CALIBRATION OF THE THERMAL INFRARED SENSOR ON THE LANDSAT DATA CONTINUITY MISSION

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1. INTRODUCTION

The Landsat series of satellites provides the longest running continuous data set of moderate-spatial-resolution imagery beginning with the launch of Landsat 1 in 1972 and continuing with the1999 launch of Landsat 7 and current operation of Landsats 5 and 7[1]. The Landsat Data Continuity Mission (LDCM) will continue this program into a fourth decade providing data that are keys to understanding changes in land-use changes and resource management. LDCM consists of a two-sensor platform comprised of the Operational Land Imager (OLI) and Thermal Infrared Sensors (TIRS). The calibration and characterization of TIRS is the subject of this paper.

2. TIRS DESCRIPTION

The earliest versions of the Landsat platforms did not include spectral coverage at wavelengths in the thermal infrared (TIR) (8-12 micrometers). Landsat-3 marked the first attempt at including TIR data but that band operated for only a short period of time after launch. Subsequent Landsat platforms (Landsats 4-7) included a single TIR band as part of the Thematic Mapper (TM) on Landsats 4 and 5, Enhanced Thematic Mapper (ETM) on Landsat 6 (which failed to achieve orbit), and Enhanced Thematic Mapper Plus (ETM+) on Landsat 7. Landsat TIR data are currently used operationally to monitor water consumption on a field-by-field basis in the western states of the United States of America and internationally. Other applications of Landsat TIR data include examination of urban heat islands, mapping sensible heat flux, volcanic surveillance, and monitoring fire-induced vegetation depletion through burnt area mapping.

A departure from past Landsat missions is that TIRS will operate in concert with, but independent from OLI as opposed to the TM, ETM, and ETM+ cases where the thermal band was part of the same sensor using the same entrance optics as the shorter-wavelength bands. Past Landsat thermal sensors relied on a whiskbroom scanning approach that provided high-quality imagery across the full 185-km swath, but with a trade in signal-to-noise ratio. Both the OLI and TIRS sensors are moving to a pushbroom approach leading to decreased sensor size while still improving signal-to-noise ratio from past sensors. The final key difference between LDCM TIRS and Landsat thermal-band data is that TIRS will operate with two spectral bands (10.8 and 12 micrometers) as opposed to the current single band TIRS. The swath of TIRS is similar to the 185-km swath of previous Landsat sensors and the spatial resolution is required to be the same as the 120-m resolution of TM. The resulting data set from TIRS and OLI will be radiometrically-calibrated, geo-located image data. Data products from TIRS and OLI will be processed and merged into a single data product by the United States Geological Survey (USGS)/Earth Resources Observation and Science (EROS) facility.

3. CALIBRATION OVERVIEW

A large part of the success of the Landsat program is attributed to the emphasis placed on knowledge of the calibration of the sensors, both geometric and radiometric [2, 3]. The radiometric assessment of the sensors has relied on a combination of prelaunch and post-launch efforts using laboratory, on-board, and vicarious calibration methods (where vicarious calibration refers to any method not relying on on-board calibrators). The radiometric calibration of these systems helps characterize the sensors allowing the full Landsat data set to be used in a quantitative sense for such applications as land-use and land-cover change.

LDCM will continue the emphasis on calibration, both for OLI and TIRS. Rigorous attention to NIST-traceability of the radiometric calibration, knowledge of out-of-band spectral response, characterizing and minimizing stray light effects is necessary to provide a sensor that meets the quality of Landsat heritage. Described below are the methods and facilities planned for the calibration of TIRS. The overall philosophy is to measure at the component, subsystem and system level. Calibration testing will take place in a vacuum test chamber at NASA GSFC using a recently-developed calibration system that is the centerpiece of the calibration process. Testing of calibration methods and approaches will make use of a functional performance model of the sensor that has similar detectors and optics to the anticipated flight unit.

4. TIRS CALIBRATION SYSTEM

Calibration of TIRS will use a 16-aperture source system combined with a 9-filter system to simulate spatial and radiometric sources. The radiometric source is a NIST-calibrated blackbody that provides the full range of testing temperatures. An off-axis parabola (OAP) collimator coupled to a two-axis steering mirror allows the source to be placed anywhere in the TIRS field of view (FOV). The size of the OAP is large enough to fill the aperture of TIRS permitting full-field, full-aperture calibration. The maximum size of the source available through the 16 apertures is much smaller than the full field, thus a second source is included in the calibration system to provide a source that fills the full field without requiring movement of beam. The flood source provides a means for evaluating detector-to-detector response effects as well as providing a large-sized source to evaluate out-of-field spatial response. Spectral response of the sensor will be determined using a monochromator source external to the vacuum chamber but coupled to the OAP through a zinc-selenide (ZnSe) window on the chamber and coupled to optics within the calibration system.

The radiometric source for the calibration source is a conically-based blackbody designed for stability and accuracy. Knowledge of the sources output will be through NIST-traceable thermometers integrated to the blackbody. The blackbody will also be calibrated at NIST to determine an effective emissivity. Evaluation of the calibration system relies on a functional performance model (FPM) of the TIRS sensor. The FPM is used to determine optimal methods for testing the flight unit with the calibration system. The description of the calibration system, calibration methodology, and the error budget for the calibration system shows that the required 2% radiometric accuracy for scene temperatures between 260 and 330 K is well within the capabilities of the system.

5. CONCLUSIONS

The success of Landsat relies heavily on consistent calibration of the sensors that are part of the data stream across the many missions. Thus, the TIRS mission depends heavily on an accurate characterization of the sensor's behavior and in response to this GSFC has acquired a calibration test system for TIRS. Early results from the calibration system along with early error budget analysis shows that the TIRS should meet its radiometric requirements permitting its inclusion in the Landsat history while paving the way for multispectral thermal data sets within the Landsat archive.

6. REFERENCES

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