Introduction to the Special Issue on Analysis of Multitemporal Remote Sensing Data

IN THE LAST decade, a large number of new Earth observation satellites have been launched resulting in a dramatic improvement in the capabilities of acquiring images of the Earth surface. This resulted in an enhanced capability to acquire multitemporal images of large areas of the Earth surface, which have improved temporal and spatial resolutions with respect to traditional satellite data. These new sources of imagery significantly increase the interest of the remote sensing community in the multitemporal domain, requiring the development of novel data processing techniques and making it possible to address new important and challenging applications. Nonetheless, the properties of the images acquired by the last generation sensors (e.g., very high geometrical resolution, large time series of images) pose new methodological problems that require the development of a new generation of methods for the analysis of multitemporal images and temporal series of data. This is common to both passive (multispectral, hyperspectral, etc.) and active (synthetic aperture radar (SAR), lidar, etc.) sensors. The need for the technological development is reinforced from the increased awareness of the importance of monitoring the Earth surface at local, regional, and global scale. Assessing, monitoring, and predicting the dynamics of land covers and anthropologic processes is at the basis of both the understanding of the problems related to climate changes and the geopolitical basis for a sustainable development of the world. The enhanced capability to perform multitemporal analysis of local areas at a very detailed scale is put beside these global themes and represents another strategic area of application.

Because of the aforementioned reasons, ten years after the first special issue of the IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, focusing on both theory and applications in the analysis of multitemporal remote sensing images, the time is ripe for a new special issue on the recent advances in these topics. This special issue addresses the problem of the analysis of multitemporal remote sensing data, by describing the most advanced methodological and application-oriented developments of multitemporal data analysis. It is composed of 24 papers selected according to the standard review process of the IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING. The issue is organized in three sections. The first one (13 papers) is devoted to *Methods for the Analysis of Image Time Series*, the second one (five papers) deals with *Change Detection Techniques*, and the last one presents papers on *Applications of Multitemporal Images and Time Series* (six papers).

The section on *Methods for the Analysis of Image Time Series* covers a wide range of topics. Two manuscripts by Angal *et al.* and Song and Bo deal with the important issue of integrating low spatial resolution images showing a high temporal resolution with high spatial resolution and low temporal resolution data. The former explores the cross-calibration issue, whereas the latter investigates super-resolution techniques. Other two manuscripts deal with the problem of the effective representation of the huge amount of information present in long time series. Marcio *et al.* present a method that efficiently synthetizes the information in time series, in order to enhance the spectral variation over time. Zurita-Milla *et al.* propose a self-organizing-map data-mining approach to identify specific spatiotemporal patterns over large areas. Atto *et al.* illustrate a method based on divergence metrics suitable for the detection of images with singular behavior within a time series. A system for novelty detection in multitemporal images based on a semisupervised approach is presented by de Morsier *et al.* A topic widely addressed by using image time series is the analysis of the time evolution of vegetation. Many indexes can be used to this end, such as fraction of absorbed photosynthetically active radiation (fAPAR) and leaf area index (LAI). The behavior of fAPAR is widely analyzed by Meroni *et al.*, where a comparative analysis of three fAPAR time-series products is presented to assess their spatial and temporal agreement. Verger *et al.* propose an approach to smooth and fill gaps in LAI long time series, which is based on the typical seasonal pattern of each pixel. Three manuscripts deal with the processing of SAR image time series. Methods are presented devoted to the analysis of urban areas. The first paper by Bonano *et al.* aims at investigating the possibility to improve the detection of deformation phenomena in urban areas by means of differential interferometric SAR (DInSAR) techniques applied to new-generation X-band SAR sensors rather than to previous C-band systems. The work by Chen *et al.* exploits full polarimetric SAR data for the detection of damages caused by tsunami in urban areas. Ban *et al.* propose an approach to object-based fusion of SAR and optical images for urban mapping. The work by Lacava *et al.* deals with passive-microwave radiometer systems and provides an approach to identify areas within Advanced Microwave Scanning Radiometer for EOS (AMSR-E) data that are affected by radio frequency interference. The last work of this section by Philpot *et al.* is devoted to atmospheric normalization of multitemporal images. The paper provides a derivation of an analytical formula that relates pseudoinvariant features to the radiometric properties of the scenes and discusses the robustness of the approach and implications raised by viewing and illumination angles.

Manuscripts in the section on *Change Detection Techniques* are mainly devoted to the analysis of multitemporal SAR images. The manuscript by Aiazzi *et al.* introduces a novel feature capturing the structural change between two SAR images. This

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feature demonstrated to be robust to the statistical changes that may be originated by speckle and coregistration inaccuracies. The recently developed nonlocal means denoising algorithm has been adapted to improve change detection in urban areas using multitemporal SAR images by Yousif *et al.* Bovolo *et al.* present an approach to change detection in multitemporal very high resolution SAR imagery that exploits a hierarchical representation of information and uses prior information for optimizing the change detection process in complex scenarios. The approach is applied to freight surveillance at maritime docks. Pratola *et al.* report on an approach to automatic change detection that utilizes a combination of artificial neural network architectures. The only work on change detection dealing with optical images presented in this issue is proposed by Klaric *et al.* The authors have developed an automatic system for exploitation of high-resolution panchromatic and multispectral imagery, which performs coregistration, feature extraction, change detection, and other services for users.

The set of manuscripts in the last section deals with *Applications of Multitemporal Images* and *Time Series*. Zhao *et al.* present an analysis of patterns and trends of land surface phenology in association with climatic variables within a corridor area along the Appalachian Trail over more than 30 years. Rodrigues *et al.* present the PhenoSat tool for vegetation phenology analysis. PhenoSat performance on time series from different satellite sensors are compared with those achieved by other state-of-the-art tools. Vaduva *et al.* perform the analysis of Earth surface dynamic evolution using attributes of change that are computed in order to express the land dynamic between consecutive image acquisitions. Duveiller *et al.* use thermal time and pixel purity for enhancing biophysical variable time series. The contribution by Zorer *et al.* presents an approach based on MODIS imagery to select areas suitable for the economic growth of particular grapevine varieties. The MODIS data extends the areas that can be explored much beyond those only monitored by ground-based weather stations. Finally, the contribution by Faruolo *et al.* provides a new approach for increasing the available imagery for flooded areas through the use of a sensor-independent algorithm. This capability improves flood coverage mapping for use by emergency responders.

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