DERIVATION OF LANDSAT 5 TM DETECTOR RELATIVE GAIN MODELS USING THE USGS IMAGE ASSESSMENT SYSTEM (IAS)

J. Dewald, D. Helder

EECS Dept Image Processing Laboratory
South Dakota State University, Brookings, SD 57007 USA

1. INTRODUCTION

Historical efforts to gather and utilize Landsat Thematic Mapper radiometric information from Earth images and the sensor internal calibration systems were typically manual in nature and hence limited in terms of data sampling and subsequent analysis. Multiple government agencies and private corporations operated the Landsat TM missions over their respective lifetimes resulting in a sparse sporadic collection of information in terms of operating conditions, failures, etc. These detrimental external factors pointed to the need for an automated analysis system to study Landsat data and improve product quality. The Image Assessment System (developed by NASA, USGS, SDSU, and other partners) has recently been expanded to incorporate the Landsat 4 & 5 TM instruments [1]. Ongoing processing via the IAS, and the public data production system (LPGS) has resulted in a database of calibration information exceeding 120,000 scenes that is being actively mined for historical information on the performance of the Landsat TM sensors. This paper will elaborate on the data mining effort and discuss in detail the derivation of L5 TM detector relative gain models, used to remove detector stripping. Many historical efforts have been made (typically using limited data) to model Landsat 5 TM relative gains. One such extensive and recent study performed without benefit of the IAS which can be used in a baseline comparative sense to compare / assess calibration improvements is: [2, 3].

2. IMAGE ASSESSMENT SYSTEM CAPABILITIES

The Image Assessment System currently has capabilities to process Landsat ETM-TM data sets and in the near future will incorporate MSS data from Landsat 1 thru 5. For the Thematic Mapper, the system ingests raw L0Rp data, applies corrections for Bias Shifts, Memory Effect Artifact, Detector Relative Response, converts DN to Radiance, and produces systematic and terrain corrected geo-located products. Throughout the process flow, detailed information is captured in various time and spatial frames of reference including: scan based, detector based, and scene based. These data can then be aggregated into acquisition interval and / or other time durations up to and including multi-decadal trends. The resulting relational database is available to calibration analysts to perform routine monitoring and special studies (addressed in the next section) with an eye toward improving processing algorithms and establishing calibration consistency for the multi-mission Landsat data archive.

3. STUDIES AND SAMPLE RESULTS

Numerous investigative studies are being performed using the IAS relational database and include the following: quantification of multiple bias states and shift transitions between states, establishment of detector temperature sensitivity parameters and the focus of this paper, i.e., determination of systematic detector relative gain models for the Landsat 5 TM sensor. Sample characterization and trend plots (~120,000 images) follow in Figures 1-3 focusing on three Landsat 5 TM detectors and their relative response (or gain) over time in an effort to demonstrate the current dense data sampling available within the IAS. The figures shown below demonstrate several interesting features and characterization modeling challenges. First, Figure 1 indicates that Band 4, Detector 6 had a fairly stable relative gain trend until ~ day 8500 where a step discontinuity occurred and data variability appeared to increase dramatically. The root cause of this effect is unknown; however the high sampling rate of IAS data has raised awareness of the issue, and provides a means to quantify the effect and revise associated models. Similarly, shown in Figure 2, Band 4, Detector 15 exhibits multiple step discontinuities in later years of operation. Interesting to note is the tendency for the system to self correct, and return the detector's relative gain to the nominal trending baseline observed in early life. This type of multiple stepping effect is characterized and used to create piecewise temporal models for this particular detector. When finished, these updated results will be integrated into the LPGS data processing system to improve the final publicly available data products. And finally, as a rather interesting case, Figure 3, Band 5, Detector 10 (residing on the cold focal plane) exhibits a random drift in regards to relative gain. The high frequency oscillations that are observable have been traced to contamination buildup on the focal plane [4]. This well known effect impacts the absolute gain of the band, but heretofore was not observed in relative gain estimates. The presentation and paper provides details on use of IAS-based data for improved modeling of instrument relative gains leading to improved data products. Both qualitative and quantitative examples will be given.

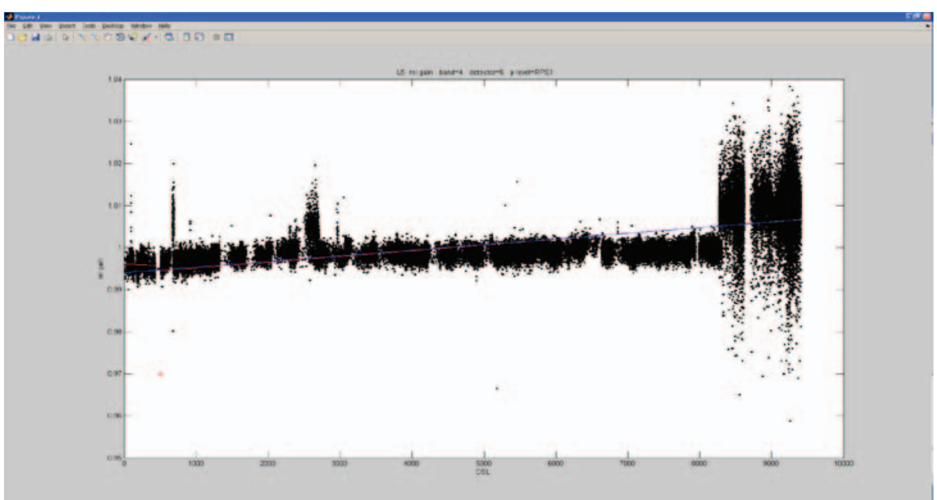

Fig 1. Band 4, Detector 6 Relative Gain Lifetime Trend

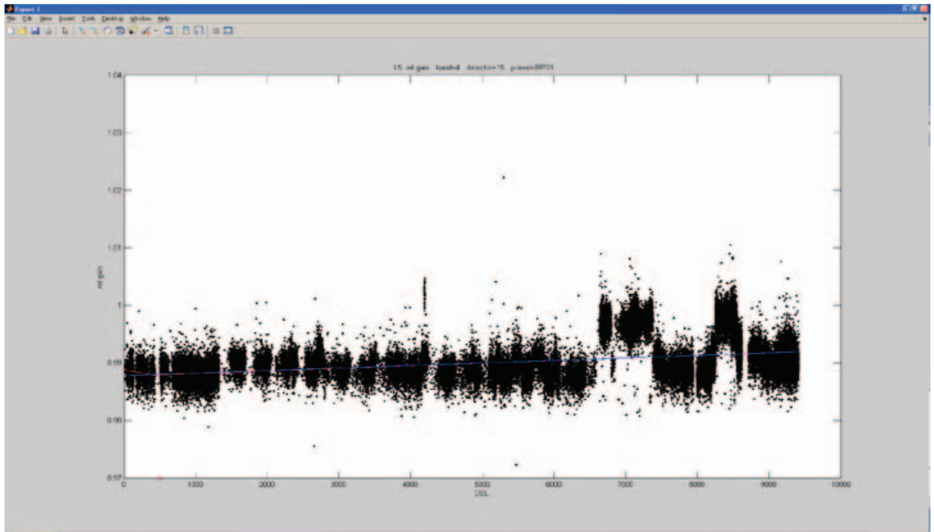

Fig 2. Band 4, Detector 15 Relative Gain Lifetime Trend

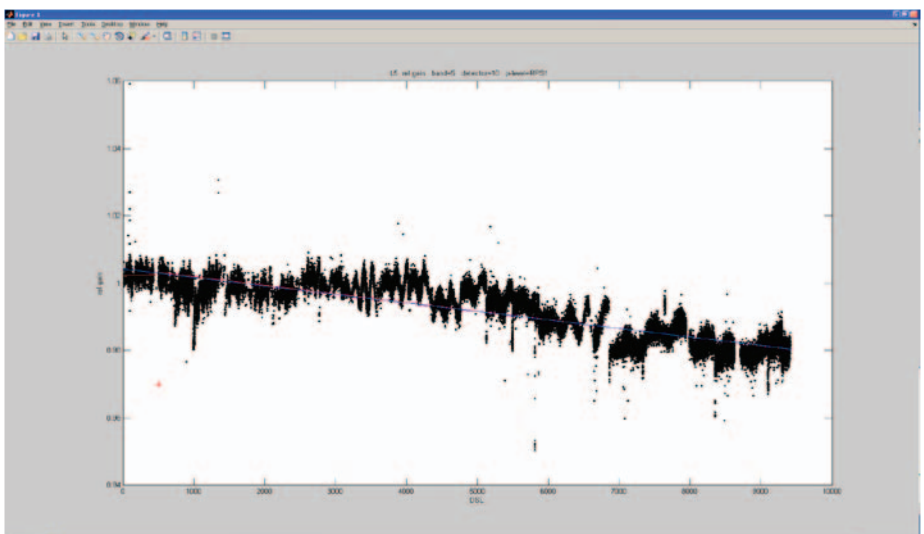

Fig 3. Band 5, Detector 10 Relative Gain Lifetime Trend

4. CONCLUSIONS

Use of the Landsat Image Assessment System has allowed analysis of system artifacts at a level of detail previously unavailable. As a result, refinements have been made for a number of these artifacts in the Landsat TM instrument that have led to a reduction in image noise and subsequent improvements in data quality for those who use these data sets.

5. REFERENCES

[1] USGS-Dept of Interior, "Landsat 4/5 Thematic Mapper Image Assessment System Radiometric Algorithm Theoretical Basis Document", USGS-EROS, Sioux Falls, SD, 2009.

[2] S. Madhavan, "Thesis: Landsat 5 Relative Gain Analysis Characterization of the Relative Radiometric Gain of All Reflective Channels of the Landsat 5 Thematic Mapper", South Dakota State University, Brookings, SD, 2004

[3] D. Helder, T. Ruggles, J. Dewald, S. Madhavan "Landsat Thematic Mapper Reflective Band Artifacts," IEEE Transactions on Geosciences and Remote Sensing, Vol. 42, No. 12,pp.2730-2746, Dec, 2004.

[4] D. Helder, E. Micjevic, "Landsat Thematic Mapper Out Gassing Effects," IEEE Transactions on Geoscience and Remote Sensing, Vol. 42, No. 12, pp.2717-2729, Dec,2004.