A Landsat 7 Calibration Base for Australia

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ABSTRACT

Landsat TM imagery is being used to monitor landcover change in a number of operational projects in Australia. Most recently, the Australian Greenhouse Office (AGO) has undertaken a project to provide historical monitoring of changes in woody vegetation across the continent. In order to map and monitor landcover changes in a consistent and comparable manner across broad areas, it is highly desirable to have a consistently calibrated numerical base. To this end, the AGO has supported the creation of a rectification and calibration base for Australia, using Landsat TM data; 369 Landsat 7 images from the period July 1999 to September 2000 were purchased from the Australian Centre for Remote Sensing (ACRES). This paper describes the processing and production of the calibration base from these images.

1. INTRODUCTION

Remotely sensed data usually is affected by the solar incidence angle, solar azimuth, earth-sun distance, viewing angle, atmospheric effects, the effect of bidirectional reflectance distribution function (BRDF) of the surface sensed, and sensor band spectral response functions. These combine to produce significant band-dependent radiometric differences, confounding the interpretation of both temporal and spatial data sets. When using Landsat TM satellite imagery to map vegetation cover or monitor vegetation cover changes, it is desirable to remove these effects by implementing a method which can produce a radiometrically consistent time series of images and mosaics covering large areas. This enables indices or classifications derived for individual satellite scenes to match other scenes both spatially and over time, and it enables better use of field measurement sites as signatures derived for field sites can be used in the classification of multiple scenes.

There are a number of physical models for calculating surface reflectance from remotely sensed data but it is often difficult to get the required inputs at a resolution that is consistent with Landsat TM imagery [1,2]. In this study a hybrid approach was adopted where the "top-of-atmosphere" (TOA) reflectance was first calculated based on a physical model and the Landsat TM sensor calibration. An empirical BRDF model was then used to correct for the remaining scene-to-scene differences. The model used is a simple three-parameter kernel model where the kernel parameters were calculated by solving equations based on the image overlap areas of the Landsat TM scenes, and the same kernel parameters were applied to all scenes. While it would be desirable to fit different kernel coefficients for each land cover type, this data was not available for the continent so a generalised correction for all land cover types was applied. The investigation of various BRDF models and land cover effects are discussed by Danaher *et. al*. [3].

All imagery had previously been purchased from ACRES as a level 5 product. After all Landsat scenes have been ortho-rectified, the following physically based procedures were applied to produce the base for each scene:

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- scaled TOA reflectance, sun angle and distance corrections, which includes the application of the gain and offset correction, and the sun angle and distance computation and correction.
- application of a combination of two BRDF kernels (a simple variation of Walthall's model).

2. CALIBRATION STEPS

Three calibration steps were considered in the radiometric correction procedure for Landsat imagery: 1) Gain and offset calibration; 2) Sun angle and distance correction; and 3) BRDF calibration. Each step is briefly described in the following subsections (more detailed descriptions of the methods can be found in [3]).

2.1 Gain and Offset Calibration

The gain and offset calibration is applied once the gain and offset are supplied for each image band. The gain and offset for each image band are obtained from the ACRES report file associated with each Landsat 7 scene.

2.2 Sun Angle and Distance Correction

The sun zenith angle for each pixel and the distance from the scene centre to the sun are calculated, then the reflectance correction is calculated for each band as in Vermote *et. al.* [4].

The details of how to apply the gain and offset calibration and the sun angle and distance correction can be found in Section 2 in [3].

2.3 BRDF Calibration

A two-kernel empirical BRDF model was used to correct for the remaining scene-to-scene differences. Walthall's model seemed to most closely match our experience. Simple variations of Walthall's model, which are described by Danaher *et. al*. [3], were used in our BRDF calibration approach. The model is a three-parameter model (see Equation 3 in [3]), where the three parameters were calculated by solving equations based on the image overlap areas of the QLD Landsat TM scenes, and the same parameters were applied to all scenes (see Table 1).

Each pixel of the geo-rectified Landsat image has its own view zenith and azimuth angles which can be calculated based on the pixel's map projection coordinates (easting and northing) and the satellite position at a certain scanline. Since the across-scan coverage of a Landsat image is near 200 kilometres, the sun zenith and azimuth are also treated as different at different locations. The orientation of the Landsat 7 images were extracted from the image header files and used to calculate relative azimuths. The relative azimuth was calculated by subtracting the solar azimuth from the azimuth of the image scan lines. The scan line azimuth was defined in an easterly direction e.g approximately 100^o. The scan angle was calculated for each pixel in the image using the distance from the pixel to the nadir point of the same scan line in the image and the height of the Landsat 7 satellite. Scan angle was defined as positive in the easterly direction and negative in the westerly direction.

Table 1
BRDF correction coefficients for each band.

	a	*b*	*c*
Band 1	0.99707	0.009819	0.018906
Band 2	-0.53200	-0.005423	-0.006888
Band 3	-0.75085	-0.012555	-0.011285
Band 4	-1.00000	-0.006400	-0.008647
Band 5	0.99609	0.014900	0.006204
Band 7	-1.00000	-0.017147	-0.012555

3. CALIBRATION PREPARATION

All 369 Landsat 7 scenes have been ortho-rectified using PCI's OrthoEngine software before the calibration was applied. The details for each geo-rectified scene received from the AGO include:

- 25 metres resolution in the easting and northing directions.
- 6 image bands in the ER Mapper raster format (band 1 to 7 except band 6).
- An ACRES report file is attached to the image — the report provides the basic information, such as the image acquisition date, overpass time, scene orientation, and the scene centre's longitude and latitude.

The above data files were input into a calibration program and the outputs were the calibrated scenes (see the next section).

4. CALIBRATION WORK PROCEDURE

The three calibration steps in section II above were merged and implemented in a computer program called B_TM. B_TM reads all necessary parameters from the ACRES report file and imagery data, then automatically calibrates each scene. B_TM was used to calibrate all 369 Landsat 7 scenes for the AGO mosaicking project.

The outputs from B_TM are 369 calibrated 6-band scenes with 25-metre resolution. The 369 calibrated scenes were then mosaicked using ER Mapper software. Landsat 7 mosaics of the Australian continent are shown in Figs. 1 and 2 (band 1 to 7 except band 6).

5. SOME REMARKS AND RECOMMENDATIONS

While Danaher *et. al*. [3] showed that there were considerable differences in BRDF caused by different land cover types, it is only possible to correct for these differences if each land cover type can be identified at the same resolution as the imagery. It would be desirable to use different kernel coefficients for each land cover type. However, the land cover data were not available for the continent so a generalised correction for all land cover types was applied, which seems to have produced acceptable results.

The effects of using a common set of coefficients for all scenes, and of using varying coefficients for each scene were compared in [3]. While using different coefficients for each scene seemed to produce good scene-to-scene matches, it did not remove the east-to-west illumination effect and it also removed some real change. It was decided that a common set of coefficients should be used.

The resulting individual images were mosaicked and inspected for edge effects. The results indicated that the majority of the initial differences between scenes (with similar seasonal conditions) were systematic and were removed by this radiometric correction method. The range of dates used in the mosaic resulted in a number of edge effects which were interpreted as real landcover change effects. A series of images from August 1999, from a number of paths across desert regions in WA and the NT, appeared consistently bright in comparison with their neighbours. A statistical examination of these edges indicated that a common gain adjustment for these images produced a better match with the neighbouring images and this correction was applied.

ACKNOWLEDGMENTS

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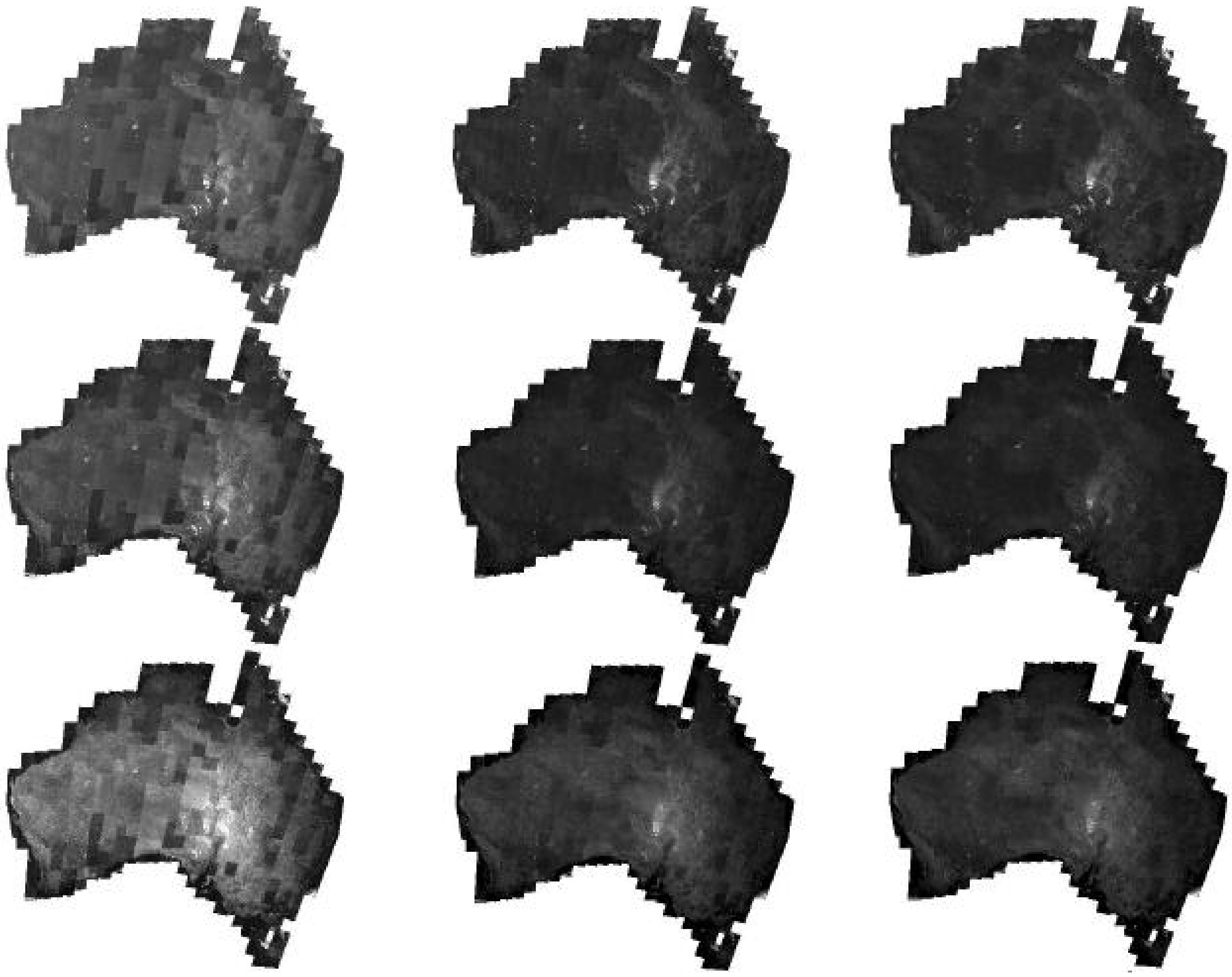

Fig. 1. Landsat 7 Mosaics of the Australian Continent (band 1,2,3).
Image bands are arranged as follows: bands 1,2,3 from the first row (top) to the third row.
Images in the left column are the mosaics from ACRES raw imagery data without applying any correction.
Images in the middle column are the mosaics after applying the gain and offset and sun angle distance corrections.
Images in the right column are the mosaics after applying gain and offset, sun angle distance and BRDF corrections.

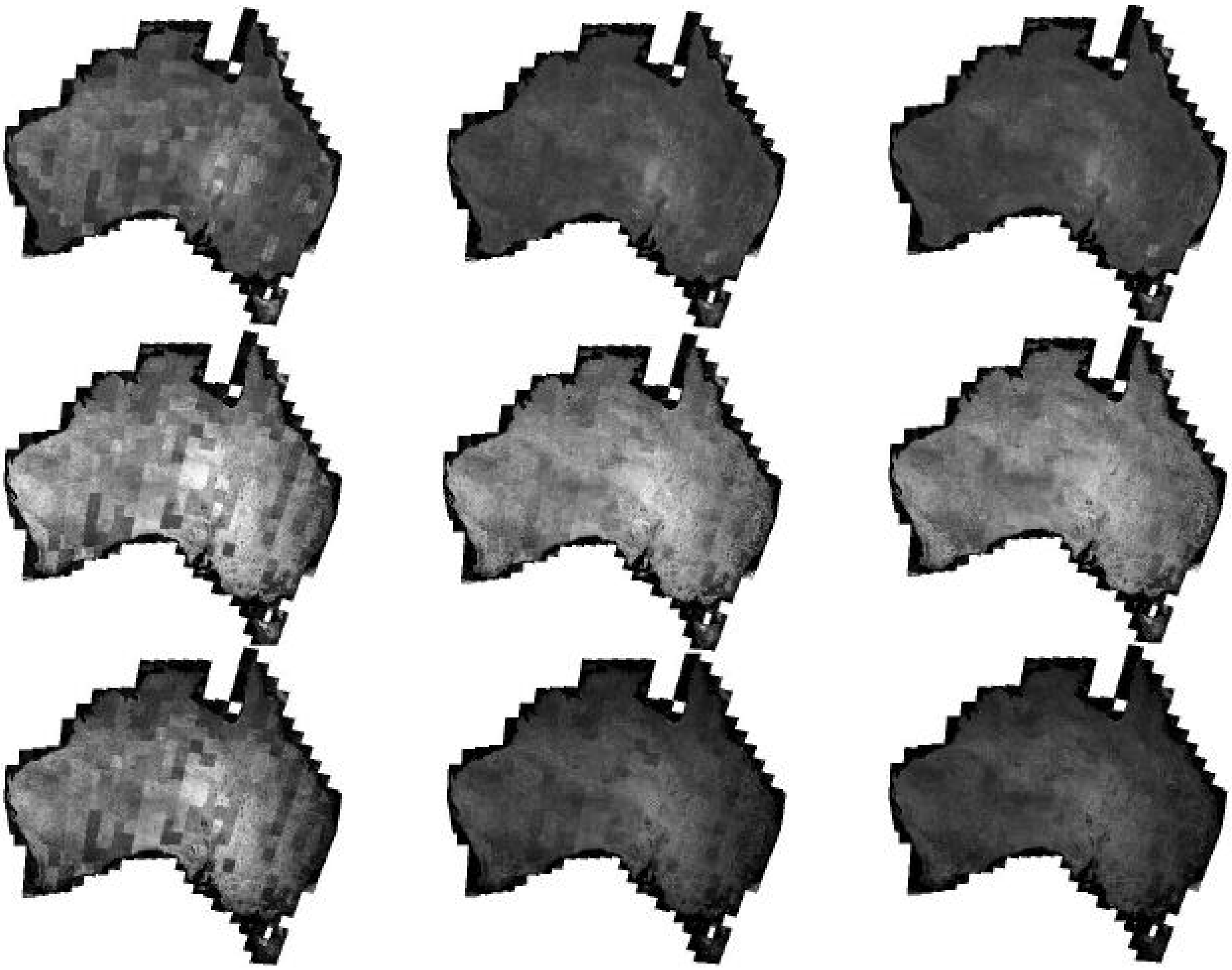

Fig. 2. Landsat 7 Mosaics of the Australian Continent (band 4,5,7).
Image bands are arranged as follows: bands 4,5,7 from the first row (top) to the third row.
Images in the left column are the mosaics from ACRES raw imagery data without applying any correction.
Images in the middle column are the mosaics after applying the gain and offset and sun angle distance corrections.
Images in the right column are the mosaics after applying gain and offset, sun angle distance and BRDF corrections.