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Editorial

Innovative Technologies for Terrestrial Remote Sensing

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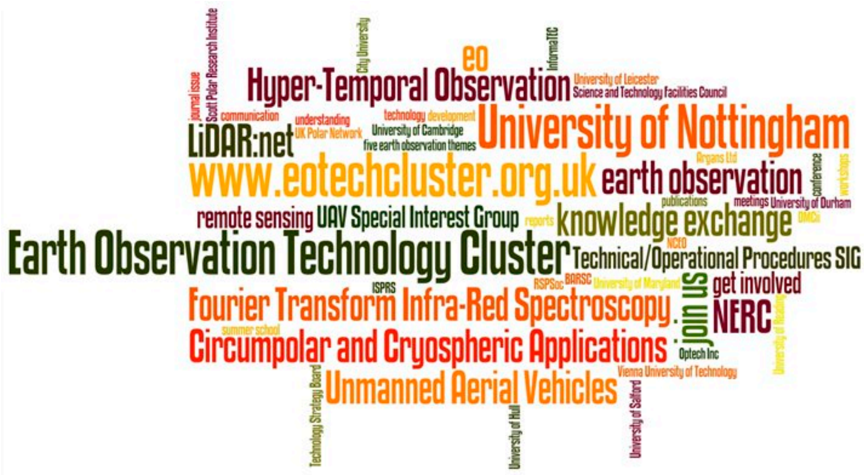
Characterizing and monitoring terrestrial, or land, surface features, such as forests, deserts, and cities, are fundamental and continuing goals of Earth Observation (EO). EO imagery and related technologies are essential for increasing our scientific understanding of environmental processes, such as carbon capture and albedo change, and to manage and safeguard environmental resources, such as tropical forests, particularly over large areas or the entire globe. This measurement or observation of some property of the land surface is central to a wide range of scientific investigations and industrial operations, involving individuals and organizations from many different backgrounds and disciplines. However, the process of observing the land provides a unifying theme for these investigations, and in practice there is much consistency in the instruments used for observation and the techniques used to map and model the environmental phenomena of interest. There is therefore great potential benefit in exchanging technological knowledge and experience among the many and diverse members of the terrestrial EO community.

The Earth Observation Technology Cluster (EOTC) is a major knowledge exchange initiative, established to promote development, understanding and communication about innovative technology used in remote sensing of the land surface among the wide community of interested researchers, technology developers and end-users (Figure 1). To ensure broad relevance and widespread interest in the initiative, the EOTC covers the full range of remote sensing operation, from new platform and sensor development, through image retrieval and analysis, to environmental modelling and data applications. (For more details about the achievements of the EOTC, see [1].) Following a public consultation, certain topical and strategic themes were identified for detailed investigation: unmanned aircraft systems, terrestrial laser scanning, field-based Fourier transform infrared spectroscopy, hypertemporal image analysis, and circumpolar and cryospheric applications. This paper provides an introduction to the

Remote Sensing Special Issue entitled ‘Earth Observation Technology Cluster: Innovative Sensor Systems for Advanced Land Surface Studies’. Various innovative technologies for terrestrial remote sensing are presented, including examples of the principal developments and priorities in some of the theme topics, through reference to the papers collected together in this Special Issue.

Figure 1. Earth Observation Technology Cluster word cloud, showing the initiative’s principal EO technology connections and collaborations.



As noted above, the scope of the EOTC was broad to encourage engagement from many diverse disciplines. Examples from some of the main themes are provided below, but the initiative covered broader developments across the range of remote sensing operation. For instance, in this issue, Wang and Shao [2] describe the benefits of an unconventional remote sensing platform—a high altitude platform, or near-space vehicle—for acquiring and processing passive radar imagery. Novel sensor developments are presented here by, for instance, Lato *et al.* [3], who demonstrate the use of a gigapixel laser scanner for terrestrial photogrammetry applications. Similarly, Content *et al.* [4] outline a new hyperspectral imaging approach which exploits advanced microslice technology and renders an image as unconventional spectral/spatial units, significantly increasing its spatial information content compared to traditional pixel-based representation. Additionally, novel image processing technology is introduced in this issue by Tommaselli *et al.* [5] who present a means of exploiting low-cost digital camera technology through automated calibration of multiple oblique scenes to create large synthetic images.

Contemporary remote sensing hardware is represented in the EOTC through terrestrial laser scanner (TLS) technology, which has become a well-established method of non-invasive survey in a wide range of disciplines, including engineering, architecture, mining, urban planning, ecology and remote sensing science. Current technology trends are, on the one-hand, towards lighter, faster and easy-to-use systems, and on the other hand towards full-waveform systems recording multiple laser wavelengths. These systems offer the opportunity for extracting quantitative information on the spectral properties of objects in the scene, and some have been designed specifically for measuring forest canopies. In this issue, Ramirez *et al.* [6] demonstrate the benefits of TLS over traditional hemispherical photography for characterizing forest canopy gaps. Despite the significant potential of TLS, various issues related to the modelling, registration, processing, visualization and storage of TLS data still need to be addressed.

There is a lack of dialogue between scientists developing TLS applications, instrument developers, and manufacturers, which in many cases, leads to inefficient and sub-optimal use of the data.

Novel remote sensing analysis is represented in the EOTC through hypertemporal imaging, which refers to a situation where we have an excess of multitemporal data, collected frequently enough to capture the dynamics of the phenomenon of interest. There is now a real opportunity for hypertemporal remote sensing capability by exploiting new EO constellations or 'virtual constellations' (*i.e.*, taking advantage of observations from any appropriate EO sensor that views a particular area) which have the potential to provide daily observations of the land surface at a spatial resolution of up to 10 m. A series of technical challenges related to preprocessing must be overcome to make hypertemporal imagery useful for rigorous scientific work. While we await the launch of sensors, which truly offer hypertemporal remote sensing, there are lessons to be learned from the recent rapidly growing interest in using near-surface terrestrial sensors, which have a (sub) daily temporal resolution. In this issue, for example, Morris *et al.* [7] explore the potential for automatic extraction of vegetation phenological metrics from traffic webcams.

Significant remote sensing applications are represented in the EOTC through circumpolar and cryospheric studies. Indeed, a large range of polar and cryospheric remote sensing data are freely available to the research community [8]. Glaciology represents one prime example of a cryospheric application exploiting contemporary remote sensing technology. Various advanced EO approaches including gravimetry, laser and radar altimetry, and multispectral classification have been used to characterize key properties of the terrestrial cryosphere such as glacier velocity, volume and albedo variation. In this issue, Racoviteanu and Williams [9] combine visible imagery, topographic information and kinetic temperature to classify debris cover on glaciers in the eastern Himalayas. In a wider polar context, multiple satellite platforms have enabled unprecedented visualization of sea ice dynamics, as well as analysis of permafrost and lake dynamics in many regions of the high Arctic. For instance, this issue includes a study by Reschke *et al.* [10] using C-band synthetic aperture radar to monitor high-latitude carbon-storing wetlands.

The Earth Observation Technology Cluster was funded in the UK by the Natural Environment Research Council (NERC), and involves a partnership between three main UK umbrella bodies responsible for remote sensing development, practice and exploitation—the Remote Sensing and Photogrammetry Society (academia), the National Centre for Earth Observation (government) and the British Association of Remote Sensing Companies (industry). Importantly, to ensure global relevance and impact, the EOTC is supported by leading international organizations, most notably the International Society for Photogrammetry and Remote Sensing's Technical Commission VII on Thematic Processing, Modeling and Analysis of Remotely Sensed Data.

The EOTC forms part of the NERC technologies theme which aims to stimulate technology development to meet the challenges associated with next generation platforms, remote sensing instruments, in situ sensors and modelling technology. The activities and initiatives summarized by the EOTC themes demonstrate that technologies are helping to reinvigorate Earth Observation by addressing both existing and new scientific challenges. This Special Issue introduces a range of contemporary technological development in EO of the land surface, covering platform and sensor development, as well as data processing and application. The papers presented, and the EOTC more broadly, identify opportunities and challenges for exploitation of EO technology by a wide community of users. The impact of the work presented here stems from close engagement between technologists and application scientists across a range of disciplines and the legacy of the EOTC depends on continuing this fruitful engagement.

Acknowledgments

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Author Contributions

Paul Aplin led both the Earth Observation Technology Cluster initiative as a whole and the writing and compilation of this paper. Doreen Boyd wrote the section on hypertemporal remote sensing and otherwise supported the writing and editing of the paper, and the EOTC in general.

Conflicts of Interest

The authors declare no conflict of interest.

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