Landsat Thermal Data

How to derive temperature images from thermal bands

Background

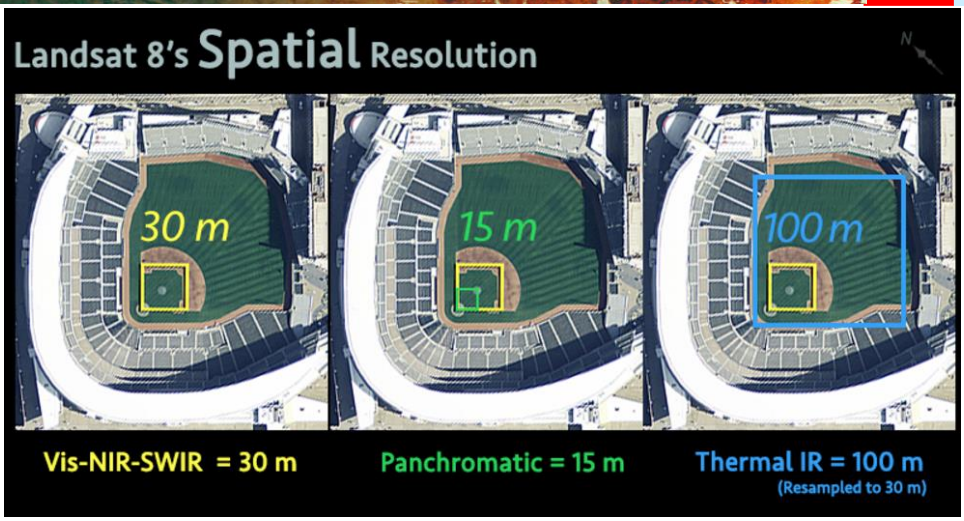
The thermal infrared bands (or simply thermal bands) capture data in the electromagnetic spectrum's far infrared range (10.4-12.5 µm). Landsat 4 (having sensor thematic mapper) was the first satellite to have a thermal band (band 6) having a spatial resolution of 120 m. This was further improved in Landsat 7, which had an Enhanced Thematic Mapper+ (ETM+) sensor. With a spatial resolution of 60 m (for ETM+), this was the highest resolution amongst the available thermal sensors onboard different satellites. The current Landsat satellites (8 and 9) have two thermal bands capturing data at 100m spatial resolution, but the final product is resampled at 30 m for the end-users. The thermal band is helpful in calculating the brightness temperature (in ^{o}Kelvin).

The Landsat satellites orbit the Earth at an altitude of 705 kilometres in a 185-kilometre swath, following the Worldwide Reference System (WRS-2). Each satellite has a temporal resolution of 16 days, *i.e.* it crosses every point on Earth once every 16 days. Thus, one can have a thermal band at this frequency.

Applications of thermal imagery: Thermal imagery can be used for estimating soil moisture, mapping soil types, urban heat islands, land surface temperature, determining rock and mineral types, coal mine fires, wildland fire management, and identifying leaks or emissions.

Landsat Thermal infrared bands (TIR) specifications.

Satellite/sensor	Band Numbers	Spectral Range (µm)	Quantization Levels (bits)	Spatial Resolution (m)
Landsat 4-5/Thematic Mapper (TM)	B6	10.40 - 12.50	8	120
Landsat 7/Enhanced Thematic Mapper+ (ETM+)	B6	10.40 - 12.50	8	60
Landsat 8/Thermal Infrared Sensor (TIRS)	B10 (TIR I)	10.6 – 11.90	12	100 (resampled to 30 m)
	B11 (TIR II)	11.50-12.51		



Source: NASA

Deriving temperature data from Landsat thermal bands

The following steps are followed to retrieve temperature from thermal images. All the coefficients and Min/max values are available in the metadata file of each Landsat scene and can be calculated in ArcGIS/ENVI/QGIS.

i. ***Calculation of radiance images***

The raw digital number (DN) values are converted to radiance as follows:

$$L^* = \frac{(L_{max} - L_{min})DN + L_{min}}{DN_{max}}$$

where L^* is the spectral radiance received at the sensor; L_{min} and L_{max} are the minimum and the maximum spectral radiance for the sensor, respectively; DN_{max} is the maximum DN.

ii. ***Calculation of brightness temperature***

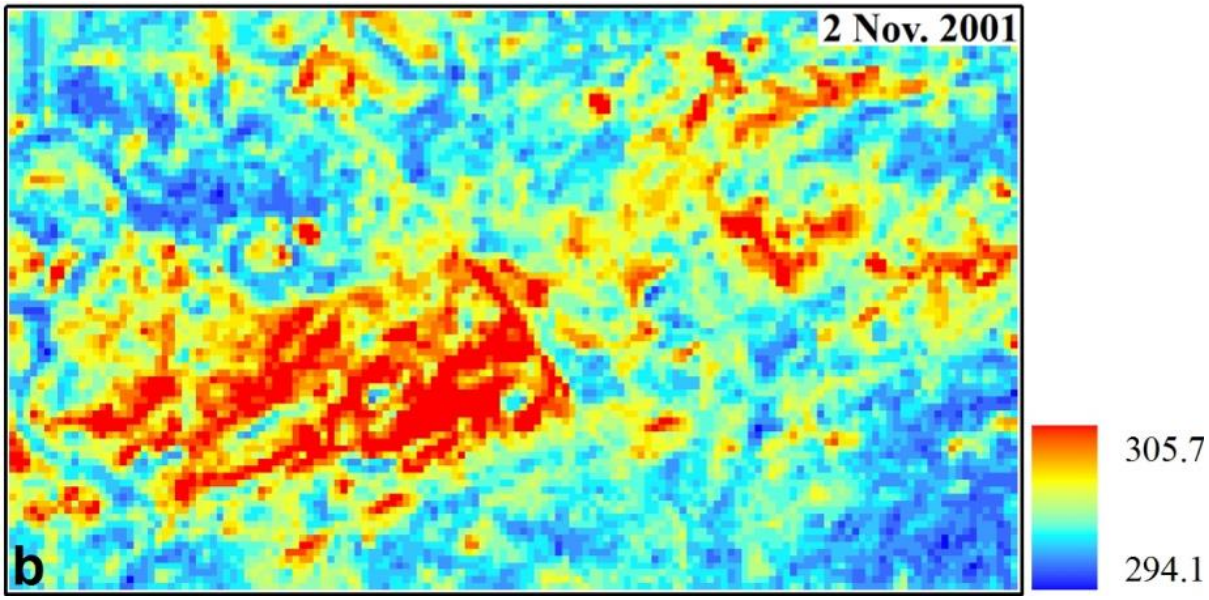
The radiance images derived from thermal bands are then used to calculate radiant temperature using the formula:

$$T_r = \frac{K2}{ln\left(\frac{K1}{L^*} + 1\right)}$$

where T_r = temperature (in ºKelvin); *K1* and *K2* = pre-launched calibration constants 1 and 2 respectively (W/ (m^2 sr µm)) L^* = spectral radiance.

By default, thermal images are shown as greyscale and are typically single-band images. Darker areas are cooler, while lighter or brighter ones are warmer. To better illustrate temperature variation, single-band thermal images can also be shown in pseudo-colour (see example below).

Example: Temperature images derived from Landsat 5 TM band 6



A greyscale and colour-coded thermal temperature image of a coal mine under fire in Dhanbad, India. The brighter the pixel in the temperature image, the higher its temperature will be. The pixels shown as bright white in the centre of the greyscale image above have the highest temperature (305.7 ºK).

Further Information

For more information or access to thermal data, please email spatial.imagery@environment.nsw.gov.au or contact Sue Rea on 02 6640 2577