Landsat Science Team Meeting Summary: Winter 2016

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Landsat Science Team: 2016 Winter Meeting Summary

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Introduction

The winter meeting of the joint U.S. Geological Survey (USGS)–NASA Landsat Science Team (LST) was held January 12-14, 2016, at Virginia Tech University in Blacksburg, VA. LST co-chairs Tom Loveland [USGS’s Earth Resources Observation and Science Data Center (EROS)—Senior Scientist] and Jim Irons [NASA’s Goddard Space Flight Center (GSFC)—Landsat 8 Project Scientist] welcomed more than 50 participants to the three-day meeting. The main objectives of this meeting focused on identifying priorities and approaches to improve the global moderate-resolution satellite record. Overall, the meeting was geared more towards soliciting team member recommendations on several rapidly evolving issues, than on providing updates on individual research activities. All the presentations given at the meeting are available at landsat.usgs.gov/science_LST_january2016.php.

USGS and NASA Headquarters Perspectives

Tim Newman [USGS Headquarters (HQ)—Land Remote Sensing Program Coordinator] and Virginia Burkett [USGS HQ—Associate Director for Climate and Land Use Change] briefed the LST on several issues pertaining to current and future Landsat missions. Both Newman and Burkett stressed the need for a concerted communications strategy to continue educating others about the benefits of Landsat and its future synergy with the European Space Agency’s Sentinel-2 mission.

David Jarrett [NASA Headquarters—Landsat Data Continuity Mission Program Executive] informed the team that Landsat 9 is fully funded and is now optimistically slated for a 2021 launch date. With the recent completion of the Sustainable Land Imaging (SLI) report, Jarrett emphasized the importance of establishing a long-term (i.e., ~20-year) vision for Landsat 10 and beyond. Although there is a strong desire to improve Landsat’s capabilities, Jarrett encouraged the team to balance improving technology with the growing demand for consistent and repeatable high-frequency, moderate-resolution observations.

Landsat Product Improvements: Collection Concepts

Brian Sauer [EROS—Landsat Sustaining Engineering Project Manager] provided an update on several new Landsat products that are currently under development at EROS. This includes a new collection-management approach that will offer more detailed labeling and versioning of all Landsat images so that users can more easily see when and what processing updates have occurred. Images will also be assigned to one of two tiers based on several quality criteria. In addition to reformatting product file names to facilitate user queries, all Landsat Thematic Mapper (TM), Enhanced Thematic plus (ETM+), and Operational Land Imager (OLI) images will also include a new quality-assessment (QA) band that will identify radiometric saturation, as well as pixels potentially contaminated with clouds, shadows, snow/ice, and water. Per-pixel solar illumination and sensor view-angle coefficients will also be disseminated starting with Collection 1. Collection 1 for Landsat 4-7 TM and ETM+ is slated for release in June 2017; Collection 1 for Landsat 8 OLI-Thermal Infrared Sensor (TIRS) will be released in November 2017.

Although updates to the Landsat Multispectral Scanner (MSS) instrument will not be included in Collection 1, they will be added in future releases as issues specific to MSS images are dealt with. Overall, the LST voiced their support for the proposed changes.

John Schott [Rochester Institute of Technology] provided an update on the ongoing effort to develop and validate a Landsat global surface temperature product. Because errors increase near clouds, the data are being binned so that users can interactively decide what data are acceptable for their individual applications. In an effort to expand the approach globally, Schott’s team is evaluating the use of NASA’s Modern-Era Retrospective Analysis for Research and Applications (MERRA) data to correct for atmospheric effects and the use of the Moderate Resolution Imaging Spectroradiometer (MODIS) Sea Surface Temperature (SST) product as a reference source for validation.

Landsat Surface Reflectance: Improving Consistency

Curtis Woodcock [Boston University—LST Co-Leader] made the case for improving the

1 See additional discussion of Sentinel-2 and Landsat issues beginning on page 20.
2 The official launch date for Landsat 9 is 2021, but there is a push to be ready by 2020 in order to maximize likelihood of overlap with Landsat 7. Thus, different dates or date ranges are used in this summary depending on the specific context of the discussion.
consistency of surface reflectance (SR) estimates from different Landsat sensors. In particular, he discussed the three main sources of error that contribute to systematic variations in SR from different Landsat sensors. These include internal calibration (e.g., 8-bit vs. 12-bit data), spectral bandwidth, and sensor-specific SR-correction algorithms.

Standing in for LST member Eric Vermote [GSFC], Belen Franch [GSFC] provided an overview of the current Landsat 8 SR algorithm (referred to as L8SR). The L8SR algorithm, which is based on widely available and validated radiative transfer code, relies on MODIS Collection 6 aerosol and water vapor products to correct for atmospheric effects. While initial validation results are encouraging, some LST members voiced concerns about potential smoothing effects introduced during spatial averaging, as well as occasional occurrences of visual artifacts in areas of high relief and dense forest cover. More details on L8SR, including implementation and algorithm performance, will be available in the forthcoming Landsat 8 special issue of Remote Sensing of Environment.

Feng Gao [U.S. Department of Agriculture’s Agricultural Research Service] described research on fusing MODIS and Landsat data to map evapotranspiration (ET). He presented results that showed similar systematic biases between Landsat 7 and 8 found by other researchers.

John Dwyer [EROS—Landsat Project Scientist] provided an update on the status of SR products being processed and distributed by USGS EROS. Because L8SR is still awaiting formal publication, the data released so far are considered provisional. The LST encouraged the USGS to increase efforts to develop and implement a single atmospheric correction algorithm that works across all Landsat sensors.

Landsat Analysis-Ready Data

Curtis Woodcock introduced the topic of Landsat Analysis-Ready Data (ARD), which offer users direct access to the highest-quality Landsat data so that landscape change can be studied with minimal independent preparation of the data. Also given that SR will form the basis of the ARD gridded, tiled, and seamless time series stacks distributed by EROS, Woodcock reiterated some of the discussion from the previous session about the urgent need to deal with atmospheric correction of SR data.

David Roy [South Dakota State University (SDSU)—LST Co-Leader] followed by recapping his experiences developing, producing, and distributing Web-enabled Landsat data (WELD). Using the context of WELD, Roy underscored many of the challenges associated with creating operational Landsat products including the need for peer-reviewed science algorithms, standardized products, dedicated science support staff, and systematic production on dedicated computing facilities.

John Dwyer returned with an overview of the USGS definition for ARD. One of the main goals of ARD is to significantly reduce the burden of processing large data streams. Toward that end, USGS aims to offer data that have been consistently processed to the highest scientific standard. ARD will consist of both Landsat top-of-atmosphere (TOA) and SR products that are gridded, tiled, and seamlessly delivered in Albers Equal Area projection (for the conterminous U.S.) Initial production will first focus on U.S. coverage (including Alaska and Hawaii), then will gradually expand globally, followed by the addition of Landsat MSS data. ARD will be distributed through a new application program interface; given the large amount of processing required, new acquisitions will have slightly longer latency times than past products. With increased temporal density (due to inclusion of side-lap from adjacent scenes) and newly added QA bands, ARD is poised to revolutionize the way users obtain and analyze Landsat data.

Mike Wulder [Canadian Forest Service] offered perspectives on how Landsat time series are being used to map and analyze forest disturbance and recovery dynamics across Canada. He showed how change metrics derived from Landsat time series are increasingly being used as model inputs, as well as how temporal grain and extent matter when defining change products. In addition to monitoring change, Wulder also stressed the importance of using time series to identify undisturbed forests, as they are also ecologically important.

Sentinel-2 and Landsat

Bianca Hoersch [European Space Agency (ESA)—Sentinel-2 Mission Manager] provided an update on ESA’s Copernicus mission, including the status of the recently launched Sentinel-2A satellite. She reported that Sentinel-2 data were officially released to the international user community on December 3, 2015, and that imagery are currently available for download through ESA’s scientific data hub (scihub.copernicus.eu). So far, users have been pleased with the radiometric quality of the imagery, with many citing improved vegetation discrimination with the red-edge band and good overall alignment with Landsat spectral signatures.

6 The Albers Equal Area (conic) projection system uses two standard parallels; it shows areas accurately, but distorts shapes. Both the USGS and U.S. Census Bureau make use of this projection.

5 ESA’s Sentinel-2 mission is a land-monitoring constellation consisting of two satellites. The first, Sentinel-2A, launched in June 2015; Sentinel-2B is scheduled to launch in mid-2016. Both satellites carry the MultiSpectral Imager (MSI), which produces images with resolution similar to those obtained by OLI onboard Landsat-8.

6 To learn more about WELD, visit globalmonitoring.sdstate.edu/projects/weld.
Ferran Gascon [ESA] reported on Sentinel-2 data quality. Initial analysis indicates that the signal-to-noise ratio (SNR) measured with the diffuser onboard Sentinel-2’s MultiSpectral Instrument (MSI) is exceeding prelaunch mission requirements. Although some minor misregistration problems have been reported for bands 11 and 12, the overall geometric quality of the data appears to be good. Gascon also noted that improvements to the Global Reference Image (GRI), which should be completed by the summer of 2017, ought to reduce geolocation errors to 7-8 m (~23-26 ft).

Jeff Masek [GSFC—Landsat 9 Project Scientist] provided an update on NASA’s experience with Sentinel-2A data. Masek said NASA is currently exploring the possibility of producing seamless, near-daily, 30-m (~98-ft) surface reflectance records from Landsat and Sentinel-2 data. This effort, known as the Harmonized Landsat-Sentinel (HLS) project, is a collaborative venture among GSFC, the University of Maryland, and NASA’s Ames Research Center. Implemented on the NASA Earth Exchange (NEX), a data cube processing system (analogous to ARD, described above) is being developed for a limited set of test sites. The plan is to release four products [MSI SR 10-m (~33-ft), MSI SR 30-m, OLI SR 30-m, and 5-day composites, based on a best-pixel approach] for users to evaluate. Masek noted that if demand is high enough, this could become a future operational product.

David Roy briefed the LST on his initial findings prototyping a Landsat 8/Sentinel-2 global burned-area product. He said the burn-detection algorithm being developed can be used interchangeably with Landsat 8 and Sentinel-2 data. Initial results in Africa appear promising when compared with the MODIS burned-area product (i.e., MOD45). Due to Sentinel-2’s wider swath width, Roy stressed the importance of correcting for bidirectional reflectance distribution function (BRDF) effects. He also noted a few areas of concern, including the presence of random data gaps in the Sentinel-2 images and an apparent misregistration between Sentinel-2 and Landsat 8.

Jim Storey [EROS—Landsat Geometric Calibration Scientist] provided an assessment of Sentinel-2’s geometric image-registration and band-registration accuracy. To examine performance of Sentinel-2 the MSI Level-1C data were processed for compatibility with Landsat 8 geometric characterization tools. Comparison with USGS Global Land Survey (GLS) ground control points (GCPs) showed that Sentinel-2/Landsat 8 registration accuracy was well within Landsat data requirements. Due to differences in ground control (i.e. GLS versus GRI), Storey cautioned that misregistration between Landsat 8 and Sentinel-2 would likely persist until ESA completes the GRI update slated for the summer of 2017.

Brian Markham [GSFC—Landsat Calibration Scientist] presented preliminary results from the Landsat Calibration and Validation Team’s evaluation of Sentinel-2A’s on-orbit radiometric performance. He reported that MSI TOA reflectance was consistently within ±5% of vicarious measurements (both with and without ground measurements) which is at, or near, Landsat 8 requirements. From an absolute calibration perspective, Markham noted that the MSI visible and near-infrared bands are showing good stability but the shortwave infrared bands, which are on separate cold focal planes are showing a ±2% decrease in responsivity during periods when the focal plane is first warming up. Although initial results appear encouraging, he said it will likely take until the launch of Sentinel-2B in mid-2016 before Sentinel-2A’s radiometric processing stream is stable enough to fully evaluate compatibility with Landsat 8.

Crystal Schaaf [University of Massachusetts Boston] discussed her team’s use of Sentinel-2A data in the Landsat 8 albedo processing routine. She reported that initial albedo results from Sentinel-2A appear promising.

John Dwyer updated the LST on EROS plans to archive and distribute Sentinel-2A data. He stated that the USGS will begin downloading the data soon after the ESA international data hub is active in mid-February 2016.

Introduction of Jennifer Gimbel

Tom Loveland welcomed Jennifer Gimbel [Department of the Interior (DOI)—Assistant Secretary for Water and Science]. Gimbel offered several examples of how important Landsat is to the current administration, and encouraged the LST to continue doing science that will improve Landsat data both now and in the future. She also congratulated LST agency co-chair Tom Loveland, who was recently awarded the Distinguished Service Award (DSA)—DOI’s highest civil servant award—for his career-long contributions to science, and specifically, for his role in land-use and land-cover change research and his contributions to advancing Landsat science and applications. Following this, the LST members in attendance each gave Gimbel a short (~30-second) overview of their Landsat-related research activities.

Landsat 9 Status

Del Jenstrom [GSFC—Landsat 9 Project Manager] gave an update to the team on the current status of Landsat 9. Working off the success of its predecessor,

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7 For more on Sentinel-2A product specifications and performance, see the technical documents at sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-2-msi.

8 The USGS began distributing Sentinel-2 data in March 2016. For data access, see ero.usgs.gov/sentinel-2.
Landsat 9 will be a full Class-B rebuild of Landsat 8. As in previous missions, NASA is responsible for the space segment, including instrument and launch, and on-orbit checkout, while USGS will develop and manage the ground systems, including data collection, processing, archiving, and distribution. Jenstrom reported that funding is secure and in place, and the project has been directed to pursue a 2020 launch date. Jenstrom also noted that Landsat 9 data will have 14-bit quantization, an improvement over the 12-bit data offered by Landsat 8.

**Sustainable Land Imaging and Landsat 10**

Dave Jarrett provided an update on the status of the Sustainable Land Imaging (SLI) program and Landsat 10. He provided a brief overview of some of the technology studies that are underway for scoping systems innovations and potential hardware and systems upgrades for Landsat 10. Jarrett also discussed development of a FY2016 pathfinder servicing mission called RESTOR-L, which aims to use advanced robotic servicing to refuel and redeploy satellites to extend the life of future missions. He concluded by encouraging the LST to begin focusing on desired capabilities for Landsat 10 and beyond.

**User Requirements for Land Imaging and SLI**

Tim Newman briefed the LST on the current status of the Requirements, Capabilities, and Analysis for Earth Observation (RCA-EO) project. This initiative was established to identify Earth-observation solutions to meet evolving user needs, as well as to help inform and prioritize future SLI missions. Newman said the objective in FY2016 will be to focus on expanding the collection of user needs to other federal agencies outside of DOI, and to more closely engage the international community in looking for gaps in data or services, which could be addressed with new products or enhanced collaboration.

**Landsat 7-8 Status Update**

Brian Sauer [EROS—Landsat Sustaining Engineering Project Manager] offered an update on the mission status of Landsats 7 and 8. Sauer reported no change for Landsat 7, which has been in orbit for 17 years. Options for extending the Landsat 7 mission, which could allow for continued operation until the launch of Landsat 9 in 2020-2021, are being explored. Sauer also mentioned that Landsat 8 TIRS data collected since November 2015 will be reprocessed and released quarterly, with full capability to be made available by April 2016. Sauer also discussed the current status of the ongoing Landsat Global Archive Consolidation (LGAC) effort to repatriate data from international ground stations. For more on the LGAC effort, visit dx.doi.org/10.1016/j.rse.2015.11.032.

**Gene Fosnight** [EROS—Landsat Data Acquisition Manager] summarized changes in the Long Term Acquisition Plan (LTAP) that governs Landsat 7 and 8. Currently, the Landsat 7 continental model is being tuned to acquire as many quality images as possible without affecting mission length. He also discussed special requests for scenes over the Arctic and Antarctic (including off-nadir acquisitions), scenes over water (to support ocean monitoring of oil seeps and spills), and scenes at night (to monitor volcanoes, urban heat islands, and active fires).

**Virginia Tech Remote Sensing Activities**

Meeting host Randy Wynne [Virginia Tech University] and his colleagues from Virginia Tech made several presentations, showcasing a number of ongoing research projects that were of interest to the LST. They covered a wide range of topics including: urban temperature mapping, automated cloud detection, history of surface coal mining in Appalachia, statistical algorithms for mapping forest change, and an overview of on-campus high-performance computing capabilities. For more on these and other presented topics, please see the meeting presentations available on the Landsat Science Team website, as noted earlier.

**Landsat MSS: Using the Full Landsat Record**

Warren Cohen [U.S. Forest Service] presented the case for improving the Landsat MSS record. He showed how the birth of the environmental movement in the early 1970s gave rise to the vision of William Pecora, former Director of USGS, and his idea to use land-observing satellites to monitor our changing planet. Cohen demonstrated that despite its many issues, MSS is the only option for assessing environmental degradation prior to the early 1980s. He also discussed his team’s work improving the compatibility of MSS data for use with other Landsat sensors.

**Dennis Helder** [SDSU] discussed his team’s efforts to cross-calibrate MSS with the SDSU Modtran Atmospheric Compensation for Any-time and Any-location (SMACAA) algorithm. He also discussed the implementation of SMACAA on SDSU’s cluster computing environment and progress made on processing the roughly 1.3-million MSS images in the EROS archive.

**Ron Morfitt** [EROS] discussed the different varieties of MSS data that have come in through the LGAC effort. He also discussed issues with radiometric and geometric quality, as well as efforts to transfer Landsat 8 reflectance back through the archive.
Yongwei Sheng [University of California Los Angeles] presented results from his team’s work developing an image-matching approach to orthorectifying MSS data.

Doug Bolton [University of British Columbia] encouraged the USGS to continue improving the MSS archive, which would greatly improve his work estimating post-fire regrowth dynamics in slow-growing boreal forests.

At the end of this session, the LST endorsed the need to improve the MSS record and encouraged the USGS to present improvement plans at future LST meetings.

Landsat 8 Thermal Infrared Sensor Status Update

Matt Montanaro and Aaron Gerace [both from Rochester Institute of Technology (RIT)] provided an update on the stray-light correction algorithm being developed for the Thermal Infrared Sensor (TIRS) on Landsat 8. Montanaro explained how stray light entering the optical path from outside the direct field of view is causing significant nonuniform banding in TIRS bands 10 and 11. In order to correct for this issue the approach being developed uses TIRS data to estimate the out of view signal based on in-scene statistics. Initial validation results based on comparison with MODIS underpass data are encouraging. Once the algorithm is finalized, all Landsat 8 TIRS data will be reprocessed and made available to the user community.

Jim Storey gave an update to the team on the status of the Landsat 8 TIRS scene select mechanism encoder anomaly, explaining how degradation of the side-A and side-B encoder electronics has impacted the ability to control the mirror that rotates the sensors field of view toward Earth. Storey noted that extensive testing is underway to ensure this issue will not affect TIRS2, which is slated for launch on Landsat 9.

Conclusion

The 2016 winter LST meeting focused on identifying a number of important priorities for improving various aspects of the Landsat program. LST members offered guidance and recommendations on development of new Landsat products, enhanced synergy with Sentinel-2, and improvement of the MSS data record. The LST also identified short- and long-term goals for enhancing the consistency of surface reflectance measurements.

The next LST meeting will be held July 26-28, 2016, at SDSU in Brookings, SD.

Leonardo DiCaprio Visited NASA’s Goddard Space Flight Center to Discuss Earth Science

Academy Award®-winning actor and environmental activist Leonardo DiCaprio visited NASA’s Goddard Space Flight Center (GSFC) on Saturday, April 23, 2016. During his visit, DiCaprio interviewed Piers Sellers, [GSFC—Former Astronaut and Deputy Director of the Sciences and Exploration Directorate]. The two discussed the different missions NASA has underway to study changes in the Earth’s atmosphere, water, and land masses for a climate change documentary that DiCaprio has in production.

Using the NASA Hyperwall, which shows visual representations based on actual science data, DiCaprio and Sellers discussed data results from NASA’s fleet of satellites in Earth’s orbit. During his visit, DiCaprio also visited the facility holding NASA’s James Webb Space Telescope.

Photo credits: NASA/GSFC/Rebecca Roth