Landsat-7 ETM+ Radiometry: Satellite, Image and Ground Calibration

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(as of 10-Nov-04)

Reflective Bands 1-5, 7, 8: Stable and Accurate

Stability: < ±0.5% Accuracy: ±5%

Radiometric Calibration Methods
(sampling per year)

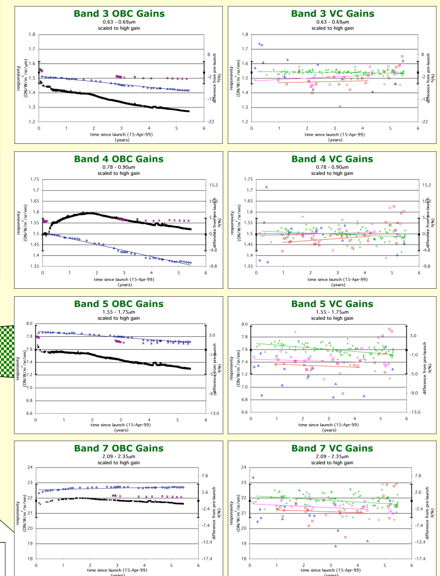
Instrument Based Calibration
- × Internal Calibrator, primary lamp, high and low gain state gains merged where available, data from IAS database, USGS/EDC, through 10-Nov-04 (~1500)
- ✳ Internal Calibrator, redundant lamp, high and low gain state gains merged where available, data from IAS database, USGS/EDC, through 10-Nov-04 (0-20)
- ◇ Full Aperture Solar Calibrator (10-12)

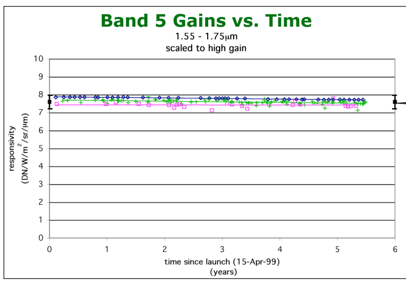
Image Based Calibration
- \+ Relative stability invariant sites (scaled to pre-launch) (15-20)

Ground Based Calibration
- □ University of Arizona absolute calibration, Railroad Valley (5-10)
- □ University of Arizona absolute calibration, Ivanpa Playa (5-10)
- △ South Dakota State University absolute calibration (2-4)

Pre-Launch Absolute Calibration
- ■ Pre-launch (1)

Onboard Calibration   Vicarious Calibration

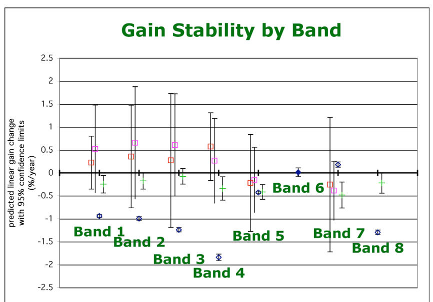




The Landsat-7 ETM+ sensor has three on-board calibration devices for tracking radiometric calibration for the reflective bands, the Internal Calibrator (IC) lamps, the Full Aperture Solar Calibrator (FASC) panel and the Partial Aperture Solar Calibrator (PASC) pin-hole mirror. The IC consists of a lamp source and a black background on a shutter, viewed with every scan of the scanning mirror. Though the system has two lamp sources on the shutter, only a single lamp is used operationally. System gains calculated based on the IC have shown anomalous behavior, thought to be associated with IC-related vacuum shifts, filament flares, instrument temperature and current, and lamp usage, so have not been used for calibration as of yet. The FASC is a solar diffuser panel, located outside of the instrument and deployed in front of the entrance aperture approximately once per month. The gains calculated based on the FASC acquisitions generally show downward trends across the reflective bands (0 to -2%/year), though this is mostly thought to be due to panel degradation. The PASC results have been anomalous and not well understood, so will not be discussed here.

Science team members from University of Arizona (UAz) and South Dakota State University (SDSU) conduct ground look calibration campaigns in the western United States to validate the on-board calibration devices. The gains calculated based on the UAz campaigns are not statistically significant through the first four years since launch. Recent data show a higher response, though this may be a field instrument problem.

Four homogeneous scenes (CV = ±3-6%) in North Africa and Arabia are being used to monitor gain stability. These "relative stability invariant sites" show weighted average downward trends in all bands (0 to -0.5%/year).



- Onboard calibration devices, although very precise, are changing more rapidly then the instrument, based on the vicarious and invariant site results.
- With no strong indication of change, the processing system continues to use the pre-launch determined gains to calibrate the imagery ordered by users.
- Absolute calibration is generally consistent with other instruments and methods to 5%, though biases are present.

Atmospheric Correction Parameter Calculator
http://tightrope.gsfc.nasa.gov/atm_corr

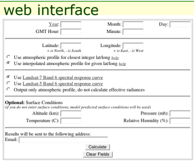
Removing the effects of the atmosphere in the thermal region is the essential step necessary to use thermal band imagery for absolute temperature studies. The emitted signal leaving a target on the ground is both attenuated and enhanced by the atmosphere. With appropriate knowledge of the atmosphere, a radiative transfer model can be used to estimate the transmission, and upwelling and downwelling radiance. Once these parameters are known, it is possible to convert the space-reaching radiance to a surface-leaving radiance:

$$L_{TOA} = \tau\varepsilon L_T + L_u + \tau (1-\varepsilon) L_d$$

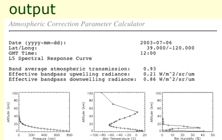
where τ is the atmospheric transmission,
ε is the emissivity of the surface,
L_T is the radiance of a blackbody target of kinetic temperature T,
L_u is the upwelling or atmospheric path radiance,
L_d is the downwelling or sky radiance, and
L_{TOA} is the or top-of-atmosphere (TOA) radiance measured by the instrument.

Radiances are in units of W/m^2·ster·µm and the transmission and emissivity are unitless. Radiance to temperature conversions can be made using the Planck equation.

web interface



output

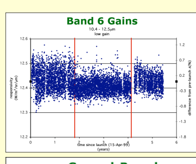


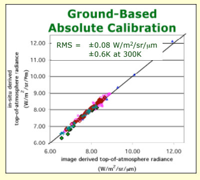
The TOA temperature is not a good estimate of surface temperature. Neglecting atmospheric correction in the thermal band will result in systematic errors in the predicted surface temperature. The Atmospheric Correction Parameter Calculator provides an automated method to derive atmospheric correction parameters needed for generating surface temperatures. It uses modeled atmospheric profile data from the National Centers for Environmental Prediction (NCEP) as input for the user specified date and location. The atmospheric profile is processed through MODTRAN and the spectral transmission (τ), upwelling radiance (L_u) and downwelling radiance (L_d) are calculated. The results are displayed to the web page and emailed to the user,

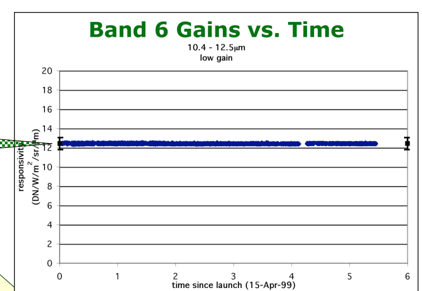
Using the above equation and the results of the Parameter Calculator, the user can remove the effects of the atmosphere to get a prediction of surface temperature.

Thermal Band 6: Stable and Accurate

Stability: < ±0.25% Accuracy: ±0.6K at 300K







Radiometric Calibration Methods
(sampling per year)

Instrument Based Calibration
- ◆ Blackbody Calibrator, low gain state gains, data from IAS database, USGS/EDC, through 15-Nov-04 (~1500)

Ground Based Calibration
- △ NASA/Jet Propulsion Laboratory absolute calibration prior to SLC failure (5-10)
- \+ NASA/Jet Propulsion Laboratory absolute calibration after SLC failure (5-10)
- □ Rochester Institute of Technology absolute calibration prior to SLC failure (15-25)
- ◇ Rochester Institute of Technology absolute calibration after SLC failure (15-25)

Pre-Launch Absolute Calibration
- ■ Pre-launch (1)

The Landsat-7 ETM+ sensor has a single on-board calibration device for tracking radiometric calibration for the emissive thermal band; the Internal Blackbody Calibrator (BB) which also functions as a reflective band calibration source, consists of a hot blackbody and an ambient temperature background and is viewed with every scan of the scanning mirror. The gains calculated from the BB for the thermal band have been stable to within ±0.25% since launch, though within the last year, the gain appears to be changing (the slope is significant).

Science team members from NASA/Jet Propulsion Laboratory (JPL) and Rochester Institute of Technology (RIT) conduct ground look calibration campaigns to validate the on-board calibration devices. They initially discovered a 0.31 W/m^2/sr/µm (~3K at 300K) error in offset which was corrected in the processing system by 01-Jan-01. The failure of the SLC has changed the internal operating temperatures of some of the instrument components, but still, neither team has detected any addition errors, with an RMS error of ±0.08 W/m^2/sr/µm or ±0.6K at 300K.

Landsat References

Landsat-7 Science Data User's Handbook: http://ltpwww.gsfc.nasa.gov/IAS/handbook.html
USGS Earth Explorer: http://earthexplorer.usgs.gov
Atmospheric Correction Parameter Calculator: http://tightrope.gsfc.nasa.gov/atm_corr

References

B.L. Markham, K.J. Thome, J.A. Barsi, E. Kaita, D.L. Helder, J.L. Barker, P.L. Scaramuzza, "Landsat-7 ETM+ On-Orbit Reflective Band Radiometric Stability and Absolute Calibration," *IEEE Transactions on Geoscience and Remote Sensing*. Vol. 42, No. 12 , pp. 2810-2821, Dec 2004.

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