

## Converting Landsat TM and ETM+ thermal bands to temperature

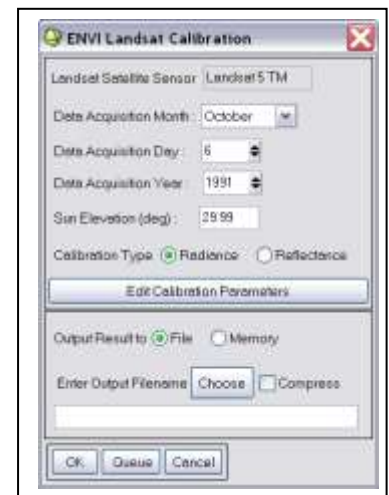
The Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) sensors acquire temperature data and store this information as a digital number (DN) with a range between 0 and 255. It is possible to convert these DNs to degrees Kelvin using a two step process. The first step is to convert the DNs to radiance values using the bias and gain values specific to the individual scene you are working with. The second step converts the radiance data to degrees Kelvin.

### Convert DN to Radiance:

#### USGS GeoTIFF with Metadata format data

The USGS now provides data in the GeoTIFF with Metadata format. Using ENVI software you can easily convert the thermal band to radiance. Open the file that ends with “\_MTL.TXT”. ENVI will automatically open the Landsat image as multiple files; the 6 bands of optical data as one file, and the thermal band as another. In the case of ETM images the thermal file will have two bands and there will also be a single band file for the panchromatic band.

To create a radiance data layer, from the ENVI main menu bar, select **Basic Tools** → **Preprocessing** → **Calibration Utilities** → **Landsat Calibration**. Select the thermal file and the *ENVI Landsat Calibration* dialog should open with all of the calibration parameters filled in. Click on the *Radiance* radio button and enter an output file name. After saving this file you can proceed to the section **Convert Radiance to Kelvin** to generate a new data layer of brightness-temperature in degrees Kelvin.



#### Other Landsat data

For Landsat images that are not in the original USGS “GeoTIFF with Metadata” format you will need to manually convert these data to radiance. To do this you need to get the gain and bias (offset for TM) values from the header file. You need to use the values for band 6, which is the thermal band on these sensors. Look for a file name such as LT5171034009024510.WO, or with met or txt as the file extension.

For ETM+ images the bias and gain values for the two thermal bands will generally be in the header file for the thermal bands. Look for a file name on the CD such as L71171035\_03520000905\_hm.fst. Remember that the ETM+ sensor has two thermal bands so you may want to convert both the low-gain and high-gain bands to temperature.

You can also locate appropriate values from the USGS page of [Landsat Calibration](#) values.

The formula to convert DN to radiance is:

$$CV_R = G(CV_{DN}) + B$$

Where:

- CV<sub>R</sub> is the cell value as radiance
- CV<sub>DN</sub> is the cell value digital number
- G is the gain
- B is the bias (or offset)

**The ENVI formula in Band Math will look like:**

$$0.05518 * (B1) + 1.2378$$

using a scene specific gain value of 0.05518 and an offset value of 1.2378. In the Band Pairing dialog you should match B1 with the thermal band(s).

### Convert Radiance to Kelvin:

Once the DNs for the thermal bands have been converted to radiance values, it is simply a matter of applying the inverse of the Planck function to derive temperature values.

The formula to convert radiance to temperature is:

$$T = \frac{K_2}{\ln\left(\frac{K_1 * \epsilon}{CV_R} + 1\right)}$$

Where:

- T is degrees Kelvin
- CV<sub>R</sub> is the cell value as radiance
- ε is emissivity (typically 0.95)

	Landsat TM	Landsat ETM
K <sub>1</sub>	607.76	666.09
K <sub>2</sub>	1260.56	1282.71

**The ENVI formula in Band Math for a TM scene will look like:**

$$1260.56 / \log(((607.76 * 0.95) / B1) + 1)$$

In the Band Pairing dialog match B1 with the radiance band created above.