Remote Sensing of Natural Disasters

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Earth is an integrated, complex system with strong coupling among atmosphere, hydrosphere, biosphere, and lithosphere processes. In recent years, we have witnessed the complex interplay between these processes and the vulnerability of human society to disturbances in both the timing and intensity of these regional or global scale processes. Seismic and volcanic activity, typhoons and torrential rains, and other geological and environmental hazards have had major impacts on human populations. Many of these natural hazards may well increase in both frequency and intensity under projected climate change and their impacts enhanced because of anthropogenic activities. Worldwide, we have seen efforts at increasing our ability to forecast and, ultimately, mitigate the impact of these natural disasters on human society.

This special issue provides tutorial treatment of some of the new and recent remote sensing technologies, tools, and integrated systems for decision support in early warning, prevention, reduction, and mitigation of natural disasters.

The U.S. Geological Survey has reported globally more than 17 earthquakes per year with a magnitude 7 and higher in the last 18 years. The tsunami generated by the great 2011 M9.0 Tohoku earthquake in Japan resulted in unprecedented social and economic impacts locally and globally; the accompanying nuclear disasters will affect the Earth ecosystem for many years to come. The impacts of the 2008 M8.0 Wenchuan earthquake in China, the 2010 M8.8 Pelluhue earthquake in Chile, and the 2010 M7.038 Leogane earthquake in Haiti were exacerbated by the inaccessibility of affected areas, inadequate infrastructure, and limited early knowledge of the affected areas. The February 2011 Christchurch earthquake in New Zealand claimed a significant number of fatalities and caused significant damages and liquefaction of the affected area. The remote sensing community is actively and quickly moving toward more advanced methodologies, linking remote sensing with *in situ* measurements and ancillary data for more precise mapping, faster analysis, and more effective forecasting and data delivery to the user community. Remote sensing represents a unique and valuable source of information to monitor changing conditions in both the atmosphere and on the Earth's surface at a variety of spatial and temporal scales. The application of remote sensing science and technologies for natural disasters is a broad, interdisciplinary area of research. Many techniques permit all-weather observations and remote sensing is able to provide either needed reconnaissance or quantitative and sustained measurements, even under challenging situations, for example, because of the large area extent of impacted areas, the potential lack of

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on-the-ground access because of damaged infrastructure, remoteness, or sociopolitical reasons. As remote sensing, both from spaceborne and airborne platforms, undergoes further technical evolution, we continue to see novel remote sensing methods being applied to assess and mitigate the damages caused by natural disasters, such as: landslides and land subsidence, earthquakes and tsunamis, droughts and floods, volcanic eruptions, hurricanes, and environmental disasters caused by human disturbance or technical failures. High- resolution imagery with under 1-m spatial resolution has been made available from various platforms and sensors. By integrating constellations of multisatellite systems, frequent observations are highly feasible and can provide timely information for an early warning system.

This special issue provides tutorial treatment of some of the new or recent remote sensing technologies, tools, and integrated systems for decision support in early warning, prevention, reduction, and mitigation of natural disasters. The papers address fundamental issues such as the scientific basis of the methods; the technology of the measurements; the modeling of the physics; and the data, image, and signal processing for several kinds of sensors onboard satellite and airborne platforms.

The 11 papers included in this special issue cover a wide spectrum of disasters, with topics addressed by leading experts of respective areas. The topics include earthquakes and tsunamis, mega city subsidence, volcanic eruptions, floods, oil pollution, and disease outbreaks, as well as issues with a broader focus, highlighting innovative tools and procedures to exploit Earth observation data on a transnational collaborative basis.

The first paper "ASTER satellite observations for international disaster management," by Duda and Abrams, presents the use of Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) onboard NASA's Earth Observing System (EOS) satellite system to support emergency situations for over a decade through its expedited tasking and near-real-time data delivery capabilities. The International Charter "Space and Major Disasters" was established to enable such collaboration in sensor tasking during times of crisis and is often activated in response to calls for assistance from authorized users. Insight is provided from a U.S. perspective into sensor support for Charter activations and other disaster events. The paper also offers excellent examples of successes achieved and challenges encountered in international collaboration to develop related systems and fulfill tasking requests and suggests operational considerations for new missions as well as areas for future enhancements. The paper entitled "Human sensor networks for improved modeling of natural disasters," by Aulov and Halem, proposes a human sensor network incorporated into geophysical models together with other scientific data such as satellite observations and sensor measurements. Example of oil spill predictions is discussed to validate the model improvement. The paper "Remote sensing contributions to prediction and risk assessment of natural disasters caused by large-scale Rift Valley Fever outbreaks," by Anyamba *et al.*, discusses the critical role played by remote sensing measurements in anticipating, preventing, and managing disease epidemics and epizootics and other climate-related disasters for the past 30 years of the experiment. In "Mapping geo-hazard by satellite radar interferometry," Chang *et al.* highlight the application examples of satellite interferometric synthetic aperture radar (InSAR) in exploring potential geo-hazards and mapping geo-related disasters, including earthquakes, landslides, and land subsidence, triggered by natural forces and/or human activities in two highly geo-hazard prone countries: Taiwan and Vietnam. The paper addresses the fact that urbanization and land subsidence are well interconnected because water demand–supply structure changes. Excessive groundwater abstraction can have profound effects. Therefore, before the control of land subsidence can occur, detection and recognition of land subsidence must be conducted. The authors conclude that a constant and continuous monitoring of land surface deformation becomes essential. Furthermore, the advance of satellite radar interferometry provides a vital mapping in detecting and identifying the geo-hazard and the potential geo-disaster and emphasizing the importance of the constellation of satellite systems for disaster management support. Two papers exploit the power of fully polarimetric synthetic aperture radar in monitoring the disasters. The paper "Disaster monitoring by fully polarimetric SAR data acquired with ALOS-PALSAR," by Yamaguchi, presents natural disaster monitoring of volcanic activity, snow accumulation, landslides, and tsunami effects caused by great earthquakes using novel target decomposition model to enhance the recognition of a disaster area. The author argues that since disaster events cause the changes of each scattering power, it becomes straightforward to recognize the changes of the color in the polarimetric decomposed images provided time series data sets are made available. In "Polarimetric SAR analysis of tsunami damage following the March 11, 2011 East Japan earthquake," by Sato *et al.*, detailed mapping and analysis using imagery acquired by spacecraft and aircraft are presented. In particular, to estimate the extent of a building collapse, polarization orientation angle was used to understand the damage effect in the built-up areas. Flooded areas were automatically detected using the cross-polarization component with relatively high accuracy. The significant contributions of polarimetric SAR imagery to provide timely spatial information of the devastated areas, as described in these two papers, provided justification for the prompt determination of launching ALOS-2 in 2013, after its forerunner ALOS failed in 2011.

In "Remote sensing and earthquake damage assessment: Experiences, limits, and perspectives," Dell'Acqua and Gamba review the techniques and data sets used to evaluate earthquake damages using remote sensing data. Results are summarized to conclude that it is likely that the interest in remote sensing data for natural hazard management will increase, with the wider availability of new optical and radar data sets and wider recognition of the need for global monitoring. A collaborative effort among data providers, analysts, and users should cause a positive response to the request. In the paper "GEOSS-based thermal parameters analysis for earthquake anomaly recognition," by Wu *et al.*, searching of thermal features for earthquake anomaly is demonstrated using satellite remote sensing data. The scientific basis is built on the lithosphere–coversphere–atmosphere (LCA) coupling due to stress enhancement in seismogenic zone. In total, six thermal parameters, including surface latent heat flux (SLHF), thermal infrared radiation (TIR), outgoing long-wave radiation (OLR), diurnal temperature range (DTR), atmospheric temperature, and skin temperature, are proposed as the feature set. It has been shown through a series of tests that composite thermal anomaly is of precautionary significance. It must be pointed out that such research is still in early stages and requires more work in the future. In "Remote sensing of volcanic hazards and their precursors," Hooper *et al.* focus on combining interferometric SAR and spectroradiometry; the former is used to detect displacements of a volcano's surface due to magma movement beneath the ground, while the latter is used to monitor a volcanic eruption through the detection of hot spots, and quantification of the ash and SO_2 emitted by volcanos into the atmosphere.The interferometric SAR is also demonstrated to identify precursors to eruptions and to track the evolution of eruptions. The paper "Remote sensing of ocean oil-spill pollution," by Schistad Solberg, addresses the operational oil-spill monitoring currently done using a combination of satellite monitoring and aircraft surveillance. Spaceborne SAR provides an overview of large ocean areas, and surveillance aircrafts can be directed to check possible oil-spill locations to verify the spill and catch the polluter. The author also develops a unique target feature based on polarimetric response of SAR imagery, which proved to be very effective in identifying oil spills. Finally, the paper "Information extraction from remote sensing images for flood monitoring and damage evaluation," by Serpico *et al.*, offers excellent treatment of information extraction from various kinds of remote sensing data in line of both the time scale and the spatial scale in support of flood monitoring and post-flooded damage estimation. The authors review future technical and scientific challenges and highlight the importance of proposing more accurate and reliable processing methods and of keeping these methods continuously updated with new sensors and satellite missions, new types of remote sensing data (e.g., further improved spatial resolutions and revisit times), new input information sources (e.g., wireless sensor networks and social networks), and new computing capabilities (e.g., cloud computing). They conclude that it is a challenge to fully exploit the potential of remote sensing data for flood risks, also from an organizational viewpoint, because it may require modifying or reconfiguring currently consolidated operational chains for flood-risk management to take advantage of the availability of additional information extracted from satellite observations.

Last but not least, it is our pleasure to present this collection of papers on Remote Sensing of Natural Disasters to the readership of the Proceedings of the IEEE. We would like to thank all the authors and reviewers for their invaluable contributions and efforts. We are very grateful to the managing editor Jim Calder and the publications editor Jo Sun for their vital role through the course of this editorship. ■

ABOUT THE GUEST EDITORS

Kun-Shan Chen (Fellow, IEEE) received the Ph.D. degree in electrical engineering from the University of Texas at Arlington, Arlington, in 1990.

Since 1992, he has been with the faculty of the Center for Space and Remote Sensing Research, National Central University, Taoyuan, Taiwan, where he served as Director from 2001 to 2004 and has held a remote sensing chair professorship since 2008. He has been the Director of the Communication System Research Center at the same university. He is awarded a distinguished visiting chair professorship from the National United University in Taiwan in 2009 for a six-year term. He has authored and coauthored over 100 refereed journal papers, contributed five book chapters, and is a coauthor (with A. K. Fung) of the book *Microwave Scattering and Emission Models for Users* (Reading, MA: Artech House, 2010). His research interests include image processing and analysis of remote sensing data, remote sensing for natural hazards and disasters, and microwave scattering and emission theory and modeling from terrain with applications to environmental watch and resource investigation, and wireless communications.

Dr. Chen received an outstanding contribution award from the Vietnam Academy of Science and Technology in 2009 for his long-term involvement in cooperative research on rupture deformation and subsidence in Vietnam. He also received the 2012 distinguished award of the National Science Council. He was a Guest Editor for the IEEE Transactions on Geoscience and Remote Sensing Special Issue on Remote Sensing for Major Disaster Prevention, Monitoring and Assessment (2007), a Founding Chair of the GRSS Taipei Chapter, an Associate Editor of the IEEE Transactions on Geoscience and Remote Sensing (2000–2011), the Deputy Editor-in-Chief of the IEEE Journal on Selected Topics in Applied Earth Observations and Remote Sensing (2008–2010) of which he is now an Associate Editor. He has been actively involved in establishing a GRSS link to Asia and Southeast Asia, in lines of natural disaster monitoring by remote sensing.

Sebastiano B. Serpico (Fellow, IEEE) received the Laurea degree in electronic engineering and the Doctorate from the University of Genoa, Genoa, Italy, in 1982 and 1989, respectively.

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Prof. Serpico is the Chairman of the Institute of Advanced Studies in Information and Communication Technologies (ISICT). He is an Associate Editor of the IEEE Transactions on Geoscience and Remote Sensing. He was a Guest Editor of two Special Issues of the IEEE Transactions on Geoscience and Remote Sensing on the subject of the "Analysis of Hyperspectral Image Data" (July 2001) and on the subject "Advances in Techniques for the Analysis of Remote Sensing Data" (March 2005). From 1998 to 2002, he was the Chairman of a SPIE/EUROPTO series of conferences on Signal and Image Processing for Remote Sensing.

James A. Smith (Fellow, IEEE) received the B.S. and M.S. degrees in mathematics and the Ph.D. degree in physics from the University of Michigan, Ann Arbor, in 1963, 1965, and 1970, respectively, and the M.S. degree in computer science from the Johns Hopkins University, Baltimore, MD, in 1991.

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Dr. Smith served twice as the Editor-in-Chief of the IEEE Transactions on Geoscience and Remote Sensing and received the IEEE Geoscience and Remote Sensing Society Outstanding Service Ward. He is a recipient of the NASA Exceptional Service Medal in recognition of his contributions to the establishment and development of the land processes and biospheric physics program and was appointed a NASA Goddard Senior Fellow in recognition of outstanding contributions to the Nation's Space Research Program. He is a Fellow of the American Association for the Advancement of Science, and the International Society for Optics and Photonics (SPIE).