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URBAN REMOTE SENSING APPLICATIONS: TIMS OBSERVATIONS OF THE CITY OF SCOTTSDALE

Philip R. Christensen, David E. Melendrez, Donald L. Anderson, Victoria E. Hamilton, Melissa L. Wenrich, and Douglas Howard

Department of Geology
Arizona State University
Tempe, AZ 85287-1404

1. INTRODUCTION

A research program has been initiated between Arizona State University and the City of Scottsdale, Arizona to study the potential applications of TIMS data for urban scene classification, desert environmental assessment, and change detection. This program is part of a long-term effort to integrate remote sensing observations into state and local planning activities to improve decision making and future planning. Specific test sites include a section of the downtown Scottsdale region that has been mapped in very high detail as part of a pilot program to develop an extensive GIS database. This area thus provides excellent "ground truth" for surface classification models and contains an excellent time history of the evolution of the city infrastructure, such as the timing and composition of street repavement. A second area of study includes the McDowell Mountains immediately east of the city. These mountains are currently undergoing intensive study by state and local agencies to assess potential sites for urban development as well as preservation. These activities are of particular relevance as the Phoenix metropolitan area undergoes major expansion into the surrounding desert area.

The objectives of this study in urban areas are aimed at determining potential applications of TIMS data for classifying and assessing land use and surface temperatures. Land use centers on surface impermeability studies for storm runoff assessment and pollution control. These studies focus on determining the areal abundance of urban materials such as pavement, concrete, building footprints, and pools versus urban vegetation and undeveloped soil. Highly experimental applications include assessment and monitoring of pavement condition. Temperature studies focus on determining swimming pool area and temperature for use in monitoring evaporation and urban water consumption. These data will also be used to determine building and ground temperatures for assessing changes in the urban environment.

The desert terrain mapping aspect of this study is aimed at combining soil and rock composition and vegetation studies with digital terrain models to aid in the identification and preservation of unique desert environments. Derived products and applications will include the overlay of TIMS-derived compositional classifications on ~1 foot horizontal and vertical resolution Digital Elevation Model data acquired by the City of Scottsdale for input into flood runoff predictive models. The TIMS data will also be combined with NS001 data acquired simultaneously by the C130 aircraft and 6 inch resolution air digital orthographic color images acquired by the City of Scottsdale for scene classification.

The TIMS data were collected by the Ames C130 aircraft on August 18, 1994, with three image lines over the central urban region of Scottsdale and six covering the McDowell Mountains. The Scottsdale images were taken at an average altitude of 4900 feet (AGL) and have a calculated scale of about 12.2 feet/pixel (3.7 m/pixel) (assuming 2.5 mrad IFOV). We estimate the actual spatial resolution to be about 13-16 feet (~4-5 meters). Over the McDowells, the surface elevation varies by about 3500 feet with respect to the average aircraft altitude of 9400 feet (MSL). Image scale can therefore only be approximated to be about 12.4 ± 3.1 feet/pixel (~3.8 ± 1 m/pixel). The images are 638 samples by 7600-8900 lines in size.

2. SPECTRAL AND GEOMETRIC CALIBRATIONS

The spectral calibration procedures have primarily focused on optimizing the atmospheric water and ozone corrections. We are continuing to investigate the relative affects of both water and ozone on the six-point spectra obtained from the images in both radiance- and emissivity-space. The standard radiometric correction routines within the VICAR software package are being used, one of which runs "lowtran7" as a subroutine.

Because the images were collected over the Phoenix area on a warm Summer morning, it is likely that the atmosphere was relatively dry compared to the standard "northern hemisphere mid-latitude Summer" model used in lowtran. Also, the lack of a detailed atmospheric profile for that day has required a very systematic approach to best determine the correct ozone- and water-factors for use in the calibration.

2.1 Spectral and Temperature Data Extraction

The McDowell images have about a 40-45% cross-track overlap (Figure 1). We have chosen the two westernmost images of the McDowells (hereafter referred to as L8 and L9) for the calibration study. The images L8 and L9 contain a water canal in the area of overlap which can be used for extracting radiance and emissivity spectra and water temperature values at a variety of emission angles and viewing perspectives . For the emissivity calculations, the 8-bit emissivity DN values are stretched to fit a max. and min. emissivity of 0.985 and 0.7, respectively, with band six constrained as the reference band held fixed at the max. emissivity.

Five data points along the water canal are being used consistently throughout: three within the area of overlap and one at the nadir point for each image (Figures 1, 2). The spectral calibrations are work in progress although we are clearly seeing that the spectra are much more sensitive to atmospheric water than ozone. Also, it appears that fractional lowtran water values (0-0.25) are yielding the best results.

2.2 Geometric Corrections

Preliminary spatial warping and geometric corrections have also been performed. A portion of the TIMS image covering the Scottsdale Civic Center was warped to fit a digital street grid. Approximately 120 ground control points were collected between the two images (using the ERDAS Imagine software) which equates to a 13th- or 14th-order polynomial fit. This was done subsequent to the correction for instrument scan distortions in VICAR. The poly-warp was significantly better than the scan mirror correction alone with only minor residual differences from the city grid. Future plans call for all the Scottsdale TIMS images to be rectified to the city grid. The images of the McDowells will eventually be mosaicked and tied to either Landsat or aerial photos of the area in a UTM projection.

3. PRELIMINARY SCENE CLASSIFICATIONS

A major expense for the City of Scottsdale is street maintenance. The ability to classify the pavement condition by remote sensing could potentially save many dollars/man hours. As a test case, a TIMS image covering the downtown section of the City of Scottsdale is being used for classification of urban materials. The scene contains materials such as vegetation (golf course, baseball stadium, lawns), water (ponds, fountains, pools, canals), concrete (sidewalks, medians, parking structures), roofing materials (asphalt/cedar shingles, metal, clay, slate, foam/paint), and street materials (old/new pavement, chip sealing, red brick, dirt, people, vehicles).

The method used for image classification is target transformation principal component analysis (Anderson, 1993). Six point TIMS spectra of known materials directly from the image are used as endmembers. The spectra are transformed into the fourier domain prior to classification to decorrelate each of the bands. The street boundaries can be masked from the rest of the image for more specific classification using the Scottsdale GIS street easement information. Preliminary results show significant differentiation of many endmembers, including newly paved/sealed versus older asphalt. Future work entails combining the TIMS images with those from NS001 and Scottsdale visible digital color orthographic images for even better material differentiation. Radar images have also been recently acquired which should be useful for surface roughness as a classifier of pavement condition.

4. ACKNOWLEDGMENTS

We wish to express of sincere thanks to the entire crew of the Ames C130 aircraft team for the acquisition of the high-quality data used in this study, and for their enthusiasm for our participation in the data collection flights.

5. REFERENCE

Anderson D.L., 1993, Fourier Domain Target Transformation Analysis in the Thermal Infrared (abstract), In *Lunar and Planetary Science XXIV*, Lunar and Planetary Institute, Houston, p. 31.

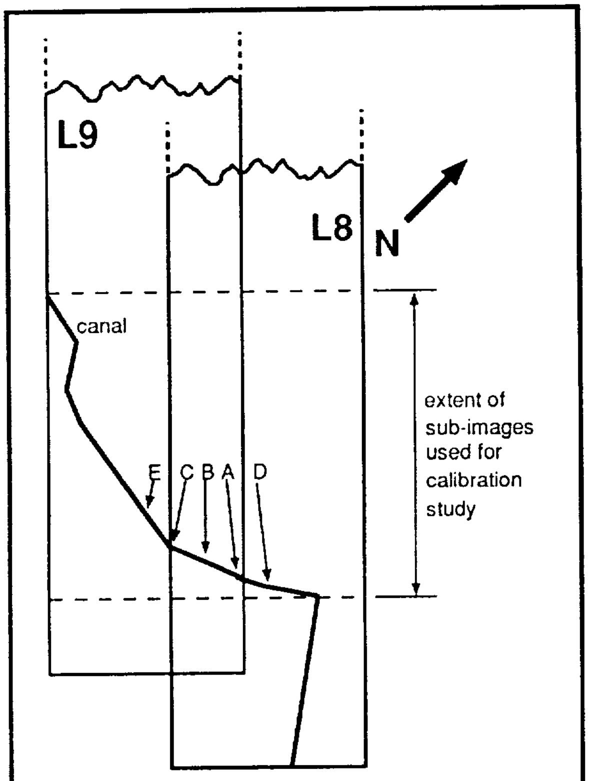

Figure 1. Schematic of TIMS images L8 and L9 covering the western portion of the McDowell Mountains. Data points A-E are being used for extraction of radiance and emissivity spectra as well as temperatures of canal water from various emission angles and viewing perspectives.

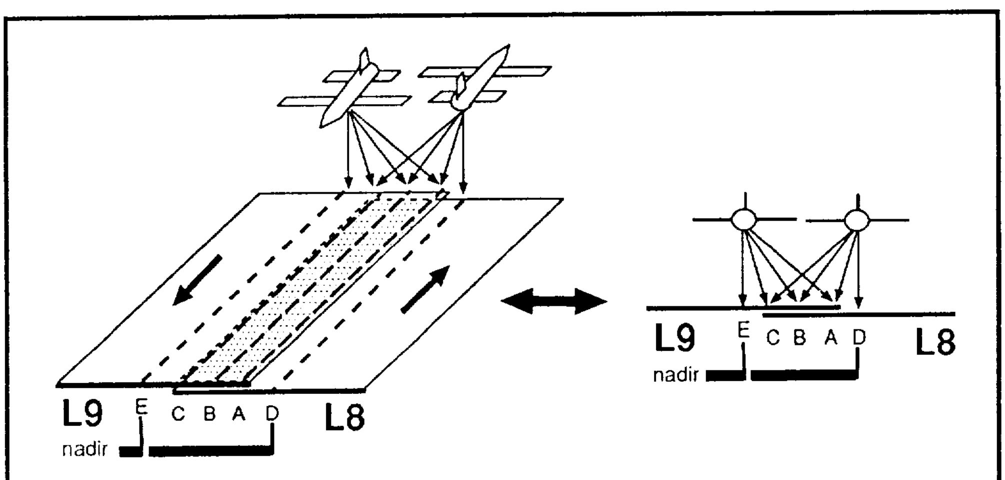

Figure 2. Representations of TIMS images L8 and L9 illustrating viewing angles of data points A-E from adjacent aircraft flight lines. The left diagram shows a perspective view of the flight lines and overlap between images. The right diagram better illustrates the relationship between the viewing and emission angles. Points B have been chosen to be both equidistant (in pixels) and equiangular from nadir.