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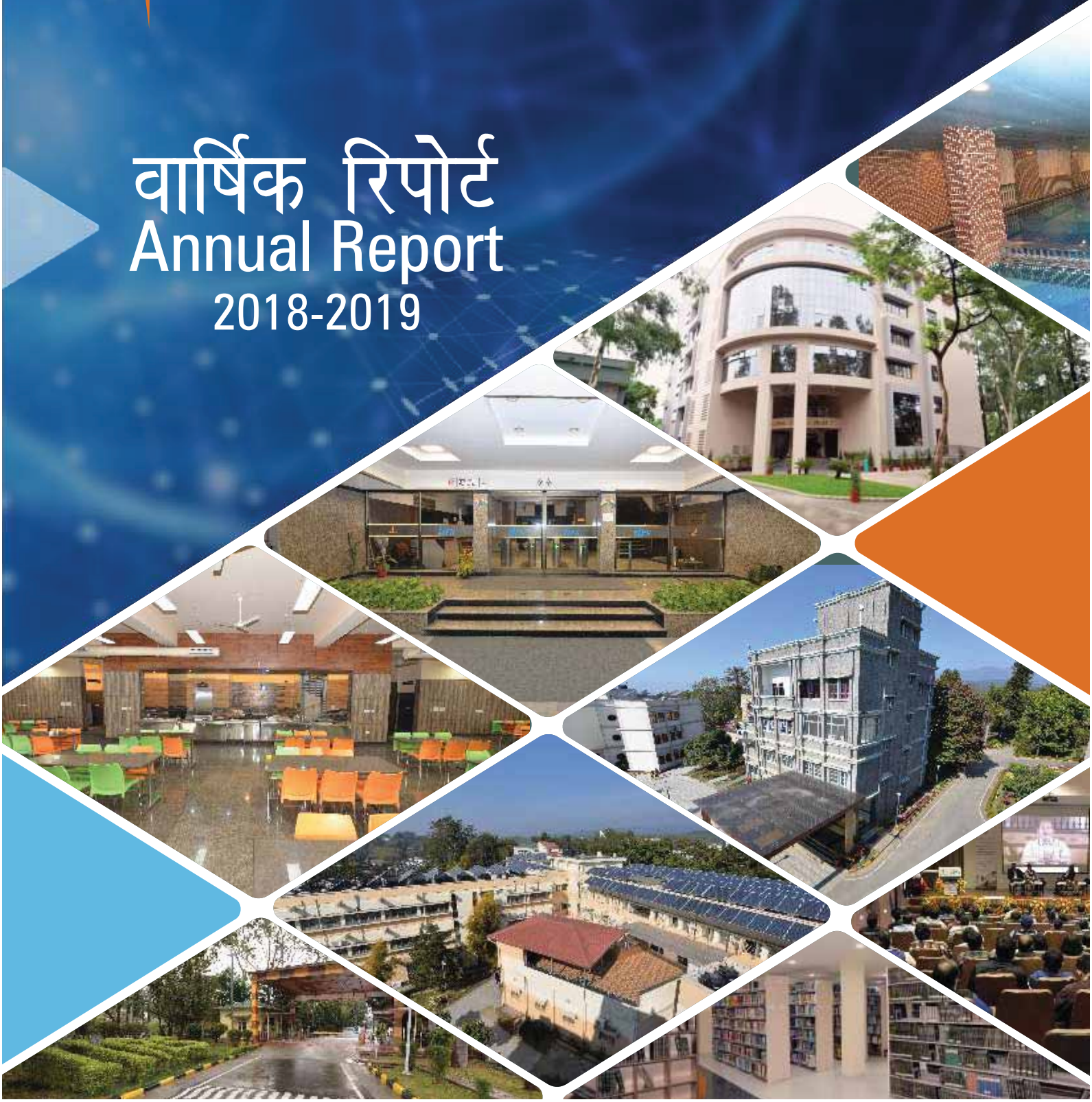
वार्षिक रिपोर्ट
Annual Report
2018-2019



भारतीय सुदूर संवेदन संस्थान

Indian Institute of Remote Sensing

देहरादून / Dehradun

Contents

Director's Desk

HIGHLIGHTS OF ACTIVITIES & ACHIEVEMENTS OF IIRS

The Indian Institute of Remote Sensing (IIRS), a Unit of Indian Space Research Organization (ISRO), Govt. of India is striving continuously for the capacity building in the field of Remote Sensing (RS), Geographical Information System (GIS) and their applications through training, education and research. IIRS is playing a key role since five decades of its establishment in the country and Asian region in capacity building of various target groups, ranging from fresh graduates, engineers and postgraduate students to policy makers. The institute also hosts and conducts the training and educational programmes on RS & GIS offered by the Centre for Space Science & Technology Education in Asia and the Pacific (CSSTEAP), affiliated to the United Nations. As an integral part of capacity building, the institute undertakes applied research in Remote Sensing & Geoinformation science, technology and applications and also participates in various research programmes of ISRO.

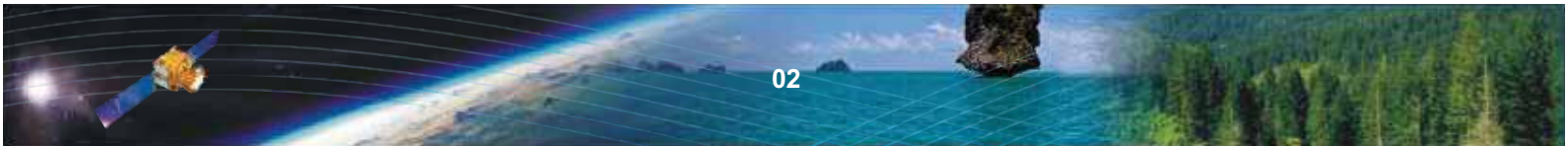
A. Managerial Activities

Several activities have been taken up during last year in addition to the continuation of ongoing regular capacity building, research and operational programmes. IIRS Academic council (AC) and Board of Studies (BoS) have been reconstituted to provide guidance and suggestions to realize the vision, mission and objectives of the institute. Experienced Scientists/ Engineers of ISRO/ DOS centres and Subject Matter Experts from reputed academic institutions, universities and organizations are included as Members of AC and BoS of the Institute.

B. Capacity Building Activities

During FY: 2018-19, a total of 635 participants have benefited from regular training, educational programmes (PG Diploma, M.Tech., M.Sc., Decision Makers, ITEC sponsored, certificate programme, ISRO-NNRMS sponsored programme for University Faculty, etc.) and special courses as part of capacity building activities. In addition to regular training programmes, the customized special courses were organized for various target groups wherein around 411 participants have benefited.

IIRS distance learning programmes - both Live and Interactive classroom (Edusat programme), and Online e-learning programme have significantly contributed in the mass capacity building activity of the institute. In the year 2018, 174 new institutes were added into IIRS Outreach network. Under IIRS outreach programme, several modules of Learning Management Systems (LMS) for various certificate courses in geospatial technology were developed.



C. Research Activities

IIRS is involved in a number of research projects of ISRO/ DOS such as Earth Observation Application Mission (EOAM: 9 nos.), Disaster Management Support (DMS: 2 nos.), National Carbon Project (ISRO-GBP: 3 nos.) and other Mission Projects (SARAL-ALTIKA & INSAT INSAT-3D Utilization Projects). In addition to these ISRO/ DOS projects, IIRS faculty have significantly contributed in the research activity through 17 ongoing TDPs and other in-house research projects. As many as 65 research papers were published in peer reviewed international and national journals.

IIRS has been participating in CEOS-WGCapD's annual meetings every year since the inception of the Working Group in 2012. In this meeting, status and progress of various activities were discussed e.g., e-learning programme, data democracy, populating capacity building portal, supporting CEOS in disaster risk management related capacity building activities and future plans.

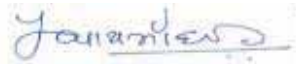
D. Other Activities

The Department study visit to Dehradun of the Parliamentary Standing Committee (PSC) on Science & Technology, Environment & Forest to Dehradun and Jim Corbett National Park (Uttarakhand) took place in IIRS on June 02, 2018. Field instruments used by IIRS faculty and students were also demonstrated before the Honourable Members. Committee generally expressed immense satisfaction on activities of IIRS & made some suggestions.

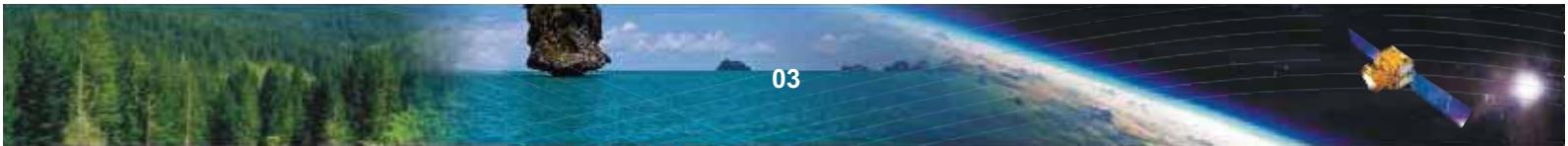
First IIRS Academia Meet (IAM-2019) on theme 'Capacity Building in Geospatial: Requirements, Challenges and Opportunities' was held on March 14, 2019 at IIRS. There were more than 200 participants from various academic institutions, government departments, industries, Edusat-users from all over India besides faculty and student participants from IIRS.

I am thankful to Dr. K. Sivan, Chairman, ISRO for his continuous support and guidance on various initiatives and endeavours of IIRS.

I highly appreciate the suggestions and contributions made by the members of Management Council (MC), Academic Council (AC) and the Board of Studies (BoS) and wish to have their support and encouragements in future.



Dr. Prakash Chauhan
Director, IIRS



IIRS PROFILE

Indian Institute of Remote Sensing (IIRS) is a constituent unit of Indian Space Research Organisation (ISRO), Department of Space, Government of India. Since its establishment in April 1966, IIRS has been a premier institution and key player for capacity building in the field of Remote Sensing and geospatial technology, and its applications through training, education and research.

Considering enhanced capacity building needs, IIRS has been given the status of an independent Unit of ISRO with effect from April 30, 2011. Over the years, the Institute is playing a major role in **capacity building activities** which can be primarily grouped into the following three domains:

- Training & Education Programmes
- Research Programmes
- Outreach Programmes

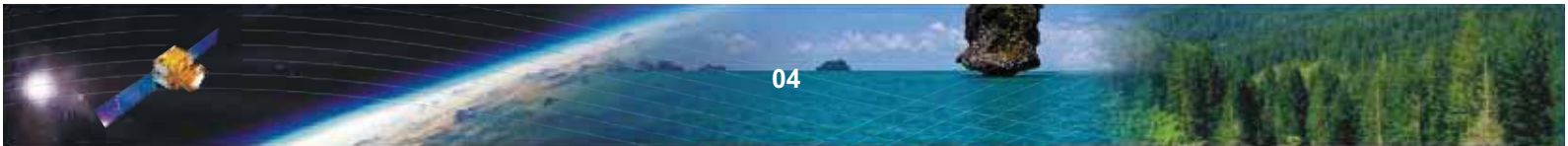
Formerly known as Indian Photo-interpretation Institute (IPI), the Institute is the first of its kind in entire South-East Asia. While nurturing its primary endeavour to build capacity amongst the user community by training mid-career professionals, the Institute has enhanced its capability and evolved many training and education programmes that are tuned to meet the requirements of various target groups, ranging from fresh graduates to policy makers including academia. IIRS is also one of the most sought after Institute for conducting specially designed courses for the officials of Central and State government ministries and stakeholder departments to make more effective utilization of Earth Observation (EO) data and use of Geographic Information System (GIS) tool. As a follow up of the National Meet held on September 07, 2015. IIRS is also given a special responsibility of Capacity Building needs for effective governance using space technology based tools in Ministries and Department under Central & State governments.

About 40 courses are conducted every year and 11,753 professionals and students have been trained/educated since establishment of the Institute. About 50 students supervised by IIRS faculty have received Ph.D degrees till date from different Indian universities. IIRS also received the 'ABP New Education Leadership Award' on November 28, 2018.

To widen its outreach, IIRS has started live and interactive distance learning programme (DLP) in 2007. Further, graduate and postgraduate students from universities spread across the country have also benefitted through EDUSAT-based distance learning programmes being offered by the Institute till date. Today, more than 990 institutions/ organizations are networked with IIRS.

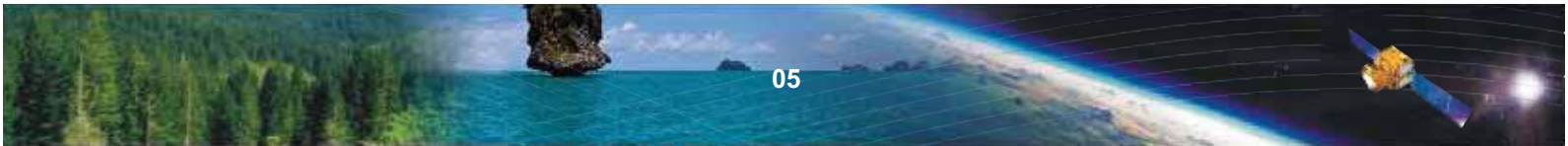
Efforts are underway to develop the e-learning content (also in Hindi) for various RS and GIS applications. The Institute campus also houses the headquarters of the Centre for Space Science and Technology Education in Asia and The Pacific (CSSTEAP), affiliated to the United Nations and first of its kind established in the region in November 1995.

IIRS, as host institution provides support to conduct all its Remote Sensing and GIS training & education programmes at postgraduate level also. The headquarters of Indian Society of Remote Sensing (ISRS), one of the largest non-governmental scientific society in the country, is also located in the Institute's campus.



The Institute has a strong, multi-disciplinary and geospatial solution-oriented research agenda that focuses on developing improved methods/ techniques for processing, visualization and dissemination of EO data & geo-information for various societal applications and better understanding of Earth's system processes.

Currently, microwave, hyperspectral and high-resolution EO data processing and their applications is the main research focus. Various state-of the-art laboratories, field-based instrumentations and observatories networks help meeting the research goals and objectives.



IIRS - GROUPS AND DEPARTMENTS

Programme Planning and Evaluation Group (PPEG)

The Institute receives various requests for conducting training throughout the year. Programme Planning and Evaluation Group (PPEG) under Director's office coordinates the training and capacity building, human resources development, budget, hostel, library, etc. activities of the Institute. PPEG also caters to various demands and requirements of the students. The entrance tests for the admission of M. Tech. and M.Sc. Courses are also coordinated by PPEG office. The planning and organisation of various intercentre assignments are also carried out in close coordination with this Group in interface with other Groups, Departments and facilities of IIRS. It also coordinates the training and research activities of external students carried out under the supervision of IIRS faculty. PPEG also maintains the IIRS alumni database. The Group is also responsible for catalyzing various technomanagerial activities assigned to IIRS and acts as secretariat of IIRS for pertinent correspondence within and outside ISRO/ DOS.

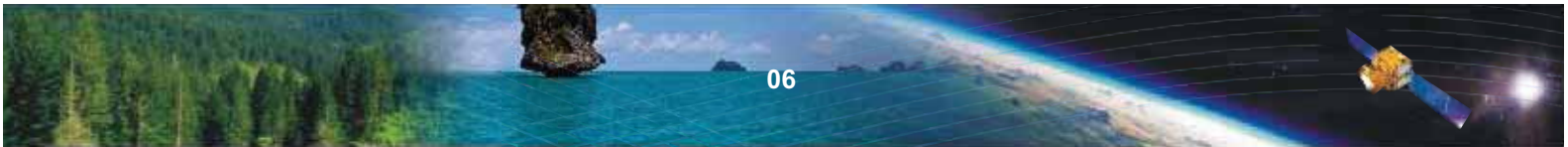
Budget Planing and Monitoring Department

With the increasing responsibilities and mandates of the Institute, it is pertinent to mention that the budgetary allocations have increased to more than three times in past five financial years. This has spearheaded the techno-managerial and financial activities and other critical correspondences with ISRO HQ and other organisaton. Hence, BPMD is one of the departments recently created in IIRS to take care of budget planning and monitoring related formalities and procedures in the Institute.

Placement for students enrolled in long-term academic courses was successfully carried out by BPMD/PPEG. Organisation of "Campus Drive" was done for the first time. Companies were provided with necessary details as per their demand. Companies visited the campus, introduced themselves in pre-placement sessions, conducted their respective rounds like technical, logical & aptitude reasoning, HR, etc to shortlist suitable candidates. It was ensured that all the placement drives were conducted at 'No cost to IIRS/ISRO'. Various job opportunities and R&D options available to students both nationally and internationally are also being communicated to the students through PPEG.

Central Library

The Library is dedicated to serve the information needs of the scientists, researchers and students of the Institute. Few highlights of IIRS Library are (i) Remote access to library e-resources (ii) Strengthening information resources (iii) Various technical journals (iv) Collection development (v) Inter Library loan / delivery with local/DOS libraries (vi) User education/ orientation.



Agriculture & Soils Department

Agriculture and Soils Department is one of the oldest departments of the Institute. The department has carried out many R&D and consultancy projects in the areas of soil surveys, watershed prioritization, soil and land irrigability assessment, land evaluation, crop resources inventory, agro-meteorology, soil suitability for crops, forestry and plantation, etc. It has also contributed significantly towards various ISRO/DOS Mission projects like Wasteland mapping, Land use/ Land cover mapping, Land degradation mapping, Integrated Mission for Sustainable Development (IMSD), Soil Carbon Pool (SCP) assessment & Soil-Vegetation Carbon flux measurement in National Carbon Project, etc. This department conducts regular long term academic and special training programs of the Institute on the theme of Agriculture & Soils. The capacity building and research activities of the department are-

Capacity Building

- Organization of short courses in- Microwave RS Applications in Agriculture & Soils, Hyperspectral RS Applications in Agriculture & Soils, Satellite Agro-meteorology, Modeling Crop Growth & Productivity, Soil erosion modeling for Watershed management,
- Organization of special courses as per the requirements of Central and State Government Ministries and Departments (Agriculture, Rural Development & Cooperation, Earth Sciences - IMD) .

Research

- Microwave (Active & Passive) and Hyperspectral Remote Sensing in soil and crop resources characterization and inventory,
- Digital soil resources characterization using GPR and geo-statistical methods,
- Process based modeling for soil erosion, sediment loss, soil carbon sequestration and soil carbon dynamics at watershed scale,
- Development of early warning system for drought monitoring by combining climate and crop model and using geospatial techniques,
- Large area fluxes over agro-ecosystem using coarse resolution geostationary satellite,
- Carbon accounting modeling by integrating flux observation & RS of major agro-ecosystems.

Forestry and Ecology Department

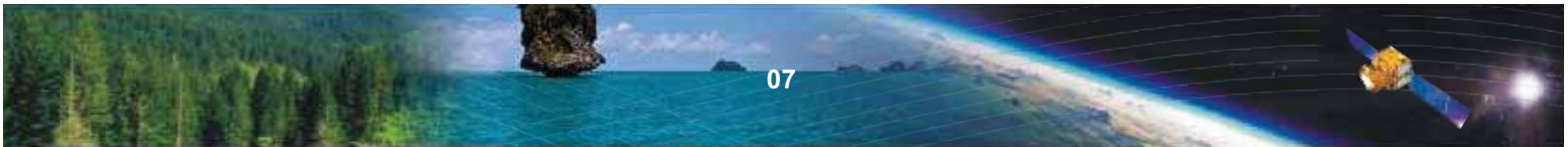
The Forestry and Ecology Department was established in 1966 with the aim of providing training and skill development on the utility of aero-space remote sensing for forest resource inventory, monitoring and management for forest managers in particular and scientific community in general. Nationwide forest cover mapping & nation-wide biome level characterization of Indian forests biodiversity at landscape level are the three major projects planned and executed by the department. A few other important research projects carried out by the department are - growing stock and biomass assessment, wildlife habitat modelling, sustainable development planning, national level carbon flux measurement and modelling, national level vegetation carbon pool estimation in India, ecosystem dynamics and hydrological modelling in north-eastern region, wildlife habitat evaluation in Ranikhet and Ranthambore Tiger Reserve, national level biome classification of natural vegetation, grassland mapping and carrying capacity estimation. The capacity building and research activities of the department are-

Capacity Building

- Organization of short courses on RS & GIS applications in Forestry for the line departments, Use of RS & GIS in forest working plan, Impact of climate change in forestry.
- Organization of short courses through IIRS Distance Learning Program on RS & GIS in applications for State forest Departments. Organization of special courses following the National Meet and meeting the Ministries' requirements.

Research

- Biodiversity Characterization, Species distribution modeling, plant invasion risk modelling.
- Synergistic use of advanced sensors (Hyperspectral, LiDAR, microwave and GPR) for forest biophysical and biochemical parameters retrieval.
- Carbon pool and flux measurement for forest productivity assessment.
- Ecosystem vulnerability assessment, forest fire risk modelling and Prediction.
- Climate change impact on forests and ecosystems.
- Ecological and wildlife corridor modelling and connectivity analysis.



Marine & Atmospheric Sciences Department

This department established in 1986 to offer training & education courses, provides research opportunities in the area of coastal processes, marine resources, ocean and atmospheric sciences applications. The department has contributed in different research and operational projects of ISRO/DOS, such as Oceansat-II, ISRO-GBP on aerosol study & atmospheric pollution, EOAM project on Northwest Himalayan study, along with several Technology Development Projects (TDPs) etc. The capacity building and research activities of the department are:

Capacity Building

- Organization of short courses on RS applications for coastal & ocean sciences, meteorology and climatological application, atmospheric pollution, numerical weather prediction, atmospheric science application, summer school for school children on environ mental scicence .
- Organization of special courses following the National Meet and meeting the Ministries'/Departments' (Earth Sciences, Fisheries, IMD etc.) requirement.

Research

- Coastal geomorphology and processes, coastal hazards and their mitigation.
- Ocean color and primary productivity.
- Upper - ocean geophysical parameter retrieval, near shore water quality, aerosol optical depth over ocean.
- Modeling of coastal dynamics, sea level rise and consequent salt water intrusion into coastal aquifers, estuaries and coastal processes.
- Indian summer monsoon studies: Intra-seasonal oscillations, active and break spells etc.
- Retrieval of atmospheric parameters.
- Ozone and its precursors: chemistry and Transport.
- Regional and global Chemistry Transport Modeling.
- Regional aerosol radiative forcing
- Regional atmospheric pollution studies
- Tropical cyclone studies

Water Resources Department

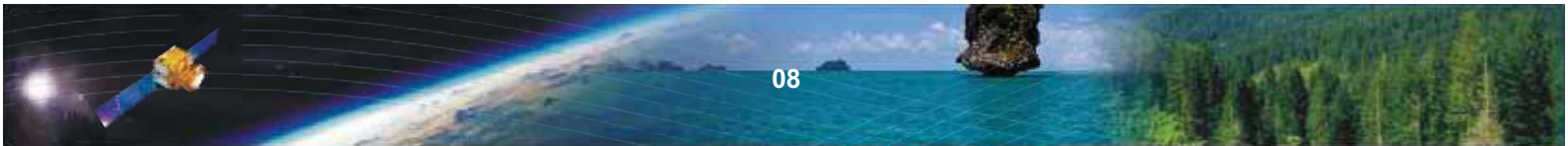
Water Resources Department (WRD) was established in the year 1986 and since then it has emerged as leader in capacity building and research in various fields of hydrology and water resources management. The department specializes in remote sensing based hydrologic parameter retrieval and modelling; data assimilation; watershed characterization and conservation planning; snow and glacier melt runoff modelling; irrigation command area inventory and irrigation water management; flood mapping, monitoring, modelling and hazard zonation; impact assessment of climate change in water resources; drought assessment; soil erosion and sediment yield modelling; reservoir sedimentation; surface and ground water studies; and hydro-environmental impact assessment and site suitability analysis of water resources projects. The department has initiated advanced research in the field of flood early warning system; polar remote sensing; microwave and hyperspectral remote sensing applications in water resources. The department is well equipped with latest field and portable equipment. It regularly conducts special courses for officials of state and central water resources department.

Capacity Building

- Organization of courses on geo-spatial technology for Water Resources Management, climate change impacts in water resources; Microwave and Hyperspectral RS applications for Water resources; Flood disasters risk reduction; hydrological and hydrodynamic modeling.
- Organization of special courses following the National Meet and meeting the Ministries'/Departments'/Research Institute requirements.

Research

- Operationalization of flood early warning system for North Western Himalayan region.
- Development of hill-slope & snow-glacier melt hydrological model for mountainous regions.
- Technique development for retrieval and Geo-physical product generation of hydrological parameters using Indian EO system and other satellite sensors data.
- Operational technique development for irrigation water management using RS & GIS.
- Technique development for retrieval of water quality parameters & snow properties using hyperspectral remote sensing.
- Climate studies with reference to hydrology.



Urban and Regional Studies Department

Urban and Regional Studies Department (URSD) was established in 1983 in collaboration with ITC, The Netherlands to meet the growing needs and challenges of urban areas for sustainable regional development. It has developed expertise in the field of urban sprawl and growth modeling, infrastructure planning, urban environment analysis and regional analysis. It works in coordination with Town and Country Planning Departments/ Urban Local Bodies and aims to spread the benefits of remote sensing technology at grassroots level. The department has carried out a number of consultancy, operational and research projects. Development planning for the Noida and Greater Noida Authority, Delhi Development Authority (Rohini scheme) and Jaipur Development Authority are some of the landmark consultancy services provided by the department. The capacity building and research activities of the department are-

Capacity Building

- Organization of regular and special courses for the utilisation of geospatial data in urban and regional planning by central/ state Govt. officials, academia, NGOs, etc.
- Organization of short courses on Geospatial Technologies for Urban planning through IIRS out-reach program.

Research

- Urban micro climate zonation for sustainable smart city planning.
- Modeling urban air and noise pollution.
- Urban material detection using hyperspectral RS data.
- Infrastructure mapping through Ground Penetrating Radar (GPR).
- Urban drainage and flooding studies.
- Solar energy potential assessment for buildings.
- Urban growth dynamic modeling.
- Impact of urban spatial growth dynamics on urban micro-climate.

Geosciences and Disaster Management Studies Group (G&DMS)

Geosciences Department

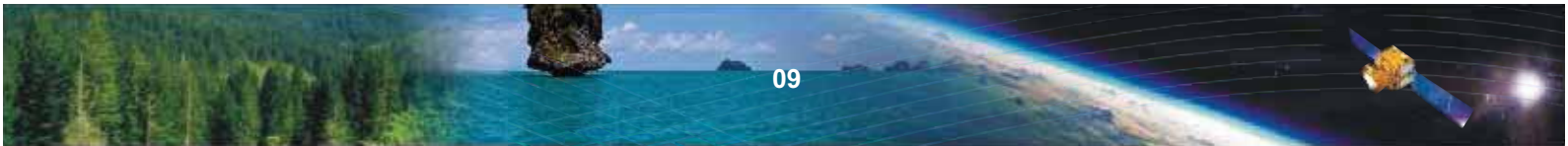
Geosciences Department (GSD) is one of the oldest departments of IIRS established in 1966 in collaboration with ITC, the Netherlands, to provide professional training to scientists and technical staff of government and public sector organizations dealing with geoscientific applications. Significant contributions of the department include landmark geological maps (Garhwal Himalaya, Cuddapah Basin etc.), groundwater prospect and quality map; providing geological inputs in national and international projects like Landslide Hazard Zonation, Highway Alignment and HE Projects, National Geomorphological and Lineament Mapping; Geodynamics and Seismicity in NW Himalaya, Seismic Microzonation, Mining and Ground Water depletion induced Land Subsidence, Coal Fire Monitoring.

Capacity Building

Besides regular long-term courses, the department conducts special courses on microwave and hyperspectral remote sensing in geological applications, geological hazard assessment, GW targeting and depletion induced impact assessment. The state of the art facility includes hyperspectral, geotechnical and geophysical lab.

Research

- Crustal deformation, geodynamics of Himalaya and earthquake precursor study
- Microwave remote sensing and SAR interferometry for monitoring of land surface deformation due to earthquake, mining and groundwater depletion
- Landslide mapping, monitoring and modelling and geotechnical assessment
- Mineral exploration using Hyperspectral Remote Sensing, Thermal RS monitoring of geological phenomena
- Planetary Geology
- Glacier morpho-dynamics and climate change study
- Planetary Geology



Disaster Management Sciences Department

Considering the importance of studying the science behind the disasters and intensity of natural and anthropogenic hazards and adverse environmental impacts such as earthquake, land slide, flood, drought, tsunami and cyclone, mine fire and roof collapse, groundwater pollution and hazards, forest fire, land degradation and coastal hazards, Disaster Management Science Department has been recently created under the aegis of Geosciences and Disaster Managements Studies Group of the Institute. The department is dedicated towards capacity building and research in the fields of remote sensing and geospatial techniques for assessment, monitoring and modelling of natural and anthropogenic disasters with prime focus on prevention and mitigation measures leading to disaster risk reduction.

Capacity Building

- Organization of short courses in "Role of RS and GIS" in the field of Disaster management (forest fire modelling and detection, floods etc.), multi-hazard assessment.
- Organization of special courses for working level professional and decision makers from central and state governments as well as for foreign nationals in the field of "Role of Remote Sensing and GIS in disaster management and disaster risk reduction".

Research

- Remote Sensing and GIS based landslide hazard assessment.
- Earthquake science and hazard assessment.
- Flood hazard modeling, risk & vulnerability assessment.
- Thermal anomaly detection and monitoring
- Drought monitoring, risk and vulnerability assessment
- Forest fire & Atmospheric Hazard analysis
- Soil erosion modelling
- Extreme climate induced hazards
- Storm surge, cyclone and coastal hazards analysis

Geospatial Technology & Outreach Programme Group (GTOPG)

Photogrammetry and Remote Sensing Department

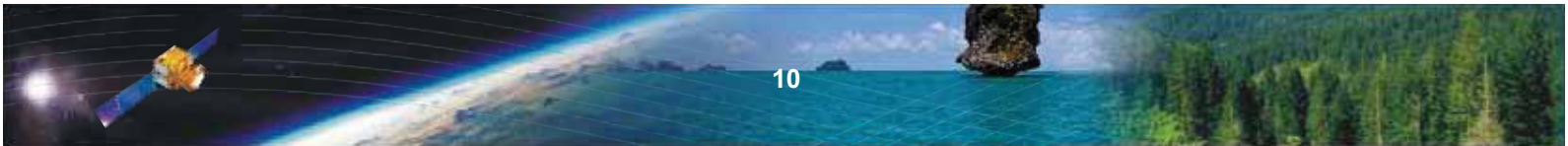
Photogrammetry and Remote Sensing Department (PRSD) established in 1966 is imparting professional training in the field of photogrammetry, cartography, remote sensing, and image processing to varied course participants: university teachers, academicians, govt. officials and freshly graduated students. It has successfully executed a number of studies/ projects on large-scale surveys and preparation of photo-maps in different parts of the country, generation of national level database on land use/land-cover, global landcover mapping using SPOT-4 Vegetation (VGT) data, augmentation of forest cover information in India and Myanmar, generation of land surface parameters for monsoon variability studies using Regional Climate Model etc., to name a few. The capacity building and research activities of the department are:

Capacity Building

- Organization of short courses on Machine Learning, Polarimetric SAR, UAV-RS & Applications, Close range photogrammetry, LiDAR Remote Sensing & Applications.
- Organization of special courses following the National Meet and meeting the Ministries' requirements.

Research

- Machine Learning for RS data processing
- LiDAR-RS (Terrestrial Scanner for Cultural, Natural Resource and Landslide monitoring).
- Multi-sensor, multi-platform data integration for extracting terrain feature.
- UAV data Processing for terrain information extraction processing.
- Automated feature extraction & large scale mapping.
- SAR Tomography (Use of space-borne SAR data for single and multi-base line PolinSAR tomography, 3D reconstruction of target & signal compression techniques and tool).
- SAR Calibration (Calibration Constant, PolSAR Calibration and minimization of cross-talks and Faraday rotation).



Geoinformatics Department

Geoinformatics Department (GID) is one of the technology development department, set-up in 1996 in collaboration with University of Twente, Netherland, Faculty of Geo-information Science & Earth Observation (ITC), The Netherlands to offer core technological courses in the field of Geoinformation Science. The M.Sc. course in Geoinformation Science and Earth Observation (specialisation in Geoinformatics) is one of its major programmes offered since 2002 as a part of Joint Education Programme of IIRS and ITC, The Netherlands. Postgraduate Diploma course in Geoinformatics (as a Joint- Education Programme of IIRS and ITC) is also offered by this department. GID imparts training, education & research in the field of GIS, D BMS , spatial analysis and modelling, Transportation GIS, 3D GIS, Spatial Data Mining, Health GIS and development of open source software tools. Technology development in the areas of GIS, database management, spatial analysis and modelling, development of decision support/ expert systems are its main focus. The capacity building and research activities of departments are:

Capacity Building

- Organization of short courses on 3D GIS, Geospatial data standards, Python for geodata processing, Geo-tagging & Mobile Apps development, Geostatistics.
- Organization of special courses following the National Meet and meeting the Ministries' requirements.

Research

- Road GIS Components (Network analysis, 3D GIS, Big data analytics, and Transportation GIS).
- Distributed GIS (Web services & Semantic web using Ontologies).
- Health GIS (Data clustering & Outbreak detection).
- 4D GIS (Spatio-temporal modelling and analysis).
- Large scale 3D modelling using High Performance Computing (HPC).

Geoweb Services, Information Technology & Distance Learning Department

Geoweb Services, IT and Distance Learning (GIT&DL) Department is a recently formed department at IIRS. The department was formed in February 2016 to cater the need of mass level training and capacity building requirements in space technologies and its applications for various user segment in the society. The focus of the department is to strengthen the Academia and User Segment in Space Technology & Its Applications using Online Learning Platforms. The major objectives of this department are:

A. Geoweb Services

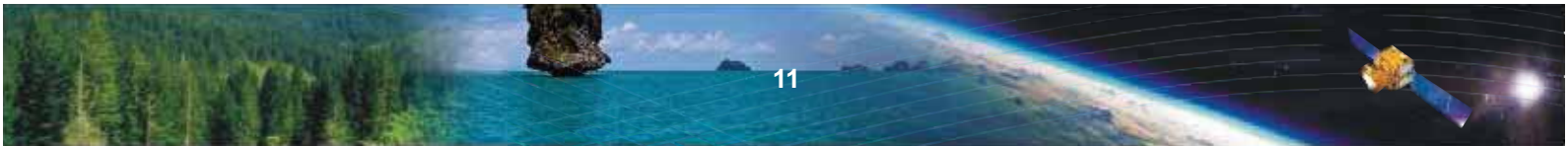
- Capacity building and R & D activities in Geoweb services and related technologies such as Web GIS, Mobile GIS, Location Based Services (LBS) and cloud GIS etc.
- Design and development of Geoweb/Web GIS based solutions for various thematic applications using desktop and mobile platforms.

B. Information Technology (IT)

- Capacity building on advancements in Information Technologies (IT) for Geospatial applications.
- Cyber GIS and computation intensive spatial analysis and processing.
- Central data, computing and Information Services.
- IT Infrastructure development, setup and operations for the Institute.

C. Distance Learning (DL)

- Capacity building in Remote Sensing and Geospatial technologies through Distance Learning mode (Live & interactive and e-learning)
- Digital contents creation for Geospatial technologies.
- R&D activities on 2D and 3D Simulations and virtualization for scientific instruments such as DGPS, TLS, spectro-radiometer etc., and practical experiments in RS&GIS
- R&D activities of methodologies on active learning .



ACADEMIC AND CAPACITY BUILDING PROGRAMMES

Highlights

The institute organises about 35-40 courses every year and it has trained 11,753 professionals (till March, 2019), including 1,197 professionals from abroad representing 96 countries mainly from the Asia, Africa and South America. A total of 198 students in M.Sc. and 327 Students in M.Tech. courses have graduated since 2002. As a follow up of the National Meet held on September 07, 2015, IIRS is also given a responsibility of Capacity Building needs for good governance in Central Ministries and state governments. IIRS provides support to conduct all its remote sensing and GIS training and education programmes at Postgraduate level. In addition to regular academic programmes, IIRS is one of the most sought after Institute for conducting specially designed courses for the officials of Central & State government ministries and stakeholder departments for the effective utilization of earth observation (EO) data.

Special/ Tailor-made courses were also designed and conducted at IIRS for various user organizations; such as GIS Based Utility Mapping of ISRO/DOS Campuses (26), Applications of Geospatial Technology (23), Space Technology Applications in Disaster Management Support (10), Summer School on Usefulness of Remote Sensing & GIS for Environmental Studies (49), Special Course on Geospatial Inputs for enabling Master Plan Formulation (41), One week orientation course for Range Forest Officers on applications of Remote Sensing & GIS in forestry (30), Remote Sensing and GIS Application for Scientist/Engineers of ISRO/DOS Centres (23), One week refresher course for IFS Officers on Advances in RS & GIS and GNSS Applications in Forestry (16), Geospatial Inputs for Enabling Master Plan Formulation under AMRUT (33), Geospatial Inputs for Enabling Master Plan Formulation under AMRUT (21), Special Course on RS, GIS & GNSS Application for Disaster Management (13), One week Training Course on RS, GIS and GNSS Applications in Biodiversity Characterisation Project (15), Geospatial Inputs for Enabling Master Plan Formulation under AMRUT (42), Geospatial Inputs for Enabling Master Plan Formulation under AMRUT (37), Workshop Training on Coastal & Ocean Management (31), etc.

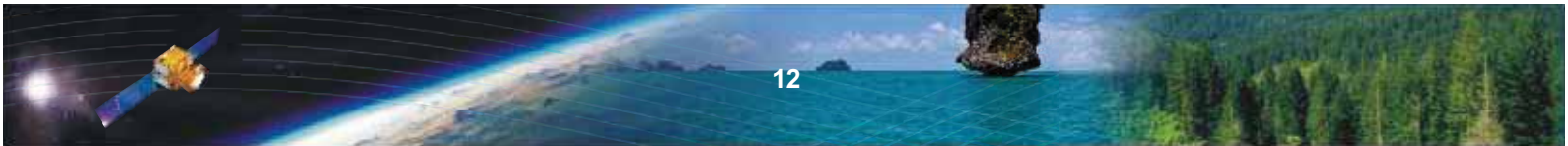
To widen its outreach, IIRS has started live and interactive distance learning programme (DLP) in 2007. Further, graduate and postgraduate students from universities spread across the country have also benefited through EDUSAT-based distance learning programmes being offered by the Institute till date. IIRS has also launched e-learning course on RS&GIS which is running successfully. The Institute campus also houses headquarters of the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP), affiliated to the United Nations and first of its kind established in the region in 1995. IIRS provides support to CSSTEAP.

Till date CSSTEAP has conducted 47 PG Courses including 20 in RS&GIS, 9 each in SATCOM, SATMET and SAS. In addition, it has also conducted 41 short courses and workshops in past 20 years. These programmes have benefited 1544 participants from 34 countries in the Asia-Pacific region and 29 participants from 18 countries outside Asia Pacific region.Till date, 136 PG students (66 in RS&GIS, 35 in SATCOM, 17 in SATMET and 18 in SAS) from 16 different countries have been awarded M.Tech. degree.

Student Outputs for Financial Year 2018-19

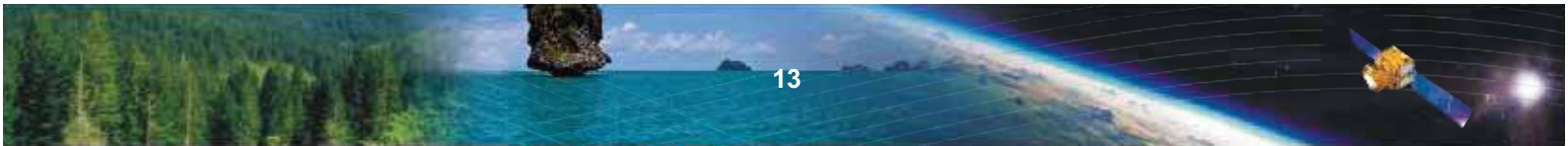
Year	Regular Programme							Special Programmes	Total
	PG Diploma*	NNRMS	ITEC	M. Tech.**	M.Sc.***	Decision Makers	Certificate		
2018 - 19	46	49	48	30	12	32	7	411	635

Completion batch: ** PG Diploma (2018-19) ** M.Tech (2016-18) *** M.Sc (2017-19)*



Details of the Special Courses organised in FY 2018-19

S.No.	Course Title	Course Duration	Course Period		No. of participants
			From	To	
1	Special course on GIS Based Utility Mapping of ISRO/DOS Campuses	1 week	09.04.2018	13.04.2018	27
2	Special Course on Customised Training Programme on "Applications of Geospatial Technology	1 week	21.05.2018	25.05.2018	23
3	Summer School on Usefulness of Remote Sensing & GIS for Environmental Studies	1 week	18.06.2018	22.06.2018	49
4	Special Course on " Space Technology Applications in Disaster Management Support"	4 days	26.06.2018	29.06.2018	10
5	Special Course on "Geospatial Inputs for enabling Master Plan Formulation"	2 weeks	09.07.2018	20.07.2018	41
6	One week orientation course for Range Forest Officers on applications of Remote Sensing & GIS in forestry	1 week	30.07.2018	03.08.2018	30
7	Remote Sensing and GIS Application for Scientist/Engineers of ISRO/DOS Centres	1 week	06.08.2018	10.08.2018	23
8	One week refresher course for IFS Officers on" Advances in RS & GIS and GNSS Applications in Forestry	1 week	27.08.2018	31.08.2018	16
9	Geospatial Inputs for Enabling Master Plan Formulation under AMRUT	3 days	12.09.2018	14.09.2018	33
10	Geospatial Inputs for Enabling Master Plan Formulation under AMRUT	4 weeks	08.10.2018	02.11.2018	21
11	Special Course on RS, GIS & GNSS Application for Disaster Management	4 days	30.10.2018	02.11.2018	13
12	One week Training Course on "RS, GIS and GNSS Applications in Biodiversity Characterisation Project"	1 week	10.12.2018	14.12.2018	15
13	Geospatial Inputs for Enabling Master Plan Formulation under AMRUT	3 days	12.12.2018	14.12.2018	42
14	Geospatial Inputs for Enabling Master Plan Formulation under AMRUT	2 weeks	07.01.2019	18.01.2019	37
15	Workshop Training on "Coastal & Ocean Management"	1 week	28.01.2019	01.02.2019	31
				Total	**411**



EDUCATION PROGRAMMES

M.Tech. in Remote Sensing & Geographical Information System (RS&GIS)

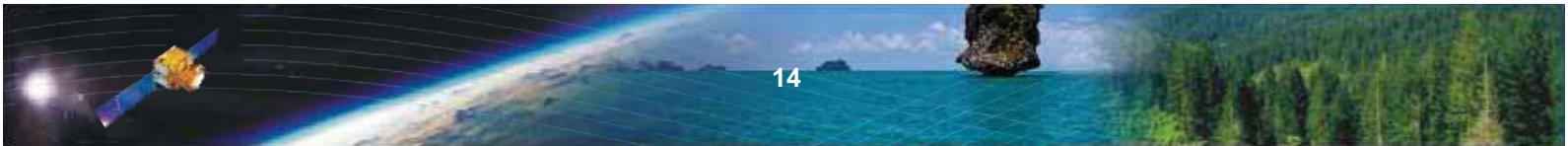
M.Tech 2016-18 & 2017-19

2 years M.Tech course conducted for 2016-18 Batch total 30 participants passed out from eight application streams. Eight application streams opted by students was; ASD- 3; FED-3; GSD-3 ; URSD- 4; MASD- 4; PRSD- 5; GID- 4; WRD-4; All M.Tech students of 2016-18 were self-sponsored. In 2017-19 batch total 30 students joined M.Tech course and Eight application streams opted by students was; ASD-4; FED-4; GSD-2; URSD-4; MASD-4 ; PRSD- 4 ;GID- 4; WRD-4; out off 30 there was one sponsored candidate.

In M.Tech course of IIRS students have to attend semester 1 (core module-1) covering geo-spatial technology related topics with five papers. Semester II (module -II) any one specialization module topics with four papers. After module II there is Semester II (module -III) with two elective papers, one research paper and one case study paper. After Semester II (module -III) students goes for one year independent project work with midterm project evaluation as well as final project defense by a committee.

Project Titles:

- Agricultural Drought Vulnerability Assessment using Geospatial Techniques at block level in Marathawada region, Maharastra
- Monitoring and Assessment of Agricultural Drought in Rainfed and Irrigated areas using Geospatial Techniques
- Urban water utilities Mapping and water supply distribution modelling using Geospatial Techniques
- Spatial Cluster Analysis of Integrated Disease Surveillance Project Data of Dehradun District
- OGC CityGML based utility network modelling for Indian Scenario
- Development of Web-Based Geospatial modelling platform using data cube for Indian Bio-resource Information Network (IBIN)
- Extreme rainfall events over the North- west Himalayan Region: Modeling and now-casting
- Rainfall pattern from coupled climate and regional models over the North-west Himalayan region
- Distribution of Oxide of Nitrogen over the Indian Subcontinent: Investigation of sources using Chemistry transport model
- Assessment of PolSAR Backscatter and optical data for improved image classification
- Studying the behavior of super resolution on soft classified output
- Flood early warning system development in North-western Himalaya Parth NaikStudy of Hybrid spectral characterization measures for fuzzy based classifier
- Intergration of remotely sensed phenology and process based model for the intra-annual variability of carbon fluxes
- 3D documentation of condition assessment of surface and Subsurface of Engineering structures



- Evaluating performance of radiative transfer model for LAI estimation of managed plantation
- Environmental epidemiology of major respiratory disorders in metropolitan cities of India using VIIRS Suomi aerosol data, google trends Vis-À-Vis morbidity : a use case on Geohealth informatics
- Single frame hyperspectral image super resolution for enhanced mapping in an urban area Prateek TripathiIntegration of Fourier Transform Infraded (FTIR) Spectroradiometer and Fieldspec Spectroradiometer data for mineral characterization Swayam Vid Predicting plant functional types in response to climate change in Western Himalaya using dynamic global vegetation model: LPJ-GUESS
- Crustal deformation analysis in parts of Himalaya using Space Borne and Ground based Geodetic Techniques
- Analysis of Multispectral and Hyperspectral data for characterization of Ore-bearing rocks and detection of potential mineralized zones
- Flood Hazard and risk assessment of Jhelum river basin using Integrated modelling and geospatial technique
- Snow avalanche hazard assessment using geospatial techniques
- Land subsidence time series analysis by advanced DinSAR and aquifer system compaction estimation techniques
- Investigating the relationship of urban built form parameters with temperature pattern
- Distribution of Ozone over Indian Subcontinent: In-situ observations and modelling
- Extraction and analysis of the tree canopy parameters from ultra-high resolution UAV datasets
- Yield Estimation of Soyabean Crop Using Temporal SAR Data In District Dewas of Madhya Pradesh, India

IIRS-ITC JEP: M.Sc. in Geoinformation Science and Earth Observation

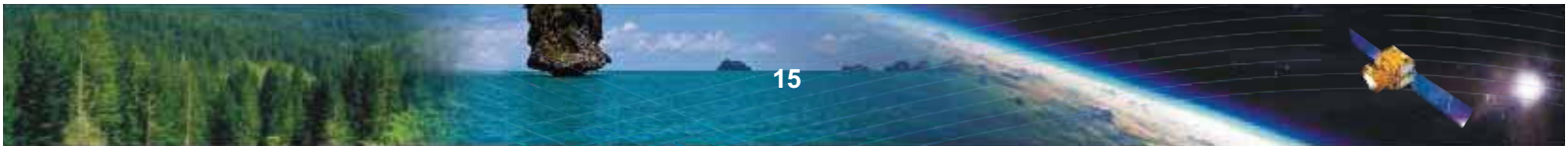
The Master of Science (M.Sc.) in Geo-information Science and Earth Observation (specialisation/ domain: Geoinformatics) is offered within the framework of Joint Education Programme (JEP) of the Indian Institute of Remote Sensing (IIRS) and the Faculty of Geo-information Science and Earth Observation (ITC) of the University of Twente (UT), The Netherlands. Students follow part of the course at IIRS and a part at the Faculty ITC, The Netherlands. The first year was taught at IIRS followed by advanced module at ITC. Students undergo research work under joint supervision of IIRS & ITC faculties. Upon successful completion of the course students receive a Master's degree from UT-ITC.

This course is targeted for those who are interested to learn Remote Sensing and GIS technologies and their applications. Both the working professionals and fresh graduates (including candidates in the final semester/year of the qualifying degree) can apply for the course.

Nine M.Sc. students joined for 2018-2020 batch and undergoing required course work for this programme at IIRS-ITC.

Twelve M.Sc Students of (2017-2019) batch have successfully completed dissertation under IIRS-ITC Joint Education Programme (JEP). This year 3 students got distinction while one student was overall topper of entire ITC M.Sc batch including ITC & remaining JEP by scoring 10/10 marks in the project work. M.Sc students of this batch worked on the following research topics:

1. Coupling airborne LiDAR and high resolution optical sensor parameters for biomass estimation using machine learning algorithms



2. Integration of social and physical traffic data for provision of near real time Bigdata analytics of the traffic situation within a city
3. Polarimetric calibration of SAR data using manmade point targets and uniformly distributed natural targets
4. Lunar Regolith Characterization for Estimation of Solar Wind Implanted Helium-3 using M^3 Spectroscopy and Bistatic Miniature Radar
5. Geostatistical dynamic simulation on Unstructured grids
6. Analysis of machine learning classifiers for LULC classification on Google Earth Engine
7. Mapping Tree Species Richness of Tropical Forest using Airborne Hyperspectral Remote Sensing
8. Glacier Facies Classification and Surface Velocity Estimation using Multi-temporal SAR and InSAR Techniques in the Indian Himalayas
9. Snow depth and SWE estimation using Space-borne Polarimetric and Interferometric Synthetic Aperture Radar
10. Surface fire detection using VIIRS and Landsat-8 / OLI data
11. Local convolution information for fuzzy based classifier
12. Snow and Cloud discrimination using Convolutional Networks

IIRS-ITC JEP: PG Diploma Course in Geoinformatics

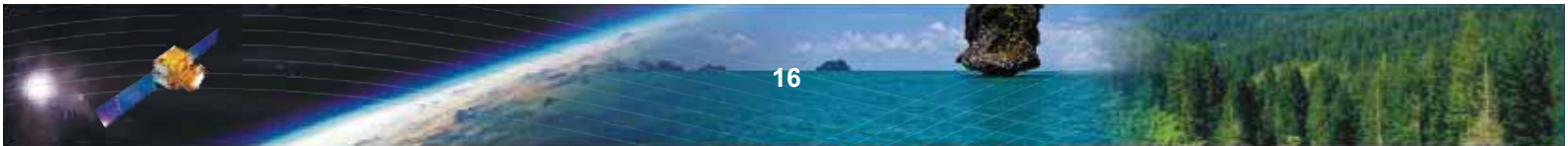
Post Graduate Diploma (P.G.D.) in Geo-information Science and Earth Observation (specialisation: Geoinformatics) is offered within the framework of Joint Education Programme (JEP) of the Indian Institute of Remote Sensing (IIRS) and the Faculty of Geo-information Science and Earth Observation (ITC) of the University of Twente (UT), The Netherlands. The course is of 9 months duration having 10 modules. Students follow the course at IIRS.

This course is targeted for those who are interested to learn Remote Sensing and GIS technologies and their applications. Both the working professionals and fresh graduates (including candidates in the final semester/year of the qualifying degree) can apply for the course.

This year 6 students from PGD (2017-18) successfully completed the course and 9 students joined for PGD (2018-19) batch.

Selection for admission to P.G. Diploma course is generally based on merit considering the academic record. However, institute may also decide conducting interviews of eligible/short-listed candidates for selection.

The lodging and boarding facilities are provided to all students at IIRS in its hostels at nominal charges.



TRAINING PROGRAMMES

IIRS-ITEC Joint Education Programme

The Indian Technical and Economic Cooperation (ITEC) Programme was instituted by a decision of the Indian Cabinet on September 15, 1964 as a bilateral programme of assistance of the Government of India. IIRS has been entrusted by Ministry of External Affairs, Govt. of India to organize training programmes each year under its Indian Technical and Economic Cooperation (ITEC). The ITEC Programme of the Ministry of External Affairs is an earnest attempt by India to share the fruits of its socio-economic development and technological achievement with other developing countries. under ITEC two short-courses are conducted as follows:

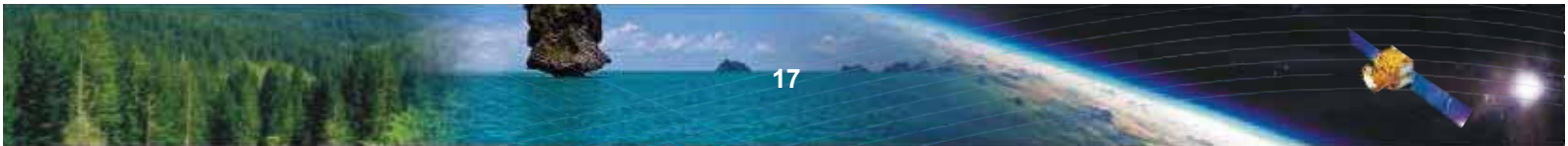
IIRS - ITEC Course on Geoinformatics
(September 17, 2018 to November 09, 2018)

There were Twenty four participants from 16 countries in this course. There were three participants from Sri Lanka, two participants each from Egypt, Ethiopia, Mauritius, Niger, Tanzania, Uzbekistan one each from Botswana, Kazakhstan, Kenya, Lesotho, Mozambique, Nigeria, Tunisia, Uganda and Venezuela. In addition two Indian participants are nominated by IAF to undergo this training programme.

The primary aim of this course was to enhance the capacity of participants in understanding various dimensions of Geo-information science and technology for natural resource management and decision making. The objective was to train professionals to acquire good working knowledge of the theory and practice of the Geoinformatics and enabling technologies. The course is modular in structure. The first module named Geoinformation Science of three weeks was devoted to Principles and potentials of GI Science, Geographic Information & Spatial Data types. The second module Earth Observation (EO) focused on Electro magnetic radiation Visual and Digital image interpretation. The third module covered advances in Geoinformatics and a small case study / project . These topics were covered in theory lecture classes and the lectures were followed up by practical demonstrations.

IIRS-ITEC Course on Remote Sensing with special emphasis on Digital Image Processing
(January 7, 2019 to March 1, 2019)

The primary objective of this course was to enhance the capacity of middle level professionals in the field of remote sensing with special emphasis on processing of remotely sensed data using digital image processing techniques. There were 22 candidates from 18 Countries who attended this programme. There were three participants from Tanzania, two



each from Sri Lanka and Ethiopia, and one each from Algeria, Bangladesh, Botswana, Cote D'ivoire, Cuba, Ghana, Kazakhstan, Kenya, Kyrgyzstan, Nepal, Niger, Nigeria, Uganda, Vietnam and Zimbabwe.

This course of 8 weeks duration was designed in such a way that it offered a blend of latest technology and conventional techniques. It covers the basic and advance concepts of Remote Sensing and Digital Image Processing. These topics were covered in Theory classes followed by practical demonstrations & field visits. An overview of various applications of RS and GIS Techniques in various thematic disciplines were delivered by Dean IIRS and respective Group Heads and Heads of departments. An educational and sightseeing tour to Delhi and Agra was organized and participants got the opportunity to attend a one day session of ISPRS GEOGLAM conference. The participants also attended the popular talk on "Climate Change and Himalayas; An Overview" Prof. S. P. Singh, F.N.A. & former Vice-Chancellor, HNB Garhwal University.

The Short Course on Remote Sensing and Image Interpretation (C-RS) was also conducted during January 7, 2019 to March 1, 2019 along with ITEC Course and was attended by 7 participants. There were two participants from NHO Dehradun, one from Kumaun University Nainital, one from Wildlife Protection department, Ladakh, one from Karnatak, one from Rajasthan, and one from Chandigarh.

Post-Graduate Diploma Courses

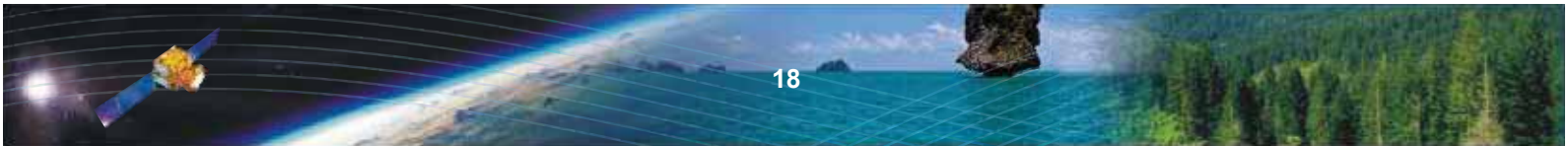
The Post Graduate Diploma in Remote Sensing and Geographic Information system is an important programme of the institute. Presently, eight specializations are offered in PG Diploma course: one in technology area, namely Satellite Image Analysis and Photogrammetry, and seven in other application areas such as Agriculture & Soils, Forest Resources and Ecosystem Analysis, Geosciences, Natural Hazards and Disaster Risk Management, Marine and Atmospheric Sciences, Urban & Regional Studies and Water Resources.

The course is designed for the mid-career working professionals, fresh university students with engineering and science background interested in remote sensing and geospatial technology and its applications. The admission to the course is based on the academic record of the candidates particularly in the qualifying examination. It involves regular classes comprising of lectures, practical, hands-on and field visits.

Based on the academic performance of the students, five fellowships are offered to the students under the prestigious IIRS Golden Jubilee Fellowship programme.

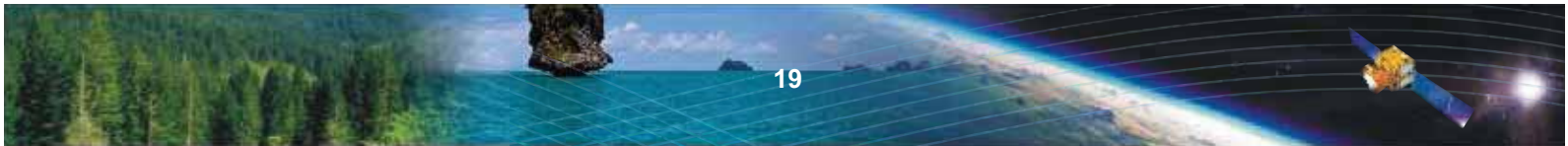
This course commenced on August 14, 2017 and got completed in June 2018. A total of 40 participants joined the course. The participants distribution across discipline were as follows- Agriculture and Soils (03), Forest Resource & Ecosystem Analysis (06), Geosciences (06), Natural Hazards and Disaster Risk Management (06), Urban & Regional Studies (05), Marine & Atmospheric Sciences (03), Satellite Image Analysis & Photogrammetry (05), Water Resources (06).

The course is structured in three modules – two modules of course work and one for pilot project study. After the completion of course work, students did pilot project study in the following topics:



Project Topic

- Assessment of crop water use and stress using multidate Resourcesat satellite Data
- Characterization of Orchads and crop using SAR
- Land Evaluation for Land Use Planning using RS & GIS
- Simulation and Analysis of extreme dust event
- Association of ENSO and IOD with summer monsoon rainfall variability over central India
- Impact of Diwali event on regional air quality over India
- Comparison on Image enhancement and colour correction technique of underwater image enhancement
- Polarimetric characterization of flooded area using L band Dual Pol SAR data A case study of Kaziranga National Park
- Airborne Hyperspectral Remote Sensing for water quality
- Comparison of Image Fusion Techniques
- Backscatter analysis of temporal SAR data for flood inundation mapping
- Urban flood mapping & modelling for Chennai 2015 floods using geospatial tools
- Mapping & simulation of debris/ice/ mud/flow at Gangotri snout using process based model & geospatial tools
- Debris flow modelling & geotech of vulnerable slope in parts of Aizwal, Mizoram
- Water level & Flow estimation using altimeter data for parts of Brahmaputra
- Landslide hazard zonation around NH 58 from Pipalkoti to Lambagard using Geospatial tools
- HRU & Grid based approach for snowmelt runoff estimation in Satluj River Basin
- Water Balance study of a water stressed basin under changing climate
- Water availability at basin scale using hydrological model and water use data
- Flood estimation using HRU based modelling approach
- Impact of basin storage in water availability
- Impact of point and non-point source pollution on water quality of the river
- Impact of land use land cover change on hydrological regime of Krishna basin.
- Analysis of TEC for Earthquake precursors studies in Himalayan region
- Development of spectral library for mineral present in Malangtoli area of Singhbhum iron ore craton and its comparison with space borne data and geochemical signatures
- Space based Glacial geomorphology, landscape evolution and ELA reconstruction of the Glacier in Dhauliganga basin, central Himalaya, India
- Mineralogical abundance mapping using field and image based spectra n Kiriburu-Mehatuburu area of Singhnhum Iron Ore craton
- Groundwater depletion, aquifer system compaction and land subsidence in and around Chandigarh
- Morpho tectonic and geophysical investigations of Himalayan Foothill region in parts of Uttarakhand
- Decadal changes in sub-tropical pine forest in part of western Himalaya
- Sentinel 1time series data analysis for forest change detection
- Integration of optical and SAR data derived parameters for forest biomass estimation using machine learning algorithm
- Mapping the spatial variability of foliar nitrogen and carbon using machine learning techniques and Sentinel-2 MSI data
- Complex network algorithm for forest fire spread modelling
- Urban repercussion pressure on water bodies using geo-spatial technology- a case study of Bengaluru
- Evaluation of Spectral indices for Extraction of Built-up-Area
- Study of Thermal Environment of Dehradun Urban Area
- Modelling growth scenarios for NCR region for sustainable regional Planning
- Urban area characterization using SAR image.



Valedictory function for the course was organized on June 15, 2018 in which the participants received their Post-Graduate Diploma certificates.

Thirty-seven participants of 63rd PG diploma course in NRM and GIS joined in August 2018. The batch will pass out in June, 2019.

ISRO-NNRMS sponsored course on RS&GIS Applications

Optimal management of natural resources is vital to meet human needs especially for the developing countries. The Government of India has set-up the National Natural Resources Management System (NNRMS) in 1983, after recognising the need and importance of natural resources management, with Department of Space (DOS) as the nodal department. IIRS conducts ISRO-sponsored NNRMS training programme for university faculty on the recommendations of NNRMS Standing Committee on Training (NNRMS SC-T) since 1994. The training programme is of 8 weeks duration and is offered in eight specializations in technology and application domains.

The prime objective of this programme is to train the University/ P.G. college teachers in RS & GIS technology and applications, so that they can further teach students in their universities and colleges. There are sixty-four seats available in each of the following disciplines:

- GIS Technology and Advances
- RS and GIS in Cartography and Mapping
- RS and GIS in Soils and Land Use Planning
- RS and GIS in Forestry and Ecology
- RS and GIS in Geosciences
- RS and GIS Water Resources
- RS and GIS in Urban and Regional Planning
- RS and GIS in Coastal and Ocean Sciences

Target participants for this course comprises of State/ Central Government-sponsored faculty/ teachers of University/ Colleges/ Govt. affiliated colleges in India. There is no course fee and the candidates, admitted to this course are paid 2nd AC fare by train and DA by the institute as per Department of Space (DOS) rules. Participants are be provided shared accomodation in IIRS hostel.

NNRMS Certificate Course of 8 weeks duration from May 01, 2018-June 22, 2018 was conducted for the faculty of Universities/ College, sponsored by ISRO, Department of Space, Govt. of India. There is a widespread recognition for RS&GIS technologies which have revolutionised the generations with reliable and updated spatial information of Natural resources in the country.They are playing a significant role in the natural resource development planning of the country. Since the capacity building is recognized as a critical element to strengthen the human resource at grass root level, this training program is designed to train the university faculty members in particular.

In this program, 49 candidates from different parts of the country have participated. The course is designed in modular structure. It comprises of four modules, each one of two weeks duration (total 8 weeks). First three modules are devoted to the teaching of the subjects by the various Departments whereas 4th module is exclusively devoted for carrying out a pilot project. The participants present their pilot project work at the end of 4th module. The program is organized under the overall guidance of Director, IIRS and Dean (Academic). Group Heads and Heads of the Departments supervised and provided support towards conduct of different modules. The course modules were looked after by the course officers of the various departments for day-to-day activities. Course Director and Course Coordinator of the

course were responsible for overall coordination of the course.

Remote Sensing : An Overview for Decision makers

This course offers opportunities to Decision Makers' to understand the recent developments in EO data and geospatial technologies. The course provides insights of day to day decision making related to Remote Sensing (RS) data acquisition, utilisation and spatial and non-spatial data handling for Natural Resources Management (NRM).

Four days Decision Makers' course for 32 participants comprising of senior professionals/ managers, project leaders, planners or policy makers from different fields, such as agriculture, forestry, water resources, environment and ecology, disaster management, meteorology, geography, economics urban, oceanography has been conducted from June 12-15, 2018 on 'Remote Sensing An Overview for Decision Makers. The aim of the training course is to instill an appreciation of benefits and constraints of remote sensing technology and geographic information system techniques to aid in planning and management of natural resources and disasters. The course also enables course participants sharing of their experiences and knowledge with the aim of further enhancing the use of geospatial technology and its applications.

Salient Topic Covered

Overview of Remote Sensing and GIS, Geological Applications including disaster management, Indian Space Programs, RS & GIS Application in Agriculture & Soils, Geospatial Applications in Urban and Regional Planning, RS & GIS Application in Water Resources, RS & GIS Application for Marine Science, Weather Forecasting and Related Services, EO Applications for Air Quality Studies. Case Study demonstration: As per Interest of Individual/ Group of Participants. BHUVAN – ISRO's Geoportal Gateway to Indian Earth, Open Source Software, Datasets and India-WRIS.

SPECIAL & CUSTOMISED TRAINING PROGRAMMES

GIS Based Utility Mapping of ISRO/DOS Campuses & Workshop on Total Turnkey solution for Swachh Bharat Abhiyaan (SBA)

IIRS, organized the special training programme from April 9-13, 2018 for ISRO/DOS officials. A total of 27 participants from 14 centres/units of ISRO/DOS joined the programme.

On the last day a workshop on 'Total Turnkey Solution for Swachh Bharat Abhiyaan (SBA)' on April 14, 2018 for ISRO/DOS officials for Implementation at ISRO/DOS Campuses. Through series of lecture and hands-on sessions the participants were acquainted with the solution functionalities, usage and overall framework.

Short Course on Geospatial Modelling in Forestry and Ecology for Climate Change Studies

This training course was organized by the Centre for Space Science and Technology Education in Asia and Pacific (CSSTEAP) and conducted at IIRS during April 16-27, 2018. A total of 18 participants from 8 countries, viz., Bangladesh, India, Kazakhstan, Kyrgyzstan, Mongolia, Nepal, Sri Lanka and Tajikistan, participated in the course. The overall objective of this training course was to generate awareness among researchers, professionals, decision-makers and academicians on the recent advances in geospatial modelling in forestry and ecology for climate change response studies.

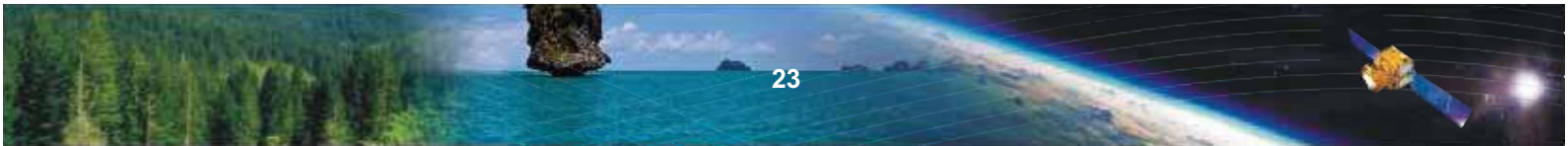
The course comprised of lectures, hands-on and field visit. The major topics covered in lectures were: Geospatial modelling in forestry and ecology; Phenological responses to climate change in Himalayan Forests; Modelling carbon fluxes in Indian subcontinent and its relation to climate change; Land use and land cover change prediction modelling for climate change studies; Species distribution modelling for climate change studies; Modelling ecological corridors and connectivity for climate change studies; Impacts of climate change in modelling biological invasion due to invasive species; and Overview of GCMs and RCMs in developing AR5 RCPs (IPCC scenarios). One-day field visit was carried out in Mussoorie forest division. The participants also carried out a one-week mini project. The course was widely appreciated by the participants.

Customized Training Programme on Applications of Geospatial Technology

A 5-days customized training programme on "Applications of Geospatial Technology" was organized for Jawaharlal Nehru Technological University (JNTU), Hyderabad students during the period 21-25 May, 2018 at IIRS, Dehradun. The main aim of this training programme was to help the students in their research and in designing courses in academics. The course was designed with a view in understanding and applications of geospatial technology in various fields such as marine sciences, water resources, agriculture & soils, disaster management, geosciences, urban and infrastructure planning, forestry and satellite navigation. Toward the training programme, a total of 23 participants including 22 students and one lecturer were attended. The students were a blend of M.Tech in spatial information technology, geo-informatics and surveying technology and water resources. The training included expert lectures, case studies, demonstrations, hands on exercises, instrumentation setup and field visits to mussoorie. The course was organized in two sessions in each day. First session included lectures and discussions and second session respective practicals/case study demonstrations.

Summer school on Usefulness of Remote Sensing & GIS for Environmental Studies

Since last seven years, IIRS is conducting a special course on "Usefulness of Remote Sensing & GIS for Environmental Studies" for school students from 9th to 12th standard. The aim of the course is to create an awareness about Remote Sensing technology & its use for the study of earth and its environment among the school students. This year, the course was organized during June 18-22, 2018. A total of 49 students from 28 different schools participated in the course. The focus of the course was on principles of Remote Sensing (RS) & Geographic Information System (GIS) and its applications for environmental studies. Broad subjects covered in the lectures are: a view of solar system from space, basics of Remote Sensing, basics of GIS, Tsunami and RS & GIS applications in geological studies, water resources, agriculture, soils, atmosphere and urban studies. Practical demonstrations were also arranged to familiarize them with satellite images, GPS technique and GIS data collection & mapping. Students had good interaction with faculty from various departments of IIRS. Videos on Indian space programme including Chandrayaan mission, Mars mission and Space Capsule Recovery Experiment were also shown to the students.



Space Technology Applications in Disaster Management Support for Uttarakhand Government Officials

A Special Course entitled "Space Technology Applications in Disaster Management Support" was conducted from June 26, 2018 to June 29, 2018 for officials of Uttarakhand Govt.

The course was attended by 10 participants from various departments of Uttarakhand State Govt. The course comprised of various lectures and practical sessions covering topics such as Remote Sensing techniques for disaster mapping, GNSS techniques for precise location/route mapping, Role of space and geo-spatial technology in earthquake risk reduction, landslide risk reduction, flood hazard modelling, forest fire hazard monitoring and modelling and Space inputs for mainstreaming disaster risk reduction in developmental planning.

At the end of the course, all participants found the course highly relevant to the current job and very useful in executing their job more efficiently in future.

Orientation Course on Applications of RS and GIS in Forestry for Range Forest Officers

A Range Forest Officer (RFO) is a front line officer in the state forest departments in India. RFO's primary function is to safeguard the forest resources as well as executive welfare schemes for forest-dependent communities. The aim of this special course was to sensitize the RFOs about the utility of RS, GIS and GNSS in effective protection and management of forests and wildlife areas. It was organized by IIRS from July 30, 2018 to August, 03 2018 for 30 RFOs of Forest Training Institute and Ranger's College, Sundernagar, Himachal Pradesh. IIRS has been organising this course for the Forest Range Officers of Forest Training Institute and Ranger's College, Sundernagar once in every two years since 2012.The course comprised of lectures, practical and field visit. The major topics covered in this course were: Introduction of RS, GIS and GNSS in forestry, Geospatial technology for enhancing governance and development, ISRO Bhuvan spatial products and services, Forest information extraction from aerial photographs, Forest type and density mapping and monitoring, Forest growing stock and biomass estimation, Forest fire assessment and monitoring, Wildlife habitat suitability analysis, Land evaluation for forestry, and Indian Bioresource Information Network. Hands-on were carried out on procurement and familiarization with satellite data, visual image interpretation as well as digital classification for forest type and density mapping, forest change detection and monitoring, and database creation and GIS analysis. There were lectures by guest faculty also. One-day field visit was carried out for ground truth collection in Forest Research Institute, Dehradun. At the end of the course, an examination was conducted.

Applications of Remote Sensing and GIS for Scientists/Engineers "SC" & "SD" of ISRO/DOS Centers

On advice of Chairman, ISRO/ Secretary, Department of Space, IIRS conducted a special training course on "Applications of Remote Sensing and GIS" for Scientists/Engineers of ISRO/DOS Centres during August 06 - 10, 2018. The course was attended by 23 scientists representing 14 Centres/ Units of ISRO.

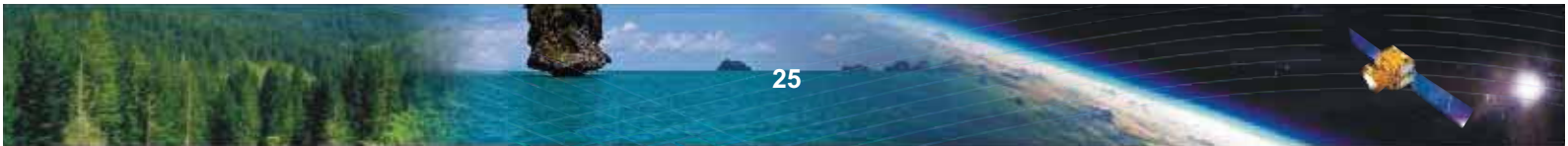
The course content was designed to give them wide exposure of various applications of Remote Sensing and GIS in Natural Resource Management, Agriculture & Soils, Water Resources, Marine & Atmosphere Science, Forestry & Ecology, Geosciences, Urban Planning, Disaster Management, Microwave Remote Sensing Applications, ISRO Bhuvan Portal, Weather Forecasting Indian Earth Observation Programmes Current & Future and ISRO Planetary Missions.

The participants were exposed to principles of Remote Sensing, Geospatial Technology, Optical and Microwave Remote Sensing Sensor. Senior Scientists from Space Applications Center (SAC), National Remote Sensing Center (NRSC) and Indian Meteorological Department (IMD) were invited to deliver specialized lectures.

Total 17 lectures and 04 practical classes were conducted. In the practical classes, participants were divided into 05 groups and each group carried out mini-project on various themes.

Refresher Course on Advances in RS, GIS and GNSS Applications in Forestry for senior Indian Forest Service Officers

On the behest of MoEFCC, Govt. of India, IIRS every year organizes a refresher course for senior IFS officers from the forest departments of state/union territories to appraise them with the latest development in the field of geospatial technologies so that its more effective use can be ensured in forest management in the country. This special course was organized by IIRS during 27-31 August 2018 for 16 IFS Officers representing 10 states, viz., Assam, Chhattisgarh, Gujarat, Jammu and Kashmir, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Uttar Pradesh, and Uttarakhand. The course comprised of lectures, hands-on and field visit. The major topics covered in lectures were: Advances in RS, GIS and GNSS in forestry: An overview; Forest working plan preparation using RS&GIS inputs; Indian Earth observation programme; Forest above ground biomass estimation using SAR with NISAR perspective; Geospatial applications for governance and development; Issues in creation of spatial database of forest boundaries; ISRO Geoportals products and services. Hands-on excercises were carried out on familiarisation to optical, SAR and LiDAR datasets; forest classification, change and terrain analysis; modelling potential distribution of target species and multi-criteria analysis for decision support. Demo on DGPS for forest surveying, and ecosystem services modelling were also conducted. One-day field visit was carried out in Mussoorie forest division.



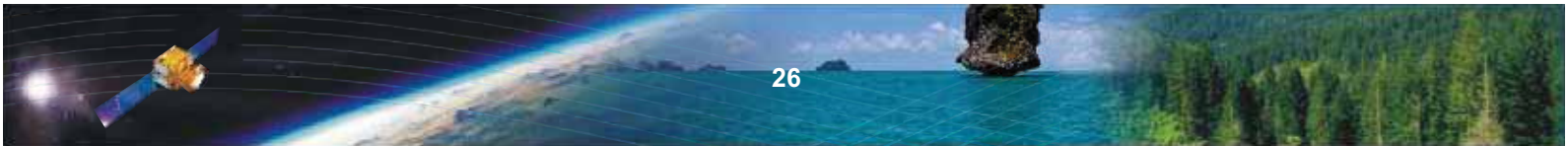
Geospatial Inputs for Enabling Master Plan Formulation under AMRUT Sub-Scheme

The Govt. of India has launched Atal Mission for Rejuvenation and Urban Transformation (AMRUT) Mission which has a sub-scheme on 'Formulation of GIS Based Master Plan for AMRUT cities'. IIRS along with Town & Country Planning Organisation (TCPO), Ministry of Housing and Urban Affairs (MoHUA), GoI has developed the course contents for country-wide training and capacity building of personnel involved in sub-scheme at three levels (Tier-1: Decision Makers, Tier-2: Middle-level and Tier-3: Junior-level Officers). The course contents are designed to build capacity among urban planning professionals for utilising geospatial data for Master Plan Formulation and for Utility Management.

IIRS has organised a series of five face-to-face training programmes and one Outreach Programme under AMRUT Sub-scheme. So far, 174 participants from 15 states have benefitted from five training programmes. The course contents comprised of lecture/ demo/ practical related to geospatial data and techniques for enabling Master Plan Formulation, utilitymanagement, etc. A panel discussion moderated by Dr. Sudhir Krishna, former Secretary, MoHUA; Director, IIRS and TCPO officials was organised on September 14, 2018 wherein senior officials from 14 states through virtual network participated and deliberated on geospatial data needs for AMRUT sub-scheme. IIRS has conducted an Outreach Programme on AMRUT where more than 1700 participants from 187 Institutes have attended the programme.

One-Day Workshop on Recent Trends and Future Perspectives of Earthquake Precursor Analysis and Geodynamics

The workshop was first on its kind in the field and was related to ongoing EOAM project on Himalayan geodynamics under IIRS`s Mountain Ecosystem project. There were forty-six participants from all across India which included speakers from IIGM, Mumbai, SAC, Ahmedabad, ISR, Ahmedabad, ARIES, Nainital, WIGH and IIRS Dehradun. There were delegates from Doon University, DBS College, Dehradun, Jammu University, Teri SAS, New Delhi, KL College, Vijaywada, NESAC, Shillong, CBRI, Roorkee. The broad themes were geodynamics, active tectonics and historical seismicity analysis and seismic precursors including Ionospheric Perturbation, TEC anomaly, VLF and others and included interactive discussions on inter-seismic coupling, stress and strain along central Himalaya prior to the 2015 Gorkha Earthquake, lithosphere-Ionosphere coupling process during earthquakes, Earthquake precursory Research at MPGO, ISR, earthquake precursors in lower and upper atmosphere: Past, Present and Future Perspectives, the status of earthquake precursory research based on the Multi-Paramteric Geophysical Observatory, Ghuttu Garhwal Himalaya, earthquakes generated landforms: implication on pattern of strain release along Himalayan arc, geodynamics of Himalaya and Tibet emerging issues and recent observations, ionosphere seismology- an emerging branch of applied geoscience, tectonic landforms in Himalaya vis-à-vis large magnitude earthquakes. The workshop was concluded with brainstorming discussion and recommendation for future R&D initiatives.



ISPRS Pre-Symposium Tutorial on Big Geospatial Data Analytics

IIRS organized a one day pre-symposium tutorial entitled 'Big Geospatial Data Analytics' on November 19, 2018 as part of the Mid Term Symposium of ISPRS Technical Commission V on Education and Outreach which was scheduled from November 20-23, 2018. The pre-symposium tutorial covers through a series of hands-on sessions, the fundamentals of storing, handling and analysing big geospatial data. Four hand-on sessions were covered in this tutorial namely:

I. Big Data Analysis using Cloudera Distribution of Hadoop (CDH)

II. Exploratory Spatial Data Analysis using GeoDa Software

III. Introduction to Big Geospatial Data Analytics using Google Earth Engine

IV. R for BigGIS Data Analysis

The tutorial was attended by 10 participants; seven were from India, two from Tajikistan and one from Bangladesh. Participants were also provided the reading material consisting of hand-on exercise as step-by-step manual as well as extra reading material in form of Journal articles on big geospatial data for their ready reference.

Training course on RS, GIS & GNSS applications in biodiversity characterisation

A nationwide project on biodiversity characterization at landscape level was carried out by IIRS, ISRO in the past. In view of that, biodiversity characterization at the community level was realized and a national level project was formulated. At the same time, Indian Biodiversity Information Network (IBIN) project was designed to serve relevant information on bioresources of the country to the professionals involved in bio-prospecting, marketing, protecting bio-piracy and the conservation of bioresources. The aim of the course was, therefore, to familiarize the project personnel of both the projects with RS, GIS and GNSS technologies so that they can effectively utilize this technology in their respective projects. This special course was organized during December 10-14, 2018 by IIRS for 15 participants which included 2 project principal investigators and 13 researchers of Department of Biotechnology and Department of Space funded projects - Biodiversity Characterisation at Community Level and IBIN. The participants were from French Institute of Pondicherry, Kerala Forest Research Institute, M.S. University of Baroda, Andhra University and IIRS.

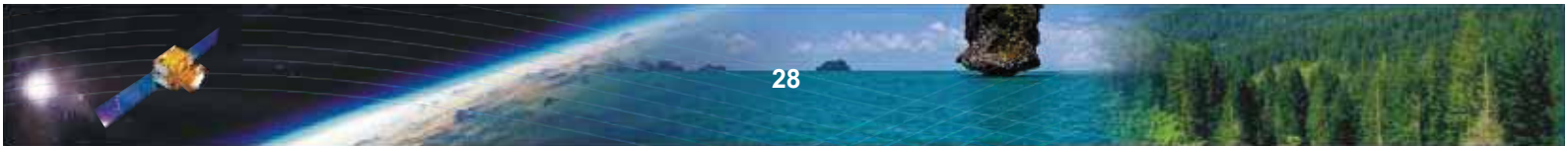
The course comprised of lectures, hands-on and field visit. The broad topics covered in lectures were: Basics of RS, GIS and GNSS; Forest type and density mapping using various methods. Hands-on excercises were carried out on vegetation classification, terrain analysis, and spatial analysis. One field visit was carried out in Mussoorie forest division.

Workshop Cum training programme on Coastal & Ocean Management

IIRS organized a special workshop cum training programme on "Coastal & Ocean Management" during January 28, 2019 - February 1, 2019. The Workshop was designed for professionals and specialists from university, educational institutes, operational & research institutes and JRFs/SRFs/ students in Marine Science, Earth Science, Oceanography, Fisheries, Environmental Science and related fields. A total of 51 applications were received and 36 participants were selected to attend the programme. However, finally 31 participants reported to undergo the training programme. The aim of the programme was to provide participants an understanding of the scientific concepts associated with coastal and marine ecosystems, coupled with a practical knowledge of marine management. The major topics covered in the programme are: Earth observations for coastal and ocean management; remote sensing perspectives of Indian coastal zones; Coastal hazards and disaster monitoring using satellite data; applications of RS & GIS for coastal zone study; atmospheric correction for ocean color data; bio-optical algorithm for ocean color retrieval; potential fishing zones: a future perspective; operational oceanography; in-situ observations for coastal and ocean studies and recent developments in Indian coastal zone management.

One-Day Workshop on IRNSS and GNSS based observations for Crustal Deformation, Weather and Soil moisture studies

A one-day workshop on 'IRNSS and GNSS based observations for Crustal Deformation, Weather and Soil moisture studies' as a part of IIRS User Interaction Meet, 2019 (March 14-15, 2019) was organized by IIRS. This was the second workshop of this year, related to ongoing EOAM project on Himalayan geodynamics under IIRS`s Mountain Ecosystem project. There were 342 participants including EDUAST Distance Learning Programme coordinators from all over India. The delegates were from IIT Roorkee, IIT Bombay, Kumaun University, Kurukshetra University, HNBG University, BHU, JNU, Punjab University, USAC, WIHG, IIT-ISM Dhanbad, DIT, SDMC-Uttarakhand and included speakers from National Centre for Seismology, MoES, SAC, Ahmedabad, ISRO HQ and IIRS. The broad themes were Overview on IRNSS system, opportunities and future plans, IRNSS data processing, data quality and application potentials, etc. There were deliberations, exchange of ideas and brainstorming discussions by technology experts and application scientists to harness the true benefits of this unique technology. The workshop was concluded with recommendation for future R&D and collaborative initiatives in the related field.



One Day Workshop on Applications of Satellite Altimetry for Inland Waterbodies

- In total, 145 participant registered and attended this workshop at IIRS Dehradun
- A live telecast of workshop proceedings was also done EDUSAT Channel at YouTube
- The importance of altimeter for river water level and flow estimation was highlighted.
- The integration of altimetry and other satellite based water level in reservoirs sedimentation and flood modelling studies were emphasised
- Five lecture and one practical demo sessions were conducted during the workshop.

Application of Remote Sensing, GIS and GNSS for Disaster Management

The course, as requested by Disaster Management and Mitigation, Government of Uttarakhand, was conducted from 30 Oct, 2018 to 2 Nov, 2018 for the Decision Makers. A total of 13 participants participated from Different departments of Government of Uttarakhand. The course had a healthy mix of theory lectures in the morning followed by practical / hands on / demonstrations in the afternoon sessions. With initial two classes on basics of Remote Sensing, GIS & GNSS, the subsequent classes were on use of the technology for Disaster Management for the different types of hazards such as floods, forest fires, earthquakes and landslides. The practical / hands on session comprised "Familiarization with remote Sensing data"; "Using RS Data for flood and landslide monitoring"; "Using RS data for forest fire damage assessment and atmospheric hazards"; "Hands-on with bhuvan and web-portals" and "Demo: Fire reporting mobile app".

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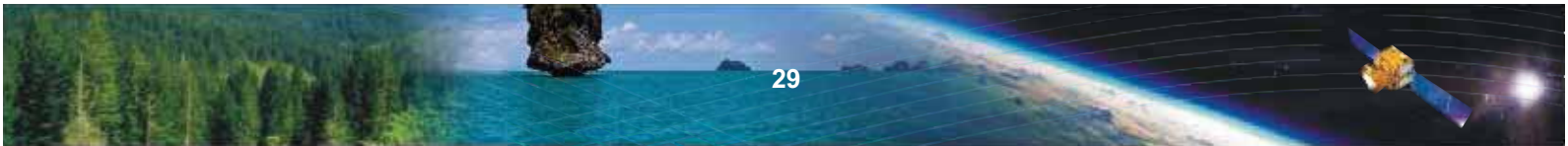


OUTREACH ACTIVITIES

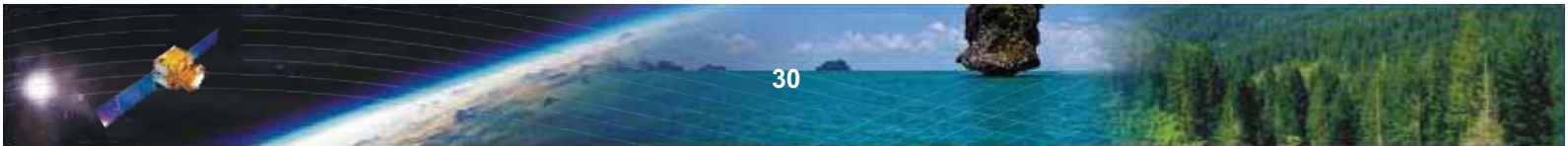
The IIRS Outreach programme was initiated in year 2007 with network of 12 universities in the country. The major objective of this programme is strengthening academia and user segment in space technology & its applications using online learning platforms. During last decade, the academic interface of IIRS has substantially increased. The programme also attracts young generation to build their career in the area of space science and its applications. Under IIRS outreach programme more than 89,000 participants from 890+ networked institutions in the country have been trained in last 11 years. In the year 2018, 174 new institutes were added into IIRS Outreach network. Till December 2018, IIRS has successfully conducted 40 outreach programs through live and interactive classrooms (also known as EDUSAT programme) and also launched five online courses under its e-learning initiatives. The present outreach programme is being conducted through following two major modes:

- Live and Interactive classroom Programmes
- E-learning based online courses.

Live and Interactive classroom Programmes

Every year, IIRS conducts various online programmes under its outreach activities. During 2018, IIRS has conducted ten online live & interactive courses and four online workshops. The status of total benefiting participants is given below :

Course Category	Course Title	Duration	No. of participants	No. of participating universities
Long Duration	Advanced Appearance Analysis	2 Weeks	1019	169
Long Duration	Geospatial Inputs for Enabling Master Plan Formulation under AMRUT Sub-scheme	2 Weeks	1491	193
Short Duration	Advanced Geospatial Modelling tools & techniques	1 week	1232	189
Long Duration	Basics of Remote Sensing, Geographical Information System and Global Navigation Satellite System	13 Weeks	5630	368
Long Duration	Remote Sensing and Digital Image Analysis	4 Weeks	3423	300
Long Duration	Global Navigation Satellite System and Geographical Information System	6 Weeks	1883	214
Long Duration	RS & GIS Applications	3 Weeks	1464	187
Short Duration	Satellite Remote Sensing in Agrometrological Applications	1 Week	975	162



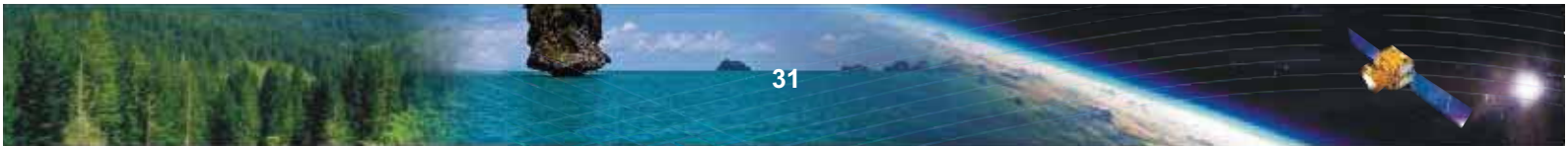
Workshop	Hydrometrological Disaster Management	1 day	1097	165
Workshop	Geo Spatial Technologies and Sendai framework for Disaster Risk Reduction	1 day	1748	174
Workshop	Crowd Sourcing and Participatory GIS	1 day	552	135
Short Duration	Geosptial Modeling for Watershed Management	1 Week	1115	184
Short Duration	Geoinformatics for forest fire management	1 Week	1667	176
Long Duration	RS & GIS applications in Water Resources	2 Week	1700	204

E-learning based online courses

To expand the outreach of geo-spatial science and technology, IIRS has developed e-learning contents and Learning Management Systems (LMS) for various certificate courses in Remote Sensing and geo-spatial technology. The e-learning courses are interactive, learner centric are self-paced. The course content is designed to include the latest developments and trends in geo-spatial science and technologies with specific focus on Indian case studies for geo-spatial applications. The learning is made available through interactive 2D and 3D animations, audio and video for lecture and practical demonstrations. The e-learning contents are created as interactive multimedia application and integrated with customized LMS based on Moodle. IIRS e-learning initiatives targets professionals, academia and research community to enhance their knowledge in Remote Sensing and Geo-spatial technology. The learners are spending 32 to 102 learning hours per course including participation in online activities like quiz, assessments, projects and online practical exercises. The expert faculty are also available for live interaction with participants. The most attractive part of these online courses is "learning anytime from anywhere". The learners can join the course any time and can complete the course at their own pace. All the courses are available in English as well as Hindi.

Subject	**e-learning hours**	
	Theory	**Practical**
Image Statistics	3	2
Basic Remote Sensing	19	3
Photogrammetry and Cartography	12	2
Digital Image Processing	14	7
Geographical Information System	19	7
Global Navigation Satellite System	4	2
Customization of Geospatial Tools	3	5
Applications of Geospatial Technologies-Theory	4	-

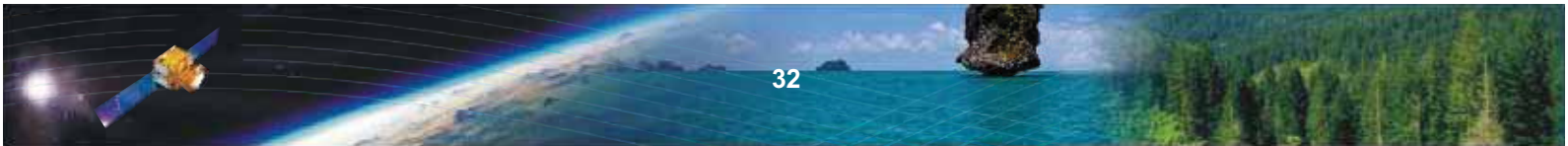
In year 2018-19, the eLearning content for eight thematic disciplines demonstrating Application of Geospatial technology is being prepared. A total of 80 hour content is under preparation. Once completed, the new eLearning course focusing on Application of Geospatial technology in various thematic areas will also be launched.



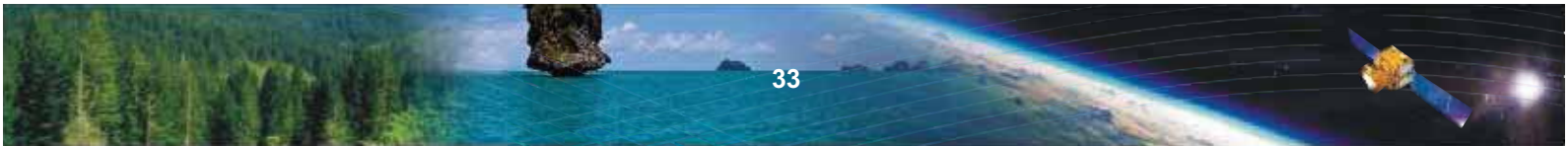
RESEARCH ACTIVITIES AND ACHIEVEMENTS

Research is an integral part of IIRS capacity building activities. IIRS is significantly contributing towards research and operational programmes of ISRO, and in the process, has maintained an interface with other ISRO Centres. IIRS is recognised as a Research Centre for carrying out Ph.D. level research by several universities, viz. IIT Roorkee, Pune University, FRI (Deemed) University, Dehradun, HNB Garhwal University, Gurukul Kangri University and Kumaun University. The major ISRO's research programmes / projects in which IIRS have participated and initiated major research projects are discussed in this section.

Earth Observation and Applications Mission
1. Mapping, Modeling and Impact Assessment of Land Subsidence in Northern India: Monitoring and Assessment of Mountain Ecosystem Services & Processes in North Western Himalaya (NWH)
2.1 Sub-Theme-2.1 : Geodynamics and Seismicity Investigations in Northwest Himalaya
2.2 Sub-Theme-2.2 : Vulnerability of Mountain Ecosystem to climate change: Ecosystem Structure and Function
2.3 (a) Sub-Theme-2.3A: Sustainable Mountain Agriculture- Climate change impact on productivity of food grains and plantation crops
2.3 (b) Sub-Theme-2.3B: Sustainable Mountain Agriculture-Assessing Soil Erosion and Nutrient Loss and its impact on Soil Quality and Crop Productivity
2.4 Sub-Theme-2.4: Water Resources Status & Availability in North West Himalayas
2.5 Sub-Theme-2.5: Modelling temporal and spatial pattern of North Western Himalayan cities
2.6 Sub-Theme-2.6: Rainfall Retrieval Using MW RS Data & Study of Extreme Rainfall Events
3. Development of spectral library and reflectance spectroscopy for mineral exploration in parts of mineral rich belts in Rajasthan and Odisha
4. Thermal anomaly detection and monitoring of coal fire in the Gondwana Coalfields of India using time-series coarse resolution multispectral TIR data and impact analysis
5. Ensemble hydrological modelling approach for integrated water balance studies for dynamic water resources assessment in geospatial environment for Indian River basins.
6. Urban micro-climatic zoning for sustainable smart city planning of Indian cities using geospatial technologies
7. Development of framework for processing ROV's Video data and validation of bathymetry from EO sensor
8. Multisensor integration for digital recording, reconstruction and realistic 3D Modeling of UNESCO World heritage sites in Northern India.



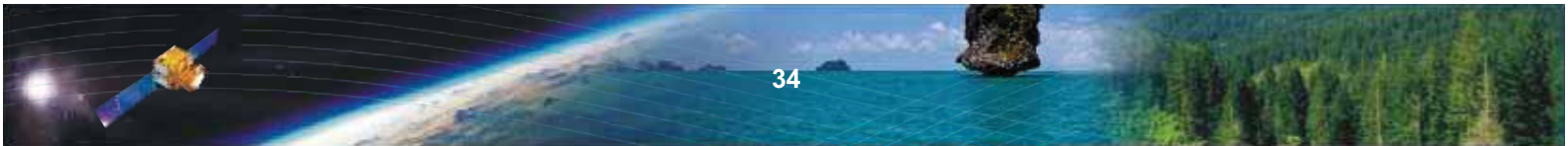
ISRO - Geosphere Biosphere Programme (Climate and Atmospheric Programme)
09. CAP: Aerosol Radiative Forcing over India(ARFI)
10. IGBP: IIRS-NCP - Soil Vegetation Atmosphere Fluxes
11. IGBP: Study of Air pollutants over the Indian subcontinent: Investigation of Source Regions Aerosol Optical Depth at 490 nm over land from Oceansat-2 (Oceansat-2 Project)
Disaster Management Support
12. Rainfall Threshold Modelling and DInSAR based Landslide movement Detection and Modelling
13. Remote sensing, ground observations and integrated modeling based early warning system for climatic extremes of North West Himalayan region.
L&S BAND AIRBORNE SAR & NISAR (RA)
14. Snow physical parameter retrieval and glacier dynamics study using L & S band Air SAR data and assimilation in snow / glacier models
15. Assessment of forest disturbance & biomass using airborne SAR polarimetry
16. Use of multi frequency Polarimetry SAR data for retrieval of crop biophysical parameter and soil moisture under variety of agricultural heterogeneties
17. Soil moisture retrieval and irrigated area mapping using L&S band air SAR band AIR-SAR data and data Assimilation in land surface models.
18. Dark Spot detection for characterization of marine surface slicks using PolSAR remote sensing
19. Generation & validation of DEMs and feature extraction using SAR & Radargrammetry data from L&S band Airborne SAR
20. Flood mapping & river morphological study using L&S band Air SAR data and data assimilation in hydrodynamic models
21. Polarimetric SAR calibration of L- and S-band PolSAR data for scattering information retrieval of Manmade and Natural Features
22. Crop monitoring and biophysical parameters studies using combined S and L- band data (NISAR project).
23. Assessment of forest disturbance and biomass using airborne SAR polarimetry
SCATSAT-Utilisation Programme
24. Algorithm development for Snow Water Equivalent (SWE) Retrieval in North West Himalaya and wind fields at polar Marginal Ice Zones (MIZs) using Ku-band SCATSAT-1 scatterometer and RISAT-1 SAR data. In-house R&Ds
In-House R&Ds
25. Application of GPR in assessing root biomass of Poplar (Populus deltoids) in agro forestry system in Northern India
26. Study of Stress and Strain distribution using GNSS and Correlation with Seismic Activity in Uttarakhand and Himachal Pradesh
27. Study of Trace Gases Over Dehradun: Role of Chemical and Dynamical Processes on the Distribution of Ozone and its Precursors
28. Urban Air Quality Assessment Using Geospatial Techniques
29. Deformation Monitoring of Land Subsidence due to Underground coal mining by Advanced DInSAR Techniques



30. Comparative study for assessment of consumptive water use for cropland using multisensor data
31. Forest Fire spread Modelling and damage assessment in fire prone regions of Uttarakhand
32. Assessment of potential vulnerability of western Himalayan glaciers to climate change
33. Analysis of sediment dynamics in the Godavari River Estuarine region
34. Urban canopy parameters computation using 3D databases in GIS: A comparative evaluation of Urban areas in varied climate zones
35. Integration of Optical and SAR data for Land use / Land cover classification
36. Evaluation and methodology development for short, medium and long term hydrologic (snow/glacier melt, soil moisture and rainfall-runoff) forecast in selected river basins in NWH.
37. Flood-prone Areas Identification and Flood Risk Assessment using Integrated Process based Modelling and Geospatial Techniques
38. Polarimetric SAR Calibration of PolSAR Data
39. Development of Geospatial Data Cube
40. Development of virtual lab for simulating field and lab experiments for capacity building in RS& GIS
41. Shadow based approach for urban feature extraction from multi-temporal, high resolution images
42. Digital soil mapping using environmental covariates for mountainous region

OTHER PROJECTS

43. Biodiversity Characterization at Community Level
44. Indian Bioresource Information Network (IBIN)

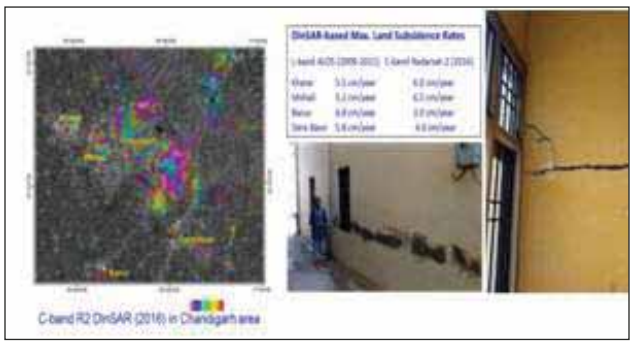


Mapping, Modeling and Impact Assessment of Land Subsidence in Northern India

This project under EOAM programme of ISRO aims to study groundwater depletion in Northern India, groundwater depletion induced land subsidence and predictive modelling of aquifer-system compaction.

Study area: On regional scale, five major drainage basins of NW India including the states of Delhi, Haryana, Chandigarh, Rajasthan, U.P., M.P., Gujarat, Uttarakhand, part of Punjab, H.P. and Maharashtra. On large scale, the major cities of NW India with records of significant groundwater depletion such as Delhi, Chandigarh and Mehsana.
Significant results achieved:

- Groundwater depletion hotspots in NW India have been identified. Space-borne GRACE gravity anomaly based groundwater storage change has been assessed and compared with GWL based groundwater storage change.
- By differential interferometric SAR analysis of selective groundwater depletion hotspots in NW India, land subsidence affected areas were identified in Delhi-Gurgaon, Chandigarh-Mohali and Mehsana (Gujarat).
- Validation by DGNSS and Precision Levelling surveys have been ongoing. DGNSS survey has been ongoing for Delhi-Gurgaon and Chandigarh-Mohali test sites since 2016. Validation for limited period has been done. Precision levelling has been ongoing in Delhi-Gurgaon & Chandigarh-Mohali test sites since 2016 by Geodetic & Research Branch, SoI.
- Groundwater depletion based predictive aquifer system compaction has been assessed in Delhi and Chandigarh-Mohali test sites. The same exercise is ongoing for Mehsana test site. Validation by sub-surface instrument based observations have been ongoing for Delhi and Chandigarh test sites in collaboration with Central Ground Water Board (CGWB).

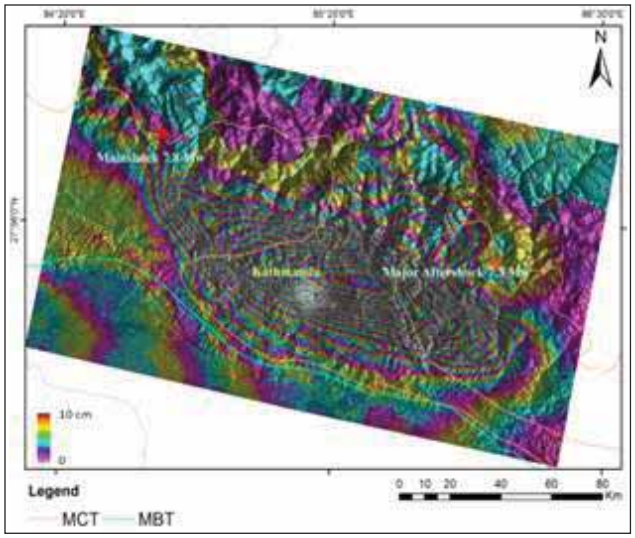


Spaceborne DInSAR based groundwater depletion induced land subsidence affected areas and impacts of land subsidence in and around Mohali-Chandigarh area of NW India.

Geodynamics and Seismicity in Western Himalaya

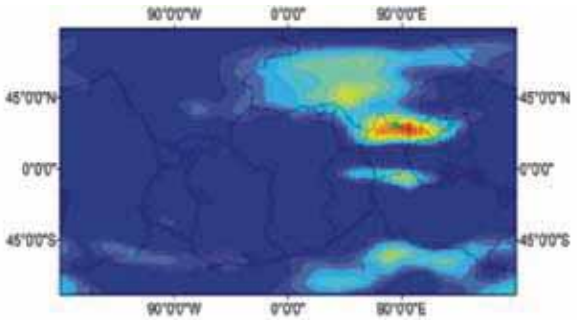
This study was carried out under EOAM programme of ISRO in collaboration WIHG, Dehradun and ARIES, Nainital with main objectives of 1) deformation monitoring using GNSS, DInSAR and ScanSAR interferometry; 2) Earthquake precursor studies; 3) Active fault mapping using high resolution EO data, geophysical investigation and trenching in selected sectors around MCT, MBT and HFT.

Progress: Fourteen GNSS/CORS are operational and two more in progress (with IRNSS capability) in UK and Himachal Himalaya; and data from CORS (ISRO and WIHG), Global IGS and 25+ campaign stations analysed to reveal precise plate motion of Indian and surrounding plates, and across Himalaya. Two more seismic stations are under installation including one set up for detection of early arrival of P-waves in IIRS campus. Innovative TEC analysis of 45+ EQ events have confirmed precursory signals. Active fault mapping, geophysical investigation and trenching revealed new characteristics of faults. SAR data analysis across three transacts in Himalaya and in Nepal has revealed long-term and co-seismic deformation. Global and local ionospheric perturbations show very good results for Nepal



Co-seismic deformation of Nepal Earthquake revealed by differential interferometry using Radarsat-2 C-band data (West pair acquired on April 12th and May 6th, 2015) and (East pair acquired on April 05th and April 29th, 2015). Maximum Line of Sight (LOS) land surface displacement is around 170 cm (approx.)

Crustal Movement: Velocities across 4 Plates including Indian Plate by using IGS (GNSS) Stations along with GNSS CORS of IIRS/ISRO.



Global ionosphere map data modelled from GNSS observations shows spatial anomaly/perturbations 14 days prior to Nepal earthquake on 25th April 2015

GNSS (IRNSS) CORS and Seismic stations of IIRS/ ISRO in western Himalaya for the study of geodynamics and seismicity.

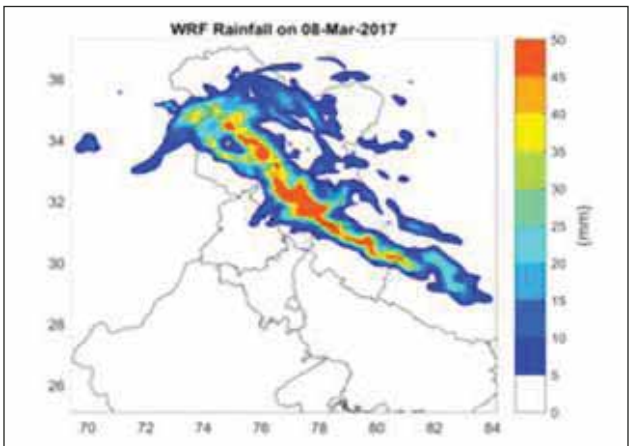
earthquake 2015 and other global earthquakes using GIM and GNSS data.

Future plans (Phase-II): Densification of CORS network in J&K and Sikkim (3 GNSS in each state) in 2019-21 with IRNSS capability and 4 VLF receivers (one each in J&K, HP, UK and Sikkim) will be installed to analyse real time ionospheric perturbations using a new methodology, S-MAPS (Space based multi-parametric approach for earthquake precursor studies).

Rainfall Retrieval Using Remotely Sensed Data and Study of Extreme Rainfall Events over NWH Region

Northern parts of India receive rainfall in the winter season (December to March) mainly due to the Western Disturbances (WD). WDs are associated with heavy precipitation in North Western Himalaya (NWH) usually in the form of snow which triggers landslides and avalanches. Therefore, accurate prognosis of WD is vital for the Himalayan region. In the present study, one month simulation from 1st to 31st of March, 2017 was carried out using the Weather Research and Forecasting (WRF) model to assess its capability to simulate WD over the North Western Himalaya. The results show that temporal evolution of WD pattern for NWH region during one month are nicely captured

by the model simulation. The first WD (7 - 11 March) extended from western Jammu and Kashmir (J&K) to Uttarakhand (shown in figure), covering most of Himachal Pradesh (HP) and further moved eastward towards Nepal and eventually dissipated. The second WD (21-22 March) was observed over North Pakistan, western J&K along with some parts of HP and the third WD (28-31 March) occurred over J&K only. This corroborates spatially as well as temporally with the IMD reports. Validation of daily accumulated rainfall from the model is also carried out using high resolution GPM IMERG satellite dataset. The amount of rainfall in higher Himalayan region accompanying the WDs is over-estimated but was able to capture the spatial structure fairly well. The study therefore reveals that high resolution mesoscale model can simulate the weather associated with WD with reasonable accuracy well in advance.



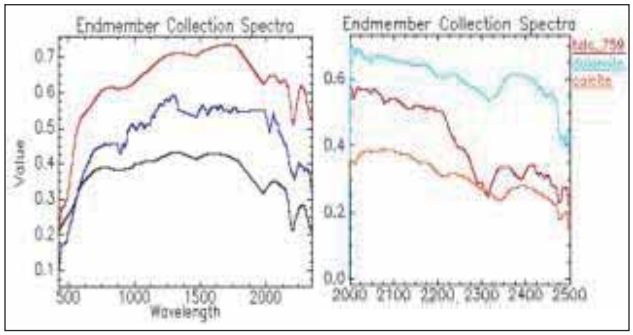
Statistics	Value (ideal value)
Hit Rate (HR)	0.95 (1)
False Alarm Rate (FAR)	0.39 (0)
Frequency Bias Index (FBI)	1.55 (1)
Accuracy	0.63(1)
Critical Success Index (CSI)	0.59 (1)

The Western Disturbance simulated by WRF on 8th March 2017 over Jammu and Kashmir, Himachal Pradesh and Uttarakhand and the lable specifies the categorical statistics associated with the event.

Development of Spectral Library and Imaging Spectroscopy for Mineral Exploration in Parts of Rajasthan and Odisha

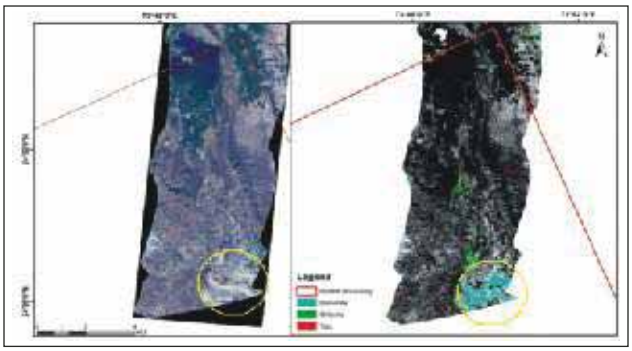
This project under EOAM programme of ISRO was carried out with main objectives of (1) field and laboratory spectra collection for rocks, minerals; (2) hyperspectral image analysis for mineral identification, abundance mapping and lithological characterization and (3) comparative evaluation of air-borne and space-borne data for mineral mapping and rock type discrimination.

Salient findings/ Outputs: (1) Development of complete spectral library: Delhi-Aravalli: Udaipur area (Bhukia-Dagocha), Salumber-Umra, Alwar (MudiyawasKhera); Singhbhum, (Kiriburu-Mehgahatuburu-Malangtoli) of ore, host rock and path finders, complimented by XRD and ICP-MS analysis; (2) Mineral abundance/ target maps (Space-borne and airborne) and metallogeneis: Target maps at different scales completed for Umra Bhukia, Alwar and Kiriburu; Base metals mostly by hydrothermally altered VE/VMS and supergene enrichment. Aid to mineral exploration: Unexplored but potentially enriched Cu-mineralization at south of Khera, Alwar basin based on litho-structural control/ altered minerals; Exploratory drilling locations given to GSI for Umra region based on mineral target maps,



Red, Blue & Black spectra represents USGS library, image, and field spectra of montmorillonite respectively in the range of 500 to 2500 nm (right); Spectral plot generated by AVIRIS image for calcite, dolomite and talc in the range of 2-2.5 nm (left)

Spectra collection in field from Joda Mines, Odisha andMatun Mines, Rajasthan using ASD Field Spec4 Spectro-radiometer (0.5-2.5 micro meters).



The image shows true colour composite (left) and classified (right) AVIRIS NG image of Umra area, Rajasthan. The encircled Jhamarkotra mine shows the presence of dolomite in the classified image, as the host rock for rock phosphate mineralization is stromatoliticdolostone.

Cu and Au areas were identified and verified in field. The 6 out of 8 drilling locations from RS data have proven to give signatures of mineralization zone in Udaipur and Alwar region; Interim report prepared.

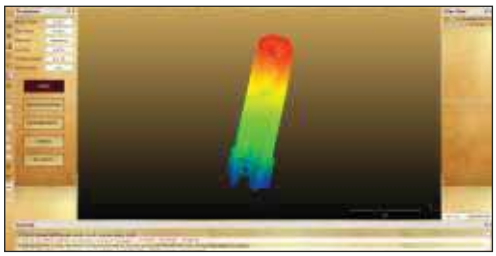
Multisensor Integration for Digital Recording, Reconstruction and Realistic 3D Modelling of Unesco World Heritage Sites in Northern India

The main focus of the study is to improve the classical method of heritage recording and documentation and utilize geospatial technology for digital documentation of cultural sites. It attemps the integration of multi-source/multi-platform (Terrestrial Laser Scanner-TLS, Terrestrial camera, UAV images and high resolution EO data) data for improved 3D documentation of built heritage sites. A comprehensive (internal and external) multi-scale documentation of heritage monuments is attempted, which would enable hierarchical database generation, digital blue printing and damage detection at very high resolution.

A Prototype framework for damage detection using point clouds and multi-scale representation for assessment and reconstruction has been designed. For this purpose a customised application tool, DHAROHAR (Digital Health Assessment from Range and Optical data for Heritage and Architectural Resources) for TLS data registration, unrolling and rasterization at different scales and multi-scale data storage and retrieval has been developed.

Main Page

Project Management



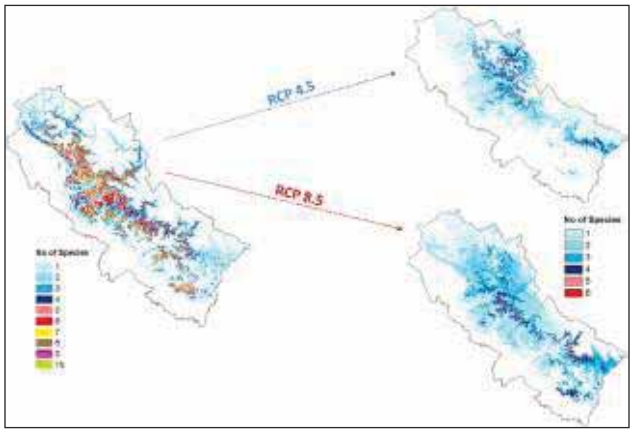
Laser data visualization

Vulnerability of Mountain Ecosystem to Climate Change: Ecosystem Structure and Function

The main objective of the project is to assess the vulnerability of the fragile mountain ecosystems in terms of ecosystem structure (Biodiversity, vegetation types, contiguity) and functioning (nutrient dynamics, carbon stock and flow, phenology) in face of global change which included: Impact of Global Change on Species Composition in Himalayas; Quantification of Ecosystem Processes; Impact of Global Change on tree line ecotone of Himalayan region & Establishment of Long Term Ecological Research Sites (LTERS).

Results show a considerable loss in the suitable climatic envelopes for majority of the species studied. Projected climate change under IPCC AR5 may result in considerable changes in species population. size and distributions. Decrease in number of species in species associations expected under climate change in western Himalaya. Newer species associations expected to arise in higher altitudes. Critical patches based on connectivity in the landscape for conservation identified. The changes in the species range and association due to projected climate change is shown below:

Index for Nitrogen for crown, soil and litter is established. Nitrogen distribution between crown, litter and soil in Pine, Oak, Himalayan moist temperate forests and Alpine medows (Above ground, Soil and Litter) is estimated in western Himalaya. Four (4) Long term Ecological Research Stations (LTERS) have been established with level 1 instrumentation.



Change in the species association due to climate change

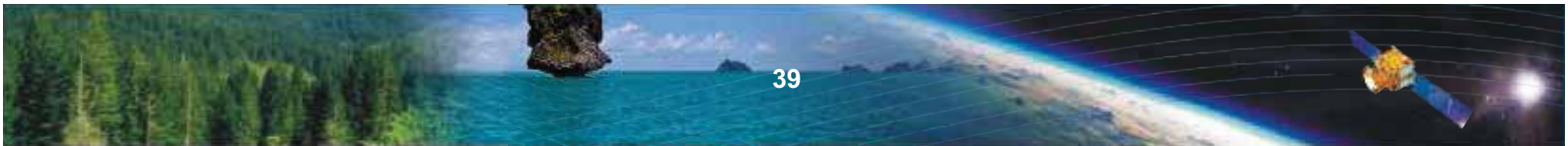
Vegetation-Atmosphere Flux: National Carbon Project

Information on CO_2, H_2O & energy fluxes of ecosystems is the key for understanding their functioning, persistence and role in climate change mitigation. The specific objectives of this project are: measurement of carbon flux between vegetation and atmosphere to assess the net sink-source nature of the terrestrial ecosystem, and integration of in-situ observations and RS-based modelling for up-scaling of net carbon balance. Two flux towers have been set up for this purpose. One is in a tropical moist deciduous forest in Barkot and the other is in a mixed plantation site in Haldwani.

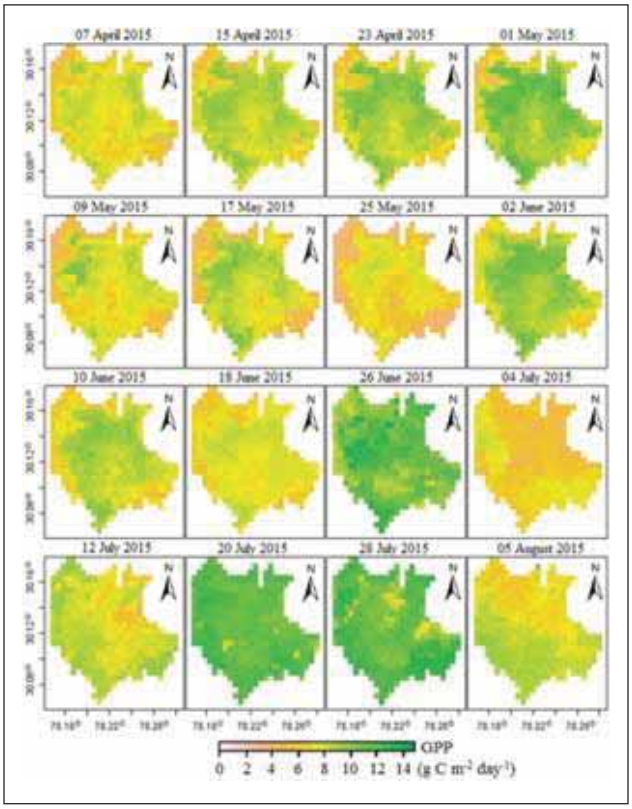
Productivity, carbon budget, eco-physiology and water use efficiency of these two ecosystems have been studied. Sal forest productivity estimates were successfully improved with RS based Light Use Efficiency (LUE) and ecosystem process models.

The study evaluated the combined use of eddy covariance (EC) data and satellite-derived variables for estimating GPP over large areas using various modelling approaches. EC observed 8-day average GPP varied from 5.38 to 12.42 $gCm^{-2}day^{-1}$. Among the studied models, the closest GPP estimate was given by LUE model.

The intra-annual variability of Net Ecosystem Exchange (NEE) of CO_2 in sal (*Shorea robusta*) forest of Uttarakhand was also studied by integrating EC data and Biome-Biogeochemical Cycle (Biome-BGC) model. Biome-BGC model output showed that the sal forest of the study area acted as a net sink of carbon in almost all months of 2015, except



April-June. Annual NEE of sal forest in 2015 was found to be -526.87g Cm-2year^{-1}. With the start of season (end of June), sal forest showed an increasing trend in NEE while decreasing trend was observed at the end of season (end of October). In addition to that, leaf area index (LAI) and light extinction coefficient (k) were mapped by integrating remote sensing imagery and field data using machine learning algorithm. The performance of PROSAIL radiative transfer model for retrieving the LAI of tropical deciduous forest plantation were also assessed.



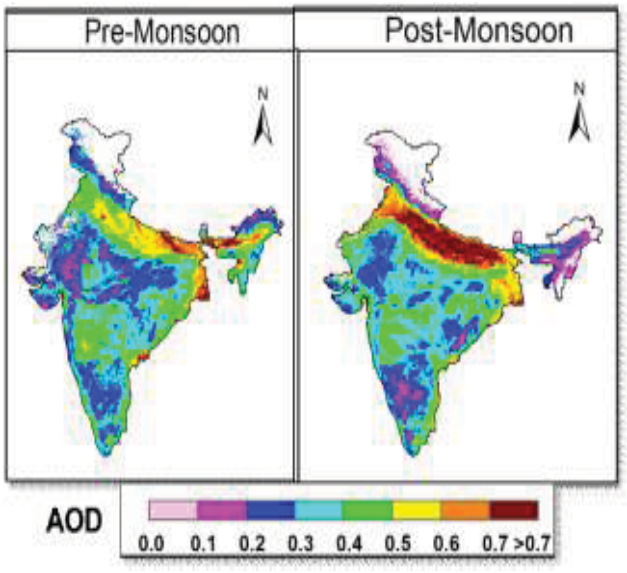
Spatio-temporal distribution of GPP using LUE model

Aerosol Characteristics and Radiative Forcing Over Northwest Himalayas

A long-term measurements of aerosols using ground instruments and satellite observations over Dehradun and surrounding regions are being carried out at IIRS. This also contributes to the regional and national repository of aerosol database.

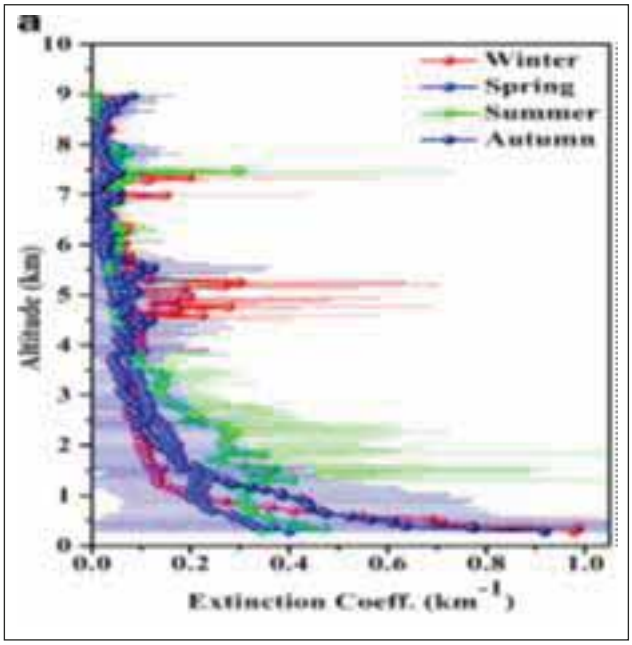
Figure shows the seasonal average climatological distribution of Aerosol Optical Depth (AOD) over Indian region based on 17 year Aqua MODIS observations during pre-monsoon (PrM) and post-monsoon (PoM) seasons. Northern India experiences several local-level convections during pre-monsoon season and produce a wide range of dust particles which are responsible for moderate to high AOD (AOD500 ~ 0.2-0.6). By the end of the monsoon, aerosol concentration starts to rise to a peak during the PoM and winter, especially over IGP due to open agriculture waste burning occurring during this season. AOD500 are below 0.3 throughout India except IGP (AOD500>0.6). The occurrence of agricultural residue burning is reported during PoM season and adds up the column concentration of aerosol particles leading to increase in AOD.

Vertical profiles of aerosols are examined based on CALIPSO observations over Dehradun and surrounding regions and is shown in figure. During PoM and winter, extinction coefficients near the surface are high approaching to 0.9-1.0 km^{-1} at 0.532 µm. They decrease rapidly above 1-1.5 km and extinction coefficient value reaches below 0.1 km^{-1} at 3-3.5 km due to the low boundary-layer height

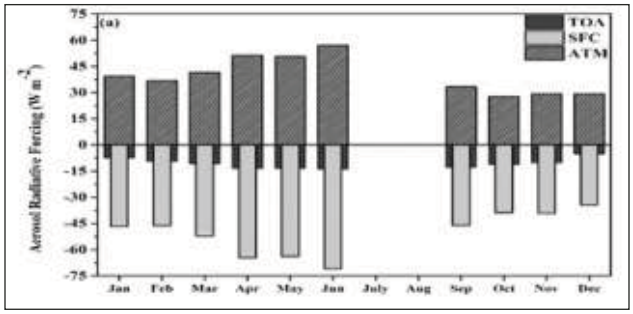


Seasonal distribution of MODIS AOD over Indian region during 2001-2017

over IGP and Himalayan foothills. During PrM, elevated aerosol layers of 0.25-0.4 km^{-1} are observed between 1.5 and 3 km, that constitute fingerprint of elevated transported dust plumes over the Himalayan region. These are all inputs to estimate the aerosol radiative forcing component.



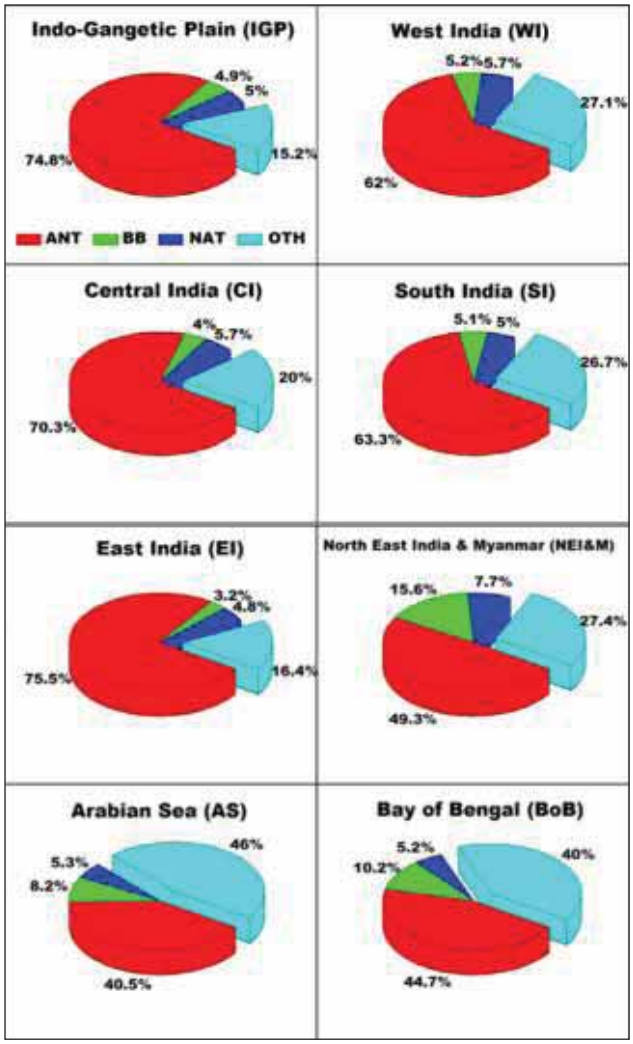
Seasonal-mean variations of the CALIPSO extinction coefficient at 0.532 μm over Dehradun during January 2007 to December 2017



Monthly variation Radiative forcing over Dehradun & surroundings during 2007-2017

Study of air pollutants over the Indian Subcontinent: Investigation of Source Region

The spatial and temporal variation of surface CO mixing ratio mainly depends on the strength of



Annual average relative contributions of different tracer (CO-ANT, CO-BIOG, CO-BIOM, CO-CHEM and CO-BACK) to the total CO over different geographical regions of India.

different man-made and natural sources. Therefore, it is important to quantify the contribution of these sources to total surface CO.

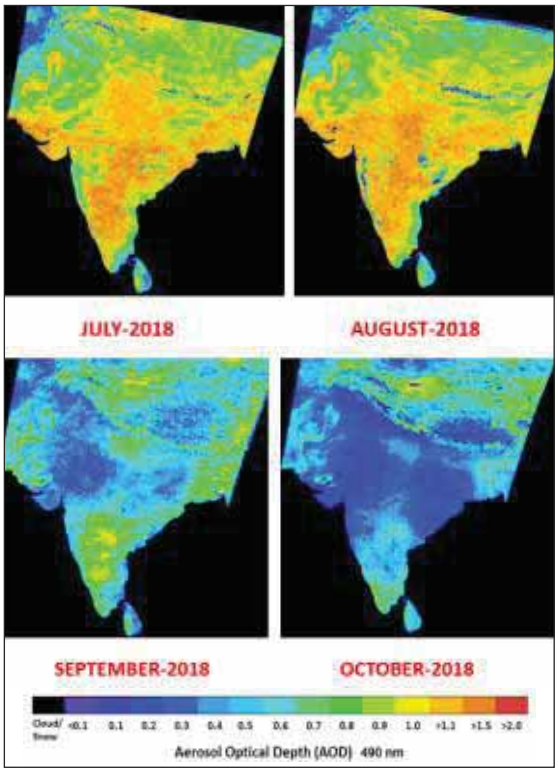
The contribution of these source regions are investigated using MOZART-4 (Model for Ozone And Related chemical Tracers version 4) global chemistry transport model. A number of synthetic CO tracers are included in MOZART to track the contribution of different sources like CO produced from the global anthropogenic emissions (ANT- CO), biomass burning emissions (BB-CO), CO originated from the biogenic and oceanic emissions which is combinedly represented as

natural CO (NAT-CO) and CO produced from oxidation of methane and non-methane hydrocarbons (OTH-CO). The simulation has been made for year 2008.

The relative contribution of different sources to the total CO over different Indian regions are depicted in the figure. The maximum contribution of ANT-CO is found over densely populated Eastern India (75.5%). BB-CO contribution is found to be highest (68.8±121.2 ppbv) over North East India and Myanmar region. Oxidation of methane and non-methane hydrocarbons (OTH-CO) is most important source of CO over marine regions. Role of natural CO is found to be negligible (< 10%) over all the geographical sectors of India.

Aerosol Optical Depth at 490 nm over Land from Oceansat-2

Studies of aerosol properties are important to climate change, including investigations of anthropogenic influences on climate (forcing), and air quality. Satellites are increasingly used to obtain information on aerosol properties (e.g., the Aerosol Optical Depth (AOD), the columnar concentration of particles, their sizes), taking advantage of technical and scientific developments.

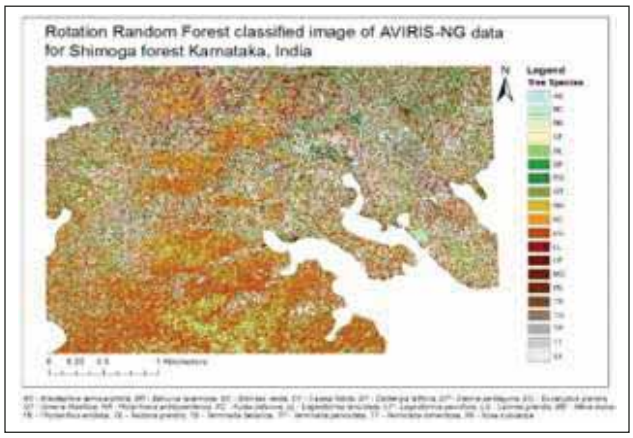


Monthly mean Aerosol Optical Depth (AOD) over land from Oceansat-2

The aerosol optical depth over ocean is easily retrieved using the NIR part of the electromagnetic spectrum in which the upwelling light emerging from the ocean is considered as negligible. However, the same approach cannot be implemented over land because of high reflectance in the NIR region. Presently the aerosol optical depth (AOD) is retrieved at 490 nm over land from Ocean Colour Monitor (OCM) sensor on board Oceansat-2. (see figure)

Tropical Tree Species and Richness Mapping in Shimoga, Karantaka using Airborne Hyerspectral Data

The information regarding tree species in tropical forest is of high priority for the effective forest management, conservation, utilization and policy development. This study made use of airborne imaging spectroscopy to map tropical tree species richness in Shimoga, Karnataka. Hyperspectral imagery with spectral variation ranging from wavelength 400-2500 nm acquired by the Airborne Visible and Infrared Imaging Spectrometer. Next Generation (AVIRIS-NG) on 1st January 2016, was analyzed to map the tree species of the tropical forest. A field survey has been conducted to collect the tree location data from the study area.



Tropical tree species map of Shimoga, Karnataka

A new method, PCA based rotation random forest (RoRF) was developed and used for mapping tree species. The results were compared with Random Forest (RF) classifier and Support Vector Machine (SVM). The performance of RoRF was found to be better than the other two classifiers. Therefore, using RoRF classifier, species richness was calculated and compared with the richness obtained from the field data. This study attempted to classify 20 tropical tree species of the study area including both rare and dominant species.

Assessing the Species Loss in Montane Temperate Forest and Alpine Vegetation in Western Himalaya

The work was carried out as part of the PhD research by a student. Ensemble distribution modelling was used using ensemble projected climate data from different Global Climate Models for modelling potential distributions of species based on their endemicity, dominance, current threat status, medicinal properties using BIOMOD2 package. To analyse the LULC change in western Himalaya in last 40 years, decadal LULC maps of different time periods - 1975, 1985, 1995, 2005 and 2015 were prepared based on visual interpretation of two season (pre-monsoon & post-monsoon) satellite images of medium spatial resolution at the scale of 1: 50,000. Logistic regression was used using nine explanatory variables to model the LULC map for the year 2055. For the validation of results for species distributions and LULC model, ROC/AUC curves were used.

Significant results include 1) When climate change and deforestation are combined, species may decline by at least 26% (RCP 4.5) and 35% (RCP 8.5) as compared with climate change scenarios only; 2) For most mid-elevation temperate species, regions with high projected climate change impacts overlap with regions of high projected land-use changes; 3) An eastwardly upward shift observed in all the species studied under each scenario of climate change and possibility of opening of new frontiers for these species to migrate and expand in the upper Himalaya with glacier retreat; 4) The loss of previous co-occurrences and the gain of novel co-occurrences are not balanced; 5) Urban areas (Built-up) have recorded highest growth as compared to any LULC class in western Himalaya with an increase of 184% from 1975 to 2015; 6) The future LULC projections indicate approximately 9% deforestation in the region by 2055 if the current rates of deforestation continues in the future; and 7) Patch parameter influences species diversity and high rates of fragmentation negatively impacts species diversity.

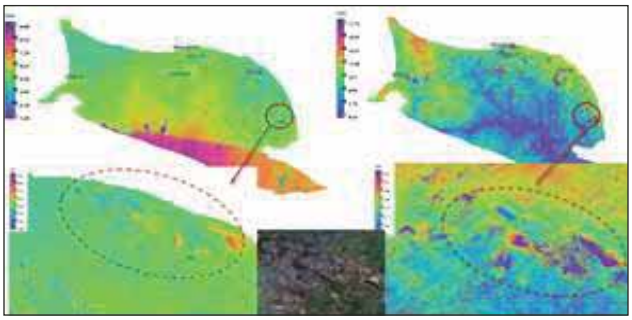
Projected shift in species mean elevation limits (m) under climate change scenarios

Deformation monitoring of land subsidence due to underground coal mining by advanced DInSAR Techniques

Surface deformation is very common phenomena in and around mining areas and spacebased SAR technique is one of the promising tool to monitor the land deformation. Monitoring of land subsidence is required to prevent further damage to the mine surrounding built-up areas and other vulnerable structures and landforms. This will further help for providing information for improved future mine layout designs and for subsidence mitigation. This study involves time series SAR data processing using C and L band datasets for monitoring land deformation using advanced Differential Interferometric Synthetic Aperture Radar (DInSAR) algorithm referred as

Persistent Scatterer (PS) InSAR technique. The advantage of using PSInSAR is that, it deals with both the decorrelation and atmospheric delay errors of conventional InSAR and provide the deformation history with subcentimeter accuracy. The study was carried out in one of the most popular and largest coal producing mining area of India i.e. Jharia coalfield, situated in Dhanbad, Jharkhand, India. The aim of this research is to present a cumulative displacement map using number of interferometric datasets and assess the geohazard activity in the study area. The data used in this study are Sentinel 1-A C-band (Aug. 2017 to Feb. 2018) and ALOS-2 PALSAR L-band (Oct. 2016 to Mar. 2019) to perform interferometric data processing and comparative analysis. The main objective of this project will be deformation monitoring and modelling for mining-induced land subsidence and its characterization using scatterer based advanced DInSAR technique.

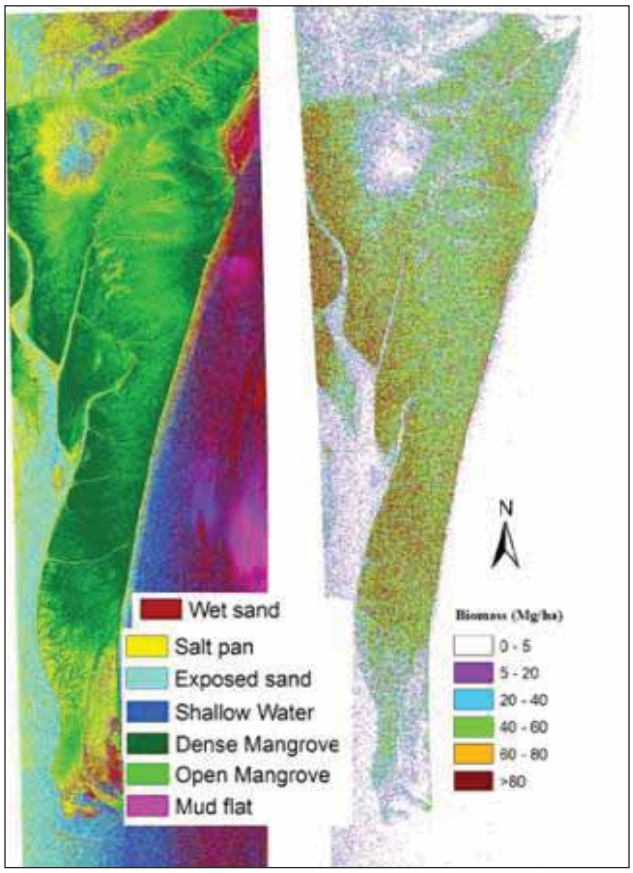
The highest rate of subsidence were observed in and around mining area and their surrounding settlements. The rate of land deformation observed was almost ± 30 mm/year in the Jharia coalfield mining area. The deformation fringes are much more clear and prominent and the subsidence were well detected in the cumulative displacement map obtained from L-band time series SAR data compared with C band data. Since PSInSAR approach is using time SAR data it can provide cumulative displacement map and rate of deformation is more accurate which is up to mm level. So, the adopted methodology can be used successfully for detection, mapping and monitoring of deformation history in the affected coal mining areas where the causes of subsidence due to mining. This approach will also help suitablity planning and designing of surface characterisation and other developmental structures in the mining areas and delinate future scene of mining. Information on the spatial extent of subsiding areas, rate of subsidence may help in identifying the areas deformed and in recommending probable mitigation measures for subsidence-induced hazards.



Vertical displacement map (cm) from Feb. 2018 differential interferogram using SENTINEL-1 & ALOS-2 data

Assessment of Coastal Vegetation, Gulf of Khambat, Gujrat using Airborne L & S band SAR data

As part of NISAR mission ecosystem science, airborne S & L band SAR information was collected in June, 2017 for mangrove ecosystem in Gulf of Khambat (GOK), Gujarat, India. It was found that the biomass estimated using S-band SAR better depicted the biomass compared to L-band SAR. The better performance of S-band SAR may be due to low satured and smaller diameter nature of

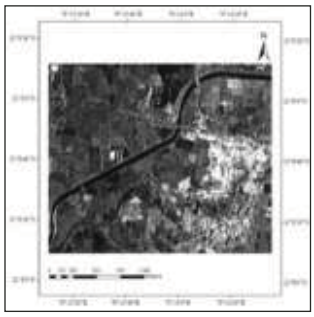


Land cover and Biomass map using S band SAR data

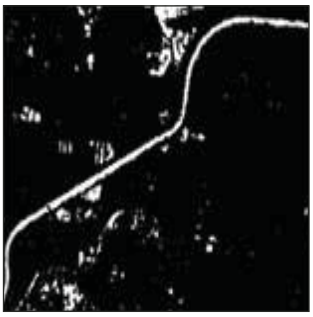
vegetation. L-band due to its longer wavelength must have less interacted with vegetation structure. Mangrove of GOK are mostly dominated by *Avicennia marina* (Forsk.) Vierh var. *acutissima* which are shrub and taller plant communities (e.g. *Rhizophora mucronata*) on the banks of rivers and fringes of the sea with typical height of 10 or 15 metres. Our study highlights the capability of airborne S-band SAR, to be deployed in NISAR mission, in capturing information of shrubs and small to medium size tree vegetation. Inability of L-band to capture information during our study was due to site condition. We believe L-band SAR of NISAR mission will prove to be an asset in monitoring of denser and woody forest vegetation.

Generation and Validation of DEMs and Feature Extraction using Radargrammetry and SAR Data from L&S Band Airborne SAR

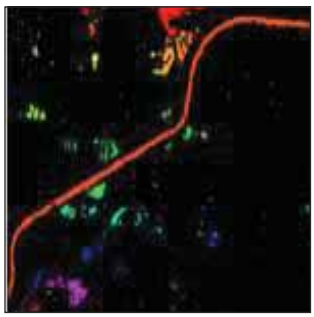
The project focuses on feature extraction from L band AirSAR flight data received under NISAR mission. Extraction of water body (canal) at Bardoli, Surat, Gujrat is achieved using CCA-based extraction together with the use of Otsu's method and morphological operators. Support Vector Machine (SVM) based classification is used to extract the built-up region, vegetation cover and fallow land from L-band (HH-Polarization) SAR image of Ahmedabad City, Gujrat.



Input image



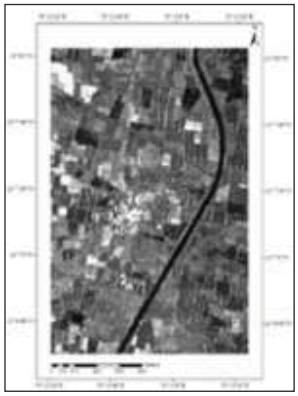
Morphologically operated image



CCA image

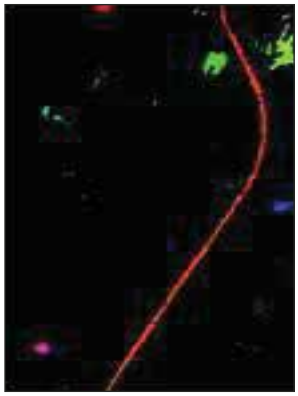
Extracted canal feature

Canal extraction for the input image of Bardoli area, Surat, Gujrat (Site 1)



Input image

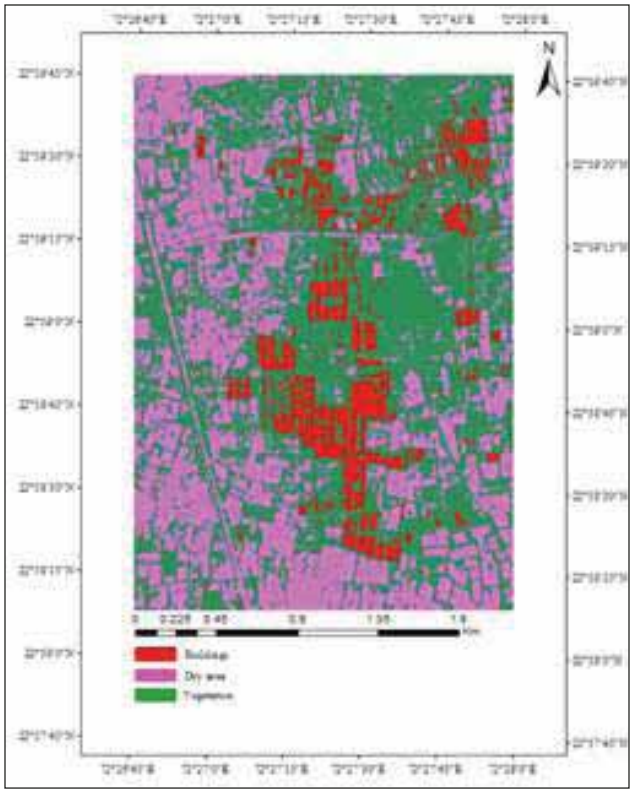
Morphologically operated image after Otsu's binarization



Connected component labelled image

Extracted canal feature superimposed on input image

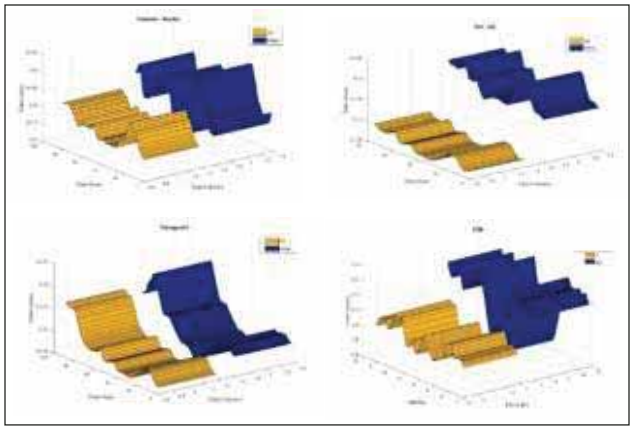
Canal extraction for the input image of Bardoli area, Surat, Gujrat (Site 2)



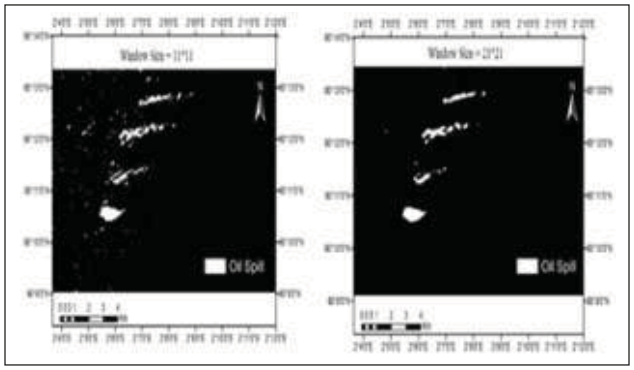
SVM classified outputs for building, dry area and vegetation cover

Dark Spot Detection for Characterization of Marine Surface Slicks using PolSAR Remote Sensing

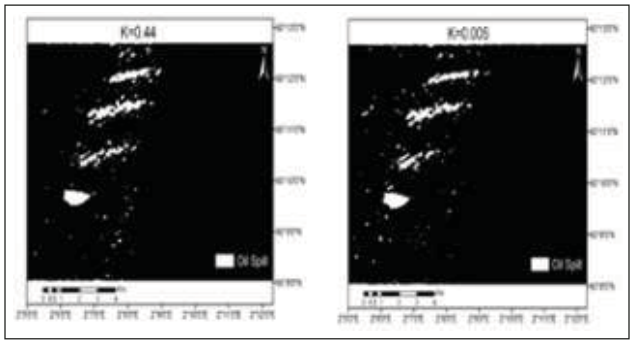
The dataset used in this study is UAVSAR quad-pol dataset and the area of interest is a part of an oil spill experiment named as the Norwegian Radar oil Spill Experiment (NORSE 2015) which was carried out in the North Sea on June 10th, 2015. The UAVSAR image has water and oil spill as scattering elements and to get respective backscattering responses, Freeman-Durden, Van-Zyl, Yamaguchi and MCSM decomposition techniques are applied. Among these decompositions, Van-Zyl decomposition gives the most suitable results as it distinguishes between the oil and water to a satisfactory level. Hence, Van-Zyl decomposition outputs are taken for further classification to extract oil spill patches. To do this, two kinds of classifications are used,



Separability Analysis of decompositions



SVM with K=0.44 and K=0.005



*WSM with window size 11*11 and 21*21*

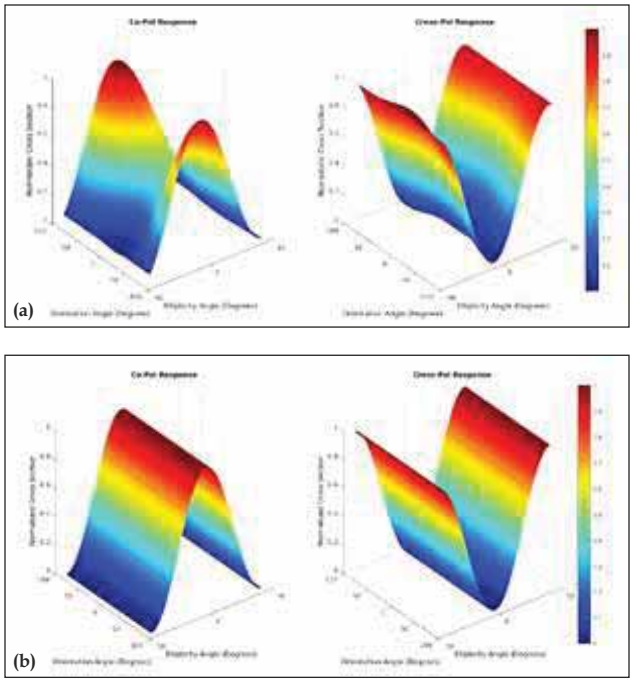
namely Wishart Supervised Classification (WSM) and Support Vector Machines (SVM). Wishart Supervised Classification with window size 21*21 provided an accuracy of approximately 83% without any postclassification analysis showing the supremacy of Wishart Supervised Classification over SVM.

Polarimetric SAR calibration of L- and S-band PolSAR data for Scattering Information Retrieval of Manmade and Natural Features

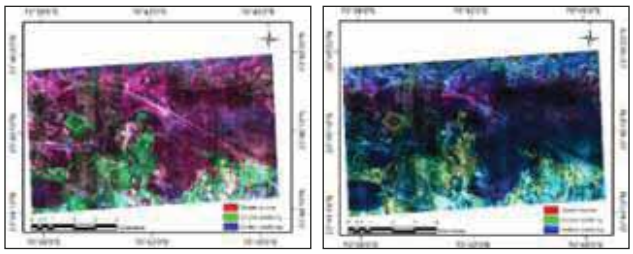
The PolSAR datasets have a wide range of applications but the polarimetric distortions in the polarimetric SAR datasets causes the Polarimetric decomposition and classification techniques to produce wrong outputs which result in misinterpreting the scattering phenomenon and the ground targets. This study evaluates the level of polarimetric distortions in Quad-pol and Compact-pol L & S abd AirSAR datasets and different methods of external polarimetric calibration to understand their potential in minimizing these polarimetric distortions. Special emphasis was given to analyze the impact of the polarimetric distortions on accurate ground target characterization before and after polarimetric calibration. The study area chosen for this study is the Desalpar, Rann of Kutch, Gujarat, where the corner reflectors were deployed.

Figures show the polarimetric signature of a Trihedral corner reflector and Cloude Compact-pol RGB composite generated from the compact-pol dataset before and after polarimetric calibration. It can be seen from the first figure that the polarimetric signatures of trihedral corner reflector exactly matches with ideal signatures after the calibration. Similarly, in the second figure barren lands show double bounce scattering (blue colour) and sparse vegetated regions showing over-estimation of volume scattering (dark green). But after calibration, the barren lands show surface scattering (blue colour) and sparse vegetation show mixture of volume and double bounce scattering (light green & yellow).

From this study, it is found that crosstalk affects the PolSAR datasets severly than the other polarimetric distortions and the polarimetric calibration should be considered as a compulsory preprocessing step for the PolSAR datasets before using them for the scientific applications.



Polarimetric Signatures of a Trihedral CR from Quad-pol dataset, before PolCal and after PolCal



Cloude Compact pol RGB image, before PolCal and after PolCal

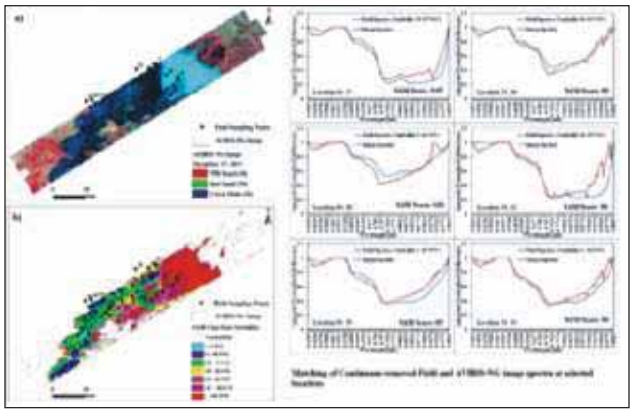
Study of Water Quality and Snow Parameters using Airborne Hyperspectral (AVIRIS-NG) Data

Water Quality Mapping

The water quality of Chilika Lake with regard to turbidity concentration has been studied using spectral similarity approach. A spectral library, specific to Chilika Lake water quality parameters, has been generated using sophisticated instruments (field spectro-radiometer, turbidity meter and hand held GPS). A very high similarity between the image

spectrum and field spectrum was found aspired level.

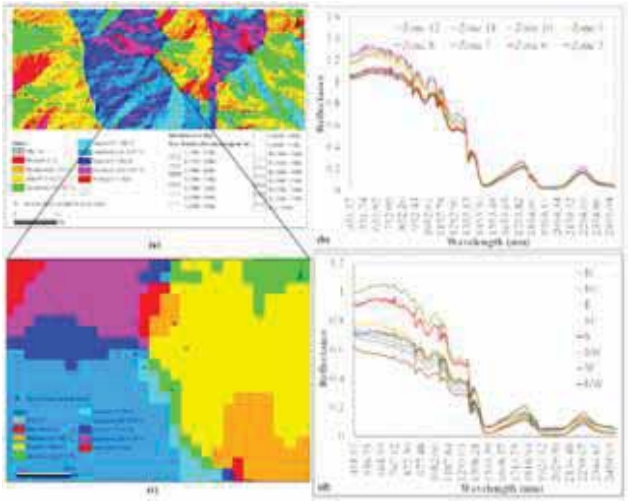
The classified image with 7 classes of turbidity in the selected region of the lake is shown in the figure.



SAM Classified Turbidity Map, Field and AVIRIS-NG image spectra matching

Analysing Effect of Slope and Aspect on Snow Spectra

In the present study, an attempt has been made to study the snow spectral characteristics with elevation, slope and aspect along with the mapping of snow grain size in the part of Himachal Pradesh, India. The analysis has been carried out on AVIRIS-NG data of February 17, 2016 belonging to Site Id 137 (Patsio Glacier region).

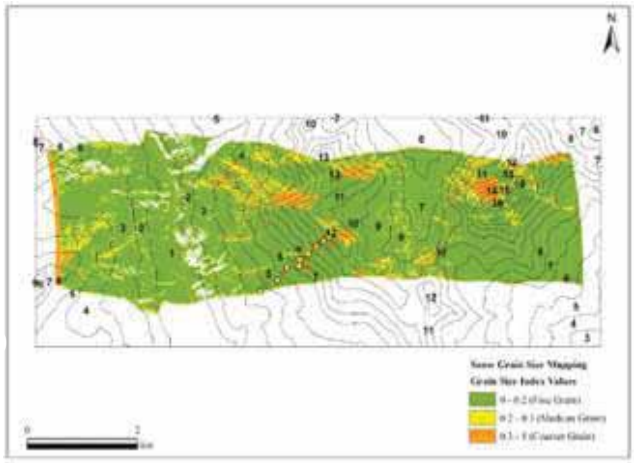


(a) Aspect Map of the region along with the elevation bands depicting points selected to study the impact of elevation on snow reflectance in each zone in south west aspect, (b) Change in spectral characteristics with elevation, (c) Zoomed image showing location in each aspect selected for analysis, (d) Change in snow spectra with change in aspect

It was found that the snow spectra changes with aspect. Highest reflectance from the snow was observed in the south aspect and the lowest in the north aspect.

Further, to study the effect of elevation on snow spectra, the snow spectra has been taken on different elevations zones mainly in south west aspect as shown in Figure. It was again found that the snow spectra changes with elevation and snow reflectance reduces with reduction in elevation. It generally change because of change in grain size, which usually changes with elevation; grain size becomes coarser as elevation decreases.

For grain size mapping, grain size index method (Grain Size Index, GI) proposed by Negi et al., (2010) based on the field collected hyperspectral reflectance data was used. As the image was of February 17, 2016, acquired on very high altitude (> 3500m), the region is covered mostly by fine grain fresh snow. The snow grain size especially in North West aspect region is coarser in nature, due to reasons discussed above.



Snow grain size mapping using GI approach and its change with elevation zone

Biodiversity Characterisation at Community level in India using Earth Observation Data

This project, funded by Department of Biotechnology Govt. of India, is targeted in developing an Earth observation based strategy for mapping and monitoring biodiversity at the community level in India. The approach is to develop a fine-grained description of vegetation structure, function, pattern and composition from detailed field studies.

Nandhaur landscape of Himalayan foothills of Uttarakhand is selected as the study site. The vegetation type/land use map of the study area is prepared using IRS LISS-IV satellite data. It is being used for vegetation stratification and field sampling.

Field inventory is being carried out in 0.1 ha plots in the forest areas of Nandhaur landscape. Drainage network, elevation, slope and aspect maps are prepared and forest boundary has been procured from Forest Department.

One-week training course on "RS, GIS and GNSS Applications in Biodiversity Characterisation" was conducted by the Forestry and Ecology Department of IIRS during 10^{th}-14^{th} December, 2018 for 15 project personnel of Biodiversity Characterisation at Community Level and Indian Bioresource Information Network (IBIN) projects.

Field sampling at Nandhaur landscape

India Biodiversity Information Network (IBIN)

IBIN (Phase-III) project funded by Dept. of Biotechnology, Govt. of India, aims to enhance distributed web services, standardize and authenticate existing datasets adapting global data standards and integrate advanced analytical and citizen centric tools to build a single window National Portal on bio-resources and biodiversity of the country.

A web application for data quality check (DOC) is under development as an attempt to correct the possible errors, homogenise the databases. The algorithm of DQC is developed as a scientifically rigorous and automated approach that provides an interactive interface to the potential reviewers to validate, verify and authenticate the species data, and finally, the data will be used as an input to a variety of modelling approaches. This DQC web application is divided into two modules:

Admin module: Administrative control over reviewer's login;

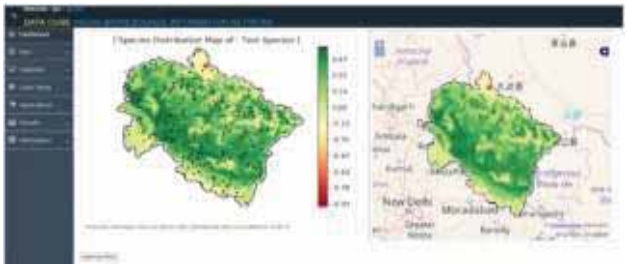
Reviewer Module: To review and provide feedback with rating on the scale of 1 to 5;

IIRS Geospatial Data Cube

An attempt is made at IIRS to develop a multi-dimensional space-time architecture for (1) easy access of Analysis Ready Data Products, and (2) efficient time series analysis and data assimilation for environmental characterization and scientific analysis. Towards this Geospatial Data Cube for Uttarakhand is prepared It is a unified data management system which can be used for

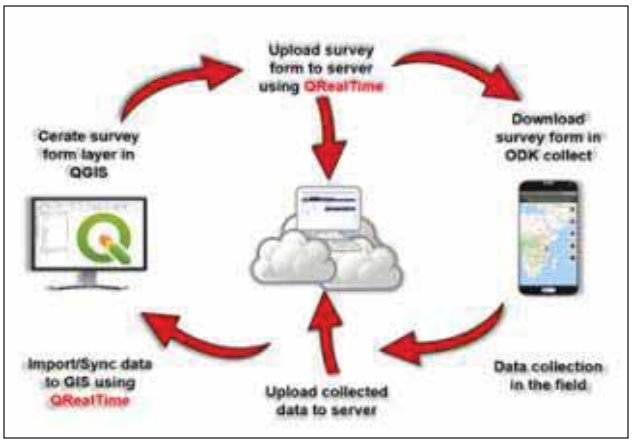
computations such as filtering, linear regression, classification, etc. via a single platform. This system is based on the "Dice and Stack architecture" where the data is stored in Nested Grids. It can supports infinite user applications, increasing and diverse datasets, and allows automated ingestion of new datasets.

The data cube currently has entire L A N D S A T collection (at every 5 year interval), LISS-3 and LISS-4 collection ingestion and ready for analysis over the state of Uttarakhand.



Entomological and Epidemiological Field data collection in ODK

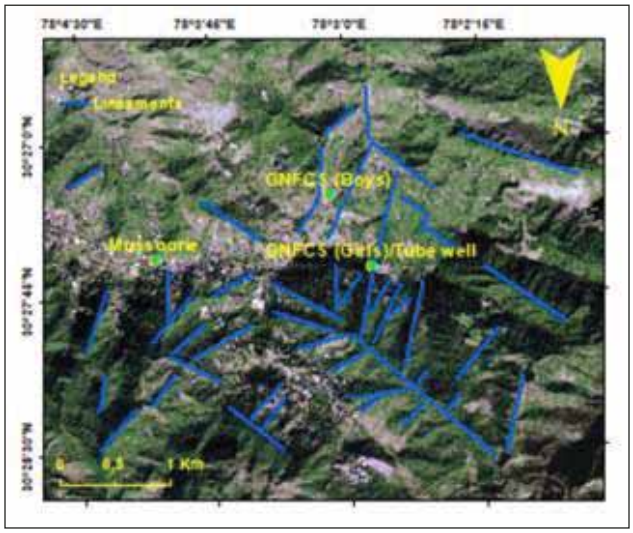
Two ODK forms has been created as per the proforma sent by the National Institute of Medical Research (NIMR). Epidemiological and Entomological proforma created in xform format for ODK would replace the paper based data collection. A separate ODK Aggregate server is deployed for this project. Both these two forms are now available with user and undergoing testing. GIS analyst can use QRealTime plugin in QGIS for real-time monitoring and analysis of survey data.



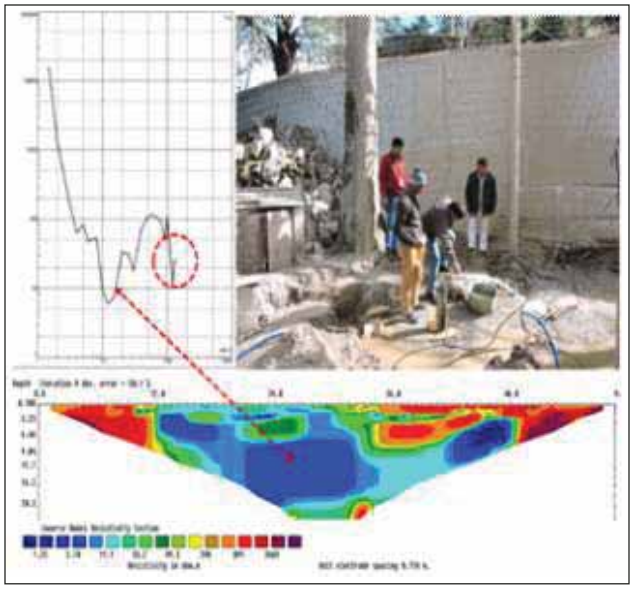
Integration of Geospatial and Geophysical Techniques to Explore Ground Water Prospects in Mussoorie Hills, Uttarakhand

This study was carried out with main objectives of integration of geospatial and geophysical techniques to improve efficiency and effectiveness of integrated approach in solving the societal problem of drinking water issues in the steep hilly terrains of Himalayan region.

The study was taken up at Guru Nanak Fifth Centenary School (GNFCS), Mussoorie which is facing acute drinking water problem as the perennial stream, their only source of water dried up some years back Cartosat-1 and LISS 4 satellite images were used to analyze the geomorphology and geology of the area along with morphometric analysis. Lineaments, which are potential zones for groundwater storage and movement were delineated on satellite images and confirmed in the field. Detailed geophysical resistivity imaging was carried out at selected places on lineaments where the presence of aquifer zones was interpreted. Following this, vertical electrical sounding and electrical resistivity tomography were carried out at the identified potential groundwater aquifer zone. The most potential zone was identified along



Lineaments mapped on Cartosat-1 and LISS IV image to identify ground water prospect zones in the Mussoorie hills, which were later confirmed using geophysical techniques and drilling.



VES profile across the fracture (lineament) showing two prospect zones; 2D inverted electrical resistivity section across the fracture zone of 40 meter indicating same resistivity anomaly.

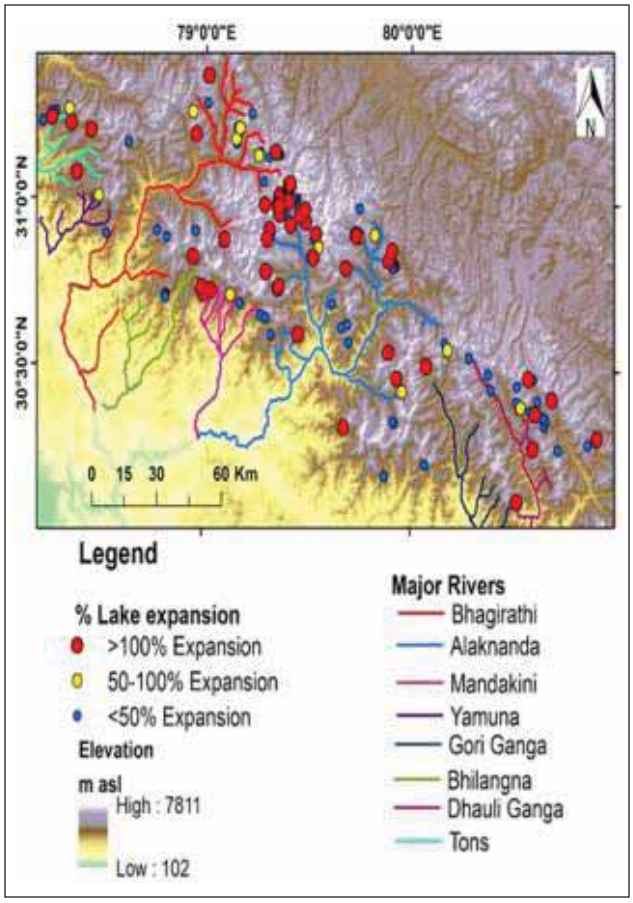
the lineament and accordingly drilling of wells for both extraction and recharge of groundwater was suggested.

Validation of Results: Drilling was carried out in the month of December, 2017 and as expected, very good amount of groundwater was discovered and the same could be extracted at the rate of 180 litres per minute from a depth of about 130 meters below the ground level.

This is the first successful scientific study carried out in the Mussoorie hills to locate groundwater prospect areas using integration of geospatial and geophysical techniques. This integrated approach can be applied elsewhere in the steep mountainous terrains of Himalayan region to locate groundwater prospect areas and make sustainable use of the same.

Glacial Lake Inventory and Expansion in Uttarakhand Himalaya

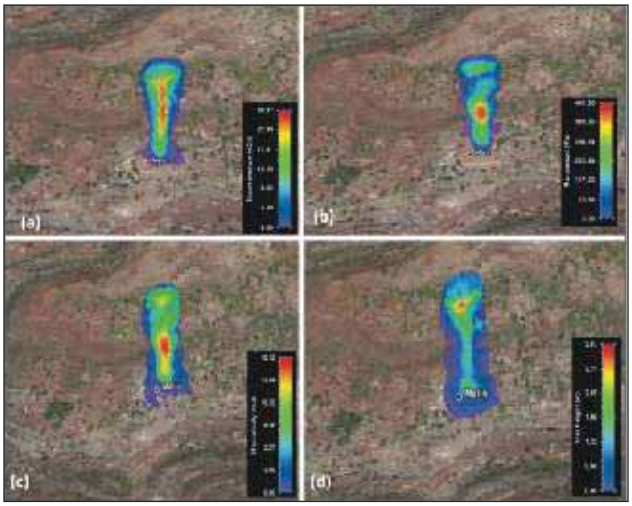
This project under TDP programme of ISRO was carried out with main objective of monitoring of glacial lakes in Uttarakhand Himalaya. Continuous monitoring of glacial lakes are essential for i) their significant role in influencing glacier mass budget and energy budget; b) their contribution in current and future water resource and c) as a source of mountain catastrophes inducing GLOFs. An inventory of glacial lakes with area >500 m^2 was carried out in the Uttarakhand Himalaya employing high resolution LISS-IV images for the year of 2015. The result showed presence of a total of 1392 glacial lakes in the Uttarakhand Himalaya covering an area of about 8.39 km^2. The expansion of the lakes were also studied between 1994 and 2017 and the result indicated remarkable expansion of glacial lakes even at higher altitude. The figure shows distribution of highly expanding lakes larger than 0.01 km^2 in the area. The expansion was derived between 1994 and 2017 using Landsat images.



Spatial distribution of highly expanding lakes in Uttarakhand Himalaya

3-Dimensional Modeling of 2014-Malin Landslide, Maharashtra using Satellite-Derived data: A quantitative Approach to Numerical Simulation Technique

This study was carried out with the main objectives of slope stabilization and debris flow modeling. A highly objective simulation technique is used to model the debris flow run-out happened in Malin in Western Ghats. This takes cues from a high resolution DEM and other ancillary ground data including geotechnical and frictional parameters. The algorithm is based on Voellmy frictional (dry and turbulent frictional coefficients, μ and ξ respectively) parameters of debris flow with pre-defined release area identified on high-resolution satellite images like LISS-IV and Cartosat-1. The model provides critical quantitative information on flow 1) Velocity, 2) Height, 3) Momentum, and 4) Pressure along the entrainment path. The simulated velocity of about 16m/s at mid-way the slide plummeted to 6.2 m/s at the base with intermittently increased and decreased values. The simulated maximum height was 3.9m which gradually declined to 1.5m near the bottom. The results can be beneficial in engineering intervention like the construction of check dams to digest the initial thrust of the flow and other remedial measures designed for vulnerable slope protection.



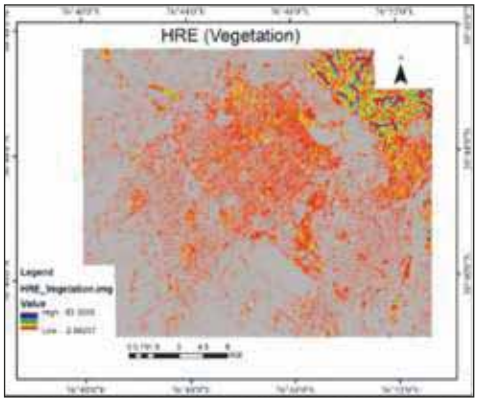
Spatial variation of vital flow parameters of the debris flow model (a) momentum (b) pressure (c) velocity and (d) height

Urban Canopy Parameters Computation using 3D Databases in GIS

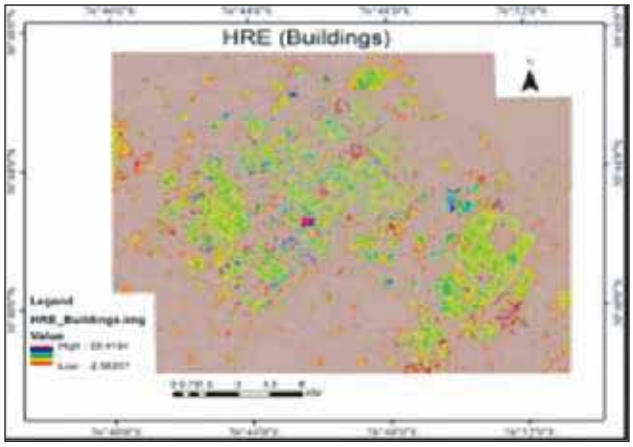
Urban Canopy Parameters (UCPs) significantly impact the UHI formation and natural ventilation in urban areas. Recently, a software has been developed at IIRS for the computation of key aerodynamic UCPs such as Frontal area index, Sky View Factor and Height-to-Width Ratio. Approaches for computation of many other 2D and 3D UCPs have also been developed and the same have been used to generate the urban ventilation path map of Delhi. The work is further extended in this project to include vegetation canopies and to extend this study to other urban areas in varied climatic zones.

Out of five cities selected in varied climate zones of India, 2D and 3D Urban Canopy parameters were computed for three cities: Delhi and Chandigarh (Composite climate), Bhubaneshwar (Warm and Humid) for urban climate studies. The retrieved vegetation and building heights from high resolution optical stereo data are shown in the figure. The class-wise error analysis of building heights reveals RMSE values of <1 m in all classes.

Validation of Building heights in different height groups			
CLASS	**MEAN ERROR**	**RMSE**	**STDEV**
Low-rise (< 10m)	-0.28	0.76	0.76
Mid-rise (10-25m)	0.004	0.42	0.45
High-rise (>25m)	0.44	0.32	0.79



Height of vegetation canopy, Chandigarh

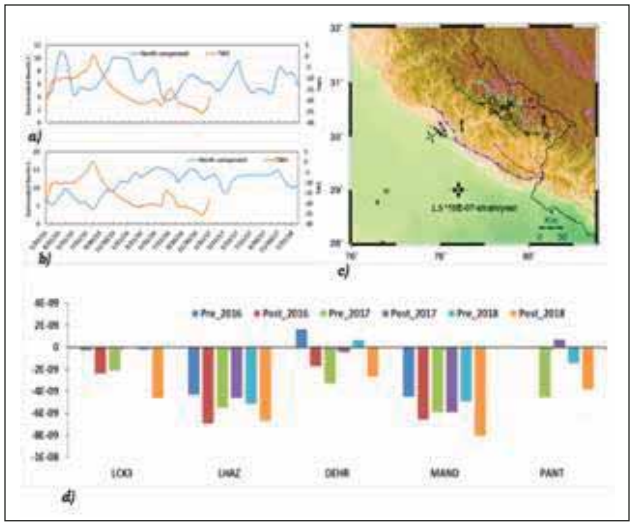


Height of Building canopy, Chandigarh

Study of Seasonal Variations of Geodetic Stress and Strain Distribution using GNSS and Correlation with Seismic Activity in Northwest Himalaya

This research project is carried out with the following main objectives: (1) to prepare a strain accumulation map using continuous geodetic measurements (GNSS) and their correlation with seismicity, (2) To determine the compressional and extensional strain in the Himalayan region, (3) To model the accumulated strain and its interaction with the ongoing deformation, (4) To establish a relation between terrestrial water storage, seasonal GNSS/GPS components (N-S, E-W and vertical), strain rate, seismicity and other geophysical parameter to give the explanation for the modulation of secular interseismic strain.

High quality GNSS data have been acquired by permanent GNSS (CORS) station and campaign mode survey. Triangulation techniques has been used to compute the mean infinitesimal horizontal strain (or instantaneous horizontal strain rate) in the crust among three GNSS sites. Seismicity data have been used from IMD and USGS website. GRACE/GLDAS data have been analyzed to estimate the Terrestrial Water Storage (TWS) over Ganga basin, Time-series analysis and correlation with other output.



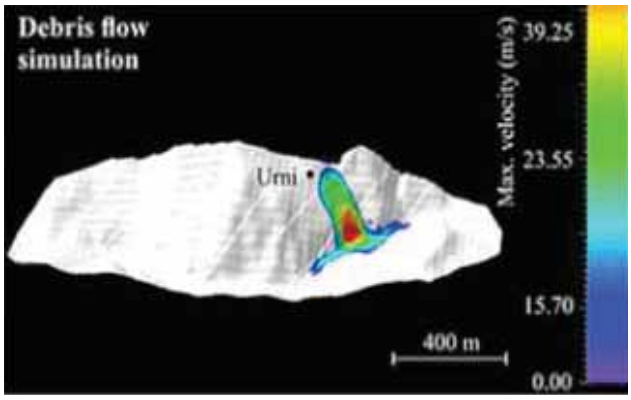
a) Comparison between detrended north component and GRACE derived TWS at Dehradun GNSS station; b) Comparison between detrended north component and GRACE derived TWS at Mandal GNSS station; c) Compressional and extensional motion across HFT and MCT derived through triangulation technique; d) Seasonal variation of strain rate in the year 2016, 2017 and 2018 period at IGS and CORS with respect to IISC Bangalore

TWSC analysis over major Indian river provides significant information on hydrological loading and causing seasonal seismicity in the Himalayan region. The geodetic displacement depicts seasonal variation due to TWS storage.

The vertical displacement component exhibits large seasonal variations compared to the horizontal displacement components. In NWH w.r.t. fixed India plate, sites move southward with comparatively greater in summer season than in the winter season. Strong correlation has been observed between TWSC and GNSS/GPS derived horizontal and vertical components. Seasonal strain rate has been estimated at CORS and CMGS, strong correlation has been observed among seasonal strain rate, TWSC, detrended GNSS/GPS components and seismicity in the Northwest Himalaya. It is found that compression is less during pre-monsoon than in the post-monsoon. The results show that the modulation of strain accumulation is taking place due to the seasonal perturbation in the Indian plate motion. Pre-monsoon velocity of Indian plate motion is found to be more than post-monsoon velocity (refer figure).

Evaluation of Potential Landslide Damming and Lake Formation: Case study of Urni Landslide, Kinnaur, Satluj valley

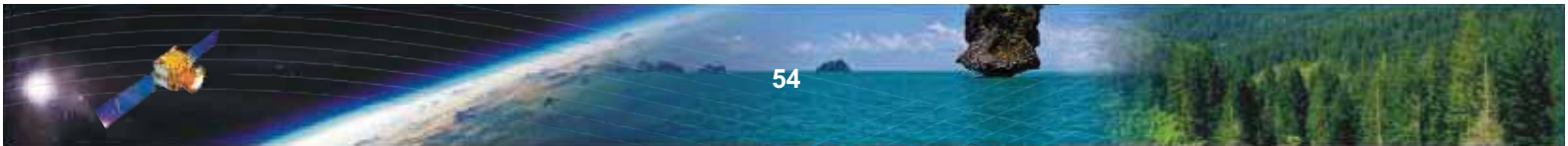
This in-house project in collaboration with WIHG, Dehradun was carried out with the main objective to understand the process of potential landslide damming using slope failure mechanism, dam dimension and dam stability evaluation. The Urni landslide, situated on the right bank of the Satluj River, Himachal Pradesh is taken as the case study. The Urni landslide has evolved into a complex landslide in the last two decade (2000-2016) and has dammed the Satluj River partially since year 2013, damaging 200 m stretch of the National Highway (NH-05). The crown of the landslide exists at an altitude of 2180-2190 m above msl, close to the Urni village that has a human population of about 500. The high resolution imagery shows 50 m long landslide scarp and 100 m long transverse cracks in the detached mass that implies potential for further slope failure movement. Further analysis shows that the landslide has attained an areal increase of 103,900 ± 1142 m^2 during year 2004-2016. About 86% of this areal increase occurred since year 2013. Abrupt increase in the annual mean rainfall is also observed since the year 2013. The extreme rainfall in June, 2013 [11 June (100 mm) and 16 June (115 mm)], are considered to be responsible for the slope failure in the Urni landslide that has partially dammed the river. The finite element modelling (FEM) based slope stability analysis revealed the shear strain in the order of 0.0-0.16 with 0.0-0.6 m total displacement in the detachment zone. Further, kinematic analysis indicated planar and wedge failure condition in the jointed rockmass. The debris flow runout simulation of the detached mass in the landslide showed a velocity of 25 m/s with a flow height of 15 m while it (debris flow) reaches the valley floor. Finally, it is also estimated that further slope failure may detach as much as 0.80 ± 0.32 million m3 mass that will completely dam the river to a height of 76 ± 30 m above the river bed (refer figure).

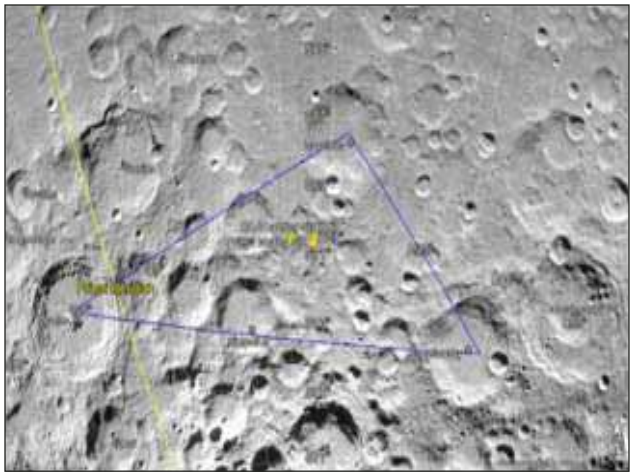


Results of the slope stability analysis (left) and maximum simulated flow velocity (right)

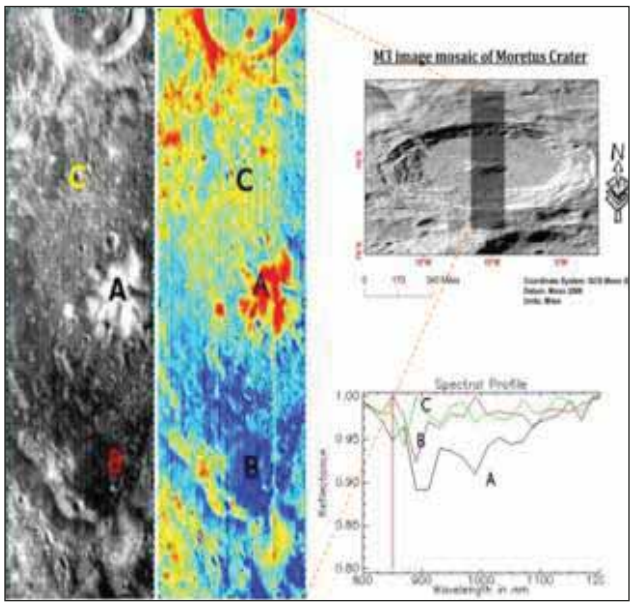
Crater Classification and Surface Composition around Chandrayaan-2 Landing Site and its Terrestrial Analogue

The study has been 'carried out under Lunar science working group-2 activity (Chandrayan-2) of SSPO, ISRO' with main objectives of characterization of crater classification and surface composition around Chandrayan-2 landing site. In this research we have evaluated the utility of imaging spectrometry to study the spatial distribution of minerals around Moretus, Boguslawsky, and Manzinus craters located near the South Pole region of the moon, in the vicinity of probable landsite site for Chandrayaan-2 (Fig) and terrestrial analogue viz. Dhinodhar volcanic plug/dome located in Kutch, Gujarat. Moon Mineralogical Mapper (M3) sensor onboard Chandrayaan 1 satellite with 85 bands and 140m spatial resolution was used for lunar crater and mineral characterization. Landsat 8, ALOS PALSAR DEM and other ancillary data were used to study the geology of Dhinodhar plug. The crater centers were found to be richly concentrated by low Ca pyroxene minerals, concentration of which diminished away from the center (Fig). There is a manifestation of high concentration of FeO near the crater center due to the characteristic ferrous





Study area enclosing the probable landing site of Chandrayan-2 in SPA basin



A: Low-Ca pyroxene (LCP) rich rocks: shades of red B: High-Ca pyroxene (HCP) and/or olivine green to yellow, C: Plagioclase and/or optically matured surfaces: blue to purple

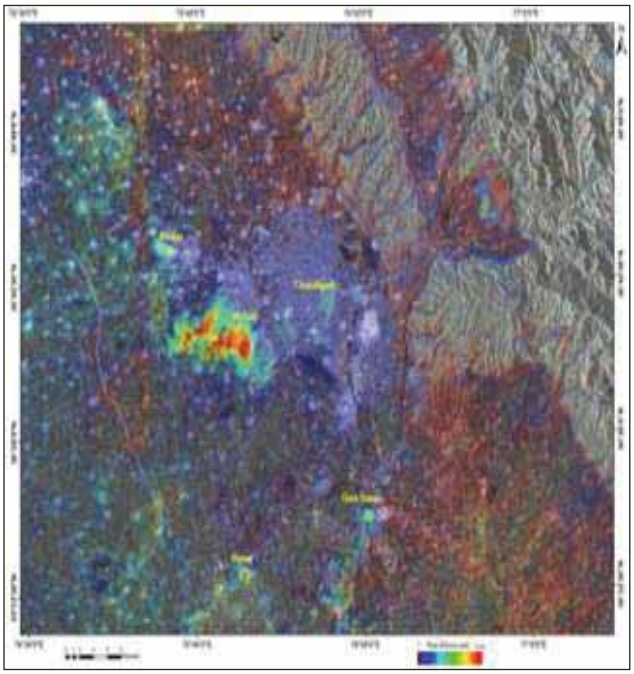
absorption indicating optically less matured materials at the center with gradual decrease of the same, away from the center indicating presence of low concentration of fresh ejecta materials along with matured soil/debris. In areas far from the crater center surface rocks are interpreted as highly optically matured anorthositic debris dominated by plagioclase feldspar. Secondary craters within the primary craters were detected in and around Chandrayan-2 landing site. The morphometry, age, size and dimensions of the craters were subsequently calculated. Spectral analysis of the collected rock and soil samples of terrestrial analogue at Dhinodhar depicted 2.2 Al-O/OH or Mg-O/OH feature and possible pyroxene absorption feature near 1 micrometer implying Alkali basalt and their weathering derivatives. These ground-based spectra were correlated with the spectra of the Moretus central peak, formed as a result of cratering. This study enriches the lunar surface geological knowledgebase in the vicinity of Chandrayan-2 landing site near South Pole.

DInSAR based Spatio-temporal Analysis of Groundwater Depletion in and around Chandigarh, India and its impact on aquifer system compaction

The study has been carried out as a part of EOAM project with main objectives of assessment of groundwater depletion using space borne gravity and ground based Ground Water Level (GWL) data, detection and mapping of aquifer compaction zones in the study area, space-borne geodetic observation by Differential Interferometric Synthetic Aperture Radar (DInSAR) and differential GNSS survey and terrestrial observation by precision leveling for measurement and monitoring of land surface deformation, and predictive modeling to decipher potential land subsidence scenario due to groundwater exploitation.

The study has shown promising results in the form of deformation fringes both on ALOS-1, 2 (L-band) and RADARSAT-2 (C-band) data (Fig). The area in which fringes were observed was highly developed locality of Chandigarh, Mohali, Kharar, Landran, DeraBassi, Banur, Lalru showing different displacement rates. DInSAR based land surface deformation is in general found to be comparable with groundwater depletion induced

aquifer system compaction in and around Chandigarh and Mohali (Punjab).

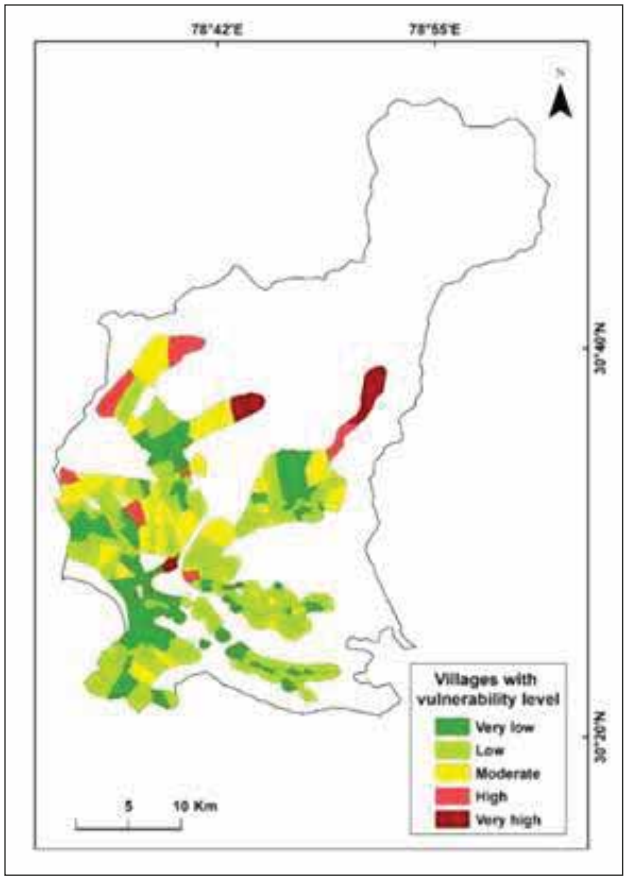


DInSAR (L-band) based land surface deformation in and around Chandigarh (2009-11)

A Multi-Hazard Risk Assessment of Bhilangana catchment, Uttarakhand using Geospatial Techniques

The study has been carried out as a part of DMSP project with main objectives of multi-hazard risk assessment of Bhilangana catchment, Uttarakhand using geospatial techniques. The main aim of the study is to develop a quantitative methodology for risk assessment at micro-level using high resolution satellite data.

A comparative vulnerability assessment mapping (CVAM) methodology for Bhilangana block was developed. This involved formulating a framework for multi hazard vulnerability assessment using factors representing physical, social, economic dimensions of vulnerability and coping capacity for each hazard.



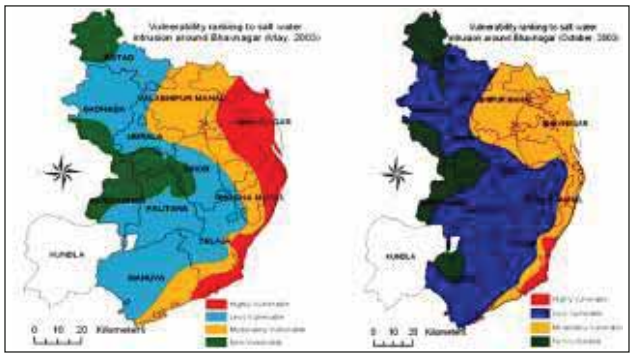
Landslide vulnerability assessment at village level in Bhilangana block, Uttarakhand

Five classes of landslide vulnerability were identified at village level for Bhilangana block. The output reveals very high and high vulnerability of landslide in villages of Gainwali, Reechak and others which require most immediate attention.

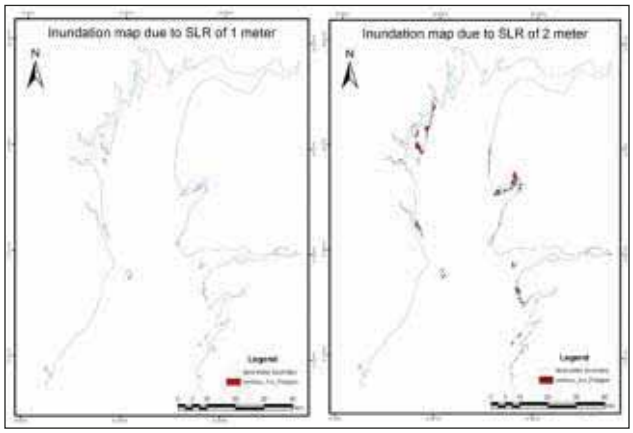
Sea Level Rise and Consequent Salt Water Ingress into Coastal Aquifer in the Low Lying Coastal Tract of Gujarat, India

Change in groundwater levels with respect to mean sea elevation along the coast largely influences the extent of seawater intrusion into the fresh water aquifers. Inundation areas due to sea level rise of 1m and 2 m has been shown in the study. Also the vulnerability ranking due to salt water intrusion in pre and post monsoon season has been studied using GALDIT model. GALDIT is a semi-empirical

additive model where the subsurface geological parameters responsible for salt water intrusion has been taken into consideration and suitable weightages as per their relative importance has been given.



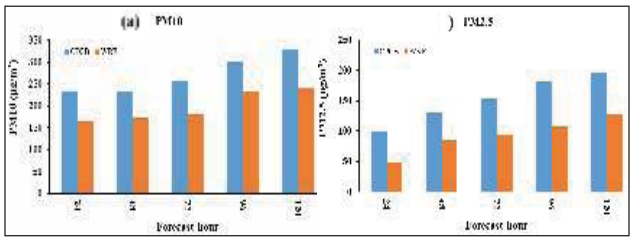
Vulnerability ranking of salt water intrusion around Bhannagar city, Gulf of Khambhat



Inundation areas due to sea level rise

Analysis of a Dust Storm Originated over the West Asia using WRF

In recent years, dust episodic events have increased over the West Asian region which impact the air quality of North India. Dust storm originated over west Asia (Iraq and Saudi Arabia) in last week of October 2017 is one of such events which is used as a case study in the present work. This dust storm was so severe, that is entered into the Indian subcontinent region, causing low visibility over the Delhi region. Present study was intended to investigate the contribution of the dust storm in degrading air quality which was originated over gulf region and transported dust particles in Delhi, which subsequently reduced the visibility of the region considerably. Numerical weather prediction model fully coupled with chemistry (WRF-CHEM) was employed here to explore the forecasting skills of such a severe dust storm well in advance. Results obtained from the model simulations show a good match with ground based estimates.



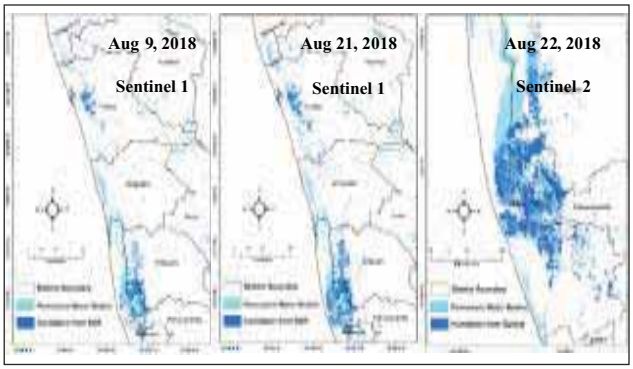
Comparison of PM10 and PM2.5 concentration between WRF simulation initiated on 01 November, 2017 and CPCB Observations at IGI Airport, Delhi.

Hydrological Study of August 2018 Kerala Floods using Remote Sensing, Hydrological Modelling and Geospatial Tools

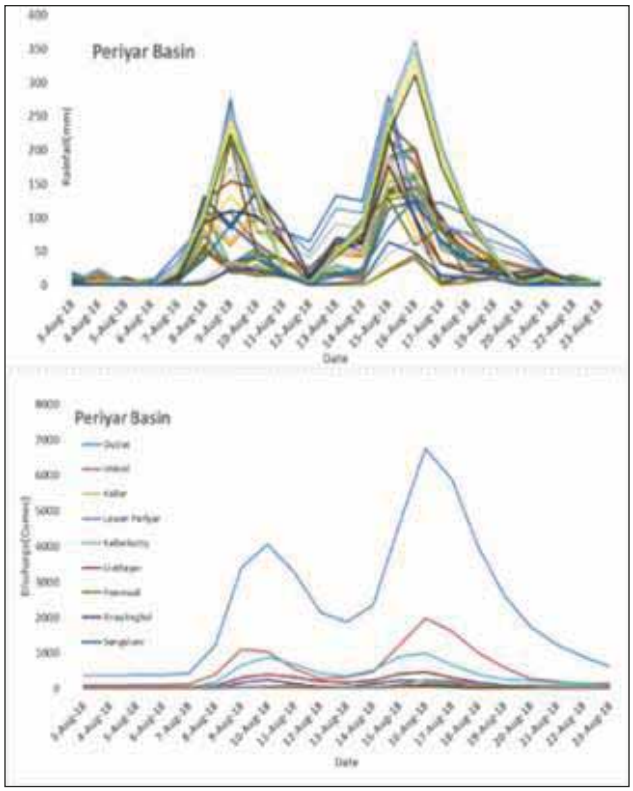
The hydrological study of Kerala floods, 2018 was carried out with following objectives:

- Study of physical features of Kerala and its surroundings.
- Flood hydrograph generation using hydral maps.
- Flood inundation mapping using remote sensing data and hydrodynamic modelling.
- Analysis of condition of reservoirs during Kerala flood of 2018.

Hydrological model has been established for 12 flood-prone basins of Kerala to analyze the hydrological response of the August, 2018 flood event. Flood mapping has also been done to analyse the severity of flood using optical and SAR data. Topographical and hydrodynamic models were simulated to identify flood-prone river reaches. The results of detailed hydrological modelling for Periyar basin with outlet at Alluva Manappuram Rail Bridge, Periyar Nagar using hydrological modelling system (HEC-HMS) model as shown in figure. The model was able to capture the peak flows.



Flood inundation map obtained from remote sensing data (Sentinel 1 and Sentinel 2)



a) Daily rainfall from IMD data for various sub- watersheds of Periyar & b) Daily flow obtained from HEC-HMS for outlets and major dams of Periyar

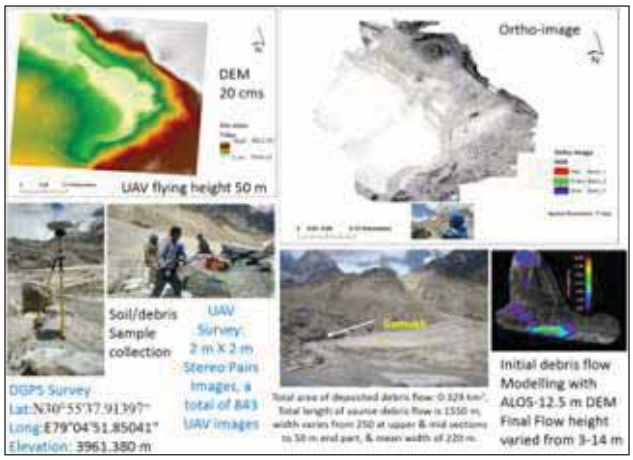
A Study on Gangotri Glacier

This study emphasizes on the estimation of retreat of Gangotri Glacier during recent years, to quantify the Bhagirathi river flow direction shift post debris flow event, pre and post debris flow terrain analysis and debris flow modelling using integration of satellite, UAV and ground data.

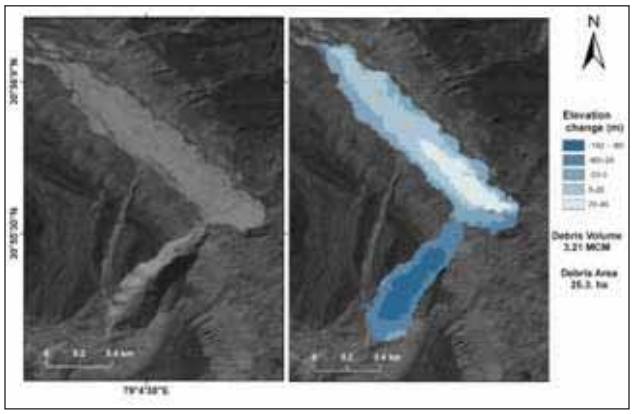
A multidisciplinary team was constituted by Additional Secretary, Disaster Management, Government of Uttarakhand to undertake field investigations in the Gaumukh area and verify the existence of lake therein and assess the threat posed by it to the downstream population and infrastructure, if any. The team made a joint visit to the Gaumukh area between 18th and 22nd June, 2018.

Quantification of debris deposition was done after the debris flow event 2017 at terminus of Meru glacier using remote sensing. The debris volume change has been calculated using Digital Elevation Model (DEM) of pre and post event.

It was observed that river course has shifted about 20-140 m towards right from April 2017 to April 2018 at various sections of river, due to glacial lake



Highlights of detailed Gangotri snout survey and initial results.



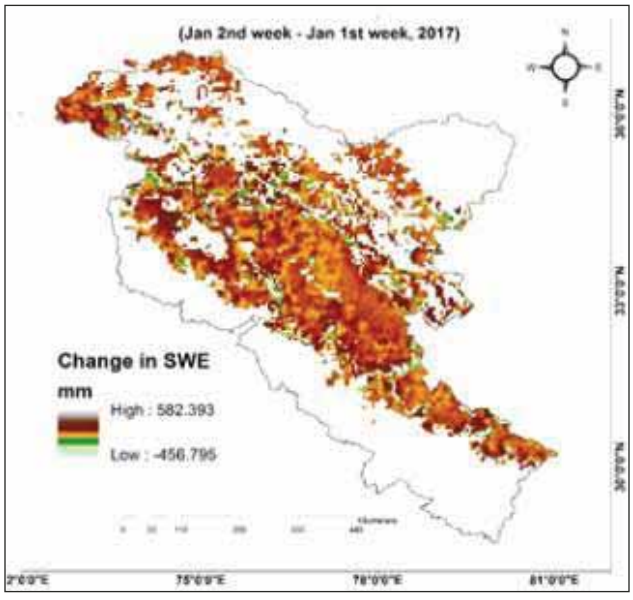
Elevation change, debris volume-area extracted from temporal DEM

breach over Meru Glacier and sub-sequent debris flow deposition around 1.8 km stretch. The reason for the breach of the glacial lake could be the heavy rainfall and piping of the deposited moraine beneath and downstream of the lake which has caused heavy amount of debris flow over the previous path of Bhagirathi River.

The UAV and DGPS data collected during field survey done has been processed to create very high resolution DEM (20 cm spatial resolution) and ortho-image (1.3 cm spatial resolution) of Gangotri snout, Gaumukh area. These data are being used for validating the high resolution debris flow model as well as eroded-deposition due to last year's debris flow.

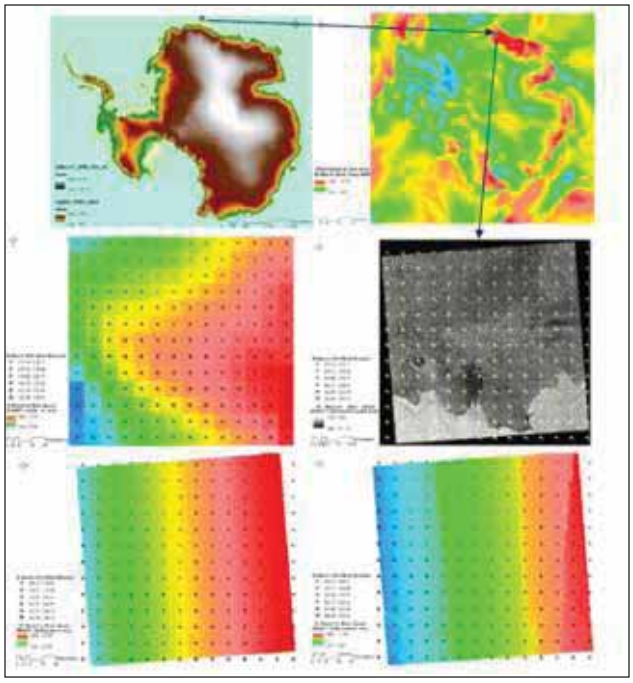
Algorithm Development for Snow Water Equivalent Retrieval in North West Himalaya and Wind Fields At Polar Marginal Ice Zones using Ku-band Scatsat-1 Scatterometer and Risat SAR Data

The main objective of the project is retrieval of gridded Snow Water Equivalent (SWE), wind fields from SCATSAT-1 scatterometer and RISAT SAR data.



Change in Snow Water Equivalent as derived from SCATSAT 1 Scatterometer data using the Change Detection Algorithm given by Yueh et al. (2009).

Daily data for SCATSAT-1 was acquired through MOSDAC and processed for NWH, Antarctica and Arctic along with the processing of RISAT-1 SAR data for polar marginal ice zones. Algorithm was developed to retrieve change in SWE by using single layer radiative transfer model and change detection technique. The correction coefficients were obtained using the ground based observations at Dhundi, Manali, H.P. Wind vectors for the polar marginal zones of Antarctica was generated from RISAT-1 MRS data using the CMOD 5, CMOD4 and CMOD IFR2 algorithms.



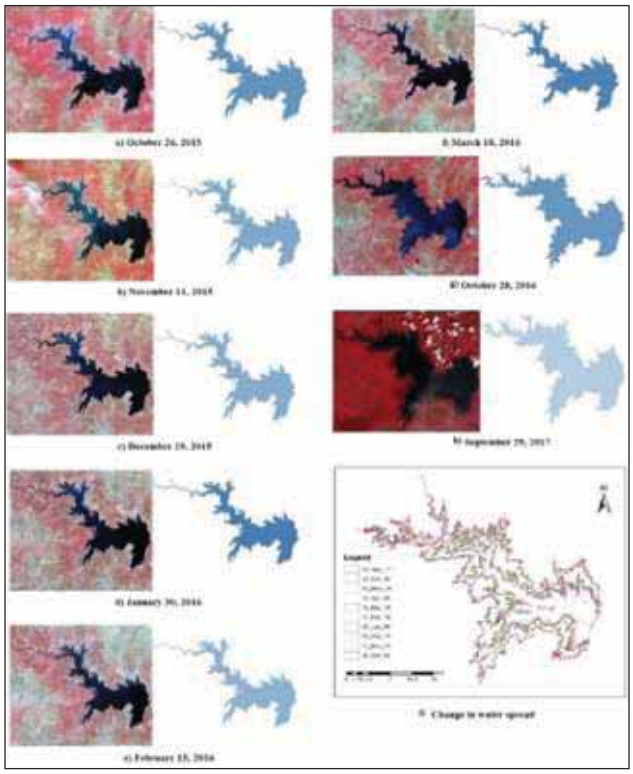
Location map of MRS data, VV backscatter derived using PR with HH data, AMPS based wind speed and direction, SAR based (CMOD-5, CMOD_IFR2) based wind speed maps.

Reservoir Sedimentation Assessment through Remote Sensing and Hydrological Modelling

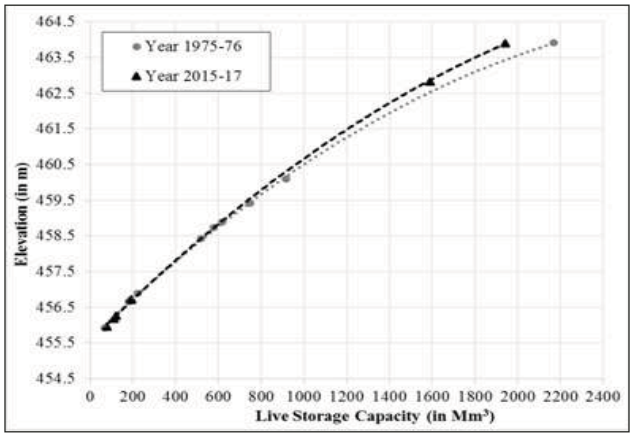
The sedimentation in Jayakwadi reservoir was assessed using Landsat 8 OLI satellite data combined with ancillary data. Multi-date remotely sensed data were used to produce the water-spread area of the reservoir, which was applied to compute the sedimentation rate.

The revised live storage capacity is assessed as 1942.258 Mm^3 against the designed capacity of

2170.935 Mm^3 at full reservoir level. The total loss of reservoir capacity due to the sediment deposition during the period of 41 years (1975-2017) was estimated as 228.677 Mm^3 (10.53%) which provided the average sedimentation rate of 5.58 Mm^3/year. As this technique also provides the capacity of the reservoir at the different elevation on the date of the satellite pass, the revised elevation capacity curve was also developed.



FCC and Water spread area of selected day during the period of 2015-2017of the Jayakwadi Reservoir



Comparisons of the capacity curve of 2015-2017 with the previously obtained results

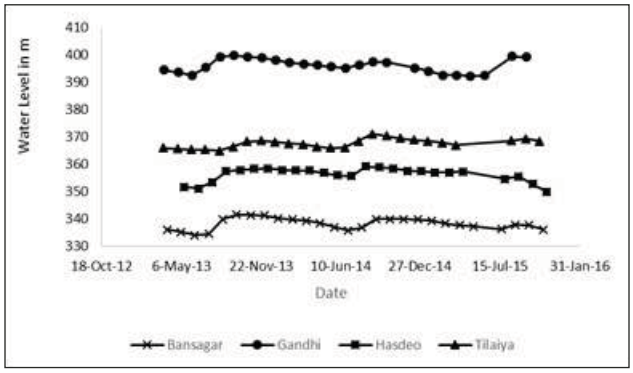
Monitoring of Inland Water Bodies using Space Based Altimeters

Reservoir Water Level Retrieval using SARAL-AltiKa

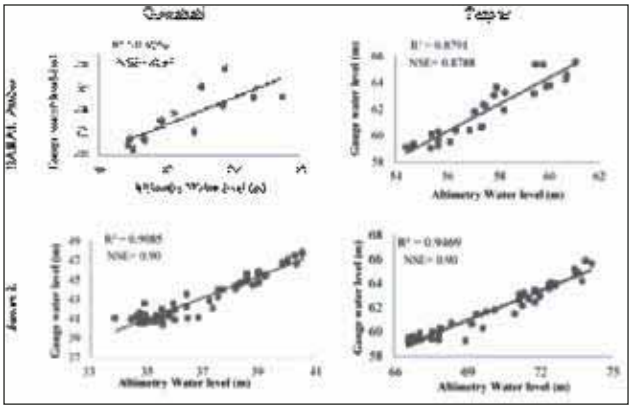
Total 54 Cycles of SARAL/AltiKA SGDR/GDR data were processed from March 2013 to May 2018. Out of 24 reservoirs studied, water level for 10 reservoirs were retrieved for more than 20 cycles, and water level for few reservoirs was estimated for more than 50 cycles. The following reservoirs were used for the validation of the water level retrieval from SARAL/AltiKA (Bansagar, Gandhi sagar, Hasdeo, Kolab, Mahi, Maithon, Massanjore, Tilaiya, Ujjaini, Ukai) against the daily observed reservoir water level available at India-WRIS portal. Some reservoirs such as Ranjit Sagar Reservoir and Rihand Reservoir show some problem with the SARAL/Altika data. Few cycles captured the exact water level but the variation of upto 50m (Rihand Reservoir) to 140 m (Ranjit sagar reservoir) is also observed.

Water Level Retrieval of wide rivers using Altimeters

The main objectives of this study are to estimate water level using altimeter data and discharge using altimeter based water-level and observed rating curve. SARAL and Jason-2 data were used to retrieve water level using re-tracking algorithm. Four virtual stations were selected based on the satellite pass. It was found that the highest water level reaches 74.7m, 63.3m, 53.6m, and 41.6m during monsoon period and lowest water level 66.6m, 54.4m, 42.2m, 33.9m during non-monsoon period over virtual stations viz. Vishwanath, near Tezpur, near Guwahati and Goalpara.



Water Level Time series of four reservoirs located in Central India



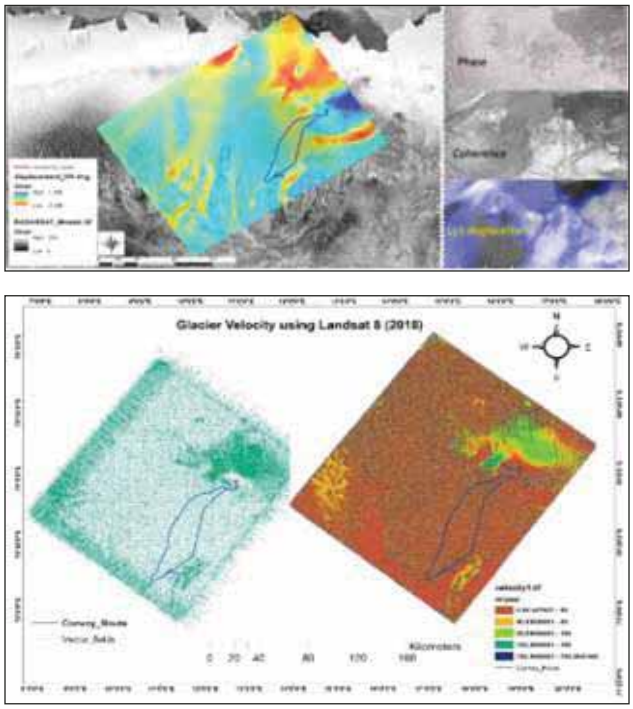
Comparison between altimeter retrieved and observed water level at two virtual gauging stations.

Ice Sheet, Glacier, Sea Ice and Lake Dynamics Study in Parts of Antarctic using Remote Sensing and Modelling Approach (Antarctica)

The main objectives of the study are (i) estimation of ice sheet and glacier velocity (ii) elevation change and sensing and ground data; (iii) Spatiotemporal analysis of ice sheet and glaciers features (iv) Monitoring of Priyadarshini lake water level to quantify its water balance.

Three personnel including a JRF from IIRS have been a part of the 36th, 37th and 38th Indian Scientific Expedition to Antarctica (ISEA) respectively. The average time spent by expedition members was around 80 days in Antarctica. IIRS and National Remote Sensing Centre (NRSC) had earlier published a high quality image album "Glimpse of Antarctica Ice sheet features and glacier landforms - As viewed by Cartosat-2", and 36th ISEA expedition project was in continuation of this work with major objective of "Validation of remote sensing and model based Antarctica Ice sheet features and glacier landforms". As part of the research objectives, major field campaigns were conducted around the Wohltat mountain area of East Antarctica for the validation of remote sensing and model based ice sheet features and glacier land form.

Expedition members travelled along with the convoy to carry out Automatic Weather Station survey for continuous weather record, Snow probe survey for snow morphological parameters, retrieval, Differential GPS survey of 103 stakes installed along the convoy route for glacier velocity estimation and Ground Penetration Radar (GPR) survey for assessment of sub-surface conditions. Also as part of the study Digital Water Level Recorder was installed in Priyadarshani Lake for continuous measurement of water level fluctuations. The results of Ice sheet surface velocities using remote sensing datasets are shown in figure. Validation of these results were performed by ground based DGPS survey of the stake network.

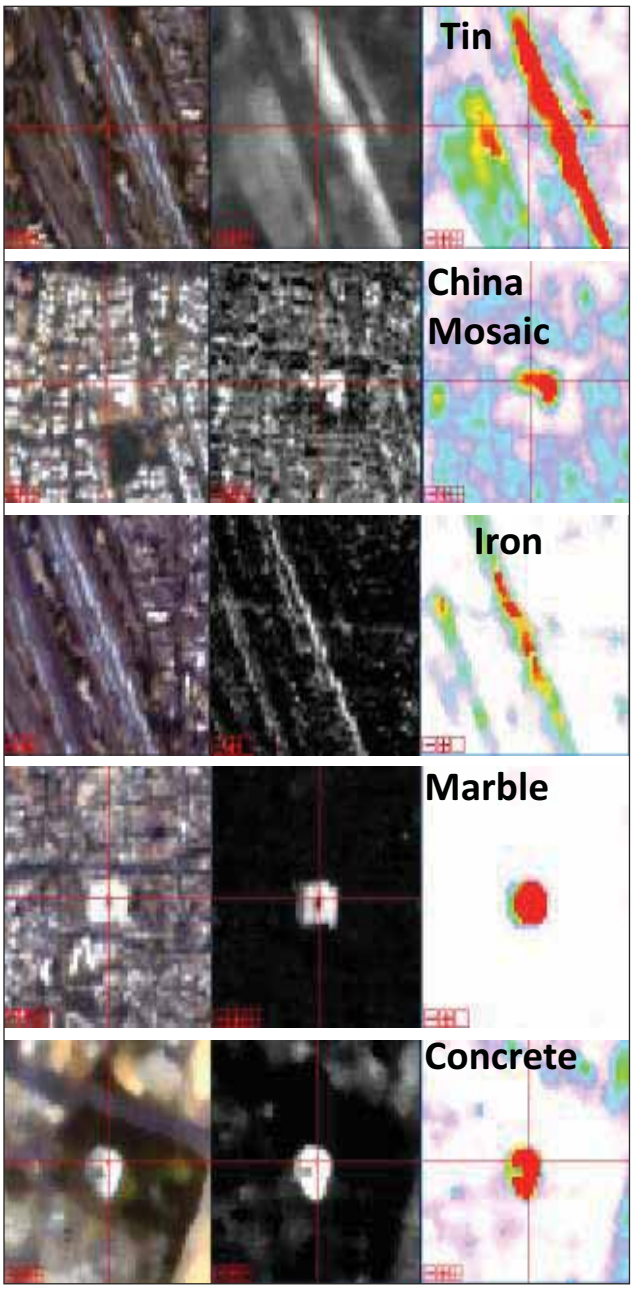


Ice sheet and glacier velocity map of Wohlthat mountain and surrounding areas using Sentinel-1 and Landsat 8 data sets for surveyed regions.

Characterization of Urban Materials using Hyperspectral Remote Sensing Data

Identification of materials in an urban scenario using hyperspectral remote sensing technique is a promising area of research today. The

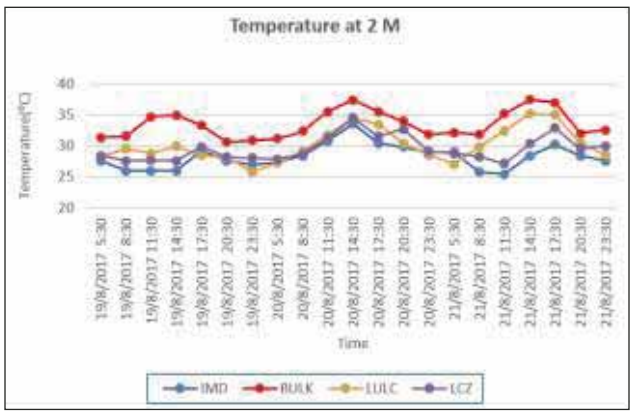
characterization of materials in an urban setup play a pivotal role in deciding the environmental regime in terms of urban heat islands (UHIs) and urban pollution islands (UPIs). The research aims at identifying the pure endmembers from the reflectance image of Airborne Visible InfraRed Imaging Spectrometer - Next Generation (AVIRIS-NG) over a part of Ahmedabad city acquired on February 11, 2016. The end members are extracted on a spatially and spectrally reduced dimension of data to enhance the interactive extraction of materials present. An enhanced matched filtering (MF) approach called Mixture Tuned Matched Filtering (MTMF) was employed on the data for the estimation of abundance images, signifying the presence of a specific chemical composition in a given pixel. The methodology adopted helped in extracting endmember abundance images while describing the presence of specific urban materials like asphalt, tin, china mosaic tiles, concrete, etc.



Identification of urban materials using MTMF technique

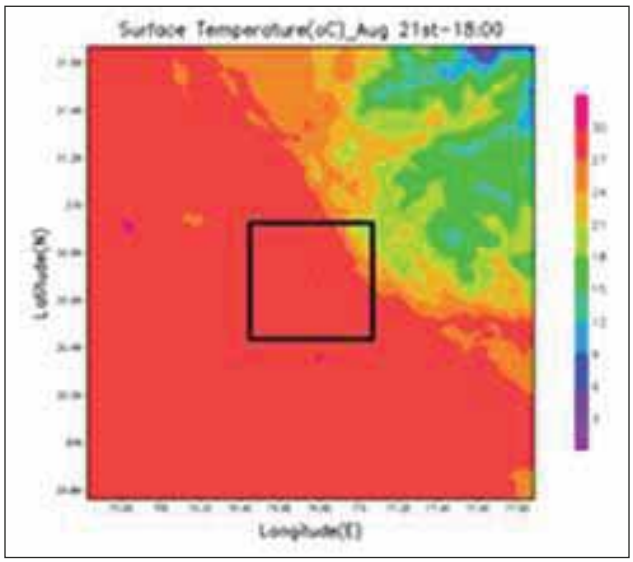
Urban Micro-climatic zoning for Sustainable Smart City Planning of Indian Cities using Geospatial Technologies

Rapid urbanization is responsible for alteration in urban climate, especially the climate below the rooftops or urban canopy layer and manifested in the form of Urban Heat Island (UHI) phenomenon. These changes at local level impact the climate not only at local scale but also the surrounding region. The community Numerical Weather Prediction Weather Research and Forecasting (WRF) model is such a meso-scale model which provides capabilities to downscale up to urban scale (0.5-1km). Besides, urban parametrization have been integrated in WRF model for the better representation of urban areas. It provides ample opportunities for multi-scale integration of urban parameters in the model.The meteorological variables in urban areas were downscaled by applying urban physics scheme. The inclusion of

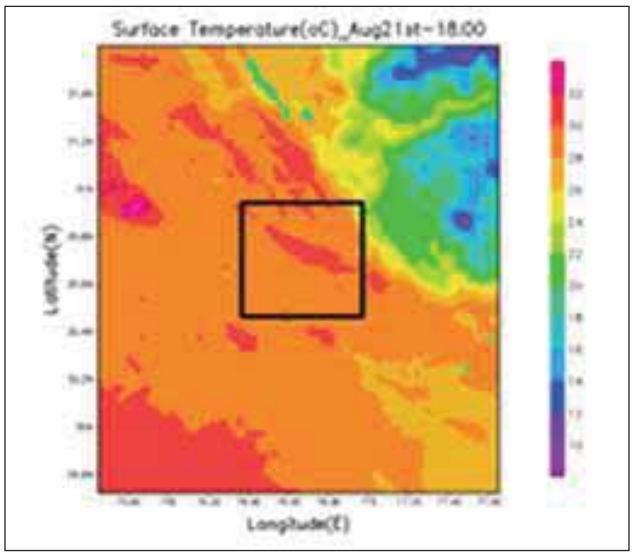


Comparison of Temperature at 2m with IMD ground Observations

urban physics schemes provided improved forecast of meteorological variables over urban areas. Further, improved urban parameterization (3-class Urban LULC and 10-class Urban built-form classification) and updated land surface parameters were ingested in WRF-Urban model and it was found that ingestion of 10-class urban built-form classification and urban LULC along with updated land surface parameters improved the forecast of meteorological variables significantly.



Urban Physics option and 3- Class Urban LULC

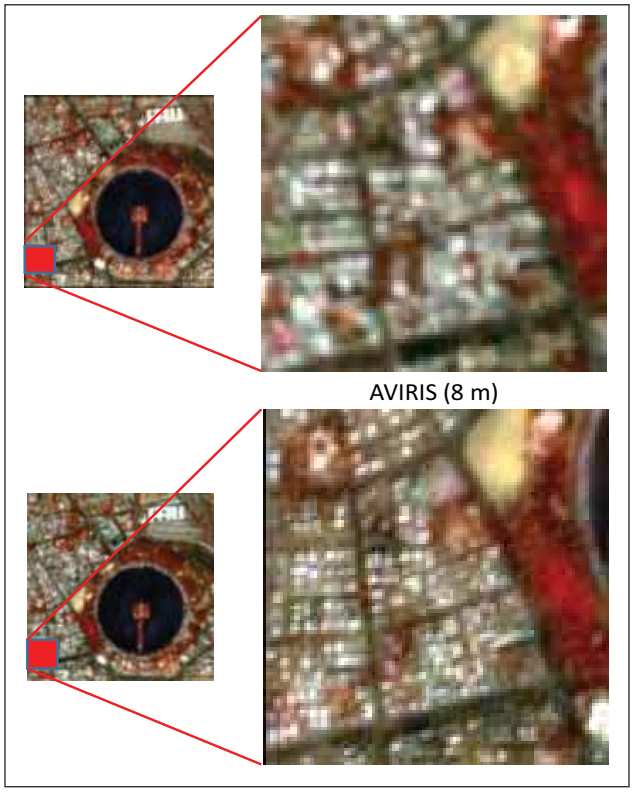


Urban physics option and 10 - class urban LULC

Image Fusion for Urban Area Characterization

Hyperspectral remote sensing images (HSIs) usually have high spectral resolution and low spatial resolution. Conversely, multispectral images (MSIs) usually have low spectral and very high spatial resolution. But urban area characterization requires very high spatial and high spectral resolution (VHSSR) images. To create VHSSR images, multi-sensor data fusion helps to incorporate the high spatial details into hyperspectral images.

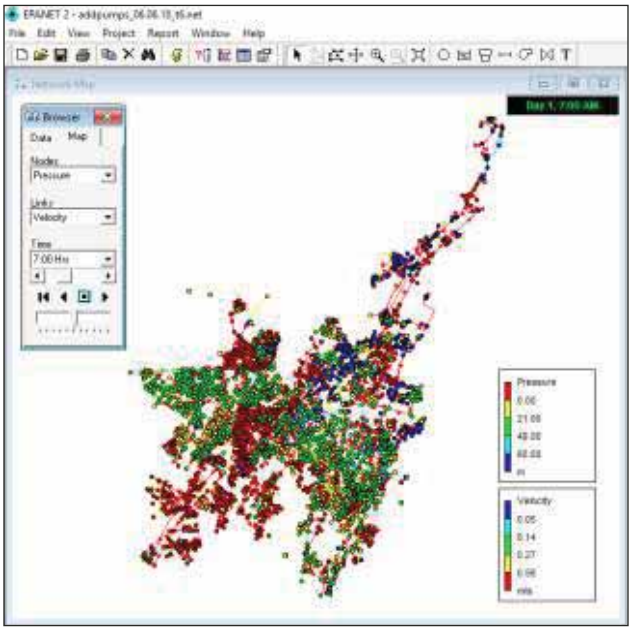
Curvelet transforms were used to create a fused image. AVIRIS (8 m) image was used as low resolution hyperspectral image and Resourcesat-2 LISS-IV (5.8 m) image was used as high resolution multispectral image. The fused image preserves the spectral information from hyperspectral image and represents urban features more precisely than in original hyperspectral image. This spatial resolution improvement enable us to identify and map the urban features and materials.



Merged Hyperspectral Image (5.8 m)

Urban Water Distribution Modelling Using Geospatial Techniques

Water utilities form the core part of any urban infrastructure. However, in developing countries, the existing Water Distribution System (WDS) has many deficiencies such as smaller pipe diameter for water distribution mains, lack of storage tanks, and uneven distribution of water supply. To overcome all these deficiencies, the urban development authorities can use hydraulic modelling tools like Environmental Protection Agency Network (EPANET) along with geospatial data as inputs for efficient planning of WDS in cities. As a case study, the spatial database of WDS for Dehradun city has been created with inputs from satellite images, scanned maps, Computer Aided Design (CAD) files, Ground Penetrating Radar (GPR), etc. The existing as well as future water demand has been estimated using various methods of population projections considering the growth potential of different wards in the city. Further, water supply-demand gap analysis has been done using this geospatial database. The mapping of existing 564 km distribution network revealed that more than three-fourth of system has Polyvinyl Chloride (PVC) and Asbestos Cement (AC) pipes. An accuracy of 93% was obtained upon validation by GPR and updation of pipe diameter in the database. According to supply-demand gap analysis, Dehradun is a water surplus city yet it suffers from water scarcity mainly due to unsatisfactory condition of existing WDS. Twenty-seven percent of existing pipes are smaller than the prescribed standards, and there is an undesirable practice of direct pumping of water from tube wells into the network and storage tanks are required for at least 29 locations in the network. Extended period simulation over the network for 24 hours in EPANET 2.0 helped to identify the localities where water supply is experienced as very low or at negative pressures. Through model simulation, it is observed that total supply-demand gap will become negative in the year 2041, if current scenario continues and adequate steps are not taken to conserve water and whole city will face huge water crisis.

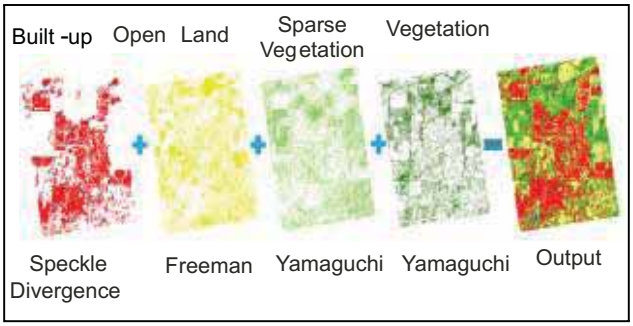


EPANET Simulation results

Complementary information extraction from Polarametric SAR data for Urban LULC

The urban land use/ land cover (LULC) information has very important role to play in land use planning, regulations and their optimal utilization. Generally, the spectral signature of urban classes have tendency to merge with several non-urban classes and prohibits their automated classification. Polarimetric SAR data minimizes the mixing of urban classes with nonurban classes.

Novel complementary information approach is proposed to improve urban LULC classification. The complementary information extraction technique combines data in such a way that open lands are from classified images of Freeman Decomposition, sparse vegetation and vegetation are from Yamaguchi decomposition and built-up information are taken from the speckle divergence image. Local speckle characteristics can provide a texture layer that highlights built-up areas.



Comparison of Accuracy Between Classified Images Through Different Approach				
	Pauli	**Freeman**	**Yamaguchi**	**Complimentary**
Overall Accuracy	62.5%	64.5%	79.1%	83.3%
Kappa Coefficient	0.55	0.575	0.75	0.8

Overall accuracy of this complimentary information approach showed better accuracy as compared to traditional methods. There is about 3% overall accuracy improvement as compared to other classified traditional methods. Overall accuracy of the classified image through complimentary information is 83.33% and kappa statistics is 0.80.

Evaluation of Cartosat-2E for Urban Area Mapping under AMRUT Programme

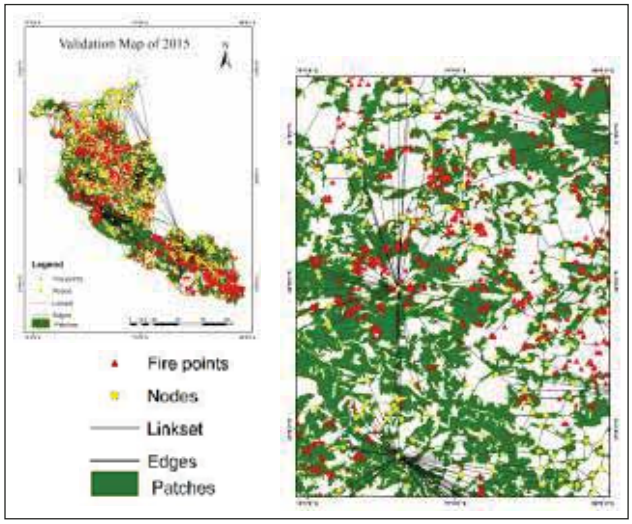
A very high resolution satellite data are crucial for various applications in urban areas such as in urban planning, infrastructure development and utility planning. Atal Mission for Rejuvenation and Urban Transformation (AMRUT) is a centrally sponsored scheme with the main objective of providing basic services to households and build amenities in cities. One of its sub-scheme is focussed on formulation of GIS based master plan. The present study has assessed the planimetric accuracy of the Cartosat 2E data for 1:4000 scale mapping and has subsequently evaluated the potential of imagery for AMRUT base layer and Urban LULC mapping. To achieve this objective, Cartosat- 2E images of Dehradun and Rishikesh cities were procured and a DGPS survey was conducted for the assessment of planimetric accuracy of the images. It is observed

Validation of Cartosat-2E data				
	Before Registration		**After Registration**	
	Dehradun	**Rishikesh**	**Dehradun**	**Rishikesh**
MAEy (m)	28.99	26.62	0.92	0.70
MAEx (m)	0.94	9.04	0.31	0.38
RMSE (m)	29.02	28.14	0.99	0.88
CE 90 (m)	69.66	67.55	2.39	2.11

that RMSE of Dehradun image is 29.02 m and of Rishikesh is 28.14 m which is very high and more than the planimetric accuracy requirement of 1 m (0.25mm of scale) at 1:4000 scale mapping. After registration of the image by using DGPS ground control point, RMSE error has come down to less than 1 m in both the areas. It necessitates the use of high accuracy ground control points for geometric correction of the imagery before it could be utilised for AMRUT mapping. Further, the AMRUT layers are also extracted from the data and it is observed that urban features can be extracted with ease except in unplanned high density and slum areas.

Forest Fire Spread Modelling

Forest fire is one of the major causes of degradation of forests in Himalayan region and is a regular feature every year causing large scale destruction of the forest ecosystems. In India, majority of fires are due to humans.



Generation of graphs for identification of potential paths for fire spread

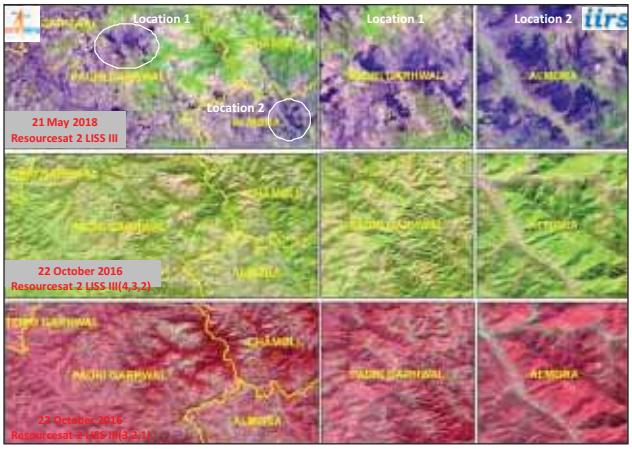
Complex network algorithm has been developed for fire spread and connectivity using graph theory. This method uses non-trivial topological features that do not occur in a simple lattice. Using a 300 meter planar graph the nodes, edges and patches were developed. On overlaying the actual fire locations, of MODIS and VIIRS, it was observed that the fire spread is along the edges generated.

Study on Forest Fire in Uttarakhand (May 2018)

Uttarakhand State, experienced widespread fires during 19-31 May 2018, which has affected a considerable area of forest in the state and has also resulted in the accumulation of smoke, aerosol, carbon monoxide and nitrous oxides in the region.

Satellite remote sensing has been used to monitor the active fires, burnt areas as well as the accumulation of aerosols and other gasses resulting from the forest fires. It has been estimated that more than 68,000 ha has been affected by fire, which in most of the cases has been ground fire and has not affected the forest canopy. The districts most affected by forest fires are Pauri and Tehri Garhwal, Almora, Nainital and Uttarkashi.

The spatial distribution of aerosol concentration due to forest fires in Uttarakhand could be seen from OceanSat and INSAT 3D. This is also collaborated from the ground based monitoring of the particulate matter mainly in the 2.5 and 10 μ range over Dehradun where it shows a peak of more than 2 times the normal range.

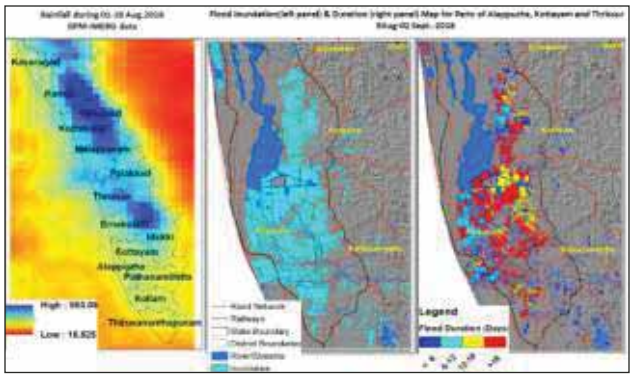


Use of SWIR band for burnt scar mapping and burnt area map of Uttarakhand on 26 May, 2018

A Study on Kerala Floods (2018)

The State of Kerala witnessed large scale flooding during August 2018, affecting millions of people and causing more than 400 deaths. In the present study historical (1951-2004) rainfall data and GPM IMERG Late precipitation data of August 2018, and multi-temporal (09, 21 & 27 Aug. and 02 Sept, 2018) Sentinel 1A and 1B SAR datasets are analyzed for analysis of Kerala floods. The historical analysis of rainfall data from IMD for last 65 years from 1951 to 2004 shows that the normal rainfall over Kerala is about 2845 mm. From the analysis of Aug. 2018 GPM IMERG data, it is observed that there were two spells (first spell 7 & 8 Aug., followed by second spell 14-16 Aug. 2018) of rainfall which affected the state of Kerala.

The extent of inundation was delineated by analyzing the backscattering coefficient (σ^0) of water applying thresholding technique. The inundation layer was then refined to extract the final flood layer which was the integrated with administrative boundaries for deriving the flood duration map and extracting inundation statistics.



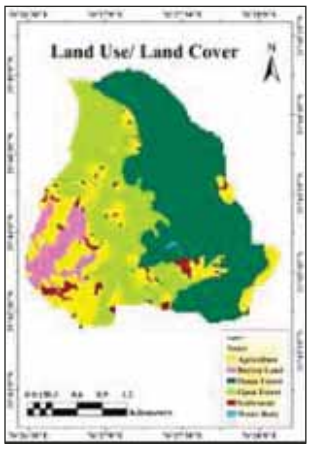
Rainfall over Kerala during 01-18 Aug.2018 (left), extent of cumulative inundation (centre) and flood duration (left) for Parts of Alappuzha, Kottayam and Thrissur districts during 9Aug-02 Sept.-2018

From the analysis it is observed that about 71,886 hectares of area was affected by flooding during 09 Aug., 2018 to 02 Sep., 2018 in parts of Kottayam, Alaphuza, Thrissur, Palakkad, Malappuram, Ernakulam and Kollam districts. On 21 August, 2018 maximum area of about 66,015 hectares was under inundation and there was a gradual decline subsequently in the inundated area. Alappuzha, Kottayam, Thrissur followed by Ernakulam were observed to be the worst affected districts. Low-lying areas especially in parts of Alappuzha, Kottayam and Thrissur districts were observed to be under flood inundation for more than three weeks.

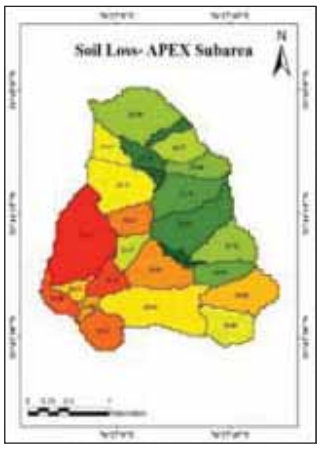
Modelling of surface runoff and sediment yield at watershed in Shiwalik region

The present study was carried out to estimate surface runoff and sediment yield using a process-based APEX (Agricultural Policy Environmental eXtender) model in a watershed (elevation 475 m to 785m) of Shiwalik region in Hamirpur district, Himachal Pradesh under EOAM Project. Land use/ land cover characteristics were extracted from Resourcesat-2 LISS-IV with ground observations. Cartosat DEM was used to delineate the watershed boundary and to identify terrain characteristics like slope, slope length and aspects. The surface runoff data from the watershed was collected using automatic pressure based water level recorder established at the trapezoidal flume structure and also sediment data from the sediment tank. This data was used for calibration and validation of the process based APEX watershed simulation model.

The APEX model was calibrated on a daily basis for 2017 and 2018. The model performed quite well for surface runoff (r2 - 0.92) and sediment yield (r2 - 0.88) with RMSE of 4.98mm and 0.20t ha^{-1} for surface runoff and sediment yield, respectively. The model was validated well for surface runoff (r2 - 0.80) and sediment yield (r2 - 0.80) with RMSE of 2.6mm and 0.11tha^{-1} for surface runoff and sediment yield, respectively. The model performance was evaluated by determining Nash- Sutcliffe efficiency (NSE) for surface runoff and sediment yield, with NSE of 0.71 and 0.70, respectively. Highest soil erosion rate was estimated from scrub land (38.42 t ha^{-1} yr^{-1}) followed by agriculture (26.97 t ha^{-1} yr^{-1}) then open forest (21.69 t ha^{-1} yr^{-1}) and lowest in the dense forest cover (14.70 t ha^{-1} yr^{-1}). It was observed that 64.61% of the study area was under moderate (10-20 t ha^{-1} yr^{-1}) erosion risk class. APEX model was helpful in determining the critical source area of soil erosion. Average annual soil loss was estimated by the model for each subarea representing critical source area in order to determine the critical area.



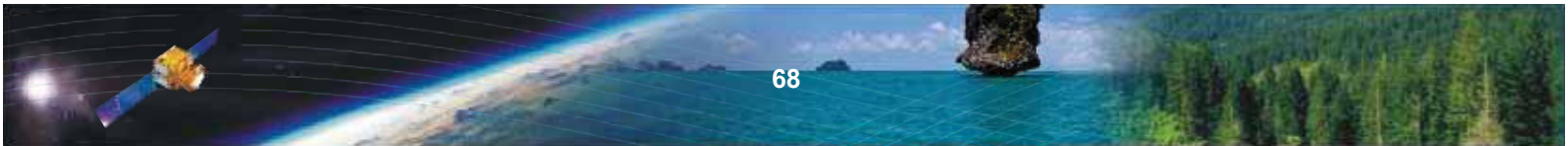
Land use / land cover types



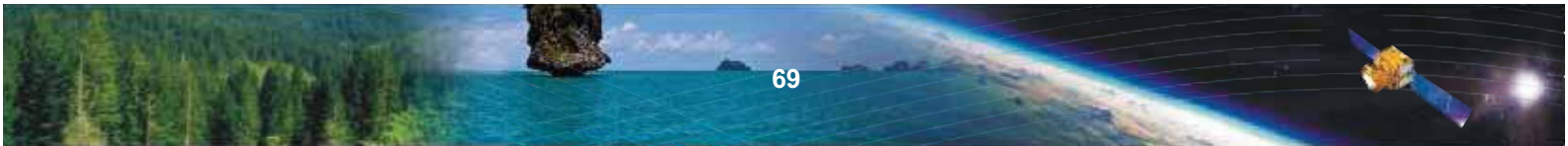
Soil erosion rate in sub-watershed

RESEARCH PUBLICATIONS

- AT.N. Dang, S. Nandy, R. Srinet, N.V. Luong, N.V., S. Ghosh and A.S.Kumar, "Forest above ground biomass estimation using machine learning regression algorithm in Yok Don National Park, Vietnam", Ecological Informatics, vol. 50, pp. 24-32, 2019.
- Chauhan S., Srivastava H.S., Patel P., "Wheat crop biophysical parameters retrieval using hybrid-polarized RISAT-1 SAR data", Remote sensing of environment, Vol. 216, pp. 28-43, 2018.
- Shukla G., Garg R.D., Srivastava H.S., Garg P.K., "An effective implementation and assessment of a random forest classifier as a soil spatial predictive model", International journal of remote sensing, Vol. 39, Issue 8, pp. 2637-2669, 2018.
- Shukla G., Garg R.D., Srivastava H.S., Garg P.K., "Using multi-source data and decision tree classification in mapping vegetation diversity", Spatial Information Research, DOI: 10.1007/s41324-018-0200-4, pp.1-13, 2018.
- Sivasankar T., Kumar D., Srivastava H.S., Patel P., "Advances in radar remote sensing of agricultural crops: a review", International Journal on Advanced Science, Engineering and Information Technology, Vol. 8, Issue 4, pp. 1126-1137, 2018.
- Sivasankar T., Kumar D., Srivastava H.S., Patel P., "Wheat leaf area index retrieval using RISAT-1 hybrid polarized SAR data", Geocarto International, pp. 1-11, 2019 doi.org/10.1080/10106049.2019.1566404.
- Sharma P.K., Kumar D., Srivastava H.S., Patel P., Sivasankar T., "Soil moisture retrieval under wheat crop using RISAT-1 hybrid polarimetric SAR data", Journal of Agrometeorology, Vol. 21, pp. 58-62, 2019.
- R. George, H. Padalia, S.K. Sinha and A.S. Kumar, "Evaluation of the use of Hyperspectral Vegetation Indices for Estimating Mangrove Leaf Area Index in Middle Andaman Island, India", Remote Sensing Letters, vol. 9, no. 11, pp. 1099-1108, 2018.
- S.P.S. Kushwaha, S. Nandy, M.A. Shah, R. Agarwal and S. Mukhopadhyay, "Forest cover monitoring and prediction in a Lesser Himalayan elephant landscape", Current Science, vol. 115, no. 3, pp. 510-516, 2018.
- Sharma P.K., Kumar D., Srivastava H.S., Patel P., "Assessment of Different Methods for Soil Moisture Estimation: A Review", Journal of Remote Sensing & GIS, ISSN: 2230-7990 (Online), ISSN: 2321-421X, Vol. 9, Issue 1, pp. 57-73, 2018.
- N. R. Patel, H. Padalia, R. Devadas, A. Huete, A.S. Kumar and Y.V.N. Krishna Murthy, "Estimating net primary productivity of croplands in Indo-Gangetic Plains using GOME-2 sun-induced fluorescence and MODIS NDVI", Current Science, vol. 114, no. 6, pp. 1333-1337, 2018.
- I.D. Rai, M. Bhardwaj, G. Talukdar, G.S. Rawat and S. Sathyakumar, "Large scale infestation of blue pine by Himalayan dwarf mistletoe in the Gangotri National Park, Western Himalaya", Tropical Ecology, vol. 59, no. 1, pp. 157-161, 2018.
- I.D. Rai, G. Singh and G.S. Rawat, "Anemone trullifolia and Berberisangulosa as new records to the flora of Western Himalaya", Journal of Threatened Taxa, vol. 10, no. 5, pp. 11679-11682, 2018.

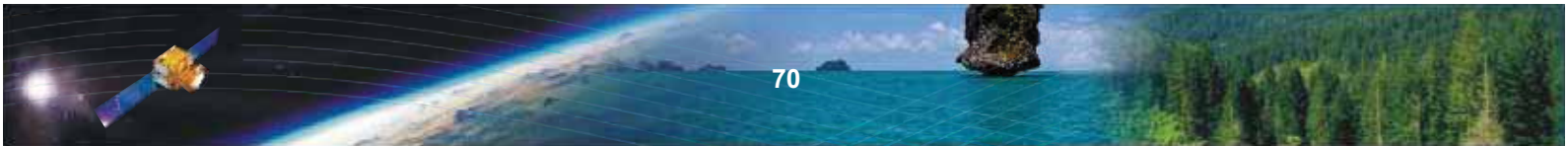


- G. Singh, M.S. Sarkar, A. Pandey, S. Lingwal, I.D. Rai, B.S. Adhikari, G.S Rawat and R.S. Rawal, "Quantifying four decades of changes in land use and land cover in India's Kailash Sacred Landscape: suggested option for priority based patch level future forest conservation", Journal of the Indian Society of Remote Sensing, vol. 46, no. 10, pp. 1625-1635, 2018.
- P. Singh, S. Saran, D. Kumar, H. Padalia, A. Srivastava and A.S. Kumar, "Species mapping using citizen science approach through IBIN portal: use case in foothills of Himalaya", Journal of the Indian Society of Remote Sensing, vol. 46, no. 10, pp. 1725-1737, 2018.
- V. Srivastava, V.C. Griess and H. Padalia, "Mapping invasion potential using ensemble modelling. A case study on Yushaniamaling in the Darjeeling Himalayas", Ecological Modelling, vol. 385, pp. 35-44, 2018.
- J.G. Kalambukattu, S. Kumar and R. Arya Raj, "Digital soil mapping in a Himalayan watershed using remote sensing and terrain parameters employing artificial neural network model", Environmental Earth Sciences, vol. 77(5), pp. 203, 2018.
- M. Sankar, S.M. Green, P.K. Mishra, J. T.C, Snöälv, N.K. Sharma, K. Karthikeyan, J. Somasundaram, D. M. Kadam, D. Dinesh, Suresh Kumar, V. KasthuriThilagam and T. A. Quine, "Nationwide soil erosion assessment in India using radioisotope tracers 137Cs and 210Pb: The need for fallout mapping", Current Science, vol. 115(3), pp. 388-390, 2018.
- H. Sahu, D. Haldar, A. Danodia, and S. Kumar, "Time series potential assessment for biophysical characterization of orchards and crops in a mixed scenario with Sentinel-1A SAR data", Geocarto International, 112, DOI:10.1080/10106049.2019.1583776, 2019.
- S. M. Shanmugapriya, D. Haldar, and A. Danodia, "Optimal Datasets Suitability for Pearl Millet (Bajra) Discrimination using Multiparametric SAR Data". Geocarto International, 114. https://doi.org/ 10.1080/ 10106049. 2019. 1585485, 2019
- D. Haldar, V. Dave, A. Misra, and B. Bhattacharya, "Radar Vegetation Index for assessing cotton crop condition using RISAT-1 data". GeocartoInternational.https://doi.org/ 10.1080/10106049.2018.1516249, 2018.
- D. Haldar, R. Dave, and V.A. Dave, "Evaluation of full-polarimetric parameters for vegetation monitoring in rabi (winter) season", Egyptian Journal of Remote Sensing and Space Science, vol. 21, pp. S67S73. https:// doi.org/10.1016/ j.ejrs.2018.05.002, 2018.
- S. Chirakkal, D. Haldar, and A. Misra, "A knowledge-based approach for discriminating multi-crop scenarios using multi-temporal polarimetric SAR parameters", International Journal of Remote Sensing, vol. 40(10), pp. 40024018, https://doi.org/10.1080/01431161. 2018.1558304, 2019.
- P. Tripathi, N.R. Patel, and S.P.S. Kushwaha, "Estimating net primary productivity in tropical forest plantations in India using satellite-driven ecosystem model", Geocarto International, vol. 33(9), pp. 988999. https://doi.org/10.1080/ 10106049.2017. 1323963, 2018.
- J.G. Kalambukattu, S. Kumar, and Y.S. Ghotekar, "Spatial variability analysis of soil quality parameters in a watershed of Sub-Himalayan Landscape - A case study". Eurasian Journal of Soil Science vol. 7(3), pp. 238, 250.https://doi.org/10.18393/ejss. 427189, 201
- B.R. Parida, S.N. Behera, B. Oinam, N.R. Patel, and R.N. Sahoo, "Investigating the effects of episodic Super-cyclone 1999 and Phailin 2013 on hydro-meteorological parameters and agriculture: An application of remote sensing", Remote Sensing Applications: Society and Environment, vol. 10, pp. 128137. https://doi.org/10.1016/j.rsase. 2018.03.010, 2018.
- N. R. Patel, H. Padalia, R. Devadas, A. Huete, A.S. Kumar and Y.V.N. Krishna Murthy, "Estimating net primary productivity of croplands in Indo-Gangetic Plains using GOME-2 sun-induced fluorescence and



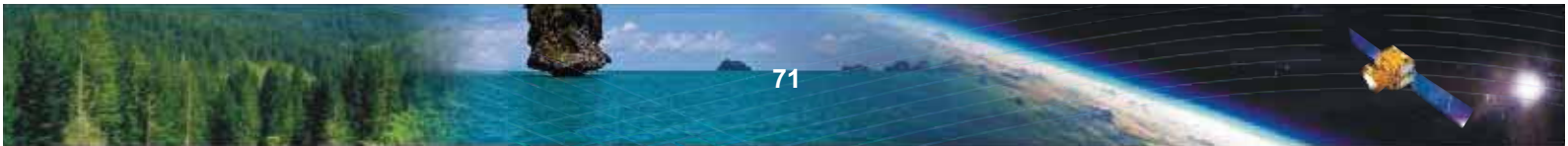
MODIS NDVI", Current Science, vol. 114, no. 6, pp. 1333-1337, 2018.

- R.N. Sahu, and N.R. Patel, "Drought assessment using satellite based vegetation condition index and rainfall anomaly index over Bundelkhand region, India". International Journal of Advance Research and Innovative Ideas in Education, vol. 4(4), pp. 257-264, 2018.
- A. Kundu, D.M. Denis, N.R. Patel, and D. Dutta, "A Geo-spatial study for analysing temporal responses of NDVI to rainfall" Singapore Journal of Tropical Geography, vol. 39(1), pp. 107116. https://doi.org/10.1111/sjtg.12217, 2018.
- S. M. Kirthiga, and N.R. Patel, "Impact of updating land surface data on micrometeorological weather simulations from the WRF model", Atmosfera, vol. 31(2), pp.165183, https:// doi.org/10.20937/ATM. 2018.31.02.05, 2018.
- G. Sharma, S. Mohanty, P. K. Champati Ray, Somorjit M. Singh, K. K. Sarma and P. L. N. Raju, (2018), "Total electron content and epicentral distance of 2015 Mw 7.8 Nepal earthquake revealed by continuous observations data," Current Science, Vol. 115, No. 1, pp 27-29,10 July 2018.
- G. Sharma, P. K. Champati ray and S. Mohanty, (2018), "Morphotectonic analysis and GNSS observations for assessment of relative tectonic activity in Alaknanda basin of Garhwal Himalaya, India," Geomorphology, vol.301, no., pp. 108-120.
- M. S. Alam, D. Kumar, R. S. Chatterjee and V. Upreti (2018), "Assessment of land surface subsidence due to underground metal mining using integrated spaceborne repeat-pass differential interferometric synthetic aperture radar (DInSAR) technique and ground based observations," Journal of the Indian Society of Remote Sensing, https://doi.org/10.1007/s12524-018-0810-2
- J. Dubey, S. N. Ali, A. Sharma, P. Morthekai, R. Singh, R. K. Sharma, P. Pandey, B. Thakur and V. Srivastava, (2019), "Glacial Geomorphology and Landscape Evolution of Thangu Valley, North Sikkim Himalaya, India," Journal of the Indian Society of Remote Sensing. https://doi.org/10.1007/s12524-019-00943-5.
- S. L. Chattoraj, P. K. Champati ray, S. Pardeshi, V. Gupta and Y. Ketholia (2018), "3-Dimensional modelling of 2014-Malin Landslide, Maharashtra using satellite-derived data: A quantitative approach to numerical simulation technique," NHESS: https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2017-382/nhess-2017-382.pdf.
- V. Kumar, V. Gupta, I. Jamir and S. L. Chattoraj (2018), "Evaluation of potential landslide damming: Case study of Urni landslide, Kinnaur, Satluj valley, India," Geoscience Frontier, Science Direct: https://www.sciencedirect.com/science/article/pii/S1674987118301063.
- A. Jhaldiyal, K. Gupta, Thakur, P.K. and Kumar, P., 2018. Urban Morphology Extractor: A spatial tool for characterizing urban morphology. Urban climate, 24, pp.237-246.
- V. Kumar, Mohan, A., Agarwal, S. and Siddiqui, A., 2018. Evaluating the Close Range Hyperspectral Data for Feature Identification and Mapping. Journal of the Indian Society of Remote Sensing, pp.1-8.
- Siddiqui, A., Siddiqui, A., Maithani, S., Jha, A.K., Kumar, P. and Srivastav, S.K., 2018. Urban growth dynamics of an Indian metropolitan using CA Markov and Logistic Regression. The Egyptian Journal of Remote Sensing and Space Science, 21(3), pp.229-236.
- S. K. Jally, A. K. Mishra, and S. Balabantaray, "Estimation of Trophic State Index of Chilika Lake using Landsat-8 OLI and LISS-III satellite data," Geocarto International, https://doi.org/10.1080/10106049.2018.1533593, 2019.
- S. Budakoti, C. Singh, and P. K. Pal, "Assessment of various cumulus



parameterization schemes for the simulation of very heavy rainfall event based on optimal ensemble approach," Atmospheric Research, vol. 218, pp. 195206, 2019.

- C. J. Johny, S. K. Singh, and V. S. Prasad, "Validation and Impact of SCATSAT-1 Scatterometer Winds," Pure and Applied Geophysics, vol. 176, no. 6, pp. 26592678, 2019.
- A. Chanda, S. Das, A. Mukhopadhyay, A. Ghosh, A. Akhand, P. Ghosh, T. Ghosh, D. Mitra, and S. Hazra, "Sea surface temperature and rainfall anomaly over the Bay of Bengal during the El Niño-Southern Oscillation and the extreme Indian Ocean Dipole events between 2002 and 2016," Remote Sensing Applications: Society and Environment. vol. 12, no. 11, pp. 10-22, 2018.
- K. Gupta, A. Mukhopadhyay, S. Giri, D. Mitra, and S. Hazra, "An index for discrimination of mangroves from non-mangroves using LANDSAT 8 OLI imagery," MethodsX 5, pp. 1129-1139, 2018.
- C. Singh, D. Ganguly, and S. K. Dash, "On the dust load and rainfall relationship in South Asia: an analysis from CMIP5," Climate Dynamics, vol. 50, pp. 403-422, 2018.
- A. K. Mishra, T. Banerjee, Y. Kant, and D. S. Shaik, "Retrieval of Aerosol Optical Depth Over Land at 0.490 µm from Oceansat-2 data" Journal of the Indian Society of Remote Sensing, vol 46 (5), pp. 761-769, 2018.
- A. Roy, and P. Rathore, "Land-use dynamics in Corbett National Park, Uttarakhand, India using CA-Markov and agent-based LULC-SaarS model", Current Science, 115(1), 136-140, 2018.
- R. Kala, D. Bhavsar, A. Kumar, A. and L. Rawat, "Quantification of potential area of incursion of pine in oak forest in western Himalaya using fuzzy classification technique", Journal of Applied Remote Sensing, 12(02), doi: 10.1117/1.JRS.12.026032, 2018
- S. Gupta, A. Roy, D. Bhavsar, R. Kala, S. Singh and A.S. Kumar, "Forest Fire Burnt Area Assessment in the Biodiversity Rich Regions Using Geospatial Technology: Uttarakhand Forest Fire Event 2016", Journal of the Indian Society of Remote Sensing https://doi.org/10.1007/s12524-018-0757-3, 2018
- P. Rathore, A. Roy, H. Karnatak,"Assessing the vulnerability of Oak (Quercus) forest ecosystems under projected climate and land use land cover changes in Western Himalaya", Biodiversity and Conservation, 28 (8-9), 2275-2294, DOI: 10.1007/s10531-018-1679-7, 2018
- Saran, S., Oberai, K., Wate, P., Konde, A., Dutta, A., Kumar, K. and Kumar, A.S., 2018. Utilities of virtual 3D city models based on CityGML: Various use cases. Journal of the Indian Society of Remote Sensing, 46(6), pp.957-972.
- Agarwal, N., Koti, S.R., Saran, S. and Kumar, A.S., 2018. Data mining techniques for predicting dengue outbreak in geospatial domain using weather parameters for New Delhi, India. CURRENT SCIENCE, 114(11), pp.2281-2291.
- Singh, P., Kumar, D. and Saran, S., 2018. Interoperable framework for improving data quality using semantic approach: use case on biodiversity. Environmental Sustainability, 1(4), pp.367-381.
- Singh, H., Verma, P.A. and Saran, S., 2019. Qalitative assessment of geostatistical and non-geostatistical fusion techniques: a case study on landsat 8 images. Spatial Information Research, 27(3), pp.275-283.
- A. Danodia, N. R. Patel, C. W. Chol, B.R. Nikam, and V. K. Sehgal, "Application of S-SEBI model for crop evapotranspiration using Landsat-8 data over parts of North India," Geocarto Int., vol. 34, no. 1, pp. 114131, 2019.
- B. R. Nikam et al., "Analyzing future water availability and hydrological extremes in the Krishna basin under changing climatic conditions," Arab. J. Geosci., vol. 11, no. 19, 2018.



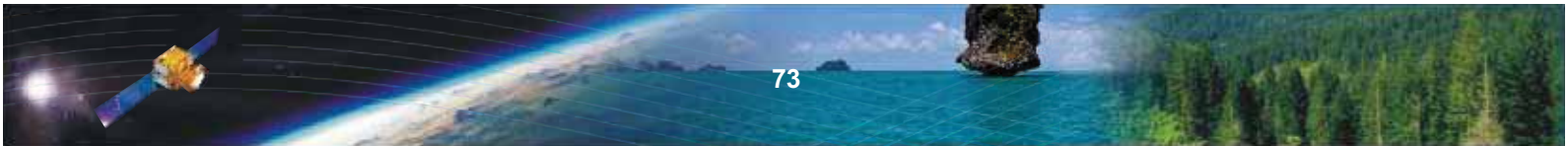
Research Publications

- C. D. Mishra, R. K. Jaiswal, A. K. Nema, V. K. Chandola, and A. Chouksey, "Priority Assessment of Sub-watershed Based on Optimum Number of Parameters Using Fuzzy-AHP Decision Support System in the Environment of RS and GIS," J. Indian Soc. Remote Sens., vol. 47, no. 4, pp. 603617, 2019.
- P. Das, M. D. Behera, N. Patidar, B. Sahoo, P. Tripathi, P.R. Behera, S. K. Srivastava, P. S. Roy, P. K. Thakur, S. P. Agrawal, and Y. V. N. Krishnamurthy, "Impact of LULC change on the runoff, base flow and evapotranspiration dynamics in eastern Indian river basins during 19852005 using variable infiltration capacity approach," J. Earth Syst. Sci., vol. 127, 2018.
- R. Foteh, V. Garg, B. R. Nikam, M. Y. Khadatare, S. P. Aggarwal, and A. S. Kumar, "Reservoir Sedimentation Assessment Through Remote Sensing and Hydrological Modelling," J. Indian Soc. Remote Sens., vol. 46, no. 11, pp. 18931905, 2018.
- R. Krishan, D. Khare, B. R. Nikam and A. Chandrakar, "Impact of Climate Shift on Rainfall and Temperature Trend in Eastern Ganga Canal Command," Int. J. of Environmental and Ecological Engineerin vol. 12, no. 8, pp. 553562, 2018.
- S. Chander, A. Gujrati, K.A. Hakeem, V. Garg, A.M. Issac, P.R. Dhote, V. Kumar and A. Sahay, "Water quality assessment of River Ganga and Chilika lagoon using AVIRIS-NG hyperspectral data," Curr. Sci., vol. 116, no. 7, pp. 11721181, 2019.
- S. K. Singh, G. Jain, A. Siddiqui, S. Naik, B.P. Rathore, V. Garg, Snehmani, V. Kumar, I. M. Bahuguna, S. A. Sharma, C. Shekhar, P. K. Thakur, K. Mishra, P. Kumar, T. H. Painter, and J. Dozier, "Characterization and retrieval of snow and urban land cover parameters using hyperspectral imaging," Curr. Sci., vol. 116, no. 7, pp. 11821195, 2019.
- S. S. Behera, B. R. Nikam, M. S. Babel, V. Garg, and S.P. Aggarwal, "The Assimilation of Remote Sensing-Derived Soil Moisture Data into a Hydrological Model for the Mahanadi Basin, India," J. Indian Soc. Remote Sens., vol. 2, 2019.
- Sundriyal S, Shridhar V., Madhwal, Pandey and K., Sharma V.,(2018), "Impacts of tourism development on the physical environment of Mussoorie, a hill station in the lower Himalayan range of India", J. Mt. Sci. (2018) 15(10): 2276-2291. DOI: 10.1007/s11629-017-4786-0
- Pandey S., Upadhyay R.K. and Pandey K. (2018), "Impact of Anthropogenic Activities onLand Use Pattern in Pathri Reserve Forest, Haridwar as Monitoredby Remote Sensing and GIS Techniques", Indian Journal of Fertilisers, Vol. 14 (8), pp.66-71.
- Pandey K., Mitra D., Maithani S, Karnatak H.C. (2018), "Urban Growth Modelling Using Cellular Automata Markov (CA-Markov) Technique", Journal of Applied Mathematics and Computation, 2(5), 178-187. DOI: 10.26855/jamc.2018.05.002
- Giribabu D., Pandey K., Rao K.R.M, Maithani S., Karnatak H.C. (2018) Cybersecurity in WebGIS Environment. International Journal of Computer and Internet Security. ISSN 0974-2247 Volume 10, Number 1 (2018), pp. 11-34.
- Singh, H., Garg, R.D., Karnatak, H.C., (2019) "Online image classification and analysis using OGC web processing service", Earth Science Informatics, Springer Berlin Heidelberg, DOI:/10.1007/s12145-019-00378-z Print ISSN 1865-0473 Online ISSN 1865-0481, pp-1-11
- Rajaram G., Karnatak H.C., Venkatraman S., Manjula K. R. and Krithivasa K., (2018) "A novel Computational Knowledge-Base Framework for visualization and quantification of Geospatial Metadata in Spatial Data Infrastructures", Geoinformtica, Springer Science Publication, DOI: 10.1007/s10707-018-0317-6.

BOOK CHAPTERS:

- S. Nandy, S. Ghosh, S.P.S. Kushwaha and A.S. Kumar, "Remote sensing-based forest biomass assessment in northwest Himalayan landscape", Remote Sensing of Northwest Himalayan Ecosystems, Singapore: Springer, pp 285-311, 2019.

- S. Nandy, S.P.S. Kushwaha and R. Srinet, "Wildlife habitat evaluation in mountainous landscapes","Remote Sensing of Northwest Himalayan Ecosystems", Singapore: Springer, pp. 341-352, 2019.
- N.R. Patel, H. Padalia, S.P.S. Kushwaha, S. Nandy, T. Watham, J. Ahongshangbam, R. Kumar, V.K. Dadhwal and A.S. Kumar, "CO2 flux tower and remote sensing: Tools for monitoring carbon exchange over ecosystem scale in north-west Himalaya", Remote Sensing of Northwest Himalayan Ecosystems, Singapore: Springer, pp. 313-327, 2019.
- S. Ghosh, S. Nandy, D. Chakraborty and R. Kumar, "Assessment of flood-emanated impediments to Kaziranga National Park grassland ecosystem A binocular vision with remote sensing and geographic information system", Geospatial Applications for Natural Resources Management, USA: CRC Press, pp. 275-290, 2018.
- S. Kumar, "Remote Sensing for Land Resource Monitoring and Management". In: Reddy G., Singh S. (eds) Geospatial Technologies in Land Resources Mapping, Monitoring and Management. Geotechnologies and the Environment, Vol 21. Springer.
- S.L. Chattoraj, P. K. Champati Ray and S. Kannaujiya (2018), "Simulation Outputs of Major Debris Flows in Garhwal Himalaya: A Geotechnical Modeling Approach for Hazard Mitigation", Remote Sensing of Northwest Himalayan Ecosystems, Springer, Singapore, pp 37-56. DOI: https://doi.org/10.1007/978-981-13-2128-3_3.
- G. Sharma, P.K. Champati ray and S. Kannaujiya (2018), "TEC modelling for earthquake precursor studies in western Himalaya using GNSS data", Remote Sensing of Northwest Himalayan Ecosystems, Springer, Singapore, pp 57-66. DOI: https://doi.org/10.1007/978-981-13-2128-3_4.
- R. S. Chatterjee, S. Nath and S. Gaurav (2019), "Morphotectonic analysis of the Himalayan Frontal Region of Northwest Himalaya in the light of geomorphic signatures of active tectonics", Remote Sensing of Northwestern Himalayan Ecosystems, Springer, Singapore, pp. 17-35.
- A. Siddqui, K.K. Kakkar, SuvankarHalder, Pramod Kumar, 2018. Smart Chandigarh Tri-City Region: Spatial Strategies of Transformation, Smart Metropolitan Regional Development: Economic and Spatial Design Strategies, Springer, DOI: 10.1007/978-981-10-8588-8_7.
- P. Kumar, A. Siddiqui, K. Gupta, Sadhana Jain, B.D. Bharath, Sandeep Maithani, 2019. Understanding Urban Environment in Northwest Himalaya: Role of Geospatial Technology, Remote Sensing of Northwest Himalayan Ecosystems, Springer, DOI: 10.1007/978-981-13-2128-3_19.
- SandeepMaithani, Kshama Gupta, Asfa Siddiqui, Arifa Begum, AniruddhaDeshmukh, Pramod Kumar, 2019. Urban Settlement Pattern and Growth Dynamics in Northwest Himalaya, Remote Sensing of Northwest Himalayan Ecosystems, Springer, DOI: 10.1007/978-981-13-2128-3_20.
- S. P. Aggarwal, V. Garg, P. K. Thakur and B. R. Nikam, "Hydrological Modelling in North Western Himalaya," in Remote Sensing of Northwest Himalayan Ecosystems, Springer, 2018, ch.9 (eBook ISBN:978-981-13-2128-3, DOI:10.1007/978-981-13-2128-3).
- P. K. Thakur, S. P. Aggarwal, P. Dhote, B. R. Nikam, V. Garg, C. M. Bhatt, A. Chouksey and A. Jha, "Hydrometeorological Hazards Mapping, Monitoring and Modelling," in Remote Sensing of Northwest Himalayan Ecosystems, Springer, 2018, ch.7 (eBook ISBN:978-981-13-2128-3, DOI:10.1007/978-981-13-2128-3).
- D. Mitra, A. Mukhopadhyaya, A. Chandra, and S. Hazra, "Landslide Risk Assessment in Darjeeling Hills using multi-criteria Decision Support System: A Bayesian Network Approach," Disaster Risk Governance in India and Cross Cutting Issues, Springer Publication, ISBN: 978-981-10-3309-4, pp. 361-386, 2018.
- Y. Kant, A. Saiful, and D. Mitra, "Analyzing the influence of urban growth on thermal environment through demographic, environmental and physical parameters in

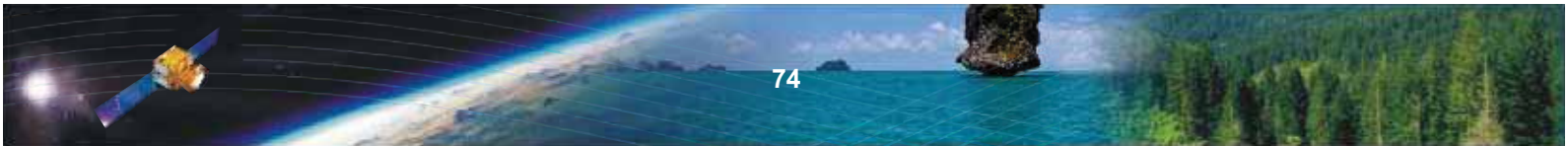


Bangladesh," Land-Atmospheric Research Applications in South and Southeast Asia, Springer, ISBN: 978-3-319-67473-5, pp. 613-639, 2018.

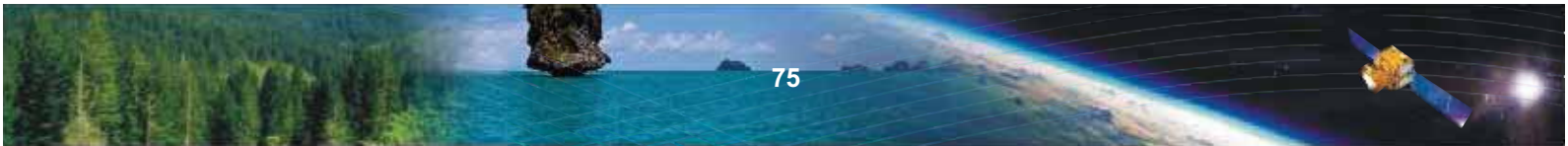
- A. Mhawish, M. Kumar, A. K. Mishra, P. K. Srivastava, and T. Banerjee, "Remote Sensing of Aerosols From Space: Retrieval of Properties and Applications," Chapter-3, 2018, Remote Sensing of Aerosols, Clouds, and Precipitation, Elsevier Inc., pp. 45-83, 2018
- S. Srivastava, I. Nandi, Y. Yarragunta and A. S. Kumar, "Carbon Monoxide Plume over Northwestern Himalaya: A Remote Sensing and Modeling Approach" Remote Sensing of Northwest Himalayan Ecosystems. Springer, ISBN 978-981-13-2128-3, pp. 329-340, 2018.
- C. Singh and V. Bharti, "Rainfall Characteristics over the Northwest Himalayan Region", Remote Sensing of Northwest Himalayan Ecosystems (Chapter -8). Springer, ISBN 978-981-13-2128-3, pp. 171-194, 2018.
- C. Singh, D. Ganguly, S. K. Dash, "Investigation of the relationship between natural aerosols and Indian summer monsoon rainfall using a climate model," Climate Change Impacts, Water Sci. Technol. Library, Springer, Springer, Singapore, ISBN-978-981-10-5713-7, vol. 82, pp. 137-143, 2018.
- P. Chauhan, A. K. Mishra, R. B. Singh, A. Sahay, N. Sanwlani, M. Raman, "Ocean's Colour from Space: Images from Oceansat OCM sensor", Atlas, Ed. Indian Institute of Remote Sensing, Dehradun, 2018.

CONFERENCE PUBLICATIONS:

- A. S. Dini Das, S. Kumar, A. Babu, and P. K. Thakur, "INSAR coherence and polarimetric parameters based characterization of flooded area -case study of a natural world heritage site kaziranga national park," ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 4, no. 5, pp. 265272, 2018.
- Srivastava H.S., Sivasankar T., "Potential of C-Band Hybrid Polarimetric RISAT-1 SAR Data for Wheat Crop Height Estimation", The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-3/W6, 2019 ISPRS-GEOGLAM-ISRS Joint Int. Workshop on "Earth Observations for Agricultural Monitoring", 1820 February 2019, New Delhi, India, Vol. 42, Issue 3/W6, pp. 637-641, 2019.
- Srivastava H.S., Sivasankar T., Patel P., "An Insight Into The Volume Component Generated From RISAT-1 Hybrid Polarimetric SAR Data for Crop Biophysical Parameters Retrieval", ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Pages 209-214, Publisher https://doi.org/10.5194/ isprs-annals-IV-5, pp. 209-214, 2018.
- Srivastava H.S., Sivasankar T., Patel P., The Sensitivity Of C-Band Hybrid Polarimetric RISAT-1 SAR Data to Leaf Area Index of Paddy Crop, ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Pages 215-222, Publisher https://doi.org/10.5194/isprs-annals-IV-5, pp. 215-222, 2018.
- A. S. Kumar and S. P. Aggarwal, "Cross border education in geoinformation technologies and applications in Asia and the pacific -A CSSTEAP experience," ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 4, no. 5, pp. 711, 2018.
- Shukla G., Garg R.D., Srivastava H.S., Garg P.K., "Evaluation of Covariates to Understand the Interactive Feedback between Soil-Landscape Parameter and Changes of Soil-Climatic Conditions", IGARSS 2018 - 2018 IEEE International Geoscience and Remote Sensing Symposium, DOI: 10.1109/IGARSS.2018.8518348, 9074-9077.
- A. K. Rastogi et al., "Integrated Flood Study of Bagmati River Basin With Hydro processing, flood inundation mapping & 1-D hydrodynamic modeling using Remote Sensing and GIS," ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 4, pp. 2023, November, 2018.
- A. Roy et al., "Intercomparison of different rainfall products and validation of WRF modelled rainfall estimation in N-W Himalaya during monsoon period," ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 4, no. 5, pp. 351358, 2018.

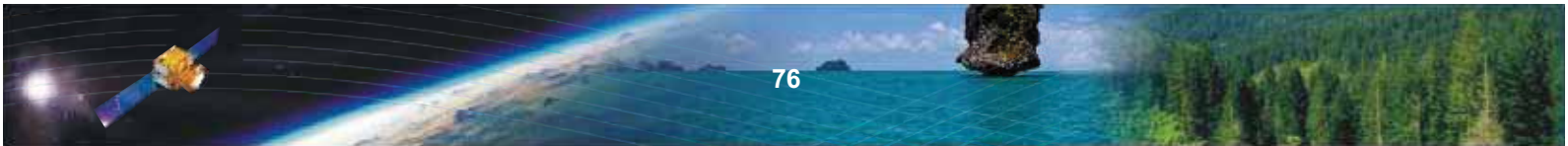


- K. Sethia, P. Pandey, S.L. Chattoraj, S. Manickam and P.K. Champati ray (2018), "Mapping, modeling and simulation of snow avalanche in Alaknanda valley, Central Himalaya: Hazard Assessment," IGARSS 2018, IEEE, pp. 5150-5153, DOI: 978-1-5386-7150-4/18/.
- A. S. Kumar, H. Ferrera, S. P. Aggarwal, and E. C. Wood, "Webinar based crossborder training initiative by CEOS WGCapD on SAR and disasters: Achievements and lessons learnt," ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 4, no. 5, pp. 6570, 2018.
- C. Nanda, Y. Kant, A. Gupta, and D. Mitra, "Spatio-temporal distribution of pollutant trace gases during diwali over India," ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., vol. IV-5, pp. 339-350, 2018.
- Y. Yarragunta, S. Srivastava, D. Mitra, and H. C. Chandola, "Seasonal and spatial variability of ozone inferred from global chemistry transport model simulations over India," ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. IV-5, pp. 375-381, 2018.
- S. Gaurav, and P. Jindal, "Radiative transfer model simulations to determine the night time fog detection threshold," Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., vol. XLII-5, 511-517, 2018.
- D. S. Shaik, Y. Kant, D. Mitra, H. C. Chandola, and S. S. Babu, "Long-term variability of MODIS 3km aerosol optical depth over Indian region," ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., vol. IV-5, pp. 359-366, 2018.
- B. N. Shashikumar, V. Garg, and B. R. Nikam, "Analytical hierarchy process for identification of suitable water harvesting site in geospatial environment," ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 4, no. 5, pp. 189196, 2018.
- D. Varshney, P. K. Gupta, C. Persello, and B. R. Nikam, "Snow and cloud discrimination using convolutional neural networks," ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 4, no. 5, pp. 5963, 2018.
- D. K. Singh, P. K. Thakur, B. P. Naithani, and S. Kaushik, "Temporal monitoring of glacier change in dhauliganga basin, kumaunhimalaya using geo-spatial techniques," ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 4, no. 5, pp. 203207, 2018.
- K. Bordoloi, B. R. Nikam, and S. K. Srivastav, "Assessment of River Bank Erosion of Subansiri River, Assam using Geospatial Techniques," 40th Indian Geographical Congress on Climate Variability, Vulnerability and Resource Management Strategies for Sustainable Development and Geospatial Technologies, Organised by NAGI, October 29-31, 2018.
- M. Muhammed, J. T. Shar, M. O. Odekunle, A. M. Touraki, and P. R. Dhote, "Flood Inundation Mapping Around Lokoja Confluence Area, Kogi State, Nigeria," 1st International Civil Engineering Conference (ICEC 2018), Department of Civil Engineering, Federal University of Technology, Minna, Nigeria, November.7-9, pp. 83-89, 2018.
- N. R. Prasad, V. Garg, and P. K. Thakur, "Role of sar data in water body mapping and reservoir sedimentation assessment," ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 4, no. 5, pp. 151158, 2018.
- P. V. Aswathi, B. R. Nikam, A. Chouksey, and S. P. Aggarwal, "Assessment and monitoring of agricultural droughts in Maharashtra using meteorological and remote sensing based indices," ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 4, no. 5, pp. 253264, 2018.
- P. R. Dhote et al., "Experimental flood early warning system in parts of Beas Basin using integration of weather forecasting, hydrological and hydrodynamic models," Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch., vol. 42, no. 5, pp. 221225, 2018.
- P. K. Thakur, S. P. Aggarwal, B. R. Nikam, V. Garg, A. Chouksey, and P. R. Dhote, "Training, education, research and capacity building needs and future requirements in applications of geospatial technology for water resources management," Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch., vol. 42, no. 5, pp. 2936, 2018.
- P. K. Thakur et al., "Indian Inland water and parts of antarctic ice sheet elevation and ice



sheet velocity monitoring using altimetry and SAR based datasets," Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch., vol. 42, no. 5, pp. 367373, 2018.

- P. K. Thakur et al., "Snow Cover and Glacier Dynamics Study Using C-AND L-BAND SAR Datasets in Parts of North West Himalaya," Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch., vol. 42, no. 5, pp. 37582, 2018.
- S. Kaushik, P. R. Dhote, P. K. Thakur, and S. P. Aggarwal, "Assessing the impact of canal network on surface waterlogging using remote sensing datasets in Rohtak District, Haryana," Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch., vol. 42, no. 5, pp. 261266, 2018.
- S. Singh et al., "Estimation of Revised Capacity in GobindSagar Reservoir Using Google Earth Engine and Gis," ISPRS - Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 42, no.5, pp. 589595, November, 2018.
- Bhavana, M., Gupta, K. and Pal, P.K., 2018. Urban Micro Climate Modelling Using Different Urban Physics Schemes and High Resolution LULC with WRF Model. International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences, 45, pp.491-498.
- Bhavana, M., Gupta, K., Pal Pradip, K., Kumar, A.S. and Gummapu, J., 2018. Evaluation of High Resolution Urban LULC for Seasonal Forecasts of Urban Climate Using WRF Model. ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences, 45, pp.303-310.
- Jaiswal, A.K., Satheesh T.A., Pandey, K., Kumar, P. and Saran, S., 2018. Geospatial Multi-Criteria Decision Based Site Suitability Analysis for Solid Waste Disposal Using TOPSIS Algorithm. ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences, 45, pp.431-438.
- Mishra, K., Siddiqui, A. and Kumar, V., 2018. A Comparative Assessment of Efficacy of Super Resolved Airborne Hyperspectral Outputs in Urban Material and Land Cover Information Extraction. International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences, Volume XLII-5, 2018, Dehradun, India, DOI: 10.5194/isprs-archives-XLII-5-653-2018.
- Shrivastava, V., Jaiswal, A., Thakur, P.K., Agarwal, S.P., Kumar, P., Kota, G.K., Carrera, D., Dhasmana, M.K., Sharma, V. and Singh, S., 2018. Application of GIS for the Design of Potable Water Distribution System in IIRS. ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences, 45, pp.87-94.
- Sett, T., Nikam, B.R., Nandy, S., Danodia, A., Bhattacharjee, R., & Dugesar, V. Estimation of instantaneous evapotranspiration using remote sensing based energy balance technique over parts of north India. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-5, 2018, pp. 345-352.
- U. Asopa, S. Kumar, and P. K. Thakur, "PSInSAR Study of Lyngenfjord Norway, using TerraSAR-X Data," ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 4, no. 5, pp. 245251, 2018.
- V. Sharma et al., "Seasonal Comparison of Era-Interim Precipitation Dataset for Entire Indian Region," ISPRS - Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci., vol.42, no.5, pp. 567573, November, 2018.
- V. Shrivastava et al., "Application of GIS for the design of potable water distribution system in IIRS," ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 4, no. 5, pp. 8794, 2018.
- V. Singh, P. K. Thakur, V. Garg, and S. P. Aggarwal, "Assessment of Snow Avalanche Susceptibility of Road Network - a Case Study of Alaknanda Basin," ISPRS - Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 42, no.5, pp. 461468, November, 2018.
- V. Garg, B. R. Nikam, P. K. Thakur, S. P. Aggarwal and P. Dhote, "Importance of incorporation of geospatial technology applications in water resources at graduate and post-graduate courses of civil engineering," Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.- ISPRS Arch., vol. 42, no.5, pp. 2023, November, 2018.



MAJOR EVENTS

IIRS Academia Meet (IAM) - 2019

IAM-2019 on theme 'Capacity Building in Geospatial: Requirements, Challenges and Opportunities' was held on March 14, 2019 at IIRS. Besides faculty & staff from IIRS there were more than 180 registered participants from various academic institutions, industries, government departments, JRFs, Students & Edusat-users from all over India.

Dr. Prakash Chauhan, Director, IIRS gave the introductory remarks during the inaugural session of the Meet, which was followed by the addresses of Chief Guest and Guest of Honours. An interactive-session and panel discussions were held with senior delegates from Academia and Industries to dwell upon the future activities of Institute on enhancing capacity-building activities and aligning them with the developmental programmes of the Government for meeting the diversified needs of the country. Outreach feedback session was organised as part of IAM-2019. The placement brochure 2019 was also released on this occasions.

An exhibition by M.Tech. & M.Sc students for showcasing the departmental activities was also organized for benefit of academia and industries highlighting training opportunities and research initiatives of IIRS students. Technical, plenary & panel discussions were organized.

The meet was followed by a workshop on 'IRNSS and GNSS based observations for Crustal Deformation, Weather and Soil moisture studies on March 15, 2019. Feedback for IIRS-DLP was also organised on March 15, 2019 wherein 81 participants attended the session.

The major recommendations of the IAM-2019 were:

- Formulation of comprehensive strategies on capacity building programmes of long-term courses, combination of specialized short-term customized courses, enriching academic interfaces and blended with vibrant out-reach programmes including e-learning.
- Enhancing institute's capacity building activities and aligning them with the developmental programmes of the Government for meeting the diversified needs of country.
- Promote web-enabled (e-learning) modular courses with virtual classrooms and labs for faster off-campus turn-out, and establish linkages with national, foreign universities/ institutes experts in order to enhance the outreach activities.
- Strengthening EDUSAT-based distance learning programme (DLP) by increasing University/Institute network.
- Explore effective strategies for expanding the target group from fresh graduates (present trend) to professionals and thematic/domain experts within the Government functionaries, NGOs, industries and other private institutions.

Management Council

The fifth IIRS-MC (MC-5) meeting was conducted in IIRS main conference hall on March 26, 2019.

Shri Santanu Chowdhury, Chairman, IIRS-MC & Director, NRSC presided over meeting. Other members present included Shri D.K. Das, Director, SAC, Ahmedabad; Dr. V.K. Dadhwal, Director, IIST, DOS, Thiruvananthapuram; Shri R. Umamaheswaran, Scientific Secretary, ISRO Hqs; Dr. P.V. Venkitakrishnan, Director, CBPO, ISRO Hqs; Dr. P.G. Diwakar, Director, EDPO, ISRO Hqs., while Shri Anoop Srivastava, Joint/Additional Secretary, DOS, DOS, Bengaluru participated through VC.

Ambedkar Jayanti

IIRS celebrated Birth Anniversary of Dr. B.R. Ambedkar. On this auspicious occasion Shri Devendra Singh, Retired Additional Director, ONGC was invited as the Chief Guest of the function. Floral tributes were offered to Dr. B.R. Ambedkar and speech on his sacrifice, vision and life were made both by Director, IIRS and Chief Guest. An informative video clip on the life of Dr. B.R. Ambedkar was played.

Swacch Bharat Abhiyan

Annual action plan for Swacch Bharat Mission was formulated. Swacchta pledge was offered to all employees of IIRS and to students, officer trainees during special campaign organized as per annual action plan and cleanliness drive was conducted at IIRS.

Parliamentary Standing Committee Visit

The Department study visit to Dehradun of the Parliamentary Standing Committee (PSC) on Science & Technology, Environment & Forest to Dehradun and Jim Corbett National Park (Uttarakhand) took place in Indian Institute of Remote Sensing, Dehradun on June 02, 2018. The Honourable Committee was headed by Shri Anand Sharma, Chairman of the Committee and accompanied by Members – Dr. Raghu Sharma, Shri Ninong Ering, and Shri Vikram Usendi visited IIRS. They were accompanied by officials of the Rajya Sabha Secretariat viz., Shri T.N. Pandey, Director; Shri Rajiv Saxena, Under Secretary; Shri Bhim Singh, Sr. Secretariat Assistant; and Shri Gautam Kapoor, PS to Chairman. Meeting began

with brief presentation on activities of ISRO by Scientific Secretary, ISRO followed by a detailed presentation on activities of IIRS by Director, IIRS. Field instruments used by IIRS faculty and students were also demonstrated before the Honourable Members.Committee generally expressed immense satisfaction on activities of IIRS.

The International Yoga Day

Prime Minister Shri Narendra Modi participated in Mass Yoga demonstration conducted on June 21, 2018 in Forest Research Institute, Dehradun. Many employees from IIRS, their family members, students, officer trainees participated in this event. The 04th International Day of Yoga was also celebrated in IIRS on June 23, 2018 in which 45 minutes practice of Common Yoga Protocol (CYP) was performed.

To promote the campaign with extreme vigor, IIRS has designed and developed geospatial solution consisting of one Android based mobile App and one web based dashboard application. The Android based mobile app allows geotagging of the sites where the yoga events are organized across the country during the International Day of Yoga.

Independence Day 2018

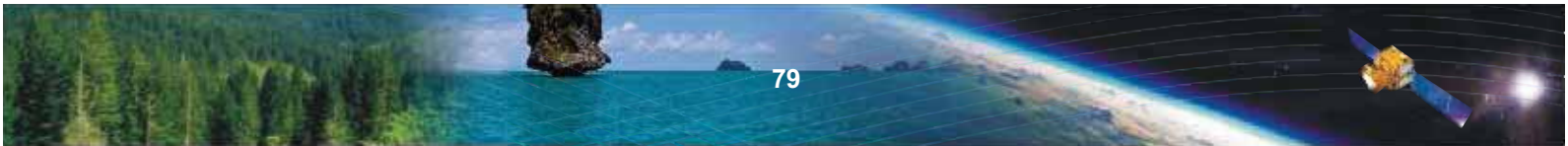
Independence Day was celebrated in IIRS on August 15, 2018. Contingency drill by CISF, cultural activity by employee/staff and their family member was performed on this auspicious occasion. Director, IIRS in his brief remark mentioned the successful launches conducted in recent past and more particularly Cartosat-2 along with 30 satellites, tests on cryogenic engine, GSLV MKIII-D2, GSAT-7A, GSAT-29 and encouraged all to deliver and do their best for the organization. IIRS celebrated this proud moment with great enthusiasm.

Vishwakarma Jayanti

Vishwakarma Jayanti is a day of celebration for Vishwakarma. It is celebrated on September 17 every year. This day was celebrated with full divine Puja and celebrations and sweet distribution at IIRS.

ISRO Inter-Center Sports Meet

This sports programme of DOS /ISRO is the event organized by Space Sports and Recreation Promotion Board (SSRPB) which was constituted by DOS. ISRO Inter Centre Sports Meet-2018 for Athletics and Indoor games was held in SDSC SHAR. IIRS has participated in the most of the events of this sports meet. IIRS Sports council congratulates all the participants for representing IIRS at ISRO Inter Centre Sports Meet-2018.

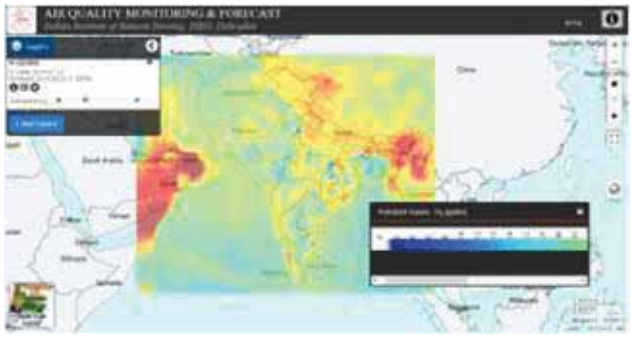


Republic Day

IIRS celebrated Republic Day with full zeal and enthusiasm on January 26, 2019. It was celebrated with active participation including family members of IIRS/CSSTEAP/CISF staff and students of various courses for IIRS/CSSTEAP. Director, IIRS in his speech shared vision of ISRO with special emphasis on Human Space Flight Mission and Chandrayan-II. The cultural activity was performed on this occasion and CISF presented a reflex shooting drill. Spot sports event for staff & studens of IIRS & CSSTEAP were organised by the IIRS Recreation Club.

Air Quality Monitoring & Forecast System

A Geoportal is developed and hosted at IIRS to disseminate model generated forecast fields and satellite based inputs for the monitoring and analysis of air quality over Indian sub-continent. (https://airquality.iirs.gov.in)

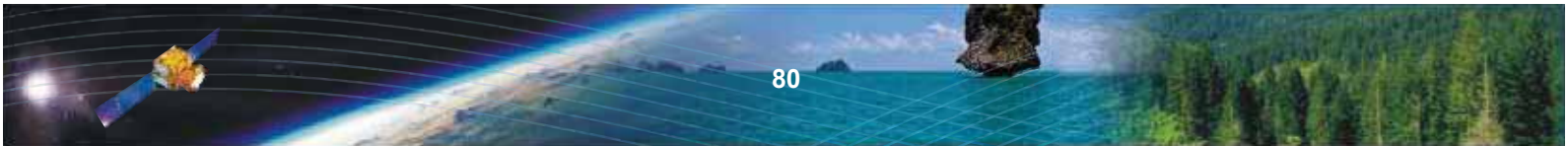


Geospatial Solution for Forest Fire Reporting

IIRS has designed and developed "Geospatial solution for Forest Fire Reporting" consisting of an Android based mobile App and web based dashboard application for Jammu &Kashmir (J & K) State Forest Department. The geospatial solution was digitally released by Shri. K. VjayKumar, Advisor to Honourable Governor (J& K) on Oct 3, 2018 in Srinagar.

ISRO-JAXA seminar on Seminar on Space Education for Educators

Two days seminar on space education for educators was jointly organized by Indian Space Research Organization (ISRO) and Japan Aerospace Exploration Agency (JAXA) during November 15-16, 2018 at Indian Institute of Remote Sensing (IIRS) Dehradun. The seminar was conducted within the framework of Asia-Pacific Regional Space Agency Forum (APRSAF)/Space Education Working Group (SEWG). The seminar was targeted to School Teachers (Class - IX to XII), Educators from planetarium and science museum. The Seminar aims at building a working knowledge of teaching tools and methods to impart space education with a scope to include in schools curricula and extra-curricular activities for future generations. The major objective of the seminar was to exchange lessons learned from previous experiences in teaching space science and technology and share ideas to let space education inspire new generation. Total 80 participants from 19 states of India and Nepal has attended the seminar.



OTHER INFRASTRUCTURAL IMPROVEMENTS

Central Dining Facility

New building for central dining & recreation facility was built in basement + two floors structure. SS based modern kitchen was established in basement floor along with service lift.

Dining hall with seating capacity of 250 was established in ground floor and first floor is multi-purpose facility for student recreation as well to support catering service for IIRS function.

All weather indoor swimming pool

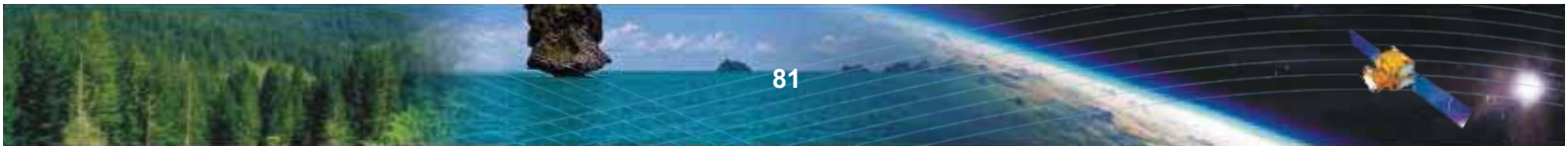
48 x 18 feet sized all weather indoor swimming pool was provided in the basement floor of newly constructed golden jubilee hostel building.

New Security Building

New security building was constructed to accommodate office of assistant commandant, arms kote etc. for IIRS CISF unit which was newly inducted in January 2018. Alongwith this building, other works viz. new CC road to access all hostel building, segregation fence between high security and low security zones were executed.

Land Reclamation

About 40% of land in IIRS Campus is located in sloppy areas and was not useful for IIRS activities. Land reclamation was taken up in phased manner. This phase–III reclamation was done near auditorium building to reclaim about 1.2 acre of land.



Passenger Lift in Main Building

In order to make all institution activity building physically handicapped person friendly, new passenger lift was provided in main building which is the main institutional building in the campus.

Improvement works in CSSTEAP

CSSTEAP head quarter was established in IIRS campus. Improvement works including upgrading the labs, interior and exterior were executed including a water fountain system in front of the building.

MANAGEMENT COUNCIL

Chairman	Director, NRSC
Alt. Chairman	Director, SAC
Members	Joint/Additional Secretary, DOS
	Director, IIST
	Scientific Secretary, ISRO
	Director, CBPO, ISRO HQ
	Director, EDPO, ISRO HQ
Member Secretary	Director, IIRS

ACADEMIC MANAGEMENT COUNCIL

Chairman	Director, IIRS
Members	Shri V. Raghu Venkataraman, ANTRIX, ISRO HQ, Bangalore
	Dr. M.V.R. Sesha Sai, NRSC, Hyderabad
	Dr. J. Krishnamurthy, ISRO HQ, Bangalore
	Dr. A. Chandrasekhar, IIST, Thiruvananathapuram
	Shri D. Dhar, SAC, ISRO, Ahmedabad
	Vice Chancellor, Andhra University, Visakhapatnam
Member Secretary	Dean (Academics), llRS
Special Invitees	Dr. I.V. Muralikrishna, Distinguished Fellow, DRDO
	Dr. P.K. Garg, Uttarakhand Technical University, Dehradun
	Dr. S. Sanjeevi, Anna University, Chennai
	Dr. Subashisa Dutta, Dept. of Civil Engineering, IIT, Guwahati

BOARD OF STUDIES

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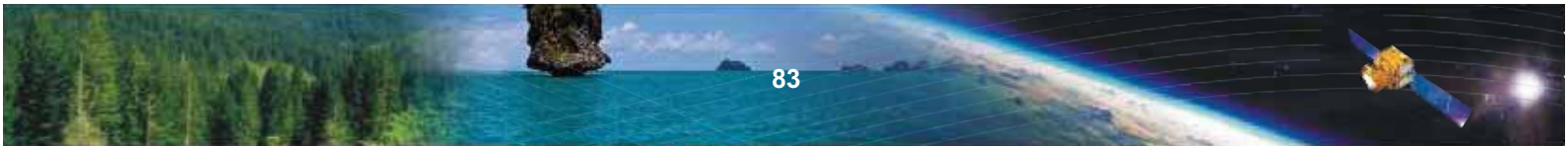
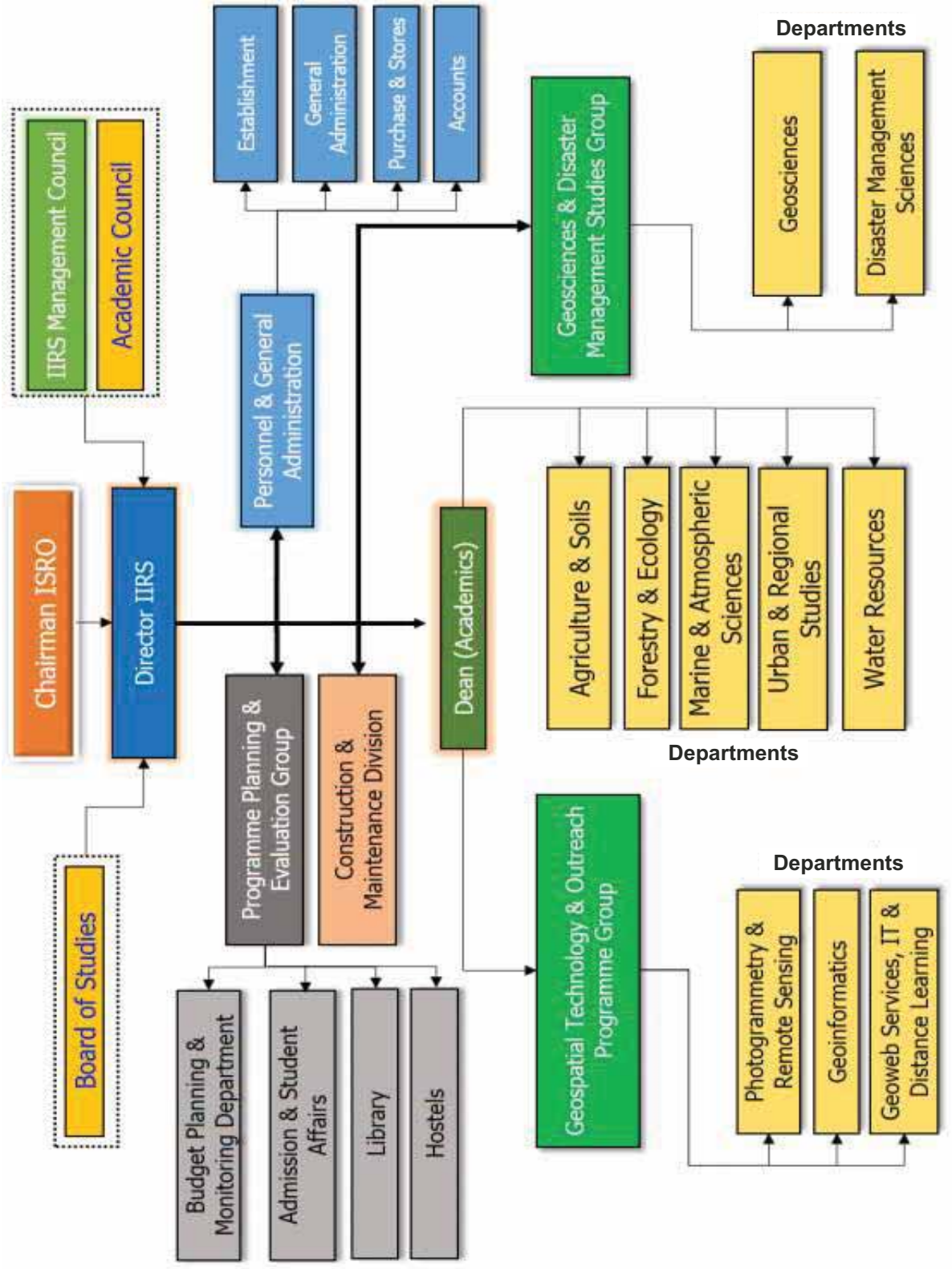
	Dr. Subashisa Dutta, IIT, Guwahati
	Dr. Hari Shanker, GH, PPEG, llRS
Member Secretary	Course Director M.Tech/PGD, IIRS



IIRS ORGANISATIONAL SET-UP

The broad setup and the organization of the IIRS may be pictorially represented as follows:



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