Lecture Notes
in Geoinformation and Cartography

LNG&C

Jukka M. Krisp
Liqiu Meng
Roland Pail
Uwe Stilla *Editors*

Earth Observation of Global Changes (EOGC)

Springer

Jukka M. Krisp · Liqiu Meng
Roland Pail · Uwe Stilla
Editors

Earth Observation of Global Changes (EOGC)

Springer

Preface

This book documents the research activities related to earth observation and global changes. The contributions originate from selected presentations at the EOGC2011—3rd Earth Observation and Global Changes Conference, which was jointly organized by Technische Universität München (TUM) in Germany, Peking University (China), and University of Waterloo (Canada). The conference was related to the JURSE2011—Joint Urban Remote Sensing Event, held in the same week at TUM. The EOGC2011 was a forum for researchers dealing on earth observation and global changes with respect to the information technology. The event was cosponsored by International Society for Photogrammetry and Remote Sensing (ISPRS), International Cartographic Association (ICA), International Association of Geodesy (IAG), International Society for Digital Earth (ISDE), and the International Office of TUM. The conference gathered 66 participants from 19 countries with 31 selected presentations covering a variety of aspects concerning Remote Sensing, GIS, Cartography, and Geodesy. Two keynote speeches were given by Prof. Reiner Rummel and Prof. Markus Rothacher. We thank all the contributors for their excellent input and all the participants for making the EOGC2011 an outstanding and multidisciplinary event.

Nineteen papers from the proceedings are elaborated and now published in this book "Earth Observation of Global Changes (EOGC)" within the Springer series "Lecture Notes in Geoinformation and Cartography". As the field of study covers a wide spectrum of research topics, the editor team assures the quality of this cross-disciplinary field. The editors are Prof. Liqiu Meng for the topic Global Change and Change Detection; Dr. Jukka M. Krisp for the topic Spatial Modelling, GIS, and Geovisualization; Prof. Roland Pail for Physical Geodesy; and Prof. Uwe Stilla for the topic Photogrammetry and Remote Sensing. Our aim is to benefit the scientific community in a wide range by presenting different topics from different perspectives.

Jukka M. Krisp
Liqiu Meng
Roland Pail
Uwe Stilla

Reviewers

The production of this book would have not been possible without the professional help of our scientific review committee. We would like to thank all the following experts who have helped to review the papers published within this book.

Bamler	Richard	Technische Universität München, Germany
Brenning	Alexander	University of Waterloo, Canada
Buchroithner	Manfred	Technische Universität Dresden, Germany
Ding	Xiaoli	The Hong Kong Polytechnic University, Hong Kong, China
Eineder	Michael	German Aerospace Center (DLR), Germany
Esch	Thomas	German Aerospace Center (DLR), Germany
Gege	Peter	German Aerospace Center (DLR), Germany
He	Yuhong	University of Toronto Mississauga, Canada
Hinz	Stefan	Karlsruhe Institute of Technology, Germany
Hugentobler	Urs	Technische Universität München, Germany
Krisp	Jukka	Technische Universität München, Germany
Li	Jonathan	University of Waterloo, Canada
Melgani	Farid	University of Trento, Italy
Meng	Liqiu	Technische Universität München, Germany
Meyer	Franz Josef	University of Alaska Fairbanks, United States of America
Müller	Jürgen	Institute of Geodesy, Leibniz University of Hannover, Germany
Pail	Roland	Technische Universität München, Germany
Seitz	Florian	Technische Universität München, Germany
Smit	Julian Lloyd	University of Cape Town, South Africa
Stilla	Uwe	Technische Universität München, Germany
Tommaselli	Antonio Maria Garcia	UNESP, Brazil
Wei	Yao	Munich University of Applied Sciences, Germany
Yang	Xiaojun	Florida State University, United States of America

(continued)

(continued)

Yi	Weiyong	Technische Universität München, Germany
Zhang	Yun	University of New Brunswick, Canada
Zhou	Fuqun	Canada Centre for Remote Sensing, Canada

Contributors

Fadwa Alshawaf Institute of Photogrammetry and Remote Sensing (IPF), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany; Geodetic Institute (GIK), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Manuel Antón Geophysics Centre of Évora, University of Évora, Évora, Portugal; Department of Physics, University of Extremadura, Badajoz, Spain

Martin Bachmann German Aerospace Center (DLR), Wessling, Germany

Yifang Ban Division of Geoinformatics, Department of Urban Planning and Environment, Royal Institute of Technology, Stockholm, Sweden

Markus Boldt Institute of Photogrammetry and Remote Sensing (IPF), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Maurice Borgeaud European Space Agency, ESRIN, Frascati, Italy

Daniele Bortoli Geophysics Centre of Évora, University of Évora, Évora, Portugal; Institute of Atmospheric Sciences and Climate, Bologna, Italy

Andreas Christian Braun Institute of Photogrammetry and Remote Sensing (IPF), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Florian Burkert Technische Universität München (TUM), Remote Sensing Technology, Munich, Germany

Emilio Chuvieco Department of Geography, University of Alcala, Alcalá de Henares, Spain

Villaroel Constanza Department of Geography, University of Concepción, Barrio Universitario, Concepción, Chile

Maria João Costa Geophysics Centre of Évora, University of Évora, Évora, Portugal; Department of Physics, University of Évora, Évora, Portugal

Amaia de Miguel German Aerospace Center (DLR), Wessling, Germany

Frank de Morsier École Polytechnique Fédérale de Lausanne, LTS 5, Lausanne, Switzerland

Denise Dettmering Deutsches Geodätisches Forschungsinstitut (DGFI), Munich, Germany

Ana F. Domingues Geophysics Centre of Évora, University of Évora, Évora, Portugal

Sabrina Eberle German Aerospace Center (DLR), Wessling, Germany

Alata Elatawneh Institute of Forest Management (IFM), Technische Universität München (TUM), Munich, Germany

Theodor Foerster Institute for Geoinformatics, University of Muenster, Muenster, Germany

Thomas Fuhrmann Geodetic Institute (GIK), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Dorothy Furberg Division of Geoinformatics, Department of Urban Planning and Environment, Royal Institute of Technology, Stockholm, Sweden

Volker Gass Swiss Space Center, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

Mario A. Gomarasca CNR-IREA, Institute for Electromagnetic Sensing of the Environment, Milan, Italy

Martin Habermeyer German Aerospace Center (DLR), Wessling, Germany

Bernhard Heck Geodetic Institute (GIK), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Stefan Hinz Institute of Photogrammetry and Remote Sensing (IPF), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Danielle Hoja Remote Sensing Technology Institute, German Aerospace Center (DLR), Wessling, Germany

Georg Kaspar Center for Digital Media, University of Muenster, Muenster, Germany

Mengistie Kindu Institute of Forest Management (IFM), Technische Universität München (TUM), Munich, Germany

Andreas Knöpfler Geodetic Institute (GIK), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Thomas Krauss Remote Sensing Technology Institute, German Aerospace Center (DLR), Wessling, Germany

Jukka M. Krisp Technische Universität München (TUM), Bauingenieur- und Vermessungswesen, Kartographie (LFK), Munich, Germany

Christoph Küchler RUAG Schweiz AG, Emmen, Switzerland

Pavan Kulkarni Geophysics Centre of Évora, University of Évora, Évora, Portugal

Xiaoguang Luo Geodetic Institute (GIK), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Christine Makasy German Aerospace Center (DLR), Wessling, Germany

Vivanco Mauricio Department of Geography, University of Concepción, Barrio Universitario, Concepción, Chile

Michael Mayer Geodetic Institute (GIK), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Arnulf Melzer Limnological Institute, Technische Universität München, Munich, Germany

Liqiu Meng Department of Cartography, Technische Universität München, Munich, Germany

Xiaolin Meng Department of Civil Engineering, The University of Nottingham, Nottingham, UK

Roderic Molina Geographical Information Systems International Group—GISIG, Via Piacenza 54, Genoa, Italy

Antonios Mouratidis ESA/ESRIN, Via Galileo Galilei, Frascati, Italy

Helmut Mühle German Aerospace Center (DLR), Wessling, Germany

Rupert Müller German Aerospace Center (DLR), Wessling, Germany

Roland Pail Institute of Astronomical and Physical Geodesy, Technische Universität München, Munich, Germany

Stefan Peters Department of Cartography, Technische Universität München, Munich, Germany; Technische Universität München (TUM), Bauingenieur- und Vermessungswesen, Kartographie (LFK), Munich, Germany

M. Lucrecia Pettinari Department of Geography, University of Alcala, Alcalá de Henares, Spain

Johannes Rahlf Institute of Forest Management (IFM), Technische Universität München (TUM), Munich, Germany

Adelheid Rappl Bavarian State Institute of Forestry (LWF), Freising, Germany

Peter Reinartz Remote Sensing Technology Institute, German Aerospace Center (DLR), Wessling, Germany

Albert Remke 52°North GmbH, Muenster, Germany

Sebastian Roessler Limnological Institute, Technische Universität München, Munich, Germany

Carolina Rojas Department of Geography, University of Concepción, Barrio Universitario, Concepción, Chile

Francesco Sarti ESA/ESRIN, Via Galileo Galilei, Frascati, Italy

Andreas Schenk Geodetic Institute (GIK), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Michael Schmidt Deutsches Geodätisches Forschungsinstitut (DGFI), Munich, Germany

Thomas Schneider Limnological Institute, Technische Universität München, Munich, Germany; Institute of Forest Management (IFM), Technische Universität München (TUM), Munich, Germany

Opazo Sergio Facultad de Ciencias, Universidad de Magallanes, Punta Arenas, Chile

Bolelang Sibolla Geomatics Division, School of Architecture, Planning and Geomatics, University of Cape Town, Cape Town, South Africa

Ana Maria Silva Geophysics Centre of Évora, University of Évora, Évora, Portugal; Department of Physics, University of Évora, Évora, Portugal

Julian Lloyd Smit Geomatics Division, School of Architecture, Planning and Geomatics, University of Cape Town, Cape Town, South Africa

Tobias Storch German Aerospace Center (DLR), Wessling, Germany

Ulrike Sturm-Hentschel Institute of Photogrammetry and Remote Sensing (IPF), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany; Institute of Regional Sciences, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Antje Thiele Institute of Photogrammetry and Remote Sensing (IPF), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Jean-Philippe Thiran École Polytechnique Fédérale de Lausanne, LTS 5, Lausanne, Switzerland

Paolo Villa CNR-IREA, Institute for Electromagnetic Sensing of the Environment, Milan, Italy

Adrian Vogel RUAG Schweiz AG, Emmen, Switzerland

Joachim Vogt Institute of Regional Sciences, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Yanbin Wang China University of Mining and Technology, Beijing, China

Malte Westerhaus Geodetic Institute (GIK), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Patrick Wolf Limnological Institute, Technische Universität München, Munich, Germany

Jiantong Zhang Department of Cartography, Technische Universität München, Munich, Germany

Yueqin Zhu Department of Cartography, Technische Universität München, Munich, Germany; China University of Mining and Technology, Beijing, China

Introduction

The general research topic "earth observation of global changes" covers many disciplines and challenges. Therefore, the contributions within this book are organized under the general headings of Physical Geodesy, Photogrammetry and Remote Sensing, Global Change and Change Detection, and Spatial Modeling, GIS and Geovisualization.

Physical Geodesy

The main tasks of Physical Geodesy are to determine the figure of the Earth, its orientation and rotational motion in inertial space, and its gravity field, as well as their temporal changes. The first issue includes the highly precise determination of positions and kinematics of the solid Earth's surface, but also the variations of the ocean surface due to ocean currents or sea level rise. The second issue deals with the highly precise determination of the Earth's rotation axis in global space and its changes due to irregular rotation motion resulting from a temporally changing moment of inertia. The gravity field defines a physical, equipotential reference surface and thus serves as zero surfaces for vertical reference frames, with respect to which small changes resulting from geophysical surface and subsurface processes can be described. Temporal gravity field variations reflect mass transport processes in our system Earth related to the global hydrological cycle, ice mass melting, ocean circulation, or atmospheric processes. Correspondingly, physical geodesy measures the Earth system processes from the deep Earth's interior up to the upper atmosphere.

In two contributions to this book, selected fields of Physical Geodesy are addressed. The first paper by PAIL reviews the huge gain of knowledge on the Earth's static and time-variable gravity field during the last decade due to dedicated satellite gravity missions such as CHAMP, GRACE, and GOCE. While GRACE has revolutionized our knowledge on global mass transport processes such as the global water cycle and ice mass melting in Greenland and Antarctica, GOCE is providing an unprecedented high-resolution picture of the static gravity field. Apart from the progress of global gravity field modelling based on these new satellite data, with emphasis on the contribution of the ESA mission GOCE, the

paper also gives insight into the impact of this improved knowledge of the global gravity field on our understanding of system Earth.

The second contribution by Zhang et al. deals with the ionized component of the upper Earth's atmosphere. Here, the free electrons and ions influence propagation of electromagnetic waves. Apart from contributing to improve the understanding of the physics of the atmosphere, it is also crucial for the processing of geodetic space techniques and remote sensing, because it influences the travel times of the primary signals. In this paper, the monitoring of the total electron content (TEC) is discussed, which is usually measured by dual-frequency GNSS. The paper investigates the optimum combination of GNSS occultation observations with information derived from low-Earth orbiting satellites, such as the altimeter satellites Envisat, Jason-1, and Jason-2 in order to enhance global vertical TEC maps. It could be shown that improvement from these additional data sources can be achieved in areas with good data coverage.

Photogrammetry and Remote Sensing

High-resolution remote sensing techniques operate in different spectral bands, from high-resolution radar satellite missions such as TerraSAR-X and TanDEM-X to optical and hyper-spectral sensors such as the RapidEye constellation or in the near-future EnMAP mission. They monitor with very high accuracy and spatial resolution the geometry of the Earth's surface, resulting in global digital terrain models with resolutions of a few meters, and also their temporal changes. Thus, they are used to derive 3-D surface deformations resulting from large Earthquakes, to monitor volcanoes, and to derive velocity fields of ice sheets and glaciers. Additionally, surface changes due to hydrology or and ice mass melting can be observed, enabling to compute volume changes and, assuming density to be known, mass balance estimates, which are important quantities to monitor natural global change processes. Remote sensing techniques provide cost-effective tools for monitoring physical quantities of components of the Earth's system. Thus they are also widely used for monitoring, mapping, and assessing of damage related to natural disaster events.

Eight contributions to this book treat techniques from Photogrammetry and Remote Sensing for a variety of applications related to different components of the earth system, e.g., monitoring of settlement changes, forests, invasive aquatic plants, and flash-flood or determination of atmospheric water vapor and ozone variation.

The contribution by De Morsier et al. describes the registration of airborne videos with reference images based on a phase-correlation approach. The task of image to image registration is frequently addressed in the literature for change detection by comparison of images taken at different time. An application named by the authors is the provision of up-to-date images for quick assessment of damaged areas after natural hazards. They show one example that their approach performs better than an approach using mutual information.

The contribution by Storch et al. gives an overview about the ground segment design of the Environmental mapping and analysis program (EnMAP) and describes the image processing chain for the intended products on different levels. The major

objectives of the first German hyperspectral satellite remote sensing mission are to measure, derive, and analyze diagnostic parameters, which describe vital processes on the Earth's surface encompassing agriculture, forestry, soil, and geological environments, as well as coastal zones and inland waters. Those geochemical, biochemical, and biophysical parameters are assimilated in physically based ecosystem models, and ultimately provide information reflecting the status and evolution of various terrestrial ecosystems.

The contribution by Sturm-Hentschel et al. focuses on the methodology for detecting and characterizing settlement changes in developing countries using very high spatial resolution (VHSR) data. In many developing countries, coastal areas show high dynamics of settlement structures, which are hardly regulated by regional planning and therefore give rise to a series of risks. Most of all, increasing settlement density and spread in areas close to the shoreline and into wetland areas appear worrying against the background of climate change and sea level rise. An approach based on both manual and segment-based (semi-)automatized building detection is described and discussed for the coastal area of Benin. Results are used to analyze the settlement process and model its further evolution by data-driven modeling.

In the contribution by Schneider et al. the potential of high-resolution satellite data for forest management planning and disaster management is investigated, driven by the fact that an increase of forest damages by natural hazards can be observed. It is emphasized that added value can be achieved by a combination of multispectral data (using the RapidEye constellation) and SAR data (TerraSAR-X). It could be shown that such a concept is appropriate to deliver relevant information for interim forest inventories, but not yet with a quality which were required for decision making. However, this situation will change with future remote sensing systems.

The contribution by Roessler et al. presents an approach to monitor invasive aquatic plants (Elodea nuttallii and Najas marina) by multiseasonal multispectral remote sensing data (RapidEye). These invasive species have been subject of multidisciplinary research for several years, as it is assumed that increasing water temperature promotes their expansion. Submerged macrophytes in freshwater lakes are used as longterm indicators for nutrient conditions. Climate change is thought to favour invasive submersed macrophytes in freshwater ecosystems and therefore to have profound influence on lake ecosystems. The information about the current state of the water body is used to produce depth-invariant combinations of spectral bands using a simple physically-based semiempirical method. In situ reflectance measurements were processed with the same method and subsequently used in a Matched Filtering spectral unmixing approach. The results show a good separation between vegetated and bare littoral areas. A reliable differentiation of plant species still requires further method development.

The contribution by Mouratidis and Sarti deals with the satellite-based monitoring of floods, which are one of the most significant natural disaster events. Remote sensing tools enable a cost-effective monitoring and mapping, but also assessment of the damages caused by floods. As selected case study regions the Balkans and several countries in East Europe are used to investigate the feasibility of SAR techniques, and their efficiency in terms of spatial and temporal resolution. Especially the latter

one turns out to be a challenge, where currently the required high repetition rate of SAR acquisitions is currently the limiting factor. Based on this analysis, the challenges and data requirements for future remote sensing missions are discussed.

The contribution by Alshawaf et al. investigates the combination of InSAR and GNSS observations to determine the atmospheric water vapor content in the troposphere, which also causes a signal delay in microwave signals. Therefore, the wet atmosphere is one of the major error sources of (interferometric) SAR applications. While with GNSS techniques the temporal variability can be estimated for a spatially sparse array, the InSAR technique provides not only point information, but also spatial water vapor variations for a whole area. The combination of these two complementary data sources has a high potential to improve spatio-temporal modeling of the wet atmosphere, and thus to compute more reliable signal delays of remote sensing systems.

The contribution by Domingues et al. investigates the seasonal variation of ozone in Portugal. Ozone plays a relevant role in controlling the chemical composition of the atmosphere, in the troposphere it is harmful to humans and plants, and it is a component of smog and an important greenhouse gas. Results were derived from spectral measurements using the terrestrial UV-Vis. Spectrometer for Atmospheric Tracers Measurements. The ground-based results are also compared with data from Ozone Monitoring Instrument (OMI) onboard Aura Satellite.

Global Change and Change Detection

Global change and change detection involves the challenging research and development questions such as how the huge amounts of sensory data and mapping data can be effectively and efficiently archived, accessed, disseminated, and integrated, what types of gradual or abrupt changes are relevant for which target groups and which applications, which methods or algorithms are available, adaptable, or still missing for the detection of the various changes. These questions are tackled by five papers in the book.

The paper from Foerster et al. is dedicated to the dissemination of large volume sensor data about global change. Based on the analysis of bottlenecks in existing approaches that are file-based, service-based, or satellite-based, the authors proposed a hybrid approach using a satellite-based system for accessing sensor data on distributed nodes and then disseminating the data in the Internet through web services. The interoperable web service interfaces allow on the one hand the providers to upload the data with appropriate metadata and on the other hand the users to directly integrate the data into their research work on global change. Two case studies with raster-based and feature-based data have been implemented using free and Open Source Software, thus proved the feasibility of the hybrid approach.

Villa et al. address in their paper a topic on harmonisation of geodata and services with a platform called HUMBOLDT in line with the European Spatial Data Infrastructure (ESDI). Two test scenarios—protected areas and maritime themes—were implemented to demonstrate the usefulness and capabilities of harmonization approach. The scenario of protected areas was designed to seamlessly transform the structure and geometry of protected areas from multiple sources at different

governance levels for the purposes of planning, management, and tourism promotion. The ocean scenario was based on a centrally running geoportal with a portrayal interface that allows users such as policy makers and scientists to view information about oil and chemical spills in three regions over European Seas and answer common queries.

The paper by Hoja et al. deals with damage assessment in the post-crisis phase, taking the Haiti Earthquake as an example. A number of (semi)automatic methods of change detection were applied to the satellite data of the capital town of Port-au-Prince and compared with manual measurements as well as the database of the Haiti Action Plan for Reconstruction. Among others, the image differencing and the Iteratively reweighted multivariate alteration detection (IR-MAD) algorithm incorporating texture information can run automatically. According to the authors, the IR-MAD algorithm could reveal a correctness of 89 %, which is at least as good as the performance of image differencing. 3-D changes in heights and volume of buildings or other objects can also be detected, but not yet verified due to hard accessibility of 3-D reference data.

Furberg and Ban reported their research work on the environmental impact assessment based on the urban land cover changes of Stockholm between 1986 and 2006. They adopted four scenes of SPOT imageries over Stockholm as test data, transformed them into seven land cover categories. Depending on factors such as proportion and condition of green areas, proximity of these areas to intense urban land use, proportion of urban areas in their immediate vicinity, and the noise level, an environmental impact index reflecting the urban growth is derived. The index scores of the individual analysis units can then be measured and ranked. The authors found out the varying changes from the center to the north and east of the Stockholm area. These findings are intended to serve as decision support for ecological urban planners.

The paper by Rojas et al. is focused on the identification of representative land cover and land use scenarios in the metropolitan area of Concepción in Chile before and after the recent earthquake. Based on a temporal analysis of satellite image classifications, they revealed and evaluated the significant land use and land cover changes. Maps were also used for the verification of their study. According to the authors, it was most difficult to identify the beach class which may be mixed either with the open lands or with the cliff due to its low spectral contrast. The recognition of wetlands and forests areas also proved rather complex. A wetland is per definition a humid land belted by water, but it can contain vegetation which may be recognized as grasslands. The detection accuracy of forests, on the other hand, depends very much on the presence and the growing phase of the trees.

Spatial Modelling, GIS and Geovisualization

As this book covers a very wide range of topics the last part includes four papers covering different ground. Therefore, this part of the book is summarized under the general topic of spatial modeling, Geographic Information Systems (GIS), and Geovisualization. Spatial modelling and GIS go hand in hand in the research papers, with GIS used as a sophisticated tool to model real world spatial relations. More

particular, the papers include investigations on a spatial GIS-based model on fire occurrences, a study on the average global fire rates. Additionally, the process of geovisualization is extended with a directed kernel density method suggesting one way how to deal with dynamic densities in a visual way. Furthermore, the achievements of how GNSS can contribute to a spatial model dealing with structural monitoring are examined in one case study.

On a general level, the paper by Sibolla and Smit explores the level of integration that can be achieved between fire modeling, as a division of environmental modelling and GIS. It focused the role of GIS in predictive fire modelling and fire management. A model developed for the important aspects of fires, like fire behaviour and fire spread is investigated. Within the paper, they develop a detailed grid-based model and suggest to extent this toward a GIS-based decision support tool.

The paper from Krisp et al. is focused on the visualization of dynamic points. The authors suggest to apply a directed kernel, based on the movement direction of each point to calculate and visualize the density. Using this method has the advantage to show the hot spot densities and indicate the movement direction of each hot spot. The paper uses a case study of a crowd of people approaching the Munich soccer stadium, and shows how particular dense parts of the crowd are moving.

The paper from Pettinari and Chuvieco investigates the correlation between the global average fire density (AFD) and variables such as lightning discharges and population density. The analysis of the association between the global average fire density and its causative agents show diverse results depending of the fuel types present. In particular, their findings show a positive correlation between the fire density and lightning with the highest coefficient values corresponding to shrubs and grasses on the tropical dry and temperate wet climates.

The contribution by Meng investigates the recent achievements in Global Navigation Satellite Systems (GNSS)-based bridge structural health monitoring (SHM) research and development. Within this paper, the author introduces the concepts of integrated monitoring and processing for the formation of a regional geo-hazard early warning system. The architecture of such a system is presented with the findings drawn from analyzing real-life monitoring data sets. The author proposes a setup to integrate the monitoring sensors installed on the slender structures such as long suspension bridges with GNSS continuously operational reference stations (CORSs) for geo-hazard monitoring and early warning purposes.

Contents