

New products from SAR Sensors



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**NRSC User Interaction Meet – 2024
12-13 Mar 2024**

Earth Observation Satellite - 04 (EOS-04)



EOS-04 Data Products



□ EOS-04 (RISAT-1A) is Follow on Mission of RISAT-1.

- **Imaging Modes:**
Stripmap, ScanSAR and Sliding-Spotlight
(FRS-1, FRS-2, MRS, CRS and HRS)
- **Polarizations:** Single, Dual, Compact (CP) & Full
- **Swath Coverage:** 10 Km to 223 Km
- **Spatial Resolutions:** 1m to 50m
- **Data availability:** 23rd March 2022 onwards.

<https://bhoonidhi.nrsc.gov.in>

Product Specifications

Parameter	EOS-04
Geo location accuracy (RMSE)	50 m
Radiometric Resolution (SLC)	3.1 dB
PSLR	-17 dB
Relative Radiometric accuracy	1dB
Absolute Radiometric accuracy	1dB

Levels of Data Products	
Level -0	Raw Signal Product (Generic Binary)
Level-1	Slant Range Geo-Tagged Product Ground Range Products (CEOS/GeoTiff)
Level-2A Georef	Enhanced Terrain Geo Referenced Product (GeoTiff)
Level-2B	Terrain Normalized Analysis Ready Data Product (GeoTiff)
Value Added Products	
Level-1C	Geo-tagged Polarimetric products
Level-3A	Geo-referenced Polarimetric products
Mosaic	India Mosaic (for systematic coverage) Large Area Mosaic
Information Product	Surface Soil Moisture Product
Projection: UTM (Level-2) Datum : WGS84 (Level-2) Resampling : CC (Level-2)	

Level-2B Terrain Normalized ARD data product

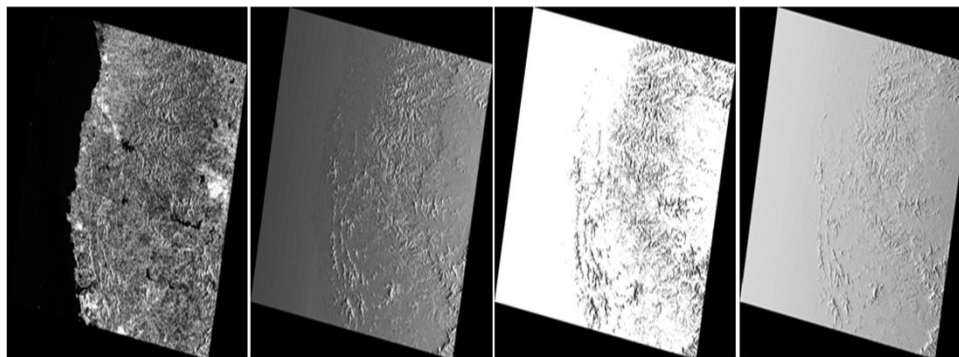
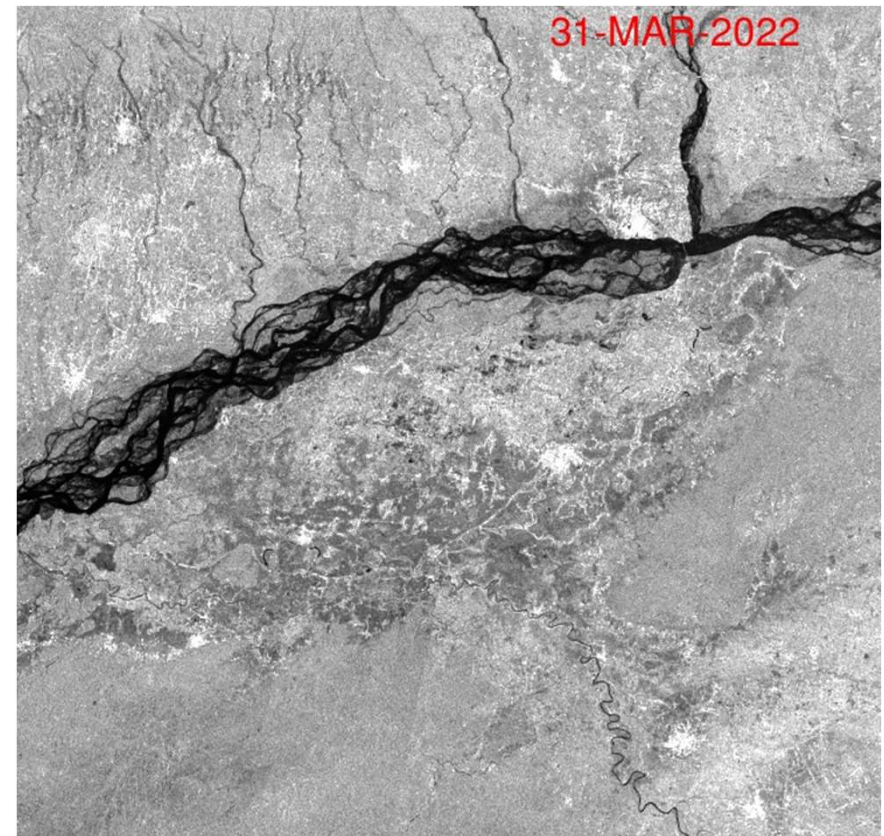


- Available for MRS, CRS imaging modes.
- Terrain induced variations are normalized by the local illuminated area.

From 1st Feb 2024 onwards, Level-2B data products can be downloaded from Bhoonidhi web portal in OpenData_DirectDownload category.

- Normalized Radar Backscatter Product (Gamma0).
- Absolute Geometric accuracy < 30m.
- This is an Analysis Ready Data (ARD) product.
- Suitable for Time Series Analysis.
- In compliance with CEOS ARD NRB v1.0 specifications.

EOS-04 Level-2B product: Assam Region (Time Series)

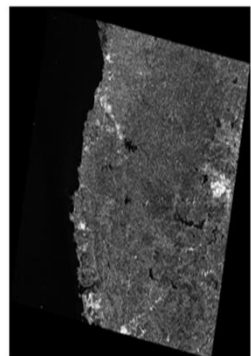


γ_E^0 ellipsoid based Gamma naught

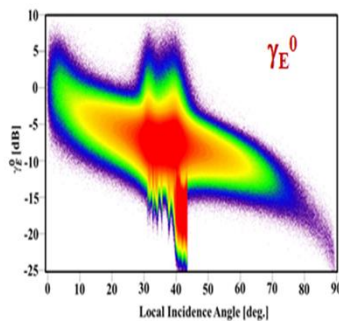
Local illuminated area (gamma plane)

Layover Shadow Mask

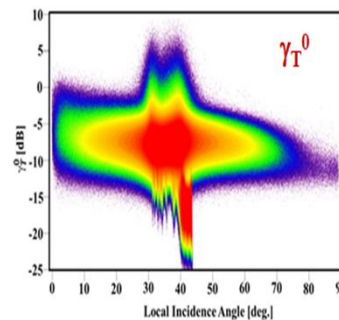
Local Incidence Angle



γ_T^0 Radiometric Terrain corrected (RTC) Gamma naught



Flattening of Terrain Normalized Gamma0 (γ_T^0) in comparison to Ellipsoid Gamma0 (γ_E^0)



Validation of EOS-04 RTC Module

EOS-04 Polarimetric Value Added Data Products



❖ EOS-04 SAR is having the Hybrid and Full polarimetric capabilities along with Single and Dual polarizations in FRS-1, FRS-2, MRS & CRS imaging modes.

Polarization	Imaging Mode	<u>Level-1C</u> 3-Layer Covariance Product	<u>Level-3A</u> M-delta decomposed Product	<u>Level-3A</u> M-chi decomposed Product
Circular Polarization	FRS-1	✓	✓	✓
	FRS-2	✓	✓	✓
	MRS	✓	✓	✓
	CRS	✓	✓	✓
	Imaging Mode	<u>Level-1C</u> 6-Layer Covariance Product	<u>Level-3A</u> Freeman decomposed Product	<u>Level-3A</u> Yamaguchi decomposed Product
Full Polarization	FRS-1	✓	✓	✓
	FRS-2	✓	✓	✓
	MRS	✓	✓	✓
	CRS	✓	✓	✓

Polarimetric data products

1. Level-1C Covariance Products
2. Level-3A Polarimetric Decomposed Products

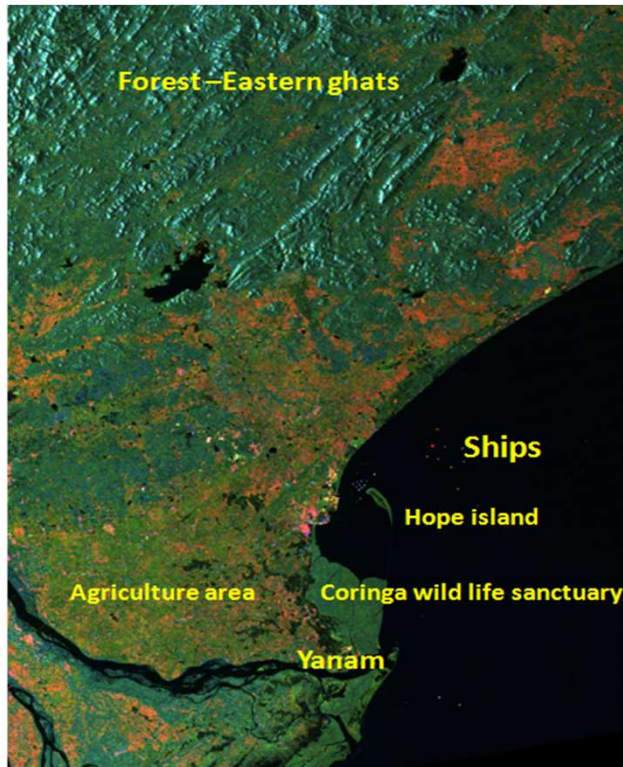
Polarimetric data products can be ordered in Bhoonidhi web portal for hybrid/full polarimetric acquisitions under

1. *OpenData_OnOrder category for MRS and CRS imaging modes*
2. *Priced category for FRS-1 and FRS-2 imaging modes*

EOS-04 Polarimetric Value Added Data Products

Applications:

- Land use/Land cover classification
- Target recognition / classification
- Forest monitoring & classification
- Crop classification etc.



MRS, Full Pol, 27th Oct 2022,
Yamaguchi decomposition



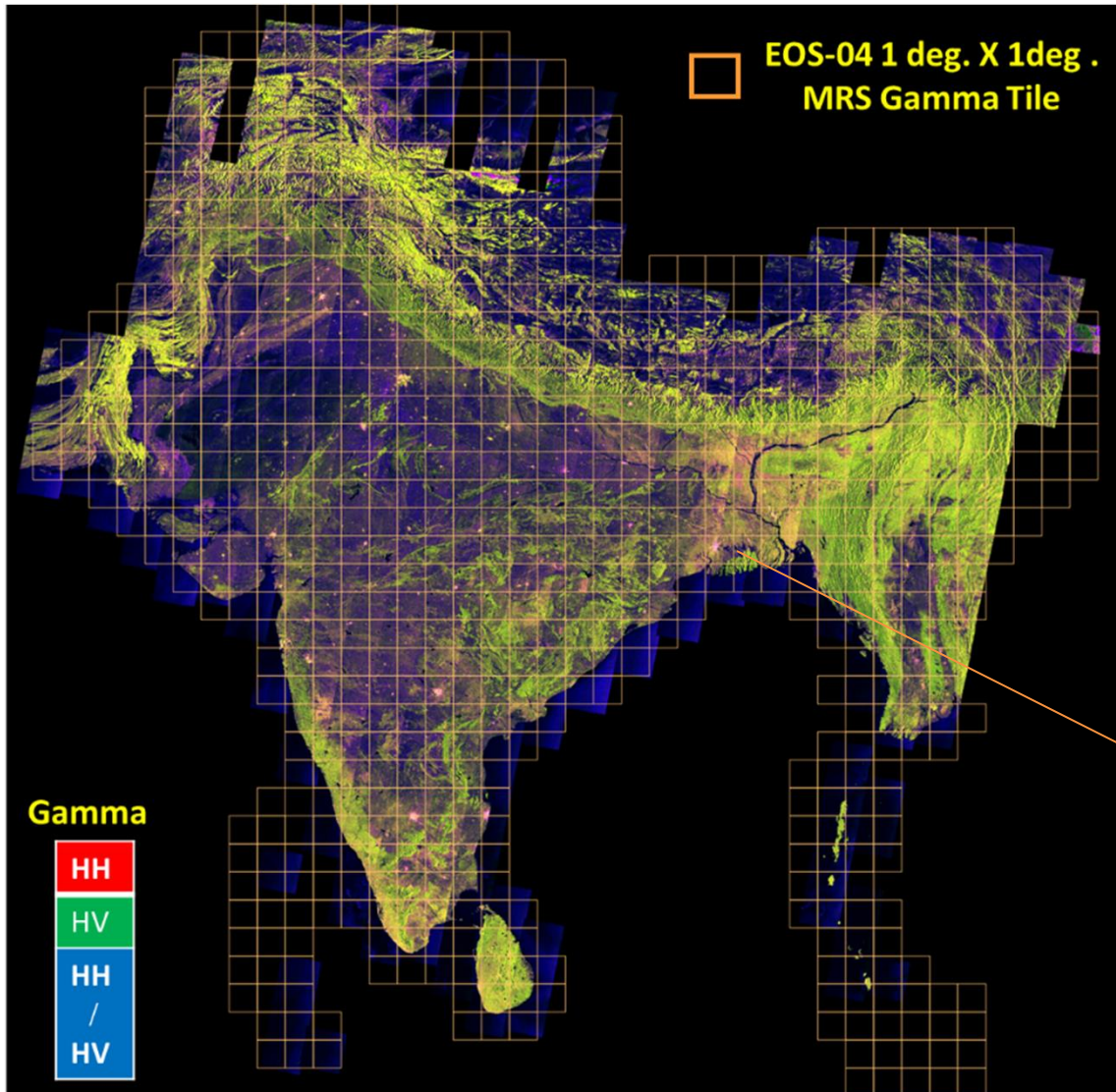
FRS-1, Hybrid Pol, M-Delta Decomposition



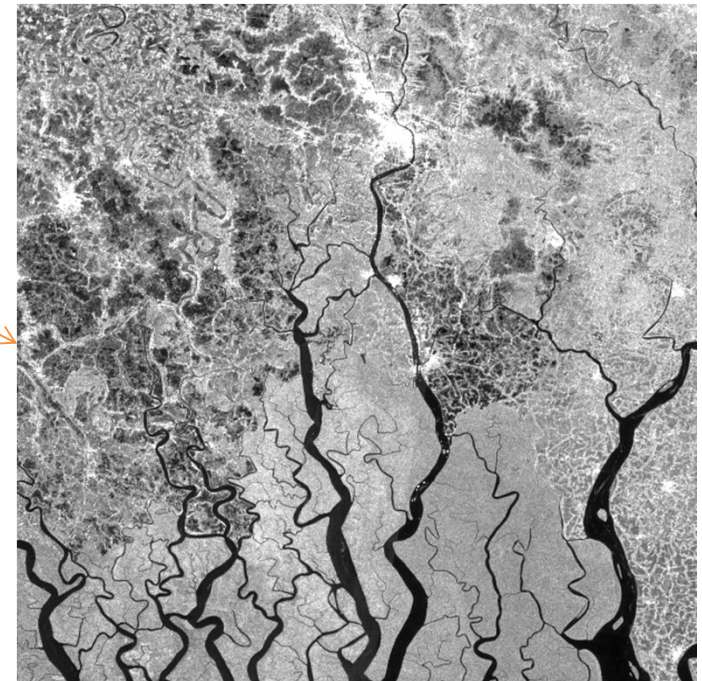
FRS-1, Full Pol, 17th Aug 2022, Freeman decomposition

Red- Even Bounce Scattering
Green - Volume Scattering
Blue - Odd Bounce Scattering

EOS-04 India Mosaic ARD Product

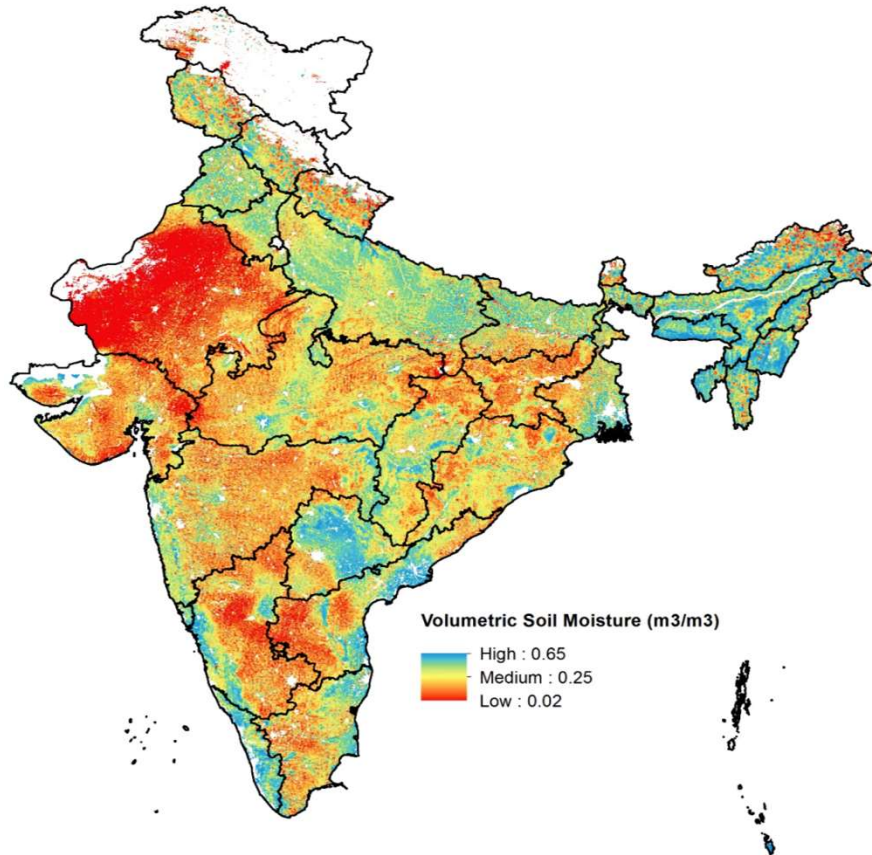


- ✓ EOS-04 India Mosaic ARD product from MRS systematic coverage acquisitions to be made available as set of 809 1 deg. X 1 deg. tiles every 17 days.
- ✓ Efficient Time –Series analysis with terrain Normalized ARD mosaic tiles.



Tile : N22E089_041_MRS_E04

EOS-04 500m Soil Moisture Data Products



All India EOS-04 derived 500m Soil Moisture Product
(17 days composites) from 04 Jan, 2023 – 21 Jan, 2023

❖ ISRO has introduced a novel Operational Soil Moisture Product(SM), leveraging the capabilities of the EOS-04 (RISAT-1A) satellite's C-band Synthetic Aperture Radar (SAR).

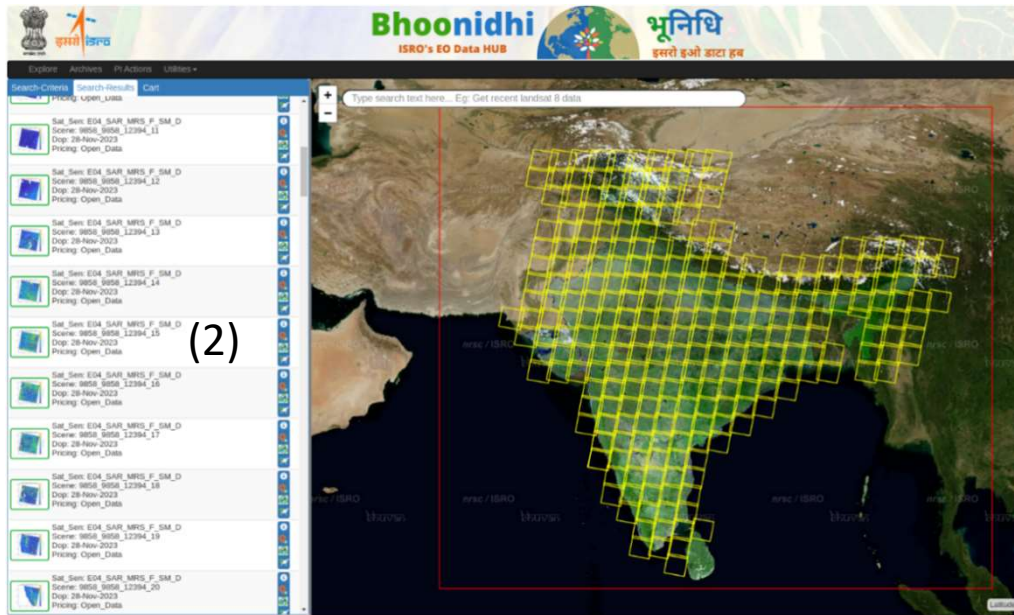
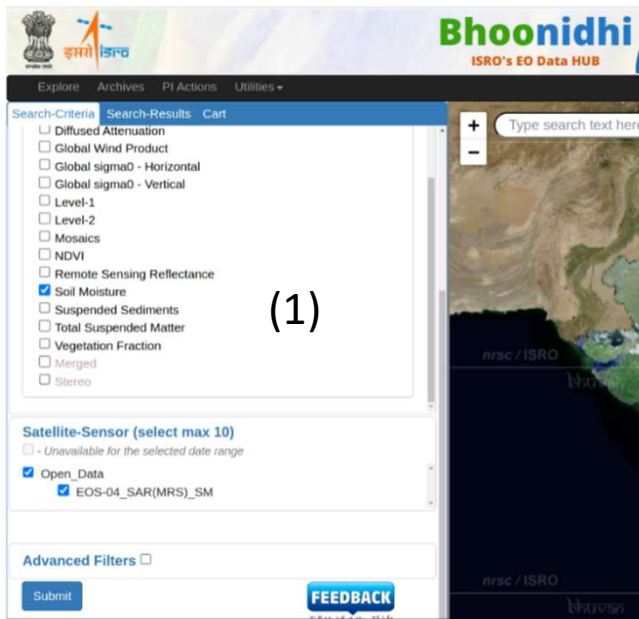
❖ This innovative product promises a spatial resolution of 500 meters, a significant leap forward in soil moisture monitoring for agricultural applications.

Applications: (Agriculture and Hydrology)

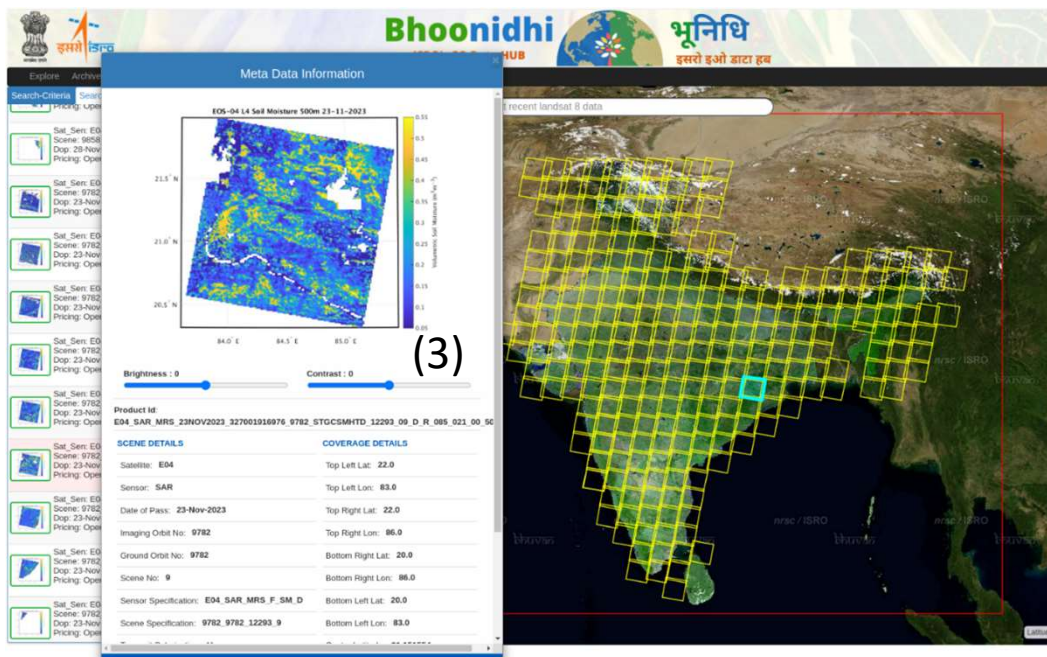
1. Monitoring & quantifying irrigation dynamics.
2. Crop water stress.
3. Early agriculture drought assessment.
4. early flood like situation monitoring.
5. predicting suitable breeding areas
6. landslides predictions.
7. root zone soil moisture modelling.
8. data assimilation in land hydrological models.
9. agro-hydrological modelling.

❖ *Soil Moisture data products can be downloaded from Bhoonidhi web portal in OpenData_DirectDownload category.*

EOS-04 Soil Moisture Data Products on Bhoonidhi



- (1) Soil Moisture (SM) Product listed as Open data in Bhoonidhi Portal
- (2) List of Available SM Data products in search-results
- (3) Quick browse image of selected SM products



Earth Observation Satellite - 09 (EOS-09)

Future Satellite



EOS-09 (RISAT-1B)
(Follow-on Mission of EOS-04)

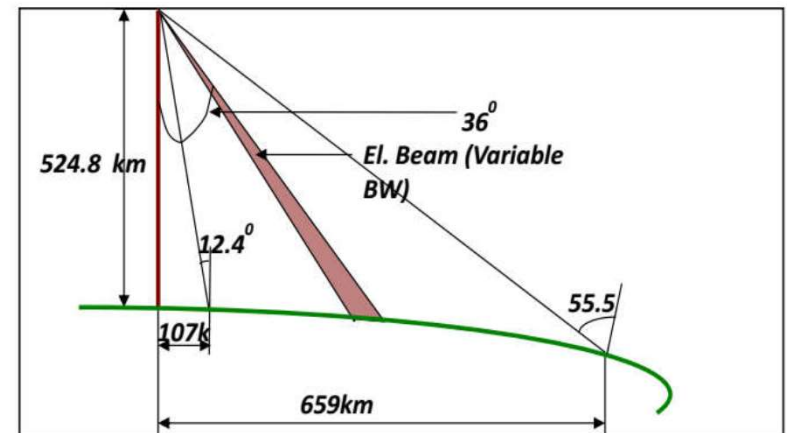


Mission Objectives

- To ensure C-Band Microwave data continuity to the user community for operational applications
- To improve the frequency of observation (Revisit time) when used in tandem with EOS-04(RISAT-1A)

Primary Payload: SAR in C-band
Secondary Payload: AIS

Interferometry imaging is planned in RISAT-1B and will be carried out by maintaining ground track within ± 500 m in the nominal orbit.



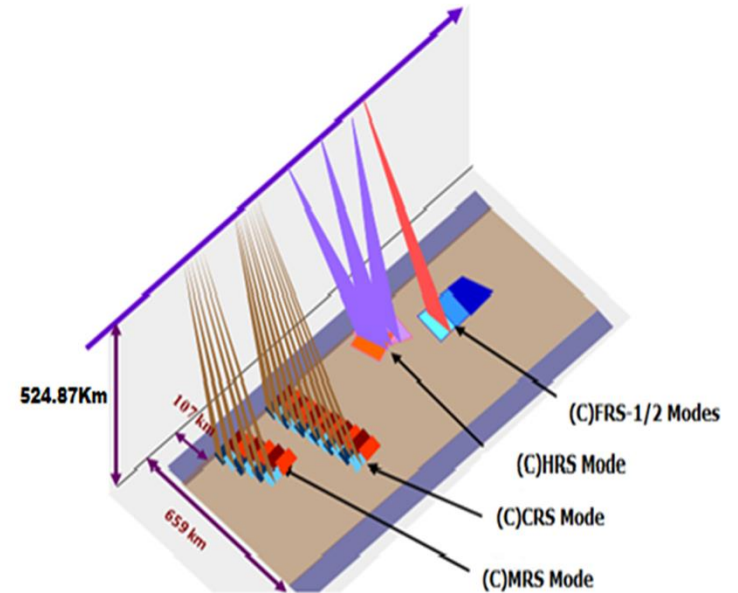
Automatic Identification System(AIS) Payload:

- 4 channel AIS receiver
- Conventional and long-range AIS in VHF
- Always ON and data is stored in micro-SSR.
- AIS receives GMSK signals from ship-borne AIS beacons and can be used for detection and localization of ships.

EOS-09 (RISAT-1B) Modes & Data Products



		Nominal Levels of Products		
		Level 0	RAW Signal Product <i>BAQ Decoded I/Q Samples and CEOS formatting</i>	
Level-1	Geo-Tagged Product <i>Slant (Level-1A) / Ground (Level-1B) Range Product along with Grid File</i>			
Level-2	Geo-Referenced Product UTM/UPS Projection using Copernicus 30 m DEM along with Grid File Level-2A : Enhanced Geo-Referenced (similar to RISAT-1A) Level-2B : ARD Enhanced Geo-Referenced Data Product			
		Value Added Products		
Level-1C	Geo-Tagged Polarimetric Product <i>along with Grid File</i>			
	<i>DP/CP: 3 Layers (2 real Diagonal: 1 complex Off Diagonal Elements of COV Matrix) FP: 6 Layers (3 Real Diagonal : 3 Complex Off Diagonal Elements of COV Matrix)</i>			
	Geo-Referenced Polarimetric Product <i>In UTM/UPS projection along with Grid File</i>			
Level-2C	Geo-Referenced Covariance Matrices GCOV (layers as per Level-1C product) <i>m-delta/m-chi decomposed</i>	<i>Yamaguchi/Freeman decomposed</i>		
Level-3A	<i>(Hybrid Pol FRS-1/FRS-2/MRS/CRS/HRS)</i>	<i>(Full Pol FRS-1/FRS-2/MRS/CRS)</i>		
MOSAICS	India Mosaic <i>(for systematic coverage)</i>	SAR + AIS	Level-3B AIS Information Product	Level-3C SAR Detected Ship + AIS Association
	Analysis Ready Data -ARD			



Img. Mode	RAW-LO (CEOS)	L1-SLC (CEOS & GeoTIFF)	L1-Ground Range (CEOS & GeoTIFF)	L2- (GeoTIFF)
FRS-1	✓	✓	✓	✓
FRS-2	✓	✓	✓	✓
MRS	✓	✓ (GeoTIFF)	✓	✓
CRS	✓	✓ (GeoTIFF)	✓	✓
HRS	✓	✓ (GeoTIFF)	NA	✓



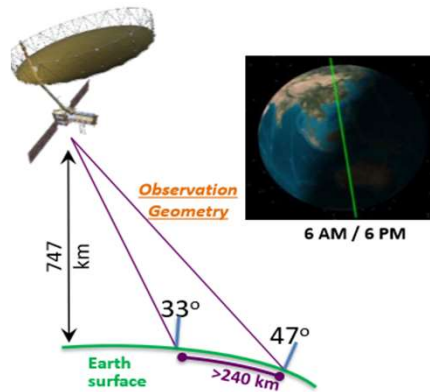
NASA-ISRO Synthetic Aperture Radar (NISAR)

Future Satellite



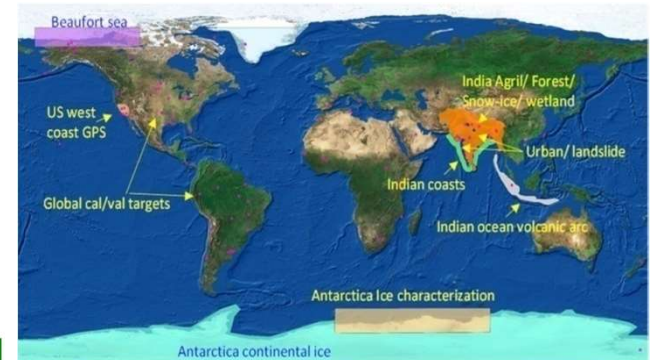
NISAR Mission - Objective

- ✓ **Collaborating Agencies:** ISRO and NASA
- ✓ **Dual Frequency SAR:** L-band from NASA
S-band from ISRO
- ✓ **Imaging Technique:** SweepSAR
- ✓ **Repeat cycle:** 12 days
- ✓ **Larger Swath & Global coverage**
- ✓ **High Spatial Resolution**
- ✓ **Full Polarimetric & Interferometric Operations**

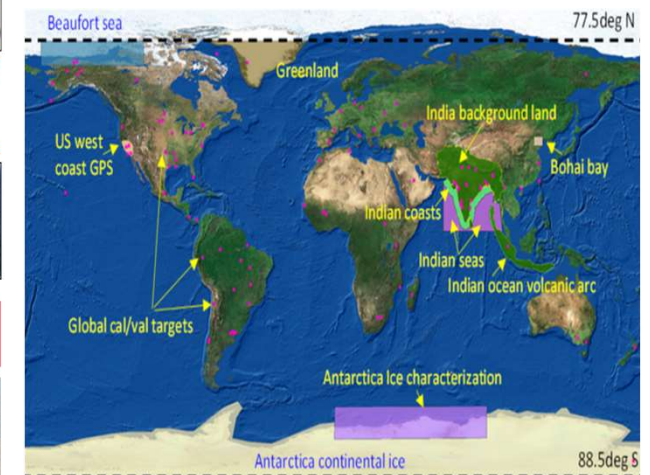


Targets of Indian interests as defined by ISRO for NISAR

Targets for Descending Orbit



Targets for Ascending Orbit



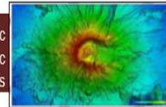
NISAR Characteristic:	Enables...
L-band (24 cm wavelength)	Low temporal decorrelation and foliage penetration
S-band (9 cm wavelength)	Sensitivity to light vegetation
SweepSAR technique with Imaging Swath > 240 km	Global data collection
Polarimetry (Single/Dual/Quad)	Surface characterization and biomass estimation
12-day exact repeat	Rapid Sampling
3 - 10 meters mode-dependent SAR resolution	Small-scale observations
3 years science operations (5 years consumables)	Time-series analysis
Pointing control < 273 arcseconds	Deformation interferometry (D-InSAR)
Orbit control < 500 meters	Short baseline D-InSAR
> 10% (S) / 50% (L) observation duty cycle	Complete land/ice coverage
Left-only pointing (Left/Right capability)	Uninterrupted time-series Rely on Sentinel-1 for Arctic

NISAR Science Applications

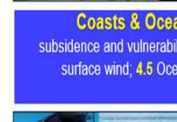


Land Ecosystems: 1.1 Crop biomass & Crop monitoring; 1.2 Forest biomass and Carbon stock; 1.3 Forest disturbance; 1.4 Mangroves & Wetlands; 1.5 Alpine vegetation; 1.6 Vegetation phenology; 1.7 Field-scale soil moisture; 1.8 Ecosystem stress assessment

Solid Earth 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 polar regions



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: 6.1 Floods; 6.2 Forest fire damage assessment; 6.3 Coastal oil spill; 6.4 Earthquakes / Others

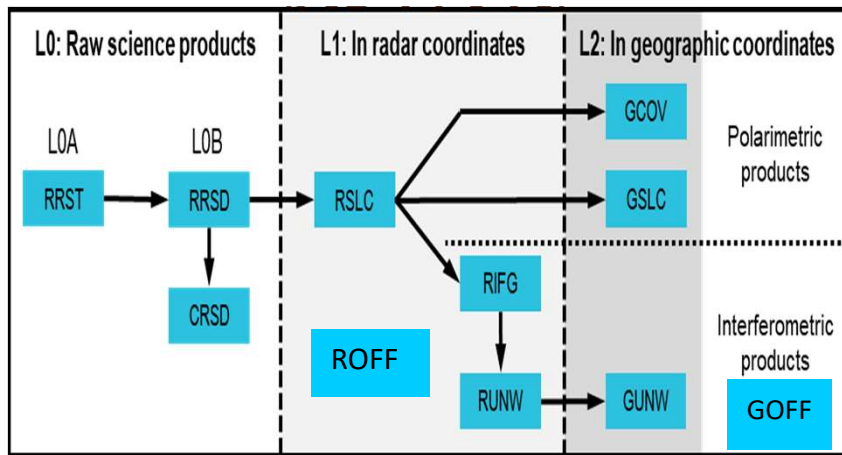
Geological Applications: 6.1 Structural & Lithological studies; 6.2 Lineament mapping; 6.3 Paleo-Channel detection; 6.4 Geomorphology; 6.5 Land degradation mapping; 6.6 Geo-archaeology; 6.7 Mineral explorations



NISAR Standard Data Products



NISAR Standard Data Products



Except RRST all products are in HDF-5 format

- 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

LOA- not for dissemination
S-BAND won't be having CRSD products,
only L-Band will be having CRSD products

- NISAR data products are free under open data policy, where all the products LOB,L1 and L2 products are free to public.
- level-1 and level-2 processed data will be hosted at Bhoonidhi server accessible to the general users ~ 2 days of data take and with the most accurate orbit ephemeris(MOE) parameters.
- For urgent and NRT product requests, data products will be generated with predicted orbit ephemeris (FOE)

Product Definitions



➤RAW Signal Product :
Individual Channel or
Digital Beam Formed



➤Products in Radar coordinates

- Geo-Tagging using satellite Ephemeris data
- Earth Geometry - Standard Ellipsoid
- Dense grid of Geo-Locations with product



➤Geocoded Products

- Horizontal datum : WGS 84
- Map Projection : UTM, UPS for polar regions
- DEM: COPERNICUS DEM(30m)
- Radiometric Terrain Corrected Product

- Level 0A**
- Data is ordered in time
 - Communication Artefacts , missing data and synchronization errors are not corrected
 - Intermediate product, Input to LOB processor
- Level 0B**
- Aligned and raw radar signal data
 - BAQ samples from RAW products are decoded and packed into complete range lines
 - Available for dissemination

RSLC

- RSLC product refers to the standard Range-Doppler geometry, Single Look Complex (SLC) image.

RIFG

- RIFG product represents the ellipsoid height-corrected, wrapped Interferogram generated from two Range-Doppler SLC products in the Range-Doppler geometry of the earlier acquisition. *Generated for Antarctica and Greenland only.*

RUNW

- RUNW product represents the unwrapped, multi-looked differential Interferogram generated from two Range-Doppler SLC products in the Range-Doppler geometry of the earlier acquisition. *Generated for all regions other than Antarctica & Greenland*

ROFF

- Unfiltered and unculled layers of pixel offsets in range-Doppler coordinates with different resolutions obtained from coherent and incoherent speckle tracking. *Generated for Antarctica, Greenland and pre-identified world mountain glaciers.*

GSLC

- Derived from Range-Doppler SLC product using a DEM and the MOE state vectors and output is in Map Projected system

GUNW

- The GUNW product is derived from the Level-1 UNW product by using a DEM to project the data into the map-projected system.

GCOV

- GCOV product is derived from slant domain Covariance matrix using a DEM to project the data into the map-projected system. The GCOV product contains the multi-looked backscatter.

GOFF

- Geocoded version of ROFF product using the MOE state vectors and a DEM. *Generated for Antarctica, Greenland and pre-identified world mountain glaciers.*

NISAR Level-3 & 4 Data Products



NISAR Higher Level Data Products (L3 & L4)



Science Products:

Ecosystems: 1. Forest cover & AGB; 2. Forest Disturbance Map
3. Active Crop area, Crop types; 4. Land inundation
5. Surface soil moisture

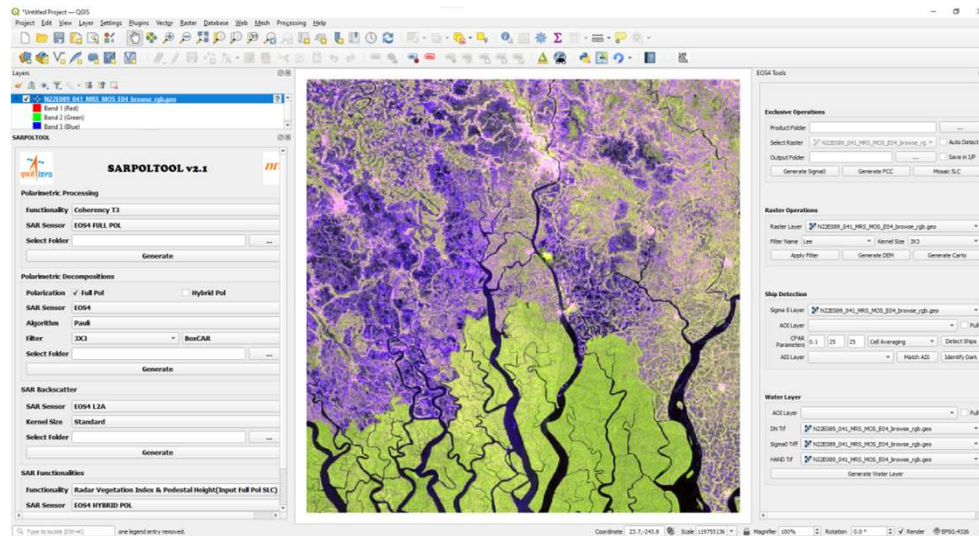
Cryosphere: 1. Himalayas Dry-wet snow, SWE, Snow density;
2. Glacier facies;
3. Glacier velocity at selected Himalayan region
4. Antarctica ice velocity; 5. Grounding line position near Antarctica Indian stations; 6. Ant. Sea-Ice type/conc.

Solid Earth Science: 1. LOS deformation
2. Time-series deform map

Ocean / Coastal: 1. Ocean surface wind speed
2. Coastal bathymetry map
3. Mangroves types/cover

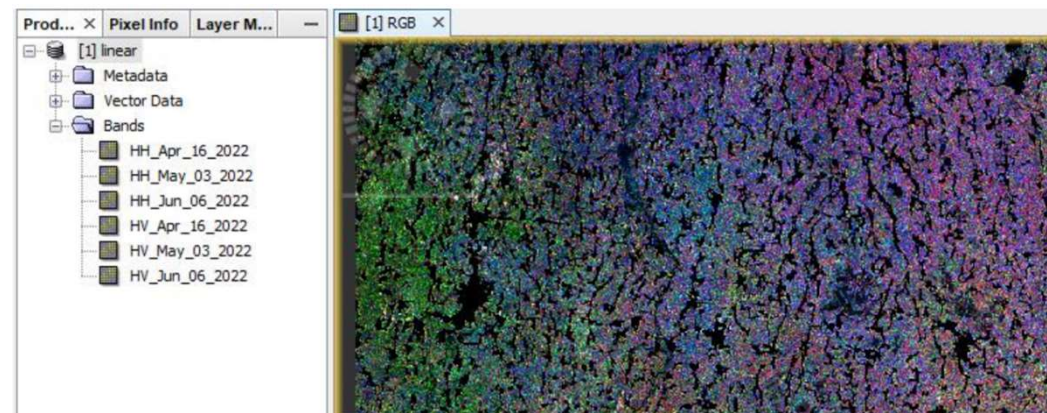
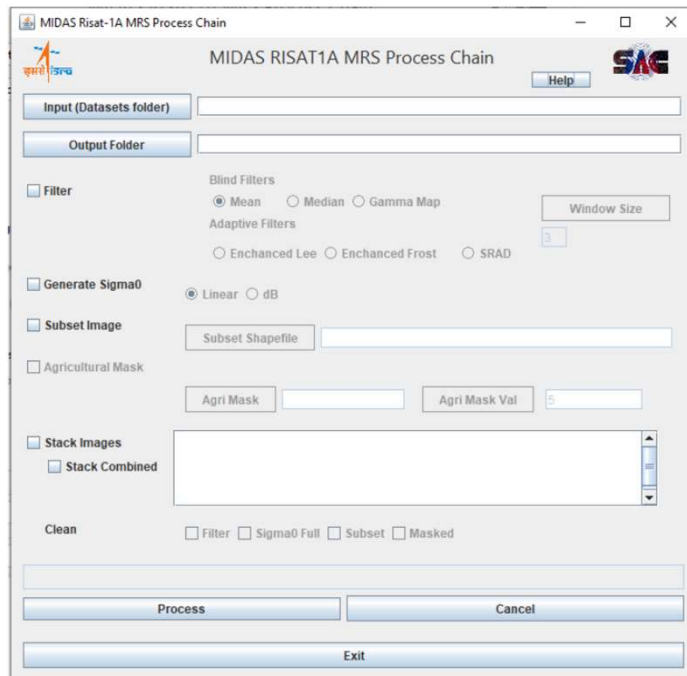
- ❖ Level-4 data products are the science products pertaining to various science requirements like Ecosystem, Deformation, Cryosphere, Solid earth, Ocean, Geology etc.
- ❖ These products will be generated after the beginning of NISAR commissioning phase and will be hosted in the “Bhoonidhi”,
- ❖ The products may be operational or semi operational. The products generation frequency may be near real-time, daily, cycle-wise, seasonal or annual or semi-annual depending upon the applications.
- ❖ The product will be validated with early science phase data and made operational.

Tools for Geospatial Analysis with SAR



SARPOLTool v2.1, a Windows plugin for QGIS, enhances PolSAR data usage in remote sensing. It supports multi-sensor SAR data analysis, focusing on target scattering, radar backscatter, and textural variations for classification. Functionalities include polarimetric processing, target decompositions, backscatter generation, and parameter estimation like oil slick characteristics. Integrated EOS-4 Toolset aids EOS-04/RISAT 1A data visualization and analysis, boosting geospatial analysis.

Download SARPOLTool at: <https://bhoonidhi.nrsc.gov.in/bhoonidhi/help/tools.html>



To enable systematic processing of MRS datasets, a bulk processing software (MIDAS RISAT1A MRS Process Chain) has been developed which is based on routines from MIDAS (Microwave Data Analysis Software) of ISRO.

Download MIDAS at: <https://vedas.sac.gov.in/en/download.html>



Thank you