remote sensing

Editorial

Introduction to the Special Issue "Uncertainty in Remote Sensing Image Analysis"

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Images obtained from satellites are of an increasing resolution. In addition, the frequency of their observations is increasing, and is expected to continue to increase in the near future. Despite these rapid developments, uncertainty is inherent in images. This occurs in all types of images, sensors and platforms, including multi-spectral (hyper-spectral) images, high spatial resolution images and LiDAR images. Uncertainty is, for example, due to mixed pixels, a lack of precise ground control points, atmospheric distortion and the vague definition of ground objects. It includes both low accuracy, as well as ambiguous definitions.

The aim of this Special Issue is to showcase methods and solutions that deal with uncertainty in remote sensing images and their derived products. Typically, image analysis methods, statistical methods, and uncertainty modelling and its propagation are of interest. This Special Issue contains nine manuscripts that all treat uncertainty in remote sensing analysis from different perspectives. The first paper, "Estimation of AOD Under Uncertainty: An Approach for Hyperspectral Airborne Data" by Nitin Bhatia, Valentyn A. Tolpekin, Alfred Stein and Ils Reusen addresses aerosol optical depth (AOD) [1]. Uncertainty in AOD inference, caused by noise, is reduced by a novel method which is applied to synthetic data and real data. This method is shown to be more precise than other atmospheric correction methods. Hence, the paper reduces uncertainty by developing a specific method, tuned towards the variable of interest. The second paper, "Comparison between AMSR2 Sea Ice Concentration Products and Pseudo-Ship Observations of the Arctic and Antarctic Sea Ice Edge on Cloud-Free Days" by Xiaoping Pang, Jian Pu, Xi Zhao, Qing Ji, Meng Qu and Zian Cheng addresses the behavior of passive microwave sea ice concentration (SIC) products for marginal ice zones [2]. It analyzes ice edges from ship observations and compares two SIC products of the advanced microwave scanning radiometer 2 (AMSR2). For this purpose, a common threshold was applied. The paper identifies differences between the two products, but also small differences between the Arctic and the Antarctic and between summer and winter. The conclusion was that the threshold is well suited to determine the ice edge from passive microwave SIC in both the Arctic and the Antarctic. In this paper, therefore, sources of uncertainty were illuminated by applying a common threshold that removes the different sources of uncertainty. The third paper "Analysis of Azimuthal Variations Using Multi-Aperture Polarimetric Entropy with Circular SAR Images" by Feiteng Xue, Yun Lin, Wen Hong, Qiang Yin, Bingchen Zhang, Wenjie Shen and Yue Zhao turns to uncertainties in synthetic aperture radar (SAR) images [3]. Recent developments present SAR modes such as wide-angle SAR and circular SAR (CSAR) with a larger azimuthal angle of view than the original SAR images. The paper separates polarimetric data into sub-apertures to provide polarimetric properties from different angles of view and presents a multi-aperture observation model which contains full polarimetric information from all angles of view. The paper demonstrates the effectiveness and advantages of multi-aperture polarimetric entropy with polarimetric CSAR data in an urban and an agricultural experiment. It is therefore able to reduce uncertainty by developing a well-tuned model that is appropriate for the data and applicable in a wide range of studies. The fourth paper, "Enhancing Land Cover Mapping through Integration of Pixel-Based and Object-Based Classifications from Remotely Sensed Imagery" by Yuehong Chen, Ya'nan Zhou, Yong Ge, Ru An and Yu Chen considers discrepancies between pixel- and object-based classifications of land cover information from remote sensing images [4]. The study reports a reduction of classification uncertainties by making a new classification method through the integration of pixel-based and object-based classifications IPOC. The effectiveness of IPOC is studied on two images. The study concludes that IPOC produces less salt and pepper noise and generates more accurate land cover details. The paper thus shows that taking an ensemble of methods may be helpful to reduce uncertainties. The fifth paper, entitled "Issues with Large Area Thematic Accuracy Assessment for Mapping Cropland Extent: A Tale of Three Continents" by Kamini Yadav and Russell G. Congalton addresses the extraction of accurate, consistent and timely cropland information over large areas [5]. The authors argue that more attention regarding the accuracy assessment of large area cropland maps is still needed. Their study specifically focused on dealing with some specific issues encountered when assessing the cropland extent on three continents. Their results indicate that the accuracy assessment can be easily accomplished for a large area, while more modifications were needed in the sampling design for other continents that had little to no reference data and other constraints. Uncertainty, in this case, could therefore be reduced by adapting the methodologies to the different conditions on the three continents. The sixth paper, "The Impact of LiDAR Elevation Uncertainty on Mapping Intertidal Habitats on Barrier Islands" by Nicholas M. Enwright, Lei Wang, Sinéad M. Borchert, Richard H. Day, Laura C. Feher and Michael J. Osland addresses limitations of LiDAR data in coastal settings, in particular addressing the uncertainty of digital elevation models [6]. The paper combines airborne LiDAR elevation data, in situ elevation observations, LiDAR metadata, and tide gauge information on a barrier island along the coast of Alabama, USA. Their methodology increases the efficiency and enhances results for habitat mapping and analyses in dynamic, low-relief coastal environments. Hence, uncertainty is reduced in this paper by using multiple data sources. The seventh paper, "Impervious Surface Change Mapping with an Uncertainty-Based Spatial-Temporal Consistency Model: A Case Study in Wuhan City Using Landsat Time-Series Datasets from 1987 to 2016" by Lingfei Shi, Feng Ling, Yong Ge, Giles M. Foody, Xiaodong Li, Lihui Wang, Yihang Zhang and Yun Du addresses classification accuracy using the temporal consistency model [7]. The authors realize that the sole use of class labels ignores the uncertainty of classification during the process. They propose an uncertainty-based spatial-temporal consistency model to solve that problem. The proposed model was used to obtain an annual map of impervious surfaces in Wuhan city with time series of images from different sensors. In this way, they could reduce the uncertainty; hence, this paper also uses multiple sources of data to reduce uncertainties. The eighth paper, "Generation of Radiometric, Phenological Normalized Image Based on Random Forest Regression for Change Detection" by Dae Kyo Seo, Yong Hyun Kim, Yang Dam Eo, Wan Yong Park and Hyun Chun Park focuses on the detection of changes on the Earth's surface [8]. They propose the use of image normalization to obtain a comparable set of images. For that purpose, they use nonlinear modeling and random forest (RF) techniques. They conclude that a normalized subject images generated by RF regression showed the highest accuracy, indicating that image normalization may be useful in change detection between multi-temporal image datasets. This study therefore signals data harmonization, but in particular also the new machine learning methods, to reduce uncertainties. Finally, the ninth paper, "Use of High-Quality and Common Commercial Mirrors for Scanning Close-Range Surfaces Using 3D Laser Scanners: A Laboratory Experiment" by Adrián J. Riquelme, Belén Ferrer and David Mas, considers 3D laser scanners [9]. Currently, this is in an experimental stage and mainly used for terrestrial products, but soon enough they will be found onboard satellites and other non-terrestrial objects. Using a simple mirror technique, the authors show that the noise introduced when scanning through a standard mirror is higher than that produced when using a high-quality mirror, but that the introduced error is lower than the instrumental error.

In summary, the special issue addresses uncertainties in images from different points of view: from the experiment to the product, from the sensor to the data and in the image analyses. The latest advances in satellite techniques are addressed. Clear directions are visible to reduce uncertainty by using more data sources, using the latest in analysis methods and combining different sub-optimal methods. All the roads lead to a reduction in uncertainty. Luckily for scientists as well as for the industry developing the technologies, the uncertainty is never completely eradicated: some remains, and that serves as the starting point for new research. As technology gains ground and remote sensing devices become more powerful, there is acknowledgement that higher resolution and dimensions create the need for larger computing power. The alternative of merging multiple data sources, shown in the papers in this special issue, is an approach that will always receive attention as a result of the lack of large computing power faced by every researcher and user.

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References

1. Bhatia, N.; Tolpekin, V.; Stein, A.; Reusen, I. Estimation of AOD Under Uncertainty: An Approach for Hyperspectral Airborne Data. *Remote Sens.* **2018**, *10*, 947. [CrossRef]
2. Pang, X.; Pu, J.; Zhao, X.; Ji, Q.; Qu, M.; Cheng, Z. Comparison between AMSR2 Sea Ice Concentration Products and Pseudo-Ship Observations of the Arctic and Antarctic Sea Ice Edge on Cloud-Free Days. *Remote Sens.* **2018**, *10*, 317. [CrossRef]
3. Xue, F.; Lin, Y.; Hong, W.; Yin, Q.; Zhang, B.; Shen, W.; Zhao, Y. Analysis of Azimuthal Variations Using Multi-Aperture Polarimetric Entropy with Circular SAR Images. *Remote Sens.* **2018**, *10*, 123. [CrossRef]
4. Chen, Y.; Zhou, Y.; Ge, Y.; An, R.; Chen, Y. Enhancing Land Cover Mapping through Integration of Pixel-Based and Object-Based Classifications from Remotely Sensed Imagery. *Remote Sens.* **2018**, *10*, 77. [CrossRef]
5. Yadav, K.; Congalton, R. Issues with Large Area Thematic Accuracy Assessment for Mapping Cropland Extent: A Tale of Three Continents. *Remote Sens.* **2018**, *10*, 53. [CrossRef]
6. Enwright, N.; Wang, L.; Borchert, S.; Day, R.; Feher, L.; Osland, M. The Impact of Lidar Elevation Uncertainty on Mapping Intertidal Habitats on Barrier Islands. *Remote Sens.* **2018**, *10*, 5. [CrossRef]
7. Shi, L.; Ling, F.; Ge, Y.; Foody, G.; Li, X.; Wang, L.; Zhang, Y.; Du, Y. Impervious Surface Change Mapping with an Uncertainty-Based Spatial-Temporal Consistency Model: A Case Study in Wuhan City Using Landsat Time-Series Datasets from 1987 to 2016. *Remote Sens.* **2017**, *9*, 1148. [CrossRef]
8. Seo, D.; Kim, Y.; Eo, Y.; Park, W.; Park, H. Generation of Radiometric, Phenological Normalized Image Based on Random Forest Regression for Change Detection. *Remote Sens.* **2017**, *9*, 1163. [CrossRef]
9. Riquelme, A.; Ferrer, B.; Mas, D. Use of High-Quality and Common Commercial Mirrors for Scanning Close-Range Surfaces Using 3D Laser Scanners: A Laboratory Experiment. *Remote Sens.* **2017**, *9*, 1152. [CrossRef]