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Editorial

Editorial for the Special Issue on Geodesy and Survey Engineering

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Geodesy is the science of accurately measuring, determining, and monitoring three fundamental properties of the Earth: its geometry, its gravity field, and its orientation in space—as well as the evolution of these properties over time. Geodesists also study corresponding topics for other planets in the solar system. Traditionally, the understanding of geodesy has led to the definition of three pillars of this field: ① geokinematics, ② Earth rotation, and ③ gravity field. As they are intrinsically linked to each other, these three pillars jointly change as a consequence of dynamic processes in the Earth system. Geodesy is now not only a fundamental subject of the geosciences, but also widely used in engineering construction.

With the advent of new space-geodetic techniques (e.g., the global navigation satellite system (GNSS), satellite laser ranging (SLR), low-Earth orbit (LEO) satellites, interferometric synthetic aperture radar (InSAR), very-long-baseline interferometry (VLBI), etc.), together with the rapid improvement of communication techniques and capacities, remarkable advances in recent years have evidenced that geodesy is undergoing fundamental changes in theory, method, engineering, technology, observation, and practice-oriented services. Nowadays, geodesy is facing increasing demands from scientists, the Earth-observation community, and society at large for improved services, observations, and products. In particular, new geodetic technologies allow us to observe changes in the Earth's shape, rotation, and gravity field with increasing spatial and temporal resolution, higher accuracy, and lower latency. Hence, geodesy today is crucial not only for Earth-observation science, but also for supporting many processes in modern society. Examples include applications in process control (e.g., farming, construction, mining), navigation and transport, infrastructure construction and monitoring (e.g., off-shore platforms, bridges, and other large civil structures), monitoring and early warning of geohazards and anthropogenic hazards, and so forth.

As the key space-geodetic technique, GNSS provides unprecedented potential for precise ground- and space-based positioning and navigation anywhere in the world with centimeter-level accuracy. In this special issue, several articles report on recent progress in GNSS technology and applications from different aspects, including GNSS precise orbit determination and clock estimation, and geodetic reference frame realization. Specifically, Steigenberger and Montenbruck present a comprehensive comparison and analysis of multi-GNSS precise orbit and clock products from the multi-GNSS pilot project Multi-GNSS Experiment (MGEX) of the International GNSS Service (IGS). They provide a good reference for IGS analysis center model improvement and future product upgrades. Toward high-accuracy geodesy reference frame maintenance, Cheng et al. propose an optimal realization of a dynamic geodetic reference frame in China and improve the China Geodetic Coordinate System 2000 (CGCS2000) frame maintenance accuracy using GNSS observations of over ten years. This study also outlines potential considerations for a next-generation millimeter-level geodesy reference frame.

Driven by LEO satellite gravity missions, such as the Gravity Recovery and Climate Experiment (GRACE), research on Earth gravity recovery with high accuracy and resolution using LEO-based observations has been very active in geodesy. Precise knowledge of the orbit of LEO satellites is one of the essential prerequisites for Earth gravity field modeling. Using spaceborne BeiDou Navigation Satellite System (BDS) and Global Positioning System (GPS) data from the FengYun-3C satellite, Li et al. investigate the contribution of BDS to LEO precise orbit determination (POD) and demonstrate the superior accuracy and reliability of GPS and BDS combined POD. Aiming at achieving a deeper understanding of the Earth's gravity field, Liang et al. develop a new gravity field model SGG-UGM-2 up to degree 2190 and order 2160 by combining satellite gravimetry, satellite altimetry, and Earth Gravitational Model 2008 (EGM2008)-derived gravity data. The new SGG-UGM-2 model, which has a spatial resolution of $5' \times 5'$ (5 min $\times$ 5 min), shows better performance in the Chinese mainland than EGM2008, and exhibits promising applications during GPS/leveling validation in the United States. This study can be used to construct height datum for global satellite mapping and to help us obtain a more profound understanding of the large-scale interior structure of the Earth system.

Remote sensing techniques (e.g., InSAR, drone images) are an effective way to obtain image information of the Earth's surface from satellites or aircraft. To overcome the limitation of digital elevation model (DEM) products in update latency and spatial scale, Yang et al. systematically analyze the potential of geosynchronous

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synthetic aperture radar (GEOSAR) in daily global DEM generation and updating. Baek and Jung test the feasibility of precise three-dimensional (3D) deformation measurement in the presence of large and complex deformation using an integrated InSAR technique and multiple-aperture synthetic aperture radar (SAR) interferometry (MAI), confirming that the 3D surface deformation field relates to the 2016 Kumamoto earthquake. The studies presented in this special issue also examine remote sensing applications in agriculture and forestry. For example, in order to detect the occurrence of pine wilt disease (PWD)-infected trees, Syifa et al. produce a land cover map by classifying drone images using artificial neural network (ANN) and support vector machine (SVM) methods. They conclude that both artificial intelligence methods can effectively distinguish PWD-infected trees from a land cover map, and indicate the potential usage of these methods in other land cover classifications.

The articles in this special issue cover all the hot research topics in modern geodesy, including reference frame, gravity field, and surface deformations. One important focus of next-generation geodesy is to integrate all sorts of Earth-observing platforms (e.g., GNSS, InSAR, LEO satellites, VLBI, SLR, etc.) to provide more detailed and exact images of the Earth's surface deformation evolutions and their underlying geophysical driving forces. Thus, the articles herein provide a good starting point for probing the status of the most recent satellite observing tools and considering how they could advance the Earth's geometric and gravimetric reference systems, as well as the detection of devastating geohazards for the benefit of humankind. We believe that the future of geodesy will flourish in the deep interconnection among Earth-observing techniques over broad spatiotemporal scales, mutually promoted interaction between massive geodetic observations, and interdisciplinary geophysical interpretations.

I would like to express our appreciation for the timely and professional comments from the reviewers of this special issue. Most importantly, I extend our thanks to all the authors who submitted their manuscripts for consideration. Their contributions have made this special issue successful. The strong support from Profs. Harald Schuh, Nico Sneeuw, Peter Teunissen, C.K. Shum, Jeffrey Freymueller, Tonie Marie van Dam, Chris Rizos, Markus Rothacher, Yuanxi Yang, Weiping Jiang, Pengfei Cheng, Kefei Zhang, Guochang Xu, Xiaoli Ding, and Xingxing Li, as well as from the editorial office, is also greatly appreciated.