Evaluation of the Landsat-5 TM Radiometric Calibration History using Desert Test Sites

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ABSTRACT

The U.S. radiometric calibration procedure for the reflective bands of the Landsat-5 Thematic Mapper was updated in May 2003. This update was based on a model of the performance of the instrument developed from its response to the best-behaved internal calibration lamp and from a cross calibration with Landsat-7 ETM+ that occurred in June 1999. Since this update was performed, there have been continued attempts to validate the model. These validations have relied primarily upon data acquired over deserts of the world. These studies have been limited by the amount of data available over any one site for the 22-year life of the mission. Initial attempts over the desert Southwest of the United States were inconclusive, though they were suggestive of additional degradation occurring in the shorter wavelength channels. More recently, significant holdings from European Space Agency of data over North Africa have been made available for analysis. The North Africa test area results to date for one site in Libya are considerably less noisy than the North American datasets. They indicate an exponential-like decay of about 19%, 16%, 8% and 4% for TM bands 1, 2, 3 and 4, with the degradation, at least in bands 1 and 2 occurring throughout the mission. The current model shows changes of roughly the same magnitude, but with the change occurring more rapidly so that nearly all the change is completed in 4 years. These results are generally consistent with independent work going on outside of this effort. Additional sites are being analyzed as data become available.

Keywords: Landsat-5, Thematic Mapper, radiometry, calibration

1. INTRODUCTION

The Landsat-5 Thematic Mapper (TM) has been nearly continuously acquiring data of the Earth surface since its launch in March 1984. Its now familiar reflective spectral bands: band 1, 450-520 nm; band 2, 520-600 nm, band 3, 630-690 nm, band 4, 760-900 nm; band 5, 1550-1750 nm; and band 7, 2080-2350 nm cover the visible to short-wave infrared portion of the electromagnetic spectrum. Given the long history of acquisitions for Landsat-5, the ground processing systems and processing algorithms have evolved. The initial US ground processing systems performed the radiometric calibration of the reflective bands using the internal calibrator (IC), a set of three lamps continually sequenced during the acquisitions and providing a signal at the end of each scan of the Earth's surface. These algorithms assumed that the lamps were constant and any change in response was treated as a change in instrument response and thus compensated for in processing. This algorithm was dropped in the implementation used by EOSAT for processing in the early 1990's, where the instrument was assumed to be more stable than the lamps, and the data were essentially left unchanged, except for destriping, and the pre-launch calibration was appended to the data. US government users could obtain Landsat TM data processed with the NLAPS system beginning in the mid 1990's. This system again used the

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lamps for calibration. Beginning in 2001, with the reversion of the operation of Landsat-5 to the US government, the NLAPS system became the primary system for processing data in the USA. With Landsat-7 launch in 1999 and the subsequent return of Landsat-5 to the US government, there was increased interest in the calibration of the Landsat-5 TM and it's cross calibration with Landsat-7 ETM+. This effort led to a reexamination of the behavior of the TM instrument, its internal lamps and the vicarious calibrations that had been done over the years. This culminated in a revised calibration procedure for the data: an exponential decay curve based on the early behavior of the best internal lamp that was tied to a cross calibration performed with Landsat-7 ETM+ in June 1999 was the new calibration curve[1,2]. An additional outgassing correction was applied to the data from bands 5 and 7 that are on the cold focal plane. Vicarious measurements confirmed that this was a reasonable model for the lifetime performance (Fig. 1). This procedure was implemented into NLAPS in May 2003 and has been used since that date. This procedure provided a more consistent calibration over the life of the mission, removing various discontinuities in the lamps' outputs as well as an increasing output of the lamps with time since about 1990.

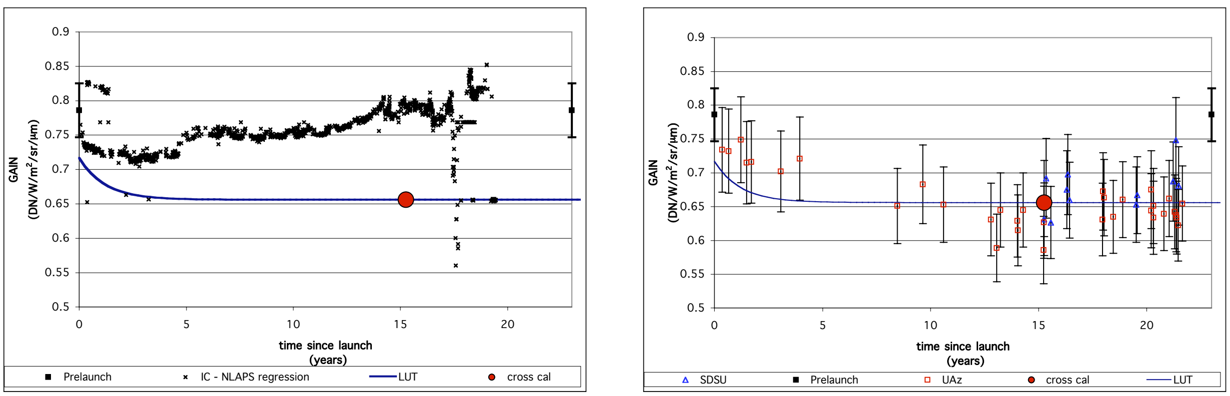

Fig. 1. Landsat-5 TM band 2 lamp based gains (IC- NLAPS regression), revised calibration curve (LUT) and vicarious calibration results (University of Arizona [UAz]) and South Dakota State University [SDSU]).

One of the concerns with this revised calibration was that there was a significant period of time from 1988 to 1992 where there was no vicarious data with which to validate the model, and in bands 1 and 2, at least, where vicarious data existed before 1988, the adopted curve went through the lower end of all the vicarious measurements error bars, i.e., there was a systematic bias between the vicarious measurements and the adopted curves.

Since the adoption of the revised calibration in 2003 there has been an ongoing effort within the Landsat calibration team to evaluate the calibration and improve it as necessary. The Landsat calibration team consists of NASA, the United States Geological Survey (USGS), and university personnel and tracks the performance of the TM sensor using on-board and vicarious techniques. This paper reports on those evaluations using several desert sites in North America and North Africa. Simultaneous to these efforts, independent efforts have been ongoing in Australia (De Vries et al 2003[3]). The surface reflectance of several "pseudo-invariant" sites in Queensland, Australia was measured on the ground and the responses to these sites, after correction for average atmospheric conditions, was used to calculate the gain of each of the TM bands, for 35 scenes between 1987 and 2003. The results for TM band 2 (Fig. 2) indicate a systematic difference in the 1992 and earlier results from the 2003 operational calibration curve. Deviations from the operational curves were also apparent for bands 1 and 4. Additionally, attempts to atmospherically correct Landsat-5 TM data acquired in 1986 using the dense-dark vegetation technique[4], have yielded negative reflectances for vegetation in the red, indicating a potential calibration problem[5].

5. SUMMARY/CONCLUSIONS

The Landsat-5 TM lifetime calibration curve implemented in 2003 provided a significant improvement in the consistency of the radiometric calibration of the data. A continuing examination of the calibration trends, based primarily on desert test sites, indicates that some of the assumptions adopted in the original model may not be correct, e.g., the origin of the initial internal calibrator lamp trends and additional degradation is occurring. The trends in bands 1-4 can be well represented by an exponential decay model like previously used, but with a significantly longer time constant, i.e. the degradation occurs over a longer period of time. Additional analyses are underway, with a goal of providing an updated calibration model by the end of 2006.