Foreword to the Special Issue on Applied Earth Observation and Remote Sensing in India

INDIA is at the forefront in several areas of research related to Earth observation and remote sensing. Its space program has been in the news often in recent times, but other aspects of Indian research in geosciences and remote sensing remain relatively unknown to the international community of researchers in the field. It is the objective of this special issue of IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING (IEEE JSTARS)—"Applied Earth Observation and Remote Sensing in India," to highlight the work of Indian scientists in these areas. A call for papers was announced during November 2016. In response, 60 manuscripts were received from variety of fields. Out of these, 17 papers were selected for publication.

I. EARTH OBSERVATION AND REMOTE SENSING IN INDIA

The importance of Earth observation and remote sensing in India cannot be overstated. From crop management to defense, astronomy to weather prediction, satellites provide vital information to Indian scientists, and operational agencies for the benefit of society. India's initiatives in Earth observation, remote sensing, and recently planetary and astrophysical missions have spurred broad innovations in design and development of sensors, pre/post processing and analyzes of data acquired, and a host of applications in communications, defense, agricultural monitoring, oceanographic studies, and disaster response, to name a few.

The first satellite designed and fabricated by India, Aryabhatta, was launched on April 19, 1975. Since then, around 50 satellites have been successfully launched. The instruments on these satellites range from X-ray sensors to hyperspectral imagers, and are placed both in Sun-synchronous and Geostationary orbits. Details of all the satellites launched can be found in [items 1), 2), and 3) in the Appendix]. Of special mention are the data acquired by the Cartosat and Resourcesat series: The data from these satellites have revolutionized the field of digital mapping in India. In the last decade, as a first step toward outer space exploration, India launched Chandrayaan-1 [item 4) in the Appendix], subsequently the Mangalayaan Mars Orbiter Mission [item 5) in the Appendix], and Astrosat, a mission to map Earth-like planets. The Indian Space Research Organisation (ISRO) has partnered with the National Aeronautics and Space Administration (NASA) on a number of missions, including Chandrayaan-1, scatterometry missions for measuring ocean winds, and most recently in developing an Earth observing science and applications mission that will exploit synthetic aperture radar (SAR). This mission, known as the NISAR Mission, is proposed to launch in late 2021 [item 6) in the Appendix]. ISRO has also partnered with other space agencies such as the French Space Agency.

Beyond the scientific successes, data from these satellites have been used at various stages of operational monitoring and policy making by the Indian government. In addition, the use and analysis of these data support the research by academicians across India. This issue includes some of these works at the forefront of their research field.

II. IEEE GEOSCIENCES AND REMOTE SENSING SOCIETY (GRSS) IN INDIA

The geophysical diversity of the Indian subcontinent and India's large population make it both necessary and challenging to develop techniques that respond to scientific and societal needs, with a number of problems unique to the subcontinent. Historically, academicians from India have not been involved to a wide extent in the International remote sensing community. This is poised to change with the new initiatives of the Advisory Committee (AdCom) of IEEE Geosciences and Remote Sensing Society (GRSS) to foster the participation of India's scientists and engineers working in remote sensing in IEEE GRSS activities worldwide. Several local GRSS chapters have been established in India [item 7) in the Appendix] include GRSS Delhi [item 8) in the Appendix], GRSS Kolkata [items 9) and 10) in the Appendix], GRSS Bangalore [item 11) in the Appendix], GRSS Gujarat [item 12) in the Appendix], GRSS Bombay, and GRSS Hyderabad Chapters. With the establishment of these Indian GRSS chapters, many young authors whose papers have been accepted for IGARSS have been provided with travel grant awards. IEEE GRSS has also supported organizing several short courses and seminars by distinguished lecturers across the chapters in India. It is the express intent of GRSS to create a strong presence of GRSS in India to increase the visibility of the work being done in India, and to foster stronger international collaborative efforts.

III. ORGANIZATION OF THE SPECIAL ISSUE

The 17 articles selected for publication are organized into the following three groups:

1) Microwave sensing-based studies (3)
2) Algorithms and frameworks (8)
3) Remote sensing applications (6)

In Group 1, there are three papers that use polarimetric SAR data. The first two papers use a nonstandard basis to classify surfaces. In the first paper, datasets from RISAT-1 acquired over Mumbai city are analyzed by using a decomposition technique that is based on an unsupervised model (A. Kumar *et al.*). In the second paper, scattering powers for the two structurally distinct crops are analyzed (V. Kumar *et al.*). The third paper uses C-Band Radarsat-2 spaceborne SAR data in a polarimetric SAR tomographic inversion (PolTomSAR) to estimate the vertical

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distribution of scattering centers in a forested area (S. Kumar *et al*.).

In Group 2, the papers rely primarily on optical data, and apply sophisticated statistical and machine-learning methods to classification and interpretation. In the first paper, using Bayesian techniques, Level-2 Aerosol Optical Depth (AOD) corresponding to three locations that have long-term data (for the period between 2001–2014), retrieved from Multi-angle Imaging SpectroRadiometer (MISR) and Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data, is merged in conjunction with AErosol RObotic NETwork (AERONET) data (Singh *et al*.). In the second paper of this group, a progress granular neural network-based classification approach developed by the authors is employed for classification of land use/land cover features from both multispectral and hyperspectral remote sensing images (D. Kumar *et al.*). In the third paper, an open issue of hyperspectral image classification with sparse labeled samples is addressed through a technique exploiting dimensionality reduction, spectral-spatial information and classification with active learning (Patra *et al.*). The fourth paper exploits a deep-learning-based framework, involving an ensemble of multiple forecasting modules to address the problem of missing data in remote sensing time series analysis. This framework would reconstruct the missing data further facilitating the analysis of remote sensing time series (Das and Ghosh). In the fifth paper, hyperspectral images are segmented by following a *k*-means clustering approach, and by following mutual interest neighbor information, segmented regions are merged in a hierarchical manner (Mehta and Dikshit). In the sixth paper, a methodology based on fractal dimension techniques is applied to identify normalized difference vegetation index (NDVI) profile patterns further to reveal patterns that would assist discrimination of different classes. The two *ad hoc* methods, namely box counting and rescaled range methods, are employed to show applications in the context of mapping vegetation phenomena from remotely sensed data. The seventh paper focuses on extracting information from time series NDVI data (at coarse spatial resolution) and testing fractal methods for pattern characterization (Chockalingam and Mondal). In the eighth paper, to denoise seismic attributes further to improve the porosity column, a diffusion filter-based scheme is proposed and demonstrated (Chaki *et al.*).

In Group 3, there are six papers dealing with science and applications. The first paper maps superglacial lakes (SGLS) of Gangotri glacier using high resolution LISS-IV data. The work uses an object-based image analysis approach, and an index is proposed for classifications of SGLs (Mitkari *et al.*). In the second paper in this group, Prakash and Nagarajan provide a detailed inventory of the spatial distribution and temporal changes of glacial lakes situated in and around the northwestern Himalaya region, recorded from Corona, ASTER, and IRS-R2 data of the years 1971, 2003, and 2011. In the third paper, a geodetic mass budget and ice velocity patterns of Gangotri glacier, one of the largest Himalayan glaciers, are estimated using optical satellite data, further analyzing the spatial distribution of ice thickness and possible locations of glacial lake formation. It is discovered that mass loss is increasing with reducing velocity patterns of the Gangotri glacier (Bhushan *et al*.). In the fourth paper, an algorithm to detect the fog over India from INSAT-3D imagery in a real-time mode is demonstrated (Chaurasia and Jenamani). In the fifth paper, aerosol optical depth over northwest Himalayan region is examined and assessed through ground-based measurements and MODIS and MISR satellite data (Shaik *et al*.). And finally, an approach to agriculture monitoring at regional scales is proposed by integrating drone data with remotely sensed data. The novelty of this work lies in developing a methodology that may be able to distinguish between sparse and dense vegetation within a field by using satellite and drone data (Murugan *et al*.).

A special issue, with its demanding solicitation, review, and production schedule, can only sample the work of the community. These seventeen papers, though only a sample, demonstrate the breadth of research being conducted in India, and the promise of a community addressing important scientific issues using cutting edge methods.

Acknowledgment

Following the hard deadlines and tight time-schedules from the phase of submitting the special issue proposal to the release of the special issue is indeed a herculean task. This task was achieved mainly due to the help of the Reviewers, Editor-In-Chief of IEEE JSTARS, Prof. Q. Du, and the authors who have patiently addressed all the queries of the Reviewers/Guest Editors/E-i-C. We gratefully acknowledge all their support. This India special issue is the brainchild of Prof. W. Emery, IEEE Publication Committee Chair. The guest editors are also grateful to the members of the IEEE GRSS AdCom.

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Appendix
Related Work

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2) P. Murugan, "Indian remote sensing missions and payloads—A glance," IRS-Programme Management Office, ISRO Satellite Centre, Bangalore, India, p. 298, 2016.
3) A. S. Kirankumar and T. Misra, "A glimpse of ISRO's EO programme," *IEEE Geosci. Remote Sens. Mag.*, vol. 3, no. 4, pp. 46–53, Dec. 2014.
4) M. Annadurai and T. K. Alex, "Chandrayaan-1: An update," *J. Aerosp. Sci. Technol.*, vol. 61, no. 1, pp. 81–87, 2009.
5) M. Kramer, "Liftoff! India's first mars probe launches toward the red planet," Nov. 2013. [Online]. Available:

http://www.space.com/23464-india-launches-mars-orbiter-mission.html. Accessed on: Oct. 31, 2017.
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8) "GRSS activities by the IEEE GRSS Delhi chapter," *IEEEE Geosci. Remote Sens. Mag.*, vol. 3, no. 2, pp. 55–57, Jun. 2015.
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11) B. S. D. Sagar and S. K. Meher, "Bangalore section chapter of the GRSS," *IEEE Geosci. Remote Sens. Mag.*, vol. 1, no. 2, pp. 72–73, Jun. 2013.
12) "IEEE Gujarat section geoscience and remote sensing society—Chapter," *Newsletter*, vol. 1, no. 1, 2013.

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Dr. Bruzzone has been a member of the Administrative Committee of the IEEE Geoscience and Remote Sensing Society (GRSS), since 2009. He ranked first place in the Student Prize Paper Competition of the 1998 IEEE International Geoscience and Remote Sensing Symposium (IGARSS), Seattle, WA, USA, in July 1998. Since that, he was recipient of many international and national honors and awards, including the recent IEEE GRSS 2015 Outstanding Service Award and the 2017 IEEE IGARSS Symposium Prize Paper Award. He was a Guest Co-Editor of many Special Issues of international journals. He is the Co-Founder of the IEEE International Workshop on the Analysis of Multi-Temporal Remote-Sensing Images series and is currently a member of the Permanent Steering Committee of this series of workshops. Since 2003, he has been the Chair of the SPIE Conference on Image and Signal Processing for Remote Sensing. Since 2013, he has been the founder Editor-in-Chief of the IEEE GEOSCIENCE AND REMOTE SENSING MAGAZINE. He is currently an Associate Editor for the IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING. He has been a *Distinguished Speaker* of the IEEE Geoscience and Remote Sensing Society between 2012–2016.

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Prof. Sagar recently co-edited a special issue on "Filtering and Segmentation with Mathematical Morphology" for IEEE JOURNAL ON SELECTED TOPICS IN SIGNAL PROCESSING (vol. 6, no. 7, pp. 737–886, 2012). He is an elected Fellow of Royal Geographical Society (1999), Indian Geophysical Union (2011), and was a member of New York Academy of Science during 1995–1996. He received Dr. Balakrishna Memorial Award from Andhra Pradesh Akademi of Sciences in 1995, Krishnan Gold Medal from Indian Geophysical Union in 2002, and "Georges Matheron Award-2011 (with Lecturership)" of International Association for Mathematical Geosciences. He is the Founding Chairman of Bangalore Section IEEE GRSS Chapter. He is on the Editorial Boards of *Computers & Geosciences*, and Frontiers: Environmental Informatics.

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