Emissivity – SP3 vs. Manually Calculated
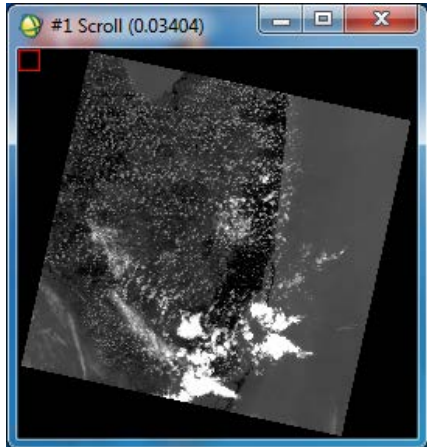
In the four Landsat 8 images, the temperatures calculated by ENVI SP3 and temperatures calculated manually in ENVI Classic Band Math were relatively significantly different (averaging a difference of between 0.5K and 7K depending on the image and TIR band). Moreover, the differences between images appear to vary with type of land cover.

Florida, Band 10 Temperature Comparison (Manual-SP3)
Example of variation in the size of the difference between the two temperature calculation methods. Temperature difference appears to vary with type of land cover (small difference = white, greater difference = black).

For its temperature calculations, ENVI SP3 lists the same formula that was used, manually, in ENVI Classic and like the manually entered formula, the formula listed in SP3 uses an emissivity of 1. However, emissivity is the only part of the equation where the difference between the two methods could be introduced. (The two methods for calculating radiance produce almost identical results.) To check the emissivity used in the SP3 formula, emissivity was manually calculated using the temperature and radiance data, with the formula:
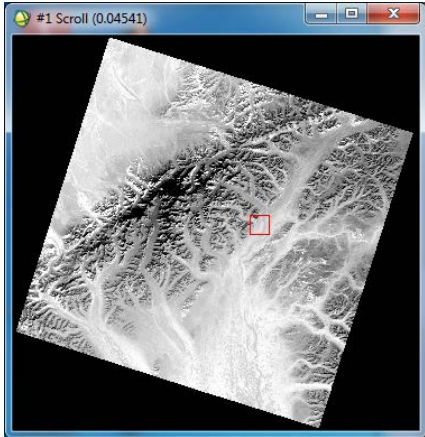
$\varepsilon = (Radiance)/ B_\lambda(T)$

After reducing the Plank Function somewhat, this was entered into Band Math as:

(B1*1000000)/((775892116.3)/(exp(1320.659697/B2)-1))

Where B1 = radiance and B2 = temperature.

Emissivity was "back calculated" using both the SP3-calculated and manually calculated temperatures and radiances. For the two temperature and radiance calculation methods, the emissivity results appeared to vary with temperature. (Land cover features of different temperatures remained distinct in all the images, i.e. clouds were distinct from ocean and land.)

Alaska Emissivity, Band 10
From manually calculated temperature and radiance. Example of emissivity variation with temperature (higher emissivity corresponds to regions with lower temperatures = black, lower emissivity corresponds to regions with higher temperatures = white). Emissivity appears to vary with land cover because temperature varies with land cover.

The variation between emissivity values was much smaller for the images using manually calculated data than the images using SP3-calculated data. (Range for emissivity based on manually calculated data, for all four images in Band 10 = 0.996923-0.997367. Range for emissivity based on SP3 calculated data, for all four images in Band 10 = 0.968621-1.113960.) The presence of any variation in emissivity of the manually calculated data, however, was attributed to artifacts from ENVI's rounding method. Because emissivity had been entered as 1 for all manual calculations, any subsequent deviation from $\varepsilon = 1$ must be due to how ENVI processed the numbers. Moreover, because the emissivity for the manually calculated data varied with temperature, it was concluded that ENVI's rounding method was, in some way, a function of temperature value. This temperature-dependent rounding also seemed a likely source of the variation observed in the emissivity values calculated using the SP3 data. To test this for both sets of emissivity values, scatter plots of the relationship between emissivity and temperature were made for each image. Both the SP3 and manually calculated emissivity and temperature values were found to vary linearly, supporting the theory that apparent variations in emissivity were actually reflecting variations in ENVI's method of rounding output values (i.e. temperature).

This linear relationship between temperature and emissivity was defined successfully for both SP3 and manually calculated data in Band10. (NOTE: negative relationship between emissivity and temperature for SP3 data and positive relationship between emissivity and temperature for manual)

Band 10, SP3 data: $\varepsilon = (-0.000461996)*T + 1.11426601$
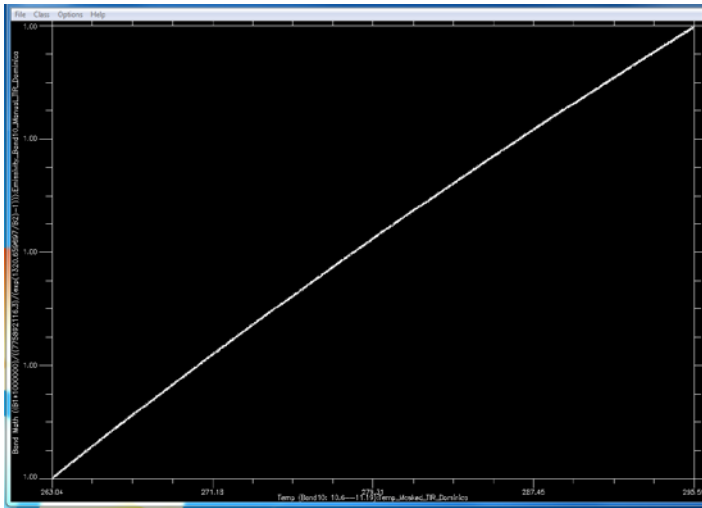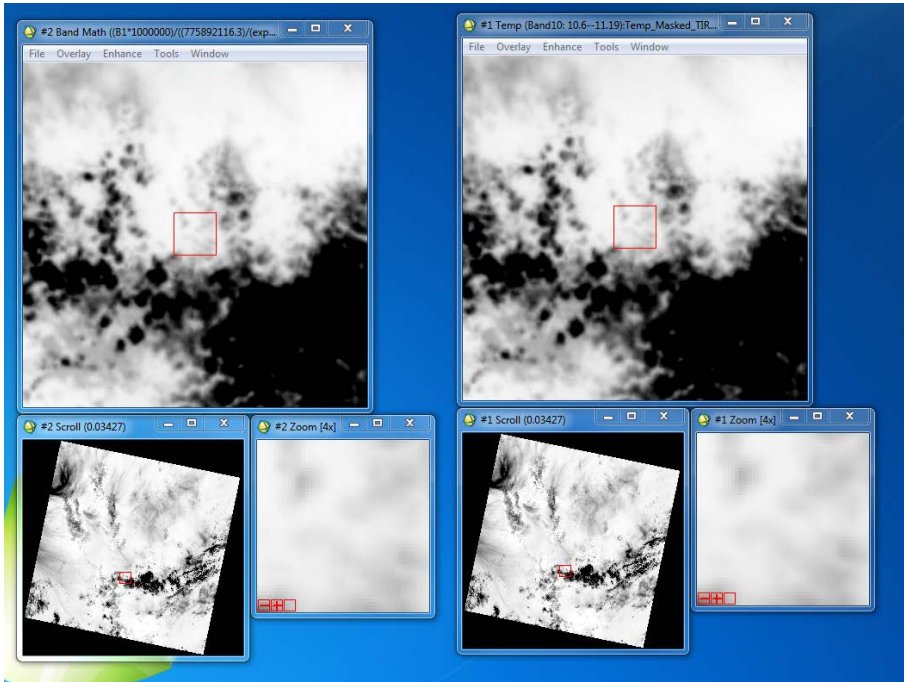Band 10, manually calculated data: $\varepsilon = (5.25114E-6)*T + 0.995721818$

Visual Display of the Emissivity, Temperature Relationship:

Images of SP3-calculated temperature (left), emissivity based on SP3 data (right). Image windows used to produce 2D scatter plot (below). Both images of Dominica, Band 10.
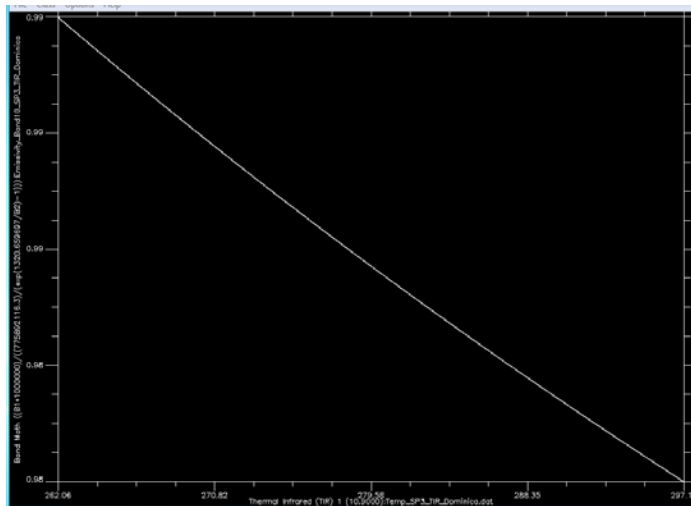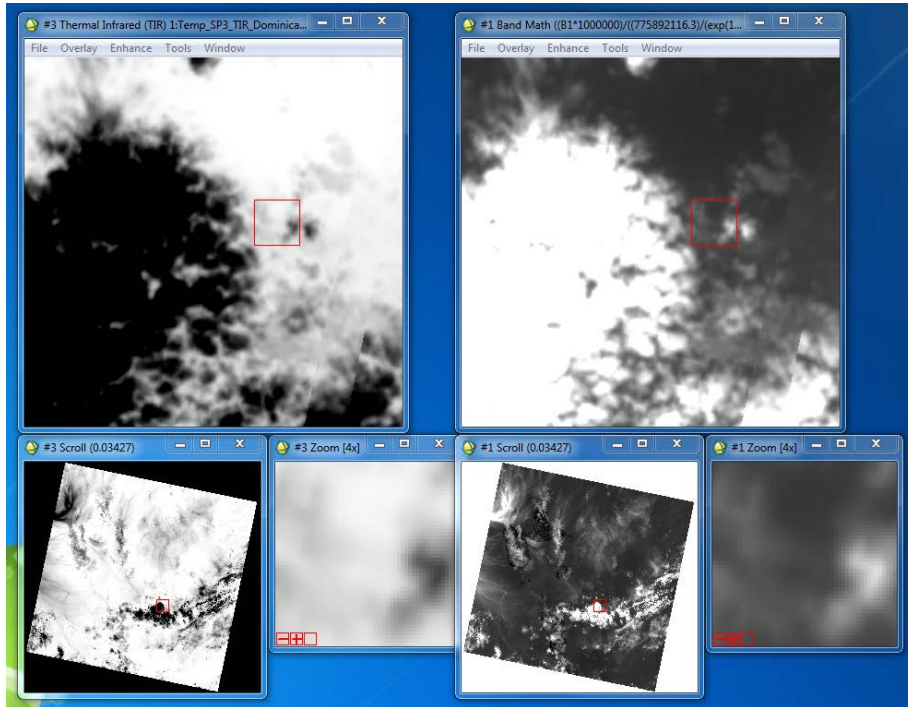
X-axis = SP-calculated temperature; Y-axis = emissivity (based on SP3 data)

Images of emissivity based on manually calculated data (left), manually calculated temperature (right). Image windows used to produce 2D scatter plot (below). Both images of Dominica, Band 10.

X-axis = manually calculated temperature; Y-axis = emissivity (based on manually calculated data)