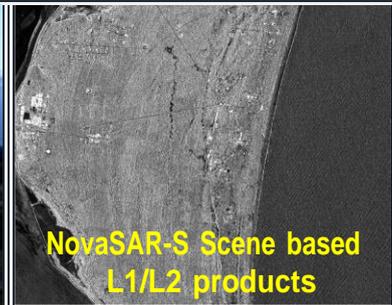
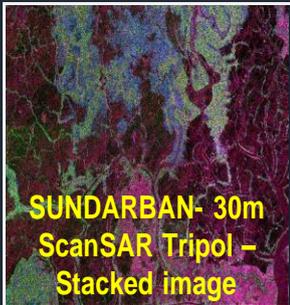
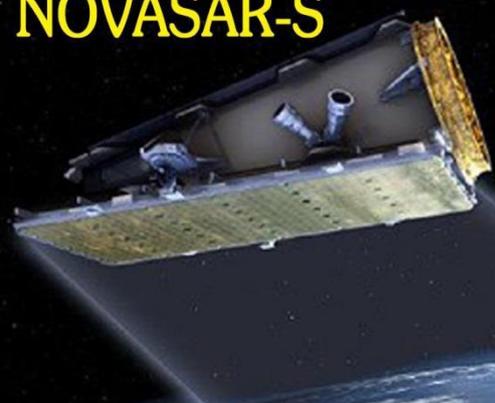




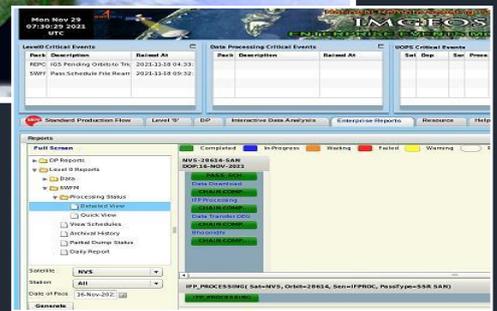
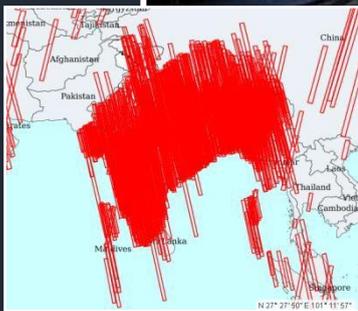
NOVASAR-S Note



NOVASAR-S

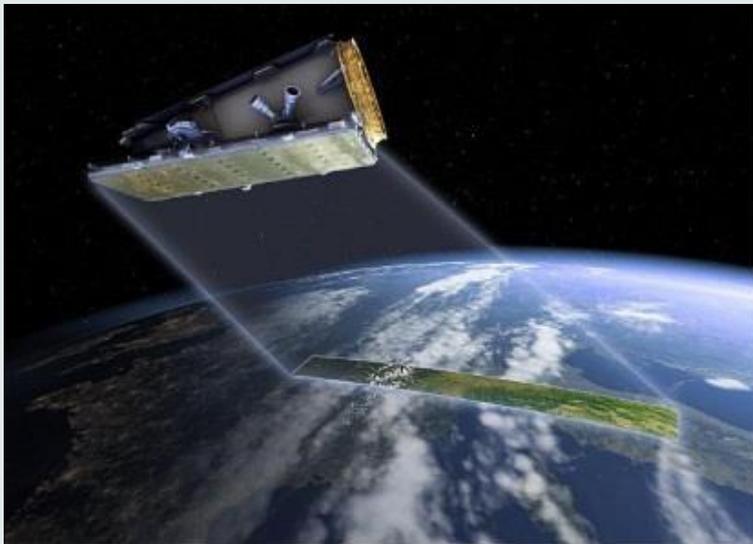


The small Satellite approach to Synthetic Aperture Radar



About NovaSAR-S

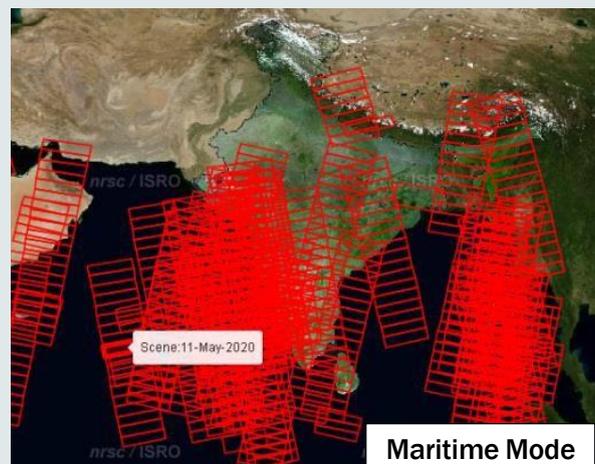
NovaSAR-S is a joint technology demonstration initiative of SSTL (Surrey Satellite Technology Ltd.), UK, and Airbus DS (former EADS Astrium Ltd, Stevenage, UK), funded by the UK Government via the UKSA (UK Space Agency). The satellite was launched on-board PSLV-C42 on 16 September 2018 (16:38 UTC) from SDSC (Satish Dhawan Space Center), Sriharikota, ISRO under commercial arrangement with Antrix Corporation Limited, Department of Space. The overall objective is to make SAR (Synthetic Aperture Radar) observation missions more affordable and to open up new application-oriented in the microwave region of the spectrum. It has S Band SAR which operates in imaging frequency band of 3.1-3.3 GHz and Automatic Identification System (AIS) for tracking ships on-board as primary and secondary payloads respectively.



NovaSAR-S is an all-weather day/night S band SAR imager providing medium resolution SAR data ranging from 6m-45m resolutions. It operates from an altitude of 580 km in Sun-synchronous orbit with a local time of 10.30 AM. The baseline SAR imaging modes are Stripmap, ScanSAR, ScanSAR wide and Maritime. It collects images with Single, Dual and Tri Polarization capability which is ideal for applications like flood monitoring, agricultural crop assessment, forest

monitoring, land use mapping and maritime applications.

NovaSAR is capable of supporting four polarisation options; HH, HV, VH, VV. It receives one polarisation (H or V) at a time and switches between them for multi-polar modes. A single receive chain is implemented which can receive either H or V in any given echo window, enabling acquisition of incoherent polarimetric imaging only (i.e. not exactly simultaneously) for dual and tri polarisation, thus not suitable for exploiting polarimetric applications.



NovaSAR-S data is received by National Remote Sensing centre (NRSC) Antenna systems, processed using SSTL supplied Processing systems which are integrated into NRSC-IMGEOS framework for seamless workflow automation, Data Archival, Web based Dissemination and Value addition.

NovaSAR-S Imaging Modes:

The payload is highly flexible and is capable of delivering a wider range of imaging modes than those of baseline modes by performing In-orbit tuning of beam shape and PRF (Pulse Repetition Frequency) for achieving maximum coverage (Refer Table 1)

Table 1: NovaSAR Imaging modes and Specifications

| Imaging Mode Type | Ground Range Resolution | Incidence Angles (Deg) (At 580 km Altitude) | Swath Width (Across track) (Km) | Worst Case Sensitivity (NESZ) (dB) | Polarization |
|-------------------|-------------------------------|---|---------------------------------|------------------------------------|--------------|
| ScanSAR | 20m | 18.1 | 100 | <-20 | (HH or VV) |
| ScanSAR | 20m | 24.33 | 50 | <-21 | HH or VV |
| Maritime | 6m - range 13.7m - azimuth | 40.85 | 400 | <-9.5 | (HH) |
| Strip Map | 6m | 15.54 – 22.3 | 20 | <-20 | (HH or VV) |
| Strip Map | 6m | (22.94 – 24.03) / (24.74 - 27.04) | 13 /15 | <-19 | (HH or VV) |
| ScanSAR Wide | 30m | 16.98 / 25 | 149 / 56 | <-21 | (HH or VV) |
| ScanSAR Wide | 30m | 26.99 | 55 | <-19.5 | (HH or VV) |
| Dual Polar | 20m | 18.46-25.28 / 15.51 | 50/60 | <-20 | (HH&VV) |
| Tri-Polar | 30m | 16.25/(20.61–24.47) | 56/50 | <-27 | (HH&VV&HV) |
| Tri-Polar | 35m | 17.58,22.34 | 100 | <-26dB | (HH&VV&HV) |
| Co + Cross Polar | 40m | 20.09 | 195 | <-21dB | (HH & HV) |
| Co + Cross Polar | 45m | 20.09 | 195 | <-26dB | (HH & HV) |
| ScanSAR Survey | 33m / 20m | 19.6 /13.11 | 195/27 | <-19.5dB | HH / HH,HV |

Imaging Capacity Share:

ISRO/NRSC has 40% imaging capacity share which amounts to about 648-720 seconds of Data per day. Indian Users can request NovaSAR-S imagery over India. SSTL, UK manages the overall imaging capacity with other mission partners.

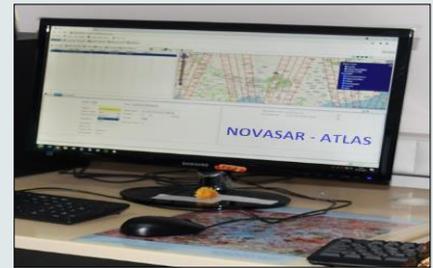
NRSC co-ordinates acquisition requests to

- Support national emergency data needs (e.g. disasters like floods...)
- Support R&D projects for the ISRO DOS community, Govt. Departments, Research community.
- Systematic coverage over India using the spare imaging duration.

Future NovaSAR-S image tasking:



Novasar-S satellite operations are tasked by NRSC to fulfil the requirement of 40% utilisation of satellite resources on every day basis. It gets connected to Atlas Server at NRSC and then to SSTL Master Scheduler at UK where other mission partners also gets connected. Maximum of one month planning can be done ahead with track status displayed based on the requirement.



Proposals can be submitted to novasar@nrsc.gov.in , which will be reviewed by the team to check the feasibility of service.

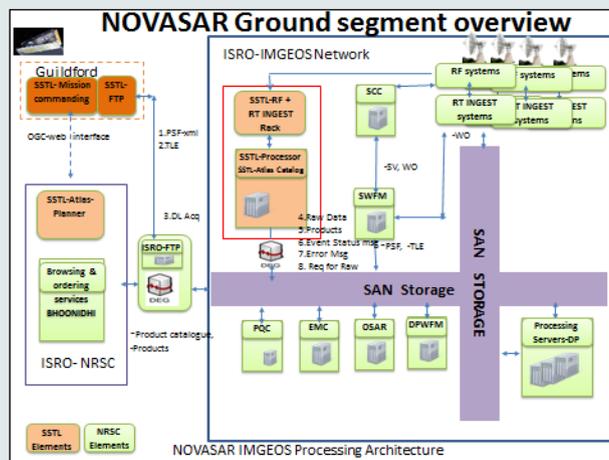
Note: In case of urgency, such as for emergency response, the same to be mentioned in the proposal. More details in:

https://bhoonidhi.nrsc.gov.in/imgarchive/bhoonidhi_videos_help/NovasarPlanningUserDocumentation.pdf

Data Reception & Processing Resources:

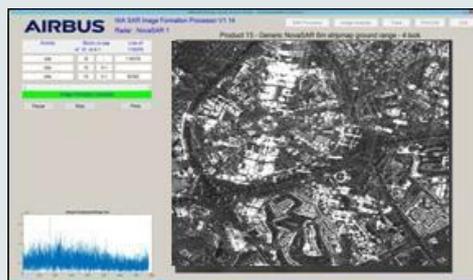
The ground station at IMGEOS receives data at X-Band in ARQ using the Saratoga protocol, which utilizes the S-Band

uplink to send packet re-transmit messages, and image downlink requests with a minimum elevation of 5° and as well as broadcast mode with a minimum elevation of 10° . The IF signal is fed to SSTL - VHR 1200 demodulator for data ingest/processing. Ground segment Workflow automation is built for seamless processing and dissemination.



SAR Data products & Archival:

For ease of handling, SSTL Level-1 strip wise Data is further processed to generate scene-framed products with 10% of overlap between the consecutive scenes in azimuth extent.



The Level-2 products are Bundled Geo-referenced product containing scene-based geo-referenced SAR imagery along with Analysis ready data products -Geo-referenced Sigma- Naught Backscatter and Surface Water Layer products.

For more information on products view:

https://bhoonidhi.nrsc.gov.in/imgarchive/bhoonidhi_videos_help/NOVASAR_PRODUCT_FORMAT_DOCUMENT_V2.pdf

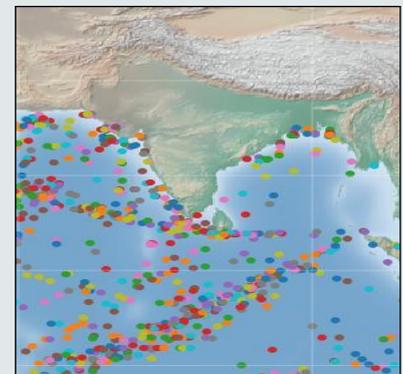
Novasar-S data collected over Indian cone in different imaging modes is available in NRSC archives from October 2019 onwards. Please visit <https://bhoonidhi.nrsc.gov.in/> for browsing and ordering the archived products . Data has been utilised for supporting disaster events as well as in R&D projects.

| Levels of Processing | DATA Products | Description |
|----------------------|---|--|
| Level-1 SLC | Scene-Based Geo-Tagged Product (For Stripmap Mode only) | Slant Range Product Format: GeoTIFF |
| Level-1 GRD | Scene-Based Geo-Tagged Product (For Stripmap Mode) | Ground Range Product Format: GeoTIFF |
| Level-1 SCD | Scene-Based Geo-Tagged Product (For ScanSAR Mode) | Ground Range Product Format: GeoTIFF |
| Level-1 Maritime | Strip-Based GeoTagged Product | Ground Range Product Format: GeoTIFF |
| Level-2 GeoRef | Scene-Based Geo-Referenced Product (For Stripmap and ScanSAR modes) | Map Projected Product with Sigma Naught Backscatter and Surface Water layer products Format: GeoTIFF |

AIS Products:

Automatic Identification System (AIS) Payload on-board NovaSAR-S is designed for the automated location and tracking of vessels. AIS transceivers are fitted on international voyaging ships with a gross tonnage greater than 300 tons and all passenger ships.

It provides information of vessel's unique Ship identification, Lat/Lon, speed, direction, heading etc. as output product in xml format. AIS data products are available on Bhoonidhi(bhoonidhi@nrsc.gov.in) for free.



Ship locations derived from

Data Access:

Users must be registered with Bhoonidhi (bhoonidhi@nrsc.gov.in) to access imagery. By registering with the Data hub, users agree to NRSC/ISRO-Bhoonidhi Terms and Conditions and the NovaSAR-S End User Licence Agreement.

To comply with Export and Sanctions regulations, presently data is available to Indian Users. The pricing is as per ISRO Remote Sensing Data policy.

https://bhoonidhi.nrsc.gov.in/imgarchive/bhoonidhi_videos_help/Novasar_EULA.pdf Contact: bhoonidhi@nrsc.gov.in

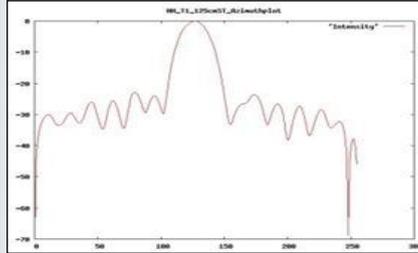


Imaging Service and Quality:

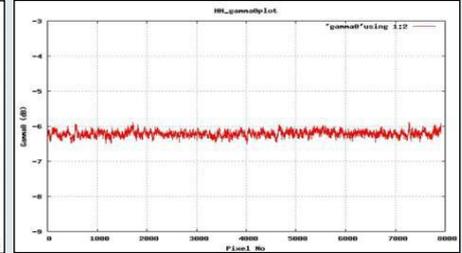
NovaSAR-S SAR images acquisition feasibility and quality depends on the health and operational performance of NovaSAR-S On-board systems and SAR Processor supplied by SSTL-UK. Point target and distributed target analysis has been carried out periodically at NRSC for monitoring the data product quality. The Geometric and Radiometric quality is limited as per processing specifications of SSTL-UK.



**125 cm Square Trihedral CR
deployed at IMGEOs Calsite,
NRSC (RCS in S-band 40.2dBsm)**



**Impulse Response Function (IRF)
of 125cm Corner Reflector (CR)**



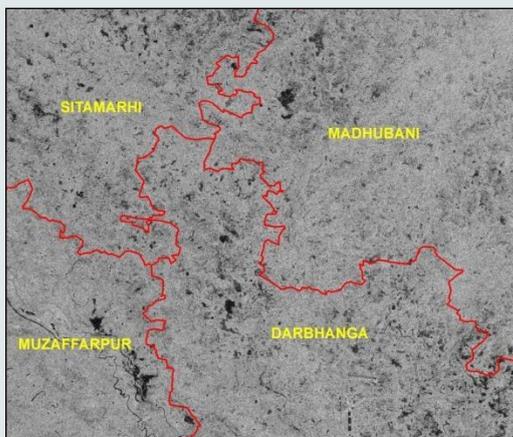
**Gamma '0' pattern derived from
Amazon Rain Forest**

Potential Applications:

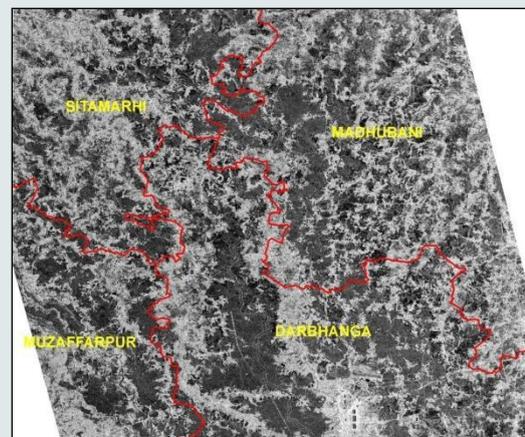
- Disaster Monitoring: Floods, Cyclones
- Agriculture: Crop Area Mapping, Crop Growth Monitoring
- Land Use and Land Cover: Changes in Land Use
- Geology: Landslides, Glaciers
- Forestry: Forest cover, Deforestation, Above Ground Biomass estimation
- Land Form: Gullies and Ravines Mapping
- Ocean Studies: Ship detection, Oil spill monitoring, Maritime surveillance

Monsoon Flood Monitoring:

The penetration capability of microwave SAR is a function of the wavelength and the S band wavelength of NovaSAR-S allows it to penetrate through the vegetative cover and assess floods that lie beneath the canopy.



**Pre Flood (03 June 2021) Sentinel SAR
Image over Bihar, India**

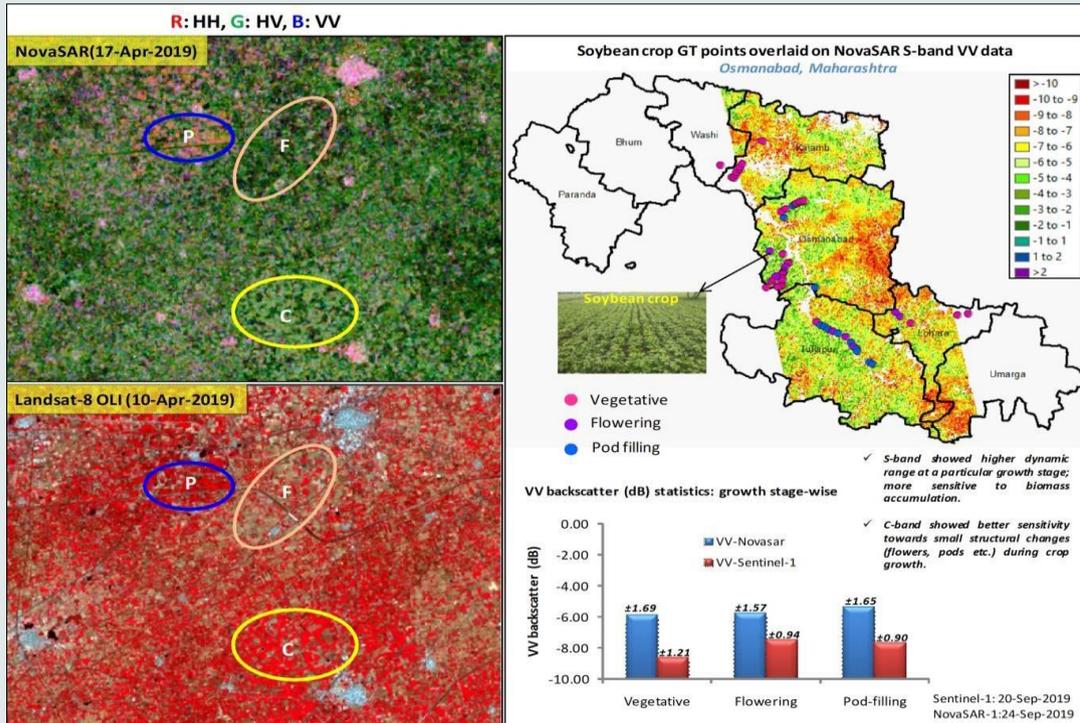


**During Flood (10 July 2021) NOVASAR-S
Image over Bihar, India**

The Pre Vs During flood satellite imagery clearly indicate the floods in the area. The low back scatter due the flood waters help in identification of the flood pockets and prepare the flood maps.

Agriculture:

NovaSAR-S band SAR data is useful for discriminating Crops., delineating field boundaries and parcel-level crop classification, Early-season drought assessment etc.

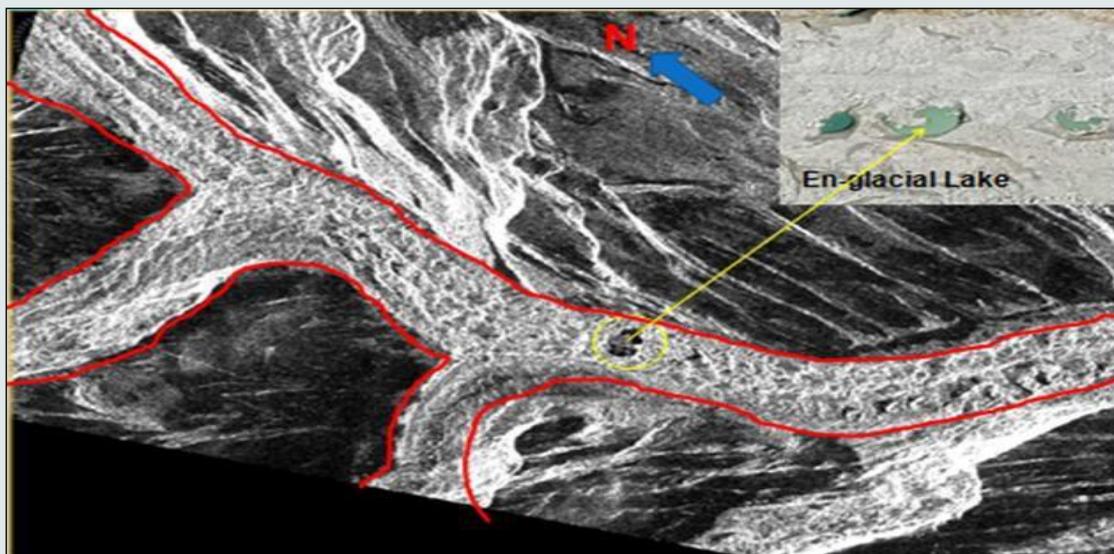


ScanSAR 30mTri-pol data over part of Surat, Gujarat, India discriminating broad land cover categories (P: Plantation, F: Fallow, C: Crop)

Colour coded VV-backscatter of NovaSAR-S band data (24 Sep, 2019) showing the spatial variability in Soybean crop lands

Glacier Studies:

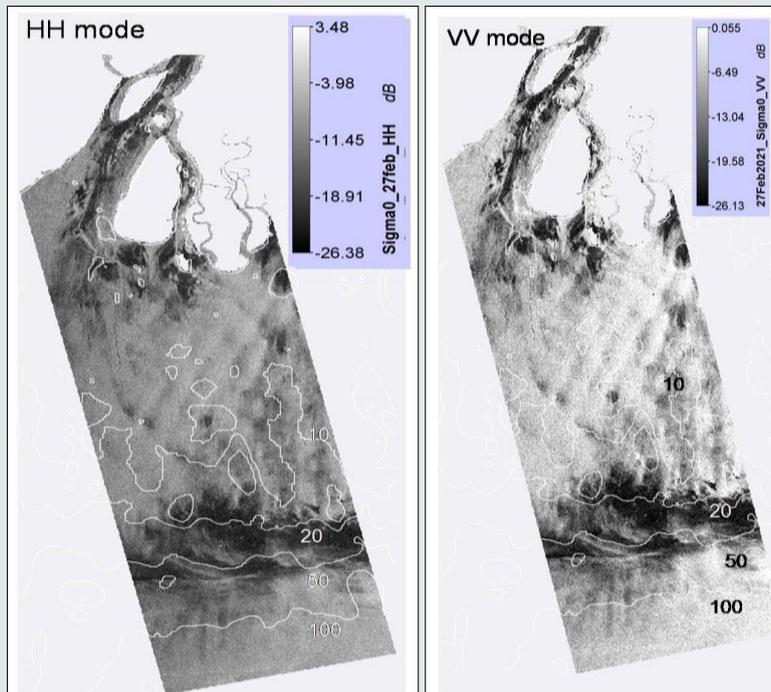
NovaSAR-S stripmap data can be useful to delineate glacier boundaries and various glacio-morphic features (glacier lake, moraine, accumulation and ablation zone etc) based on its terrain sensitivity and frequency (3.2 GHz) to distinguish between water/debris content in the glacier.



NovaSAR-S data showing various features of a glacier

Ocean Feature Mapping:

NovaSAR-S ScanSAR mode data of VV and HH polarization shows distinct coastal geometry of Hooghly estuary and tributaries over continental shelf region. Along-channel circulation patterns in the Hooghly, modulation of bathymetry in the shelf are visible in the images. Dark regions in the southern part, shows frontal regions with isobaths (parallel to the bathymetry) circulation. This is inferred from ancillary data analysis: thermal front density, residual circulation.



NovaSAR-S ScanSAR mode data of 27 Feb 2021 for Hooghly and northern BOB along with bathymetry contours (white color lines in numbers)

| NovaSAR-S Ground Segment Team: | |
|---|---|
| Data Reception Realization | C. S. Padmavathy(Team Lead), K. Usha Devi, G. Nanda Kumar, Ranjeeth kumar, Mukesh Kumar Singh |
| Mission Planning | A. V. Ramani (Team Lead) , Y. Padmaja, N. Aparna |
| Automation of Workflows ,Data Archival and Web Dissemination | Raghvendra Joshi (Team Lead), Raji Jose, Richa Goyal, Shivam Mittal, Parameshwar Reddy |
| Value addition in Data Products | Usha Sundari Ryali (Team Lead), S. Haripriya, Samavaram Sahu, Sauvic Dutta, EVS. Sita kumari |
| Data product Quality evaluation | B. Santhisree (Team Lead), S. Srisudha |
| SAR Calibration | B. Santhisree, K. Niharika, P. V. Jayasri, Usha Sundari Ryali, S. Srisudha, Y. Ramu, P.Krishnamoorthy |
| Processing Systems and Storage | B. Bikshamaiah, A.S. Aravind, G. Prasad |
| Internet connectivity and systems | Kishore SVSR, K. Mounica , C.C. Reddy |
| Products Analysis | P. Srikanth, Anurag Mishra, S. Rajesh |
| NRSC Overall Co-ordination and Realization | M. Manju Sarma |
| SSTL UK team | Geoff Tong, Andy Newton, Nick Holt, Zoe |