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TAKING THE PULSE OF OUR PLANET FROM SPACE

CEOS-Analysis Ready Data for Land (CARD4L) for SAR Prospects and Roadmap to Realization

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Presentation Overview

- Introduction to CEOS-ARD
- SAR CARD4L Specifications and Compliance
- CARD-PFS FOR SAR DATA
- NRSC/ISRO-An Overview
- In-House ARD Generation for Current SAR missions-NRB and PolSAR
- Proposals for Upcoming SAR missions
- Futuristic Deep Learning ARD Creation for SAR
- Open SAR datasets- For DL Implementation

CEOS-ARD

- CEOS Analysis Ready Data for Land (CARD4L) has been proposed to support the objective of simplified EO data handling for the user.
- CARD4L for Optical/SAR/LIDAR data are processed to a minimum set of user based requirements .
- Data providers to take the responsibility of fundamental data correction and processing tasks, so the users can take up spatial-temporal analysis and research of remote sensing data in a time-bound sense.
- Data Organized into a form that allows immediate analysis with minimum effort and time , thus facilitating inter-operability both through time and with other datasets.
- This involves data suppliers removing many of the fundamental data correction and processing tasks in order to increase the user-base .

CARD-PFS FOR SAR DATA

- The general guidance document for data providers specifies the minimum set of requirements corresponding to geometric and radiometric data corrections, ancillary meta data information and the per pixel meta data corresponding to the image.
- CARD4L Product Family Specifications (PFS) for SAR comprises four primary concepts pertaining to SAR, the Normalized Radar Backscatter (NRB), Polarimetric SAR, Geo-coded SLC and SAR Interferometry.
- The SAR product is declared to be CARD4L compliant once all the above thresholding requirements are incorporated.
- CARD for Ocean and atmospheric studies is also devised.

CARD-PFS FOR SAR DATA

CARD4L Specifications Completed and endorsed for :

✓Normalised Radar BackScatter(NRB)

✓Polarimetric Radar (POL)

Under Development:

❑ Geocoded SLC

❑Interferometric SAR

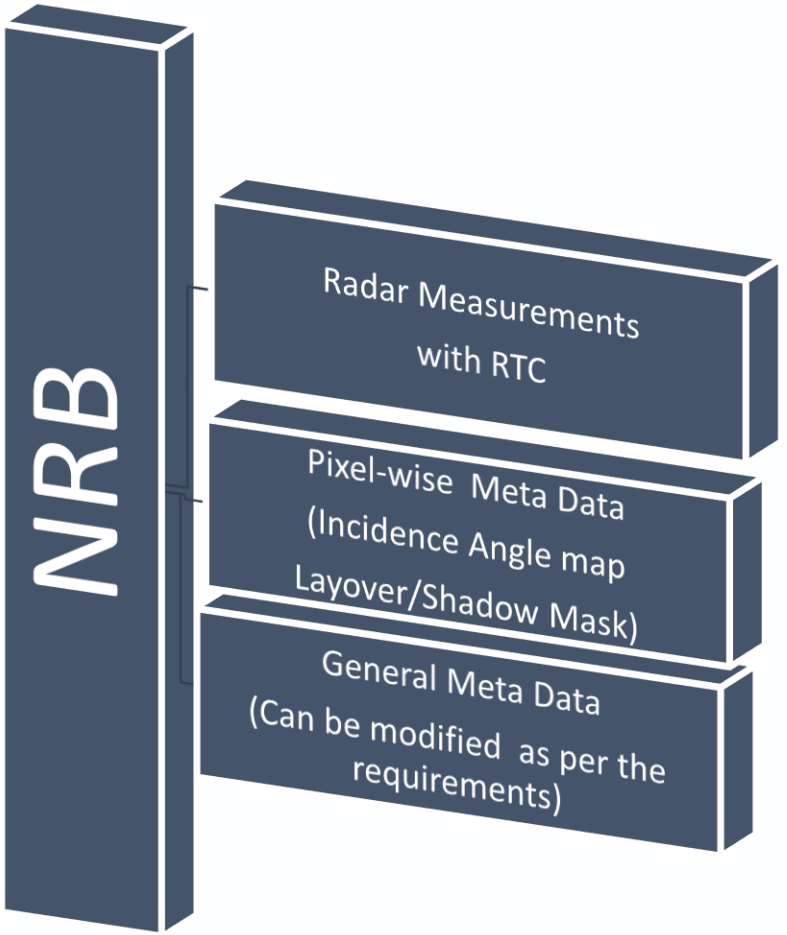
❑Ocean Radar Backscatter

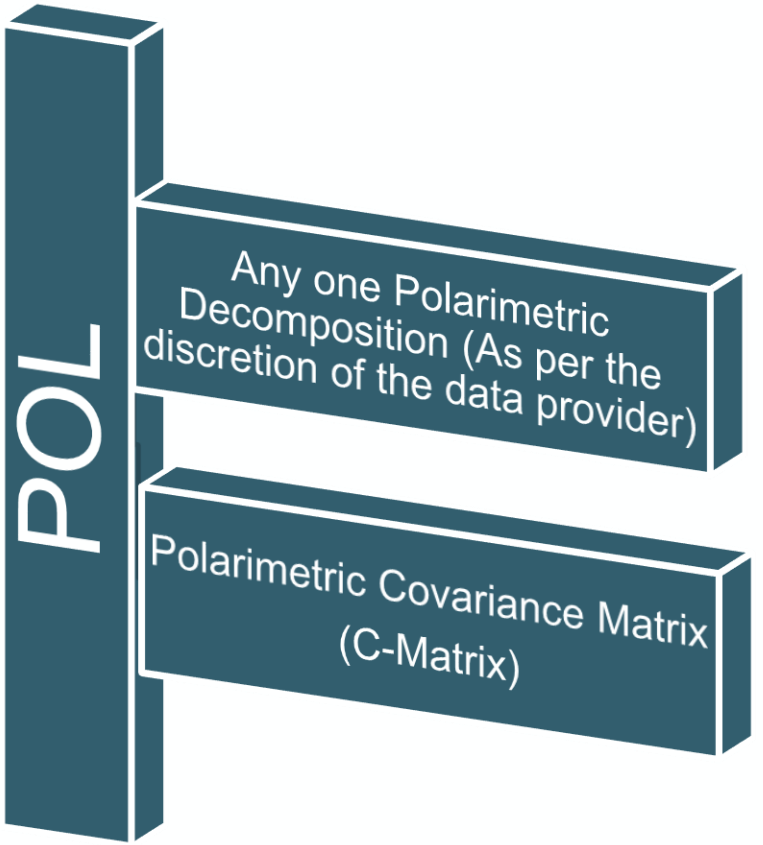
❖ **The Product Family Specifications (PFS) are the devised guidelines to the EO Data providers for catering to the minimum threshold requirements and the desired target requirements.**

CARD4L specs (Product Family Specifications – PFS)

- "Guidance document" for data providers:
  - Geometric corrections
  - Radiometric corrections
  - General meta (ancillary) data
  - Per-pixel (image) meta data
- Two levels of requirements
  - Threshold (minimum) requirement
  - Target (desired) requirement

CARD4L –PFS FOR SAR





NRSC-IMGEOS –An Overview

- National Remote Sensing Centre-NRSC is an arm of Indian Space Research Organization –ISRO and is equipped with an Integrated Multi-Mission Ground Segment for Earth Observation Satellites -IMGEOS
- IMGEOS is set for acquisition, processing and dissemination of data on a 24x7 basis from Indian and Global remote sensing satellite missions.
- The acquired SAR data corresponding to every data dump is pre-processed for extracting the Level-0 raw files which are then processed for generating the higher levels of data.
- The processed data is archived and based on the online user requests, they are either re-processed or fetched from the archives for dissemination.

IMGEOS -NRSC

RISAT-1 - Radar Backscatter and Polarimetric Products realization

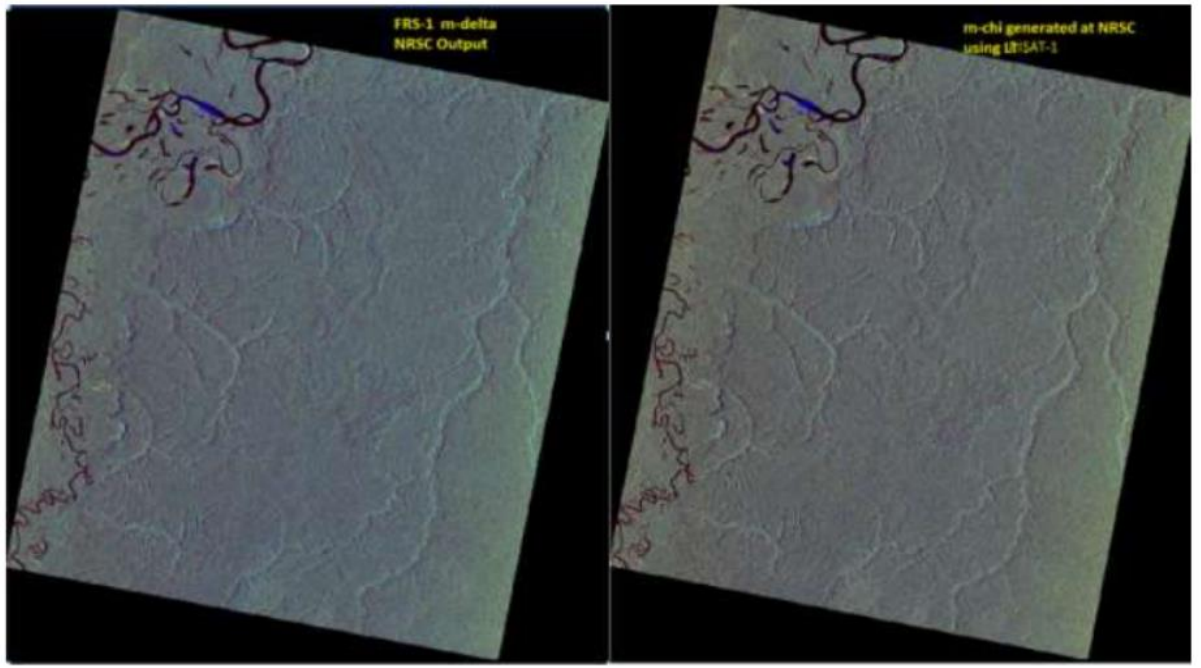
- RISAT-1 is C –Band SAR (5.35 GHz) developed and launched by ISRO in 2012.
- The primary imaging modes are Fine Resolution Stripmap (FRS1) at 3m,Medium/Coarse Resolution ScanSAR MRS/CRS with 24 m to 48m ground resolution and High Resolution Spotlight with 1m resolution.
- The TX/RX polarizations are Single (HH/VV), Dual (HH+HV/VV+VH) for all modes.
- The standard Data provided is Level-2 Enhanced ,which is Terrain Geo-Referenced with per-pixel local incidence angle map (LIA) and the Mask Layers
- Using, In-house development, the Sigma Nought Backscatter image data is generated using the LIA and the calibration values along with the image intensity values .

RISAT-1 - Radar Backscatter and Polarimetric Products realization

- RISAT-1 Imaging also features a unique Hybrid Polarimetric mode , which has enhanced our remote sensing capability and has opened a new dimension to the scientists over a wide range of applications.. The circular FRS-1 mode is realized in the Circular Transmit Linear Receive -CTLR- polarization configuration wherein, the transmission is Right Circular with linear receive giving rise to RH and RV channels.
- The CFRS-1 Single Look Complex data is in CEOS format comprising of the real and imaginary components of the processed signal.
- In –house software has been developed for polarimetric processing and derivation of the Stokes vector . Hybrid polarimetric parameters like Degree of Polarization-m, relative phase(delta) , axial ratio(AR),circular polarization ratio(CPR) from the data channels .
- These parameters are in turn used to generate the channels corresponding to Surface, Double and Volume Bounce scattering of the target area.
- Based on the scattering mechanism, hybrid polarimetric decomposition techniques m-delta and m-chi are implemented and provided for Application based studies.

Polarimetric Products –RISAT1 (CP) and Radarsat2(FP)

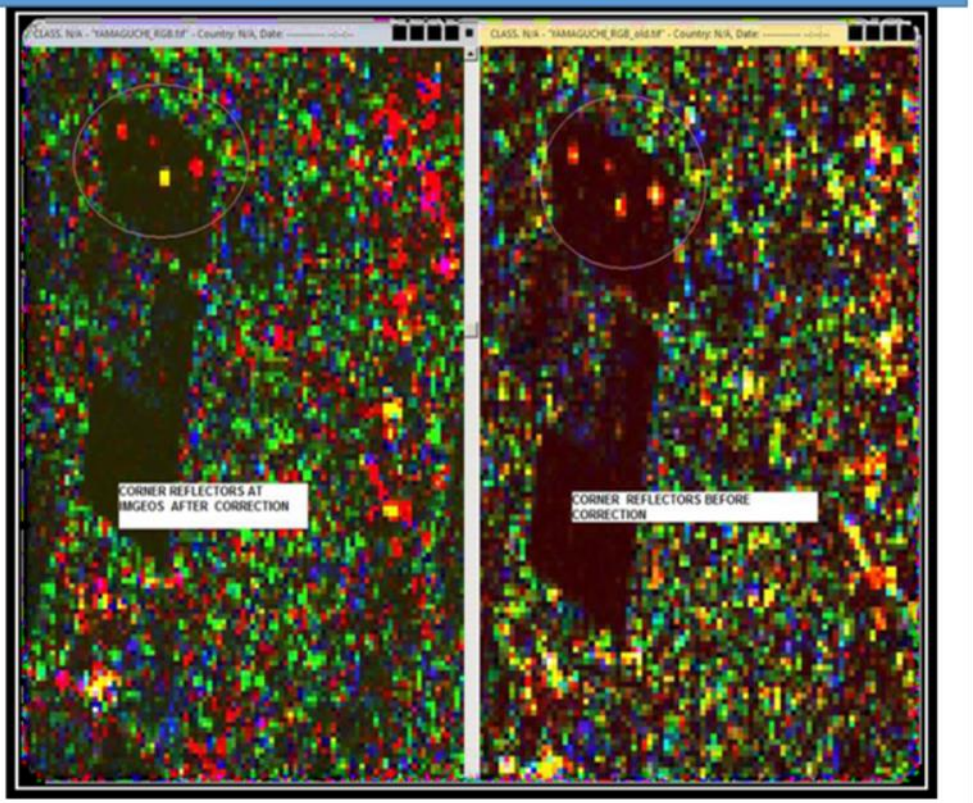
Hybrid Polarimetric Decomposition.
Sensor:RISAT-1 Orbit # 8604/8603 DOP:17/11/2013
Mode:cFRS-1



m-delta decomposition

m-chi decomposition

Yamaguchi Decomposition (After Correction) –Radarsat-2
Fine Quad Area- Shadnagar Cal-Val

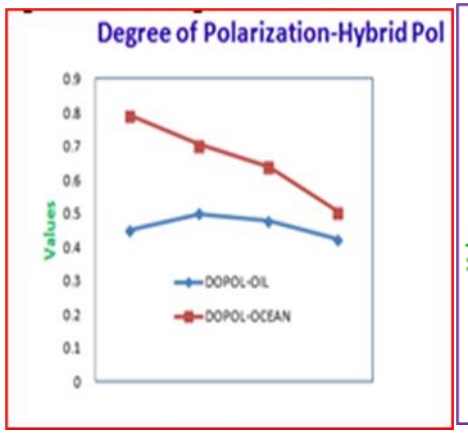


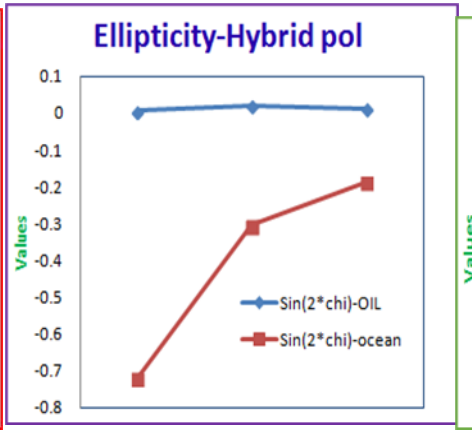
Hybrid Polarimetric Parameters derived from RISAT-1 cFRS-1 for oil-slick and look-alike signatures

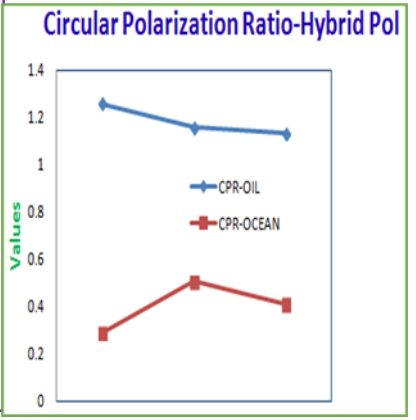
RISAT-1 cFRS1 hybrid Pol data with oilslick Date of Imaging: 17-June 2014 Orbit #: 11810/11805 Mode: cFRS-1

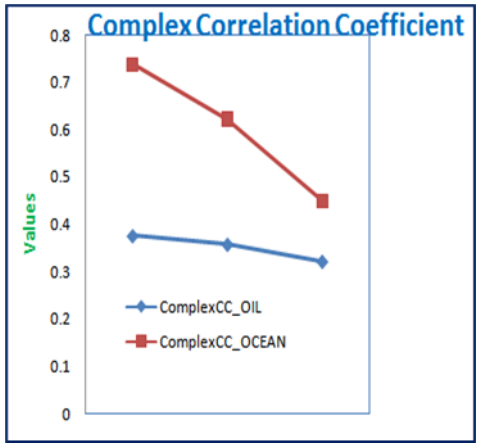
Incidence Angle: 49.4 deg

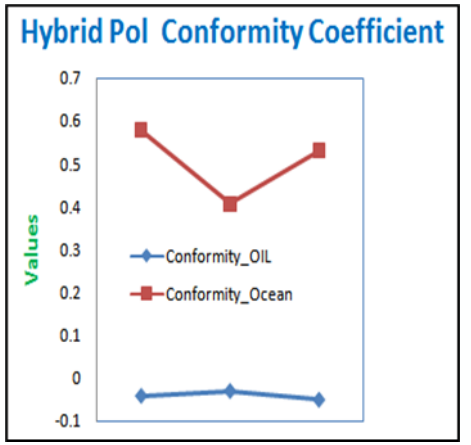
Hybrid Polarimetric Parameter	Oil-Slick covered sea	Slick-free sea surface/Look-alike
Degree of Polarization-m	0.454	0.792
	0.499	0.640
	0.477	0.705
Circular Pol Ratio(CPR)	1.258	0.290
	1.134	0.586
	1.16	0.413
Ellipticity-2χ	0.006	-0.719
	0.012	-0.305
	0.019	-0.188
Complex Correlation Coefficient	0.376	0.737
	0.358	0.622
	0.322	0.449
Conformity Co-efficient	-0.041	0.577
	-0.03	0.531
	-0.05	0.408











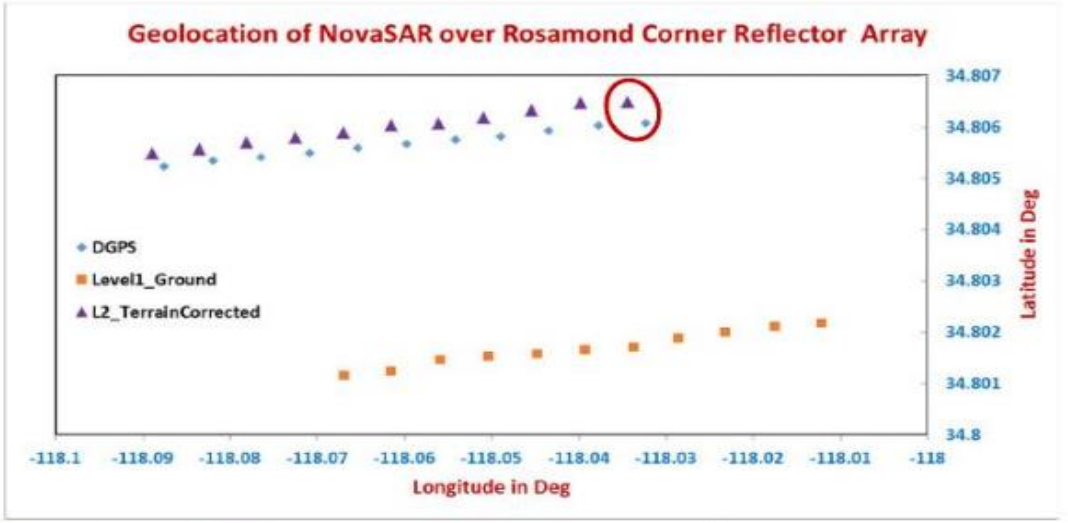
NovaSAR – Data Analysis for CARD realization

- NovaSAR (S Band-3.1-3,5GHz) is a joint technology demonstration initiative of SSTL (Surrey Satellite Technology Ltd.), UKSA, and Airbus DS. It was launched by ISRO in 2018.
- The primary imaging modes are Stripmap at 6m and ScanSAR with 25 m to 45 m ground resolution. The TX/RX polarizations are Single (HH/VV), Dual (HH+HV/VV+VH) and Tripol (HH,VV,HV) .
- The Level-1 NovaSAR products generated by the SSTL IFP (Image Formation Processor) comprise Single Look Complex (SLC) and Ground Range data for Stripmap mode and Mutilook Detected data for ScanSAR mode in various polarization combinations. The Level-1 Products are geocoded and ellipsoid corrected.

Terrain Correction for realising NovaSAR-GTC Mode:6m-Stripmap
Date of imaging: 4/8/2021;
Scene No.:15
Area: Near Uttar Pradesh, India

NovaSAR Data Analysis for CARD realization

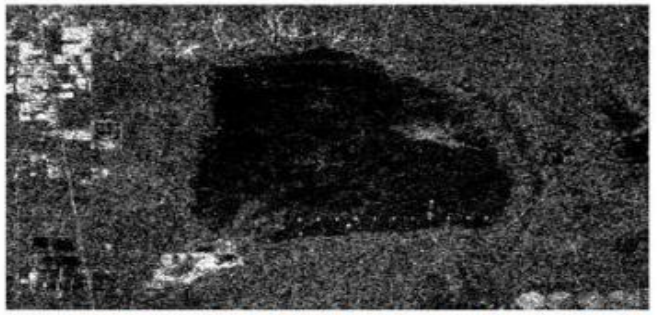
Analysis over NovaSAR data acquired over Rosamond Dry lake (USA)



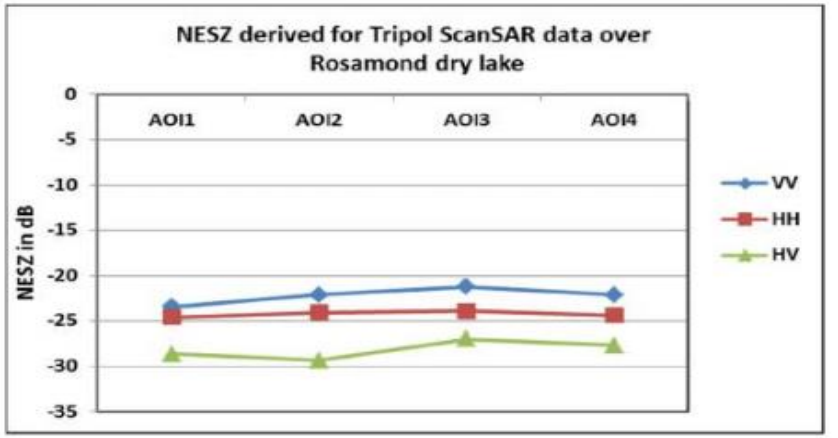
Before Terrain Correction:
Latitude error = -562 m
Longitude Error = 1.814 Km
CE90 = 1.899 Km

After Terrain Correction:
Latitude error = 50.25 m
Longitude Error = 197.94 m
CE90 = 204.21 m

Date of Pass: 26/5/2021
35m_3Pol_ScanSAR_100km_VVHHHV

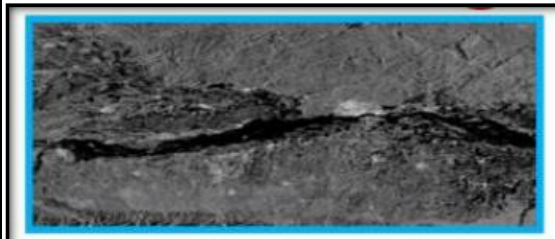


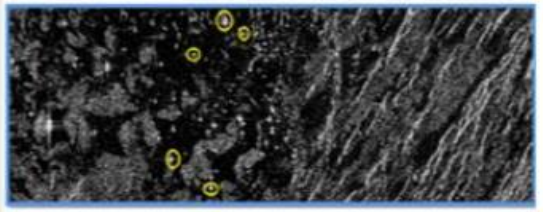
SSTL specified NES0 for Tripol data = -26dB

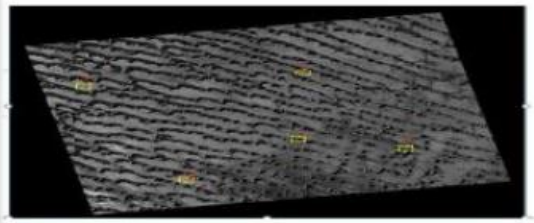


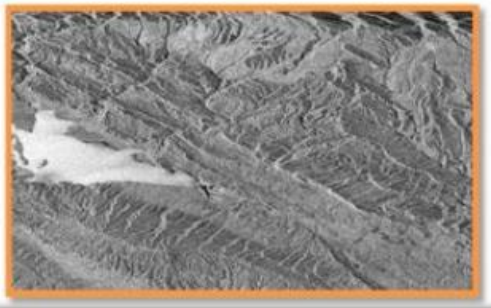
- Geometric Accuracy validation is carried out at regular intervals using corner reflectors (Point Targets) deployed in IMGEOS Cal-Val site .
- The implementation methodology for Geometric and Radiometric Corrections is being modified for improving the accuracies.

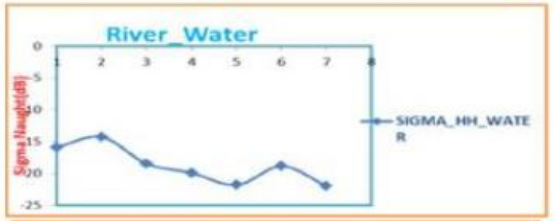
NovaSAR- Sigma Naught Backscatter Analysis

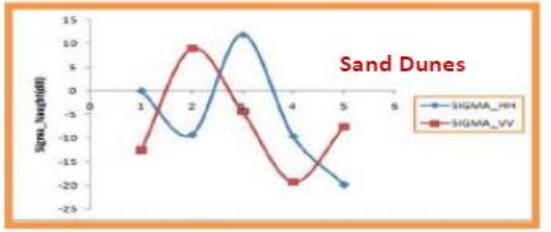


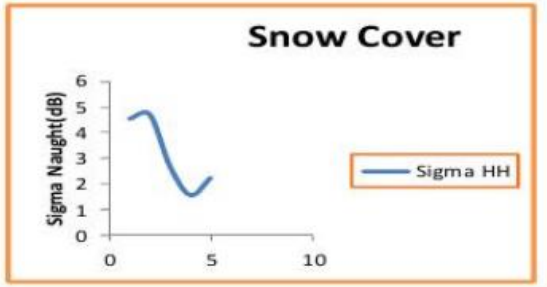












Date of Imaging :22/07/2020
Mode: ScanSAR detected
Pol :HH
Incidence Angle:21 deg
Region-Brahmaputra River

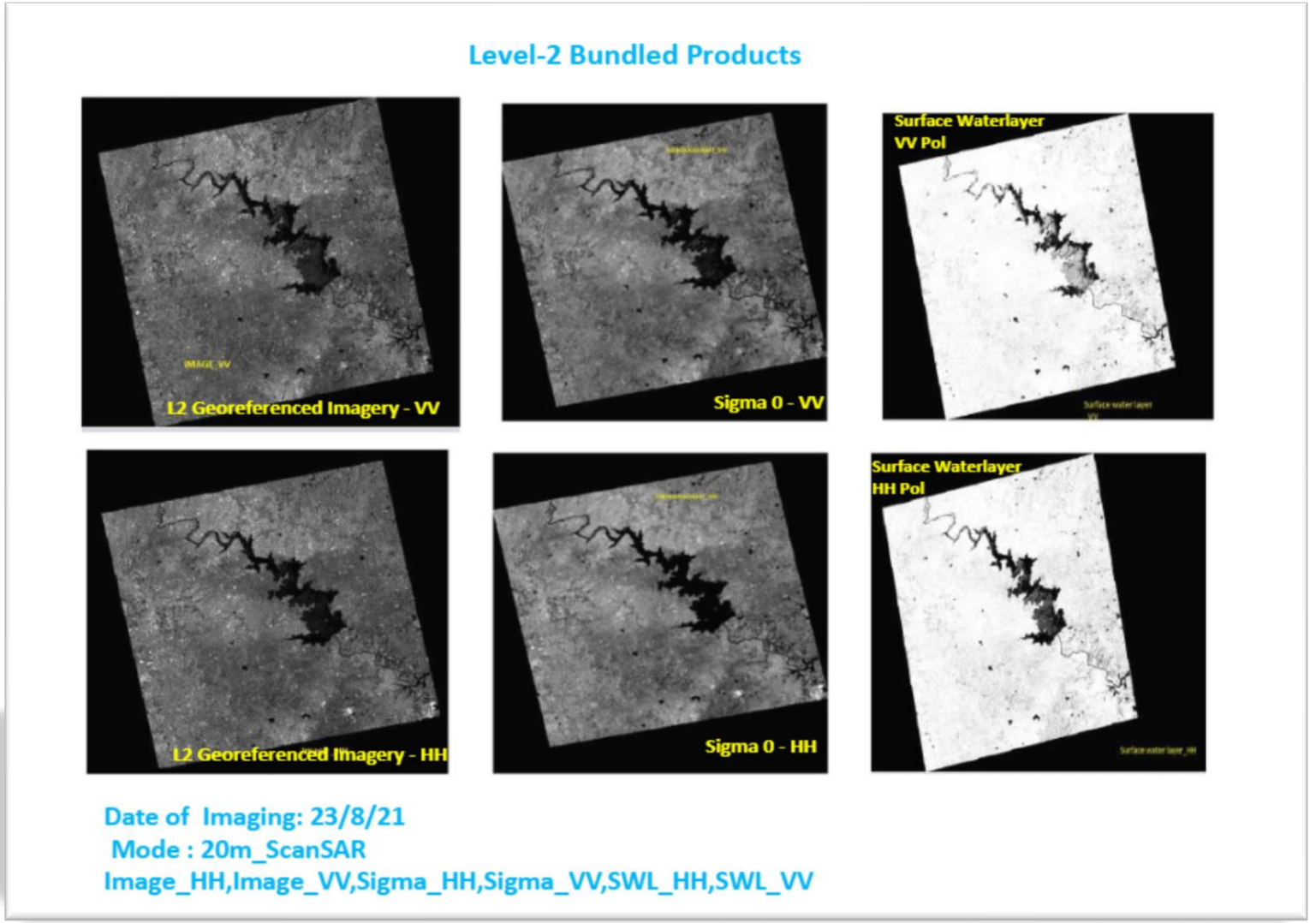
Date of Imaging :05/08/2020
Mode: ScanSAR detected
Pol :HH,VV,HV
Area –Near Gulf of Omen

Date of Imaging: 19/07/2021
Mode: 20m_2Pol_ScanSAR
Pol: HH-VV

Date of Imaging-27/07/2020
Mode :ScanSAR-33m
Pol:HH
Incidence Angle:12 deg
Area-Kashmir region

Theme	Backscatter values observed in mentioned data sets
River Body	-15dB to -24 dB for HH Pol
urban targets	3.5dB to 14 dB for HH pol 2.1 dB to 15.3 dB for VV pol
Snow Cover Region	+1 dB to +5 dB for HH Pol
vegetation cover	-5 dB to -12 dB for HH Pol -2dB to -8 dB for VV Pol
Sand dunes	-18db to +12dB for VV pol -20dB to +14dB for HH pol

NovaSAR- Sigma Naught Backscatter



- Software is developed for generation of Scene-based Data products based on the Imaging mode and archived as Level-1 Data .
- Based on the User Requests, Level-2 Bundled Products are generated in an automated fashion in the IMGEOS data production chain.
- Level-2 Bundle Product contains SAR Imagery Files , Backscatter Files for the respective polarizations along with Surface Water Layer Products.

CEOS –ARD Compliance and Challenges

CEOS- ARD compliance :

- The Realization of CEOS ARD products are to be implemented in the Automated IMGEOS Chain .
- Additional Software Tools are also under development and validation for generating ARD as per User Requirements.
- New software Plug-Ins are proposed and devised for the existing In-house Tool for generating CARD using Polarimetric and Interferometric Processing for the future SAR Missions

Challenges: With the provided Satellite Ephemeris and External DEM sources, Geometric and Radiometric Terrain Correction methodologies are implemented for the Sensor Specific SAR data formats.

- The Process is revived and modified for obtaining better Geometric and Radiometric accuracies .
- The resulting Normalised Radar Backscatter –NRB layers can be provided in the automated chain.
- For PolSAR, the CARD4L PFS requirements have been developed and analysed.

Upcoming SAR Missions

EOS04 : The Data Processing is carried out at various levels :

- ❖ Level-2 Standard Geo-referenced Products
- ❖ Level-1 Single Look Complex and Ground Range Products
- ❖ Level1C comprising Covariance Matrix and Stokes component layers
- ❖ Level3A Comprising Polarimetric Decomposition Channels

NISAR :NASA-ISRO SAR is designed to provide Polarimetric, Interferometric Products which have to be Analysis Ready evaluated for the required quality metrics at various Levels of Processing.

Futuristic Deep Learning ARD Creation for SAR

In the recent times, several Deep Learning Models have been successfully implemented for SAR data. Analysis using Fully Convolutional Neural Networks.

Training of such neural networks also requires densely annotated training data which can serve as ARD for :

- Image classification
- Scene classification:
- Semantic segmentation
- Object detection
- Registration/matching

Challenges:

- The Complex Nature of SAR Data-This means that the entire CNN must be able to handle complex numbers. For the convolution operation this is trivial. The nonlinear activation function and the loss function, however, require thorough consideration.
- Depending on whether the activation function acts on the real and imaginary parts of the signal independently, or only on its magnitude, the target classification methods are deployed.
- Wide Dynamic Range of SAR data

Open SAR datasets- For DL Implementation [8]

TABLE I: Summary of available open SAR datasets

Name	Description	Suitable tasks
So2Sat LCZ42[1] [200], TensorFlow API[2]	400,673 pairs of corresponding Sentinel-1 dual-pol image patch, Sentinel-2 multispectral image patch, and manually labeled local climate zones classes over 42 urban agglomerations (plus 10 additional smaller areas) across the globe. It is the first EO dataset that provides a quantitative measure of the label uncertainty, achieved by having a group of domain experts cast 10 independent votes on 19 cities in the dataset.	image classification, data fusion, quantification of uncertainties
OpenSARUrban[3] [199]	33,358 Sentinel-1 dual-pol images patches covering 21 major cities in China, labeled with 10 classes of urban scenes.	image classification
SEN12MS[4] [202]	180,748 corresponding image triplets containing Sentinel-1 dual-pol SAR data, Sentinel-2 multi-spectral imagery, and MODIS-derived land cover maps, covering all inhabited continents during all meteorological seasons.	image classification, semantic segmentation, data fusion
MSAW[5] [204]	quad-pol X-band SAR imagery from Capella Space with 0.5 m spatial resolution, which covers 120 km^2 in the area of Rotterdam, the Netherlands. A total number of 48,000 unique building footprints are labeled with associated height information curated from the 3D Basis registratie Adressen en Gebouwen (3DBAG) dataset.	semantic segmentation
PolSF, Data[6], Label[7] [205]	The dataset includes PolSAR images of San Francisco from five different sensors. Each image was densely labeled to five or six classes, such as mountain, water, high-density urban, low-density urban, vegetation, developed, and bare soil.	image classification, semantic segmentation data fusion

- **Annotated ARD at different frequency bands can be realised for the specific study regions and for the corresponding Land-Use Land Cover / Applications scenario with appropriate product specifications.**

References

[1] https://ceos.org/ard/

[2] ISRO NovaSAR Ground Segment ICD- NV K V - #0324588

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[5] Synthetic Aperture Radar –Radiometric Calibration-David Small Erich Meler-Department of Geography-University of Zuich- www.geo.uzh.ch

[6]J.-C. Souyris, P. Imbo, R. Fjrtoft, S. Mingot, and J.-S. Lee, “Compact polarimetry based on symmetry properties of geophysical media:Then π/4 mode,” IEEE Trans. Geosci. Remote Sens., vol. 43, no. 3, pp. 634–646, Mar. 2005.

[7] M. Nord, T. Ainsworth, J.-S. Lee, and N. Stacy, “Comparison of compact polarimetric synthetic aperture radar modes,” IEEE Trans. Geosci. Remote Sens., vol. 47, no. 1, pp. 174–188

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THANK YOU