and crop type definition and field data collection, JECAM, 2014. http://jecam.org/wp-content/uploads/2018/10/JECAM_Guidelines_for_Field_Data_Collection_v1_0.pdf: last access: 17 May 2021

involving representatives from the agencies. For the proper utilization of NISAR science products, collaborations and memorandums between ISRO and user agencies will be established and product definitions will be fine-tuned, if required, prior to the generation of science products.

Continuous efforts are being made to engage the applications community for optimum utilization of NISAR data through organization of annual user workshops, science theme specific user's workshops, training programs and offering a wealth of resources to the community in the form of technical documents, tutorials, NISAR simulated data and analysis tools. NISAR offers a science user's handbook and several applications showcase study reports for the applications community. NASA and ISRO have been supporting coordinated training and outreach programs on NISAR science themes through various platforms such as ISRO's Satellite Meteorological and Oceanographic Research and Training (SMART), Training Research in Earth Eco-Systems (TREES), and Applied Remote Sensing Training (ARSET) programs. Polarimetric SAR data acquired through NASA's UAVSAR and ISRO's L&S band airborne SAR over US region and other selected regions are available to the user community (https://uavsar.jpl.nasa.gov/cgi-bin/) supported by SAR data processing tools such as ISCE (InSAR Computing Environment), MintPy (Miami InSAR time-series software in Python) developed by NASA-JPL and MIDAS (Microwave Data Analysis Software) developed by ISRO-SAC under NISAR mission (http://vedas.sac.gov.in/)

Apart, various measures for publicity of NISAR data and products are planned, either solely or jointly with NASA prior to the mission. The publicity includes generation of short documentary videos on the application potentials of NISAR, press release of important developments and applications showcases of NISAR and publication or displaying of NISAR mission, data products and applications in major scientific events throughout world.