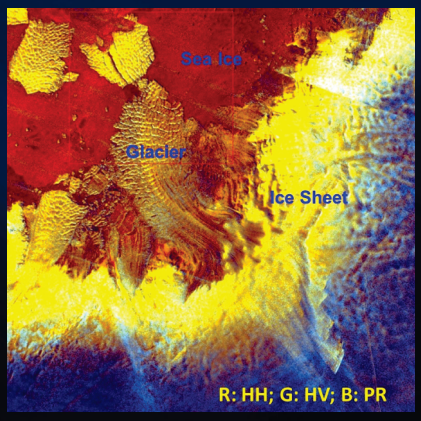
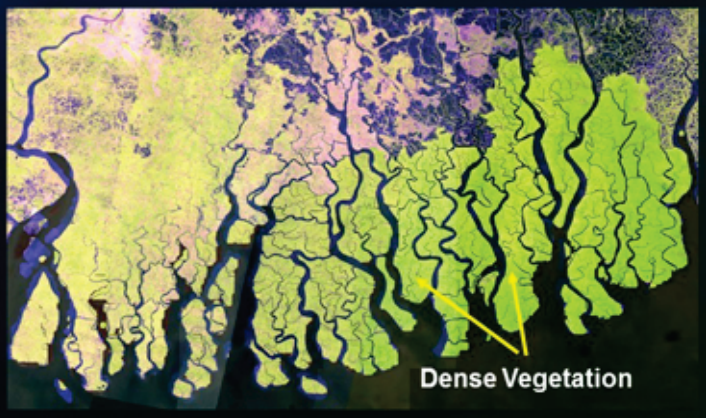
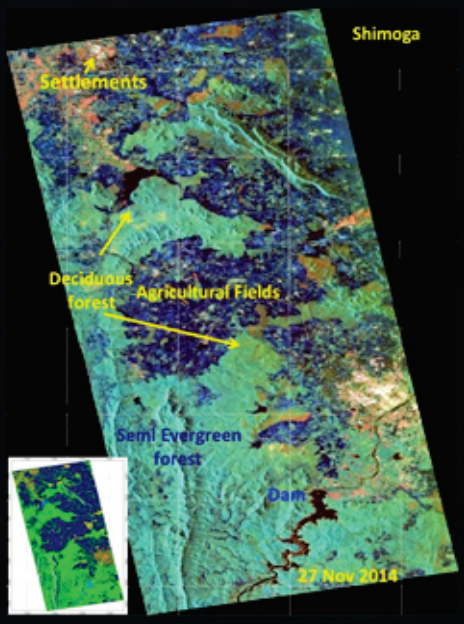
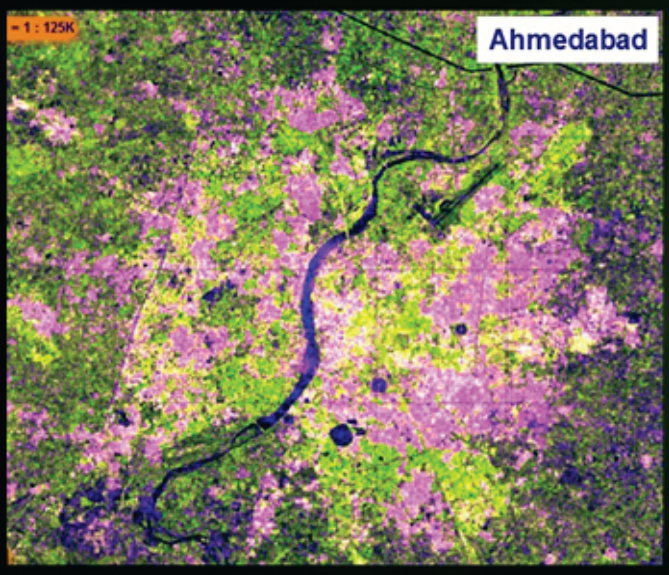
# A Glimpse of India by RISAT-1
## Part-1




**Space Applications Centre**
**Indian Space Research Organisation**
**Ahmedabad**

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# A Glimpse of India by RISAT-1

## Part-1

Prepared by
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Guidance
**Tapan Misra**

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Ahmedabad**

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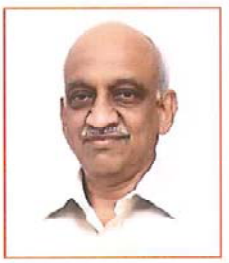
अध्यक्ष / Chairman

# FOREWORD



Microwave remote sensing program in India was initiated in the seventies with the launch of Bhaskara-1 satellite, carrying the microwave radiometer, SAMIR. India's "*Eye in the Sky*", the IRS-1A launched in 1988 marked the beginning of the earth observation activity from near earth orbit.

India, being a tropical country, has to cope with cloud cover in major parts of the country especially from June to September which limits the observations of optical and infrared sensors. Microwave sensors not only enables observation through cloud but also caters to day-night observations. ISRO has developed microwave radiometer, scatterometer and synthetic aperture radar to enhance its earth observation capabilities.

RISAT-1 with C-band SAR (Synthetic Aperature Radar) was launched in April 2012. It has captured many interesting features of earth. This compendium "A Glimpse of India by RISAT-1" is an attempt to showcase the unique features and observation capabilities of RISAT-1.

The pain taking efforts of all involved in bringing out an edition like this is highly commendable and I am sure these glimpses through the Microwave eye will trigger the imagination of the reader.

आ सी किरण कुमार

(A S Kiran Kumar)
December 22, 2016

सत्यमेव जयते

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***तपन मिश्रा***
***निदेशक***
*Tapan Misra*
*Director*


# *PREFACE*

I have experienced and witnessed the difficulties during the gestation period of SAR during the eighties and nineties. The program started off with the design and development of Airborne SAR system. This laid the foundation stone for conceiving the mammoth RISAT-1 SAR system which is no doubt the state of the art technology. When RISAT-1 was launched on April 26, 2012, it was a moment of joy and glory for all ISRO scientists.

I am overwhelmed on seeing the application potential of RISAT-1 under the umbrella -***"A Glimpse of India by RISAT-1"***. This volume has attempted to bring out a plethora of application areas arising out of the various modes of data acquisitions of RISAT. Exquisite images of the dual frequency, as well as hybrid polarimetric modes, are clear indicators of the application potentials of SAR. The areas cover Kashmir to Kanyakumari, and Dwarka to Arunachal Pradesh.

I personally feel that this volume - ***"A Glimpse of India by RISAT-1"*** will give a snapshot of images for various types of applications, which will help researchers to visualize the domain of research, and ignite their scientific interest.

Tapan Misra

Date: 12 Dec 2016
Place: Ahmedabad

(तपन मिश्रा)
(Tapan Misra)

# Acknowledgements

*We express our gratitude to Shri. A. S. Kiran Kumar, Chairman ISRO & Secretary DOS for motivating us in bringing out this volume for RISAT-1. We would like to place on record our deep sense of gratitude to Shri Tapan Misra, Director, SAC for his encouragement and guidance in bringing out this volume. We are thankful to Dr B S Gohil, Former Deputy Director, EPSA and Dr Raj Kumar, Deputy Director, EPSA for their valuable guidance and suggestions. Thanks are also due to Shri D Dhar, Dr Prakash Chauhan, Dr A S Rajawat for their whole hearted support. We would also like to thank Shri Shashikant A Sharma, Dr Markand Oza and the entire VEDAS team for hosting the RISAT-1 mosaic at VEDAS. We also put on record our sincere thanks to all those who directly or indirectly helped us in this work.*

*Jayaprasad P and Arundhati Misra*

# Contents

# Prologue

India's space borne Synthetic Aperture Radar (SAR), Radar Imaging SATellite (RISAT-1), is a state of the art Microwave Remote Sensing Satellite operating in C-band (5.35 GHz). It was launched on 26th April 2012. RISAT-1 was designed to cater to a wide variety of applications for the benefit of the society at large and to infuse enthusiasm amongst the scientific community to take up challenging R&D activities using the whole gamut of data in various mode combinations.

The first volume titled "A Glimpse of India by RISAT-1: Part-1", brings out the glimpses of utilisation potential of RISAT-1 with respect to various applications. It also envisages some of the new applications that can be taken up with future RISAT series. Applications are shown with respect to different themes. The broad themes of applications, where RISAT-1 play a specific role in terms of its viewing capabilities, are demonstrated in this document. The images are taken from RISAT-1 India Mosaic, Antarctic Mosaic and from individual scenes. The modes used for this volume are CRS, MRS and FRS-1. Thus a wide variety of applications of medium and high resolution, and with various polarization combinations, have been used to show the potential of such data sets.

# RISAT-1 SAR Specifications

| Salient Features of RISAT-1 Spacecraft | |
|---|---|
| Frequency (GHz) | 5.35 |
| Orbit altitude (km) | 536 |
| Orbit inclination (°) | 97.552 |
| Orbit period (min) | 95.49 |
| No. of orbits per day | 14 |
| Repetivity (days) | 25 |
| Look Angle of operation (°) (selectable) | 9 - 47 |
| Antenna size (m) (azimuth × range) | 6 × 2 |
| Swath (km) | 10 – 220 |
| Spatial Resolution (m) | 1 - 50 |
| Pointing accuracy (°) | 0.05 |
| Drift rate (°/sec) | $5.0 \times 10^{-5}$ |
| Attitude knowledge (°) | 0.02 |

# RISAT-1 SAR Specifications cntd..

## RISAT-1 Image Quality Parameters

| Mode / Specs | HRS/ C-HRS | FRS-1/ C-FRS-1 | FRS-2 | MRS/ C-MRS | CRS/ C-CRS |
|---|---|---|---|---|---|
| Resolution (azimuth *range) (m) | 1 x 0.7 | 3 x 2 | 9 x 4 | 21-23 x 8 | 41-55 x 8 |
| Swath (km) | 10x10 | 25 | 25 | 115 | 223 |
| Polarisation | SP/DP/CP | SP/DP/CP | QP | SP/DP/CP | SP/DP/CP |
| SP: HH/HV/VV/VH; DP: HH+HV; VV+VH; QP: HH+HV+VV+VH; CP: RH/RV | | | | | |
| Swath coverage | Selectable within 107–659 km off-nadir distance on either side | | | | |
| Incidence angle coverage | 12°–55° | | | | |

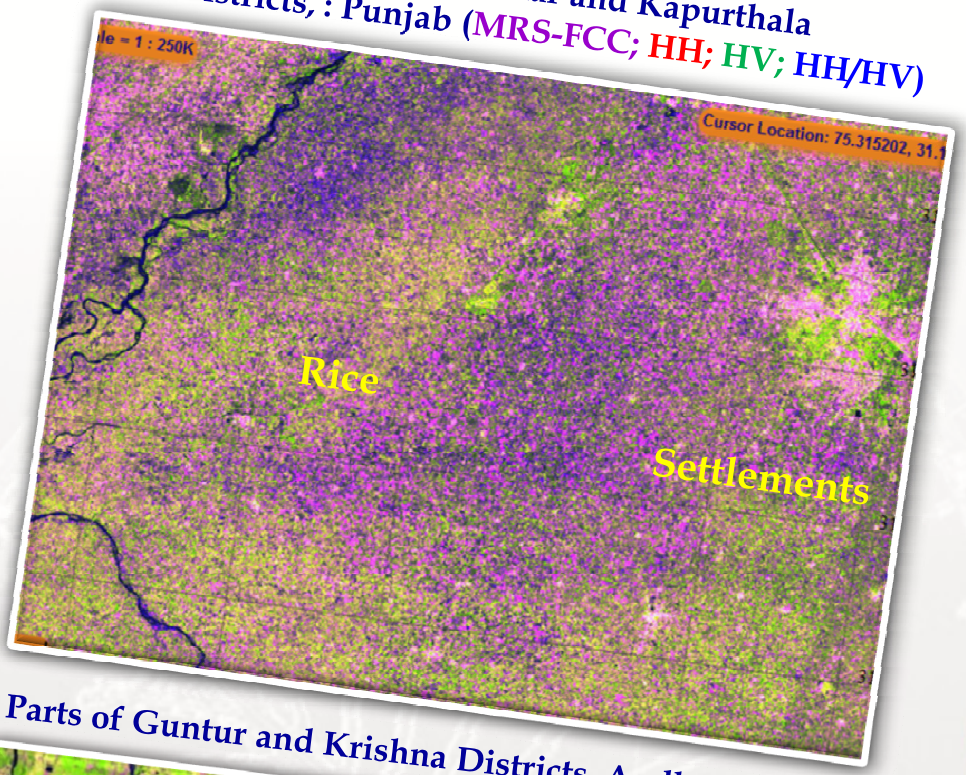
# Agriculture

In India, the major component of economy is provided by agricultural crops. About 48% of the geographical area is under cultivation, which is the highest in the world. Most of the agriculture is done during the monsoon which is a major constraint for optical remote sensing data due to cloud cover. The sensitivity of SAR to canopy geometry and moisture provide complementary information for crop discrimination and condition assessment hence SAR has the potential to improve crop discrimination and parameter retrieval. The polarization of the signal, horizontal (co & cross) or vertical (co & cross) also dictates which components of the vegetation and soil contribute to the total amount of energy scattered back to the SAR sensor. The potential of Synthetic Aperture Radar (SAR) in discriminating different agricultural crop types has been demonstrated in several studies, especially for rice and jute mapping and monitoring. Successful use of multi-temporal SAR data for rice, wheat, cotton and groundnut crop monitoring has been demonstrated by a number of investigators in the world. The accuracy of classification depends on the sensitivity of the backscattering coefficients to the differences of the biomorphological structures of the plants, hence to the different interaction behaviour between the electromagnetic wave and the structure of the canopy.

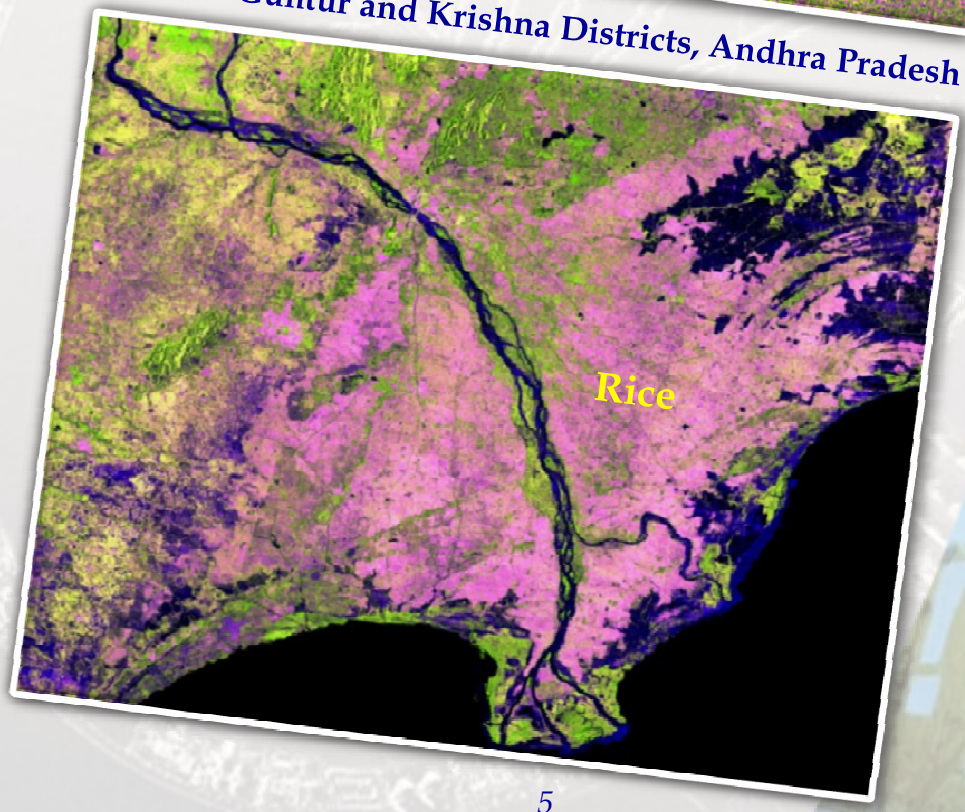
Theme "Agriculture" is one of the most important beneficiaries of RISAT-1 due to its all weather capability. Light pinkish tones represents paddy and greenish tint shows orchard in MRS FCC.

# Agriculture

Part of Jalandhar and Kapurthala Districts, : Punjab (MRS-FCC; HH; HV; HH/HV)

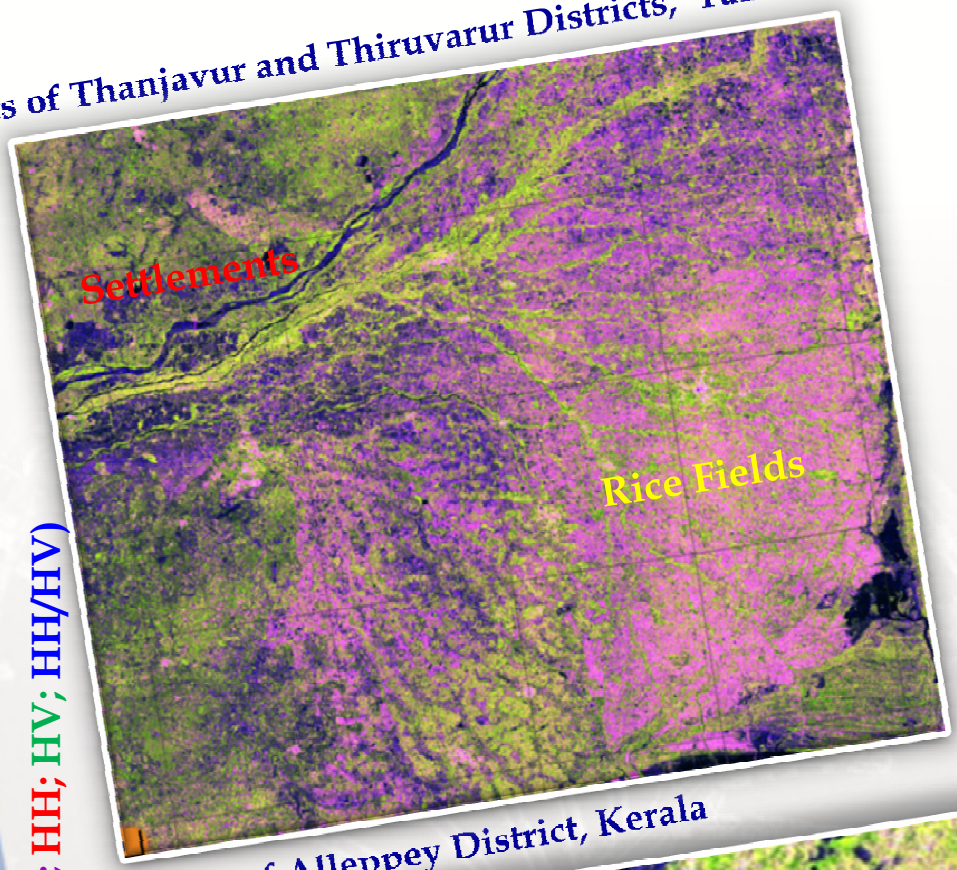



Parts of Guntur and Krishna Districts, Andhra Pradesh



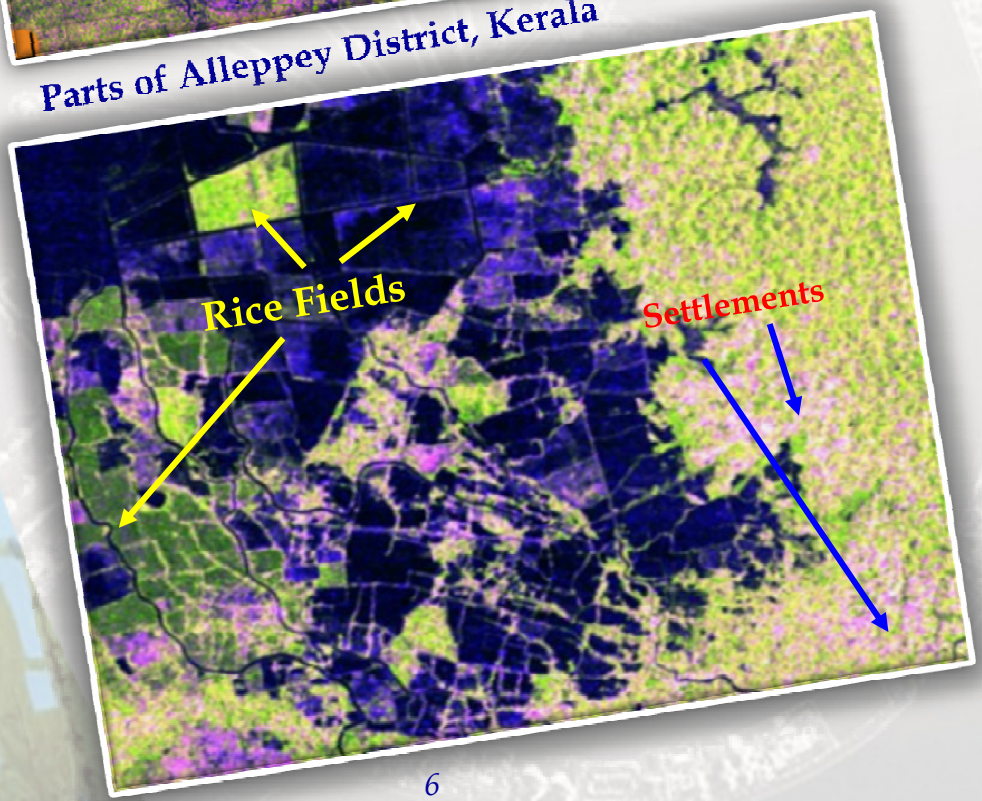
# Agriculture

Parts of Thanjavur and Thiruvarur Districts, Tamil Nadu



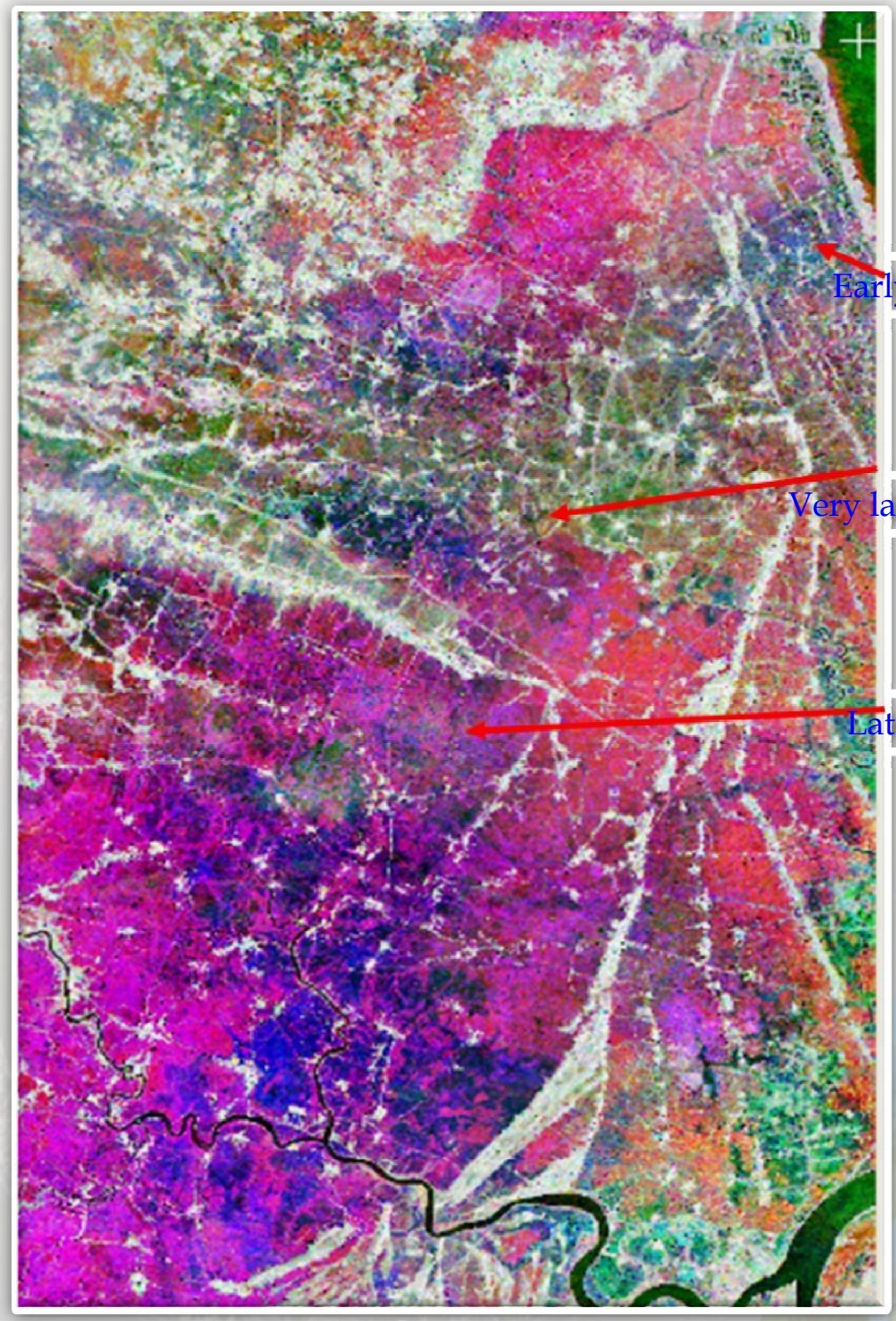

(MRS-FCC; HH; HV; HH/HV)

Parts of Alleppey District, Kerala



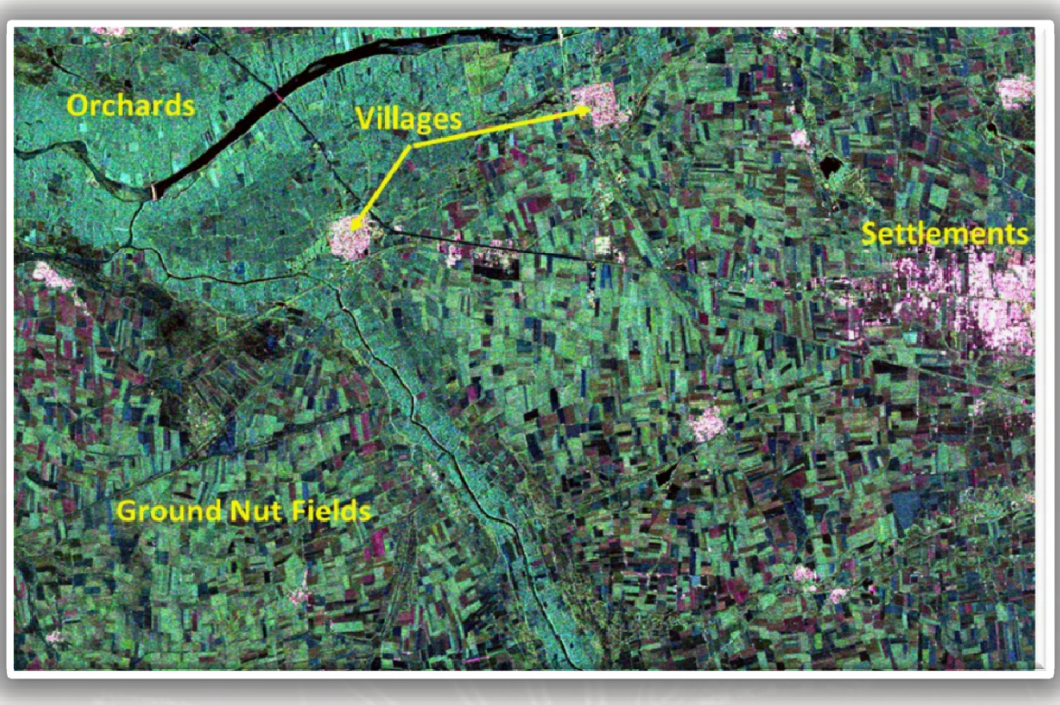
# Agriculture

**Rice Transplantation: (cFRS-1; Even; Volume; Odd)**

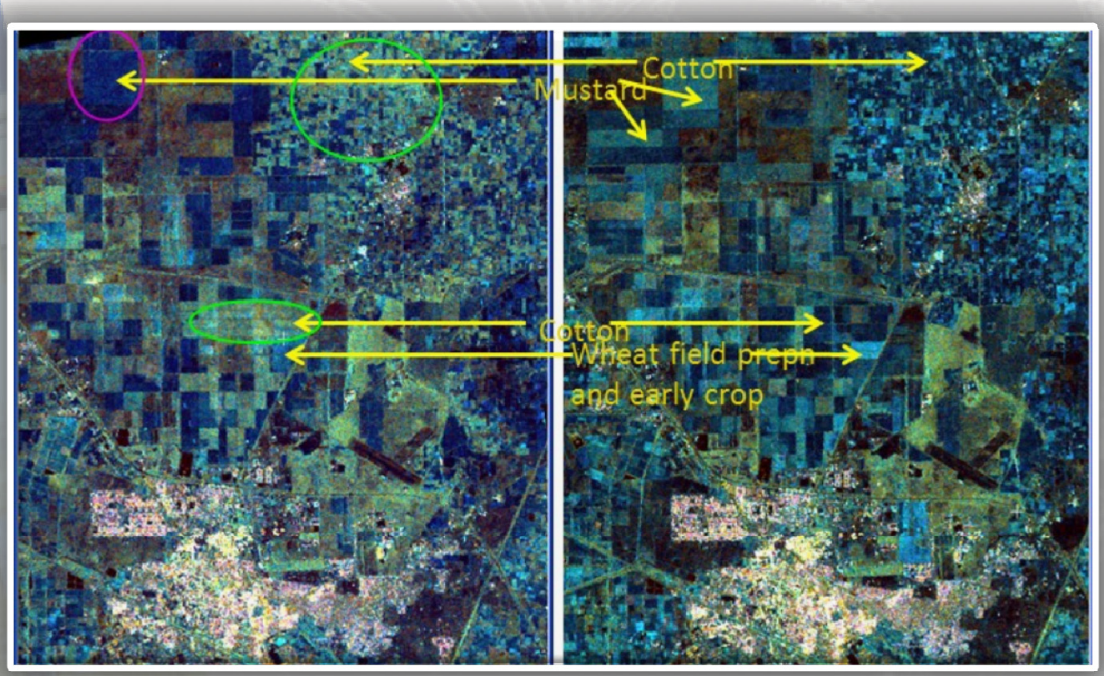


# Agriculture

## cFRS-1 Polarimetric Products
## Parts of Junagadh District, Gujarat




**M-delta decomposition image of HISAR**



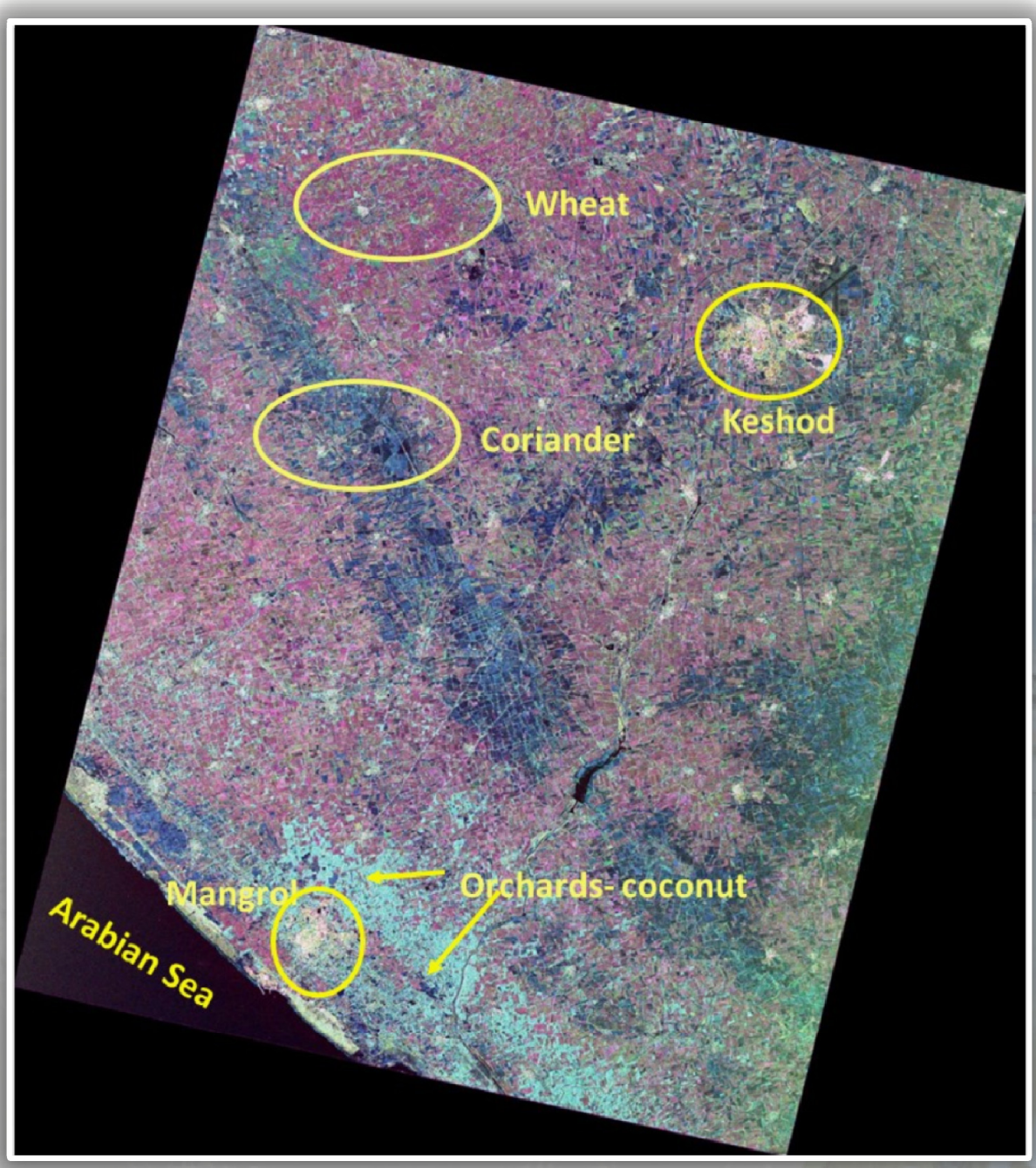

(cFRS-1; Even; Volume; Odd)

# Agriculture

**cFRS-1 M-Chi Decomposition Image: 12 Feb 2015**

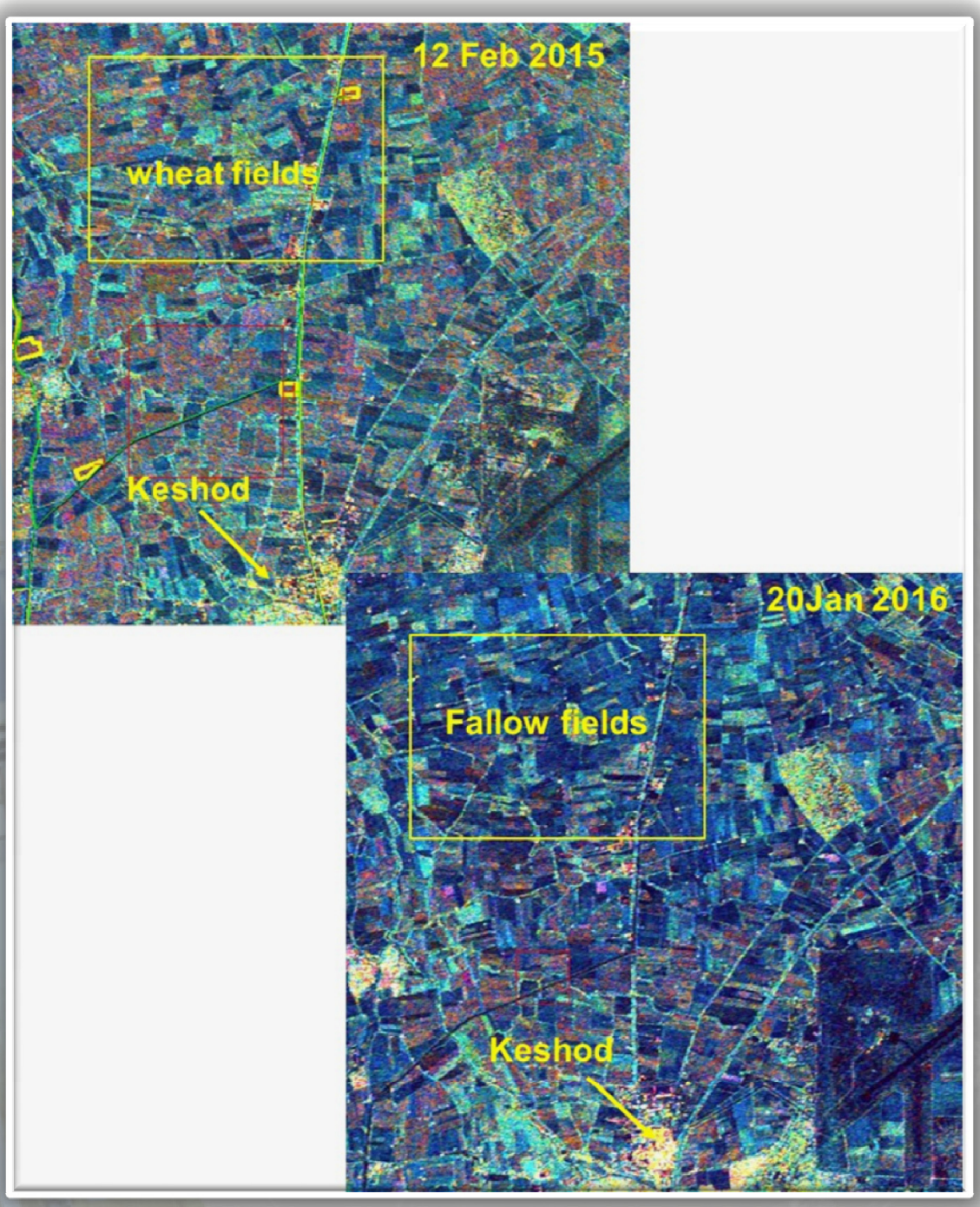
**Parts of Mangrol and Keshod, Gujarat**

**(cFRS-1; Even; Volume; Odd)**



# Agriculture

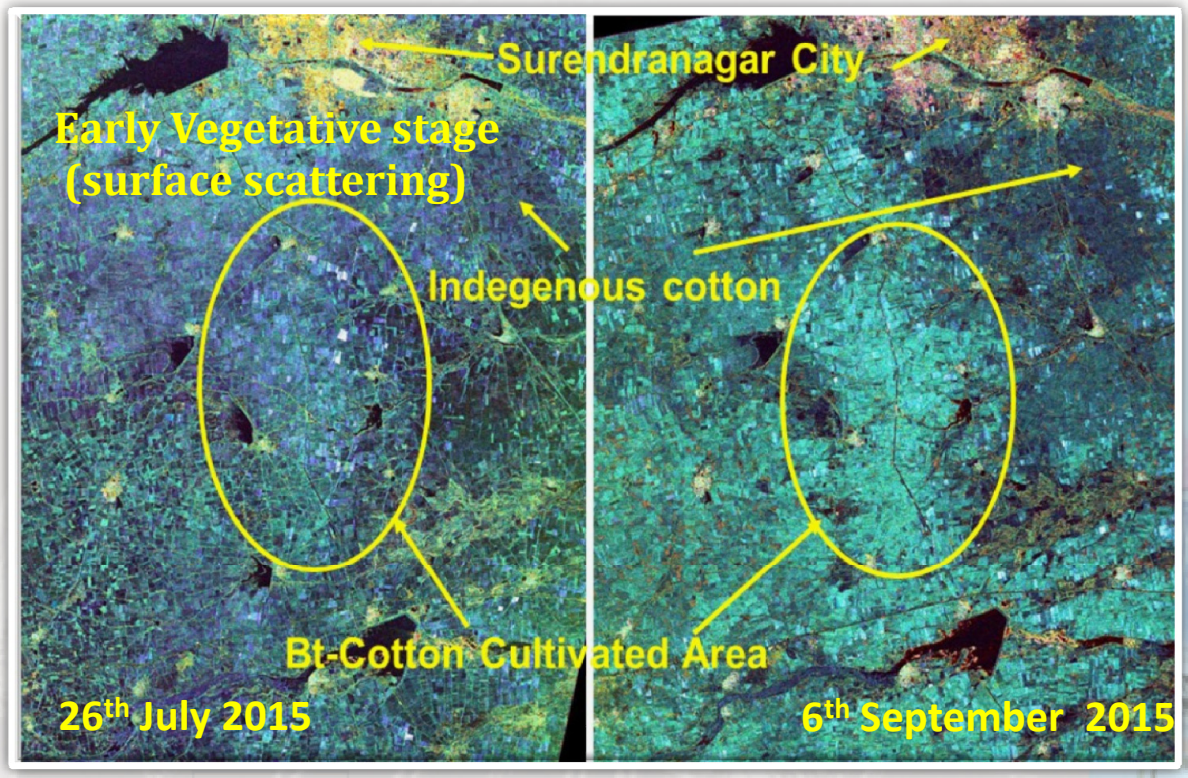
**cFRS-1 M-Delta Decomposition Image**
**(cFRS-1; Even; Volume; Odd)**



# Agriculture

## Parts of Surendranagar District, Gujarat
## Cotton Fields

(cFRS-1; Even; Volume; Odd)



# Forest

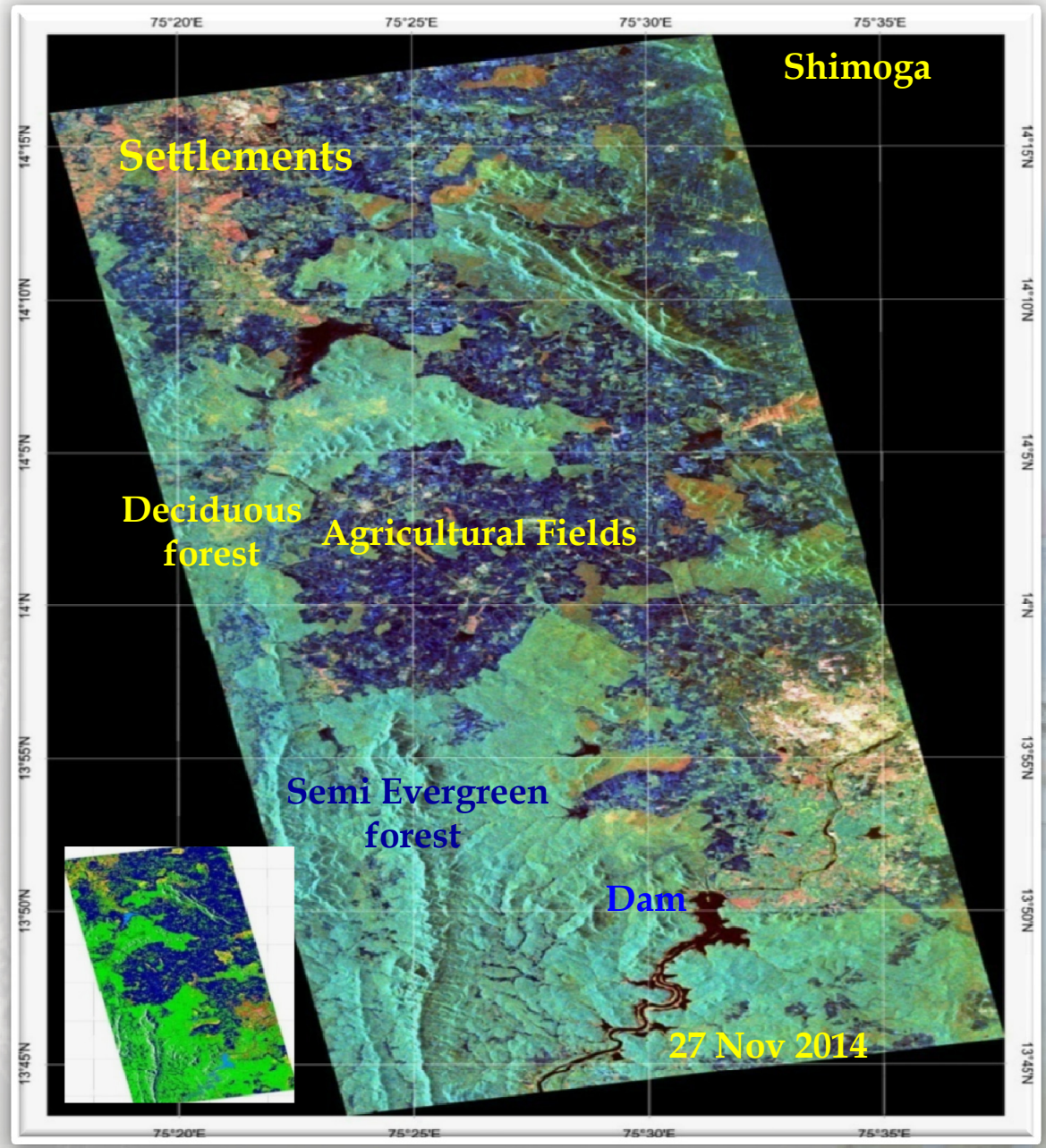
Accurate measurement of vegetation biomass of forests and wetlands, and monitoring the changes in vegetation due to natural as well as anthropogenic activities is vital for estimation of terrestrial carbon stock and carbon fluxes from forest and wetland ecosystems which has major bearing on the regional and global climate change studies. The potential of radar remote sensing for the retrieval of vegetation parameters is being established through research using available and past space borne SAR data. One of the areas of research relates to the retrieval of vegetation parameters specific to forest and wetland. This is due to the capability of SAR to provide more dynamic range for vegetation growth variables as compared to optical data. Further SAR in interferometric and polarimetric mode provides additional input like tree structure, height, age, vegetation change etc.

The radar backscatter at C and L band have been found to be significantly correlated with tree density, biomass and volume, as they penetrate below the crown. Forest vegetation shows distinct scattering mechanisms such as direct backscattering from crown (branch and leaves), crown-ground scattering, trunk-ground scattering and the direct scattering from the forest floor. Polarimetric measurements permit better identification of these scattering mechanisms and in turn help to resolve the electrical and geometrical properties of the targets.

# Forest

## Parts of Shimoga District, Karnataka

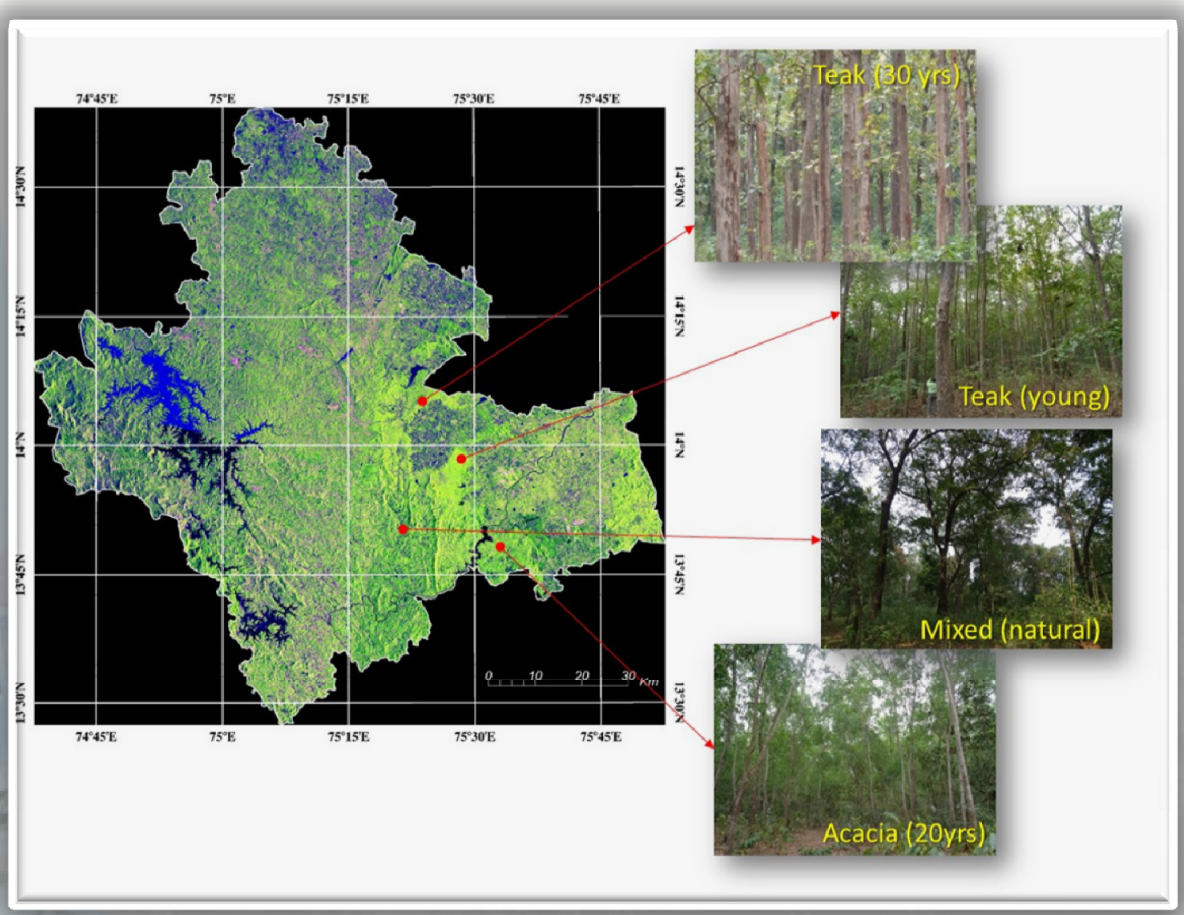
## (cFRS-1; Even; Volume; Odd)



# Forest

## Forest Vegetation: of Shimoga (Karnataka)

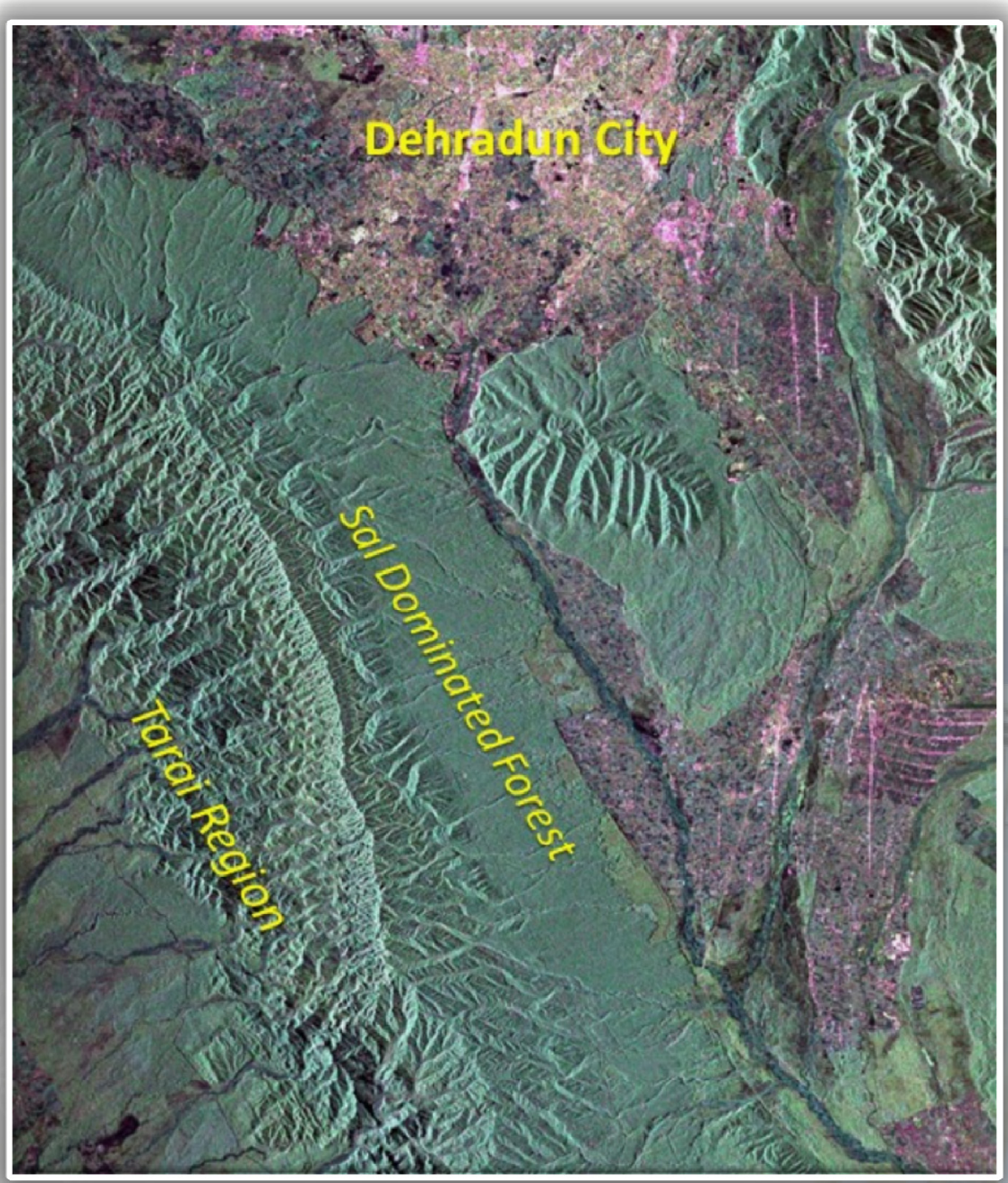
## (MRS-FCC; HH; HV; HH/HV)



# Forest

## FRS-1 Hybrid Decomposition (m-chi) Image
## Dehradun and Surroundings, Uttarakhand

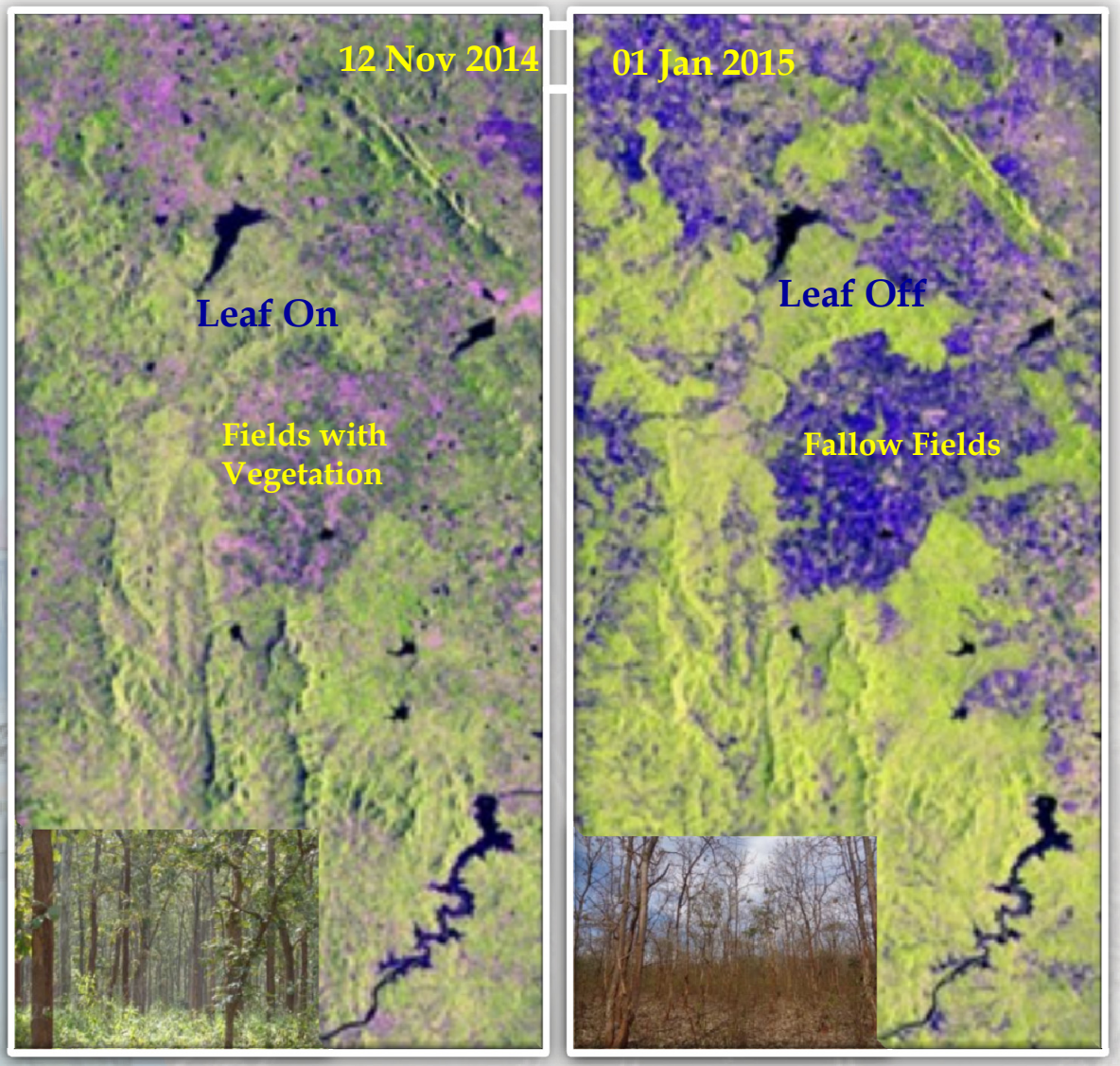
**(cFRS-1; Even; Volume; Odd)**



# Forest

## Effect of Leaf-on/Leaf-off on SAR Data

## (MRS-FCC; HH; HV; HH/HV)



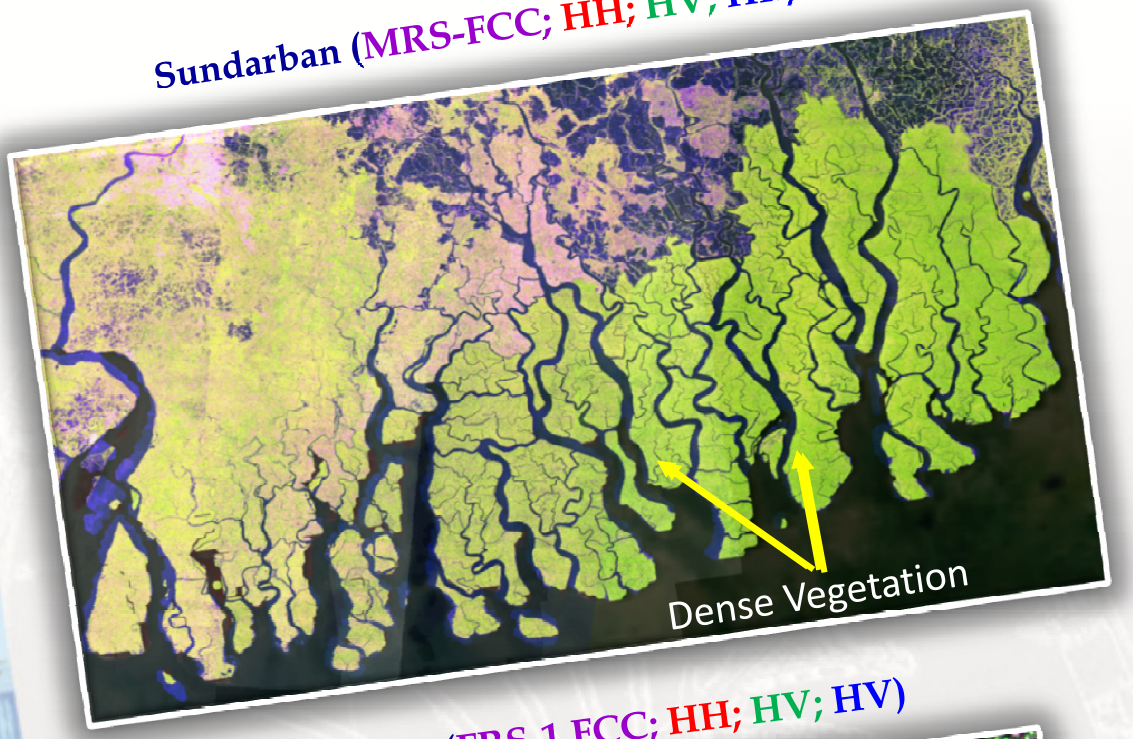
# Mangroves

Mangroves are the characteristic intertidal plant formations of sheltered tropical and subtropical coastlines. A mangrove swamp is an association of halophytic trees, shrubs, and other plants growing in brackish to saline tidal waters of tropical and sub-tropical belts. Prop-roots, knee-roots, plank buttresses, pneumatophores, sclerophyllous leaves with sunken stomata, and vivipary are some of the common adaptations.

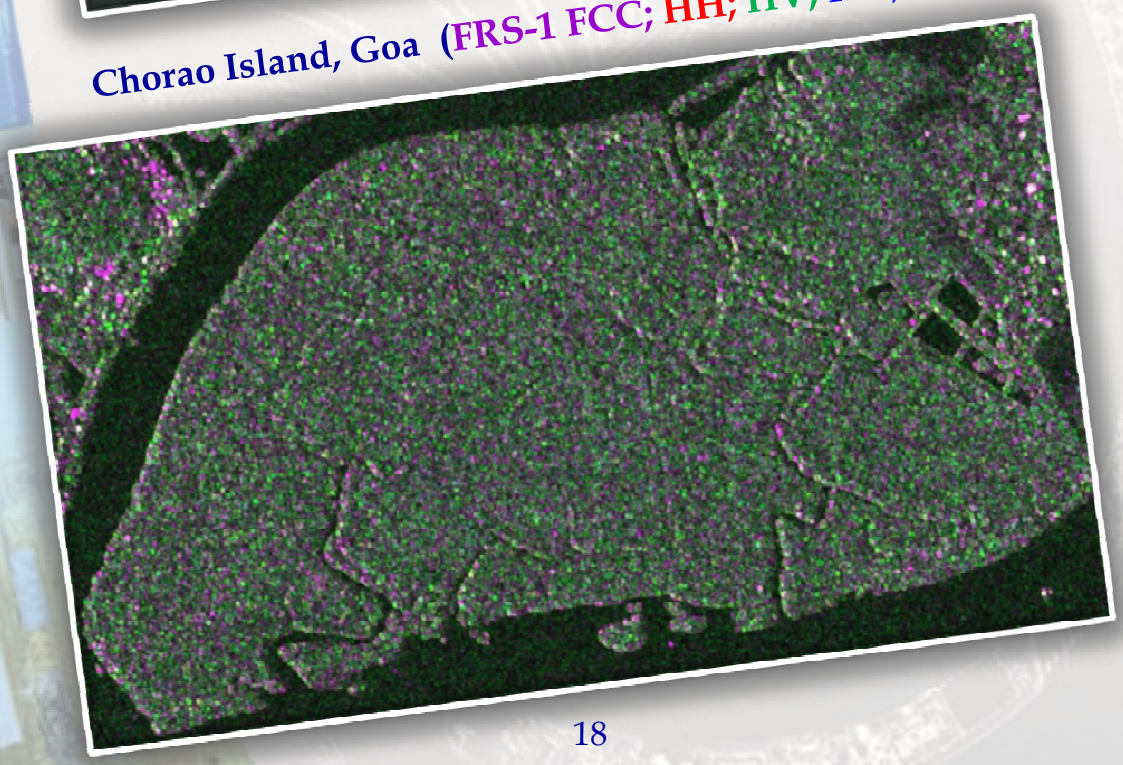
Mangroves are recognized widely for their ecological and economic functions. Mangrove wetlands play an important role in stabilizing shorelines and protect the coast by acting as barriers against storm surges and heavy tides. They are self-perpetuating littoral formations, playing a major role in the global cycle of carbon, nitrogen and sulphur. They act as sink for sediments and detritus draining from coastal catchments and help in the tertiary assimilation of wastes.

# Mangroves

Sundarban (MRS-FCC; HH; HV; HH/HV)

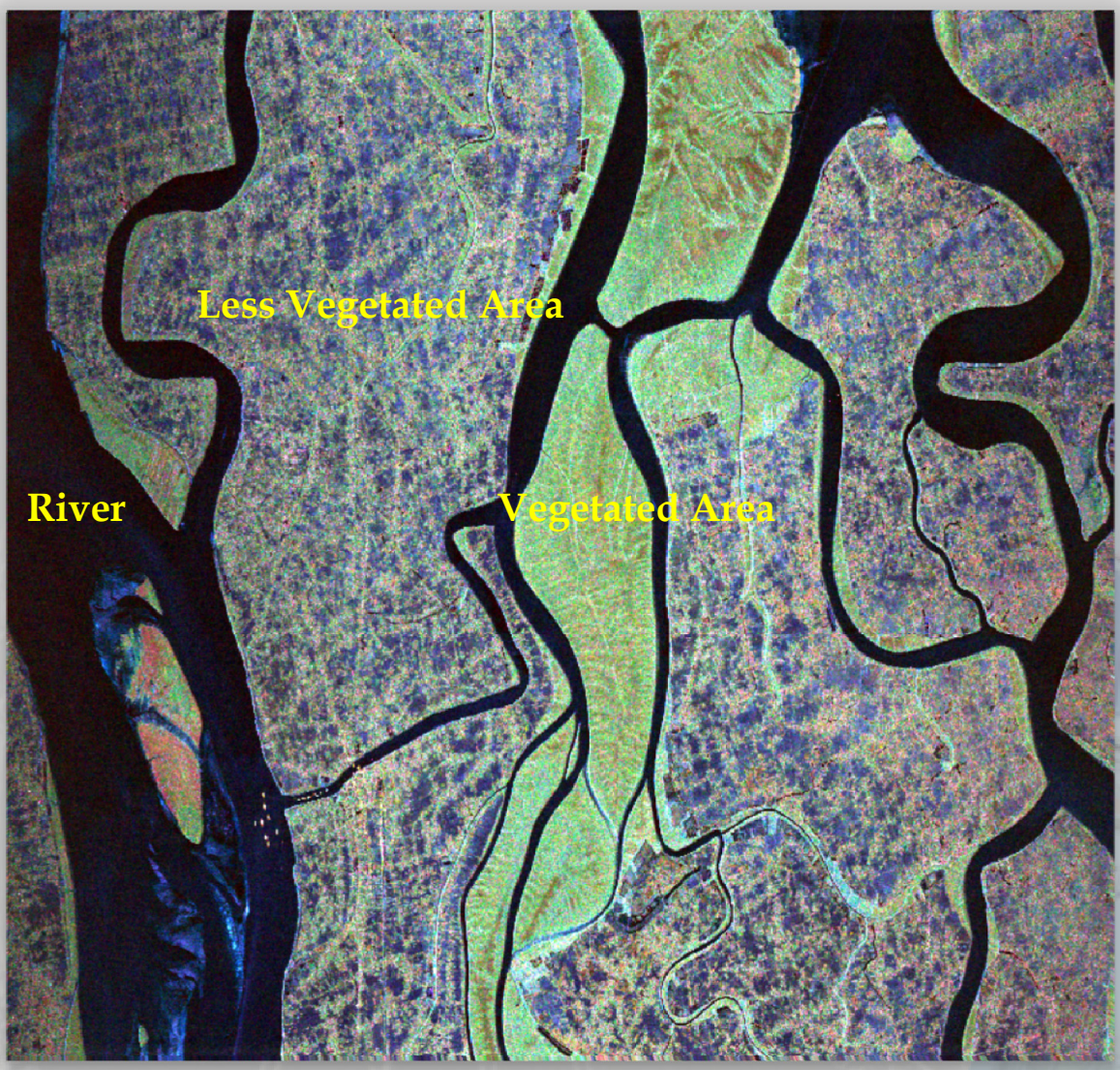



Chorao Island, Goa (FRS-1 FCC; HH; HV; HV)



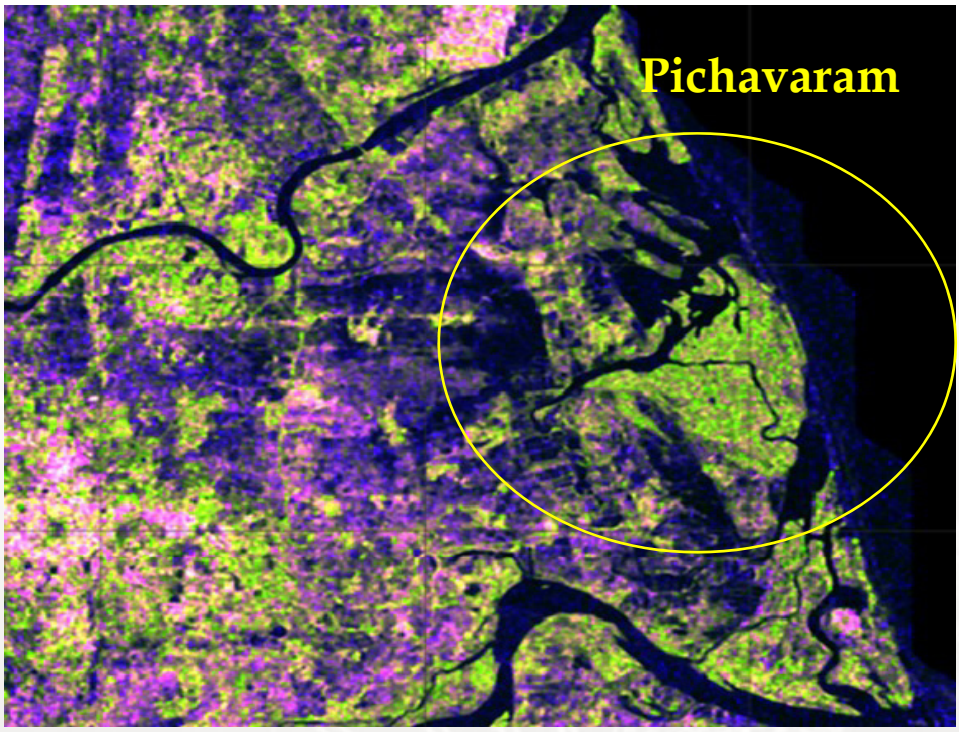
# Mangroves

**cFRS-1 Polarimetric Products**
**Parts of Sundarbans**

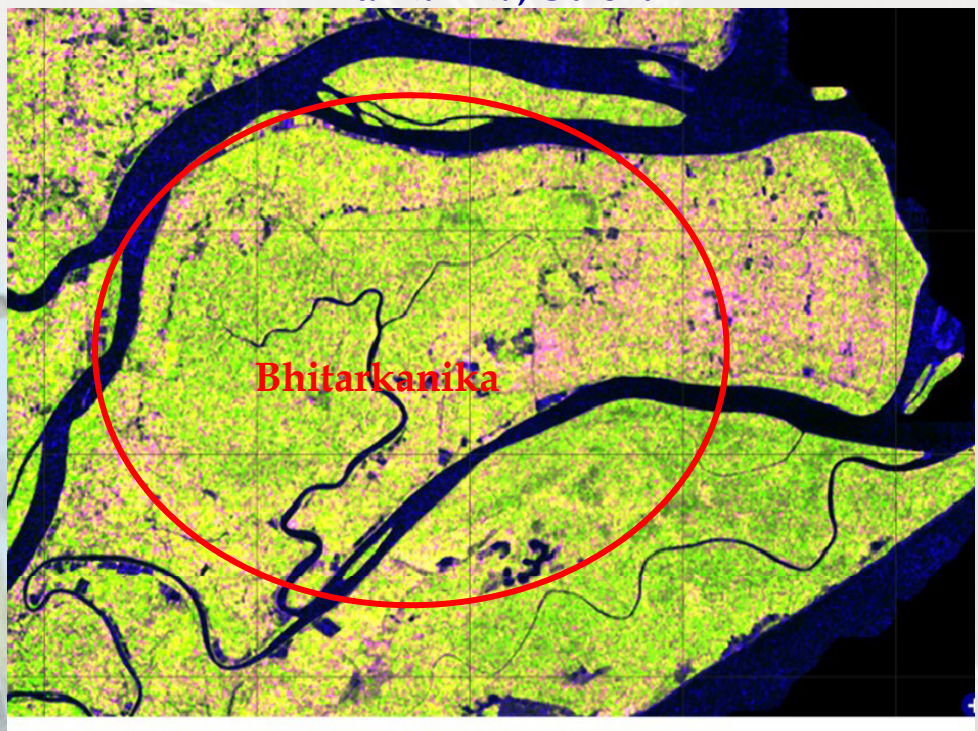


# Mangroves

Pichavaram, Tamil Nadu




Bhitarkanika, Odisha

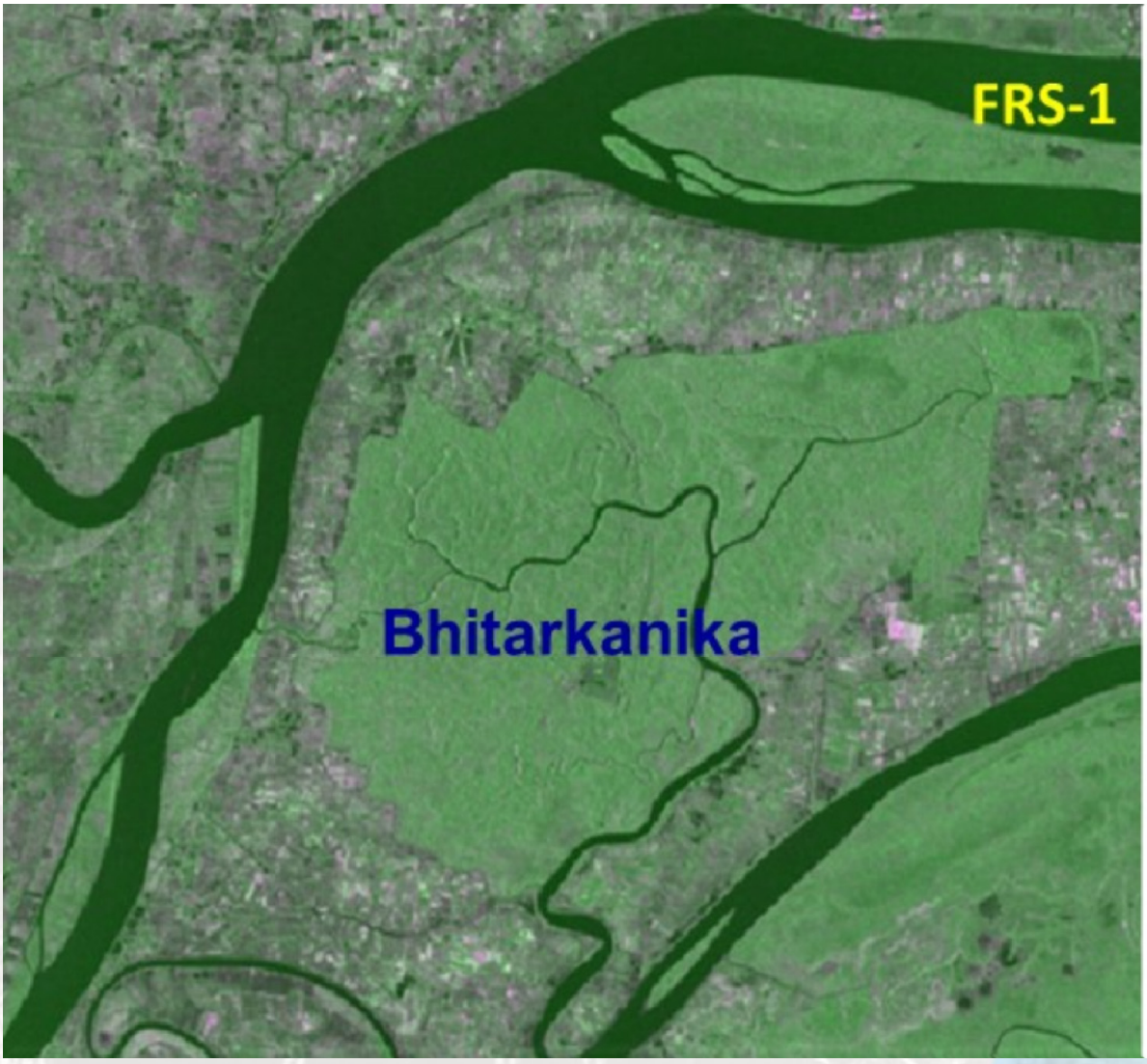



(MRS-FCC; HH; HV; HH/HV)

# Mangroves

**Bhitarkanika, Odisha**

**FRS-1 FCC: HH;HV;HH-HV**



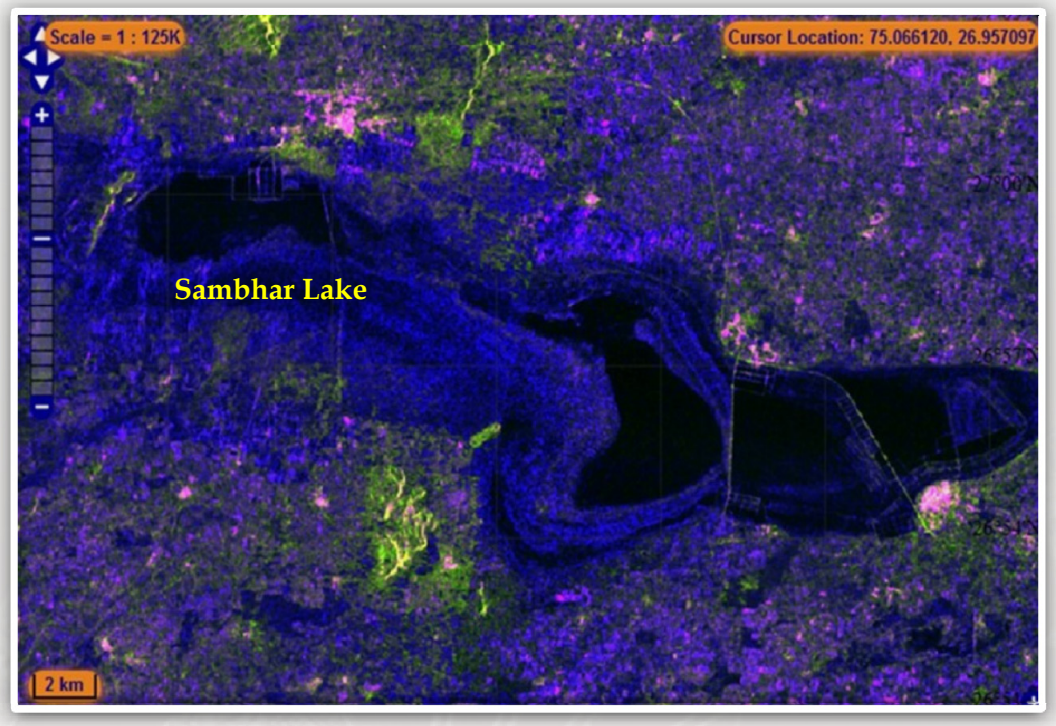
# Wetlands

Wetlands have played a major role in human history. Wetlands, whether perennial rivers or large water bodies, have always been the sites of sources of water and consequently the development of civilisations. Although they account for only about 4% of the earth's ice-free land surface they are among the most ecologically valuable ecosystems of the world in terms of productivity. The ever increasing demand for economic growth during the last half century with utter disregard for the long term ecological consequences to the human society and environment has lead to excessive exploitation of the wetlands. At this juncture, the Ramsar Convention has created a room for optimism for the conservation and restoration of wetlands.

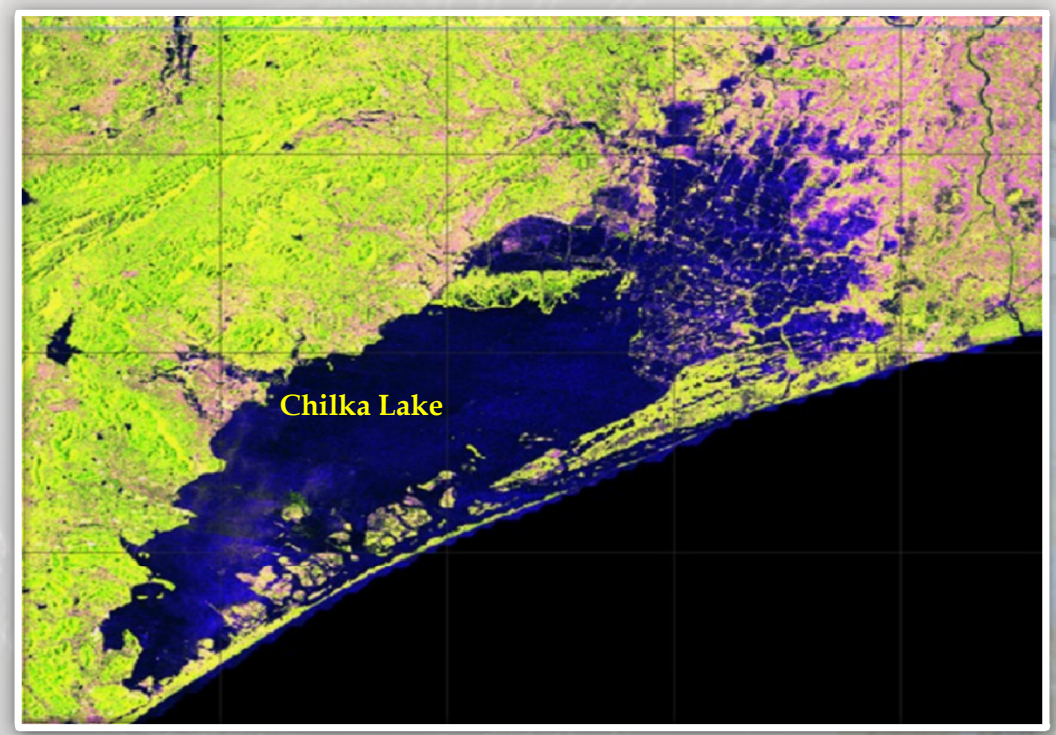
Natural Lakes and water bodies can be clearly demarcated from RISAT-1 data. The different signatures from the submerged and partially submerged vegetation also provide a clear picture of various features.

# Wetlands: Natural Lakes

## Sambhar Lake, Rajasthan




## Chilka Lake, Odisha

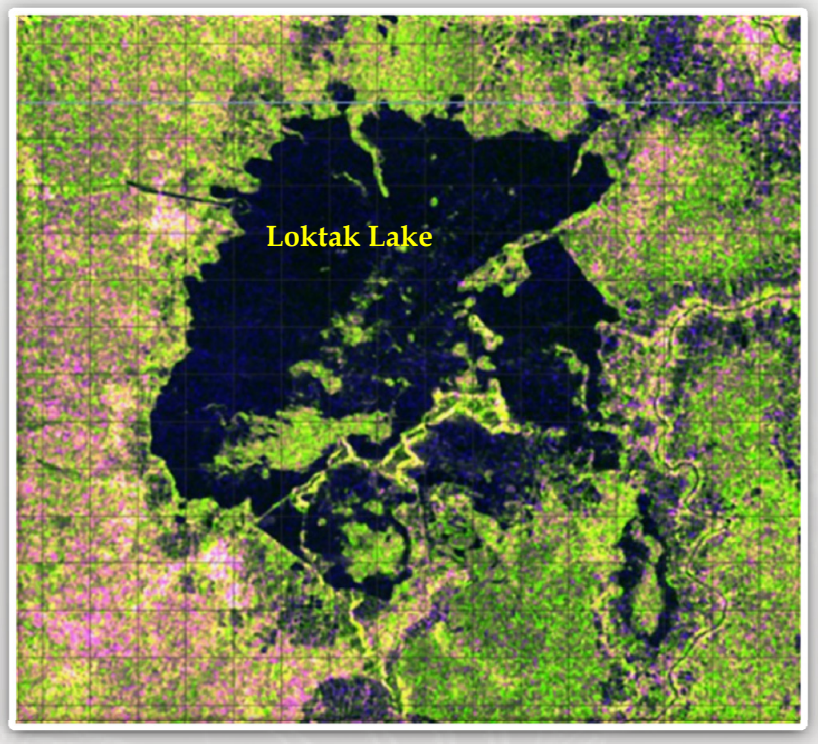



(MRS-FCC; HH; HV; HH/HV)

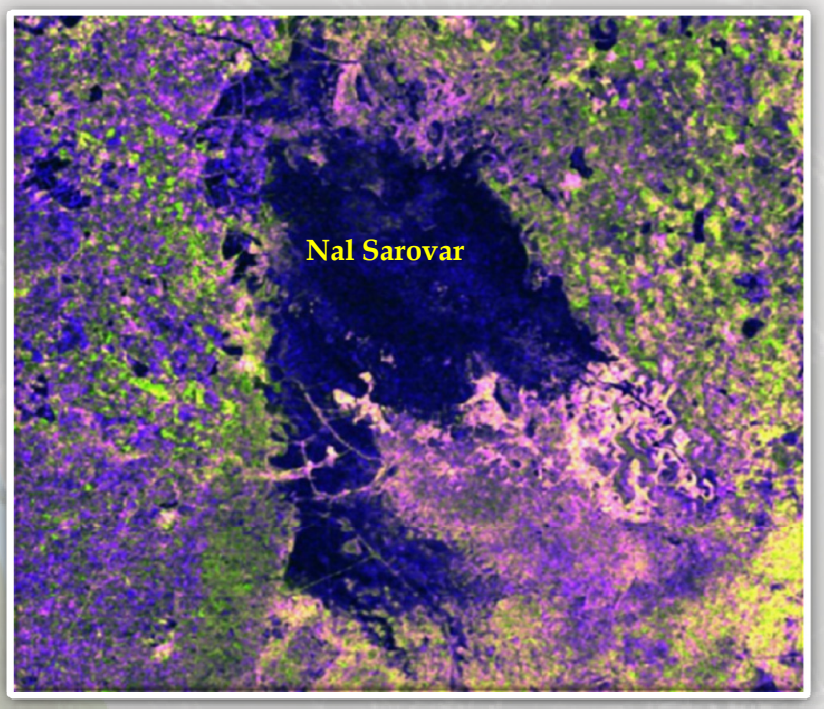
# Wetlands: Natural Lakes

(MRS-FCC; HH; HV; HH/HV)

Loktak Lake, Manipur

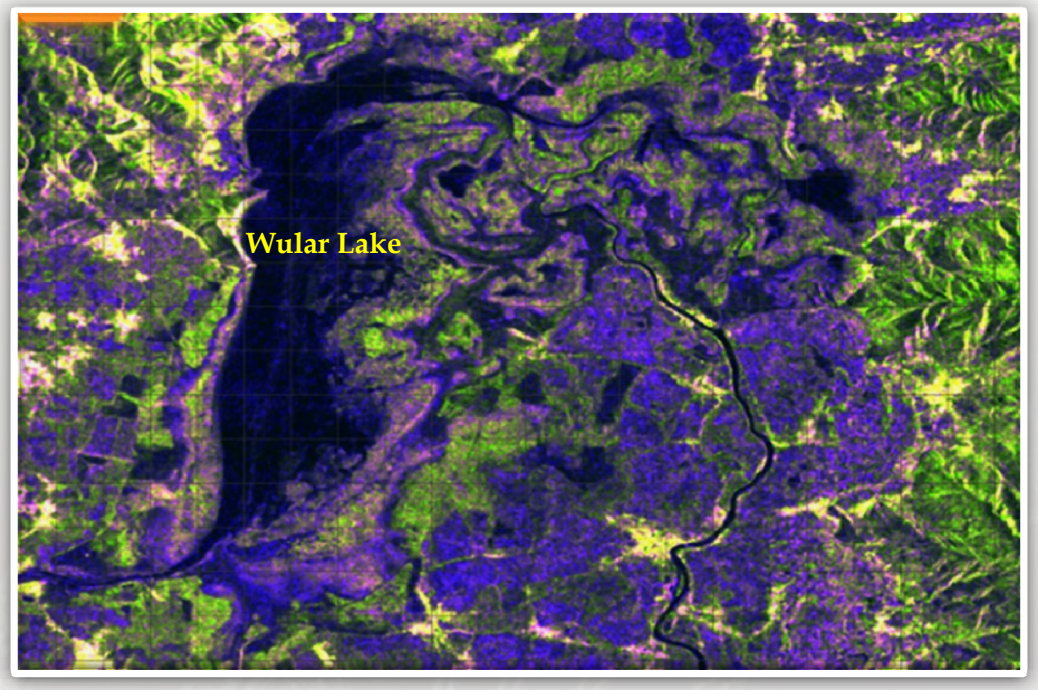



Nal Sarovar, Gujarat

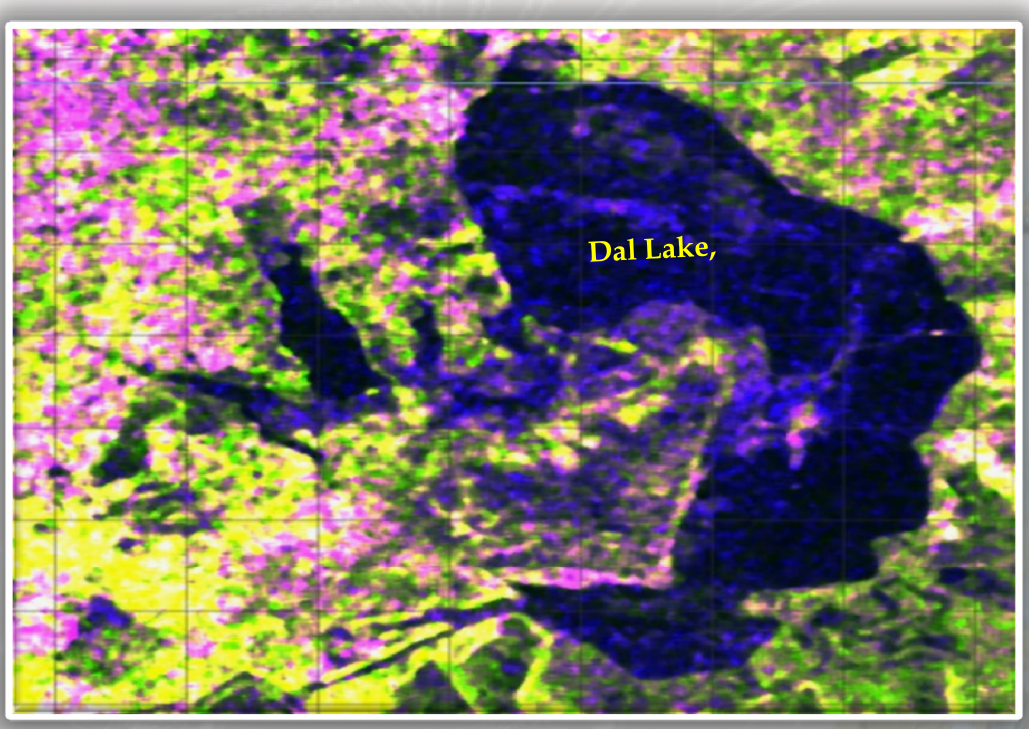


# Wetlands: Natural Lakes

## Wular Lake, Jammu and Kashmir




## Dal Lake, Jammu and Kashmir

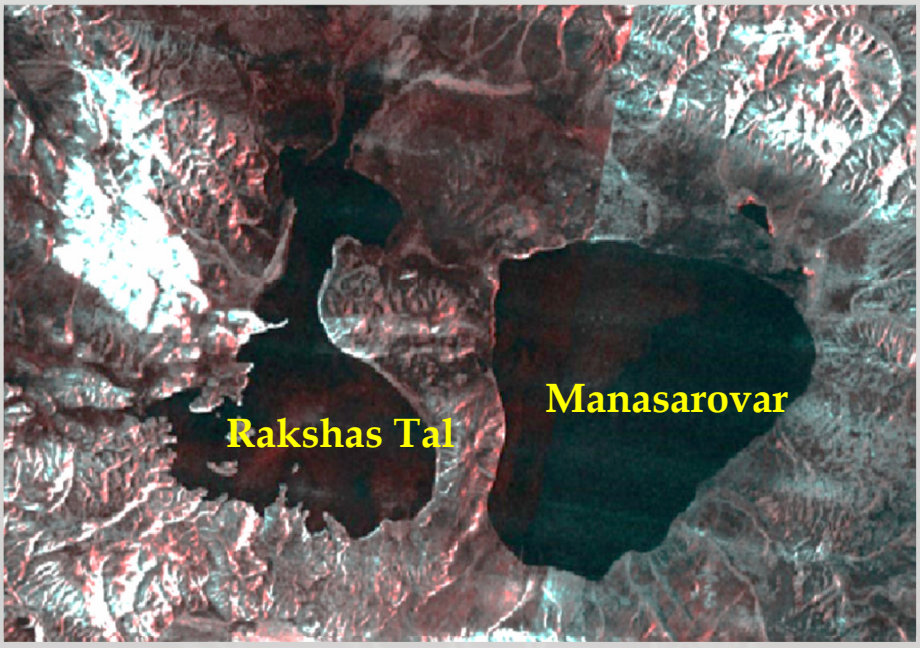



(MRS-FCC; HH; HV; HH/HV)

# Wetlands: Natural Lakes

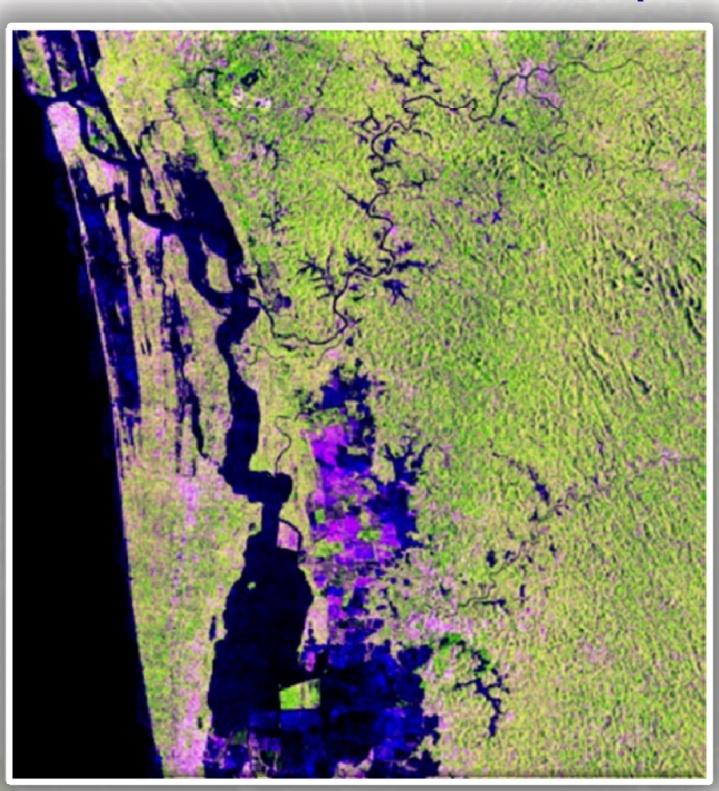
## Manasarovar and Rakshas Tal, Tibet

(MRS-FCC; HH; HV; HV)




## Back Waters of Kerala: Vembanad Kayal

(MRS-FCC; HH; HV; HH/HV)



# River Islands

**Majuli Island, Brahmaputra, Assam:**
**The Largest River Island in the World &**
**The First River Island District of India**

**(MRS-FCC; HH; HV; HH/HV)**

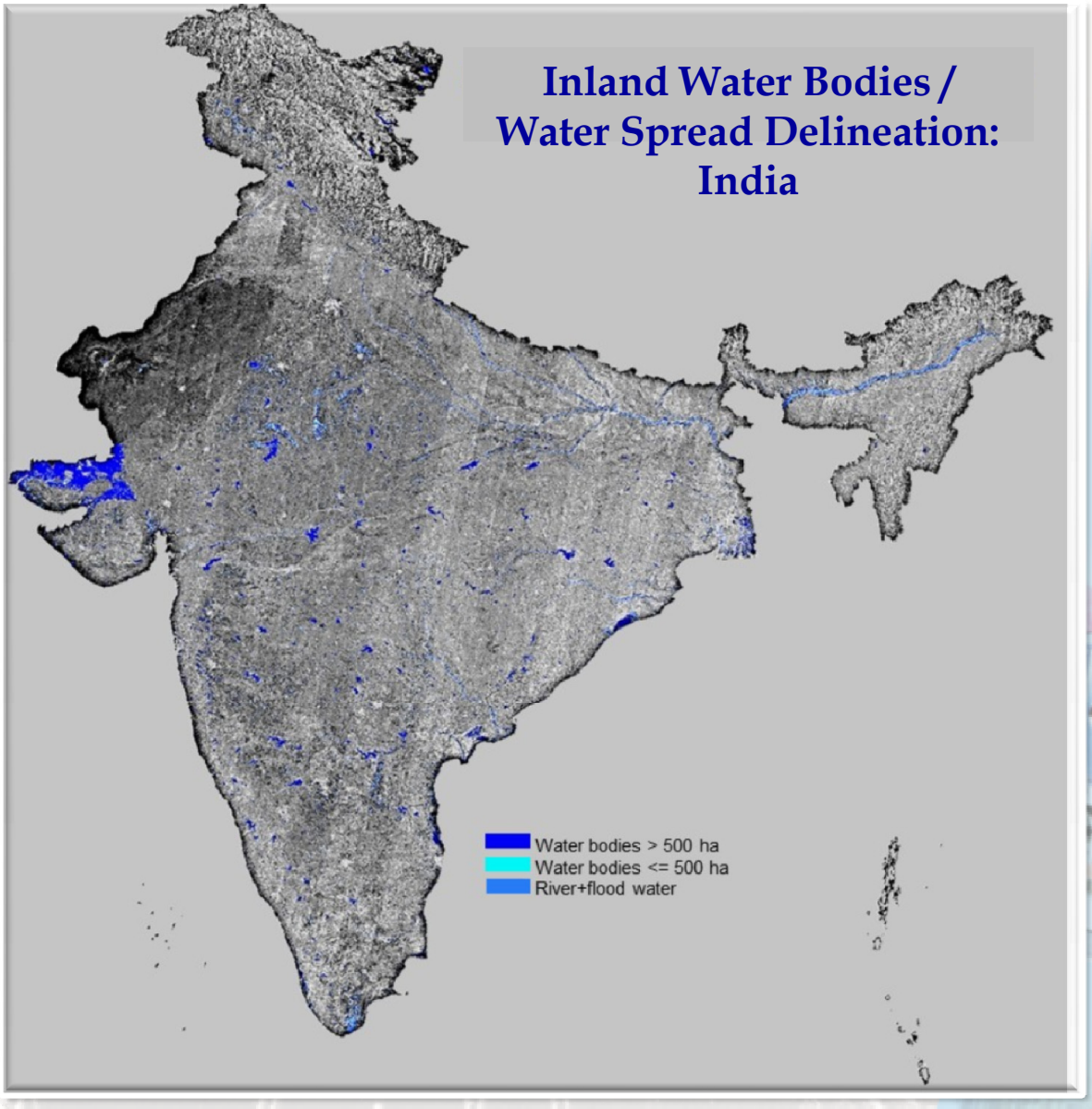
# Hydrology

Although 70 percent of the Earth's surface is covered with water, the amount of fresh water available on land surfaces is less than 1%, present in the form of groundwater, soil moisture and, river/lakes on the land surface. Water demand is growing by twice of the population growth. 1/3 of the population would be under water stress by 2025 and 2/3 of population would be under the water scarcity by 2050. Therefore, there is a need for regional satellite based observation of terrestrial surface water to diagnose where water is stored in the Earth's land surfaces, and how this storage varies in space and time?

Satellite remote sensing provides a means of observing repetitive and continuous coverage of the Earth surface and atmosphere with high spatial resolution. Microwave satellites are being used for observing hydrological state variables for the assessment and management of water resources. Such variables are rainfall, river width, reservoir/lakes/ponds water levels and spread, surface soil moisture, flood inundation areas. Some important hydrological variables which can't be measured directly but can be estimated by combining water body characteristics and hydrological hydraulic simulation models.

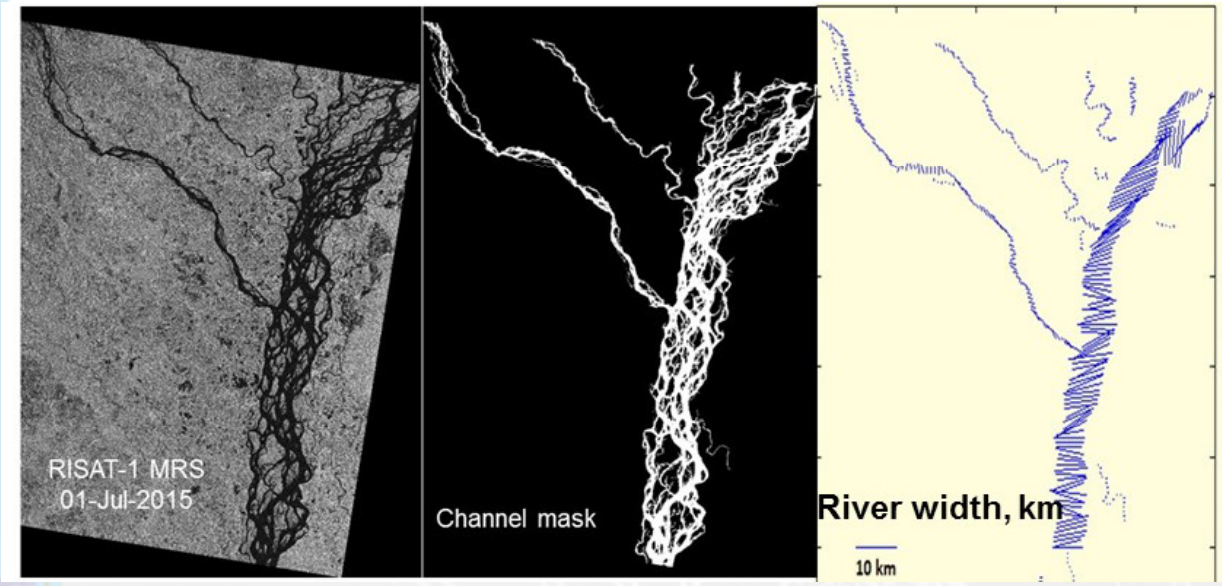
# Hydrology

## The Water Spread

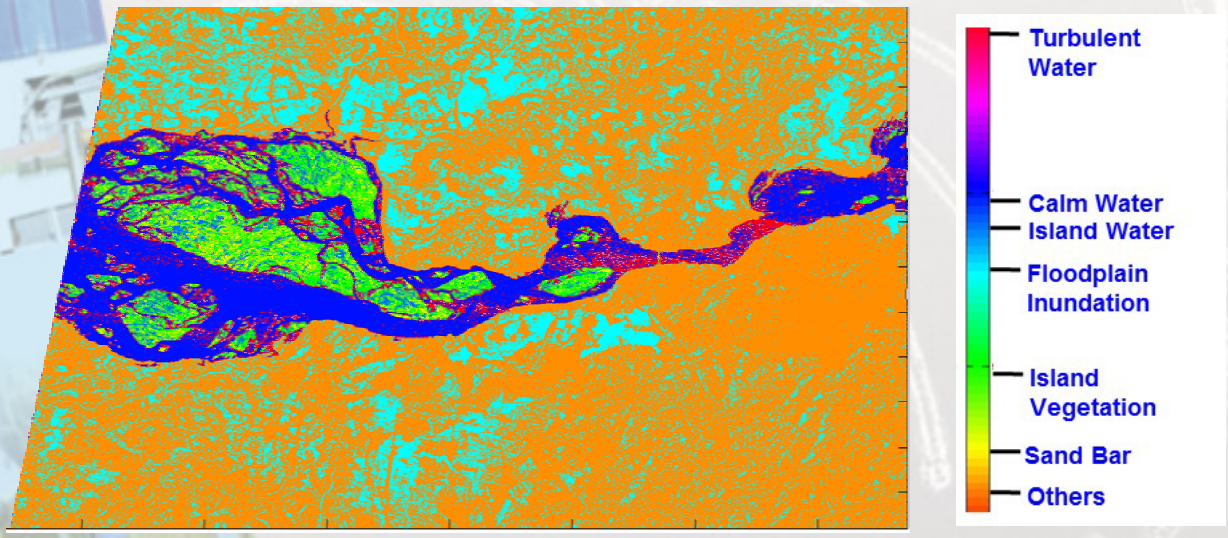


# Hydrology: River Width Brahmaputra

## Estimating River Width In Braided Rivers




## Water Spread



# Soil Moisture

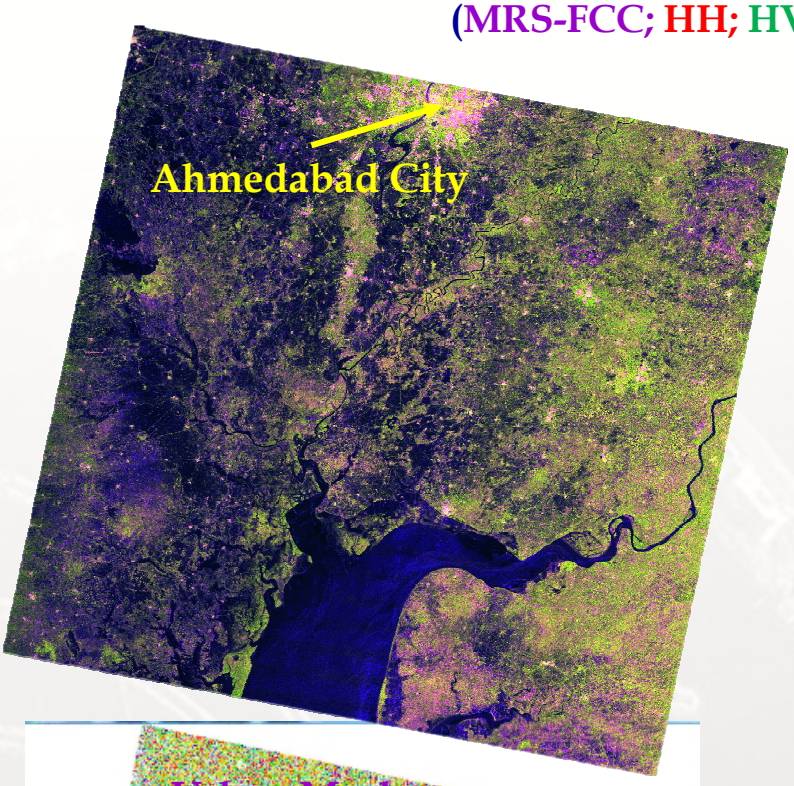
Soil moisture is a very important parameter for many of the natural resource applications. Examples are hydrological modeling, stream flow forecasting, and flood monitoring. SAR data play an important role for estimating soil moisture due to the dependence of the dielectric constant on moisture at certain microwave frequencies. The presence of vegetative cover introduces another level of complexity to soil moisture mapping due to the interaction of the microwaves with the vegetation and soil. Depending on the amount of vegetation present, its dielectric properties, height and geometry (size, shape and orientation of its components) the sensitivity of microwave backscatter to volumetric soil moisture may be significantly changed.

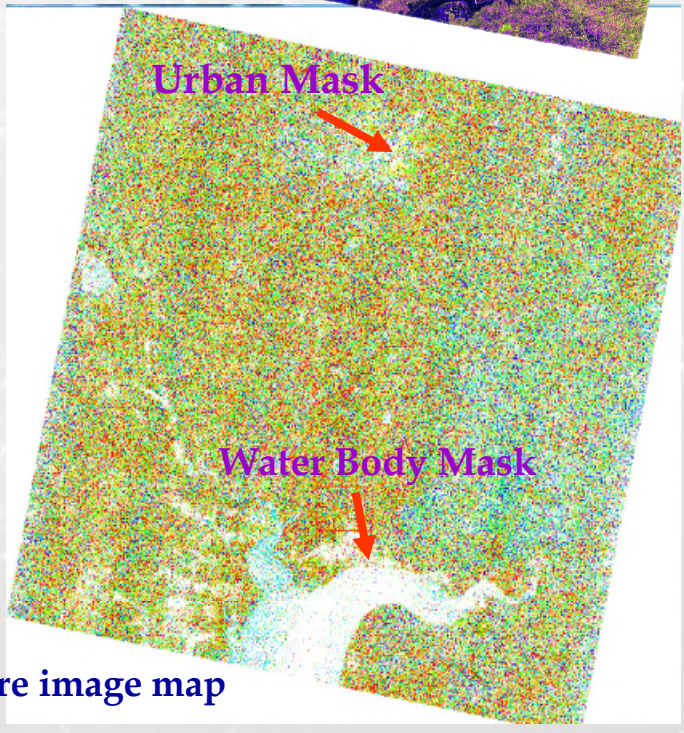
The ability to effectively map soil moisture can be improved by judicious selection of imaging parameters such as incidence angle, wavelength and polarization. Potential of C Band in the HH polarization was found to be suitable for soil moisture estimation.

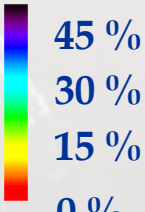
# Soil Moisture

## Ahmedabad and Surroundings, Gujarat

(MRS-FCC; HH; HV; HH/HV)



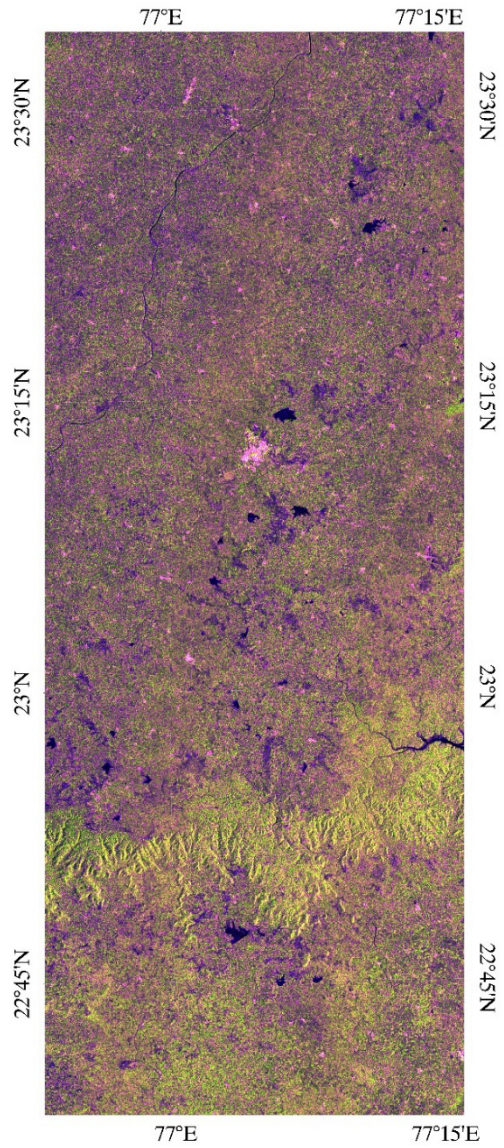




Soil Moisture image map

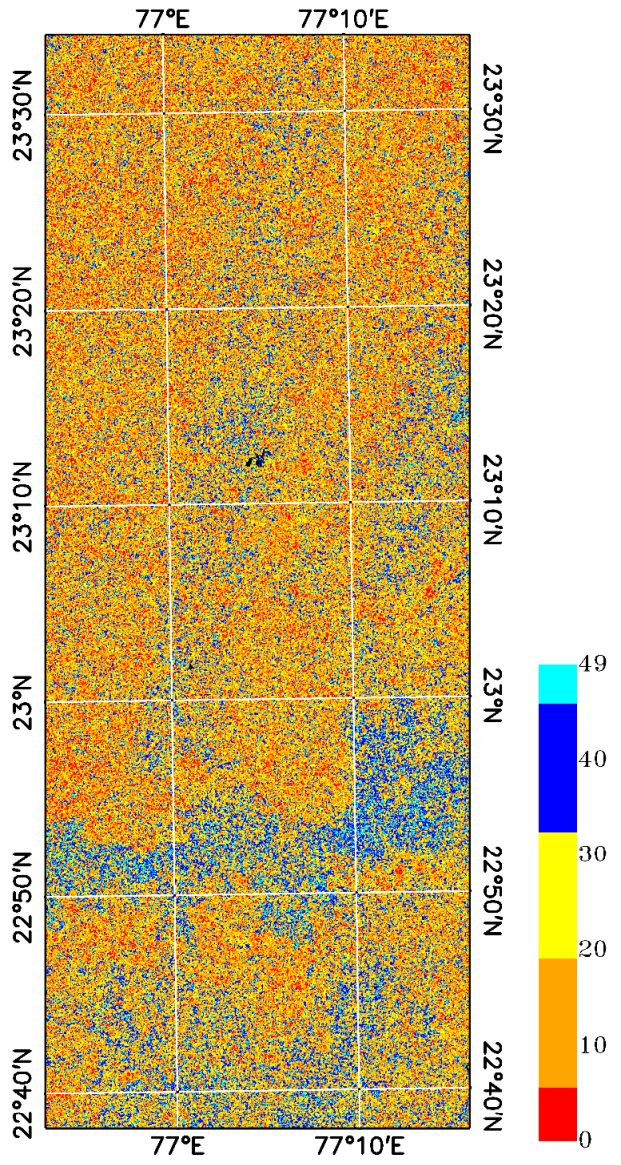
# Soil Moisture

**West of Bhopal City**
**Date of Acquisition : 1st Jan, 2015**

RISAT-1 SAR Data (RGB)




**MRS: HH; HV; HH/HV**



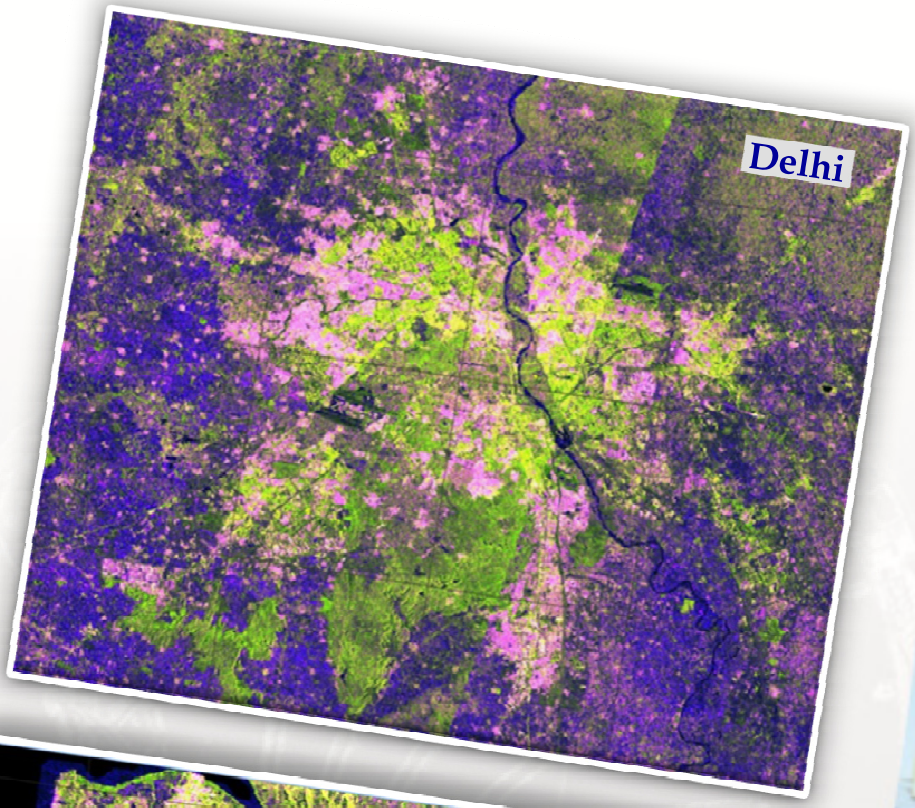
# Urban

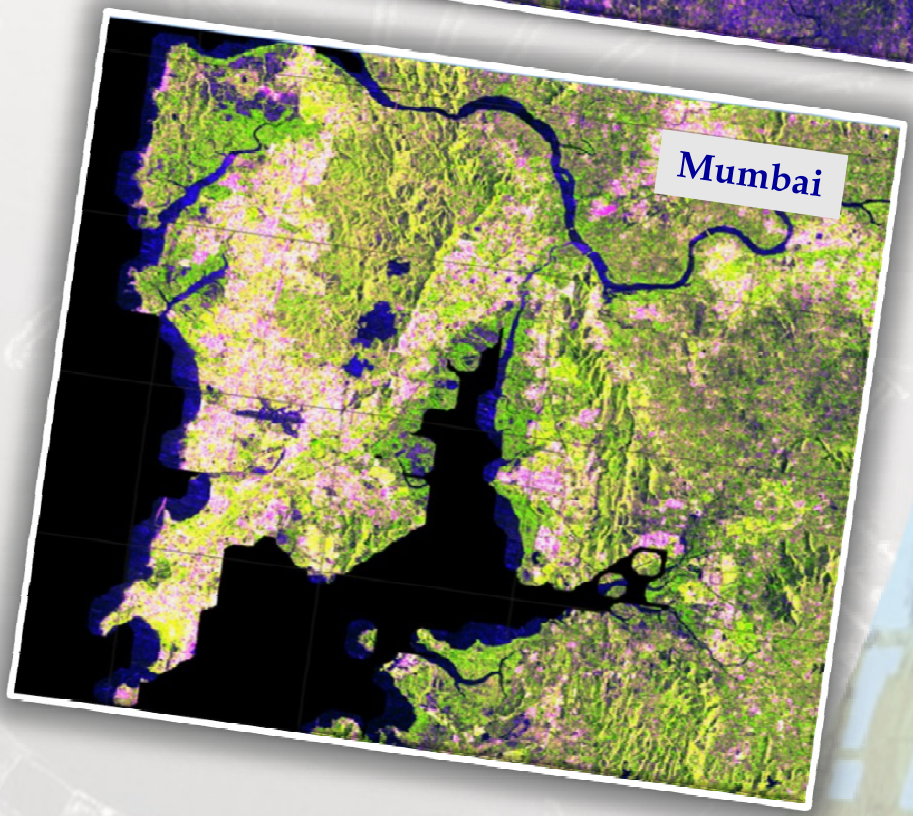
India is a rapidly developing country with a disproportionate urban growth. Percentage of population living in urban India is also rapidly increasing. Hence monitoring of the urban growth pattern and making developmental plans in a judicious way need satellite remote sensing. In India 79 million people were living in urban areas in 1961, but it went up to 285 million in 2001. After China, India's urban population is the second largest in the world. The process of urbanization in India gained momentum with the start of the industrial revolution in the 1970s followed by globalization in the 1990s.

The population from rural India is migrating to urban India due to various reasons. The most prominent among them is employment, education and quality life. As the population increases, demand for better housing, infrastructure, schools, hospitals etc. also increases.

SAR interacts with the urban targets in a different way, and the strong backscattering from man made structures such as settlement, shopping malls, flyovers, highways, and factories can be used for discriminating urban from other land classes. RISAT-1 provides a good scope of discrimination of urban features.

# Urban

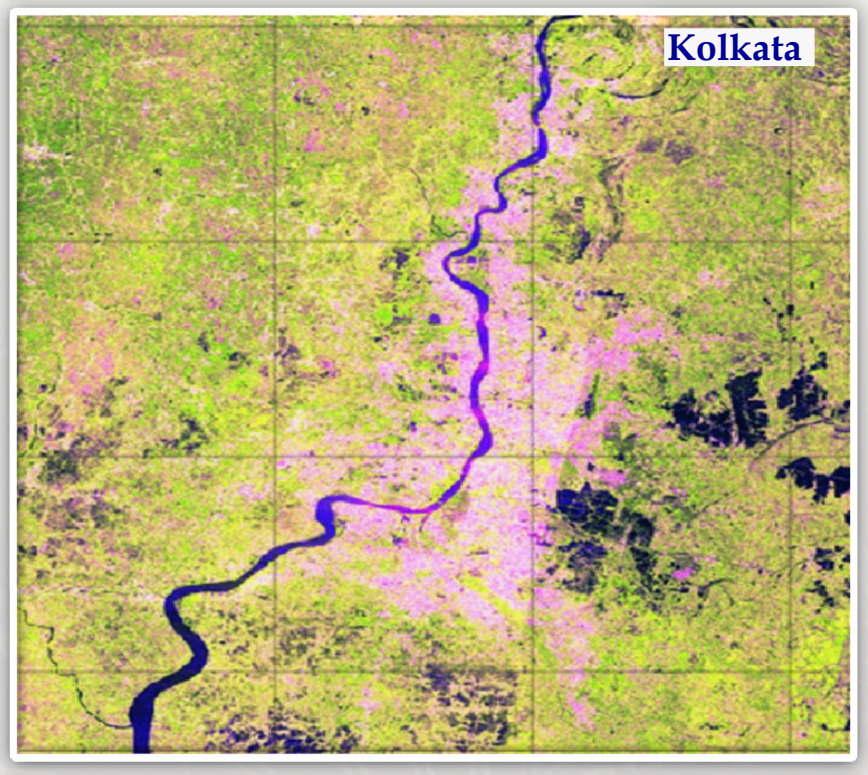


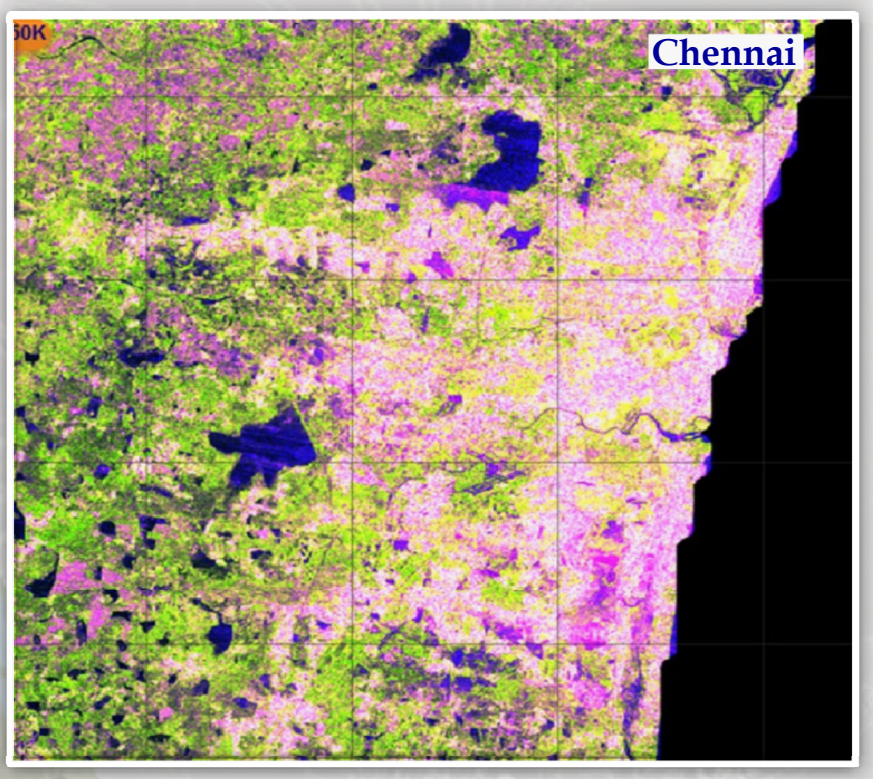




*(MRS-FCC; HH; HV; HH/HV)*

# Urban

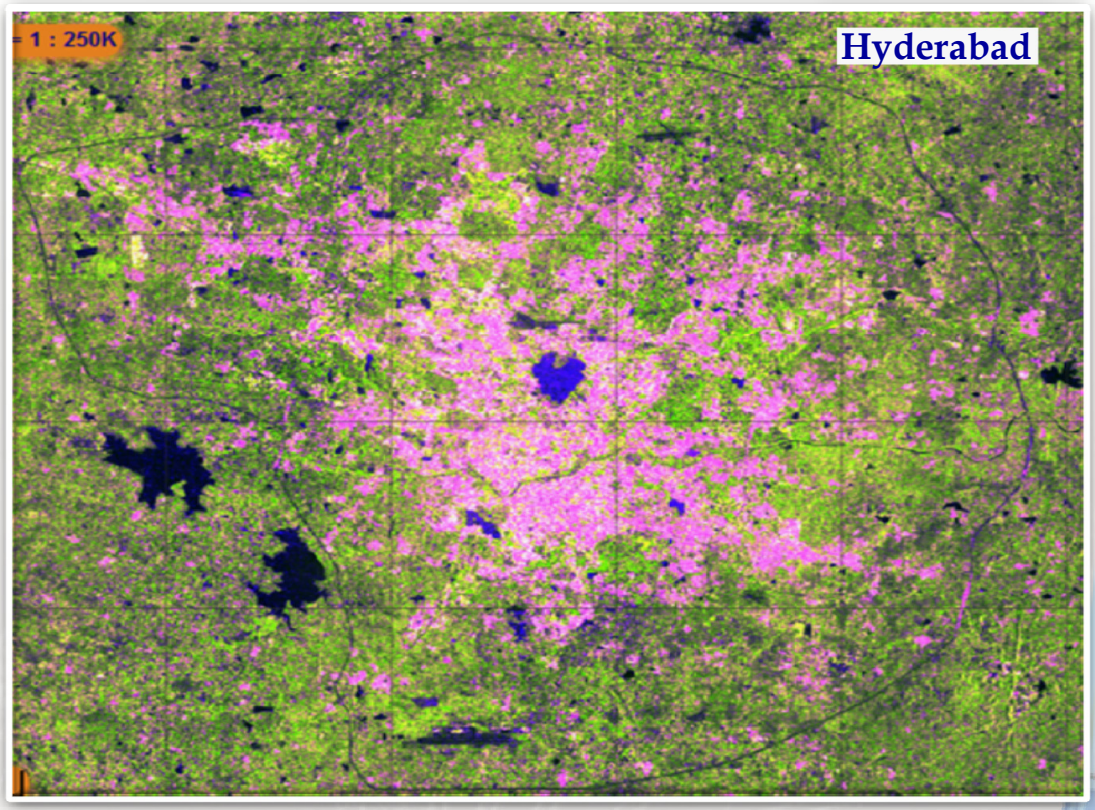
(MRS-FCC; HH; HV; HH/HV)

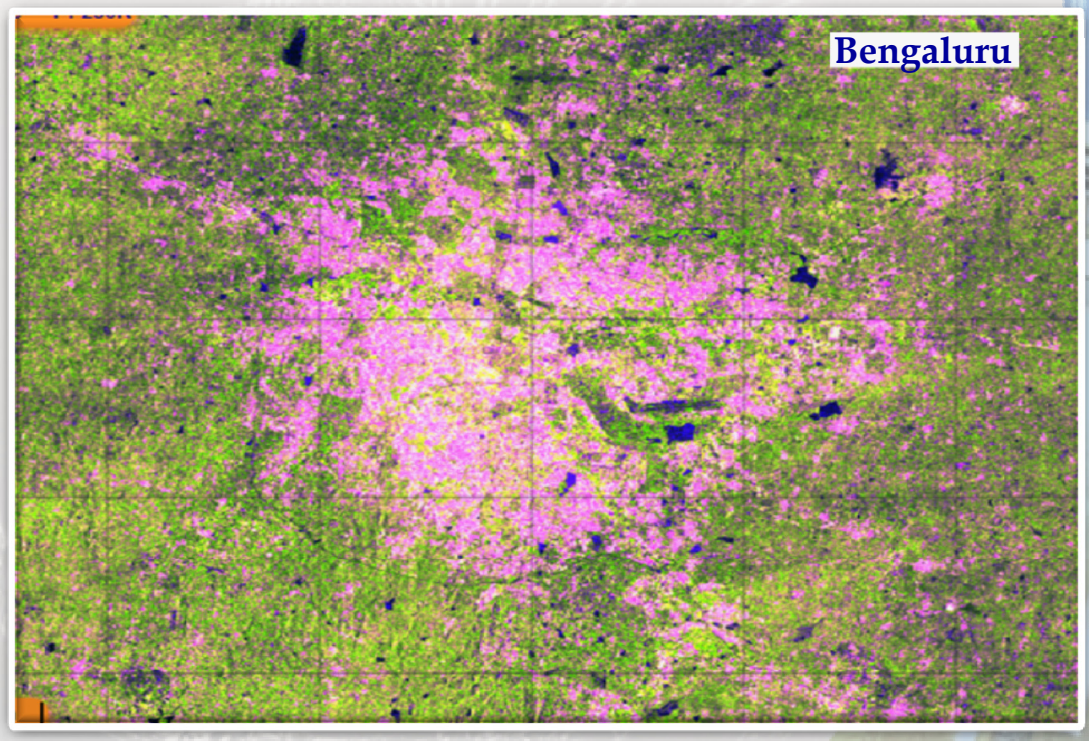


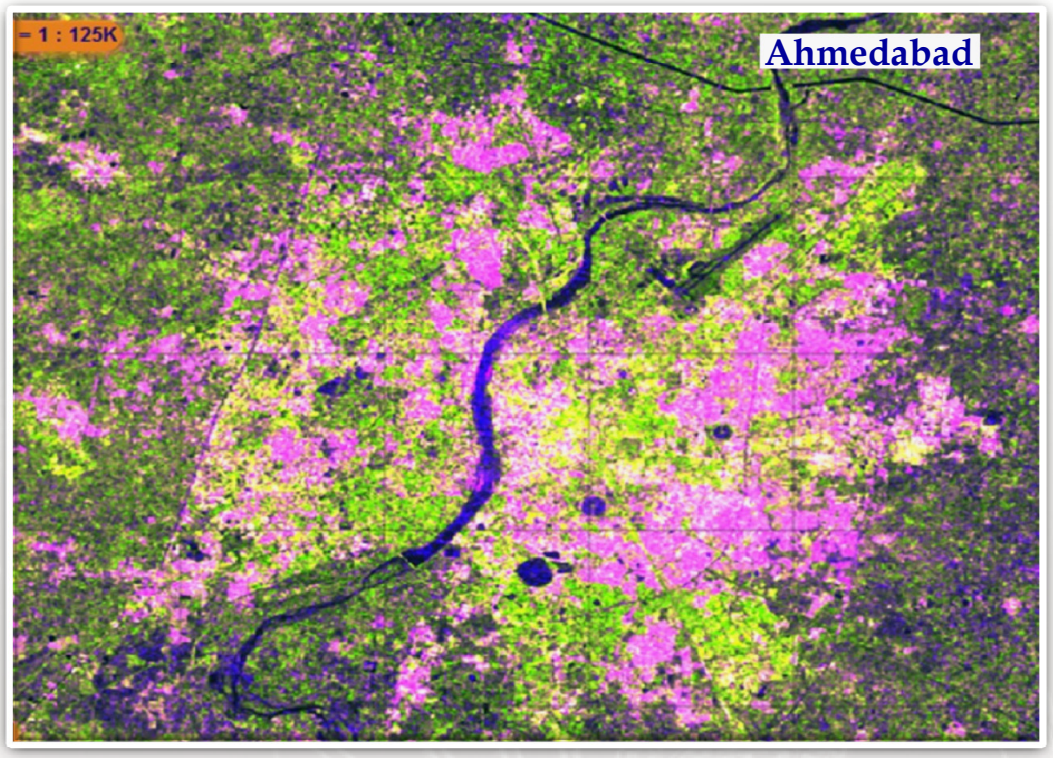
# Urban

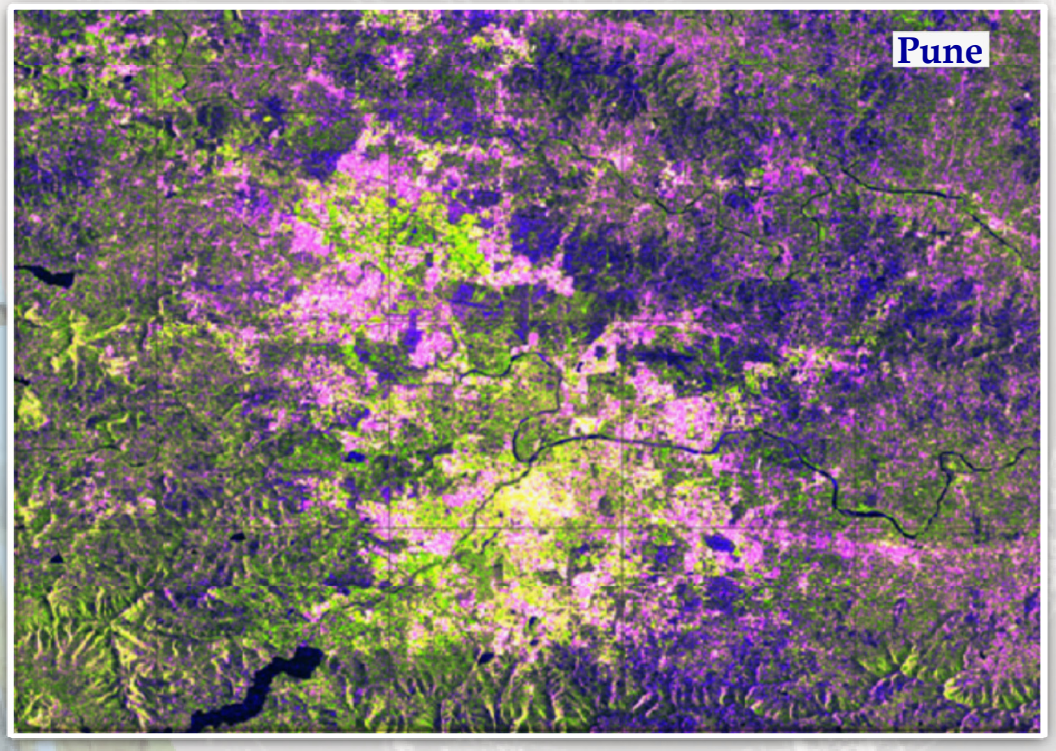
(MRS-FCC; HH; HV; HH/HV)



# Urban




(MRS-FCC; HH; HV; HH/HV)

# Infrastructure

Infrastructure development requires planning and monitoring in terms of the developmental activities. This is also very crucial for disaster management. Mapping of various infrastructure facilities and its monitoring at large temporal scales require Satellite images especially in remote areas. Damage assessment of infrastructures can be carried out using SAR data specially due to its all weather capability.

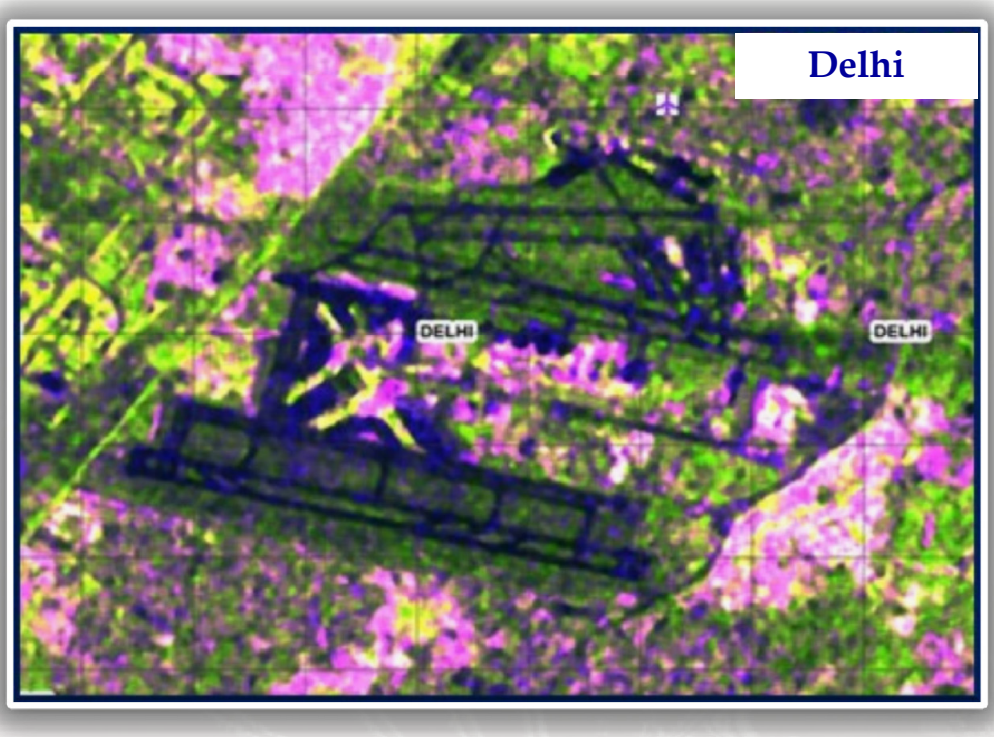
For monitoring important infrastructure developments (eg. check dams, flyovers, highways, bridges etc.) and its effectiveness SAR data has shown its potential.

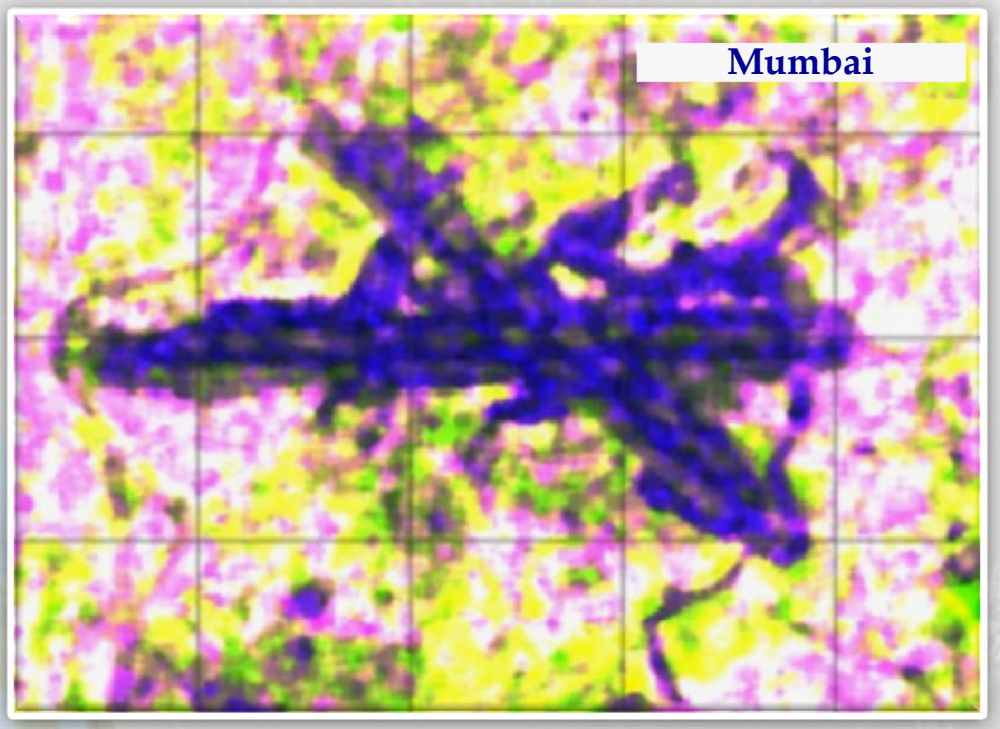
Routine monitoring of water spreads in dam catchment areas can be carried out using RISAT-1. This will help in taking the proper decisions for releasing the water when the levels are above the danger level. During floods, monitoring from space will provide a synoptic view over affected regions to take necessary steps for disaster management activities.

Two examples of infrastructure, namely major airports and dams, are shown in the subsequent pages. Bluish tint is the region of runways which act as a smooth surface where backscattering is negligible.

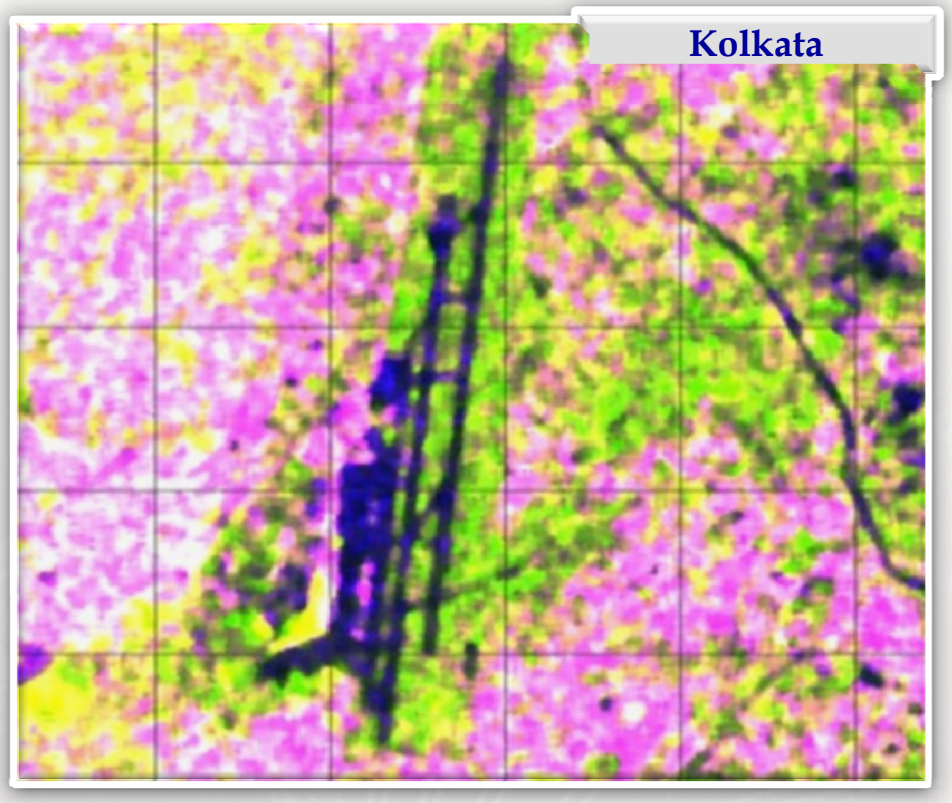
# Infrastructure : Airport

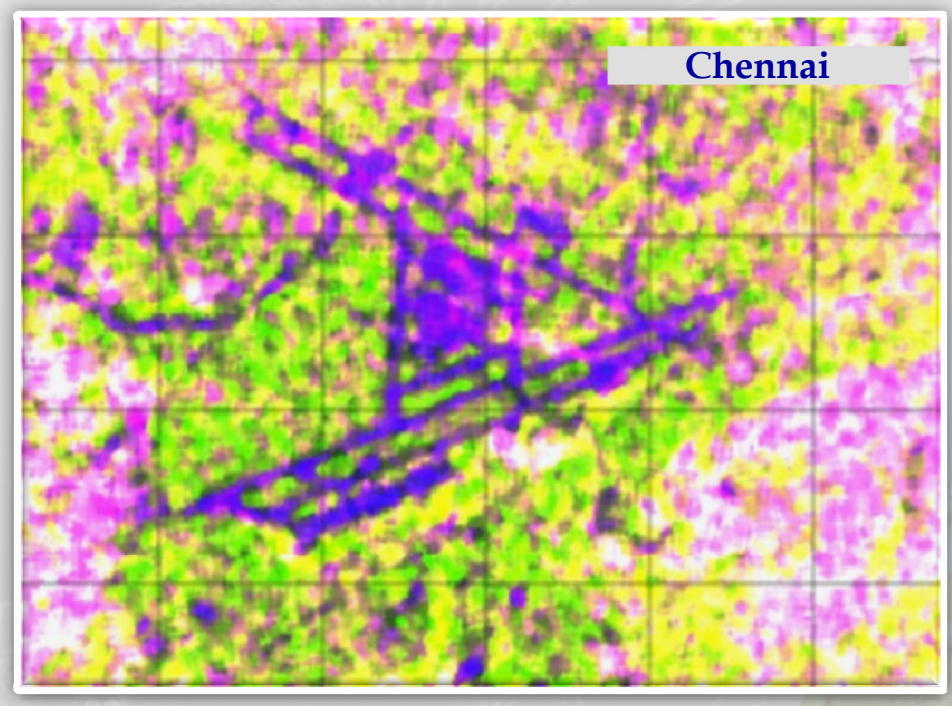
(MRS-FCC; HH; HV; HH/HV)



# Infrastructure : Airport

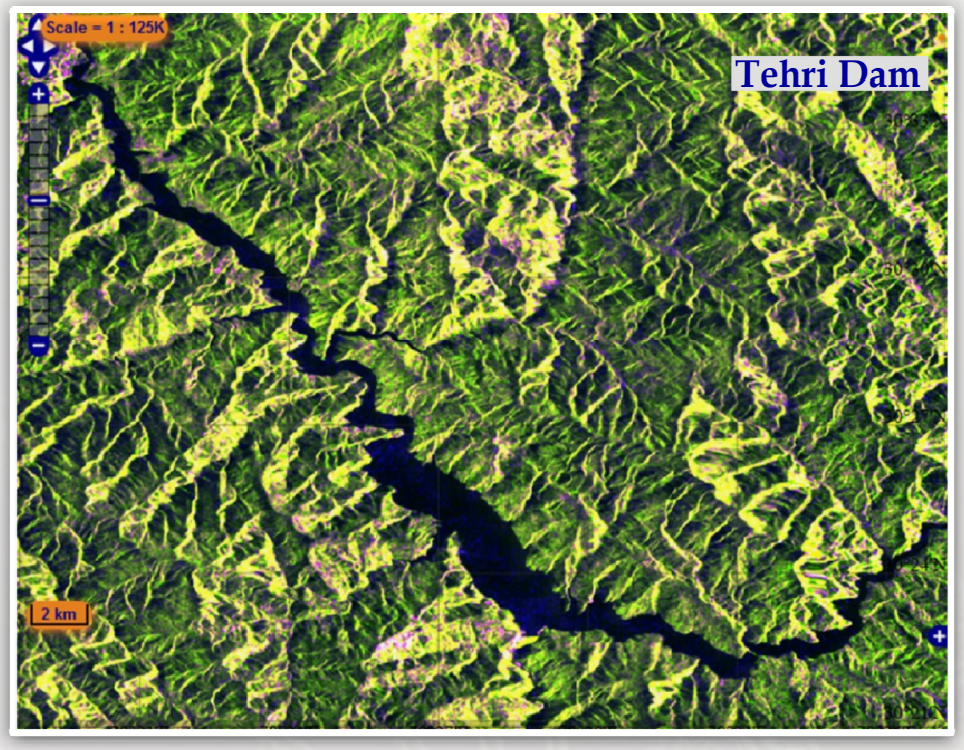


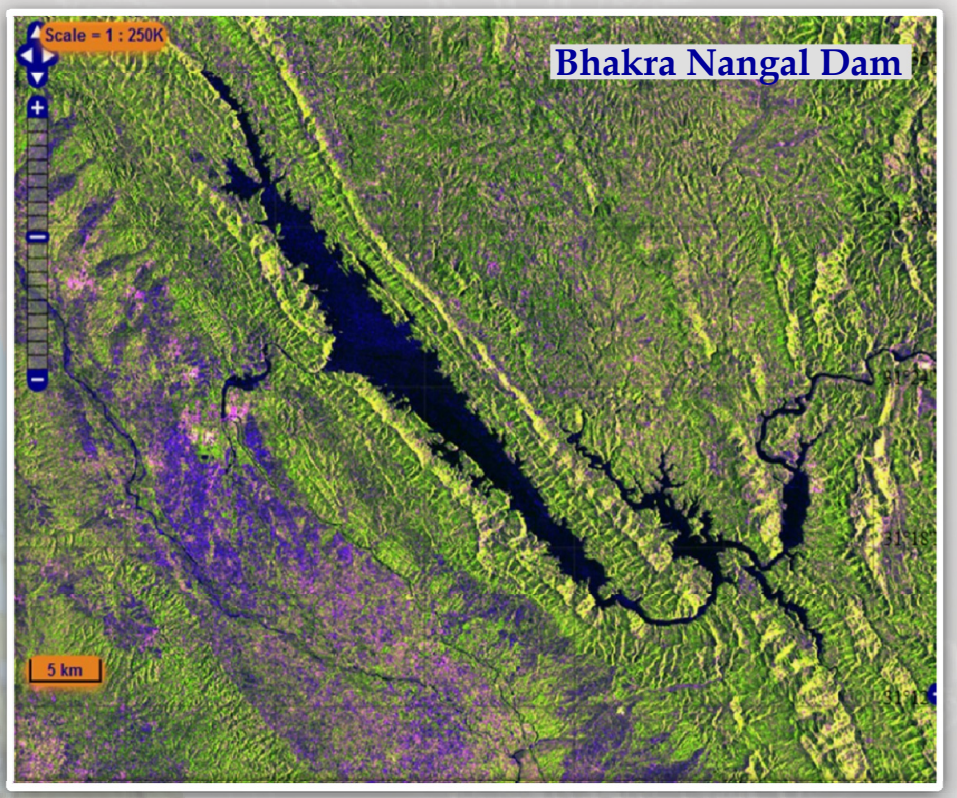




(MRS-FCC; HH; HV; HH/HV)

# Infrastructure : Reservoir / Dam

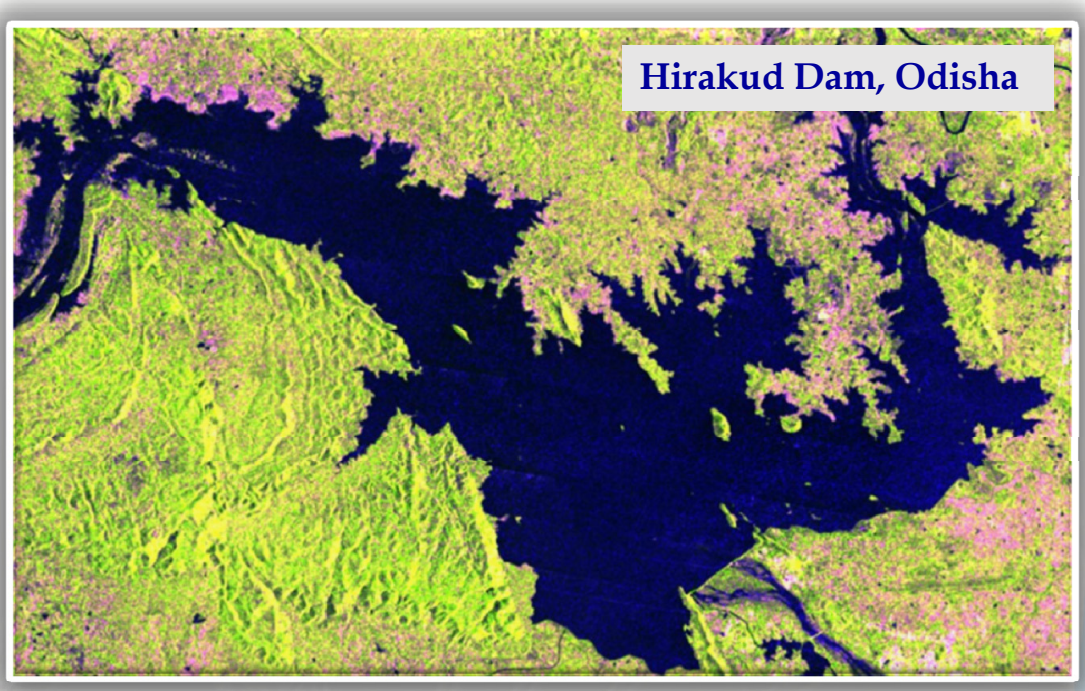
(MRS-FCC; HH; HV; HH/HV)



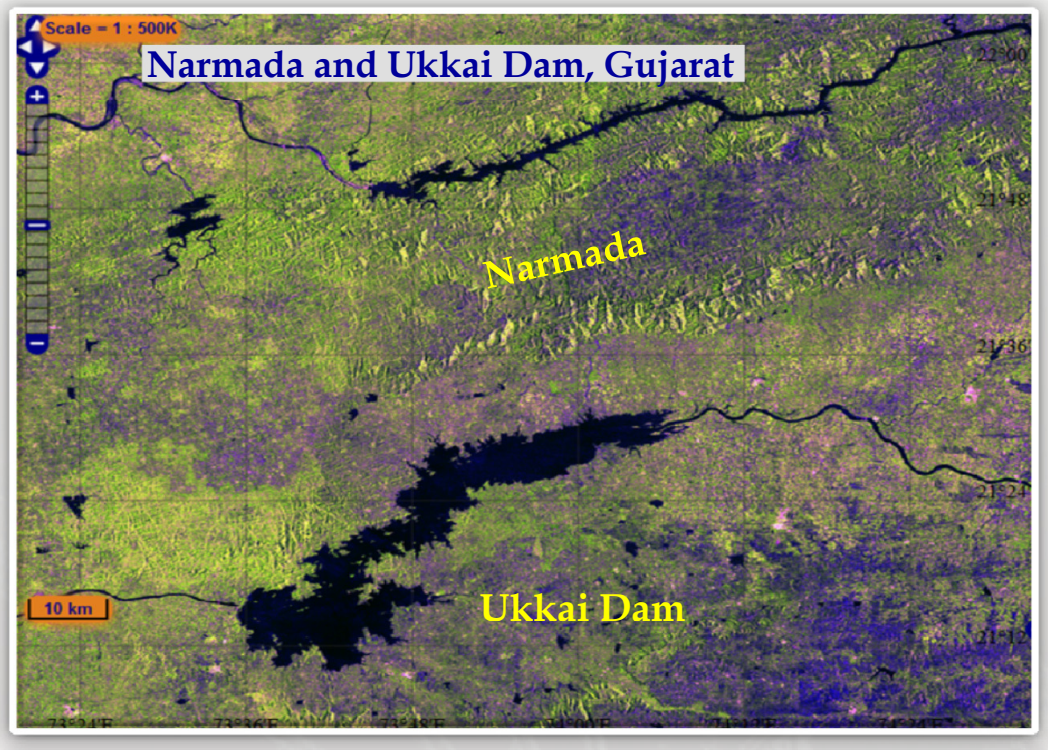



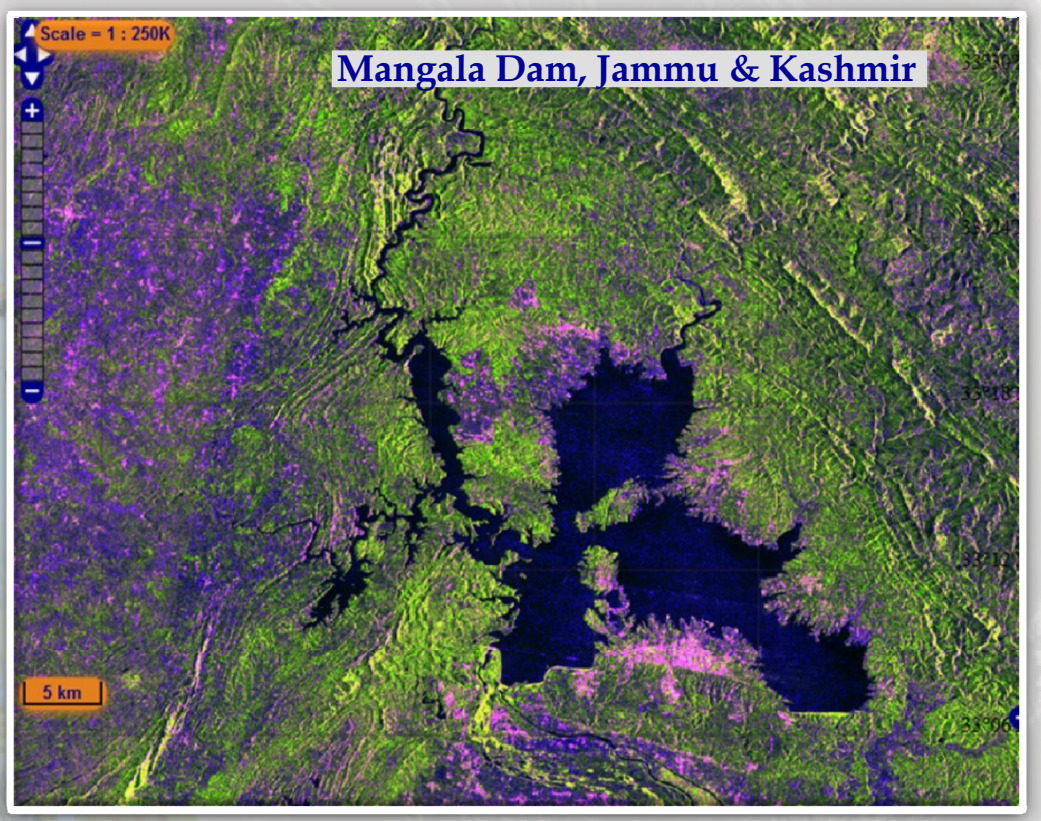
# Infrastructure : Reservoir / Dam

(MRS-FCC; HH; HV; HH/HV)




# Infrastructure : Reservoir / Dam




(MRS-FCC; HH; HV; HH/HV)

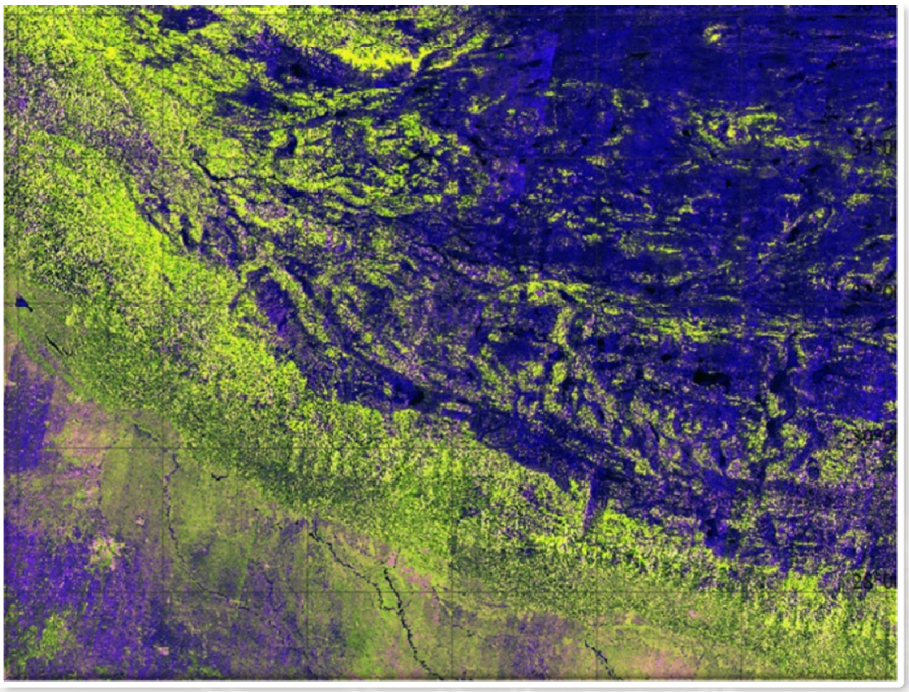
# Mountains

The Indian subcontinent is flanked by the gigantic Himalayas on its north, which had originated from the Tethys Sea. The Himalayan range play a major role in controlling the eco system, weather and other environmental factors in the Indo-Gangetic plains as well as the north-east areas. Apart from that, the Deccan plateau is flanked by the two Ghats - Western and Eastern Ghats mountains and the Vindhyas and the Satpura ranges separate the erstwhile northern and the southern Indian states. Apart from that smaller hills such as the Aravalli play a role in the local climatic conditions. Mountains are also centres of attraction for tourism and pilgrimage. The mountains are the origins of the river networks in the country. The valleys provide suitable sites for construction of dams. The mountains and hill regions are crowned with thick forests which accommodate a variety of flora and fauna.

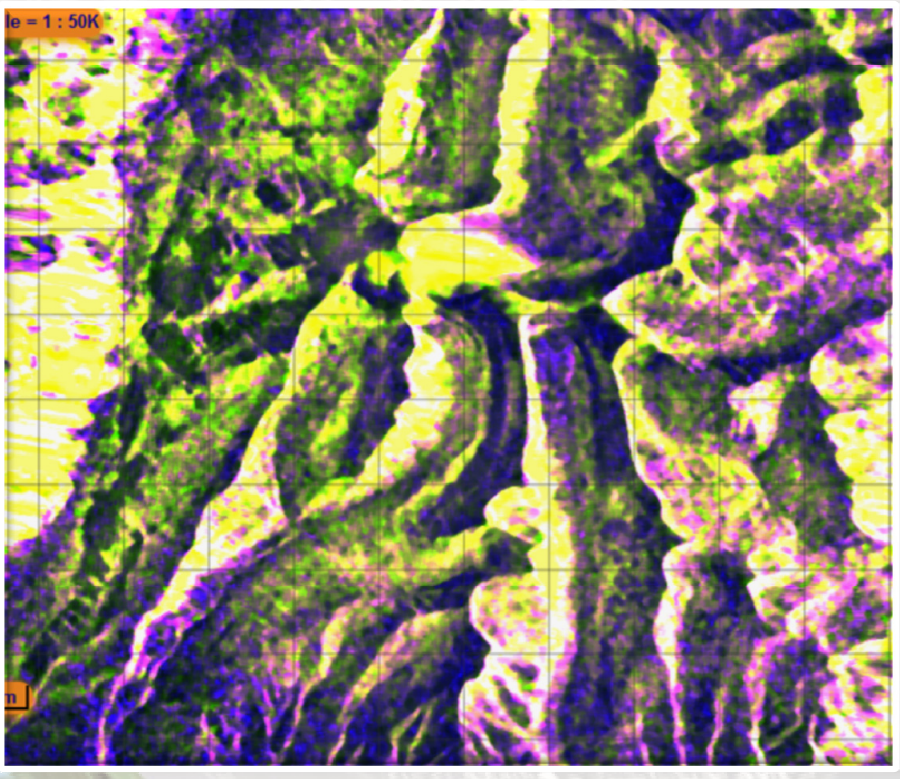
SAR data with its wide swath can provide a synoptic view of the mountainous regions which can be effectively utilised for tourism development and planning and conservation of various assets of the country. These regions also harness several types of minerals.

# Mountains

## Himalayas



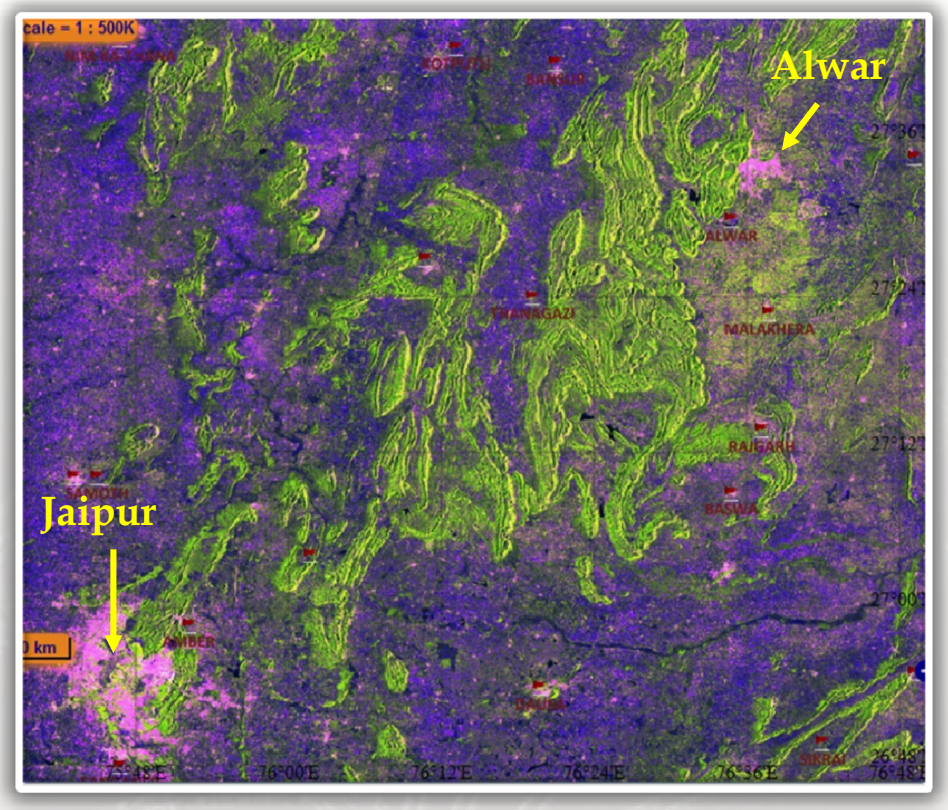
## Kailash




(MRS-FCC; HH; HV; HH/HV)

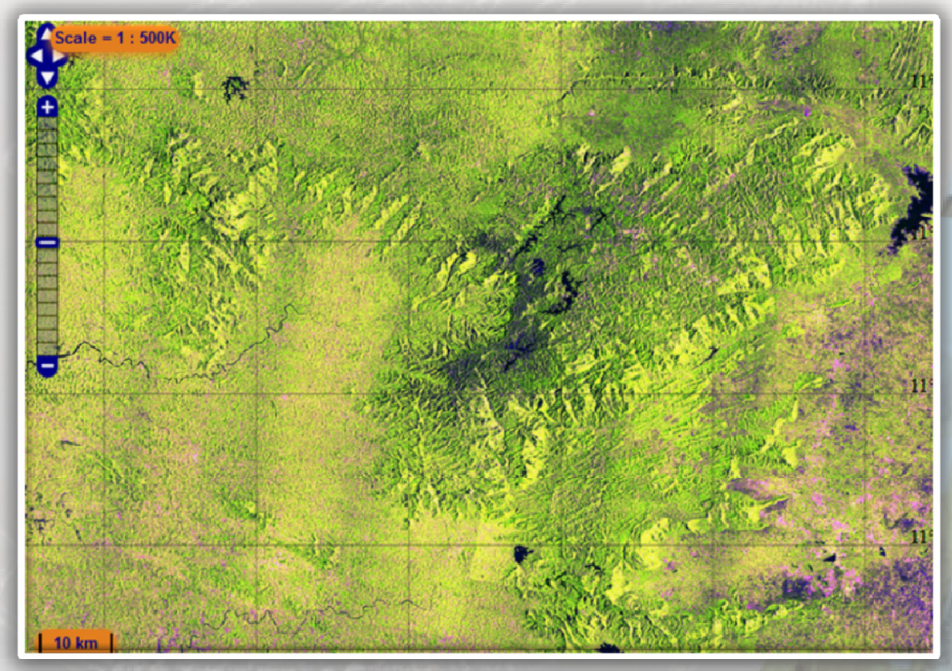
# Mountains

## Aravalli Range Between Jaipur and Alwar

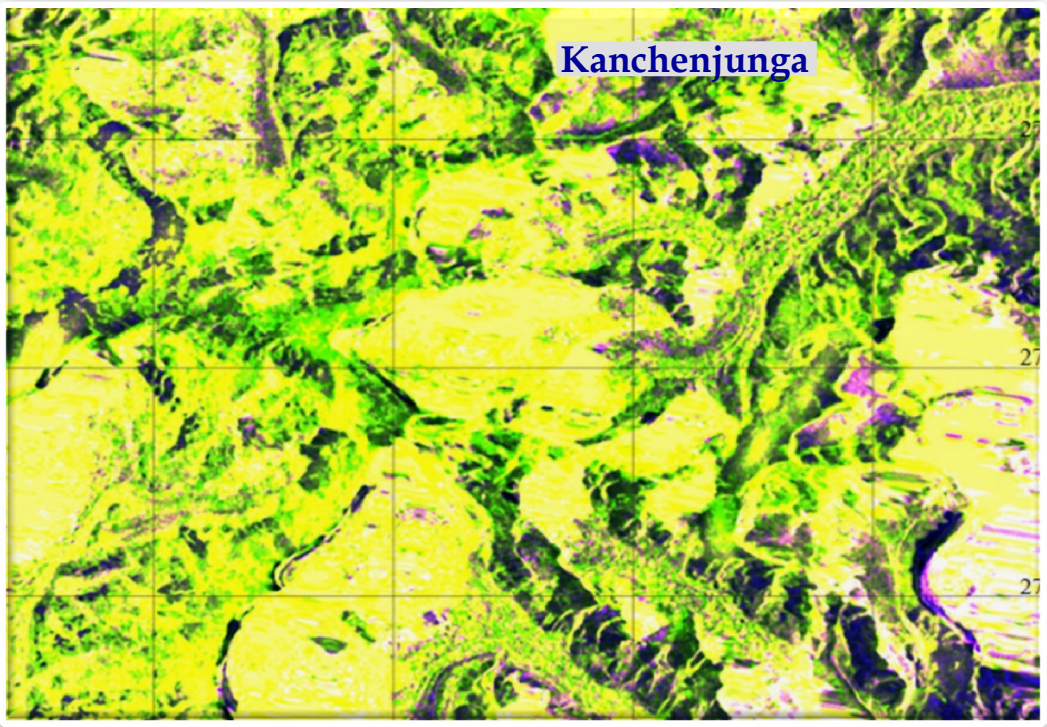


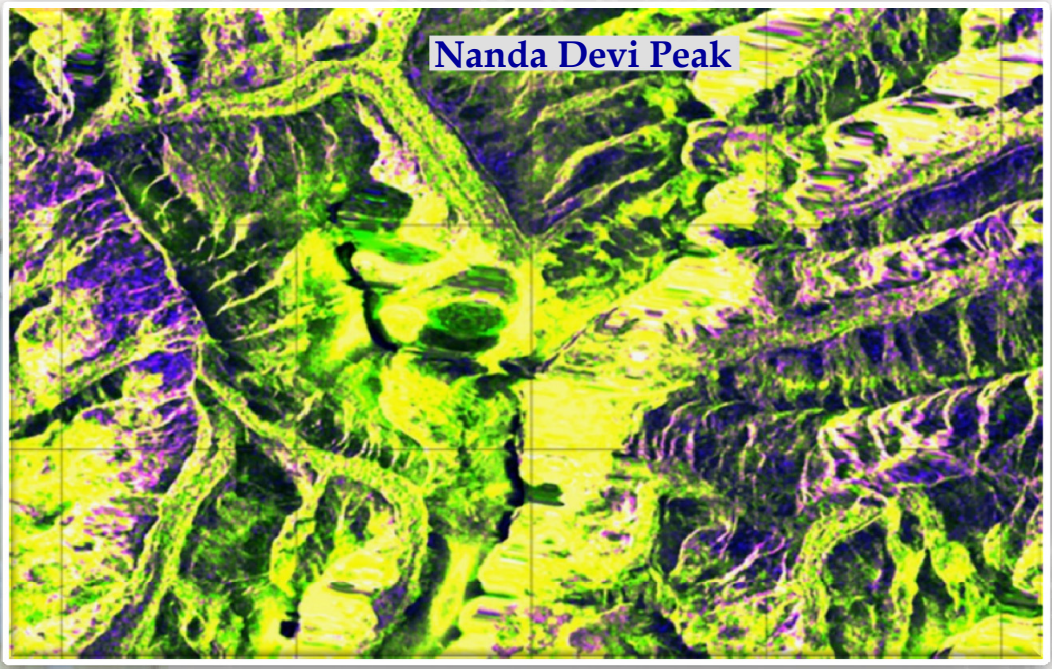

(MRS-FCC; HH; HV; HH/HV)

## Western Ghats



# Mountains




(MRS-FCC; HH; HV; HH/HV)

# Geology

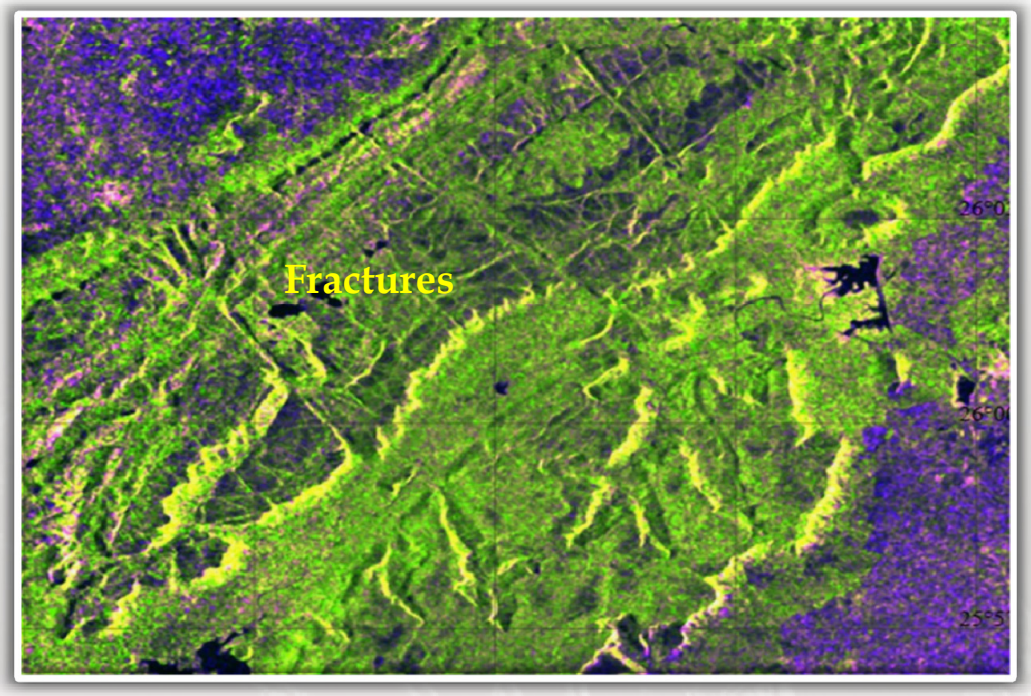
Satellites having microwave payloads have the unique potential for geological applications. Backscatter is dependent upon surface roughness, dielectric constant and geometrical orientation of the target with respect to satellite. The side looking geometry is suitable for detecting structural features such as fault zones and folds. Linear features such as faults and fracture zones perpendicular to look direction get enhanced on SAR images due to this. Lithological mapping is also possible if weathering of rock types yields varying levels of surface roughness. Structural and lithological informations are critical inputs for reconnaissance surveys for mineral and oil exploration programmes and can be obtained from SAR imageries.

SAR data can penetrate dry sand and can yield information about shallow subsurface regions such as Thar desert. The ability of penetration is maximized by low soil moisture, moderate to high look angle, longer wavelength and presence of well sorted sediments. This enables mapping of shallow buried palaeochannels and relict valleys in desert areas. Mapping of these regions is crucial, as source of potable water in arid region. Further, reconstruction of palaeodrainage networks contribute to fluvial response to tectonic forces and climate change.

# Geology

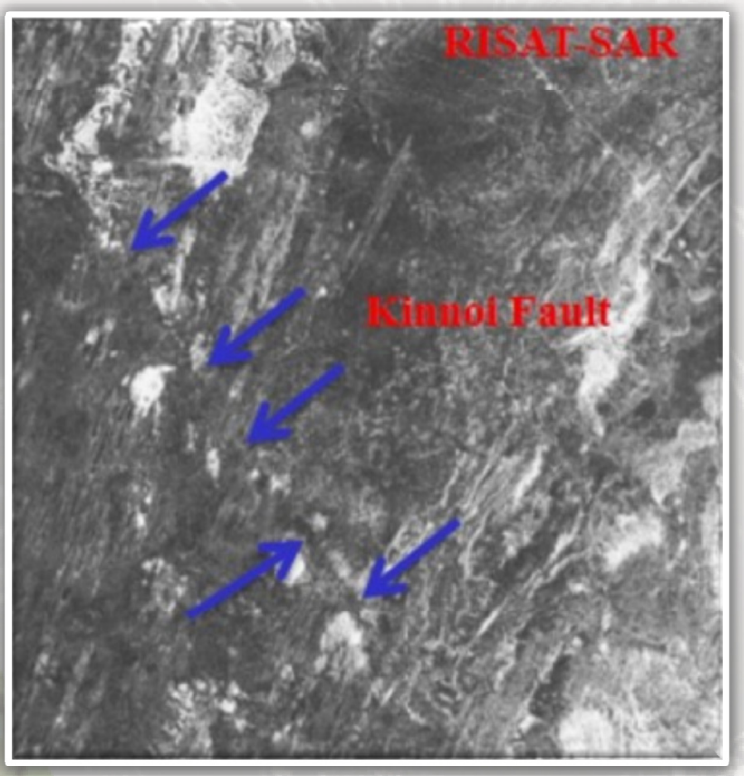
## Fault and Fractures: Jahazpur Region

(MRS-FCC; HH; HV; HH/HV)




Fault Line

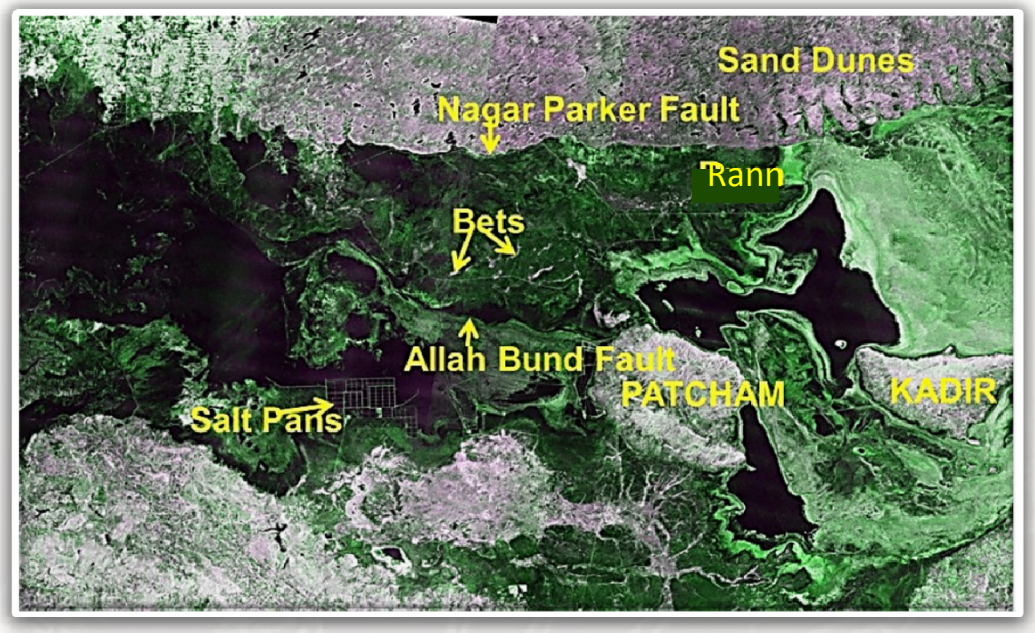
MRS
HH



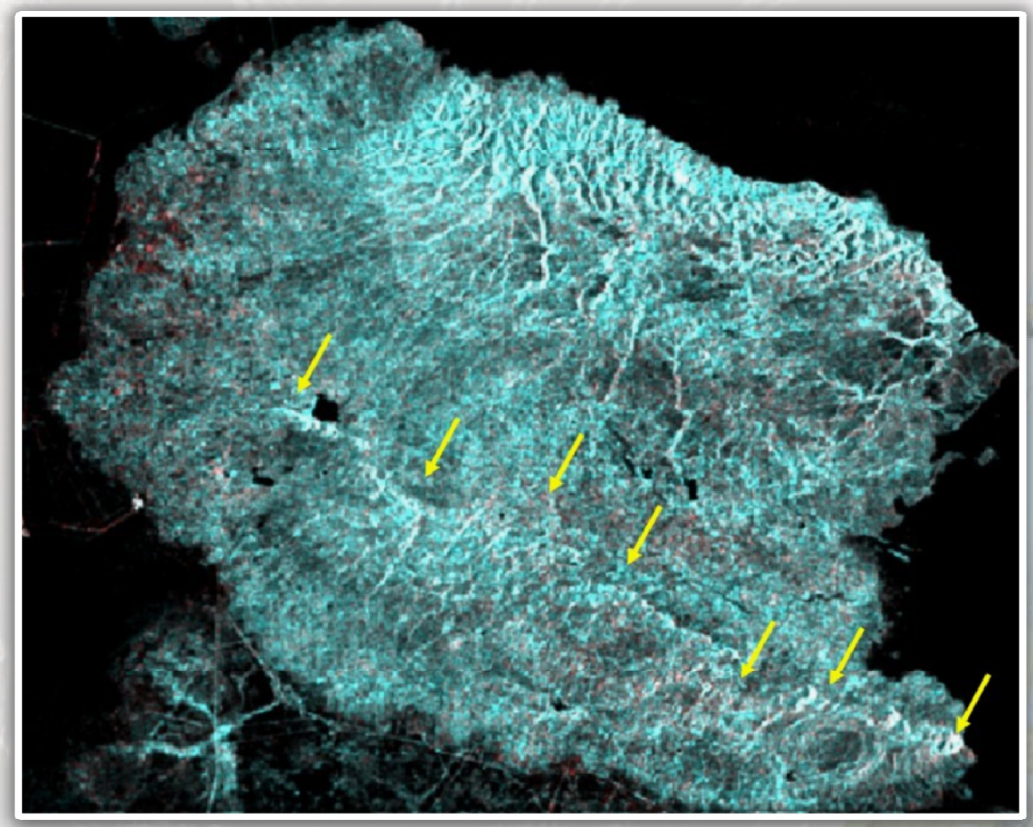
# Geology

## Fault and Fractures: Kutch

(MRS-FCC; HH; HV; HH/HV)



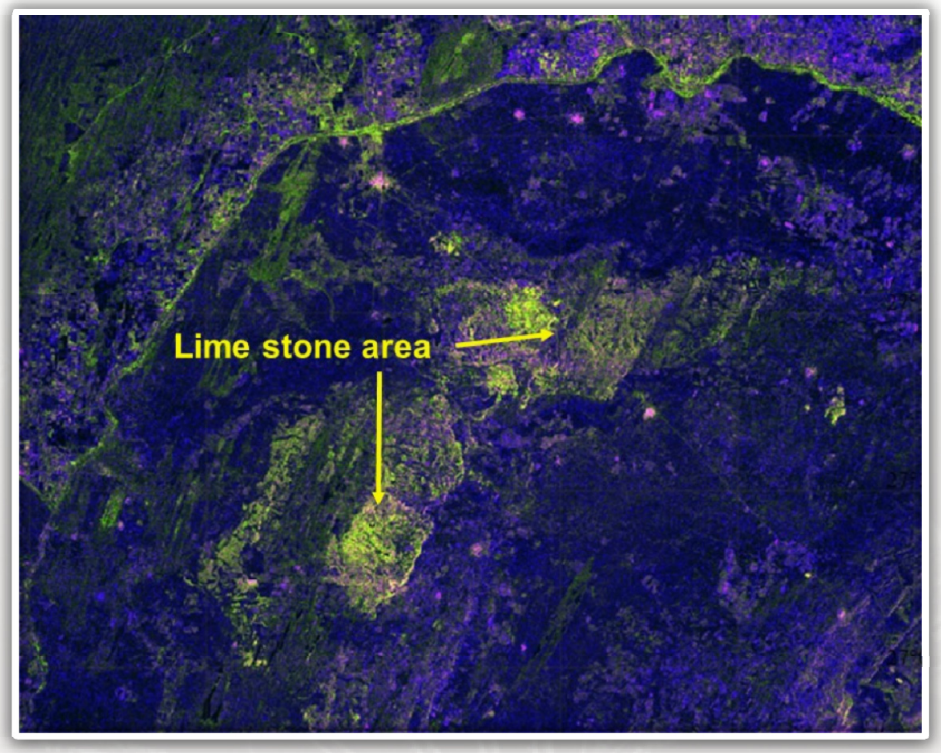

(MRS-FCC; HH; HV; HH/HV)

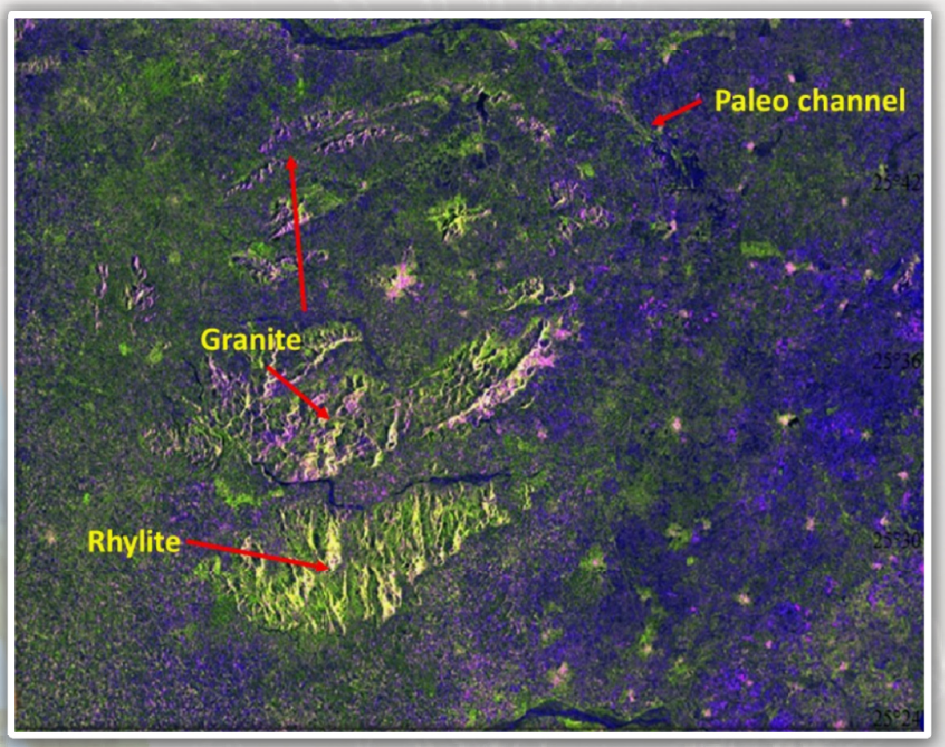


# Geology

## Mineral Mapping: Near Jaisalmer

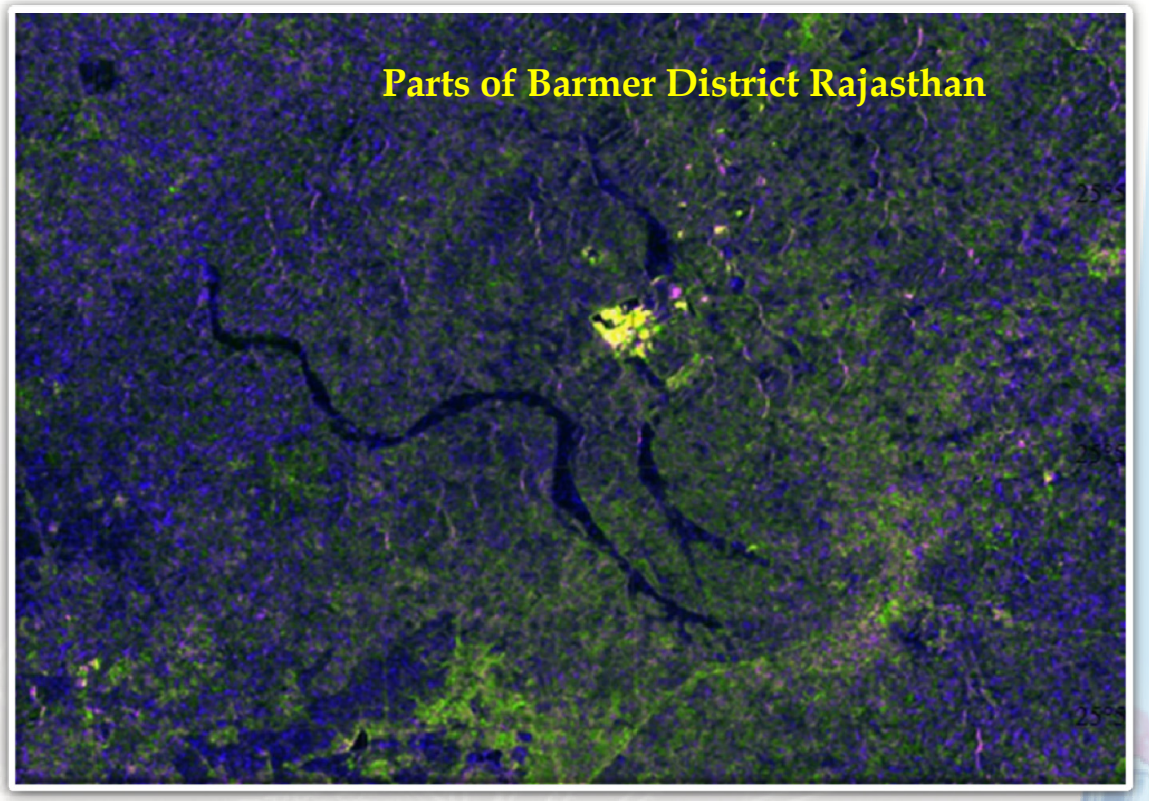
(MRS-FCC; HH; HV; HH/HV)



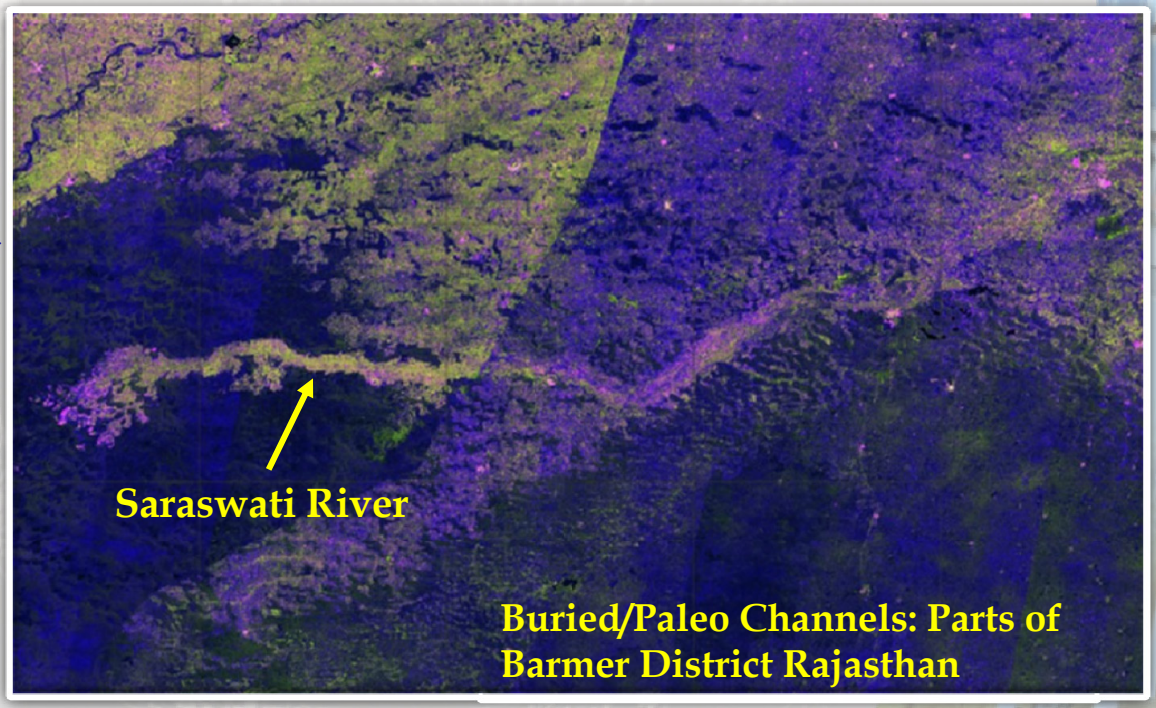



# Geology

## Buried / Paleo Channels

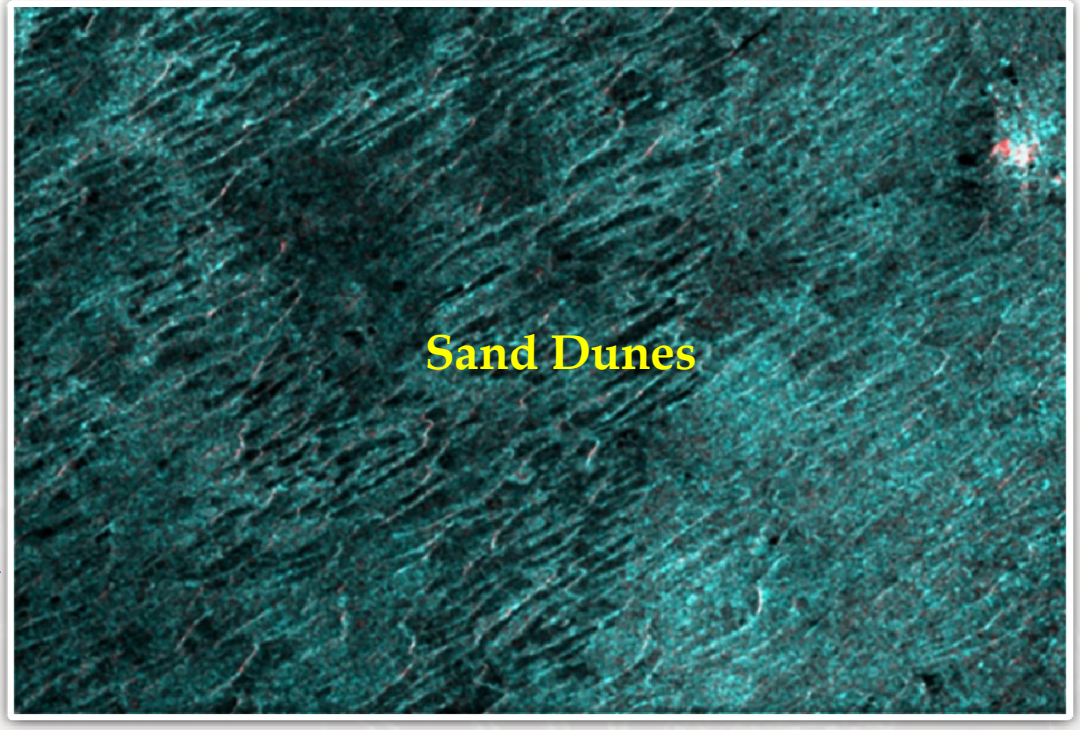



(MRS-FCC; HH; HV; HH/HV)

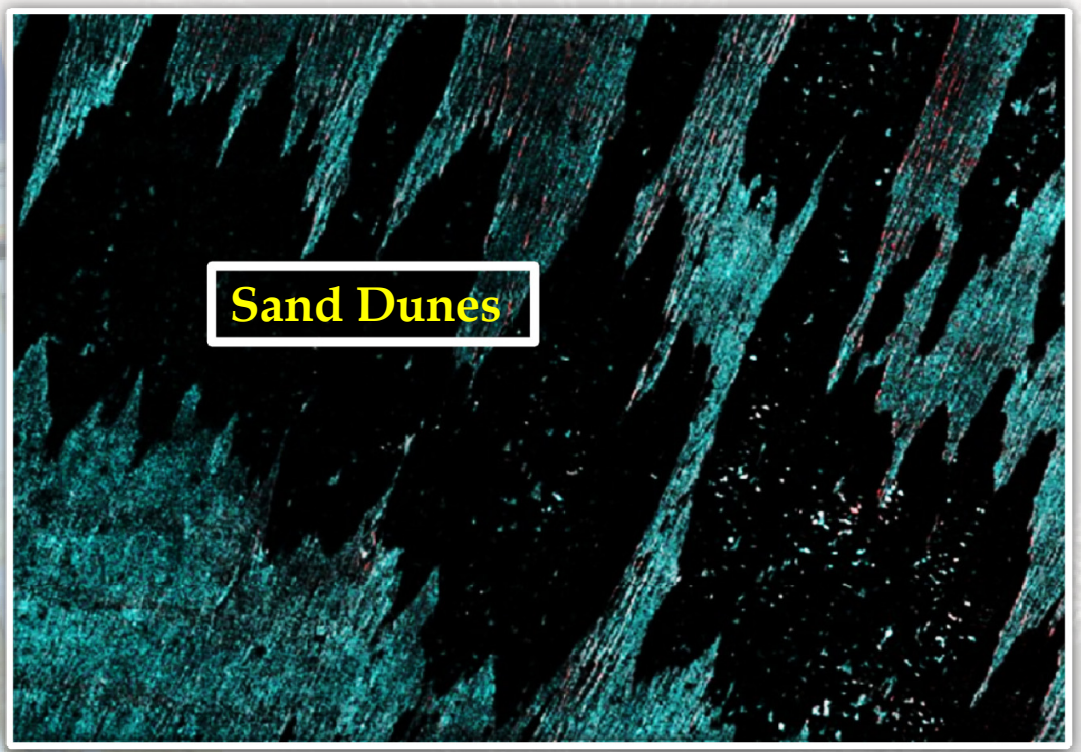


# Geology

## Sand Dunes




(MRS-FCC; HH; HV; HV)

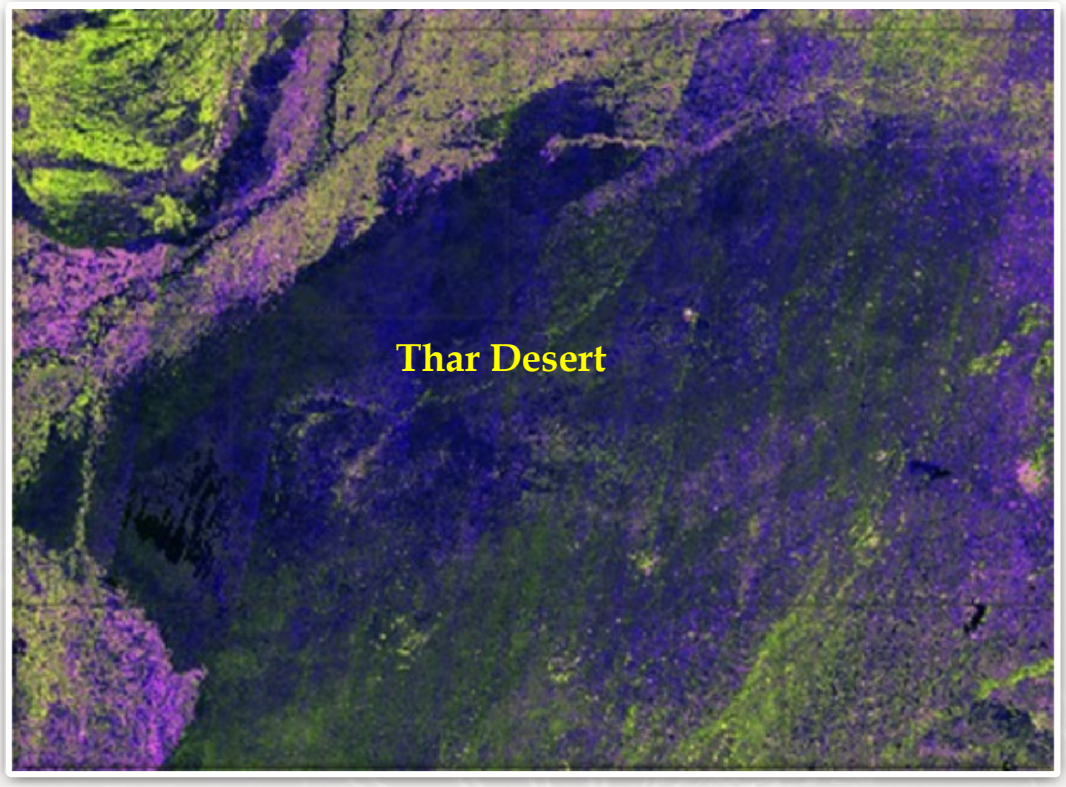


# Deserts

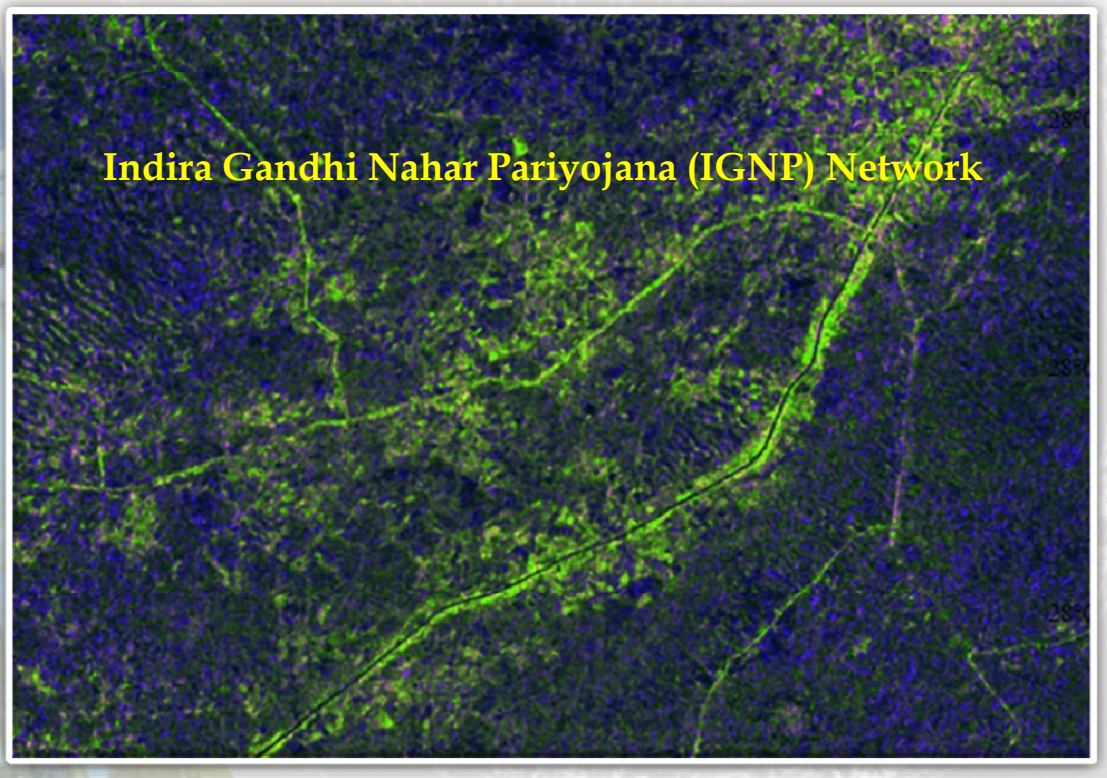
Desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities leading to loss of productive ecosystem and biodiversity. There is an urgent need to stop and reverse the process of land degradation. Sustainable management of soil, water and biodiversity are required for protecting the land from further degradation. There are global efforts to combat desertification. India is signatory to the United Nations Convention on Combating Desertification (UNCCD) and has committed to achieve the land degradation neutral status by 2030.

One of the key requirements is inventory and monitoring desertification and land degradation of the country using satellite data in Geographical Information System (GIS) environment for providing baseline data. These are being used for prioritizing areas, carrying out desertification vulnerability and risk assessment and preparing action plans for combating desertification and land degradation .

# Hot Deserts

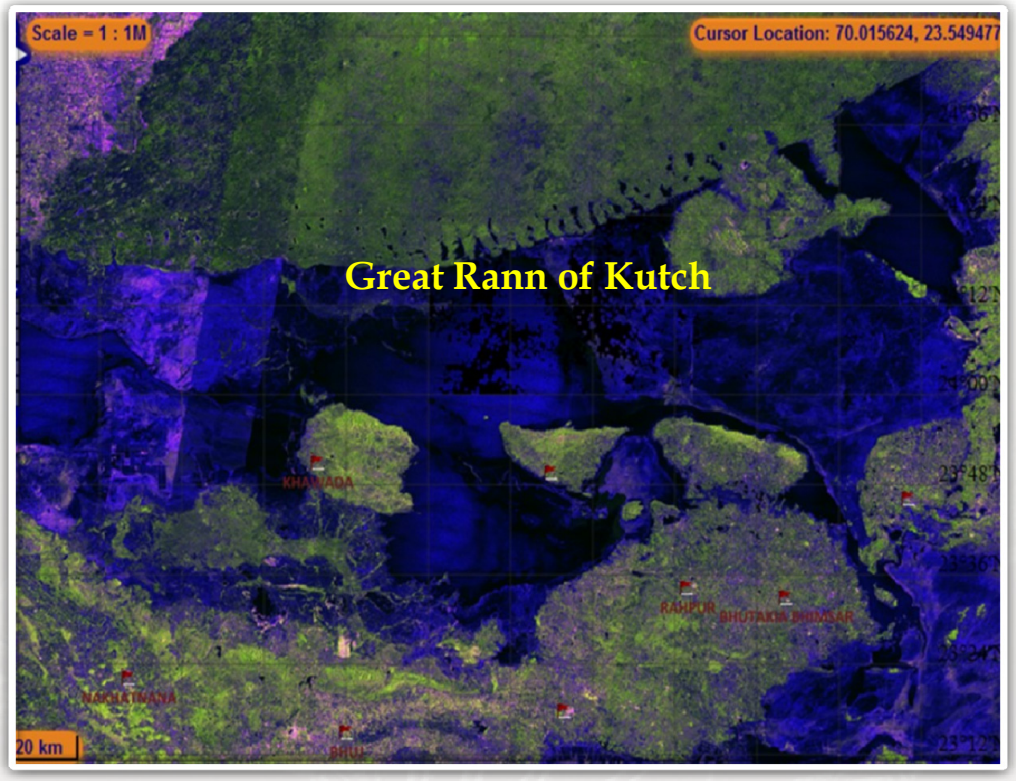


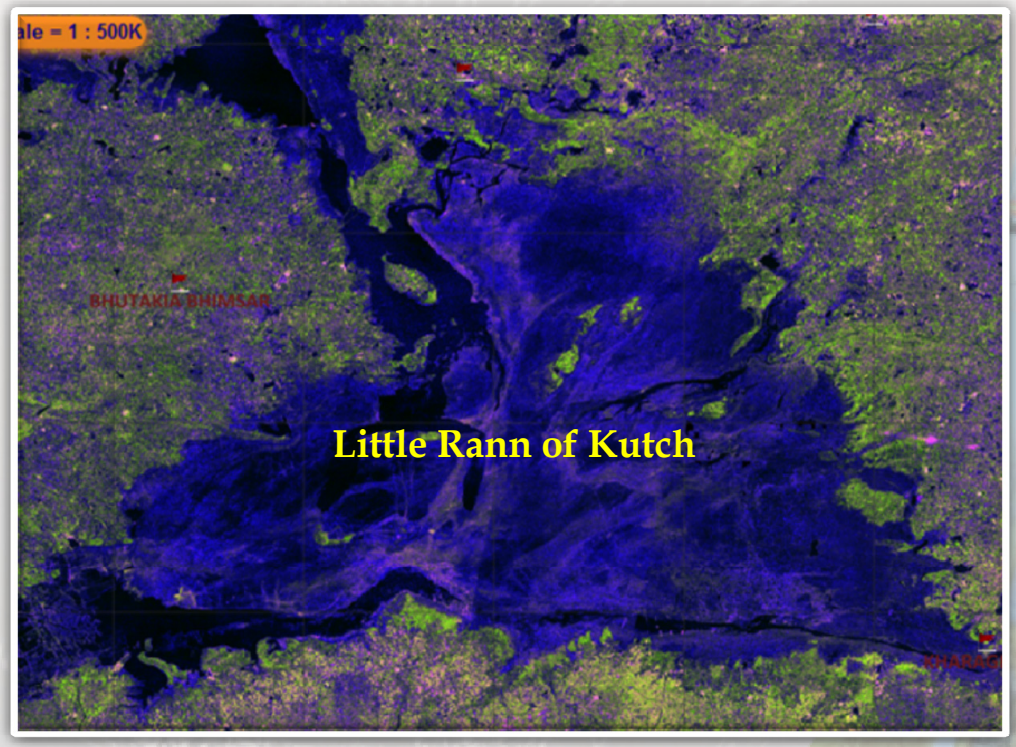

(MRS-FCC; HH; HV; HH/HV)



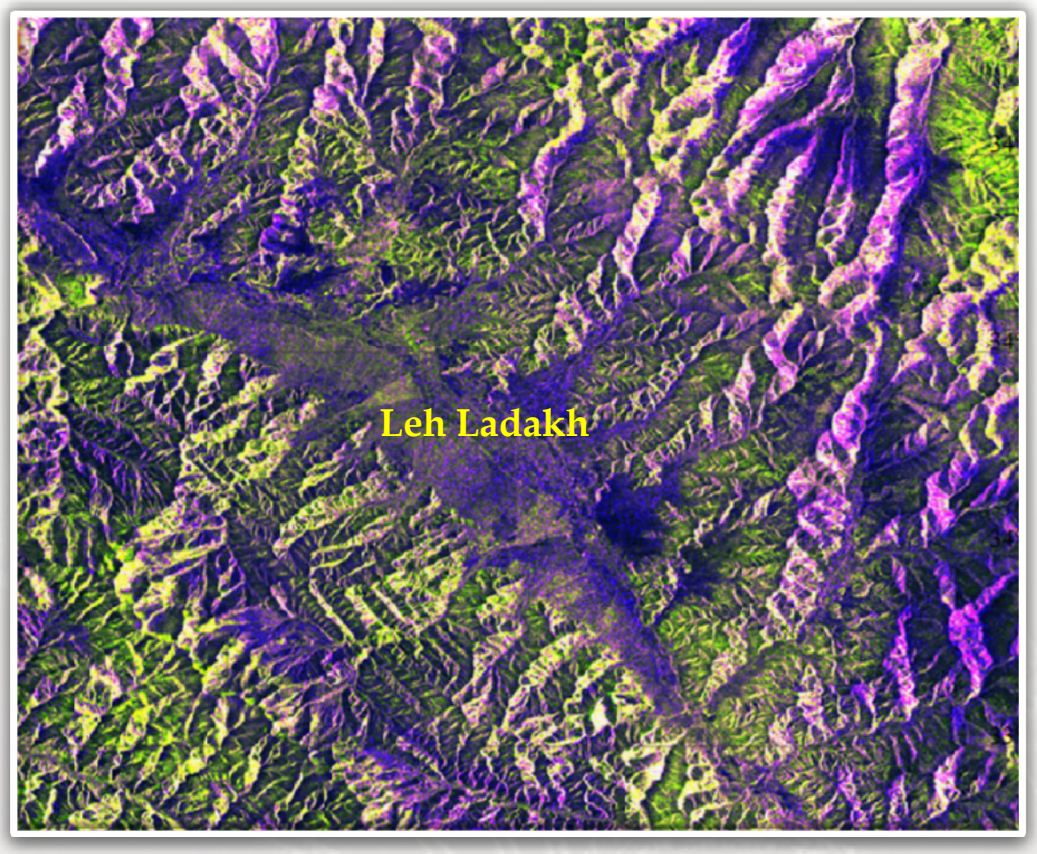
# Hot Deserts

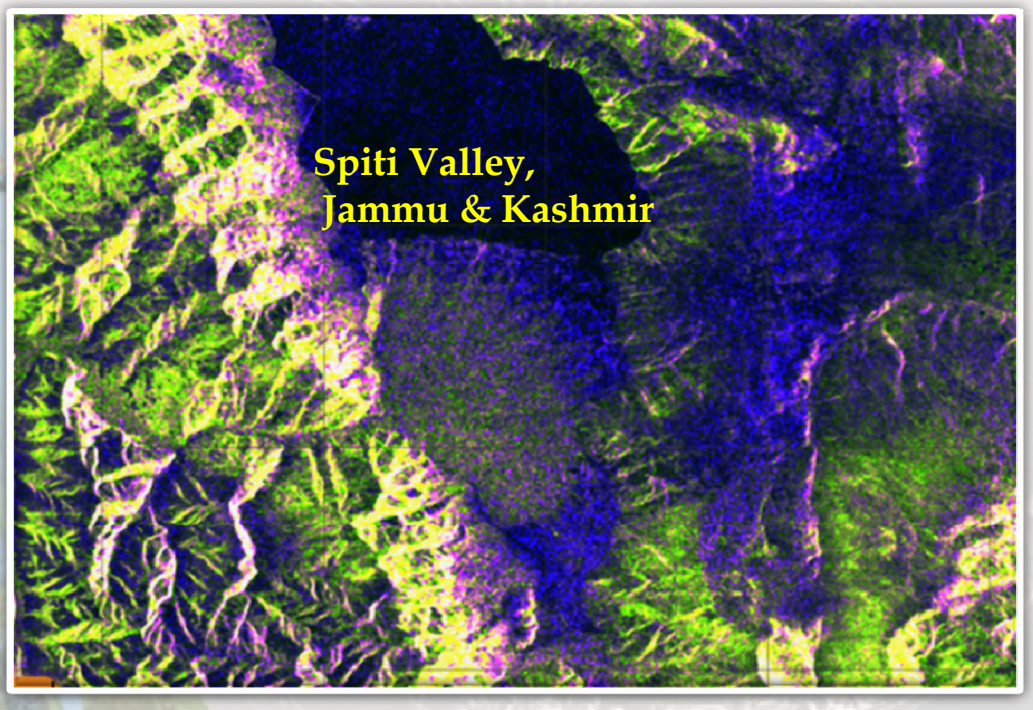
(MRS-FCC; HH; HV; HH/HV)



# Cold Deserts




(MRS-FCC; HH; HV; HH/HV)

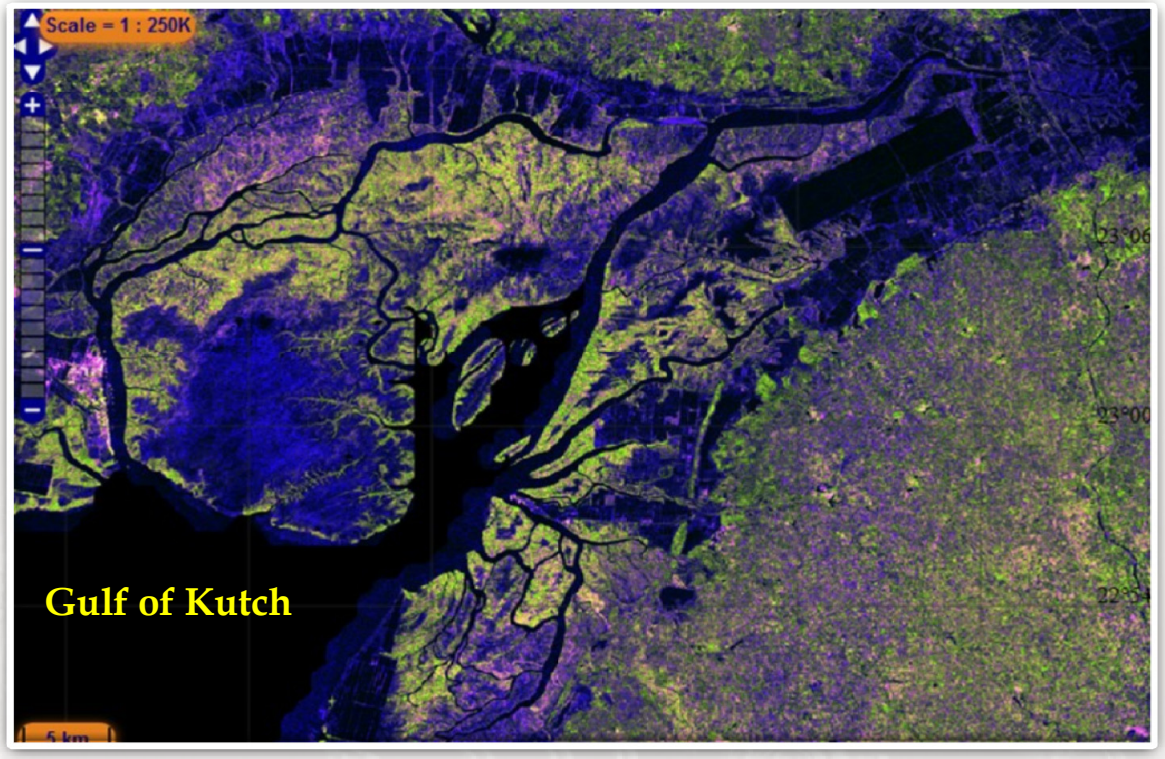
# Coastal

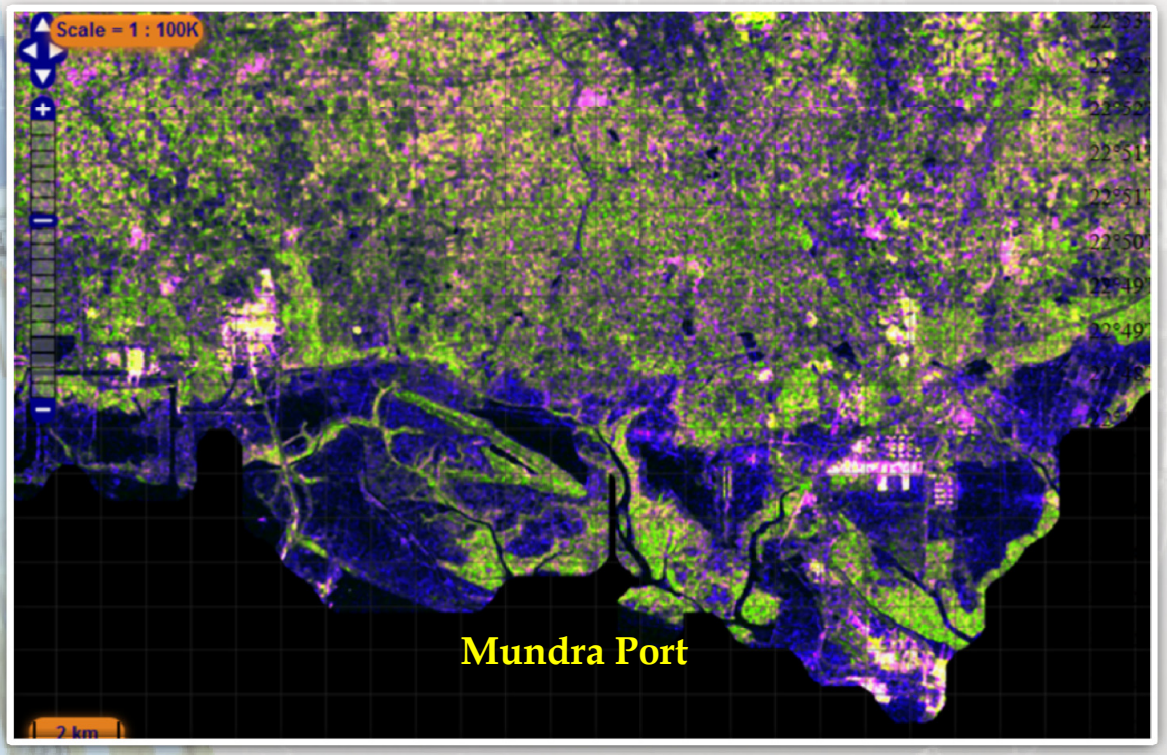
The coastal zone represents varied and highly productive ecosystems such as mangroves, coral reefs, sea grasses and sand dunes. These ecosystems are under stress on account of increased anthropogenic activity on the coast, as a result of globalisation. It is necessary to protect these coastal ecosystems to ensure sustainable development. This requires information on habitats, landforms, coastal processes, water quality, natural hazards on a repetitive basis.

SAR has potential applications in coastal regions, which comprises of varying characteristics of the land and sea. The major contribution of SAR images in the coastal system is mapping of shoals, estimation of wind, wave, currents, bathymetry and detection of internal waves, which are not possible from optical sensors. Oil spill detection, ship tracking, monitoring coastal fronts are other coastal applications, where SAR images are widely used. With the advent of polarimetric SAR data, major achievements are made in improving the coastal classification system. Soil moisture, sediment texture, mudflats roughness, classifying coastal habitat, are few of the polarimetric applications which have improved in understanding the regional coastal characteristics.

# Coastal

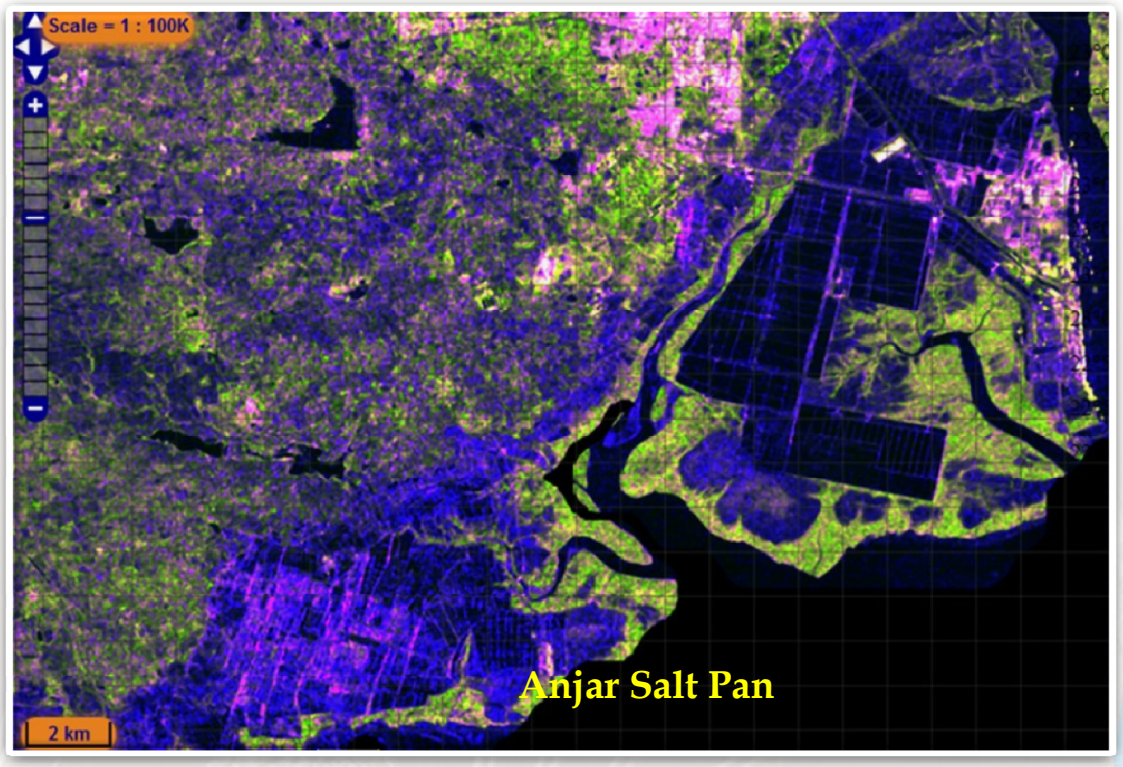
(MRS-FCC; HH; HV; HH/HV)

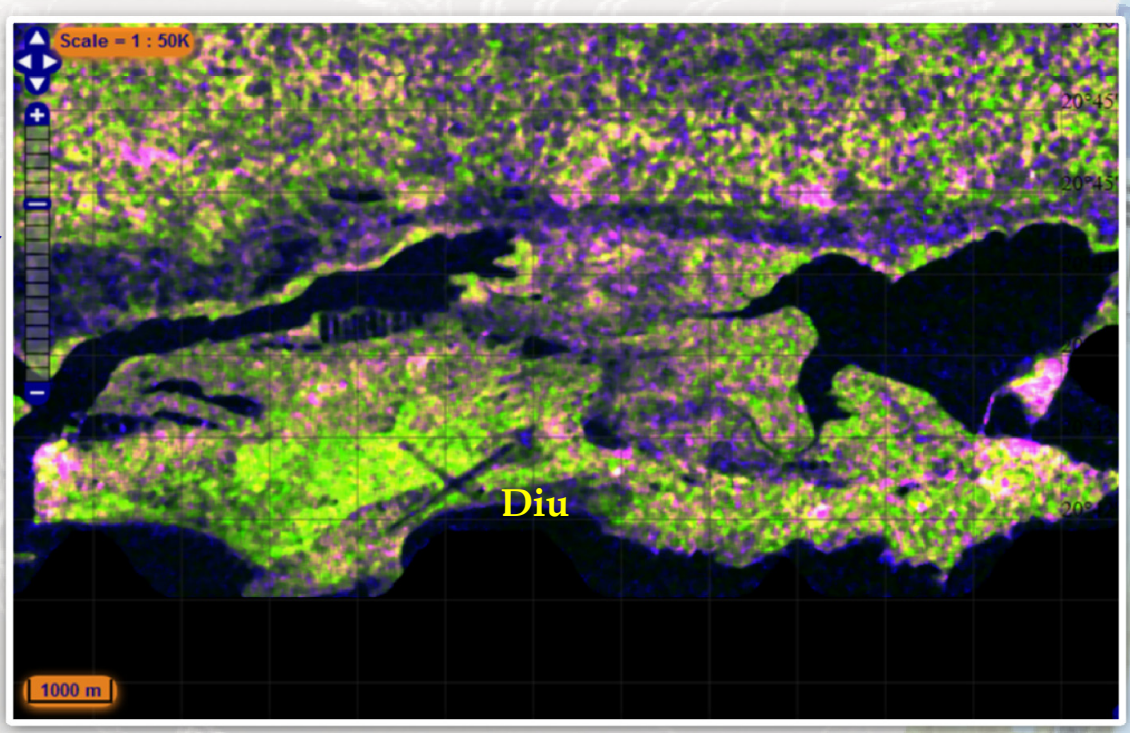


# Coastal

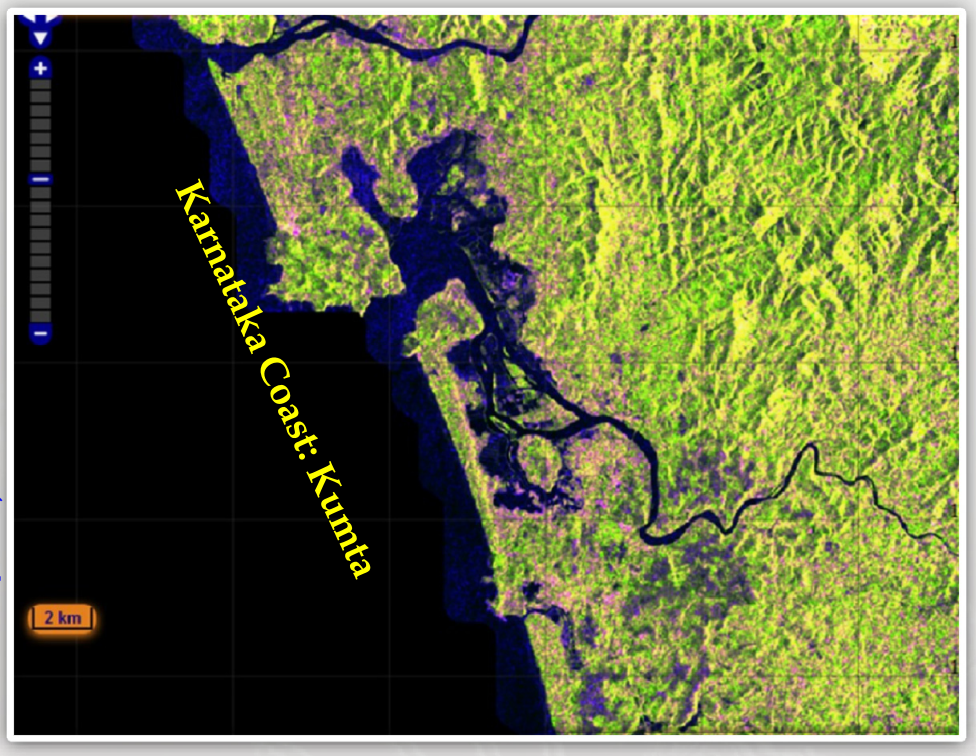
(MRS-FCC; HH; HV; HH/HV)

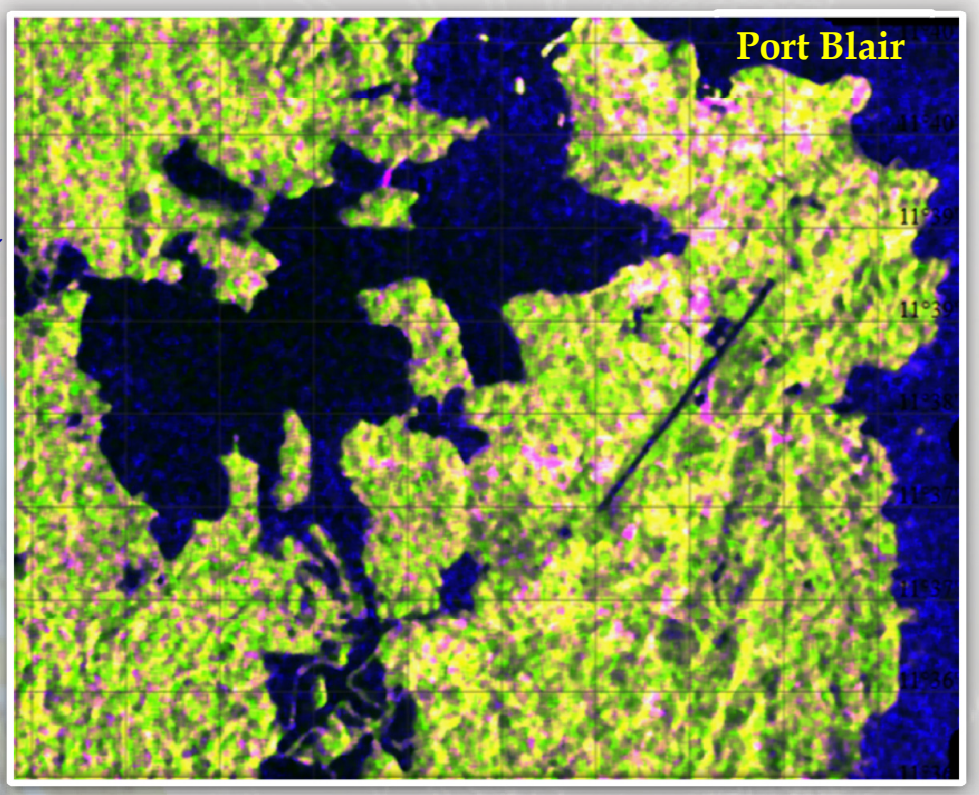


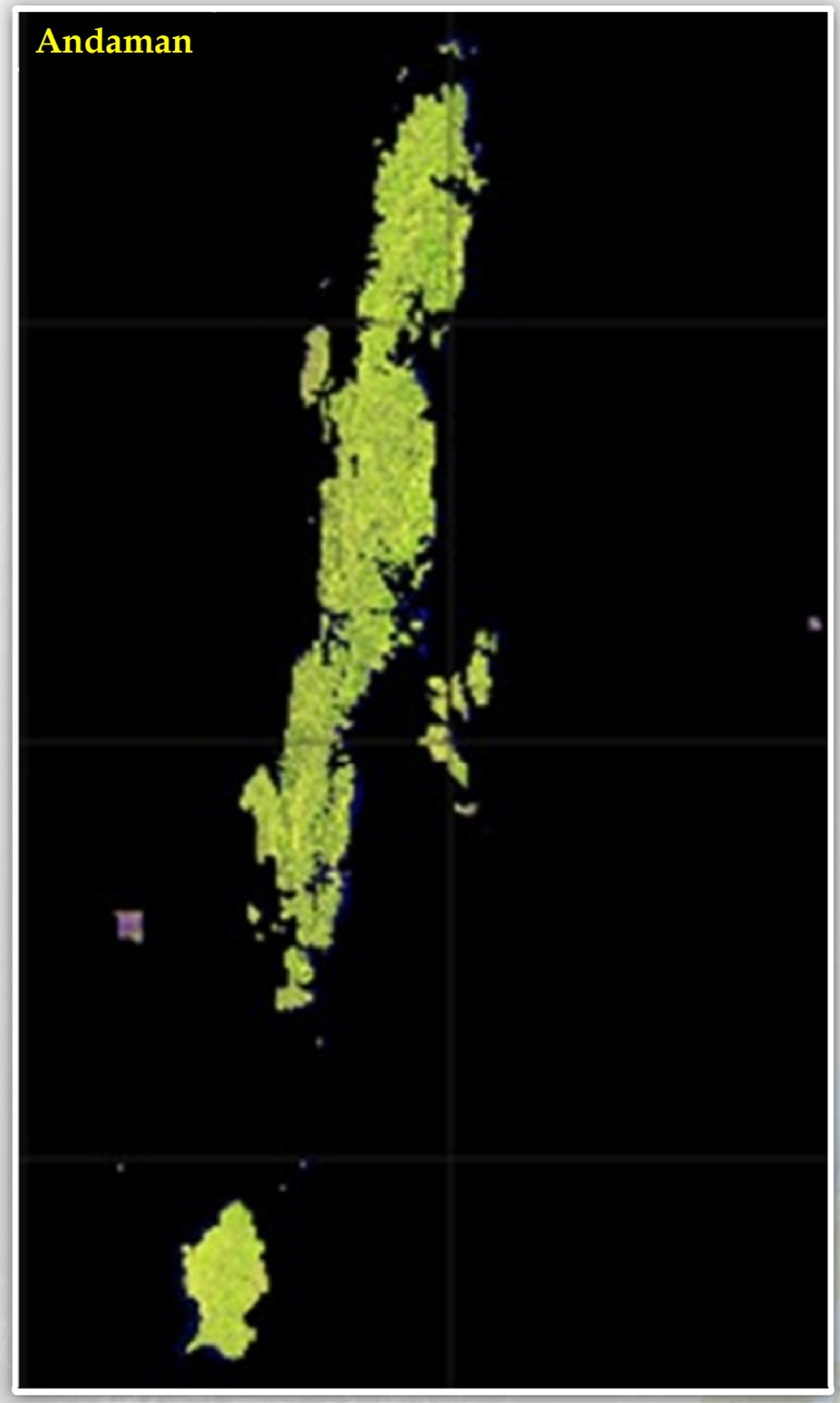
# Coastal

(MRS-FCC; HH; HV; HH/HV)



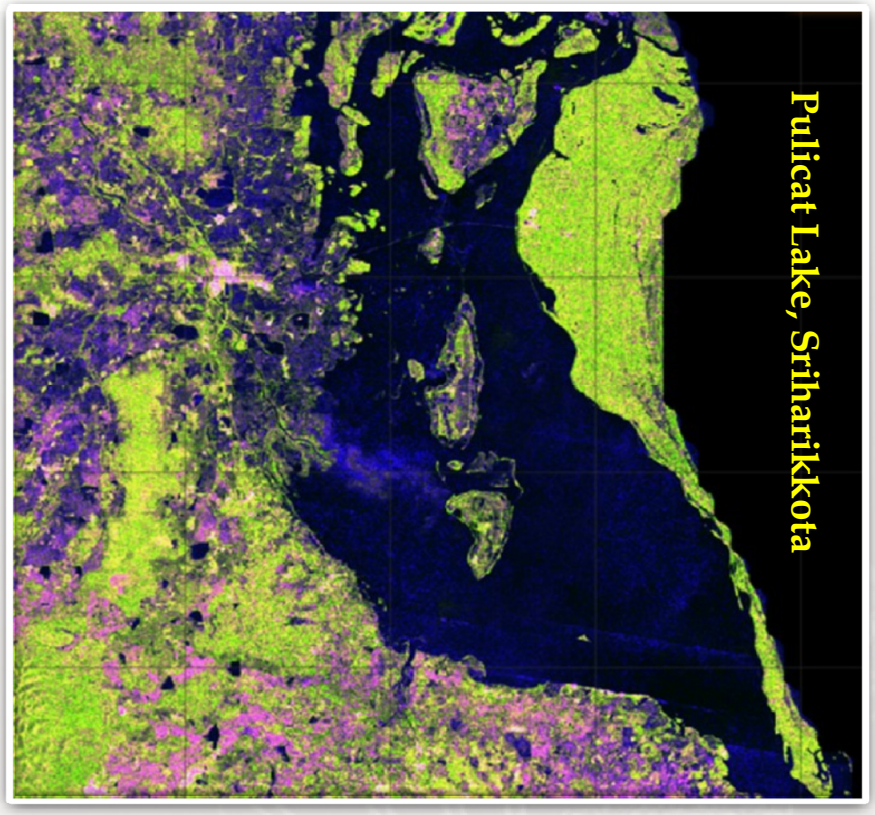
# Coastal

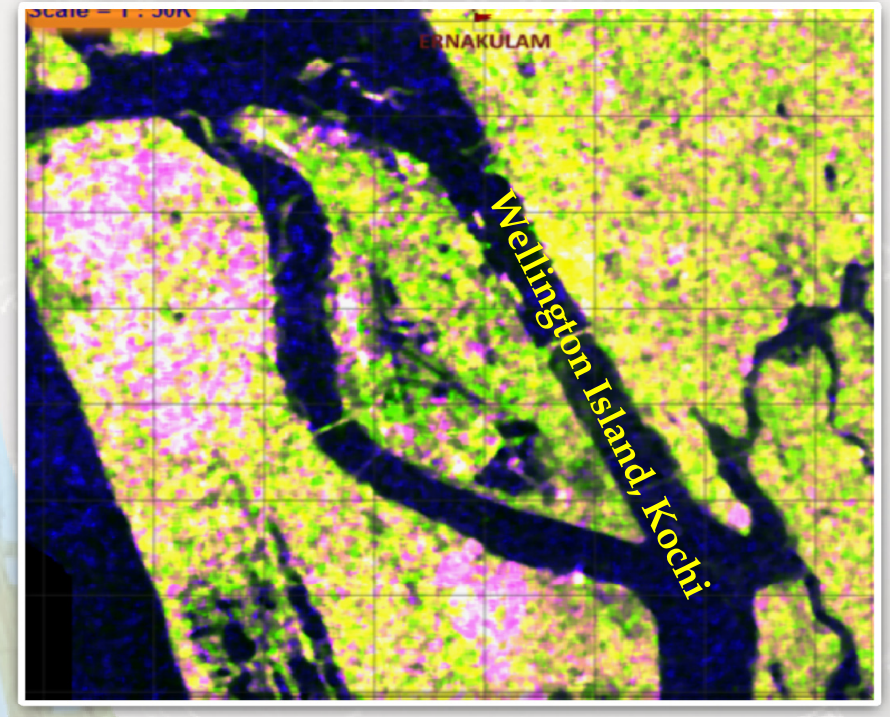



(MRS-FCC; HH; HV; HH/HV)

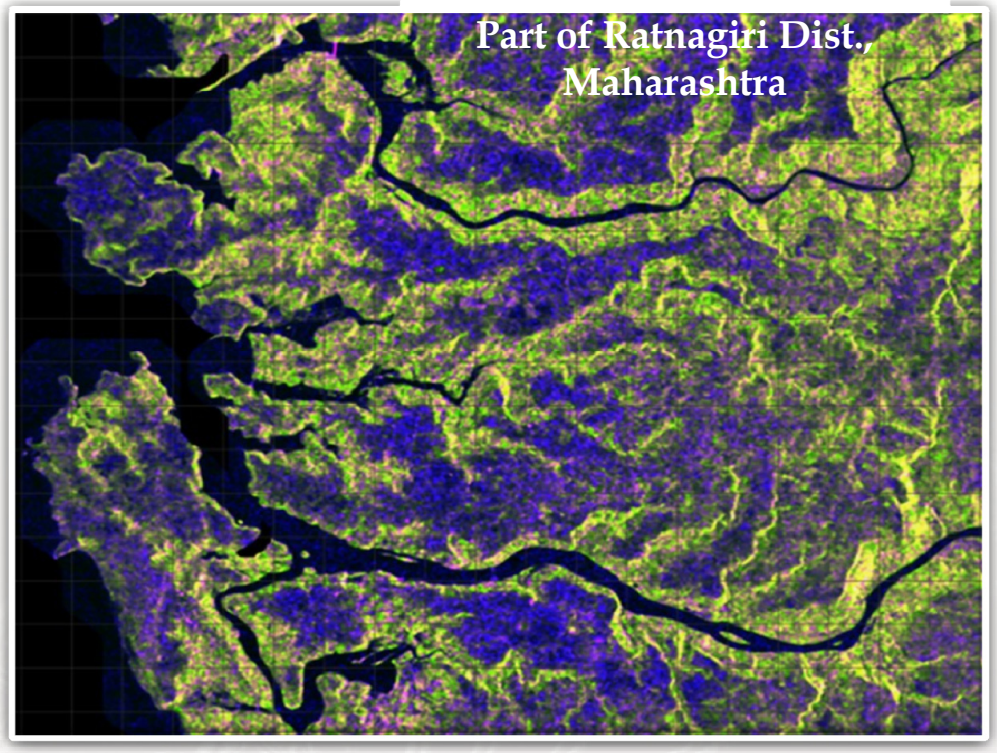
# Coastal

(MRS-FCC; HH; HV; HH/HV)



# Coastal

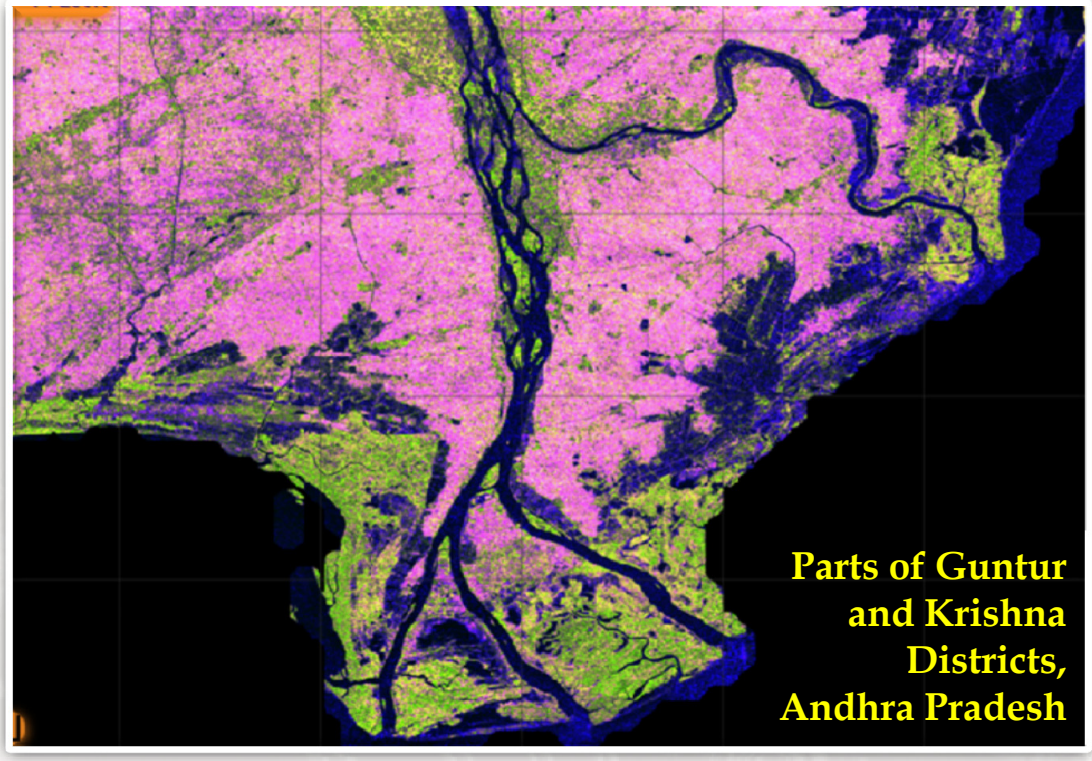


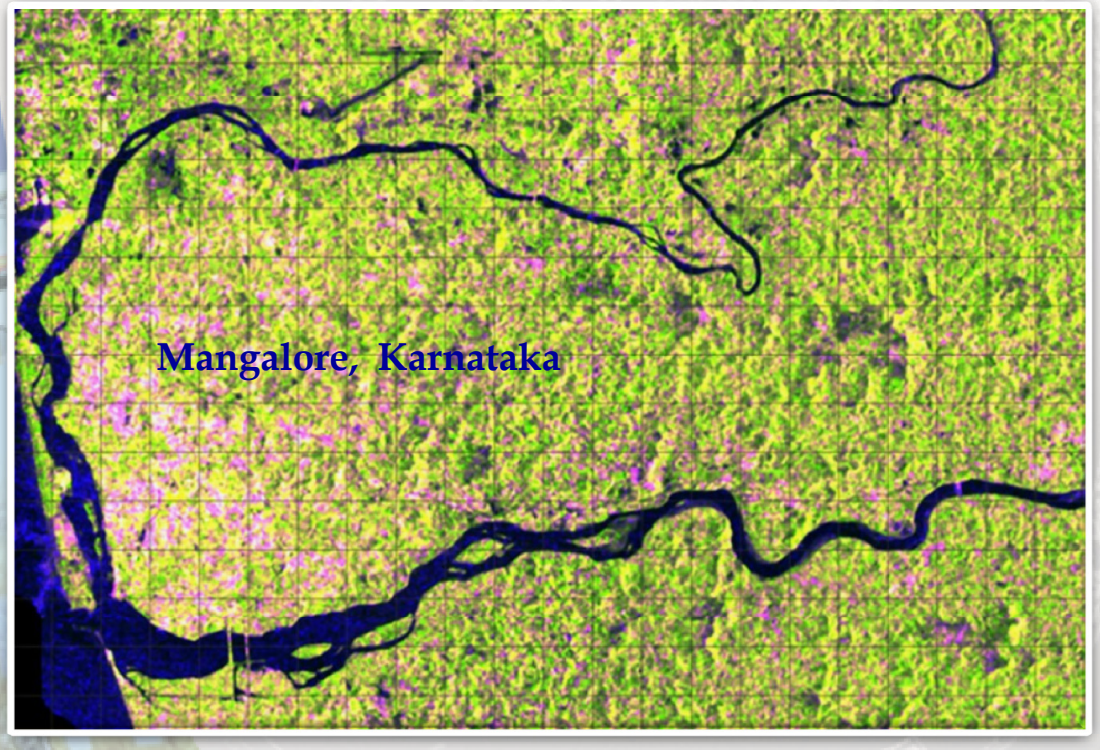


(MRS-FCC; HH; HV; HH/HV)

# Coastal

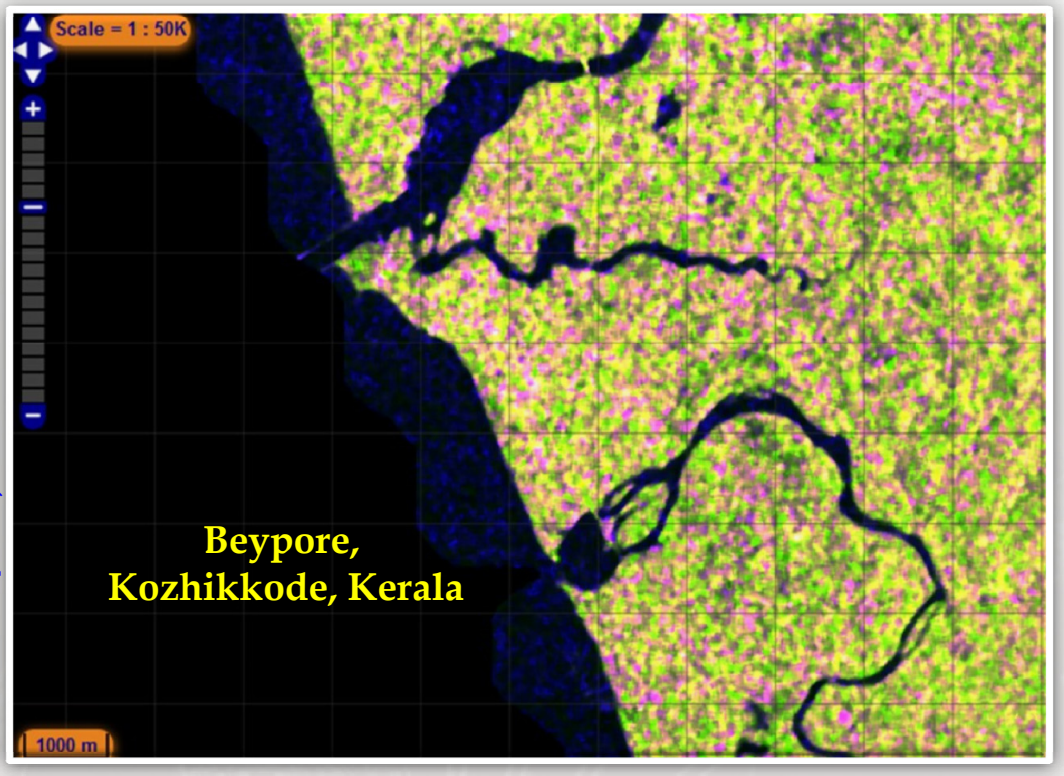
(MRS-FCC; HH; HV; HH/HV)

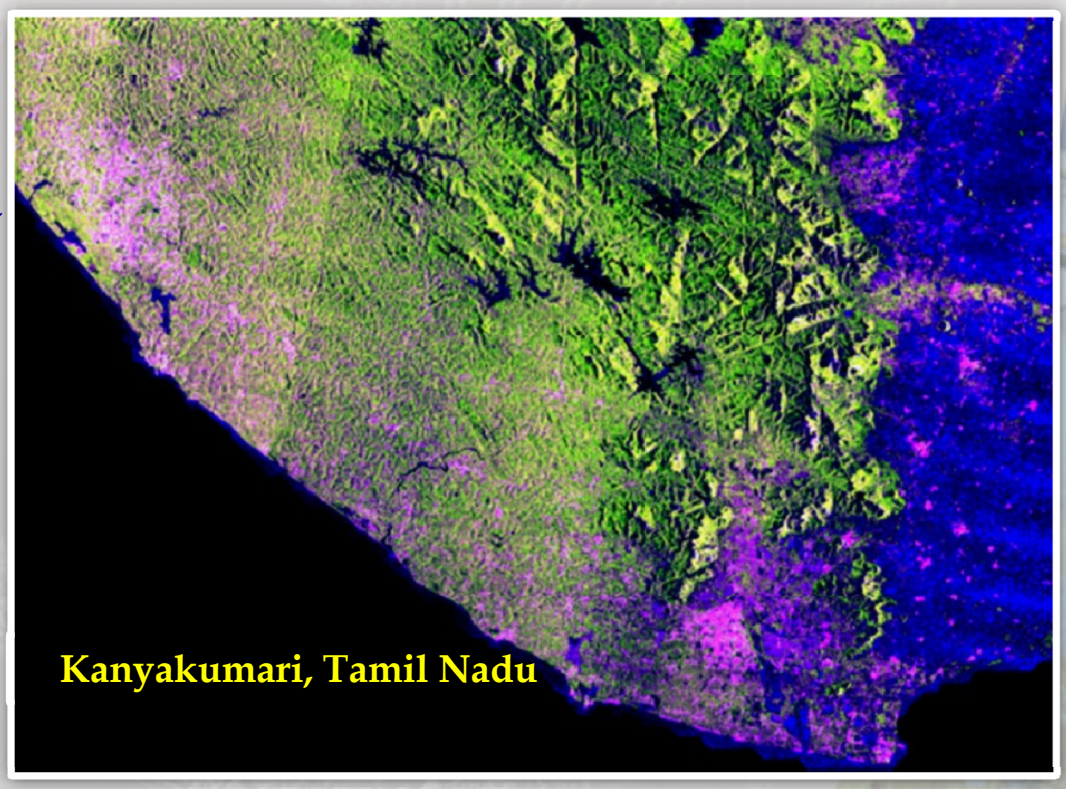


# Coastal

(MRS-FCC; HH; HV; HH/HV)

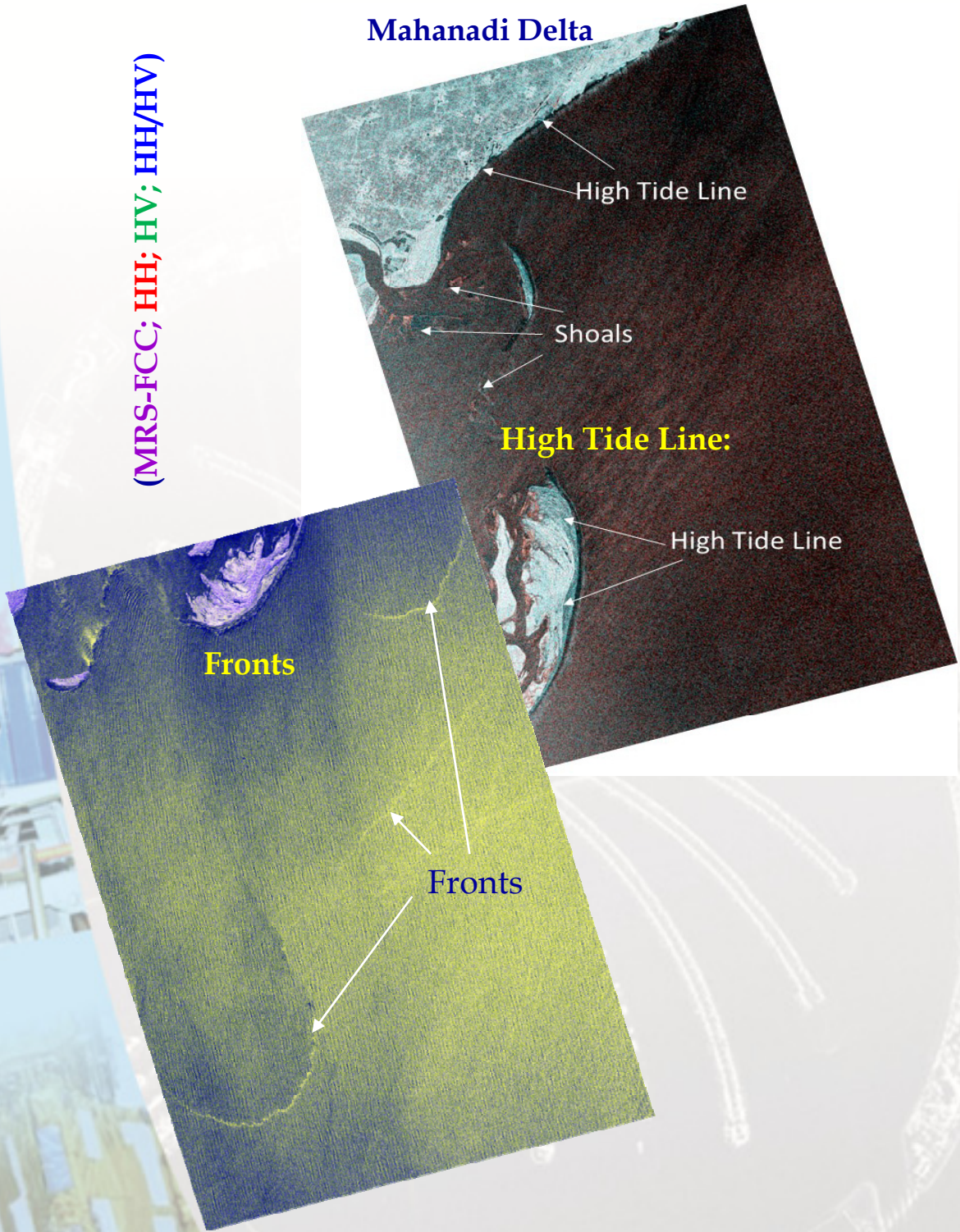


# Coastal

**Mahanadi Delta**

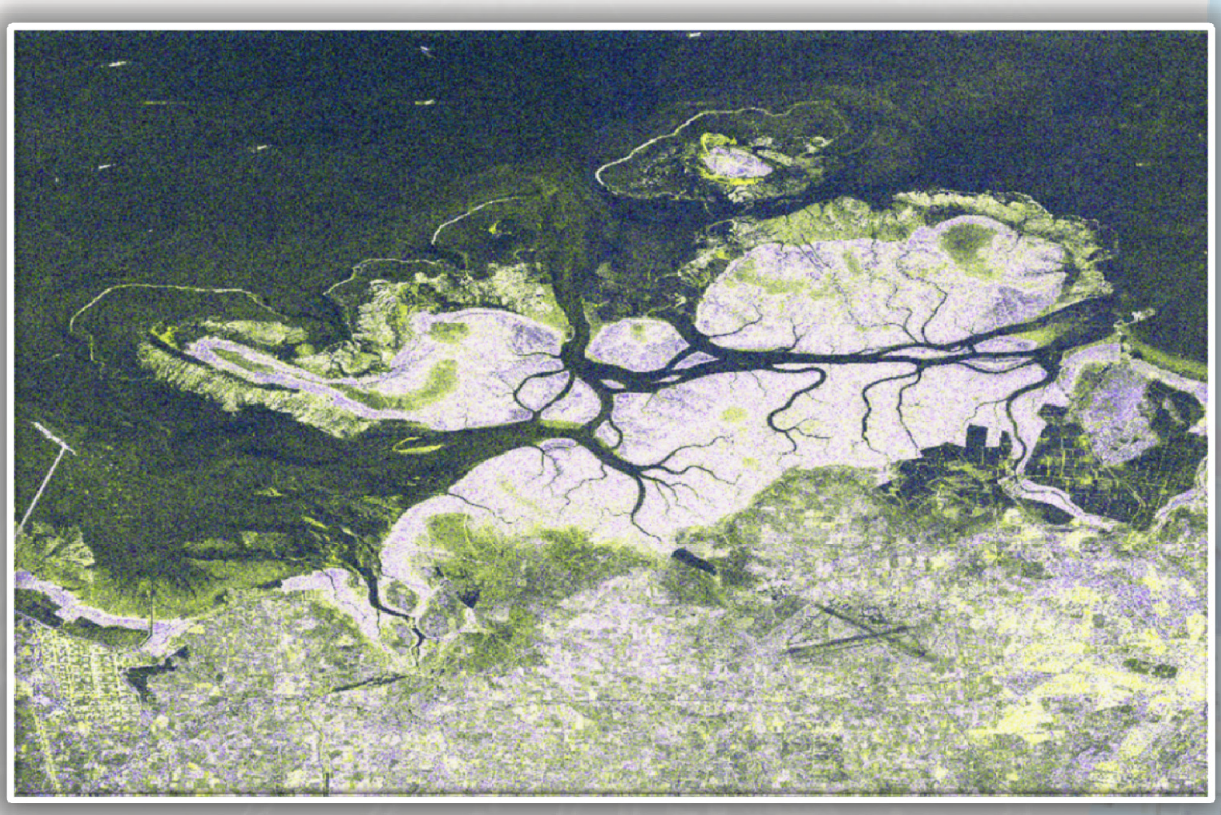
**(MRS-FCC; HH; HV; HH/HV)**



# Coastal

## Mud Flats: Gulf of Kutch

**(MRS-FCC; HH; HV;HV)**



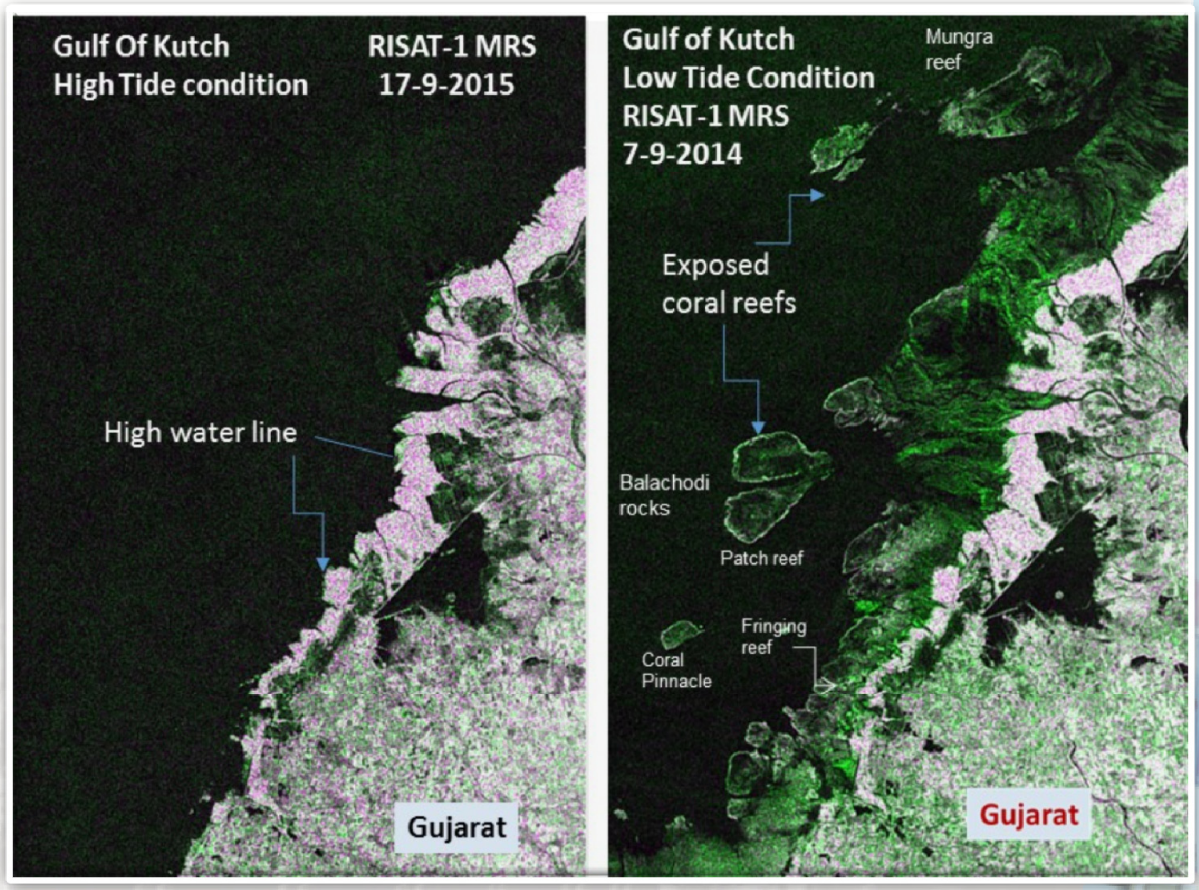
# Corals & Coral Reefs

Coral reefs represent one of the keystone ecosystems of planet earth, characterized by high biological productivity and environmental complexities. Coral reef ecosystems harbour highest concentration of marine biodiversity and their productivity supports around one quarter of marine fisheries in the world. Tropical coral reefs provide critical coastal habitats and have enormous ecological and economic resource value in terms of fishing, tourism, marine sports, constructional activities and extraction of biogeochemicals having medicinal importance. Coral reefs are extremely sensitive to the environmental conditions and hence they are used as important indicators of climate change.

Local stresses reduce the resilience of corals to withstand the global stresses. Field based or in situ study of this marine ecosystem calls for snorkelling or SCUBA diving into seas and recording underwater observations. Space based imaging have aided to a considerable extent to extract information about corals reefs in the world. A synoptic image of this shallow water target from space has become the most powerful tool to harness a plethora of information – right from their detection to zoning of these marine habitats into different reef categories.

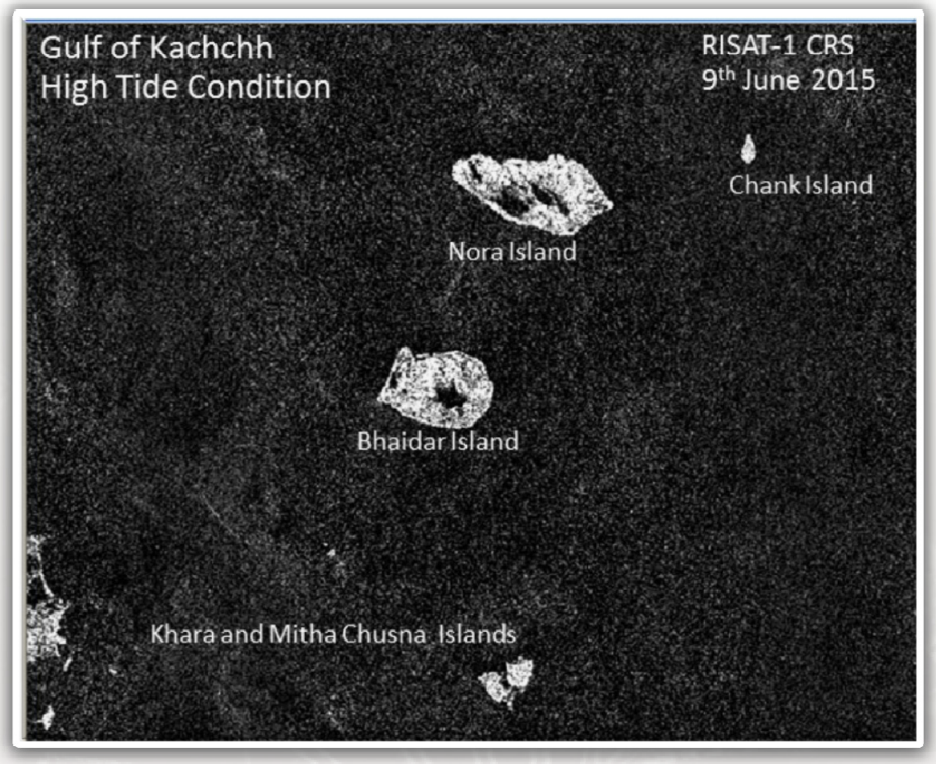
# Corals & Coral Reefs

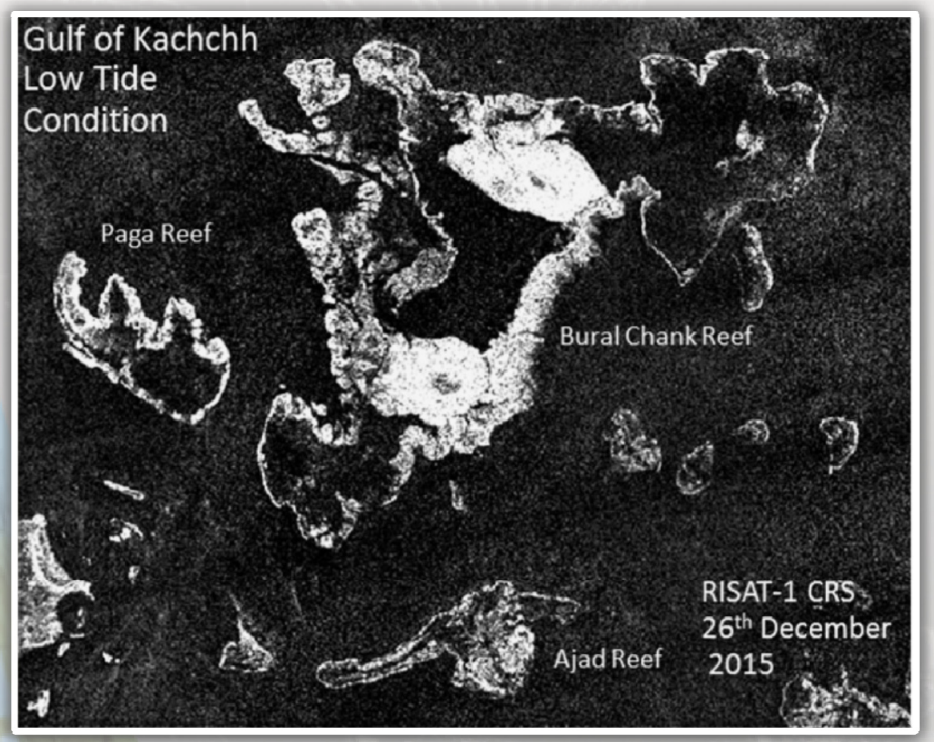
## Shallow Water Coral Reefs of Gulf of Kutch



# Corals & Coral Reefs

## Shallow Water Coral Reefs of Gulf of Kutch



# Ocean

SAR provides information that is fundamentally different from sensors that operate in the visible and infrared portions of the electromagnetic spectrum. Along with the land based processes, SAR data can also be utilized to monitor meteorological and oceanographic features such as wind speed, oil spills, significant wave height and for ship detection.

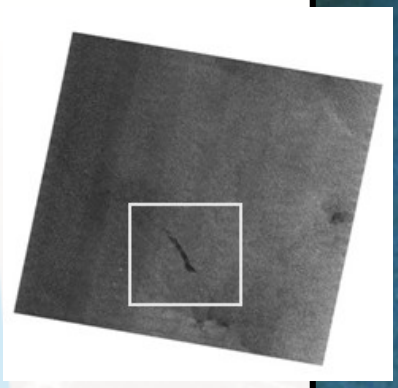
Wind speed is a crucial parameter which is routinely used in weather forecasting and monitoring by meteorological stations. Significant Wave Height (SWH) is another parameter which is needed for ocean studies. Oceanic parameters and features are of great value to the naval department.

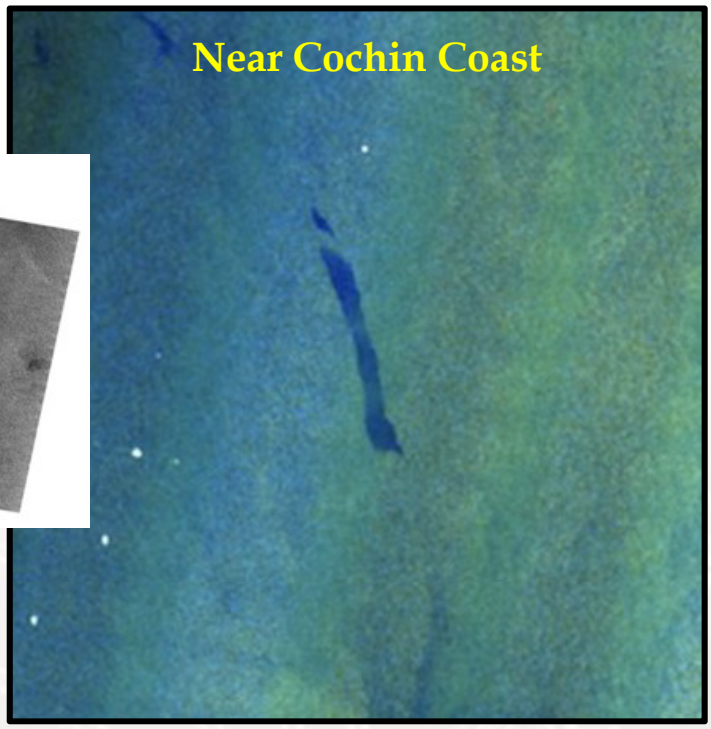
Oil spill detection and monitoring are important for pollution control and environmental protection.

Detection of ship and its wakes from SAR images are crucial for ship routing and navigating. These may also be used for surveillance purpose.

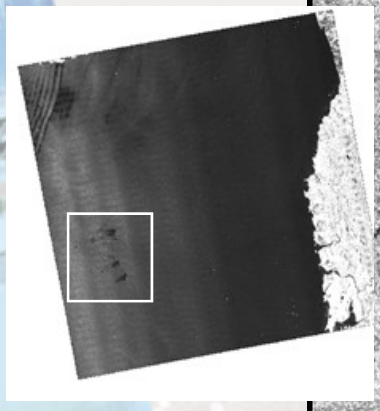
# Ocean

## Oil Spill





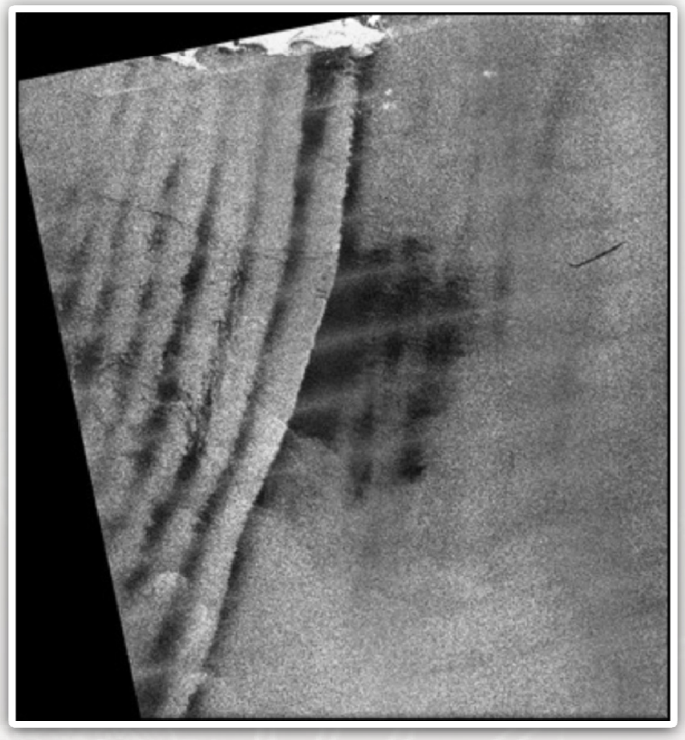

MRS
HH
HV
HV




MRS
HH

# Ocean

## Internal waves



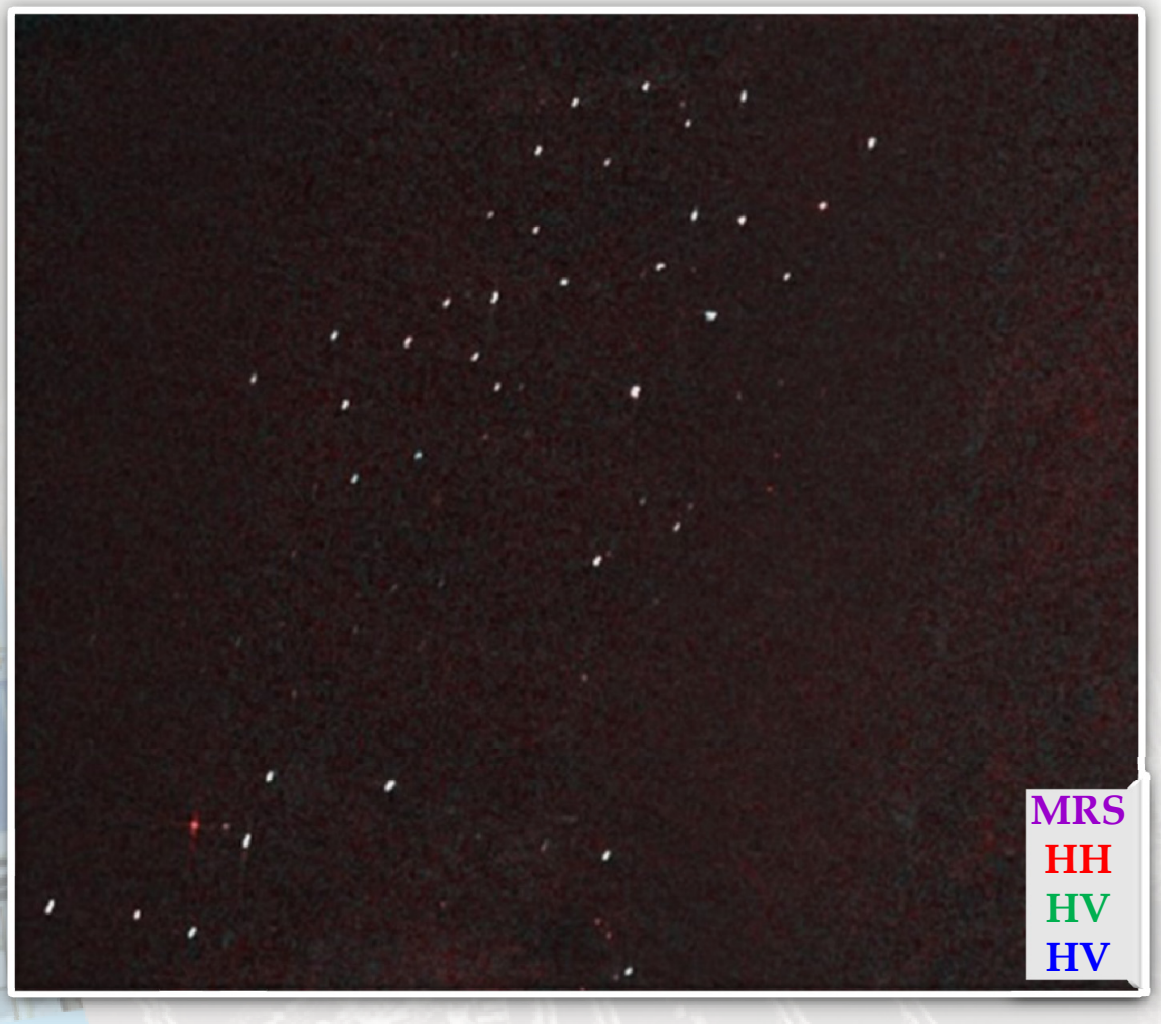
MRS
VV

## Ship Detection


MRS
VV

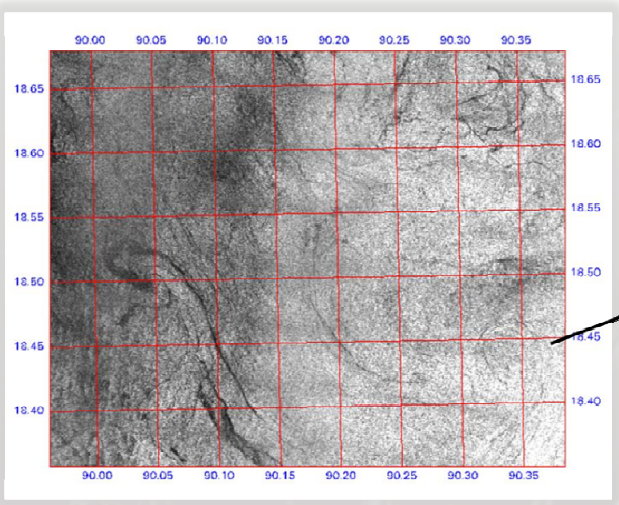
# Ocean

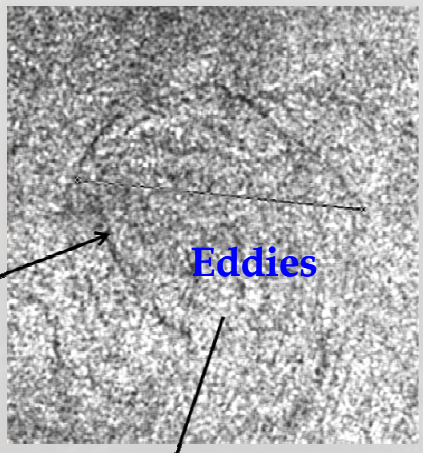
## Ship Near Mundra Port

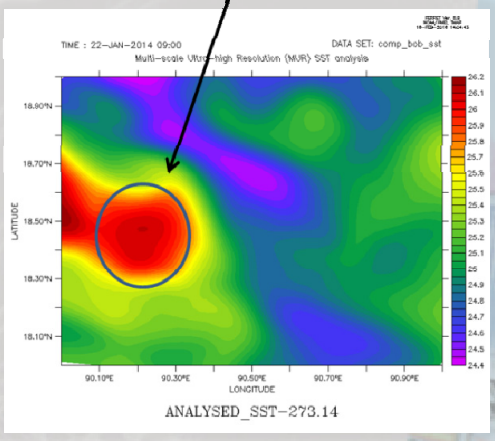


# Ocean

## Oceanic eddies



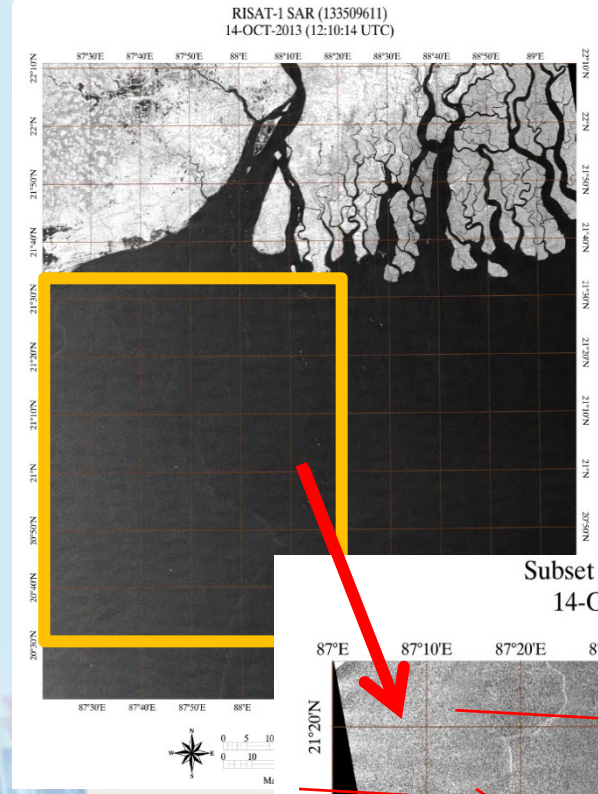



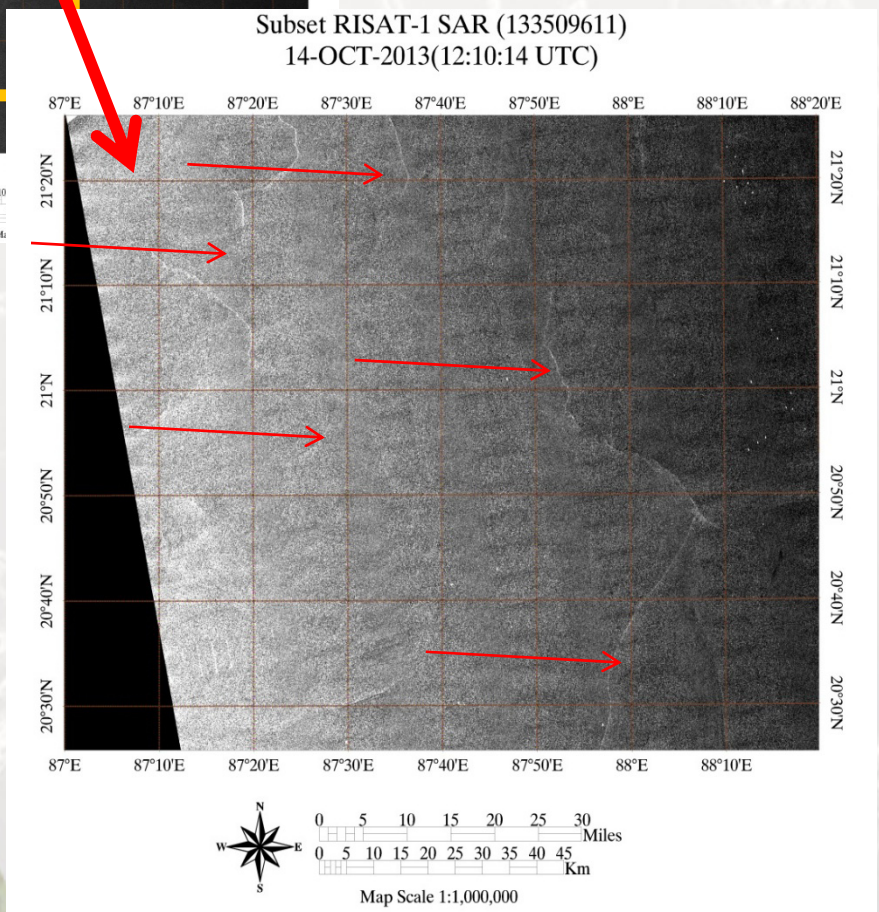

**Sub-set Image: closed circulation**

# Ocean

## Oceanic fronts




**Ocean frontal structure (river plume)**



# Disaster

Disaster such as landslides, floods, mudslides occur mostly during monsoon and post monsoon seasons. To monitor the extent of the disasters and for aiding in rescue operations, satellite imagery from SAR is very helpful as optical data is not available due to the cloud cover. During the past few years impact of cyclones on human lives has reduced drastically due to the satellite based forecasting. It is possible to predict the time, location of landfall and wind speed. Disaster caused by cyclones and floods are known to cause heavy destruction of life and properties. This has high impact on the economy of the country. RISAT-1 has shown its potential in disaster management, monitoring and mitigation. Flood mapping of the affected areas is done during such disasters to help the state and district management authorities in evolving proper and timely rehabilitation plans.

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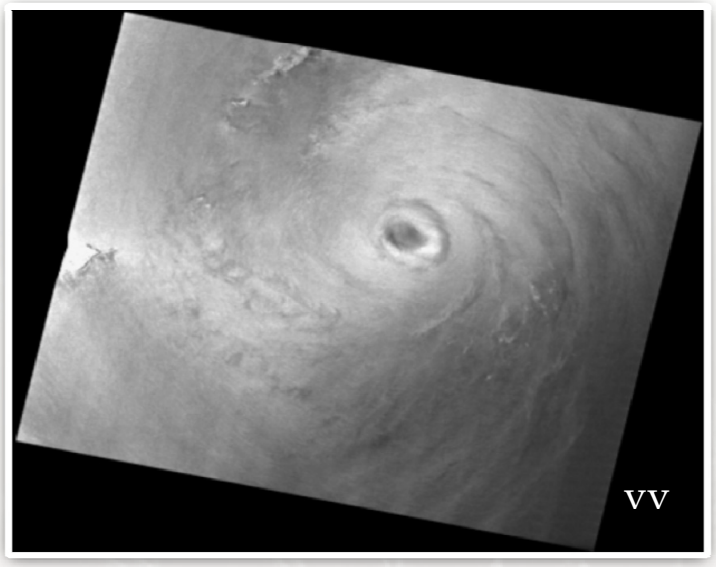
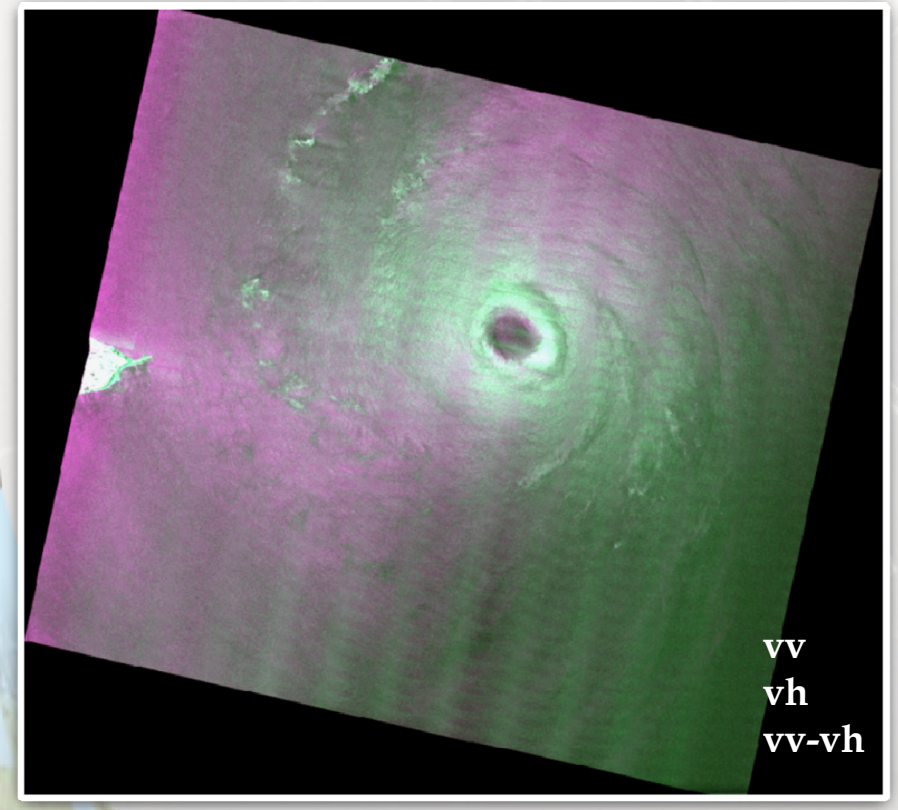
SAR data can be effectively used in monitoring volcanic eruptions, as has been reported worldwide. Interferometric mode of data acquisition is specially useful for deformation mapping and tracking of lava flow. This can also be used for predicting short range eruption events.

Time series analysis of major earthquake events have been done using interferometric SAR datasets. Seismic events have been monitored using SAR data. Future RISAT follow on missions and NISAR (NASA-ISRO SAR) missions will be catering to such services. Deformation mapping and subsidence monitoring in mining areas are also very important applications which can be done routinely by using SAR data.

# Disaster

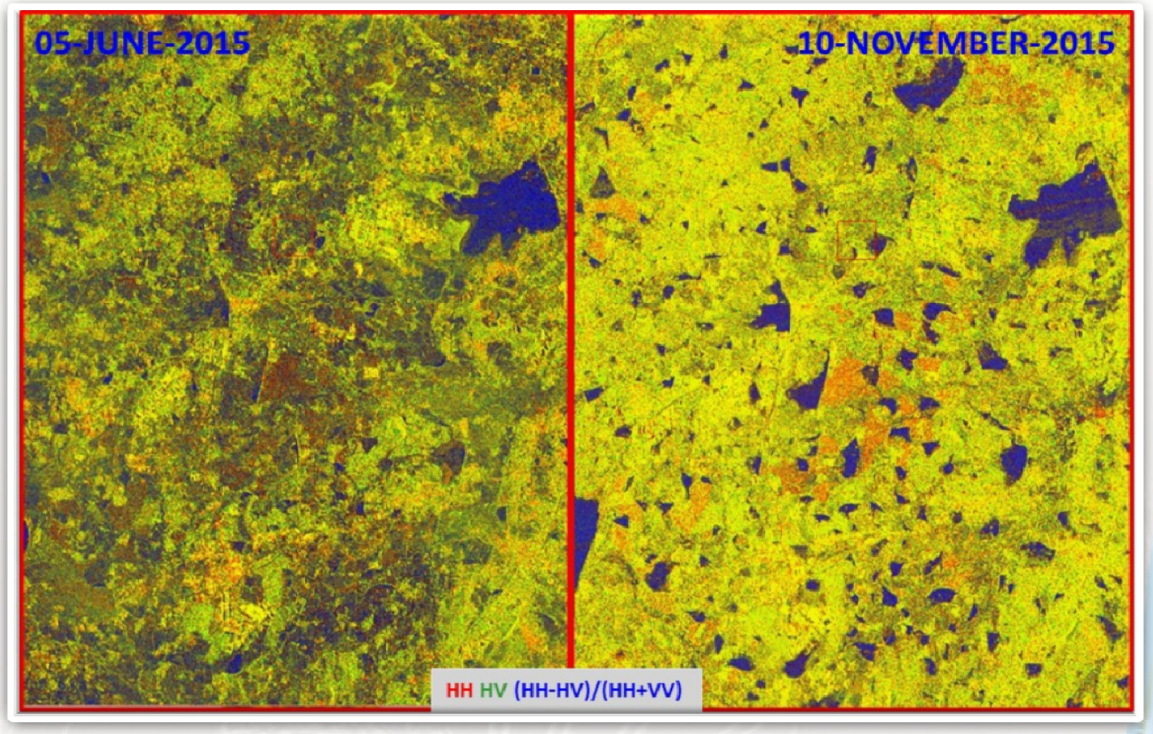
## Megh Cyclone



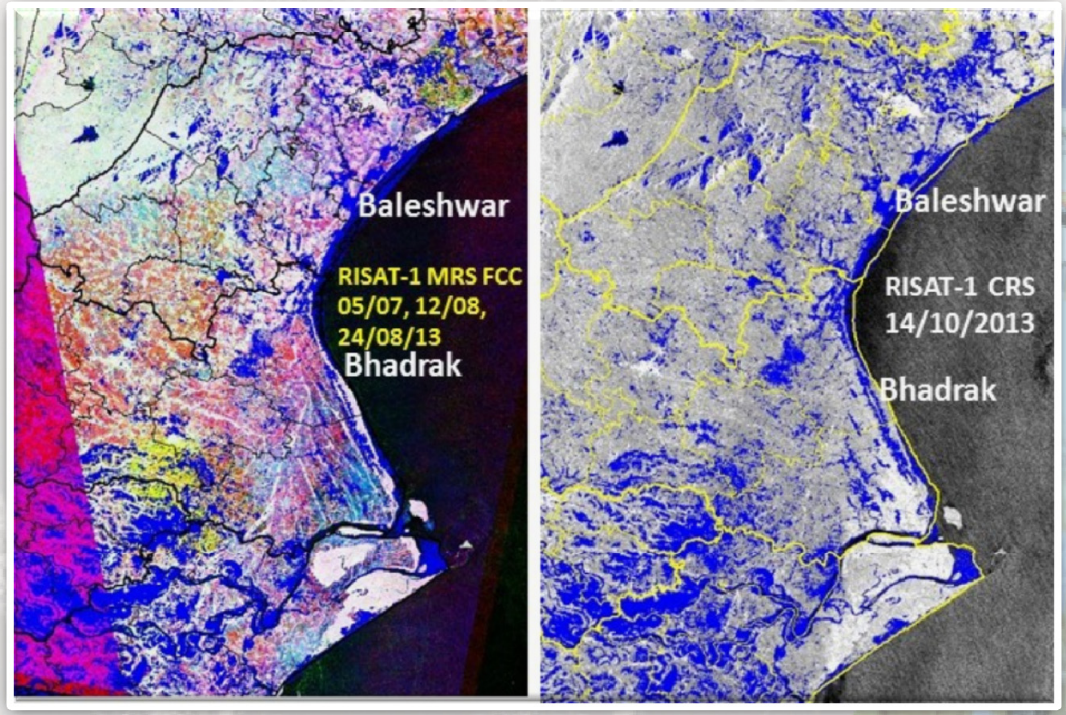



# Disaster

## Flood : Chennai

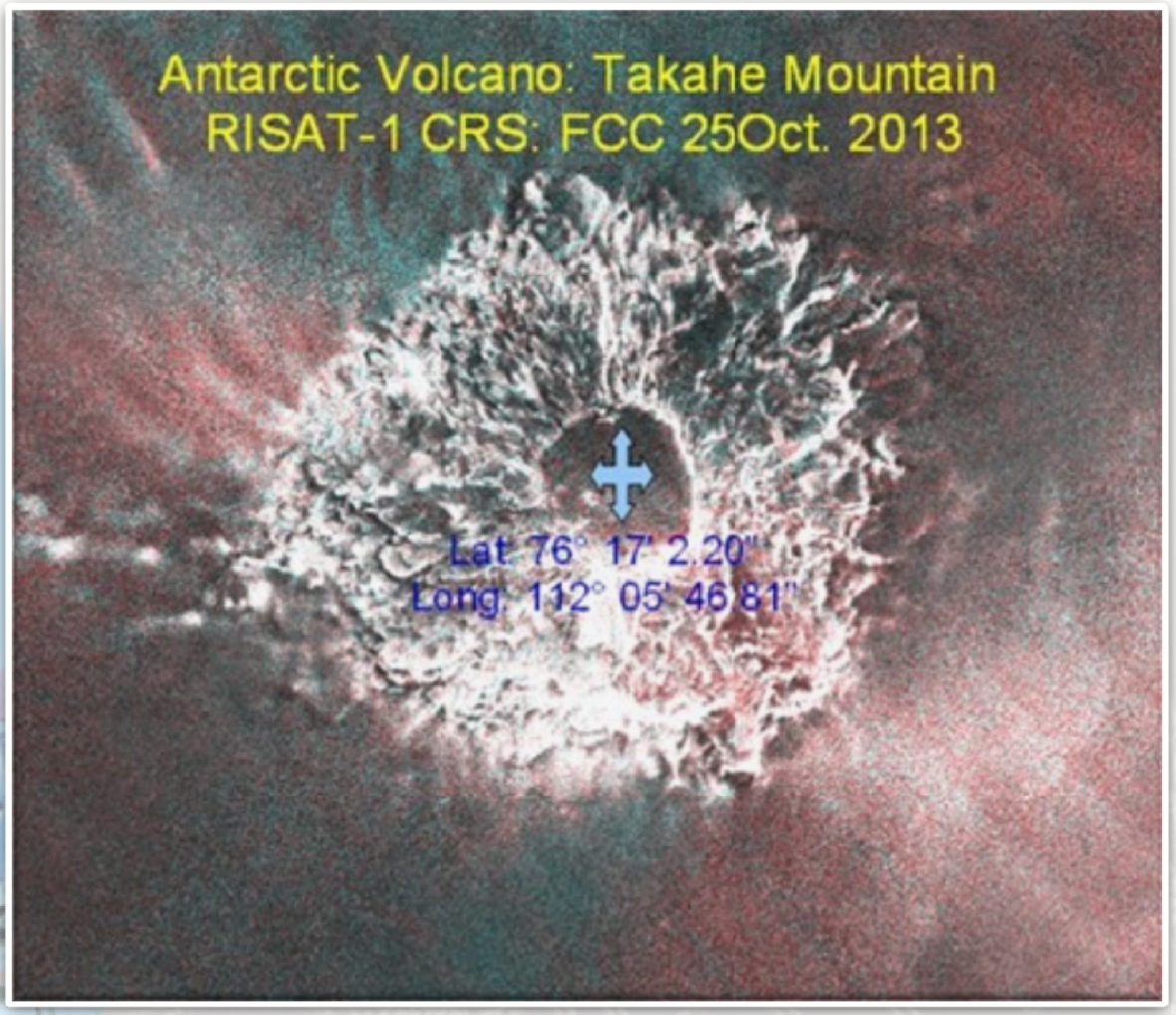


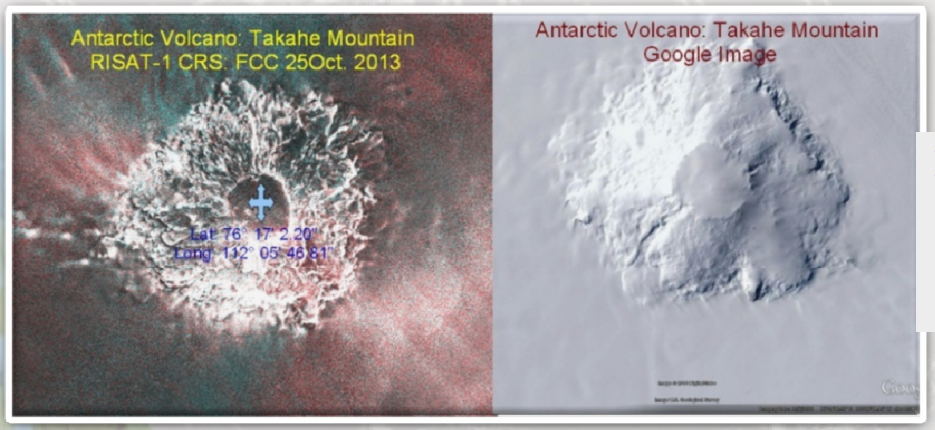

## Flood : Odisha



# Disaster

## Volcano: Antarctica

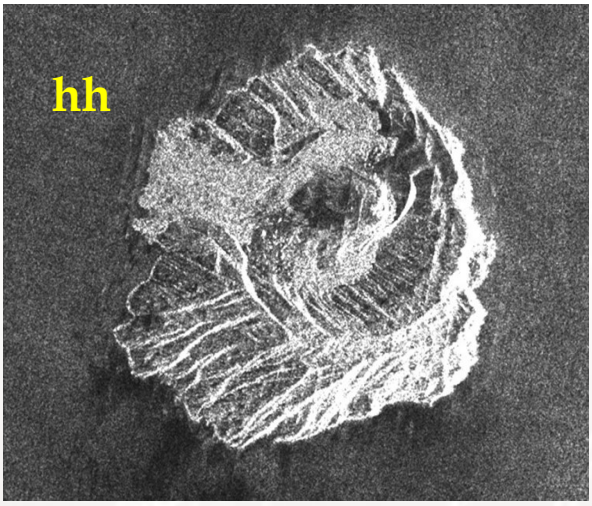


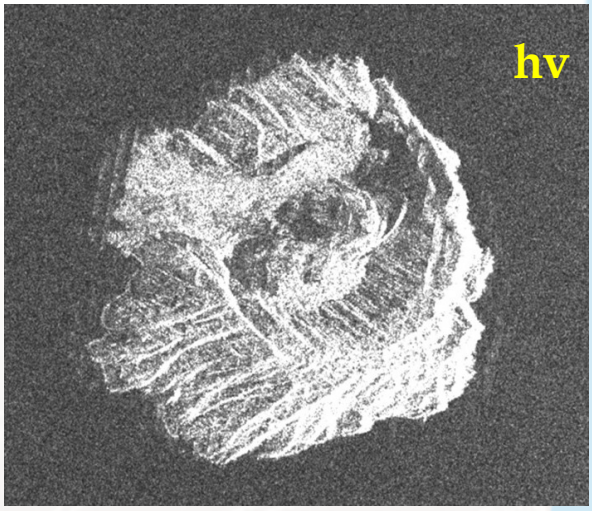




MRS
HH
HV
HV

# Disaster

## Volcano: Barren Island from FRS-1





# Himalayan Glaciers

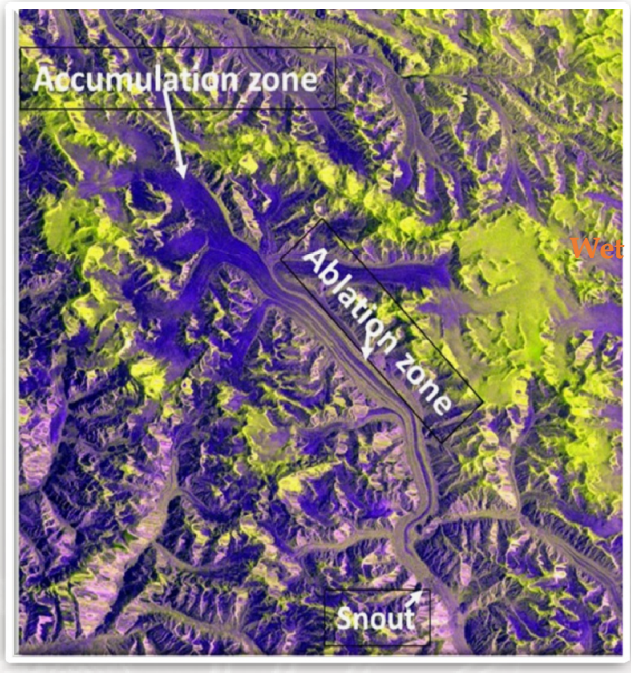
The snow fields and glaciers of Himalayan region play a vital role for human civilization. It is the snow and glacier melt runoff from Himalayan region which sustains the perennial flow of Indus, Ganga and Brahmaputra river systems. The runoff from Himalayan rivers supports domestic, irrigational and industrial water demand of a very large population residing in Himalayas and Indo-Gangetic alluvial plains. But it is being thought by scientific community that global warming caused by increase in concentration of green house gases in atmosphere can cause dramatic impact on the quantum of these resources effecting future runoff in the river systems. In view of the importance and significance of snow fields and glaciers for water security of the nation and assessing climatic variations in Indian sub-continent, these cryosphere elements need to be regularly mapped and monitored. At large snow fields and glaciers govern the climate system of Indian land mass. The glaciers of Himalaya are also the host of many glacial lakes which sometimes can become vulnerable to disasters such as Glacier Lake Outburst Flood (GLOF). Many glaciers are also characterized by crevasses which could become fatal for human movements, if not detected under snow.

Therefore, mapping and monitoring of snow fields and glaciers has become an important component of National Natural Resource Management System (NNRMS). However, in Himalayan terrain mapping and monitoring cannot be accomplished by ground based studies in terms of time and logistics. Therefore, methods based on RS coupled with GIS have become very useful for Himalayan cryosphere studies.

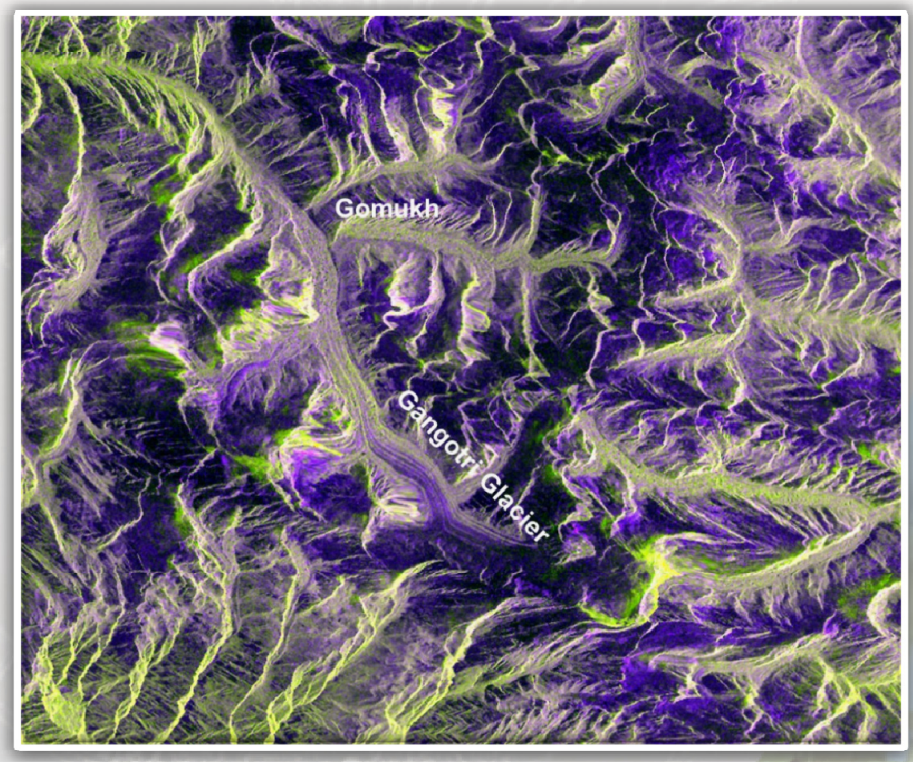
# Himalayan Glaciers

## Siachen Glacier, Karakoram Range, Jammu & Kashmir
## The longest glacier of India, ~ 72 km long

(MRS-FCC; HH; HV; HH/HV)




## Gangotri glacier of Uttarakhand: Origin of Bhagirathi River

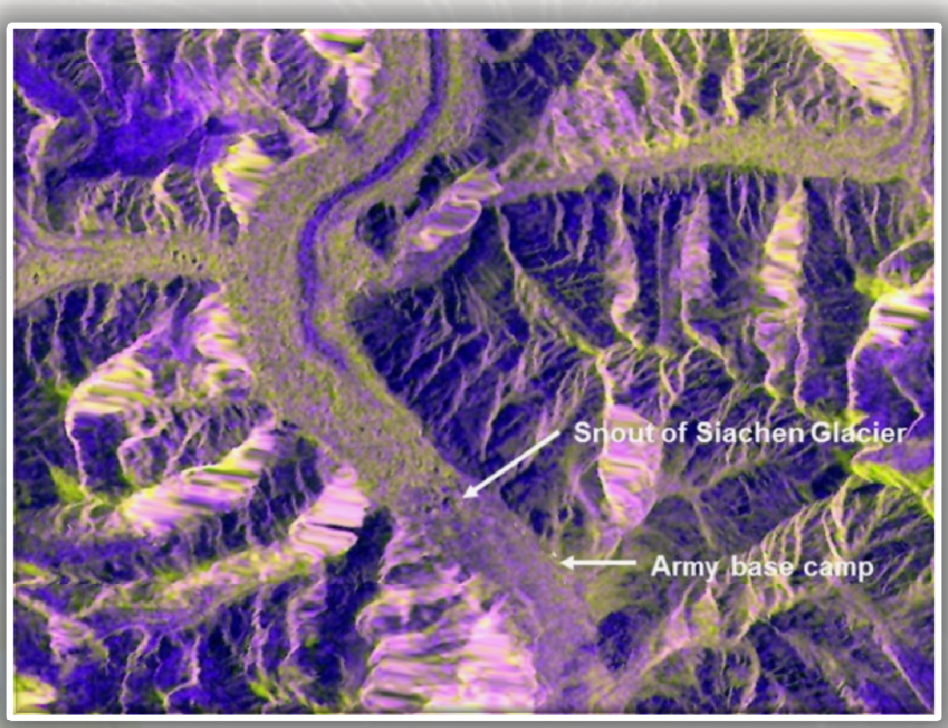


# Himalayan Glaciers

## Siachen Glacier

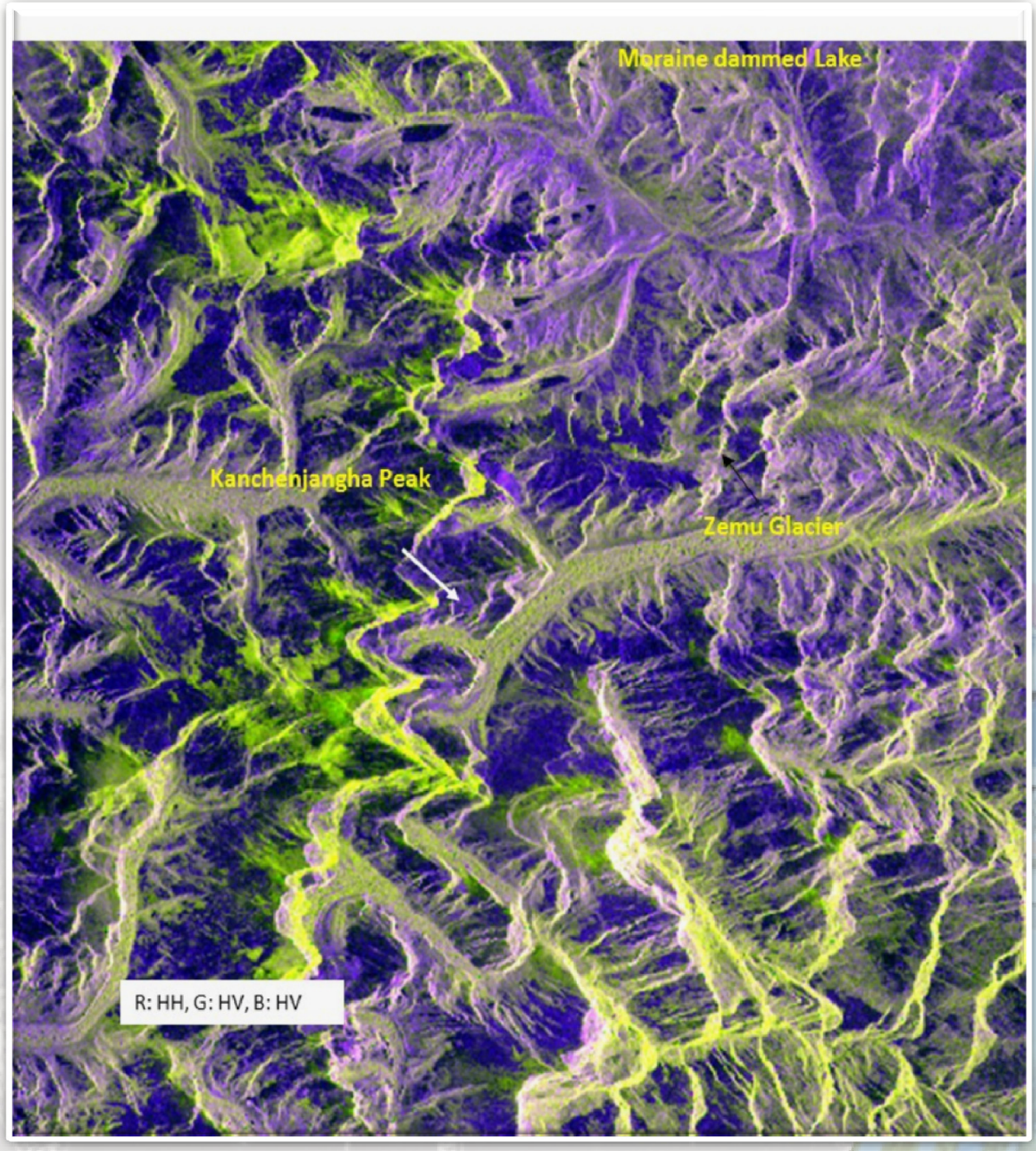

(MRS-FCC; HH; HV; HH/HV)

## Siachen Glacier: Snout



# Himalayan Glaciers

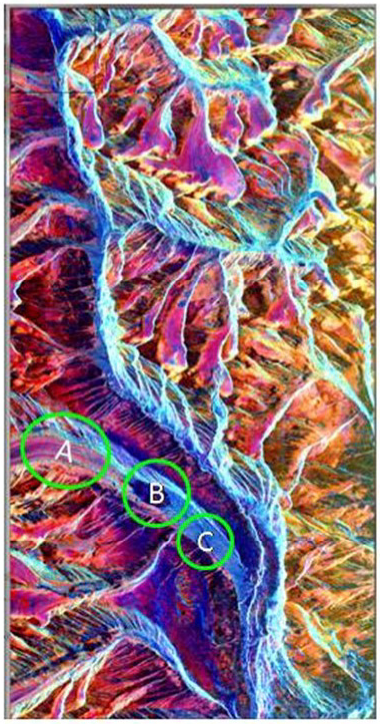
**Zemu glacier of Sikkim, originated from Kanchenjunga peak**
**Longest Glacier of Eastern Himalaya, 28 km long**




**(MRS-FCC; HH; HV; HH/HV)**

# Himalayan Glaciers

## FRS-1 Hybrid Polarimetric Images in Glaciated terrain



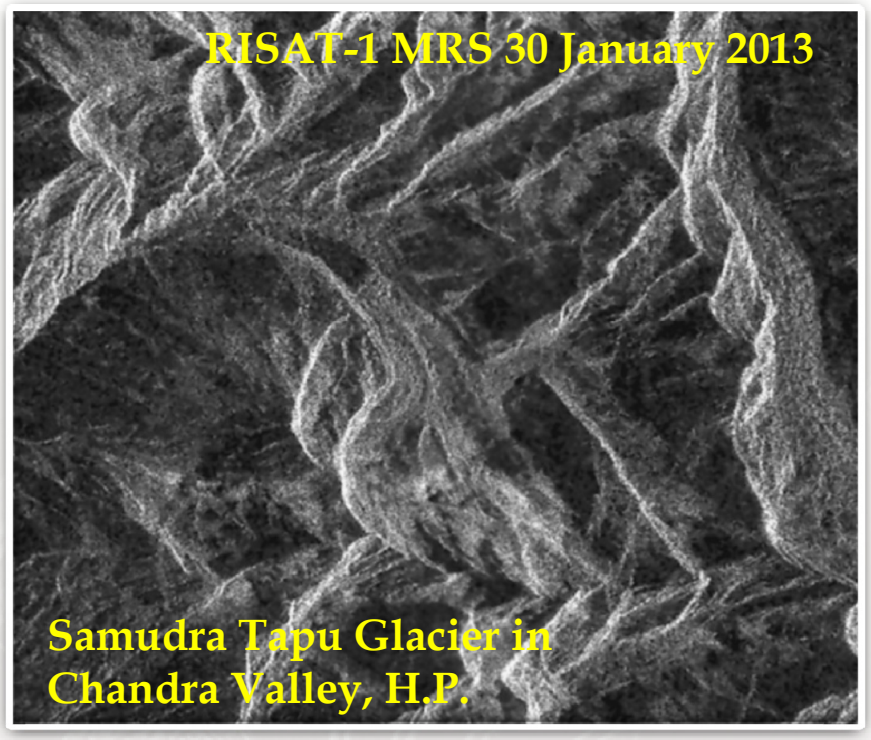

m-alpha

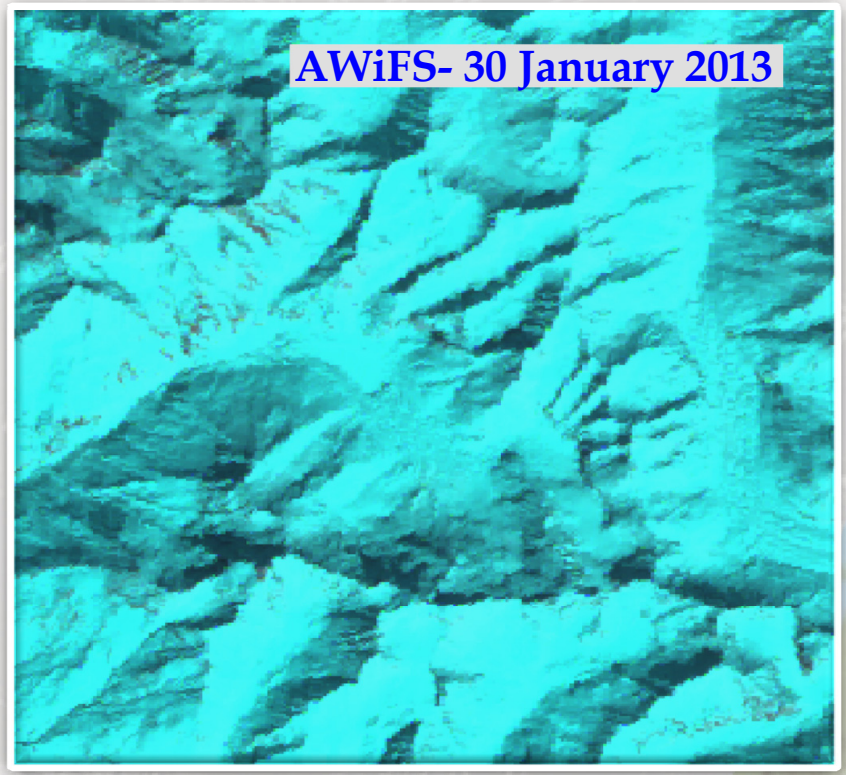
m-chi

m-delta

# Himalayan Glaciers

## Lake Buried Under Snow



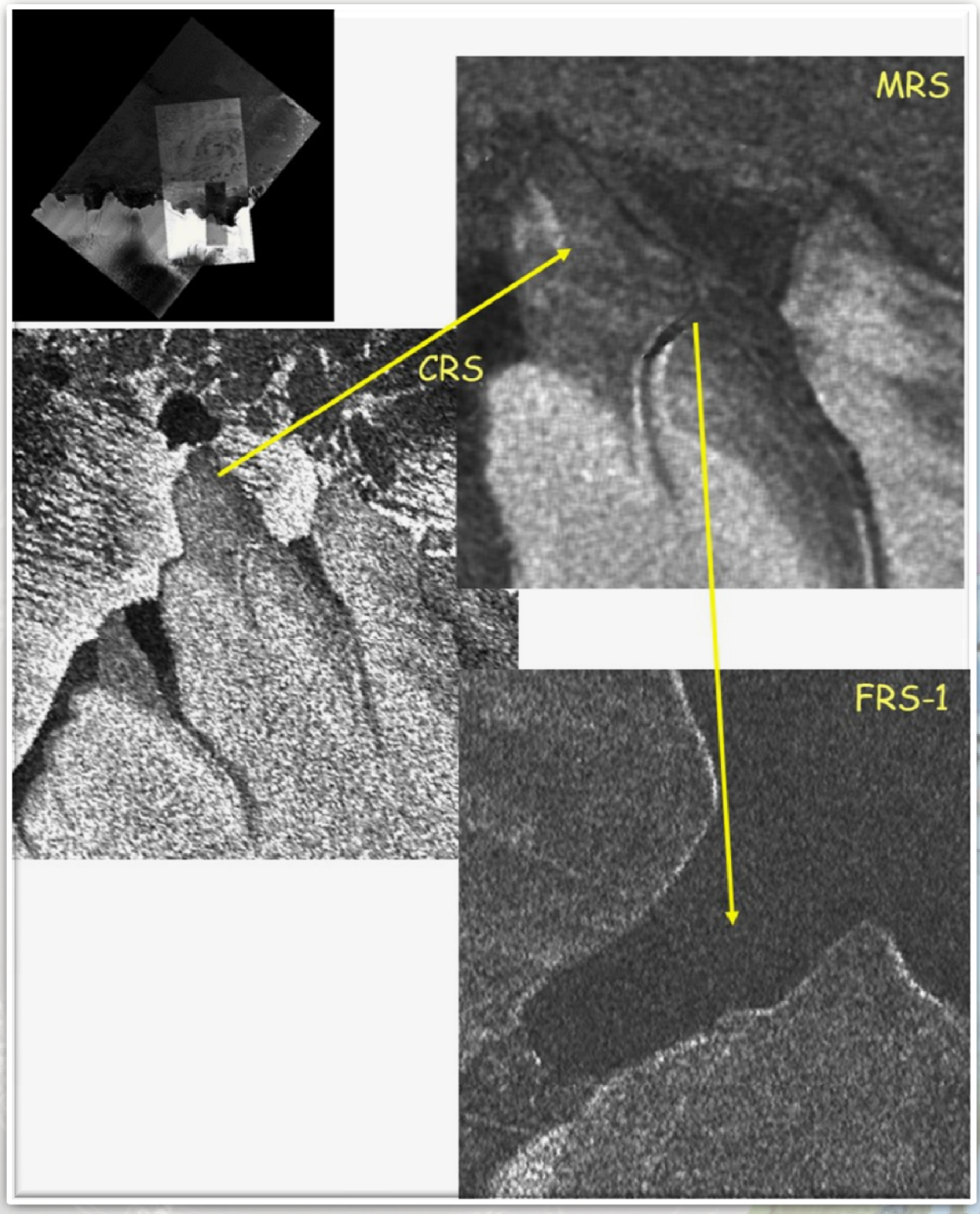
# Antarctica

Antarctica is a unique continent surrounded on all sides by ocean, where the large scale changes have an indirect indication on the global climate variation. Unusual sea ice freeze/thaw cycle, ice sheet/shelves melting, ice margin disintegration etc. are some of the major indicators of changing climate in the global scenario. Ice sheet, glaciers, ice shelf terminating at oceans may result in formation of icebergs through the process of calving. These icebergs create hindrance to ship navigation and represent a significant hazard to polar shipping and operations. India presently has two research stations Maitri and Bharati at Schirmacher Oasis and Larsemann Hills respectively. Indian Scientific Expedition to Antarctica (ISEA) has evolved as a regular programme undertaken by Ministry of Earth Sciences and coordinated by National Centre for Antarctic and Oceanic Research (NCAOR) during the last 35 years.

SAC is providing routine advisory to the ship voyage for the safe passage of our scientific and logistic team. Hence it is very important to monitor the coastal region near Bharati and Maitri as far as the ship navigation is concerned. Calving of icebergs is an important component of mass loss from the polar ice sheets and glaciers in many parts of the world especially in Antarctic ice margins. RISAT-1 data has a significant contribution to the Antarctic studies.

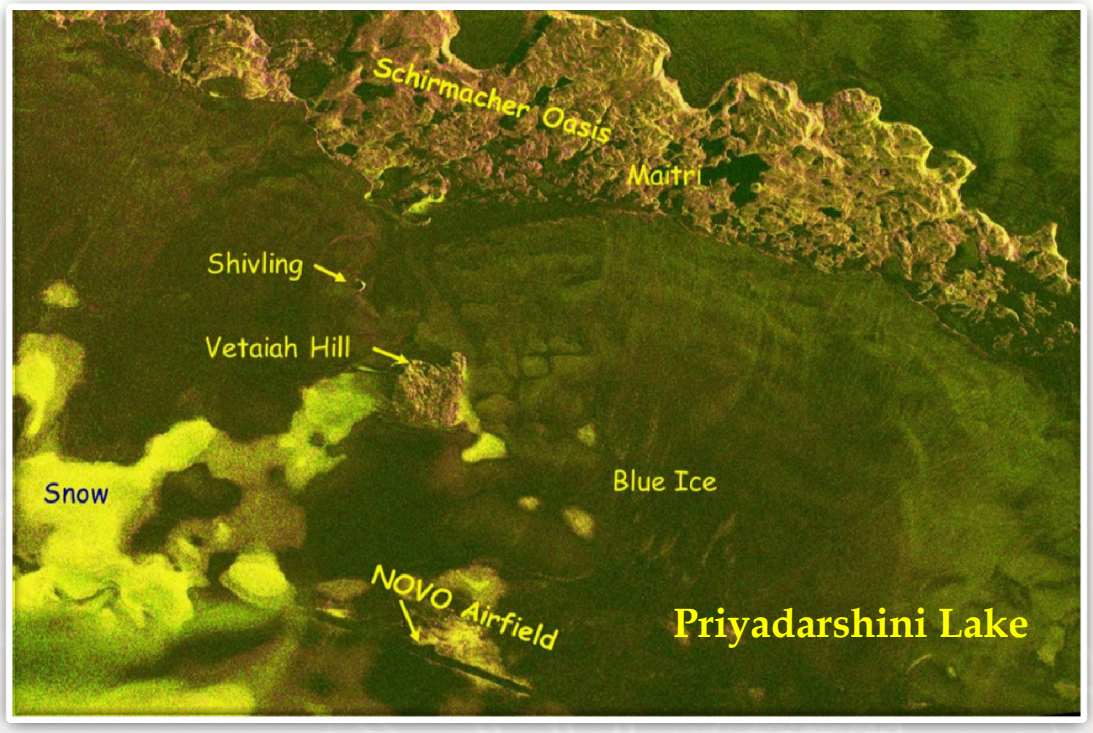
# Antarctica

## RISAT-1 FRS-1, MRS, CRS Images: Overview & Full Resolution

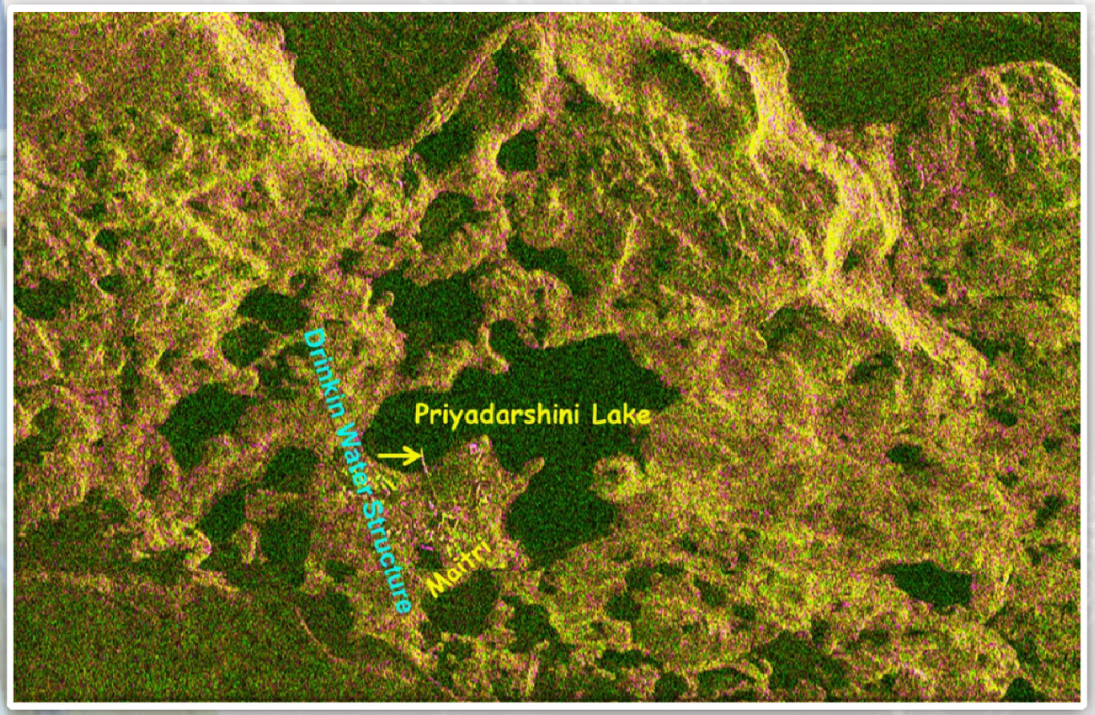


# Antarctica

## Maitri and Surroundings




## Enlarged View of Maitri




cFRS-1 FCC: RH;RV;RH-RV

# Antarctica

## Bharati and Surroundings

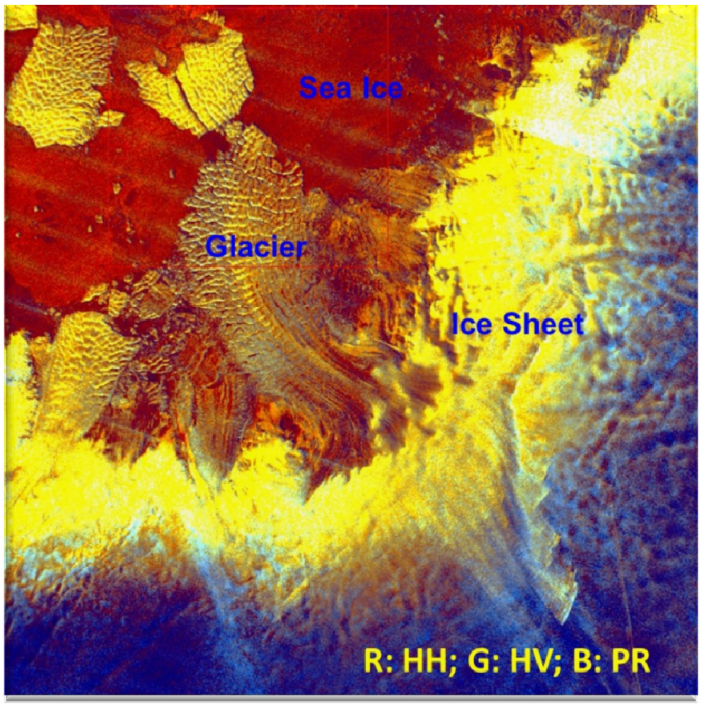

## Nearby International Research Stations


cFRS-1 FCC: RH;RV;RH-RV

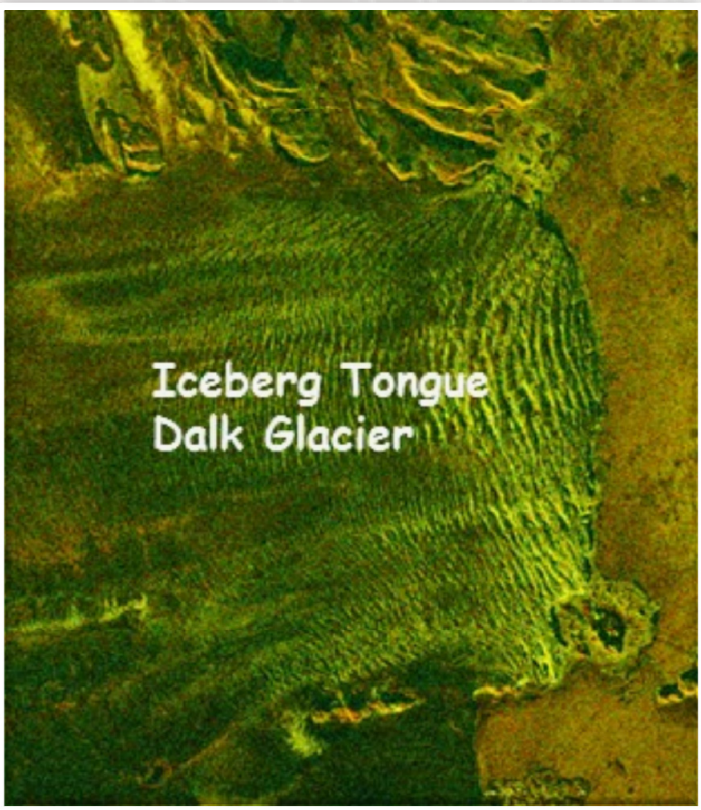
# Antarctica

## Glaciers Near Bharati

cFRS-1 FCC: RH;RV;RH/RV



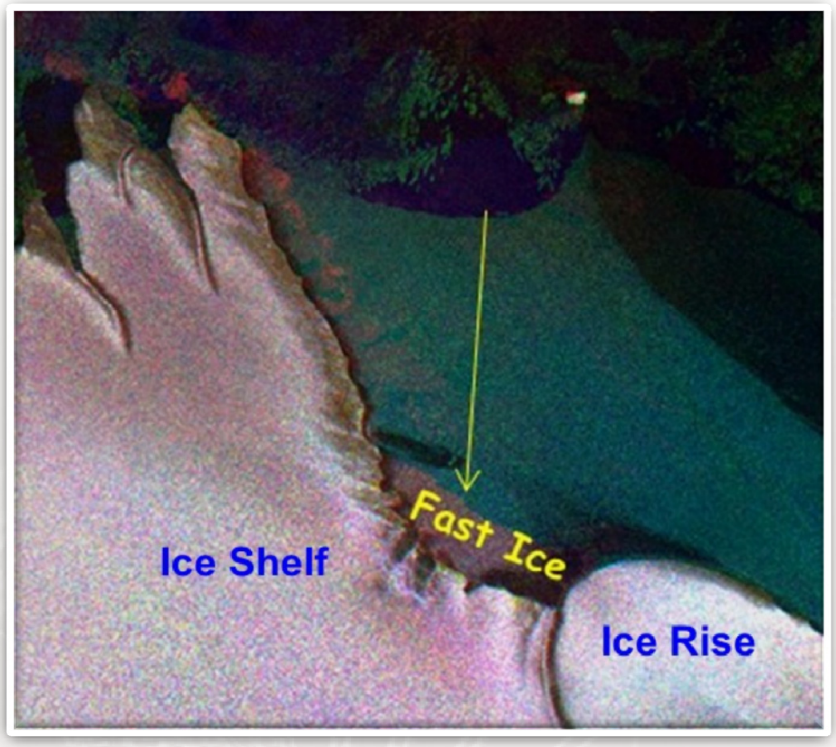

cFRS-1 FCC: RH;RV;RH-RV



# Antarctica

## Fast Ice Reduction in Multi Temporal Image FCC

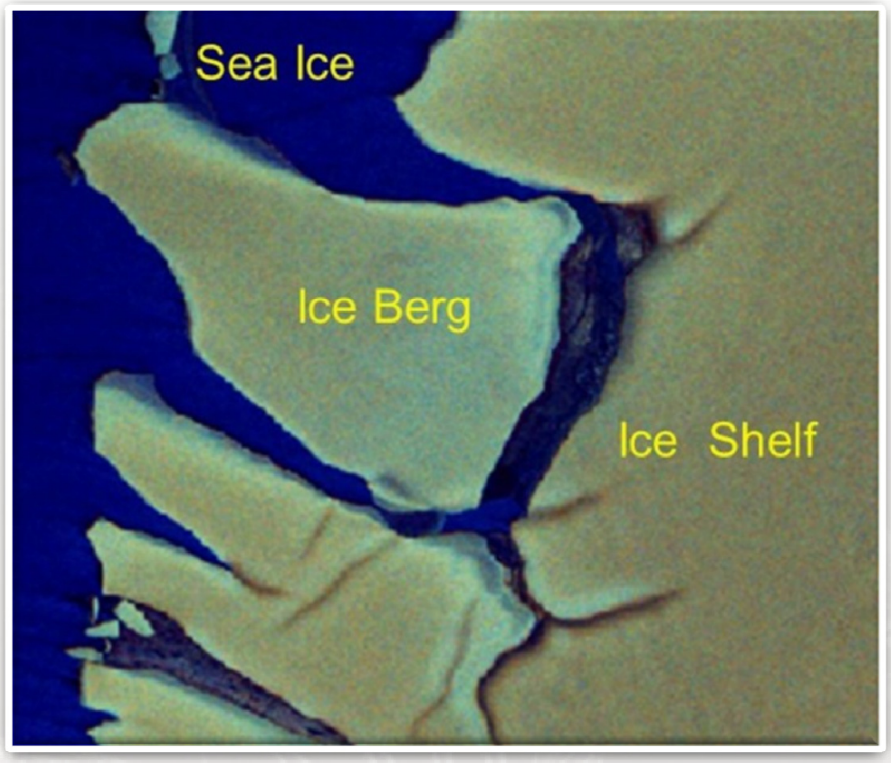
cFRS-1 FCC: RH;RV;RH-RV



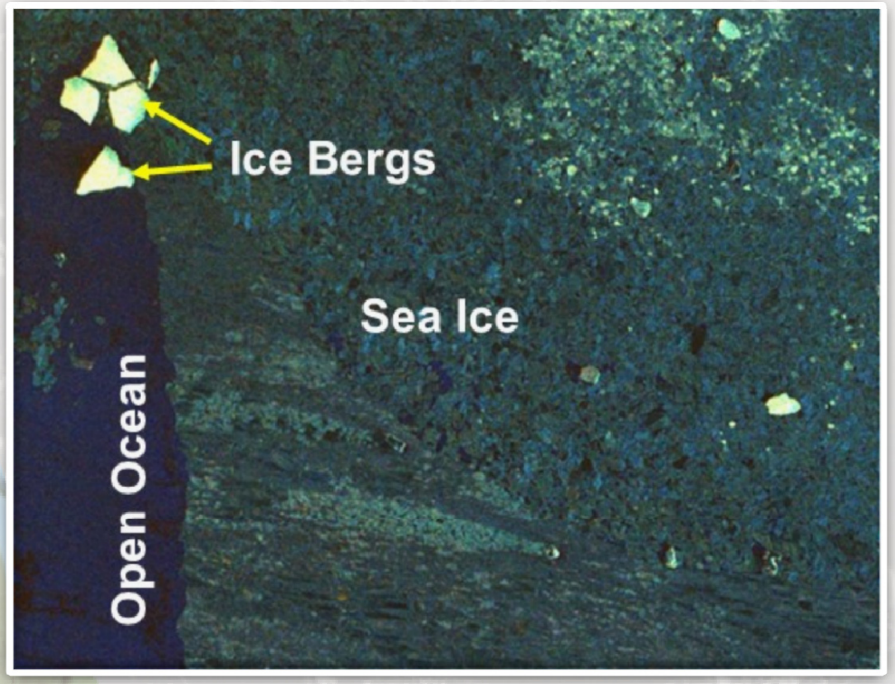

## Ship Anchored in India Bay

# Antarctica

## Ice Calving from Ice Shelf

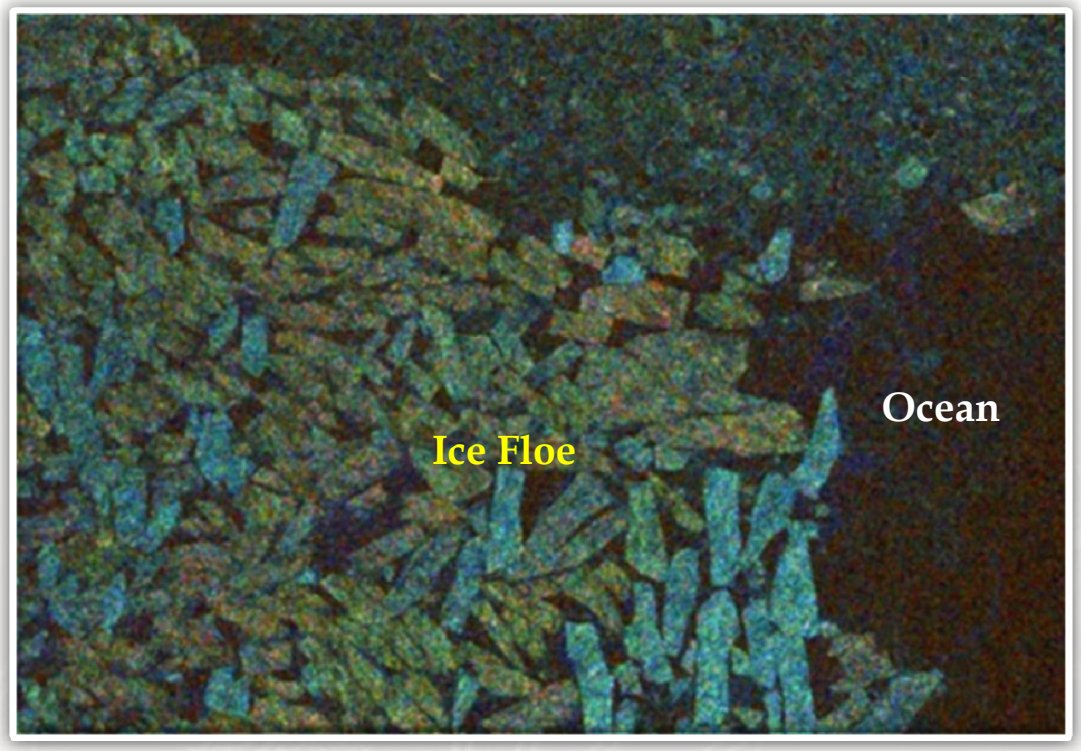



## Ice Bergs Sea Ice and Open Ocean

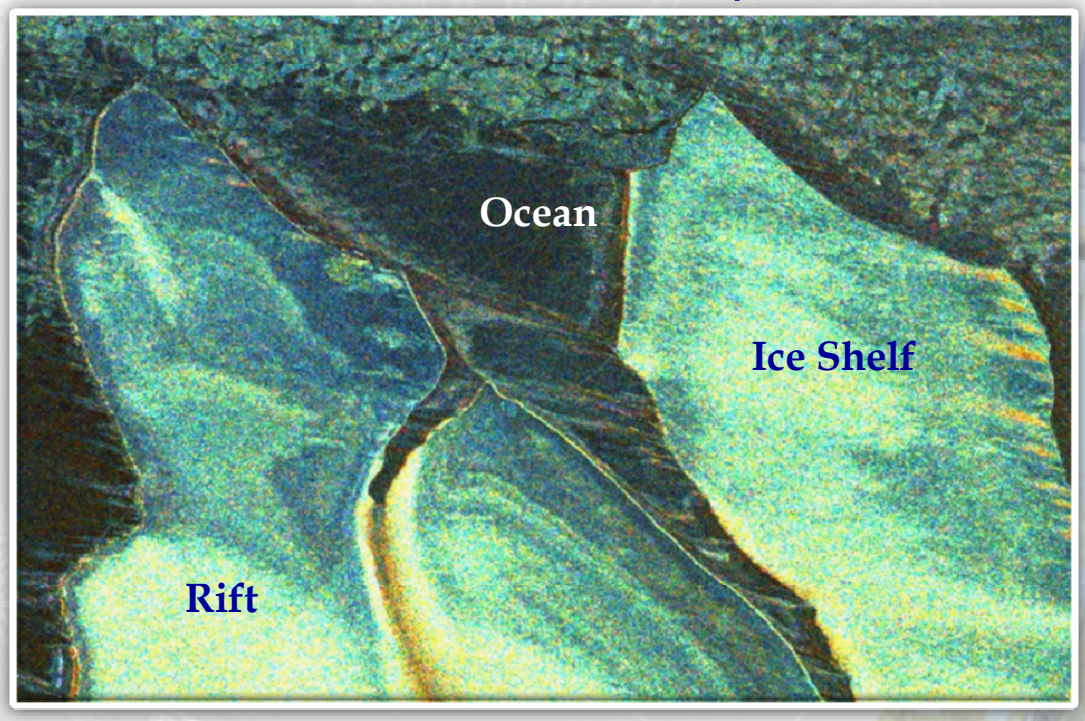


# Antarctica

## Sea Ice Floe

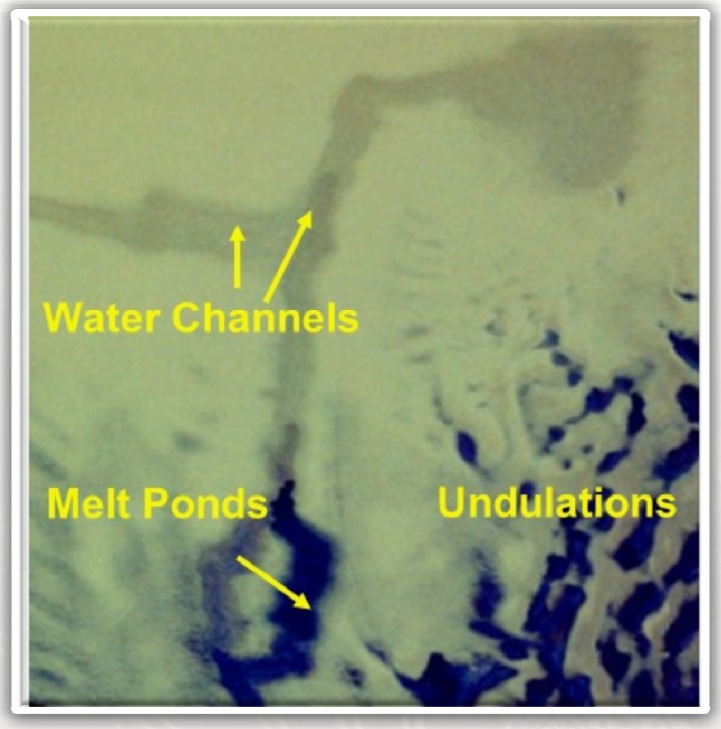



## Ice Shelf: India Bay

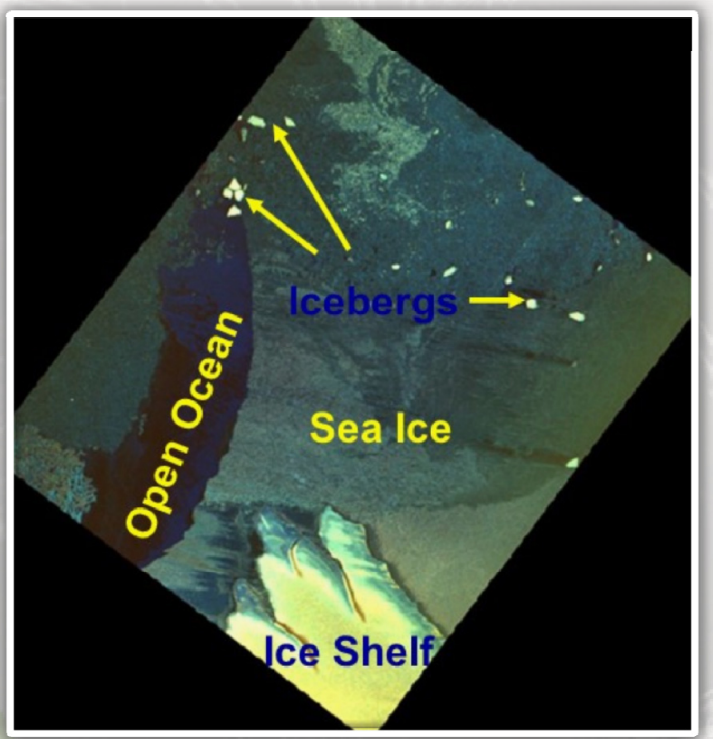


# Antarctica

## Melt Ponds, Water Channels and Undulations



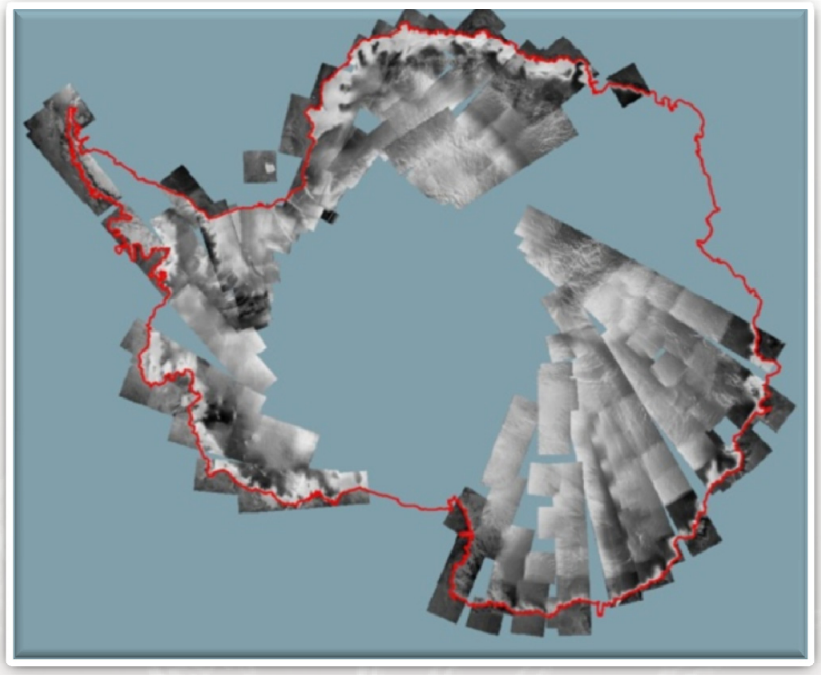

## Ice Shelf, Sea Ice, Open Ocean and Icebergs




cFRS-1 FCC: Even ; Volume; Odd

# Antarctica

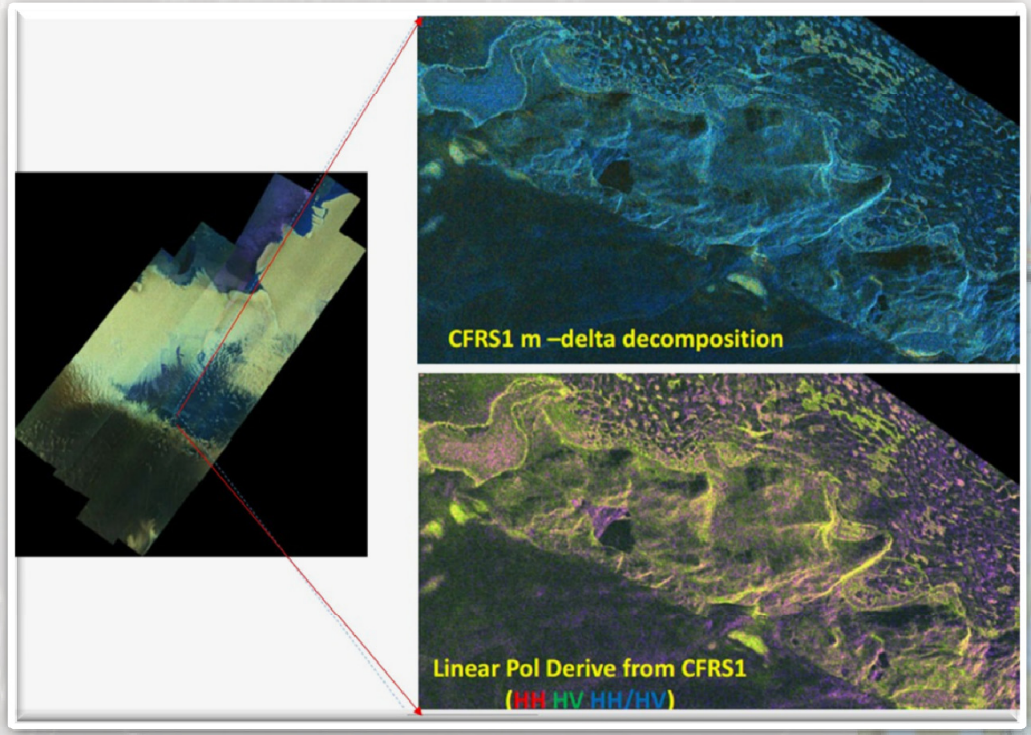
## Mosaic of AntarctIc Terrain using RIsat-1 CRS data (MAITRI)



MRS
HH

## cFRS-1 Mosaic

cFRS-1 FCC: Even ; Volume; Odd



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- Preeti Rajput
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- Sandip R Oza
- Saroj Maity
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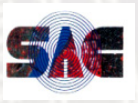

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