Development of an Innovative Method for Vicarious Radiometric Calibration of Orbital Hyperspectral Sensors

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By

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Abstract

Information derived from hyperspectral remote sensing (HRS) satellites can be intensively used in earth science, forestry, land management, conservation and many other domains. In the near future, HRS satellites are expected to play an important role in regional ecosystem studies. However, to make effective use of this prominent technology, data must first be converted into physical and chemical properties to enable a quantitative analysis. As HRS sensor performance may vary in time and space, a vicarious calibration (VC) method to retrieve reliable and accurate at-sensor radiance values is needed. Furthermore, in the case of satellites, laboratory calibration of the sensor can be done only once, prior to the launch. This issue makes finding a suitable solution for innovative VC critical. Our research has led to the development of, and significant improvements in VC via a unique method for assessing cross-calibration/validation of space-based hyperspectral data. Best practices for calibration/validation campaigns were promoted and a protocol on how to evaluate and correct possible radiometric drift in orbital HRS sensors was developed. In general, the study involved the use of airborne and spaceborne data, as well as the preparation of special ground targets composed of agricultural nets (100 x 60 m) with varying densities to simulate radiance intensity. Two areas in the desert region of Israel were selected to examine the VC methodology. The results showed a promising capability to assess the quality of HRS data as well as to rectify the data by radiance correction, thereby generating better thematic products.

General:

The study began with selecting areas for VC and then checking the net setup on a small scale for airborne sensors. After analyzing the data, which gave positive results, a set of large black agricultural nets of two densities (25%, 60%) were purchased. Then data acquisition was performed using HYPERION data and the VC setup in the Amiaz Playa.

1) Following Gilad and Karnieli's (2004) method, which explored several locations as radiometric calibration sites for multispectral sensors in the Negev area in southern Israel, we selected two areas: Shizafin Playa and Amiaz Playa in southern Israel for the VC study.

2) A simulated net experiment was performed by placing nets on the ground, and measuring the radiance and reflectance with a field spectrometer, ground-imaging spectrometer and sun photometer. Then an empirical model wasapplied to extract the reflectance of several targets in the same area. A protocol wasdelivered on how to utilize bright target areas as SVC (Supervised Vicariouse Calibration) targets for HRS sensors. In this research, we(uused three suitable bright, flat, homogeneous areas. For the airborne campaign, we used Amiaz Playa, near the Dead Sea, with 30 x 30 m nets and a Fenix HRS sensor covering the visible–near infrared–shortwave infrared (VIS–NIR–SWIR) region.

3) Based on results obtained in the airborne campaign, we extended the SVC idea to larger scales that suit orbital sensor coverage. The question was how the different bright and large (400 x 300 m) homogeneous surfaces would behave. For the spaceborne SVC mission, we will therefore needed far more net coverage. Assuming a 30-m GSD collection, a 60 x 100 m net per given density is the minimum. As such, bigger agricultural nets (60 x 100 m) at different densities were deployed on the ground at the selected site. The question was, is this technically and logistically feasible? We showed that 10 people could unfold) the net within 45 min and refold it in 30 min. It was also shown that reasonable pixels to represent each net can be extracted from the satellite image of the VC target.

4) We analyzed the data with all of the ground truth measurements performed at the Amiaz site as a master site for HYPERION. We did not check other sensors. The results showed that a) the net structure can assess the quality performance of the data and b) it could use the gain and offset extracted from the net in Amiaz Playa to correct the data from Shizafon(Playa.

5) In an ongoing mission, we are applying the obtained correction factors on HYPERION data acquired over Italy close to the calibration campaign.

6) Based on the overall results, a protocol was established to use the VC developed herein for orbital HRS.

Deliverables and significance of the research:

As the international community lacks standards and protocols, particularly for VC of orbital HRS sensors, the SVC, which approaches the VC problem from an innovative perspective, may provide an operational tool for many users with minimal effort. By establishing a suitable protocol for the entire (growing) HRS community to enable better utilization of the method, it is hoped that more areas worldwide will be used for SVC, creating a universal standard. During the study, we optimized the procedures for unfolding and refolding the nets, transporting the nets for a given mission, performing measurements at a field site, and analyzing and applying the results. Establishing more SVC sites worldwide in both the northern and southern hemispheres will increase the accuracy of the data acquired by orbital HRS sensors at any time of the year, and will enable better monitoring of the sensors' performance in the opposing summer and winter seasons of the southern and northern hemispheres. This will significantly improve the quality of the products obtained from orbit and will enable better tracking of the sensor's performance. Moreover, it will allow cross-calibration among all sensors in orbit and will be valid for multispectral sensors as well. Space agencies that are currently planning to place HRS sensors in orbit will benefit from this method, which will enable them to share fully standardized information with each other. The suggested method will not only allow correcting the radiometric calibration but will also allow tracking the sensor's stability and deterioration over time. The primary aim of the proposed was to study a novel calibration approach termed SVC and apply it to airborne, as well as various spaceborne systems. A main deliverable of this study is the protocol, describing the proposed methodology and its advantages, and the convincing results that will push more users to carry out the SVC method. The protocol will enable the remote sensing community worldwide to use the same approach. As orbital HRS sensors will soon be available on a routine basis (Buckingham and Staenz 2008), this idea might help maintain high-quality data from space, even though the sensor's original calibration will no longer be valid. The results of this project are expected to lead to significant advances in the consistency and cross-calibration/validation of long-term space-based measurements, providing a better overview of the uncertainty of available data to generate thematic products for all kinds of subjects.

Summary and conclusions

The research confirmed the applicability of the SVC method, usually utilized for airborne HRS sensors, for orbital sensors. The HYPERION sensor was used to demonstrate this capability as it was the only one in orbit covering the entire spectral region from VIS to SWIR. The logistics of the SVC method, which requires agricultural nets of various densities, was also shown to be manageable. The results were promising and further study is suggested to implement this method for other sensors in orbits (such as the superspectral WV3), as well as to prepare for the new HRS sensors in orbit (such as EnMAP and SHALOM).

Future Note

Although all of the major goals of this study, proposed in the original plans, were reached, we feel strongly that this is only the beginning. After verifying the SVC capability for orbital HRS sensors, we need to continue in the following direction:

1) Extend the method to other parts of the world, especially the southern hemisphere

2) Adapt the method for superspectral sensors that are available today, such as the WV3

3) Establish a field working group to operate the SVC targets

4) Check the performance of the SVC correction in different landscapes

5) Establish the method (area and protocol) for the forthcoming orbital HRS sensor SHALOM from ASI–ISA.

Appendix

This work has been presented in GRSG meeting in Frascati , Italy, 7–9 December 2015. Attached is the presentation.