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A note on the temporary misregistration of Landsat-8 Operational Land Imager (OLI) and Sentinel-2 Multi Spectral Instrument (MSI) imagery

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ABSTRACT

The Landsat-8 and Sentinel-2 sensors provide multi-spectral image data with similar spectral and spatial characteristics that together provide improved temporal coverage globally. Both systems are designed to register Level 1 products to a reference image framework, however, the Landsat-8 framework, based upon the Global Land Survey images, contains residual geolocation errors leading to an expected sensor-to-sensor misregistration of 38 m (2σ). These misalignments vary geographically but should be stable for a given area. The Landsat framework will be readjusted for consistency with the Sentinel-2 Global Reference Image, with completion expected in 2018. In the interim, users can measure Landsat-to-Sentinel tie points to quantify the misalignment in their area of interest and if appropriate to reproject the data to better alignment.

1. Introduction

Moderate spatial resolution (10 to 30 m) satellite data from the polar-orbiting sun-synchronous Landsat-8 and Sentinel-2 sensors together provide the opportunity for improved mapping and monitoring of the Earth's surface [Drusch et al., 2012; Roy et al., 2014]. These data advance the Committee on Earth Observation Satellites (CEOS) virtual constellation paradigm as they have similar spatial and spectral characteristics that can be managed together to provide improved temporal coverage globally [Wulder et al., 2015]. The absolute geolocation performance specification for Sentinel-2 is 12.5 m (2σ) [Trémas et al., 2015] and for Landsat-8 is 12 m (90% circular error) [Storey et al., 2014]. Our recent global analysis indicates that the Sentinel-2 and Landsat-8 data are misaligned relative to each other by 38 m (2σ), i.e., by more than three Sentinel-2 10-meter pixels and more than a Landsat-8 30-meter pixel. As discussed below, the degree of misalignment varies geographically. The purpose of this short communication is to (i) inform the user community of this issue, (ii) clarify its cause, and (iii) clarify the schedule for its resolution.

2. Cause of the sensor misregistration

The standard geometrically corrected Sentinel-2 data are available as Level-1C (L1C) top-of-atmosphere (TOA) reflectance tiles [ESA, 2015] and the equivalent Landsat-8 data are available as Level-1T (L1T) TOA reflectance images defined in the Worldwide Reference System (WRS-2) path/row coordinate system [Irons et al., 2012]. Both sensor geolocation systems use measurements of the sensor exterior orientation (attitude and position), combined with sensor and digital elevation models, to precisely geolocate every sensed instantaneous field of view. The Landsat-8 L1T products have improved geometric fidelity compared to previous Landsat missions because of the Landsat-8 pushbroom sensor design and because the satellite has a fully operational onboard global positioning system (GPS) and an attitude determination system that uses a star-tracker and inertial measurement unit to measure the exterior orientation directly [Storey et al., 2014; Roy et al., 2014]. Similarly, the Sentinel-2 uses a pushbroom sensor and has onboard GPS, three star-trackers and an inertial measurement unit [Languille et al., 2015].

Both sensor geolocation systems are designed to use ground control to improve the geolocation accuracy and repeatability. The Sentinel-2 geolocation will use a Global Reference Image (GRI) derived from orthorectified Sentinel-2 cloud-free images [Déchoz et al., 2015]. Due to the phased Sentinel-2 global acquisition schedule and because of the need to obtain cloud-free imagery, the GRI is still being assembled and is scheduled for completion by the last quarter of 2017. The Landsat-8 geolocation uses a global sample of ground control points [Storey et al., 2014] derived for each WRS-2 path/row of circa 2000

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Global Land Survey (GLS) Landsat-7 imagery [Gutman et al., 2013]. The improved Landsat-8 geolocation accuracy compared to previous Landsat missions has resulted in the identification of poorly-geolocated GLS images [Storey et al., 2014]. This also revealed errors in the GLS framework and is the dominant source of absolute geolocation error in Landsat-8 data products. The error varies among Landsat WRS-2 path/row locations and is the main cause of the relative misalignment of the Landsat-8 L1T and Sentinel-2 L1C data.

3. Expected misregistration magnitude

To derive an estimate of the expected Sentinel-2 to Landsat-8 misregistration, the GLS accuracy specification of 25 meter radial root-mean-squared error [Rengarajan et al., 2015] was converted to the equivalent 2σ value of 35 m (by multiplying by the square root of 2). The root-sum-square of this result with the observed Sentinel-2 accuracy (without GRI ground control) of 14.6 m (2σ) [ESA, 2016] yields a 38 meter (2σ) expected registration accuracy between the sensors. This estimate may be pessimistic since Landsat-8 analysis of the accuracy of the GLS framework suggests that the GLS is somewhat more accurate than specified [Storey et al., 2014]. However, a pessimistic value allows for some additional misregistration contribution due to the sensor specific impact of digital elevation model height errors on the Sentinel-2 and Landsat-8 viewing geometries.

4. Schedule for correction of the sensor misregistration

A program to improve the accuracy of the GLS framework for problematic Landsat WRS-2 path/row locations began in 2014 [Storey et al., 2014]. This effort targeted path/row locations where the GLS framework was determined to contain biases of 50 m or more, with a goal to improve the accuracy to 25 m or better, while maintaining consistency with adjacent regions. The accuracy improvement was achieved by triangulating blocks of Landsat-8 images to establish updated positions for the existing GLS control points and to extract new control points where needed. This effort included the readjustment of the GLS data in Australia to tie it to the Australian Geographic Reference Image (AGRI) [Lewis et al., 2011] using sparse AGRI tie points to control the Landsat-8 block triangulation. An expansion of this activity will apply the same methods globally, to tie the GLS to the Sentinel-2 GRI. The completion of this activity is dependent upon the availability of the final Sentinel-2 GRI and therefore is not scheduled for global availability until the second quarter of 2018. An improved global digital elevation model, based upon the results of the NASADEM development activity [Crippen et al., 2016], is planned for implementation in the Landsat product generation system in the same timeframe. Thereafter, the Landsat-8 L1T data will be reprocessed as part of a new Landsat-8 collection and will align to sub-pixel precision with contemporaneous Sentinel-2 L1C data that are processed using the GRI.

Based upon the results of the Australian readjustment and the multi-temporal registration of Landsat-8 L1T products, we anticipate Landsat-8 to Sentinel-2 registration accuracy on the order of 10 m (2σ) or better. Unfortunately, this high degree of co-registration will only be achieved once archived Landsat-8 and Sentinel-2 data have been reprocessed using the updated GLS and final GRI, respectively. This could take until the end of 2018 for Landsat-8, and the schedule for reprocessing existing Sentinel-2 data once the final GRI is released, has not yet been established.

The GLS framework is used as the control reference for L1T products from all Landsat missions to ensure multi-temporal registration across the Landsat archive. As has been the case throughout the GLS accuracy improvement effort, when the GLS control reference is updated, all affected products across the Landsat archive are reprocessed to maintain the geometric integrity of the archive. The improved absolute accuracy and registration to Sentinel-2 will thus be carried backward in time to provide multi-temporal as well as multi-sensor registration.

5. Implications for data users

Users who wish to combine contemporaneous Landsat-8 and Sentinel-2 data should be aware of the misregistration issue reported in this note. The sensor misregistration should be stable for a given site since it is due primarily to differences/errors in the sensor geometric control references. The misregistration is characterized primarily as a translational offset with some secondary scaling differences also possible. For some locations and applications the sensor misregistration may not be an issue. Users who wish to improve alignment between Landsat and Sentinel-2 Level 1 products may use manual methods of picking tie points and resampling one image to the other (common to most image processing packages), or use other, automated image-to-image registration approaches [Gao et al., 2009; Long et al., 2016, Yan et al., 2016].

Acknowledgments and data

Data supporting the analysis can be found in the references.

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