Effective Utilization of Synthetic Aperture Radar (SAR) Imagery in Rapid Damage Assessment

Case Study – Pakistan Floods

SUPARCO

M. Maisam Raza,
Ahmad H. Rabbani

SEQUENCE

- **Flood Monitoring using Satellite Technology**
- **Synthetic Aperture Radar for Flood Monitoring**
- **Copernicus Program - ESA**
- **SAR in Disaster Management-Case Study**
- **Conclusion / Recommendations**

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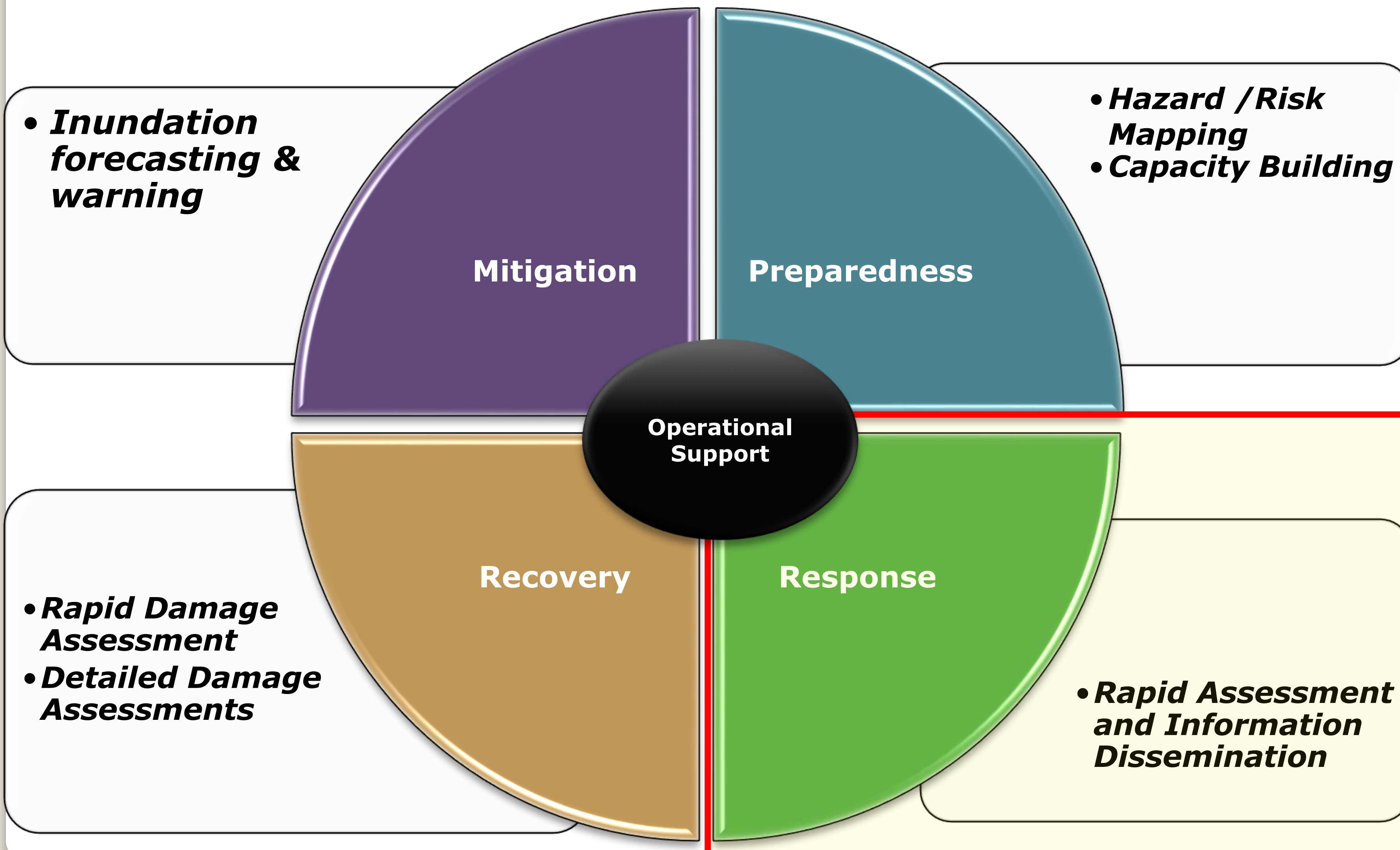
Space Application Centre for Response in Emergency and Disasters (SACRED)

- The centre provides space based information to national / provincial disaster management agencies
- Rapid assessment of the extent of natural disasters and damages to human lives, property and infrastructure.
- The centre also provides assistance to regional countries in case of natural disasters.

Web: disasterwatch.sgs-suparco.gov.pk

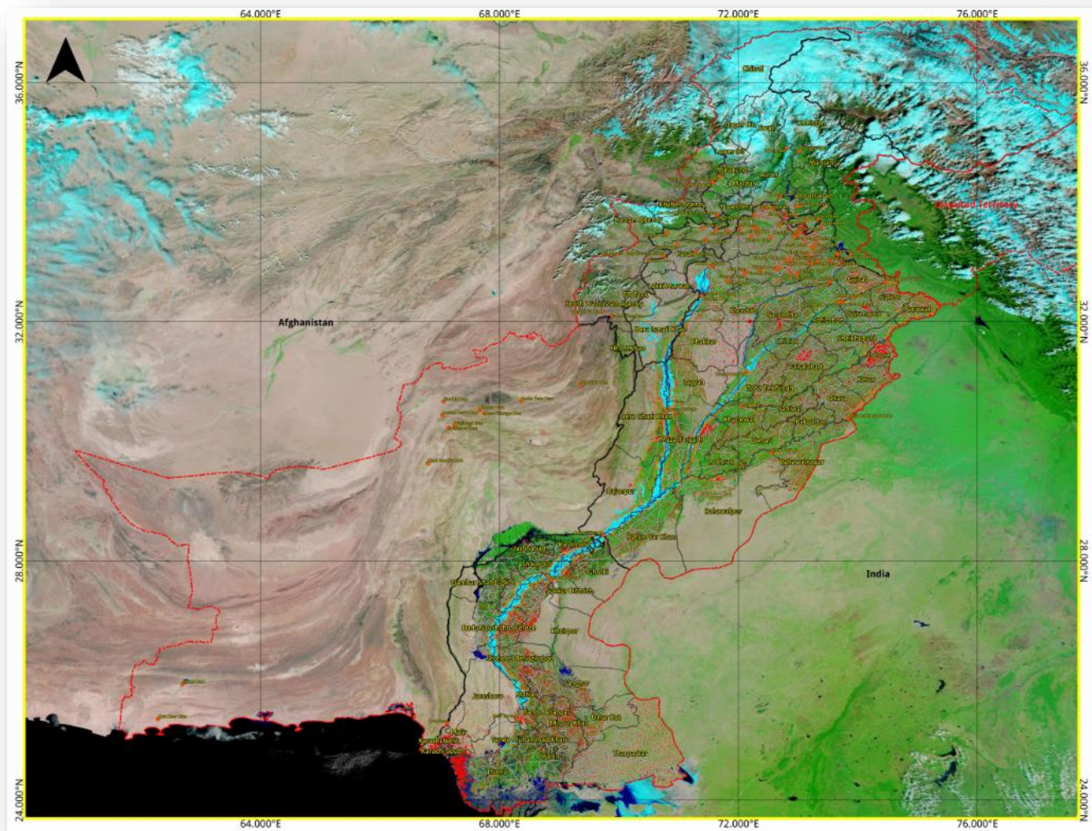
Geospatial Technologies for Flood Management



Regular River Monitoring

SUPARCO undertakes regular river monitoring using satellite technology to monitor the flooding events across the country.

Rapid response maps are generated and forwarded to the disaster management agencies and line departments to undertake the relief and rescue activities.



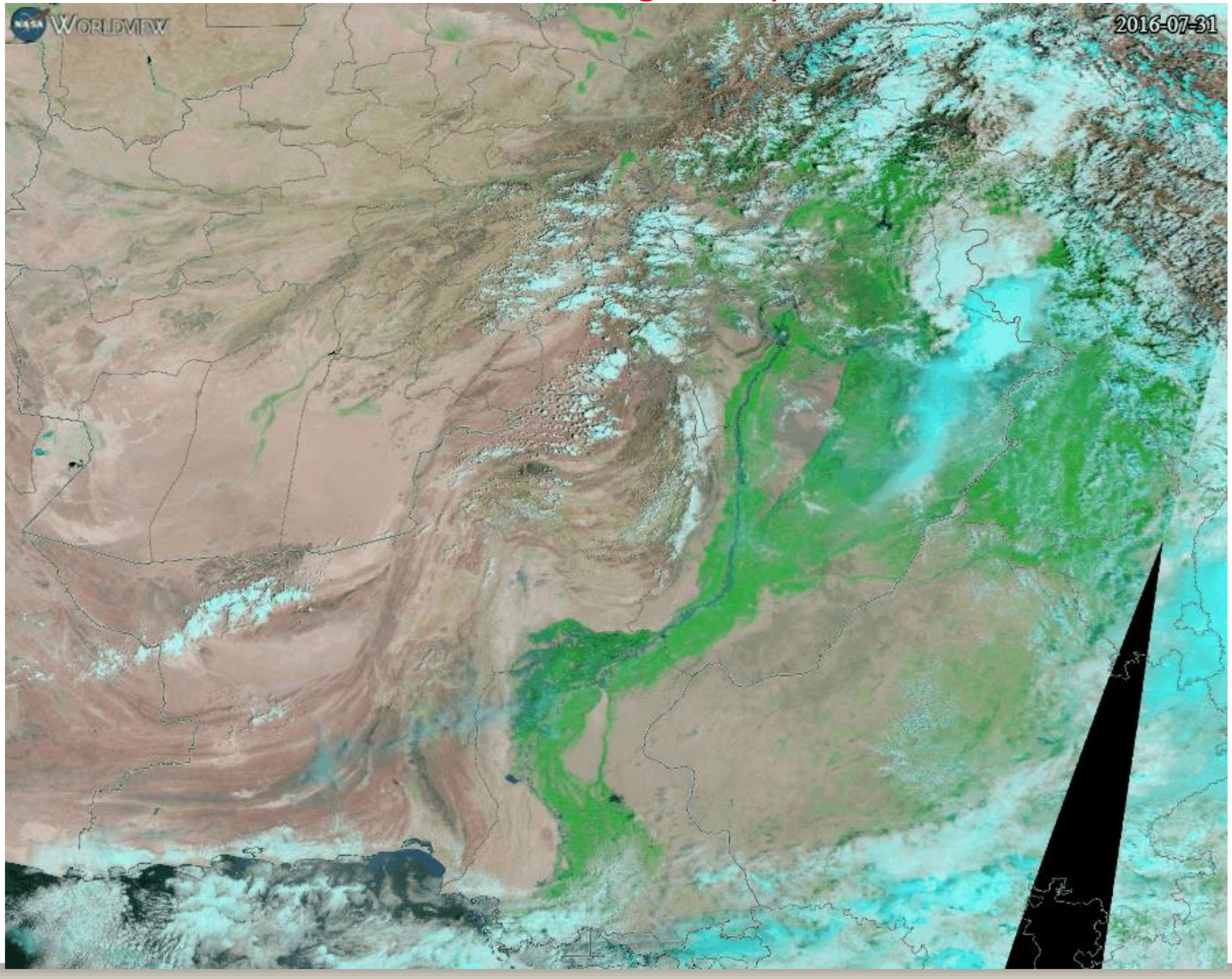
The maps provide the following information

- Inundation Extent
- Damaged Roads
- Affected Settlements
- Affected Agriculture
- Status of Flood Protection Structures

Regular River Monitoring

As the flooding typically occurs during the monsoon season, presence of persistent cloud cover makes regular river monitoring using optical satellite data, a challenging task

MODIS Time Series showing Heavy Cloud Cover



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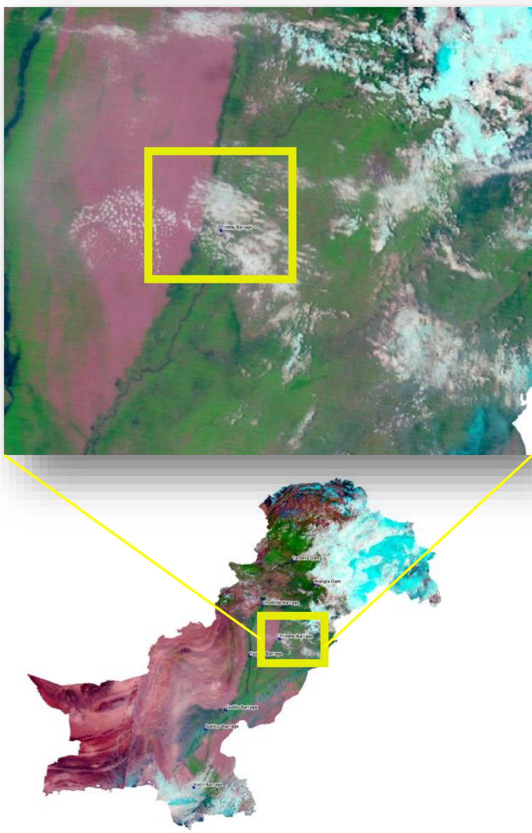
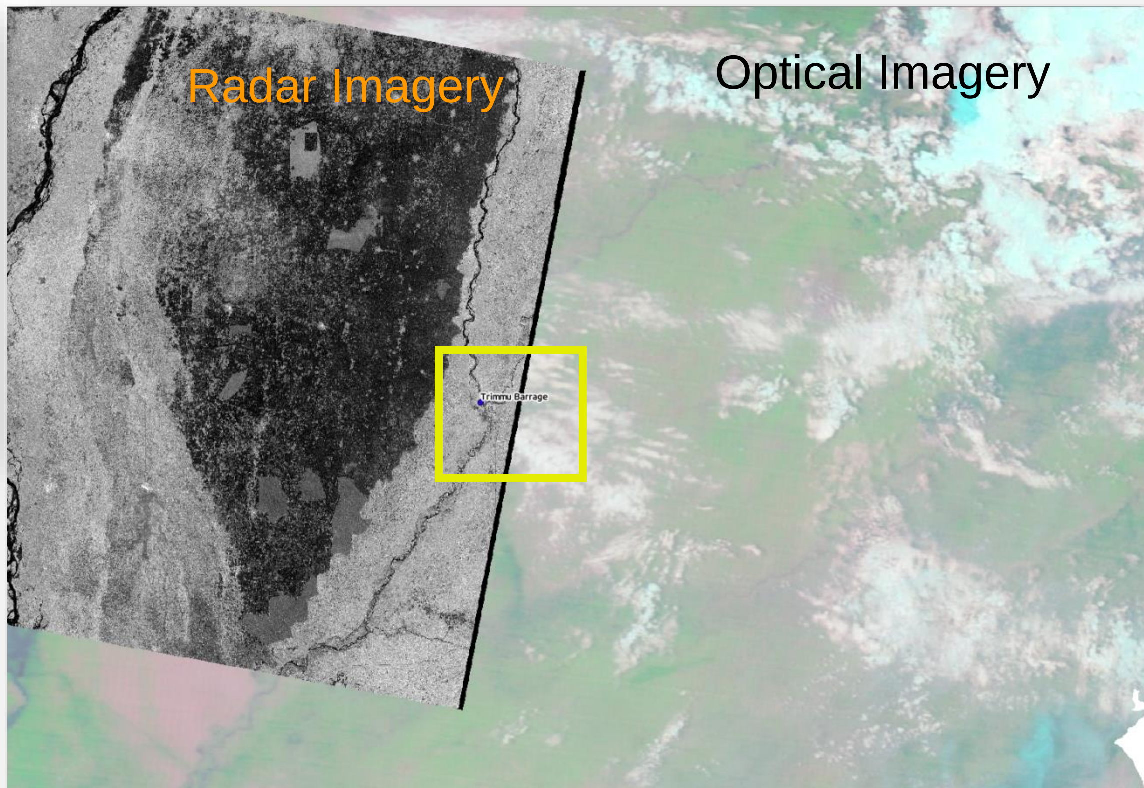
Penetration of SAR through Clouds

Penetration of microwave radar through clouds make it an ideal choice for space based disaster monitoring during the monsoon season

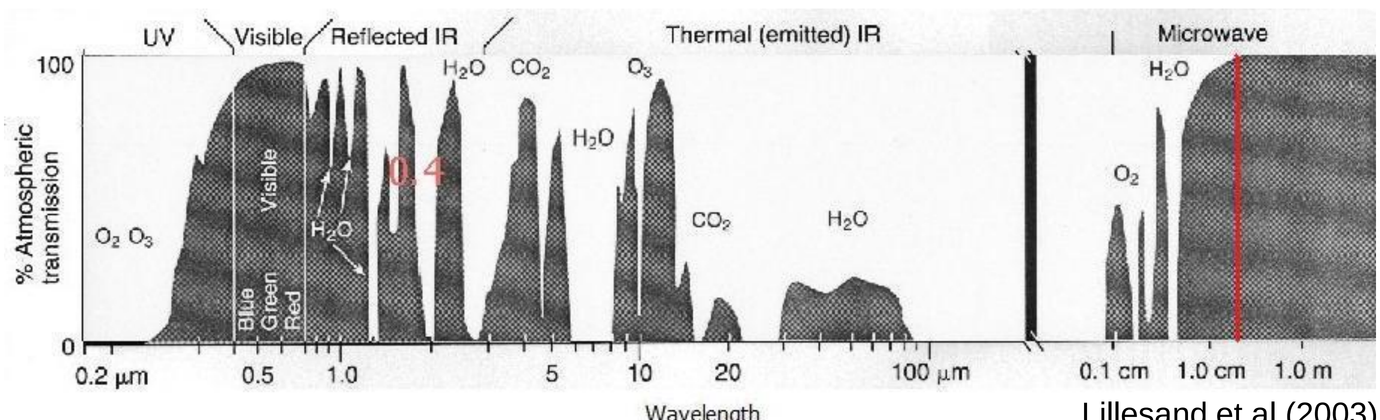




17 July 2016

Radar for Earth Remote Sensing

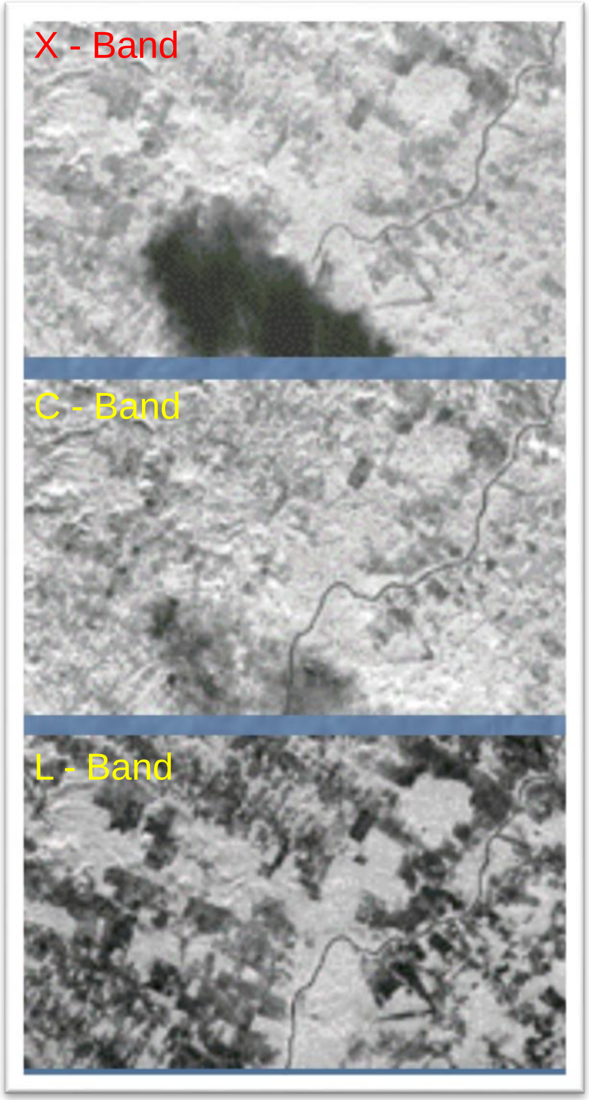
- Atmosphere is Generally Transparent for Microwave Frequencies
- Microwaves are Cloud-penetrating
- Independent of Atmospheric Conditions(dust/Haze)
- Affected by Rainfall Attenuation
- Can Operate Day & Night
- Works under Almost All Weather and Environmental Conditions
- Most common bands are L, X & C Bands



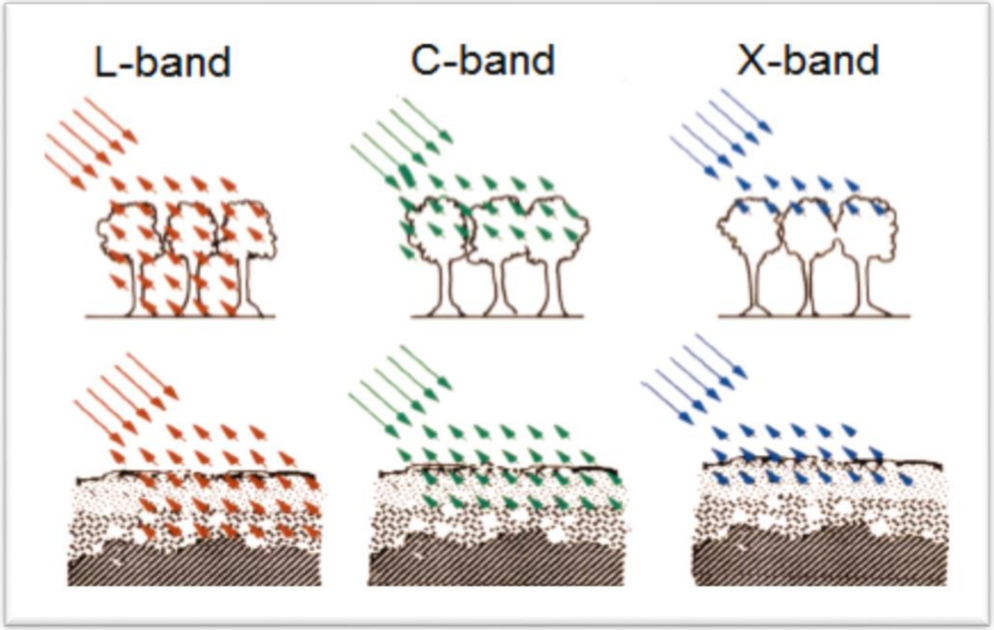
Lillesand et al.(2003)

Penetration Properties of Radar Bands

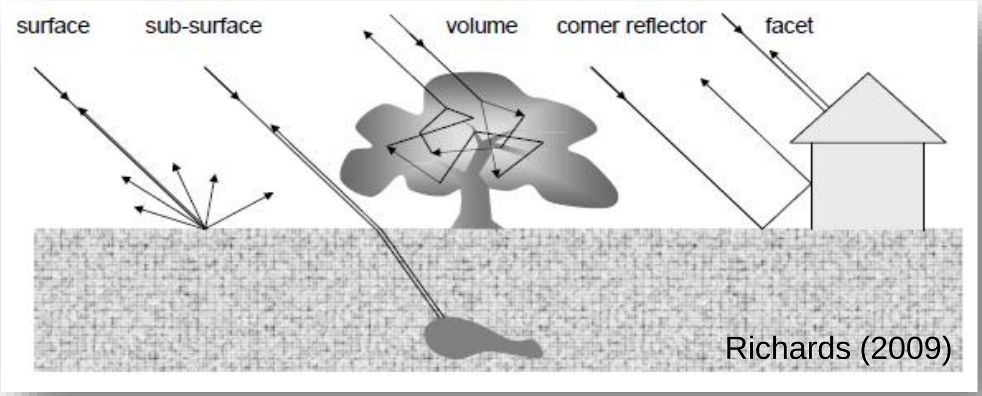
Rain Cell Penetration



Ground Target Penetrations



Target Reflections



Choices of Frequency Bands

Frequency band	*Frequency range*	*Application Example*
• VHF	300 KHz - 300 MHz	Foliage/Ground penetration, biomass
• P-Band	300 MHz - 1 GHz	biomass, soil moisture, penetration
• L-Band	1 GHz - 2 GHz	agriculture, forestry, soil moisture
• C-Band	4 GHz - 8 GHz	ocean, agriculture
• X-Band	8 GHz - 12 GHz	agriculture, ocean, high resolution radar
• Ku-Band	14 GHz - 18 GHz	glaciology (snow cover mapping)
• Ka-Band	27 GHz - 47 GHz	high resolution radars

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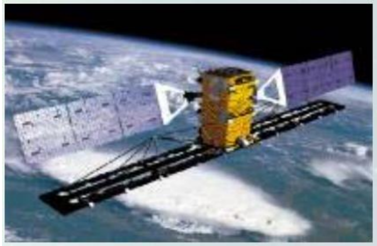
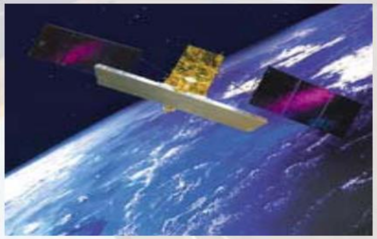
Space Based Radar Platforms..Few Examples



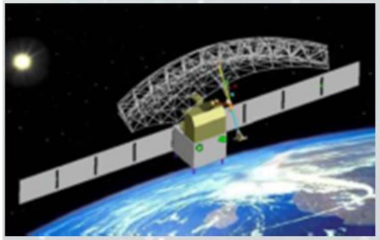
RadarSAT-II
Canadian Space Agency (CSA)
C-Band (quad), 2007

TerraSAR-X/TanDEM-X
DLR /Astrium, Germany
X-Band (quad), 2007/2010

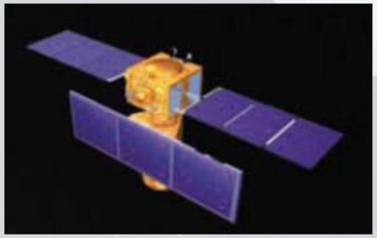


COSMO-SkyMed
ASI, Italy
4 Satellites, X-Band (dual), 2007/2010

Kompsat-5
KARI, Korea
X-band (dual), 2013



HJ-1C -SAR
CRESDA/CAST/NRSCC, China
S-Band (HH or VV), 2013

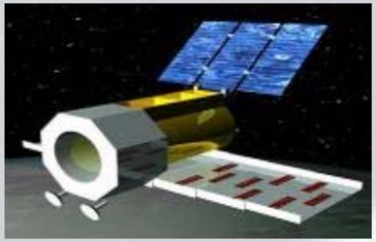


RISAT-1
Indian Space Agency (ISRO), India
C-Band (quad), 2012

SENTINEL-1a/b
ESA, Europe
C-Band (dual), 2014/2015

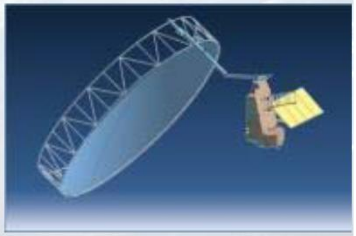
PAZ
Ministry of Defence, Spain
X-Band (quad), 2014

ALOS-2
Japanese Space Agency (JAXA)
L-Band (quad), 2014



SAOCOM-1/2
CONAE/ASI, Argentina
L-Band (quad), 2016/2018

Radarsat Constellation 1-3
CSA/MDA, Canada
C-band (dual), 2018



BIOMASS
ESA, Europe
P-Band (quad), 2020

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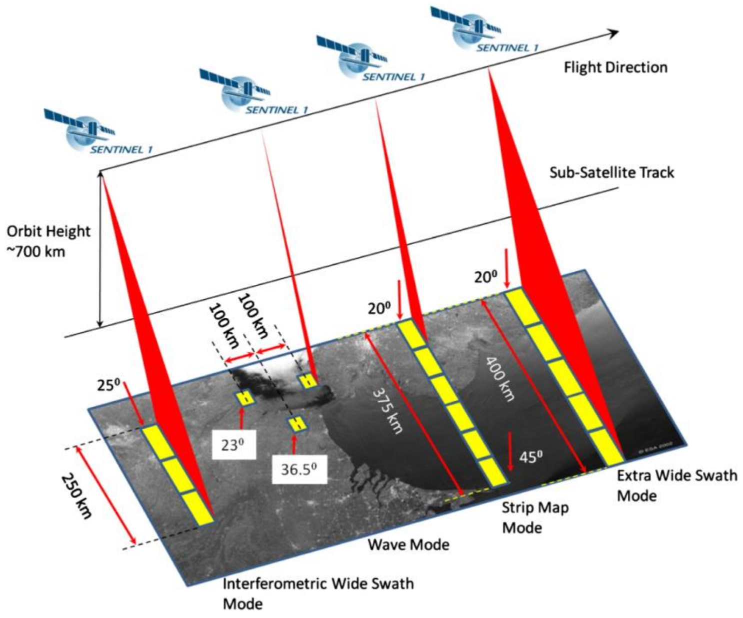
Sentinel 1 Copernicus Program - ESA

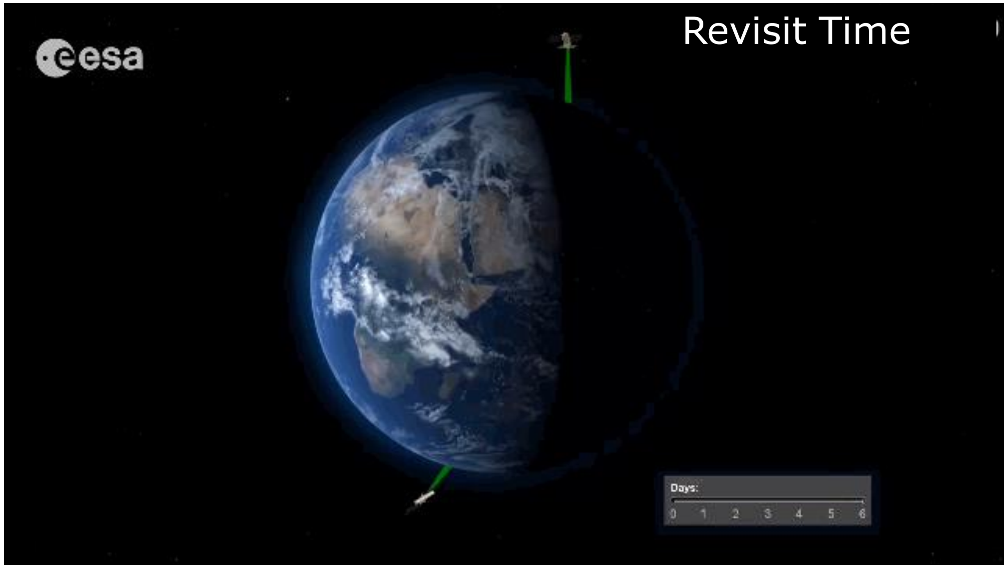
- Sentinel-1 is a Synthetic Aperture Radar (SAR) mission
- Providing continuous All-Weather Day-and-Night Imagery
- Operates at C-band (centre frequency: 5.405 Ghz)
- Open source platform available for accessing data

https://sentinel.esa.int/web/sentinel/missions/sentinel-1/overview

Sentinel 1 Copernicus Program - ESA

- Sentinel 1 A and Sentinel 1 B
- Revisit time 6 days at the poles
- Operating in four exclusive imaging modes with different spatial resolutions and coverage
- Interferometric Wide Mode with a swath width of 250 km





https://sentinel.esa.int/web/sentinel/missions/sentinel-1/overview

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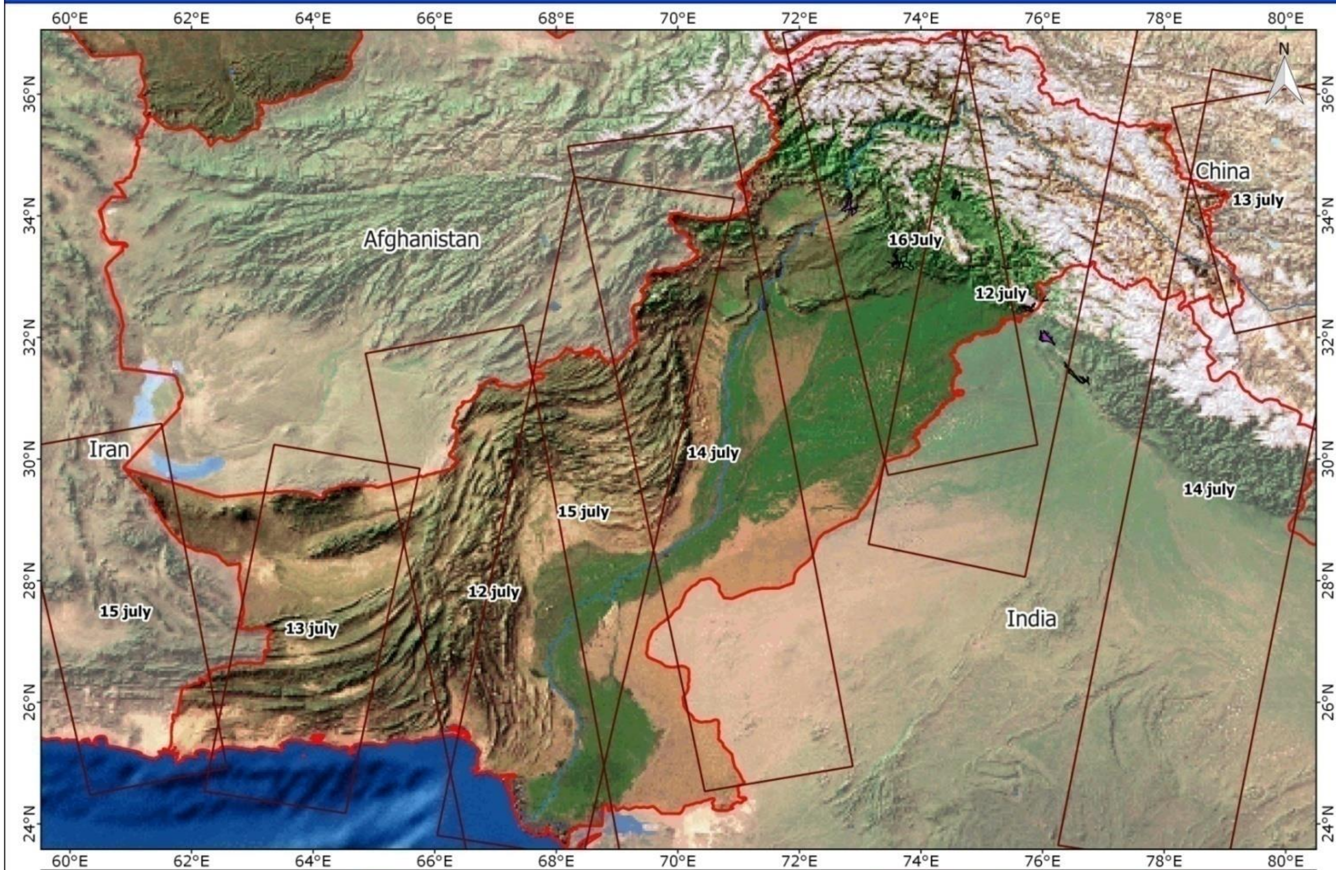
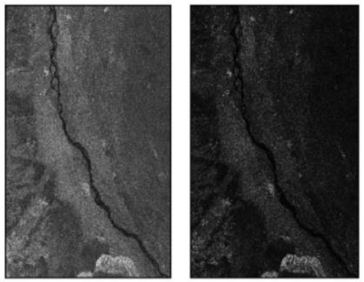
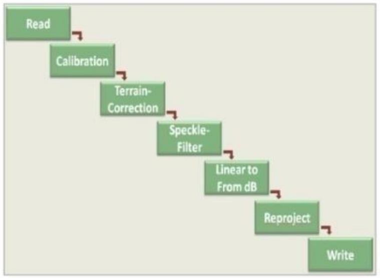
Acquisition Plan of Sentinel-1

12 July 2017 - 16 July 2017





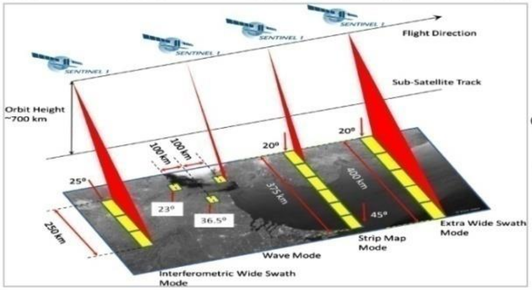
Bands of Sentinel 1 Sensor



Step by Step UN SPIDER Recommended Practice of SAR Image Processing

Time at which specific area's scenes of Sentinel-1 will be available can be estimated through its acquisition plan not only all across the Pakistan but also over some areas of neighbouring countaries as wel.

Source: Modis ,SUPARCO
Map Projection:World Mercator EPSG-4326
Date: 12-07-2017



The Interferometric Wide swath mode is the main acquisition mode over land and satisfies the majority of service requirements. IW mode captures three sub-swaths using Terrain Observation with Progressive Scans SAR (TOPSAR).

MODE	SWATH (KM)	RESOLUTION (m*m)	POLARIZATION
Stripmap	80	5*5	Dual
Wave	20	5*5	Dual
Interferometric WS	250	5*20	Dual
Extra WS	400	20*40	Single

Sentinel-1 Operative Modes

0 100 200 300 km

1:5,090,000

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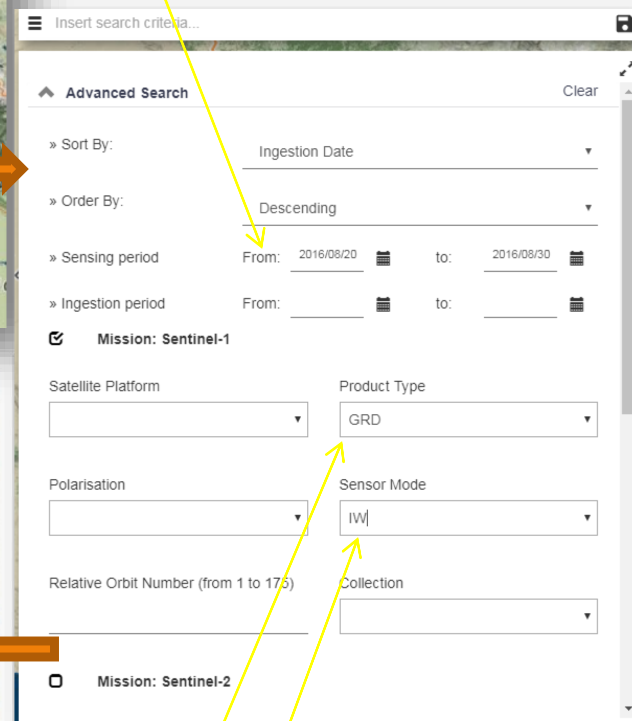
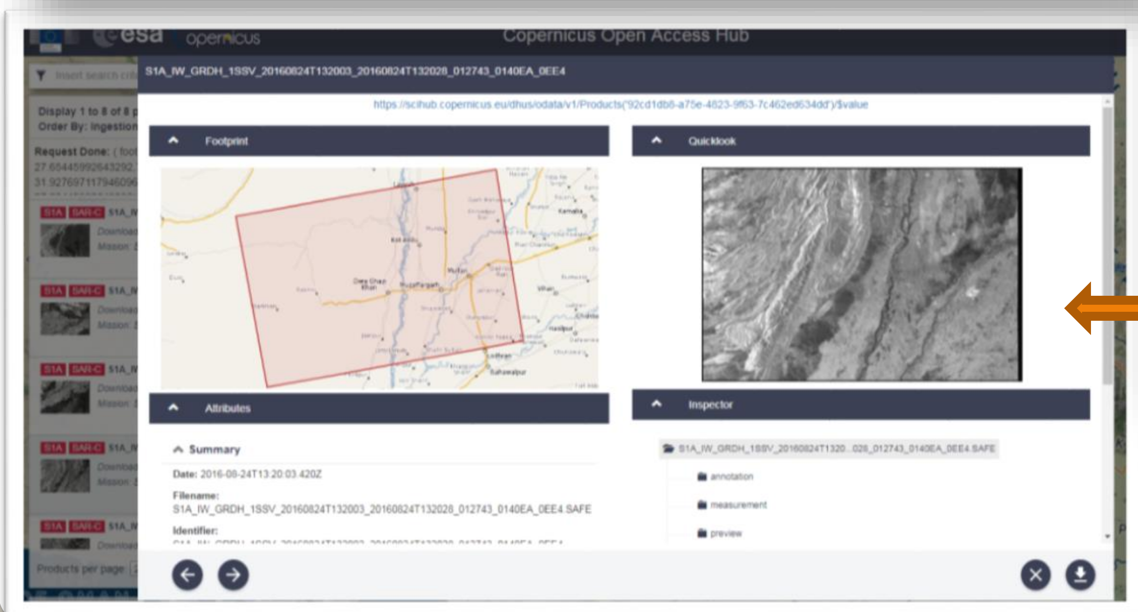
SENTINEL-1 Data Downloading

Copernicus Open Access Hub

https://scihub.copernicus.eu/dhus/#/home

Sensing Period





Ground Range Detected

Interferometric Wide Mode

Sentinel-1 SAR Data Processing Workflow

Read (IW-GRD)

Radiometric Calibration

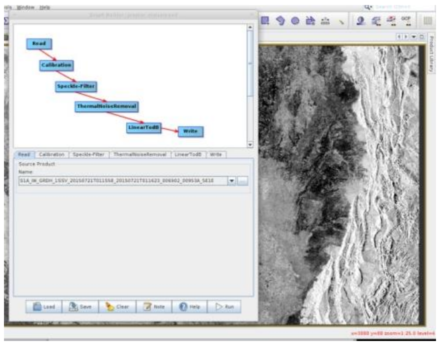
Terrain Correction

Speckle Filter

Linear to dB Conversion

Sigma0.img

Sentinel-1 Toolbox



Quantum GIS

Classification

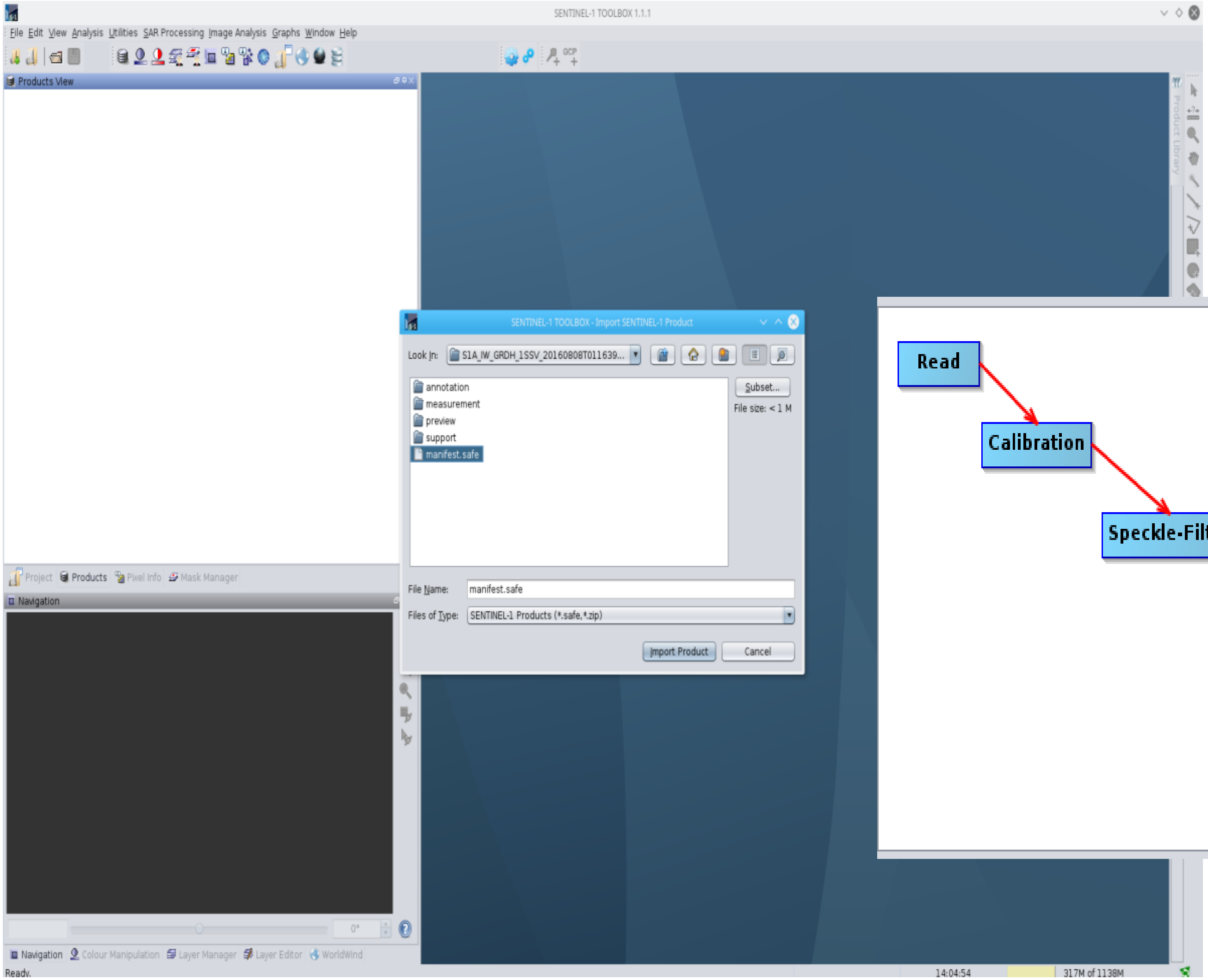
Raster to Vector

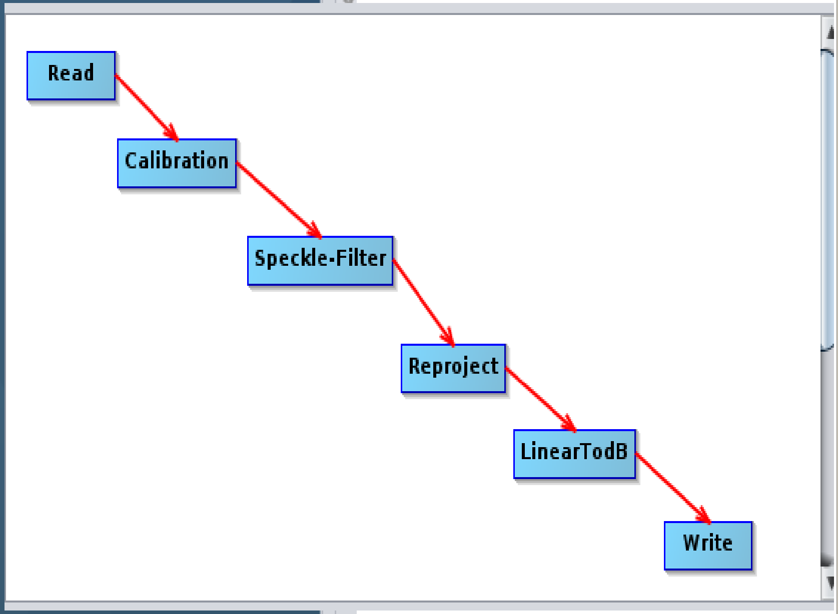
Noise Removal

Inundation Layer

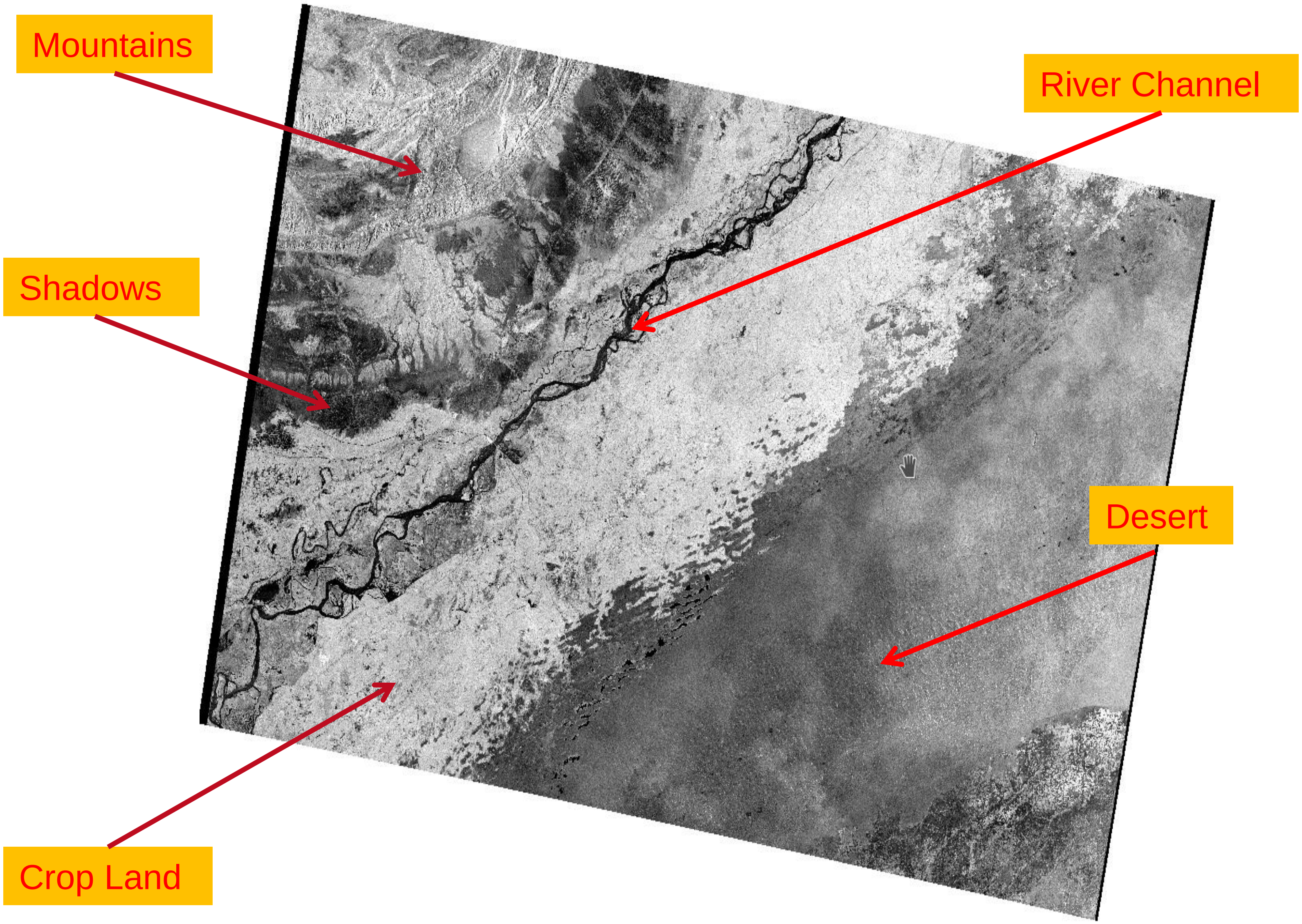
Standard S1 processing algorithm available at UN-SPIDER recommended practices – knowledge portal

Sentinel-1 Processing in S1-Toolbox



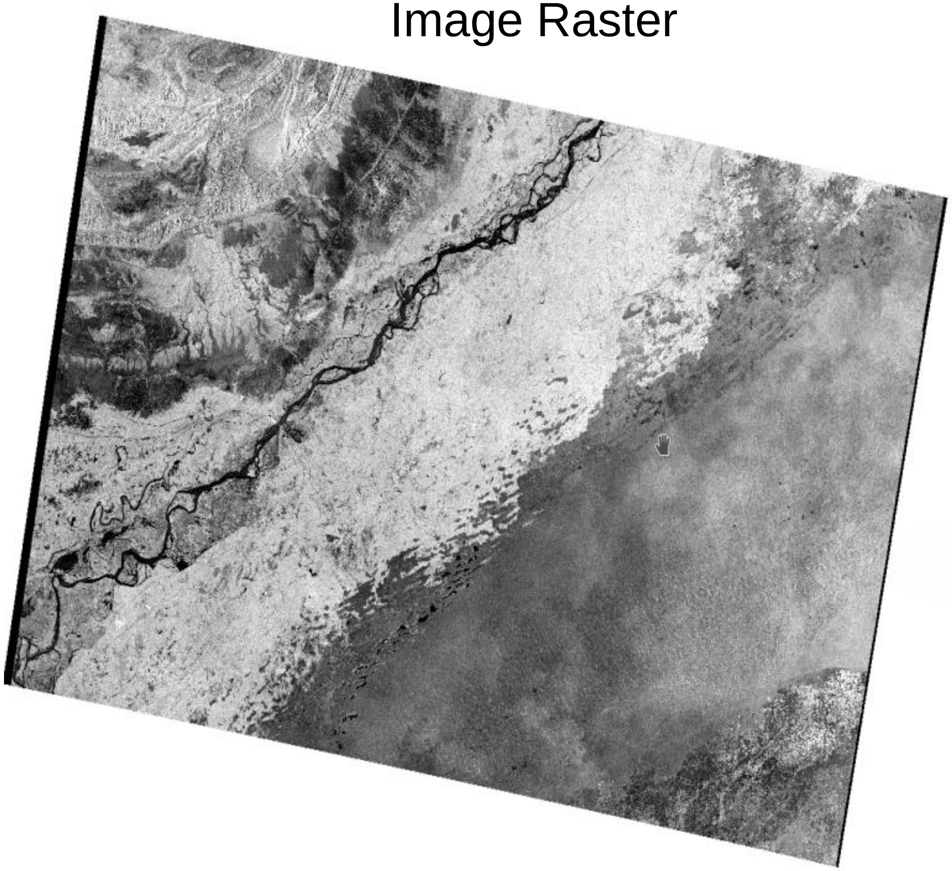


Sentinel-1 Processing Output - Image Raster

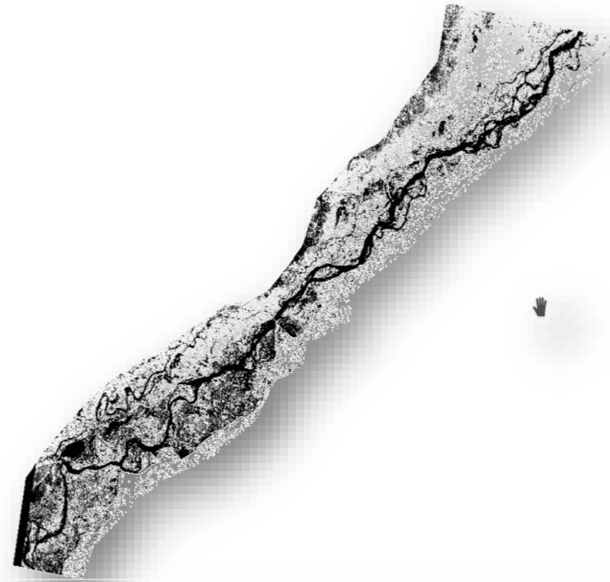


Sentinel-1 Processing Output

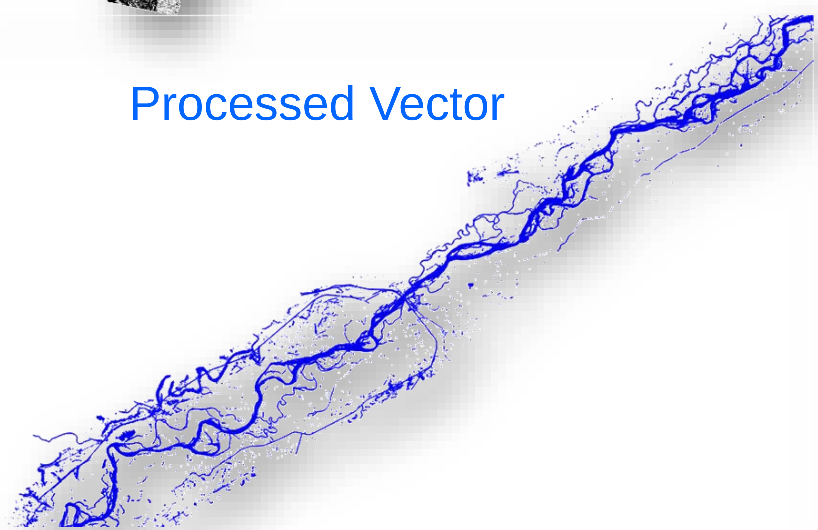
Image Raster



Classified Raster

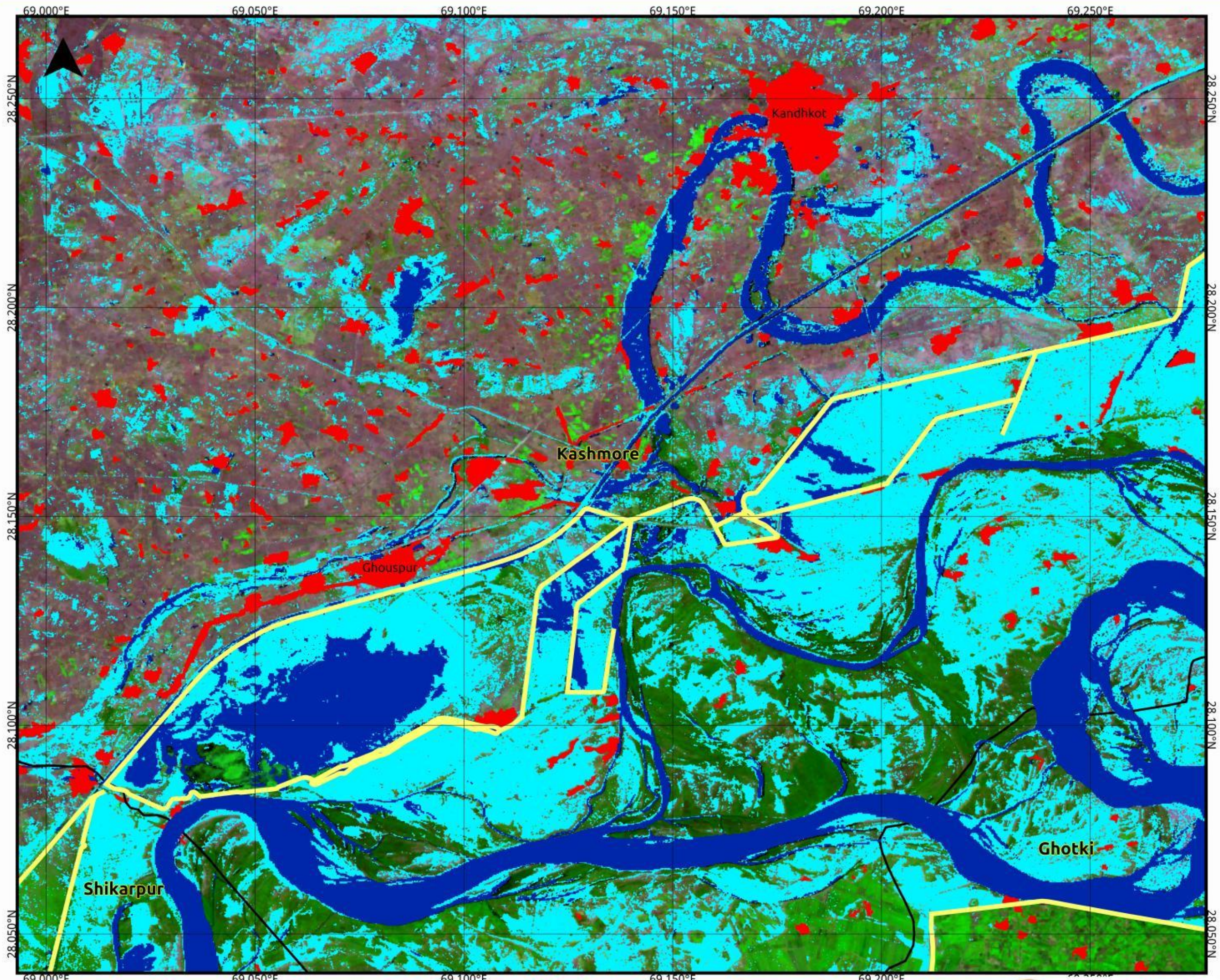


Processed Vector



Pakistan Floods 2015

Ghouspur & Kandhkot, District Kashmore

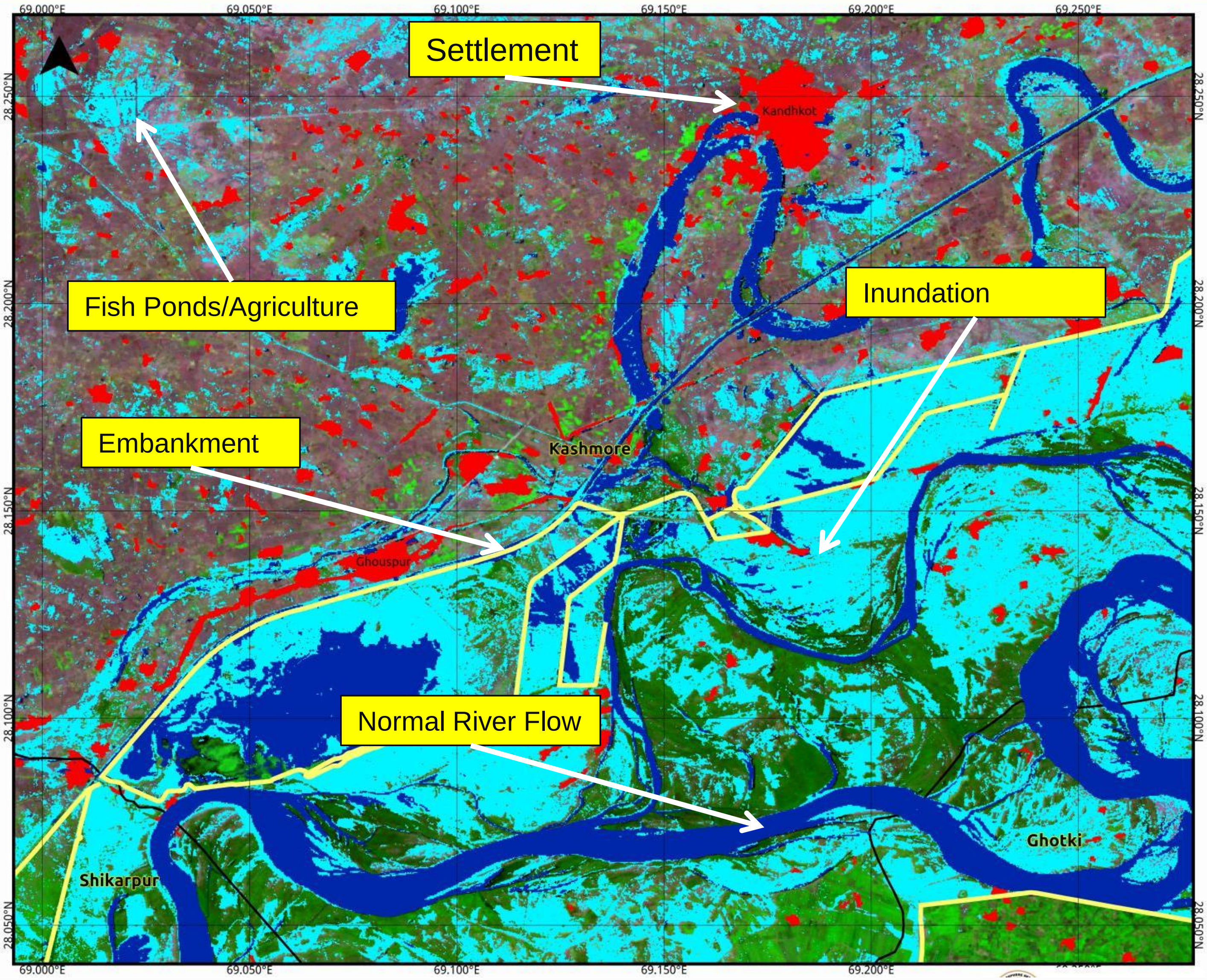


Description:
This map shows the comparison between the inundation extent as on 26-July-2015 with the pre-monsoon river extent. The area in focus is Indus River upstream of Sukkur Barrage in particular Ghouspur, Tori Bund/adjoining areas of Kashmore & Ghotki District.
The pre-monsoon river extent is extracted using Landsat-8 15 meters resolution cloud free composite data (01-May-2015 to 30-Jun-2015). The inundation as on 26-July-2015 is extracted using Sentinel-1 SAR data. The map is generated at SACRED-SUPARCO on 26-July-2015

0 1 2 3 4 km

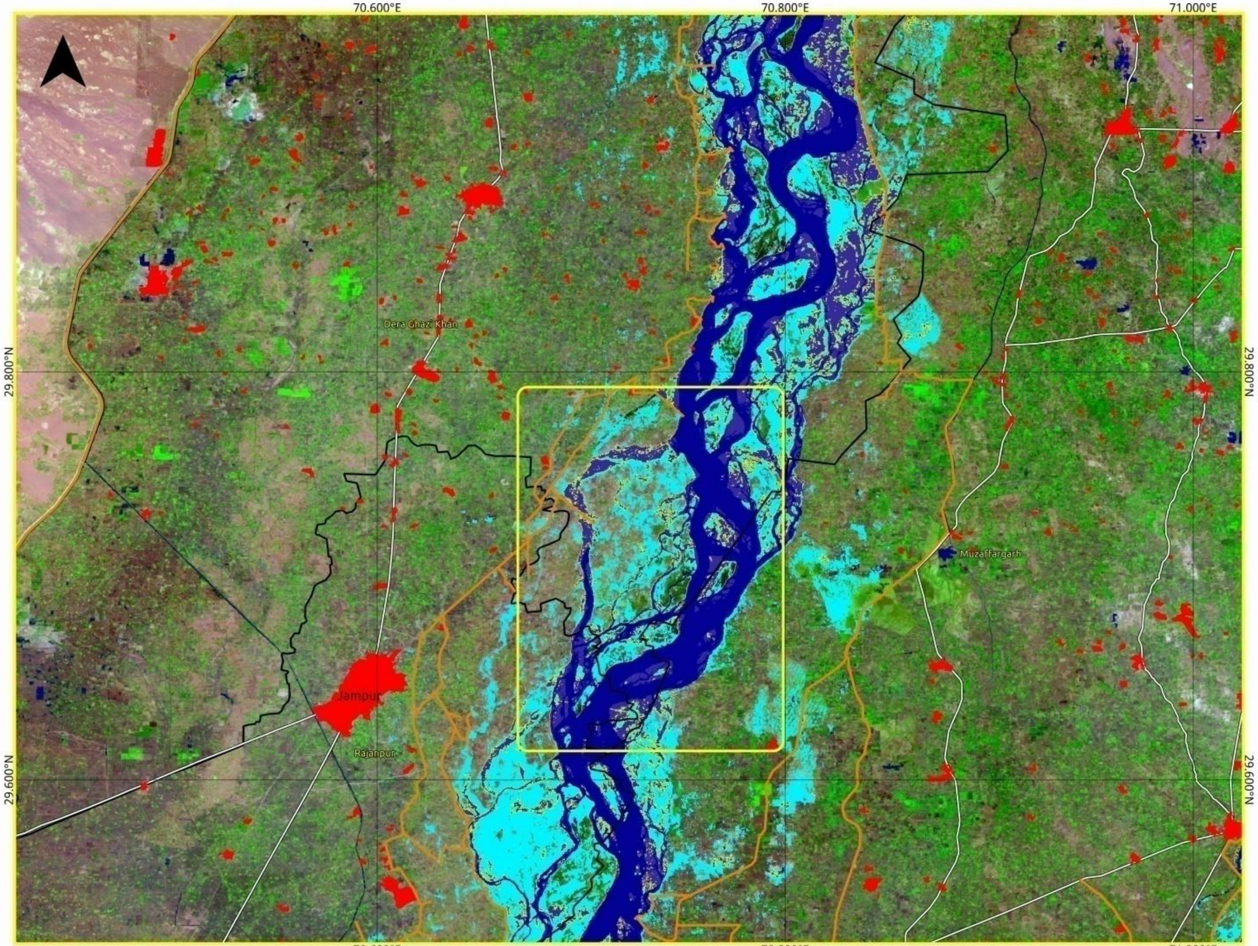
Legend
- Inundation-26-07-15
- Pre-Monsoon River Extent
- Settlements & Built-Up Area
- Districts
- Embankments

Pakistan Floods 2015
Ghouspur & Kandhkot, District Kashmore



Pakistan Floods 2015

Jakhar Imam Shah & Dera Ghazi Khan



This map shows inundation extent along the Indus River as on 30 July, 2015. The area in focus is Jakhar Imam Shah/adjoining areas & Dera Ghazi Khan. The analysis was performed on JAXA's ALOS PALSAR-2 data from 30 July, 2015 provided by Sentinel Asia, and Sentinel-1 SAR data from 21 July, 2015 provided by ESA. This analysis is yet to be validated in the field. The Indus River between Chashma and Taunsa is currently experiencing High flood levels. This information was produced at SACRED SUPARCO on 31 July, 2015.

0 5 10 15 20 km

Legend

- Pre-Monsoon River Extent
- ALOS Inundation (30/07/15)
- Sentinel-1 Inundation (21/07/15)
- Settlements & Builtup Area
- Embankments
- Road Network
- District Boundary
- Dams & Barrages

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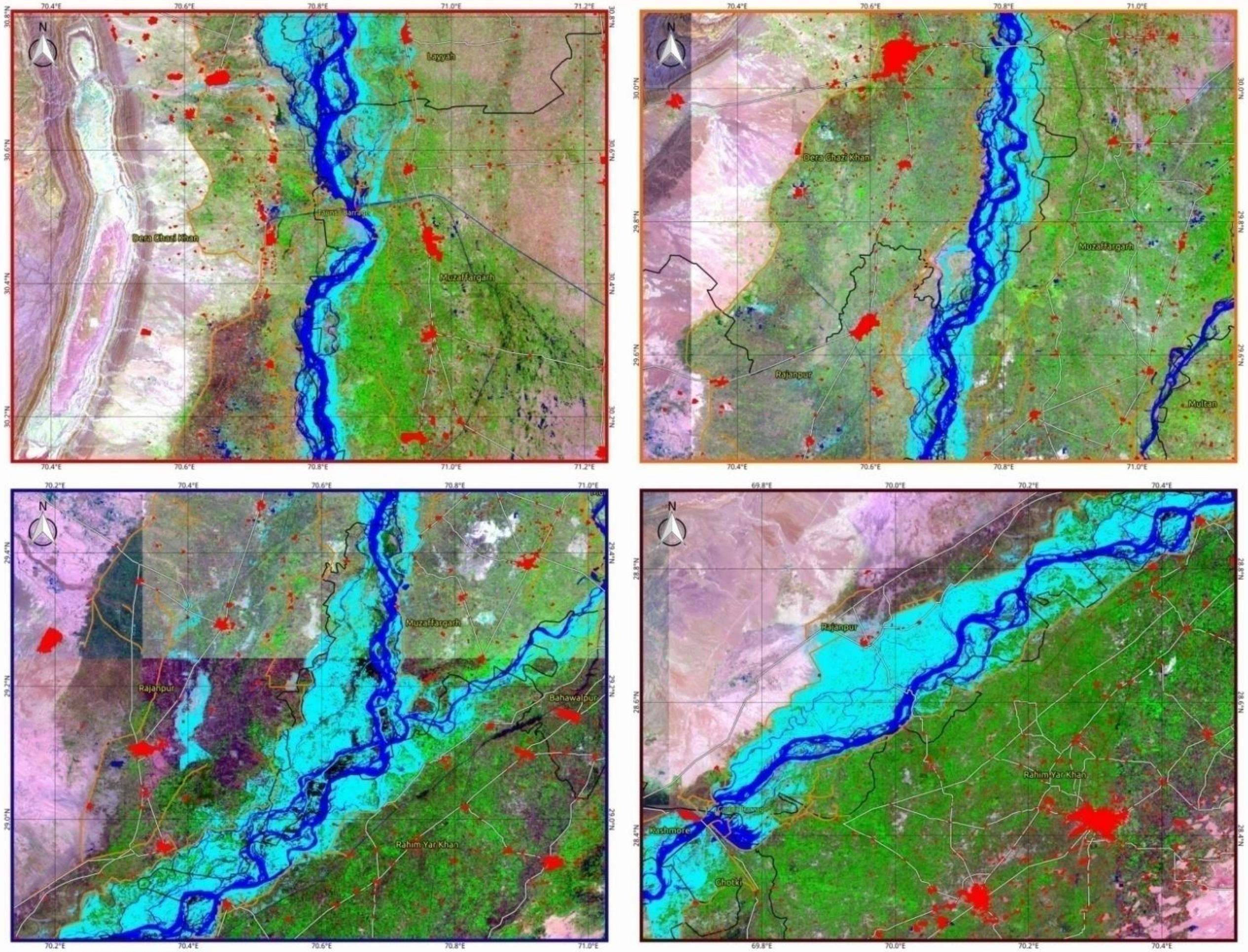
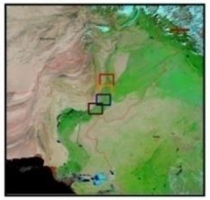
Sentinel Asia

For updated satellite based/additional spatial info go to *http://disasterwatch.sgs-suparco.gov.pk*

Pakistan Floods 2015

Inundation Situation (Indus River)





This map showsdetailed inundation extent along the Indus River as on 07 August, 2015. The area shown is Indus River, passing through Dera Ghazi Khan, Muzaffargarh, Rajanpur and Rahim Yar Khan Districts.

The analysis has been performed on Sentinel-1 SAR data acquired on 07 August, 2015 provided by ESA. This analysis is yet to be validated in the field. This information was produced at SACRED SUPARCO on 07-08-2015

0 10 20 30 40 km

Legend

- Pre-Monsoon River Extent
- Sentinel-1 Inundation
- Settlements & Builtup
- Embankment
- Road Network
- District Boundary
- Dams & Barrages

For updated satellite based/additional spatial info go to **http://disasterwatch.sgs-suparco.gov.pk**

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Conclusion/Recommendations

- Sentinel 1 for flood monitoring particularly during monsoon season
- Interferometric Wide mode - an excellent choice for mapping riverine flooding
- IW mode has limited applications in the hilly/mountainous areas therefore high res (strip map) mode may be made available publicly
- Various sources of errors in SAR data (Foreshortening /Layover, Corner Reflections, Radar Shadows, Range Ambiguities etc) should be considered while processing data

- Special thanks to EU Copernicus Program , JAXA and USGS for provision of various datasets for flood monitoring

Thank you