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# CALIBRATION OF LANDSAT-4 AND 5 TM THERMAL IR DATA FOR EARTH SURFACE TEMPERATURE MAPPING

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ABSTRACT

The procedures for calibration of the Landsat-4 TM thermal IR band and the resulting water temperature map have been reported in a previous paper (Anuta, 1984). This paper deals with the calibration of the thermal IR data collected by the Thematic Mapper sensor on board Landsat-5 and it includes a description of the procedures developed for calibration, the results of calibrated thermal IR data, and a comparison of these procedures and results with those obtained from the Landsat-4 TM data.

The calibration of the Landsat-4 TM thermal IR data was straightforward because the temperatures of the internal calibration sources (Blackbodies) were known with reliability, i.e. 260 K and 320 K, which corresponded to the 0 and 255 digital count levels respectively. On the other hand, the temperatures of the reference Blackbodies for the Landsat-5 TM sensor were not known with a high degree of accuracy (Hughes, 1985). Therefore the first step in the calibration procedure involved the determination of these two reference temperatures for the Landsat-5 TM sensor.

To determine these temperatures the minimum and maximum spectral radiances stored on the CCTs (P-tape) "radiometric ancillary records" as described by NASA's LSD-ICD-105 CCT format document, were used in conjuction with the results of the integration of Planck's equation for a bandwidth defined by the system reponse function of all four band-6 detectors as shown in the following equation :

$$W_{\overline{SR}} = \Sigma_i \left[ \left( \int_{\lambda_L + i\Delta\lambda}^{\lambda_L + (i+1)\Delta\lambda} 2hc^2 \lambda^{-5} \left( e^{hc/\lambda kt} - 1 \right)^{-1} d\lambda \right) \overline{SR}_i \right]$$

Where:

- $W$ = In-band radiance in mWatts/cm.sr
- $c$ = Speed of Ligth
- $h$ = Planck's Constant
- $\lambda$ = Wavelength
- $k$ = Boltzmann's Constant
- $T$ = Temperature in Degrees Kelvin
- $SR$ = System Response
- $\lambda_L$ = 10 µm
- $\Delta\lambda$ = 0.01 µm
- $i$ = 0-300

The Landsat-5 TM thermal IR data were calibrated for a scene collected over the Chicago, Illinois region on July 18, 1984. The resulting calibrated radiant temperatures have been compared with available reference temperatures obtained through conventional temperature measurement methods.

Four different models were derived to convert the relative digital counts into radiant temperatures:

Landsat-4 TM

Effective Bandwidth: 10.42 µm - 11.66 µm
- Reference BB Temperatures: 260 K & 320 K

a) Two-point Linear:
$T(K) = 260 + 0.235294*DC$

b) Linear Regression:
$T(K) = 262.807671 + 0.234179*DC$

c) Quadratic Regression:
$T(K) = 260.454218 + 0.294398*DC - 0\ 0002449*DC^2$

d) Cubic Regression:
$T(K) = 260.082878 + 0.313186*DC - 0.00043607*DC^2 + 5.11E\text{-}07*DC^3$

Landsat-5 TM

- Effective Bandwidth: 10.45 μm - 12.42 μm
- Reference BB Temperatures: 203.2 K & 341.2 K

a) Two-point Linear:
$T(K) = 203.2 + 0.541176*DC$

b) Linear Regression:
$T(K) = 219.97218 + 0.525959*DC$

c) Quadratic Regression:
$T(K) = 209.830966 + 0.834313*DC - 0.0013271*DC^2$

d) Cubic Regression:
$T(K) = 206.127 + 1.054*DC - 0.003714*DC^2 + 6.60655E-06*DC^3$

However, depending on the range of digital counts involved, either the quadratic or the cubic models would yield a better fit of the actual data. Therefore, it is recommended that a look-up table of the relationship between digital counts and temperatures (derived from the integration of Planck's equation) be utilized.

## AUTHOR BIOGRAPHICAL DATA

Luis A. Bartolucci received his B.S., M.S. and Ph.D. degrees in geophysics from Purdue University. He has been involved in Remote Sensing Research since 1969. He has played an active role in the development of digital remote sensing technology for applications in the area of water resources and has also made outstanding contributions in the field of thermal infrared radiation for remote sensing applications. In addition, he has served as consultant to the U.S. Information Agency, the U.S. Agency for International Development, InterAmerican Development Bank, International Atomic Enegy Agency, United Nations, U.S. Defense Mapping Agency, InterAmerican Geodetic Survey, U.S. Army Corps of Engineers, and to several Latin American development agencies. He has been Principal Investigator and Project Director of several domestic and international research and training programs involving computer-aided processing and analysis of remotely sensed data for earth resources inventories.

D. Fabian Lozano-Garcia received his B.S. degree in biological sciences, with emphasis on remote sensing of natural resources from the Universidad Nacional Autonoma de Mexico. He received his M.S. in Forestry and Natural Resources from Purdue University in 1984, and presently he is working on his doctoral degree in applications of digital remote sensing for natural resources inventories. Mr. Lozano-Garcia was a research staff member of the Instituto Nacional de Investigaciones sobre Recursos Bioticos in Xalapa, Mexico until 1981.

Paul E. Anuta received the B.S. degree in electrical engineering from Purdue University in 1957, the M.S.E.E. degree from the University of Connecticut in 1962, the M.S. degree in computer science from Purdue in 1967, and the Ph.D. degree in electrical engineering in 1985. He joined the Laboratory for Applications of Remote Sensing (LARS), Purdue University in 1967 and he has researched data handling systems, interferometer spectrometer, and other sensors. He is currently Associate Program Leader for Data Handling Research at LARS. Key data research handling areas are: image registration, geometric correction, and resolution enhancement of satellite multispectral imagery. His current interests are in the area of multitype data integration and preprocessing and analysis methods. Dr. Anuta is a member of Tau Beta Pi, Eta Kappa Nu and the American Society of Photogrammetry.