Landsat and Sentinel-2: Synergy, Opportunities, and Issues

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General Comments

This document is the Landsat Science Team response to the question:

Can Sentinel-2 data can be used for the full breadth of Landsat applications?

The Landsat Science Team concludes that Sentinel-2 provides an important means to augment Landsat's capabilities and reduce risk within the Landsat user community, but should not be viewed as a replacement or alternative. The Sentinel-2 program offers an extremely promising augmentation to the Landsat program and indeed relies on lessons learned from a long Landsat heritage. This however is not necessarily sufficient to guarantee interoperability and consistency of data and data products.

Sentinel-2 multispectral capabilities are generally consistent with those of Landsat, but there are some differences (e.g., the lack of thermal imaging on Sentinel-2) that will affect some longstanding Landsat applications. In addition, the capacity to robustly integrate measures from Landsat and Sentinel-2 must be verified once Sentinel-2 and Landsat data are available over common areas.

Sentinel-2 and Landsat operating together in a coordinated program provides a unique opportunity for achieving higher shortwave observation frequencies needed by many Landsat users. With two Landsats in 16-day orbits, and Sentinel-2's 5 day repeat time (with 2 satellites on orbit), all acquisition frequency requirements for shortwave imaging will be satisfied and improved. While promising, Sentinel-2 is not launched yet and therefore is not a clear solution as a Landsat alternative. Data quality is expected to be good, but this must be proved. As a result, a timely launch of Landsat 9 is required.

The Landsat Science Team cannot overstate the importance of the Landsat program. The US government receives tremendous value in business utilization and innovation, government program delivery and cost savings, and scientific insight from Landsat. Landsat exemplifies US leadership in civilian, publically minded, globally significant Earth observation activity.

Detailed Observations on Opportunities and Issues

Based on the Team's analysis of Sentinel-2 and Landsat capabilities and the needs of the broad Landsat user community, we offer the following specific points regarding

opportunities and issues associated with Sentinel-2 and Landsat science and applications:

- The existing specifications for Sentinel-2 indicate it will provide measurements that are similar to the Landsat series. Sentinel-2 was explicitly designed to perform similar Earth Observation functions to Landsat.

- Sentinel-2 offers significant potential to augment Landsat sensor data in most vegetation and land cover applications. The spectral bands and finer resolution of selected bands are suited for characterizing vegetation conditions and the frequency of observation is a significant advantage.

- Some applications will be impossible with Sentinel-2. Most notable are those applications dependent on thermal imaging capabilities, including energy balance-evapotranspiration-water use mapping, and assessments of volcanic activity and coastal and polar ocean thermal conditions. Based on current plans to limit high latitude Sentinel-2 acquisitions, studies of high latitude regions for cryosphere studies (e.g., monitoring Antarctic ice mass balance) will not be possible.

- The lack of thermal data will degrade algorithms for identification of clouds and cloud shadows, an integral part of emerging efforts to conduct regional to national and global studies requiring complete surface mapping under near-perfect clear-sky illumination.

- Even though the Sentinel-2 image characteristics are similar to those of Landsat, a significant research investment will be required to compare and understand the image data from the two missions and combine them for multi-temporal analysis. A period of overlap between Landsat and Sentinel-2 is required to verify the degree of applications synergy between the two data sets. Specific issues to be investigated include:

    - Compatibility of spectral measurements given the differences in band centers and ranges.

    - Impact of spatial resampling to allow for Sentinel-2's higher resolution data to be used in conjunction with Landsat 30m data.

    - Impacts of different local solar time (11am vs 10am). Some applications may benefit from Sentinel-2's 11am acquisition time due to the reduction of terrain shadow lengths, but others, such as tropical studies, may be affected by convective cloud dynamics associated with the 11am acquisition time.

    - Impacts of the wider swath and viewing angles, including bidirectional reflectance distribution function (BRDF) effects that may be significant for some surfaces (e.g., snow surfaces under melting or wind-polished

conditions).

- Differences in cartographic projection and other data set geometry specifications that may lead to Landsat and Sentinel-2 image coregistration challenges. With the importance of integrated analysis, there is a need for a significant research investment to ensure the ability to merge data sets.

Cautions and Risks

Considering potential opportunities and issues, the Landsat Science Team identifies the following cautions or risks that need to be considered when developing plans for synergistic use of Landsat and Sentinel-2 observations:

- On-orbit operation of Sentinel-2, and production of high-quality data cannot be certain until it actually happens. Launch delays or a launch failure are risks, and instrument degradation may sometimes occur after launch. In addition, launch date postponements are not uncommon and so the scheduled September 2014 launch must be considered to be tentative. Indeed, recent communications have indicated that a second quarter of 2015 launch is now scheduled. A 6 to 9 month check in period is also required before commencement of global data acquisition. As a result, given launch and check-in, there is unlikely to be northern hemisphere data in 2016.

- The time period required to verify the actual science and applications synergy between Sentinel-2 and Landsat is long. Assuming a minimum 6 month check-in period, followed by at least one season of research and comparison of Landsat 8 and Sentinel-2 data, the first possible year with northern hemisphere data collection of both Landsat 8 and Sentinel-2A is 2016. The determination of the level of applications synergy between Sentinel-2 and Landsats will therefore not be known until 2017.

- The collection, downlink, and quality of Sentinel-2 data will not be known until after Sentinel-2 check-out and testing. While Sentinel-2 data delivery plans are in place, the systems are not yet complete. As a result, we should not assume equivalency with mature, fully functional USGS Landsat portals. Because this is a new program with no ground system legacy, there is uncertainty regarding data access.

- Since the 2008 opening of the Landsat archive and the increase in data access, the capacity for pixel-based processing has become an element of continuity. Pixel-based analysis, the emerging standard for both science and applications, requires true open access to all data. This is the stated goal of the Sentinel project, but a robust implementation will be a challenge.

- Data distribution intentions are comparable to Landsat. The European Union has

adopted free, full and open access – though a set of criteria that will address the protection of the Union and its Member States' security interests will be put in place. This should not affect access in the context of Landsat and Sentinel-2 synergy, but caution is warranted. Recent communications have indicated that there some European industry reservations to the free data policy, leading to an intention to revisit the policy in 2017.

- Given the critical role Landsat plays in many US government operations, there is risk associated with the lack of control of Sentinel-2 data collection priorities, and the implemented process for processing, archiving and distribution. Missions inevitably require difficult management decisions, and losing US control of the decision process is risky.

Conclusions

Sentinel-2 will be a valuable complement to Landsat, but should not be seen as a replacement. Specifications in the Sentinel-2 Mission Requirements Document suggest considerable potential for synergy with the Landsat program. Both are governed by a free and open data policy, both offer multispectral data at resolutions of 30 m or better and both image on a 5 to 8 (10 to 16 with one platform) day cycle.

The lack of a thermal channel, and the lack of southern high-latitude data lead to significant gaps in Sentinel-2's capability with respect to the current Landsat program, both operationally and as a research tool. The lack of a legacy data distribution system at the level of the USGS EROS Data Center is also a concern for emerging pixel-based processing algorithms.

There are a number of risks associated with the assumption that Sentinel-2 could offer mandated continuity of measures akin to what is provided by the Landsat program; moreover, the interoperability of the data must be tested. Based upon the 5-year design life of Landsat 8 (not including TIRS), it is during the period of 2018 to Landsat 9 launch that the Sentinels could provide interim measurements. For science applications, and especially climate measurements, an overlap period is essential for vicarious cross calibration.

Between 2016 and 2020 we expect to gain genuine experience using the two programs synergistically. The launch of Landsat 9 with capabilities similar to Landsat 8 would satisfy all the cost effectiveness, continuity, and data quality issues and certainly does not preclude discussion on profound collaboration between the EU and US on Earth Observation missions in the next 25 years.

Thus, while Sentinel-2 may augment Landsat capabilities, especially in frequency of (some) observations, and it may provide a bridge between Landsat 8 and 9 should Landsat 8 not exceed its five-year design life, Sentinel-2 is not a replacement for a continuing, continuous Landsat program for the US.

Postscript – Lessons from the Past

The recent NASA-NOAA Terra/Aqua MODIS transition to NPP-Suomi VIIRS experience provides a cautionary example. Although the channels available on VIIRS are similar to or replicate channels on MODIS, and although both sensors are flying concurrently and inter-comparison is underway, yet the calibration of VIIRS data still continues more than two years after launch. NOAA's delivery of data and production of high quality science products (even for basic observations and quantities such as snow and cloud masks, surface reflectance, and vegetation indices) to the user community is still not operational.

The availability of truly consistent, climate-quality values requires a considerable investment in resources. The overwhelming success and utility of the Landsat program has been built on three critical elements: sensor design, data consistency, and data delivery. Sensor design refers to the spectral, spatial and temporal properties of the raw data, and includes a collection strategy that ensures data acquisition globally. Data consistency speaks to the high quality of the data (in terms of long term signal calibration, spatial geolocation and temporal consistency). Data delivery refers not just to the open data policy, but the packaging, storage, and timely electronic delivery of huge data volumes to users. All three of these elements are required to ensure long term Landsat data continuity. Indeed, the explosion in the utility of Landsat data in the last five years was catalyzed not by changes in the sensor, but in the data consistency and the ease of data delivery. Therefore a period of mission overlap (in terms of sensor design quality, data consistency and data delivery) is required before complete reliance on Sentinel-2 is warranted or wise.