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Landsat-8: Science and product vision for terrestrial global change research

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ABSTRACT

Landsat 8, a NASA and USGS collaboration, acquires global moderate-resolution measurements of the Earth's terrestrial and polar regions in the visible, near-infrared, short wave, and thermal infrared. Landsat 8 extends the remarkable 40 year Landsat record and has enhanced capabilities including new spectral bands in the blue and cirrus cloud-detection portion of the spectrum, two thermal bands, improved sensor signal-to-noise performance and associated improvements in radiometric resolution, and an improved duty cycle that allows collection of a significantly greater number of images per day. This paper introduces the current (2012–2017) Landsat Science Team's efforts to establish an initial understanding of Landsat 8 capabilities and the steps ahead in support of priorities identified by the team. Preliminary evaluation of Landsat 8 capabilities and identification of new science and applications opportunities are described with respect to calibration and radiometric characterization; surface reflectance; surface albedo; surface temperature, evapotranspiration and drought; agriculture; land cover, condition, disturbance and change; fresh and coastal water; and snow and ice. Insights into the development of derived 'higher-level' Landsat products are provided in recognition of the growing need for consistently processed, moderate spatial resolution, large area, long-term terrestrial data records for resource management and for climate and global change studies. The paper concludes with future prospects, emphasizing the opportunities for land

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imaging constellations by combining Landsat data with data collected from other international sensing systems, and consideration of successor Landsat mission requirements.

1. Introduction

At over 40 years, the Landsat series of satellites provides the longest temporal record of space-based surface observations. Landsat 1 was launched in 1972 and was followed by a series of consecutive, temporally overlapping, Landsat observatories (Landsat 2, 3, 4, 5 and 7) that have provided near-global coverage reflective and thermal wavelength observations with increasing spectral and spatial fidelity (Lauer, Morain, & Salomonson, 1997; Loveland & Dwyer, 2012; Williams, Goward, & Arvidson, 2006). Remarkably, the Landsat record is unbroken, with most land locations acquired at least once per year since 1972, capturing a period when the global human population has more than doubled (United Nations Population Division, 2011) and evidence for climate change has become discernible (Hansen, Sato, & Ruedy, 2012; IPCC, 2013). Landsat data offer a unique record of the land surface and its modification over time. The Landsat moderate spatial resolution is sufficiently resolved to enable chronicling of anthropogenic and natural change at local to global scale (Gutman et al., 2008; Townshend & Justice, 1988) and the data time series are calibrated to provide a characterized consistent record (Markham & Helder, 2012) that is needed to enable discrimination between data artifacts and actual land surface temporal changes (Roy et al., 2002). Landsat data have demonstrated capabilities for mapping and monitoring of land cover and land surface biophysical and geophysical properties (Hansen & Loveland, 2012; Wulder, Masek, Cohen, Loveland, & Woodcock, 2012) and potential utility for terrestrial assimilation and biogeochemical cycling and land use forecasting applications (Lewis et al., 2012; Nemani et al., 2009; Sleeter et al., 2012). Applications addressed with Landsat data involve both scientific discovery and managing and monitoring resources for economic and environmental quality, public health and human well-being, and national security. Analyses of the economic benefits of Landsat vary from $935 million/year (ASPRS, 2006) to $2.19 billion/year (Miller, Richardson, Koontz, Loomis, & Koontz, 2013) in support of applications including water resource analysis and management, agriculture and forest analysis and management, homeland security, infrastructure analysis, disaster management, climate change science, wetland protection, and monitoring land cover change.

The 40+ year Landsat record was continued with the successful February 11th 2013 launch of Landsat 8 from Vandenburg Air Force Base, California. This new Landsat observatory was developed through an interagency partnership between the National Aeronautics and Space Administration (NASA) and the Department of the Interior U.S. Geological Survey (USGS) (Irons & Loveland, 2013). NASA led the mission and was responsible for system engineering and design, developing the flight segment, securing launch services, flight ground systems integration, and conducting on-orbit initialization and verification. NASA referred to the effort as the Landsat Data Continuity Mission (LDCM) during the development, launch, and on-orbit commissioning. USGS led the ground system development and the LDCM was renamed Landsat 8 on May 30th 2013 when the USGS formally took responsibility for mission operations, including collecting, archiving, processing, and distributing Landsat 8 data. Landsat 8 carries two sensors, the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS), and over 500 image scenes per day are ingested into the U.S. Landsat data archive at the USGS Earth Resource Observation and Science (EROS) Center, South Dakota. The new Landsat 8 scenes complement the now more than four million scenes acquired by previous Landsat missions that are stored in the U.S. Landsat archive and are freely available via the internet (Woodcock et al., 2008).

This paper introduces the current (2012–2017) USGS–NASA Landsat Science Team (LST) efforts to establish an initial understanding of Landsat 8 capabilities and the steps ahead in support of science team identified priorities. These priorities and the purpose and focus of the current LST are first introduced. This is followed by an overview of the Landsat 8 mission objectives, sensors, orbit, data acquisition, and standard data products to provide context for the subsequent sections. Preliminary evaluation of Landsat 8 capabilities and identification of new science and applications opportunities are highlighted, followed by insights into the development of derived 'higher-level' Landsat products, international synergies between Landsat and other moderate resolution remote sensing satellites, and a conclusion that includes consideration of successor Landsat mission requirements.

2. Landsat 8 Science Team

This paper is authored by members and affiliates of the current LST. There have been several LSTs, each selected through a competitive proposal review process to serve a five-year term funded by the USGS and/or NASA. The science teams were charged to provide feedback on critical design issues, including functional performance specifications of the Landsat instruments, data systems and data formats that affect Landsat data users, and to consider interoperability of Landsat with other planned and in orbit remote sensing systems, and to provide insights on future missions. The previous LST (2005–2011) provided justification for making the U.S. Landsat data archive available at no cost, recommended strategies for the effective expansion and use of the archived Landsat data, and investigated the requirements for Landsat 8 to meet the needs of users including policy makers (Woodcock et al., 2008; Wulder & Masek, 2012). The LST prior to that (1996–2001) was formulated as part of the Landsat 7 development phase in a period when Landsat 5 was the only operating Landsat due to the 1993 Landsat 6 failure (Goward et al., 2006; Irons & Masek, 2006). It developed a Landsat 7 long-term data acquisition plan, undertook research to develop methods to analyze Landsat data for global change studies, and evaluated the data quality acquired by Landsat 7 after it was launched in April 1999 (Arvidson, Gasch, & Goward, 2001; Goward, Masek, Williams, Irons, & Thompson, 2001).

The current LST (2012–2017) was selected with an aim to represent the breadth of Landsat user perspectives and their requirements. The LST is comprised of 21 principal investigator-lead teams of scientists and engineers drawn from academia, U.S. Federal science and mission agencies, and includes representation from non-U.S. institutions to ensure an international perspective. The majority of the science team members have expertise in processing and characterizing Landsat data and/or expertise using Landsat data for a specific application domain. The LST met prior to and shortly after Landsat 8 launch and established the following four core priorities for the next five years:

(1) evaluation of Landsat 8 capabilities and identification of new science and applications opportunities,
(2) development of strategies and prototype approaches for the development of 'higher-level' derived Landsat science products needed in support of global change research,
(3) identification of international land imaging constellation opportunities,
(4) definition of science and applications requirements for succeeding Landsat missions for operational long-term observational continuity.