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Tanvir Islam *Editors*

Remote Sensing Applications in Environmental Research

Springer

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The Society of Earth Scientists Series aims to publish selected conference proceedings, monographs, edited topical books/text books by leading scientists and experts in the field of geophysics, geology, atmospheric and environmental science, meteorology and oceanography as Special Publications of The Society of Earth Scientists. The objective is to highlight recent multidisciplinary scientific research and to strengthen the scientific literature related to Earth Sciences. Quality scientific contributions from all across the Globe are invited for publication under this series.

Foreword

Remote sensing science and technologies emerged as an important new tool for environmental applications over four decades ago. The environmental applications of remote sensing have gained an irreversible momentum ever since. From early multispectral sensors flown during the NASA Apollo missions in the 1960s that gave birth to the famous LANDSAT series of remote sensing satellite to the present day collection of remote sensing satellites from space agencies across the globe (USA, Russia, Europe, Canada, Japan, India, China, and Brazil, to name a few), the unabated rapid progress in both the sensors and the platforms have provided a major impetus for the use of remote sensing in environmental applications. The results of these applications have been spectacular. Researchers have made groundbreaking observations about the environmental phenomena, and the decision makers have used the information in dialogs over management and policy issues related to the environmental impacts and sustainability.

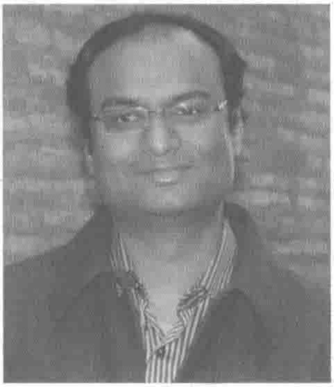
Over 30 years ago, I stated in one of my early research papers that "*remote sensing has added a new dimension to the analysis and studies of environmental processes, issues and decision-making.*" This statement is still true today as evidenced by the contents of this book *Remote Sensing Applications in Environmental Research edited by Dr. Prashant K. Srivastava, Prof. Saumitra Mukherjee, Dr. Manika Gupta and Dr. Tanvir Islam.* This is indeed a welcome and timely contribution to the growing field of environmental remote sensing.

This book is a compilation of authoritative and comprehensive papers on methods, techniques, and applications as well as illustrative examples of advancements of environmental applications of remote sensing. The editors have organized the book into two parts: Part I is devoted to "classic" applications of remote sensing using various environmental research studies. Part II addresses the advancements in environmental applications of remote sensing. The contributors have covered a wide variety of sensors from a diverse array of remote sensing platforms (Landsat TM and ETM+, MODIS, IRS-LISS, and Hyperspectral) and discussed new approaches to image processing and algorithm development. In addition, a glimpse into the future challenges of environmental applications of remote sensing will offer food for thought for all.

The editors have skillfully presented this detailed and technical content in a user-friendly and coherent format. I am confident that the readers of this book will quickly appreciate the rapid advancements being made in this field. I am positive that the researchers and students alike will gain insights into the new dimensions of applying remote sensing to environmental analysis and understanding. I wish the editors and publishers of this important volume a great success.

Houston, Texas Kamlesh Lulla

About the Editors



Dr. Prashant K. Srivastava is a Research Scientists at Hydrological Sciences (Code 617), ESSIC/NASA Goddard Space Flight Center, Greenbelt, Maryland, USA. He received his B.Sc. degree in Agriculture Sciences from Institute of Agricultural Sciences, Banaras Hindu University, India in 2004 and M.Sc. degree in Environmental Sciences from School of Environmental Sciences (SES), Jawaharlal Nehru University (JNU), India in 2006. He joined as an Assistant Professor in Department of Environmental Sciences, NVPAS, Sardar Patel University, Gujarat in 2007. In 2010, under the Commonwealth Scholarship and Fellowship Plan (CSFP), he joined Department of Civil Engineering, University of Bristol, Bristol, for his doctoral thesis. His Ph.D. research was focused on the soil moisture retrieval algorithm development from SMOS satellite and mesoscale model for hydrological applications. Following his Ph.D. in 2013, he joined as a research scientist in the ESSIC/NASA Goddard Space Flight Center, Hydrological Sciences Branch on SMAP satellite soil moisture retrieval algorithm development. Dr. Srivastava has been a recipient of many awards including Commonwealth fellowship, UK, CSIR fellowship (twice), MHRD and UGC fellowships from India. He has published more than 48 peer-reviewed journal papers and more than 20 conference papers. Currently, he is serving as an editorial board member of five journals related to remote sensing and environmental sciences. He is currently a member of Indian Society of Geomatics, Indian Society of Remote Sensing, Indian Association of Hydrologists (IAH), International Society for Agrometeorology (INSAM), and International Association of Hydrological Sciences (IAHS).

Dr. Saumitra Mukherjee is Professor of Geology, Remote Sensing and Space sciences at School of Environmental Sciences, Jawaharlal Nehru University, Delhi. He obtained his M.Sc. and Ph.D. in Geology from Banaras Hindu University, Varanasi, India. Prior joining JNU in 1992, Prof. Mukherjee served as Hydrogeologist and Remote Sensing Scientist, Government of India. He has vast experience on satellite like IRS, LANDSAT, SPOT, Indian Remote sensing Satellites, Hyperion, ResourseSat, LIDAR, and SOHO data for Sun–Earth Environment. He has authored seven books in the field of Remote sensing and environmental sciences. He has published more than 80 papers in the peer-reviewed journals with nearly 60 conference contributions. He has supervised 18 doctoral theses and completed 14 collaborative projects funded by National and International agencies, and also involved in the projects funded from NASA on sun–earth connections. Prof. Mukherjee has been designated as UGC Professor of Geology and Remote sensing in view of his contribution in the field of Geology and Remote sensing. He has also served as an executive commonwealth Fellow for University of Liverpool, UK. He is a recipient of many awards including Ministry of Environment and Forest, Government of India on his academic contributions. He is serving as an editorial board member of four journals. Currently, he is a member of number of pioneer organizations in world including American Geophysical Union, European Space Agency, European Geosciences Union, SOC, JPL/CALTECH/NASA, European Fleet for Airborne Research, Canadian Remote sensing Society, Indian Society of Remote Sensing and Executive Fellow (Earth Sciences-India).

Dr. Manika Gupta received her Master degree in Environmental Sciences from School of Environmental Sciences (SES), Jawaharlal Nehru University (JNU), India in 2006. She worked as a research personnel on remote sensing applications from SES, JNU for a year before joining Department of Civil Engineering, Indian Institute of Technology, New Delhi, India for her Ph.D. in 2007 as a UGC fellow. Her Ph.D. focuses on numerical modeling for water resource management. She is also working as a research consultant for satellite based slum area delineation of Jaipur, India. She has collaboration with number of pioneer organizations in the world such as University of Bristol, NOAA, and NASA on remote sensing advancements. Her current research involves assimilation of hyperspectral and microwave (precipitation) data in numerical model for pesticide and soil moisture prediction. Dr. Manika Gupta has been a recipient of many awards including EIPRS (Australia), COSPAR (China), CSIR, ICMR, and UGC fellowships from India. She has published more than 25 peer-reviewed journal papers and more than 15 conference papers. Currently, she is serving as an editorial board member of two journals related to remote sensing and environmental sciences. She is also member of Indian Society of Geomatics, Indian Society of Remote Sensing, Indian Association of Hydrologists (IAH), and International Society for Agrometeorology (INSAM).

Dr. Tanvir Islam received the Ph.D. degree in remote sensing from the University of Bristol, Bristol, UK, in 2012. His Ph.D. research was focused on the remote sensing of precipitation through the use of radar polarimetry, especially towards algorithm developments and data quality improvements. Following his Ph.D., he joined the University of Tokyo as a visiting scientist, more specifically, as part of the NASA/JAXA precipitation measurement missions. Since 2013, he has been with the NOAA Center for Satellite Applications and Research, as a CIRA fellow, working on the development of satellite remote sensing algorithms, with an emphasis on microwave variational inversion techniques. Currently, he is the scientific algorithm developer for the NOAA's Microwave Integrated Retrieval System (MiRS). Dr. Tanvir was the recipient of the Faculty of Engineering Commendation from the University of Bristol for his outstanding Ph.D. thesis and nominated for a University Prize, in 2012, the JAXA visiting fellowship award, in 2012, and the CIRA postdoctoral fellowship award, in 2013. He is member of the American Geophysical Union (AGU), International Association of Hydrological Sciences (IAHS), and American Society of Civil Engineers (ASCE).

Introduction

**Prashant K. Srivastava, Saumitra Mukherjee,
Tanvir Islam and Manika Gupta**

Remote Sensing Advancements for Environmental Applications

Satellite remote sensing has been transformed in less than 30 years from being a sparse research tool into a commodity product available to a broad user community. However, after three decades of remote sensing advancements, still there is a need for standardized data processing techniques that may take into account the special properties of remote sensing datasets. The major advantage of satellite images is that it varies in spectral, spatial, and temporal resolution, and therefore can be used for variety of applications and provide a more complete view of the observed objects. Hence, seminal views on recent advances in remote sensing techniques from classical to new advancements are very much required.

With increasing numbers of Earth-observing satellites in space, huge volumes of remote sensing data will be produced and there are many more coming in future. Classical remote sensing data processing and distribution methods generally suffer from poor performances and thus make it unsuitable for various end users and real-time forecasting. More detailed analysis and efficient datasets may help the satellite data usage with more confidence. Day-by-day, the earth remote sensing data retrieval, processing, distribution, and application are becoming more challenging and hence require a more detailed analysis on a regular basis. One of the challenges are maintaining the high volumes of satellite datasets and transferring them into a form which is conveniently used by nearly all scientific communities again by utilizing very less space. Custom-made satellite remote sensing data with interactive graphical user interface on a GIS/Web-GIS compatible format is very important for a lot of end users, especially for novice users. On the other hand, more widely distributed Earth-observing remote sensing data in different formats through diversified protocols will result in better usage of future Earth-observing satellite systems. To address these issues, data compressing and preprocessing (sub-setting and sub-sampling), data format conversing (easy accessing data format such as GIS compatible format), GIS and Open GIS applications, and simple real-time data processing for future Earth-observing satellite systems can be a promising approach.

The future of remote sensing lies in making numerous types of accurate, current, and high-resolution remotely sensed data and derived geospatial information products readily available for every area of interest. Scientific community looks forward to the day when datasets are readily available for analysis in nonspecialized software packages. Challenges facing terrestrial and atmospheric remote sensing are unlimited as the different topographies behave differently with particular land surface dynamics and meteorological conditions across the globe at the various spatial and temporal domains. The main goals are to make accurate estimates of selected key sets of geophysical variables, with the intention of either making accurate predictions across time and spatial boundaries of various geographical conditions, or advancing fundamental knowledge through the development of empirical and/or theoretical models. The other challenges are related to our understanding of the geophysical processes, the sensor physics, optical and microwave properties of the surface as well as the sampling capabilities for accurate measurements.

Many new technologies are required for the improvement of individual system capabilities and for the operation of large numbers of sensors. Because of fundamental physical limit, future projection is difficult which therefore creates a question mark on future progress. Therefore, it is required to outline the generalized form of future remote sensing systems and the technologies they will rely on. The abovementioned technological challenges for future global Earth observation can best be met through the combined efforts of the international community. To help make this vision a reality, NOAA/NASA remote sensing experts recommended a number of challenges over the next two decades. According to them, scientific community should focus on improving the accuracy, resolution, timeliness, and ease-of-use of remotely sensed data as well as improving the delivery of remotely sensed data via the Internet, so that users can more easily find and retrieve the exact data and information as per their requirements. NOAA/NASA further stresses on natural and human-induced disaster mitigating strategies by providing high-resolution data of affected areas immediately. There are a number of sensors both on optical and microwave platforms, each with some unique capabilities. If they are to be used synergistically (or fused), it will improve the quantity and quality of information available to the public. Further to software support group, it is suggested to improve the software so that remotely sensed data can be quickly and easily processed and analyzed, and simultaneously yield information needed by professionals.

In this edited volume, the advancements in remote sensing are discussed in terms of the design of techniques able to deal with the high-dimensional nature of the data, and to integrate the spatial and spectral information in a synoptic and more directive way. The recent advancements are discussed in brief along with performances in terms of case studies in different analytical scenarios. All state-of-the-art remote sensing techniques are discussed for specific applications with efficient parallel implementations of some of the algorithms. Synoptically, these parts provide an excellent snapshot and offer a thoughtful perspective on future potentials and emerging challenges in the design of robust remote sensing applications. These advancements are not limited to only communication and extra celestial sciences but now spread over a variety of terrestrial, oceanic, and atmospheric application. In the past few years, there have been many developments in our understanding of optical and microwave remote sensing approaches for environmental applications within land cover, climate change, vegetation, meteorology, hydrology, atmospheric sciences, and oceanic studies. The purpose of this book is to provide a platform for scientists and academicians all over the world to promote, share, and disseminate the new advancements in satellite remote sensing for the abovementioned applications. The chapters are presented in such a way so that they will focus on nearly all issues from classical remote sensing to advanced remote sensing techniques.

Structure of the Book

The book is mainly divided into two parts. The first part covers the classical remote sensing applications while the second part focuses on the advanced remote sensing techniques for the environmental applications. The chapters primarily cover the remote sensing applications in earth and environmental sciences. Furthermore, advancements in line of remote sensing are discussed and provided, such as GIS, GPS, and geospatial techniques.

The classical remote sensing is basically focussed on products or application derived using the previously developed techniques or model, but very important for societal benefits. These techniques form a fundamental for advanced remote sensing development. The classical remote sensing part covers the variety of topics from atmosphere to land applications. The first chapter in this part provides MODIS-based determination of conifer needle flushing (CNF) phenology over boreal-dominant regions. The second chapter deals with Watershed Management using Information System integrating with Remote Sensing and GIS. Over here, attempt has been made to integrate dimensions in Agriculture–Water–Soil–Climate continuum for sustainable management using the WATMIS (Watershed Management Information System) tool. Third chapter discusses land surface temperature (LST) retrieval using spectral index (NDVI), spectral radiance, and surface emissivity using Landsat data for a moist deciduous tropical forest. This study is very useful for forest conservation and management. In fourth chapter, a brief investigation of sensitivity analysis has been performed using SimSphere Land Surface Model, which is very promising for operational products development from Earth Observation (EO) data. The fifth chapter in this part provides geospatial techniques integrated with IRS P6 LISS III data to analyze the precise estimation of the percentage of the soil organic carbon associated with organic matter in soil in Tropical Wildlife Reserve.

The advanced remote sensing part covers the latest techniques developed for environmental applications. The first chapter in this part provides fuzzy unordered rules induction algorithm and j48 decision tree models for spatial prediction of shallow landslides. The landslide conditioning factors derived from remote sensing and GIS are used for the development of landslide hazard maps. Flooding is one of the severe disasters that causes mass demolition of properties and affects human lives. The next chapter attempts to address this problem using the remote sensing and GIS techniques. The submergence zone categorization integrated with Town Planning Scheme (TPS), water level and flood inundation maps are generated on remote sensing and GIS platform. In next chapter, the regional measurements of fire is discussed using the MODIS data. The spatial variations in vegetation fires and carbon monoxide concentrations in South Asia are presented to evaluate its role in environmental pollution. However, in remote sensing, land use/land cover change detection is a very important component. The next chapter provides a brief background of fragstats modelling for driving landscape matrices derived from remotely sensed data (LANDSAT and IRS 1D LISS III) aiming to characterize the historical trends of landscape changes. This study is important for deriving the changes on a long term and will be helpful in mitigating adverse impact of these changes. The tenth technical chapter deals with the hyperspectral data analysis for deriving chlorophyll which is an important component for yield measurements and agricultural crop monitoring for diseases or any stress. In this chapter the Linear Regression Algorithms is used for predicting chlorophyll using the ground spectro-radiometer data supplemented with ground verifications. The last chapter covers the artificial intelligence technique integrated with remote sensing for archaeological site management. This chapter opens new paradigm in archaeological site location and managment using high resolution optical satellite based datasets such as from advanced wide field sensor.

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Part I
Classical Remote Sensing Applications