meeting summaries

2014 Landsat Science Team Meeting

Thomas Loveland, U.S. Geological Survey Earth Resources Observation and Science Center, loveland@usgs.gov
Michael Wulder, Canadian Forest Service, Pacific Forestry Centre, Natural Resources Canada, mwulder@nrcan.gc.ca
James Irons, NASA's Goddard Space Flight Center, james.r.irons@nasa.gov

Introduction

The U.S. Geological Survey (USGS)-NASA Landsat Science Team (LST) met in Corvallis, OR, July 22-24, 2014. The U.S. Forest Service Pacific Northwest Research Station and Oregon State University hosted the meeting. Objectives for the meeting included reviewing the status and operations of Landsat 7 and 8, reporting on the status of programmatic sustainable land imaging, developing concepts and specific actions for making the Landsat archive more relevant to the scientific community, and identifying Landsat products that expand Landsat's usefulness for science and applications. All meeting presentation materials are available at *landsat.usgs.gov/science_LST_July_22_24_2014.php*.

Landsat Science Team members in Corvallis, OR. **Image credit:** Thomas Loveland

The LST co-chairs **Thomas Loveland** [USGS Earth Resources Observation and Science (EROS) Center—*Senior Scientist*] and **Jim Irons** [NASA's Goddard Space Flight Center (GSFC)—*Landsat 8 Project Scientist*], opened the three-day meeting with a review of the maturation of the Landsat program and the increasing advances in Landsat use across a wide range of scientific and operational investigations. Operational natural resources monitoring programs are finding Landsat 8 data to be of superior quality to that of previous Landsat satellites. The 2008 Landsat free data policy has transformed Landsat applications and has stimulated the growth of time-series studies spanning large areas and long temporal periods. As a result, the need for Landsat imagery—and especially new higher-level Landsat products—has grown substantially.

Landsat Status

Brian Markham [GSFC—*Landsat 8 Calibration Scientist*] reported that Landsat 8 radiometric and geometric performance was excellent. Data from the Operational Land Imager (OLI) have signal-to-noise ratios that are two-to-three times better than specifications and up to eight times better than the Landsat 7 instruments. OLI radiometry has been quite stable since launch and the OLI absolute radiance uncertainty requirement of <5% is being met. Image geodetic and geometric accuracies are exceeding requirements and the improved geometric accuracy is better than the locational Ground Control Points (GCP) currently used for orthorectification. As a result, Landsat 8 images will be used to improve the accuracy of the Landsat GCP library.

Regarding the Thermal Infrared Sensor (TIRS), radiometric performance is relatively stable for both thermal channels. Markham reported that there are cross-track artifacts in the thermal bands that appear as ghost signal values. While both bands are affected, with a bias adjustment, band 10 now has errors of 1 K or less. The problem is more evident in band 11; as such, the use of band 11 and split-window surface temperature techniques are not recommended. Stray light has been identified as the cause of the ghosting, and procedures are being evaluated to correct the problem.

Brian Sauer [USGS EROS Center—*Landsat Sustaining Engineering Project Manager*] provided an update on Landsat operations and archive status. In particular, he stated that Landsat 7 continues to function well. Solid-state data recorder capacity has declined (currently at 80% of original), but some of the lost storage may be recoverable. The number of daily acquisitions has been increasing and is currently around 440 sunlit scenes per day—well exceeding the design requirement of 250 scenes per day. The projected fuel-based end of mission for Landsat 7 is expected to be in early 2018, so fuel levels are being monitored closely. He noted that operational practices could affect the projected date.

Landsat 8 is also functioning nominally. On a couple of occasions, the spacecraft and systems went into a "safe hold" mode due to performance anomalies occurring

during calibration maneuvers. However, the events had no significant impact on Landsat 8 systems. The USGS is evaluating the acquisition capacity of Landsat 8 during the 2014 growing season. Currently, 725 sunlit scenes are being collected daily—beyond the design requirement of 400. The performance and cost of the expanded acquisition rates will be evaluated at the end of the growing season; a decision will then be made regarding the long-term acquisition plan. **Darrel Williams** [Global Science and Technology, Inc.—*Chief Scientist*] put this into historical context by noting that during the Landsat commercial era (1980s and 1990s), only 50 Landsat scenes were collected each day.

Sauer also reported that the Landsat archive now holds almost 5.3 million images. The archive is growing rapidly due to the success of the Landsat Global Archive Consolidation (LGAC) activity in which more than 3 million historical images—dating back to 1972—have been recovered from International Cooperator (IC) archives around the world; almost all past ICs are cooperating. European holdings are currently being transferred, and plans are underway to receive Landsat holdings from Thailand and possibly India.

Finally, Sauer summarized plans for Landsat product improvements, including:

- Implementation of a new cloud mask algorithm, called *fmask,* developed by Boston University for use with Landsat Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and OLI data (early 2015);
- improvement of the Landsat GCP library (beginning in late 2014);
- generation of systematic terrain-corrected ETM+ images when precision ground control corrections cannot be applied (schedule TBD);
- increased Landsat distribution cache capacity (fall 2014);
- generation of scene-based, top-of-atmosphere (TOA) reflectance scaling factors for Landsats 1-7 (winter 2015);
- provision of TOA reflectance enhanced metadata that includes scene-specific, per-pixel, solar azimuth and sensor viewing angle metadata for use in reflectance conversions for Landsats 4-8 (winter 2014);
- production of quality bands for Landsats 1-7 (planning phase initiated);
- correction of TIRS ghosting (TBD); and
- improvement of digital elevation models used for orthorectification (study yet to be initiated).

John Dwyer [USGS EROS Center—*Landsat Project Scientist*] provided an update on plans to provide a data quality band for Landsats 1-7, based on the Landsat 8 data quality band. Dwyer also reported that work is underway to provide atmospherically corrected Landsat 8 surface reflectance products by late 2014. These will be consistent with Landsat 4-7 surface reflectance datasets. Research is continuing on surface temperature capabilities. Provisional Landsat 4-7 products should be available by the middle of 2015.

Sustaining Land Imaging Discussion

NASA and USGS representatives presented their perspectives on efforts to develop a long-term Landsat strategy. **Jim Irons** summarized the public information that has come from the NASA–USGS Architectural Study Team (AST) that is exploring technical options for future Landsats. The AST has evaluated a wide range of technical approaches that will be considered by NASA and Department of the Interior (DOI) leadership. **Tim Newman** [USGS—*Land Remote Sensing Program Coordinator*] and **Sarah Ryker** [USGS—*Acting Associate Director*] described ongoing efforts to better understand Landsat requirements. A DOI priority is avoiding data gaps, and maintaining the current eight-day repeat capabilities afforded by Landsats 7 and 8. They also mentioned that the National Earth Observations Task Force of the Office of Science and Technology Policy just released a strategic plan for Earth observations (*www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC/national_plan_for_civil_earth_observations_-_july_2014.pdf*). The plan identified Landsat as one of the highest-impact U.S. observation programs.

Other Landsat Topics

Holly Miller and **Larisa Serbina** [both at USGS' Fort Collins Science Center] presented the results of research on the users, uses, and value of Landsat imagery. Their team recently completed a survey of more than 13,000 Landsat data users. Survey results show that the use of Landsat is growing and that users have greater dependency on Landsat imagery to meet their work responsibilities than ever before. Using a contingent valuation method, they estimated that the 2012 economic value of Landsat data to U.S. users alone was approximately $1.79 billion. They also reviewed a series of Landsat applications associated with water resources as a way to illustrate the growing value of Landsat data. The full report is available at *pubs.usgs.gov/of/2013/1269/pdf/of2013-1269.pdf*.

Kass Green [Kass Green & Associates] provided an update on the activities of the Landsat Advisory Group (LAG), a subcommittee of the DOI National Geospatial Advisory Committee. The LAG recently completed reports on future Landsat products, cloud computing, and the National Research Council's

Landsat and Beyond study. The LAG is now focused on updating their earlier report on Landsat uses.

Rick Lawrence [Montana State University] gave an overview of AmericaView, a university-led consortium composed of consortia from 39 different states (*www.americaview.org*) dedicated to advancing remote sensing education, outreach, and research. Currently, there are nearly 40 AmericaView members, associates, and affiliates. AmericaView supports between 70 and 80 research projects dealing with ecological monitoring, land cover change, agricultural management, wildfire risk assessment, water quality monitoring, and other topics.

Landsat and Sentinel-2 Collaboration

Benjamin Koetz [European Space Agency (ESA)] described the developmental status of ESA's Sentinel-2. This mission will have capabilities similar to Landsat, with 13 multispectral bands, multiresolution imaging over a 290-km (~180-mi) swath at resolutions of 10, 20, and 60 m (~33, 66, and 197 ft, respectively), five-day revisit time with two satellites, and plans to systematically image the global landmass and coasts. Sentinel-2a is scheduled for launch in spring 2015 and the Sentinel-2b launch date is scheduled to take place a year later (spring 2016). The ramp-up to operational status for Sentinel-2 will take approximately one year and the mission will follow a free and open data policy.

Jeff Masek [GSFC—*Landsat Project Scientist*] and **John Dwyer** discussed U.S. efforts to archive and distribute Sentinel-2 imagery, and improve synergy between Sentinel-2 and Landsat. Masek reported on efforts between NASA and ESA to evaluate Landsat 8 OLI and Sentinel-2 Multi-Spectral Instrument (MSI) sensor characteristics in order to advance the interoperability of data from the two missions prior to launch. In addition, NASA is funding research to look at several Landsat/Sentinel-2 topics, including harmonized surface reflectance and other higher-level science products, as well as common gridding approaches. Dwyer summarized USGS plans to redistribute Sentinel-2 projects. At a minimum, the USGS will provide access to orthorectified, TOA reflectance (Level 1C) products in ESA's standard 100 x 100-km (~62 x 62-mi) tiles. The USGS is also evaluating higher tiers of service that would enable more direct integration of Sentinel-2 products with those from Landsat.

Landsat Science Presentations

LST member and meeting host, **Warren Cohen** [U.S. Forest Service Pacific Northwest Research Station] organized a series of presentations by his research team from the Laboratory for Applications of Remote Sensing in Ecology (LARSE). A centerpiece of LARSE research is a national interagency effort to establish a Land Change Monitoring System (LCMS) based on Landsat. Cohen featured three projects, including an investigation using Landsat data from 1972 to the present to identify the remaining original, native forests in Haiti; a study of the causes and consequences of increased insect and disease activity in the Western U.S. (with **Justin Braaten** [Oregon State University (OSU)]); and a study characterizing forest stress and vulnerability in the Pacific Northwest using Moderate Resolution Imaging Spectroradiometer (MODIS) and Landsat (with **David Mildrexler** [OSU]).

The LST members then gave brief highlights of their recent Landsat research, which are presented in **Table 1**.

Table 1. Presentation highlights from LST members.

Presenter(s)	Affiliation(s)	Highlight
Martha Anderson	U.S. Department of Agriculture's Agricultural Research Service	Landsat, MODIS, and Geostationary Operational Environmental Satellite data are being successfully integrated to estimate daily water use at field scale.
David Johnson	USGS National Agricultural Statistical Service	Landsat 8 could finally make it practical to have operational cropland monitoring in developing countries.
John Schott	Rochester Institute of Technology	Research is proceeding that should result in Landsat surface temperature products, first for North America, but eventually globally.
Valerie Thomas and Randy Wynne	Virginia Tech	Landsat 8 research is addressing leaf area estimation, accounting for cirrus clouds in land cover classification, and monitoring forest change.
Joel McCorkel	GSFC	Landsat 8 OLI data intercomparisons were made with aerial and *in situ* radiometric measurements.
Curtis Woodcock	Boston University	Image classifications made using Landsat 8 are superior to results obtained from Landsat 7.

Table 1. (cont.) Presentation highlights from LST members.

Presenter(s)	Affiliation(s)	Highlight
Ted Scambos	University of Colorado	Landsat 8 data are showing good results in characterizing a range of snow and ice phenomena including ice flow tracking, melt lake depth, and thermal mapping of the Antarctic interior.
Robert Kennedy	Boston University	Time-series analysis in a cloud-based computing environment is investigated.
David Roy	South Dakota State University	Progress is being made in creating seamless temporal composites for the U.S. using Landsat 8 and for the globe using Landsat 5 and 7.
Eric Vermote	GSFC	Landsat 8 surface reflectance processing algorithms were developed and tested with positive results.
Rick Allen Ayse Kilic	University of Idaho University of Nebraska	Analyses were carried out to determine specifications for thermal imaging on Landsat 9 and beyond.
Mike Wulder	Canadian Forest Service	Canada's contemporary forest history is being recreated using Landsat time-series data.
Alan Belward	European Commission Joint Research Centre	A Sentinel-2 global surface water monitoring strategy was prototyped using Landsat data.
Yongwei Sheng	University of California, Los Angeles	Substantial progress has been made mapping lakes across the globe using Landsat data.

Future Landsat Science Products

The final topic of the meeting involved requirements and specifications for higher-level Landsat science products, led by **David Roy** [South Dakota State University] and **Curtis Woodcock** [Boston University], co-leaders of the LST. As a general philosophy, the LST recognized three levels of Landsat products:

1. **Level 1T (L1T)**: The basic Landsat product that is essential for remote sensing methods research and scientific investigations in which there is a need to control processing steps.
2. **Analysis Ready Data**: Seamless (mosaiced) data that include individual cloud-free pixels as well as pixel-based layers processed to higher levels of temporal aggregations and that have advanced corrections applied. All Landsat archive scenes are included.
3. **Derived Landsat Science Products**: Geospatial datasets and statistical summaries describing geophysical properties, biophysical conditions, and land cover characteristics and dynamics.

The LST also emphasized the importance of considering broad community requirements, transparency in planning and evaluating Landsat product concepts (e.g., including the development of Algorithm Theoretical Basis Documents), the use of peer-reviewed methods, and adherence to definitions and standards identified by national and international science forums. The team also stressed that products need to be generated from the full Landsat archive, including the Multispectral Scanner (MSS). However, they also recognize the need to phase development by instrument groups (e.g., MSS, TM, ETM+, and OLI).

Regarding future L1T improvements, LST recommendations included:

- Improving the technical depth and quality of L1T documentation;
- making the 30-m (~98-ft) Digital Elevation Model used for Landsat terrain corrections available;
- improving the use of the Landsat 8 cirrus band in cloud and shadow masking;
- producing spatially explicit cloud and shadow masks for Landsats 1-7; and
- extending metadata content to facilitate derivation of solar and viewing geometry for Landsats 1-7.

The LST also recommended that greater attention be given to Landsat L1T versioning so that users are aware of the date, level, and specific parameters (e.g., Calibration Parameter Files) associated with the data they are currently using.

Regarding analysis-ready Landsat data, this is an area where more discussion is needed before a

meeting summaries

consensus can be reached. Basic properties of analysis-ready data include:

- Immediate access to the full Landsat archive (vs. on-demand processing);
- access to individual-pixel observations and seasonal composites;
- surface reflectance and temperature measurements;
- cloud and shadow detection and masking;
- bidirectional reflectance distribution function (BRDF) normalization;
- gridded composites; and
- robust data-delivery services.

With analysis-ready data, consistency and traceability are critical. As Landsat data are increasingly used for long-term climate studies, establishing collections in which the entire Landsat archive is processed using consistent, traceable, and peer-reviewed procedures was encouraged.

The discussion of higher-level Landsat science products was limited due to time constraints; exploration of this topic will be continued in future meetings. Generally, the team suggested that—based on the Landsat mission goal of global land change monitoring—emphasis should be given to land-change science products. It is important that the definitions used for MODIS products and those used for the Suomi National Polar-orbiting Partnership satellite's Visible Infrared Imaging Radiometer Suite products remain consistent, and that all products adhere to international standards. Attention must also be paid to both categorical and quantitative land cover and condition measures.

The final topic of discussion was the relationship between Landsat and Sentinel-2 datasets. In order to benefit from the synergy associated with the two similar multispectral missions, the LST recommended that, at a minimum, USGS should be archiving and distributing Sentinel-2 L1C data. Beyond that, the LST encouraged development of processing techniques that allow interoperability. In addition, they encouraged research that addresses different BRDF effects, efforts to ensure consistency in surface reflectance products, and work on understanding and correction of spectral bandwidth differences. Some of these issues are already being addressed by NASA-sponsored research.

The next meeting is tentatively set for February 3-5, 2015; at GSFC in Greenbelt, MD. ■

announcements

Come Explore NASA Science at the 2014 Fall AGU Meeting

Please plan to visit the NASA booth (# 2335) during the American Geophysical Union's (AGU) forty-seventh annual Fall Meeting! This year's exhibit hall will open on Monday, December 15, and will continue through Friday, December 19.

Throughout the week representatives from several different programs and missions are scheduled to give dynamic Hyperwall and Keynote presentations. Presentations will cover a diverse range of research topics, science disciplines, and programs within NASA's Science Mission Directorate, including Earth Science, Planetary Science, Astrophysics, and Heliophysics.

At the booth there will also be a wide range of other science presentations, demonstrations, printed material, and tutorials on various data tools and services.

A daily agenda will be posted on the Earth Observing System Project Science Office website—*eospso.nasa.gov*—in early- to mid-December.

We hope to see you in San Francisco!

A NASA Science presentation using the dynamic Hyperwall display during the 2012 AGU Meeting. **Image credit:** NASA