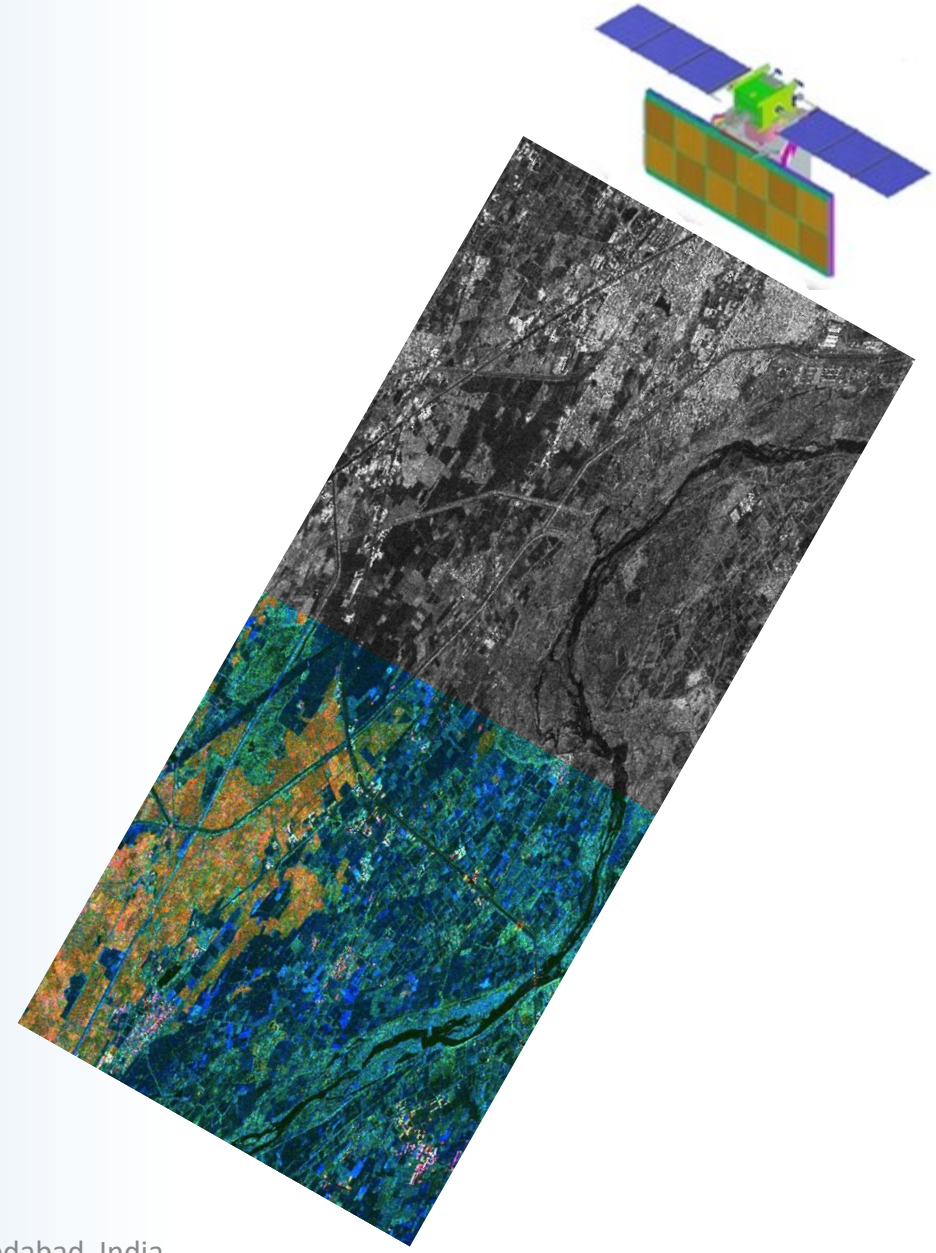
ISRO's Roadmap for Analysis Ready SAR Data Products



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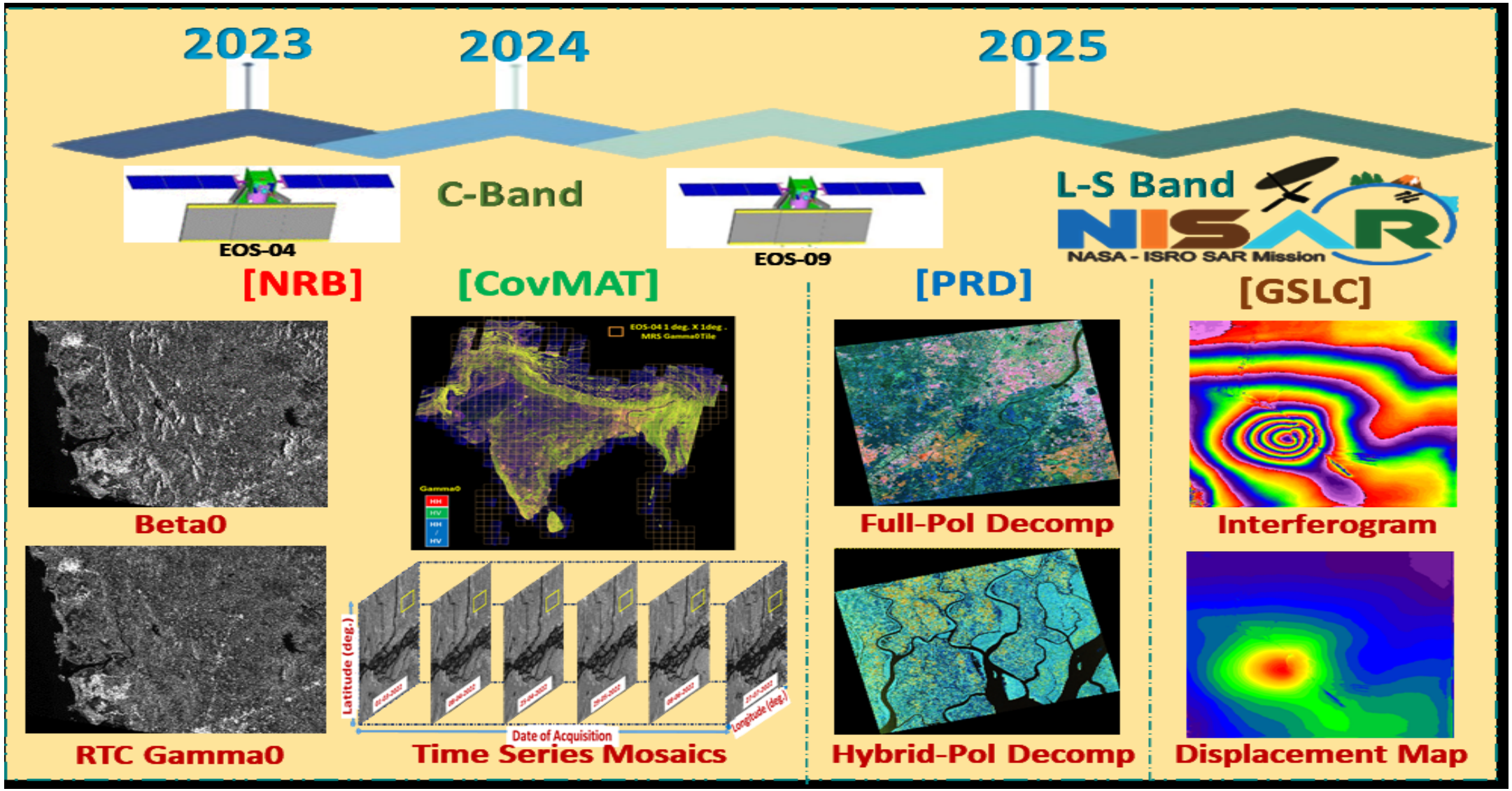
Space Applications Centre (SAC)
Indian Space Research Organization (ISRO)

Co-Authors: **Krishna Murari Agrawal, Jalpa B Modi**
V M Ramanujam

ISRO's SAR Analysis Ready Data (ARD) Product Summary



#EOS-04 Data Products Calibration Updates -12th Nov 2024

ISRO CEOS-Compliant ARD Product Generation – A Road Map

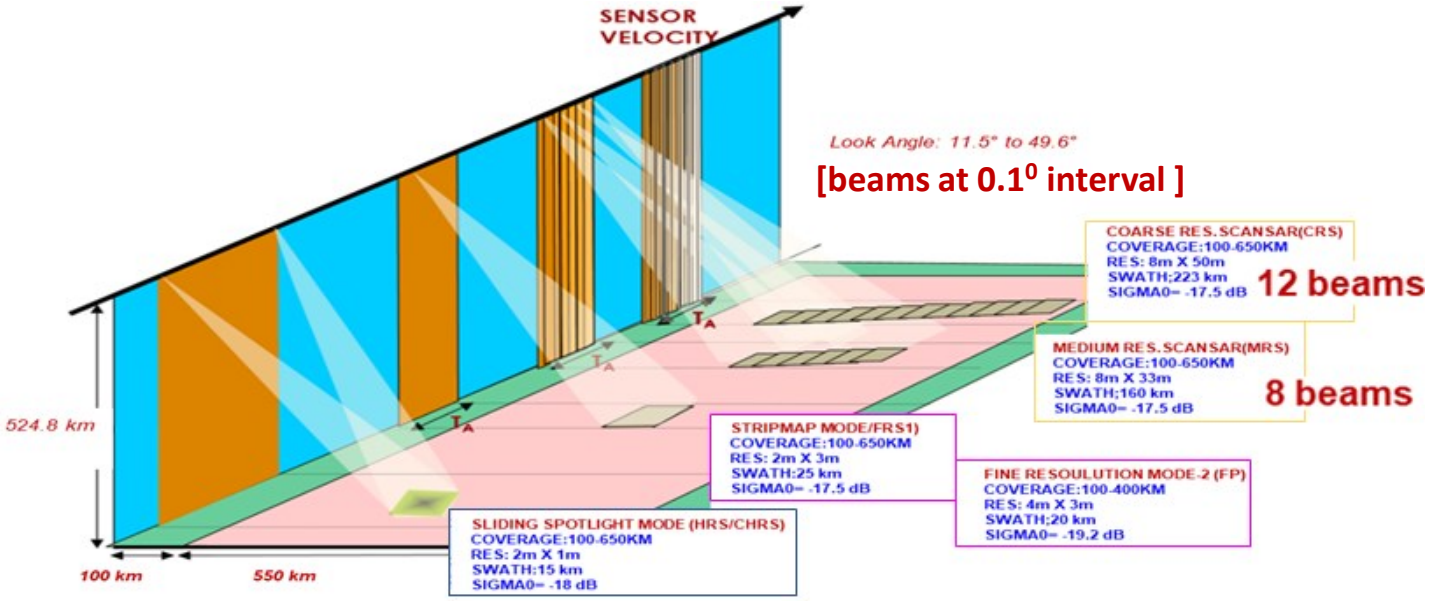
SNO	ARD Product	Sensor	Product Type	Timeline	CEOS Endorsement Status
1	Normalised Radar Backscatter	EOS-04 / EOS-09* (RISAT-1A / RISAT-1B)	Level2B[NRB]	2024 / 2025*	Completed
		EOS04/ EOS-09*	India Mosaic[NRB] (Tiled Product)	2024 / 2025*	Submitted to CEOS for self-assessment
2	Polarimetric Radar	EOS04/ EOS-09*	Geocoded Polarimetric Decomposition Products (Level-3B) [PRD]	2025	Design level product package is under validation at ISRO
		EOS04/ EOS-09*	GCOV (Geocoded Covariance Product) [CovMAT]	2024 / 2025*	Design level product package is under validation at ISRO
		NISAR	GCOV (Level-2) [CovMAT]	2025	-
3	Geocoded Single Look Complex	NISAR	GSLC (Level-2)[GSLC]	2025	-
4	Interferometric Products	NISAR			

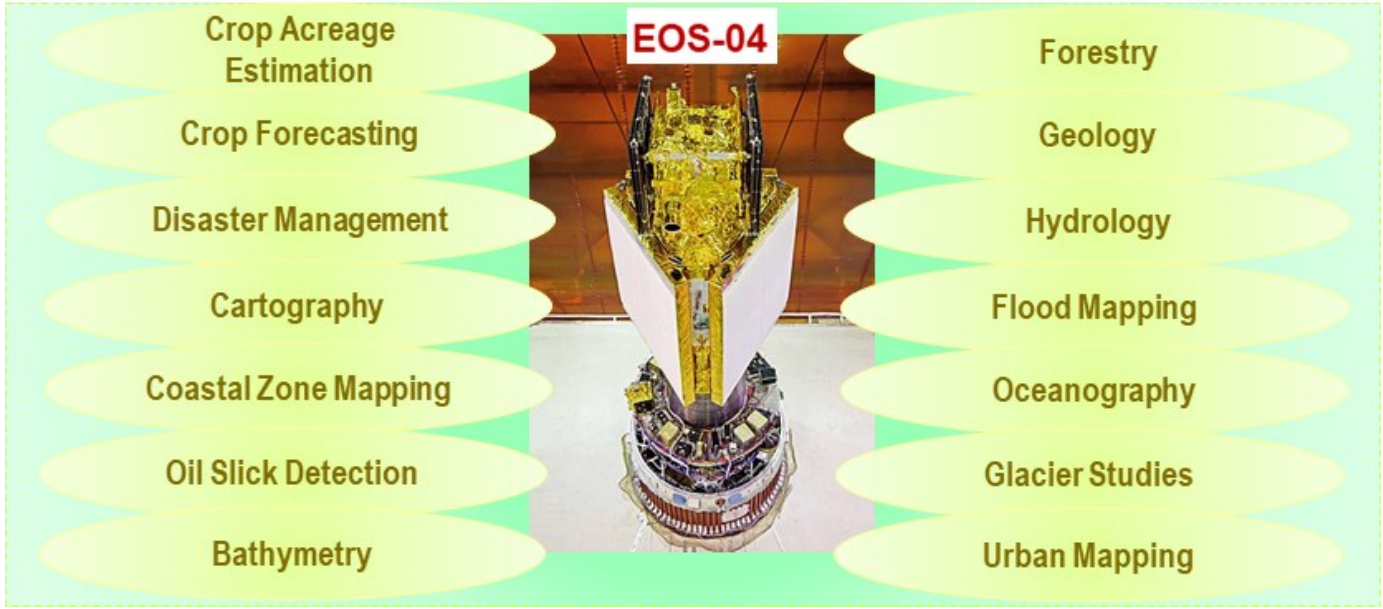
** - Launch planned in first quarter of 2025 - EOS-09 (follow-on of EOS-04 C-band SAR)*

[ ] CEOS ARD Product Family

EOS-04 Synthetic Aperture Radar (SAR) Specifications

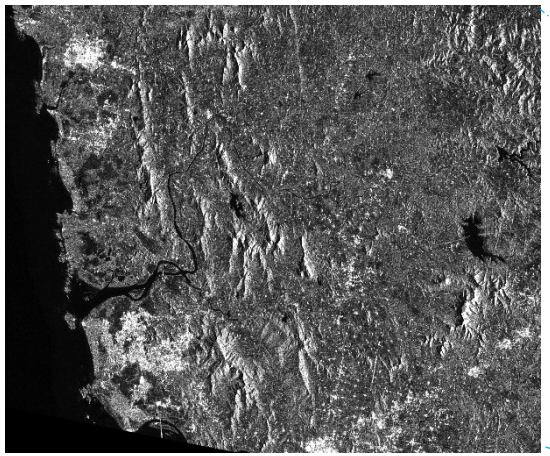
Parameter	Specification
Launch Date	14th February, 2022
Orbit	Circular Polar Sun Synchronous
Orbit altitude	524.8 km
Orbit inclination	97.552°
Orbit period	95.49 min
Operating Frequency	C-Band (5.4 GHz)
Operating Modes	FRS1, FRS2, MRS, CRS & HRS
No. of orbits per day	14
Equator crossing	6.00 a.m./6.00 p.m.
Polarizations	Single, Dual, Compact (CP), Full-Polarization (FP)
Pointing accuracy	0.05°
Swath Coverage	10 Km to 223 Km
Spatial Resolution	1 m to 50 m
Repeativity	17 days
Systematic Coverage of Indian Landmass	6 am pass in Medium Resolution ScanSAR (MRS) mode
Imaging Capability	Both Right and Left Look





#[EOS-09]

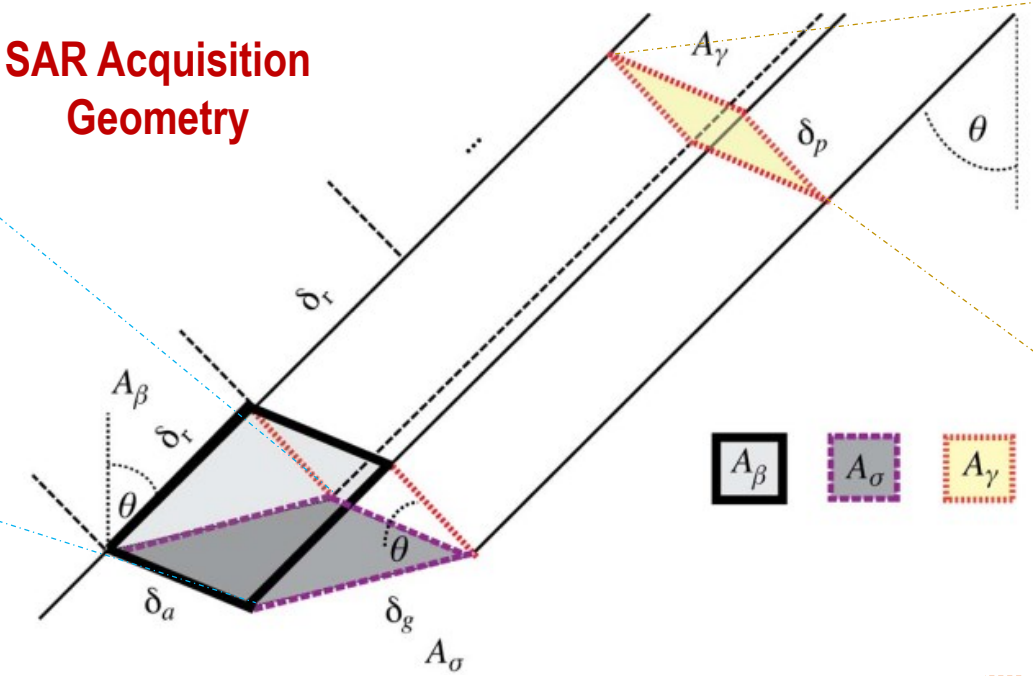
SAR Radiometric Terrain Correction [NRB]

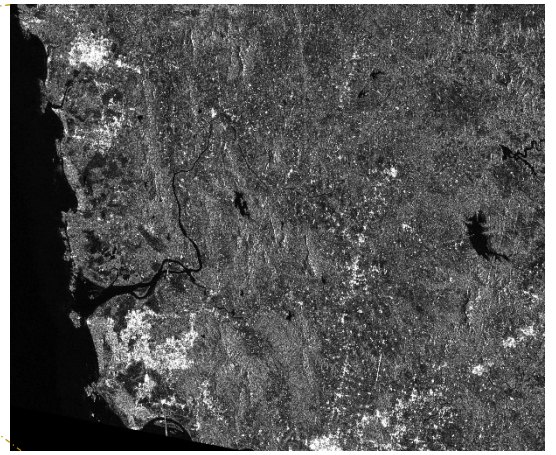


Terrain Flattened Sigma0 σ_T^0

$$\sigma_T^0 = \beta^0 \sin\theta_{LIA}$$

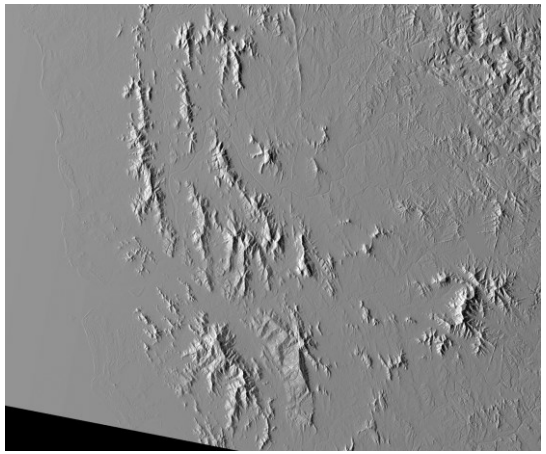
SAR Acquisition Geometry



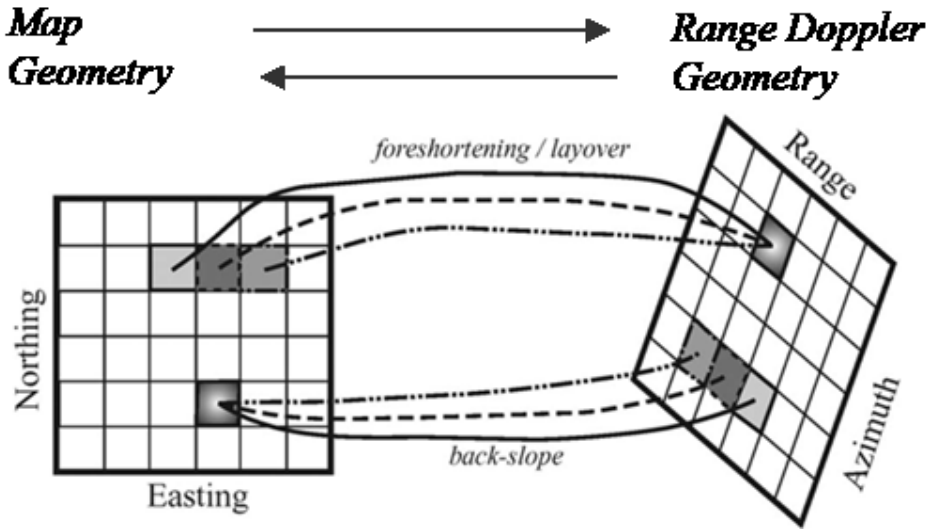


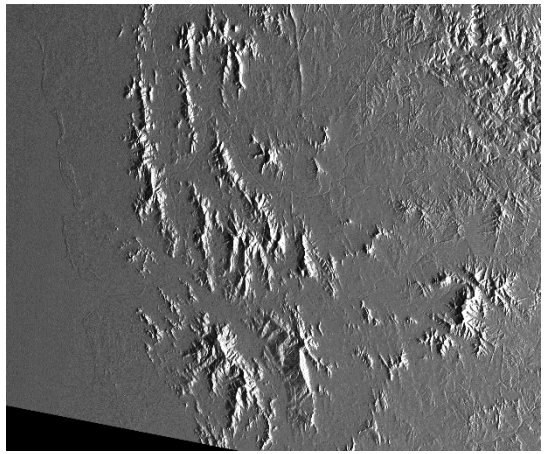
Terrain Flattened Gamma0 γ_T^0

$$\gamma_T^0 = \frac{\beta^0}{Area\ Normalization\ Factor}$$



Local Incidence Angle θ_{LIA}





Area Normalization Factor (Gamma Plane)

Ref. David Small , "Flattening Gamma: Radiometric Terrain Correction for SAR Imagery" *IEEE Trans. Geosci. Remote Sens. Vol 49, no. 8 Aug. 2011*

EOS-04 Radiometric Terrain Correction Process Flow

Radiometric Terrain Correction Flow

Determine Geo-location offsets by Registration of DEM and SAR Image in the Map Domain. Convert them to Slant-Range and Time Offsets **A**

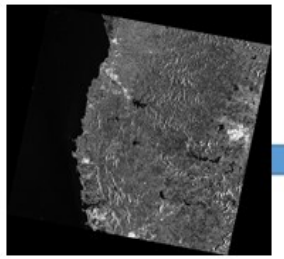
1. Generate Beam-wise Beta0 ScanSAR images in Slant Range Geometry.
2. Generate Gamma Plane Local Illuminated Area, Layover-Shadow Mask for terrain normalization. Local Incidence Angle (LIA) also generated. **B**

Generate Beam wise Terrain Normalized Gamma0 images using Local Illuminated Area and accounting for layover and shadow regions **C**

Mosaic ScanSAR beams and generate ortho-rectified product in the Map Domain (UTM/UPS) projection **D**

Generate output product in Cloud Optimized GeoTIFF Format for Gamma0, Area, Mask, LIA **E**

EOS04 SAR and Copernicus DEM Image Co-Registration



EOS-04 Map Projected image in equal MapX MapY

Determine Phase Correlation based ΔMapX; ΔMapY shifts with COPERNICUS 30m DEM **A**

ΔMapX
ΔMapY

Determine corrected MapX MapY for EOS-04 Map Projected Image using Δ MapX and Δ MapY

Using Inverse Map Projection ;determine Latitude Longitude for corrected MapX MapY for Image Grid

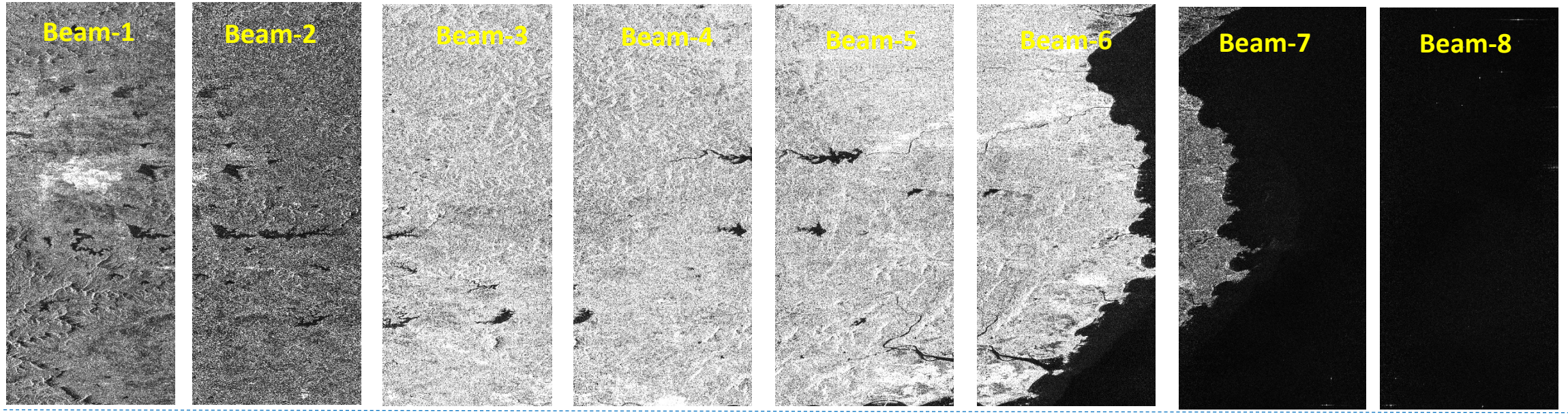
Using SAR Geolocation algorithm ;determine Scan Pixel for corrected Latitude Longitude for Image Grid

For Every Image Grid Point, determine Δ Scan and Δ Pixel error, using original and corrected Latitude Longitude

Mean Δ Scan error gives Along Track (Time) error
Mean Δ Pixel error gives Across Track (Range) error

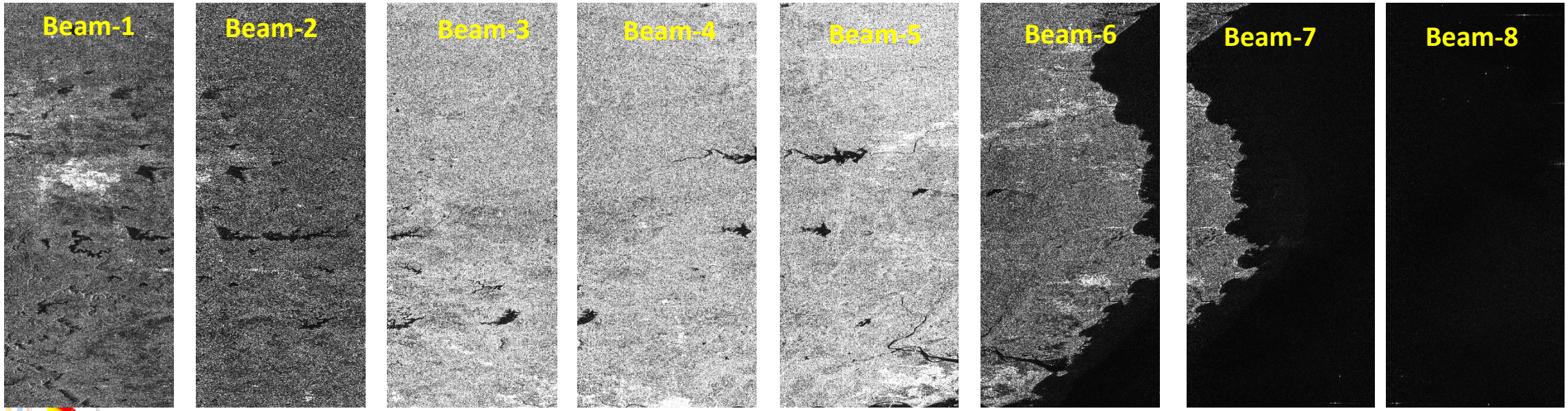
Generate Level-2 Map Projected image incorporating Time and Range errors

EOS-04 ScanSAR Beam Wise Radiometric Terrain Correction



B

Beam wise Un-Normalized β^0 Images

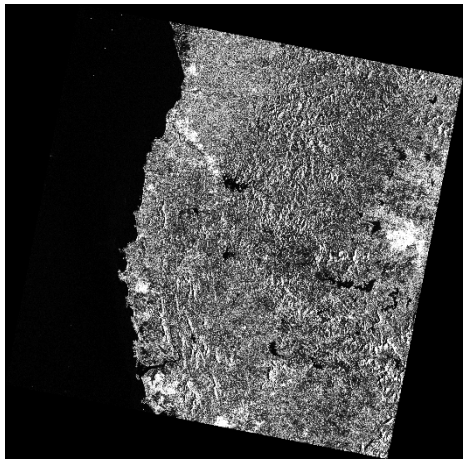


C

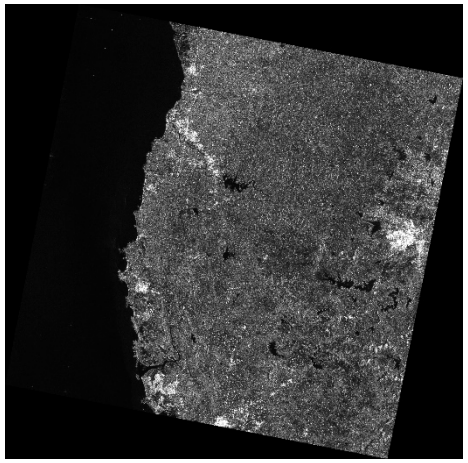
Beam wise Radiometric Terrain Corrected γ_T^0 Images

EOS-04 ScanSAR ARD Product Examples and Contents

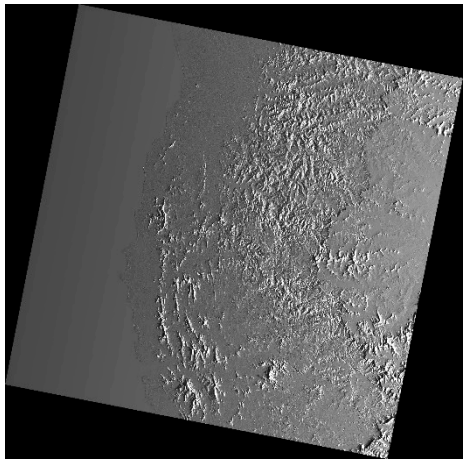
γ_E^0 ellipsoid based Gamma naught



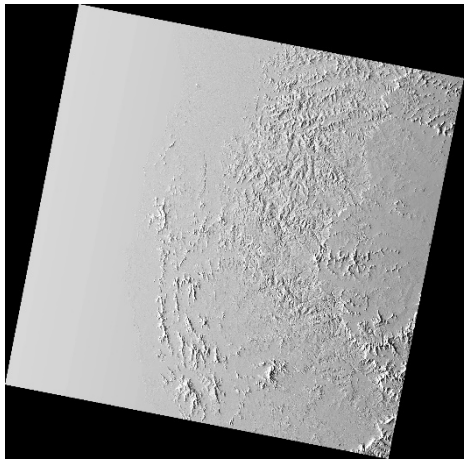
γ_T^0 Radiometric Terrain corrected (RTC) Gamma naught



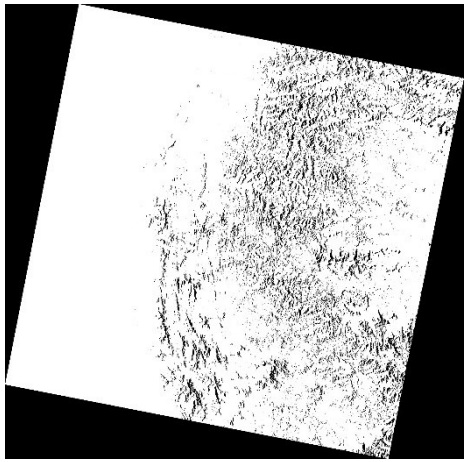
Area Normalization Factor (Gamma plane)



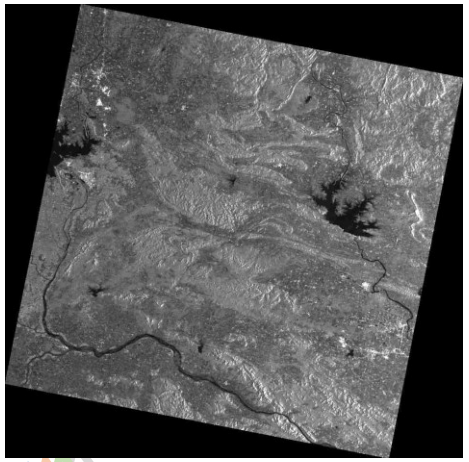
Local Incidence Angle

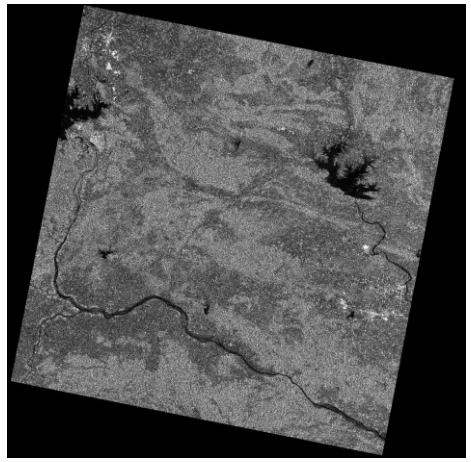


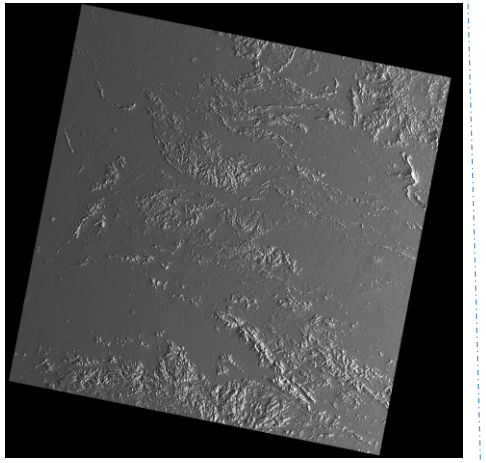
Layover Shadow Mask

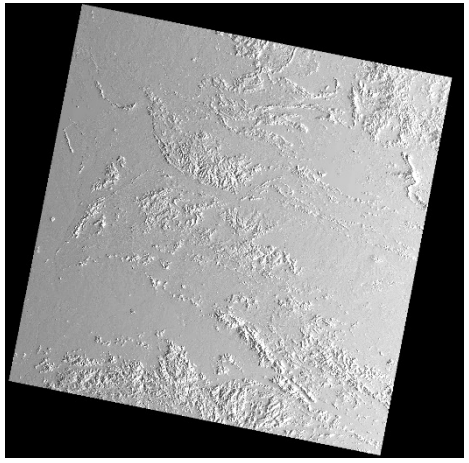


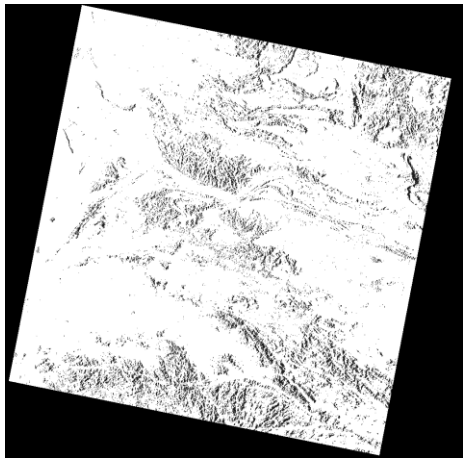
Example -1





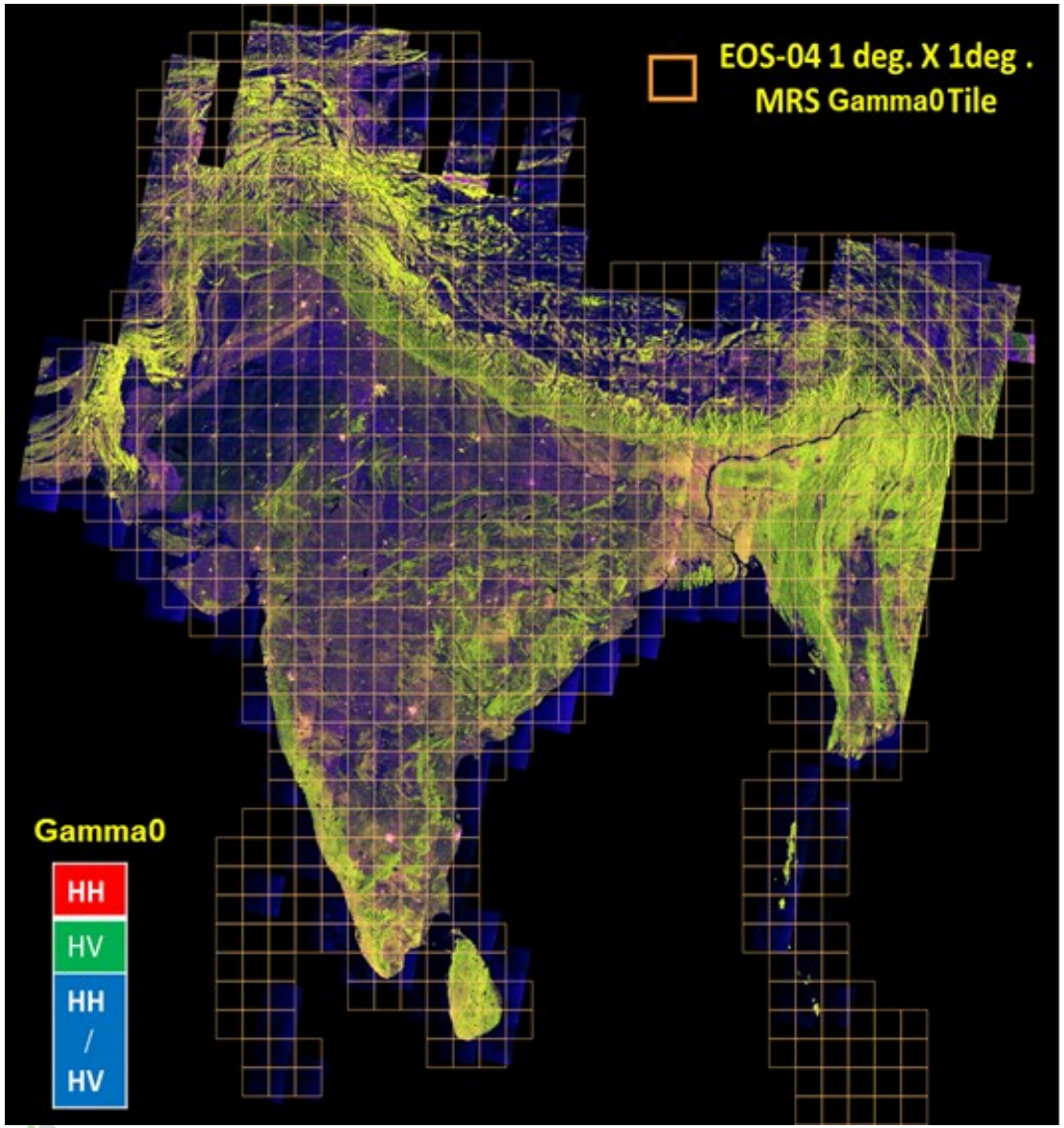




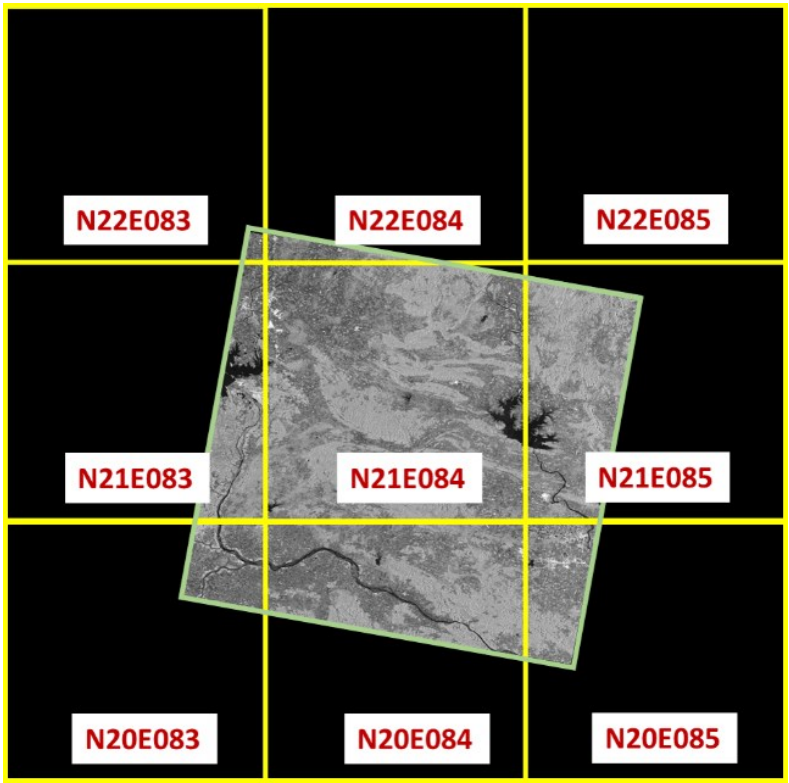


Example-2

EOS-04 ScanSAR (MRS) Tiled India Mosaic ARD Product



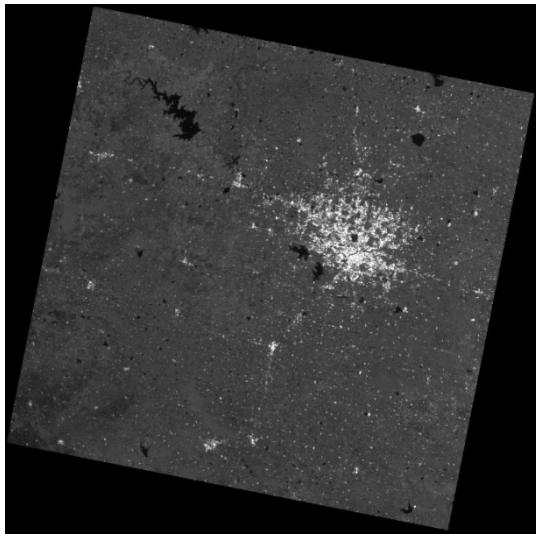
Systematic coverage over Indian sub-continent with 17 days repeat cycle in Medium Resolution ScanSAR (MRS -HH+HV polarization) mode during descending (6AM passes) with Right-Look imaging geometry is the workhorse mode for EOS-04.



UTM projected MRS scene Re-sampled to equal Latitude-Longitude tiles of size 1^0 X 1^0 at 0.000164^0 spacing (degree equivalent of 18 m)

EOS-04 MRS- India Mosaic ARD Gamma0 Product available every 17 *(~10 +[EOS-09])* days

EOS-04 ScanSAR ARD Time Stack Validation

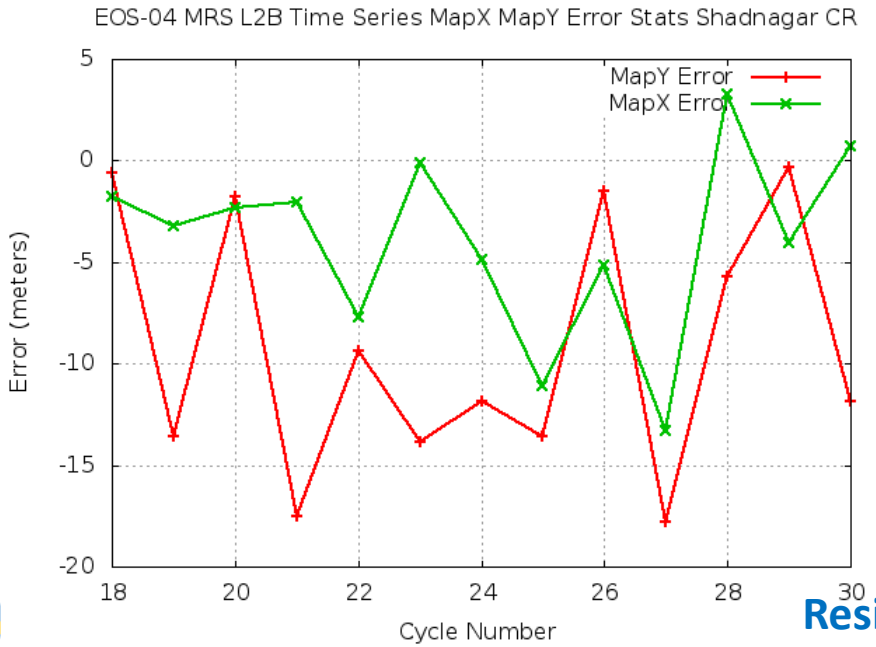


Shadnagar CR Site

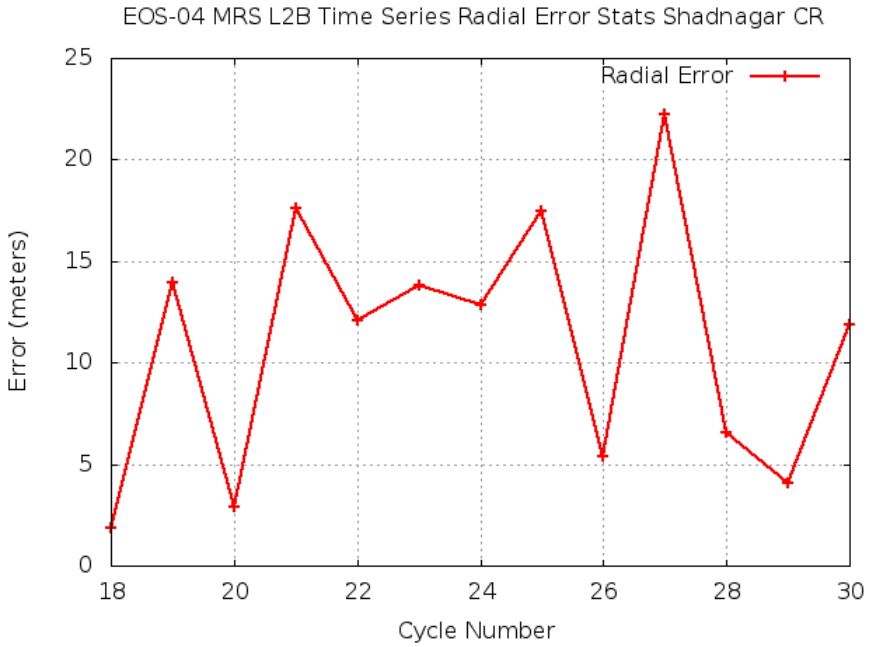
Reference CR Coordinates (GPS)	
Latitude	17.03548 deg.
Longitude	78.18315 deg.

IMGEOS Cal Site CR 125 cm Time Series

*Residual Absolute and Relative Radial Error within One MRS Pixel size of **18 meters***



Geo-Location Estimated from Interpolated Corner Reflector (CR) peak



Residual Geo-Location Errors

ISRO CEOS-Compliant ARD Product Generation – CEOS Certification

EOS-04 Level-2B ARD Product Contents

Gamma0, Local Illuminated area, layover-shadow mask, LIA	Cloud Optimized GeoTIFF (COG)
Meta Data	product.xml in machine readable XML format
Browse Images	Geo pngs's both in Gray scale and RGB
Product Shape File	Kmz file for overlaying on google earth
Repository	https://bhoonidhi.nrsc.gov.in

India Mosaic ARD Product Specifications

Total No. of Tiles (India Mosaic Product) per cycle		809	
Layers per Tile Product		6 : HH-HV Gamma0, LIA, Area, Mask, Date	
Tile Spacing		0.000164^0	
Volume per Tile Product		314 MB	
Format of tile Product		Cloud Optimized GeoTIFF (COG)	
Gamma0, Mask, Date	Unsigned Short Int 16	**Area, LIA**	Float32

Scenewise Level-2B Product

CEOS ARD CERTIFICATION

(A… Research Institute)	S… ce Temperature	v5.0	AIR-CAS (China)	Landsat 8	100%	Not assessed	Link	Link	PDF	PDF
NovaSAR-1 RTC	NRB	v5.5	CSIRO	NovaSAR-1	100%	Not assessed	Link	Link	ZIP	ZIP
PROBA-V L3 (0.1/0.333/1 km) TOC	Surface Reflectance	v5.0	VITO / ESA	PROBA-V	100%	Not assessed	Link	Link	PDF	PDF
Sentinel-1 RTC	NRB	v5.5	Sinergise & Digital Earth Africa	Sentinel-1 (A, B)	100%	Not assessed	Link	Link	PDF	PDF
Sentinel-2 Level-2A	Su… ce Re…	v5.0	ESA	Sentinel-2A, 2B	100%	Not assessed	Link	Link	PDF	PDF

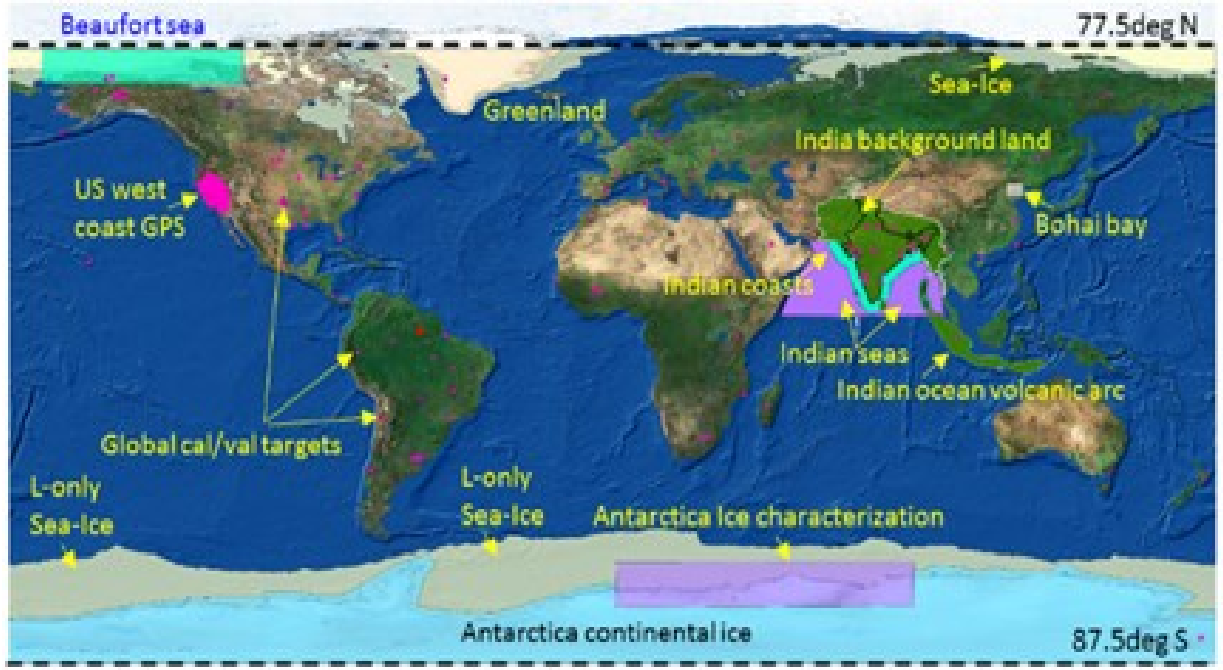
India Mosaic Tiled Product

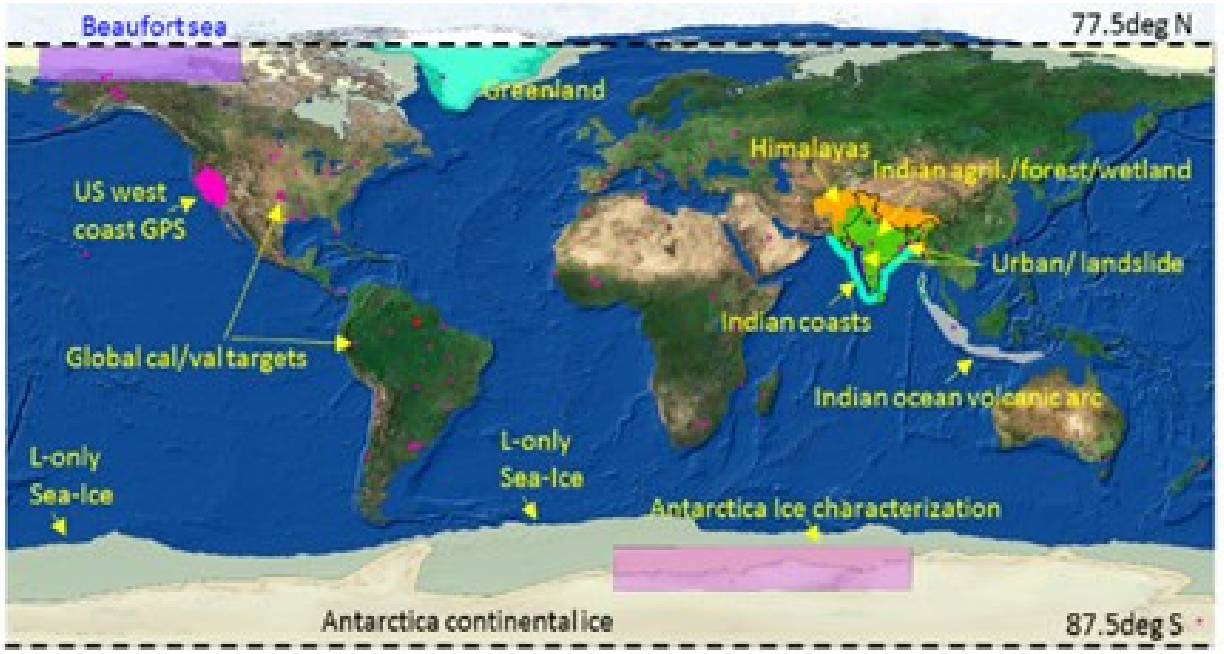
Under Peer Review

https://ceos.org/ard/

	CEOS-ARD Type	PFS Version	Agency	Mission / Instrument(s)	Access (DOI)	Info	Self Assessment	Peer Review	Sample Products
DESIS L…	Surface Reflectance	v5.0	DLR	DESIS-on-ISS	TBA	TBA	TBA	TBA	TBA
Gaofen-1/6 SR	Surface Reflectance	v5.0	AIR-CAS (China)	Gaofen-1	TBA	TBA	TBA	TBA	TBA
Opera RTC Sentinel-1	NRB	v5.5	NASA/JPL	Sentinel-1 (A, B)	TBA	Link	PDF	TBA	Link
Catalyst/PCI Sentinel-1 NRB	SAR-NRB	v1.1	Catalyst/PCI	Sentinel-1 (A, B)	TBA	TBA	DOC	TBA	TBA

NISAR ISRO's Observation Plan





Ascending Orbits

$$\begin{pmatrix} C_{11} & C_{12} \\ C_{12}^* & C_{22} \end{pmatrix}$$

Dual, Circular Polarization

$$\begin{pmatrix} C_{11} & C_{12} & C_{13} \\ C_{12}^* & C_{22} & C_{23} \\ C_{13}^* & C_{23}^* & C_{33} \end{pmatrix}$$

Full Polarization

Descending Orbits

Geo-Coded Covariance Matrix Product

[CovMAT]

EOS-04, EOS-09, NISAR

#India, Antarctica Mosaics

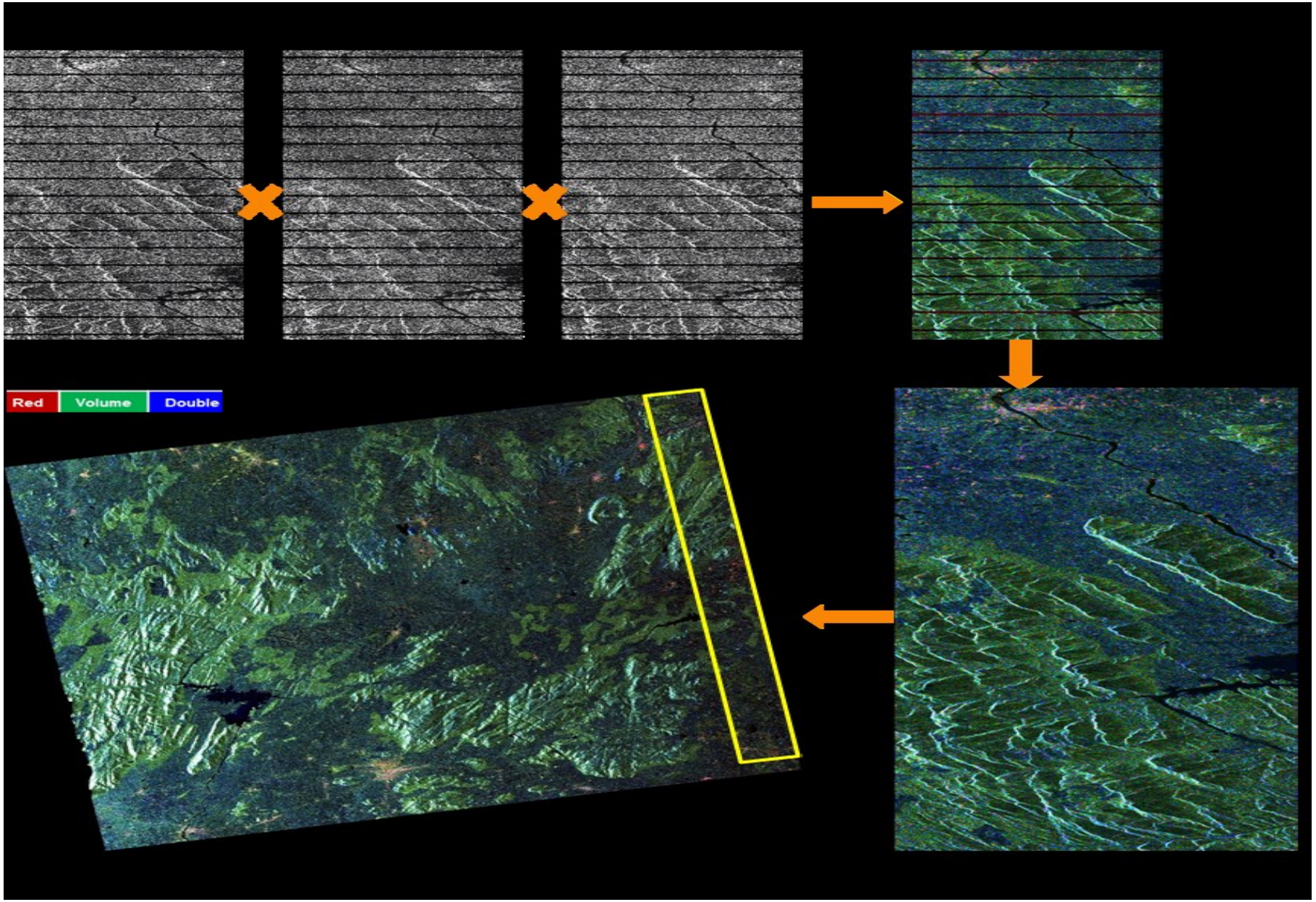
Geo-Coded Single Look Complex Product

[GSLC]

NISAR

EOS-04 Wide Swath ScanSAR Polarimetric Data Product [PRD]

Burst wise EOS-04 ScanSAR SLC Data Product



EOS-04 CEOS ARD [PRD] Product

ISRO's Polarimetric SAR [PRD] Analysis Ready Data Products

For Hybrid and Full Polarimetric Acquisitions

Fine Resolution Stripmap (FRS-1) Mode

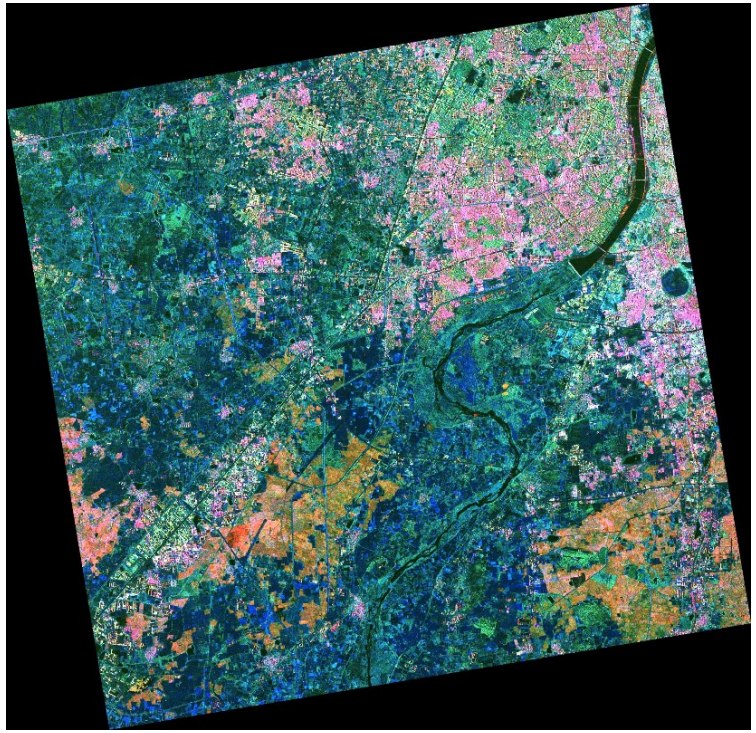


Image Size	20 Km X 20 Km
Date of Pass : Region	3rd Apr '22 : Ahmedabad , India
Mode : Resolution	StripMap : 3 meters

Medium Resolution ScanSAR (MRS) Mode

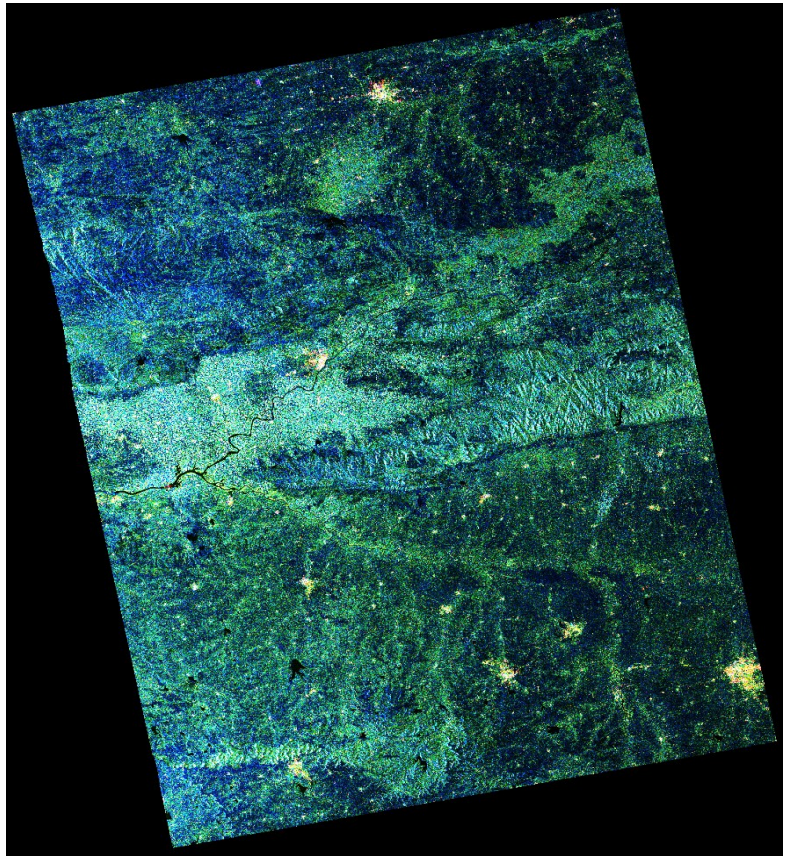


Image Size	160 Km X 115 Km
Date of Pass : Region	10th March '22 : Burhanpur, India
Mode : Resolution	ScanSAR (8 beams) : 33 meters

Coarse Resolution ScanSAR (CRS) Mode

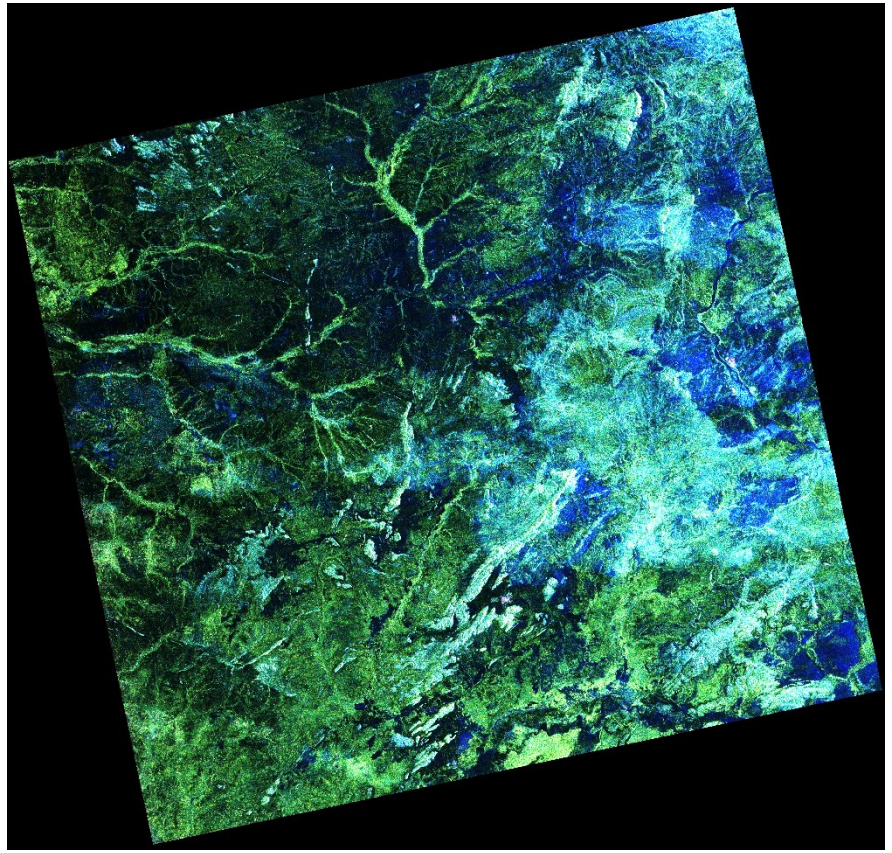
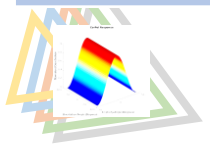


Image Size	160 Km X 168 Km
Date of Pass : Region	10th June '22 : Chad, Central Africa
Mode : Resolution	ScanSAR (12 beams) : 48 meters



Even Volume Odd

Thank You

raghavmehra@sac.isro.gov.in