Bharathidasan University

Tiruchirappalli – 620 023, Tamil Nadu

6 Yr. Int. M.Tech. Geological Technology and Geoinformatics

Course Code : **MTIGT0902**

Thermal and Microwave Remote Sensing

Unit-5 : APPLICATIONS OF MICROWAVE REMOTE SENSING

Dr.K.Palanivel

Professor, Department of Remote Sensing

Course Objectives

- To study the principles thermal remote sensing
- To learn the interpretations and applications of thermal band
- To study the principles of microwave remote sensing
- To study about space borne radar remote sensing and the sensors
- To learn about the applications of microwave remote sensing.

MTIGT0902 - Syllabus

Unit:1. Thermal Remote Sensing: Principles - Definition - Radiant temperature - Black body radiation - Thermal Emissivity of materials - Thermal energy interaction with atmosphere and terrain elements - Kinetic and radiant temperature - Thermal energy detectors - Thermal radiometers - Thermal scanners and data collection. **16 hrs.**

Unit:2. Interpretation and Application of Thermal data: Day time and night time thermal data behaviour and manifestation of objects - Thermal inertia - thermography and heat loss - geometric characteristics of thermal scanner imagery (scale distortion, relief displacement, flight parameters distortion) - Radiometric calibrations- SST and LST mapping- application of thermal remote sensing in urban climate, soil moisture and environmental studies. **12 hrs.**

Unit:3. Microwave Remote Sensing: Basic principles - RADAR systems - SLAR operations - Antennas (receivers), Spatial resolution - geometric characters of SLAR imagery (Slant Range and distortion, relief displacement, parallax) - influence of earth surface features over Radar energy (geometry, electrical property, soils, vegetation, water, etc.) - interpretation of Radar imagery. **12 hrs.**

Unit:4. Space Borne Radar Sensing: Seasat - SIR - ERS-I - Radarsat - JERS - Elements of passive microwave remote sensing (sensors) - applications of LIDAR and ALTM. **12 hrs.**

Unit:5. Applications of Microwave Remote Sensing: Applications of Microwave remote sensing in Earthquake study; Din-SAR, Surface and subsurface Lithological Mapping - Paleo channel mapping. SAR Interferometry and its applications. **12 hrs.**

Unit:6. Current Contours: (Not for Final Exam; only for Discussion): Change Detection Analysis: Urban Heat Island, Sea surface Temperature Mapping, Land Surface Temperature Mapping- Mapping of hard rock fracture system. Microwave Remote Sensing: Mapping of subsurface lithology.

References:

1. American Society of Photogrammetry, Manual of Remote Sensing (2nd Edition), ASP Falls Church, Virginia, 1983.
2. Curran, P. Principles of Remote Sensing, Longman, London.1985.
3. Barrett, E.C. and L.R. Curits, introduction To Environmental Remote Sensing, Halstged Press, Wiley, New York.1976.
4. Lillisand, T.M. and Kiefer, P.W, Remote Sensing and Image interpretation, John Wiley&Sons, New York.1986.
5. Lintz, J. and Simonett L.S. (Eds.), Remote Sensing of Environment, Addition-Wesley, Readings, Mass.1976.
6. Lo. C.P. Applied Remote Sensing, Longman, London.1986.
7. Richadson, B.F.Jr.(Ed), Introduction To Remote Sensing of The Environment, Kendall / Hunt, Dubuque, Iowa.1978.
8. Sabins, F.F.Jr., Remote Sensing Principles and interpretation, Freeman, Sanfrancisco.1978.
9. Schanda,E. (Ed), Remote Sensing for Environmental Science, Springerverlag.1976.
10. Burney, S.S Application of Thermal Imaging, Adam Hilger Publications.1988.
11. Hord R.Michel, Remote Sensing Methods and Application, John Wiley and Sons.1986.
12. Drury S.A, A Guide to Remote Sensing - interpreting Images of Earth, Oxford Science Publications, Oxford.1990.
13. Floyd M. Henderson; Principles & Applications of Imaging Radar, John Wiley & Sons, New York, 1998.
14. Alexay Bunkin& Konstantin Volia. K, - Laser Remote Sensing of the Ocean Methods & Publications. John & Wiley & Sons, New York, 2001.

Course Outcomes:

1. Students will learn about the difference among reflection, scattering and emission from earth materials.
2. Students will understand the principles of thermal and microwave remote sensing.
3. Students will come to know the applications of thermal and microwave remote sensing.
4. Students will learn about application of microwave remote sensing in earthquake field.
5. Students will understand the LIDAR and ALTM applications
6. Students will also learn about application of microwave data in subsurface lithological mapping.

UNIT - 5

APPLICATIONS OF MICROWAVE REMOTE SENSING

Unit:5. Applications of Microwave Remote Sensing: Applications of Microwave remote sensing in Earthquake study; Din-SAR, Surface and subsurface Lithological Mapping **-** Palaeochannel mapping. SAR Interferometry and its applications. **12 hrs.**

LIDAR APPLICATIONS

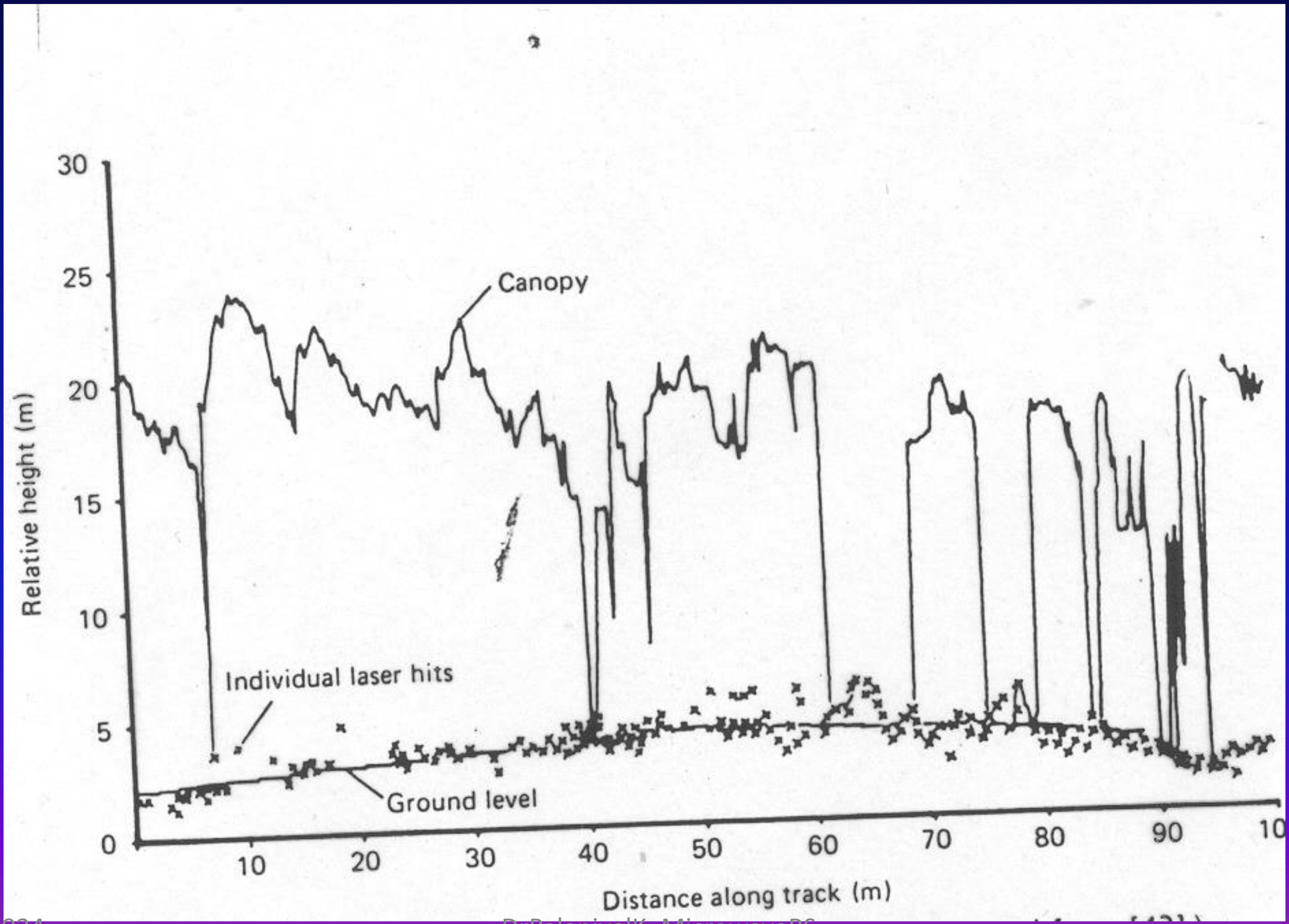
→ **Height of the Trees**

1. Stronger reflection first comes from the canopy

2. Individual beams hit the bottom topo through gaps

3. The bottom signals are used for topo profiling and the difference for measuring the heights and the timber volume

LIDAR returns measured over a forest canopy



LIDAR APPLICATIONS

LIF: LASER INDUCED FLUOROSENSE

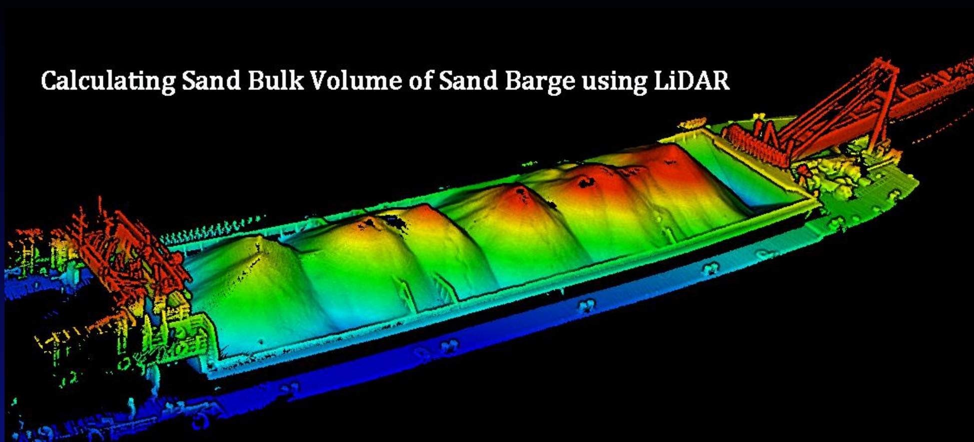
❖ **Absorb one wave length and emit larger wave length**

LASER FLOURO SENSER --- SINGLE CHANNEL BEAM ILLUMINATES THE OBJECTS

---- MULTI CHANNEL RECODER RECORDS THE EMITTED ENERGY

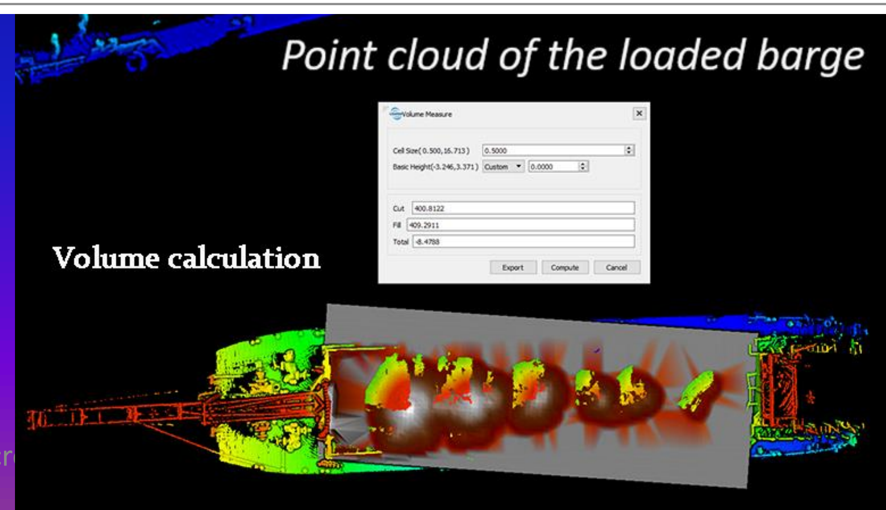
APPLICATIONS OF LIF (LASER INDUCED FLOURO SENSOR)

1. OIL SILKS
2. WATER POLLUTANTS
3. CHLOROPHYLL CONCNTRATION
4. PLANT SPECIES & STRESS DETECTION



Measurements	Measured value with GVI solution (m^3)	Reference value provided by client (m^3)	Difference (m^3)	Relative Accuracy (%)
1	2029.537	1962.362	67.175	3.42%
2	2047.227		84.865	4.32%
3	2038.791		76.429	3.89%
Average	2038.518		76.156	3.88%

To quickly and accurately measure the volume of sand barge cargo load in various operating environments



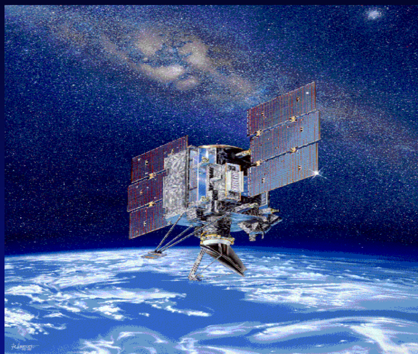
Microwave Remote Sensing

- Research and application of microwave technology to remote sensing of
  - Oceans and ice
  - Solid earth and Natural hazards..
  - Atmosphere and precipitation.
  - Vegetation and Soil moisture

Microwave Remote Sensing— Ocean and Ice

- Winds
  - Scatterometer.
    - Quickscat, Seawinds
  - Polarimetric radiometer
- Ocean topography
  - Radar altimeters
- Ocean salinity
  - AQUARIUS
    - Radiometer and radar combination.
      - Radar to measure winds for correcting for the effect of surface roughness.

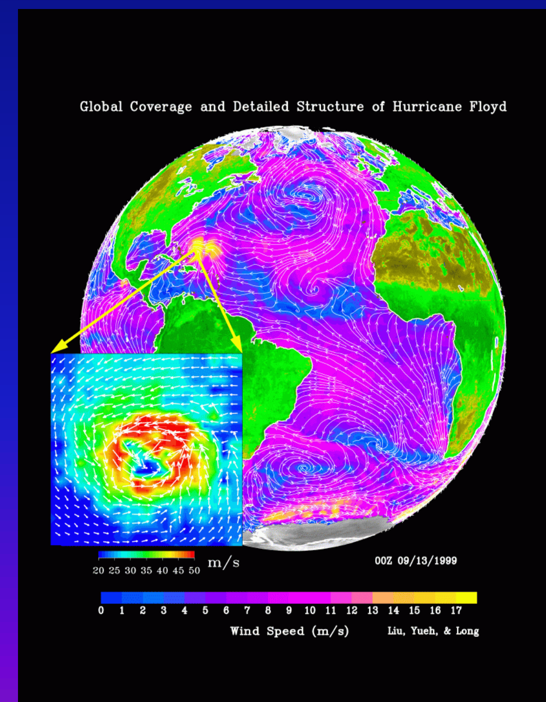
Ocean Vector Winds— Scatterometers



QuikScat

Scatterometers send microwave pulses to the Earth's surface, and measure the power scattered back. Backscattered power over the oceans depends on the surface roughness, which in turn depends on wind speed and direction.

SeaWinds



<u>QuikScat</u>

- Replacement mission for NSCAT, following loss of ADEOS
- Launch date: June 19, 1999

<u>SeaWinds</u>

- EOS instrument flying on the Japanese ADEOS II Mission
- Launch date: December 14, 2002 ????

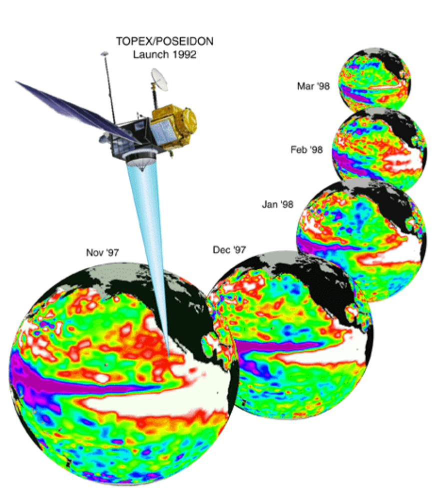
<u>Instrument Characteristics of QuikScat and SeaWinds</u>

- Instrument with 120 W peak (30% duty) transmitter at 13.4 GHz, 1 m near-circular antenna with two beams at 46º and 54º incidence angles

Advanced sensors– larger aperture antennas. Passive polarimetric sensors.

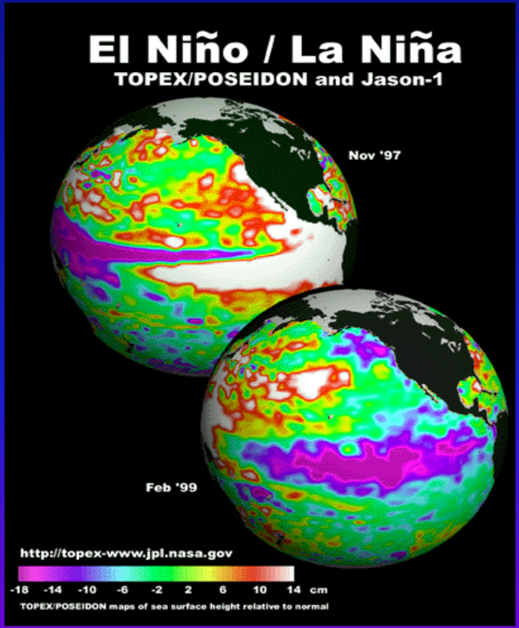
Ocean Topography Missions

The most effective measurement of ocean currents from space is ocean topography, the height of the sea surface above a surface of uniform gravity, the geoid.



TOPEX/Poseidon and Jason-1

- Joint NASA-CNES Program
  - TOPEX/Poseidon launched on August 10, 1992
  - Jason-1 launched on December 7, 2001
- Instrument Characteristics
  - Ku-band, C-band dual frequency altimeter
  - Microwave radiometer to measure water vapor
  - GPS, DORIS, and laser reflector for precise orbit determination
- Sea-level measurement accuracy is 4.2 cm
- *TOPEX/Poseidon & Jason-1 tandem mission for high resolution ocean topography measurements*



TOPEX/Poseidon Ocean topography of the Pacific Ocean during El Niño and La Niña.

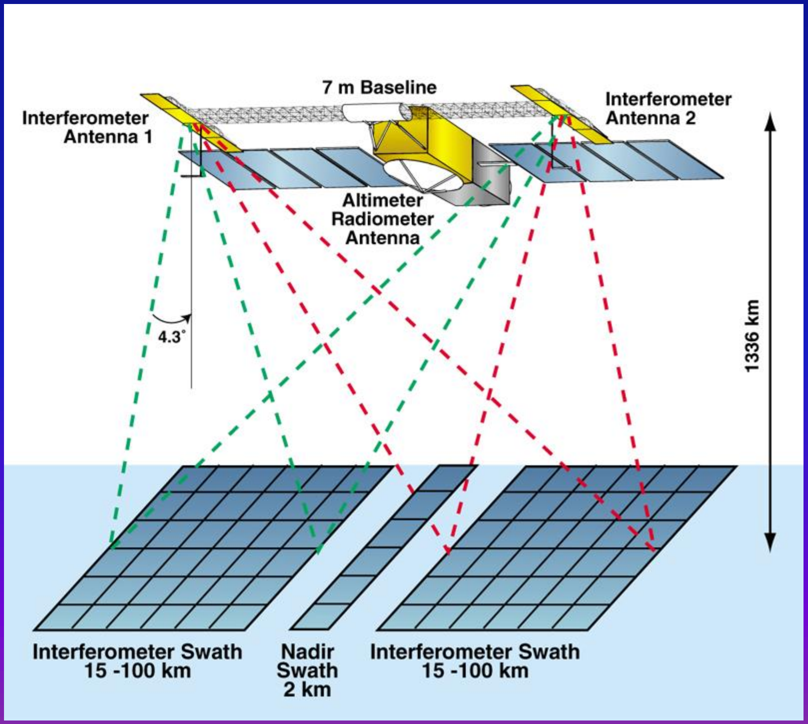
The priority is to continue the measurement with TOPEX/Poseidon accuracy
on a long-term basis for climate studies.

Ocean Surface Topography Mission

An Experimental Wide-Swath Altimeter

By adding an interferometric radar system **to a conventional radar altimeter system, a swath of 200 km can be achieved, and** eddies can be monitored over most of the oceans every 10 days**. The design of such a system has progressed, funded by NASA's Instrument Incubator Program. This experiment is proposed to the next mission, OSTM (Ocean Surface Topography Mission)**

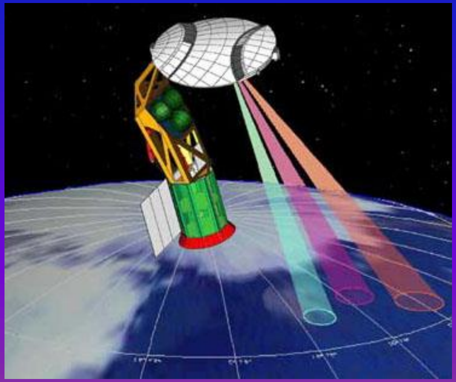
South America

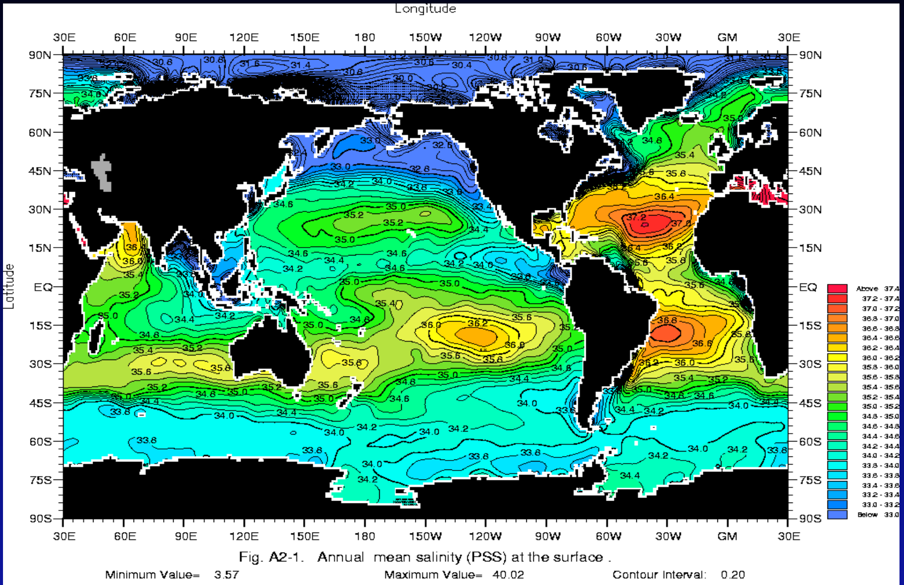


Courtesy: Yunjin Kim, JPL

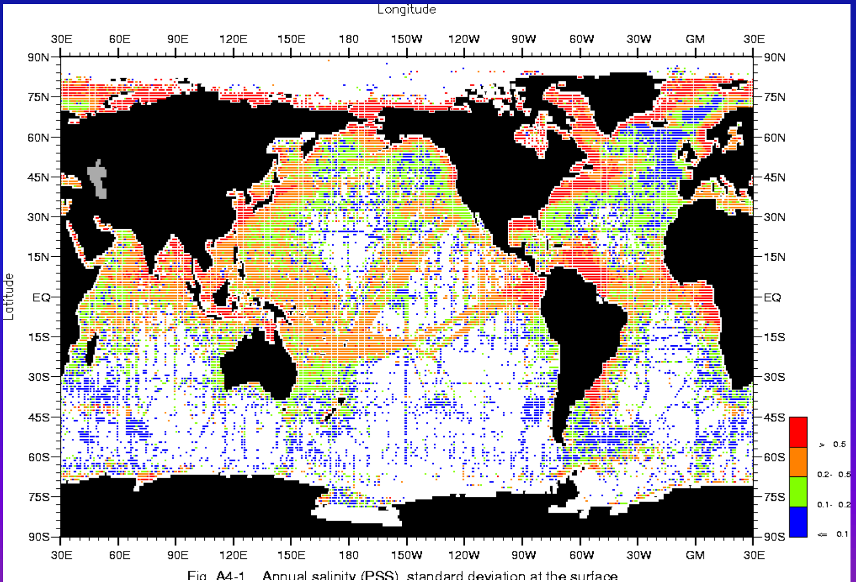
Global Ocean Salinity

- Aquarius (JPL, GSFC, CONAE)
  - ESSP-3 mission in the risk mitigation phase
- First instrument to measure ***global*** ocean salinity
  - Passive and active microwave instrument at L-band
  - Resolution
    - Baseline 100km, Minimum 200km
  - Global coverage in 8 days
  - Accuracy: 0.2 psu
  - Baseline mission life: 3 years



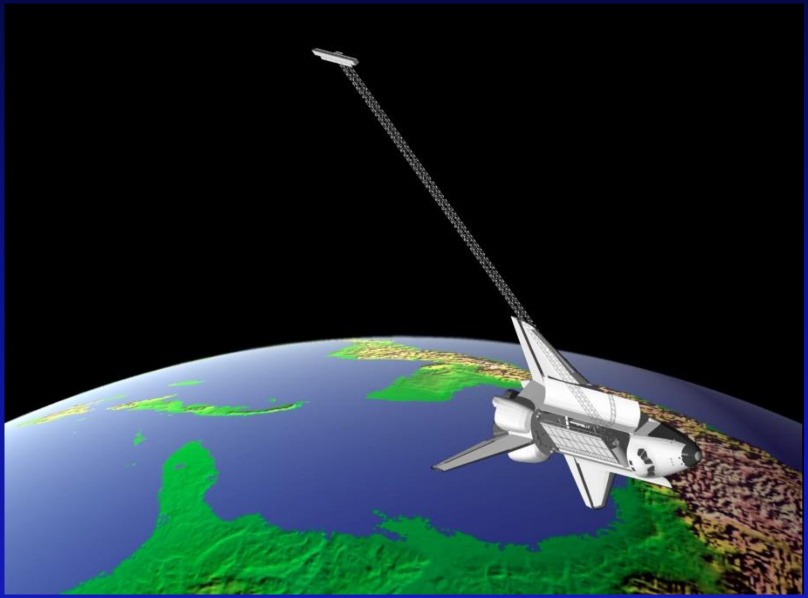


1 week of salinity measurements from space



100 yrs of salinity measurements by ship

SRTM (Shuttle Radar Topography Mission)



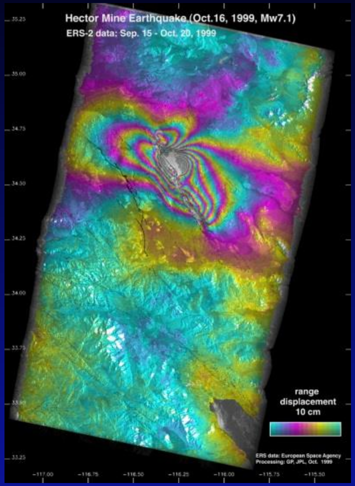
- ***Partnership between NASA and NIMA (National Imagery and Mapping Agency)***
- ***X-band from German and Italian space agencies***

Courtesy: Yunjin Kim, JPL

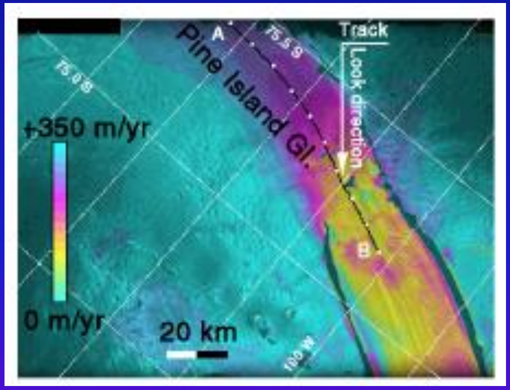
- C-band single pass interferometric SAR for topographic measurements using a 60m mast
- DEM of 80% of the Earth's surface in a single 11 day shuttle flight
  - 60 degrees north and 56 degrees south latitude
  - 57 degrees inclination
- 225 km swath
- WGS84 ellipsoid datum
- JPL/NASA will deliver all the processed data to NIMA by January 2003
- Absolute accuracy requirements
  - 20 m horizontal
  - 16 m vertical
- The current best estimate of the SRTM accuracy is
  - 10 m horizontal and 8 m vertical

L-band InSAR Technology

- Interferometric Synthetic Aperture Radar (InSAR) can measure surface deformation (mm-cm scale) through repeated observations of an area
  - L-band is preferable due to longer correlation time due to longer wavelength (24cm)
- Solid Earth Science Working Group recommended that
  - In the next 5 years, the new space mission of highest priority for solid-Earth science is a satellite dedicated to InSAR measurements of the land surface at L-band

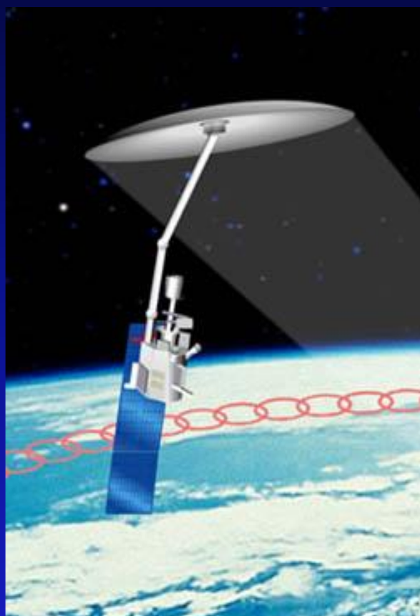


Surface deformation due to Hector Mine Earthquake using repeat-pass InSAR data



InSAR velocity difference indicates a 10% increase in ice flow velocity from 1996 to 2000 on Pine Island Glacier
[Rignot et al., 2001]

Microwave Remote Sensing—Soil Moisture.



Radar
Pol: VV, HH & HV

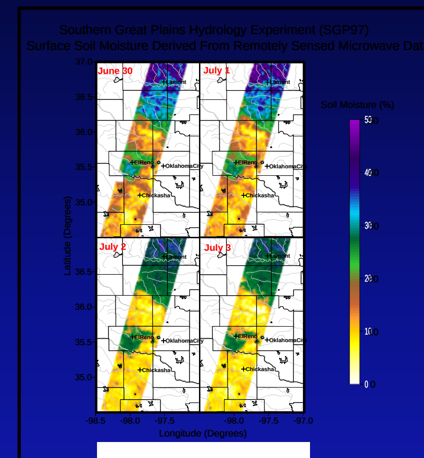
Res – 3 and 10 km

Radiometer

Pol: H, V

Res =40 km,

dT= 0.64º K



SGP'97

Courtesy: Tom Jackson, USDA

- HRDROS
  - Back-up ESSP mission for global soil moisture.
    - L-band radiometer.
    - L-band radar.

Microwave Remote Sensing— Atmosphere and Precipitation

CloudSAT

Salient Features

NASA ESSP mission
First 94 GHz radar space borne system
Co-manifested with CALIPSO on Delta launch vehicle
Flies Formation with the EOS Constellation
Current launch date: April 2004
Operational life: 2 years
Partnership with DoD (on-orbit ops), DoE (validation) and CSA (radar development)

Science

Measure the vertical structure of clouds and quantify their ice and water content

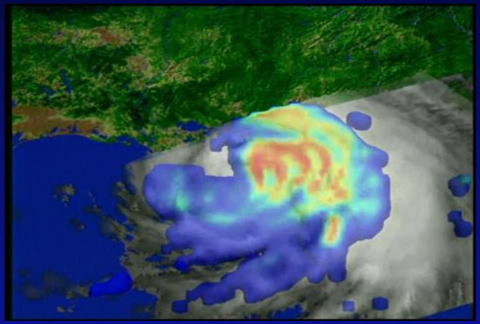
Improve weather prediction and clarify climatic processes.

Improve cloud information from other satellite systems, in particular those of Aqua

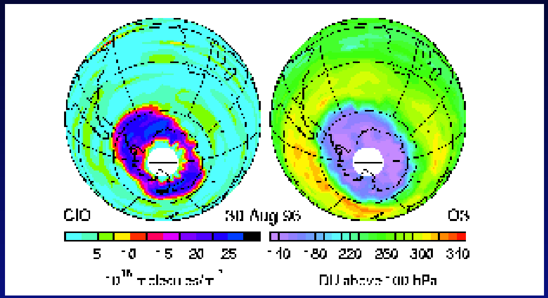
Investigate the way aerosols affect clouds and precipitation

Investigate the utility of 94 GHz radar to observe and quantify precipitation, in the context of cloud properties, from space

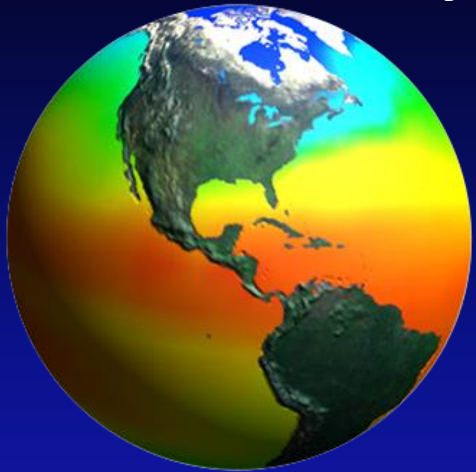
Earth Science and RF Radiometery



Precipitation



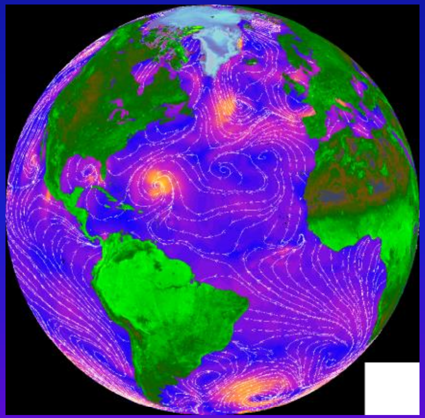
Atmospheric chemistry



Sea surface temperature/ Sea surface salinity

Microwave Radiometry Applications.

Hartley, NASA



Ocean surface wind

Atmospheric temperature, humidity, and clouds

Soil moisture

DInSAR Applications

- Monitoring subsurface coal fires in Jharia coalfield using observations of land subsidence from Differential INterferometric Synthetic Aperture Radar (DInSAR)
- DInSAR for a Regional Inventory of Active Rock Glaciers in the Dry Andes Mountains of Argentina and Chile with Sentinel-1 Data
- Integrated analysis of differential interferometric synthetic aperture radar (DInSAR) and geological data for measuring deformation movement of Kaligarang fault, Semarang-Indonesia
- PS-InSAR Monitoring of Landslide Activity in the Black Sea Coast of the Caucasus

- Mapping interactions between geology, subsurface resourceexploitation and urban development in transforming cities usingInSAR Persistent Scatterers: Two decades of change in Florence, Italy
- Monitoring land subsidence in Yangon, Myanmar using Sentinel-1 persistent scatterer interferometry and assessment of driving mechanisms
- Landslide susceptibility map refinement using PSInSAR data

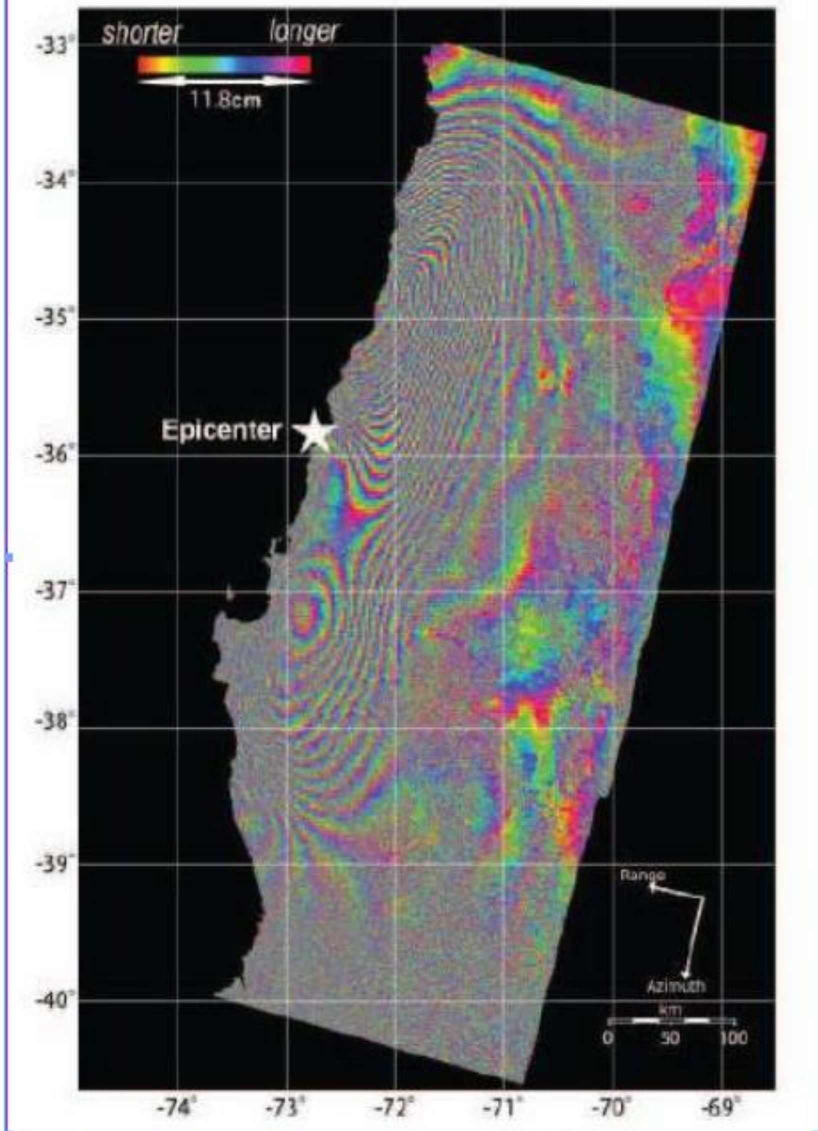


Figure 11 Chilli earthquake deformation map, (Miyawaki, et al., 2011)

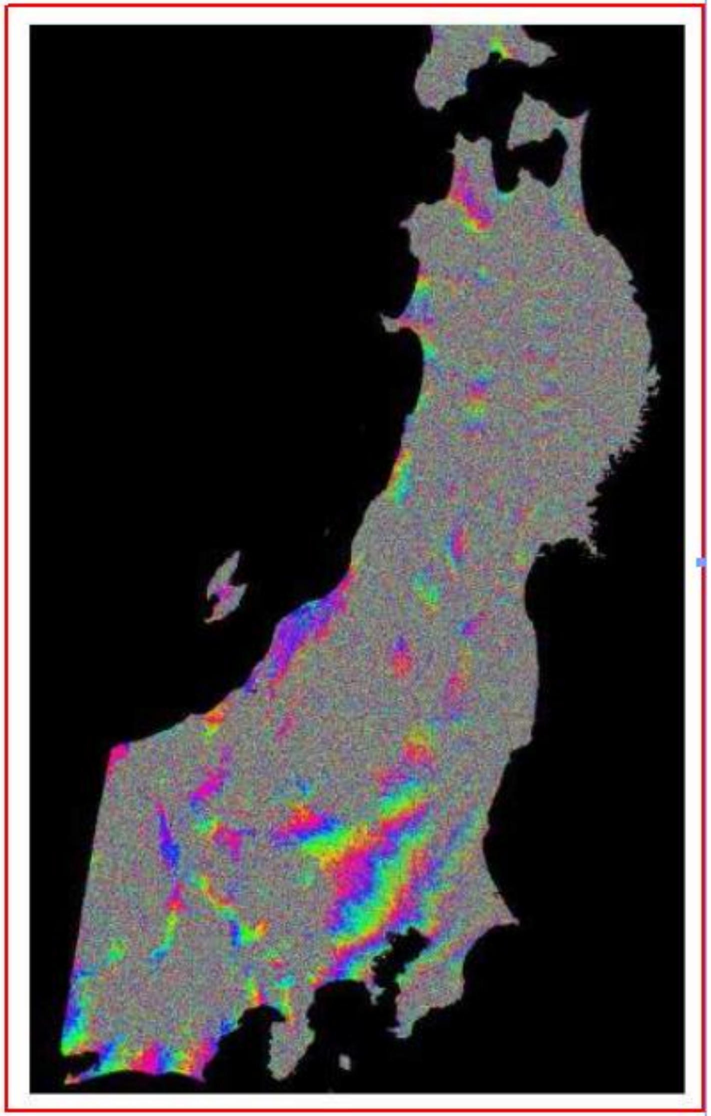


Figure 10 Tohoku, japan earthquake deformation map (Miyawaki & Kimura, 2013)

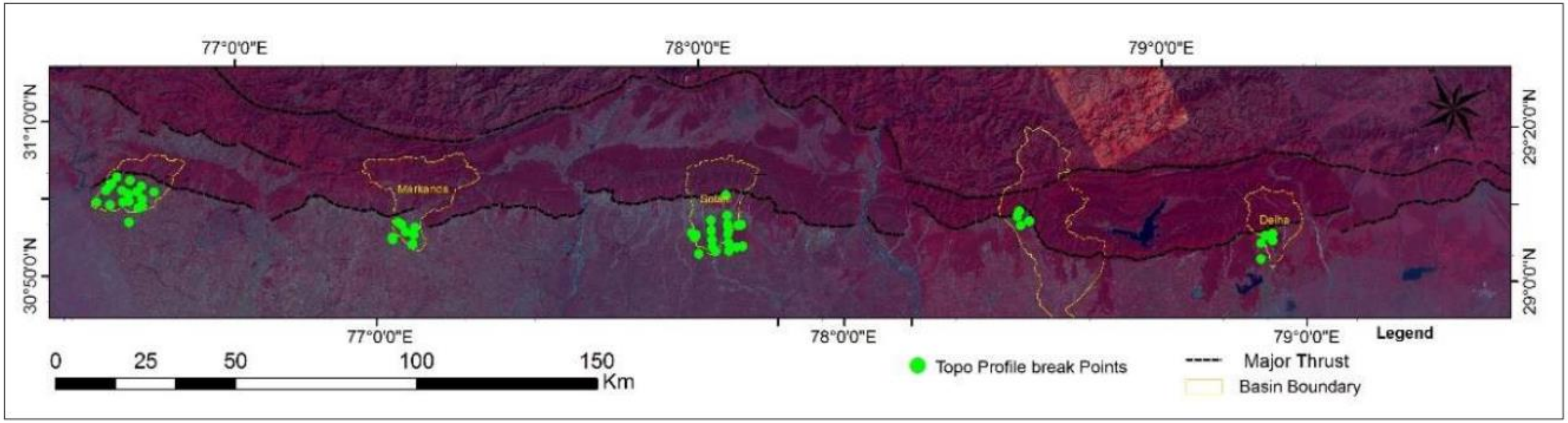


Figure 30 Overall Terrain Break point map

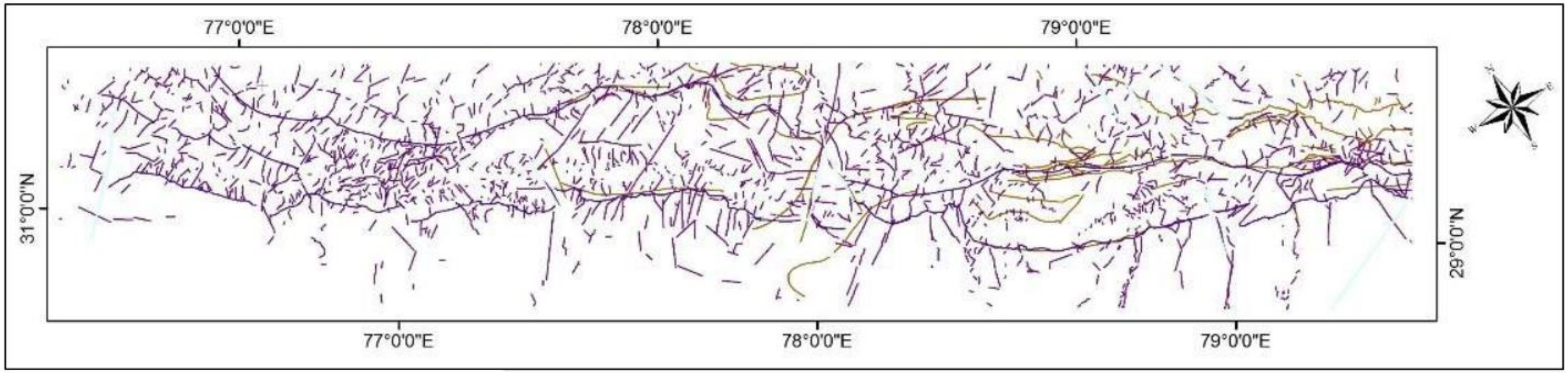


Figure 31 Lineament Map

The overall mapped lineament direction showing NE-SW direction and its matched with Himalayan orogeny trend.

Microwave ScanSAR data is more use full to map lineament and structural feature.

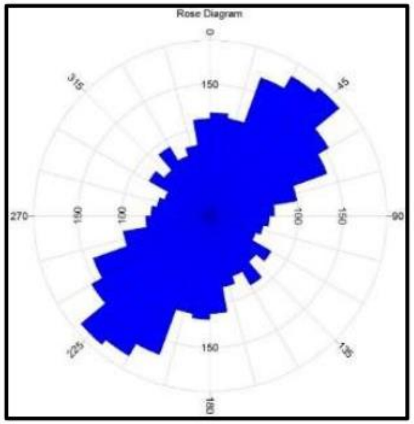


Figure 32 Rose diagram of lineament

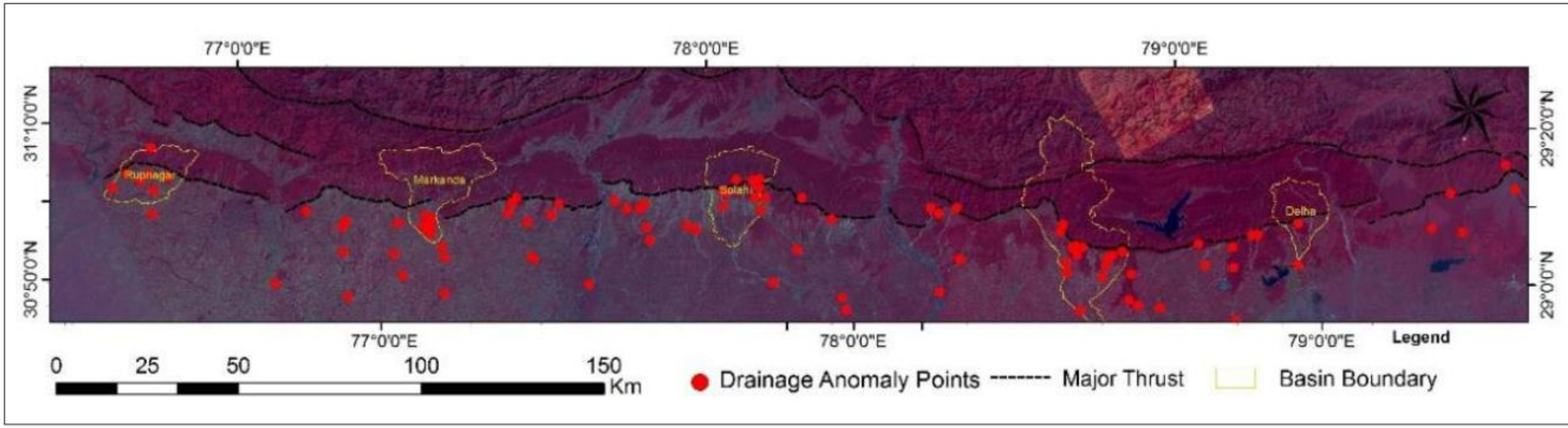


Figure 33 Overall Drainage Anomaly Point map (over LISS III mosaic)

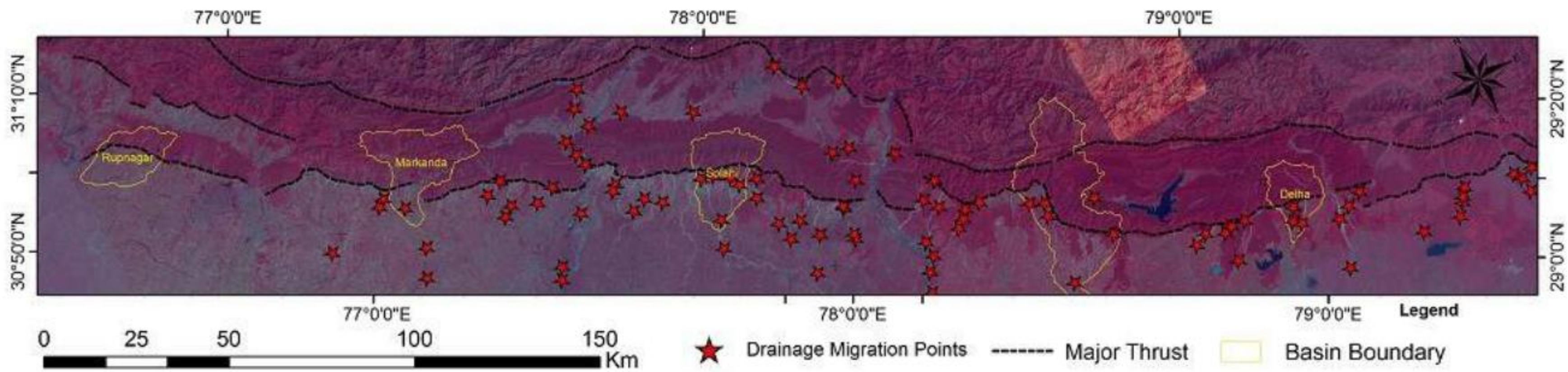


Figure 34 Overall Drainage migration Point map

In the above figure the star points indicate the drainage migration in the four basin viz., Dhela, Khoh, Solani and Markanda. Drainage shifting activity were found more in easter side of the HFT and decreases as we move towards western side of the HFT.

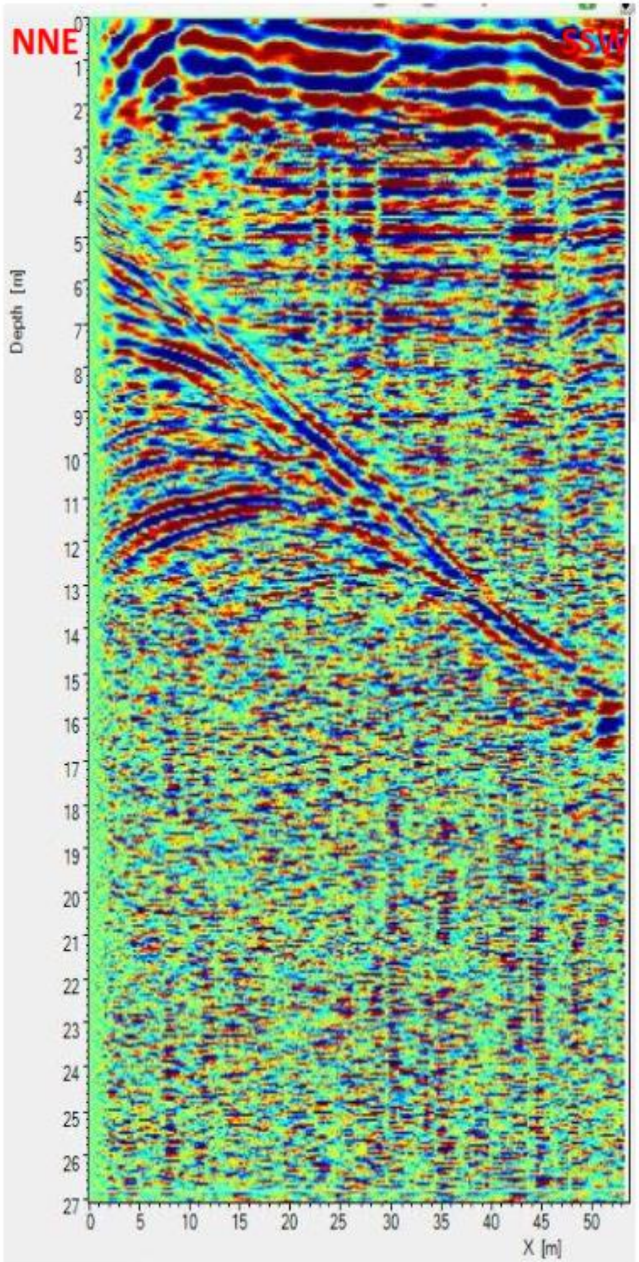
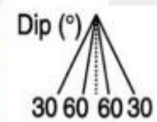


Figure 45 Processed GPR Profile in NNE-SSW direction across fault line.



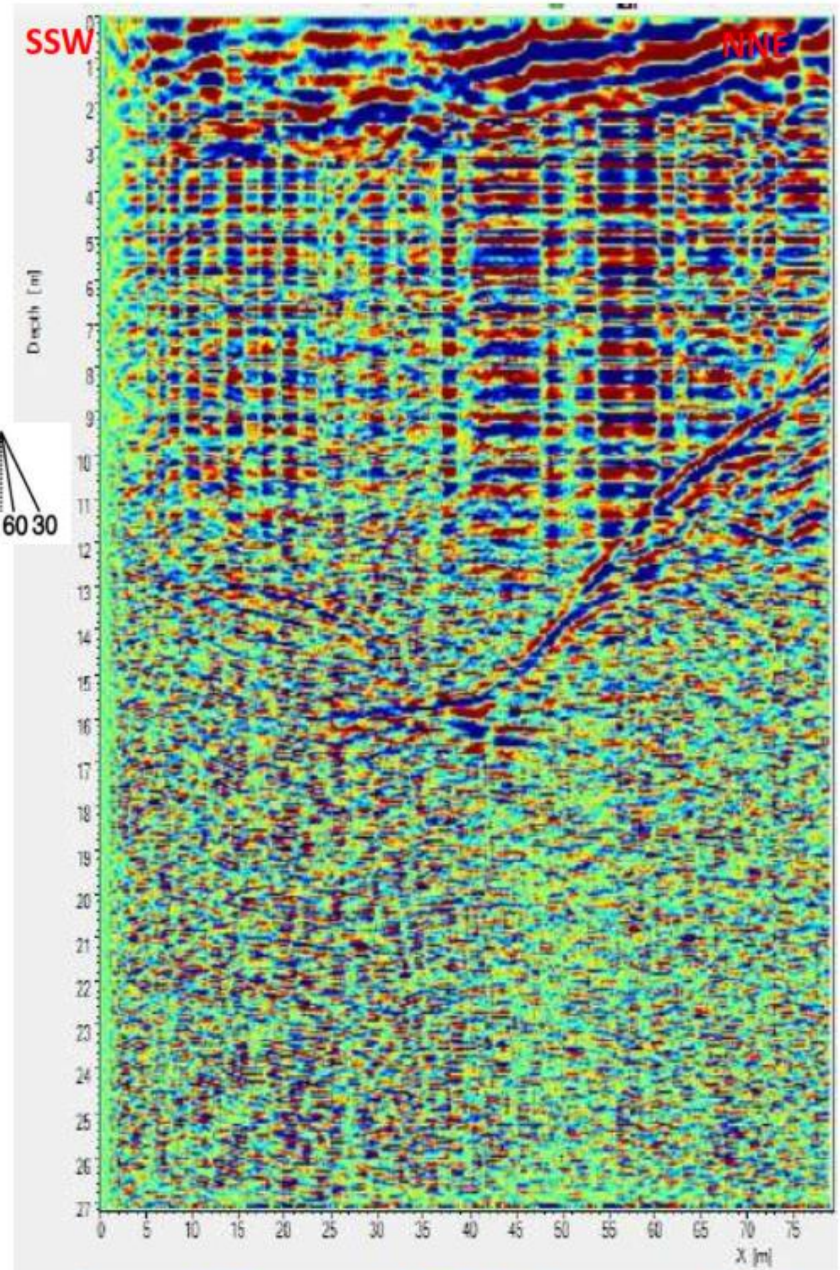


Figure 46 Processed GPR Profile across fault line in reverse direction (SSW-NNE)

Identification & Characterization of active fault by space borne ScanSAR and Ground based GPR in NW Himalayan Foot Hill Region, India

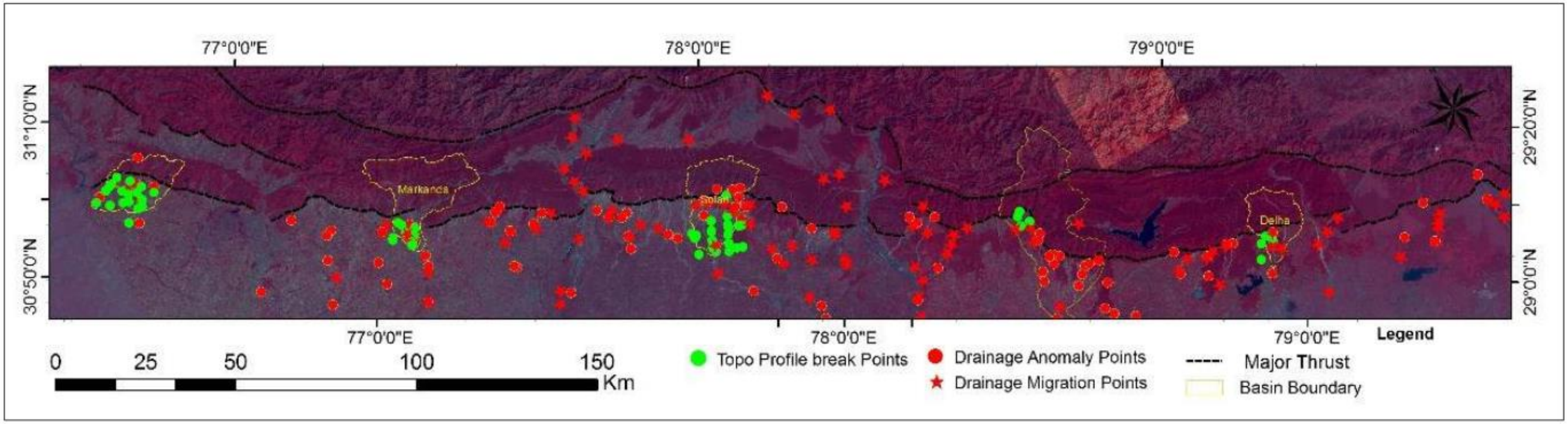


Figure 36 Study area showing all anomaly

Above figure shows the integrated occurrence of drainage anomaly, drainage shift/migration and topographic break.

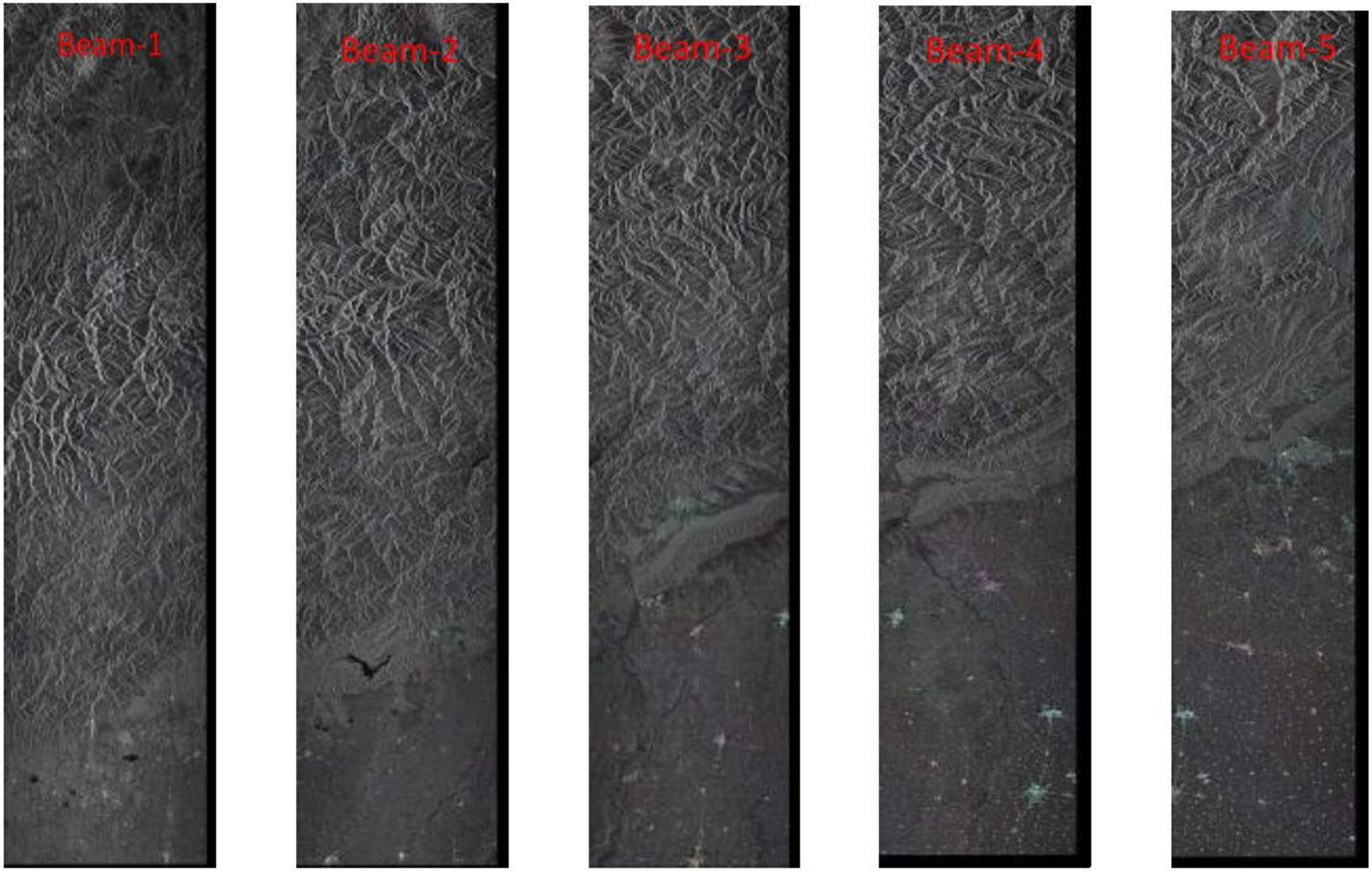


Figure 49 Differential Interferometry of each beam

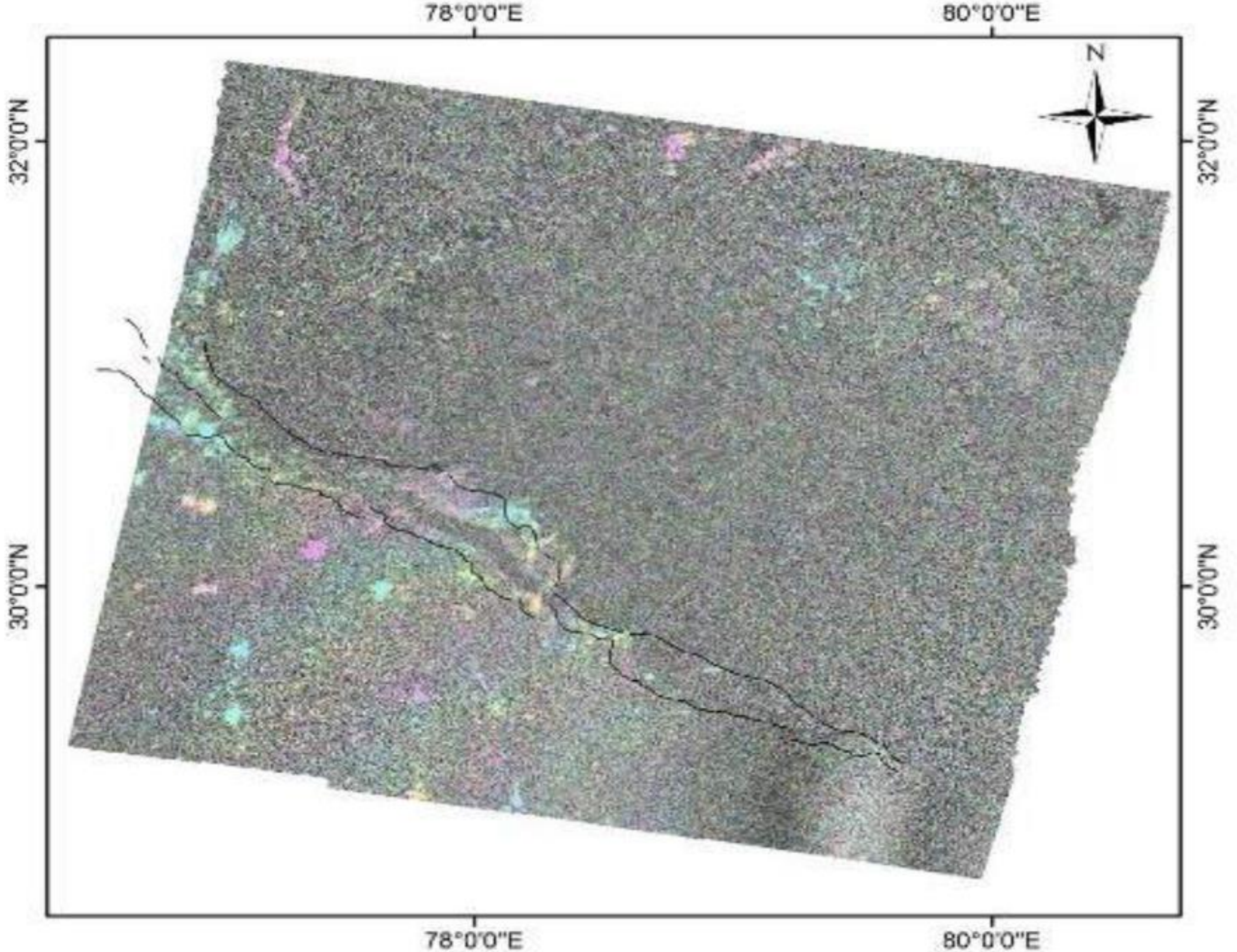


Figure 52 Geocoded filter ScanSAR-ScanSAR Images with Major thrust

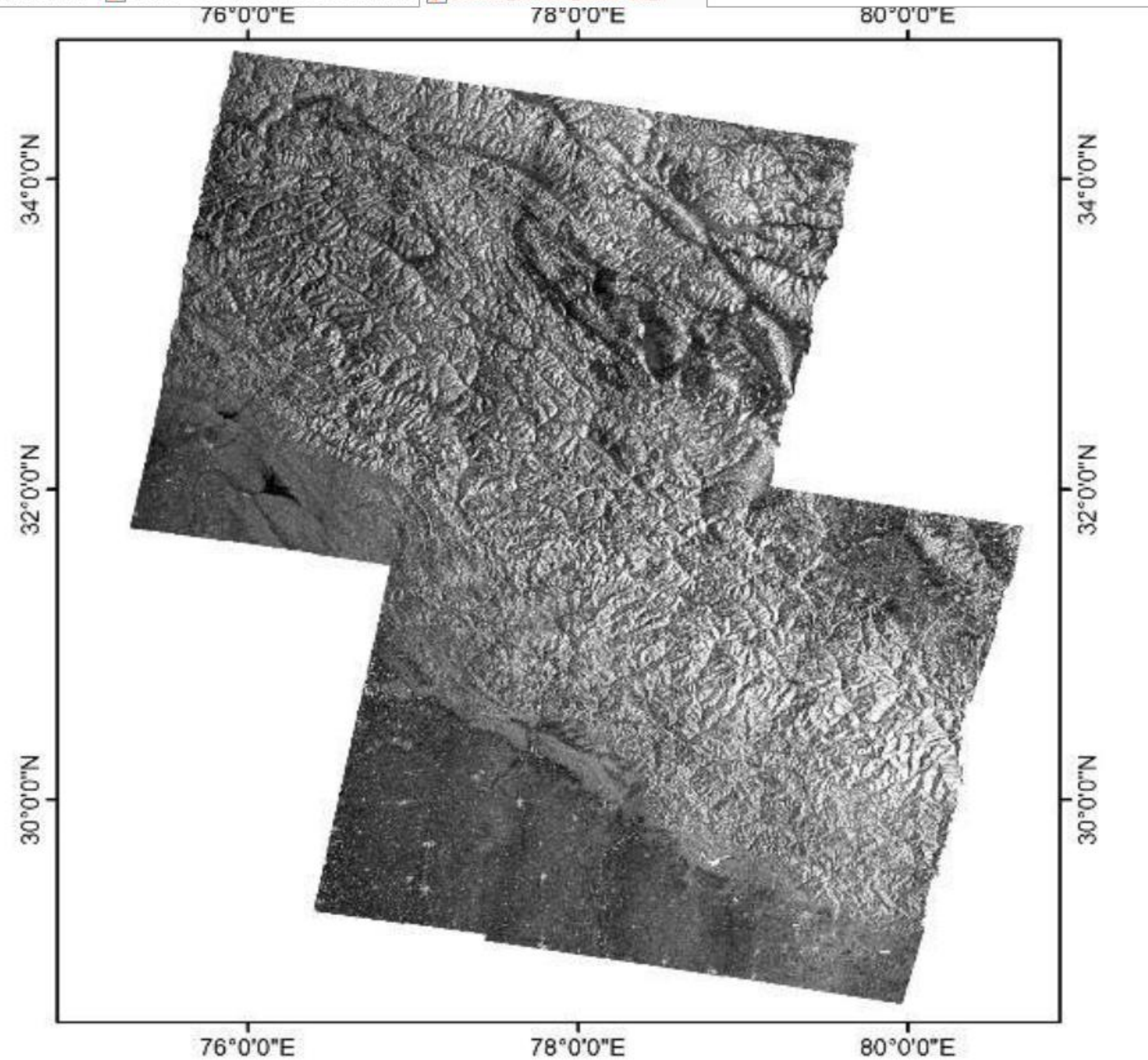


Figure 53 Mosaicked ScanSAR MLI image

6 CONCLUSIONS

The present study has attempted to identify tectonically active zone, possible locations of active faults their relation between surface indicators like drainage anomaly, trends drainage shift and subtle topographic breaks. The integrated approach comprising multi temporal satellite data analysis, high resolution topographic analysis, drainage anomaly analysis supported by field check and GPR survey have made it possible to identify the probable locations of active faults in the study area by using geophysical signature like termination of radar reflectors, dipping layers of reflection along the fault line and changes in facies of reflectors, corroborate the location of a fault with subsurface evidence.

The following conclusion were drawn.

- Drainage anomaly and topographic anomaly analysis using multi-temporal satellite images and high resolution DEM could efficiently identify the probable locations of active fault.
- GPR survey successfully confirmed the presence of active faults based on the geometry of the subsurface layers upto a depth of ~ 30m.
- DInSAR analysis using ScanSAR data could provide preliminary deformation phase pattern in the differential interferogram which require further analysis and additional data for the preparation of horizontal strain accumulation and displacement scenario.

6.1 Recommendations

There are few things which can be taken further to carry out this work further to different direction. They are mentioned as below. Recommendations for the future work are as follows:

- The GPR survey technique should be applied in 3-D mode for better characterization of subsurface fault. Further study should be conducted in another location where high active zone was found in present study area.
- For better assessment of ScanSAR Differential interferometry more datasets should be used and high resolution DEM used for topographic noise removal.
- Detail Geological map (1:25000) of the area can be beneficial in respect of Georadar reflector characteristics in terms of lithology.

Laser Interferometric Sensor for seismic waves velocity measurement

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ABSTRACT

Laser interferometry is one of the most sensitive methods for small displacement measurement for scientific and industrial applications, whose wide diffusion in very different fields is due not only to the high sensitivity and reliability of laser interferometric techniques, but also to the availability of not expensive optical components and high quality low-cost laser sources. Interferometric techniques have been already successfully applied also to the design and implementation of very sensitive sensors for geophysical applications.[1] In this paper we describe the architecture and the expected theoretical performances of a laser interferometric velocimeter for seismic waves measurement. We analyze and discuss the experimental performances of the interferometric system, comparing the experimental results with the theoretical predictions and with the performances of a state-of-the art commercial accelerometer. The results obtained are very encouraging, so that we are upgrading the system in order to measure the local acceleration of the mirrors and beam splitter of the velocimeter using an ad hoc designed monolithic accelerometers for low frequency direct measurement of the seismic noise.

Keywords: Velocimeter, Seismic Sensor, Laser Interferometry

1. INTRODUCTION

The most common differential length measurement is a measurement of the length fractional change of a given baseline, referred in geophysics as local strain. The magnitudes of the strains encountered in practice are spread over a wide range: Earth-tide strain may be as large as 10^{-7} while strains produced by teleseismic earthquakes rarely exceed 10^{-9}. The strain noise at quiet sites has been measured by Berger and Levine,[2] who used data from very different instruments located about 2000 km apart in very different geological conditions. Nevertheless, their results are in good agreement over the frequency range extending from approximately 1 $cycle \cdot month^{-1}$ to several $cycles \cdot sec^{-1}$. Therefore, it seems reasonable to assume that their results represent a reasonable estimate of the earth noise.

There are many kinds of instruments adequate for the observations of seismic signals. The periods of these signals are of the order of seconds or minutes and these periods are sufficiently short (relatively speaking) so that considerations on the instrument long-term stability or on its sensitivity to slowly changing environmental parameters (such as environmental temperature) are usually not so relevant for the design success. In particular, a strainmeter is generally considered adequate for a measurement if it is limited by earth noise over its whole operating frequency range. On the other hand, the secular stability and the residual sensitivity to external noise souces like the environmental temperature usually completely dominates the noise budget of instruments designed to observe signals with periods of a few hours or longer. The residual sensitivity to fluctuations of the environmental temperature or of the barometric pressure often sets a lower-bound on the minimum detectable

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Thank you