

Exercise 13: Processing Thermal Data

44 Points scaled to 20 Points

Introduction

In this exercise, you will process a Landsat 8 Thermal Infrared Sensor (TIRS) image collected on September 11, 2019 to obtain an estimate of surface temperature. You will convert the data from calibrated DN values to estimate at-satellite brightness temperature using equations and available metadata. You will then convert to estimate surface temperature by considering emissivity of surface materials and the sensed wavelength. This exercise was adapted from an exercise produced using QGIS by Nektaria Adaktylou. It was also partially based on the following post:

<https://giscrack.com/how-to-calculate-land-surface-temperature-with-landsat-8-images/>

Objectives

- *Interpret thermal data*
- *Process data using standard equations and metadata*
- *Explain emissivity and thermal inertia concepts relating to different surface materials*

Prerequisite Materials

- ❖ Modules: Thermal/Hyperspectral/SAR
- ❖ Videos
 - Lab 13 Intro: <https://youtu.be/9bx-xD723tE>
 - Raster Calculator: <https://youtu.be/2fDysFAO75c>

Data

- ❖ **ls8_oli_9_11_2019.tif**: Landsat 8 Operational Land Imager (OLI) image collected on September 11, 2019 over Morgantown, WV
 - Band 1 = Blue
 - Band 2 = Green
 - Band 3 = Red
 - Band 4 = NIR
 - Band 5 = SWIR1
 - Band 6 = SWIR2
- ❖ **ls8_B10_9_11_2019_sub.tif**: Landsat 8 TIRS image collected on September 11, 2019 over Morgantown, WV. Only TIR1 (Band 10) is included

- ❖ **nlcd_2011_lc.tif**: categorical land cover raster from the 2011 National Land Cover Database (NLCD). These data were provided just for reference.

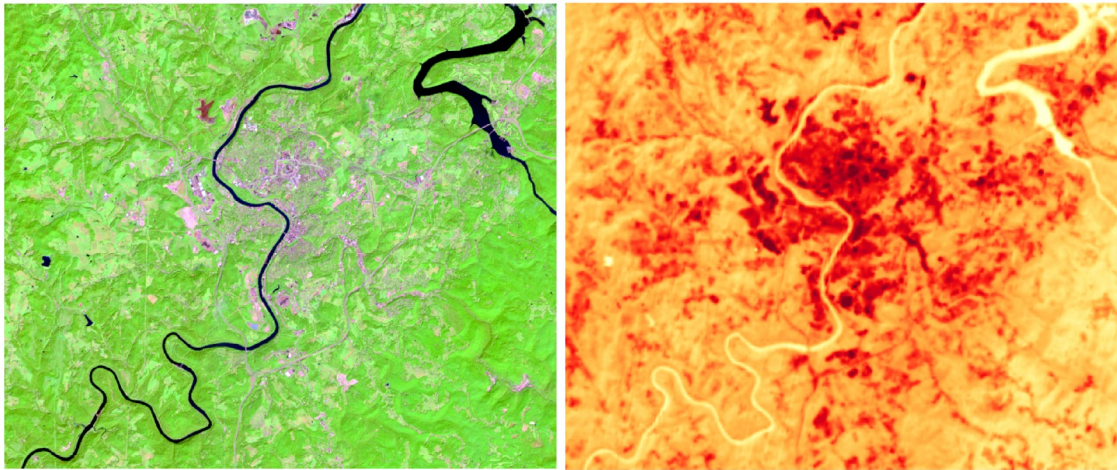


Figure 1. Landsat 8 OLI (Red = SWIR2, Green = NIR, Blue = Green) and TIRS1 (Band 10)

Background Questions

Question 1. Is the Landsat 8 TIRS sensor active or passive? Explain your answer. (4 Points)

Question 2. Explain the difference between the concepts of heat and temperature. (4 Points)

Question 3. Explain why water generally has less diurnal or daily fluctuations in temperature than pavement. (4 Points).

Question 4. Explain the difference between a black body radiator and a gray body radiator. (4 Points)

Question 5. Explain the difference between a gray body radiator and a selective radiator. (4 Points)

Question 6. Explain how emissivity is used to estimate kinetic temperature from radiant temperature for a gray body radiator. (4 Points)

Required Steps

- ❖ Open the provided project file.
- ❖ Convert the **ls8_B10_9_11_2019_sub.tif** layer to at-satellite reflectance using the equations below. Note that we are not undertaking an atmospheric correction

here, which is necessary to obtain a more accurate estimate of brightness temperature. The provided metadata file provides the required coefficients:

LC08_L1TP_017032_20190911_20190917_01_T1_MLT.txt

Band	MULT	ADD	K1	K2
10				

To convert to Top of Atmosphere (TOA) Radiance

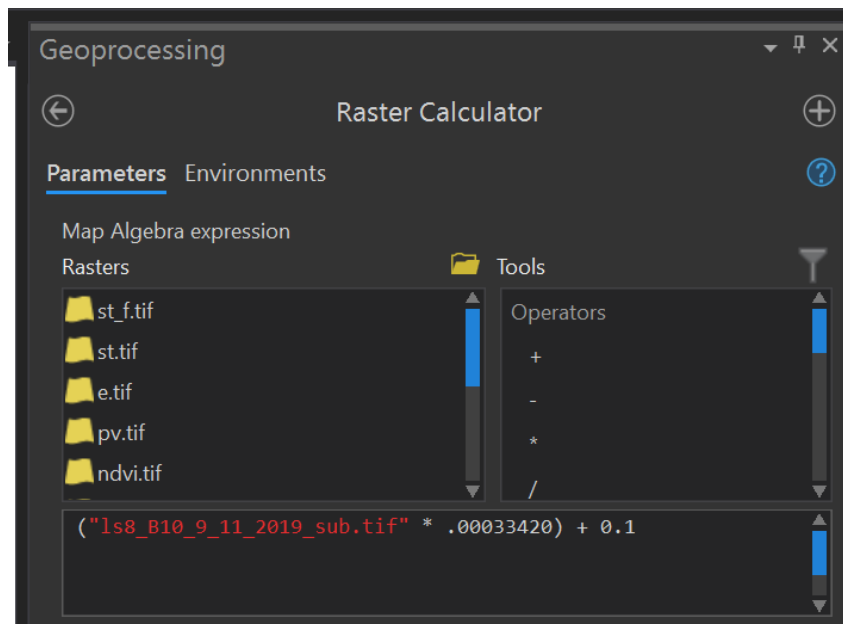
$$L_{\lambda} = M_L Q_{cal} + A_L$$

L_{λ} = TOA spectral radiance (Watts/(m2 * srad * μ m))

M_L = Band-specific multiplicative rescaling factor from the metadata
(RADIANCE_MULT_BAND_x, where x is the band number)

A_L = Band-specific additive rescaling factor from the metadata
(RADIANCE_ADD_BAND_x, where x is the band number)

Q_{cal} = Quantized and calibrated standard product pixel value (DN)



Convert TOA radiance to TOA brightness temperature (in Celsius)

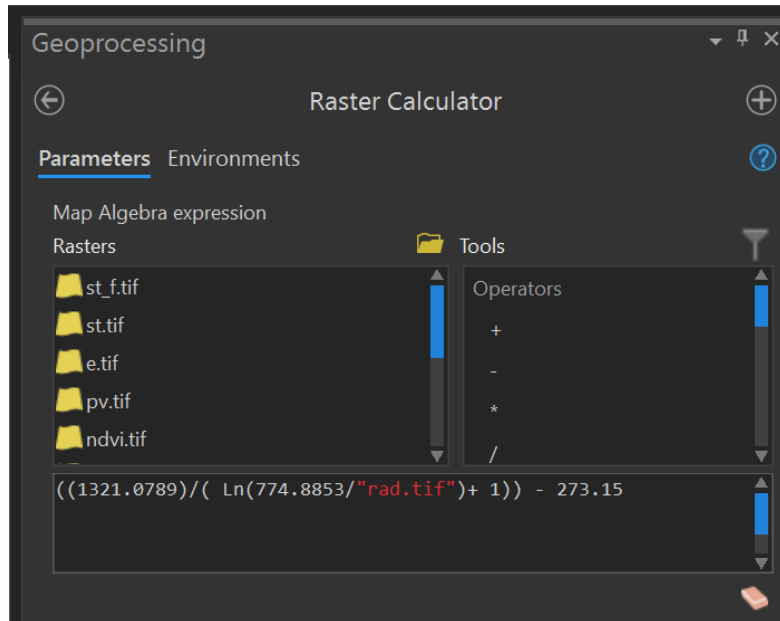
$$T = \frac{K_1}{\ln((K_1 / L_{\lambda}) + 1)} - 273.15$$

T = TOA brightness temperature (K)

L_{λ} = TOA spectral radiance (Watts/(m² * srad * μm))

K_1 = Band-specific thermal conversion constant from the metadata
(K1_CONSTANT_BAND_x, where x is the thermal band number)

K_2 = Band-specific thermal conversion constant from the metadata
(K2_CONSTANT_BAND_x, where x is the thermal band number)



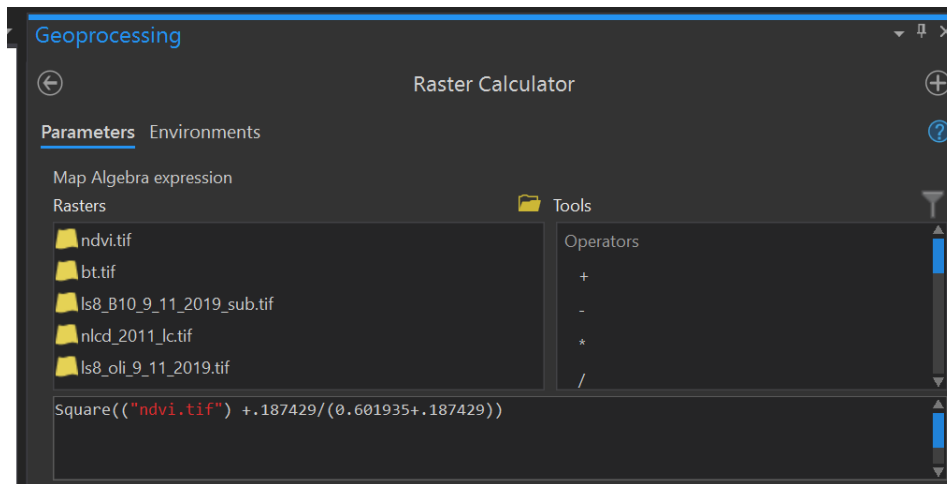
❖ Estimate land surface emissivity using the following steps:

- Calculate NDVI using Band 4 (NIR) and Band 3 (Red) from the **ls8_oli_9_11_2019.tif** image.

$$NDVI = \frac{(NDVI - RED)}{(NDVI + RED)}$$

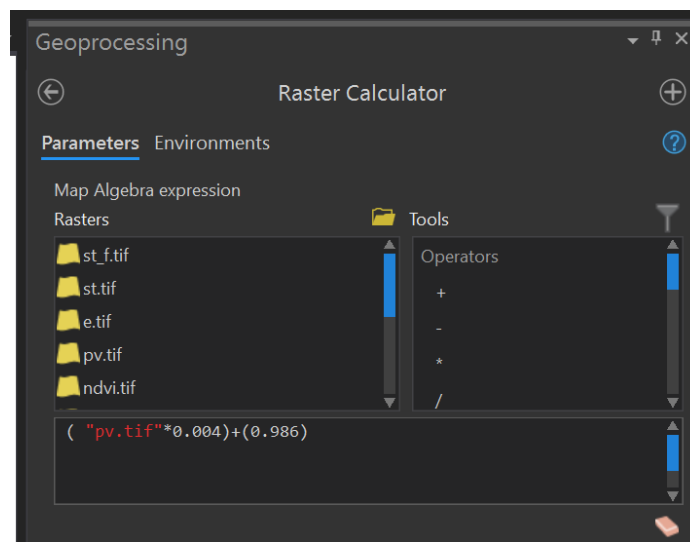
- Estimate proportion of vegetation (PV) from NDVI using the following equation. Note that the minimum and maximum can be obtained from the minimum and maximum values displayed in the Content Pane along with the raster symbology.

$$PV = \text{Square}\left(\frac{(NDVI - \text{Min}(NDVI))}{(\text{Max}(NDVI) - \text{Min}(NDVI))}\right)$$



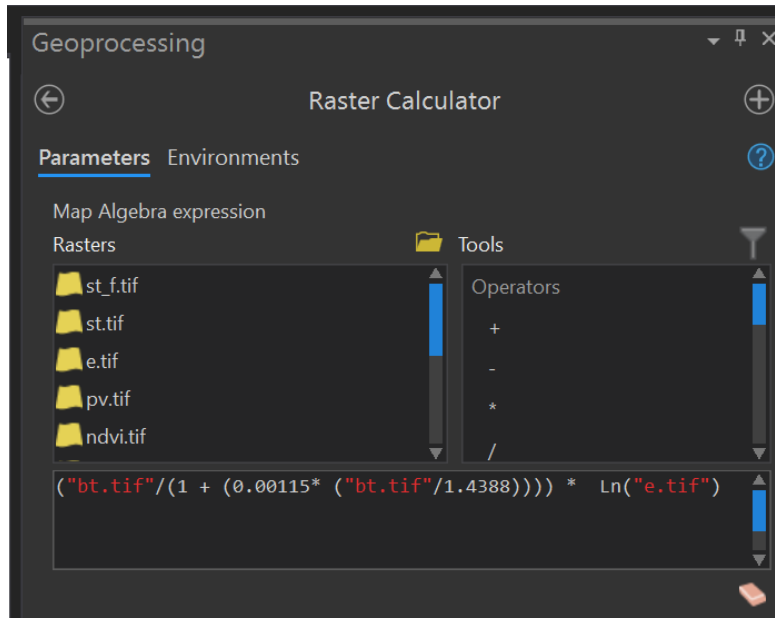
- Estimate land surface emissivity from PV using the following equation:

$$E = 0.0004 * PV + 0.986$$



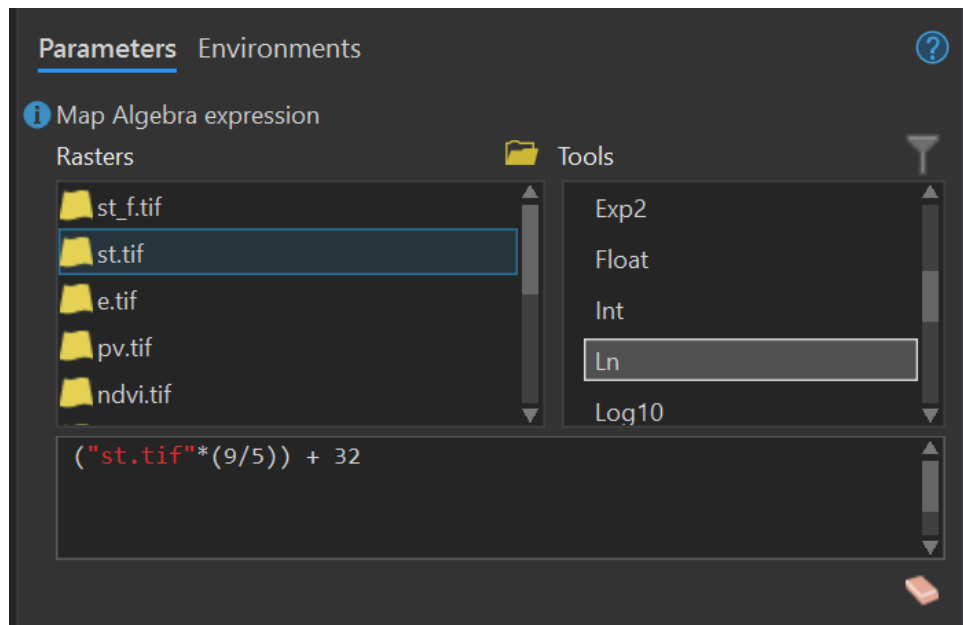
- ❖ Estimate land surface temperature using the TOA Brightness Temperature and Emissivity. BT = TOA Brightness Temperature, E = Emissivity.

$$\text{Surface Temperature} = \frac{BT}{(1 + [((0.00115*BT)/1.4388)\ln(E)])}$$



- ❖ Convert from Celsius to Fahrenheit using the following equation:

$$\text{Temperature in Fahrenheit} = ((9/5) * \text{Temperature in Celsius}) + 32$$



Deliverable 1. Create a map layout showing (1) the false color Landsat 8 OLI composite and (2) the resulting surface temperature estimation in Fahrenheit. These should be in separate map frames. Make sure to list what bands are mapped to each color in the false color image, and provide a legend for the temperature data. Include a title, cite the Landsat Program, and add a north arrow and scale bar for at least one of the map frames. The layout will be partially judged on neatness and use of space. (20 Points)